The 1997-1998 El Niño: Evaluating a Variety of Methods to Test Climate Model Response

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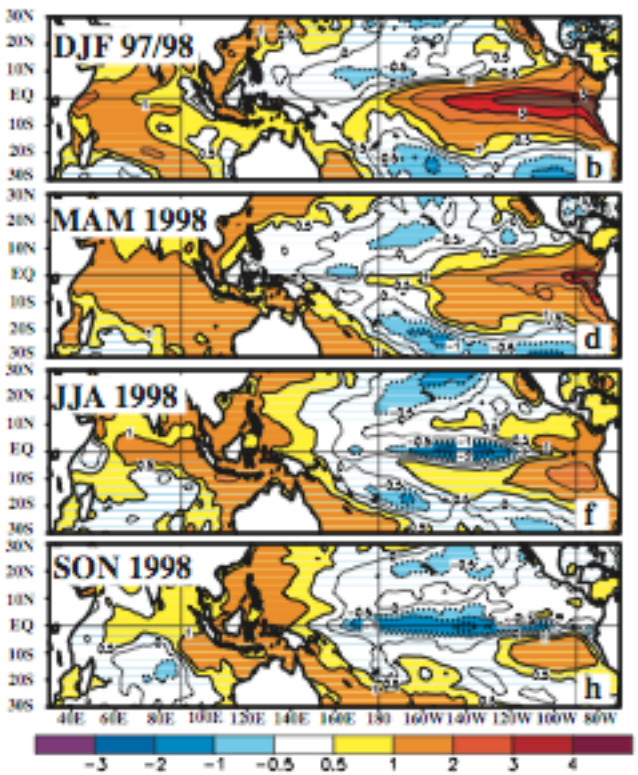
Greetings from Bob Cess

Outline

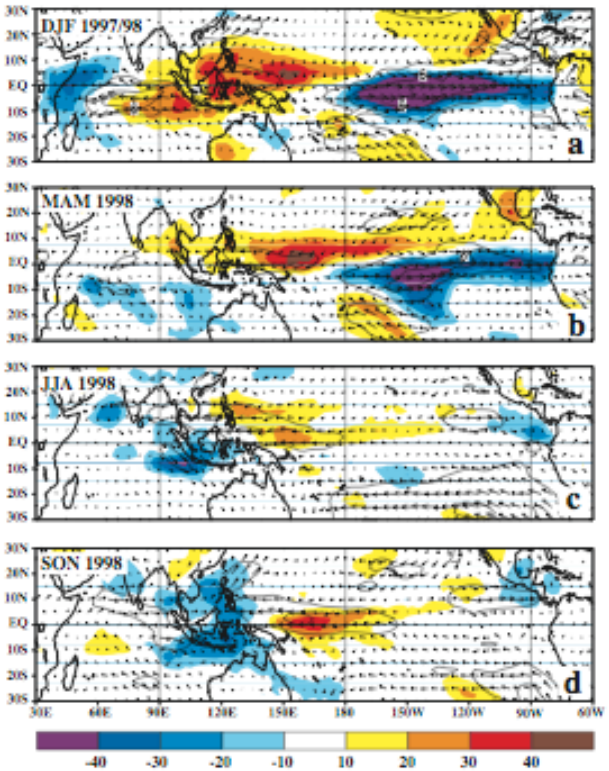
- The 1997-98 El Niño (anniversary)
  - Large-scale effect effects
  - Characteristics – case study
- Models from IPCC/AMIP
- Evaluating models
- NWP approach

The 1998 El Niño as a case study

Temperature anomaly



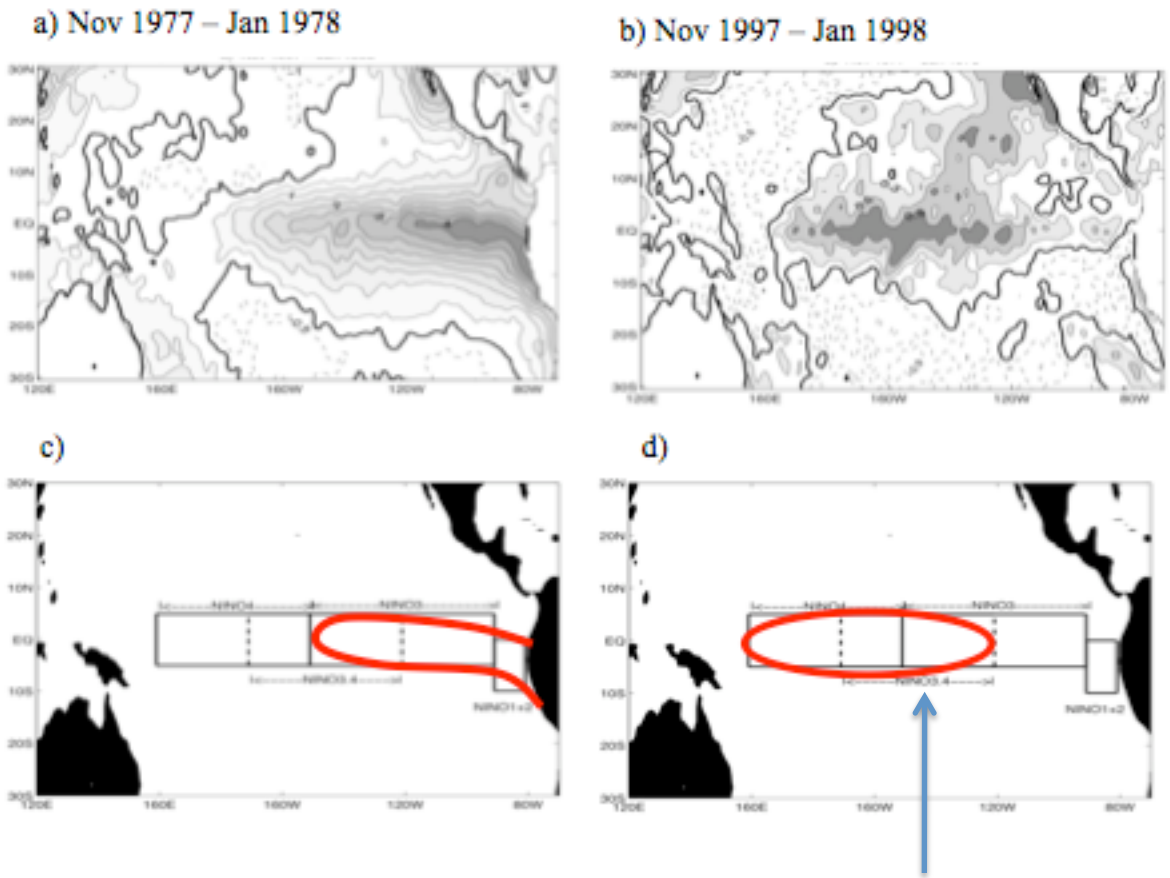
OLR anomaly and 850 hPa wind anomaly



Climate Assessment for 1998 Bell,et al. BAMS, Vol. 80, No. 5, May 1999

Kao and Yu (J. Clim. in revision) characterized the 1997-98 El Niño

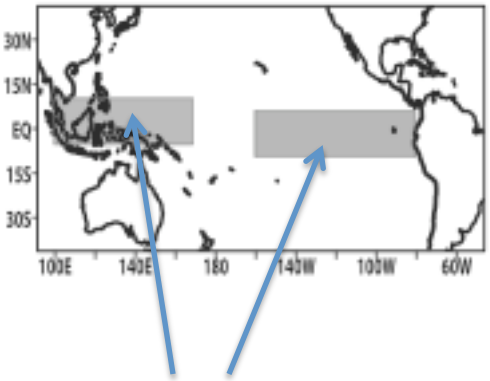
SST anomalies



This type of ENSO does not involve thermocline variation and is likely forced by the atmosphere. It has a stronger teleconnection with the Southwestern Indian Ocean.

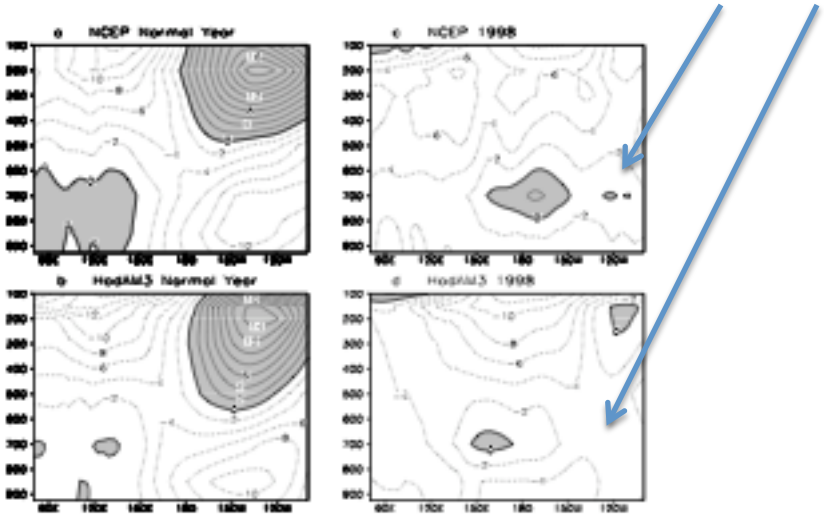
Lu et al. et al. paper

- El Niño paper
- Diagnose models using CERES data for 1998



Study areas

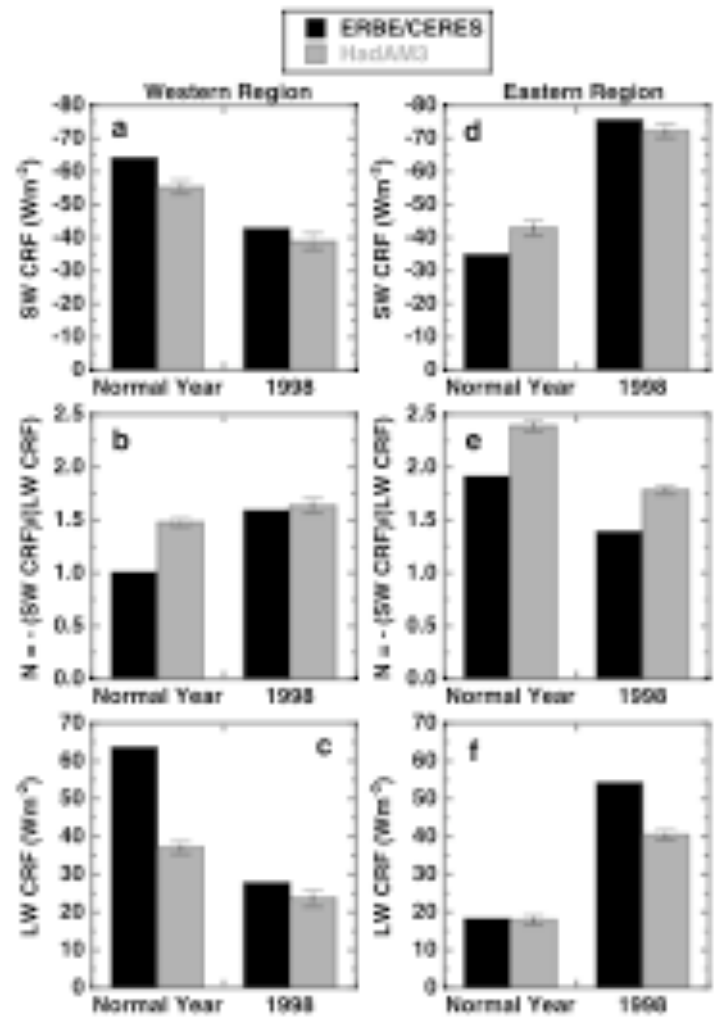
Zonal wind response to 98 El Niño



We found the HadAM3 was the only model to successfully simulate the Walker circulation collapse.

We used the ratio of SW_{crf} to LW_{crf} to show the cloud height change from East to West Pacific

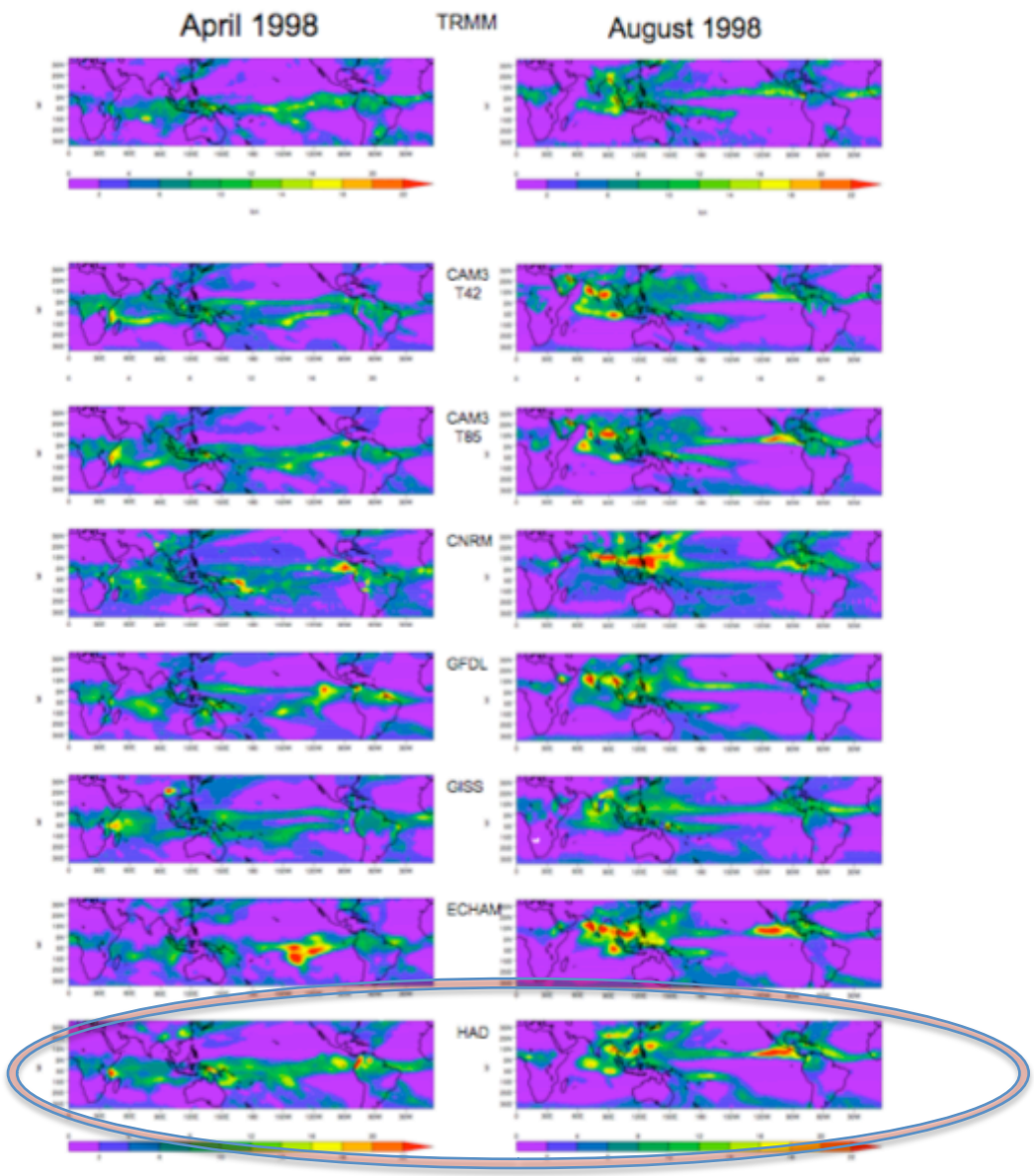
$$N=-(SW_{crf}/LW_{crf})$$



Clouds higher and deeper in the East in 1998

We looked through the IPCC-AMIP data base and we were hard-pressed to find any other models that produced a believable response to the El Niño

AMIP models' precipitation showed a wide range of response to the 1997-98 El Niño



A lot of things going on…

Minghua Zhang introduced a slightly modified representation of stream function to simplify presentation of the Walker circulation

$$\frac{1}{a\cos\theta}\frac{\partial u}{\partial \lambda}+\frac{\partial v}{a\partial\theta}+\frac{\partial \omega}{\partial p}=0$$

$$\frac{1}{a\cos\theta}\frac{\partial u}{\partial \lambda}+\frac{\partial v}{a\partial\theta}+\frac{\partial \omega}{\partial z}=0$$

Rewrite continuity equation for z instead of p

Or simply

$$\frac{\partial \rho u}{\partial x}+\frac{\partial \rho v}{\partial y}+\frac{\partial \rho \omega}{\partial z}=0$$

Define the stream function and velocity potential

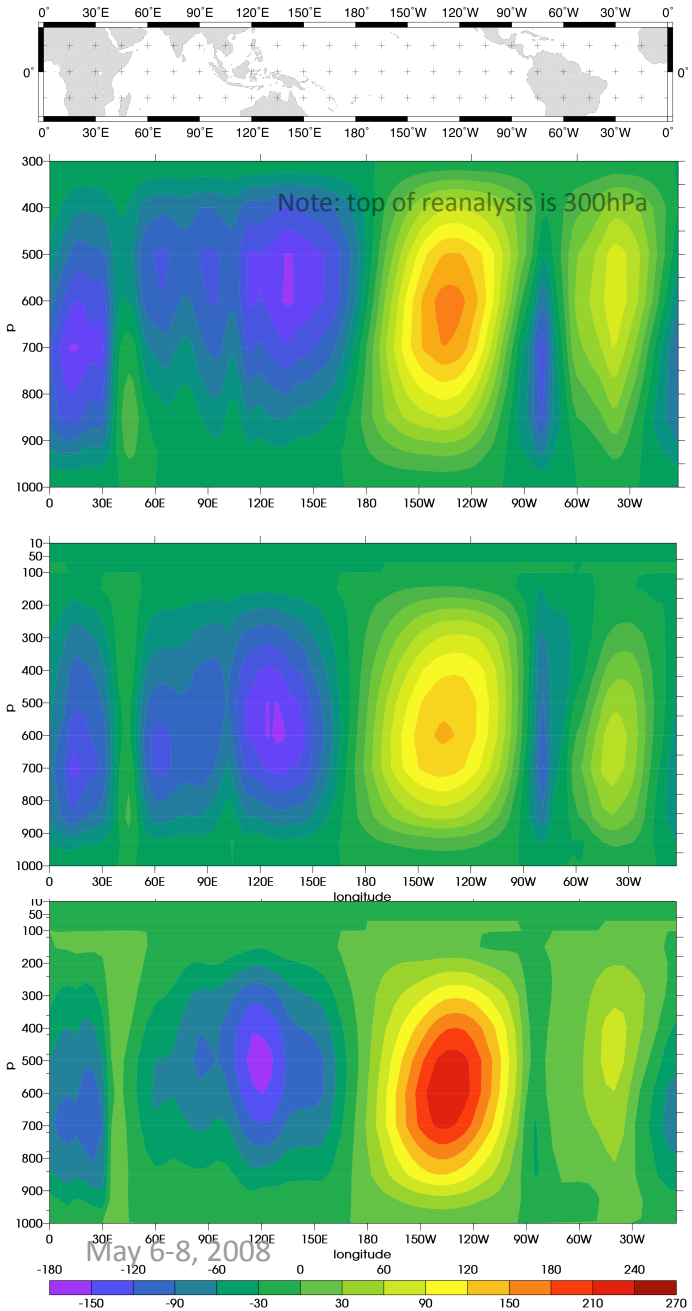
$$\rho u=-\frac{\partial \psi}{\partial z}+\frac{\partial \phi}{\partial x} \qquad \rho w=\frac{\partial \psi}{\partial x}+\frac{\partial \phi}{\partial z}$$

$$\nabla^2\psi=-\frac{\partial \rho w}{\partial x}+\frac{\partial \rho u}{\partial z} \qquad \nabla^2\phi=\frac{\partial \rho u}{\partial x}+\frac{\partial \rho w}{\partial z}$$

Ψ

DJF Climatology

5°N-5°S average



NCEP reanalysis

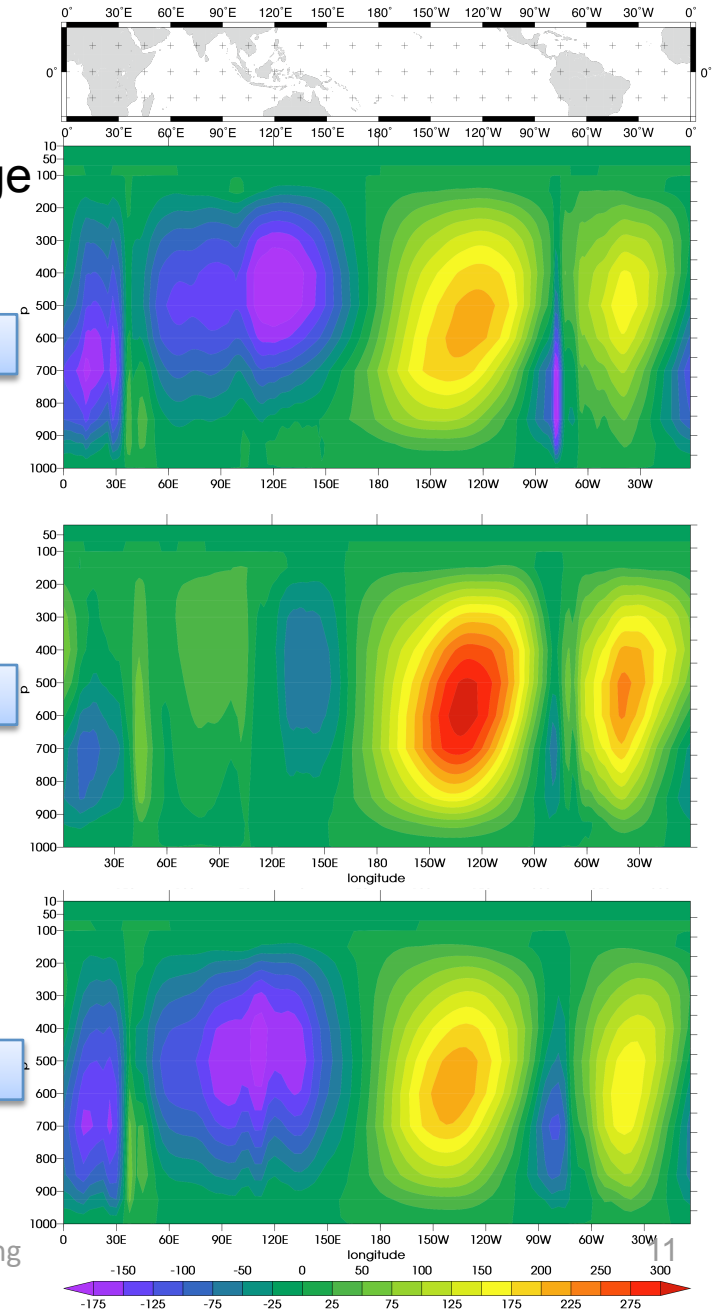
CNRM

GISS

CCSM

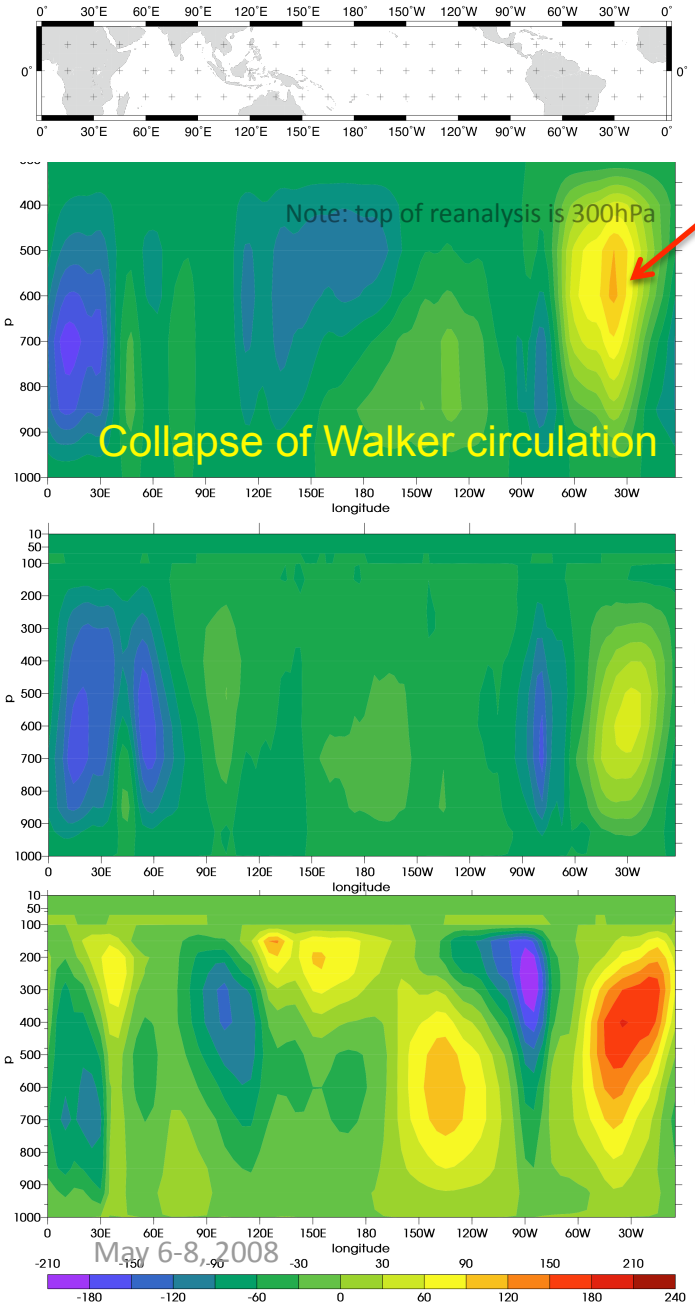
UKMO

IPSL



DJF 1997-1998 El Niño

Intensification over Atlantic influenced by Indian Ocean



NCEP reanalysis

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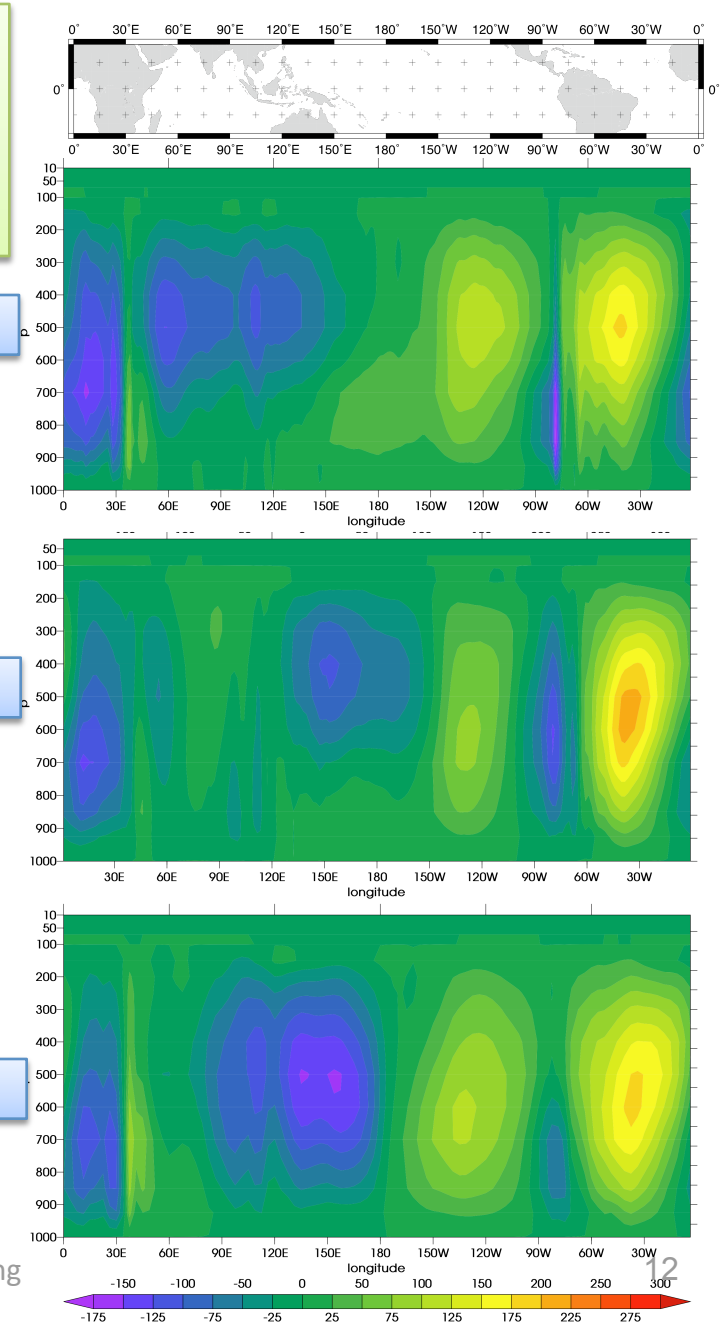


CCSM

UKMO

IPSL

Indicates the global scale effects

Shouldn't the models respond better to this large forcing of SST?

- What if we give a model the SST <u>and</u> the atmospheric state?
- Should we be able to identify errors in 12-36 hours?
- Borrow from DOE's ARM program

Evaluating the CAM3

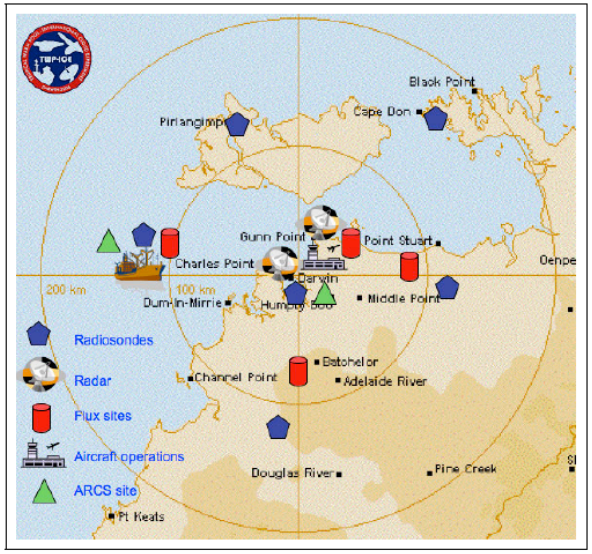
- The atmospheric part of the CCSM is set up to input atmospheric state data from the NWP analysis
  - Poor man's data assimilation
- Used in ARM program to evaluate model at ARM site for case studies
- Generally run 3-5 day forecasts – collect 12-36 hour forecasts and compare with observations

Using CAPT* approach,

- Identify early errors and compare with CERES
- Spatial errors difficult to diagnose in tropics
- Cloud objects present an interesting way to determine the properties responsible for the biases

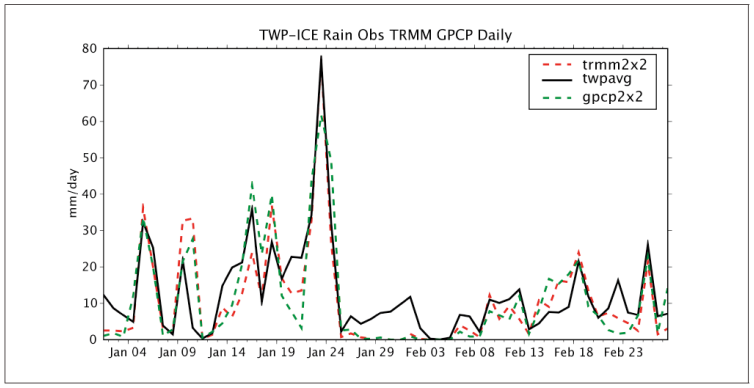
* Climate Change Prediction Program/Atmospheric Radiation Measurement Parameterization Test bed

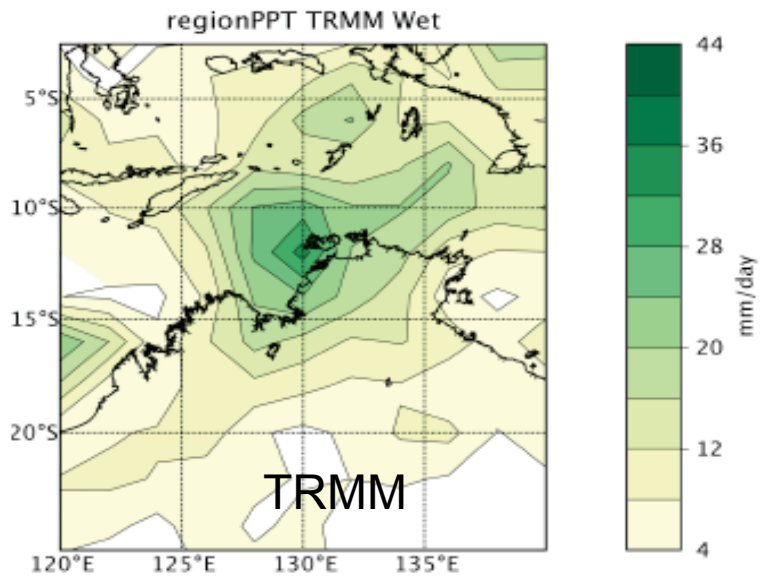
Using the CAM3 in forecast mode in a limited region

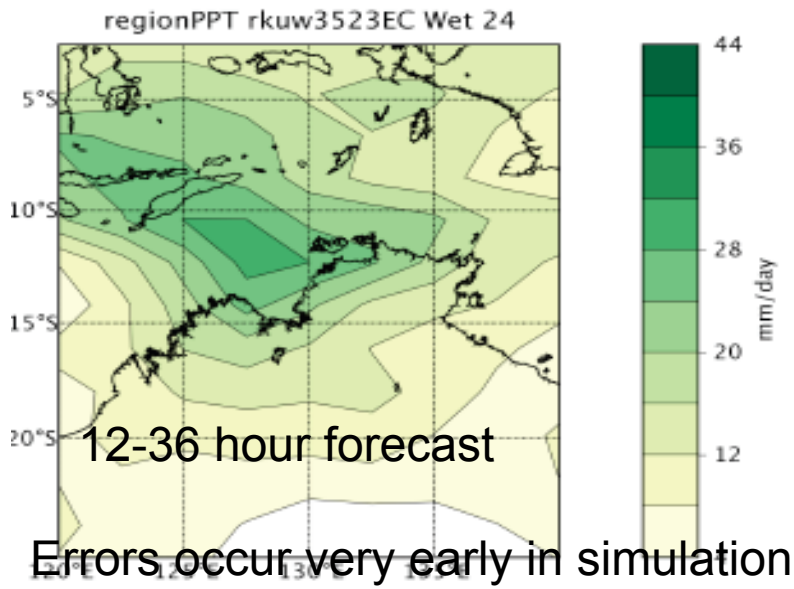


Example: the ARM TWP-ICE IOP Jan-Feb 2006

- 13 - 25 January Wet Monsoon across Northern Australia
- 26 January - 2 February Dry Monsoon (LandFoon)
- 3 - 13 February Break Monsoon Period







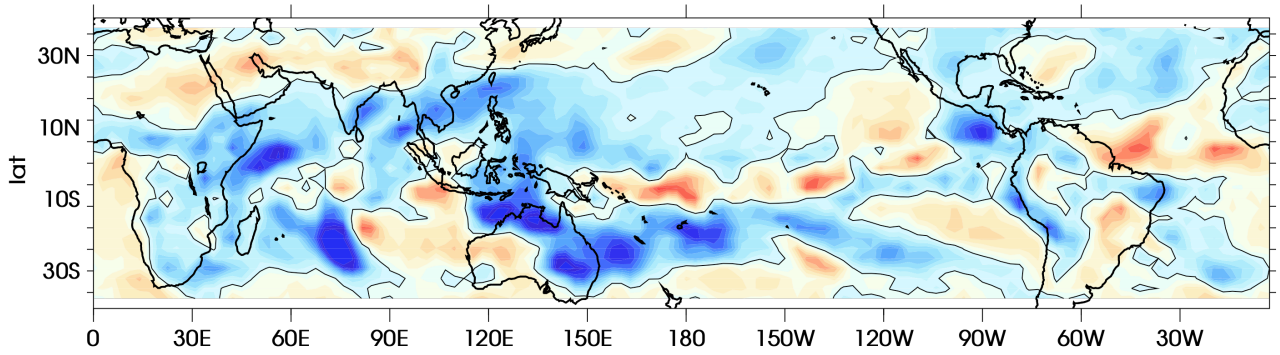
Errors occur very early in simulation

Expand the area to the entire tropics

- Use the 1997-98 El Nino as a case study
- Well observed
- CERES on TRMM
  - Thanks to Norman

For a larger area
TOA LW

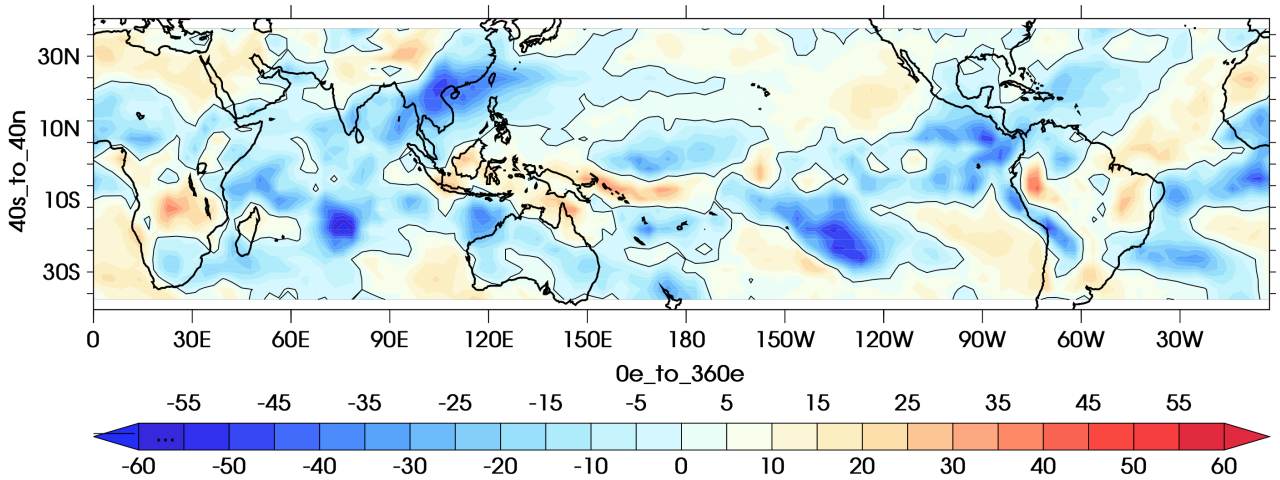
15 day average bias (model-CERES) March 1-15, 1998



Model performance at early times

Essentially, the beginning of an AMIP run

Average of individual 12-36 hr forecasts bias (model-CERES) March, 1998
-each forecast was initialized in forecast mode by ERA-40



A series of short-tem forecast put together. The model is reminded of the observed state every 3 days

The problem

- Even if the climate model is given the correct atmospheric state, it is still difficult to produce some of the basic spatial signatures of this large event

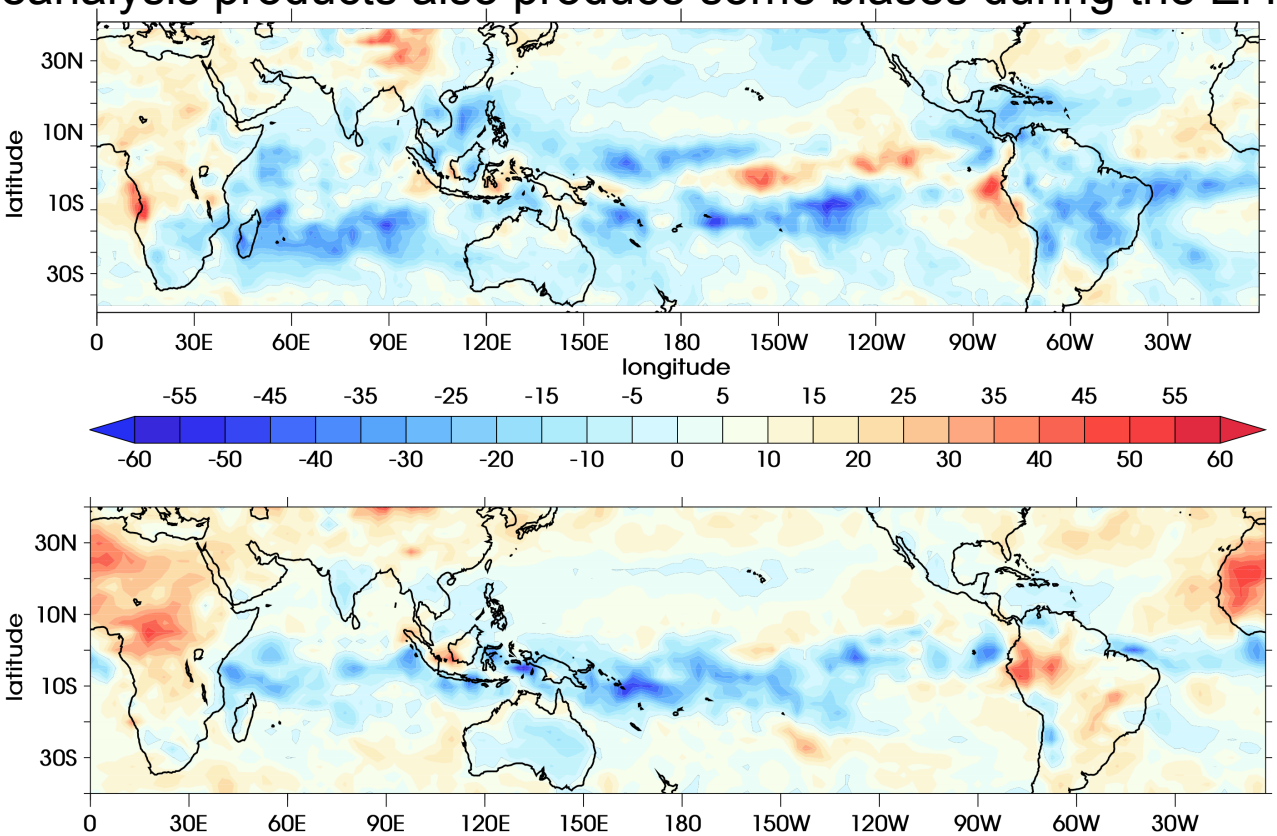
Does the initialization have influence?

TOA LW from Reanalysis – CERES March 1998

The reanalysis products also produce some biases during the El Nino

NCEP

ERA-40



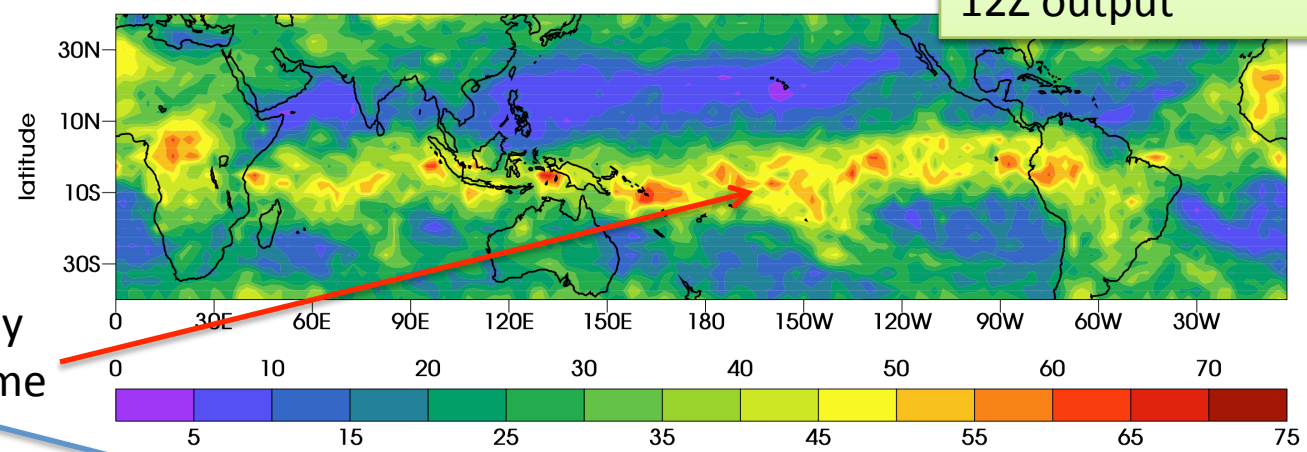
In the study area, the ERA-40 appears to have slightly better agreement with CERES

We are using the ERA-40 to initialize CAM3

OLR comparison with the ERA-40 daily data – 12Z output

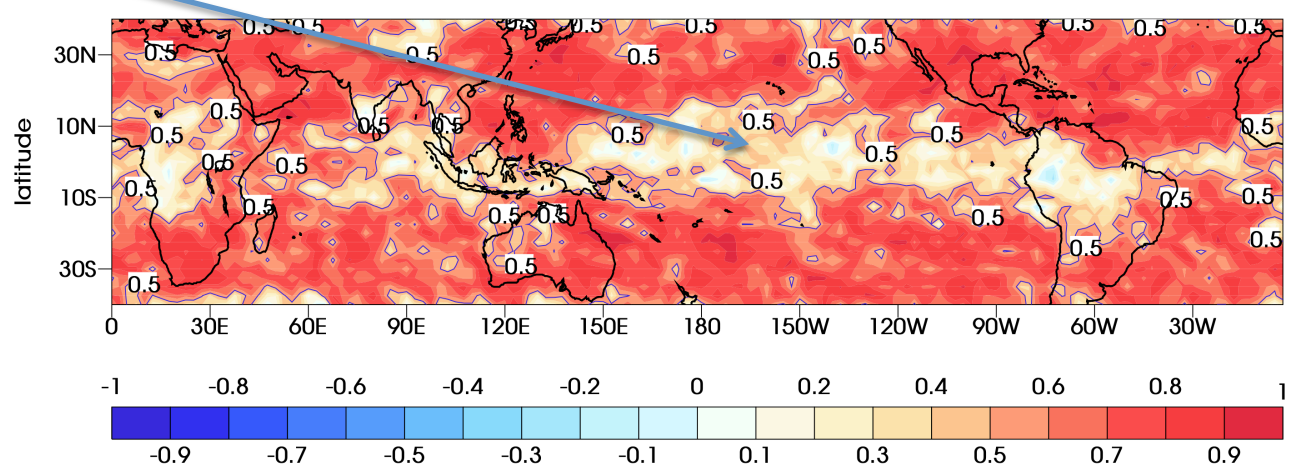
March 1998

RMS error

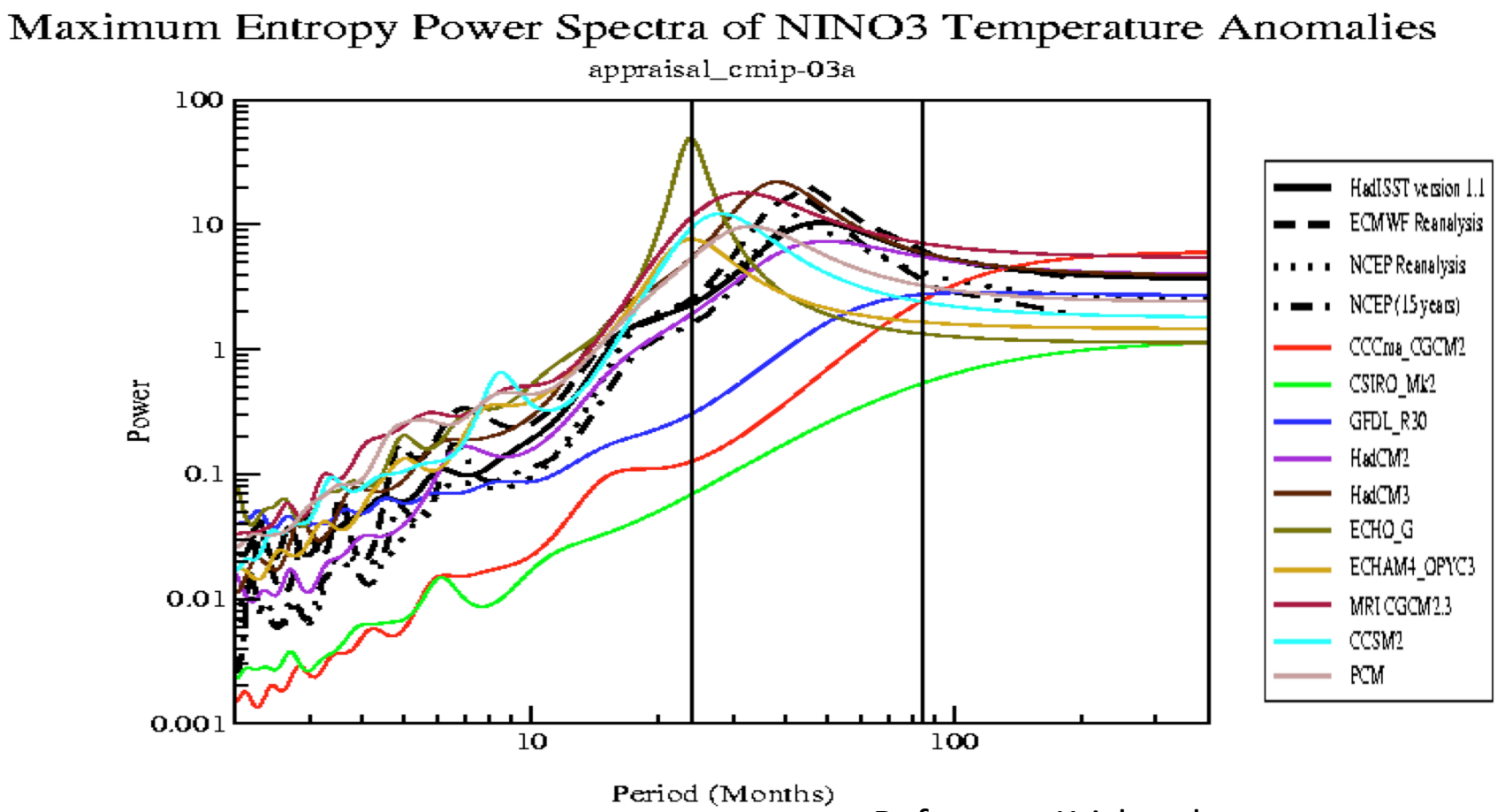


The errors in the study region will give us some pause

correlation



Adding to problems are the models' inability to produce El Niño in coupled mode



Reference Krishna here-------

Summary

- Climate model response to the extraordinary El Niño of 1997-98 may be a necessary but not sufficient test of climate models
- It will be necessary to use an NWP-type approach to effectively evaluate climate models for this unique test case
- Identifying and analyzing cloud objects present an interesting way to understand regional/global climate model cloud properties
- The rapid drift of the model away from observations is a problem

Unrelated issues

- For data to be useful to the modeling community, CF compliance is a great help
  - http://www.cgd.ucar.edu/cms/eaton/cf-metadata
- *Adopted by: PCMDI and *MIP, PRISM, ESMF, NCAR, Hadley Centre, GFDL, various EU projects*
- *Supporting software: CF-checker.*

Documentation available

NetCDF Climate and Forecast (CF) Metadata Conventions Version 1.1, 17 January, 2008