Under global surface warming, increased weather extremes reduce crops yields.

AGU Fall 2021

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American Geophysical Union Fall 2021 Conference

IPCC August 2021, 6th assessment, Working Group 1 (Science)
AR6 WG1)

2021 Abstract Title: **Under global surface warming, increased weather extremes can reduce crops yields**.
Using the IPCC AR6 WG 1 interactive atlas, we find yield declines may compromise world food security at 1.5°C which may be severe for major food producing regions at 2°C, especially if compound extremes, and increased surface ozone.

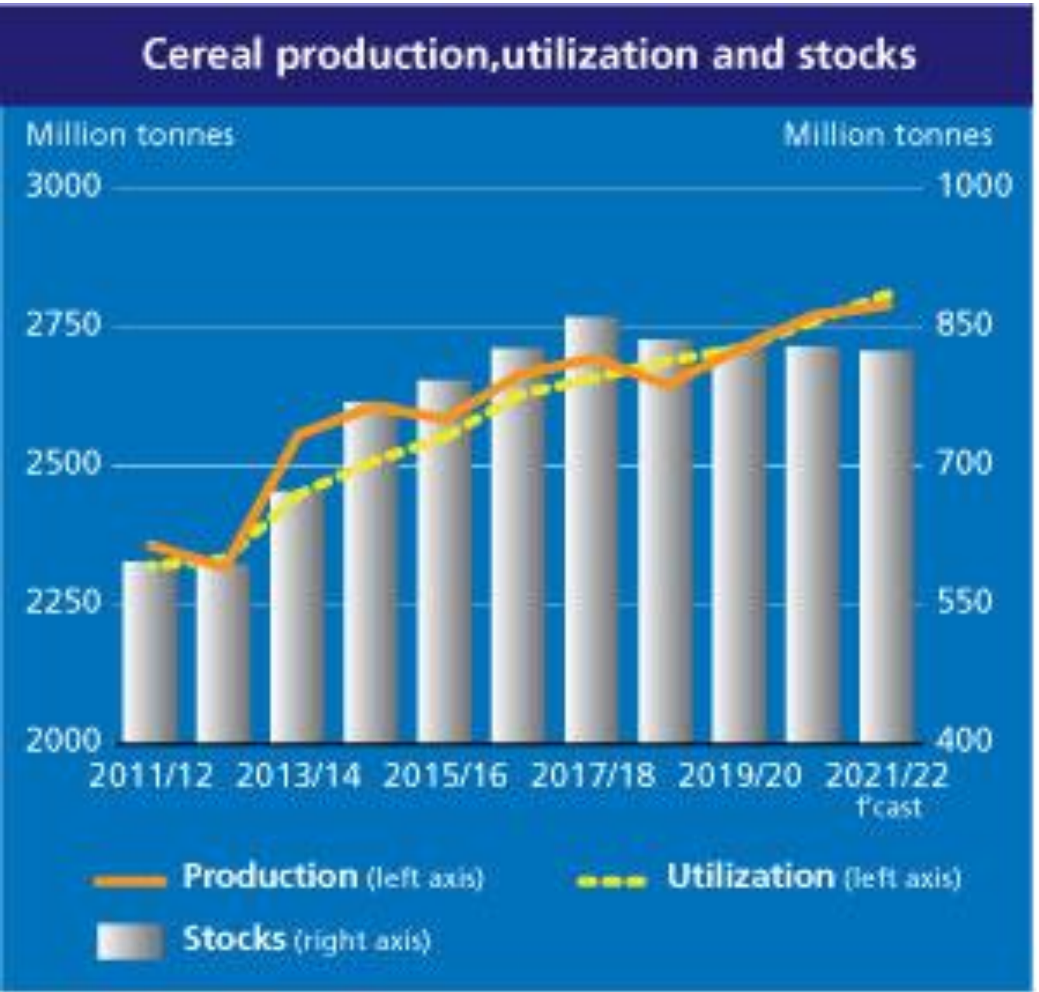
Final Paper Number: NH15G-2160
Session Number and Title: NH15G: 2021 Extreme Weather Events and Natural Hazards III
13 December 2021

FAO (UN Food and Agriculture Organization) World Food Situation December 2021

World cereal production is still increasing (though slower since 2019)

- but so are extreme weather events

FAO December 2021



Severe Weather Events

- Super-storms
- Extraordinary cold snaps
- Hurricanes-cyclones
- Tornadoes
- Torrential rains
- Flooding
- Heatwaves
- Forest fires
- Drought
- Compound events

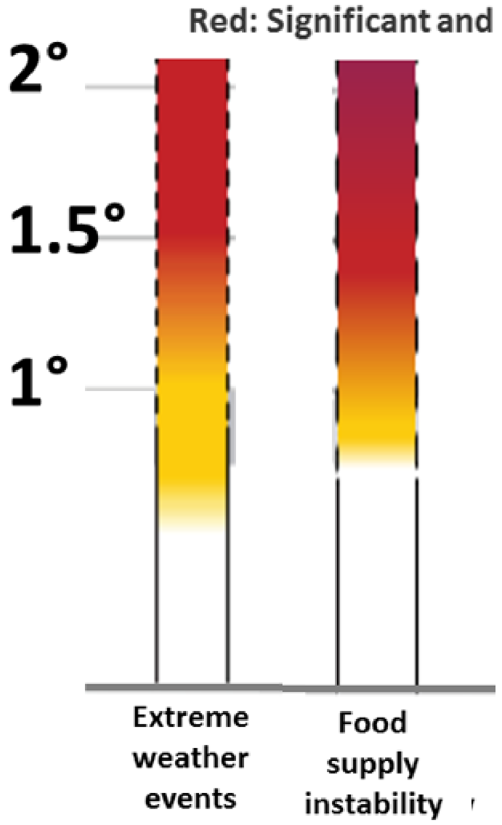
All being affected
by climate change with
adverse effects,
most with examples of
extreme damage
-including to crops ,
as well as soil erosion
and land degradation

IPCC Extreme Events

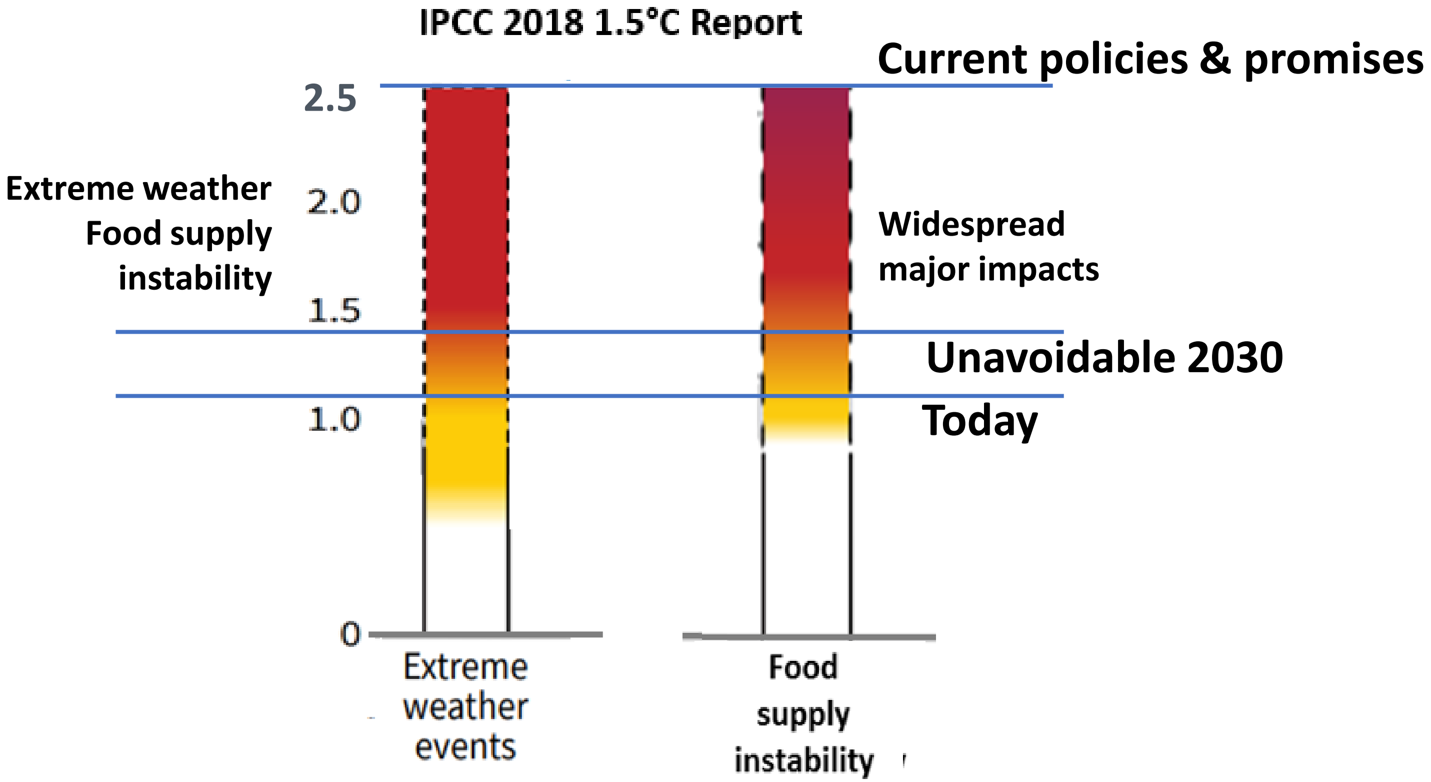
In the IPCC treats extreme whether events as on impact category, in which forest wild-fire are included

The extreme weather impact is most damaging to human population and crops, doubly damaging for labor intensive agriculture

Increasing extreme weather on agriculture is the most vitally important effect of climate change (disruption) effect **today**

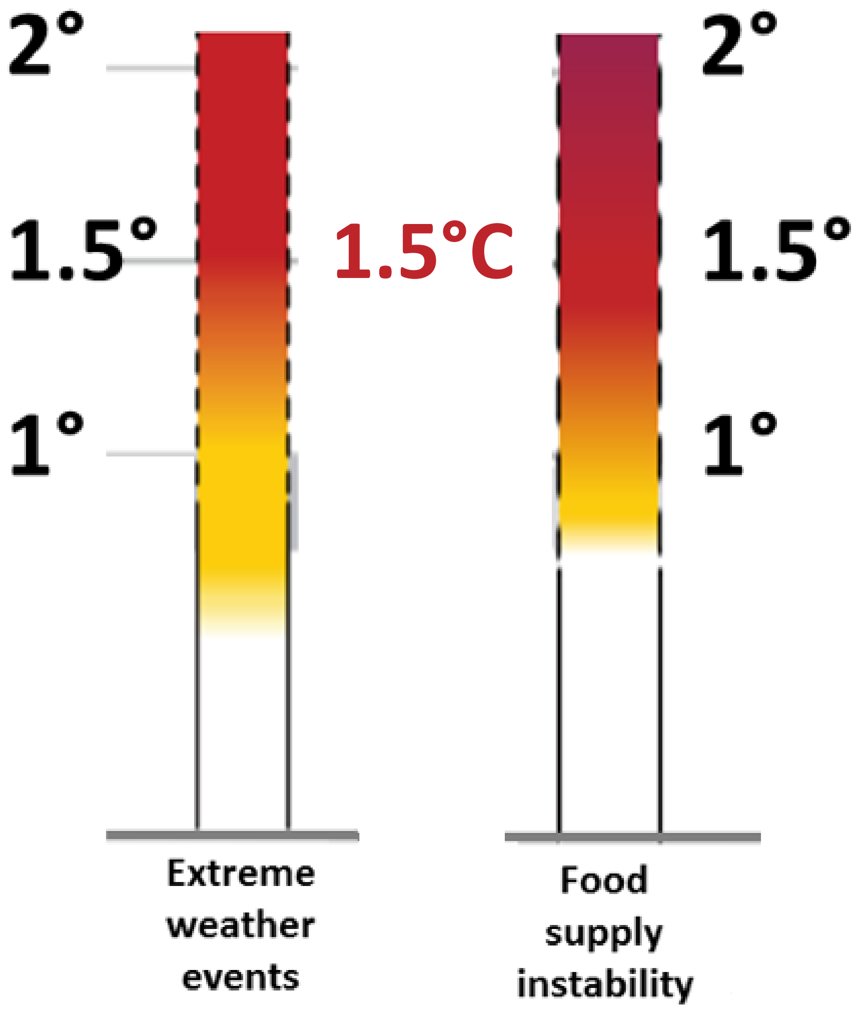


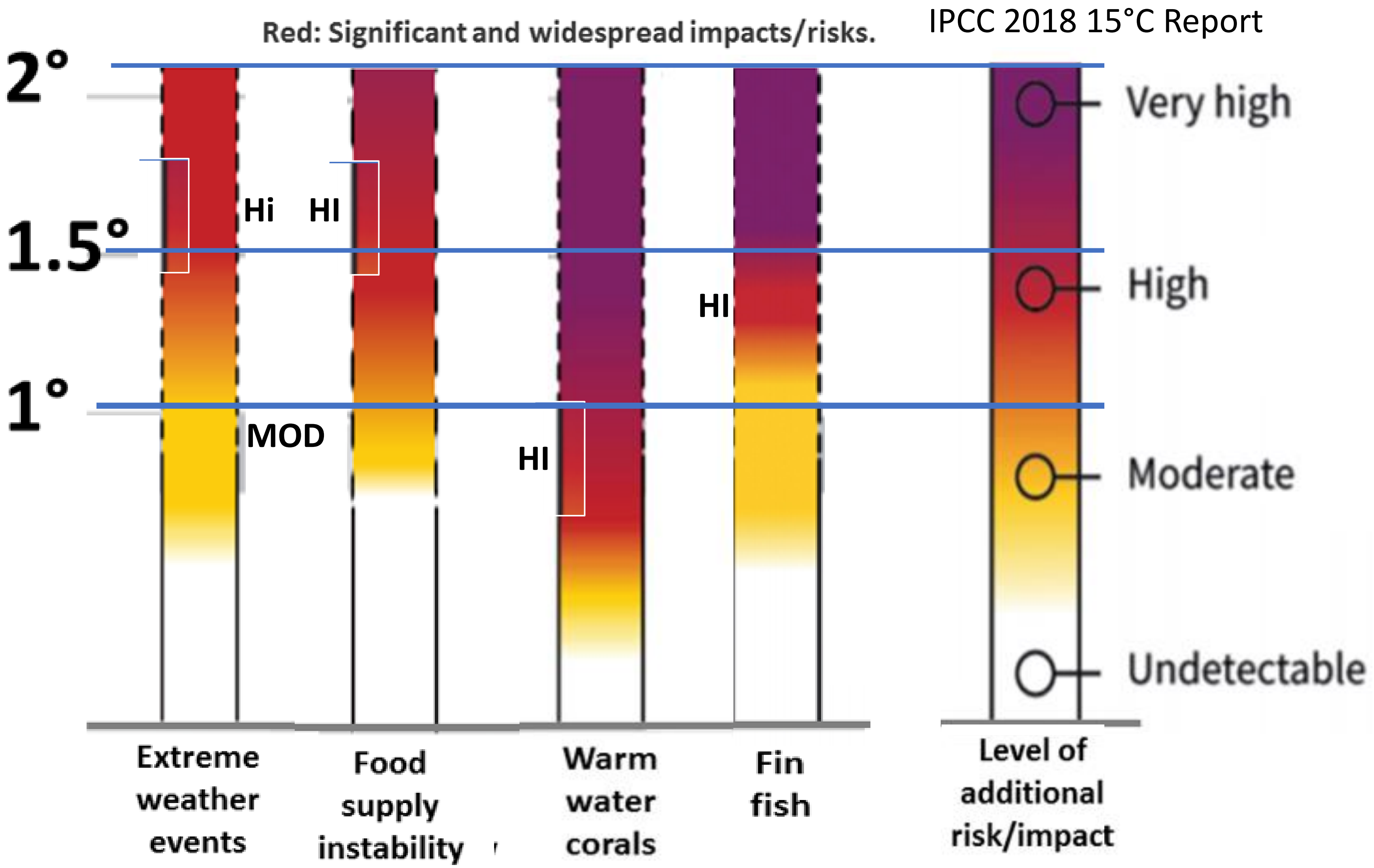
IPCC Reasons for Concern "burning embers"



The world has now entered the world food insecurity stage of global climate disruption

Red: Significant and widespread impacts/risks.





IPCC 2018 15°C Report
Red: Significant and widespread impacts/risks.
2°
1.5°
1°
Hi
HI
MOD
HI
HI
Very high
High
Moderate
Undetectable
Extreme weather events
Food supply instability
Warm water corals
Fin fish
Level of additional risk/impact

IPCC 4th assessment 2007

Global production potential as equivalent to crop yield or Net Primary Productivity (NPP), is threatened at +1°C local temperature change

(IPCC 2007 AR4 5.4.2.2 p.285
Review of crop impacts versus incremental temperature change)

Persistent Extreme Drought Affecting Western USA and Central Canada

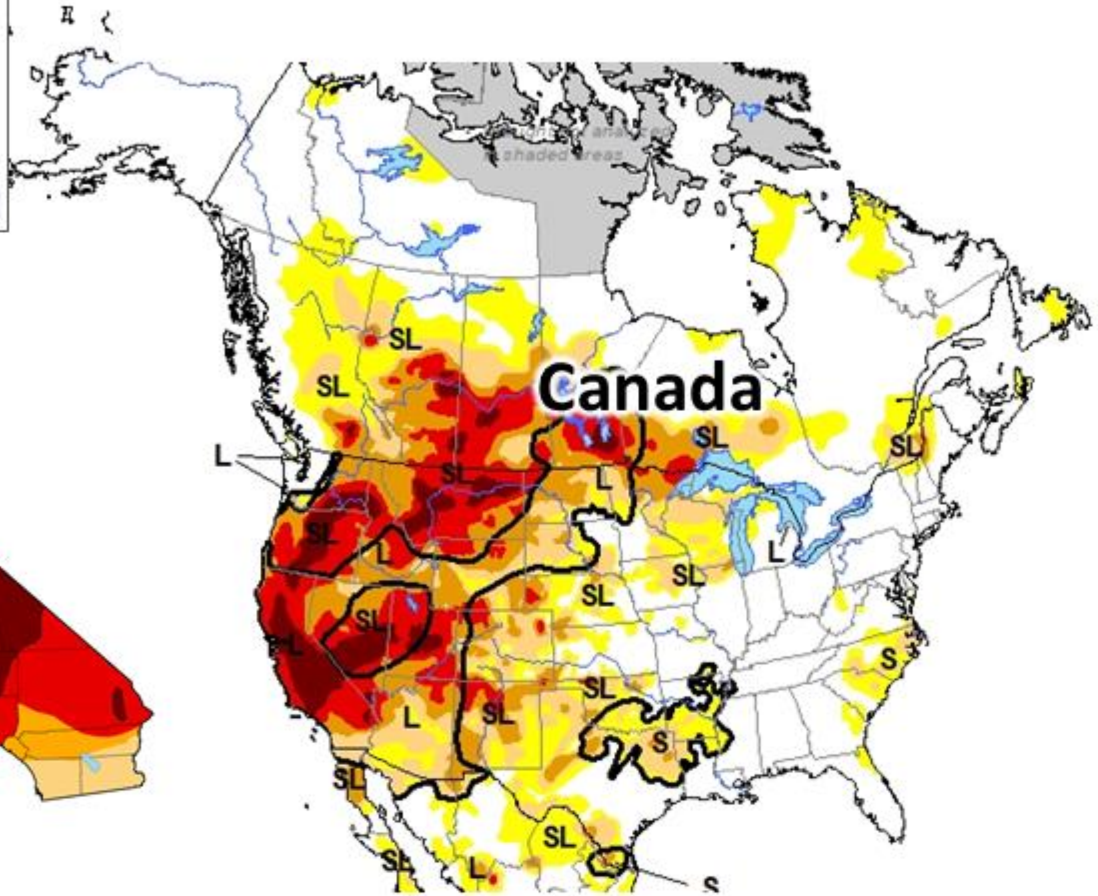
31 October 2021

North American Drought Monitor

October 31, 2021

Intensity:

- Abnormally Dry
- Drought - Moderate
- Drought - Severe
- Drought - Extreme
- Drought - Exceptional



California

Peter Carter, Climate Emergency Institute

Key Research Paper

Influence of extreme weather disasters on global crop production

Corey Lesk, et al, Nature, 6 January 2016
UBC and McGill

We show that droughts and extreme heat significantly reduced national cereal production by 9–10%.

A 7% greater production damage from more recent droughts (?getting worse)

There was 10% more damage in developed countries than in developing ones.

Key Background Research Paper

Ariel Ortiz-Bobea et al, Nature, 1 April 2021,

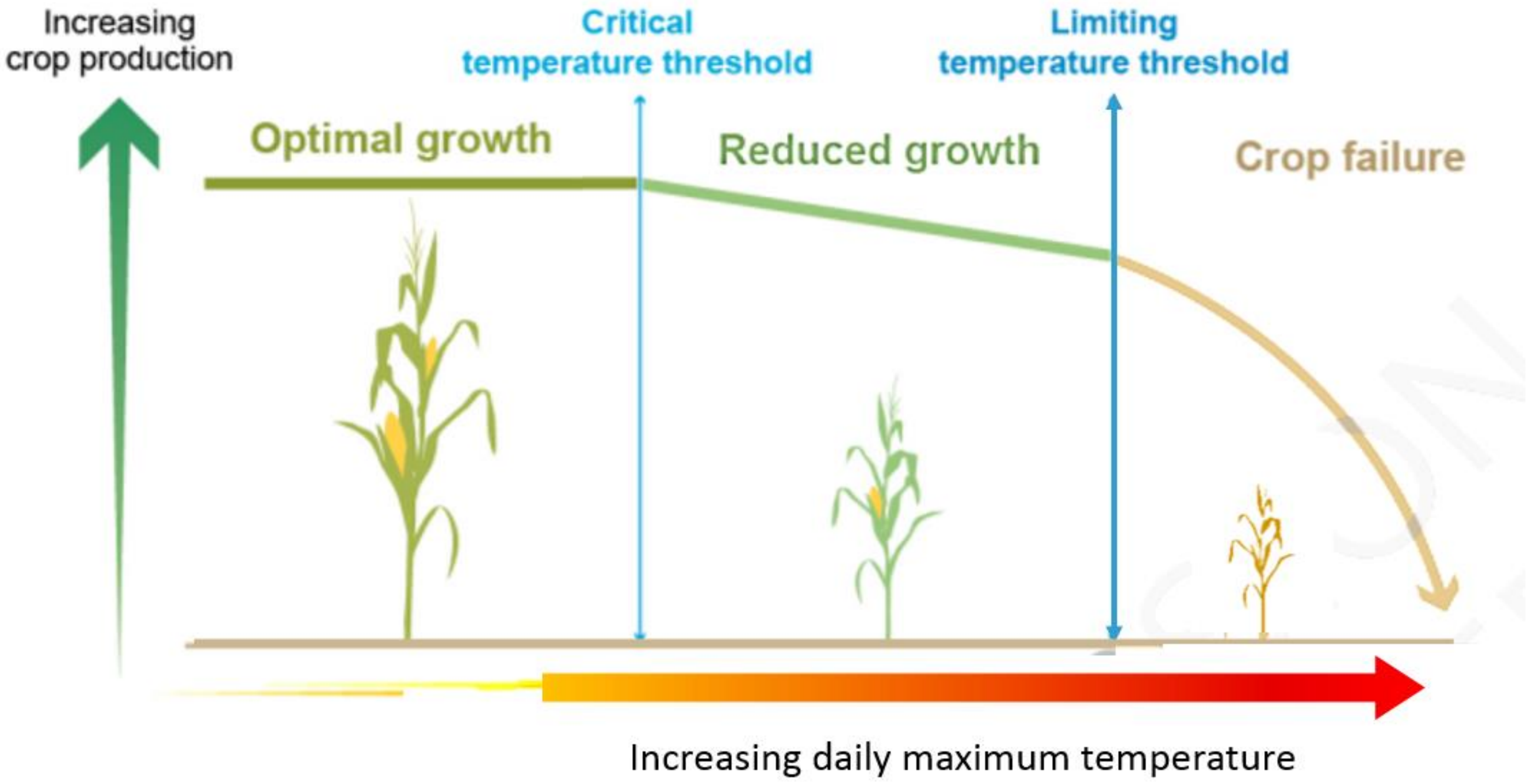
Anthropogenic climate change has slowed global agricultural productivity growth
(Total factor productivity)

IPCC August 2021, WG1 (Science)

Temperature
as
limiting factor of crop growth

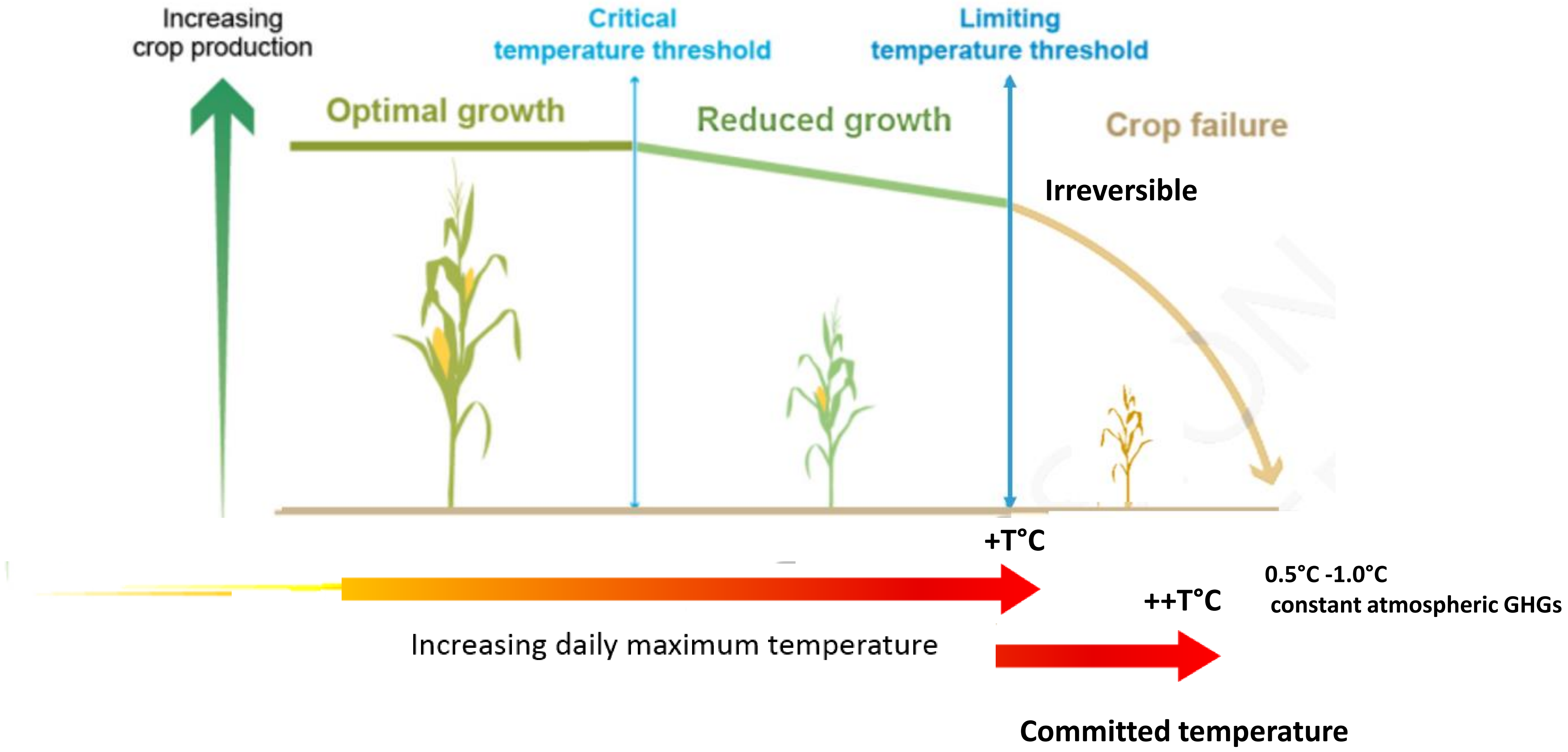
FUNDAMENTAL: Surface temperature is the crop yield limiting factor for agriculture (without irrigation)

IPCC AR6 WG1



Global Surface Heating Agricultural Tipping Point

At crop intolerance temperature increase tipping point- decline is irreversible and committed temperature increase is higher

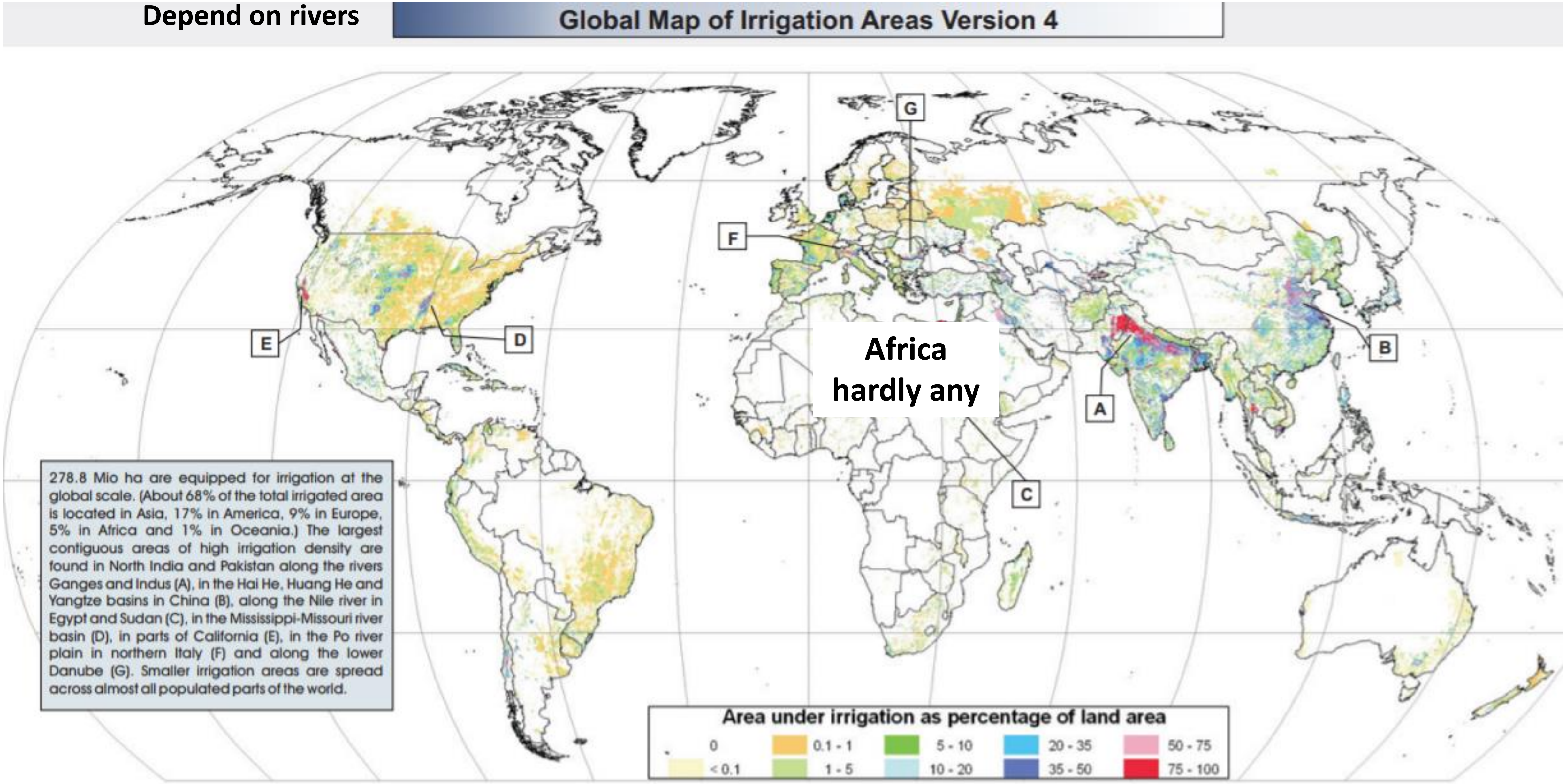


Irrigation

Large benefit against heat and drought

but likely has a limit to effectiveness

Agriculture Irrigation



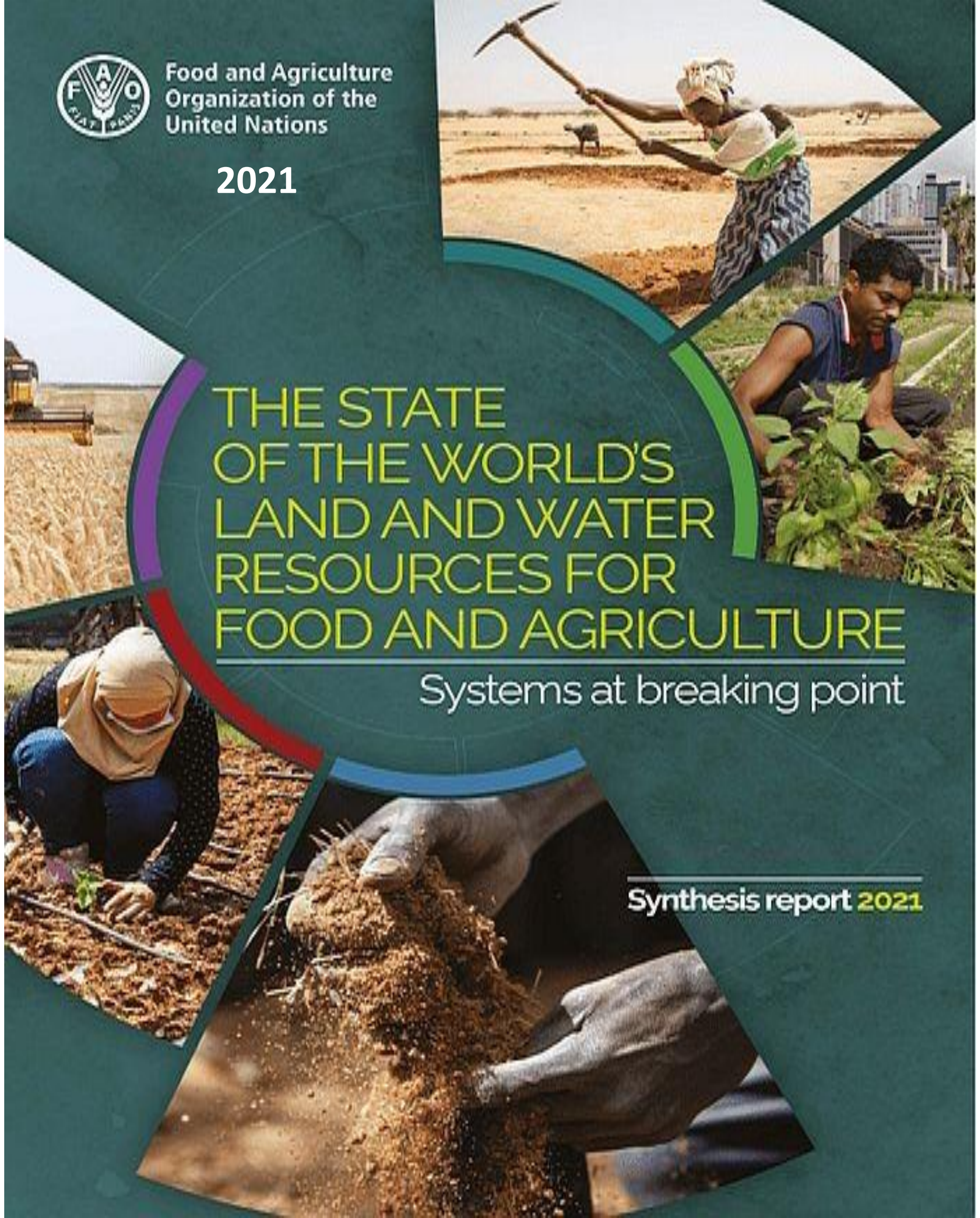
THE STATE
OF THE WORLD'S
LAND AND WATER
RESOURCES FOR
FOOD AND AGRICULTURE

Systems at breaking point

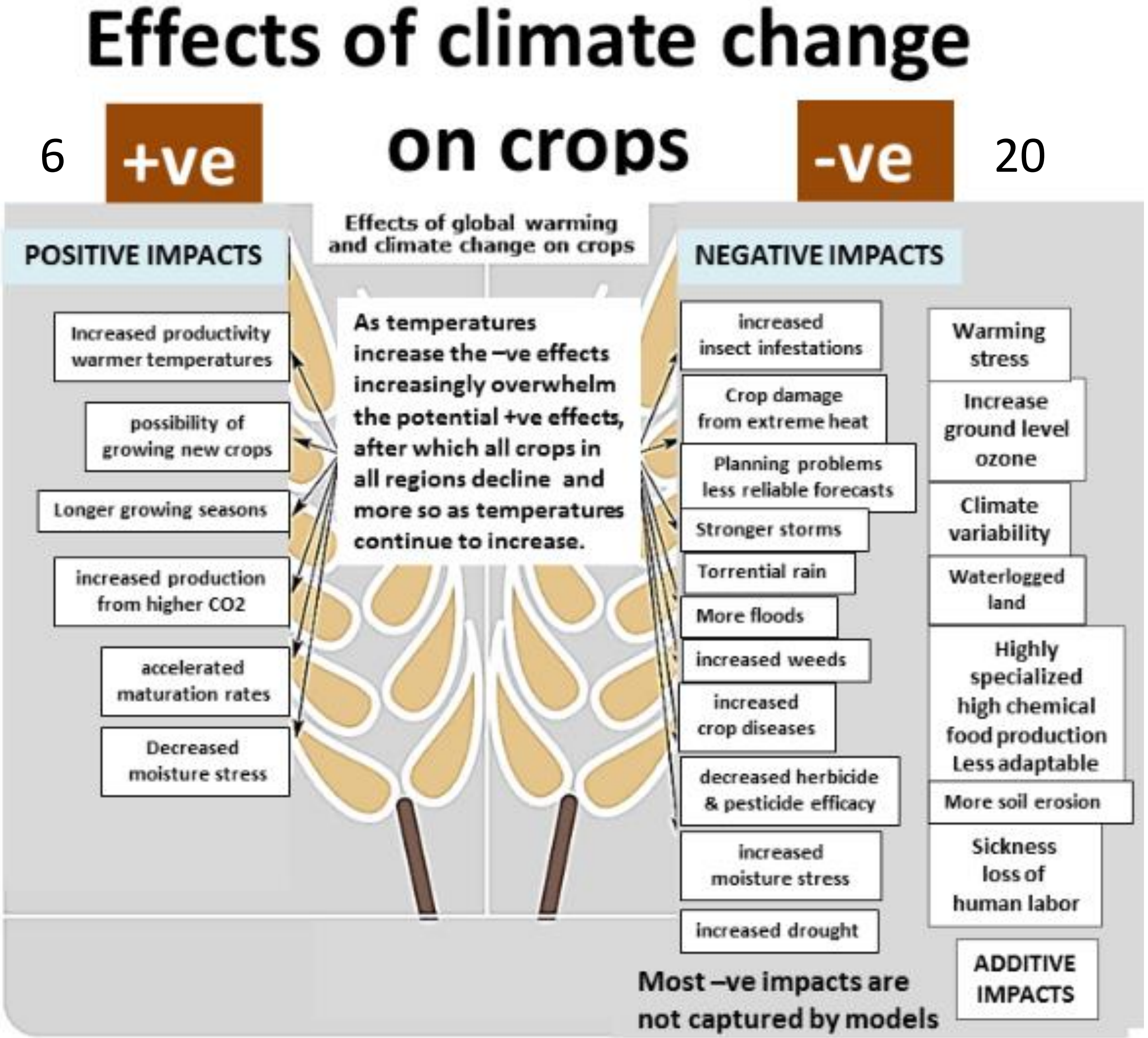
FAO, 9 December 2021

Increasing extreme weather events come on top of this

World Agriculture
at
Breaking Point


Food and Agriculture
Organization of the
United Nations
2021
THE STATE
OF THE WORLD'S
LAND AND WATER
RESOURCES FOR
FOOD AND AGRICULTURE
Systems at breaking point
Synthesis report 2021

FOOD SECURITY

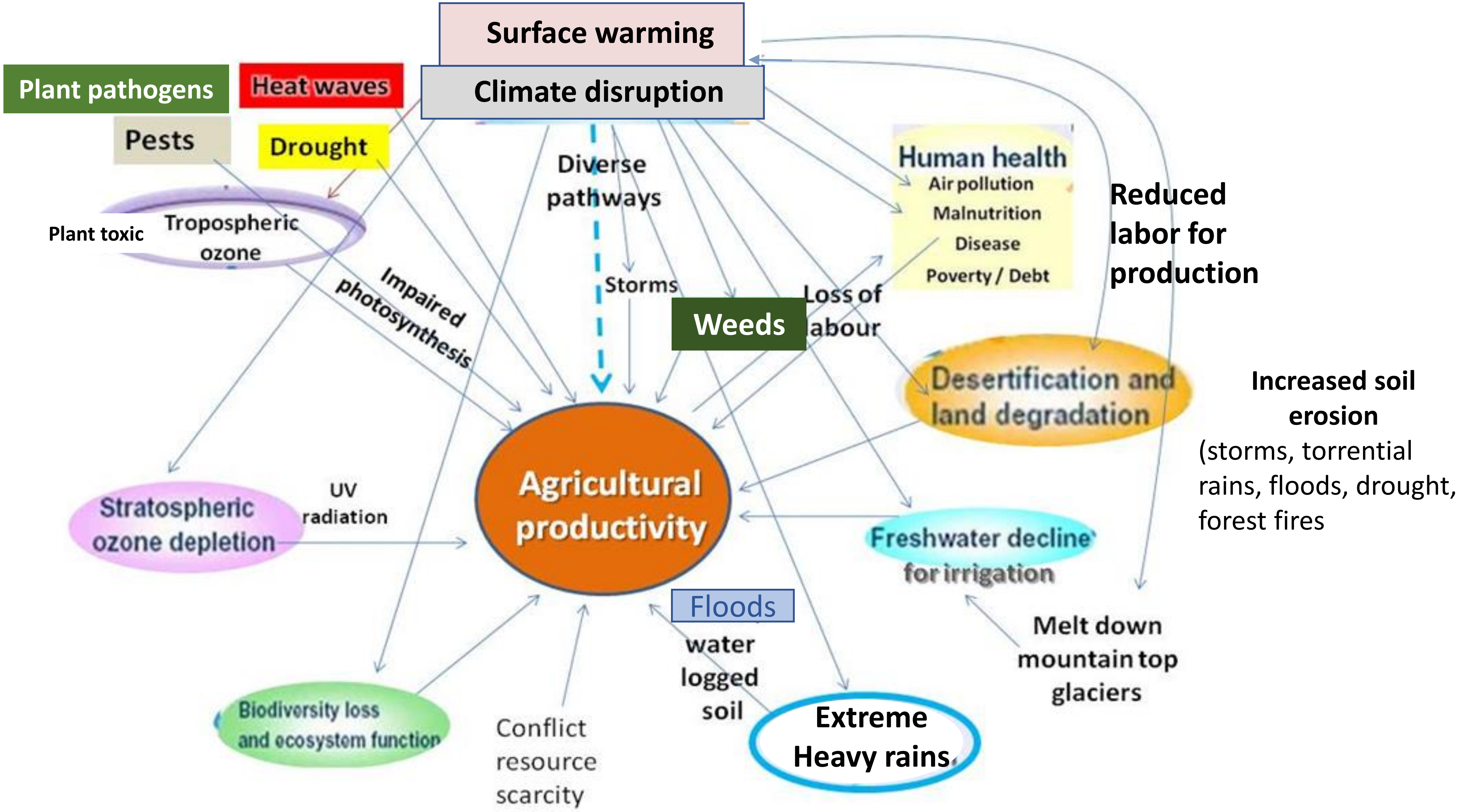


6

20

Feedback global warming acceleration

So many adverse impacts of global surface heating and climate disruption on agriculture

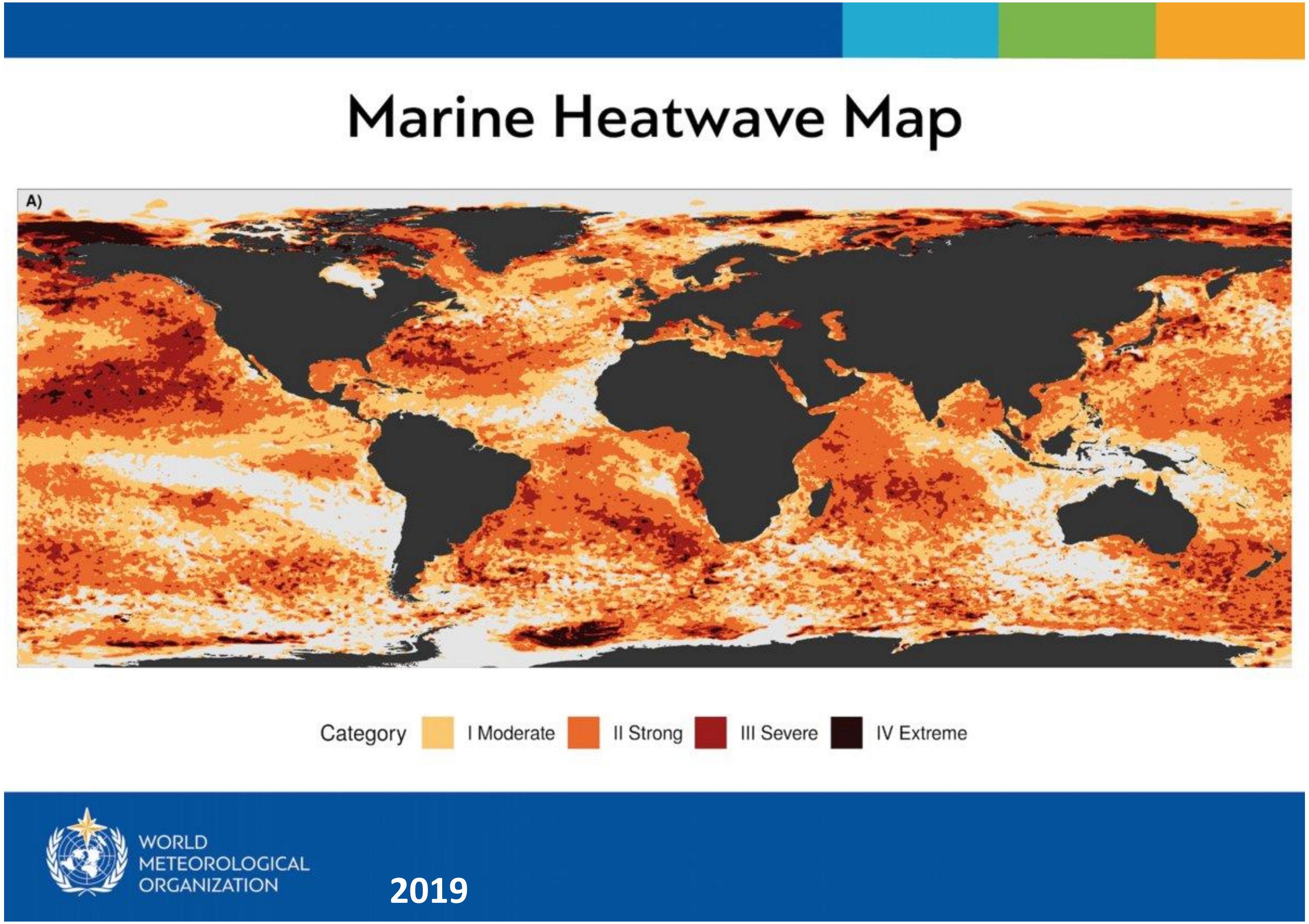


Heat Extremes Affect All Food Sources

Crops, Livestock, Fisheries

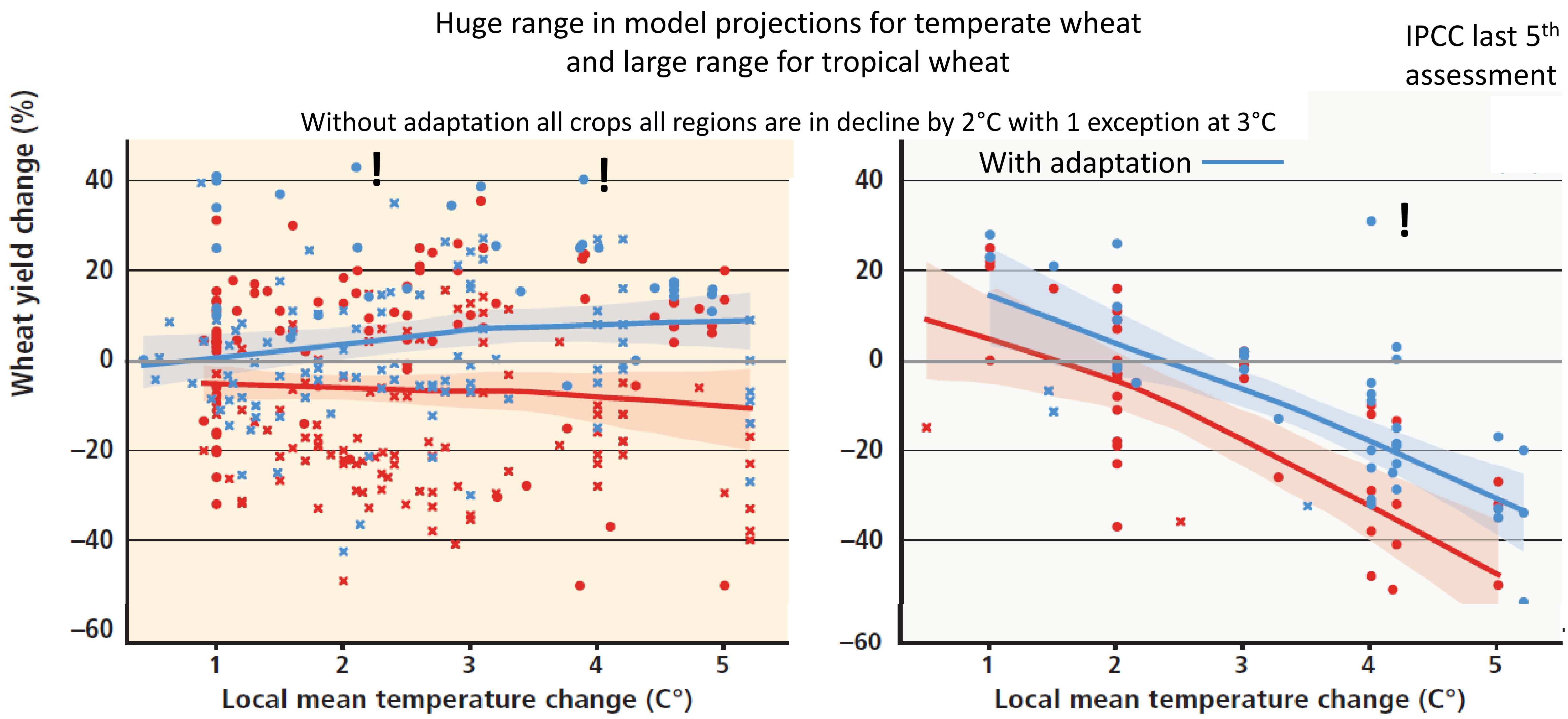
Fisheries: Extreme Sea Surface Heat Events (2019)

On top of ocean heating



Model Projections of climate change impact on crops are linear
They don’t capture extreme events

The several non-linear extreme events are not captured by models



IPCC 2014 AR5 Figure 7-4 | Percentage simulated yield change as a function of local temperature change for the three major crops and for temperate and tropical regions.

Many Climate-Crop Model Gaps

Assessment of crop yields under climate change assume linear changes as temperature changes, so does not account for abrupt changes under extreme weather events, nor for compound events.

Weeds, pests and plant pathogens are no captured by models

Tropospheric ozone is not accurately captured

Combined adverse impacts are not captured

Effects on soil erosion and land degradation are not captured.

The does not provide what needed for future crop production

There will abrupt, hard to predict losses with climate variability and extreme events

In IPCC projections adaptation is assumed to be successful even at rising degrees of climate change, and to be able to reverse risks to crops.

In addition, if a crop decline is observed at a particular temperature +T°C, that decline will continue because the temperature increase will continue, so we don't need simple %age crop decline at corresponding +T°C, we need to project full crop decline and loss at the committed temperature ++T°°C.

As population grows **water resources** per capita per year are **decreasing** rapidly

from
6994.9 m^3 in 2000

to **6029.4** m^3 in 2012

to **5630.2** m^3 in 2018

Food and Agriculture Organization of the United Nations

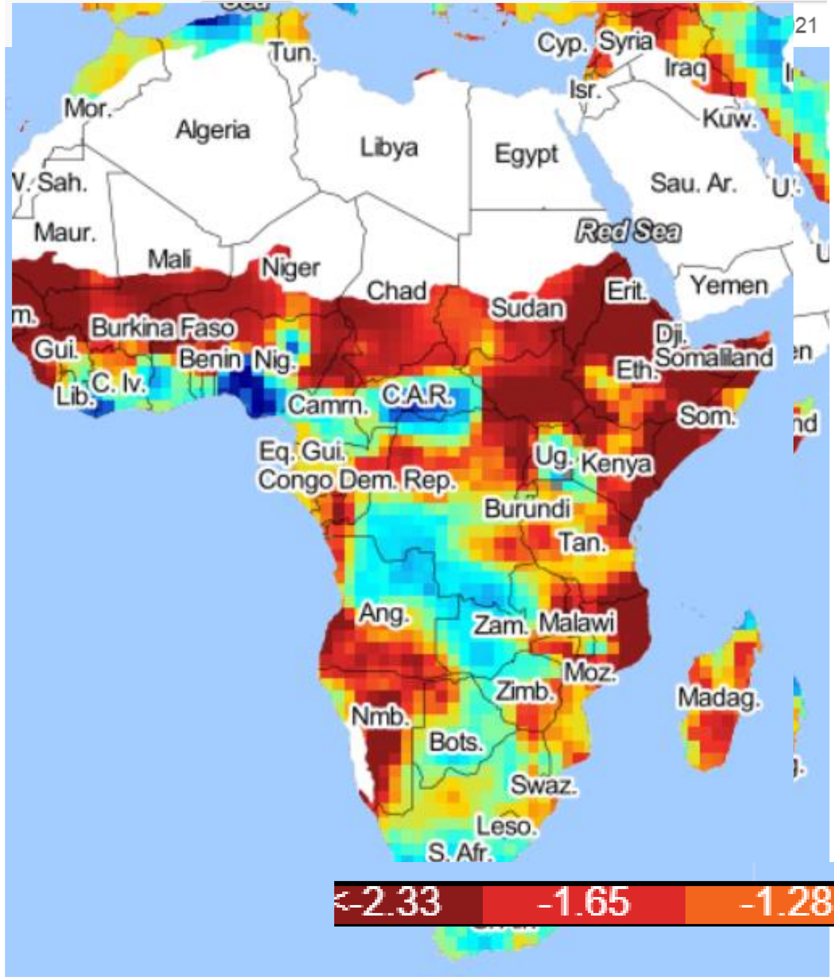
About 58.6 million people are facing severe acute food insecurity in East Africa.

East Africa Regional Food Security & Nutrition Update (World Food Program))

Africa is projected to suffer increasing drought with little to no irrigation

December 2021

Past 1 months



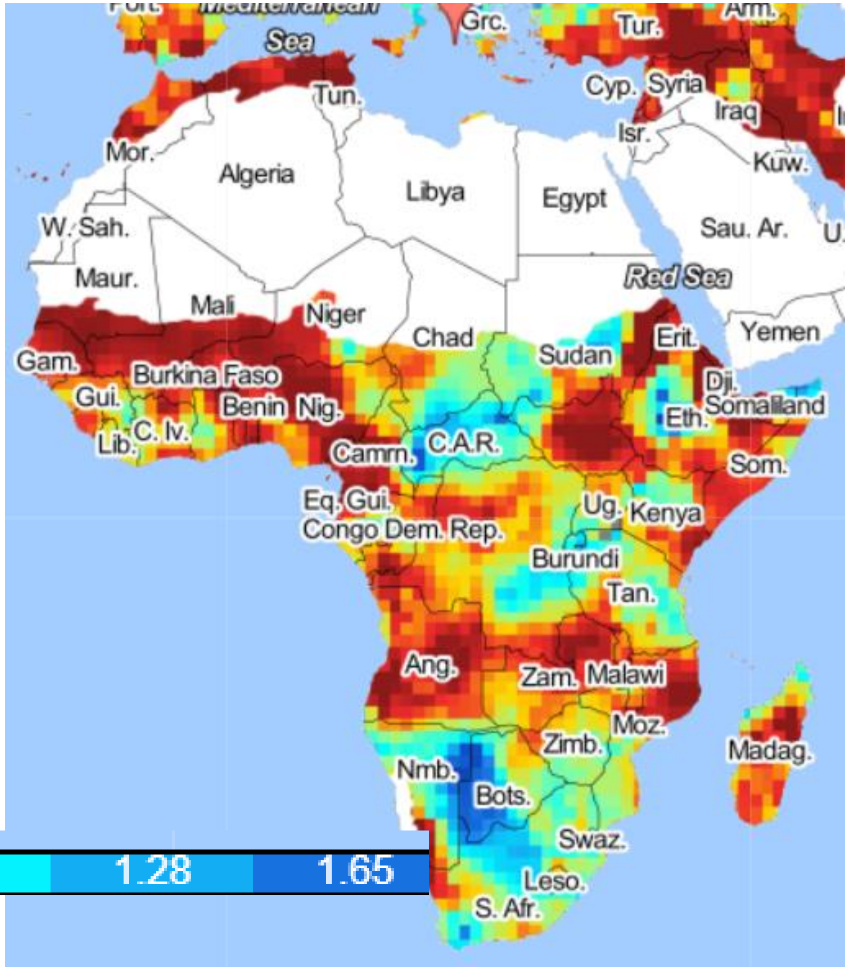
Drought (SPEI)

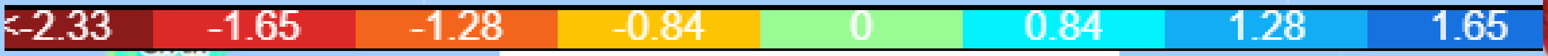
(Standardised Precipitation-Evapotranspiration Index)

INCREASING DROUGHT

Compared to past 12 months (left) the past 1 month (right) shows large expansion and increasing drought severity

Past 12 month





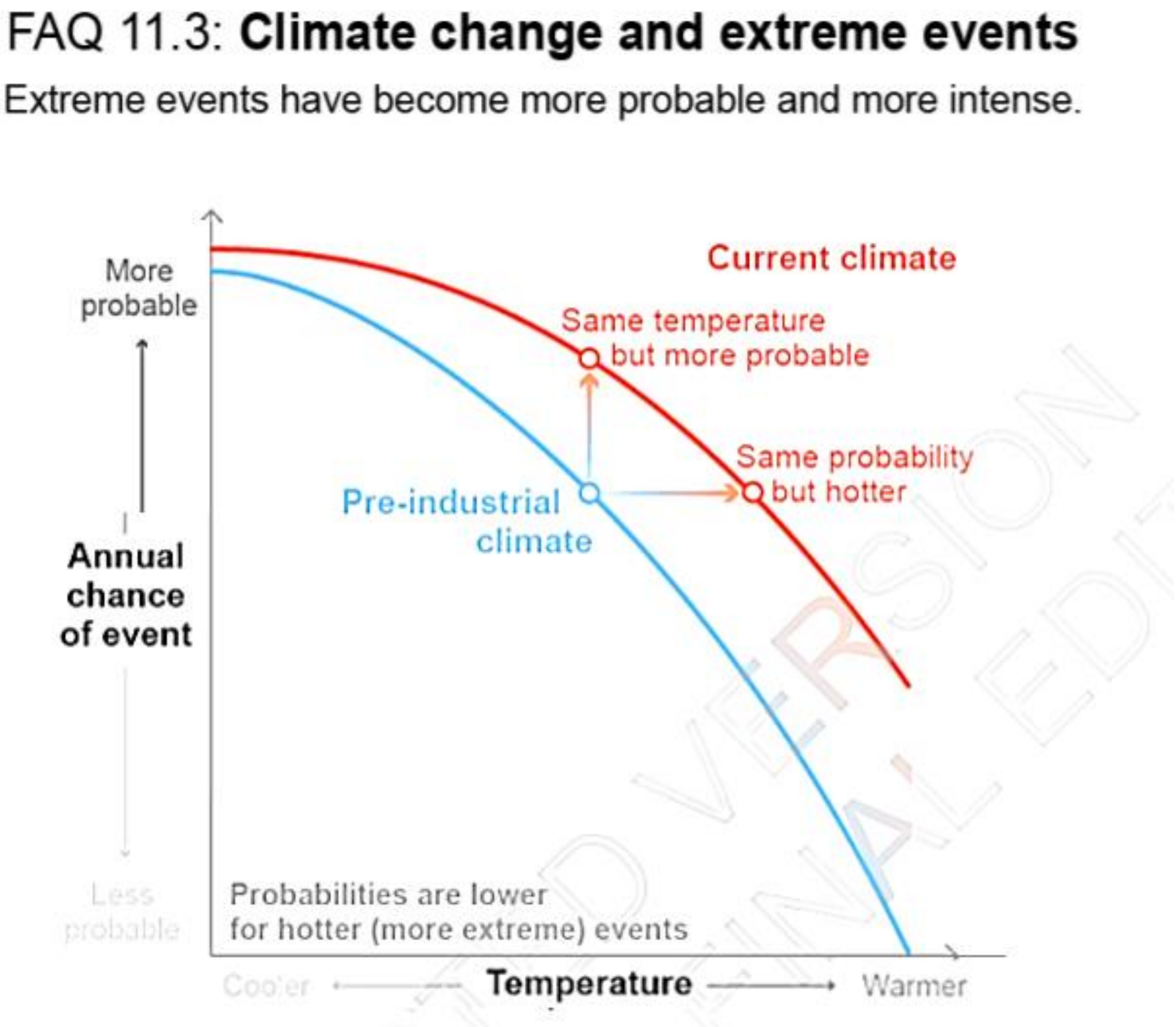
Government of Spain, SPEI Global drought monitor , Santiago Beguería et al

Peter Carter, Climate Emergency Institute

IPCC August 2021 6th Assessment (AR6)
Working Group 1
Science

Chapter 11: Weather and climate extreme events in a changing climate

(in assessment for the first time)



FAQ 11.2: **Will climate change cause unprecedented extremes?**

Yes, in a changing climate, extreme events may be unprecedented when they occur with...

Larger magnitude

Increased frequency

New locations

Different timing

New combinations

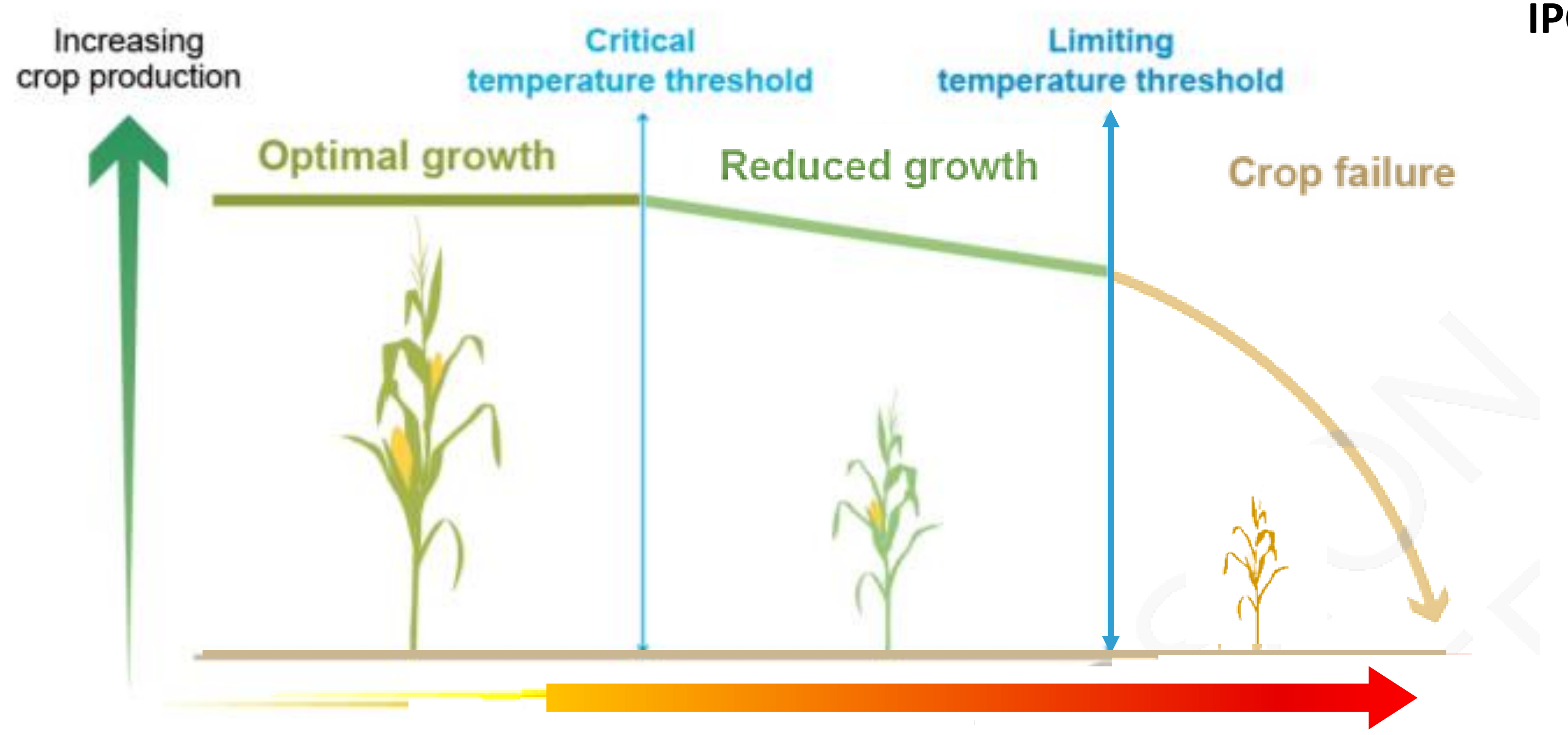
Extreme weather Is increasing attributed to emissions driven climate change and will continue to increase

IPCC August 2021, 6th assessment, WG1

Crop tipping point: maximum heat tolerance

At temperature tolerance limit of a crop it growth crashes

IPCC AR6 WG1

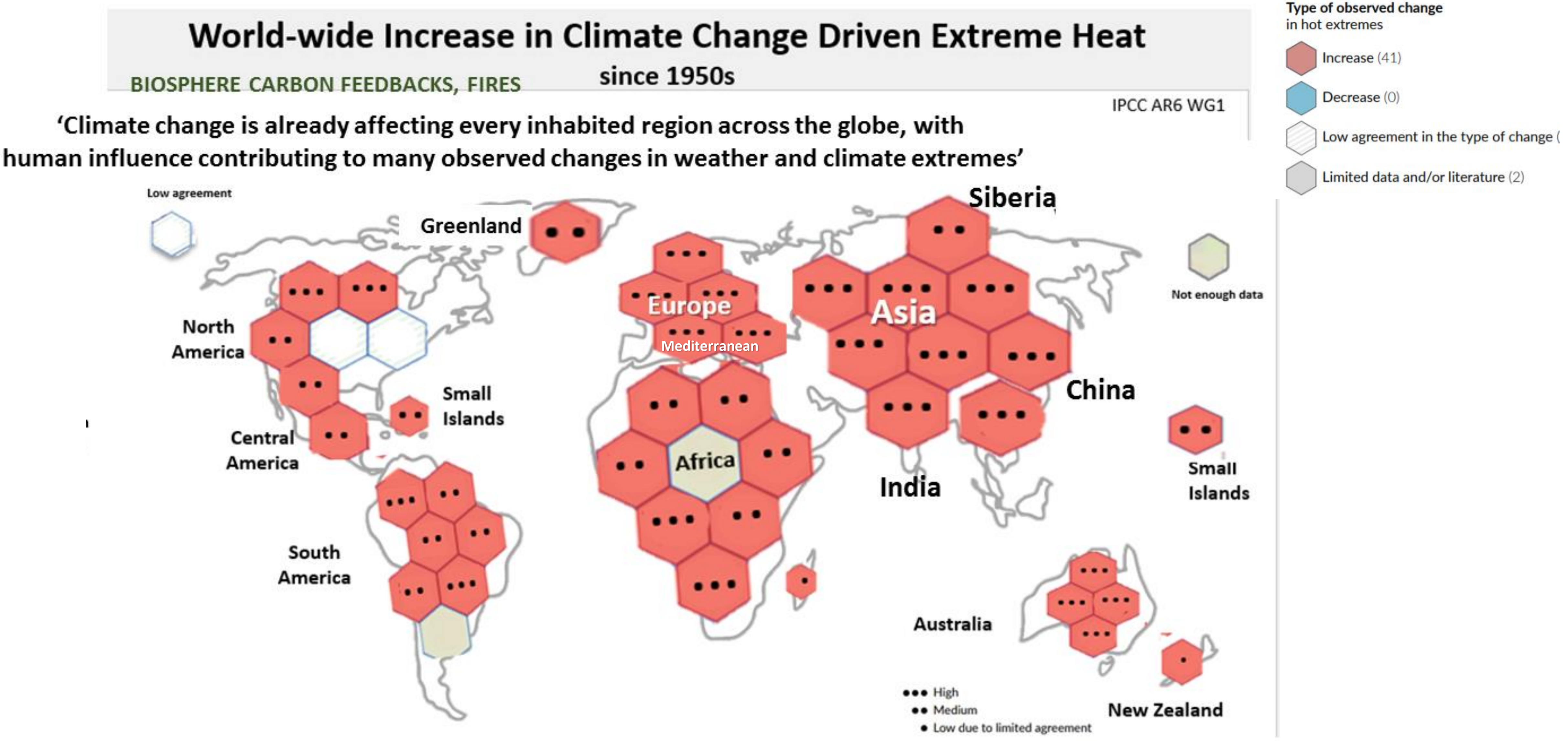


Increasing daily maximum temperature

FAQ12.2, Figure 1: **Crop response to maximum temperature thresholds.** Crop growth rate responds to daily maximum temperature increases, leading to reduced growth and crop failure as temperatures exceed critical and limiting temperature thresholds, respectively.

Hot Extremes

IPCC AR6 WG1, Figure SPM.3 | Synthesis of assessed observed change in hot extremes attributed to human contribution



Adapted from IPCC AR6 WG1, synthesis of assessment of observed change in extremes and confidence in human contribution to the observed changes in the world's regions

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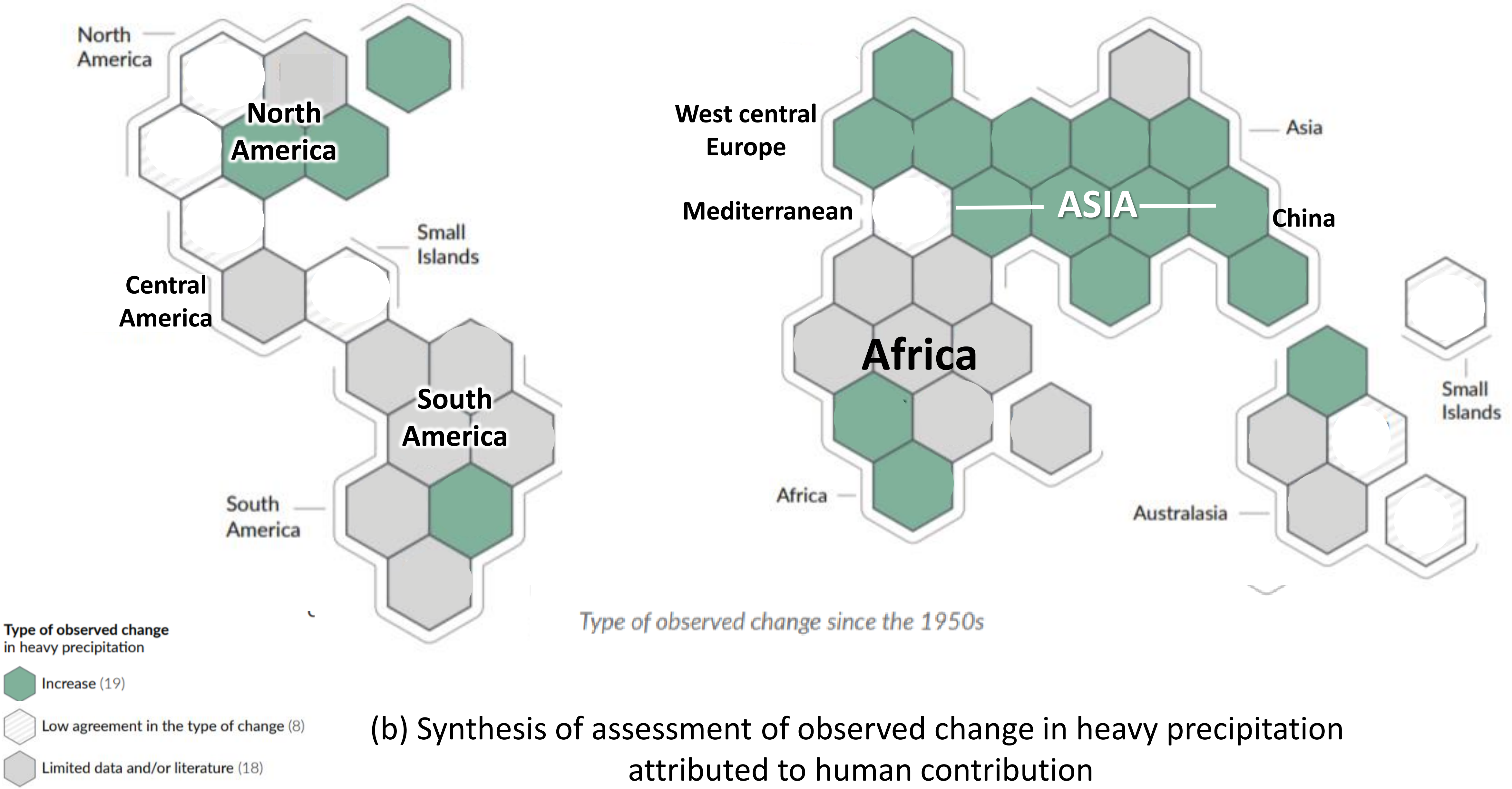
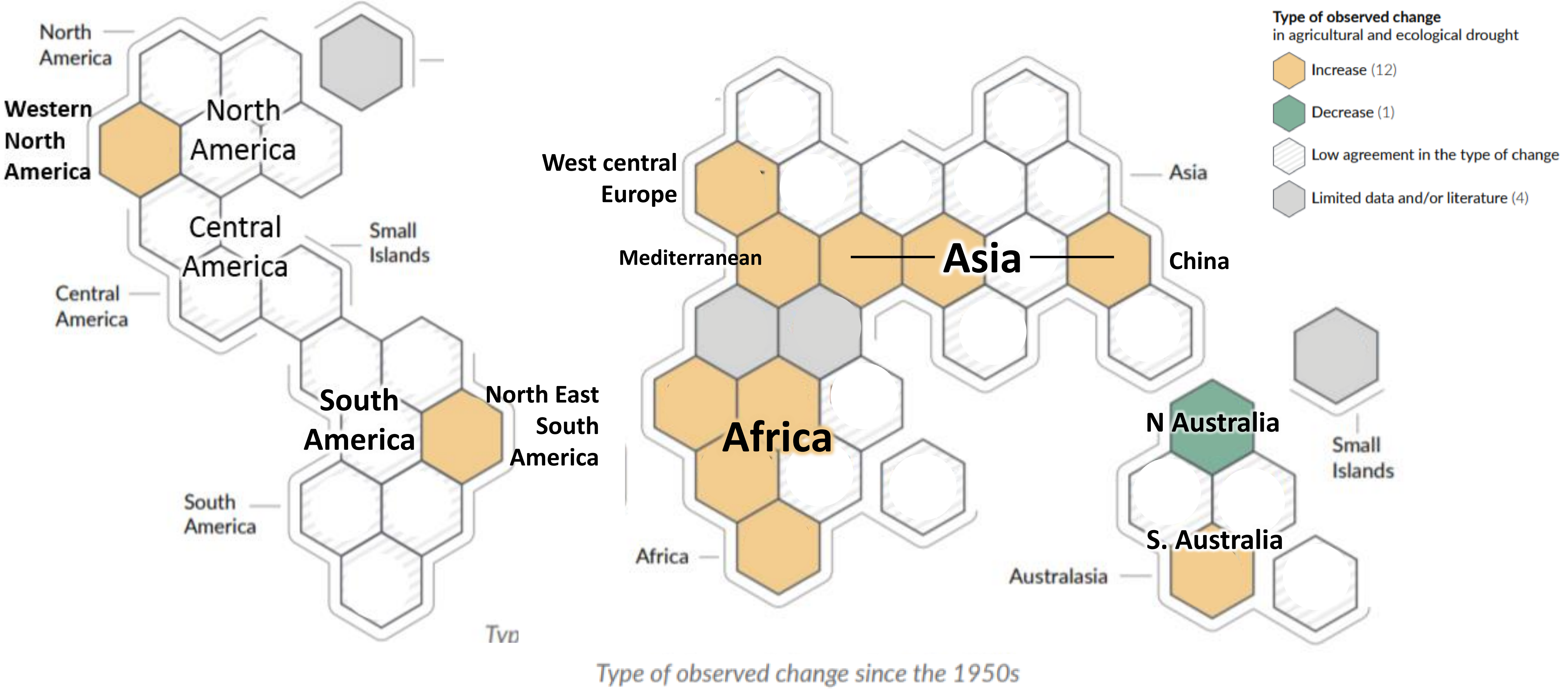
Heavy Precipitation



(b) Synthesis of assessment of observed change in heavy precipitation attributed to human contribution

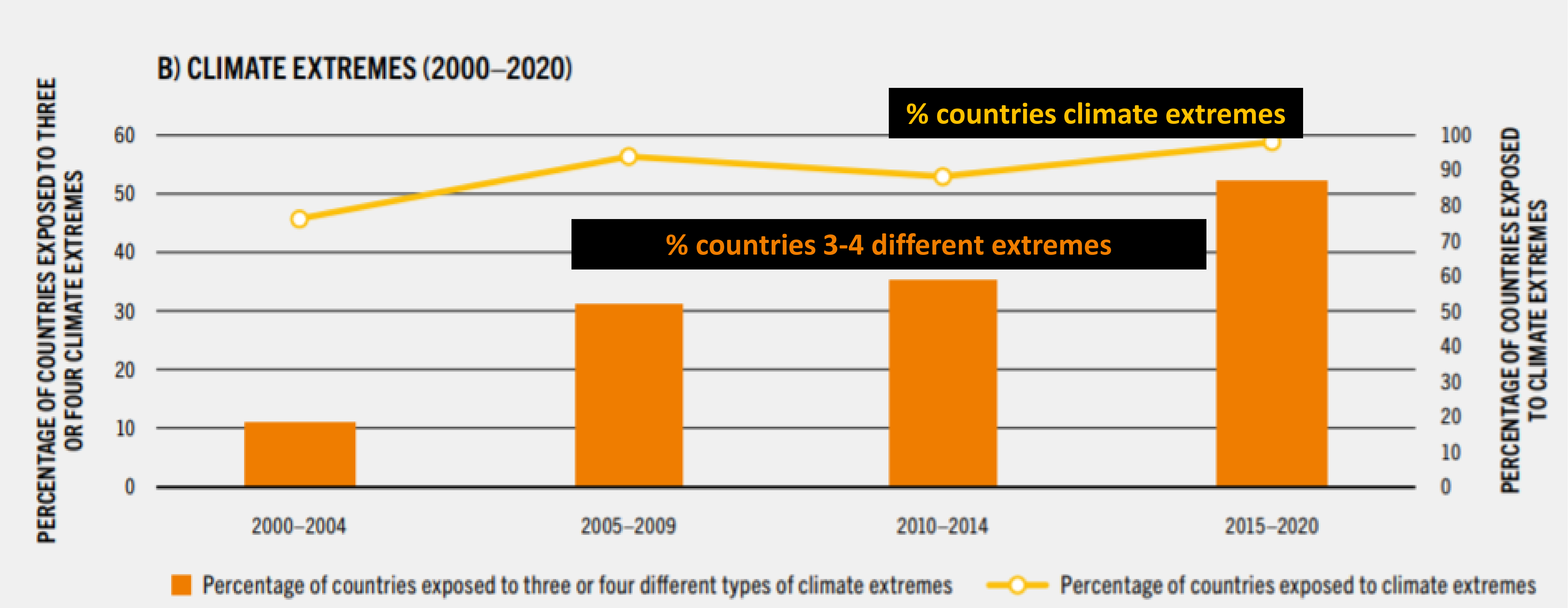
Drought



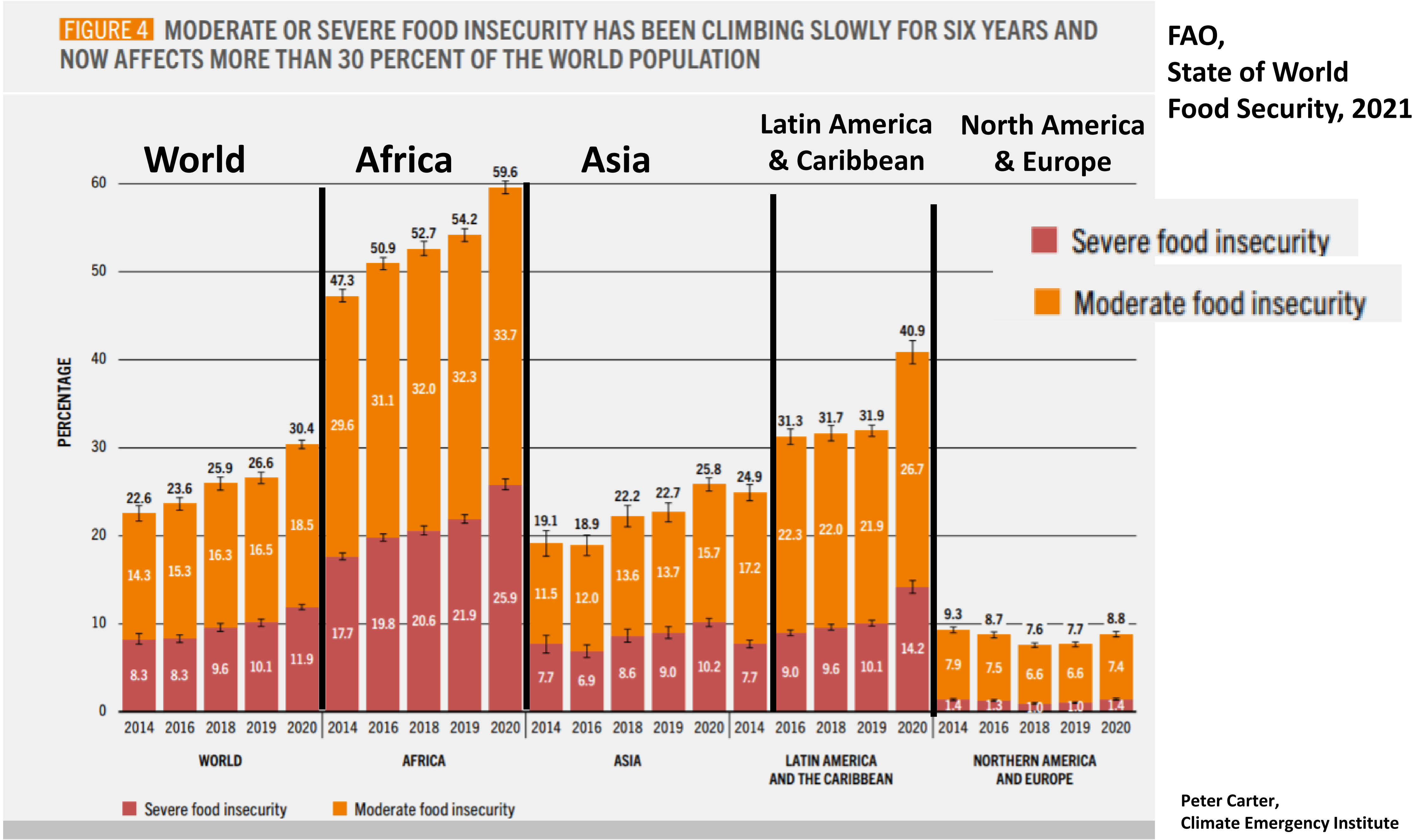
IPCC AR6 WG1, Figure SPM.3 Synthesis of assessment of observed change in agricultural and ecological drought attributable to human contribution

Climate Extremes

FAO state of World Food Security 2021



Food insecurity now affects over 30% of the world population



FAO, State of World Food Security, 2021

Peter Carter, Climate Emergency Institute

How climate change drives extreme events impact on crops

Increasing extreme weather is being driven by climate change and so will increase with global temperature increase.
They have yield impact shocks, depending on severity, duration and combination of extreme events

IPCC has Extreme Weather Events (that includes fires)
as a single category of climate change impacts
It is the most damaging impact to people and crops
- even more so on crop yields with labour intensive
Africa and lower latitude food production

Climate change crop impacts

IPCC AR6 WG1 included compound events

MORE:

- Extreme heat
- Wild fires
- Drought

} Global surface warming

Surface ozone
is increased by heat
toxic to crops

- Powerful storms
- Heavy precipitation
- Floods

} Lower atmosphere energized
Increased water vapor

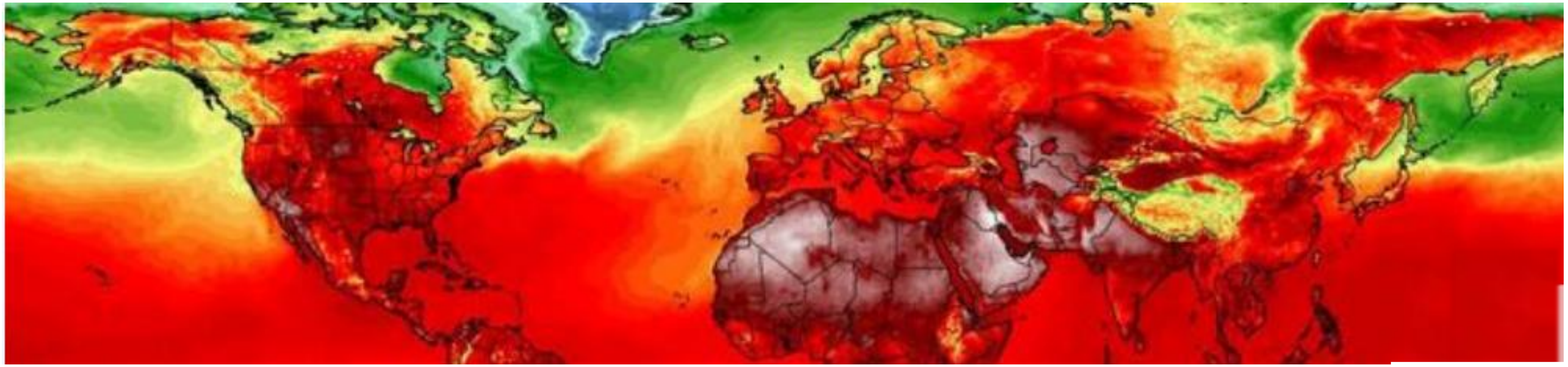
Water logged land
Soil erosion
Increased surface ozone

MODELS Climate change crop yield models in climate change assessments do not capture the impact of extreme weather

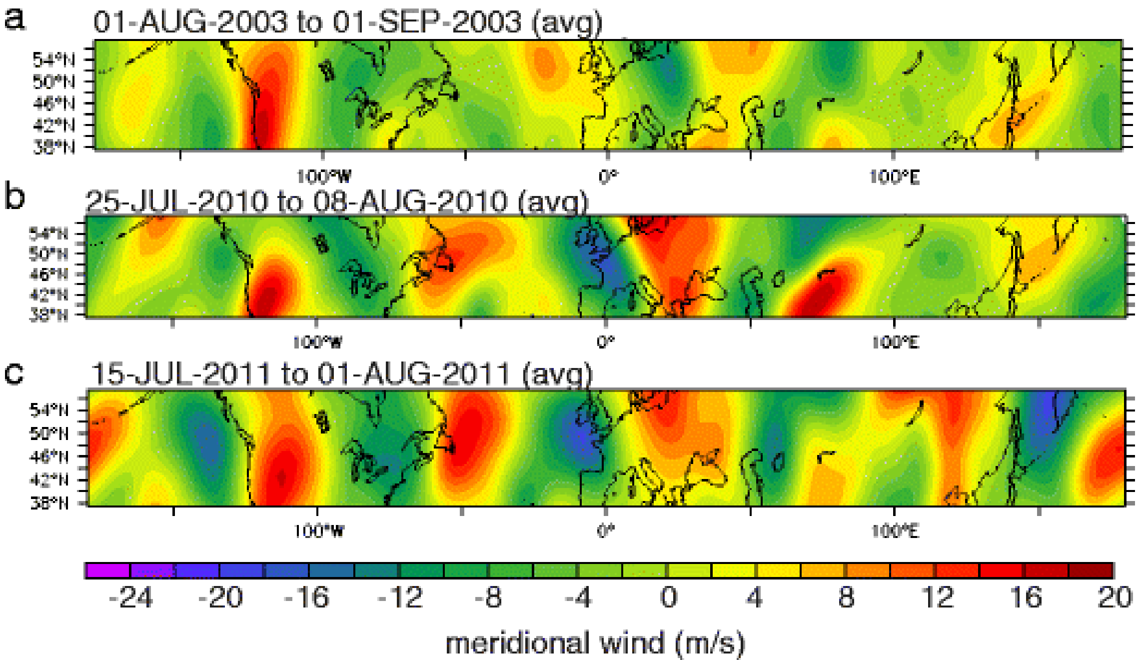
CLIMATE SHOCKS Extreme weather acts as production shocks, but if severe, widespread and long lasting (blocking phenomenon) can impact a regional harvest.

Intense Prolonged Northern Hemisphere Extreme Events

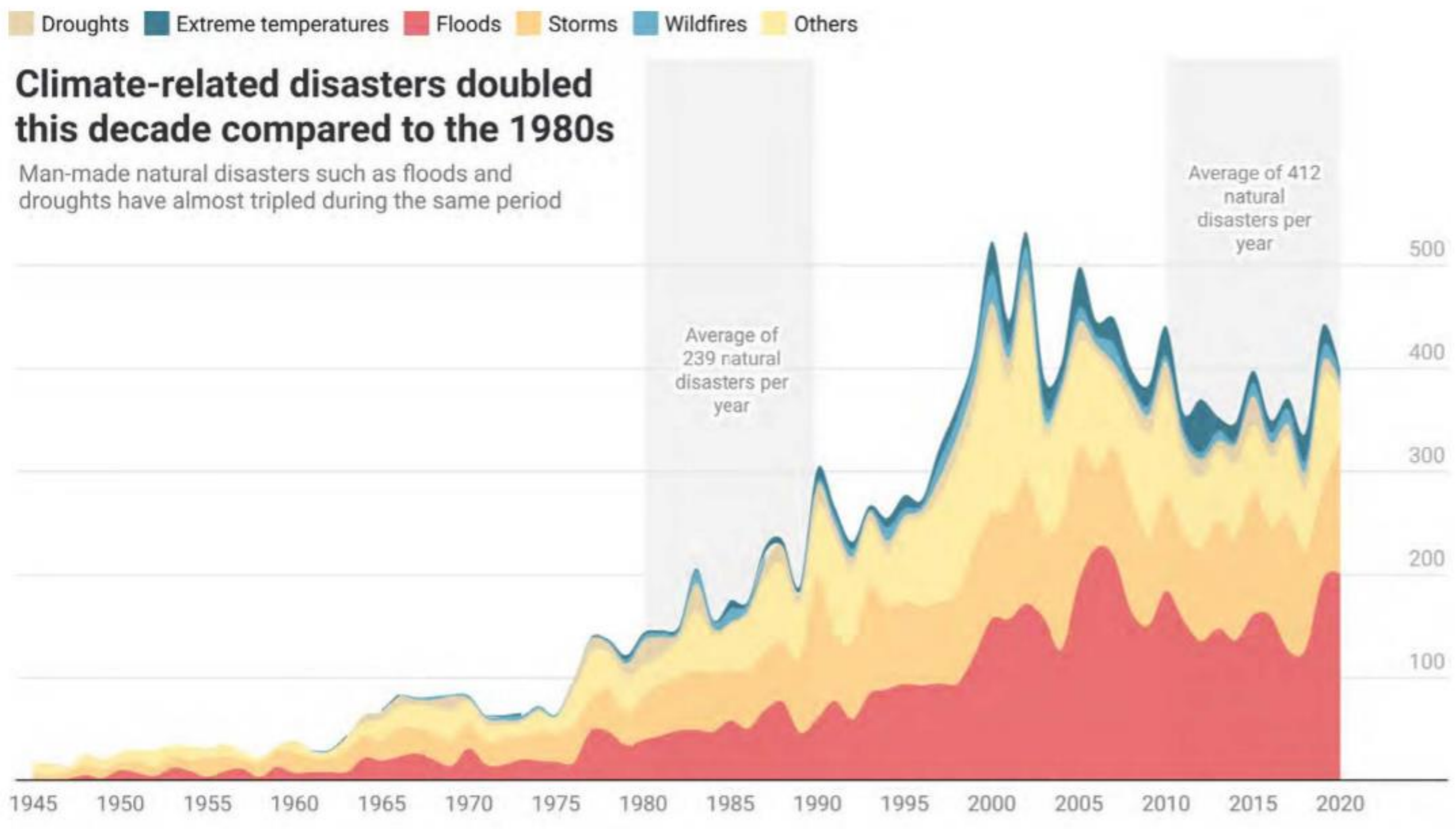
7 Jul 2018 **Killer heatwave grips Northern Hemisphere as temperature records broken from Canada to Oman**
At least 54 people have died amid an extreme heatwave in the Canadian province of Quebec



Quasiresonant amplification of planetary waves and recent Northern Hemisphere weather extremes
Vladimir Petoukhov, et al, PNAS,
January 16, 2013



Climate change driven disasters are increasing and will continue to increase with global surface temperature



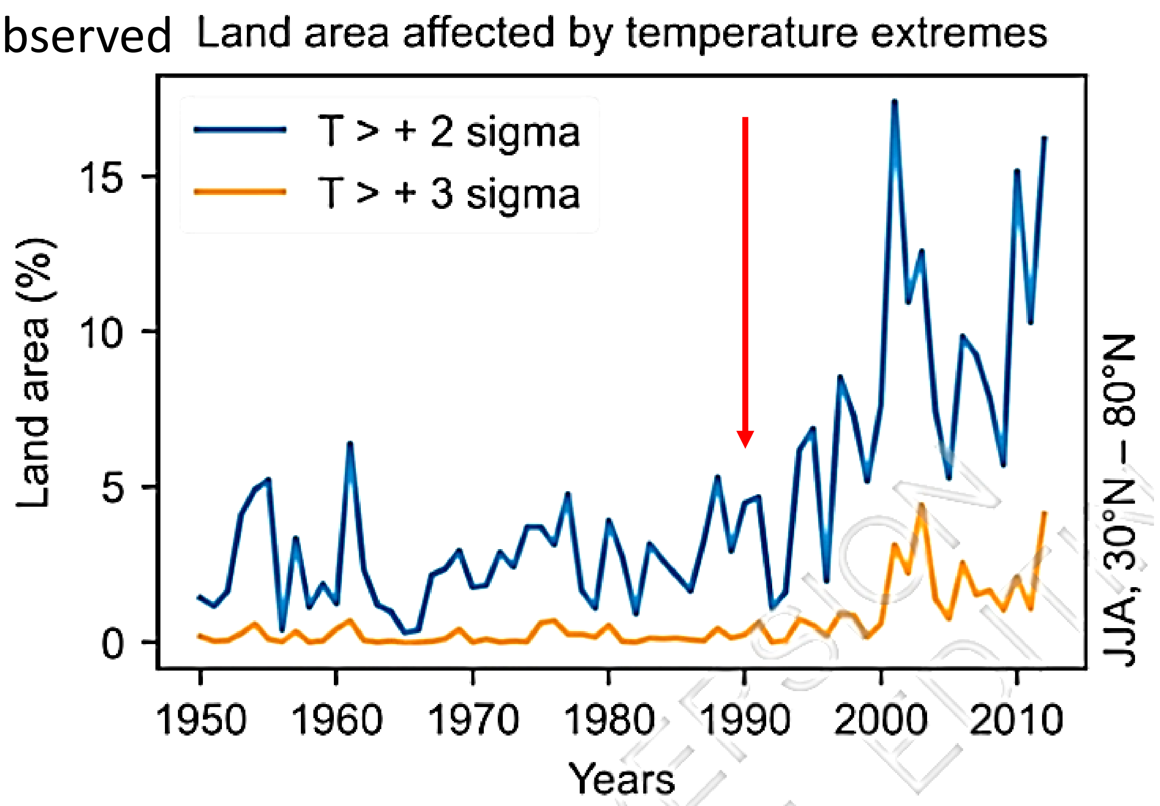
Source: The December 2021Global Humanitarian Overview 2022,
United Nations Office for the Coordination of Humanitarian Affairs (OCHA)

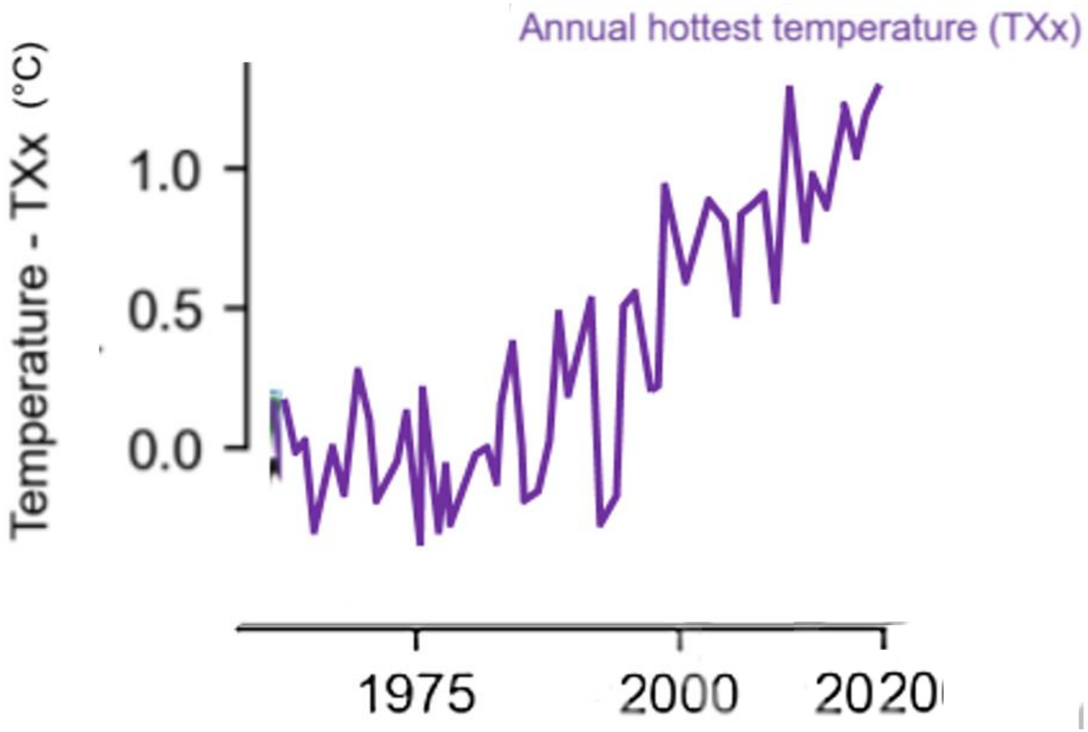
Observed Northern Hemisphere Heat Extremes

IPCC AR6 WG1

Increasing northern hemisphere land area affected by extreme heat and increasing extreme heat temperatures over time

Observed



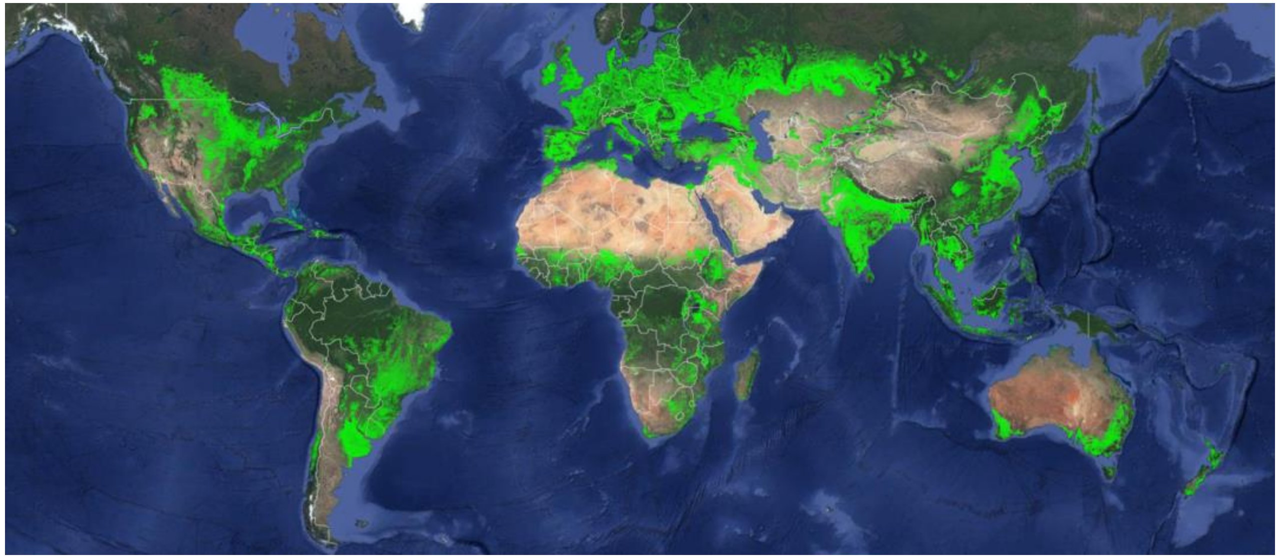


IPCC 2021, AR6, WG1, Box 11.4, Figure 1: Analysis of the percentage of land area affected by temperature extremes larger than two (orange) or three (blue) standard deviations in June-July-August (JJA). These panels show for both estimates a substantial increase in the overall land area affected by very high hot extremes since 1990 onward.

Extreme Heat Will Affect Most Food Producing Regions

from AR6 WG1 interactive atlas

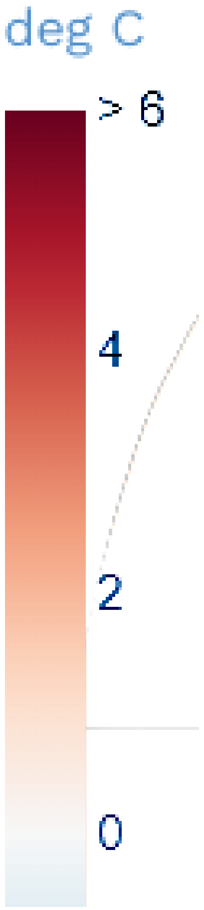
Crop extent and density

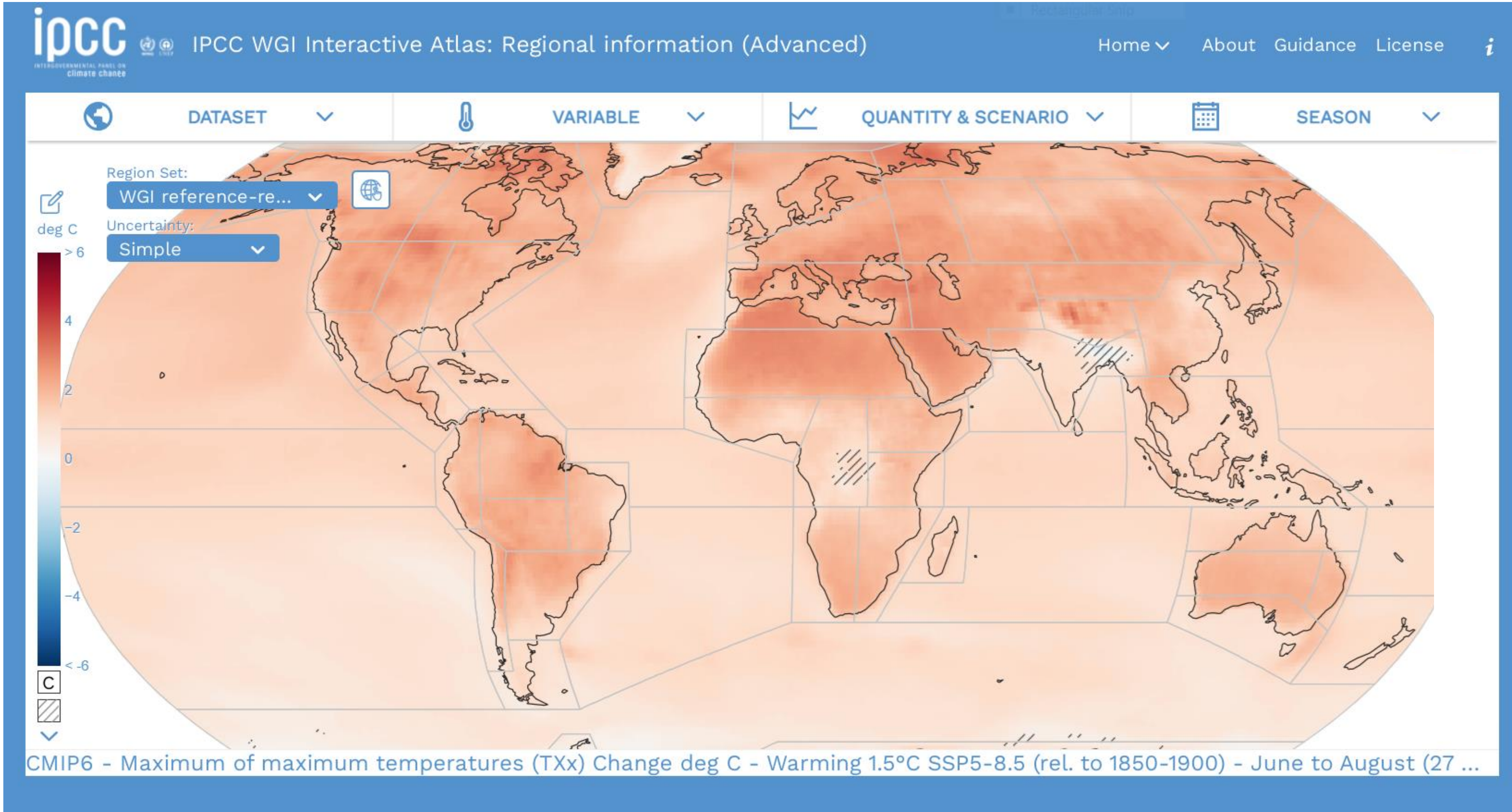


USGS Crop area and density 2017 (satellite data)

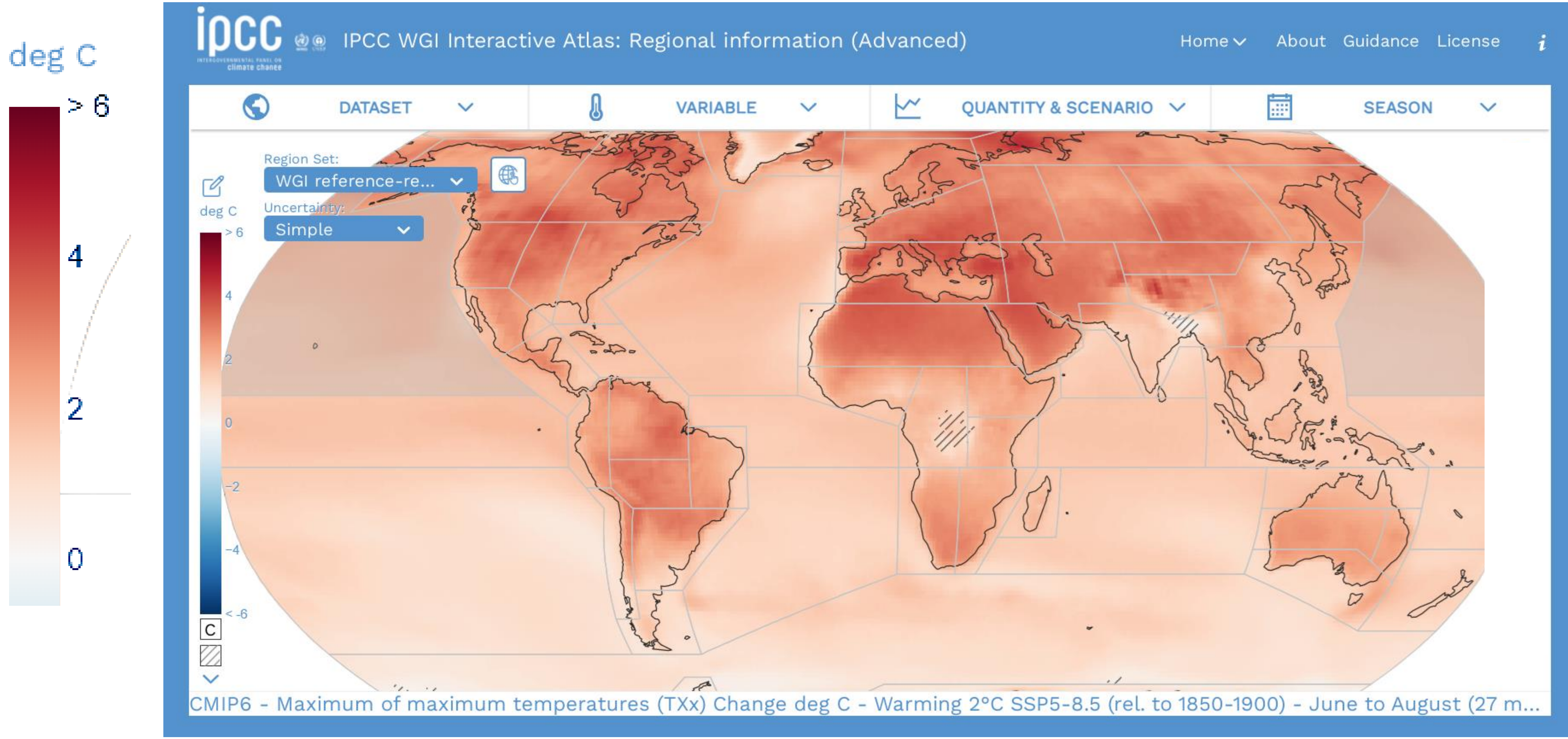
Peter Carter, Climate Emergency Institute

Extreme heat
1.5°C

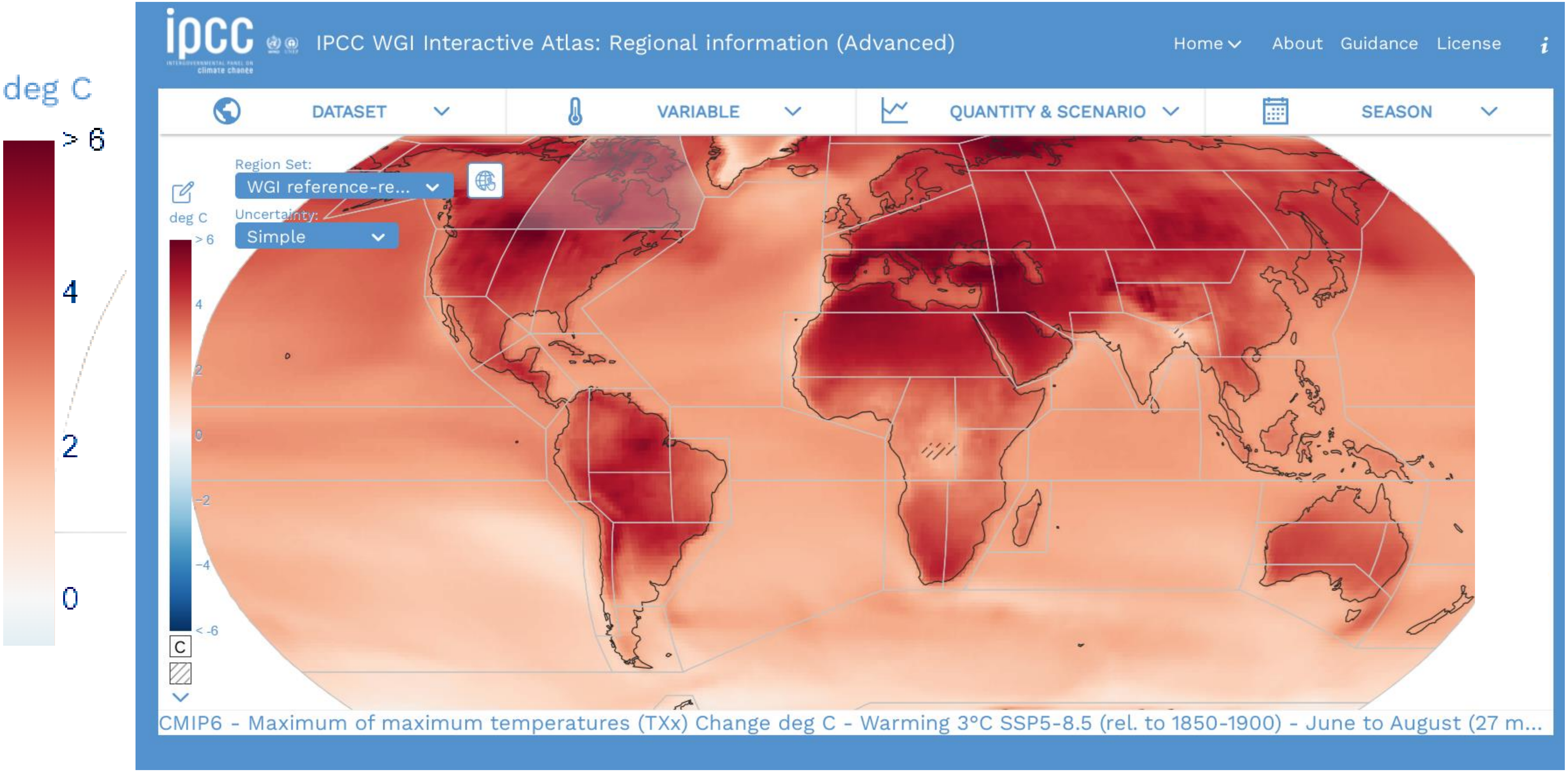




Extreme heat
2°C



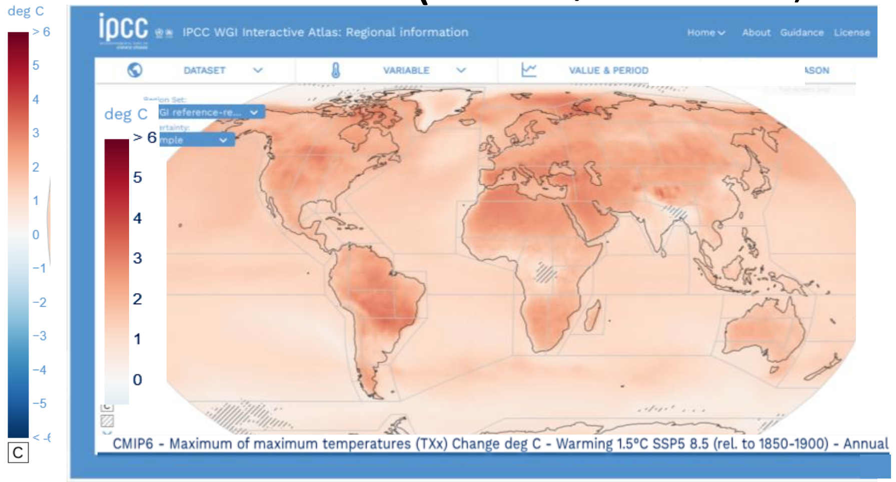
Extreme heat
3°C



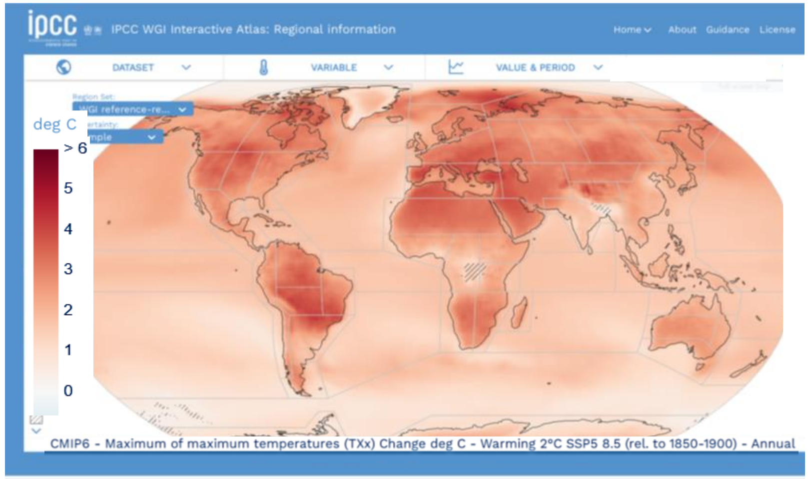
Extreme Heat Will Affect Most Food Producing Regions

Extreme heat at 1.5°C, 2°C and 3°C from IPCC AR6 WG1 Interactive Atlas

+1.5°C (2030 /soon after)

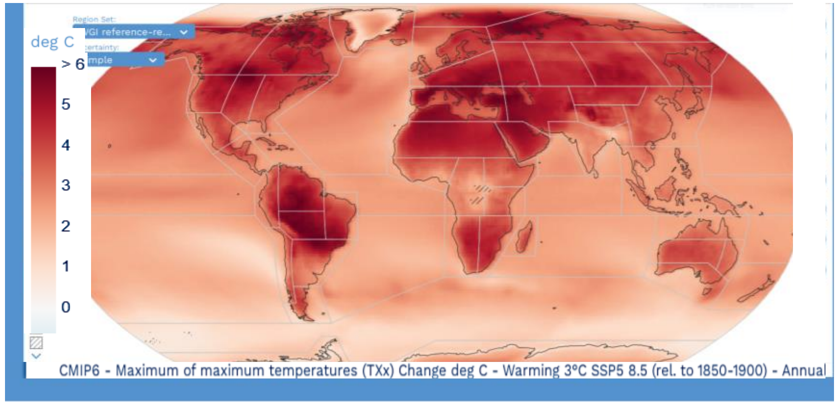


+2.0°C (2045)

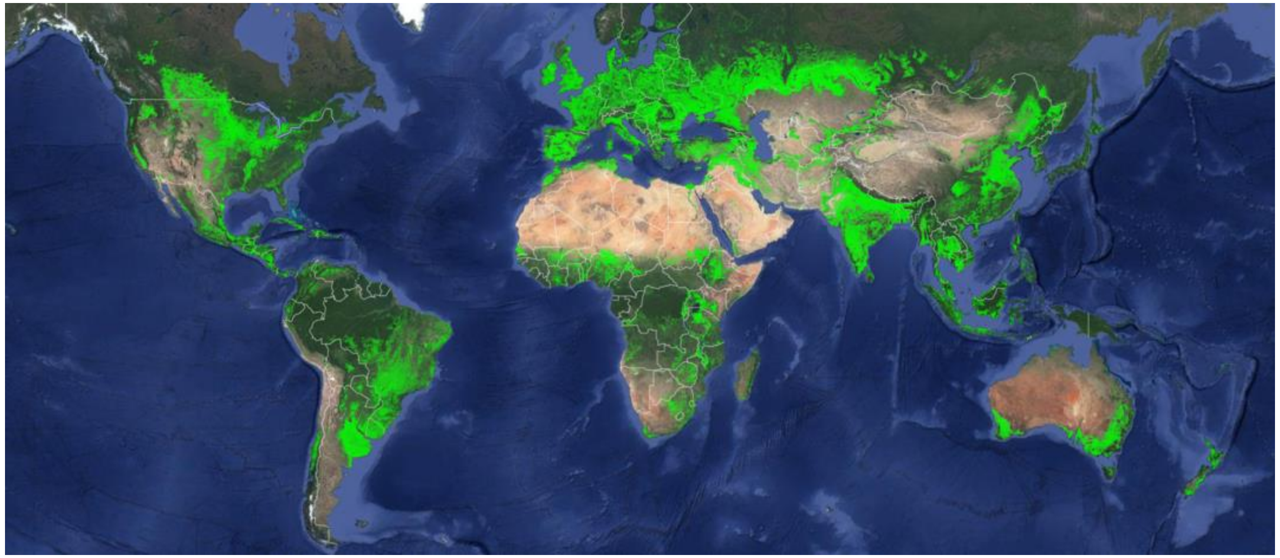


+3.0°C

(by national emissions targets)



USGS Crop area and density 2017 (satellite data)

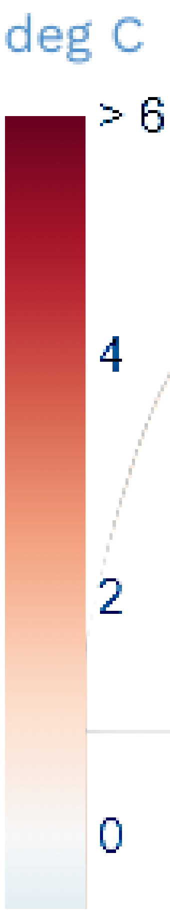


Studies have documented a large negative sensitivity of crop yields to extreme daytime temperatures around 30°C. These sensitivities have been identified for several crops and regions and exist throughout the growing season (high confidence)

IPCC, 2014, AR5 WG2, Ch.7
Food Security and Food Production Systems

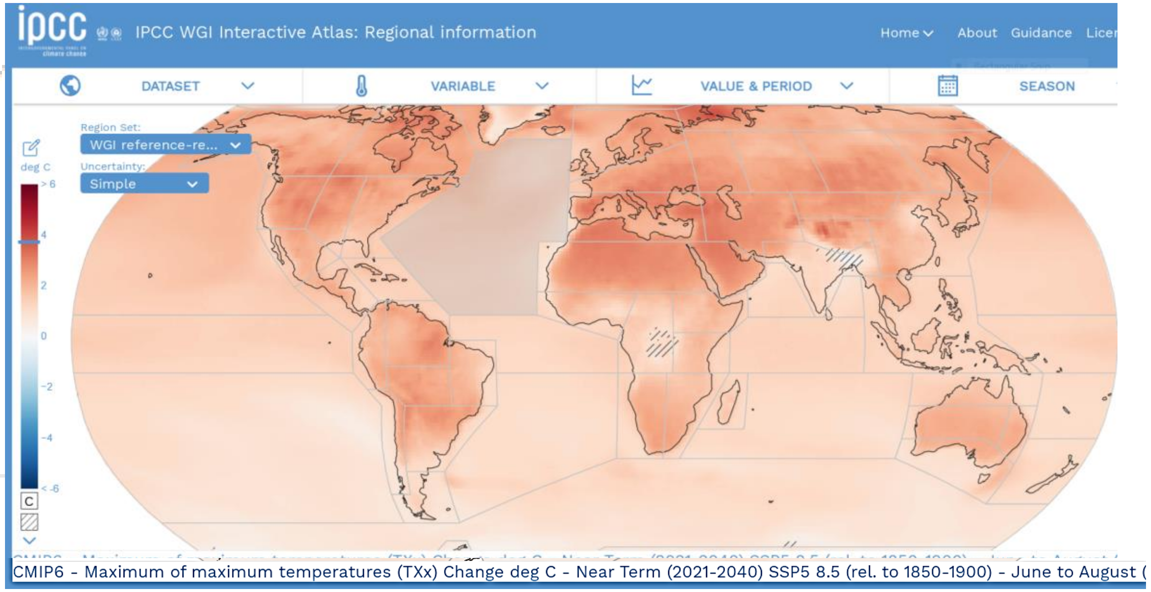
Peter Carter, Climate Emergency Institute

Extreme heat affects major food producing regions at 1.5°C-2°C

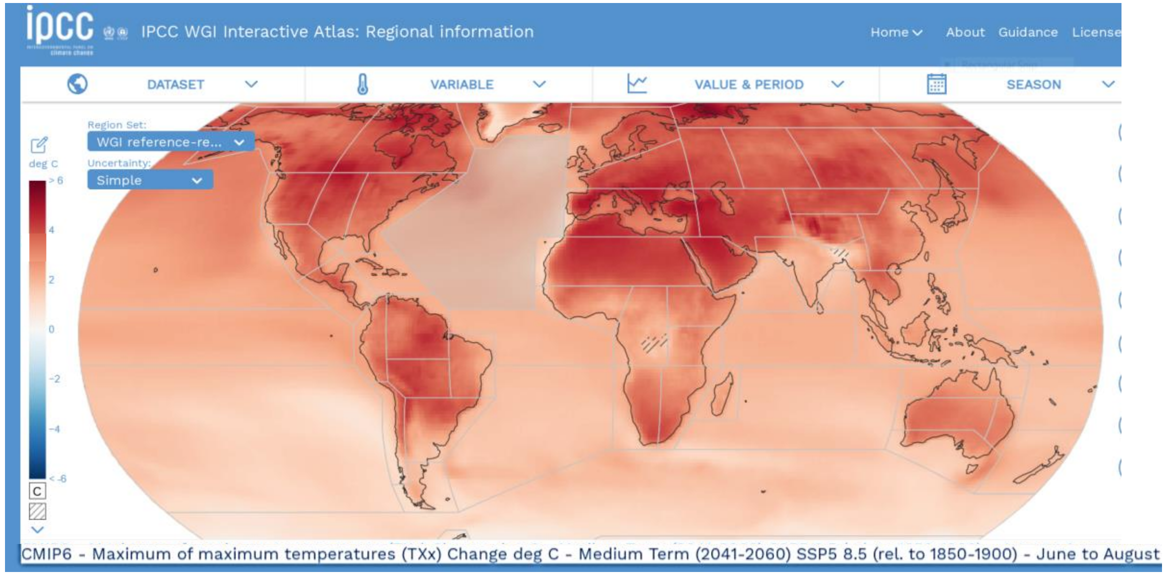


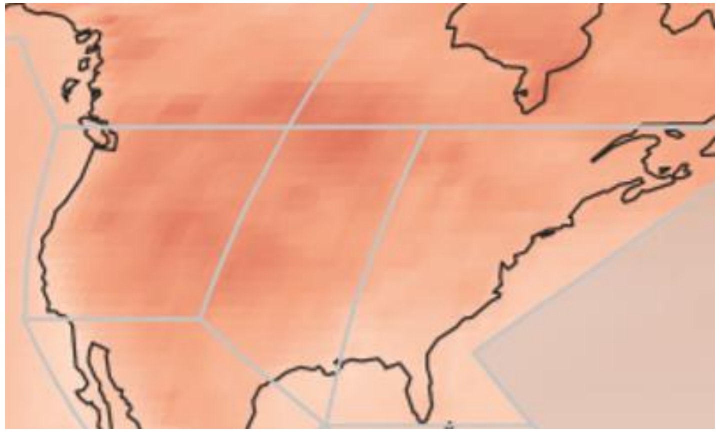
Maximum of maximum temperature (TXx) global change °C , June-August relative, to 1850-1900

1.5°C

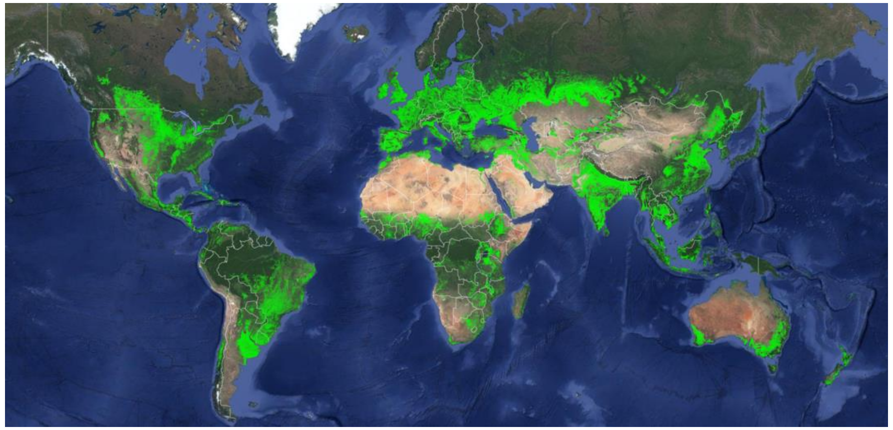


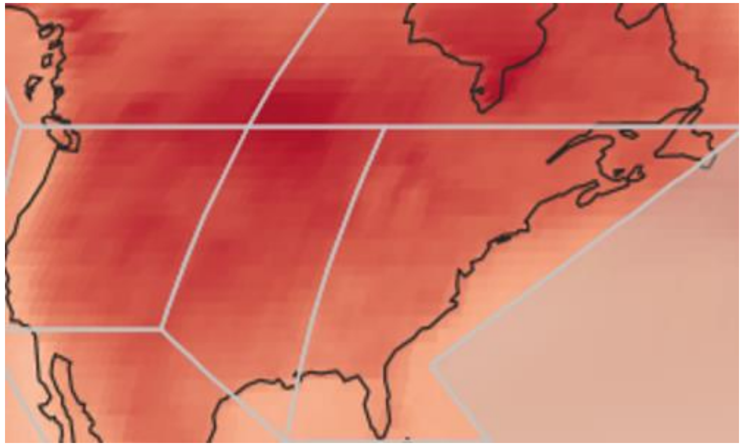
2°C



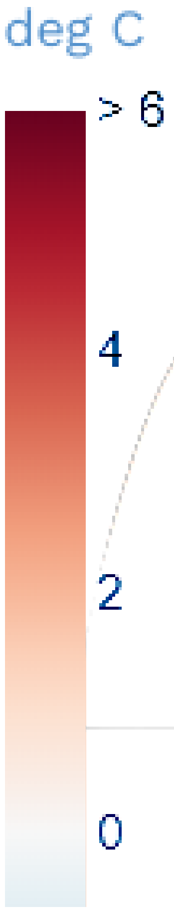


USGS Crop area and density 2017 (satellite data)



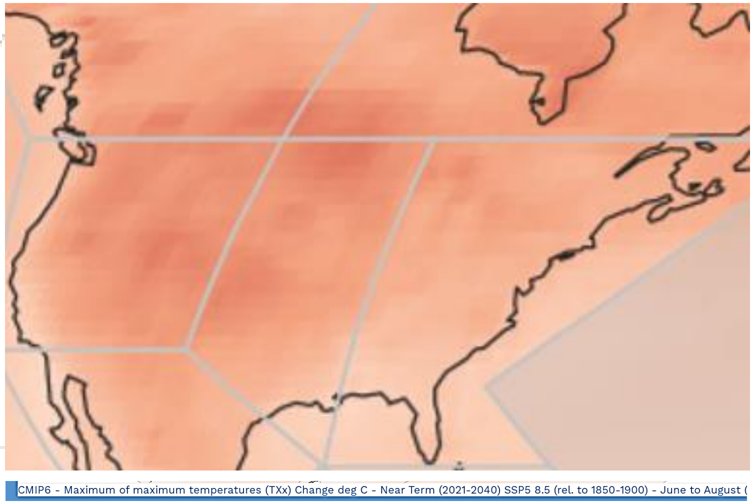


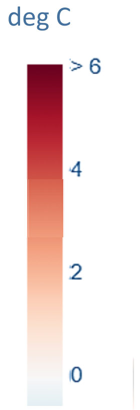
Extreme heat affects US food producing regions at 1.5°C-2°C

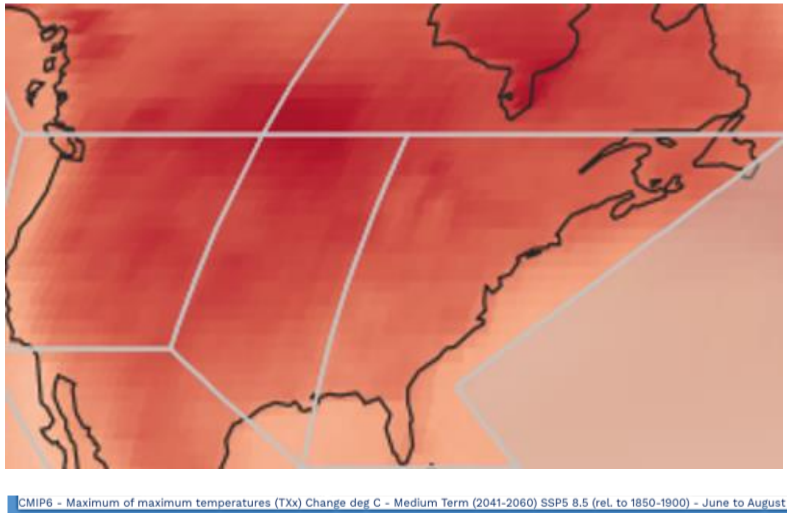


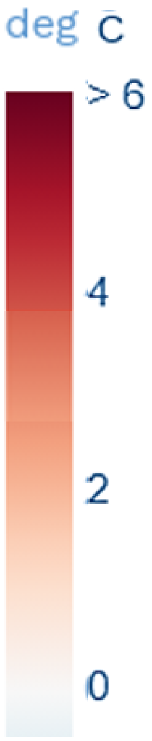
Maximum of maximum temperature (TXx) change °C June-August relative to 1850-1900

1.6°C of increasing severity **2.4°C**









USGS Crop area and density 2017 (satellite data)

Days of temperatures above 35°C

‘Studies have documented a large negative sensitivity of crop yields to extreme daytime temperatures around 30°C.

These sensitivities have been identified for several crops and regions and exist throughout the growing season (high confidence)’

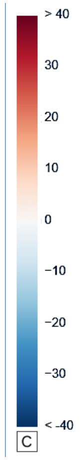
IPCC, 2014, AR5 WG2, Ch.7
Food Security and Food Production Systems

Heat stress temperatures to crops is projected in major food producing regions for an increasing number of days, from 1.5°

Days of temperatures above 35°C

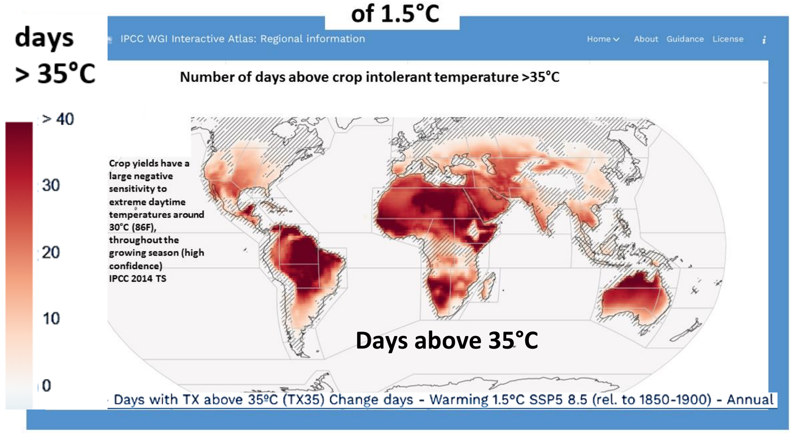
August 2021 IPCC AR6 WG1 Interactive Atlas

days
> 35°C



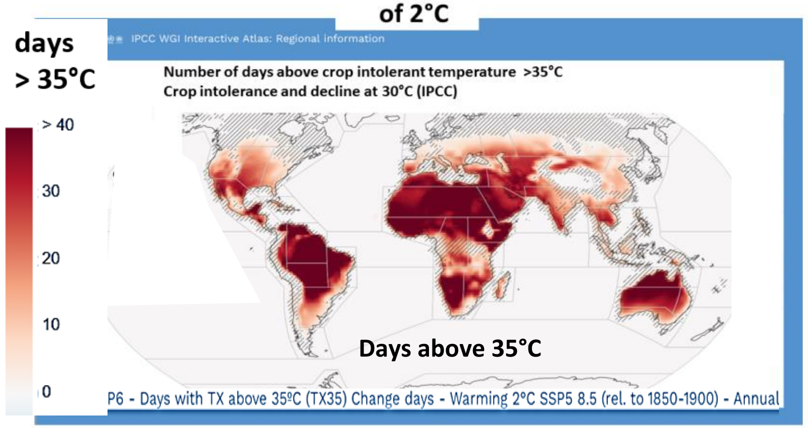
1.5°C: now unavoidable, 2030

Maximum Summer Temperatures above 35°C at global warming of 1.5°C



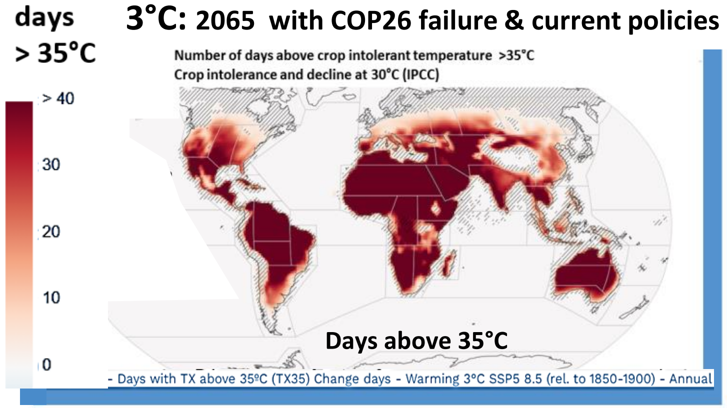
2°C: 2045

Maximum summer Temperatures above 35°C at global warming of 2°C



Maximum Summer Temperatures above 35°C at global warming

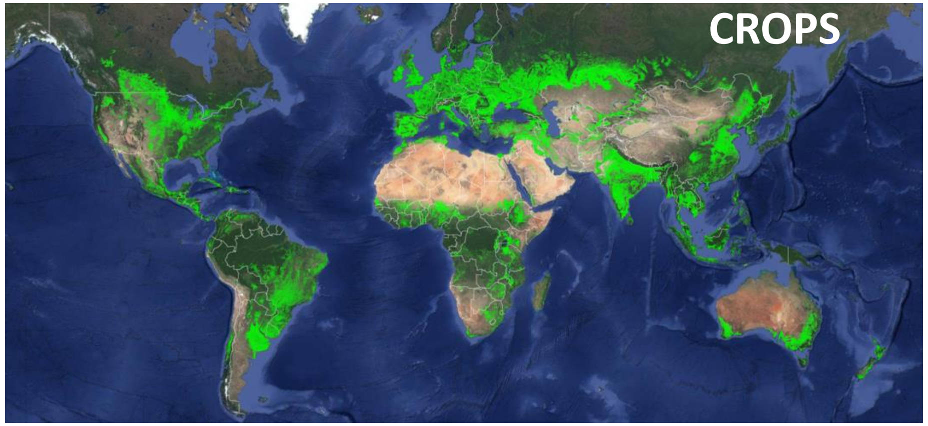
3°C: 2065 with COP26 failure & current policies



Studies have documented a large negative sensitivity of crop yields to extreme daytime temperatures around 30°C. These sensitivities have been identified for several crops and regions and exist throughout the growing season (high confidence)

IPCC, 2014, AR5 WG2, Ch.7
Food Security and Food Production Systems

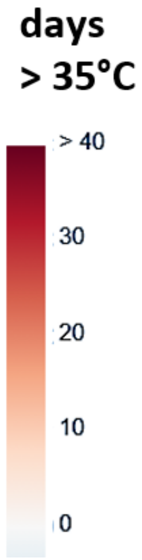
USGS Crop area and density 2017 (satellite data)

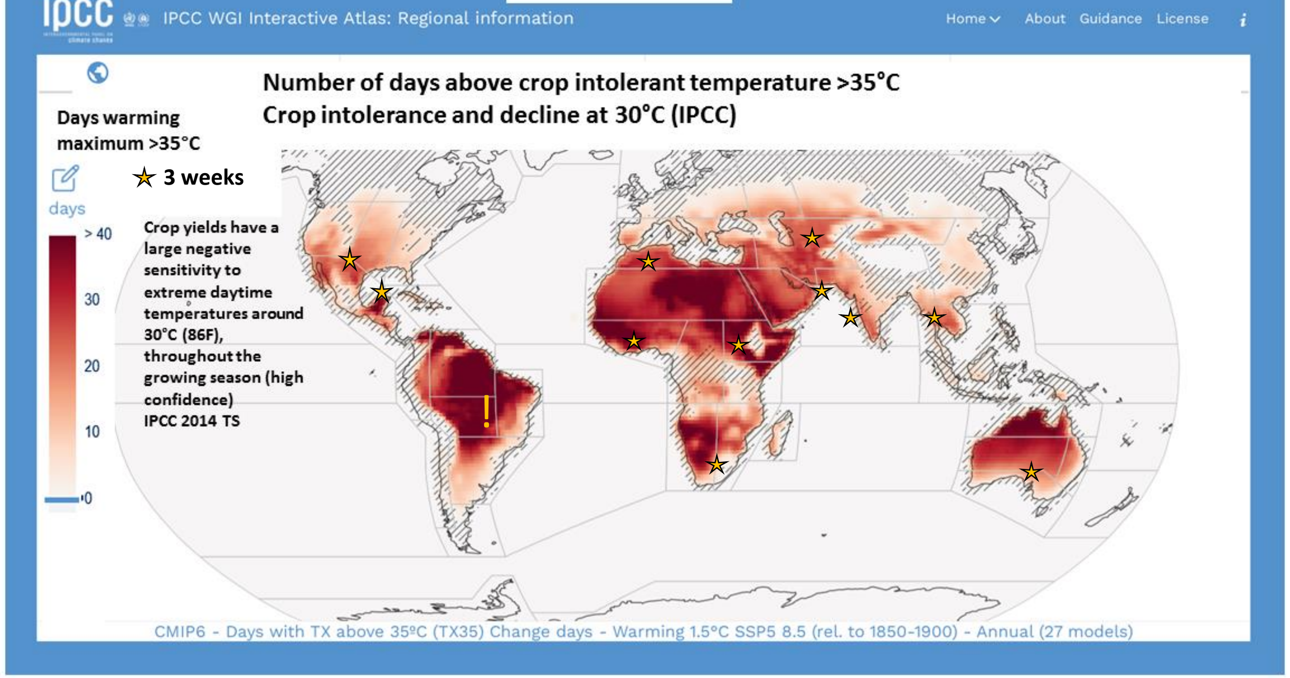


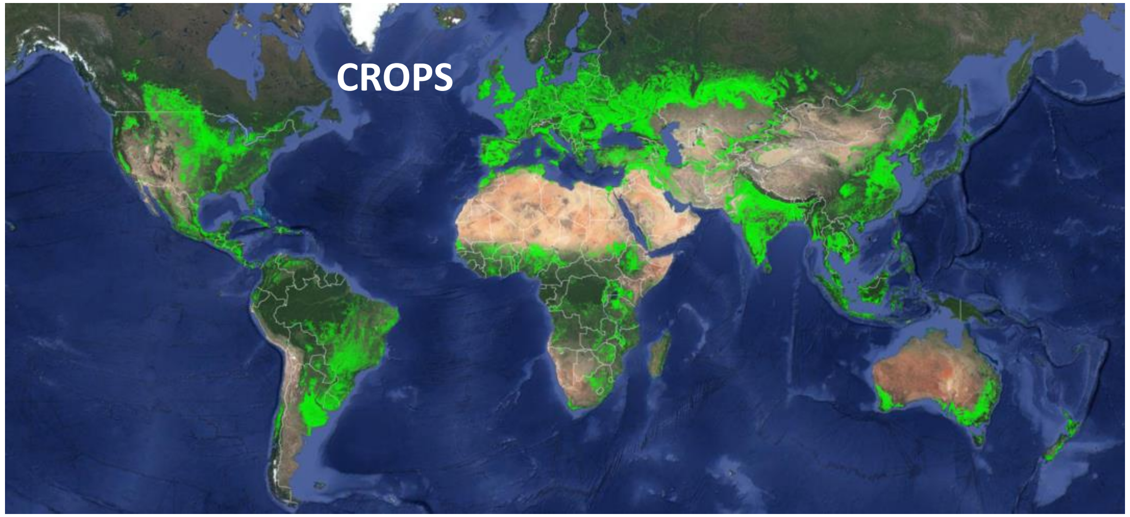
August 2021 IPCC AR6 WG1 Interactive Atlas

Peter Carter, Climate Emergency Institute

Maximum Summer Temperatures above 35°C at global warming of 1.5°C

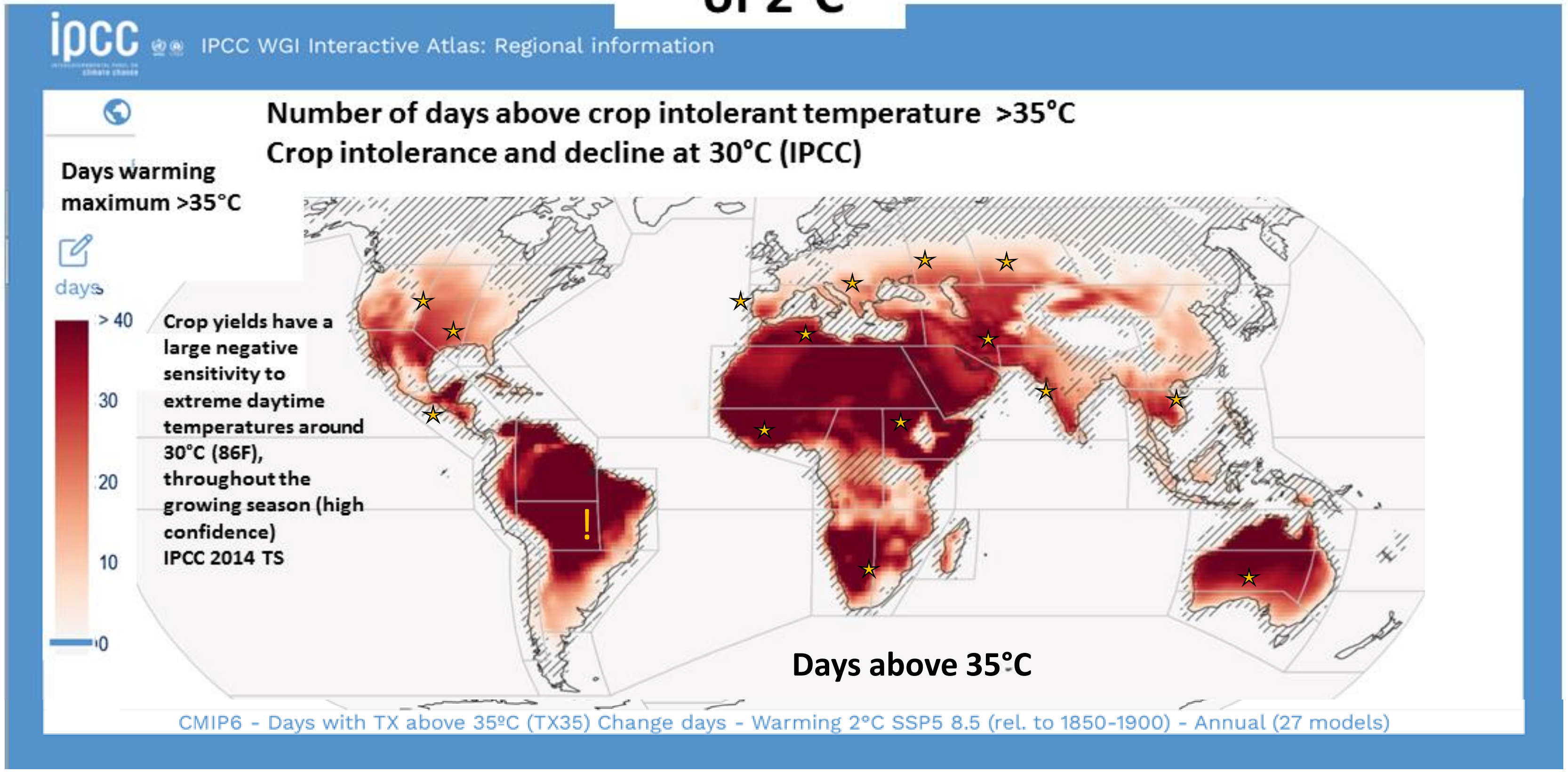






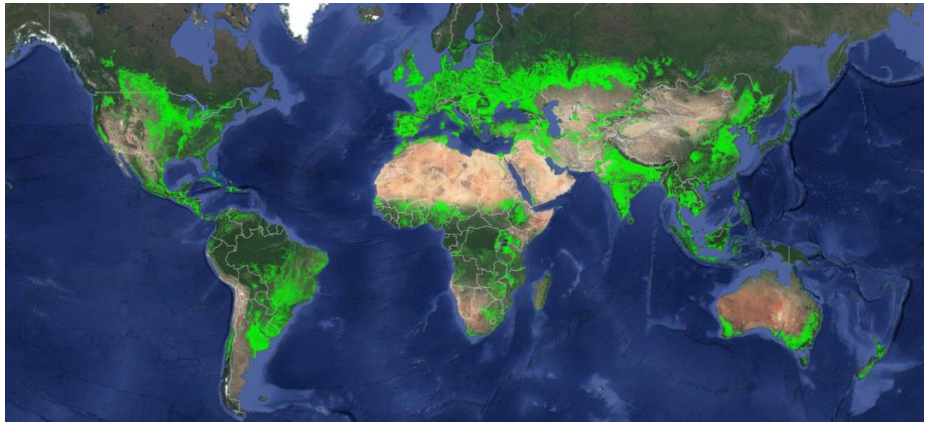
Maximum summer Temperatures above 35°C at global warming of 2°C

Affects
USA
South America
Spain
Saudi Arabia
Iraq
Iran
Pakistan
Turkey
The …stans
All African regions
Thailand
Cambodia
Australia
Affected but less so
(Italy)
(Greece)
(China)



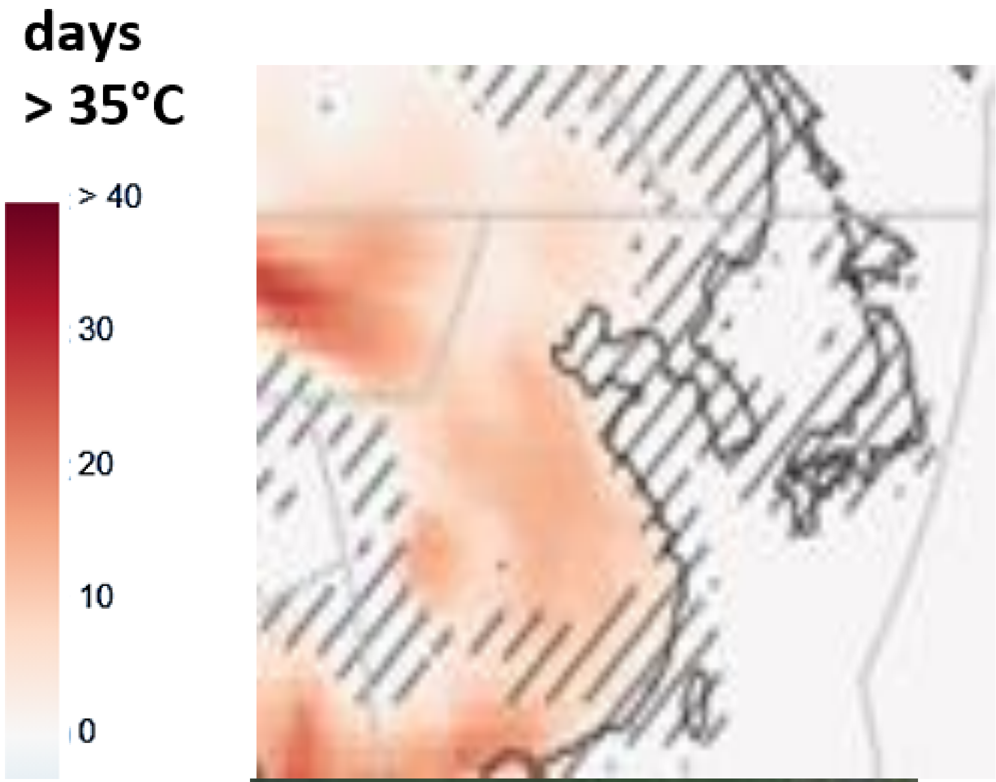
days
> 35°C

> 40
30
20
10
0



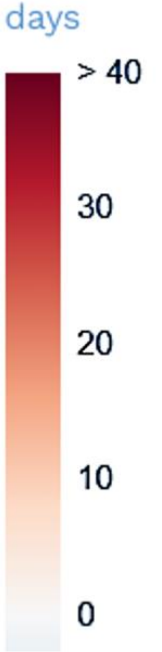
China at 2°C

China ranks first in the world in terms of the production of cereals, cotton, fruit, vegetables, meat, poultry, eggs and fishery products. (FAO)



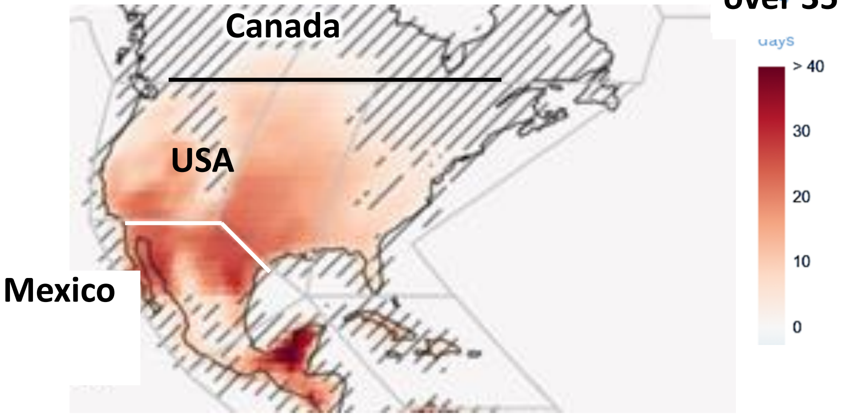
Heat Stress affects crops in US and Mexico food producing regions for an increasing number of days at and from 1.5°C
Canada's grain belt is also stressed

Days over 35°C



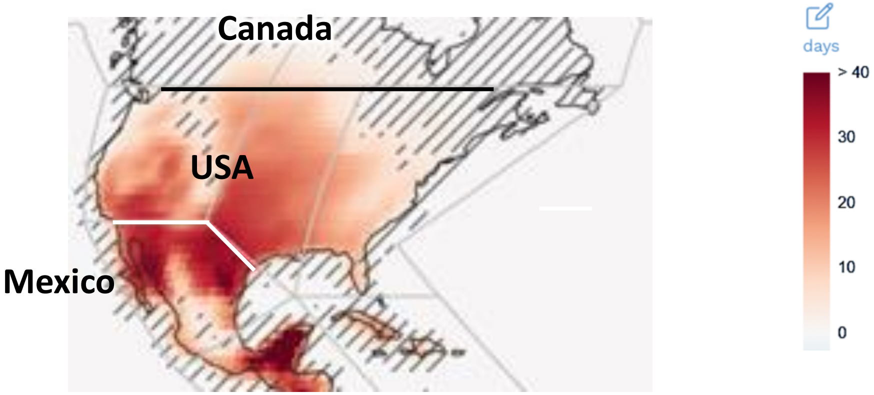
Days of temperatures above 35°C

1.5°C (2030)

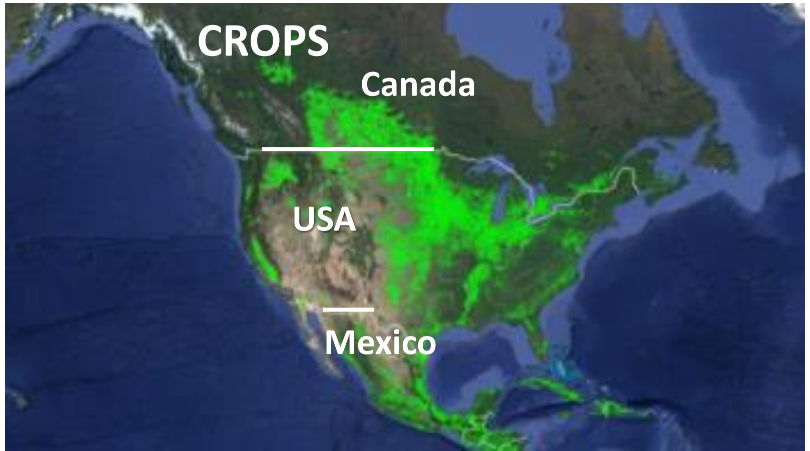


Days over 35°C

2.0°C (2045)



USGS Crop area and density 2017 (satellite data)



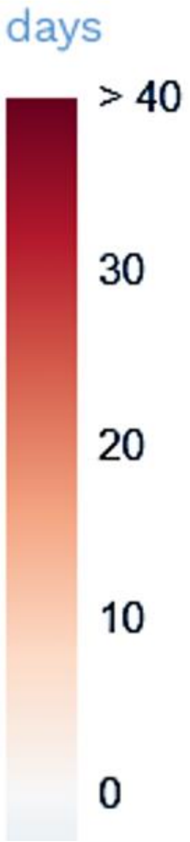
August 2021 ,IPCC AR6, WG1, Interactive Atlas

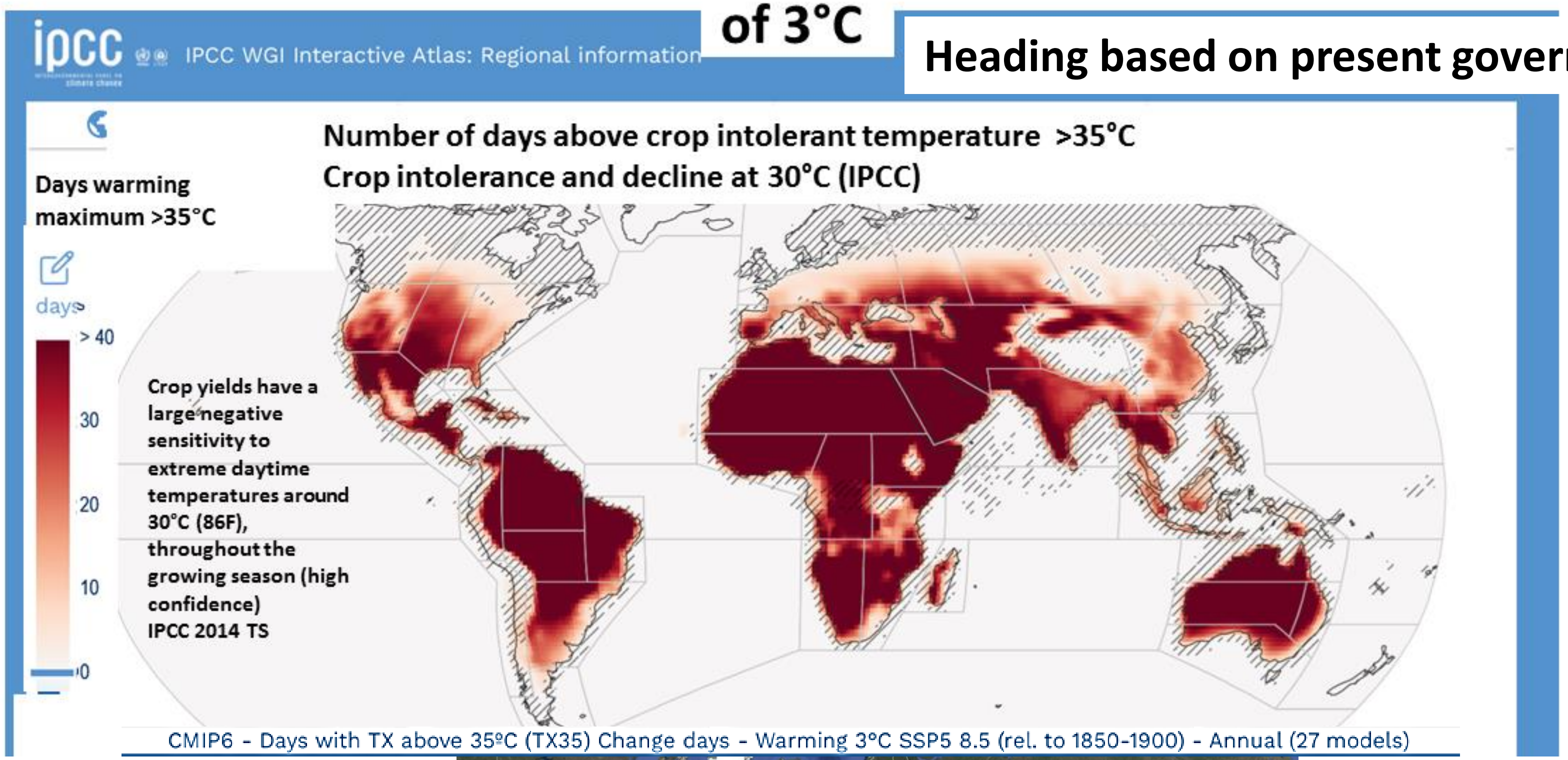
Peter Carter, Climate Emergency Institute

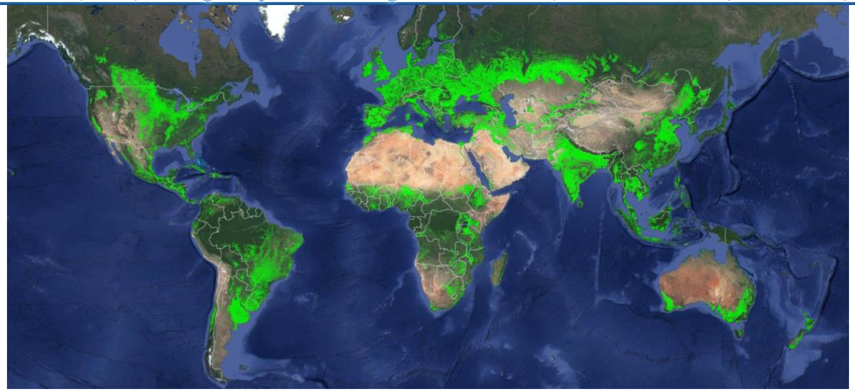
At 3°C of global warming almost all food producing regions have maximum high temperatures above 35°C for many days- long periods in USA and Mexico

Maximum Summer Temperatures above 35°C at global warming of 3°C

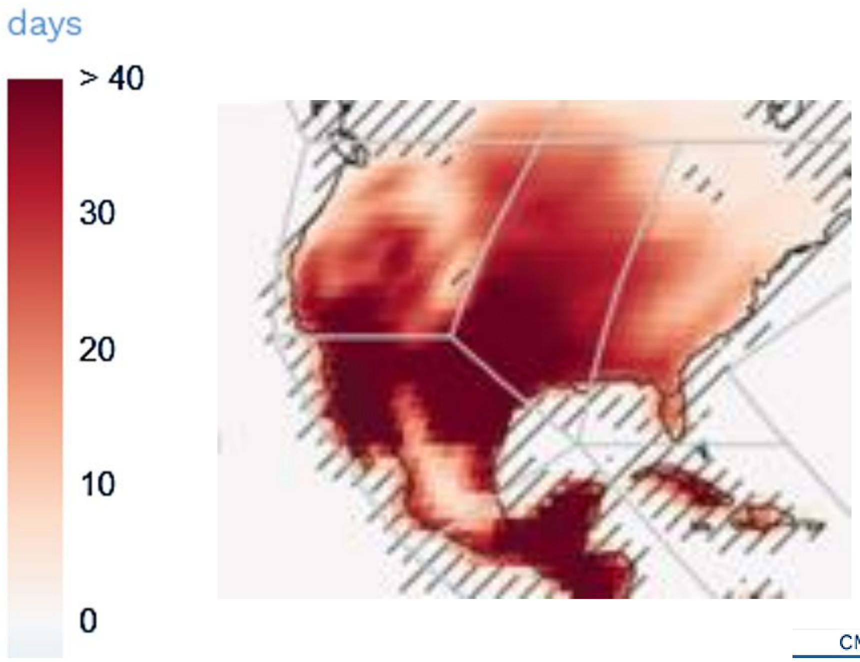
Heading based on present government policies







At 3°C of global warming almost all food producing regions have maximum high temperatures above 35°C for many days- Longest USA and Mexico



CMIP6 - Days with TX above 35ºC (TX35) Change days - Warming 3°C SSP5 8.5 (rel. to 1850-1900) - Annual (27 models)

Toxic Surface Ozone

Formed from fossil fuel air pollutants

Also called tropospheric or ground level ozone

Toxic to humans and green plants, so crops

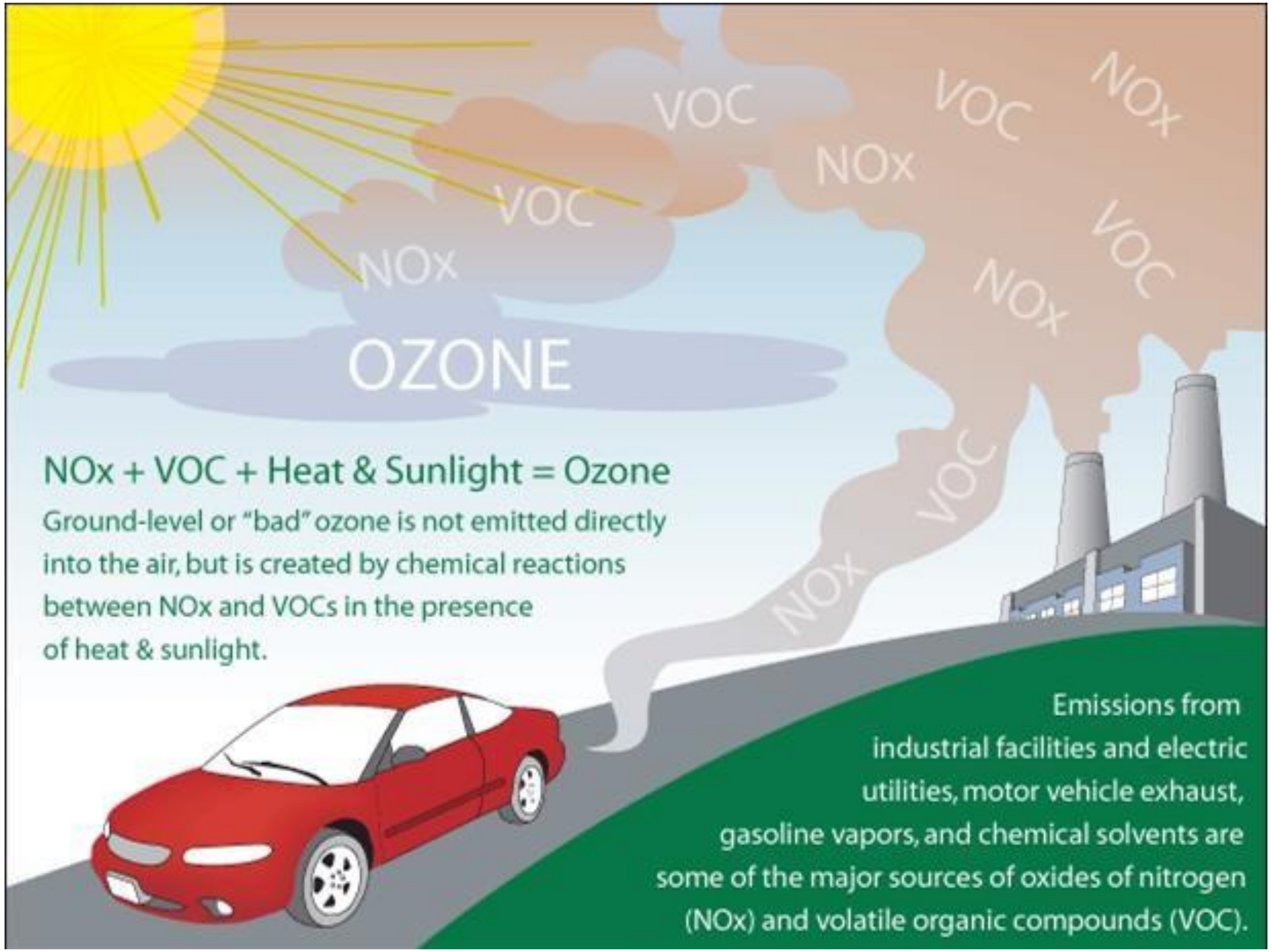
It is increased by heat

-so increased by heat waves

Chemical reaction
Fossil fuel air pollutants
Heat from the sun

Toxic Surface Ozone

Toxic to humans and green plants
Increased by heat

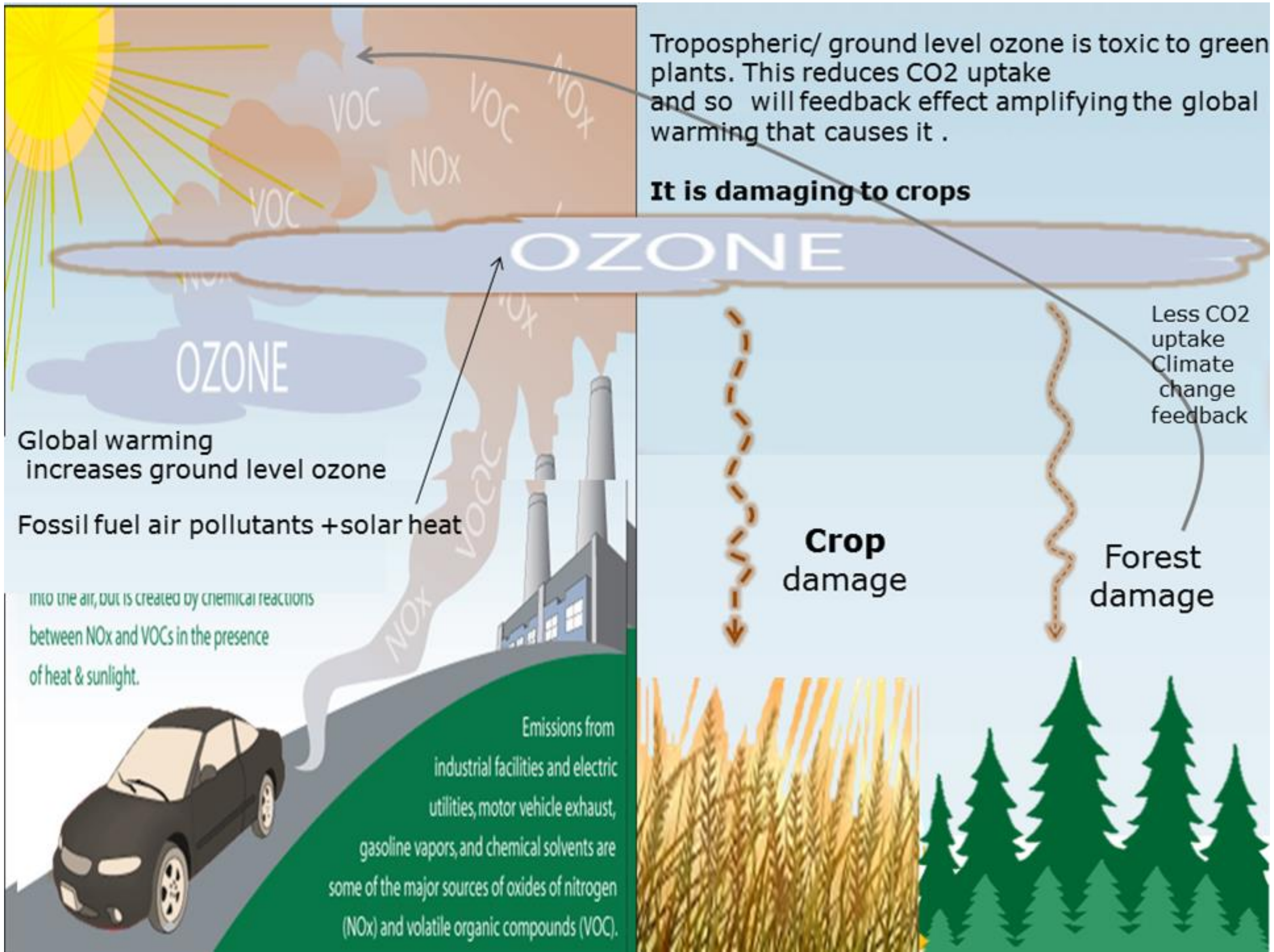


EPA

Toxic Surface Ozone

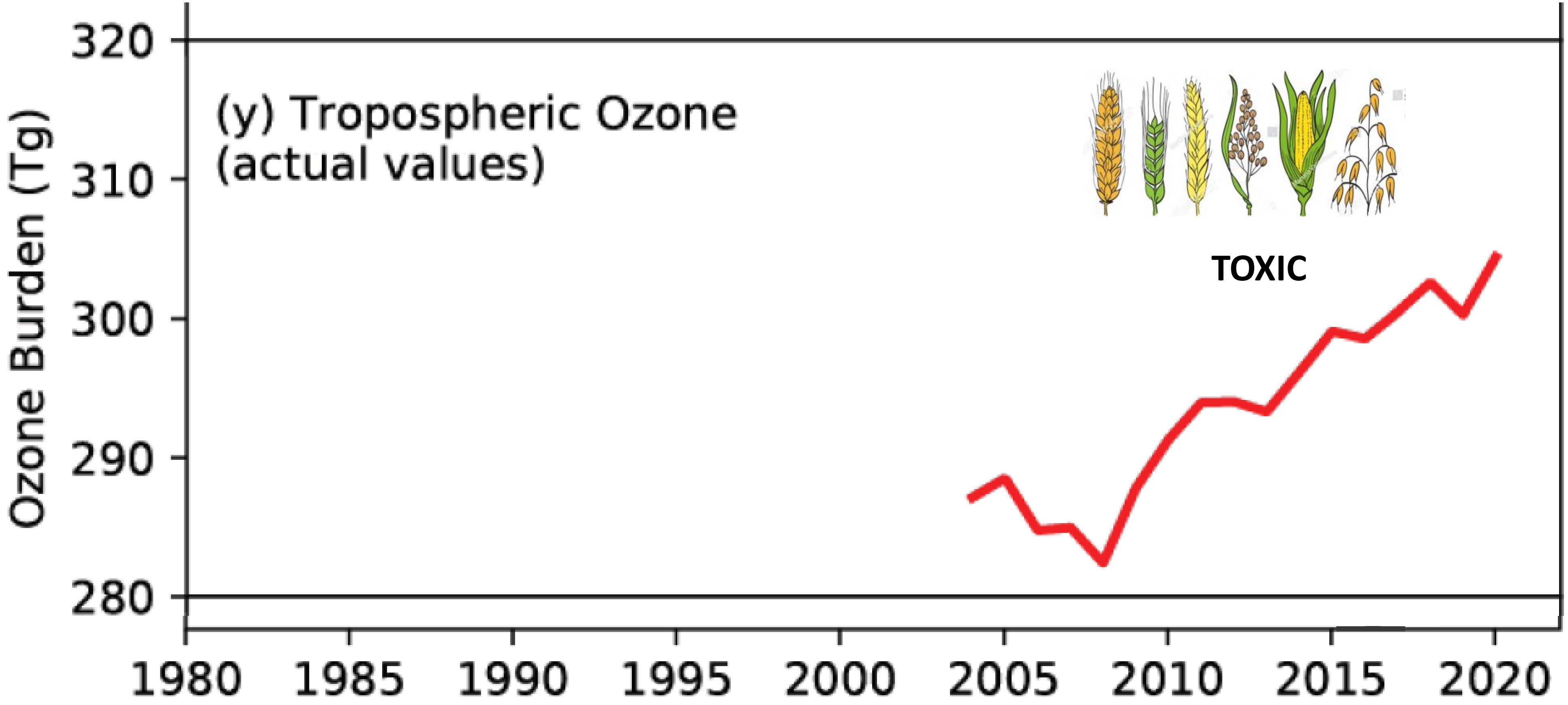
Chemical reaction
Fossil fuel air pollutants
Heat from the sun

Toxic to humans and green plants
Increased by heat



Increasing Surface Ozone (mainly northern hemisphere)

Tropospheric (surface or ground level) ozone is a toxic air pollutant, toxic to green plants including crops
- as well the human respiratory tract
Its level increases with surface temperature



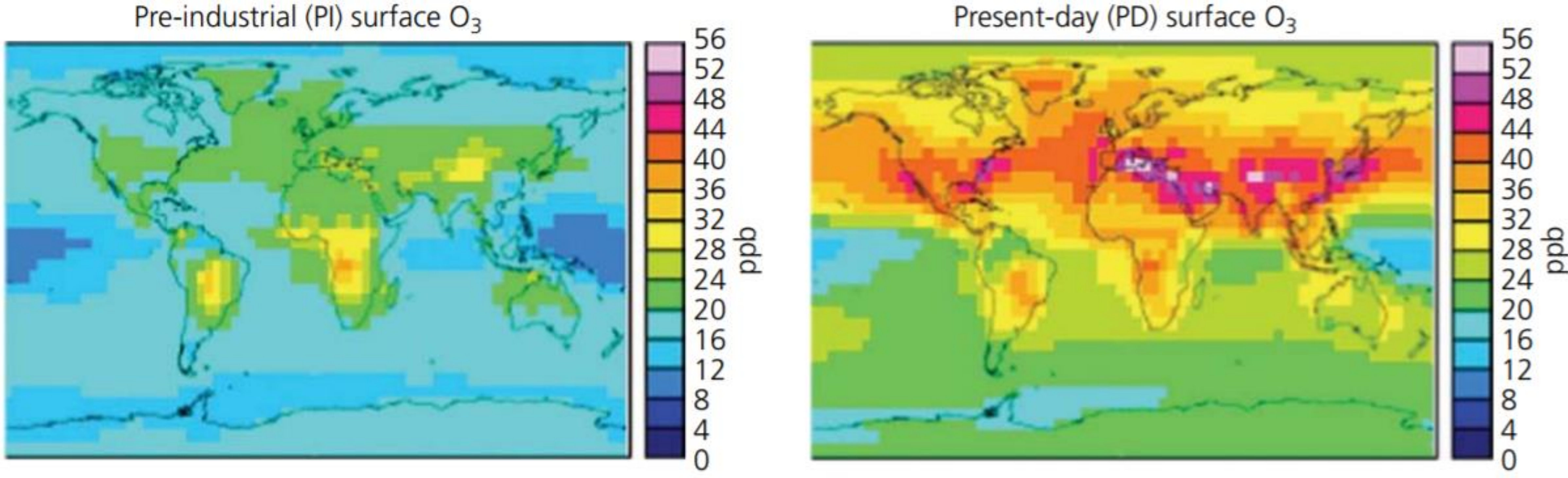
Special Supplement to the Bulletin of the American Meteorological Society, Vol. 102, No. 8, August, 2021,

ALSO

Aircraft observations since the 1990s reveal increases of tropospheric ozone at multiple locations across the Northern Hemisphere,
A. Gaudel et al, 21 August 2021

Surface ozone has increased mainly in the northern hemisphere with increasing air pollution and global surface warming

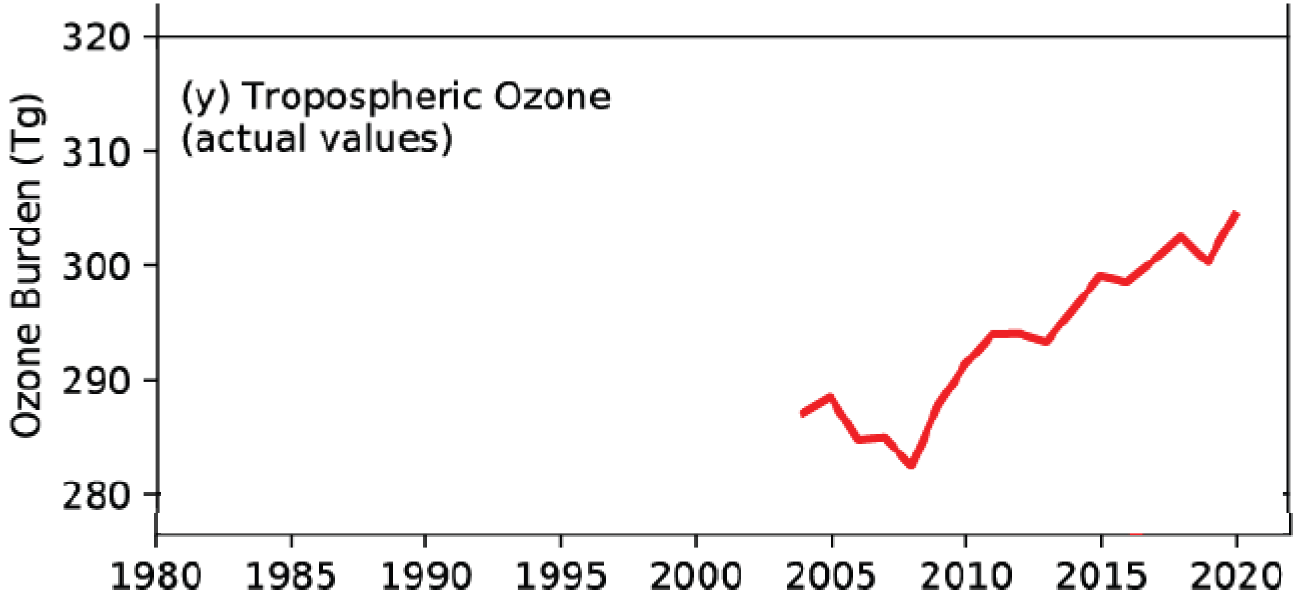
Ground-level ozone in the 21st century: future trends, impacts and policy implications, Royal Soc, 2008



Tropospheric (surface/ground level) **Ozone Rapid Increase**

Mainly the temperate northern hemisphere

Heat increase surface ozone,
which is **toxic to crops** as well as human health



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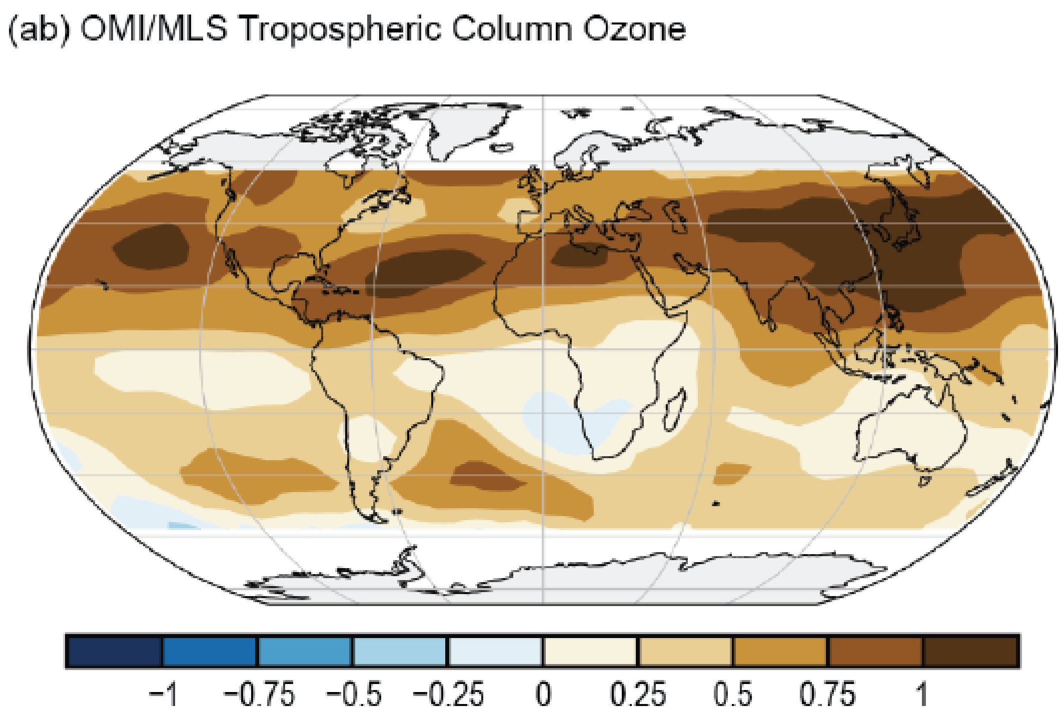
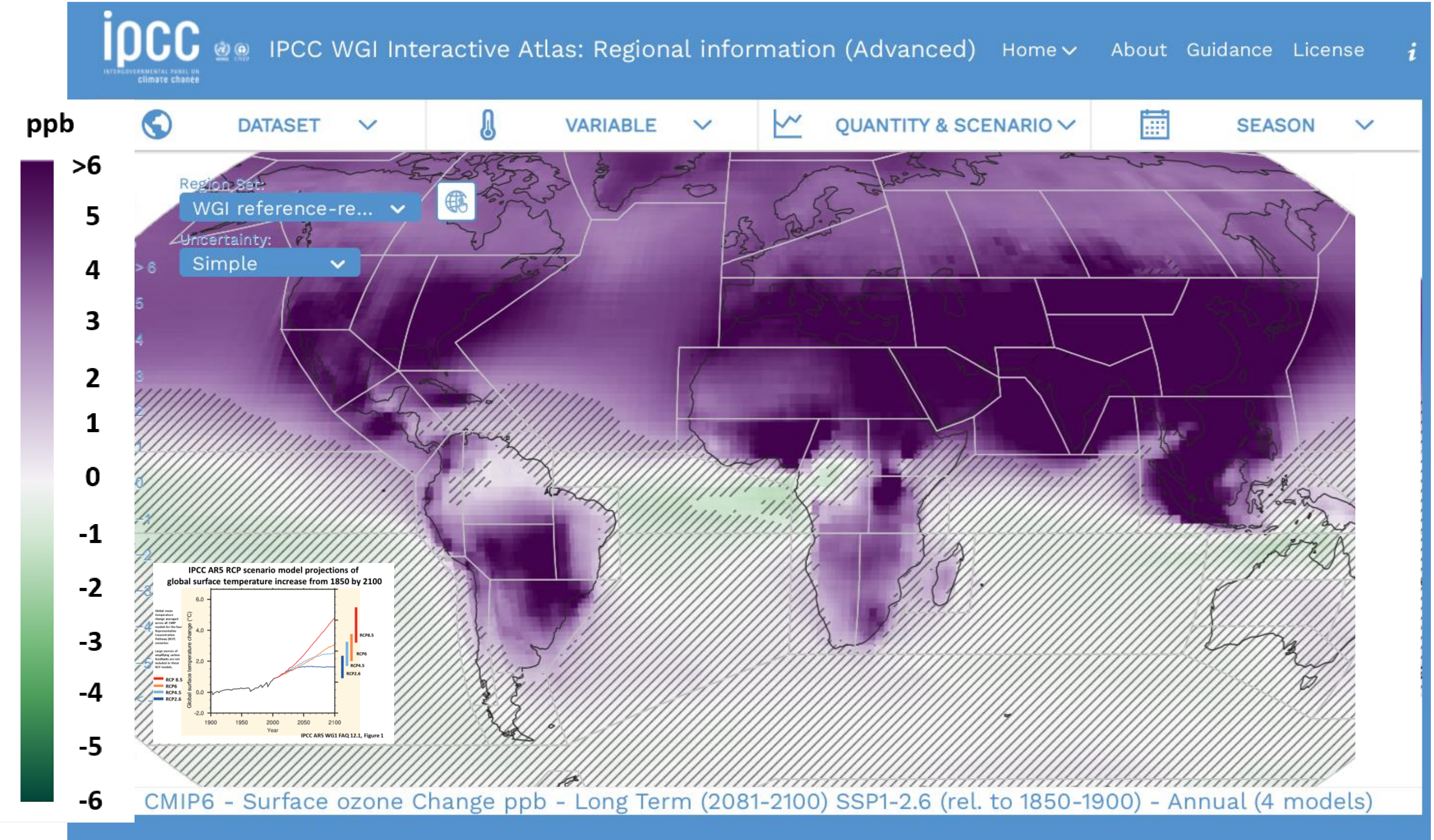
August 2021



Special Supplement to the *Bulletin of the American Meteorological Society*,
August 2021

1.5°C



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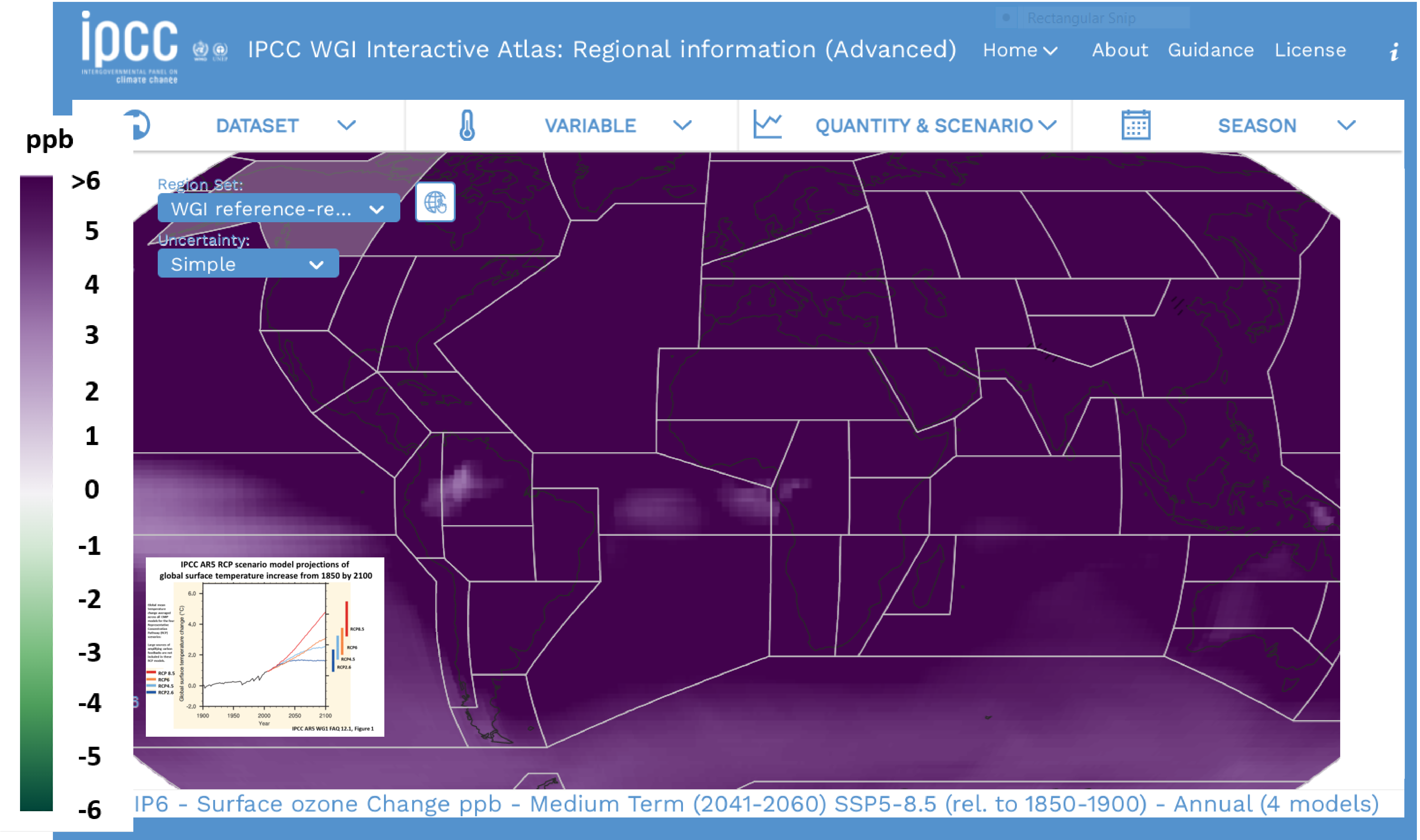
IPCC AR5 RCP scenario model projections of
global surface temperature increase from 1850 by 2100
RCP8.5
RCP6
RCP4.5
RCP2.6
IPCC AR5 WG1 FAQ 12.1, Figure 1
CMIP6 - Surface ozone Change ppb - Long Term (2081-2100) SSP1-2.6 (rel. to 1850-1900) - Annual (4 models)

2°C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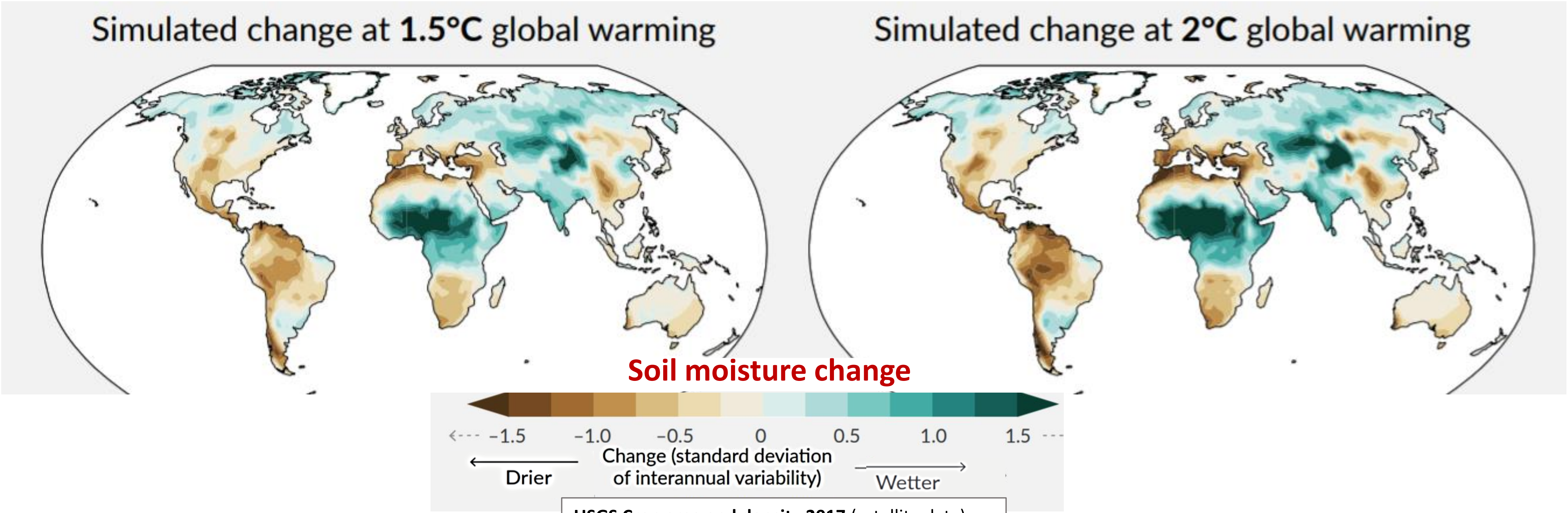
RCP6
RCP4.5
RCP2.6
IPCC AR5 WG1 FAQ 12.1, Figure 1
IP6 - Surface ozone Change ppb - Medium Term (2041-2060) SSP5-8.5 (rel. to 1850-1900) - Annual (4 models)

Drought

Increasing world–wide drought from 1.5°C affecting major food producing regions

AR6 WG1
soil moisture



USGS Crop area and density 2017 (satellite data)

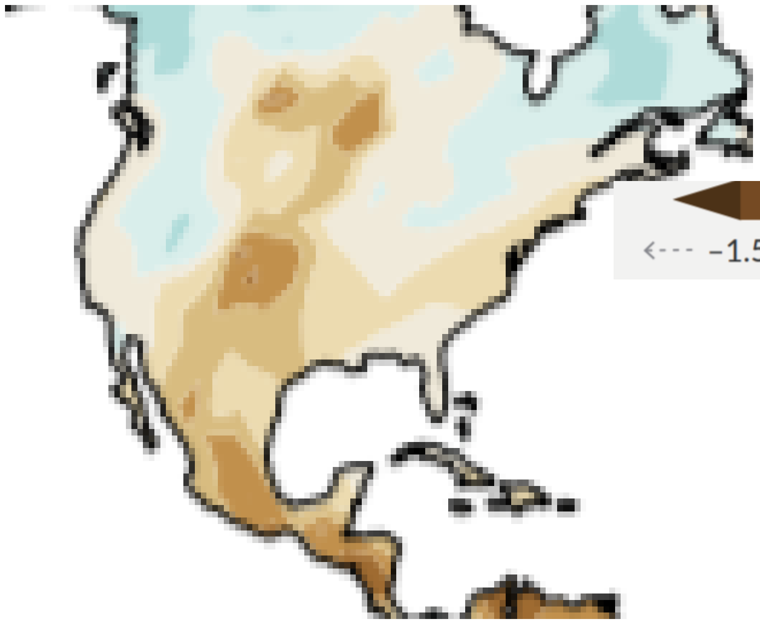
CROPS

IPCC, 2021, AR6 WG1, SPM, Figure SPM.5 | Changes in …soil moisture

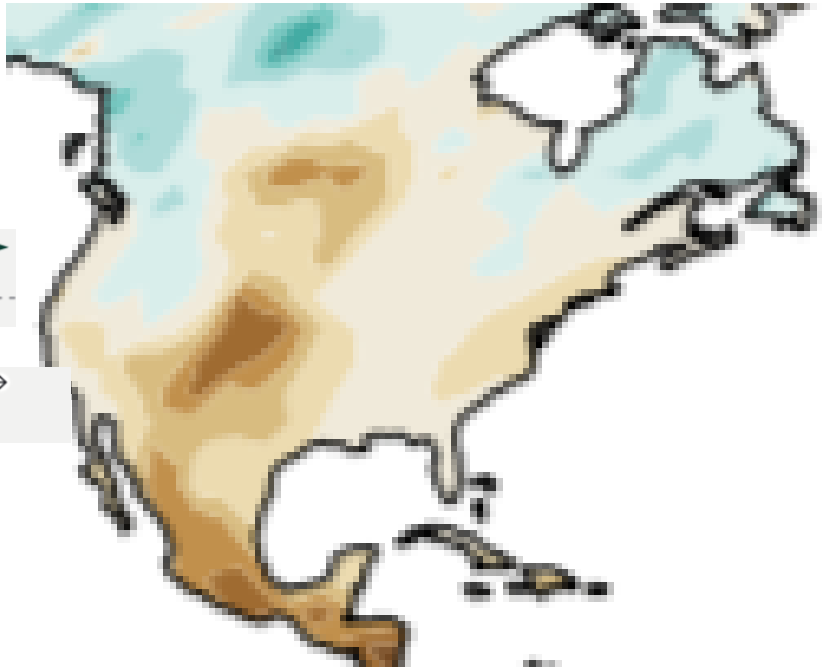
Soil Moisture Change at 1.5°C and 2°C

DROUGHT

1.5°C

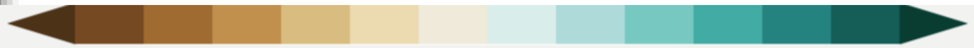


2°C



(d) Annual mean total column soil moisture change (standard deviation)

Soil moisture change



Drier — Change (standard deviation of interannual variability) — Wetter

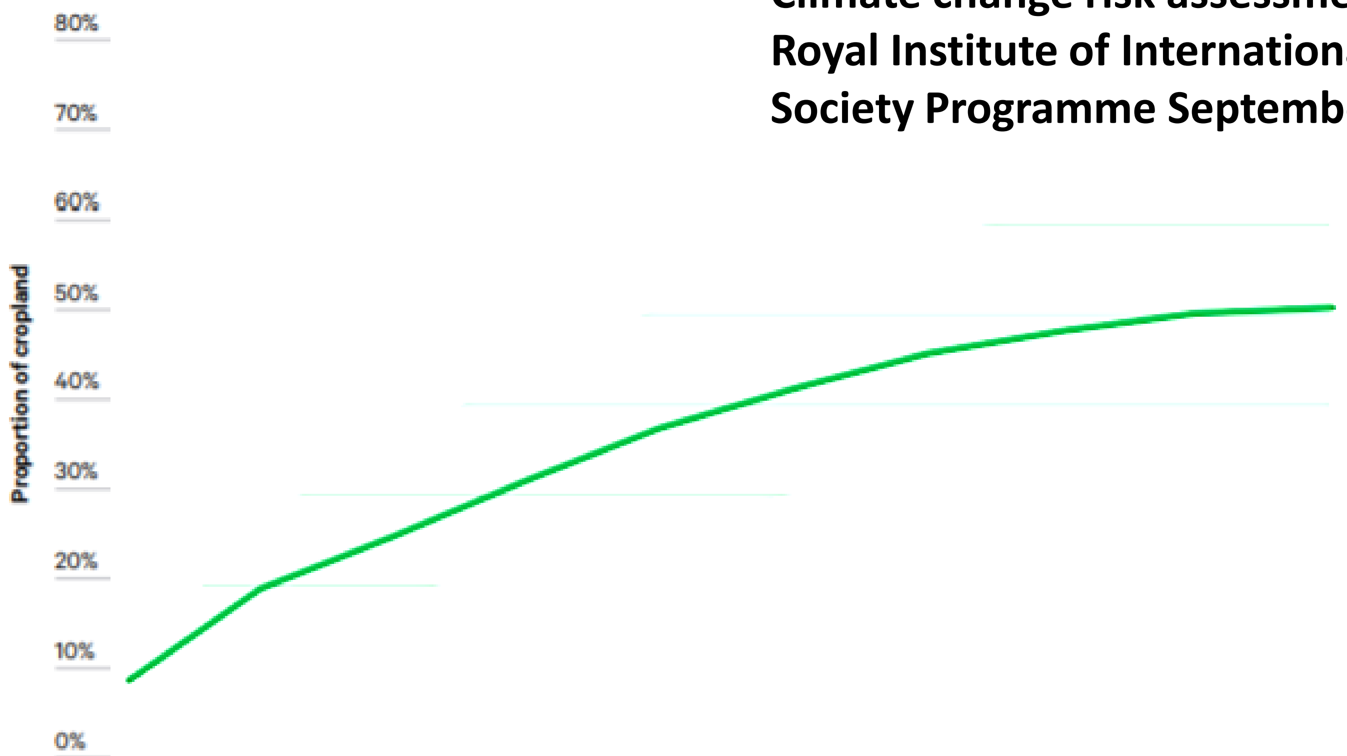
USGS Crop area and density 2017 (satellite data)

IPCC, 2021, AR6 WG1, SPM, Figure SPM.5 | Changes in …soil moisture

% Increases in drought at 2.4°C

By 2040, the average proportion of global cropland affected by severe drought will likely rise to 32 per cent each year, more than three times higher than the historic average.

Figure 9a. Proportion of global cropland experiencing severe drought of three months or more per year



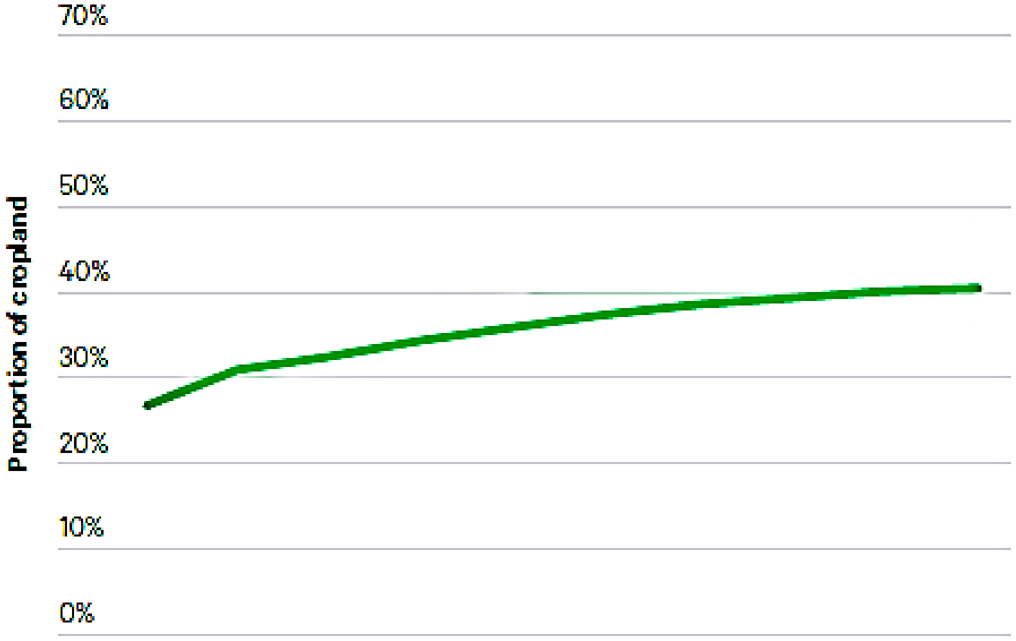
Source: Adapted from Arnell et al. (2019).

Climate change risk assessment 2021, Chatham House Royal Institute of International Affairs, Environment and Society Programme September 2021, Daniel Quiggin et al

% Increases in drought at 2.4°C

Figure 10a. Proportion of global winter wheat crop area experiencing damaging hot spells

Figure 10b. Proportion of global rice crop area experiencing damaging hot spells



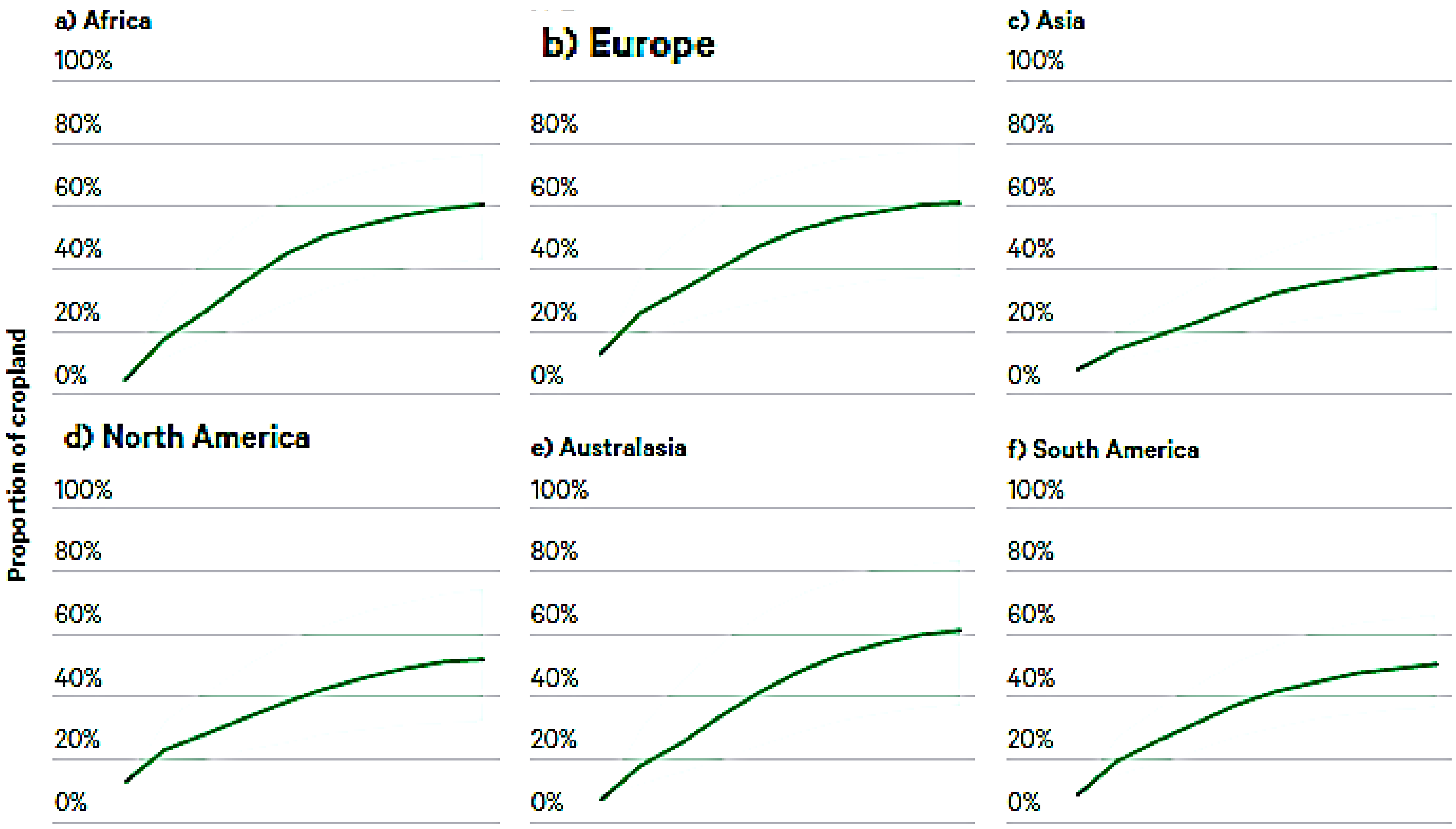
Source: Adapted from Arnell et al. (2019).

Climate change risk assessment 2021, Chatham House Royal Institute of International Affairs, Environment and Society Programme September 2021, Daniel Quiggin et al

% Increases in drought at 2.4°C

Figure 12. Proportion of continental cropland experiencing severe drought of three months or more

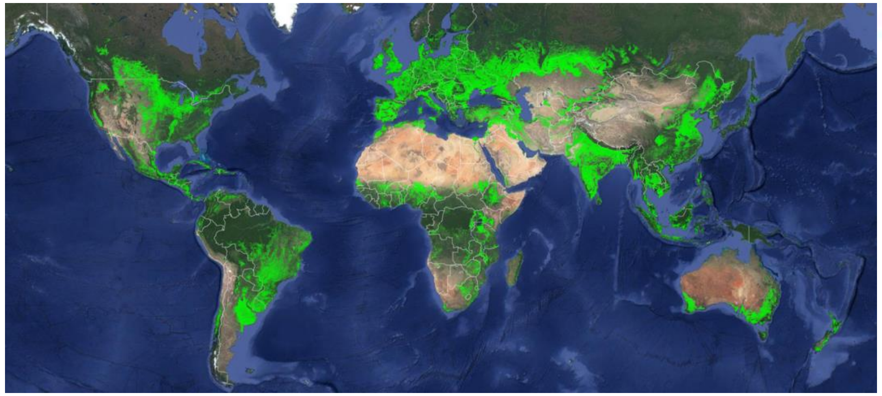
2.4°C



Source: Adapted from Arnell et al. (2019).

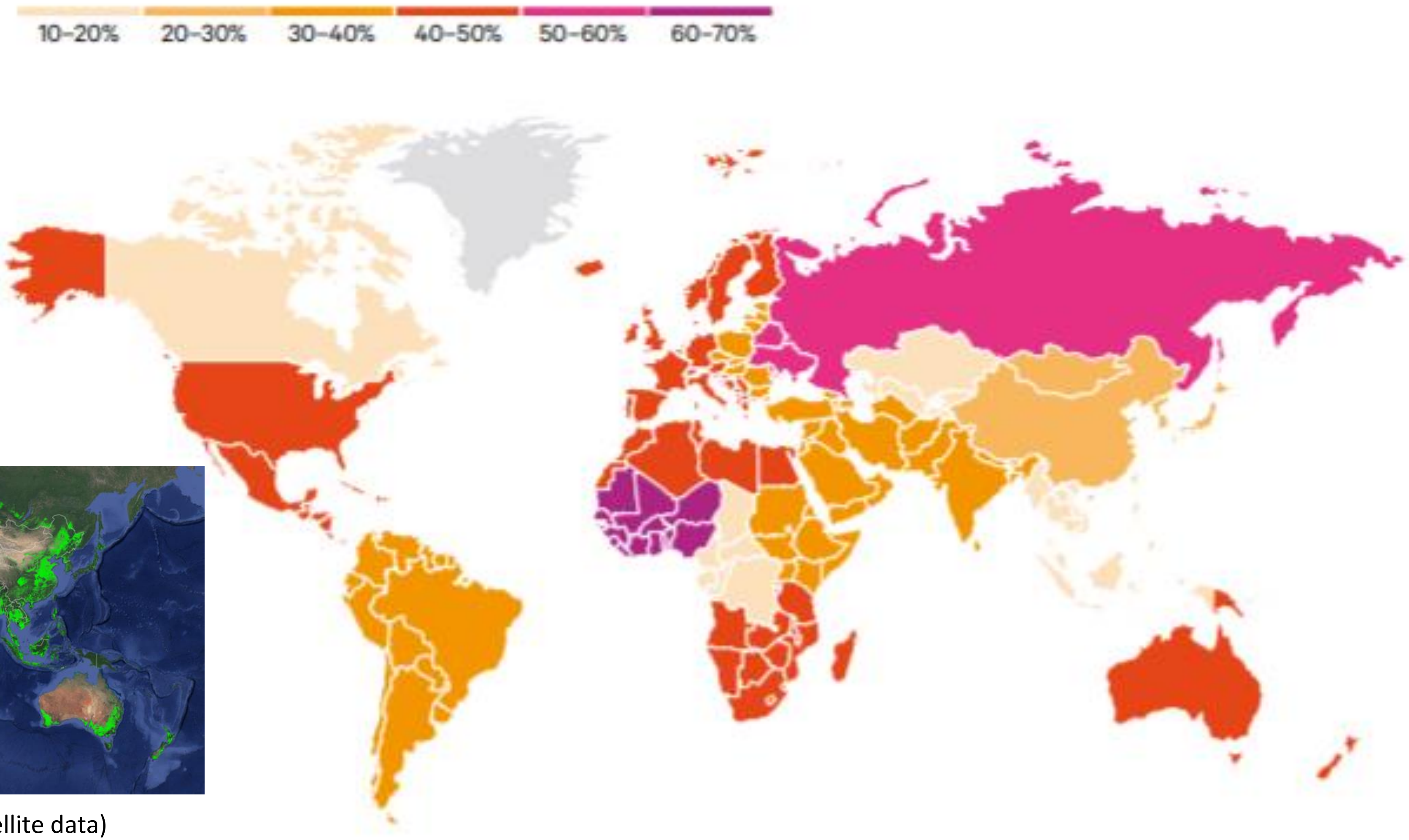
Proportion of regional cropland exposed to severe drought, in 2050

CROPS



USGS Crop area and density 2017 (satellite data)

Figure 9b. Proportion of regional cropland exposed to severe drought, in 2050



Source: Adapted from Arnell et al. (2019).

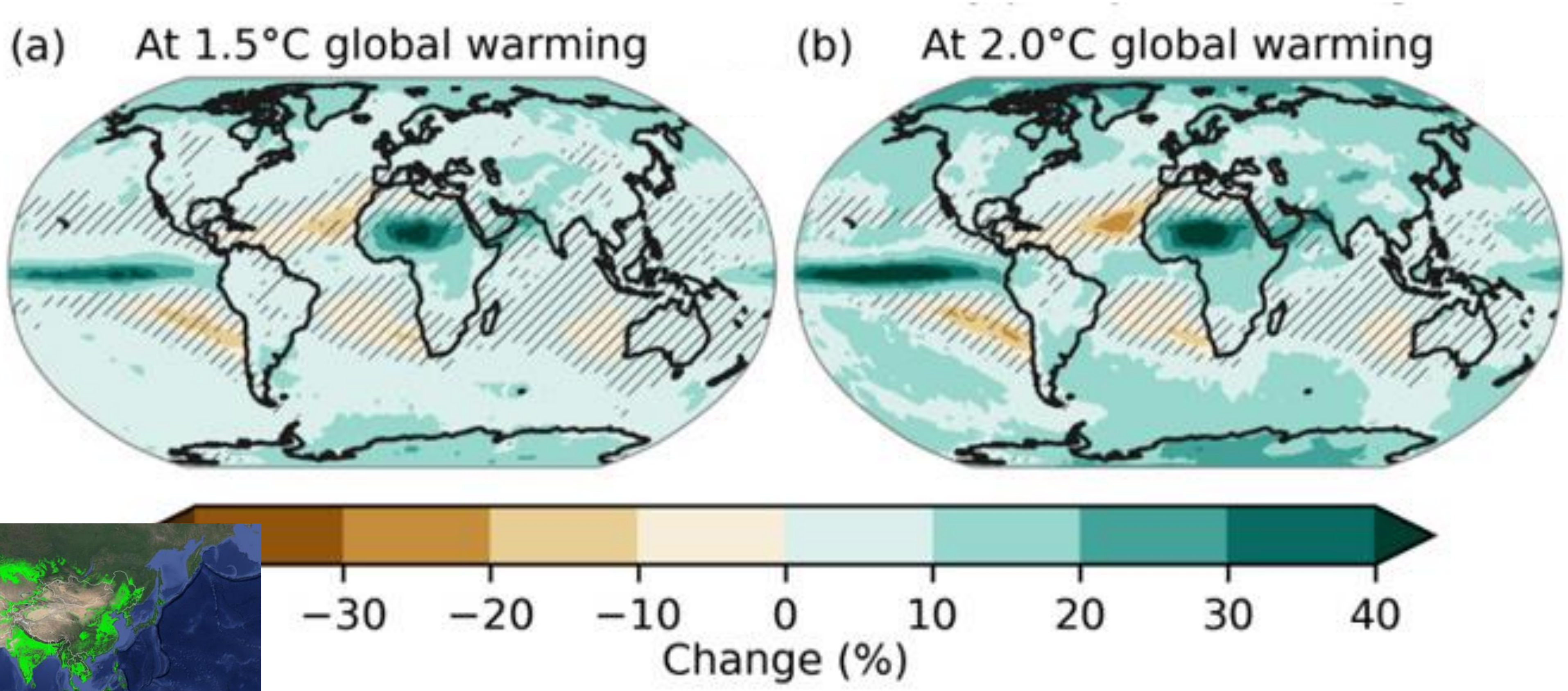
Extreme Rainfall
Floods

Annual maximum daily precipitation change (Rx1day) – median

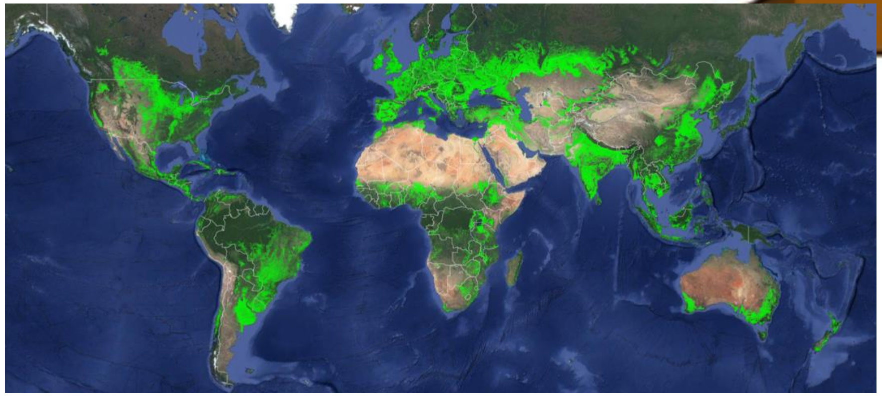
Almost all countries affected at 2°C

IPCC AR6 WG1

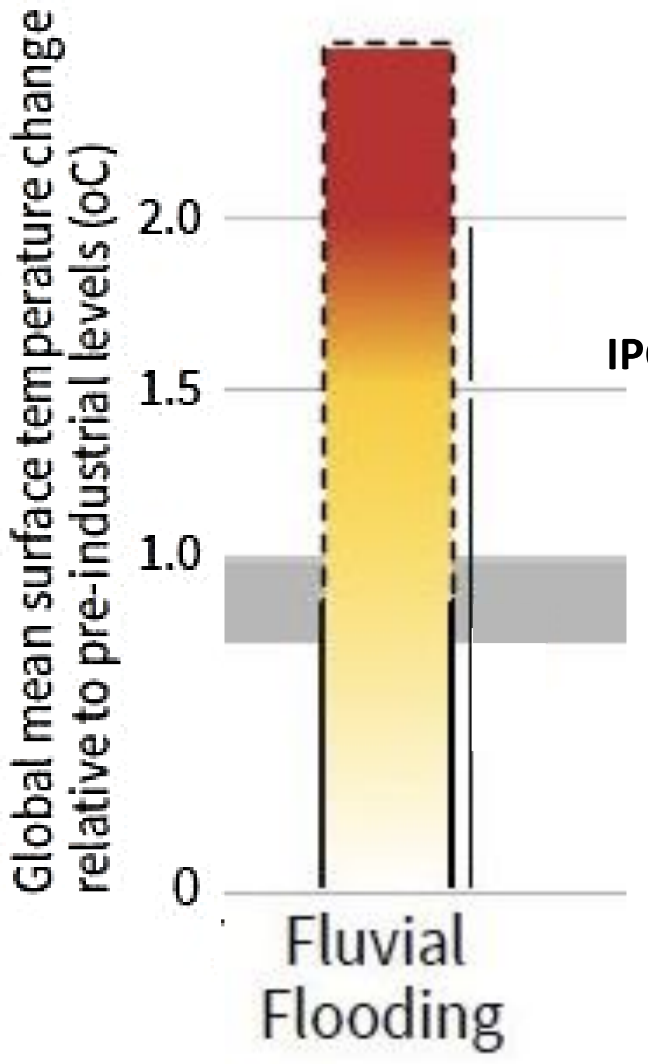
Damaging to crops and agricultural land



CROPS



River Flooding

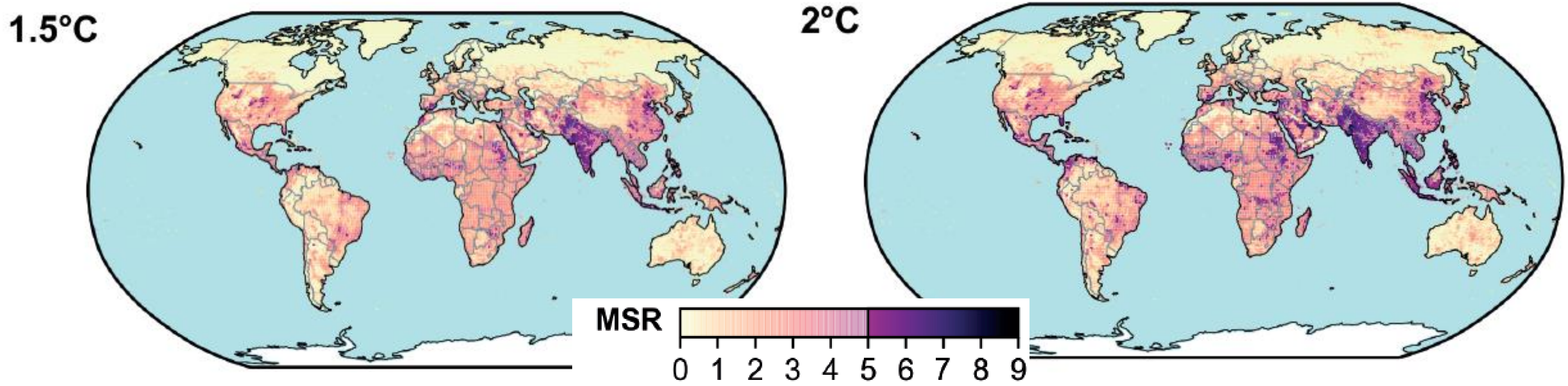


IPCC, 2018 1.5°C Report

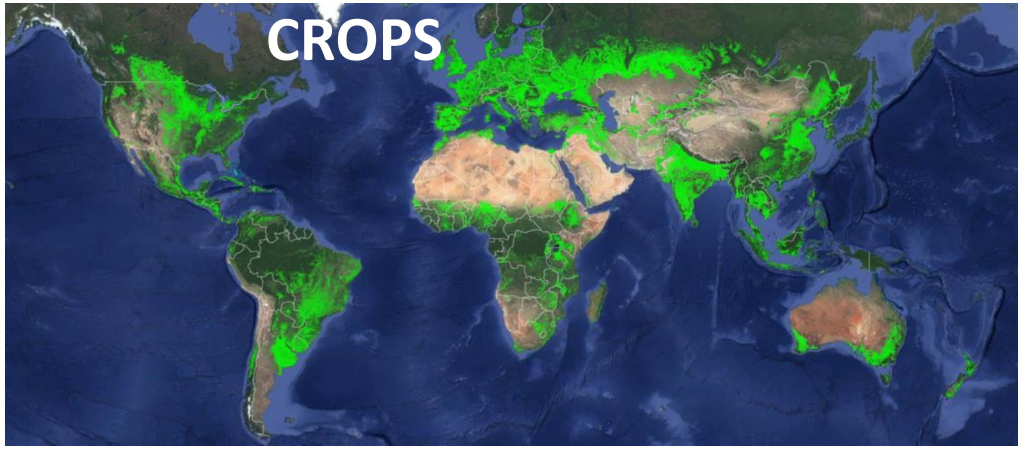
Compound extreme events

IPCC, 2018, 1.5°C Report

Interacting and Cascading Risks



IPCC 2018, 1.5°C Report ,Figure 3.19 | Multi-sector risk maps for 1.5°C and 2°C



USGS Crop area and density 2017 (satellite data)

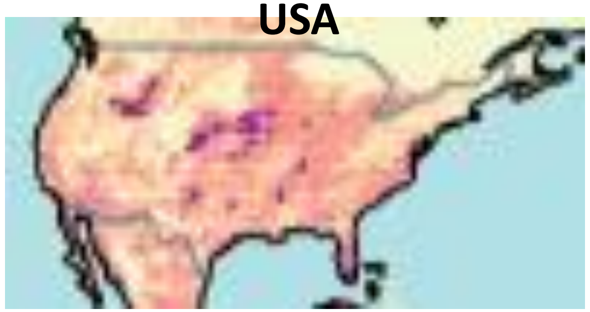
Compound extreme events

IPCC, 2018, 1.5°C Report

Interacting and Cascading Risks

1.5°C

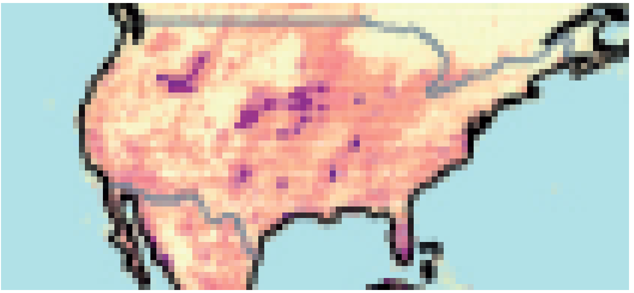
USA



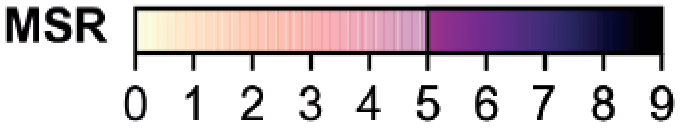
China

2°C

USA



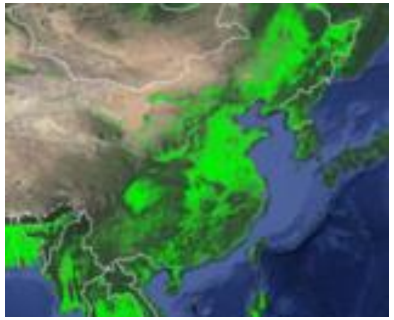
China



IPCC 2018, 1.5°C Report ,Figure 3.19 | Multi-sector risk maps for 1.5°C and 2°C

USA

China



USGS Crop area and density 2017 (satellite data)

CONCLUSION

The world today is in a state of world food insecurity emergency due to impacts at already committed degrees of climate change at 1.5°C to 2°C

The world's food producing regions are impacted substantially by multiple extreme weather events at 1.5°C increasing to 2°C

This includes compound extreme events

Increased surface ozone is an added adverse effect of high temperatures and heat waves, particularly the temperate northern hemisphere

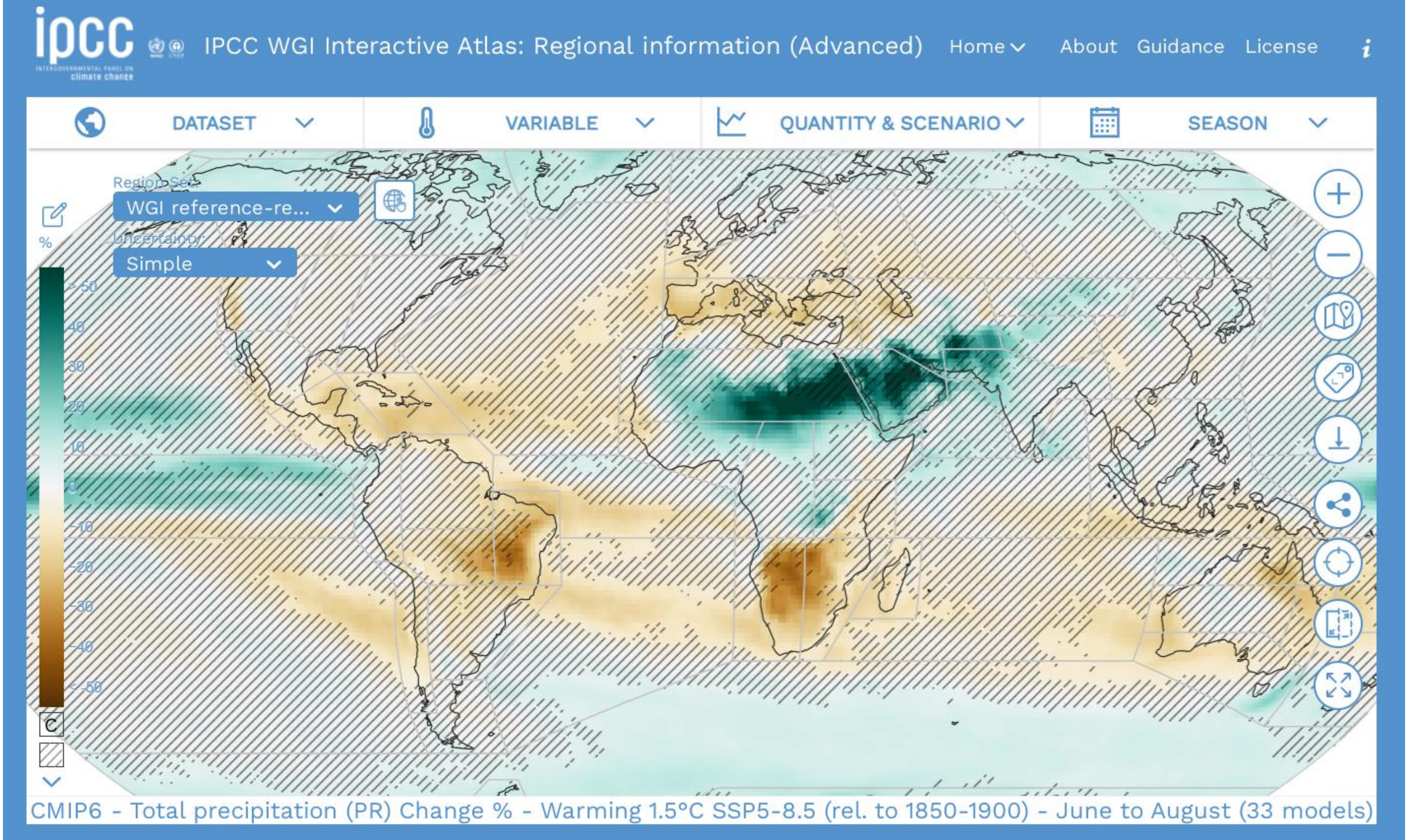
These impacts affect the industrialized northern hemisphere as well as the south
This includes top world food producing countries, USA and China

Africa is impacted by far the worst

These impact on top of world agriculture systems at breaking, and also on top increasing linear impacts of global climate change on food production

The world today is in a world food

The climate change background of increasing extreme events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CMIP6 - Total precipitation (PR) Change % - Warming 1.5°C SSP5-8.5 (rel. to 1850-1900) - June to August (33 models)

IPCC WGI Interactive Atlas: Regional information (Advanced)

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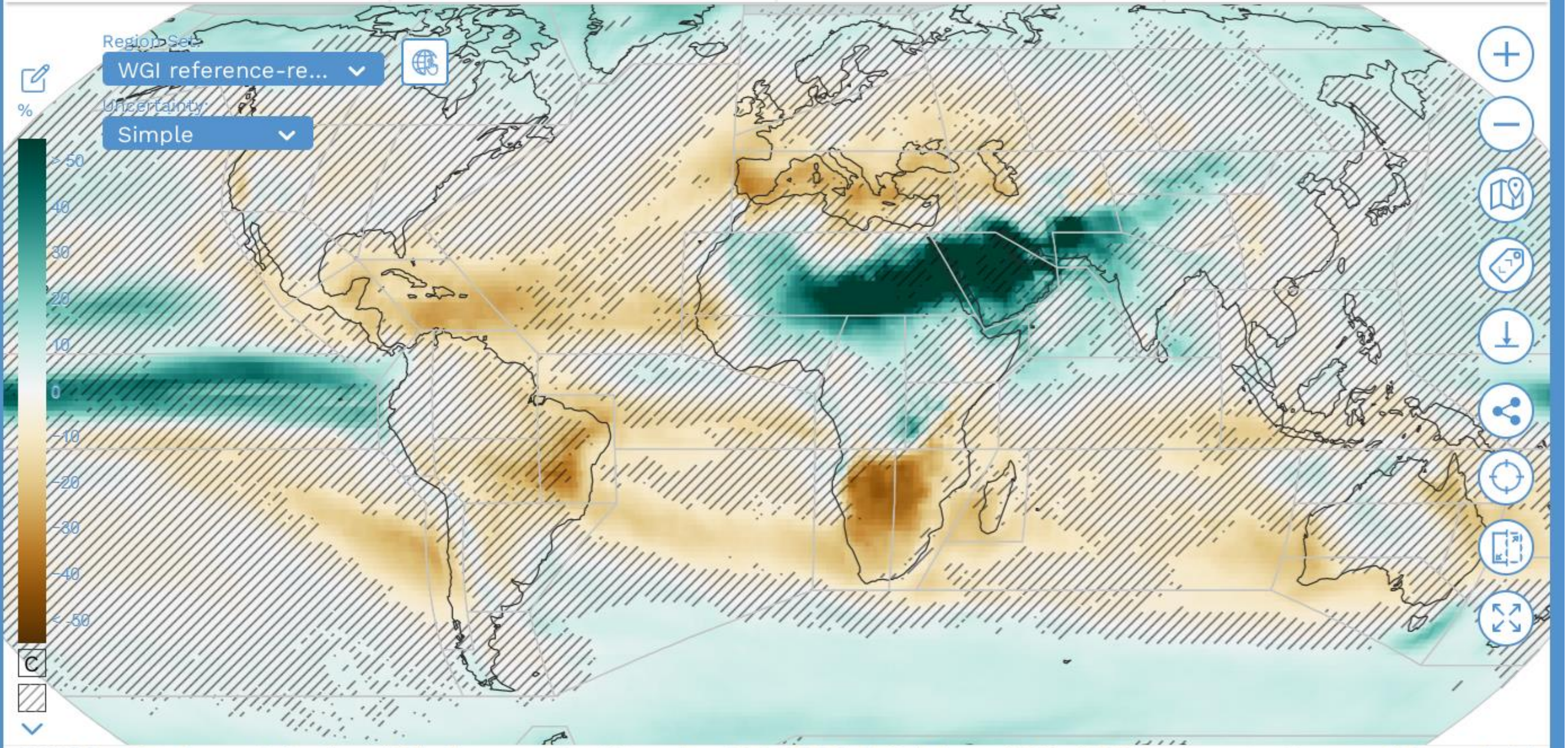
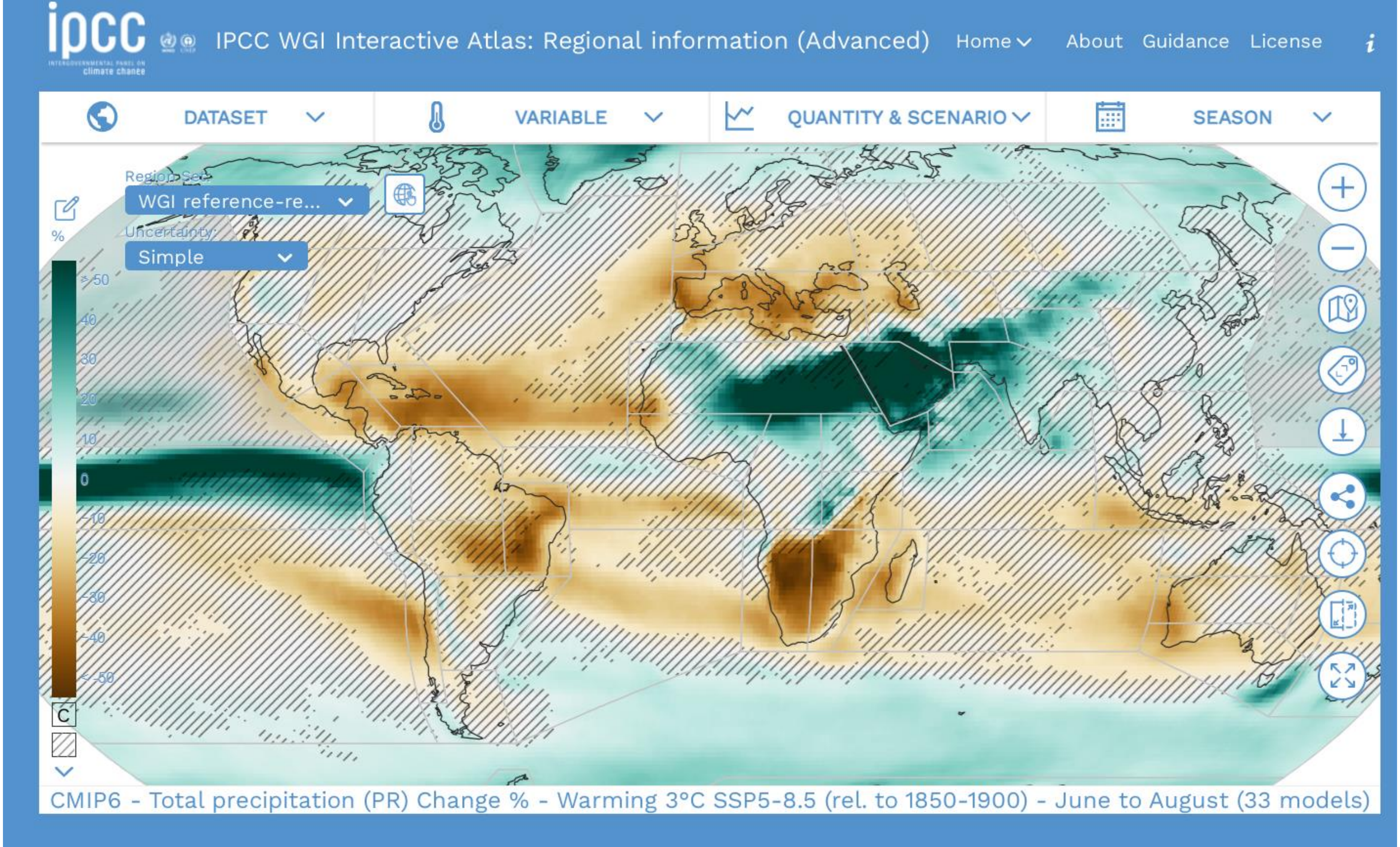


CMIP6 - Total precipitation (PR) Change % - Warming 2°C SSP5-8.5 (rel. to 1850-1900) - June to August (33 models)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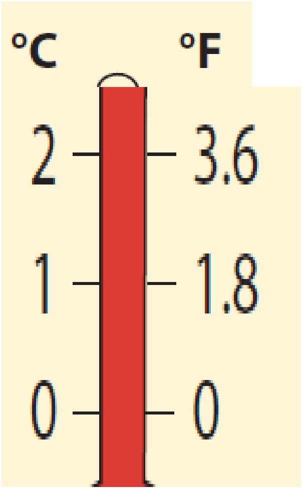
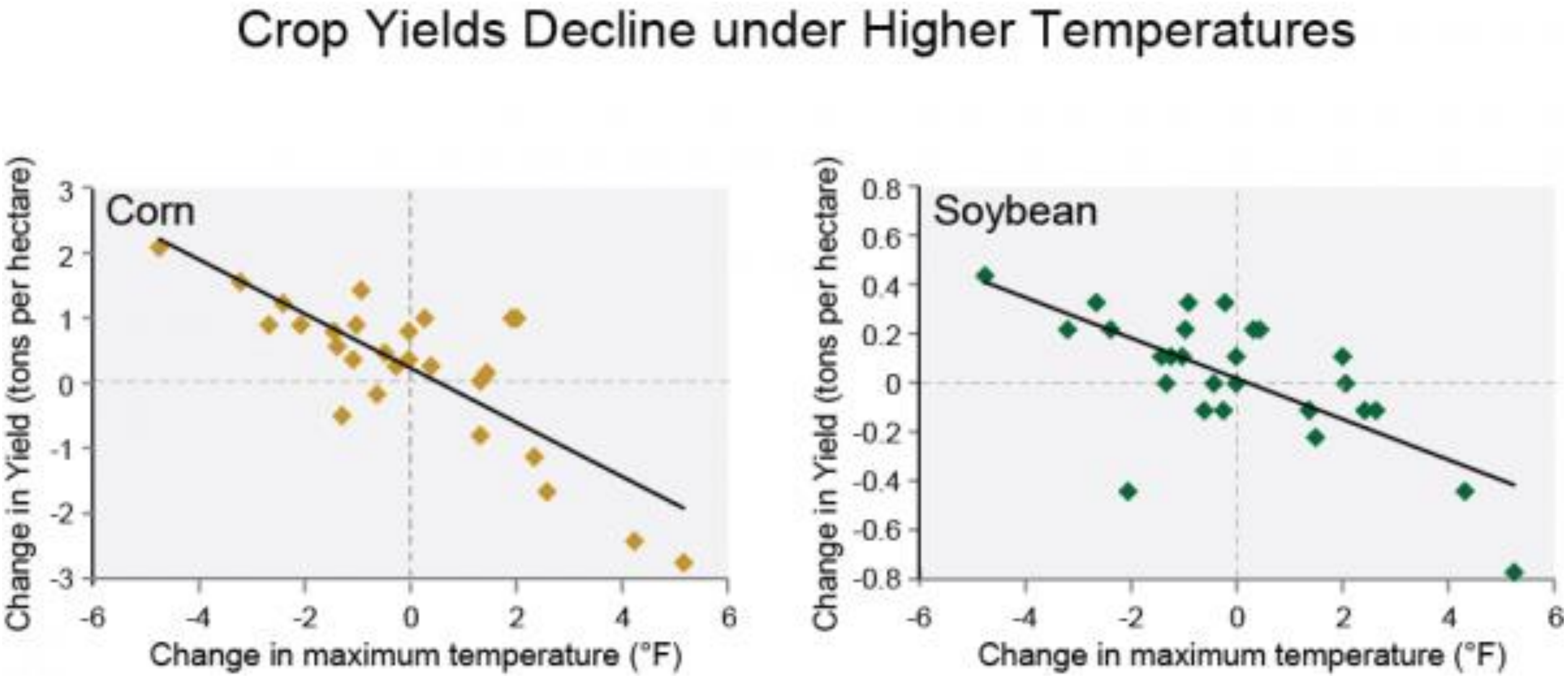
CMIP6 - Total precipitation (PR) Change % - Warming 3°C SSP5-8.5 (rel. to 1850-1900) - June to August (33 models)

USA crop yields under higher temperatures

US global change research, 2019





Crop yields are very sensitive to temperature and rainfall. They are especially sensitive to high temperatures during the pollination and grain filling period. For example, corn (left) and soybean (right) harvests in Illinois and Indiana, two major producers, were lower in years with average maximum summer (June, July, and August) temperatures higher than the average from 1980 to 2007. Most years with below-average yields are both warmer and drier than normal., There is high correlation between warm and dry conditions during Midwest summers due to similar meteorological conditions and drought-caused changes

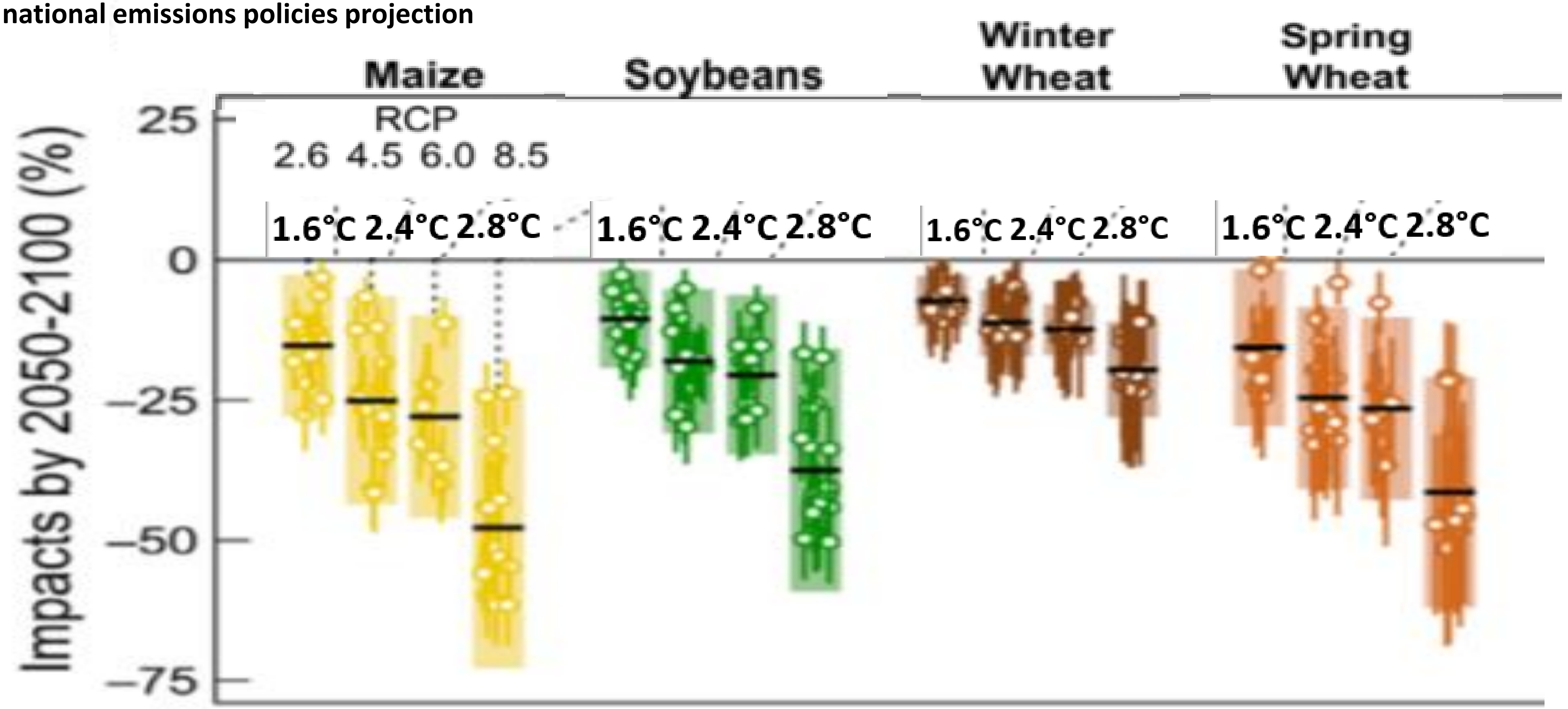
Increasing US crop yield decline with increase of global warming above 1.5°C

***Unpacking the climatic drivers of US agricultural yields*, 2019**

1.6°C: unavoidable,

2.4°C: requires immediate rapid emissions decline

2.8°C : national emissions policies projection



***Unpacking the climatic drivers of US agricultural yields*, A. Ortiz-Bobea , H, Wang, Carrillo and T. Ault, 29 April 2019**

Figure 4.Climate change impact projections on United States crop yields. Each dot represents a particular GCM in CMIP5 for the end of the century (2050–2100). Vertical lines around each dot represents the 95% confidence . The horizontal solid black line and the colored bands correspond to the mean and ± two standard deviation of each ensemble, respectively. Climate change scenarios are increasingly severe from RCP 2.6–8.5). Traditional model with constant intra-seasonal effects of precipitation and temperature.

Peter Carter, Climate Emergency Institute

Anthropogenic climate change has slowed global agricultural productivity growth

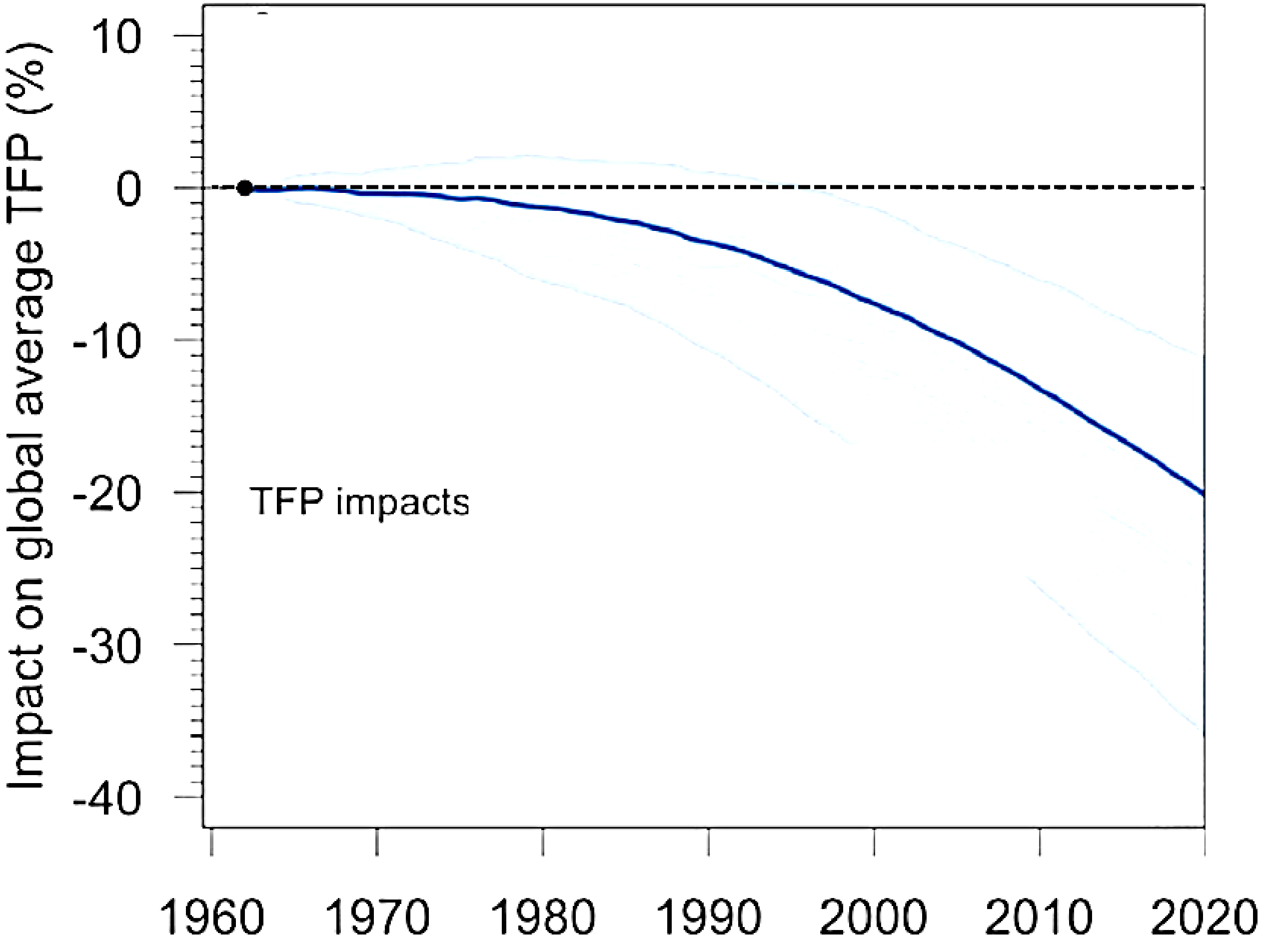
01 April 2021, Nature, Ariel Ortiz-Bobea, Toby R. Ault, Carlos M. Carrillo, Robert G. Chambers & David B. Lobell

TFP measures aggregate total output per unit of measured aggregate input

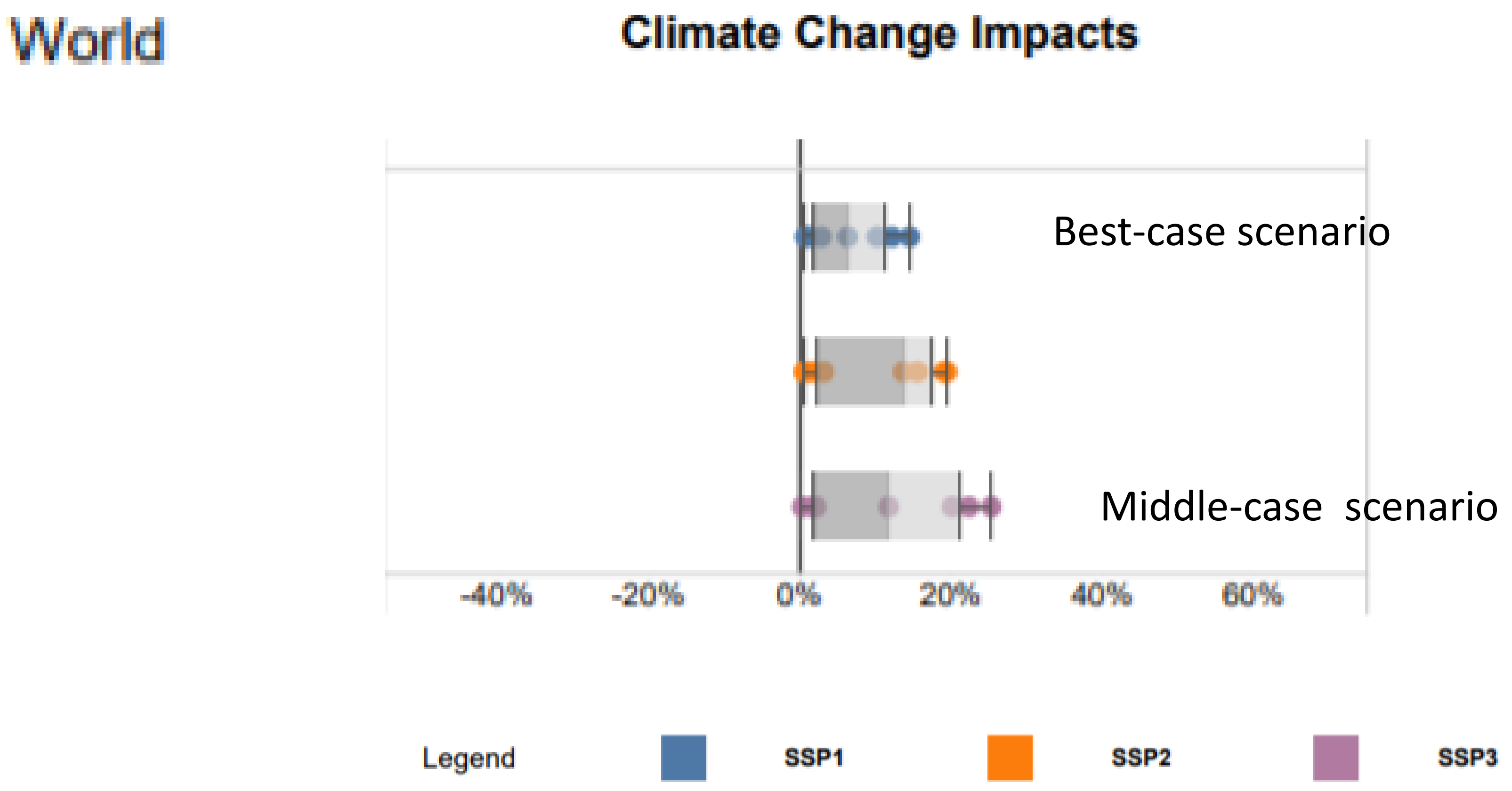
"Anthropogenic climate change has reduced global agricultural TFP by about 21% since 1961, a slowdown that is equivalent to losing the last 9 years of productivity growth.

The effect is substantially more severe (a reduction of ~30-33%) in warmer regions such as Africa and Latin America and the Caribbean.

We also find that global agriculture has grown more vulnerable to ongoing climate change."



IPCC 2019 Land Report, food Prices under climate change



IPCC 2019 Land Report Figure 5.14 | Regional impacts of climate change on food price in 2050 under different socio-economic scenarios (SSP1, SSP2 and SSP3) based on AgMIP Global Economic Model analysis.