2015

Surface Sensible Heat Loss in the Tropics

Andrew R. Shipotofsky

Surface Sensible Heat Loss in the Tropics

Andrew R. Shipotofsky

Dept. of Marine and Environmental Systems, Florida Institute of Techonology

Abstract

A study using reanalysis data from the Earth Systems Research Laboratory to examine the difference in heat loss for precipitation compared to that of the heat loss from the sensible heat flux near the boundary layer. Using GrADS, grid analysis and display system, the data was analyzed in order to look for a circumstance that would give similar heat losses. The main area of focus was in the tropics from 30ºN to 30ºS. It was found that the area of the Maritime Continent during a La Niña had very similar value for heat flux.

Introduction

The top layer of the ocean is generally a well-mixed layer due to wind-generated turbulence. This top layer can have abrupt changes in temperature with depth, which often indicates the base of the mix layer. The first law of thermodynamics governs that rate of change through the mixed layer, “The sensible heat of rainfall in the tropical ocean” (Fairall, Gosnell, and Webster 1995).

$$C_{ps}\frac{\partial}{\partial t}\int_0^h \rho_s T_s d_z = Q_{net} - R_T(h) + A - Q_M(h) - Q_p$$

The equation for the first law of thermodynamics, above, shows the change in heat content if a water column. The schematic diagram in figure 1 will show how the right side of the equation works.

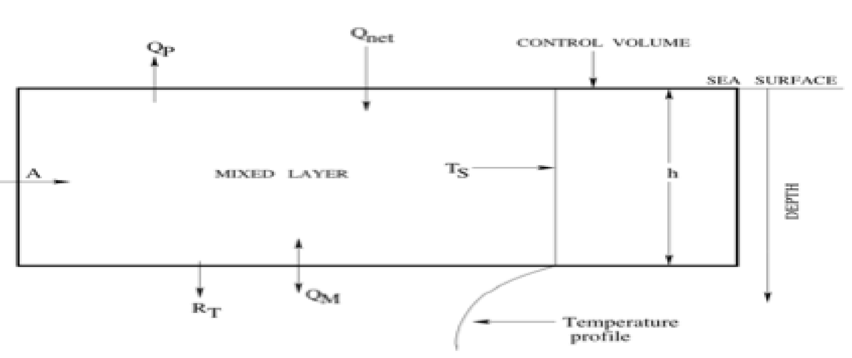


Fig 1: A schematic diagram of the workings of the mix layer described in the First Law of Thermodynamics

Q_{net}, the net heat flux at the surface, and Q_p, cooling due do to precipitation are a large focus of this study. The other variables control the entrainment at the base of the mix layer (Q_M), advection (A), and penetration of solar radiation (R_T), “The sensible heat of rainfall in the tropical ocean” (Fairall, Gosnell, and Webster 1995).

Qnet=Qsn-QLN-QLH-QSH

The Q_{net}, normal net heat flux, is made up of net shortwave radiation (Q_{sn}), net outgoing longwave radiation (Q_{LN}), latent heat flux (Q_{LH}), and sensible heat flux (Q_{SH}). Of these sensible heat flux is the smallest term that makes up the normal net heat flux.

QSH=ρα x Ch x U x Ts-Ta x Cp

Sensible heat flux (Q_{SH}) is the energy to change the temperature without a phase change at the boundary layer. Sensible heat flux is comprised of: density of air (ρ_a), exchange coefficient (C_h), wind speed at ten meters (U), difference in surface and air temperature (T_s – T_a), and ambient conditions (C_p). Sensible heat flux is measured in *Wm2*.

Qp= CwR(To-Tr)

Q_p is the heat loss due to precipitation in *J/sm2*. It is calculated using the specific heat of water (4186 *JKgK*), the rate of precipitation (R), the bulk sea surface temperature or skin temperature (T_o), and the mass- mean temperature of the rain or wet bulb temperature (T_r). The heat loss from precipitation is also normally not included in the Q_{net} term, nor the First Law of Thermodynamics, due its small size.

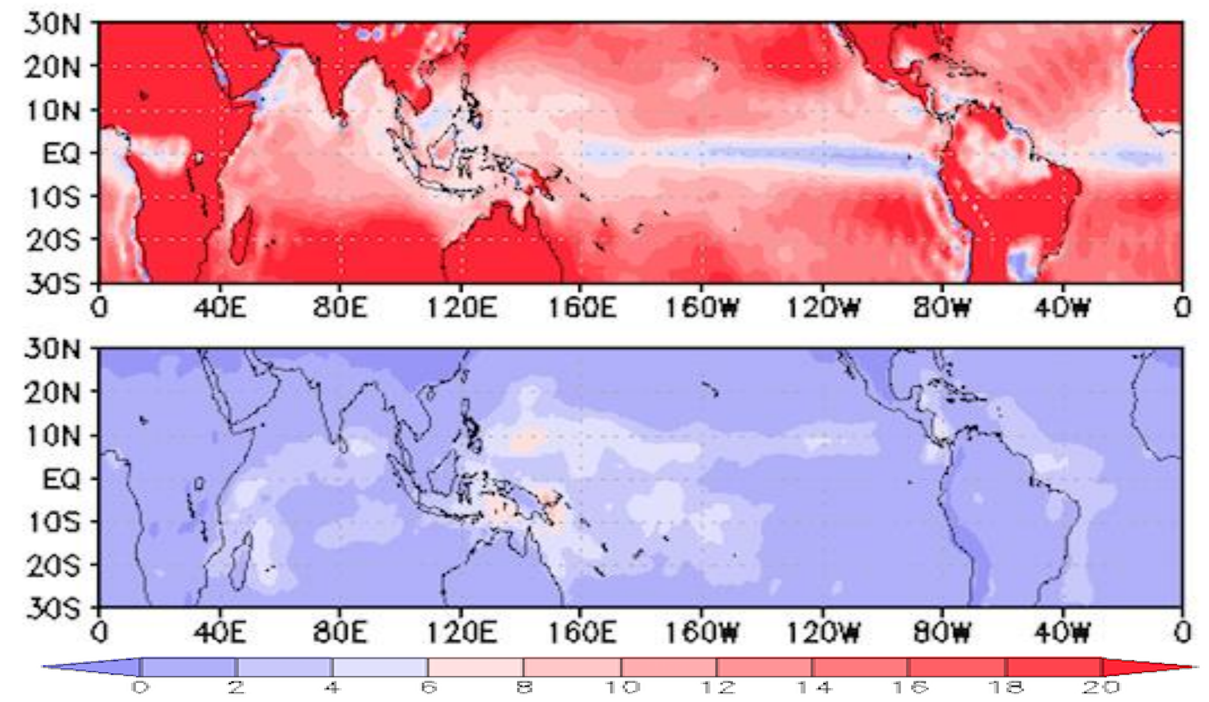
Methods

To analyze the differences in sensible heat flux and heat loss from precipitation in order to see if there is a significant difference, data was collected from the Earth System Research Laboratory in the National Oceanic and Atmospheric Administration. The variables used were reanalyzed monthly means at 2.5 x 2.5 degree grid boxes to calculate the heat loss precipitation. Reanalyzed data is the combination observations and model output. The time frame of tl data ran from January 1, 1996 to December 31, 20(This was because years of 1997 and 1999 had stro Oceanic Niño Indices to describe El Niño and La Ni events.

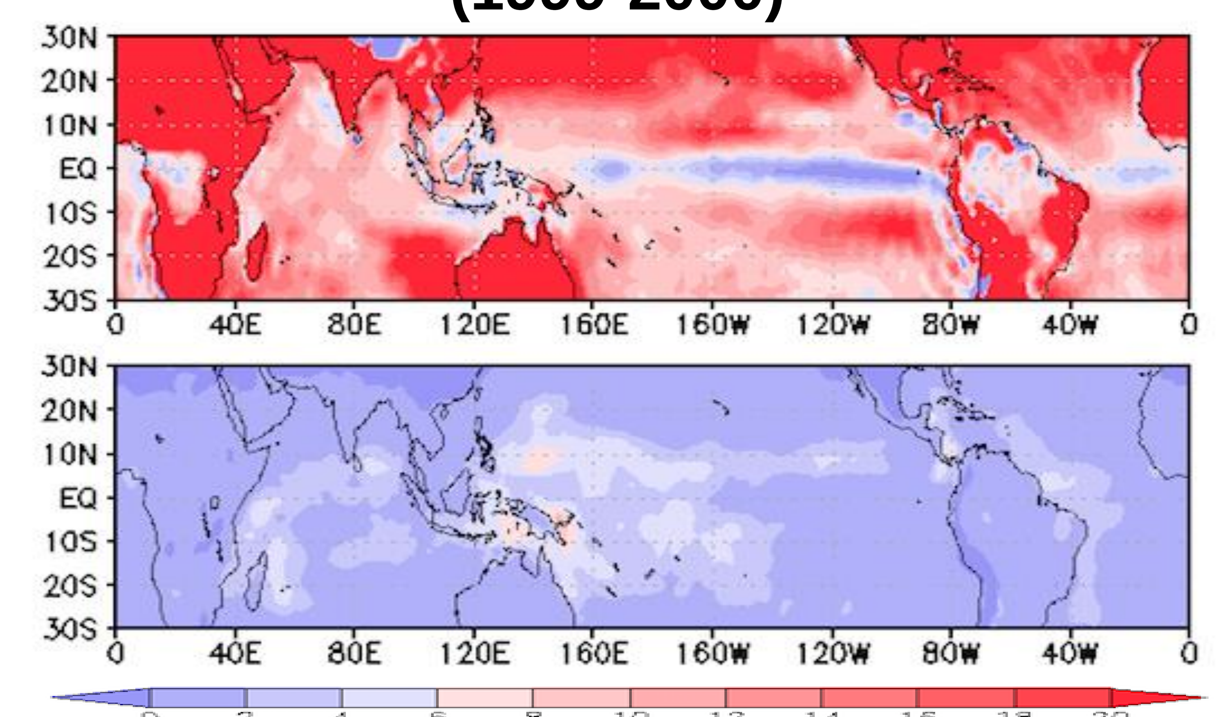
Of the reanalysis data, the only variable that needed to be additionally calculated in order to complete the heat loss from precipitation was the wet bulb temperature. The equation used to find the wet bulb temperature was from the work of Roland Stull, “Wet-Bulb Temperature from Relative Humidity and Air Temperature” (Stull 2011).

With the help of the wet bulb calculated with the Stull equation, the heat loss from precipitation could be calculated. This data was ran through a Grid Analysis and Display System (GrADS), which is used to access, manipulate, and visualize the reanalysis data.

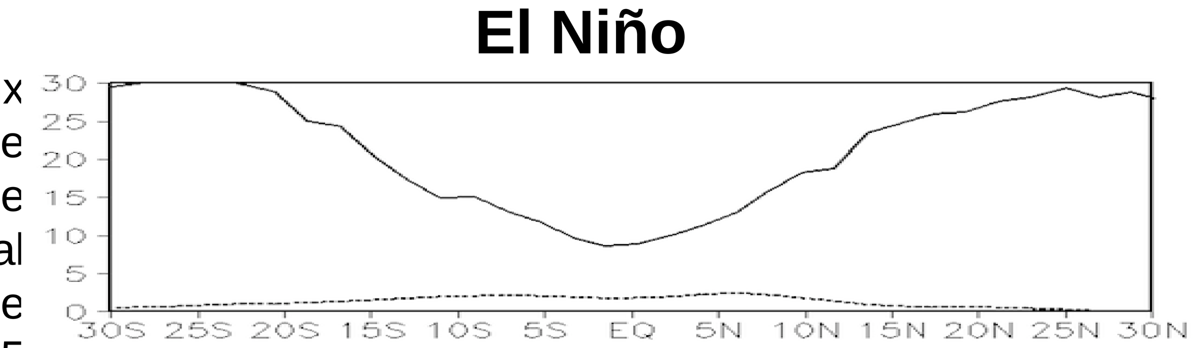
Mean Sensible Heat Loss (1996-2000)



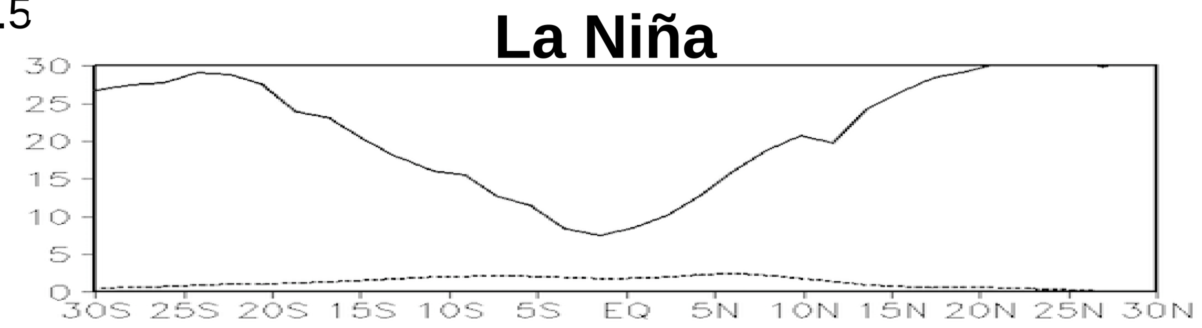
Sensible Heat Loss During La Niña (1999-2000)



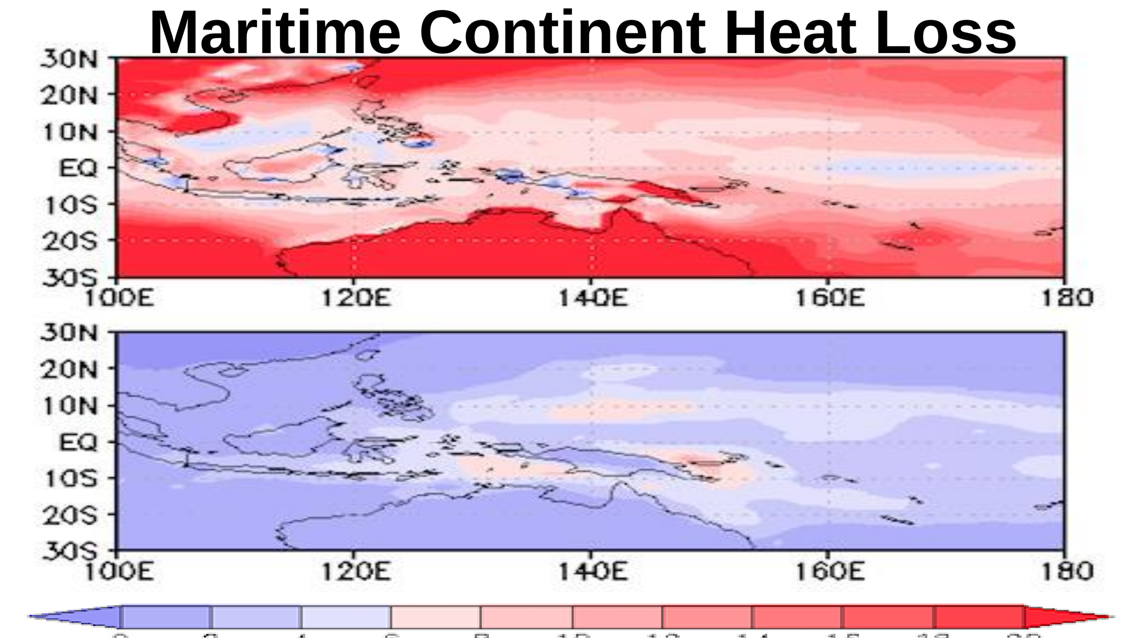
El Niño



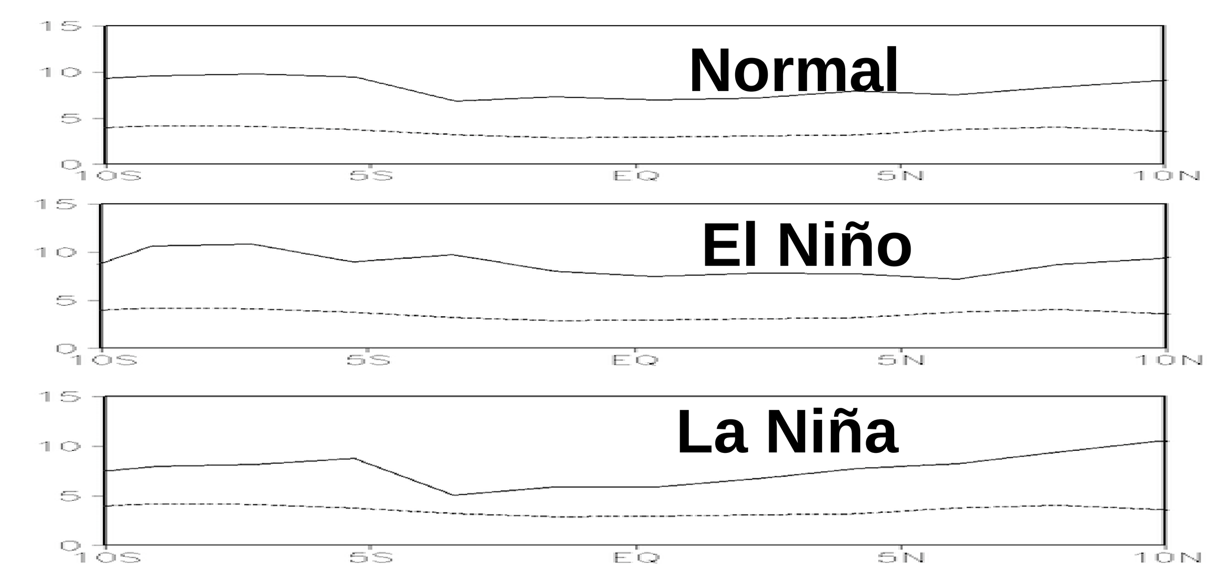
La Niña



Maritime Continent Heat Loss



Maritime Continent Heat Loss



Conclusion

- Sensible Heat loss is larger than the heat loss due to precipitation
- Both variables are closest in the Maritime Continent during La Niña events
  - Sensible heat loss: 6-7 W/m^2
  - Heat loss from precipitation: 4-5 W/m^2
- This shows that heat loss due to precipitation could be an important part of the system and needs to be included in climate models

Future Work

- To quantify the major factors that influence the sensible heat loss and precipitation heat loss
- Separate precipitating and non-precipitating days to compute the sensible heat loss
- Estimation and addition of the precipitation heat loss into climate models

Acknowledgements

I would like to thank Dr. Pallav Ray for his time and explanations in learning the GrADS package, as well as pointing me in the right direction. I'd also like to thank Marcus Morgan for helping with GrADS and helping work through key variables. I am also thankful for the support for my field project colleagues.

Resources

Fairall, C.W., R Gosnell, and P.J. Webster, *The Sensible Heat of Rainfall in the Tropical Ocean*. Journal of Geophysical Research, 18437 pp, 1995

Kalnay et al.,*The NCEP/NCAR 40-year reanalysis project*, Bull. Amer. Meteor. Soc., 77, 437-470, 1996.

Stull, R., *Wet-Bulb Temperature from Relative Humidity and Air Temperature.* University of British Columbia, 2267 pp, 2011

Cold & Warm Episodes by Season. Climate Prediction Center NOAA, 1 pp, 2014