SURFACE COOLING DUE TO PRECIPITATION OVER THE TROPICAL OCEAN

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1 - INTRODUCTION:

- Precipitation cools the ocean surface because the temperature of the raindrops is lower than the temperature of the surface. However, this cooling term due to precipitation (Q_p) is often not included in the models.
- Q_p can be as high as 200 W m^{-2} affecting significantly the skin temperature of the ocean (Gosnell et al. 1995).
- As the skin temperature provides boundary conditions to the atmosphere above it, this might be critical to the processes within the planetary boundary layer (PBL, Chen and Dudhia 2001).

2 - OBJECTIVES:

- Provide a documentation of the spatio-temporal variability of Q_p over the tropical oceans using a variety of observational datasets.
- Discuss the implementation of this process into a simplified 3D ocean model coupled to the WRF model
- Explore the role of Q_p on large rain events

3 - DATA:

Rain: TRMM 3B-42, 0.25°x0.25°, 3-hrly, from 1998 to 2013

Pressure: NCEP Reanalysis 2 (6-hrly, data provided by the NOAA/OAR/ESRL PSD).

Latent and Sensible Heat, specific humidity and temperature at 2m and surface temperature (skin temperature): Objectively Analyzed Air-Sea Fluxes (OAFlux, 1.0°x1.0°)

Buoy: TAO buoy (0°N, 165°E) data for December 2006 to compare different components of the surface fluxes with Q_p.

Model initial and boundary condition: ERA-Interim reanalysis. The sea surface temperature data (RTG_SST) is from NCEP/MMBA.

4 - MODEL:

- 2-way nested domains using the ***WRF 3.7 model***
- The outer (inner) domain has a grid spacing of 30 km (10 km).
- Q_p and a fresh water input were added to a 3D simplified ocean model (PWP) coupled to the WRF model (Price et al 1994; Price et al 1986).

5 - METHODOLOGY:

The Q_p is given by (Gosnell et al. 1995):

$$Q_P = C_W\, R\, (T_0 - T_r) \qquad (1)$$

C_W = specific heat of water (4186 J kg^{-1} K^{-1}),

R = rain rate

T_0 = bulk SST approximated by the skin temperature

Tr = temperature of raindrops when it reaches the surface. Tr is approximated by the wet bulb temperature following Stull (2011)

6 a – RESULTS AND DISCUSSION

Q_p Climatology

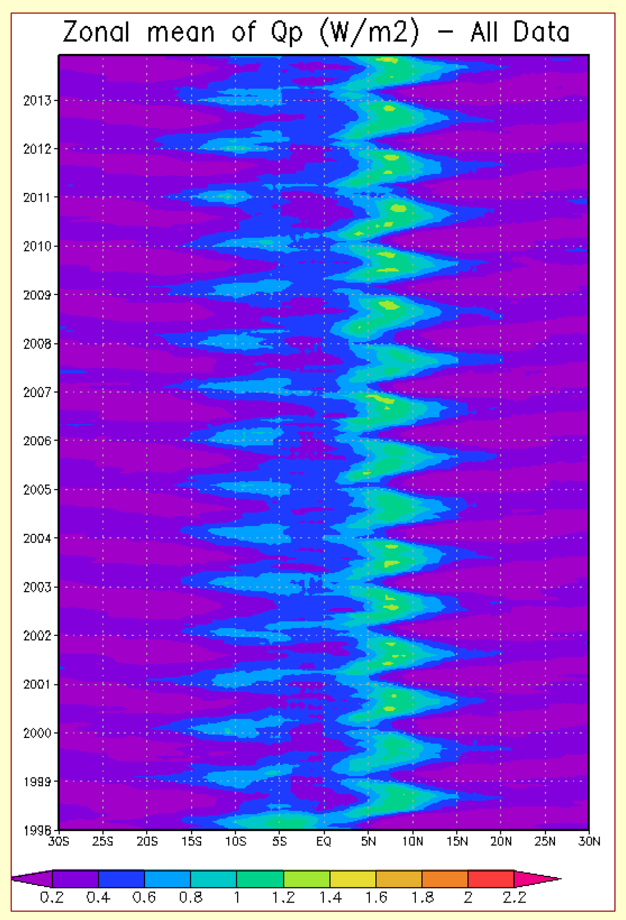

Figure 1: Time evolution of monthly averaged Q_p (zonally averaged; 1998 to 2013 – W m^{-2}) using precipitating and non-precipitating days

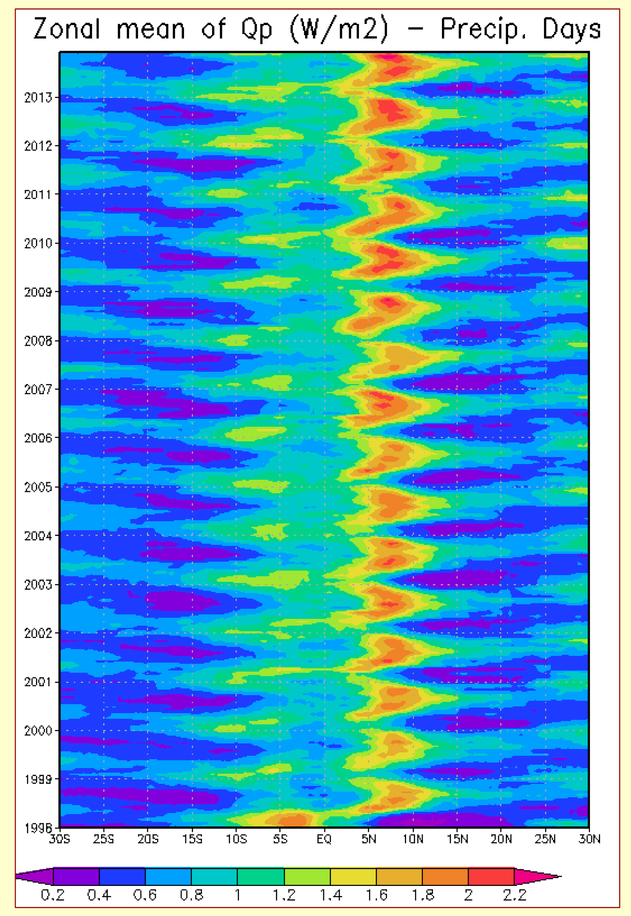

Figure 2: Time evolution of monthly averaged Q_p (zonally averaged; 1998 to 2013 – W m^{-2}) using only precipitating days

- Monthly averaged Q_p was calculated from January 1998 to December 2013 in the tropics (30°S to 30°N).
- Lowest values of Q_p correspond to the driest months (February to April)
- Highest Q_p occurs during the rainiest months (October to December) that coincides with the ITCZ passage from the northern to the southern hemisphere.
- There's also a secondary peak of Q_p (May to July) that correspond to the Indian Monsoon and the ITCZ.
- Monthly climatology values only go up to 2 W m^{-2} but, this average considers precipitating and non-precipitating days.
- When we consider only precipitating days, some areas with values up to 4 W m-2 appear around 7°N still following the ITCZ movement.

6 b – RESULTS AND DISCUSSION

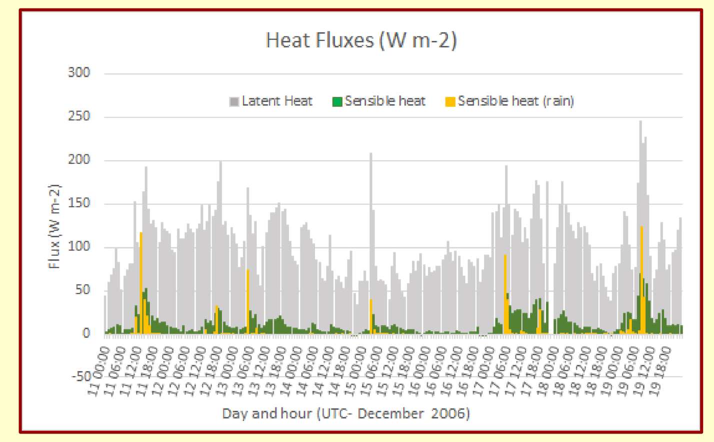

Figure 3: TAO buoy - Latent heat flux Q_{LH} (gray), sensible heat flux Q_{SH} (green) and Q_p (yellow) in W m^{-2} for 11-19 December 2006 at 0°N;165°E

- Hourly observation data with large precipitation shows that Q_p values can get much larger. (Fig. 3)
- It shows that Q_p can exceed 100W m-2 and be up to 5 times the value of Q_{SH} and in certain occasions even exceed the value of Q_{LH}

Simulated Qp

- Qp term added to the PWP model coupled to the WRF model
- One month simulation over an ocean area (centered on the buoy from Fig. 3), for December 2006. It spans from 10°S to 10°N and from 155°E to 175°E.

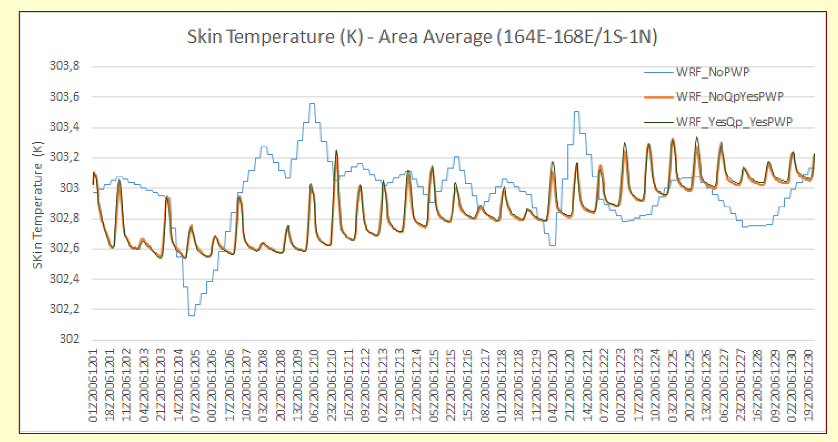

Figure 4: Area averaged skin temperature (K) without PWP model (blue), with PWP and with Q_p (green) and the PWP without Q_p (orange)

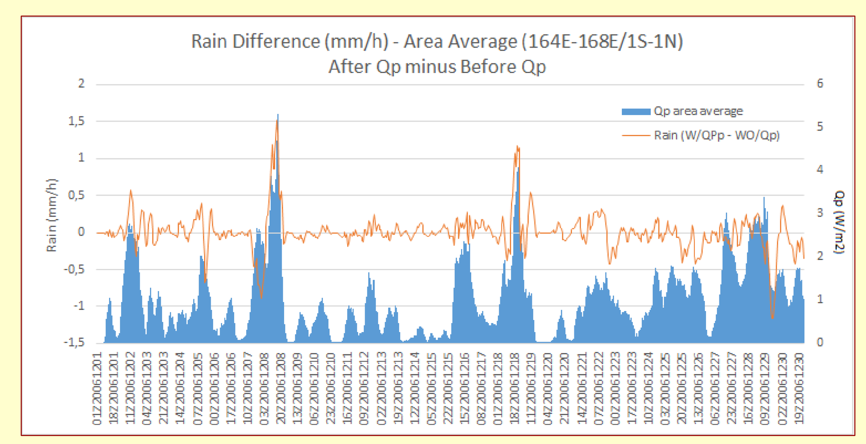

Figure 5: Area averaged difference between with and without Q_p. Q_p in W m^{-2} (blue bars) and skin temperature difference in Kelvin (orange line).

7 - CONCLUSIONS:

- Q_p can have the same or larger magnitude Q_{SH} and even LH.
- Simulations with Q_p has significant impact on the upper ocean dynamics and thermodynamics and also on the atmosphere. As Q_p lowers the surface temperature, it tends to delay/reduce the atmospheric convection.

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