The Entropy and Water Budgets Calculated from HS3 Dropsonde Data

Ana Juračić, David Raymond and Carlos López-Carrillo

New Mexico Insittute of Mining and Technology, Socorro, NM

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Introduction

The moist entropy and water budgets of the storm can give us information about moistening of the system, which is important in storm's evolution. Two big contributions to those budgets are the divergence of flux and surface fluxes. Those can be calculated from dropsonde data and the sea surface temperatures. The divergence of flux, when integrated over the volume, represents the exchange between the storm and the environment and the gain or loss that comes with it. Other contrubutions are radiation on the top and irreversible generation for entropy budget, and precipitation and evaporation for moisture budget.

In this research, only the divergence of flux and surface fluxes are calculated so far and those results will be presented here. The cases shown will be three HS3 missions into TC Gabrielle and the wave that preceded it.

The dates of HS3 missions and the status of Gabrielle:

- August 29-30, 2013: wave
- September 04-05, 2013: tropical depression -> disturbance
- September 07-08, 2013: disturbance

Methods

During the flight, the drop positions are spaced irregularly. In order to get the 3-dimensional fields on the regular grid, the 3D-Variational method is imposed. The horizontal resolution is 0.5 degrees and vertical grid points are 200 m apart. The fields used in this calculations are: wind ($\overrightarrow{v}$), air density (ρ) , moist entropy per unit mass (s) and mixing ratio of water vapor (r).

The 3-D divergence of moist entropy flux ($\nabla \cdot (\rho\vec{v}s)$) and moisture flux ($\nabla \cdot (\rho\vec{v}r)$) are calculated at each grid point. The 3-D divergence can be separated into horizontal and vertical part. If the former is horizontally averaged, the result is a vertical profile of lateral entrainment. The integration of such profile yields the entropy or moisture tendency due to lateral entrainment.

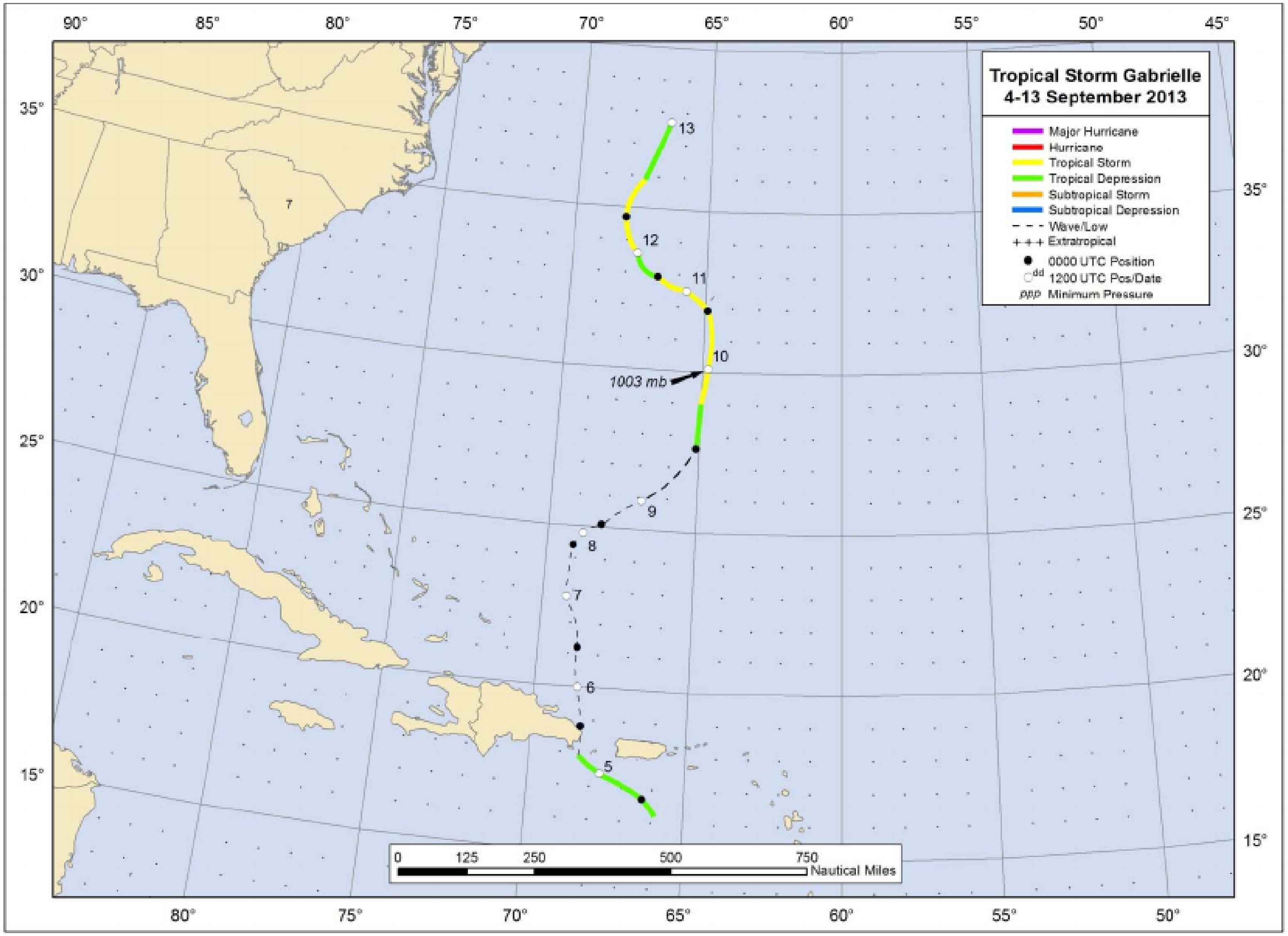
The surface fluxes are calculated by bulk formula:

$$SF = C_E \rho v_s \left(x_s - x_0 \right)$$

C_E is the bulk humidity flux coefficient,
v_s is the surface wind speed,
$\rho$is the air density,
$\boldsymbol{x}$ is $\boldsymbol{s}$ or $\boldsymbol{r}$, x_s being the value at the surface and x_0 at the lowest grid level.

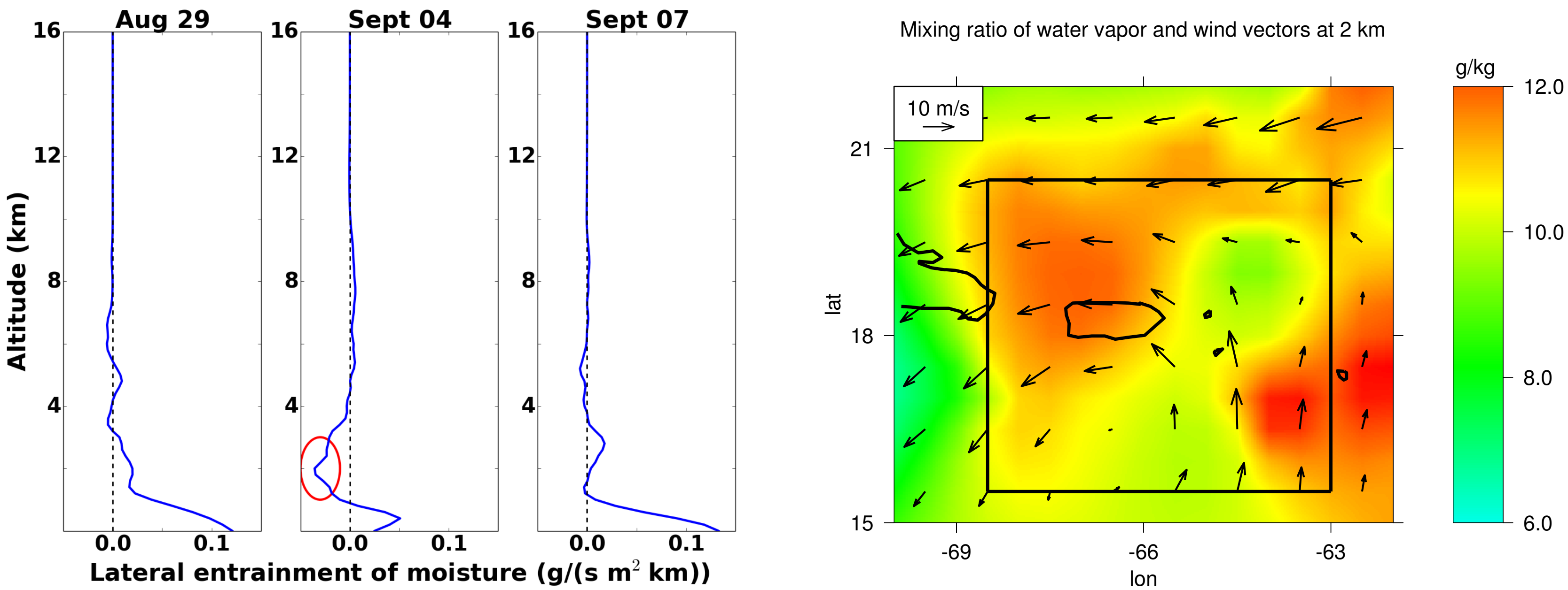
Surface value is chosen to be saturated value at SST and lowest grid level is 0 m, which is closest to often used 10 m value.

TS Gabrielle



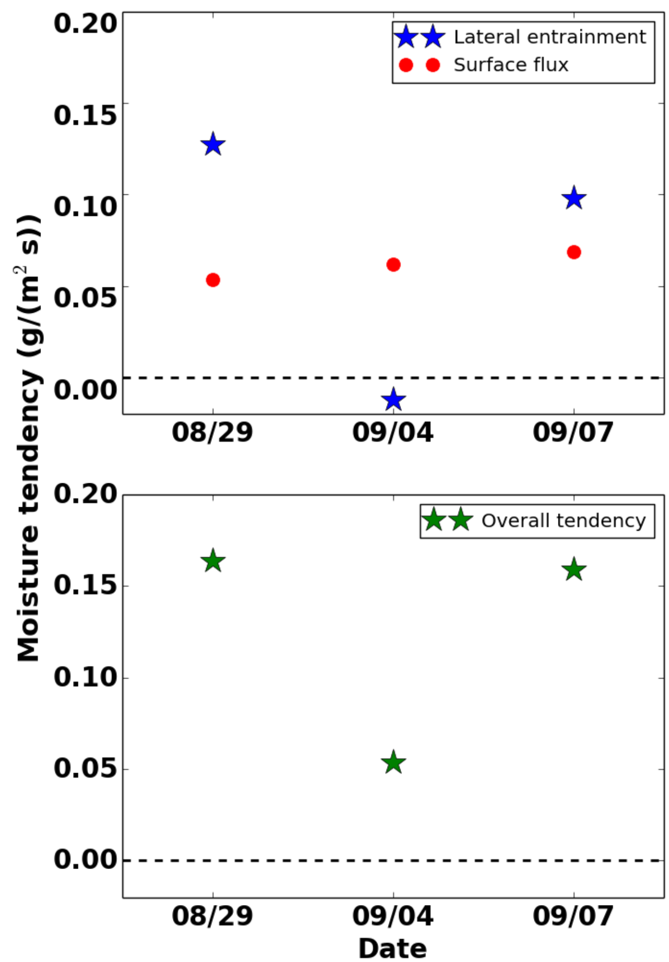
Best Track positions for TS Gabrielle, Source: NOAA/AOML/HRD, Avila, L. A. : Tropical cyclone report, Tropical Storm Gabrielle

Lateral Entrainment of Moisture



Vertical profiles of lateral entrainment of moisture for all three misions and the horizontal cross-section at 2 km (height indicated by circle on vertical profile) for Sept 04 mission showing the mixing ratio of water vapor in colors and wind vectors

Moisture Tendencies

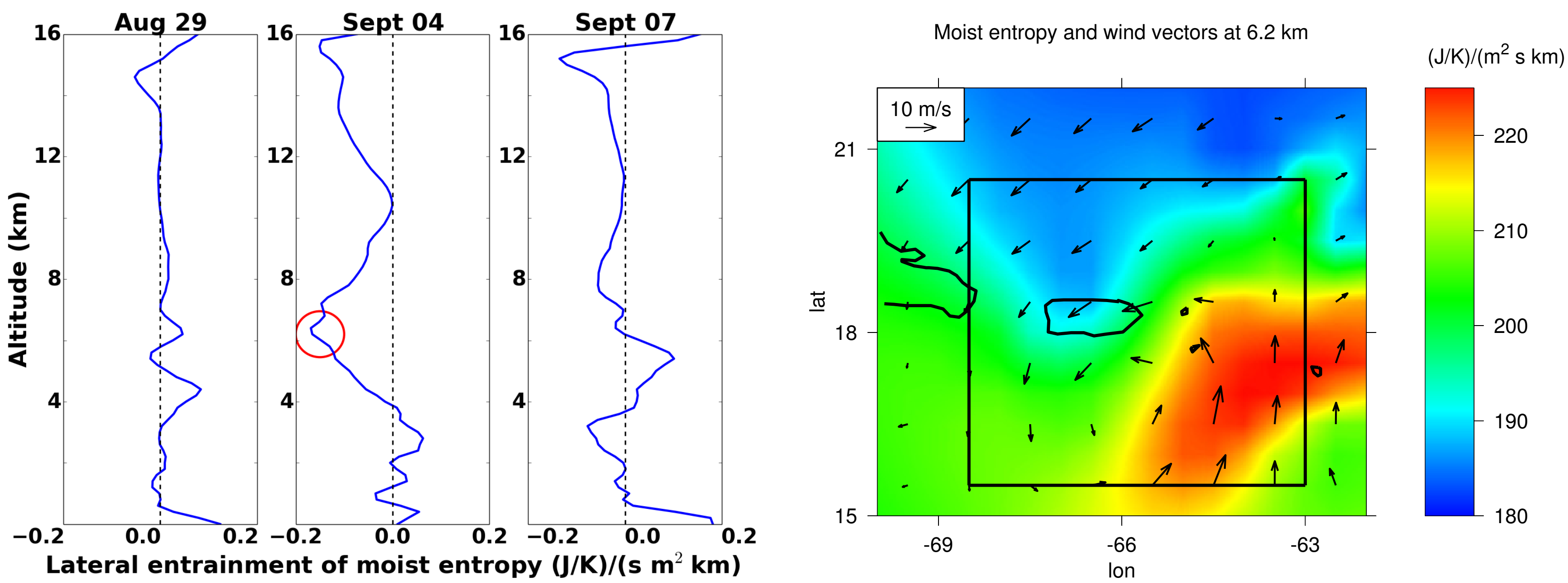


Plots of moisture tendencies.

Top: tendencies due to the lateral exchange with the environment (blue stars) and due to surface fluxes (red dots)

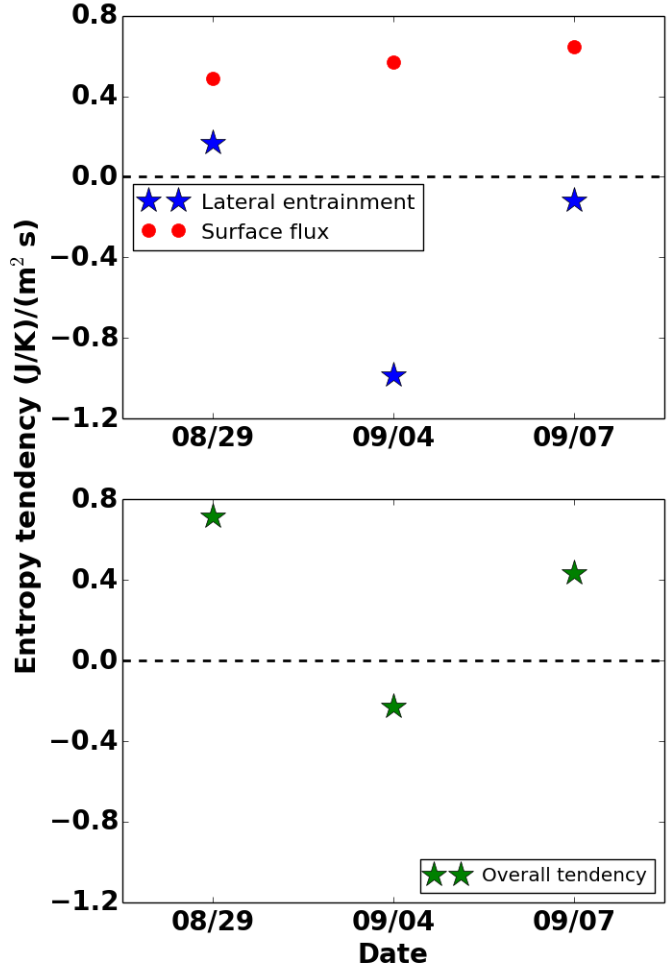
Bottom: overall tendency due to lateral exchange, surface fluxes and the exchange at the top

Lateral Entrainment of Moist Entropy



Vertical profiles of lateral entrainment of moist entropy for all three misions and the horizontal cross-section at 6.2 km (height indicated by circle on vertical profile) for Sept 04 mission showing the moist entropy in colors and wind vectors

Moist Entropy Tendencies



Plots of moist entropy tendencies.

Top: tendencies due to the lateral exchange with the environment (blue stars) and due to surface fluxes (red dots)

Bottom: overall tendency due to lateral exchange, surface fluxes and the exchange at the top

Conclusions

The overall moisture tendency is positive for all three cases

The overall moist entropy tendency is positive for first and third, but negative for second mission (Sept 04)

The decaying case (Sept 04 mission):

- Both moisture and entropy are lost through the lateral exchange with the environment
- Moisture surface fluxes were strong enough to overcome the loss
- Moist entropy surface fluxes were not strong enough to overcome the loss in entropy and overall tendency stayed negative