Moisture sources for the North American Monsoon and their influence on Precipitation Events

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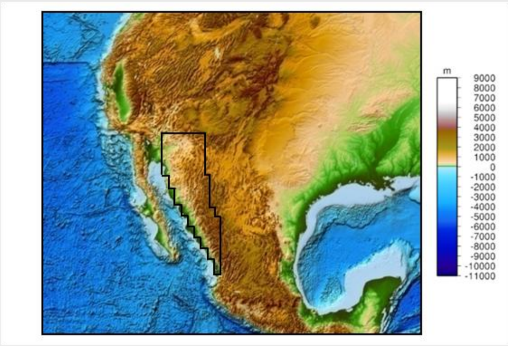
INTRODUCTION

The North American Monsoon System (NAMS) is the large-scale atmospheric circulation system that drives the dramatic increase in rainfall experienced in the desert southwestern US and northwestern Mexico during the summer months of July, August, and until mid-September. Seasonal reversals of the wind are less pronounced than in other monsoons of the world, and complex interactions between surface heating, topography, and large-scale circulation patterns can modulate the moisture amount that reach this tropical and subtropical region.



Map of the study region
ETOPO1 Ice Surface Global Relief Model

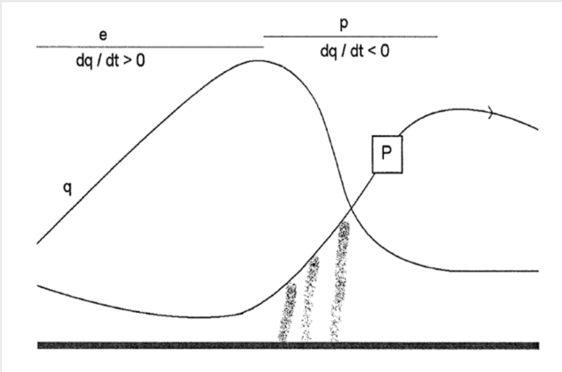
There has been a considerable debate on the relative role of the oceanic sources of monsoonal moisture. A heat low over the southwest US steers moisture up from the waters of the Gulf of California and eastern Pacific. Moisture at higher levels in the atmosphere from the Gulf of Mexico and the Caribbean Sea may also contribute to monsoon precipitation. In addition to these two sources, recent works also highlight the role of moisture recycling over the core monsoon region mainly due to seasonal greening of local vegetation.

The main objective of this work is to study the origin of the water that arrives to the NAM by using a Lagrangian diagnostic method, assessing thus the implications into the monsoon development.

METHODS

- **FLEXPART** model (Stohl et al., 1998) split the atmosphere homogeneously in "particles".
- The particles move with the observed wind.
- Particle positions and interpolated q values are recorded in output files and "e – p" is diagnosed from a particle's "q" change between two output times:

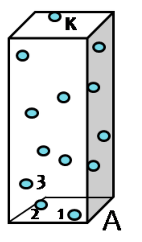
$$e - p = m\frac{dq}{dt}$$



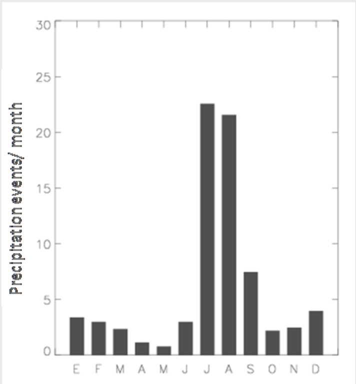
Sketch of a particle undergoing an evaporation – precipitation cycle

- To diagnose the surface freshwater flux (E-P) in an area A, the moisture changes of all particles in the atmospheric column over A are amassed (Stolh and James, 2004; 2005).
- *A* general view of the moisture sources (and sinks) can be attained by adding the net freshwater flux from day 1 to day 6, **(E – P)$_{1\text{-}6}$** (sum of $(E-P)_1$, $(E-P)_2$,. . ., to $(E-P)_6$).

$$(E-P) \approx \frac{\sum_{k=1}^{K}(e-p)_k}{A}$$

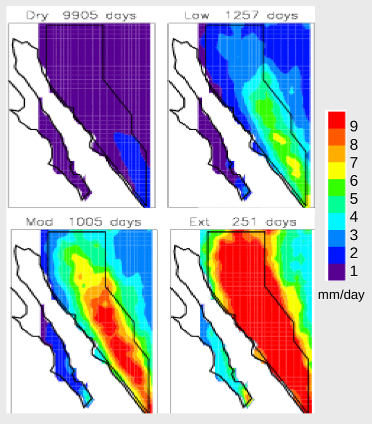


Advected moisture may or may not produce effective precipitation → We need to track particles that discharge rainfall at its arrival → Common precipitation days are defined for the study region



Precipitation events for the NAM.
Data: CHIRPS (Funk et al., 2015).

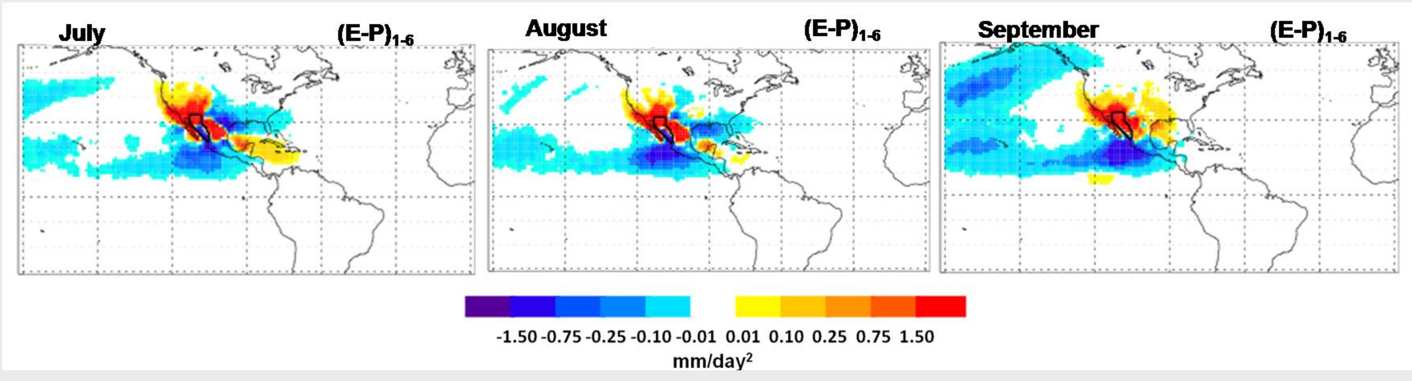
- Values above 10% of its corresponding σ were considered as an individual precipitation event. To obtain a **common precipitation day**, 41.3% of grid points inside the region must present precipitation simultaneously.
- P10 and P50 of the rainfall series must be exceeded in at least 41.3% of the total numbers of grid points to compute extreme and moderate precipitation days.

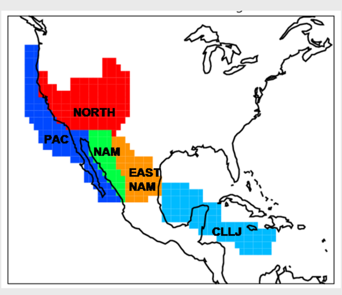


Composites for the different precipitation categories.
Data: CHIRPS (Funk et al., 2015).

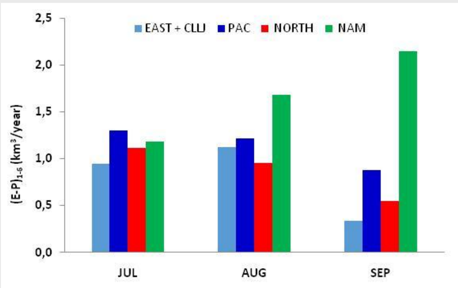
RESULTS

Main moisture sources for the NAM





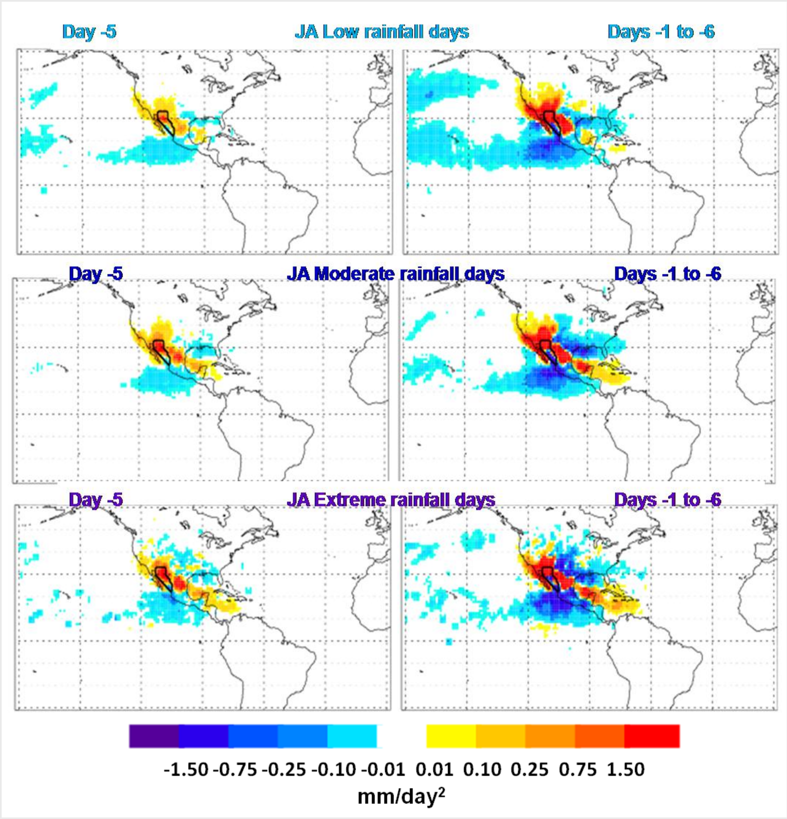
Moisture source regions defined for the NAM



Monthly time series of $(E-P)_6$ integrated over the PAC, the eastern regions (EAST NAM + CLLJ), the NORTH and the NAM itself.

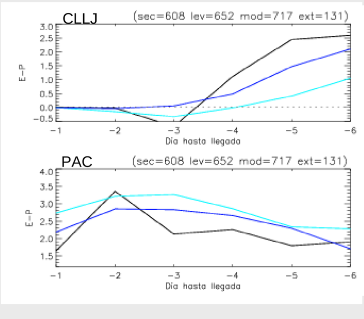
- During July, all the moisture sources present a strong contribution.
- From August to September the recycling is significant, being the main moisture source.

Moisture transport and rainfall intensity



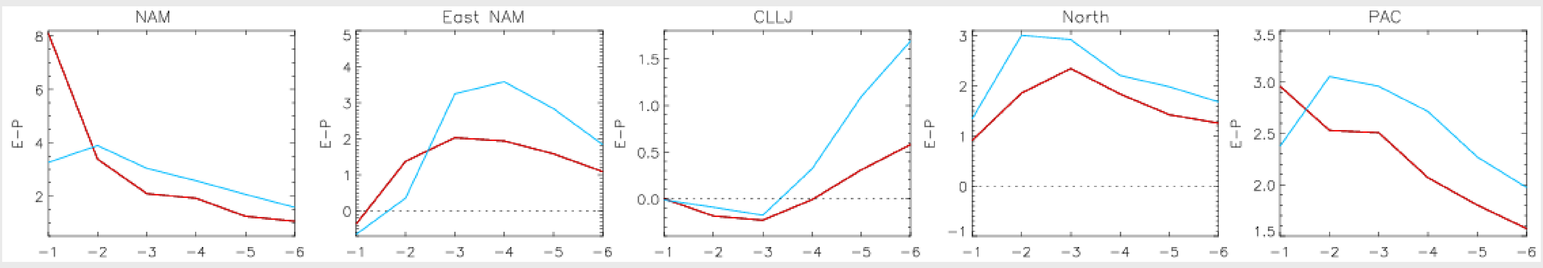
The moisture recharge seems to be more intense over the CLLJ region as the intensity of precipitation over the NAM increases.

The moisture transported by the CLLJ since day -6 to day -3 before the arrival, is revealed as one of the most important factors affecting the precipitation intensity.



JA time series of $(E-P)_n$ (n=1 to 6) integrated over the CLLJ and the PAC. Composites for low (light blue line), moderate (blue line), and extreme precipitation (purple line) are shown.

Moisture transport and rainfall development



July-August time series of (E–P)n n =1 to 6) integrated over PAC, NORTH, EAST NAM, CLLJ and NAM itself. Composites for wet days (blue line) and dry days (red line) are shown.

Recharges over all the moisture source regions are greater before the wet days.

Summary and conclusions

- ✓ Five major moisture sources have been identified for the NAM: the western Pacific Ocean including the Gulf of California (PAC), The northern NAM (North), the east of the NAM (East NAM), the Atlantic Ocean over the Caribbean Low Level Jet (CLLJ) and the NAM itself.
- ✓ The Pacific Ocean is the main moisture source during July and the recycling process is the main moisture source during August and September.
- ✓ All the identified moisture sources could be important for rainfall development during the NAM season.
- ✓ The CLLJ contributions seems to be determinant for rainfall intensity.

References

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