Manabe and Wetherald (1967)

• Subgrid scale phenomena:
  – “Free and forced convection, and mixing by large scale eddie, prevent the lapse rate from exceeding a critical lapse rate equal to 6.5 K/km” (page 242)
  – Relative humidity is fixed
  – Clouds are fixed
  – The ocean is basically a source of moisture

• Results:
  – Water vapor feedback (via fixed RH) doubles climate sensitivity
  – Mechanism:
    • “In order to compensate for the decrease of net outgoing radiation at the top of the atmosphere due to the increase in CO2 content, it is necessary to increase atmospheric temperature” – heat balance of the atmosphere as a whole (rather than at the surface)
  – 2xCO2 climate sensitivity is 2.3C (compare with the present IPCC 2007 range of 2°C to 4.5°C)
  – Stratospheric cooling
FIG. 1. Latitude-height distribution of relative humidity for both summer and winter (Telegadas and London, 1954).
What is ‘climate’? What is your ‘climate model’? How has it been altered (or not)?

• Clement climate:
  – Global climate change/sensitivity is water vapor feedback + clouds, neither of which depend on resolved mesoscale phenomena in the ocean
  – Climate variability (which is more relevant for regional climate) is a set of weakly coupled modes of atmospheric variability (SO/PNA/Hadley) that feel the effects of the mean ocean circulation, but not ocean HT variability (very strongly); mesoscale ocean phenomena can be parameterized
  – Also, some (not insignificant) fraction of cloud cover variability is related to large scale circulation changes (small-scale processes are organized by the larger scale)

• Revision:
  – Long-term mean climate includes sea ice, which is sensitive to mean ocean circulation and possibly eddies (good future problem)
  – Resolved ocean eddies play a role in carbon draw down (B&K); may play a role in carbon transport in the ocean, but time-scale dependent
  – (based on discussions- not papers) There is no complete theory for AMOC- so how do we know what processes are important in determining its strength?
• Why do we care about global climate sensitivity?
  – IAM- damages can be tied to global mean temperature
  – attribution
Themes

• Challenge of experimental design to test importance of phenomena operating at different scales
• Tradeoff of completeness vs. understanding
• Challenge of testing with observations
• Scaling up and scaling down
- **Held and Soden, 2006**
  - Tradeoff of completeness vs. understanding \( \rightarrow \) GOLDEN
  - From clausius-clapeyron, we can predict robust responses of: global atmospheric overturning; precipitation pattern; OAHT
  - Problems in the southern ocean (signals are not robust); problems with clouds (also not robust)
  - Big problem: Observational test????

- **Enderton and Marshall, 2009**
  - Tradeoff of completeness vs. understanding \( \rightarrow \) another good example
  - Details of the large-scale ocean circulation are important for climate (global mean temperature) because of melting sea ice

  - Scaling up: (to the extent that this is the best illustration of the role of eddies in the adjustment of southern ocean to winds) the role of eddies has not been convincingly shown since its is not coupled. That is, if winds increase, which increases the poleward OHT, how does this affect the atmosphere- is it a negative feedback?

- **Kang et al. (2009)**
  - Scaling up: Convective parameters can influence the climate (OAHT + ITCZ position) adjustment to interhemispheric forcing ; but maybe we can exclude some range of parameters as not being realistic; even if those parameters change with climate, is the effect first order?

- **Booth and Kamekovich (2008)**
  - Challenge of experimental design to test role of different scales- they have an elegant approach to this issue; but it is limited because they can’t address the role of active tracers
  - Subsurface ocean variability can influence the draw-down of carbon at the surface

- **Wyant et al. (2009)**
  - Challenge of comparing against observations: they use an enormous amount of computing power, but end up with a lackluster comparison with observations
  - Tradeoff of completeness vs. understanding- just adds another parameterization, but have we really understood anything more about clouds?
• **Seo et al. (2006)**
  – Challenge of experimental design to test role of different scales: Parameterizations are SCALE dependent

• **Ito et al. (2010), Naveira Garabato et al. (2007)**
  – ITO et al: Challenge of experimental design to test role of different scales: TIMESCALE. At interannual timescale (which are computationally feasible), Ekman dominates (role of eddies is not as significant). Perhaps eddies are important in the long-timescale adjustment – when do they become important

• **Fedorov et al. (2010), Sriver and Huber (2007), Emanuel (2001)**
  – Mesoscale phenomena (hurricanes) may scale up … BUT (see Jaimes comments)

• **Clement Rousset coupled model simulation**
  – Higher resolution results in a warmer climate (scaling up)

• **Yanyun Liu (NOAA-AMOL) “Future Impact of Reduce Loop Loop Current on the Warming of the Gulf of Mexico”**
  – Regional scale ocean phenomena (i.e. the loop current) are important to understand the response of the regional climate AND IMPACTS ON ECOSYSTEMS to GHG forcing.
  – A consistent modelling framework (scaling down coarse resolution models) exists to address this issue. CAVEAT: if the coarse models are not getting the AMOC response right, then the BCs which influence the result are not right.
  – Do we have a reason to think that the projected weakening of the AMOC (by coarse res models) is not right? Not going to happen?
Parting thoughts from Borges

“On Exactitude in Science . . . In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitiilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.”

-Suarez Miranda, Viajes de varones prudentes, Libro IV, Cap. XLV, Lerida, 1658

From Jorge Luis Borges, Collected Fictions, Translated by Andrew Hurley Copyright Penguin 1999.
What next?

• Land reading group
  – Betts papers
  – Drought
  – Paleo papers
• The Warming Papers
• Informal ‘Climate’ research presentations
Focus topics

• Land (i.e. snakes and buckets)
  – Paleo droughts
  – Sahel
  – Processes (betts papers)

• Sea ice
  – Gildor and tziperman
  – Arctic sea ice (why is it melting?)
  – Antarctic sea ice (does it change?)

• Carbon Cycle
  – Role of the ocean

• Decadal variability