Agricultural impacts of climate change

Professor Jørgen E. Olesen

AARHUS
UNIVERSITY
DEPARTMENT OF AGROECOLOGY

15 SEPTEMBER 2021

JØRGEN EIVIND OLESEN
HEAD OF DEPARTMENT, PROFESSOR

Climate change – food, agriculture and land use

Complex problem

- Increasing wealth and consumption
- Very large differences in productivity and efficiency
- Large differences in waste and use of side streams
- Agriculture delivers food, materials and bioenergy

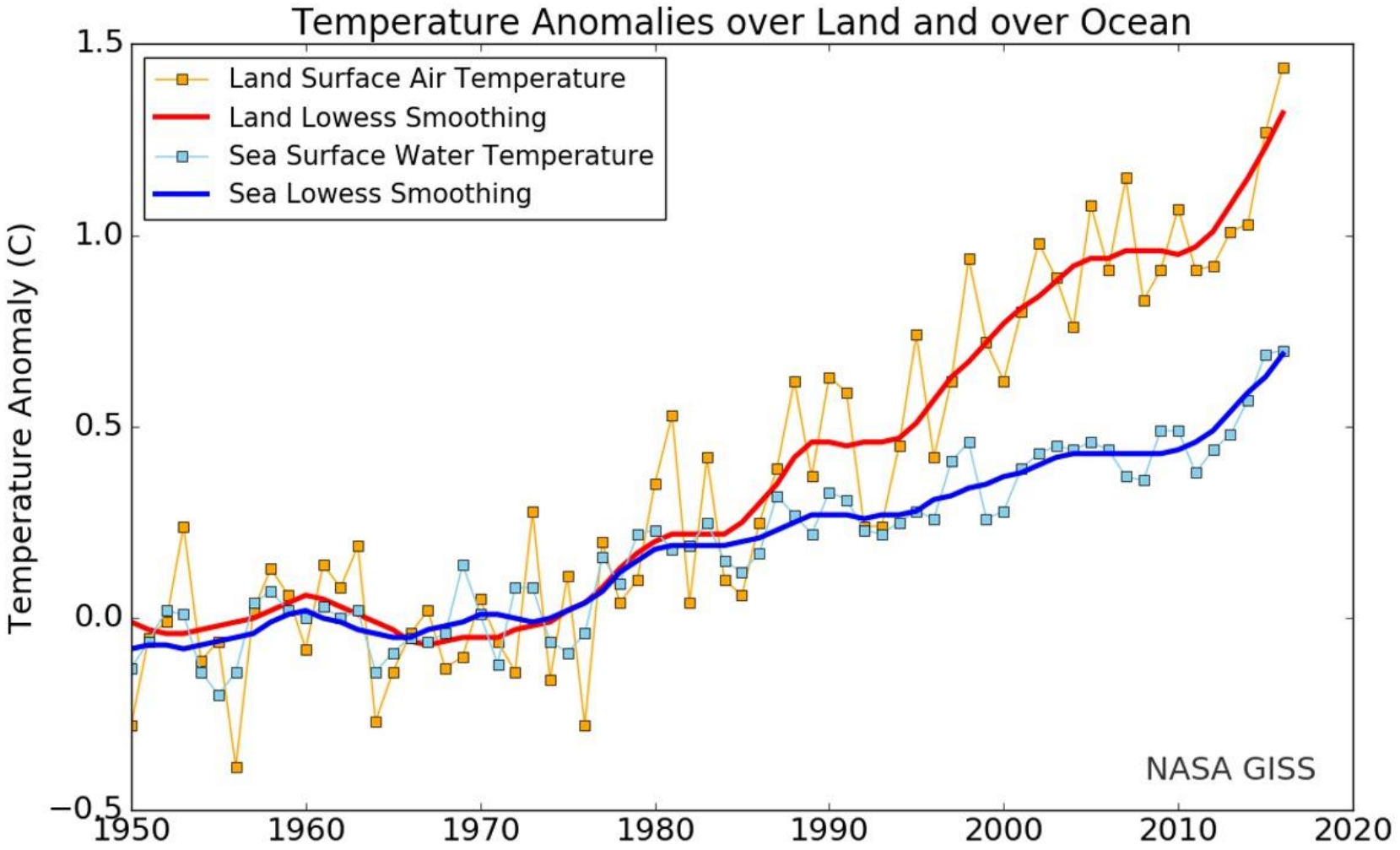
Many causes of greenhouse gases

- Food consumption
- Agricultural production
- Land use (including iLUC – indirect land use change)

Climate change and adaptation is also important

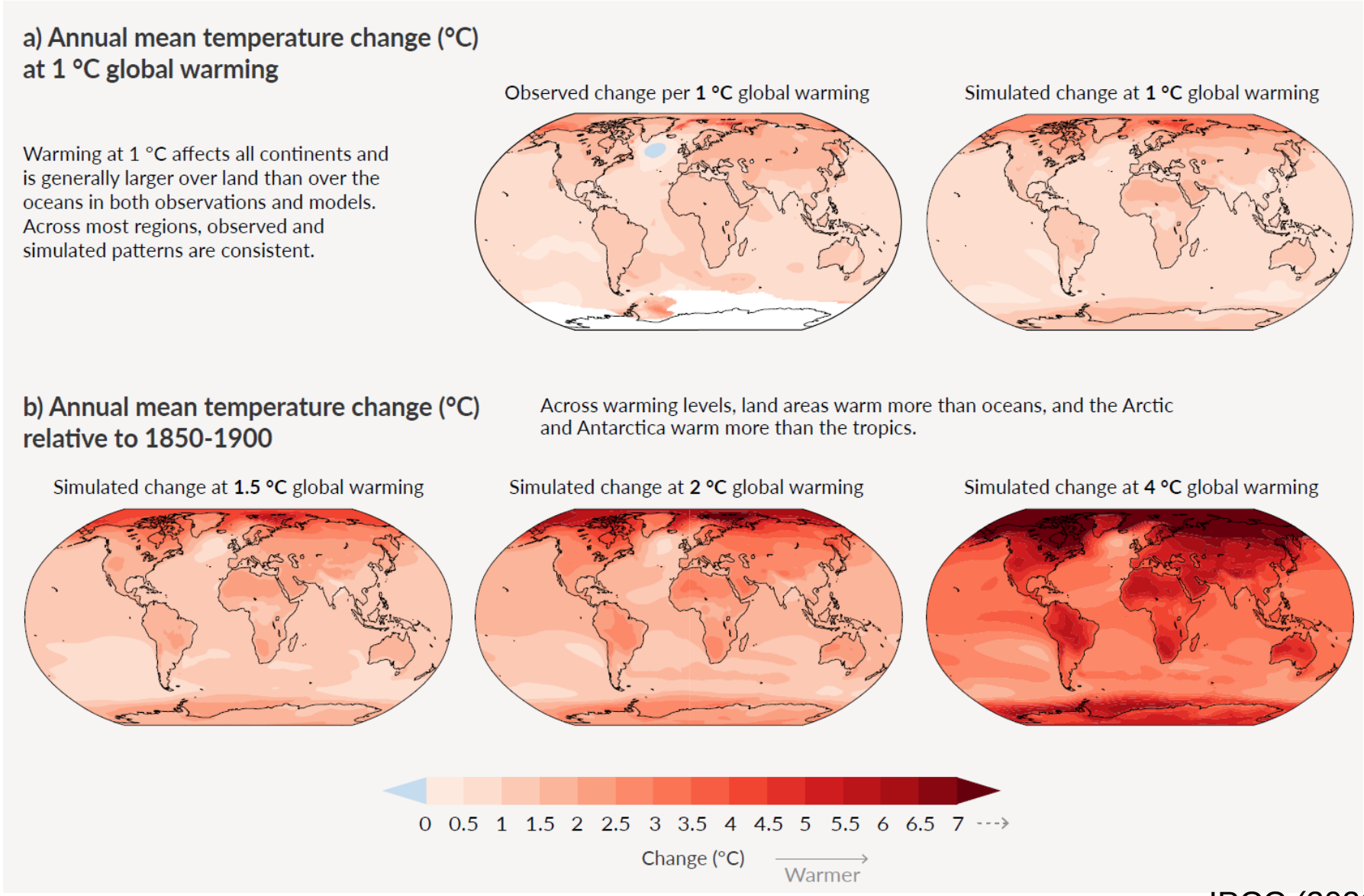
- Climate change will happen even with mitigation
- Warmer climate, more extremes, droughts, floods
- World food supply will be threatened

Temperature over land increase more over land than oceans



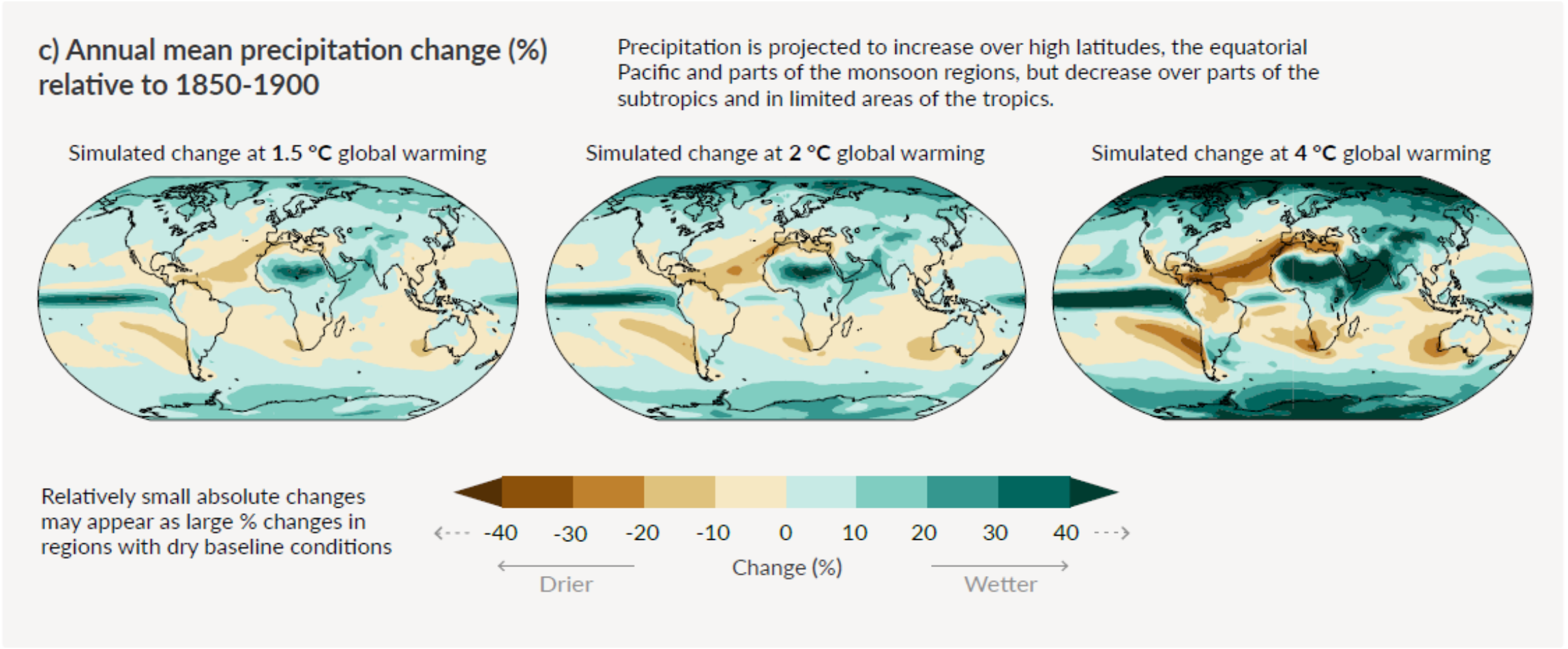
EEA (2017)

The warming is not evenly distributed



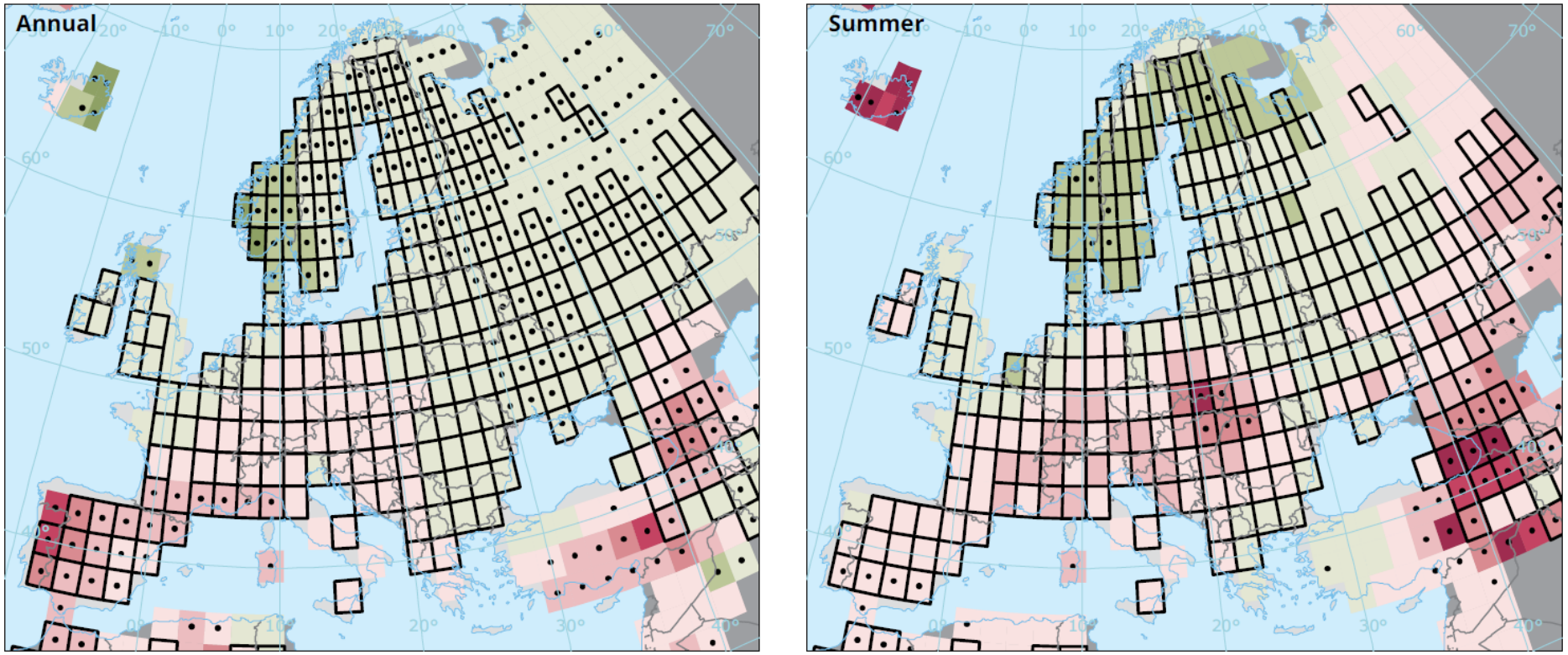
IPCC (2021)

The change in precipitation is not evenly distributed



IPCC (2021)

Spatial trends in precipitation



EEA (2017)

The climate is getting more extreme

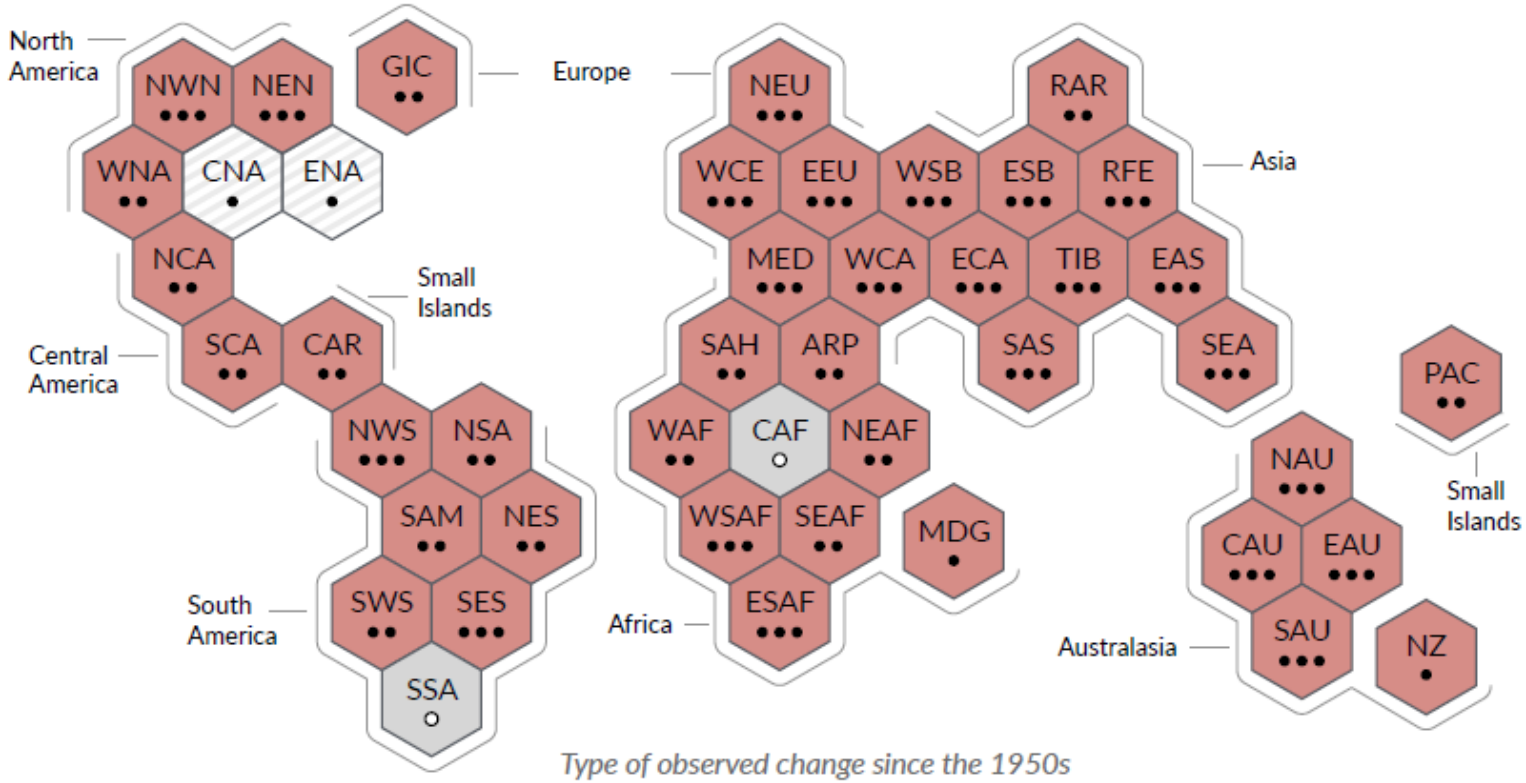
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in hot extremes

- Increase (41)
- Decrease (0)
- Low agreement in the type of change (2)
- Limited data and/or literature (2)

Confidence in human contribution
to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



Type of observed change since the 1950s

IPCC (2021)

The climate is getting more extreme

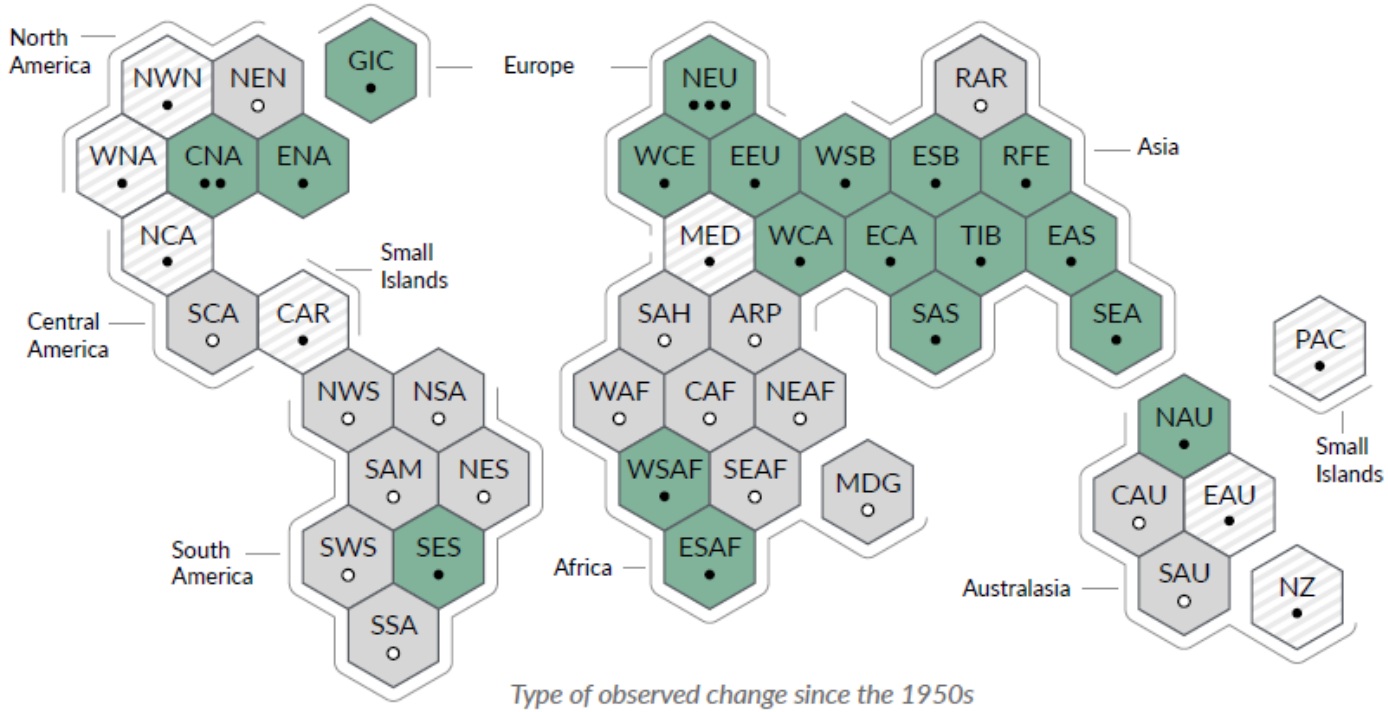
b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in heavy precipitation

- Increase (19)
- Decrease (0)
- Low agreement in the type of change (8)
- Limited data and/or literature (18)

Confidence in human contribution
to the observed change

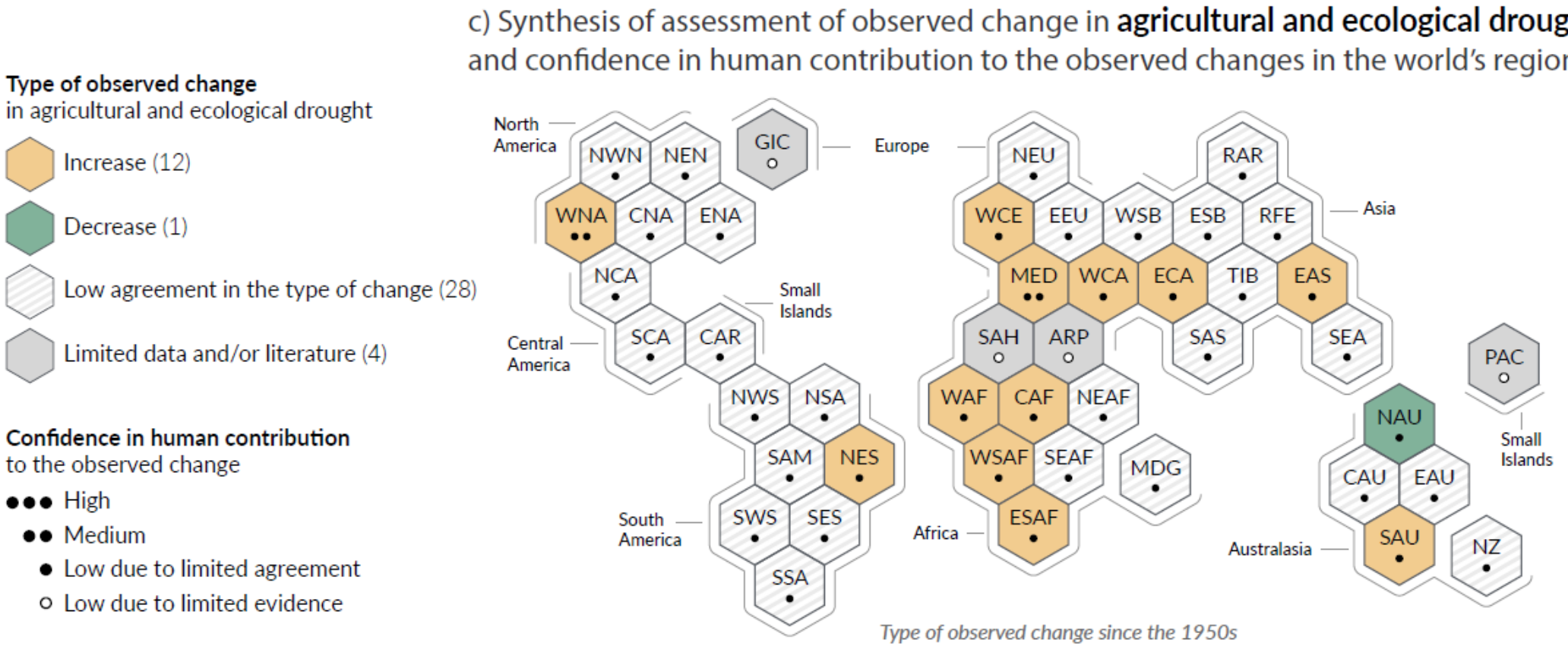
- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



Type of observed change since the 1950s

IPCC (2021)

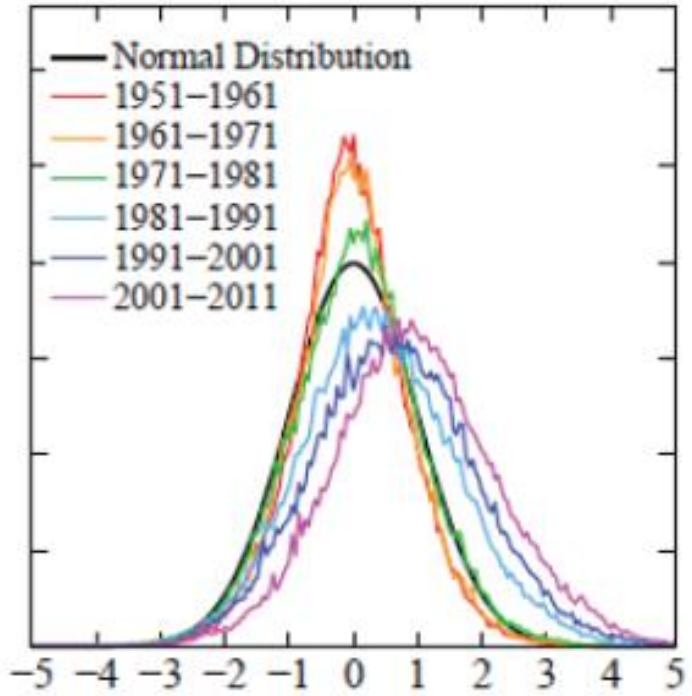
The climate is getting more extreme

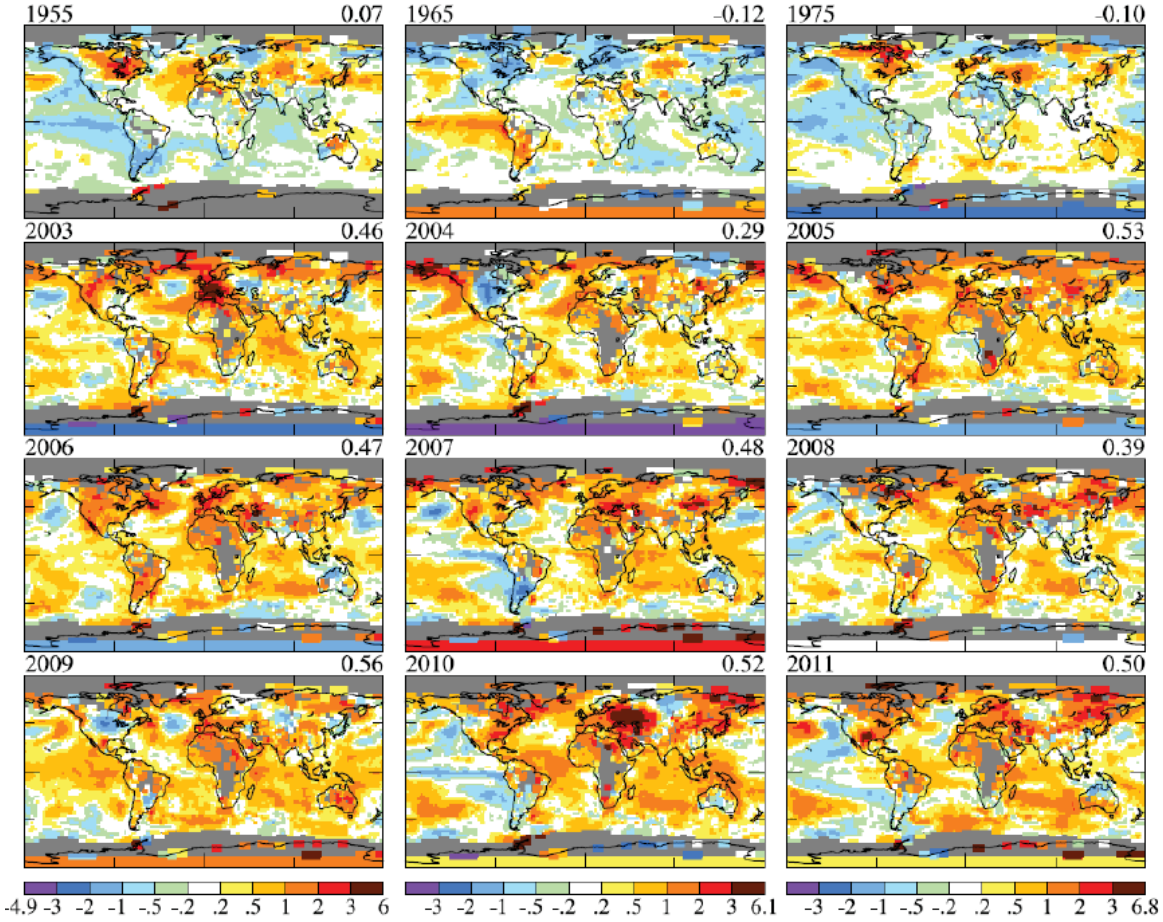


IPCC (2021)

Summer temperatures are getting more extreme

- Global mean temperature increases
- But so does the interannual variation





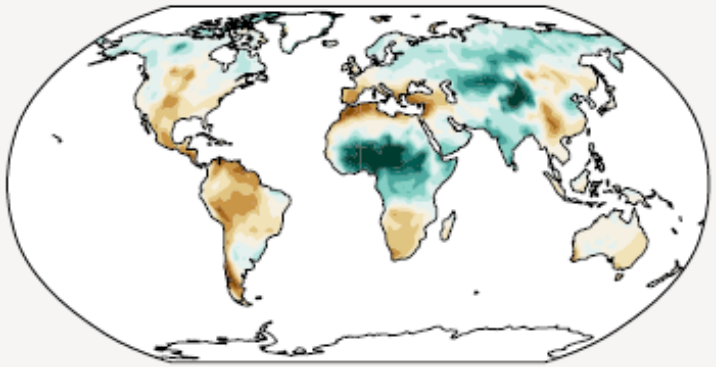
Hansen et al. (2012), PNAS 109 E2415-E2423

The change in soil moisture is not evenly distributed

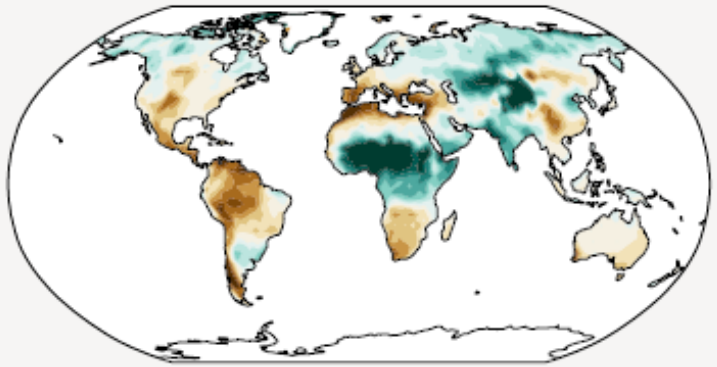
d) Annual mean total column soil moisture change (standard deviation)

Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.

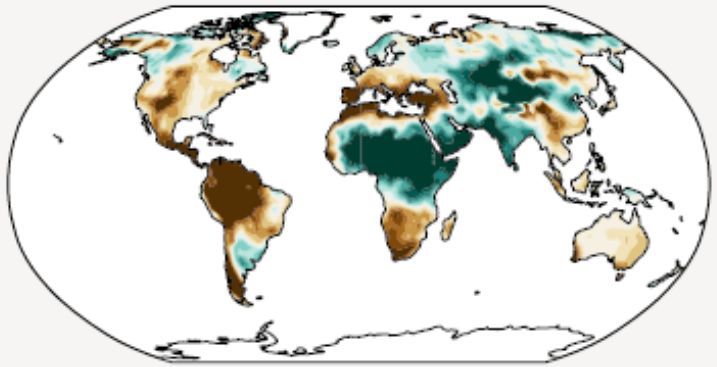
Simulated change at **1.5 °C** global warming



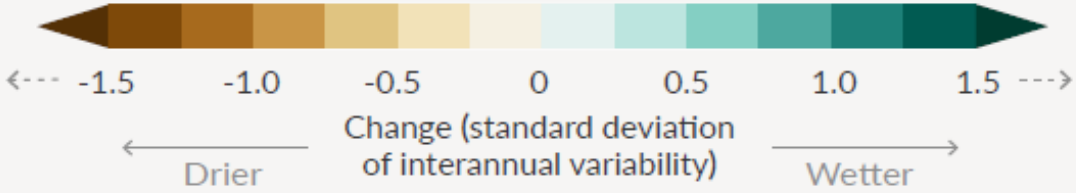
Simulated change at **2 °C** global warming



Simulated change at **4 °C** global warming



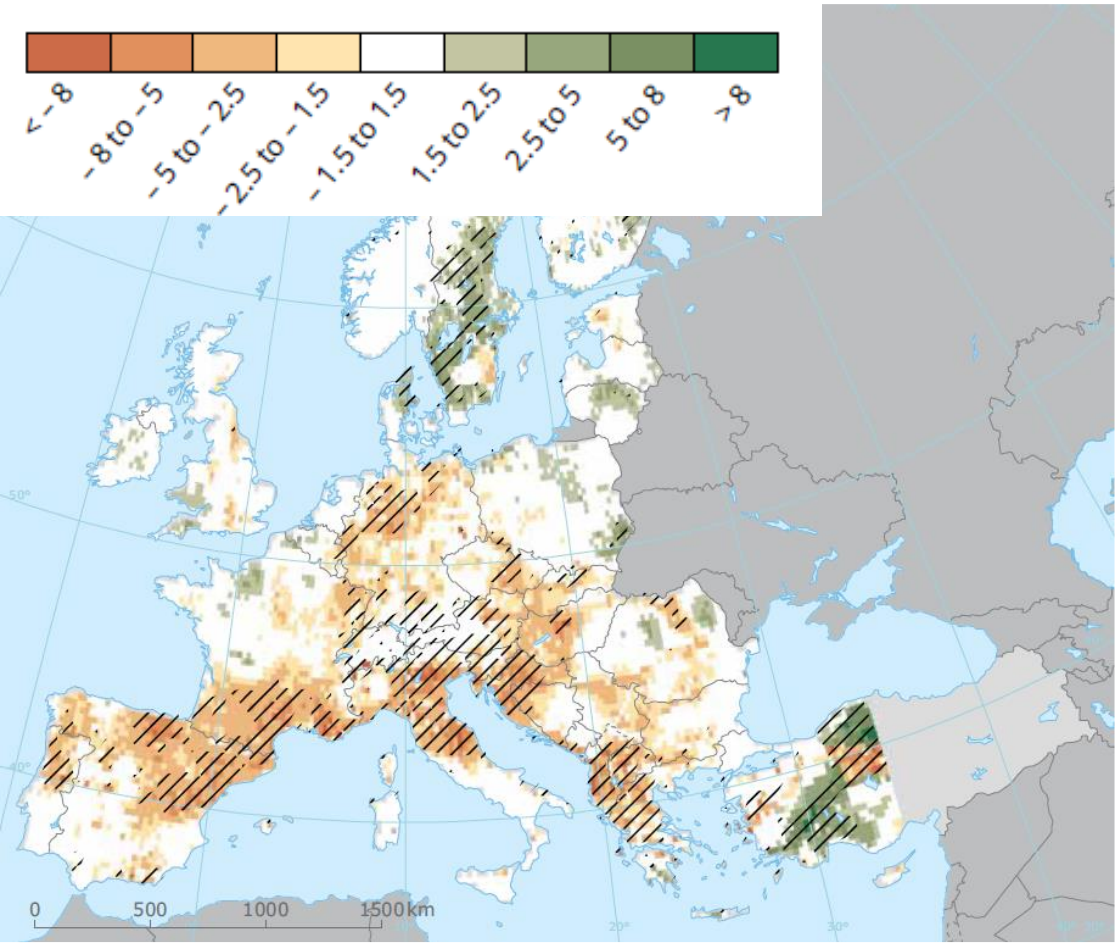
Relatively small absolute changes may appear large when expressed in units of standard deviation in dry regions with little interannual variability in baseline conditions



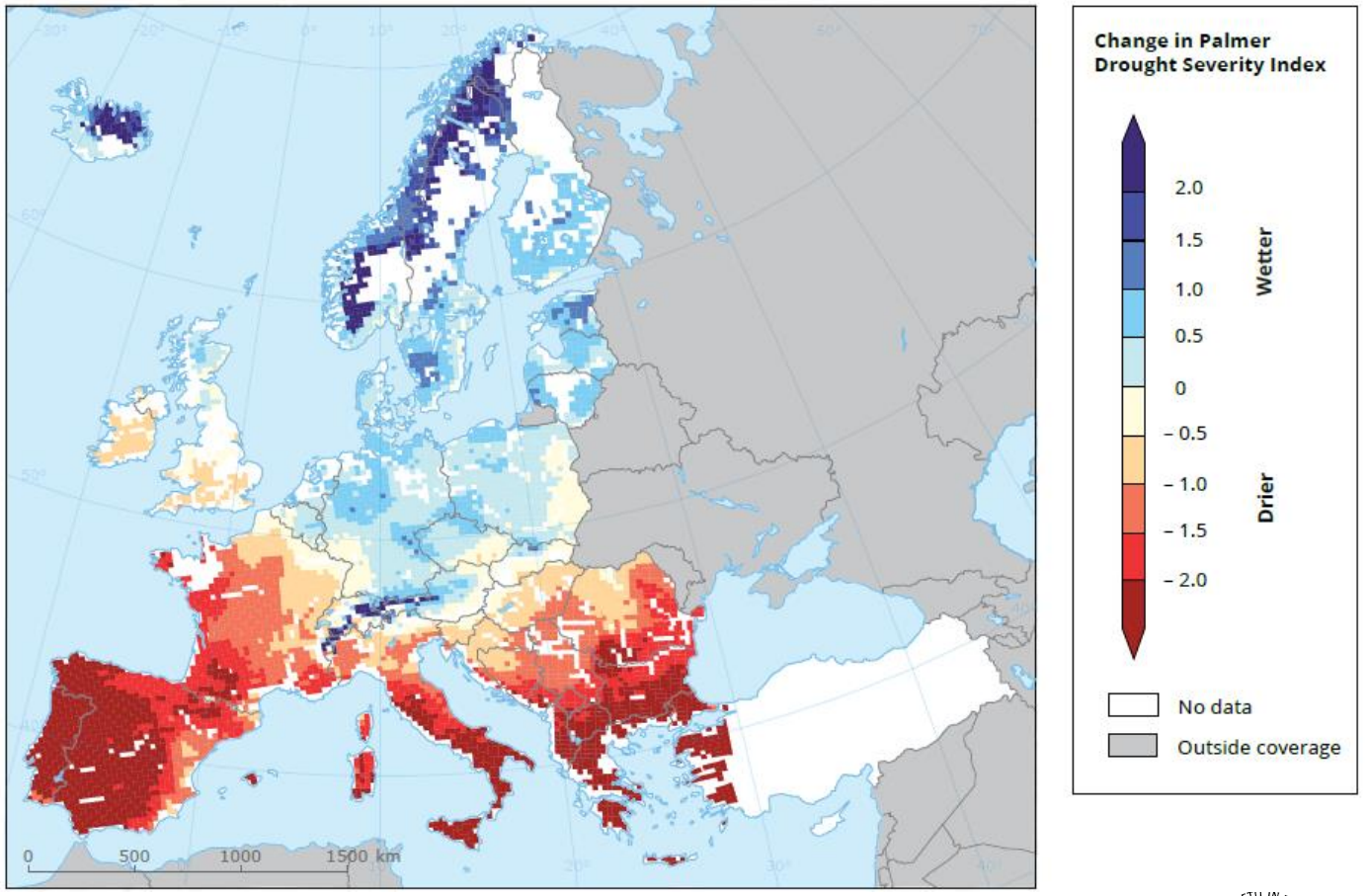
IPCC (2021)

Trends in summer soil moisture

Trend 1951-2012



Projection until 2050s



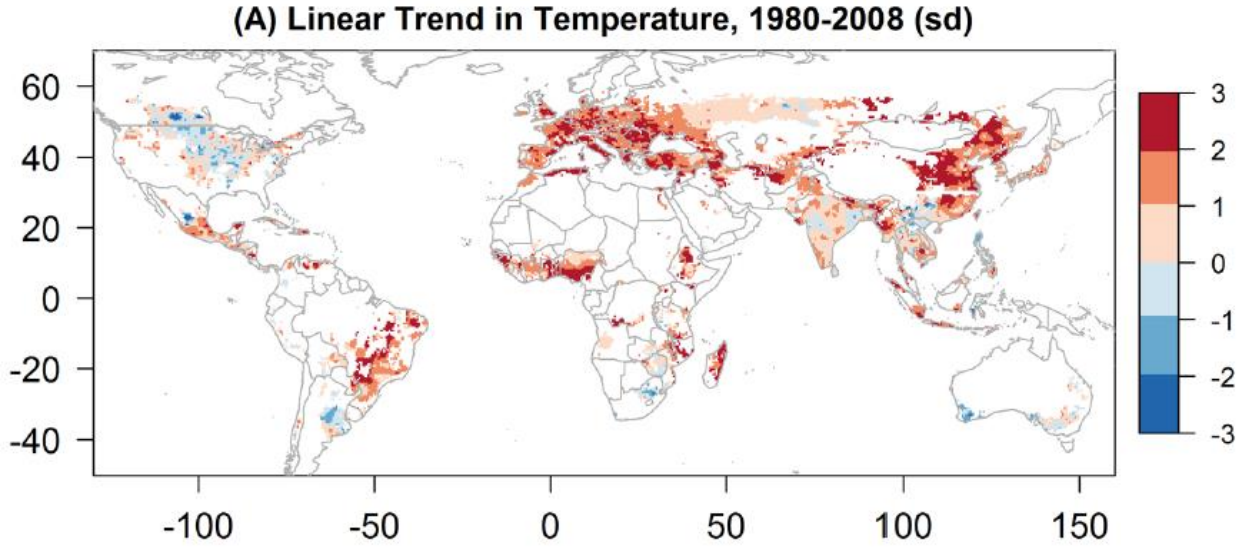
EEA (2017)

Climate change poses risks to current systems

- Risks to production systems are mostly related to extreme events and new biotic interactions
  - Heat waves
  - Frost, snow, ice
  - Droughts
  - Intense or long lasting rainfall (floods)
  - Storms
  - Pest and diseases
- Climate change increases
  - Frequency of extreme events
  - Inter-annual variability

Observed impacts on crop yield of climate change globally

Crop	Global production (1998-2002 average, million metric tons)	Global yield impact of temperature trends (%)	Global yield impact of precipitation trends (%)	Subtotal	Global yield impact of CO_2 trends (%)	Total
Maize	607	–3.1 (–4.9, –1.4)	–0.7 (–1.2, 0.2)	–3.8 (–5.8, –1.9)	0.0	–3.8
Rice	591	0.1 (–0.9, 1.2)	–0.2 (–1.0, 0.5)	–0.1 (–1.6, 1.4)	3.0	2.9
Wheat	586	–4.9 (–7.2, –2.8)	–0.6 (–1.3, 0.1)	–5.5 (–8.0, –3.3)	3.0	–2.5
Soybean	168	–0.8 (–3.8,1.9)	–0.9 (–1.5, –0.2)	–1.7 (–4.9, 1.2)	3.0	1.3



Lobell et al. (2011)

Plant and animal responses to temperature

Development (phenology)

- Timing of events, in particular reproduction

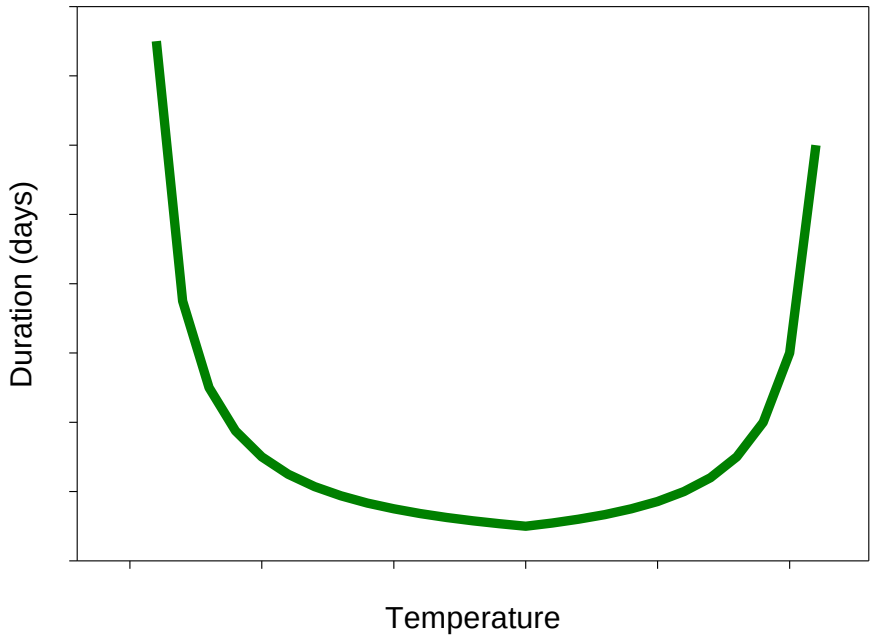
Growth

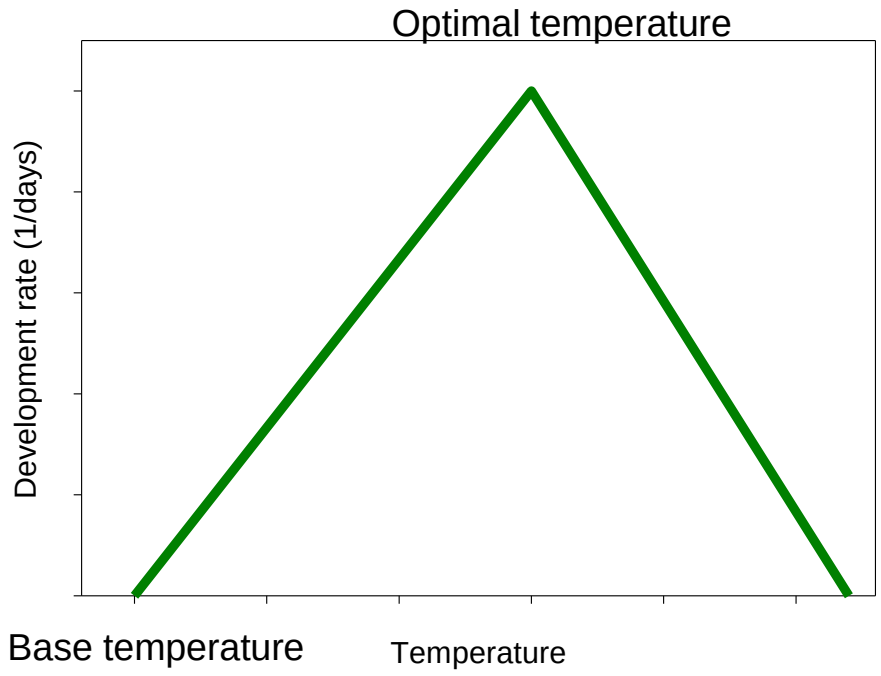
- Assimilation of energy and nutrients
- Respiration

Animal body temperatures

- Endotherms (constant body temperature)
- Poikilotherms (facultative endotherms)
- Ectotherms (body temperature depends on external temperature)

Developmental rate



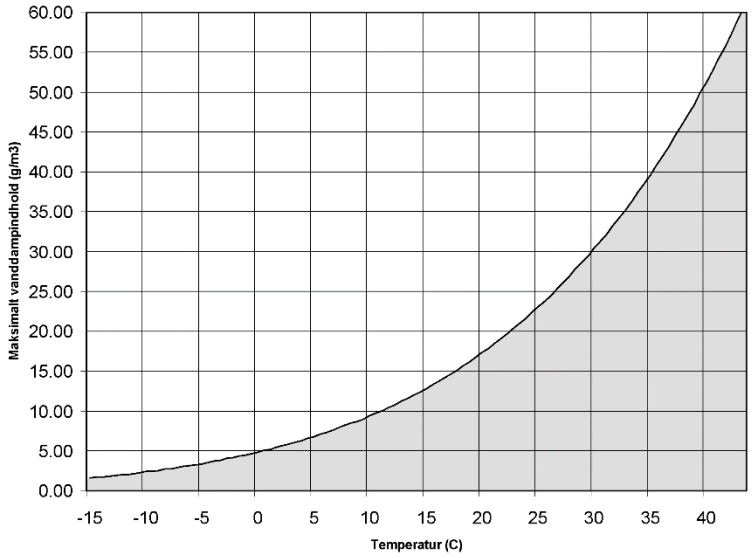


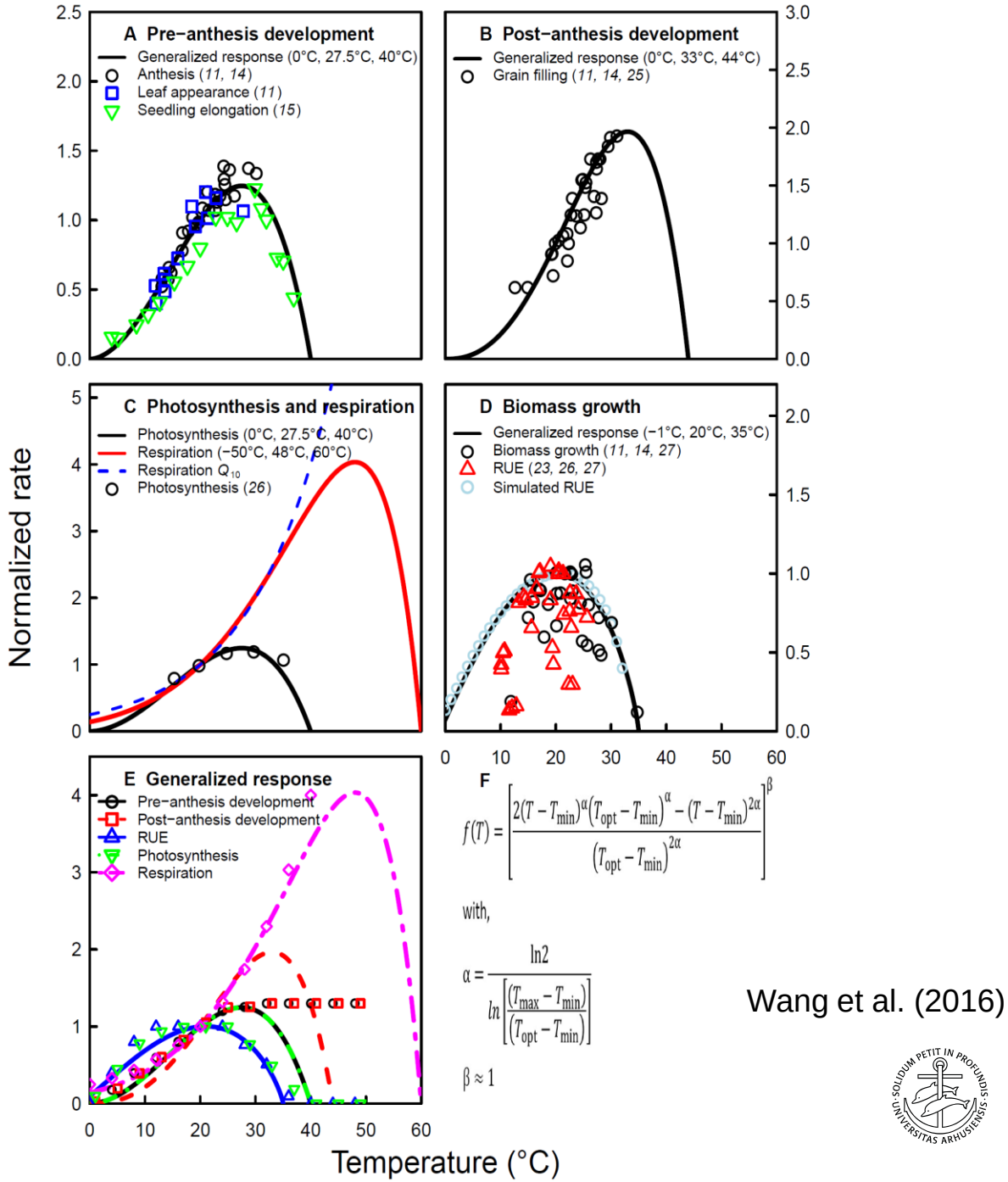
Growing degree days (GDD) or Effective temperature sum (ETS): $\sum(T\text{-}T_b)_+$

Temperature responses

Evapotranspiration increases with increase temperature due to the vapour pressure curve that increases vapour pressure deficit with increasing temperature.

Saturated water vapour – temperature curve





Wang et al. (2016)

Projected yield change

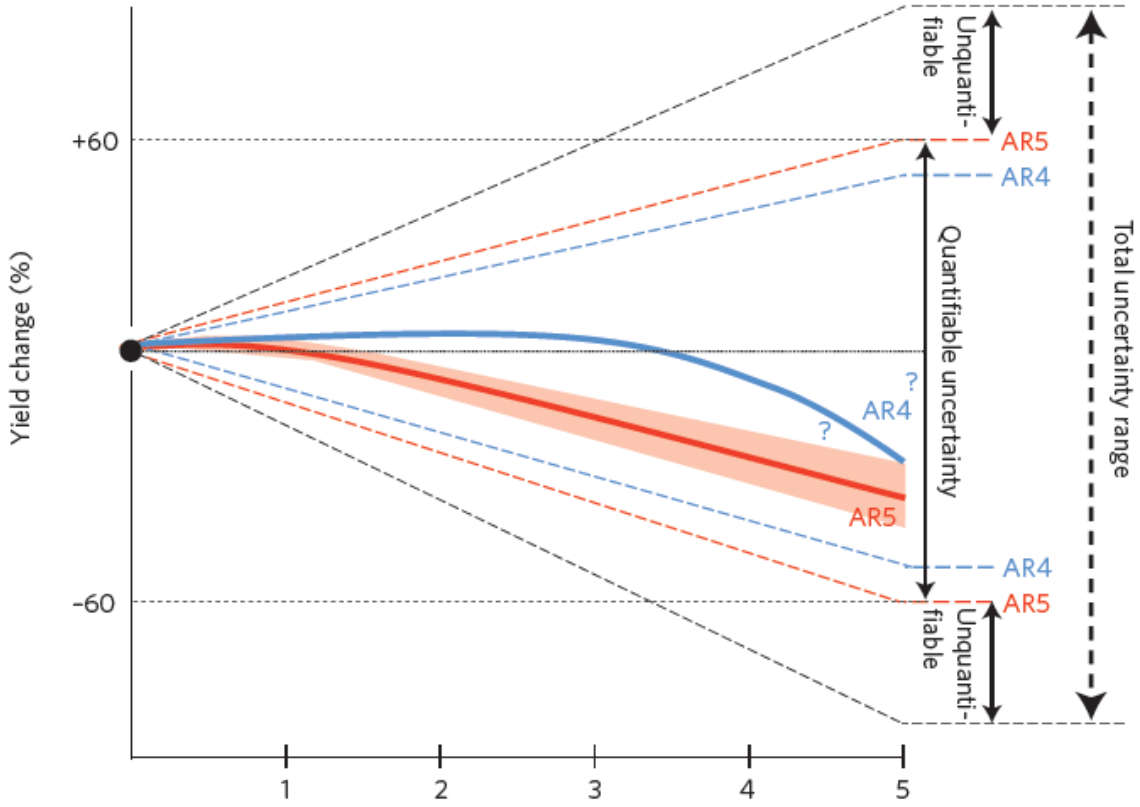


Figure 1 | Schematic illustration of the relationship between total uncertainty, projected ranges of relative yield changes and best fits of aggregate yield changes. The figure refers to model-based results from AR4 (ref. 5) and AR5 (WGII chapter 'Food security and food production systems') and indicatively depicts the main message and novelties of this study[4]. Figure modified from ref. 6.

Rötter et al. (2014)

Projected yield change

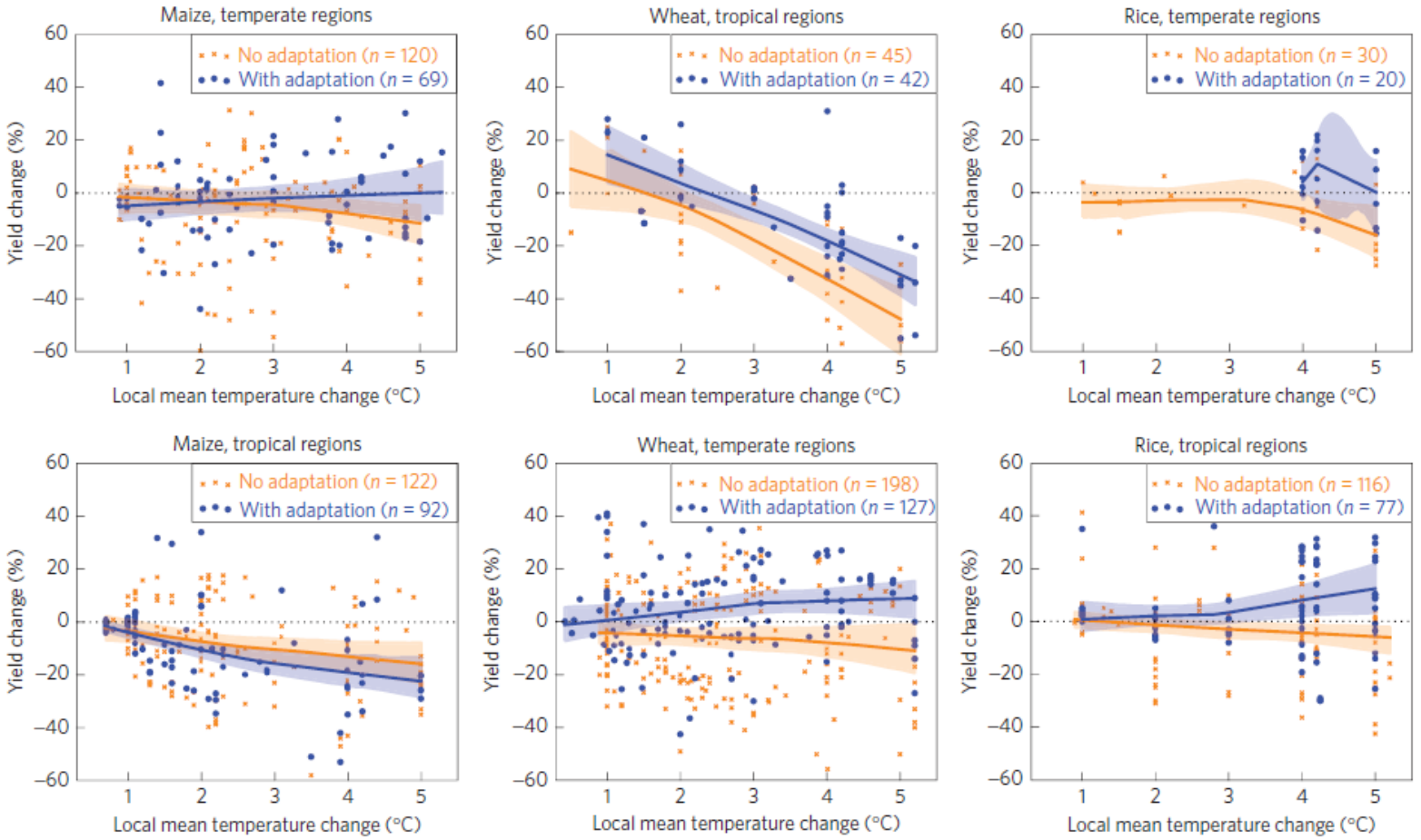
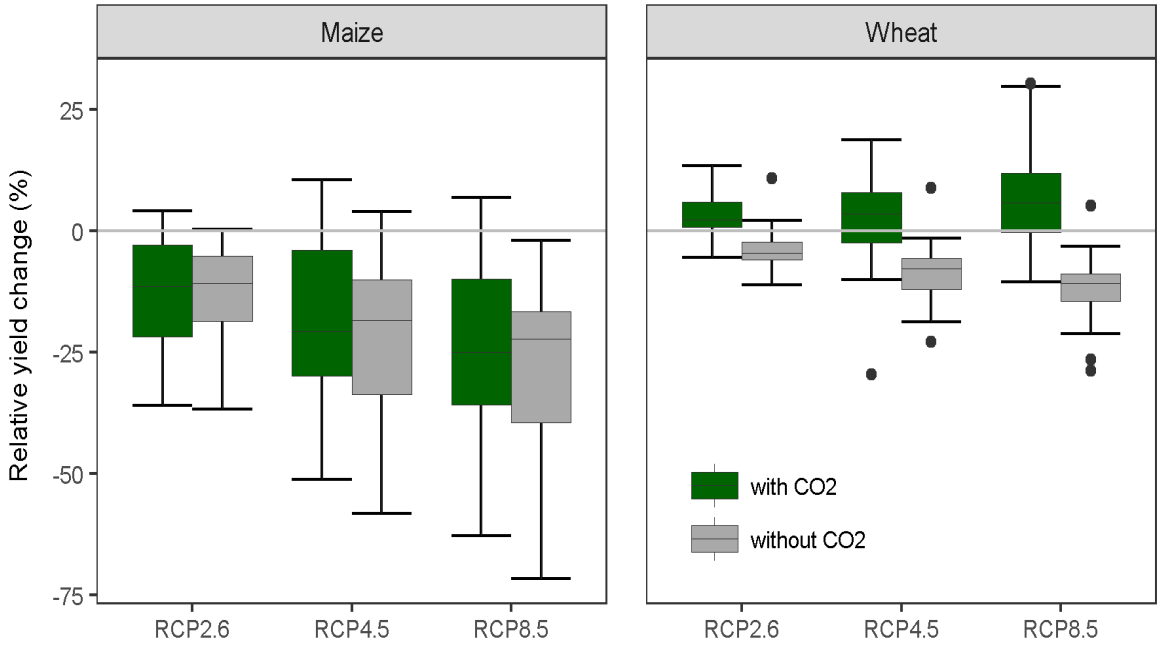
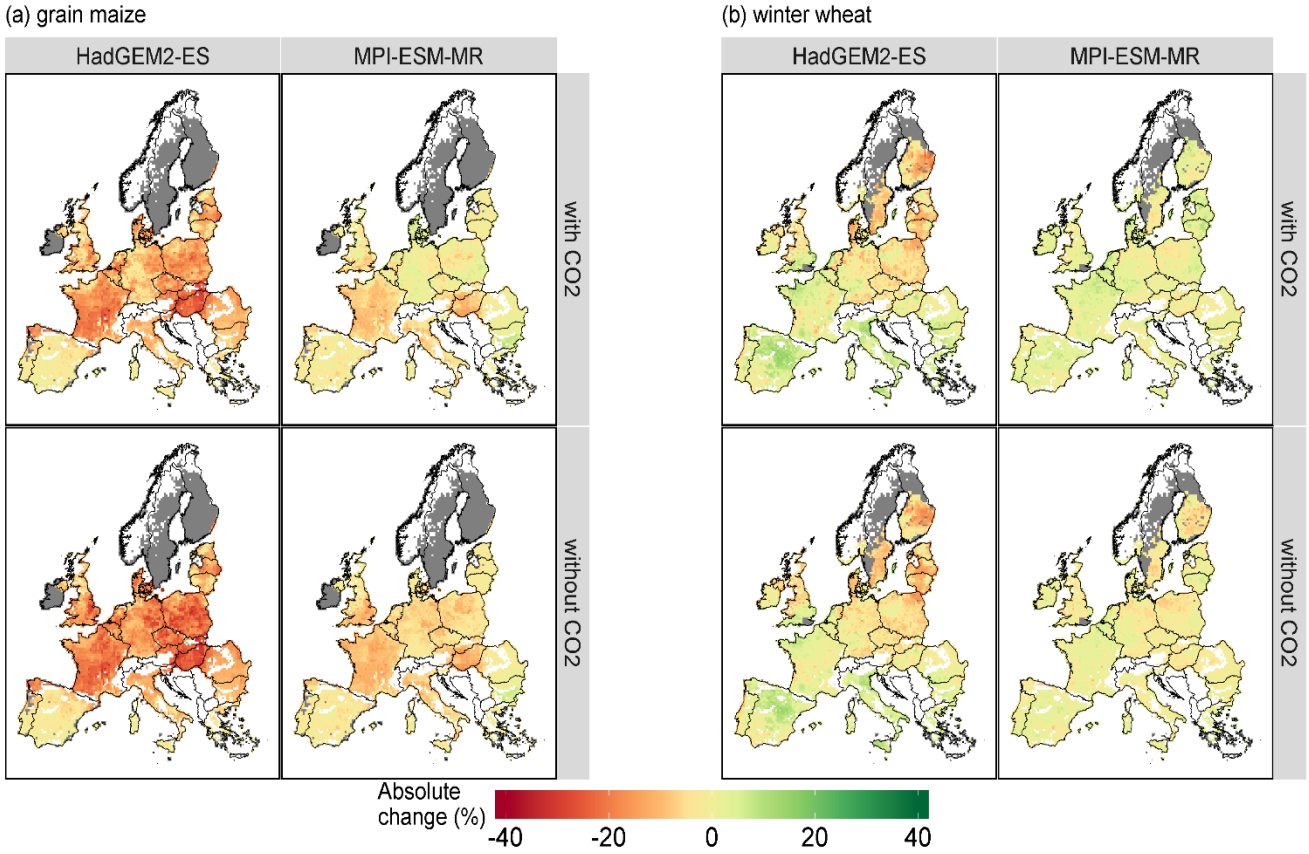


Figure 1 | Percentage yield change as a function of temperature for the three main crops and for temperate and tropical regions for local mean temperature changes up to 5 °C (n = 1,048 from 66 studies). Shaded bands indicate the 95% confidence interval of regressions consistent with the data based on 500 bootstrap samples, which are separated according to the presence (blue) or absence (orange) of adaptation. Note that four data points across all six panels are outside the yield change range shown. These were omitted for clarity. Supplementary Fig. 4 shows data from across all temperatures and yield ranges.

Challinor et al. (2014)

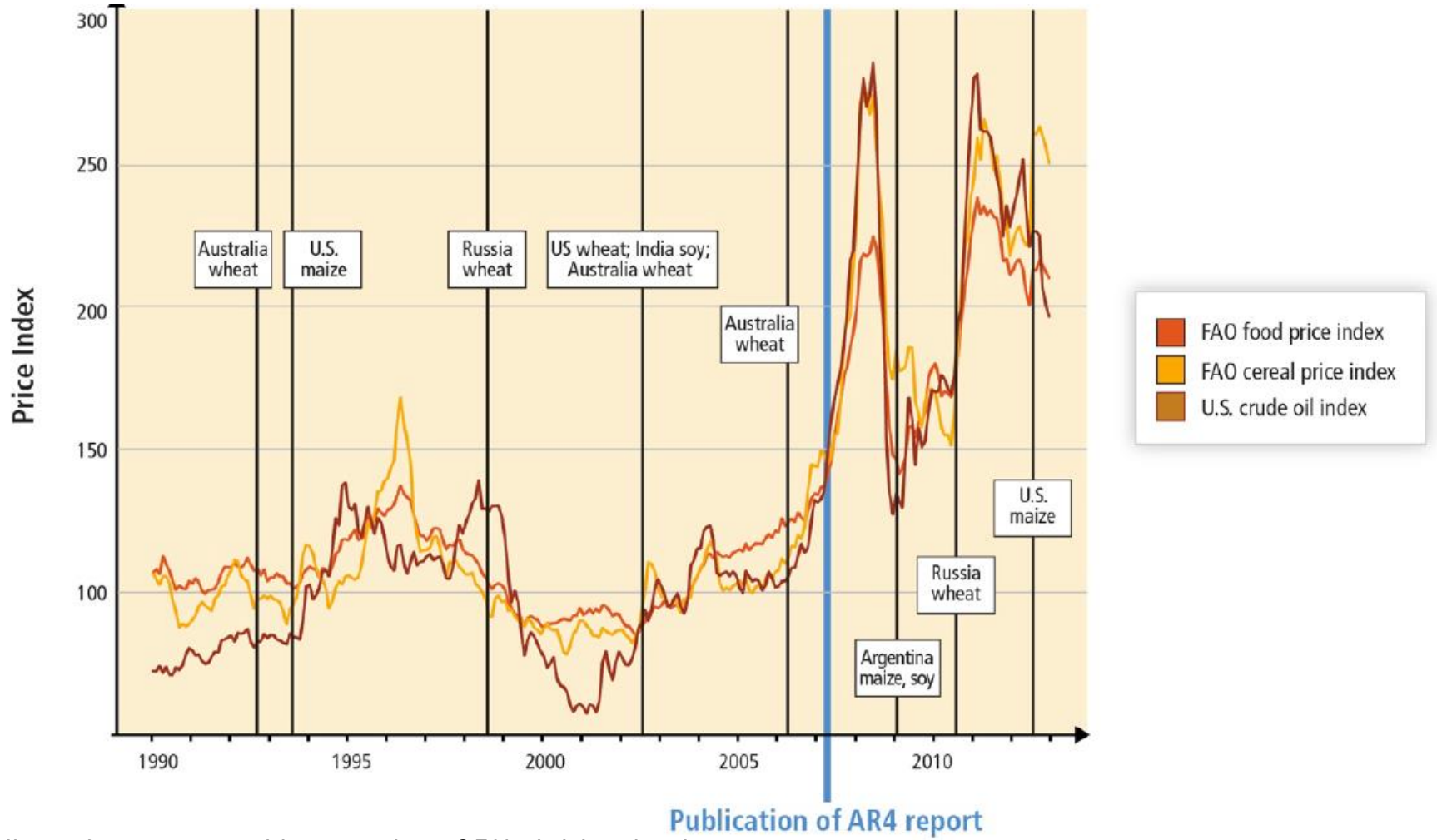
Drought is the major threat for cereals under climate change in Europe (2050s)





Webber et al. (2018) Nature Com. 9, 4249

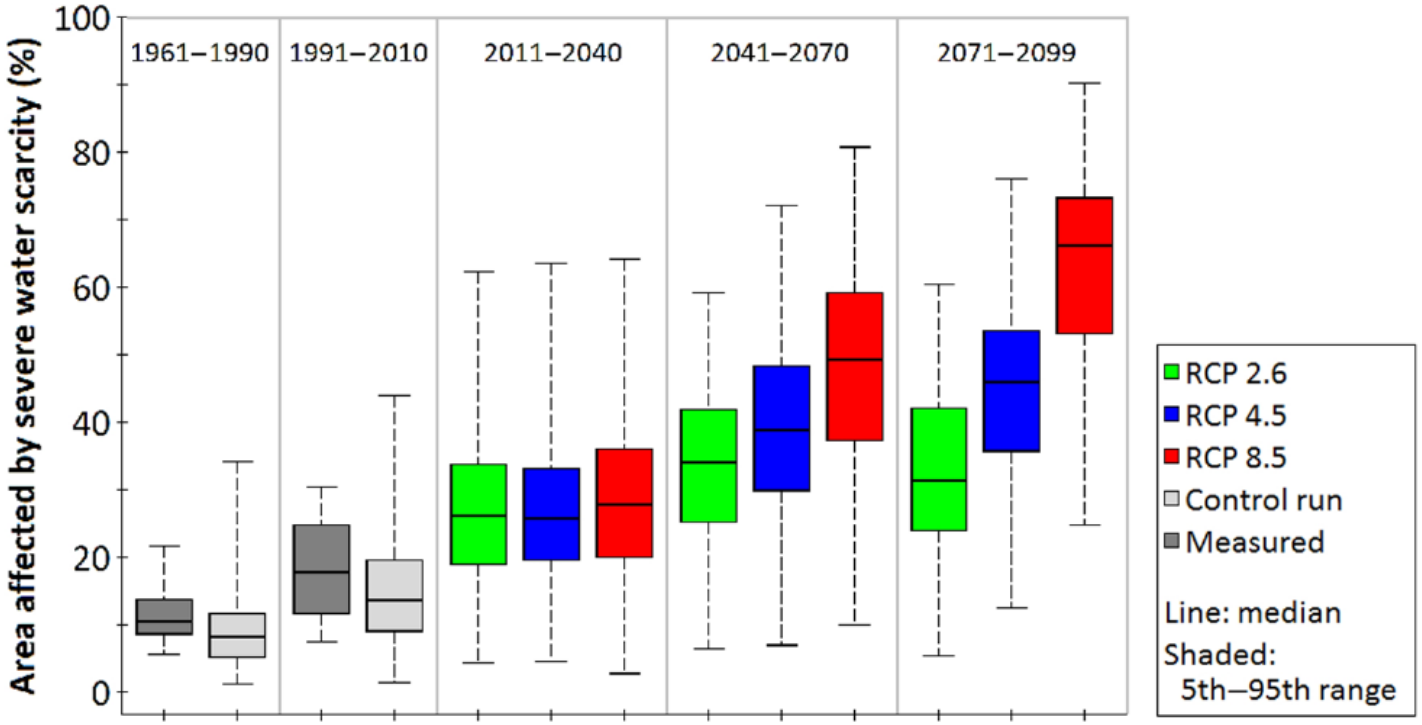
Does weather contribute to yield variation?



Vertical lines show cases with more than 25% yield reduction

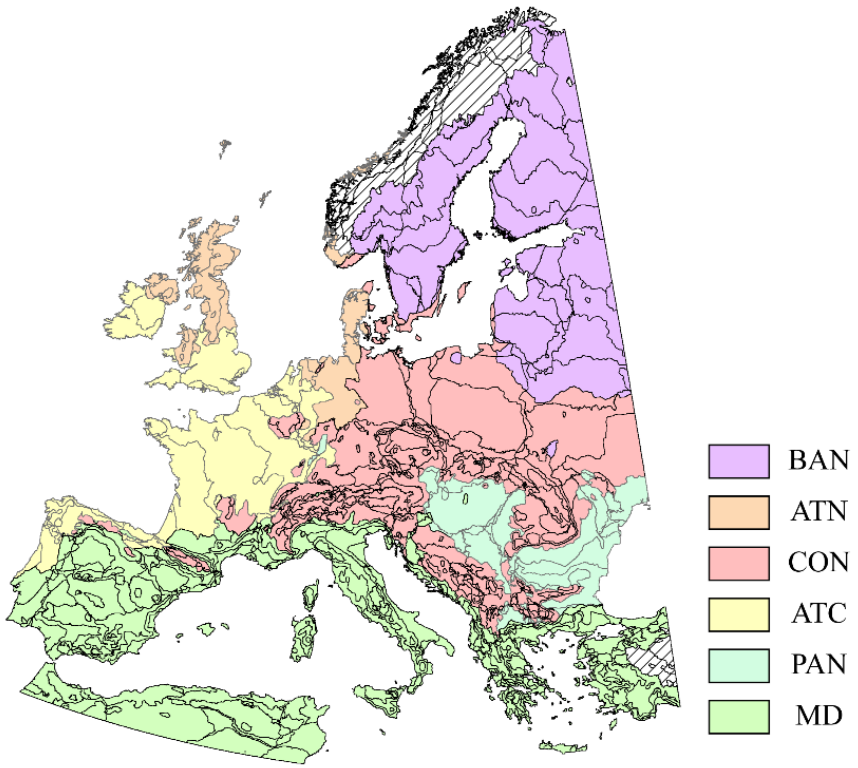
Future severe drought in wheat

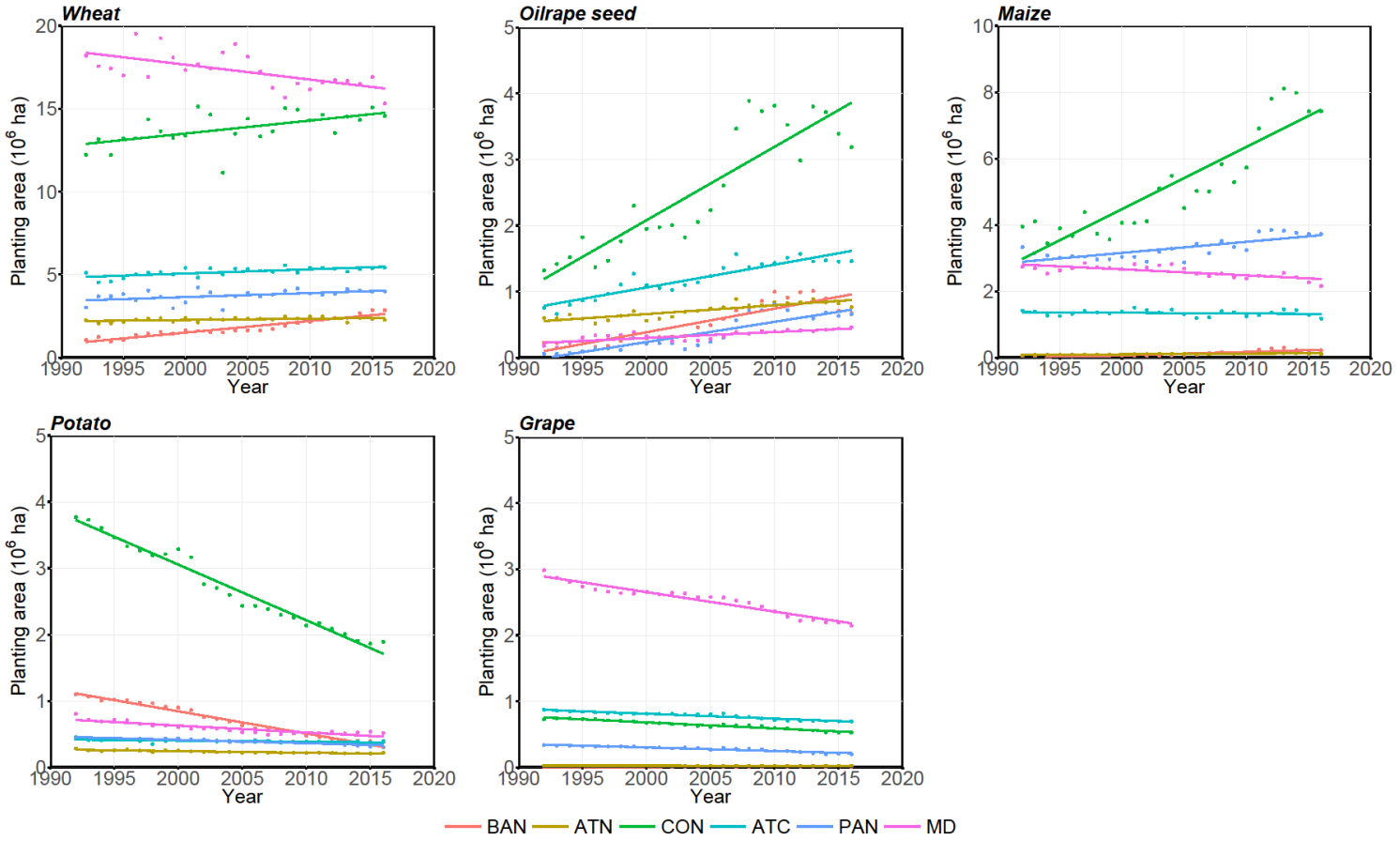
- Calculated area with severe drought for the world wheat area over the growing period for wheat
- The area with severe drought has increased by 50 % relative to 1961-1990
- Under moderate climate change the area with severe drought will quadruple by mid century
- This increase in severe drought also happens in the world wheat exporting countries, affecting grain price



Trnka et al. (2019) Sci. Adv. 5, eaau2406

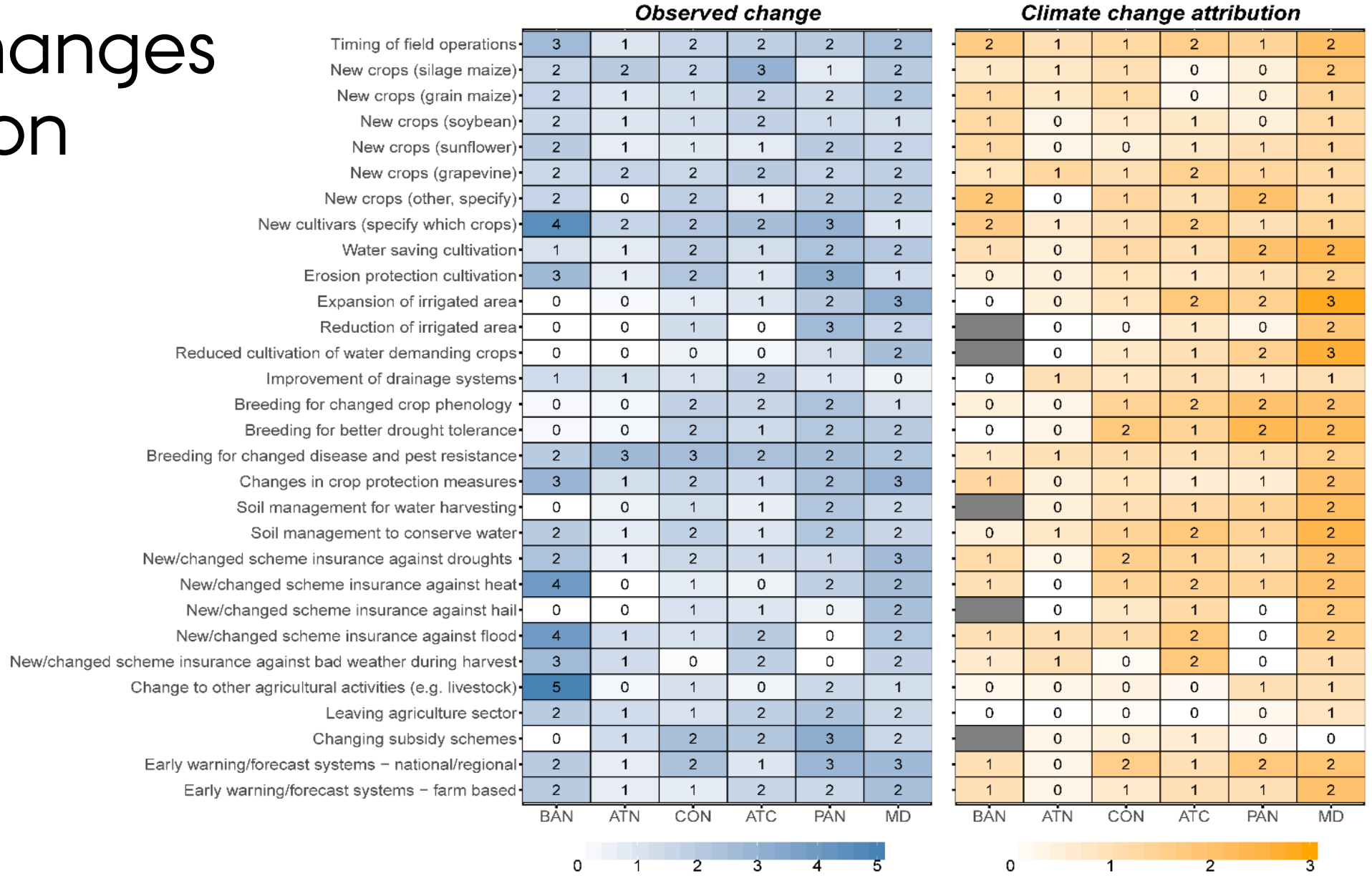
Survey of impacts and adaptation in European crops



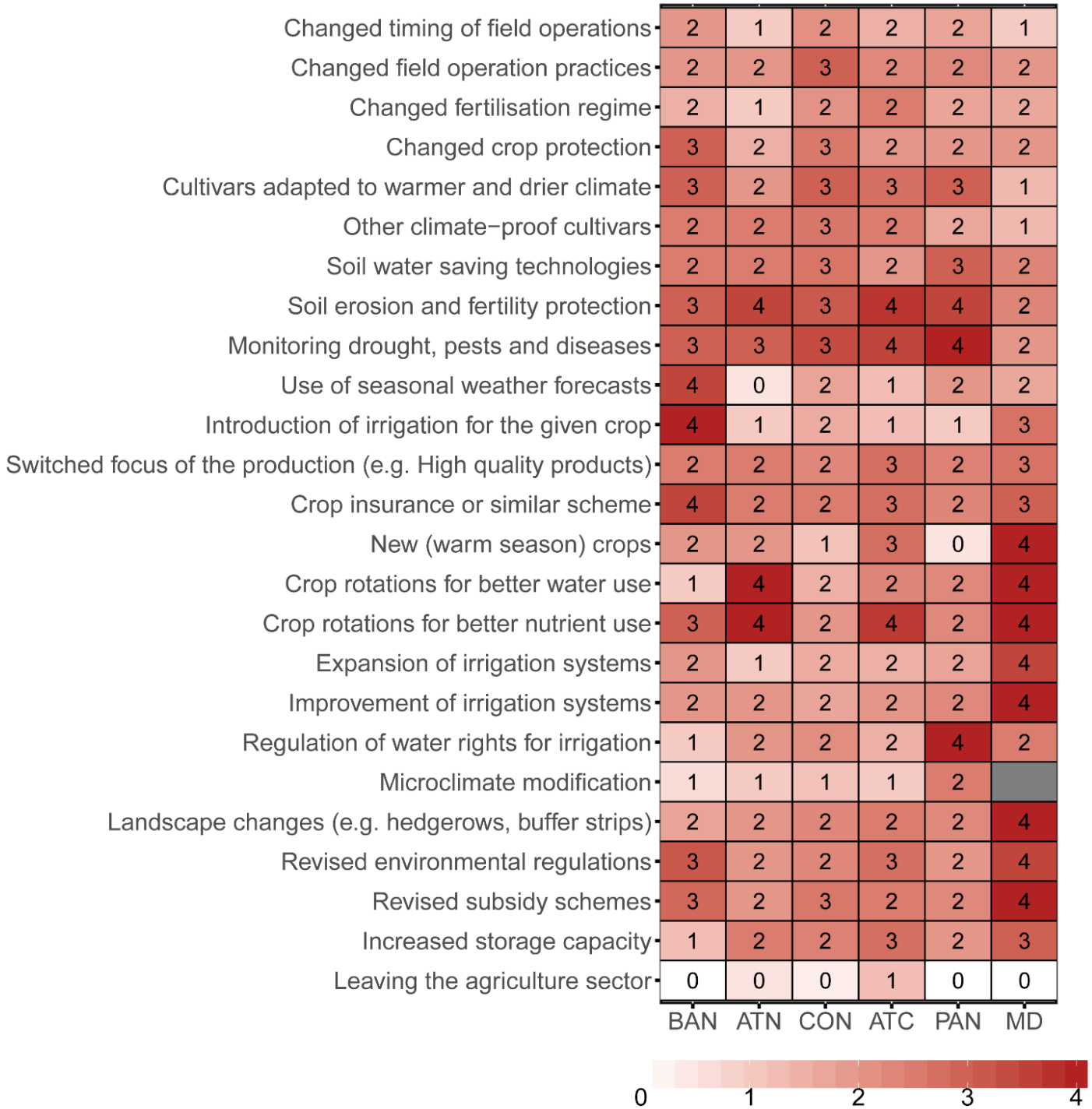


JØRGEN EIVIND OLESEN
HEAD OF DEPARTMENT, PROFESSOR

Observed changes and attribution



Planned adaptations



Response of agriculture to climate change

- The ongoing climate change with higher temperatures, increased variability and extremes will challenge most agricultural systems and often make mitigation efforts more challenging
- Globally, climate change will increase extent and frequency of drought, negatively affecting food supply and food security
- This necessitates development of technologies and agricultural systems that emphasize both low GHG emissions as well as resilience to climatic stresses

Satellite image showing drought in 2018 over West Zealand

AARHUS
UNIVERSITY