What Have We Learned from 2009 Dry Run?
-A Retrospective Analysis

Zhuo Wang

Department of Atmospheric Sciences

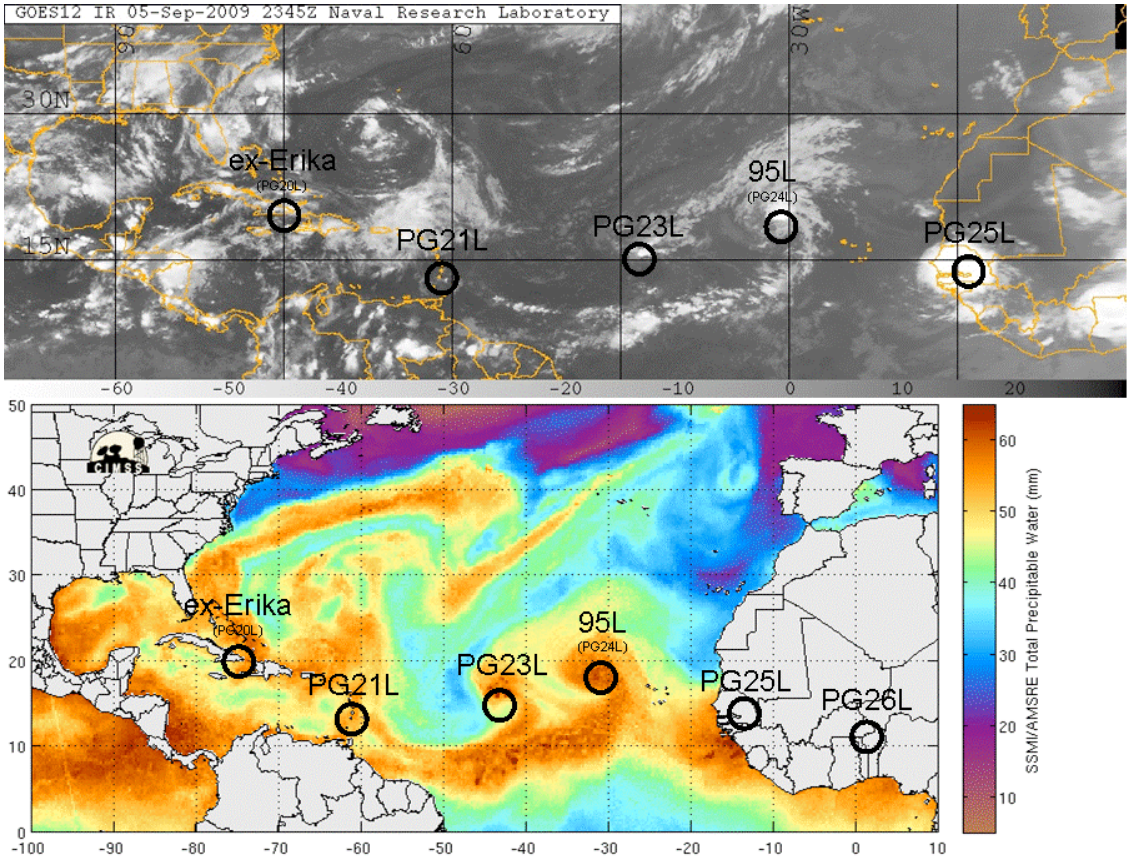
University of Illinois Urbana-Champaign

Collaborators: Michael Montgomery, Mark Boothe and Rob Leejoice
Naval Postgraduate School

2009 Dry Run

- NSF-PREDICT Dry Run: 08/15-09/15
- NASA-GRIP Dry Run: 09/01-09/30
- NOAA IFEX: an ongoing experiment that started in 2005
- Our Tracking period: 07/20-10/11
- Tracked more than 30 waves, including eight tropical storms and one tropical depression
- Wave pouch tracking in 2008 over the Atlantic, the East Pacific and the WN Pacific

Wave-Pouch Tracking for 2009 NSF-PREDICT/NASA-GRIP Dry Run



Mark Boothe and Rob LeeJoice will provide an overview of the "marsupial" products tomorrow.

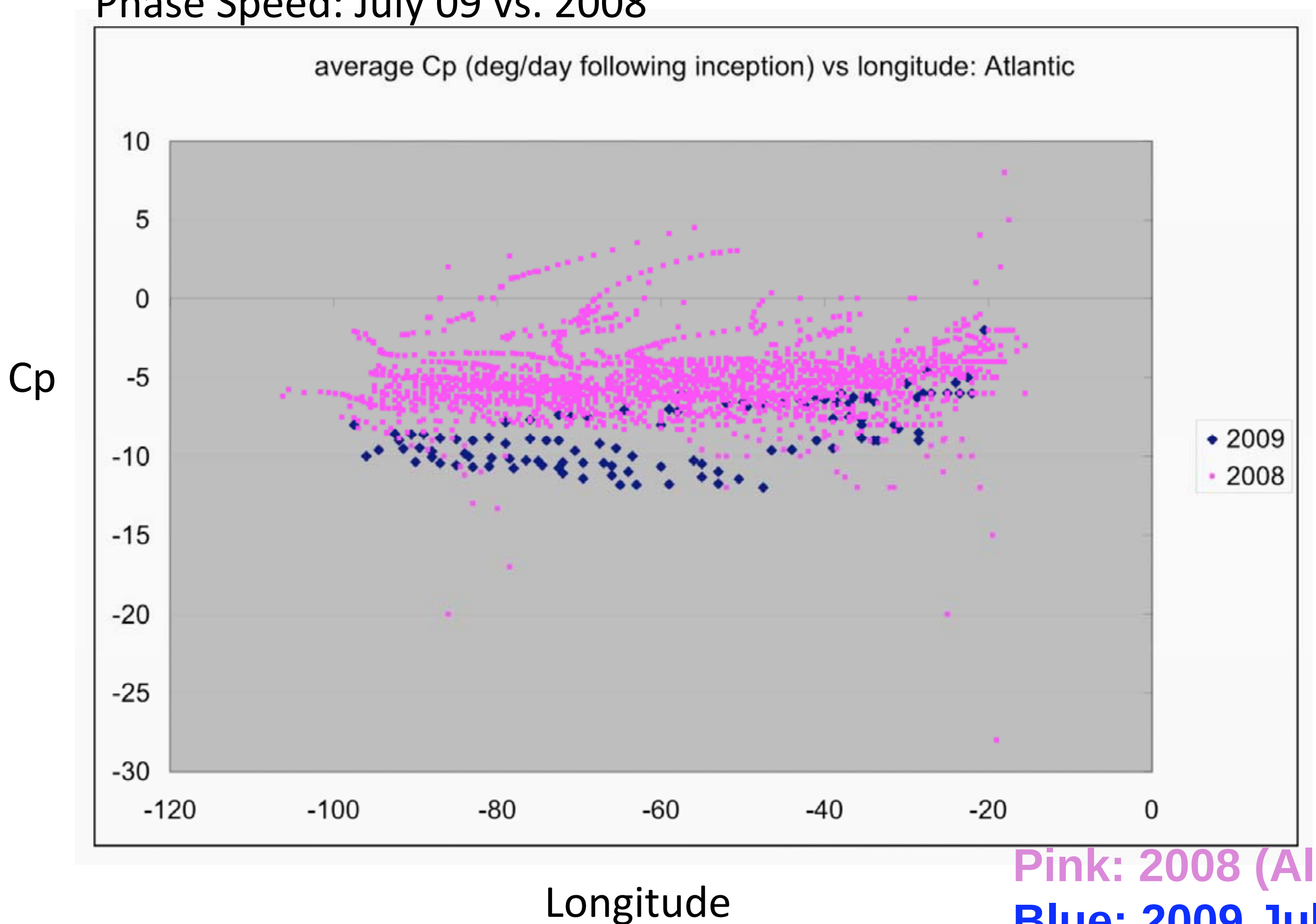
http://www.met.nps.edu/~mtmontgo/storms2009.html

Different wave scenarios

- Diagnosis of the waves in 2009 summer using GFS analysis:
  - Fast propagating waves without a pouch
  - Waves with a shallow pouch
  - Waves with a deep pouch that developed
    - Bill, Erika, Fred
  - Waves with a deep pouch that did not develop
- A brief summary
- Some questions to be addressed

Fast Propagating Waves

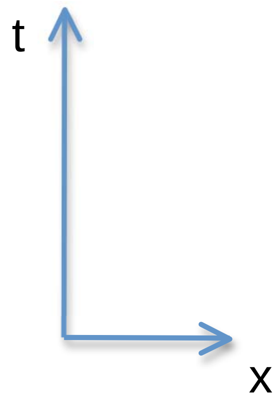
Phase Speed: July 09 vs. 2008



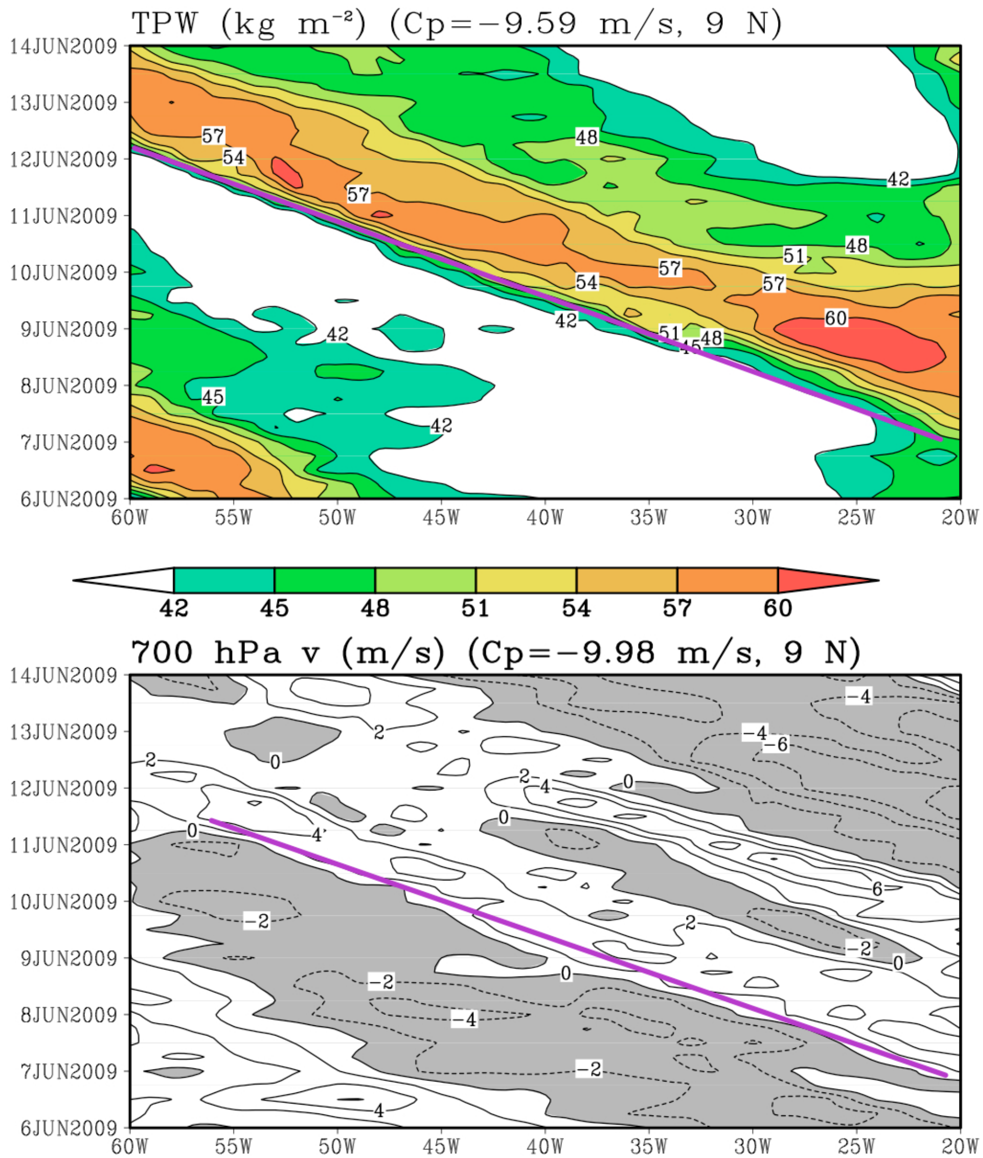
Pink: 2008 (All season)
Blue: 2009 July

Courtesy T. Dunkerton

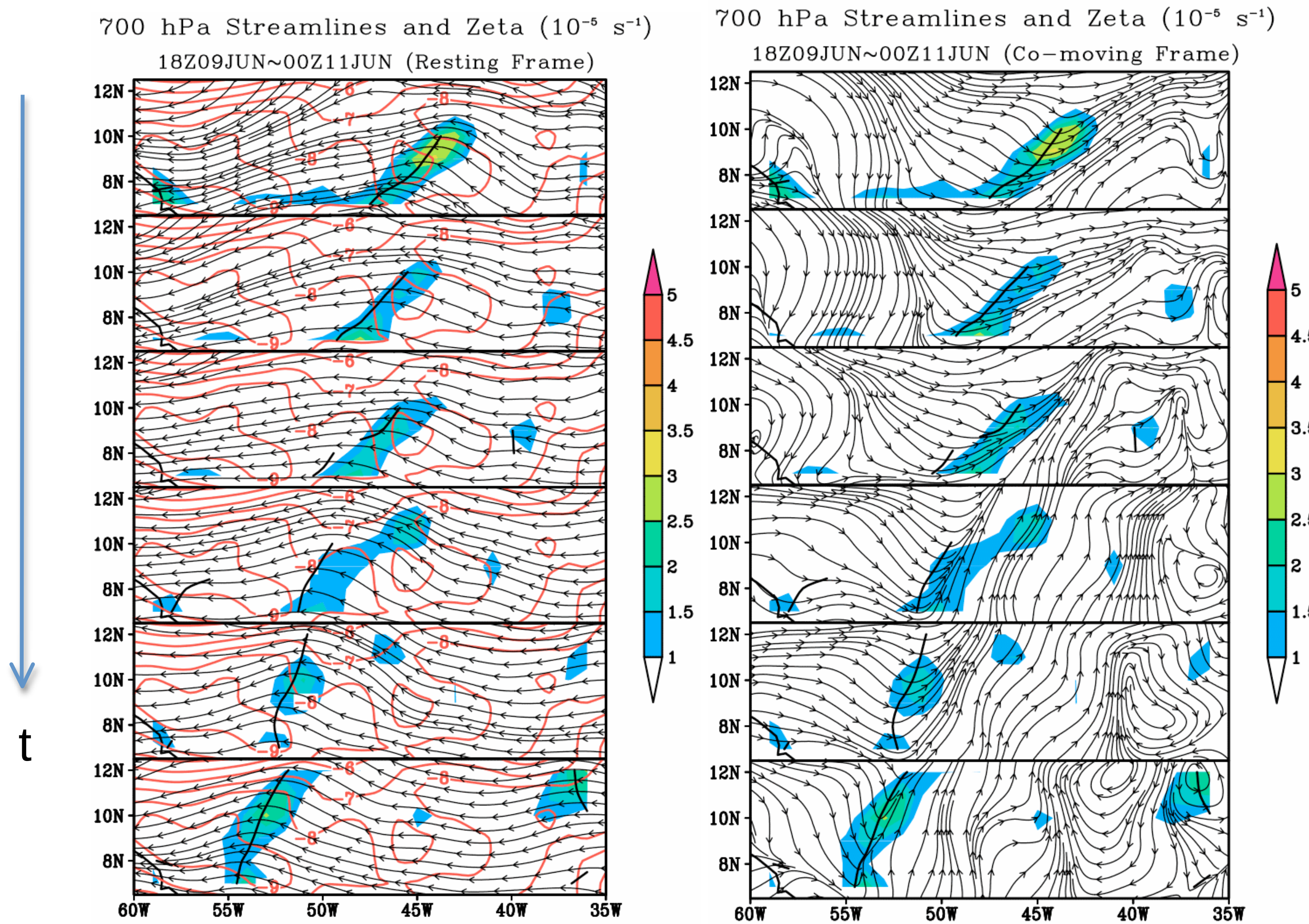
An Example of Fast Propagating Waves
(June 6-14)



CP ~ -9.8 m/s



An Example of A Fast Propagating Wave



Fast propagating waves without a pouch

- NOT all waves have a critical layer or a pouch.
- Waves may propagate faster than the mean flow or the wave amplitude is too weak: No critical surface; no wave pouch.
- Such waves did not develop: No tropical waves evolved into a tropical storm before August 11 (TD #1 formed at 37° N from (sub)Tropical Transition (TT) in May).
- Q: How are these fast propagating waves related to the large-scale circulation? How are they related to variations of the tropical cyclone activities over the Atlantic?

Waves with a shallow pouch

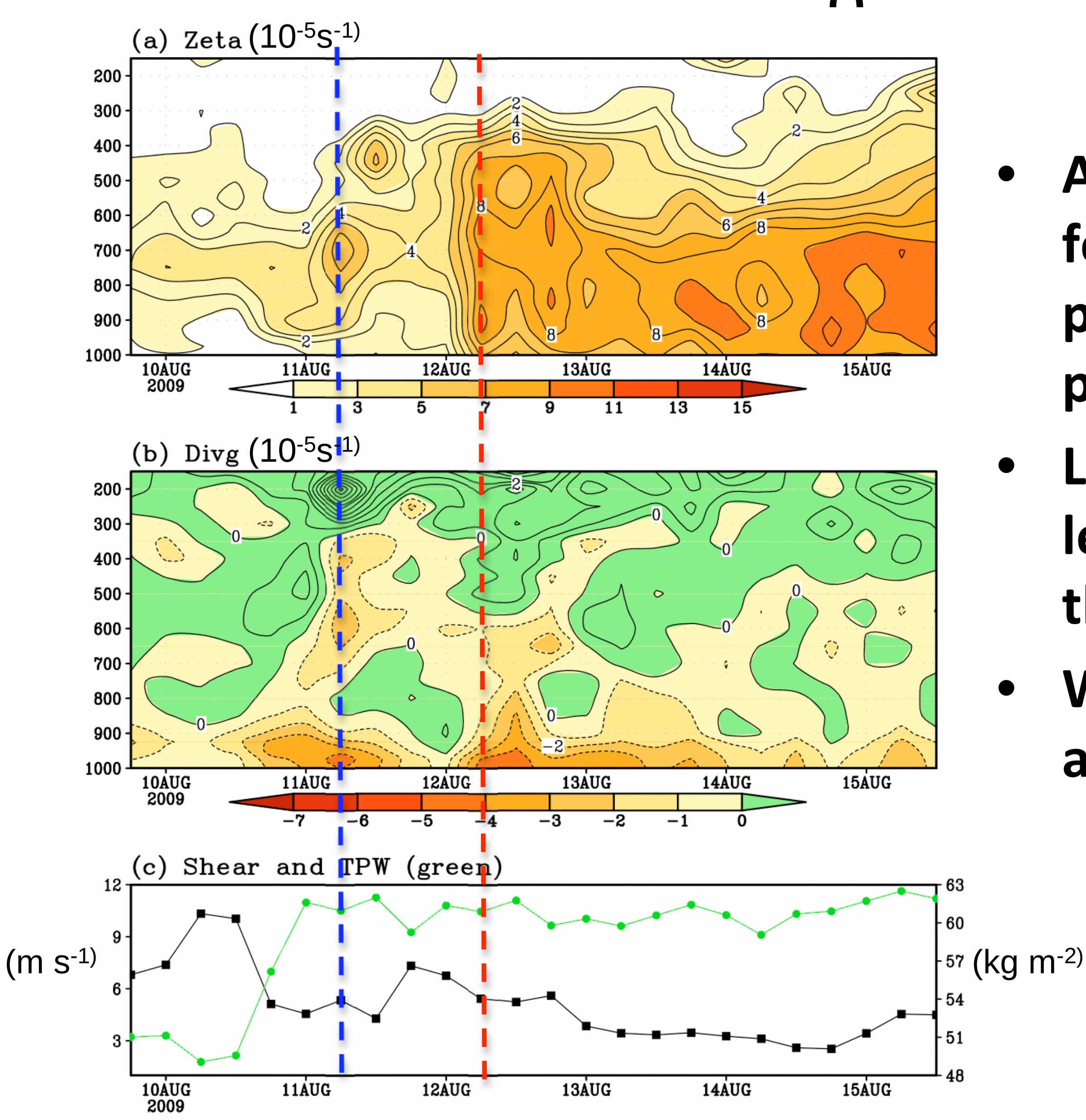
- Vertical structure properties
  - When above the PBL, usually observed over West Africa or the East Atlantic
  - When confined primarily within PBL, usually observed for weak waves or decaying waves

- Most did not intensify. In some cases, they persisted for a long time and became reinvigorated in a more favorable environment (or when interacting with other systems), such as Claudette and Jimena.

- e.g. PG15L (Jimena over Epac)
  - The wave can be tracked back to West Africa.
  - Due the the impacts of the SAL or mid-level dry air, the pouch was primarily confined around 700 hPa, and extended down to the PBL over the West Atlantic after escaping from the impacts of the SAL.
  - The wave tracked over central America and developed into Cat-4 Hurricane Jimena over the East Pacific.

Developing waves with a deep pouch:

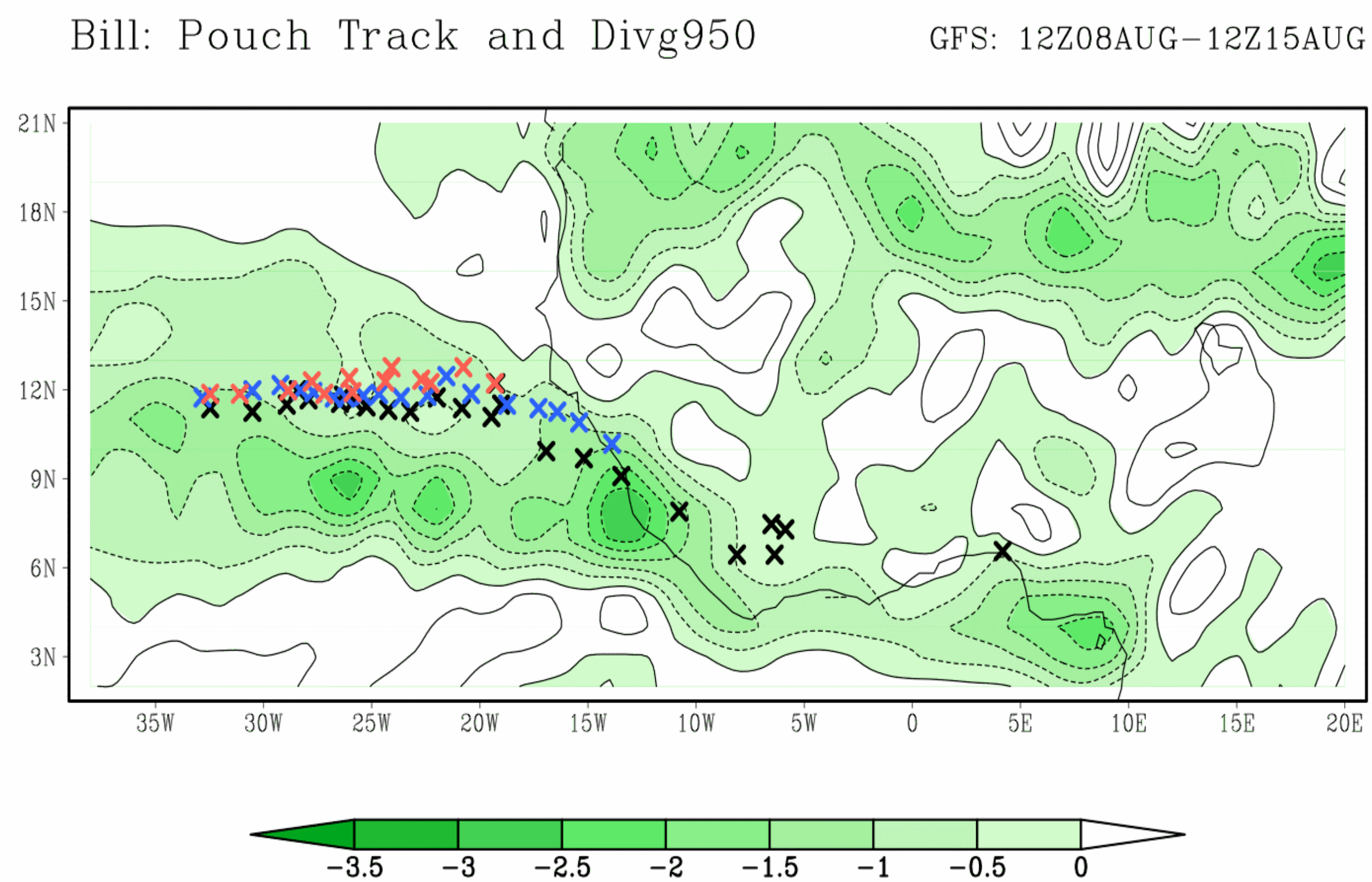
Time Evolution of the Wave Pouch (Bill): Day -6 ~ Day 0



- **Averaged in a 3X3 box following the propagating wave pouch.**
- **Low-level convergence leads the increase of the low-level vorticity**
- **Weak vertical shear and high TPW.**

GFS analysis

Bill: Pouch tracks at different vertical levels



Black: 700 hPa
Blue: 850 hPa
Red: 950 hPa

A wave is propagating along the northern edge of the ITCZ, and is enhanced by the ITCZ and convective bursts

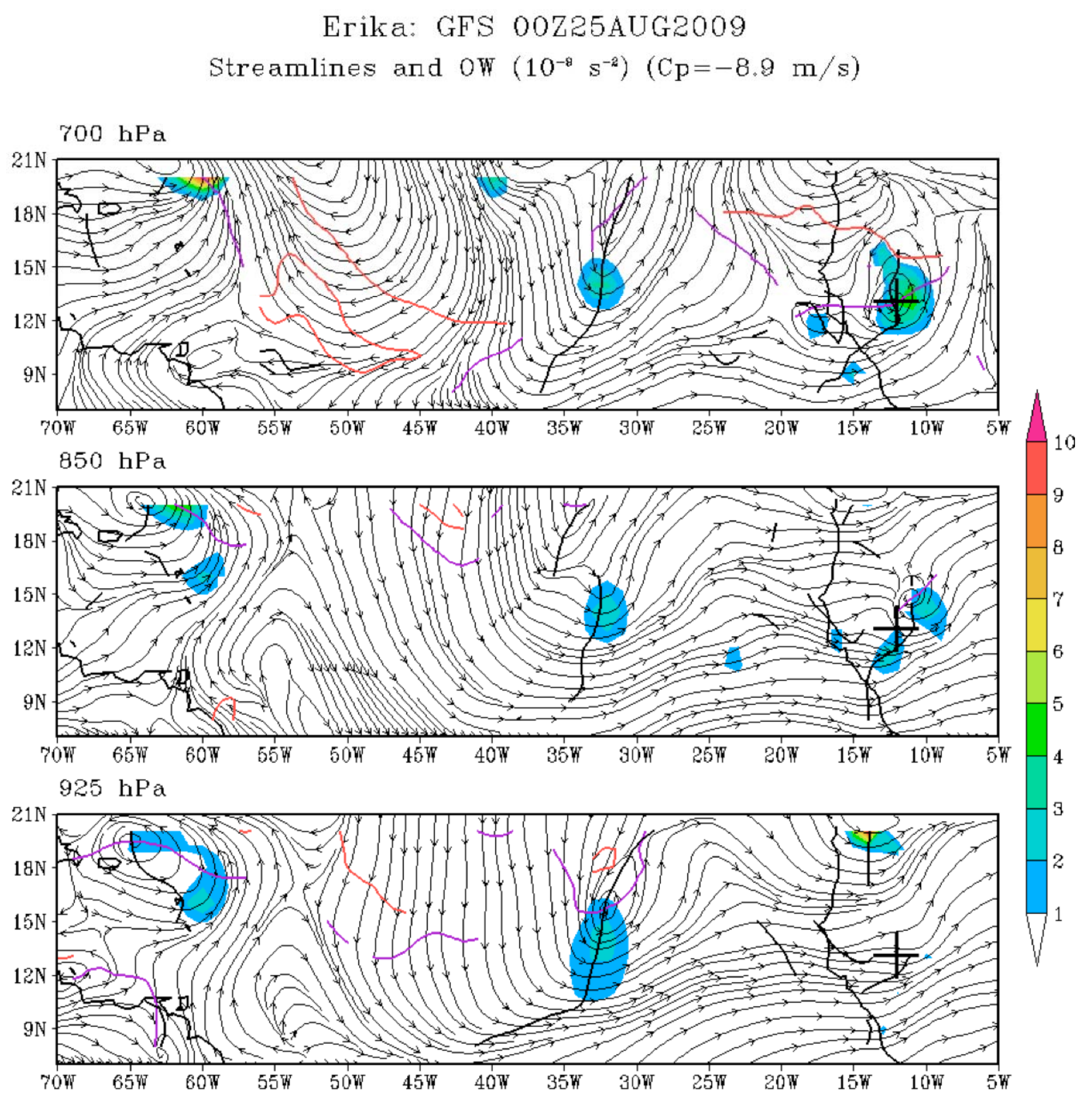
Developing waves with a deep pouch: Erika

Jet axis

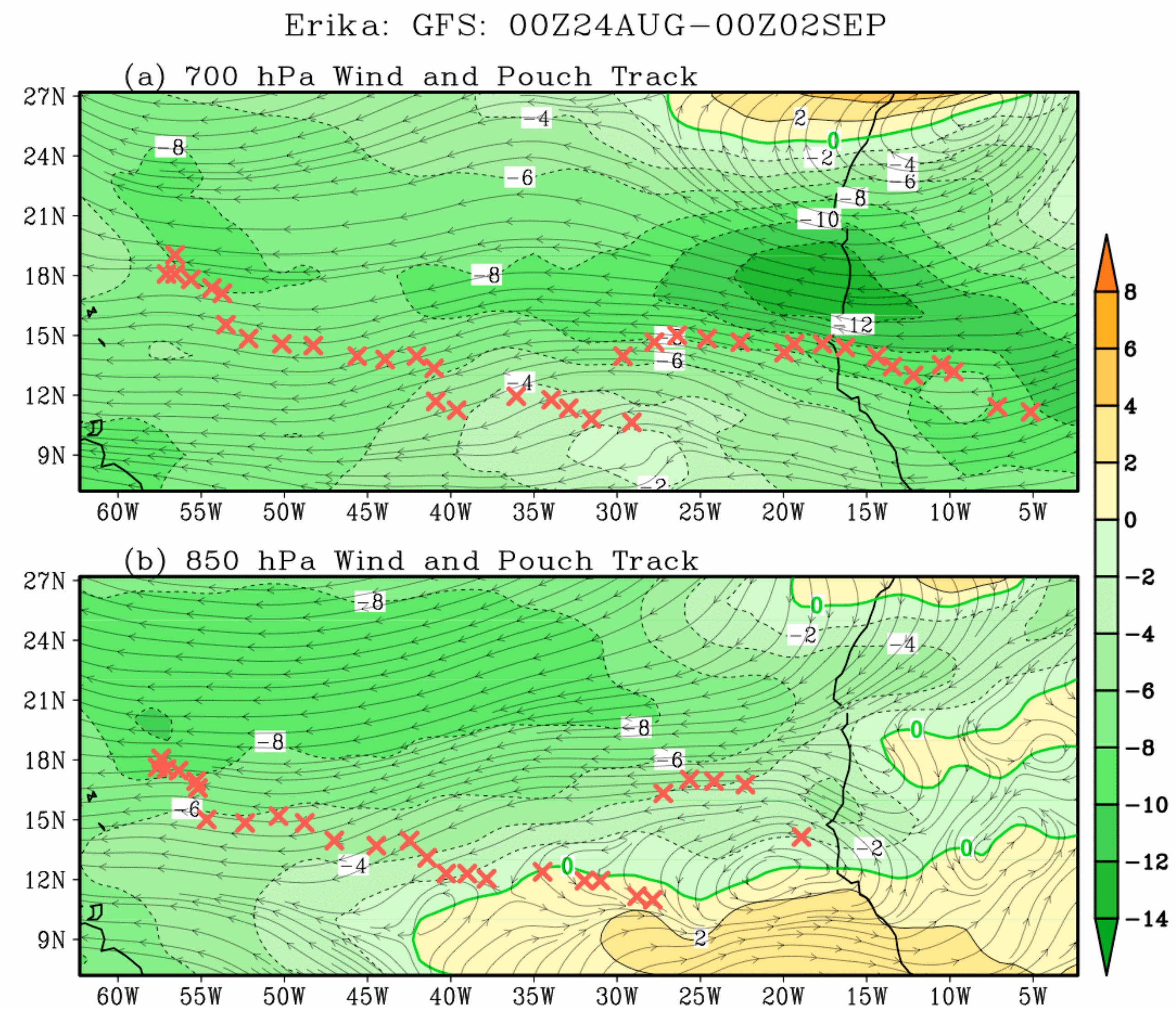
CL

Trough

Streamlines are shown in the co-moving frame.

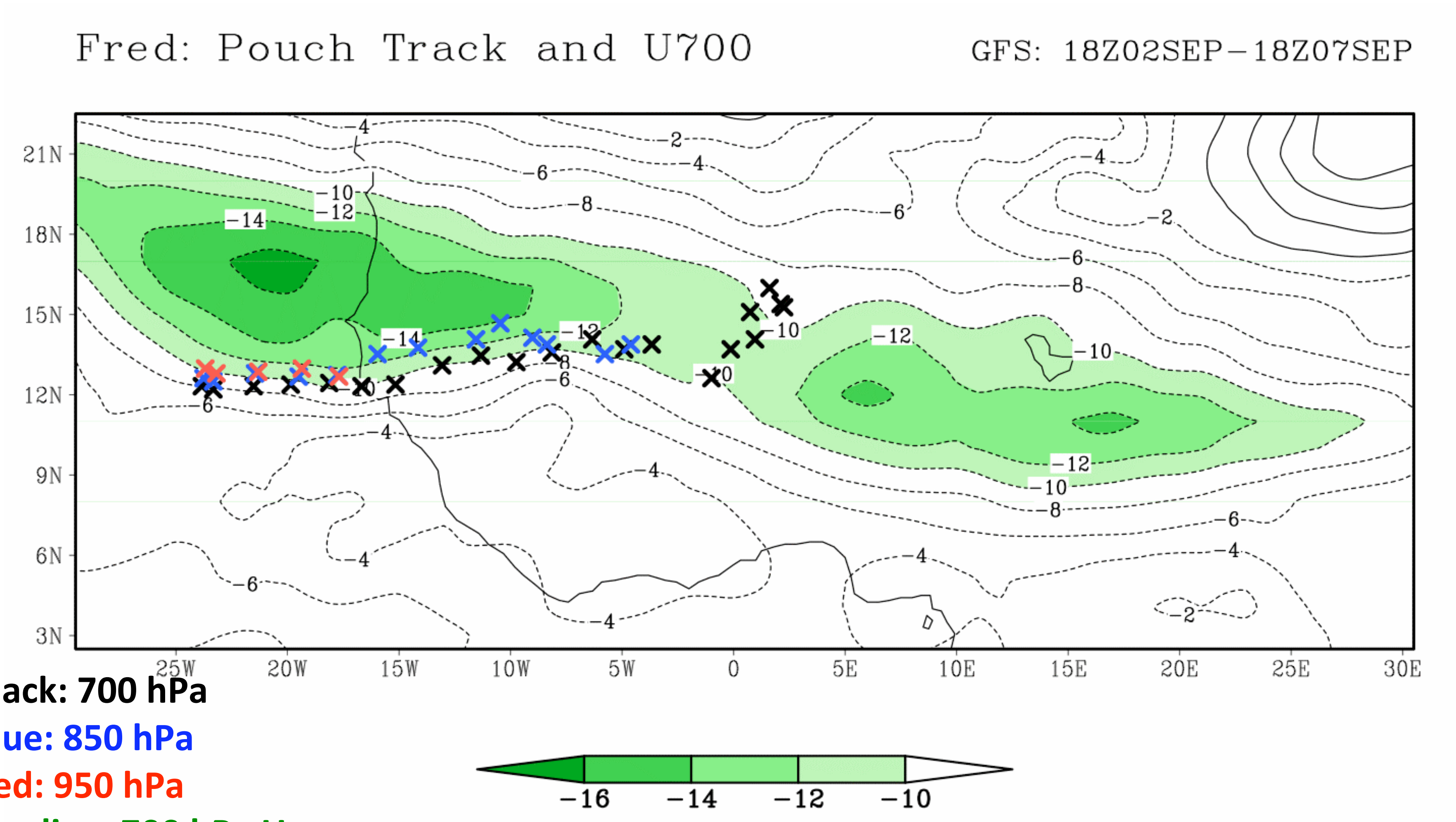


700 hPa and 850 hPa Wave-Pouch Tracks



A new wave originating from ITCZ-AEW Interaction

Developing waves with a deep pouch: Fred



Black: 700 hPa

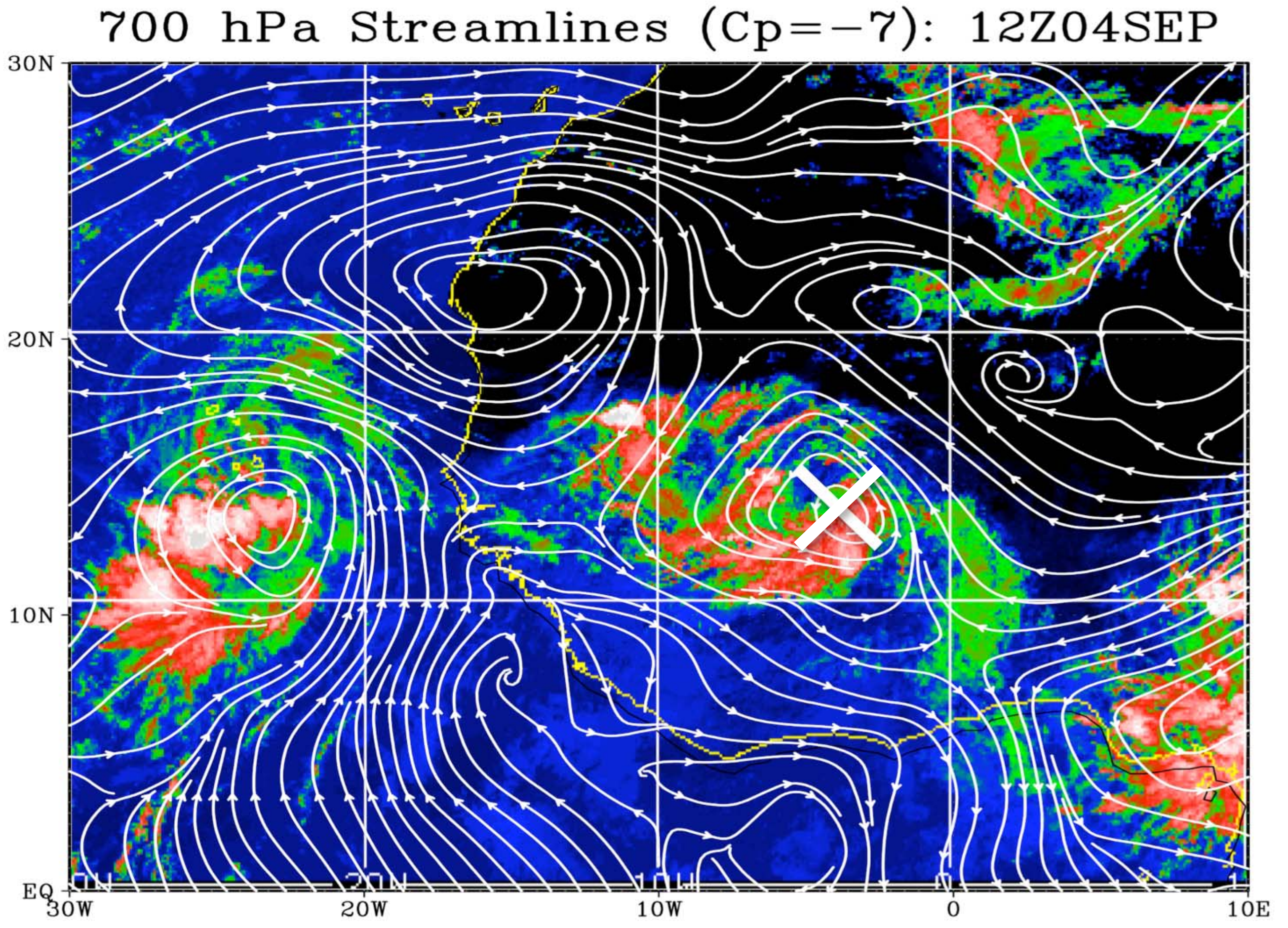
Blue: 850 hPa

Red: 950 hPa

Shading: 700 hPa U

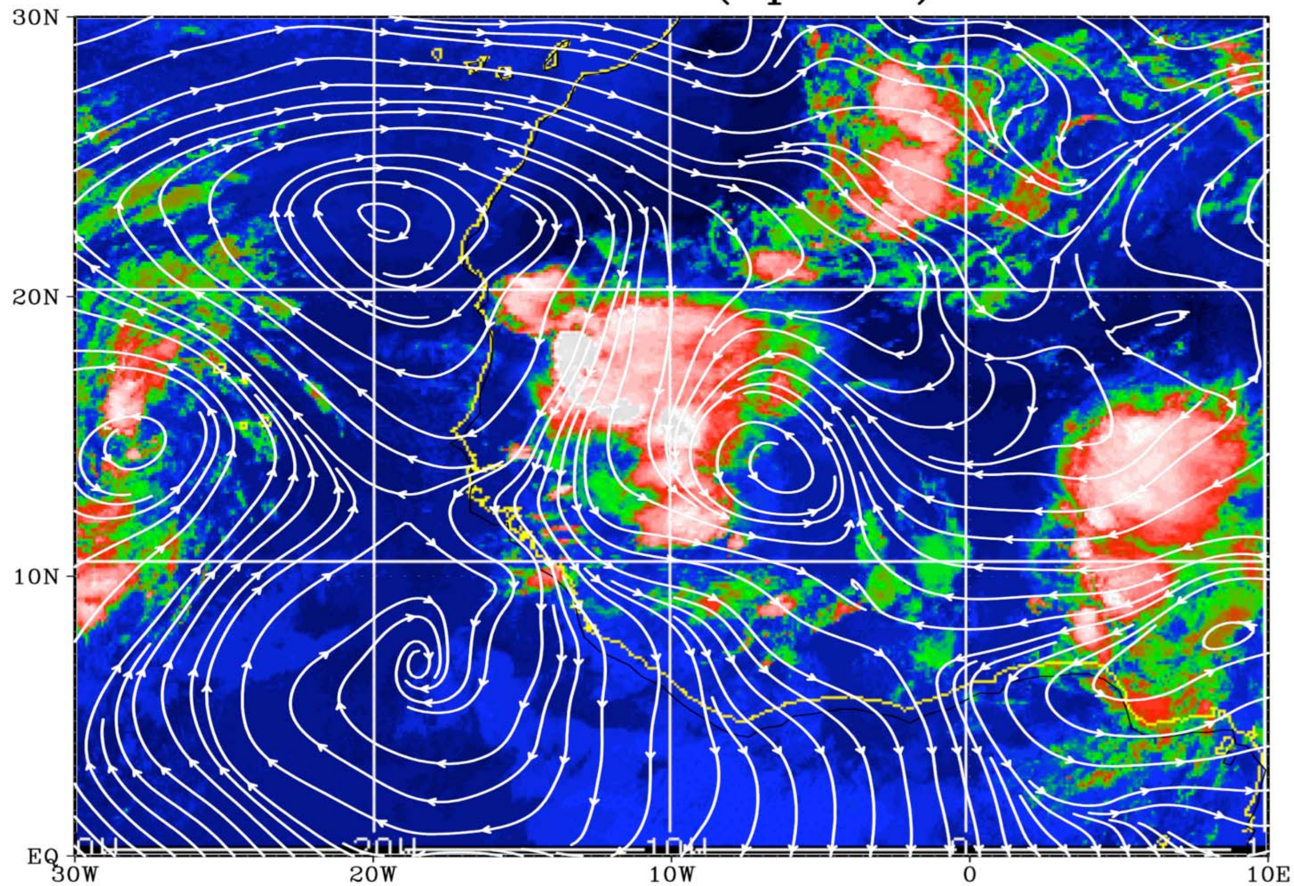
Fred formed on 21Z Sep 7th.

700 hPa co-moving streamlines and IR

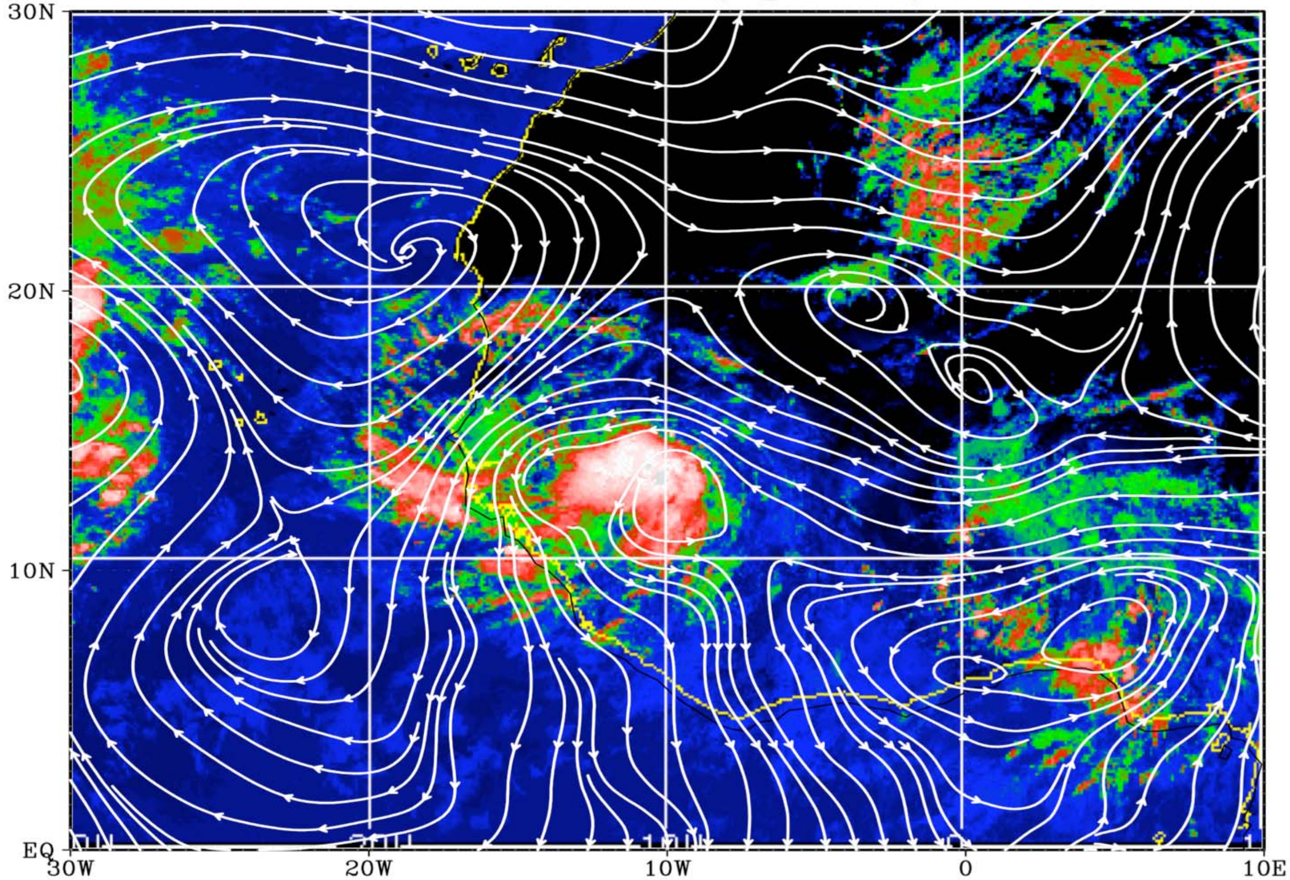


IR imagery from CIMSS Tropical Cyclone Data Archive

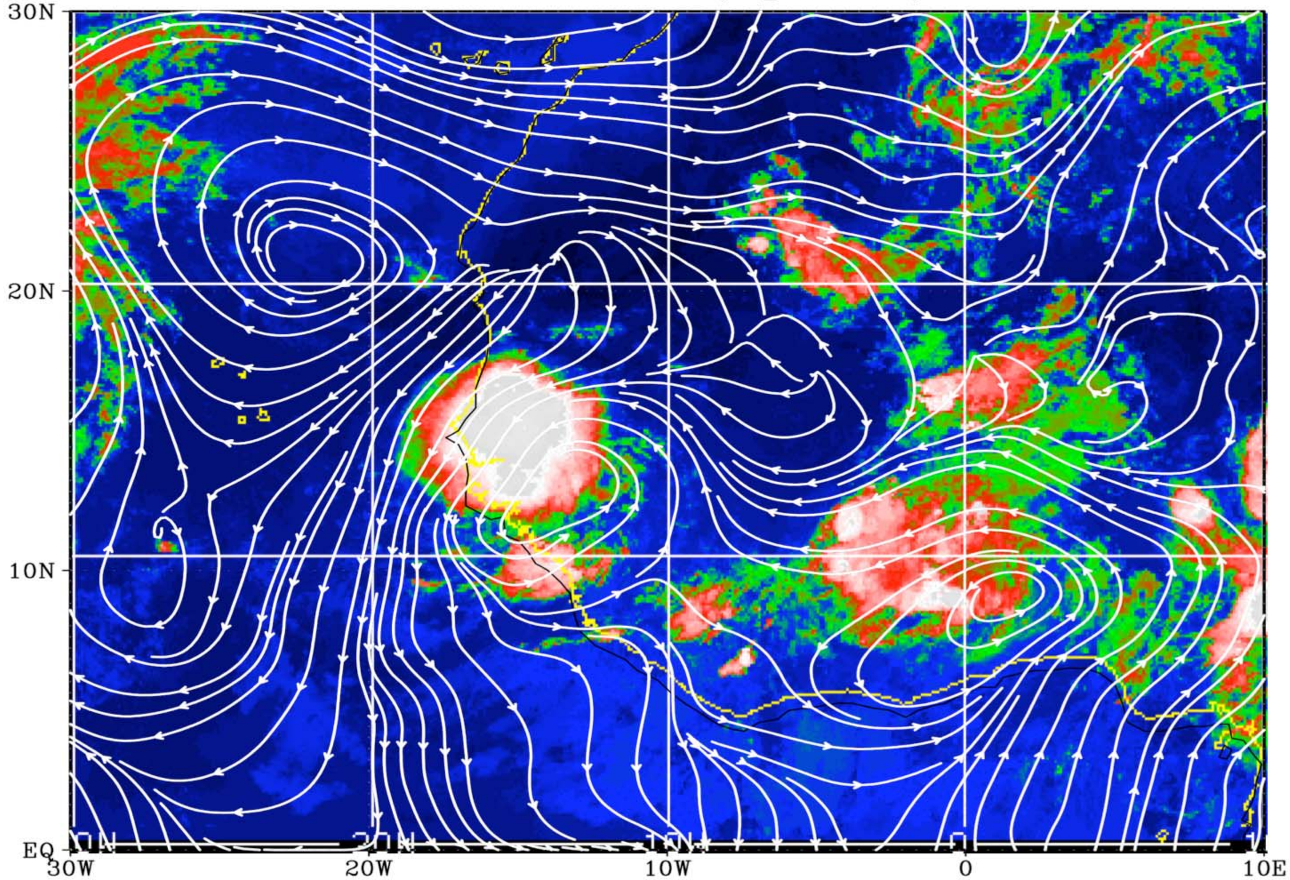
700 hPa Streamlines (Cp=−7): 00Z05SEP

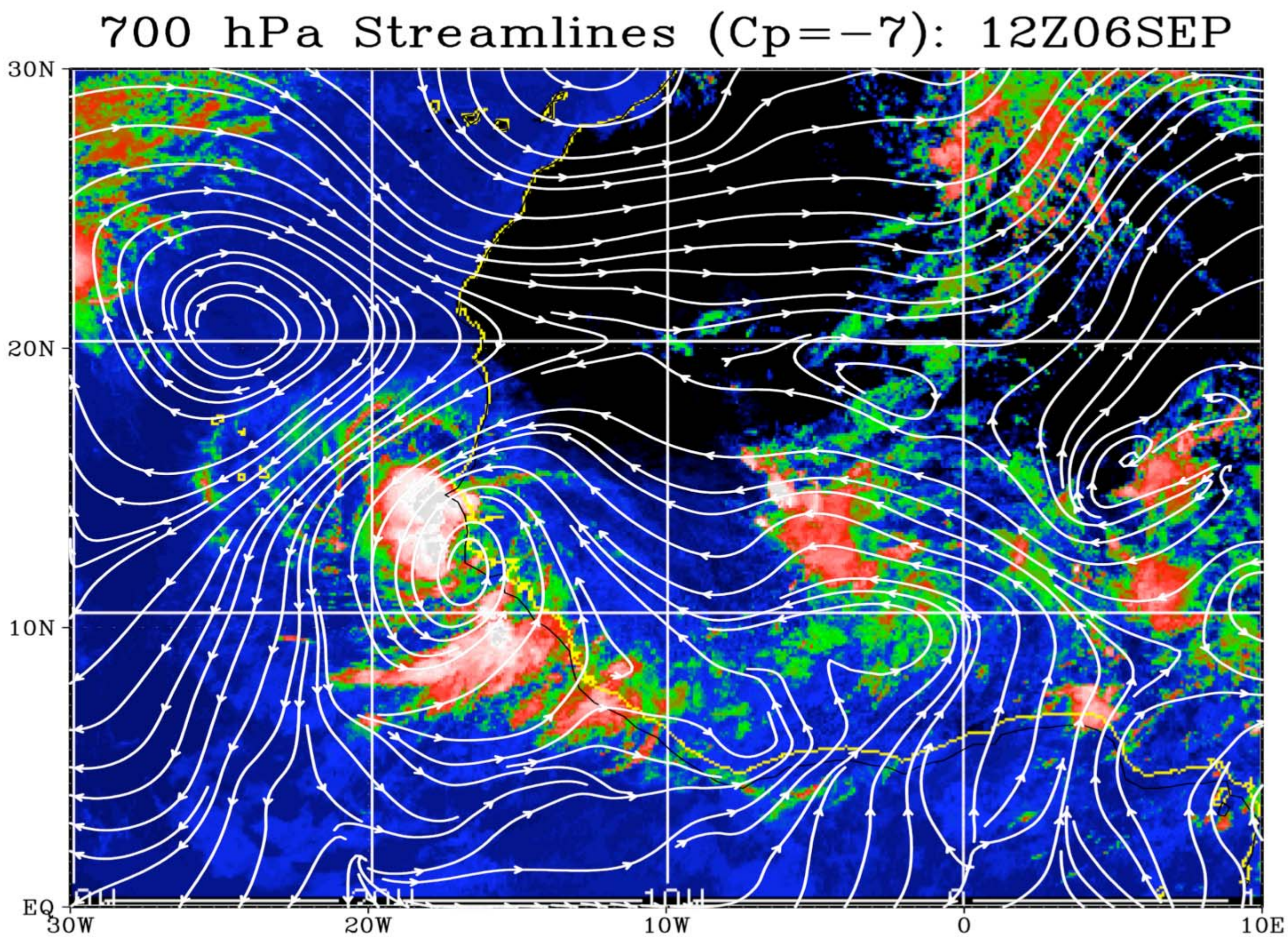


700 hPa Streamlines (Cp=−7): 12Z05SEP

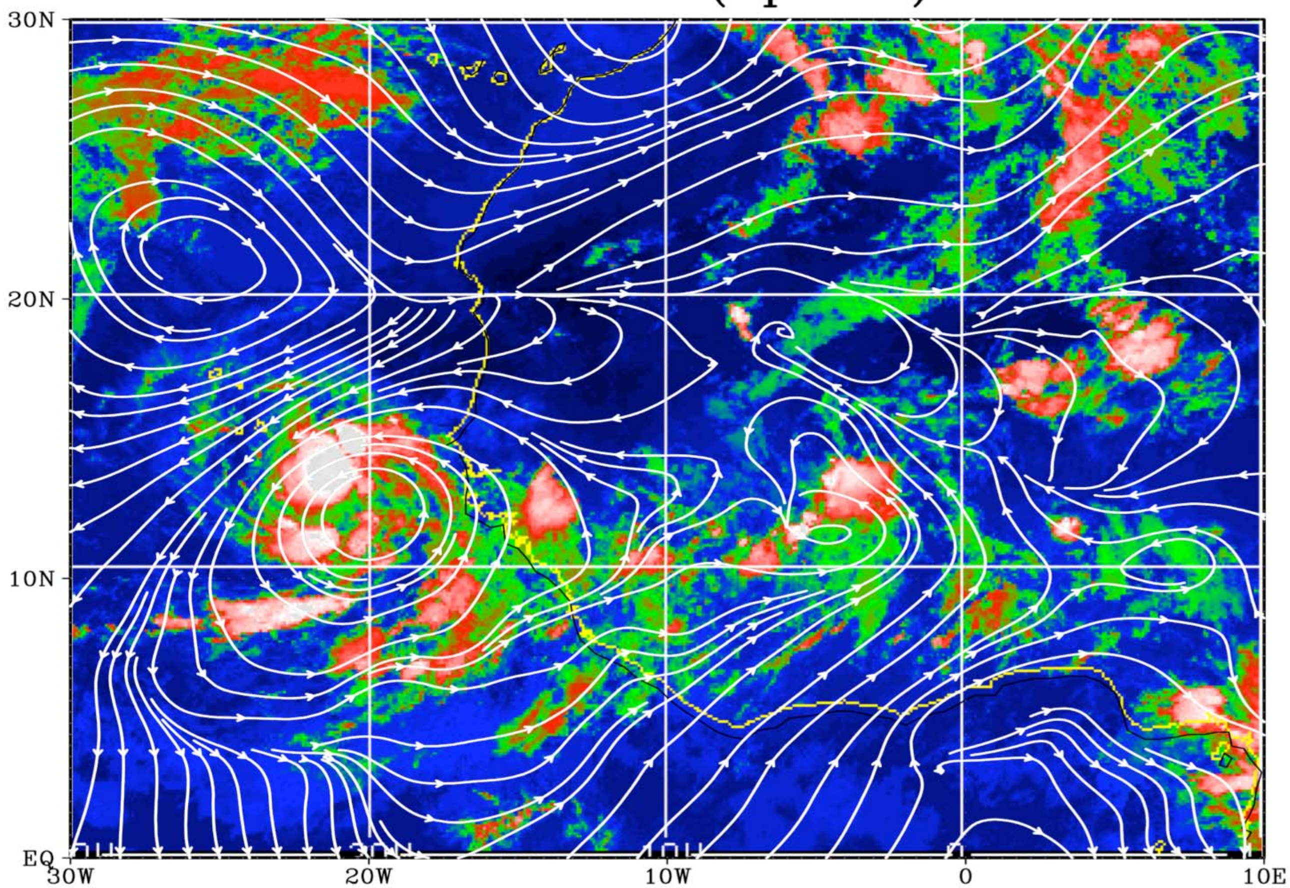


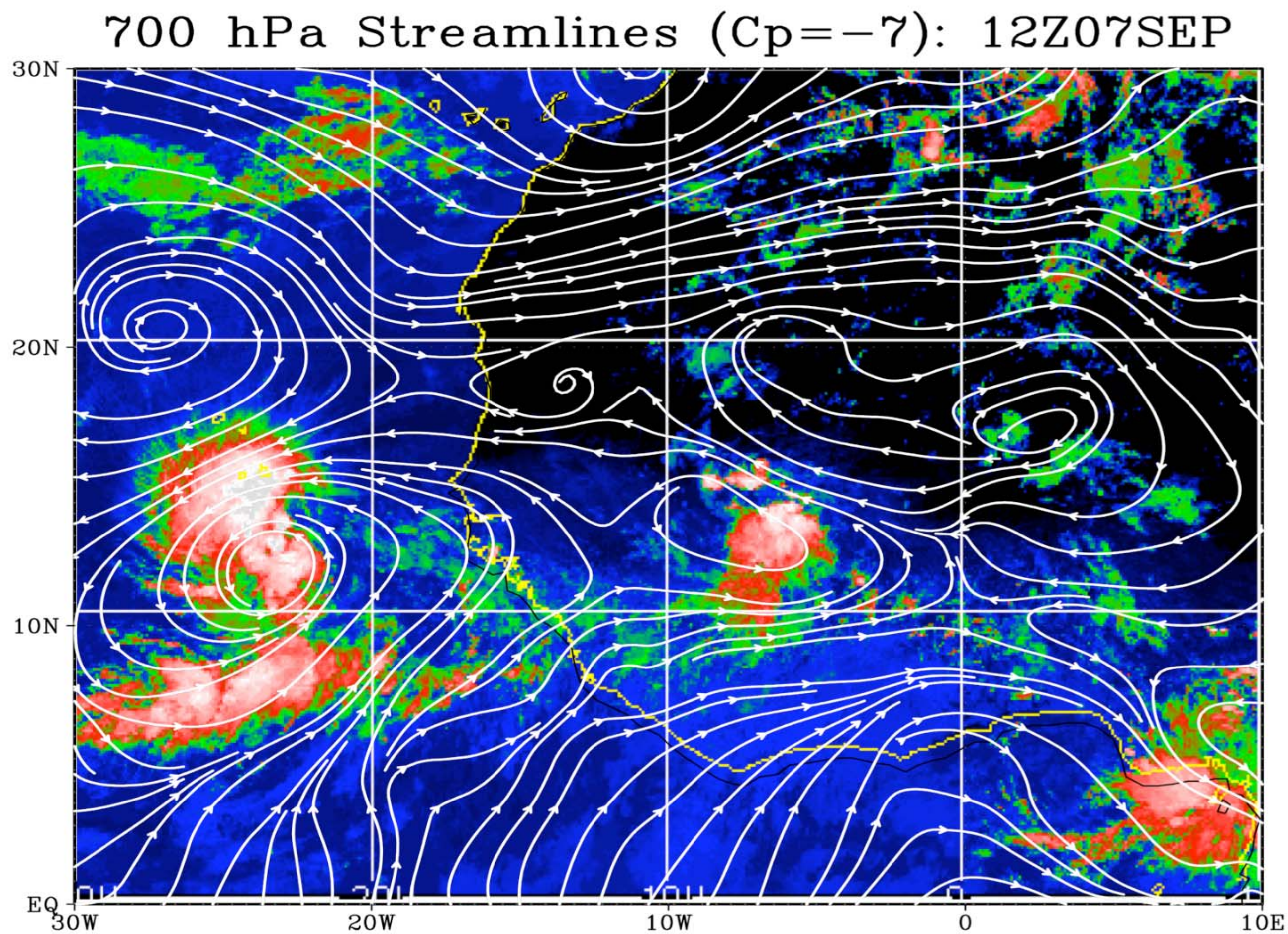
700 hPa Streamlines (Cp=−7): 00Z06SEP




700 hPa Streamlines (Cp=-7): 12Z06SEP
30N
20N
10N
EQ
30W
20W
10W
0
10E

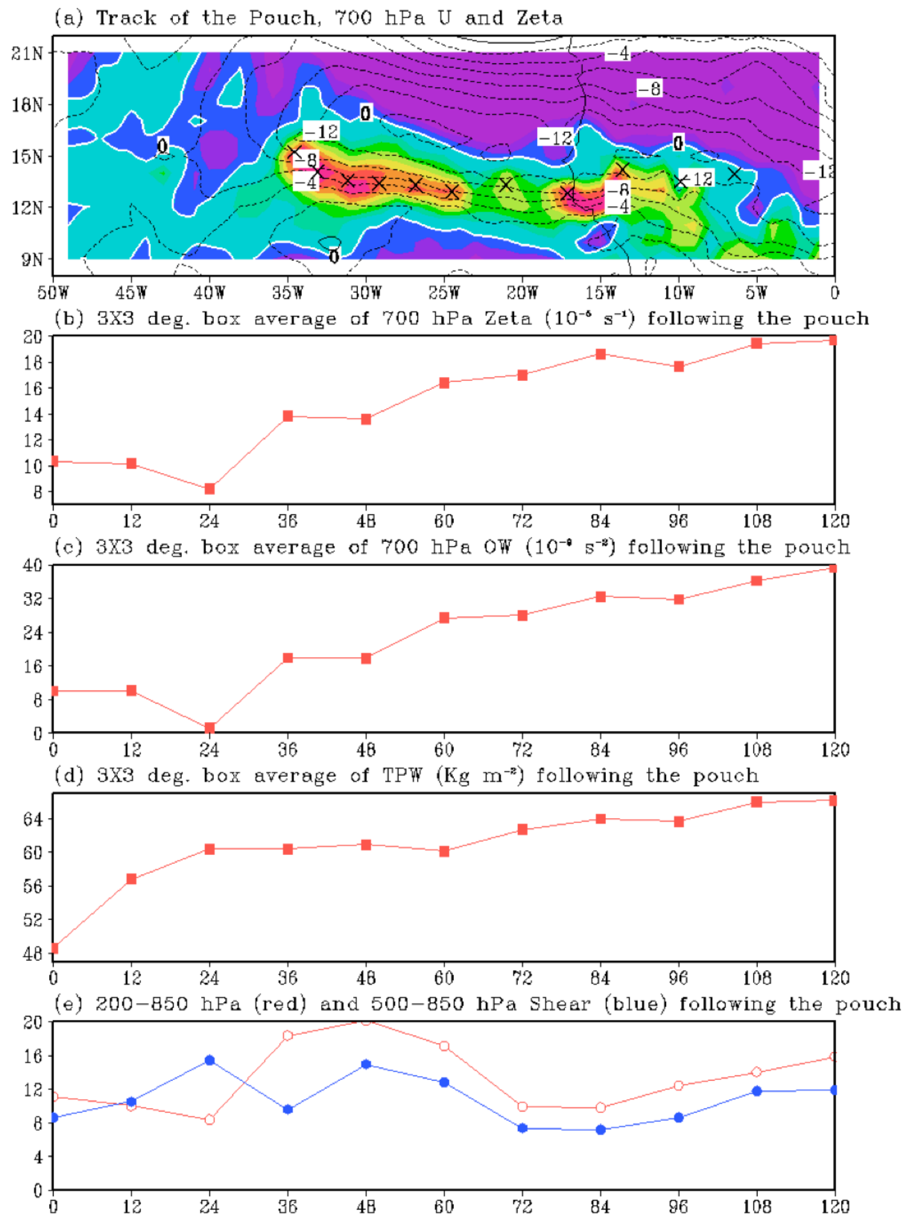
700 hPa Streamlines (Cp=−7): 00Z07SEP




700 hPa Streamlines (Cp=-7): 12Z07SEP
30N
20N
10N
EQ
30W
20W
10W
0
10E

Pouch Evolution based on GFS Forecasts

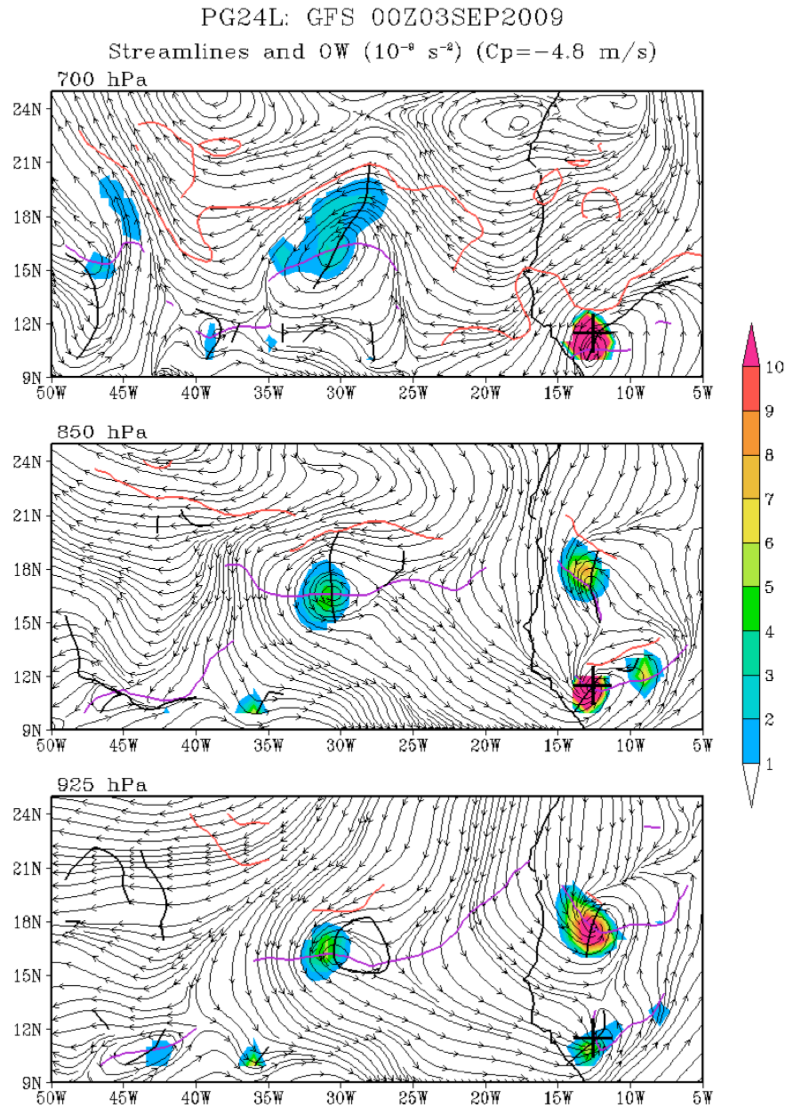
(00Z Sep 05)



Nondeveloping waves with a deep pouch

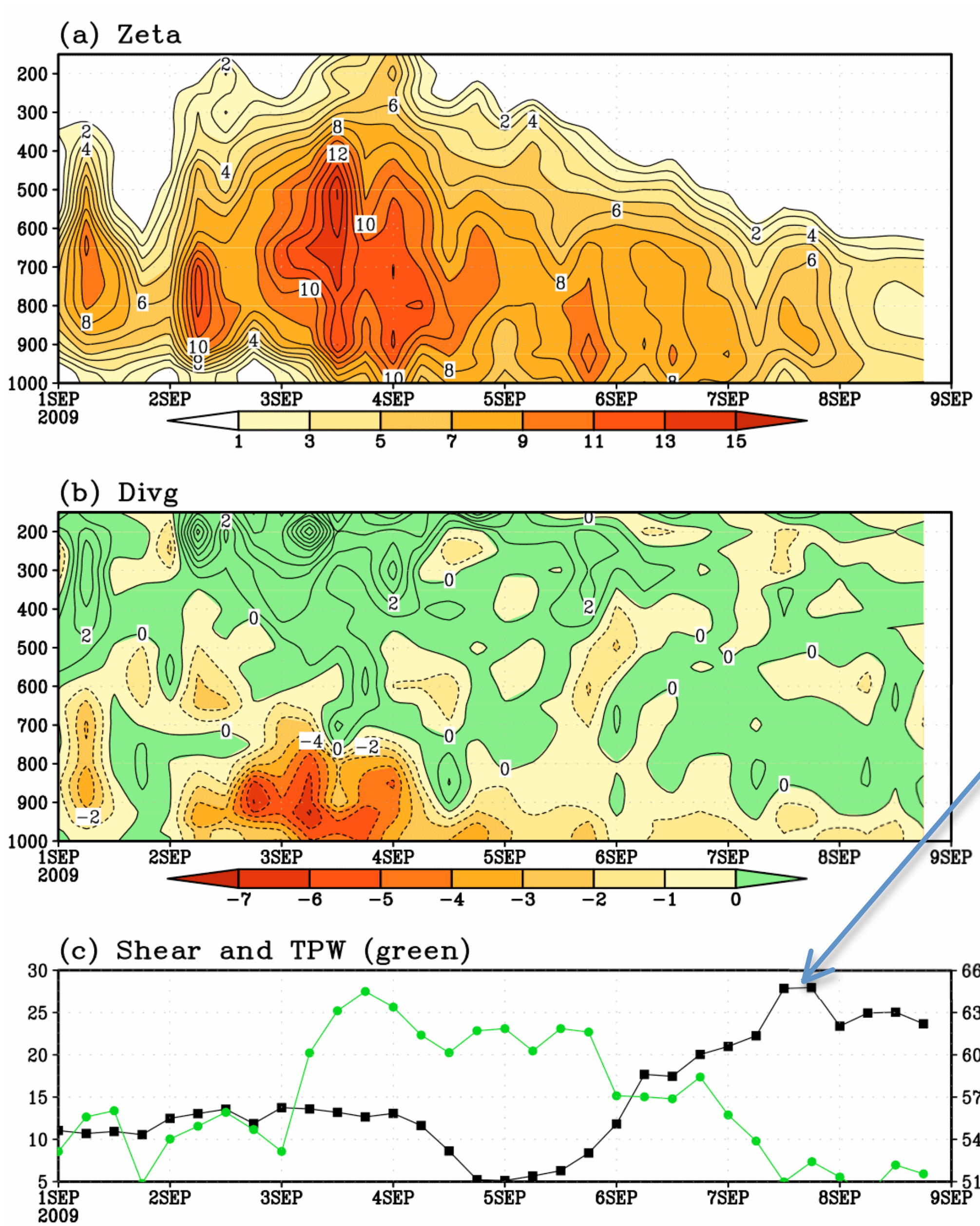
PG24L: **inhibited by strong vertical shear**

- The wave had a deep pouch before moving off the west coast of Africa.
- The pouch had strong OW (~10^-8) and abundant moisture, but the strong vertical shear at the later stage prevented further development.



Co-moving frame

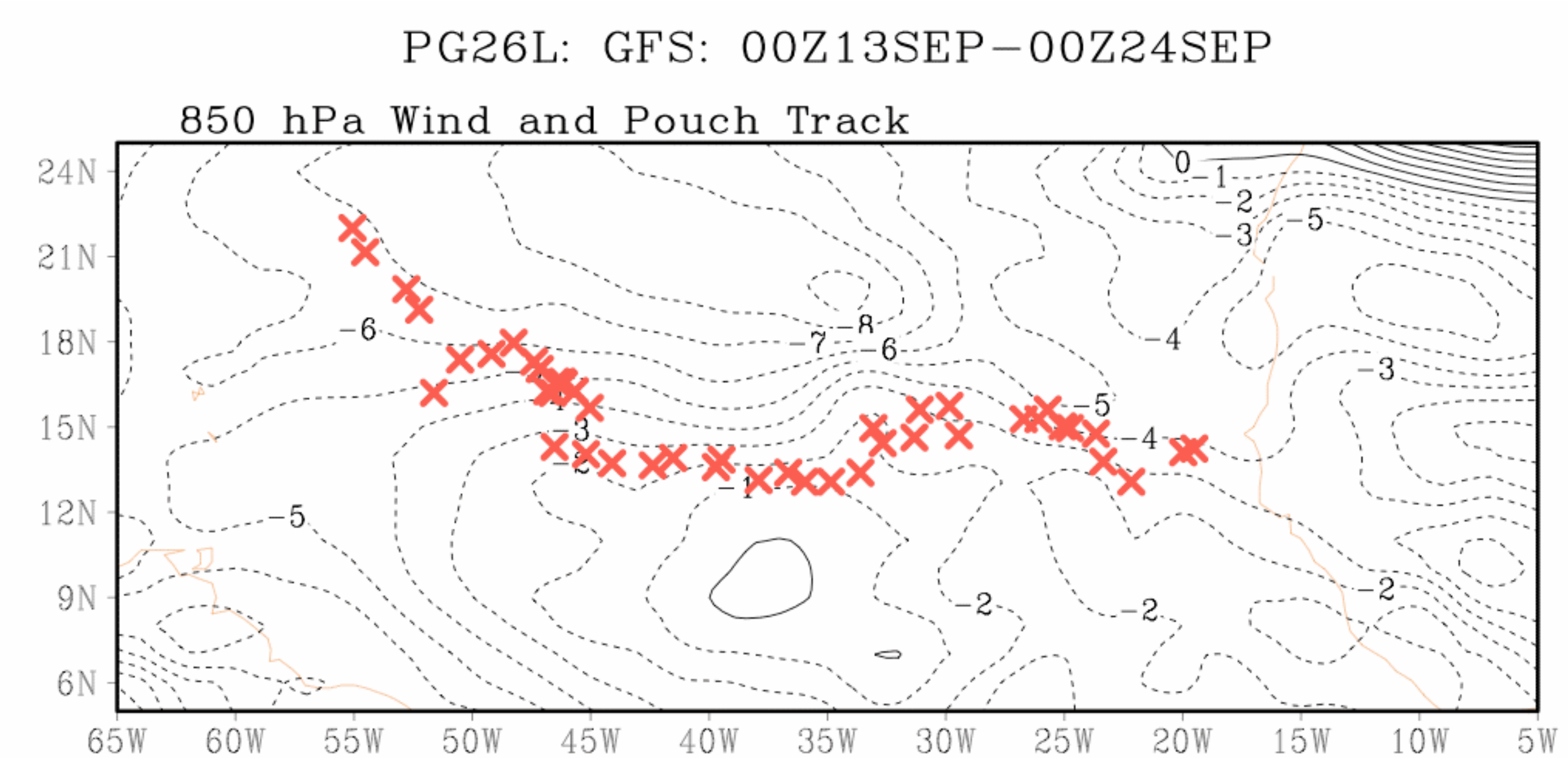
Time Evolution of the Wave Pouch (PG24L)



Strong deep vertical shear (> 25 m/s)!

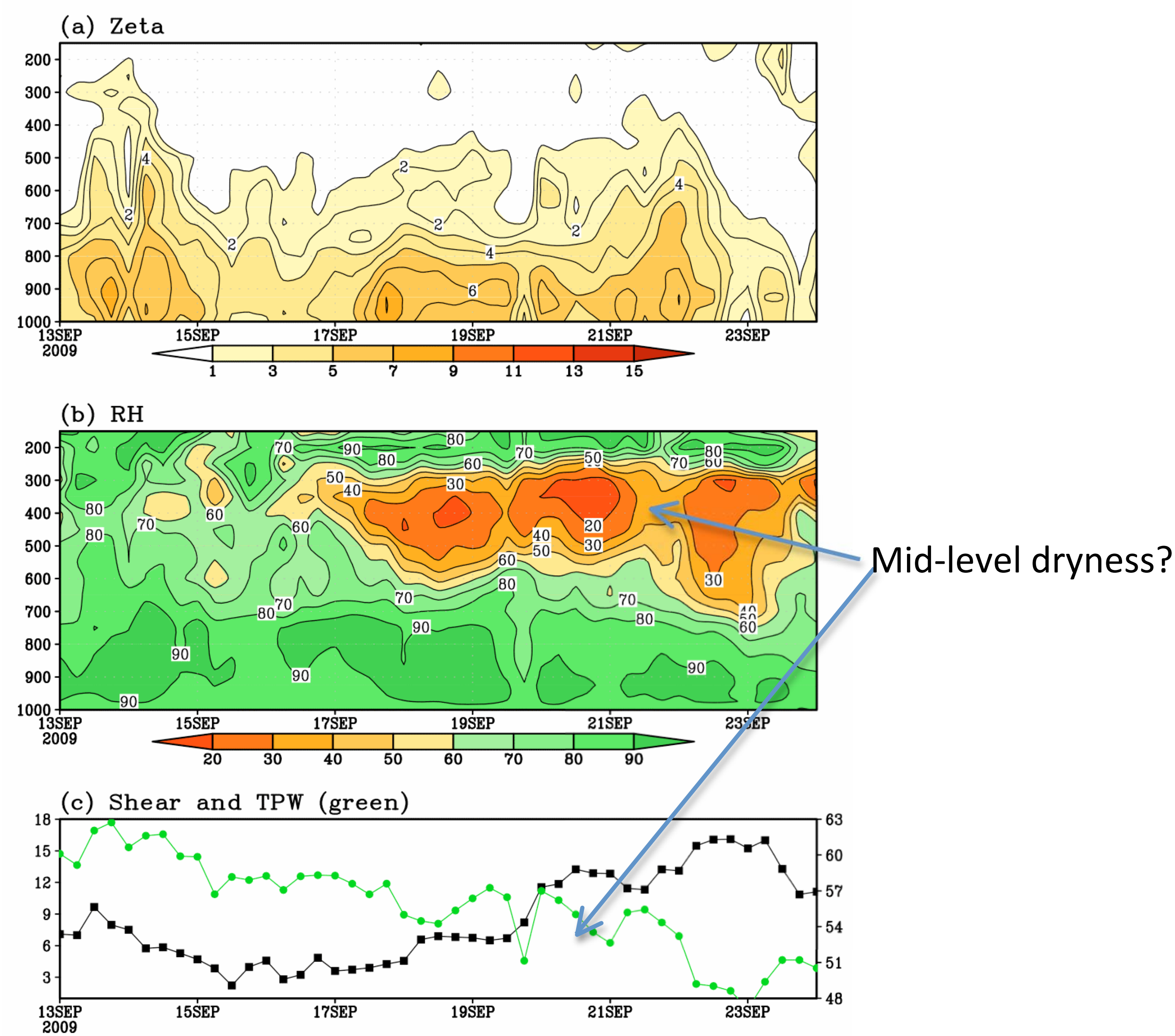
Nondeveloping waves with a deep pouch

PG26L: suppressed by the dry air

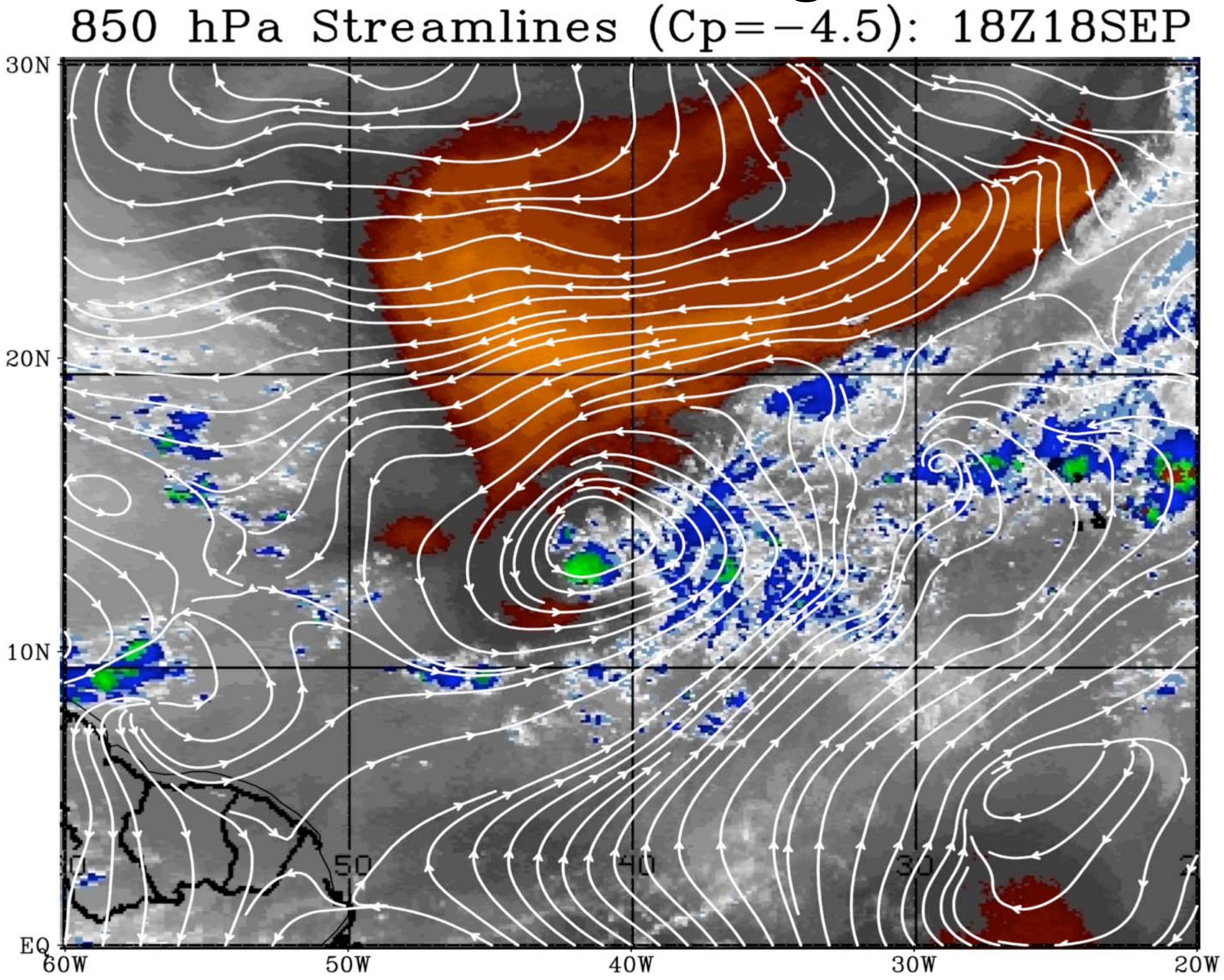


A wave with a deep pouch that lasted more than 10 days and can be tracked back to West Africa. It was designated as an invest (98L) by the NHC but failed to develop.

Time Evolution of the Wave Pouch (PG26L)



CIMSS-Mid Level Water Vapor Enhanced for Dry Air Tracking



Water vapor imagery from CIMSS Tropical Cyclone Data Archive

Summary

What we have learned from the 2009 Dry Run:

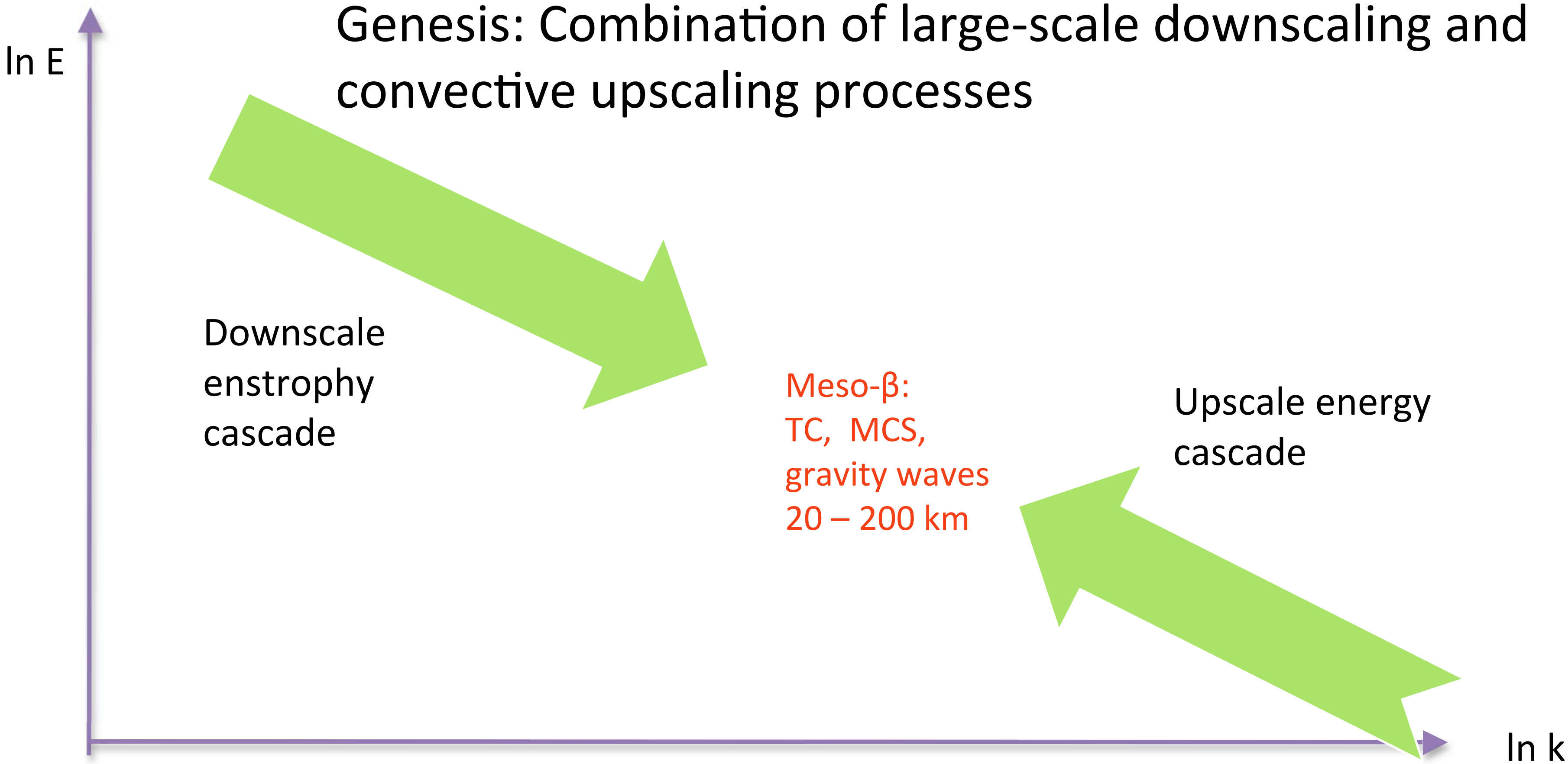
- Not all waves have a critical layer or a pouch!
- A deep, moist pouch may be a necessary condition for tropical cyclone formation
  - Favorable condition for deep convection
  - Upscale organization of mesoscale convection
- Why do some waves with a deep pouch fail to develop? Good candidates for the "null case"
  - mid-level dry air
  - Vertical wind shear
  - Lack of CAPE
  - Strong CIN (Convective Inhibition)

➔ Lack of persistent convection

What controls the development or nondevelopment of a wave?

What controls the development or nondevelopment of a wave?

Genesis: Combination of large-scale downscaling and convective upscaling processes



Synoptic
Easterly Waves
Hydro instability of ITCZ
Subtropical intrusions
2,000 – 8,000 km

Meso-α:
Easterly wave critical layer
K
Isolated recirculation regions
Inertia gravity waves
200 – 2,000 km

Meso-γ:
VHTs, Congestus, Precip.
Driven downdrafts, Gust fronts
2 – 20 km

Further Analysis

- Further analysis underway

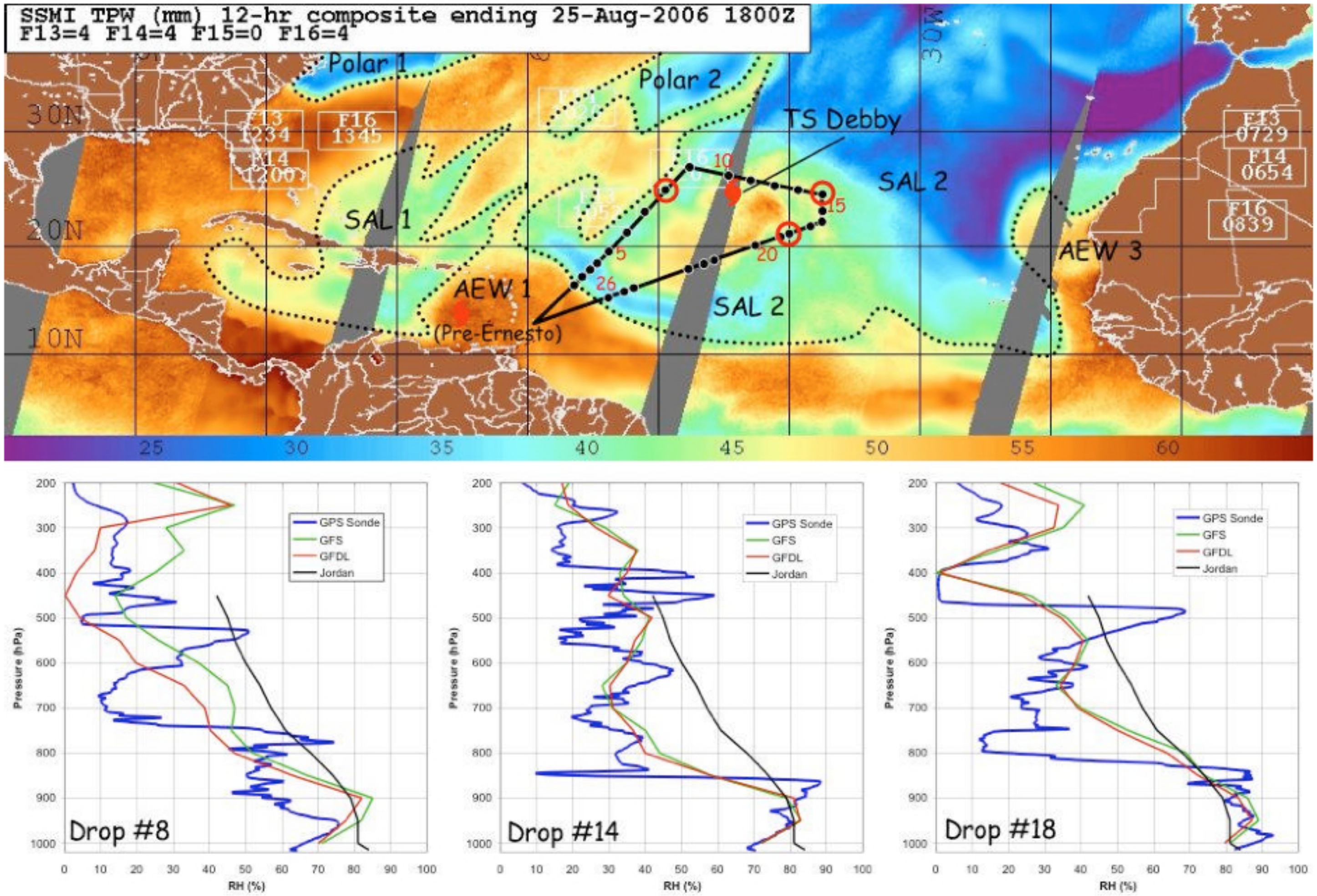
	Nondevelopers				Developers		Diabatically activated		SAL/mid-level dry	
	No pouch	Shallow pouch above PBL	Shallow pouch within PBL	Deep pouch	Deep pouch	Shallow pouch	Yes	No	Protected	Non-protected
Number of cases										

Questions to be addressed

- Questions to be addressed using PREDICT field data:
  - Is there a strong inversion layer present?
  - Is there insufficient CAPE within the pouch?
  - Are the middle levels too dry?
  - How fast is the near-surface pouch moving? Is it too fast to sustain organized deep convection near the pouch center?
  - Why do some pouches prevent dry air intrusion while others do not?
  - how well do these global models represent/forecast the pouch evolution?

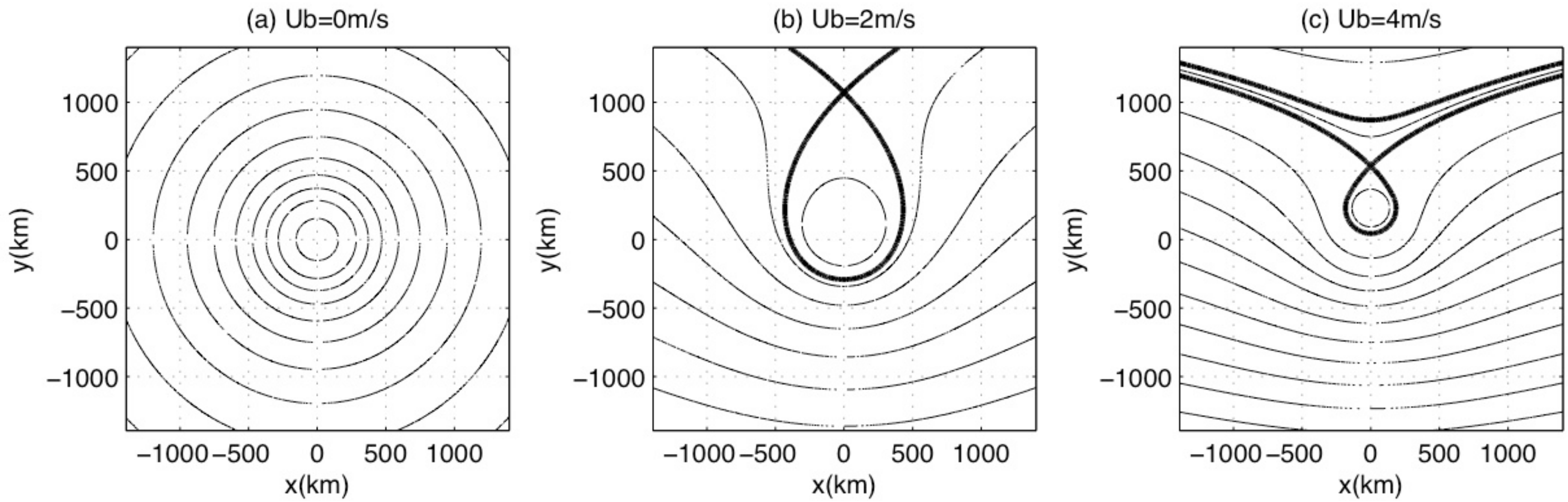
End of Talk
Thanks

Mid-level Dry Air



From Zipser et al. 2009

Rankine Vortex Embedded Within A Uniform Mean Flow



$$V_\Theta(r) = \begin{cases} \frac{V_0 r}{R}, & (r \le R) \\ \frac{V_0 R}{r}, & (r > R) \end{cases}$$

If the vortex is very weak (small V_0), a shear flow may rip open the vortex and no closed circulation would exist even in the moving frame of reference.