Recent Developments in PBL and Shallow Convection Parameterization at NCEP/EMC

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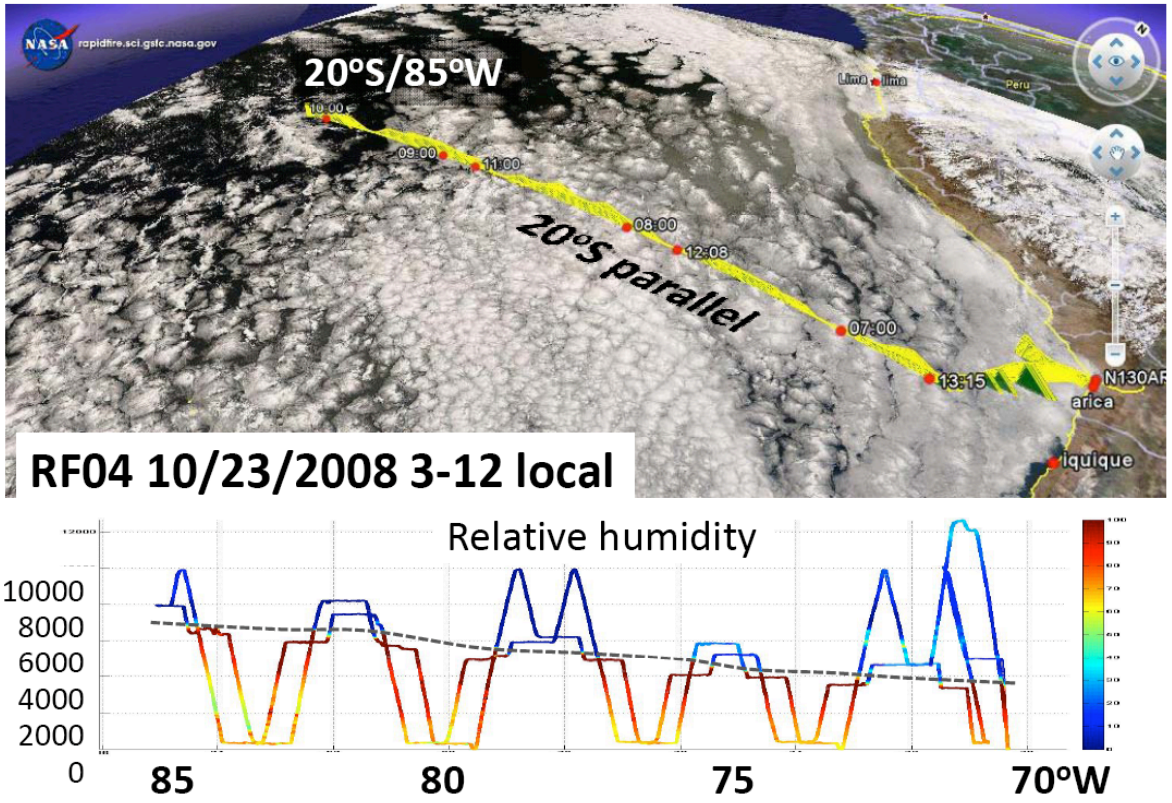
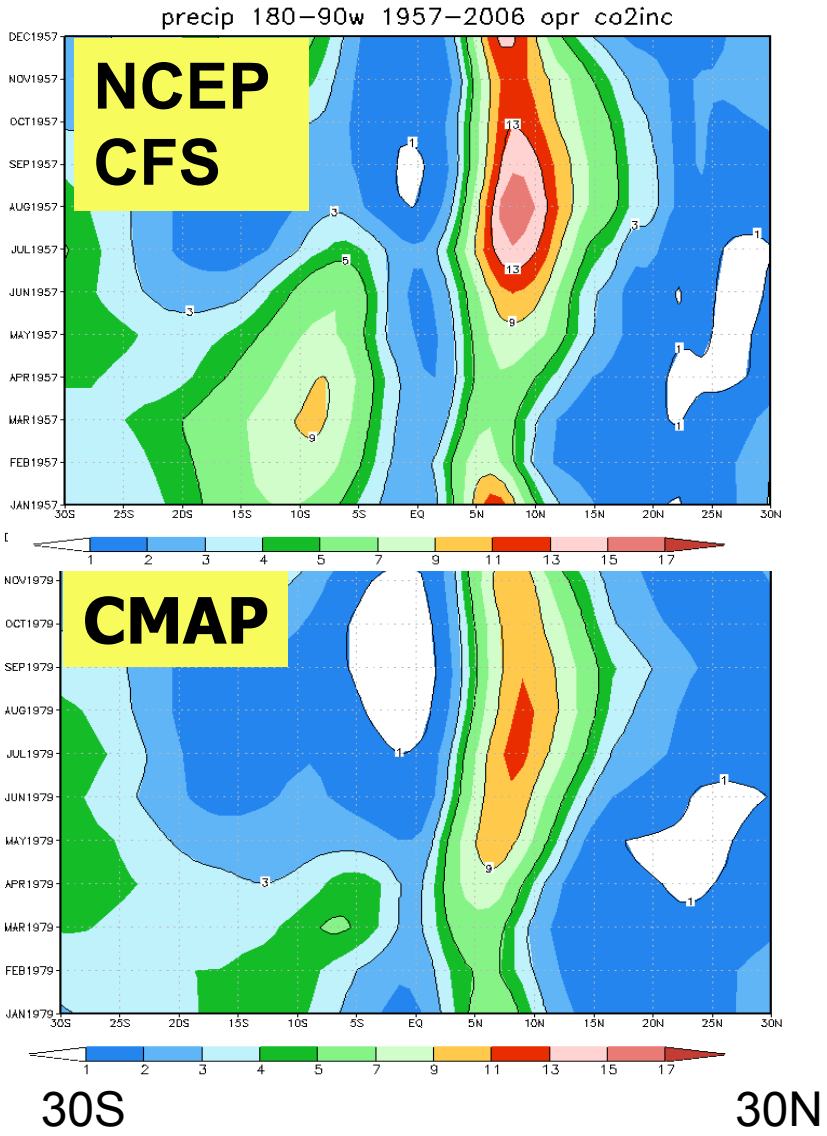
UCLA: C. R. Mechoso, H. Xiao



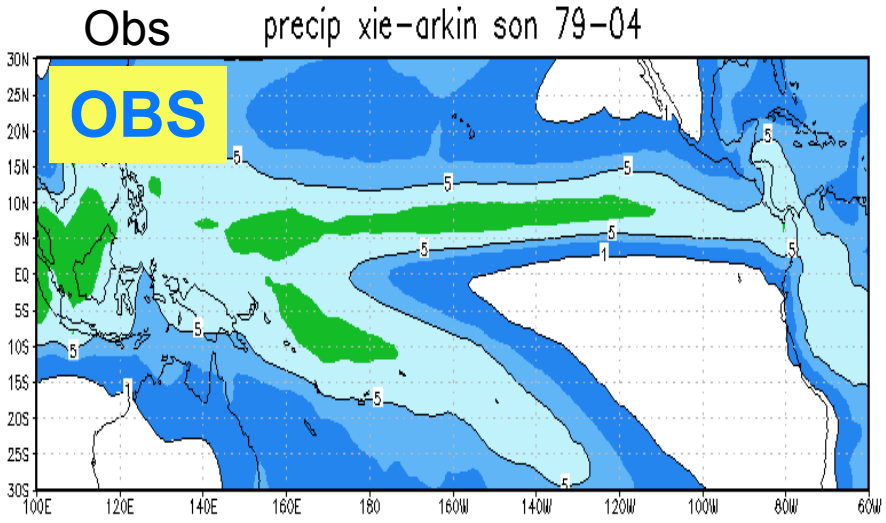
The Double ITCZ Syndrome of CGCMs

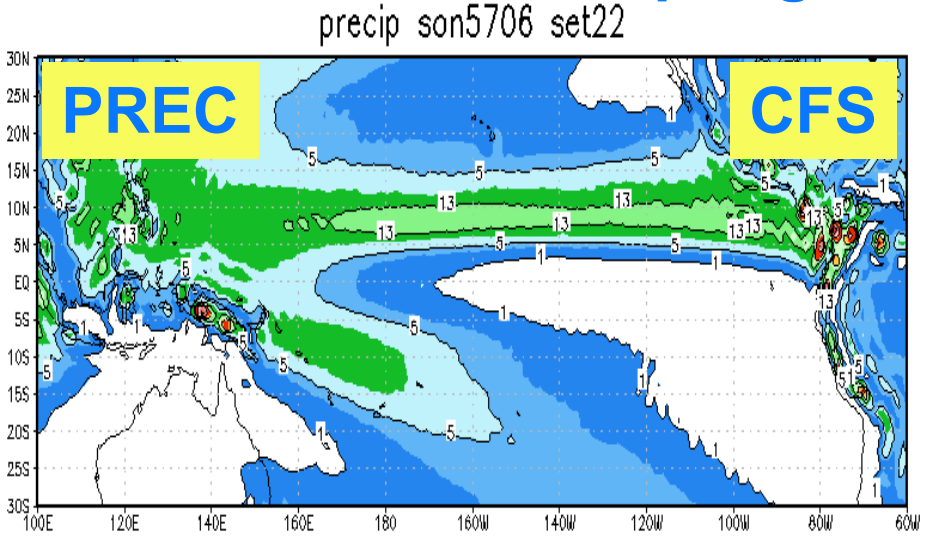


Annual cycle of precipitation in the East Pacific

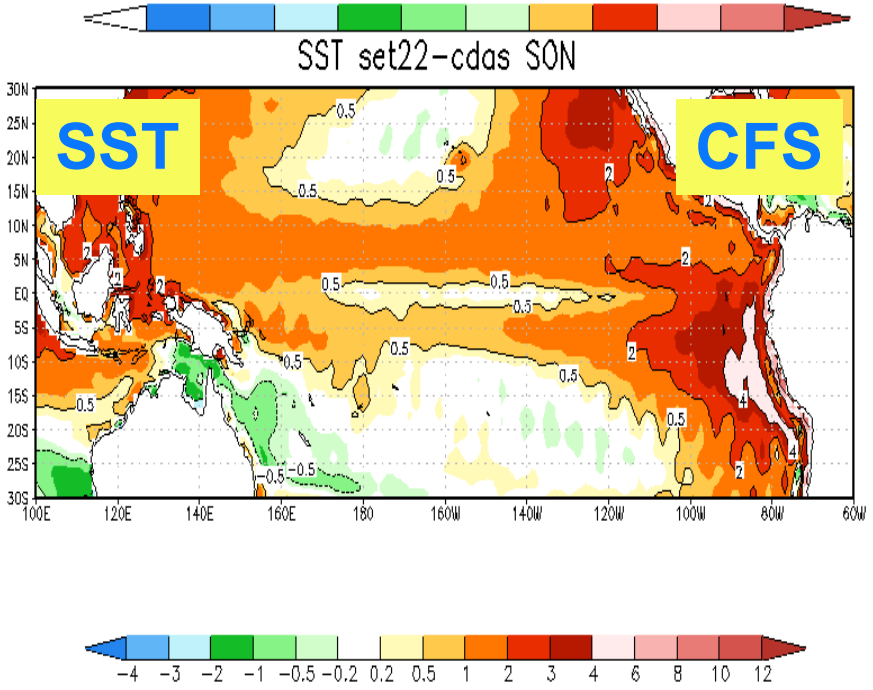
In the southeastern Pacific, most CGCMs have difficulties with the simulation of the ITCZ and SPCZ south of the equator, and /or the SST under the stratocumulus decks.

NCEP Coupled GCM Errors in the Southern Spring





During the southern spring, NCEP's Climate Forecast System (CFS) predicts for the eastern Tropical Pacific not enough stratocumulus and too warm SSTs.



Model	Levels	Resolution
NCEP GFS OPS: current operational version (*) CTL: experimental version of GFS EXP1a: Simple Modifications 1 EXP1b: Simple Modifications 2 EXP2: New parameterizations	64	T126 ~100km
MOM3	40	1/3x1 - 1x1
UCLA AGCM v7.3	29	2x2.5, ~250km
MIT OGCM	46	1/3x1 - 1x1

(*) 2009

In the current (*) operational GFS:

- The shallow convection parameterization is applied wherever the deep convective parameterization is not active.
- It is applied via enhanced vertical diffusion in the cloud layers below $p_T = 0.7p_s$, where p_s is surface pressure.
- Cloud top is defined as the layer above the highest positively buoyant layer below p_T.
- The shallow convection parameterization erroneously contributes to the lack of the stratocumulus.

(*) Moorthi

Exp1a: Simple modifications to improve stratus simulation in OPS GFS (*)

- Condition for CTEI is

$$C_p \Delta\overline{\theta}_e < 0.7 L \Delta\overline{q}_t$$

where $\Delta\overline{\theta}_e$ and $\Delta\overline{q}_t$ are the equivalent potential temperature and total moisture jumps across the inversion;

If the condition for CTEI is not satisfied, then the top of shallow convection is set to be just below the inversion.

- The background vertical diffusion coefficient is set to zero above inversion

Exp1b: Additional modifications

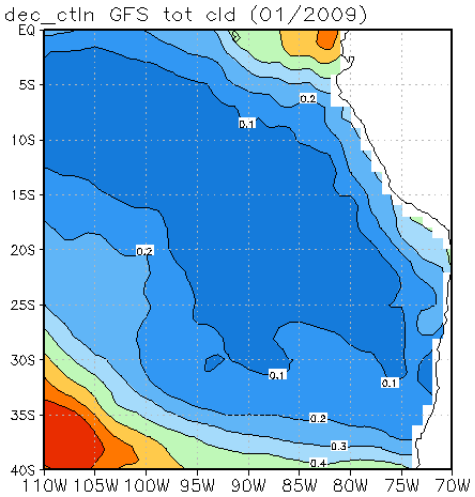
An additional set with modification of the original shallow convection (by limiting the cloud top to below the region of negative buoyancy) and adding an additional layer when condition for CTEI is satisfied. (*)

Methodology

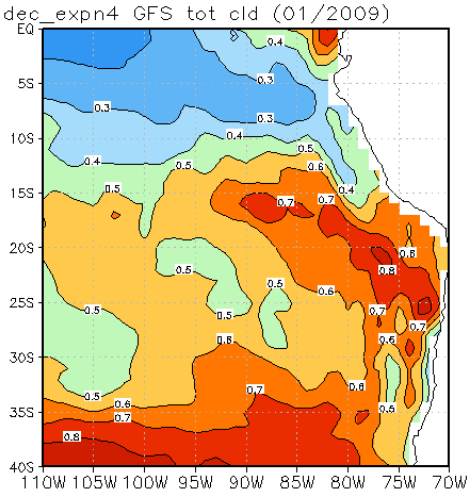
- Ensembles of four control and sensitivity experiments (with the modifications) are performed
- Simulations are 48-day long and use observed SSTs. Initial conditions correspond to Dec 15, 00Z 2008 and June 15 00Z, 2008.
- RAS version 2 (updated version of Moorthi and Suarez, 1999) is used for convective parameterization.
- A critical relative humidity of 90% is used with Zhao microphysics
- Resolution: T126, 64 levels

Total Clouds in Southeast Pacific

JAN GFS* OPS



JAN GFS* EXP1a



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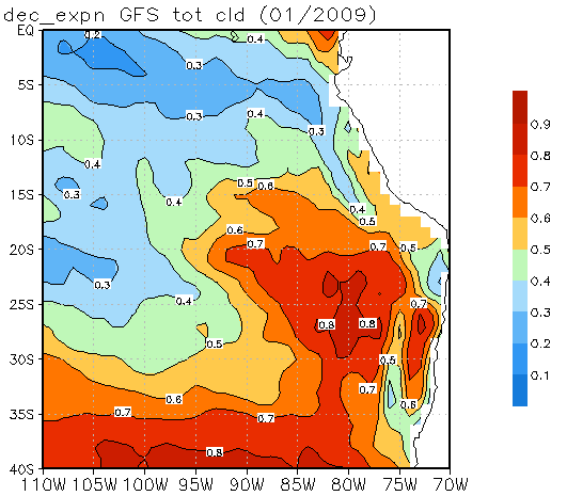

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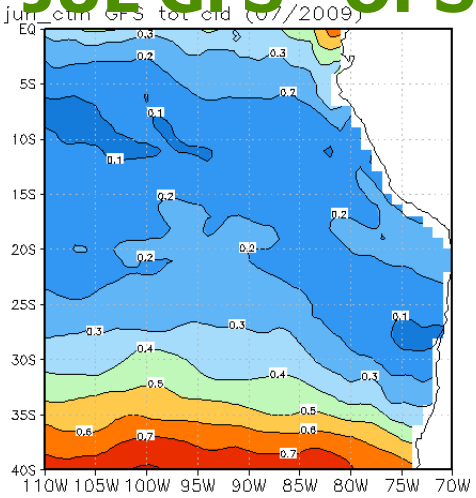

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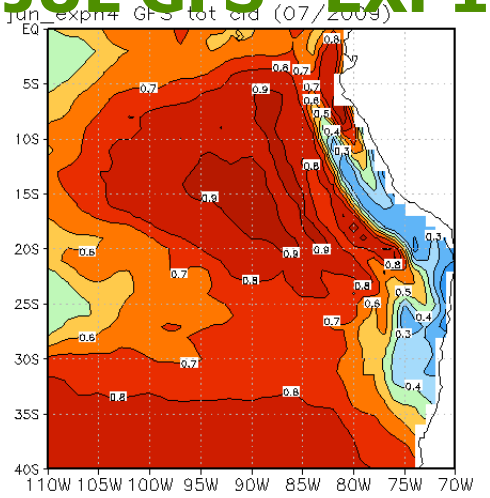

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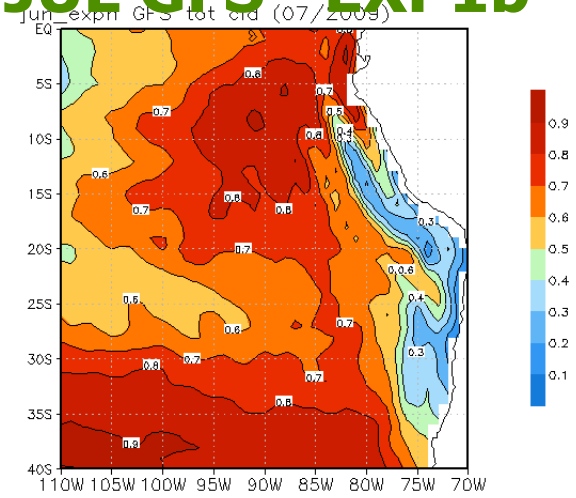
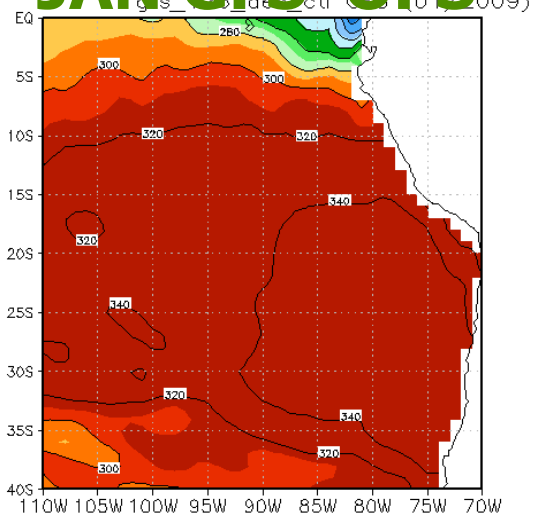
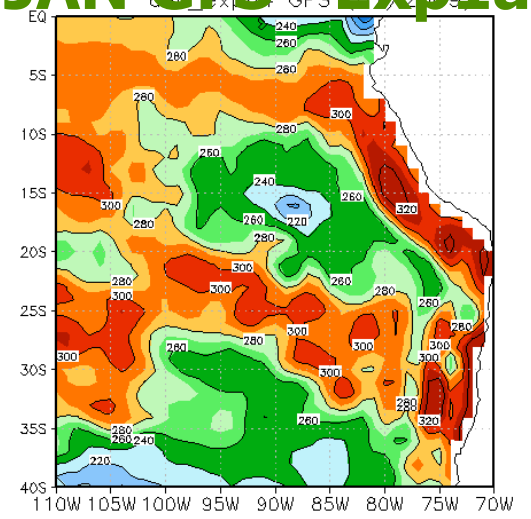


Net Short Wave Radiation at the Surface

JAN GFS_OPS



JAN GFS* Exp1a



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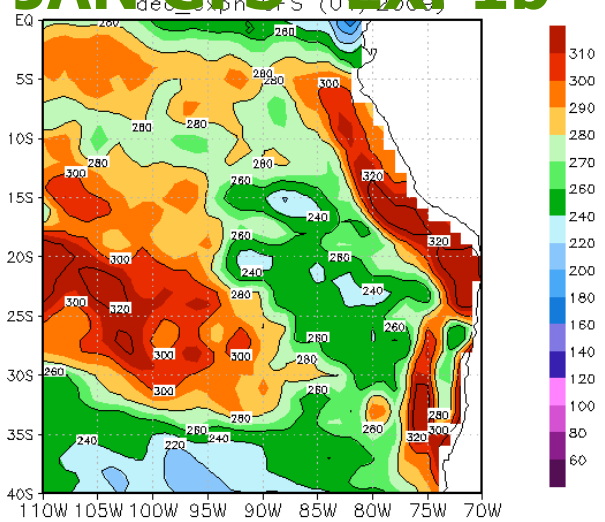

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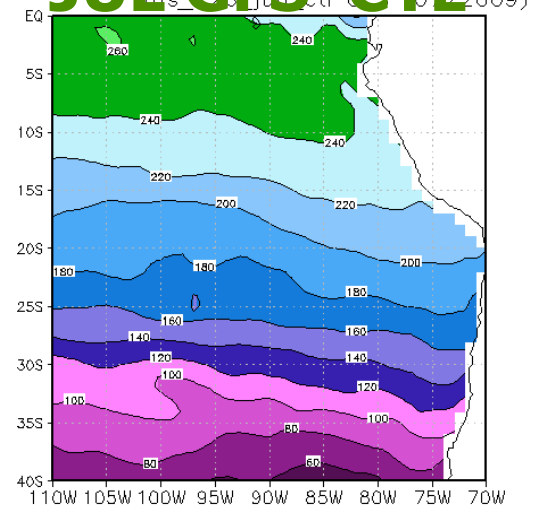

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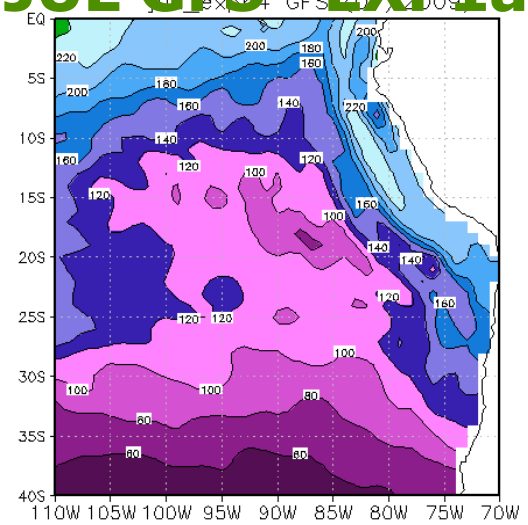

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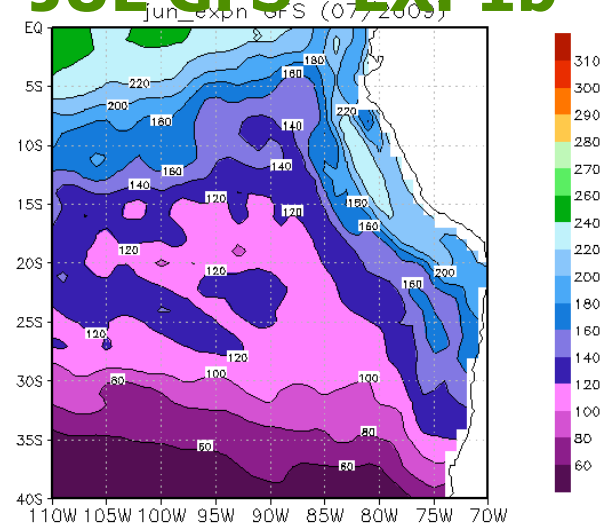
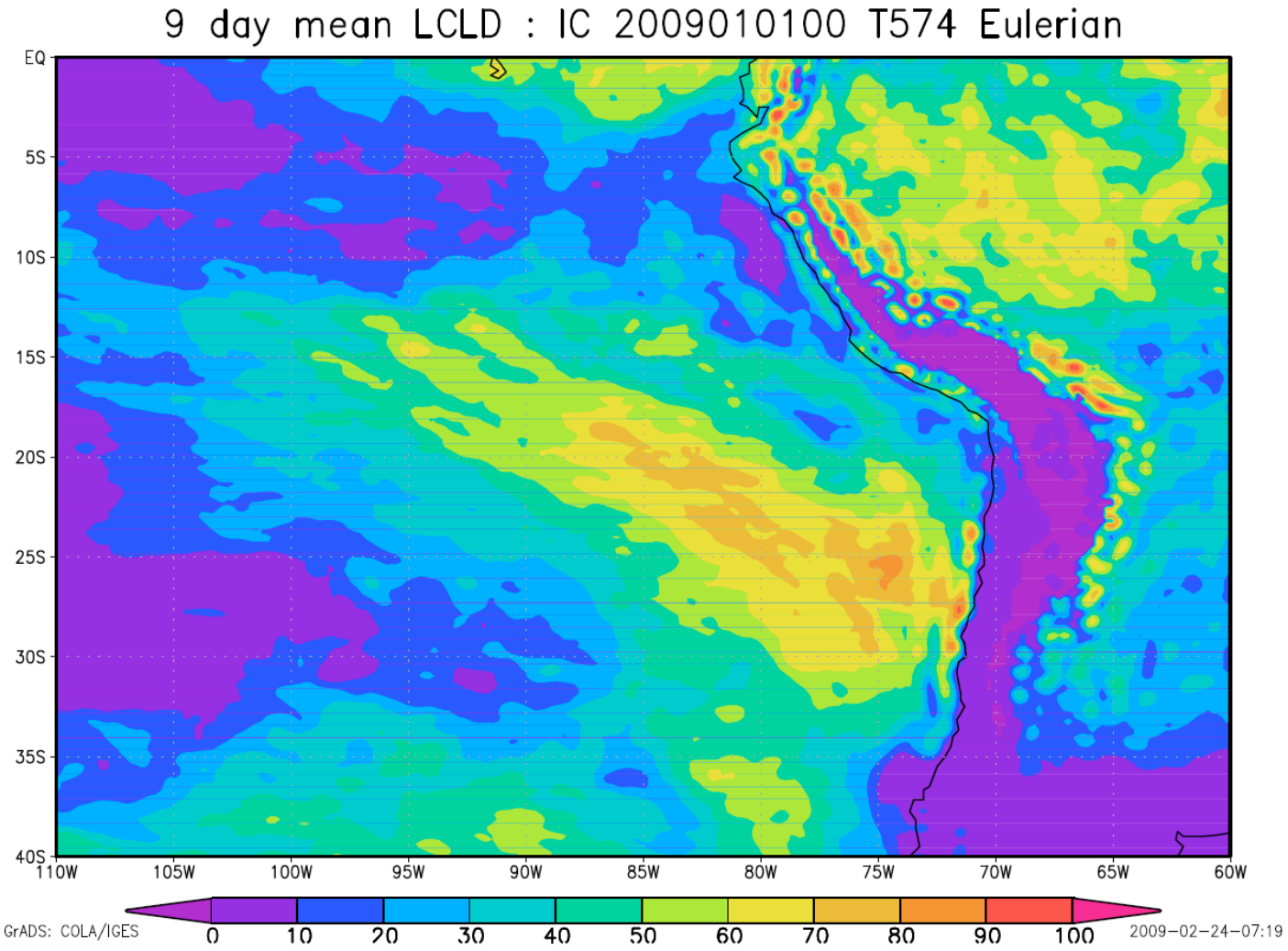


Impact of Resolution (in EXP1)



New parameterization for moist turbulence processes (*)

- Include stratocumulus-top driven turbulence mixing in the lower troposphere
- Enhance local diffusion in cloudy air
- Specify explicit entrainment at PBL top
- Use local diffusion for the nighttime stable PBL
- Include non-local mixing for momentum

(*) Han and Pan

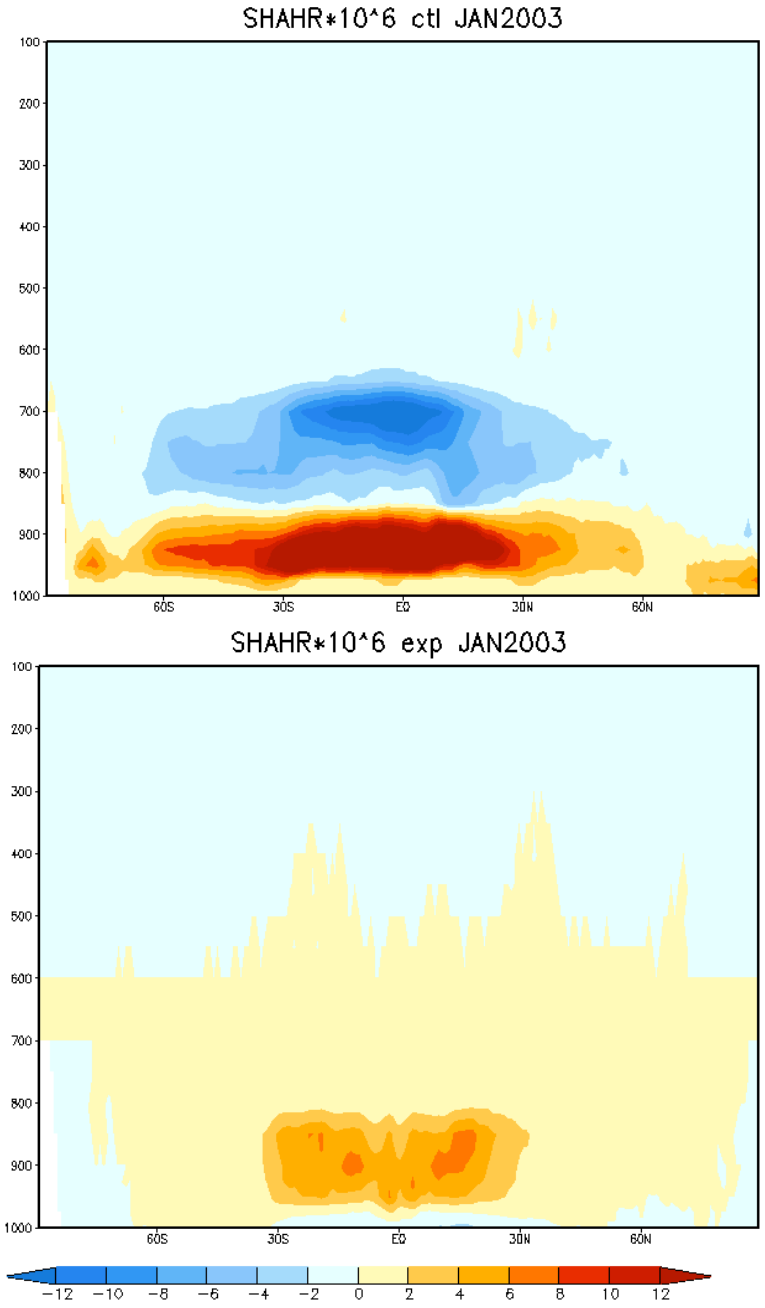
New shallow cumulus convection parameterization (*)

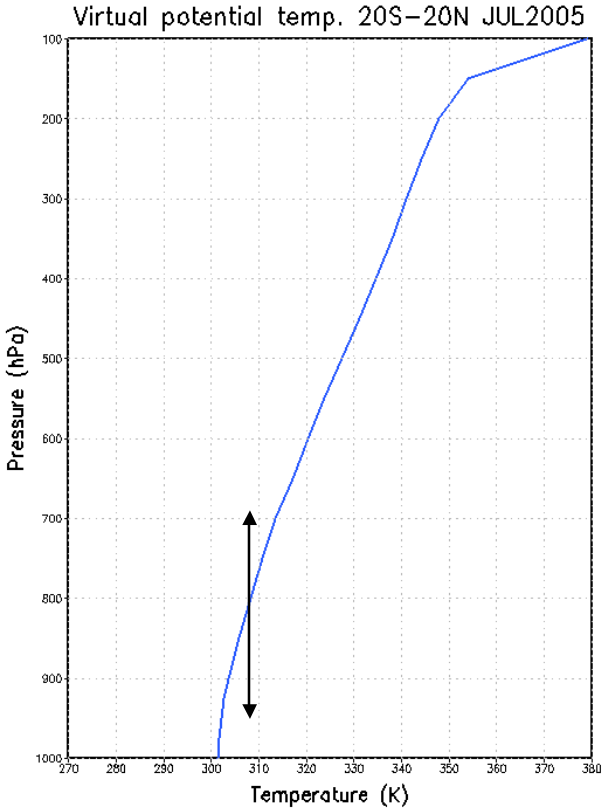
- Use a bulk mass-flux parameterization
- Based on the simplified Arakawa-Shubert (SAS) deep convection scheme, which is being operationally used in the NCEP GFS model
- Separation of deep and shallow convection is determined by cloud depth (currently 150 mb)
- Main difference between deep and shallow convection is specification of entrainment and detrainment rates
- Only precipitating updraft is considered; downdraft is ignored

(*) Han and Pan

Opr

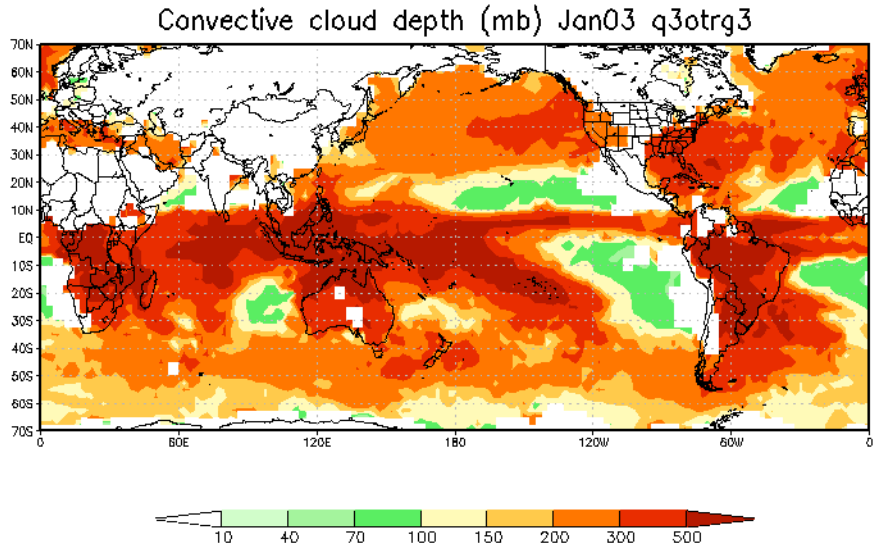
New shallow convection scheme



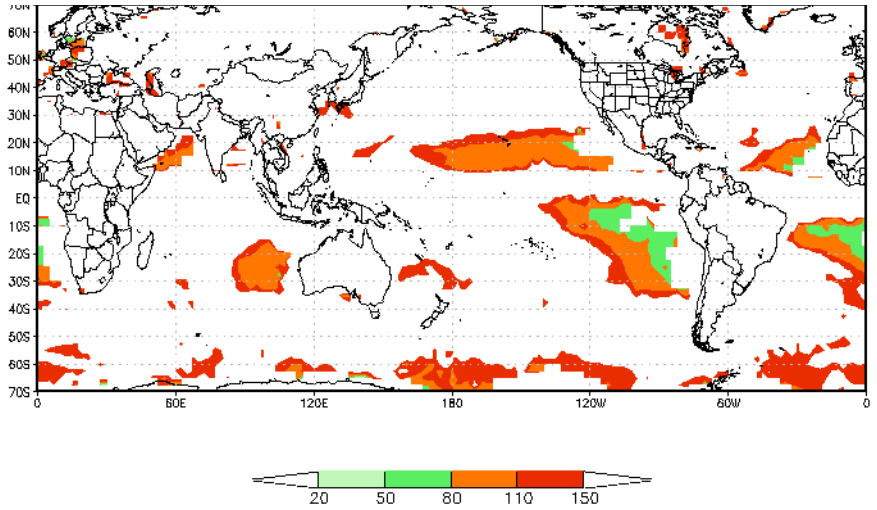


Cloud Depth (mb) January

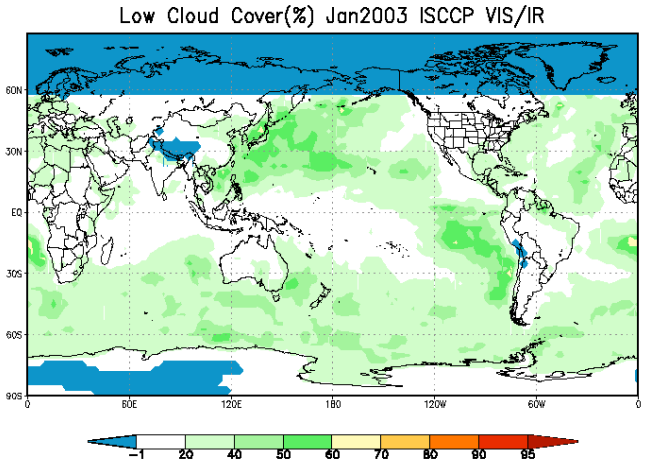
Deep and shallow



Shallow only (<150mb)



CFS PBL and Low Clouds (combined)



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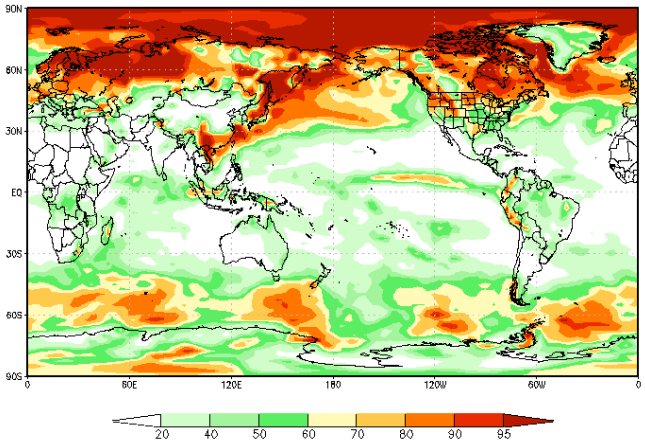

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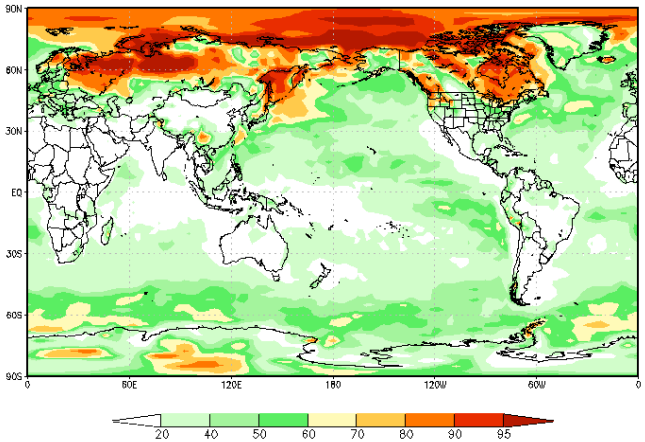
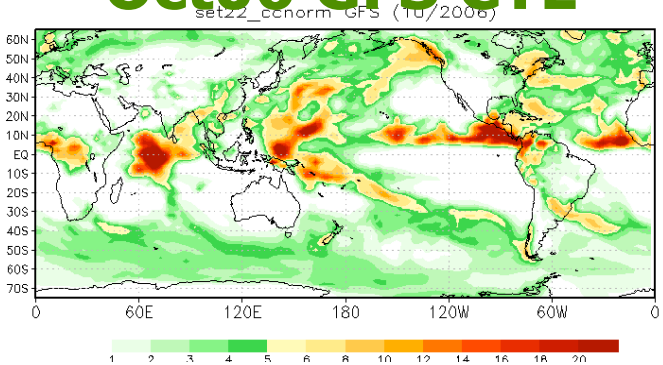


New PBL and shallow convection

Precipitation

Oct06 GFS CTL



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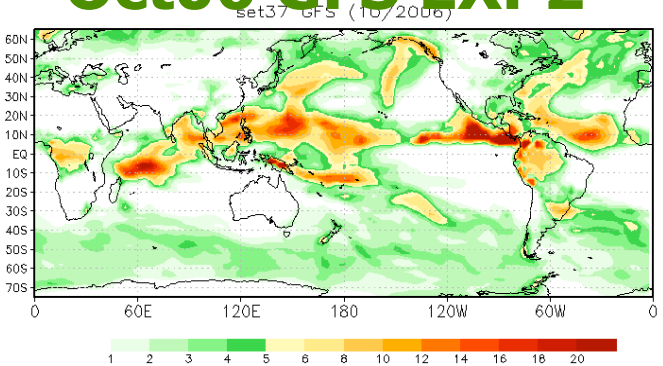
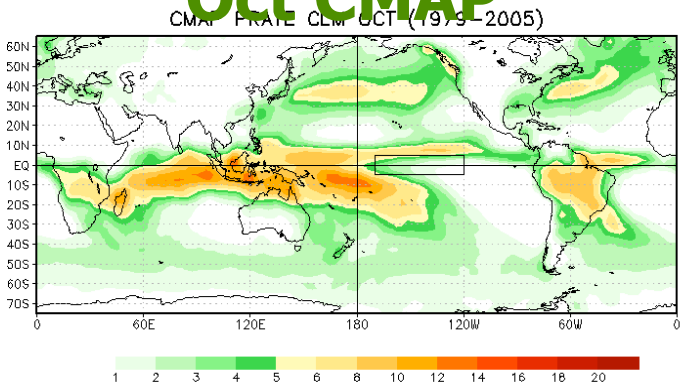
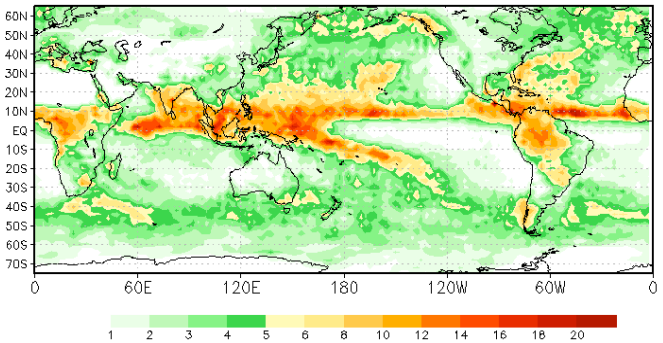


Oct CMAP



Oct 06 UCLA AGCM



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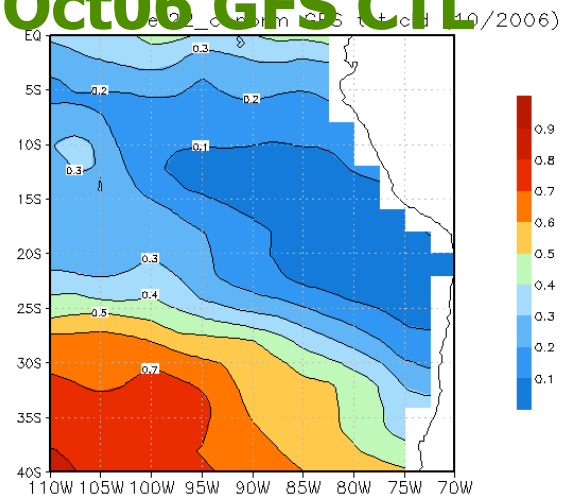
Total Clouds in Southeast Pacific

Oct06 GFS CTL



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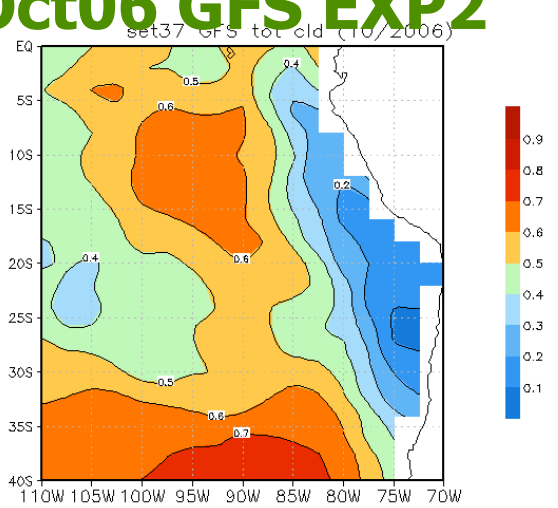

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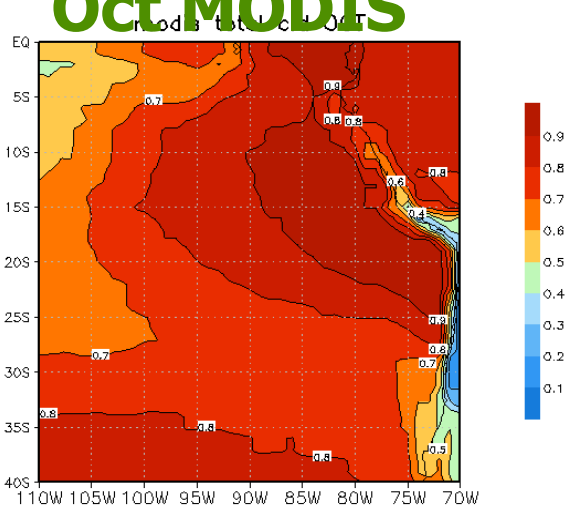

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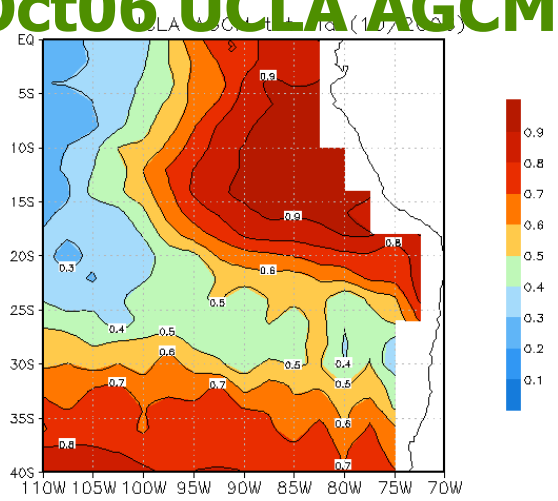

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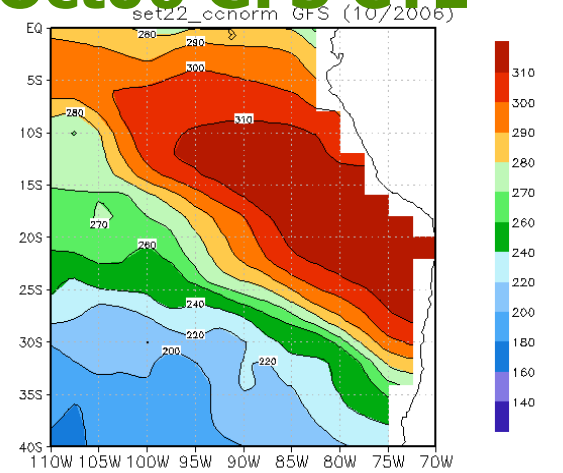
Net Short Wave Radiation

Oct06 GFS CTL



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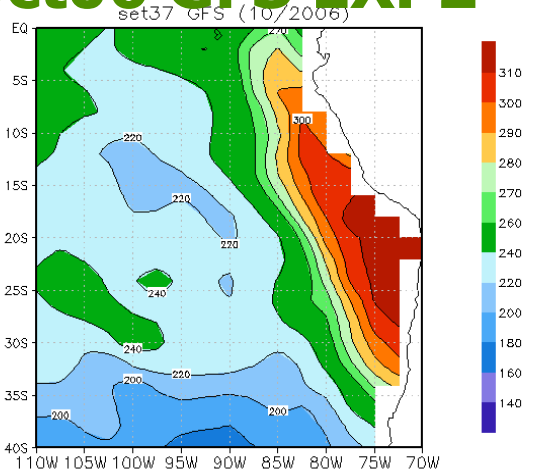

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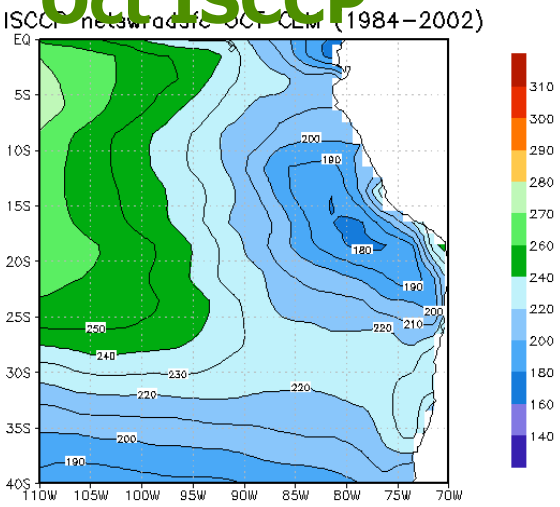

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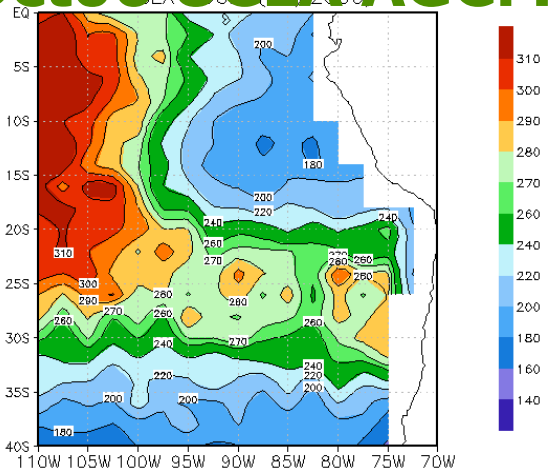

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Precipitation

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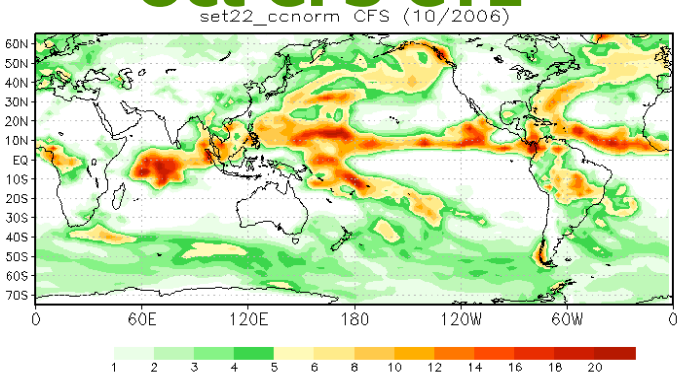

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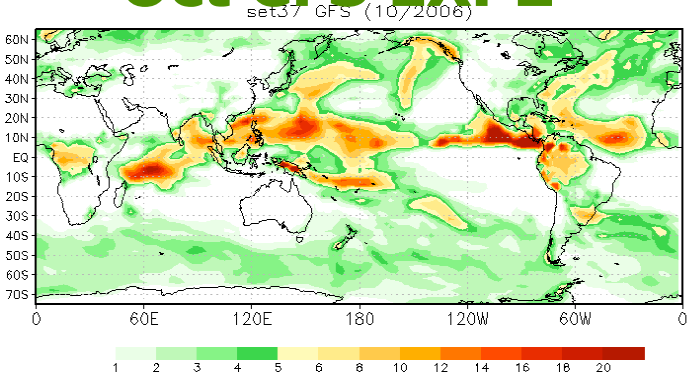

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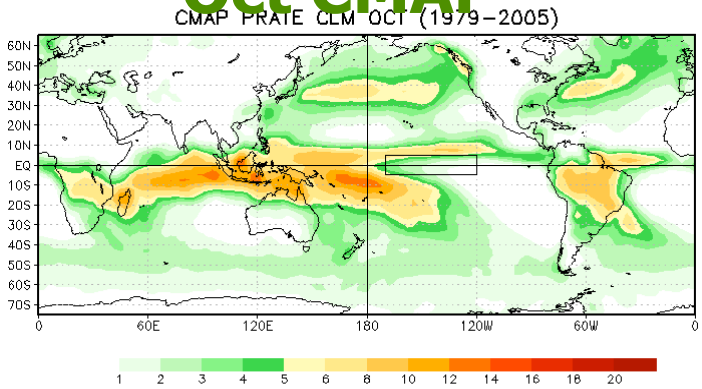

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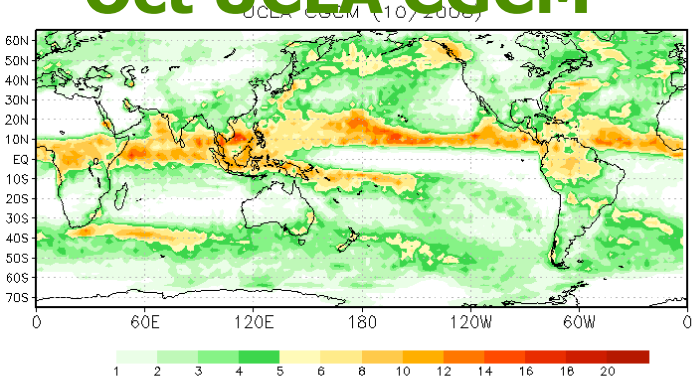

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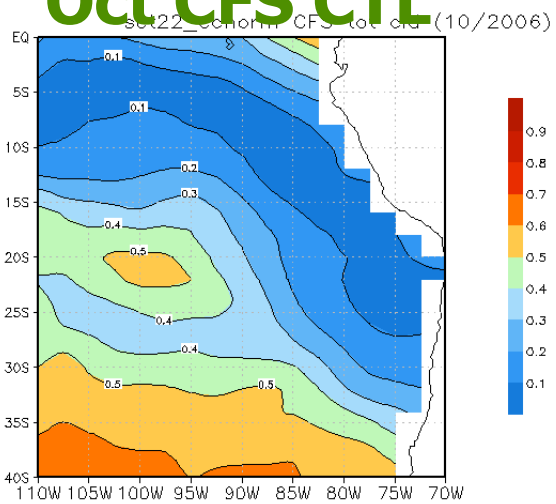
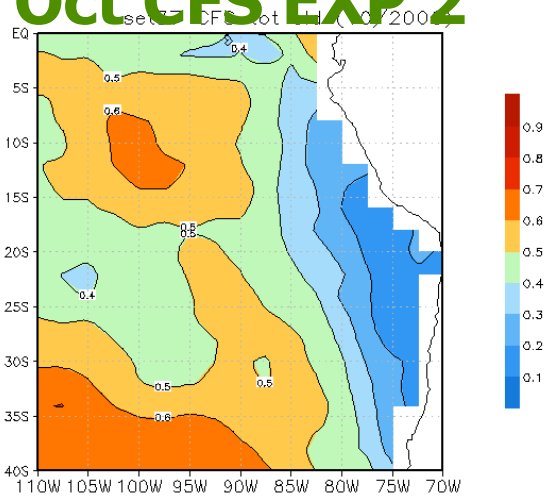
Total Clouds in Southeast Pacific

Oct CFS CTL



Oct CFS EXP 2



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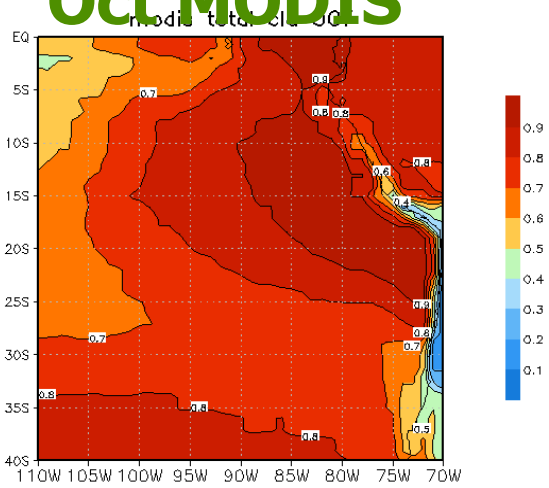
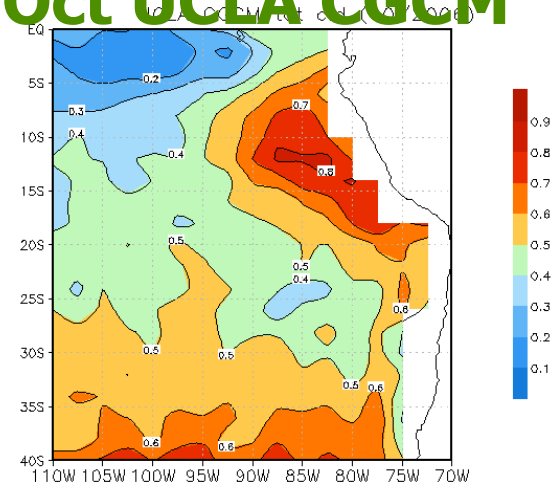


Oct UCLA CGCM



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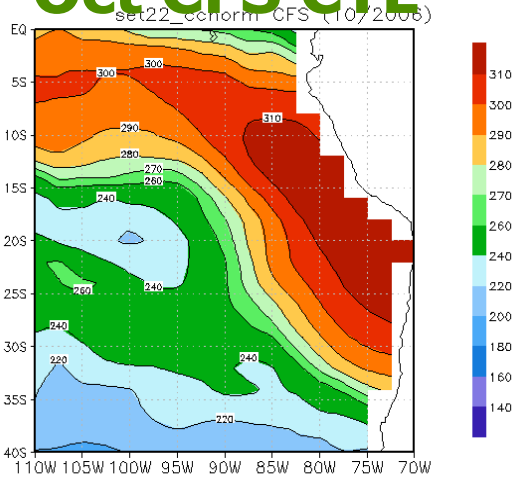
Net Short Wave Radiation

Oct CFS CTL



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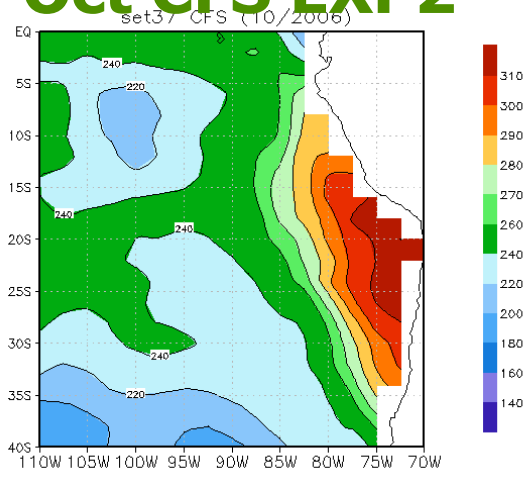

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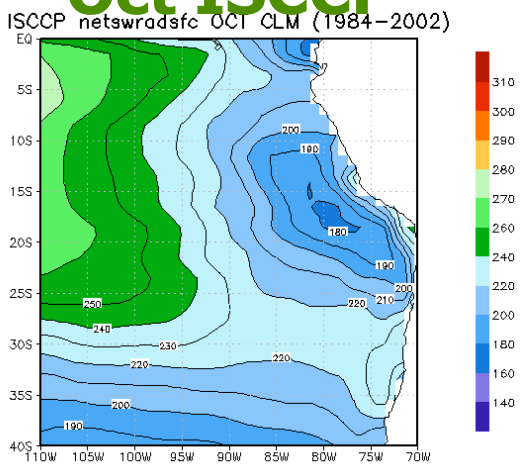

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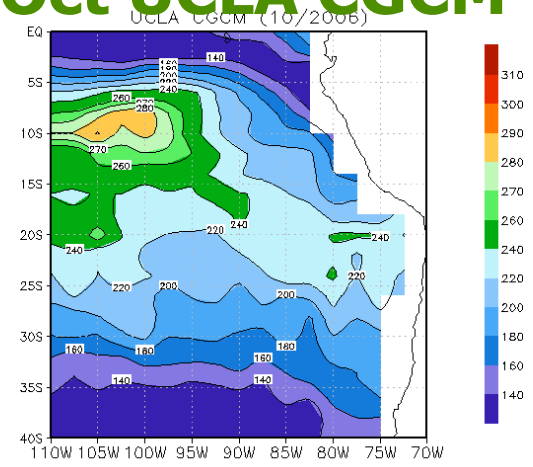

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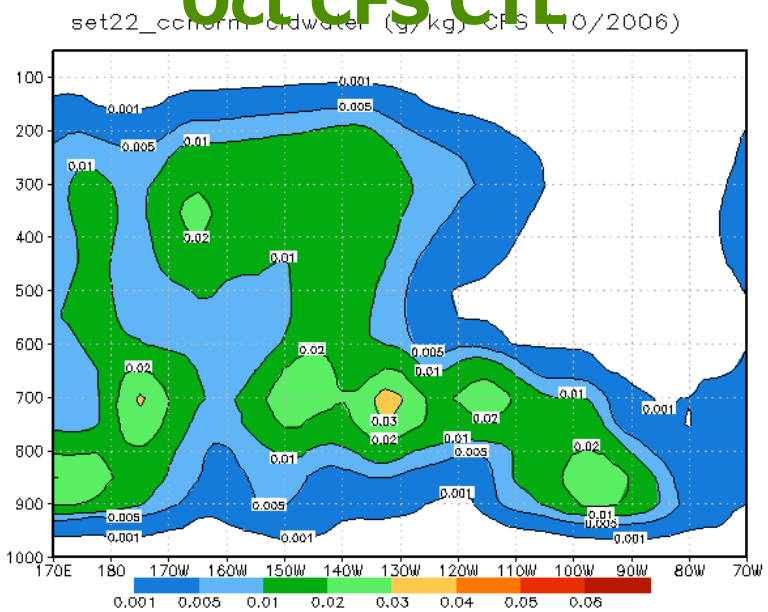
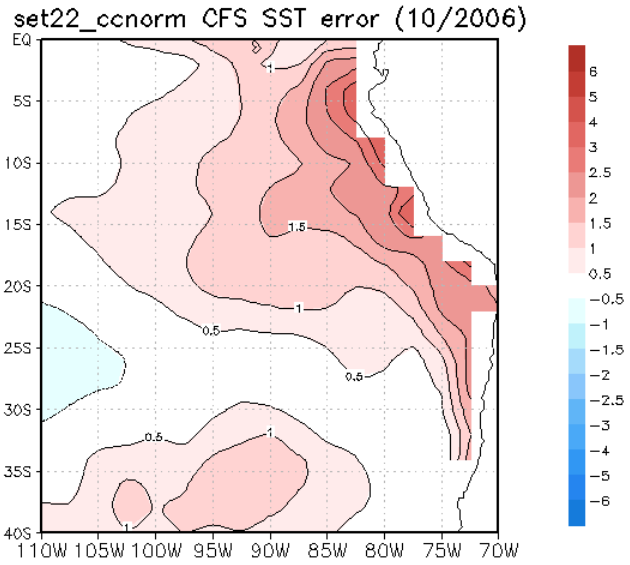
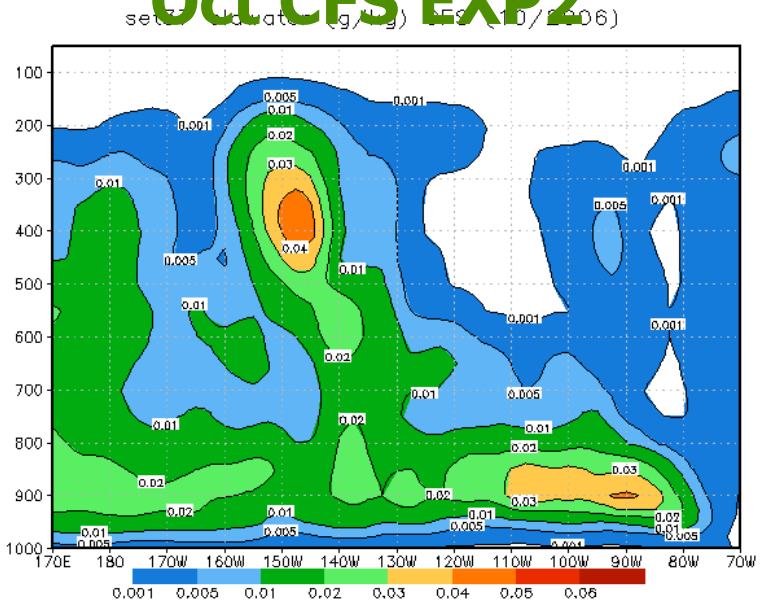
Cloud Liquid Water and SST Errors

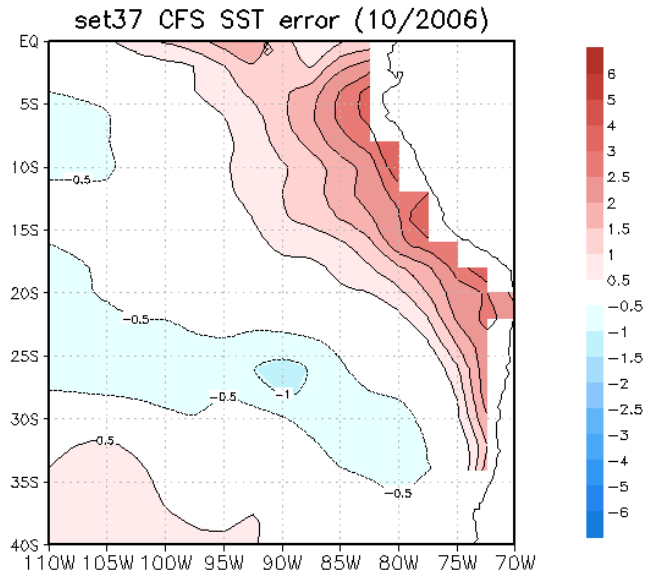
Oct CFS CTL





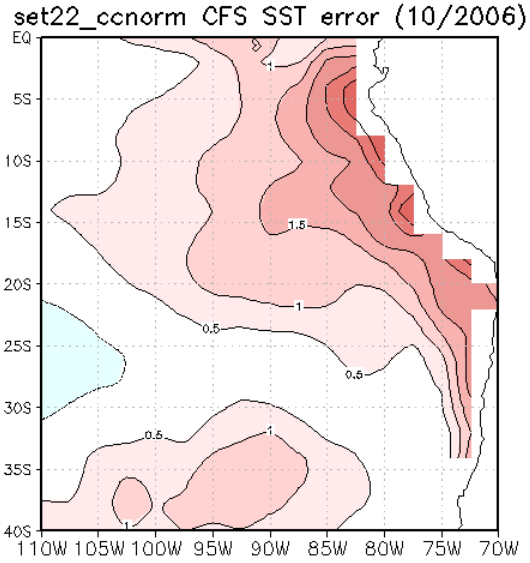
Oct CFS EXP2



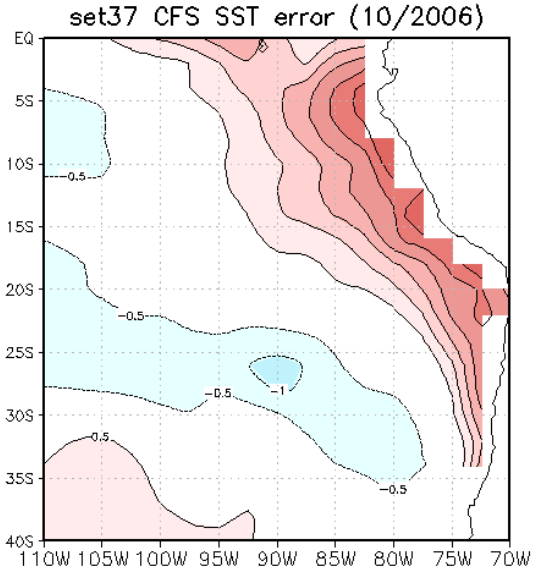


SST Errors in the Southeastern Pacific

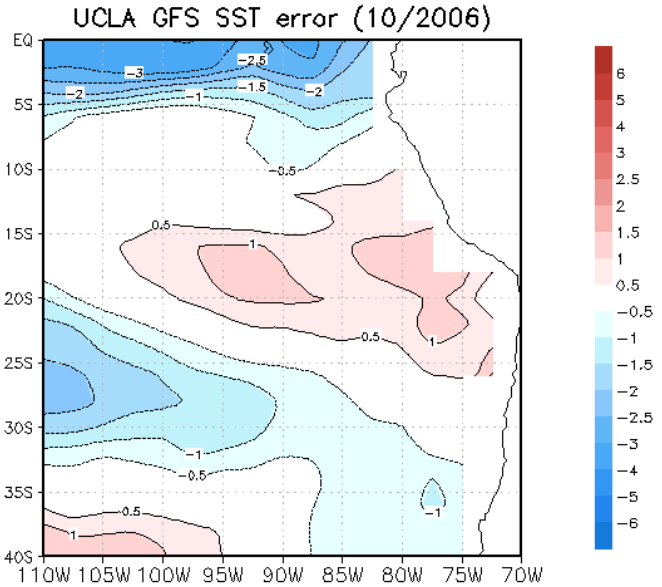
Oct CFS CTL



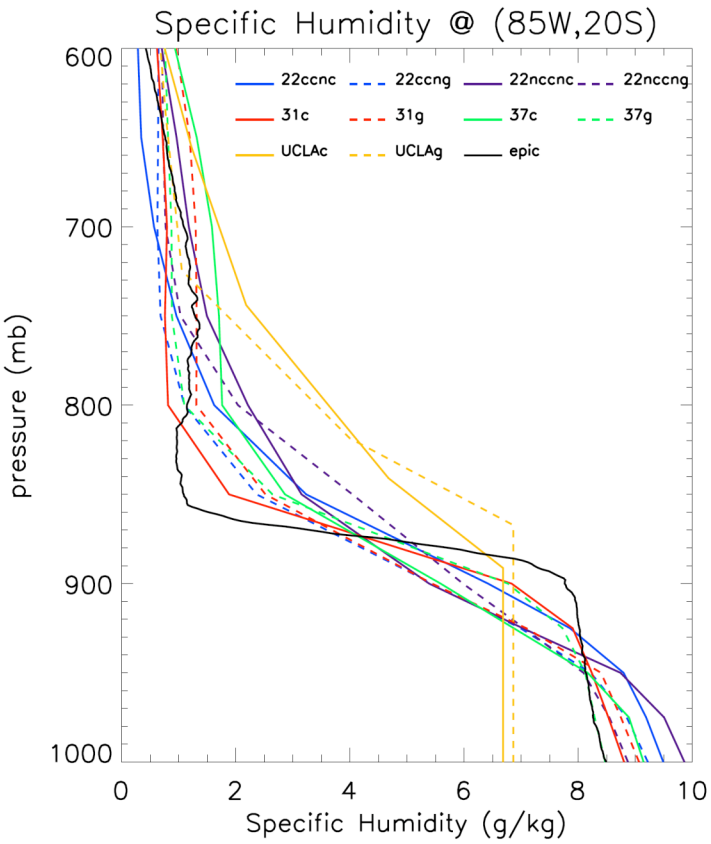
Oct CFS EXP2

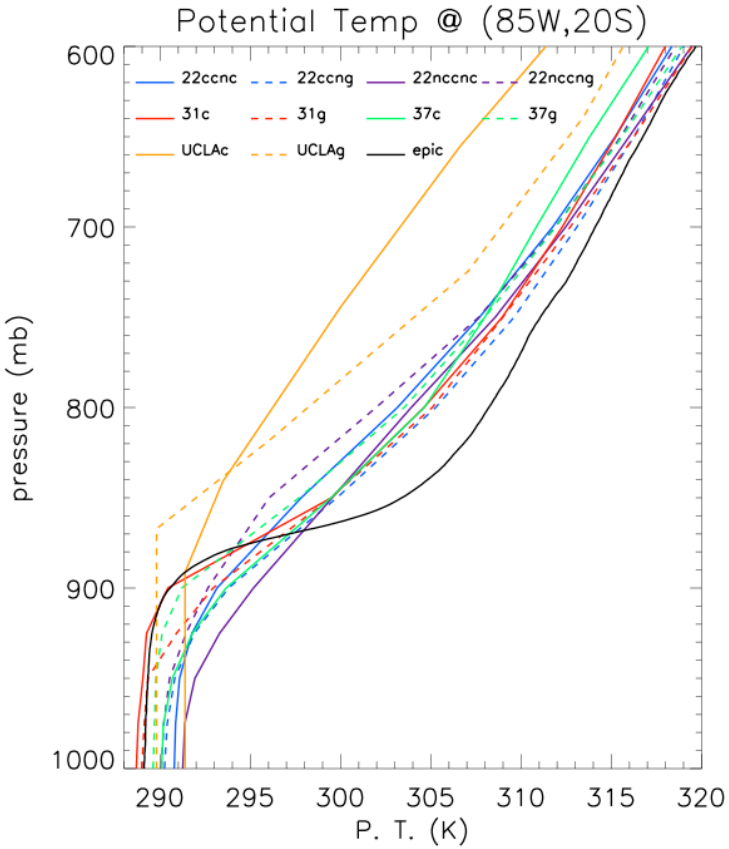


Oct UCLA CGCM



Profiles at (85W, 20S)





Summary

- Intense work has been made to improve PBL and Low Clouds in NCEP/EMC models
- Simple modifications to the code based on inversion height were tested (Exps 1a and 1b).
- New parameterizations of moist turbulence processes and Shallow Convection were incorporated (Exp. 2)
- Significant improvements have been achieved
- Flow near high orography shows errors. These decrease with increased resolution