# CONVERSION FROM SHEAR TO CURVATURE VORTICITY, ORGANIZATION OF CONVECTION, AND HURRICANE GENESIS

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Synoptic-Dynamic Meteorology
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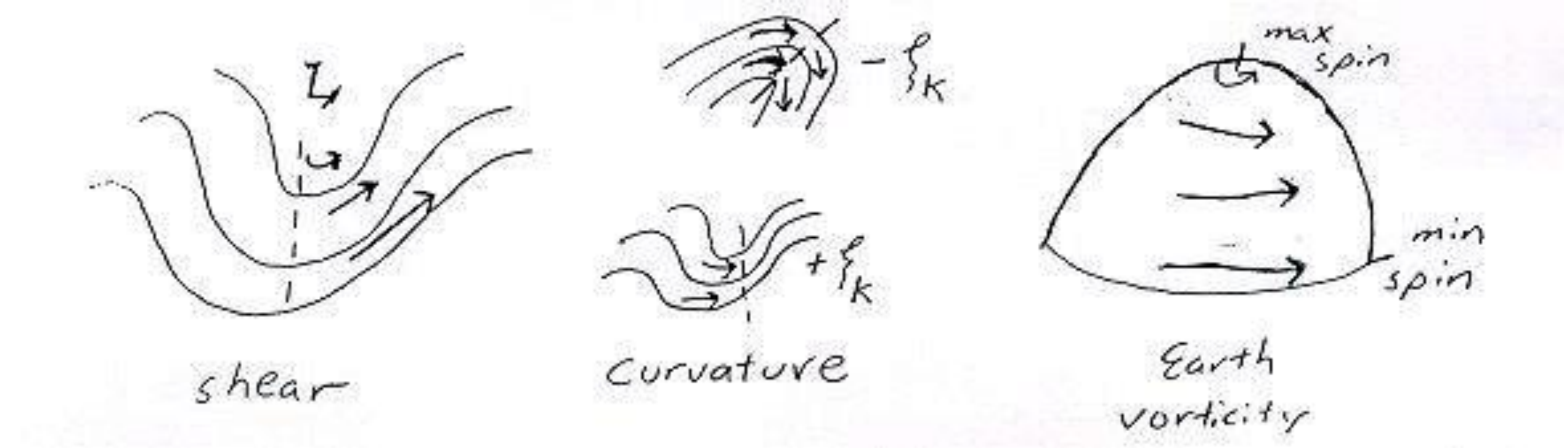
# Introduction

- Krishnamurti et. al. (1986) showed a non-divergent BAROTROPIC model had more skill than persistence for 48 hours over West Africa
- Norquist et. al. (1977) observed that conversion of energy via barotropic processes plays important role in wave maintenance and amplification after wave moves off African continent
- Thorncroft and Hodges (2001) showed correlation between occurrence of 850 mb circulations and frequency of hurricanes in Atlantic
- Ability to predict formation and  behavior of AEWs key to improving tropical cyclone forecasts
- Can use barotropic dynamics as a tool

# Dynamics Review

- Shear Vorticity : $-\frac{\partial V}{\partial n}$

  Curvature Vorticity: $\frac{V}{R_s}$




Haby, 2007: Example of shear, curvature, and planetary vorticity

# Dynamics Review

- Absolute vorticity composed of three components:
  1. Shear Vorticity
  2. Curvature Vorticity
  3. Planetary Vorticity

$$\xi_a = \zeta_c + \zeta_s + f$$

# Dynamics Review

- Keyser and Bell (1993) derive curvature and shear vorticity tendency equations in natural coordinates:
- Curvature Vorticity Tendency Equation:

$$\frac{d}{dt}\left(f + V\frac{\partial \alpha}{\partial s}\right) = -\frac{\partial V}{\partial s}\frac{d\alpha}{dt} - \frac{\partial}{\partial n}\left(\frac{\partial \phi}{\partial s}\right) - \left(f + V\frac{\partial \alpha}{\partial s}\right)\nabla_p \cdot \vec{V} - \vec{V}\frac{\partial \omega}{\partial s}\frac{\partial \alpha}{\partial p}$$

- Shear Vorticity Tendency Equation:

$$\frac{d}{dt}\left(-\frac{\partial V}{\partial n}\right) = \frac{\partial V}{\partial s}\frac{d\alpha}{dt} + \frac{\partial}{\partial n}\left(\frac{\partial \phi}{\partial s}\right) - \left(-\frac{\partial V}{\partial n}\right)\nabla_p \cdot \vec{V} - \vec{V}\frac{\partial \omega}{\partial n}\frac{\partial V}{\partial p}$$

# Background Theory

- Study argues importance of barotropic dynamics in the *formation* of a tropical cyclone
- Assuming there are no significant changes in latitude, absolute vorticity is materially conserved:

$$\frac{d\xi_a}{dt} = 0 = \frac{d\zeta_c}{dt} + \frac{d\zeta_s}{dt}$$

- As shear goes into curvature, parcels will move radially inward towards the center of the disturbance leading to an "organization of convection"
- The concentration of convection will allow for baroclinic based processes to further intensify the storm

# Methodology

- Organization of convection was measured using satellite derived cloud liquid water from AQUA, the DMSP series, and TRMM (NOTE: DMSP-f15 not available for AEW)
- Data is derived from brightness temperatures and is only available over water (Wentz, 1997)
- Resolution of the data is 25 km
- Data was cast into cylindrical coordinates and a Fourier transform was performed on the data at radii ranging from 25 km to 125 km (in 25 km intervals) from the storm center
- Try to determine at which radius organization is predominating and how quickly it is occurring
- Growth in the magnitude of wavenumbers 0,1, and 2 is indicative of organization occurring

# Methodology

- MM5 used as source for u, v, and $\phi$ that are needed for calculating shear to curvature conversions for Cartesian coordinates as derived by Bell and Keyser (1993)
- 3 single way nests with resolutions of 27 km, 9 km, and 3 km with 32 unevenly spaced vertical levels
- NCEP 1º x 1º FNL used for boundary and initial conditions for 27 km domain
- 2 coarser domains run for 60 hours (12 hours before period of interest)
- Innermost domain run for 48 hours
- MM5 Model Configuration:
  - Blackadar planetary boundary layer
  - Betts-Miller convective scheme with shallow convection
  - Goddard cloud microphysics
  - Cloud radiation scheme

# Methodology

- Study involves developing and non-developing case:
  1. Hurricane Nate (2005): 09/05/05 18Z – 09/07/05 18Z
  2. African Easterly Wave (2006): 08/25/06 00Z – 08/27/06 00Z

# Results – Hurricane Nate

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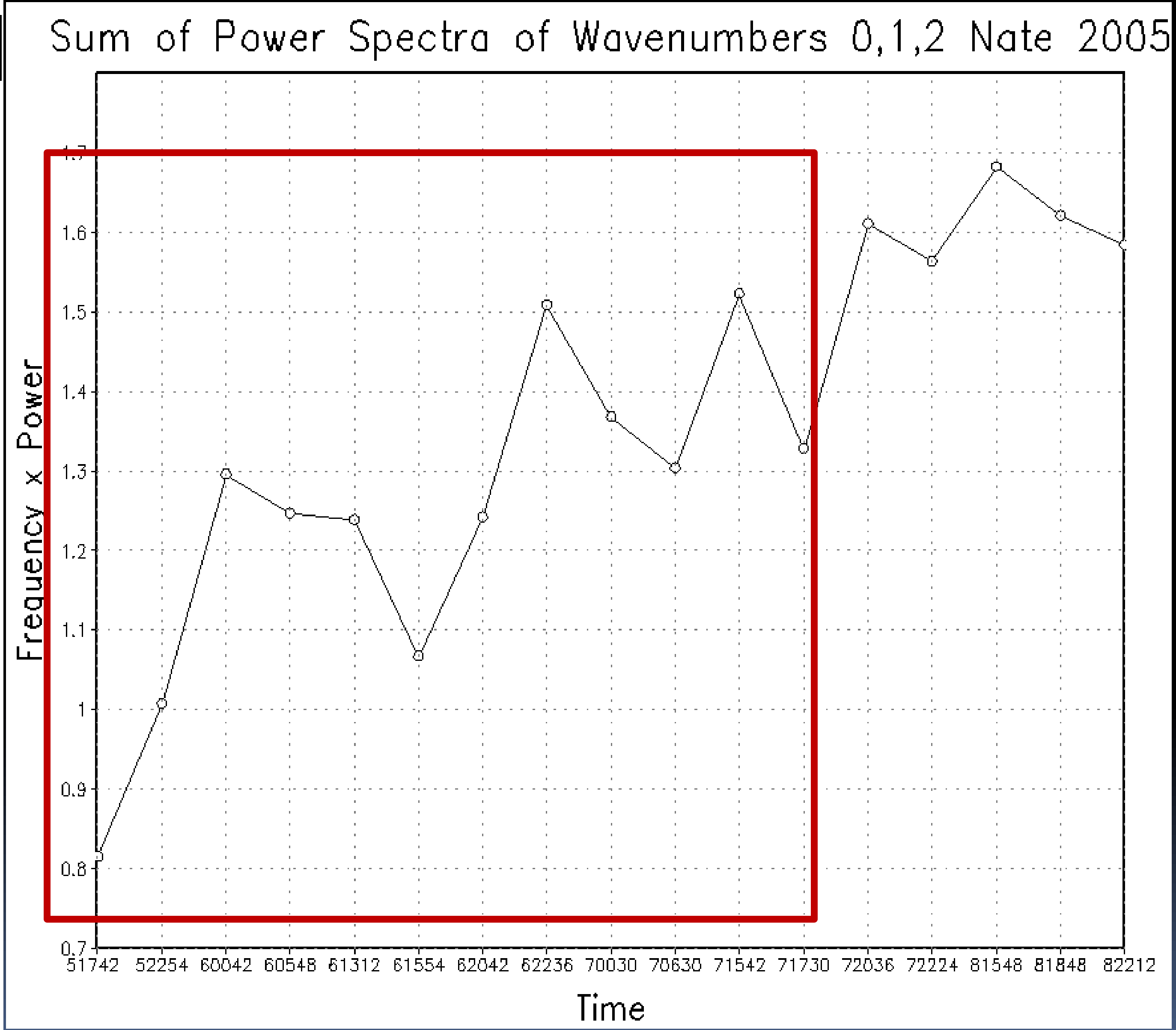
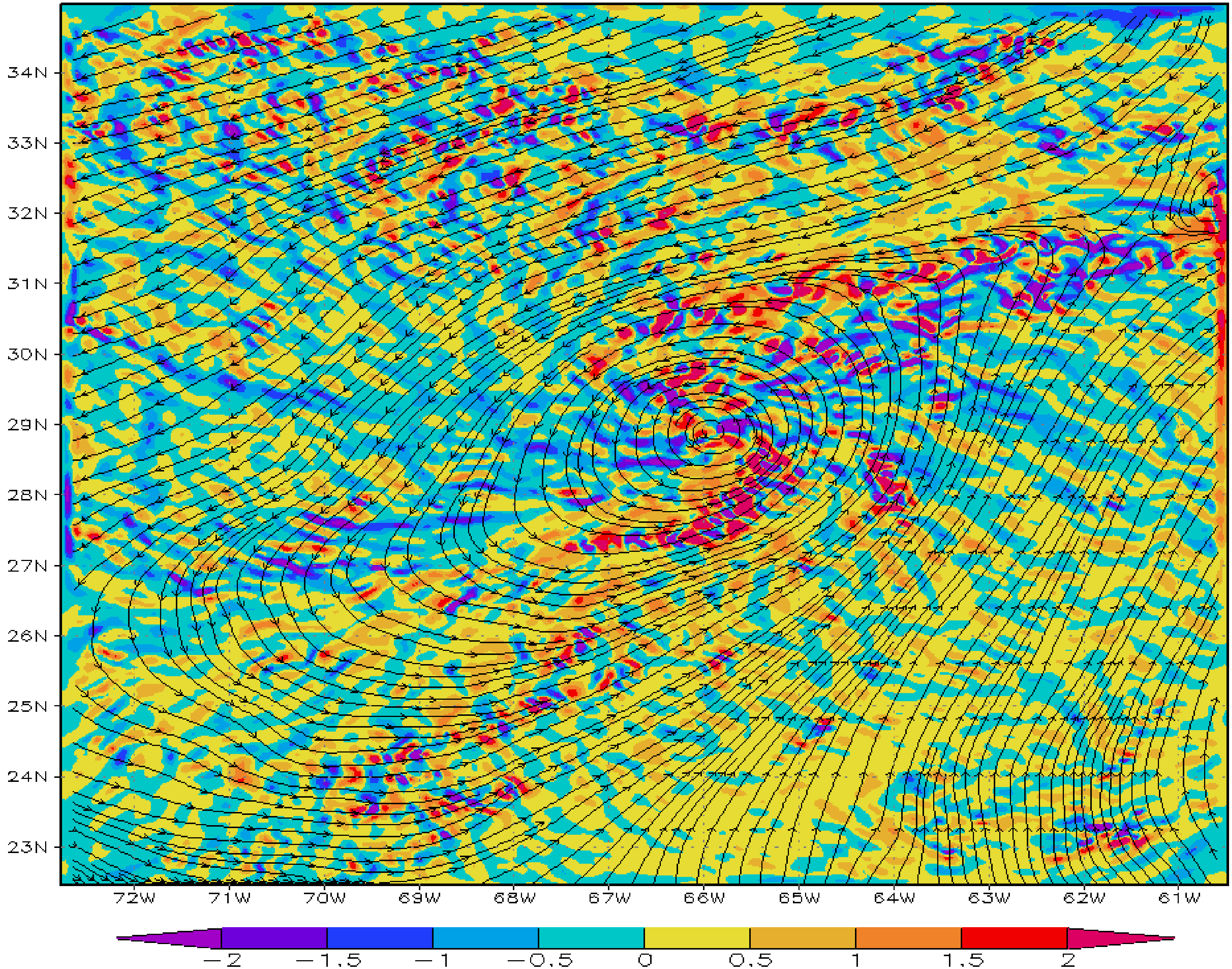


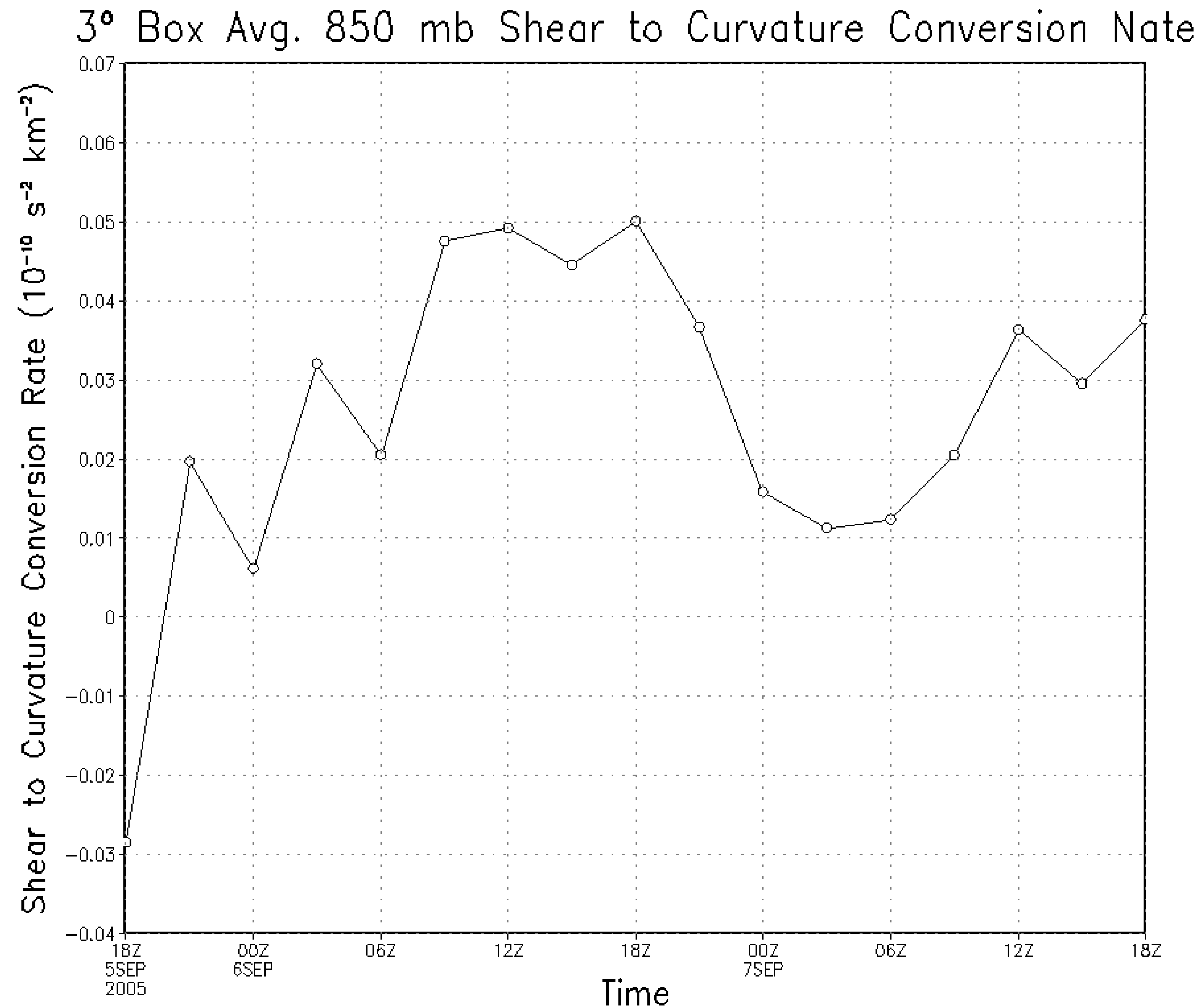

- Forecast takes place between 9/05/05 18Z and 9/07/05 18Z
- 0.5-0.7 increase in spectra
- Indicative of organization occurring over this 3+ day period

850 mb S2C Conversion 09/07 03Z ($10^{-10}$ $s^{-2}$)

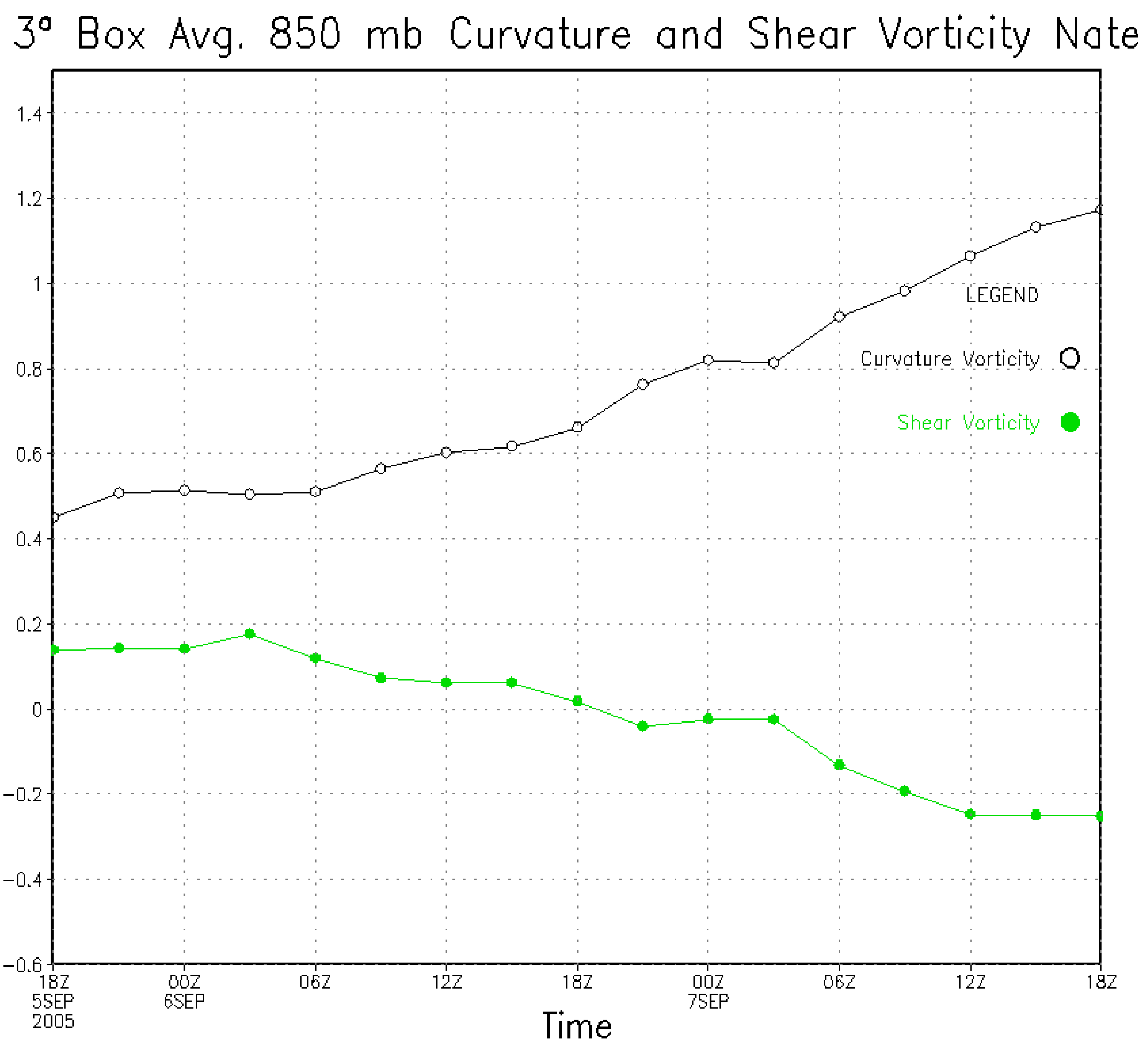


# Results – Hurricane Nate

- Gradual increase in conversions over first 24 hours
- Dip and recovery around last 24 hours
- Overall, positive conversions!

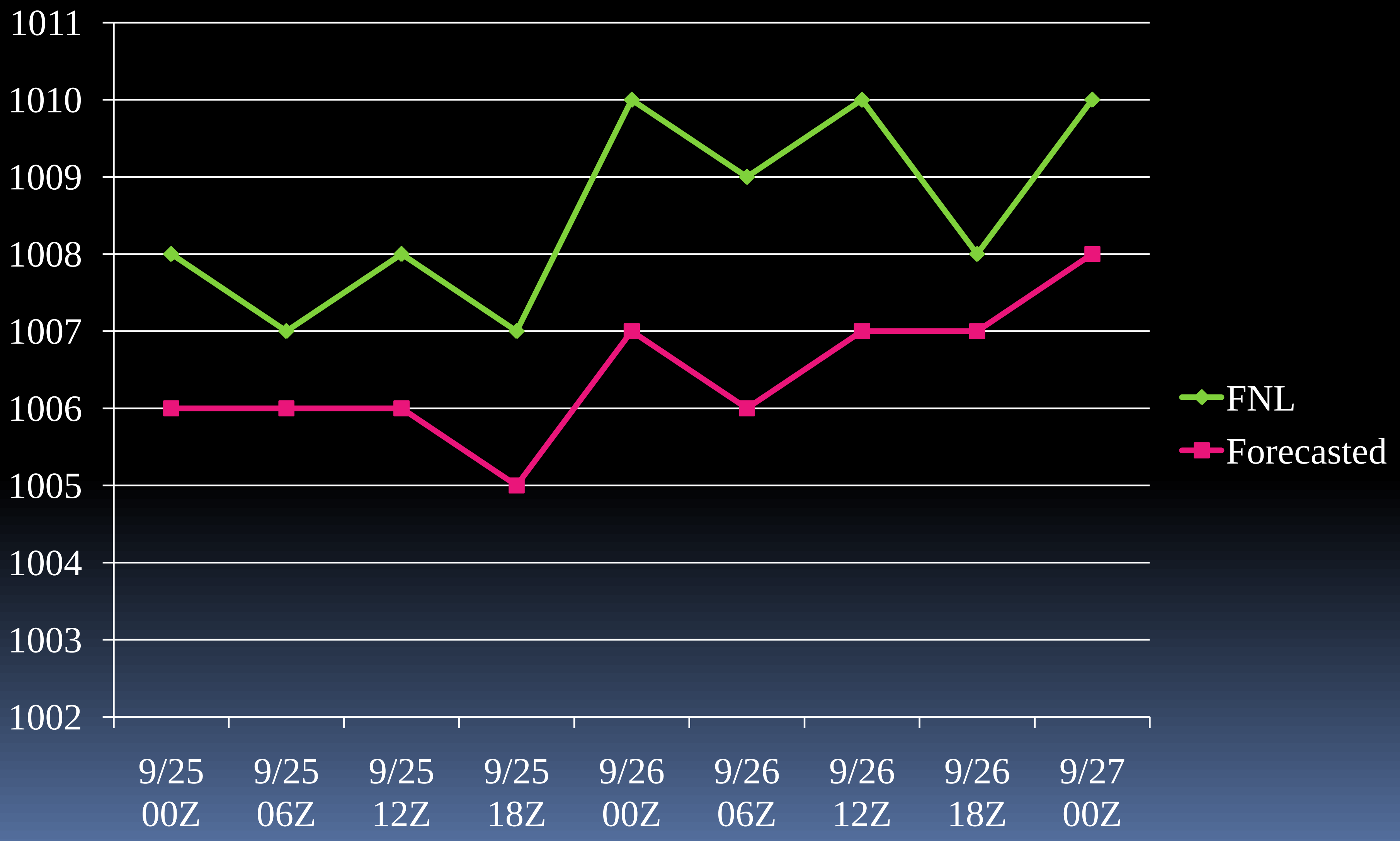


# Results – Hurricane Nate




- Remain steady for first 12 hours, afterwards:
  - Increase in curvature vorticity
  - Decrease in shear vorticity
- Shear vorticity becomes increasingly negative indicative of increasing anticyclone shear
- Magnitude of change in curvature vorticity is higher than shear vorticity
- Conversion terms playing role, but creation of vorticity through divergence and tilting also plays a large part

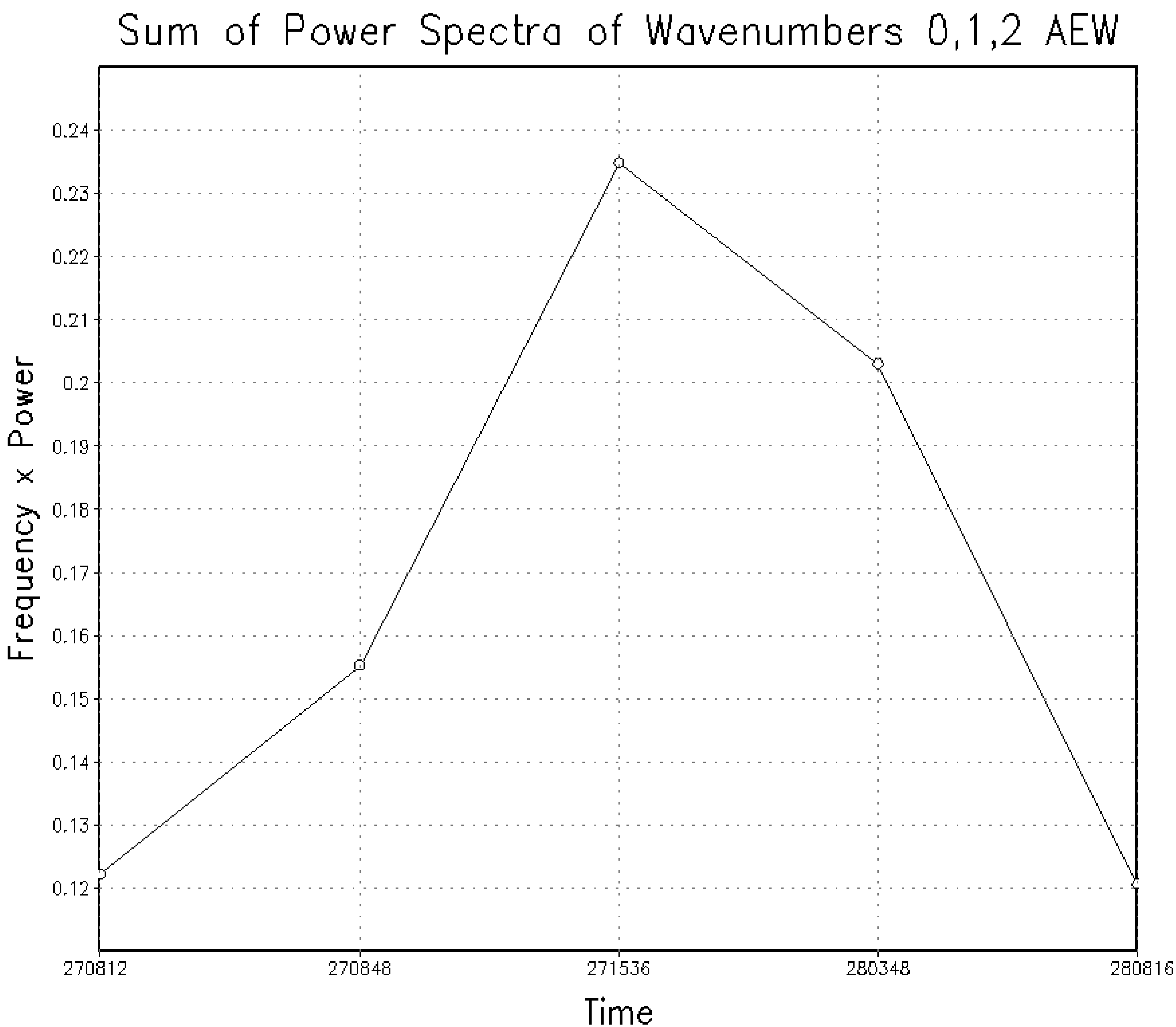
# Results – AEW



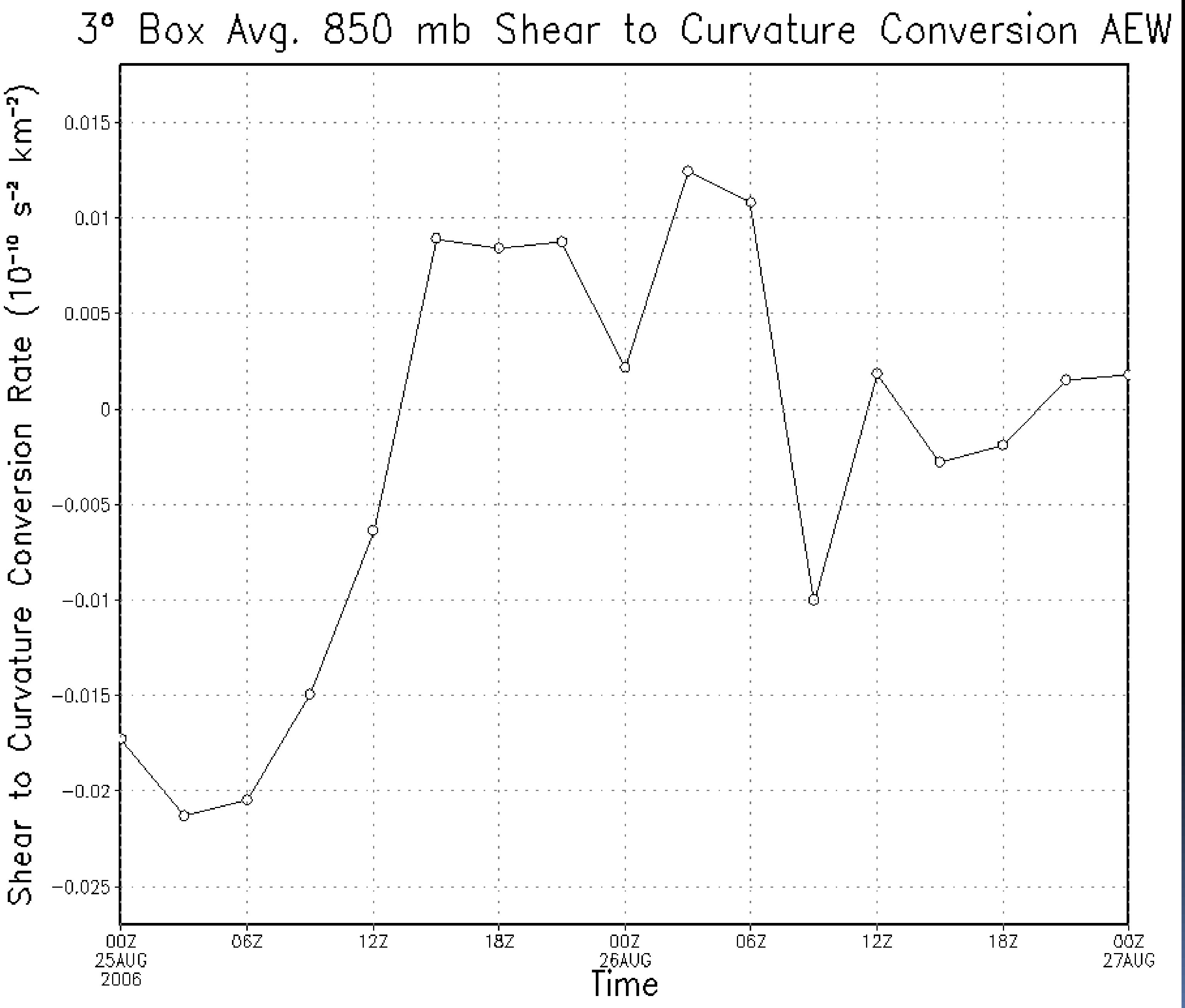
1011
1010
1009
1008
1007
1006
1005
1004
1003
1002
9/25 00Z
9/25 06Z
9/25 12Z
9/25 18Z
9/26 00Z
9/26 06Z
9/26 12Z
9/26 18Z
9/27 00Z
FNL
Forecasted

# Results - AEW

- The forecast period is not represented in this data
- Notice the magnitude of the power spectra compared to that for Nate

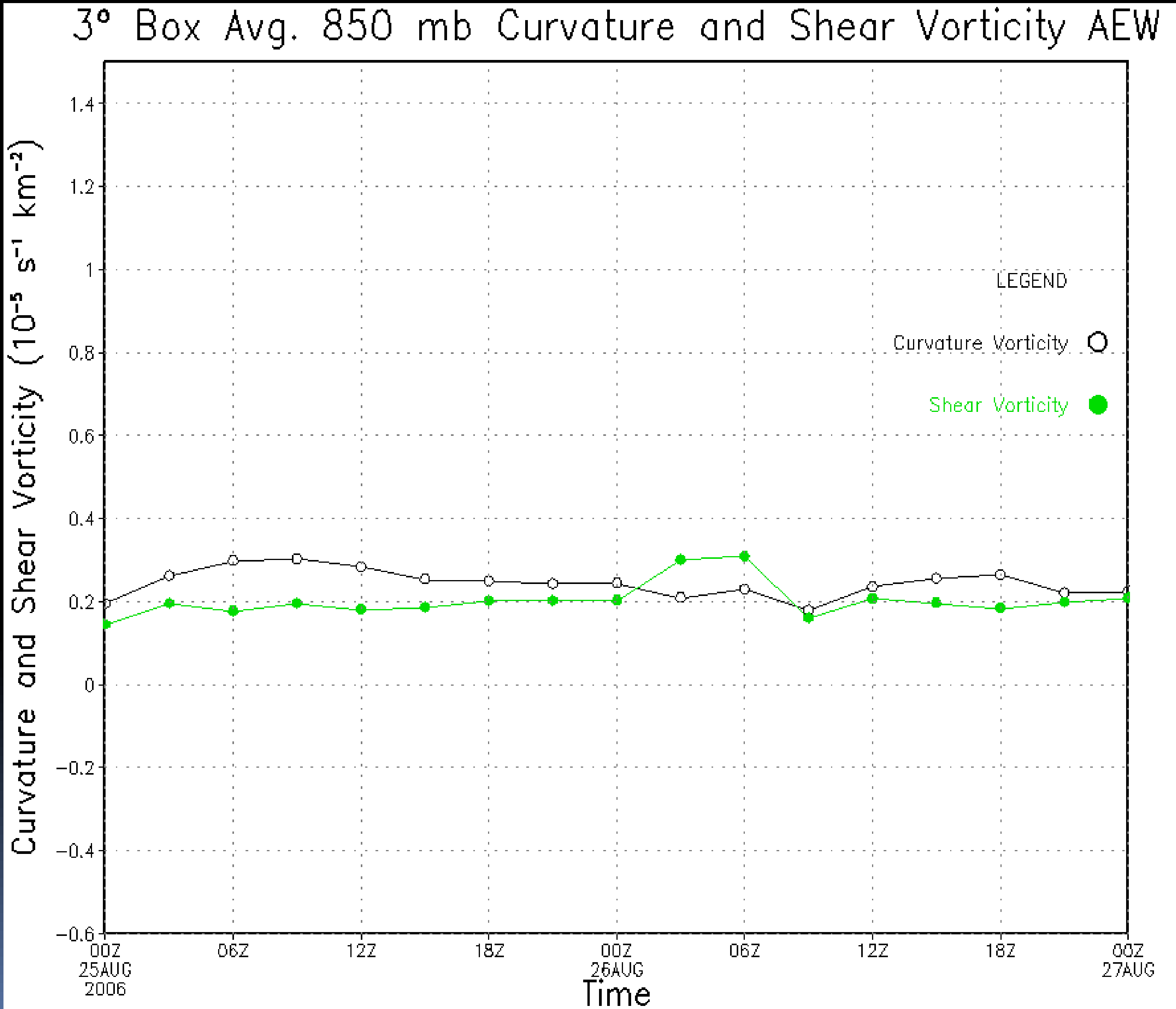


# Results AEW




- The magnitude of shear to curvature conversions is much smaller than for Nate
- Marginal changes in conversions over forecast period

# Results - AEW




- Curvature and Shear vorticity same magnitude
- No changes in curvature and shear vorticity in agreement with non-development

# Conclusions

- Distinct differences between non-developing and developing cases as expected:  between organization rates, conversion rates, and magnitudes of vorticity
- Shear to curvature may play important role, but calculations of divergence and tilting terms must be done
- Additionally, MM5 should be run using explicit convection scheme
- More cases must be done to compare to as well
- Until then results are inconclusive

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