第七章:

大气环流模式

(**G**eneral **C**irculation **M**odel)

授课教师：张洋

2019. 12. 4

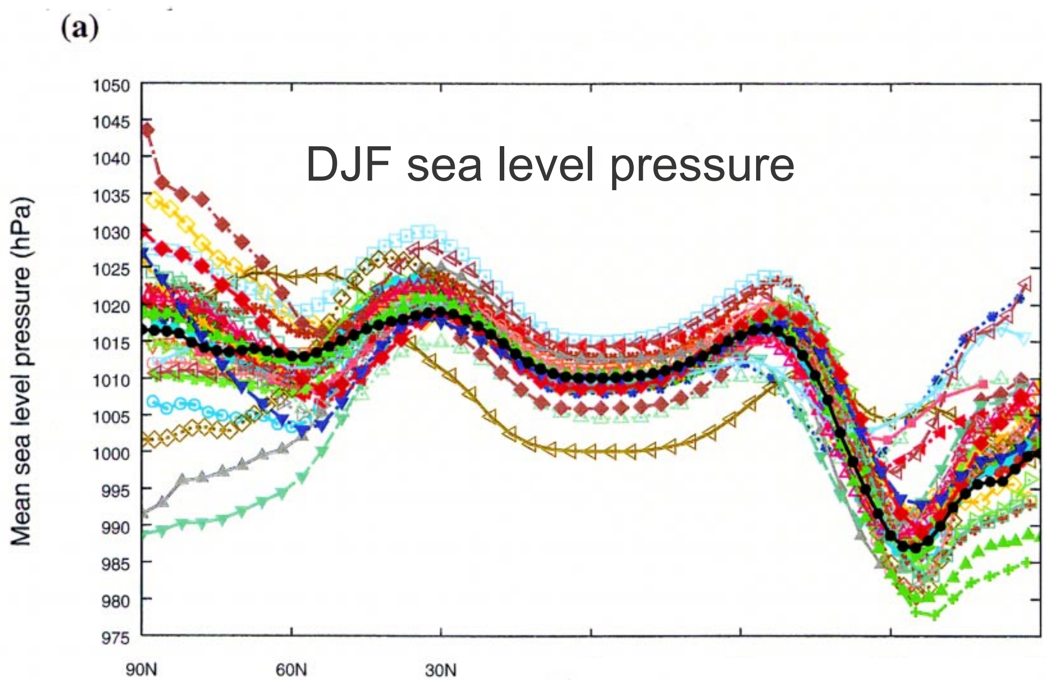
Uncertainties of full GCM

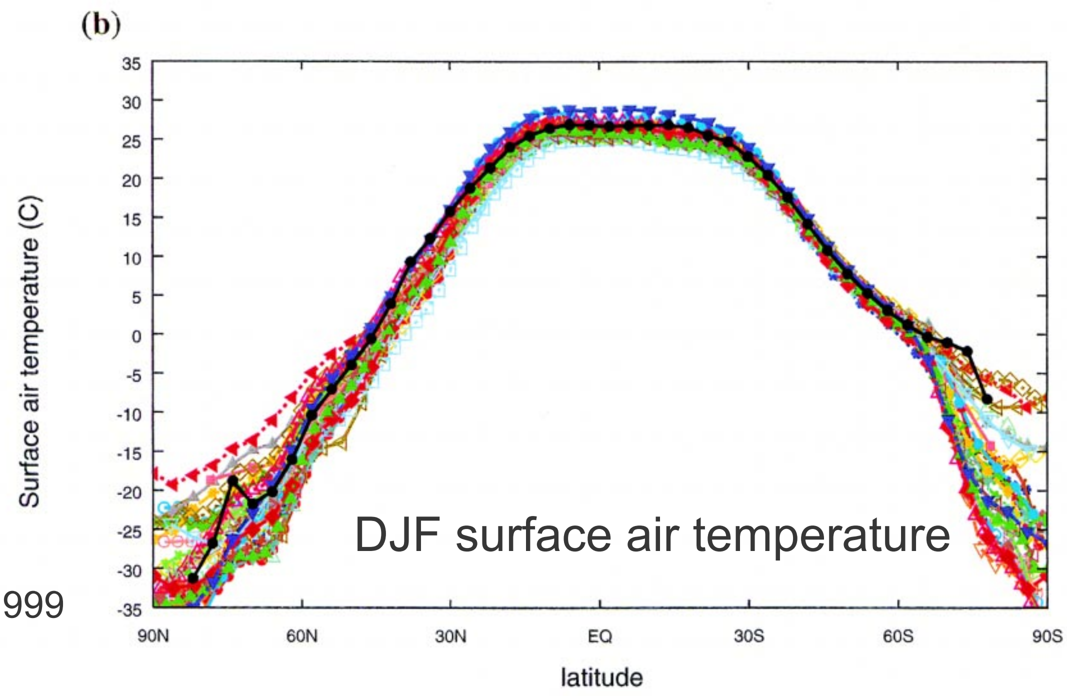
- Model Inter-comparison Projects (e.g. AMIP, CMIP)

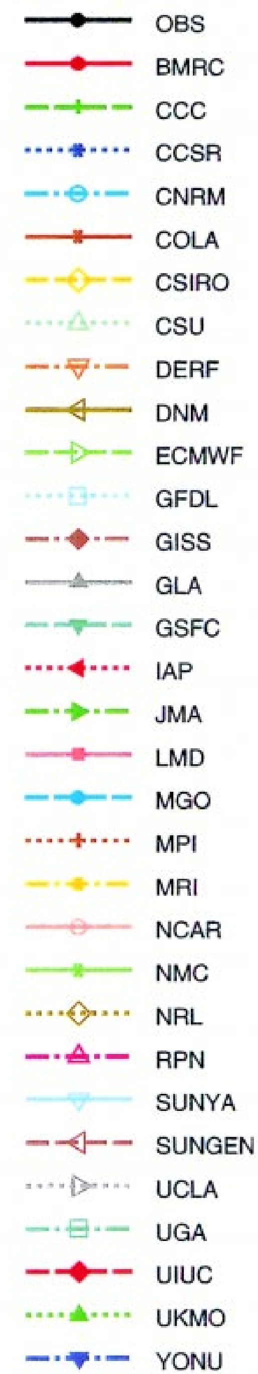
  The Atmospheric Model Inter-comparison Project (AMIP), initiated in 1989 under the auspices of the World Climate Research Programme, undertook the systematic validation, diagnosis, and intercomparison of the performance of atmospheric general circulation models.

- Taken AMIP I as an example
  - all models were required to simulate the evolution of the climate during the decade 1979–88;
  - under the observed monthly average temperature and sea ice and a common prescribed atmospheric CO_2 concentration and solar constant;
  - 31 modeling groups, representing virtually the entire inter- national atmospheric modeling community, had attended the project.

GCM

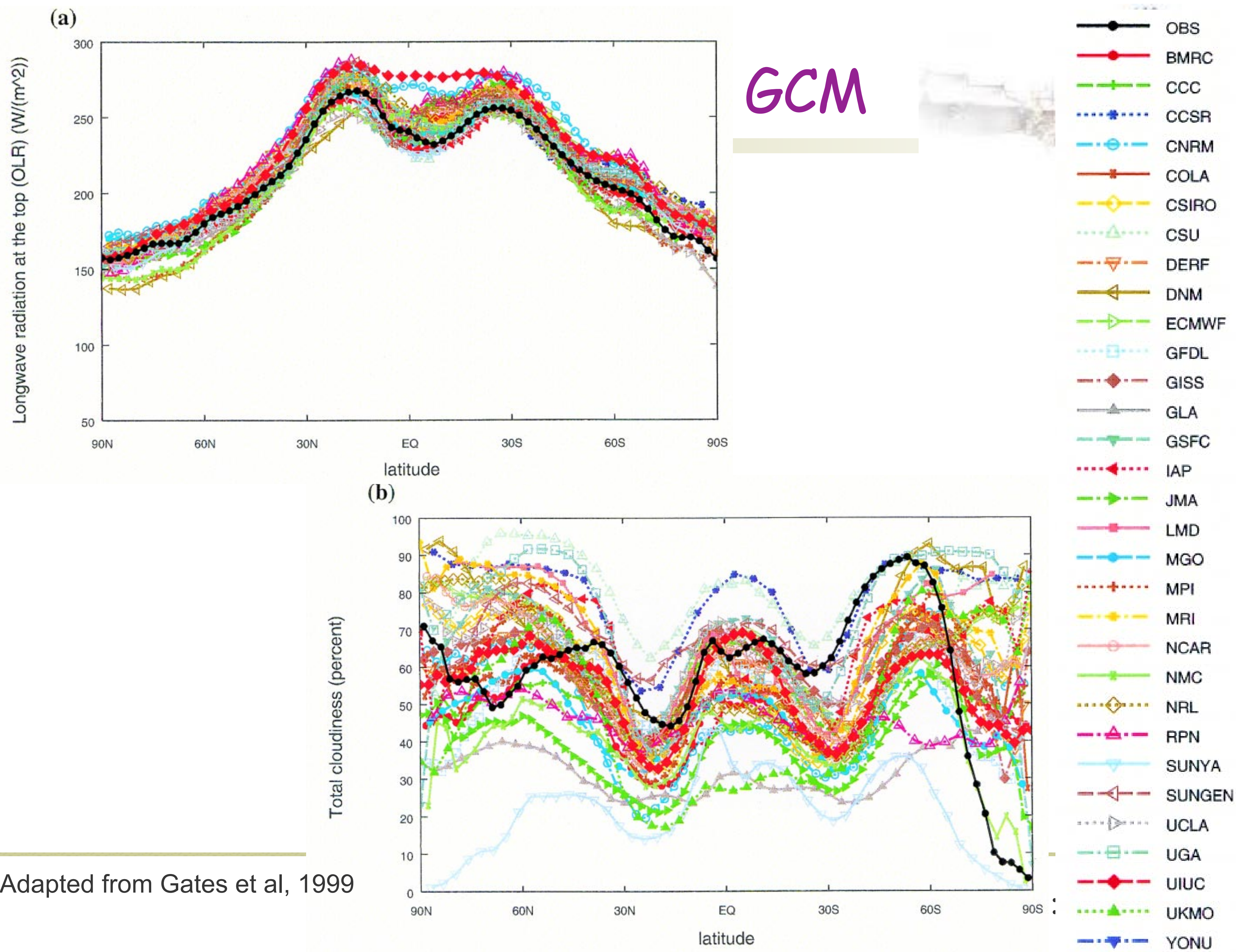






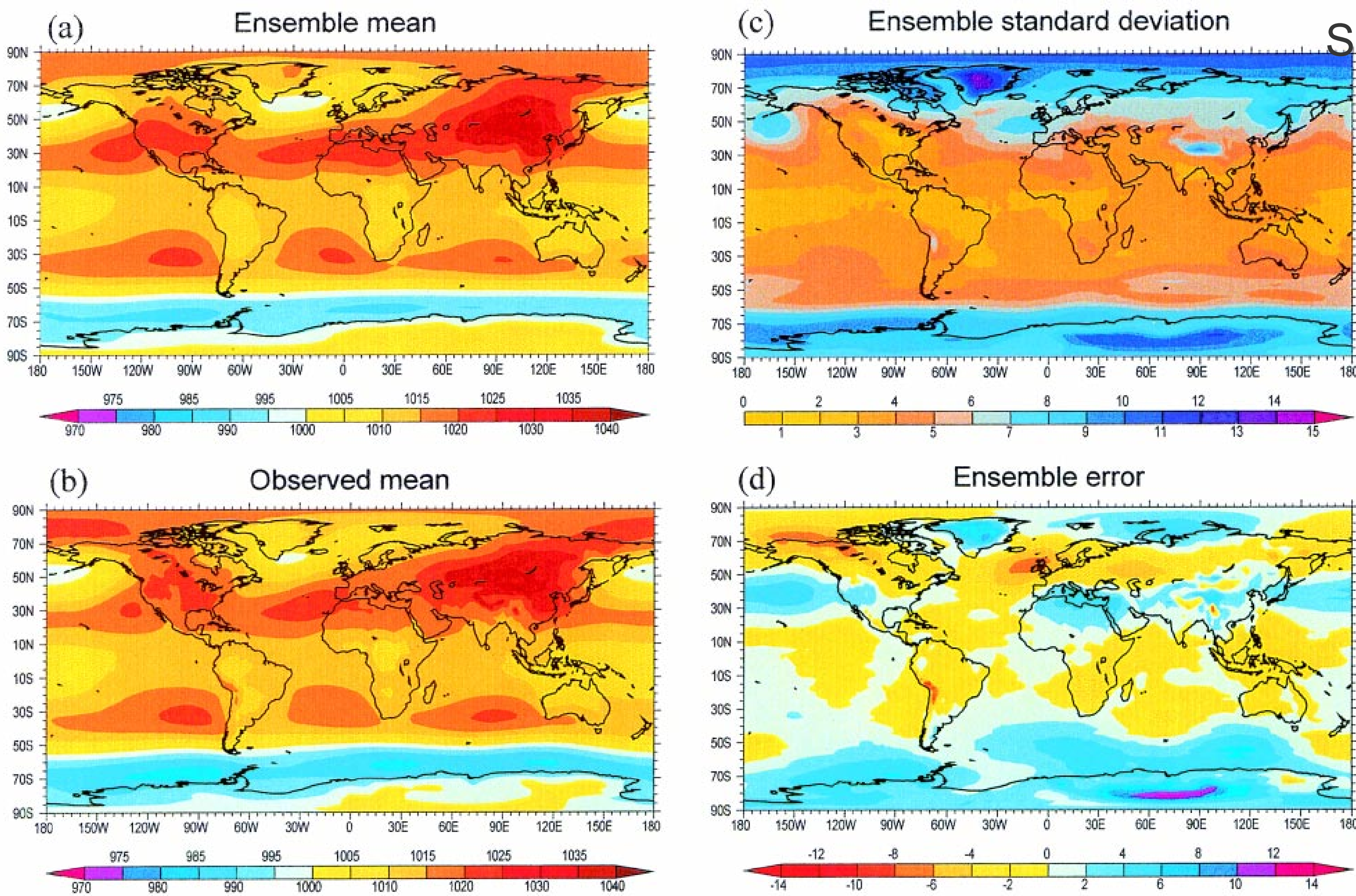
Adapted from Gates et al, 1999

GCM



Adapted from Gates et al, 1999

Uncertainties of full GCM

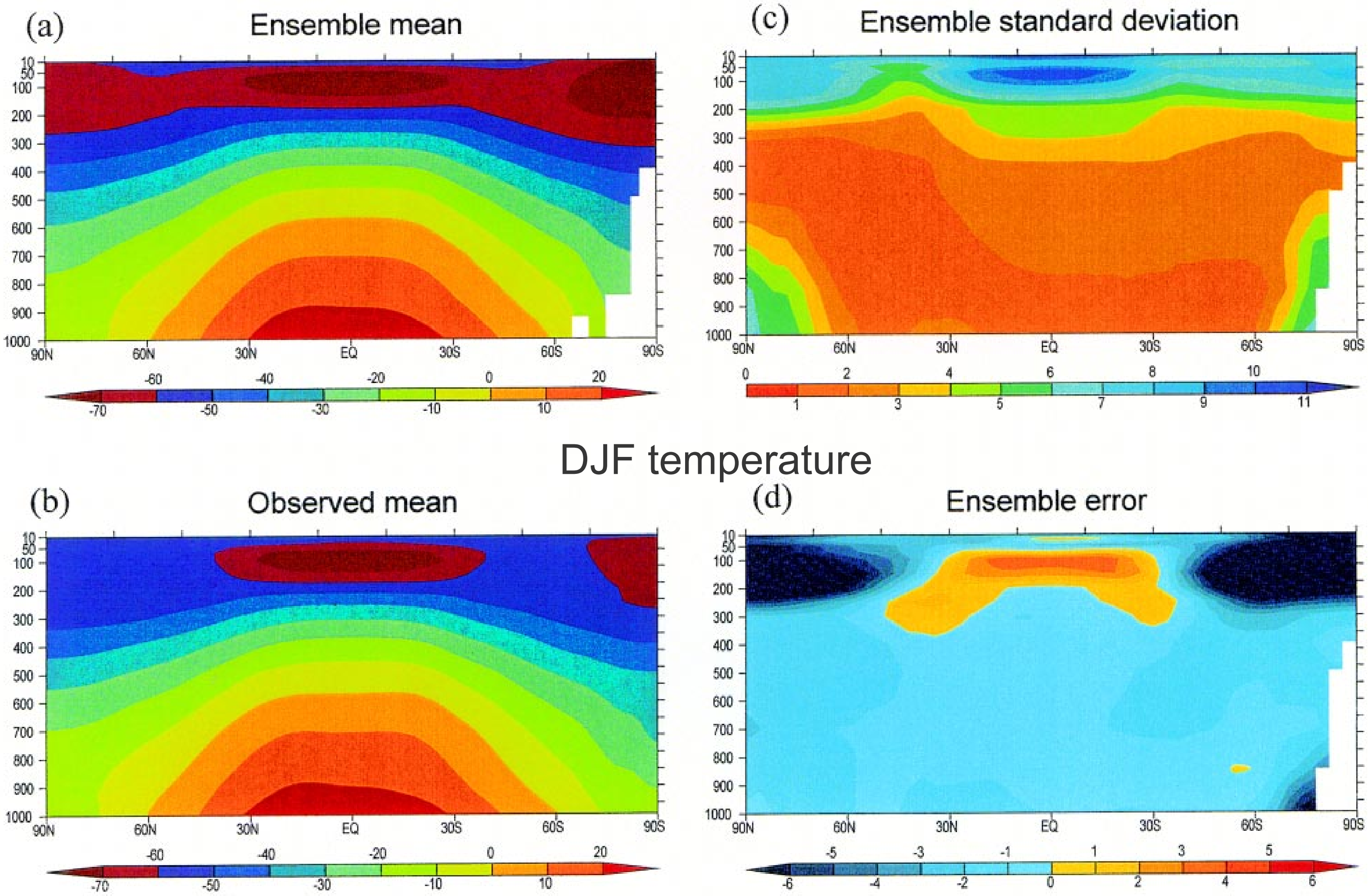


Sea level pressure in DJF

Gates et al, 1999

FIG. 1. The geographical distribution of mean sea level pressure (hPa) in DJF of 1979–88 given by (a) the AMIP ensemble mean, and (b) by data from the ECMWF reanalysis (Gibson et al. 1997) for 1979–88. (c) The standard deviation (hPa) of the model ensemble, and (d) the error (ensemble mean minus observation; hPa).

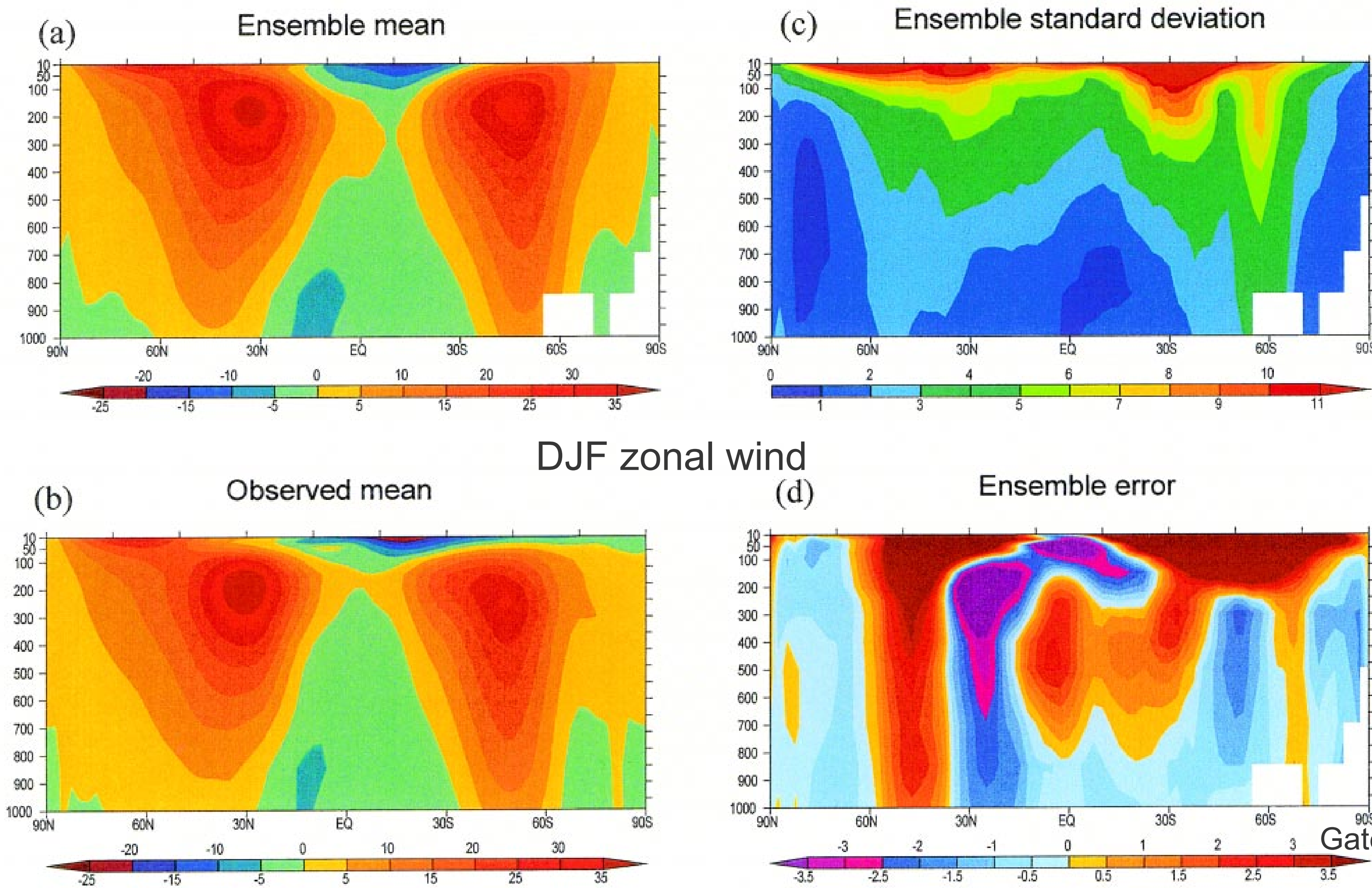
Uncertainties of full GCM



Gates et al, 1999

FIG. 8. (a) The latitude–pressure meridional section of the temperature (°C) given by the AMIP ensemble mean and (b) the observed data from the ECMWF reanalysis (Gibson et al. 1997). (c) The standard deviation of the ensemble mean. (d) The ensemble error. The pressure units are hPa.

Uncertainties of full GCM

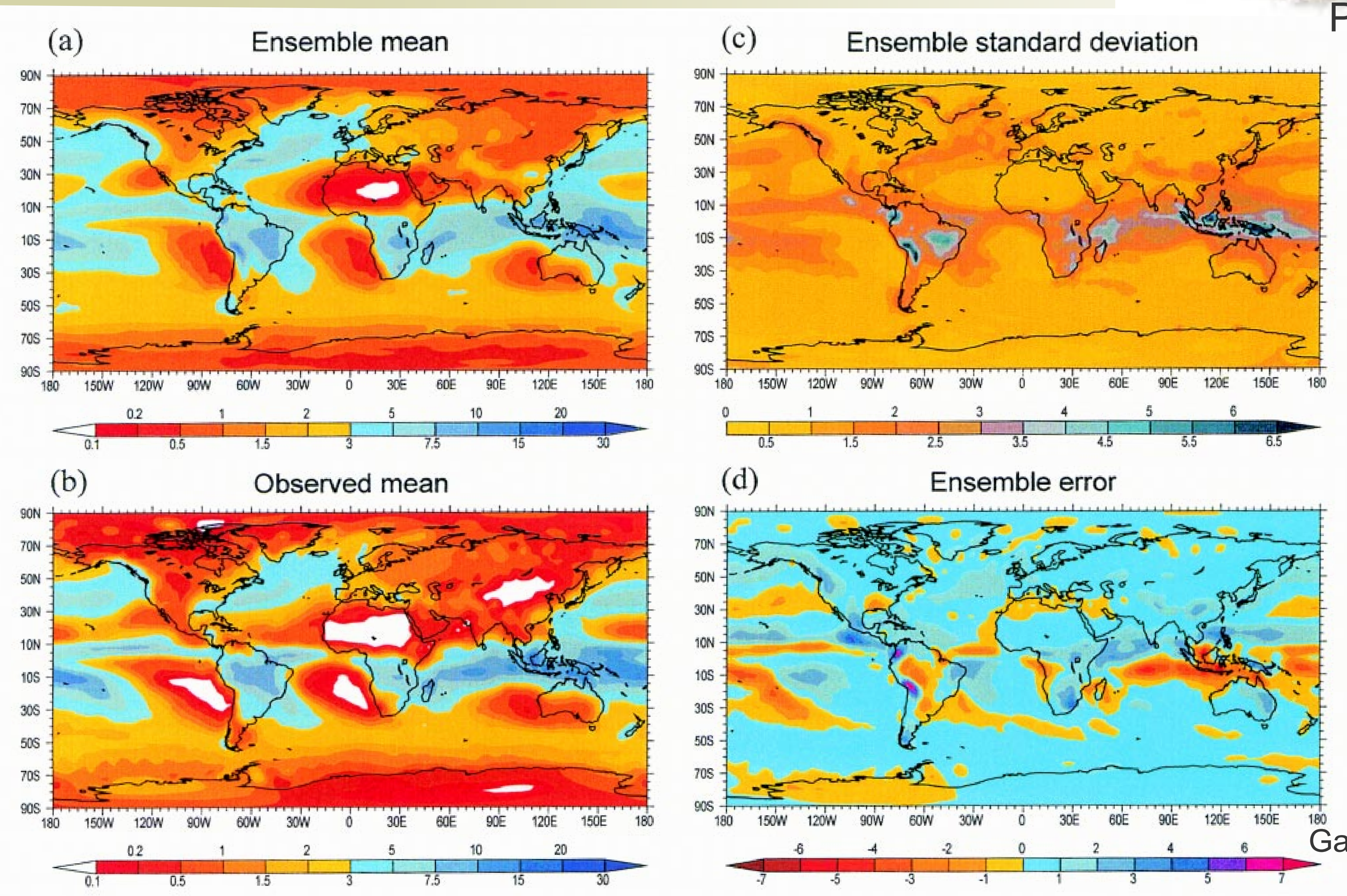


Gates et al, 1999

FIG. 9. As in Fig. 8 except for the zonal wind (m s^{-1}), with the observed estimate taken from the ECMWF reanalysis (Gibson et al. 1997).

Uncertainties of full GCM

Precipitation in DJF

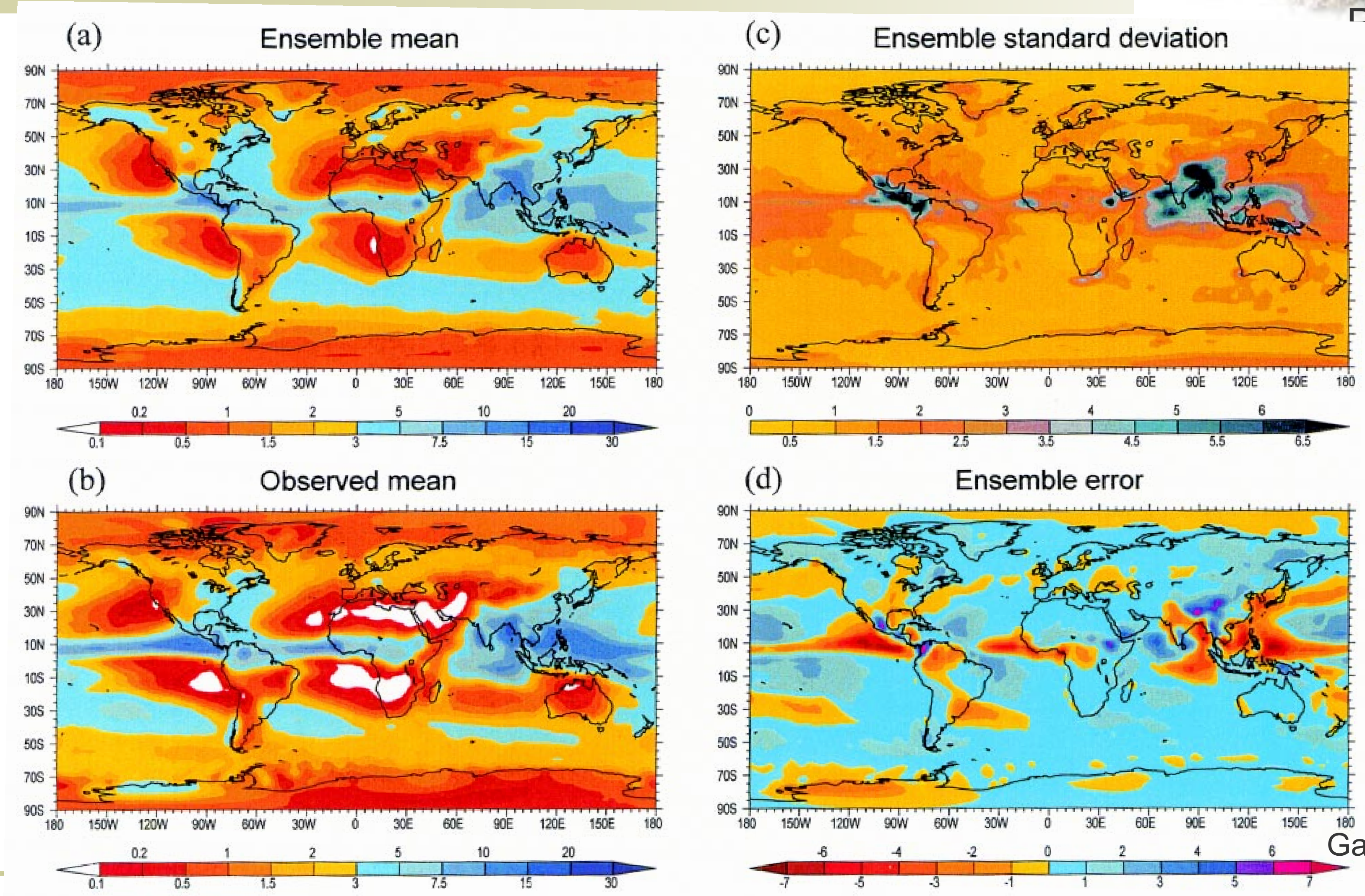


Gates et al, 1999

FIG. 3. As in Fig. 1 except for precipitation (mm day^{-1}), with observations for 1979–88 from the NCEP database (Xie and Arkin 1997). Note the nonlinear scale in (a) and (b).

Uncertainties of full GCM

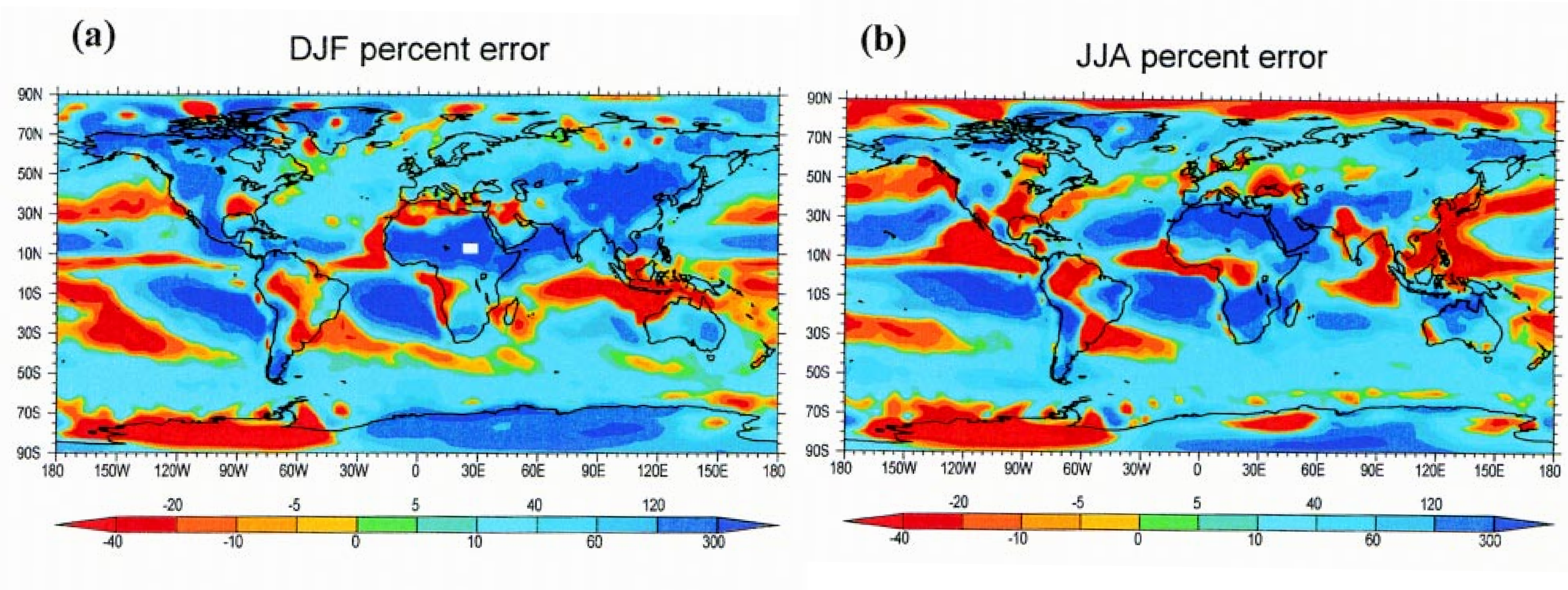
Precipitation in JJA



Gates et al, 1999

FIG. 4. As in Fig. 3 except for JJA.

Uncertainties of full GCM



precipitation

Gates et al, 1999

Uncertainties of full GCM

- A summary from the AMIP I results:
  - Ensemble mean shows that the average large-scale seasonal distributions of pressure, temperature, and circulation are reasonably close to what are believed to be the best observational estimates available;
  - The average large-scale distributions of pressure, temperature and circulation shows relatively large intermodel differences in high/polar latitudes compared to low/mid latitudes.
  - The large-scale structure of the ensemble mean precipitation also resembles the observed estimates but show particularly large intermodel differences in low latitudes.
  - The total cloudiness, on the other hand, is rather poorly simulated.

Outline

- Introduction
- A historical review of GCMs

    from the numerical wether prediction, idealized model to full GCMs
- Uncertainties of full GCMs
- A hierarchy of GCMs
- Some examples

A hierarchy of GCMs: From idealized model to full GCM

The need for model hierarchies

The complexity of the climate system presents a challenge to climate theory, and to the manner in which theory and observations interact, eliciting a range of responses. On the one hand, we try to *simulate* by capturing as much of the dynamics as we can in comprehensive numerical models. On the other hand, we try to *understand* by simplifying and capturing the essence of a phenomenon in idealized models, or even with qualitative pictures.

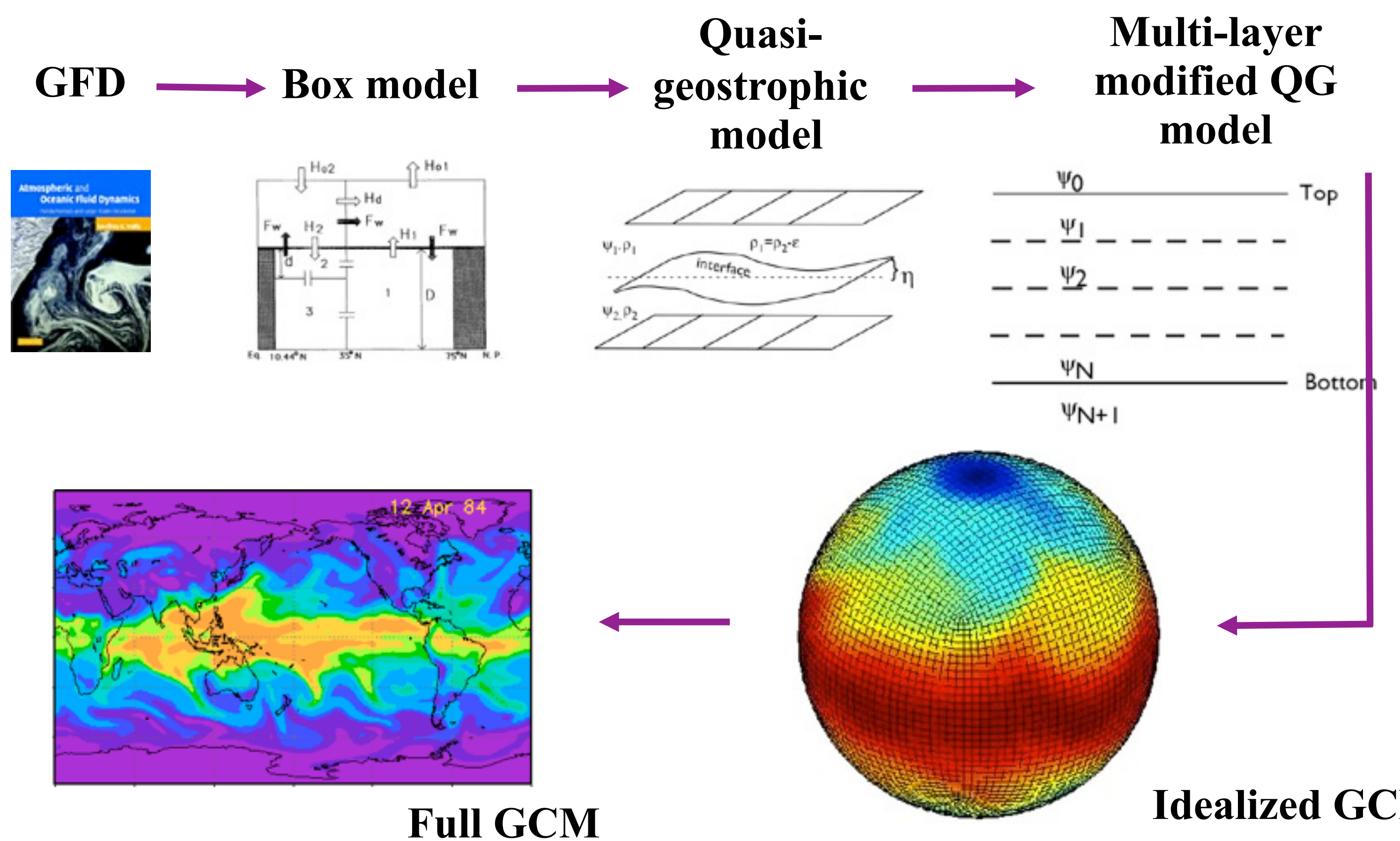
Constructing a hierarchy

The simpler the model that explains some aspect of climate dynamics the better! But the claim is that there are sources of complexity in the climate system that prevent us from generating convincing simple quantitative theories for many of the questions that interest us. My concern here is with models that attack some of the core sources of complexity in the climate system, that allow one to address questions of climate maintenance and sensitivity...

From Issac Held, *The Gap between Simulation and Understanding in Climate Modeling*, BAMS, 2005.

A hierarchy of GCMs: From idealized model to full GCM

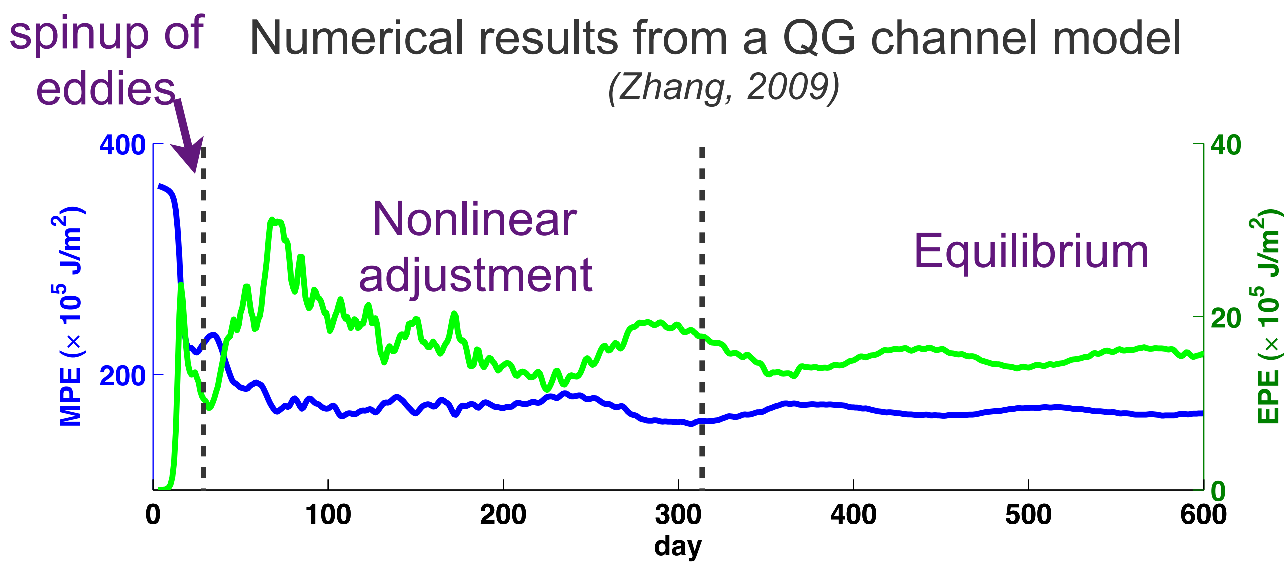
- An example for using hierarchy of models to study the role of eddies



Some examples of idealized model

QG channel model

From Chap4.3, baroclinic eddies



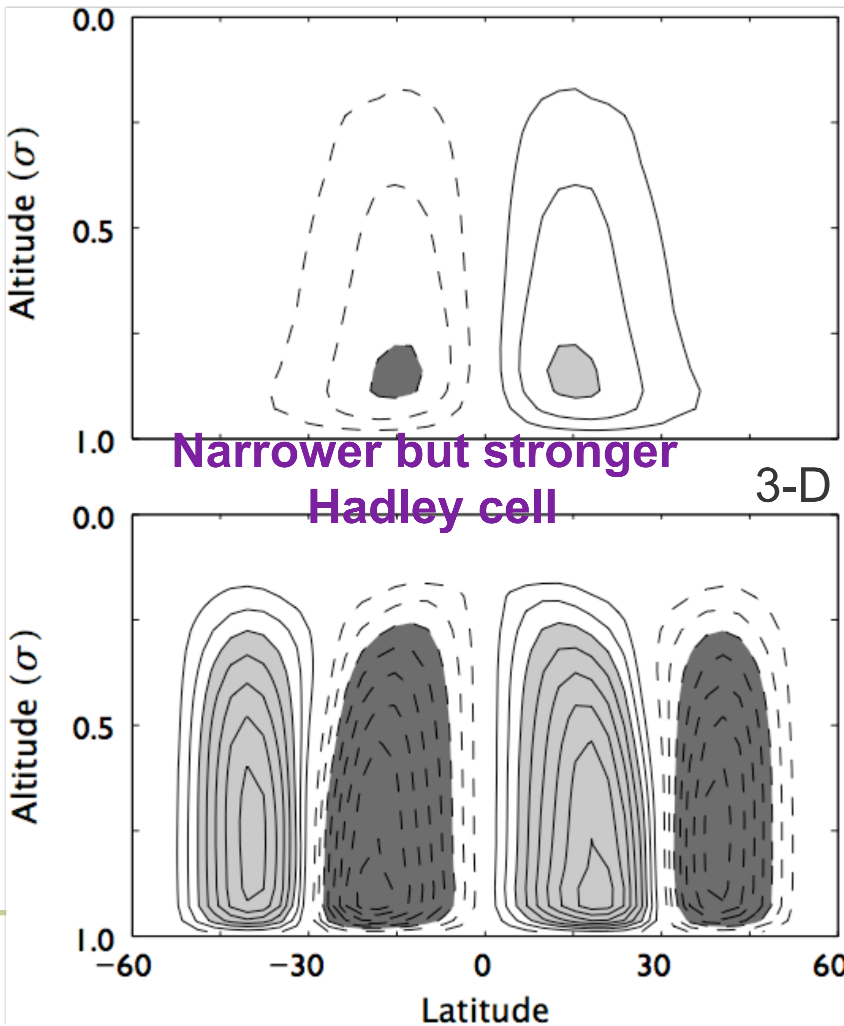
Some examples of idealized model

Dynamical core

From Chap3.2, Hadley Circulation

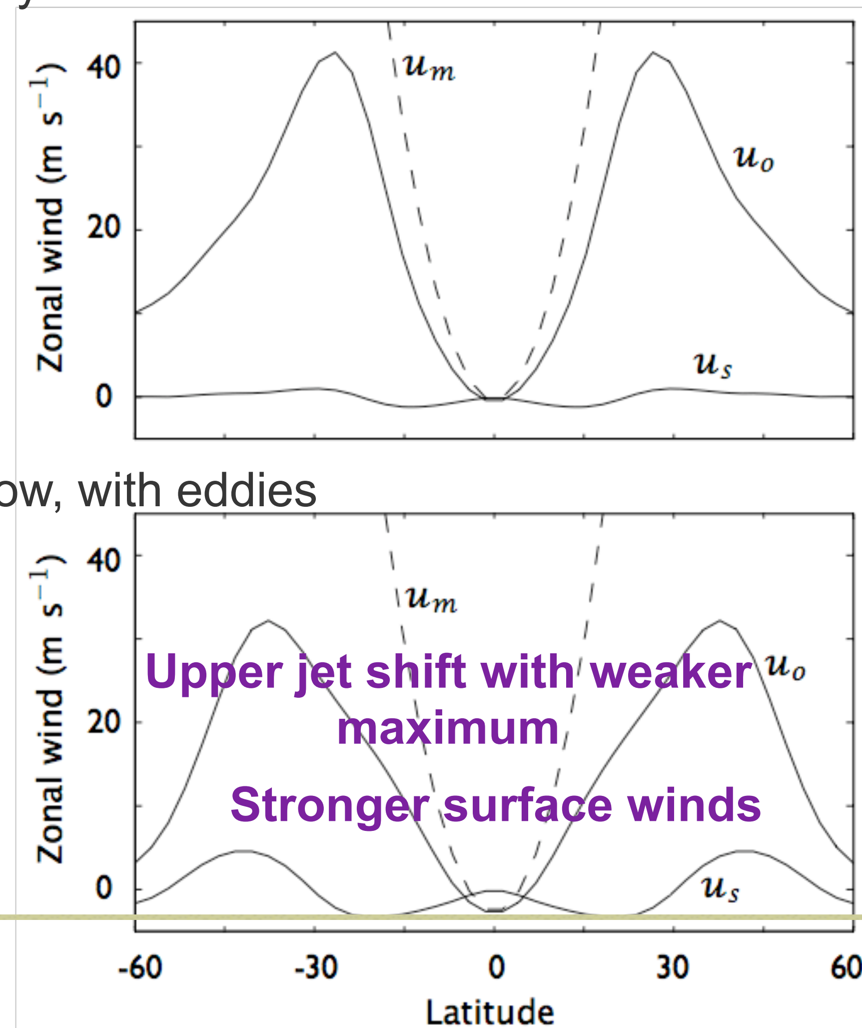
Vallis, 2006,
numerical results from idealized GCM

axisymmetric



Narrower but stronger Hadley cell

3-D flow, with eddies

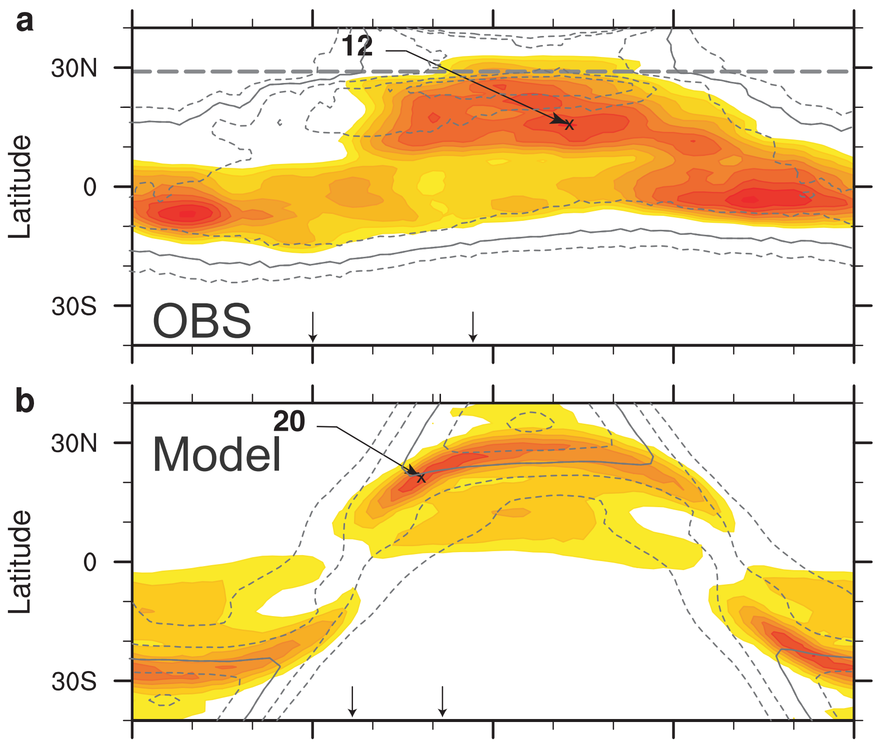


Upper jet shift with weaker maximum

Stronger surface winds

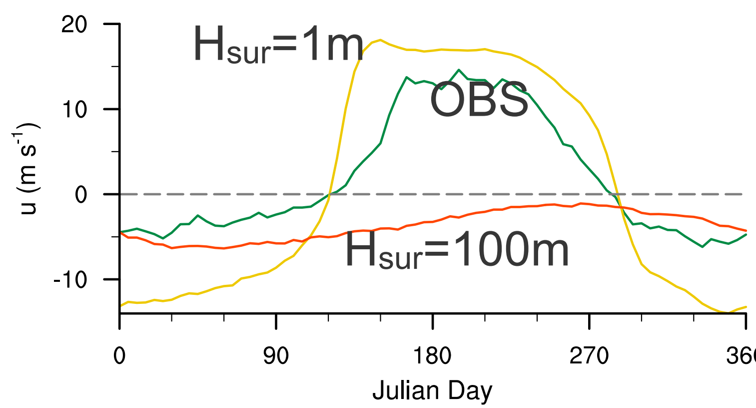
Some examples of idealized model

Aqua-planet model



Numerical results from idealized aqua-planet model:

- ocean surface all the globe
- no orography
- only vary depth of the ocean mixed layer



From Chap 6.2, monsoonal circulation

(Bordoni and Schneider, 2010)