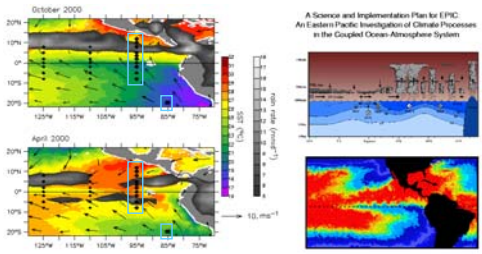
Local Forcing of the Surface Heat Budget of the Equatorial East Pacific

Meghan F. Cronin (NOAA PMEL), Chris Fairall (NOAA ETL), Michael J. McPhaden (NOAA PMEL), Robert Weller (WHOI)

Eastern Pacific Investigation of Climate (EPIC) experiment



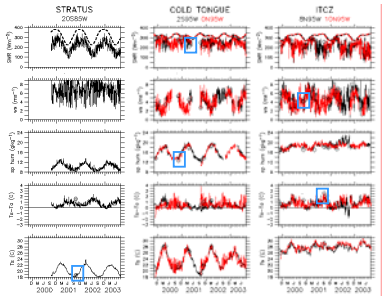
This study uses ship and buoy data along 95W and at 20S, 85W to evaluate air-sea heat fluxes in the stratus deck / cold tongue / ITCZ complex.

This figure shows winds, SST and rain in the eastern tropical Pacific. During boreal fall, the cold season, the equatorial cold tongue is well formed and extends far west. The ITCZ is at its northernmost extent, stratus deck extends from the cold waters off Chile across the equator.

During the warm season in the boreal spring, the cold tongue and stratus deck recede, and a double ITCZ sometimes forms.

The challenge for modelers is that if you don't get the stratus correct, you won't get the cold tongue right. And if you don't get the cold tongue right, you won't get the ITCZ, and vice versa. If you don't get one right, the others won't be correct.

Thus we have the E P I C experiment. As part of EPIC the easternmost TAO line was enhanced with 3 buoys and sensors, and an IMET mooring was deployed at 20S, 85W.



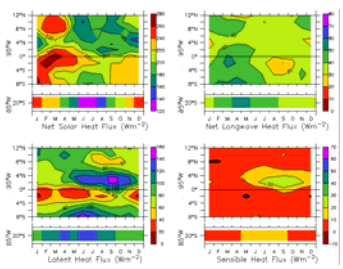
Our goal is to use these buoys as reference sites for NWP. As a first step we need to compare the buoy measurements to shipboard measurements shown here by circles.

I've highlighted a few of these comparisons. Initial comparisons are quite good, although care must be taken in making proper temporal and spatial averaging.

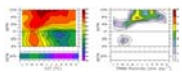
Latent and sensible heat flux calculations from buoy data

- Used Fairall et al. (2003) v3.0a bulk flux algorithm.
- Used hourly-averaged data (fill gaps with telemetered daily-averaged data).
- Applied warm layer and cool skin corrections to extrapolate 1 m SST to surface (Tskin).
- Used winds relative to surface currents.

$$Q_0 = Q_{sw} - Q_{lw} - Q_{lat} - Q_{sen}$$



ITCZ
cold tongue
stratus deck



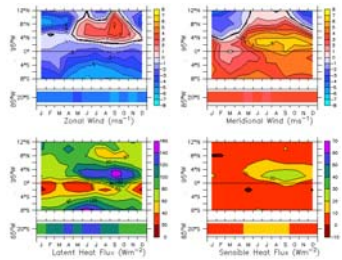
- $Q_0 \sim Q_{sw} - Q_{lat}$
- Q_{lat} and Q_{sen} max over frontal region
- Q_{lat} near zero over cold tongue and is weakest during warm season.

Mean Annual Cycle for Shortwave (UL), net longwave (UR), sensible (LR) and latent heat loss (LL).

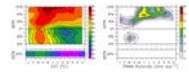
Not necessarily mean annual cycle since based on 3-4 years of gappy data.
Nevertheless a few patterns can be seen here:

1) terms on the right (sensible heat flux & longwave) have much smaller dynamic range than the terms on the left. Variability in net surface heat flux is controlled primarily by solar radiation and latent heat loss.
2) Max latent and sensible heat loss are co-located.
3) Q_{lat} is small just south of equator.

PBL stabilized over cold tongue and destabilized over frontal region



ITCZ
cold tongue
stratus deck

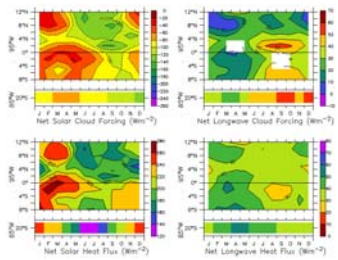


- $Q_0 \sim Q_{sw} - Q_{lat}$
- Q_{lat} and Q_{sen} max over frontal region
- Q_{lat} near zero over cold tongue and is weakest during warm season.

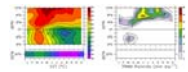
The patterns of Latent heat loss (LL), Sensible heat loss (LR), can be understood by looking at the corresponding zonal (UR) and meridional (UL) wind fields.

1) Max latent and sensible heat loss are co-located with maximum meridional winds. Consistent with destabilized PBL bringing dry air and strong winds to surface.
2) Minimum latent heat loss on equator is due to weak winds there and is consistent with stabilized PBL over cold tongue.
3) However, the weakest latent heat loss on equator is during the warm season not the cold season. So largescale variations in winds also play role.

Cloud Forcing is reduction or enhancement in surface radiation caused by clouds



ITCZ
cold tongue
stratus deck



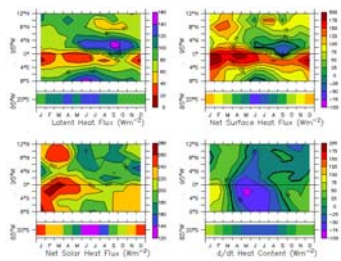
- $Q_0 \sim Q_{sw} - Q_{lat}$
- Q_{lat} and Q_{sen} max over frontal region.
- Q_{lat} near zero over cold tongue and is weakest during warm season.
- Q_{sw} and Q_{lw} modulated by clouds.

Now lets look at the patterns of net shortwave and longwave radiation.
These fields are strongly modulated by clouds.
Solar Cloud forcing (shown in the upper left panel) is defined as the reduction in shortwave radiation by the clouds.
Longwave cloud forcing (upper right panel) is the enhancement in surface longwave radiation by the clouds.

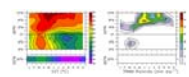
For example, clouds associated with the ITCZ cause reduction of ~120 W/m2 in the surface solar radiation.

Low clouds tend to radiate at higher temperature therefore the stratus deck has high ir cloud forcing during latter half of year in southern hemisphere.

$Q_0' \sim Q_{sw} - Q_{lat} \sim ? \; d(HC)/dt$
HC = 30 m Heat Content

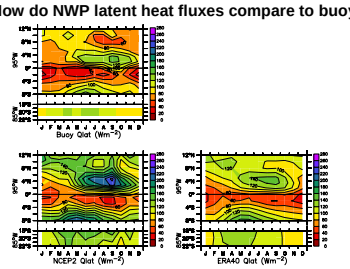


ITCZ
cold tongue
stratus deck

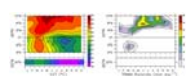


- $Q_0 \sim Q_{sw} - Q_{lat}$
- Q_{lat} and Q_{sen} max over frontal region
- Q_{lat} near zero over cold tongue and is weakest during warm season.
- Q_{sw} and Q_{lw} modulated by clouds.
- Ocean processes also important

How do NWP latent heat fluxes compare to buoy?



ITCZ
cold tongue
stratus deck



- NCEP2 latent heat flux is much stronger than buoy (cold bias)
- ECMWF is more realistic but still over estimates in ITCZ

Conclusions

- Stabilized PBL causes low latent heat loss over cold tongue; and destabilized PBL causes maximum latent heat loss over frontal region.
- Solar radiation, latent heat loss and ocean processes control SST variability in the east Pacific stratus deck / cold tongue / ITCZ complex.
- ECMWF latent heat loss appears to be more realistic than NCEP2.
- ECMWF has a warm bias (due to latent heat flux) in stratus deck region and cold bias in cold tongue / ITCZ complex. NCEP2 has a cold bias everywhere.
- SST biases associated with latent heat biases are HUGE when integrated over a year.