HOWARD UNIVERSITY
1867

Comparison of the Initial Development and Genesis of Hurricane Karl (2010) and Tropical Storm Mathew (2010).

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Group Meeting
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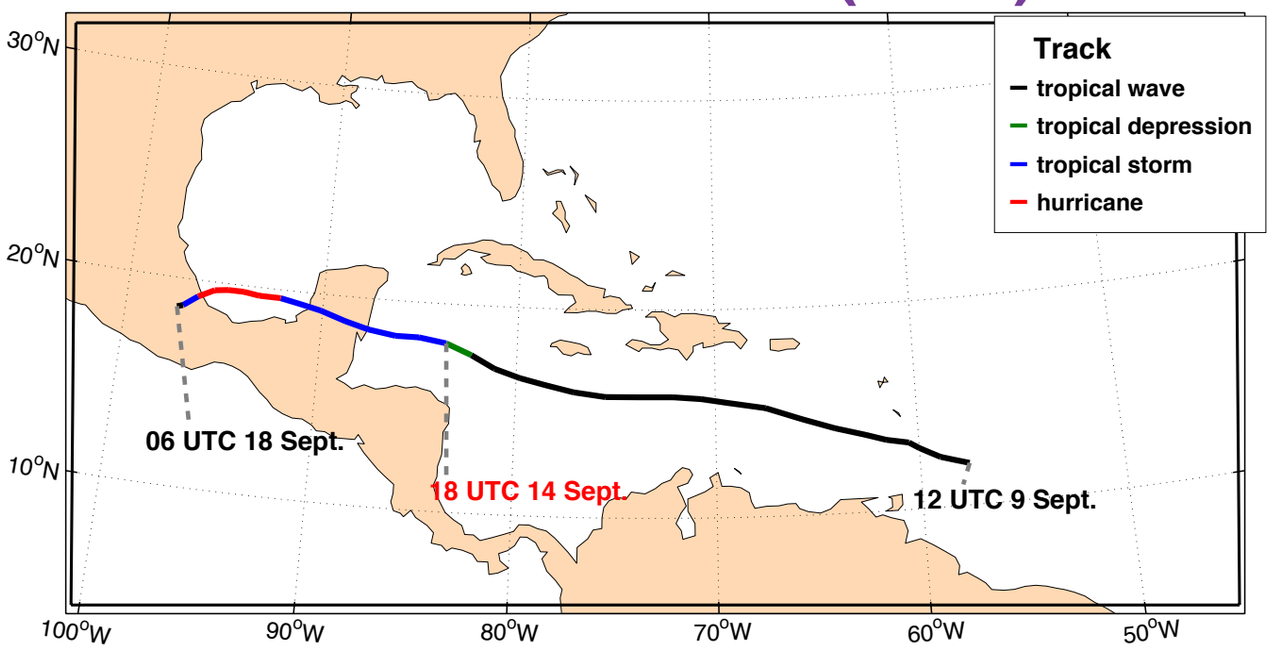
Introduction

This study makes use of a coupled EnKF-4DVar data assimilation method (known as **E4DVar**) to assimilate conventional and field campaign observations taken during NASA Genesis and Rapid Intensification Processes (GRIP) and NSF Pre-depression Investigation of Cloud Systems in the Tropics (PREDICT) conducted in summer of 2010.

For this study we will examine and compare the initial development and genesis of hurricane Karl and tropical storm Mathew of the 2010 hurricane season.

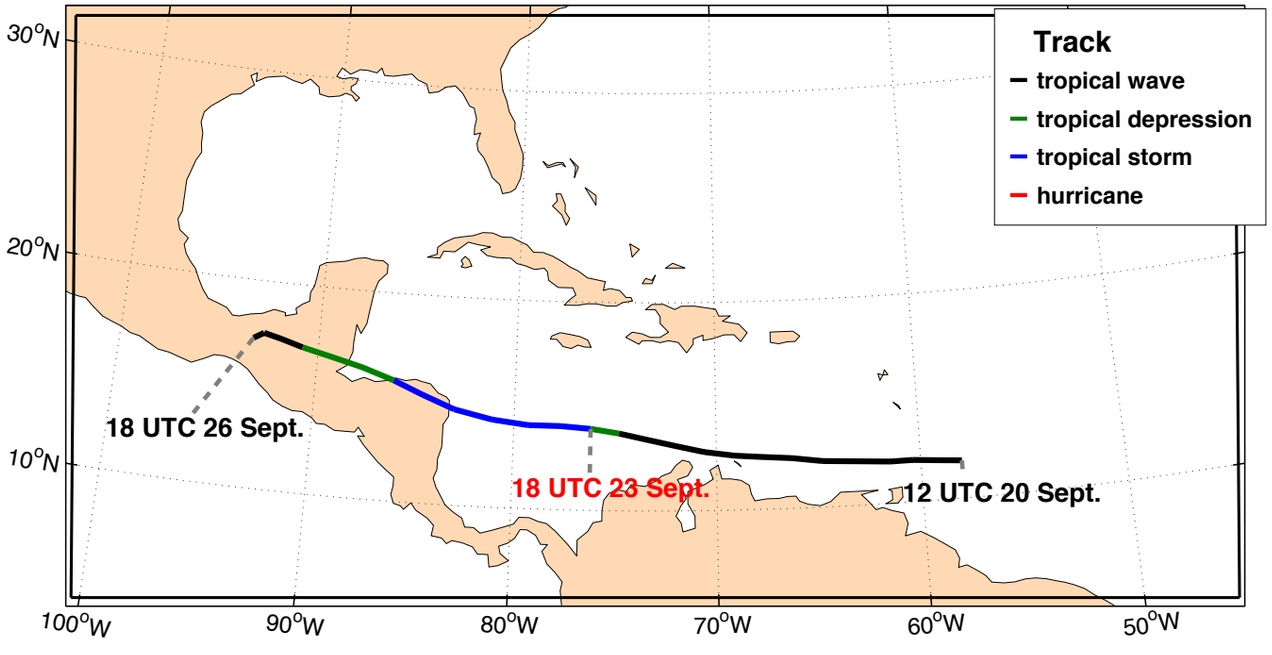
Case Studies

Hurricane Karl (2010)



- Karl was a category 3 hurricane with a minimum central pressure of 956 hPa and maximum sustained winds of 110 knots. Formed at 18.1 N, 83.6 W on September 14th at 18Z.

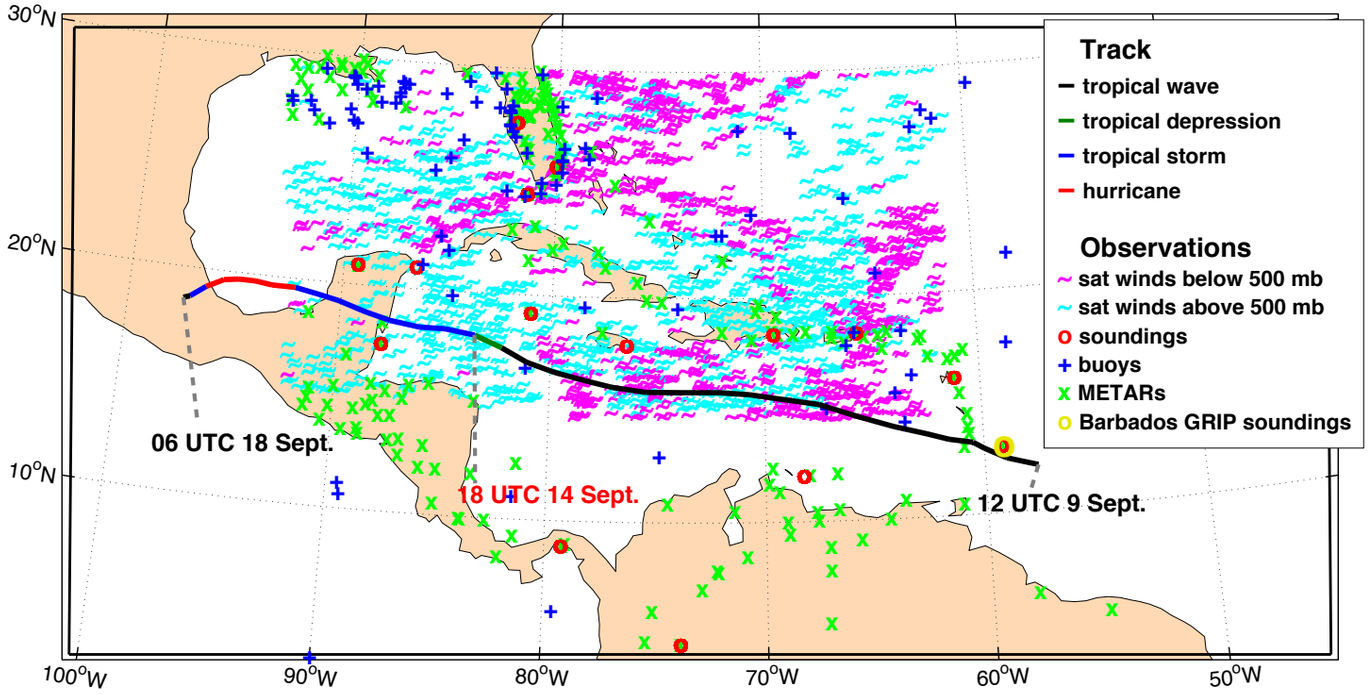
Tropical Storm Mathew (2010)



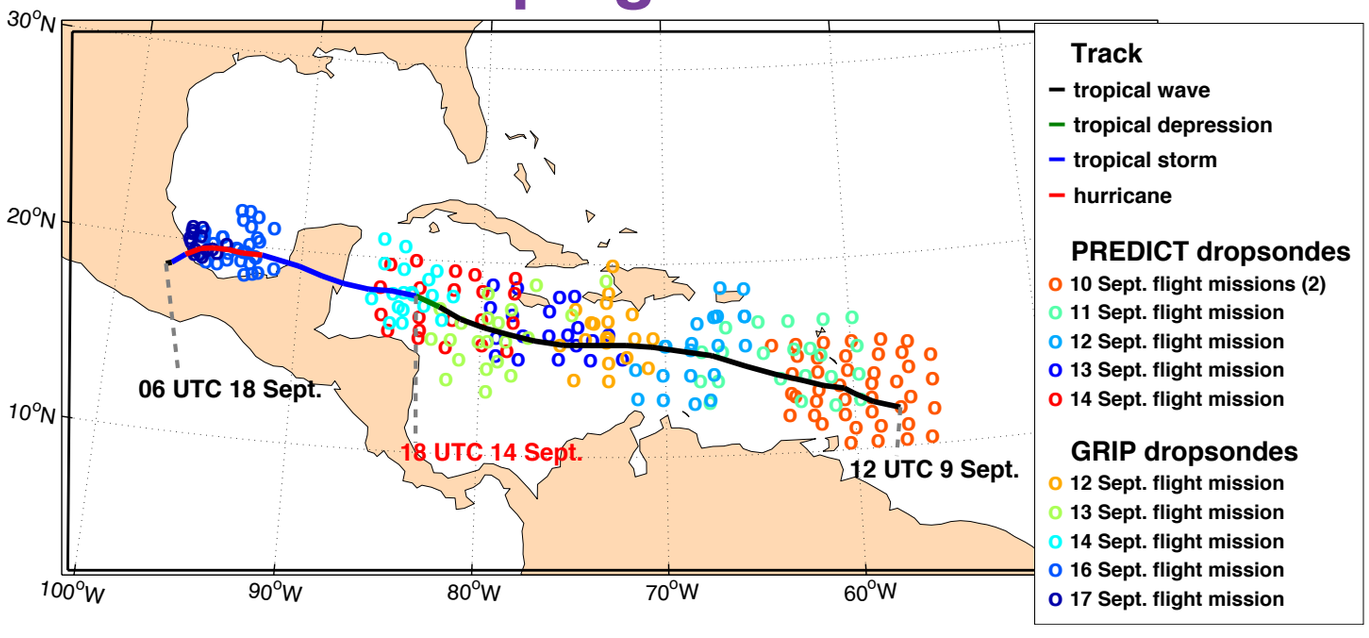
- Mathew had a minimum central pressure of 998 hPa and maximum sustained winds of 50 knots. Formed at 13.9 N, 76.2 W on September 23rd at 18Z.

Observations

Conventional Observations



Field Campaign Observations



- Conventional observations were obtained from the Meteorological Assimilation Data Ingest System (MADIS).

- The assimilated data include conventional observations from MADIS, dropsonde measurements collected during PREDICT and GRIP field campaigns and 3-hrly soundings from Barbados.

Coupled EnKF-4DVar Data Assimilation Schematic

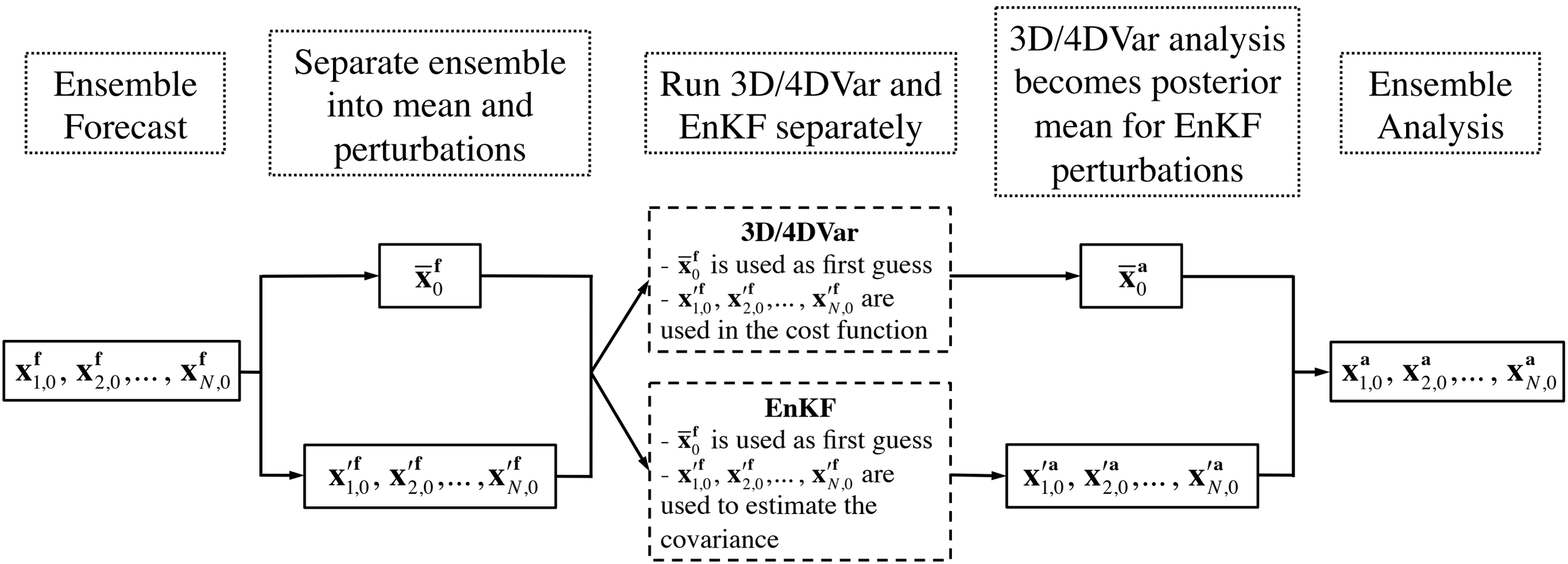
Ensemble Forecast

Separate ensemble into mean and perturbations

Run 3D/4DVar and EnKF separately

3D/4DVar analysis becomes posterior mean for EnKF perturbations

Ensemble Analysis



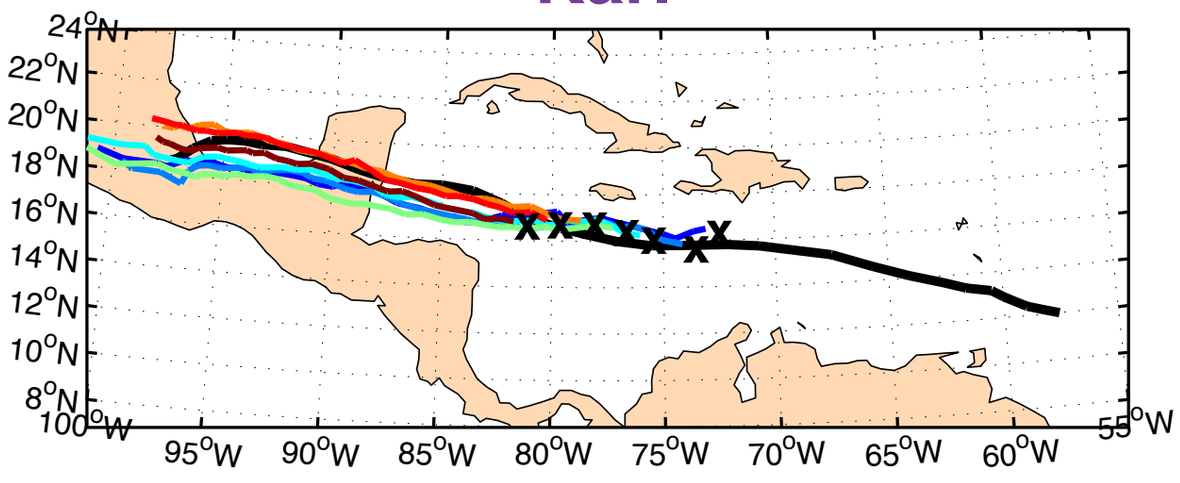
Zhang and Zhang (2012), Poterjoy and Zhang (2014)

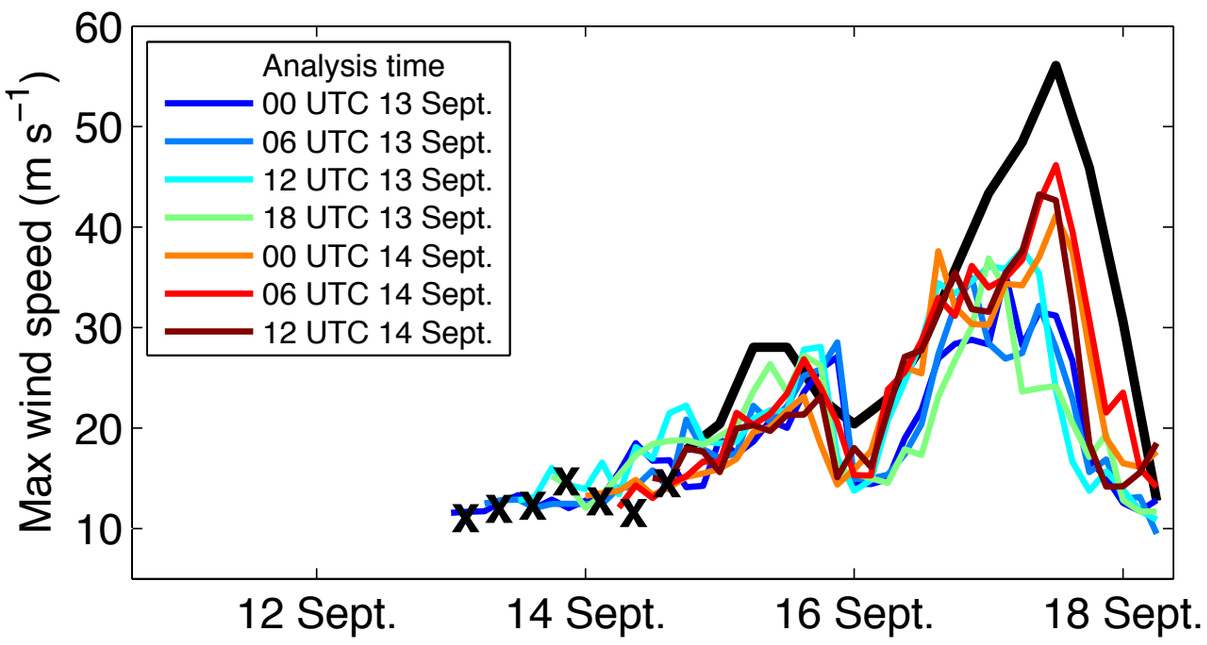
Experimental Design

- 60 ensemble members
- Localization of 900 km in the horizontal & 15 levels in the vertical
- Relaxation coefficient of 0.8
- Two way coupling between EnKF and 4DVar
  - 4DVar uses ensemble mean first guess and ensemble perturbations
  - EnKF update the ensemble members
  - Hybrid 4DVar analysis replaces the EnKF analysis
- 80% of the increment comes from the ensemble perturbations during the hybrid minimization.
- Assimilation performed on 13.5-km grid spacing with 35 vertical levels together with a 4.5-km and 1.5-km two-way nested forecast.
- Experiments were initialized from GFS/GDAS analysis and cycled every 6 hours.

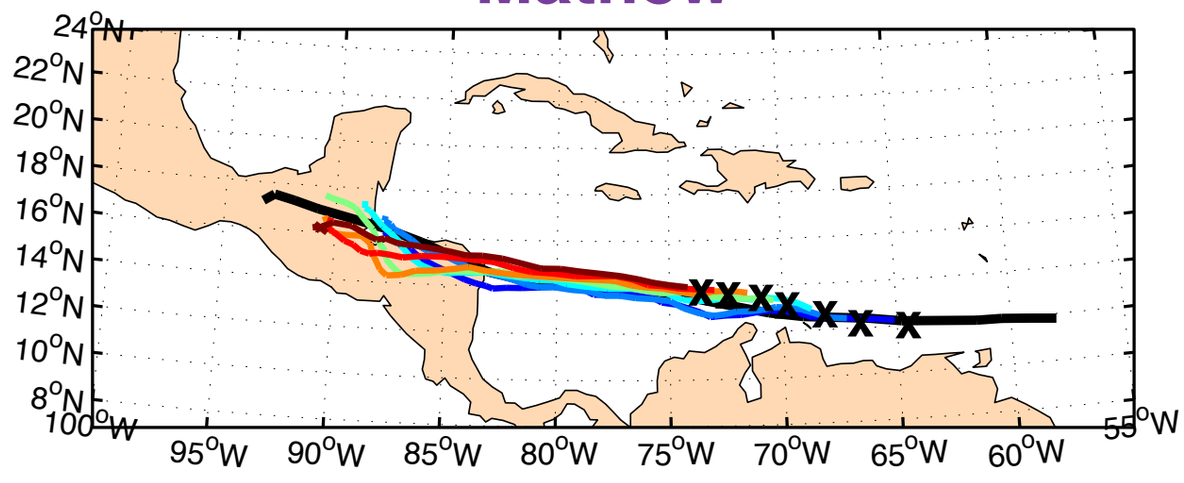
Deterministic Track and Intensity Forecasts

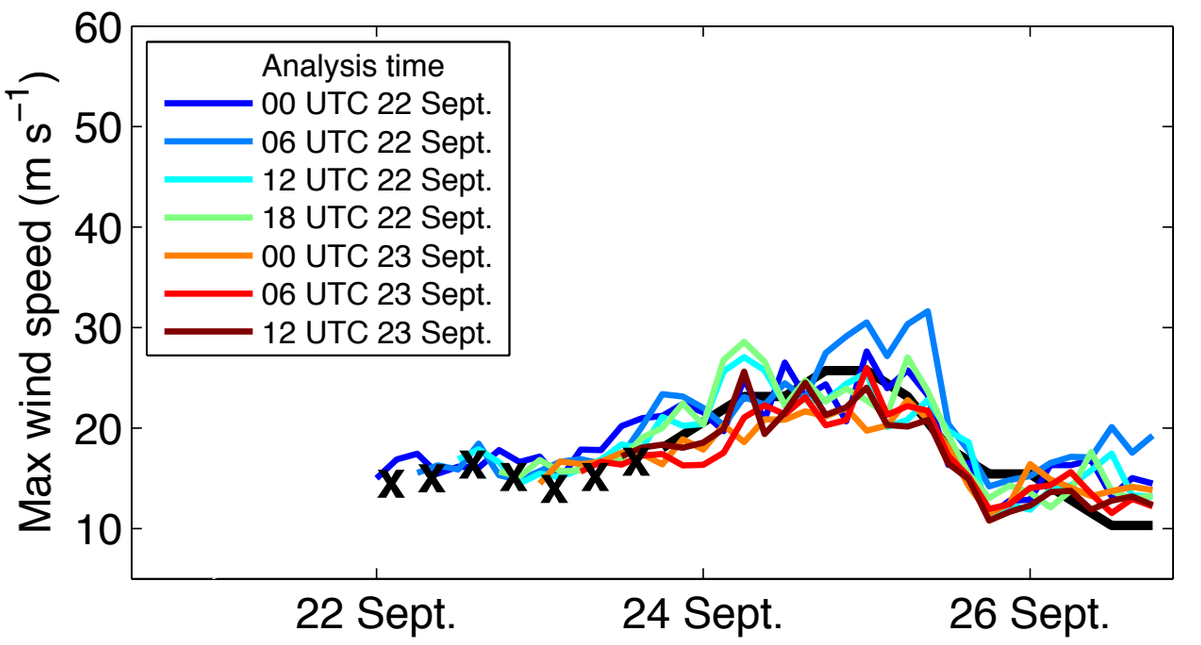
Karl





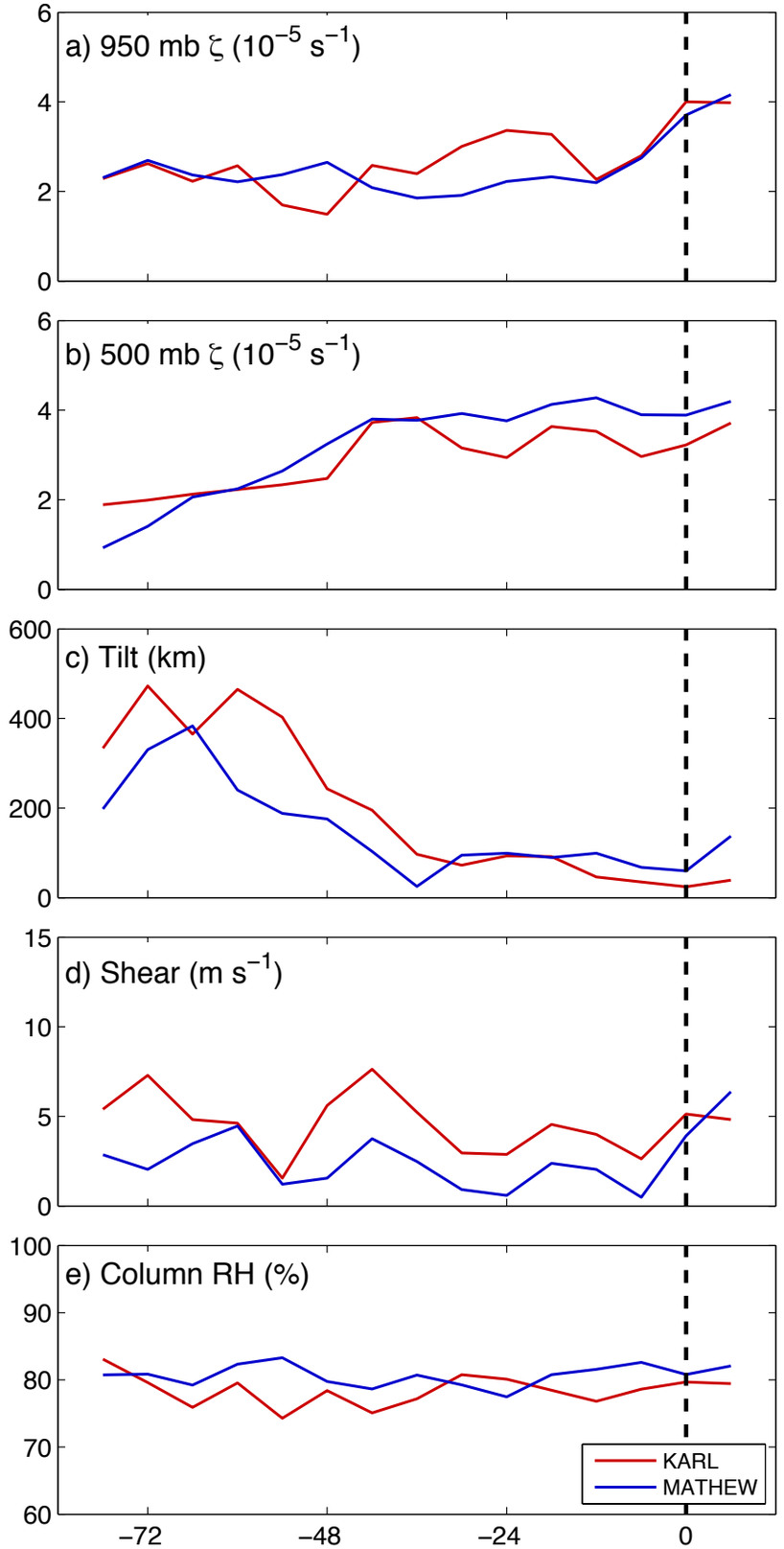
Mathew





- Forecasts initialized within 6-42 hrs before genesis.

E4DVar Analyses

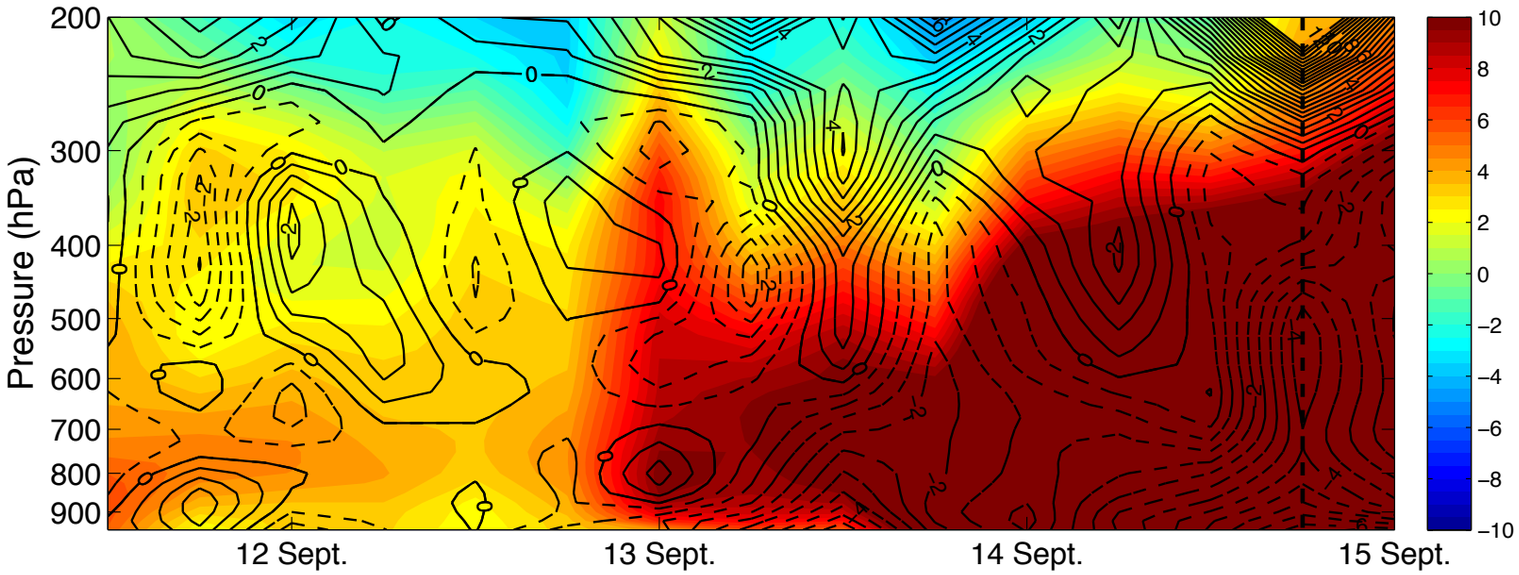


- Karl's analyses from 12 UTC Sept. 11th to 00 UTC Sept. 15th.
- Mathew's analyses from 12 UTC Sept. 20th to 00UTC Sept. 24th.
- Vorticity, Tilt, Shear and Column RH calculated within 3 degrees of the storm center.
- Both Karl and Mathew showed relatively the same trend prior too and during genesis.

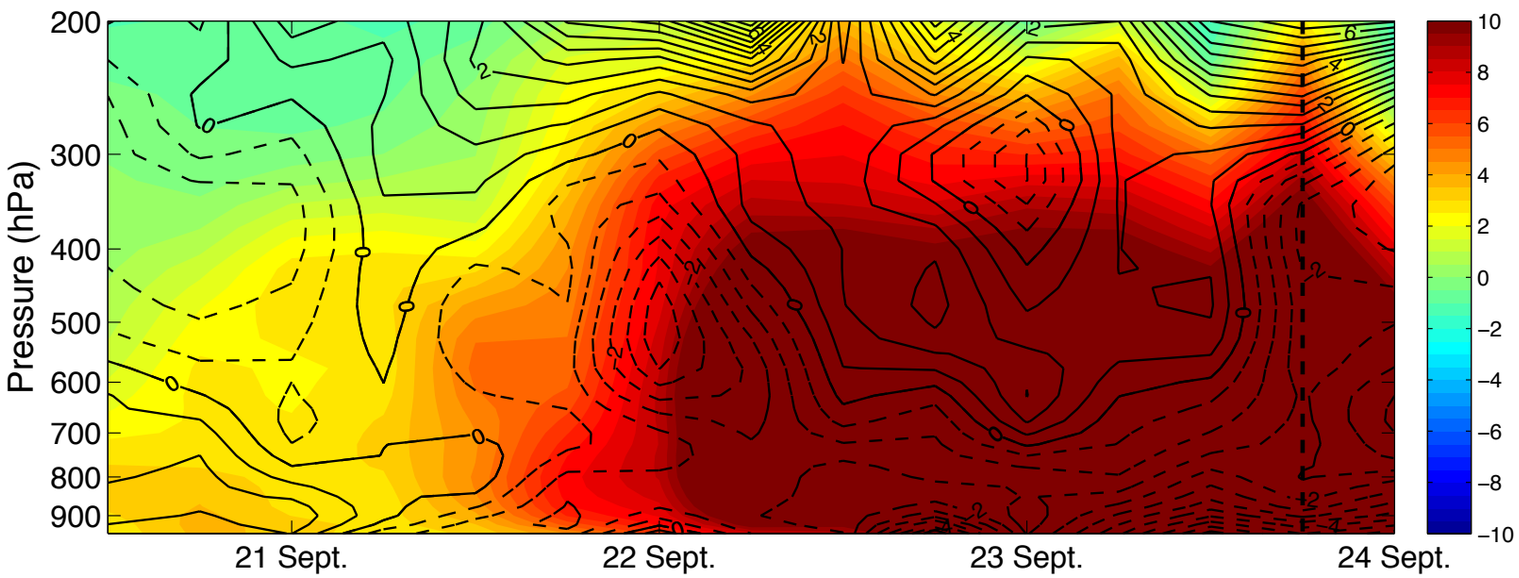
100 KM STORM CENTRE ANALYSES

Vorticity (ζ) Profile with Divergence Overlay

Karl



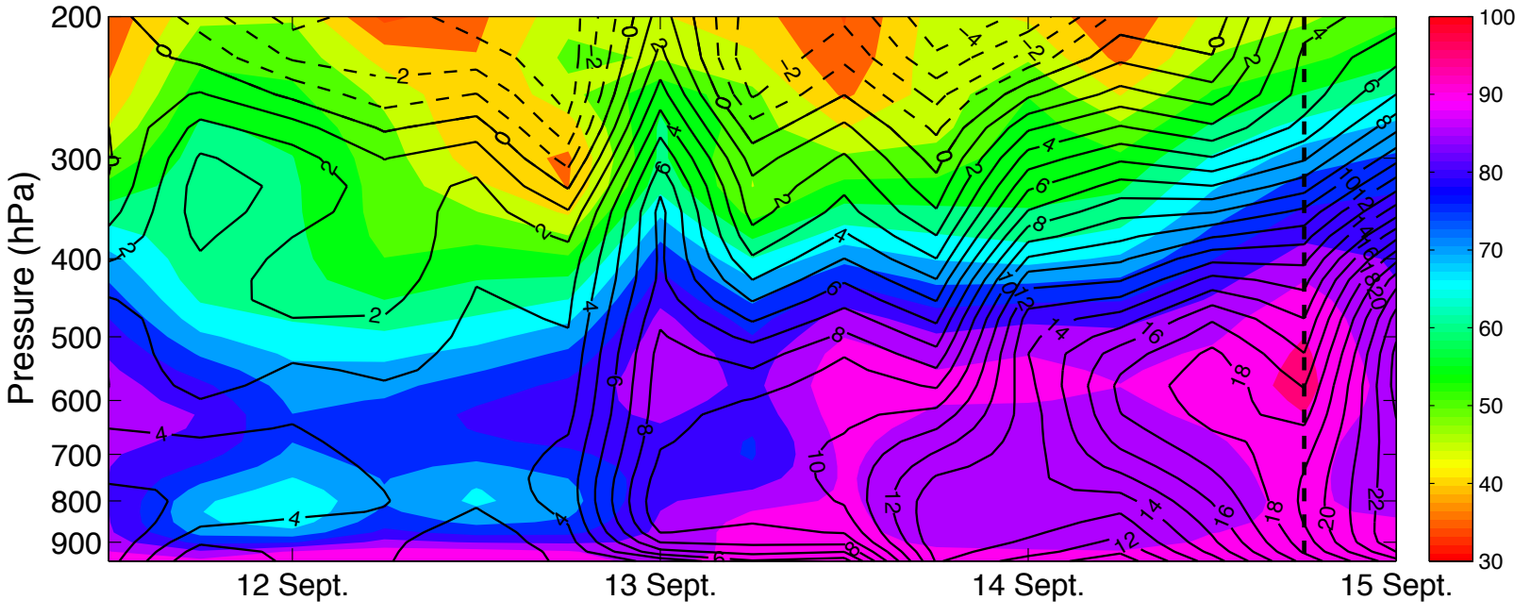
Mathew



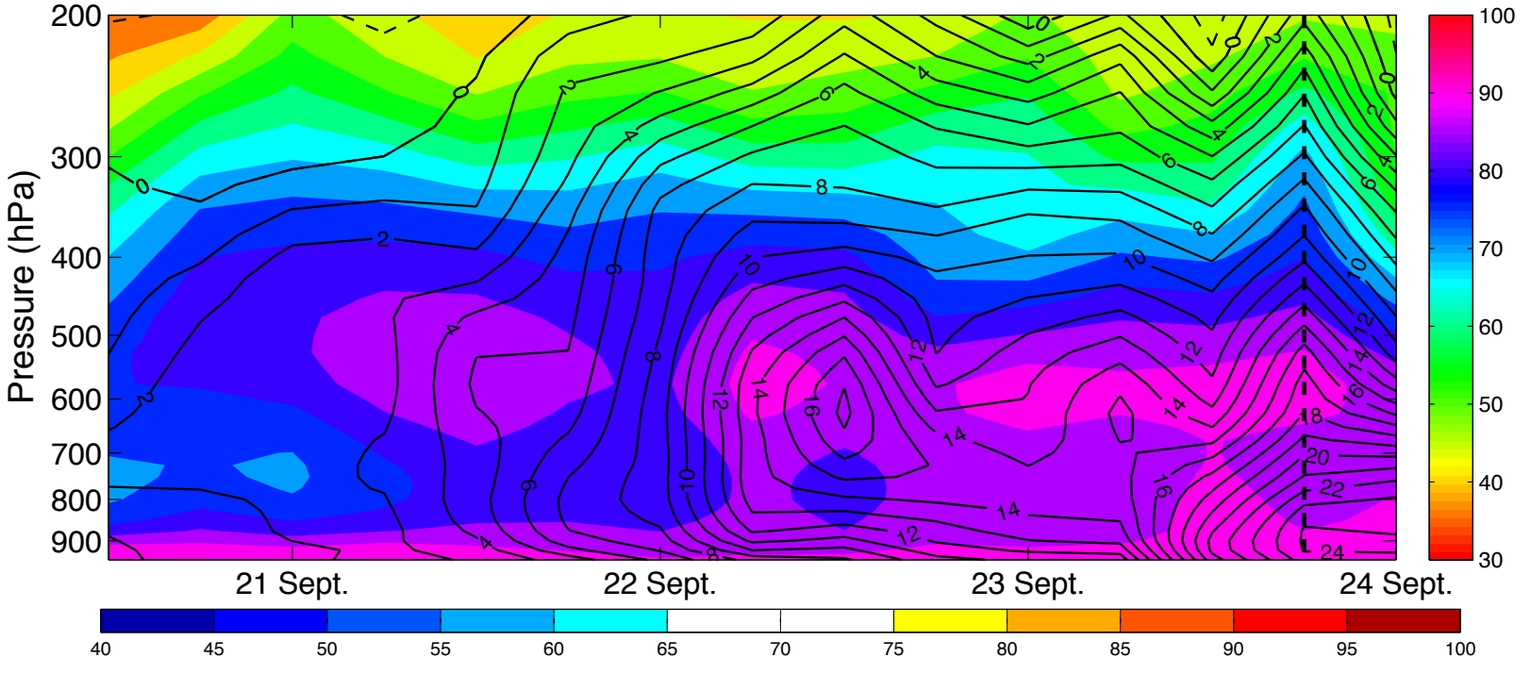
- Vorticity significantly increased in the middle levels 52 hrs prior to genesis.
- There is also a noticeable increase in the mid-level convergence around the same time.

Relative Humidity Profile with Vorticity (ζ) Overlay

Karl



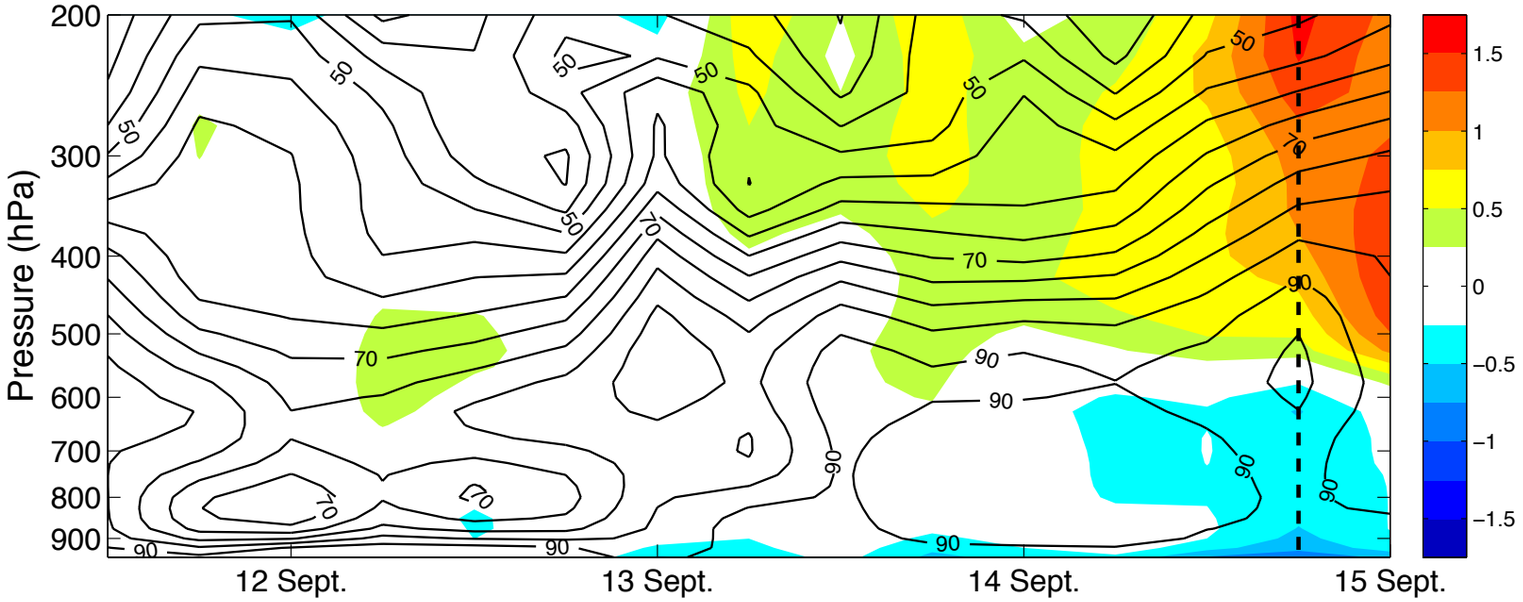
Mathew



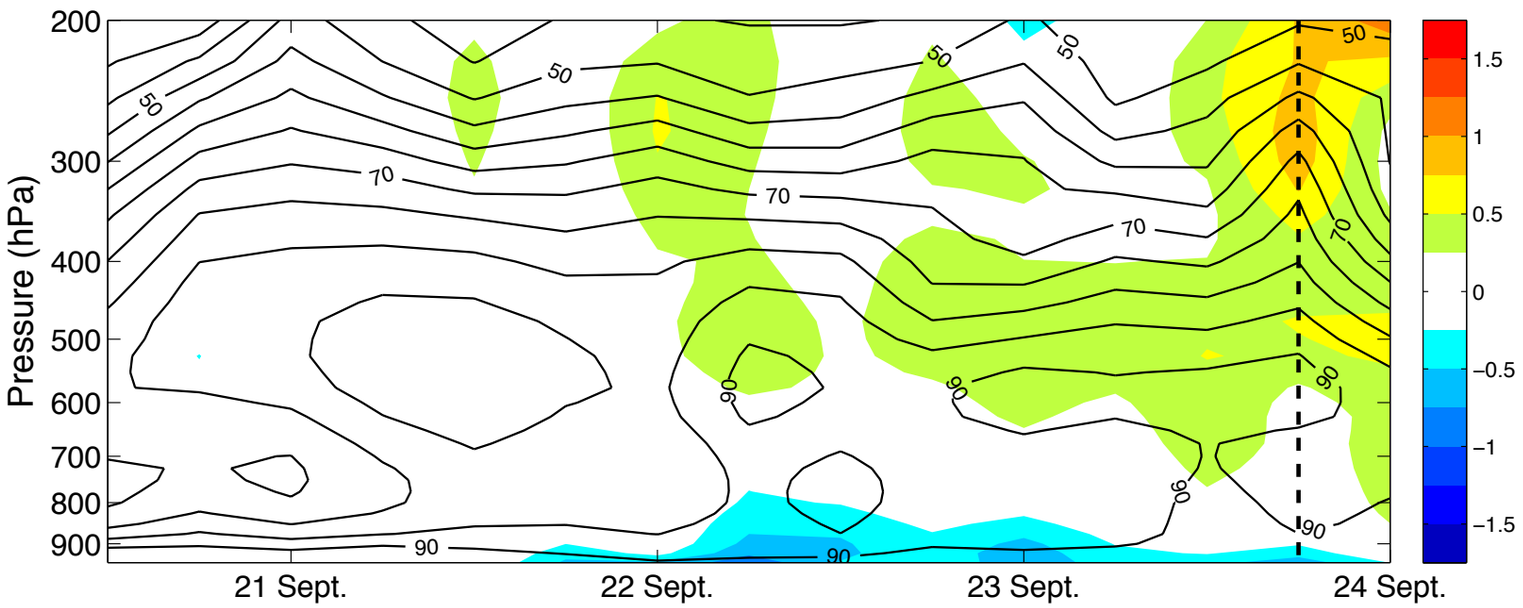
- The increase of vorticity in the lower atmosphere is correlated to the increased moisture.

Perturbation of Potential Temperature (θ') Profile with RH Overlay

Karl



Mathew

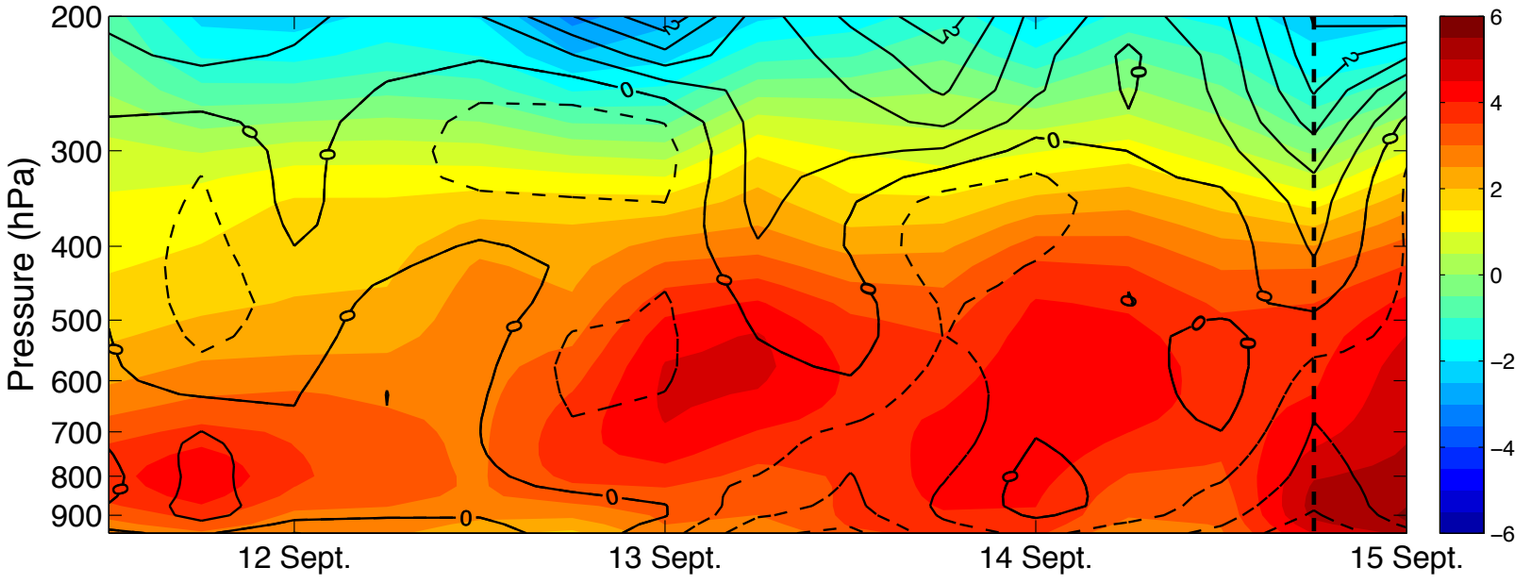


- Warm core pool in the mid to upper levels prior to genesis.
- At time of genesis the warm core pool is well defined with a cold pool at the surface.
- Low level moisture increases approximately 42 hrs prior to genesis.

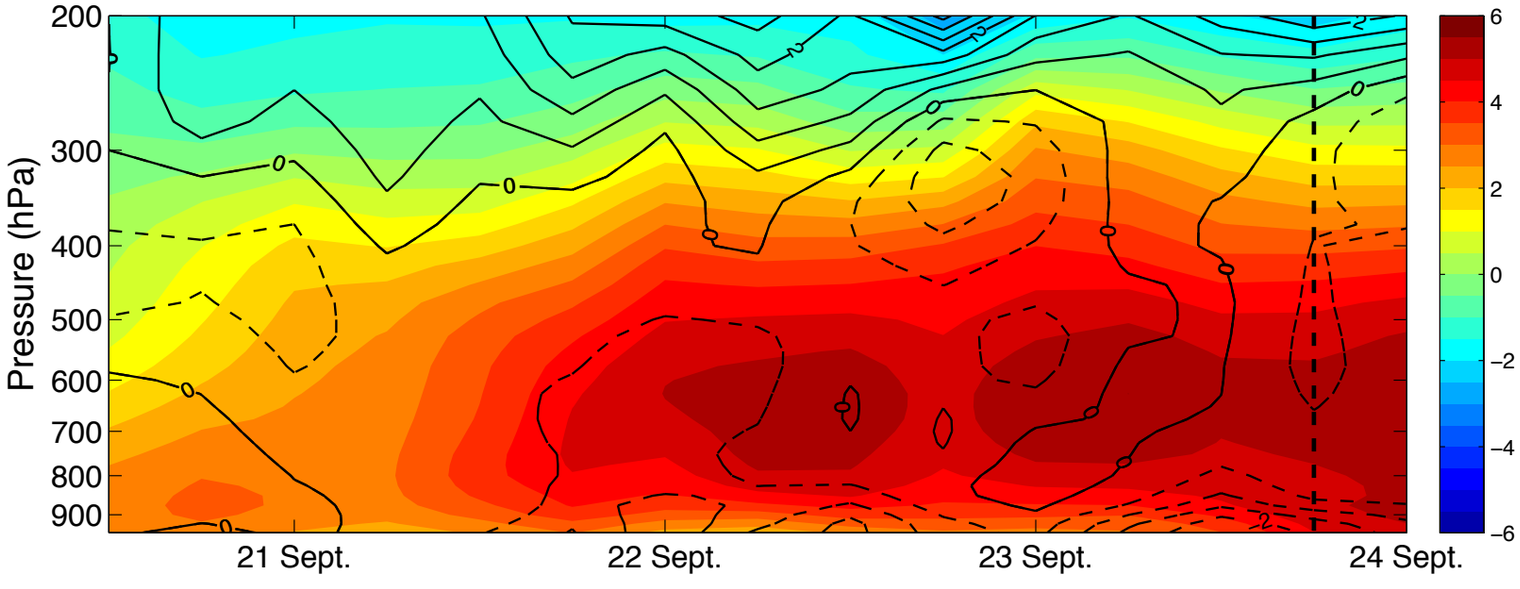
300 KM STORM CENTRE ANALYSES

Vorticity (ζ) Profile with Divergence Overlay

Karl



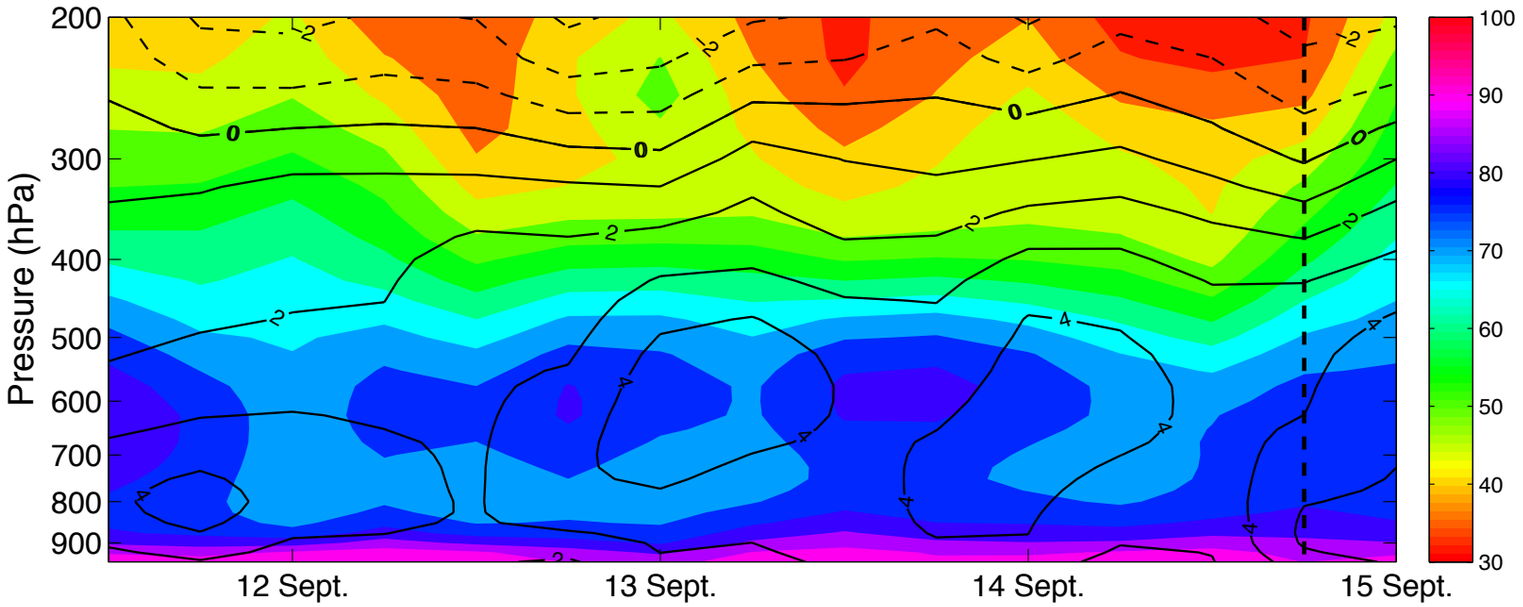
Mathew



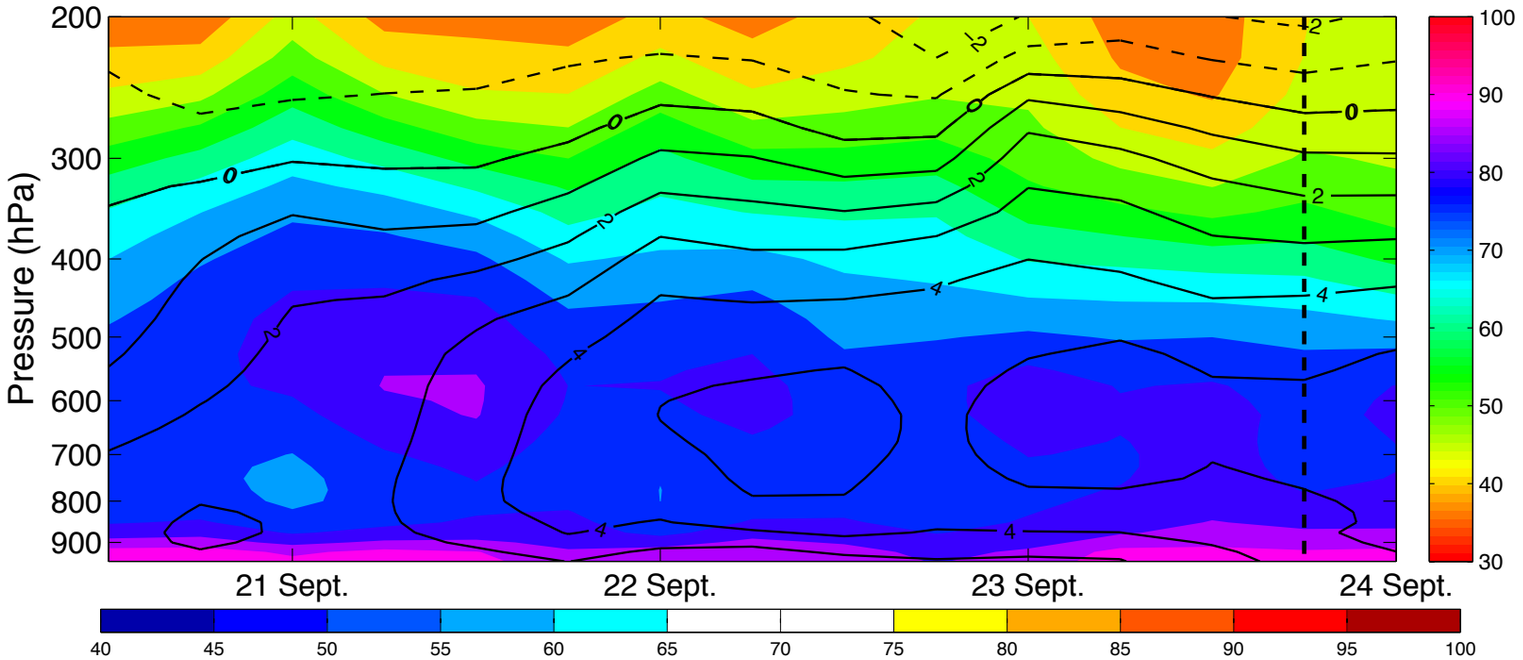
- Vorticity increased in the middle levels 52 hrs prior to genesis.
- Mid-level convergence is observed around the same time.

Relative Humidity Profile with Vorticity (ζ) Overlay

Karl



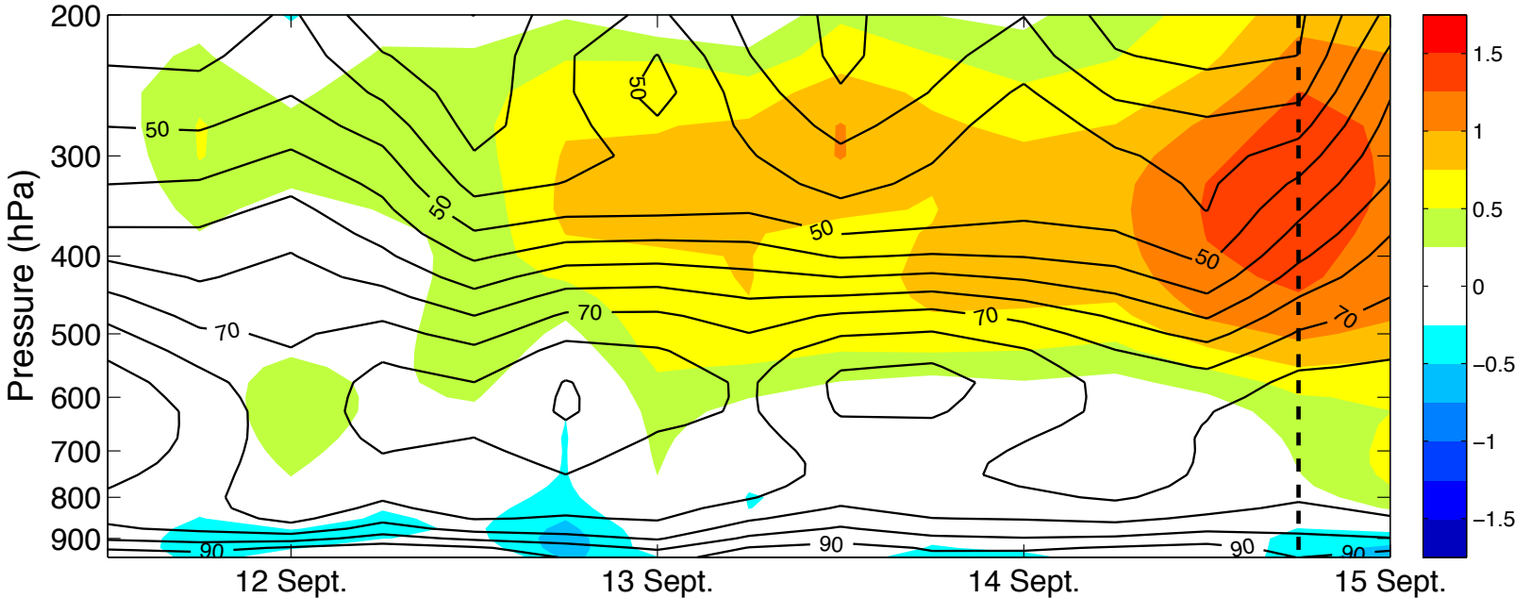
Mathew



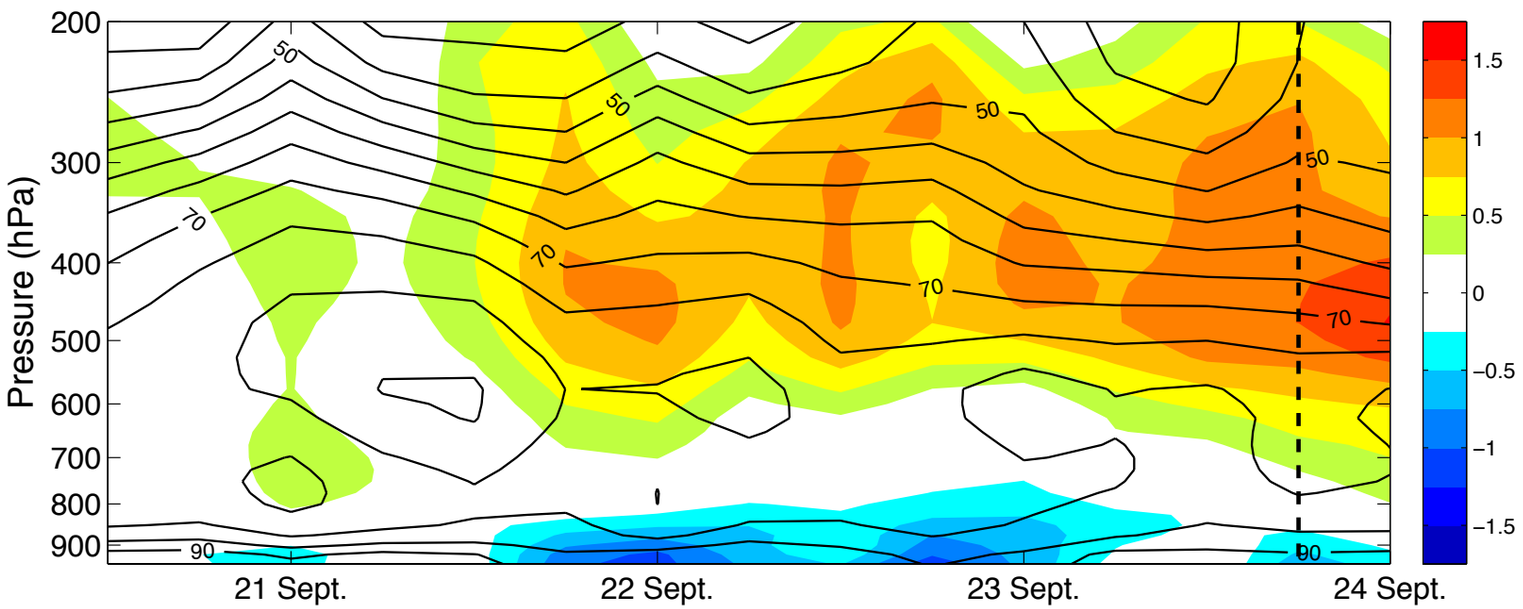
- The areas of maximum vorticity is accompanied by moisture as shown before.

Perturbation of Potential Temperature (θ') Profile with RH Overlay

Karl



Mathew

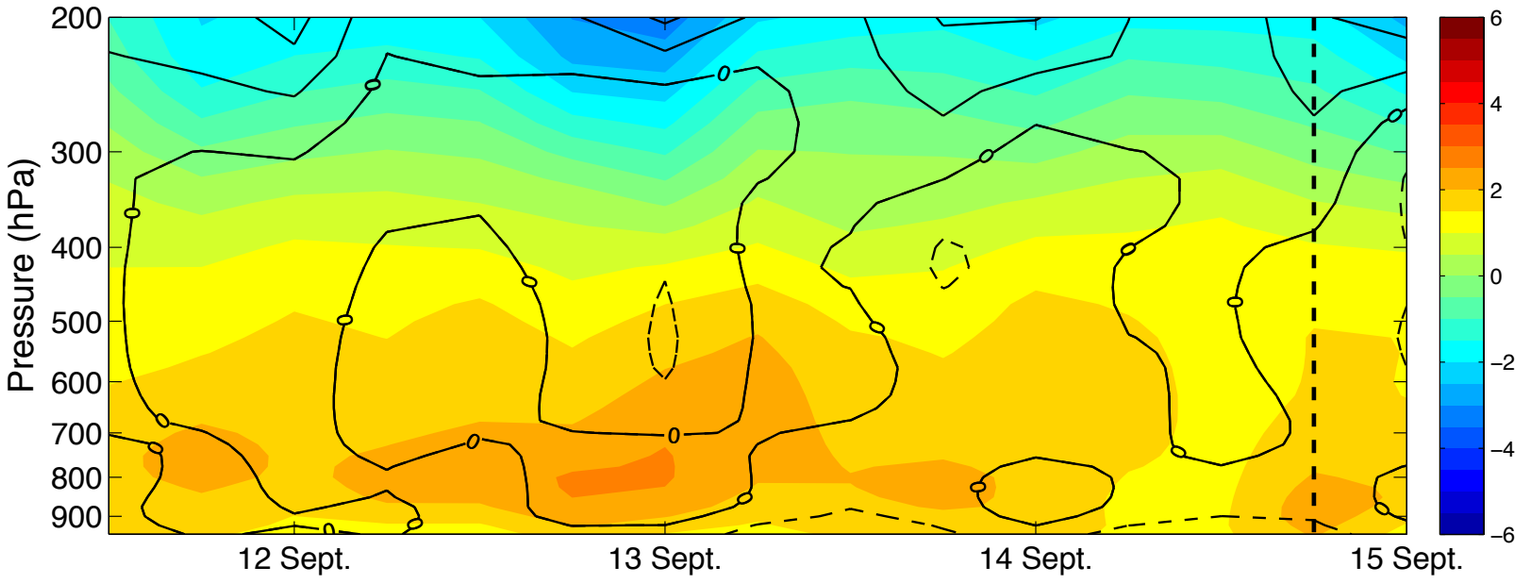


- Warm core pool in the mid to upper levels prior to genesis.
- At time of genesis the warm core pool is well defined with a relatively shallow cold pool at the surface.
- Low level moisture remains relatively constant.

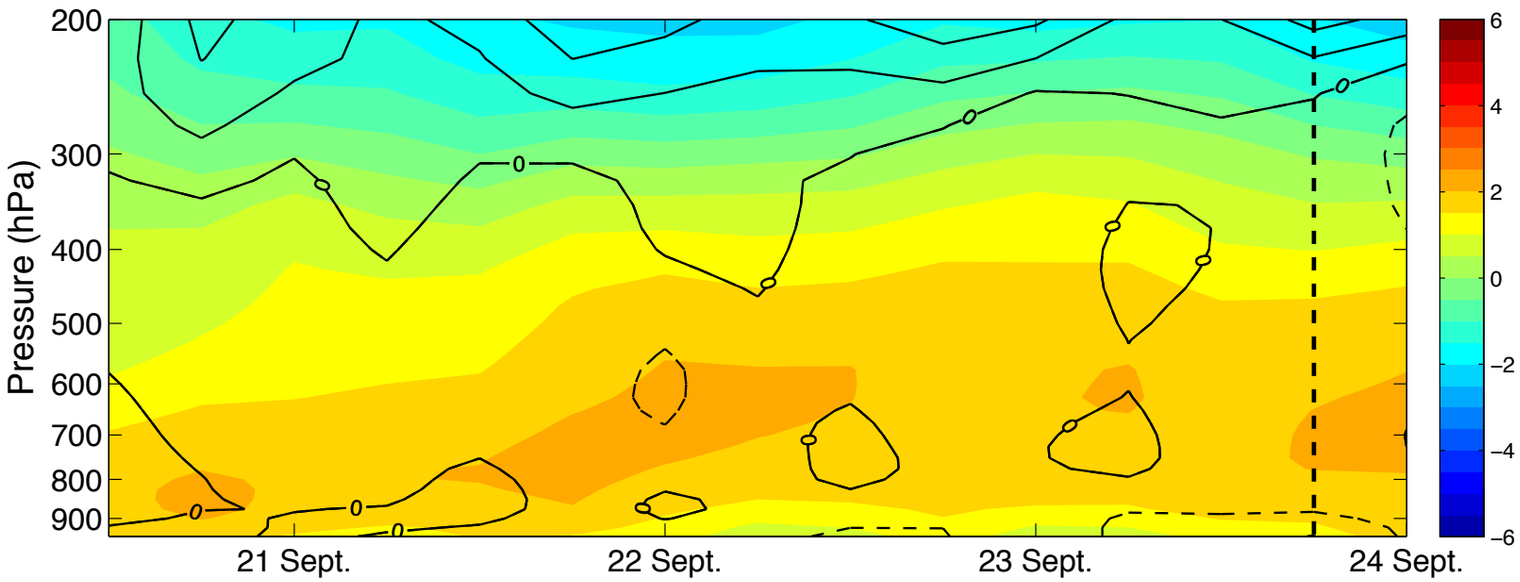
500 KM STORM CENTRE ANALYSES

Vorticity (ζ) Profile with Divergence Overlay

Karl



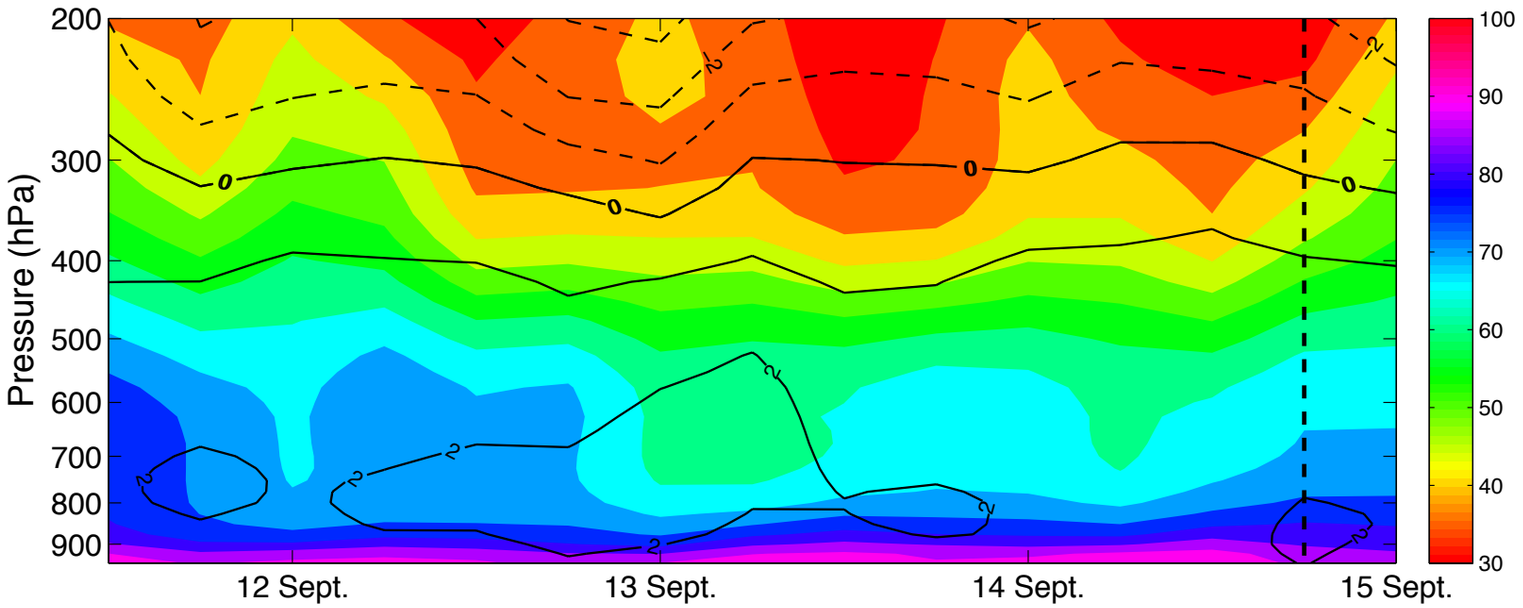
Mathew



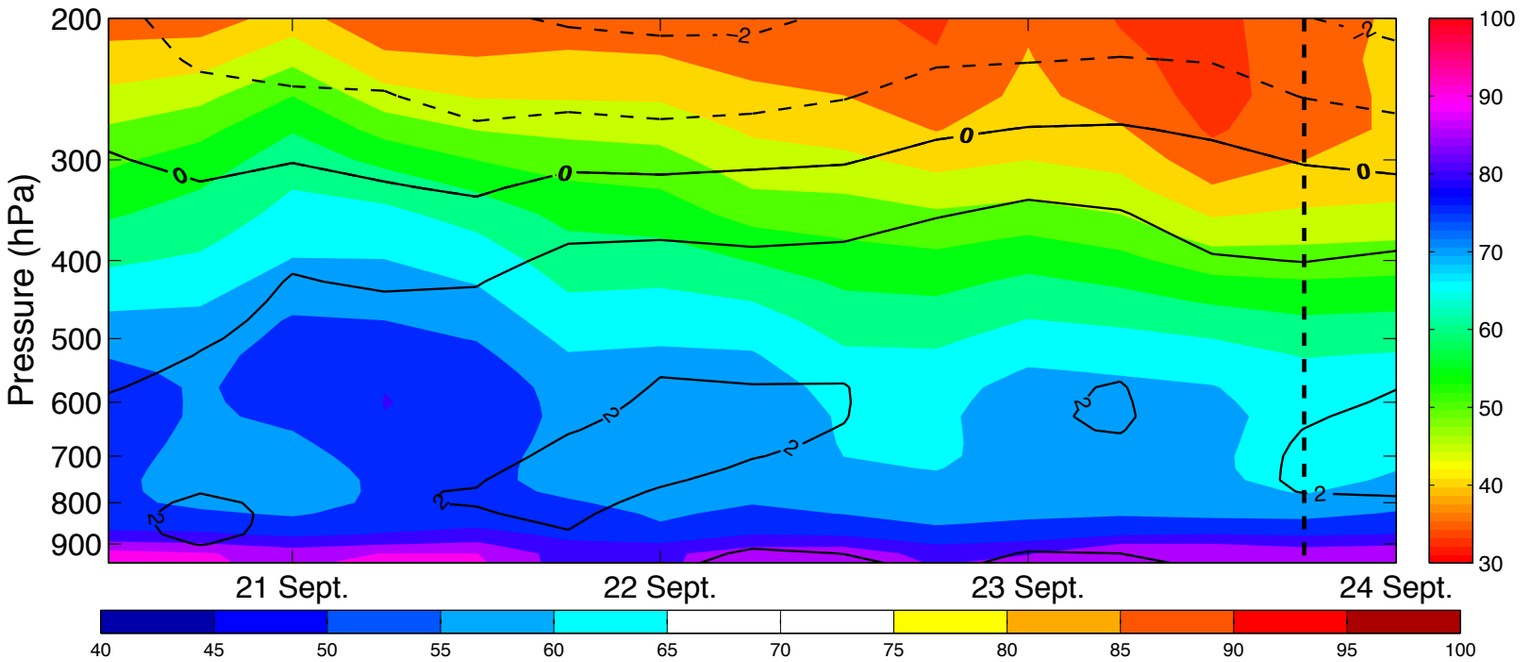
- Vorticity significantly weaker when compared to 100 and 300 km analyses.
- Karl and Mathew had a diameter on average between 700 - 850 km.

Relative Humidity Profile with Vorticity (ζ) Overlay

Karl



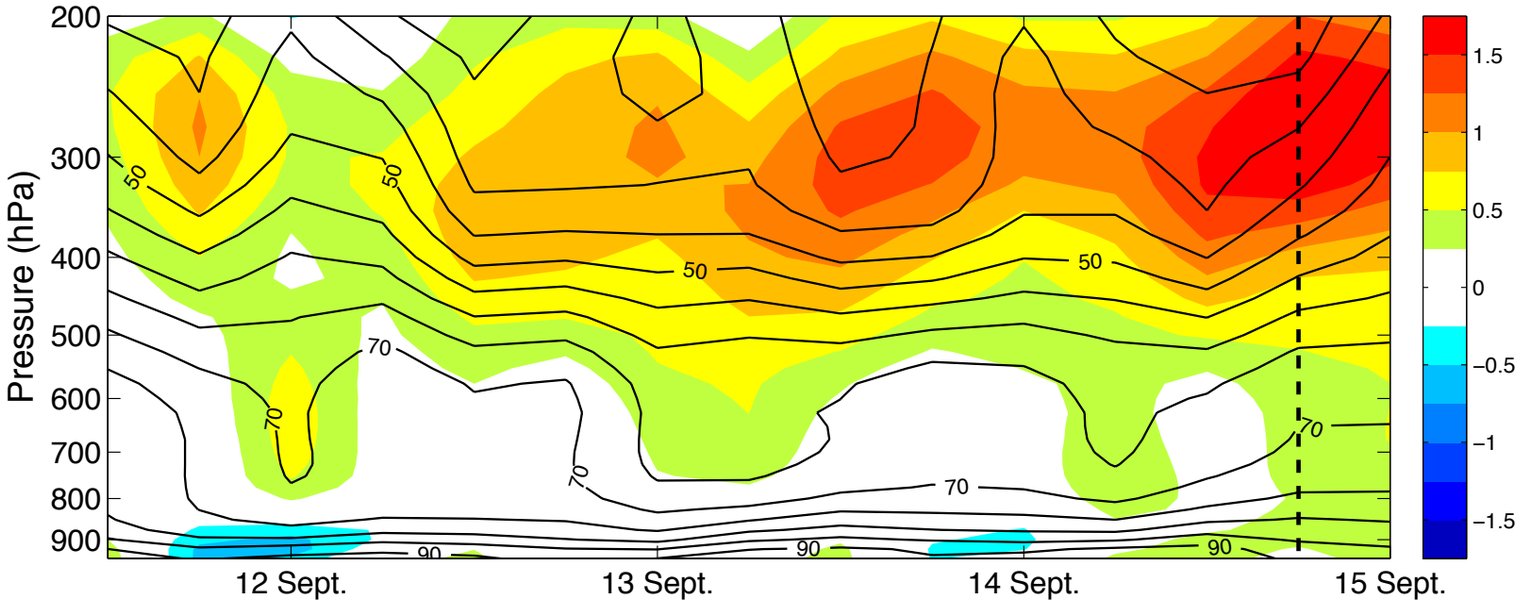
Mathew



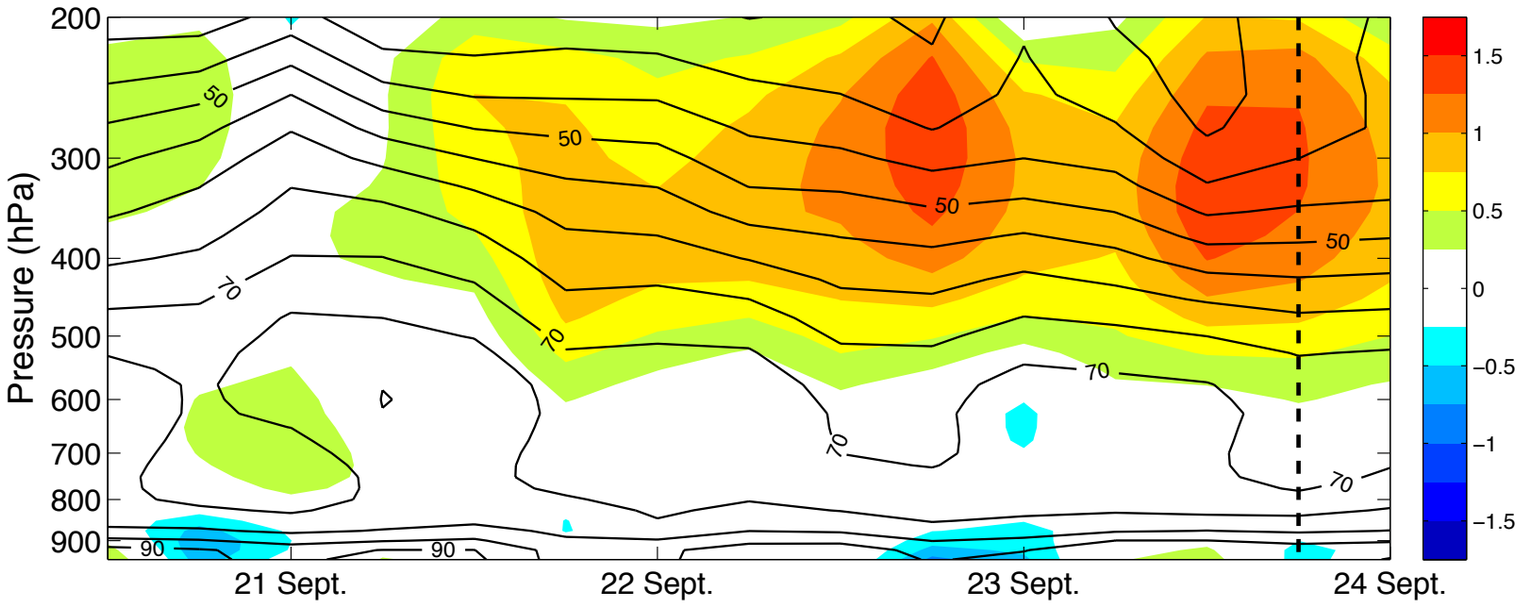
- The areas of maximum vorticity is accompanied by moisture as shown before.

Perturbation of Potential Temperature (θ') Profile with RH Overlay

Karl



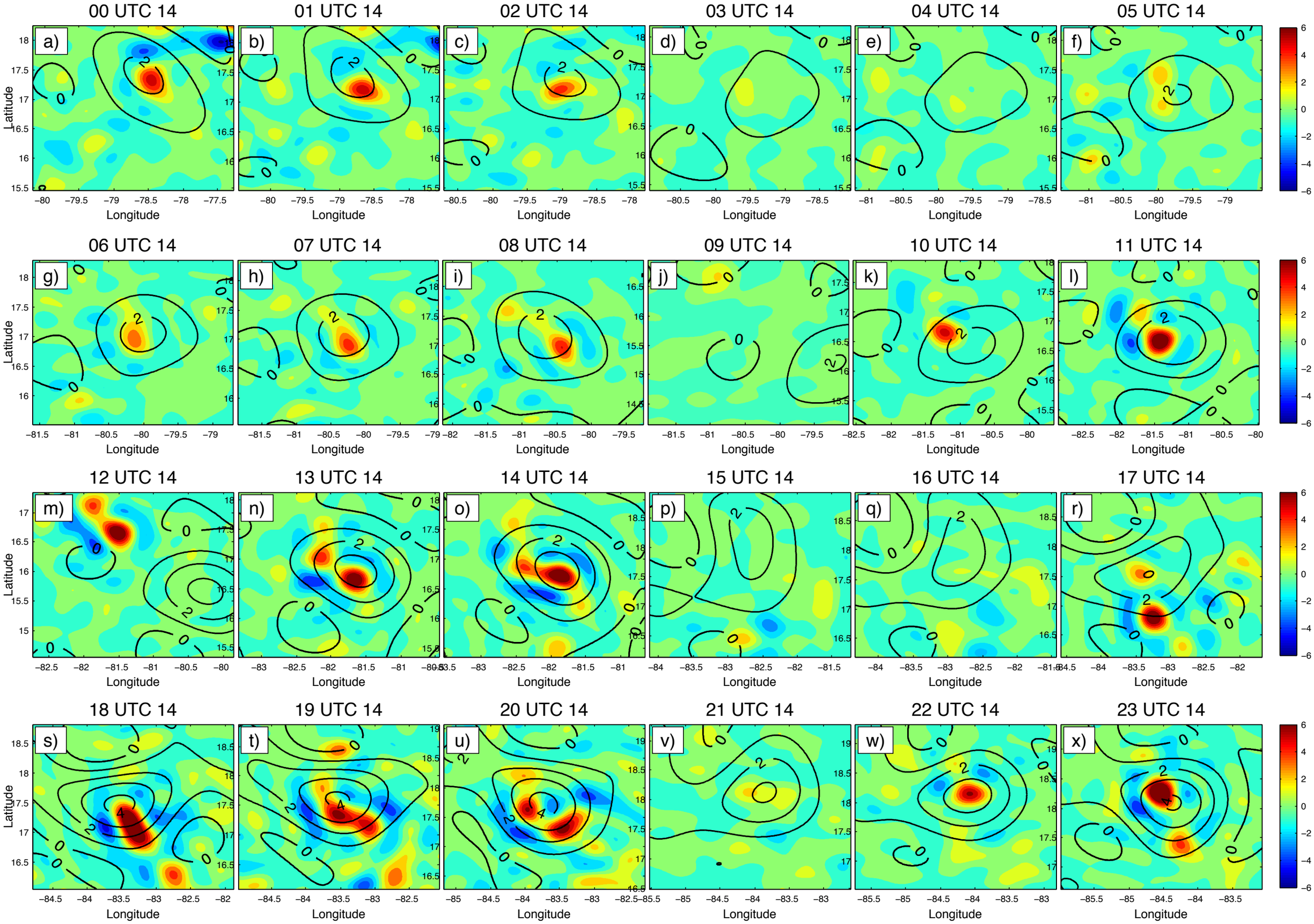
Mathew



- Warm core pool in the mid to upper levels prior to genesis with a distinct diurnal cycle.
- At time of genesis the warm core pool is well defined with the surface cold pool being nonexistent.
- Surface cold pool maybe nonexistent due to sensible heat flux from the ocean.

Spectral Decompostion of Vorticity (ζ) Over Analysis Window

Karl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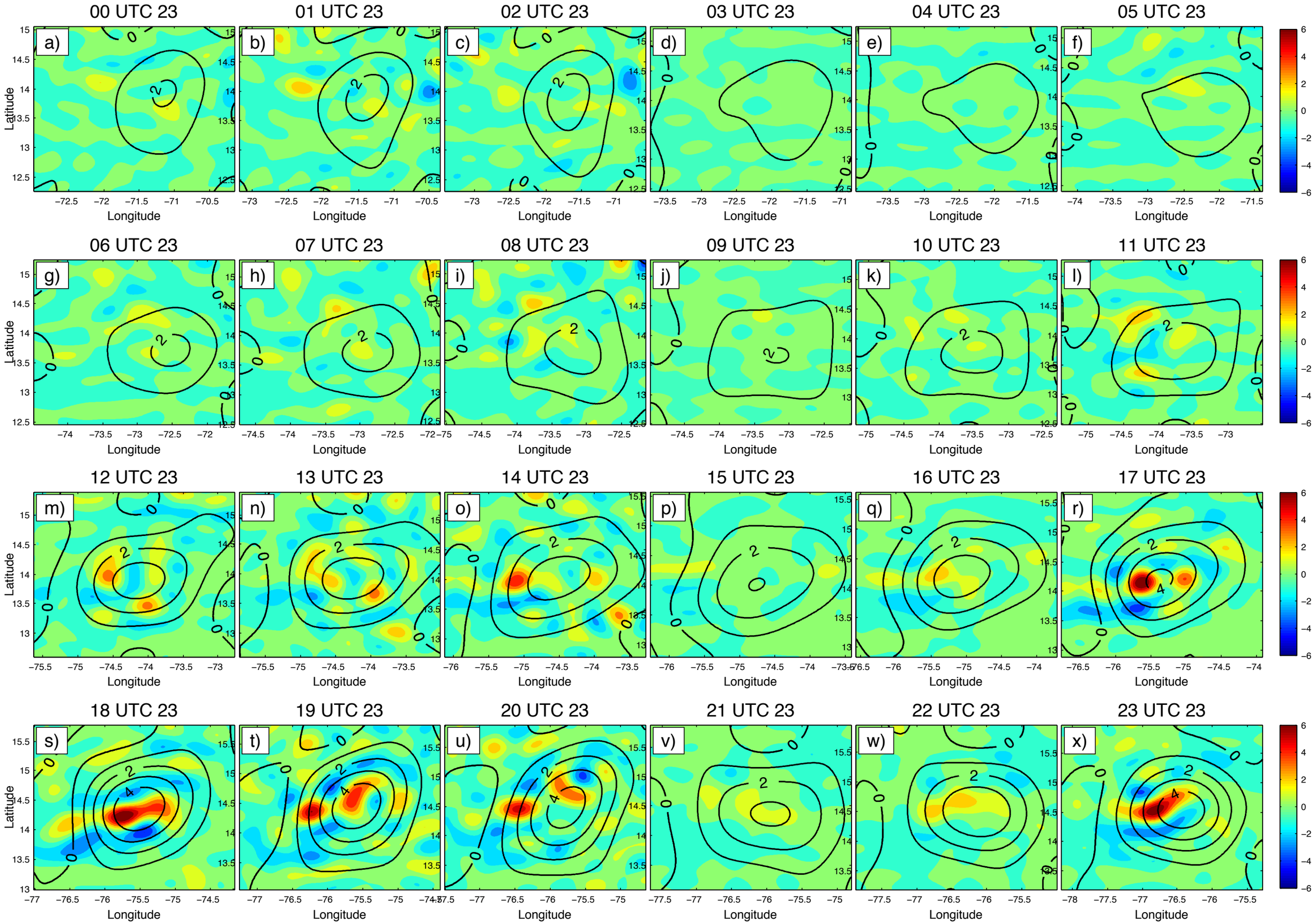
Mathew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Summary and Future Work

- E4DVar has shown significant skill in the genesis of both hurricane Karl and tropical storm Mathew.
  - E4DVar is able to accurately predict the genesis of both Karl and Mathew 42-hrs in advance.

- Development of both systems was as a result of the bottom-up process.

- Both systems showed the presence of possible stratiform dynamics prior to genesis.

★ Perform vorticity budget on 1.5 km forecast within analysis window for both Karl and Mathew.

THANK YOU