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°*0.25°, 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°*1.0°)
- **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):
  \[ Q_p = C_{lw} R (T_0 - T_r) \]
- $C_{lw}$ = specific heat of water (4186 J kg$^{-1}$ K$^{-1}$),
- $R$ = rain rate
- $T_0$ = bulk SST approximated by the skin temperature
- $T_r$ = temperature of raindrops when it reaches the surface. $T_r$ is approximated by the wet bulb temperature following Stull (2011)

6 a – RESULTS AND DISCUSSION

**$Q_p$ Climatology**

- 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 ITZC 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 ITZC.
- Monthly climatology 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 ITZC movement.

6 b – RESULTS AND DISCUSSION

**Surface Cooling Due to Precipitation Over the Tropical Ocean**

- Hourly observation data with large precipitation shows that $Q_p$ values can get much larger.
- It shows that $Q_p$ can exceed 100 W m$^{-2}$ and be up to 5 times the value of $Q_{sh}$ in certain situations even exceed the value of $Q_{h}$

**Simulated $Q_p$**

- $Q_p$ 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 3:** TAO buoy - Latent heat flux $Q_{sh}$ (gray), sensible heat flux $Q_{s}$ (green) and $Q_p$ (yellow) in W m$^{-2}$ for 11-19 December 2006 at 0°N/165°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) and the PWP without $Q_p$ (orange).

**Figure 5:** Area averaged difference between with and without $Q_p$, $Q_{sh}$ 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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