

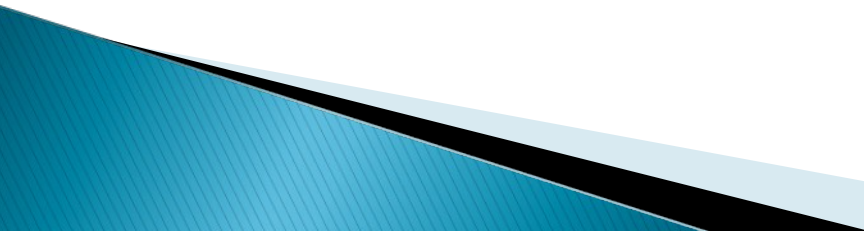
On Climate Scenarios for the Region

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*Thanks to: Č. Branković & I. Güttler
Croatian Weather Service (DHMZ)*

OUTLINE

- Data: *Global Past, Present →?→ Future*
 - Numerical Models ⇔ Simulators
 - Climate vs. Weather: expect ≠ get
 - More of Current Results: *Present → Future*
 - Regional Climate Change
 - Tentative Conclusions → *Discussion*
- 

... in the past [see
erson, 2003]. To quote
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in the Past

es for Earth are most
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*et al., 2001; Smith and
 n et al., 2006*].
 record part of Figure 1
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rohan et al., 2006].
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Earth's crust such that progressively deeper
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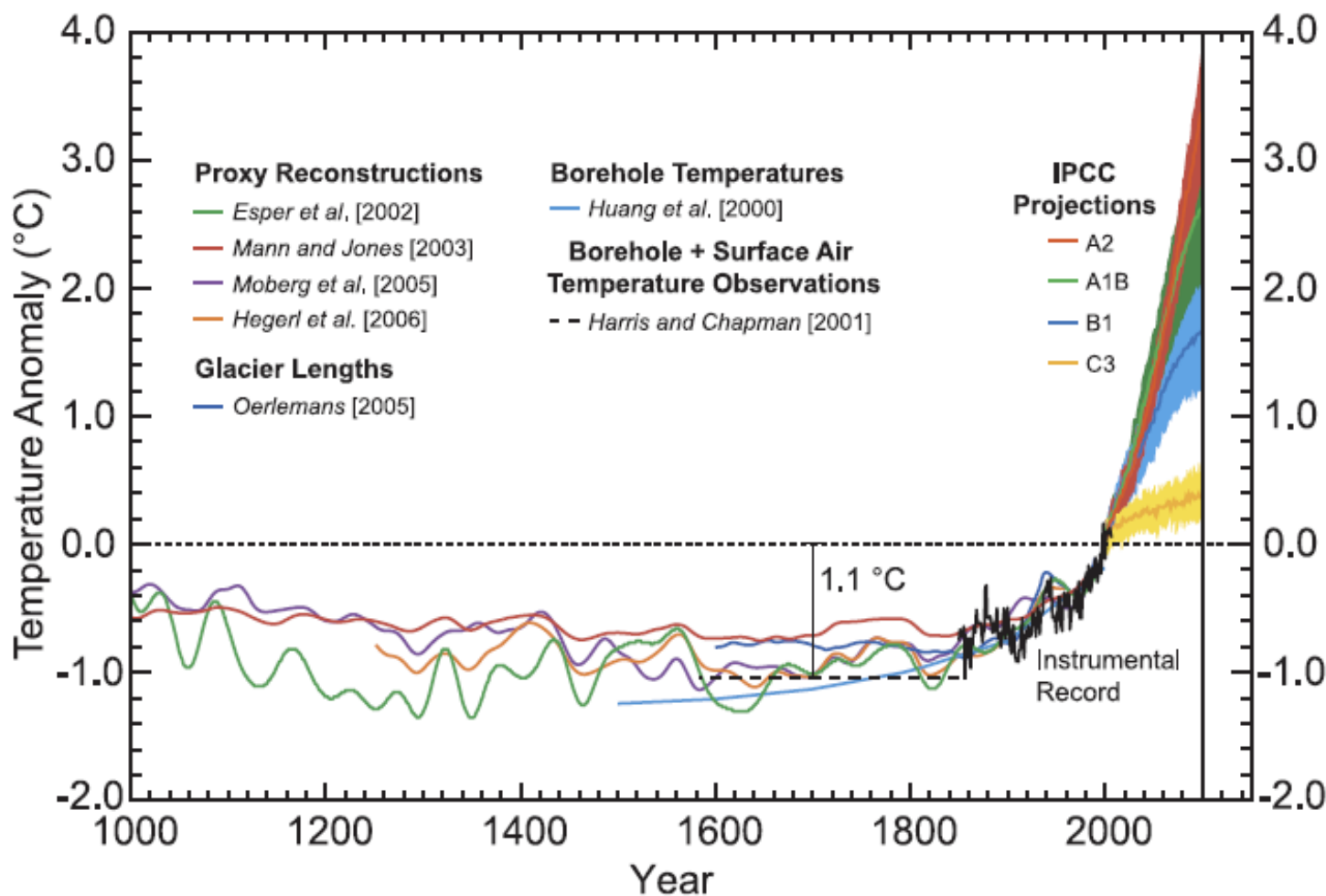
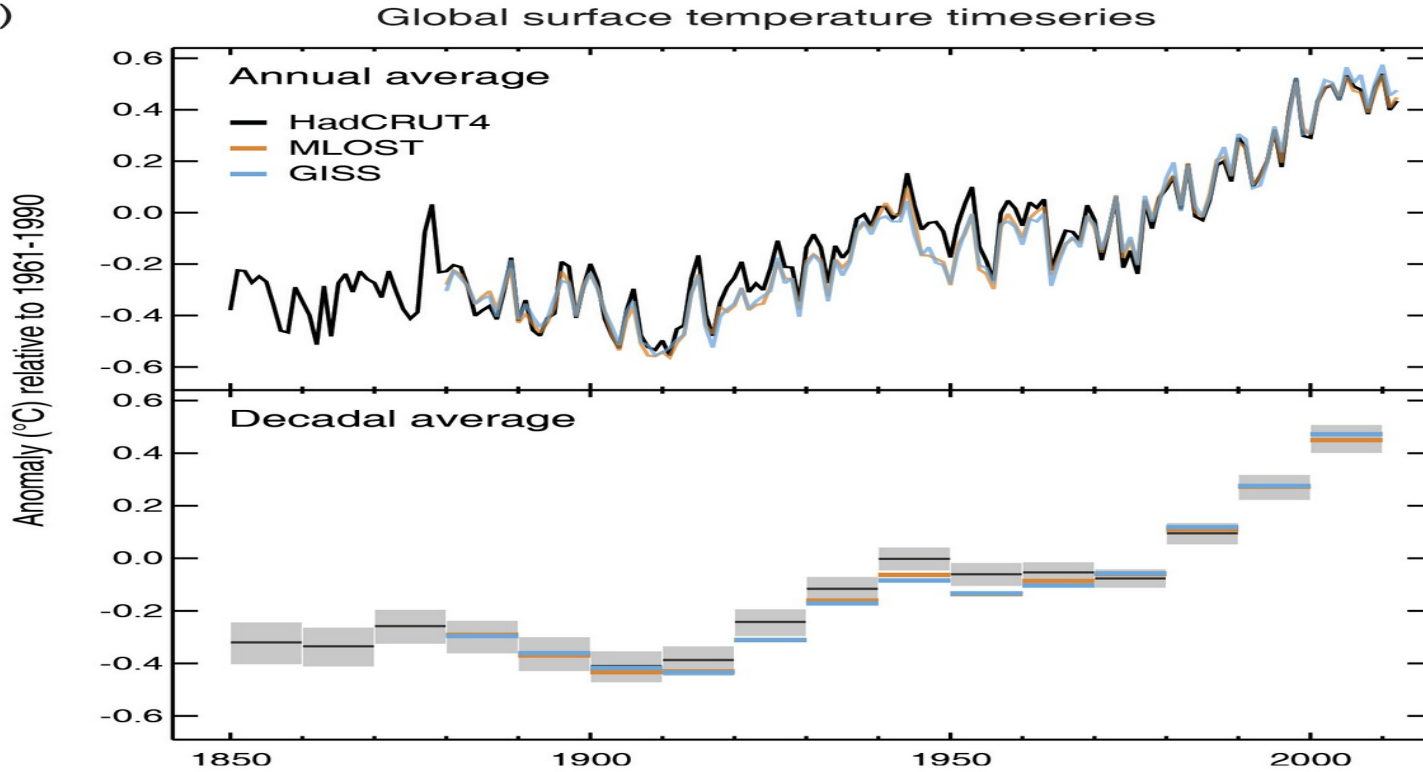


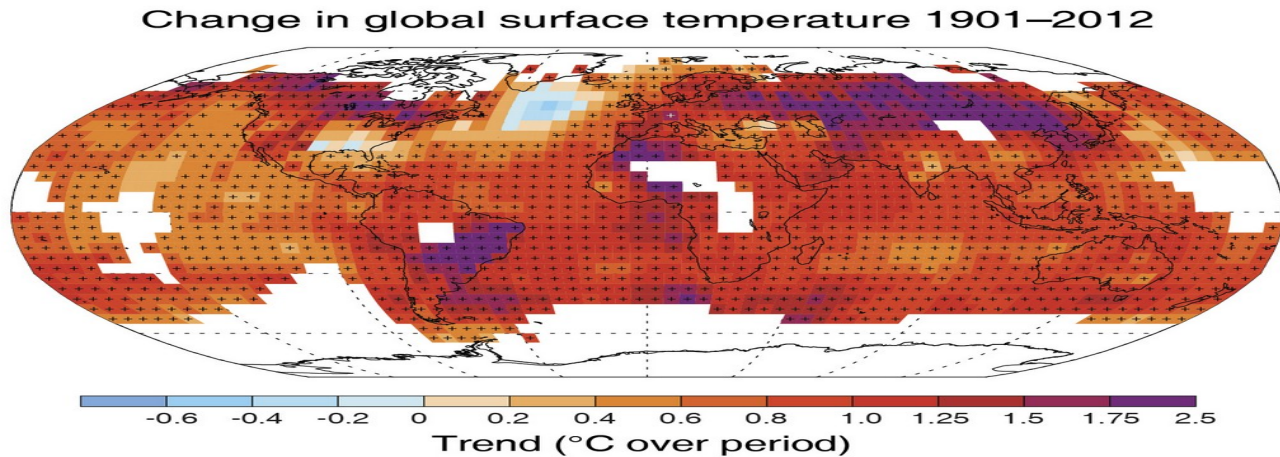
Fig. 1. Views of temperature change in the next century are informed by temperature changes in the past. For illustrative and educational purposes, three sets of surface temperatures have been assembled: 1000-year reconstructions of past temperature change based on proxies (tree rings, corals, etc.), glacier lengths, and borehole temperatures; the instrumental record; and Intergovernmental Panel on Climate Change (IPCC) projections for temperature change from 2000 to 2100. Figure modified from National Research Council [2006] and IPCC [2007].

5th IPCC, late 2013 - observed data

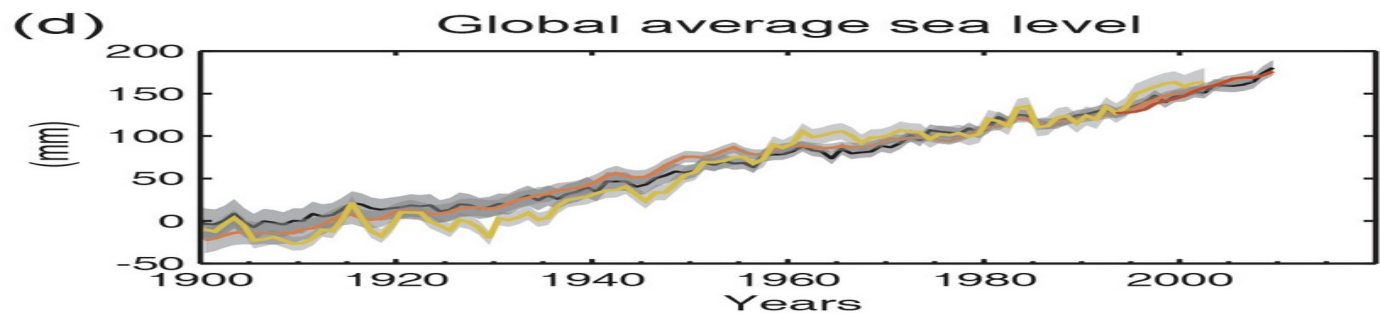
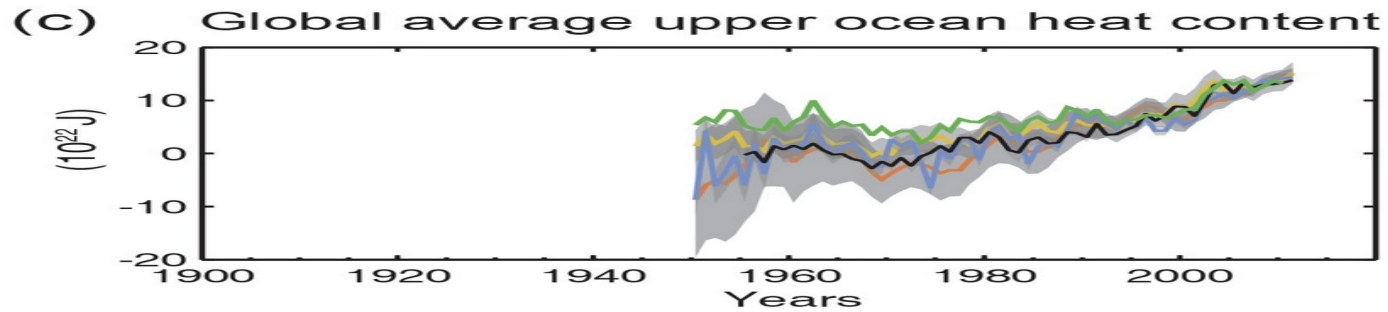
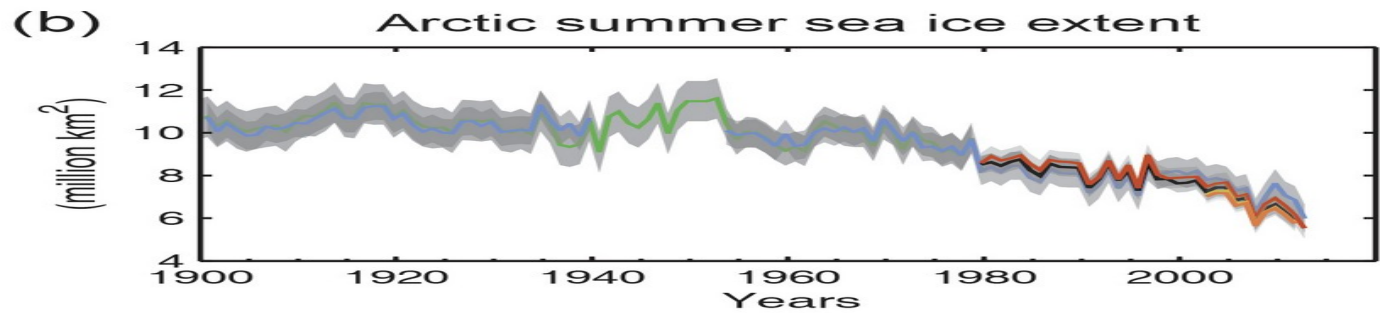
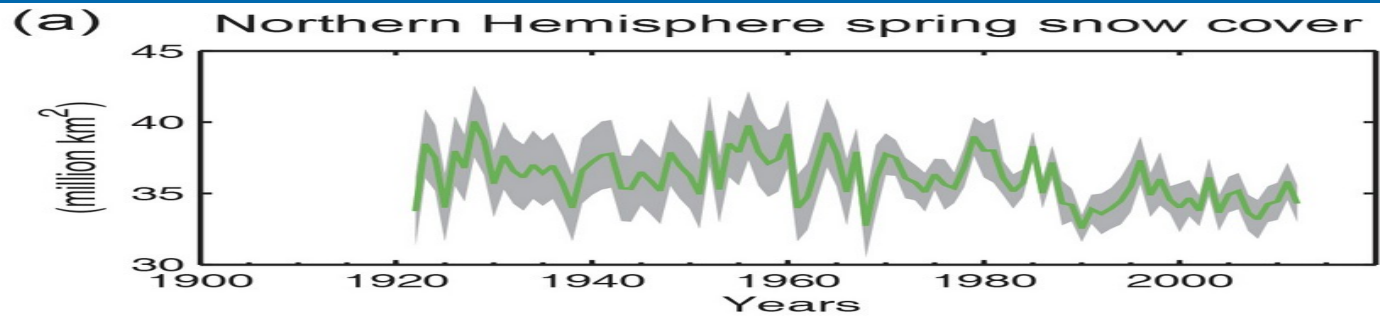
(a)



(b)



5th IPCC, late 2013 - observed data



Meteorology, Oceanography, Glaciology, Vulcanology,... ⇔ Climatology

BASIC ISSUES:

- **MEASUREMENTS**, WITH THEIR ERRORS, ARE SPARSE IN SPACE & TIME. THUS, INITIAL STATE OF THE ATMOSPHERE & OCEAN IS ONLY KNOWN PARTLY
- NUMERICAL WEATHER PREDICTION (NWP) & CLIMATE **MODELS** CAN'T FULLY RESOLVE IN SPACE & TIME ALL THE RELEVANT PHYSICAL PROCESSES (ASIDE APPROXIMATIONS)
- ATMOSPHERES & OCEANS ARE INHERENTLY CHAOTIC BESIDES STRONG DETERMINISTIC COMPONENTS

Numerical modeling of weather & climate

- The atmosphere's behavior is governed by a set of **physical conservation laws** telling how the air moves (Newton's laws of motion), about heating-cooling (laws of thermodynamics), roles of moisture...
- The governing Partial Differential Equations (**PDE's**) can't be solved analytically – only **numerical** (i.e., approximate) solutions are possible
- * Given the current state, *I.C.* & *B.C.*, the equations may be used to pass the info forward in time \Leftrightarrow forecast
- * The observations give the sparse current state – an incomplete picture, the weather & climate models may process the obs. \rightarrow a fuller picture of reality

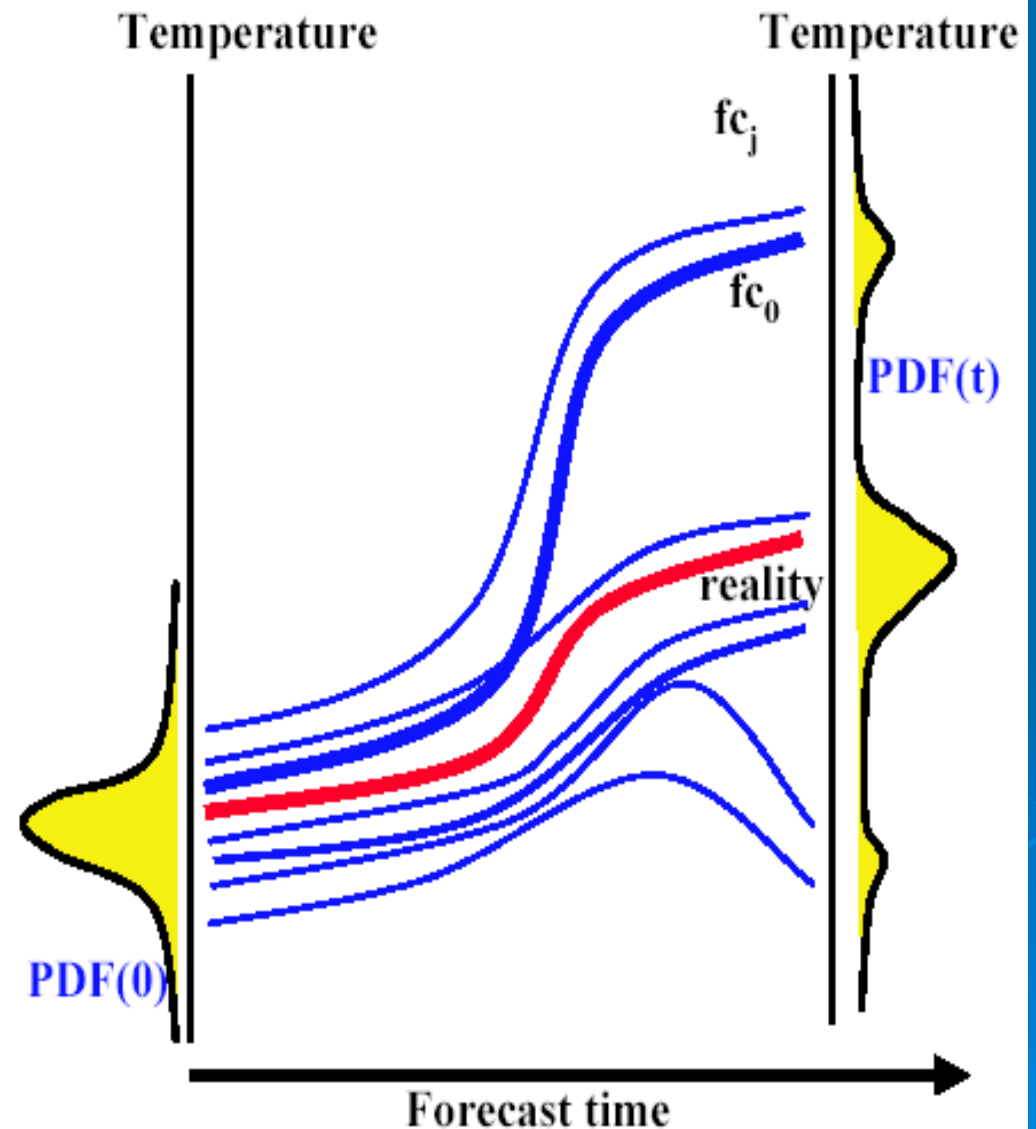
Unresolved Processes ⇔ Parameterized

- Small scale processes are not resolved by large scale models, because they are **sub-grid**.
- The **effect** of the sub-grid process on the large scale can only be represented statistically.
- The procedure of expressing the effect of sub-grid process is called **parametrization**.

Parameterized: Radiation, Moist Processes, Turbulence,...

Predictability, like Turbulence, is Flow Dependent

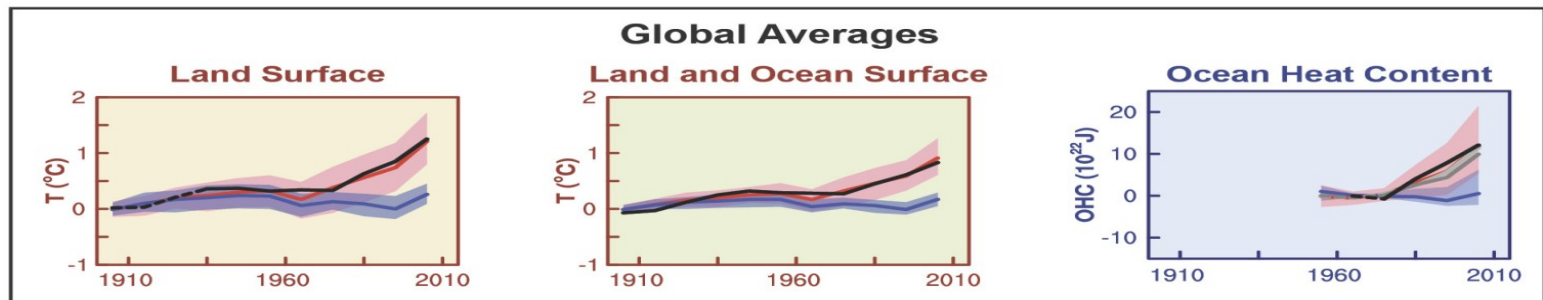
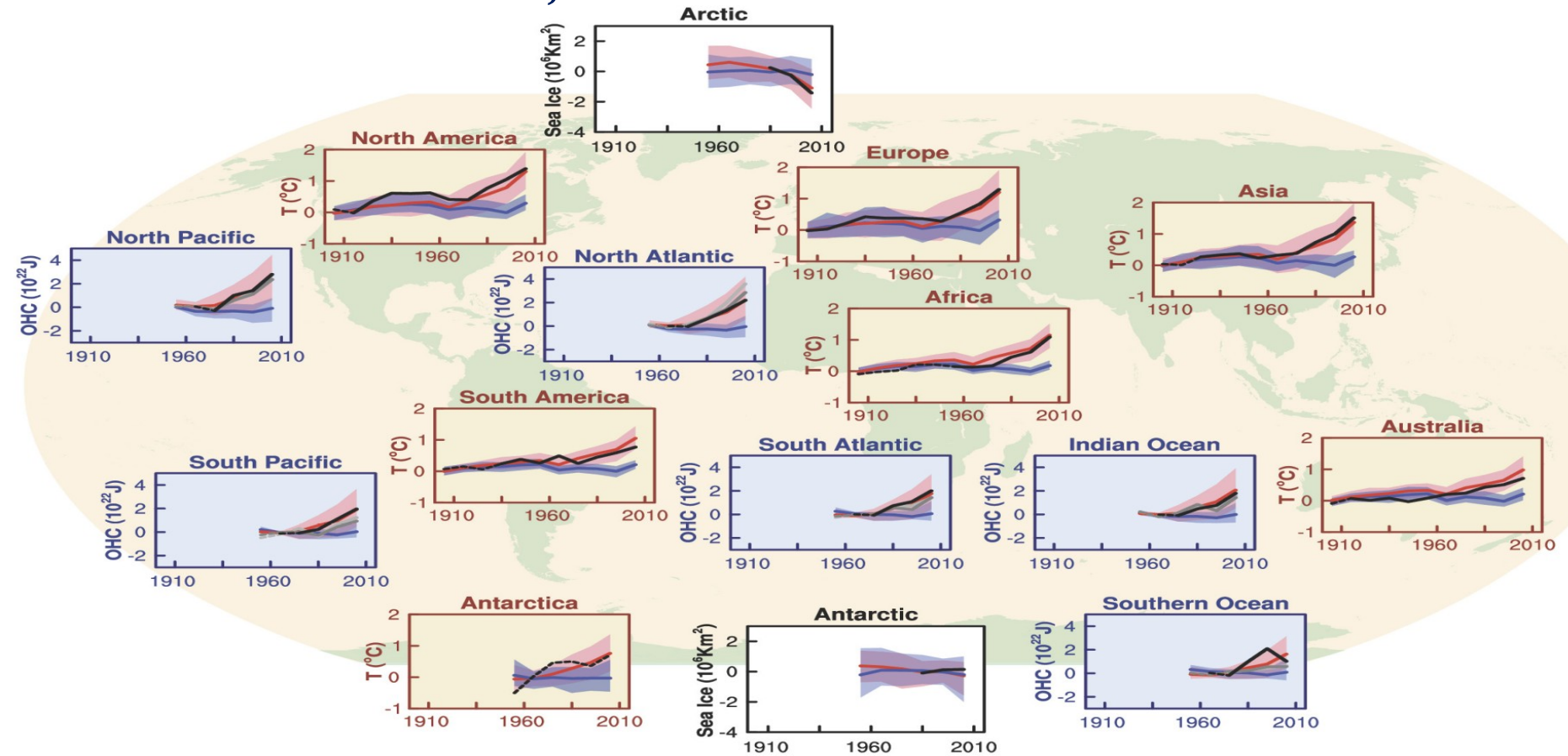
- Two are the main sources of error growth: **initial** and **model uncertainties**.
- Predictability is flow dependent.
- A complete description of weather prediction can be stated in terms of an appropriate **probability density function (PDF)**. Ensemble prediction based on a finite number of deterministic integration appears to be the only feasible method to predict the PDF beyond the range of linear growth.



Weather vs. Climate Models

- Resolution & integration length of the governing **PDE**'s (motion, mass, thermodynamics, species)
- Parameterizations (different space - & time-scales) e.g., weather models might have slight drift (may avoid some feedbacks, etc.) ...climate modes not!
- Sometimes numerics, due to numerous couplings (feedbacks) being modeled differently, etc.
- Oceans, soil, biosphere, ice,... treated differently

5th IPCC, late 2013 - numerical simulations



— Observations

■ Models using only natural forcings

■ Models using both natural and anthropogenic

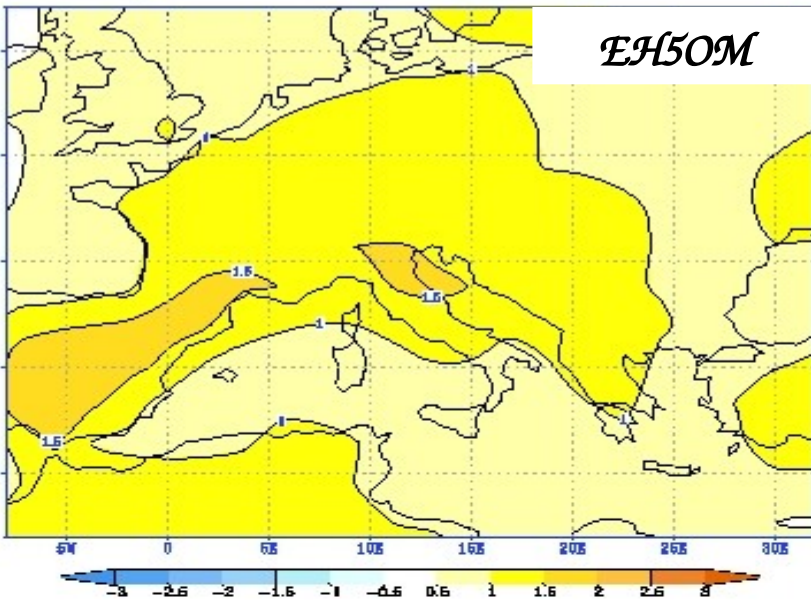
Is the extreme weather we see today really caused by global warming?

- Claims are made that push beyond what science can tell us. Attributing cause ↔ effect to individual weather events is fiendishly difficult. Climate is about patterns, statistical behavior...

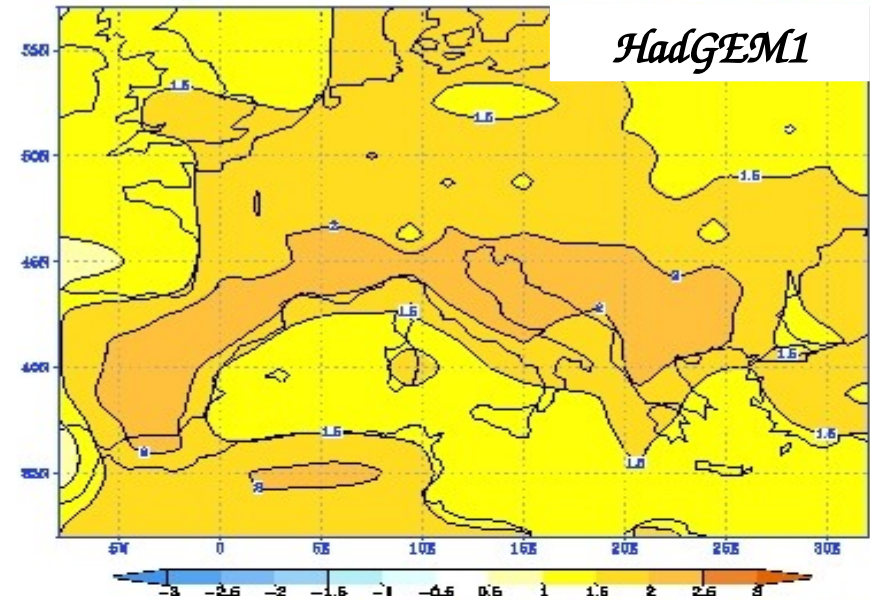
Extreme weather event	No global warming link	May change with global warming but amount not established	Evidence of global warming link
Hurricanes		X	
Tornadoes	X		
Droughts		X	
Forest fires		X	
Heat waves			X
Coastal floods			X
Earthquakes	X		
Floods		X	

Temp. at 2m, Summer (201-40) minus (1961-90, reanalys. obs.)

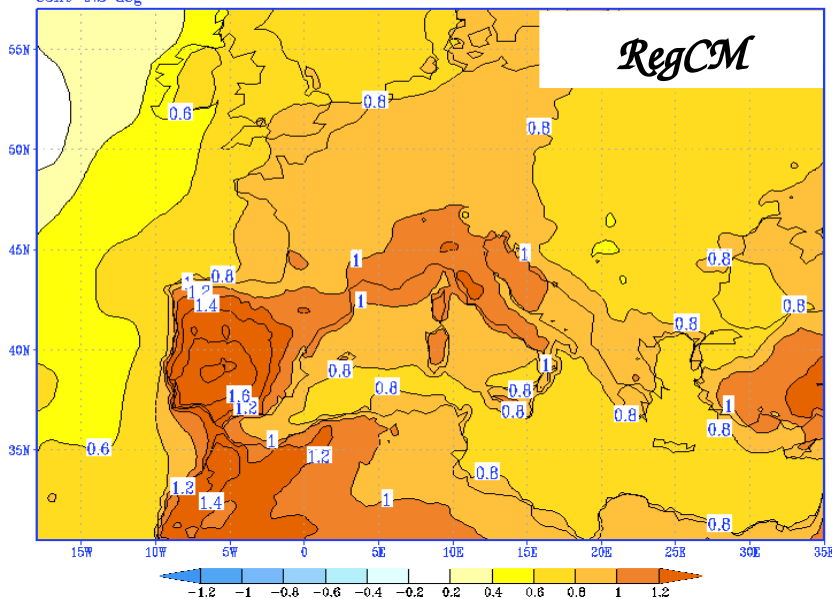
mean; tas; surf; jja; [2011,2040]-[1961,1990]; A2; EH50M
cont=0.5 deg



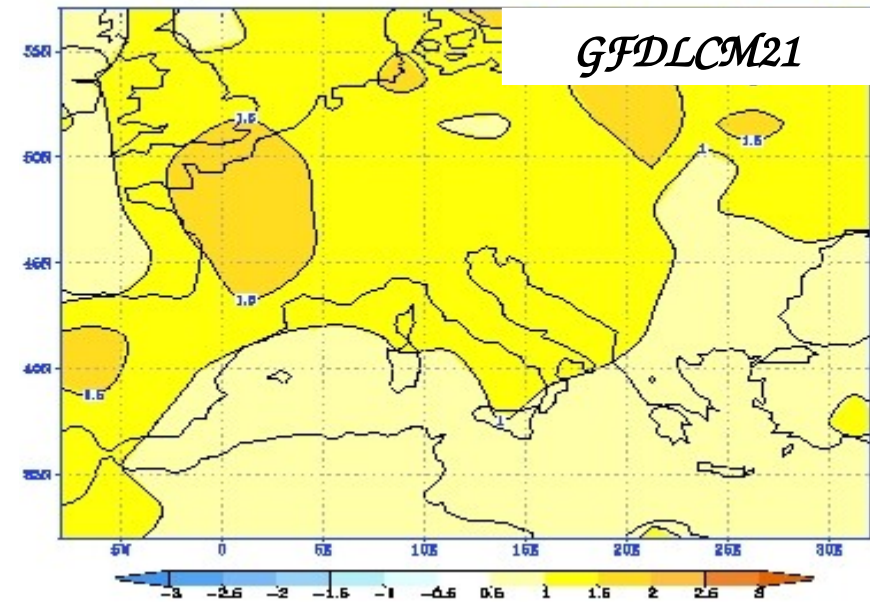
mean; tas; surf; jja; [2011,2040]-[1961,1990]; A2; HadGEM1
cont=0.5 deg



T2m JJA; P1 - P0
cont=0.2 deg

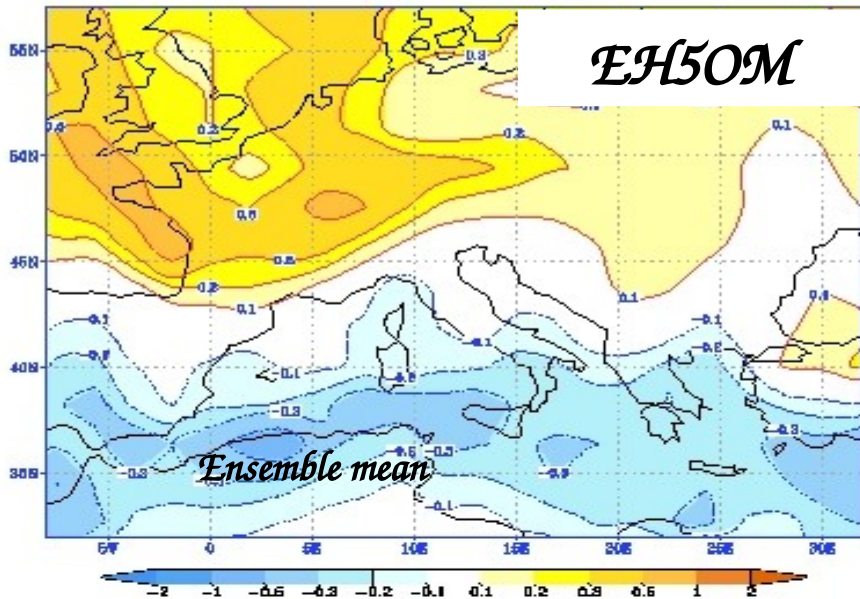


mean; tas; surf; jja; [2011,2040]-[1961,1990]; A2; GFDLCM21
cont=0.5 deg

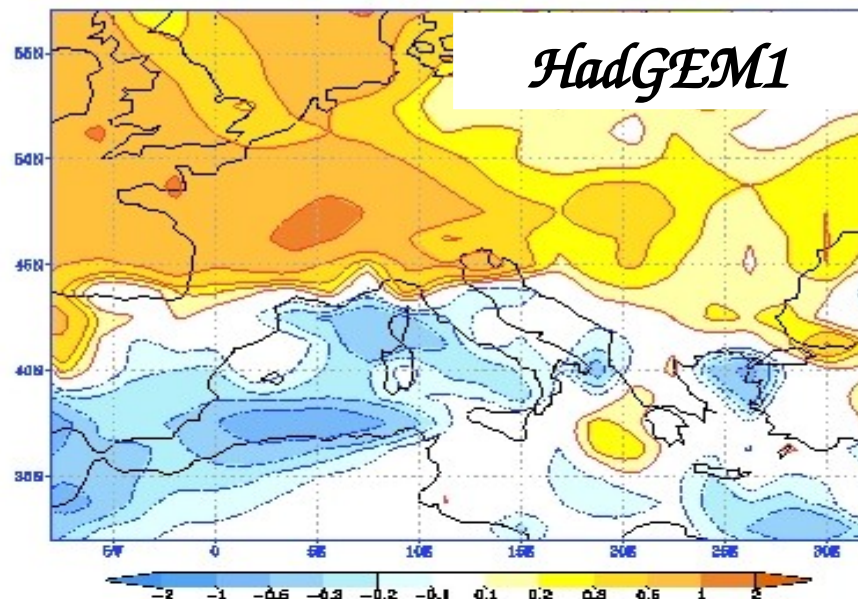


Precipitation, winter (2011-40) minus (1961-90, reanalysis. obs.)

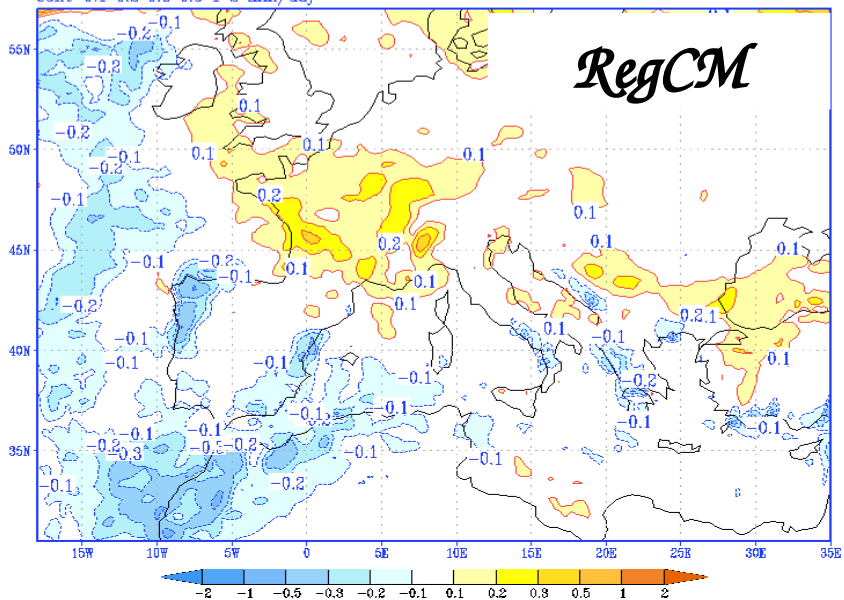
mean; pr; surf; djf; [2041,2070]-[1961,1990]; A2; EH50M
cont=0.1 0.2 0.3 0.5 1 2 mm/day



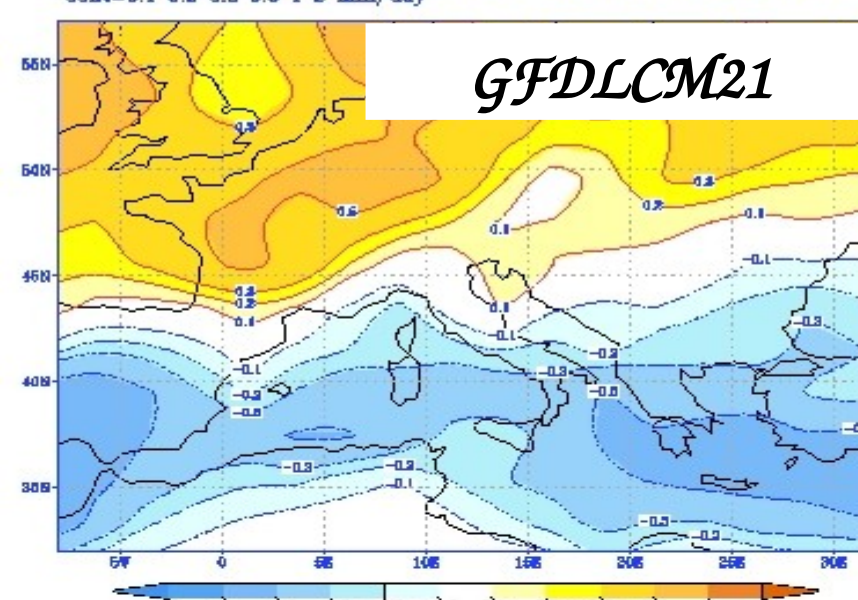
mean; pr; surf; djf; [2041,2070]-[1961,1990]; A2; HadGEM1
cont=0.1 0.2 0.3 0.5 1 2 mm/day



Total precipitation DJF; P1 - P0
cont=0.1 0.2 0.3 0.5 1 2 mm/day



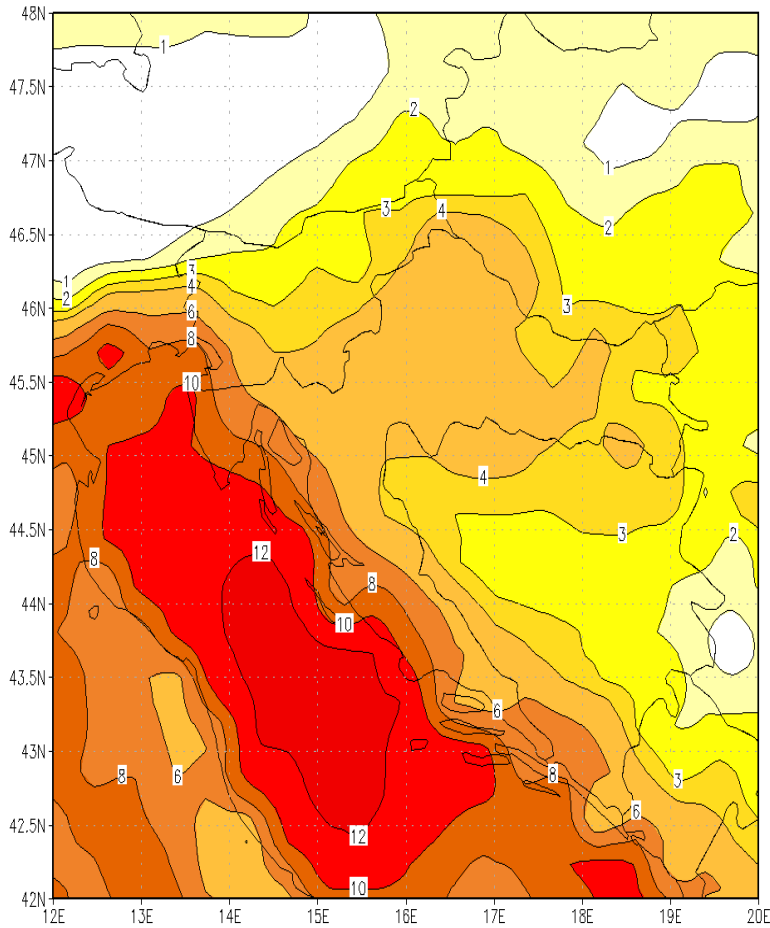
mean; pr; surf; djf; [2041,2070]-[1961,1990]; A2; GFDLCM21
cont=0.1 0.2 0.3 0.5 1 2 mm/day



Extreme Events

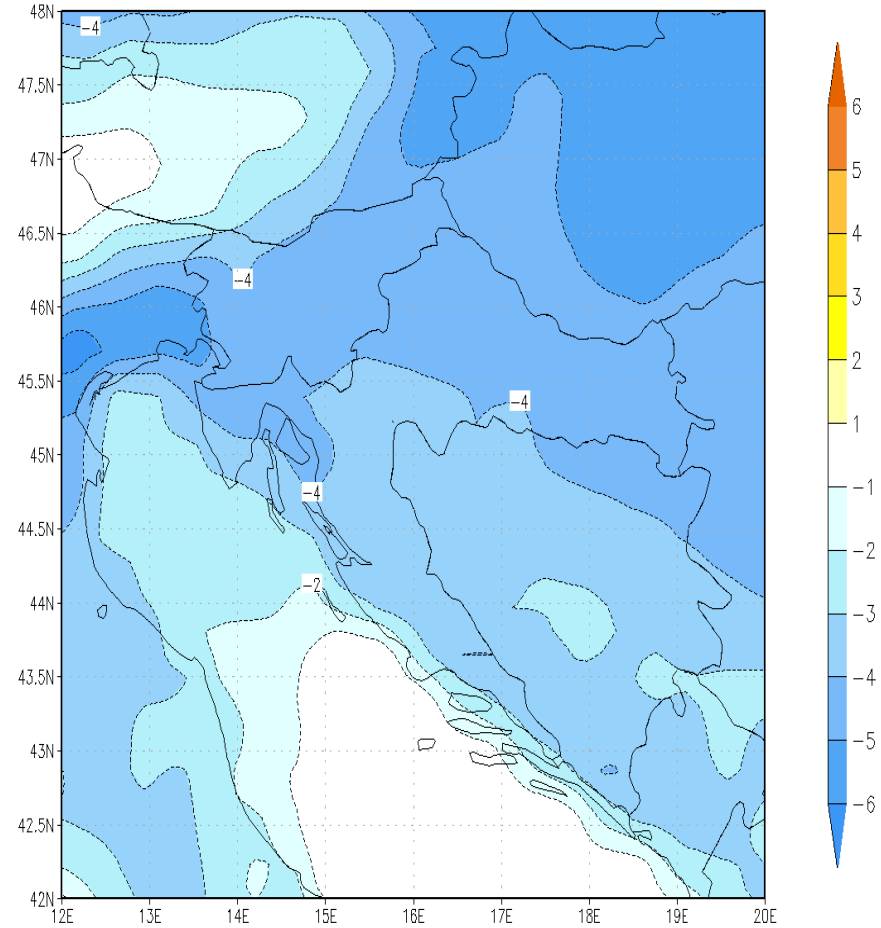
No. Summertime Warm Days

Days with $T_{2max} \geq 25$ C; ave; JJA;
ens; P1-P0



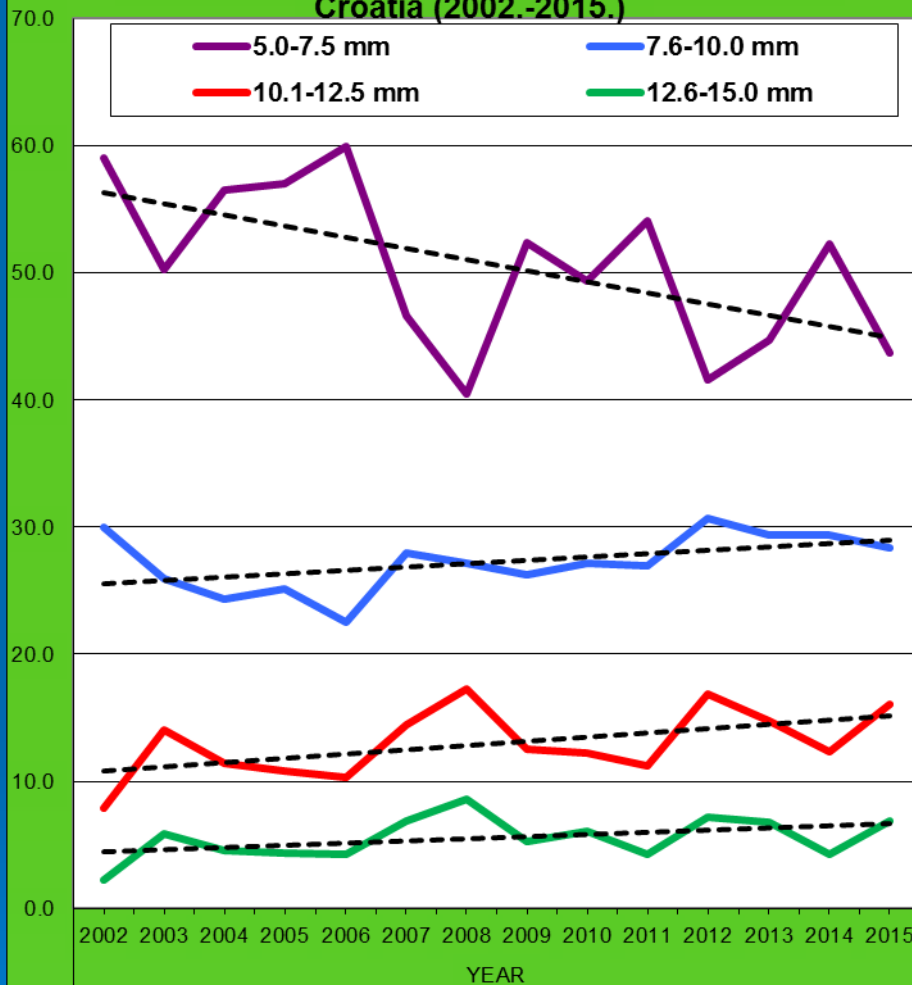
No. Wintertime Cold Days

Days with $T_{2min} < 0$ C; ave; DJF;
ens; P1-P0

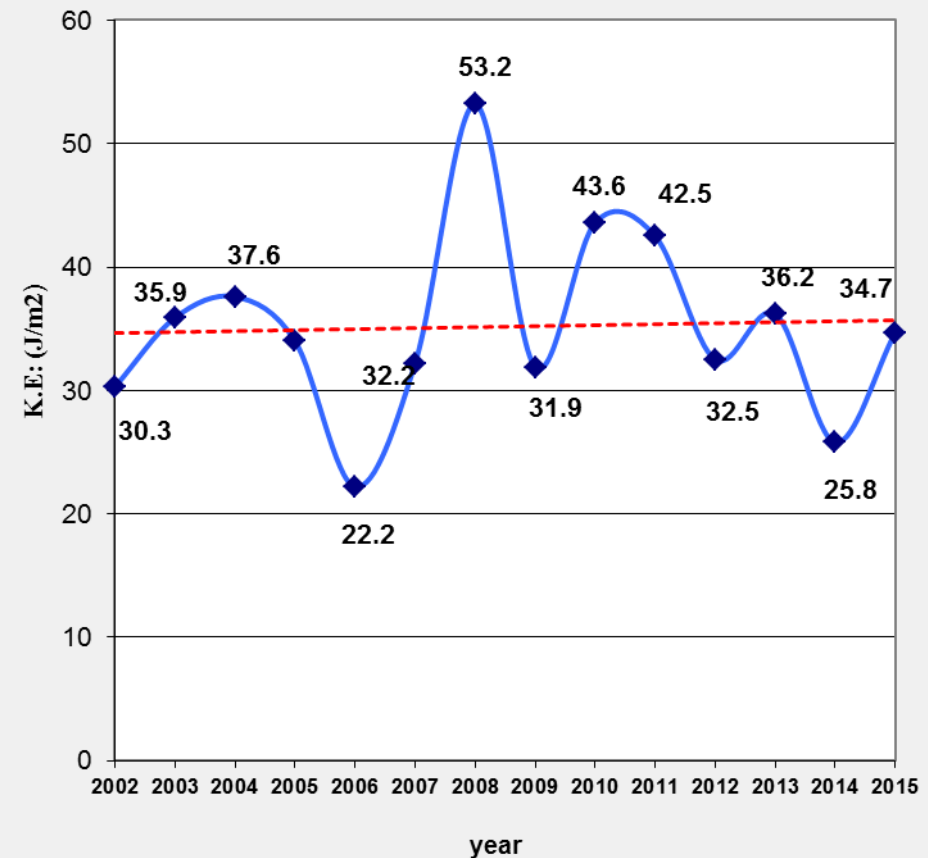


Courtesy of Damir Počakal, DHMZ

Distribution and trend for relative frequency of hailstone diameter in the continental part of Croatia (2002.-2015.)



Average values of kinetic energy for the continental part of Croatia (2002. - 2015.)



- There is a +trend in the mean duration of hailstone events in cont. Croatia, Počakal (2012)
- But typical, standard climate models don't have those variables - should be included!

TENTATIVE CONCLUSIONS

- Current surface temp. upward trends & future predictions are unusual, unexplained by natural internal climate variability
- “Predictions” based on greenhouse gas emission scenarios & links the gases concentrations ↔ temp. via modeling & simulations
- Included: population growth, economic development, technol. change, social interactions
- Besides large spatio-temporal variations, global warming is real, it exceeds in magnitude & pace natural changes over the last 10^3 yr.
- No detailed clim. projections for hail-storms in/around Croatia



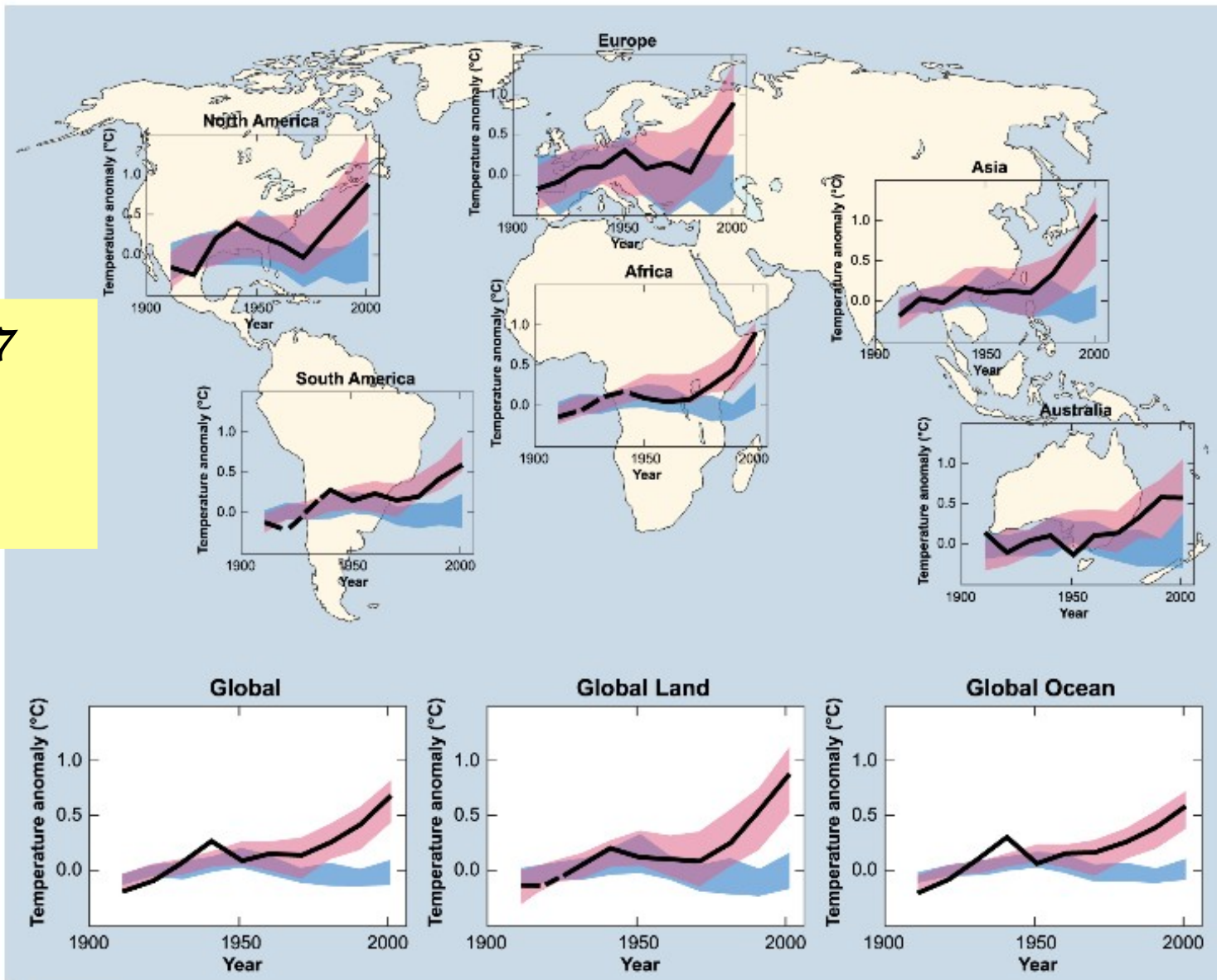
**I'M AN
AIR-CONDITIONED
MIAOU-UU
..but soon maybe
dead..**

bgrisog@gfz.hr
www.pmf.unizg.hr/geof

TENTATIVE CONCLUSIONS cont'd

- Immediate changes seem needed: lowering emissions of greenhouse gasses to meet the scenario with global $\sim +2^{\circ}\text{C}$ in \approx yr. 2100
- Targeting and promoting more human technologies, renewable energies, healthier food & water \Leftrightarrow Humanistic approach needed!
- It is wrong to deploy “instrumental rationalism” (max. efficiency only) & blind pragmatism based on e.g., large resources & markets
- Make reliable regional climate - economy projections for next few decades (agronomy, energy, tourism, education, etc.)

GLOBAL AND CONTINENTAL TEMPERATURE CHANGE



IPCC 2007
Model
Simulations

models using only natural forcings
 models using both natural and anthropogenic forcings
 observations

Global Energy Flows $W m^{-2}$

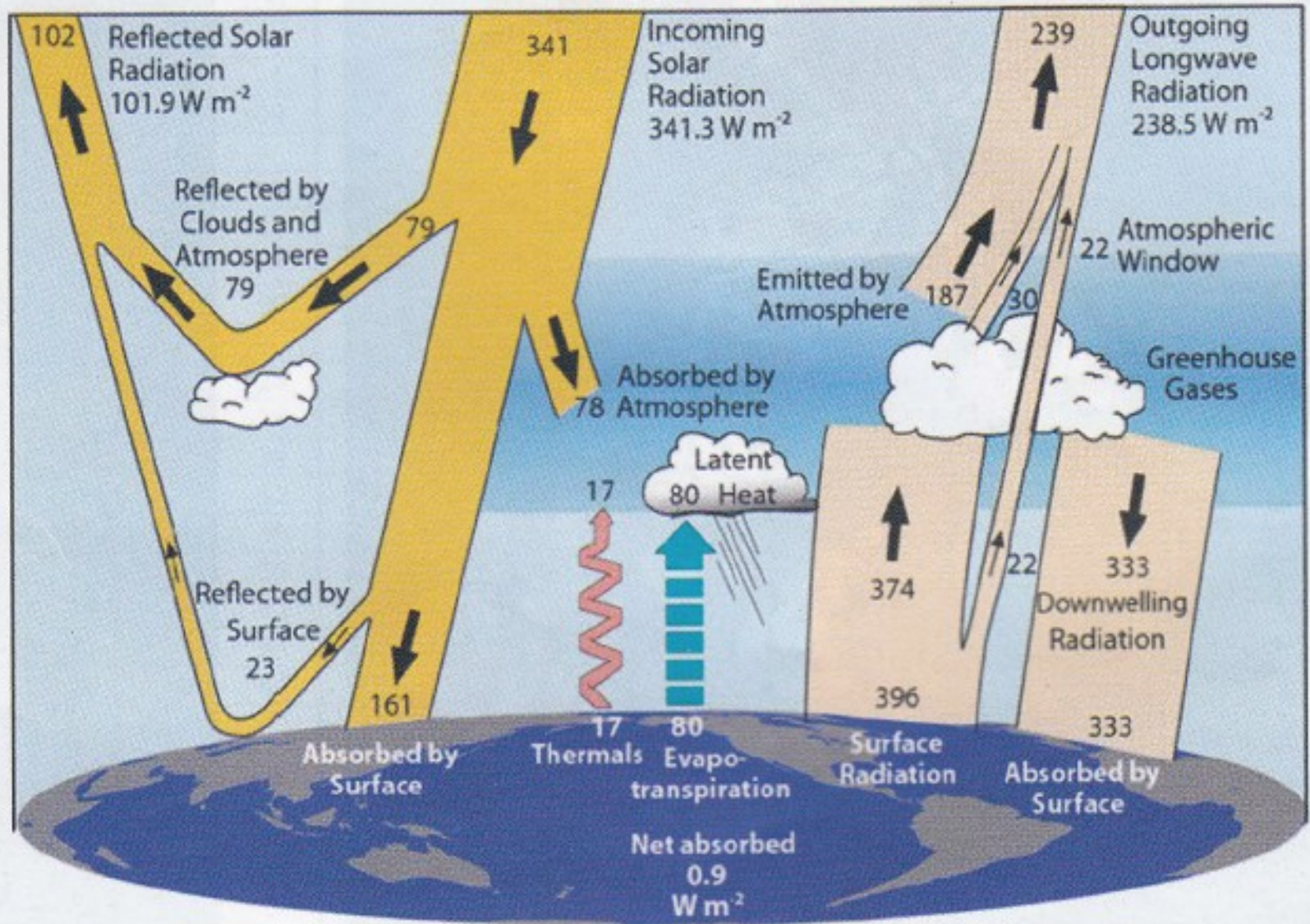


Figure 1. The global annual mean energy budget of Earth's climate system (Trenberth and Fasullo, 2012.)