New developments in climate prediction at NCAR: CCSM, Progress and Plans

Joe Tribbia*
NCAR
APEC Workshop 23 June 2010

*with G. Danabasoglu, J. Anderson

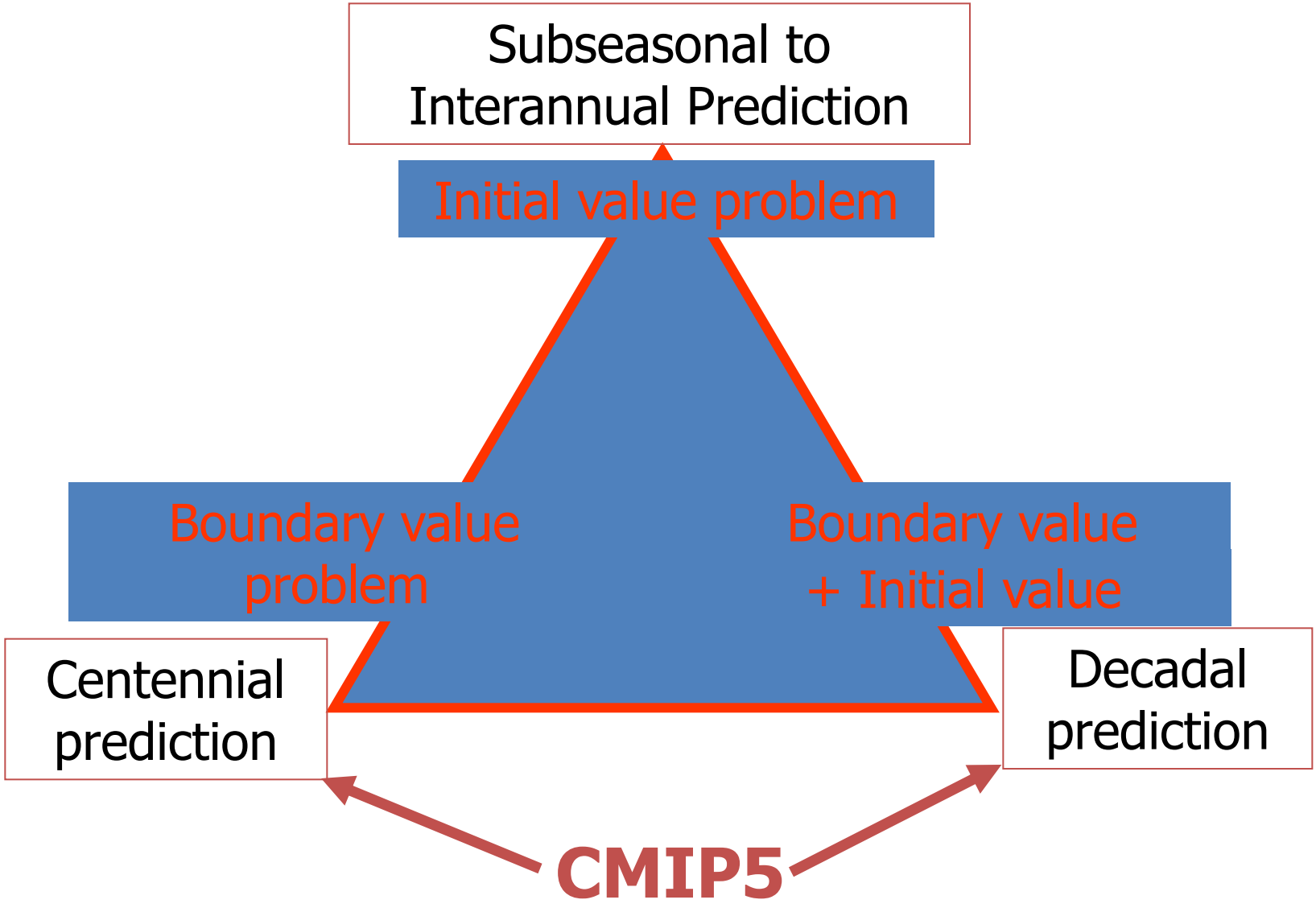
Outline

- Status of data assimilation
- Status of couple simulations–ENSO sensitivity
- Status of high resolution

NCAR's route to SEAMLESS Climate Prediction via AR5 CMIP5 'Decadal Predictions'

- Informed guidance on near–term evolution of the climate system
- Reduced uncertainty from GHG emission scenarios
- Information from 'initial state'
- Short range and higher resolution for regional guidance
- Target 'modes' of natural decadal variability (PDO, AMO, AO etc)

Climate Prediction

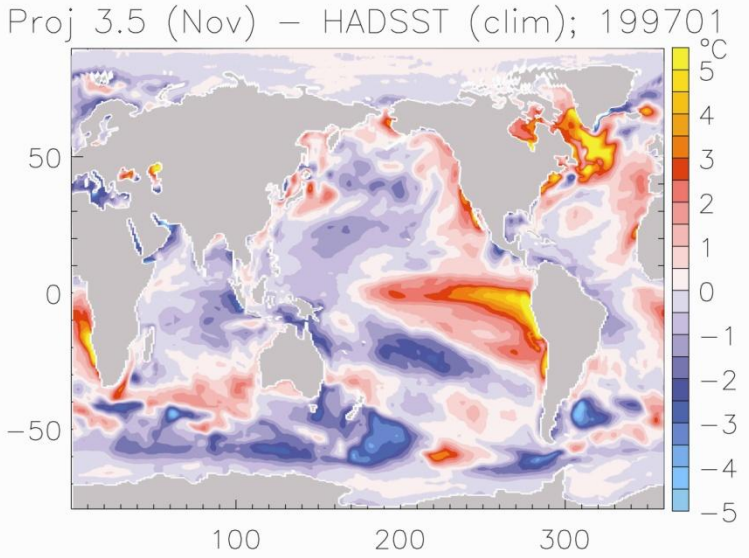


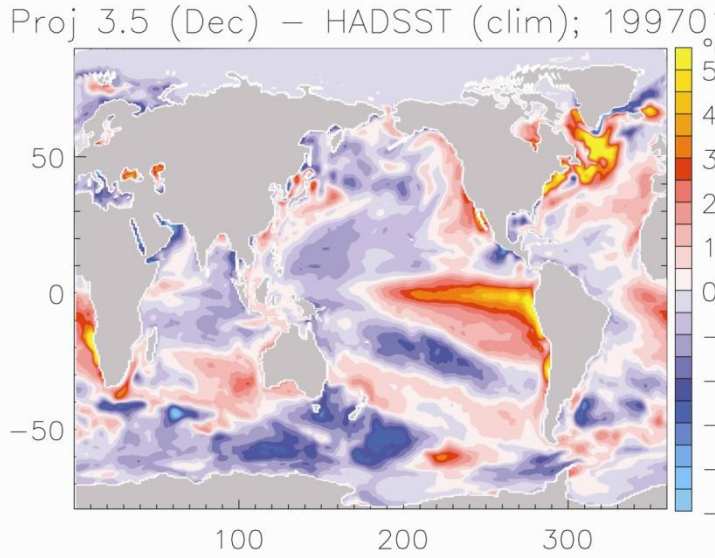
Initial Initialization Options

1) Use ocean model ‘hindcast/spin-up’ for ocean and ice, AMIP for land
2) Use modified ocean analyses from another center, compatible ice and AMIP for land
3) Embark on ocean data assimilation using DART (Jeff Anderson et al CISL/IMAGe)

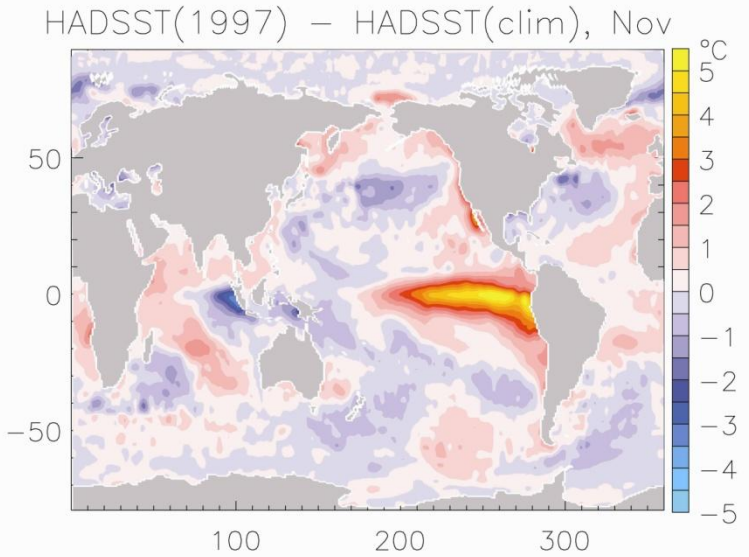
Using GFDL Analysis
Successful prediction of ’97-’98 ENSO – one year in advance

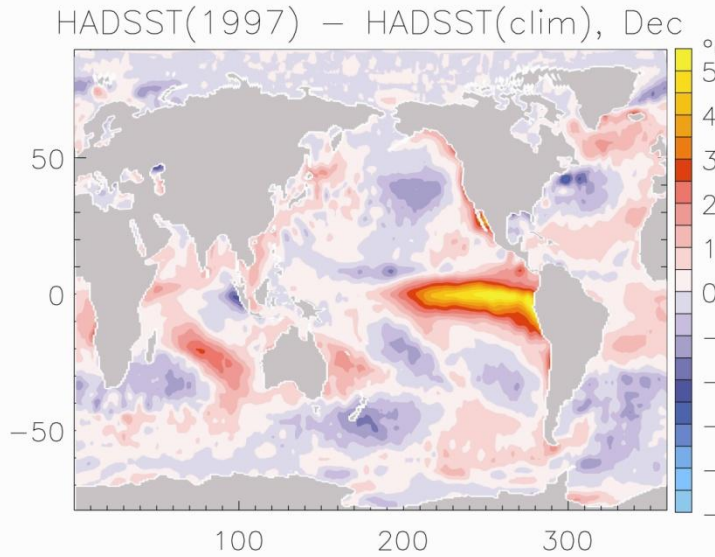
Forecast Anomalies wrt HadSST Climatology





Analyzed Anomalies

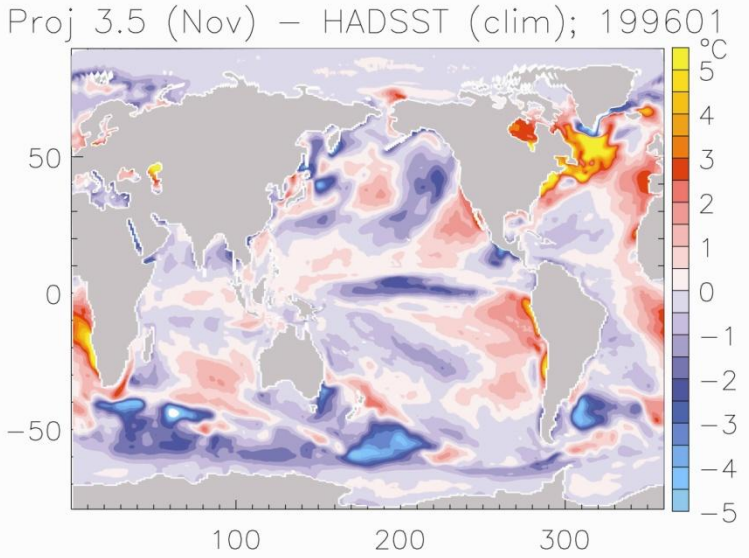


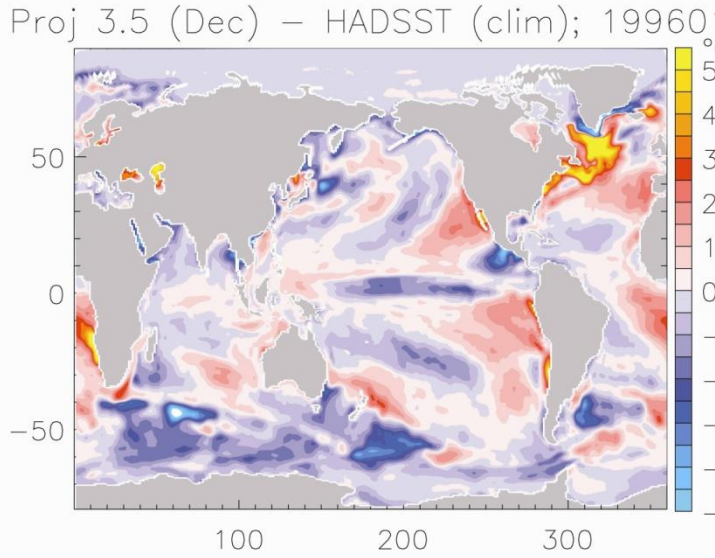


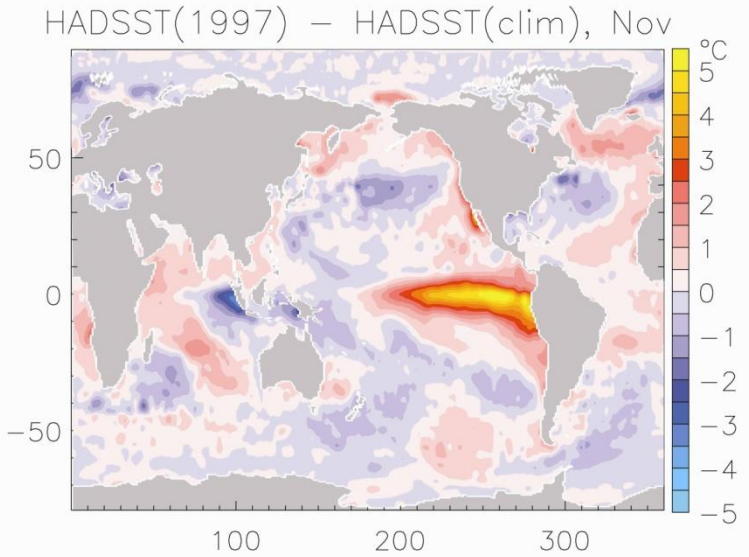
Two year prediction---not successful

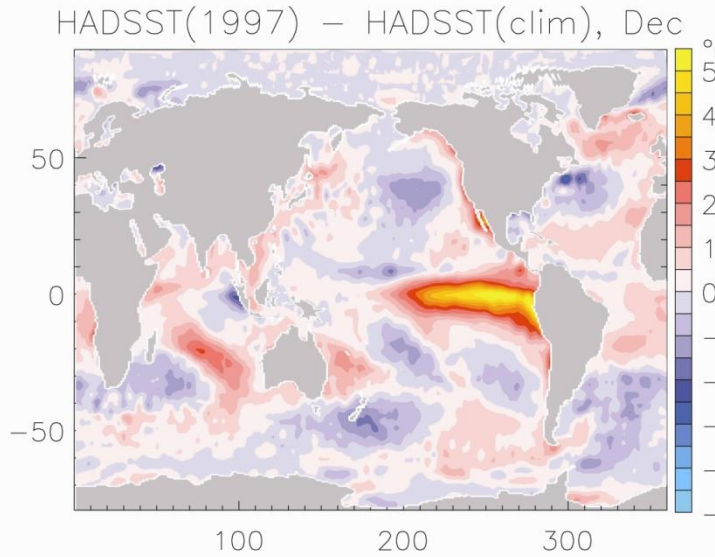
Forecast Anomalies

Analyzed Anomalies



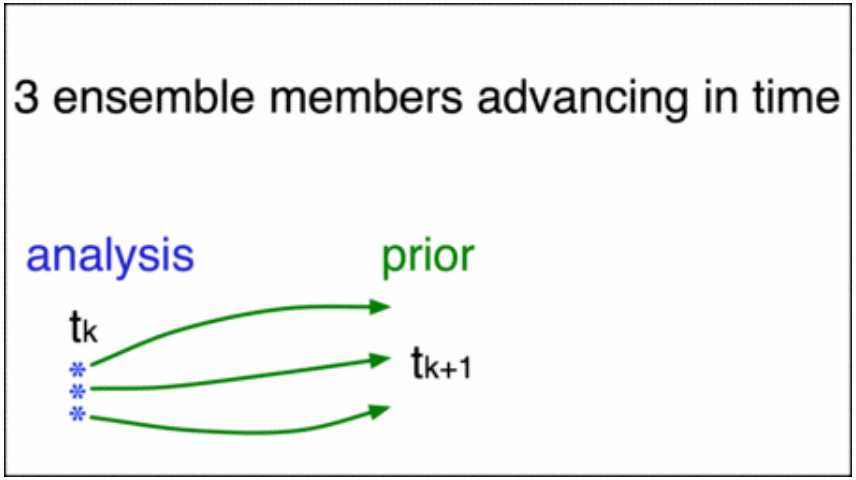






Initialization /drift issue push to ODA

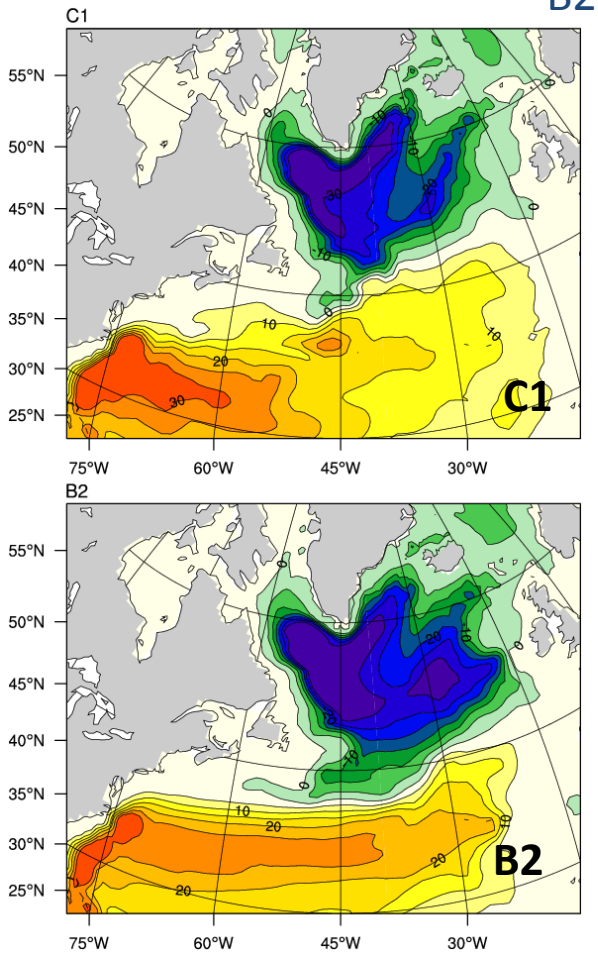
Ensemble Kalman Filter Assimilation in Schematic Form



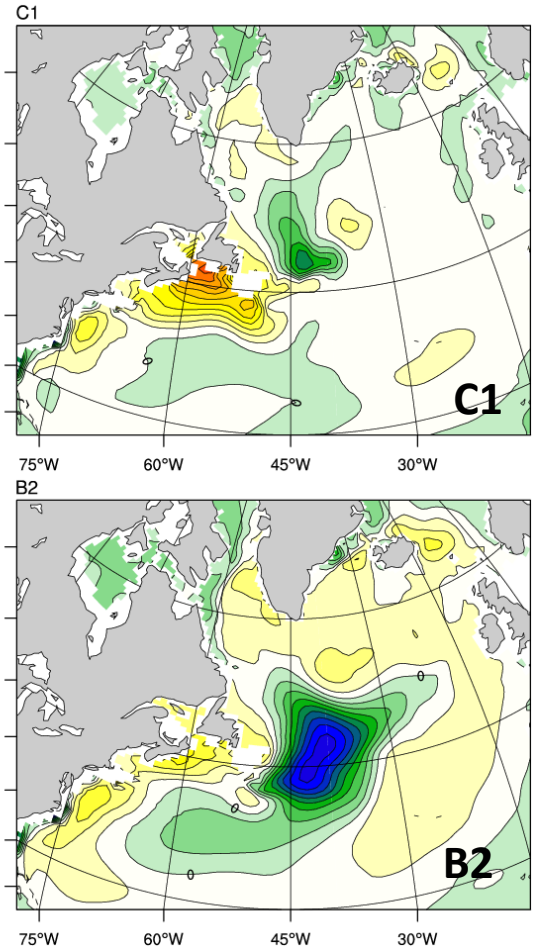
- Initial configuration: 1° data atm; ens. ocean (8 members)
- Daily assimilation :T&S nudge SST
- Successful with adaptive cov. Inflation
- Problem: ensemble too sharp

Benefits of Assimilation: reduced bias good AMOC

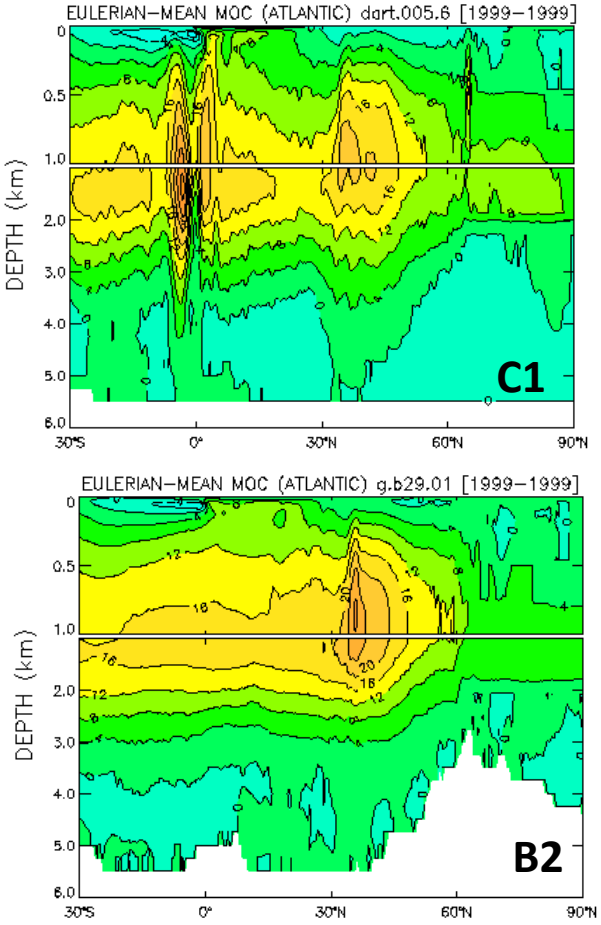
B2=hindcast C1=ocean assimilation



Barotropic Streamfunction

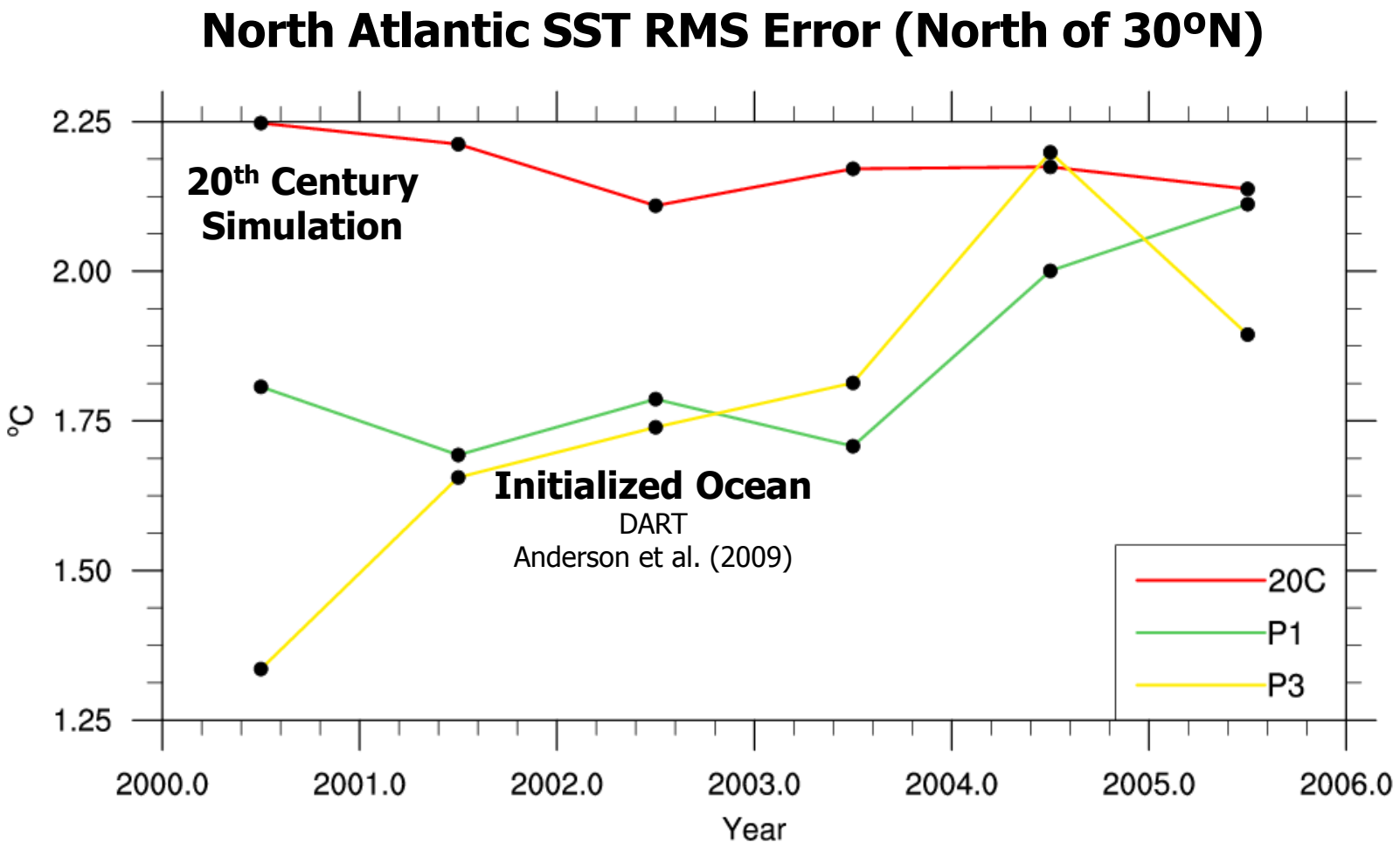


TS anomaly



AMOC

CCSM4.0: Initialized (Decadal) Predictions



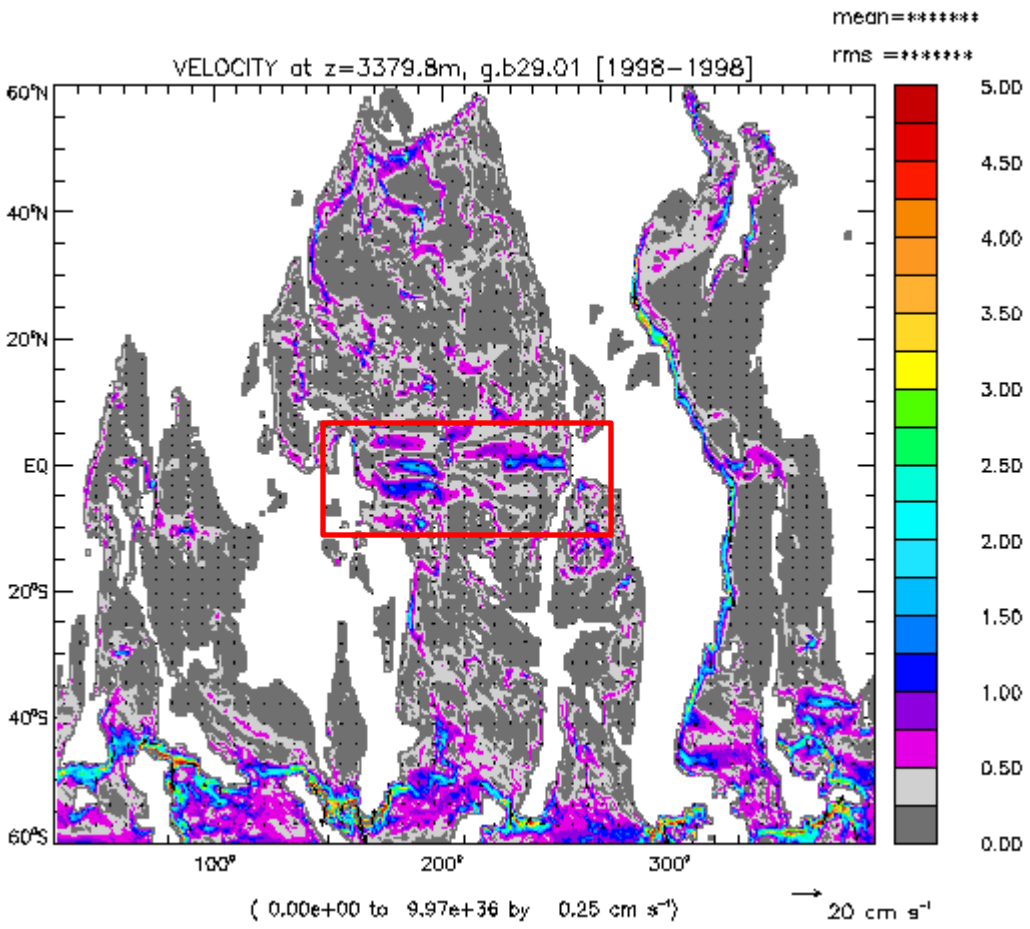
Persistence of large-scale SST bias reduction

Yeager et al. (2010)

Move to ‘weakly coupled’ assimilation

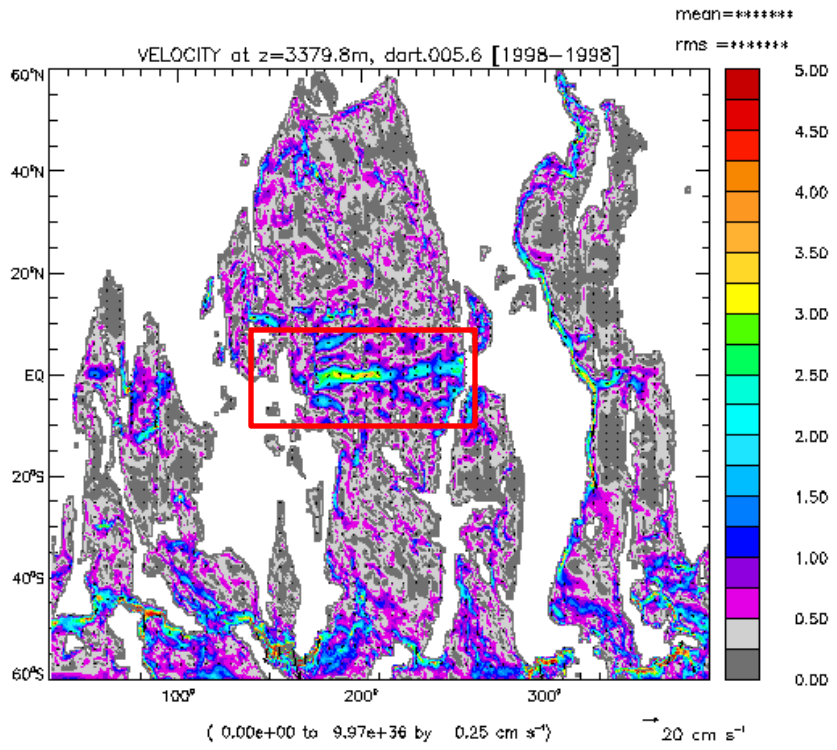
- Atmospheric model assimilates obs with ’observed’ SST (80 members)
- 48 member atm ensemble forces 48 member ocean ensemble assimilating T, S, SST(nudged)
- Repeat daily
- Resolves ensemble sharpness issue
- HOWEVER…..

Problem:
deep ocean currents

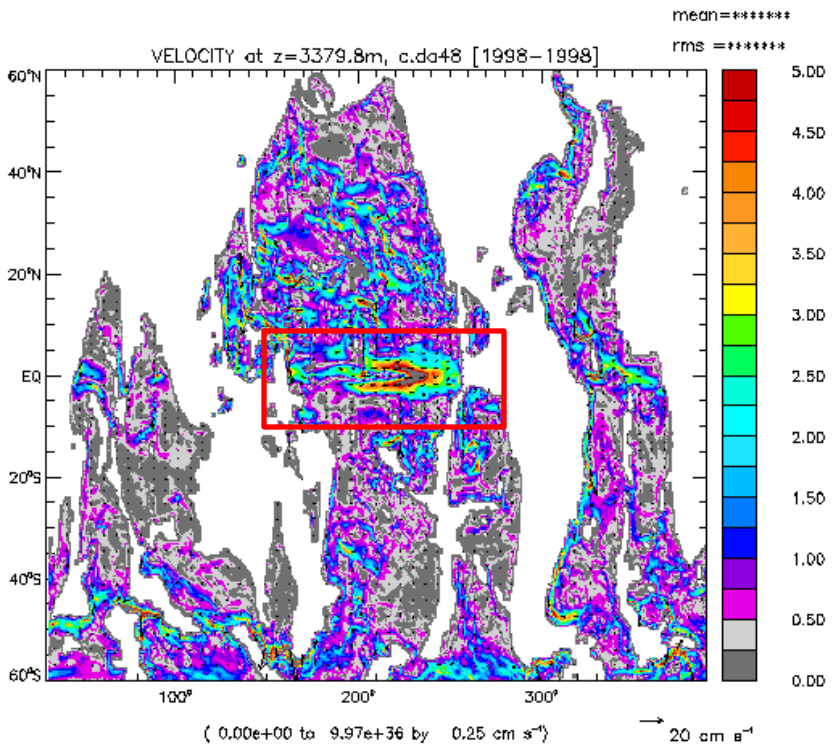


Problem : deep ocean currents

DART Ocean Assimilation



Weakly Coupled assimilation



Present CCSM Status

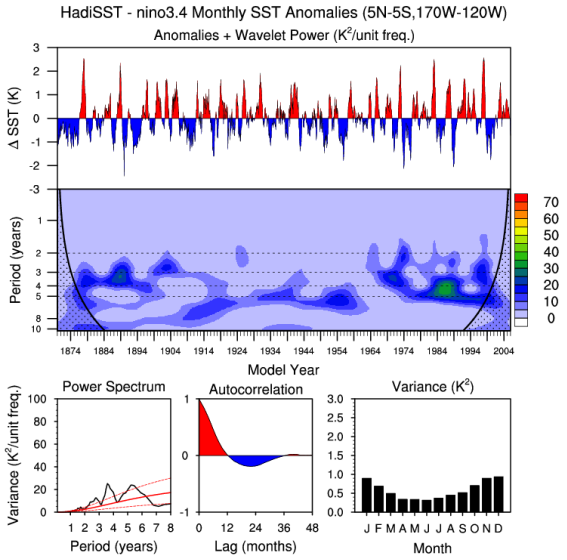
- Following CMIP5 Experimental Design (Taylor et al. 2009):
  - o A set of coordinated climate model experiments;
  - o Five-year design, but majority completed in 2010;
  - o *Initialized decadal prediction* and climate change (through 2300)
  - o Includes carbon cycle, paleoclimate and whole atmosphere

Release Schedule

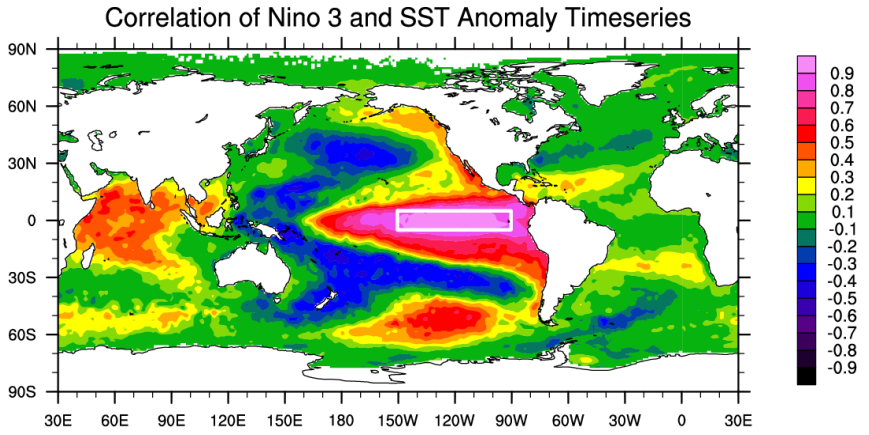
- April 1, 2010: CCSM4.0 release
  - ✓ full documentation, including User's Guide, Model Reference Documents, and experimental data
- June 21, 2010: CESM1.0 release
  - ✓ ocean ecosystem, CAM5 interactive chemistry, WACCM

ENSO as Observed
ENSO metrics for CCSM4/CESM1

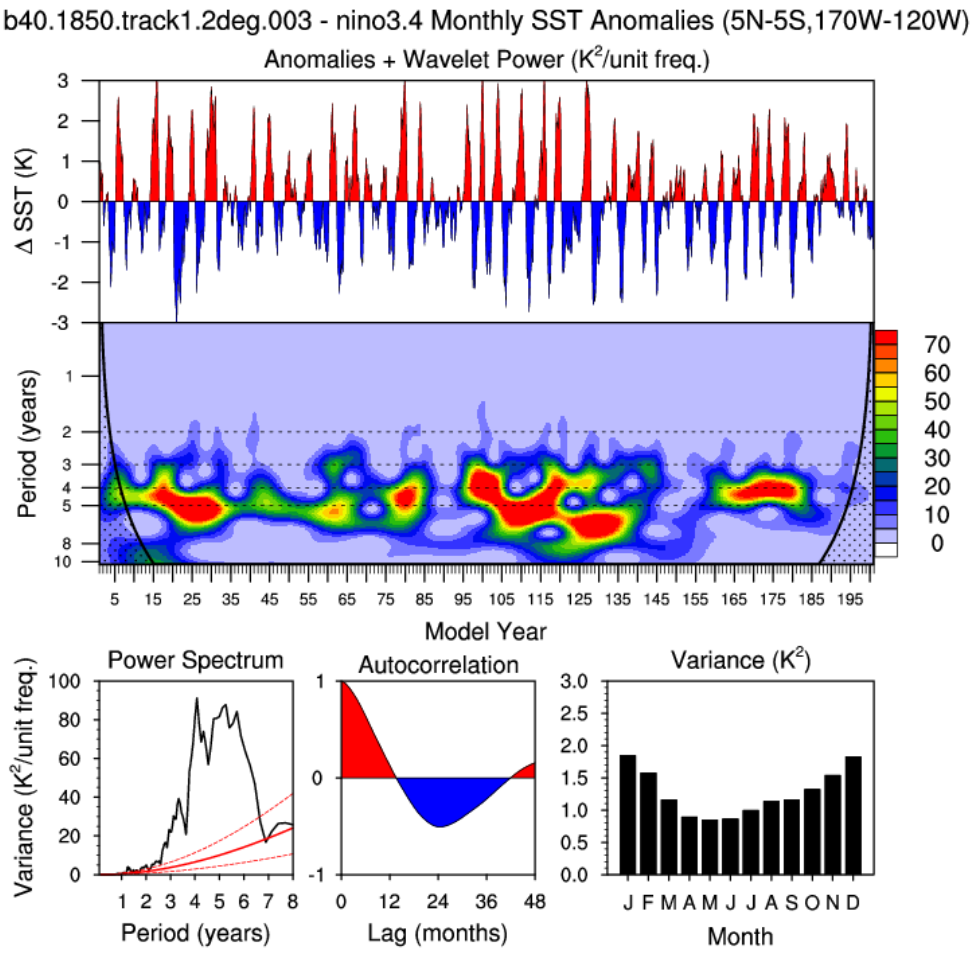
Nino 3.4 time series, power
And wavelet analysis



Correlation with nino3.0

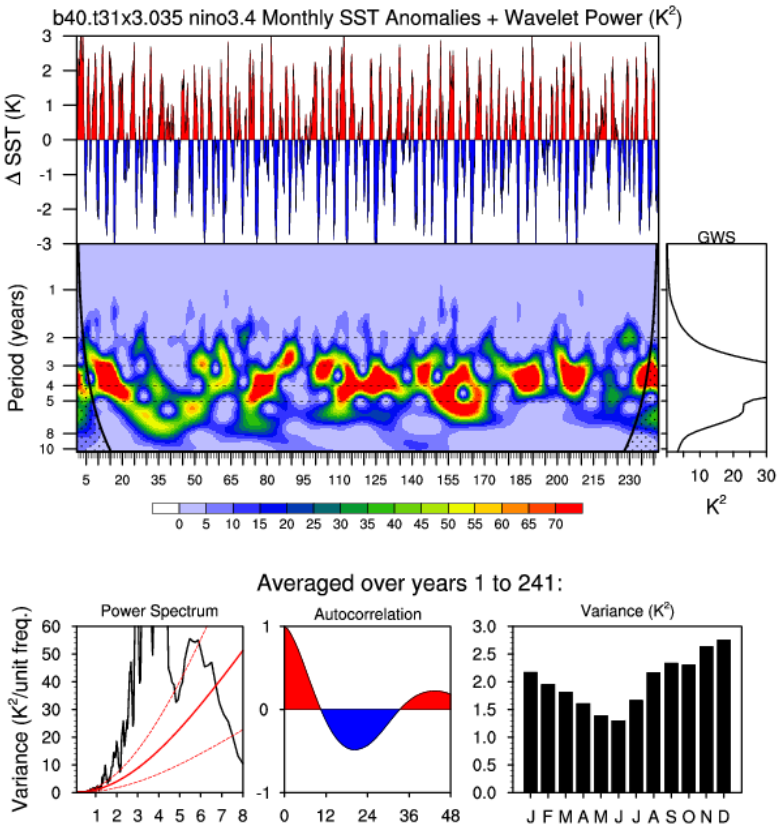


Natural variability of ENSO in CCSM4: CAM4 2° 1850 control

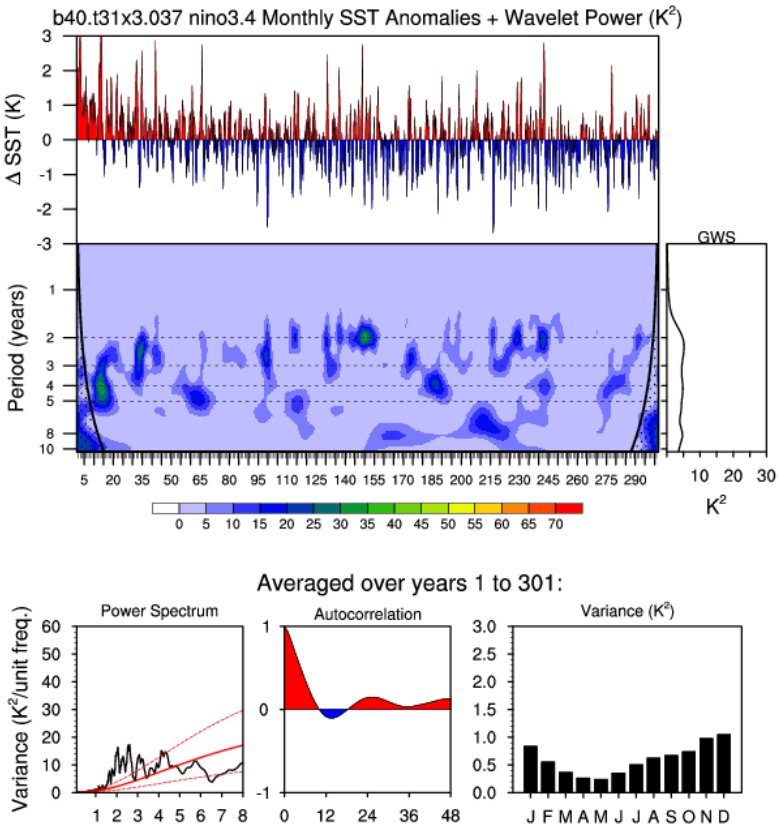


Turbulent Mountain Stress Effect in Paleo Model

T31 CAM4 no TMS

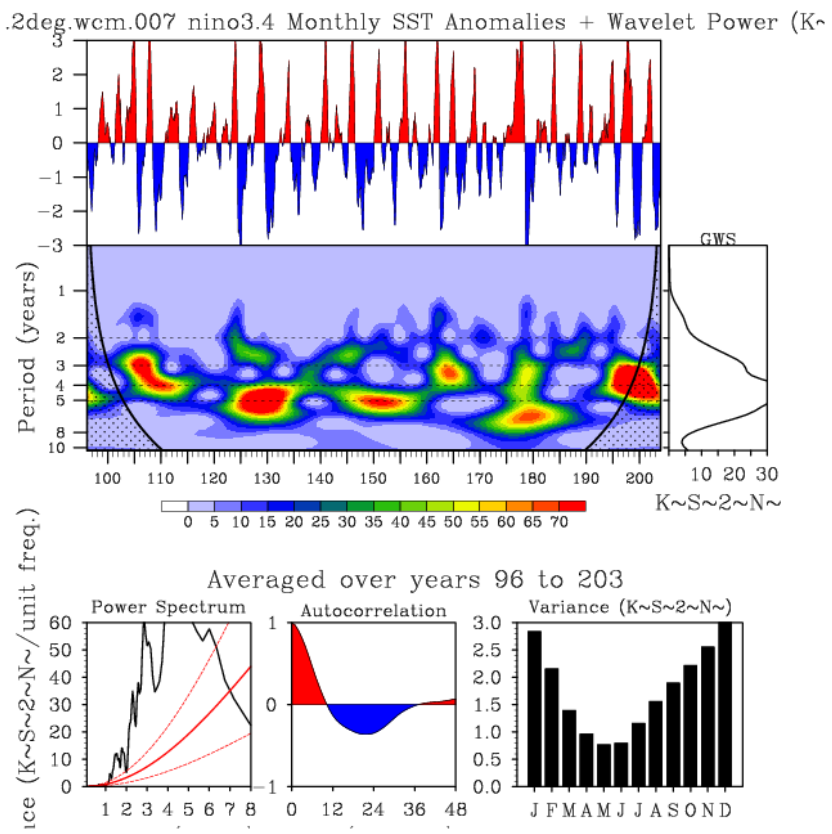


T31 CAM4 with TMS

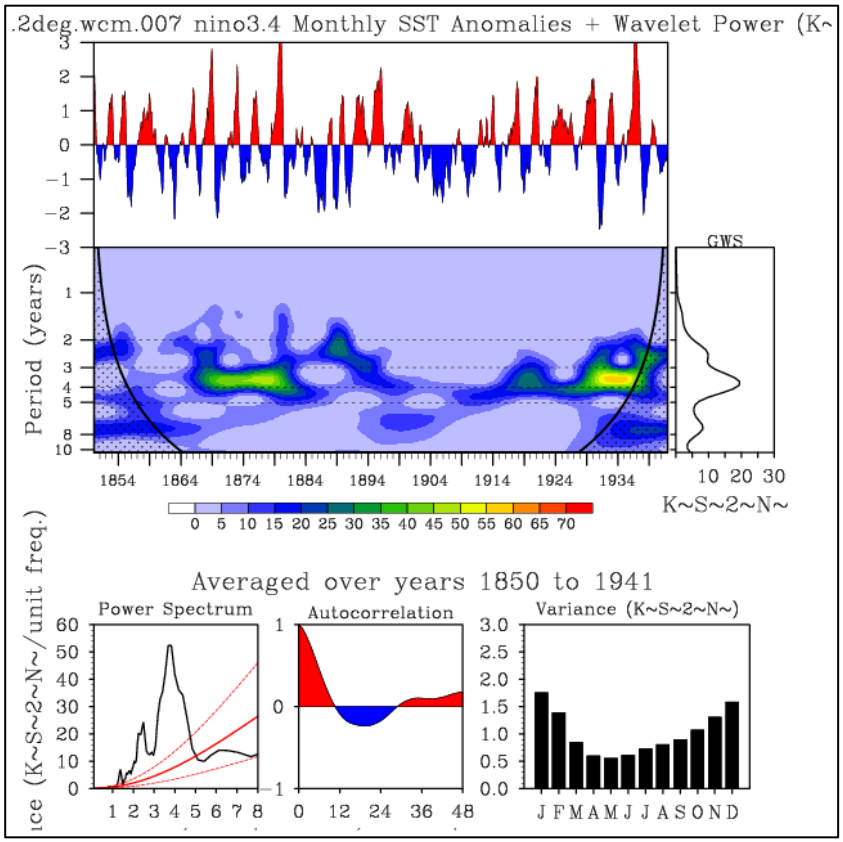


Volcanoes and ENSO in WACCM 1882,1902,1951,1991

WACCM Control Run

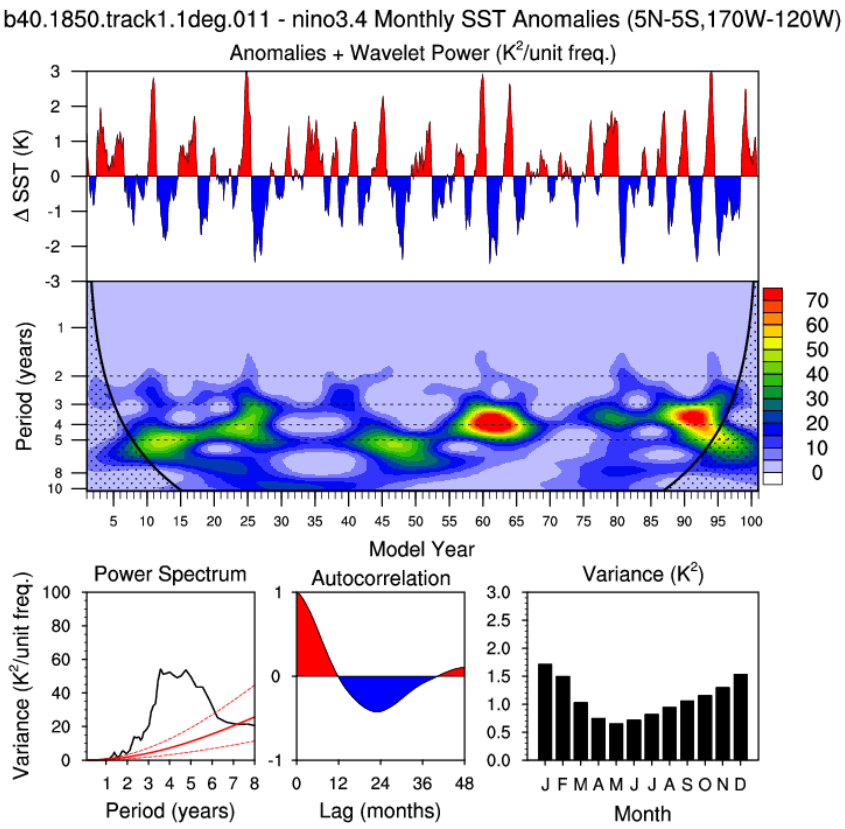


WACCM with volcanoes

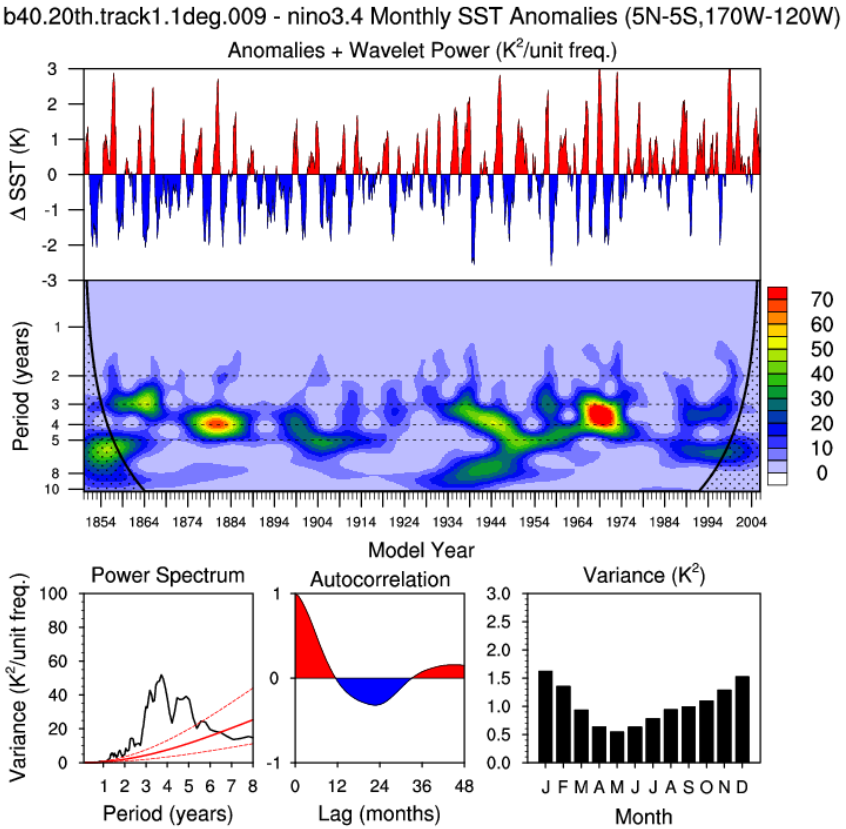


20th Century Climate change and ENSO

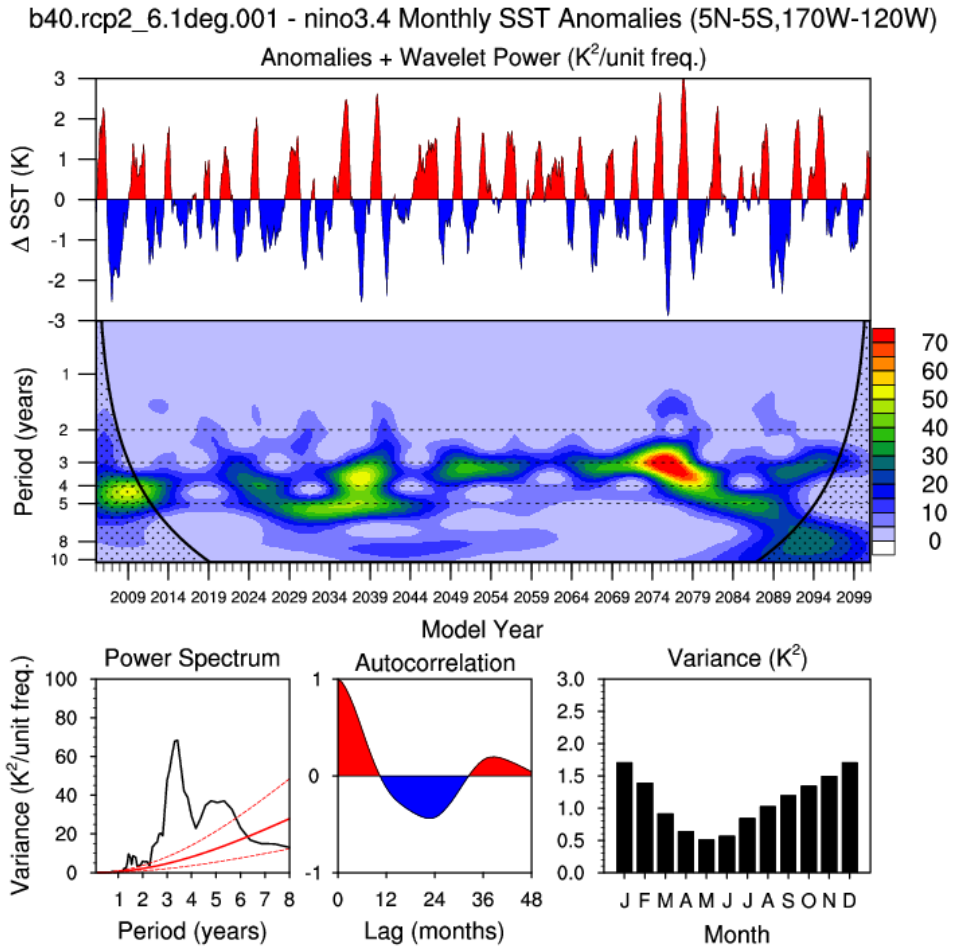
Pre-industrial ENSO



ENSO in the 20th Century

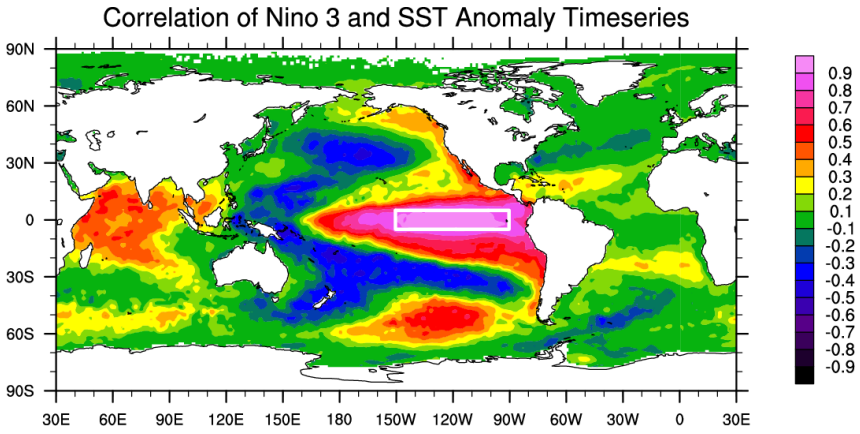


ENSO in a warming climate
CCSM4

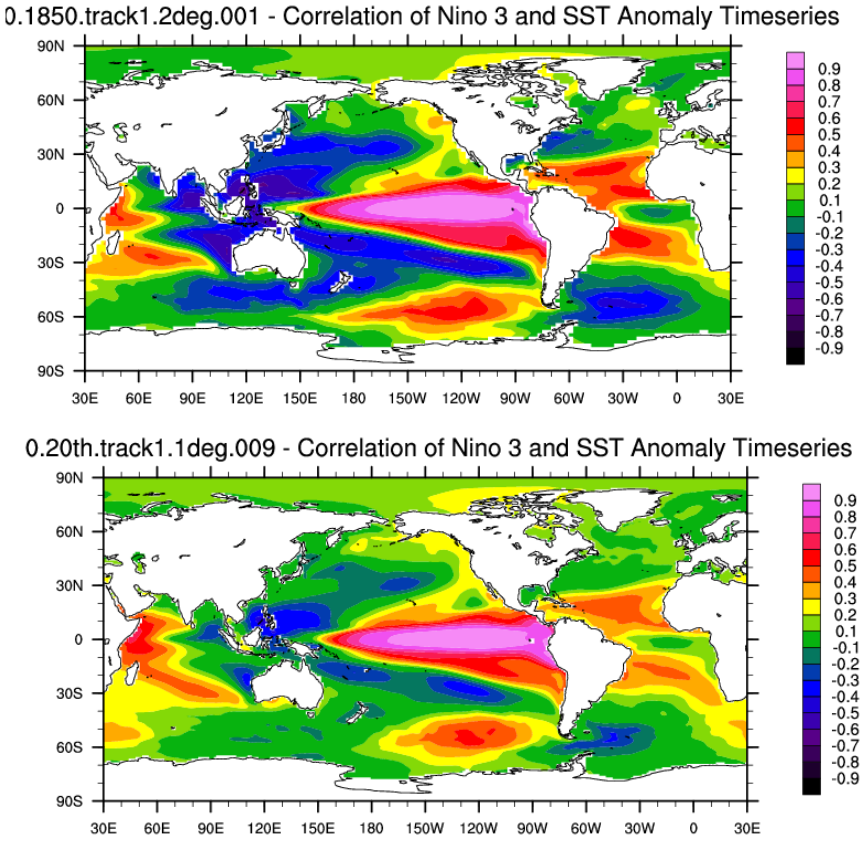


ENSO structure and resolution

Observed Correlation
SST with nino3

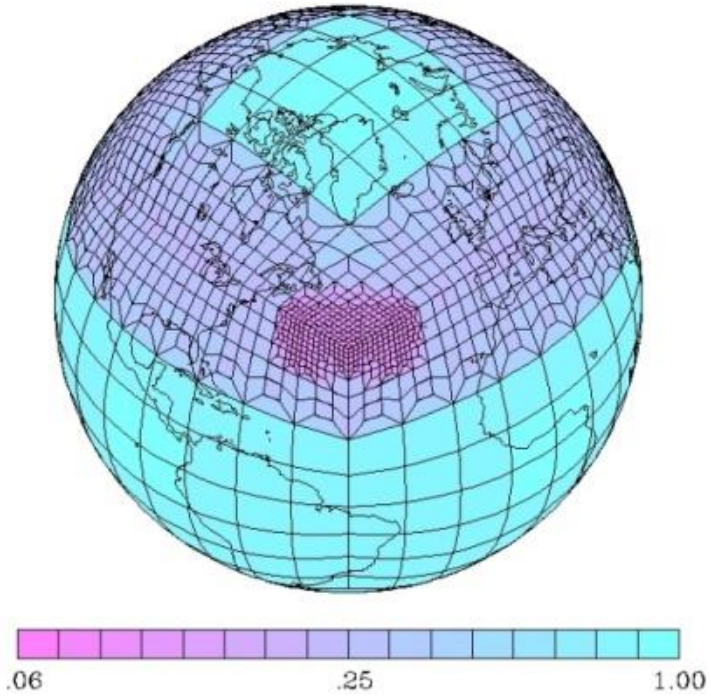


2° vs 1° CAM4 structure

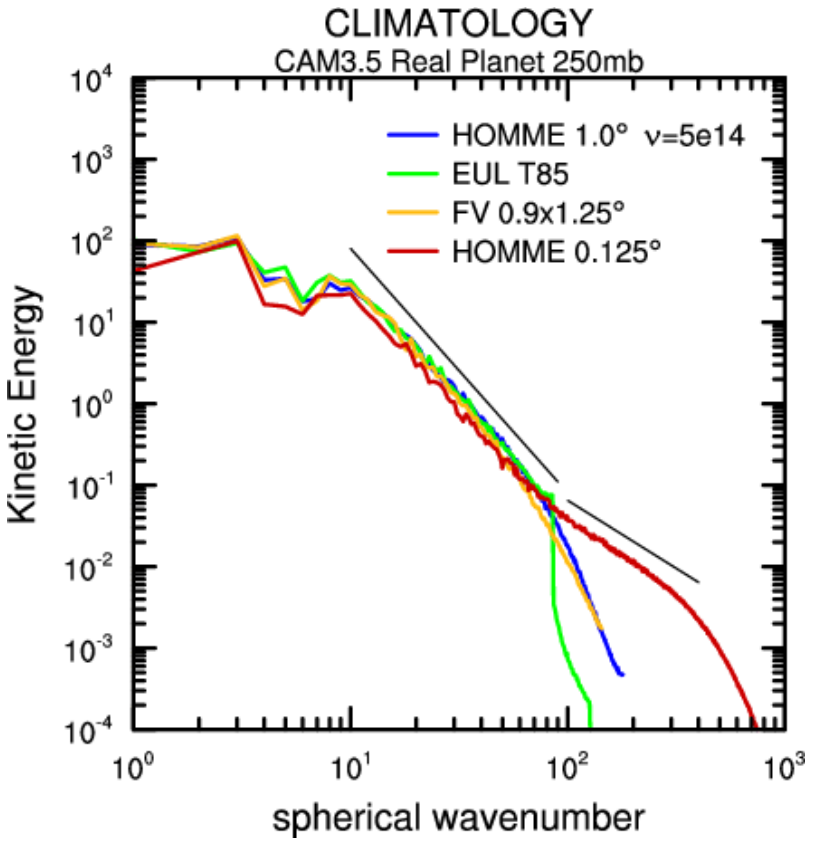


3) High Resolution Option: 1/8°atmosphere 1/10° ocean

Spectral Element Cubed Sphere



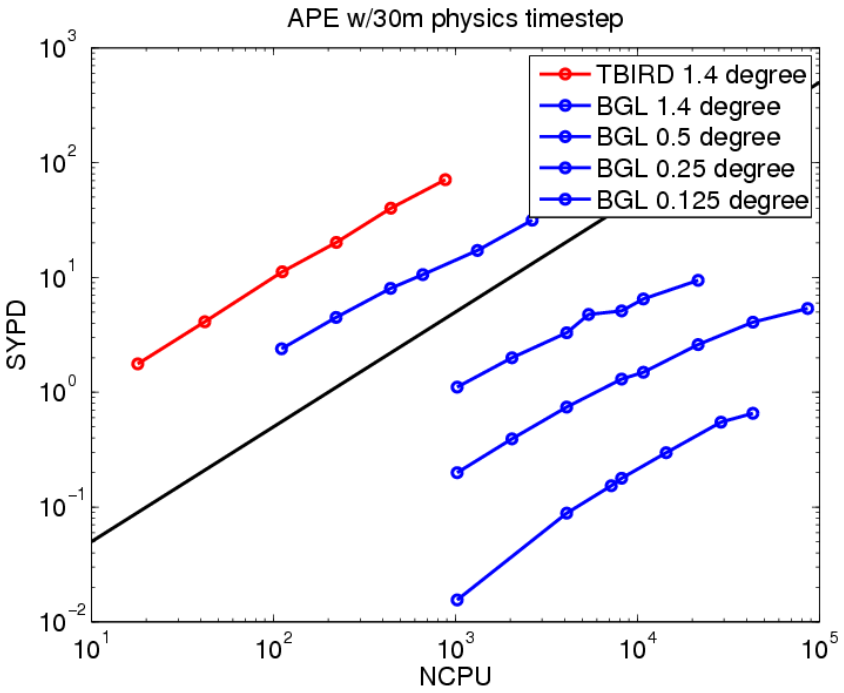
Mesoscale Variability :-5/3



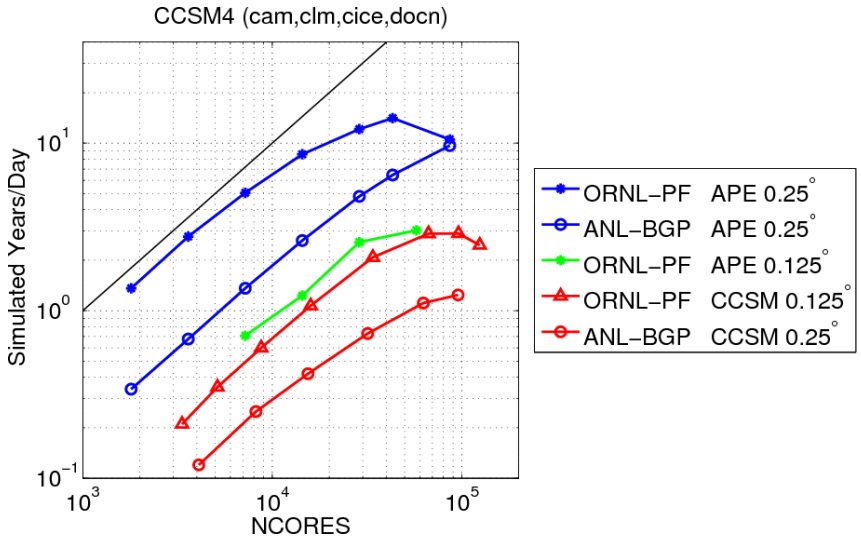
Courtesy of Mark Taylor SNL

Highly Scalable

At 1/8° model scales to 100K processors

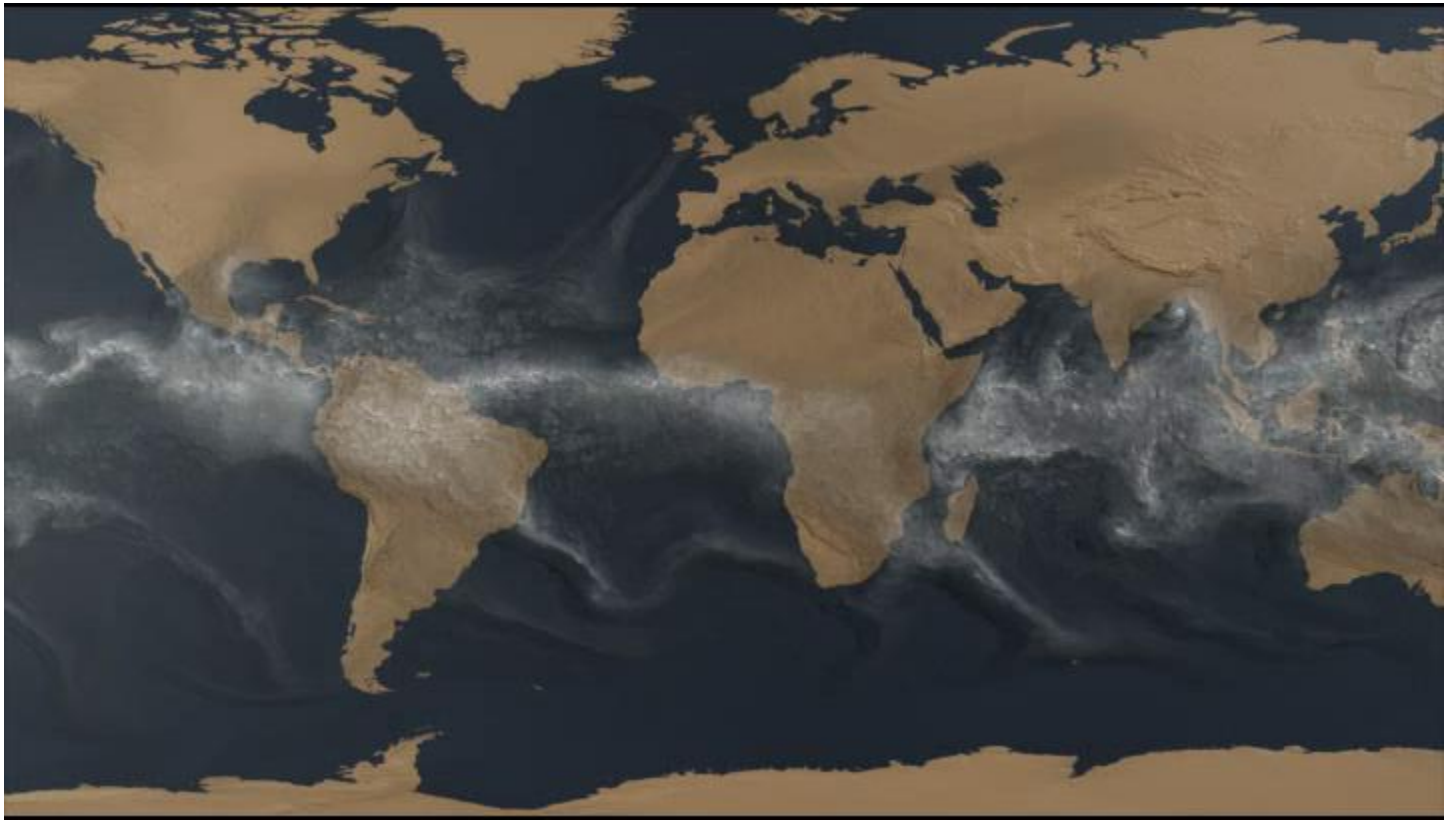


Fully coupled CCSM also scales out to 100K processors



Courtesy of Mark Taylor SNL

AMIP(2000) integration at 1/8°



Courtesy of Mark Taylor SNL

Summary

- NCAR developing community tools for climate prediction
- Coupled Ensemble Kalman Filter for initialization
- ENSO sensitivity to mountain stress, volcanoes and GHG
- High resolution ESM capability

Issues and Questions for Climate Prediction

- Very few observed realizations of climate variability(1-4 decadal; 10-30 S-I)
- Many climate modes of variability reside mainly in the ocean- *poorly observed -especially before 2003!*
- Are atmospheric decadal modes of variability predictable in any sense?
- Do we have the proper tools to realize the predictability? (Observations, assimilation, models)

Final Comments

- Climate in Prediction in Infancy
  (~NWP in 1965)
- Climate Prediction is NOT extended weather Prediction
- Bad is GOOD (at this point)