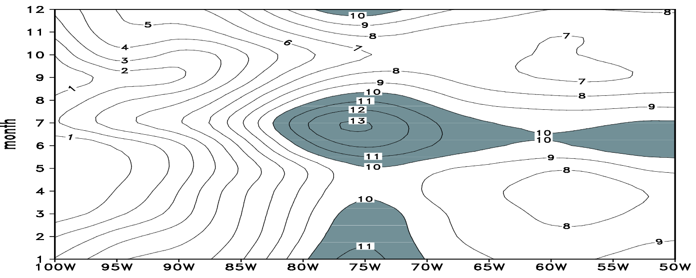
The Intra Americas Seas climate

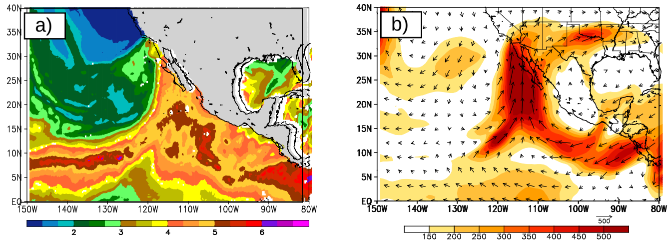


Jorge A. Amador

School of Physics

Centre for Geophysical Research

University of Costa Rica, 11501 San Jose, Costa Rica



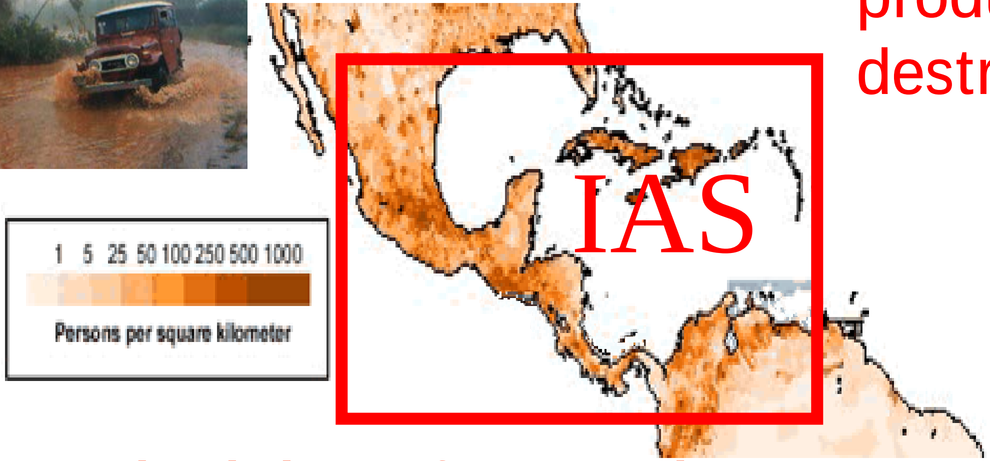
Workshop on the Science of Climate Change: a focus on Central America and the Caribbean Islands
Antigua, Guatemala
13-16 March 2017

Acknowledgements

University of Costa Rica colleagues
School of Physics and
Center for Geophysical Research

Societal Motivation

W&C at different time and space scales produce catastrophic losses of life and destruction of infrastructures and properties



The IAS region is home for more than one hundred million people; some countries are among the poorest in the Americas, and in the world

Small countries are particularly vulnerable: Grenada´s losses of US$919 as a result of hurricane Ivan in 1994 were equal to 2.5 times its gross domestic product (Wahlström 2009)

Outline

1. Rationale

2. Background and issues I: Local, regional variability and some processes

    2.1 Regional rainfall variability (Mid Summer Drought, Dry Corridor)
    2.2 Western Hemisphere Warm Pools (WHWP)
    2.3 Caribbean (Intra Americas) Low-Level Jet (CLLJ, IALLJ)
    2.4 Atmospheric rivers
    2.5 Tropical cyclones (TC)

3. Background and issues II: regional to global influences on IAS climate

    3.1 Teleconecctions
    3.2 Moisture sources and sinks

4. Final remarks (*Some key issues*)

1. Rationale (IAS)

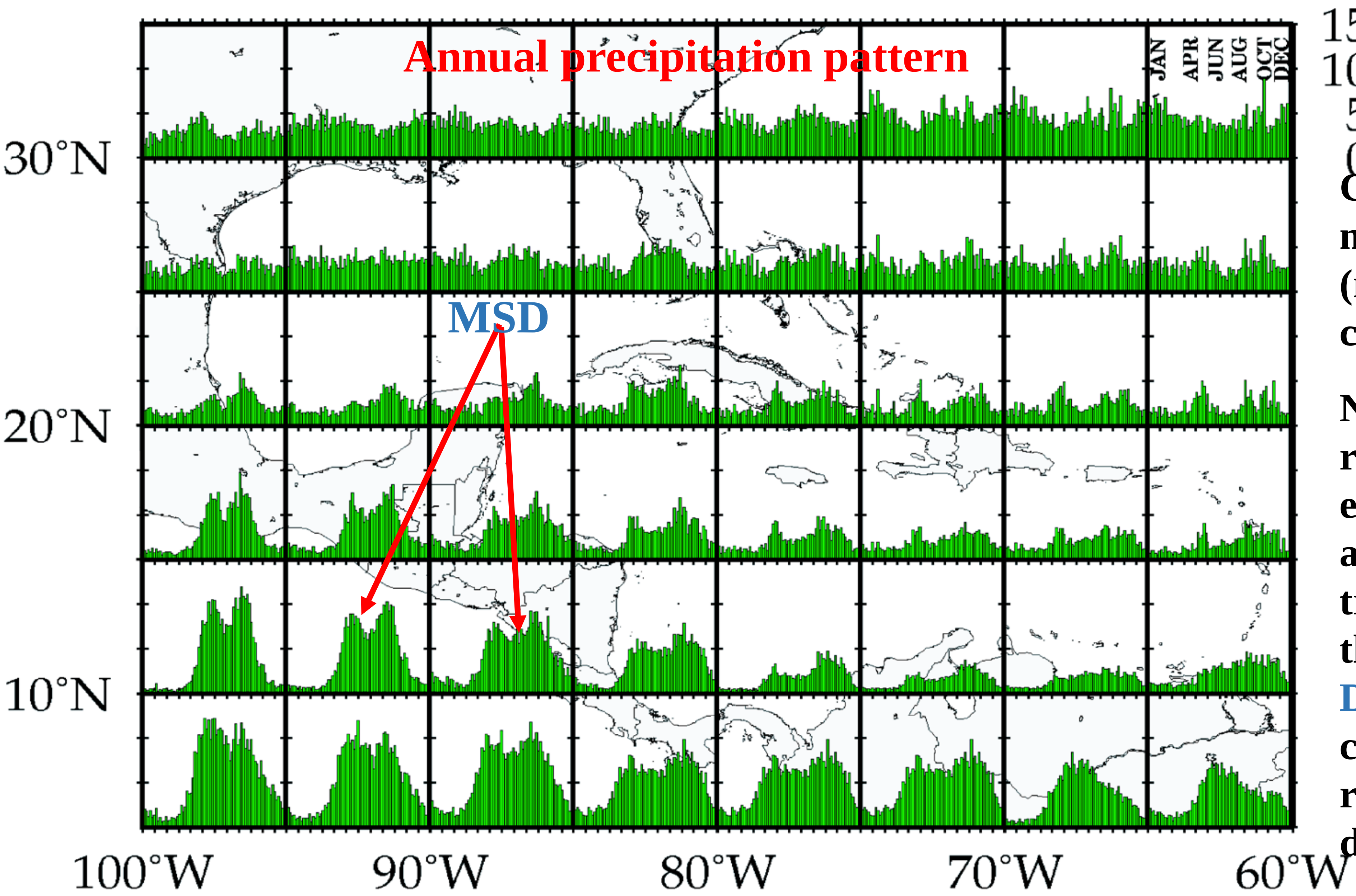
•

1. Vulnerability to climate variability
   Floods and Drought, Tropical Cyclones, Impacts on Water Resources and Ecosystems
2. Nexus between IAS and North and South America, and for the Pacific and Atlantic (American Monsoon System)
3. Climatic impacts on geochemical and ecological systems
4. Rich climatic phenomena: diurnal to multi-decadal time scales
5. Ideal location for studying air-land-sea interaction
6. Large biases in global climate models to capture climate features

7. Need for capacity building in the region

2. Background and issues I: Local, regional variability and some processes

2.1 Regional rainfall variability (Mid Summer Drought, Dry Corridor)



Climatological five-day mean precipitation rates (mm day-1) for contiguous 5° x 5° areas.

Note the bimodal rainfall distribution, especially on coastal areas of the eastern tropical Pacific showing the Mid-Summer Drought (MSD), canícula or veranillo, a reduction in rainfall, during July-August.

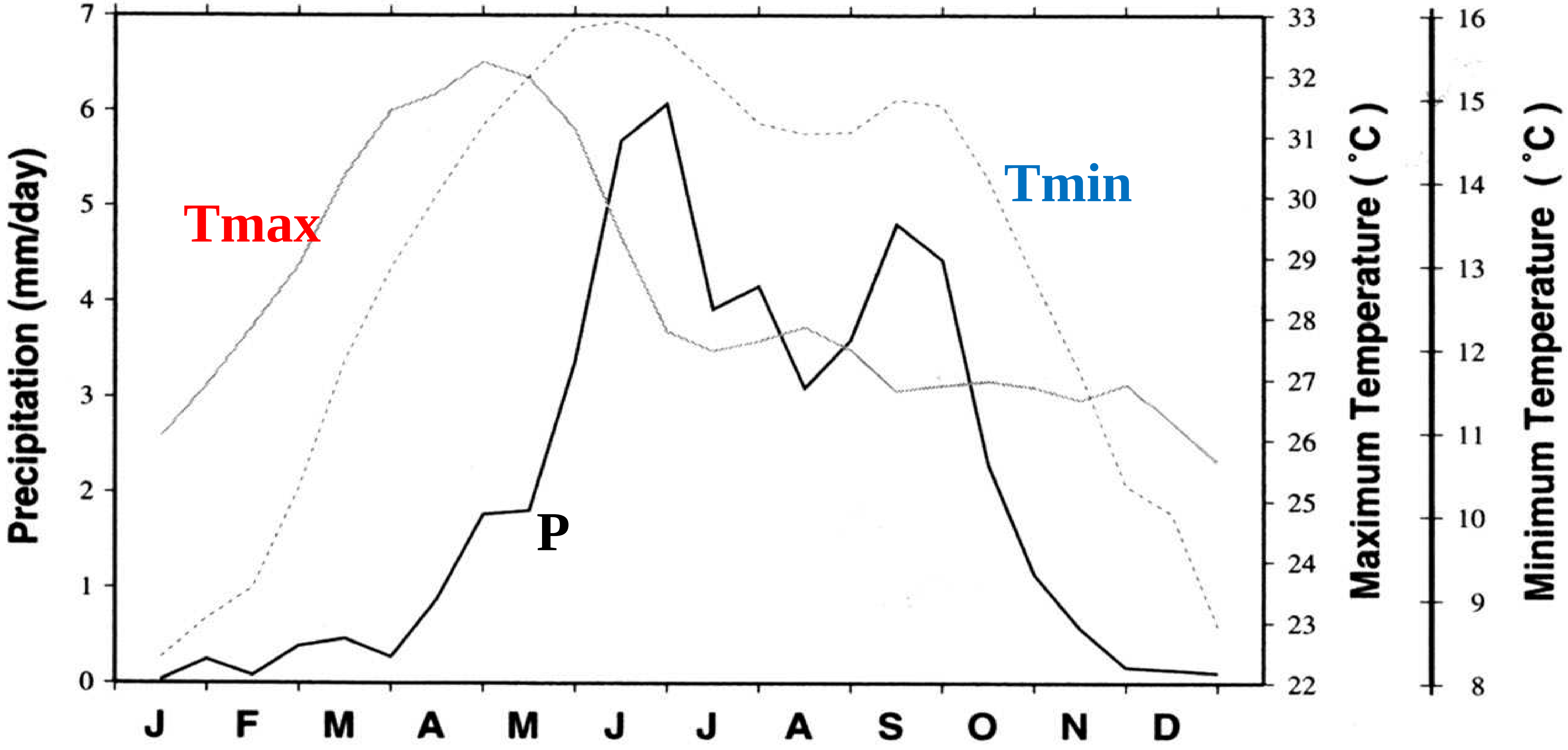


FIG. 2. Precipitation (black solid line), maximum temperature (gray solid line), and minimum temperature (dotted line) biweekly climatologies for Oaxaca, Mexico (17°N, 97°W).

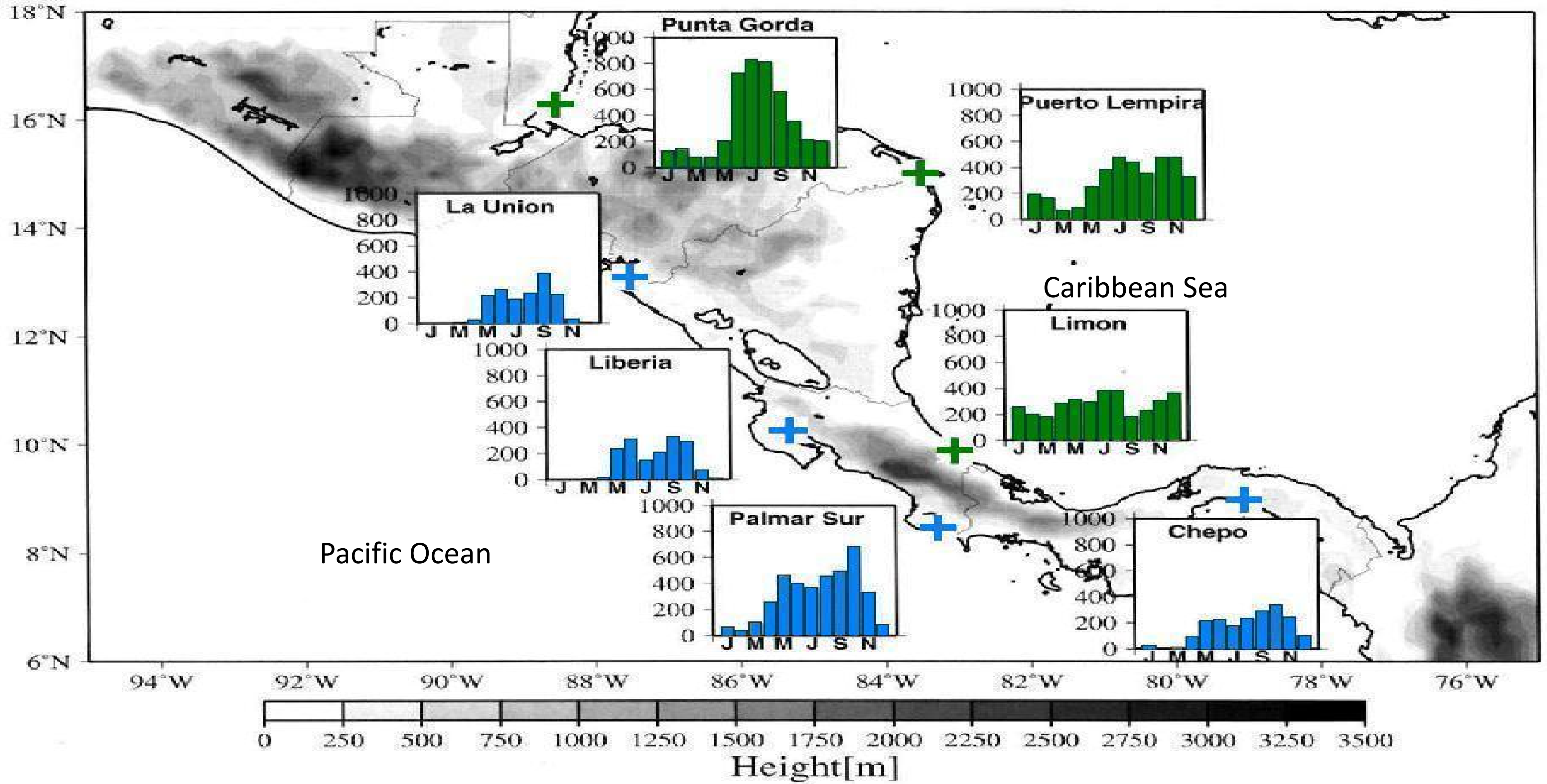
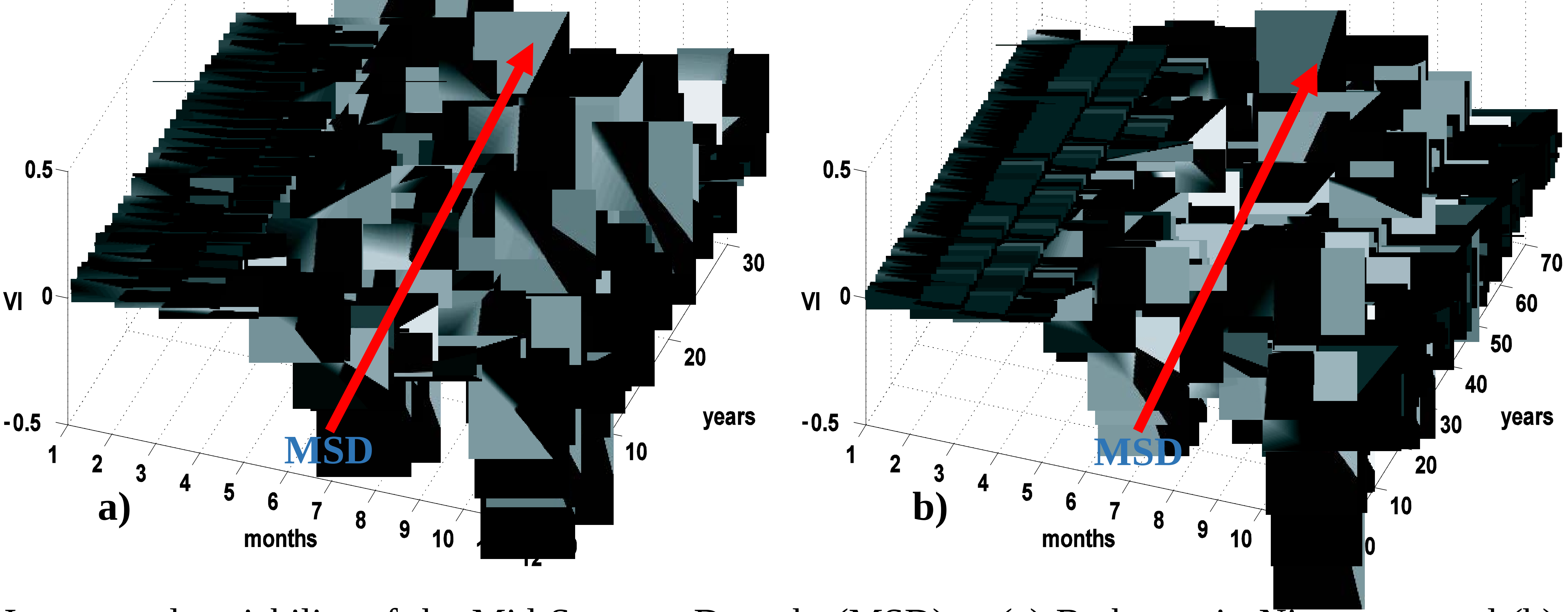


FIG. 9. Central American topography and monthly precipitation (mm) climatologies for stations along the Caribbean and the Pacific coast.

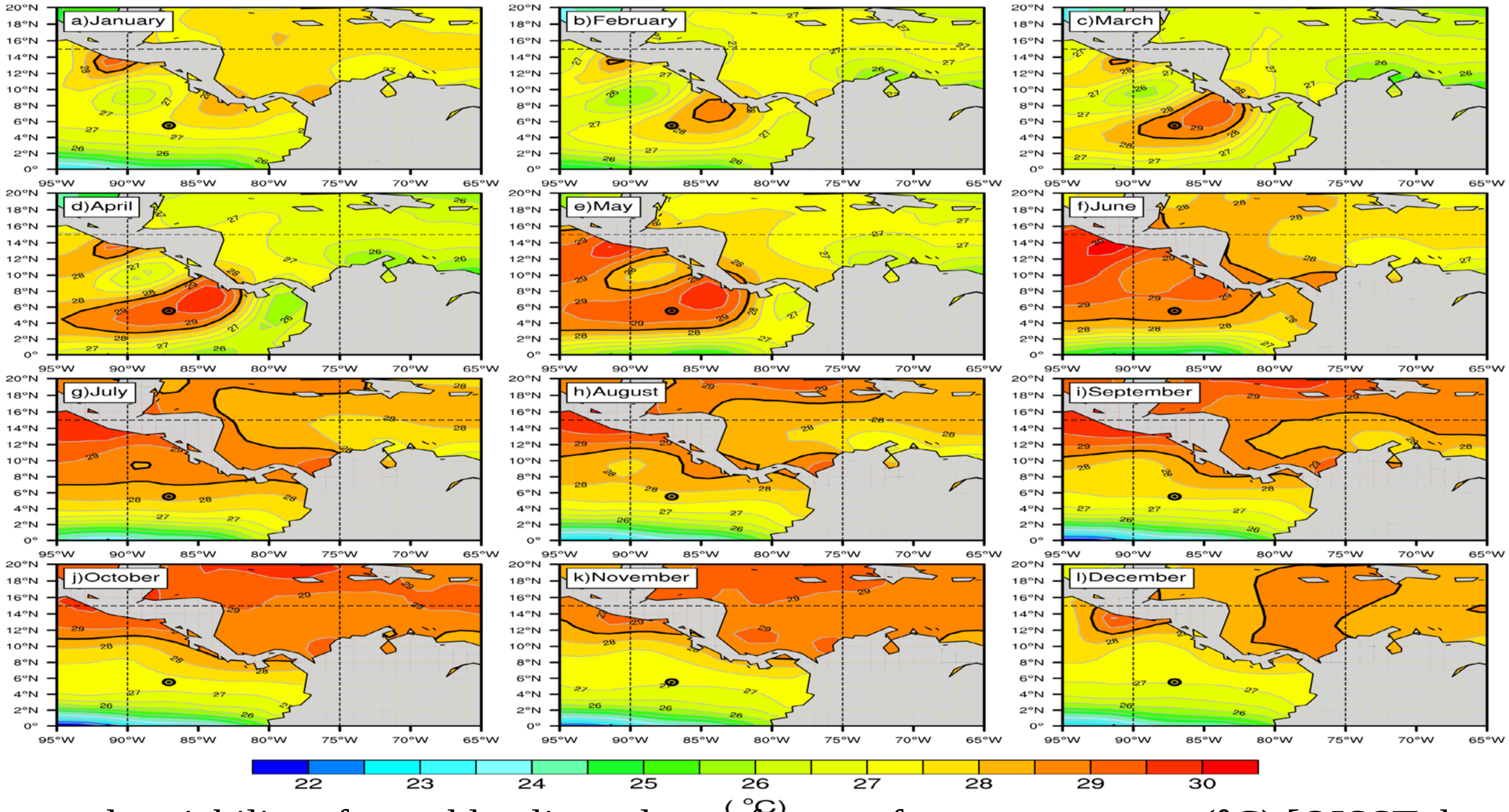
Magaña, Amador and Medina, J. Clim. 1999

The **VI** was calculated as: $VI_{k+1} = \{(P_{k+1} - P_k) / P_m\}$, where $k = 1, \ldots, M$. M is the total number of months in record in chronological order, P_k is the precipitation for a given month k, and P_m is the mean annual rainfall for the station estimated over the number of years in record.

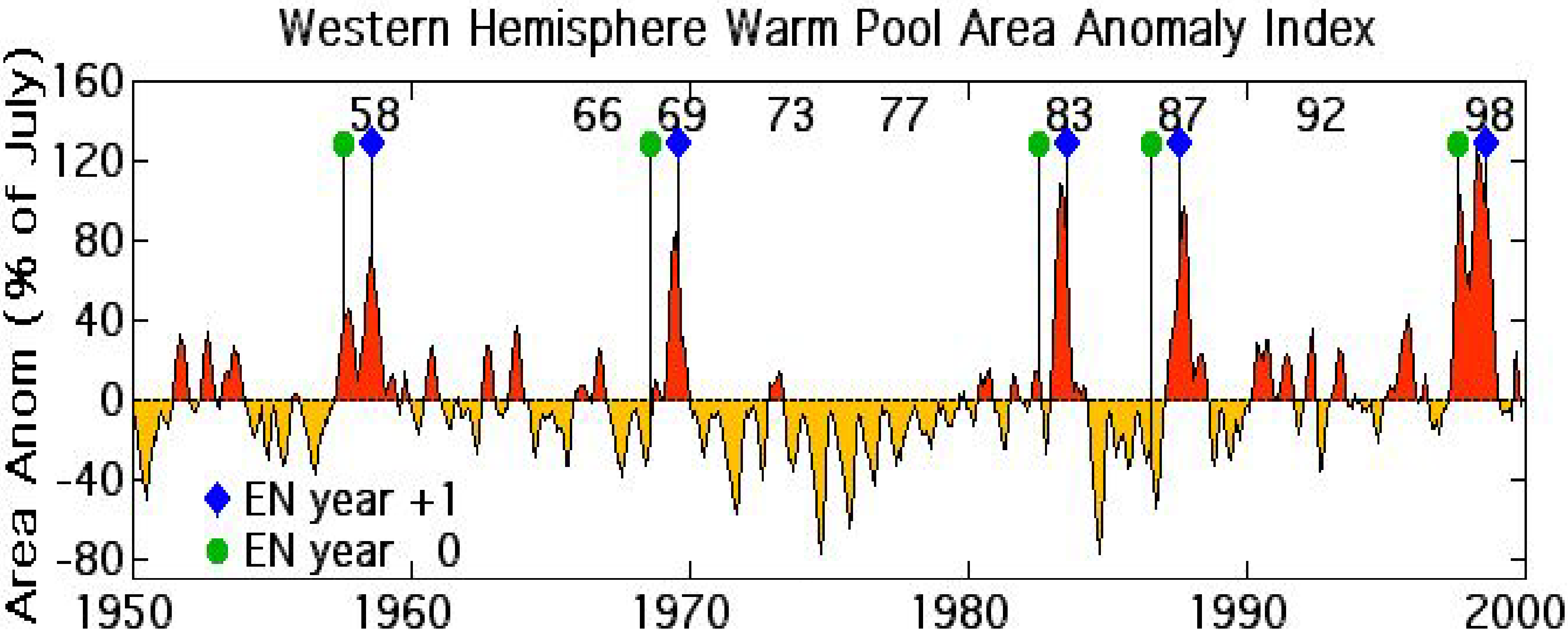


Interannual variability of the Mid Summer Drought (MSD) at (a) Barbacoa in Nicaragua, and (b) Usulutan in El Salvador, both in the Pacific coast of Central America. The Variability Index (VI) is defined in the text (section 4.2.).

2.2 Western Hemisphere Warm Pools (WHWP)

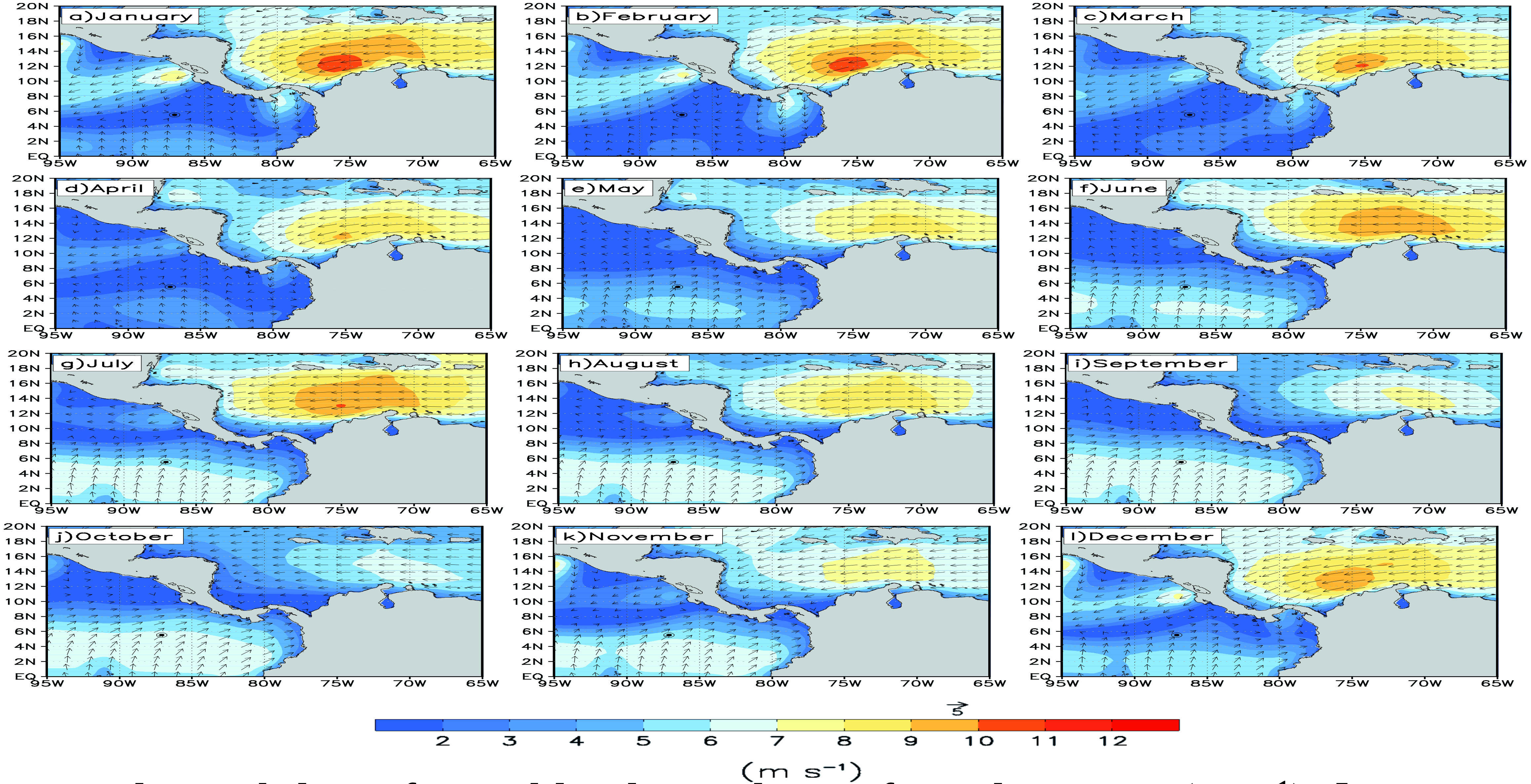


Seasonal variability of monthly climatology of sea surface temperatures (°C) [OISST dataset].

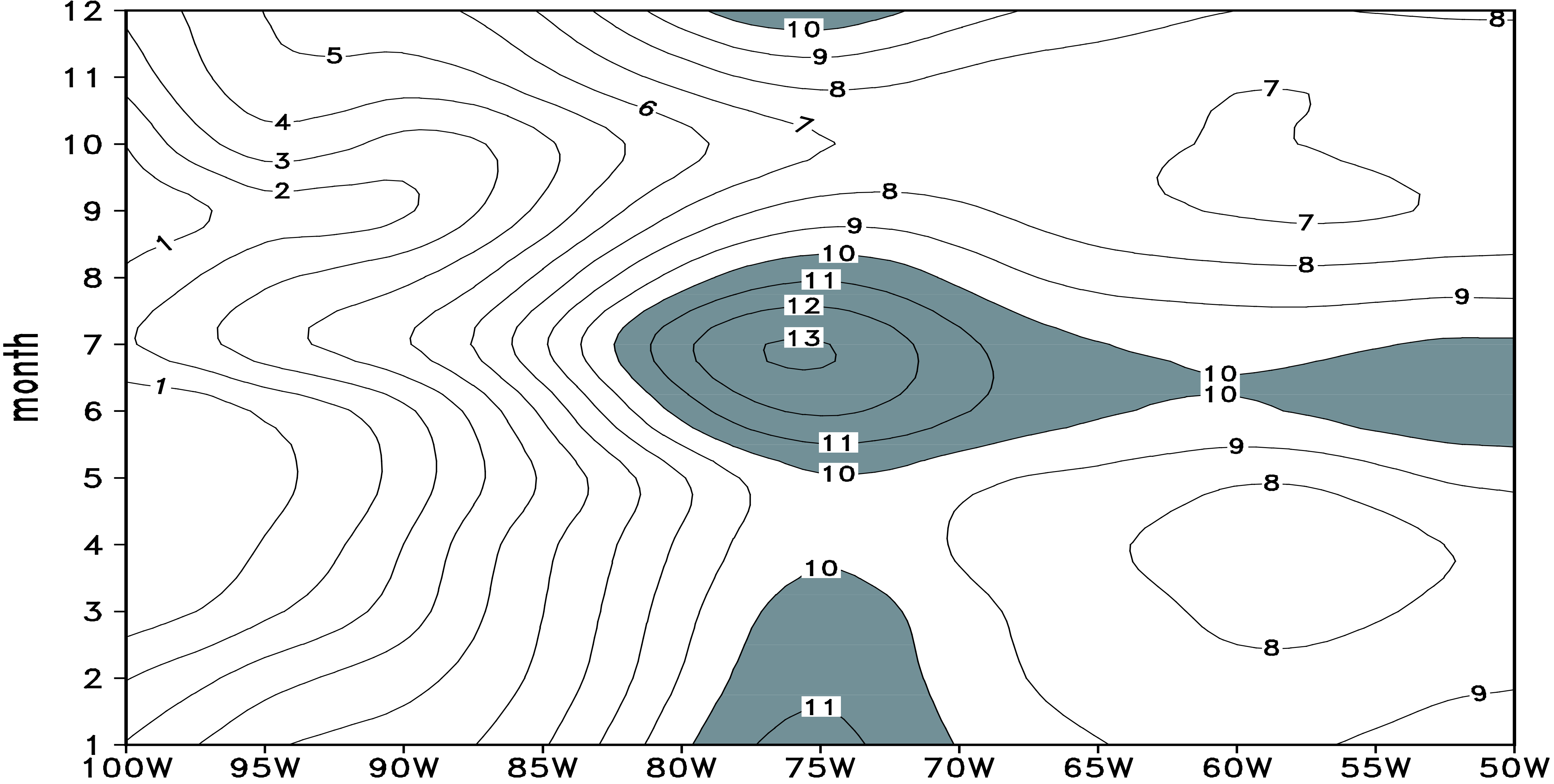


Anomaly time series of the WHWP area surrounded by the 28.5 °C isotherm. The series is expressed as a percentage of the climatological mean area for July. The July values of the five largest anomalies are indicated by the blue diamonds, and the July values of the prior years by green circles. Years of major ENSO warm events are also marked (From IASCLIP, VAMOS 10, Chile, 2008).

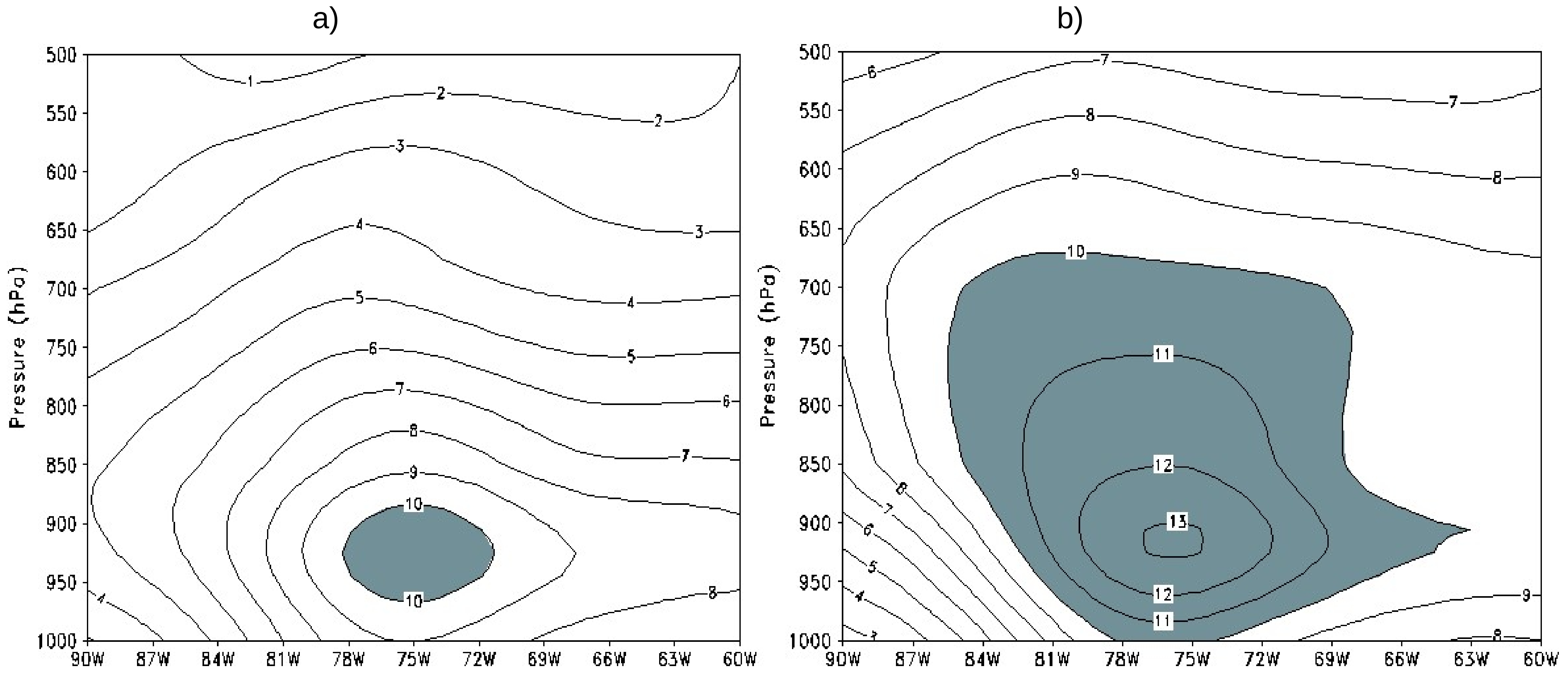
2.3 Caribbean (Intra Americas) Low-Level Jet (CLLJ, IALLJ)



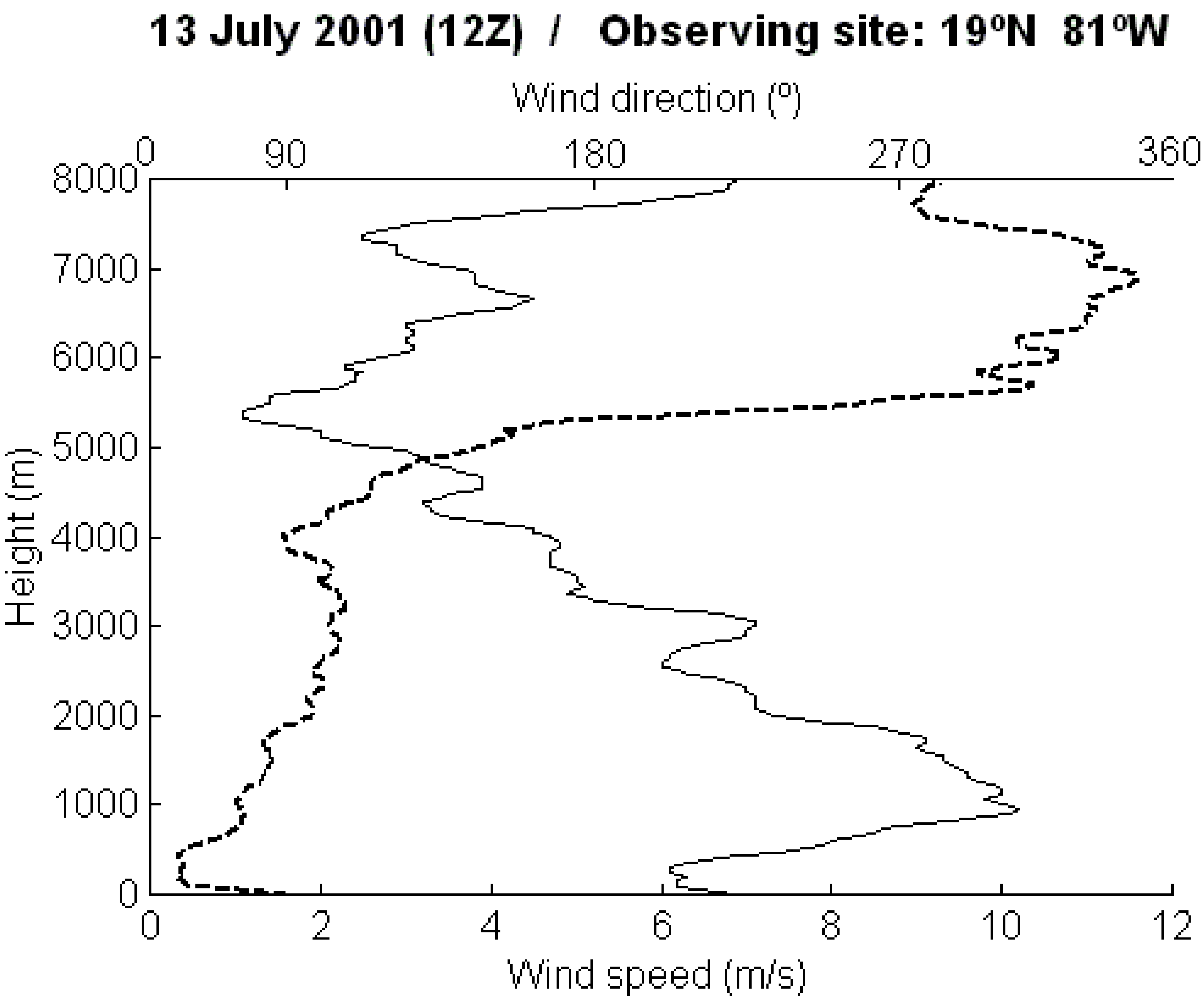
Seasonal variability of monthly climatology of wind at 10 m (m s^{-1}). [1980-2012]



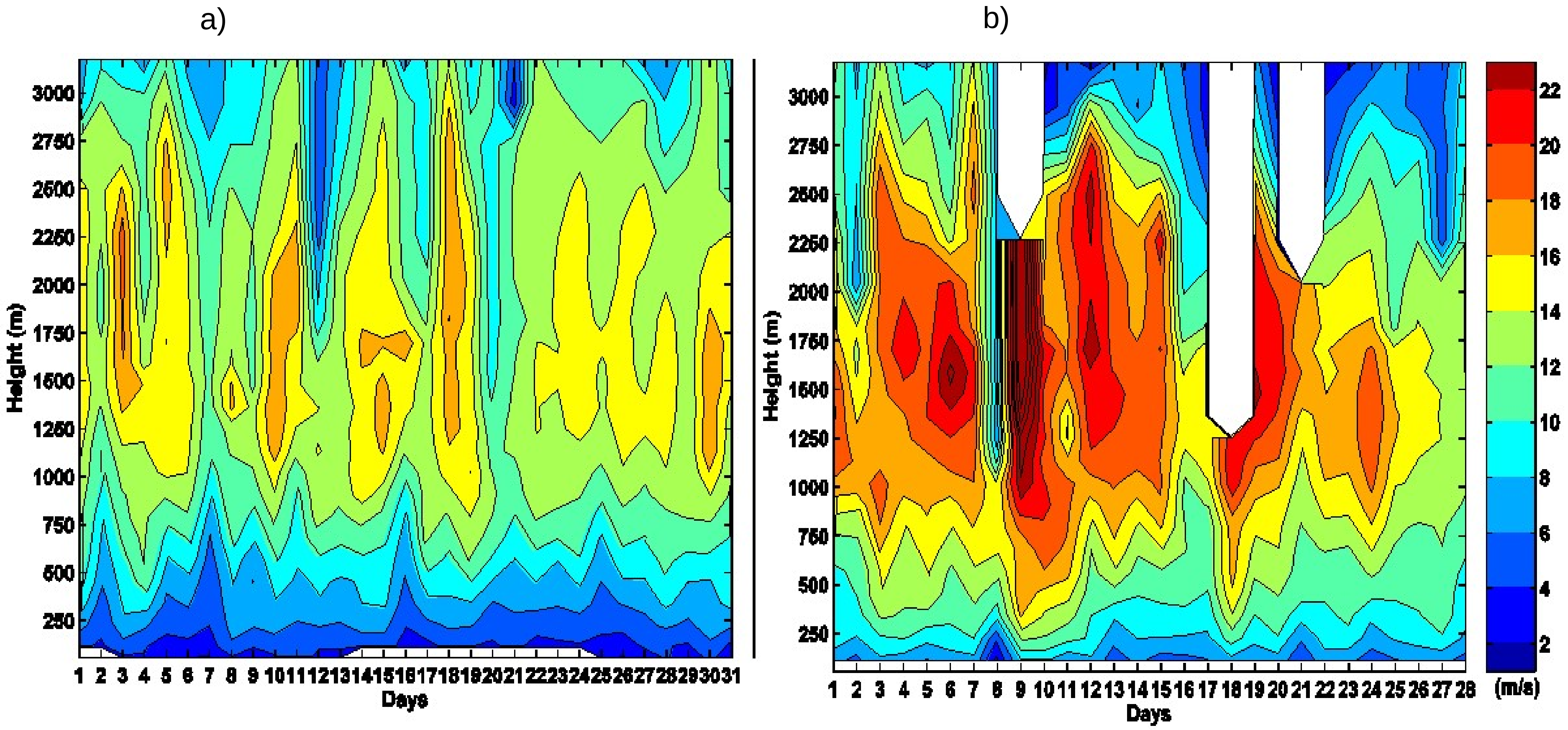
Time–longitude cross section of monthly mean wind speed (m/s) at 925 hPa averaged from 12.5 to 17.5°N from Reanalysis [Amador 2008, ANYAS].



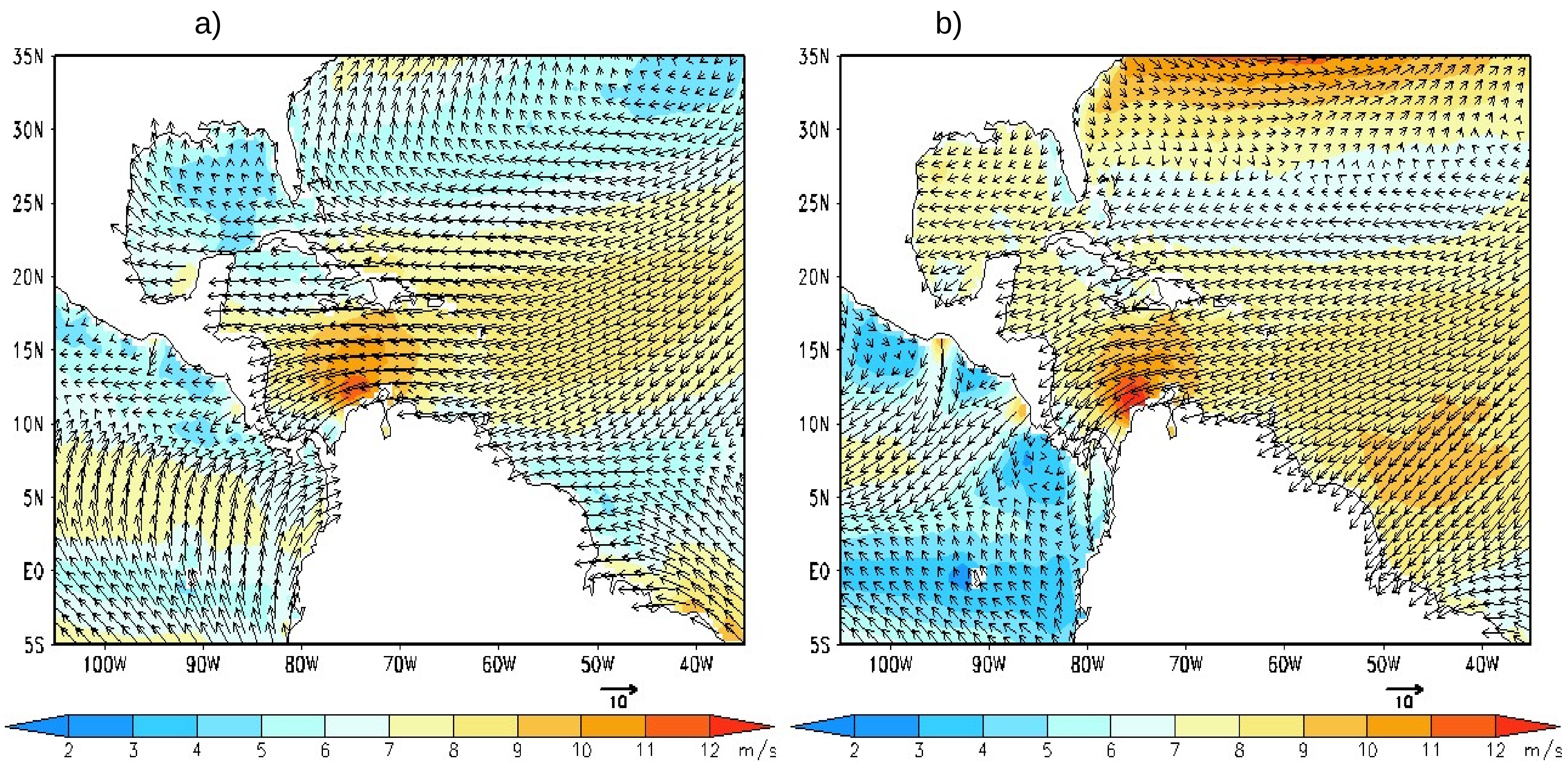
Vertical profile of monthly mean wind speed (ms-1) averaged from 12.5 to 17.5oN for (a) February and (b) as in (a) but for July from Reanalysis [Amador 2008, ANYAS].



Observed profile of the wind speed (solid line) and direction (dashed line) during the third phase of the Warm Pool Climatic Experiment (In Spanish, Experimento Climático en las Albercas de Agua Cálida, ECAC-3) over the Caribbean Sea, on 13 July 2001 at 12Z near 19º N 81º W, just to the north of the IntraAmericas jet mean core position at 15º N. (From Amador et al 2005).



Mean low-level flow (m/s) at Managua, Nicaragua for (a) July and (b) February from PACS-SONET data. Table 2 contains the station characteristics and periods used.



Mean QuikScat winds (m·s-1) for (a) July, and (b) February for the period 2000-2007.

2.4 Atmospheric rivers

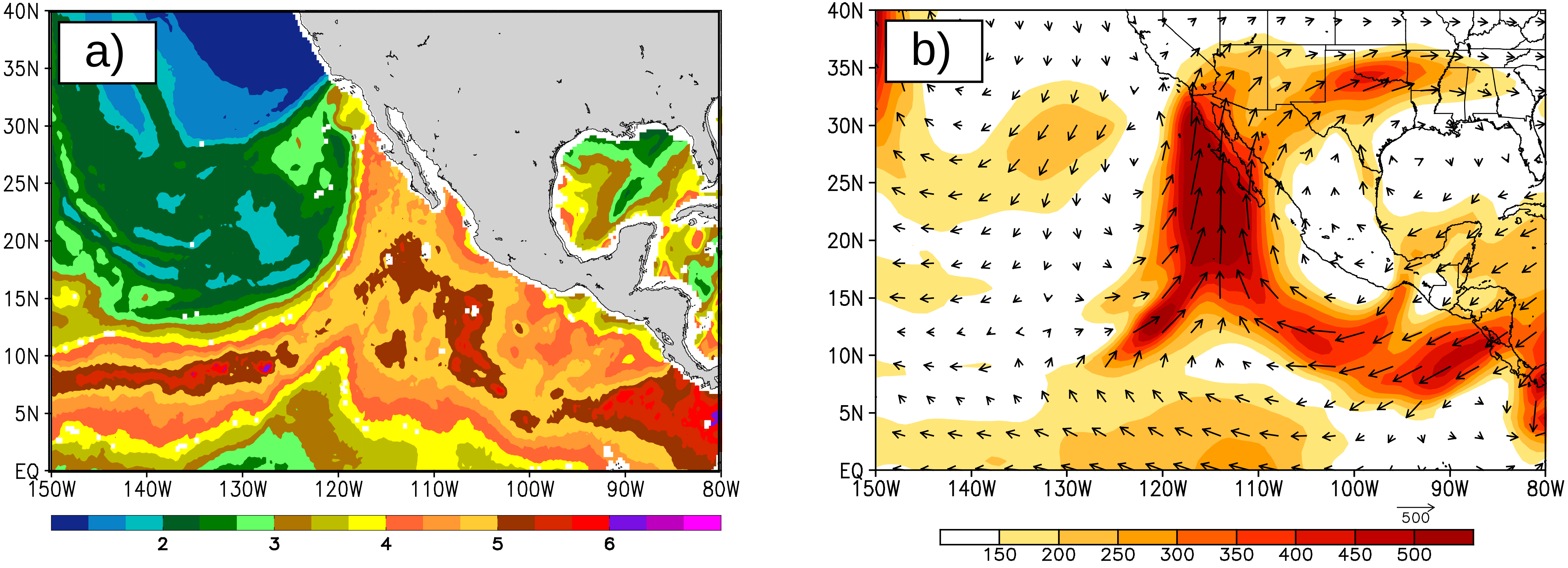


Figure S1. a) SSM/I precipitable water (cm) and b) ERA-Interim vertically-integrated water vapor transport (kg m^{-1} s^{-1}; color shadings with vectors superimposed) fields associated with an AR rooted in the eastern tropical Pacific that impinged the Baja Peninsula in Mexico and portions of the Southwestern United States during 30 November 2007 (Rivera 2016).

2.5 Tropical cyclones (TC)

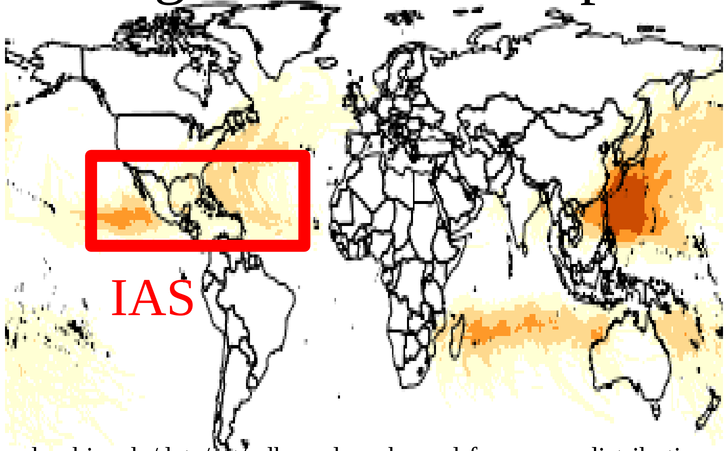
The presence of :

1- The Western Hemisphere Warm Pools in the IAS

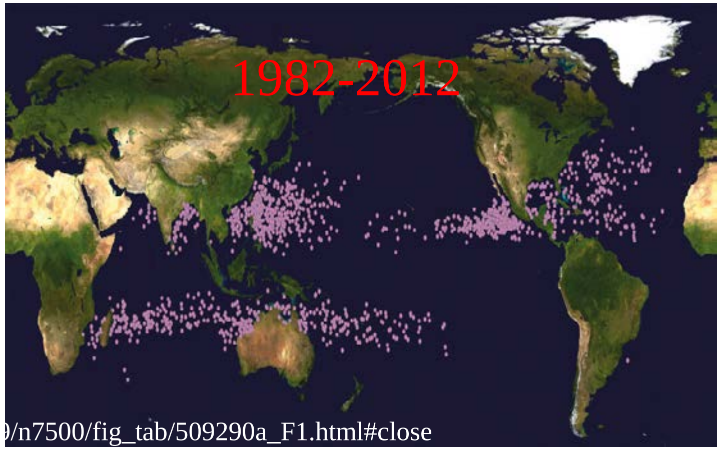
2- The annual and inter-annual variability of the CLLJ (Amador, 2008) and,

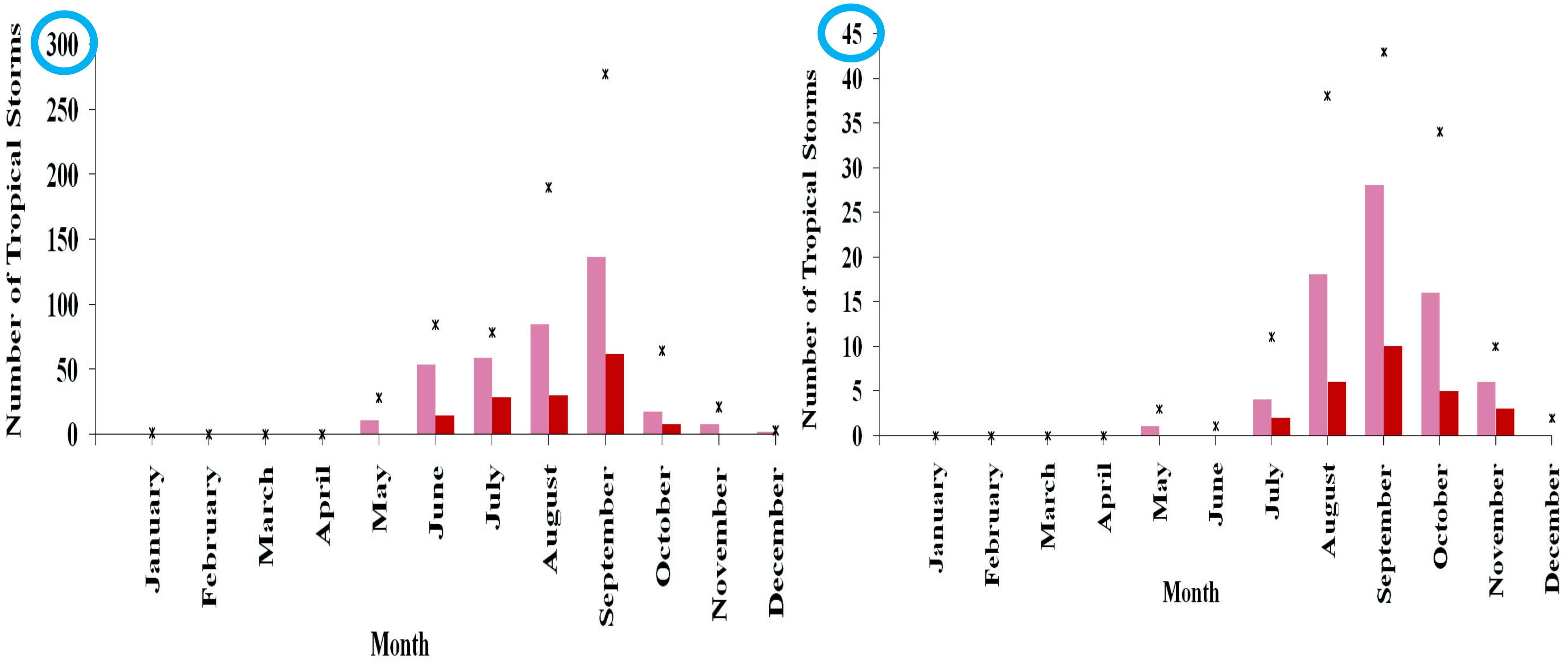
3- The regional moisture transport by this circulation (Durán-Quesada et al., 2010), provide favorable conditions for tropical cyclone (TC) development. Easterly waves, tropical waves and other tropical disturbances associated with strong convective activity are often the precursors of TCs. These factors, among others, make the IAS, one of the most active regions in the world, as far as the generation of tropical cyclones is concerned.

1980-2000

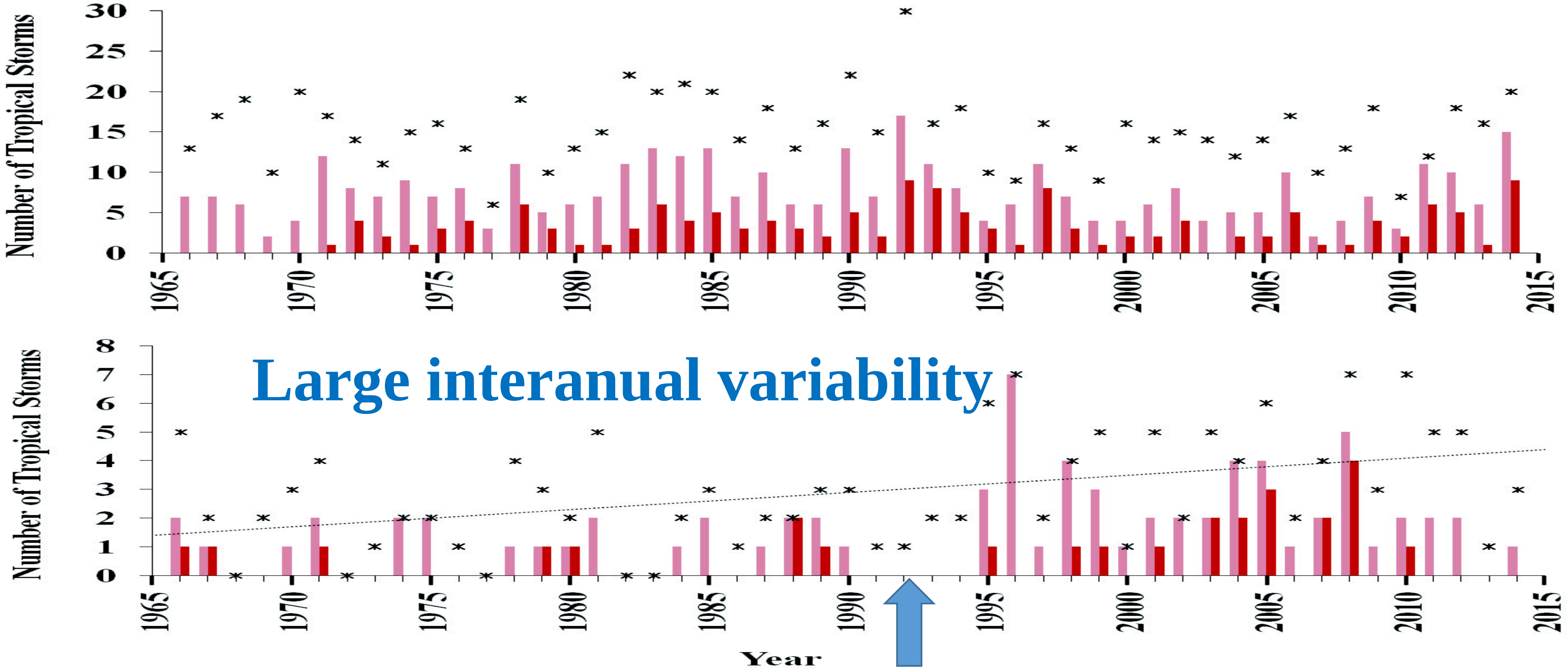


http://sedac.ciesin.columbia.edu/data/set/ndh-cyclone-hazard-frequency-distribution





Mean monthly frequency of total named tropical storms (asterisks), hurricanes (light red) and major hurricanes (hurricane intensity reached or surpassed category 3 in red) over the eastern tropical Pacific (left) and over the Caribbean Sea (right) from 1966 to 2014.



Annual frequency of total named tropical storms (asterisks), hurricanes (**pink**), and major hurricanes (hurricane intensity reached or surpassed status 3, **red**) over the Eastern Tropical Pacific (top) and over the Caribbean Sea (bottom) from 1966 to 2014. The dotted line in the bottom panel is the linear trend of TS. See Table 1 in Amador et al. (2016a, b) for details on data and data sources.

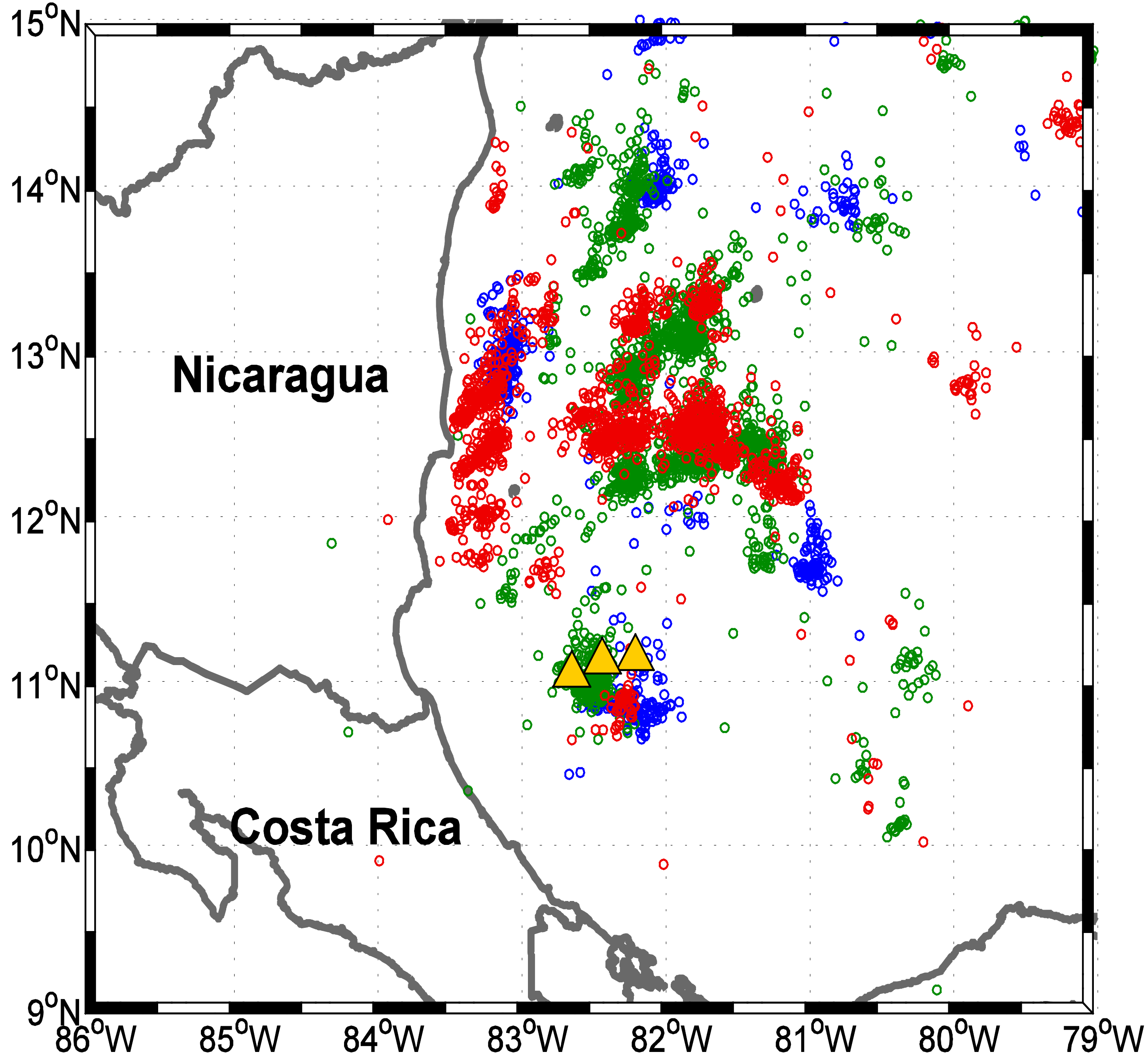
A good example of variability of phenomena in the IAS region is Major Hurricane Otto in November 2016.

The late-season hurricane set several historical records.

When Otto became a hurricane at 1800 UTC 23 November, it surpassed by one day Hurricane Martha of 1969 as the latest hurricane formation in a calendar year in the Caribbean Sea. Otto became the strongest hurricane so late in the year, the latest hurricane on record to be located in the Caribbean Sea, and Otto’s landfall on 24 November is the latest hurricane landfall in the Atlantic basin within a calendar year.

Otto’s landfall is also the southernmost hurricane landfall in Central America, surpassing Hurricane Irene (1971), which also made landfall in southern Nicaragua but about 25- 30 n mi north of where Otto crossed the coast.

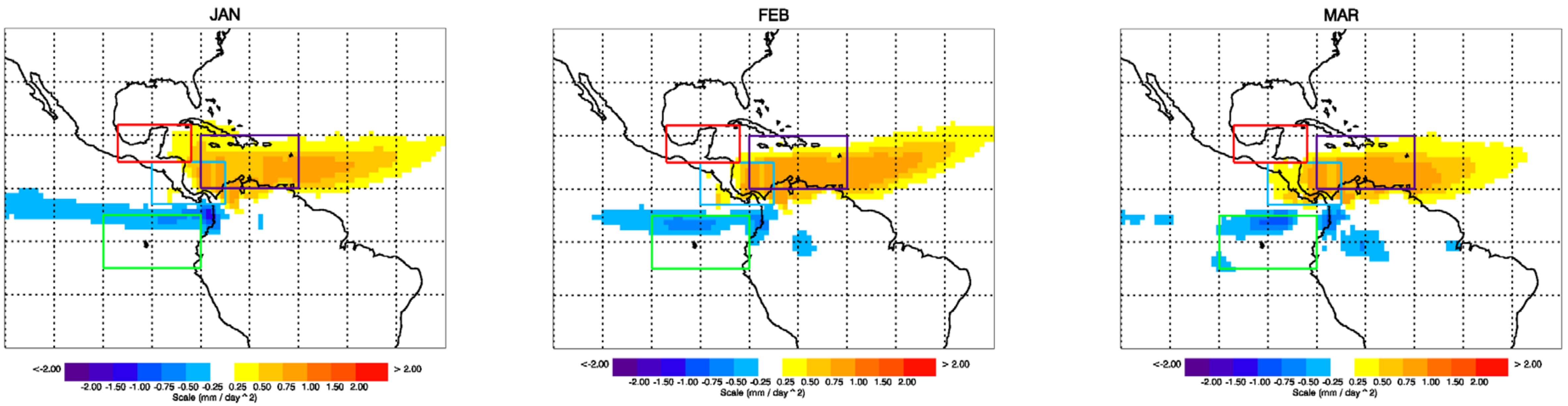
Otto is also the only known hurricane to move over Costa Rica (see listed reference, Brown 2017).



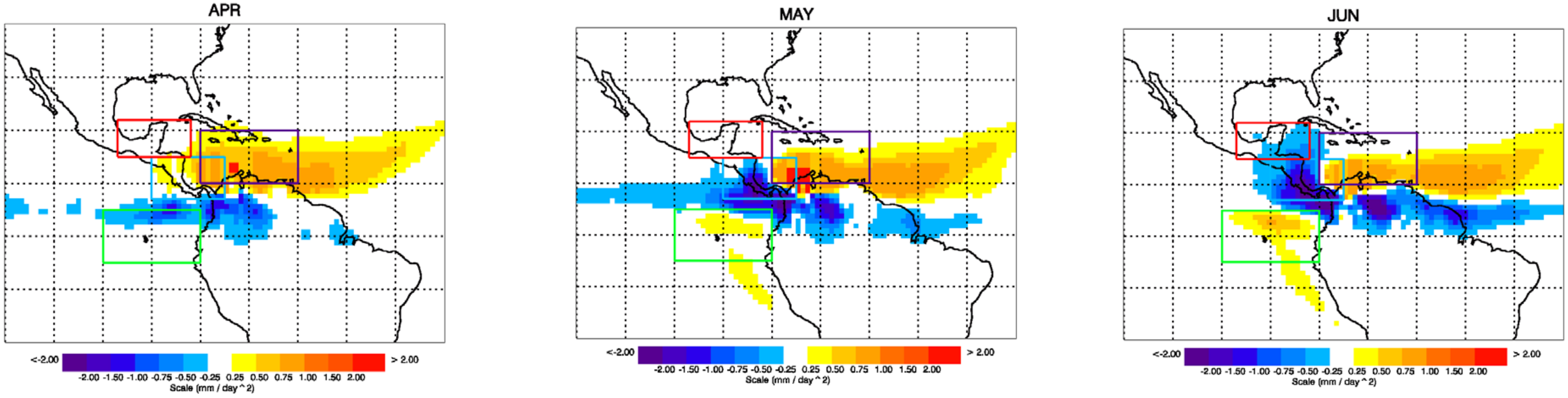
Lightning activity associated with **Hurricane Otto** showing the northern rain-bands moving westward from 04.00 to 04.59 UTC (blue open circles), from 06.00 to 06.59 UTC (green open circles) and from 08.00 to 08.59 UTC (red open circles). Yellow triangles represent the approximate westward track of Otto at 04.00, 06.00, and 08.00 UTC estimated from the National Hurricane Center best track information. **Data is from the WWLLN global data base downloaded at the Center for Geophysical Research WWLLN station, University of Costa Rica (http://webflash.ess.washington.edu/).**

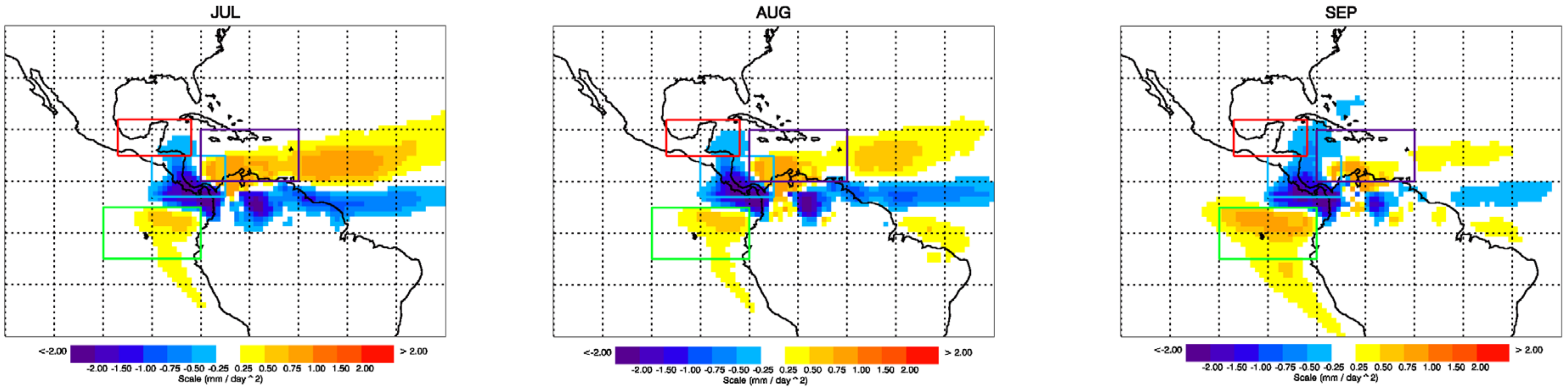
3. Background and issues II: regional to global influences on IAS climate

Regional moisture sources and sinks



Duran-Quesada et al. 2010, JGR





Duran-Quesada et al. 2010, JGR

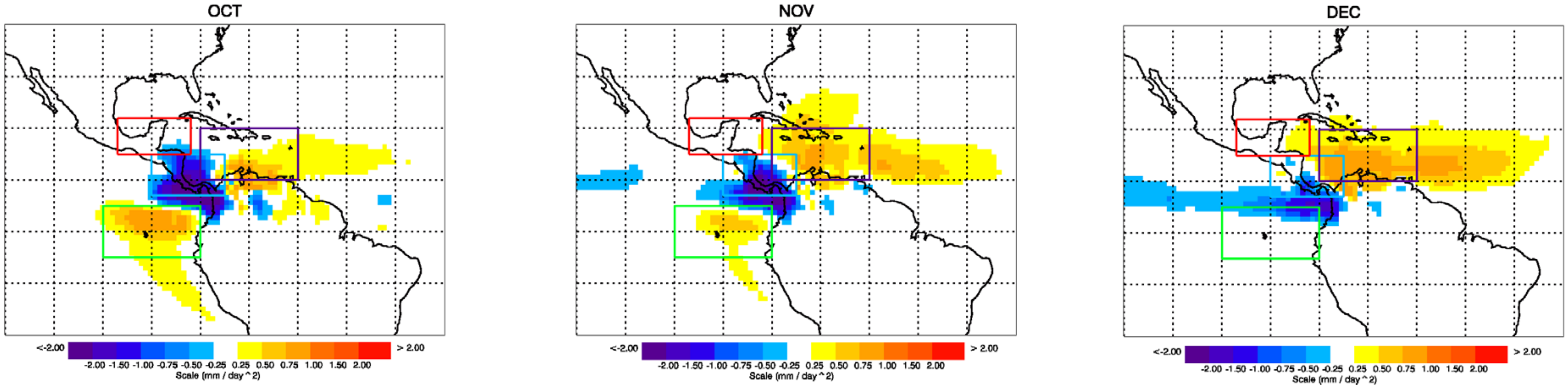
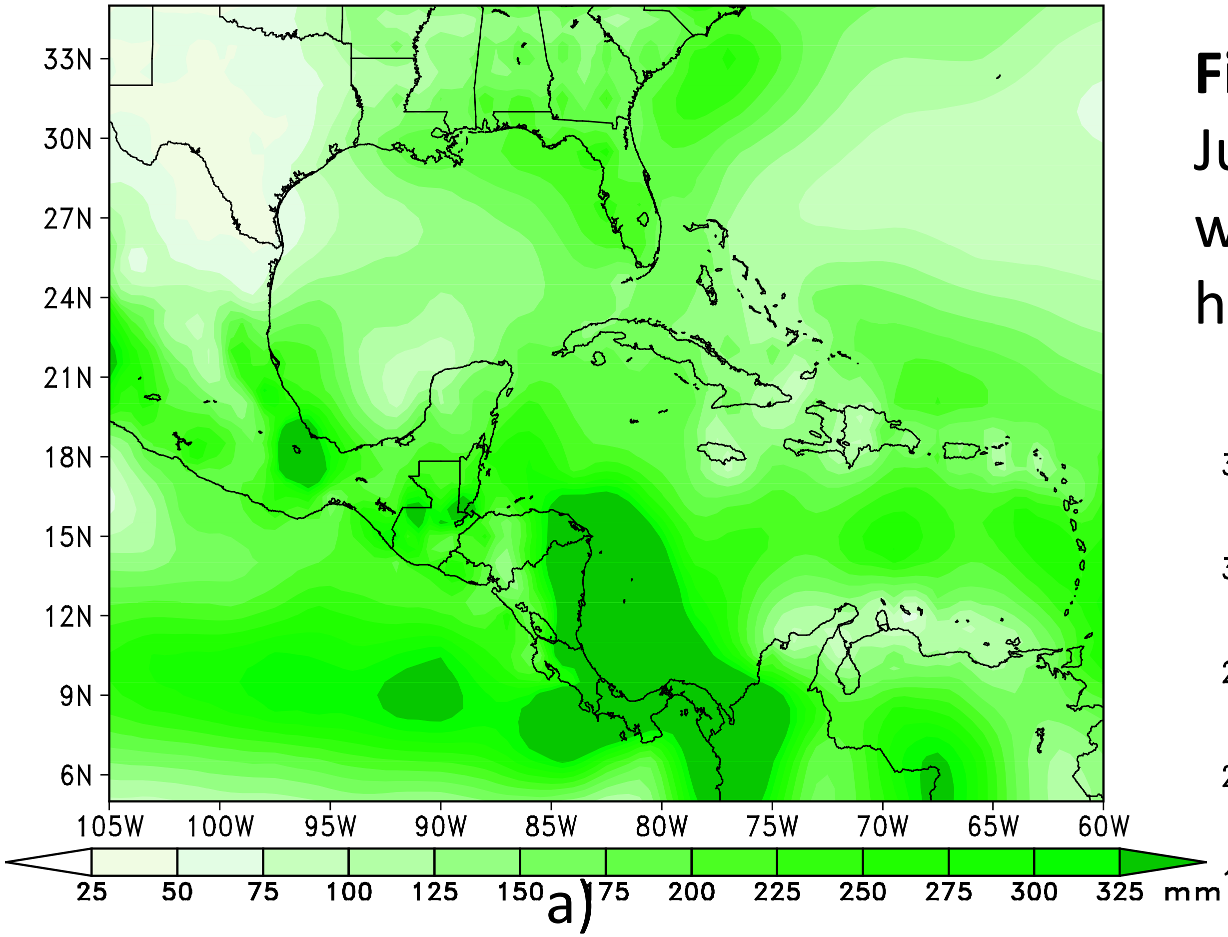


Figure 9. (a) Precipitation (mm) distribution for July (CRN073 data, [45, 56]), and (b) pattern of wind divergence-convergence (10-6/ s) at 925 hPa for July from Reanalysis [68]. Amador (2008).



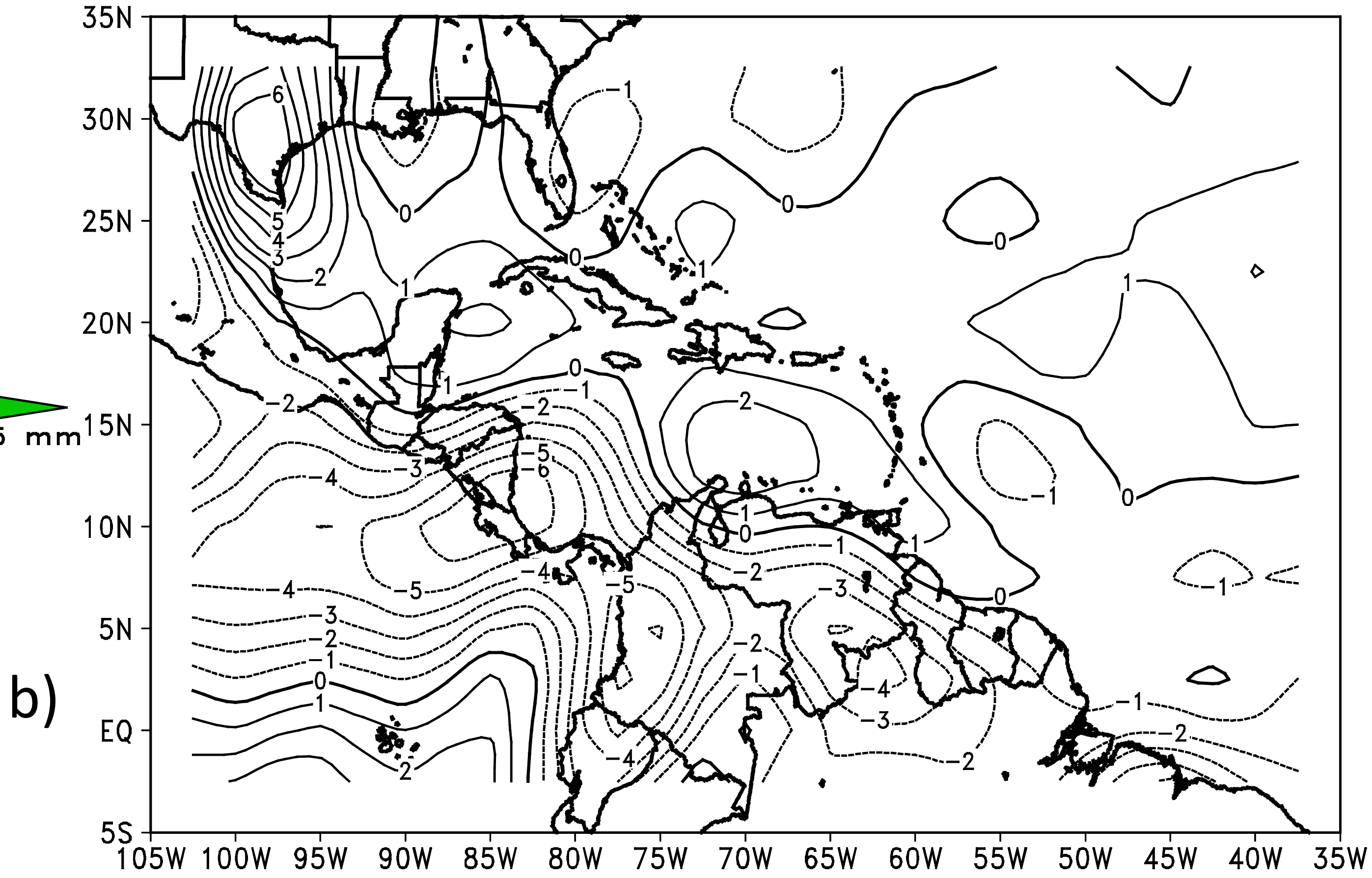
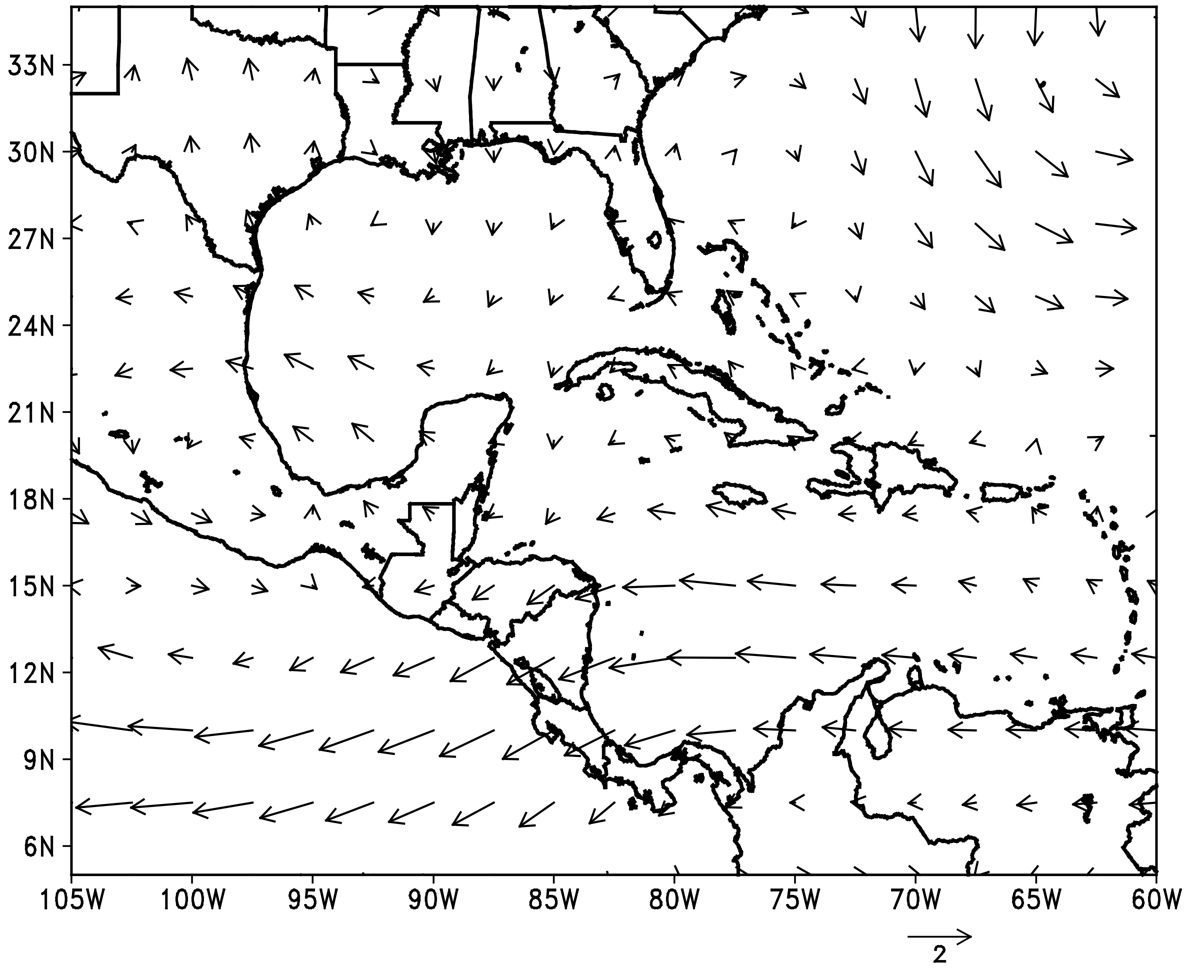


Figure 11. July LTM (1958-1999) during a warm ENSO event (El Niño) for (a) wind anomalies (ms-1) at 925 hPa, and (b) precipitation anomalies (mm). Amador (2008).



a)

b)

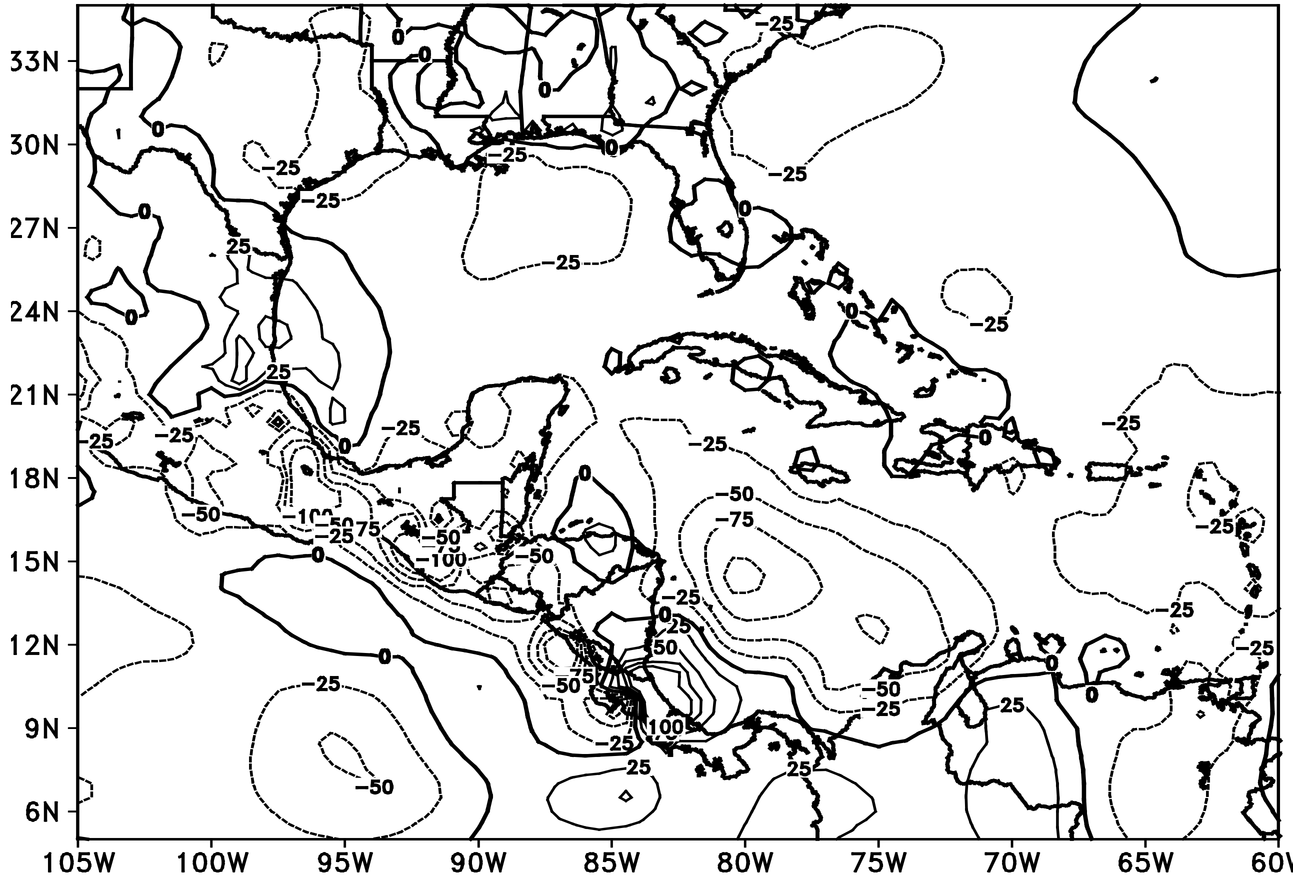
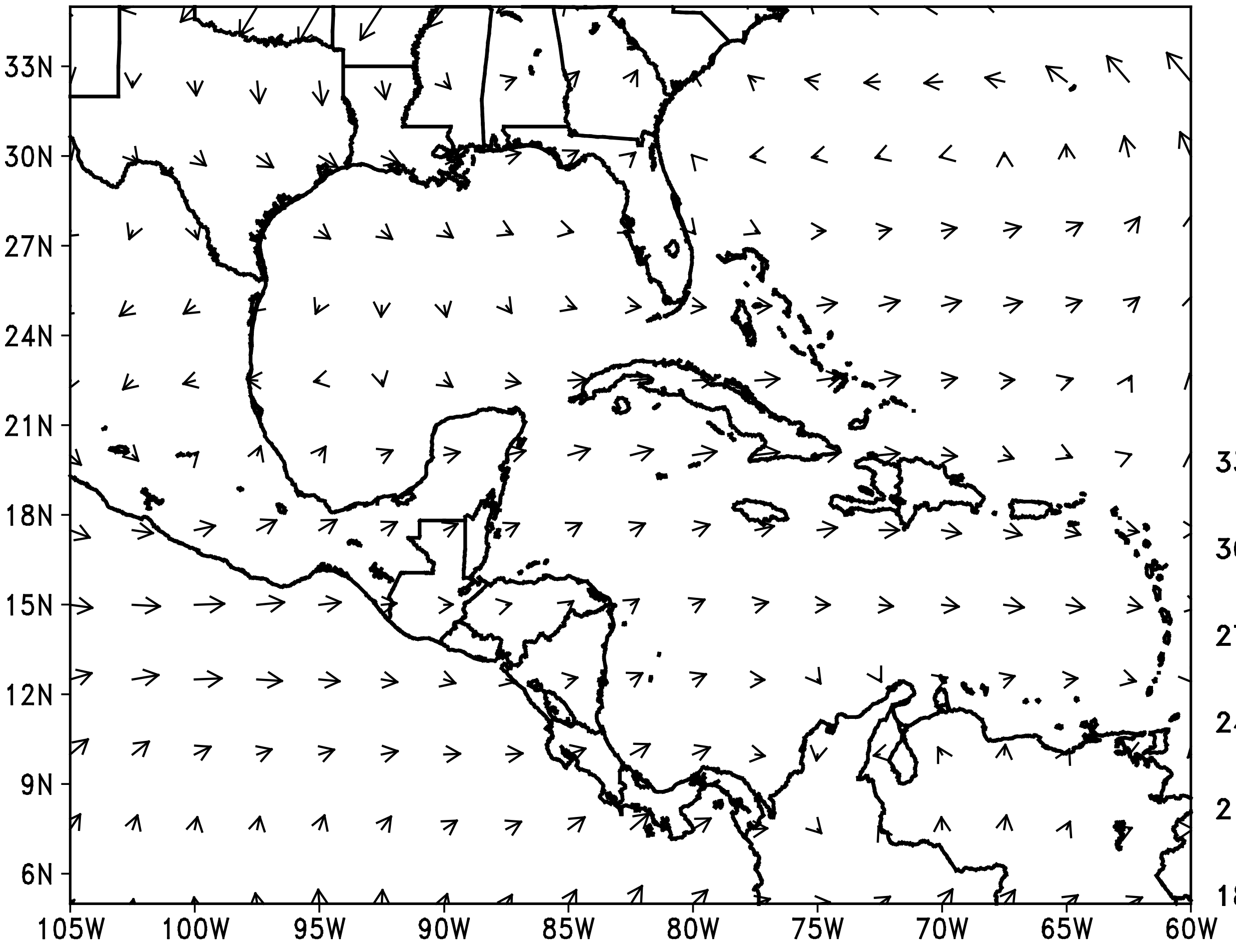
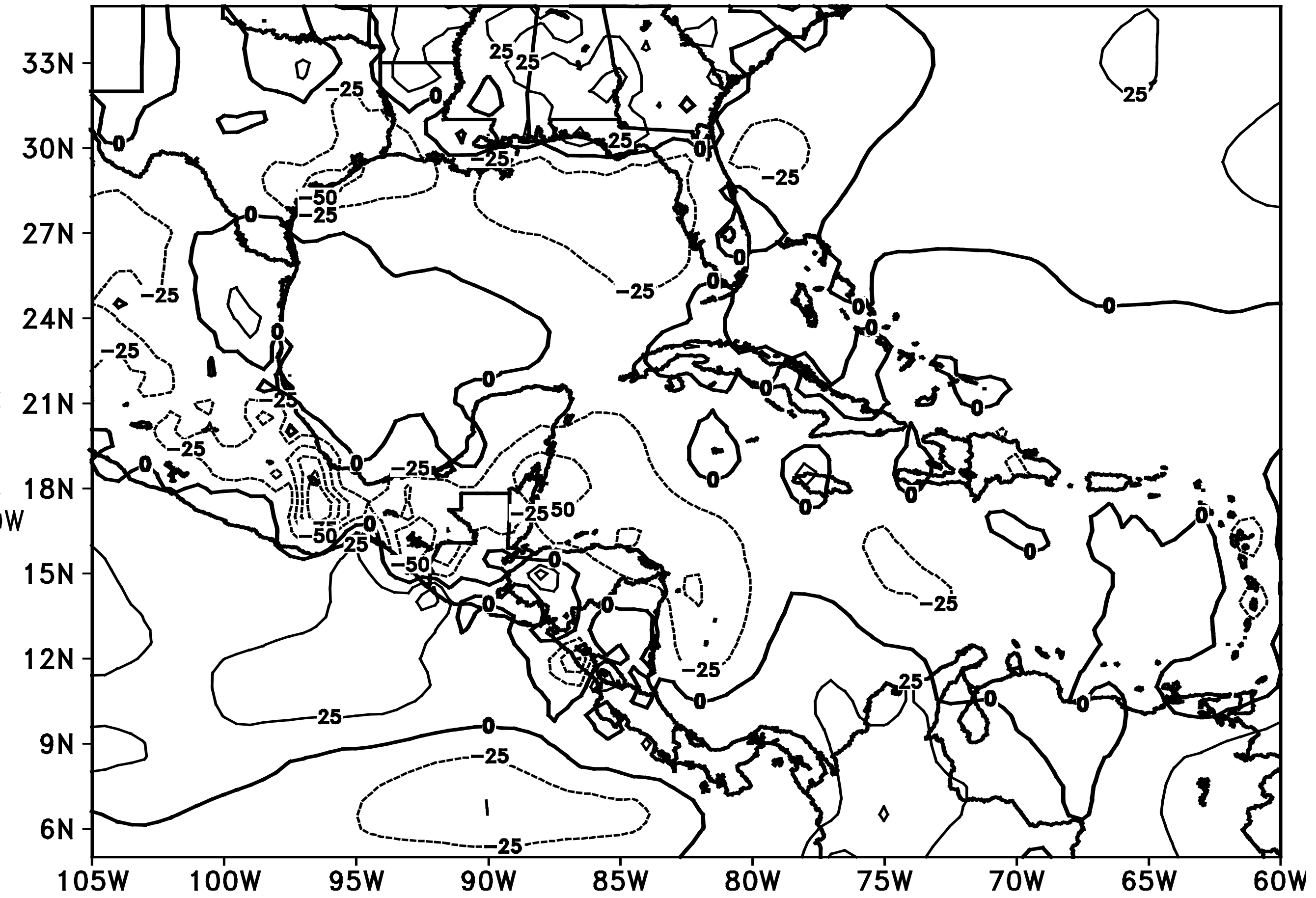


Figure 12. As in Figure 11 but, for a cold ENSO event (La Niña). Amador (2008).



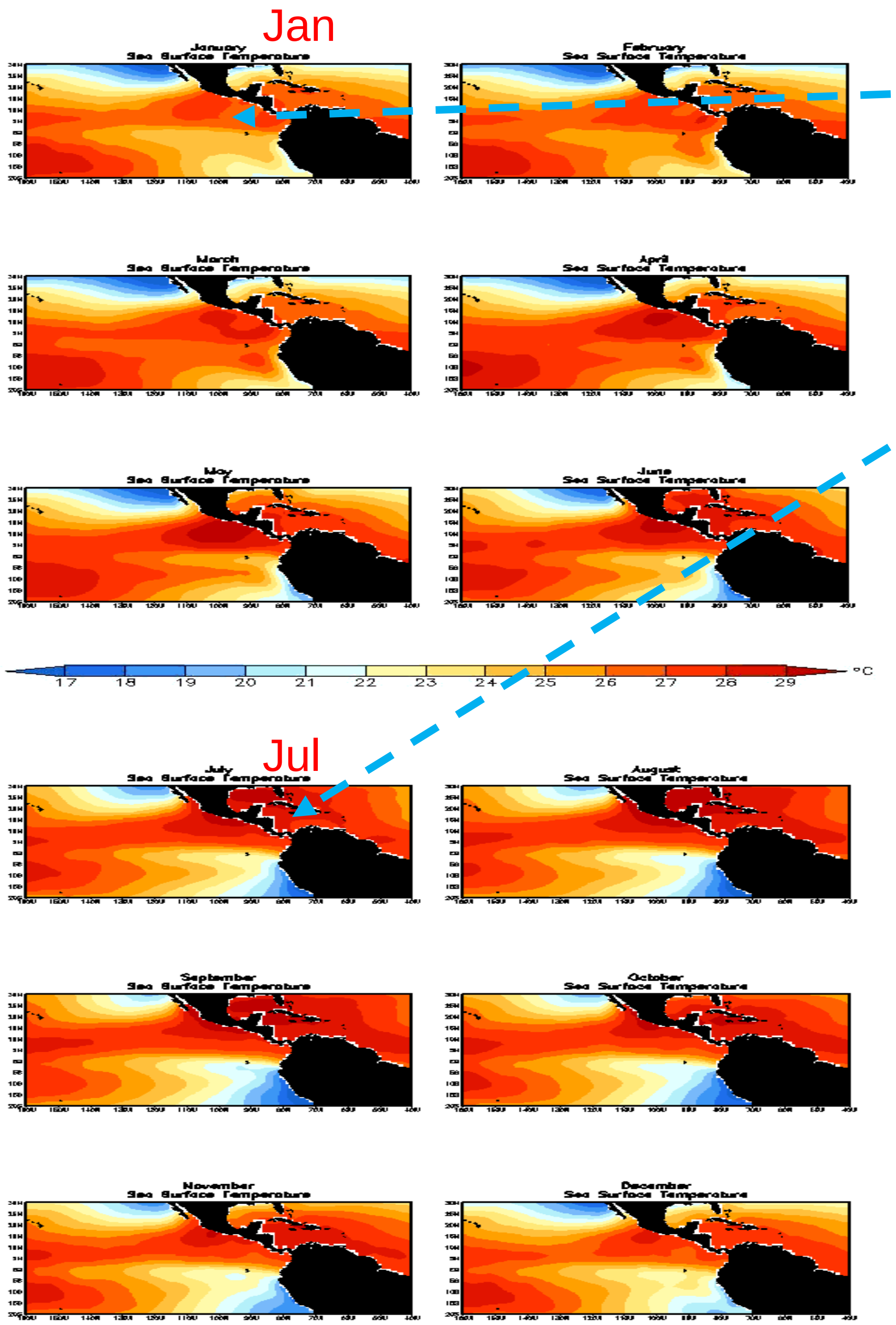
a)

b)



NASH

4. Final remarks (*Some key issues*)



Western Hemisphere Warm Pool (WHWP)

***(a)** What are the mechanisms by which the WHWP influences precipitation in the IAS region?*

***(b)** What are the mechanisms for the variability of the WHWP?*

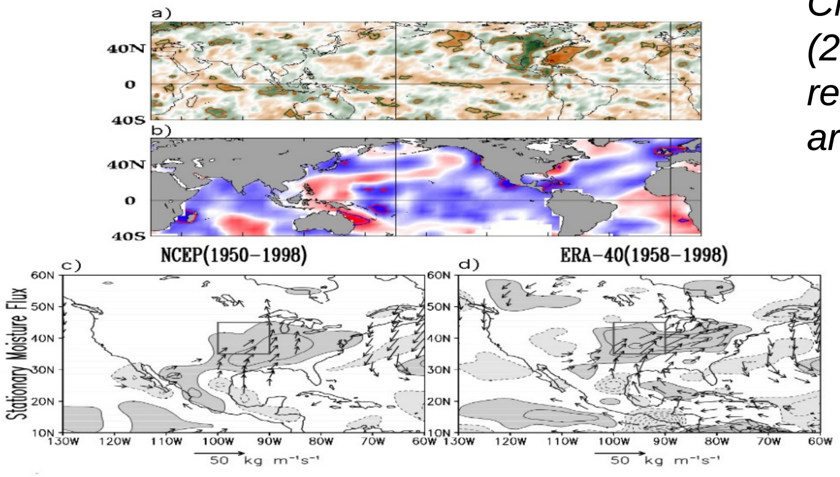
***(c)** How well can the WHWP be reproduced by ocean models?*

***(d)** How does the warm pool influence hurricanes?*

Seasonal distributions of SST for the tropical WHWP: (a) Mar, (b) Apr, (c) May, (d) Jun, (e) Jul, (f) Aug, (g) Sep, and (h) Oct. The shading and dark contour represent water warmer than 28.5°C (Amador et al. 2006).

Water vapor transport

Upper panels: Correlation of northward moisture flux across the Gulf of Mexico with CMAP precipitation (a) and sea surface temperature (b), from Mestas-Nuñez et al. (2007). Lower panels: Regression of NCEP reanalysis precipitation (c) and ERA reanalysis precipitation (d) on summer precipitation over the Great Plains (box area), from Ruiz-Barradas and Nigam (2005).



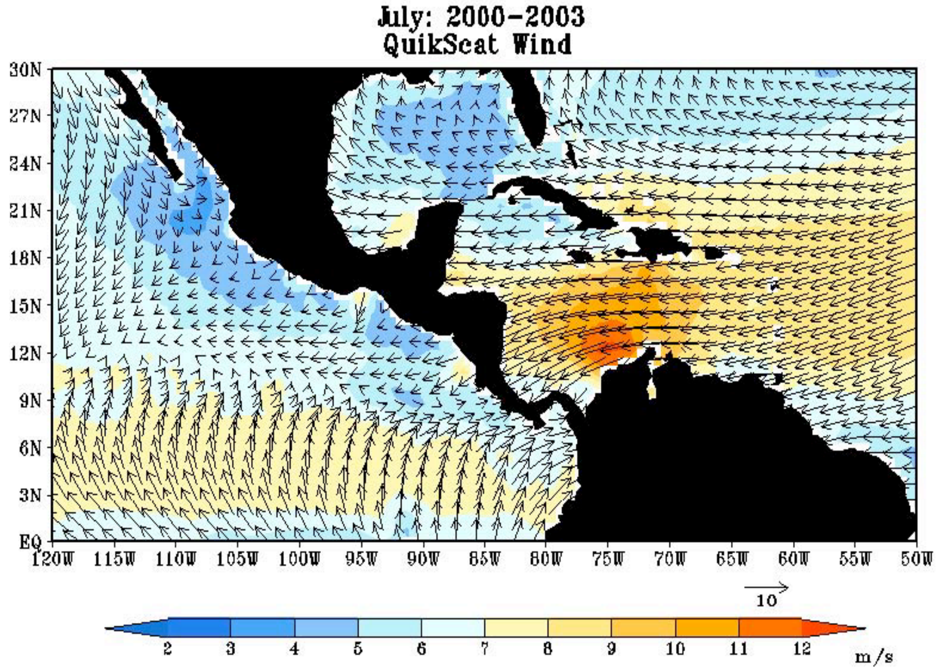
(a) What is the structure and dynamics of the low-level jets in the IAS?

(b) What are the mechanisms for the interannual variability of water vapor transports?

(c) How well do global and regional models reproduce the low-level jets? –

(d) What are the major uncertainties and problems with reanalyses?

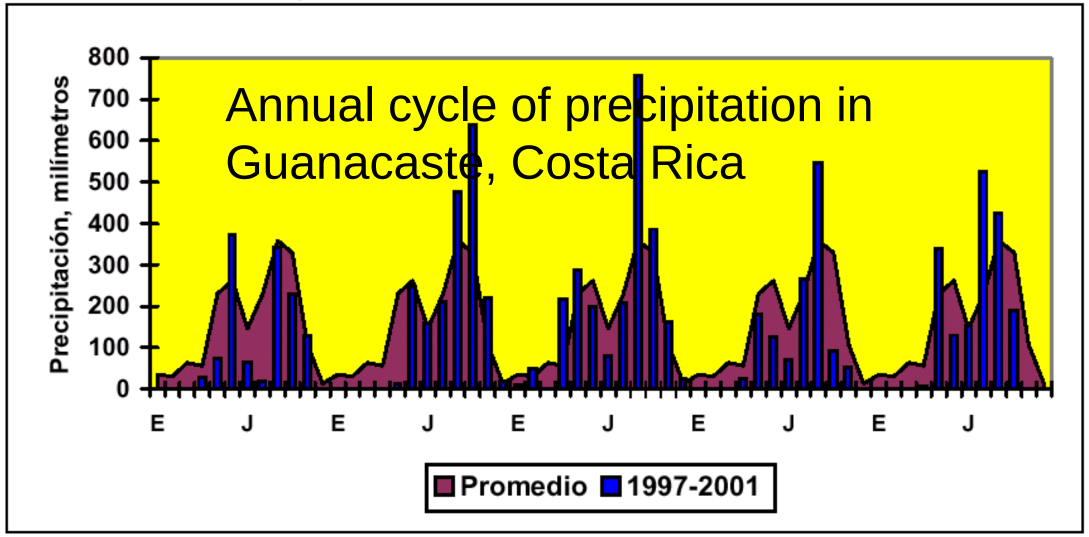
(e) What are the linkages between the IAS and the Pacific? IALLJ and Choco Jet?



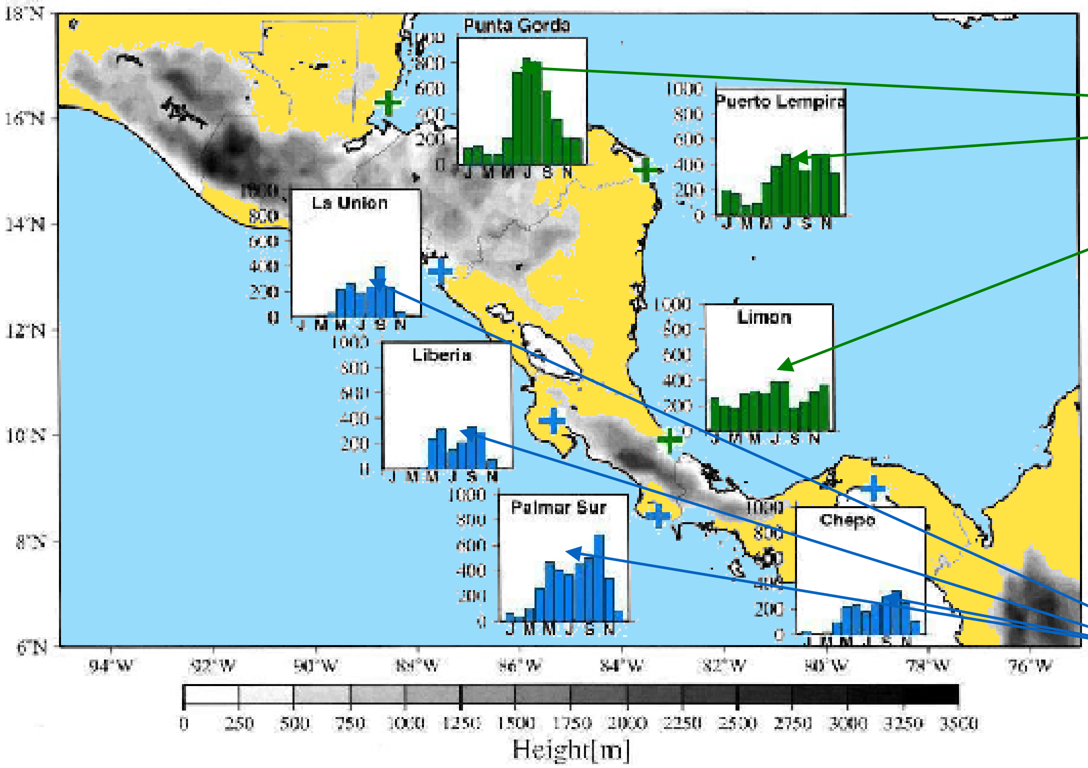
July mean QuikScat winds (m s-1) for the period 2000-2003 (from Amador et al. 2006, Amador 2008)

Multiscale interaction :The Mid Summer drought (MSD)

Interannual variability of the midsummer drought in Central America and the connection with sea surface temperatures, 2016. **T. Maldonado, A. Rutgersson, E. Alfaro, J. A. Amador, and B. Claremar.** **Adv. in Geophysics.**



MSD : WHWP, PDO, ???



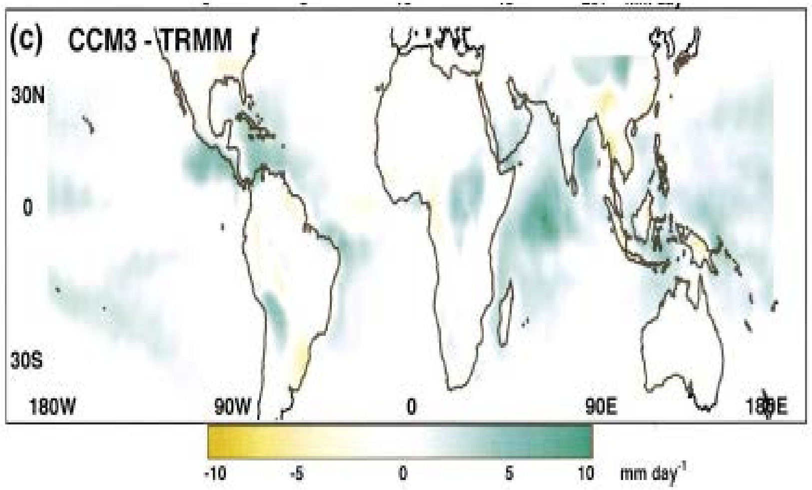
Maximum in precipitation in July

Minimum precipitation in July (MSD)

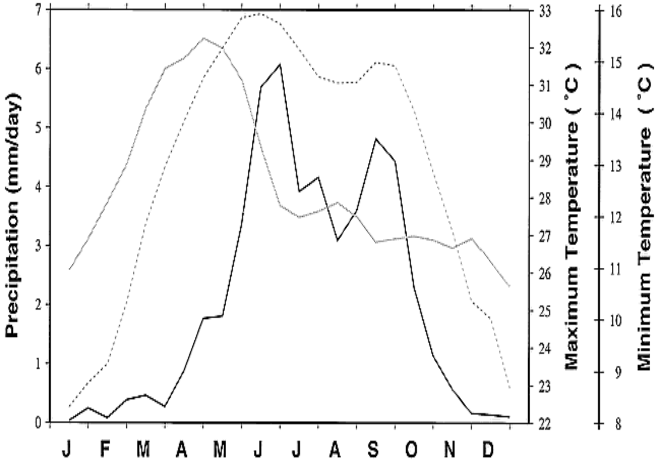
Land-air-sea interaction

(a) *How does land affect surface and low-level pressure distributions?*

(b) *Why do many, if not most, GCMs misrepresent the spatial distribution of precipitation in the IAS region?*



Mid-summer drought (MSD)



Biweekly climatology of precipitation (black solid line), maximum temperature (gray solid line), and minimum temperature (dotted line) for Oaxaca, Mexico (17.8˚N, 97.8˚W). (From Magana et al. 1999)

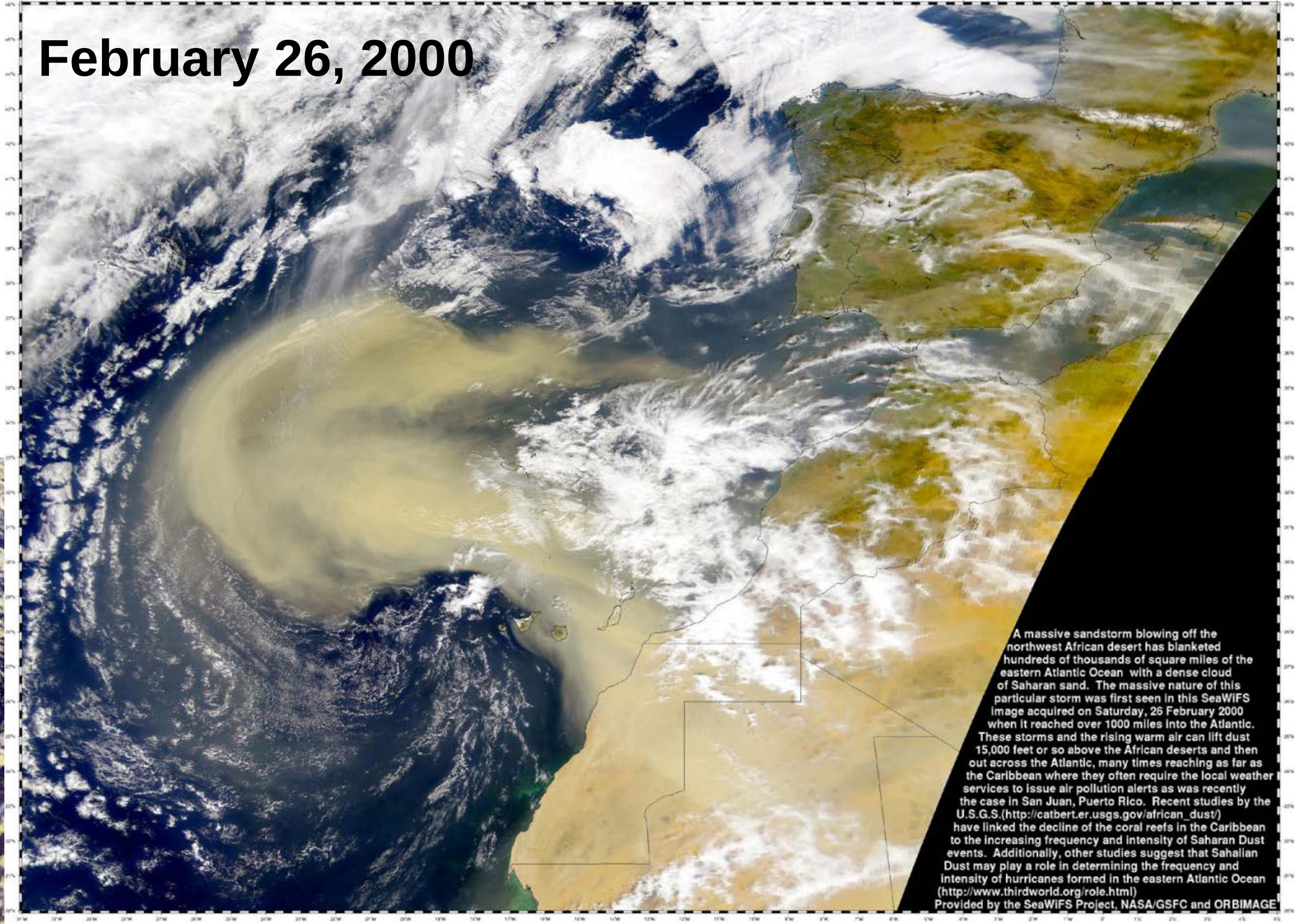
(a) *What are the relative importance of ITCZ, SST, IALLJ, land effects, and related local atmospheric circulation in the MSD and its inter-annual variability?*

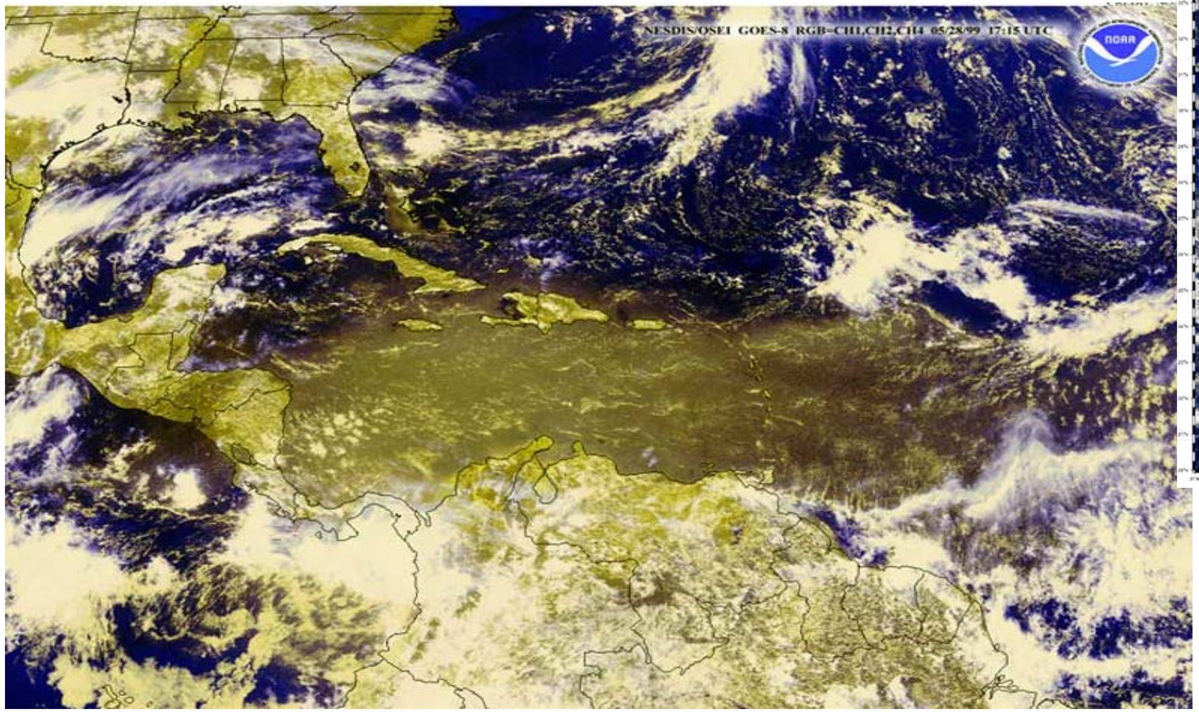
(b) *What are the typical errors in global and regional models in their simulation and prediction of the MSD?*

Key issue

Effect of African aerosols

Modulation of rainfall?





Satellite image (05/28/1999) showing dust covering the southern Caribbean, (From NOAA, Prospero and Stone, 1997)

What is the relationship between aerosols and seasonal climate variation in the IAS?

Elements to consider….

- Quantification of model errors and identify their sources, quantification of errors and uncertainties in (global and) regional data assimilation products
- Empirical analyses of existing data for statistical relationships in observations
- Model sensitivity and predictability studies (model improvement)
- Process studies
- Data mining and assimilation (a regional issue!!!)
- Coordinate climate assessment/prediction efforts (regional collaboration)
- Education component (virtual courses?)


Muchas Gracias !!

Hypotheses:

- Predictability of climate variability in the IAS region are affected by both remote (e.g., ENSO, NAO, TAV) and local (warm pools, land, EW, LLJ) factors;
- High impact weather (e.g., TC, flood, severe storms) play critical roles in local manifestations of climate variability and change in the IAS region;
- Easterly waves-mean flow interaction is crucial to understand climate in the IAS and cyclone formation;
- Air-land-sea interaction and tropical-extratropical interaction are the thrusts of climate variability in the IAS region.
- Multiscale interaction is crucial to rainfall variability in the IAS region.