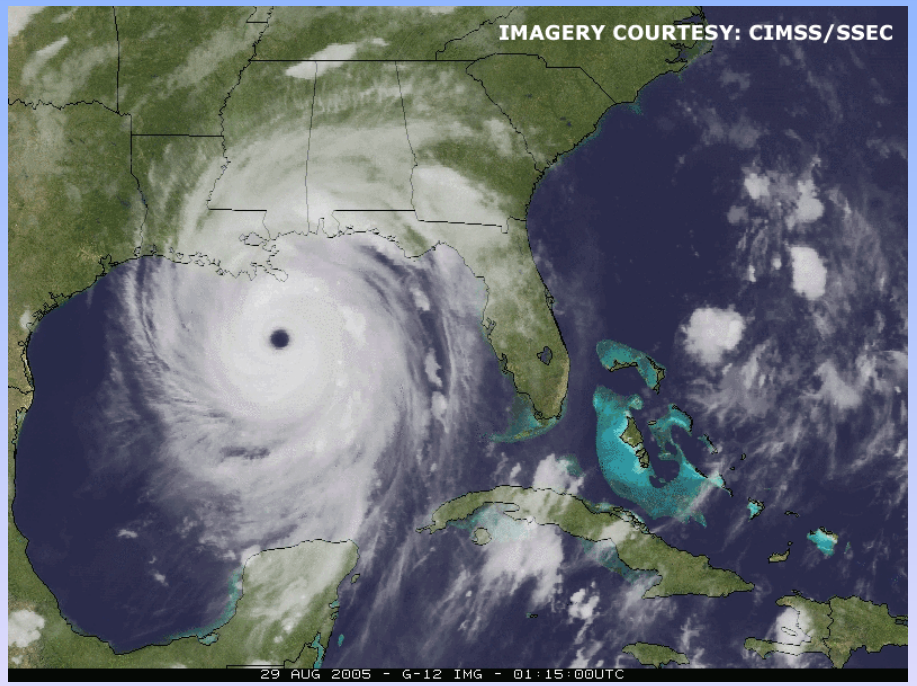
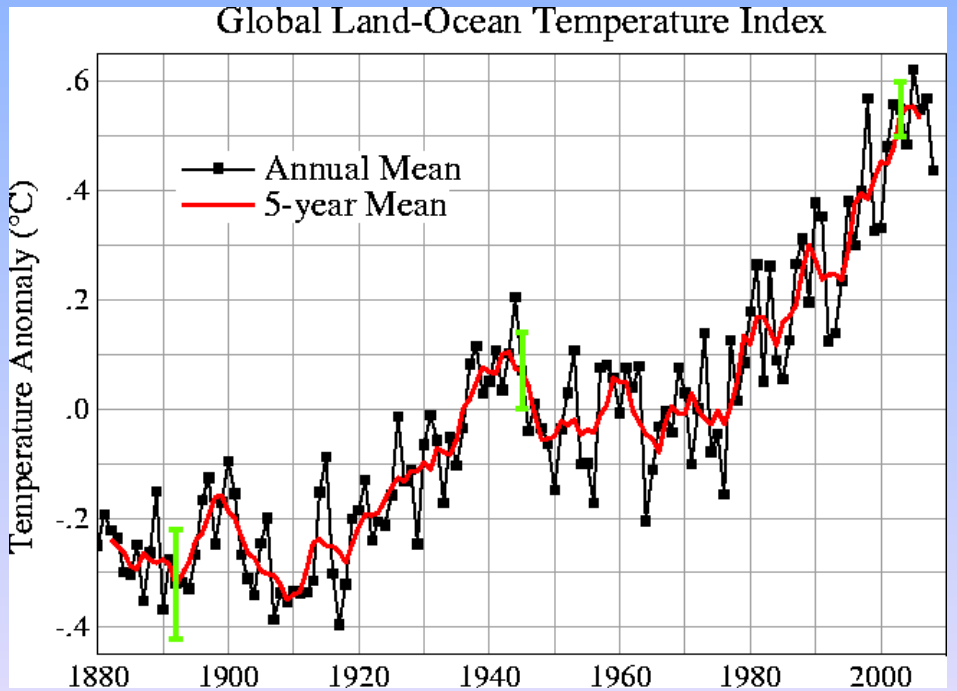
From Weather to Climate Prediction

Mojib Latif

Leibniz Institute of Marine Sciences at Kiel University





Weather forecasts can be verified on a day-to-day basis

Outline

- Weather and Climate
- Model bias
- Complexity
- Where shall we go?

Definition of Climate (WMO)

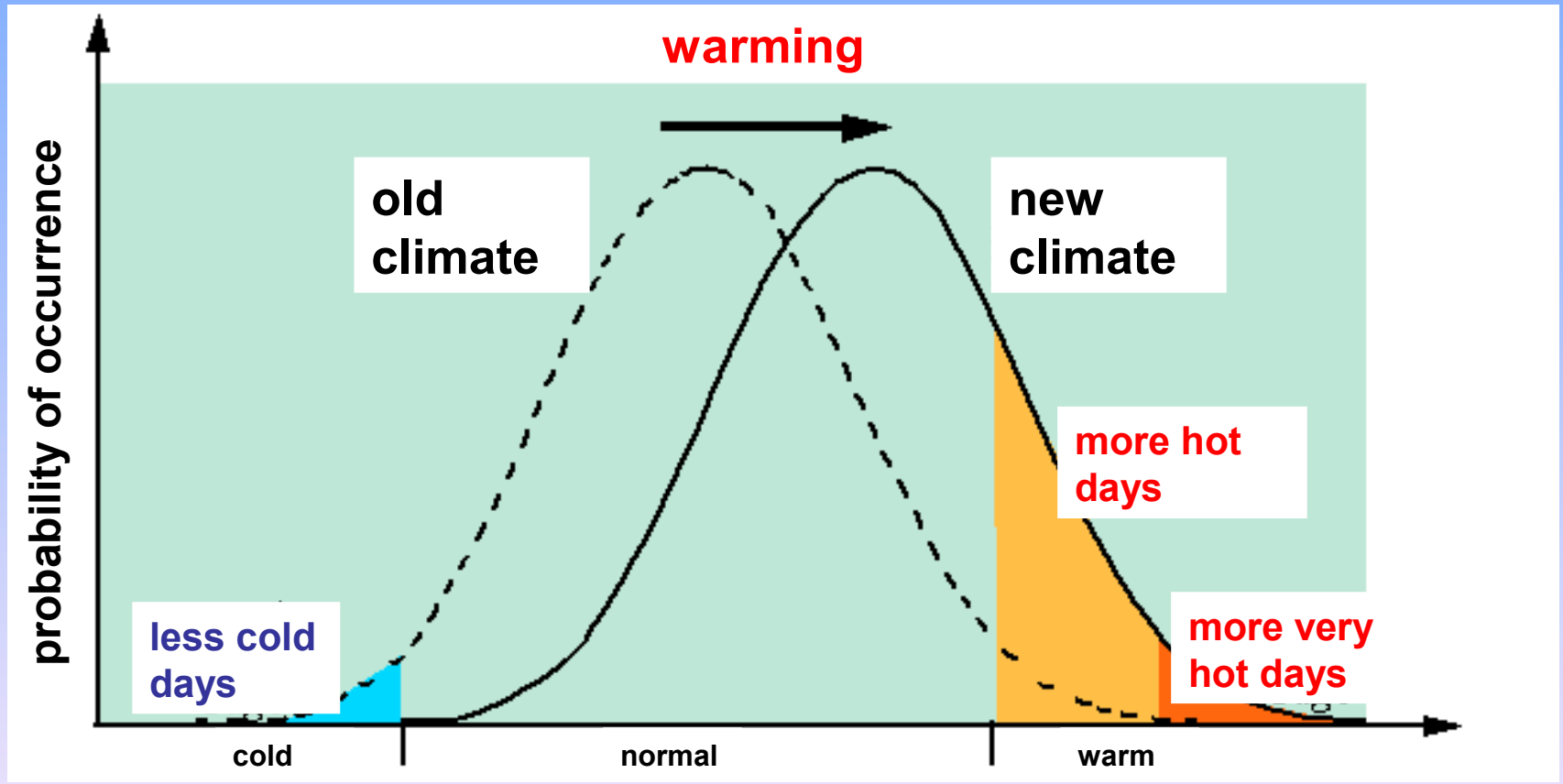
Climate … is usually defined as the "average weather" or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO).

Climate is intimately linked to the statistics of weather

Two types of predictability (after Lorenz)

- **Predictability of the first kind**: arises from the initial conditions (weather prediction, seasonal and decadal climate forecasting)
- **Predictability of the second kind**: arises from the boundary conditions (global change projections)
- **Global change prediction**: mixture of both

Example: Surface air temperature



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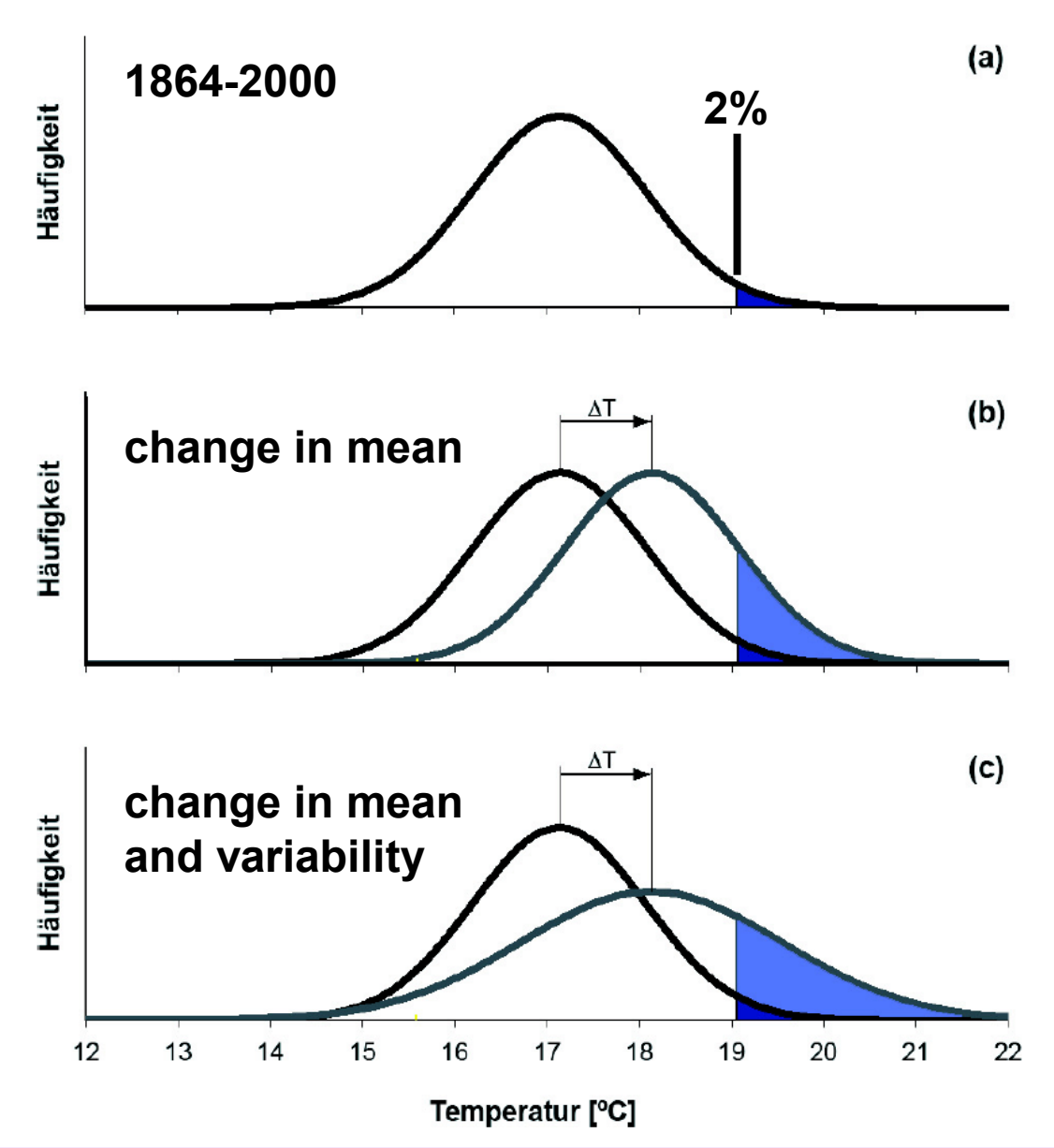
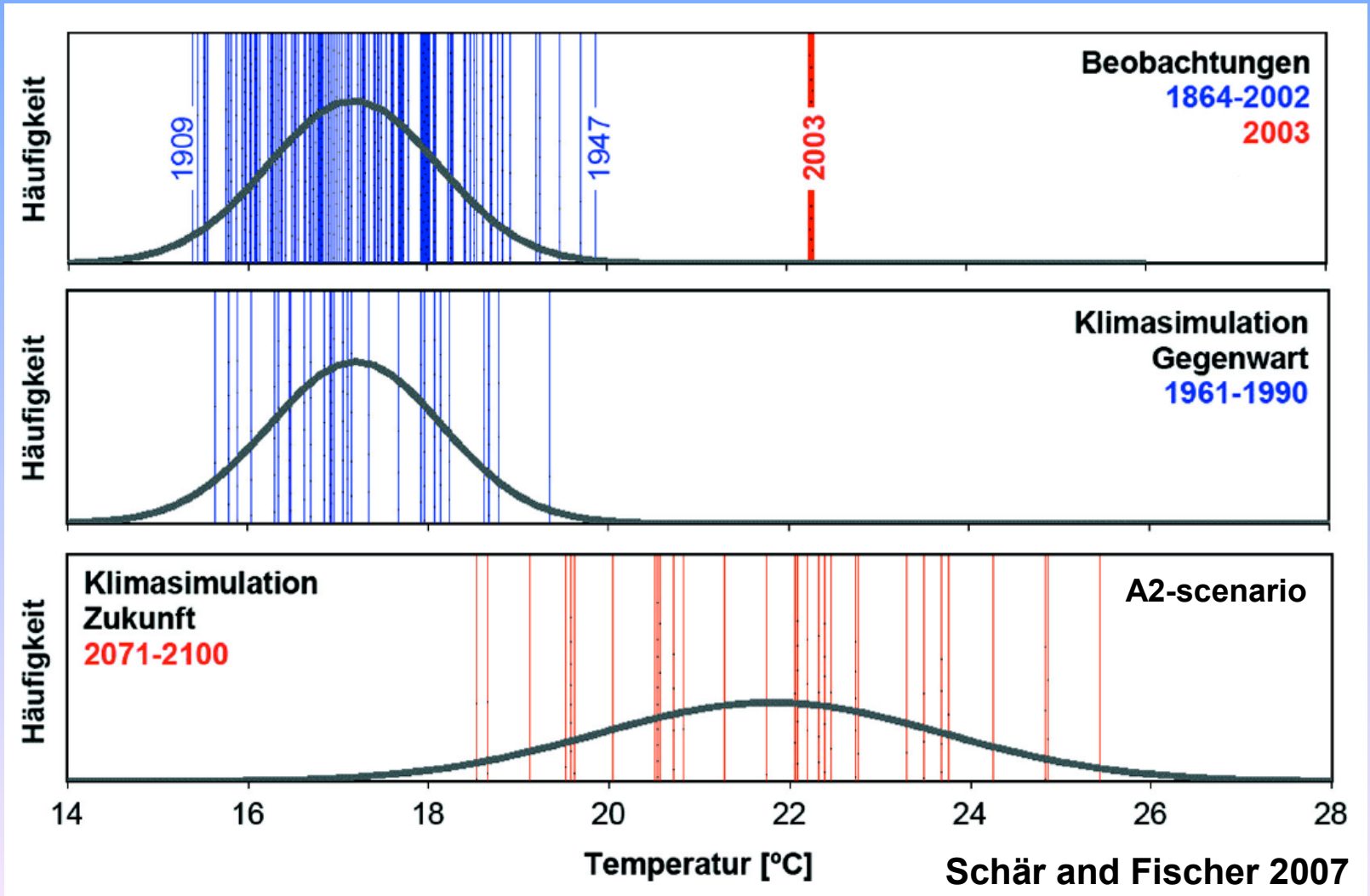
Swiss summer temperatures



Schär and Fischer 2007

Future change in summer temperature extremes



Schär and Fischer 2007

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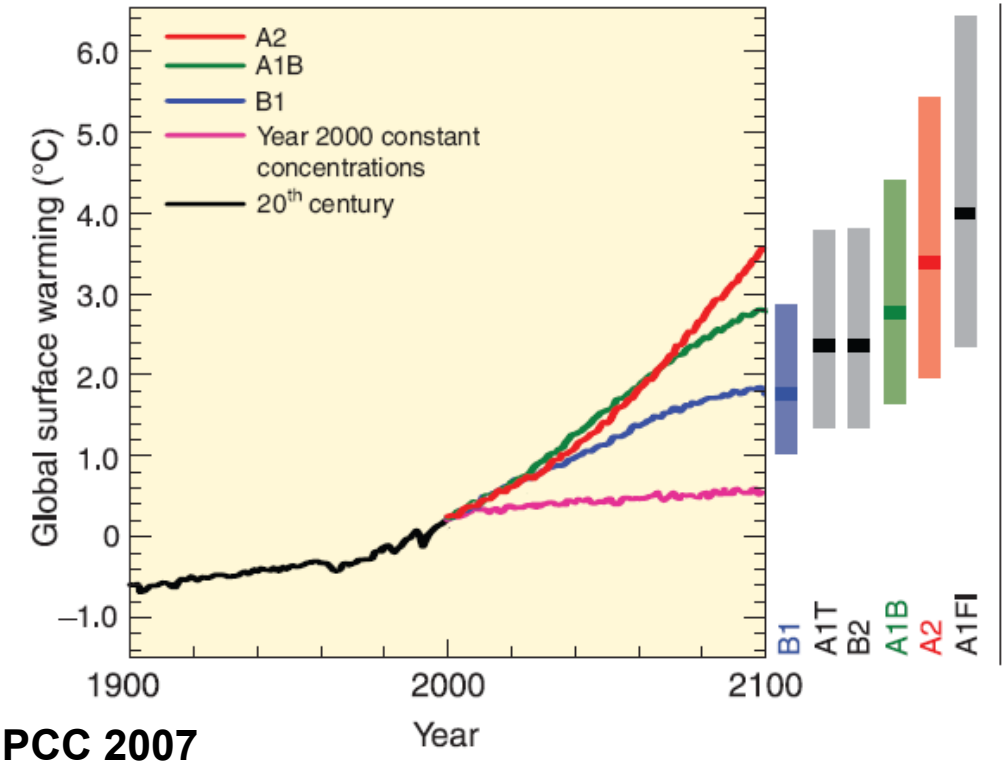
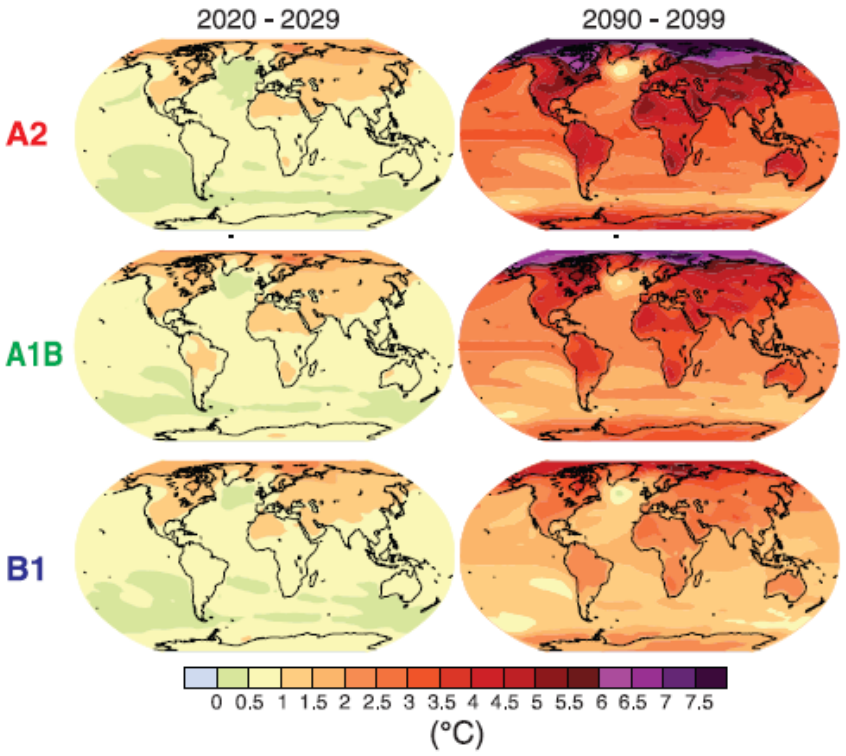
- **Model bias**
- Complexity
- Where shall we go?

Must climate models realistically simulate the statistics of weather?





IPCC 2007

I simply don‘t know, probably not in some cases

Dresden, 29 July 2009

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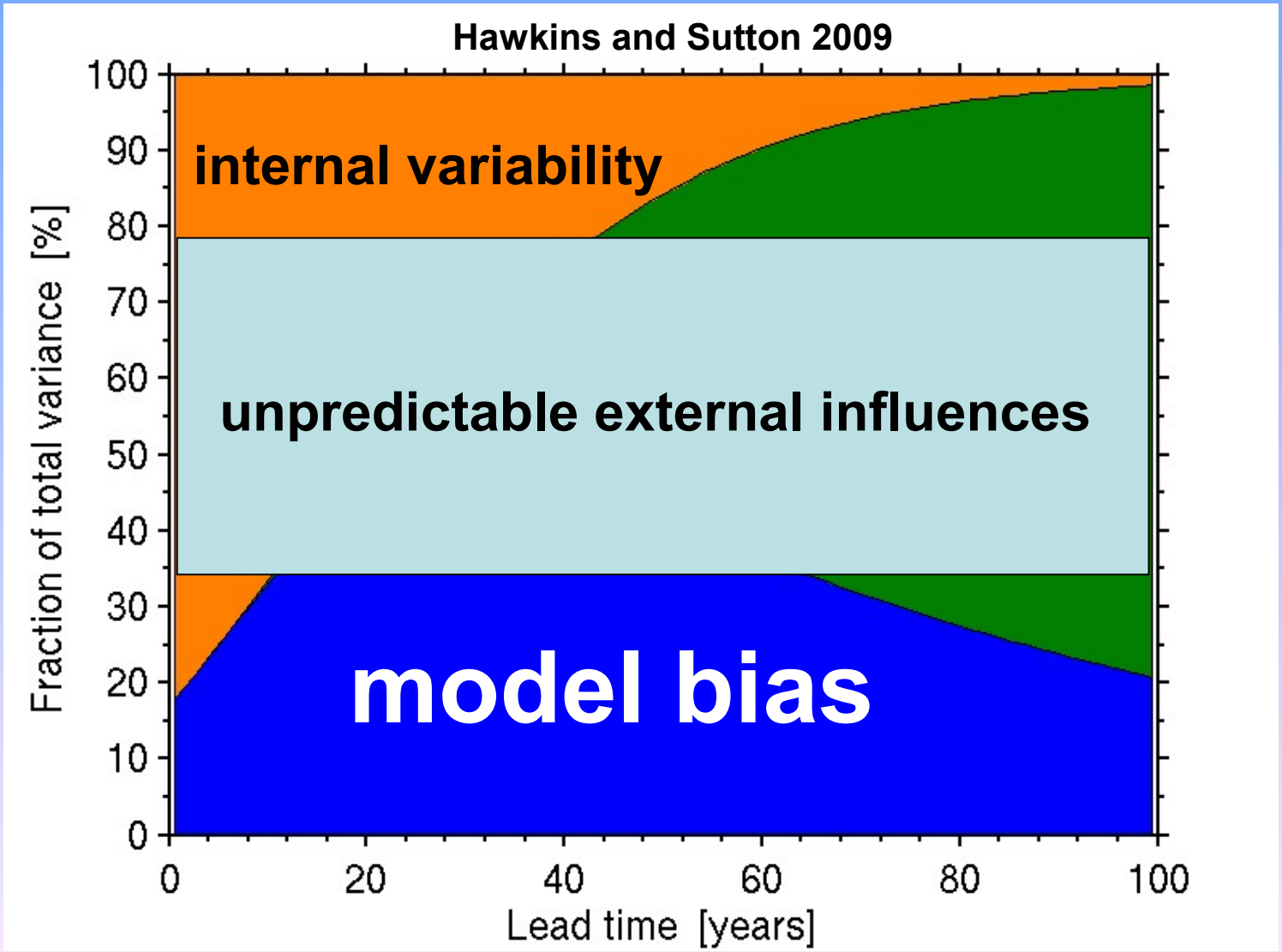
The uncertainty in climate projections for the 21st century



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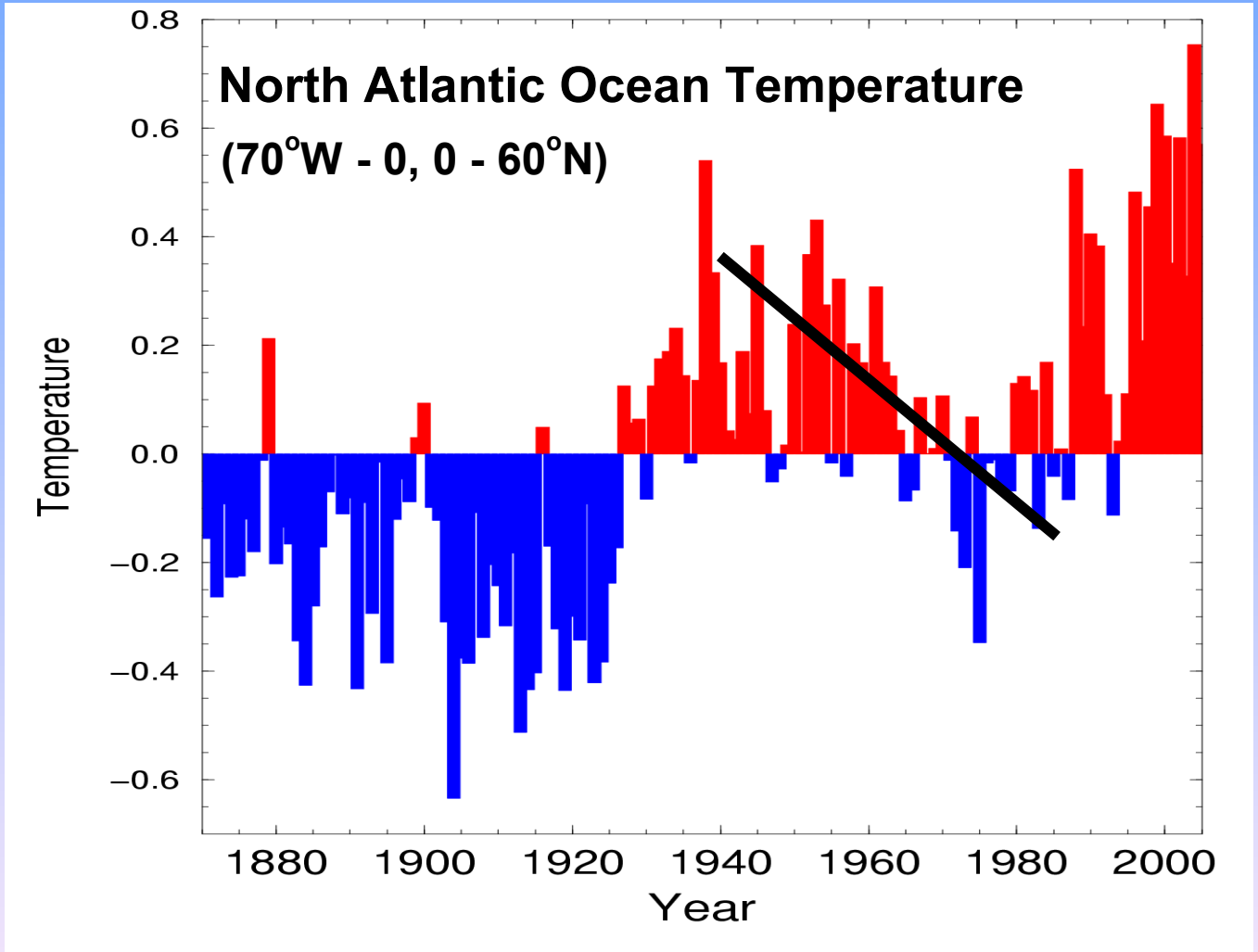
Decadal variations in the North Atlantic



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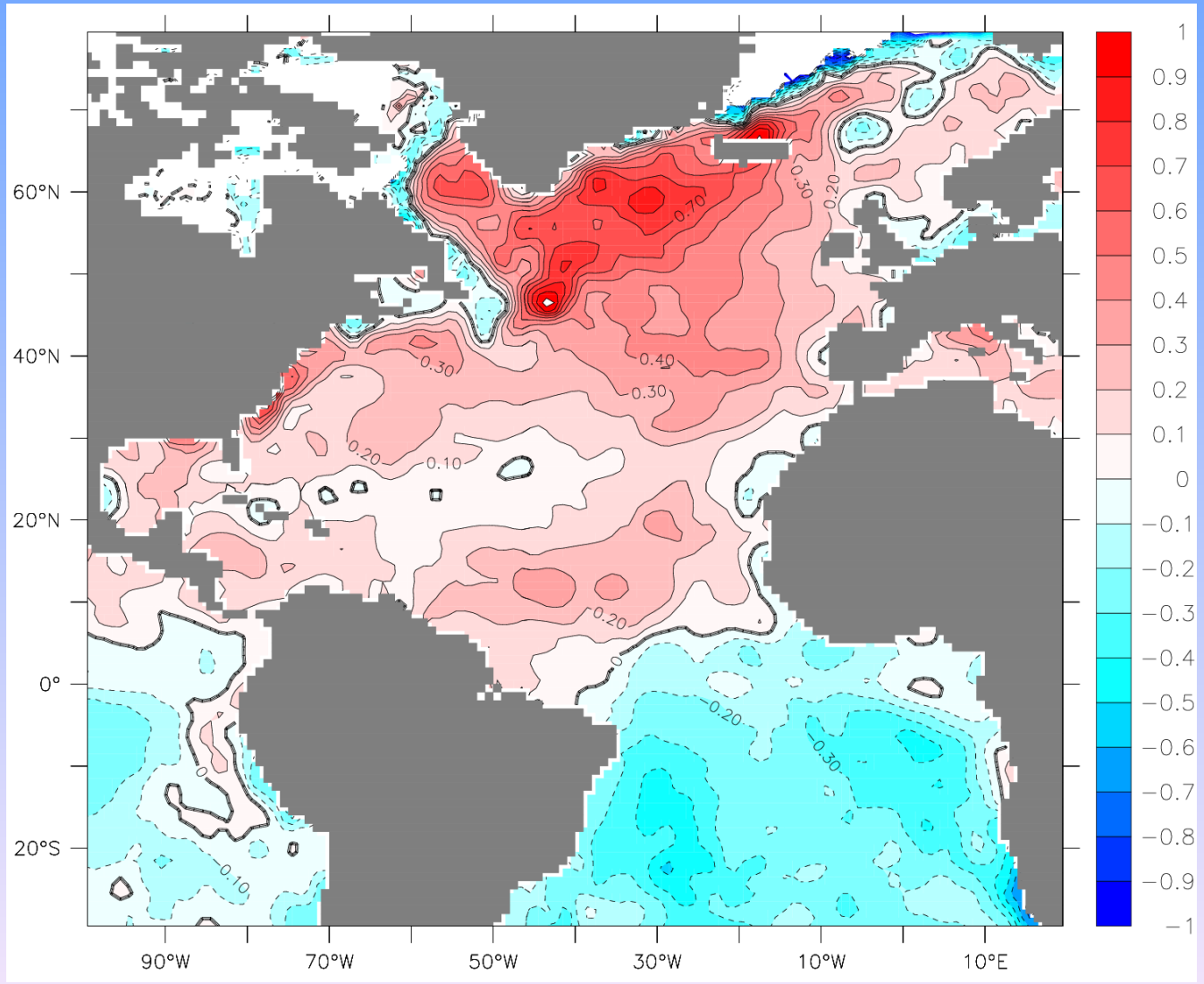
SST 1941-1960 minus 1971-1990



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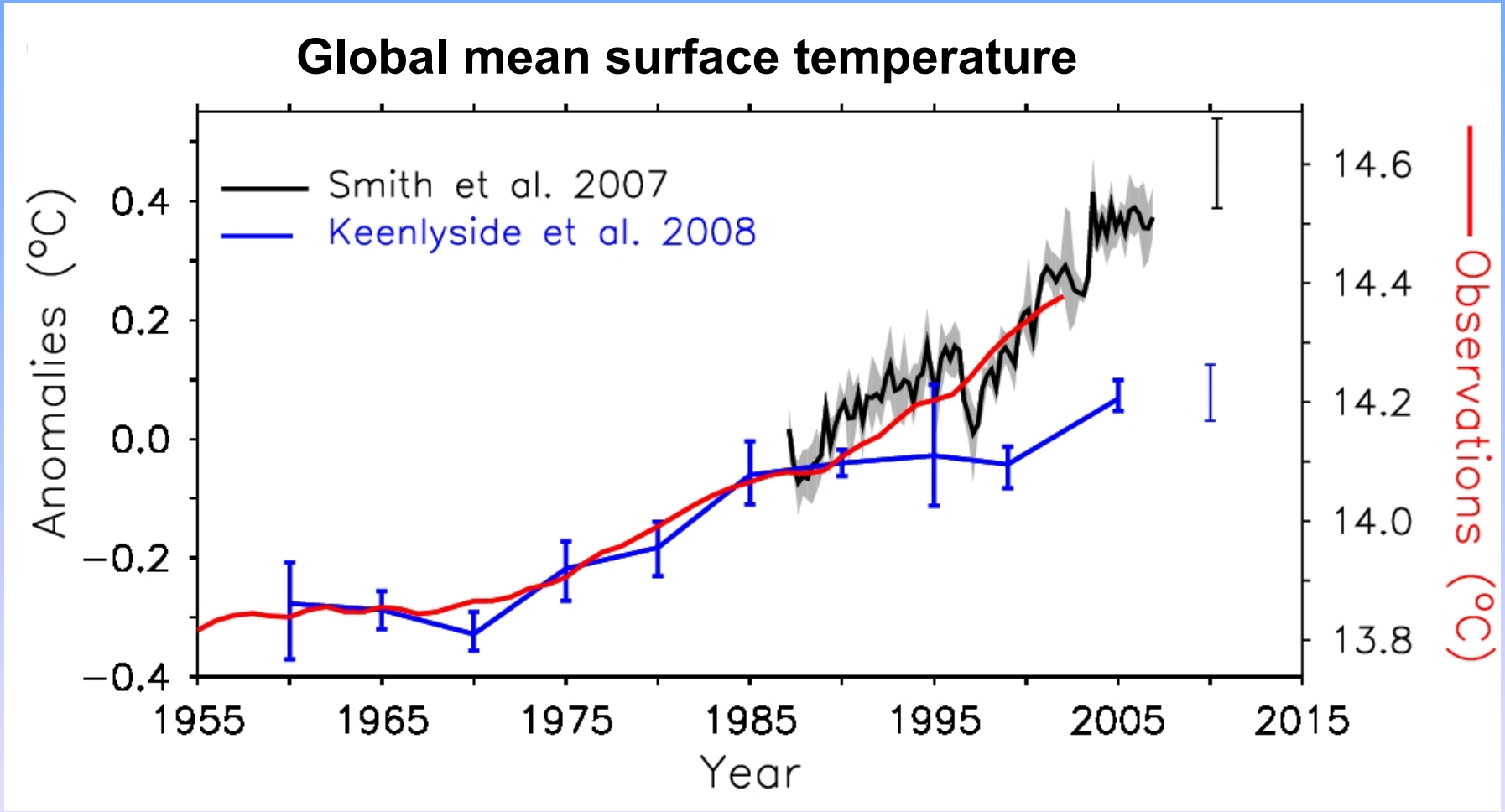
The real thing



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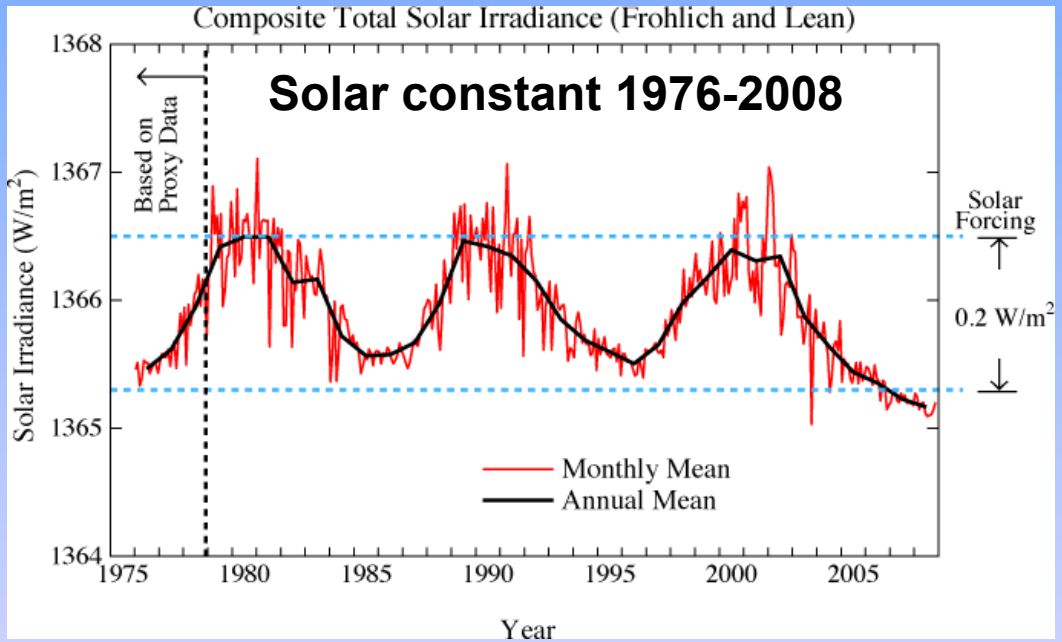
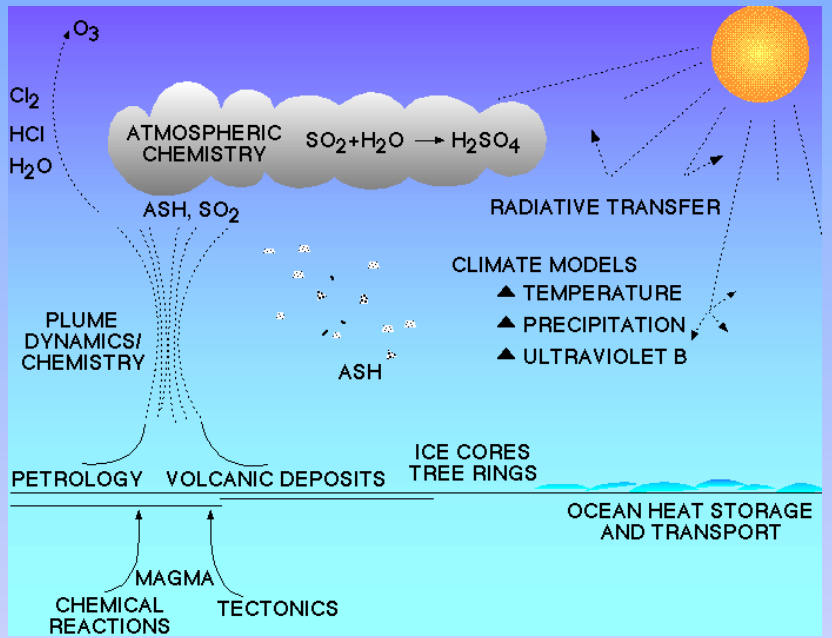
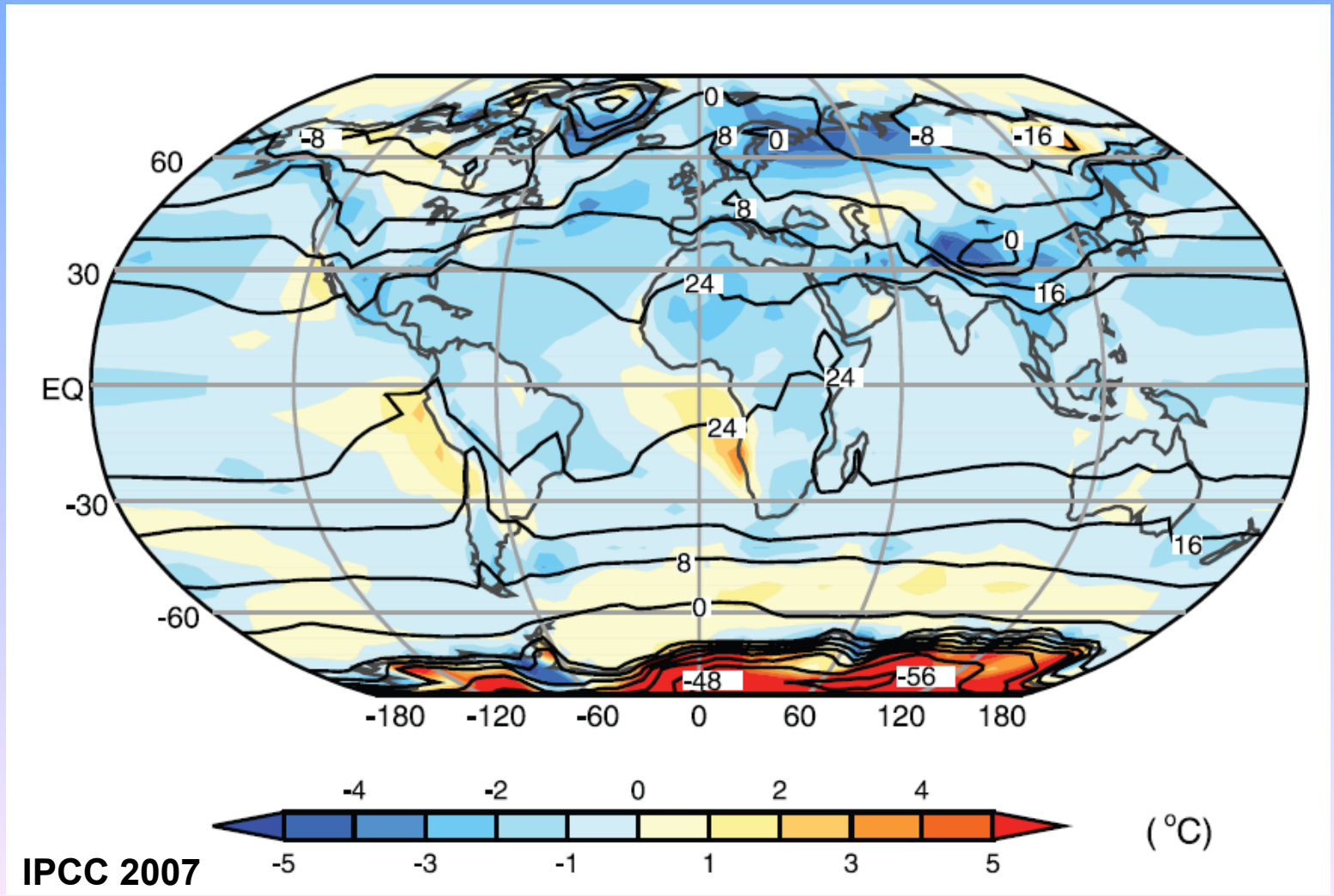
Unknown external influences





Strong volcanic eruptions, for instance, can cause global cooling of about 0,2°C for a few years and persist even longer in the ocean heat content.

Typical bias in surface air temperature (SAT)



IPCC 2007

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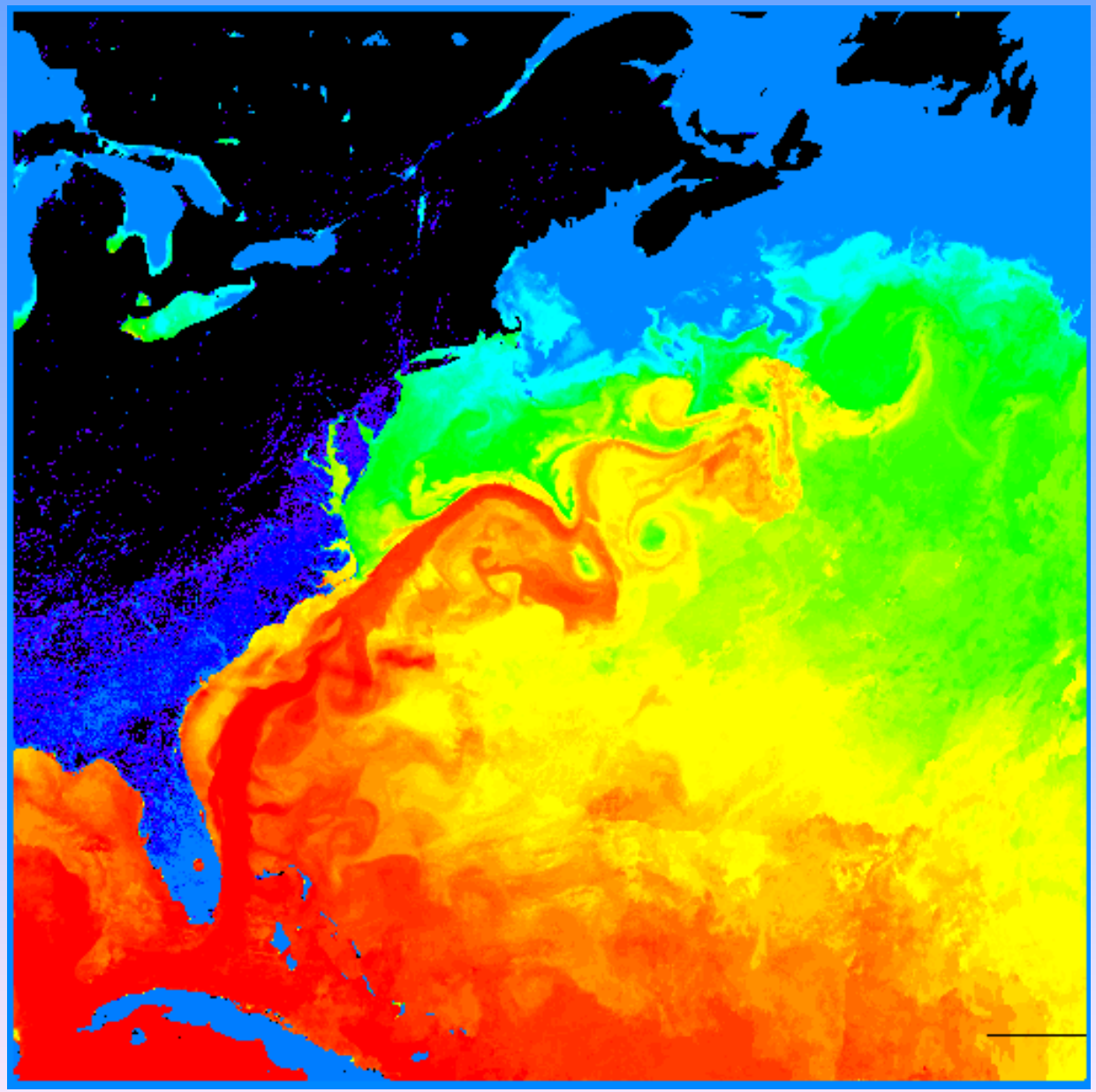
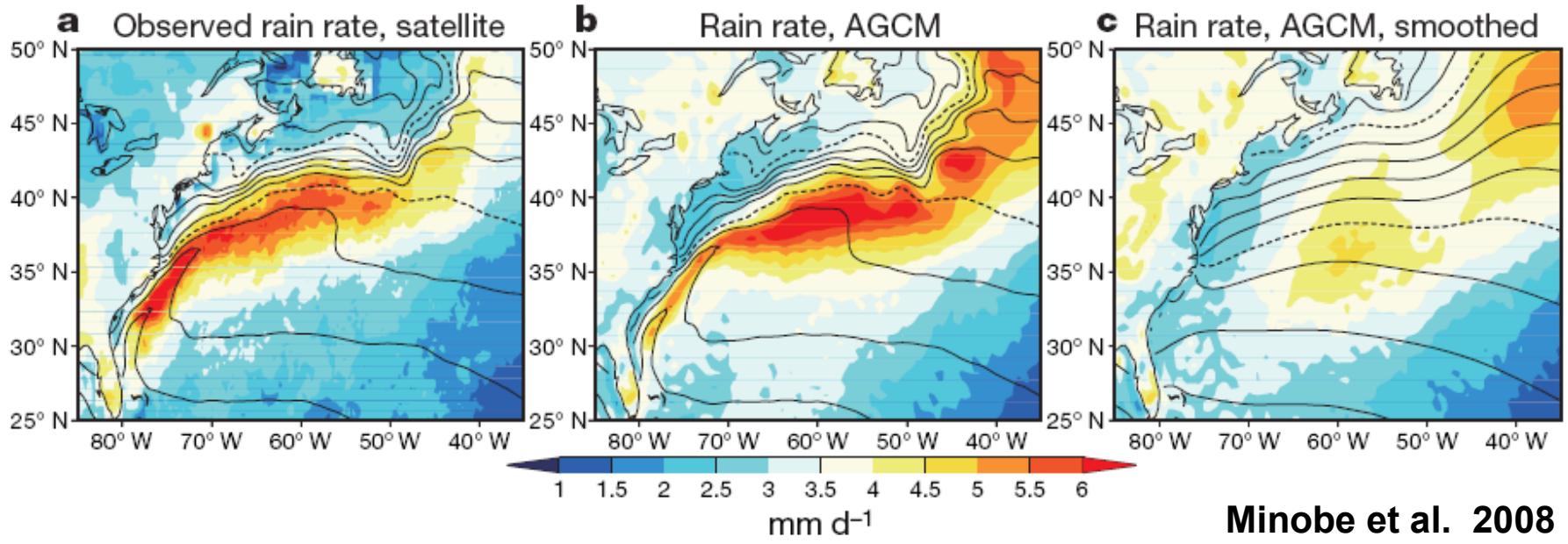
Gulfstream SST front



Resolution matters



Minobe et al. 2008

The AGCM has T239 horizontal resolution (~50 km) and 48 levels

$$-(u +v)\rho = (p \quad +p \quad)\varepsilon/(\varepsilon +f \quad)$$

$$\varepsilon p + H(a_x + v_y) = -2\gamma$$

Relation between the SST laplacian and wind convergence, Lindzen and Nigam 1987

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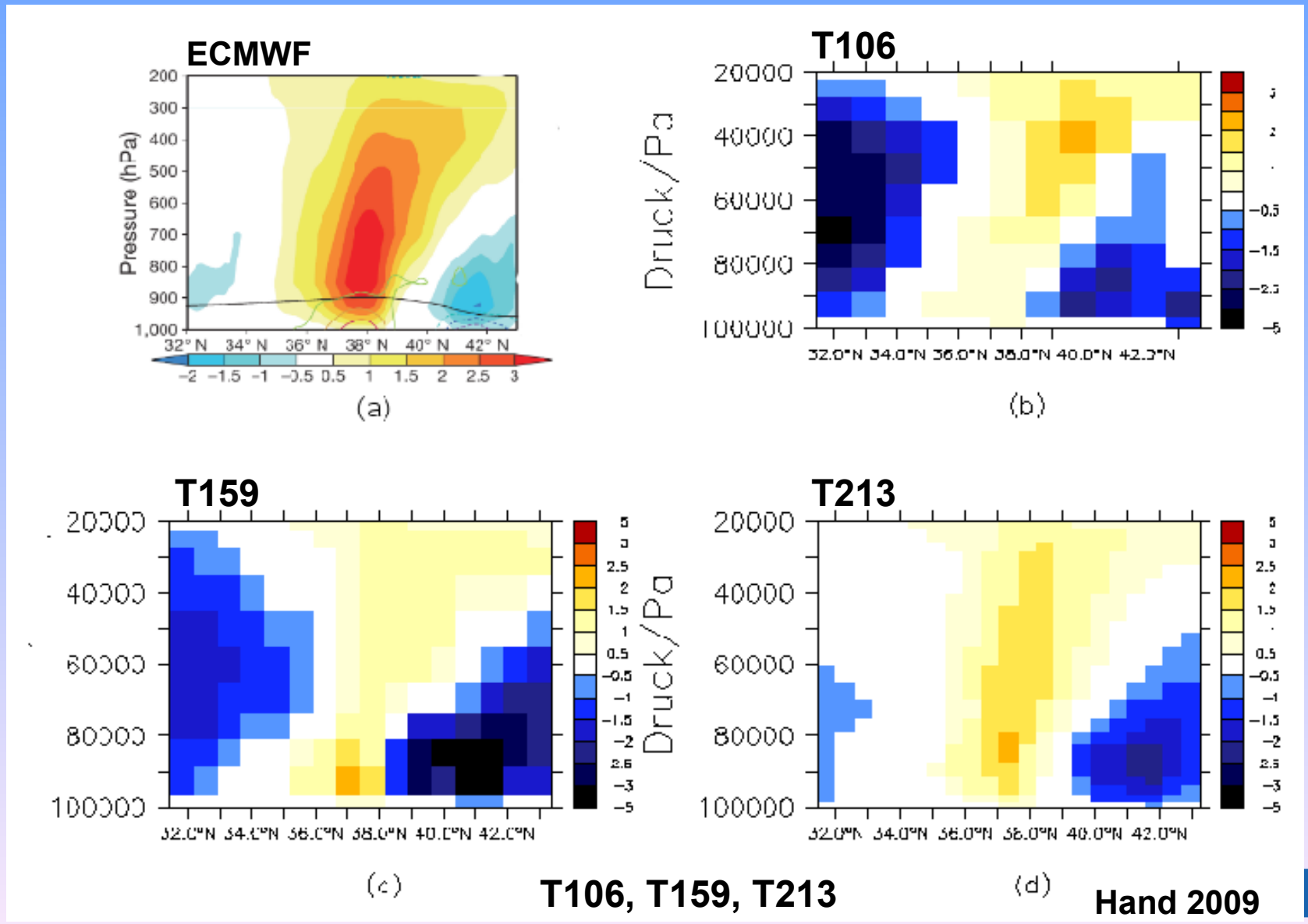
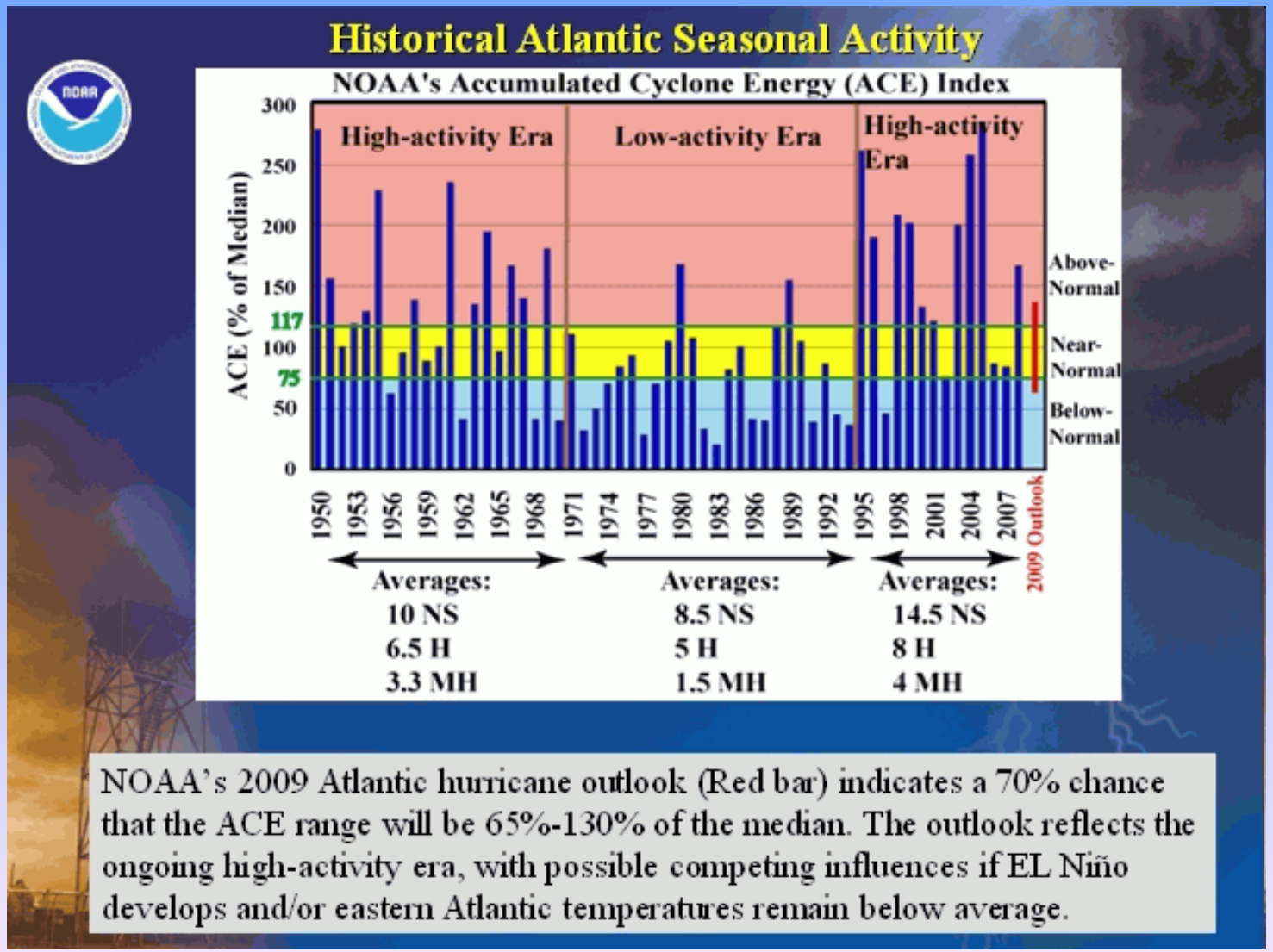
Upward wind over the Gulfstream



T106, T159, T213

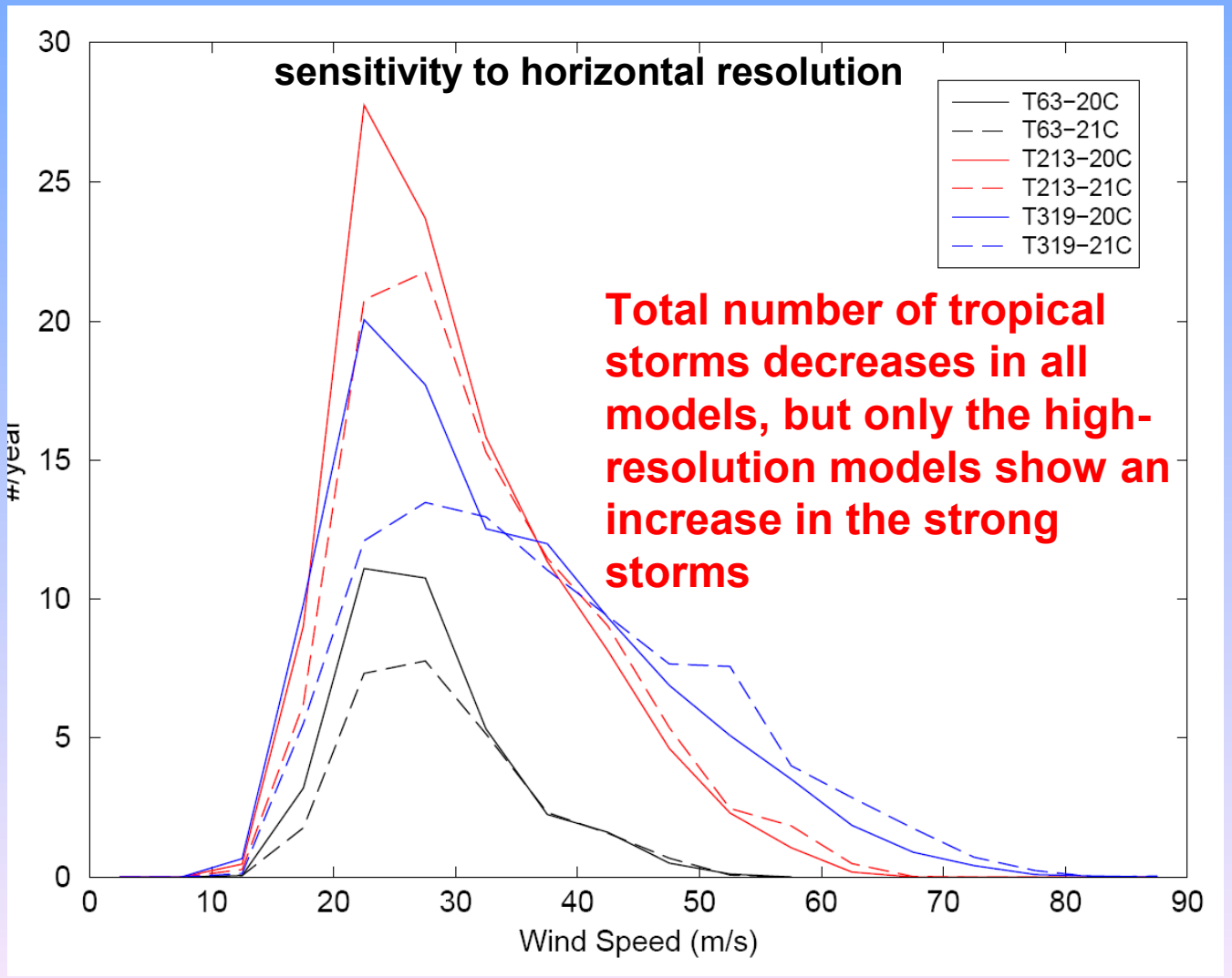
Hand 2009

Hurricane prediction



NOAA's 2009 Atlantic hurricane outlook (Red bar) indicates a 70% chance that the ACE range will be 65%-130% of the median. The outlook reflects the ongoing high-activity era, with possible competing influences if EL Niño develops and/or eastern Atlantic temperatures remain below average.

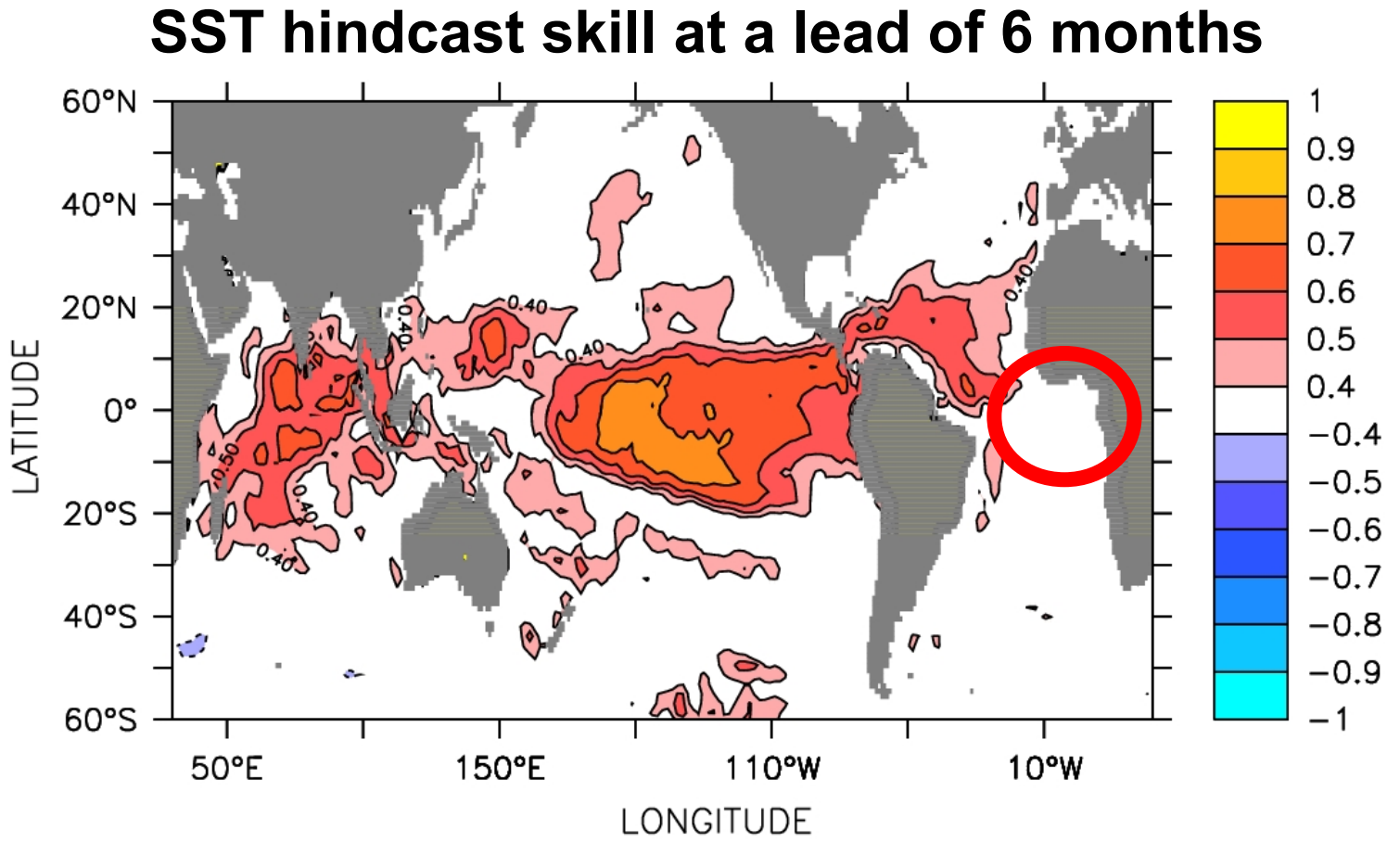
Hurricane wind speeds, response to global warming



There are more elegant ways

- Ensembles with single models by varying the initial conditions
- Multi-model ensembles by (implicitly) varying model physics
- Re-think the philosophy of parameterization, e.g. stochastic physics taking into account the inherently chaotic nature of the unresolved processes

Seasonal prediction skill



Ding et al. 2009, to be subm.

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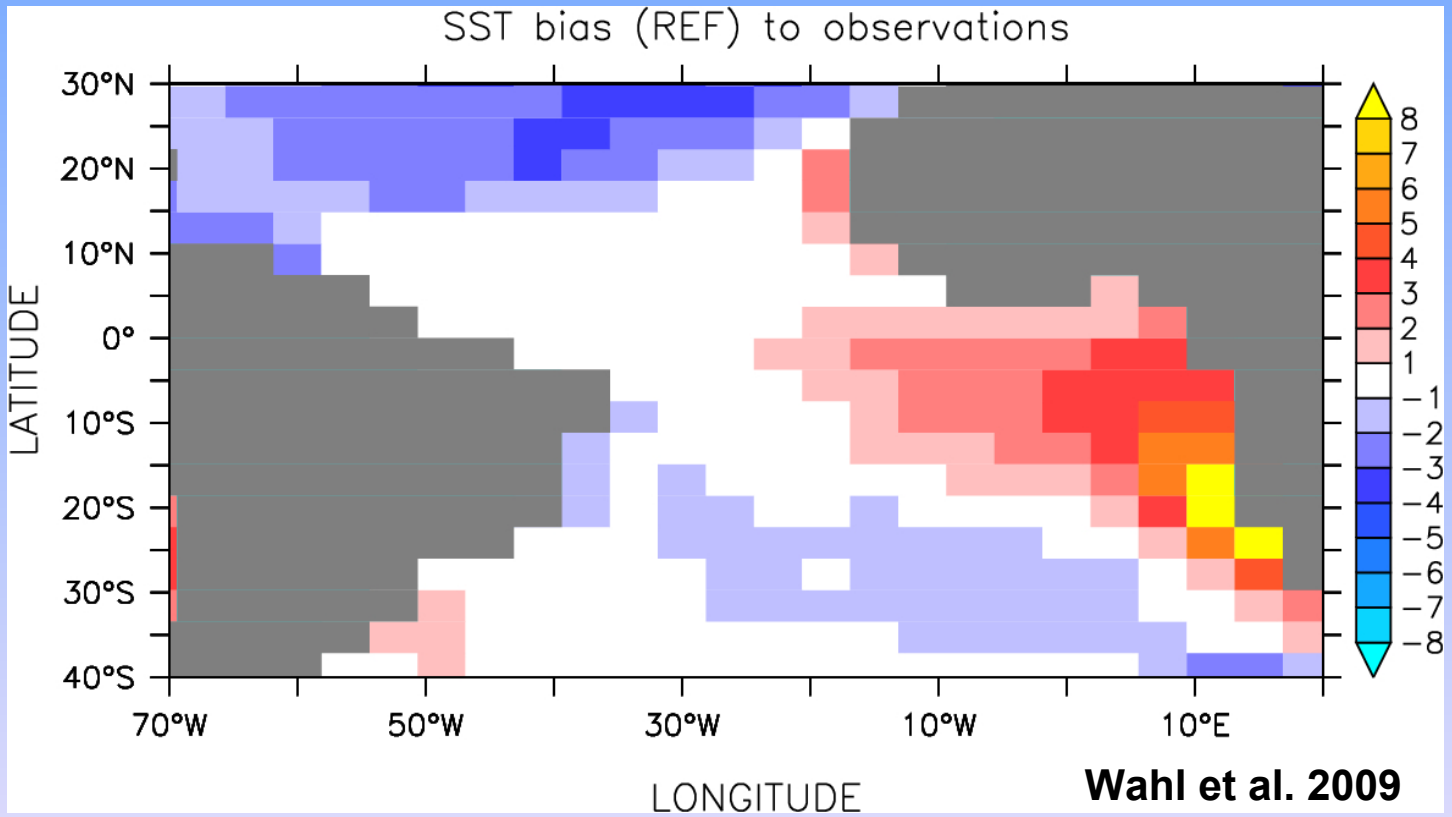
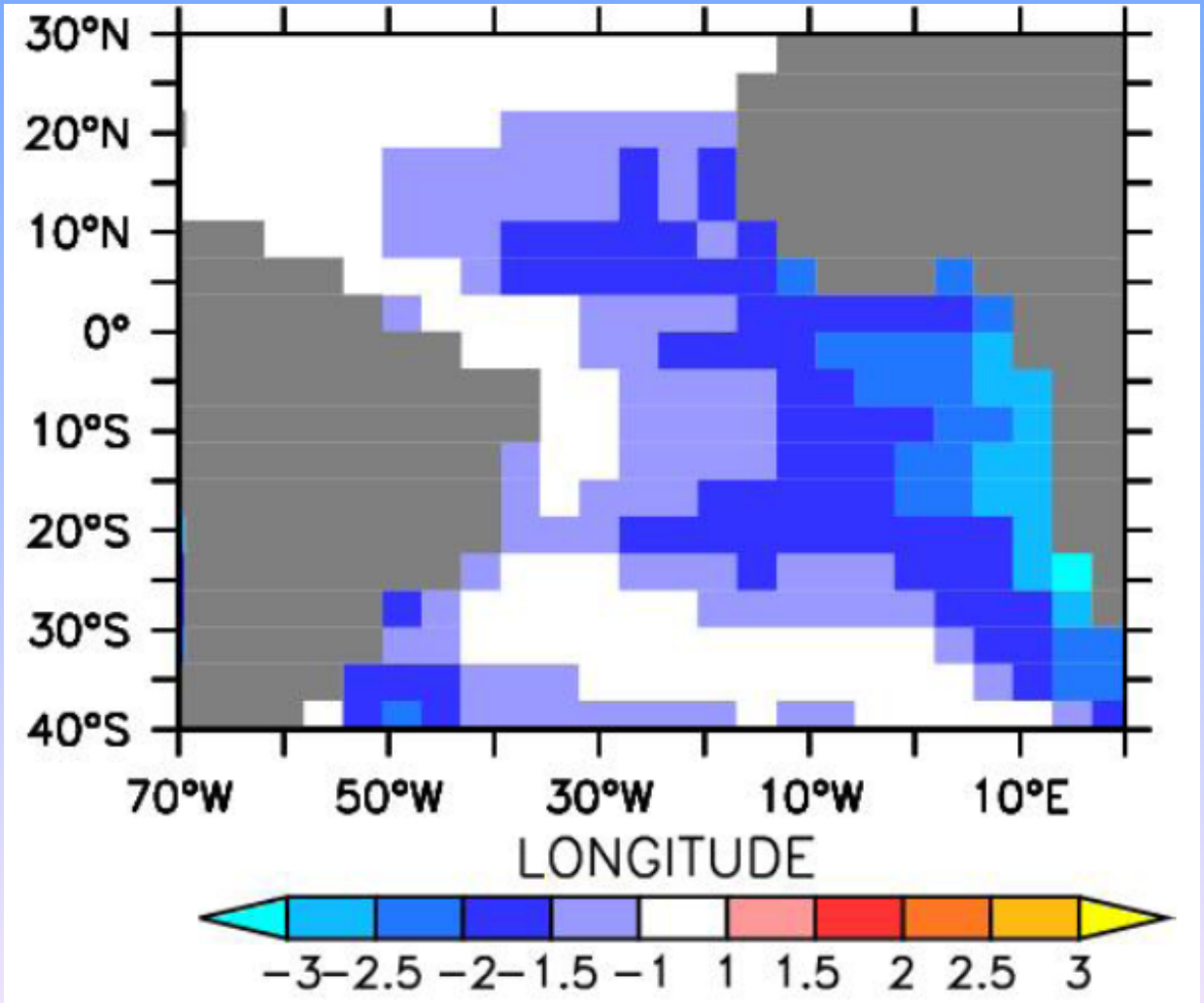
The Tropical Atlantic SST bias in the Kiel Climate Model (KCM)



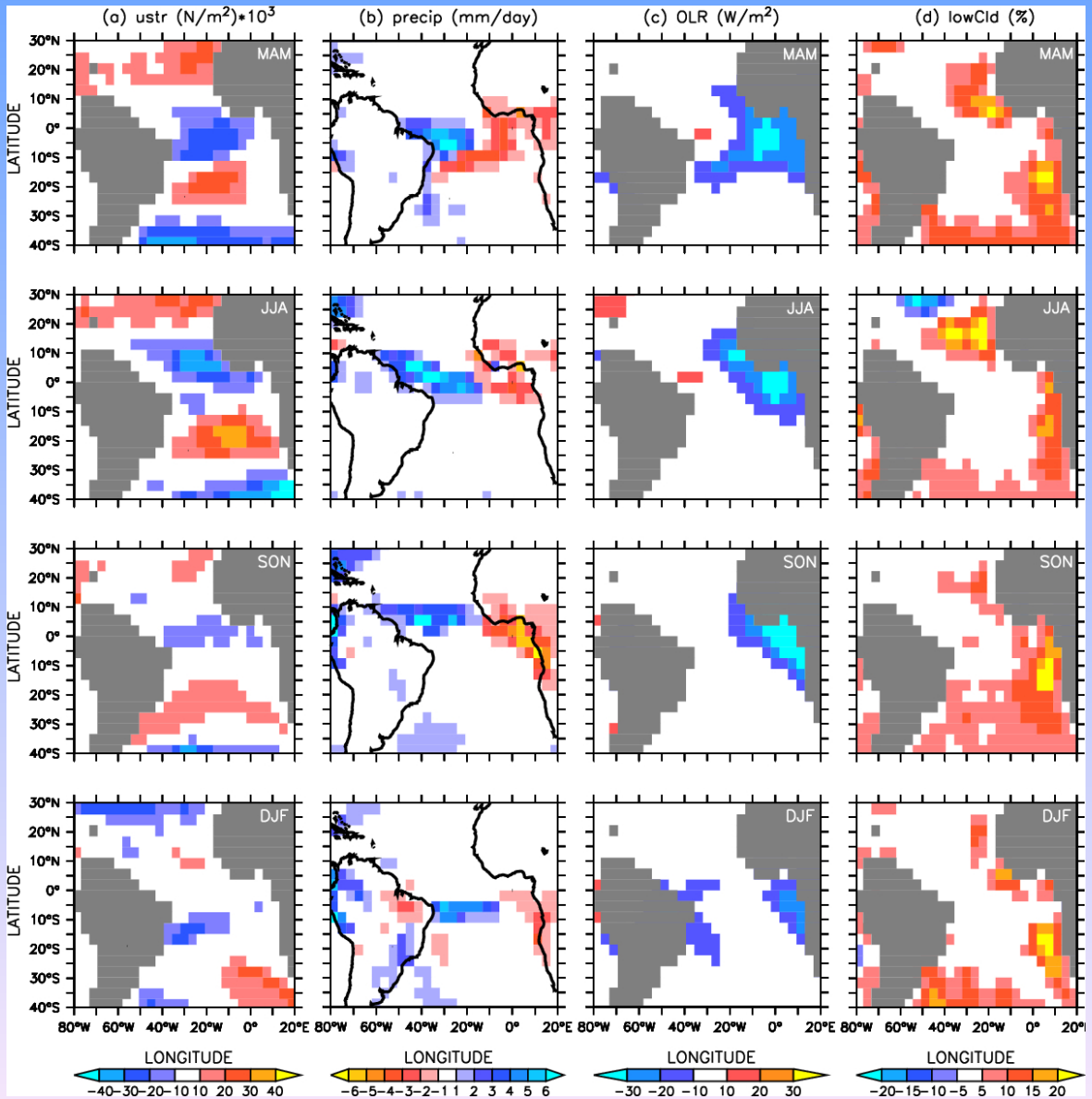
The zonal gradient along the equator is reversed in many models

Changed convection parameters reduce SST bias



Wahl et al. 2009

Changes in large-scale flow



Wahl et al. 2009

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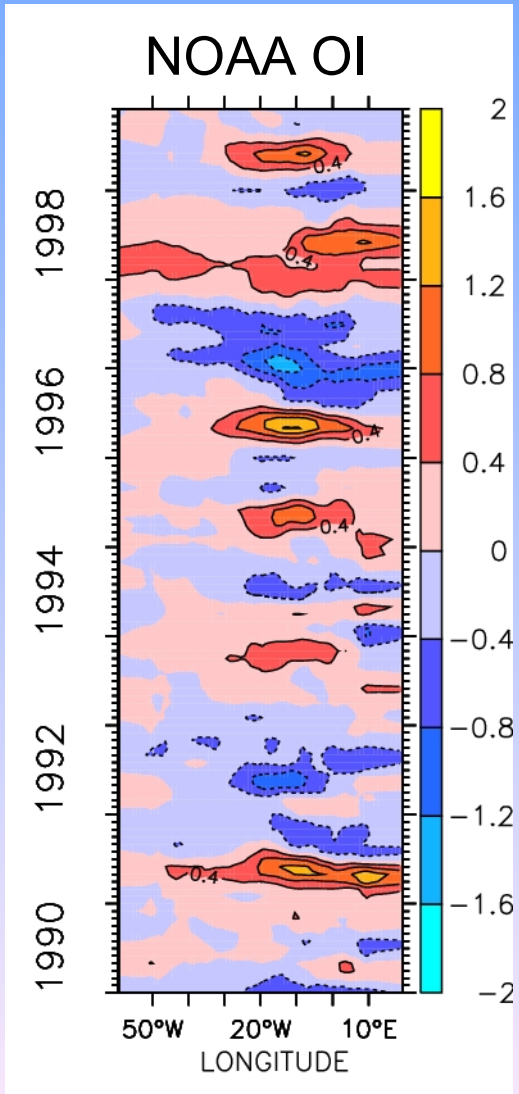
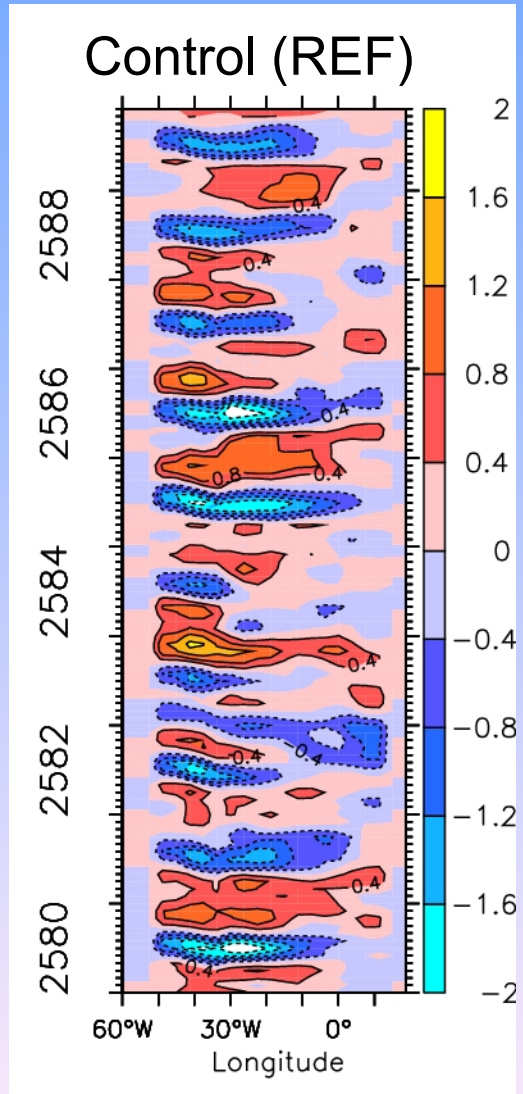
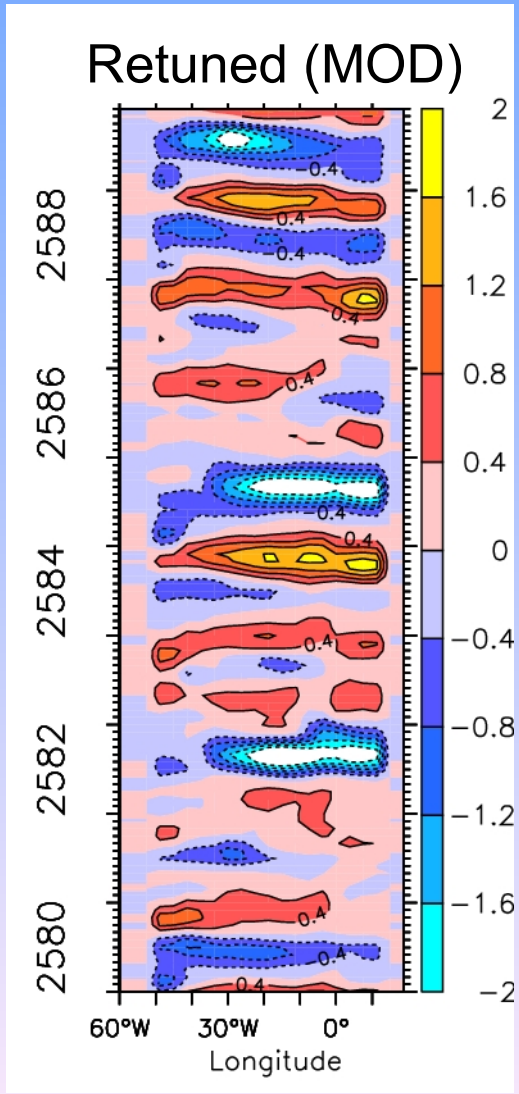
Changes in inter-annual variability: equatorial SST anomalies







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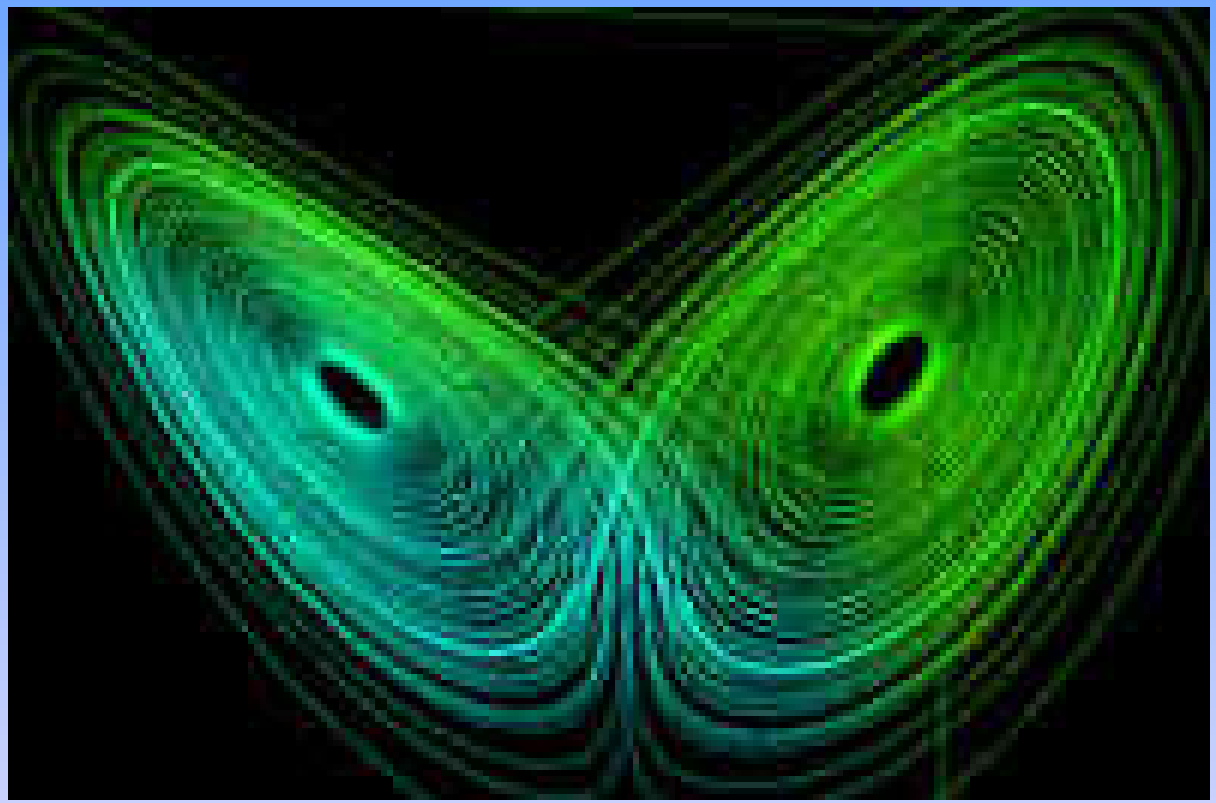
Weather and Chaos (Lorenz)

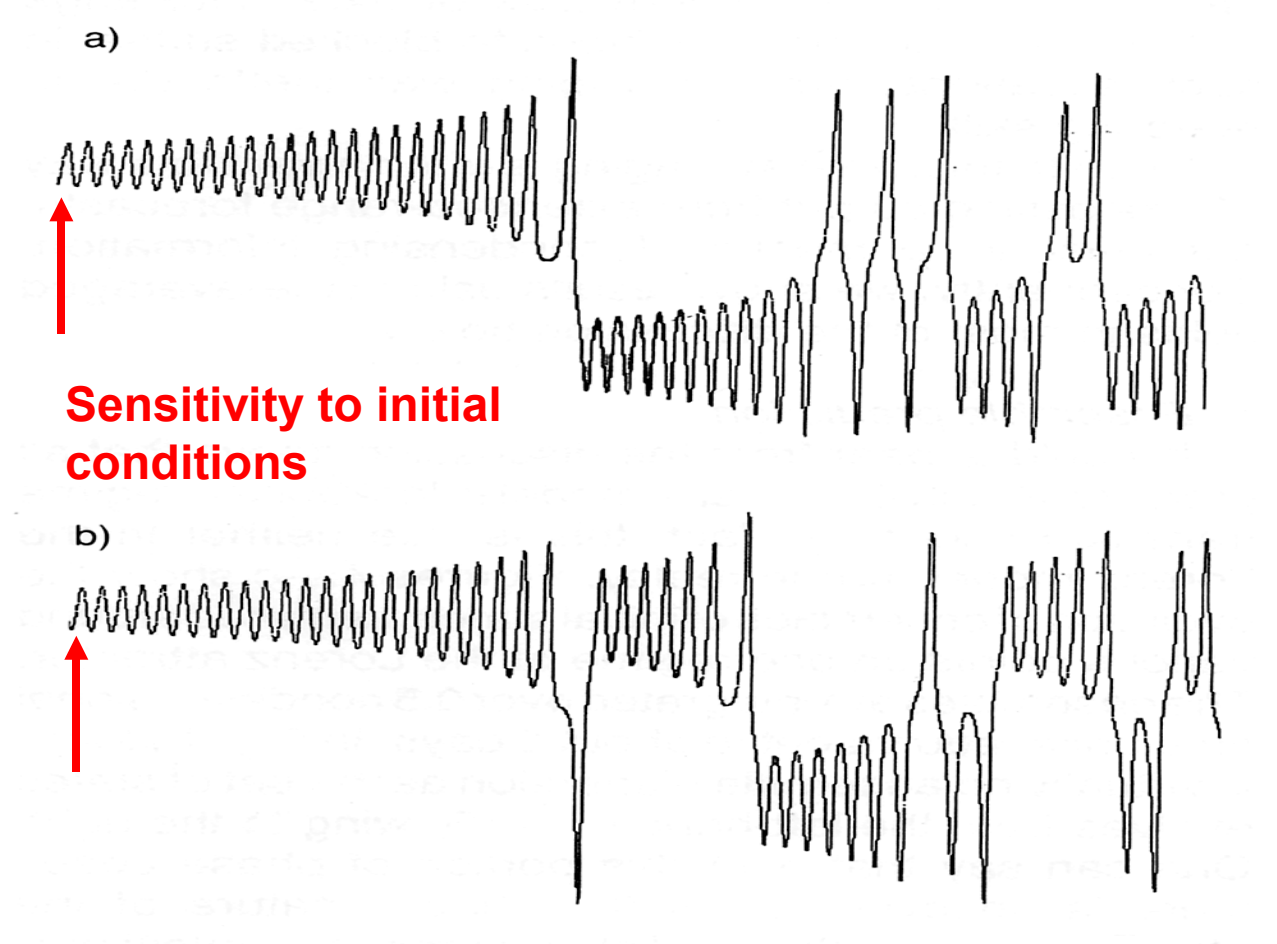


$$\dot{X} = -\sigma X + \sigma Y + f_0 \cos\theta$$

$$\dot{Y} = -XZ + rX - Y + f_0 \sin\theta$$

$$\dot{Z} = XY - bZ,$$

Chaos: The atmosphere is a good example



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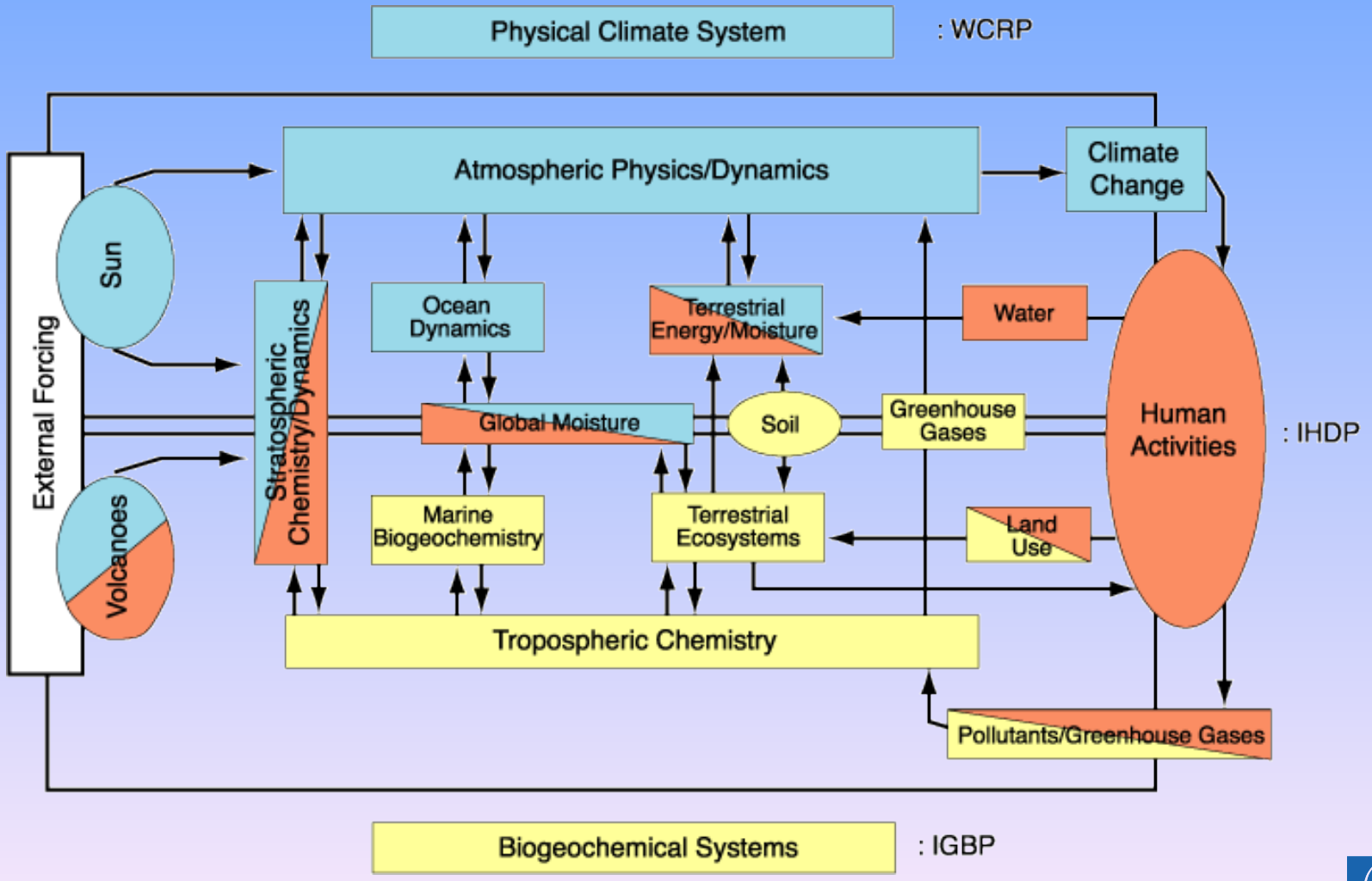
From climate models to Earth system models



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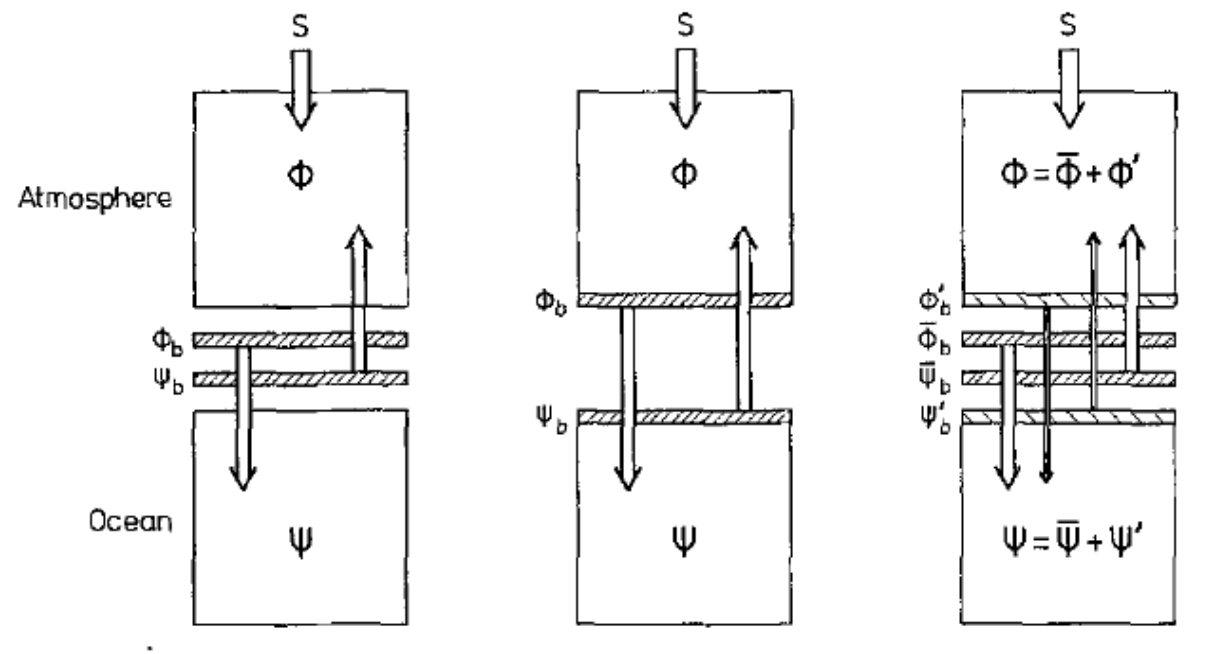
How to couple climate subsystems? Flux correction?



$$\frac{\partial \Phi}{\partial t} = \frac{\partial \Phi_{true}}{\partial t} + E_A(\Phi, \Psi, t)$$

$$\frac{\partial \Psi}{\partial t} = \frac{\partial \Psi_{true}}{\partial t} + E_O(\Phi, \Psi, t)$$

Sausen et al. 1988

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- **Where shall we go?**

What do we need?

- Better understanding of the processes
- Better observing system (e.g., subsurface ocean data)
- Better initialization (which data are needed, improved techniques)
- „Good“ models! We know from NWP that reduction of systematic bias helps. But biases in climate models are still rather large
- Correction techniques?