

# APPENDIX

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# APPENDIX A



# **APPENDIX A.1**

**Chiara Sacchi**

**(Argentina)**

### Chiara Sacchi (Haedo, Argentina)

Chiara Sacchi has lived in Haedo, Argentina all seventeen years of her life. Part of Greater Buenos Aires, Haedo is in the Pampa Húmeda ecoregion, which typically has hot summers, cold winters, and moderate precipitation. The climate is changing though. As Chiara explains, lately the climate has become extreme, with weeks of intense heat in the summer. Sometimes, a week of this unusual heat will uncharacteristically arrive in the middle of winter.

Haedo is a densely built urban environment, with plenty of concrete and limited green space. Chiara, who likes to spend her free time with her friends in the plaza drinking mate and talking, is finding it difficult to adjust to the new climate. When it gets blistering hot, it is difficult to be outside. “In the summer, it is very hard to be out and about. It is unusually hot and it is hard for us to get used to that,” Chiara explains. “The streets are all asphalt so that makes it even hotter.”

The extreme heat has also significantly increased the use of air-conditioning units, placing pressure on the electricity grid. Frequent power outages are common. Chiara explains that in the past, air-conditioning units were not necessary, “but now every home is equipped with a unit and the demand for electricity has increased. The infrastructure is not prepared for this, so that brings very frequent power losses.”



*Flooding in General Rodriguez, 40 km from Chiara's hometown, Haedo.*

The electricity outages interrupt Chiara's daily life. For example, Chiara cannot complete her homework during power outages because the school system uses web-based platforms. In the extreme heat of summer, power outages quickly ruins food in the refrigerator. The outages also affect Chiara's mother, Perla, who is a farm-to-table chef.

More powerful and frequent storms are also hitting Haedo, like much of Argentina. Chiara recounts, “There are now storms with heavy winds and rain that is very unfamiliar to our area. About a year or two ago, a

windstorm blew the roofs of our neighbors' houses and that is unthinkable for our climate. These last few years there have been too many storms and there's been severe flooding. One particularly bad storm dropped hail the size of tennis balls.”

The storms damage buildings and flood the urban landscape. “We are not prepared to deal with rains and floods,” Chiara explains. “The entire province of Buenos Aires is mainly now like a

cement block rather than in the past we used to have green spaces. Now all the cities and towns are connected and there is no place for precipitation- everything is cemented and everything is built.”



*The impact of a heavy storm in Chiara's neighborhood: flooding and damage.*

Despite facing these challenges, Chiara feels more fortunate than many others living in Argentina. “The truth is we are lucky enough to be in a home. We don’t have an air conditioner, but we have fans. There are people in the streets that don’t have a home and it’s horrible. It is either too hot or too cold. We are lucky enough to not be as affected as other people.”

All of the climate harms Chiara is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

Chiara was aware of climate change growing up through her mother and social media. For example, climate change and other environmental issues are threatening her mother’s ability to source materials for her cooking. Recently, Chiara’s awareness of climate change has heightened because of her own experience in Haedo and from her participation in Terra Madre, a global project that seeks to protect and support small-scale food producers. Through Terra Madre, she has learned how climate change threatens the livelihoods of many small-scale food producers.

Chiara is scared of the future. The changes she is experiencing in Haedo makes her “think a lot with uncertainty about the future and that perhaps the country and the people are not ready to deal with what’s to come.”

“It’s hard to imagine a future with all these events. I think we are all quite desperate. I feel kind of—I don’t want to say lonely—but I can’t get the right word. It feels like we are alone, like no one knows what to do, and when you know what to do, nobody takes action.”

Her friends and she question whether to have children in this changing world. “Yes, I’m scared to death. Why would I bring another human being here when we don’t



*Chiara striking for a better future and a better environment.*

know what we will do with the ones that are already here. It's very hard to control that, and I have spoken to a lot of young people that feel this way."

Chiara feels angry about the global community's response to climate change. "I'm truly mad. It's not like 'oh, I'm sad.' I'm angry! We are alone here and there aren't a lot of people that will take action. I'm mad."

Chiara believes that young people must lead in the fight against climate change. "I mainly believe that the youth are the protagonists because we are the generation that are coming and who have to deal with that."

"I wish I could beg for attention," she says. "I think we need to be responsible. We need to make a change. We need to move and we need to do things right – the future is here. We don't have any time. We cannot consider the world as we do now – there are no walls with climate change. We are here, we are all together."

**APPENDIX A.2**

**Catarina Lorenzo**

**(Brazil)**

### Catarina Lorenzo (Salvador, Brazil)

Catarina Lorenzo was born and raised in Salvador, located in Brazil’s northeastern state of Bahia. An aspiring professional surfer, Catarina has spent a lot of time on Brazil’s beaches and in the ocean. But, according to Catarina, who is twelve, the ocean and the beaches are much hotter than before. In the summer now, Catarina explains that “the water is so hot” and the sand is too hot to touch. Recalling a swim in the ocean this past summer, Catarina describes:

“The water was really, really hot and the coral was white – it was dead. I had to swim away from the coral reef because it was all white and there were pieces of the coral reef floating around the water. The water surrounding the reef was too hot and unbearable – I had to get out of the water. I couldn’t stay in the water.”



*Catarina on Salvador’s coast.*

Brazil has six major coral reef areas, and the Abrolhos Bank reef, which is the southernmost reef located in the state of Bahia – close to Salvador – is the largest reef in Brazil. The Abrolhos Bank reef is important because it contains mushroom-shaped coral species that no longer exists in other Atlantic reef beds. Heat waves between 2014 and 2017 resulted in coral bleaching across Brazil’s reefs, including among the Abrolhos reefs.



*Coral bleaching off Salvador’s coast.*

Catarina has seen coral bleaching affect the sea life surrounding the reefs as well: “There are many animals that are dying from the dead reef.”

And while the summers are getting hotter than Catarina ever remembers them to be, Catarina explains that the winters are getting colder. “Each year the summer is too hot and the winter is too cold. Now it’s winter – it’s colder for me.”

There are other changes too, notes Catarina. “It’s raining less now. It should rain between April through August, but now it’s just raining between July and August.” This brings numerous problems, says Catarina. “We are having water shortages. There are times when the city lacks water for a day or two and cuts off our water supply for that time.” Because of these water shortages – which come without warning from the local government – Catarina and her family save water in a tank in preparation for the next water shortage. Some of her neighbors, however, who do not



have access to a large water tank, try to store water in buckets to use for showering or washing dishes, or otherwise go without water, having to use a neighbor or friend's water supply to wash up.

The lack of rain, Catarina explains, is also causing drier conditions: "The rain should make the soil muddy. Instead, the soil is staying dry. The soil is not like before." Indeed, the lack of rain is a prime concern for Brazil and for Brazil's forests, including the Amazon. This summer Amazon rainforest fires destroyed thousands of acres of forests, in part, the result of the drier climate and in other part, the result of Brazil's new policy of increased agricultural development. Catarina remarks that there is a "lack of supervision" and often times "invaders take advantage of forest fires to invade the land."

Brazil's forest fires are exacerbated by the drier climate, which spreads the fires to unmanageable sizes at a much faster rate. In August 2019 alone, there were more than 27,400 fires detected in the Amazon. Although the Amazon is located in the western part of Brazil, the effect of the damage goes far beyond Brazil and its borders. The Amazon rainforest contains enormous amounts of carbon as wood and other organic matter that, when burned, contribute to the climate crisis. In its pristine state however, the Amazon rainforest is a major contributor in reducing carbon dioxide from the earth's atmosphere, acting to cool the planet. "It makes me feel really sad that people would try to destroy the trees – something that helps them and the planet" remarks Catarina.

Catarina also describes that Salvador is experiencing more severe storms. "Here in Bahia for the first time ever we had a tropical cyclone." In March 2019, a rare South Atlantic tropical storm, named "Iba", surged along Bahia's coast. "There was a lot of flooding where people lost their houses, their boats, and the waves were gigantic because of the high winds." Another high impact storm with heavy rain and strong winds hit Bahia this year in July, damaging Catarina's home: "In my house some roof tiles flew off the exterior and the wooden lining of our house got wet and is now warped."

Catarina emphasizes that the government is ill-equipped to handle the intense rainfall from these strong storms. The heavy rains from the July storm caused the overflow of a local dam due to water pressure, resulting in flooding and the evacuation of hundreds of families from their homes. Additionally, Catarina explains, "in Salvador when it rains a lot the government opens the sewage system, which is jammed with water, and dumps the sewage into the river and ocean because the water pumps don't work." But



*Catarina in front of the ocean in Salvador.*

such a move pushes toxic waste into water streams and beaches, and “we risk getting diseases,” says Catarina.

All of the climate harms Catarina is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

The extreme temperatures and changing weather patterns worry Catarina. “I feel that I don’t know exactly what will happen in the future. If we don’t act to stop the climate crisis, it will be the kids who pay the consequences.” Although she is only twelve-years-old, Catarina fears what will happen to her future, and the future of her children, if she decides to have any. “The future will not be the same as today.”

To the world leaders, Catarina says that they “need to respect the limits of planet earth. They need to understand they cannot detract all the natural resources and pollute the atmosphere because other people and living things need to continue living in the future.” She explains that it is the children of the world who stand to suffer the most from the climate crisis: “It is our future and world leaders should hear us. If they don’t act to stop the climate crisis it is our future that will be affected.”



# **APPENDIX A.3**

**Iris Duquesne  
(France)**

### **Iris Duquesne (Bordeaux, France)**

The first summer of sixteen-year-old Iris Duquesne's life was the hottest summer in Europe since 1540. Born in Bordeaux, France on April 22, 2003, Iris was three months old when the deadly heat wave of 2003 swept France. It was one of the worst weather events in the Continent's history, killing as many as 70,000 Europeans, some 15,000 in France alone. The most vulnerable to heat stress are the very old, the very young, and the infirm. Iris's parents, Christine and Gregory, were scared they would lose their baby girl to the heat.

The family had moved to Bordeaux before Iris was born. As Iris grew up, Bordeaux experienced climate change induced temperature extremes they had never anticipated.

The 2003 heat wave was followed by another in 2006, which claimed around 2000 lives, a lower toll thanks to a National Heat Wave Plan and adaptation measures. But the heat has stayed. The five hottest summers in Europe since 1500 have all occurred after 2002. In 2003, Bordeaux reached an all-time high of 40.7°C; in July 2019, two months after Iris's 16th birthday, Bordeaux broke that record at a scorching 41.2°C.

Indeed, the increased heat has affected Bordeaux's local economy. Iris notes that Bordeaux is known as one of the world's top wine regions, and grape harvests, which used to take place in September, now because of the heat occur in mid-August – which impacts the assembly process and delivery.

Storms have also hit Bordeaux with more frequency and intensity. In February 2010, Cyclone Xynthia struck southwestern France, causing deadly floods. The river Gironde almost broke its



*Flooding from the 2018 rainstorm in Bordeaux.*

banks in the city. Iris was eight when the cyclone struck: she and her mother were caught outside and raced home on foot in the lashing winds and rain. Iris was terrified of the storm: "I was really scared, I went into my room and hid under my pillows and blankets." After that, Iris developed a fear of rain. She had recurring nightmares of tsunamis and storms.

Yet major storms came more frequently; on May 28, 2018, a violent hailstorm ravaged Bordeaux. At the Duquesne's home, the hail was the size of golf balls. The street flooded like a stream. Water poured into their house through a leaky roof. When Iris's mother, Christine, was growing up, these

kinds of storms were rare: “I only remember 3 storms—big, big storms like that—in 16 years.” For Iris they are regular events.



*Bordeaux's Atlantic coast.*

The sea level along Bordeaux's coast has also risen. Tides are getting higher, pushing the coastline closer inland. Iris recalls in 2014, one of Bordeaux's largest buildings, known as “le signal”, was evacuated as the coastline almost reached the base of the building. Christine, remembers “le signal was too close from the ocean” and people feared “it might fall in.”

Moreover, the changing weather patterns has brought with it an influx of tiger mosquitoes, which Iris says, were not present before. “Five years ago, there were only a few in Bordeaux, but now it became

an indigenous population, spreading diseases like chikungunya and zika.” Christine explains that because of this new increase in tiger mosquitoes “in summer being outside is more difficult” as there is a greater risk of contracting one of the mosquito-borne diseases.

All of the climate harms Iris is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit. Indeed, experts predict that climate change will only increase the frequency and intensity of such heat waves and storms in Europe.

Iris first heard about climate change from her teachers in primary school. In seventh grade, Iris began to understand the global nature of climate change. “We read an article in class and the teacher asked what was global warming, and I said that it was something happening in France... And the teacher told me that I was right except that it was happening everywhere in the world. And that is when I realized, ‘oh ok, that is bad, that is important.’”

Iris eventually conquered her fear of water. But she cannot shake her fears rooted in living through extreme weather events.

Now, at 16, Iris thinks about climate change every day: “I’m wondering, ok, what is going to happen today. Sometimes I try to figure out solutions in my mind.” She often feels powerless. She fears what the



*View of Bordeaux's Atlantic coast from above.*

future will bring: “The world is going to be sad. There will be climate refugees everywhere in

Europe and the US. There will be tension and pollution and the geography will be completely changed. There are islands that are going to disappear and countries like the Netherlands that will disappear.”



*Iris with family and friends on Bordeaux's beaches.*

In thinking about her future, Iris says, “I don’t want to have kids if they’re going to live in a world like that.”

Iris feels betrayed by authorities: “It just makes me angry. They’re supposed to be our government and they’re supposed to protect us . . . they’re supposed to protect us now and in the future, and they’re not doing anything . . . they don’t realize it will cost less money if we act now than if we act later.”

In 2019, Iris moved with her family to California, where she is finishing high school. She wants to attend university in North America before returning to France. She is not sure if she would want to return to her home city: “It would be hotter and harder to live.”

# **APPENDIX A.4**

**Raina Ivanova**

**(Germany)**

### Raina Ivanova (Hamburg, Germany)

As countries all over Europe reached peak and record-breaking temperatures this summer, so too did Germany, which recorded its highest-ever temperature of 40.5 Celsius (105 Fahrenheit). Unsurprisingly, the unprecedented sweltering heat has severely affected people and the environment.



*Dried out canal bed in Hamburg.*

For Raina Ivanova, a 15-year-old Hamburg native, going to school is not like it once was. Hamburg’s recent blazing spring and summer temperatures force Raina and her classmates to switch classrooms and take breaks in an attempt to disrupt the lingering warm, clammy air, making it harder to concentrate on school subjects. Heat waves are not the only consequence of the climate crisis that Raina is experiencing. Hamburg’s famous canals – which fill with water from the Elbe and Alster Rivers – have taken a severe hit in recent years. Boats that once beautifully lined the city’s smaller canals have suspended services as high summer temperatures have led to dangerously low river levels, and by default, shockingly low canal water levels where locals, like Raina, for the first time “see the sand that’s on the bottom” of the canal bed.

At other times, intense rainfall and storms has caused the canals to overflow, flooding nearby land, and pushing canoes over canal beds in Raina’s neighborhood. Raina has seen this firsthand. In October 2017, Hamburg experienced a severe storm, dubbed “Herwert”, which had winds blowing up to 176 km/h (109 mph) in parts of Germany, and flooding the streets of Hamburg. Neighbors and friends saw their garages fill with water and ruin their belongings, while Raina and her friends walked in knee-high water in her school’s football field.

These weather patterns are “very shocking” for Raina and her friends, and are changing the landscape of her beloved city. The increasingly powerful storms have specifically posed a danger to Hamburg’s trees; Raina remembers:





*Hamburg after Herwert hits the city in 2017.*

Near our house by the channel there is a little island and there used to be a very big [willow] tree and it was very pretty. When we were little we took the canoe and paddled to the island under the willow tree. After the storm they cut [the willow tree] down and now it's not there anymore.

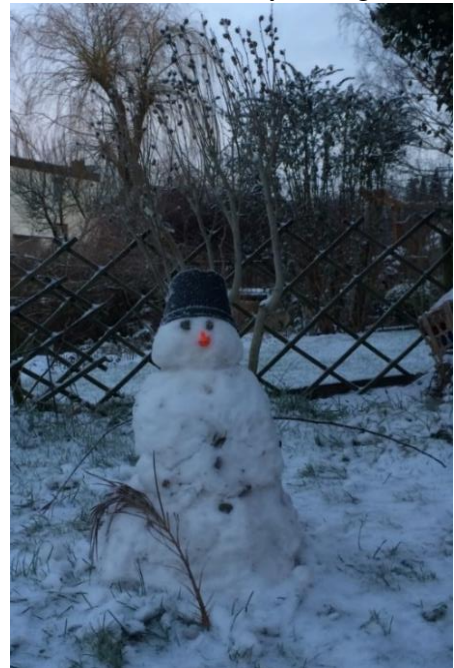
In fact, Raina acknowledges that “there were a lot of trees in our neighborhood and so they decided to cut some big ones that could

possibly fall on houses if there is again such a bad storm.”

The ramifications of these changing weather patterns include unfamiliar winters as compared to historically picturesque white winters in Hamburg. This is because as the summers in Germany have been heating up, the winters have also gotten much warmer. Raina recalls ten years ago when Hamburg used to get moderate amounts of snow, and now “there is barely any snow and it doesn't stay for long”, unable to stick to the warm ground below. Even Hamburg's canals, which were known for freezing up in the winter – something that the locals used to take full advantage of by ice skating on the frozen surface – nowadays, and in particular the channels in Raina's neighborhood, forms an ice layer “so thin the ice can barely even hold one person.”

All of the climate harms Raina is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

Raina's focus is no longer solely on her studies; rather, in the back of her mind there is a looming fear that she cannot ignore – the fear that one day her world, “*our world*,” as she expressed it will be different, scary, and sad. This sadness and fear and a belief to overcome it has driven her to participate in “Fridays for the Future” – a movement initiated by global activist Greta Thunberg, in which youths, like Raina, forego school on Fridays in an effort to bring awareness and spark action to combat climate change. On these Fridays, Raina and her friends go to Hamburg: “we



*“The Last Snowman”*



*"Fridays for the Future" in Hamburg.*

draw signs and we go around the Alster" – a lake within the city limits of Hamburg – "and we sing songs about the climate ... and we have flyers that we give to people that are around there to help them see the need to do more ." She participates in these events hoping to spark an interest among "the adults" to act, to make a change for children like herself.

The consequences of climate change disrupt Raina's daily life, thoughts, and dreams. Her sisters, all younger than her, have begun to ask her about the rising temperatures. Raina tries to soothe her little sisters' worries, although she herself shares those same concerns. As she says, "[climate change] makes me really sad" and "is something that really scares me when I talk about it with my little sister" because "global warming will have a bigger impact on our lives." Raina encourages her family

to actively do their part, however small it may be, to prevent contributing to global warming. "I try to turn down the heat in my room also in the winter" and "we have solar panels on our roof and we try to use more renewable energy and less energy in general."

Indeed, Raina's experiences and the more she learns about the changing climate has made her question whether she herself wants to fulfill her "dream" of having children one day:

When I was younger I was very sure that I wanted to have children and to live in Hamburg but because of all these consequences [as a result of climate change] I'm not sure I would want my children to face this or to live in such an environment that they have to worry about their lives because of the weather.



*Raina (right) and her friends.*

Having experienced in her short lifetime these dramatic weather patterns, climate change "is something very emotional" for Raina. She hopes that world leaders "know that the little children in [her] generation sometimes cry because of the decisions [world leaders] make." Raina knows she is likely to live in a world where climate change is very present: "it will



affect my life and the life of my children, if I decide to have some.” But she remains hopeful that her politicians and “the adults” in a position to make a change – who “didn’t really have to face all these problems and issues that we have to face now because in their childhood they didn’t have to think about these consequences” – “know what will happen if we don’t act the right way now.”

**APPENDIX A.5**  
**Ridhima Pandey**  
**(India)**

### Ridhima Pandey (Haridwar, India)

Eleven years old Ridhima Pandey moved to the northeastern town of Haridwar, India, six years ago, from Nainital. Haridwar is known as the “holy area” of India, Ridhima explains, where many Hindu temples are located, including Lord Shiva’s temple. Central to the holy area, is the nearby Ganges River: “Every year in July, there is a festival, known as Kanwar Yatra. People come to Haridwar from all over India to collect water from the Ganges, and give back to the Lord Shiva with the Ganges’ holy water.” This tradition, notes Ridhima, is specific to Haridwar and the greater state of Uttarakhand since the Ganges only runs through the northeastern part of the country.

The holy Ganges River, however, faces lowering water levels from recent droughts – threatening the religious rituals that are centered around it. Ridhima says: “the temperature is increasing. The environment here used to be very cool and now it is very hot. And in the winter the temperature is much hotter.” Ridhima’s father Dinesh explained that this is causing more droughts in the summer months which “seems to be drying out the Ganges more in the summer.”



*People come to Haridwar from all over India during Kanwar Yatra to collect water from the Ganges River.*



*Lower water levels in the Ganges.*

The Ganges River, spanning 2,520 kilometers from the Gangotri glacier in Uttarakhand on the border of Tibet to the Bay of Bengal, is among the world’s most endangered rivers. The Gangotri glacier rests almost 5,000 meters above sea level and provides 70 percent of the river’s water, but is shrinking by 22 meters per year, almost twice as fast as it was 20 years ago. Groundwater discharge and rainfall contribute the remainder of the river’s flow, but increased summer temperatures have dried out

nearby land, reducing the groundwater flow to the river by 50 percent.

And, as Ridhima explains, “the rainy season is getting shorter. The rain used to last for weeks during the rainy season” – June through September – “but now the rain that does fall only lasts for a day every once in a while. It is not consistent like before.”

The lack of rain is intensifying water shortages in some areas. Ridhima and her family experienced water shortages when they lived in Nainital. Although water shortages are a concern in Nainital the entire year, with water outages lasting two to three days at a time, “the lack of rain increases the water problem.” Ridhima explains, “the ground water level is very low there. We had to store water in underground tanks.”

Now though, the few times it does rain, “the raining is heavy,” says Ridhima. Ridhima explains, there are times when it rains so hard that “the [Ganges] river gets to the danger mark. If the water level crosses the danger mark, the water will come out and overflow onto the land.” Ridhima notes, however, that in the past the rain did not cause as much damage as it does now: “Now if a heavy rain occurs the river overflows and those living near the river get stuck there.”



*Pollution combined with increased extreme weather patterns has caused an influx of mosquitoes.*

The increased intensity of rainstorms has challenged the local infrastructure, causing water to pool and sewage to overflow into the Ganges. “The drainage is not proper, and the water will collect and come out in some places closing the streets and schools.”

The polluted environment, stagnant water, and increased flooding in the area is also creating an influx of mosquitoes, says Ridhima. As a result of a mosquito bite, Ridhima’s mother “suffered typhoid one month ago and had to go to the hospital.”

Ridhima explains, “my mother had high fever, body pains, and was very cold. The doctor put her on glucose and medicine, and after a month she took the vaccine.”

All of these developments, which Ridhima attributes to the changing weather patterns, has made Ridhima very vocal about her government’s contribution to the climate crisis.





*Aftermath of the 2013 rainstorm that devastated Uttarakhand.*

In 2013, Ridhima and her family in Uttarakhand experienced a devastating rainstorm that resulted in flooding and many casualties. “Everything in the area got damaged. People were dying – they were stuck under the stones, the sand. The holy places got flooded.” This destructive 2013 rainstorm sparked Ridhima’s interest in advocating against the climate crisis. “At that time I realized all these things were happening due to global warming, and I got interested.

I feel really bad that we, the humans, are spoiling our nature and future. We are destroying the future of other generations and our future.” From that point on Ridhima began reading and learning about the climate crisis to understand how should could become a better advocate.

In 2017, at just nine years old, Ridhima decided to sue the Indian government for failing to take adequate action to tackle climate change: “I sued my government because I want a better future. I want to save my future. I want to save our future. I want to save the future of all the children and all people of future generations. In India, the government is not acting as they should to prevent climate change.” Although the court of first instance – the National Green Tribunal, a specialized court established in 2010 to hear environmental cases – dismissed Ridhima’s petition, she has appealed to the Supreme Court of India and her case is currently pending there.



*Ridhima gives a speech at her school on protecting the environment.*

“People in India are not making the environment a priority,” says Ridhima. “We are destroying all our resources – wasting water and polluting our air so badly.” And while Ridhima faults the

Indian government for their contribution to the climate crisis, she acknowledges that “it is not a problem which any country can solve on its own. All the countries must join their hands together to solve this crisis as it is a global issue.”

Indeed, all of the climate harms Ridhima is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

“When I think about the future with global warming, I feel very disappointed because I can’t imagine a healthy and long life. Every person deserves to live in a healthy environment. We, children, want a better future. I personally don’t want to suffer – I want a healthy future, I want to live a healthy life. And future generations also have the right to live a healthy future.”

# **APPENDIX A.6**

**David Ackley III**  
**(Marshall Islands)**

### David Ackley III (Majuro, Marshall Islands)

David Ackley III (“David”) is a sixteen-year old living on Majuro, the capitol of the Republic of the Marshall Islands, in a town called Uliga. Although Majuro always served as his “home base” and most of his extended family lives there, David was born in Illinois while his father, David Jr. completed his residency. Their family moved from Illinois to the Hopi Reservation in Arizona for eight years, and then spent three years in Honolulu, Hawaii while his father worked for the US Public Health Service. When David was eleven years old, his family moved back to Majuro permanently.



*David Ackley III in Majuro*

David feels lucky to live in a place where he is surrounded by his culture, family, and friends. “I goof around a lot on this island, but it’s easier to do that when you know everyone and everyone knows you.” According to David’s mother, Neilani, to be Marshallese in the Marshall Islands “means safety” – not having to worry where her son is because she knows her neighbors and everyone in their community. “Everyone is close,” David agreed. Majuro is a place where David can “actually be a Marshallese person,” which he appreciates even more after facing prejudice in other places. In particular, David and his mother experienced racism in Hawaii, recalling that people looked down on them for being Marshallese.

On Majuro, David and his family can keep alive traditions, and “be Marshallese”. For example, Neilani describes one tradition in particular, *kemem*, which is a baby’s first birthday celebration where friends and family gather outside the hosts’ home, singing, dancing, and celebrating all night long. According to Neilani, the tradition arose long ago because there used to be a risk that a



*Majuro dump, two days after fire in March 2019.*

newborn baby would die before reaching its first birthday, and *kemem* is when the baby is named to celebrate the baby’s survival. David does not think *kemem* would be the same outside of the Marshall Islands – it would be harder to celebrate when you are not surrounded by community members who understand *kemem*: the “neighbors might call the police in the middle of the night,” rather than coming out and joining the singing and dancing.

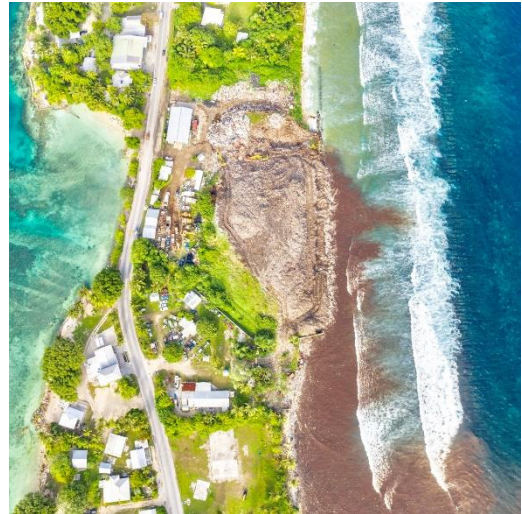
Now, David’s home, traditions, and way of life are all at risk. David first heard about the climate crisis in fifth grade: “I thought this was immediate, and I was scared. Now that I know it takes longer, it is more subtle, and I am less scared, but I still think



about it a lot. I feel lost. I like to keep my mind off it because it scares me, but it still pops up a couple of times a day.”

The Marshall Islands have already suffered severe climate crisis impacts and are facing complete destruction as sea levels continue to rise. Greenhouse gas emissions of major emitting countries thousands of miles away are threatening the approximately 59,677 citizens living on 29 low-lying coral atolls, 1,156 islets, and five single islands that make up the Marshall Islands. Rising temperatures and sea levels, combined with droughts and dying coral reefs have already begun to change this island nation, and unless other countries urgently make significant changes, its islands will be unrecognizable in 40 years, if they exist at all.

In just five years, David has seen these impacts on Majuro firsthand. King tides, which are exceptionally high tides, now consistently breach the sea wall and damage homes. King tides also cause the landfill, which is located on a thin strip of reef between two islands to overflow, and push trash onto Majuro. According to David Jr., “when it rains, colored water runs into the ocean from the landfill.” Although David’s family home is located approximately fifty meters inland from both the lagoon- and ocean-sides of Majuro, his neighbors’ oceanfront houses flood at least once a year – every time there is a king tide – and some have had to abandon their homes to seek higher ground during floods, which often overtake the main road on the island, making travel difficult and unsafe.



*Aerial view of the Majuro Dump*

David works part time at his family’s docking business and at a restaurant and night club his grandmother runs. King tides have damaged both of these businesses. Last year the dock collapsed during a high tide that also damaged the restaurant. The family restaurant is built right on the water, “so you sometimes get splashed.” This used to be just part of the experience, because, according to David, “everything tastes better with a little saltwater on it.” Now, however, their family has contemplated moving the restaurant because of how often it floods. These predictable floods that accompany king tides are a new phenomenon - Neilani does not remember her mother’s restaurant flooding when she was younger.

The coral surrounding Majuro is also mostly dead, although David recalls that when he was younger, the coral on the lagoon side, was, at least, “not as dead as it is now, even though the oceanside coral was always dead.” Now, the reef is bleached “almost everywhere.” This, too, is a change that took place in the span of one generation; when Neilani was David’s age, the coral on both sides of the island was vibrant and alive. David has also noticed that it is becoming a lot

harder to find fish. David goes spearfishing as often as he can, but now he has to take a boat to one of the smaller islands to catch anything. Additionally, some of the fish David and his family used to eat have become poisonous, likely from ciguatera, and Neilani knows that people have recently died from eating these fish.

Storms on Majuro have also increased in frequency and violence. Recently the winds from the lagoon side were unusually strong and a fishing boat crashed onto the shore from the water. El Niño events, which Neilani says “seem to happen every year now” rather than once every five to ten years, bring drought and excessive heat, causing the grass, banana, and breadfruit trees in David’s yard to turn brown.

Mosquito-borne illnesses have also become much more common on Majuro. According to David Jr., Majuro previously had instances of dengue, but chikungunya and zika are new to the islands since 2015, and all three have become more common. As of August 20, 2019, Majuro was in the middle of a dengue outbreak. Last October, David contracted chikungunya, one of the newly arrived mosquito-borne illnesses. For an entire week, David felt weak and dizzy, he kept throwing up, and his arm went numb. Luckily, David did not have to go to the hospital because his father brought home an IV to treat David there.



*View from Majuro, Marshall Islands*

David and his family talk about climate change fairly often: it is hard to avoid the topic when you can see the impacts of climate change creeping up onto your island with the rising sea. David’s family wonders if they will have to move away from their home, something that worries David, who wants to live in the Marshall Islands when he grows up. He does not want to be separated from his community, his homeland and his culture, and does not want to move to a place where he might face racism and prejudice again. But, all the climate harms David is experiencing will worsen, only the extent to which depends on how much Greenhouse Gas the world continues to emit.

When David thinks about his future, he is not sure what he wants to do, but he is sure he wants to live on Majuro, that when he eventually has a family, he wants his children to grow up where he did. “The experiences I’ve had here are different than what there is in other places. This is a place where you can actually be a Marshallese person.”

# **APPENDIX A.7**

**Ranton Anjain**

**(Marshall Islands)**

### Ranton Anjain (Ebeye, Marshall Islands)

Ranton Anjain is a sixteen-year old Marshallese living on Ebeye Island, the most populous of the Marshall Islands. Although he was born on Majuro, Ranton has lived on Ebeye for most of his life, and his father, Jelton, was “born and raised” on Ebeye. Ranton appreciates that growing up on Ebeye allowed him to go swimming and fishing every day, something he realizes you cannot do in most places. Ranton also enjoys learning about his culture and his community. For Ranton, the Marshallese community is built on respect, “it is what makes us Marshallese.”



*Ranton on a fishing trip when younger.*

Ranton’s way of life on Ebeye is threatened, however. The Marshall Islands have already suffered severe climate crisis impacts and are facing complete destruction as sea levels continue to rise.

Greenhouse gas emissions of major emitting countries thousands of miles away are threatening the approximately 59,677 citizens living on 29 low-lying coral atolls, 1,156 islets, and five single islands that make up the Marshall Islands. Rising temperatures and sea levels, combined with droughts and dying coral reefs have already begun to change this island nation, and unless other countries urgently make significant changes, its islands will be unrecognizable in 40 years, if they exist at all.

Ranton has felt a lot of these changes firsthand. Ranton and Jelton used to go fishing on the weekends with a fishing trawler. But now, it is too hot to be outside for long, and the water has



*Ranton places a quadrant while studying coral.*

gotten noticeably warmer. Poisonous fish have become more common: Ranton and his dad now avoid bottom fish and explained that “red snapper from the northern part of the atoll is a ‘no-no’, but if the snapper is from the southern part it is ok.” Ranton has also seen increased coral bleaching. In 2018, Ranton participated in a program where he measured coral vitality, and found that the bleached, dead coral outnumbered living coral.



The increasing heat has brought more frequent outbreaks of dengue, which is spread by mosquitos and known as “bone-break fever” because of the pain it can cause. The dengue outbreaks during the summers of 2018 and 2019 were both grave enough for the government to declare a state of emergency. Ranton caught dengue during the 2019 emergency and his father Jelton caught dengue in 2018. According to Jelton, a six-year old child died from dengue during late summer 2019. Jelton does not remember dengue outbreaks on Ebeye when he was younger, nor does he remember the government issuing an emergency declaration warning residents of dengue outbreaks prior to last year’s.



*Ebeye Island in 1971 and 2016.*

Ranton has also experienced worsening storms on Ebeye. “In 2015, we were inside my house, my dad was off island for meetings, and a really strong wind came and opened the roof of my house. It flooded my house. I was with family, but then we evacuated to our neighbor’s house.” This storm had a profound effect on Ranton. “After experiencing the open-roof house storm, I wanted to learn how to speak in public so I could ask for help from other places.”

Ebeye has also seen significant flooding on the causeway, which connects the islands of Ebeye and Gugeegue for pedestrians and vehicles. According to Ranton, “when I was young the causeway didn’t flood like how it’s flooding today. The first time I saw the causeway flood really badly was when the same typhoon in 2015 came that tore open the roof of my house. But, even with no typhoon, the causeway still floods when the tide is really high. Pebbles and trash wash up from the side of the causeway and also from the ocean.” Recently Jelton was caught on the causeway when the flooding water breached it and felt “inundated when all the debris came in and blocked the road.” According to Jelton, “one of our high schools is located on an island connected by the causeway and students usually are forced to collect rocks and other debris from the road so they could get to and from school.”

The Marshall Islands, including Ebeye, rely predominately on rainwater for clean water: according to Ranton, “if there is no rain, there is no clean water. And this happens usually during the summer, that is when the drought comes in.” When there is not enough rain, people have to rely on the stored groundwater, which the rising sea-level is already infiltrating. “You have to boil it, and it is a bit salty.”

Ranton noticed a lot of these changes on his island before he attributed them to the climate crisis. He heard about “climate change” when he was younger, but “I thought it was a hoax. I didn’t believe in sea level rise, all those things. I just said it’s from us, Marshallese people who are the ones ruining all this, causing all this.”

Ranton attended a summer camp in 2018 where he learned about the gravity of the climate crisis, and finally understood its implications, connecting it to the impacts he had already seen on his island. “After learning about climate change and what it meant, it was pretty scary.” All of these climate harms Ranton is experiencing will only worsen, but to what extent depends on how much Greenhouse Gas the world continues to emit.

“Now I think about it every day. Every day. Sometimes in my mind I just see Ebeye sinking and a lot of people drowning.”

Ranton talks to his friends about these concerns “every day – we have a group chat. We ask each other how our islands are doing, what has happened. We talk about how hot it is and how it is getting warmer, discussing sea level rise as well.” When Ranton returns to school this fall, he wants to speak more about the impacts of the climate crisis even though there are no classes on the subject.

What worries Ranton the most is sea level rise. “It’s not the whole island that I believe is going to go underwater. It’s the parts where I see sea level rise that I worry about – mostly the lagoon side, where I’m from.”

“I don’t want to be underwater. I want future generations to experience what I experience, I want them to experience living on Ebeye. It still saddens me – I want them to experience the same things I did.”



*Typhoon Nangka, 2015.*

**APPENDIX A.8**

**Litokne Kabua**

**(Marshall Islands)**

### Litokne Kabua (Ebeye, Marshall Islands)



*Litokne weaves a basket out of pandanus leaves.*

According to Litokne Kabua, a sixteen-year old Marshallese, his family has lived on Ebeye Island “since the beginning of time.” His home is a two minute walk to the ocean, where he often goes swimming. The relationship between Ebeye and the ocean that surrounds the island is paramount: according to Litokne, “culturally, the ocean is the center-way of life.” It has allowed generations of Marshallese to travel to the other islands to connect with each other and is a major source of food.

“We use the ocean for navigation, transporting our people and supplies.” The ocean connects Litokne to his family on the outer islands where there are limited resources, and the residents need to have food and supplies brought in by boat. The ocean also provides food, and fishing is a big part of Litokne’s life and subsistence – red snapper and tuna often comprise parts of his lunch or dinner.

Now, Litokne’s way of life is threatened. The Marshall Islands have already suffered severe climate crisis impacts and are facing complete destruction as sea levels continue to rise. Greenhouse gas emissions of major emitting countries thousands of miles away are threatening the approximately 59,677 citizens living on 29 low-lying coral atolls, 1,156 islets, and five single islands that make up the Marshall Islands. Rising temperatures and sea levels, combined with droughts and dying coral reefs have already begun to change this island nation, and unless other countries urgently make significant changes, its islands will be unrecognizable in 40 years, if they exist at all. Through climate change induced sea-level rise and warming, the ocean is becoming the biggest potential threat to the existence of the Marshall Islands.



*The Marshall Islands consist of 29 low-lying coral atolls, 1,156 islets, and 5 islands.*

Fish are becoming harder to find. “My grandpa used to get more fish, like a lot more fish than the number of our family. But nowadays when we go fishing, you could come home with a bucket of nothing.”

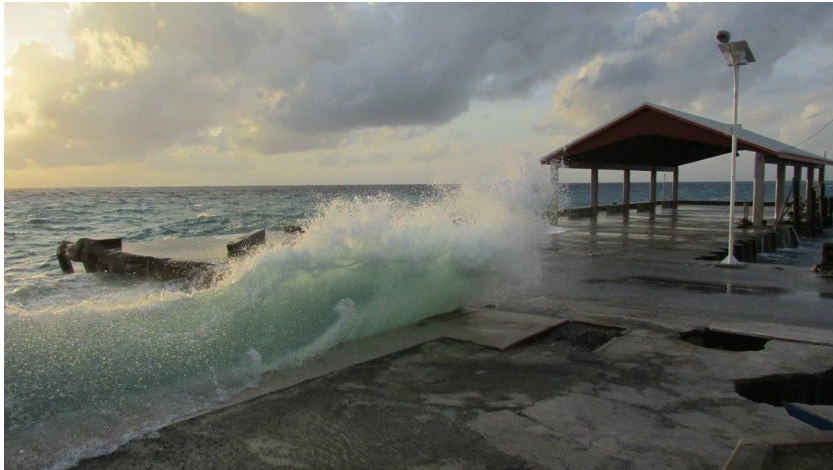


The most pressing concern Litokne has about the climate emergency, however, is the rising sea level, which threatens to submerge his home during his lifetime, and is already causing stronger storm surges and other flooding events. His stepfather, Carl, explained, “nowadays it is harder to live – it is hotter – the climate is so hot. The level of sea level rise you see, it is so crazy, it’s scary.” Litokne’s mother, Anta, worries about her family and their livelihoods. “How do we make our way of life? It has all been



*High tides creep onto a dock in Ebeye Island.*

damaged by the sea level rising. It destroys everything.” Anta’s uncles have a garden where they grow coconut trees, pandanus, taro, papaya, and breadfruit. According to Anta, beginning about five years ago, the garden floods with sea water two to three times a year, forcing her uncles to pull all of the crops out every time and start fresh. Because of the rising sea level he has seen, when Litokne thinks about his future, he thinks climate change will be hard to overcome. “The ocean might start eating up my islands, the ocean might be a lot stronger than it was before.” Anta adds “the island is getting smaller, in twenty years, a lot of it will be under water.”



*A wave crashes over a dock on Ebeye Island.*

Litokne has also noticed increasingly violent storms on Ebeye, which have caused Litokne and his family to seek shelter on the US Kwajalein Atoll Army base. Litokne explains that all the communications systems on Ebeye announce the coming of big storms with alerts, sirens, and radio announcements. Litokne recalls a particularly bad storm: “it was scary – the

ocean was really, really crazy and it was very dangerous to go through, so we had to stay on the base, overnight, just for that storm.” The ocean gets really rough during these more violent storms, and “waves smash into people’s houses,” sometimes breaching the sea walls.



*High waves overtake a home on Ebeye Island.*

According to Carl, there are also more droughts, requiring the government to take action and bring water and food supplies to the outer islands. Litokne explained, “with severe droughts and climate change impacts we are unlikely to be able to make traditional medicines, including banana leaves that are pounded to make liquid medicine. Bananas are the most common traditional medicine we make for reduction of body pain and easing toothache.” Litokne also discussed how “ground cherries (*Physalis peruviana*) and scented fern are mixed for patients to drink to treat diabetes,

which are the common uses of our traditional medicine, but with the droughts and surging rising seas, these medicines will be rarely used” as the plants used struggle to survive.

These impacts, Litokne understands, are the consequences of the climate crisis. Litokne first learned about “climate change” in school, and that it would impact his surroundings. Litokne now “knows” his home and his island “are not here forever... they will disappear, unexpectedly.” Litokne worries too that his family and community will lose a source of income from making handicrafts as palm trees and pandanus trees disappear. Despite the fact that “Ebeye might get smaller, and the waves are still eating up the islands,” when Litokne grows up, he says, “I want to live here. It is my home, there is no place other like Ebeye.” Ebeye is special to Litokne because he is part of such a close cultural community. Litokne is able to spend time with his friends, learn traditional arts, and listen to stories from his elders. Litokne feels “disappointed, and kind of sad” at the thought of losing all of that.

Litokne has worked to convince everyone he knows about the impacts the climate crisis will have on their home and way of life: “it is the first thing you see when you go outside. It is happening a lot more, a lot more . . . you cannot ignore it.” All of the climate harms Litokne is experiencing will only worsen, but to what extent depends on how much Greenhouse Gas the world continues to emit.

When he grows up, Litokne wants to work for the government so it will become more



*High waves surge over a home on Ebeye.*

active the fight against the climate crisis, reaching out to bigger countries like the United States to encourage them to help his country. If he was working for the government now, Litokne would emphasize that everyone has to take responsibility – his generation and those already in power, and they must do so immediately: “If the government does not act now, then who will? If the time to act is not now, then when will it be? So, it is now or never if we are going to combat climate change.”

**APPENDIX A.9**  
**Deborah Adegbile**  
**(Nigeria)**

### Debby Adegbile (Lagos, Nigeria)

Twelve-year old Deborah (“Debby”) Adegbile has lived her entire life Lagos, Nigeria. Debby believes the city itself is heating up and undergoing significant changes to its climate. Looking back at when she was a child, Debby’s mother Ronky recalls that Lagos used to be “surrounded by water where everyone would go to the beach all day and enjoy the natural resources, but now the industrialization and expansion has changed Lagos, making the air and water dirtier.”

Lagos is the largest city in Nigeria, covering 1,171 kilometers with over 17 million residents. It is one of the most populated cities in the world and operates as Nigeria’s economic nerve center. Geographically, Lagos is located on the West African coast where high rainfall is common and sits slightly above sea level. Its density, size of the population, and poor infrastructure makes it one of the most vulnerable cities to the deleterious impacts of the climate crisis.

Historically, with its tropical climate, Lagos had a rainy season that generally spanned from April through September, but recently with climate change, “the rainy season extends to December,”



*Flooding in Maryland, Lagos, May 2018.*

says Debby, which, apart from the obvious effects of increased rainfall, poses serious logistical and health problems. For example, Debby explains that “every time it rains in Lagos, there is flooding and the rainfall has intensified.” Debby’s mother remembers, “it used to take five hours of rainfall to flood the streets, and now it just takes one hour.” For Debby, however, the intense rainfall and frequent flooding is something to which she has always been accustomed.

Unfortunately, Debby explains that the frequent flooding is extreme, making it difficult to walk and commute by car while also increasing the spread of diseases and other illnesses.

Ronky says that although the schools do not close when it floods, the flooding makes it much more difficult for parents to get their children to the classroom, with many of them missing classes because it is near impossible for the children to walk in the high waters. Debby recalls:





*Flooding makes commuting and walking difficult and dangerous.*

“If it floods too much – it can flood up to three feet off the ground – my parents have to carry me and my two siblings, lifting us off the ground because we can’t walk. They pick me up and carry me to school, and they have to carry all of us, me and my siblings, one by one to school.”

The flooding has also caused Debby, along with her family, to more frequently contract malaria. The increased floodwater lingers in the streets, creating an influx of mosquitoes, which carry diseases such as malaria. Ronky reports that every member in Debby’s family has had malaria – and gets it at least once a year. Debby, on the other hand, gets malaria two or three times every year. The fever often lasts for three days, forcing Debby to go to the hospital to get medication, which can come at a high cost.

In addition to malaria, Debby also reports that she has asthma, which intensifies with hotter temperatures. “Whenever I have an attack it takes about 5 days to get over it, and I’m usually hospitalized.” And again, as the hospital provides Debby with “medications and injections” to feel better, the cost can be quite expensive. Indeed, Debby’s frequent illnesses and hospitalization forces her to miss school, where she has to try and catch up with her classmates. Debby exclaims, “I really feel odd about getting sick!” She is growing up expecting that every year she’ll become ill, and knows she will need to be hospitalized at least a few times as well.

But Debby’s illnesses have not stopped her advocating against the climate crisis and the effects that she is seeing in Lagos:

There is not enough awareness and efforts to address climate change. There is lots of flooding and many areas have little to no drainage and bad roads make the impacts of climate change worse. Poor electricity and power results in too many generators owned by individuals releasing too much carbon and affecting children’s health. Poor waste management increases diseases. And there is no disaster management such that many people die in floods or accidents during heavy rains.

Debby explains that the climate crisis has resulted in sea level rise and ocean surges, which threaten ecosystems and freshwater sources while also eroding the coast line in Lagos. “The houses are sinking into the sand. There are lots of places that used to be land but now they are part of the sea,” explains Ronky.



Debby explains, “I sincerely don’t think Lagos will get any better with the way we are using the environment presently. It depends on the way we start caring about our environment.” And this lack of environmental concern, makes Debby worried about the future: “I feel scared about the future considering the terrible experiences I have been through in the places I have lived where I have to wait for the rains to subside before leaving for school or stay at home at times when the rain is unbearable due to the weather condition.”

All of the climate harms Debby is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.



*Debby advocating against plastic pollution.*

As a result of these changes, Debby has become an advocate for ocean protection. Last June Debby participated in the Summit for Empowerment Action and Leadership. Through the program, she spoke to legislators in Sacramento, California, advocating for plastic reduction – which she has seen affect the ocean and marine species off the coast of Lagos. When she grows up, she “wants to become a lawyer and advocate for endangered species in the ocean that are put at risk from pollution, such as plastic waste, and the heating climate.”

To our world leaders, Debby says:

I will tell our world leaders to pay attention to the cries of their citizens about the effect of this climate change such as flooding, housing problems, food scarcity, traffic congestion due to flooding and blocked drains due to plastic pollution and the outbreak of diseases such as malaria due to mosquito bites, asthma, colds, and other diseases.

For Debby, “children can speak out to global leaders” because the climate crisis “is an issue that children are more affected by because they are helpless and forced to change things like school, home, and lifestyle due to flooding and other impacts which affects their health, family, and well-being.”

# **APPENDIX A.10**

**Carlos Manuel**

**(Palau)**

### Carlos Manuel (Koror, Palau)

Carlos Manuel and his family moved from the Philippines to Koror, Palau, nine years ago. At the time, Carlos was eight years old. The first thing Carlos did when he arrived was jump in the ocean



*Carlos swimming in the ocean with friends.*

and swim. His fondest early memories in Palau are spending full days at the beach with his family and friends and swimming in the refreshing ocean. Now, although the beach is just a short walk away, Carlos says “it’s too hot to go to the beach and the water feels like it is boiling. It’s just not as refreshing anymore.” Carlos now spends more time inside.

Palau is a small island nation of 18,000 people that consists of 586 islands, only 12 of which are inhabited. Unlike the majority of small-island states, much of Palau’s landmass is more than ten meters

above sea level. However, most Palauans live and work in the country’s coastal lowlands, as the higher ground is hilly and thickly forested. Tourism, subsistence agriculture and fishing are the main drivers of the Palauan economy.

Carlos, who is now 17, learned about the climate crisis in 9th grade from a friend. He began to understand that the climate crisis is a global issue that “is not just affecting one country but our whole planet, and it doesn’t just affect us humans.”

The increasingly hot ocean and air temperatures are not the only climate change impacts confronting Palau. Since 1993, the sea level rise around Palau has been measured at about 0.3 inches per year. Sea level is expected to continue rising, perhaps by more than 3 feet (1 meter) by the year 2100. Palau is also expected to experience more regular and intense droughts, while typhoons and other severe storms are predicted to increase in frequency and strength. Palau’s reliance on the ocean as an island nation make it particularly vulnerable to these impacts.



*Super Typhoon Haiyan passes through Palau in 2013.*

Carlos has observed many of these harms already. In November 2013, super typhoon Haiyan devastated the island of Kayangel in Palau's north. Carlos remembers that the typhoon’s

incredibly strong winds “completely wiped out the whole island so the people from Kayangel had to move to another island.”

Carlos has also noticed that increasingly high tides and storm surges have forced many people living near the beach, including one of his good friends, to abandon their homes. Sea level rise is also requiring the government to relocate Koror’s only hospital.



*Record high tide caused flooding on Koror in late August 2019.*

Intense drought is also wreaking havoc in Palau. In 2016, the government issued a state of emergency in response to one of the worst droughts in Palau’s history. The extreme drought particularly harmed traditional Palauan families who grow Taro and Tapioca for their subsistence. As part of a community education program, Carlos and his friend interviewed one elder woman who was struggling to grow crops for food and subsistence because the increasing temperature and drought have dried up the soil and depleted rivers.

Carlos has also seen coral bleaching due to increasingly warm ocean water temperatures. Although some reefs around Palau are thriving, many are unhealthy.

Carlos is unsure whether he will be able to live in Palau as he gets older. “If no one tries to listen and make a change and take action, this island will just get worse every day. If no one takes action we won’t have a place to live in.” All of the climate harms Carlos is experiencing will only worsen, but to what extent depends on how much Greenhouse Gas the world continues to emit.

Although he is worried about the future, he is also hopeful. “I hope everything could change so that it doesn’t get worse than it is now. That’s why I’m trying to do this work to make the world a better place”. Carlos has become a leading advocate in his community for protecting the ocean and taking action against the climate crisis. He is motivated to spread awareness of the global heating to other children and adults so that “we can do more work to stop climate change and make this planet a better place to live in.” Carlos believes:

“We all have the right to enjoy our planet and we should all protect that right. Our generation is trying to prevent climate change for our future generation.”



*Carlos attending a Climate Youth Summit in 2018.*

Carlos recognizes that world leaders need to do much more. “I would be disappointed with myself and our leaders for not taking action. I would feel I failed myself for not having those leaders take action because we are kids and we have a voice to make the change, but we don’t have the power to make it. We could say everything we want to say, but it’s still in their hand to make those changes.”

**APPENDIX A.11**  
**Ayakha Melithafa**  
**(South Africa)**



### **Ayakha Melithafa (Cape Town, South Africa)**

Ayakha Melithafa, who is 17 years old, lives in Eerste River on the outskirts of Cape Town in the Western Cape province of South Africa. Her mother Nokulunga lives in the Eastern Cape Province of South Africa, some 1000km from Cape Town. Nokulunga is financially supporting Ayakha, her siblings and her cousin through various work, including farming.

The Eastern Cape, like many parts of South Africa, has been badly affected by drought, explains Ayakha. “Climate change has affected my mom and me because of the terrible drought it is causing. If they can’t plant in the Eastern Cape and the livestock can’t eat and drink, my mom and other farmers can’t earn any money”.

In Cape Town, Ayakha describes her own experience with the climate crisis. Between 2017 and 2018, Cape Town saw a period of unprecedented severe water shortage, compounded by dam levels that had been declining since 2015 and very limited rainfall. In early 2018, Ayakha, along with the other residents of Cape Town, prepared for “Day Zero” - the day when municipal water supplies would largely be switched off and residents would have to queue for their daily ration of water. This would make the City of Cape Town the first major city in the world to potentially run out of water.

According to Ayakha, “the water crisis was really bad because we always had to buy water. At home we had to take shorter showers. We had to water our garden less or not at all. We had to be really cautious so we don’t reach Day Zero. There were a lot of water restrictions. There are other people who grow their own food where I live, and it was really hard on them. It was hard to see them unable to feed their families because of the water restrictions.”

During the water crisis Ayakha noticed that the quality of the fresh produce she was used to purchasing from local vendors had deteriorated or was no longer available. Accordingly, she has had to travel by bus much more frequently to get to a supermarket to buy food for her and the family, at higher prices. She also is incurring additional expenses for the bus fare and has concerns for her personal safety when taking the bus in the evenings, especially after dark.

The climate crisis has also brought intense changes in weather patterns to Ayakha’s home. A few months ago, her area suffered severe rain and flooding. Ayakha explains that this flooding caused delays of 30 minutes to an hour in getting to and from school on the bus. The floods also affected the water quality, and Ayakha knows many people who became sick from the drinking water. Many of her friends, who live in informal settlements, experienced water damage to their homes and personal items. The houses in informal settlements are generally made with poor quality materials, with little or no access to adequate services and sanitation.

Ayakha has noticed that a lot of people, especially farmers, are migrating from rural areas to live in Cape Town because of “climate change”. Ayakha notes, they are hoping to avoid flood disasters and drought – “they are looking for something more stable”. Ayakha says that in some ways, the influx of people migrating to Cape Town is affecting her negatively, although she enjoys the

diverse mix of people. “It is also hard on infrastructure. The sewage system cannot handle the influx.”

South Africa is extremely vulnerable to the impacts of climate change - its existing water scarcity is predicted to intensify in many regions and a global average temperature increase of 2°C translates to up to 4°C for South Africa by the end of the century. In the last five years, South Africa has experienced record temperature highs, droughts, devastating floods, and fires. This has cost the country billions; and has impacted food prices and exacerbated the already high poverty levels in South Africa. These consequences are only expected to worsen. Climate change has already made events like the 2015-2018 Western Cape drought three times more likely. With an additional 1 degree warming, the chances of the drought recurring are again tripled.



*Ayakha participating in the Project 90 by 2030 YouLead Initiative.*

“The changes in the weather make me feel sad and angry. There are things you can do about this, but no one is doing anything. It is hard for young people to tell adults what to do, and to get them to listen. Climate change affects us as youth more because we still have a life to live. People who are older aren’t paying as much attention because they will not be as affected. They don’t take us children seriously, but we want to show them we are serious. We want to show them we are dedicated and we know what we are talking about. I want

to make sure that I will be part of the solution to climate change, and not just part of the people who are causing the problem.”

The changes around her have led Ayakha to become a dedicated climate activist in her community. She is part of the Project 90 by 2030 YouLead initiative, and acts as a recruitment official for the African Climate Alliance. Ayakha believes “we, as society, have a chance now to change things”.

Ayakha shares her knowledge and experiences in climate activism with the people in her community, and tries to show people how to live with a low-carbon footprint, through calling and participating in regular meetings to discuss relevant climate and environmental issues; and through initiatives supporting practical solutions in her community such as planting vegetable gardens, building solar-powered phone chargers, and waste use and recycling initiatives.

For Ayakha, a future impacted by climate change is a “miserable future”. “I don’t want to be stranded at home not able to go out because it is too hot. Or deal with flooding or drought. It is worse for the people living in poverty. They have to live with and are most vulnerable to the effects of climate change.”

All of the climate harms Ayakha is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

Ayakha would be sad to see the natural world, including the animals and the Fynbos, a small belt of natural shrubland or heathland vegetation, in the Eastern and Western Cape provinces, around her impacted by climate change. It is anticipated that as the Western



*Ayakha advocating against climate change with her classmates.*

Cape, where Ayakha lives, becomes hotter and drier, with less winter rainfall and more irregular rainfall events, this will have severe detrimental effects on biodiversity, and result in significant species losses in the Cape Floristic Region.

Ayakha doubts that she would want to have children in the future because of the environment they would grow up in, and the higher costs of living and food. “I wouldn’t be able to live the life I want”, she says. “I wouldn’t enjoy my future very much knowing that there is this climate change future”.

“If I could speak to the President of South Africa I would ask to have mandatory teachings for climate change in schools, and make everyone learn about climate change and the solutions. I’m tired of people saying ‘I don’t know if that is true’”. Ayakha would also ask the President to implement ways to reach 100% renewable energy in South Africa, and she would ask the President and other global leaders to stop using fossil fuels, especially coal, and instead to use technology to fight climate change.

# **APPENDIX A.12**

**Ellen-Anne**

**(Sweden)**

### Ellen-Anne (Karesuando, Sweden)

Ellen-Anne is an eight-year-old living in Karesuando, Sweden, 200 kilometers north of the Arctic Circle. She is Swedish and a member of the Sami community. The Sami people have lived in the Arctic regions for thousands of years in what is now Norway, Sweden, Finland and Russia. The Arctic region where the Sami people live and carry out reindeer herding, and other livelihoods and cultural practices connected to nature is called Sapmi. The Sami people, particularly those involved in reindeer husbandry who today depend on reindeer for their livelihood, live close to nature and must be aware of changes in nature. They must adjust their lifestyle to assure the welfare of the reindeer. They value the land and the natural order in cultural and spiritual terms, as well as economic terms. Reindeer are a central part of the Sami heritage. Sami people have been taking care of reindeer in the Sapmi for thousands of years.

The Sapmi and the Sami livelihoods and culture are severely threatened by the climate crisis. The global heating in this part of the world has reached a 2°C increase since the onset of the industrial era. The disruption of the seasons and the changing climate in the Sapmi are threatening the Sami's traditional methods of reindeer herding. Reindeer are wild animals and the Sami migrate with the animals into the lowlands in the winter and to the mountains in the summer. However, in recent decades the increased warming and increased rains have severely threatened the winter food supply. Winter rains, previously uncommon, now freeze to form an impenetrable ice cover beneath the snow, on top of the lichens and moss essential to the reindeer's survival in the winter. The result is increased costs of reindeer herding, geographic displacement of the reindeer herds as they search for food, and the need to supplement the reindeer's entirely natural sources of food. All of this taken together poses a fundamental threat to the Sami people's livelihood that has existed for thousands of years.



*Ellen-Anne leading her reindeer. Kebnekaise Mountains in the background after a glacier has melted. September 2019.*



Ellen-Anne belongs to a reindeer-herding family. Her parents belong to different Sami villages on the grounds of birthright. Her mother Susanna explains how the work with reindeer was passed down to her from her father.

I was very little when I was with him the first time, but I don't know if I was too much help then. I first went in the summer when I was maybe-five years old. The children are usually with the parents except when the children are in school. We brought our own child when she was only two months old up to the mountain when we were working with the reindeer. The reindeer are an intrinsic part of our whole lives and how we live.

Ellen-Anne, now in the second grade, also loves to go with her parents when they are reindeer herding. Ellen-Anne says, "I like to go up into the mountains with the reindeer because they are such beautiful creatures, and I have learned to throw a lasso around their horns." Susanna further explains the importance of reindeer herding to their way of life:

The reindeer is our life. It's everything. We live with, and we live off the reindeer, and I can't even imagine a life without them. Reindeer herding is our livelihood, our economy, our culture, our way of living for many, many generations. We and the reindeer depend on each other. I plan to be a part of reindeer herding my whole life and will do everything I can to assure my children can continue with it.

Susanna and Per-Jonas (Ellen-Anne's father) have already introduced their daughter Ellen-Anne to reindeer herding, just as they were introduced to it:

It's part of bringing the children up, they are usually part of most of the work we have around the reindeer. It's maybe in the winter when they are small that we protect the children from the extreme cold weather, but that's their life too. The children are intimately connected to the life of living with the reindeer, and they learn



*Ellen-Anne feeding calves placed in a corral due to poor pastures and deep snow.*



this culture by doing and helping out. They have to be there to see how it's happening, how do you move the reindeer, how do you help them.

Susanna explains that in Sampi and in the Sami culture, there are eight seasons, not four. In each season there are different tasks to be carried out to take care of the reindeer, and each season offers different plants and lichens for the reindeer to eat for their survival, and the reindeer graze in different areas in different seasons.

A normal good climate used to mean that we get a good fall that prepares the ground for good winter grazing. A normal good fall is dry and cold before the first snowfall that covers the plants and lichen on the ground. These frozen plants are accessible as food to the reindeer who can dig down through the snow.

But nowadays, we get warmer temperatures, and more rain that cause the soil and snow to get really wet, and then the snow freezes to ice, and the food reindeers need is now covered by ice. Even if reindeer can dig down in the snow, they can't get to the food because of the ice layer. This is a serious problem and then we have to drive out into the lowlands on snowmobiles with food supplements for the reindeer to survive in the winter.



Because of this new climate phenomena, the reindeers now need to start walking to other areas to find food. In the old days, there can be more reindeer in an area for a longer time before they would start migrating to another area. So now they have move around more when they also would need the time for more winter rest. We want them to be in the same place, but the reindeer start to move because they don't get any food.

*Ellen-Anne and Susanna driving food out to reindeer due to ice-locked pastures. Winter/ Spring.*

This winter food situation is aggravated by the disappearance of the old forests because of new deforestation type logging. Old pine forests have a special kind of lichen hanging from the trees that reindeer eat in the winter, but that lichen does not grow in the newly planted trees.

This all creates so much more work and costs for the reindeer herders – the reindeer herders have to work longer days, have to drive around much more with their snowmobiles, and the expenses for fuel has increased a lot. The climate crisis for

us who live with reindeer is like when you throw a rock in the water, the problem just spreads as ripples and cause many new types of problems.

Susanna explains that the elders in the community have intimate knowledge of the 8 seasons that relate both to when is the right time to, for example, start moving reindeer, and how to safeguard the health of the reindeer herds. Ellen-Anne says, “my grandfather knows so much about the reindeer.” The value and use of this knowledge is threatened by the climate crisis. According to Susanna:

Another problem with the disruption in the climate and the seasons in the Sami culture is that we are losing our special need and use of the knowledge of the elders. They knew all these special calendar dates over the whole year, if it’s cold this day, or if it’s very wet this day, that will forecast the weather or what to do with regards to herding reindeer. they call it marking days. They knew these days and recognized them but all that kind of deep knowledge of nature that they knew so much about, does not hold up anymore. It doesn’t make the same sense now with the disruptions. The wisdom they had, we needed it, but now we have lost our ability to know and predict the seasonal changes.



*Susanna earmarking the calves to identify the family it belongs to.*

Ellen-Anne already knows what she wants to be when she grows up. “When I grow up, I want to work with reindeer.” However, Susanna is seeing in her own lifetime the severe changes in the Arctic environment, and she worries what life she can pass on to her children and future generations.

It has become more difficult, and I worry about the future. I wish that my children will continue to be able to herd reindeer, but reindeer are not like cows or cattle, they must wander freely in nature, and to be feeding them supplements is not going to work very well. I can’t see how that situation can work. The winter is the most valuable time for the reindeer, that’s when they need to have peace and rest and be more stationed in one place and eat; but now they are kind of forced to be moving. It’s not only an economic problem, it is not only about the economic value of a reindeer, it’s the whole culture. The value is in the culture of living with reindeer and in nature- all of which is being threatened for the first time in thousands of years.

Susanna explains that climate change science is warning us, and she and the Sami people see the warnings in their environment. All of the climate harms Susanna and Ellen-Anne are experiencing will only worsen, but to what extent depends on how much Greenhouse Gas the world continues to emit. According to Susanna,

Climate change is real. It is so hurtful to listen to others in authority say it is not real because we are affected by it. It's not a coincidence. The normal winters feels like they are gone now. We see it and our elders see it every season, every year.

# **APPENDIX A.13**

**Greta Thunberg**

**(Sweden)**

### **Greta Thunberg (Stockholm, Sweden)**

Greta Thunberg is a sixteen-year-old resident of Stockholm, a densely populated city in Northern Europe that as a result of the climate crisis has shifted from a cold-temperature climate to a warm-temperature climate with fewer snowy winters. Stockholm's freshwater reserve, provided by its third largest lake, Mälaren, is threatened by predicted sea water rise to be contaminated with salt water from the Baltic Sea.

When Greta was eight years old, she watched a documentary in school on something called "climate change." She and her classmates were terrified. But, when the documentary was over, her fellow students seemed to move on, and their worries shifted back to less existential concerns. For Greta, it was not so simple. This knowledge changed her entire life. Once Greta understood the climate crisis, she could not "un-understand it."

"I remember thinking that it was very strange. That humans who are an animal species among others could really be changing the earth's climate. Because if we were, and if it was really happening, we wouldn't be talking about anything else. As soon as you'd turn on the TV, everything would be about that."

Greta began researching the climate crisis, reading everything she could over the next few years. To her, the crisis was akin to a world war. Greta, however, could not understand why none of the



*On August 20, 2018, Greta Thunberg began striking for the climate outside the Swedish Parliament.*

adults were acting to prevent it. "How could we just continue like before? Why were there no restrictions? Why wasn't it made illegal. To me, that did not add up. It was too unreal. So when I was eleven, I became ill. I fell into depression, I stopped talking, and I stopped eating. In two months, I lost about 10 kilos of weight." Moved to tears, Greta later explained that already, the impacts of the climate emergency are deeply felt: "over 200 species becoming extinct every single day, erosion of fertile topsoil, deforestation of our great forests, toxic air pollution, loss of insects and wildlife, the acidification of our oceans – these are all disastrous trends being accelerated by a way of life that we in our financially fortunate part of the world see as our right to simply carry on."

Educating herself and others about the climate crises became Greta's coping mechanism. The climate crisis remains an ever-present fear, but taking action has helped her manage: "I thought about this very often – I had climate anxiety. But now I don't really have that anymore the same way, because it has just become such a normal part of



my life that I don't even think about it. This is just sort of a full time job. . . But of course, I sometimes get worried and scared about how the future will be ... I don't know how it will become... I do know that change needs to happen now if we are to avoid the worst consequences.” Greta began to focus on what she, as an individual, could do – and in taking action began to combat the feelings of despair and anxiety that at first overcame her.

Recognizing how much of a carbon footprint each person has, Greta minimized her own. Greta chooses to travel in the most-carbon neutral method available, such as trains and subways whenever possible.



*“School Strike week 52.” Greta Thunberg on the Malizia II, a solar-powered racing yacht, crossing the Atlantic Ocean.*

Greta recognizes that while the climate emergency has affected her in a personal manner, it is a “very global problem,” affecting some people more than others. Speaking with children from countries in the global south, Greta was able to confirm what she feared: these children are facing more extreme weather, food shortages, and are experiencing water shortages. Greta sees this as profoundly unfair. Countries in the global south have generally contributed the least to the climate emergency, and yet they will be affected the most. According to Greta, climate justice means that everyone should be protected from the impacts of the climate

crisis, no matter where they live or what their economic status is.

Greta worries what the future will look like – “it is not just the weather. [The climate emergency] means also, lack of food and lack of water . . . places that are unlivable and refugees because of it. It is scary.”

And yet, despite these weighty concerns, Greta persists. Over the course of barely a year, Greta has become a global ambassador for climate change, speaking out despite backlash and the dramatic change wrought on her life. In August 2018, Greta began protesting outside of the Swedish Parliament during school hours with a sign painted with the words, “Skolstrejk for Klimatet” (“School Strike for Climate”). She has continued striking every Friday, inspiring hundreds of thousands of children worldwide to follow her example. Like so many children facing this crisis, Greta feels that she has had to educate the world on this issue that adults should have tackled decades ago. “The climate crisis has already been solved. We already have all the facts and solutions. All we have to do is wake up and change.”

Although Greta has expressed that she just “wants to be a kid,” she is determined to continue protesting: “I am going to do everything I possibly can as long as there is still time to do that, and I guess I am waiting for something to happen – a change. And I am trying to – because I know that change is going to come – I mean – it *has* to come – so I am just trying to help push it to happen sooner because I know there is no second option.” For Greta, activism is the only way to gain a sense of agency. She hopes that others who are also scared of what the future holds will join a movement and try to do something. “That is the best medication and the best cure against anxiety about this and feeling helpless.”

The climate harms that Greta feels so personally, and that are impacting so many children around the world, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

“What we do or don’t do right now will affect my entire life and the lives of my children or grandchildren. What we do or don’t do right now my generation can’t undo in the future.”

# **APPENDIX A.14**

**Raslen Jbeli**

**(Tunisia)**

### Raslen Jbeili (Tabarka, Tunisia)

Raslen Jbeili grew up in Ouechtata, a town in north-western Tunisia nestled between the mountains and the Mediterranean Sea. Seven years ago, his family moved to Tabarka, a coastal town in north-western Tunisia, close to the border with Algeria. Tabarka is a small town with natural beauty, well known for its beaches, vibrant coral reefs, and easy access to the extensive cork-oak forests of the Kroumirie Mountains.

Tabarka usually has mild and dry summers, and rainy and cold winters. Raslen, who is now seventeen, is worried though. The climate in Tabarka has changed considerably the past few years.

“Tabarka used to have four distinct seasons,” Raslen and his mother, Chadhlia recall. “Now we have two main seasons—summer and winter—which is completely different from before. Or we can have four seasons in one day! In February we can have very hot days, which is very abnormal. We also have been getting a lot more rain. But mainly, the weather is getting hotter and hotter, and winter is starting later than usual.”

Summers have been extremely hot, with temperatures exceeding 40°C. “We can’t go outside,” says Raslen. “We will melt if we go outside.”

Wildfires are also increasing. Raslen participates in the Access Program, a school program that allows him to research climate change and other environmental issues affecting Tabarka. Through his research, Raslen documented 146 fires in 2017, a dramatic increase from the 37 he documented in 2016. One fire last year came a little too close for comfort. “We heard screams and yelling in the night,” he recalls. “I looked up and saw a huge fire approaching our home and we could do nothing. We just prayed for the fire not to reach our home. Although we were spared, it burned down many of our neighbor’s homes.”

Over the past two years, Tabarka has also experienced heavier rainstorms that flood roads and buildings. When it rains intensely, Raslen’s school floods because it is located in a low-lying area surrounded by wetlands. Sometimes the floods submerge the school up to four feet. Raslen explains, “When we have consecutive or



*Raslen's school flooding from heavy rains.*

heavy rains our school floods and closes. I don't want to miss school, and last year we had no school for a week." In one terrible incident, Raslen recounts how overflowing rivers fatally swept away some school-children on their way home from school.

Although more intense rains are occurring, the climate has gotten drier. Tunisia, which is a water-scarce country, is particularly vulnerable. Over the past few years, drought has threatened the



*Raslen participating in the Access Program cleaning litter in Tabarka.*

country's water supply. Tabarka, which typically has more precipitation than most of the country, has also experienced frequent supply disruptions. "The water is shut-off without any notice, sometimes for hours, sometimes for days," laments Raslen. "Last year we had three days without water. Once it is shut-off, we don't know when it will return." Raslen and his family have had to buy water in these situations, making it "too hard to cook, shower, and clean."

Raslen has also noticed changes to the sea. "The water is much hotter than before," says Raslen. "It is too hot and not refreshing." The storm surge is also much higher. For the first time that Raslen and his family remember, a storm pushed the tide and waves above the rocky barrier protecting the town, flooding and damaging restaurants and other buildings situated near the sea. "This never happened before. The tide came up four to five meters, submerging the restaurants and

cafes in the harbor."

All of the climate harms Raslen is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

The changing climate is deeply affecting Raslen. "I sometimes have nightmares that climate change is destroying our world. I am very worried about the future. If we don't do something, maybe we will face extinction. That is scary." He adds, "It is not fair that my generation has to experience this."

Raslen is also uncertain he can stay in Tabarka. "In the future, I think we will be suffering more and more. We would have to move away from here if we don't solve the problems we are facing." He questions whether he can have children. "I am worried about having children without stopping the threat of climate change. I don't know what will happen to my children. I want them to live as comfortably as possible."

"Unfortunately, governments are ignoring us," says Raslen. With regard to his government in particular, Raslen says, "they are more concerned with politics than with environmental or social



issues as they try to build a country based on democracy after the revolution.” But Raslen notes that although the Tunisian government is trying to rebuild itself to become a strong nation, it cannot ignore the imminence of the threat of the climate crises: “the problem is we don’t have the years to wait.”

As to world leaders, Raslen states, “they are careless about climate change in general. I would tell the leaders that if they are humans, they will do anything to stop climate change because if they don’t their children will be suffering.”

Yet, Raslen is “hopeful we can make a change. It is our duty as children to do anything no matter the cost to save our planet and to live in a safer world.”

# **APPENDIX A.15**

**Carl Smith**

**(USA)**

### Carl Smith (Akiak, Alaska, USA)

Seven years ago, Carl Smith, a seventeen-year old Yupiaq, moved to Akiak, Alaska with his family after spending the first ten years of his life in Anchorage. The Yupiaq of Akiak, are an indigenous Tribe that live in southwestern Alaska next to the Kuskokwim River. The river and its surrounds are teeming with biodiversity, including dozens of species of fish and animals.

The Akiak are a self-sustaining people, who have practiced traditions of subsistence hunting and gathering for as long as they can remember. The Yupiaq hunt moose, caribou, rabbit, deer, beaver, muskrat, and occasionally, porcupine. They fish lush fish, black fish, and especially salmon. Hunting, fishing, and gathering are integral to maintaining their livelihoods and the traditional cultural and spiritual practices passed down from their ancestors for generations. Carl cannot imagine living anywhere else. “Everyone is our family here. Our parents taught us to respect our teachers, adults, the elders especially whenever they need it. It’s like a big family here. Everyone is friends and cousins. Everyone helps each other out.”



*Smith family, 2019: (clockwise) Dylan, Carl, Kimberly, Clifton, Eva, Keilani, Harper, Brody.*

Carl appreciates how much he has learned about Yupiaq traditions since moving to Akiak. The elders in the Tribe educate the younger generations about cultural practices and the importance of fishing and hunting. Carl’s uncles, grandfather, and father have taught him hunting and fishing, and the traditions surrounding these generations-old practices. “They teach us discipline and to respect everyone. It’s really important because when we get older, we will have to teach our kids how to do it so they can survive in the winter.” Carl is also hoping to renew old traditions, including starting a Yupiaq dance group in Akiak, a tradition that has been lost, along with the Yupiaq language, to the younger generations, although Carl’s grandmother is teaching the Yupiaq dance to the children. Carl’s mother Kimberly explained that the dance tells stories of hunting and fishing.

The sharing of harvests with elders and others from within the community is also a key component of maintaining and strengthening tribal and communal cultural and social connections. Carl explained that there is a “first catch” celebration when a young hunter catches their first animal. The animal is butchered, and the young man will give all of it away to the elders who can no longer hunt for themselves – this is called “*payugteq*”. After the food is given away, there is a village feast. Carl’s first catch was moose– “I was thirteen or fourteen.” Moose, Carl’s mother, Kimberly,

explains, are special: “when a moose presents itself that means the creator is giving it to you – that the moose is giving itself to you. You have to be respectful to the catch because it gave its life to you.”

“The main thing is to respect your catch,” Kimberly continued. “Whether it is fish or meat, the entire animal is consumed; even the fish guts are used to make fermented fish heads.” There is no waste in the preparation of the game animals that Carl and his family bring home. Kimberly explains that, “they eat everything, so nothing goes to waste, except the guts in the mammals. They eat the stomach, the liver, the heart. “My mom cooks the moose nose and she cooks the brain and the hooves, but the men don’t usually eat the hooves,” Carl explained, “because it is bad luck.”



*Kimberly Smith, holding king salmon, 2019.*

According to Kimberly, while the men go out and hunt, the women take care of the home. “I learned a lot from my grandma and my mom. I learned how to cut fish, how to make fur booties - *kameksak* – and fur hats – *malakais* – they also taught me how to prepare food, how to butcher a moose, how to process meats and anything that the men bring back for us.”

Wild berries are also critical to the Akiak diet. Salmon berries are used to make *akutaq*, eskimo ice cream, and *mak-aq*, yogurt with berries. The berries are also used in dishes with liver, fish, and eggs. When Carl’s family lived in Anchorage, his grandparents worried where they would get their berries. Kimberly explained “when we lived in Anchorage, we didn’t know where to go to pick berries. And my parents would ask me where I would pick berries, and I would tell them that I had



*Carl cutting red salmon, 2019.*

to pick them from COSTCO.” It is important to Kimberly to be able to pass along not only the traditional dishes, but also gathering – “It is not only me – it is my mom teaching my kids and I’m constantly getting direction from my parents on how to cook certain foods or how to make something. It’s really important for me, even if they don’t have these things, that they learn about them at least.”

The changing climate as imperiled all of these traditions. Carl said “there hasn’t been a lot of snow in the winters, and the berries need the water from the snowmelt. It is starting to rain during the winter, though, and it never used to. It used to get to -30 or -40 and now it stays in the teens.” The summers are hotter too. While the summer temperature used to stay at about 70 or

80 degrees Fahrenheit, now it is getting as hot as 105 degrees Fahrenheit, something Carl and Kimberly do not remember happening in the past.



*Carl and his father Clifton  
returning home with a moose,  
2019.*

Hunting and fishing are becoming more difficult. Caribou, a staple in Yupiaq diets, has become more elusive. Last year, Carl's family did not catch any caribou, which only pass by the Yupiaq hunting region from November to December each year. Carl explained that the river must freeze solid to allow the hunters to access the land on the other side of the river with their snowmobiles where the caribou pass through, and last year it did not get cold enough. According to Kimberly, by mid-November, the Kuskokwim river would be frozen solid, and that is when the men would cross the river on snowmobiles to hunt the caribou, but now, in November, "they are still using boats."

The rising temperature has also affected the men's ability to fish, a large part of which is done on the ice during the winter. Traditionally, "we used to go on the river and set fish nets and fish traps," Carl said. But now, with the river no longer freezing solid, fishing has become dangerous. "One of my buddies fell through the ice," Carl said.

Kimberly expanded, "usually we are good to travel on the river through end of April, beginning of May – but this last winter we had five people fall through the ice and two didn't survive. You can't go up and fish during the fall time and winter time because the ice is thin." Carl's family used to set their traps in the winter when the river freezes over, but that is becoming harder, and more dangerous, to do.

Carl explains that "we mainly collect our food during spring and fall and we need it during the winter. In the village, most families aren't doing good financially and we need it during the winter so that we don't have to buy it from the store." However, fishing in the winter have become even more important because summer fish, especially salmon, are also becoming harder to find. Fishing regulations in the summer restrict how much chinook, a type of salmon with a higher fat content than any other fish, they can catch. According to Kimberly, these "fishing regulations make it harder for us to fish in the summer and the salmon count is a lot lower than it used to be. This summer, we noticed fish that had died and were just floating in the river."



*Carl's grandfather Sammy Jackson,  
working on a fishing net, 2019.*



In preparing the catch of fish the men brought in this year, Kimberly said: “We’ve noticed this year the fish were smaller and there were some fish that when we cut them, there was a *stink*. When women cut fish, we know how they smell and look. Because we clean fish every day; when I noticed a really bad odor coming from the fish, I moved them away from the good fish to dry them and feed to the dogs. Some of the fish also have parasitic looking things in the meat. I’ve been cutting fish since I was seven or eight years old, and that’s about 30 years, and the last few years the fish were like that –with the parasites. This is the first year we noticed stink fish. We never had that smell before. And there is one family that will not eat their salmon because they are scared to eat it.”

Even though Kimberly and her children have been able to pick their own berries since moving back to Akiak, that tradition is also under threat. This past July, when she and her children went berry picking, they noticed a new kind of caterpillar on the plants. Carl said, “they were yellow and black with spiky hairs, and they were on every salmon berry, every stem, eating the salmon berries.” According to Kimberly, “everyone came home with lots of bumps on their bodies and they turned into this puffy – I don’t know it was so gross. We had to treat the kids and it took 3 weeks.” Carl said he still has scars from the scabs he got from touching the caterpillar’s hair, and “my younger sister went to the hospital. The bumps were like the size of her chest and stomach.” Kimberly explained that while her two year old daughter had to be admitted to the hospital, all of her children had to make multiple visits to the clinic, and four out of six of her children had to be put on antibiotics. “It was really bad.” Kimberly looked up the caterpillars afterwards, because she had never seen them before. She read a newspaper article describing the caterpillars as invasive to the area, and not usually seen so far north. “I’m not going back to that place again, I’ll have to find a completely different place to get my berries,” Kimberly worried. “I’ll probably have to go further away, there is no way I’m going to go back there.” Carl added she will need to find “a colder place.”



*Invasive caterpillars,  
2019.*

Now, because her family is catching and gathering less food, Kimberly has to buy more food for her family than she used to, which is an added cost and less-nutritious. The Yupiaq usually do not buy or sell goods; instead they trade with others for items they need and cannot get, and so shopping for food is atypical. “Because I have a huge family, we usually relied on one to two moose per year, one to two caribous, and a whole lot of fish. Last year we were only able to catch one moose, so I catch myself having to buy processed meat when I don’t want to. Because what we eat is what we catch, and I’ve noticed that we’ve had to buy a lot of store bought food – even when I was little I grew up eating the Yupiaq food off the land, but now...” Kimberly added,



*A fish camp balances precariously on the edge of the Kuskokwim River following massive overnight erosion, May 2019.*

“people are starting to garden more to get their vegetables, but I would rather feed my kids moose and caribou and fish than other things.”

The Akiak are also confronting other climate-related threats. The Kuskokwim River is eroding because of excess rain, the breaking up ice on the river, and unusual high winds. According to Carl, because of “south winds in front of the villages – they get three to five foot waves and it crashes against the river bank and it takes away sand and the bank starts falling over, and there is starting to be little cliffs. This year in May sixty feet eroded

and our fish camp got lost in the erosion.” Kimberly explained, “we lost a lot of riverbank. There was a spring storm where the water was really high and overnight, there are several houses now in danger of falling into the river, so they are working on getting those houses moved. They placed sand bags as a temporary measure to stop the erosion from happening, but when we have strong storms that pass through, it will erode more. All that I knew growing up is gone.”

Carl also felt the impacts of a forest fire in July on a nearby mountain. “There was a big forest fire and the smoke went through to the river and we could barely get the boat around. I breathed in the smoke, it was hazy outside and the air smelled. It lasted for about a week until the wind changed, and the smoke blew away. Last year when this happened it pushed more animals towards the village; this year there were wolves at the airport.” All of the climate impacts Carlos is experiencing will only worsen, but to what extent depends on how much Greenhouse Gas the world continues to emit.

All of these changes signify to Carl the loss of his way of life. “Climate change might change everything – how we feel, how we hunt. It is scary because if I have kids, I want them to live like I did – to hunt, fish, gather. I want to teach them but I’m scared because there might not be any more subsistence. There will be less fish and there won’t be any more ice in the winter, and it will be warm, and it might not be the same. I feel scared, like we’ll have to adapt to climate change, and teach them a different way.” After living in the city for part of his life, Carl is not hopeful that the Yupiaq would be able to maintain their culture and traditions if they did not live off the land in Akiak, like they have done for generations. “They might learn a little bit of the lifestyle, but they won’t understand. I’m worried because I feel like I might have to live in the city to find a job.”

For Kimberly, “It’s scary for me to think that I’ll have grandkids that I won’t be able to teach how I grew up – how to cut fish, how to put away moose and caribou and to know that the home I’ve always known is slowly eroding and fading away and it is going to be gone. I wish more people cared about climate change – I’m hoping that people who otherwise wouldn’t know what climate change was; I want them to know that the way of life that we’ve lived for thousands of years is coming to an end. If we ruin it, there is no going back. We’re destroying our world and it seems like not enough people care about that.”



*Over 60 feet of the Kuskokwim River eroded in one night in May 2019.*

Carl added, “I hope this will change it. Our culture is dying slowly, and our hometown is eroding and there might be no more villages, no more Yupiaq. There won’t be any more natives. If I could, I would tell the United Nations that it is hard to live here because everything is changing that we need to teach our kids how we lived, and to teach them our way of life. If the world leaders listen to us, children can make a difference in this world, because we’re the ones that are going to be affected.”

# **APPENDIX A.16**

**Alexandria**

**Villaseñor**

**(USA)**

### Alexandria Villasenor (California and New York, USA)

It was less than a year ago that Alexandria Villasenor, a fourteen-year old living in California first understood what it meant to be impacted by the climate crisis. Alexandria's hometown, Davis, California, is located about an hour away (about 100 miles) from Paradise, California – where in November 2018, one of the deadliest wildfires blazed across 153,336 acres, destroying nearly 14,000 residences and killing about 85 people. It took firefighters close to twenty days to put out the fire. Global heating is contributing to the increase in wildfires. Significantly, over the last 100 years, California has warmed by about 3°F (1.7°C). As a result, the hotter climate dries the plants and soil, leaving shrubs, grassland, and trees in California prone to burning.

The black smoke clouds and ashes from the Paradise wildfire effected areas hundreds of miles away. Before any news of the wildfire had been released, Alexandria remembers feeling as if needles were pricking her chest. Indeed, the toxic clouds easily reached Alexandria's home in Davis, California As the fire spread, Alexandria recalls:

I would wake up nauseous from all the smoke because the smoke was seeping into our house. We had rolled up wet towels and put them under doors and windows to keep the smoke from coming in. Because I have asthma, it was a really scary situation.



*Smoke from the 2018 Paradise wildfire spreading across California.*

This experience was so distressing for Alexandria that she “compartmentalized” those traumatizing memories, and only recalled them after recently locating a journal she had kept during the frightening wildfires. She remembered:

It was really scary. At nighttime I'd sleep next to the air filter. I'd get a wet washcloth and I'd have to keep it over my face because the smoke was preventing me from actually sleeping . . . I'd have sleep deprivation because I'd be so worried to fall asleep and I would have panic attacks.

Because of the deadly air quality and her quickly deteriorating asthma, Alexandria fled to New York City, where her mother was living. An excerpt from her journal just before she left for New York City reads:



12:35 AM | 11/29/18

It's technically the next day but I'm still counting it as Monday. So, it's a good thing I'm leaving because I smell smoke inside the house. I have a cold washcloth over my face but I still feel sick. Smelling in the smoke gets me anxious. Earlier I had a panic attack, it wasn't as bad as others but still not the most fun. With me getting like this I'm so scared to go on a plane by myself. I feel like crying rn honestly. I'm holding it in though.

*"It's technically the next day but I'm still counting it as Monday. So, it's a good thing I'm leaving [Davis] because I smell smoke inside the house. I have a cold washcloth over my face but I still feel sick. Smelling in the smoke gets me anxious. Earlier I had a panic attack, it wasn't as bad as others but still not the most fun. With me getting like this I'm so scared to go on a plane by myself. I feel like crying [right now] honestly. I'm holding it in though."*

In New York, Alexandria continued feeling the effects from the smoke inhalation. She was bedridden for three weeks and had to go to the emergency room for her asthma. Although, New York City has been an "escape" for Alexandria from the Paradise wildfire, she fears that more fires like the Paradise Fire will break out next year. And while Alexandria is currently living in New York City with her mother, she will return to Davis at the end of the year; however, her mother has decided to keep a home in New York City in the likely event another wildfire breaks in California and Alexandria needs to escape.

Meanwhile, New York City has also affected Alexandria's health. Alexandria's inhaler has become her "best friend", accompanying her everywhere around the city to make sure her asthma does not land her back in the emergency room.

New York City ranks as one of the worst cities for air quality in the country. While the city itself is almost free from particle pollution – pollution that results from wildfires, wood-burning devices, coal plants, and diesel engines – New York City consistently has a thick layer of smog from ozone pollution. An American Lung Association study revealed that hotter temperatures increase ozone pollution, and as the climate crisis increases temperatures, with 2015-2017 being the three warmest years on record, ozone pollution has worsened. Ozone pollution has serious damaging effects, essentially leaving a sunburn on the lungs. Breathing in ozone can cause shortness of breath,



*Alexandria in the emergency room following the Paradise wildfire.*

coughing, intense asthma attacks, and premature death. The American Lung Association underscored that children and teens are some of the most vulnerable to the risks from breathing ozone.

Alexandria, just like children around the world, is experiencing what she coins, “the new normal” – that is, a world very different from the one that her parents and grandparents grew up in. The annual wildfires in her hometown and the worsening air quality in New York City has relegated Alexandria to a life indoors – preventing her from playing outdoors with friends and going to the beach.

This “new normal” includes a world where many animal species and insects are near extinction or already extinct. The thought of koalas, monarch butterflies, fireflies, and other creatures becoming

extinct often makes Alexandria cry and fearful of the future. The extinction of these species coupled with the impacts of the climate crisis has made Alexandria not want to have children because she believes subjecting a new generation to the climate emergency would be unjust.

These fears are deeply rooted in Alexandria’s thoughts, in particular, her thoughts about the future. While the climate continues to heat up, Alexandria dreams of living on a beach when she grows up, asserting that “if I have to die” because of the climate emergency “at least I’ll be on a beach.”

Many children, who like Alexandria are anxious about the future, are mobilizing and striking on Fridays, foregoing school classes, to bring awareness and incite action by world leaders to combat global heating. Alexandria, inspired by Greta Thunberg, has been a leader of these strikes in the United States:



*Alexandria protesting outside the United Nations building in New York City. She has been protesting every Friday for the last eight months.*

“I’ve been forced to organize a revolution instead of doing normal kid things.”

All of the climate harms Alexandria is experiencing, will only worsen, but to what extent depends on how much greenhouse gas the world continues to emit.

Understanding the immediacy of the climate crisis, Alexandria – in the mere span of eight months – has started and organized her own youth-led non-governmental organization, Earth Uprising, which, has already expanded to over 150 cities in 50 countries. Earth Uprising mobilizes youths, giving them the necessary tools to raise awareness and spark action within their own countries to respond to the climate emergency. Alexandria hopes that our world leaders will listen and will quickly take action to save their future.



*Alexandria leading March 15th protests for climate action in Columbus Circle, New York City.*

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# APPENDIX B

# Grantham Institute

## Science Brief

September 2019

# Climate physics consequences of further delay in achieving CO<sub>2</sub> emission reductions and intergenerational fairness

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## Highlights

- Global warming is broadly proportional to the total cumulative amount of carbon dioxide (CO<sub>2</sub>) emitted into the atmosphere
- This geophysical fact results in key consequences for intergenerational fairness and equity:
  - To halt global warming at any level global man-made CO<sub>2</sub> emissions have to decline to net zero;
  - The total cumulative amount of CO<sub>2</sub> emitted until the time of reaching net zero, also referred to as carbon budget, determines to a large degree the maximum amount of warming.
- The remaining carbon budget for limiting warming to 1.5°C or lower relative to preindustrial levels is small and will be exhausted unless net global CO<sub>2</sub> emissions have been strongly reduced over the next decade.
- Failure to reduce CO<sub>2</sub> emissions in the next years and decade:
  - Commits future generations to steeper and more challenging emissions reductions in the decades thereafter to stay within the same carbon budget;
  - Commits future generations to higher levels of risk that limiting warming to acceptable levels will become impossible;
  - Commits future generations to rely on the wide-spread deployment of at present unproven and controversial technologies to actively remove CO<sub>2</sub> from the atmosphere;
  - Creates an imminent risk that it will be impossible to “make up” for lost mitigation opportunities and will undermine the sustainable and safe livelihood of future generations.
- Risks of crossing critical temperature thresholds can be robustly lowered through stringent and effective emissions reductions in the next year and decade.
- Mitigation options are available to achieve the required emissions reductions and decarbonisation of energy, industry and society as a whole, and require targeted policy decisions to materialize.

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## Introduction and context

Climate change is a global challenge that is caused by, affects and has to be addressed by human society over time horizons from the immediate present to future years, decades, and centuries. The main activities that are causing climate change started over a century ago when Western industries started burning fossil fuels for energy at the beginning of the industrial revolution (1, 2). As a result, past and present climate changes can be attributed to these century-long activities (3, 4). At the same time, if humanity indeed intends to limit climate change to a level that is currently considered acceptable (5, 6), solutions and strategies to limit and ultimately halt climate change should be implemented now and continue over the next several decades (7-9). The impacts of climate change are persistent and at times further materializing, even if global carbon-dioxide emissions would be brought to zero (8, 10-12). These impacts will thus be experienced and suffered by the future generations that live during the next decades and centuries to come. Climate change therefore poses both a global and an intergenerational problem. This characteristic is a direct consequence of the physical principles that underlie our robust scientific understanding of climate change (13).

Global warming (that is, the global average temperature increase of our planet relative to pre-industrial times) is not something that is typically experienced by individuals directly. However, global average temperature increase is shown to be a good proxy for the severity of some of the more direct, local impacts, like extreme heat during specific seasons, extreme rainfall, or disruptive storms, or crop failures (12, 14, 15). Other impacts, like sea-level rise, are more closely related to the trajectory of global warming over time instead of the instantaneous amount of global warming. **In all cases, global average temperature increase is either a direct or an indirect proxy for the risk of local climate change impacts that are harming people and putting a life sustaining environment at risk** (12, 14, 16).

## The link between global warming and CO<sub>2</sub> emissions

On-going global warming, also referred to as climate change, is caused by human activities that generate waste gases or other emissions that are released into the common global atmosphere of our planet. This disturbs the equilibrium of the natural uptake and release of greenhouse gases like carbon dioxide (CO<sub>2</sub>) or methane (CH<sub>4</sub>) and results in increasingly higher levels of these greenhouse gases in the atmosphere. This increase is the main culprit for raising the overall average temperature of our planet (1). CO<sub>2</sub> is the

most important of these greenhouse gases from human activities (1). In the last decade, climate science has established that there is a robust, broadly linear relationship between the total amount of CO<sub>2</sub> emissions that humanity emits into the atmosphere and the total amount of long-term global warming that the planet will experience (1, 17-26). A direct consequence of this relationship between the total cumulative amount of CO<sub>2</sub> that humanity has added to the planet's atmosphere and global average temperature increase is that to halt global warming to any level – be it 1.0 degrees C, 1.5°C, 2°C or higher – the total of CO<sub>2</sub> emissions emitted by humanity has to be kept to within a given maximum amount, or a carbon budget (27). This linear relationship and the idea that a global carbon budget ultimately determines the amount of global warming also comes with further important implications for the challenges, fairness, and responsibility for climate change and its solutions across generations.

## Consequences for intergenerational fairness and equity

Every ton of CO<sub>2</sub> emitted by human activities causes roughly the same amount of global warming, whether it is emitted in the past, present, or future (13). **At present, however, activities of past generations have already increased the global mean temperature of our planet by about 1°C relative to pre-industrial levels (3, 8). If warming is to be kept under or at 1.5°C or well-below 2°C as referenced in the UN Paris Agreement (5), this leaves a much smaller remaining carbon budget for future generations compared to what was emitted by current and past generations (9).** Halting global warming to below a limit of 1.5°C or less requires staying within a carbon budget which can only be achieved if global annual CO<sub>2</sub> emissions are reduced to net zero (8, 13). Any climate policies that aim at providing a long-term solution to climate change should hence include a clear milestone target of when net-zero CO<sub>2</sub> emissions are going to be achieved (19, 28, 29).

**A further consequence of carbon budgets is that unwillingness or failure by governments to reduce either national or global CO<sub>2</sub> emissions over the next decade results in a higher burden on future generations to reduce global emissions faster later on.** This is a straightforward consequence of a higher share of the remaining carbon budget being used up if emissions stay at higher levels over the next years (13). Steeper emissions reductions are generally considered more risky and potentially more disruptive or costly compared to emissions reductions that start early and follow a more gradual path (7). Currently, global CO<sub>2</sub> emissions are still on the rise and every year an increasing amount of the remaining carbon budget is being used up, currently at a rate of more than 40



billion tons of CO<sub>2</sub> (Gt CO<sub>2</sub>) a year (2). This continued rise in global CO<sub>2</sub> emissions resulting from our economic activities implies a stronger burden on future generations, with higher risks of exceeding temperature thresholds that are considered dangerous (5, 6). These risks are linked to both the risk of higher near-term warming and risks that the required emissions reductions that are presumed by the current delay in meaningful global CO<sub>2</sub> emissions reductions are not achievable.

The precise amount of global warming as a result of staying within a specific carbon budget is uncertain. Remaining carbon budgets that are consistent with limiting warming to a specific level are therefore typically reported for various levels of likelihood of success. For example, to limit warming to no more than 1.5°C relative to preindustrial level, the latest assessment of the Intergovernmental Panel on Climate Change (IPCC) reported a remaining carbon budget of 580 Gt CO<sub>2</sub> to have a one-in-two chance that warming is effectively limited to that level, and of 420 Gt CO<sub>2</sub> for a two-in-three chance of success (8, 9). Several other factors, some of which can be influenced by targeted policy decisions, are known to further affect the remaining carbon budget consistent with a given temperature limit or, vice versa, to change the temperature outcome for a given carbon budget (30).

However, an important insight for intergenerational fairness is that the uncertainty in remaining carbon budgets and global warming outcomes can be hedged against by reducing emissions more strongly in the near-term. Emission reductions in the next decade reduce the risk that stronger-than-assumed warming would render impossible the ability to keep global warming to safe levels at or below 1.5°C or well-below 2°C. Decision makers often design climate policies based on today's central estimate of the remaining carbon budget or climate uncertainties, or a pathway consistent with, for example, a two-in-three chance of limiting warming to 1.5°C or 2°C (31, 32). This approach neglects potentially disastrous climate outcomes that are currently still well in the realm of the possible and where the planet warms much more than the central estimate (33, 34). A strategy that pursues a pathway in line with a one-in-two or two-in-three chance of success does not effectively limit the risks of climate change, but rather intentionally leaves open the possibility that future generations will have to shoulder much stronger emissions reductions compared to those considered today, or will have to suffer the consequences of a planet that was heated beyond what today is considered a safe level, or both.

Finally, the warming that is expected as a result of a certain total amount of CO<sub>2</sub> will remain virtually constant for centuries even if humanity stops adding CO<sub>2</sub> to the atmosphere (13, 27, 35, 36). The warming caused by CO<sub>2</sub> is therefore at times referred to as irreversible (35). In other

words, even if global man-made CO<sub>2</sub> emissions are reduced to net zero, the warming caused by the CO<sub>2</sub> emitted into the atmosphere will continue to linger for centuries. Our current understanding of climate physics indicates that the only hypothetical way to undo this warming at some point in the future is by trying to remove the cause of it through actively removing CO<sub>2</sub> from the atmosphere at a rate faster than would be the case naturally (3, 9, 13, 37).

## **Available mitigation opportunities and options for reducing greenhouse gas emissions**

Reducing national and global CO<sub>2</sub> emissions to net zero requires rapid, far-reaching changes on an unprecedented scale (8, 9, 38). Importantly, quantitative pathways that describe how these stringent emissions reductions can be achieved have been identified (8, 9, 38-42). These include changing the way energy is produced, away from fossil fuel burning, the ways in which we design sustainable infrastructure and cities, or the ways in which we consume and produce food, to only name a few (8, 9, 38). As a common feature, all identified pathways necessarily bring about the stringent emissions reductions that are required to halt warming at the temperature levels included in the Paris Agreement (8, 9). However, the rich literature also shows that there are still important societal choices and value judgments that have to be made regarding the strategies that we pursue to achieve these emissions reductions (9, 43). Although not all measures that reduce emissions are compatible with the broader societal goals of sustainable development and poverty eradication, mutually beneficial strategies have been identified and are helped by early mitigation action and emissions reductions (8, 9, 41, 43).

## **Imminent risk of lost mitigation opportunities and the undermining of a sustainable and safe livelihood of future generations**

The current delay in meaningful and adequate emissions reductions implies irreversible and high-risk consequences that will have to be shouldered by future generations. Several independent analyses consistently show how current pledged actions by countries are insufficient, either at a national or global level, to limit warming to the safe levels defined in the Paris Agreement (31, 34, 38, 44-46). This shortfall in climate action and resulting high-risk warming outcomes are illustrated in Tables 1 and 2.

A consequence for intergenerational fairness of heating the planet beyond a level that is considered safe, is thus that



future generations are committed to suffer higher climate change impacts than are currently deemed unacceptable, or to actively drawdown CO<sub>2</sub> from the atmosphere (also known as carbon-dioxide removal or CDR) to slowly recover from these higher temperatures. At the same time, both these consequences expose future generations to significantly higher levels of risk.

Risks of triggering an irreversible collapse of unique and threatened ecosystems, like tropical coral reefs, is markedly increased with global warming exceeding 1.5°C, and so are the risks for extreme weather events, and impacts that particularly affect vulnerable people (8). The risk of crossing of tipping points (47) is also increased (8). For many of these tipping points, like the disintegration of the Greenland Ice Sheet or the unstoppable release of CO<sub>2</sub> from thawing permafrost, there is certainty that they exist, but the ability to determine at what level of warming they would precisely occur, is limited (8). Risks are often projected to increase markedly when the planet is heated beyond 1.5°C relative to preindustrial levels (8, 16). This combination of deep uncertainty about when these tipping points would take place and the large-scale impact they would have on future societies makes them particularly important to consider in the context of future risks and intergenerational equity.

**Further risks future societies would be exposed to if the planet is heated beyond a level that is considered safe is that there are no readily available solutions to reverse warming.** Technologies or measures to achieve the required active drawdown of CO<sub>2</sub> are currently still speculative and important trade-offs have been identified for their implementation at a globally significant scale (48–51). For example, bio-energy is assumed to be used in combination with technologies that could capture and sequester CO<sub>2</sub> underground (abbreviated to CCS) to drawdown CO<sub>2</sub> from the atmosphere. However, this bio-energy production can compete with agricultural production over land and water resources, and other sustainable development goals (38, 43, 48), and so can other methods like large-scale afforestation on land that would be needed to feed a growing global population. Insufficient emissions reductions over the next decade(s) will increase the need for large-scale carbon-dioxide removal with an important burden on a sustainable development, and the food and water security of future generations that will be increasingly hard to avoid. **If mitigation opportunities are squandered today, it very well may be too late to “make up” for them later.** This is hence a second important dimension where insufficient emission reductions in the next decade undermine the sustainable and safe livelihood of future generations.

## Conclusion

In conclusion, the fundamental scientific understanding of the physics governing climate change thus results in a series of key consequences for intergenerational fairness. Past and current emissions of CO<sub>2</sub> either have used up or are continuing to deplete the carbon budget consistent with keeping warming to safe levels, to the detriment of future generations. The lack of globally significant CO<sub>2</sub> emissions reductions that would bring global CO<sub>2</sub> emissions to net zero as soon as possible puts an increasing burden of steeper and more disruptive emissions reductions on future generations. Options are available to reduce emissions in line with limiting warming at or below 1.5°C or well below 2°C relative to preindustrial levels but require policy decisions and action to materialize. Finally, the high risk of failure and the currently limited global emissions reductions are committing future generations to levels of climate change that at present are already deemed unacceptable, and also commit future generations to depend on the unproven and in many cases contentious global deployment of carbon-dioxide removal measures, some of which can have important negative side effects on water and food security, biodiversity, and sustainable development as a whole.

## About the author

**Dr Joeri Rogelj** is a Lecturer in Climate Change at the Grantham Institute for Climate Change and the Environment at Imperial College London (UK). He researches the implications of our understanding of the Earth system for climate policy. He has published more than 70 peer-reviewed contributions to the scientific literature on carbon budgets, climate change mitigation, societal transitions consistent with limiting warming to 1.5°C, and climate change mitigation equity. He served as a Coordinating Lead Author on the Special Report on Global Warming of 1.5°C of the Intergovernmental Panel on Climate Change (IPCC). He has been a Lead Author on the annual UN Environment Emissions Gap Reports since their inception in 2010. Currently, he serves a Lead Author on the Physical Science Assessment for the Sixth Assessment Report (AR6) of the IPCC and is a member of the UN Secretary-General Climate Science Advisory Group.



## Accompanying data tables

The following pages contain two accompanying data tables that illustrate the current inadequacy of proposed, pledged, or implemented policies in limiting global warming to well below 2°C or 1.5°C relative to preindustrial levels.

Table 1 shows the estimated historical greenhouse gas emission for the years 2010 and 2016 for a set of countries and regional or political groups as well as for the entire globe. These estimates are taken from the peer-reviewed scientific literature and use data provided by third-party sources to increase the independence of the estimates (52). These historical estimates provide context for the estimates of future emissions that either reflect projections of current policies and pledged actions under the Paris Agreement (referred to as Nationally Determined Contributions, NDCs) or emissions levels in 2030 at the national or regional level that are deemed consistent with limiting warming well below 2°C or to 1.5°C relative to preindustrial levels. The latter estimates are taken from two sources: the 2018 Emissions Gap Report (31) published by the United Nations Environment Program (UNEP, currently called UN Environment) and the analyses of a research consortium that tracks climate action called Climate Action Tracker ([climateactiontracker.org](http://climateactiontracker.org)).

Table 1 illustrates that despite uncertainties and variations in current and pledged climate actions, all but one country listed here are currently implementing emissions reductions measures that can be considered adequate to limit warming well below 2°C, and no country is implementing measures in line with limiting warming to about 1.5°C relative to preindustrial levels. In most cases, the warming implied by the lack of mitigation action would lead to global temperature rise in the range of 3 to 4°C.

Table 2 provides an overview of estimates of global mean temperature increase, based on the globally aggregated emissions that are estimated to be emitted under currently adopted and planned policies or under the full implementation of pledged action as reflected in the Paris Agreement NDCs.





**Table 1: Overview of current and projected emissions per country or country group, as well as corresponding emission levels in 2030 consistent with limiting global warming to below 1.5°C or 2°C**

	PRIMAPHIST <sup>a</sup> Third-party data based			UNEP Emissions Gap <sup>b</sup> Based on multiple independent studies				Climate Action Tracker <sup>c</sup> Independent research consortium						
	2010	2016	% share of globe in 2016	2010	Current Policy 2030	Unconditional NDC 2030	Conditional NDC 2030	Current Policy 2030	Unconditional NDC 2030	Conditional NDC 2030	<2.0°C	<1.5°C	Implied warming by 2100 if whole world implements comparable emissions reductions <sup>†</sup>	
[Unit]	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	%	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	MtCO <sub>2</sub> e per year	Following current policy	Following NDCs <sup>‡</sup>
Argentina	335	358	0.8%	448	530	483	369	490	422	322	256	205	exceeding 4°C	below 4°C
Brazil	1030	1080	2.3%	1301	1328	1200	same	1119	890	same	744	432	below 3°C	below 3°C
China	10800	12400	26.3%	10180	14438	14388	same	15125	15192	same	10686	8399	below 4°C	below 4°C
France <sup>#</sup>	515	473	1.0%	NR	NR	NR	NR	395	403	same	165	42	below 4°C	below 4°C
Germany <sup>#</sup>	926	887	1.9%	NR	NR	NR	NR	735	553	same	285	65	below 4°C	below 3°C
India	2720	3450	7.3%	1848	4861	5241	4633	4558	5068	same	6194	4520	below 2°C	below 2°C
Turkey	413	505	1.1%	357	745	928	same	853	999	same	434	357	exceeding 4°C	exceeding 4°C
United States <sup>*</sup>	6710	6350	13.5%	6206	5566	4805	same	6254	5522	same	3488	1761	exceeding 4°C	exceeding 4°C
European Union	4860	4430	9.4%	4449	3428	3131	same	3427	3404	same	1918	758	below 3°C	below 3°C
G20 (incl. EU)	37702	39549	84.0%	32900	40714	39694	38274	41881	41348	40968	29283	19807	NR	NR
Marshall Islands	0.127	0.172	0.0%	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Global	43900	47100	100.0%	50000**	59000**	56000**	53000**	58983	55582	54164	40000**	24000**	See Table 2	See Table 2

Notes and sources:

MtCO<sub>2</sub>e per year stands for million metric tons of CO<sub>2</sub> equivalent emissions per year. CO<sub>2</sub> equivalent emissions are reported using conversion factors known as GWP-100 which stands for "Global Warming Potentials over a 100-year time horizon" as reported by the UN Intergovernmental Panel on Climate Change in its Second Assessment Report (SAR). "NR" means "not reported" by this specific source, in most cases because this country's climate policy and nationally determined contribution (NDC) under the UNFCCC is part of the broader EU28 NDC and can thus not be assessed in isolation.

a) Latest values of national and global greenhouse gas emissions excluding land-use change emissions. Note that the NDC emissions levels can also include land-use change emissions, which are very uncertain and for which limited independent sources are available. From: Gütschow, Johannes; Jeffery, Louise; Gieseke, Robert (2019): The PRIMAP-hist national historical emissions time series (1850-2016). V. 2.0. GFZ Data Services. <http://doi.org/10.5880/PIK.2019.001>

"Third party data based" values are labelled HISTP in the original data source, and prioritize third party data over country reported data to estimate historical emissions.

b) Source: Central values from UNEP (2018). The Emissions Gap Report 2018. Nairobi, Kenya, UNEP: 1-113. ISBN: 978-92-807-3726-4. "Chapter 2. Trends and progress towards the Cancun pledges, NDC targets and peaking of emissions" and "Chapter 3. The emissions gap"

c) Estimates by the Climate Action Tracker research consortium. [www.climateactiontracker.org](http://www.climateactiontracker.org) - 17 June 2019 update. Where ranges are reported in the original source, the center-point of the most ambitious NDC target is taken.

The conditional end of the global pathway is the lower end of the range of pledges assessed globally.

<sup>#</sup> Values for current policies and NDCs for Germany and France are based on an assessment of national policies and targets, respectively. These estimates are not publicly available on the Climate Action Tracker website but assessed with similar methods. Values consistent with limiting warming below 2°C or 1.5°C for France and Germany are based on the European Union's (EU28) values and adjusted based on EU internal effort sharing decisions. Unadjusted for EU internal effort sharing the emission values in 2030 for limiting warming to below 2°C and 1.5°C would be 203 and 80, and 364 and 144 MtCO<sub>2</sub>e per year for France and Germany, respectively. Also the implied warming by 2100 is estimated with this adjustment method. France's unconditional NDC assessment assumes the use of gross-net land-use, land-use change and forestry (LULUCF) accounting. Tightening the LULUCF accounting to net-net would lower France's NDC projection to 312 MtCO<sub>2</sub>e per year in 2030, implying a global warming of below 3°C if the whole world implements comparable emissions reductions.

<sup>\*</sup> The United States' NDC is defined for 2025 and in absence of an updated NDC for 2030 emissions here listed as constant after 2025.

<sup>\*\*</sup> Rounded global values from the 2018 UN Environment Emissions Gap Report. "<2.0°C" scenarios are consistent with holding global warming to below 2°C with 66% probability. "<1.5°C" hold warming to below 1.5°C in 2100 with 66% probability but have a lower probability over the course of the century. Increasing the probability that warming would be held to below these limits would imply these benchmarks to be lowered.

<sup>†</sup> Estimated by comparing the emissions projected for the year 2030 that result from either the implementation of current climate change mitigation policies (labelled as 'Following current policy') or the current NDCs (labelled as 'Following NDCs') with the science-based effort sharing ranges estimated by the Climate Action Tracker research consortium.

<sup>‡</sup> In case a country has both a conditional and an unconditional NDC, the average is taken for estimating the illustrative implied warming.



**Table 2: Estimates of global warming resulting from current levels of climate policies and climate pledges**

	Current policies	Unconditional NDCs	Conditional NDCs
UNEP Emissions Gap <sup>a</sup>		around 3.2°C (with a range of 2.9–3.4°C) relative to pre-industrial levels by 2100	about 0.2°C lower in 2100 than projections for unconditional NDCs
Climate Action Tracker <sup>b</sup>	3.1–3.5°C relative to pre-industrial levels by 2100. Optimistic interpretations of current policies bring it down to 3.0°C	2.7–3.0°C relative to pre-industrial levels by 2100	
<b>Notes:</b> a) Source: Central values from UNEP (2018). The Emissions Gap Report 2018. Nairobi, Kenya, UNEP: 1-113. ISBN: 978-92-807-3726-4. "Chapter 3. The emissions gap" b) Estimates by the Climate Action Tracker research consortium. <a href="http://www.climateactiontracker.org">www.climateactiontracker.org</a> - accessed 26 July 2019			

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# APPENDIX C

## Scientific Report on Impacts and Drivers of Climate Change

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**Date:** 10 September 2019

### About Climate Analytics

Climate Analytics is a non-profit climate science and policy institute based in Berlin, Germany with offices in New York, USA, Lomé, Togo and Perth, Australia, which brings together interdisciplinary expertise in the scientific and policy aspects of climate change. Our mission is to synthesise and advance scientific knowledge in the area of climate change and on this basis provide support and capacity building to stakeholders. By linking scientific and policy analysis, we provide state-of-the-art solutions to global and national climate change policy challenges.

Climate Analytics was founded in 2008 in Potsdam, Germany by Dr (h.c) Bill Hare, Dr. Malte Meinshausen and Dr. Michiel Schaeffer to bring vanguard climate science and policy analysis to bear on one of the most pressing global problems of our time: human induced climate change. We are motivated by the desire to empower those most vulnerable – small island states and least developed countries – to use the best science and analysis available in their efforts to secure a global agreement to limit global warming to levels that don't threaten their very survival.

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# 1. Global Impacts



## Global Impacts

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## 1. Summary

There are currently 2.3 billion children under the age of 18 living on earth who are among the group of people most vulnerable to climate change. Already today the global average temperature is 1°C above pre industrial times. The likelihood of children to live in a 1.5°, 2° and 3° world is significantly higher than for adults. Almost all children will experience 1.5° warming. Mitigation efforts of countries to date are insufficient to achieve the 1.5°C limit (or lower) of the Paris Agreement, but rather set the world on track towards a 3°C warming by the end of the century. Under such a pathway, 92% of all 16-year-old children alive today are expected to live in a 2°C warmer world and 4% will experience a 3° warmer world.

Global sea levels have risen by about 20cm since pre-industrial times. Current projections show a risk for **global sea level rise** of up to 1m by 2100. Sea level rise will continue for centuries to millennia after emissions have been reduced to zero and could amount to many meters. Only limiting warming to 1.5°C in line with the Paris Agreement may hold long-term sea level rise in 2300 below 1m. Every delay of 5 years in peaking of emissions will lead to a 20cm increase in sea level rise over that time frame.

**Extreme events** will increase in frequency and intensity. Heat waves and extreme hot summers such as the 2003 Central European hot summer, which would have been a 1 in a 100-year event without climate change, is currently projected to be a 1 in a 4-year event and is projected to happen almost every other year under 1.5° warming. Six out of 10 central European summers would be like that or warmer if there is a 2°C warming. Even at 1.5°C warming in comparison to present day warming levels, globally twice as many megacities will be exposed to heat stress exposing up to 250 million additional people to deadly heat wave conditions by 2050.

Tropical cyclones as severe as Irma, Harvey or Maria which hit the Caribbean in 2017, are likely to reoccur or worsen in strength, with global warming.

The IPCC has identified five key “**reasons for concern**” summarizing the **impacts of climate change**. Risks and impacts related to all five reasons will worsen to high or even very high if warming of 1.5°C is exceeded. Without additional substantial emissions reduction, children of today will live half their lives in a world characterized by high climate risks across a broad range of impacts.



The costs of preventing workplace heat-related illnesses through worker breaks suggest that the difference in economic loss between 1.5°C and 2°C could be approximately 0.3% of global gross domestic product (GDP) in 2100.

Since 2008, climate-related **displacement** has affected an estimated 22.5 million people per year on average - equivalent to 62,000 people every day. Populations of Small Island Developing States in particular are being threatened by sea level rise and are threatened for their very survival. In response to that existential threat, Kiribati was the first island state to actually purchase land in Fiji to consider the migration of a whole nation due to future sea level rise which will make the island uninhabitable.

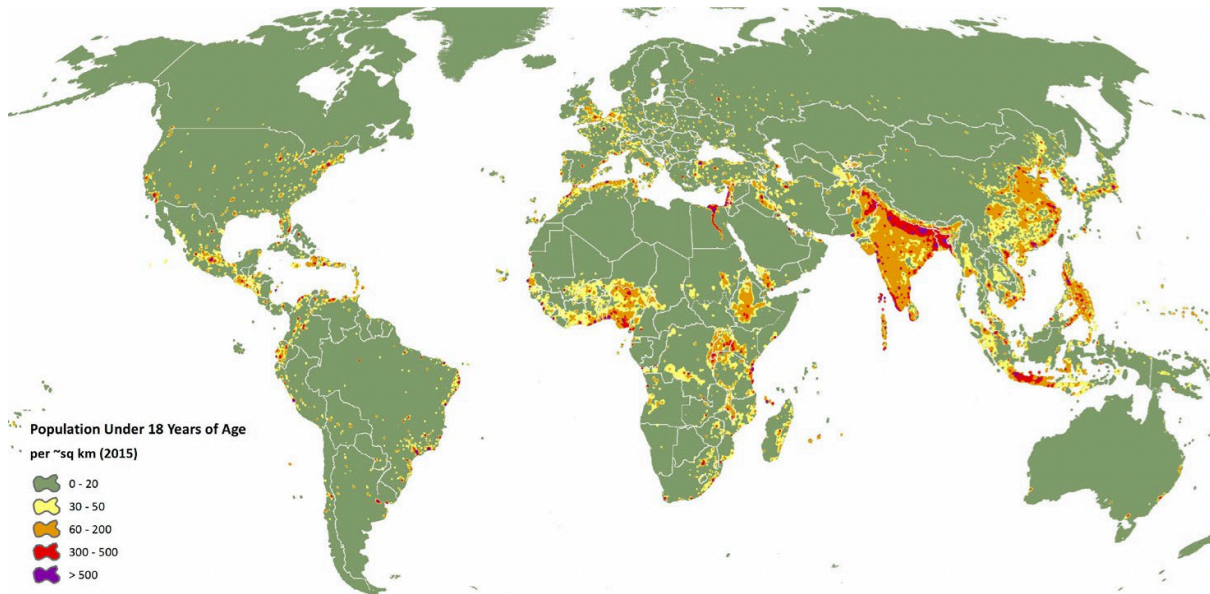
Already today at about 1°C global warming, **poverty** and disadvantage have increased and are likely to increase even further with rising temperatures. At approximately 1.5°C of global warming, climate change is expected to be a poverty multiplier. Climate change alone could force 3 million to 16 million people into extreme poverty, mostly through impacts on agriculture and food prices.

Sea level rise and other extreme events will impact **Cultural heritage**. A global analysis of sea level rise risk to 720 UNESCO Cultural World Heritage sites projected that about 47 sites might be affected under 1°C of warming, with this number increasing to 110 and 136 sites under 2°C and 3°C, respectively.

Soft and hard limits of adaptation will cause irreversible **loss and damage** already for warming levels at around 1.5°C and even more so if 1.5°C is exceeded. Exceeding the limits of adaptation can trigger escalating losses or result in undesirable transformational changes such as loss of livelihoods in Small Island Developing States.

## 2. Demographic developments (global)

Based on the 019 revision of the United Nation's population prospects, the world is currently populated by about 2.5 billion children, up to the age of 19, comprising more than a third of the world's total population (United Nations, 2019). The youngest populations tend to reside in the least developed countries which are still undergoing early phases of demographic transitions and are still experiencing high fertility rates.



**Figure 2:** Global map of where the 2.3 billion children currently live (population below the age of 18). Source: UNICEF, 2015

### 2.1. Likelihood of children to experience 1.5, 2 and 3°C

Today's children are expected to live longer, and be healthier and better educated than any of their ancestors, though with large disparities between countries. An average 16-year-old citizen of the world is expected to live until the age of 82 (World Data Lab, 2019), with a 98% probability to experience the 1.5°C world (~2035), 92% for a 2°C world (~2055). About 4% of today's teenagers are expected to live until the end of the century when the current emissions pathways could bring about a 3°C warmer climate (Climate Action Tracker, 2018).

## 3. Observed and projected impacts

Today the impacts of climate change are noticeable around the world. With increasing global warming, the impacts on humans and natural systems will increase. Demographic developments increase the likelihood of children to experience a 1.5°, 2° and even 3° warmer world. Impacts from these global temperature increases are considered in the analysis of projected impacts.

### 3.1. Representative Concentration Pathways – temperature warming

Representative Concentration Pathways (RCPs) are a suite of scenarios considering future emissions and concentrations of greenhouse gases, aerosols, and land use (Moss et al., 2008). The International Panel on Climate Change (IPCC) and the climate modelling community use four different scenarios named after their radiative forcing potential (RCP 2.6, 4.5, 6.0, 8.5) (Moss et al., 2010). Each RCP is associated with an approximation for the range of the temperature increase by 2100 in comparison to pre-industrial times. The table below shows the median temperature estimate of this range. RCP2.6 is the pathway compatible with the Paris Agreement and would lead to about 1.5°C by the end of the century. RCP4.5 translates to about 2.5°C warming by 2100, RCP6.0 to about 3° warming and is corresponding to a business-as-usual approach to emissions reduction, in line with current policies (Climate Action Tracker, 2018). RCP8.5 is a high emissions scenario reaching more than 4°C by 2100. Many studies in climate research use a subset of the RCPs and hence do not provide estimates



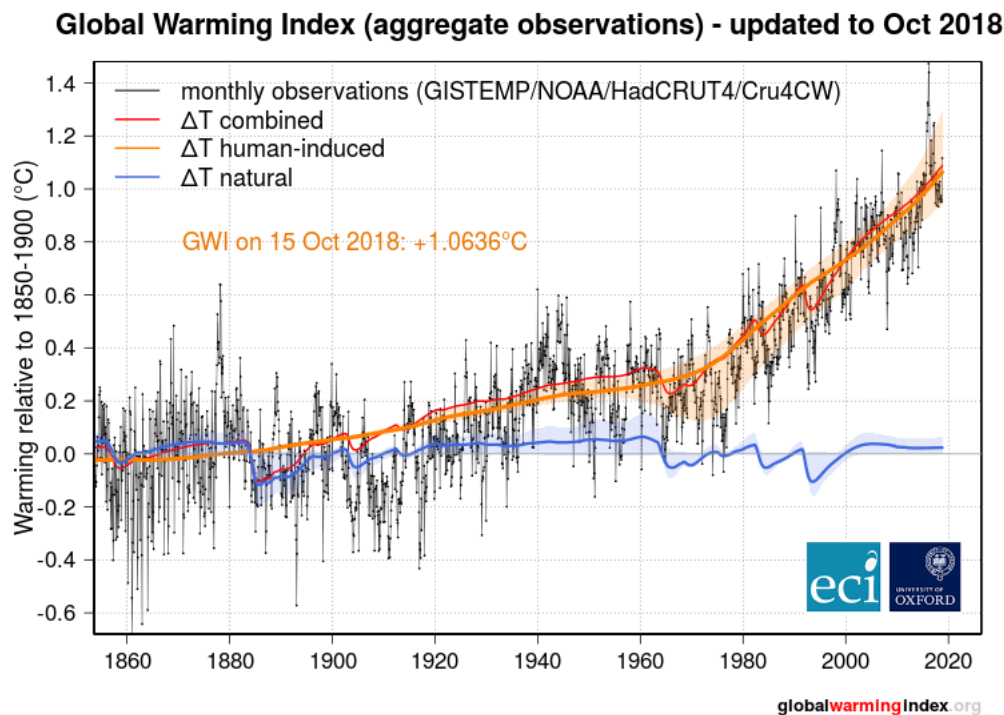
of impacts under all warming levels. In the analysis on global and national impacts, we will refer to the expected temperature increase by 2100 rather than the RCP. For high emission scenarios either RCP8.5 and 6.0 are used, while 2.6 is consistently used for a low emission scenario.

Name	Expected temperature increase in 2100 (median)
RCP2.6	1.6°C
RCP4.5	2.4°C
RCP6.0	2.8°C
RCP8.5	4.3°C

**Table 1:** Representative Concentration Pathways scenarios and their approximate temperature increase by 2100 in comparison to pre-industrial times). Source: Field et al., 2014)

### 3.2. Temperature increase globally

Reflecting the long-term warming trend since pre-industrial times, observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (likely between 0.75°C and 0.99°C) higher than the average over the 1850–1900 period (very high confidence). Estimated anthropogenic global warming matches the level of observed warming to within  $\pm 20\%$  (likely range). Estimated anthropogenic global warming is currently increasing at 0.2°C (likely between 0.1°C and 0.3°C) per decade due to past and ongoing emissions (high confidence). (IPCC, 2018)



**Figure 3:** Global warming index – warming levels Oct 2018 1.06°C Source: globalwarmingindex.org

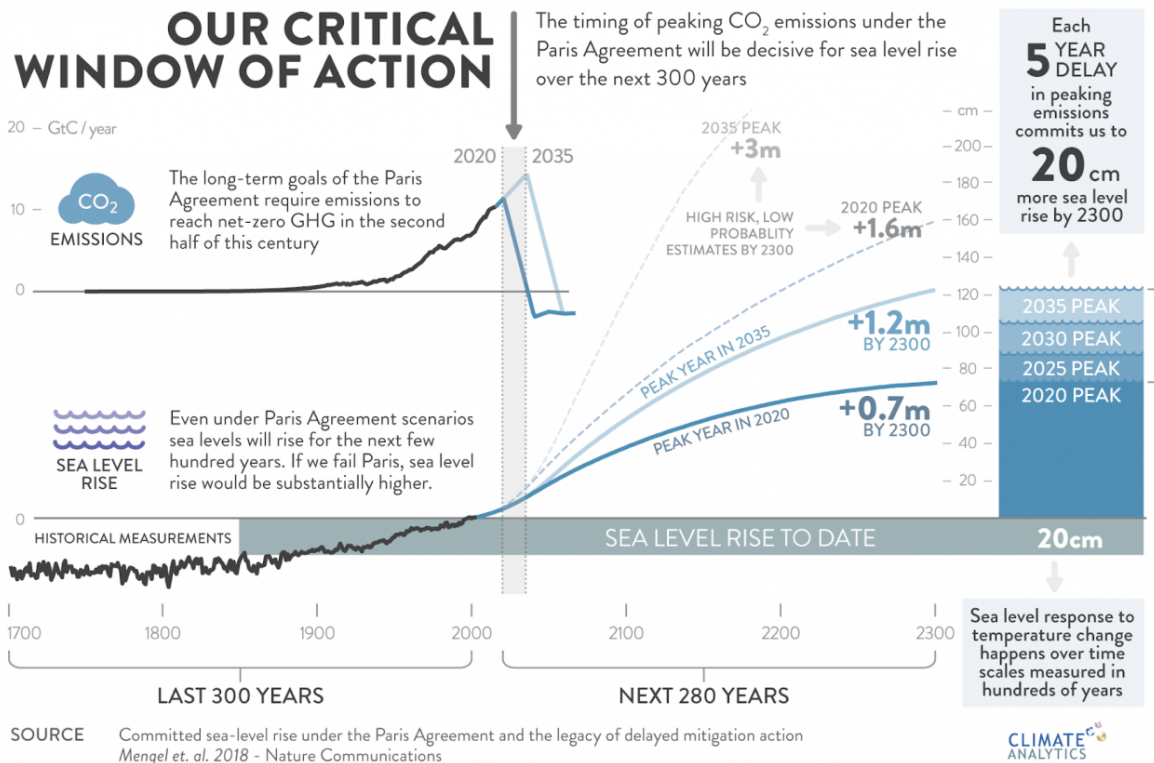
Human-induced warming reached approximately 1°C (*likely* between 0.8°C and 1.2°C) above pre-industrial levels in 2017 (high confidence) (Allen et al., 2018). The global temperature increase is an average across the world. Research has shown that the warming above land is generally higher than above the ocean. Additionally, specific regions and seasons experience a higher warming with the Arctic reaching two to three times higher temperatures than the average (high confidence) (IPCC, 2018).

Today, 20-40% (depending on data source) of the world population has already experienced more than 1.5° warming in at least one season in the decade 2006-2015.

Past emissions are unlikely to raise temperatures above 1.5°C above pre-industrial levels (medium confidence). Based on current emissions, 1.5°C warming will likely be reached between 2030 and 2052 (IPCC, 2018). Based on the Climate Action Tracker information 2°C warmer world would be reached in about 2055 (median) and a 3°C towards 2100 (median) (Climate Action Tracker, 2018).

### 3.3. Sea Level Rise globally

Sea level rise will continue beyond 2100 even if global warming is limited to 1.5°C in the 21st century (high confidence). Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-meter rise in sea level over hundreds to thousands of years. These instabilities could be triggered at around 1.5°C to 2°C of global warming (medium confidence).



**Figure 4:** Our critical window of action. Source: (Mengel et al., 2018b)

Currently the world has experienced about 20 cm of global sea level rise since pre-industrial times.

The IPCC states with high confidence that the sea level will continue to rise well beyond 2100, and the magnitude and rate of this rise will depend on future emission pathways. For 1.5°C the IPCC report projects a sea level rise of up to 0.77m by 2100 (Ove Hoegh-Guldberg, Jacob, Taylor, & et al, 2018) for scenarios not exceeding 2°C. Sea levels could be much higher, for higher warming scenarios (Nauels et al., 2017).

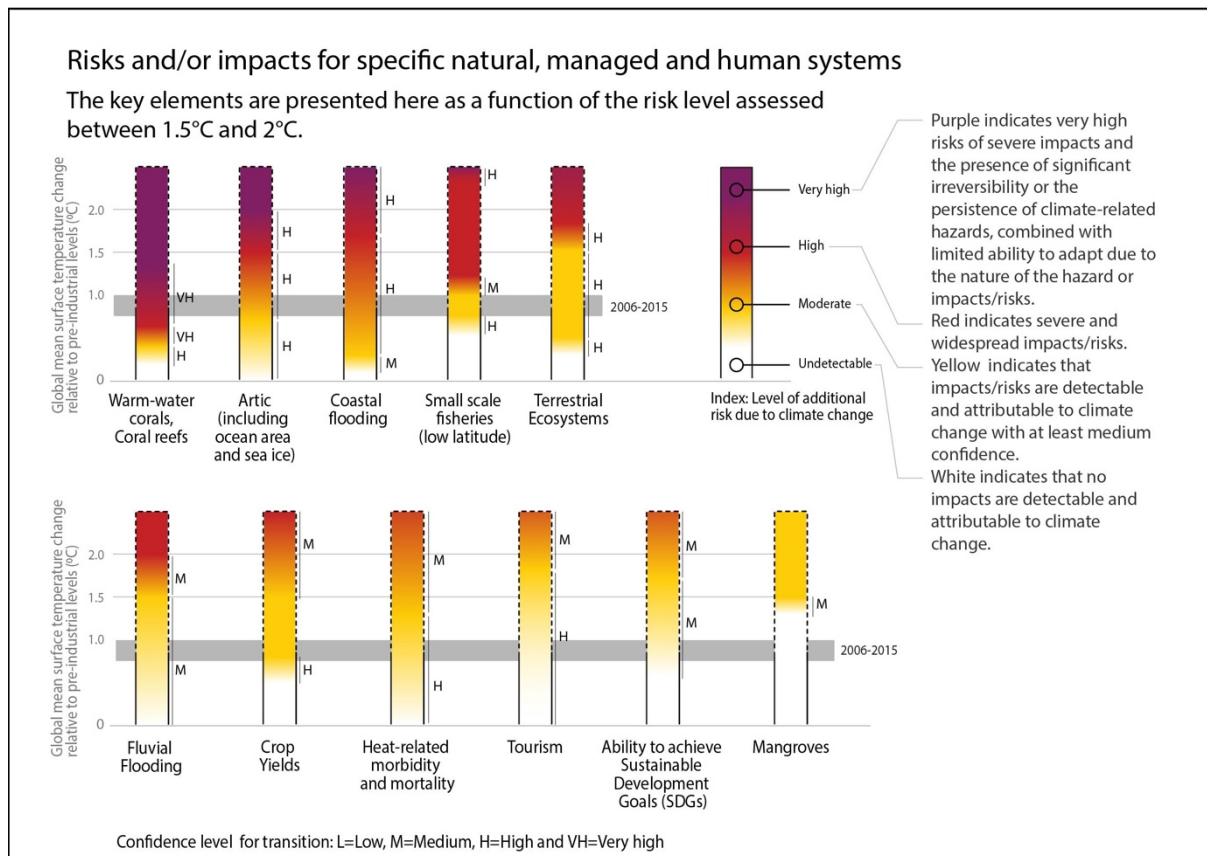
The paper from Mengel et al. 2018 analyses the relationship between future emission pathways and sea level rise. As Figure 4 shows the timing of mitigation actions matters for long-term sea level rise. Every 5-year delay in limiting CO<sub>2</sub> emissions will increase the sea level rise in 2300 by 20 cm. This analysis was only done for 1.5°C emission pathway (RCP2.6). For higher emission scenarios, reaching 2°, 3° or even 4°C higher levels of sea level rise can be expected. Future generations will therefore be affected by actions taken within the next decades (Mengel et al., 2018a). A reduction of 10 cm in global sea level rise would translate into 10 million fewer people exposed based on the population of 2010 (high confidence). Particularly Small Island Developing States (SIDS), low-lying coastal areas and deltas are at risk of increased flooding and loss of land due to sea level rise. A slower rate of sea level rise will enable these regions with a greater opportunity for adaptation (medium confidence). These regions have an increasing risk of experiencing saltwater intrusion, flooding and damage to infrastructure (high confidence) (Ove Hoegh-Guldberg et al., 2018).

Furthermore, the oceans have been absorbing about 30% of the past CO<sub>2</sub> emissions which has led to ocean acidification and changes to the carbonate chemistry (high confidence) impacting marine organisms and ecosystems. There is also *high confidence* that global warming has resulted in an increase in the frequency and duration of marine heatwaves (IPCC, 2018).

Considering that cold regions are warming more rapidly , by a factor of 2-3 times , the Arctic is likely to experience a warming of up to 4.5°, associated with a global increase of 1.5°C (high confidence). For a 2° warmer world Arctic temperatures would be expected to go up to 8°C (high confidence). Landscapes such as the tundra would shift northwards. Permafrost would likely deteriorate (IPCC, 2018).

Instabilities for both the Greenland and the Antarctic ice sheets exist, which could result in a multi- measure sea level rise. These instabilities are less likely to be triggered at a lower warming level (1.5°C) than higher ones (medium confidence). The Arctic sea ice is likely to be maintained under the 1.5°C scenario. For 1.5 to 2° warming, scientists expect every second summer to be ice-free. For 2 to 3°C, the Arctic is very likely ice free in summer. Polar bears, whales, seals and sea birds would lose their natural habitat (IPCC, 2018).

The impacts that climate change has on the ocean system go beyond the impacts felt in the Arctic region and include erosion of land, loss of land, loss of mangroves and loss of coral reefs. The following figure (5) shows the expected impact of different warming levels on different natural and human systems and the respective confidence level.



**Figure 5:** Risks and/or impacts for specific natural, managed and human systems. Source: Ove Hoegh-Guldberg et al., 2018

### 3.4. Intensity of weather events

Evidence from attributed changes in some climate and weather extremes for a global warming of about 0.5°C supports the assessment that an additional 0.5°C of warming compared to present is associated with further detectable changes in these extremes (medium confidence). Several regional changes in climate are assessed to occur with global warming up to 1.5°C compared to pre-industrial levels, including warming of extreme temperatures in many regions (high confidence), increases in frequency, intensity, and/or amount of heavy precipitation in several regions (high confidence), and an increase in intensity or frequency of droughts in some regions (medium confidence) (IPCC, 2018).

Extreme weather events are among the most prominent impacts of climate change. Many extreme weather events including heat waves, extreme precipitation, tropical cyclones, drought and associated wildfires, and flooding have already increased in frequency and intensity due to observed climate change and will continue to do so with increasing warming. An increasing number of extreme events can be attributed in part to climate change (see figure 6).

#### Heat waves

Regarding hot extremes, the strongest warming is expected to occur at mid-latitudes in the warm season (with increases of up to 3°C for 1.5°C of global

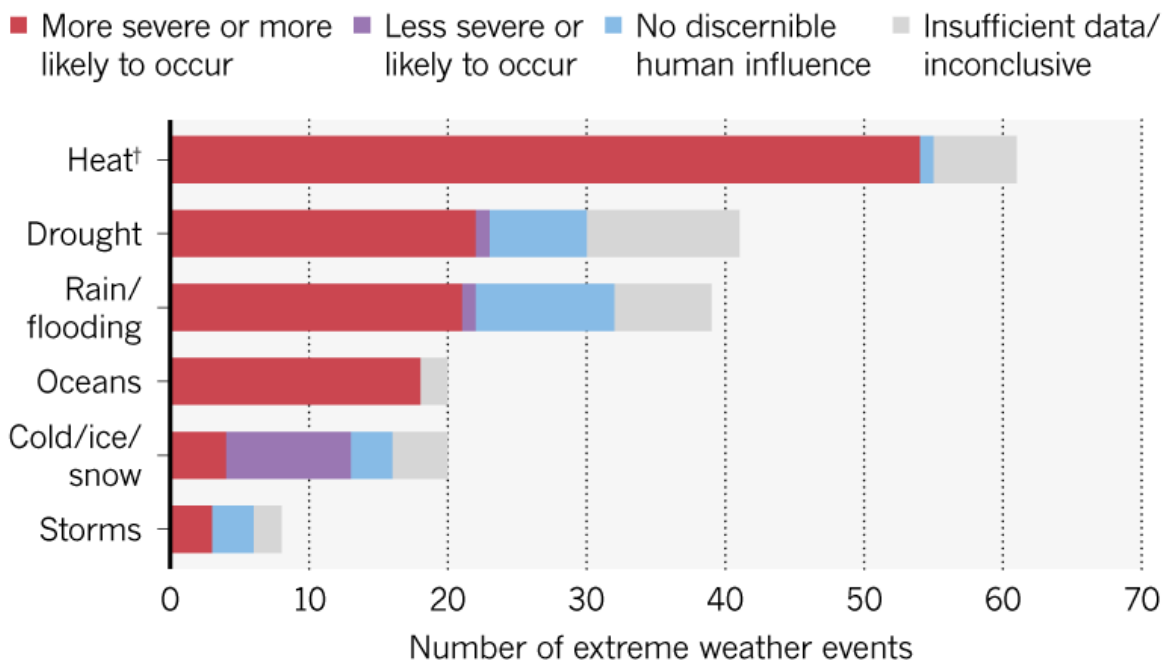


warming, i.e., a factor of two) and at high latitudes in the cold season (with increases of up to 4.5°C at 1.5°C of global warming, i.e., a factor of three) (high confidence). The strongest warming of hot extremes is projected to occur in central and eastern North America, central and southern Europe, the Mediterranean region (including southern Europe, northern Africa and the Near East), western and central Asia, and southern Africa (medium confidence). The number of exceptionally hot days are expected to increase the most in the tropics, where interannual temperature variability is lowest; extreme heatwaves are thus projected to emerge earliest in these regions, and they are expected to already become widespread there at 1.5°C global warming (high confidence). (Ove Hoegh-Guldberg et al., 2018)

Attribution studies show that extreme heat experienced today can already be associated with anthropogenic climate change. Particularly for heat related studies, scientists were able to show that due to human-induced climate change heat related events are more severe or more likely to occur.

## Attribution science

Researchers have published more than 170 studies\* examining the role of human-induced climate change in 190 extreme weather events.



©nature

\*Studies from 2004–18 collated by *Nature* and CarbonBrief. †Heat includes heatwaves and wildfires; Oceans includes studies on marine heat, coral bleaching and marine-ecosystem disruption.

**Figure 6:** Studies in attribution of human-induced climate change and extreme weather events. Source: Schiermeier, 2018

Studies by King & Karoly (2017) show the increasing likelihood of similar heatwave events occurring with current temperature increase of about 1°C, for 1.5 and 2° warming in comparison to a world without climate change. When looking at the 2003 heat wave in central Europe this would be a once in 100 years event without climate change. At current warming

levels a similar event can be expected once every four years. For 1.5°C warming the likelihood increases to 4 out of 10 summers and for 2°C warming reaches 6 out of 10.

For the 2018 north hemispheric concurrent heat events, attribution to climate change even goes further. Vogel et al. (2019) found that these events would not have occurred without human-induced climate change and that these events would be exceeded in severity or frequency annually under 2°C warming.

—— Likelihood of similar event per year ——

EVENT	CONTEXT, IMPACT	VARIABLE	NATURAL	CURRENT	1.5°C	2°C
Europe 2016	Hottest year on record	T	0% (0%)	27% (17-37%)	52% (42-63%)	88% (83-92%)
Central England 2014	Hottest year on record	T	0% (0-1%)	19% (13-25%)	29% (21-37%)	48% (38-59%)
Central Europe JJA 2003	Hottest summer on record, thousands of heat-related deaths	T	1% (1-2%)	25% (17-33%)	42% (32-51%)	59% (50-70%)
		TXx	2% (0-6%)	21% (7-37%)	21% (9-34%)	31% (14-50%)

**Figure 7:** Likelihood of similar heat waves occurring without climate change, at current warming levels, for 1.5° and 2° warming. Source: King & Karoly, 2017

According Chapter 3 of the IPCC 1.5 Special Report limiting global warming to 1.5°C means that 420 million fewer people will be exposed to extreme heatwaves and 65 million less are exposed to exceptional heatwaves (medium confidence). The report also points out that twice as many megacities will be exposed to heat stress at 1.5°C warming in comparison to present day warming levels exposing up to 250 million additional people to deadly heat wave conditions by 2050 (Roy et al., 2018).

## Drought

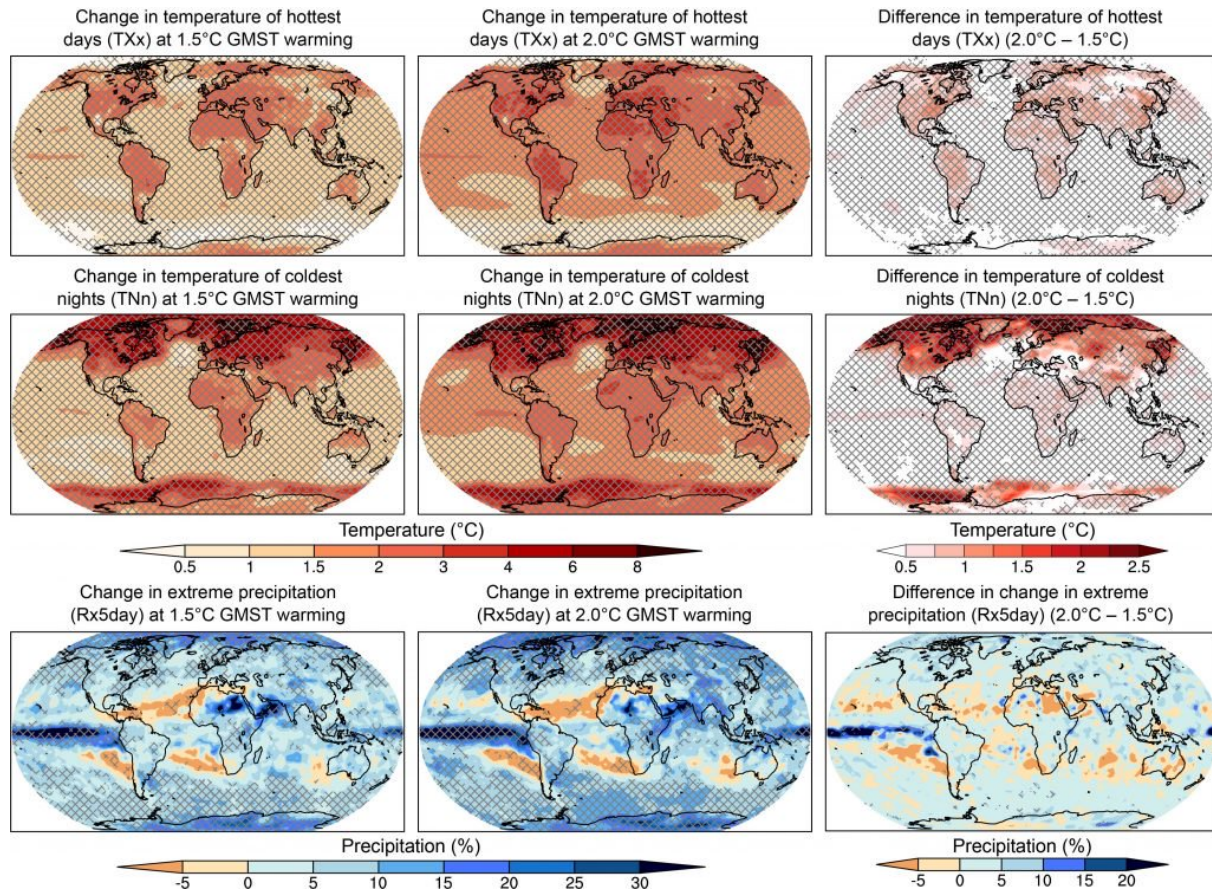
The frequency and intensity of droughts has already increased in some regions, including the Mediterranean, west Asia, many parts of South America, much of Africa, and north-eastern Asia (IPCC, 2019b). The risk of extreme drought is substantially higher for 2°C warming levels and above than for 1.5°C global warming (medium confidence). The Mediterranean region and southern Africa particularly will be affected by extreme drought including increasing water stress (Ove Hoegh-Guldberg et al., 2018).

The IPCC report offers a detailed analysis for the Eastern Mediterranean region showing that the drought episode between 2007-2010 was the longest and most intense one in 900 years. A comparison between the 2008 drought and the drought in 1960 for Syria which was similar in precipitation, but with lower temperatures than 2008, shows that the increased evapotranspiration due to higher temperatures and the increase in population (from 5 to 22 million) amplified the drought in 2008 (Ove Hoegh-Guldberg et al., 2018).

## Extreme precipitation

There is medium confidence that extreme precipitation events have increased in frequency, intensity and/or amount of heavy precipitation due to anthropogenic climate change on a

global level which affect all sectors including agriculture, transport, health, freshwater availability, biodiversity, forests, etc. Heavy precipitation (aggregated at a global scale) is projected to increase with higher temperatures (IPCC, 2018). The largest increase in heavy precipitation is expected in high-latitude regions (e.g. Alaska /western Canada, eastern Canada/ Greenland/Iceland, northern Europe and northern Asia); mountainous regions (e.g., Tibetan Plateau); eastern Asia (including China and Japan); and eastern North America (medium confidence). Heavy precipitation associated with tropical cyclones will increase with higher temperatures (e.g. 2°C instead of 1.5°C of global warming).



**Figure 8:** Projected changes in extremes at 1.5°C (left) and 2°C (middle) of global warming compared to the pre-industrial period (1861–1880), and the difference between 1.5°C and 2°C of global warming (right). Source: Ove Hoegh-Guldberg et al., 2018

Figure 8 from the IPCC 1.5 special report shows the global increase in extreme precipitation for the world (bottom left and middle for 1.5°C and 2°C warming respectively). The bottom right graph shows the difference in change between 2°C and 1.5°C warming. The top six maps show the change in temperature extreme for hottest days and coldest nights.

## Floods

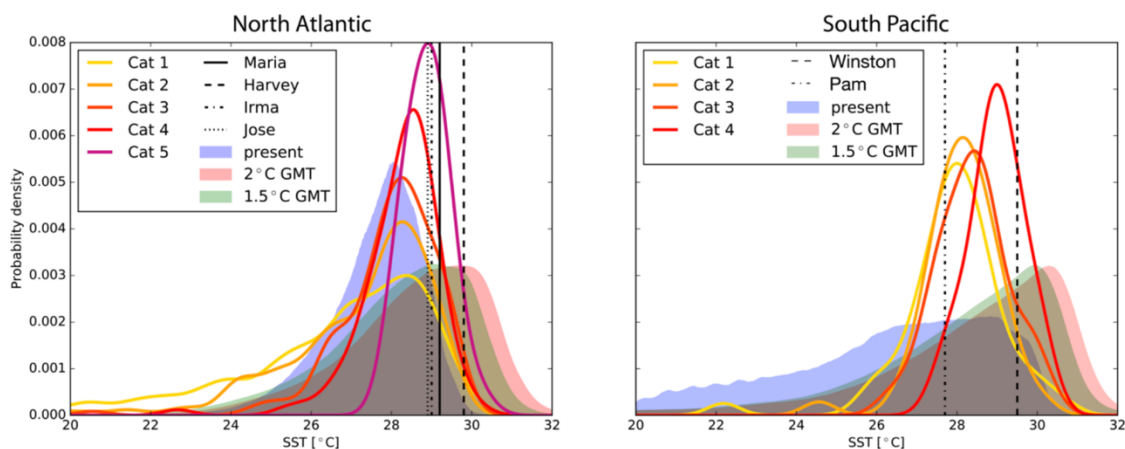
According to the IPCC 1.5 special report, the expected frequency and magnitude of floods are likely higher for temperatures exceeding 1.5°C warming (medium confidence). At 1.5°C global warming the IPCC 1.5 special report gives medium confidence for an expansion of the areas with significant increases in runoff and areas affected by flood hazards. For 2°C further



increase in runoff and flood hazards is expected (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

## Tropical cyclones

While tropical cyclones are projected to decrease in frequency they will increase in the number of very intense cyclone (limited evidence, low confidence). Major tropical cyclones develop at sea surface temperatures of 27°C and above. With increasing global temperatures, sea surface temperatures also increase making Cat. 3-5 tropical cyclones more probable (Ove Hoegh-Guldberg et al., 2018). The following graphic supports the shift towards an increase of Cat. 3-5 cyclones both in the Caribbean and the Pacific region.



**Figure 9:** Probability density of tropical cyclone formation against sea surface temperatures (SST) in the formation region by cyclone category for the North Atlantic (left) and the South Pacific basin (right). Black lines show recent tropical cyclones. The shaded areas show monthly sea-surface temperature (SST) distributions for the months of the main cyclone season including all grid cells of the main development region. Present (blue) for the period 1986-2005. Projections for 2°C global warming (red) and 1.5°C global warming (green) are presented for a multi-model mean of CMIP5 models. Source: Thomas, Pringle, Pfeleiderer, & Schleussner, 2017

Tropical cyclones are often linked to extreme precipitation and extreme sea level rise which creates a compound climate hazard (Ove Hoegh-Guldberg et al., 2018).

A recent study on wave-driven flooding shows that most atolls located in the tropics will be uninhabitable by 2050 due to expected annual wave overwash which will contaminate available freshwater resources without allowing them to recover and will damage the infrastructure of these islands (Storlazzi et al., 2018).

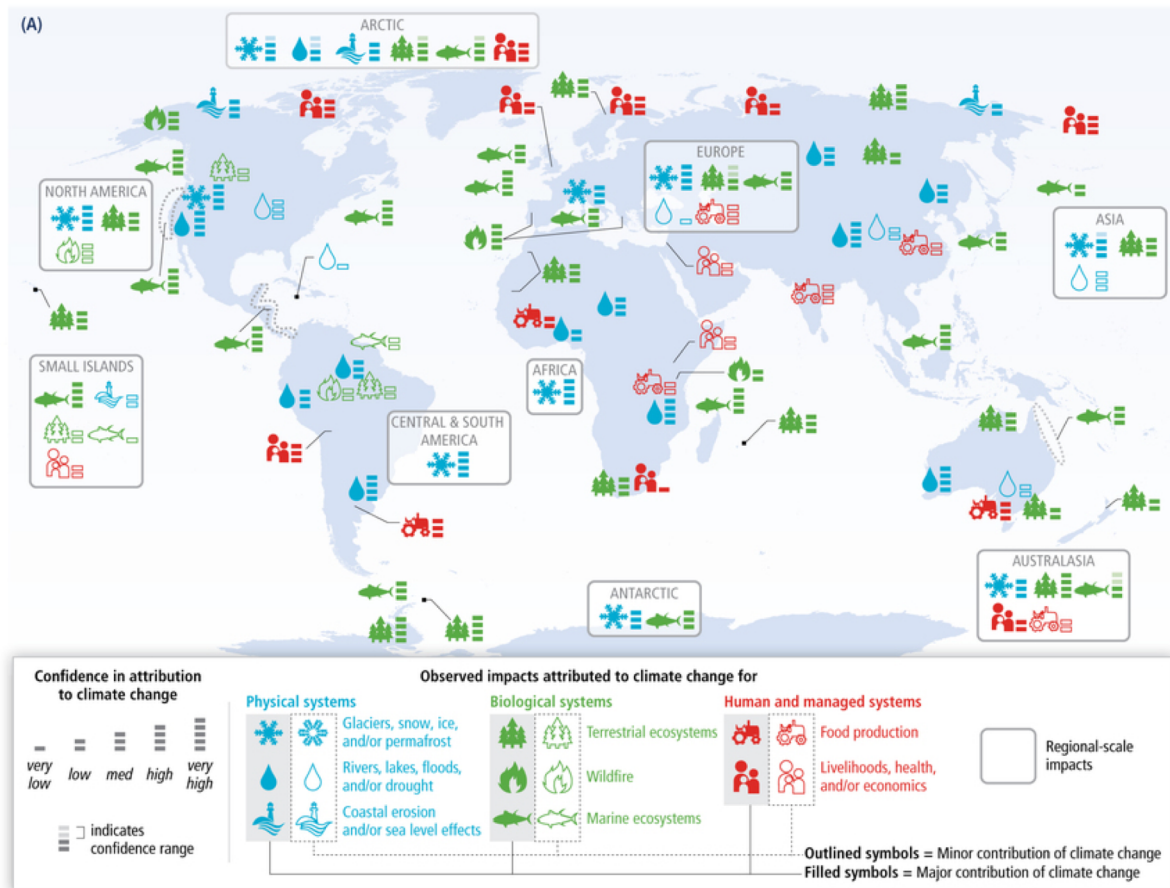
## Wildfires

Due to increasing droughts and heat waves, wildfires are increasing in intensity. The Mediterranean in particular will experience an increase under 1.5°C warming. Under 2°C warming, the USA and Canada are projected to experience increasing wildfires. According to the IPCC 1.5 special report, there is still little information available for many world regions including Central and South America, Australia, Russia, China, and Africa (Ove Hoegh-Guldberg et al., 2018). The IPCC 5<sup>th</sup> Assessment Report rates with medium confidence that the frequency of wildfires in subarctic conifer forests and tundra will increase (Field et al., 2014).

### 3.5. Impacts on different sectors

The global climate has changed relative to the pre-industrial period, and there are multiple lines of evidence that these changes have had impacts on organisms and ecosystems, as well as on human systems and well-being (high confidence) (Ove Hoegh-Guldberg et al., 2018).

The IPCC 5<sup>th</sup> Assessment Report gives an overview of key sectors that are already impacted by climate change in different regions.



**Figure 10:** Widespread impacts in a changing world. Global patterns of impacts in recent decades attributed to climate change, based on studies since the AR4. Impacts are shown at a range of geographic scales. Symbols indicate categories of attributed impacts, the relative contribution of climate change (major or minor) to the observed impact, and confidence in attribution. Source: C B Field et al., 2014

The newly published special report on climate change and land assesses the risk to humans and ecosystems from changes in land-based processes as a result of climate change and is able to show that today at 1°C warming impacts are noticeable and will increase significantly for 1.5°C, 2°C and further degrees of warming. Food supply insecurity in particular could affect whole regions periodically (medium confidence) (IPCC, 2019b).

## A. Risks to humans and ecosystems from changes in land-based processes as a result of climate change

Increases in global mean surface temperature (GMST), relative to pre-industrial levels, affect processes involved in desertification (water scarcity), land degradation (soil erosion, vegetation loss, wildfire, permafrost thaw) and food security (crop yield and food supply instabilities). Changes in these processes drive risks to food systems, livelihoods, infrastructure, the value of land, and human and ecosystem health. Changes in one process (e.g. wildfire or water scarcity) may result in compound risks. Risks are location-specific and differ by region.

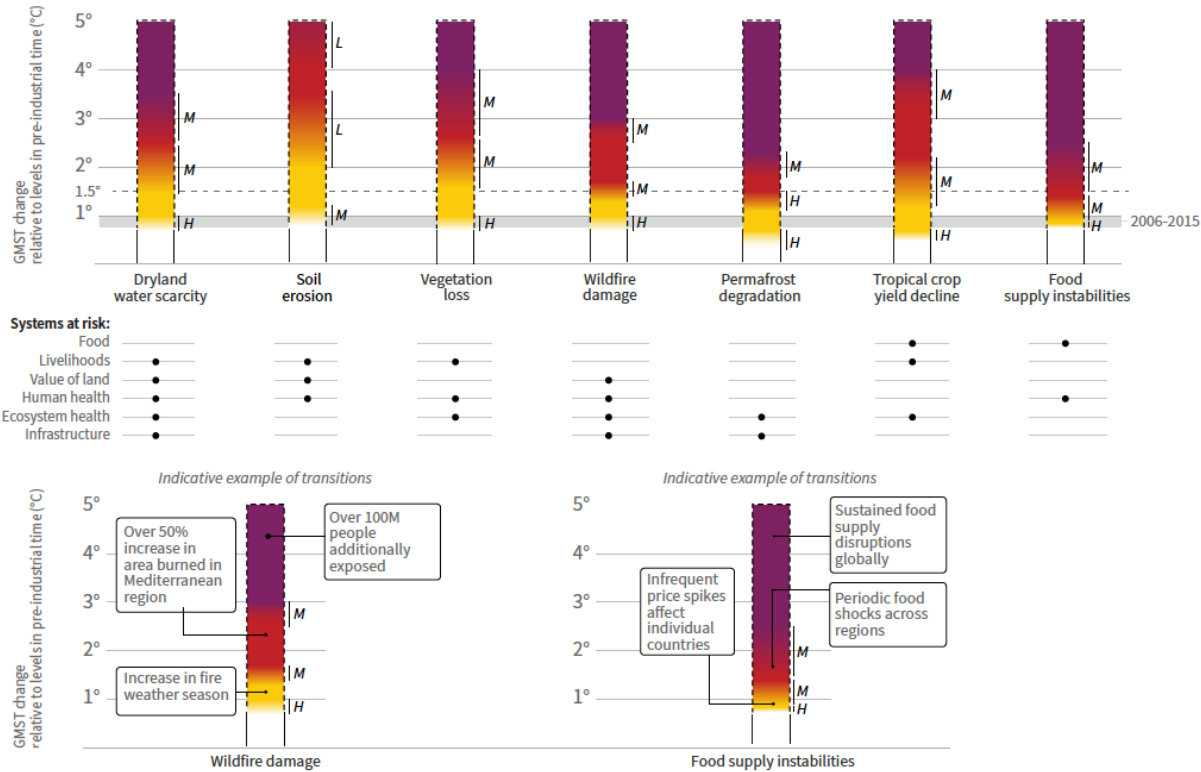


Figure 11: Risks to land-related human systems and ecosystems from global climate change, socio-economic development and mitigation choices in terrestrial ecosystems. Source: IPCC, 2019

### 3.5.1. Crops

Climate change impacts on crop yields have been detected and attributed to climate change with *high confidence*. Today crop production has been affected by climate change impacting particularly local crops that grow under specific climate conditions, such as for example olives or grapevines in Mediterranean. Among the main agricultural crops worldwide, particularly wheat and maize have experienced the highest negative impact. While some high-altitude areas experience an increase in crop yield; tropical crop yield in West Africa, Southeast Asia and Central and South America in particular are at a significant risk of declining for a global temperature increase of 2° and more (high confidence). West Africa has been identified as a hotspot for negative impacts from climate change on crop yields and production for 2° warming endangering food security in the future (Ove Hoegh-Guldberg et al., 2018).

For each degree of global mean temperature increase, a significant reduction in global production of all main agricultural crops is projected. Reductions in global production are projected to be as follows: wheat (by  $6.0 \pm 2.9\%$ ), rice (by  $3.2 \pm 3.7\%$ ), maize (by  $7.4 \pm 4.5\%$ ), and soybean (by  $3.1\%$ ). Adaptation measures such as adjusted planting times, fertilizers and irrigation may increase wheat and maize yields by 7-12% (de Coninck et al., 2018).



Heat stress impacts livestock causing increased animal mortality, increased water need and reduced production of e.g. milk. At approximately 2°C of warming a global loss of 7–10% of rangeland livestock is projected, with considerable economic consequences for many communities and regions (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

### *3.5.2. Freshwater availability*

Water scarcity has been an increasing problem which has worsened due to changes in climate, water consumption behavior, population growth and distribution, ranging from .24 billion (14% of the global population) in the 1900s, to 3.8 billion (58%) in the 2000s. 1.1 billion people (17% of the global population) mostly in South and East Asia, North Africa and the Middle East faced serious water shortage and high water stress in the 2000s (Ove Hoegh-Guldberg et al., 2018).

Even though regions particularly affected by drought will face an increasing impact on the level of water stress, the IPCC 1.5 special report concludes that the changes in population will generally have a greater effect on water resource availability. At 1.5°C warming the percentage of the world population expected to be exposed to water stress will increase by 4%, while 8% more - will be exposed at 2°C warming (Roy et al., 2018).

Small islands in particular will face water stress linked to coastal flooding and sea level rise which is expected to be worse at 2°C in comparison to 1.5° warming (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

### *3.5.3. Biodiversity/ecosystems*

The IPCC 1.5 special report confirms the findings of IPCC 5<sup>th</sup> Assessment Report which concluded that the geographical ranges of many terrestrial and freshwater plant and animal species have moved over the last several decades in response to warming: approximately 17 km poleward and 11 m up in altitude per decade (Ove Hoegh-Guldberg et al., 2018).

Of 105,000 species studied, 6% of insects, 8% of plants and 4% of vertebrates are projected to lose over half of their climatically determined geographic range for global warming of 1.5°C, compared with 18% of insects, 16% of plants and 8% of vertebrates for global warming of 2°C (medium confidence). Impacts associated with other biodiversity-related risks such as forest fires and the spread of invasive species are lower at 1.5°C compared to 2°C of global warming (high confidence) (IPCC, 2018).

Alpine regions are generally regarded as climate change hotspots given that rich biodiversity has evolved in their cold and harsh climate, but with many species consequently being vulnerable to increases in temperature. Under regional warming, alpine species have been found to migrate upwards on mountain slopes (Reasoner and Tinner, 2009), an adaptation response that is obviously limited by mountain height and habitability (Ove Hoegh-Guldberg et al., 2018).

#### 3.5.4. Forests

Forests, particularly tropical forests are considered the biggest carbon sink and afforestation and reforestation are part of mitigation strategies to store carbon.

Projected impacts on forests as climate change occurs include increases in the intensity of storms, wildfires and pest outbreaks (Settele et al., 2014), potentially leading to forest dieback (medium confidence). Warmer and drier conditions in particular facilitate fire, drought and insect disturbances, while warmer and wetter conditions increase disturbances from wind and pathogens (Seidl et al., 2017). Particularly vulnerable regions are Central and South America, Mediterranean Basin, South Africa, South Australia where the drought risk will increase (Ove Hoegh-Guldberg et al., 2018).

The increase in frequency of forest fires in North America between 1984-2015 has been attributed to climate change. Compared to what would have been expected without climate change, forest fires via the mechanism of increasing fuel aridity almost doubled in the western USA (Ove Hoegh-Guldberg et al., 2018).

High-latitude tundra and boreal forest are particularly at risk, and woody shrubs are already encroaching into tundra (*high confidence*) and will proceed with further warming. Increased disturbance from fire, pests and heat-related mortality may affect the southern boundary of boreal forests in particular (*medium confidence*) (Ove Hoegh-Guldberg et al., 2018).

At 1.5°C warming levels, deforestation and fire increases pose an uncertain risk to forest dieback. At 2- 3°C warming levels, a reduced extent of tropical rainforest is expected for Central America, where the tropical rainforest biomass would be reduced by about 40% under global warming of 3°C, with considerable replacement by savanna and grassland. With a global warming of close to 1.5°C in 2050, a biomass decrease of 20% is projected for tropical rainforests of Central America. If a linear response is assumed, this decrease may reach 30% (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

#### 3.5.5 Land degradation, permafrost and biomes

Climate change exacerbates land degradation, particularly in low-lying coastal areas, river deltas, drylands and in permafrost areas (high confidence). People living in already degraded or desertified areas are increasingly negatively affected by climate change (high confidence) (IPCC, 2019b).

Land degradation resulting from the combination of sea level rise and more intense cyclones is projected to jeopardize lives and livelihoods in cyclone prone areas (very high confidence). Within populations, women, the very young, elderly and poor are most at risk (high confidence) (IPCC, 2019b).

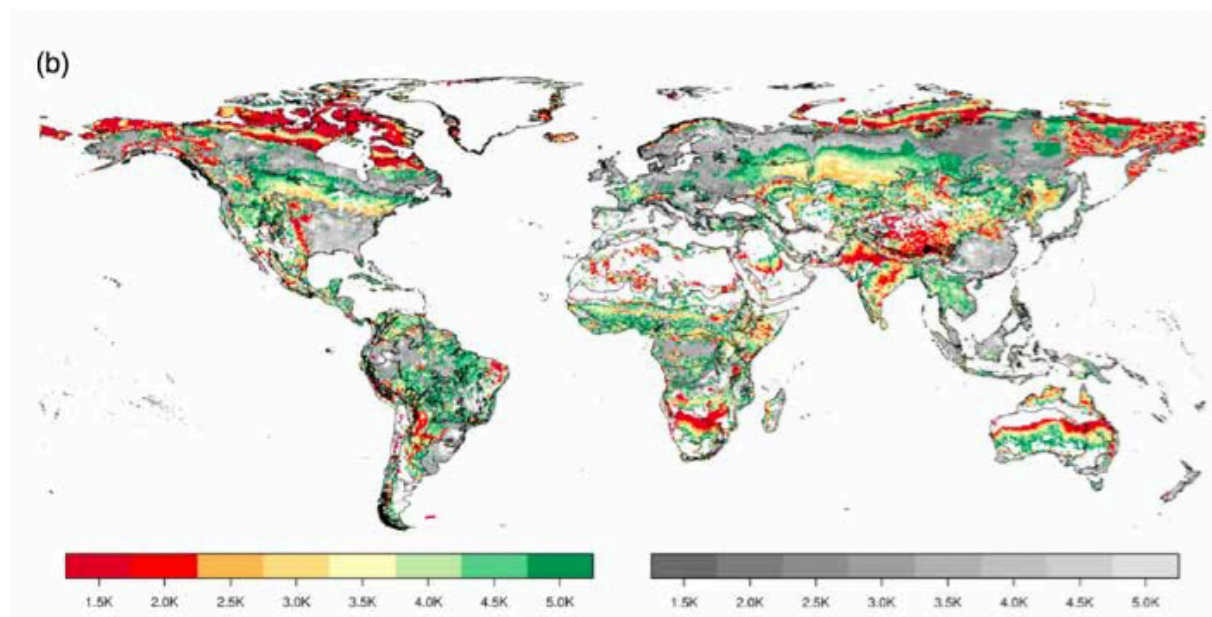
Climate change can lead to land degradation, even with the implementation of measures intended to avoid, reduce or reverse land degradation (high confidence). Examples of climate

change induced land degradation that may exceed limits to adaptation include coastal erosion exacerbated by sea level rise where land disappears (high confidence), thawing of permafrost affecting infrastructure and livelihoods (medium confidence), and extreme soil erosion causing loss of productive capacity (medium confidence) (IPCC, 2019b).

The Arctic tundra biome is experiencing increasing fire disturbance and permafrost degradation (Ove Hoegh-Guldberg et al., 2018).

At a 1.5°C warming scenario, a biome shift in the tundra and permafrost deterioration are likely. A 17-44% reduction in permafrost is projected for under 1.5°C warming, compared to 28-53% for under 2°C warming. For more than 2°C warming there is potential for permafrost to collapse (low confidence). In any case, the reduction of permafrost will cause an irreversible loss of stored carbon (Ove Hoegh-Guldberg et al., 2018).

The map shows the results of an ecosystem model illustrating that biome shifts in the Arctic, Tibet, Himalayas, southern Africa and Australia would be avoided by constraining warming to 1.5°C compared with 2°C (Ove Hoegh-Guldberg et al., 2018).



**Figure 12:** Level of global temperature anomaly above pre-industrial levels that leads to significant local changes in terrestrial ecosystems. Regions with severe (coloured) or moderate (greyish) ecosystem transformation; delineation refers to the 90 biogeographic regions. All values denote changes found in >50% of the simulations. Source: (Gerten et al., 2013). Regions coloured in dark red are projected to undergo severe transformation under a global warming of 1.5°C while those coloured in light red do so at 2°C; other colours are used when there is no severe transformation unless global warming exceeds 2°C. Source: Ove Hoegh-Guldberg et al., 2018

### 3.5.6. Economic impacts

Global economic damages of climate change are projected to be smaller under warming of 1.5°C than 2°C in 2100. The mean net present value of the costs of damages from warming in 2100 for 1.5°C and 2°C (including costs associated with climate change-induced market and non-market impacts, impacts due to sea level rise, and impacts associated with large-scale

discontinuities) are \$54 and \$69 trillion, respectively, relative to 1961–1990 (Ove Hoegh-Guldberg et al., 2018).

As almost all impacts will worsen with increasing temperatures, the costs associated with these impacts will increase as well. At the same time, extreme events and slow-onset events as well as related health impacts such as heat stress will decrease the GDP. The IPCC 1.5 special report states that at 2°C global warming, lower economic growth is projected for many countries than at 1.5°C of global warming, with low-income countries projected to experience the greatest losses (low to medium confidence) (Ove Hoegh-Guldberg et al., 2018). A recent paper from Burke et al. (2018) shows decreases of global GDP for different warming levels between 10 and more than 30% for 1.6 and 4.3° warming levels by 2100 respectively (RCP2.6 and RCP8.5).

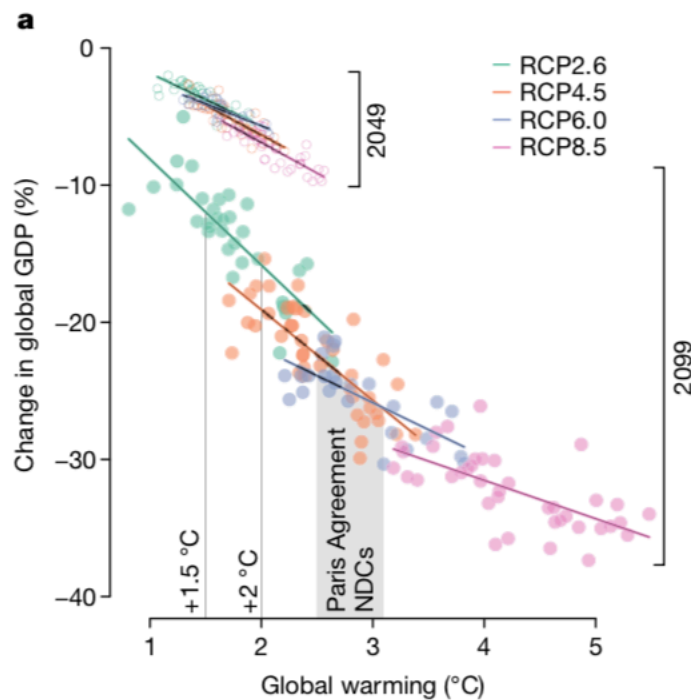


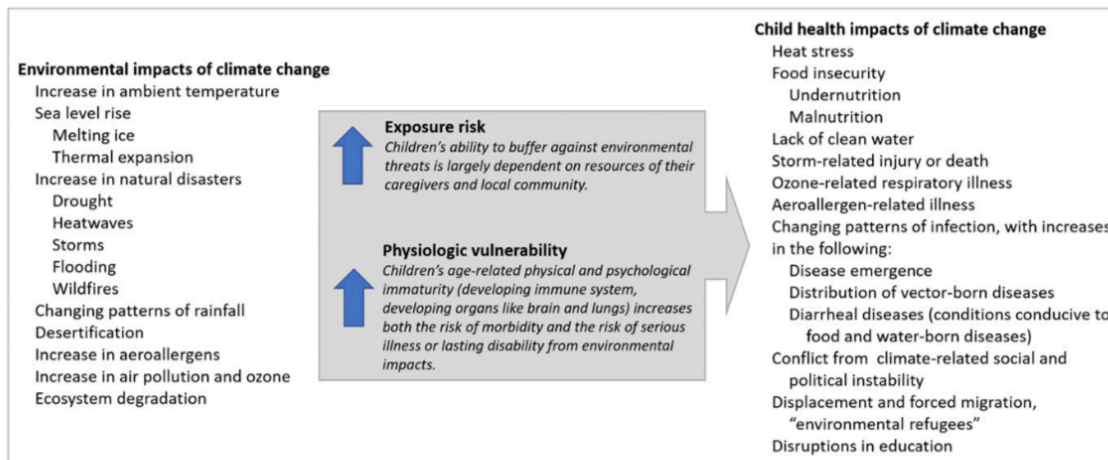
Figure 13: The impact of global warming on global GDP per capita, relative to a world without warming, for different forcing levels. Projected percentage change in global GDP for different climate models under different warming levels (RCPs), relative to a no-warming baseline. Colours denote different warming levels. Green about 1.6°C warming by 2100, orange about 2.3°C warming by 2100, purple 2.8°C warming by 2100 and pink 4.3°C warming by 2100. Warming is relative to pre-industrial levels. Unfilled points show mid-century projections, filled points show end-of-century projections. Vertical lines show the UN temperature targets as well as the range of estimates of end-of-century warming under current Paris commitments.

### 3.6. Health

The IPCC 5<sup>th</sup> Assessment Report concluded there is high to very high confidence that climate change will lead to greater risks of injuries, disease and death, owing to more intense heatwaves and fires, increased risks of undernutrition, and consequences of reduced labour productivity in vulnerable populations (Ove Hoegh-Guldberg et al., 2018).

In every crisis, children are amongst the most vulnerable. The same is true for climate change. Considering that areas at risk for flood and drought often overlap with areas of higher poverty, the most disadvantaged will be unproportionally affected by climate change (UNICEF, 2015). This definition is in line with the one of the IPCC 1.5 special report which defines the population at highest risk to include older adults, children, women, those with chronic diseases, and people taking certain medications (*very high confidence*) (Ove Hoegh-Guldberg et al., 2018).

These effects will impact children more significantly than adults, as they do not only face direct risks of climate change, but are also affected indirectly for example if their parents lose their livelihood or are affected by crop failure (UNICEF, 2015). Additionally and compared to adults, children are physically more vulnerable to the direct effects of extreme heat, drought, and natural disasters (Currie & Deschênes, 2016). The following overview shows the health impacts children face due to the diverse environmental impacts of climate change.



**Figure 14:** Climate-related environmental health threats to children. Source: Pass Philipsborn & Chan, 2018

### 3.6.1. Health impacts linked to temperature rise

*Any increase in global temperature (e.g., +0.5°C) is projected to affect human health, with primarily negative consequences (high confidence) (Ove Hoegh-Guldberg et al., 2018).*

Higher temperature increase will have a negative effect on heat-related morbidity and mortality (*very high confidence*), and for ozone related mortality (*high confidence*). Urban populations in particular will be affected by amplified impacts due to urban heat islands (*high confidence*) (Ove Hoegh-Guldberg et al., 2018). The extent that urban populations are at risk of being impacted negatively by climate change depends on human vulnerability and the effectiveness of adaptation for regions (coastal and non- coastal), informal settlements and infrastructure sectors (such as energy, water and transport) (*high confidence*) (Ove Hoegh-Guldberg et al., 2018).



Additionally, poverty and disadvantage have increased with recent warming (about 1°C) and are expected to increase for many populations as average global temperatures increase from 1°C to 1.5°C and higher (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

### *3.6.2. Health impacts linked to extreme weather events*

Due to several major global trends, including demographic and migration trends, more and more people are living in disaster-prone areas and exposed to weather extremes (UNICEF, 2015).

According to the report from UNICEF (2015) 500 million children live in extremely high flood occurrence zones and 160 million live in high or extremely high drought severity zones. With an expected increase in the frequency and intensity of these events driven by climate change, children will face even greater risk of exposure in the future. Infrastructure such as schools, hospitals and transport, as well as natural goods such as water systems and crops are crucial for the well-being of children and can get destroyed or damaged during floods and droughts.

#### **Mortality**

Studies have shown that children under 12 months old are particularly vulnerable to heatwaves. The mortality rate of infants and small children who are more likely to die or suffer from heatstroke because they are unable or lack agency to regulate their body temperature and control their surrounding environment. Dehydration can be caused by extreme heat stress which slows the sweating rate leading to hyperthermia and infant mortality. Diarrhea is another factor that can increase the risk of heat injury and death (UNICEF, 2015).

#### **Physical impacts**

The long-term effects of experiencing flooding can be substantial for children and has not only psychological impacts but results in physical impacts as well. A long-term study on children exposed to El Niño flooding in 1997/98 showed that five years later they were found to be smaller (1-1.8cm shorter than their peers), had higher incidence of stunting and lower body weight for age (0.38kg) compared to the control group (UNICEF, 2015).

Heatwaves can cause heat rash, heat-related cramps, exhaustion and stroke particularly in young children. Children with chronic health conditions, those living in poverty, those who lack adequate nutrition, water and sanitation face a higher risk (UNICEF, 2015).

#### **Psychological impacts**

Extreme events can cause emotional distress for children including fear of separation from their families, mounting tensions and pressures within households, a lack of emotional support at family level, and increased workloads (UNICEF, 2015).

A study conducted in southeast USA following Hurricane Andrew and another study in Poland conducted after the 1997 floods showed that children are 2-3 times more likely to suffer from posttraumatic stress disorder (UNICEF, 2015).



## Other health impacts

Potential wildfires resulting from extreme heat and drought can cause death and displacement or destruction or damage of essential services, shelter and food (UNICEF, 2015).

### 3.6.3. Food security

An estimated 821 million people are currently undernourished, 151 million children under 5 are stunted, 613 million women and girls aged 15 to 49 suffer from iron deficiency, and 2 billion adults are overweight or obese. The food system is under pressure from non-climate stressors (e.g., population and income growth, demand for animal-sourced products), and from climate change. These climate and non-climate stresses are impacting the four pillars of food security (availability, access, utilization, and stability) (IPCC, 2019a).

Climate change has already affected food security due to warming, changing precipitation patterns, and greater frequency of some extreme events (high confidence) (IPCC, 2019b). The people most affected live in low and middle-income countries some of which already at present day face a decline in food security partly due to migration and poverty (Allen et al., 2018).

Although hunger has been declining for the past 3 decades, undernutrition has worsened, particularly in parts of sub-Saharan Africa, South-Eastern Asia and Western Asia, and recently Latin America. Deteriorations have been observed most notably in situations of conflict and conflict combined with droughts or floods (IPCC, 2019a). The stability of food supply is projected to decrease as the magnitude and frequency of extreme weather events that disrupt food chains increases (high confidence). Increased atmospheric CO<sub>2</sub> levels can also lower the nutritional quality of crops (high confidence) (IPCC, 2019a).

Overall, food security is expected to be reduced at 2°C global warming compared to 1.5°C, owing to projected impacts of climate change and extreme weather on yields, crop nutrient content, livestock, fisheries and aquaculture and land use (cover type and management) (high confidence) (Ove Hoegh-Guldberg et al., 2018). The West Sahel zone is projected to face serious food security issues above 2°C (Ove Hoegh-Guldberg et al., 2018).

Considering that children need to consume more food and water per unit of body weight than adults, they are more vulnerable to deprivation of food and water. Therefore, undernutrition affects children over-proportionally and is responsible for nearly half of all under-five deaths. Extreme events such as droughts increase the direct risk of undernutrition, but also impacts children indirectly. The weight of children born to women exposed to drought in the year before giving birth can be negatively impacted. Furthermore, exposure to undernutrition in their first two years of life can cause stunting in children which affects physical and cognitive development, impacting the rest of a child's life – including his or her schooling, health and livelihood (UNICEF, 2015).

#### 3.6.4. Spreading of diseases

Changing weather patterns are associated with shifts in the geographic range, seasonality and transmission intensity of selected climate-sensitive infectious diseases (Ove Hoegh-Guldberg et al., 2018).

##### **Vector-borne diseases**

Children face a higher vulnerability to vector-borne diseases such as dengue and malaria (UNICEF, 2015). The World Health Organization (WHO) has estimated that 88 % of the existing burden of disease as a result of climate change occurs in children under five years of age (Ahdoot & Pacheco, 2015). Malaria is estimated to be responsible for 438,000 deaths in 2015 of which two-thirds were children below the age of five (UNICEF, 2015).

Risks for some vector-borne diseases, such as malaria and dengue fever are projected to increase with warming from 1.5°C to 2°C, including potential shifts in their geographic range (*high confidence*). Overall for vector-borne diseases, whether projections are positive or negative depends on the disease, region and extent of change (*high confidence*) (Ove Hoegh-Guldberg et al., 2018).

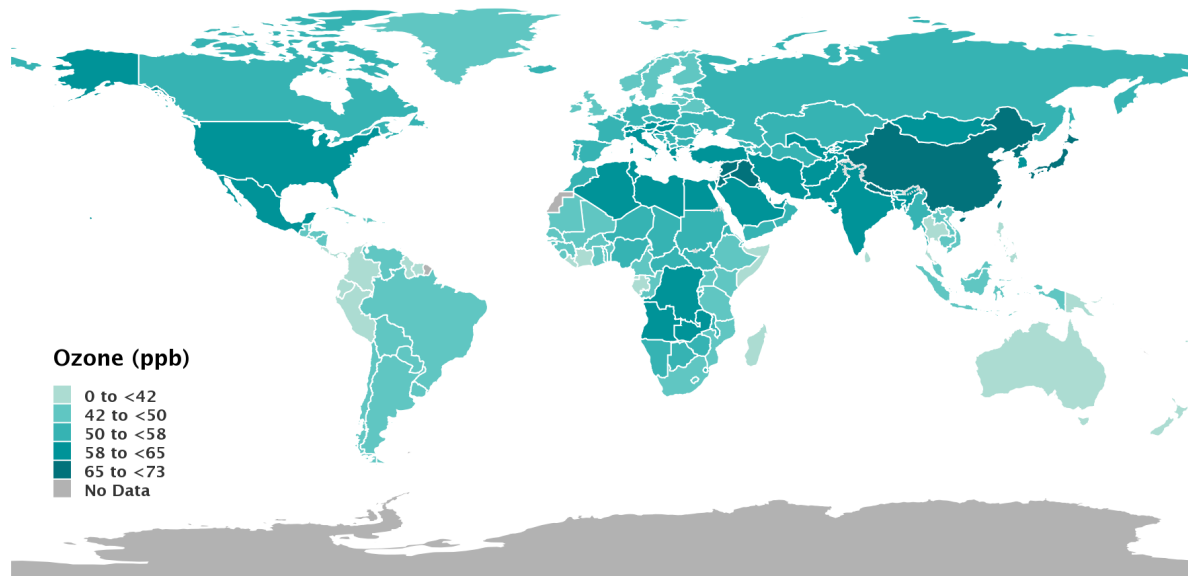
##### **Water-borne diseases**

Diarrheal diseases are estimated to have caused 480,000 deaths of children in 2016 alone (United Nations Children's Fund, 2018). They rank among the top five causes of death for children under five. Extreme events such as floods, droughts and severe storms which are increasing in frequency and intensity due to climate change, disrupt the access to safe water and sanitation which can lead to contamination of water resources resulting in water-borne diseases (UNICEF, 2015).

#### 3.6.5. Air quality

Because ozone formation is temperature dependent, projections focusing only on temperature increase generally conclude that ozone-related mortality will increase with additional warming, with the risks higher at 2°C than at 1.5°C (*high confidence*) (Ove Hoegh-Guldberg et al., 2018).

Average Seasonal Population–Weighted Ozone Concentrations in 2017



State of Global Air

**Figure 15:** Global ozone concentrations in 2017 (shown as population-weighted seasonal averages) Source: Health Effects Institute, 2019

Due to smaller lungs and a twice as rapid breathing rate up until the age of 12, children inhale proportionally more polluted air. Ozone as one of the increasing pollutants is a trigger of childhood asthma. It can exacerbate asthma symptoms in children. Children may be exposed to higher levels of ozone as they are likely to be outside during peak ozone times (UNICEF, 2015).

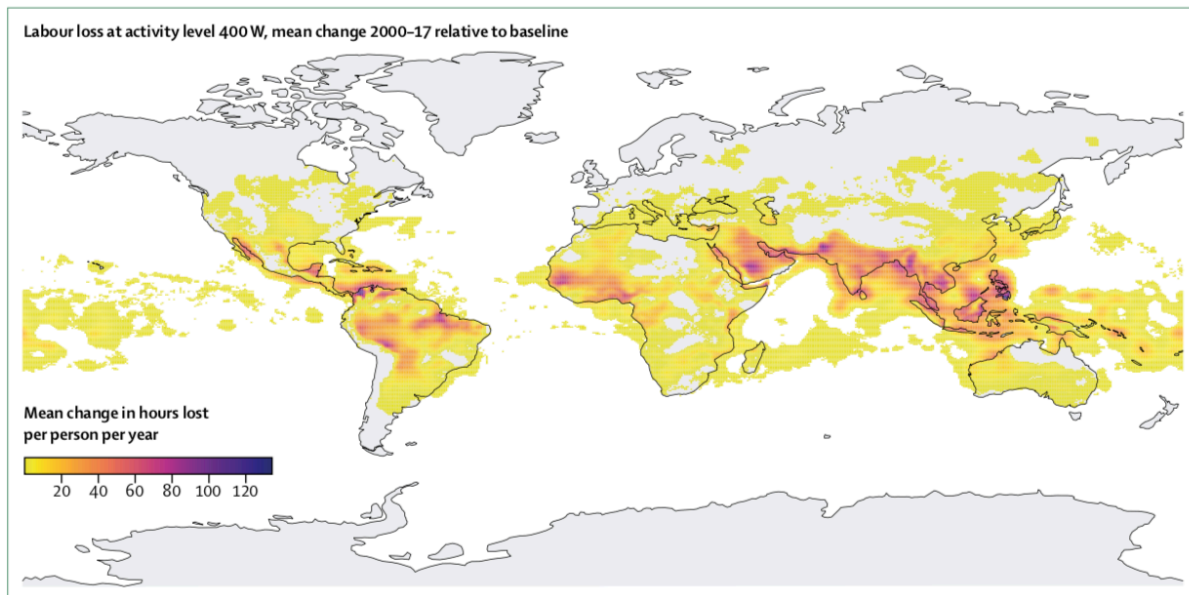
Increasing global temperatures increase pollen production and result in higher levels of natural allergens increasing the severity of asthma and other respiratory conditions (UNICEF, 2015).

Smoke from wild fires resulting from extreme heat and drought periods cause 260,000 to 600,000 deaths annually. Due to the higher breathing rate of children under 12, the impact on their health is particularly severe (UNICEF, 2015).

### 3.6.6. Occupational health

Increasing temperature and higher humidity levels pose additional stress on individuals engaging in physical activity. Safe work activity and worker productivity during the hottest months of the year would be increasingly compromised with additional climate change (medium confidence) (Ove Hoegh-Guldberg et al., 2018).

The Lancet report estimates 153 billion hours of labor were lost in 2017 which equals an increase of 62 billion in comparison to the year 2000. 80% of the losses are linked to the agricultural sector. The areas most affected are India, southeast Asia, and sub-Saharan Africa, and South America (Watts et al., 2018) which is visible in Figure 16.



**Figure 16:** Mean change in total hours of labor lost at the agricultural activity level (metabolic rate of 400 W) over the 2000–2017 period relative to the 1986–2005 baseline. Source: Watts et al., 2018

The impacts of occupational health will become even more pressing with increasing temperatures. According to the IPCC 1.5 special report, the costs of preventing workplace heat-related illnesses through worker breaks suggest that the difference in economic loss between 1.5°C and 2°C could be approximately 0.3% of global gross domestic product (GDP) in 2100 (Ove Hoegh-Guldberg et al., 2018).

### 3.7. Societal impacts

Drought significantly increases the likelihood of sustained conflict for particularly vulnerable nations or groups, owing to the dependence of their livelihood on agriculture. This is particularly relevant for groups in the least developed countries, in sub-Saharan Africa and in the Middle East (Ove Hoegh-Guldberg et al., 2018).

#### Conflict

According to the IPCC 5<sup>th</sup> Assessment Report, climate change can indirectly increase risks of violent conflicts in the form of civil war and inter-group violence by amplifying well-documented drivers of these conflicts such as poverty and economic shocks (*medium confidence*). Multiple lines of evidence relate climate variability to these forms of conflict (IPCC, 2014).

According to the IPCC 1.5 special report a 1°C increase in temperature or more extreme rainfall increases the frequency of intergroup conflicts by 14%. If the world warms by 2°C–4°C by 2050, rates of human conflict could increase. Some causal associations between violent

conflict and socio-political instability were reported from local to global scales and from hour to millennium time frames. A temperature increase of one standard deviation increased the risk of interpersonal conflict by 2.4% and intergroup conflict by 11.3% (Ove Hoegh-Guldberg et al., 2018).

## Migration

Changes in climate can amplify environmentally induced migration both within countries and across borders (medium confidence), reflecting multiple drivers of mobility and available adaptation measures (high confidence). Extreme weather and climate or slow-onset events may lead to increased displacement, disrupted food chains, threatened livelihoods (high confidence), and contribute to exacerbated stresses for conflict (medium confidence) (IPCC, 2019b).

Conflict as well as natural disasters can lead to migration. The social, economic and environmental factors underlying migration are complex and varied; therefore, detecting the effect of observed climate change or assessing its possible magnitude with any degree of confidence is challenging (Ove Hoegh-Guldberg et al., 2018). Since 2008, climate-related displacement has affected an estimated 22.5 million people per year on average - equivalent to 62,000 people every day (UNICEF, 2015).

Even though migration cannot be easily attributed to climate change, the IPCC report does conclude that temperature has had a positive and statistically significant effect on outmigration over recent decades in 163 countries, but only for agriculture-dependent countries (*medium confidence*) (Ove Hoegh-Guldberg et al., 2018). The conflict in Syria follows a multi-year drought period which is one of the stressors that contributed to the outbreak of conflict as recent research shows (Gleick, 2014). The following figure (17) shows asylum seeker flows around the world clearly shows the migration waves particularly leaving Syria (Western Asia).

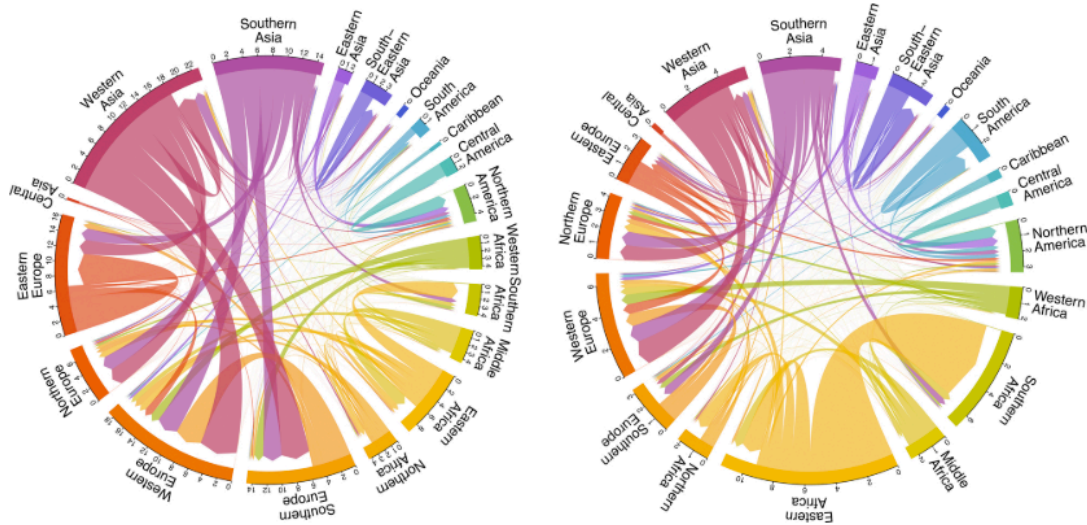


Fig. 2. Asylum seeking flows by world region, 2006–2010 and 2011–2015.

**Figure 17:** Asylum seeker flow by world region, 2006-2010 and 2011-2015. Source: Abel, Brotrager, Crespo Cuaresma, & Muttarak, 2019

Migration in small islands (internally and internationally) occurs for multiple reasons and purposes, mostly for better livelihood opportunities (high confidence) and increasingly owing to sea level rise (medium confidence) (Ove Hoegh-Guldberg et al., 2018). Kiribati was the first island state to actually purchase land in Fiji to consider the migration of a whole nation as a back-up option for future generations (Caramel, 2014).

Warming levels of 2°C have potential for significant population displacement concentrated in the tropics with possible moving distances greater than 1000 km. A disproportionately rapid evacuation from the tropics could lead to a concentration of population in tropical margins and the subtropics, where population densities could increase by 300% or more (Ove Hoegh-Guldberg et al., 2018).

### Educational attainment

Extreme weather events, conflict and migration have an impact on the educational attainment of children, as the economic resources of parents are reduced by e.g. destroyed crops, or the loss of livelihoods. One result may be that parents spend less on their children's schooling or children need to seek work to contribute to the income of the family. Both leads to a decrease in the children's overall educational attainment (Fuller et al., 2018).

Additionally, schools may be damaged or used as shelter during extreme events and are therefore not available for their original purpose (UNICEF, 2015).

### Loss of livelihoods and cultural heritage

Sea level rise, loss of sea ice and glaciers, as well as extreme events can have implications of the livelihoods of people around the world.



Tourism as one of the largest industries is already affected by climate change, with increased risks projected under 1.5°C of warming in specific geographic regions and for seasonal tourism including sun, beach and snow sports destinations (very high confidence). Risks for coastal tourism, particularly in subtropical and tropical regions, will increase with temperature-related degradation (e.g., heat extremes, storms) or loss of beach and coral reef assets (high confidence) (Ove Hoegh-Guldberg et al., 2018).

Beyond 1.5°C warming, both ocean warming and acidification increase, with substantial losses likely for coastal livelihoods and industries (e.g., fisheries and aquaculture) (medium to high confidence). Marine systems and associated livelihoods in Small Island Developing States face higher risks at 2°C compared to 1.5°C (medium to high confidence) (Ove Hoegh-Guldberg et al., 2018).

Today at about 1°C global warming, poverty and disadvantage have increased and are likely to increase even further with rising temperatures. At approximately 1.5°C of global warming (2030), climate change is expected to be a poverty multiplier that makes poor people poorer and increases the poverty head count. Climate change alone could force more than 3 million to 16 million people into extreme poverty, mostly through impacts on agriculture and food prices (Ove Hoegh-Guldberg et al., 2018).

Cultural heritage will be impacted by sea level rise and extreme events. A global analysis of sea level rise risk to 720 UNESCO Cultural World Heritage sites projected that about 47 sites might be affected under 1°C of warming, with this number increasing to 110 and 136 sites under 2°C and 3°C, respectively (Ove Hoegh-Guldberg et al., 2018).

#### 4. Loss and Damage

Long-term risks of coastal flooding and impacts on 2. populations, infrastructures and assets (high confidence), freshwater stress (medium confidence), and risks across marine ecosystems (high confidence) and critical sectors (medium confidence) are projected to increase at 1.5°C compared to present-day levels and increase further at 2°C, limiting adaptation opportunities and increasing loss and damage (medium confidence).

Within the IPCC 1.5 special report Loss and Damage is associated with adverse impacts of climate change on human and natural systems and includes impacts from extreme events (e.g. cyclones) and slow-onset processes (e.g. sea level rise). Loss and damage refer both to economic (loss of assets and crops) and non-economic impacts (biodiversity, culture, health) and irreversible and permanent loss and damage (e.g. loss of coral reefs). The IPCC report addresses both soft and hard limits to adaptation. Soft limits are described as adaptive actions currently not available, while hard limits are adaptive actions which appear infeasible leading to unavoidable impacts (Roy et al., 2018).

For a global warming levels of 1.5°C and 2°C, soft and hard limits will be reached and will be experienced by children living today. Particularly Small Island Developing States populations are threatened to lose their livelihoods forcing people to migrate. In some situations, exceeding the limits of adaptation can trigger escalating losses or result in undesirable transformational changes (medium confidence), such as forced migration (low confidence), conflicts (low confidence) or poverty (medium confidence) (IPCC, 2019b).

System/Region	Example	Soft Limit	Hard Limit
Coral reefs	Loss of 70–90% of tropical coral reefs by mid-century under 1.5°C scenario (total loss under 2°C scenario) (see Chapter 3, Sections 3.4.4 and 3.5.2.1, Box 3.4)		✓
Biodiversity	6% of insects, 8% of plants and 4% of vertebrates lose over 50% of the climatically determined geographic range at 1.5°C (18% of insects, 16% of plants and 8% of vertebrates at 2°C) (see Chapter 3, Section 3.4.3.3)		✓
Poverty	24–357 million people exposed to multi-sector climate risks and vulnerable to poverty at 1.5°C (86–1220 million at 2°C) (see Section 5.2.2)	✓	
Human health	Twice as many megacities exposed to heat stress at 1.5°C compared to present, potentially exposing 350 million additional people to deadly heat wave conditions by 2050 (see Chapter 3, Section 3.4.8)	✓	✓
Coastal livelihoods	Large-scale changes in oceanic systems (temperature and acidification) inflict damage and losses to livelihoods, income, cultural identity and health for coastal-dependent communities at 1.5°C (potential higher losses at 2°C) (see Chapter 3, Sections 3.4.4, 3.4.5, 3.4.6.3, Box 3.4, Box 3.5, Cross-Chapter Box 6, Chapter 4, Section 4.3.5; Section 5.2.3)	✓	✓
Small Island Developing States	Sea level rise and increased wave run up combined with increased aridity and decreased freshwater availability at 1.5°C warming potentially leaving several atoll islands uninhabitable (see Chapter 3, Sections 3.4.3, 3.4.5, Box 3.5, Chapter 4, Cross-Chapter Box 9)		✓

**Table 2:** Soft and hard adaptation limits in the context of 1.5°C and 2°C of global warming. Source: Roy et al., 2018

Limits to adaptation are also discussed in the IPCC 5<sup>th</sup> Assessment Report. Chapter 23 on Europe gives a detailed overview of the limits to adaptation for different sectors summed up in the following table:

Area/location	System	Adaptation measures	Limits to adaptation measure(s)	References
Low-altitude/small-size ski resorts	Ski tourism	Artificial snowmaking	Climatic, technological, and environmental constraints; economic viability; social acceptability of charging for previously free skiing; social acceptability of alternatives for winter sport/leisure	Steiger and Mayer (2008); Unbehaun et al. (2008); Steiger (2010, 2011); Landauer et al. (2012)
Thermal power plants/cooling through river intake and discharge	Once-through cooling systems	Closed-circuit cooling	High investment cost for retrofitting existing plants	Koch and Vögele (2009); van Vliet et al. (2012); Hoffman et al. (2013)
Rivers used for freight transport	Inland transport	Reduced load factor of inland ships	Increased transport prices (Rhine and Moselle market)	Jonkeren et al. (2007); Jonkeren (2009)
		Use of smaller ships	Existing barges below optimal size (Rhine)	Demirel (2011)
Agriculture, northern and continental Europe	Arable crops	Changing sowing date as agricultural adaptation	Other constraints (e.g., frost) limit farmer behavior.	Oort (2012)
		Irrigation	Groundwater availability; competition with other users	Olesen et al. (2011)
Agriculture, viticulture	High-value crops	Change distribution	Legislation on cultivar and geographical region	Box 23-1
Conservation; cultural landscapes	Alpine meadow	Extend habitat	No technological adaptation option	Engler et al. (2011); Dullinger et al. (2012)
Conservation of species richness	Movement of species	Extend habitat	Landscape barriers and absence of climate projections in selection of conservation areas	Butchart et al. (2010); Araújo et al. (2011); Filz et al. (2012); Virkkala et al. (2013)
Forests	Movement of species and productivity reduction	Introduce new species	Not socially acceptable; legal barriers to non-native species	Casalegno et al. (2007); Giuggiola et al. (2010); Hemery et al. (2010); García-López and Alluéa (2011)

**Table 3:** Limits to adaptation to climate change in Europe. Source: (Sari Kovats et al., 2014)

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## 2.1. Argentina

### Country Profile: Buenos Aires, Argentina

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#### Summary

Argentina has already experienced changes in temperatures, rainfall and extreme events because of climate change. These impacts are set to worsen with increasing warming, leading to negative impacts on agricultural production, health and urban infrastructure.

Increasing warming will result in more frequent droughts, floods and extreme heat events, with impacts worsening substantially at warming levels above 1.5°C. At 1.5°C, strong El Niño events, which typically lead to increasing rainfall and floods, are set to occur at twice the frequency of pre-industrial times. Extreme rainfall events are projected to become 19% more frequent under 1.5°C of warming, but 40% more frequent under 2°C. The frequency of heat events in south-eastern South America would double at 1.5°C, but almost triple at 2°C. Such heat events can increase morbidity and mortality, especially among the elderly and young. Risks in cities such as Buenos Aires, where high numbers of children live, are particularly high because warming is worsened by the urban heat island effect.

Buenos Aires is projected to be substantially affected by sea level rise, particularly at higher levels of warming. In 2100, limiting warming to 1.5°C would keep sea level rise in Buenos Aires to about 45 cm, about 10 cm less than under warming of 2.5°C. Storm surges will become increasingly frequent and severe and are set to affect growing numbers of people in Buenos

Aires. Under current emission trajectories, Argentina's children of today will spend more than half their lives in a world warmer than 1.5°C above pre-industrial levels.

Agriculture – a major sector in Argentina's economy – is highly vulnerable to future warming and associated climate variability, with floods, droughts and heat extremes posing increasing risks to agricultural production. Water deficits are projected to worsen in dry regions (Northern Argentina), and glacial retreat and changing snowpack are expected to shift peak river flows to earlier in the Spring, leading to reduced flows during times of peak summertime demand. Water supply reductions also present risks for urban areas and hydropower production.

In addition to the negative impacts of extreme events on health, climate change is expected to play a role in the spread of malaria and the incidence of dengue in Argentina. Children are particularly vulnerable to these diseases.

## 1. The IPCC Reports' summary on Climate Impacts in Argentina

The IPCC 5<sup>th</sup> Assessment Report (G. O. Magrin et al., 2014) found “increasing trends in annual rainfall in south-eastern South America (SESA; 0.6mm/day/50yr during 1950-2008)”, while decreases were experienced in southwest Argentina. “Increases in temperature extremes have been identified in ...most of ...subtropical SA [South America] (medium confidence), while more frequent extreme rainfall in south-eastern South America has favored the occurrence of landslides and flash floods (medium confidence)”. “By 2100 projections show an increase in ...warm days and nights in most of South America (medium confidence).” Projections in rainfall are uncertain, but suggest an increase in south-eastern South America.

The report also found that “Changes in streamflow and water availability have been observed and [are] projected to continue in the future in ... South America, affecting already vulnerable regions (high confidence). The Andean cryosphere is retreating, affecting the seasonal distribution of stream flows (high confidence).” Changes in snowpack exacerbate this effect, reducing flows in the dry seasons and increasing them in the wet seasons. “Increasing runoffs in the La Plata River basin and decreasing ones in the Central Andes (Chile, Argentina) ...in the second half of the 20th century were associated with changes in precipitation (high confidence).” “Risk of water supply shortages will increase owing to precipitation reductions and evapotranspiration increases in semi-arid regions (high confidence) ... thus affecting water supply for cities (high confidence) ..., hydropower generation (high confidence) ..., and agriculture.”

On agricultural impacts, the recent Special Report on Climate Change and Land (SRCCL) found that Argentina has already seen an increase in yield variability of maize and soybeans, which has impacted the agriculture, human health and biodiversity of the country (IPCC, 2019). “In...western Argentina, yields could be reduced by water limitation”, and fruit and vegetable growing in northern Patagonia could be negatively affected by reduced rainfall and river flows.

The IPCC 1.5 special report also found that the nutritional quality of rice and wheat will reduce as CO<sub>2</sub> levels rise, and that limiting warming to 1.5°C would limit this effect.

Regarding health impacts, the IPCC 5<sup>th</sup> Assessment Report found that changes in weather and climatic patterns are already negatively affecting human health in South America “by increasing morbidity, mortality and disabilities (high confidence), and through the emergence of diseases in previously non-endemic areas (high confidence)”. Climate-related drivers are associated with, among others, respiratory and cardiovascular diseases, vector- and water-borne diseases (such as malaria, dengue and visceral leishmaniasis), and psychological trauma. Vulnerabilities vary with geography, age, gender, race, ethnicity, and socioeconomic status, and are rising in large cities (very high confidence).” The worsening of air quality and higher temperatures in urban settings [in South America] are increasing chronic respiratory and cardiovascular diseases, and morbidity from asthma and rhinitis..., but also atherosclerosis, pregnancy-related outcomes, cancer, cognitive deficit, otitis, and diabetes.” “Climate change will exacerbate current and future risks to health, given the region’s population growth rates and vulnerabilities in existing health, water, sanitation and waste collection systems, nutrition, pollution, and food production in poor regions (medium confidence)”.

The IPCC 1.5 special report assessed recent projections of the potential impacts of climate change on malaria and found that the geographic range, seasonality and intensity of transmission of malaria in South America are driven in part by weather and climate. Additional warming will affect malaria risk, but in a complex way (IPCC, 2018b).

## 2. Demographics and intergenerational aspects

Argentina have a population of about 44 million, out of which 33% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 17-year-old Argentinian citizen, the petitioner’s peer, is expected to live until the age of 86 (World Data Lab, 2019). The demographic estimates can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (Climate Analytics; Ecofys; New Climate Institute, 2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median), 2°C around 2055, and more than 3°C in 2100. Today’s Argentinian 17-year-old has a 99% probability of being alive in 2035, 94% in 2055 and 4% in 2100. Nearly all children in Argentina therefore have a high probability of experiencing a 2°C world and the ensuing impacts, with a portion of them living to possibly experience an even higher warming.

## 3. Temperature increases

Over the period 1901 – 2012 the average temperature across most of Argentina increased by about 0.5°C – a little lower than the global average (Vicente Ricardo Barros et al., 2015). While the annual peak temperature declined over 1953-2003, a trend that is consistent with the observed increase in summer precipitation, there has been a strong warming in night time

temperatures, resulting in fewer cold nights and more warm nights (Vicente Ricardo Barros et al., 2015). The number and intensity of heat waves has increased (Vicente Ricardo Barros et al., 2015).

In a 2°C warmer world, the Atlantic coast of Argentina would see about 0.5-1.5°C warming by 2100 (compared with a 1951-1980 baseline), while northern Argentina would see up to 2.5°C of warming. However, in a 4°C warmer world the Atlantic coast could warm by 2-4°C, and northern Argentina could warm up to 6°C (Schellnhuber et al., 2014). Figure 1 shows warming levels relative to the period 1986-2005, hence the levels of warming depicted are slightly lower than when compared to the period 1951-1980.

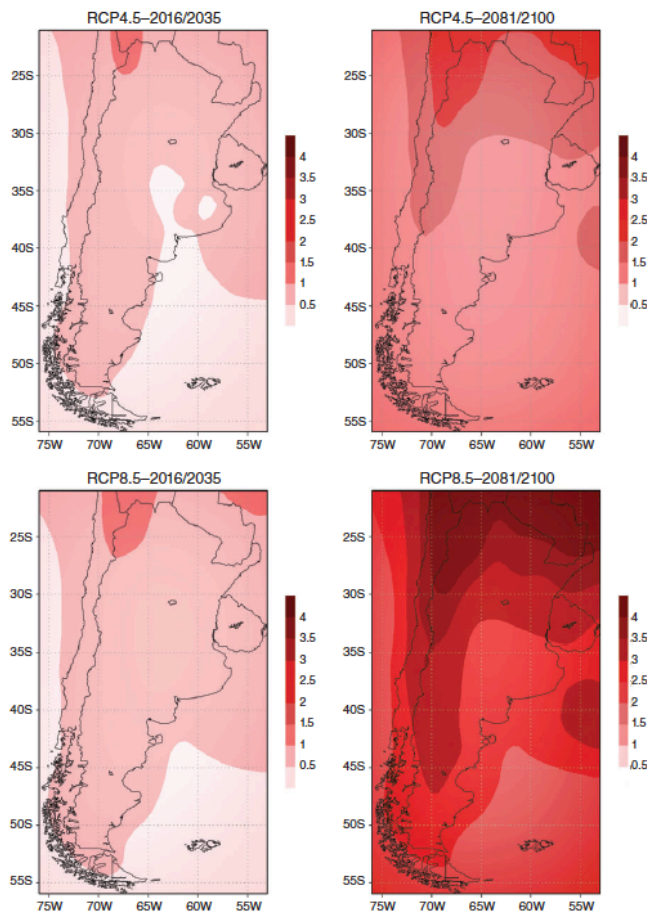


Figure 1: CMIP5 multi-model ensemble mean of projected changes (°C) in annual temperature for the near-term (2016-2035), left, and long-term (2081-2100), right, relative to 1986-2005, for a 2.4°C warmer world by 2100 (RCP4.5) (top) and a 4.4°C warmer world by 2100 (RCP8.5) (bottom). Source: Barros et al., (2015)

Extreme heat events will become more common with further warming. Under 1.5°C of warming, the frequency of heat events in south-eastern South America would double, while under 2°C it would almost triple (an increase in frequency of 288%) (Carbon Brief, n.d.; V. et al., 2018). In a 4°C world, events that are extremely rare today will become the new norm. In other words, temperature levels that are currently extremely unlikely (i.e. events that are less frequent than 100-year events) would be exceeded over at least half of the summer months

(Schellnhuber et al., 2014). Warm spells will also become longer: warm spells could be 30-90 days longer in a 4°C world (RCP 8.5) (Schellnhuber et al., 2014), and 15 – 18 days longer in a 2°C world (Aerenson et al., 2018; Carbon Brief, 2019). Limiting warming to 1.5°C would limit the lengthening of warm spells to 7 – 13 days (Aerenson et al., 2018; Carbon Brief, 2019).

#### 4. Precipitation

Annual precipitation has increased over the past four decades in subtropical (north-eastern) Argentina, but this increase has been concentrated in the heaviest rainfalls, while precipitation during dry months has decreased (Vicente Ricardo Barros et al., 2015). Figure 2 shows that the frequency of heavy rainfall days (>100 mm) in Buenos Aires has increased in recent decades (Vicente Ricardo Barros et al., 2015). Further south in northern Argentine Patagonia, average precipitation has decreased since the middle of last century (Vicente Ricardo Barros et al., 2015).

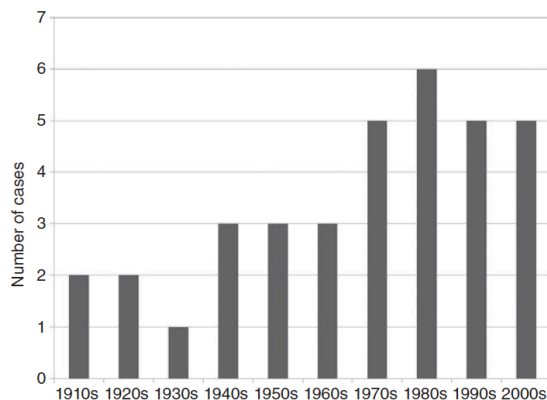


Figure 2: Number of days per decade with precipitation over 100 mm in the city of Buenos Aires. Source: Barros et al., (2015)

With increasing global warming, precipitation in northern and central regions is projected to increase, particularly during the summer months, while the dry central-western region and Patagonia will experience less precipitation (see figure 3) (Vicente Ricardo Barros et al., 2015; Schellnhuber et al., 2014). In other words, most dry regions may get drier, while wet regions may get wetter. In a 4°C world, Patagonia (which is already dry) is projected to become 60% more arid (Schellnhuber et al., 2014).

Increases in extreme precipitation are projected to continue in eastern Argentina (the Pampas region), hence it can be expected that flooding events will also become more frequent (Vicente Ricardo Barros et al., 2015; Schellnhuber et al., 2014). Limiting warming to 1.5°C, rather than 2°C or even 4°C, would significantly reduce these changes in heavy rainfall events (Schellnhuber et al., 2014) (Carbon Brief). For example, for south-eastern South America, rainfall extreme events are projected to become 19% more frequent under 1.5°C of warming, but 40% more frequent under 2°C (Carbon Brief, 2019; Kharin. et al., 2018).

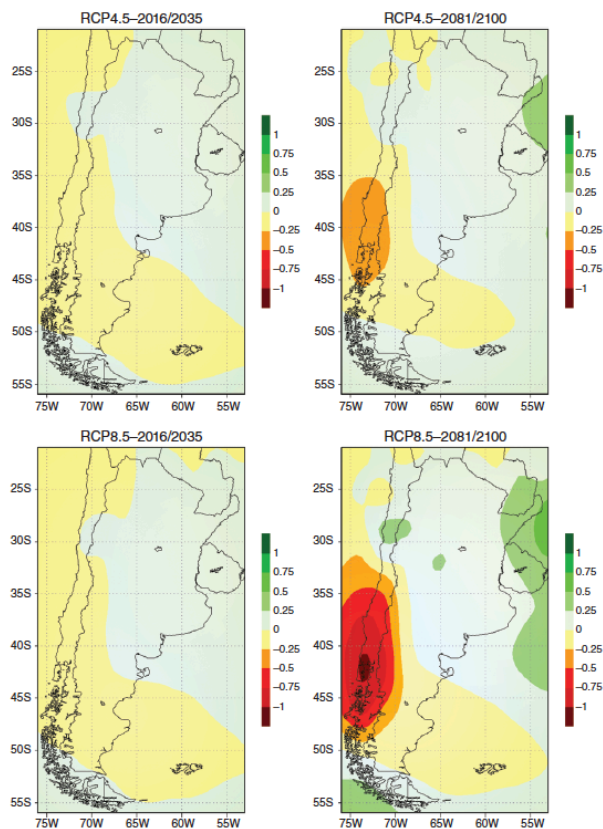


Figure 3: CMIP5 multi-model ensemble mean of annual precipitation (mm/day) for the near-term (2016-2035), left, and long-term (2081-2100), right, relative to 1986-2005, for a 2.4° warmer world by 2100 (RCP4.5) (top) and a 4.4° warmer world by 2100 (RCP8.5) (bottom). Source: Barros et al., (2015)

## 5. Glaciers and Andean rivers

Rising temperatures and declining precipitation over the southern Andes mountains have caused glaciers to retreat, with a loss in volume of about 20% over the 20<sup>th</sup> Century (Schellnhuber et al., 2014). Glaciers in Patagonia are also retreating: at the southern end of Argentina, at least 48 out of 50 glaciers are receding (Vicente Ricardo Barros et al., 2015). For example, San Quintín in Northern Patagonia lost 14.6 % of its area between 1870 and 2011 (NASA, 2016). According to scientists at NASA, “Patagonia glaciers experience some of the world’s most dramatic thinning per unit area, more than Alaska or Iceland or Svalbard or Greenland.” (NASA, 2016).

Glacier retreat has caused peak river flows to shift earlier, increasing the flow rate during the spring, and decreasing it during the summer, when agricultural demand for water is high (Vicente Ricardo Barros et al., 2015).



Ice fields and glaciers in the extratropical Andes in Argentina face substantial reductions under climate change. Under 2°C of warming, the glaciers of the southern Andes could lose about 20% of their mass (compared with 2015), compared with about 50% in a 4°C world (RCP8.5) (see figure 4) (Hock et al., 2019).

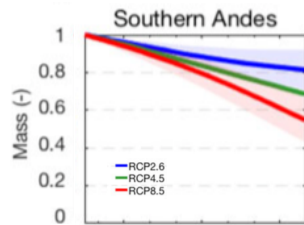


Figure 4: Projected time series of glacier evolution 2015–2100 the Southern Andes, based on three warming levels (RCPs). Glacier mass is normalized to mass in 2015. Thick lines show the means of all model projections (all available glacier models and GCMs) based on the same RCP, and the shading marks  $\pm 1$  Std dev. (not shown for RCP4.5 for better readability). Source: (Hock et al.,

The retreat of glaciers and ice fields is expected to affect water availability in Argentina. Accelerated glacier melting leads to increased runoff early in the melt season, but decreased runoff during the dry season (G. O. Magrin et al., 2014), which could substantially increase water deficits in downstream areas. This is likely to be particularly problematic later in the summer when agricultural demand for water is highest (Vicente Ricardo Barros et al., 2015; G. O. Magrin et al., 2014). The vulnerability of highly populated basins with high water demand for irrigation and hydropower production is expected to rise (see water availability) (G. O. Magrin et al., 2014).

## 6. Sea level rise

Buenos Aires is projected to be substantially affected by sea level rise, particularly at higher levels of warming. In 2100, limiting warming to 1.5°C would keep sea level rise in Buenos Aires to about 45 cm, about 10 cm less than under warming of 2.5°C (Climate Analytics, n.d.; Kopp et al., 2014). 4°C of warming is projected to cause sea level rise in 2100 of about 76 cm, reaching 193 cm by 2200 (Climate Analytics, n.d.; Kopp et al., 2014) (see figure 5).

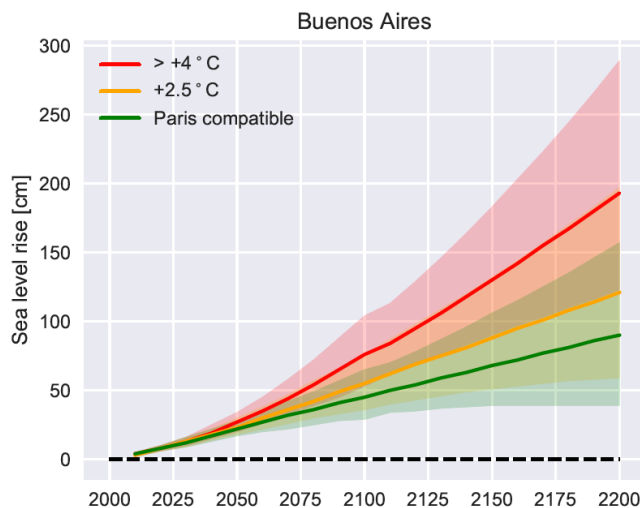


Figure 5: Local sea level projections for Buenos Aires for a scenario compatible with the Paris agreement (green), a scenario leading to +2.5°C global mean temperature (orange) and a

scenario exceeding +4°C (red). The solid lines represent multi-model medians, the shaded areas include 66% of the models. Source: (Climate Analytics, n.d.; Kopp et al., 2014)

With rising sea levels, storm surges are projected to become more frequent and more severe in the Plata River coastal areas, including around Buenos Aires (Vicente Ricardo Barros et al., 2015). At present, about 200,000 people in Buenos Aires are estimated to be affected by extreme storm surge events with a 20-year return period; this number is projected to almost triple under a scenario of 50cm sea level rise (Vicente Ricardo Barros et al., 2015).

## 7. Extreme events and El Niño

### Flooding:

Changing rainfall patterns have had implications for flooding events. In the extended flat plains in the north of Argentina, the frequency of prolonged flooding events increased in the 1980s and 1990s: four of the five largest floods in the 20<sup>th</sup> century have occurred during the last two decades (Gosling et al., 2011). These flooding anomalies, the result of more frequent extreme river discharges in the Paraná and Uruguay rivers, connected to El Niño events and related precipitation trends (Vicente Ricardo Barros et al., 2015).

There are high uncertainties in projections of future flood risk under climate change in Argentina, but the literature suggests that the risk of extreme floods will increase in the future (Gosling et al., 2011). For example, one study using 21 climate models found that under a scenario in which warming reaches 2.8 °C in 2100 (scenario A1B, comparable to RCP6.0), the majority of models project an increase in flood risk during the 21<sup>st</sup> century, with the most pronounced changes occurring later in the century (Gosling et al., 2011). Flooding events are also influenced by El Niño (see below).

### ENSO events: El Niño and La Niña

Latin America is particularly exposed to the effects of the El Niño Southern Oscillation (ENSO). Strong El Niño events typically lead to increasing rainfall and floods in Argentina, which has impacts for agricultural productivity, water supply, energy production, infrastructure and public health, as well as economic losses. (Schellnhuber et al., 2014). Recent research suggests that global warming will lead to more frequent extreme El Niño events: under 1.5°C of warming, the number of events could double from the frequency in pre-industrial times, to one every ten years (IPCC, 2018a; Wang et al., 2017).

La Niña events tend to cause dryness over southern Argentina (Gosling et al., 2011). In recent decades this has led to significant negative impacts on the yields of maize and soybean in Argentina (see figure 6) (Iizumi et al., 2014).

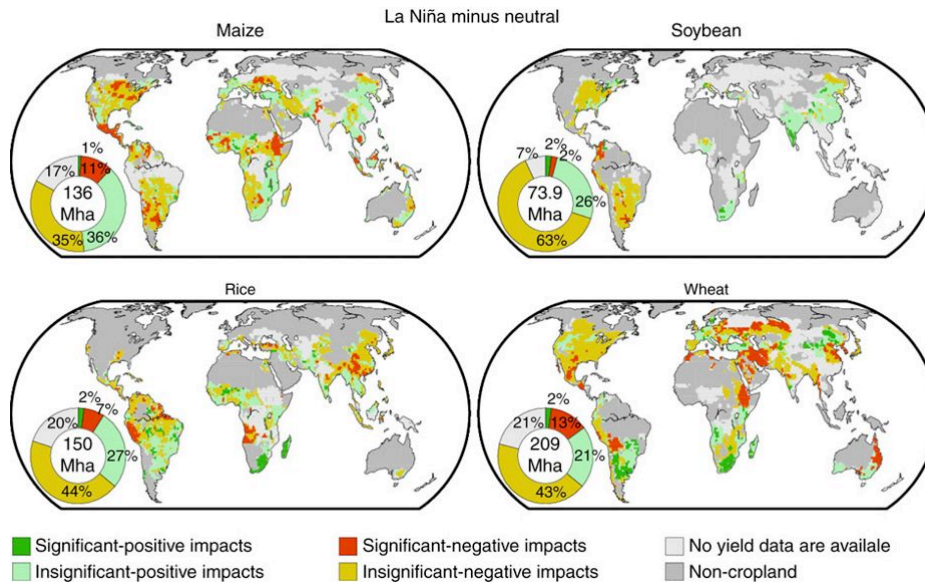


Figure 6: Impacts of La Niña on crop yield anomalies of four crops, compared with normal years, for the period 1982-2006. Pie diagrams show the percentages of harvested area. Source: (Iizumi et al., 2014)

## 8. Sectoral Impacts

### 8.1. Health

Malaria incidence has increased in Latin America in recent decades, partly because of land use change. Periodic epidemics have been associated with warm phases of ENSO (Schellnhuber et al., 2014). There is evidence to suggest that higher temperatures could cause malaria to spread to high altitude cities, but it is likely that the influence of climate change on malaria transmission will not be uniform (Schellnhuber et al., 2014). At high levels of warming reaching 4.3°C by 2100 (about 4°C in 2080; RCP8.5) an increase in the length of transmission period for malaria is projected for some highland areas of Argentina (Caminade et al., 2014; Schellnhuber et al., 2014).

Argentina is at the southern limit of dengue transmission in South America. Outbreaks of dengue in Argentina are associated with outbreaks in neighbouring countries as well as mild temperature conditions during autumn (Carbajo et al., 2018). While it is often difficult to separate social influences on dengue incidence from the impacts of climate change, it is expected that climate change will play a role in future dengue outbreaks (Schellnhuber et al., 2014).

Children are particularly vulnerable to vector-borne diseases such as malaria and dengue (UNICEF, 2015). Hence increases in the length of transmission period of malaria and expansion in the range of Dengue will pose greater risks for children.

Extreme heat events can increase morbidity and mortality, especially amongst the elderly and young and in cities where the urban heat island effect raises temperatures further. In Buenos Aires, 10% of summer deaths are already associated with heat strain (Wong et al., 2013). High density areas in the city have more than 950 inhabitants per hectare and a substantial heat island effect has been observed (one study found a 3.5°C difference between dense urban areas and areas close to the river (Leveratto et al., 2000). Heat extremes are projected to become more frequent in a warming climate (see above).

Extreme flooding events have caused evacuation and even deaths in Argentina. For example, in 2018, heavy rain and flash flooding caused 3000 people to be evacuated, mostly from Buenos Aires, and four people were killed (Floodlist, 2018).

## 8.2. Agriculture

Agriculture is an important sector for Argentina's economy, currently contributing about 6% of Argentina's GDP (World Bank, n.d.). In 2016, Argentina ranked sixth in the world for agricultural product exports, and second in Latin America (FAO, 2018). However, most agricultural activities in the region are rain-fed, and are highly vulnerable to climate variability and future climate change.

*Observed impacts:* In the Pampa region, simulations suggest that yields of some major crops (wheat, maize, soy) have increased, largely as a result of increased rainfall (Vicente Ricardo Barros et al., 2015). However, in some areas, increases in minimum temperatures during winter and spring have led to smaller yield increases or even yield decreases for wheat (Leary et al., 2009; Graciela O. Magrin et al., 2009). There has been an observed increase in yield variability in Argentinean maize and soybean as a result of climate change, meaning that yields have become more unstable (Iizumi & Ramankutty, 2016). Extreme flooding and droughts events related to ENSO have caused losses in agricultural production (Iizumi et al., 2014; Schellnhuber et al., 2014) (see figure 7).

*Projected risks:* Extreme weather events such as floods and droughts also pose increasing risks to agricultural production (Vicente Ricardo Barros et al., 2015). Changing rainfall patterns and rising heat extremes are expected to impact the yields of maize and soy, although there will be regional variation in the extent of these impacts (Schellnhuber et al., 2014).

The greatest body of evidence is for impacts on crops in South America as a whole, or for regions within South America, rather than at the country level. The IPCC 1.5 special report found that limiting warming to 1.5°C, compared with 2°C, would result in smaller net reductions in maize, rice and wheat in South America, as well as reductions in the nutritional quality of rice and wheat (which decreases at elevated CO<sub>2</sub> levels) (IPCC, 2018). In the Southern Cone of South America, maize yields are projected to decline by 30 – 45 % under 3°C of warming compared with 1971 – 2000 levels, or 15 – 30 % if warming is limited to 2°C (Schellnhuber et al., 2014), although these estimates do not include the highly uncertain

effects of CO<sub>2</sub> fertilization, which may lead to a net increase in yields (Schellnhuber et al., 2014).

Within Argentina, evidence suggest that losses are likely in the main producing regions, although there may be gains in the southern and western Pampa region (Vicente Ricardo Barros et al., 2015). Higher temperatures are expected to exacerbate existing water deficits in northern parts of Argentina (Schellnhuber et al., 2014) and the Mendoza region, where grapes for wine are grown (McMartin et al., 2018). Strong or extreme ENSO events elevate the risks of flooding or drought during the cropping season (Schellnhuber et al., 2014), posing risks to agricultural production (see extreme events and water availability).

The livestock sector plays a key role in the Argentinian economy, but studies of the potential impacts of climate change are scarce (Reyer et al., 2017). Heat stress is known to reduce productivity, for example, by reducing cattle food intake and milk production and by affecting reproduction, growth and mortality rates (Reyer et al., 2017). Under 1 – 2 °C of warming, farmers in the Andes are less likely to choose beef cattle and dairy cattle for their livestock, and more likely to increase sheep ownership (Seo et al., 2010). This is because sheep are better adapted to warmer and drier conditions.

### 8.3. Water availability

In central Western Argentina, where rainfall levels are low, river discharge is directly affected by the amount of snow accumulation during the winter. Freshwater availability is therefore highly dependent on meltwater from the mountain snowpack, which varies substantially from year-to-year (Schellnhuber et al., 2014). Warming temperatures have caused a greater number of high flow discharges during autumn, due to precipitation falling more as rain rather than snow. Conversely, during spring and summer there has been an observed drop in annual low-flow levels in some river basins. A continued trend of lower discharges during the dry season could present risks for water supply in urban areas, including for hydropower production (Schellnhuber et al., 2014).

### 8.4. Infrastructure

During the extreme December heat wave of 2013, the power system in Buenos Aires and other big cities collapsed due to extreme demand for air conditioning (Vicente Ricardo Barros et al., 2015). Increasingly frequent floods in Buenos Aires have damaged property, impaired living and working conditions, and negatively affected public health (C40, n.d.).

Extreme flooding and heat events are projected to increase in frequency and intensity with warming (see temperature increase and extreme events sections above).

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## 2.2. Brazil

# Brazil – Salvador

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### Summary

Brazil is experiencing increasing climate change today that manifests itself in a range of impacts for humans and ecosystems. Under scenarios of ongoing temperature increase exceeding 4°C in 2100, the annual average temperature in Brazil is expected to be above 30°C in 2100. Over central Brazil, annual mean precipitation is projected to drop by 20% in a 4°C world. Due to its proximity to the sea, Salvador is exposed to the threat of sea level rise, with a warming of 2.5°C by 2100, about 60 cm rise are expected. Brazil is also suffering from more frequent and intense weather events such as floods, heat waves, drought and wildfires.

The agricultural sector, including the economically important livestock sector, is expected to be severely impacted by climate change, with a potential reduction of approximately 11 million hectares of high-quality agricultural land. The health of people, in particular children, will be adversely affected by rising temperatures, heat waves and the spread of vector and water-borne diseases. Research in São Paulo (Brazil) found that for every degree increase above 20°C, there was a 2.6% increase in overall mortality in children under 15, meaning that a 26% increase in overall child mortality is to be expected under scenarios of 4.3°C expected temperature increase by 2100. The livelihoods of mangrove fishermen along the coast are also

threatened through rising sea levels and rising water temperature. Under current emission trajectories, Brazilian children will spend more than half of their lives in a world warmer than 1.5°C above pre-industrial levels.

The threats by climate change to the Amazon are exacerbated by deforestation. In addition to the severe damage to biodiversity on the global scale, the loss of parts of the Amazonian rainforest would have far reaching effects for precipitation across South America. Without stringent climate mitigation, even the crossing of a tipping point for the Amazon rainforest cannot be ruled out.

## 1. The IPCC report's summary on climate impacts in Brazil

“Warming has been detected throughout South America” and “changes in climate variability and in extreme events have severely affected the region (medium confidence)”. “Increases in temperature extremes have been identified in most of tropical and subtropical South America (medium confidence)”. “Climate projections suggest increases in temperature (...) (medium confidence)” and “a reduction of –22% in northeast Brazil” for rainfall. Indeed, “Changes in streamflow and water availability have been observed and projected to continue in the future in South America, affecting already vulnerable regions (high confidence)”. “Sea level rise (SLR) and human activities on coastal and marine ecosystems pose threats to fish stocks, corals, mangroves, recreation and tourism, and control of diseases (high confidence)” (Magrin *et al* 2014).

In South America as a whole, the IPCC's Special Report on 1.5 found that risks to tropical crop yields are projected to increase with warming levels: at more than 2°C of warming, substantial reductions in crop yields are very likely, while risks would be significantly lower, if warming is limited to 1.5°C (Ove Hoegh-Guldberg *et al* 2018). “In northeast of Brazil (...), increases in temperature and decreases in rainfall could decrease the productivity in the short term (by 2030), threatening the food security of the poorest population (medium confidence)”. “Changes in weather and climatic patterns are negatively affecting human health in South America (...), by increasing morbidity, mortality, and disabilities (high confidence), and through the emergence of diseases in previously non-endemic areas (high confidence). With very high confidence, climate-related drivers are associated with respiratory and cardiovascular diseases, vector- and water-borne diseases” (Magrin *et al* 2014).

## 2. Demographics and intergenerational aspects

Brazil has a population of about 210 million people, 31% of which are under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital 2018). An average 12-year-old Brazilian citizen, the petitioner's peer, is expected to live until the age of 86 (World Data Lab 2019). These demographic estimates can be coupled with the projections of global mean temperature increase. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (2019), an increase in the global mean temperature of 1.5°C will be exceeded around the year 2035, 2°C around 2055, and more than 3°C in 2100. Today's Brazilian 12-year-old has a probability of 99% to be alive in 2035, 95% in 2055 and 12% in 2100. Nearly all of Brazil's children therefore have a very high probability of experiencing a

2°C warmer world and the ensuing impacts, with more than 10% of them living to possibly experience an even higher warming.

### 3. Temperature increase

Over the period 1960-2010, there has been warming in the Northern, Eastern and Southern regions of Brazil for both summer (December to February) and winter (June to August) (Met Office 2011). The average temperature for the period 1861–1890 (pre-industrial period) for Brazil is 24.41 °C. Since pre-industrial times, the average temperature in Brazil has increased by around 1°C (Figure 1).

Temperature projections show that under scenarios of 2.4°C expected temperature increase by 2100 (RCP 4.5, purple line in Figure 1), the annual average temperature will be 25.8 °C in 2020, will reach 28°C in 2100, and a maximum of 28.8 °C at the end of 2300. Under scenarios of 4.3°C expected temperature increase by 2100 (RCP 8.5, red line in Figure 1) the annual average temperature is expected to be above 30°C in 2100. The duration of warm spells are also predicted to increase, with 28 days at a 1.5°C warming and 71 days at a 2°C warming in the Amazonia region (Carbon Brief 2019).

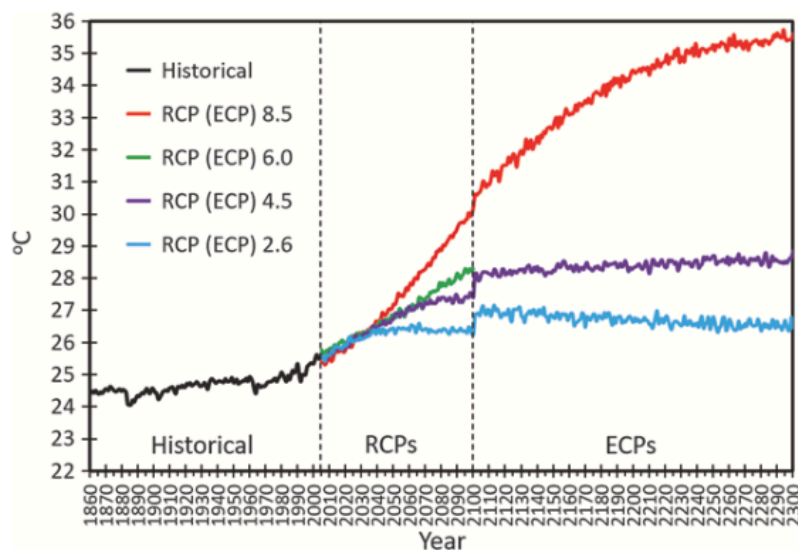


Figure 1: Temporal series of annual average temperatures climate close to the surface of Brazil for the period 1860-2300 (Nobre et al 2018)

### 4. Precipitation

Between 1960 and 2003, a small increase in annual total precipitation was observed over Brazil, variations that are linked to natural inter-annual and decadal variability (Met Office 2011). Based on the data from the National Institute of Meteorology of Brazil, the largest precipitation anomalies in 2018 in Brazil occurred in the Amazon region, with a reduction in precipitation compared to the 1981-2010 reference period (Figure 2). Along Brazil's coastline, including Salvador, slight increases in precipitation were observed.

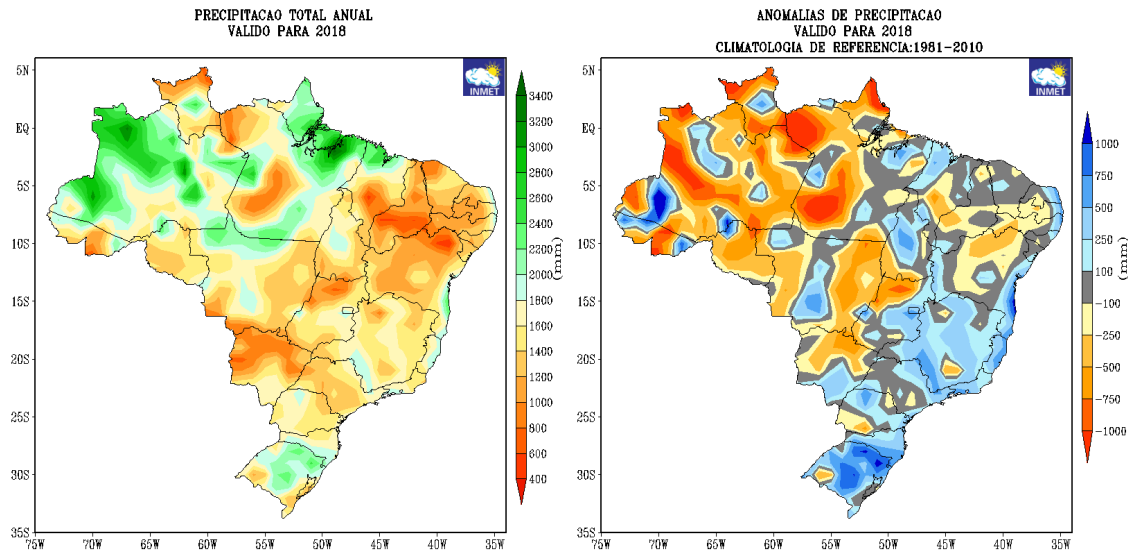


Figure 2: Total annual precipitation in Brazil in 2018 (left) and anomalies in precipitation in 2018 based on the reference period 1980-2010 (Retrieved from: <http://www.inmet.gov.br/portal/index.php?r=clima/page&page=desvioChuvaAnual>)

Projected changes in precipitation remain uncertain over most land regions in South America. However, in a 4°C world, annual mean precipitation is projected to drop by 20% in central Brazil by the end of the century due to a strong and robust decrease in dry season (JJA) precipitation (-50%) (Figure 3).

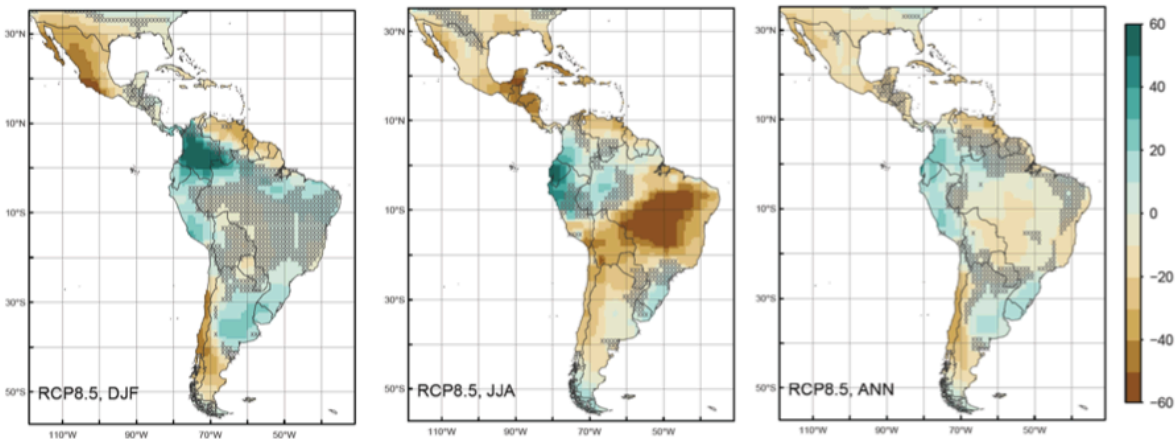


Figure 3: Multi-model mean of the percentage change in austral summer (DJF, left), winter (JJA, middle) and annual (right) precipitation for RCP8.5 (4.3 °C world by 2100) for Latin America and the Caribbean by 2071–2099 relative to 1951–1980. Hatched areas indicate uncertain results, with two or more out of five models disagreeing on the direction of change. Note that projections are given as percentage changes compared to the 1951–1980 climatology, and thus, especially over dry regions, large relative changes do not necessarily reflect large absolute changes (Reyer et al 2017)

## 5. Sea level rise

Brazil is projected to experience above-average sea level rise, with a median estimate of 0.63 m in a 4°C world (Reyer et al 2017). Figure 4 shows the projections of sea level rise for the tide



gauge station in Salvador. In 2100, limiting warming to 1.5°C would keep sea level rise in Salvador to about 50 cm, about 10 cm less than under warming of 2.5°C. 4°C of warming is projected to cause sea level rise of 80 cm in 2100, reaching 197 cm by 2200.

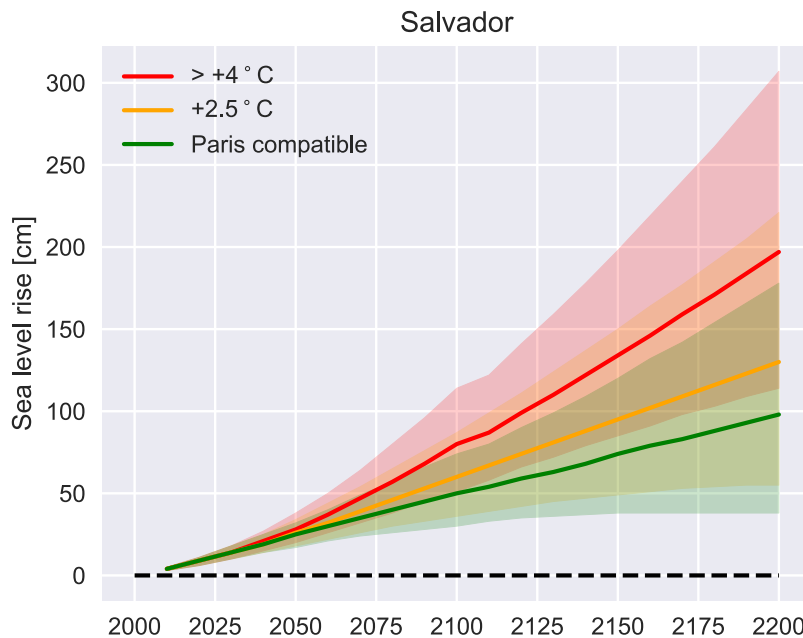


Figure 4: Local sea level projections for Salvador for a scenario compatible with the Paris agreement (green), a scenario leading to +2.5°C global mean temperature (orange) and a scenario exceeding +4°C (red). The solid lines represent multi-model medians, the shaded areas include 66% of the models (retrieved from <http://localslr.climateanalytics.org/location/Salvador>)

## 6. Extreme weather events

### 6.1 Floods

Catastrophic flooding has affected Brazil in recent years, triggering landslides and mudslides which can be a consequence of flooding exacerbated by deforestation and poor urban planning (World Bank 2014). In April 2015, Salvador was hit by the heaviest rains in two decades, with more than half of the monthly average falling within 10 hours, triggering two landslides killing 14 people and sweeping away numerous homes (BBC News 2015). In April 2009, floods and mudslides also affected over 186,000 people in North-East Brazil as this region experienced its worst deluge in over 20 years (Met Office 2011). Regarding flood projections in North-East Brazil, the direction of discharge and groundwater recharge trends vary due to diverging rainfall projections (Reyer *et al* 2017).

### 6.2 Heat waves

Over South America and in particular Brazil, there is a lack of analysis regarding the characterization of heat waves and evaluating their impacts (Son *et al* 2016, Geirinhas *et al* 2018). However, Salvador, in the Northeast Brazilian which is characterized by semi-arid climate (with dry and extreme hot periods) has recorded gradual increase of extreme heat waves, especially since 1990 (Geirinhas *et al* 2018).

### 6.3 Droughts

The drought in the South-East of the Brazil in 2014–2015 was considered the fifth costliest natural disaster in the world in 2014 by MunichRE (the oldest reinsurance company in

Germany), with estimated losses around 5 billion USD (Nobre *et al* 2018). Currently, drought magnitude is one of the largest in the world in North-Eastern Brazil (Naumann *et al* 2018). With a 1.5°C warming, drought magnitudes are projected to rise rapidly, with a doubling of drought magnitude in parts of Brazil (Naumann *et al* 2018). In addition, strong rises in the recurrence frequency of droughts with warming are also projected for the eastern regions of Brazil (ibid). When accounting for the effects of runoff and evaporation and local soil and vegetation, it was found that Brazil (except the Southern coast) will be facing severe to extreme drought conditions relative to the present climate under a scenario of 2.4°C global warming expected by 2100 (Reyer *et al* 2017). In Northeastern Brazil, at 1.5°C warming, 6 million people will be exposed to water scarcity, with 2°C, it will be a total of 7m people (Carbon Brief 2019).

## 6.4 Wildfires and forest impacts

Brazil's National Institute for Space Research (INPE) reported a record 72,843 fires in 2019 (until end of August), representing an 80% increase from last year. While drought has played a large role in exacerbating fires in the past (World Meteorological Organization 2019), the current 2019 fires seem to be deforestation driven and started by humans (Gibbens 2019). These fires are a great threat to many indigenous communities (World Meteorological Organization 2019), trigger great loss of biodiversity and harm those dependent on this biodiversity (Gibbens 2019). In addition, these wildfires also release harmful pollutants including particulate matter and toxic gases that can travel far with strong winds, as far as the Atlantic coast of Brazil (World Meteorological Organization 2019). Studies projecting future fires in the Amazon are scarce. However, fires are projected to increase along major roads in the Southern and Southwestern part of Amazonia for scenarios of 4.3°C expected temperature increase by 2100 (RCP 8.5). High rates of deforestation would contribute to an increasing fire occurrence of 19 % by 2050, whereas climate change alone would account for a 12 % increase (Reyer *et al* 2017).

# 7. Sectoral impacts

## 7.1 Agriculture

Most of the global and regional-scale studies project yield losses for soybean, maize and rice, three of Brazil's major crops, as a consequence of climate change (Met Office 2011). In Brazil, at 2°C warming, crop yields could decrease by up to 70 % for soybean and up to 50 % for wheat relative to a 1989–2009 baseline (World Bank 2014). The livestock sector of high economic importance in Brazil will also be severely impacted by climate change regarding the quantity and quality of feed and heat stress (Assad *et al* 2013). Brazil could face a reduction of approximately 11 million hectares of high-quality agricultural land as a result of climate change with the South Region (current grain belt) being the worst impacted losing ~5 million hectare of 'low climate risk' crop land (ibid).

## 7.2 The Amazon forest

Brazil holds the biggest share of the Amazon rain forest, the largest tropical rain forest system on the planet. The Amazon is under severe threat by human stressors such as climate change

and deforestation. The Amazon is not only a unique biodiversity hotspot, it also serves as a key climate regulator for all of South America with about 25% or more of all precipitation falling in southern Brazil originating from the Amazon (Zemp *et al* 2014).

With ongoing warming and a regional drying trend, the threats to the Amazonian rainforest are also on the rise. For global warming scenarios reaching temperatures above 4°C in 2100 (RCP8.5), even a potential of crossing a tipping point to large scale Amazon dieback cannot be excluded (Zemp *et al* 2017, Malhi *et al* 2009). Severe damage to the Amazon forest would thereby have profound consequences for all of Brazil and beyond, affecting regional climate as well as one of the most important carbon sinks of the planet (Bastin *et al* 2019).

### 1.1 Health impacts from heat waves

Climate change is expected to increase mean annual temperature and the intensity and frequency of heat waves resulting in a greater number of people at risk of heat-related medical conditions. The elderly, children, the chronically ill, the socially isolated and at-risk occupational groups are particularly vulnerable to heat-related conditions (World Health Organization and United Nations 2015). For warming levels of 1.5°C, 2°C and 4°C, Brazil is projected to experience respectively 0.9%, 1.6% and 5.2% excess deaths due to heat. Research in São Paulo (Brazil) found that for every degree increase above 20°C, there was a 2.6% increase in overall mortality in children under 15 (same as for those over 65), with an almost certainly high increase for younger children (Bartlett 2008). Considering that under scenarios of 4.3°C expected temperature increase by 2100 (RCP 8.5) the annual average temperature is expected to be above 30°C in 2100 in Brazil, a 26% increase in overall child mortality is to be expected.

### 1.2 Health impacts from vector and water-borne diseases

Climate conditions are projected to become significantly more favorable for transmission of some of the world's most virulent infections, slowing progress in reducing burdens, and increasing the populations at risk. In Brazil during the period 2001–2009, a 1°C increase in monthly minimum temperature was associated with a 45 % increase in dengue fever cases the following month and a 10 mm increase in precipitation with a 6 % increase (Reyer *et al* 2017). With a warming of 1.5°C, 2°C and 3.7°C by 2100, the annual cases of dengue fever in Latin America is projected to reach respectively 4.5 million, 5 million and 7.8 million people (Carbon Brief 2019). Warmer average temperatures are expanding the areas where many tropical diseases can occur, with children most often being the victims (Bartlett 2008). Children's mental growth can also be affected by intestinal parasites, diarrheal disease and malaria (ibid).

### 1.3 Livelihood

In Cairu, 150 km South from Salvador, fishermen have been hunting crabs along coastal mangrove forests for their living for decades. However, they have testified about rapid alterations of the environment: the average daily catch is half of what was 10 years ago, the water line has advanced 3 m inland from where it used to be and rising water temperature are killing off marine life (Doce 2019). With increasing sea-surface temperatures, most coral reef locations in the Western Atlantic are projected to have a 60–80 % probability of annual bleaching events with a 2 °C warming by 2050 (Reyer *et al* 2017). By the year 2100, almost all coral reef locations are expected to be subject to severe bleaching events occurring on an annual basis in a 4 °C world (ibid).

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## 2.3. France

# FRANCE – Bordeaux

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### Summary

France is experiencing an increase in temperature well above global average that manifests itself in a range of impacts for humans and ecosystems.

If global warming exceeds the Paris Agreement limit of 1.5°C, France, including Bordeaux, will experience an increase in average temperatures and a decrease in annual precipitation in the south. Extreme weather events will become more frequent and more intense in particular heat waves, heavy precipitation, droughts and floods.

France has already suffered from high numbers of heat-related deaths (about 15,000 during the 2003 heat wave) and the number of people at risk of heat-related medical conditions is projected to increase. The climate conditions will also become more favorable for the spread of diseases such as dengue, yellow fever and chikungunya. Bordeaux is also potentially endangered by floods linked to sea level rise. For the region of Bordeaux, its cultural heritage is seriously threatened as the wine industry is impacted by higher temperatures and increasing extreme weather events affecting the yield of the vineyards and the quality of the wine. Under current emission trajectories, French children will spend more than half of their lives in a world warmer than 1.5°C above pre-industrial levels.



## 1 The IPCC report's summary on climate impacts in France

The IPCC (2014) states that “observed climate trends and future climate projections show (...) projected increases in temperature throughout Europe” and “decreasing precipitation in Southern Europe”. In addition, “climate projections show a marked increase in high temperature extremes (high confidence), meteorological droughts (medium confidence), and heavy precipitation events (high confidence)”. “Climate change is very likely to increase the frequency and intensity of heat waves, particularly in Southern Europe (high confidence)”. It is “expected to impede economic activity in Southern Europe more than in other sub-regions (medium confidence)” and is “*likely* to affect human health in Europe”, for example, “heat-related deaths and injuries are likely to increase, particularly in Southern Europe (medium confidence)” (IPCC, 2014).

### 1. Demographics and intergenerational aspects

France has a population of about 65 million people, one quarter of which are under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 16-year-old French citizen, the petitioner's peer, is expected to live until the age of 91 (World Data Lab, 2019). These demographic estimates can be coupled with the projections of global mean temperature increase. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (2019), increase in the global mean temperature of 1.5°C will be exceeded around the year 2035, 2°C around 2055, and more than 3°C in 2100. Today's French 16-year-old has a probability of 99% to be alive in 2035, 96% in 2055 and 10% in 2100 (Climate Action Tracker, 2019). Nearly all of France's children therefore have a very high probability of experiencing a 2°C warmer world and the ensuing impacts, with a portion of them living to possibly experience an even higher warming.

### 2. Temperature increase

Since pre-industrial times, increasing temperatures have been observed: the increase global mean surface temperature reached 0.87°C in 2006-2015 (Hoegh-Guldberg et al., 2018). *Figure 1* shows that under a scenario where global mean temperature peaks at 2.4°C in 2100, mean temperature will increase by 1-2.5°C by mid-century in the region, compared to the baseline 1976-2005. The highest increases will be experienced in summer.

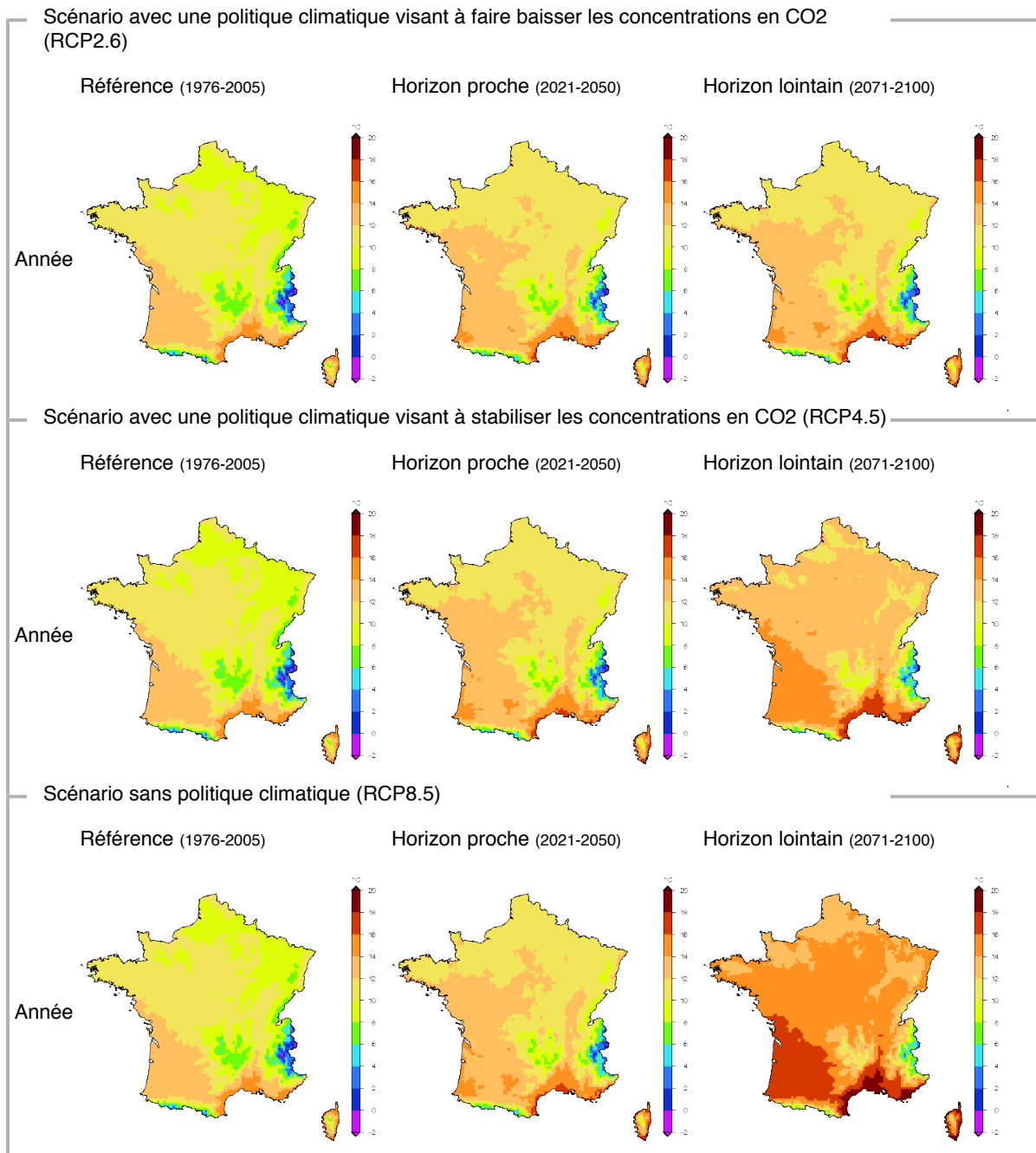


Figure 1: Average daily temperature with scenarios of 1.6°C, 2.4°C and 4.3°C expected temperature increase by 2100 (respectively RCP 2.6, RCP4.5 and RCP 8.5) from the model Aladin of Météo France/CNRM2014 (Drias, 2019)

### 3. Precipitation

Figure 2 shows that decreases in precipitation have been observed in Southern France over the 1959-2009 period. Combined with a temperature-driven increase in evapotranspiration, this decrease in rainfall has resulted in significant augmentations of drought frequency, severity and duration over the 1950-2012 period in Southern France (Spinoni et al., 2015).

Evolution observée du cumul annuel de précipitations sur la période 1959-2009

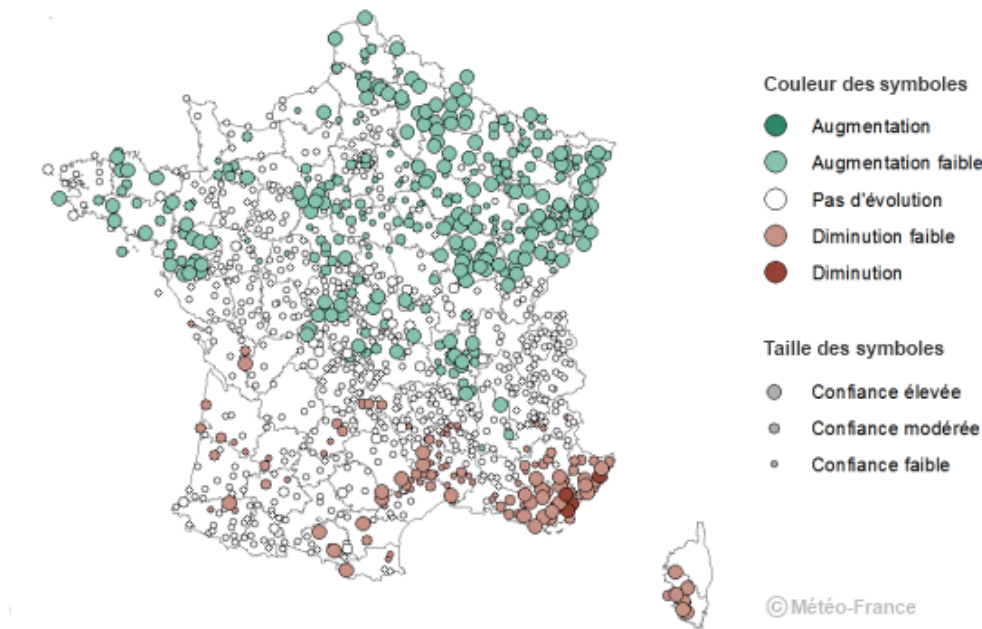


Figure 2: Observed change in total annual precipitation over the period 1959-2009 (Météo France, 2019a)

Figure 3 shows that cumulated annual precipitation is projected to experience a significant decrease by 5-15% by the end of the century compared to 1971-2000, under warming scenario of 2.8°C by 2100 (scenario A1B corresponding to RCP 6.0 (O'Donnell, 2019)), which is approximately in line with the projections for current policies estimates (Climate Action Tracker, 2019). Changes are highest for summertime and would be amplified for a higher-emission scenario (Füssel et al., 2017a; Jacob et al., 2014). This is consistent with other studies indicating moderate model agreement for significant changes towards more droughts over this region in the future (Stagge et al., 2015).

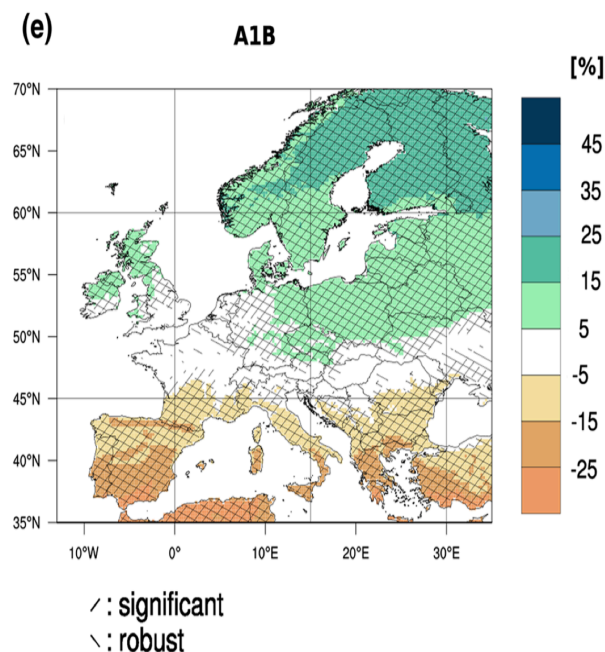


Figure 3: Projected changes of total annual precipitation (%) for 2071–2100 compared to 1971–2000, for A1B scenario. Hatched areas indicate regions with robust and/or statistical significant change (Jacob et al., 2013)

#### 4. Sea level rise

Mean and extreme sea levels have increased globally and along most coasts in Europe (Füssel et al., 2017b). Currently, global mean sea level is about 20 cm higher than at the beginning of the 20<sup>th</sup> century (EEA, 2017). Figure 4 shows the projections for the tide gauge station of Port Bloc about 100 kms North-West from Bordeaux.

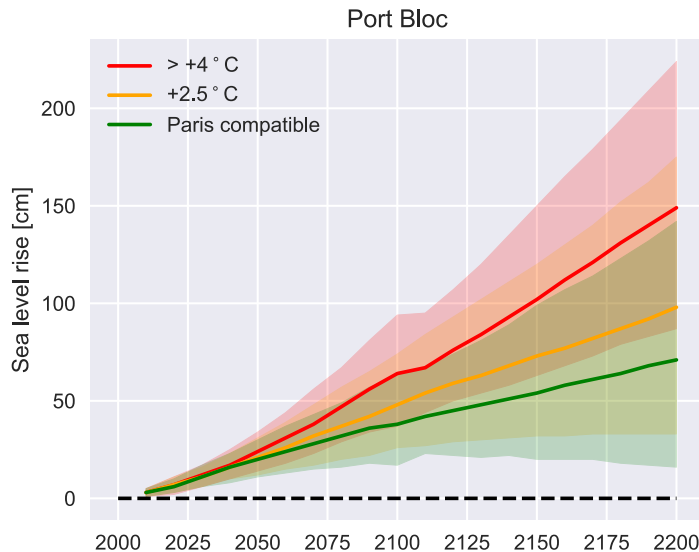


Figure 4: Local sea level projections for Port Bloc for a scenario compatible with the Paris agreement (green), a scenario leading to +2.5°C global mean temperature (orange) and a scenario exceeding +4°C (red). The solid lines represent multi-model medians, the shaded areas include 66% of the models.

The French Coastal Protection Agency estimates, based on the assumption that sea levels will have risen 22 cm by 2050 and 44 cm by 2100, that the effects of erosion and those of submersion are likely to have a limited impact in France, to the order of around 2,000 hectares for erosion and 36,000 hectares for submersion (French Institute for Public Health Surveillance, 2010). Figure 5 highlights that Bordeaux, located close to the European Atlantic coast, is likely to be affected by floods linked to sea level rise.

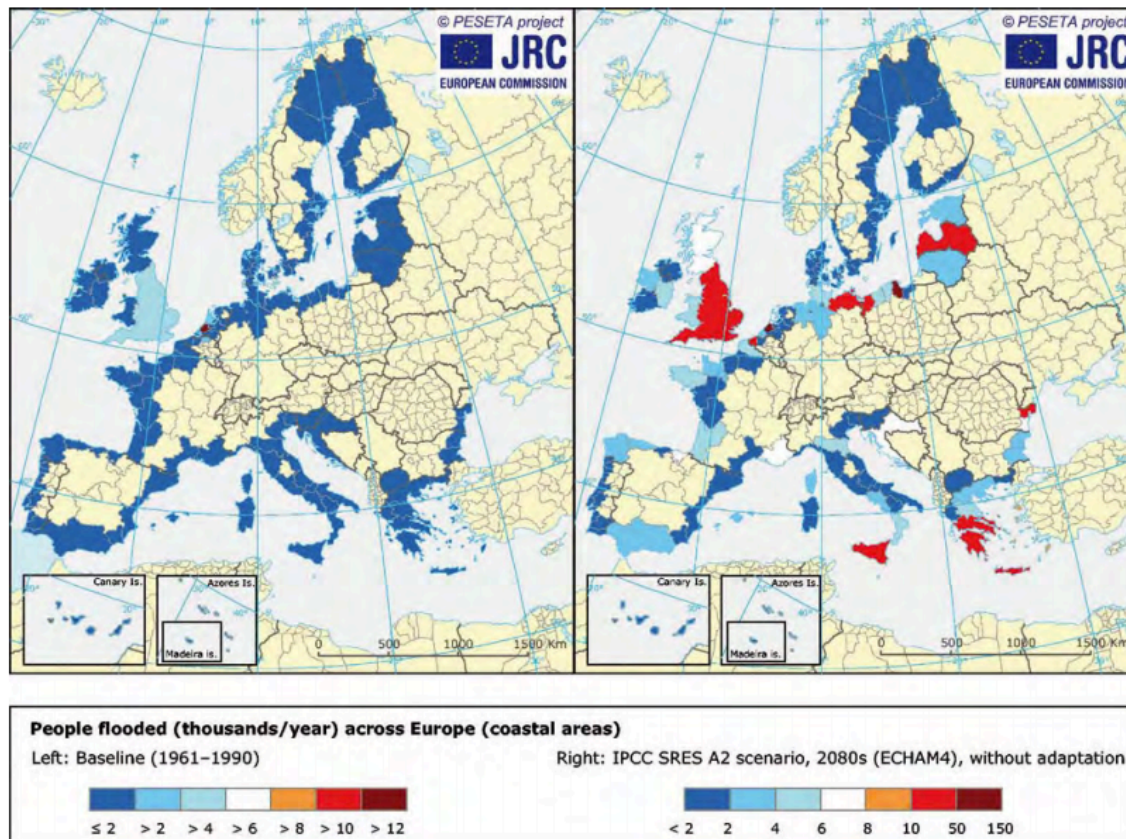


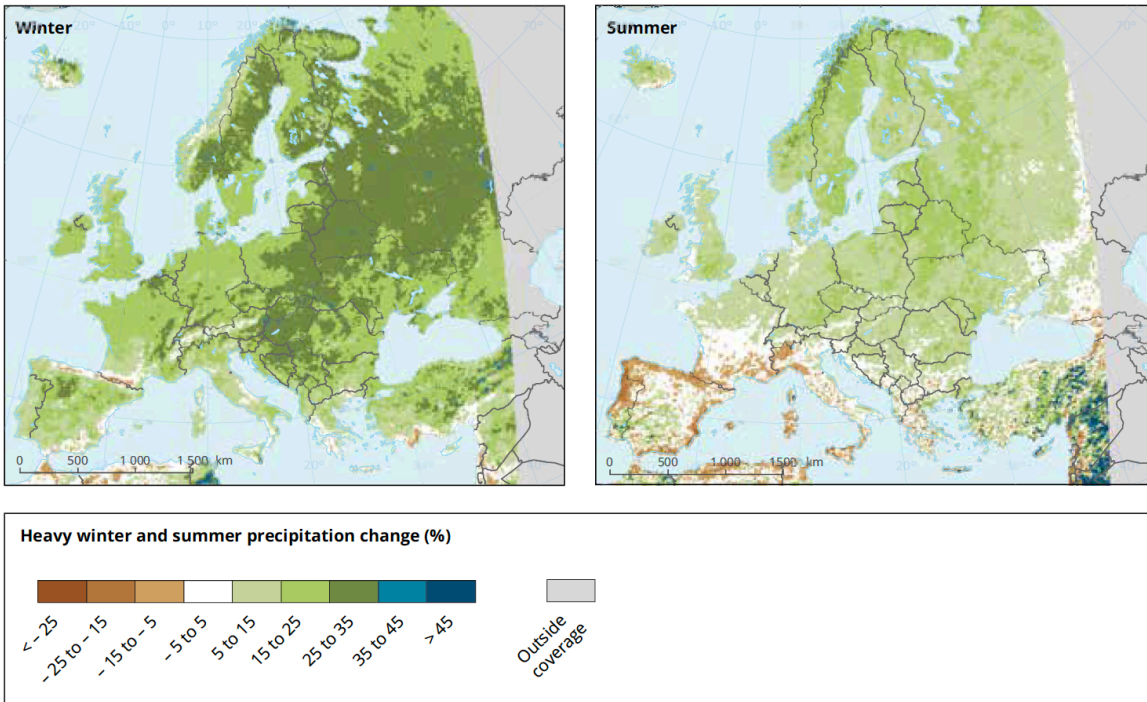
Figure 5: Populations impacted by floods linked to rising sea levels during the period from 1961-1990 (left) and 2080 (right) (French Institute for Public Health Surveillance, 2010)

## 5. Extreme weather events

### 5.1 Heavy precipitation events

There is low agreement on the past evolution of heavy precipitation events in Southwestern Europe (Füssel et al., 2017a). *Figure 6* shows an increased intensity of heavy precipitation events in all seasons except summer in the future over Southern France.





**Note:** This map shows projected changes in heavy daily precipitation (%) in winter and summer for 2071–2100, compared with the baseline period 1971–2000, for the RCP8.5 scenario based on the ensemble mean of different RCMs nested in different GCMs.

**Source:** EURO-CORDEX (Jacob et al., 2014).

Figure 6: Projected changes in heavy precipitation in winter and summer. From (Füssel et al., 2017a), based on (Jacob et al., 2013)

## 5.2 Heat waves

On a national level, there have been 3 times more heat waves during the past 30 years, compared to the period 1947-1989 (Météo France, 2019b). Since 2010, 16 heat waves have occurred, 2014 is the only year without a heat wave (ibid). Heat waves are also becoming longer and more severe, the worst heat wave observed was in August 2003 (ibid). In June 2019, France broke its previous temperature records, including Bordeaux which hit 41.2°C (Lenley, 2019). Figure 7 shows the deviation of monthly temperature averages for June 2019.

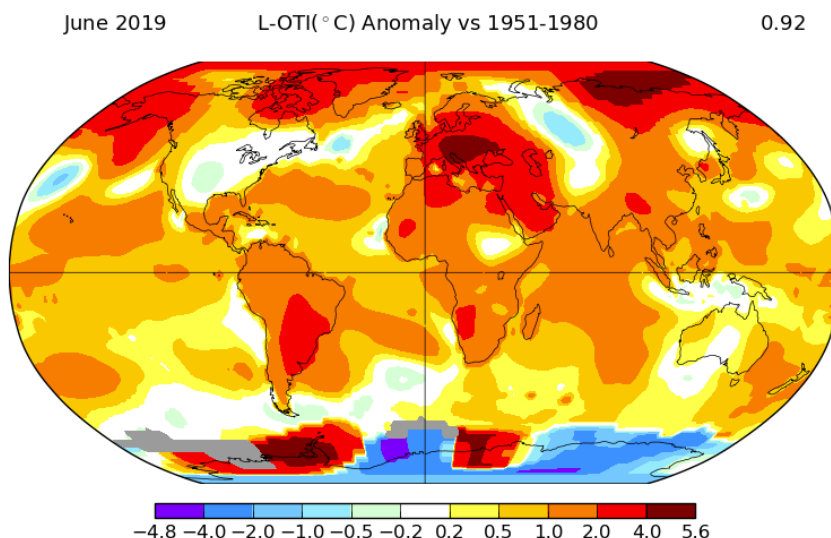




Figure 7: Deviation of monthly temperature averages in June 2019 in comparison of those between 1951-1980. (source: NASA: GISS Surface Temperature Analysis: <https://data.giss.nasa.gov/gistemp/maps/>)

Every heat wave in Europe is made more likely and more intense by human-induced climate change (Jan van Oldenborgh et al., 2019). An attribution study combining climate models and observations concludes that the June 2019 heat wave was made *at least* 5 times more likely by climate change (ibid). In addition, studies by King & Karoly (2017) show the increasing likelihood of similar heatwave events occurring with current temperature increase of about 1°C, for 1.5°C and 2°C warming in comparison to a world without climate change. When looking at the 2003 heat wave in central Europe, during which 15,000 deaths were recorded in France alone (French Institute for Public Health Surveillance, 2010), this would be a once in 100 years event without climate change. At current warming levels a similar event can be expected once every four years. For 1.5°C warming the likelihood increases to 4 out of 10 summers and for 2°C warming reaches 6 out of 10 (Figure 8).

—— Likelihood of similar event per year ——

EVENT	CONTEXT, IMPACT	VARIABLE	NATURAL	CURRENT	1.5°C	2°C
Central Europe JJA 2003	Hottest summer on record, thousands of heat-related deaths	T	1% (1-2%)	25% (17-33%)	42% (32-51%)	59% (50-70%)
		TXx	2% (0-6%)	21% (7-37%)	21% (9-34%)	31% (14-50%)

Figure 8: Likelihood of similar heat waves occurring without climate change, at current warming levels, for 1.5° and 2° warming (King & Karoly, 2017)

### 5.3 Droughts

Generally, there has been a constant increase in droughts in France during the 20<sup>th</sup> Century. By the end of the 21<sup>st</sup> Century, the average humidity level of the soil is projected to correspond to the extremely dry level of the reference period 1961-1990 (Drias, 2019) (Figure 9).

Horizon moyen (autour de 2055)

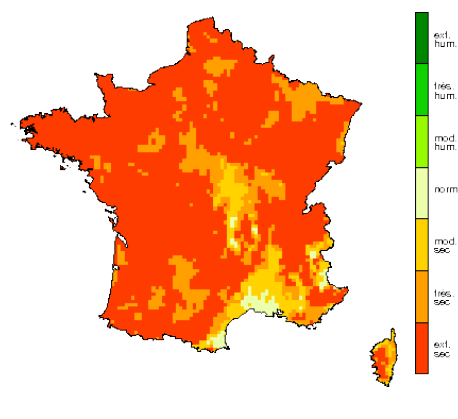
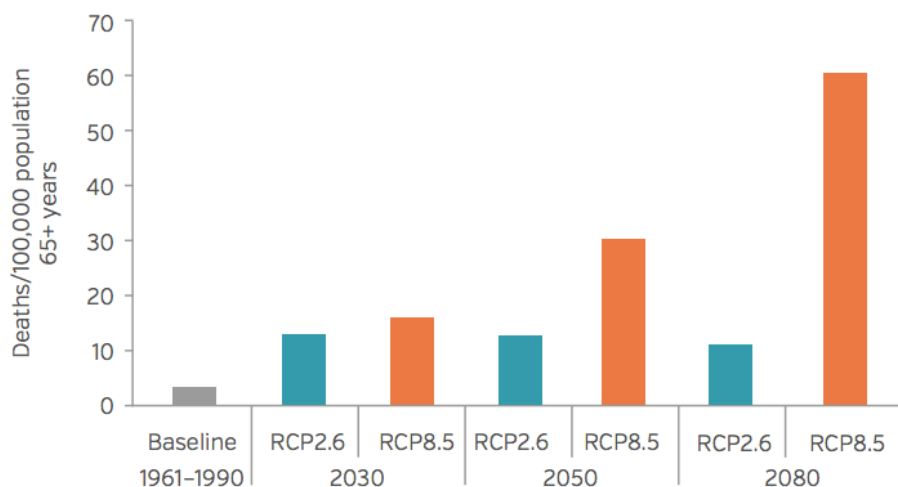


Figure 9: Indicator of soil drought for the ISBA model (Météo France/CLIMSEC – CERFACS/SCRATCH08) based on the A1B scenario (corresponding to RCP 6.0, a scenario of 2.8°C expected temperature increase in 2100 (O'Donnell, 2019)). The reference period used is around 1970 for a mid-term horizon around 2055. (Drias, 2019)

## 6. Sectoral impacts

### 6.1 Health impacts from heat waves

The impacts of heat waves on mortality and morbidity rates are well-documented in France today. Nearly 15,000 deaths were recorded during the heat wave in 2003, and nearly 2,000 during the heat wave in 2006 (French Institute for Public Health Surveillance, 2010). During the heat wave in 2018, 1,500 deaths were recorded, 10 times less than in 2003, mainly thanks to improved prevention measures that have been implemented (Le Figaro, 2018). Climate change is expected to increase mean annual temperature and the intensity and frequency of heat waves resulting in a greater number of people at risk of heat-related medical conditions (WHO, 2015). The elderly, children, the chronically ill, the socially isolated and at-risk occupational groups are particularly vulnerable to heat-related conditions (ibid). *Figure 10* shows that under a scenario of 4.3°C expected temperature increase by 2100 (RCP8.5), heat-related deaths in the elderly are projected to increase to about 61 deaths per 100,000 by 2080 compared to the estimated baseline of about 4 deaths per 100,000 annually for the period 1961-1990. In 2080, the nowadays 16-year-old child will be 77, part of the vulnerable group exposed to heat-related conditions.



*Figure 10: Heat-related mortality in population 65 years or over, France [deaths/100,000 population 65+ years] (WHO, 2015)*

### 6.2 Health impacts from infectious and vector-borne diseases

Vector-borne diseases that may be affected by climate change in France include chikungunya, dengue, yellow fever and leishmaniasis. Climate conditions are projected to become significantly more favorable for transmission, slowing progress in reducing burdens, and increasing the populations at risk if control measures are not maintained or strengthened. *Figure 11* shows that under a scenario of 4.3°C expected temperature increase by 2100 (RCP8.5), around 26% of the geographic area of France is projected to exceed the threshold suitable for dengue transmission for at least 3 months a year (compared to the baseline of less than 5% of the country annually for the period 1961-1990) (WHO, 2015).

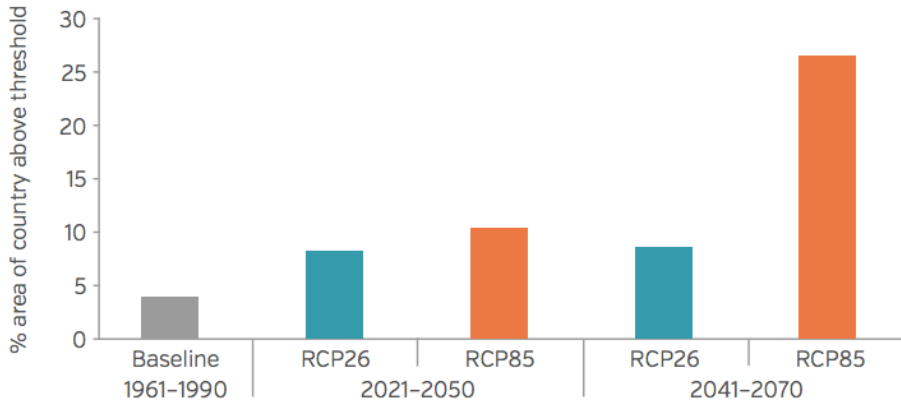


Figure 11: Dengue fever transmission in France (% area of the country with 3 months or greater above threshold for dengue transmission) (WHO, 2015)

### 6.3 Cultural heritage of the wine industry

The IPCC has stated that “climate change will change the geographic distribution of wine grape varieties (high confidence) and this will reduce the value of wine products and the livelihoods of local wine communities in Southern and Continental Europe (medium confidence)” (IPCC, 2014). Bordeaux is one of the world’s oldest wine growing regions and rising global temperatures are threatening this cultural heritage, the livelihood of 14,000 wine growers around Bordeaux and its \$4.2 billion wine industry (Ruitenbergh, 2015).

Higher temperatures have impacts on grapevine yield and affect the quality of the wine (IPCC, 2014). Extreme weather such as storms, heavy rains and hail storms during summer destroy the grapes (Fichtner, 2014). Mild temperatures in winters and at night time do not allow the plants to rest. Therefore, for the grape varieties that do not tolerate the heat, maturation processes are impaired (ripening processes are getting shorter, harvest season is earlier) (ibid).

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## 2.4. Germany

### Country Profile Germany – Hamburg

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#### Summary

The city of Hamburg is already experiencing climate change impacts today: heatwaves, sea level rise and storm intensities that are increasing leading to a salinization of groundwater. Moreover, extreme precipitation is increasing leading to an increased risk of both local flooding events as well as increased river or coastal flooding. Due to the urban heat island effect, extreme temperatures in Hamburg are increasing faster than the average of Germany.

If global warming exceeds 1.5°C, Hamburg has a 59% chance to experience an extreme heat wave such as in the summer of 2003. Moreover, the probability of a 7-day period of consecutive rain days is projected to increase by about 18% under 2°C global warming. Under current emission trajectories, Germany's children will spend more than half their lives in a world warmer than 1.5°C above pre-industrial levels.

Future impacts of climate change will strongly affect the population of Hamburg. Children are particularly vulnerable to increasing floods as it takes more time to evacuate in cases of emergency. There are also a number of increasing health related risks for children related to climate change and fossil fuel combustion, such as increasing air pollution and the spread of pathogens or carriers of infectious diseases.