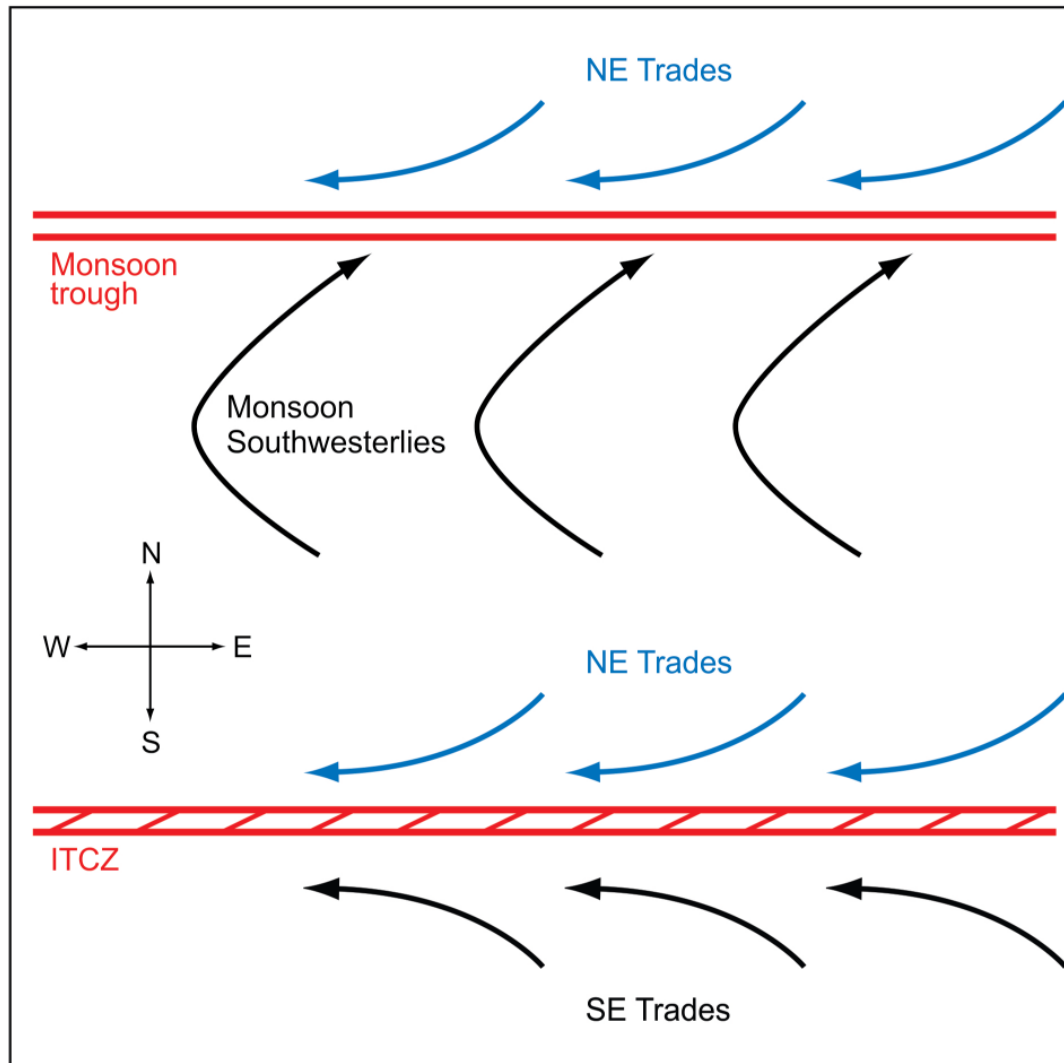


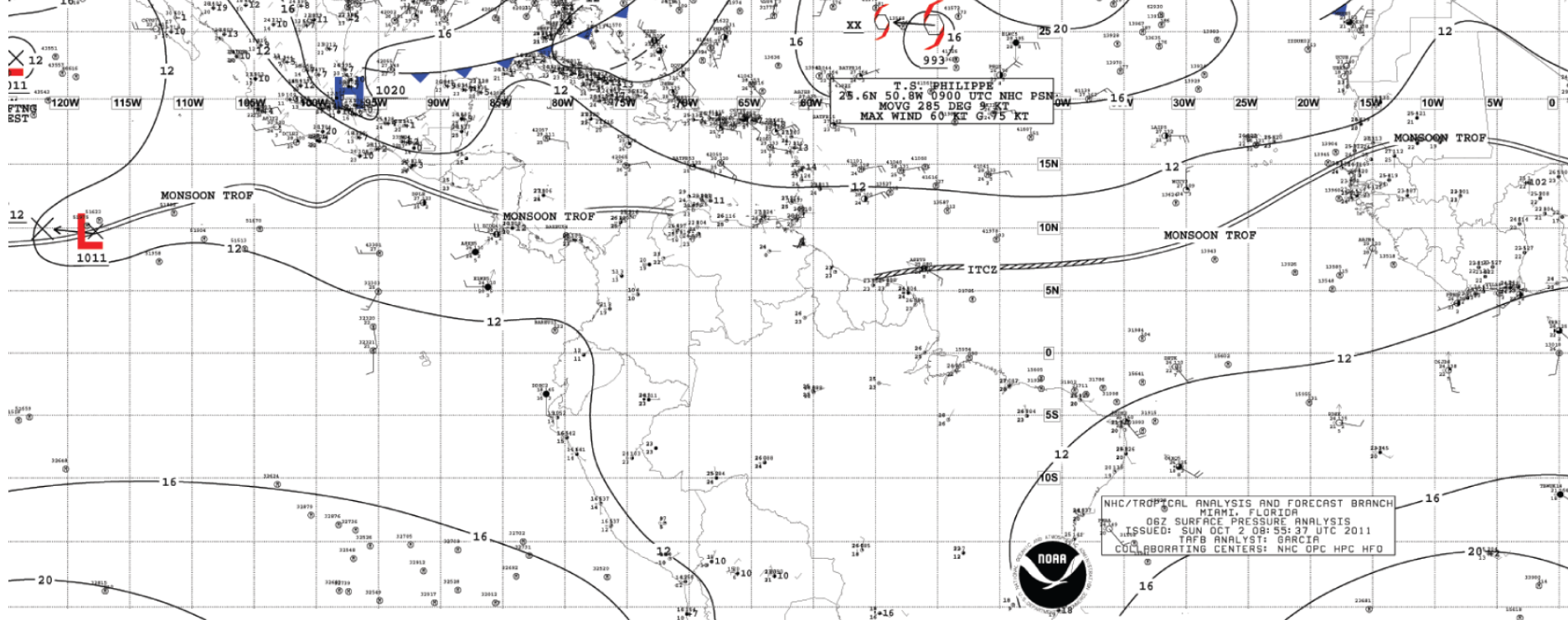
The Monsoon Trough



Andrew Levine

Chris Landsea

NHC/TAFB



National Hurricane Center (NHC)

Hurricane Specialist Unit (HSU)

- TC forecasting
- Coordinate watches and warnings

Tropical Analysis and Forecast Branch (TAFB)

- Unified surface analysis
- Daily tracking of precursor disturbances
- Incorporate disturbances into our marine products - including precursor disturbances

Unified surface analysis is the foundation on which our forecasts are built. During hurricane season, this product is used to depict regions which may be favorable for tropical cyclogenesis. With this in mind, TAFB started to include a depiction of the monsoon trough during the 2011 season

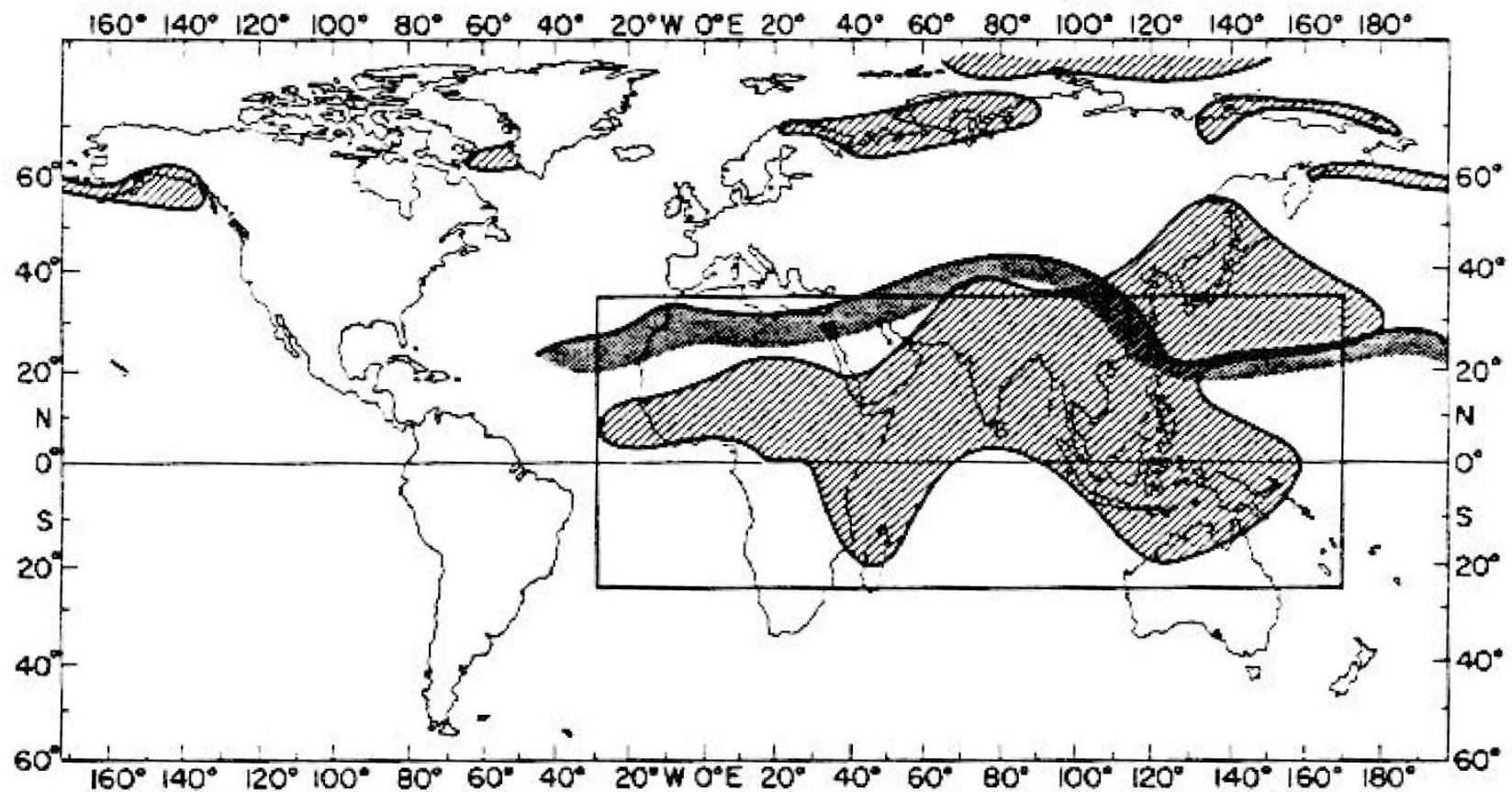
NHC Definition of Monsoon

A large-scale, seasonally-reversing surface wind circulation in the tropics accompanied by large amplitude seasonal changes in precipitation.

NHC Definition of Monsoon

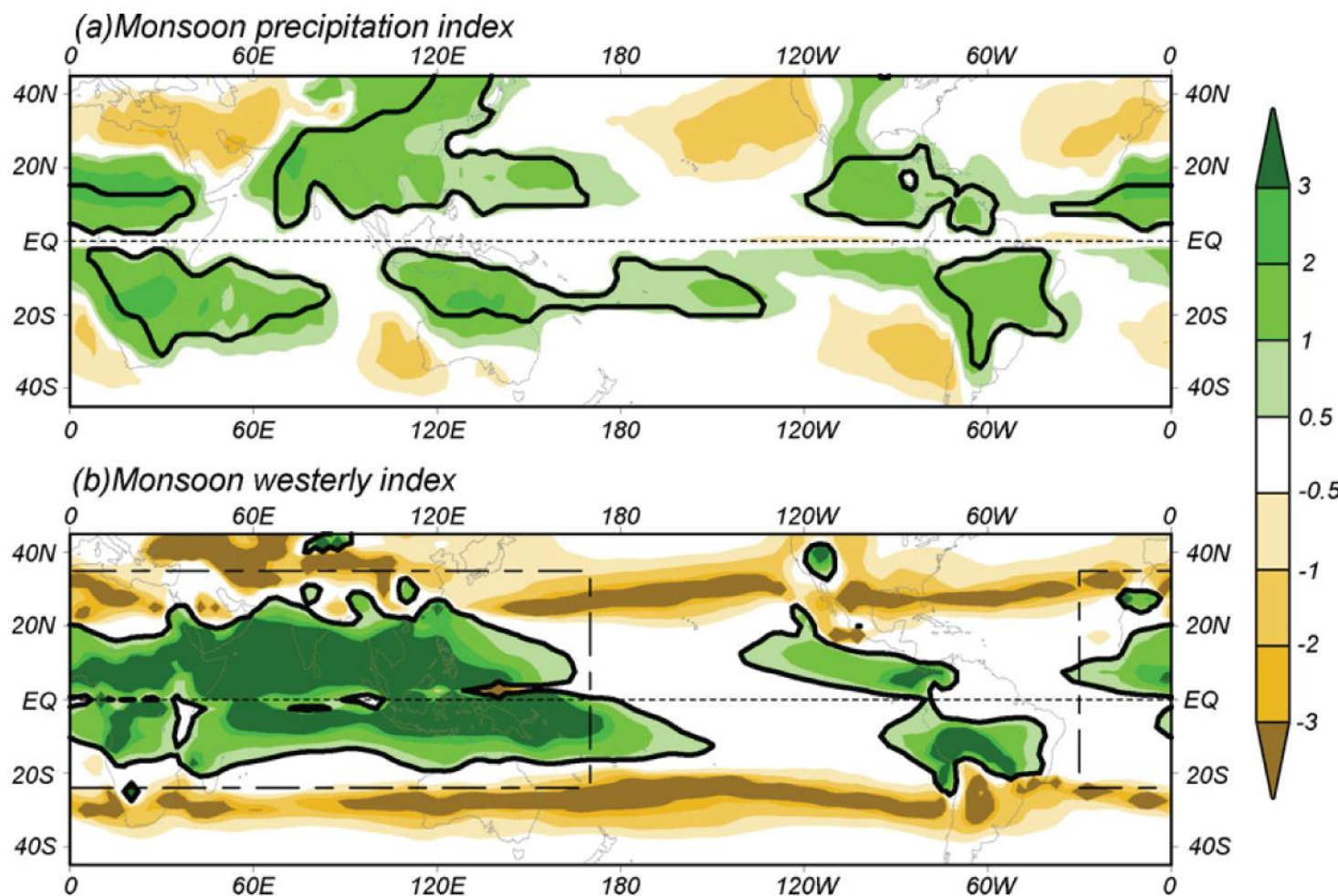
A large-scale, seasonally-reversing surface wind circulation in the tropics accompanied by large amplitude seasonal changes in precipitation.

“The primary cause is the much greater annual variation of temperature over large land areas compared with neighboring ocean surfaces, causing an excess of pressure over the continents in winter and a deficit in summer, but other factors such as the relief features of the land have a considerable effect. The monsoons are strongest on the southern and eastern sides of Asia, the largest landmass, but monsoons also occur on the coasts of tropical regions wherever the planetary circulation is not strong enough to inhibit them.” - WMO

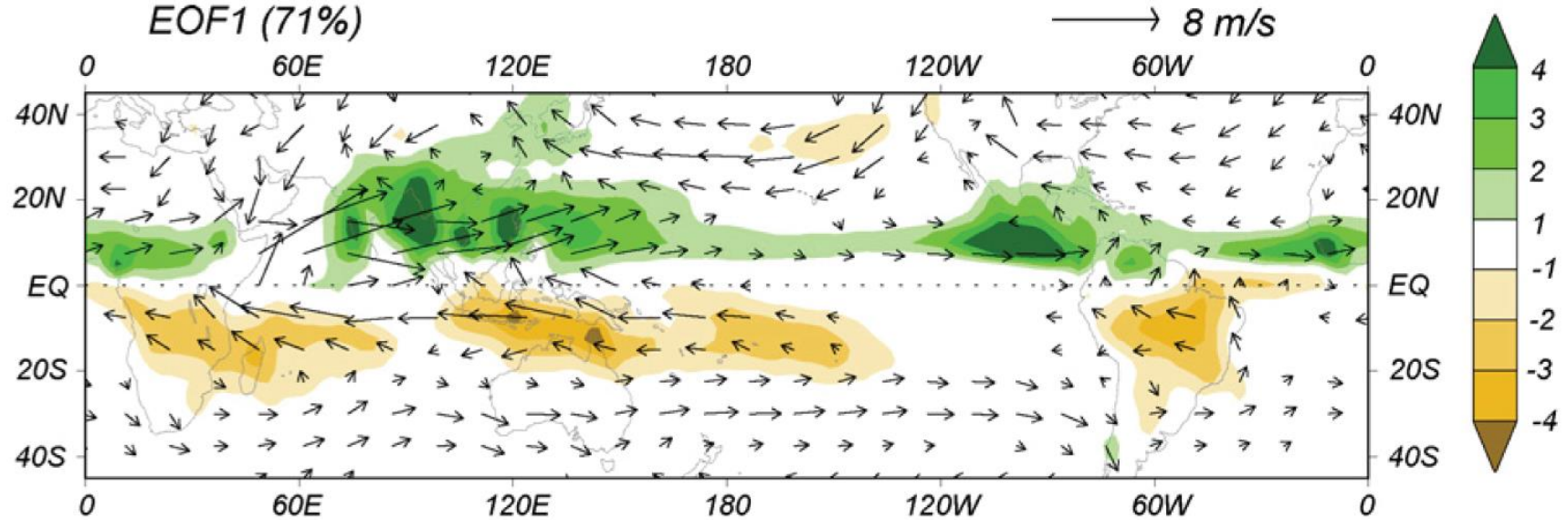


Monsoon region based on Ramage (1971) definition. Hatched areas are monsoonal according to the surface wind criteria. Heavy line marks the northern limit of the region with low frequencies of surface cyclone-anticyclone passage in summer and winter. The rectangle encloses the monsoon region that satisfies all 4 criteria.

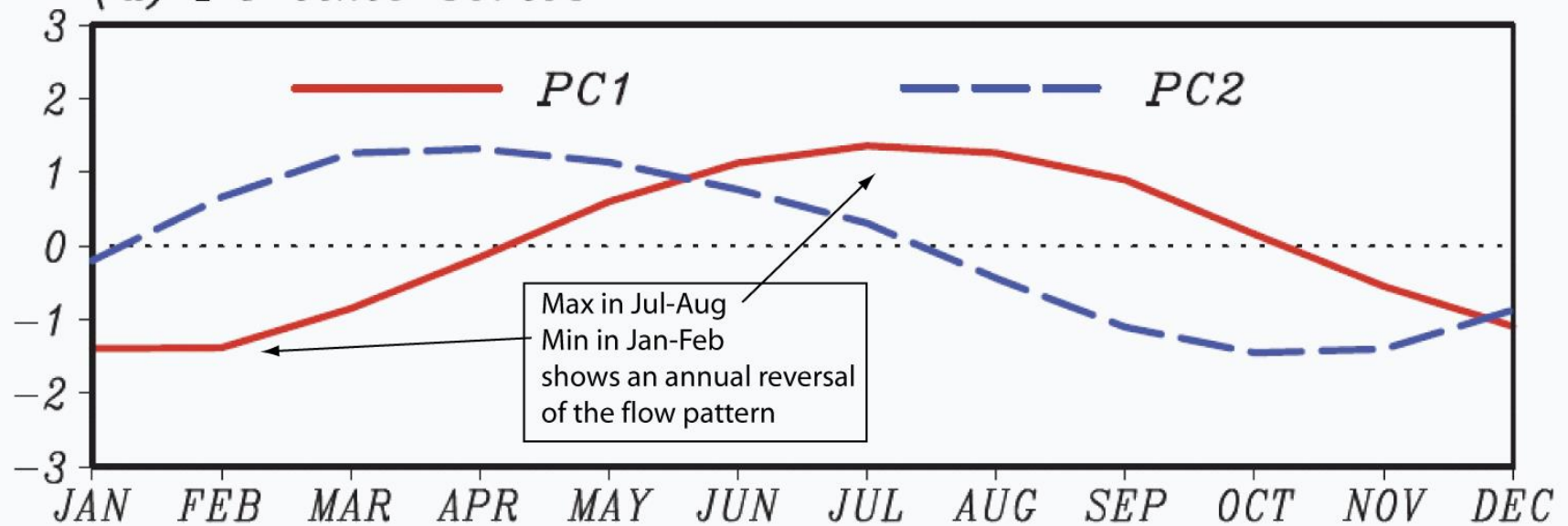
$$MPI = \frac{\text{Annual range of precipitation}}{\text{Annual mean precipitation}}$$



- (a) Monsoon precipitation index, MPI (color shading) and the monsoon precipitation domain outlined by the black curves. The monsoon precipitation domain here is defined by $MPI > 0.5$ and the annual range of precipitation is greater than 300 mm. The data used are CMAP precipitation measurements.
- (b) Monsoon westerly index, MWI (color shading) and the monsoon westerly domain outlined by the black curves. The monsoon westerly domain here is defined by $MWI > 0.5$. The wind data used are 850 hPa zonal wind component derived from NCEP2. The dashed rectangle indicates the monsoon domain defined by Ramage (1971). From Wang and Ding (2008).

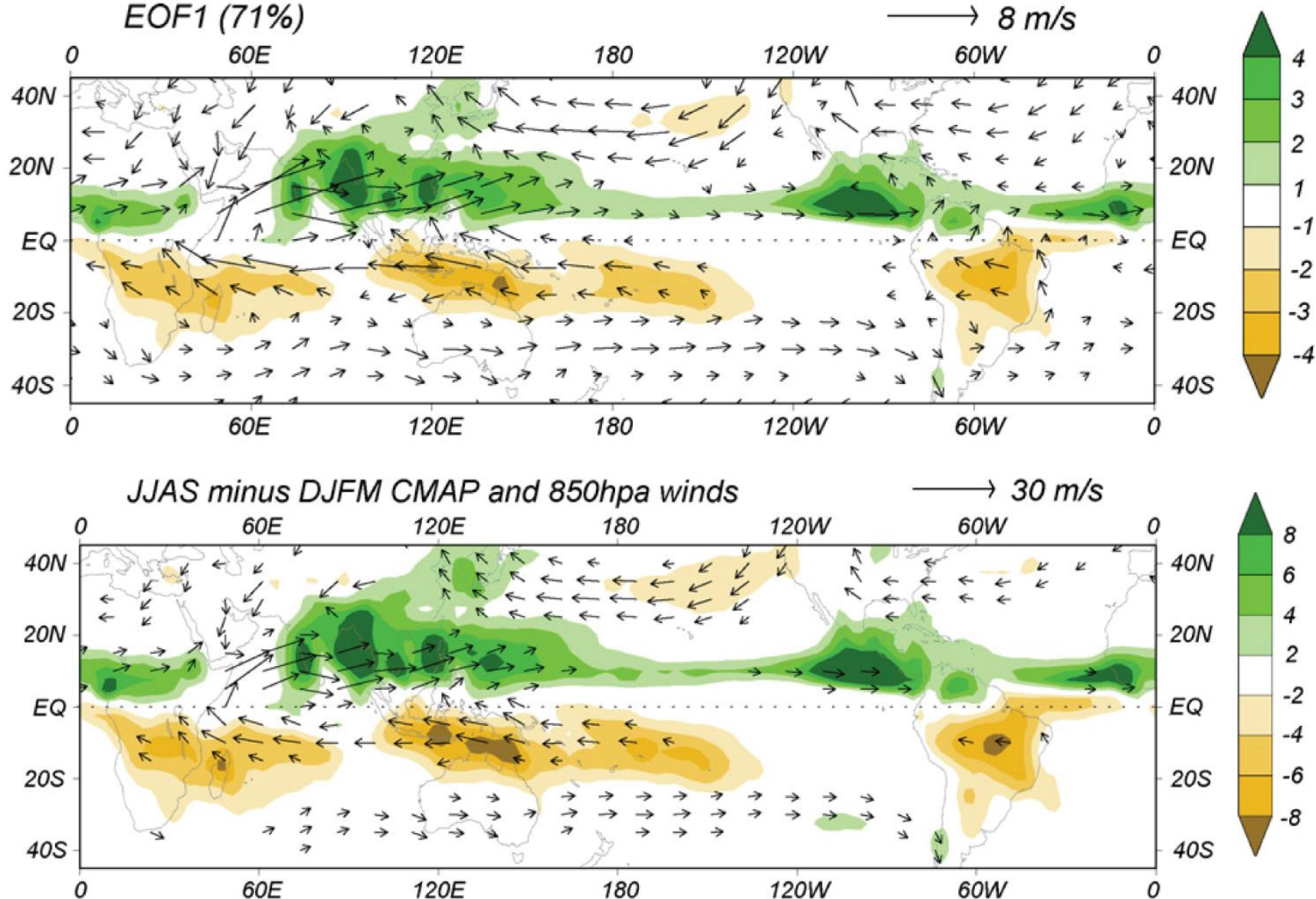


(a) PC time series



Top: The spatial pattern of the first multi-variable EOF mode (which accounts for 71 % of the variance) of the climatological monthly mean precipitation (shading, unit: mm day^{-1}) and the winds (vectors in units of ms^{-1}) at 850 hPa and:

Bottom: corresponding normalized principal component (Wang and Ding, 2008)



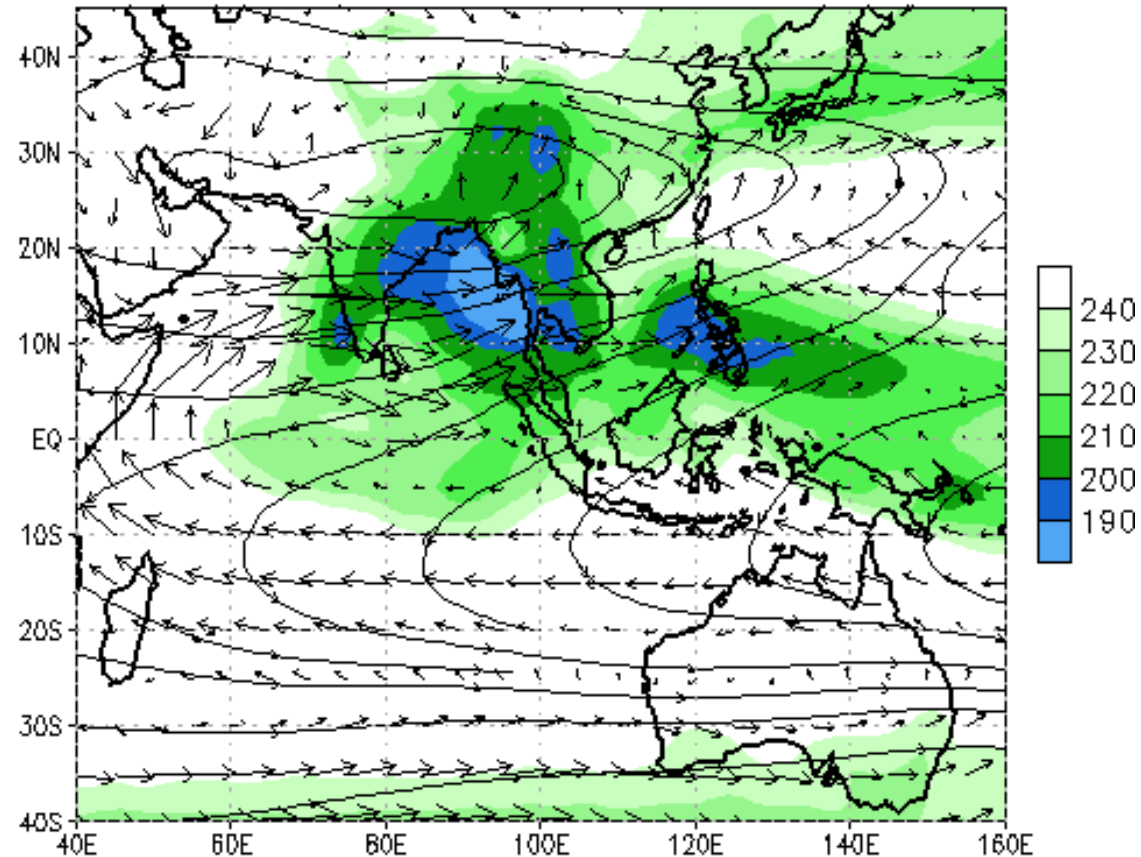
Top: The spatial pattern of the first multi-variable EOF mode of the climatological monthly mean precipitation (shading, unit: mm day^{-1}) and the winds (vectors in units of ms^{-1}) at 850 hPa

Bottom: The spatial patterns of the first multi-variable EOF mode of the climatological monthly mean precipitation (shading, unit: mm day^{-1}) and the winds (vectors in units of ms^{-1}) at 850 hPa (Wang and Ding, 2008)

Asian-Australian monsoons

OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995)

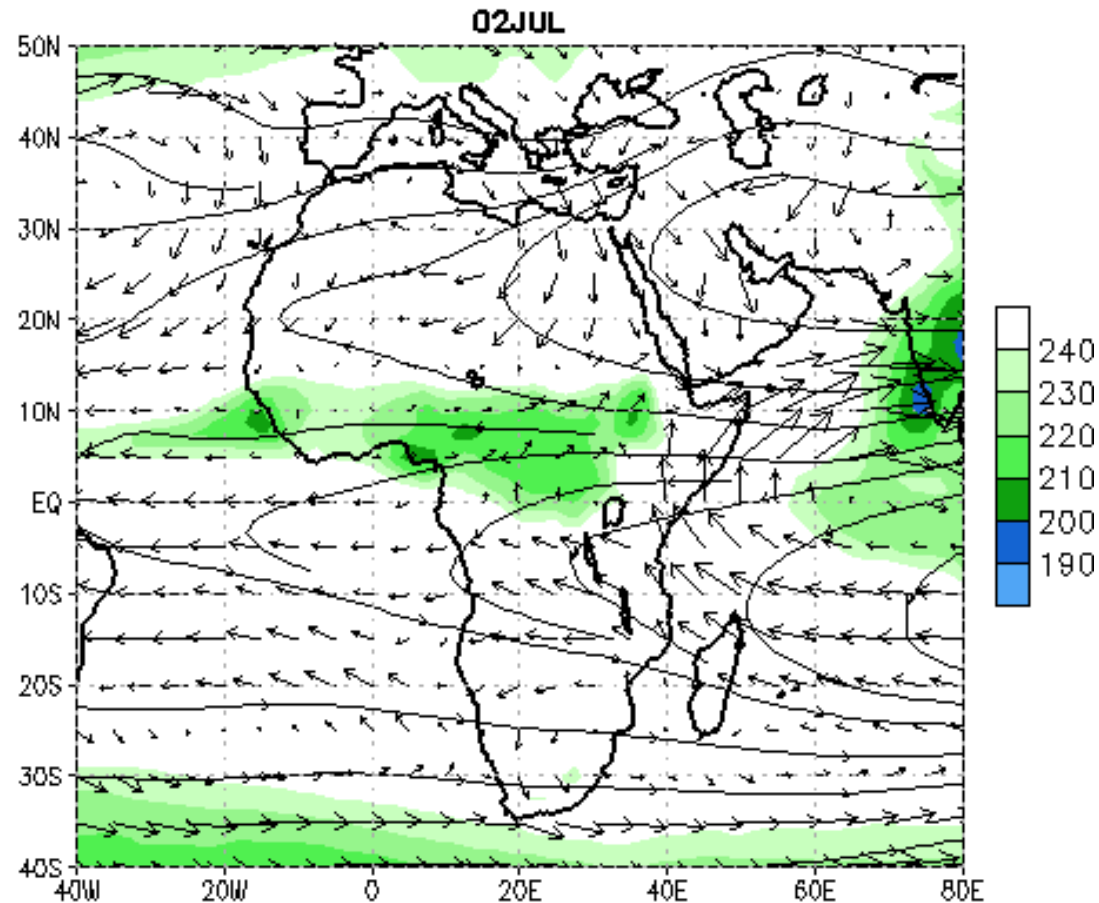
02JUL



Data Sources: OLR - NESDIS/ORA, Winds - NCEP CDAS/ Reanalysis

African monsoons

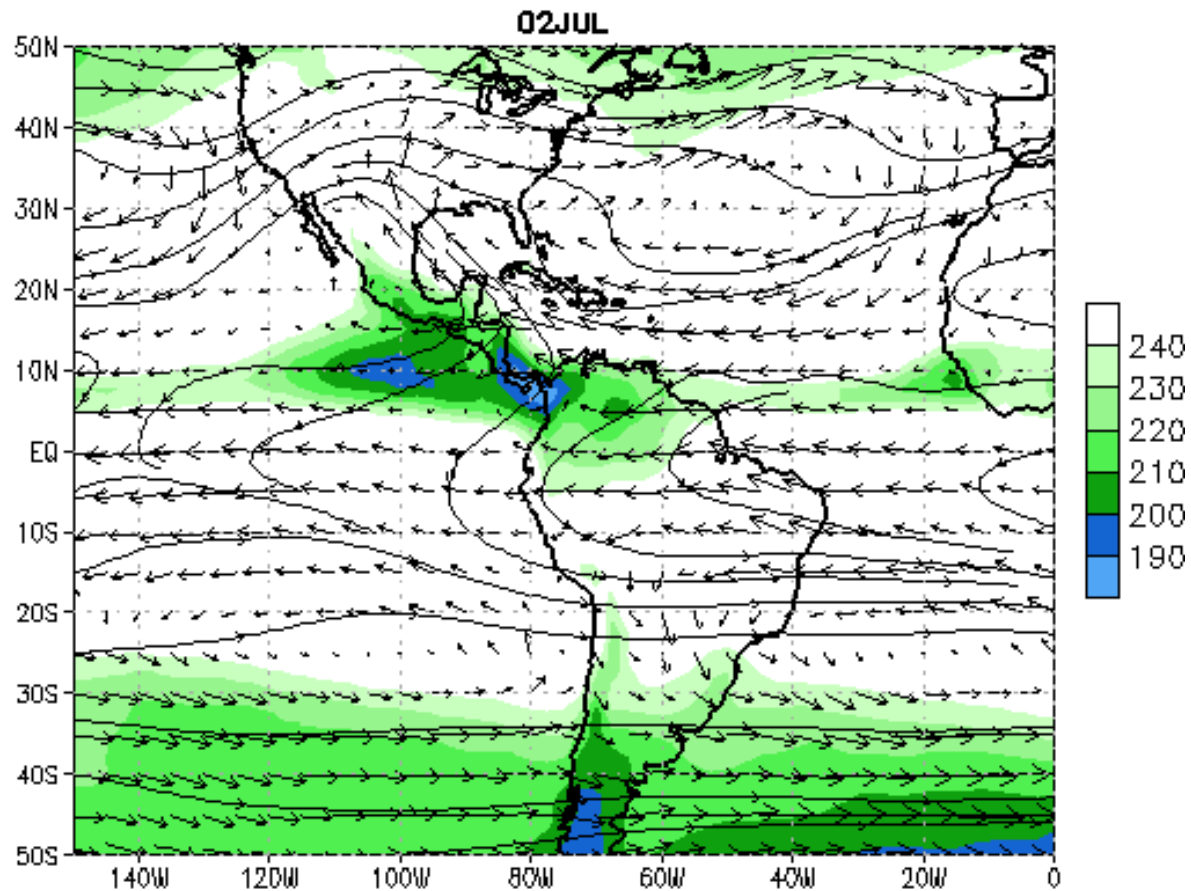
OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979–1995)



Data Sources: OLR – NESDIS/ORA, Winds – NCEP CDAS/ Reanalysis

American monsoons

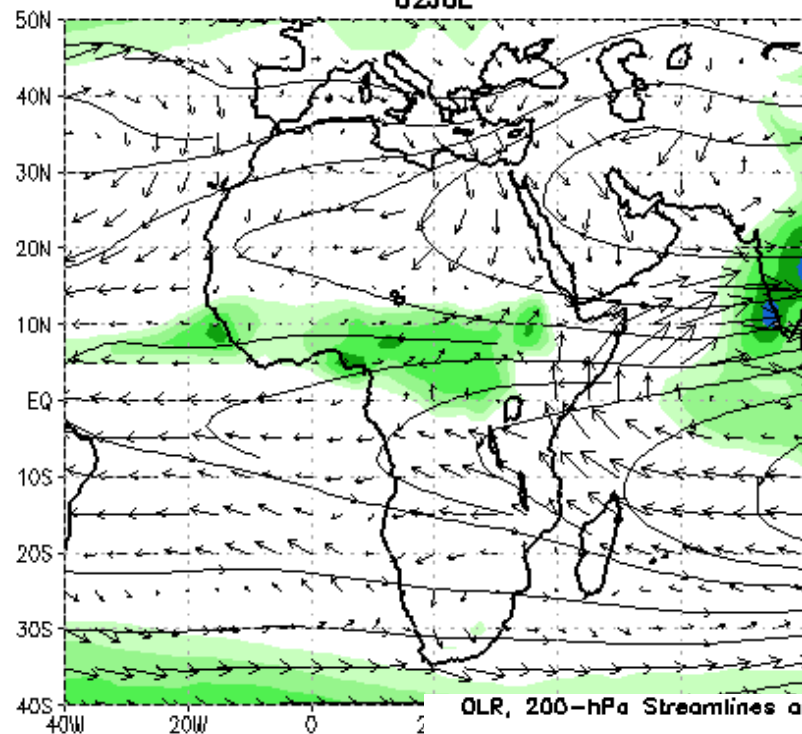
OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979–1995)



Data Sources: OLR — NESDIS/ORA, Winds — NCEP CDAS/ Reanalysis

OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995) I.R, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995)

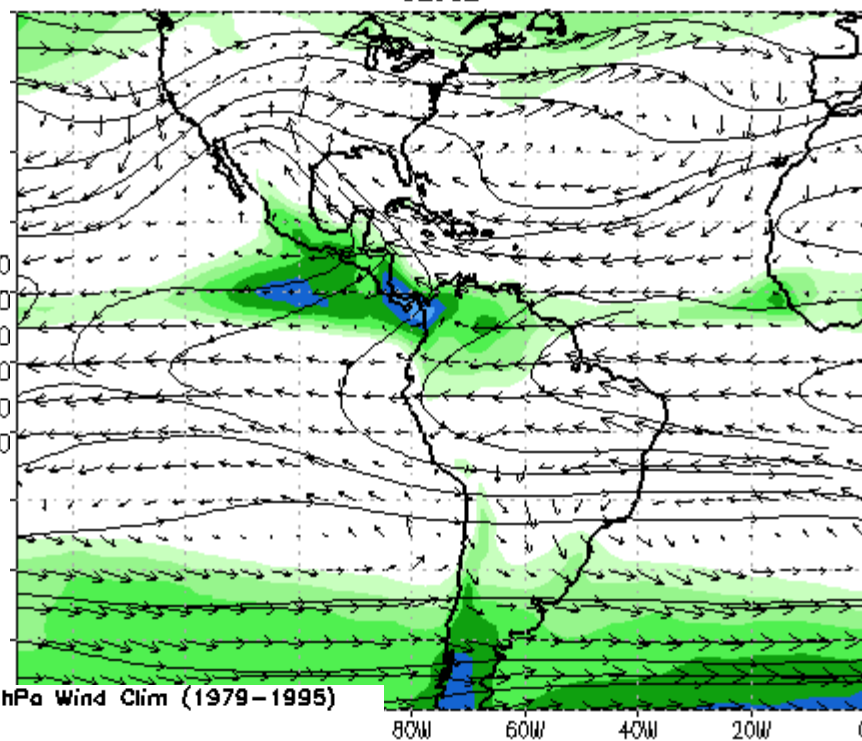
02JUL



OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979-1995)

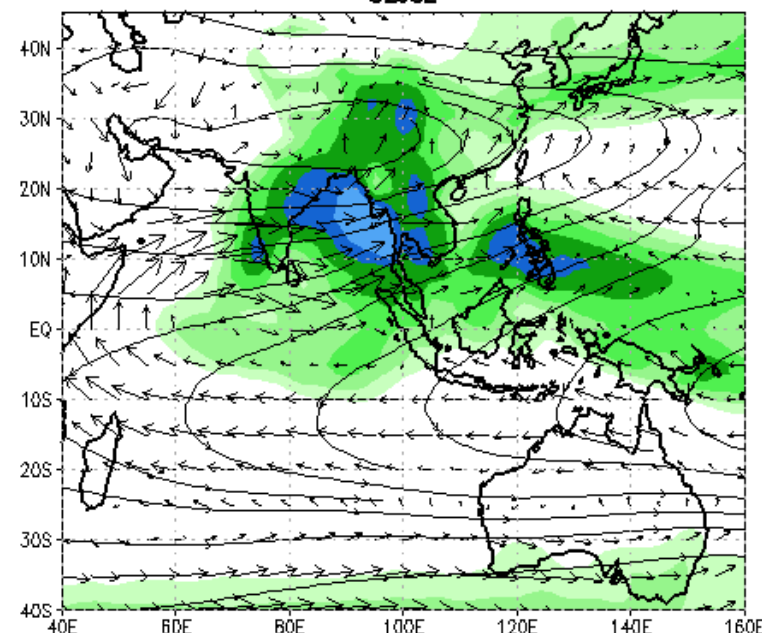
02JUL

02JUL

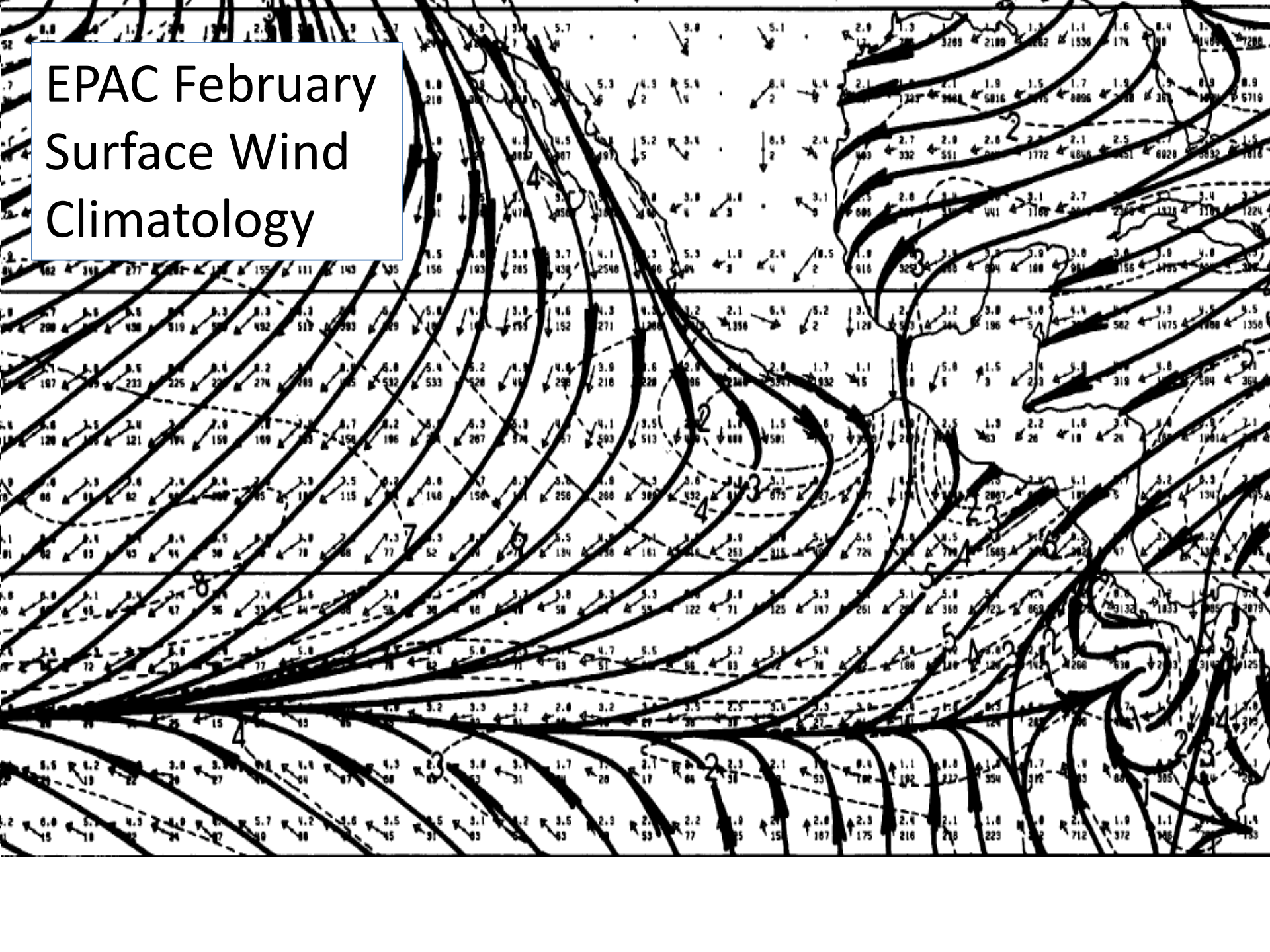


Data Sources: OLR - NESDIS/ORA,

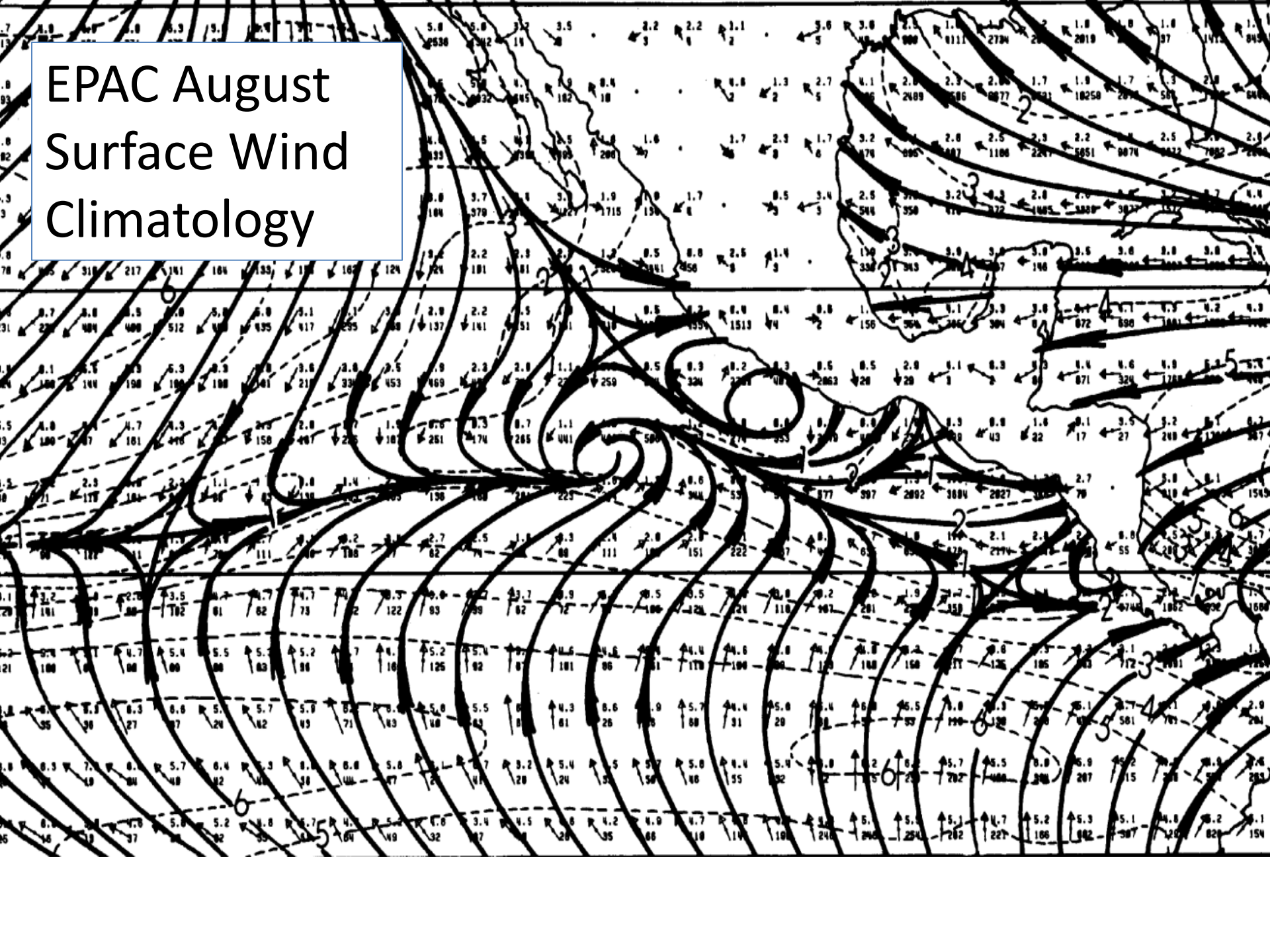
Winds - NCEP CDAS/ Reanalysis



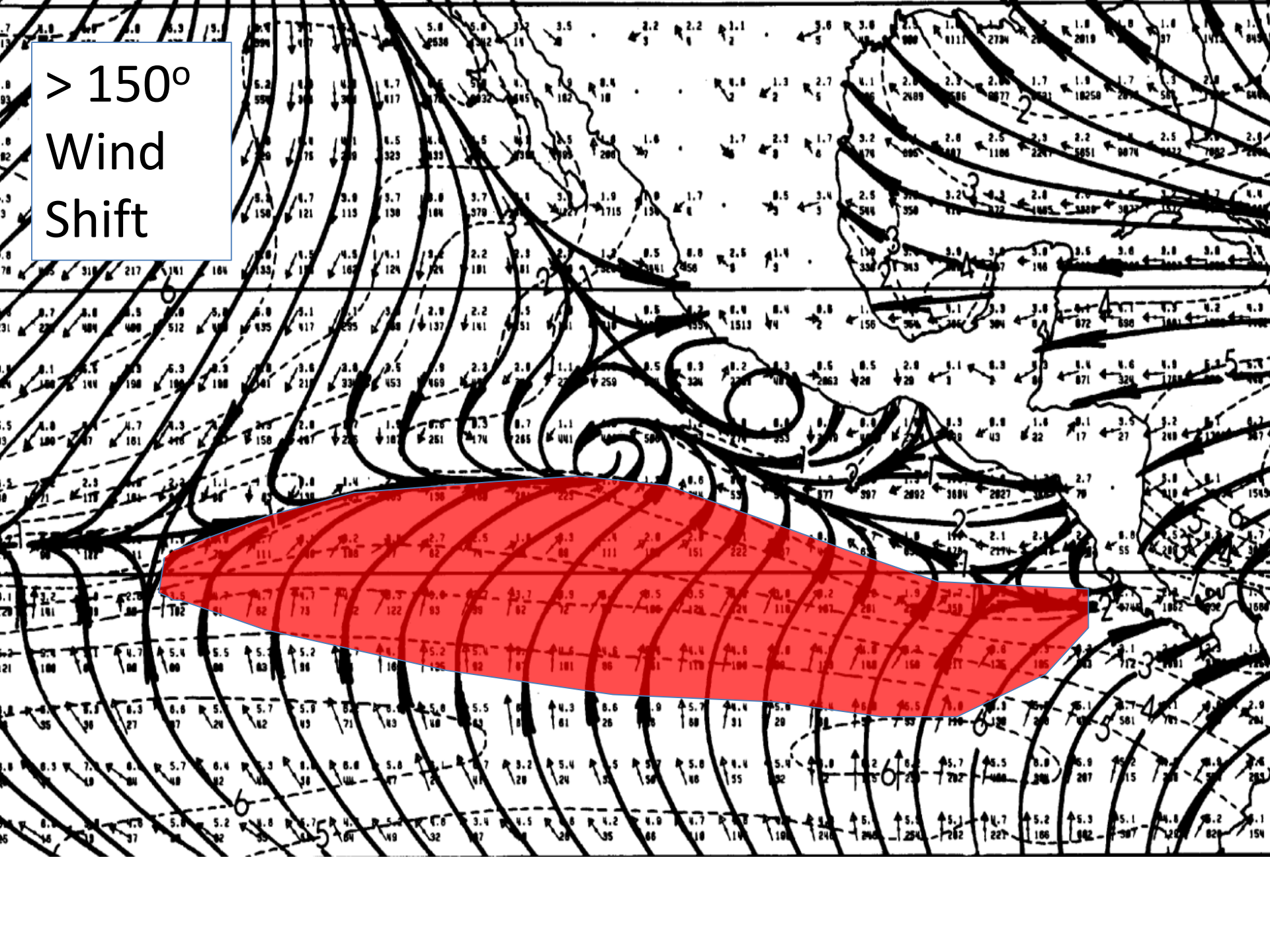
EPAC February Surface Wind Climatology



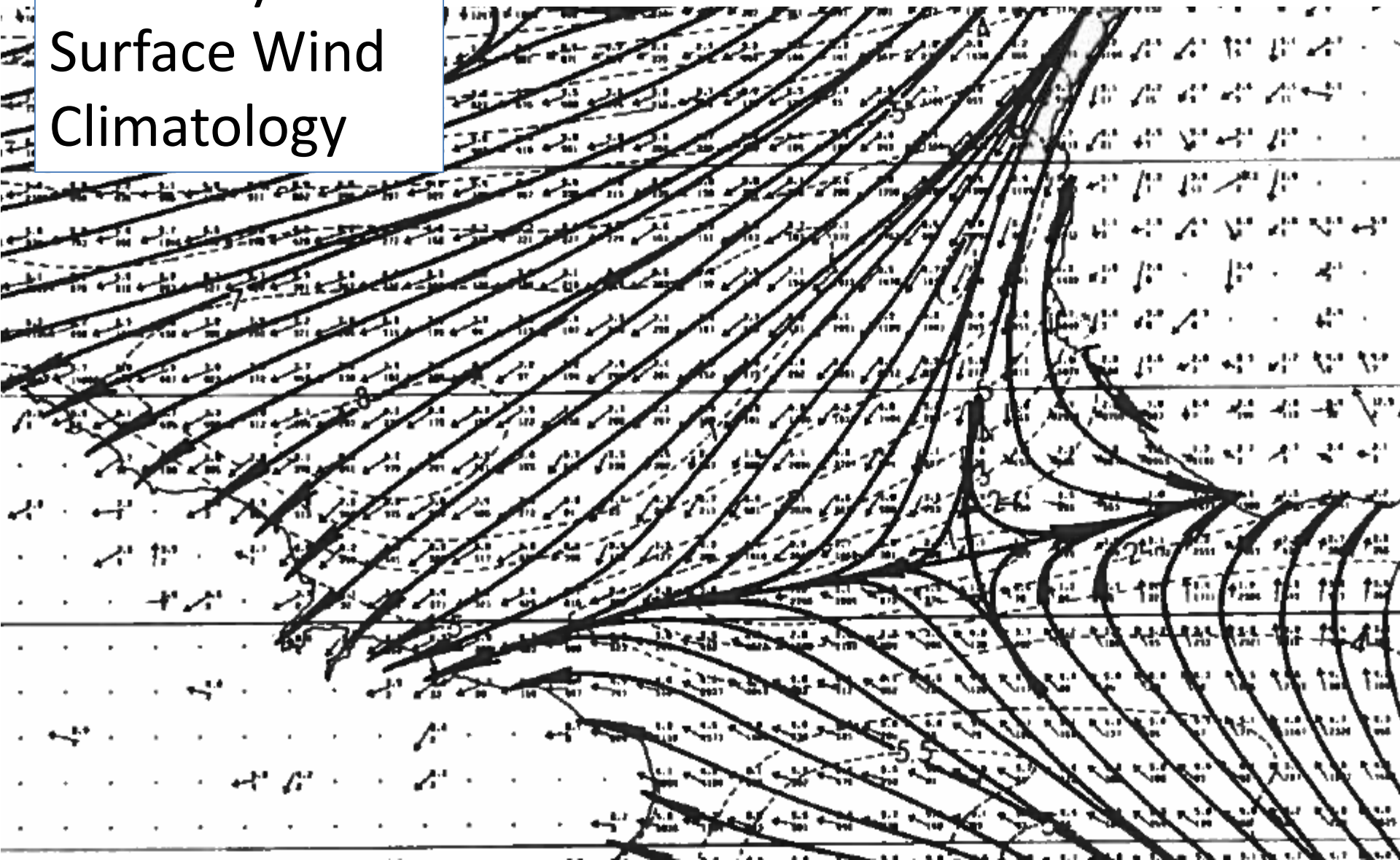
EPAC August Surface Wind Climatology



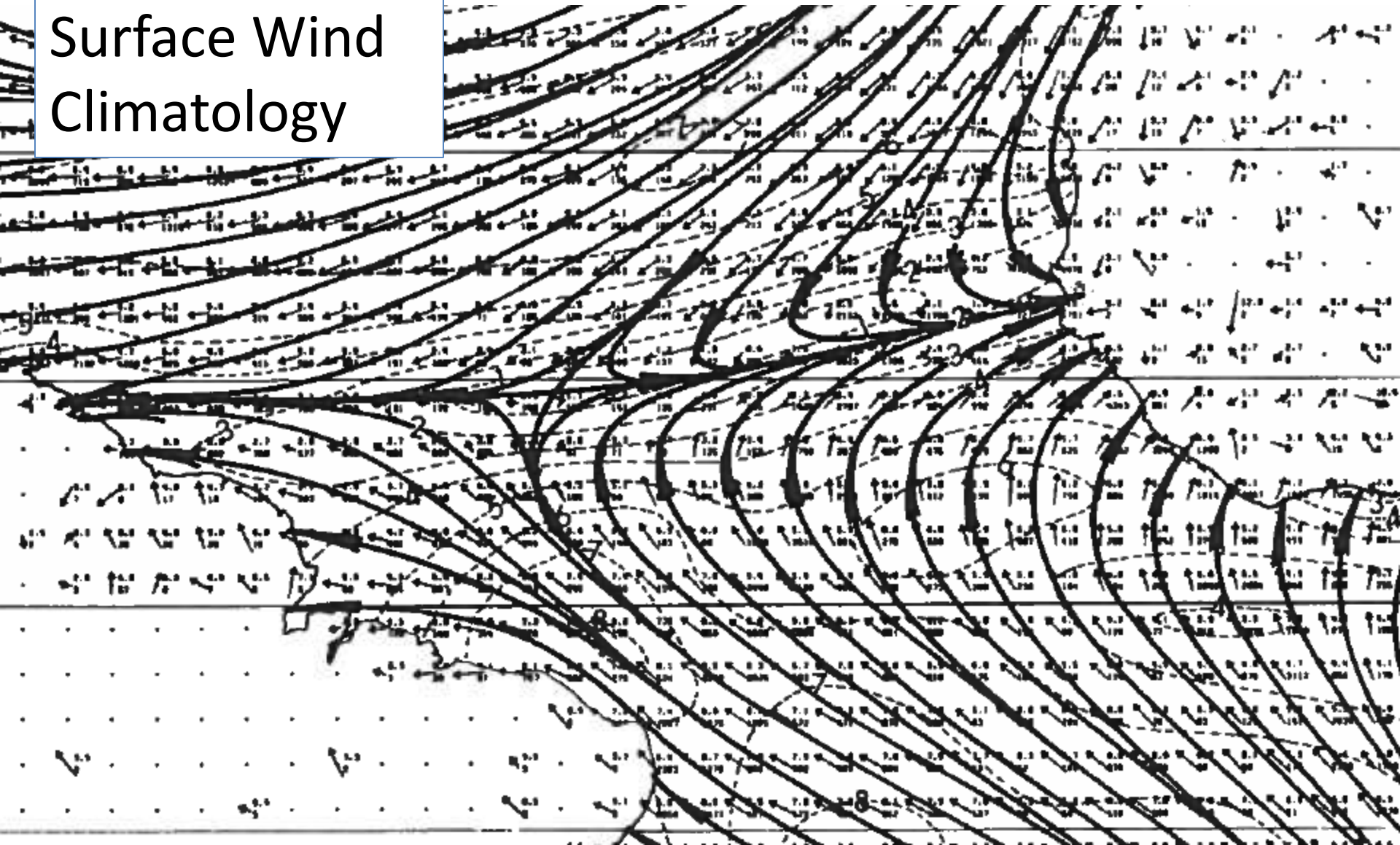
> 150°
Wind
Shift



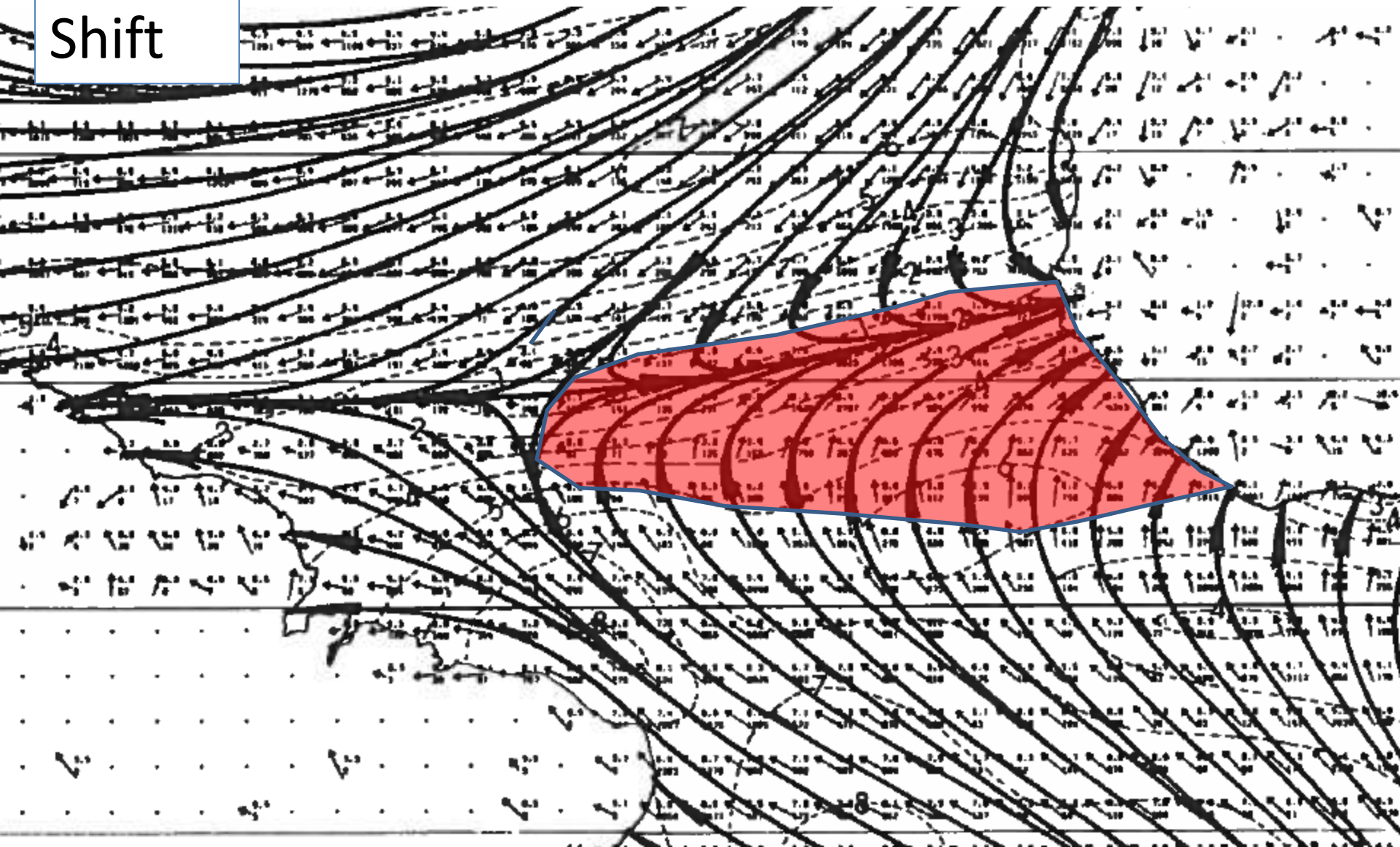
Atlantic February Surface Wind Climatology

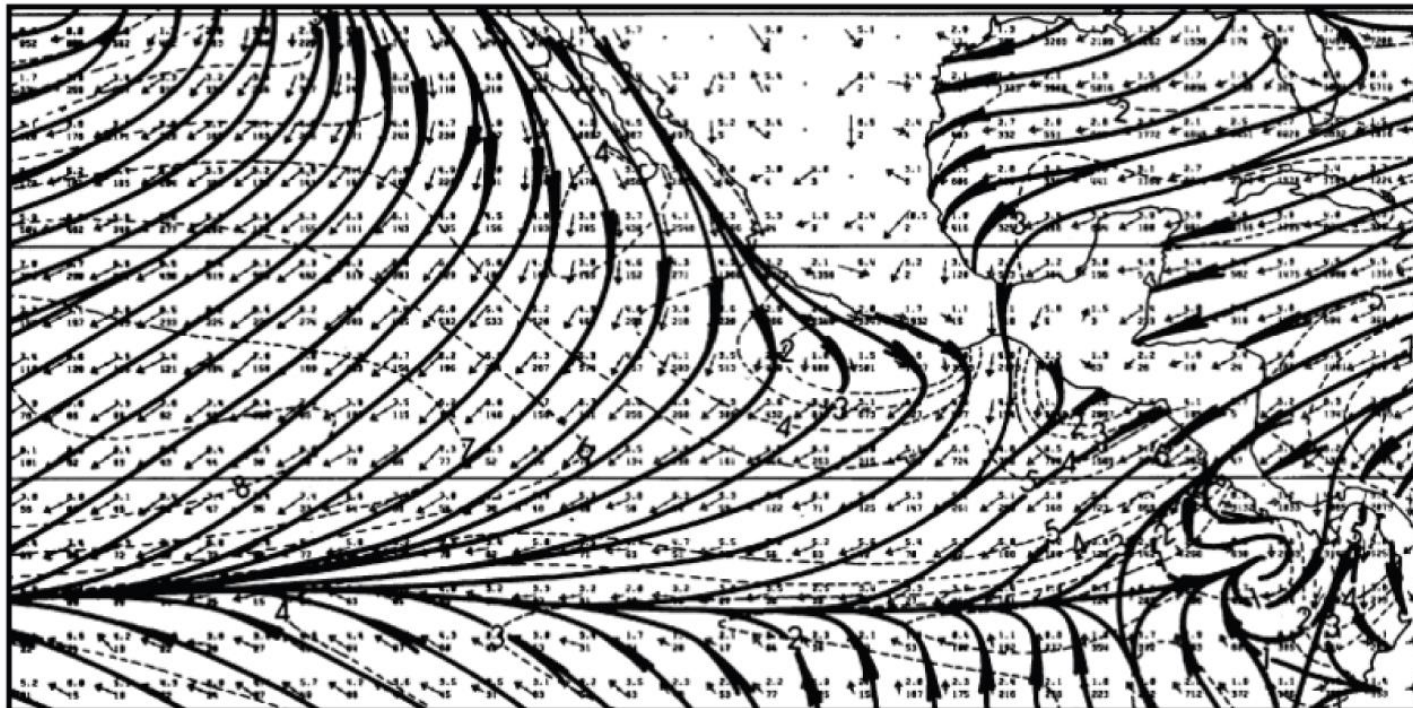


Atlantic August Surface Wind Climatology



> 150°
Wind
Shift





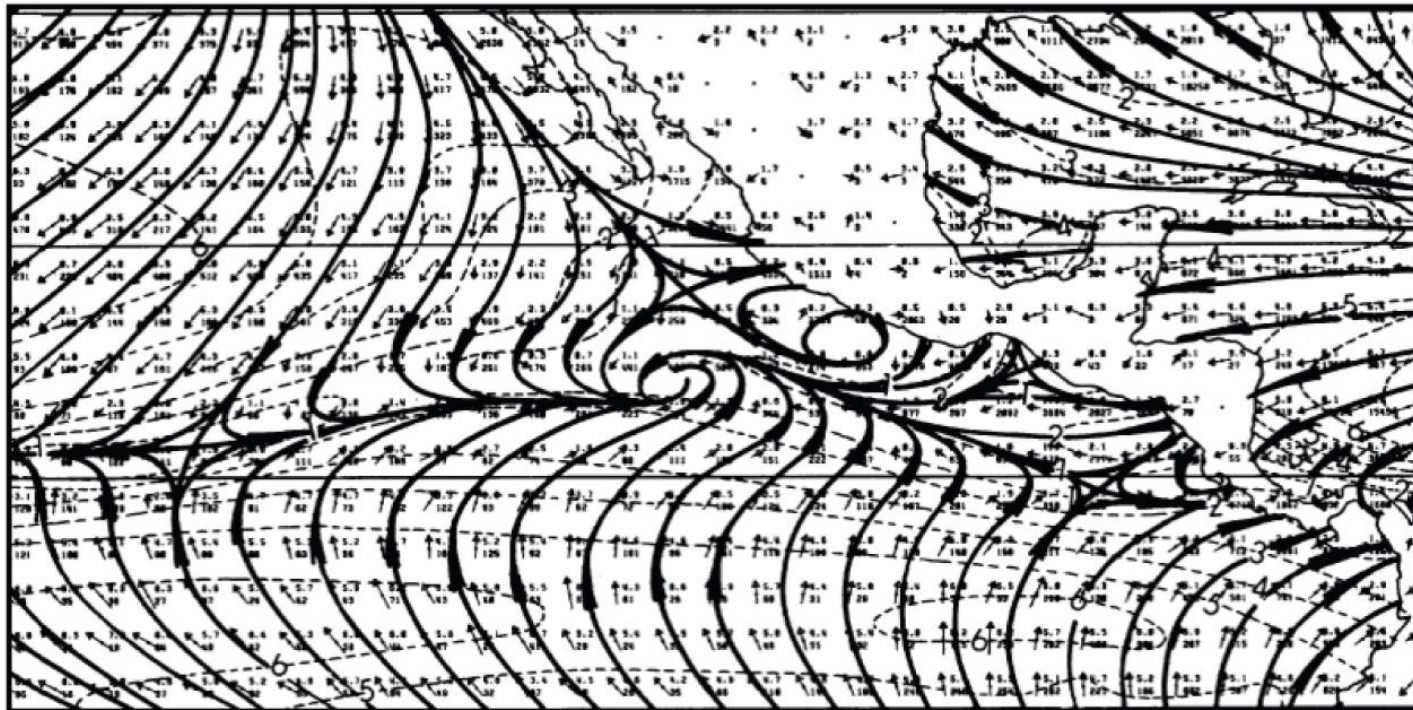
Surface Winds

Pacific

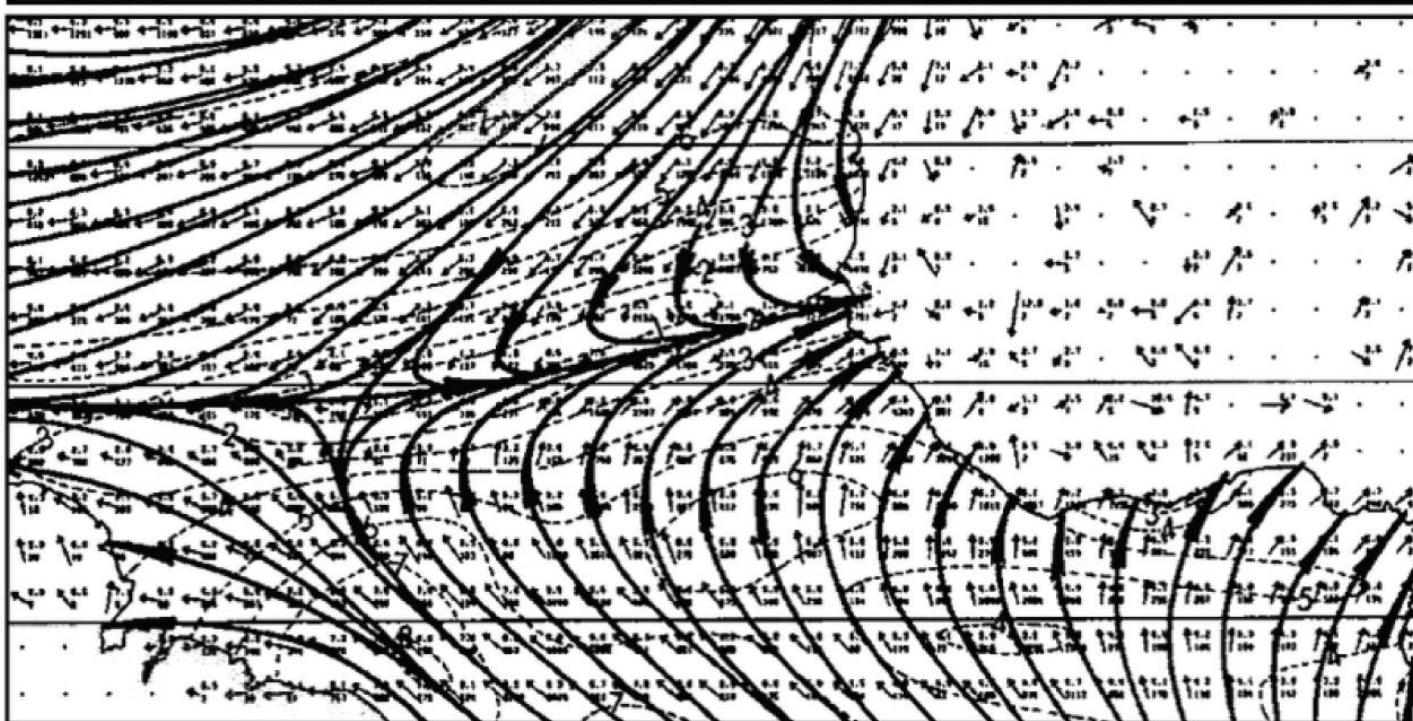


February
Climatological
streamlines

Atlantic



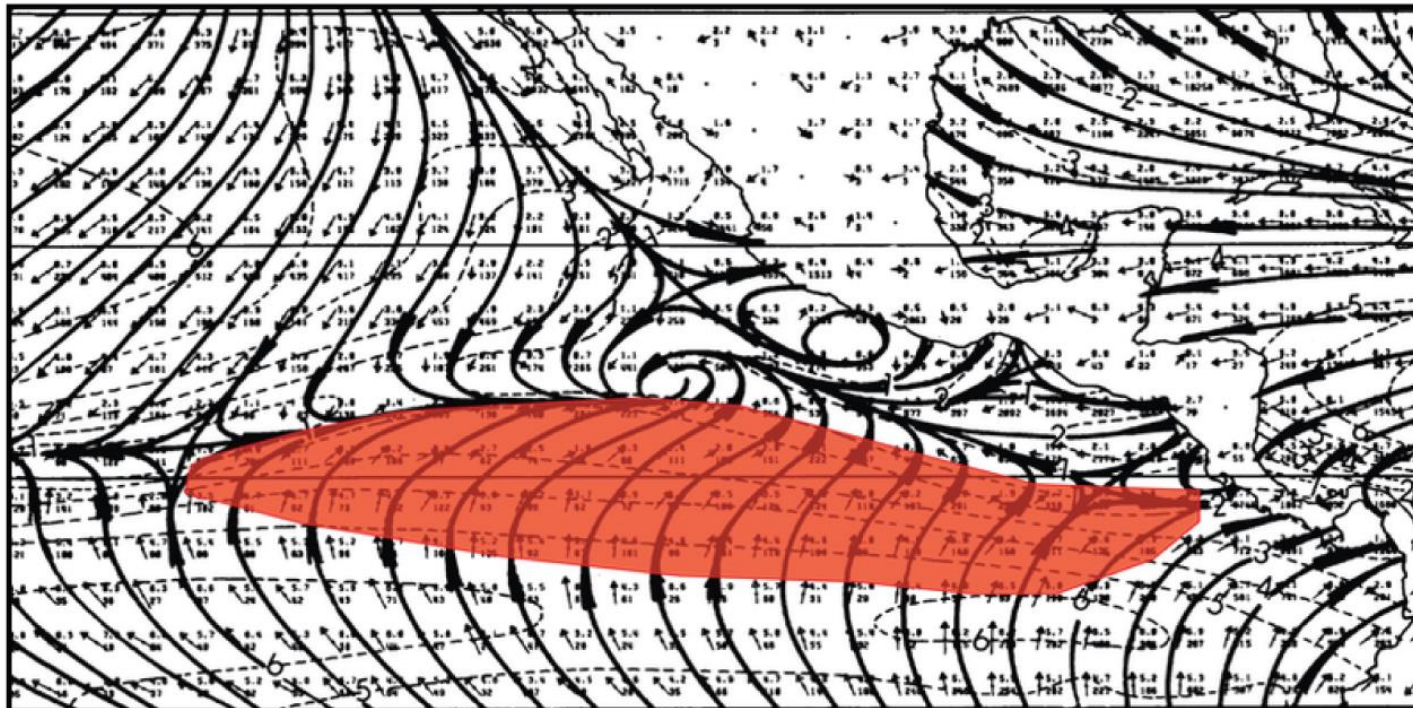
Surface Winds



Pacific

August
Climatological
streamlines

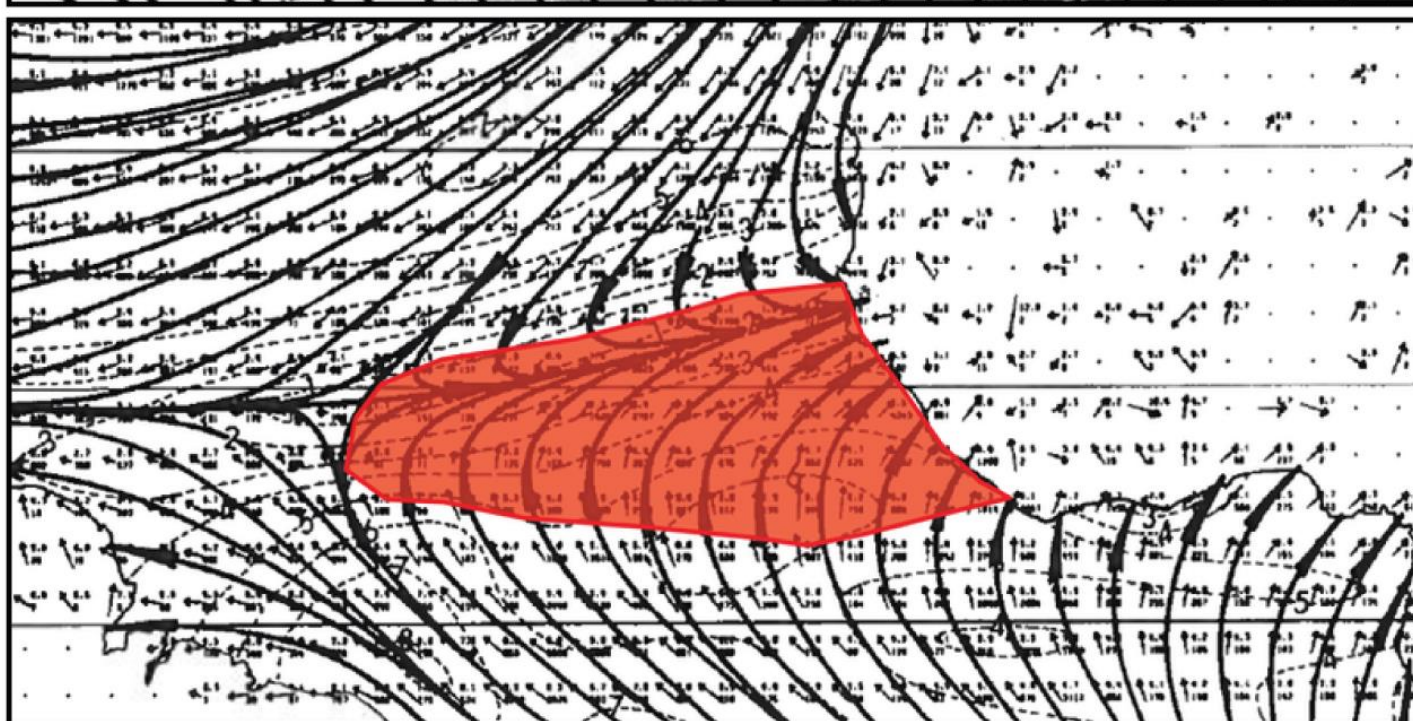
Atlantic



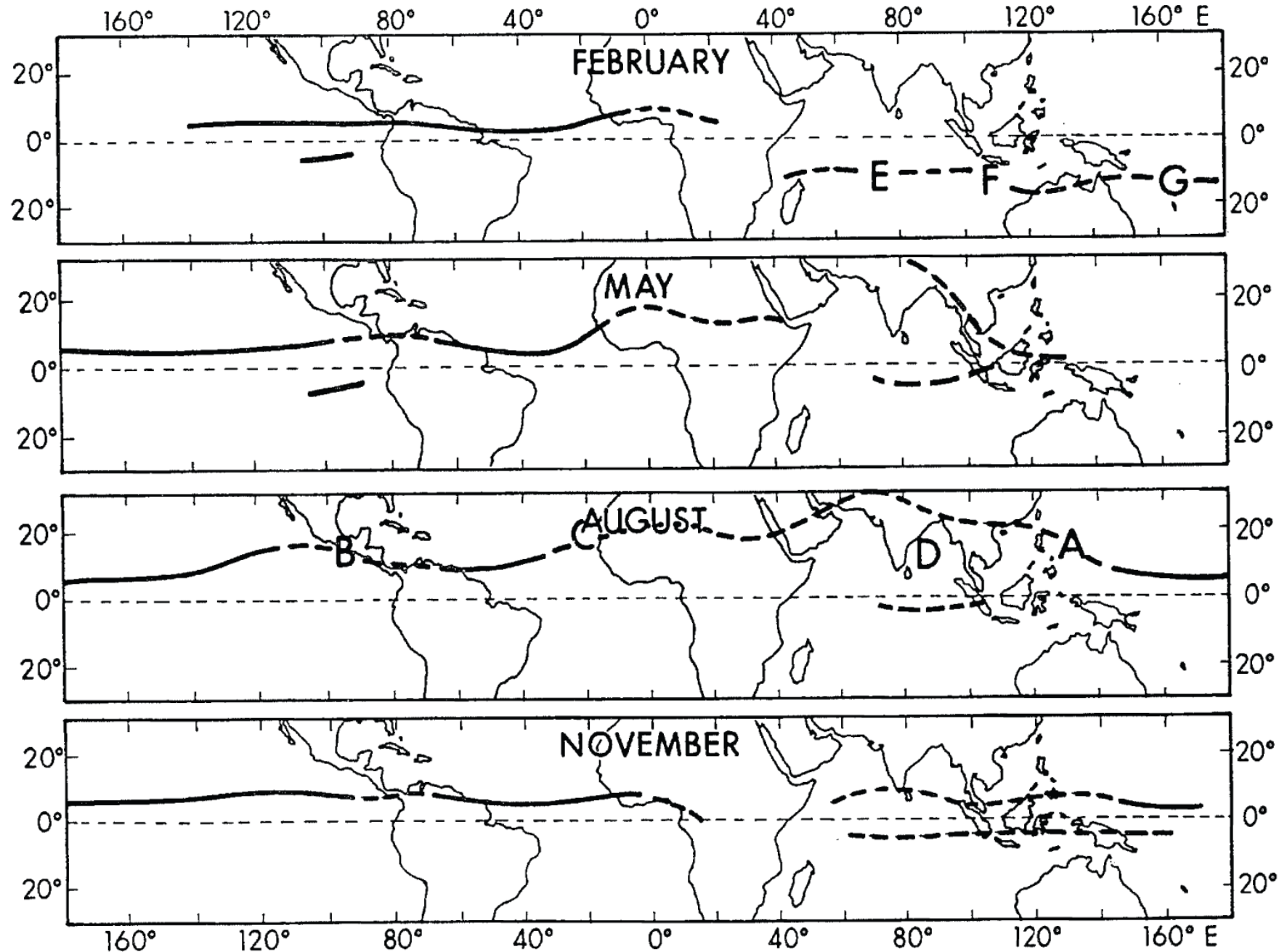
Surface Winds

Pacific

Climatological
Feb-Aug wind
shift $> 150^\circ$

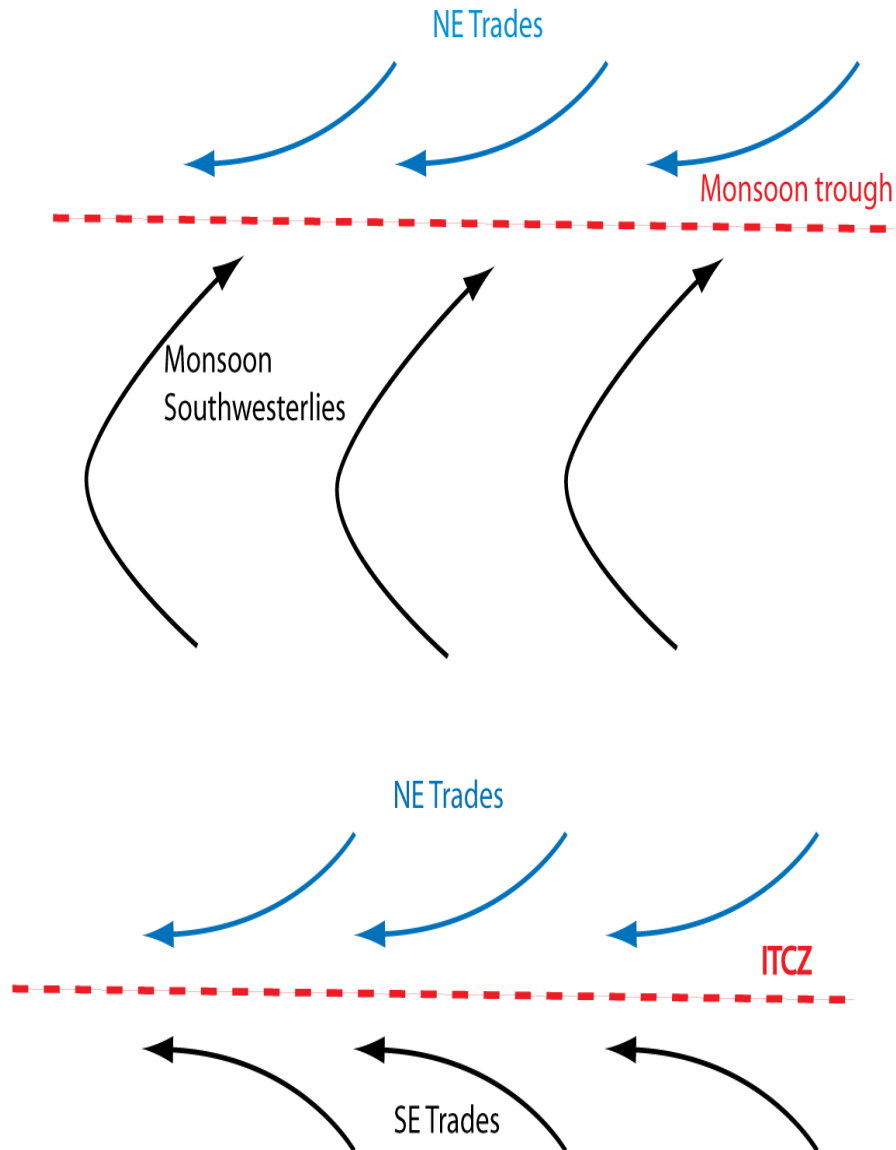


Atlantic



Locations of near-equatorial tradewind convergence (solid lines) and the monsoon troughs (dashed lines) (from Ramage, 1995 adapted from Atkinson and Sadler, 1970).

Monsoon Trough vs. ITCZ



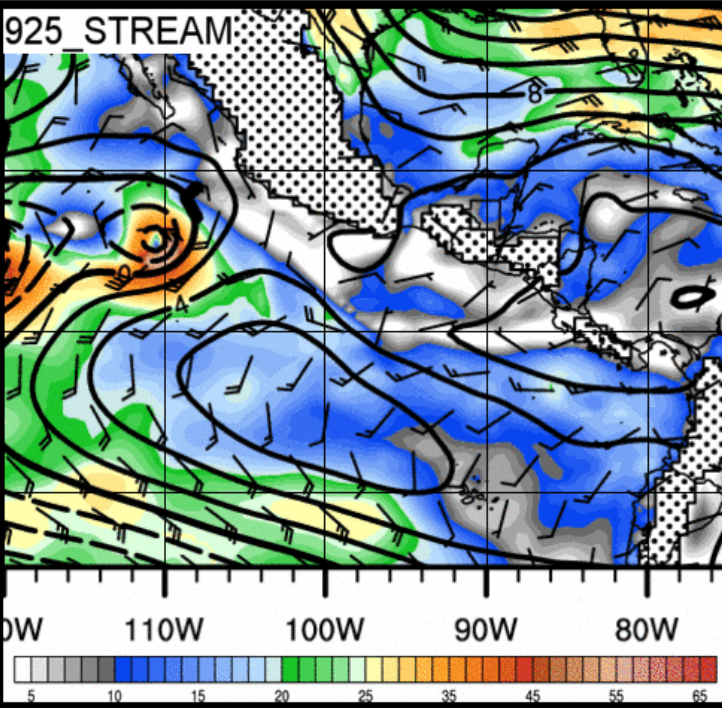
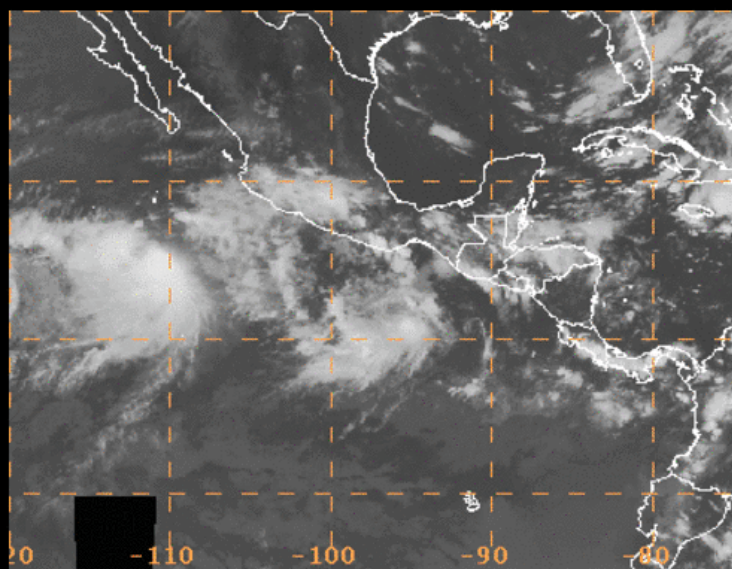
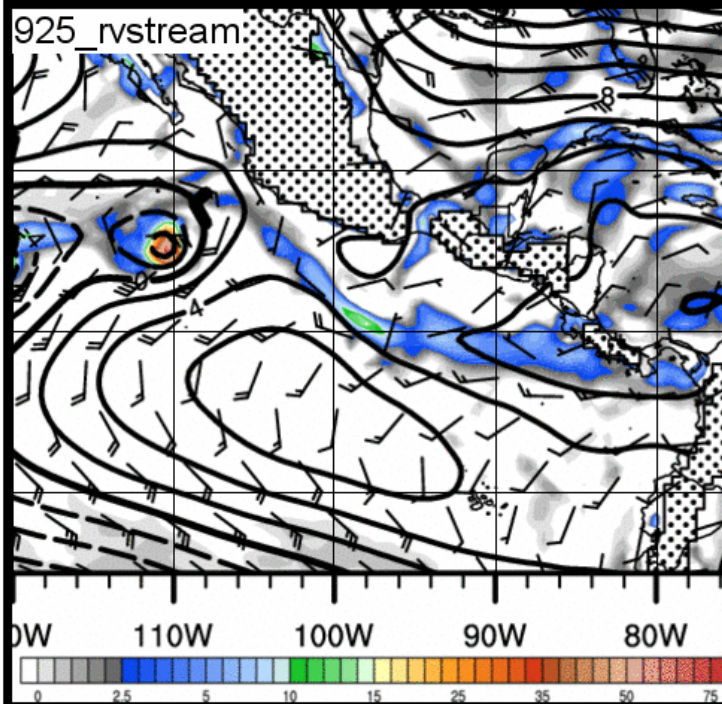
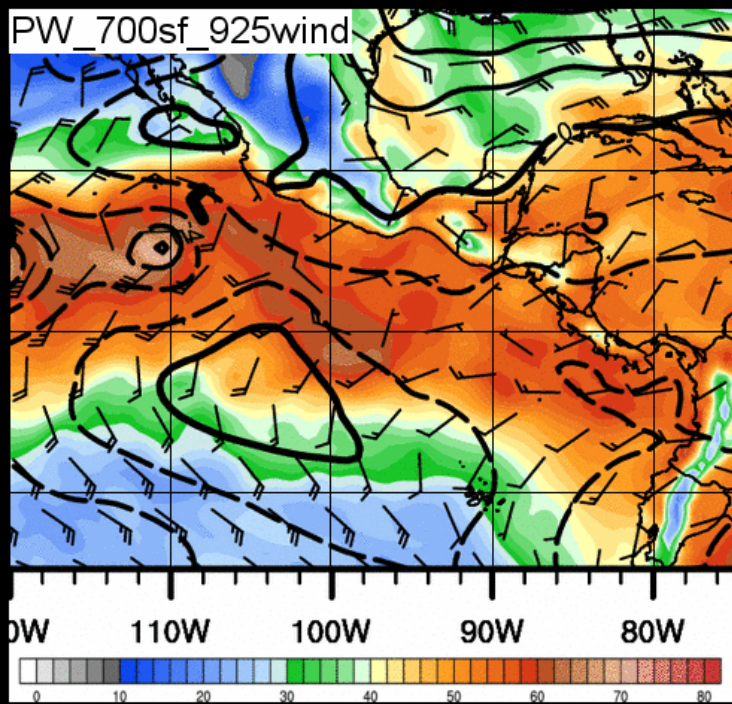
Intertropical Convergence Zone and Monsoon Trough Definitions used at NHC

- **Monsoon Trough** - A surface trough in association with a monsoon circulation. This is depicted by a line on a weather map showing the location of minimum sea level pressure coinciding with the maximum cyclonic turning of the surface winds, with southwesterly or northwesterly flow prevailing equatorward and northeasterly flow prevailing poleward of the typically zonally oriented trough axis.
- **Monsoon** - A large-scale, seasonally-reversing surface wind circulation in the tropics accompanied by large amplitude seasonal changes in precipitation.
- **Inter-Tropical Convergence Zone** - a zonally elongated axis of surface wind confluence typically of northeasterly and southeasterly trade winds in the tropics.

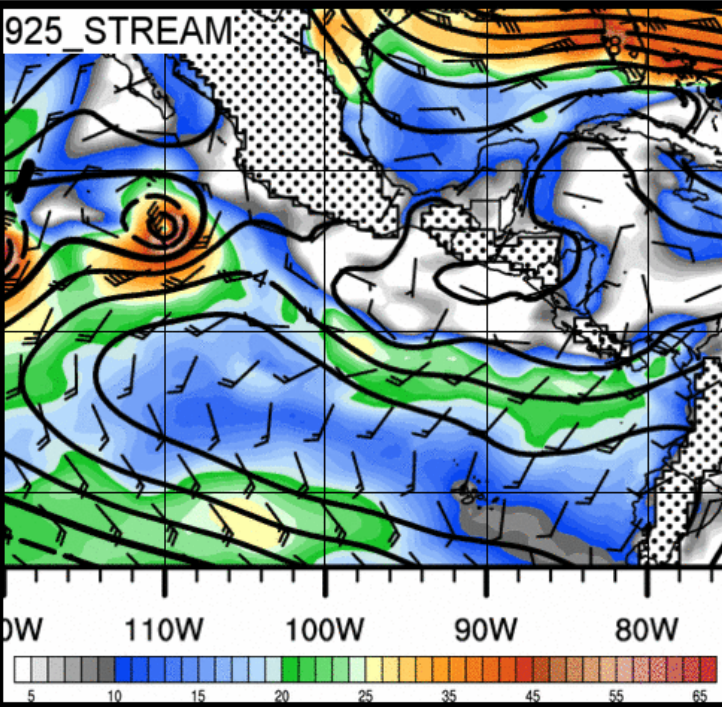
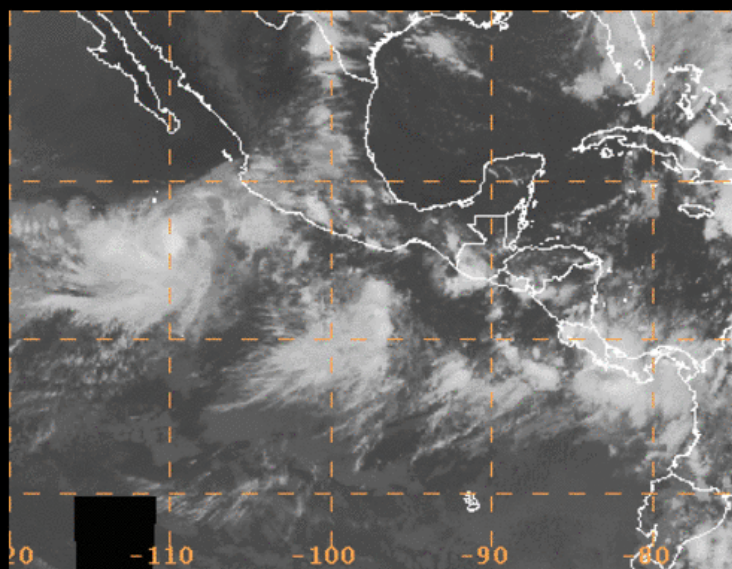
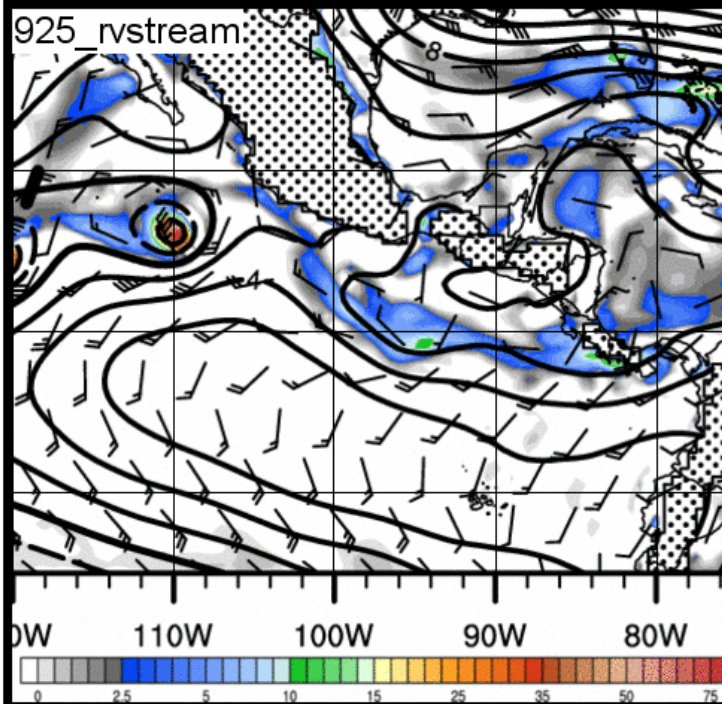
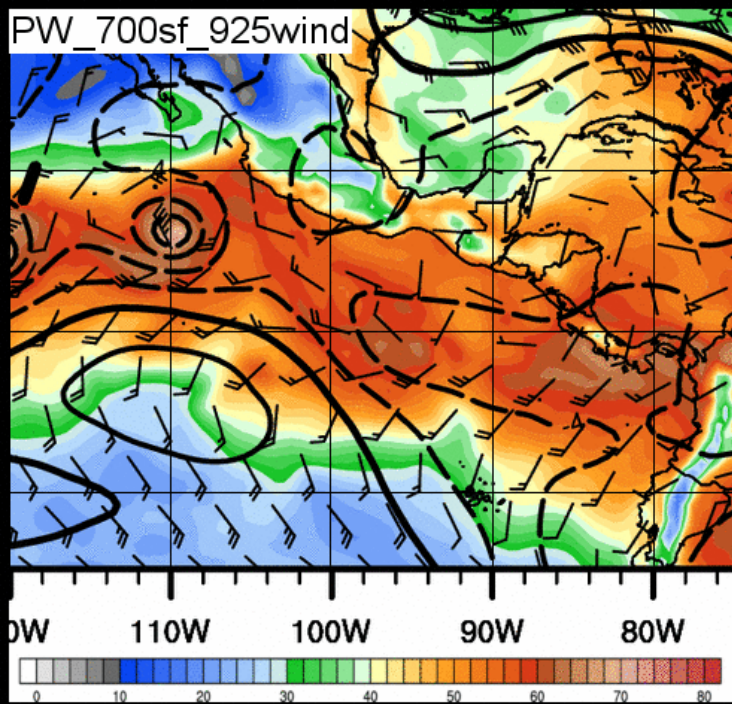
Impacts of monsoon trough

Heavy rain events over Central America and Southern Mexico as an active monsoon trough moves northward

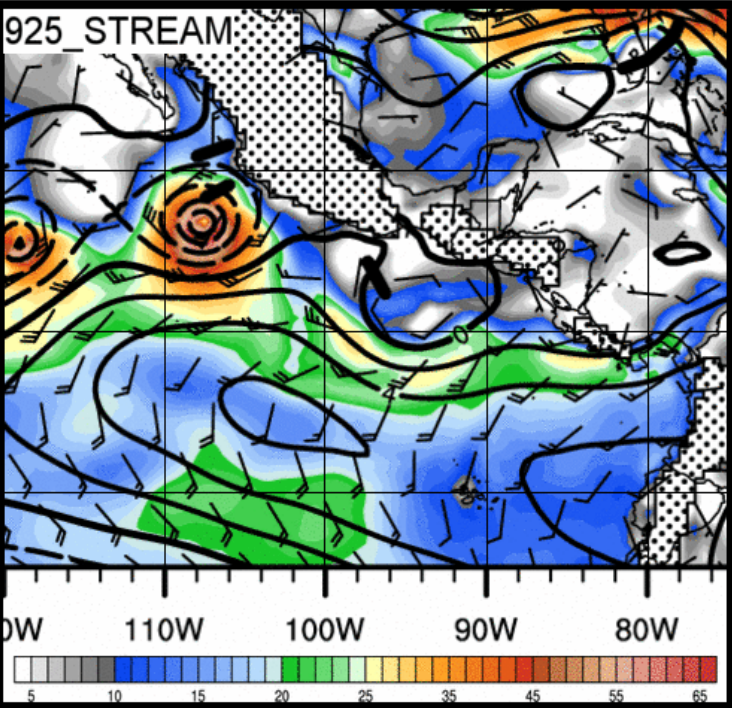
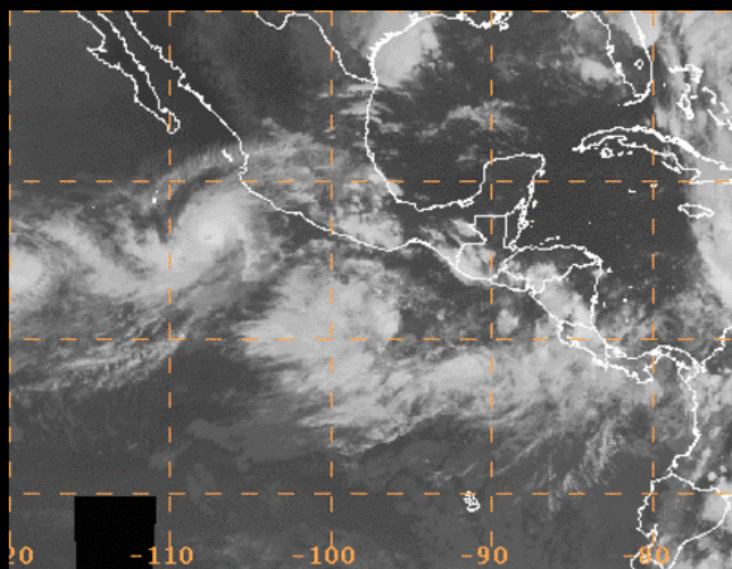
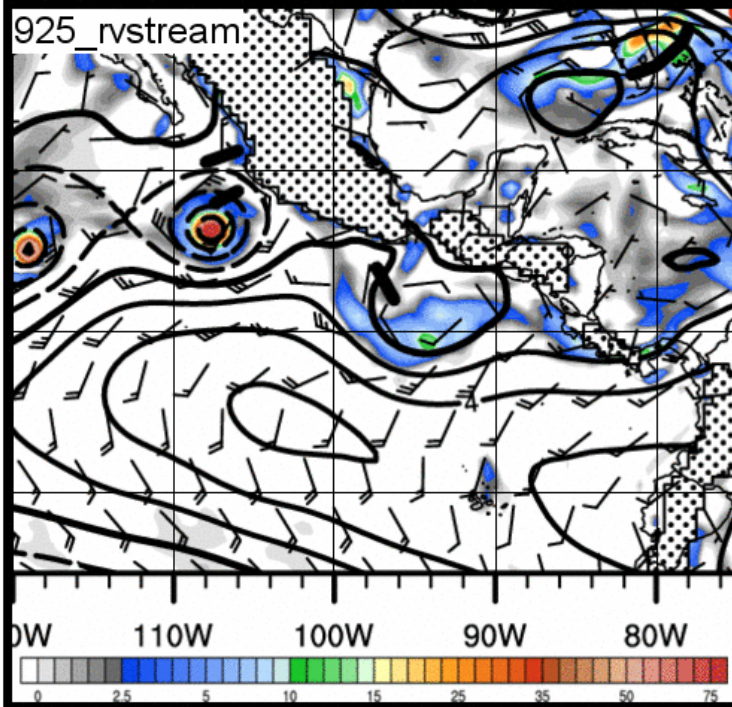
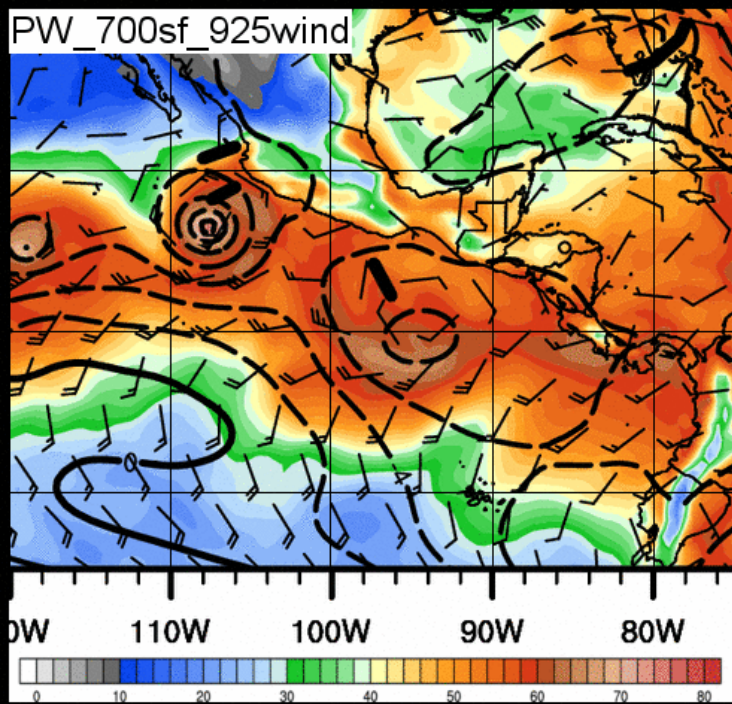




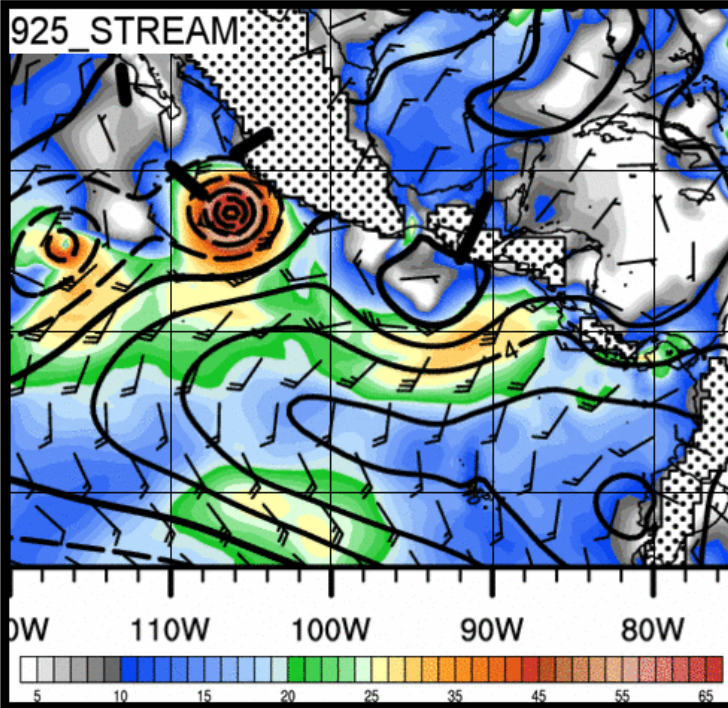
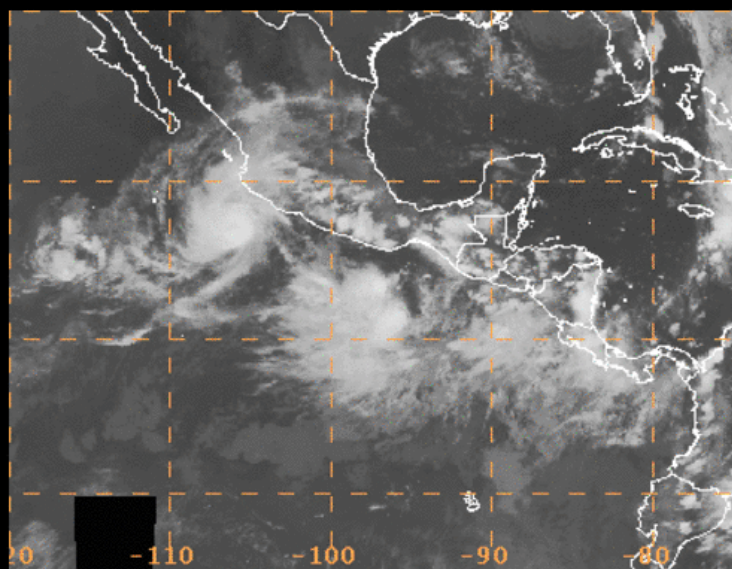
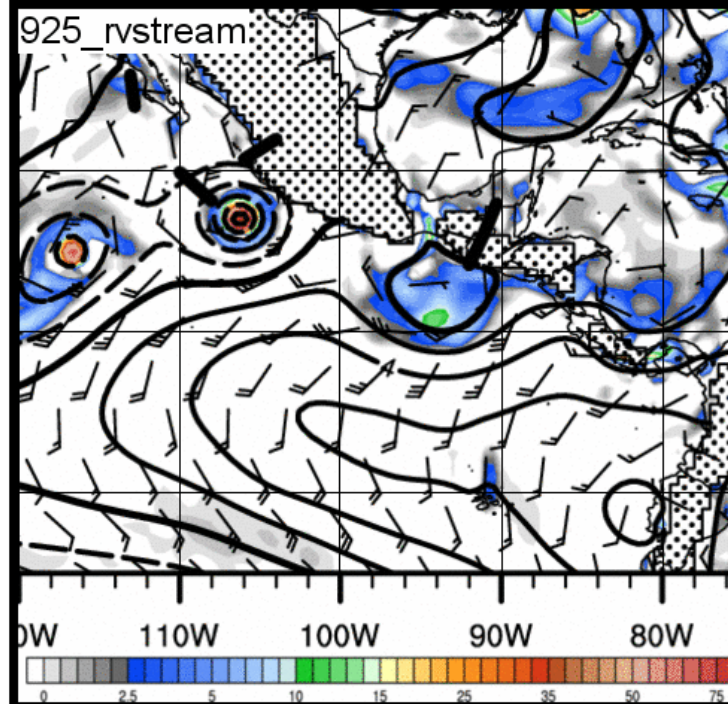
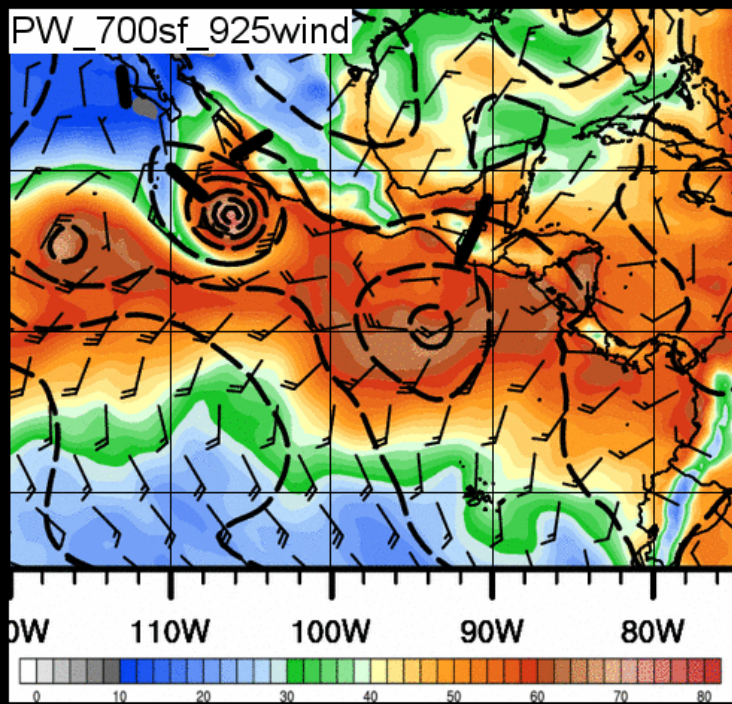
Oct 08, 2011
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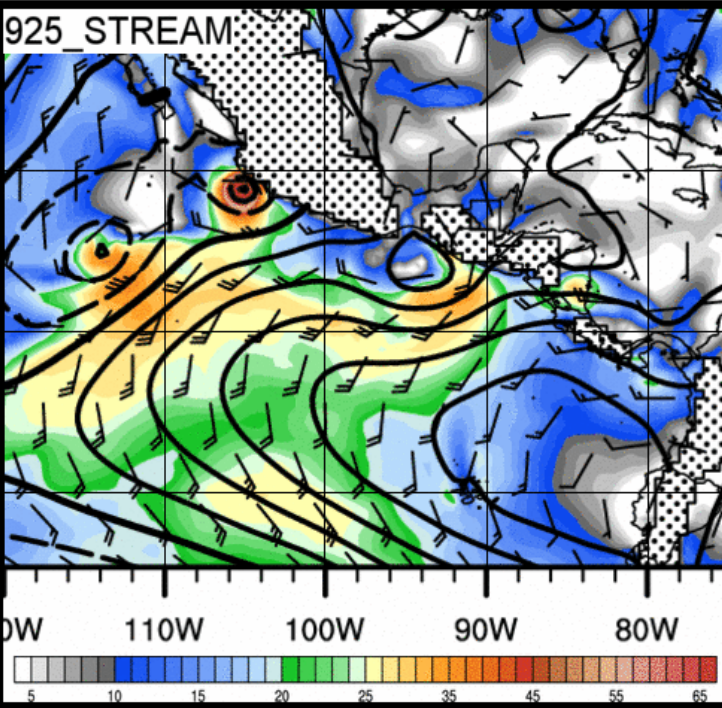
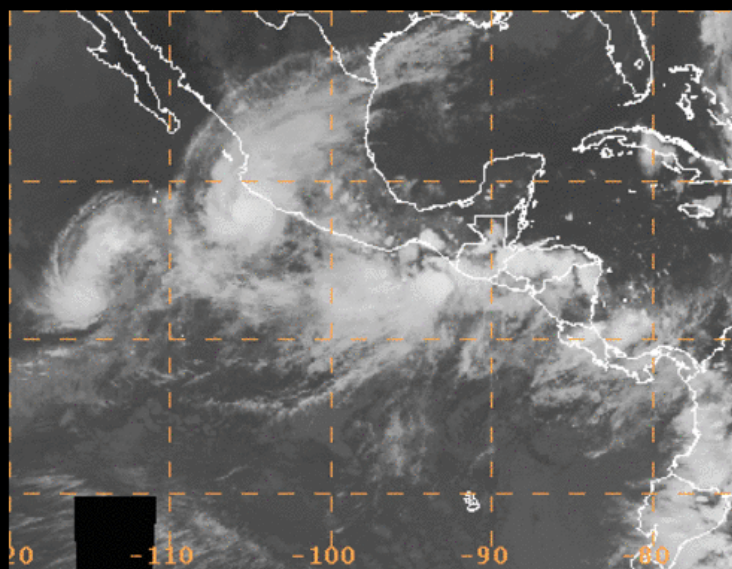
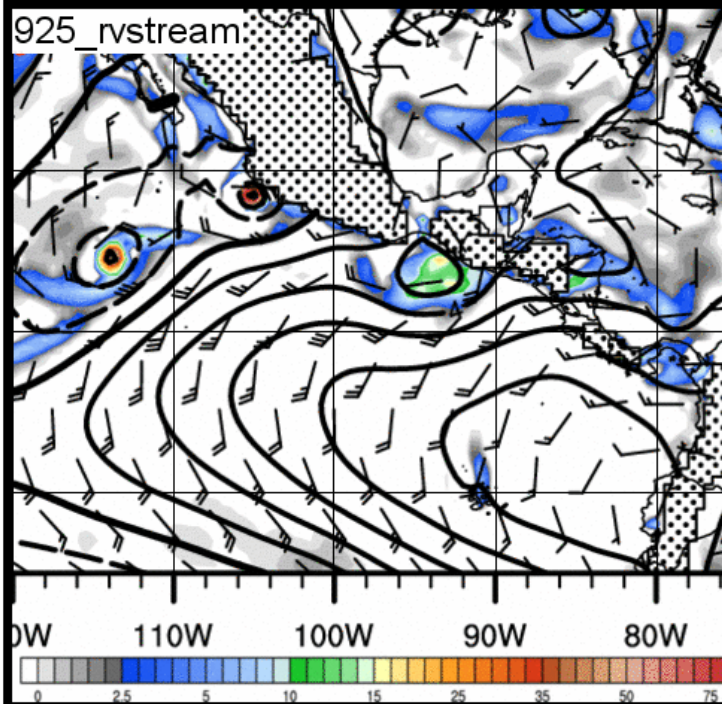
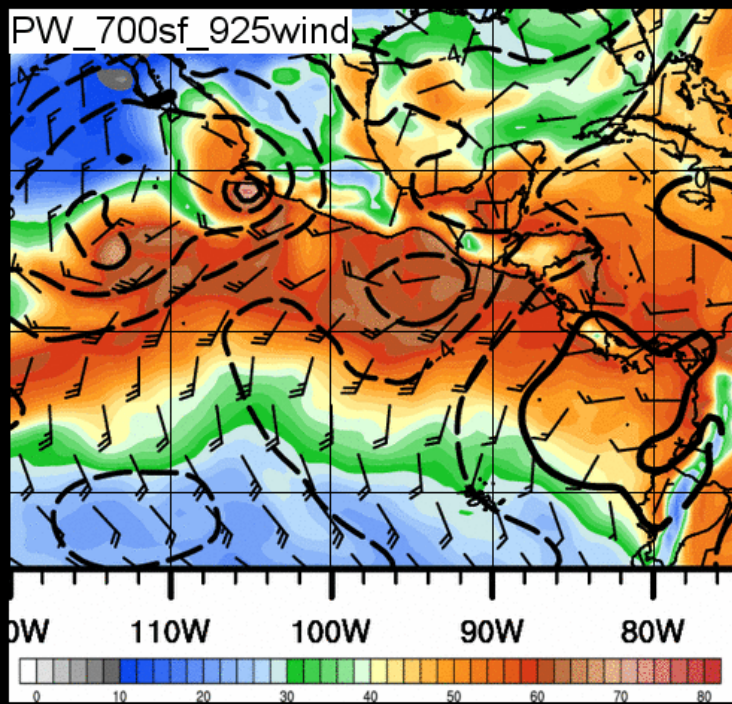
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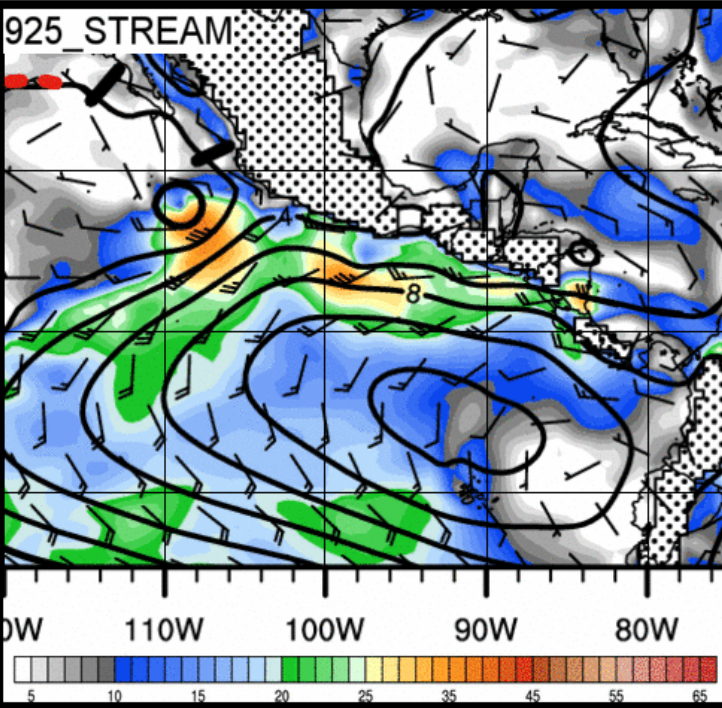
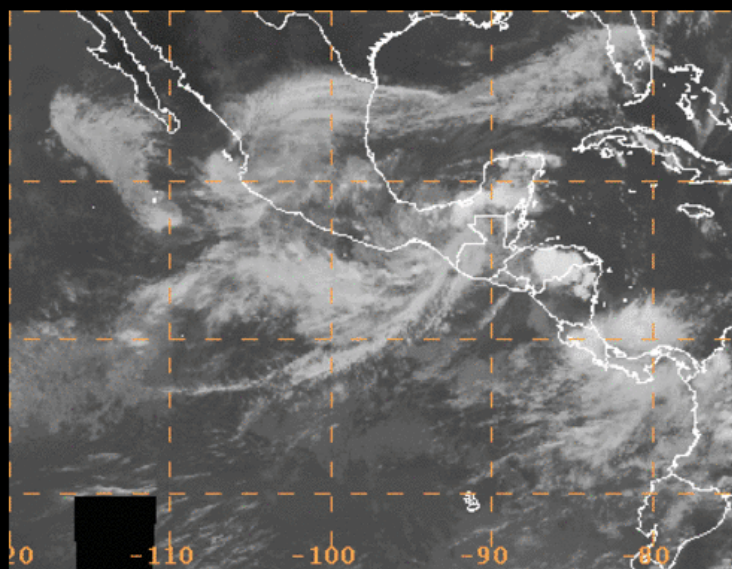
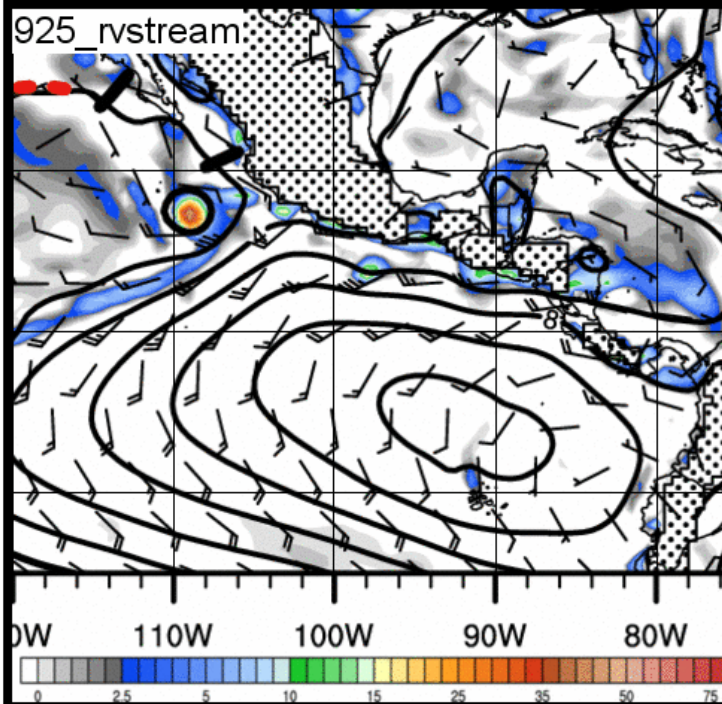
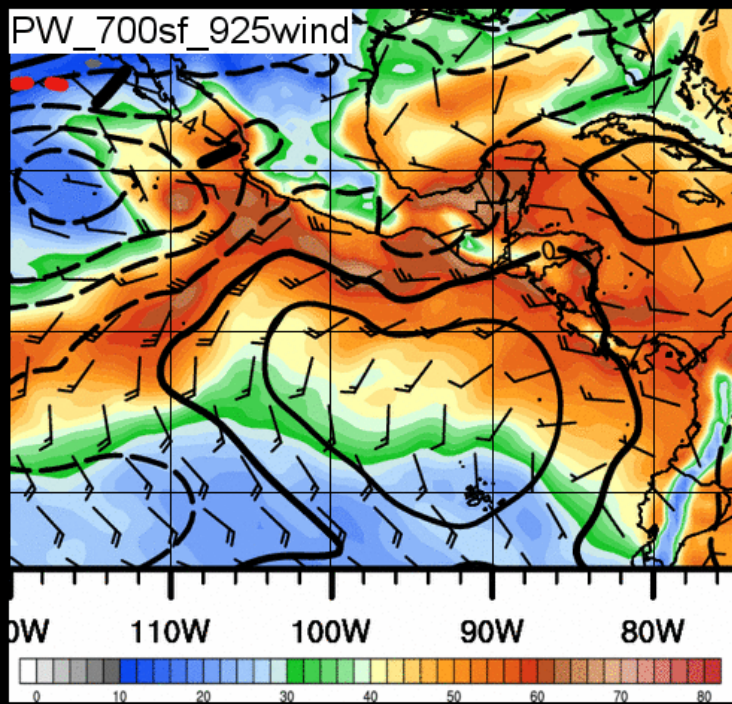
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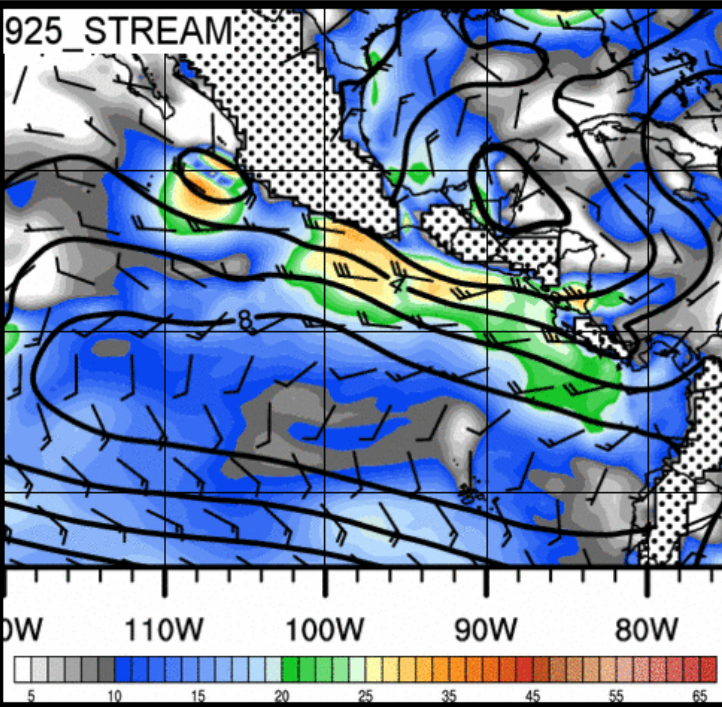
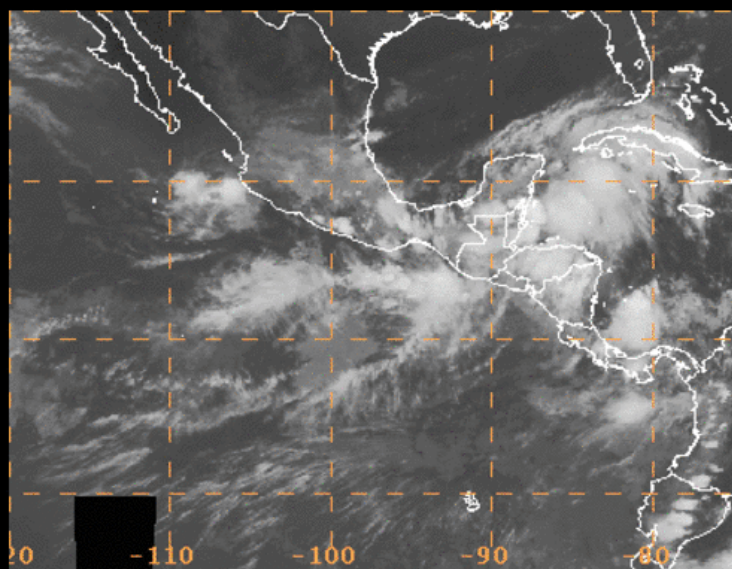
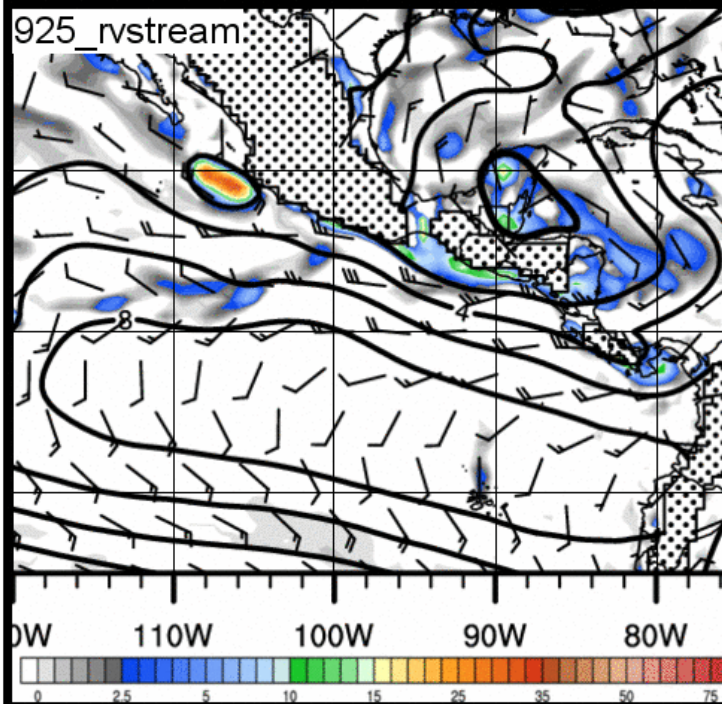
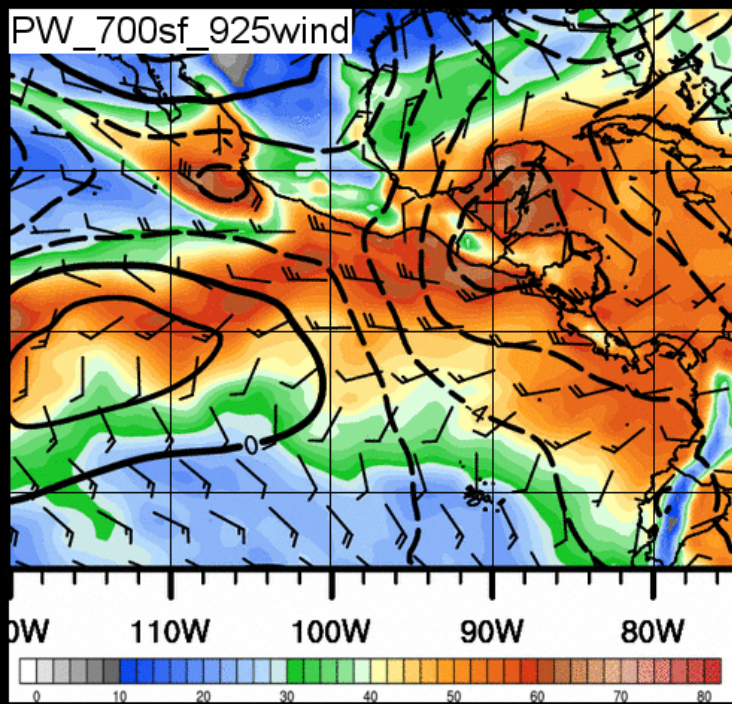
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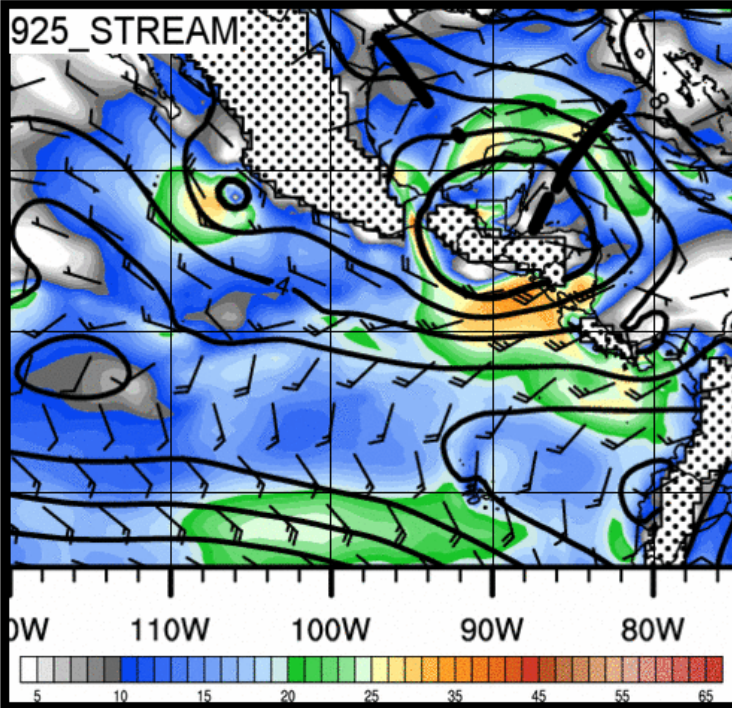
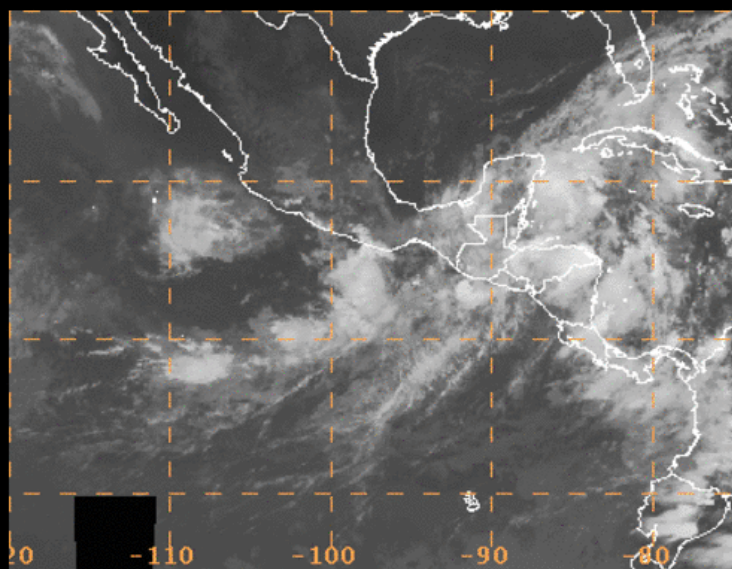
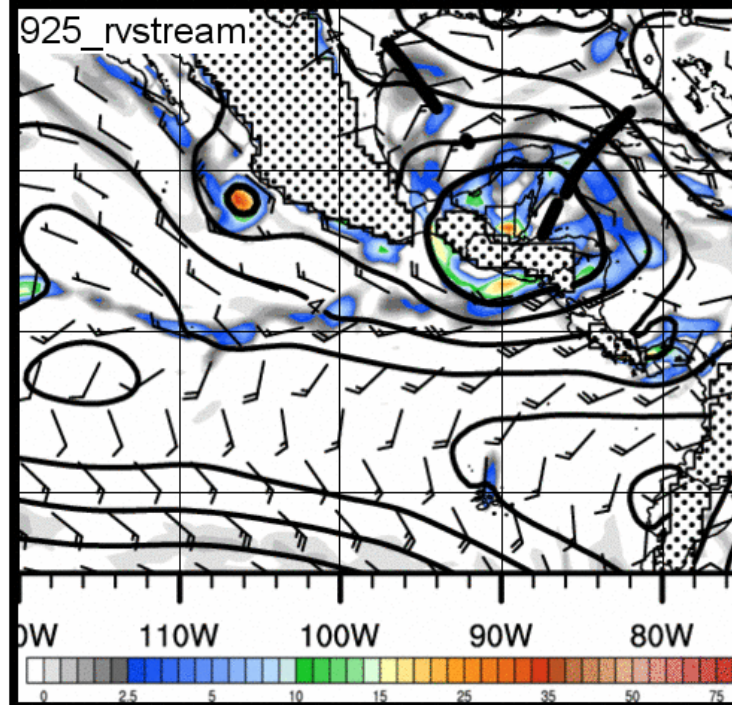
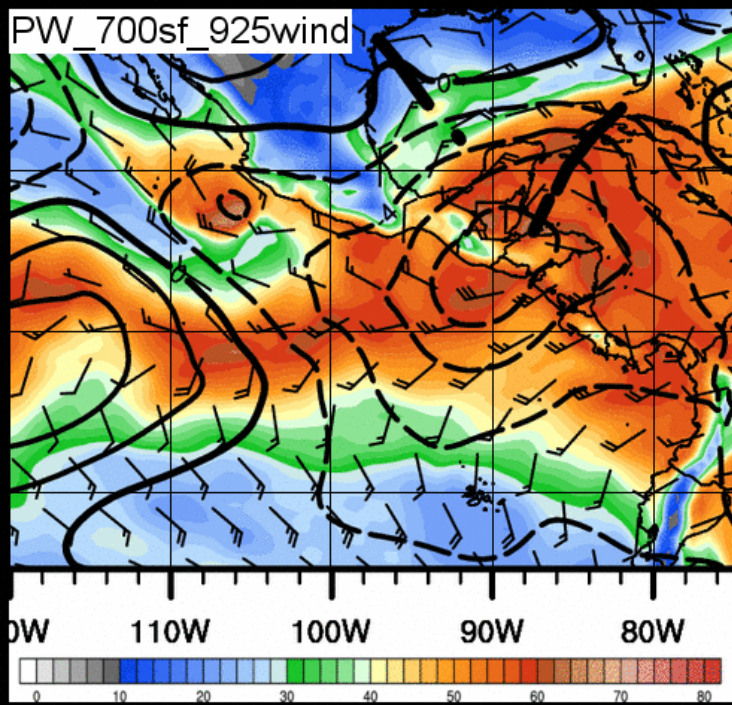
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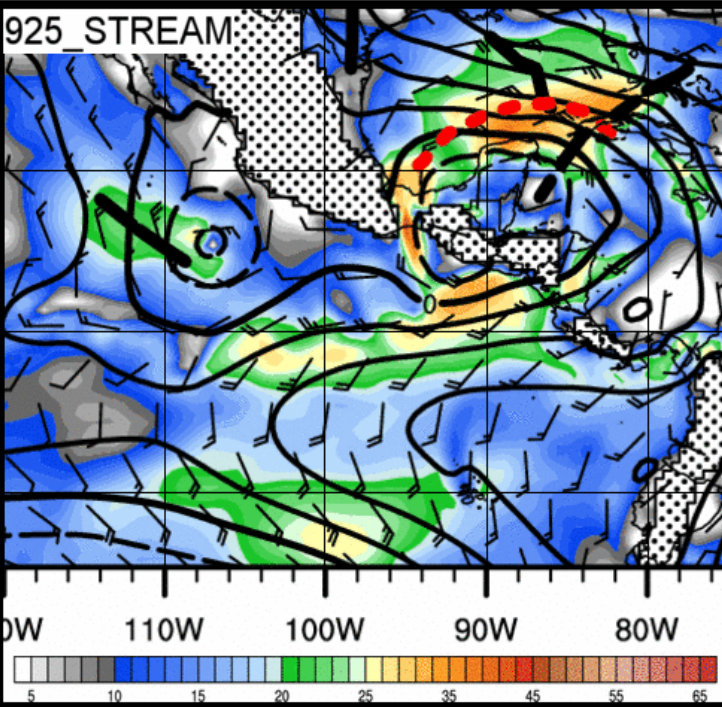
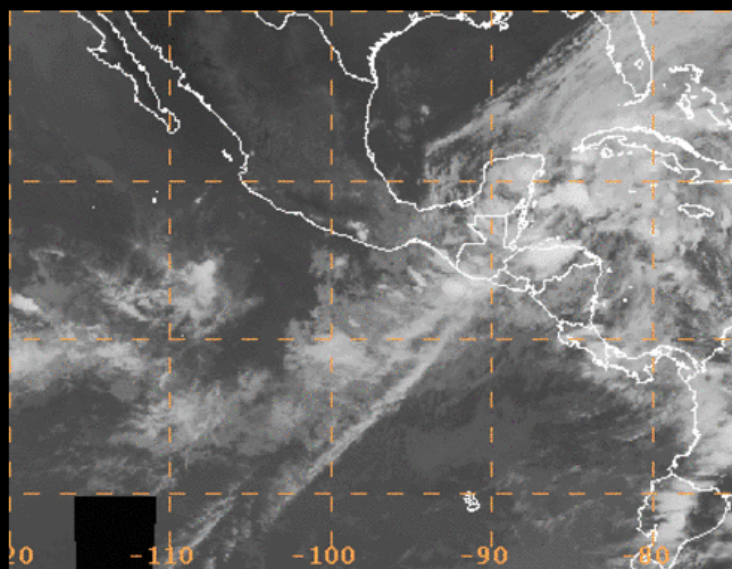
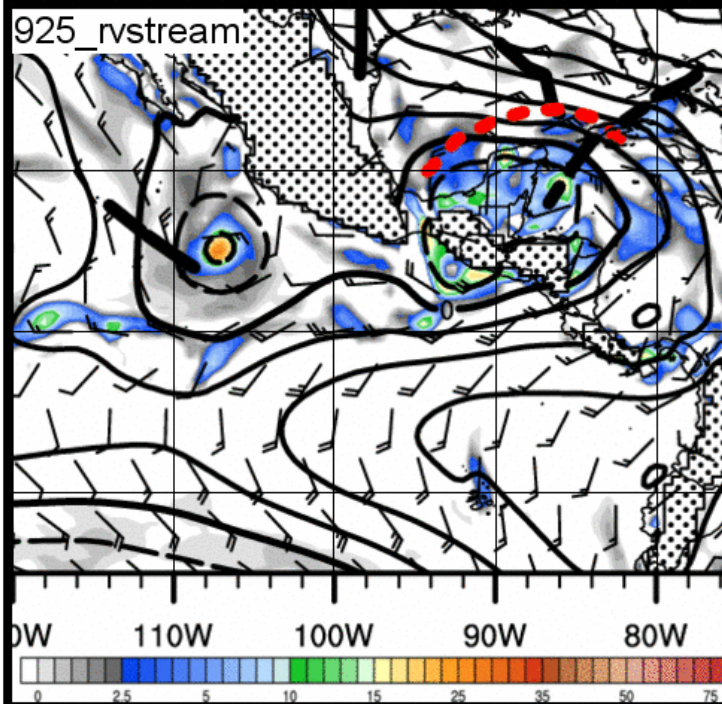
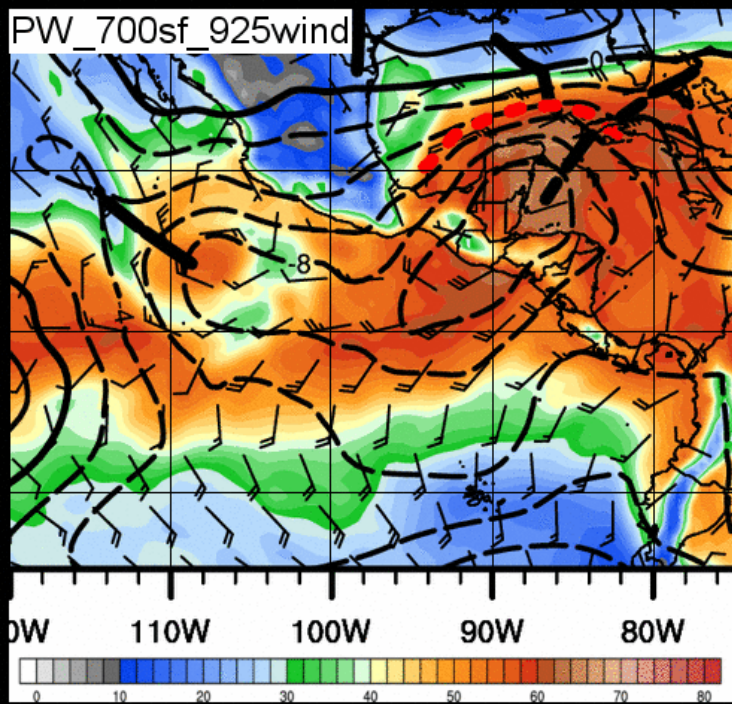
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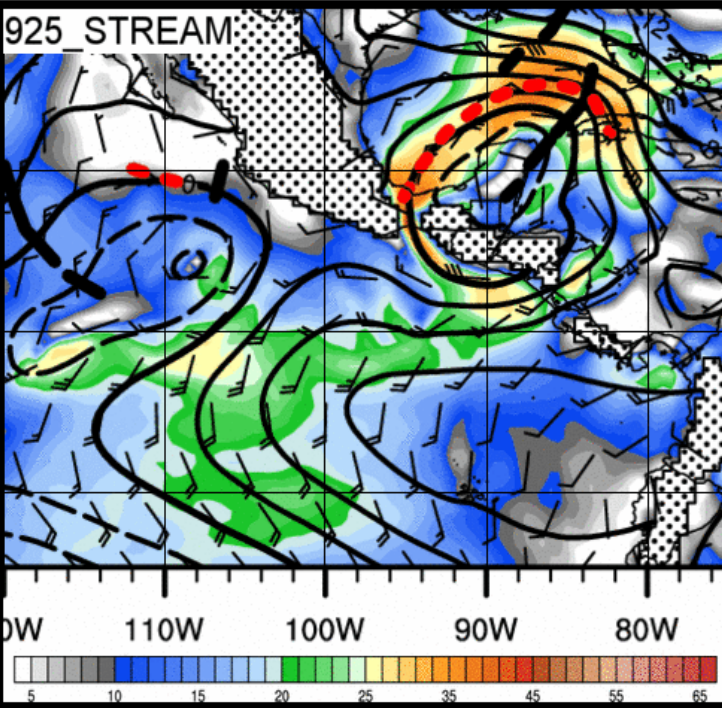
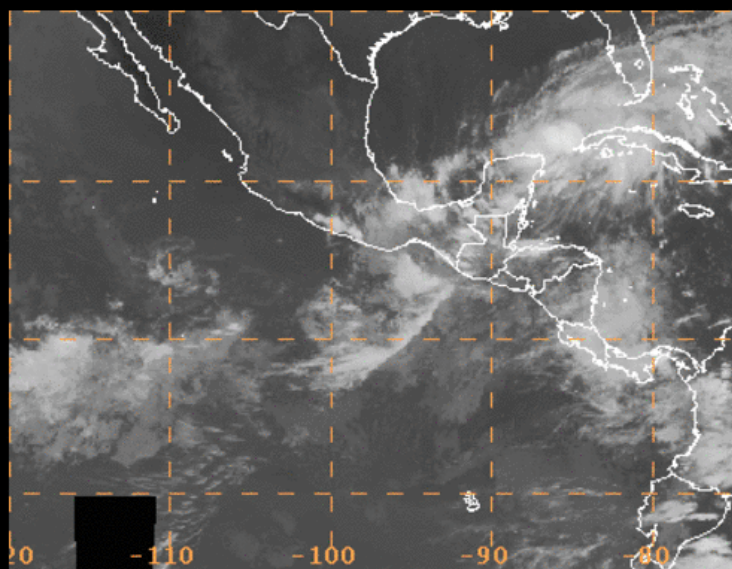
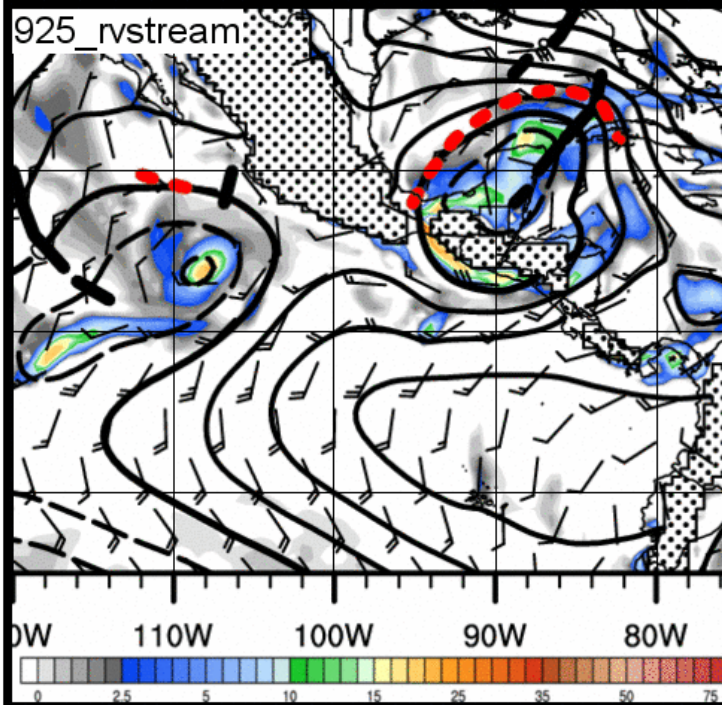
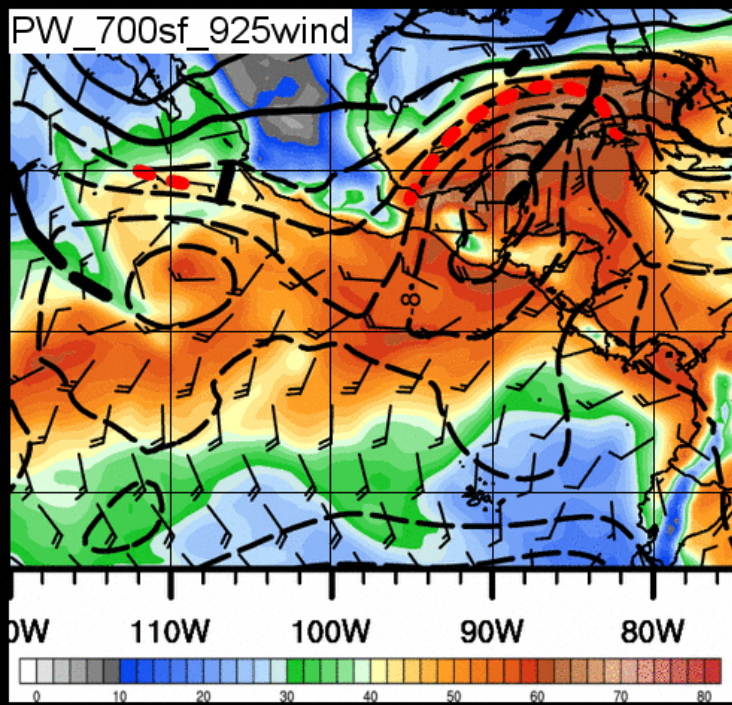
Oct 14, 2011
00 UTC



Oct 15, 2011
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Oct 16, 2011
00 UTC



Oct 17, 2011
00 UTC



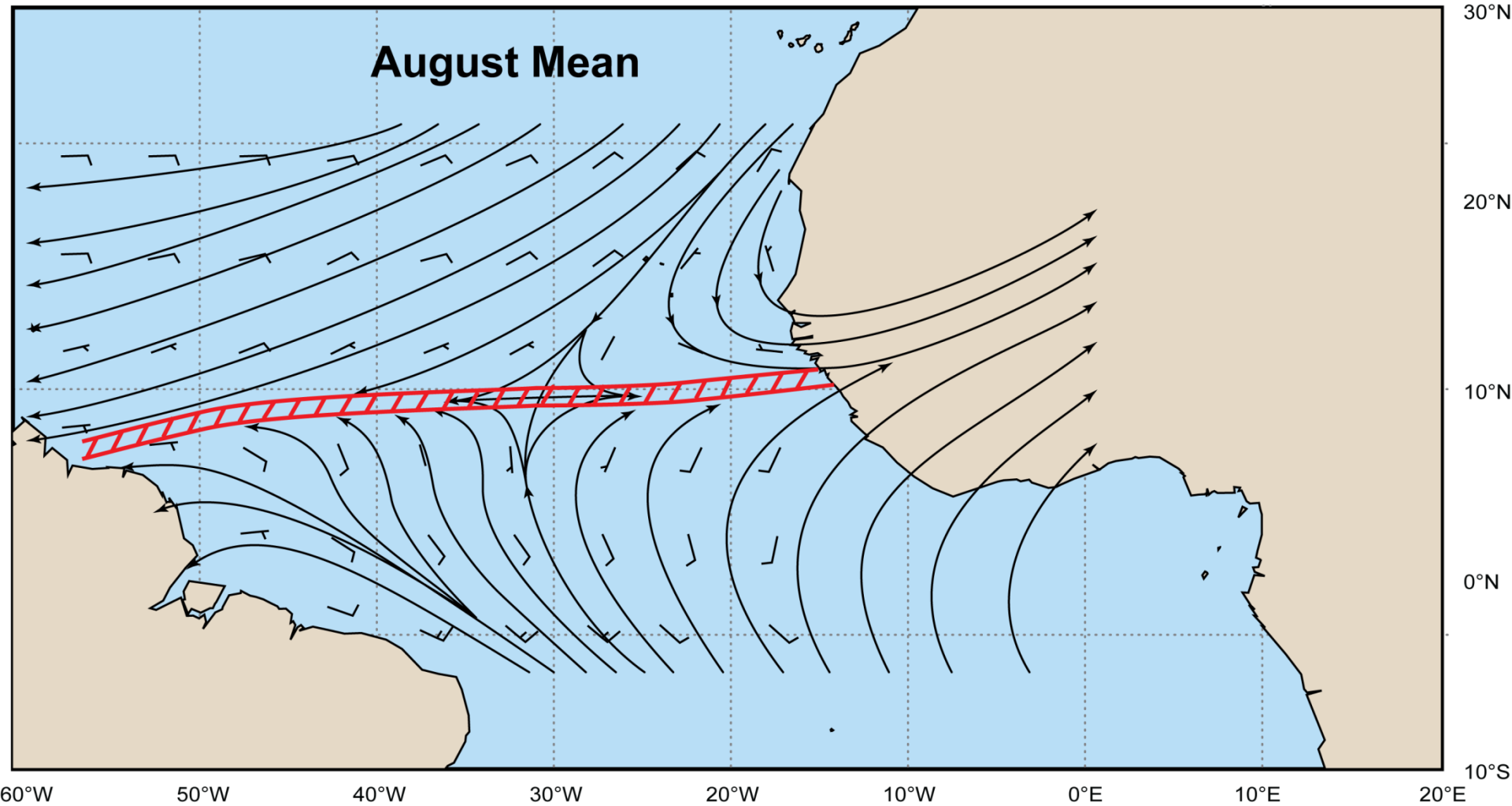
NUMBERS AT A GLANCE

USAID FACT SHEET #1, FISCAL YEAR (FY) 2012 OCTOBER 20, 2011

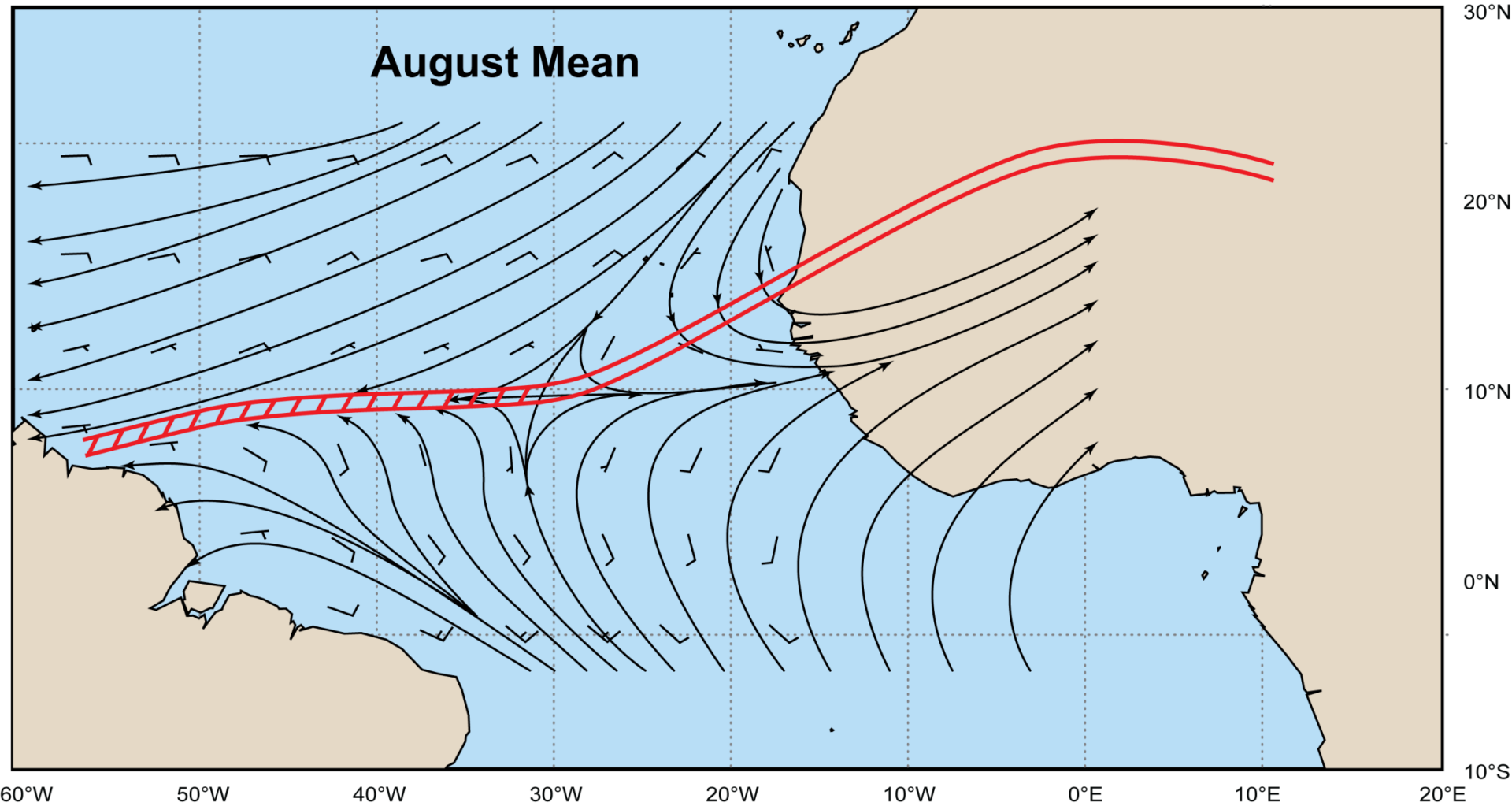
Country	Number Affected	Number Evacuated	Deaths	Source
Guatemala	593,418	29,207	38	GoG ¹ – October 19, 2011
El Salvador	150,000	21,617	32	OCHA ² – October 17, 2011
Honduras	57,788	11,297	13	GoH ³ – October 19, 2011
Nicaragua	134,000	6,920	8	GoN ⁴ – October 17, 2011
Costa Rica	Undetermined	1,000	Undetermined	GoCR ⁵ – October 18, 2011

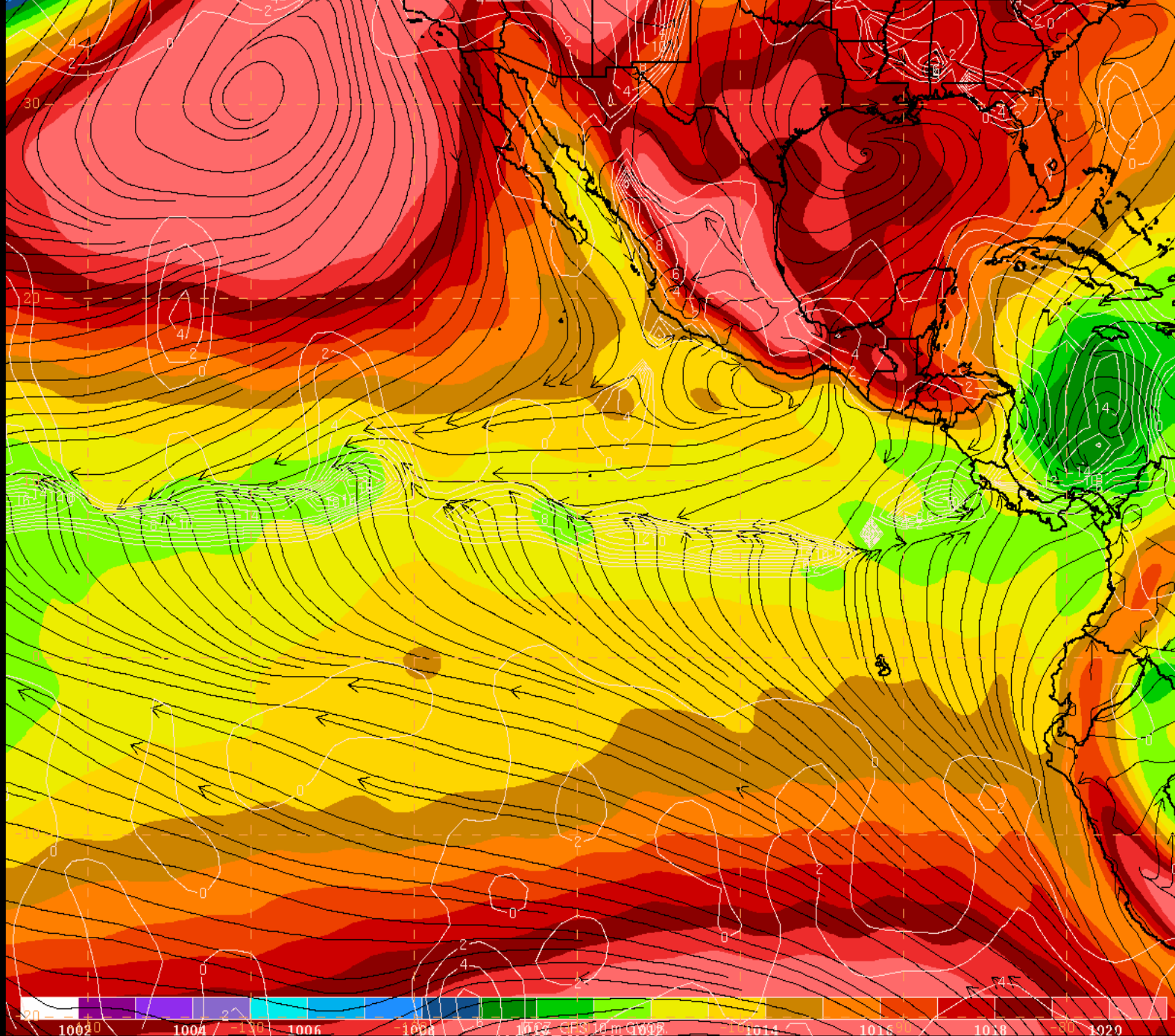
Depicting the monsoon trough and ITCZ on the Unified Surface Analysis

Previous depiction

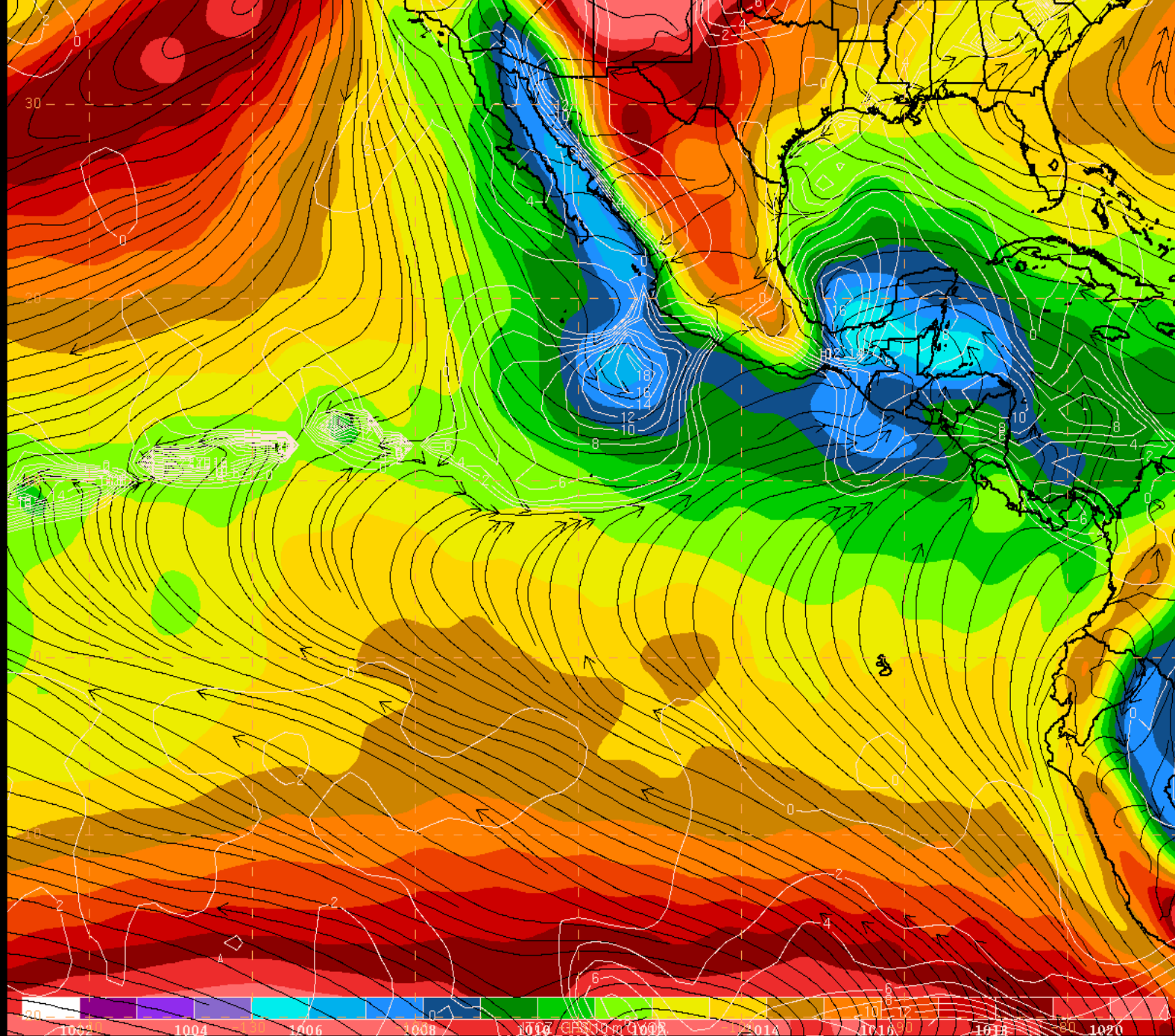


Current depiction

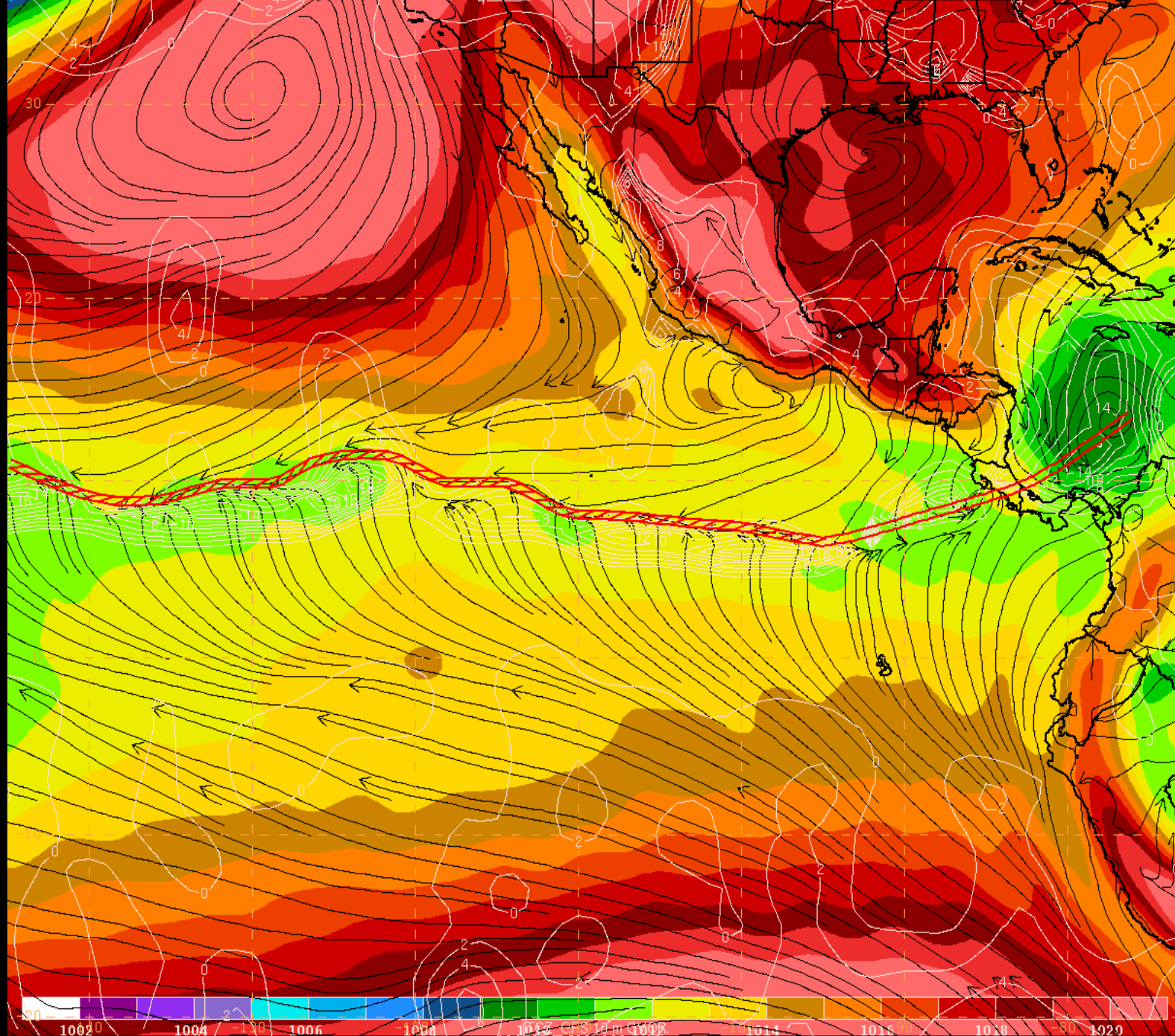




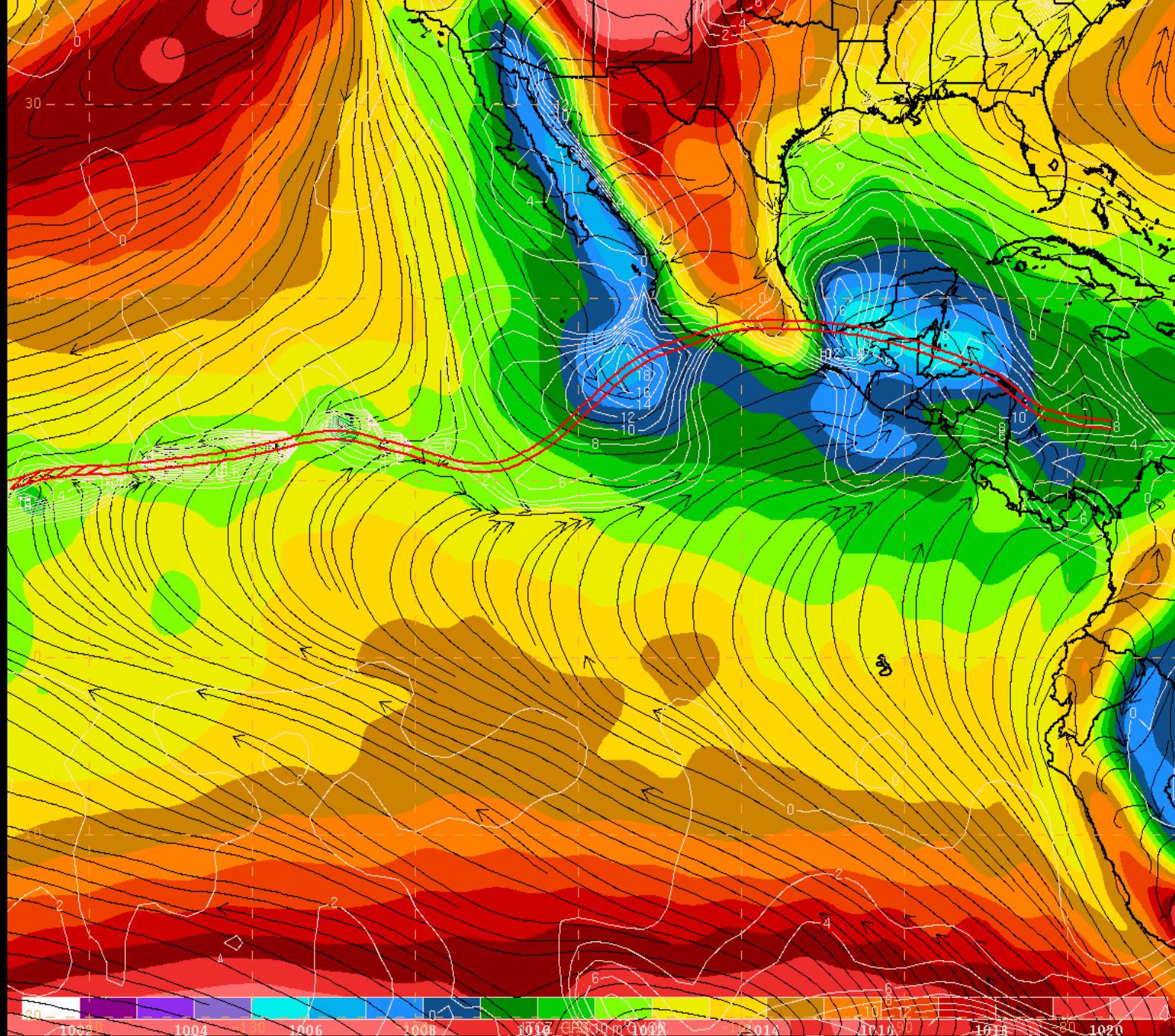
ITCZ_GFS SAT 101009/0600V000 10m AGL STREAMLINES
ITCZ_GFS SAT 101009/0600V000 MSLP



ITCZ_GFS SUN 100926/0600V000 10m AGL STREAMLINES
ITCZ_GFS SUN 100926/0600V000 MSLP



ITCZ_GFS SAT 101009/0600V000 10m AGL STREAMLINES
ITCZ_GFS SAT 101009/0600V000 MSLP



ITCZ_GFS SUN 100926/0600V000 10m AGL STREAMLINES
ITCZ_GFS SUN 100926/0600V000 MSLP