Interaction between a shear line and the Inter Tropical Convergence Zone in the Northwestern Coast of Venezuela.

25 November 2010 Heavy Rainfall Event

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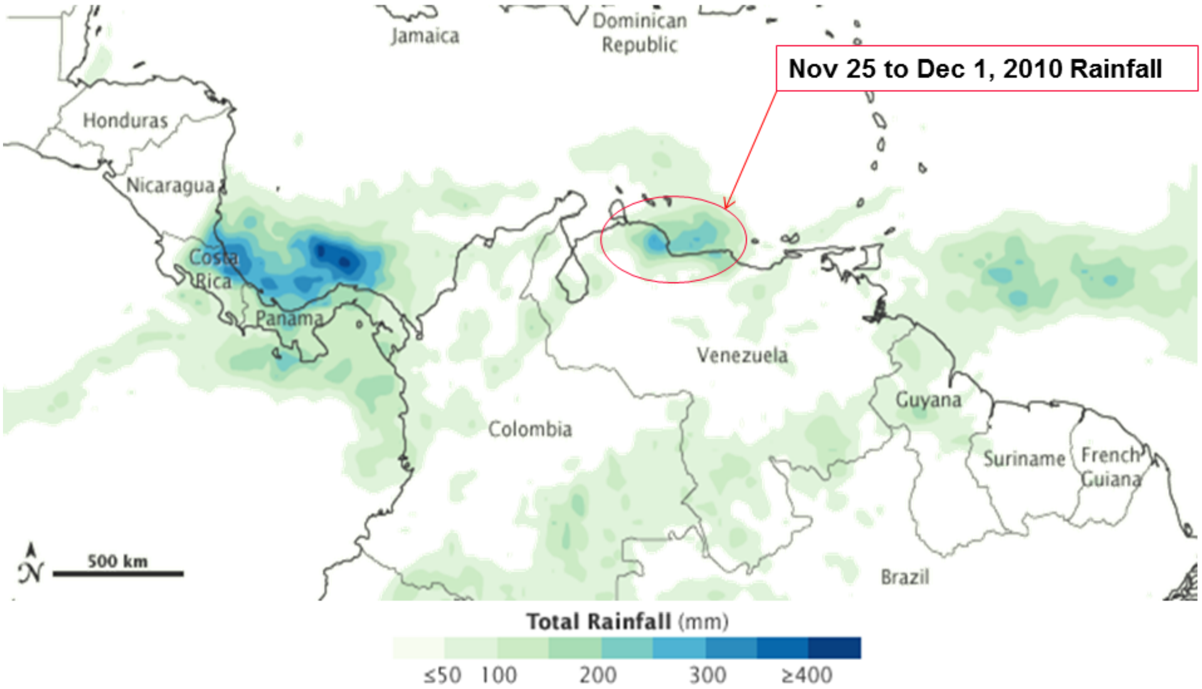
This work describes the interaction between a shear line and the Inter Tropical Convergence Zone that produced heavy rains in a usually dry region of the northern coast of Venezuela. The event occurred during 25-30 November 2010 producing rainfall totals near 80% of the annual total in only six days. This generated severe flooding in the Coro, Falcon region in Venezuela.

The short case study was conducted by Julio Cabanerit from INAMEH (Instituto Nacional de Meteorologia e Hidrología) as part of the WPC Tropical Desk Training carried out during the April-July 2016 period.

TRMM* Multisatellite Precipitation Analysis produced at NASA's Goddard Space Flight Center.

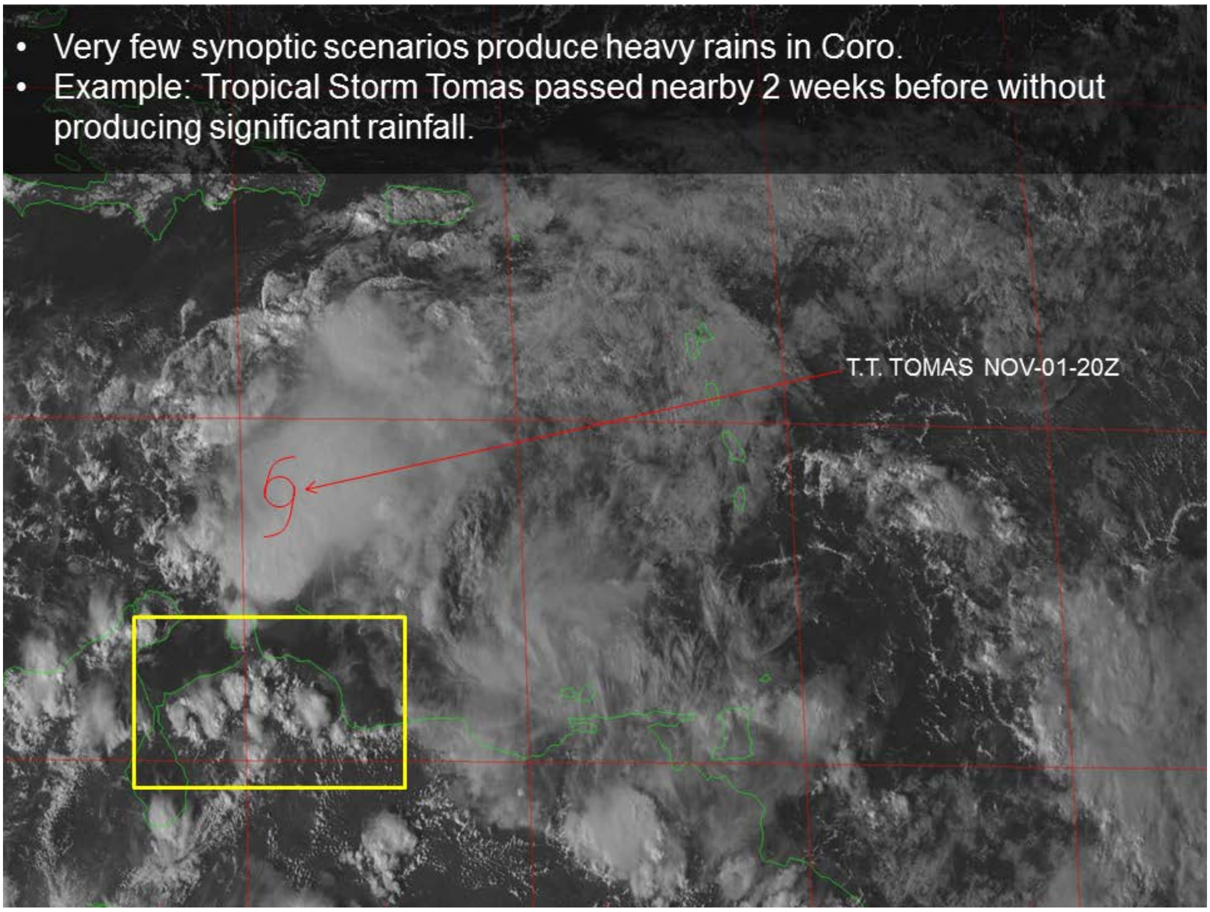


*TRMM=Tropical Rainfall Measuring Mission

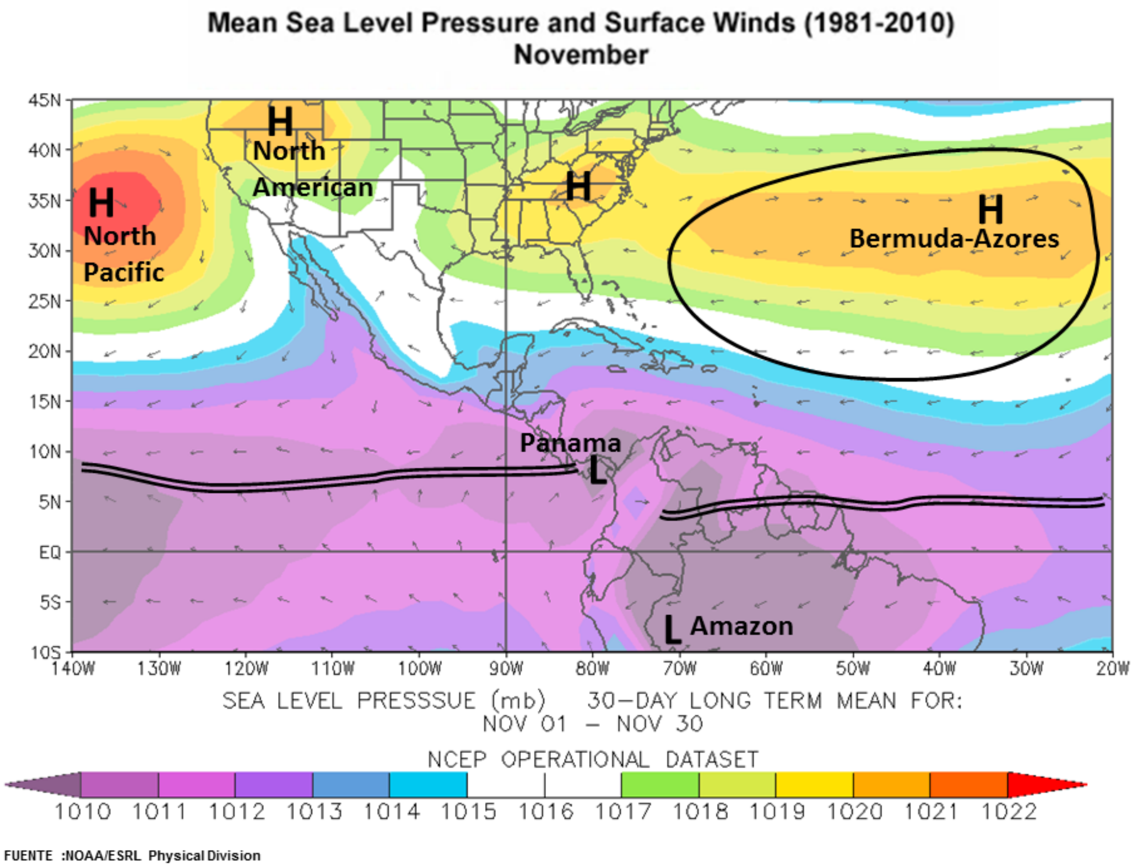
Source: NASA Earth Observatory, 2010

Heavy rainfall events in the Northern Coast of Venezuela are rare. Climatologically, this region of the Caribbean is characterized by a persistent low-level divergent wind pattern in association with the entrance of the South Caribbean Low-Level jet. This jet also provides enhanced low-level shear that often disintegrates deep convective structures rather than enhancing them. Active deep convection over the continent usually leads to subsidence along the southern Caribbean, which further limits the development of deep convection and large rainfall accumulations.

The image presented in this slide is a Multisatellite Precipitation Analysis produced at NASA's Goddard Space Flight Center using data from the TRMM (Tropical Rainfall Measuring Mission) satellite. It shows rainfall totals of 200-350mm in the northern coast of Venezuela over the 25-30 November 2010 period. Note that annual totals in this region are in the order of 400mm/yr.

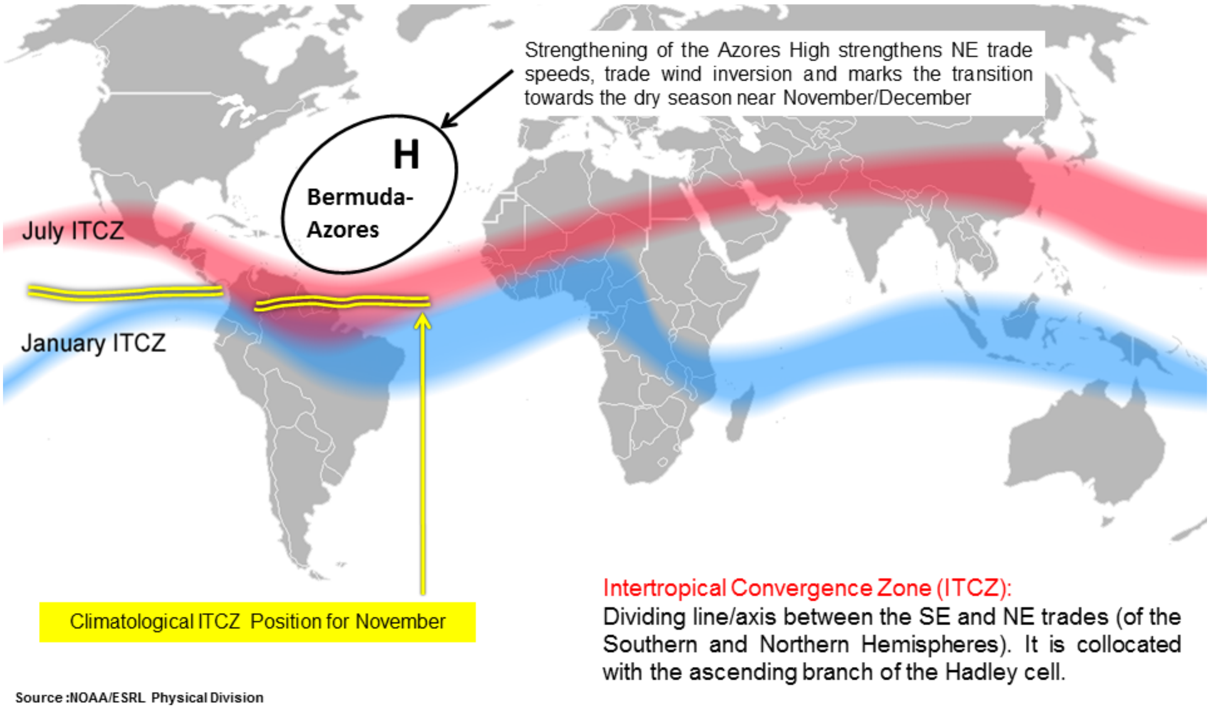


This slide shows the presence of Tropical Storm Tomas using a visible satellite image. Tomas passed just to the north of the affected area three weeks prior to the heavy rainfall event. The goal of this slide is to show that even tropical cyclones passing nearby are usually not able to produce such heavy rainfall totals in the region.



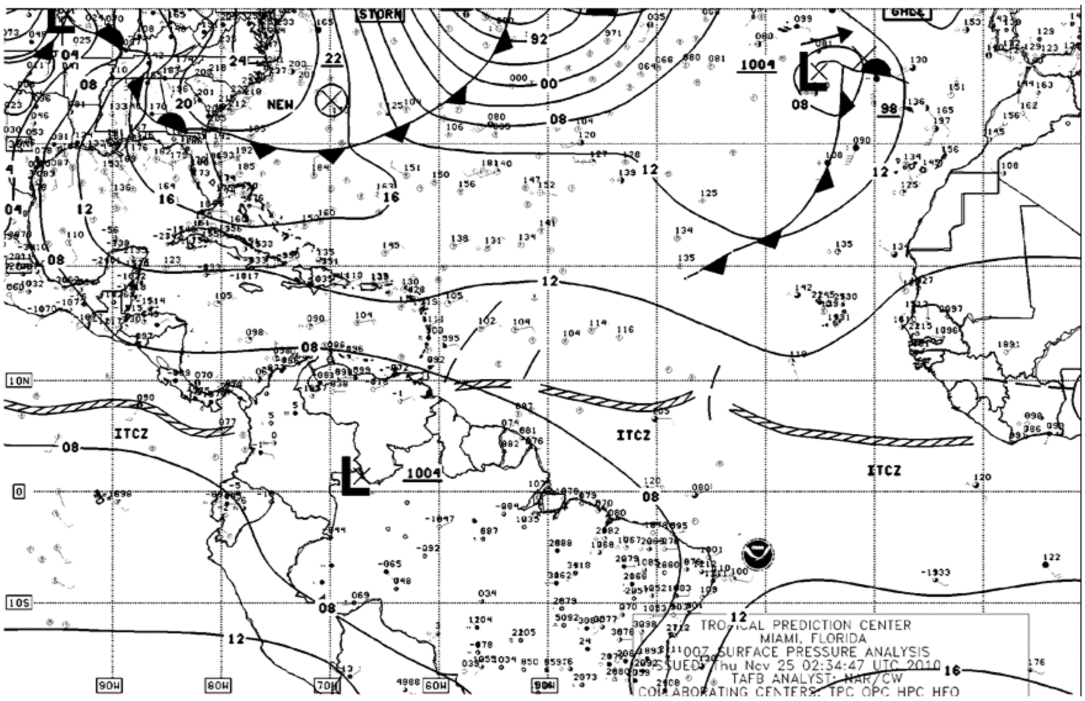
The chart above shows the climatology of Mean Sea Level Pressure and Surface Winds for November constructed using NCEP/NCAR Reanalysis data courtesy of the NOAA-ESRL Physical Division. Relevant weather systems have been outlined. The ITCZ/NET (Near equatorial Trough) is analyzed across the Guianas into Southern Venezuela and Eastern Colombia. Other system of interest is the Bermuda-Azores High. The western tier of this low-level high pressure system starts intensifying during November across the Tropical North Atlantic and starts expanding to the south. This leads to a tighter pressure gradient across the Southern Caribbean and a resulting increase in the speed of the trades. They also shift to east-northeasterlies versus easterlies during previous months. The intensification of the trades and their northeasterly component is one of the factors that aids the ITCZ/NET to migrate to the south. The intensification of the high also enhances the strength of the trade wind inversion. A stronger inversion and southward migration of the ITCZ/NET mark the wet-to-dry transition in the Caribbean Coast of Venezuela, which usually happens sometime between October and November.

- **ITCZ: Main feature associated with rainfall distribution in Venezuela.**
- **It meanders from Central America/Caribbean to Tropical South America through the year.**



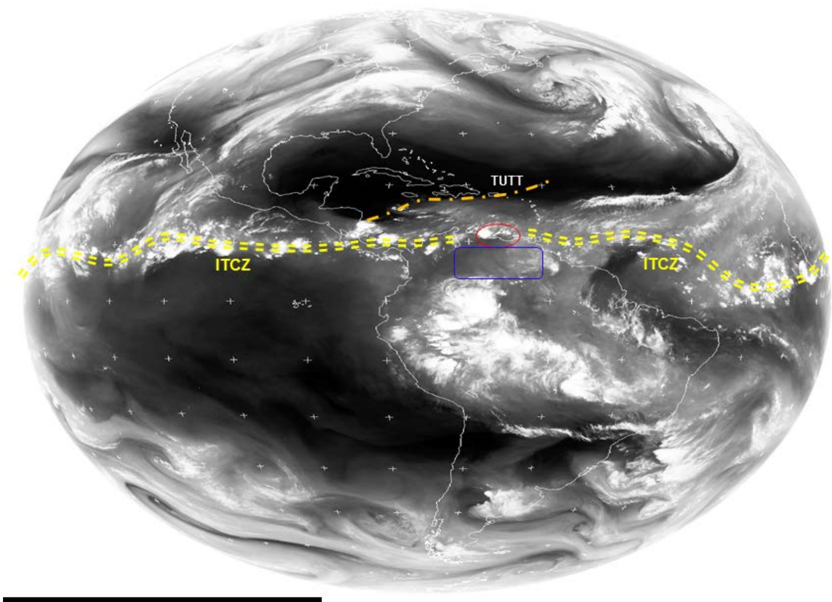
This is another slide showing the approximate locations of the Inter tropical Convergence Zone during July vs January, and the average position of the Azores-Bermuda High.

NHC-TAFB Surface Analysis from 00Z 25 Nov 2010



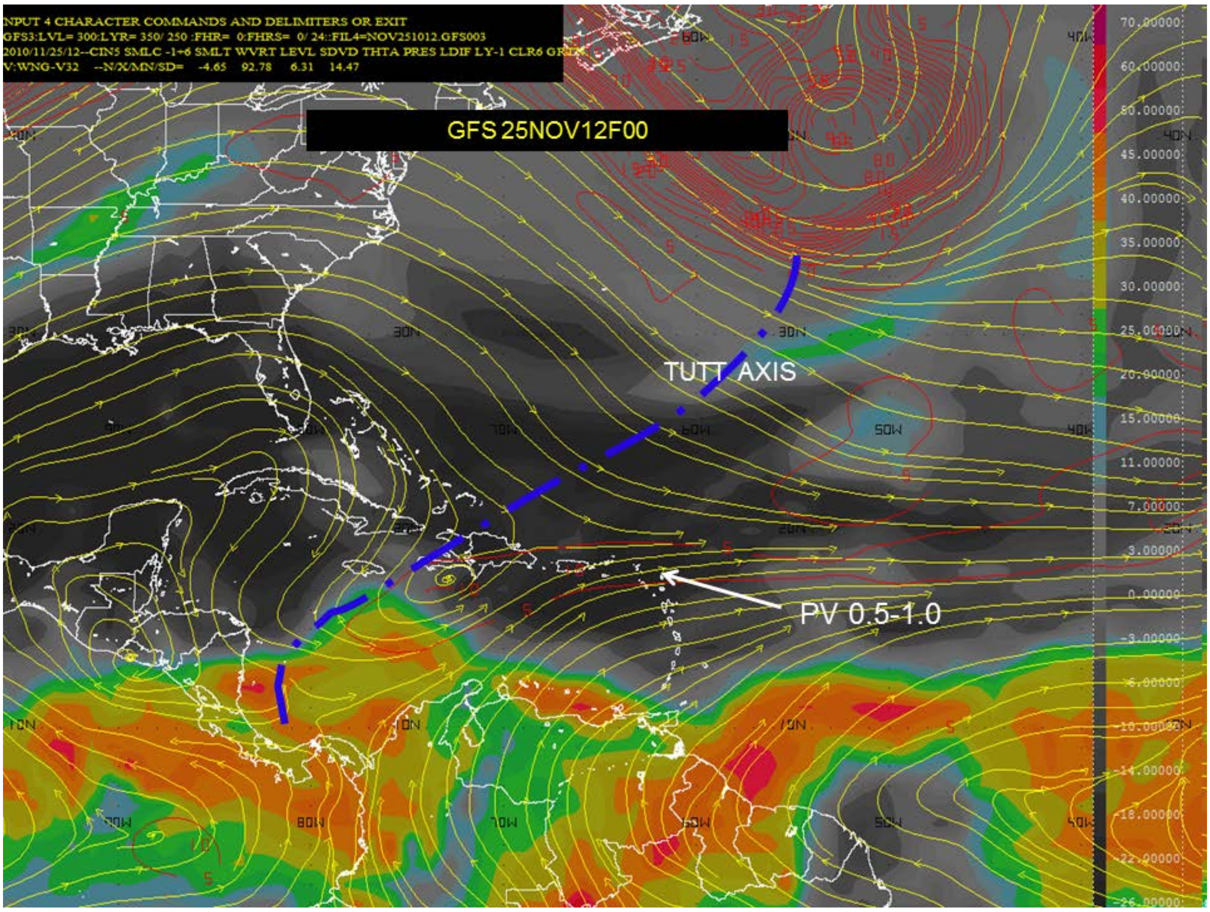
The Caribbean Surface Analysis constructed by NHC-TAFB shows an easterly wave approaching eastern Venezuela and a surface cold front to the north of the Bahamas.

WV Satellite NOV2510 06Z-09Z-12Z

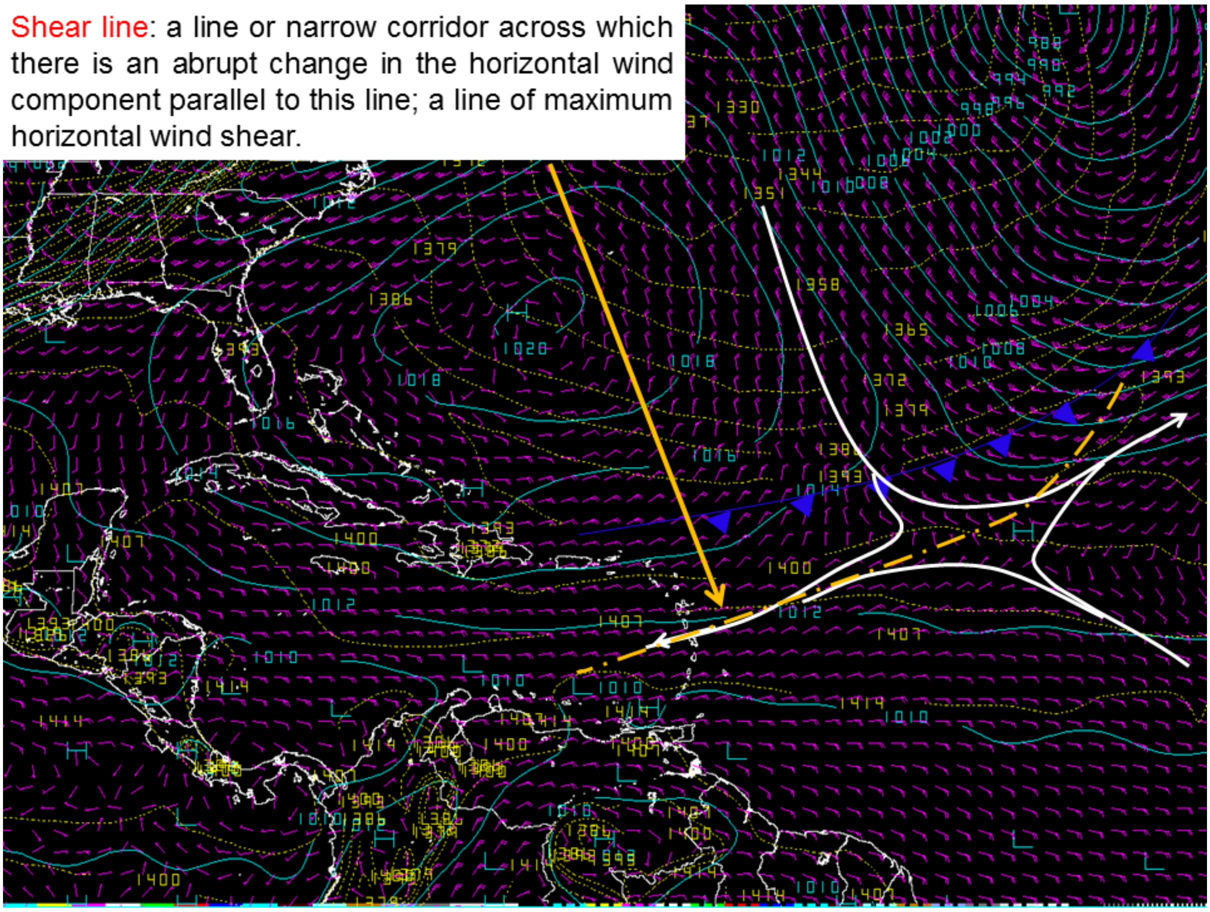


Source: sat.dundee.ac.uk

The water vapor image during the day of the event shows the reflection of the ITCZ/NET in the upper troposphere in the form of cold towers and cirrus. It shows the line of enhanced convection along the northern coast of South America. A TUTT (Tropical Upper Tropospheric Trough) is also present to the north.

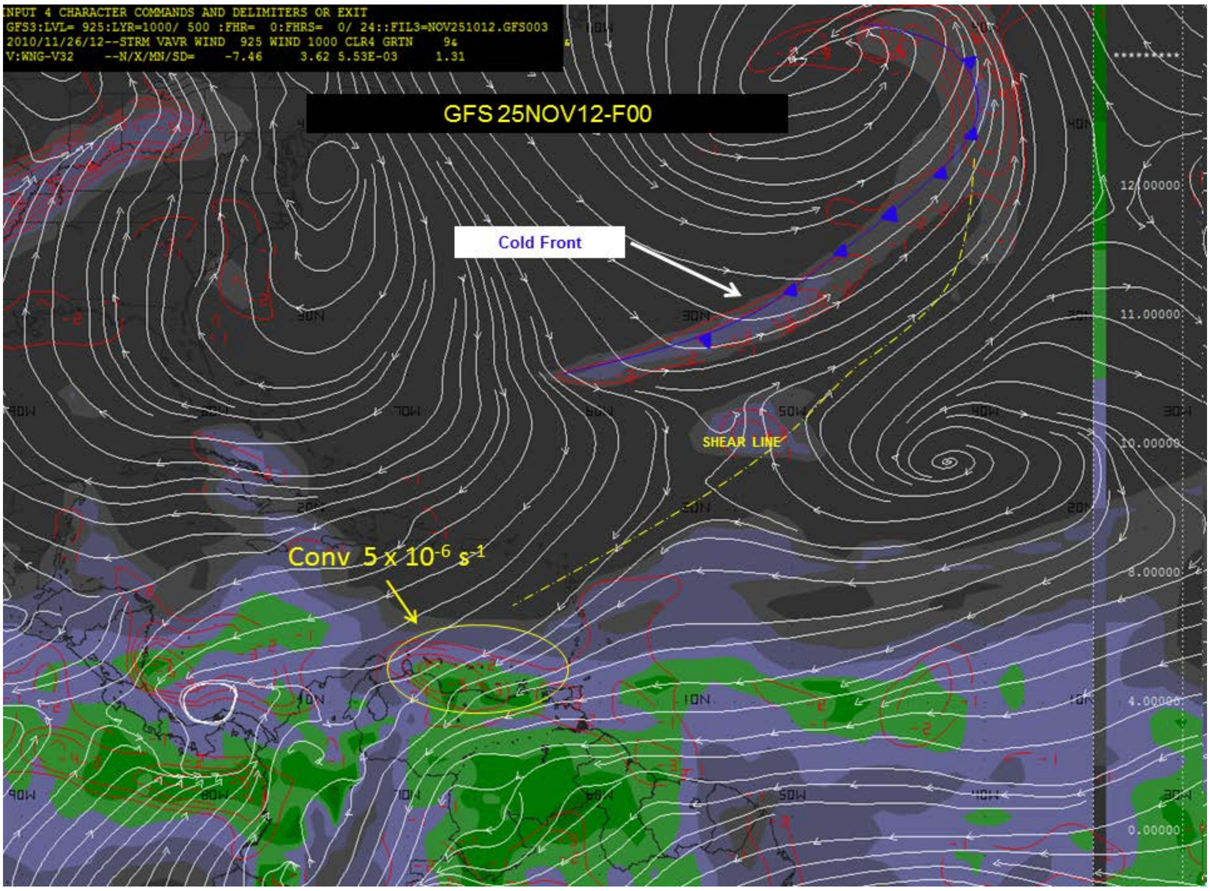


GFS model data is used to show the presence of a TUTT (300 hPa yellow streamlines), 300 hPa potential vorticity maxima (red contours) and instability (Gálvez-Davison Index in colors). The graphic was constructed using Wingridds. The axis of the TUTT is indicated using a dashed blue line. Potential vorticity values of 0.5-1 suggest an intrusion of stratospheric air. This is usually a signature of a strong upper trough. Strong upper troughs have a stronger reflection at low-levels. In the Caribbean means a higher potential for a surface front and a shear line in association with the upper trough.



Definition of a shear line: A narrow corridor along which there is an abrupt change in the horizontal component of the wind. It is a line of maximum horizontal wind shear that occurs when easterly trades interact with winds with an enhanced northerly component (in the north hemisphere) that develop ahead of a cold front. For a shear line to occur, a cold front and associated upper trough must be present. The shear line can be an important source of convection as is often associated with strong low-level moisture convergence.

The graphic above shows mean sea level pressure in hPa (light blue), 1000 hPa wind barbs in kt (pink) and 1000-850 hPa thickness in yellow dashed contours. The cold front, col ahead of the front, and the shear line have been indicated.



This figure illustrates 925-100 hPa moisture flux convergence in shaded, 925-1000 hPa averaged streamlines in black and associated wind divergence in red contours. The cold front and the shear line are indicated.

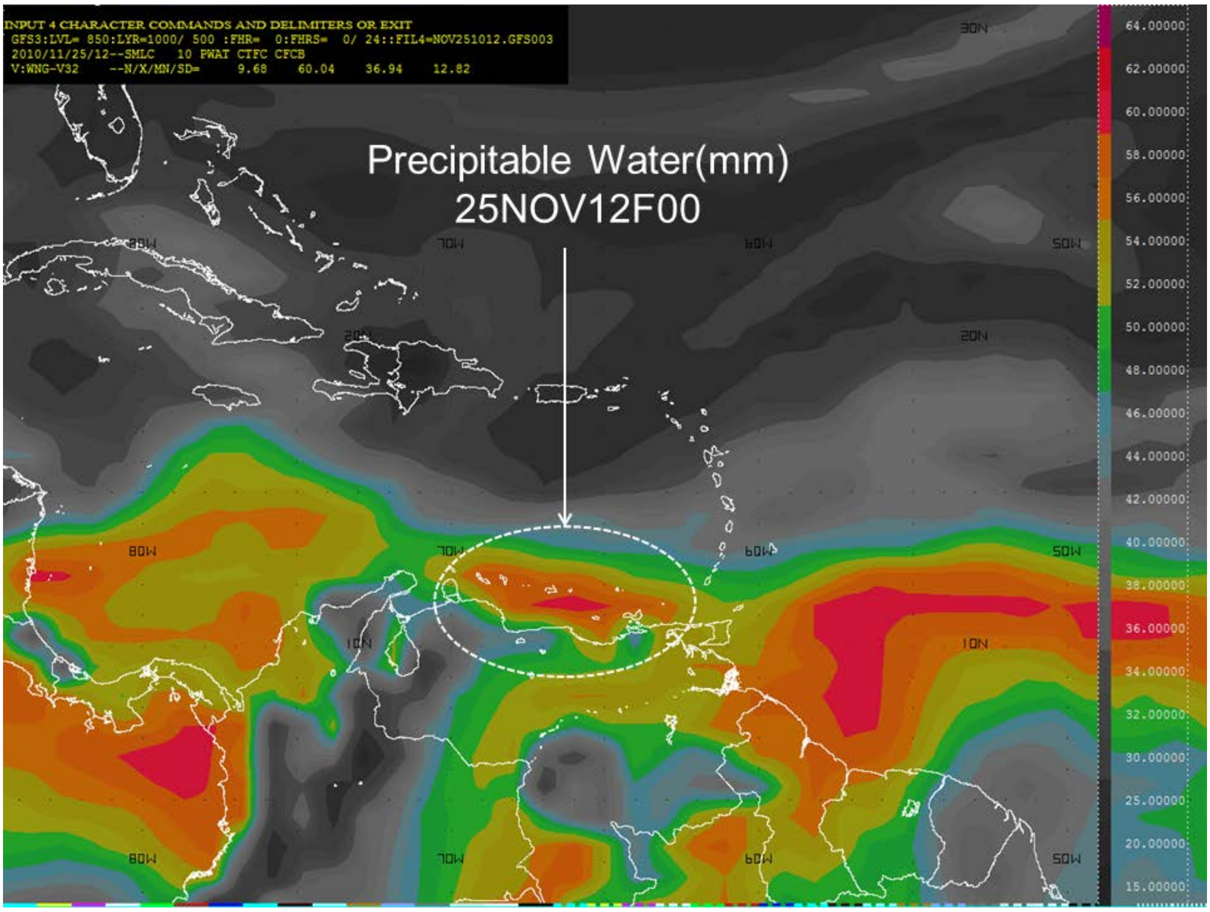
Stability Indices, Convergence and Moisture Flux Convergence

INDEX	GFSNOV2312Z F48	GFSNOV2412Z F36	GFSNOV2500Z F12	GFSNOV2512Z F00
K	34/36	34/36	36/38	34/36
Showalter	-1	-1	0	0
Lifted Index	-4	-4	-4 / -5	-4
Convergence 10^{-6} s^{-1}	4	5	5	5
TT	43	43	43/44	44
GDI	45	45/50	50/55	45/50
Moisture Flux Convergence 10^{-7} m^{-2} s^{-1}	10	11-12	+12	12

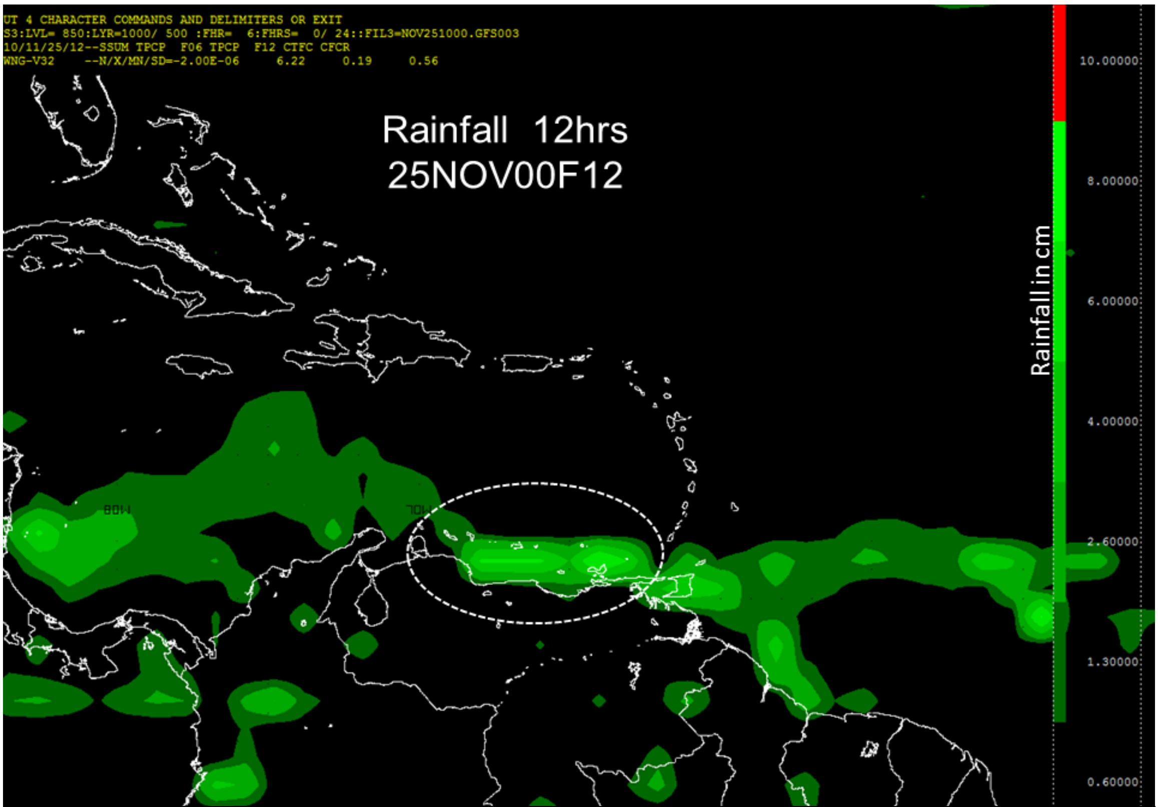
The table shows predictor values during event peak time, 12Z 25 November 2010. The values are shown for this period but using GFS simulations initialized at different periods. This is a method equivalent to ensemble forecasting. If the model is consistent among different initializations, then the confidence on the values of the predictors increase.

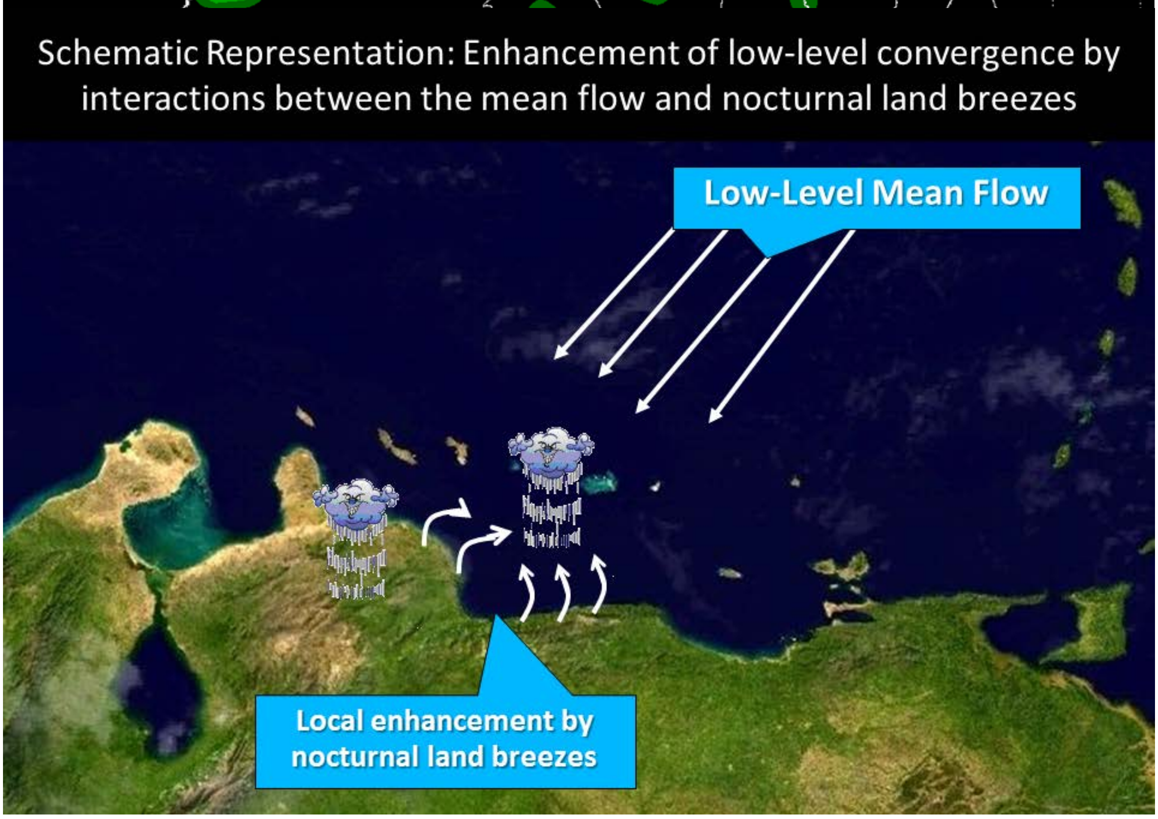
From the stability indices explored, the K index showed values in the order of 34-36. The Showalter index varied from -1 to 0. The Lifted Index varied between -4 and -5. The Total Totals (TT) varied between 43 and 44. The GDI varied between 45 and 55. The simulation that showed the largest instability was that initialized at 00Z on November 25th, 12 hours prior to the event.

The convergence and moisture flux convergence were also explored. The convergence values were between 4 and 5 x 10^{-6} s^{-1}. Moisture flux convergence was in the order of 11-12 m^{-2} s^{-2}.



Analysis of precipitable water during the peak time of the event shows a maximum just to the north of the Venezuelan coast. This maximum peaks at 60+ mm, which is high. Precipitable water is also a very useful field to illustrate the position of the ITCZ/NET. In this case, the precipitable water analysis suggests the presence of the NET along the northern coast of Venezuela/extreme southern Caribbean. Climatologically, by late November the NET should cross South America somewhere between Southern Venezuela and extreme Northern Brazil/Guianas.

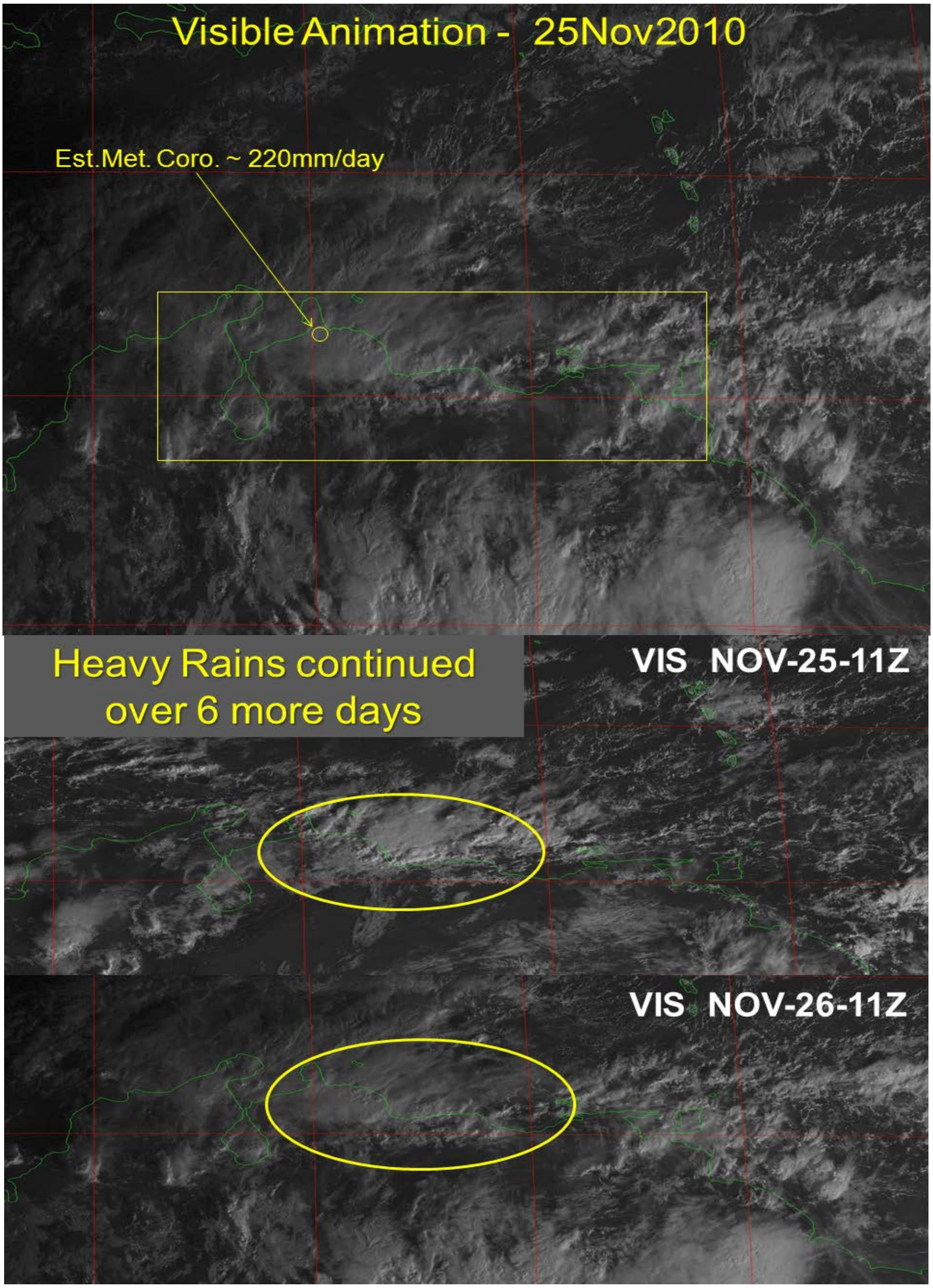


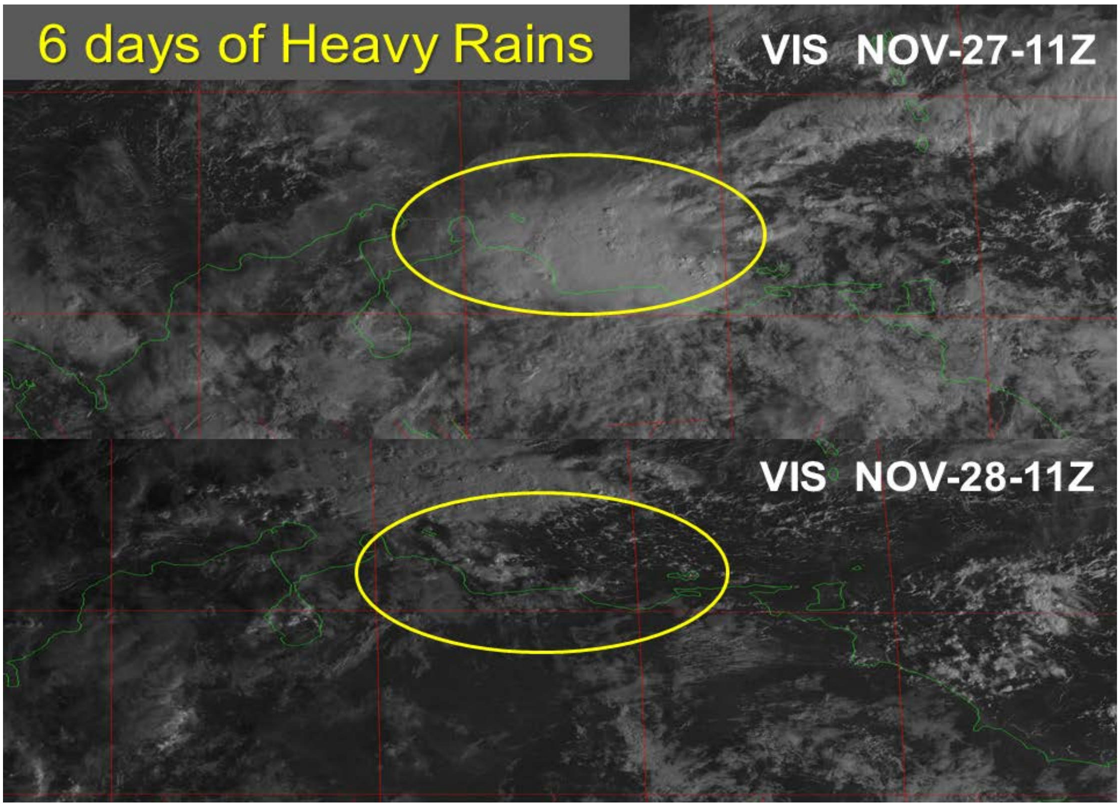


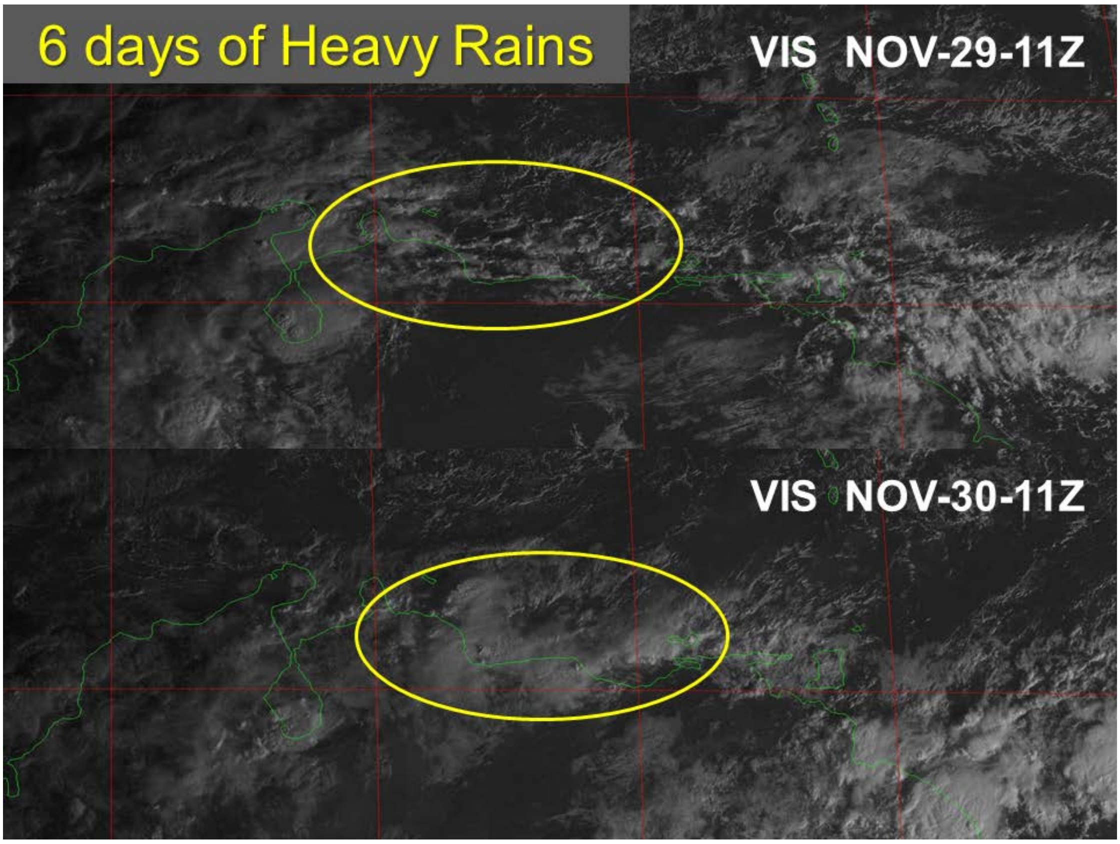
The upper slide shows GFS model rainfall forecast.

The lower slide shows a schematic representation of the enhancement of low-level convergence by nocturnal land breezes. This is particularly true for a low-level mean flow that has a northeastern component.

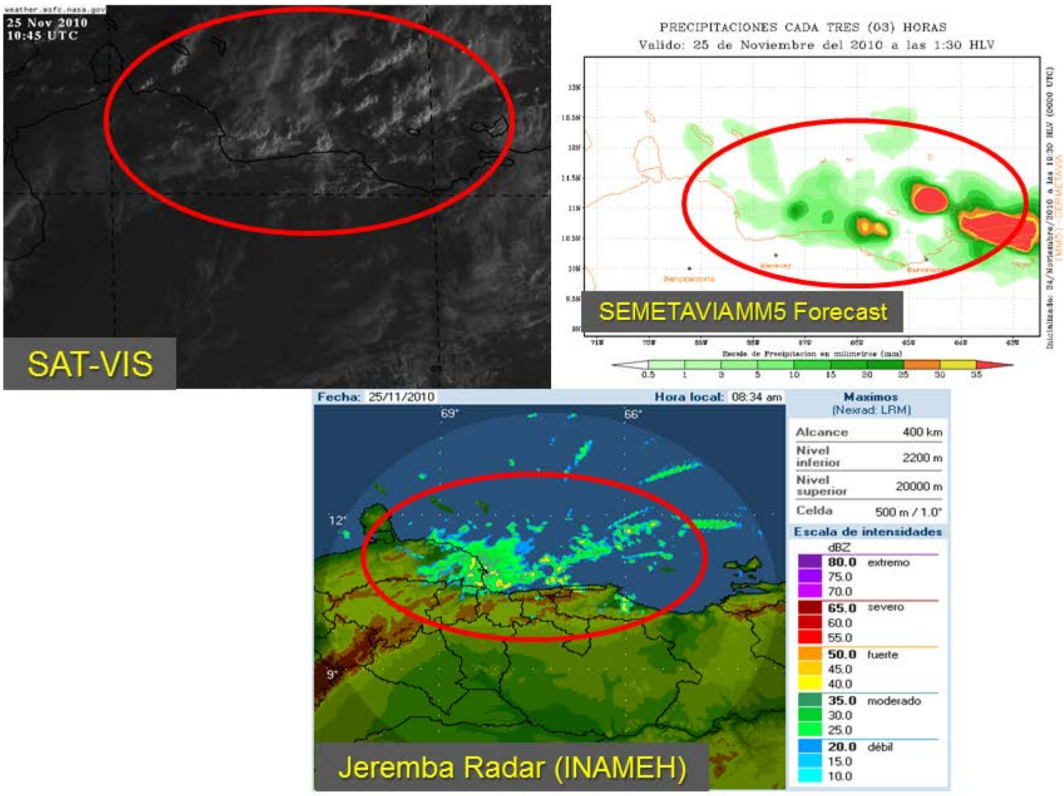
The upcoming slides are visible satellite images that correspond to the early morning in Venezuela (11 UTC) for 6 days between 25 and 30 November 2010. They show the persistence of enhanced deep convection along the northern coast of Venezuela.




6 days of Heavy Rains
VIS NOV-27-11Z
VIS NOV-28-11Z


6 days of Heavy Rains
VIS NOV-29-11Z
VIS NOV-30-11Z

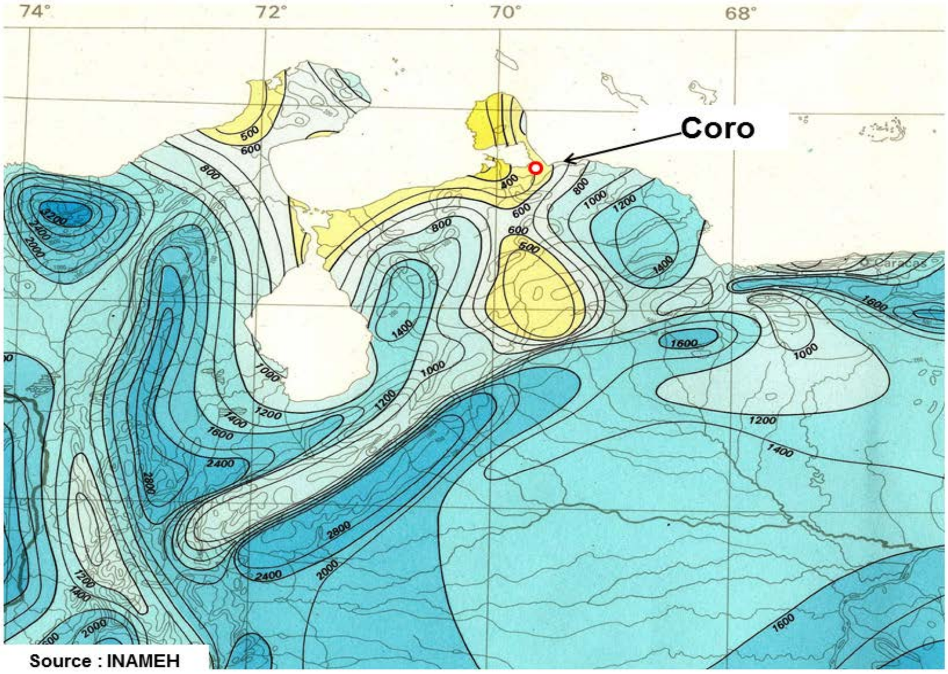
Event Signature on other Tools



The unusually strong convection had also signatures in other observation platforms. The Jeremba radar captured the event pretty well. Radar rainfall estimates approached the observations and satellite estimates. The slide also shows heavy precipitation forecasted by the MM5 model from SEMETAVIA.

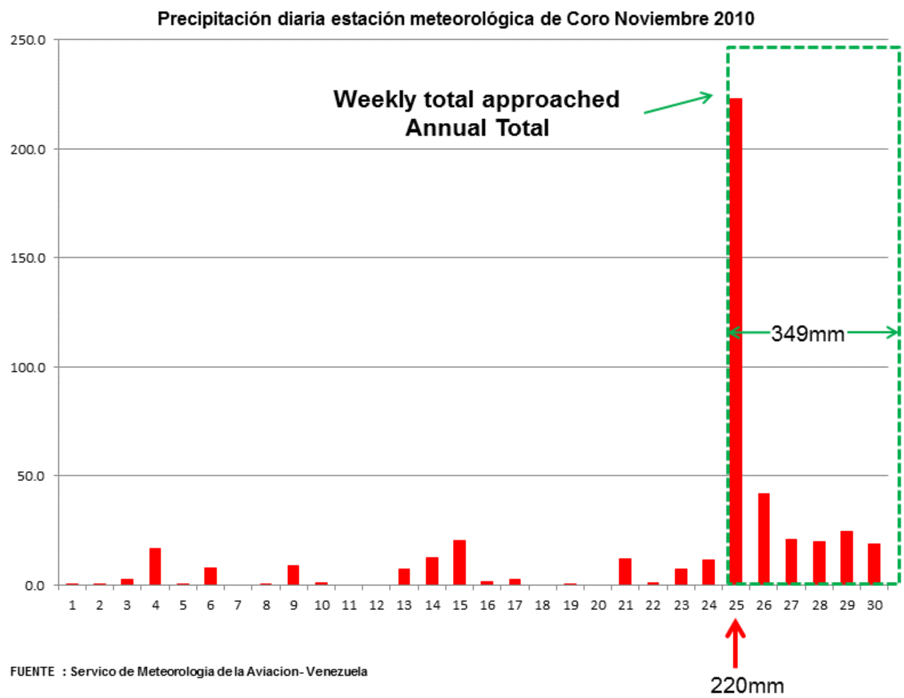
Annual Rainfal Climatology

Note: Coro receives 400mm/yr. During 25Nov2010 it received 220mm/day

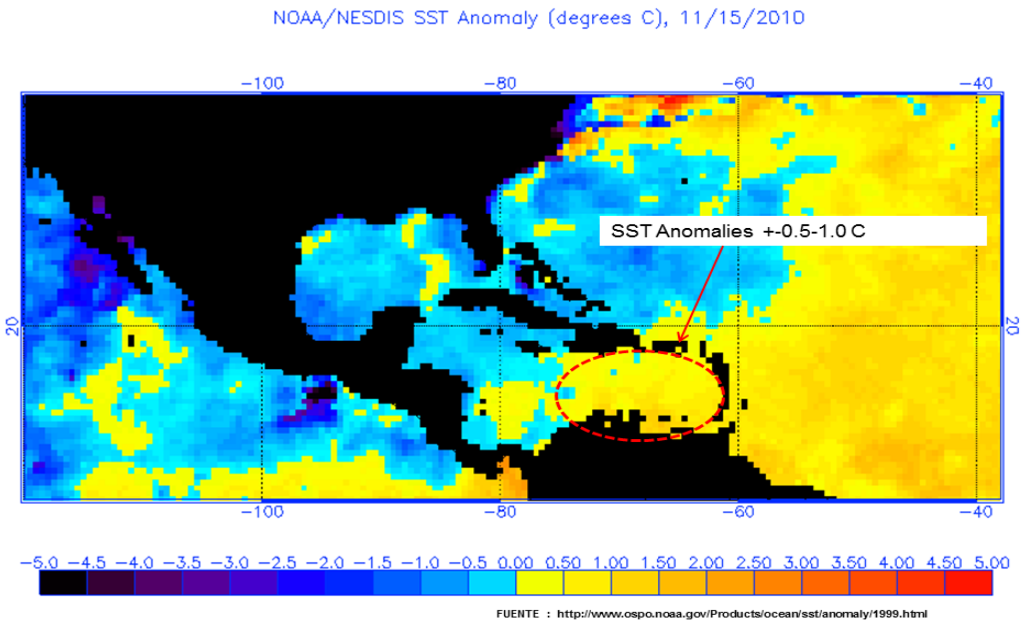


This climatology chart from INAMEH shows annual rainfall totals near 400 mm in Coro.

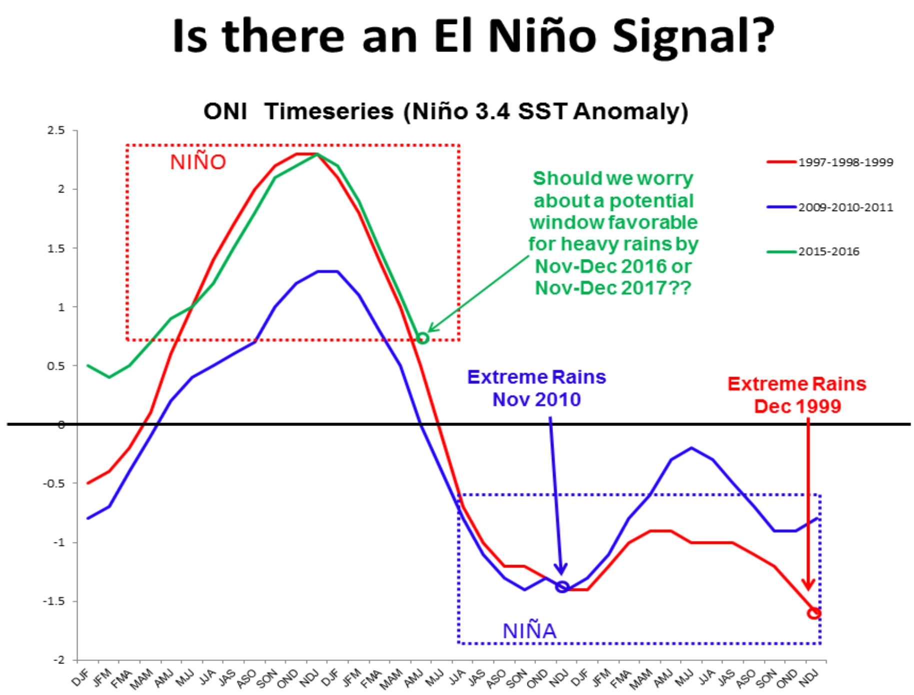
Coro Daily Rainfall Timeseries



Daily rainfall time series at the Coro station show accumulations of 349mm during the period of frequent rains. They also show that 220 mm fell in less than 24 hours during November 25th.



Sea Surface Temperature anomalies show a warm pool of +0.5 to +1.0°C extending along the northern coast of Venezuela. It also shows below-normal temperatures to the north of the Greater Antilles. Sea surface temperatures not only affect the weather conditions locally, but to affect the depth of the troposphere.



Two extreme rainfall events along the northern coast of Venezuela occurred during November/December in La Niña years. The Oceanic Niño Index (ONI) is shown in red for the deadly December 1999 Vargas event, and in blue for the November 2010 Coro event. They both show values near of below -1.5°C, and occurred after a transition from a strong El Niño.

Summary and Conclusions

Suggested by this short case study

What to look for to forecast the potential for heavy rains in Northwestern Venezuela?

1.- Shear lines

2.- High values of the following Stability Indices:
- GDI (> 50-55)
- K (>36-38)
- Total-Totals (>43-44)

3.- High Precipitable Water values (> 50mm)

4.- TUTT or Polar Trough in North-Central Caribbean

5.-Nocturnal Breezes

6.- Positive SST Anomalies (>10.°C)

7.- Slow/delayed southward migration of the ITCZ (favors enhanced instability due to higher frequency of upper troughs late in the year)

8.- Transition towards La Niña or La Niña well established ?

PUENTE DEL RÍO CORO

CARRETERA FALCÓN LARA A LA ALTURA DE TOCOPERO

Testimonios Fotográfico Inundación en Falcón

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