Changing climate and varying extremes

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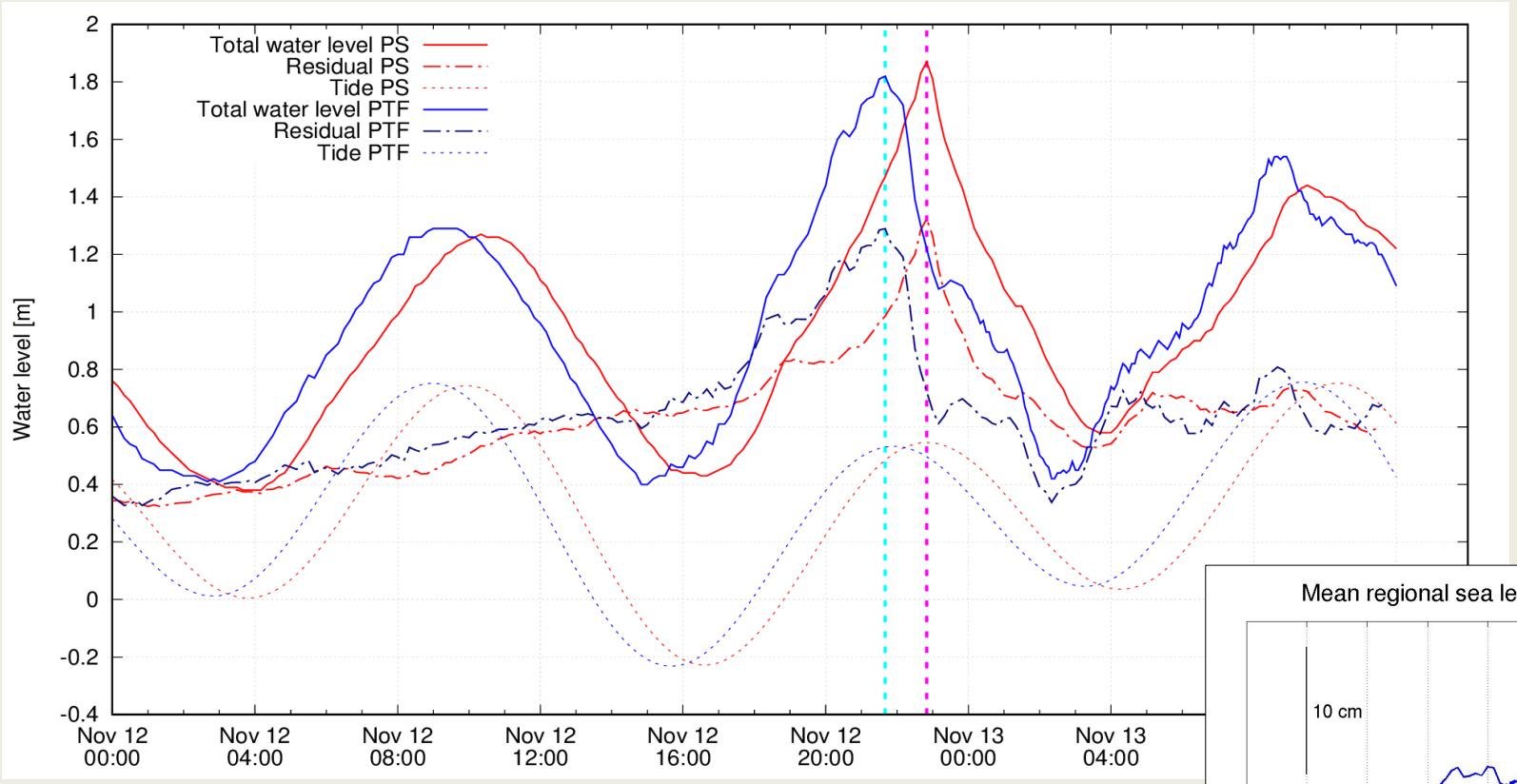
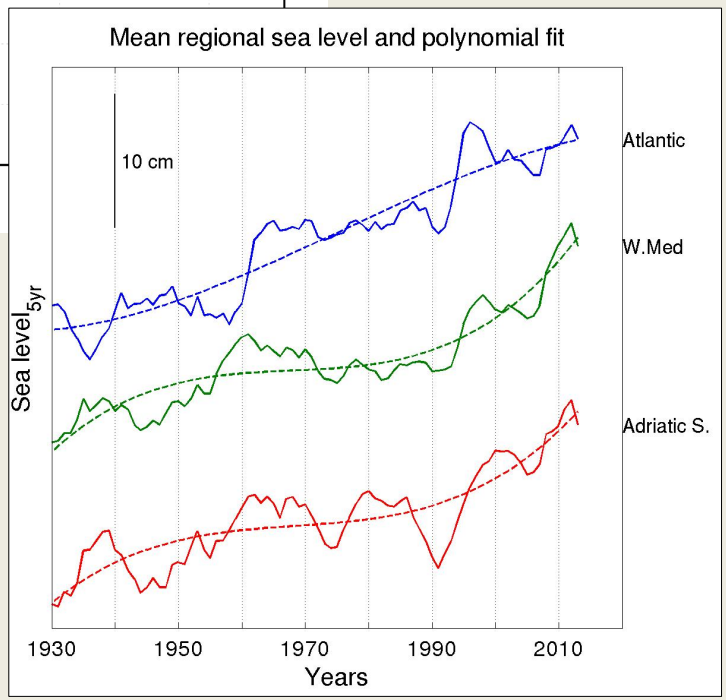
Hydrological Measurements in a Changing World, Zagreb, 2019

Venice, 12 November 2019, second-highest sea level

Contributions to sea level

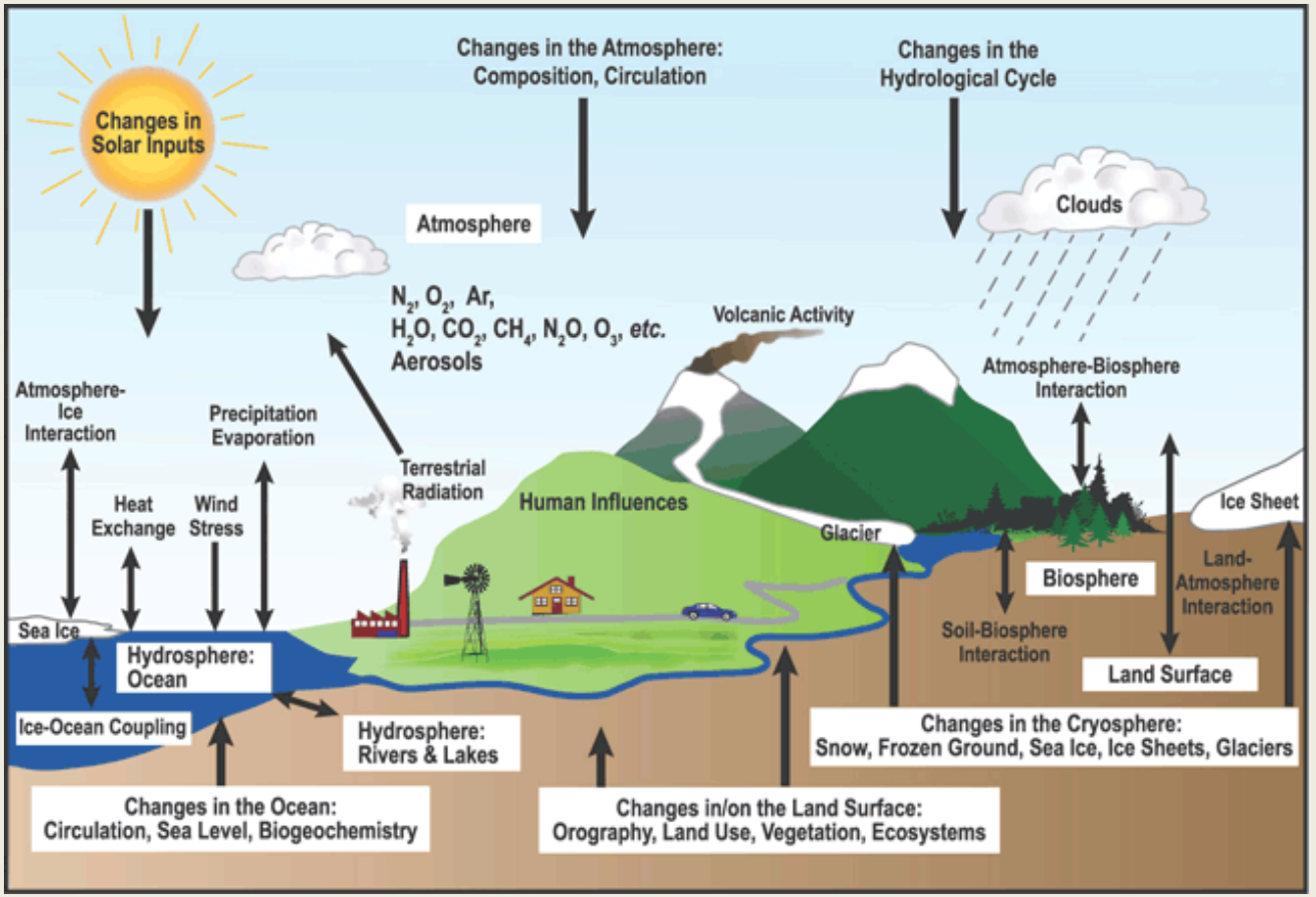


G. Umgiesser et al. (2019)



M. Orlić et al. (2018)

Climate system



- Atmosphere
- Oceans and seas
- Cryosphere
- Rivers and lakes
- Ground water
- Land
- Biosphere

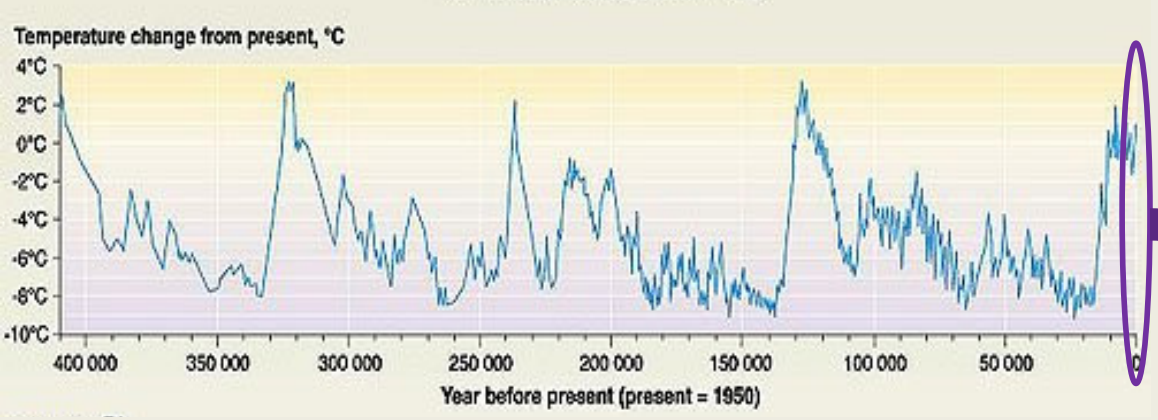
Measurement of temperature

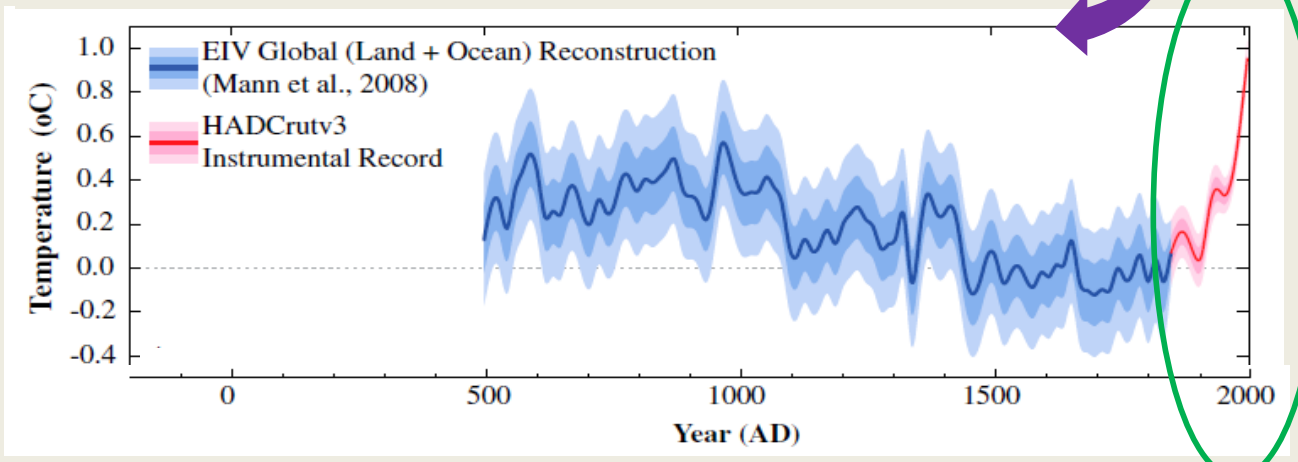
Ice core

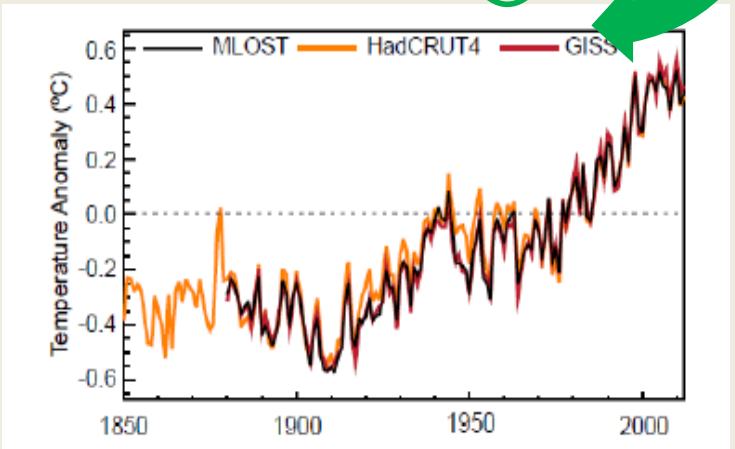
Thermometer

Satellite sensor

Observed temperature changes

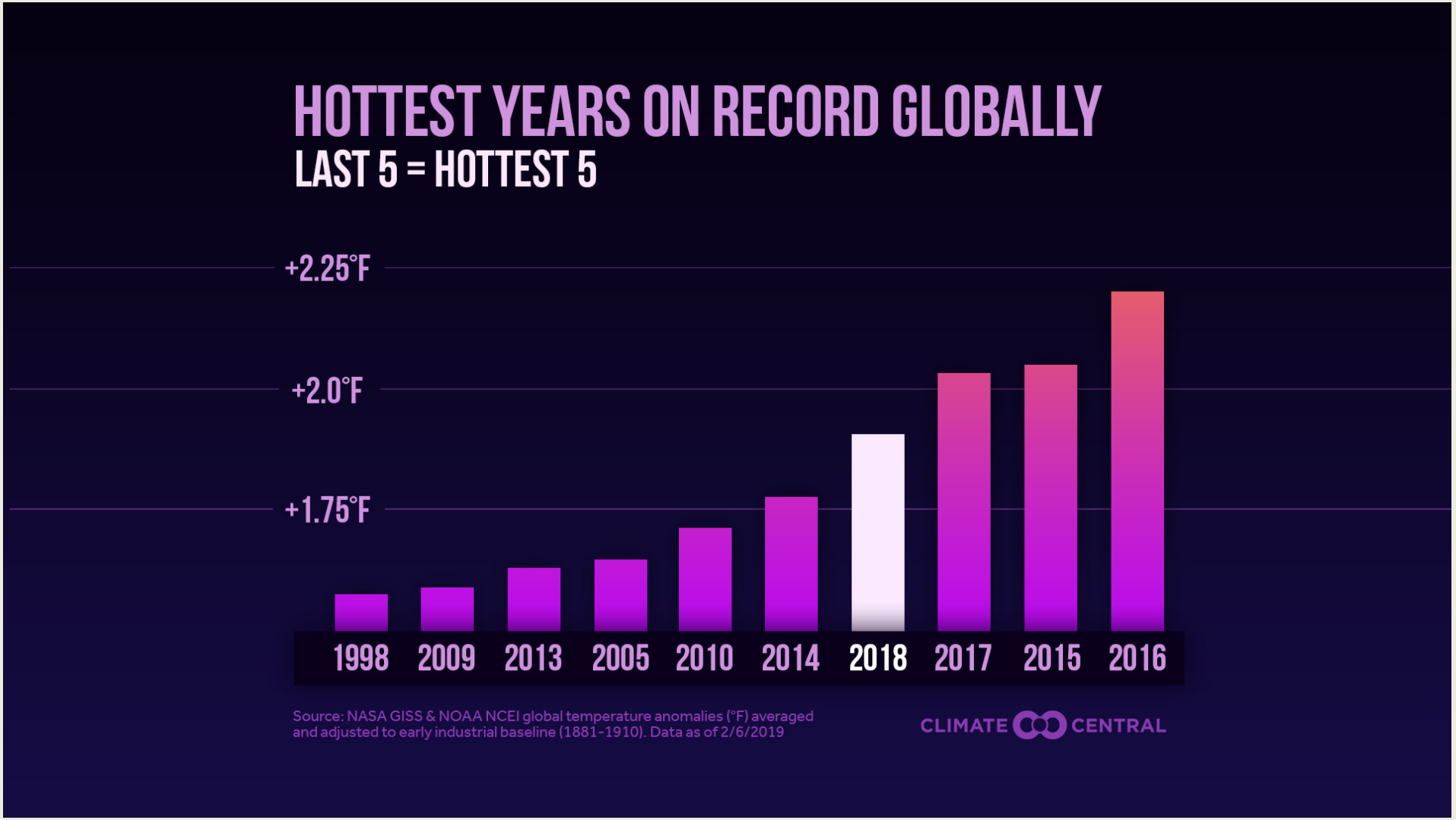




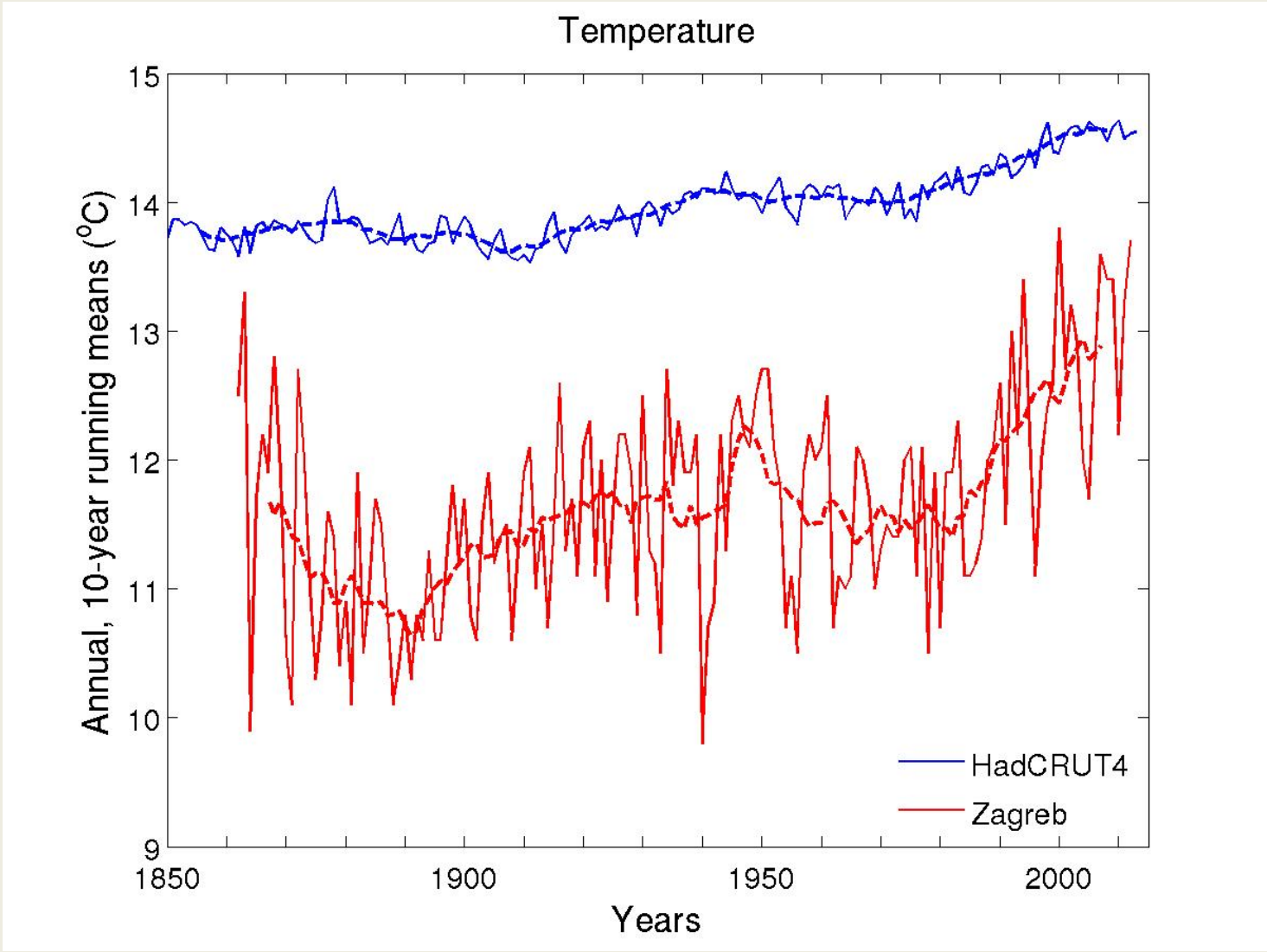


J. R. Petit et al. (1999),
A. C. Kemp et al. (2011),
IPCC (2013)

Temperature records



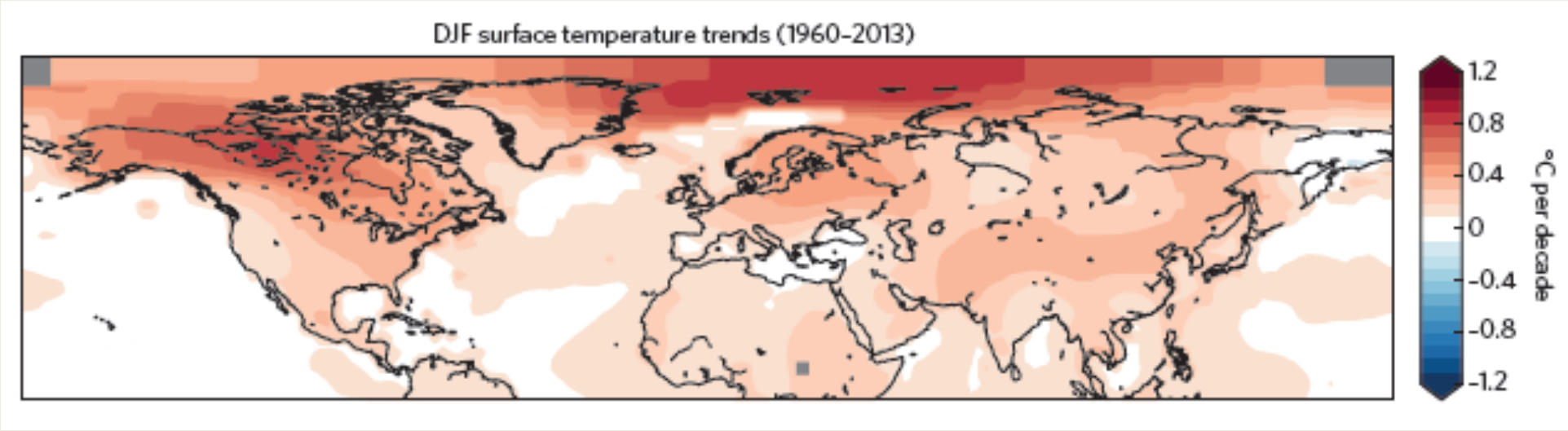
Comparison of global and regional temperatures



M. F. Maury (1853)

I. Stožir (1861)

Wintertime temperature trends 1960–2013

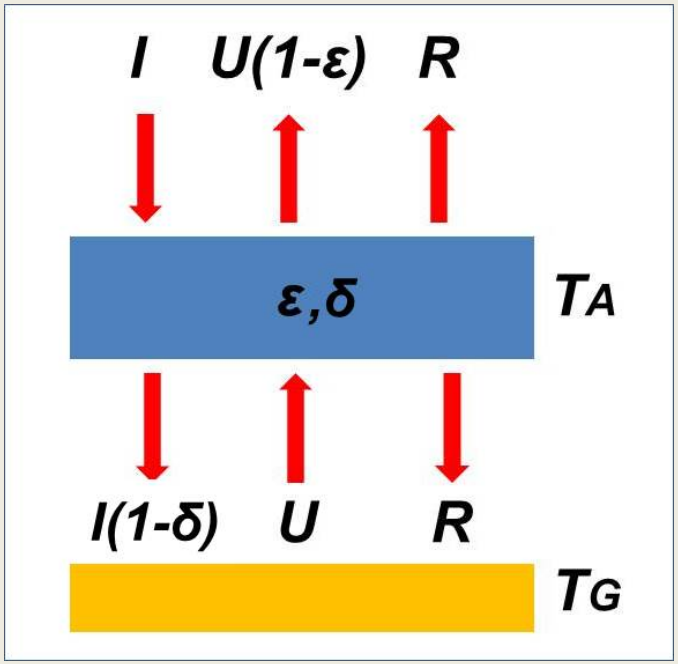


J. Cohen et al. (2014)

Process influencing the extremes

Greenhouse effect and its changes

S. Arrhenius (1896)

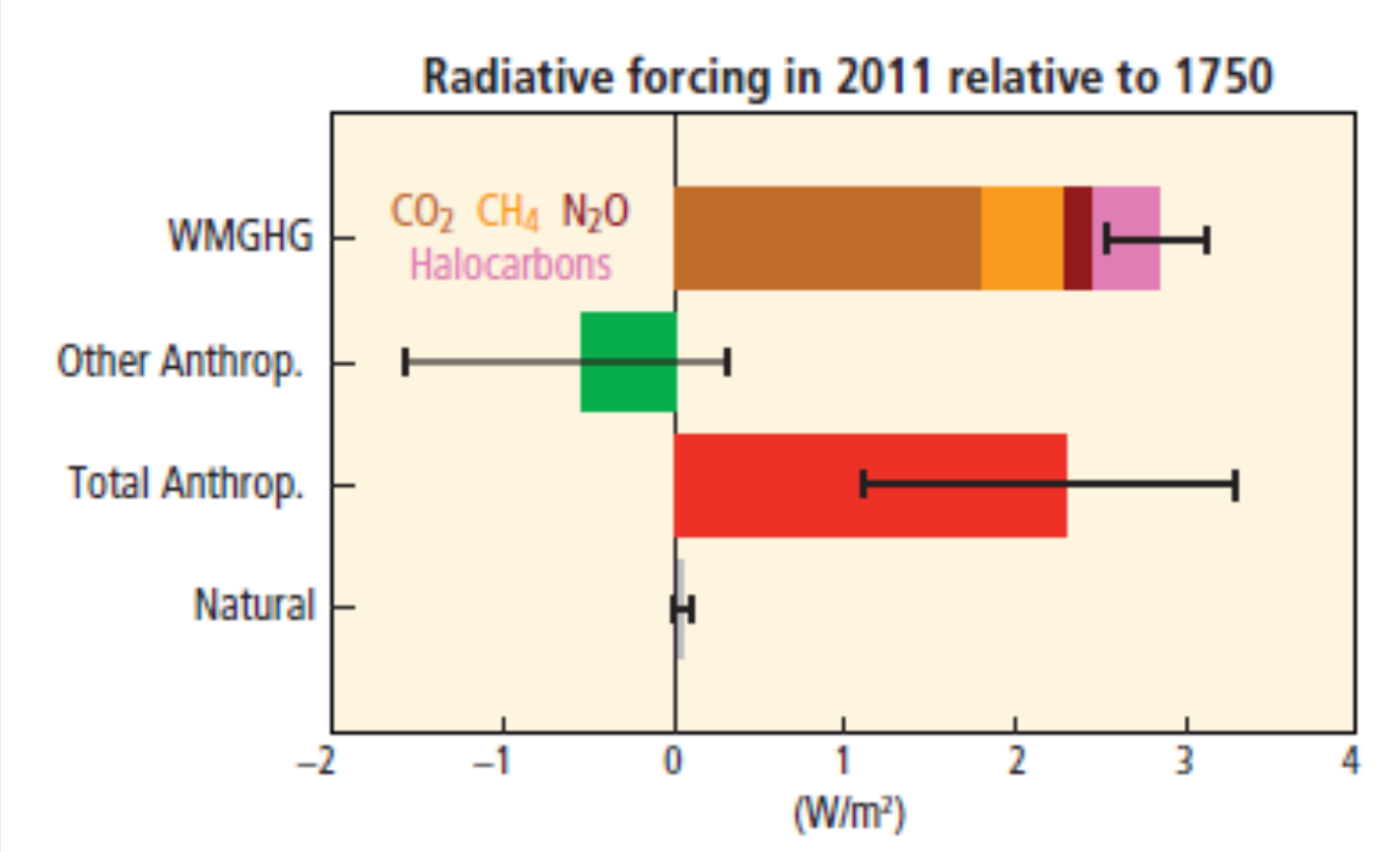


$$U = \frac{I(2-\delta)}{2-\varepsilon}, R = \frac{I(\varepsilon+\delta-\varepsilon\delta)}{2-\varepsilon},$$

$$T_G = \sqrt[4]{\frac{I(2-\delta)}{\sigma(2-\varepsilon)}}, T_A = \sqrt[4]{\frac{I(\varepsilon+\delta-\varepsilon\delta)}{\sigma\varepsilon(2-\varepsilon)}}$$

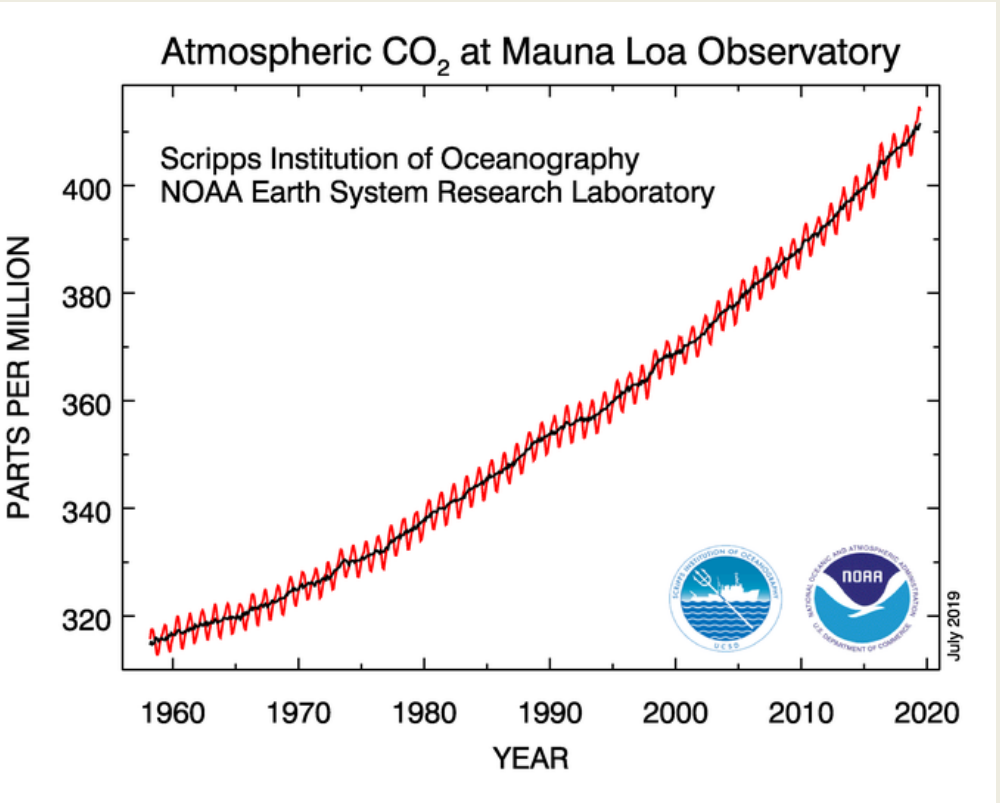
$$I = 239\ \frac{W}{m^2}, \sigma = 5.67\ 10^{-8}\ \frac{W}{m^2K^4}, \varepsilon = k_e\rho_e H, \delta = k_d\rho_d H$$

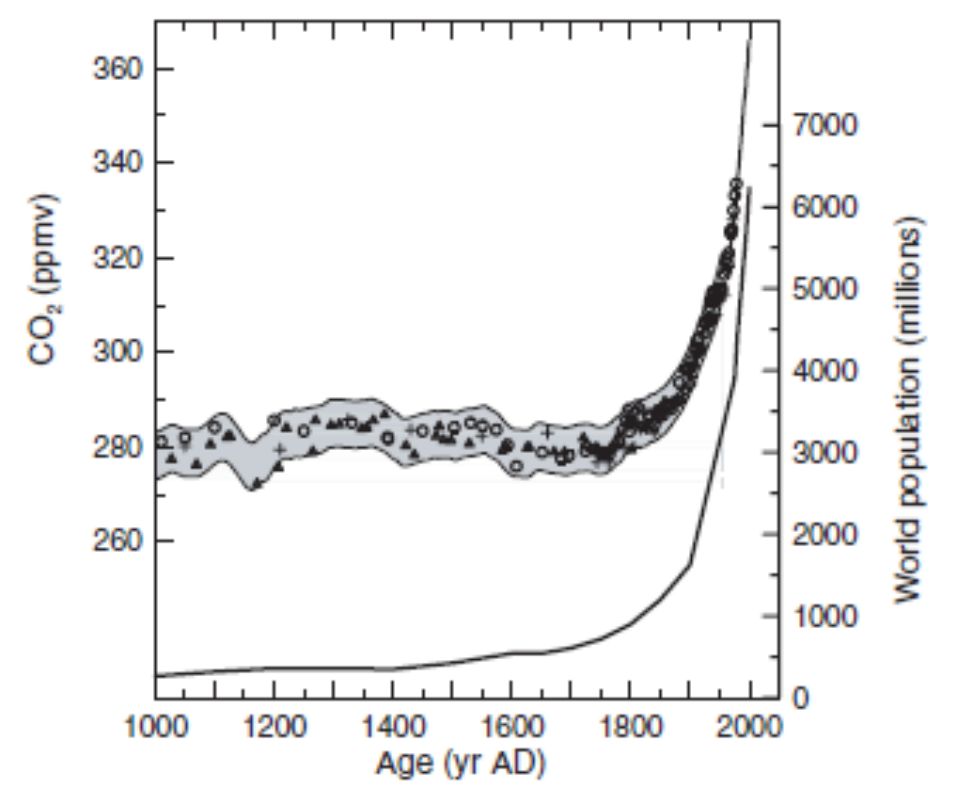
External influences imposed on the models



IPCC (2014)

Greenhouse gases (CO_2…)





J. M. Barnola (1999)

Numerical modeling

J. G. Charney et al. (1950)

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho}\frac{\partial p}{\partial x}+F_x$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho}\frac{\partial p}{\partial y}+F_y$$

$$0=-\frac{1}{\rho}\frac{\partial p}{\partial z}-g$$

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x}(\rho u)+\frac{\partial}{\partial y}(\rho v)+\frac{\partial}{\partial z}(\rho w)=0$$

$$p=\rho RT$$

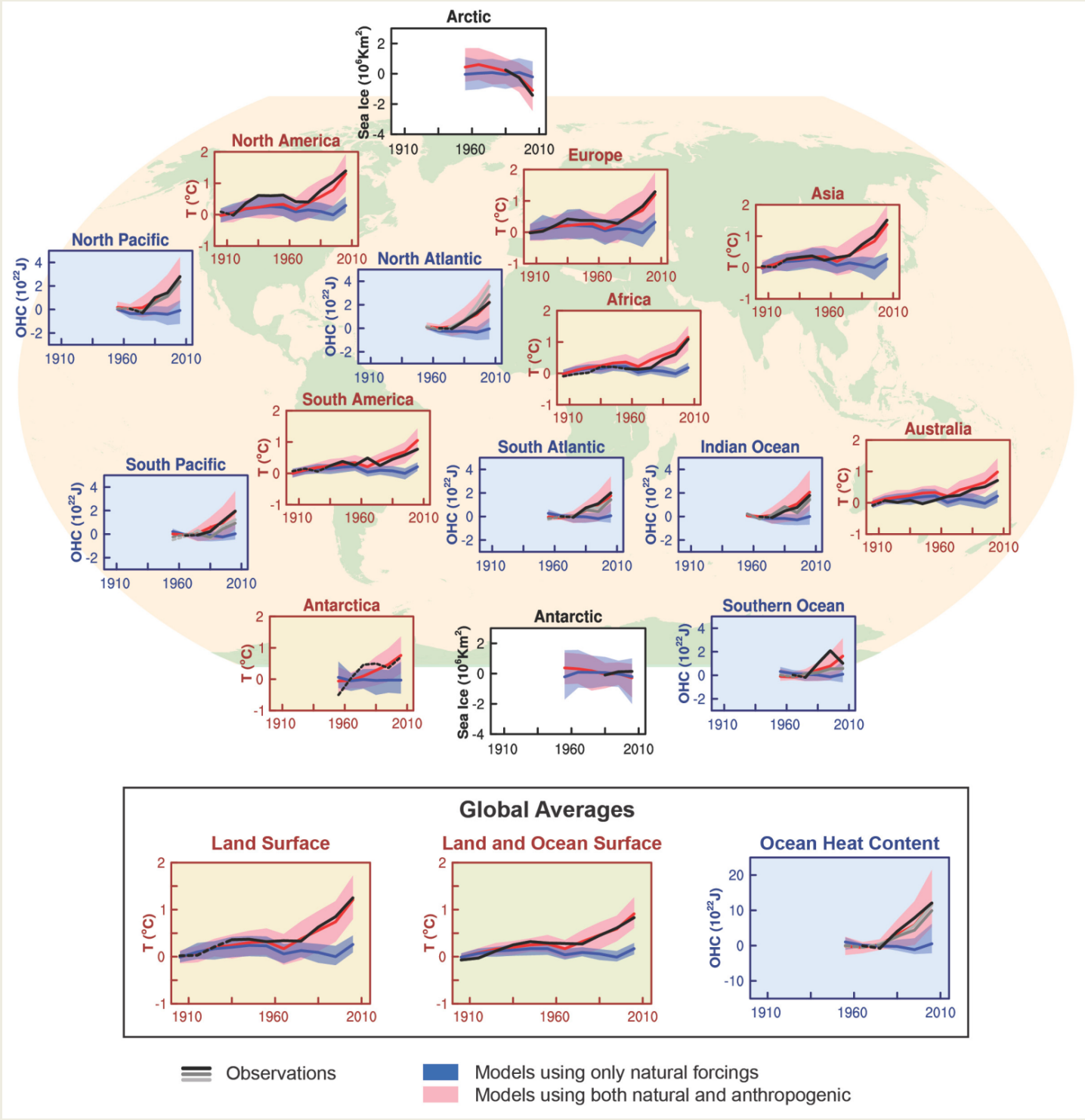
$$C_p\frac{dT}{dt}-\frac{1}{\rho}\frac{dp}{dt}=Q$$

IBM POWER7 775 cluster

F_x, F_y – *friction*

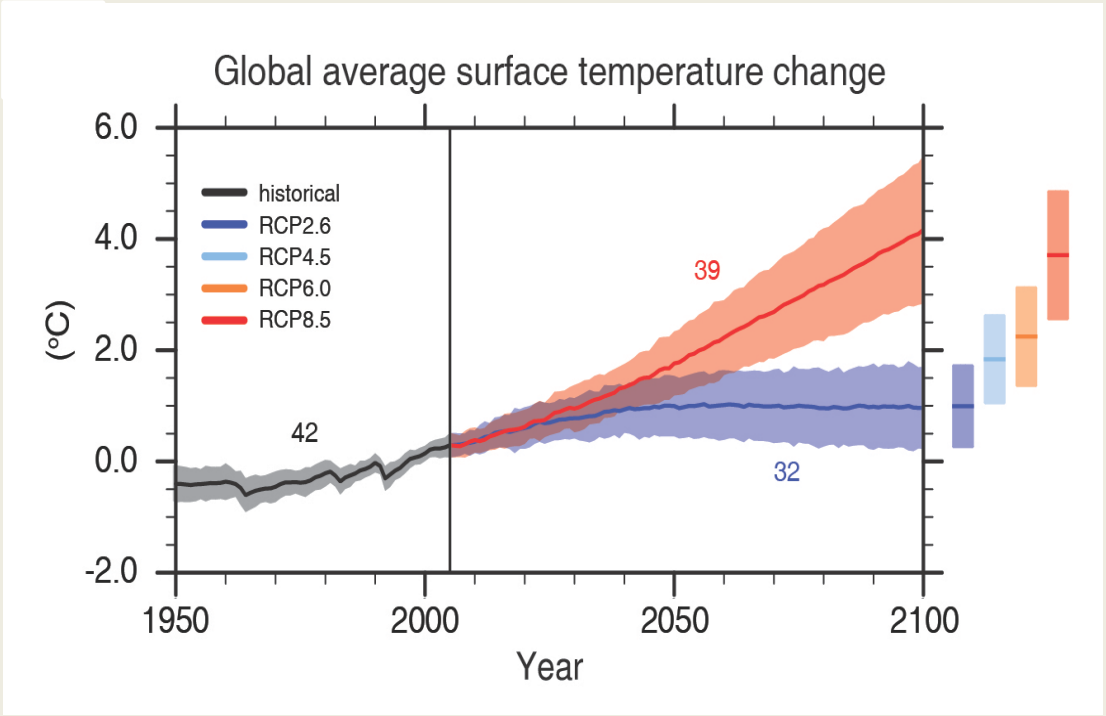
Q – *heating / cooling*

Modeling results

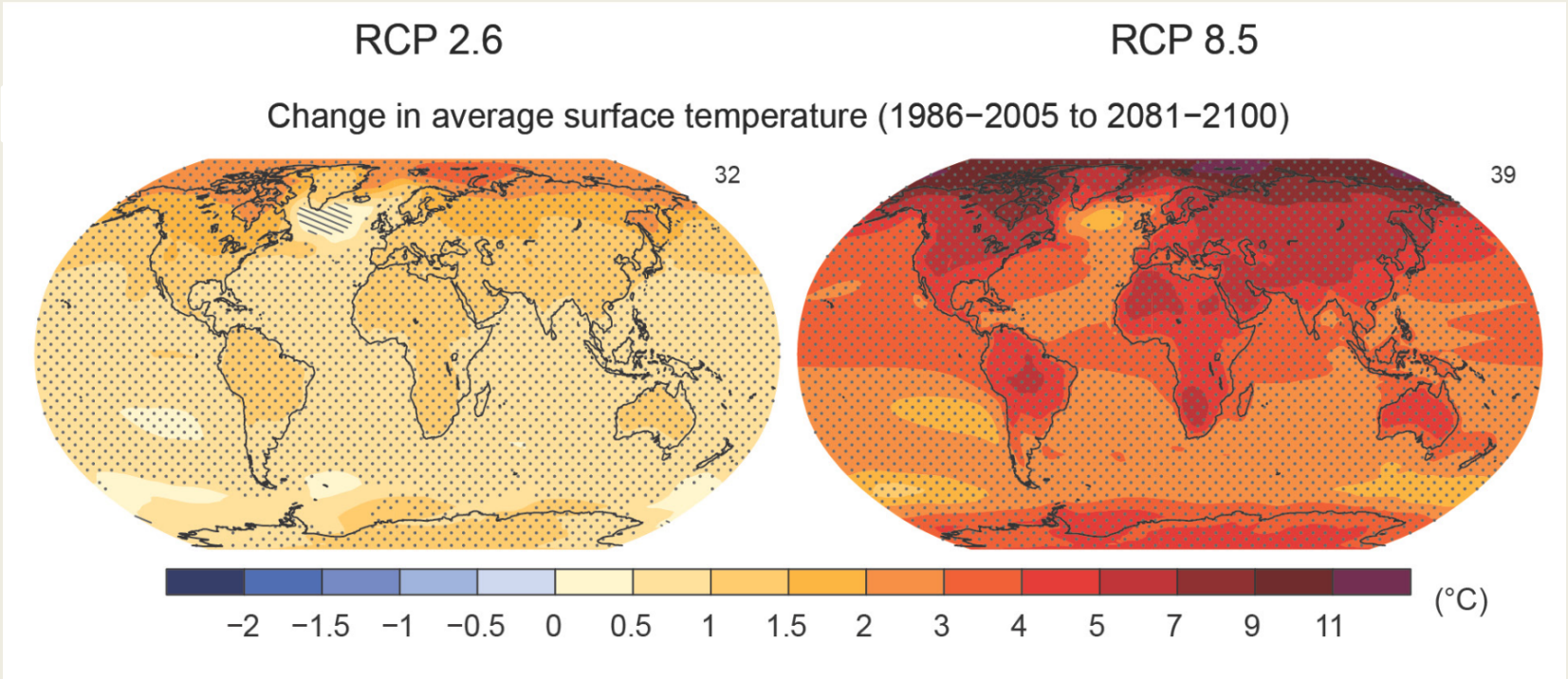


IPCC (2013)

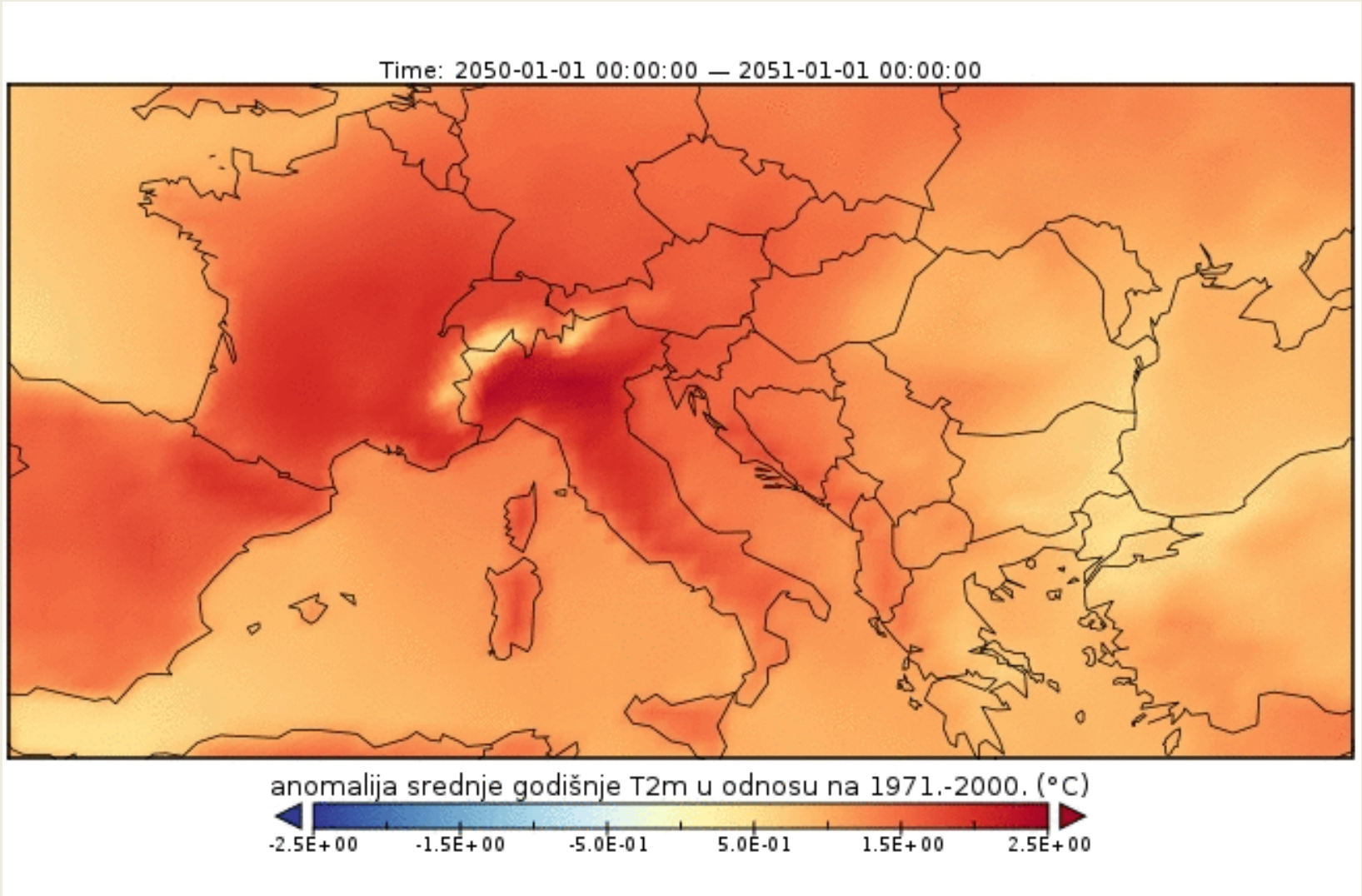
Temperature projections



IPCC (2013)

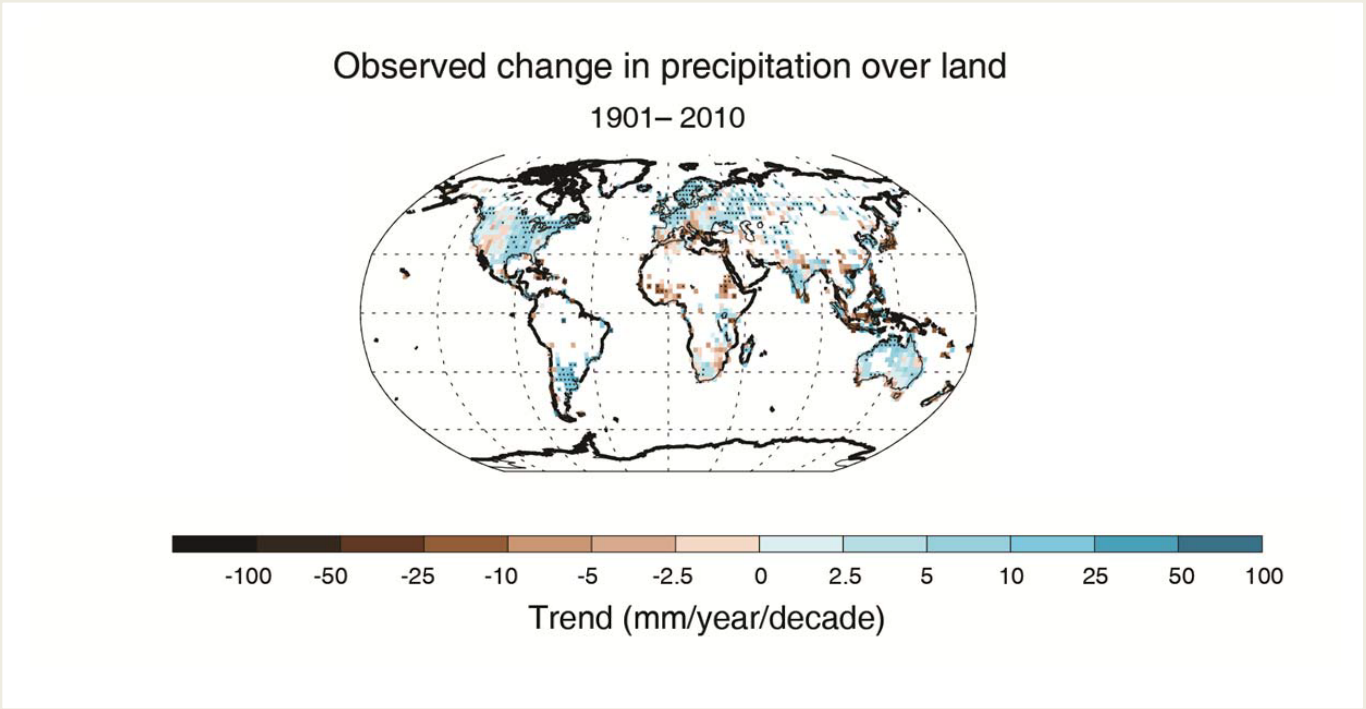


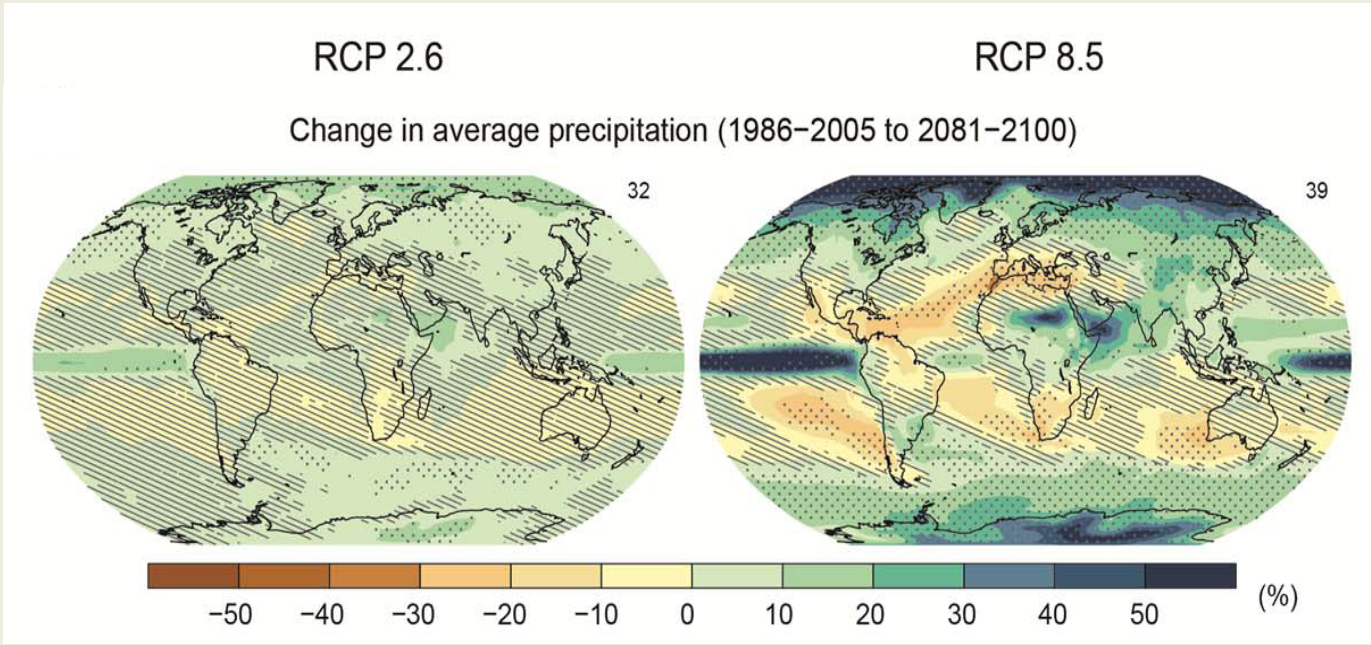
Simulation of regional temperatures (1970–2050)



RCM RegCM4 (12.5 km) + CMIP5 GCM EC-Earth
1970–2005: measured concentration of greenhouse gases
2006–2050: IPCC scenario RCP4.5

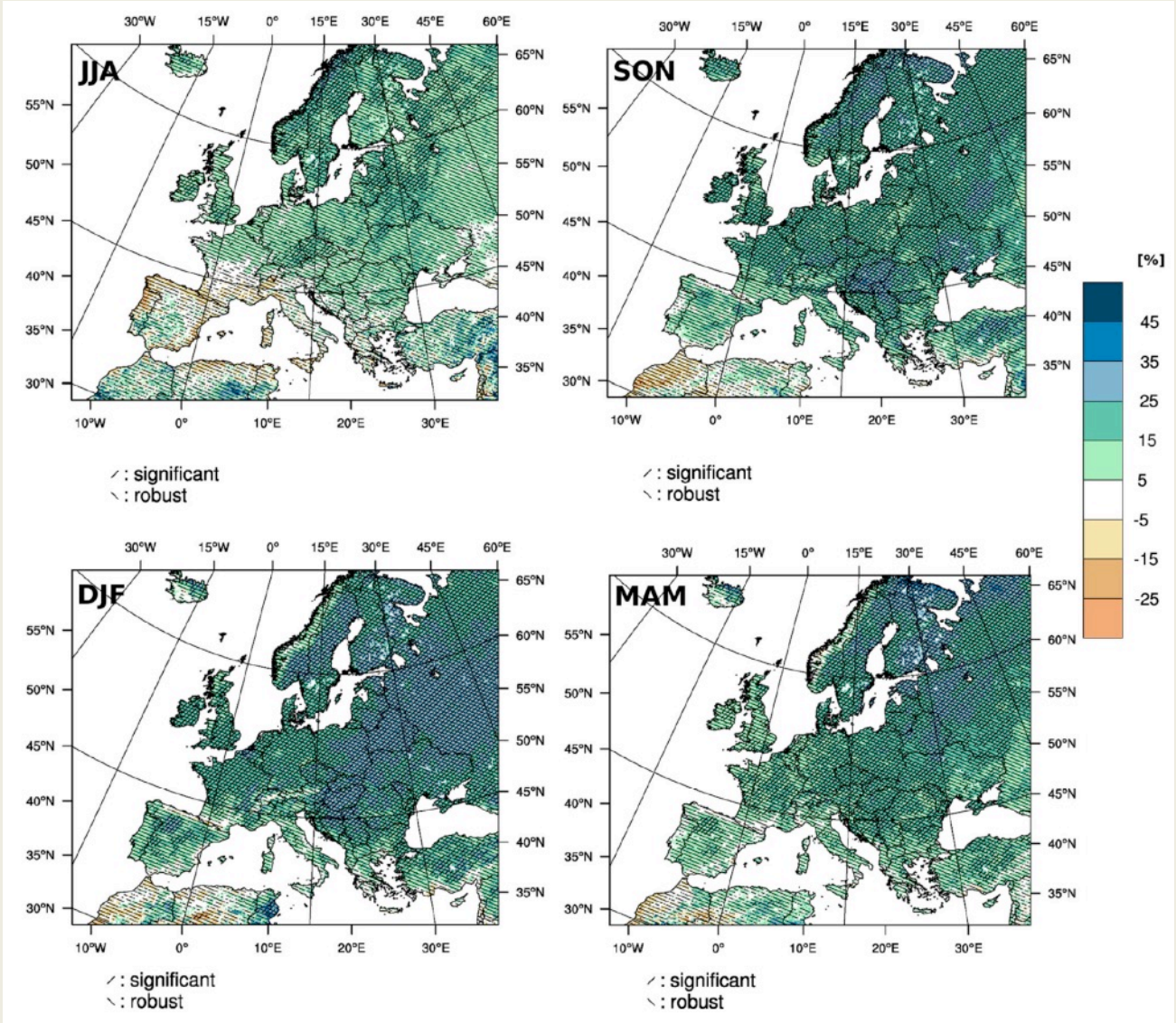
Past and future precipitation





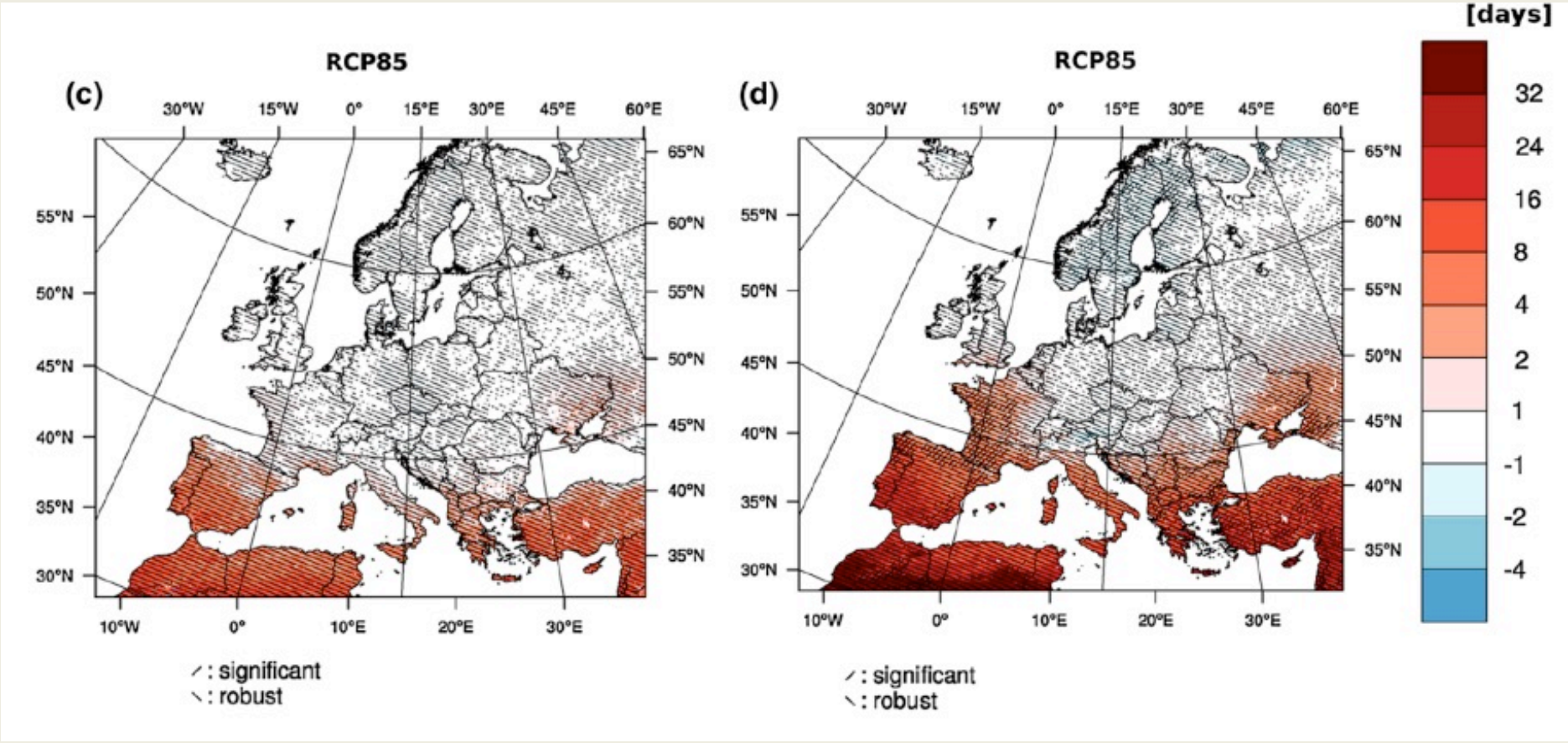
IPCC (2013)

Change of heavy precipitation (percent, 1971/2000–2071/2100, scenario RCP8.5)



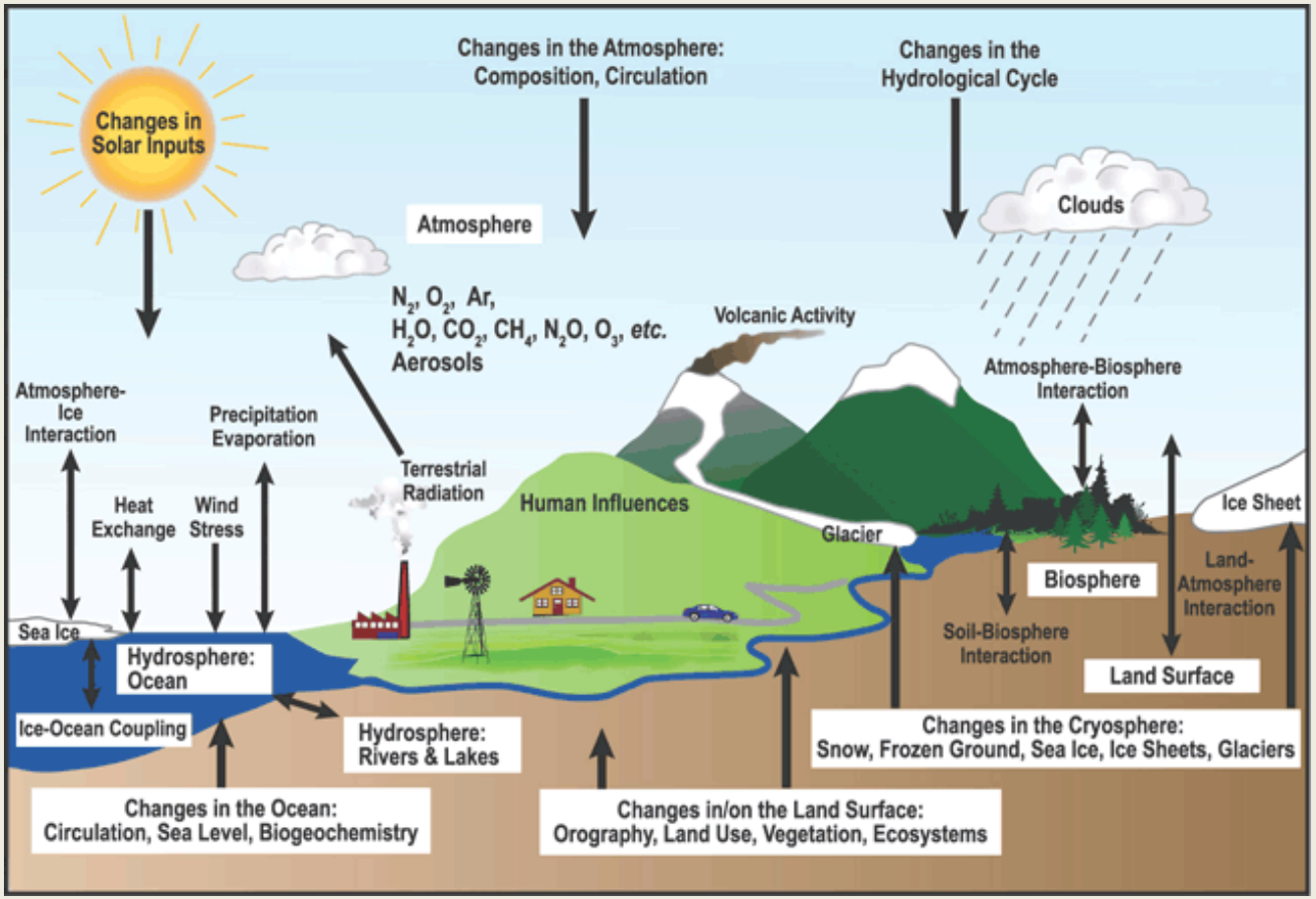
D. Jacob et al. (2014)

Change of the duration of dry spells (1971/2000–2021/2050, 1971/2000–2071/2100)



D. Jacob et al. (2014)

Climate system



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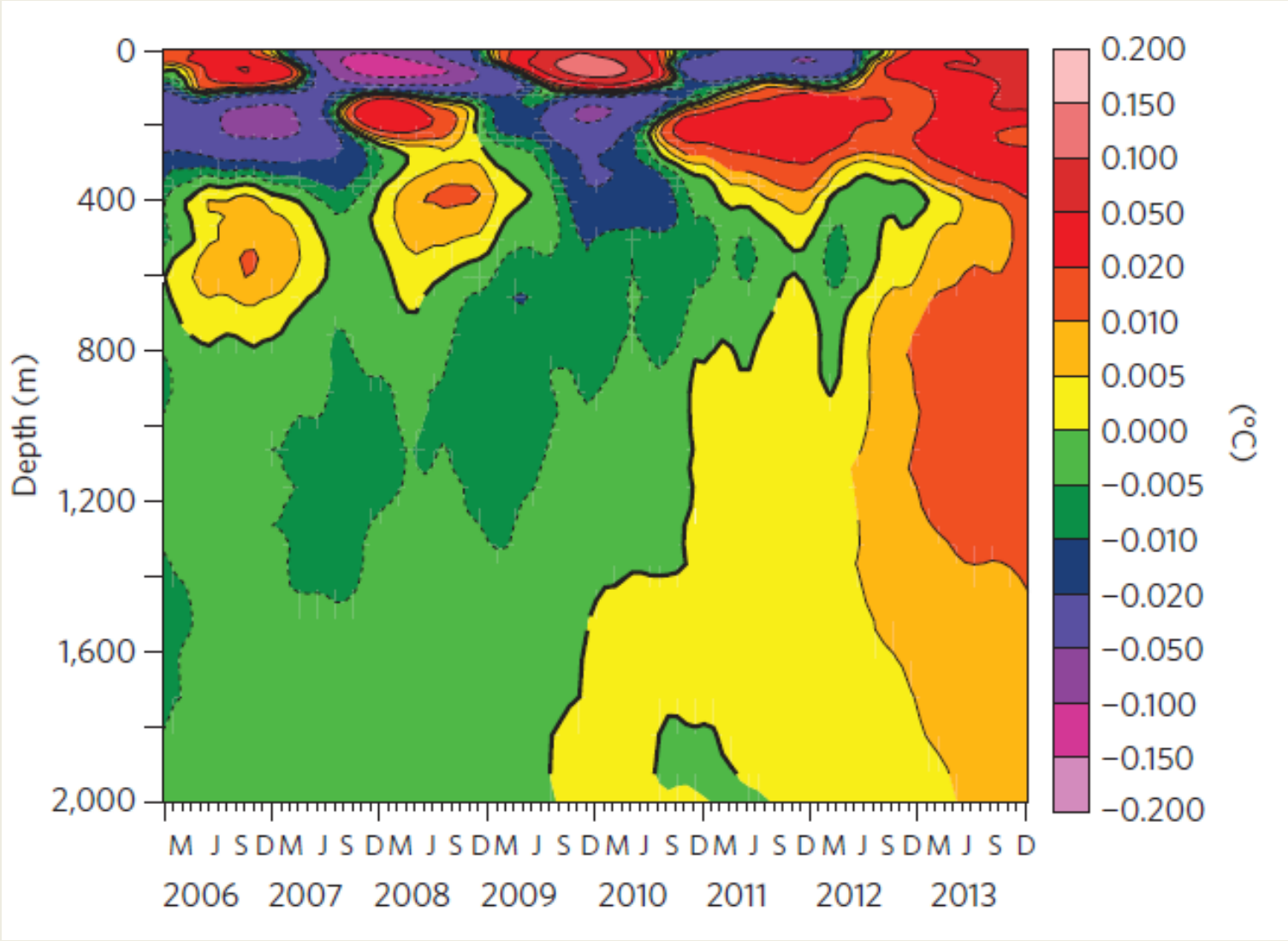
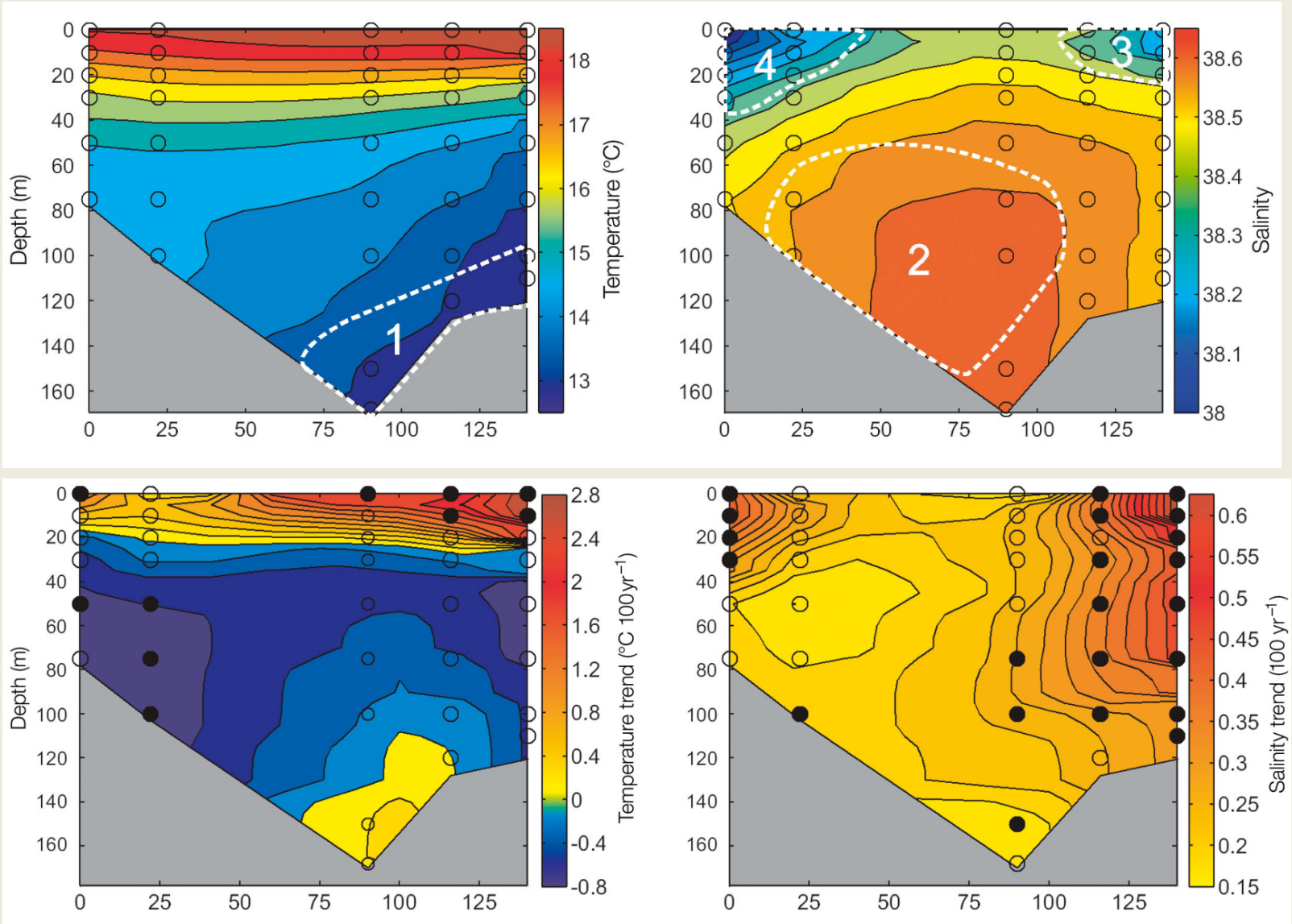
Measured sea temperatures (ARGO network)



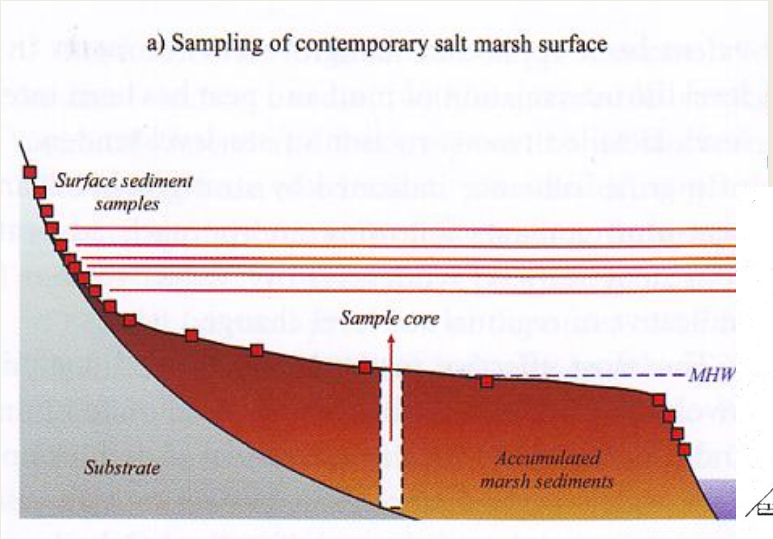
D. Roemmich et al. (2015)

Temperature and salinity of the Adriatic Sea: mean values and trends (1952–2010)

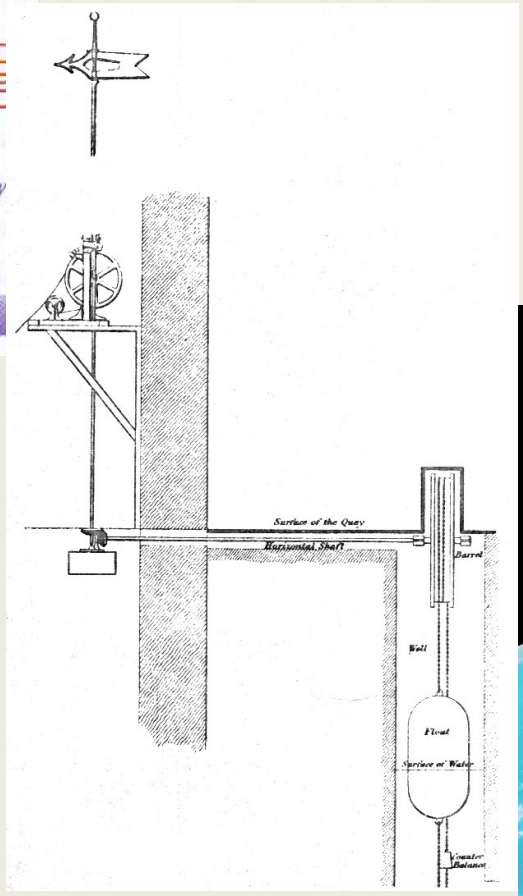


I. Vilibić et al. (2013)

Measurement of sea-level height

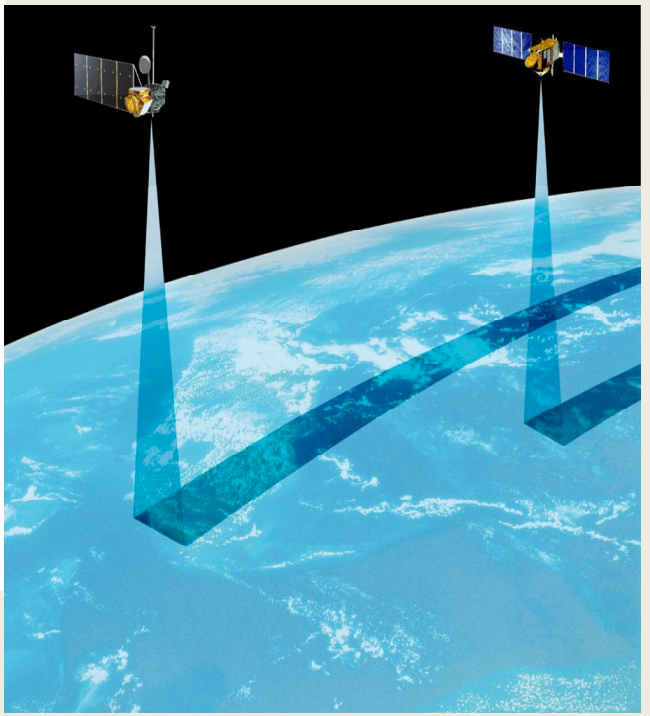


Sediment core

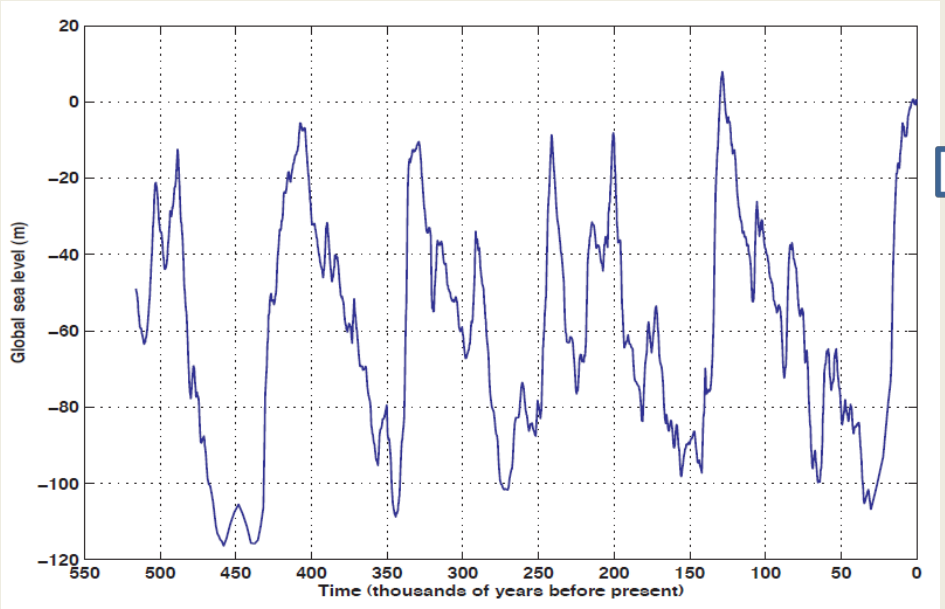


Tide gauge

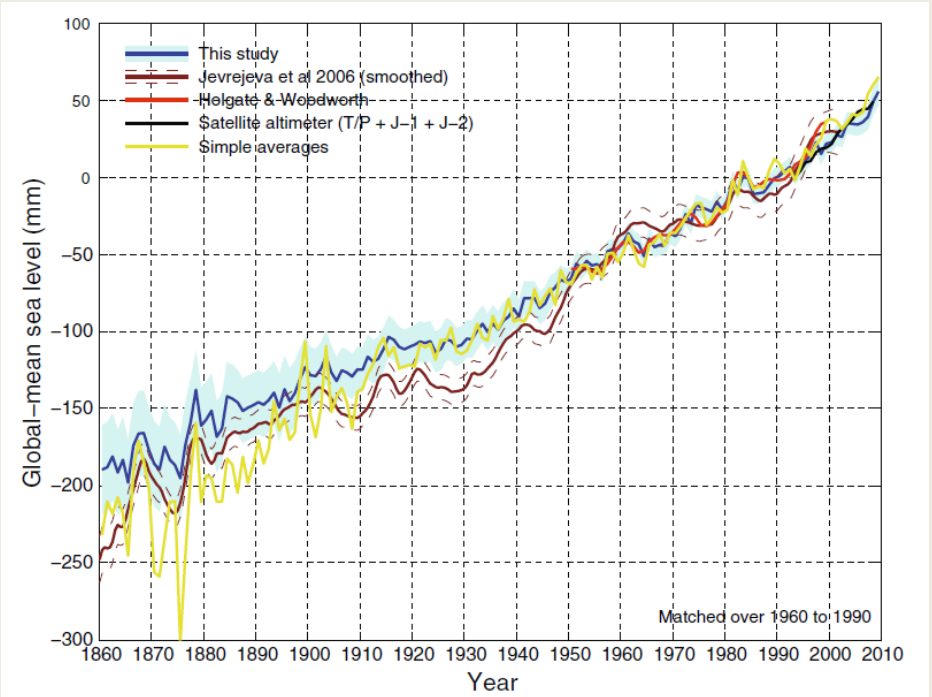
Satellite altimeter



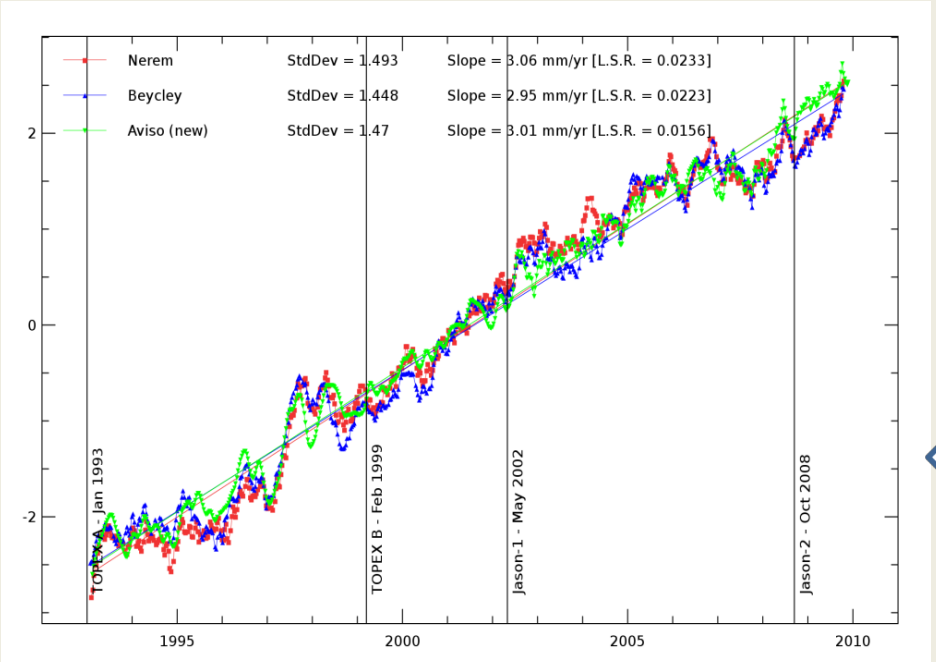
Global sea-level variability



E. J. Rohling et al. (2009)

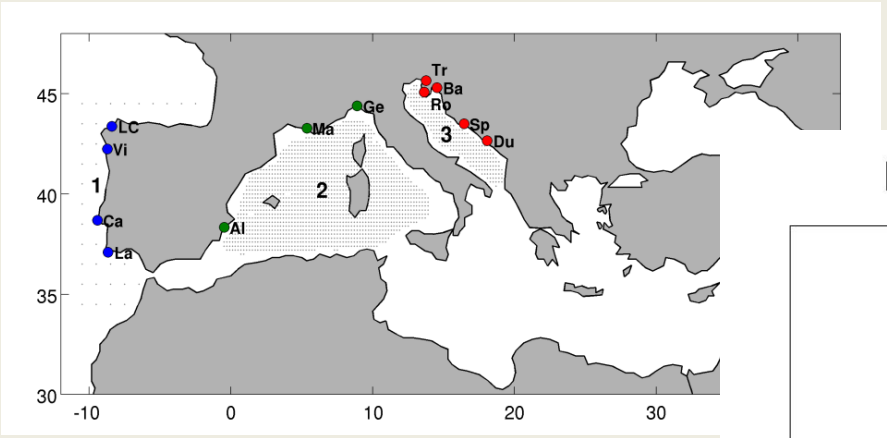


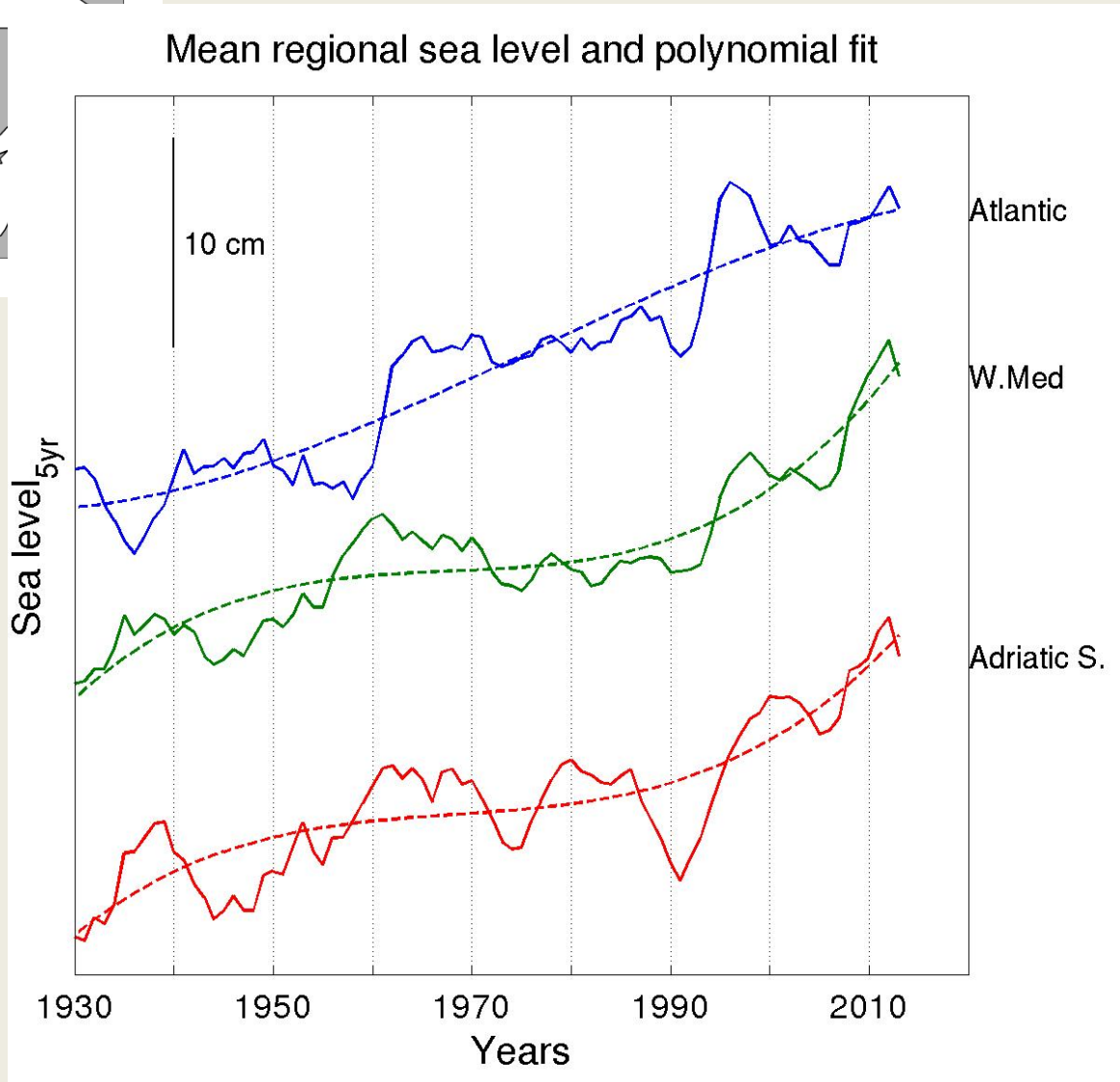
J. A. Church, N. J. White (2011)



A. Cazenave (2010)

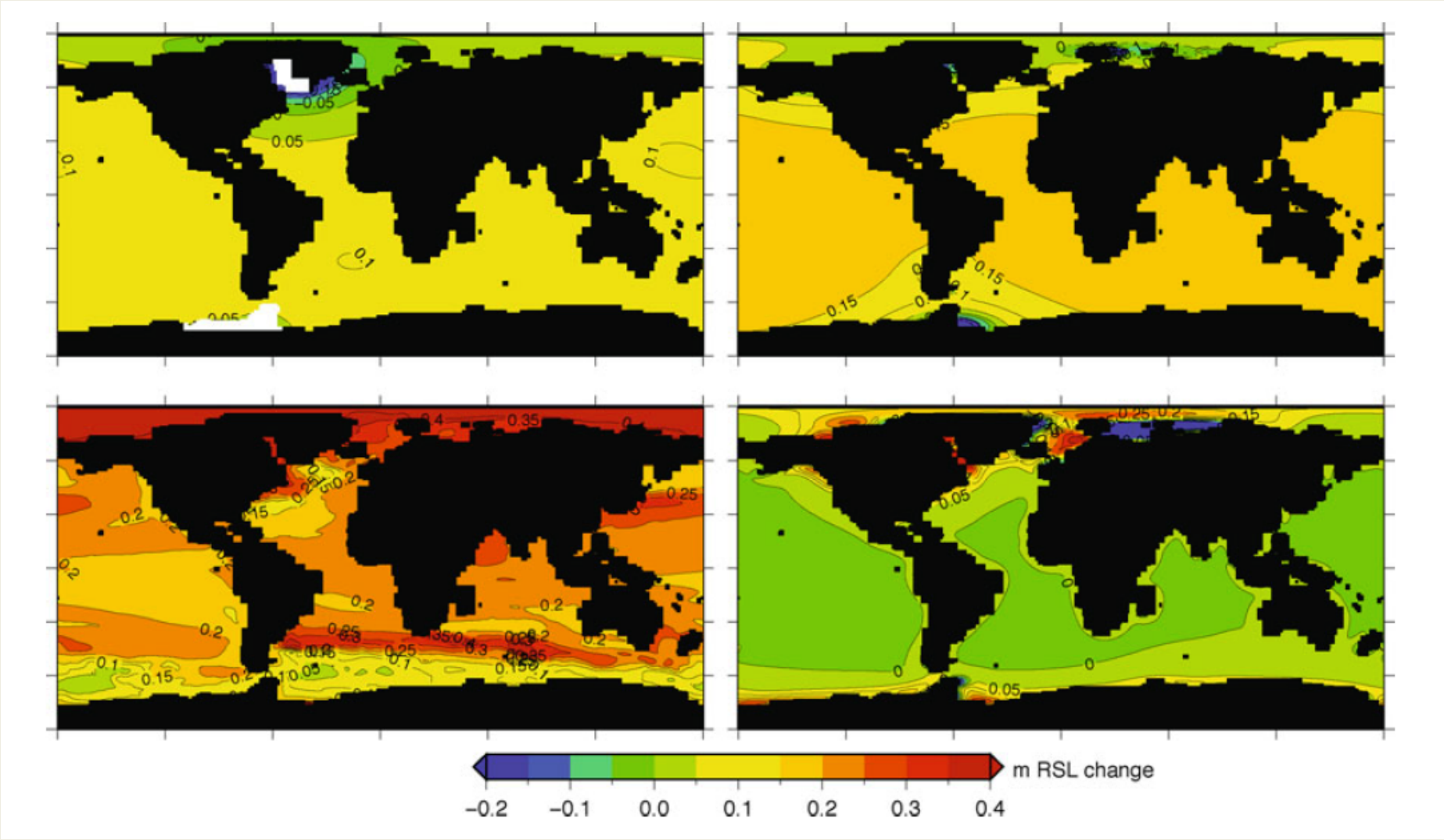
Mediterranean sea level





M. Orlić et al. (2018)

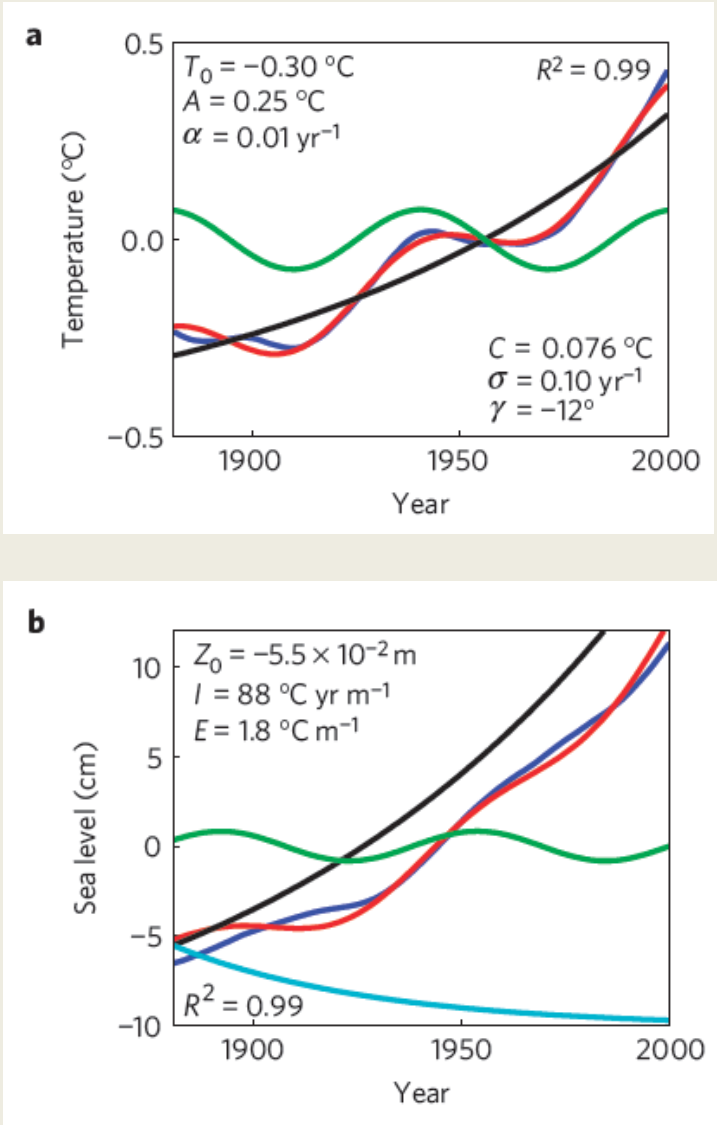
Global sea-level projections – modeling (change from 1980/1999 to 2090/2099, scenario A1B)



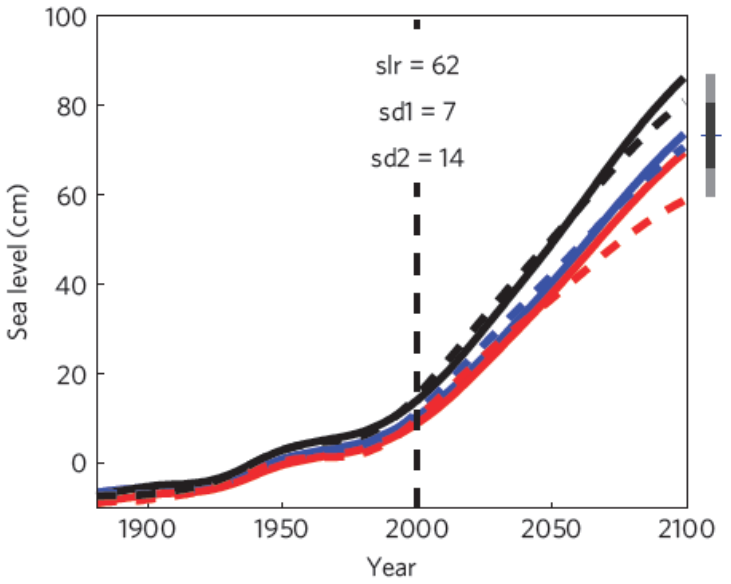
A. B. A. Slangen et al. (2012)

Global sea-level projections – semi-empirical method

Analysis

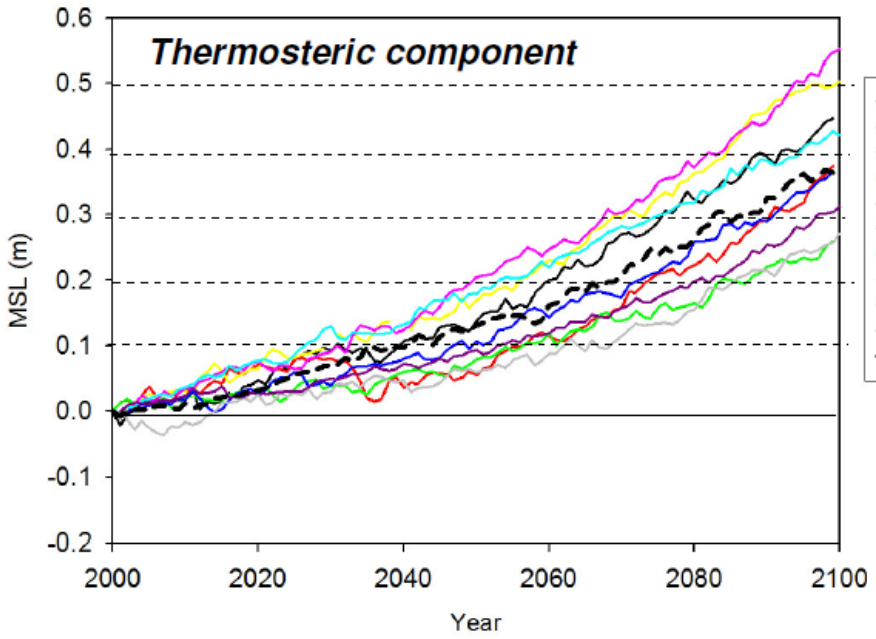


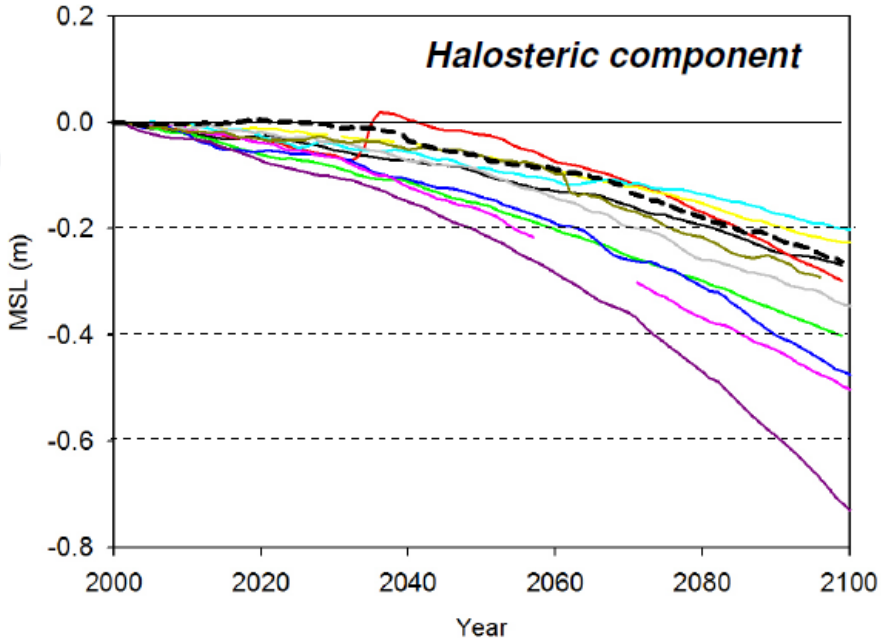
Projection (scenario B1)



M. Orlić, Z. Pasarić (2013)

Projections for the Mediterranean (scenario A2)

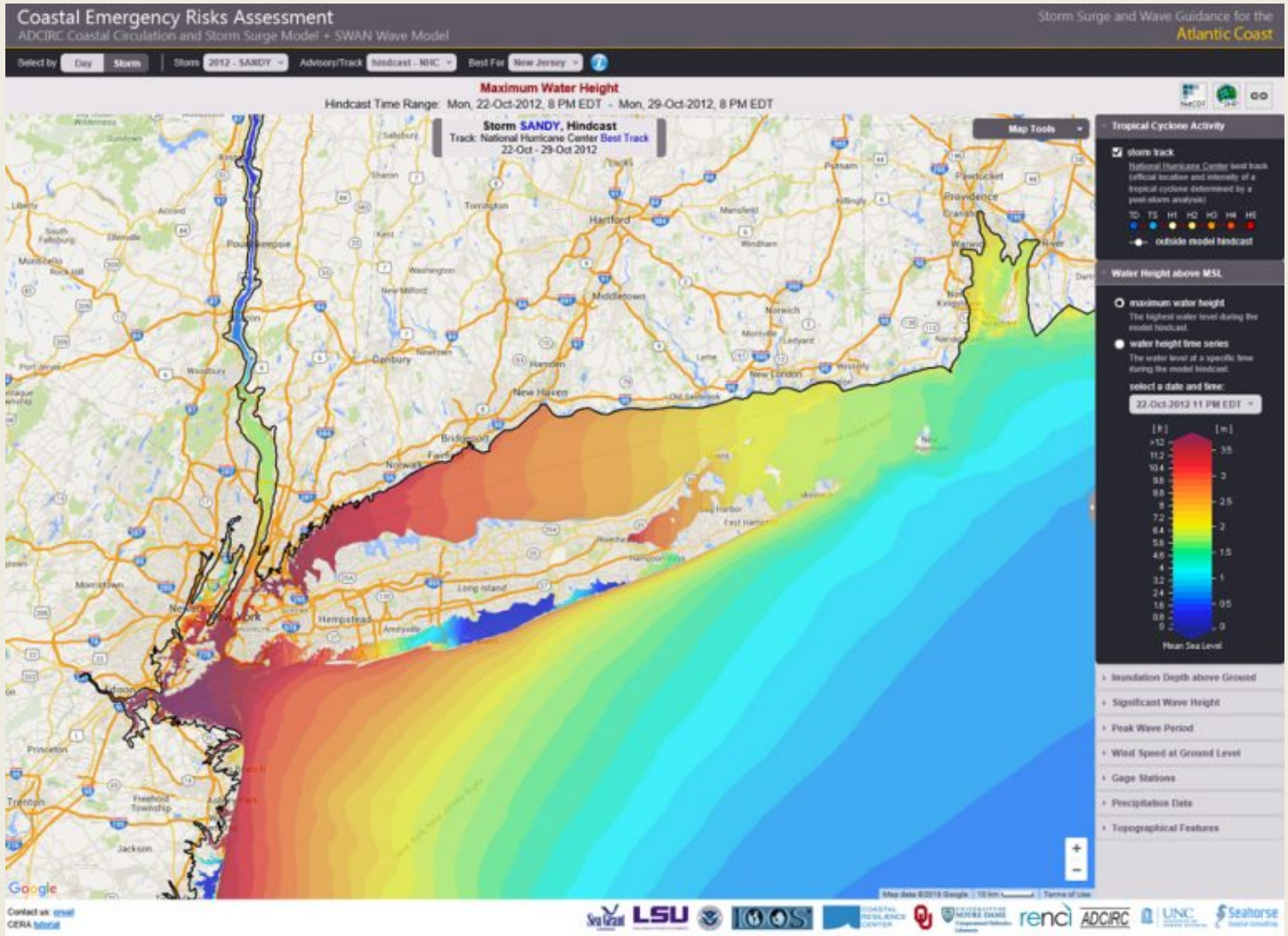




M. Marcos, M. N. Tsimplis (2008)

Storm-surge events

Storm-surge modeling (New York, 2012)



Coastal Resilience Center (2017)

Adaptation: dams off London and Rotterdam

The Adriatic flood of 1 November 2012


Rijeka


Rab

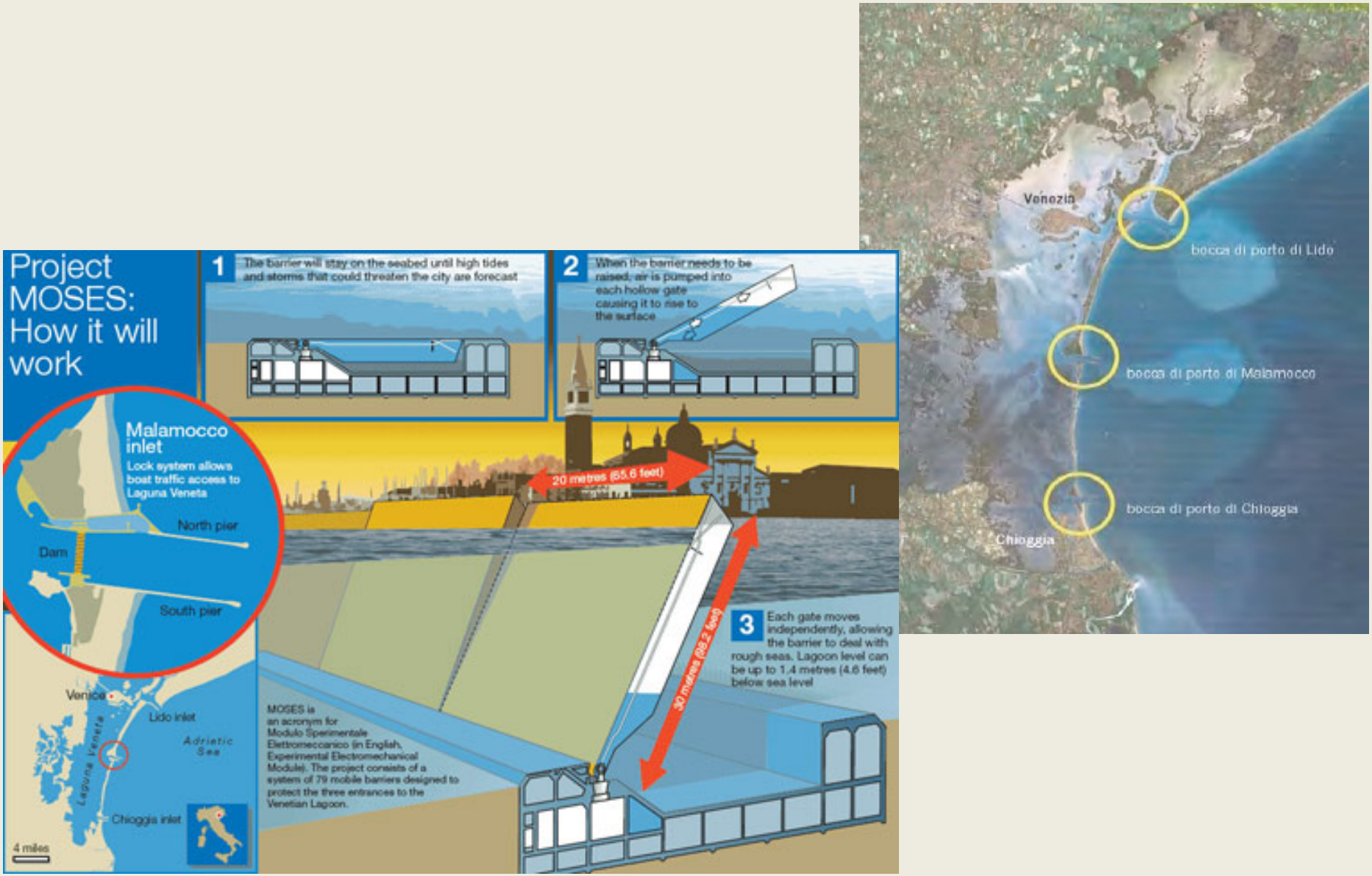

Cres


Murter

Record high sea levels at Bakar (station founded in 1929)

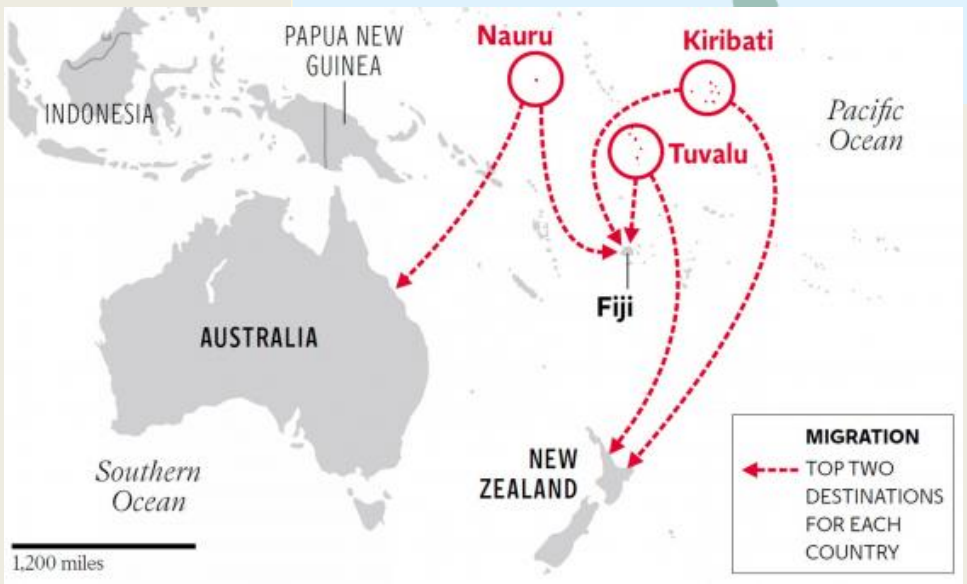
Date	Time (LT)	Height above MSL (cm)
29 October 2018	21:25	127
1 November 2012	7:20	122
1 December 2008	8:18	120
10 December 1990	2:36	114
25 December 2009	2:18	112
25 October 1980	10:54	111
Etc.	…	…

Adaptation: dams under construction off Venice



Influence on coastal population

Deltas (R. J. Nicholls, P. P. Wong, 2007)

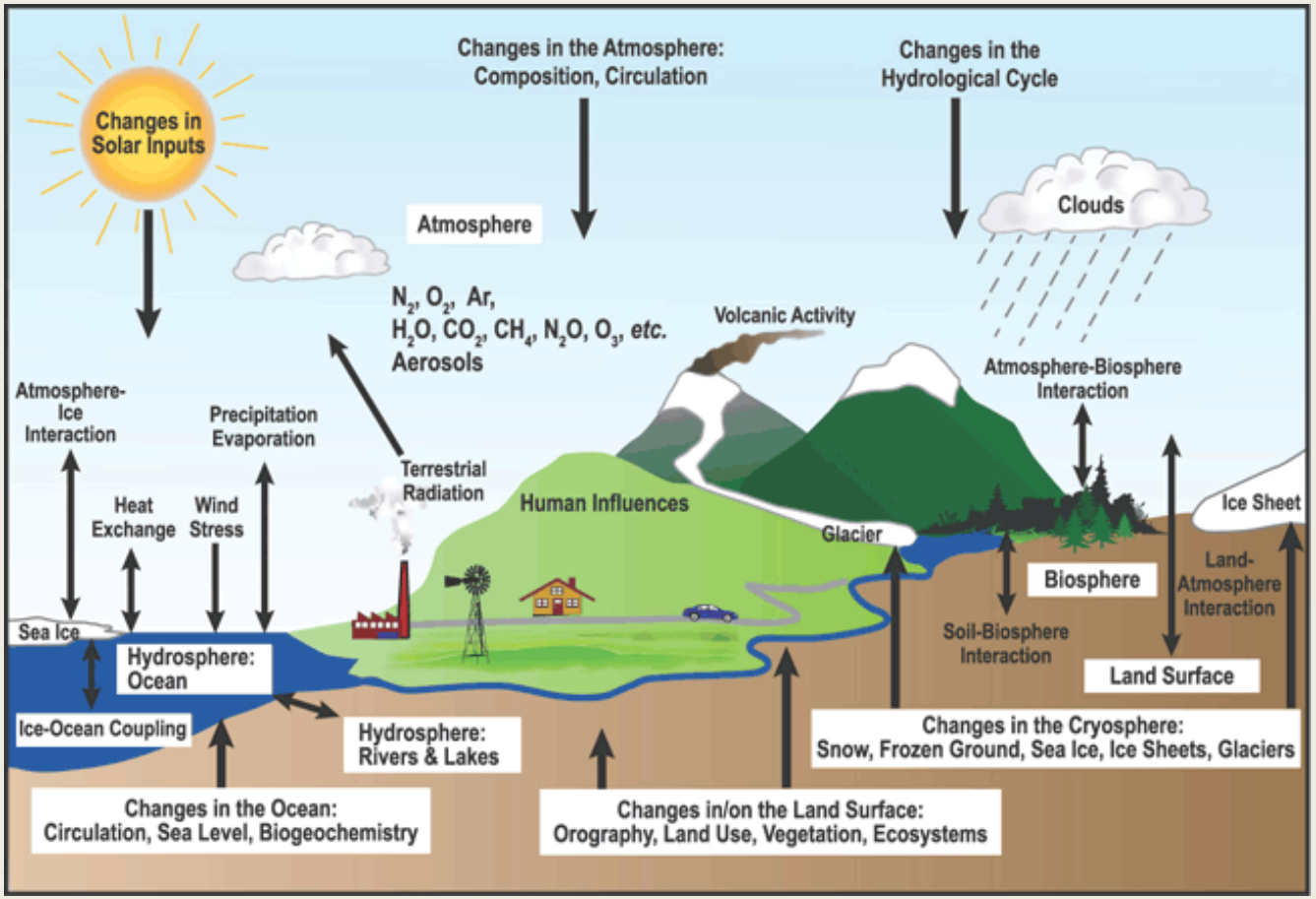


Islands (T. Bawden, 2015)

Expected damage in Croatia

According to a recent study prepared by researchers from the Global Climate Forum (Berlin) and Christian Albrechts University (Kiel), it is expected that the annual damage due to the coastal flooding events in Croatia will amount to 0.9 – 8.8 billion dollars by the end of 21st century.

Climate system



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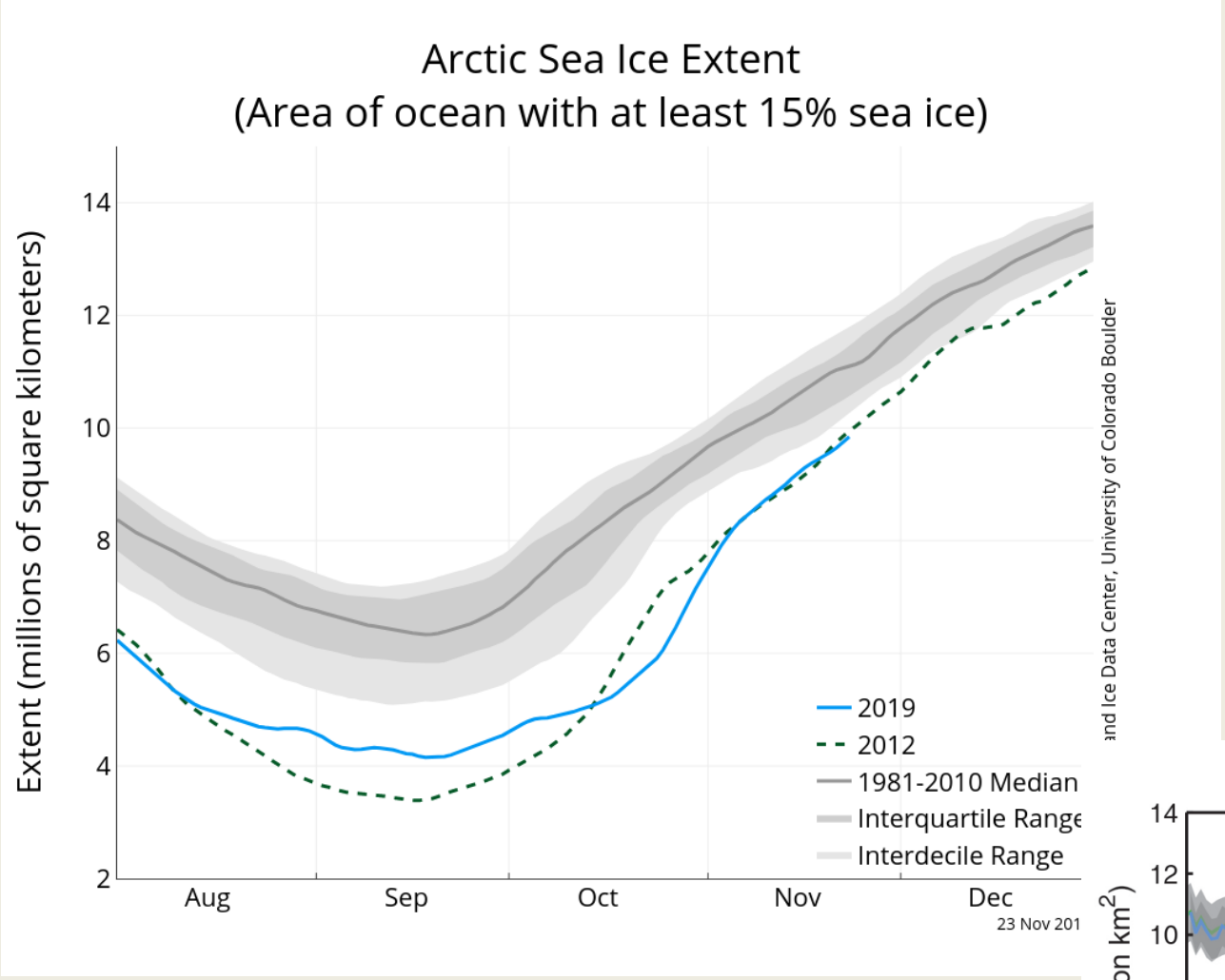
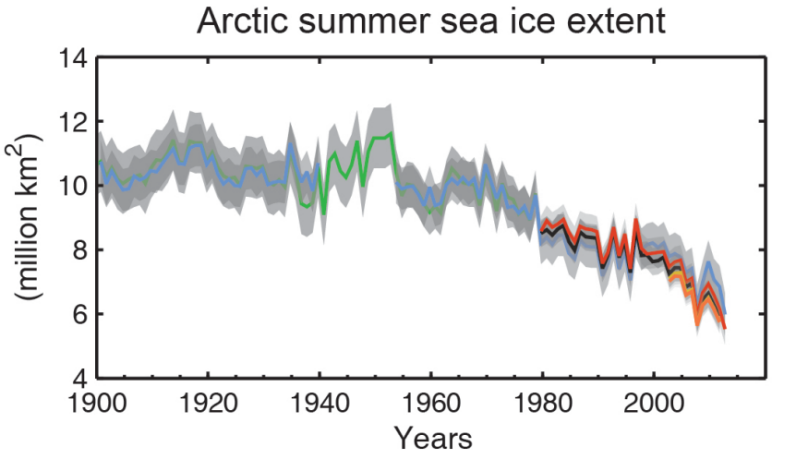
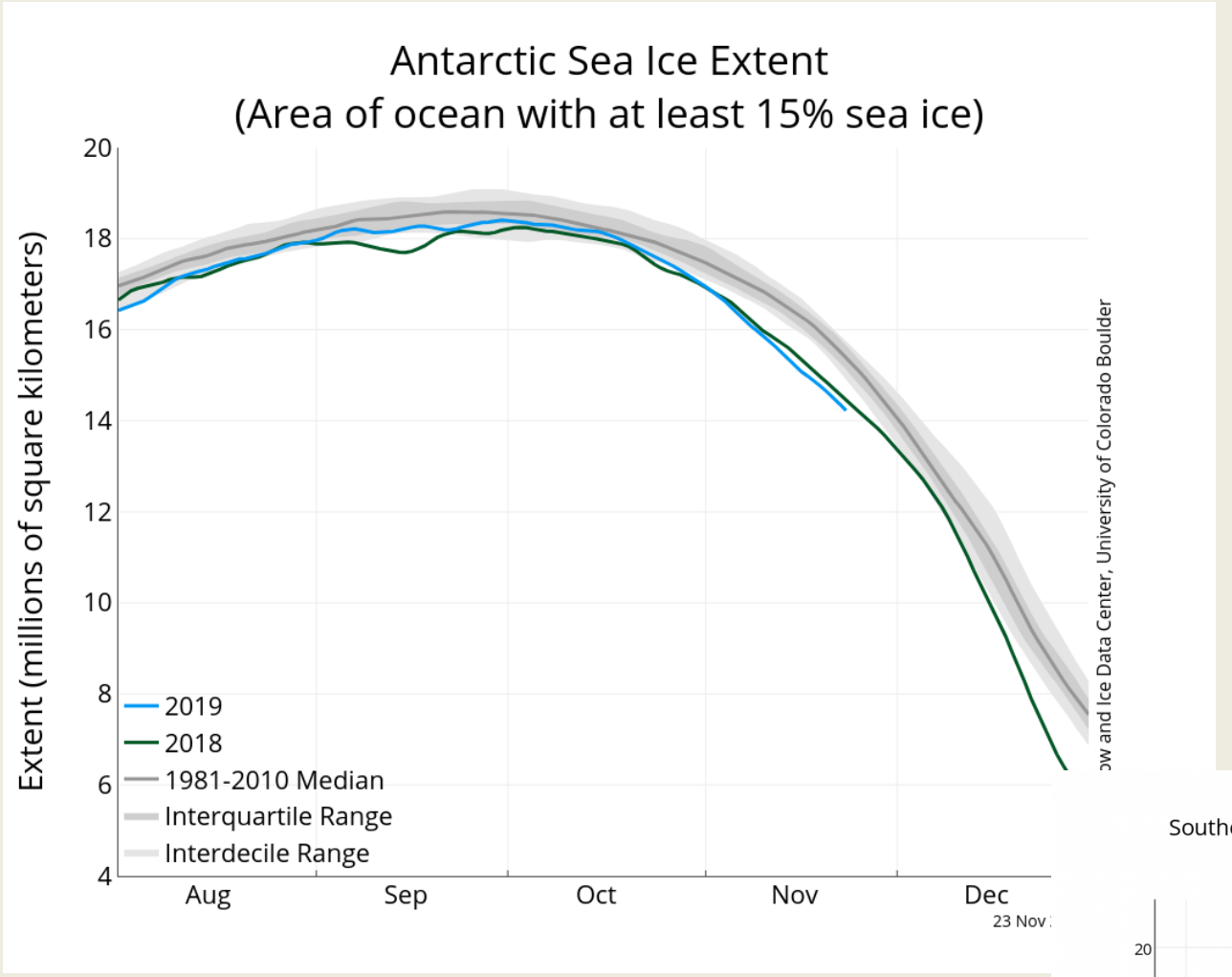
Arctic sea ice

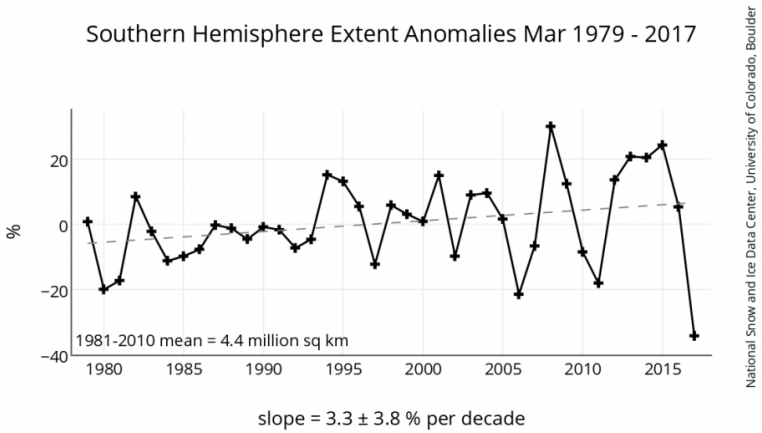




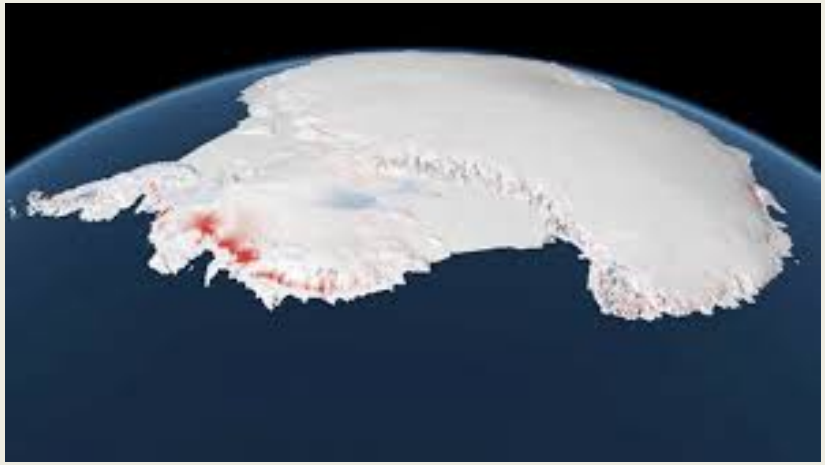
IPCC (2013)

Antarctic sea ice

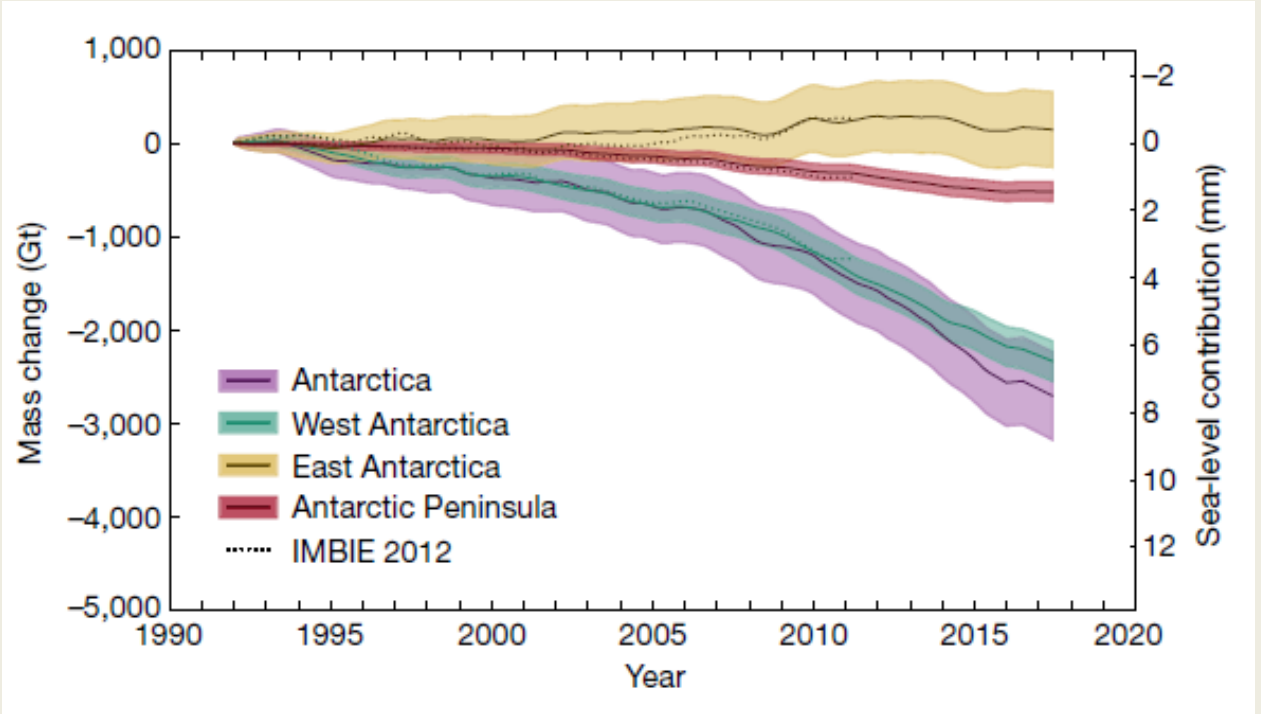




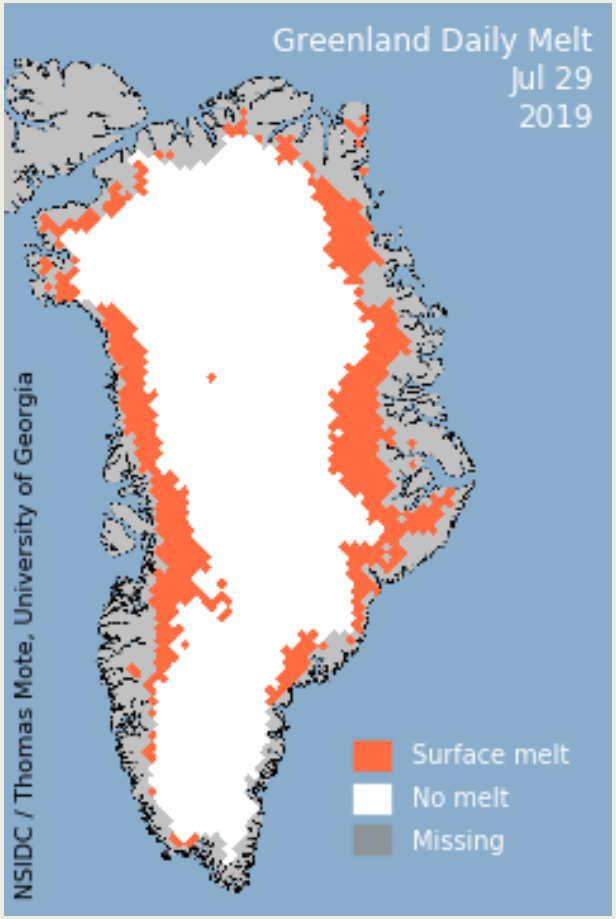
Antarctica ice sheet

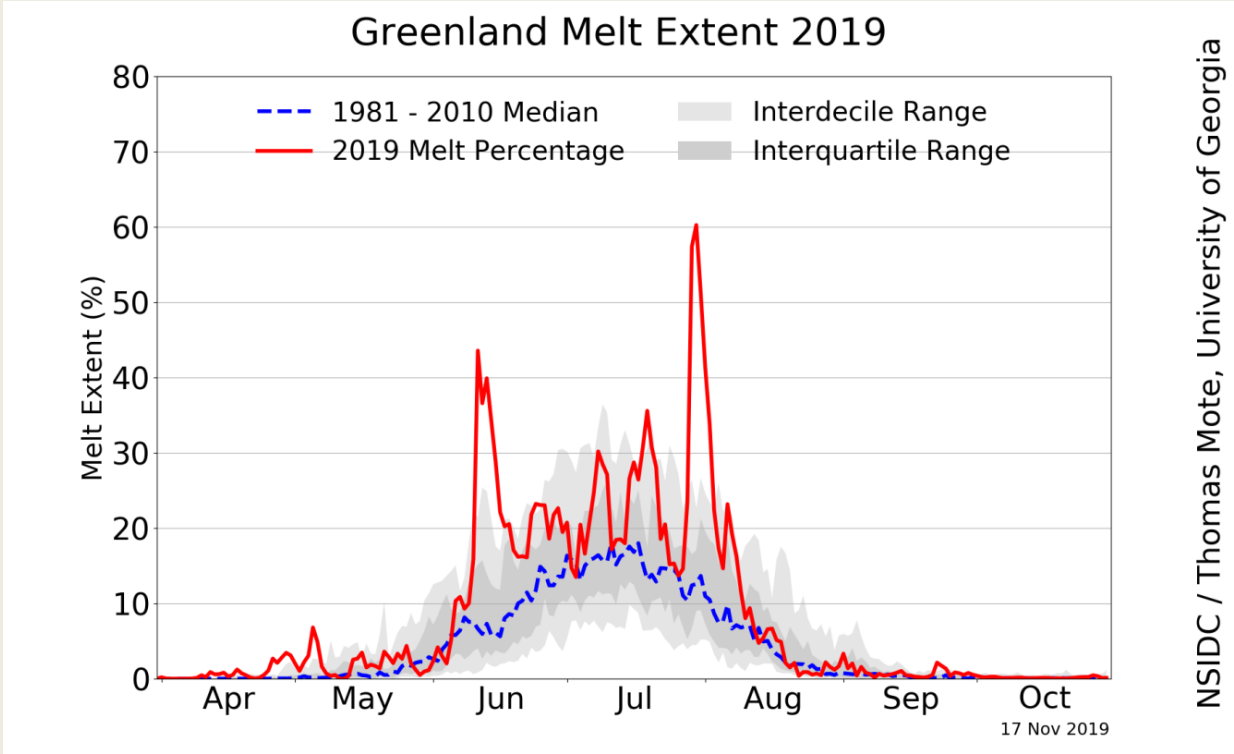


IMBIE (2018)



Recent melting of Greenland ice sheet

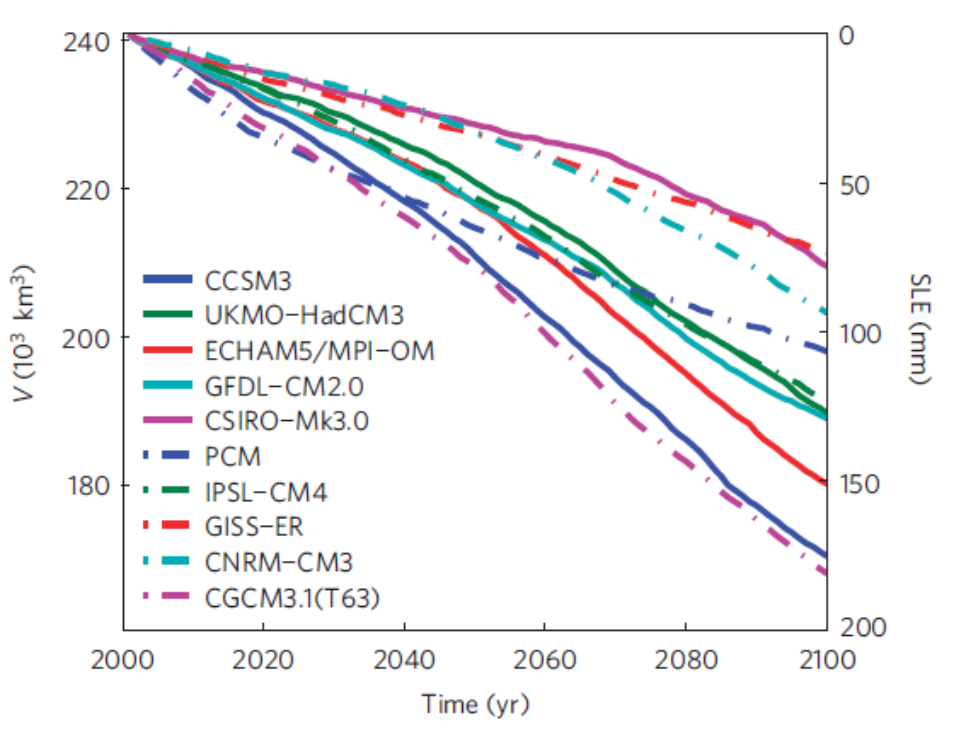




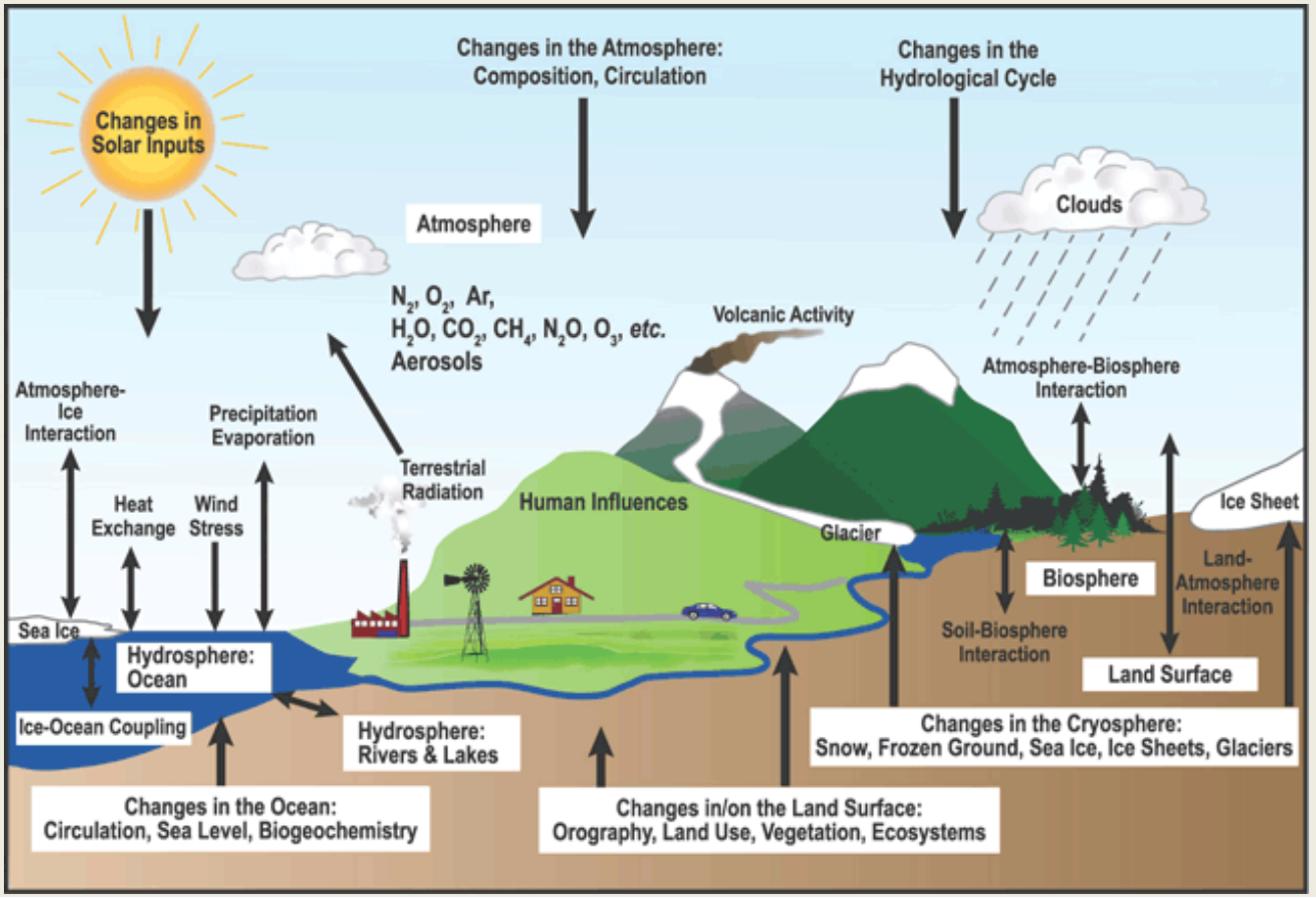
Past and future melting of glaciers

Cassandra
G. Nangeroni (1957), R. Scotti (2011)

V. Radić, R. Hock (2011)

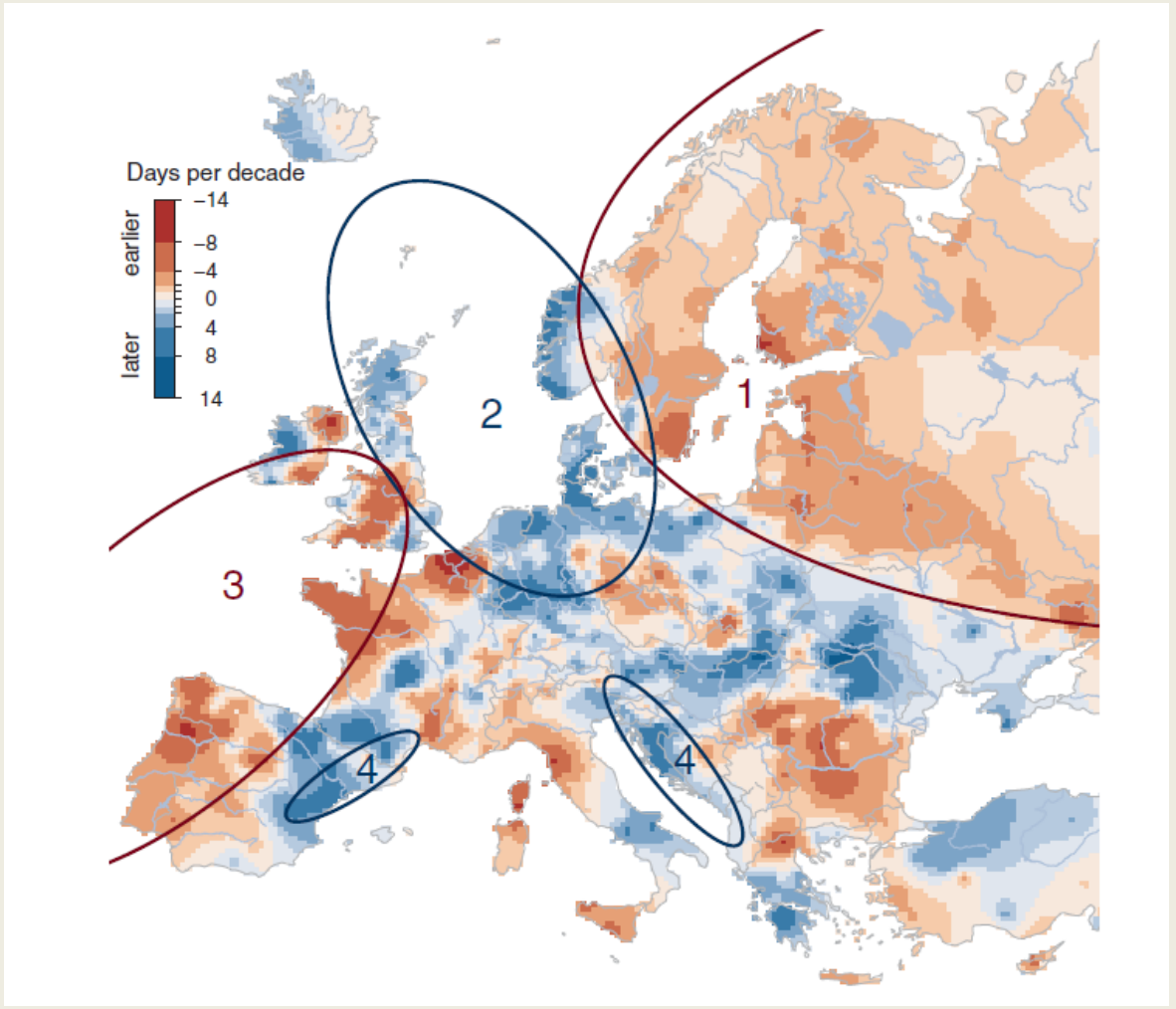


Climate system



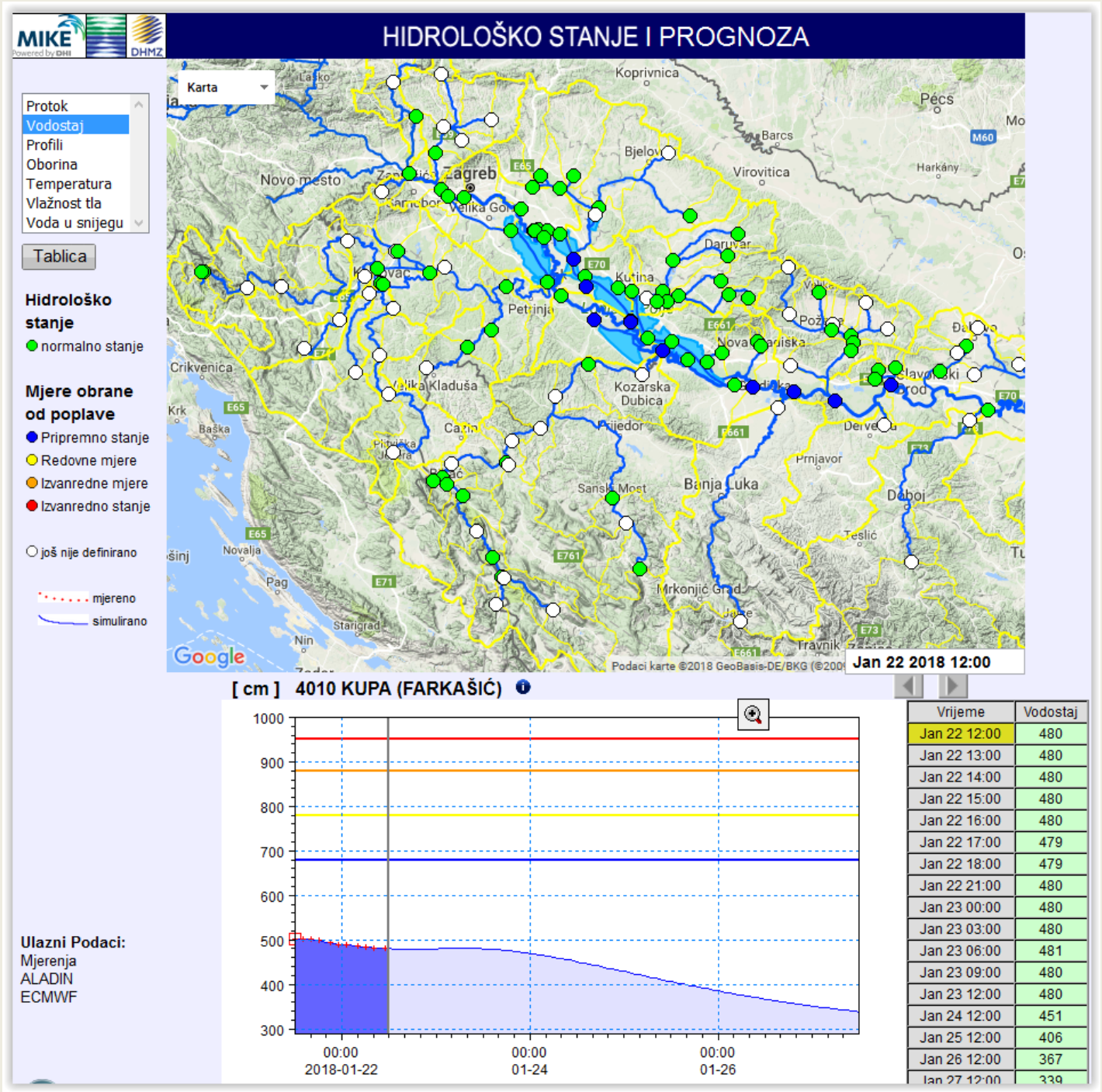
- Atmosphere
- Oceans and seas
- Cryosphere
- Rivers and lakes
- Ground water
- Land
- Biosphere

Long-term measurements of river levels and time of the occurrence of river floods in Europe (1960–2010)

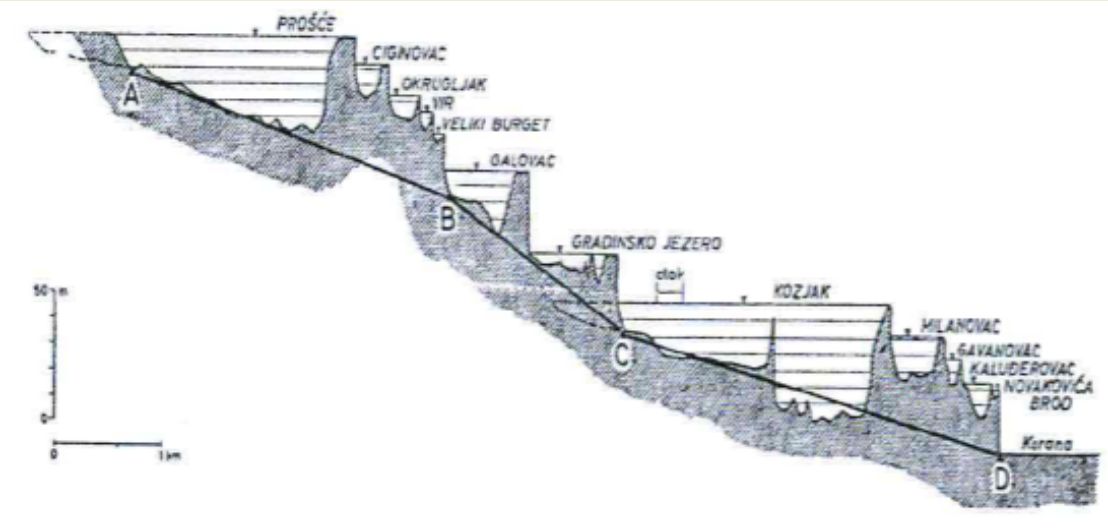


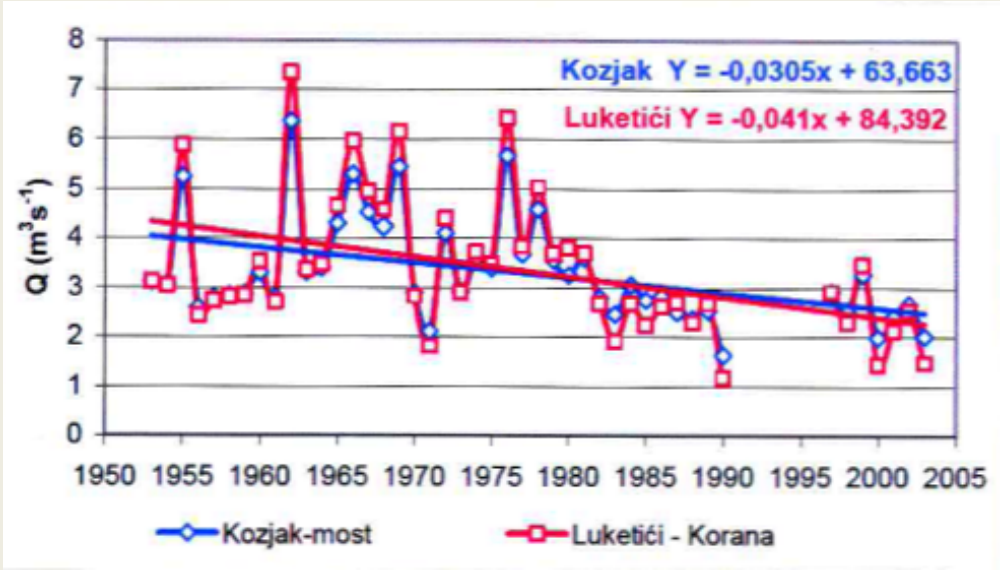
G. Blöschl et al. (2017)

Numerical modeling of rivers



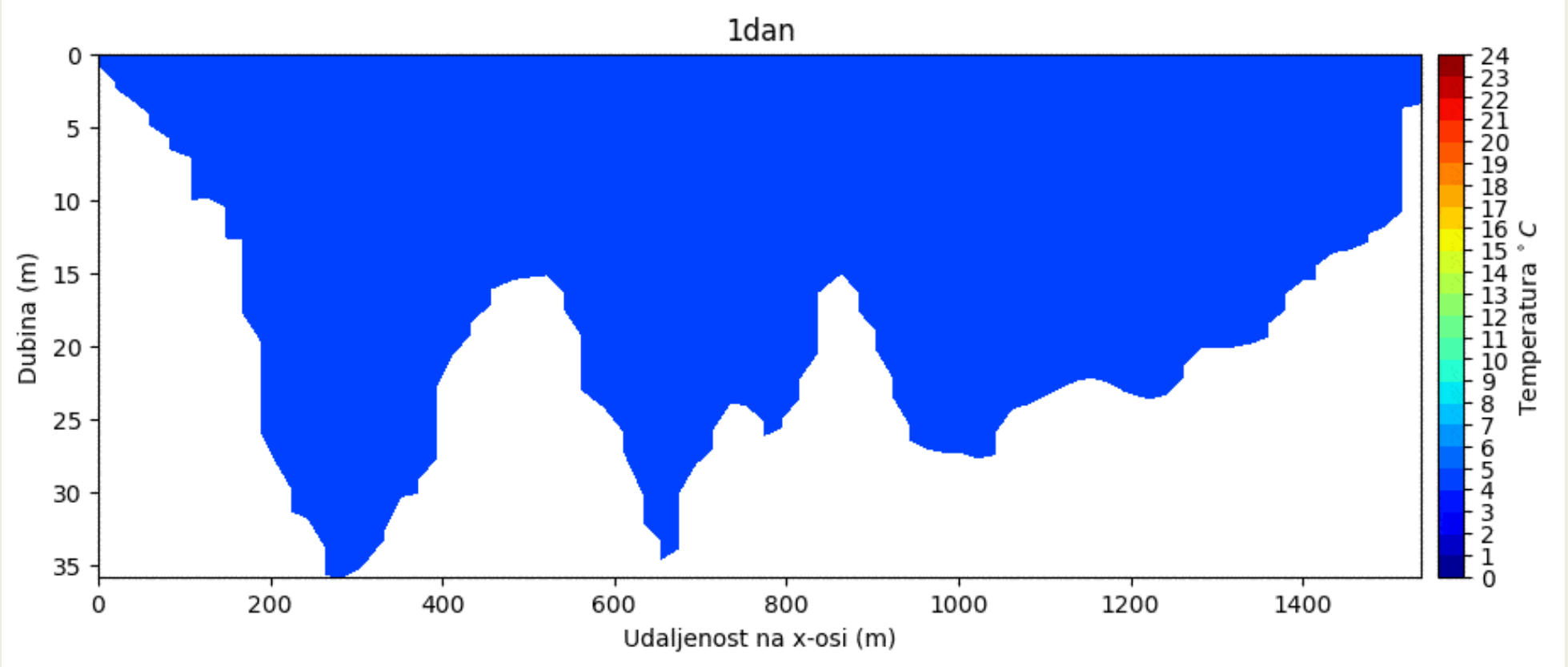
Long-term changes of transport through the Plitvice Lakes





J. Rubinić et al. (2014)

Numerical modeling of lakes
(thermal regime of the Prošće Lake, Plitvice)



Z. Bencetić Klaić et al. (2017)

Conclusion

→ Global temperature increased over the past century by 0.8ºC.
→ A larger part of the increase since 1950s may be attributed to the human influence (with a 95-100% probability).
→ Temperature increase was accompanied by change of a number of other parameters and thus, for example, global sea level rose over the past century by 17 cm.
→ Sea-level rise was due to the expansion of water column and the melting of glaciers and ice sheets.
→ Assuming that the concentration of greenhouse gases will double with respect to the preindustrial values, a global temperature increase of 1.1-2.6ºC may be expected until the end of the present century.
→ The heating will be accompanied by a change of the whole climate system: e.g., a global sea-level rise ranging between 32 and 63 cm is expected by the year 2100.
→ Change of climate is accompanied by an intensification of extremes.

What scientists can do

- Perform research with the aim of reducing uncertainties in the projections (*investigation*).
- Explore how to reduce climate changes in order to avoid the worst scenarios (*mitigation*).
- Consider the possibilities of adjusting to the changed conditions wherever possible (*adaptation*).

Intergovernmental Panel on Climate Change (IPCC), Assessment Reports (1990, 1995, 2001, 2007, 2013, forthcoming in 2020)

What politicians can do

- Develop policies that enable their countries to adapt to the climate change.
- Support participation of the countries in the international mitigation projects.
- Stimulate international cooperation that allows for the fact that the developed countries have contributed most to the climate change whereas developing countries will be affected most.

Paris Climate Agreement (2015)

Popularization:
A. LeWinter and J. Orlowski, Greenland, 28 May 2008
(J. Balog, Extreme Ice Survey)