



Climatic change: Past, current, future

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What is it about...

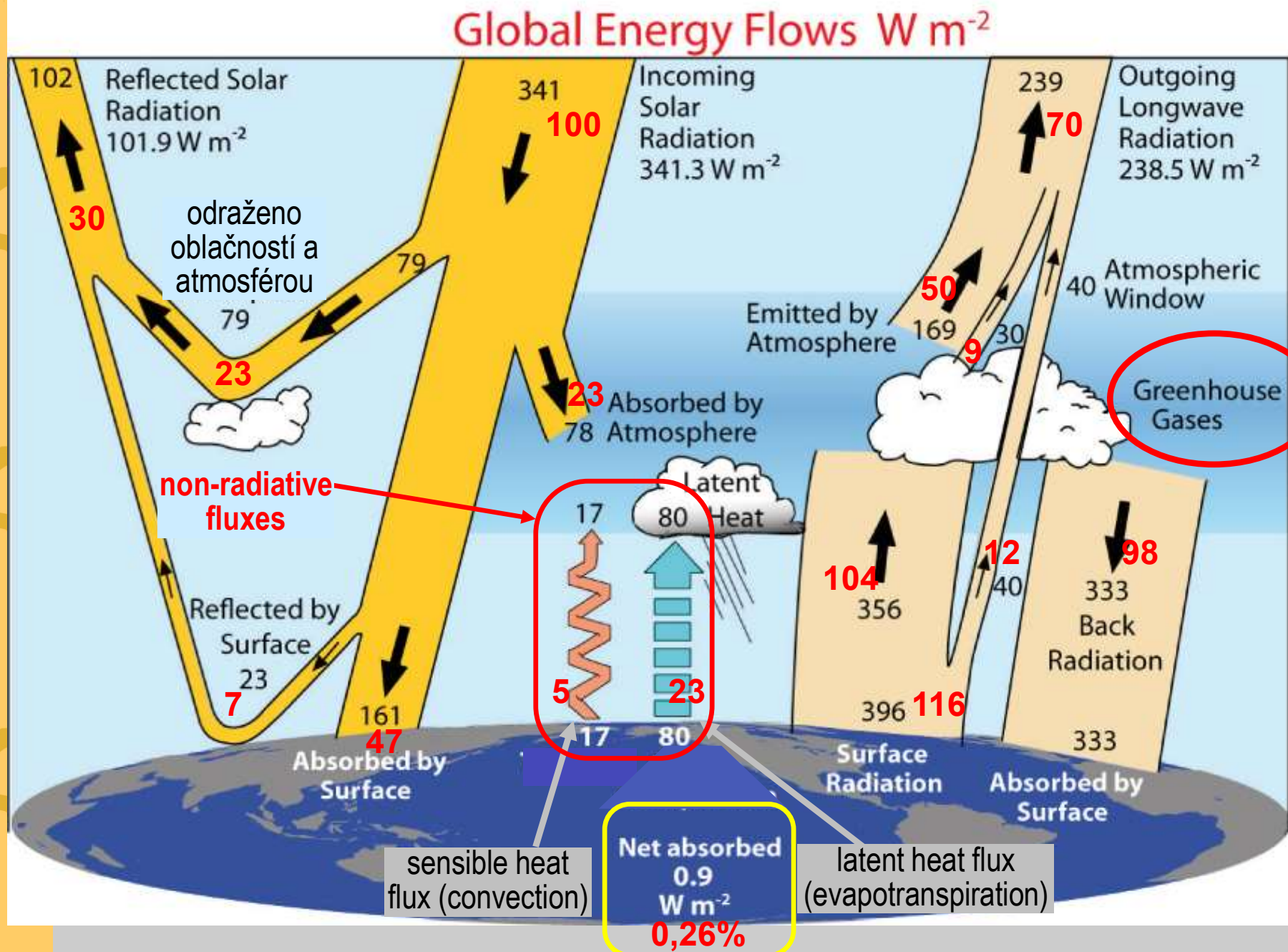
- ★ greenhouse effect
- ★ how is climate changing? observed climate change
- ★ how will climate change? and how can we know it?
- ★ why is climate changing?
- ★ and (if we have time) what can we do with it?





1. Greenhouse effect







Greenhouse effect

★ substance:

- atmosphere is well permeable to incoming short-wave solar radiation
- atmosphere is almost impermeable to long-wave radiation of Earth surface





Radiatively active (greenhouse) gases



- ★ water vapour (H_2O)
- ★ carbon dioxide (CO_2)
- ★ methane (CH_4)
- ★ nitrous monoxide (N_2O)
- ★ freons (chlorofluorocarbons)
- ★ ozone (O_3)
- ★ ...

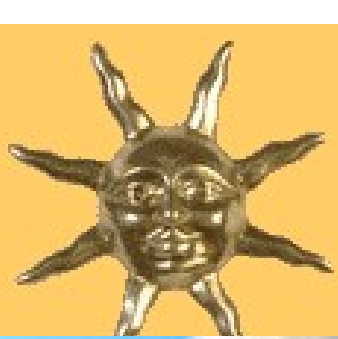




Major GHGs

- ★ water vapour
- ★ concentrations not directly affected by human activities





Major greenhouse gases

CO₂ – carbon dioxide





Major greenhouse gases

★ CH_4 – methane



Major greenhouse gases

★ N_2O – nitrous oxide

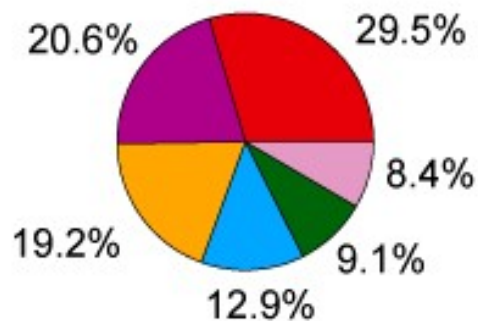
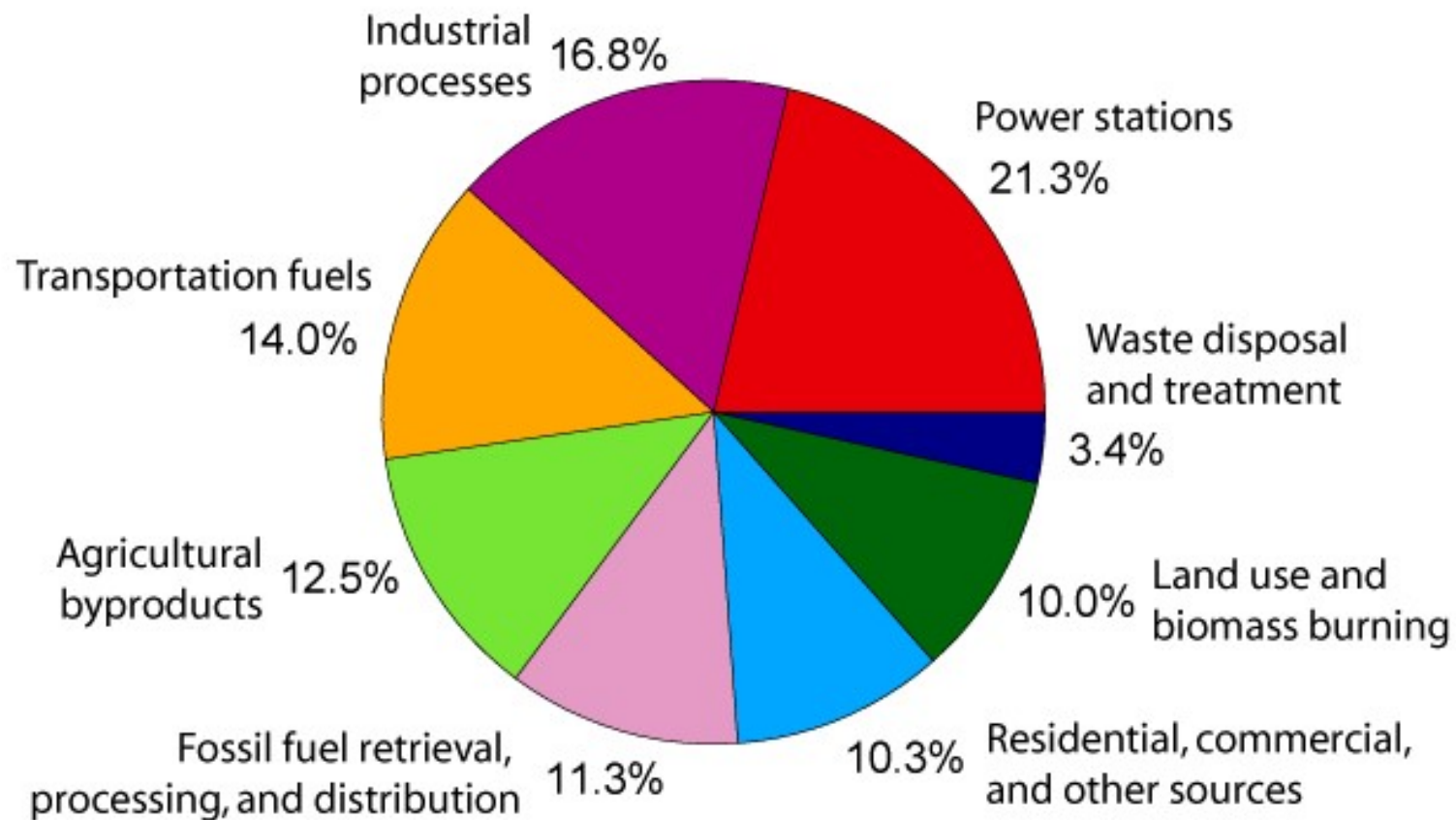


Major greenhouse gases

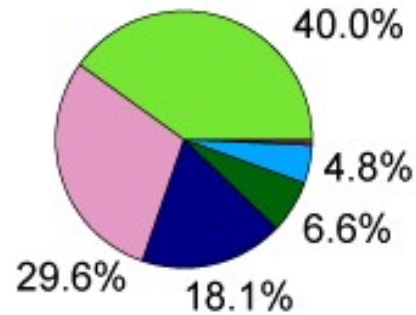
★ freons (chloro- & fluoro-carbons): CCl_4 , CFCl_3 , ...



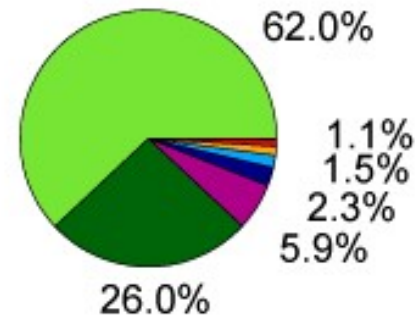
Annual Greenhouse Gas Emissions by Sector



Carbon Dioxide
(72% of total)



Methane
(18% of total)



Nitrous Oxide
(9% of total)



2. How is climate changing?





Global mean temperature



... but what is it actually?

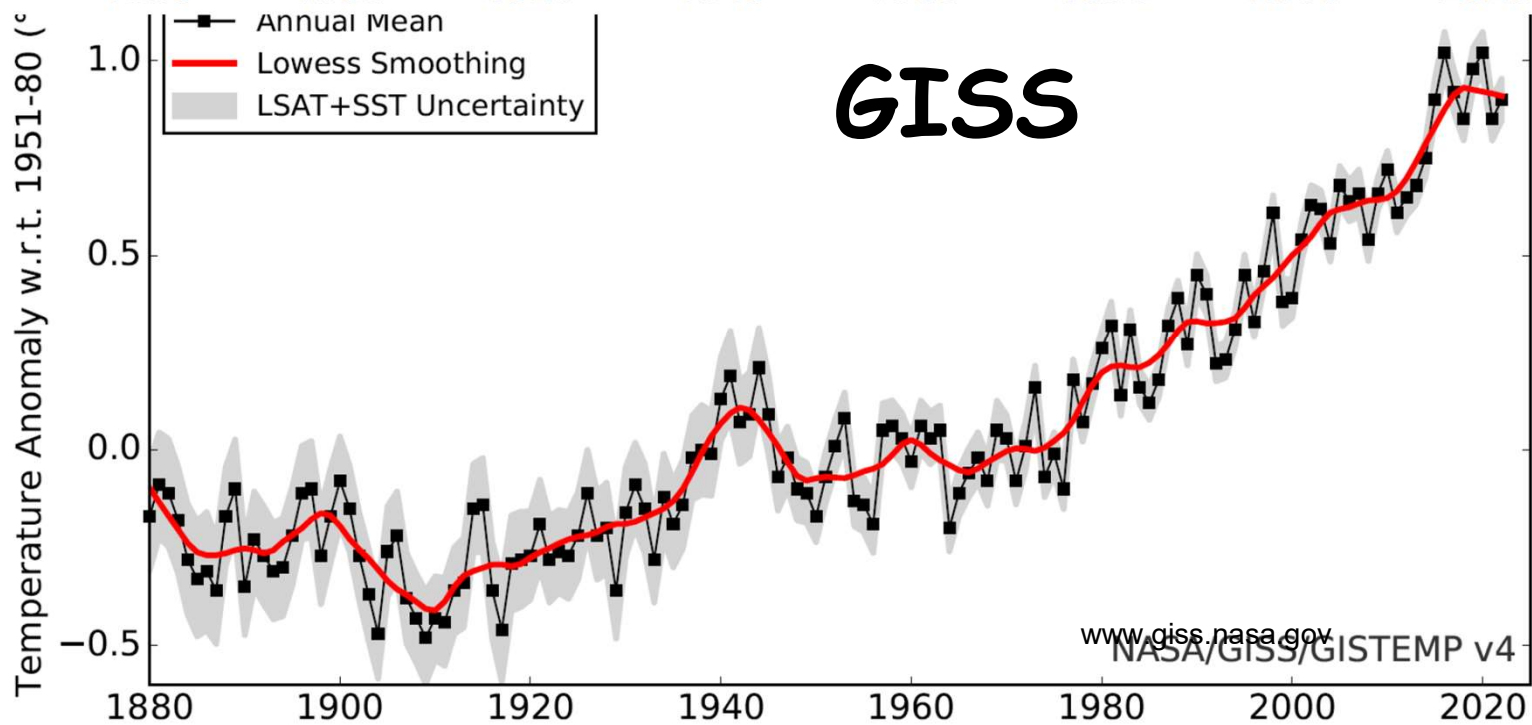
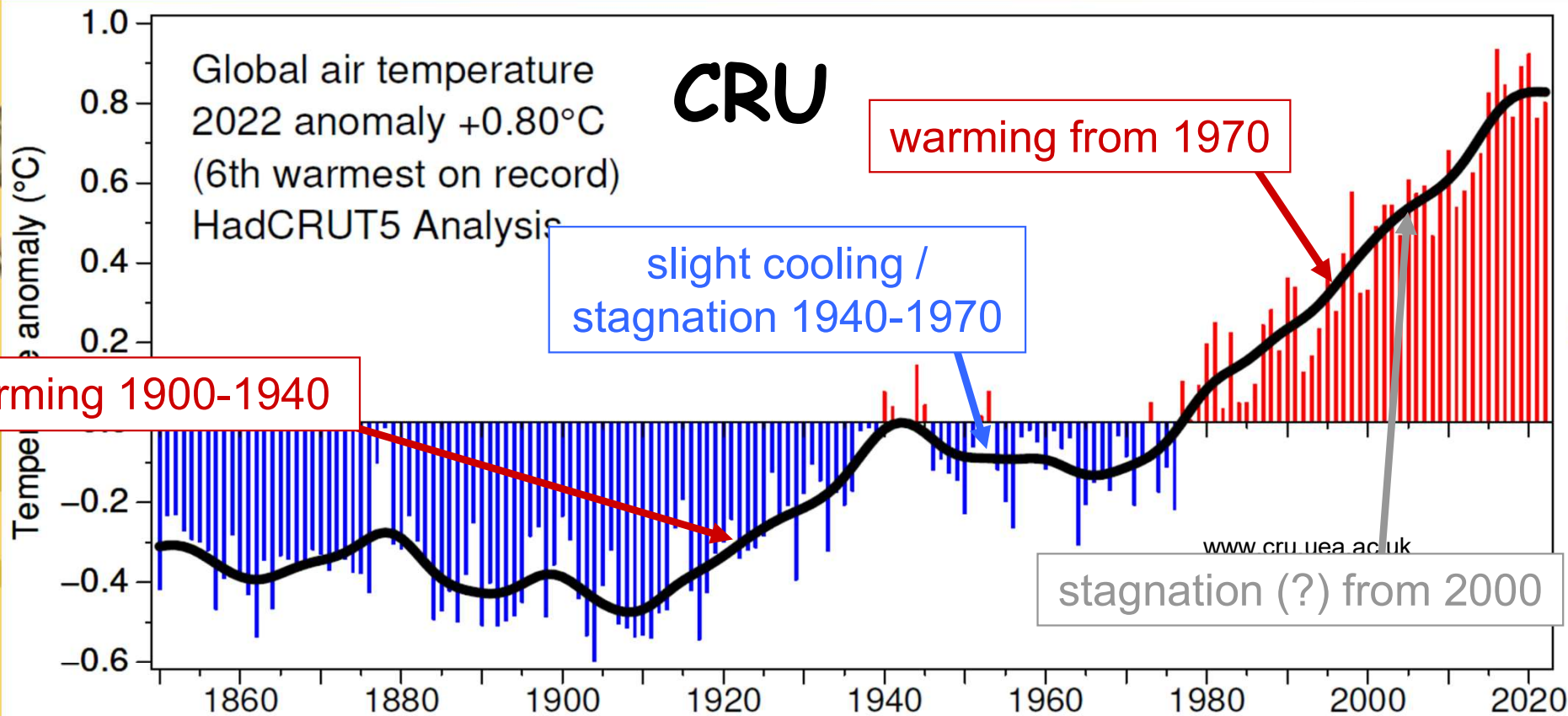




Global mean temperature

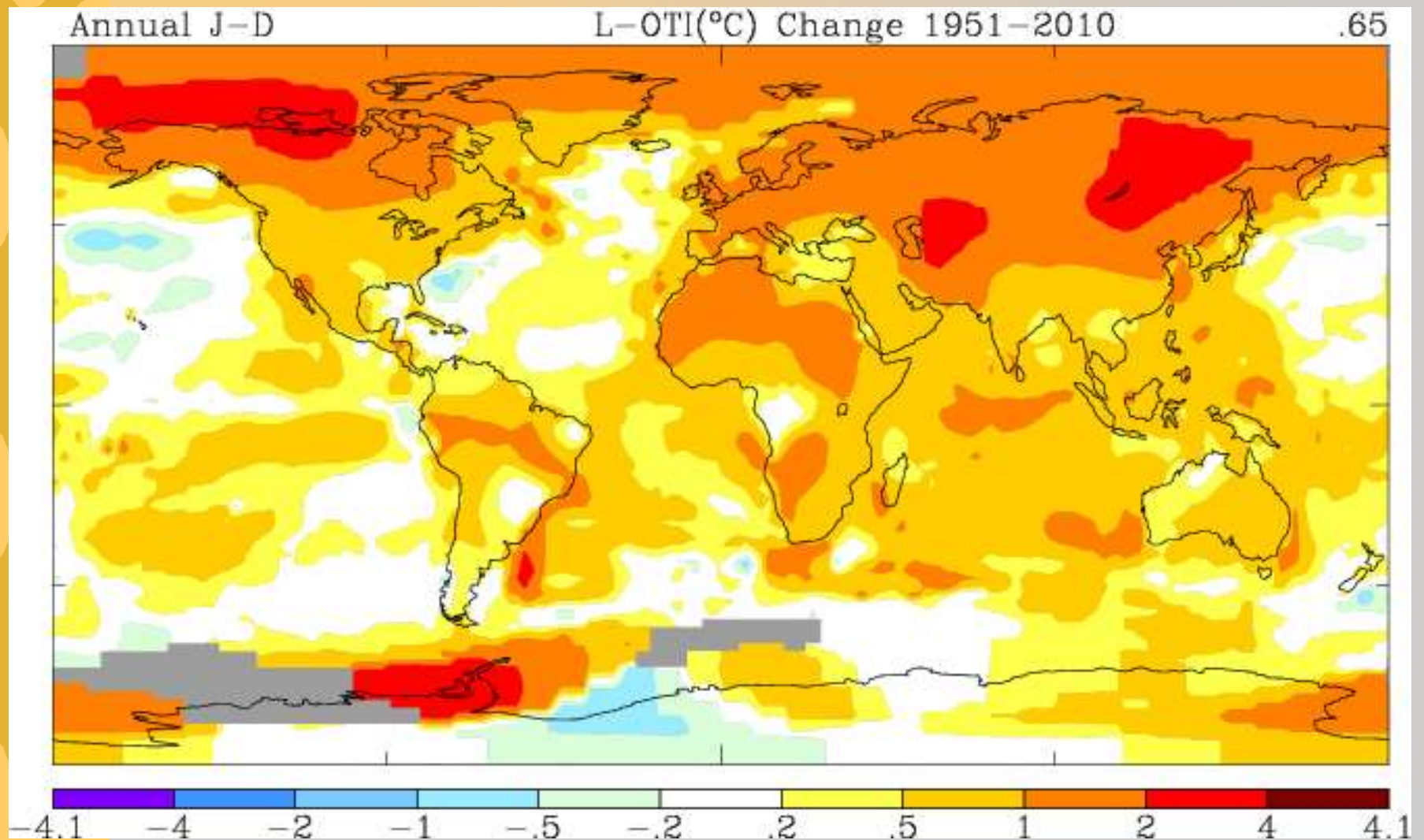
- average temperature of the entire surface of Earth
- cannot be measured immediately
- must be calculated from available measurements
- continents – monthly means of air temperature (in 2 m) at stations (> 3000 stations at the end of 20th century)
- oceans: sea surface temperature (measured from ships)





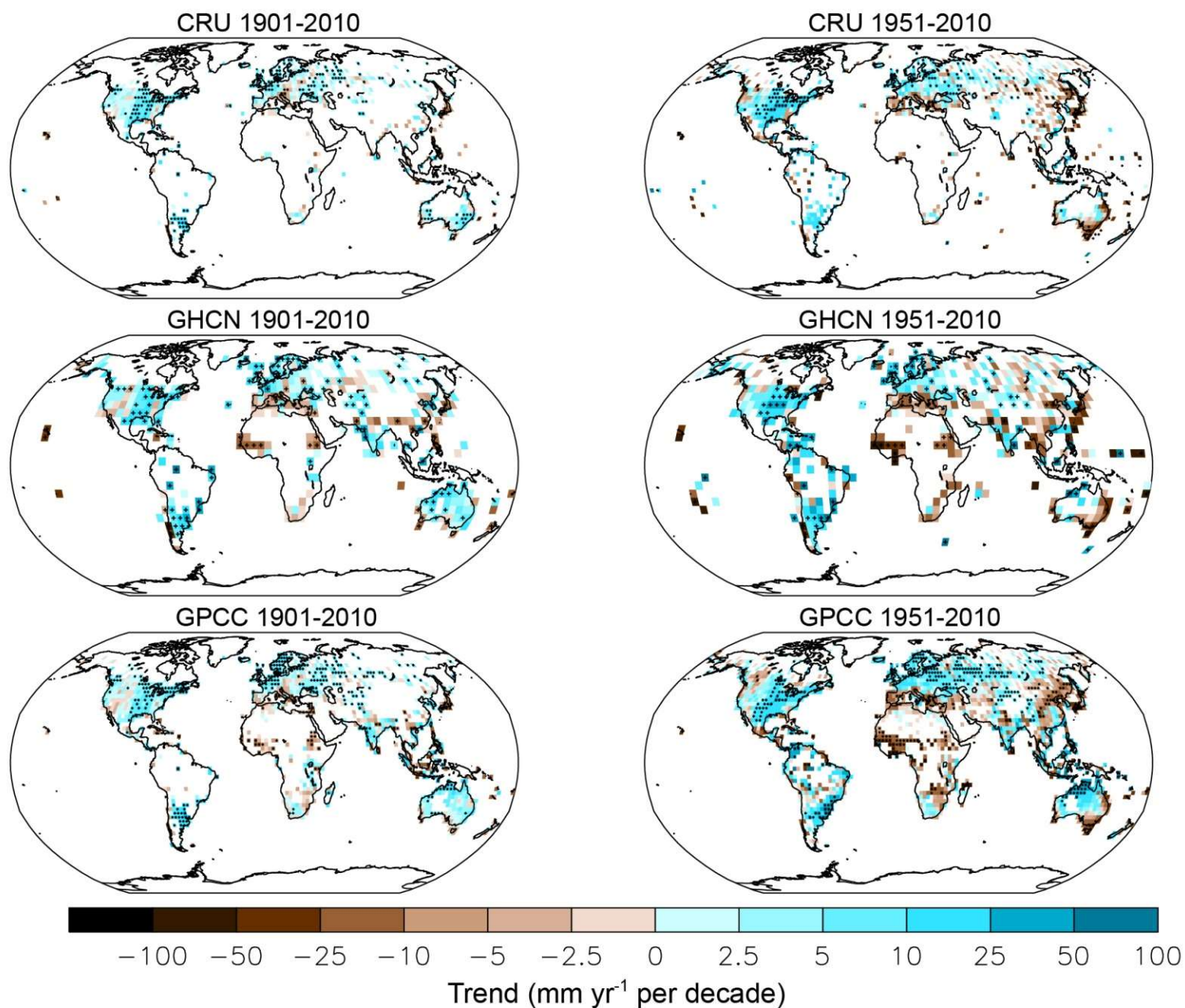


Temperature change 1951-2010



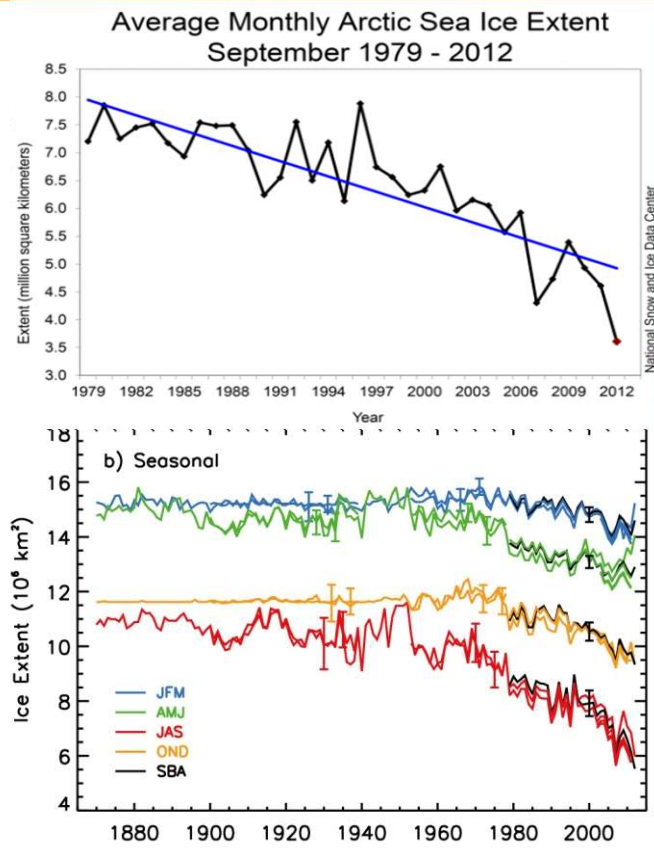
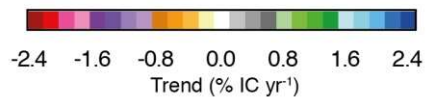
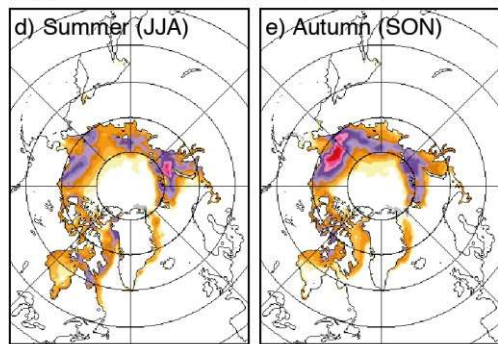
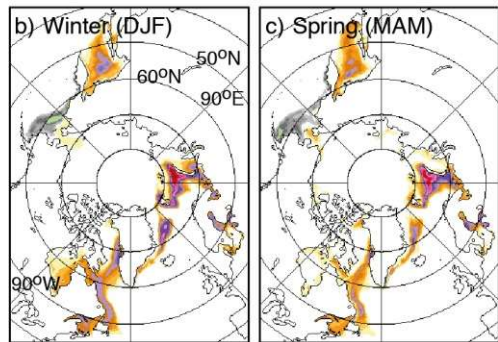
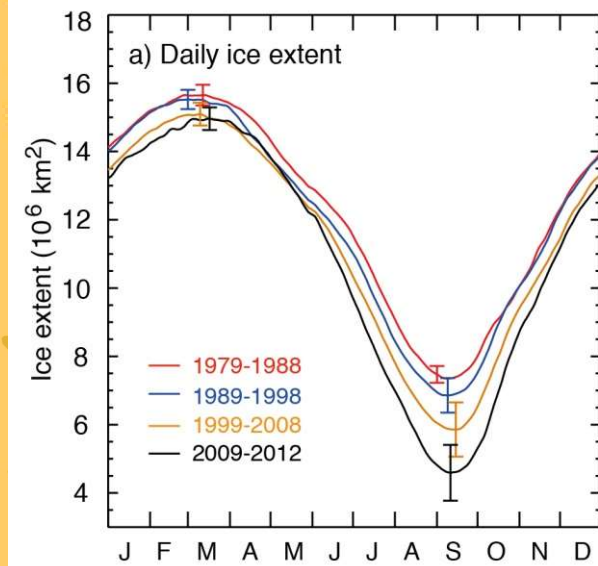


Precipitation change 1951-2010

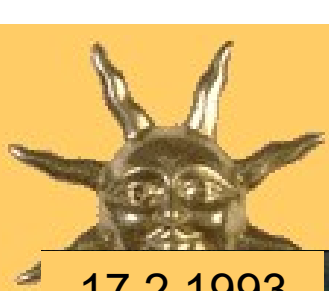




Arctic sea ice change



Median minimum extent of ice cover (1979-2000)



Changes of cryosphere

17.2.1993

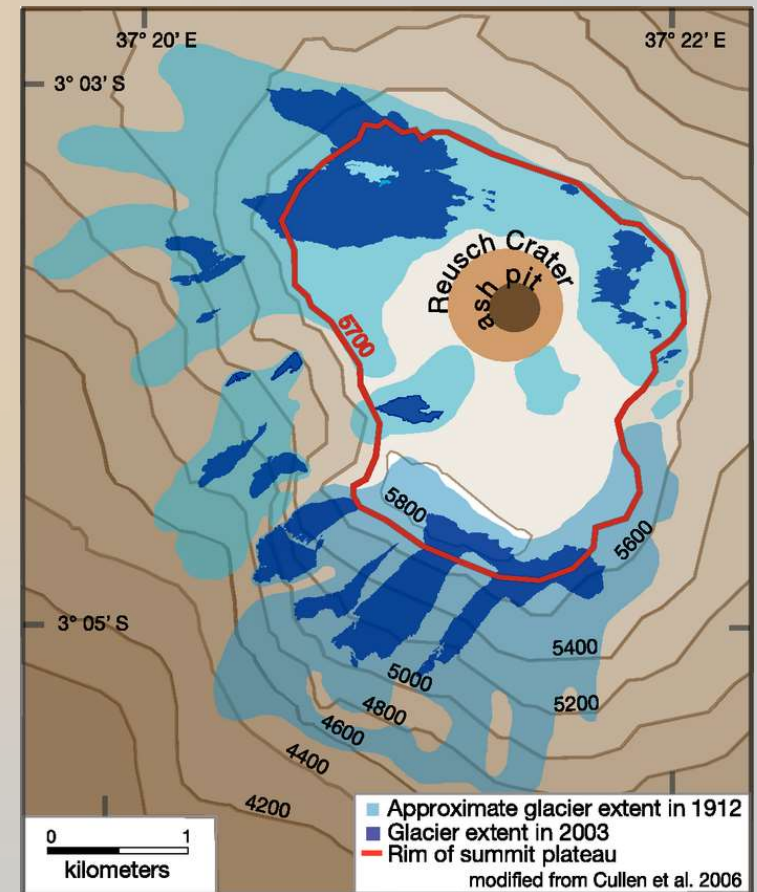
Mt. Kilimanjaro



21.2.2000



glacier retreat



glaciers at Mt.
Kilimanjaro



Cryosphere changes

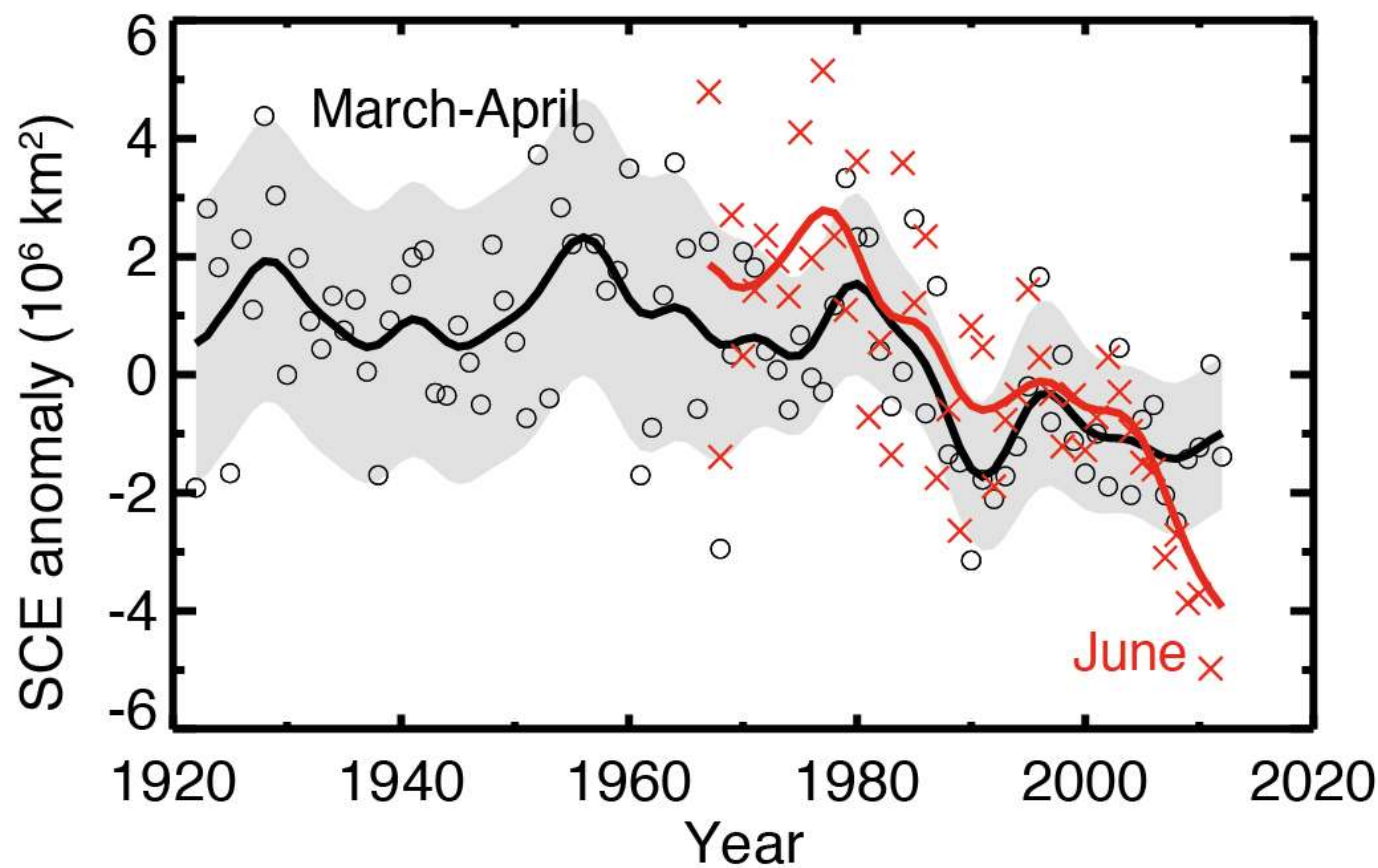
★ permafrost thawing





Snow

Snow cover of Northern Hemisphere,
III-IV; VI (in mill. km²)
mean value = 37 mill. km²

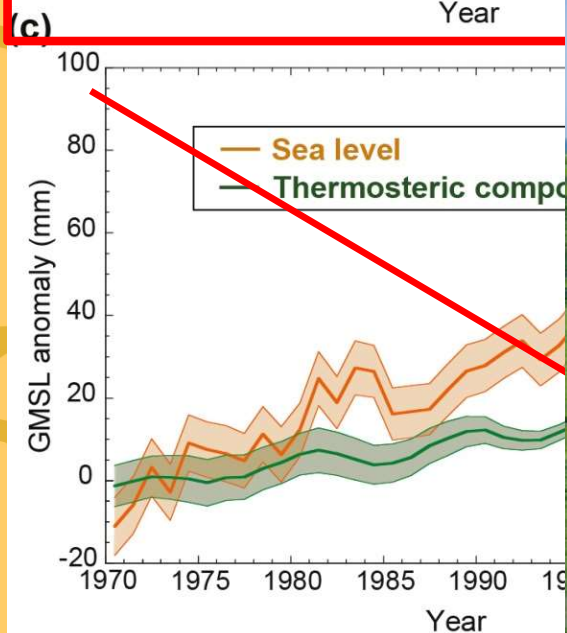
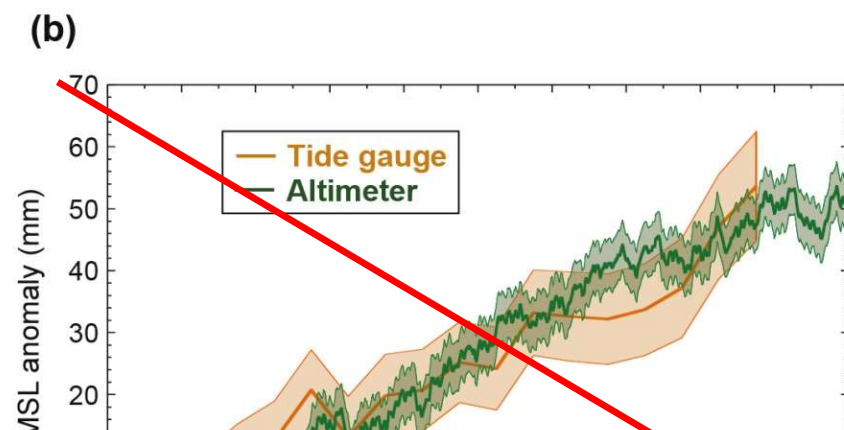
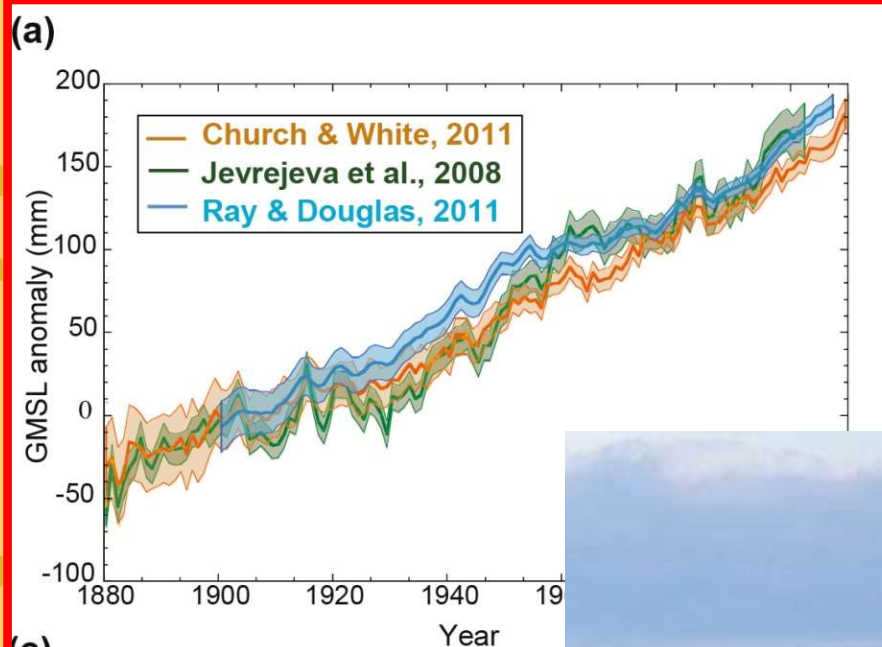


Long term trends of snow
cover in NH (in mil. km² /
10 yr)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1967–2012	0.03	−0.13	−0.50	−0.63	−0.90	−1.31	n/a	n/a	n/a	n/a	0.17	0.34	−0.40
1922–2005	n/a	n/a	−0.25	−0.35	n/a	n/a	n/a	n/a	n/a	0.24	n/a	n/a	n/a



Sea level rise





3. How will climate change?





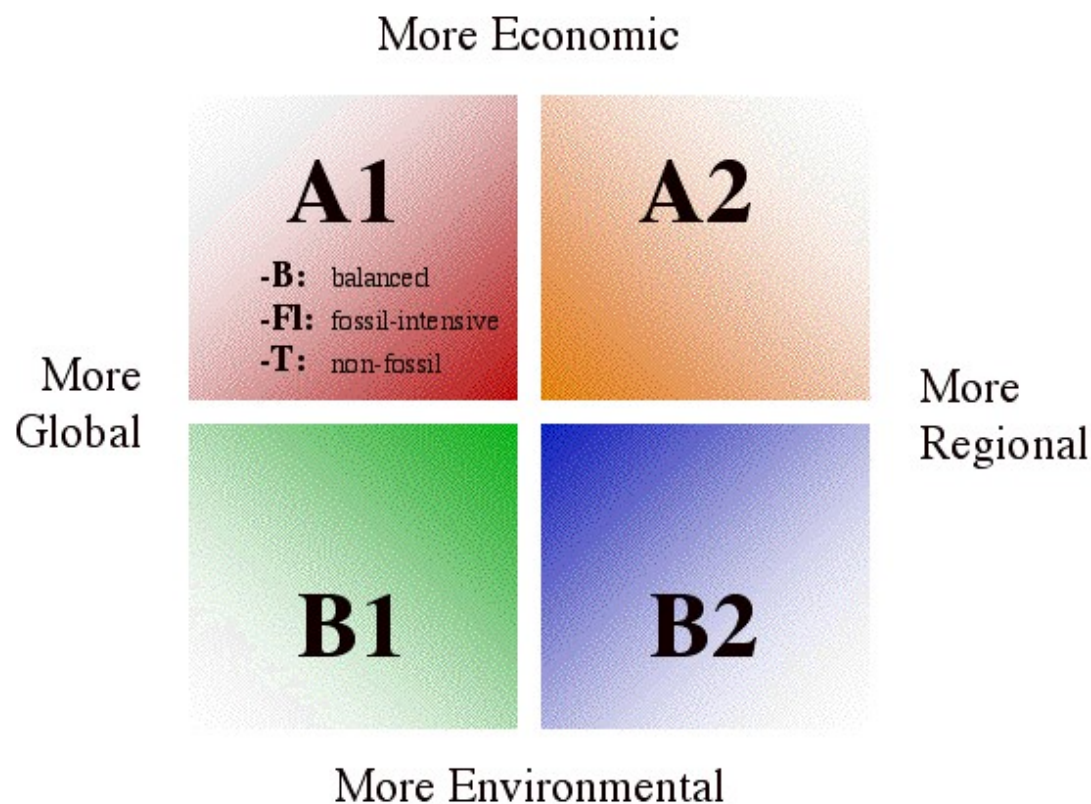
Emission scenarios

- ★ emissions scenario – estimate of future evolution of greenhouse gas emissions
- ★ based on estimates of future socio-economic development
- ★ but we do NOT know the future socio-economic development → several different scenarios
- ★ individual scenarios describe “alternative futures”





Families of scenarios



Adapted from **IPCC**, 2001: *Climate Change 2001: Synthesis Report. A contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Watson, R.T. and the Core Writing Team (eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, 398 pp.



How we model (simulate) climate ...

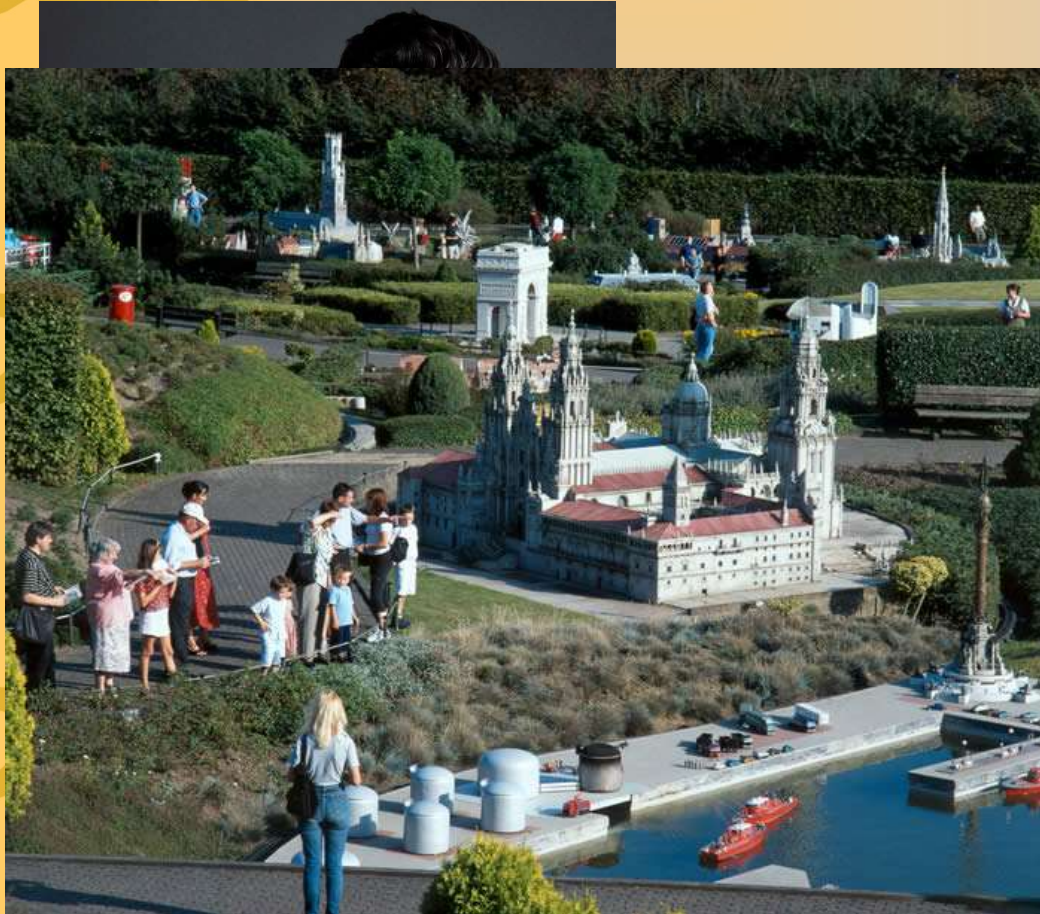


- ★ global climate model is “run”
 - for given external forcings that affect climate
 - natural
 - solar activity
 - volcanic activity (eruptions)
 - anthropogenic
 - greenhouse gases
 - aerosols
 - for the required time interval (tens to hundreds of years)

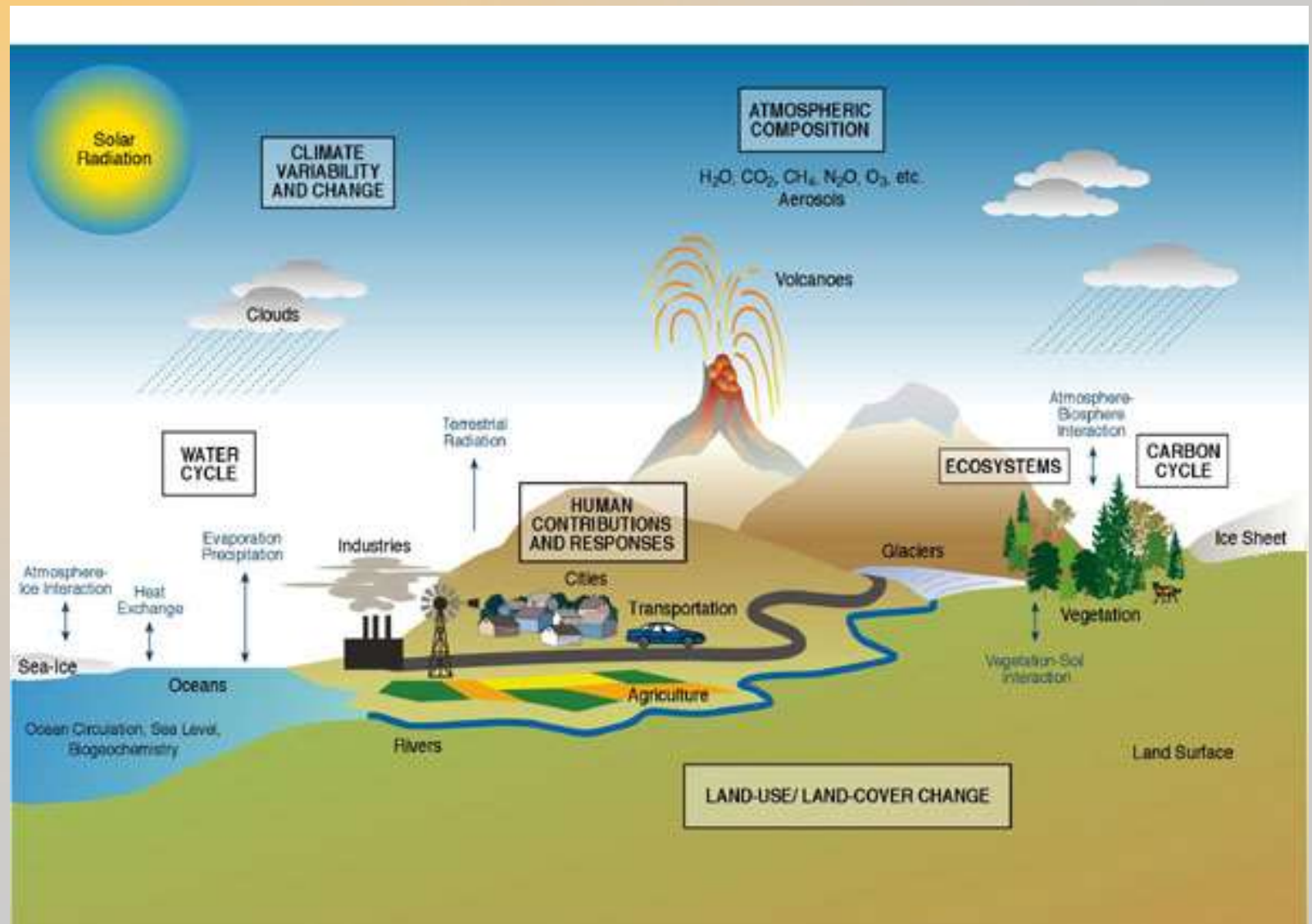


Model...

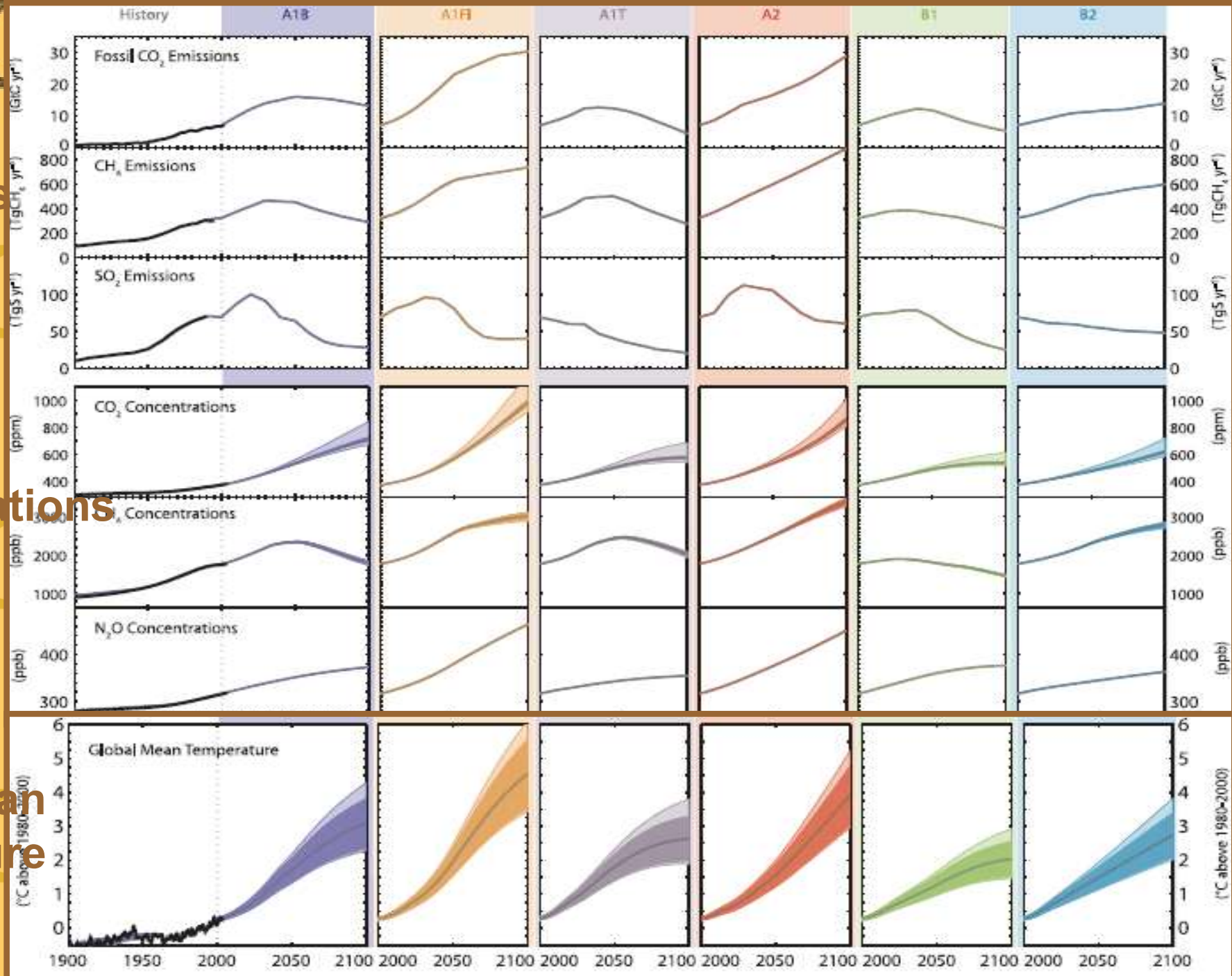
★ try to google it... ☺



Climatic system



emission scenarios



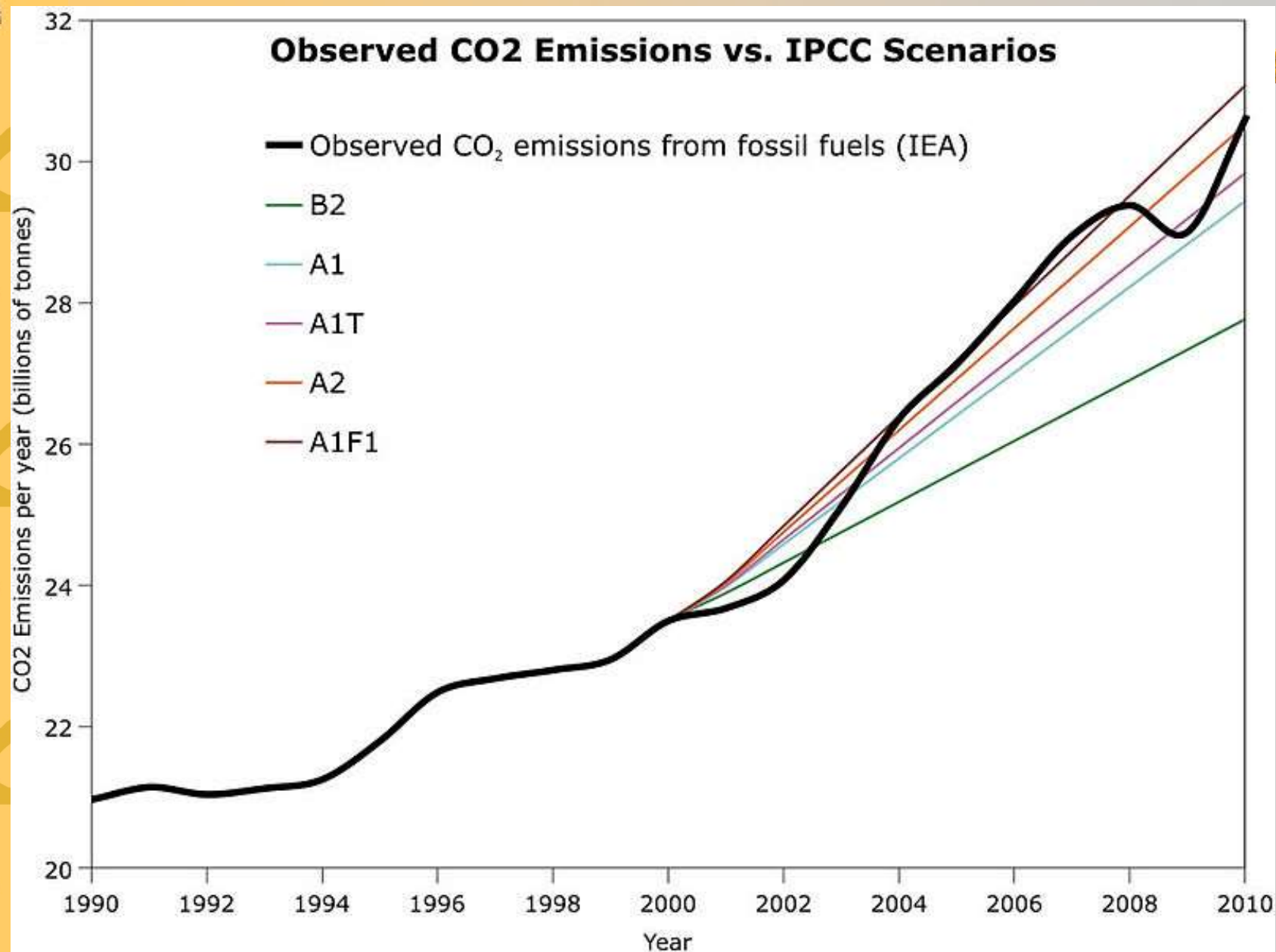
emissions

concentrations

glob.mean
temperature



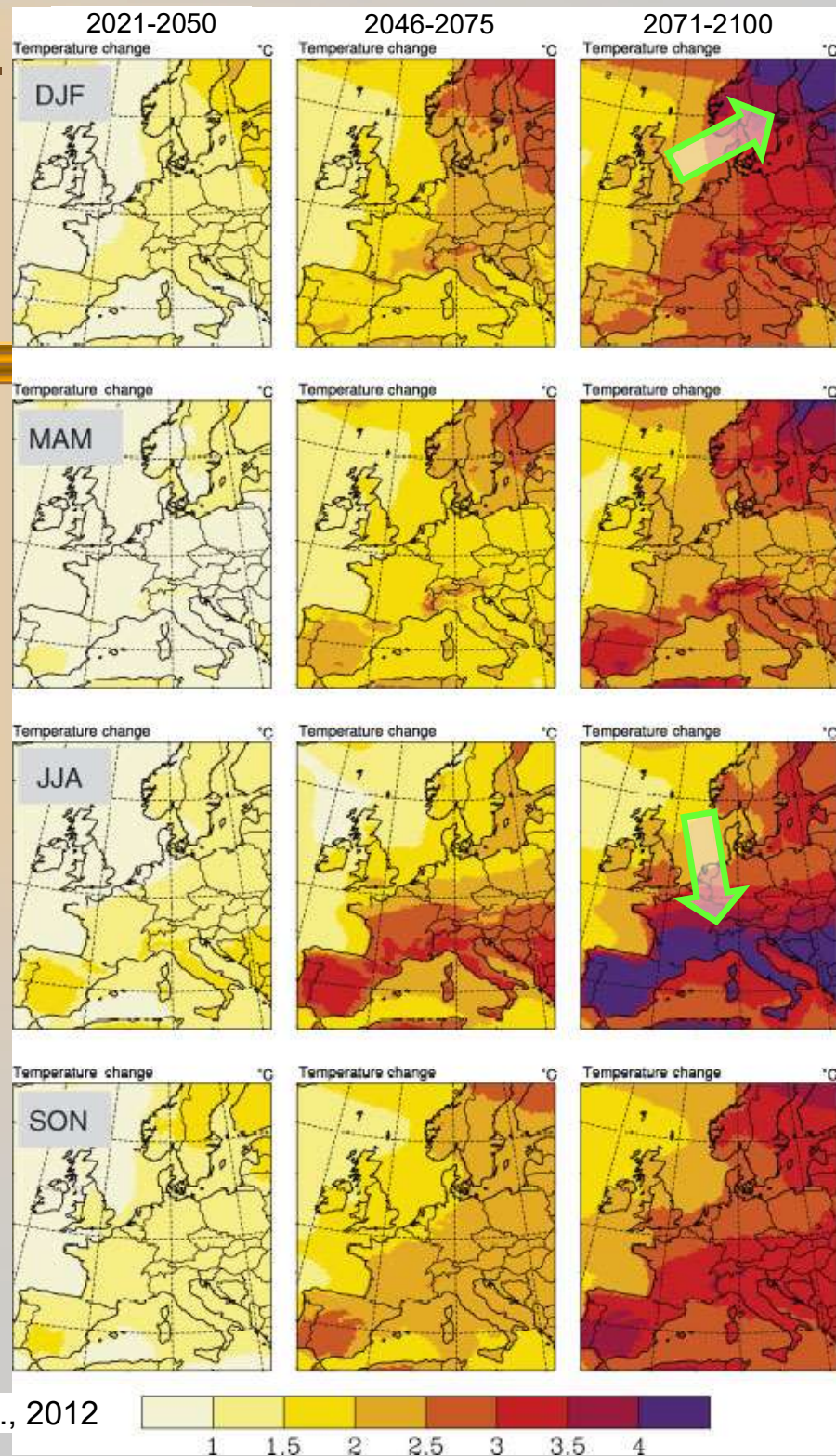
Real CO₂ emissions vs. emission scenarios





Future climate change – surface temperature, Europe

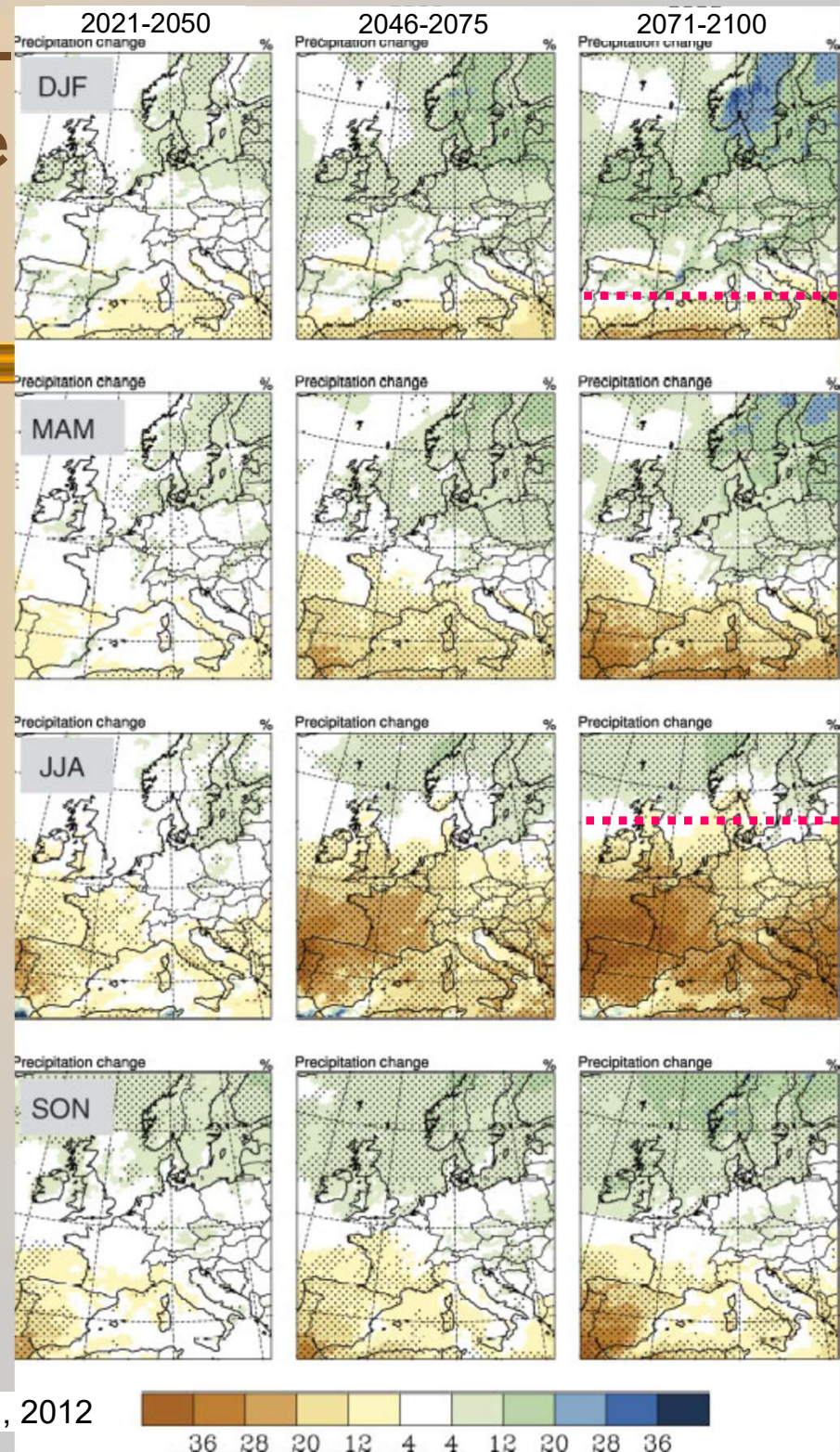
difference (warming) against
1980-2009 (in °C)
average of ensemble of RCMs





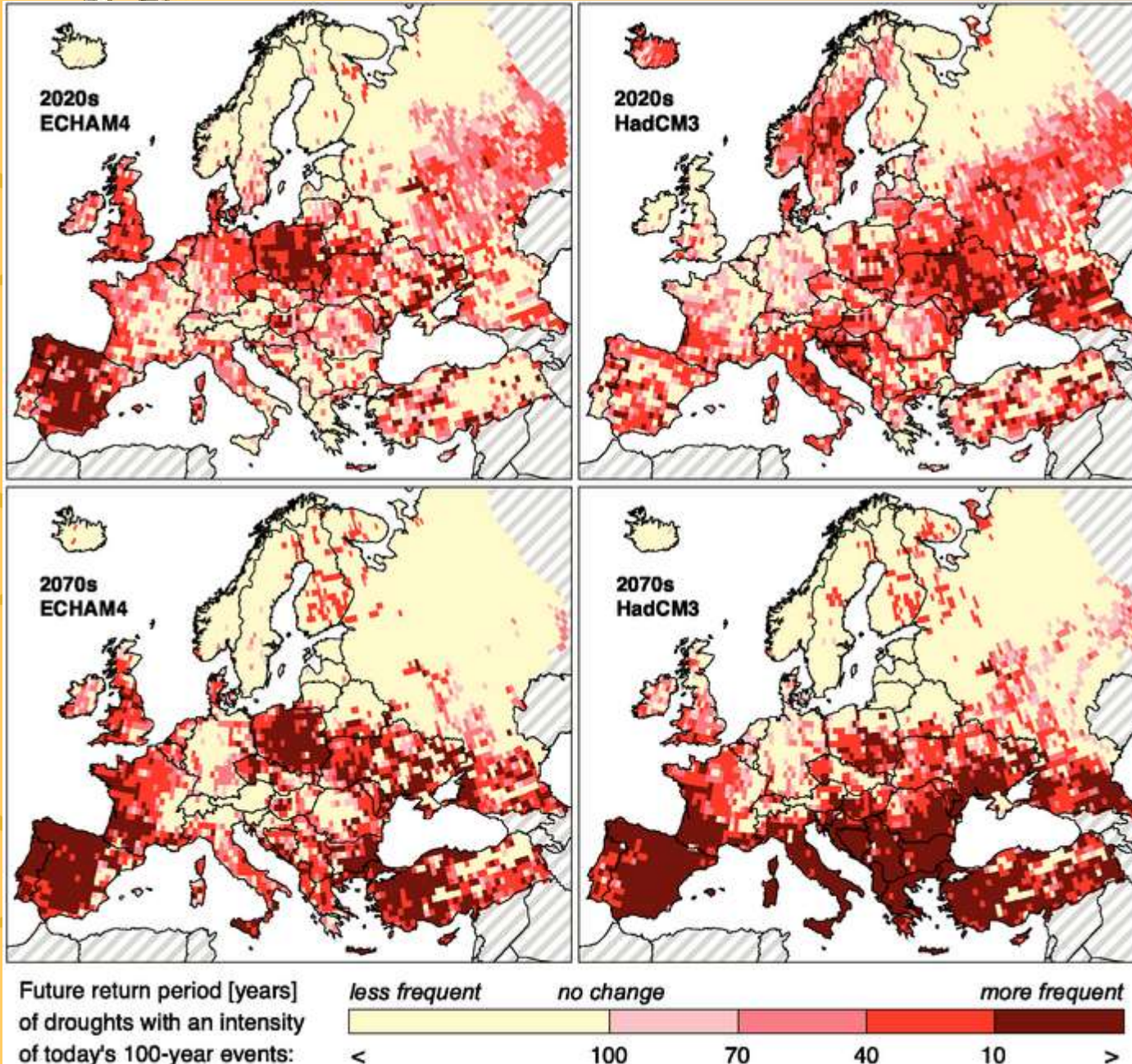
Future climate change – precipitation, Europe

difference against
1980-2009 (in %)
average of ensemble of RCMs
stippling: sign of the change
agrees in $\geq 80\%$ of models





Future climate change – drought



change of return period
of 100-year drought
relative to 1961-90



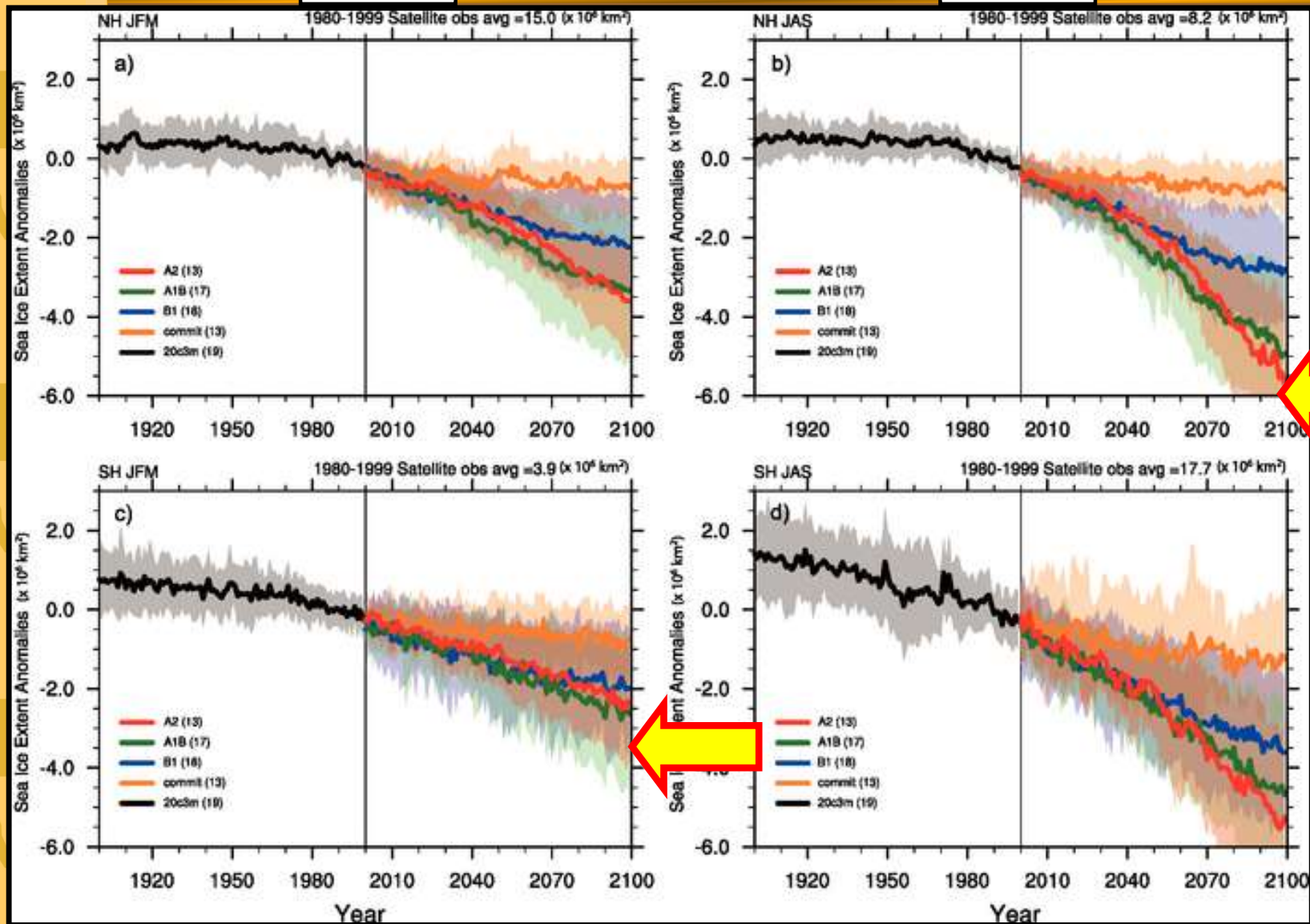
Future climate change – sea ice

JFM

JAS

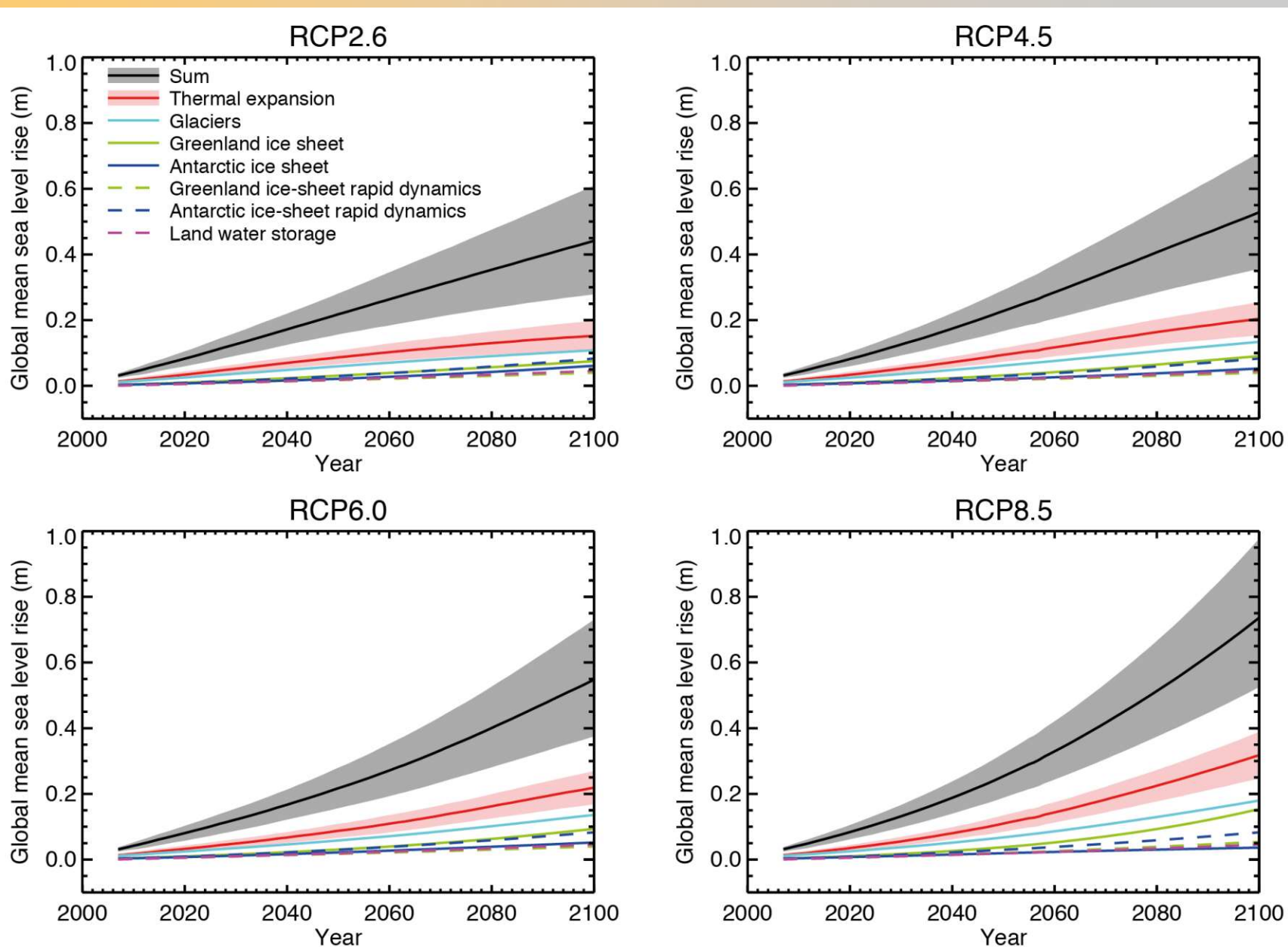
NH

SH

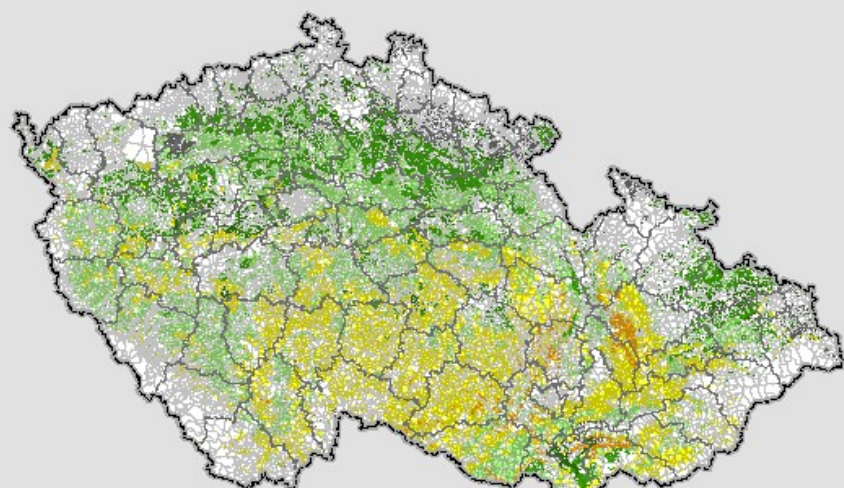
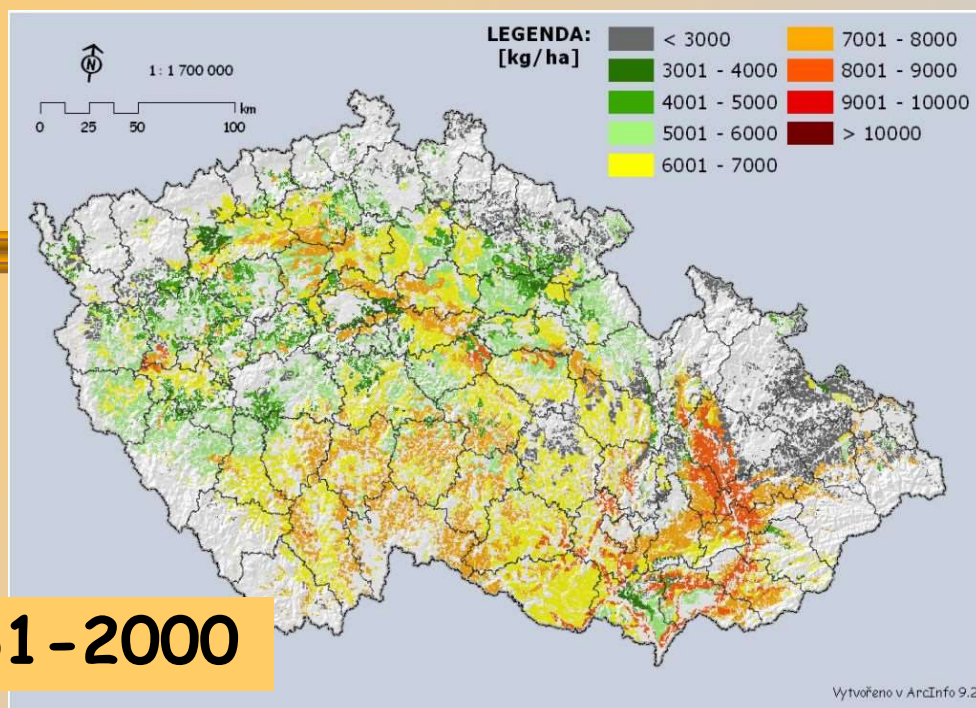




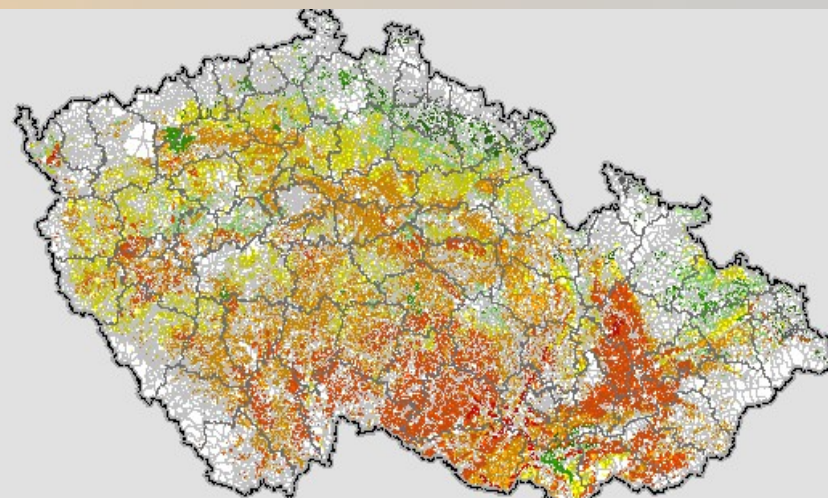
Future climate change – sea level



Climate change impacts on potential yield of winter wheat



without direct CO₂ effect
(effect of climate only)

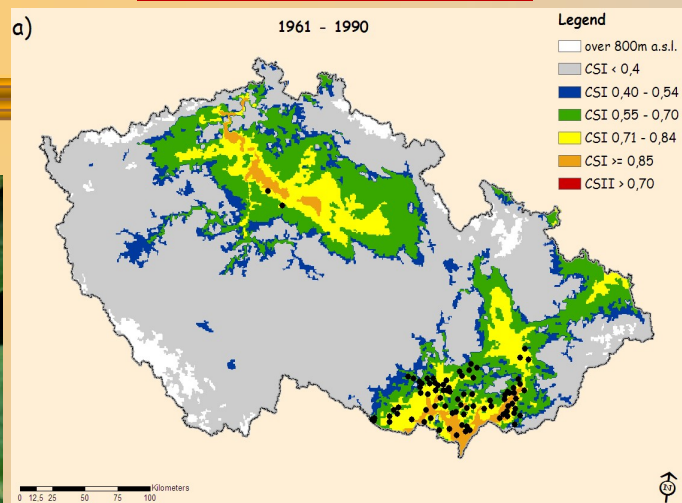


including direct CO₂ effect
(both climate & fertilization)

European corn borer (*Ostrinia nubilalis*)

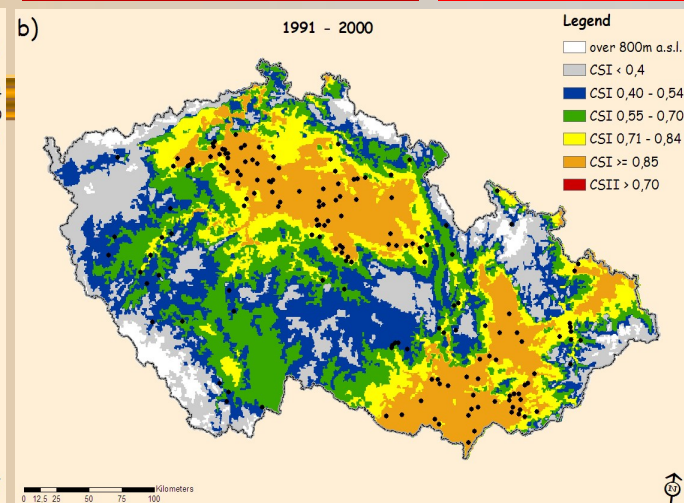


1961-1990

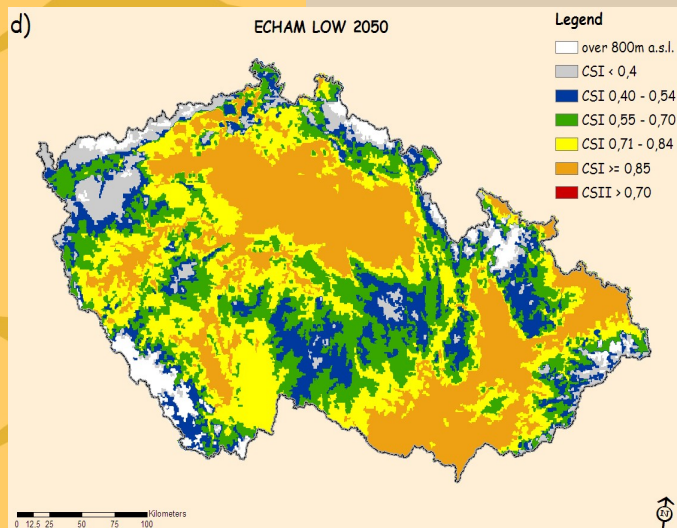


1991-2000

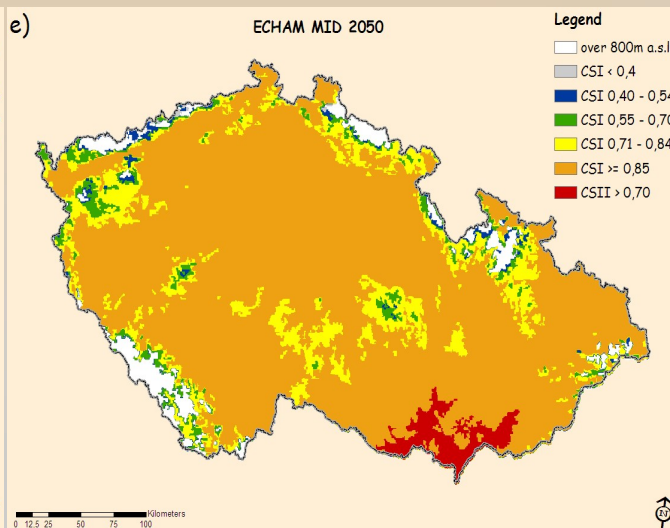
+0,6°C



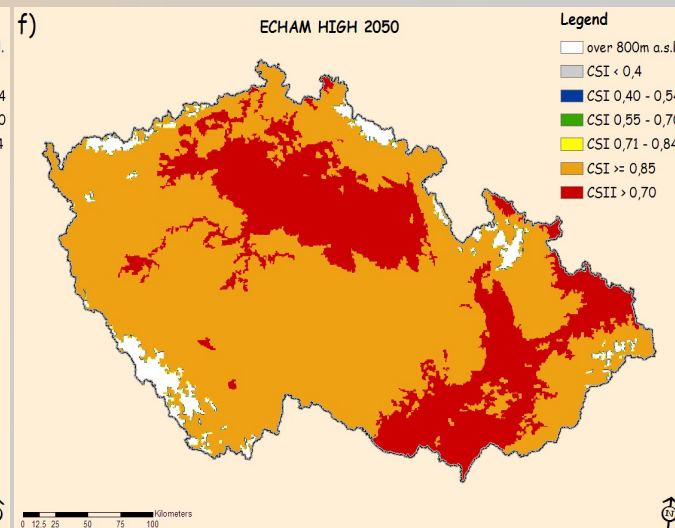
+1,0°C



+1,8°C



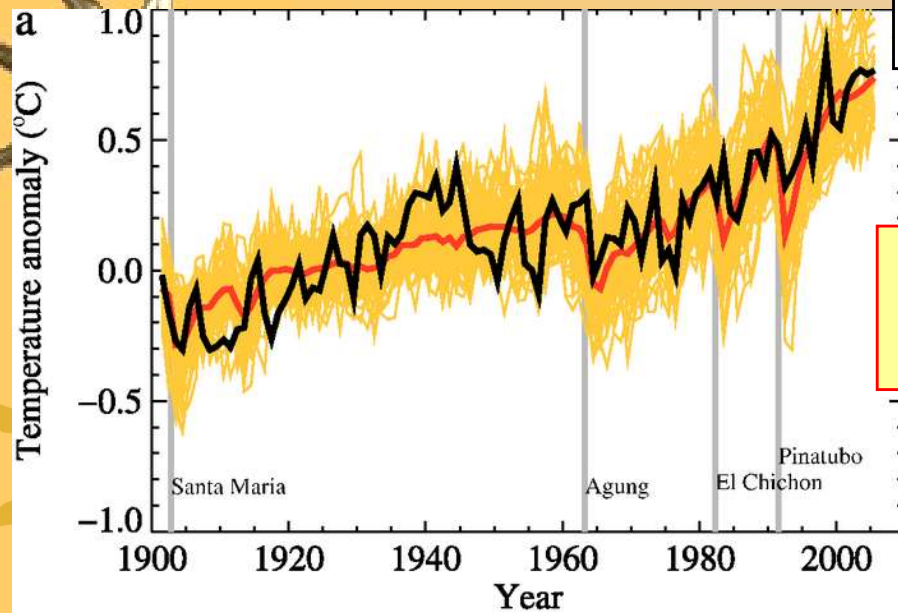
+2,5°C





5. Why is climate changing?

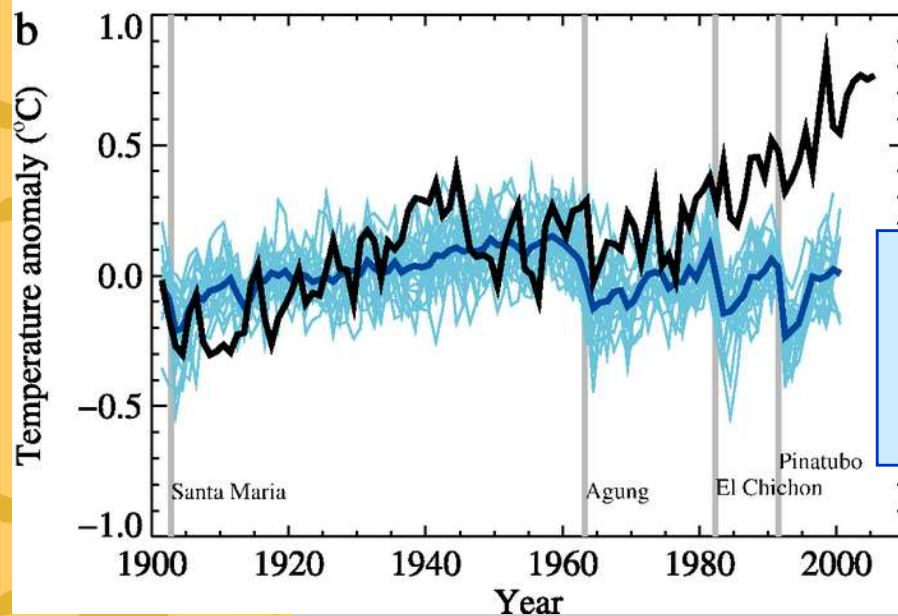




observations

**models: all forcings
(natural & anthropogenic)**

global mean surface
temperature



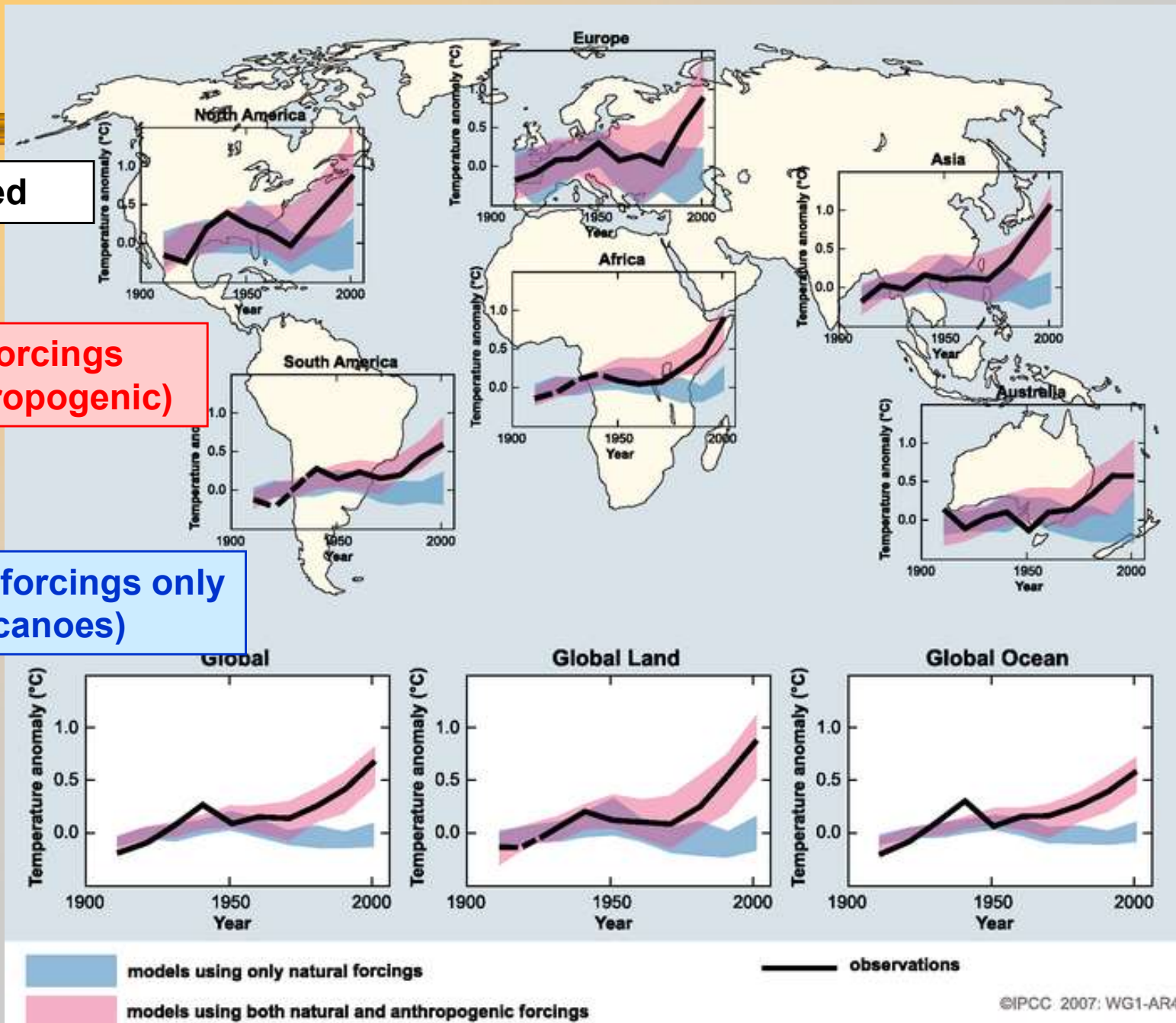
**models: natural
forcings only
(sun + volcanoes)**

continental mean surface temperature

observed

models: all forcings
(natural & anthropogenic)

models: natural forcings only
(sun + volcanoes)



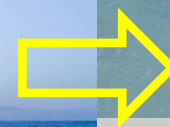
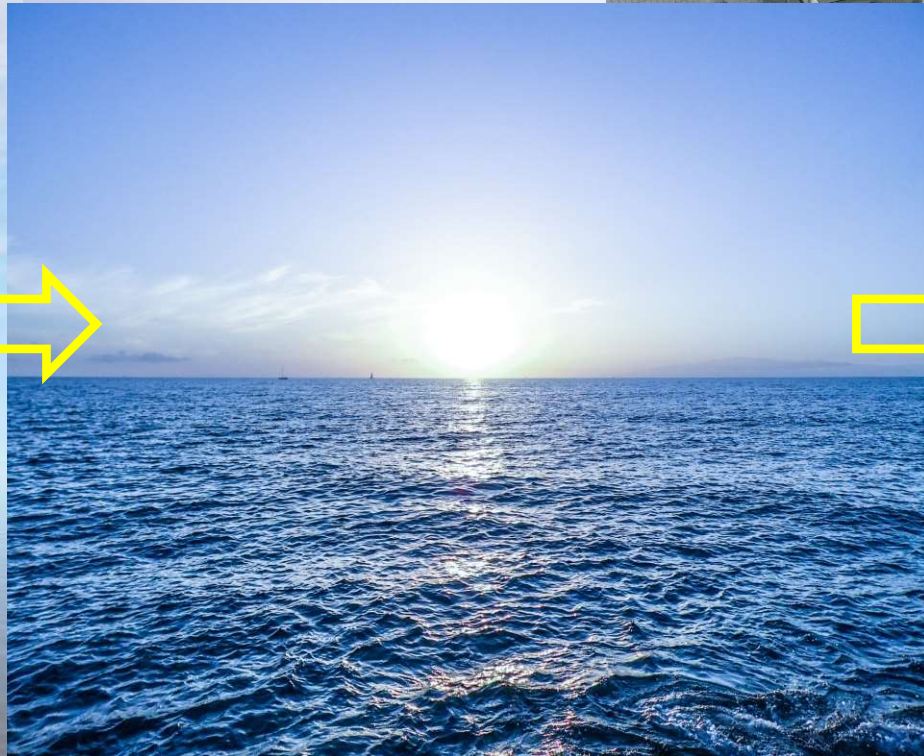


6. And what to do against climate change?





What to do?



?????



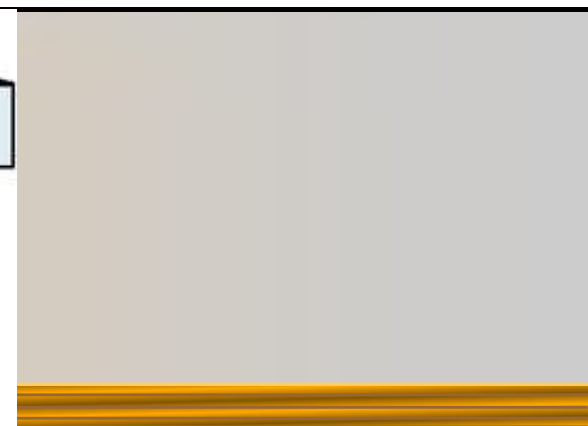
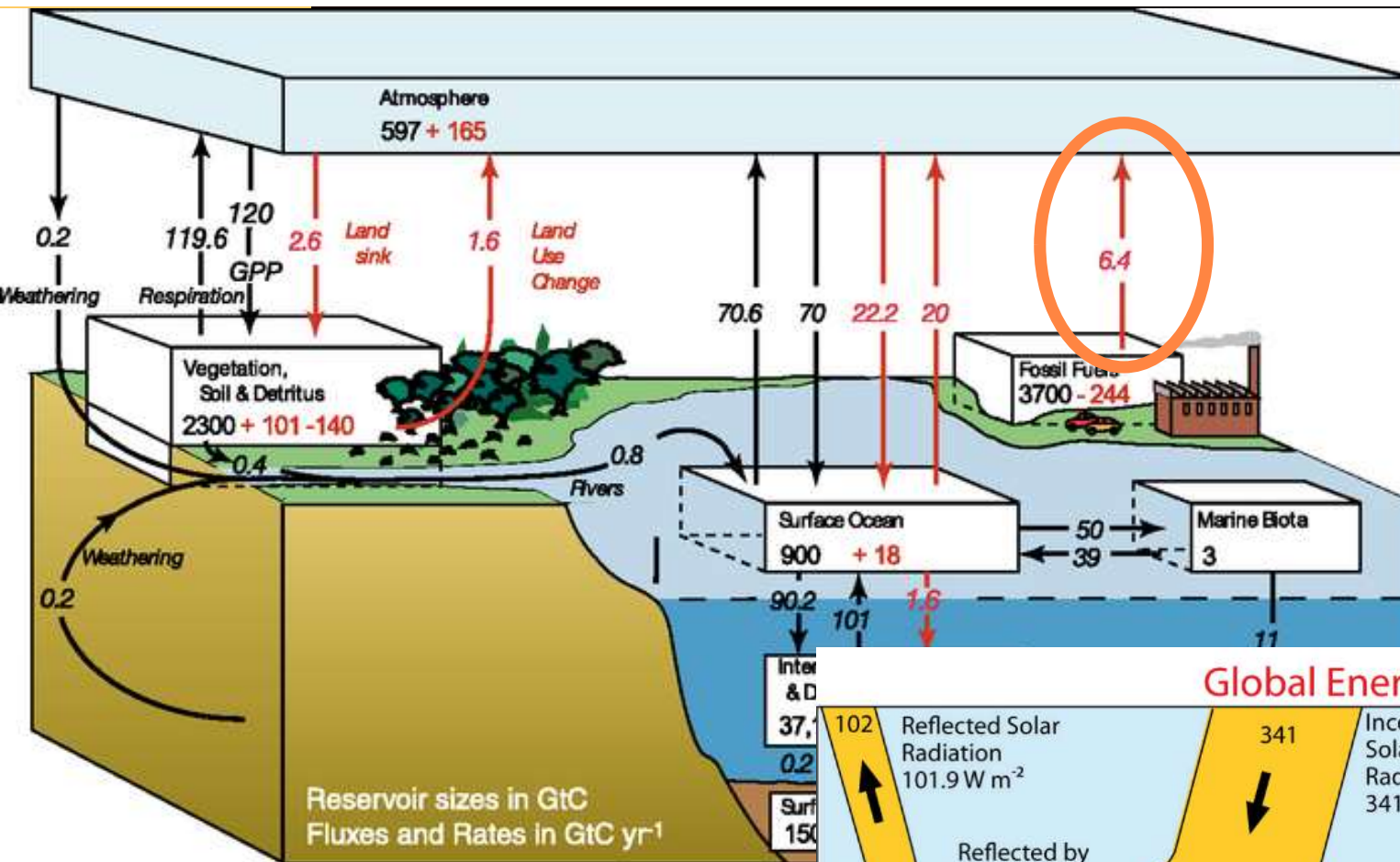


What to do?

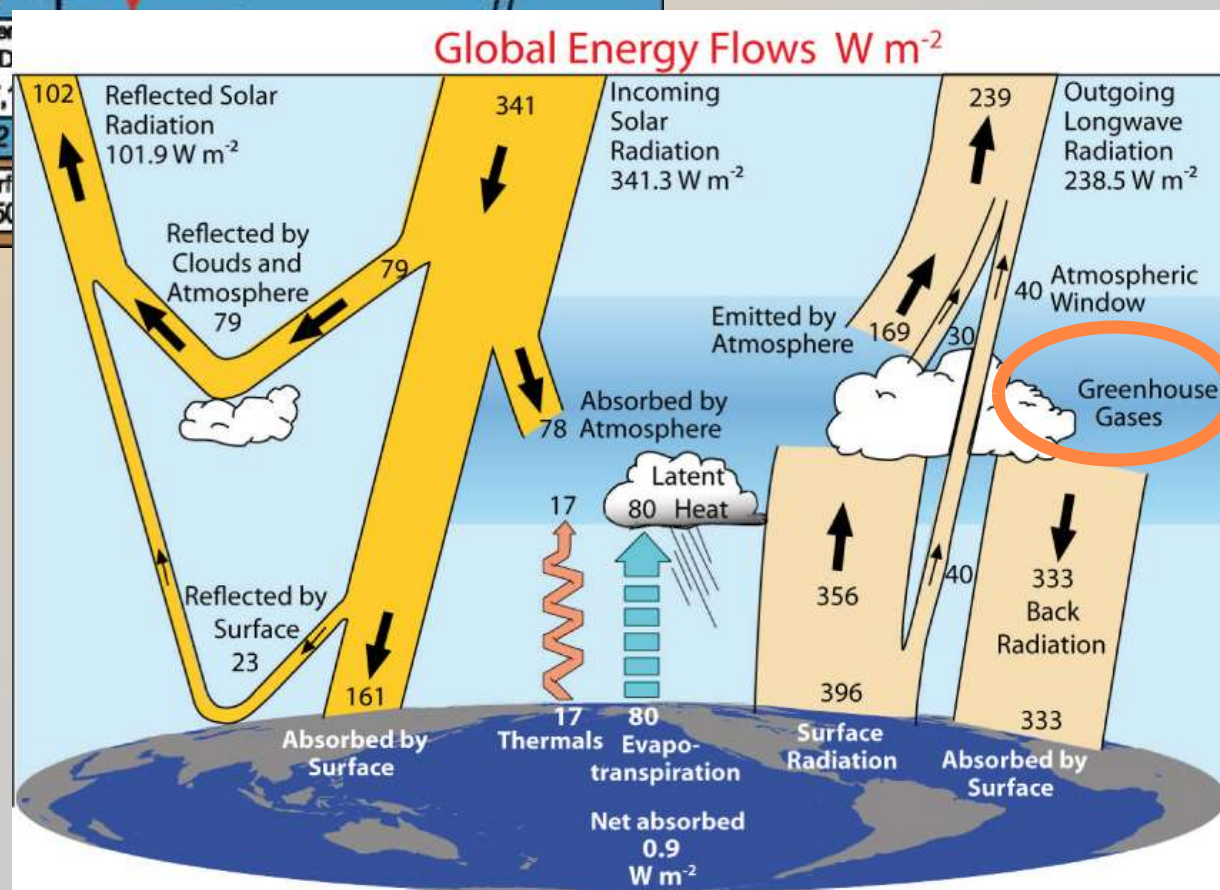
★ way 2: mitigation

- measures to reduce climate change itself





measure #1
reduction of emissions



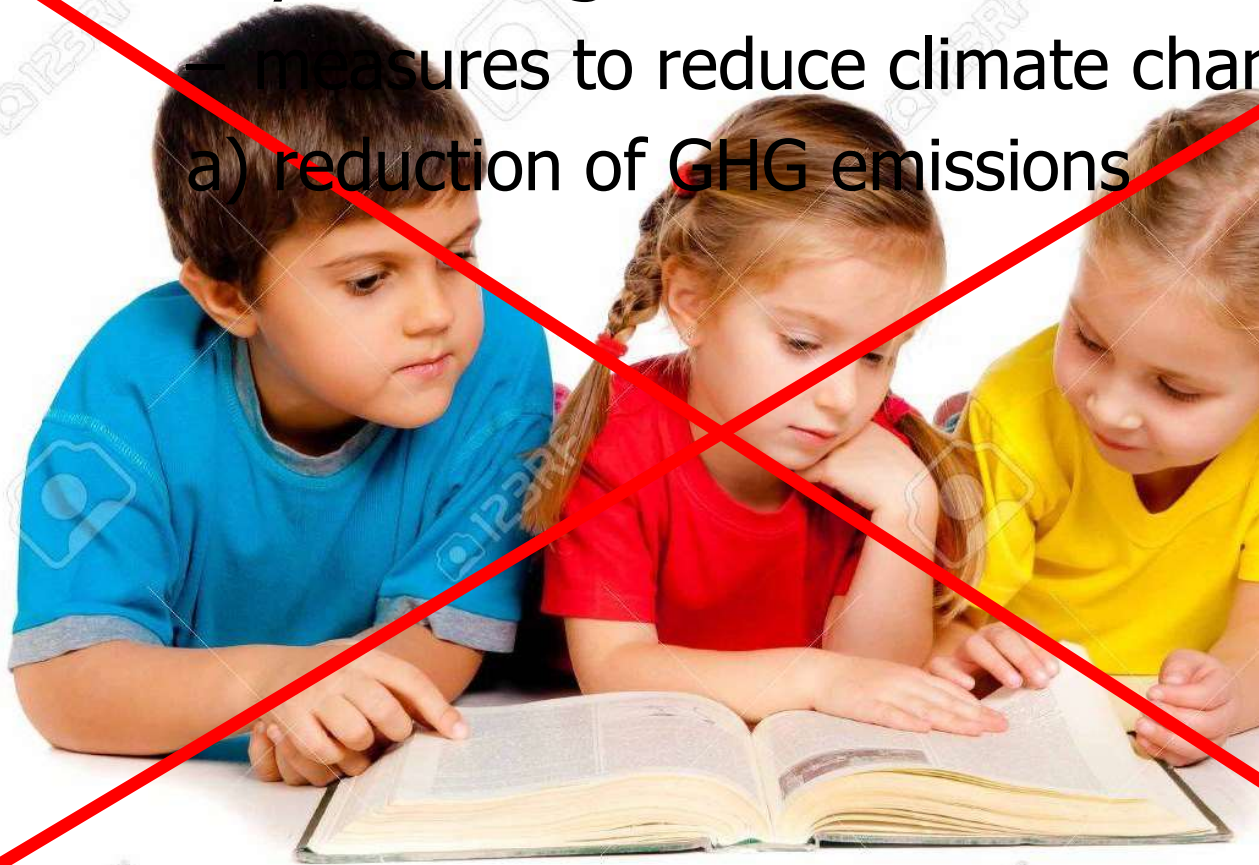


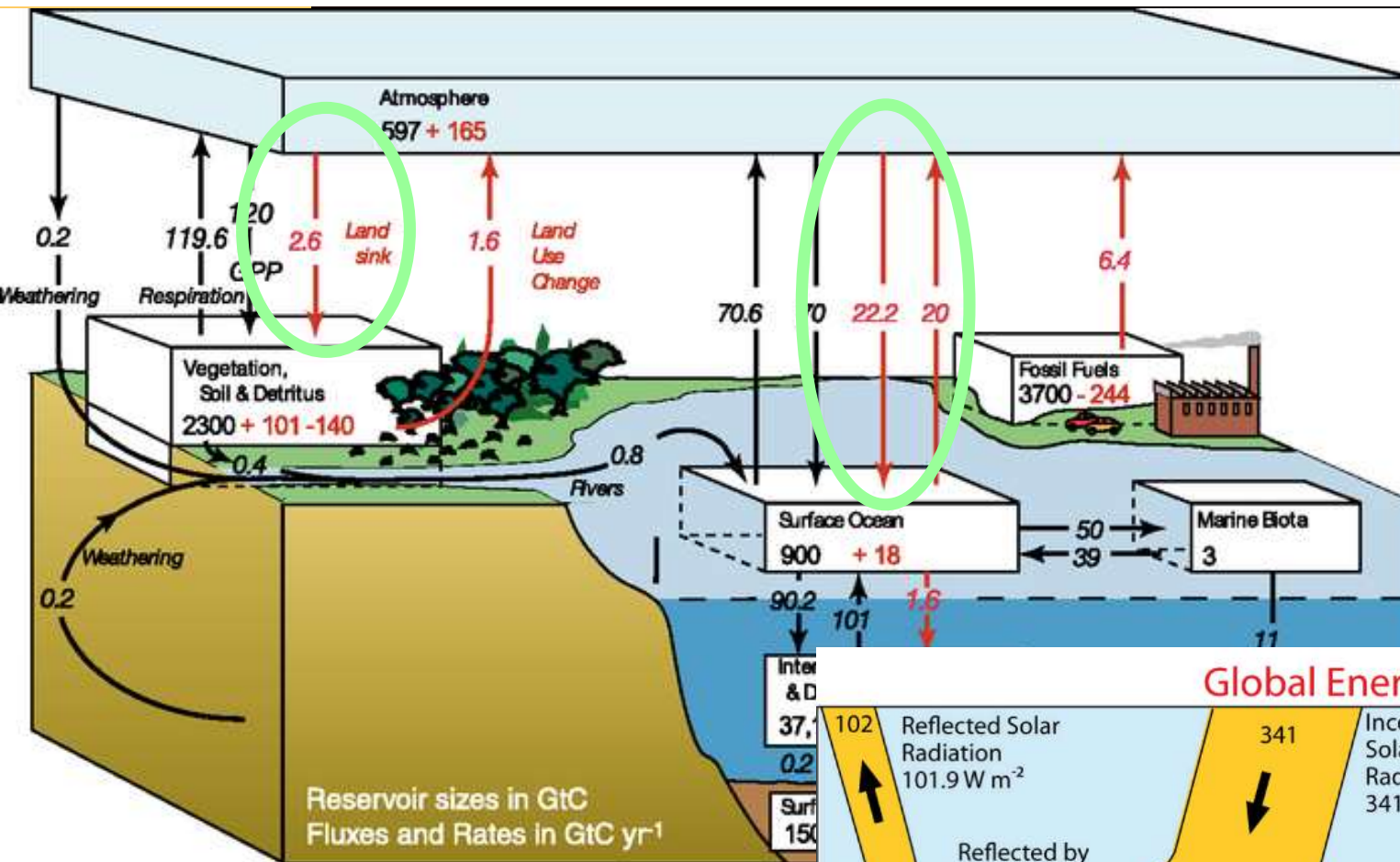
What to do?



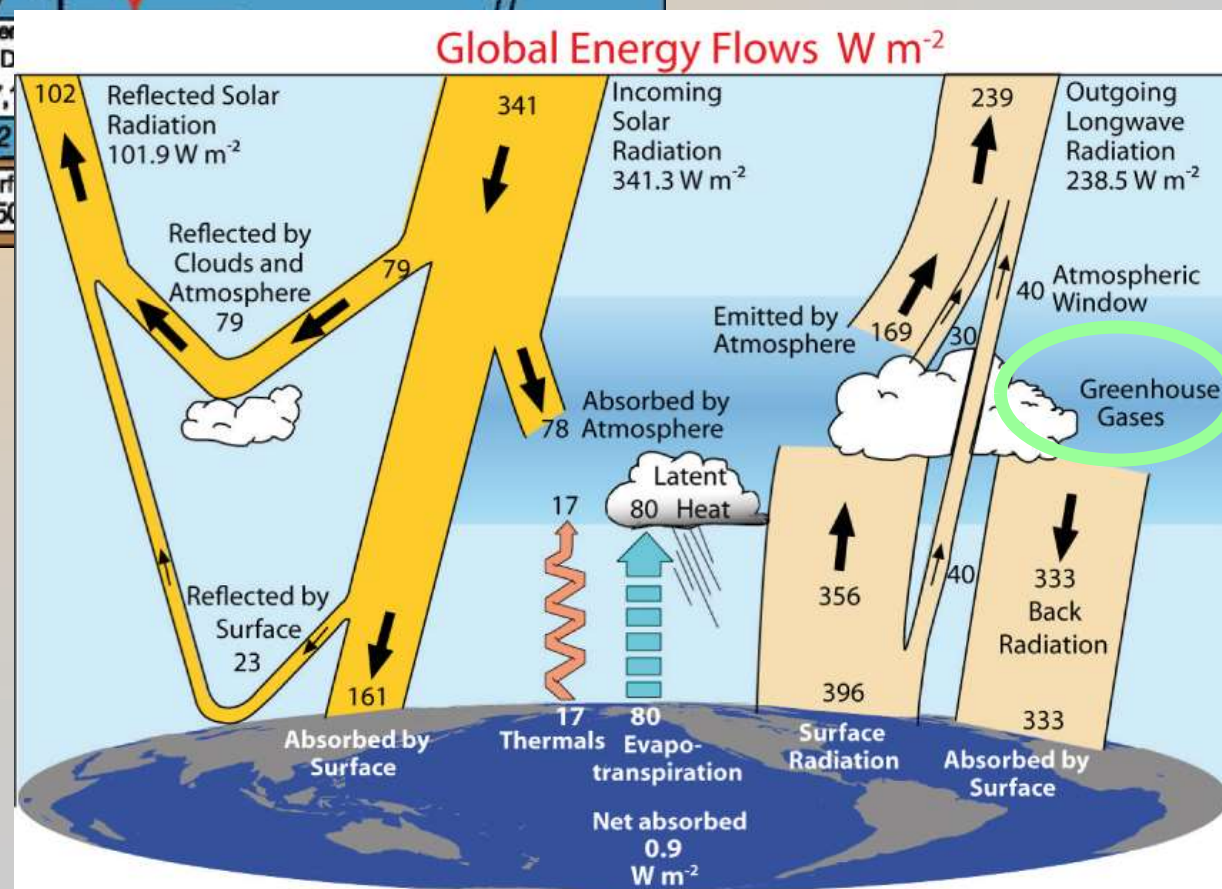
★ way 2: mitigation

— measures to reduce climate change itself
a) reduction of GHG emissions





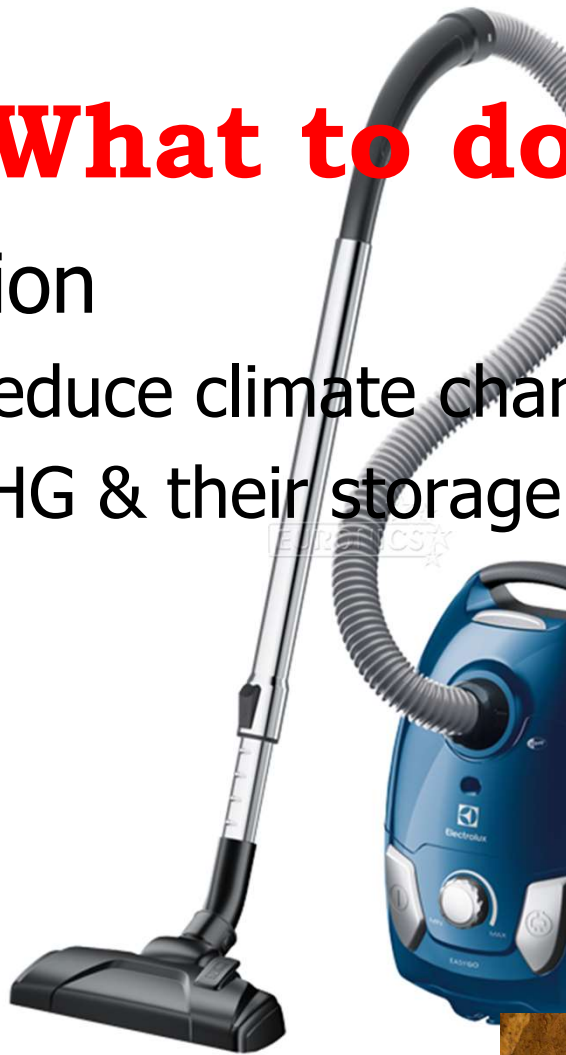
measure #2
sequestration
(removal of CO₂ & its
storage)

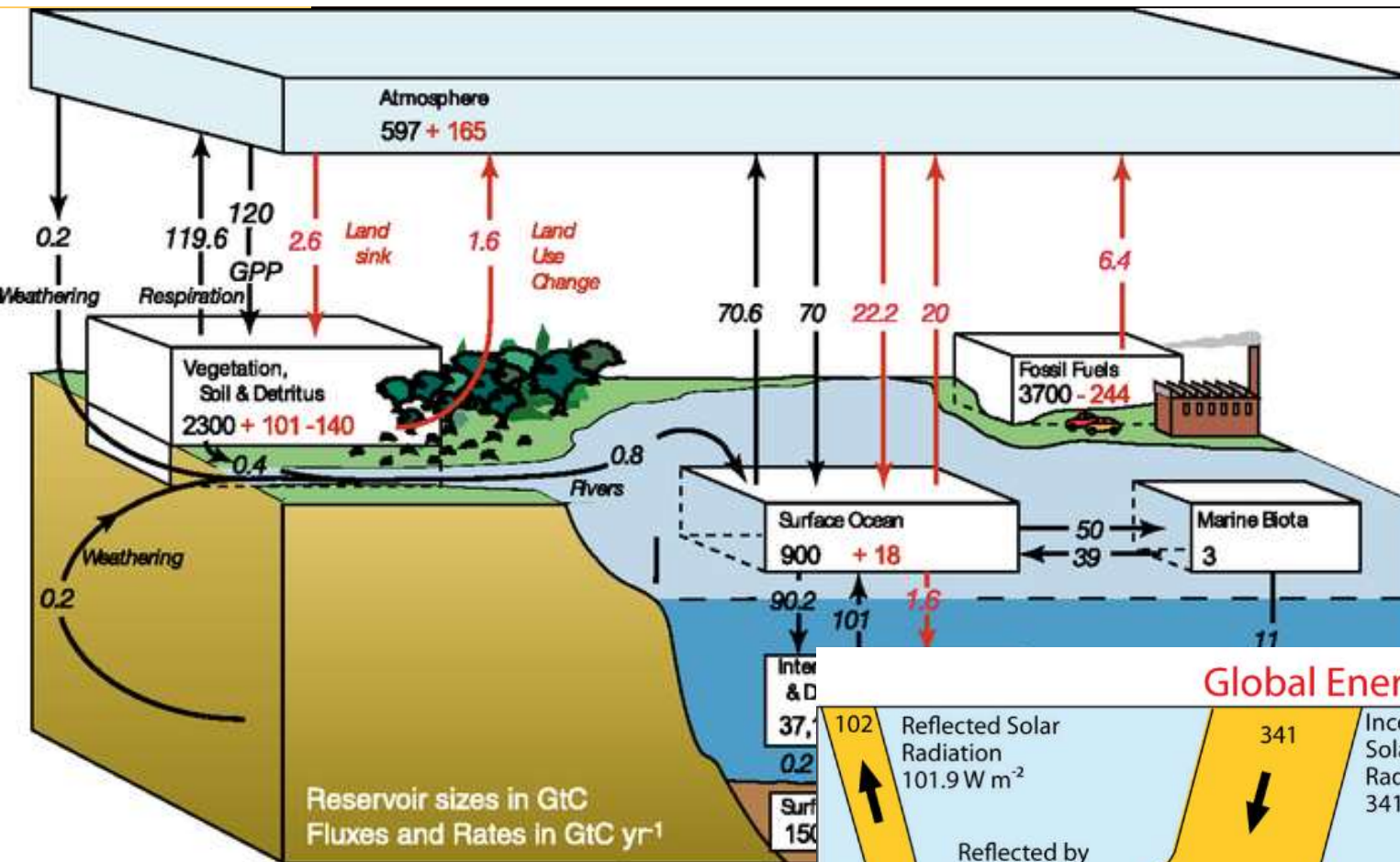


What to do?

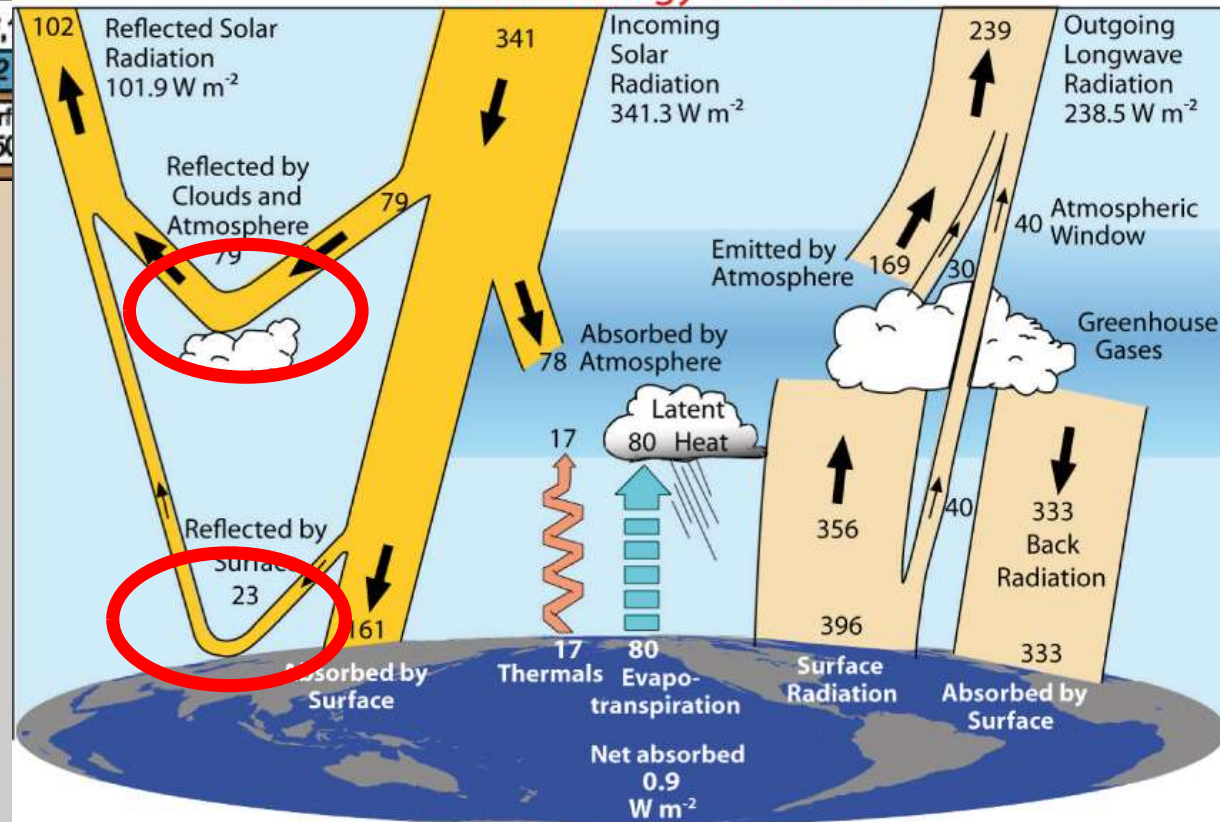
★ way 2: mitigation

- measures to reduce climate change itself
- b) removal of GHG & their storage (sequestration)





Global Energy Flows W m⁻²



measure #3
increase of planetary
albedo
(geoengineering)

What to do?

★ way 2: mitigation

- measures to reduce climate change itself
- c) reduction of absorbed solar radiation (geoengineering)

