LAOF and Frontiers of Tropospheric Physics

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Outline

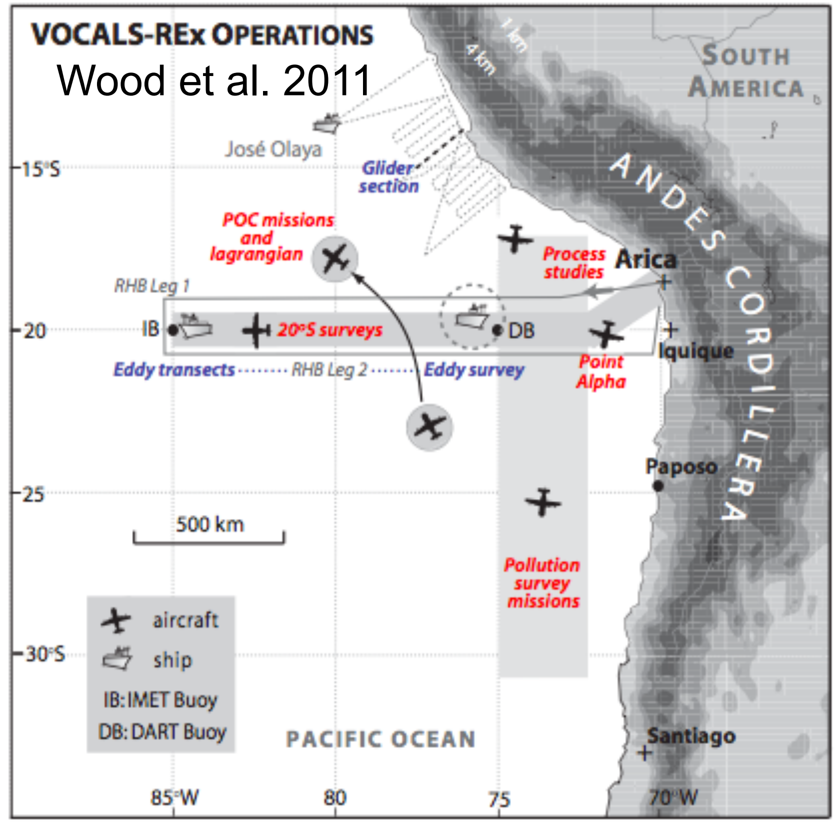
- Tropospheric climate science issues/trends for the next decade
- Role of exploratory observations

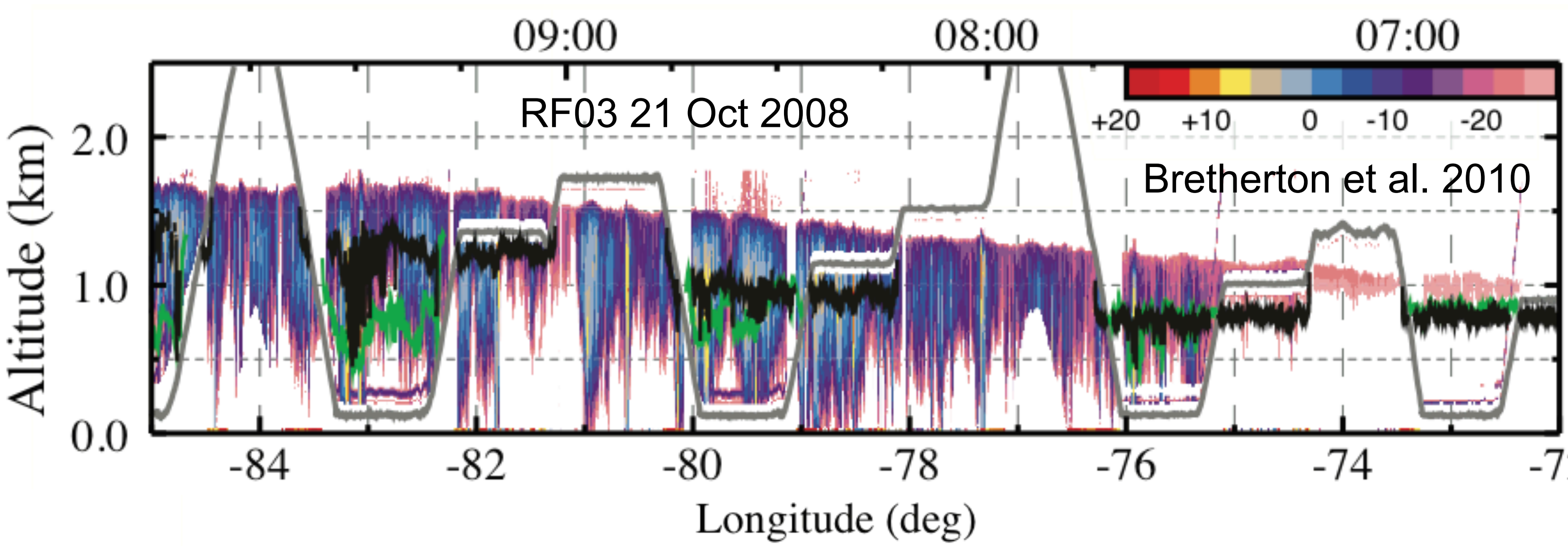
My fingers in the climate science business

- I’m mainly a process modeler interested in clouds, turbulence and cumulus convection.
- Helped develop the CAM5 boundary layer, shallow cumulus and subgrid cloud parameterizations.
- I’m currently working on gaining a richer physical understanding of both boundary layer cloud feedbacks on global warming and cloud-aerosol interaction, using LES, and with NCEP on GFS moist physics parameterizations.
- Helped plan and analyze data from some field programs:
    - Hawaiian Rainband Project (1990)
    - Atlantic Stratocumulus Transition Experiment (1992)
    - Monterey Area Ship Tracks experiment (1994)
    - East Pacific Investigation of Climate (2001)
    - VOCALS Regional Experiment (2008)

VOCALS REx (2008)

- SE Pacific cloud/aerosol/ precipitation interaction
- EOL: C130, Iquique GAUS
- Great suite of EOL and PI aerosol/chemical/cloud measurements on C130
- U. Wyo. cloud radar/lidar
- C130 range a key advantage





Tropospheric issues and trends in climate science

- High-resolution modeling
  orography and surface heterogeneity
- Scale interaction
  multiscale Cu convection, extreme weather
- Weather-climate synergy
- Sophisticated simulation of trace chemicals and isotopes
- Aerosols and cloud microphysics over remote oceans
- Ice and mixed-phase microphysics
- Reducing biases and uncertainty through testing and improvement of parameterizations and their interaction.
- Biosphere/atmosphere interaction
- Stable multidecadal climate observing system

High-resolution climate modeling

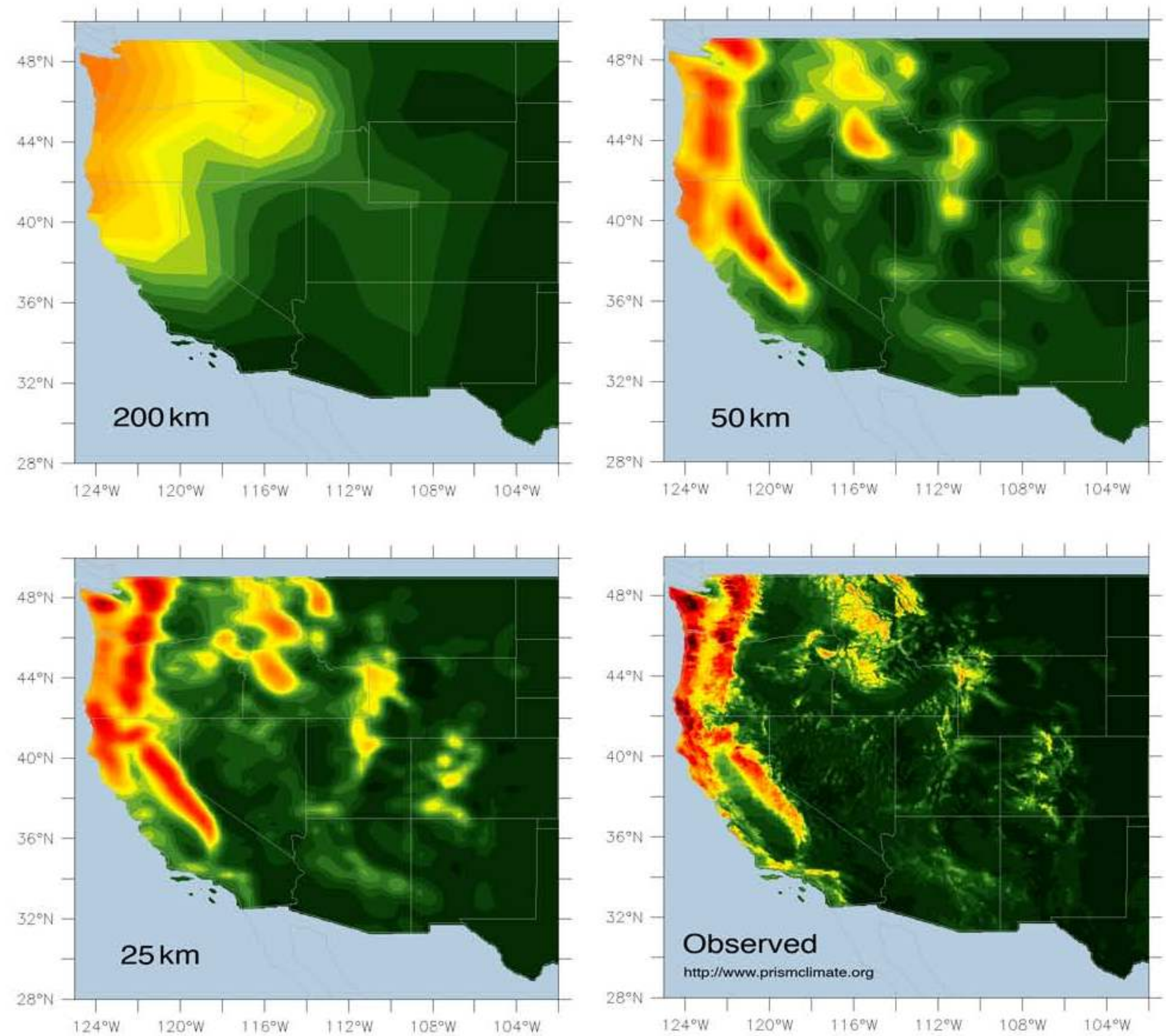
Global atmospheric model grid spacing 2012 ➔ 2022

Typical

100 ➔ 25 km

Cutting edge

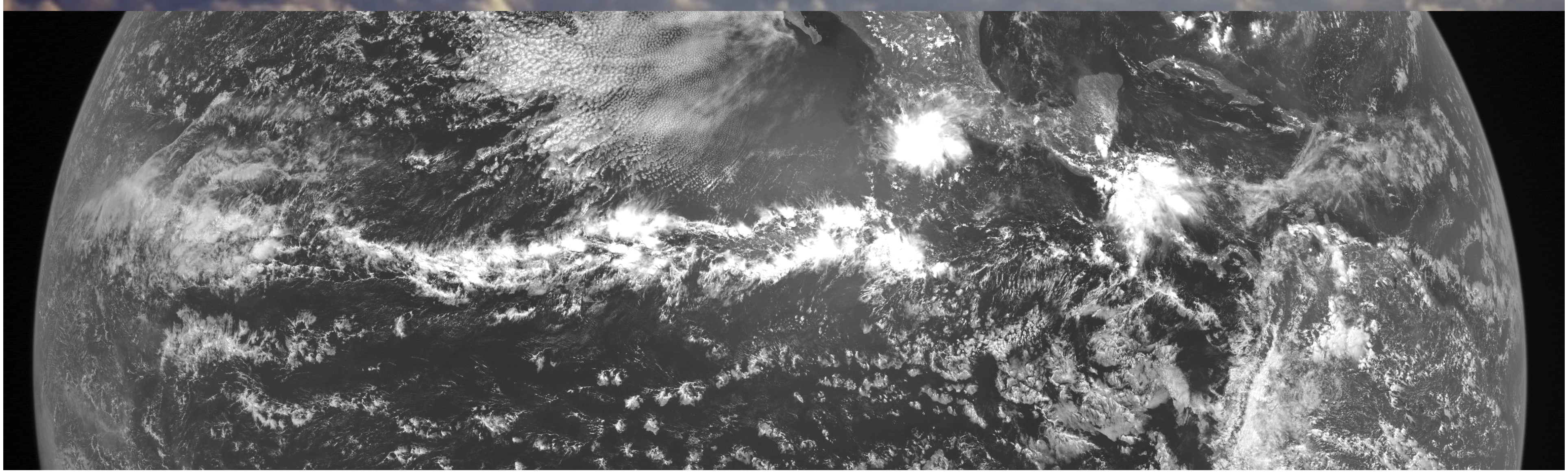
5 ➔ 1 km



Higher resolution, continued

- Brings better representation of multiscale interactions, surface heterogeneity and orography, local variability, extreme weather, chemical transport, cloud systems.
- Enhanced interest in measurements in complex terrain (NAME, T-REX) and near coastlines (TWP-ICE)
- Relevant interacting processes: boundary layer, cloud formation/microphysics, convective initiation/precipitation, chemical transport, gravity waves/breaking/drag… and many parameterizations poorly suited to complex terrain.
- Orography is a challenge for observing systems, needs a suite of coordinated measurement platforms.

Scale interaction



Scale interaction

- 1 km: Cumulus updrafts/downdrafts

  10 km: Gust fronts and cold pools

  100 km: Stratiform anvils and small MCSs

  1000 km: Superclusters, westerly wind bursts

  10000 km: MJO scale
- Projects like DYNAMO try to address this with multiscale observations (point, radar, aircraft, satellite)
- What is the most effective way to deploy such observations to test models that simulate an increasing range of scales? To gain multiscale science insight?

Weather-Climate Interface

- See 2012 ASP summer colloquium…
- ‘Fast physics’ of climate models like CESM are increasingly tested in weather forecast mode.
- Weather forecast models such as GFS and WRF have become the basis of climate models.
- At UKMO, one unified code is used for regional and global weather and climate modeling.
- Allows direct testing of climate models against IOP data, with meteorology mostly controlled for.
- Allows more effective comparison of an integrated suite of measurements (e. g. aerosol, clouds, chemistry) vs. model.

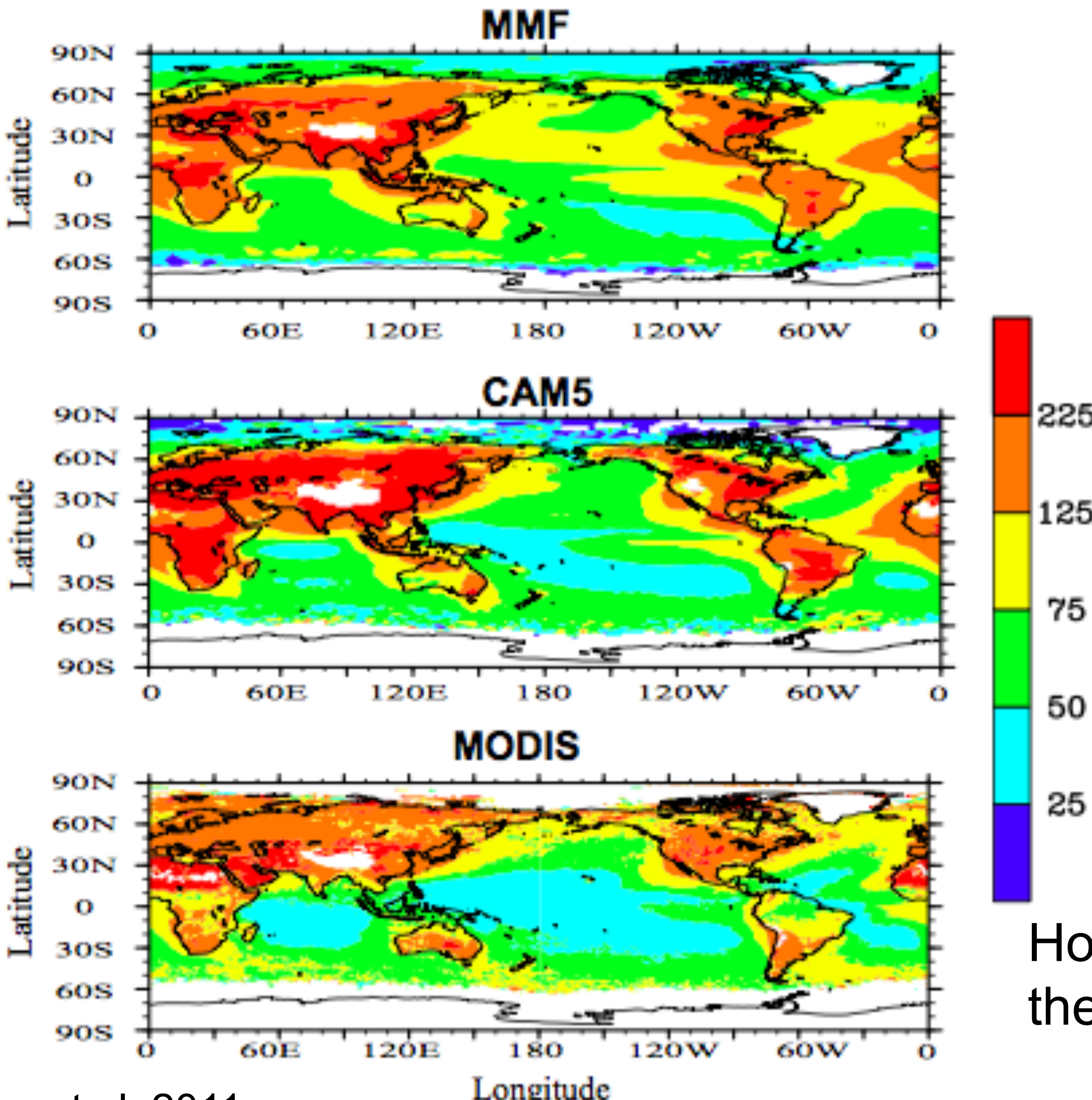
Chemistry and Isotopes

- Earth system models predict aspects of tropospheric chemistry and are starting to incorporate physically-based water isotope fractionation capability.
- Provide insight into transport and mixing processes as well as chemistry/aerosols/radiation. (e. g. CO_2, CO, O_3, DMS, black carbon).
- Different climate models can predict strikingly different tracer distributions (superparameterized CAM vs. CAM5 distribution of black carbon over the Arctic, or of vertical distribution of CO_2 in the tropics)
- This will provide increasing demand for chemical measurements in support of convection and dynamics-oriented experiments.

Aerosols and cloud microphysics over remote oceans

- Over the past 5-10 years, many global climate models (e. g. GFDL, NCAR) introduced physically-based predictions of aerosol concentrations and aerosol-cloud interactions.
- Key modeling issue for aerosol indirect effect on climate:

  What processes control cloud condensation nucleus concentrations over remote oceans (e. g. Southern Ocean)?
  - CCN driven locally (e. g. by salt or DMS) or remotely?
  - How do anthropogenic aerosols modify this regime?
  - Role of supercooled, mixed-phase and ice clouds that are common in midlat ocean storm tracks?
- Need more in-situ measurements in these remote locations



How much should we trust the satellite retrieval?

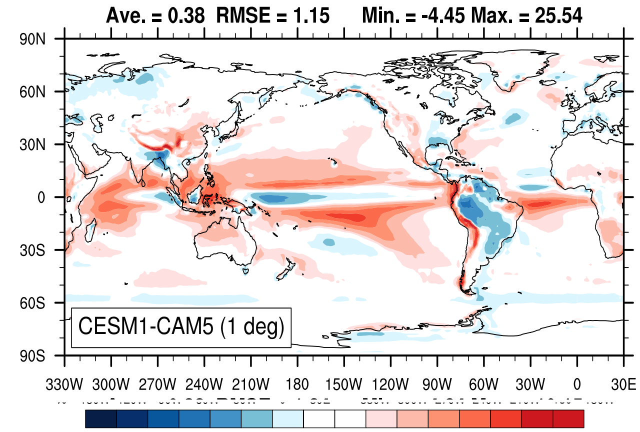
Wang et al. 2011

Fig. 6. PD annual-averaged cloud-top droplet number concentrations (cm^{-3}) derived from the MMF (upper panel), CAM5 (middle panel) and MODIS (lower panel).

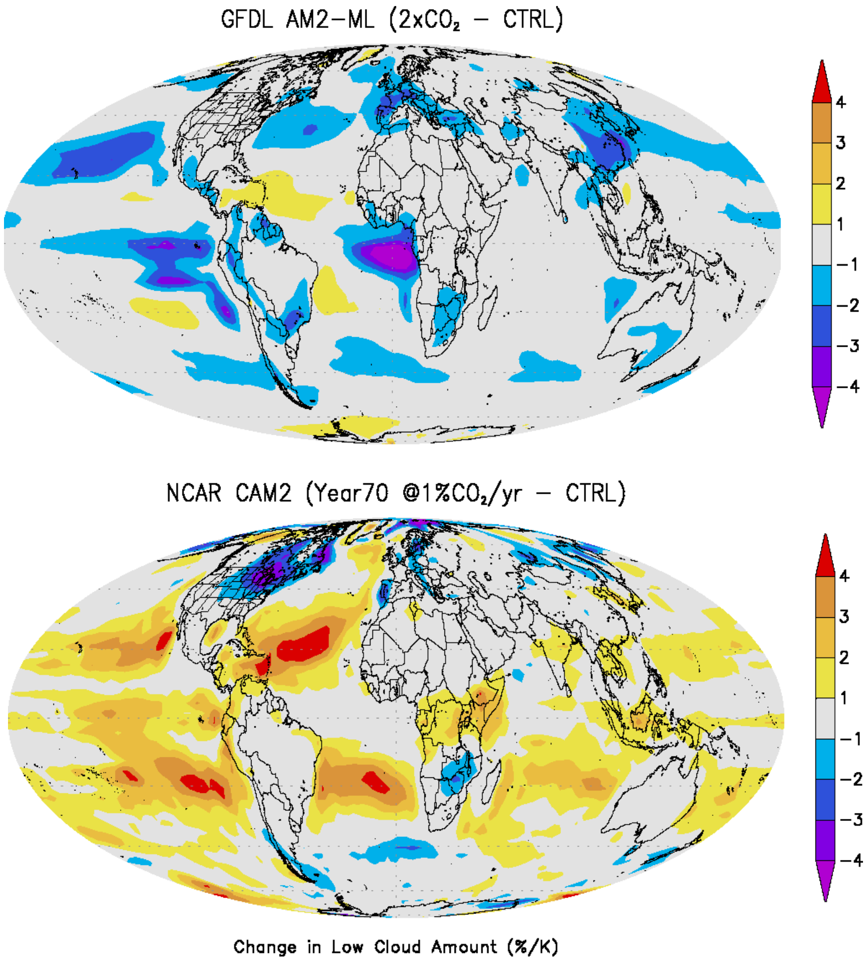
Testing and improvement of parameterized physics

- Three long-standing climate change science problems:

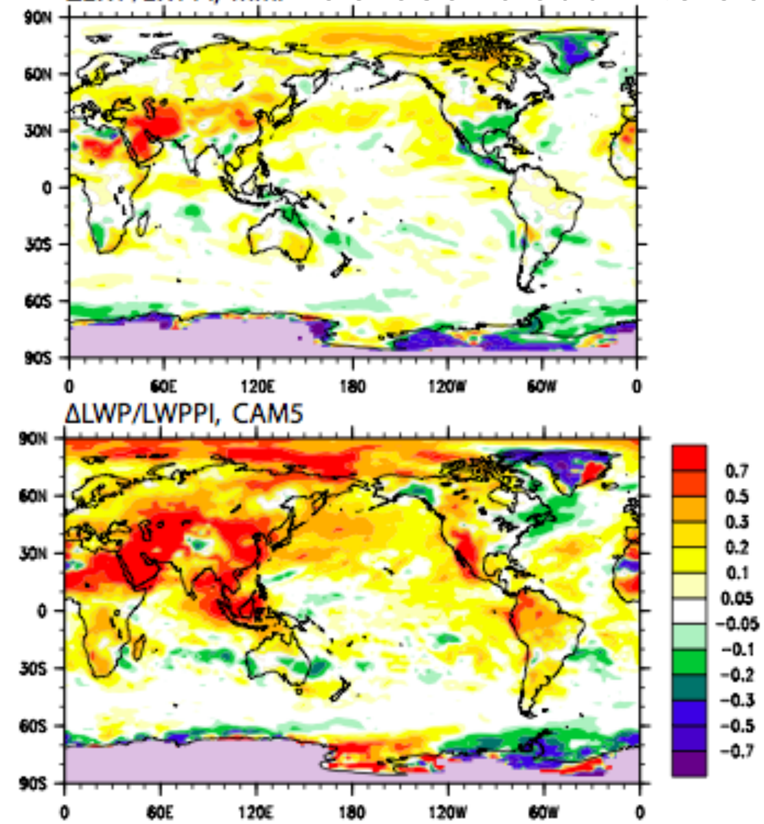
precipitation biases/trends



cloud feedbacks & climate sensitivity

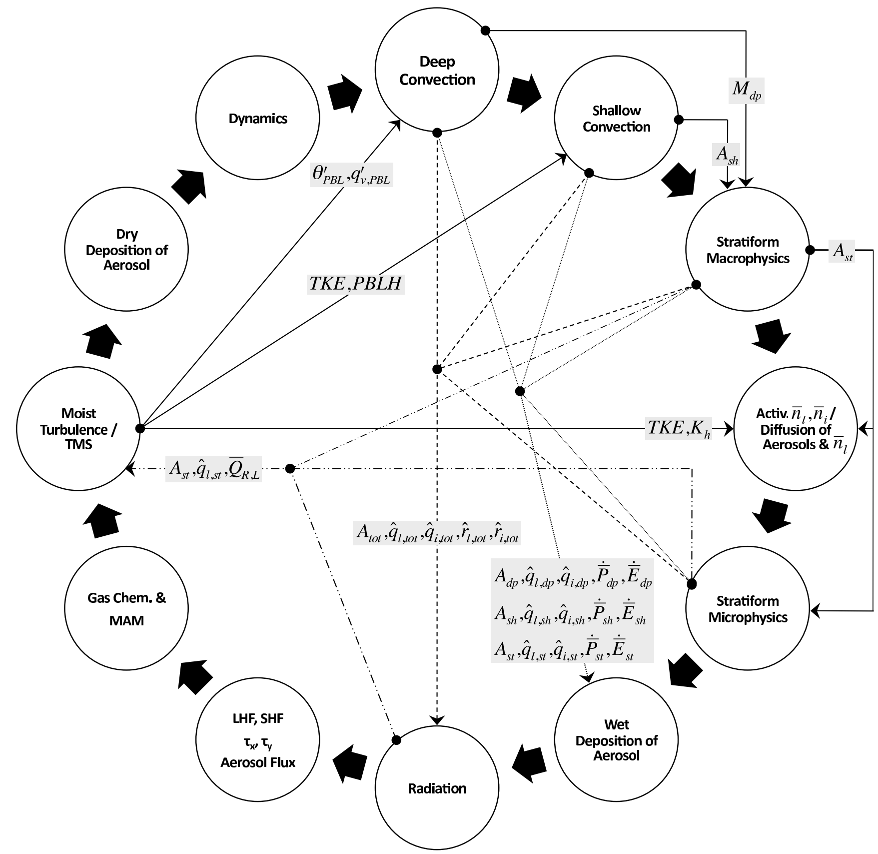


aerosol-cloud interaction



- These problems involve interaction of boundary-layer turbulence to global scale circulations with complex cloud physics – will require parameterization a decade hence.
- Parameterization systems are ‘cartoons’ with many user assumptions built in that need observational testing.
- To improve them requires sustained dedicated effort.

CAM5 moist process flow chart



- Optimal experimental designs for doing this may be different than those for inquiry-driven science, and emphasize small-scale relationships between variables.

More thoughts

- Need integrated measurement suites (clouds and precipitation and aerosol) combining remote sensing and in-situ measurements to get maximum value out of survey missions to remote locations. In particular, the combo of multiwavelength radar, lidar, multichannel microwave on G-V would complement in-situ cloud/aerosol measurements.
- Data synthesis (field data, satellites, NWP) needs to be an important part of project planning/execution.
- EOL ground-based precipitation radars are great, but would be useful to have a top-notch precipitation radar on a long-range platform.
- Continued need for distributed sensor systems and remote sensing (e. g. Doppler lidar) to sample atmospheric physics/chemistry in complex terrain.