Towards Pan-Spectral OSSE Results from Multiple Climate Models

Daniel Feldman[1]

Bill Collins[1,2], Daniel Coleman[1]

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[1] Lawrence Berkeley National Laboratory, Earth Sciences Division
[2] University of California-Berkeley, Department of Earth & Planetary Science

Outline

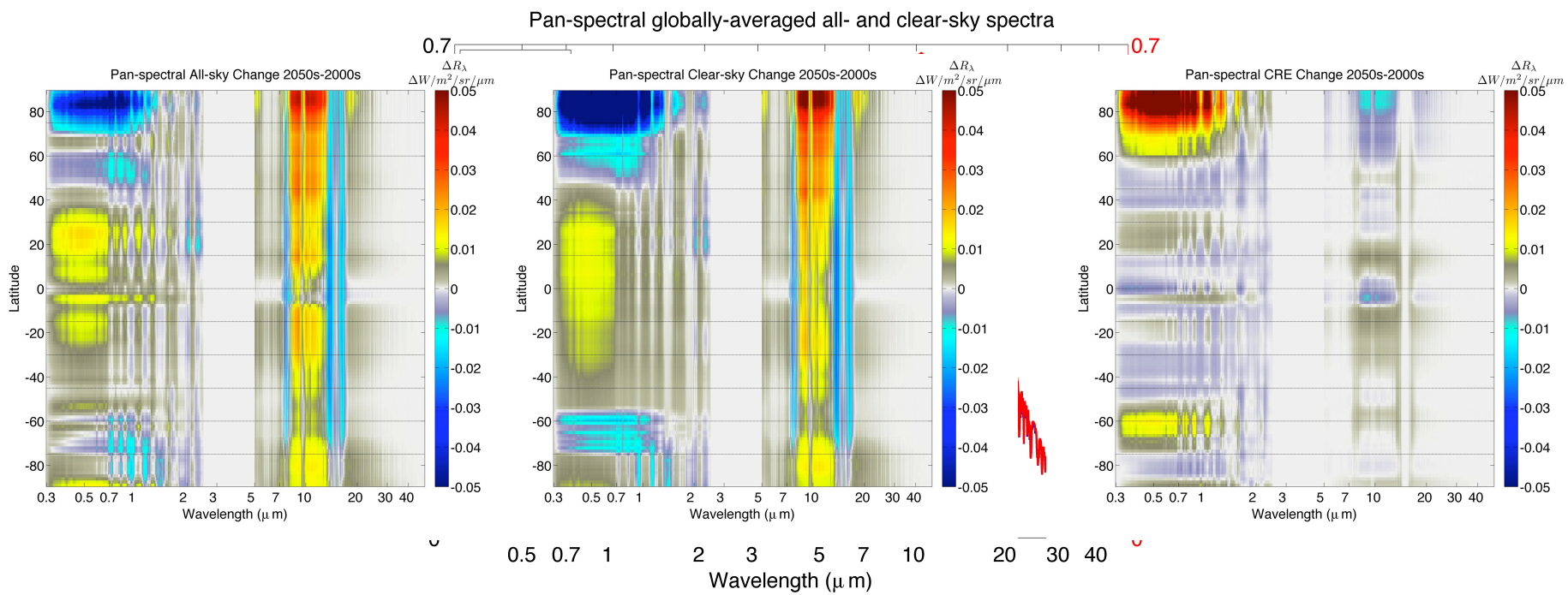
- Recap of tasks proposed.
- Pan-spectral development update.
- Development update on multi-model OSSEs.
- Discussion.

Proposed Tasks for the CLARREO SDT

- The Berkeley group has proposed to contribute the following to the CLARREO SDT:
  - Utilization of simulated CLARREO data to estimate change detection time in SW reflectance spectra
  - Production of pan-spectral (SW+IR) OSSE spectra.
  - Interfacing different scenarios (varying forcings and feedbacks) of CCSM3 into the CLARREO OSSE framework.
  - Production and analysis of spectra derived from different orbits.
  - Development and implementation of tools to produce OSSE spectra based on CMIP5 database.

SW Reflectance & LW Radiance Spectra

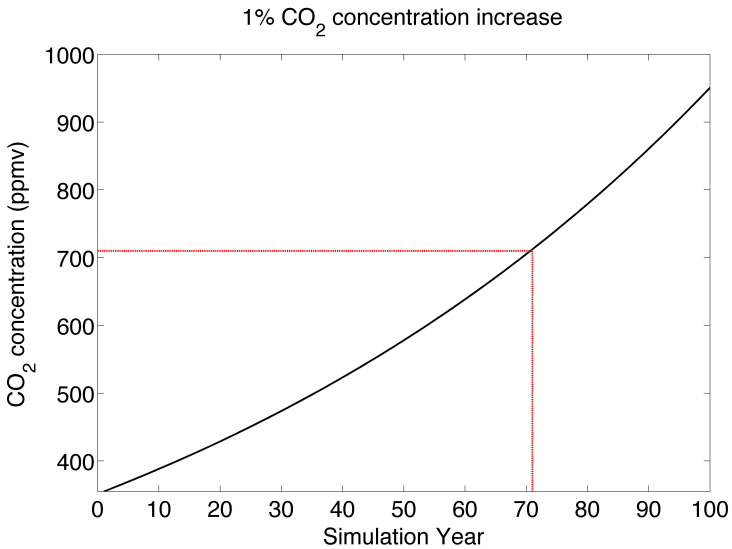
Surface reflection, aerosols, (low) clouds and water vapor can be seen in SW spectra.
Temperature, water vapor, trace gas profiles and (high) clouds can be seen in LW spectra.



Feldman et al, GRL (In Review)

Variable Resolution Simulations

- We have analyzed CCSM3 simulations forced only with CO_2 increasing at 1% per year.
- Simulations are at T31 (~ 3.75°), T42 (~2.8°), and T85 (1.4°) horizontal resolutions.
- Cloud feedbacks are stronger for higher spatial resolution models
  - Due to boundary-layer parameterizations that lead to over-prediction of low-level cloud fraction from inefficient mixing of drier air in the boundary layer.

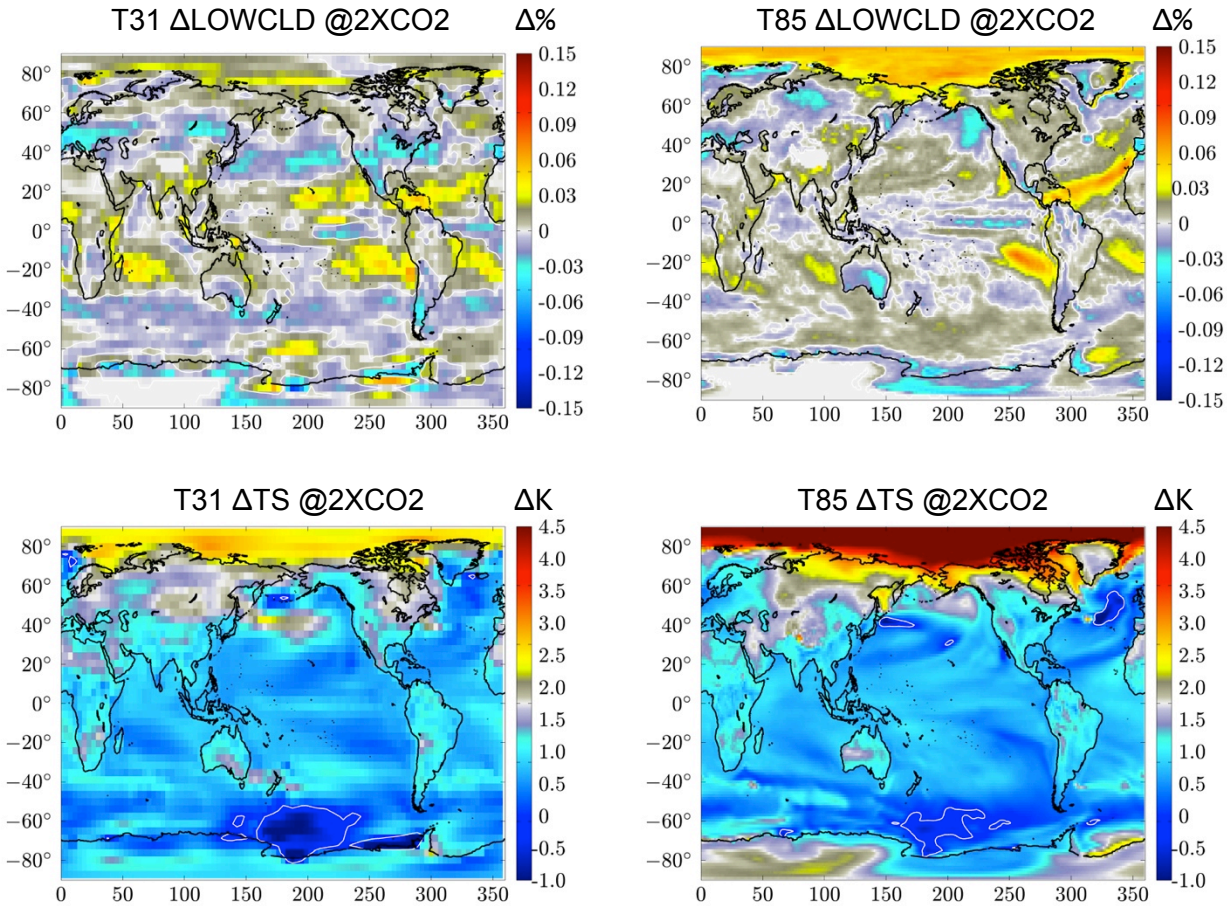


CCSM3 Feedback strengths ($W/m^2/°C$)				
Model	λ lw clr	λ lw cld	λ sw clr	λ sw cld
T31	1.5	-0.32	0.7	-0.63
T42	1.52	-0.33	0.87	-0.61
T85	1.62	-0.41	0.83	-0.41

Adapted from Kiehl, et al, 2006

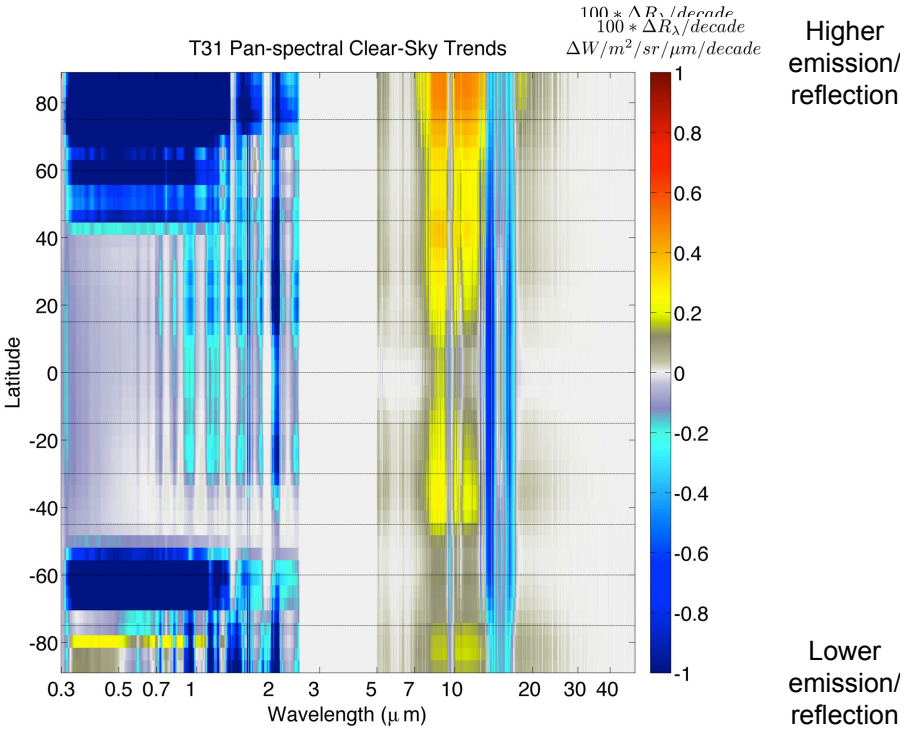
Results of Different Climate Sensitivities at 2xCO2

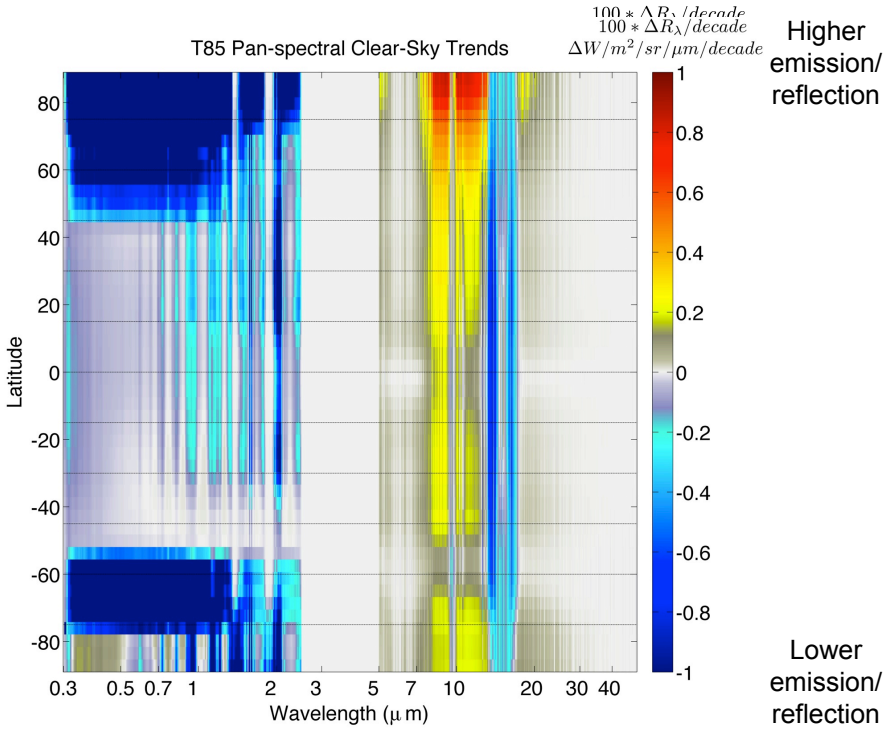
- Highest-res (T85) run has 17% higher equilibrium climate sensitivity than lowest-res (T31) run. T85 has 5% higher transient sensitivity than T31.
- Differences in TS and LOWCLD in arctic and over storm tracks.



Differences in Pan-Spectral Simulations

Models with different cloud feedbacks can be differentiated by:
Window and H2O overtone bands in SW.
Window bands and H2O vibration-rotation band in LW.

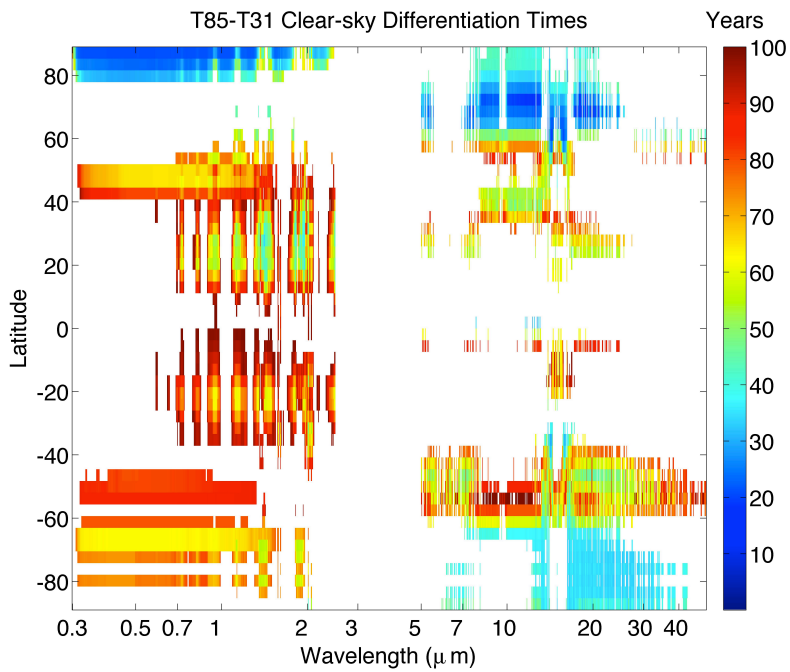


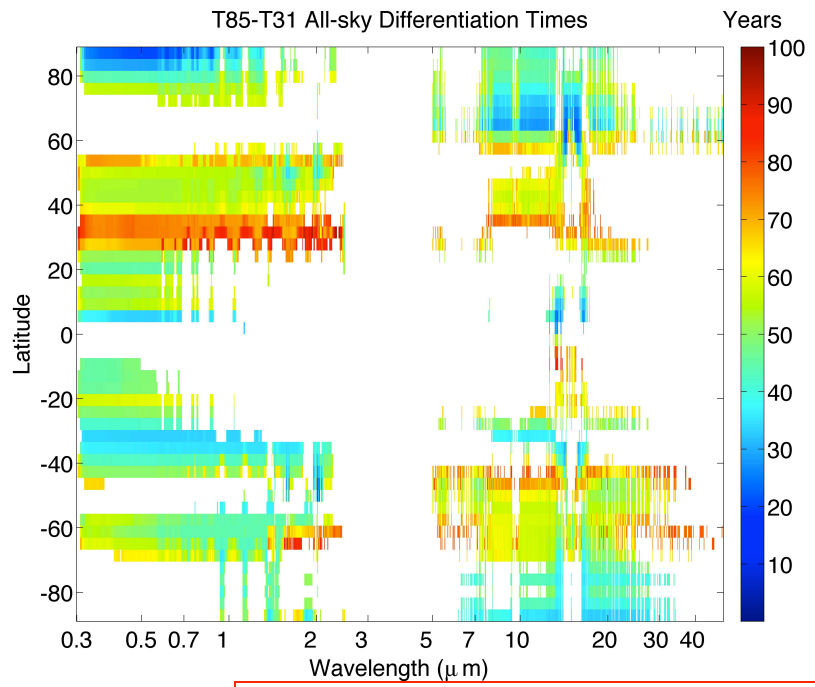


Feldman et al, J. Climate (In Review)

Model Differentiation with Pan-spectral Simulations

Colors indicate where spectral measurements differentiate models faster than broadband.
Multi-decadal continuous records are required. No calibration drift allowed.

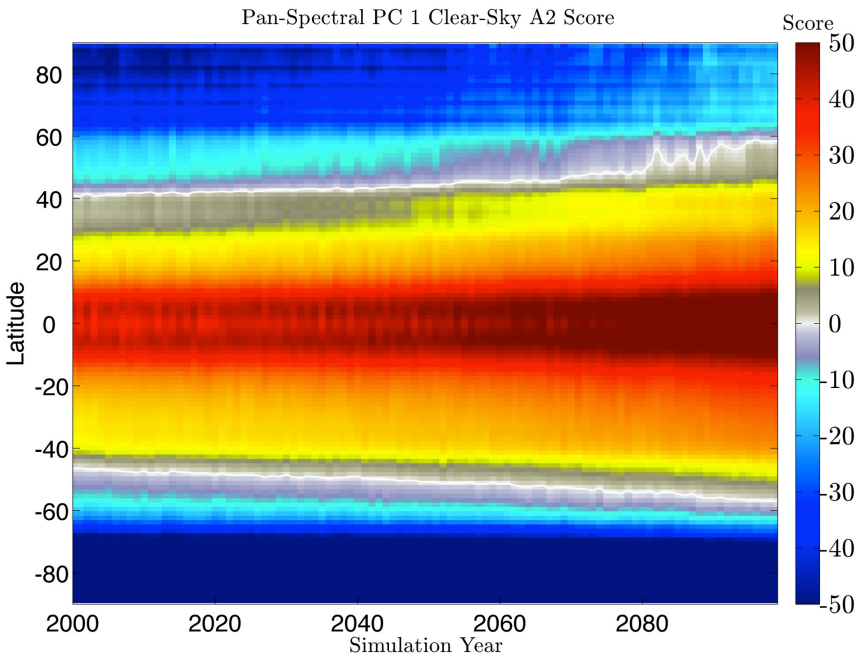


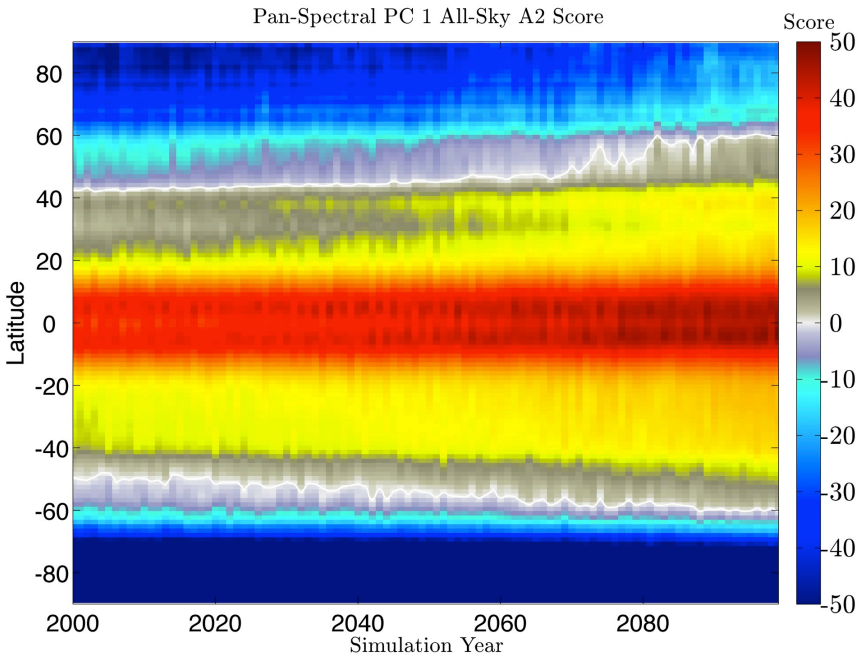


Feldman et al, J. Climate (In Review)

PC Analysis and Long-Term Detectability

Mature signal analysis methods are based on principal component scores rather than spectral measurements themselves to take full advantage of spectral correlations.
We are implementing these techniques with assistance of Roberts & Pilewskie.





Feldman et al, JGR (In Prep)

Current Status of OSSE Simulations

Data are available for all who are interested!

CCSM3 A2 & Control Runs		
Model	Control	A2
LW	100%	100%
SW	100%	100%

CCSM3-CM2 Historical Comparison		
Model	CCSM3	CM2
LW	100%	1%
SW	64%	1%

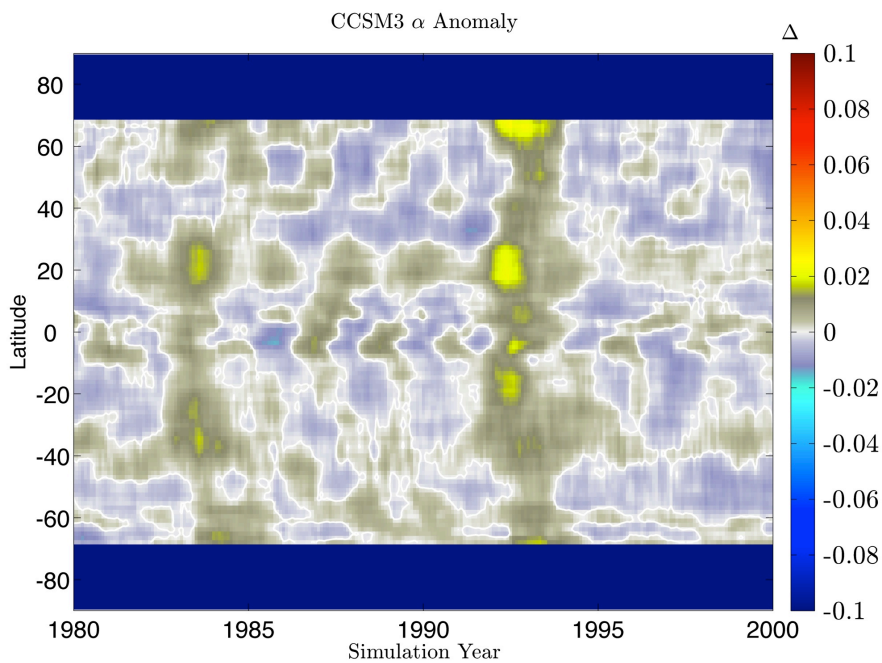
Multiple Resolution Simulation Completion			
Model	T31	T42	T85
LW	100%	100%	100%
SW	100%	100%	100%

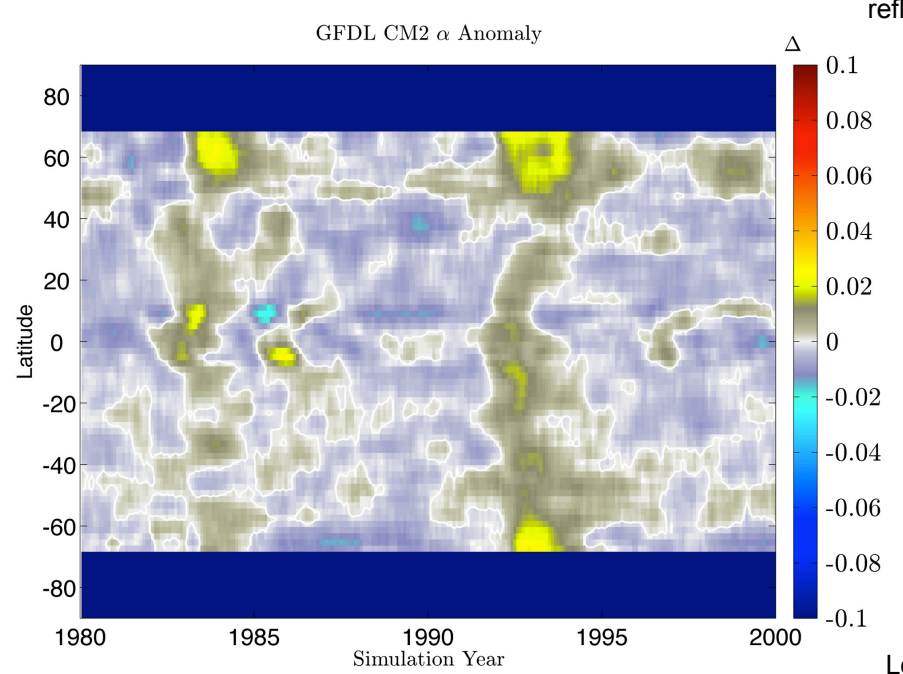
Preliminary CCSM3-CM2 Comparison

- NCAR's CCSM3 and GFDL CM2 climate models exhibit different climate sensitivities.
- Historical simulations provide opportunities to evaluate pan-spectral signals with identical forcings where early satellite observations existed.
- Collaboration with Yi Huang is ongoing and comparison with previous high-temporal resolution LW OSSE results will provide an important validation exercise.

All-Sky Albedo Anomalies

Strong signals associated with major volcanic eruptions.
More interannual cloud albedo variability in CCSM3 than CM2.



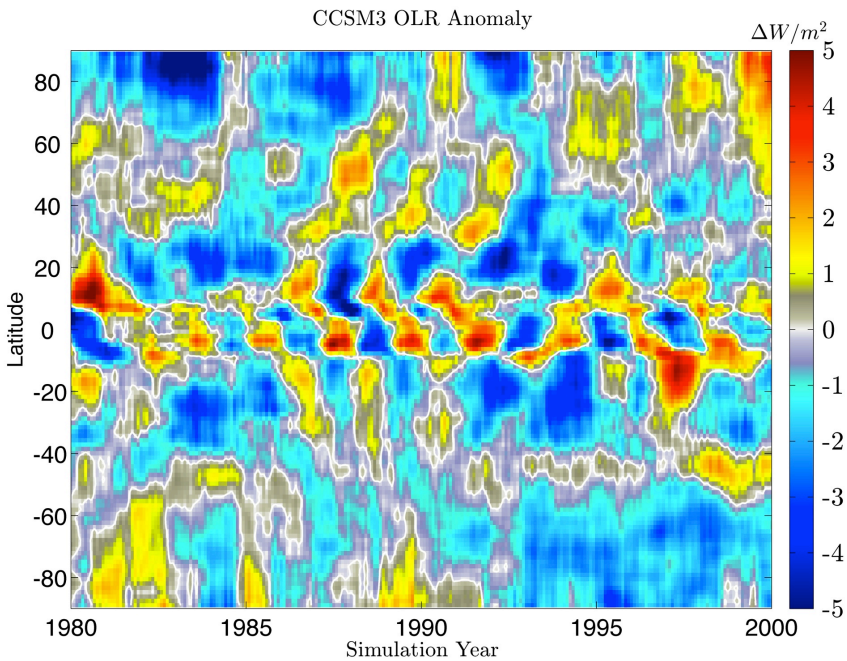


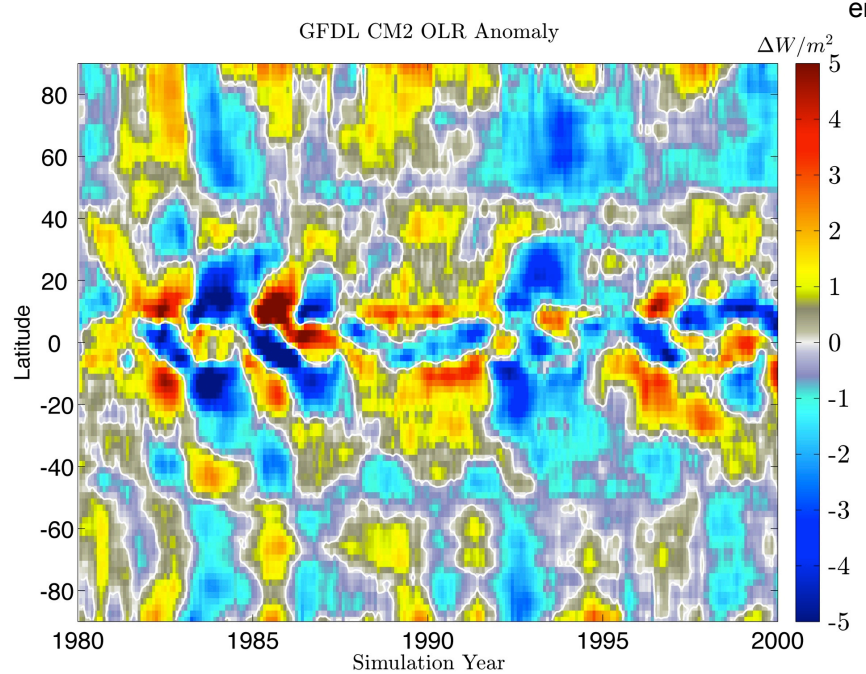
Higher reflection

Lower reflection

All-Sky OLR Anomalies

Strong cooling signals associated with major volcanic events.
More interannual cloud albedo variability in CCSM than CM2.



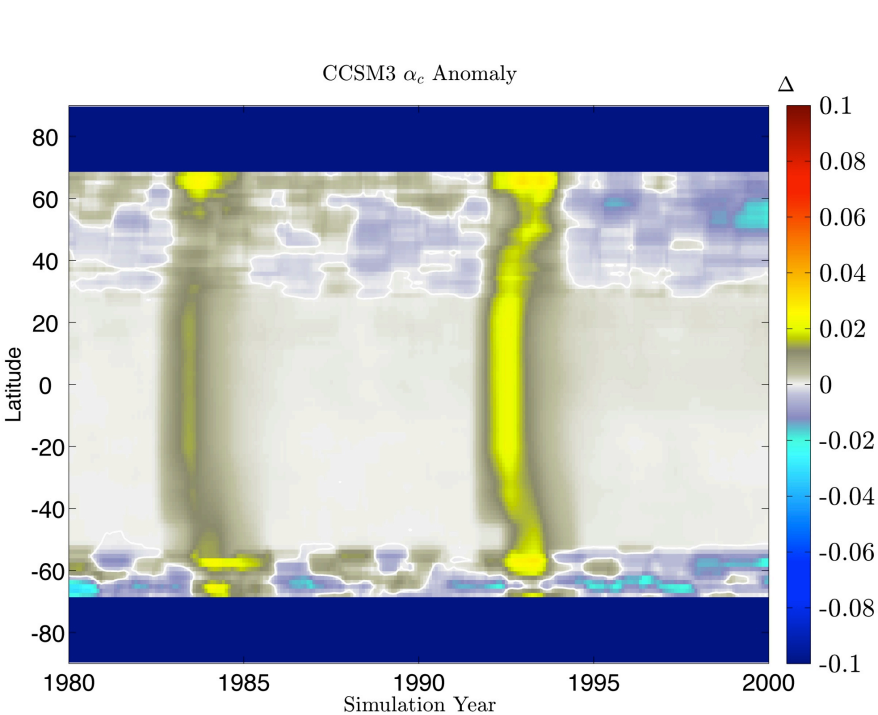


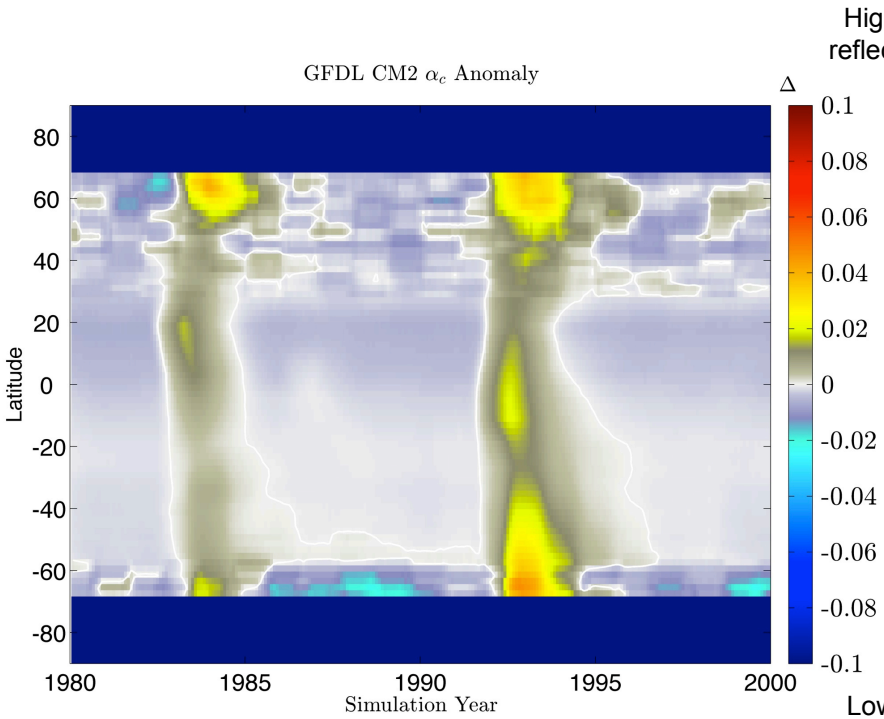
Higher emission

Lower emission

Clear-Sky Albedo Anomalies

Anomalies dominated by brightening from volcanic events.
Interannual variability in sea-ice (and albedo) larger in CCSM3 than in CM2.





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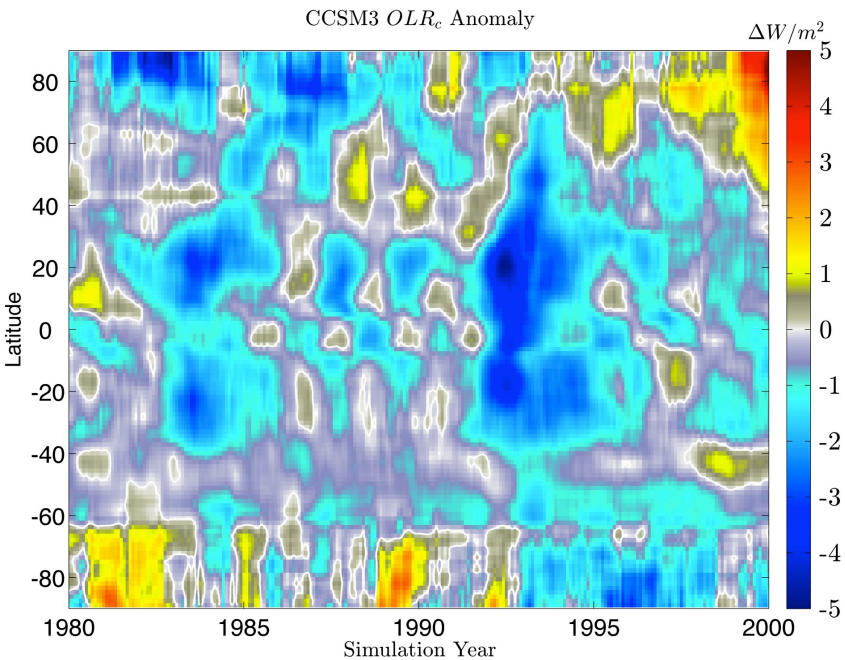
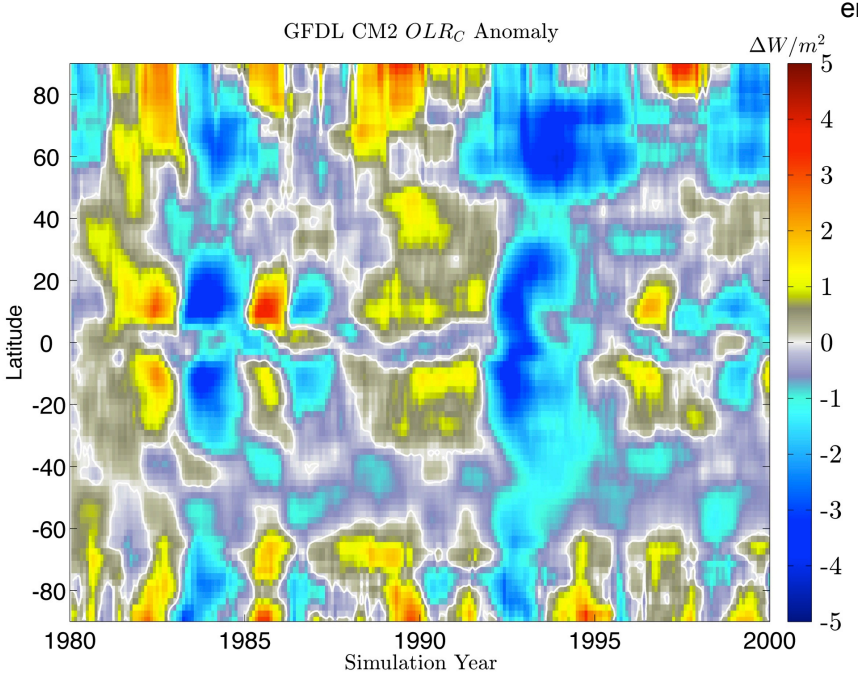


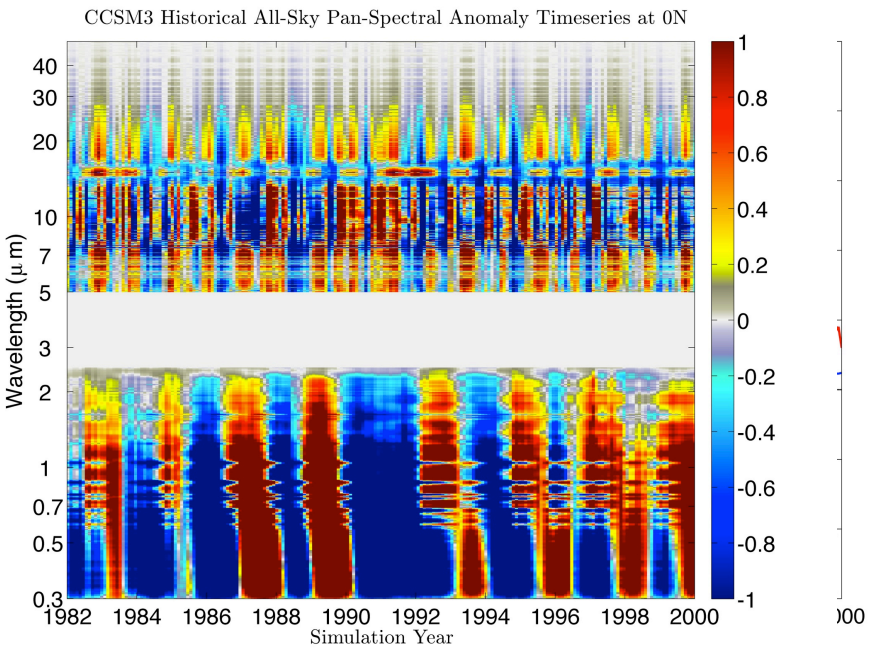


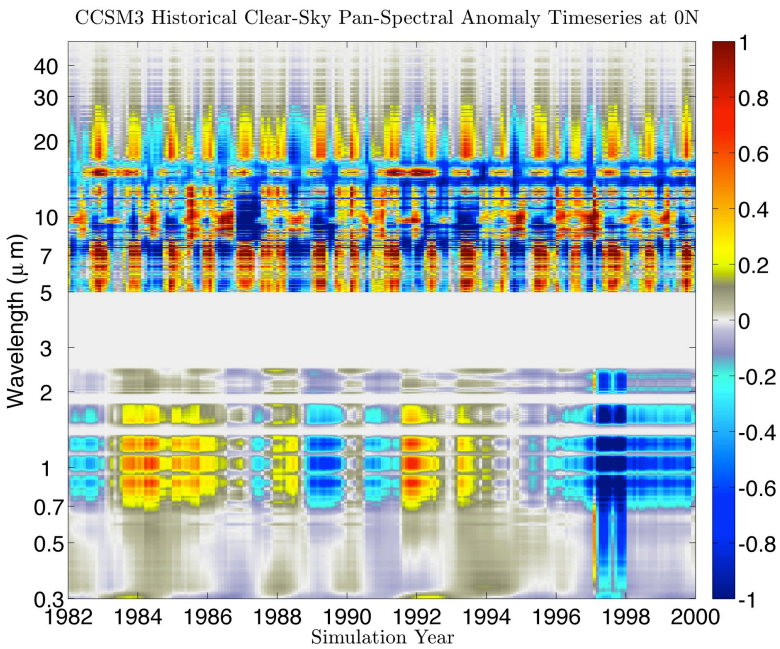
Higher emission

Lower emission

Time-Series Analysis

ENSO and volcanic events show up in dipole features of clear-sky and all-sky pan-spectra.



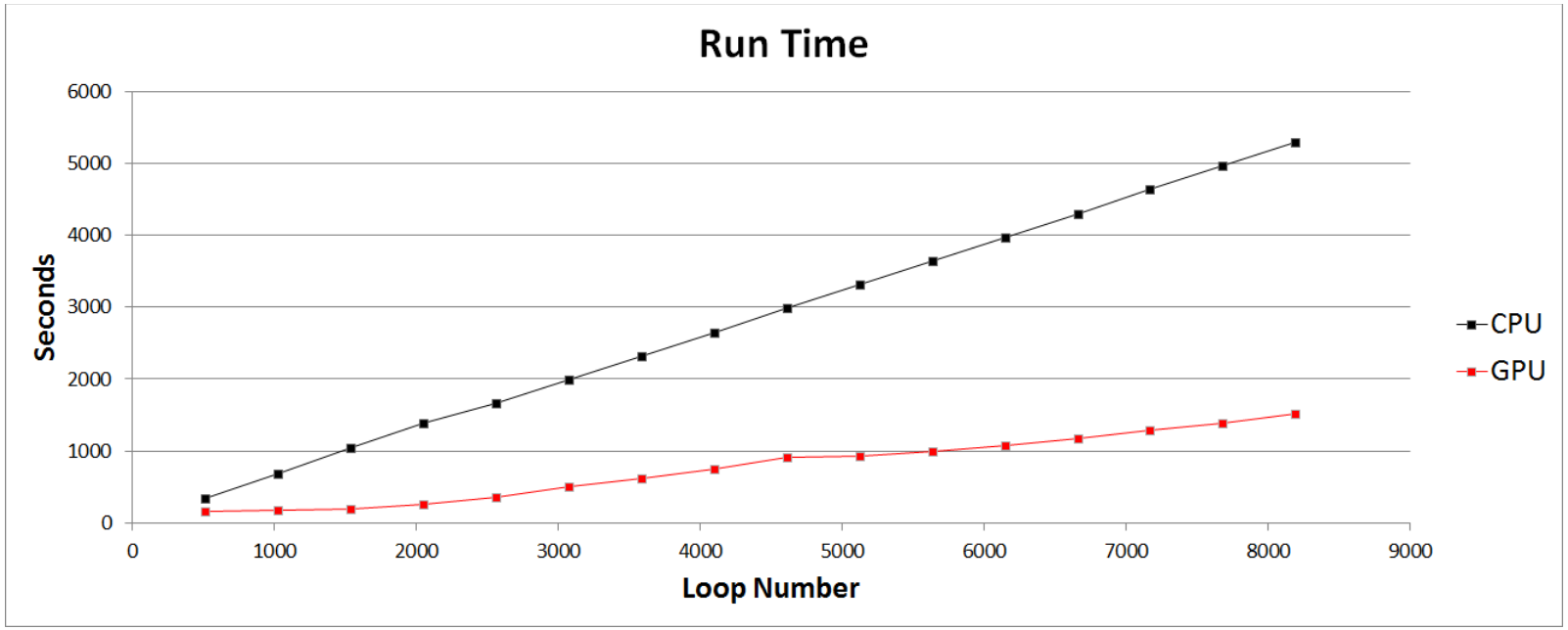


Utilization of Fast RT (PCRTM)

- From Xu Liu's visit in September 2012, OSSE now can compute LW radiances 30x faster than MODTRAN using PCRTM in parallel.
  - Additional speedups possible if PCRTM initialization calls can be minimized.
  - Development is ongoing for PCRTM SW implementation.
- The soft-coding of the OSSE for GFDL CM2 model coupled with PCRTM will greatly reduce barrier to entry for OSSEs based on the CMIP5 archive.

Optimizing PCRTM for GPUs

PCRTM can be optimized further with Graphical Processing Units for a 5.4x speedup.



Coleman and Feldman, 2012, IEEE JSTARS (In Review)

Towards OSSEs with CMIP5 Data

- CMIP5 reporting requirements indicate that pan-spectral simulations based on monthly-averaged results are achievable.
- Future collaboration with COSP team will be critical to advancing the project.
  - Ultimate goal to tie RF and/or feedback differences to CLARREO-like measurements.

Summary

- The pan-spectral OSSE for CCSM3 is fully-operational and is being used to explore observational tests for climate model response.
- Differentiation time analysis for the multiple resolution calculations indicates that SW and LW window bands can separate models with feedback strengths that differ by 0.1 W/m2/K on decadal time-scales.
- Adaptation of OSSE to handle GFDL's CM2 results for historical simulations is ongoing and will lay the groundwork for multi-model comparison.
- Bringing PCRTM into the OSSE framework may enable a larger number of simulations once it is implemented and validated.

Future Directions

- Finish comparison between CM2 and CCSM3.
- Implement PCRTM LW+SW into OSSE and validate.
- Continue laying the groundwork for OSSE simulations to utilize the CMIP5 database.

- Acknowledgements:
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