A review of VOCALS Hypothesis

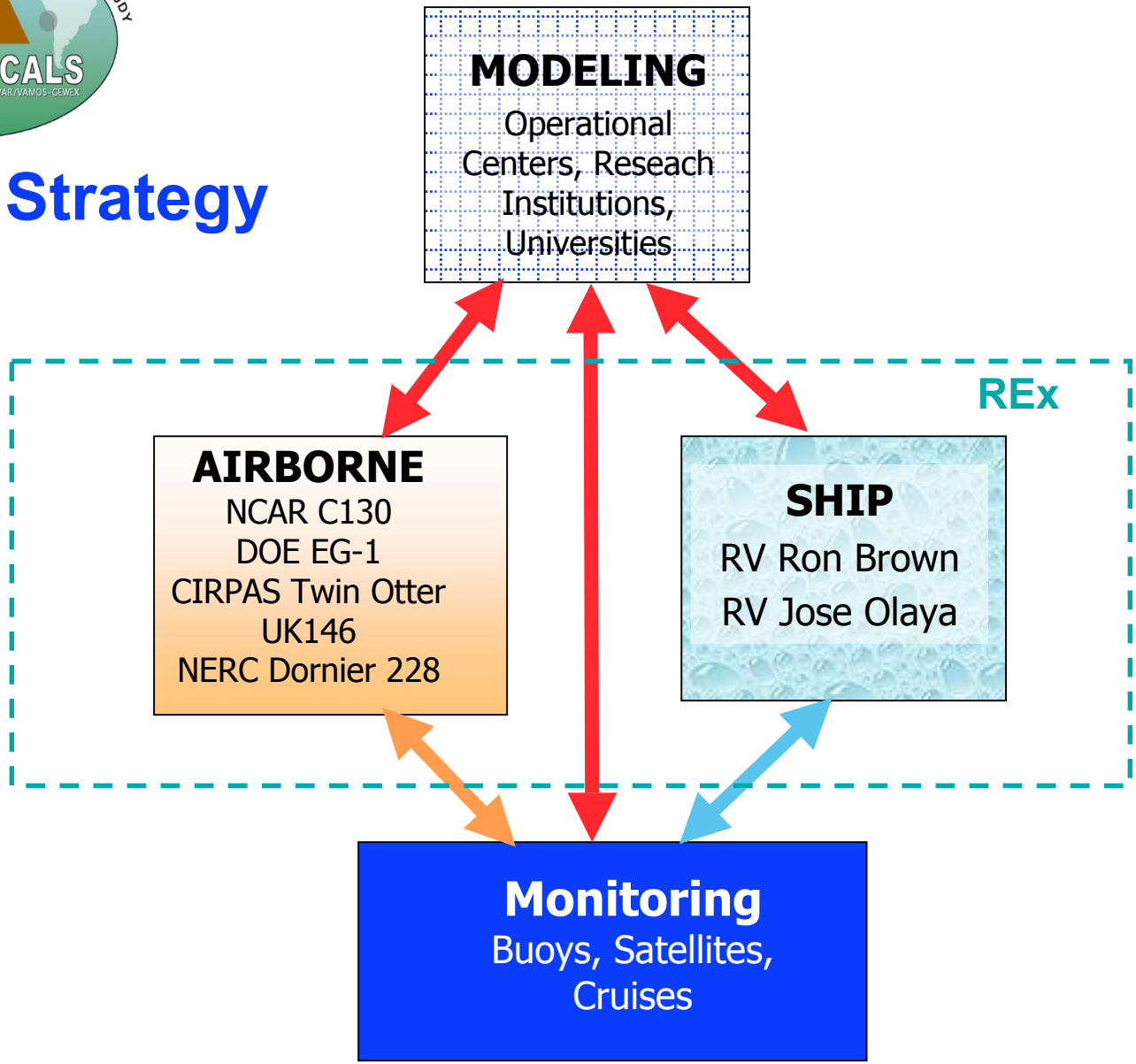
VOCALS Science Meeting

12-14 July 2009

Seattle Washington

C. R. Mechoso, UCLA

VOCALS Strategy

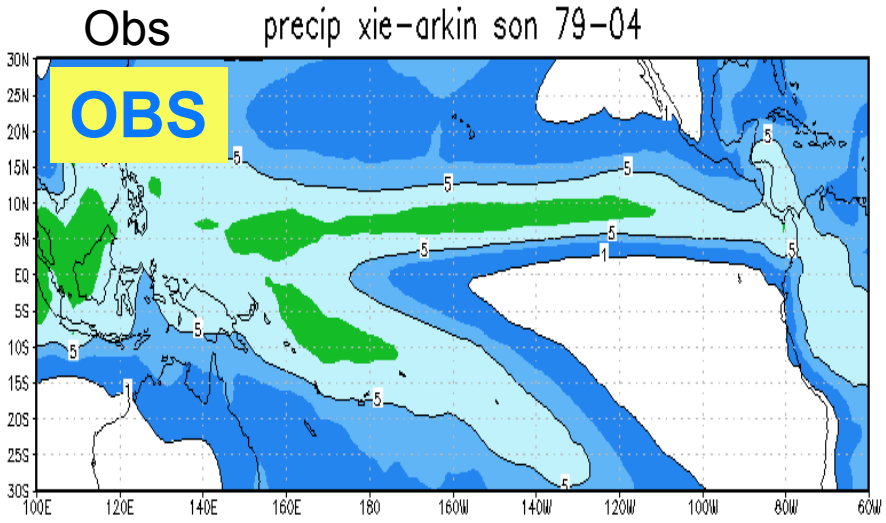


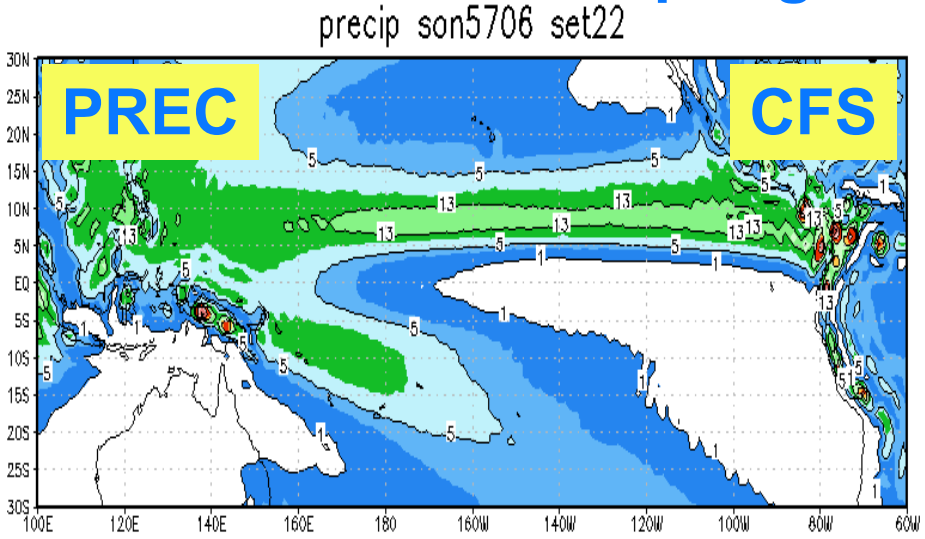
VOCALS Hypotheses

Coupled Ocean-Atmosphere-Land Hypothesis #1: Improvement of CGCMs performance in the Eastern Tropical Pacific is key to successful simulation of ITCZ/SPCZ, which will also benefit simulation of other regions.

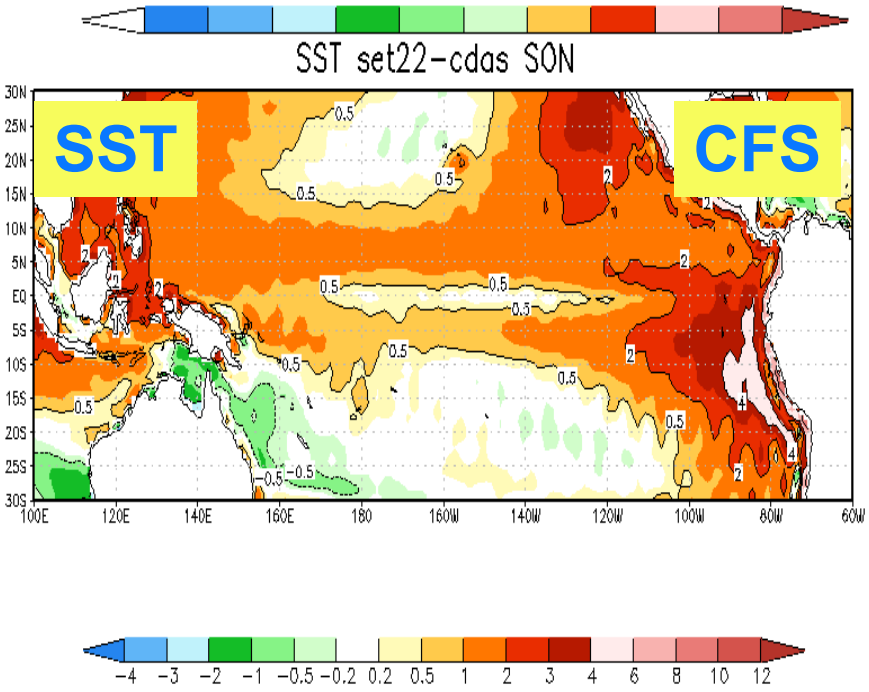
Synthesis: Major progress has been achieved in the parameterization and simulation of marine stratocumulus. However, the models still have difficulties with the ITCZ/SPCZ, transition to other cloud regimes, and SST errors in the eaastern tropical oceans.

NCEP Coupled GCM Errors in the Southern Spring

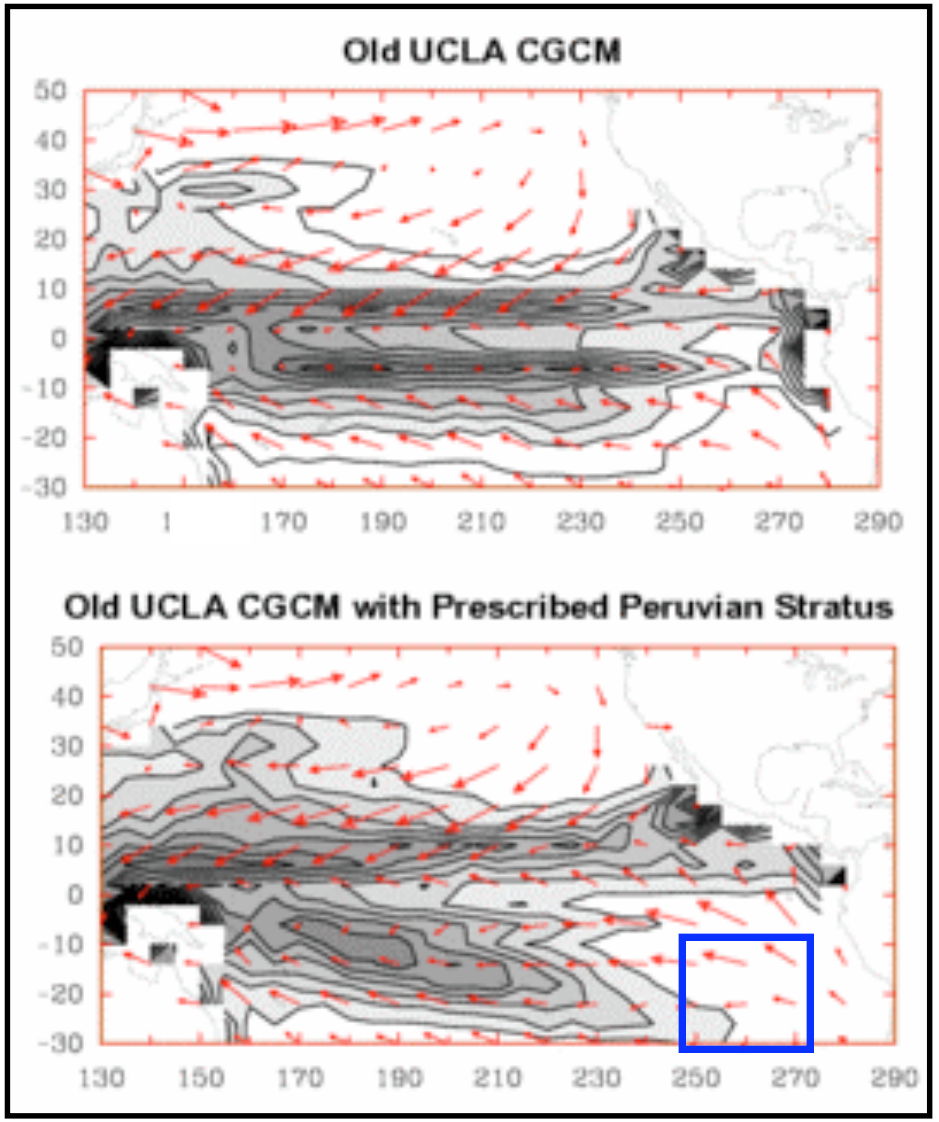




During the southern spring, NCEP's Climate Forecast System (CFS) predicts for the eastern Tropical Pacific not enough stratocumulus and too warm SSTs.



Poor representation of Scu-topped PBL and near coastal winds provides a major contribution to systematic errors of coupled atmosphere-ocean GCMs in the SEP.



Precip [mm day^{-1}]

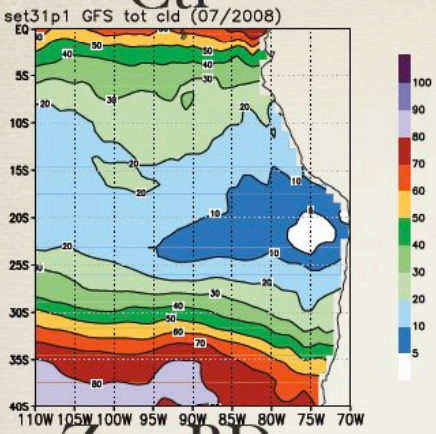
0 2 4 6 8 10 12 14

Yu and Mechoso 2001

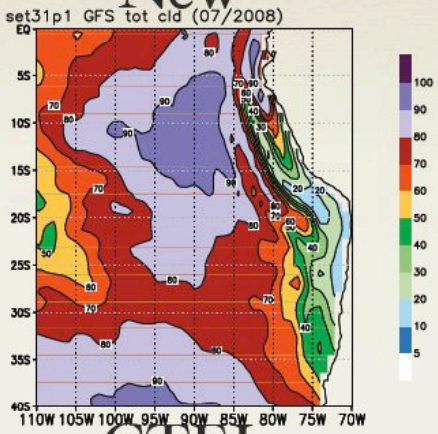
The NCEP GFS

Total cloud (July)

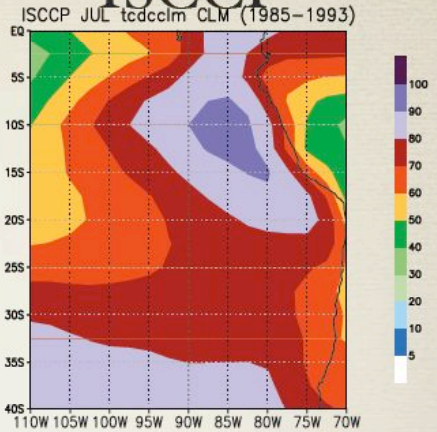
Ctl



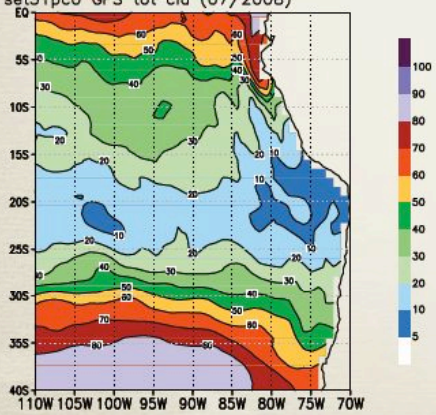
New



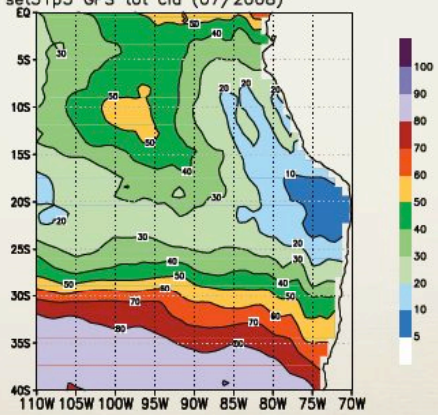
ISCCP



ZeroBD



CTEI



Moorthi and Sun (2009)

ECMWF Forecasts during VOCALS-REx

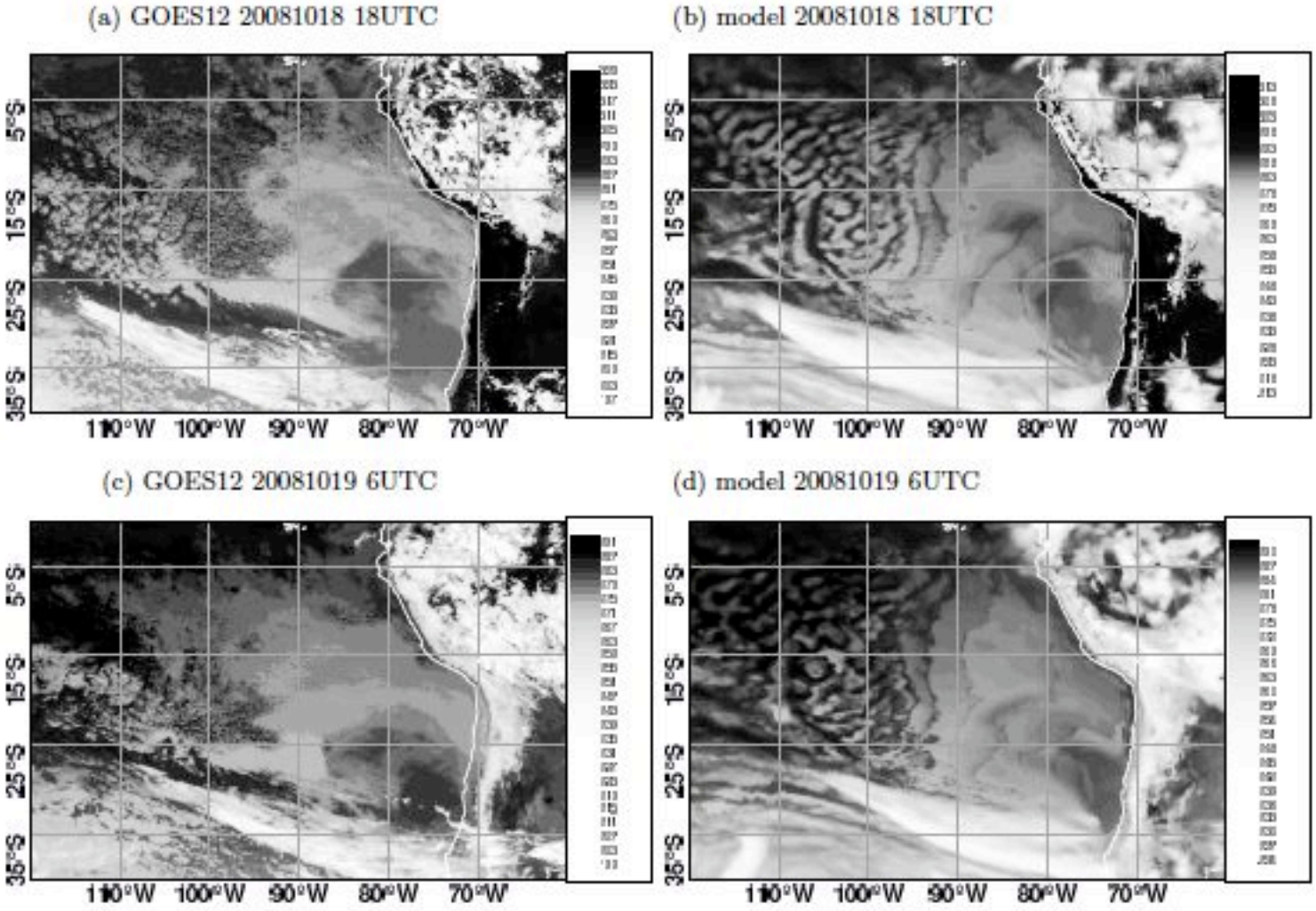


Figure 2. GOES12 satellite 10.8μm infrared band brightness temperature are compared to model generated images. The model was initialized on 20081018 00UTC. Panels (b) and (d) correspond to 18 and 30 hour forecasts representing daytime (10-14LT) and nighttime 22-02LT) respectively.

M. Kohler (2009)

VOCALS Hypotheses

Coupled Ocean-Atmosphere-Land Hypothesis #2: Oceanic mesoscale eddies play a major role in the transport of heat and fresh water from coastally upwelled water to regions further offshore.

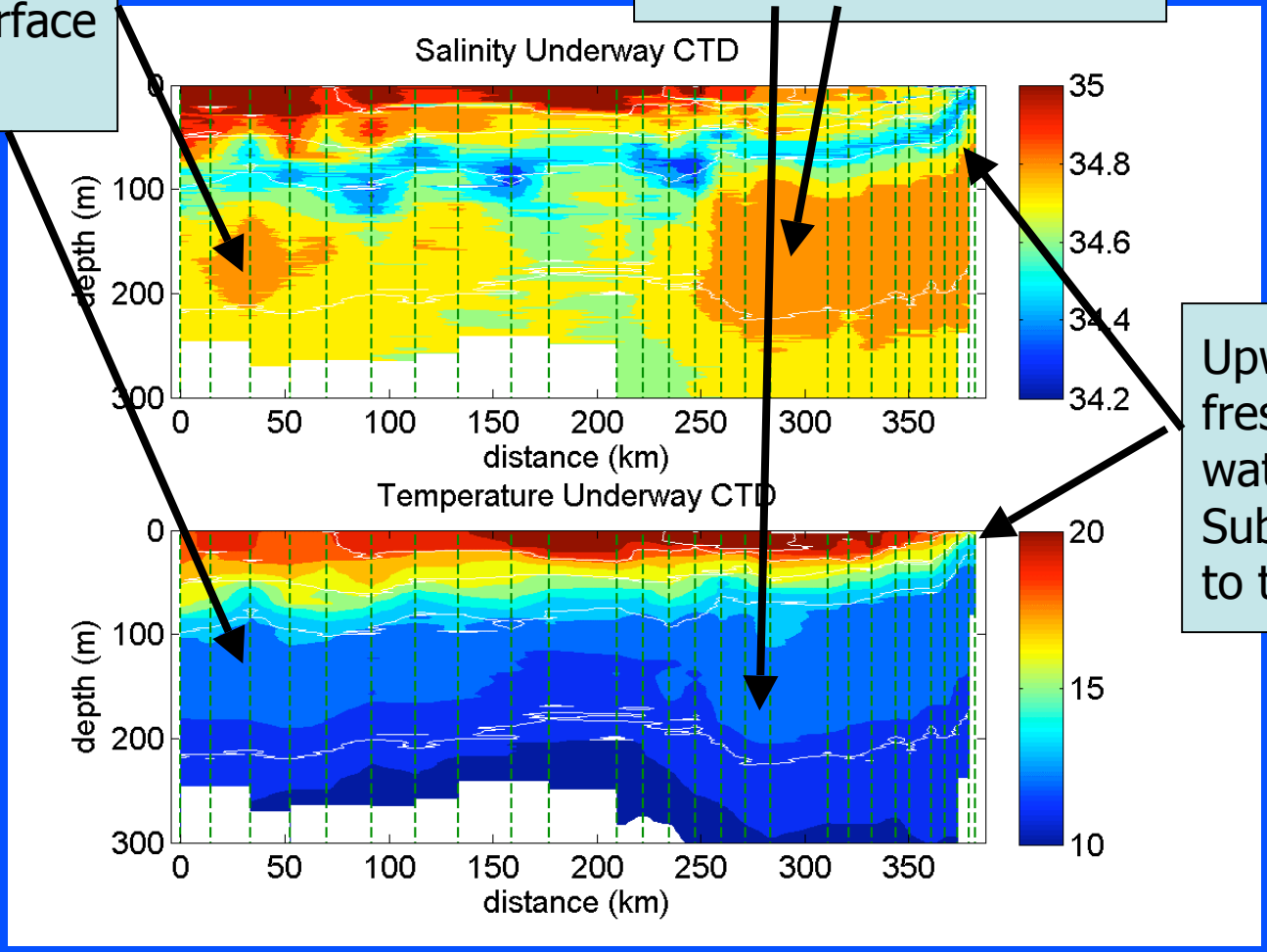
Synthesis: Oceanic mesoscale eddies were surveyed. Work with very high resolution coupled GCMs supports this hypothesis. Detailed comparisons of observations and simulations are under way.

Coastal Upwelling and Source of Eddies

Ron Brown CTD section up to the coast of Chile - Fiamma Straneo

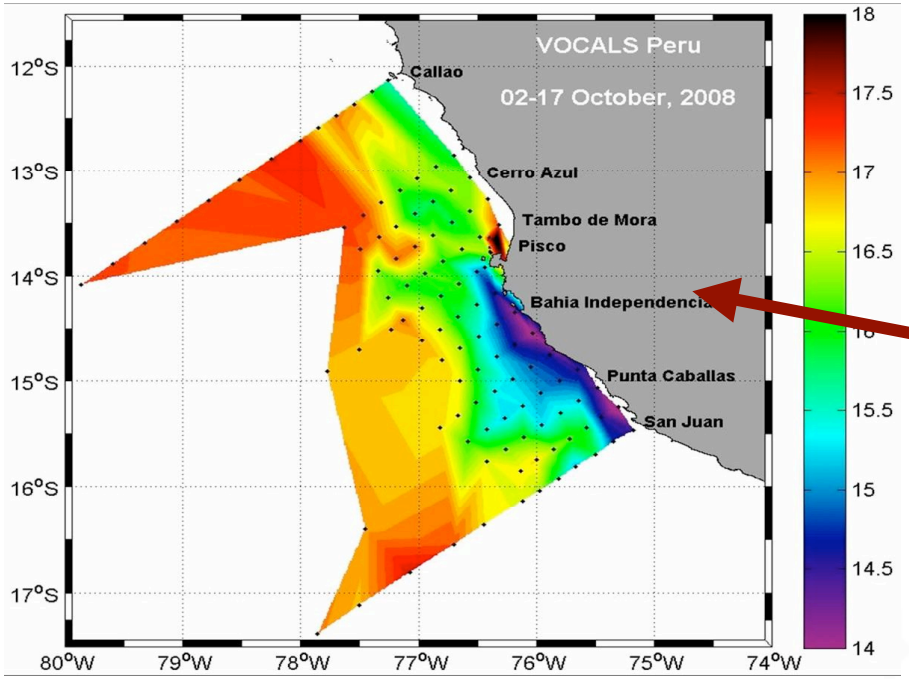
Cyclonic Eddy with a warm salty sub-surface core

Boundary current with same properties As the eddies' core



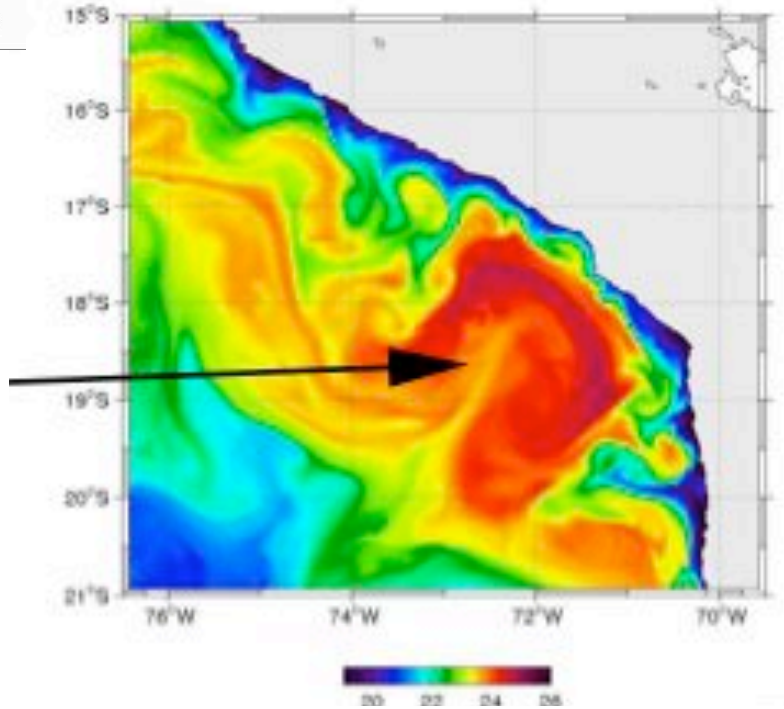
Upwelling of fresh and cold waters of Subpolar origin to the surface

OCEAN EDDIES



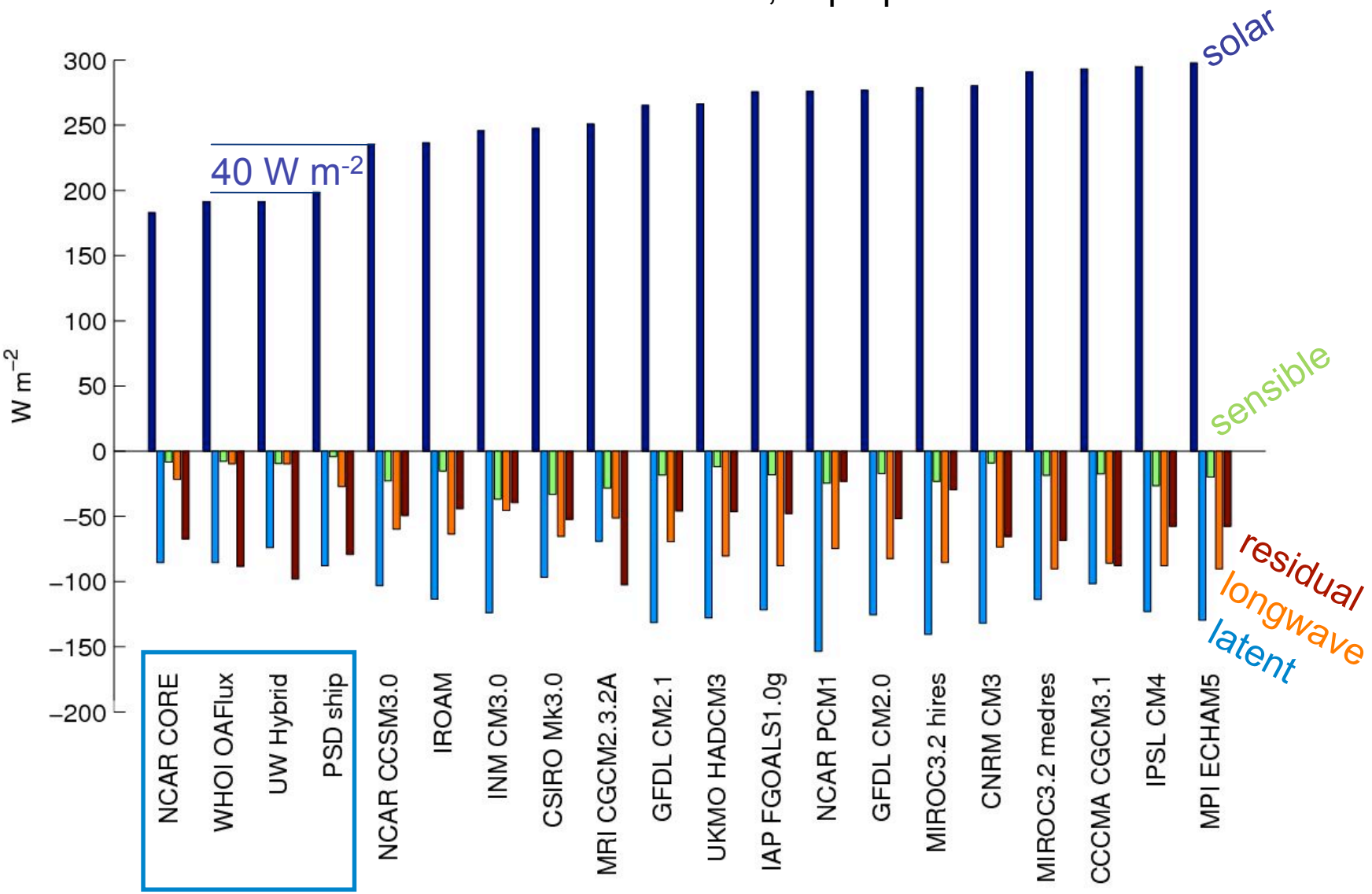
SST from oceanographic cruise October 2008
(C. Grados)

SST from very-high resolution, regional coastal ocean model (ROMS)
(McWilliams et al.)

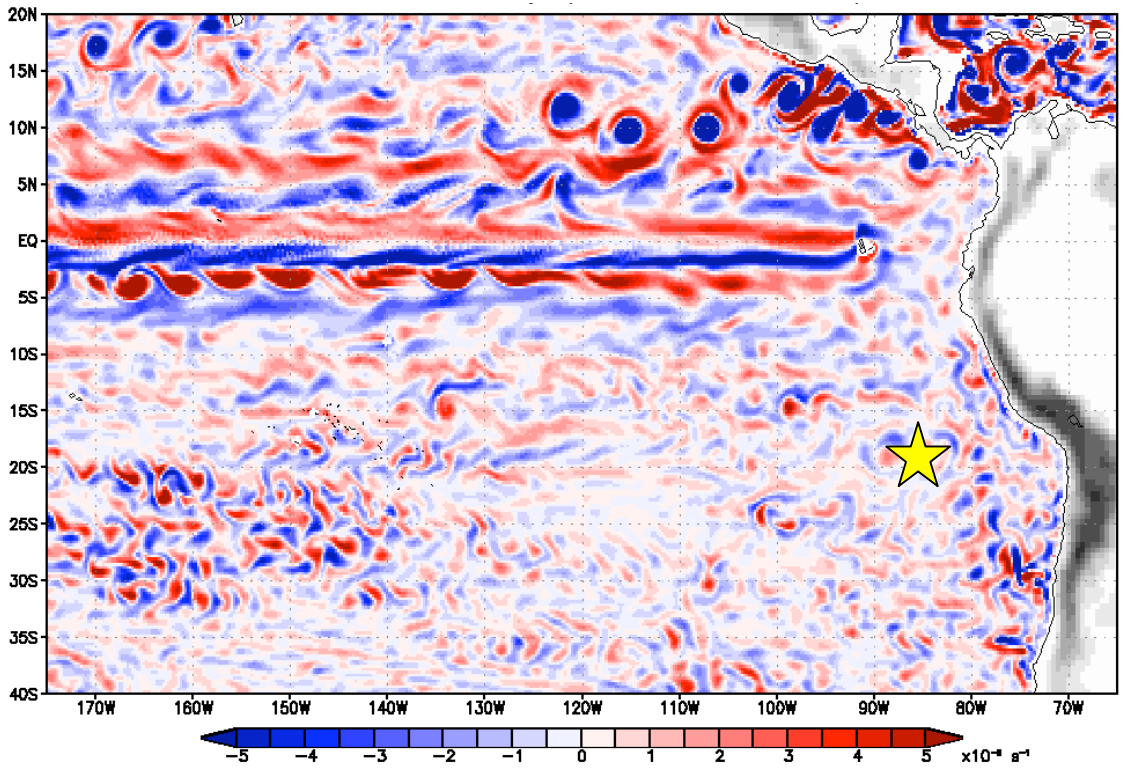


Surface heat balances along 20°S, 75-85°W

de Szoeke et al. 2009, in preparation



Ocean Eddies in a high-resolution OGCM: 0.25 lat x lon; 54 levels; 16 Sept)



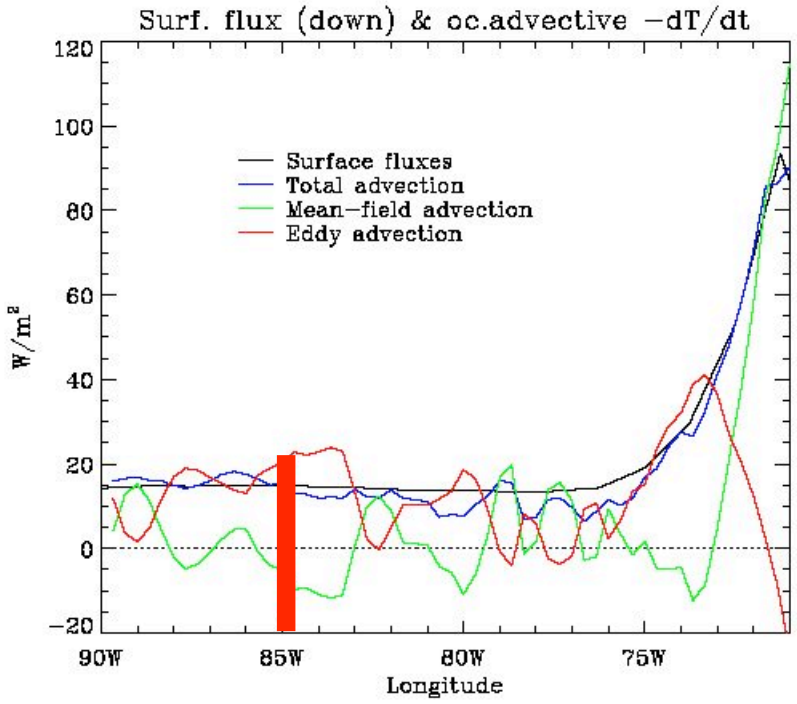
We computed heat fluxes in HiGEM;
AGCM: 1.25 lon, 0.83 lat, L38;
OGCM: 1/3 long, 1/3 lat, L40)

$$\mathbf{u}\cdot\nabla T = \mathbf{u}\cdot\nabla T + \mathbf{u}'\cdot\nabla T' + \mathbf{u}'\cdot\nabla T + \mathbf{u}\cdot\nabla T'$$

rectifying non-rectifying

$\mathbf{u}' = \mathbf{u}'_1 + \mathbf{u}'_2$ etc.; spatially or temporally filtered components

Toniazzo et al. (2009) found that geostrophic transients with 4 month < Period < 1 yr are dominant, and organised in large-scale pattern in simulation by HiGEM



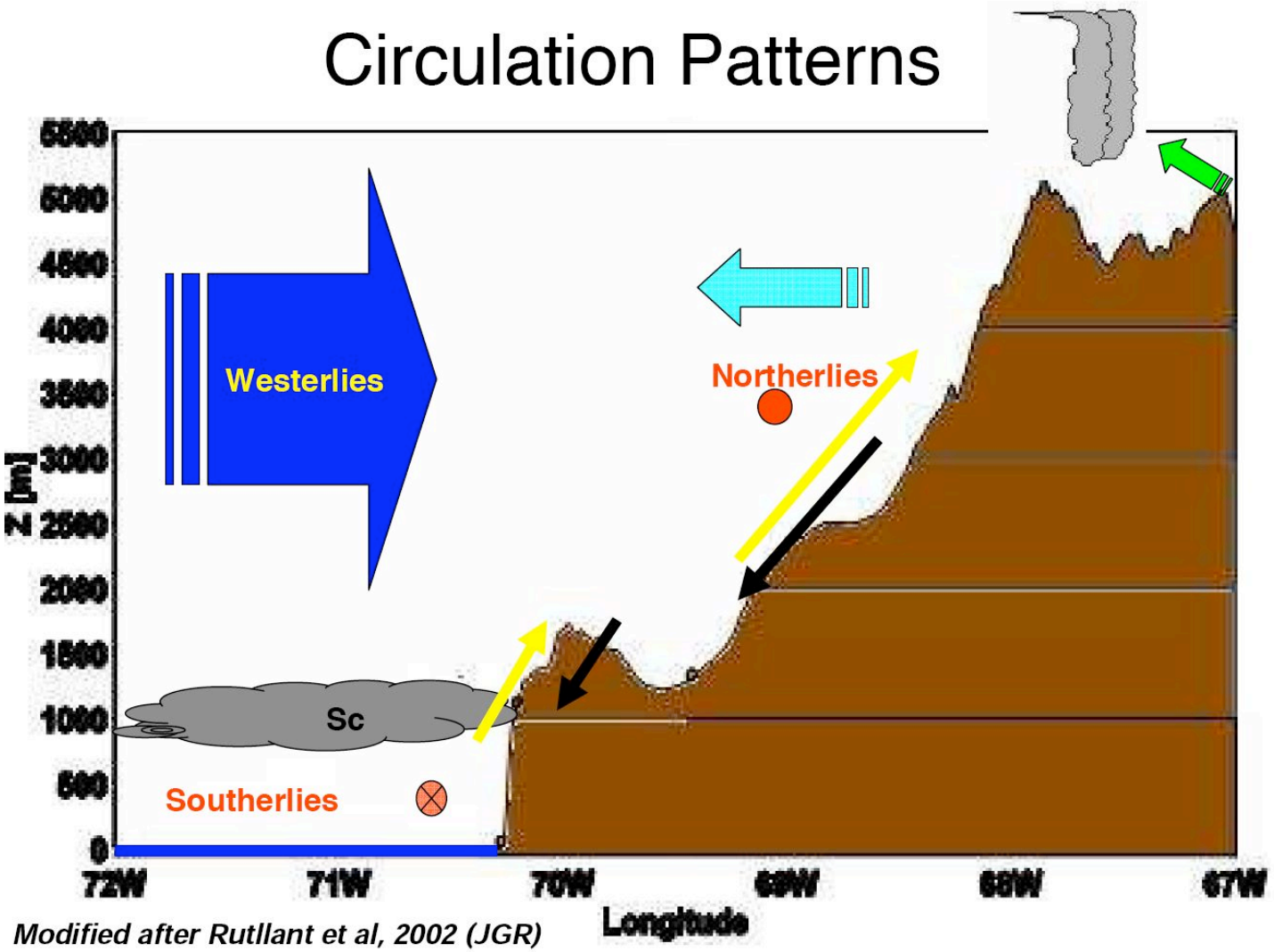
Toniazzo et al. (2009)

VOCALS Hypotheses

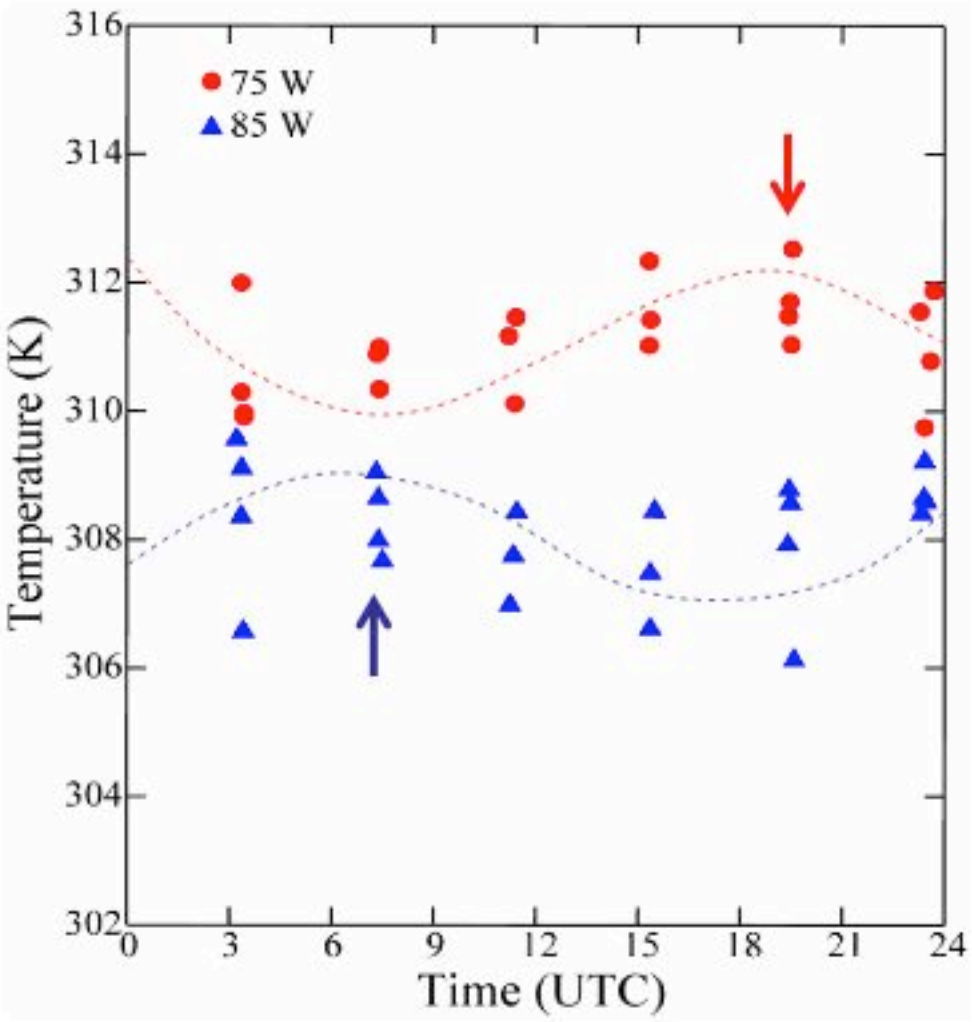
Coupled Ocean-Atmosphere-Land Hypothesis #3: The diurnal subsidence wave ("upsidence wave") originating in northern Chile/southern Peru has an impact upon the diurnal cycle of clouds that is well-represented in numerical models.

Synthesis: A preliminary examination of ship radiosondes confirms the existence of the wave. UKMO operational analysis also capture it. Current work targets

Circulation Patterns



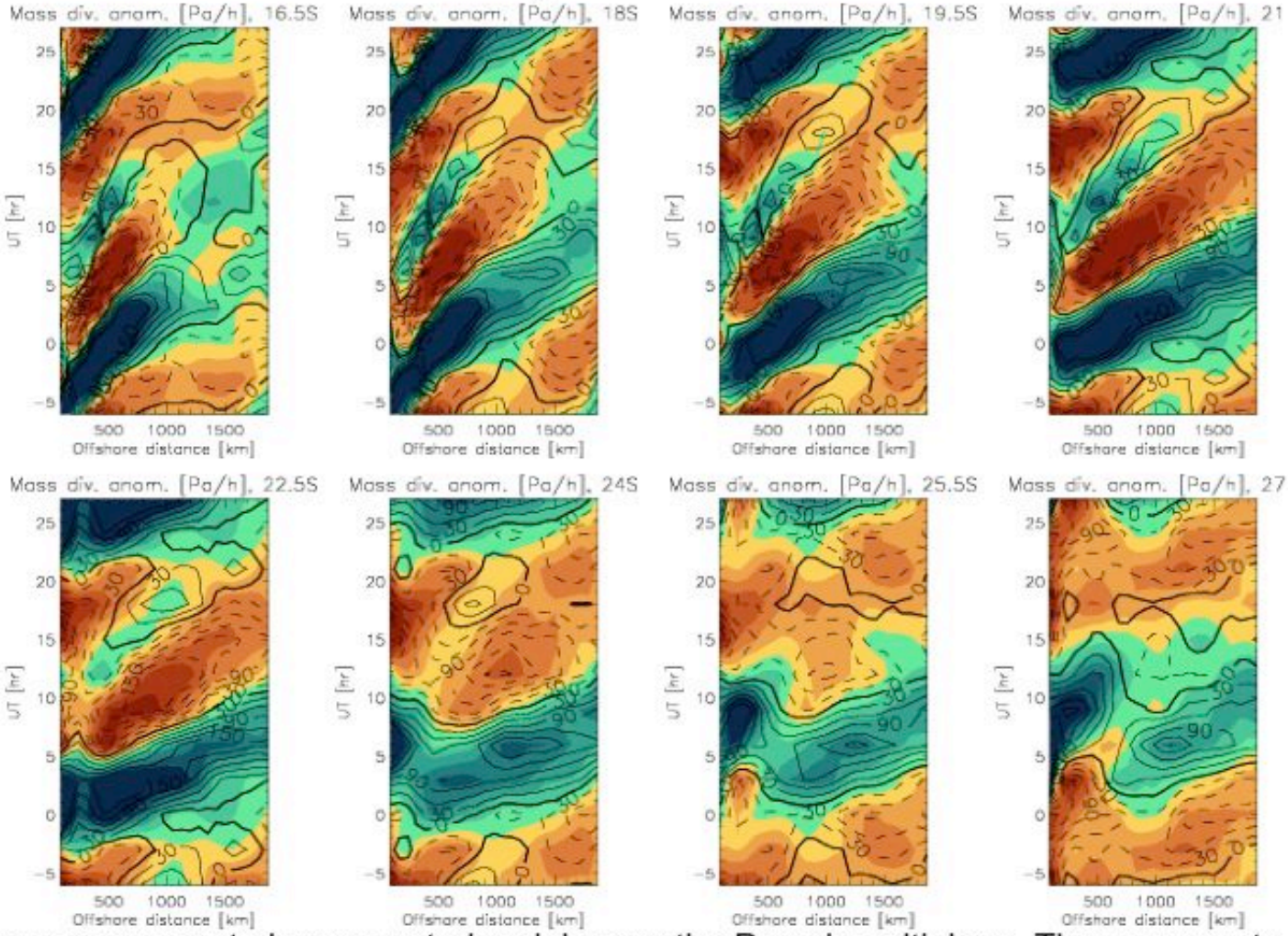
Modified after Rutllant et al, 2002 (JGR)



Hourly 2.5-km potential temperature at 20°S-75°W (red circle) and 20°S; 85°W (blue triangle) from Ron-Brown radiosondes. Dashed lines are the average potential temperature at these two location obtained from a 2 month WRF simulation. The 6-hr lag in θ max (arrows) is due to the westward progression of the "upsidence wave" emanating from the Chile-Peru coast.

Rahn and Garreaud, DGF-UCH. More in Dave Rahn's presentation….

The diurnal cycle near the coast



Gravity waves appear to be generated mainly over the Peruvian altiplano. They propagate offshore in a SW direction. The propagation speed (15-20 m/s) is broadly consistent with satellite cloud features. Weaker propagating signals further S.

Tonniazzo et al. (2009)

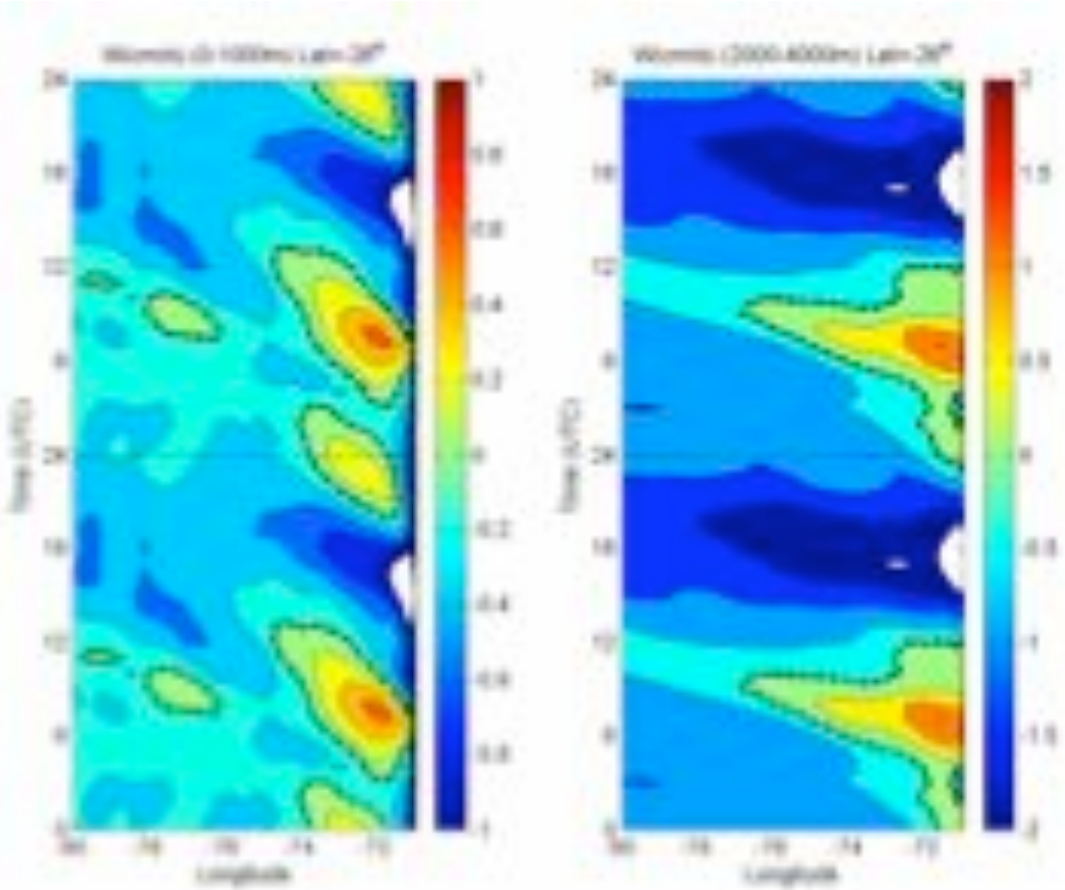
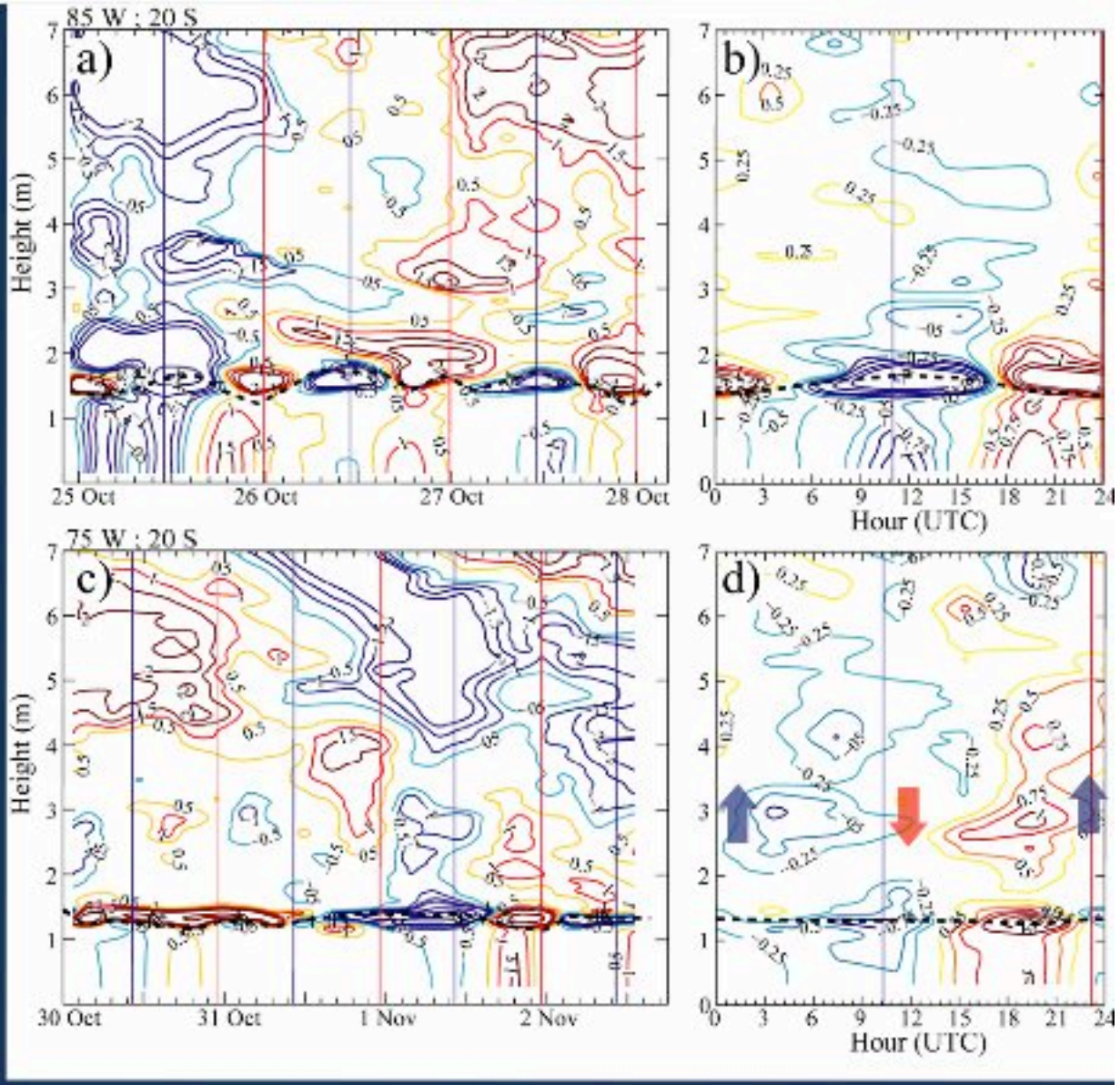


Figure 8. Hovmuller diagrams for W diurnal cycles at 26°S. Left panel for 0-1000 masl averages and right panel for 2000-4000 masl averages.

Muñoz and Garreaud (2006)

RB soundings

- 20°S, 85°W
  - MBL exhibits typical cloud-toped MBL characteristics, i.e. deepens overnight, thins during the day.
  - Not much of a diurnal signal aloft
- 20°S, 75°W
  - MBL is much flatter.
  - Some trend of increasing MBL with time.
  - A clear diurnal signal is seen around 2-3 km.



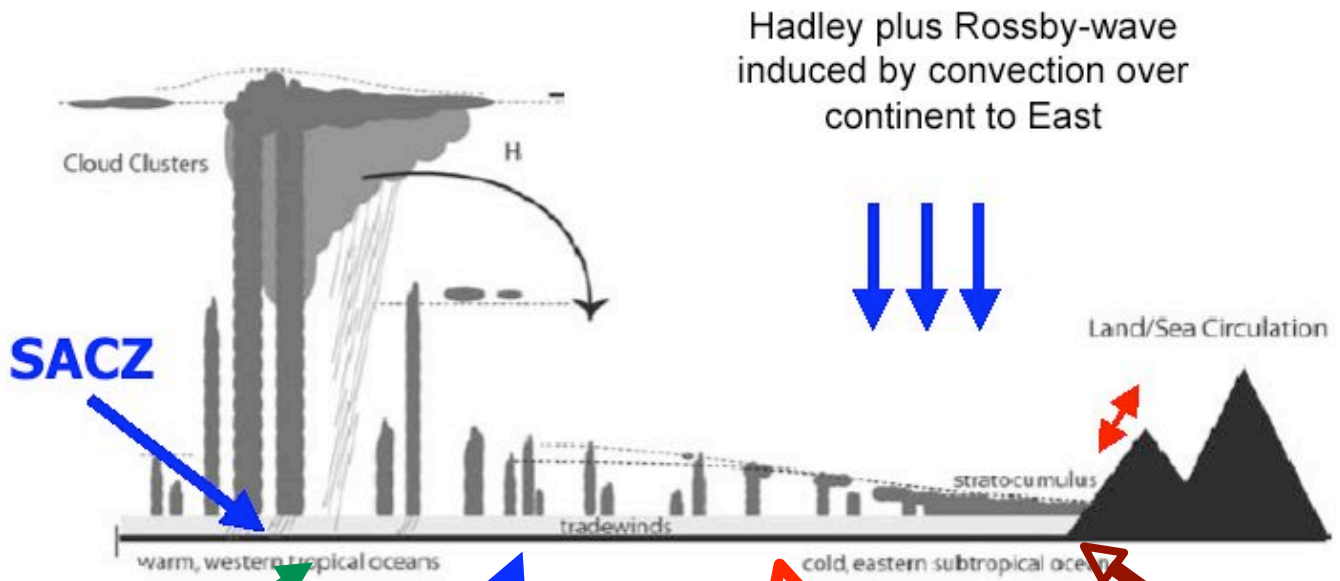
Potential temperature anomalies from the mean state taken from Ron Brown soundings along 20°S at 85°W (a and b) and 75°W (c and d) shown as a time series (a and c) and as an average diurnal anomaly (b and d). MBL depth is indicated by bold dashed line. Blue and red vertical lines indicate local sunrise and sunset, respectively.

VOCALS Hypotheses

Coupled Ocean-Atmosphere-Land Hypothesis #4: The entrainment of cool fresh intermediate water from below the surface layer during mixing associated with energetic near-inertial oscillations generated by transients in the magnitude of the trade winds is an important process to maintain heat and salt balance of the surface layer of the ocean in the SEP.

Synthesis: No progress reported so far.

The Southern Tropical Pacific (10-20S)



Transition to deep convection

Shallow convection

Transition to shallow convection

Coastal clearing Aerosol

VOCALS Paradigm C. R. Mechoso

END

VOCALS Hypotheses - Rex Observations

Aerosol-Cloud-Precipitation Hypothesis #1:

Variability in the physicochemical properties of aerosols has a measurable impact upon the formation of drizzle in stratocumulus clouds over the SEP

Aerosol-Cloud-Precipitation Hypothesis #2:

Precipitation is a necessary condition for the formation and maintenance of pockets of open cells (POCs) within stratocumulus clouds.

Aerosol-Cloud-Precipitation Hypothesis #3:

The small effective radii measured from space over the SEP are **primarily controlled by anthropogenic, rather than natural**, aerosol production, and entrainment of polluted air from the lower free-troposphere is an important source of cloud condensation nuclei (CCN).

VOCALS Hypotheses - Rex Observations

Synthesis #2: All POCs sampled in REx contained drizzling cells, but the surrounding overcast stratocumulus commonly also supported some drizzle. Thus drizzle seems necessary, but not sufficient, to cause transition of closed-cell convection into a POC.

Synthesis: Measured cloud droplet concentrations were closely correlated with those of accumulation mode aerosol particles. Such aerosols mainly seemed to derive from pollution injected into the boundary layer at the coast, but entrainment of thin tongues of high SO_2 (and other mainly gaseous pollutants) far offshore may also promote the growth of Aitken mode aerosol particles to CCN size.
Atmospheric DMS concentrations were not strongly elevated near the coastal upwelling zone. Atmospheric photochemical destruction of DMS, however, seemed to be the dominant source of new sulfate far offshore, dominating SO_2 entrainment from the free troposphere in some cases.

Synthesis: All POCs showed much lower CCN concentrations than the surrounding regions; air exiting from their cloudly updrafts was often observed to be nearly entirely cleansed of all condensation nuclei.

Preliminary Confrontation of VOCALS Hypotheses with Rex Observations

Aerosol-Cloud-Precipitation Hypothesis #3: The small effective radii measured from space over the SEP are **primarily controlled by anthropogenic, rather than natural**, aerosol production, and entrainment of polluted air from the lower free-troposphere is an important source of cloud condensation nuclei (CCN).

Synthesis: Measured cloud droplet concentrations were closely correlated with those of accumulation mode aerosol particles. Such aerosols mainly seemed to derive from pollution injected into the boundary layer at the coast, but entrainment of thin tongues of high SO_2 (and other mainly gaseous pollutants) far offshore may also promote the growth of Aitken mode aerosol particles to CCN size.

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Preliminary Confrontation of VOCALS Hypotheses with Rex Observations

Aerosol-Cloud-Precipitation Hypothesis #4: Depletion of aerosols by coalescence scavenging is necessary for the maintenance of POCs.

Synthesis: All POCs exhibited much lower CCN concentrations than in the surrounding regions, and air exiting from their cloudly updrafts was often observed to be nearly entirely cleansed of all condensation nuclei of any size.

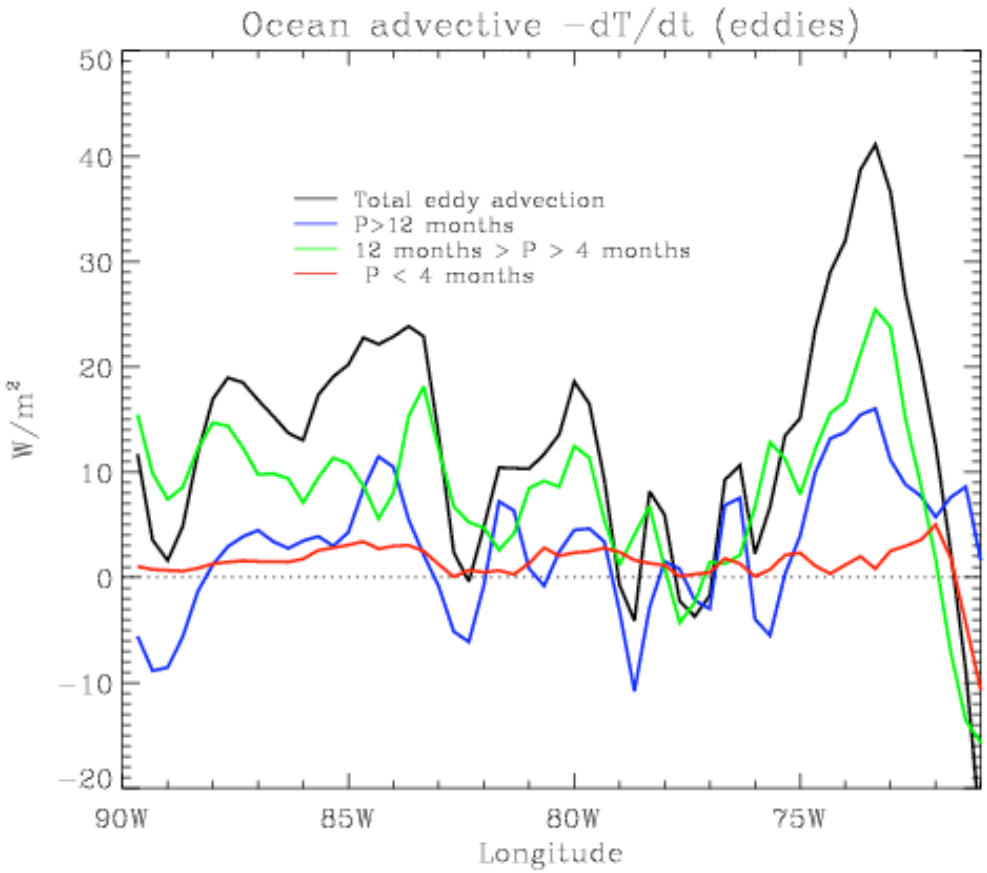
Organizational issues

1. AGU and other upcoming meetings. Where to hold subsequent VOCALS meetings? Are there any big meetings in the UK or Europe coming up that we could channel US collaborators to?

2. Special journal issue - possible to use JGR (can cover both ocean and atmosphere in one issue) - JGR have a 10 week window when ALL the articles must be submitted. Should we aim for a late 2009/early 2010 submission window if we go with this option?

3. Structure of BAMS paper(s).

SST change by Eddy Advection



SST change by Surface Fluxes and Advection