Global Models

- **VOCALS Modeling Hypotheses**
- **Double ITCZ, stratus and warm bias**
- **Cross-equatorial and coastal surface winds**
- **Upwelling and ocean eddies**
- **Proposal for MUSSIP**

C. R. Mechoso, UCLA

VOCALS Modeling Hypotheses

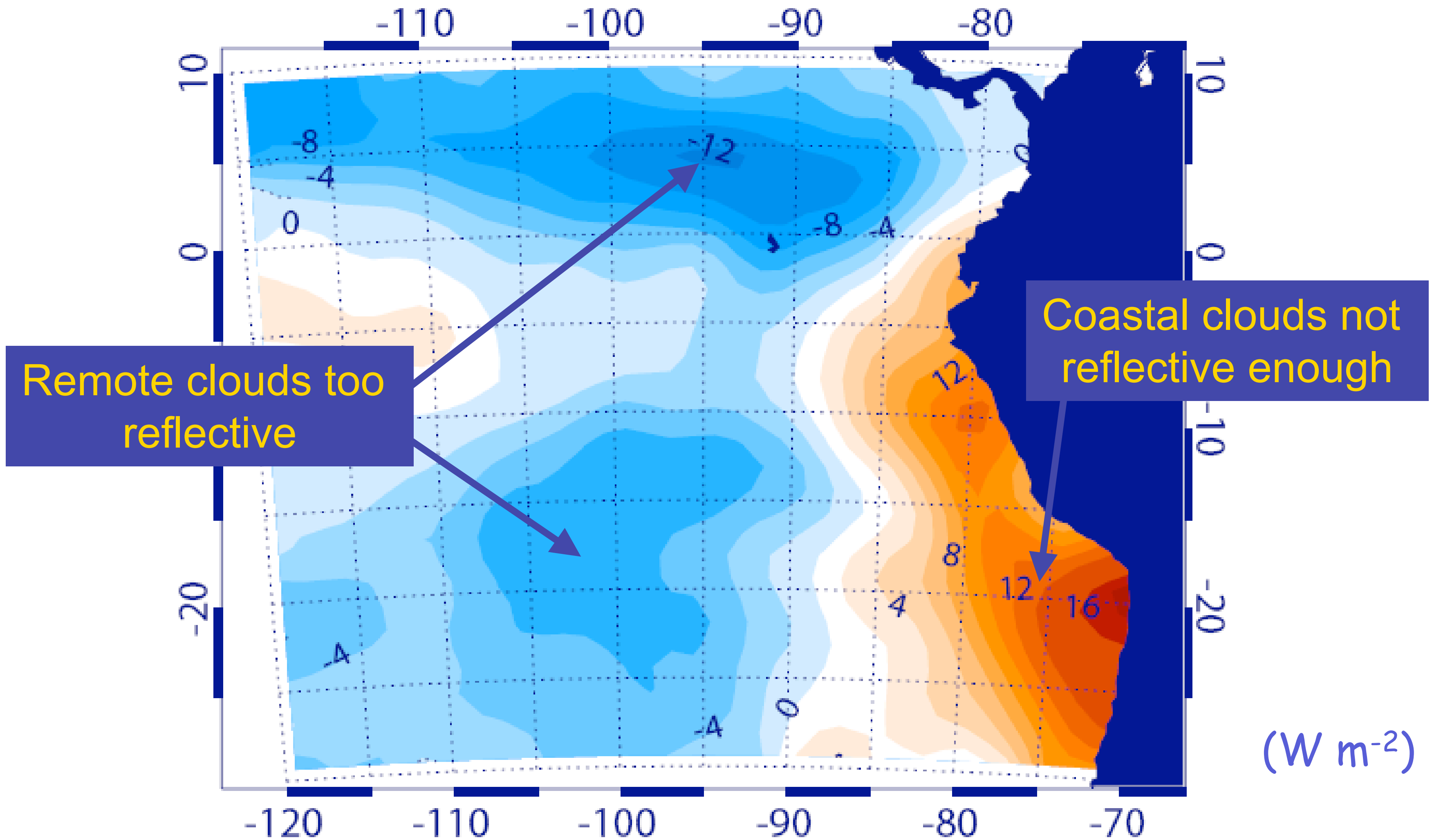
a. The CGCMs difficulties with the downstream effects on the SEP of a region with strong coastal upwelling and high Sc incidence are key contributors to the model errors in the SEP.

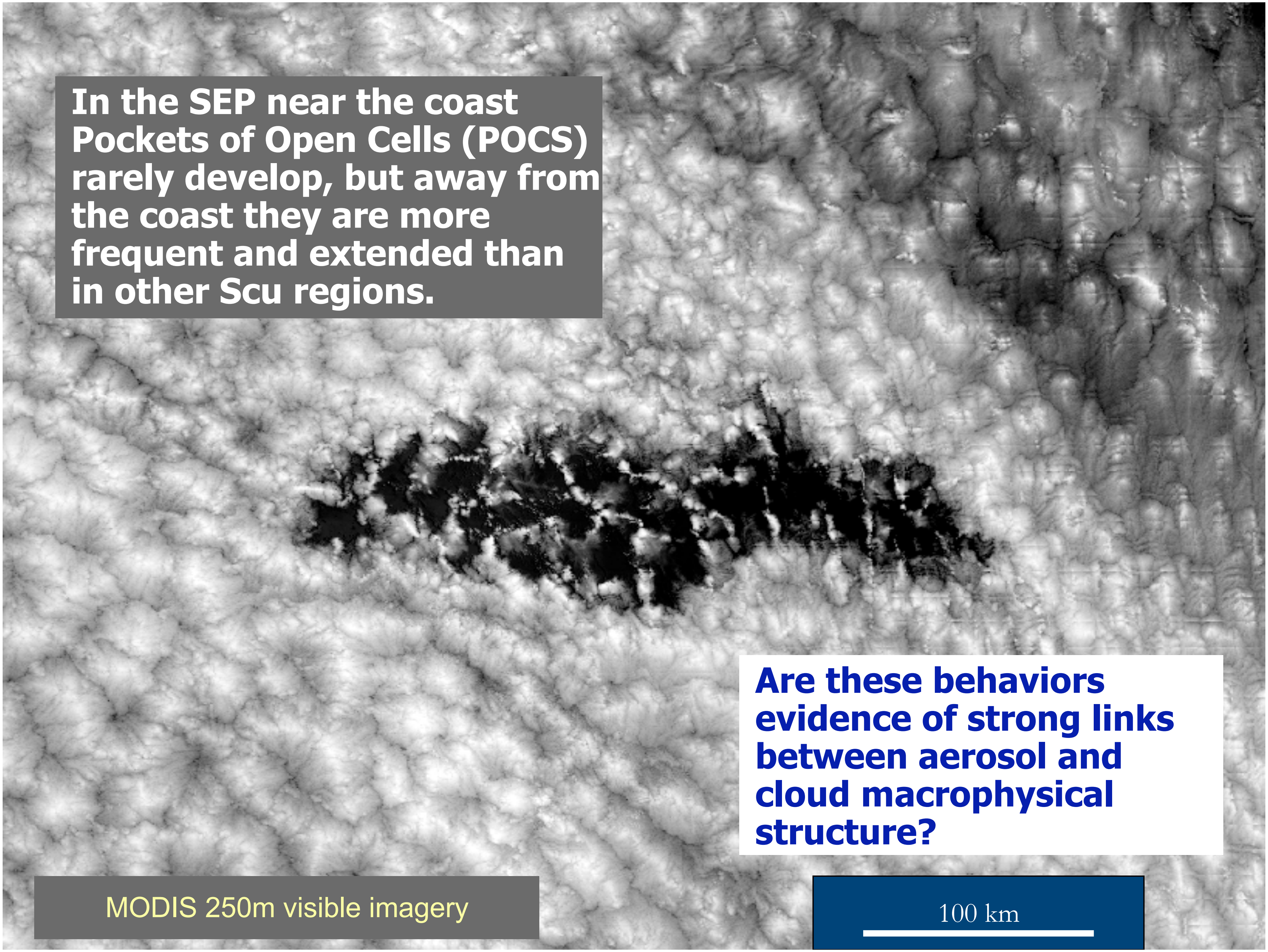
b. In the atmosphere, southeast trades from the South American coast flow from a cool and dry PBL over strong SST gradients and regions where trade cumuli form moistening the lower troposphere.

c. In the ocean, mesoscale eddies not captured by OGCMs, play a major role in the transport of heat and fresh water from coastally upwelled water to regions further offshore.

d. The highest potential for overcoming climate models difficulties in the SEP within the VOCALS timeframe is based on a multi-scale approach.

Error in TOA net SW radiation caused by assumption of constant cloud droplet effective radius




In the SEP near the coast Pockets of Open Cells (POCS) rarely develop, but away from the coast they are more frequent and extended than in other Scu regions.
Are these behaviors evidence of strong links between aerosol and cloud macrophysical structure?
MODIS 250m visible imagery
100 km

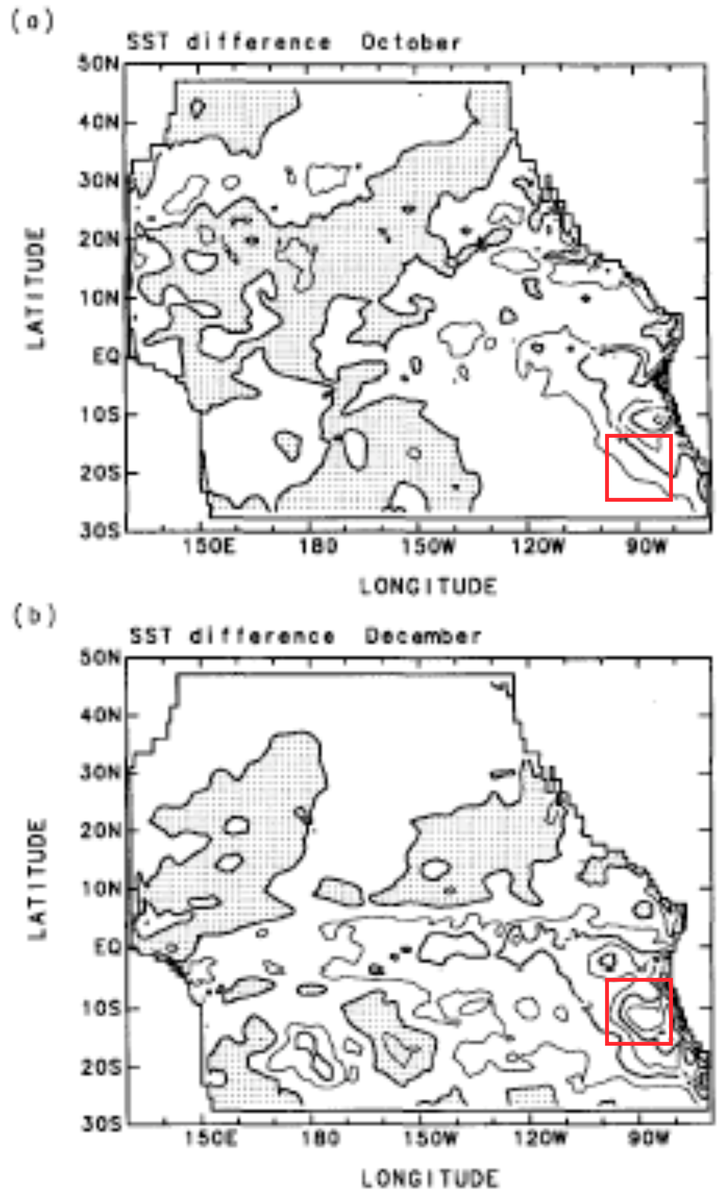


FIG. 7. Difference in simulated SST between the stratus experiment and the control simulation for (a) October and (b) December. Contour interval is 1 K; regions with positive values are stippled.

Hypothesis-Testing Experiment:

Stratocumulus incidence in a coupled GCM was set to 100% within the red square

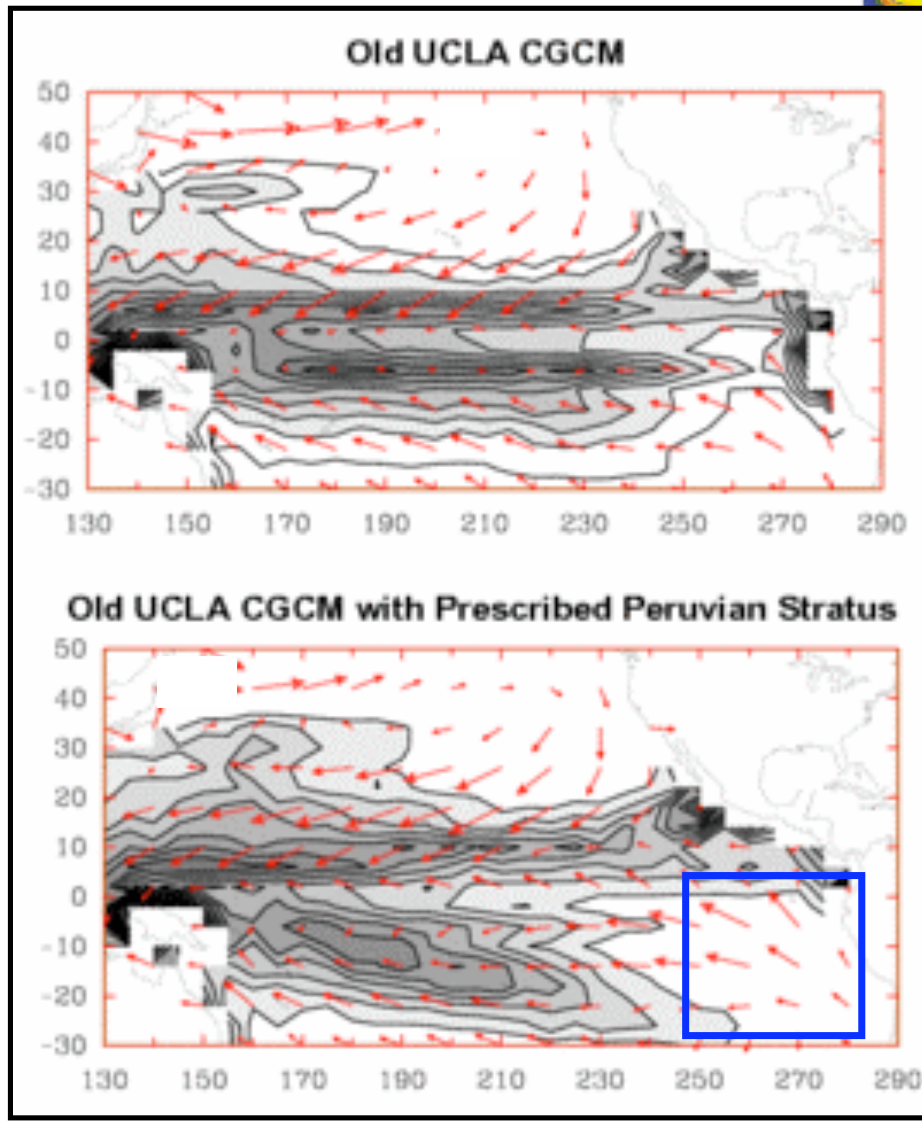
Note the increase in extent of the affected region

Ma, C.-C., C. R. Mechoso, A. W. Robertson and A. Arakawa, 1996. *J. Climate*, **9,** 1635-1645

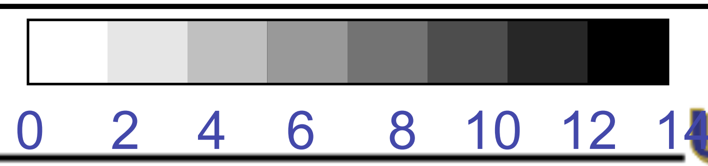
A coupled problem

- Correct prediction of stratus properties is important for the correct prediction of the climate over the tropical warm pool
- connections with ITCZ through both ocean and atmosphere

(Yu and Mechoso 2001)

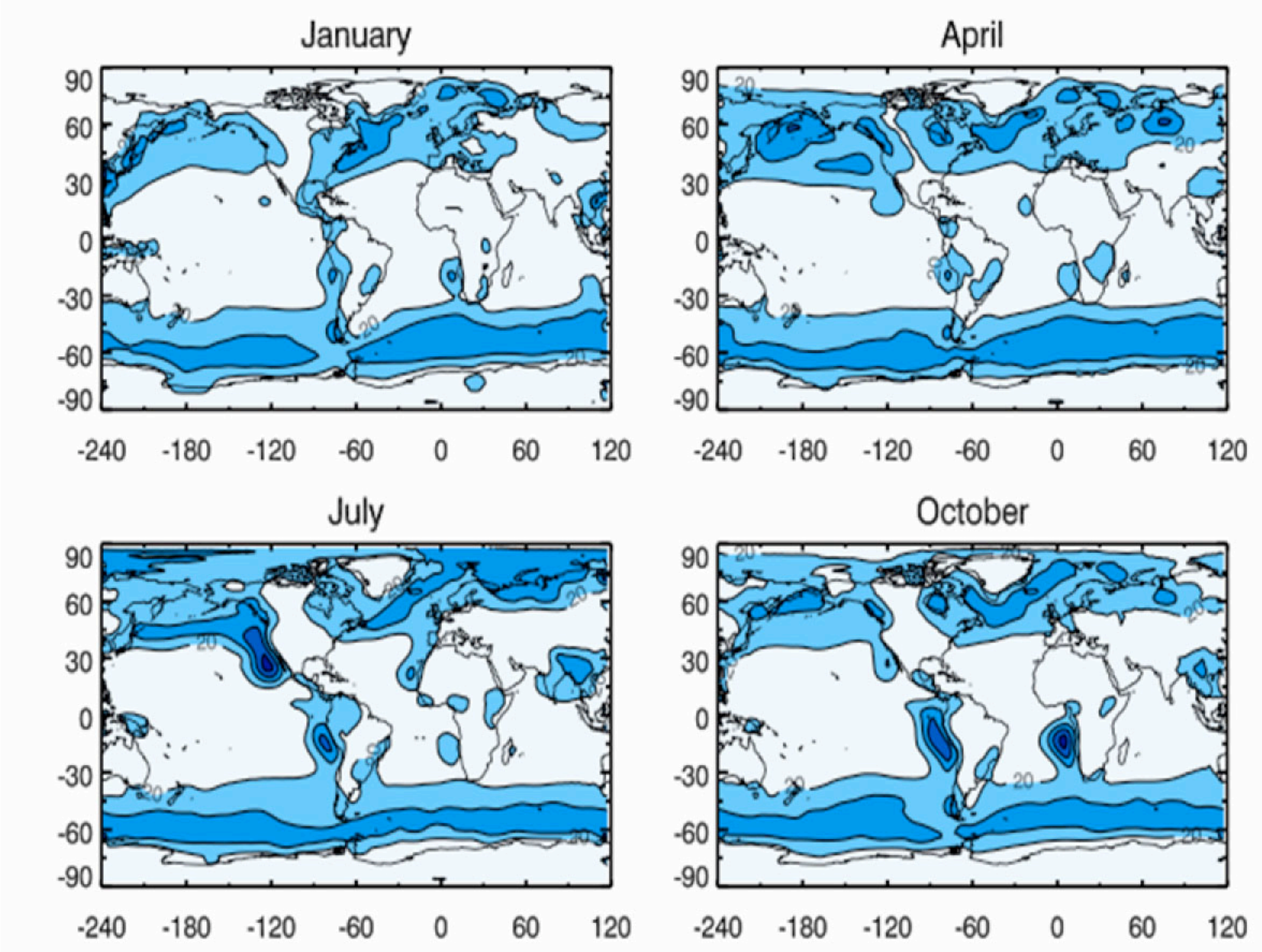


Precip [mm day^{-1}]



UCLA

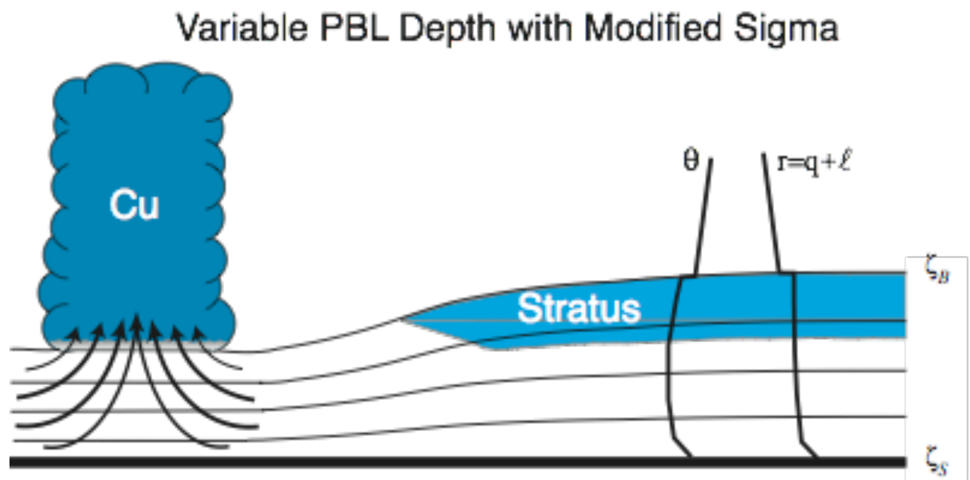
Stratocumulus Incidence by AGCMs has improved



***Prescribed SSTs**

UCLA AGCM v7.1 2.5x2x29L

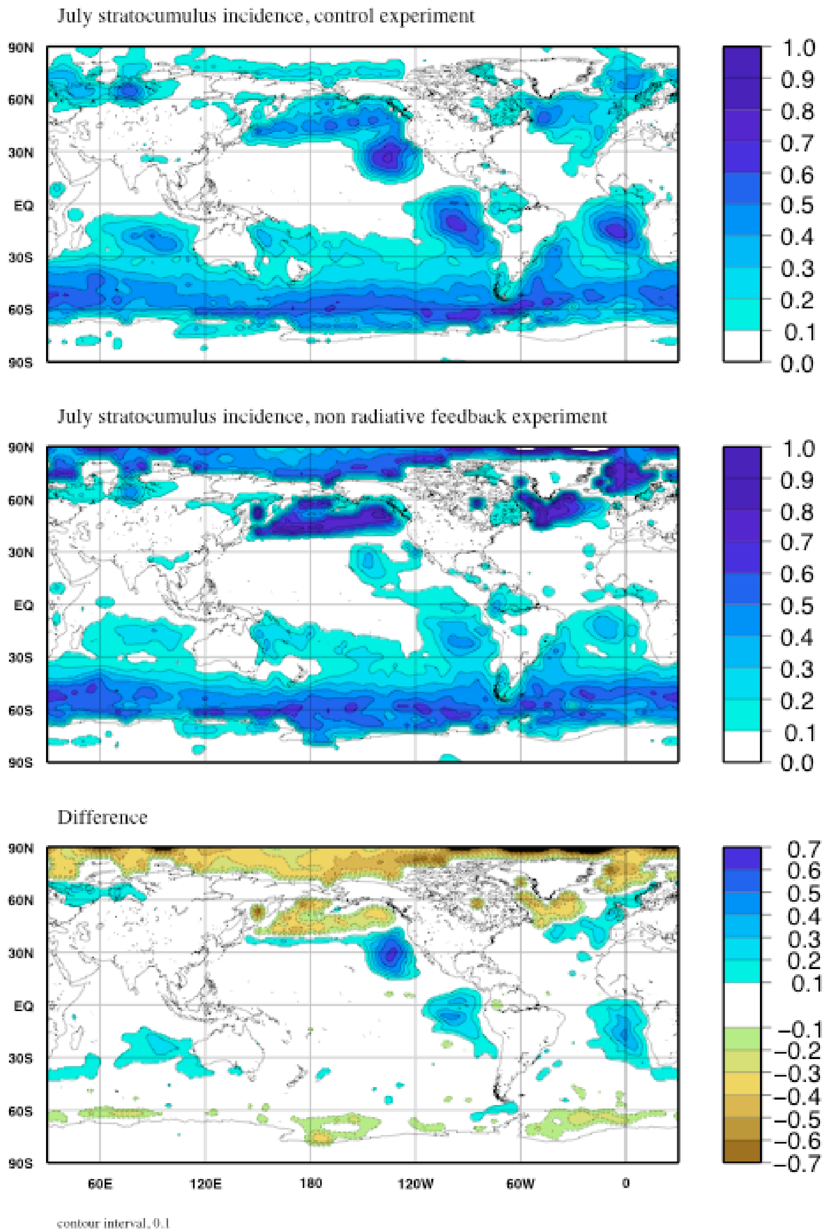
Vertical Structure of UCLA (and CSU) AGCM



- The PBL framework is built upon interactions between different types of clouds and PBL processes
- Implementation of the framework leads to coordinate surfaces that move with moving PBL top. This slightly complicates the dynamics, but greatly simplifies the physics

UCLA

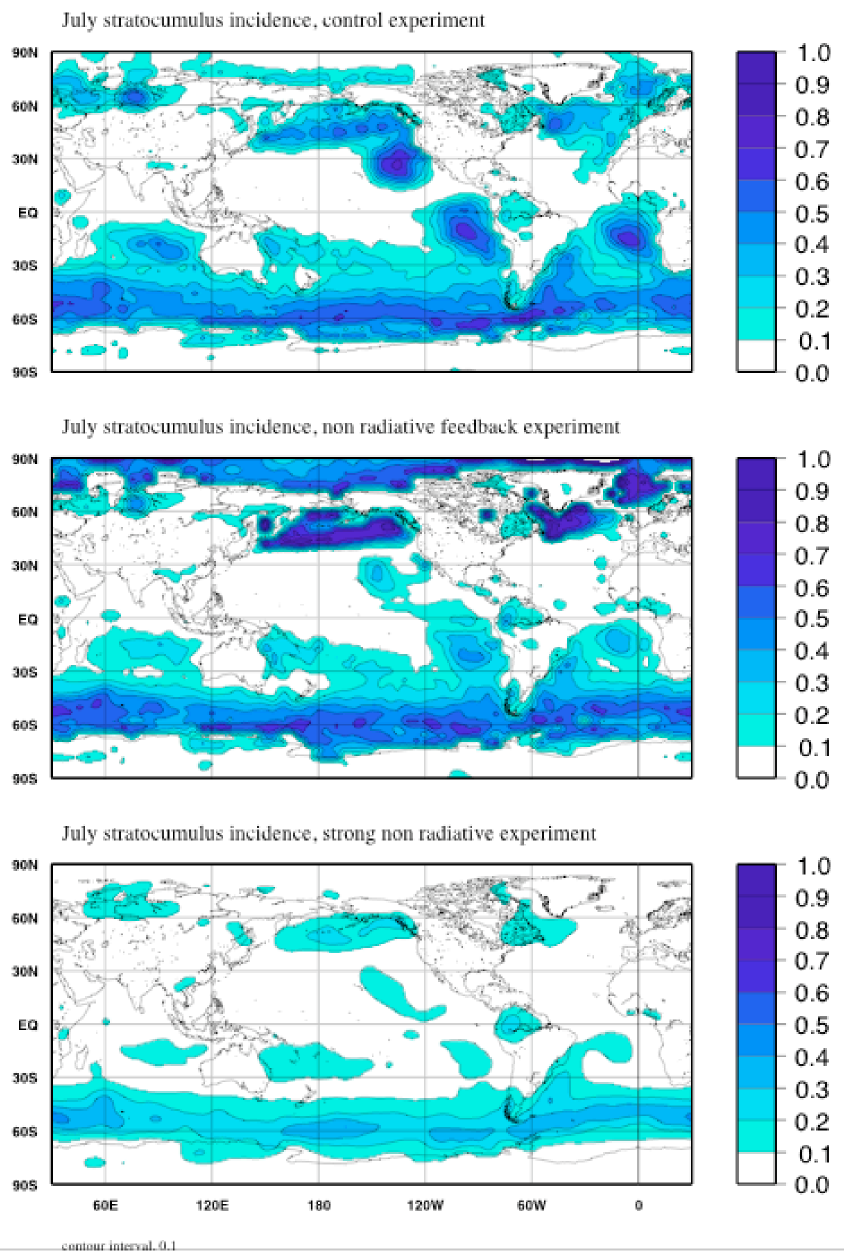
Scu: Radiative Feedbacks



Radiative cooling at PBL top is not included in entrainment and TKE calculation

Cazes-Boezio, 2007

UCLA



Scu: Radiative Feedbacks

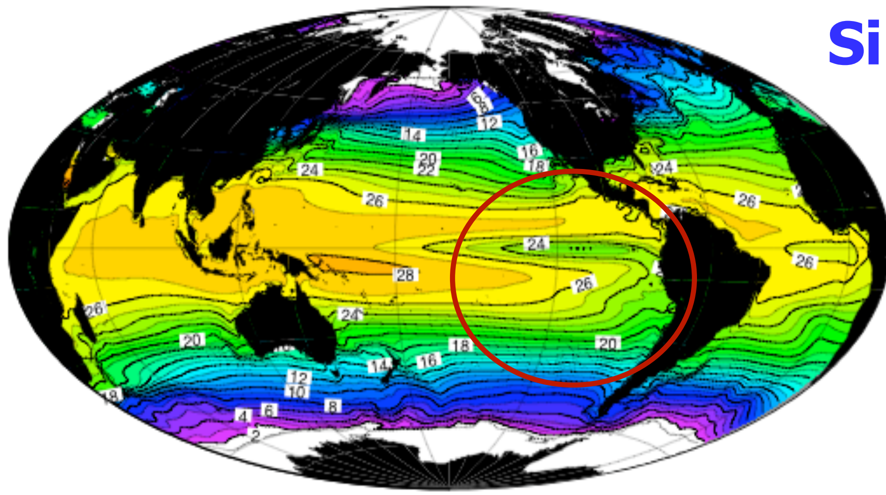
- Control
- Radiative cooling at PBL top not in E nor TKE
- No radiative effects in PBL

Cazes-Boezio, 2007

UCLA

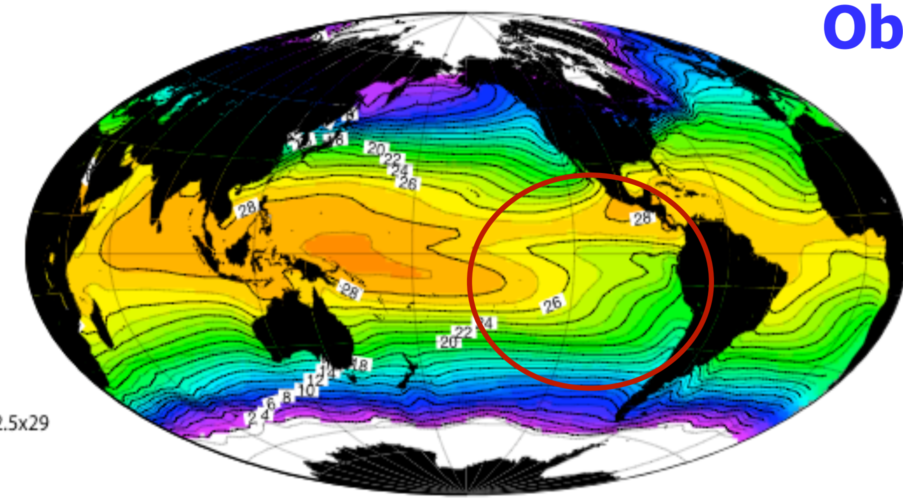
The excessive symmetry about the equator of SST simulated by CGCM remains

Annual Mean SST Simulation



Simulated annual mean SST

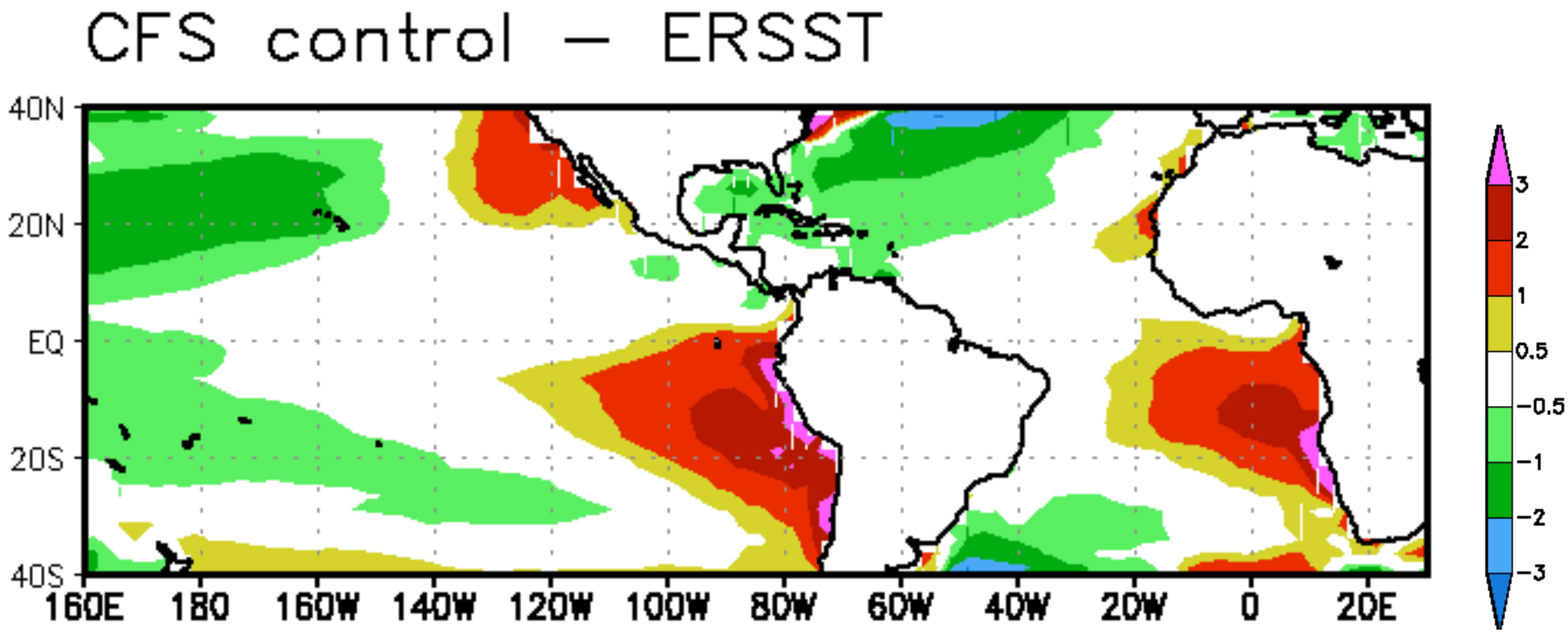
Annual Mean SST: Reynolds analysis



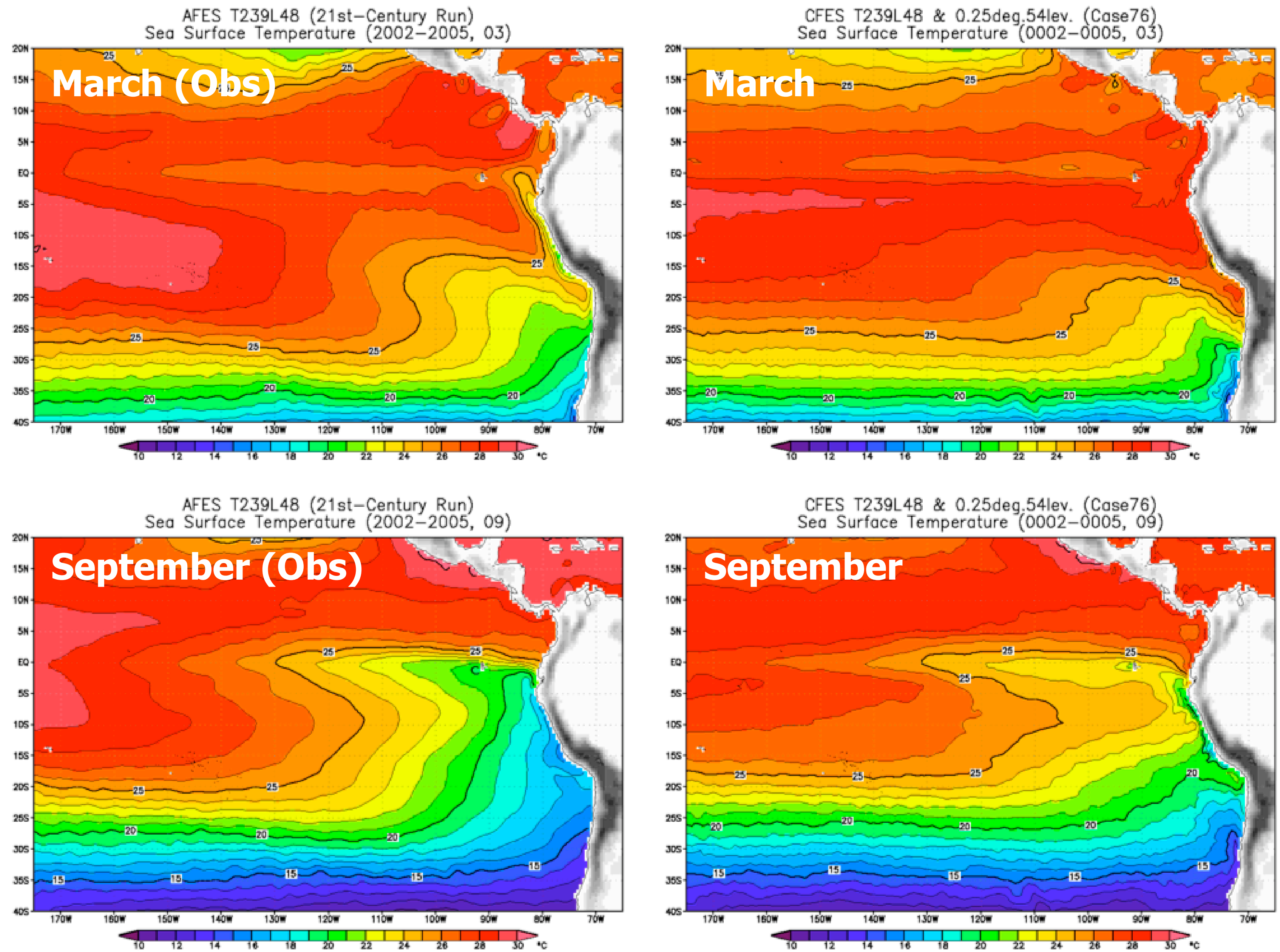
Observed annual mean SST

UCLA AGCM 8.0 2x2.5x29
MIT OGCM Global

Annual mean SST errors in CFS CMIP simulation



- Warm SST bias over the Southeastern Pacific (SEP) and Southeastern Atlantic

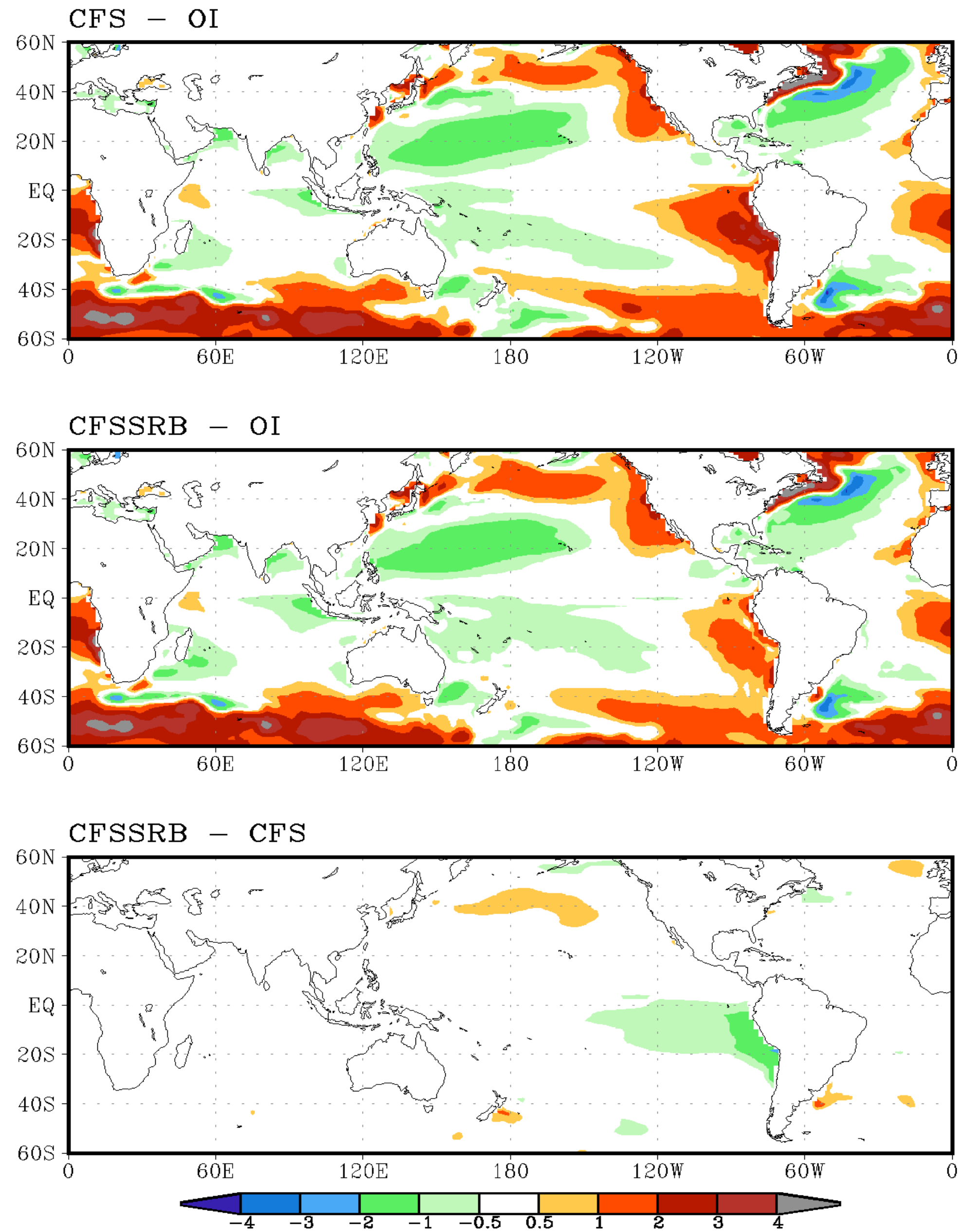

AFES T239L48 (21st-Century Run)
Sea Surface Temperature (2002–2005, 03)
March (Obs)
CFES T239L48 & 0.25deg.54lev. (Case76)
Sea Surface Temperature (0002–0005, 03)
March
AFES T239L48 (21st-Century Run)
Sea Surface Temperature (2002–2005, 09)
September (Obs)
CFES T239L48 & 0.25deg.54lev. (Case76)
Sea Surface Temperature (0002–0005, 09)
September
20N 15N 10N 5N EQ 5S 10S 15S 20S 25S 30S 35S 40S
170W 160W 150W 140W 130W 120W 110W 100W 90W 80W 70W
10 12 14 16 18 20 22 24 26 28 30 °C

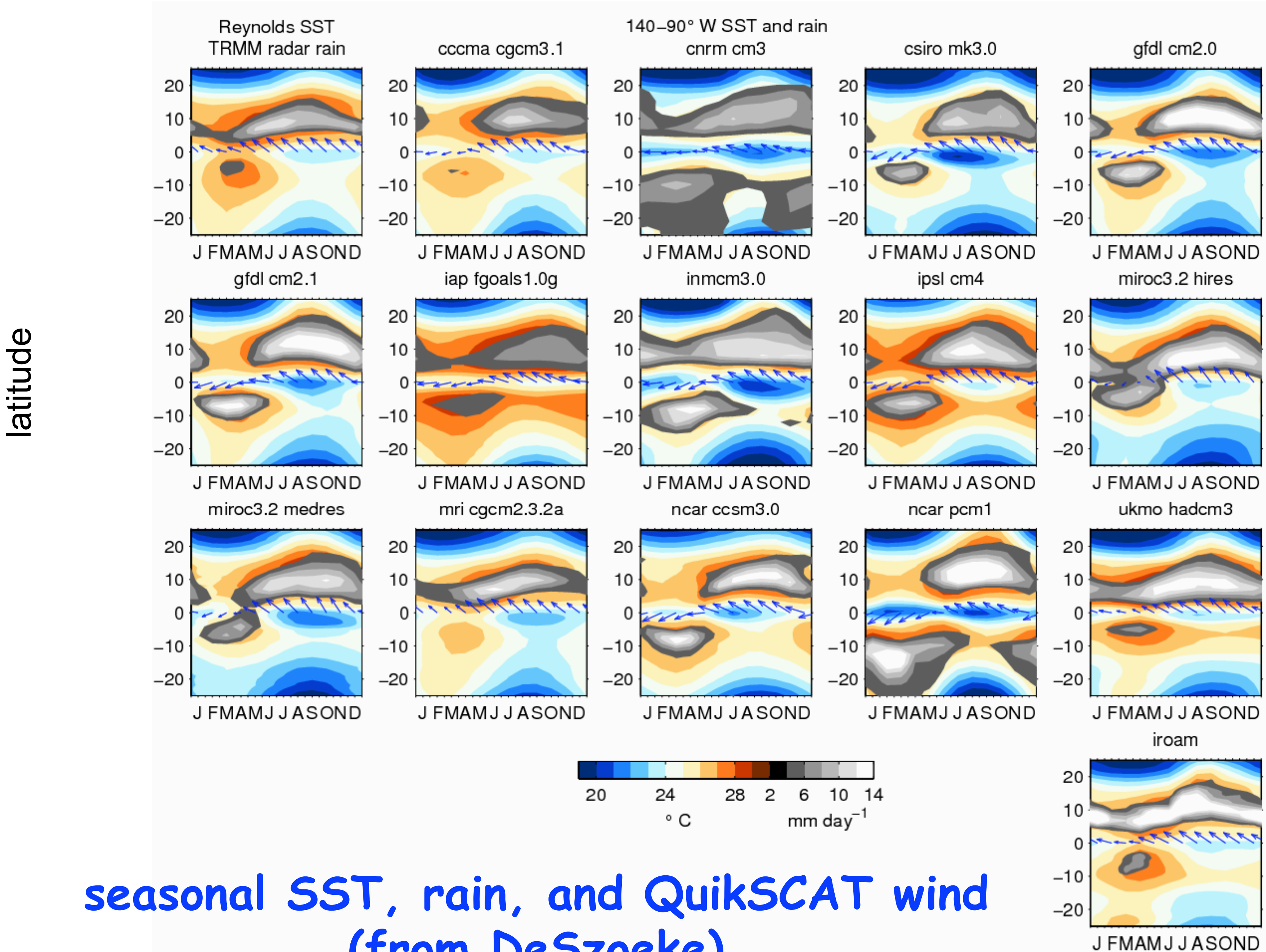
Radiation Processes

In the NCEP CFS model, the warm SST bias over the SEP is reduced by about half if radiation at the ocean surface in the region is prescribed from a climatology.

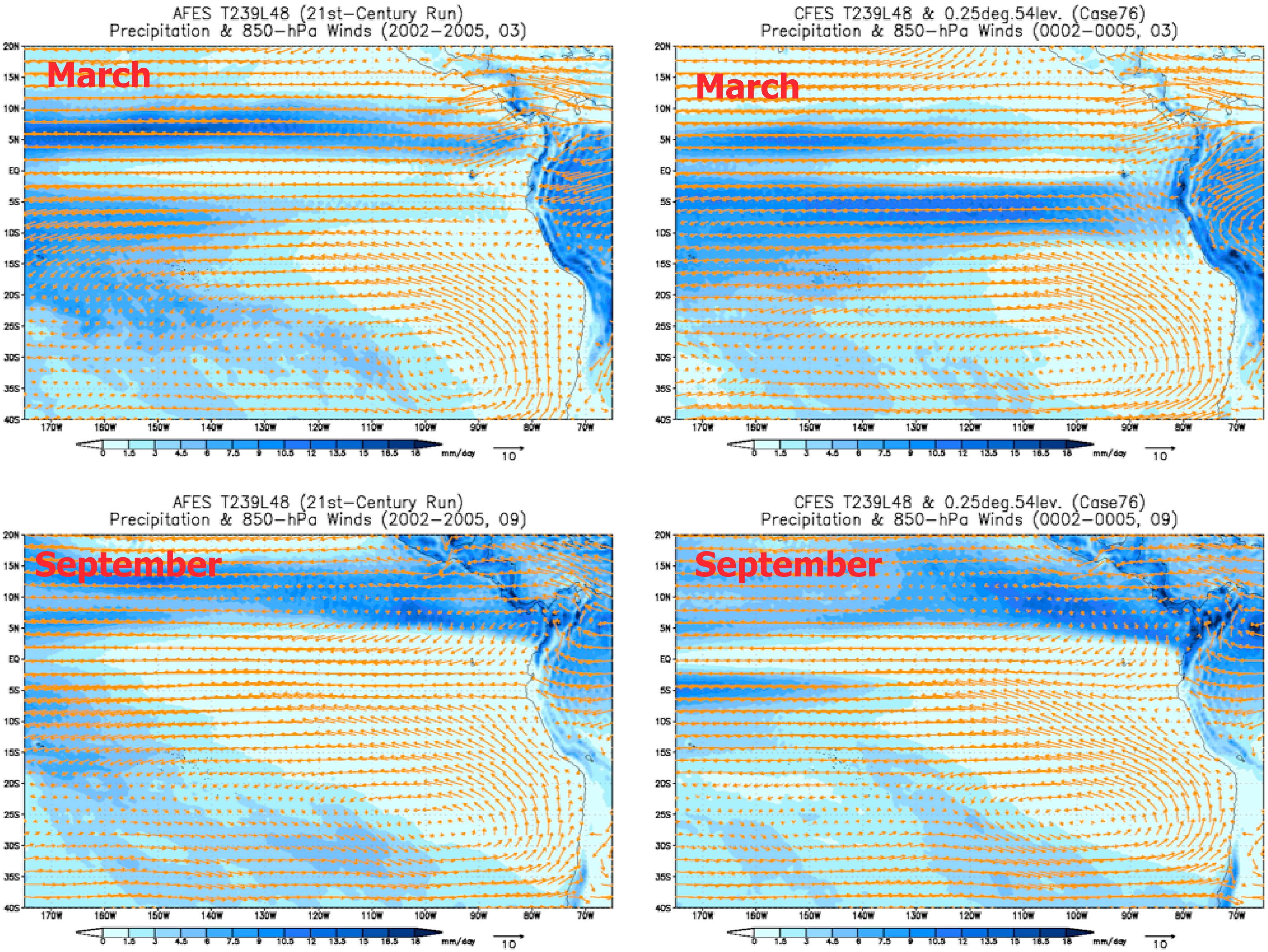
Also, interannual variability is very weak.

Artificial GCM fixes do not work!

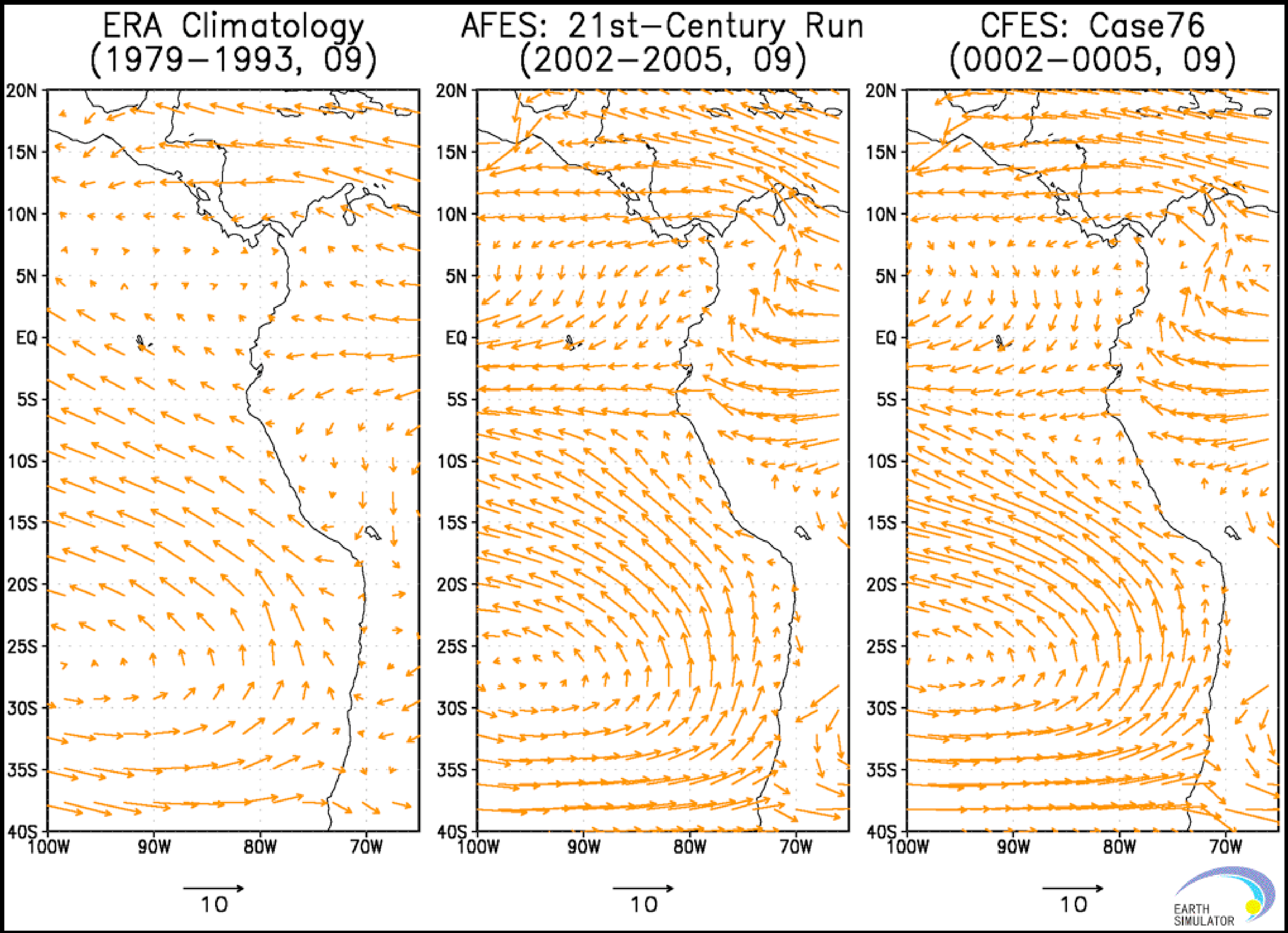




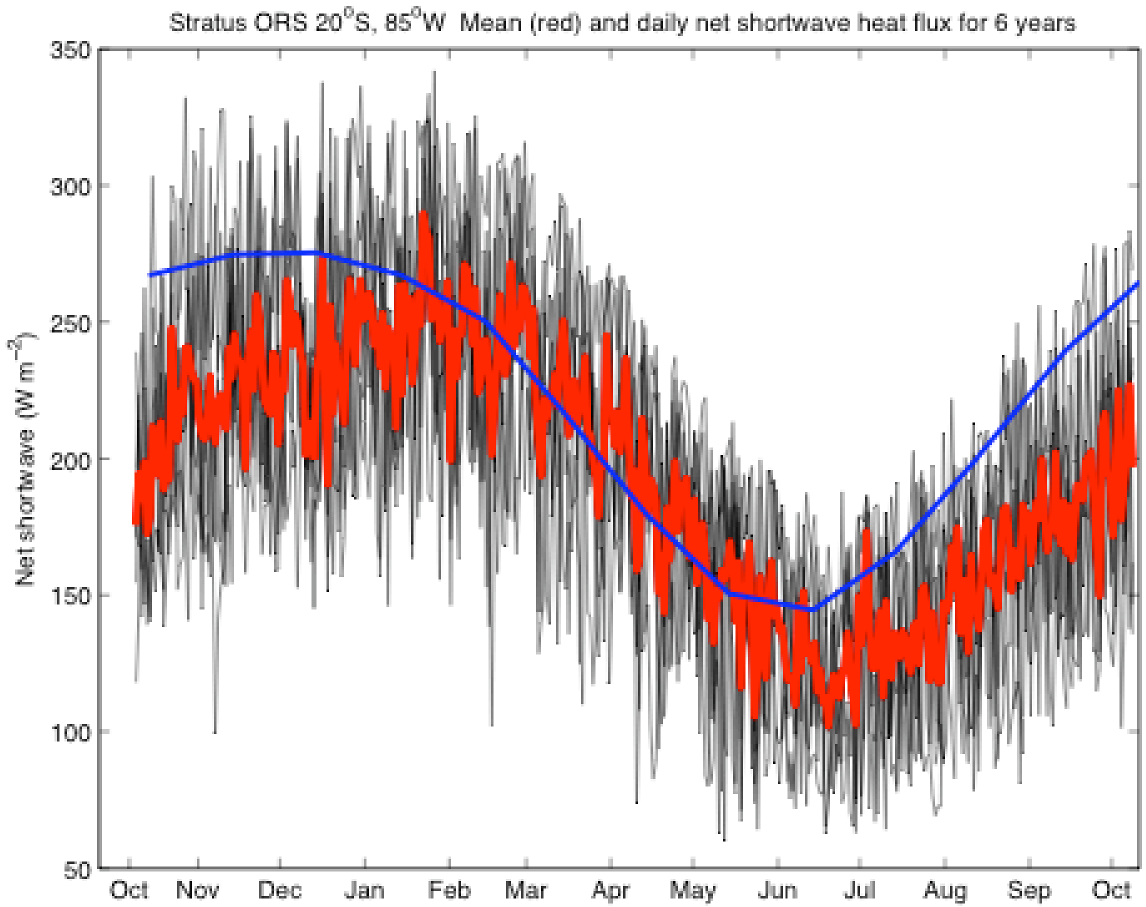
seasonal SST, rain, and QuikSCAT wind
(from DeSzoeke)


AFES T239L48 (21st-Century Run)
Precipitation & 850-hPa Winds (2002-2005, 03)
March
CFES T239L48 & 0.25deg.54lev. (Case76)
Precipitation & 850-hPa Winds (0002-0005, 03)
March
AFES T239L48 (21st-Century Run)
Precipitation & 850-hPa Winds (2002-2005, 09)
September
CFES T239L48 & 0.25deg.54lev. (Case76)
Precipitation & 850-hPa Winds (0002-0005, 09)
September
mm/day
10

Winds at 850 Hpa - September



Net Shortwave at IMET Buoy (85W, 20S)



Blue line: ERA 40

From R. Weller

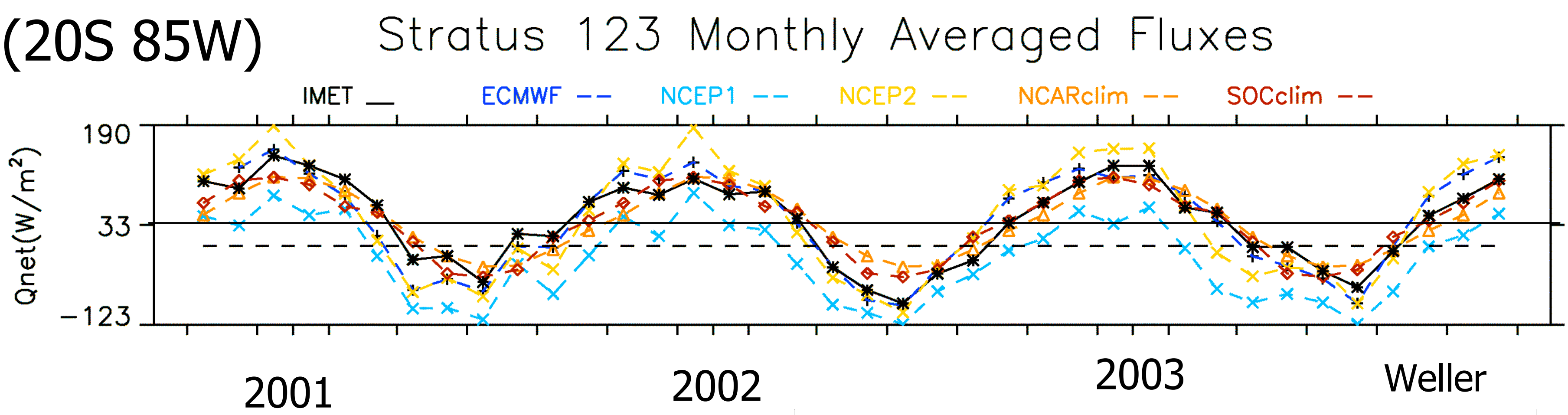
Upwelling and Ocean Eddies

The oceanic wind-driven circulation in the SEP develops a vigorous mesoscale and submesoscale eddy field that covers a much larger area than the coastal upwelling zone. The extent to which OGCMs capture this extension is unclear, but is unlikely to be realistic.

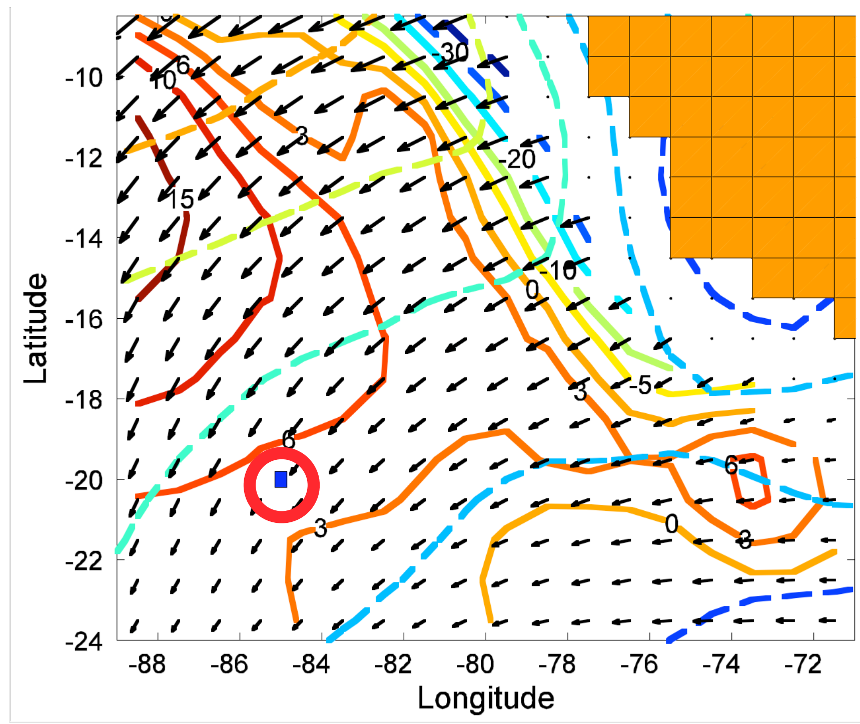
Global OGCMs have difficulties with the simulation of eddy transports of heat, salinity, and nutrients in the SEP, most plausibly because they do not resolve well the regional upwelling, currents, and eddies.

UCLA

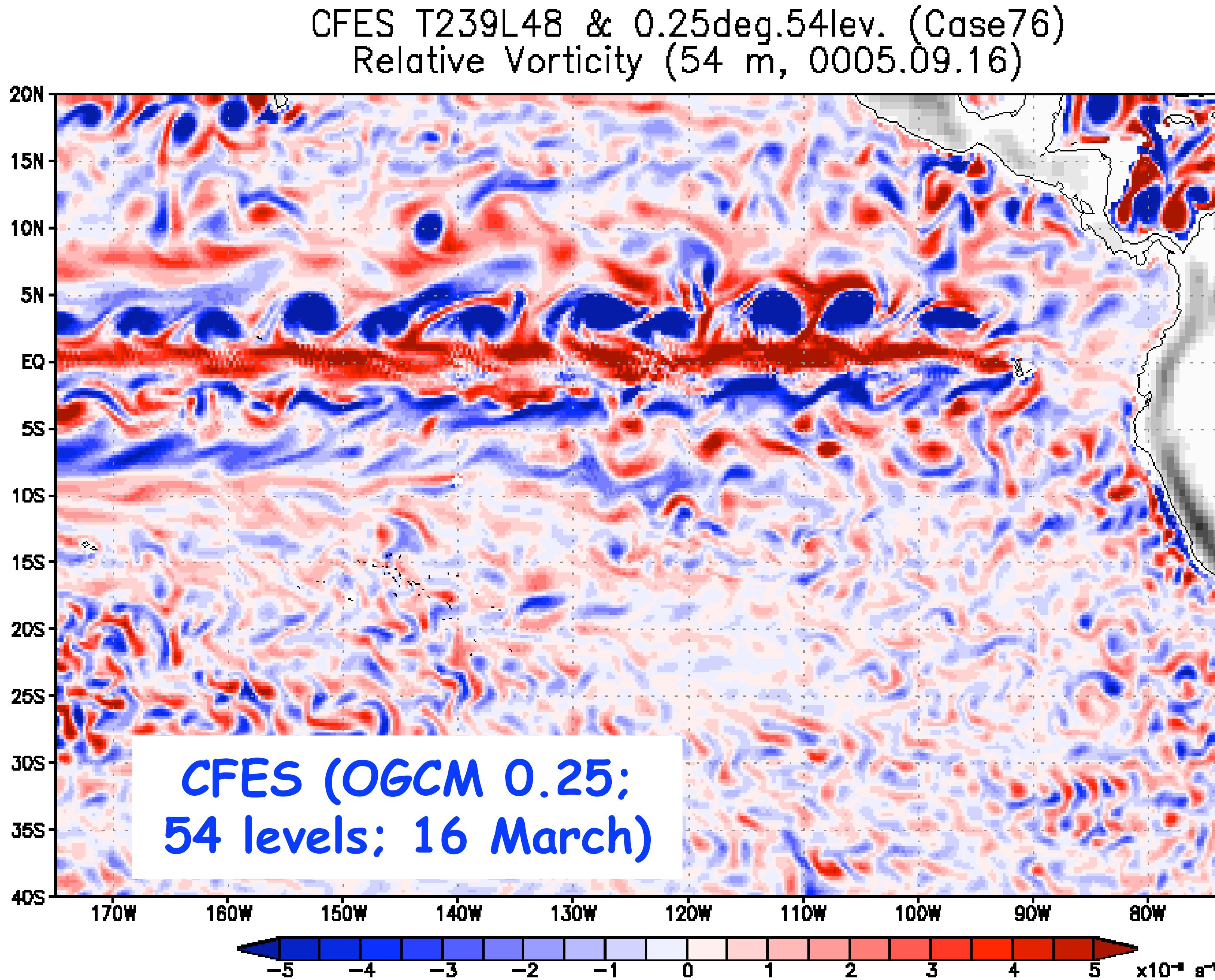
Heat budget does not close at buoy location



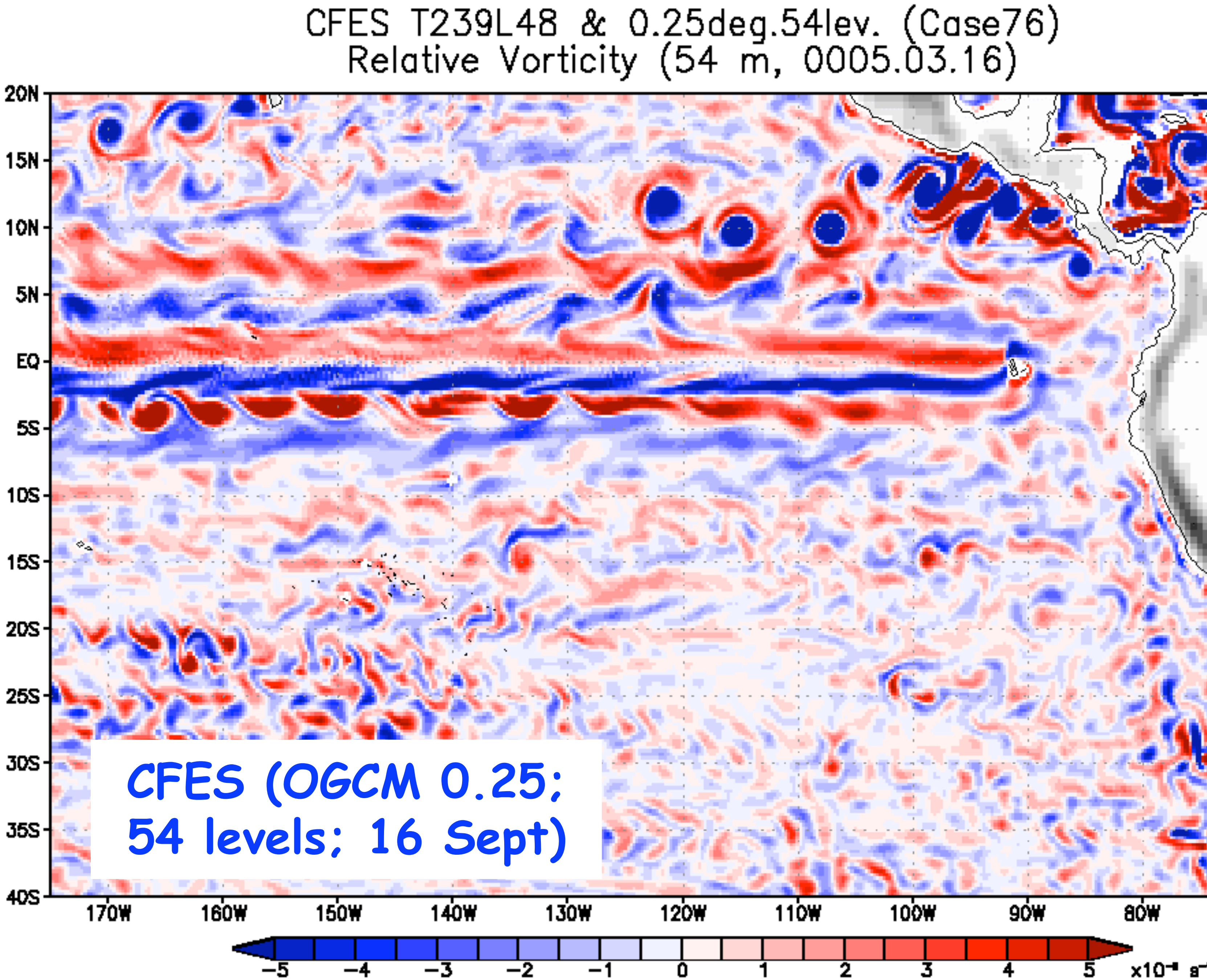
Annual-mean heat flux **into** ocean ~ 30 W m^{-2} at 1500 km offshore under persistent low cloud!



Is this net warming at the surface balanced by heat transports by ocean eddies?



CFES T239L48 & 0.25deg.54lev. (Case76)
Relative Vorticity (54 m, 0005.09.16)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
170W
160W
150W
140W
130W
120W
110W
100W
90W
80W
70W
−5
−4
−3
−2
−1
0
1
2
3
4
5
CFES (OGCM 0.25;
54 levels; 16 March)

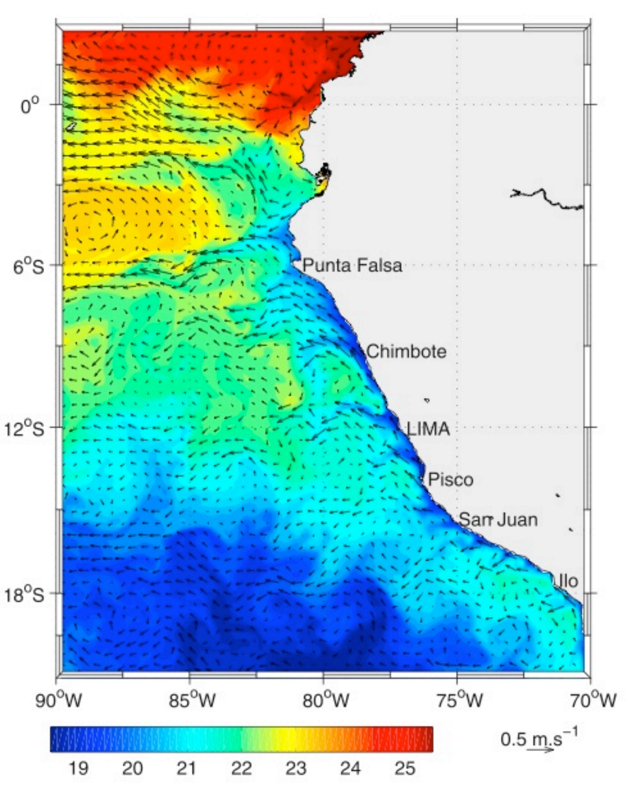


CFES T239L48 & 0.25deg.54lev. (Case76)
Relative Vorticity (54 m, 0005.03.16)
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
170W
160W
150W
140W
130W
120W
110W
100W
90W
80W
70W
-5
-4
-3
-2
-1
0
1
2
3
4
5
CFES (OGCM 0.25;
54 levels; 16 Sept)

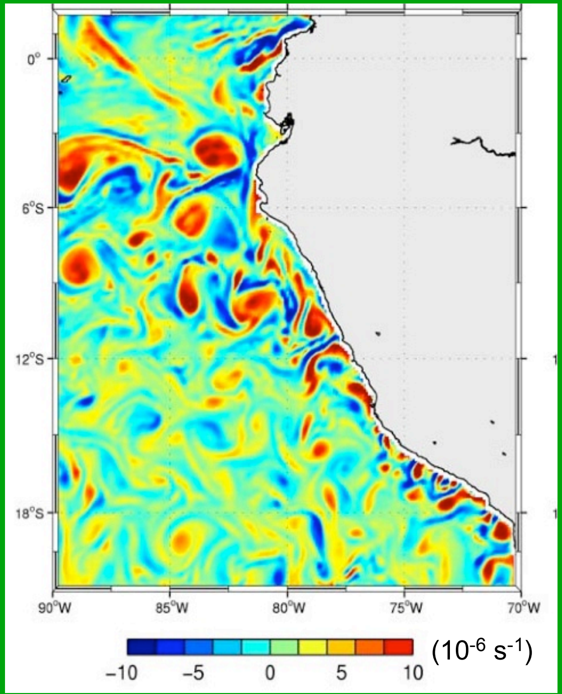
Perú Current by ROMS

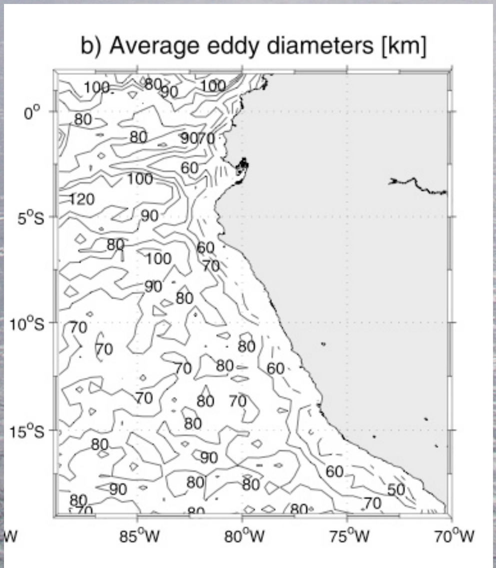
P. Penven, V. Echevin, J. Pasapera, F. Colas,
and J. Tam. JGR, 2005

- Surface Currents
- and SST



Vorticity at 20m

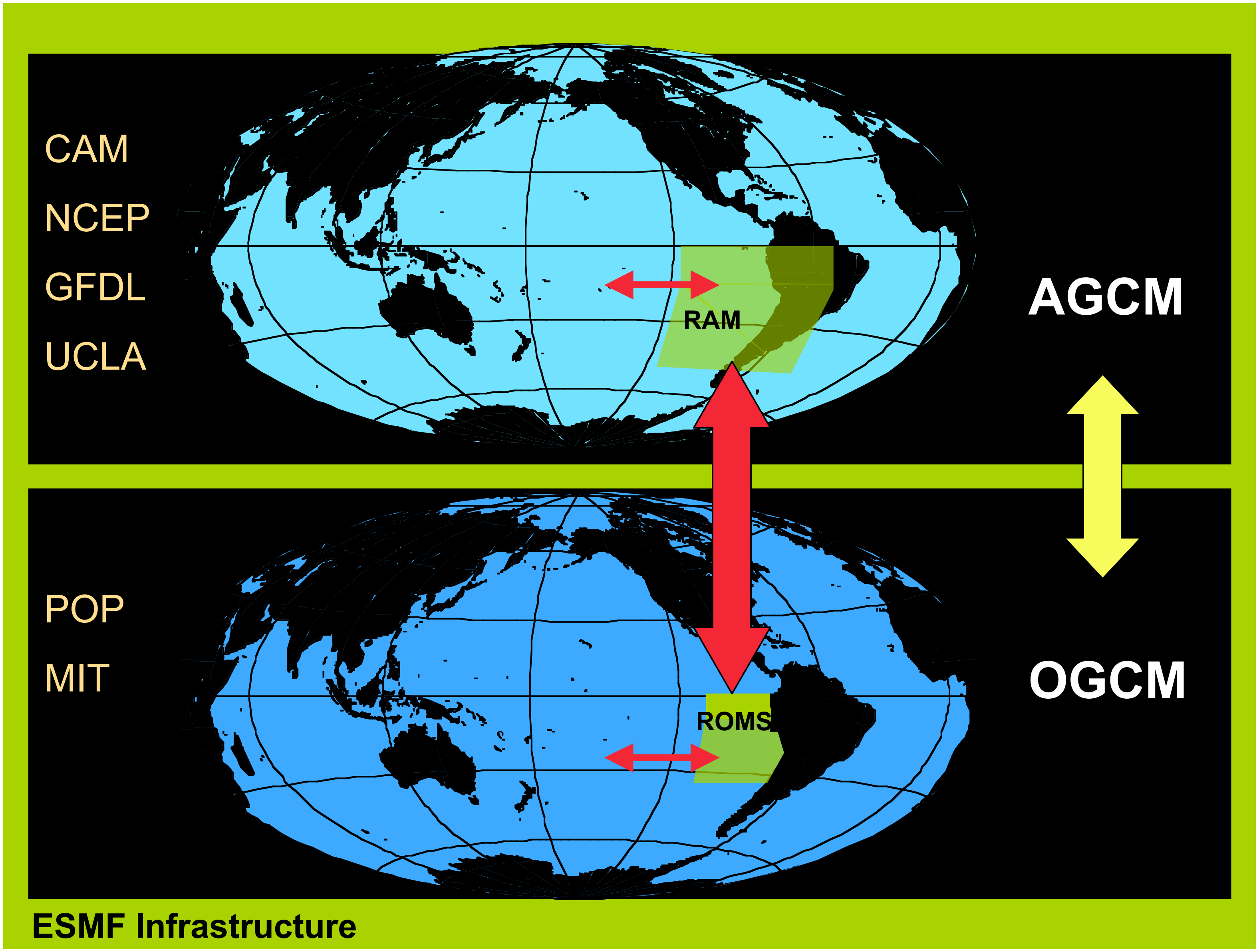




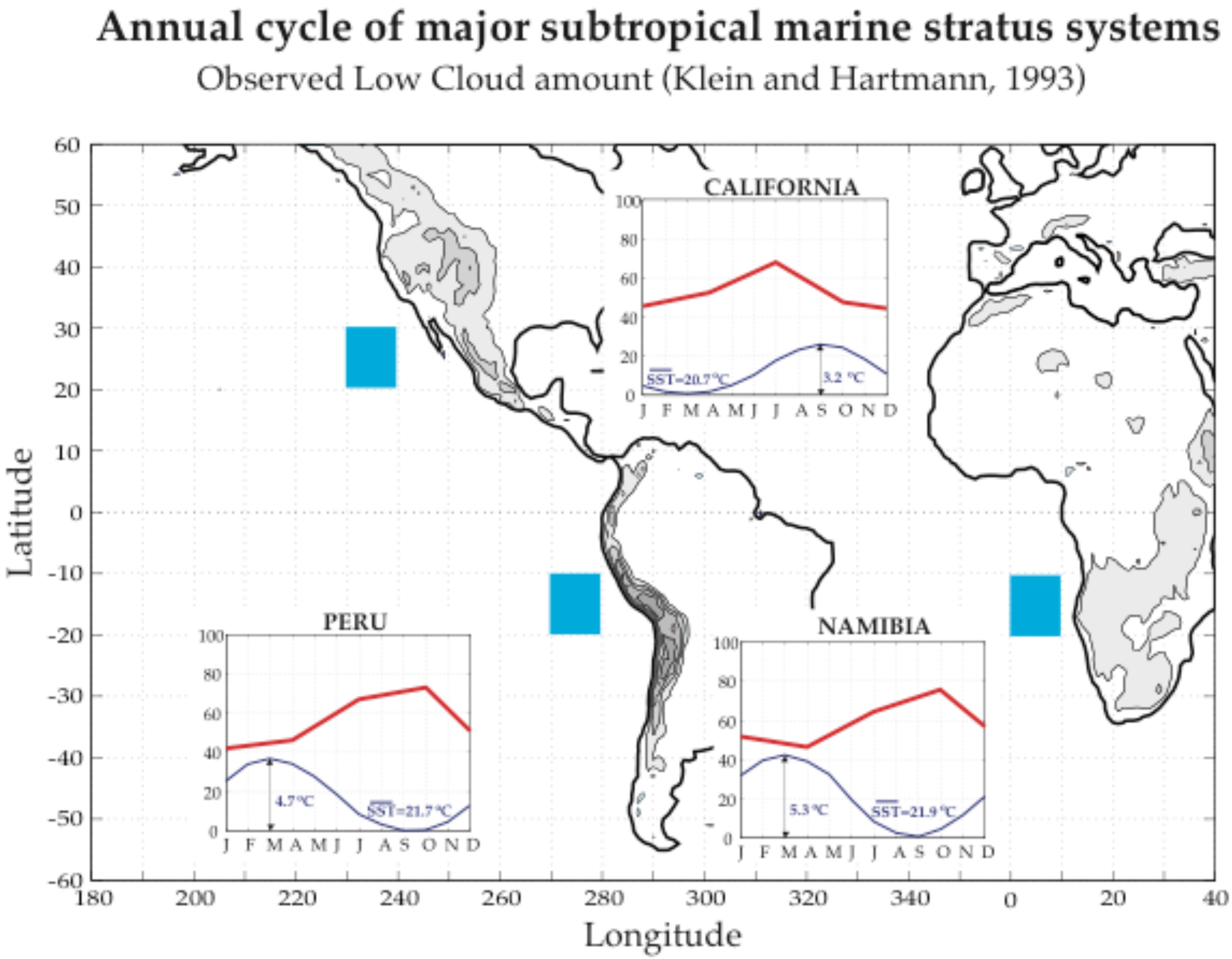
An approach, based on regional and high-resolution coastal models embedded within the seasonally and interannually varying global climate can overcome these model difficulties: MUSSIP

AGCM:
Atmosphere
General
Circulation
Model

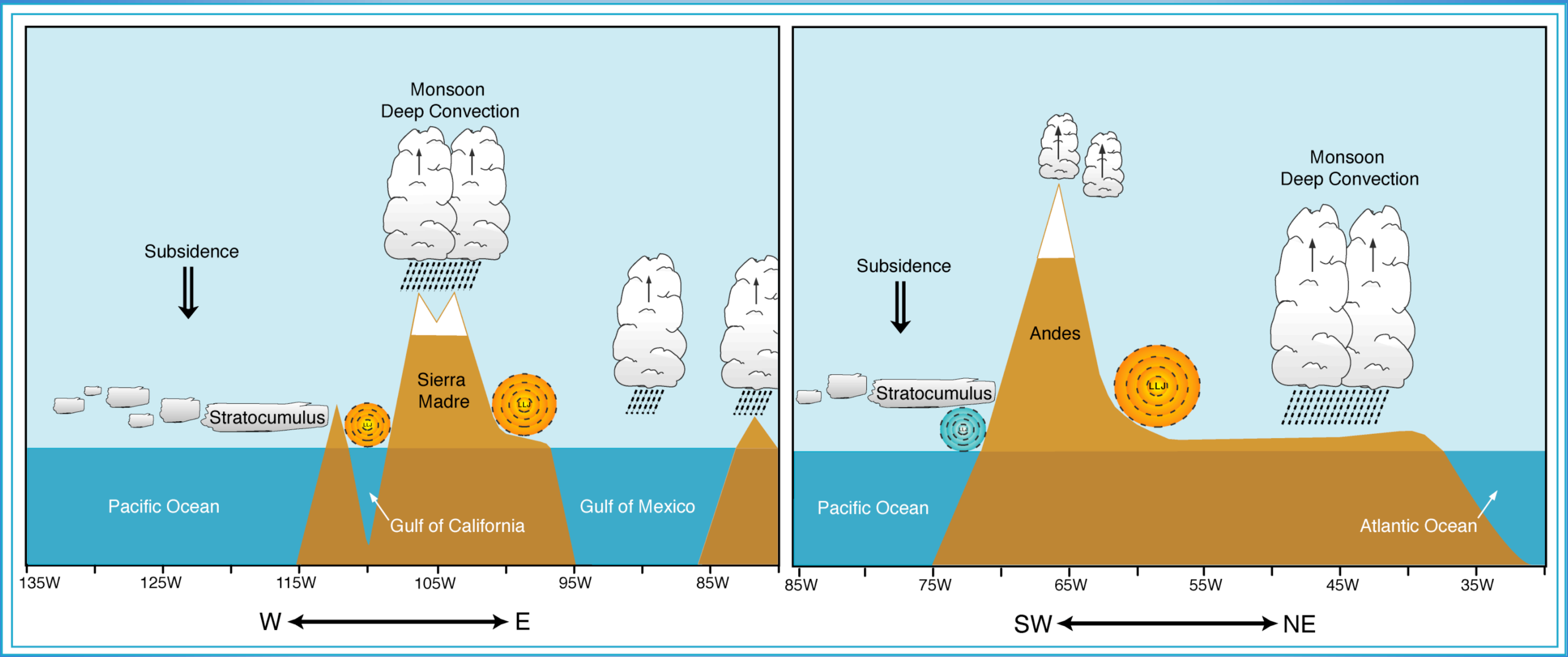
OGCM:
Ocean
General
Circulation
Model



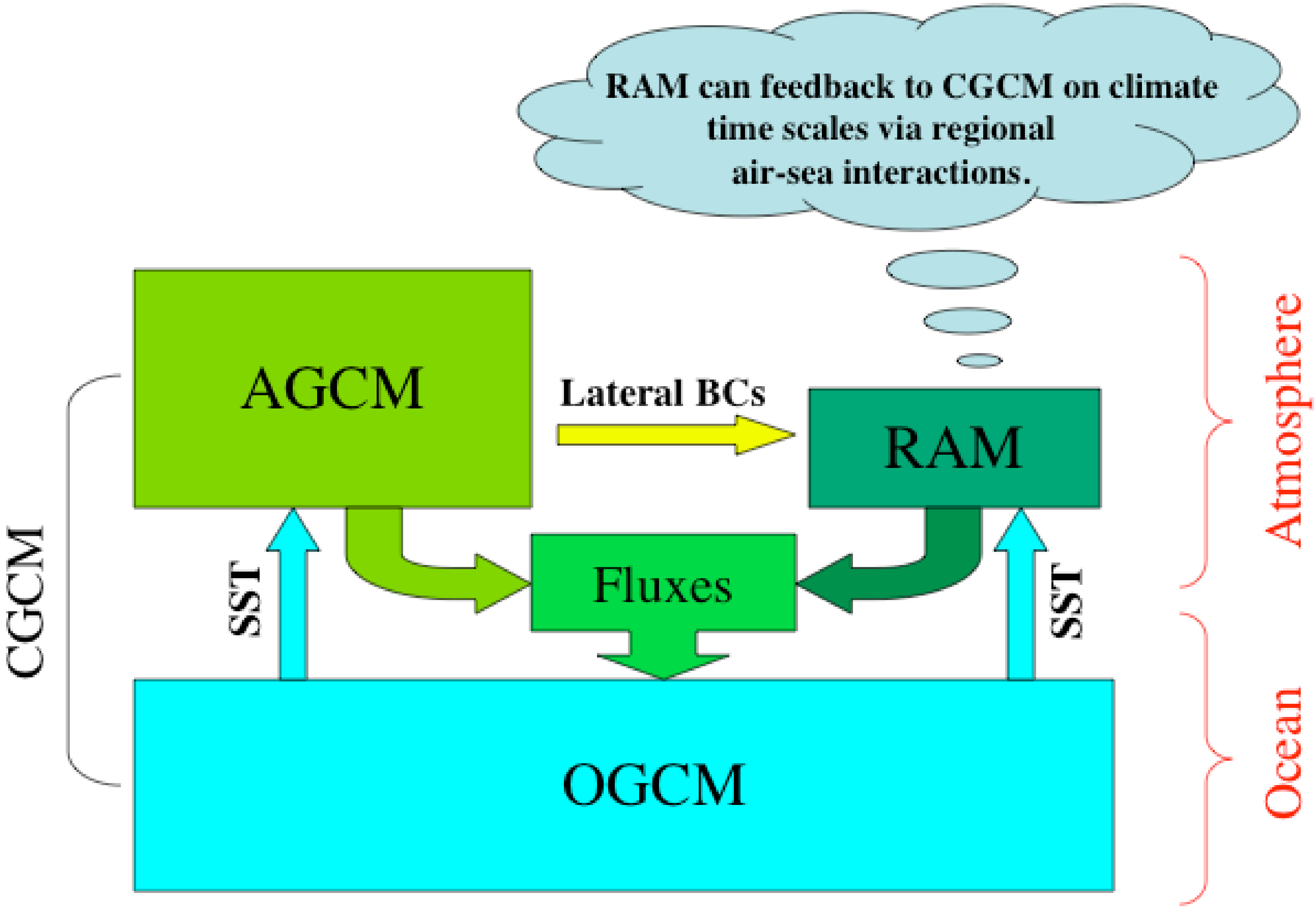
Role of stratus on double ITCZ bias



Monsoon Systems
Ascent to the east - Descent to the west



RAM interactively embedded into global CGCM



Summary - VOCALS Modeling

1) CGCMs have improved in the in the 1995-2005 period, especially in the extreme eastern Pacific: How much? Why?
2) Double ITCZ bias and too warm SSTs in the east remain in many models: Impact on ENSO predictions? Cure?
3) Surface winds in the eastern Pacific may not be adequate to simulate upwelling: How to improve? Higher resolution?
4) Mesoscale ocean eddies and mixing effect of wind transients: How to incorporate?
5) Indirect aerosol effects (e.g. distribution of cloud drop effective radius): How to parameterize?
6) Mesoscale features in the clouds decks: How to parameterize
7) MUSSIP: Is it ready to start implementation? Models? Framework?

Frontier's High Res CGCM

	AFES	CFES
AGCM Resolution	**T239 L48**	
AGCM Initial Condition	ECMWF Reanalysis Feb 11, 2001	ECMWF Reanalysis Jan 1 (Climatology)
Ocean	**RTG SST** (0.5°)	**OFES** 0.25° 54 level
	Feb 11, 2001--	T, S: WOA Jan no motion

EARTH SIMULATOR

Main Components of bulk parameterization

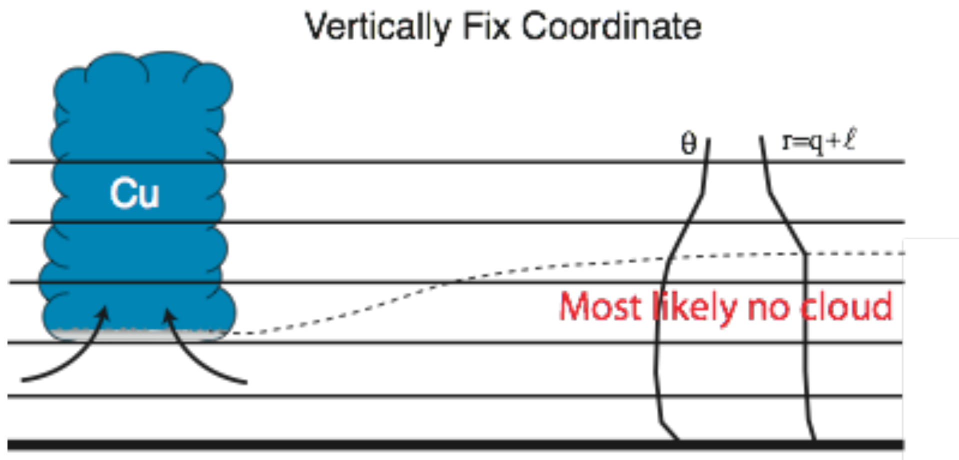
- **Bulk TKE (e_{PBL})** is predicted through a budget equation
- **Surface fluxes** are given by

$$
\left.
\begin{aligned}
F_v &= \rho_s C_U C_U \max\left(u_M\ ,\ \alpha_1 \sqrt{e_{PBL}}\right)\mathbf{v}_M \\
F_\theta &= \rho_s C_U C_T \max\left(u_M\ ,\ \alpha_2 \sqrt{e_{PBL}}\right)\left(\theta_G - \theta_M\right) \\
F_q &= \rho_s C_U C_T \max\left(u_M\ ,\ \alpha_2 \sqrt{e_{PBL}}\right)\left(q_G - q_M\right) k
\end{aligned}
\right\}
$$

- **Entrainment** is parameterized as function of TKE (e_{PBL}) and the jumps at PBL top of radiation, virtual dry static energy, and critical virtual static energy.

Vertical Structure of GCMs

(e.g.,NCAR,ECMWF,NCEP)

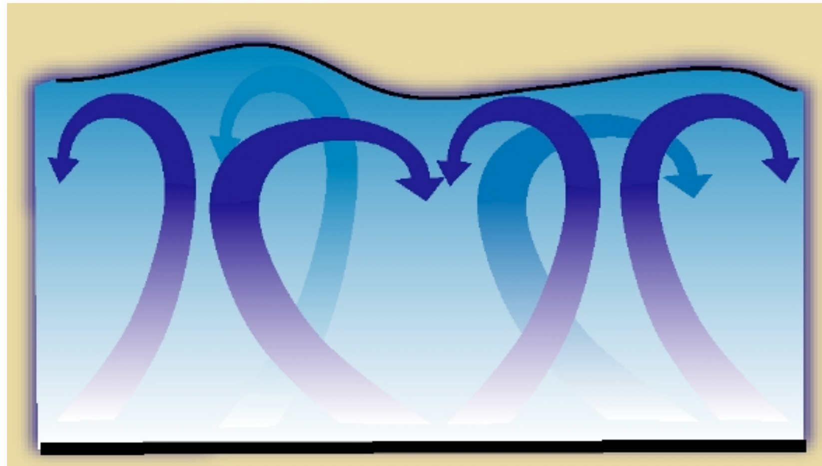


- Vertical coordinate surfaces are fixed
- Profiles may deviate from well mixed ones.
- Processes near the PBL top are difficult to simulate properly (even with moderately high vertical resolution).
- It is difficult to keep track of budget of PBL quantities.
- Thus, a realistic simulation of PBL cloud incidence may be difficult.
- It is difficult to simulate PBL-free atmosphere exchange realistically.

Hybrid approach to determine turbulence fluxes

• Effects of large-scale convective eddies are represented by a bulk PBL parameterization. Their fluxes are determined by interpolating conserved quantities such as moist static energy and total water mixing-ratio from surface to PBL top.

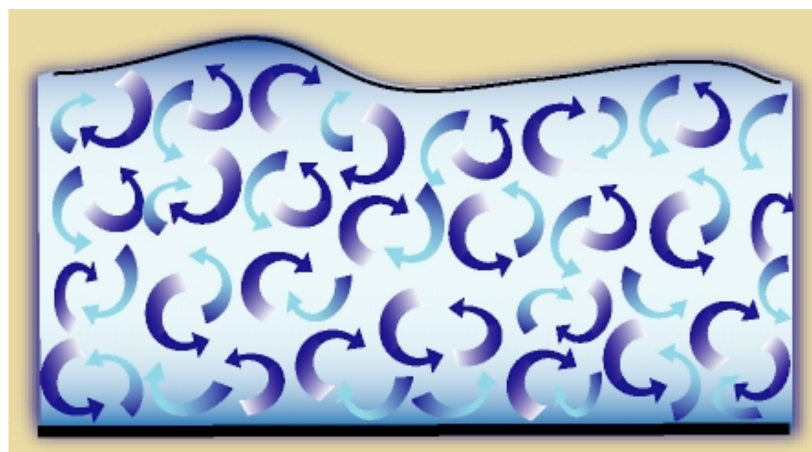
$$F_{\psi} \equiv a\left(F_{\psi}\right)_{S} + \left(1-a\right)\left(F_{\psi}\right)_{B}$$

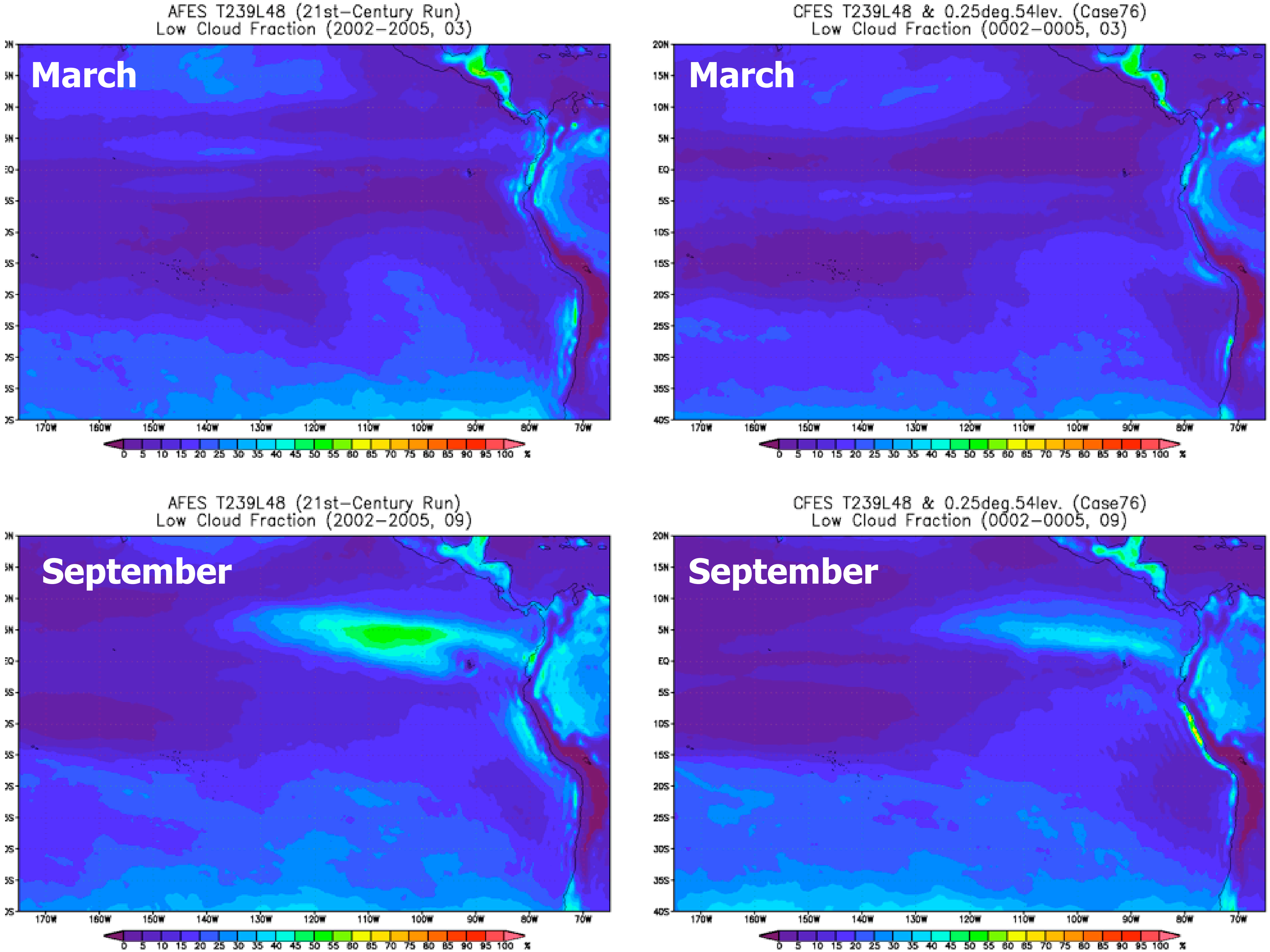


Bulk formulation determines the surface and PBL-top fluxes,

• Effects of small scale diffusive eddies are represented through a K-closure formulation

$$\tilde{F}_{\psi} \equiv -\rho K\left(\frac{\partial \psi}{\partial z}\right)$$




AFES T239L48 (21st−Century Run)
Low Cloud Fraction (2002−2005, 03)
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170W 160W 150W 140W 130W 120W 110W 100W 90W 80W 70W
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0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 %