Large vs. to small scale controls on climate

Reading group for Spring 2011
“All models are wrong, but some are useful*”

*“Useful” implies some definition of what you are trying to explain
Things about the climate one might want to explain

• Energy balance
• Atmospheric CO2
• Mean climate
• Climate variability
  – Regional
  – Large-scale (e.g. ENSO, NAO, PDO….)
  – AMOC
• Climate change
  – Sea level
  – Global climate sensitivity
  – Hydrological cycle/Regional climate change
Energy balance (Trenberth 2009)
• Water vapor provides the strongest positive feedback in GCMs.
• Water vapor and lapse-rate are strongly correlated.
Satellite-Observed and Model-Simulated Changes in Atmospheric Water Vapor

El Nino (warm)  La Nina (cold)  Pinatubo  El Nino  La Nina
Hydrological cycle (Held and Soden, Vecchi and Soden 2007)

A simple balance argument (Held and Soden 2006):

\[ P = Mq \]

\( M = \) upward convective mass flux

\( q = \) boundary layer humidity

Written as a fractional change:

\[ \frac{dP}{P} = \frac{dM}{M} + \frac{dq}{q} \]

For constant relative humidity, \( q \) scales with Clausius-Clapeyron (7% per degree C)

\[ \frac{dM}{M} = \frac{dP}{P} - 0.07 \, dT \]

If the fractional change in precip keeps pace with moistening, there is no change in circulation.
Water vapor increases with surface temperature at a rate predicted by C-C in climate models.

Precipitation increases at a slower rate implying a weaker circulation.

IPCC AR4 models under the A1b scenario. Differences are 2080-2100 minus 2020-2000.
Large-scale climate variability

Clement et al. (2010)
Regional climate (Kirtman)

HRC, LRC

Observational Estimate

Surface Current Speeds
Rainfall: HRC, and LRC

Rainfall: Observational Estimate
CFC in the North Atlantic with and without eddies (Kamenkovich)

- Differences between the standard and “no eddy” simulations are large in the subpolar gyre

- Eddies mix CFC along isopycnals, away from the paths of boundary currents
- In the absence of eddies, CFCs concentrate in the high latitudes and circulate within boundary currents

CFC cross sections at 40°W (pMol/kg)

CFC on deep isopycnal surface $\sigma_\theta=27.8$
Paper ideas

• OCEAN
    • Also: Toggweiler & Samuels (1998) and/or Gnanadesikan et al (1999),
    • Connection with CO2 Anderson et al (2009) and d’Orgeville et al (2010)
  – North Atlantic CFC distribution (Kamenkovitch paper)
  – Hughes et al. (need ocean mixing and buoyancy fluxes to get AMOC)
  – Subtropical cells and tropical instability waves (Not sure this has been shown with a model, but I have heard it argued by Martin Visbeck)
  – Markus Jochem’s papers
  – Lozier papers

• ATMOSPHERE
  – Response to GHG forcing of the hydrological cycle (Held and Soden (2006); Vecchi and Held (2007))
  – Robust surface temperature patterns: Xie et al
  – Robust climate variability: Clement et al. (2010)
  – Ben K. presents 1o ccsm4 simulation- what is different from the coarser resolution?
  – Kang paper- details of convective parameterization matter
  – Brian M paper on MJO?
  – Super-parameterization papers- Explicit representation of sub-grid scale in the atmosphere

• Land ice
Scales of climate processes

- Climate variation
- ENSO
- Seasonal cycles
- Intraseasonal (MJO)
- Planetary waves
- Tropical cyclones
- Fronts, squall lines
- Cloud clusters
- Thunderstorms
- Tornadoes
- Thermals
- Turbulence

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