Reduction of biases in the Community Climate System Model version 3.5

Peter Gent

Chairman

CCSM Scientific Steering Committee

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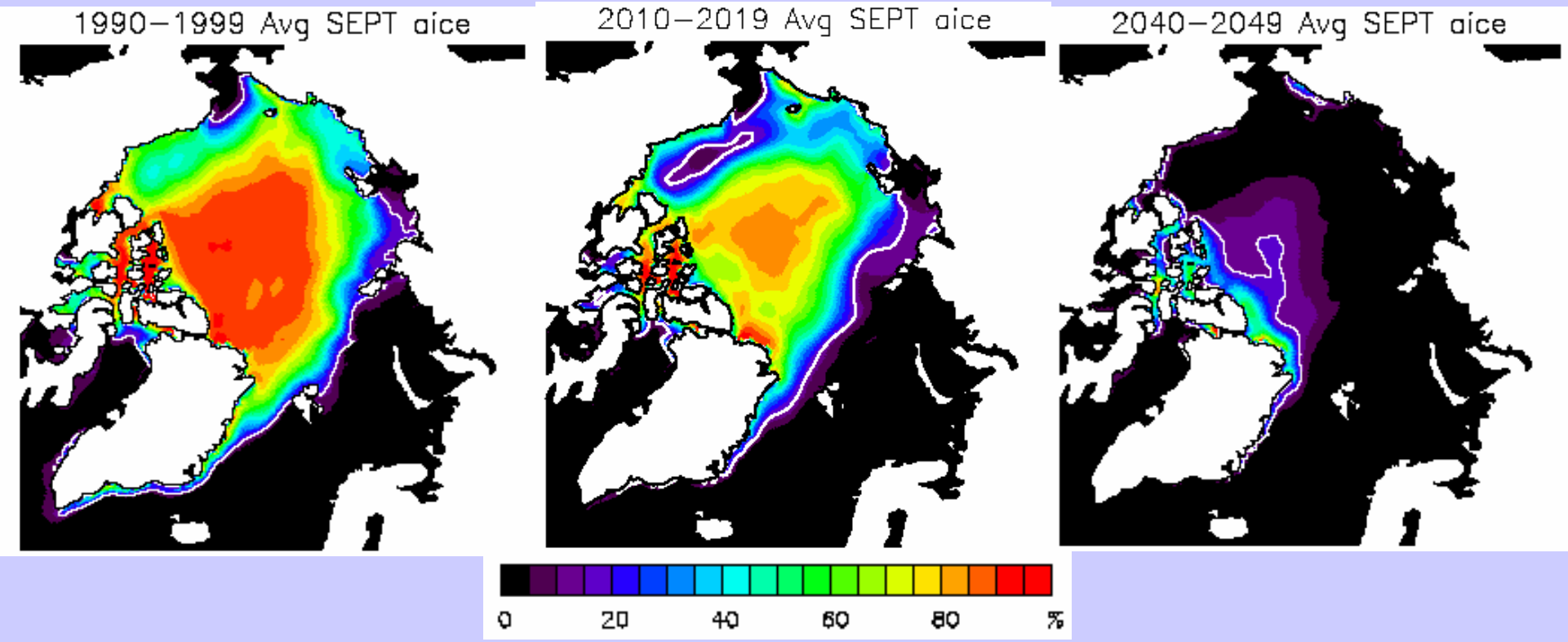
NCAR

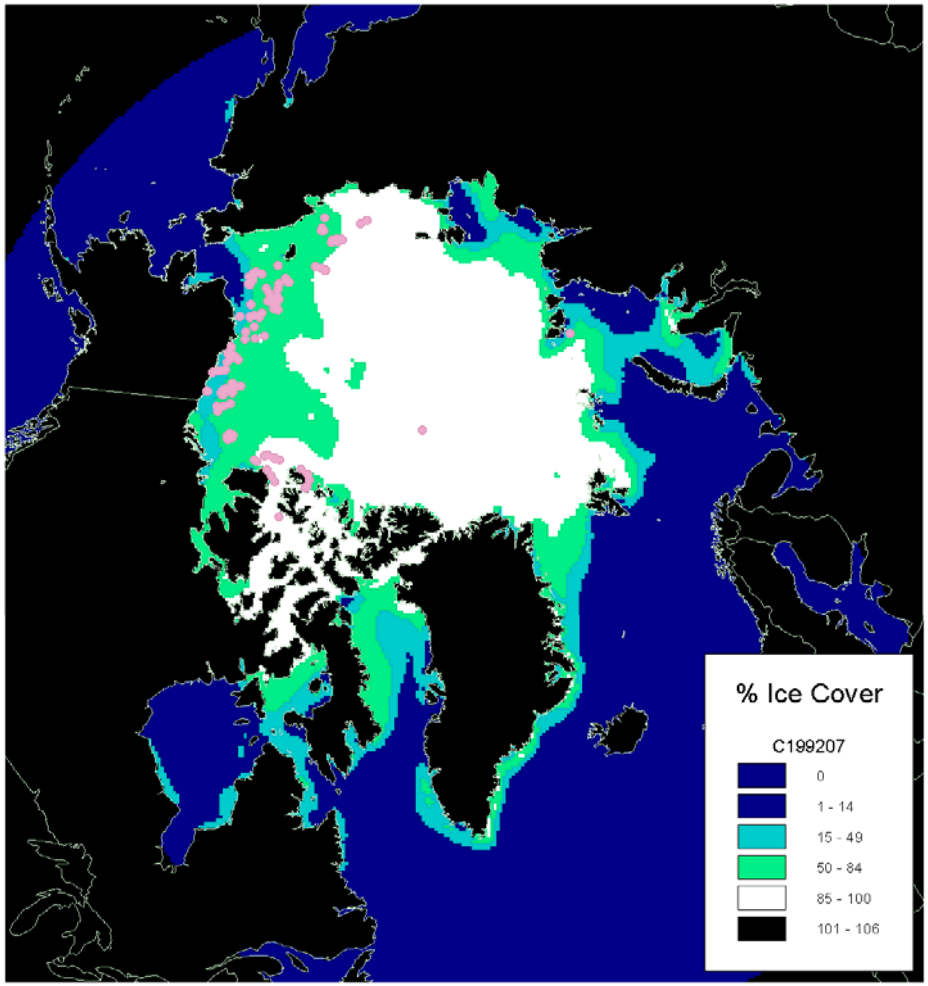
Arctic Sea Ice Concentration



September is mostly ice free by 2050 for A1B scenario

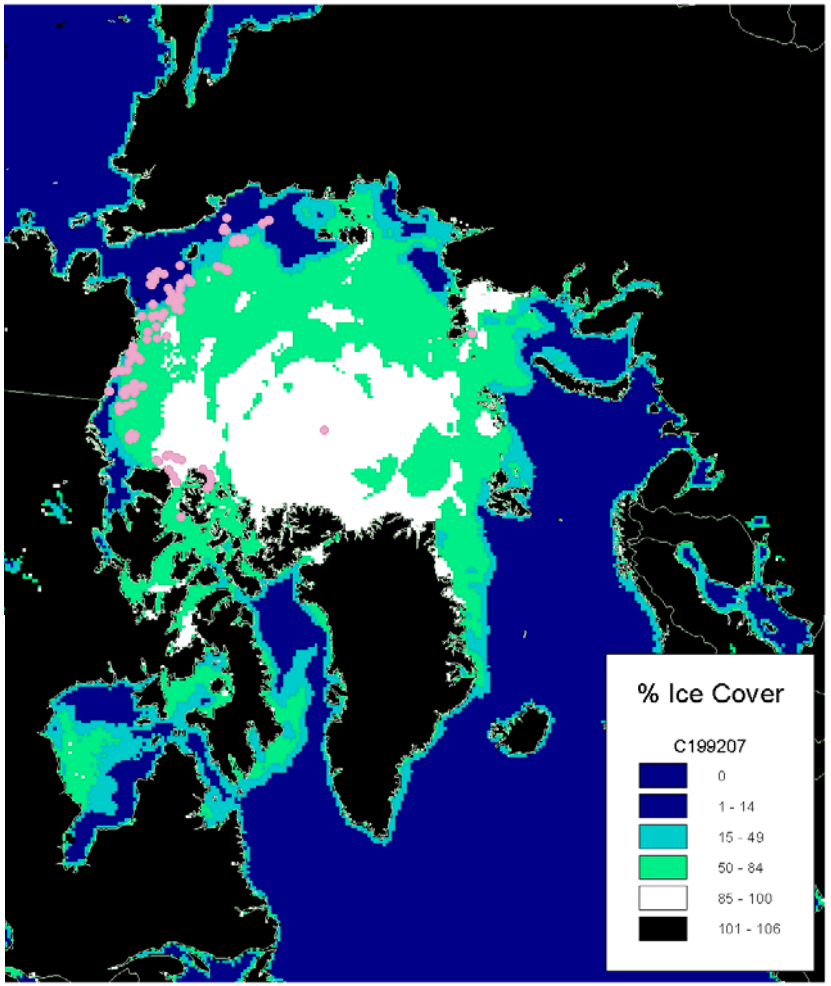
Polar Bears – Threatened Species?

- Dr David Douglas and others at the USGS Biology and Geography Center, Juneau, are writing the document making this case.
- They are collaborating with Marika Holland and David Bailey to use future projections from the CCSM and Hadley Centre models.
- This started at the instigation of the USGS scientists.



CCSM3 – Fully Coupled

July 1992



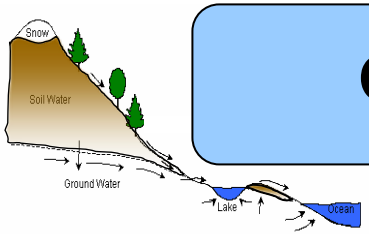
NASATeam SSM/I

July 31, 1992

NCAR

Polar Bear Locations: July 20-30, 1992

USGS



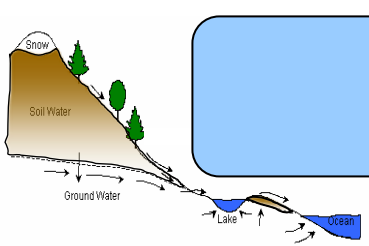
CLM Community Hydrology Project (CLM3.5)

Modifications to hydrology

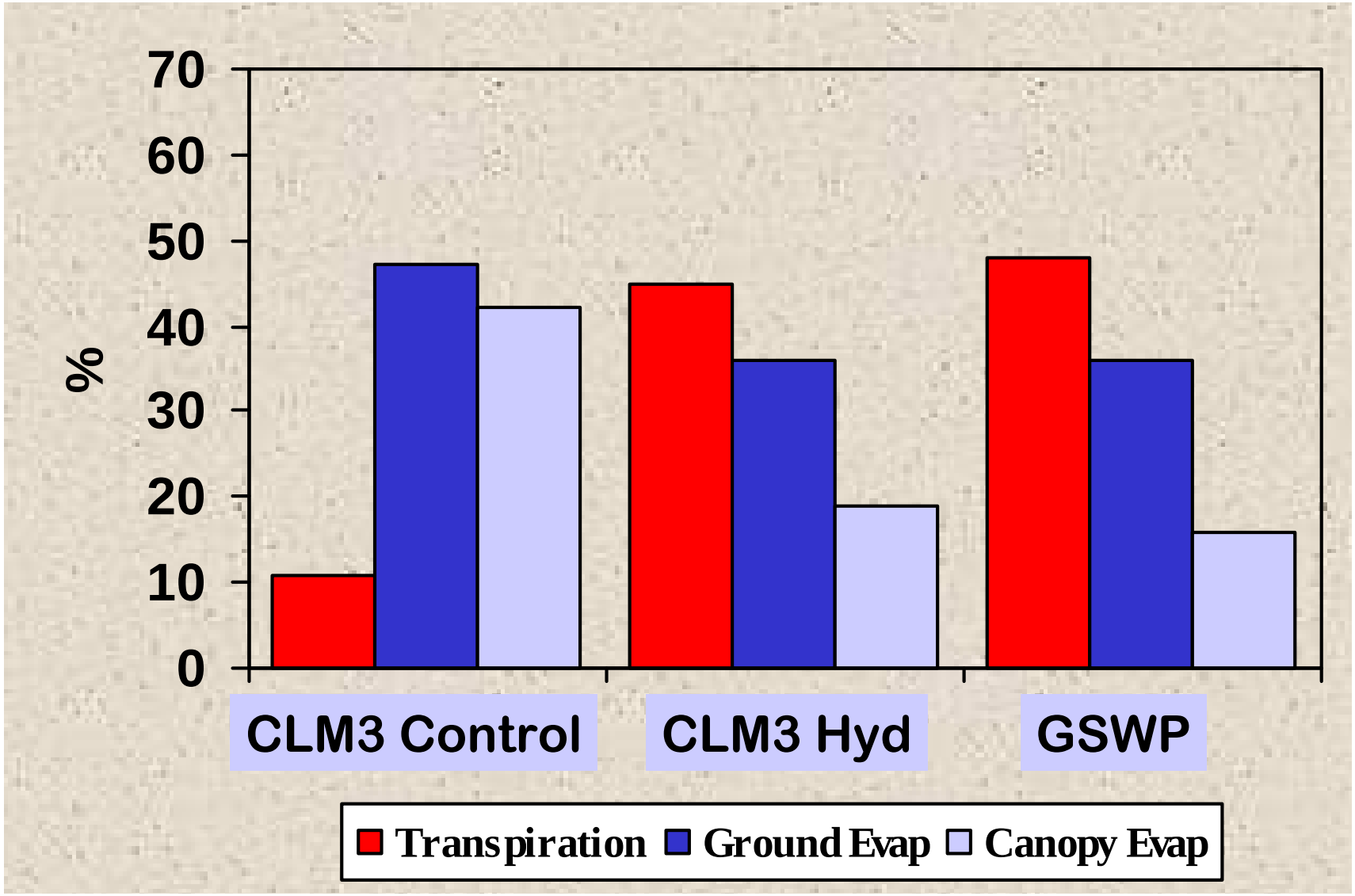
- Adopt SIMTOP (TOPMODEL-based surface runoff)
- Adopt SIMGM (groundwater model)
- New frozen soil scheme (freezing point depression, permeability of icy soil)
- Added soil evaporation resistance term that is function of soil moisture

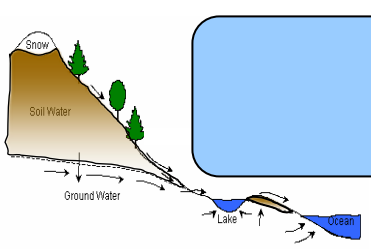
Other changes

- New surface dataset (PFTs, LAI) based on MODIS data
- Revised canopy integration including 2-leaf (sunlit/shade) model
- Canopy interception scaling
- Added PFT-dependency to soil moisture stress function
- Permit root water uptake from mixed liquid/ice layers
- Effective nitrogen limitation

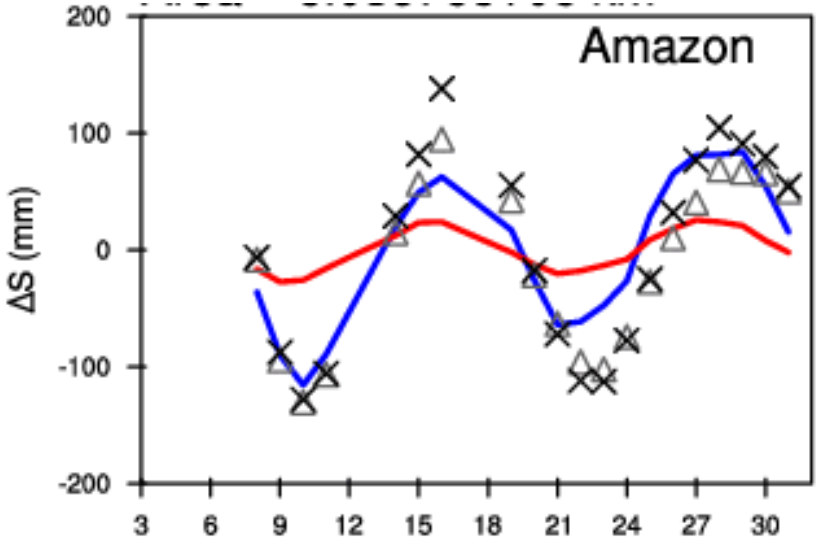


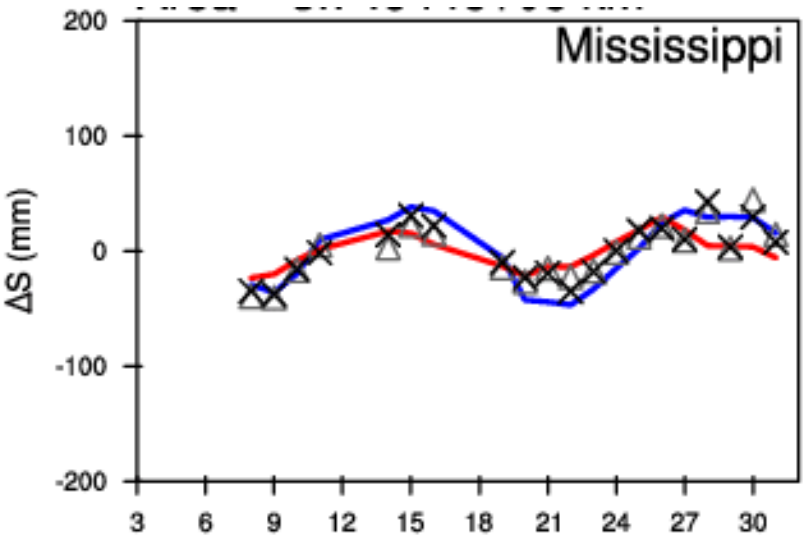
Global Partitioning of Evapotranspiration

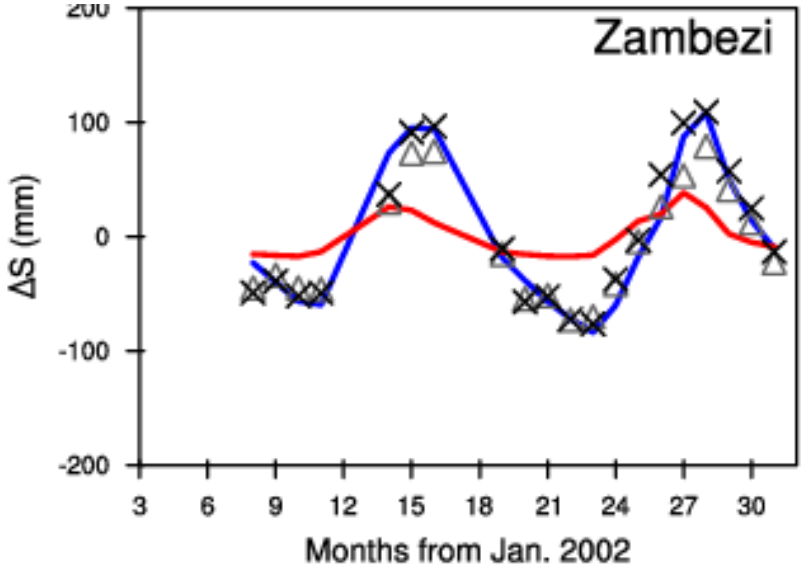




Water storage





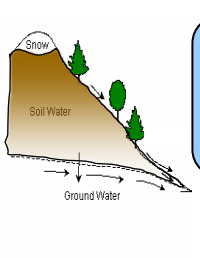


GRACE 1

GRACE 2

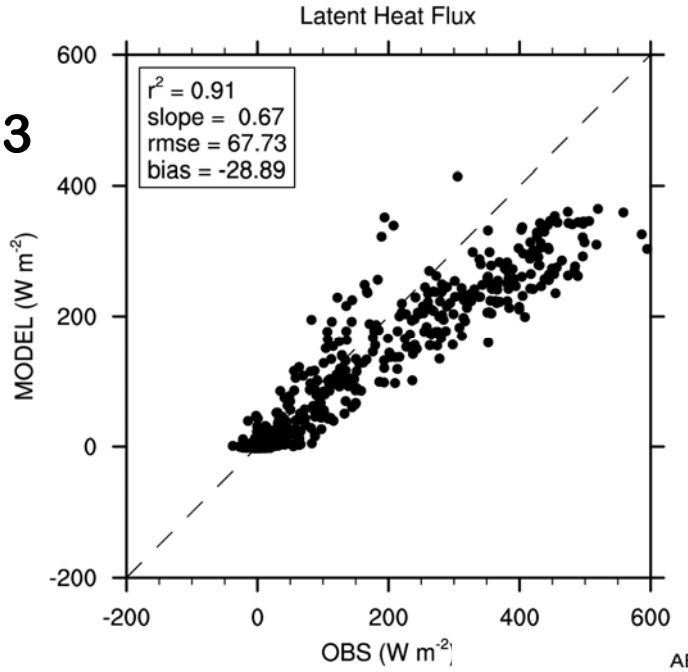
CLM3 CONTROL

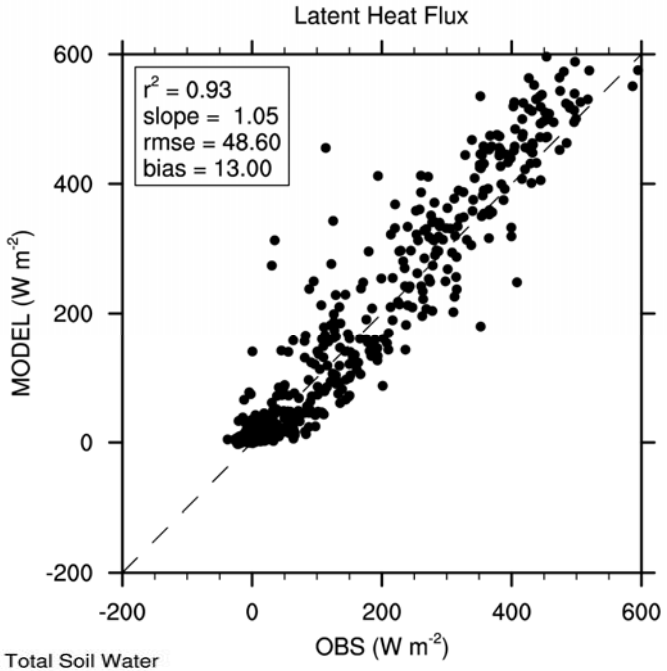
CLM3 LMWG Hyd



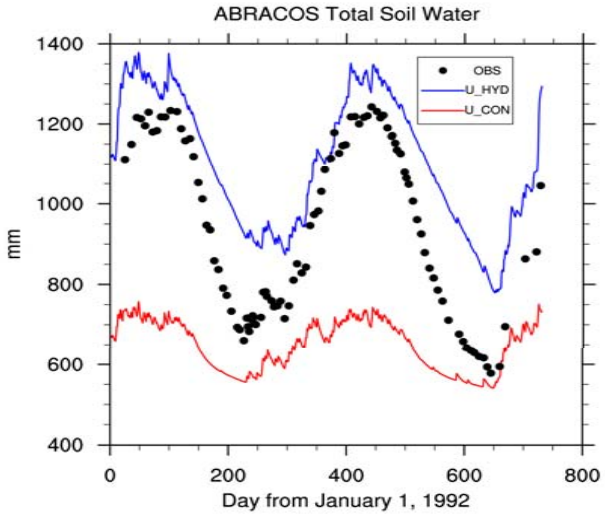
Abracos tower site (Amazon)

CLM3





CLM3.5



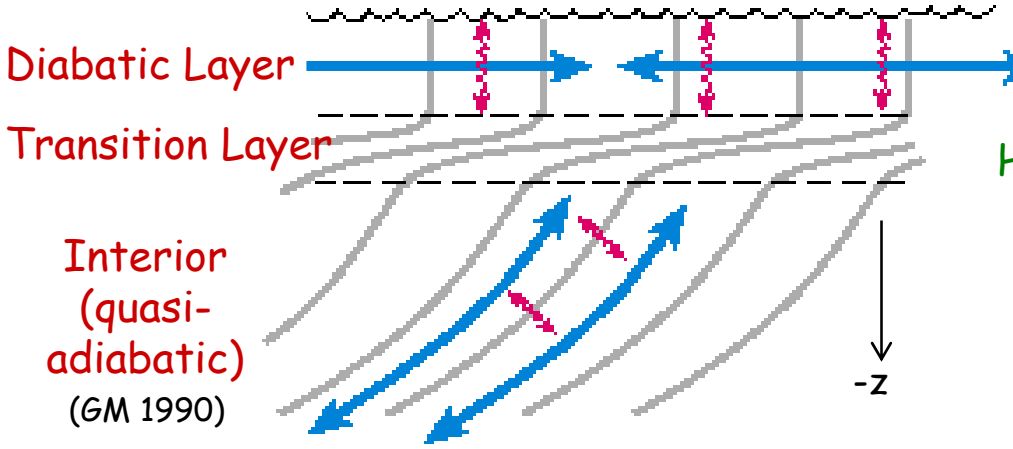
CLM3.5

CLM3

Sea Ice Model Development for CCSM version 3.5

- Transition to CICE 4.0
  - Software Engineering enhancements
  - Improved ridging parameterization
  - Improved snow treatment

NEAR-SURFACE EDDY FLUX SCHEME (Ferrari & McWilliams)

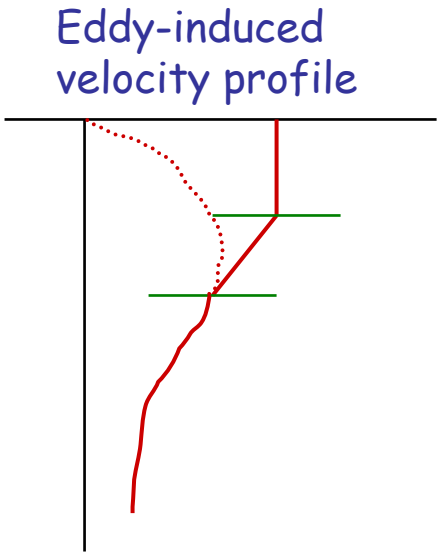


Diffusivities

Horizontal

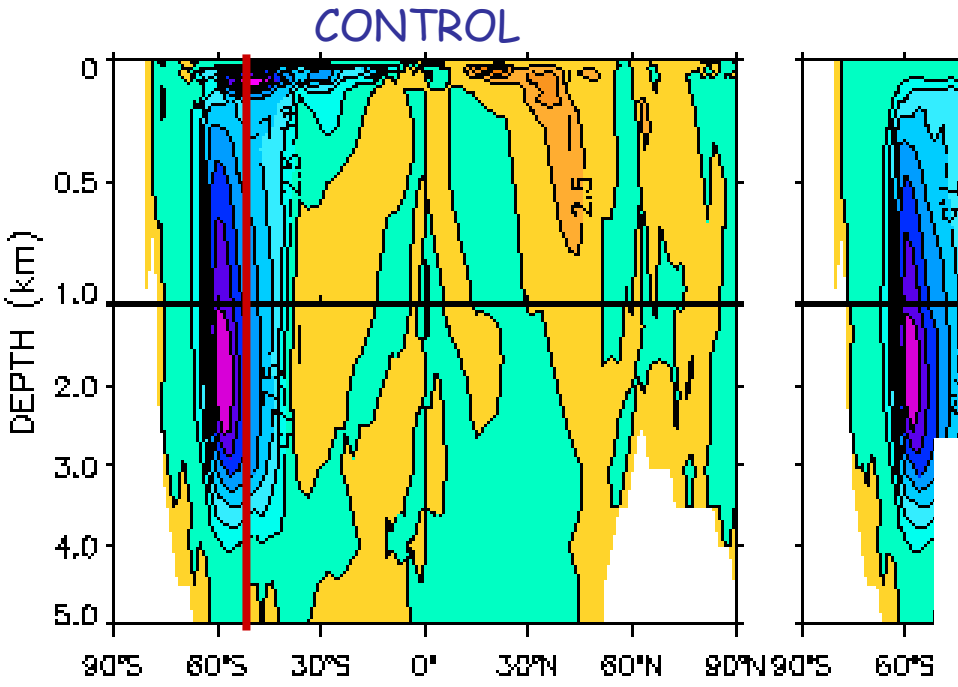
Horizontal/Isopycnal

Isopycnal

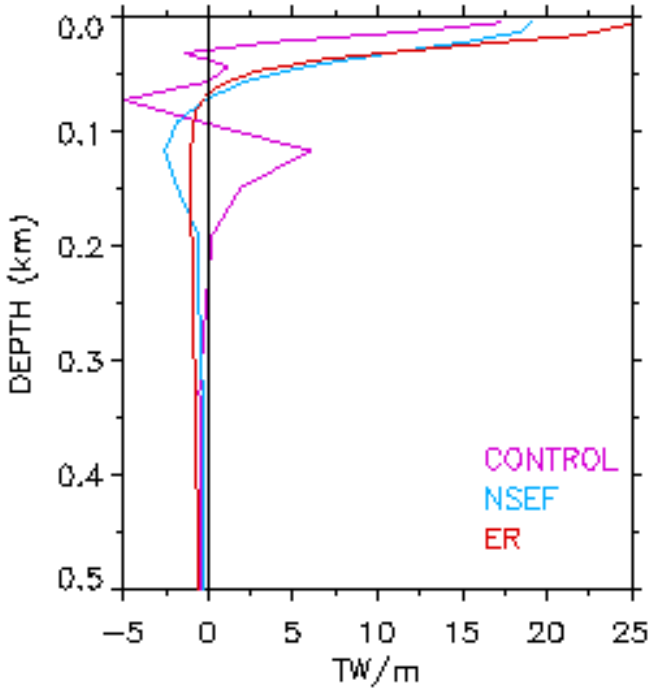


This replaces the standard approach in the past of applying near-surface taper functions for the isopycnal and thickness diffusivities.

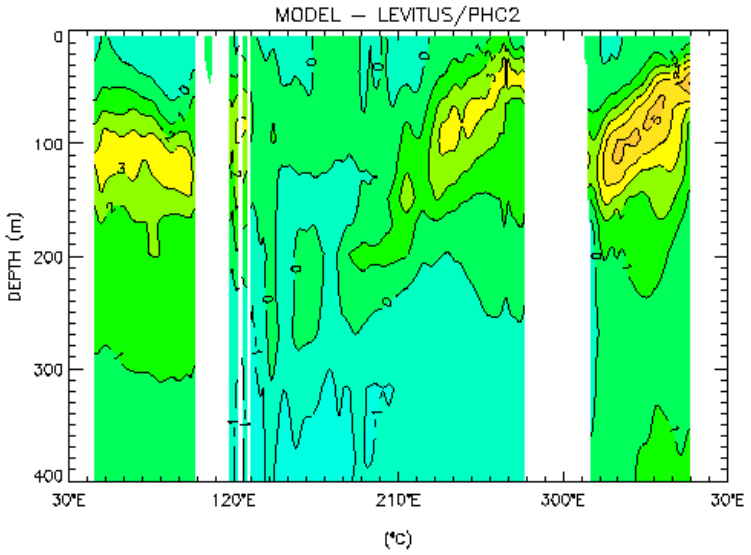
EDDY-INDUCED MERIDIONAL OVERTURNING (GLOBAL)

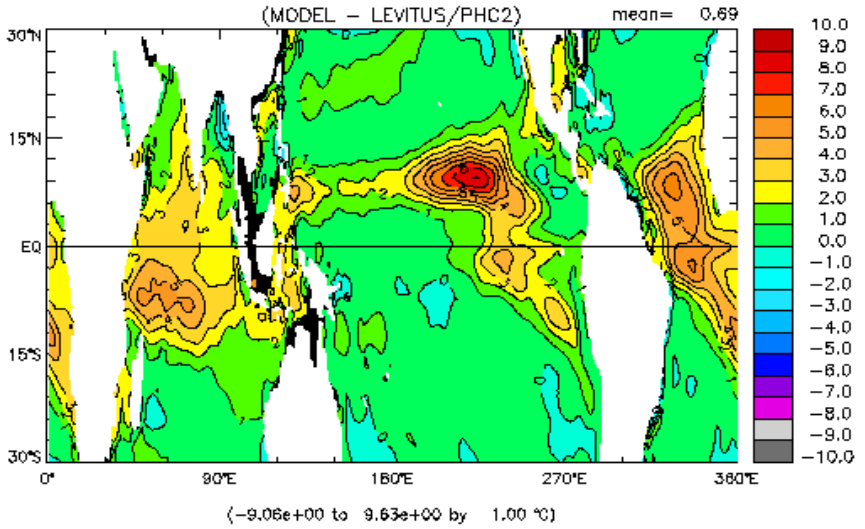


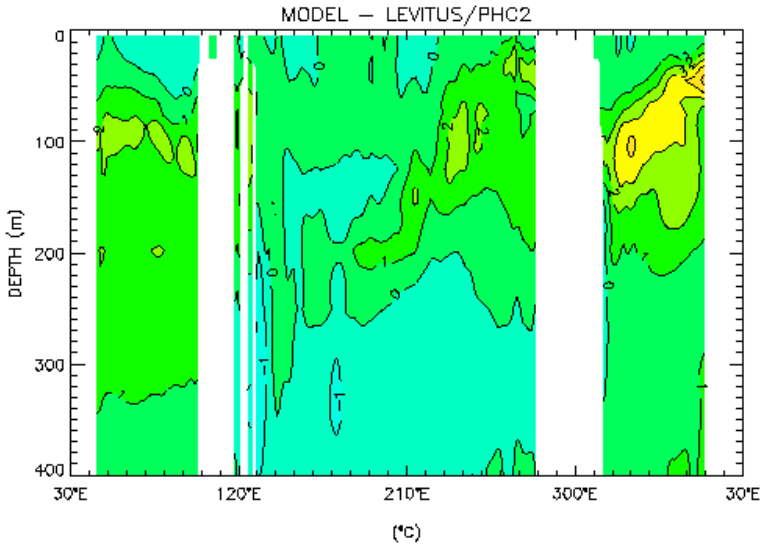
Vertical profile of zonally-integrated total advective heat flux at 49°S

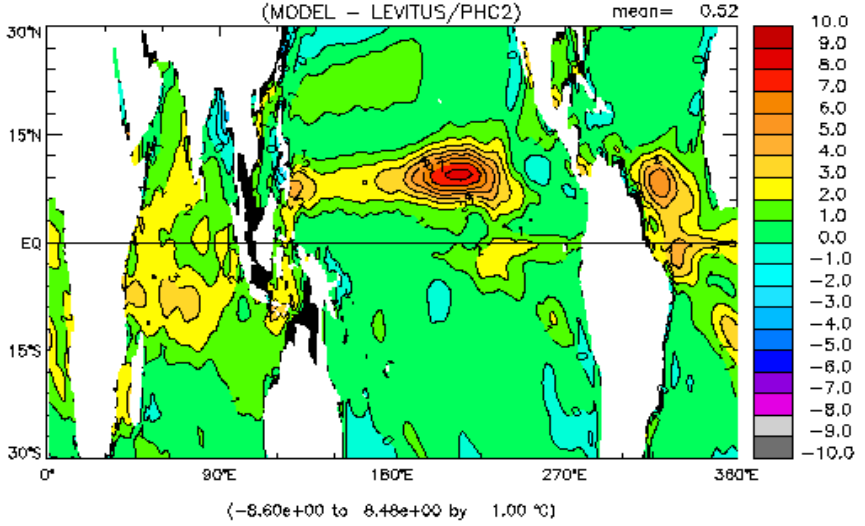


Ocean-alone runs using 40 and 60 levels in POP 2









Equatorial Temperature

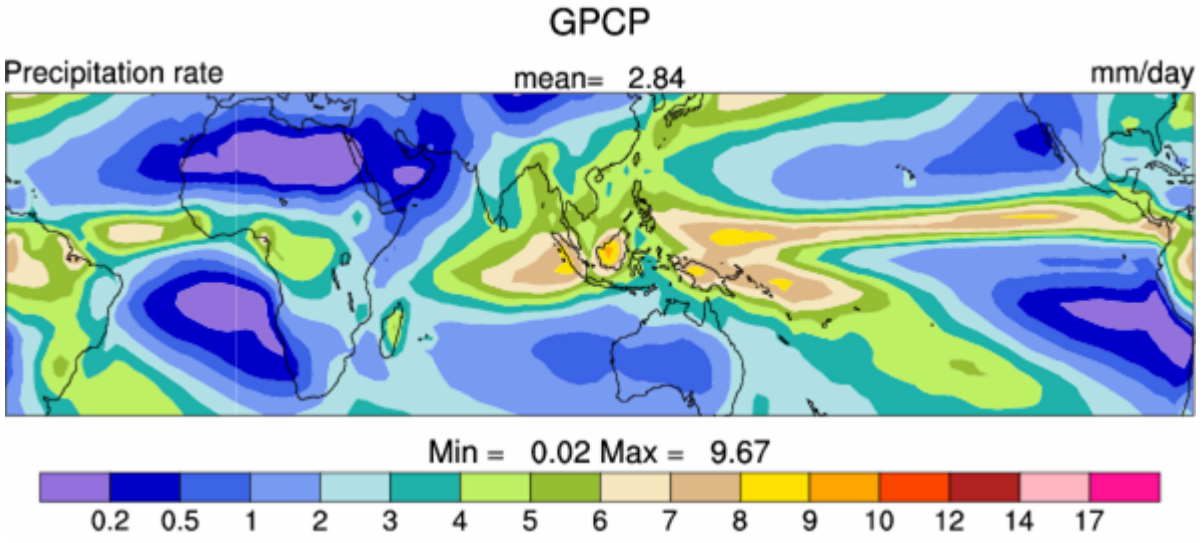
100m Temperature

Deep Convection Modifications

- **Neale and Richter**
  - Convective vertical momentum transport
  - Dilute instead of undilute plume calculation, with freezing of cloud water

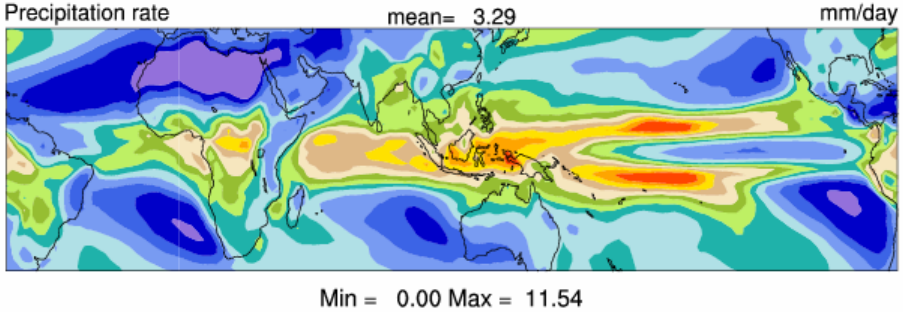
- **Zhang**
  - Convective inhibition (no conv CIN>400 J/kg)
  - d(CAPE)/dt from large-scale > 0 J/kg/hr

- **Wu**
  - Convective momentum transport
  - Convective inhibition (no conv CIN>400 J/kg)
  - d(CAPE)/dt from large-scale > 20 J/kg/hr



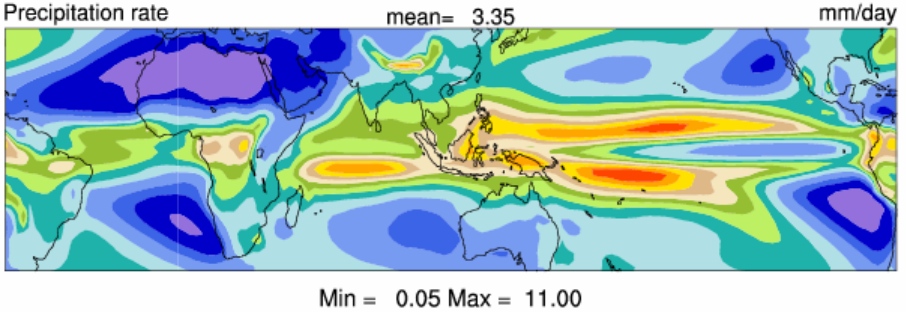
Control

b31.001 (yrs 75-80)



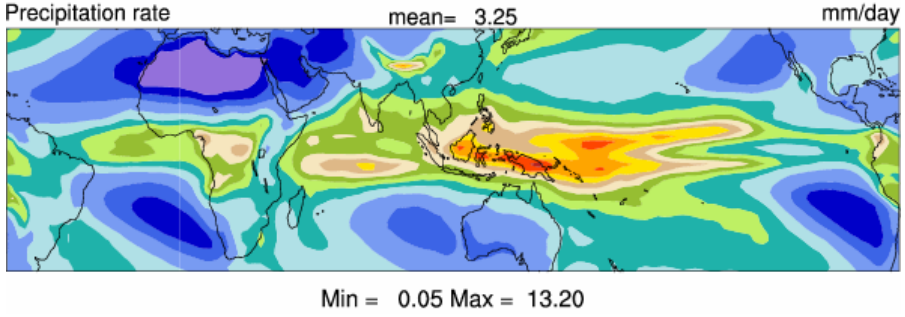
Neale+Richter

b31.002 (yrs 60-99)



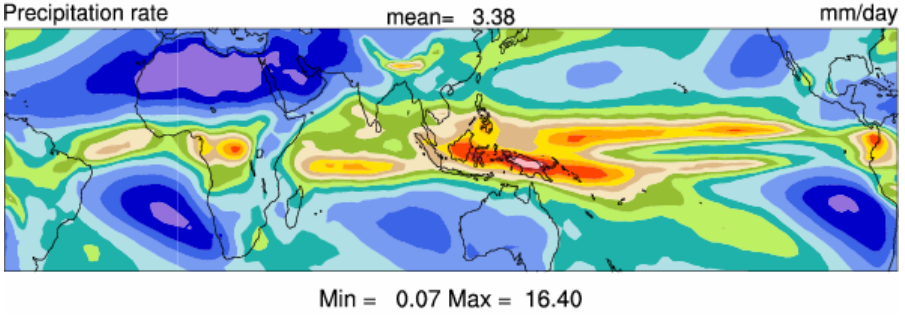
Zhang

b31.006 (yrs 81-100)



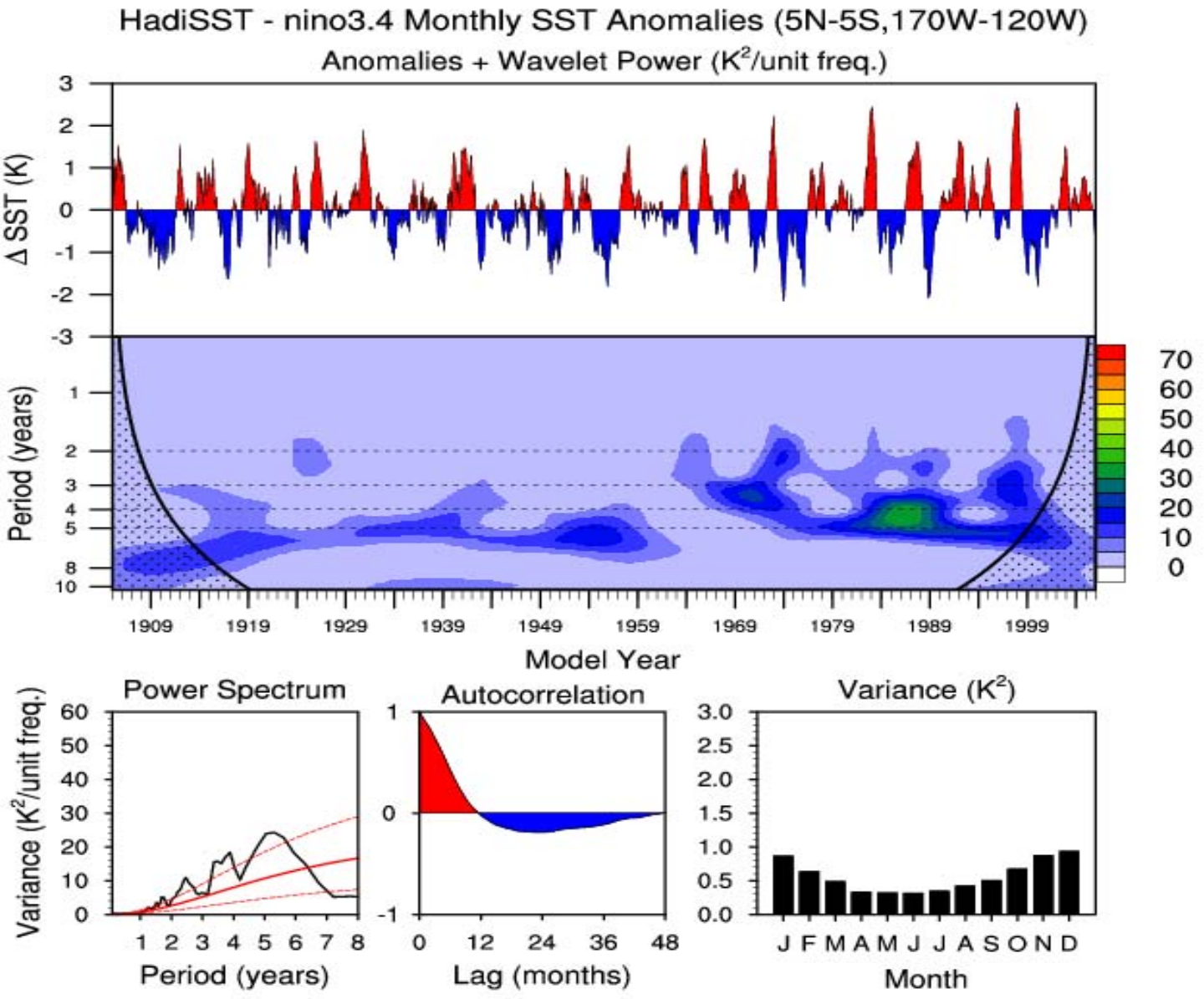
Wu

b31.007 (yrs 81-100)

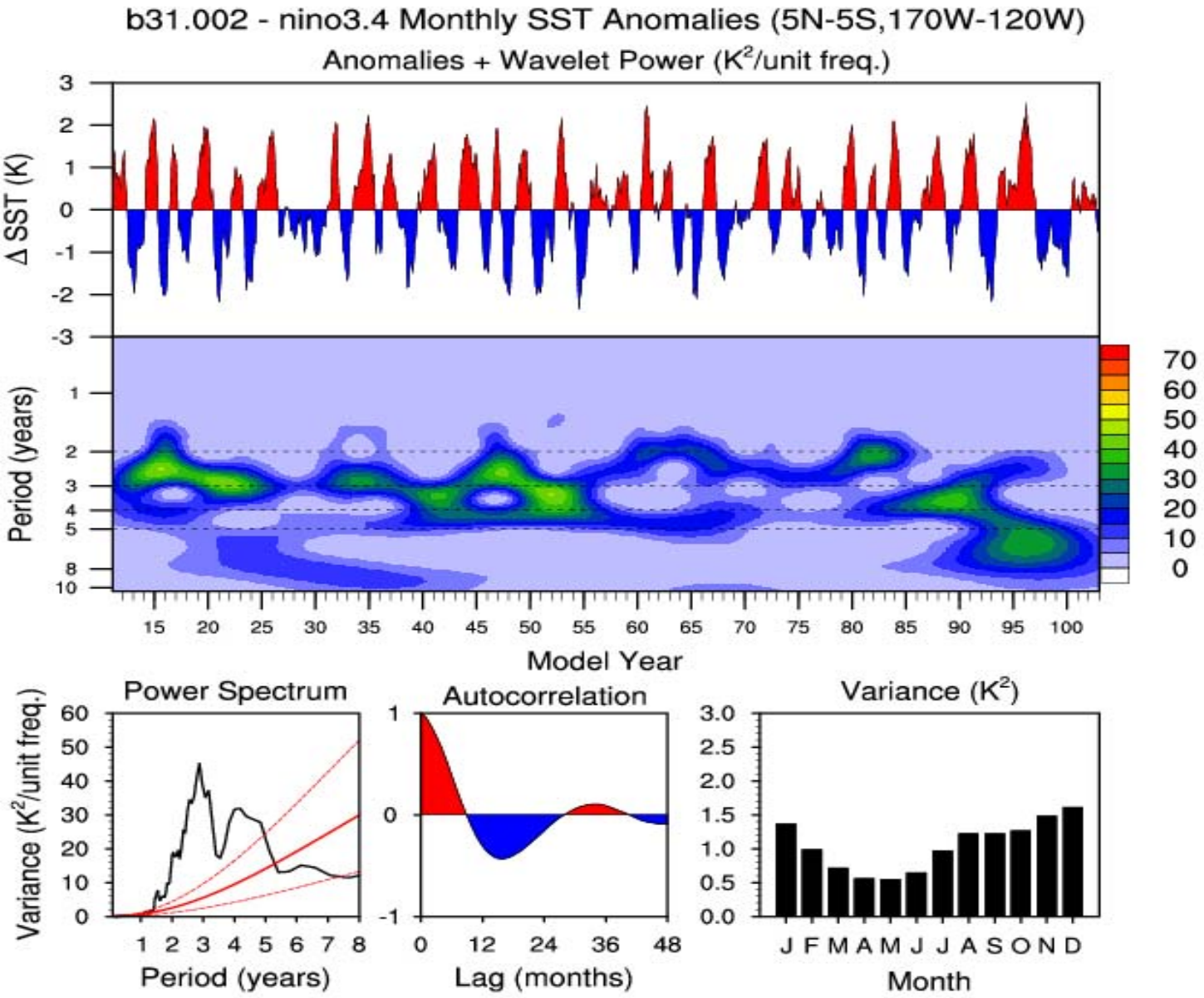


HadiSST

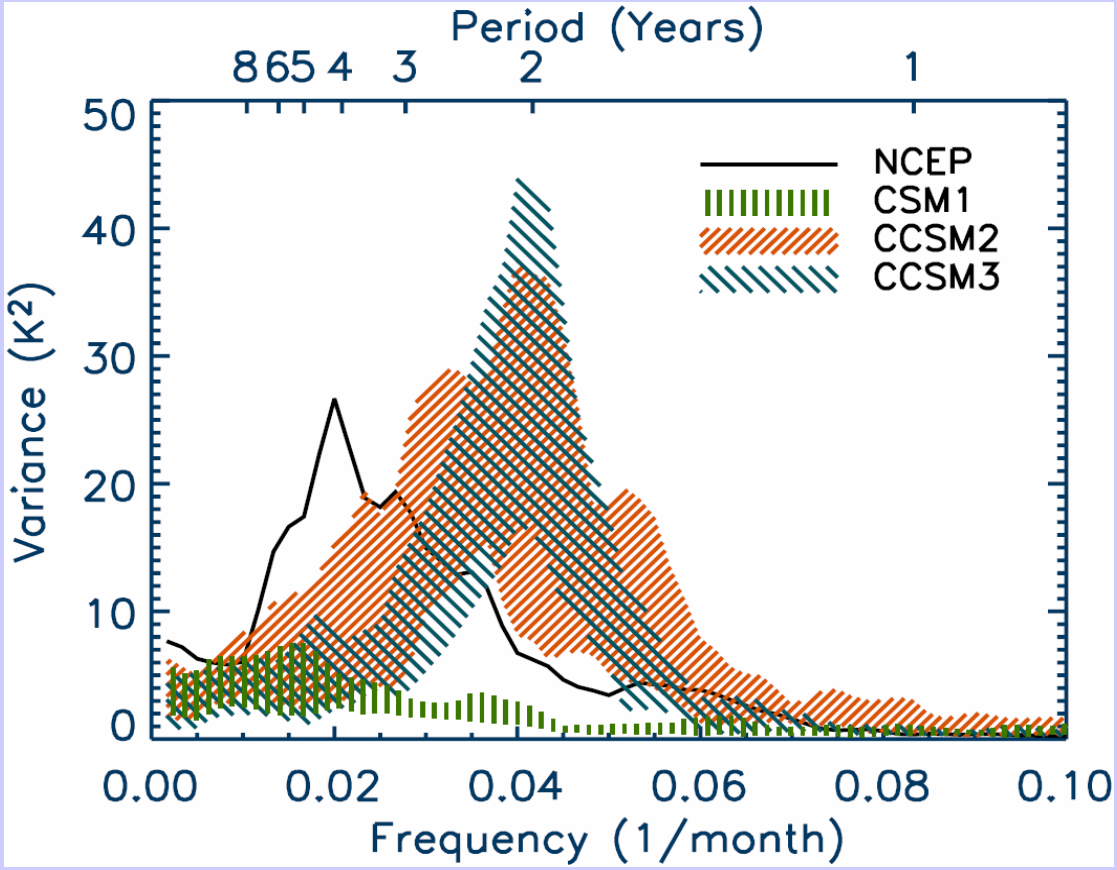
Obs


HadiSST - nino3.4 Monthly SST Anomalies (5N-5S,170W-120W)
Anomalies + Wavelet Power (K²/unit freq.)
Δ SST (K)
Period (years)
Model Year
Power Spectrum
Variance (K²/unit freq.)
Period (years)
Autocorrelation
Lag (months)
Variance (K²)
Month
J F M A M J J A S O N D

Neale and Richter mods

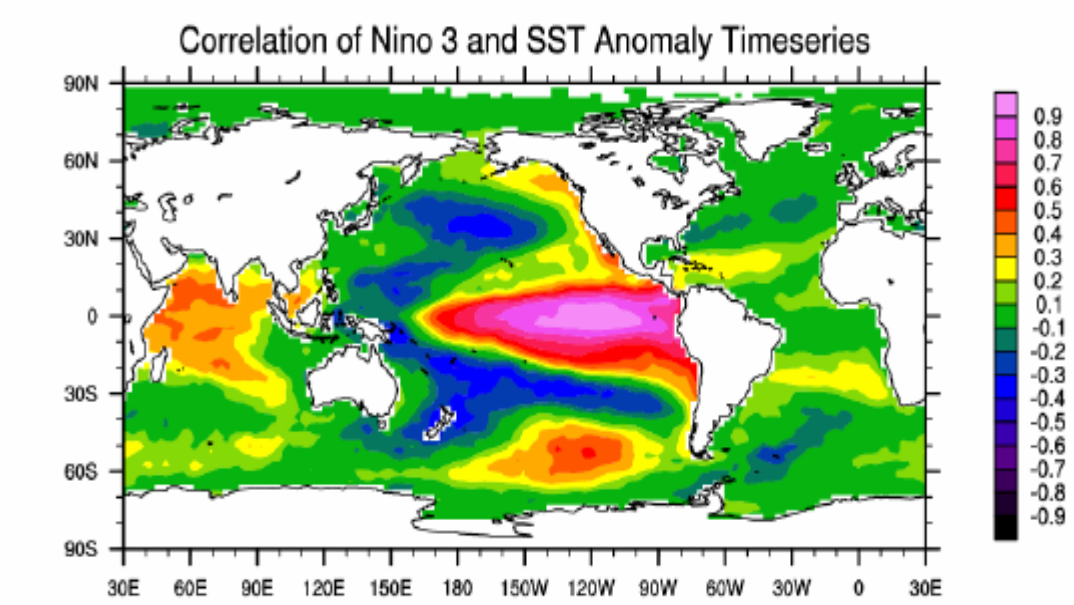


Nino3 SST Power Spectra

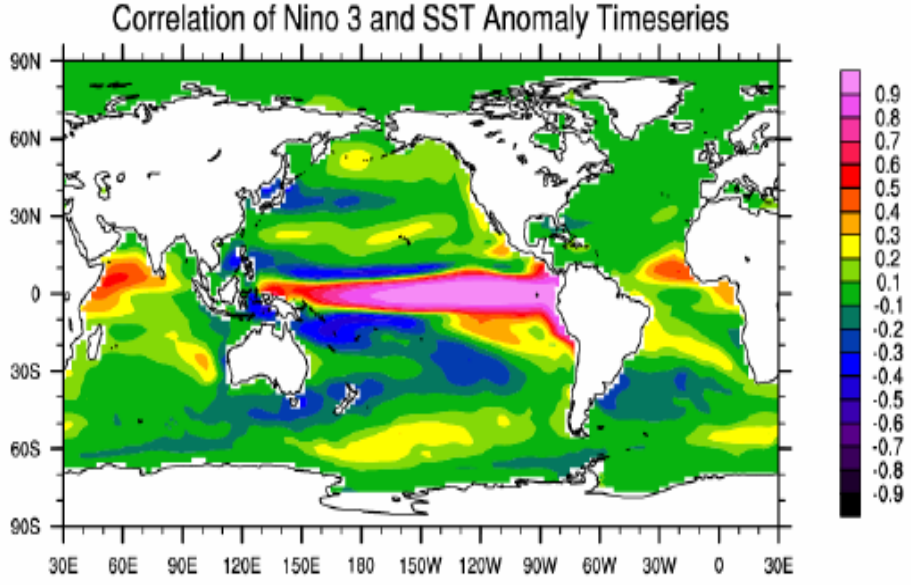


Gent and Kiehl, 2004; Collins et al, 2006

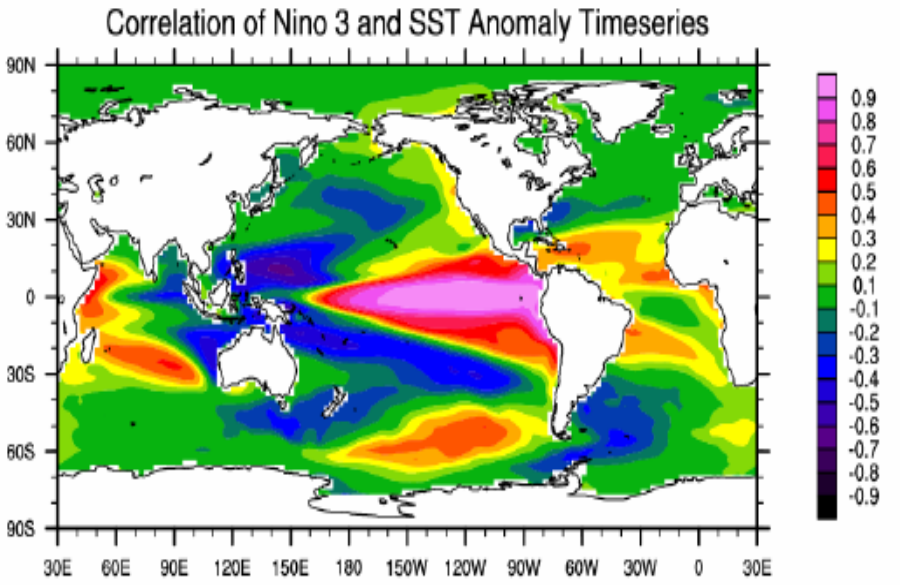
HadiSST Obs



Control



Neale+Richter



CCSM Carbon LAnd Model Intercomparison Project (C-LAMP)

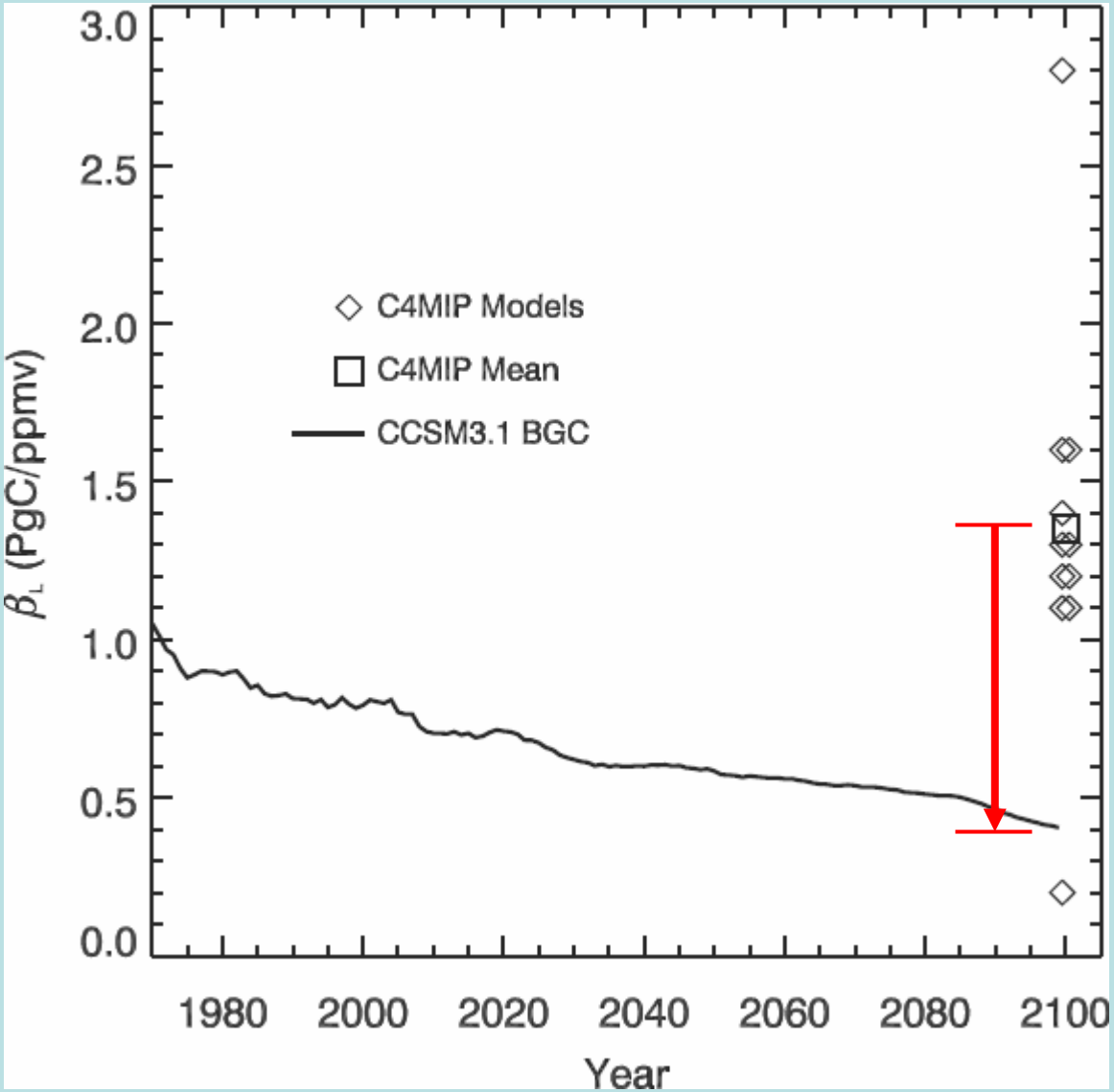
Develop observational datasets and metrics to evaluate land carbon model (& improve CCSM Land-BGC model)

- Compare to 2 or 3 land carbon models against data
  - CLM-CN
  - CASA'
  - LSX-IBIS (not currently coupled to CLM)
- Run simulations in CCSM 3 at T42 at DOE-Oak Ridge
- Archive and make available results at DOE-PCMDI
  - Spin-up completed (mostly) for CLM-CN & CASA' (year 2500)
  - Substantial progress on global & flux tower datasets
  - Underway with C-LAMP 19 & 20th century historical simulations:

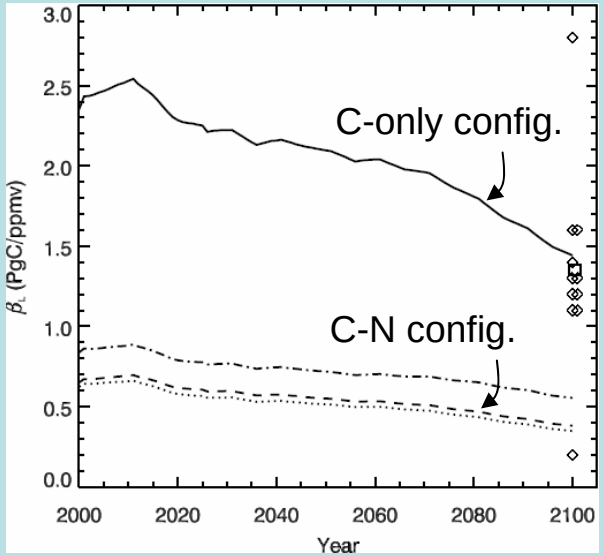
  Expt 1 (NCEP forcing) & Expt 2 (Coupled CAM-land)
  - Interest from international C^{4}MIP community

Land biosphere sensitivity to increasing atmospheric CO_2 (β_L)

CCSM with C-N coupling, compared to C4MIP



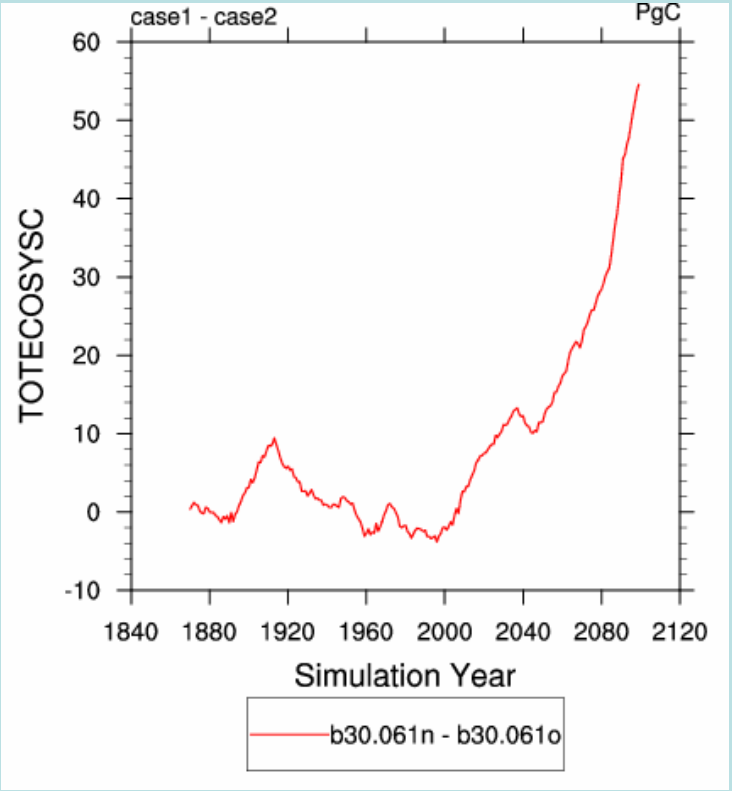
Offline CLM-CN results

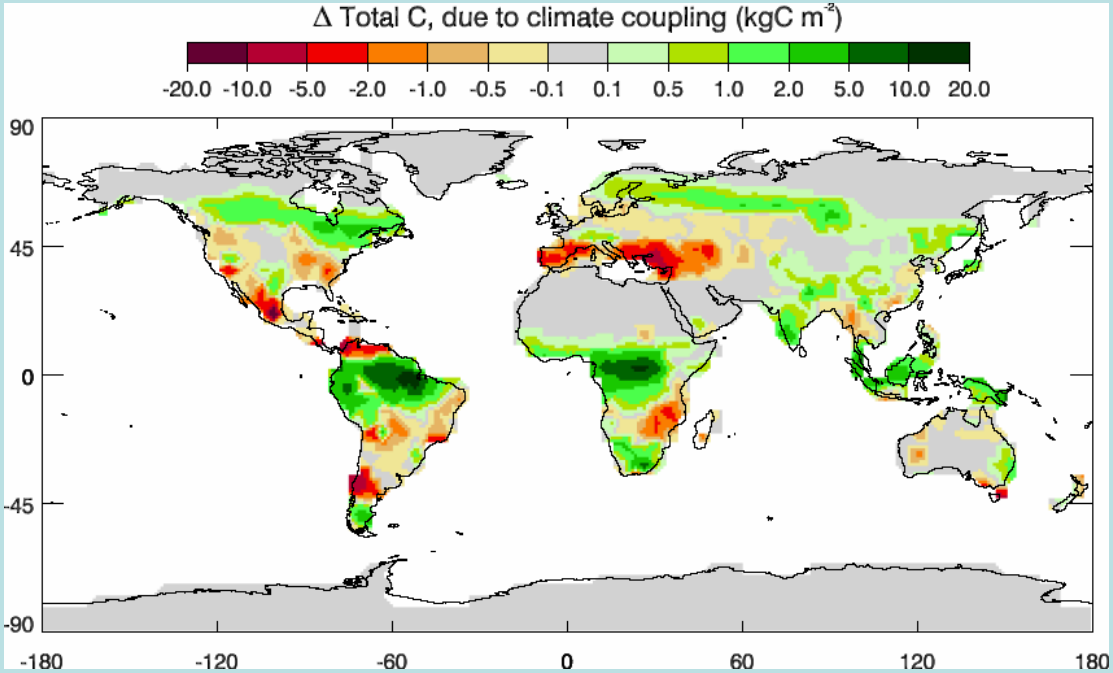


C-N coupling **reduces** the CO_2-fertilized carbon-uptake capacity of the land biosphere (as measured by β_L) by about a factor of 3.

Climate-carbon cycle feedbacks

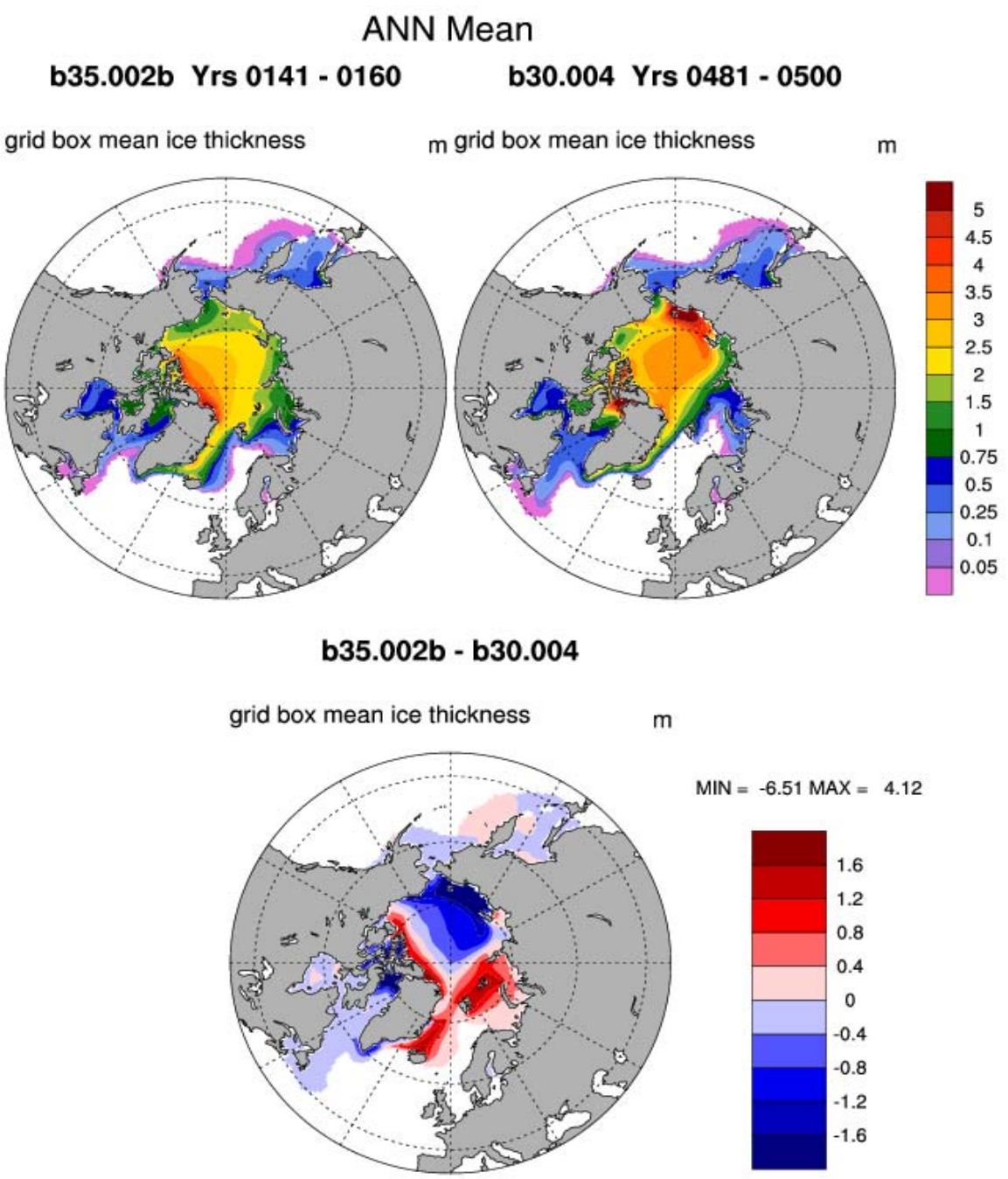
CO_2-induced climate change (warmer and wetter) leads to **increased** land carbon storage





CCSM 3.5

FV 1.9x2.5

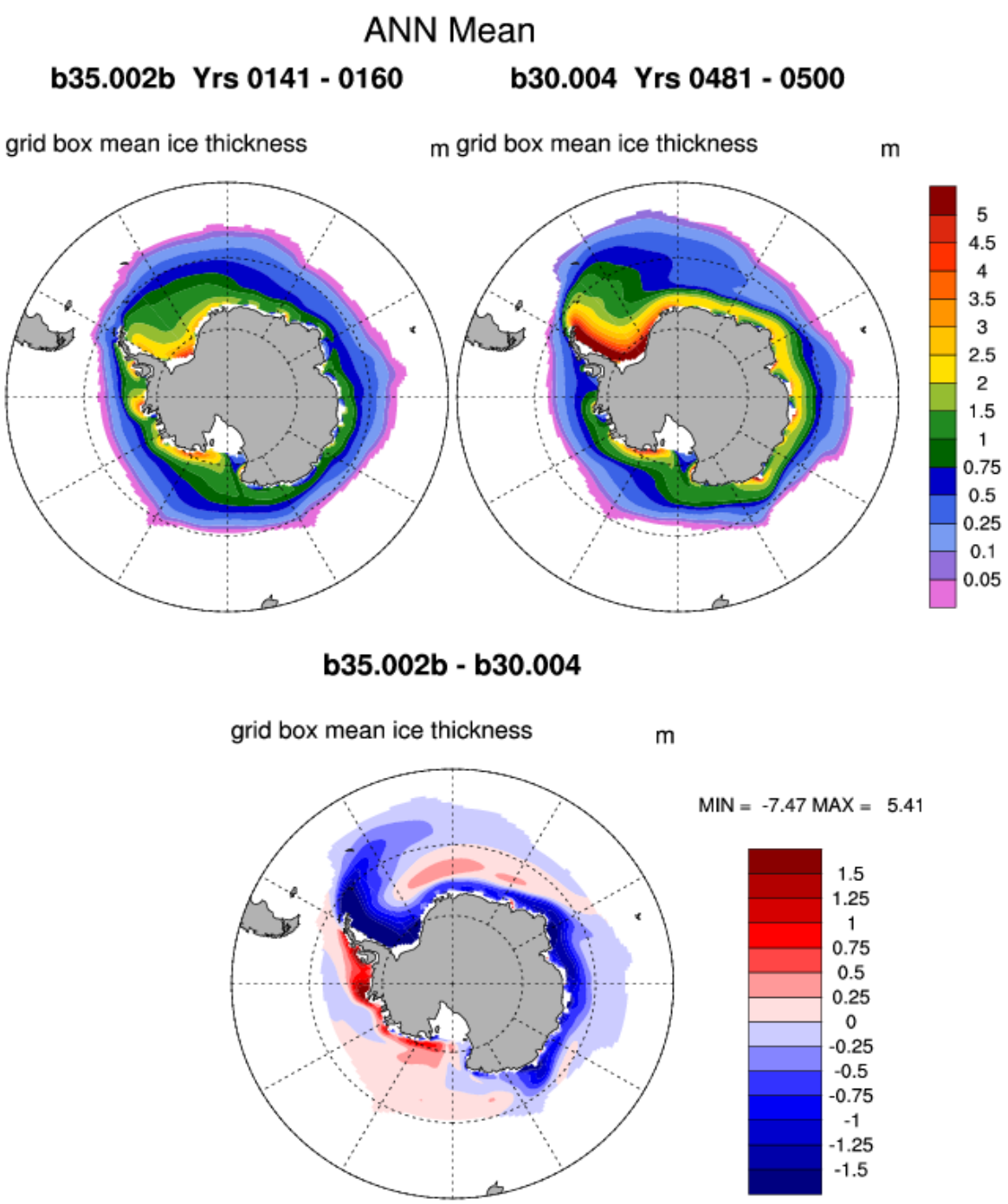


CCSM 3

T 42

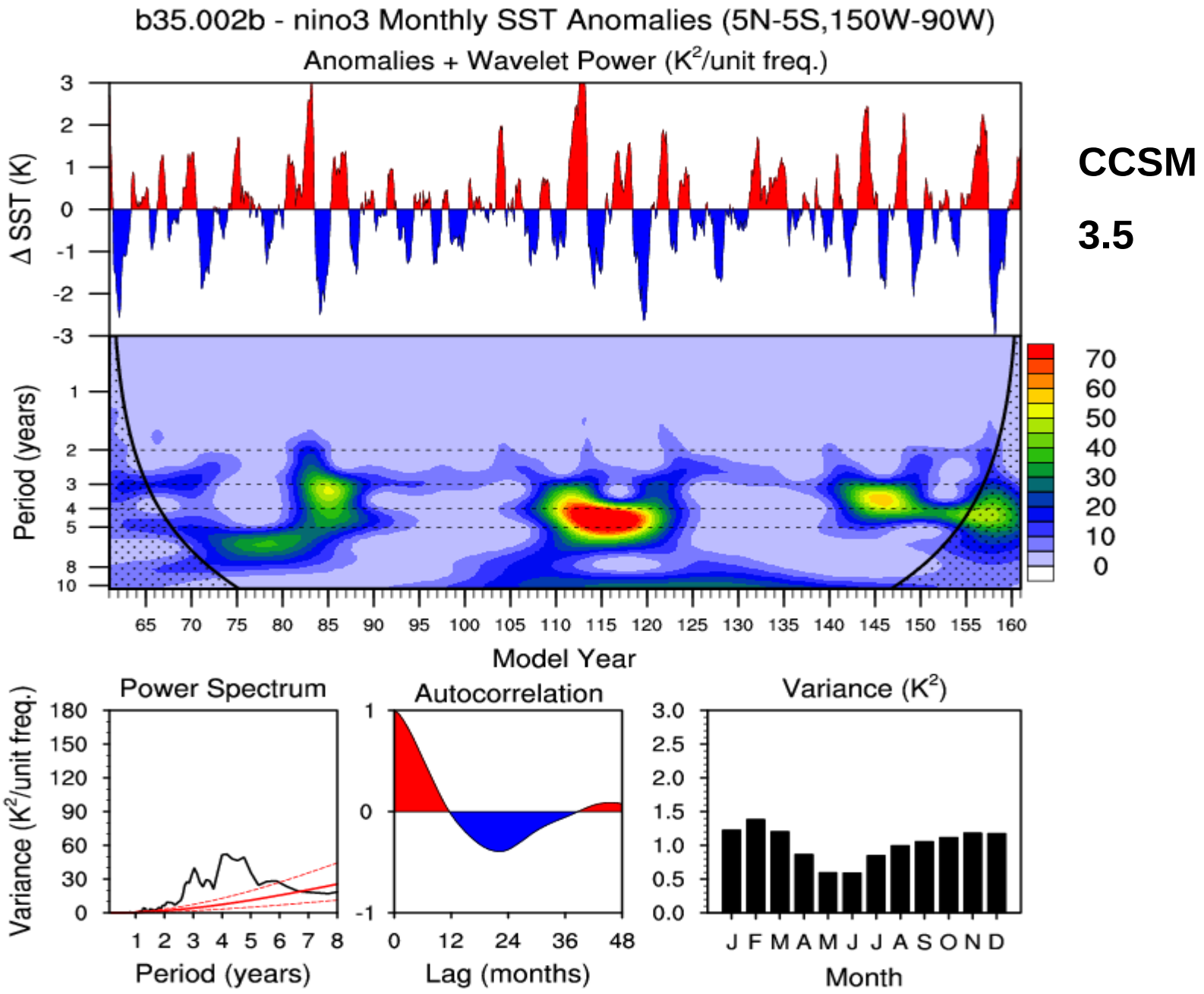
CCSM 3.5

FV 1.9x2.5



CCSM 3

T 42


b35.002b - nino3 Monthly SST Anomalies (5N-5S,150W-90W)
Anomalies + Wavelet Power (K²/unit freq.)
Δ SST (K)
Period (years)
Model Year
Power Spectrum
Variance (K²/unit freq.)
Period (years)
Autocorrelation
Lag (months)
Variance (K²)
Month
J F M A M J J A S O N D

CCSM

3.5

Conclusions

- Significantly reduced some major biases.
- ENSO frequency, mean tropical Pacific windstress and precip, high latitude (Arctic) temperature and low cloud biases.
- Much improved surface hydrology CLM3.5
- Improved ocean and sea ice components.
- Have assembled an interim version 3.5 so that a carbon-nitrogen cycle can be added, and run in an up-to-date version of CCSM.