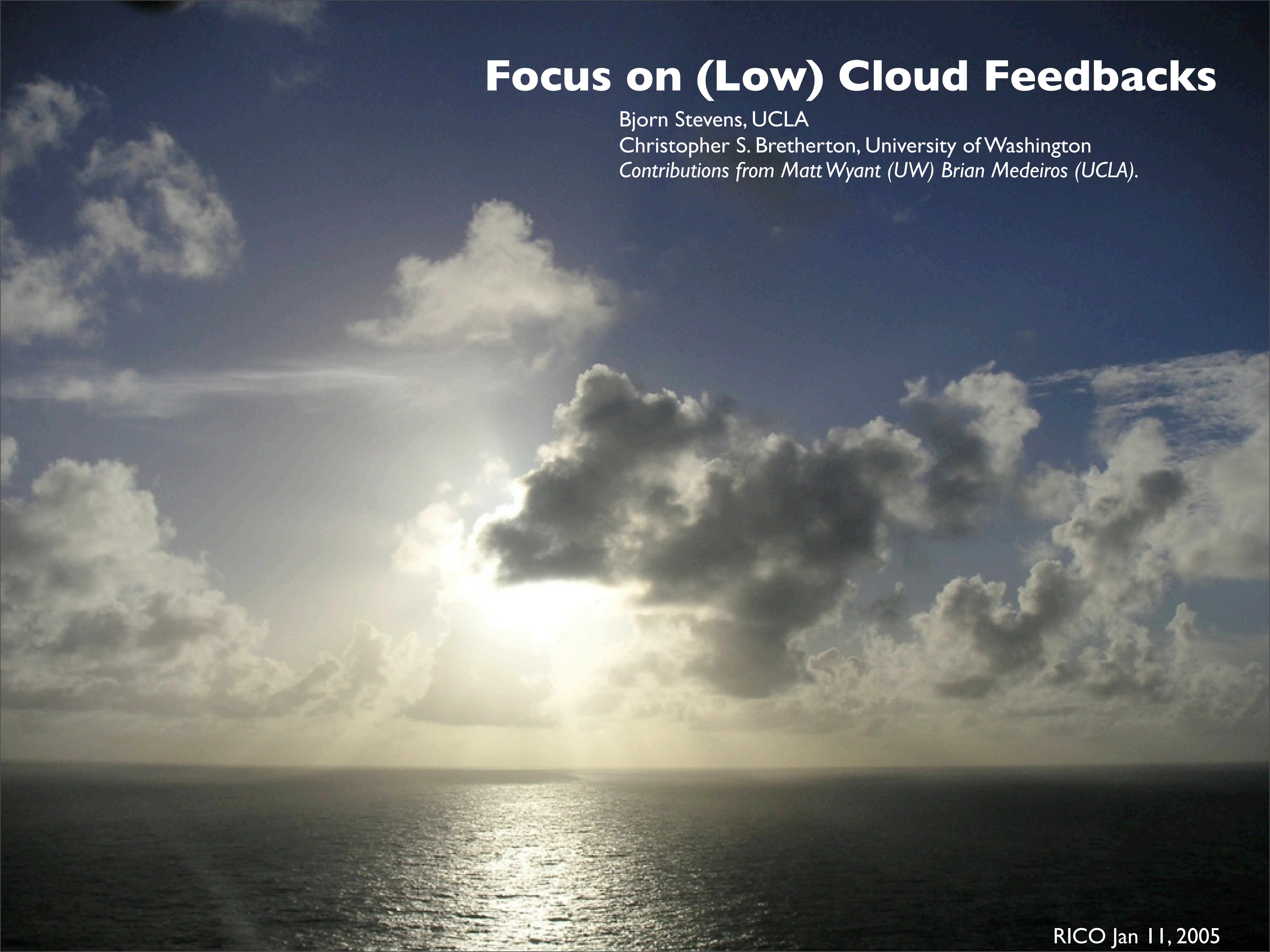
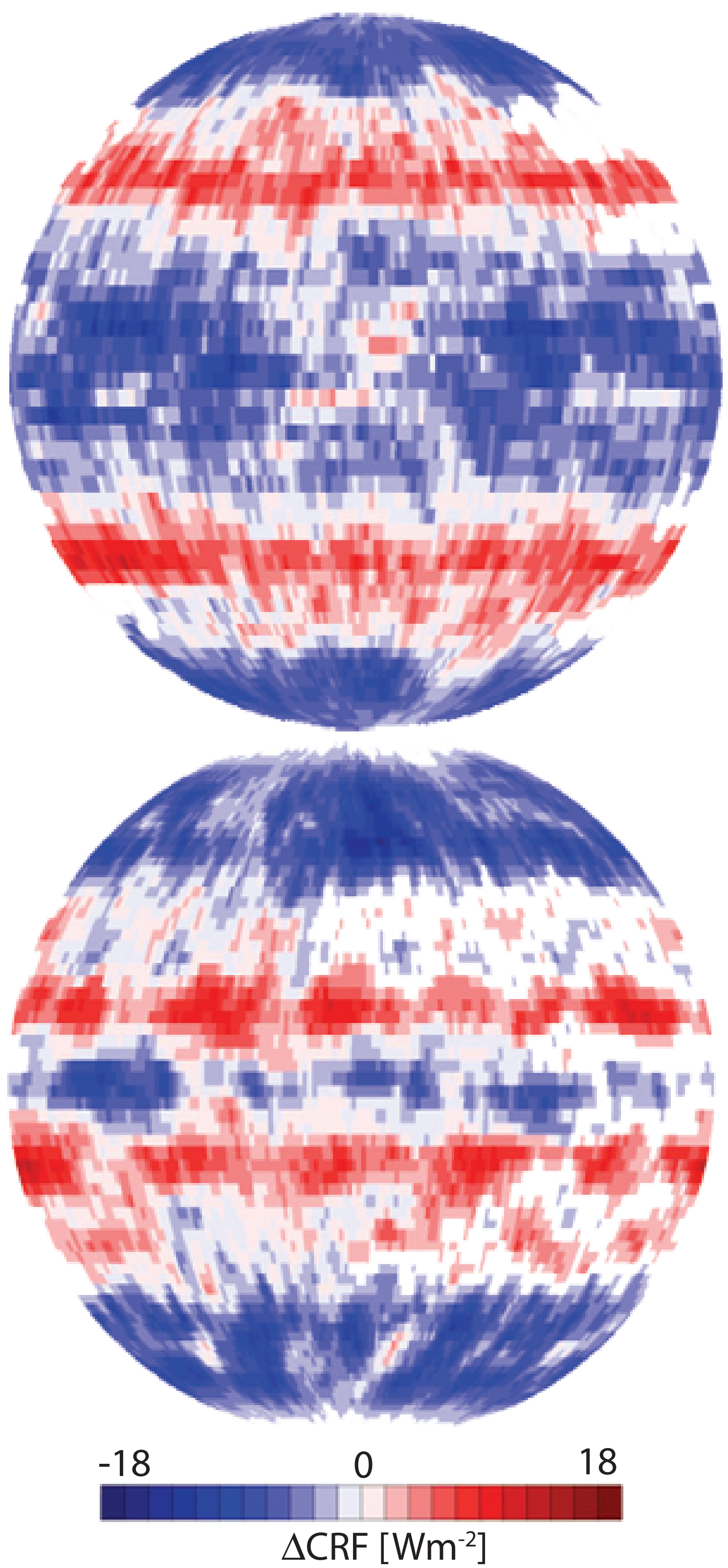
# Focus on (Low) Cloud Feedbacks

Bjorn Stevens, UCLA
Christopher S. Bretherton, University of Washington
*Contributions from Matt Wyant (UW) Brian Medeiros (UCLA).*



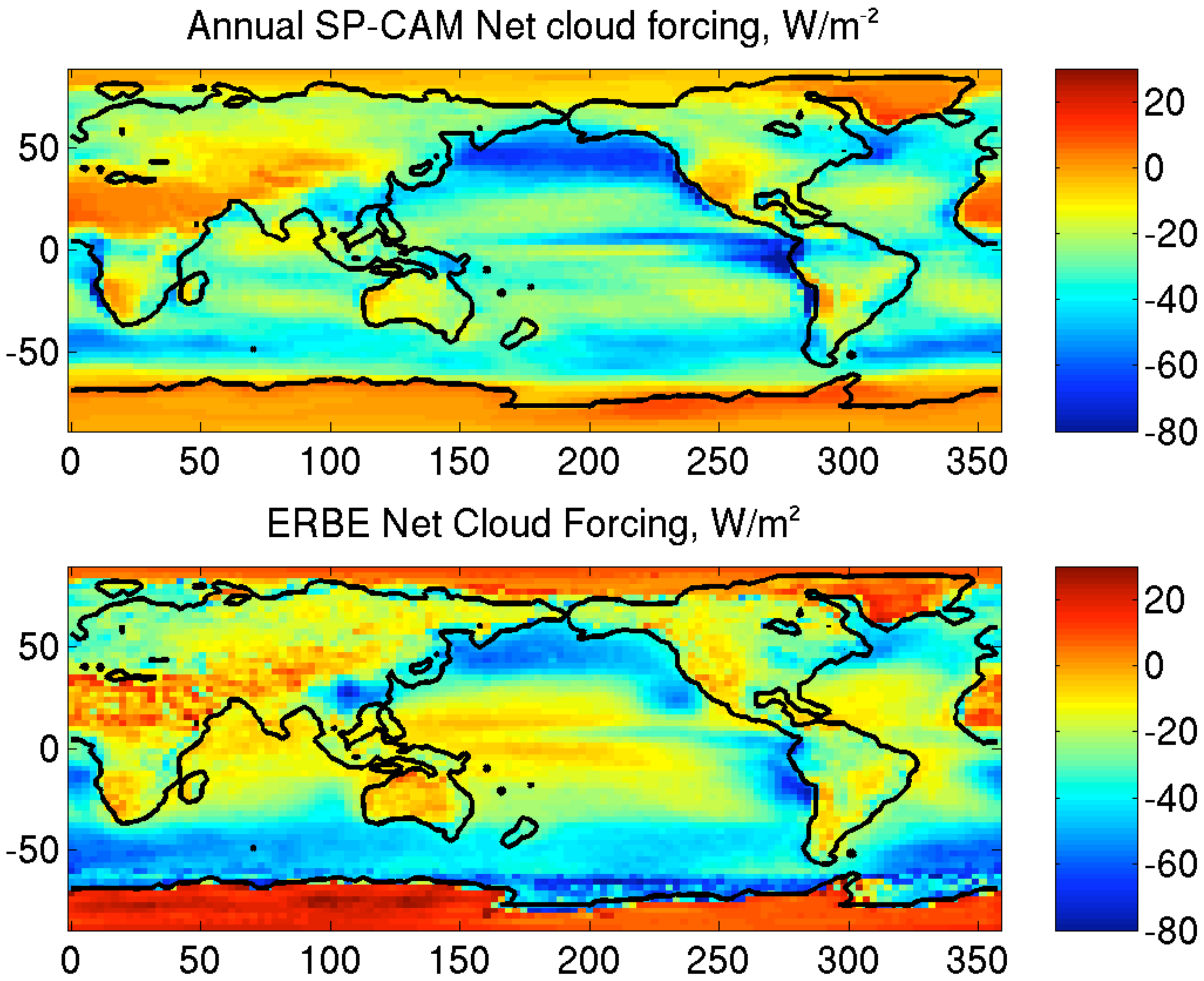
RICO Jan 11, 2005

# *recall the issue*



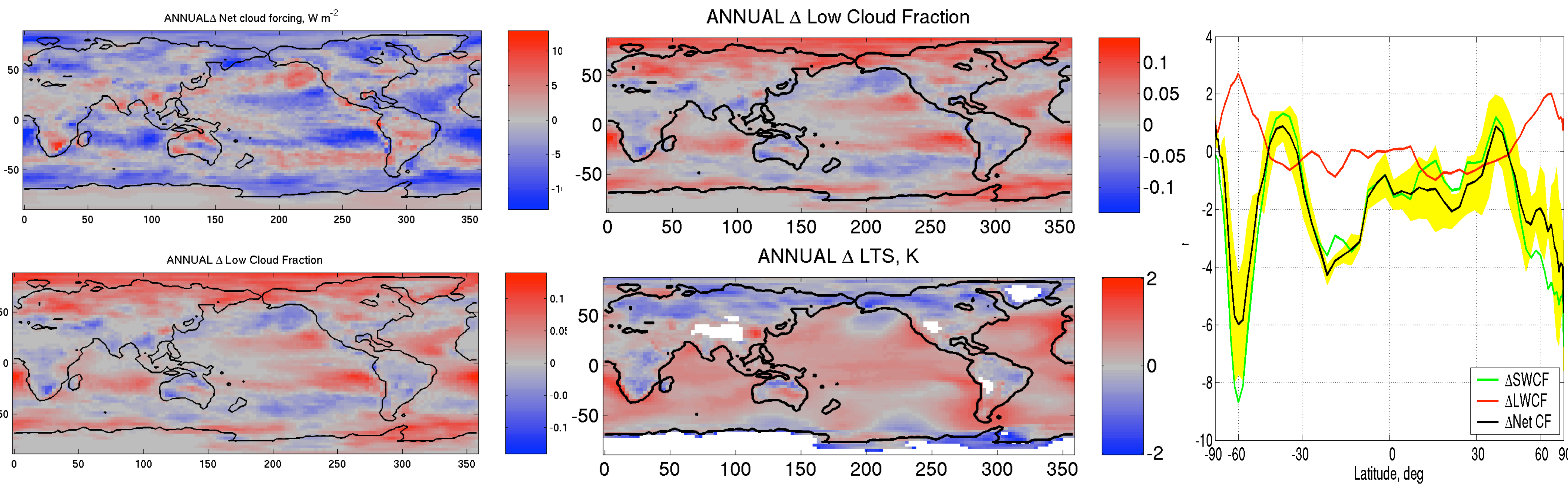

- "... the modelling of time dependent clouds is perhaps the weakest aspect of the existing general circulation models and may be the most difficult task in constructing any reliable climate model" --- Arakawa (WMO,1975)
- "It must thus be emphasized that the modeling of clouds is one of the weakest links in the general circulation modeling efforts" --- Charney (NRC,1979)
- "Probably the greatest uncertainty in future projections of climate arises from clouds and their interactions with radiation ... even the sign of this feedback remains unknown" --- IPCC (TAR 2001)
- "Cloud feedbacks are a primary source of inter-model differences in equilibrium climate sensitivity, with low cloud being the largest contributor" --- IPCC-Summary for Policy Makers (draft language 2006)
- Cloud effects "remain the largest source of uncertainty" in model based estimates of climate sensitivity --- IPCC, Summary for Policy Makers (2.2.2007)
- Martin thinks they are important as well

# *Initial explorations with the MMF*



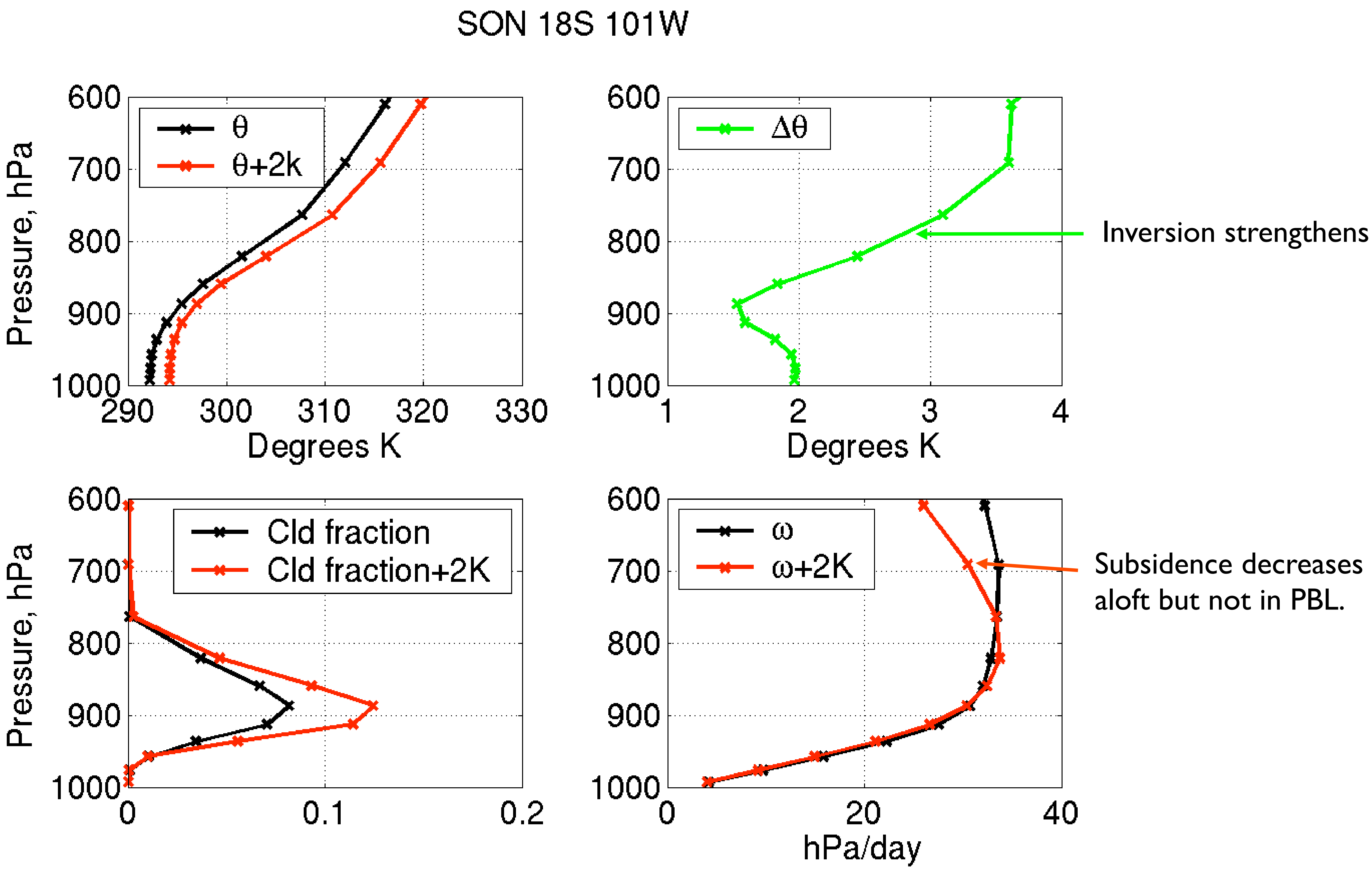

- FANGIO (aka Cess type experiments) with realistic topography.
- Base simulation on left is reasonable, also vertical distribution (not shown).
- Caveats: low-cloud zonal asymmetries are too weak (bright trades, dim stratus); and coastal stratocumulus is too concentrated near surface.

# Geographic distribution of changes



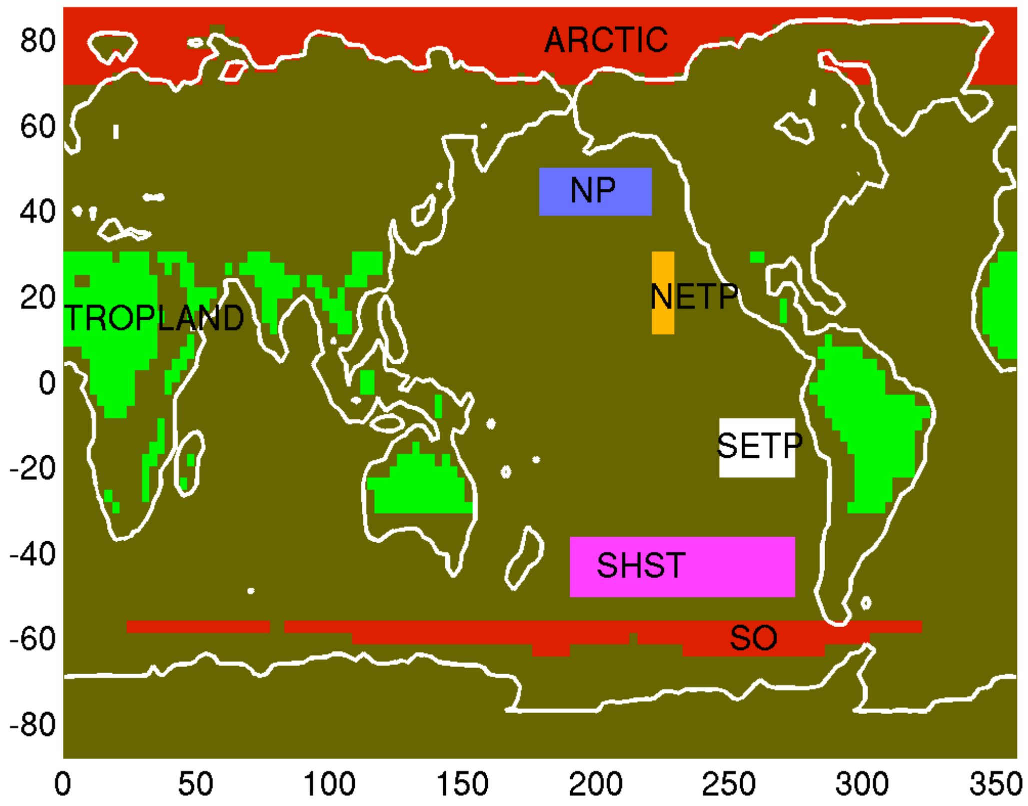

- Change in cloud radiative forcing seems to scale with change in cloud fraction, which in turn scales with lower tropospheric stability.
- Geographical distribution reminiscent of aquaplanets, i.e., reduction of lowclouds in subtropics, increases in polar latitudes.

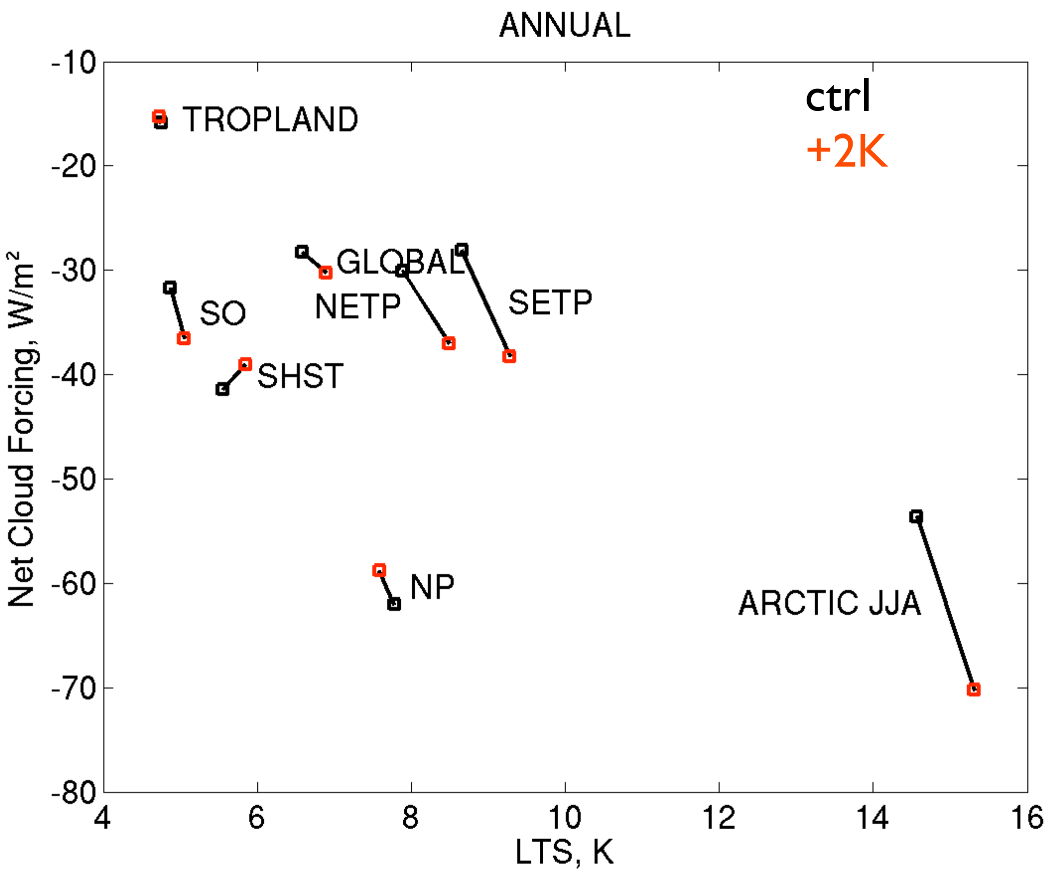
# *Typical vertical structure in Sc-Cu transition (SE Pac)*




- Cloud fraction and inversion strength increase together
- Condensate (not shown) proportional to cloud fraction. distribution reminiscent of aquaplanets, i.e., reduction of lowclouds in subtropics, increases in polar latitudes.

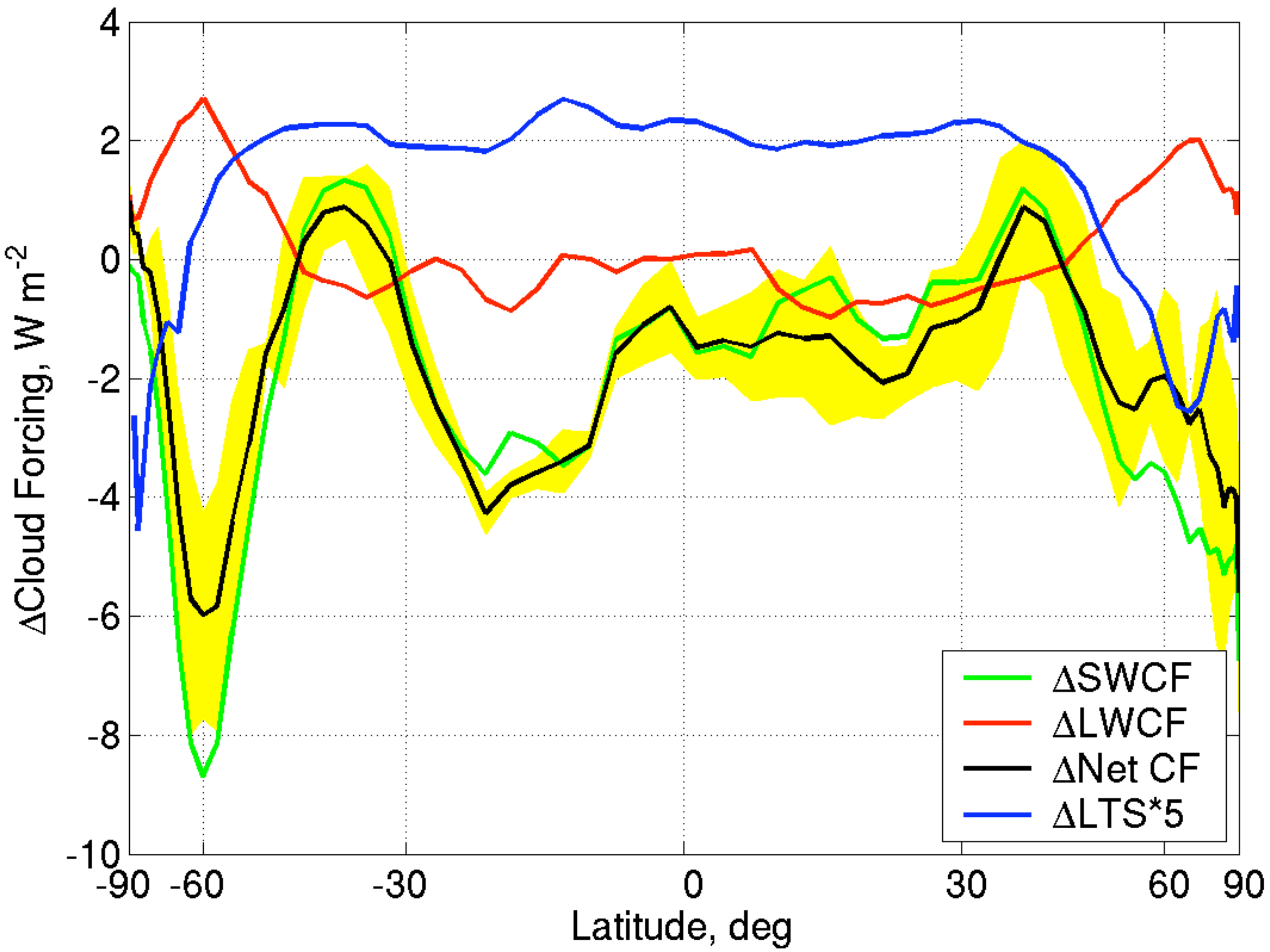
# Relation between ΔCRF and ΔLTS



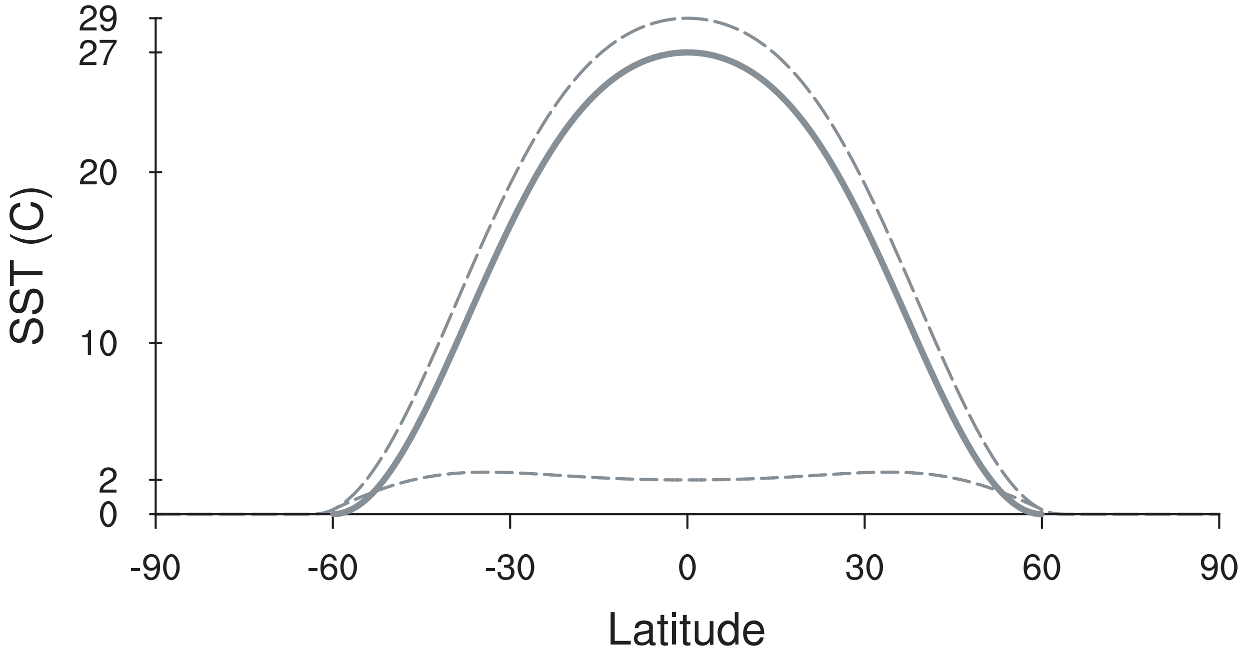

- Change in cloud radiative forcing is roughly anticorrelated with change in lower tropospheric stability (LTS).
- Details of changes in the LTS are unclear.
- Southern hemispheric stormtracks exhibit anomalous cloud response.

# *Caution about MMF global low cloud response*

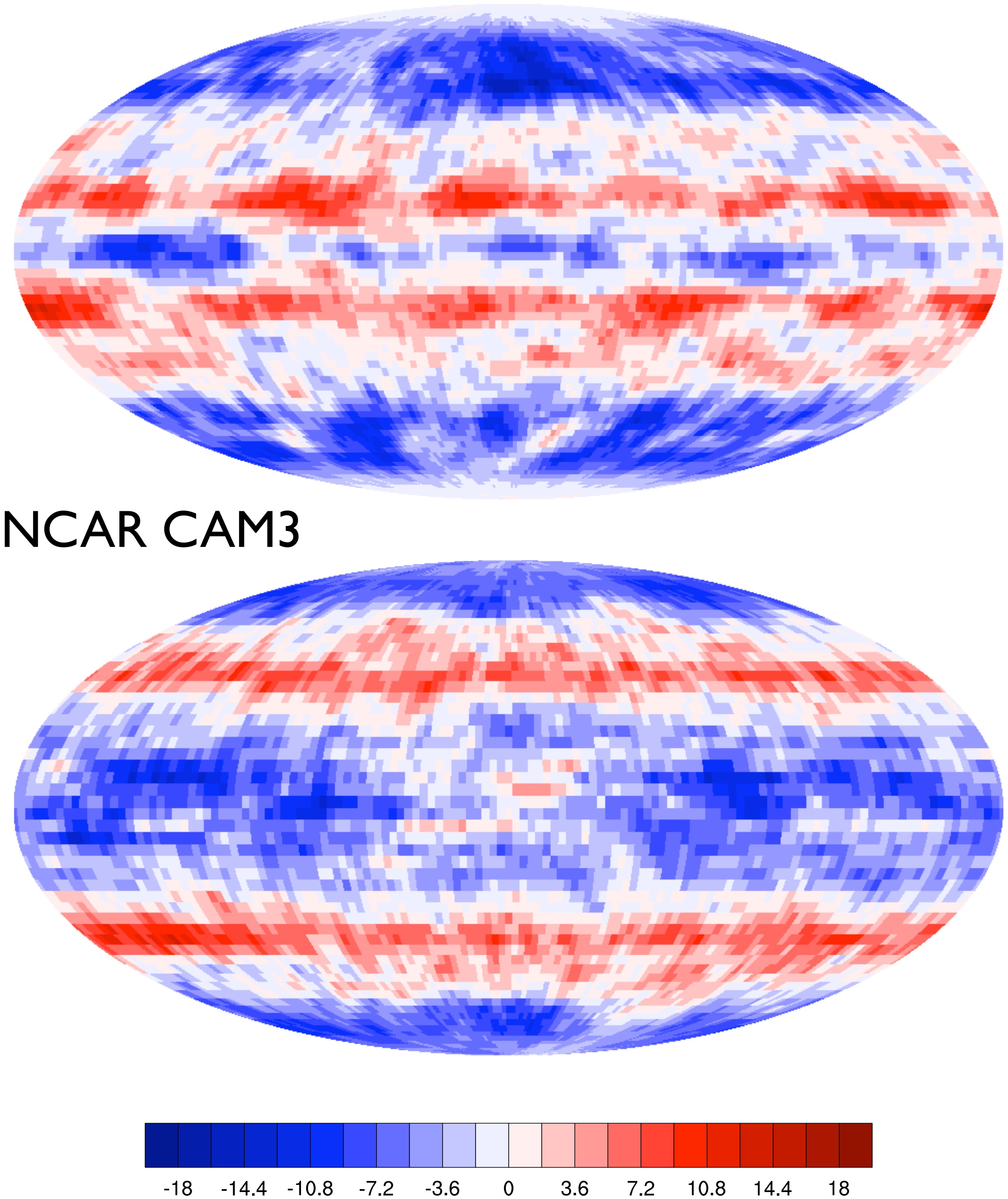



- Zonal-mean LTS (blue) increases 0.4 K, and at almost all latitudes, due to stabilization of moist adiabat at higher temperatures.
- But zonal-mean Δcloud forcing poorly correlated to ΔLTS.
- Global changes in clouds not related to global changes in tropospheric stability

# *circulation or cloud differences?*



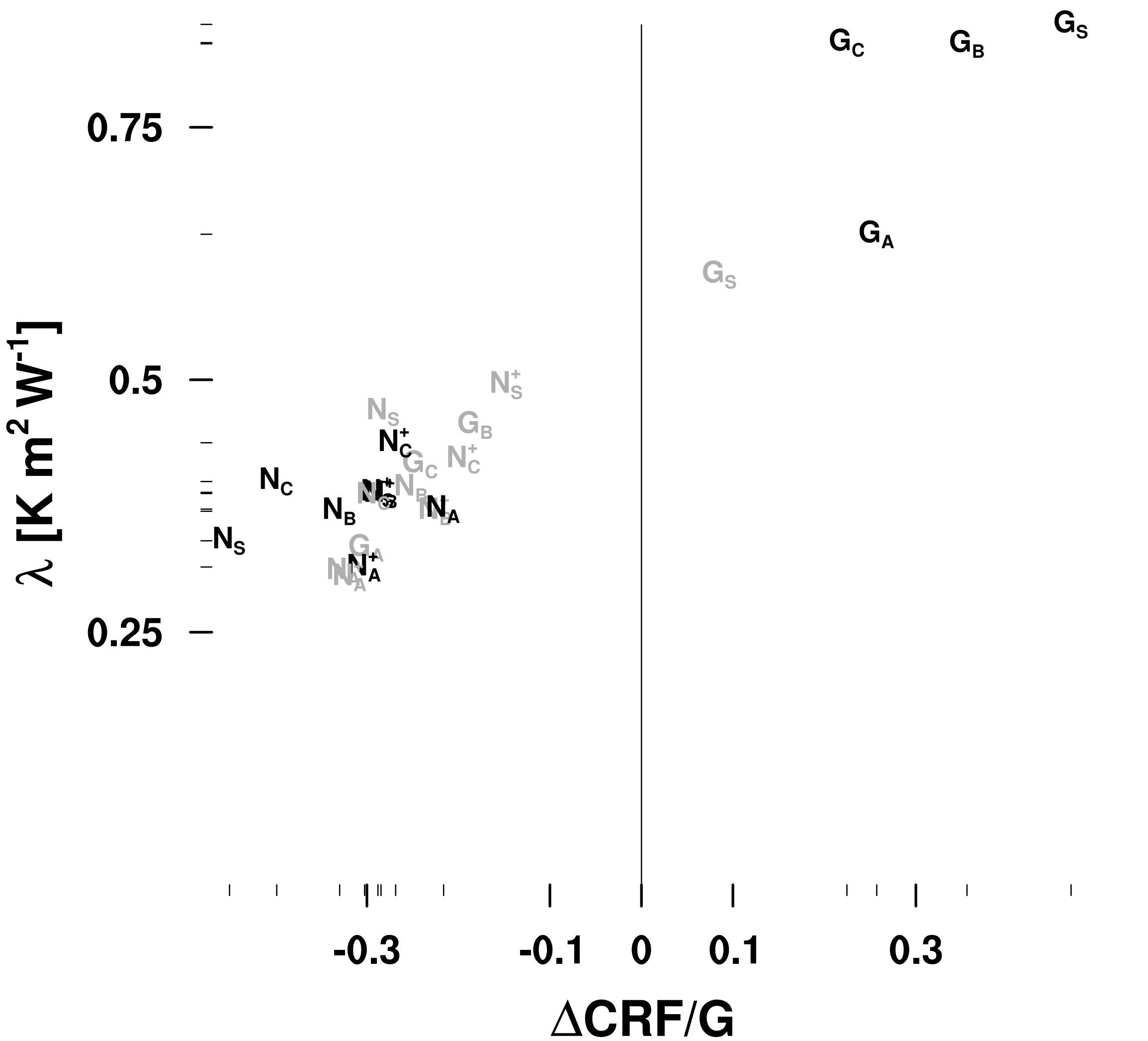

GFDL AM2

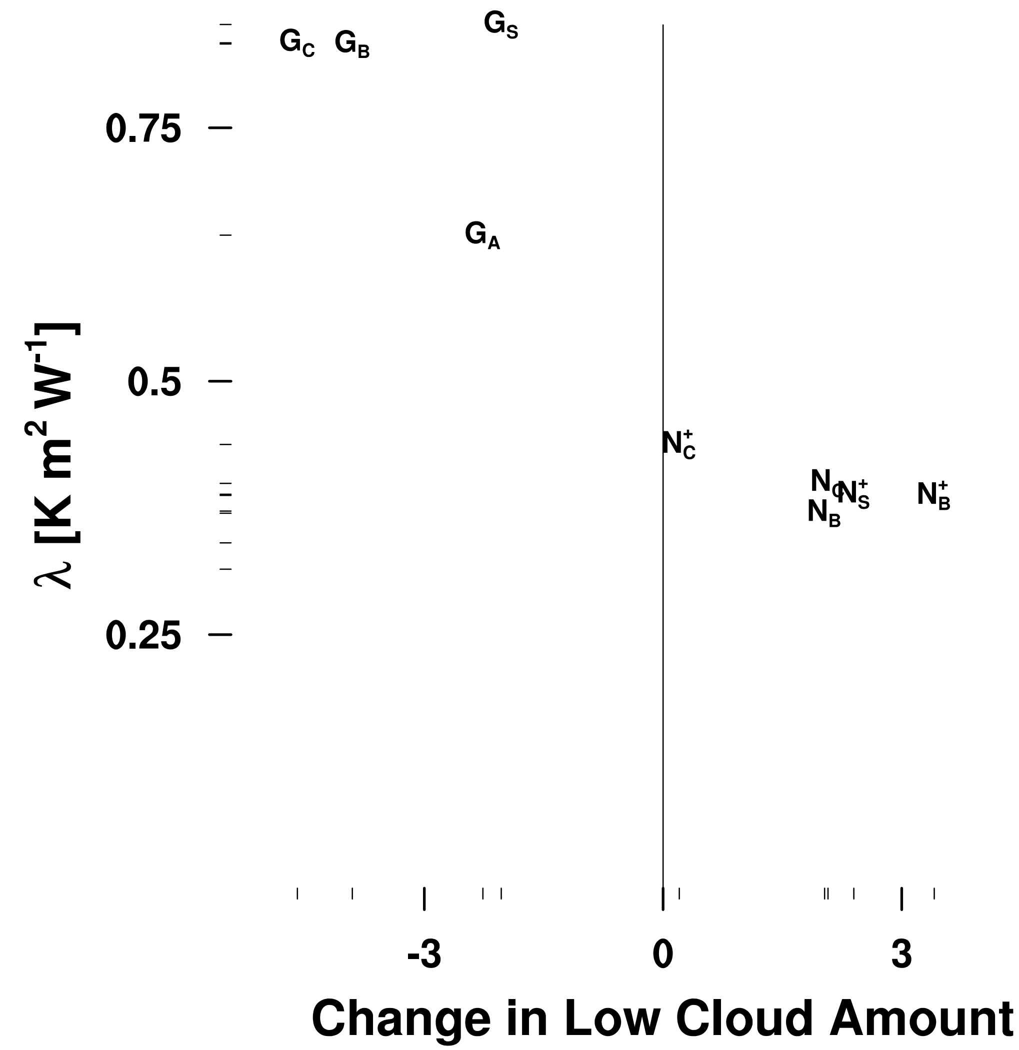





Medeiros, Stevens et al., (2006, in preparation)

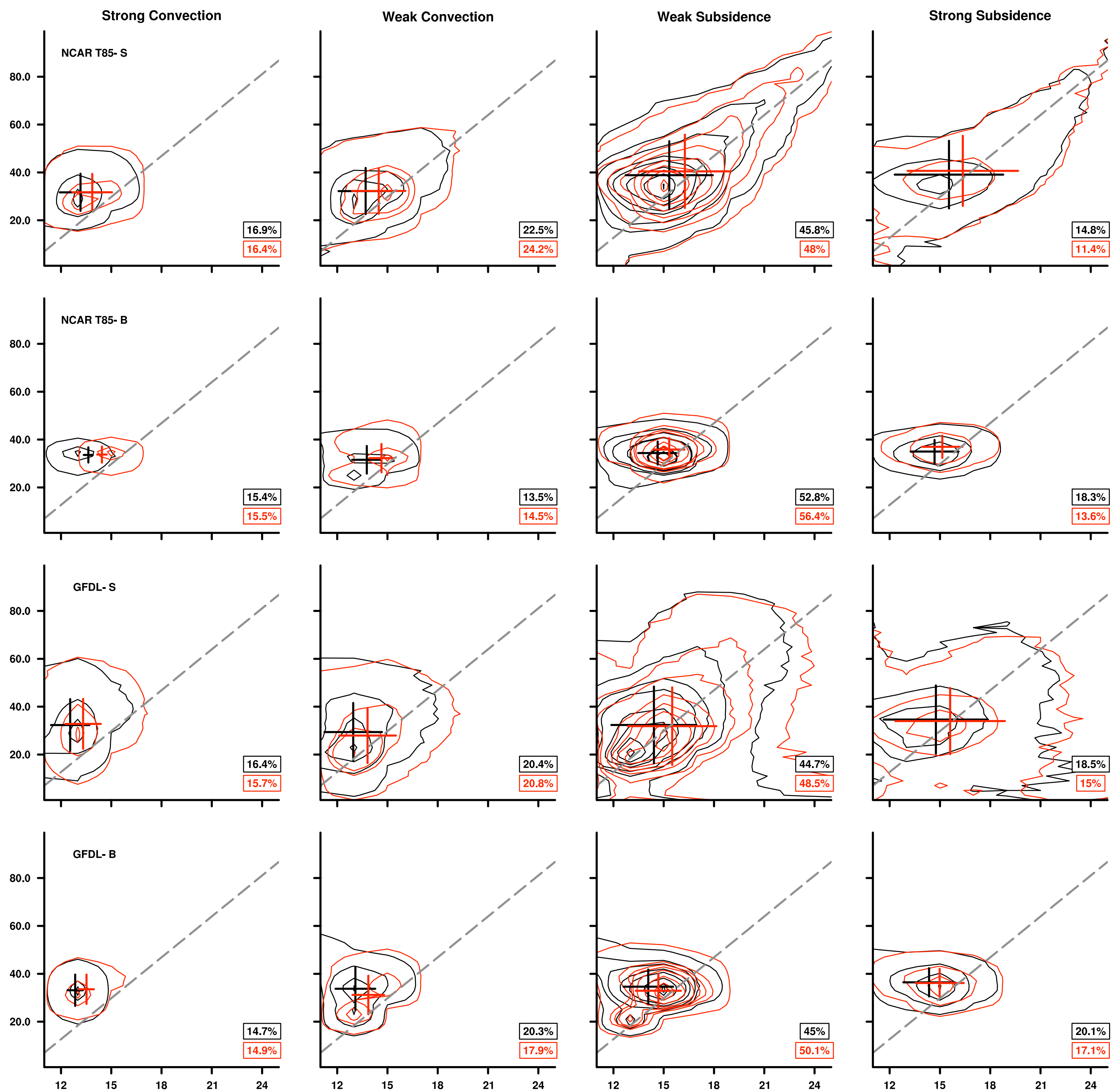
# *Circulation versus cloud response*




G denotes GFDL AM2, N represents CAM at T42. N+ denotes CAM at T85. Grey symbols denote global measure, black denotes near tropics (+/- 35 deg). Subscript "S" denotes earthlike configuration; "A", "B" and "C" denote analytic APE SST specifications with A being the most peaked, C being the flattest.

# lowcloudfraction-LTS histograms




- cloud regimes not especially evident in the distribution modes.
- persistent stratocumulus especially evident in default configuration of CAM (imposed?).
- little evidence of stratocumulus in the aqua planets.

# Remarks

- The aqua-planet representations of CAM and AM appear to be a good predictor of the tropical low cloud response in more earthlike configurations of these models.
- Cloud changes are ultimate rather than proximate causes of the different climate sensitivity.
- The trade-cumulus response appears to dominate. CloudSat should help here.
- CAM MMF looks like CAM: lowcloud increase in downwelling zones, decrease in extratropical stormtracks, too much coastal and vertical confinement of stratocumulus.
- Lower tropospheric stability appears to be a regionally useful predictor of low cloud response in the MMF-CAM, especially over the ocean, but it is not a useful global predictor
- Caveats: low-cloud zonal asymmetries are too weak (bright trades, dim stratus); and coastal stratocumulus is too concentrated near surface.
- Idealized LES, and case studies performed in the context of GCSS are providing valuable constraints that we need to integrate into the center's activities. This is being done.
- We need to consolidate around a fixed goal (this should now be clear), a set of strategies which incorporates the old working groups, and tactics which help us keep on track.

# Where to from here?

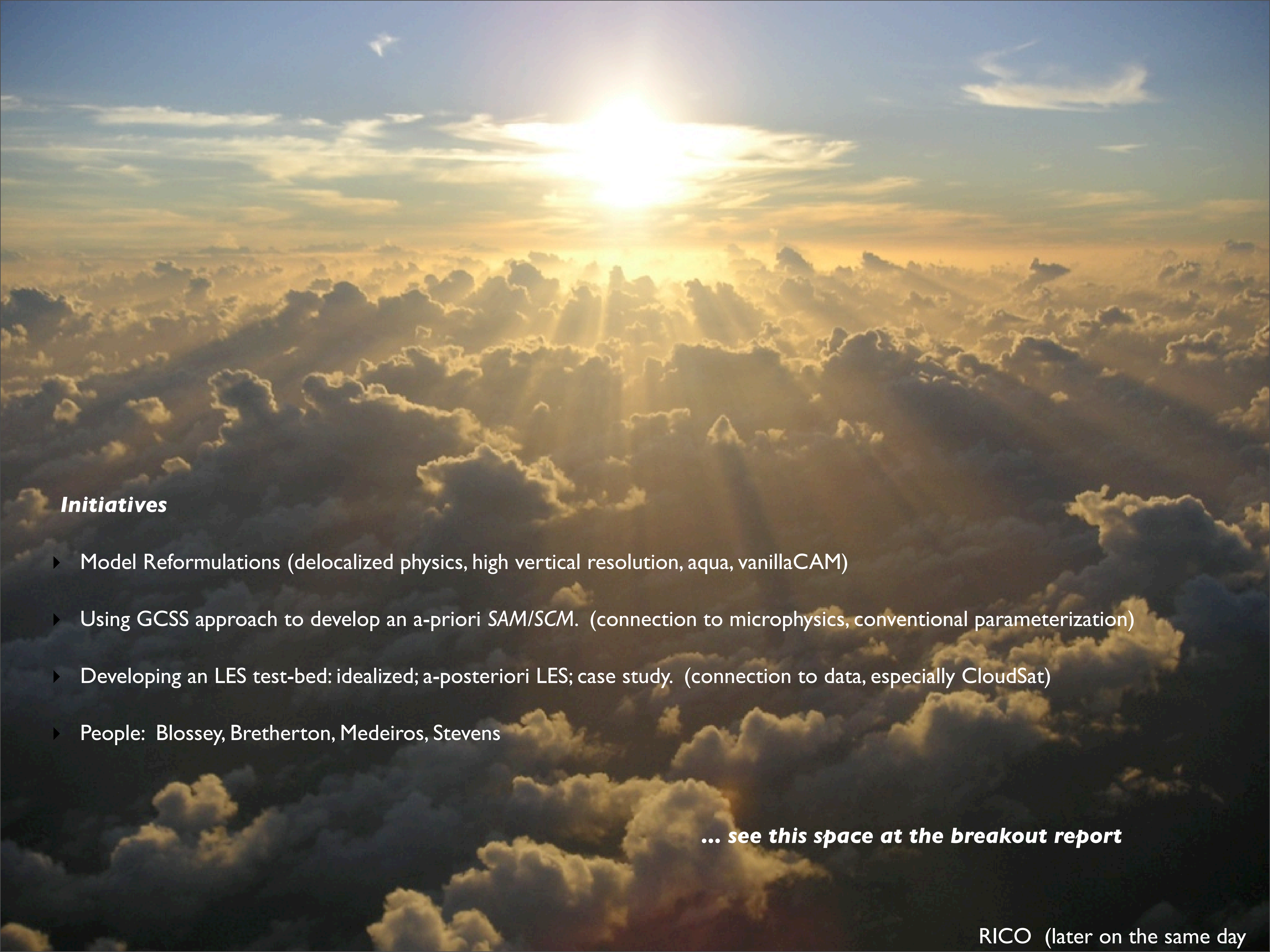
***We need to consolidate around a fixed goal (see below), a set of strategies which incorporates the old working groups, and tactics which help us keep on track.***

***Can we use our break out session to do this? I would like to agree on our goal and strategies relatively quick and then focus our efforts on tactics.***

***Goal:*** To develop at least a ``medium" level of scientific understanding of how low-clouds behave in the climate system. I would characterize our current level of scientific understanding as low, or very low.

***Strategy:***

- Targeted use of a full range of models and observations, especially CloudSat and the prototype MMF.
- Active engagement in international efforts directed toward understanding cloud feedbacks, especially the GCSS boundary layer working group.
- The use of our developing understanding to improve existing models, with a focus on those expected to contribute to future efforts by the IPCC.
- The identification and clear articulation of specific questions that can be answered in a one to three year time frame and around which our activities can be organized.
- The prioritization of CMMAP funding for team members who contribute to the tactics, strategies and goals of the focus group.
- The identification of activities which both span the group (thereby allowing minor participation) as well as those that are concentrated within sub-groups (thereby allowing individuals or smaller collections of people the freedom to pursue some issues on their own).



***Initiatives***

- Model Reformulations (delocalized physics, high vertical resolution, aqua, vanillaCAM)
- Using GCSS approach to develop an a-priori *SAM/SCM*. (connection to microphysics, conventional parameterization)
- Developing an LES test-bed: idealized; a-posteriori LES; case study. (connection to data, especially CloudSat)
- People: Blossey, Bretherton, Medeiros, Stevens

***... see this space at the breakout report***

RICO (later on the same day

# *Near Term Focus (circa aug 06)*

Work in the context of past and ongoing GCSS cases to define appropriate form of CRM (resolution/parameterizations) for use in MMF (Henderson/Khairoutdinov/Lappen/Xu) *--- This is happening, but in a framework of diagnosing biases rather than deciding optimal configuration.*

Using existing CESS and future Aqua-Planet runs to study cloud feedbacks in MMF (Stevens/Bretherton) *--- Progress has been made (see previous slides), but still no MMF following APE.*

Evaluate deep cumulus and cumulus/PBL parameterizations versus MMF in the context of the ARM diurnal cycle over land study. (Klein) *--- Work at LLNL on this topic, but unsure of status.*

Development/testing of more sophisticated Cloud/Aerosol interactions through interactions with Microphysics working group and GCSS Boundary Layer Working Group studies. (RICO) *--- A great deal of activity in the context of GCSS; definition of case study; output diagnostics from RICO being constructed; insights on warm rain. Also development of microphysical interface for MMF.*

Broaden concept of MMF through studies using regional nesting (i.e., WRF), embedded LES, GxCRM studies. (Bretherton, Moeng, Stevens). *--- This activity has been languishing. Mini LES exists, but not really a mini LES. It needs to be a mini-LES, i.e., 3D and a delocalized vertical grid.*

Work to integrate MMF MJO evaluation studies with broader MJO community specifically Clivar MJO working group and channel WRF activity (CMMAP/NCAR, CSU) *--- Mitch has made great progress in making this a reality.*

# *Breakout Notes*

### *Initiatives*

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### *Meeting Notes*

- Derive a rich forcing data set for observational comparision and LES/SCM offline forcing (Brian)
- spCAM CESS.. also an Aqua Version (Marat)
- Delocalized Physics? Dare Sam, I am (fine vertical grid)
- GCSS development and perhaps SCM run with “rich” forcing (Cara-Lyn, Steve with NCEP?)
- Begin thinking of observational constraints (Kuan-Man, Charlotte)

# *Near Term Focus (circa 2.22.07)*

*What are the characteristics of the forcing/response across aqua planets (GFDL/CAM/CAMsp)? Can this be constrained observationally or with fine-scale, off line, models? How does it relate to earth-like configurations of the model?*

- Run an Aqua-planet CAMsp FANGIO experiment. (Marat & Brian)
- Develop daily time-series of the atmospheric state/forcings in trade-cumulus regions from family of aqua planets. (Brian)
- Explore time-series with an eye toward observational constraints. Is there an intersection in the change in forcings for control/plus2 among models with different responses? If so are there observational analogs to these situations which can constrain the model behavior? What data-sets should we be exploring to help constrain the model? (Brian & Group)
- Use timeseries for single column investigations. What are the statistics of the response, i.e., how long is long enough? How do parameteric & physical (aerosol/chemistry) assumptions affect the response? This work will naturally lead into the type of CRM/LES studies we want to get to. (Cara-Lyn and Brian)

Mid-term milestones: Sample Time-Series (April 1); Aqua CAMsp (May 1); Data pow-wow (June 1).

*Can we use the MMF as a means to embed LES in the GCM?*

- Develop SAM test bed for this using SamSimilarity (or big Brother SAM). Here we will use SAM as both the large-scale and CRM to address vertical resolution issues (this framework is computationally more convenient at the moment for vertical resolution sensitivity studies). We will explore whether a beta-plane aqua SAM (perhaps in DARE mode) looks anything like the similarly forced aqua planets and the extent to which this framework can be used as a testbed for delocalization strategies (i.e., running baby SAM on a different grid) (Peter).
- Develop framework for allowing CRM to be delocalized from grid of CAM; thus allowing for the use of embedded LES and or the use of the CRM at only select latitudes (to be started).

# *Near Term Focus (circa 2.22.07)*

*Parallel, nascent, or cross-cutting activities that we expect to come into better focus.*

- Systematic, multi model exploration of GCSS cases with SAM, other GCSS class models (including vvCRM) run on various grid resolutions. How confident can we be? How much does microphysics matter? (Anning? Robert/Pete Henderson)
- Development of data products capable of providing new constraints on LES and GCM representation of shallow convection, especially as a function of precip.
- Capability/Execution for very high resolution, next generation, LES to explore (off line) physical issues related to shallow cloud feedbacks, especially cloud/precip/aerosol processes and meso-scale structures (e.g., in connection with the shallow deep group).
- Development and exploration of ideas for conventional parameterization.

*Participants*

- Brian Medeiros, Peter Blossey, Cara-Lyn Lappen, Bjorn Stevens, Christopher Bretherton, Robert Pincus
- Charlotte DeMott, Steve Krueger (and student), Kuan-Man Xu, Anning Cheng, Wojtek Grabowski, Graeme Stephens (student)
- Hugh Morrison, Martin Miller, Maika Ahlgrimm, Takanobu Yamaguchi
- Can we make better use of (find support for) Matt Wyant?

*Suggestions & Joint Activities*

- Full participation in GCSS, targeted interactions with the Frankfurt School and CFIP, maintain connections with GFDL.
- Representation interaction with Yearly full group meeting
- Half-year meetings on themes (... starting August?)