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The atmospheric hydrological cycle and the El Niño Southern Oscillation in the inter-American seas

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INTRODUCTION

Some of the greatest year-to-year climatic contrasts occur in relation to the occurrence of El Niño and La Niña (Días and Markgraf 1992). Among the greatest observed changes are those related to the hydrological cycle. Thus, in the tropical Americas, meteorological droughts or anomalously intense rainfall conditions can occur due to the dominance of one phase of El Niño Southern Oscillation. Given this, it is necessary to ask how the water content in the atmosphere changes due to El Niño or La Niña and whether this is sufficient to affect the rainy season.

Objective

To compare the components of the water balance equation in the presence of an El Niño event and a La Niña event.

METHOD

The water balance equation states that:

$$\frac{\partial PW}{\partial t} = E - P - \frac{1}{g}\int_{1000}^{500} \nabla \cdot Vq\, dp$$

Where $\frac{\partial PW}{\partial t}$ is the variation in precipitable water over time, E is the evaporation (mm), P is the Precipitation (mm) and the expression $\frac{1}{g}\int_{1000}^{500} \nabla \cdot Vq\, dp$ represents the vertically integrated moisture flux (VIMF), g is the acceleration of gravity (m/s^2),V are the components zonal and meridional wind speed (m/s), q is the specific humidity (kg/kg), and p is the atmospheric pressure (mb).

To compare an El Niño year with a La Niña year, data from the ERA-5 reanalysis of the variables involved in the previous equation were used. A comparison is made between the summer of 1982 (El Niño) and the summer of 2010 (La Niña), since, after analyzing precipitation anomalies, they recorded the highest values (negative/positive) for the study area.

RESULTS & DISCUSSION

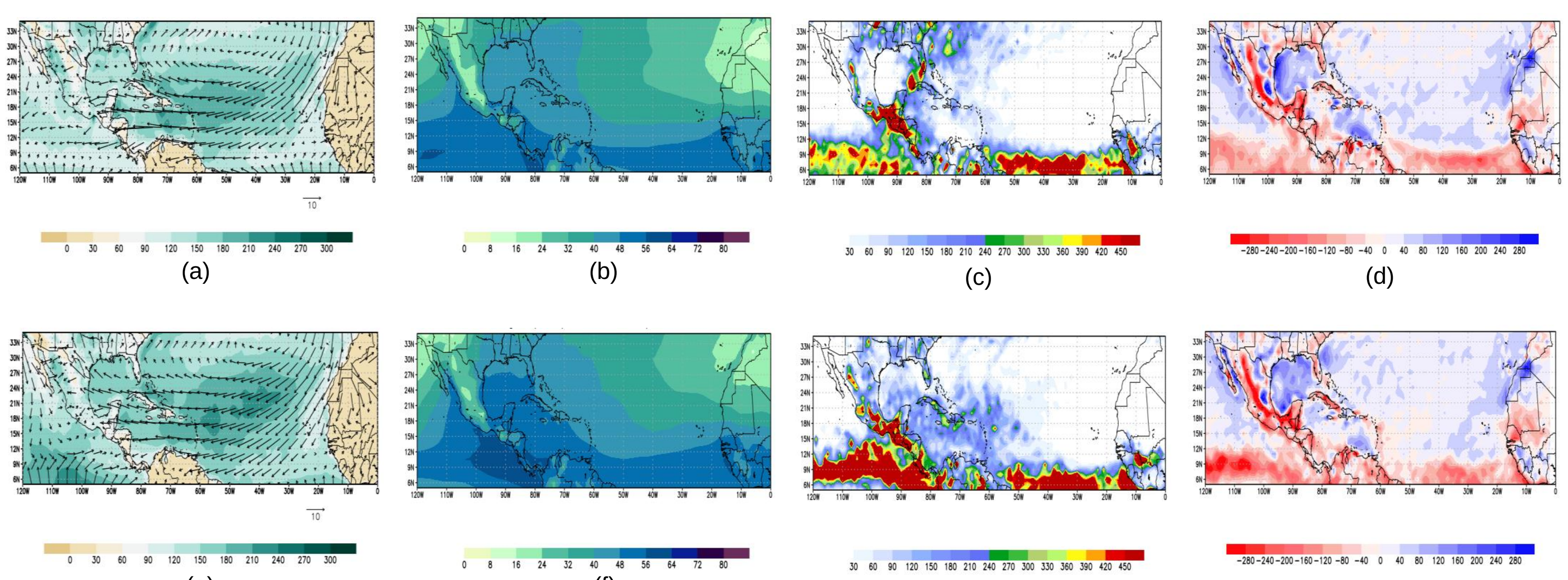

Figure 1. Comparison of the variables of the water balance equation from June to September in the years 1982 (first row) and 2010 (second row) (a)(e) Evaporation (mm/month) and surface wind field (m/s) (b)(f) Precipitable water (mm/month) (c)(g) Precipitation (mm/month) (d)(h) Vertically integrated moisture flux (mm/month) (blue: areas of divergence, red: areas of convergence).

In the eastern Caribbean Sea and Atlantic Ocean, there is a zone of maximum evaporation that contributes to the increase in precipitable water in the Mexican and Central American regions, primarily through the transport of moisture in the easterly flow. The region of maximum evaporation coincides with zones of flow divergence (Gimeno et al., 2010), accompanied by high Sea Surface Temperature (SST) values and strong winds.

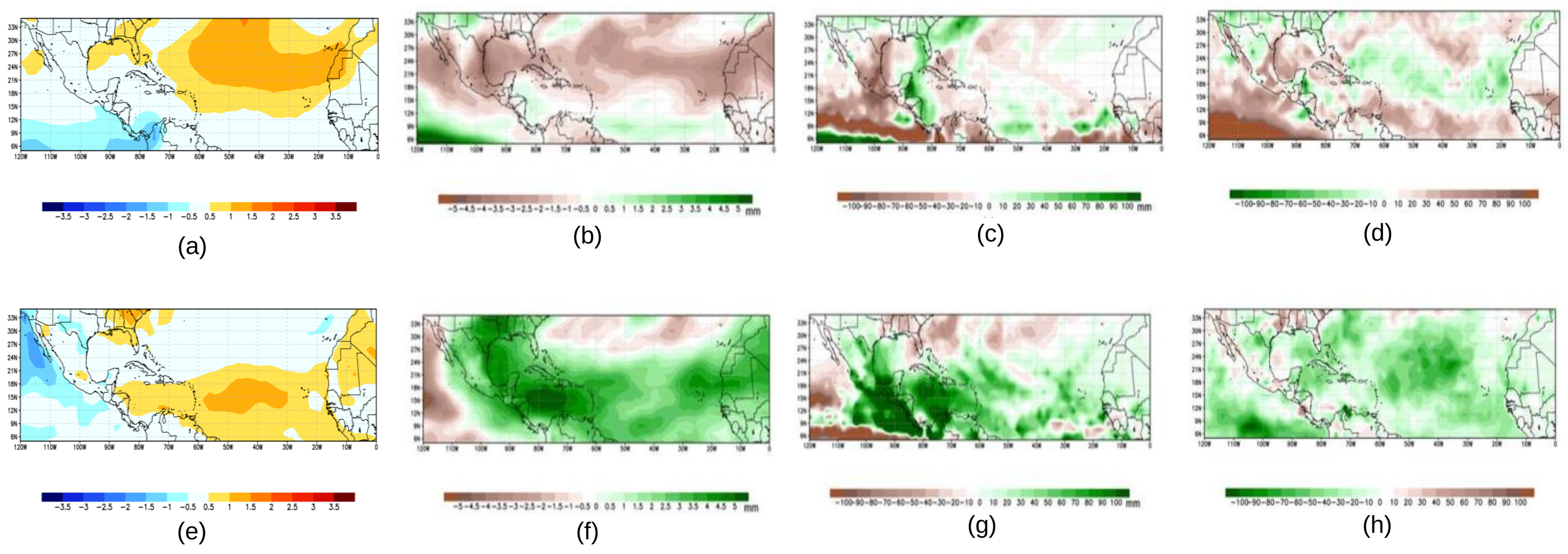

Figure 2. (a)(e) Sea Surface Temperature Anomaly (°C) (b)(f) Precipitable Water Anomaly (mm/month) (c)(g) Precipitation Anomaly (mm/month) (d)(h) Evaporation Anomaly (mm/month) 1982 (first row) and 2010 (second row).

During the presence of El Niño, the Intra-American Seas region experiences negative anomalies in precipitable water content, resulting in a drier-than-normal summer with a significant decrease in precipitation. Meanwhile, the presence of La Niña during the summer causes higher precipitation in this region, resulting in a wetter-than-normal summer with positive anomalies in atmospheric precipitable water content.

SST anomalies in the tropical Atlantic play a fundamental role in water vapor thermodynamics extending to the Intra-American Seas. An anomalously cold condition not only reduces evaporation but also reduces the atmospheric water vapor holding capacity. Although to negative SST anomaly was recorded during 1982, the highest temperature values were located further north of the zone of maximum evaporation.

In 2010, evaporation in the Atlantic and eastern Pacific was greater than in 1982. The increase in rainfall in the eastern Pacific is due to moisture convergence from the subtropics, not in situ evaporation. However, evaporation from the Atlantic to the subtropics does significantly influence not only convergence in the Atlantic Intertropical Convergence Zone, but also the flow of moisture to the Intra-American Seas and, consequently, the availability of precipitable water for precipitation processes.

CONCLUSION

During El Niño (La Niña) summers, evaporation and precipitable water decrease (increase) in the region, leading to a decrease (increase) in accumulated precipitation.

The atmospheric hydrological cycle is a complex mechanism that maintains the continuous circulation of water and involves several factors. It will be affected not only by variations in the components of the water balance equation, but also by other mechanisms such as easterly waves and teleconnection patterns, as in the case of the El Niño-Southern Oscillation.

FUTURE WORK / REFERENCES

As future work, it is proposed to perform this analysis for each of the El Niño/La Niña events with the objective of establishing a better relationship between said event and the components of the water balance equation.

Diaz, H. F., Markgraf, V. (1992) El Niño: Historical and Paleoclimatic aspects of the Southern Oscillation. Cambridge University Press. ISBN: 0521430429.

Gimeno, L., Drumond, A., Nieto, R., Trigo, R.M., Stohl, A., 2010: On the origin of continental precipitation. Geophys. Res. Lett., 37(13), doi:10.1029/2010GL043712.