A Numerical Study of Hurricane Noel (2007). Model Verification and Extratropical Transition

Shunli Zhang and G.W.K. Moore
Department of Physics, University of Toronto

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Outline

- Introduction and objective
- Model verification
- Extratropical Transition (ET) of Hurricane Noel
  - a) ET definition
  - b) potential vorticity (PV) perspective
  - c) Eliassen-Palm (E-P) flux
- Summary

Introduction

- Extratropical transition (ET) of a decaying tropical cyclone may result in strong winds, heavy rains, storm surge and large waves to pose a serious threat to land and maritime activities.

- Extratropical transition poses a significant challenge to the forecaster.

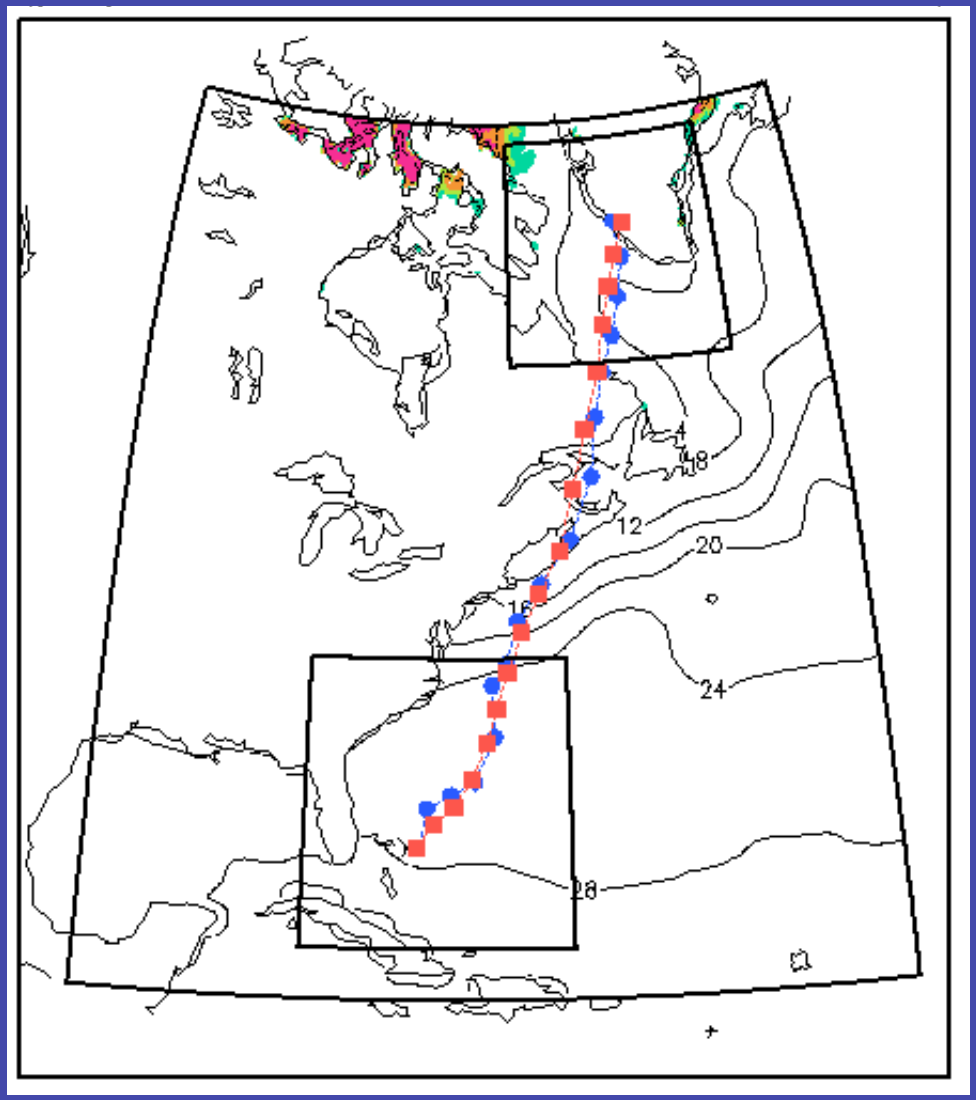
Objectives

- To analyze the performance of numerical model.

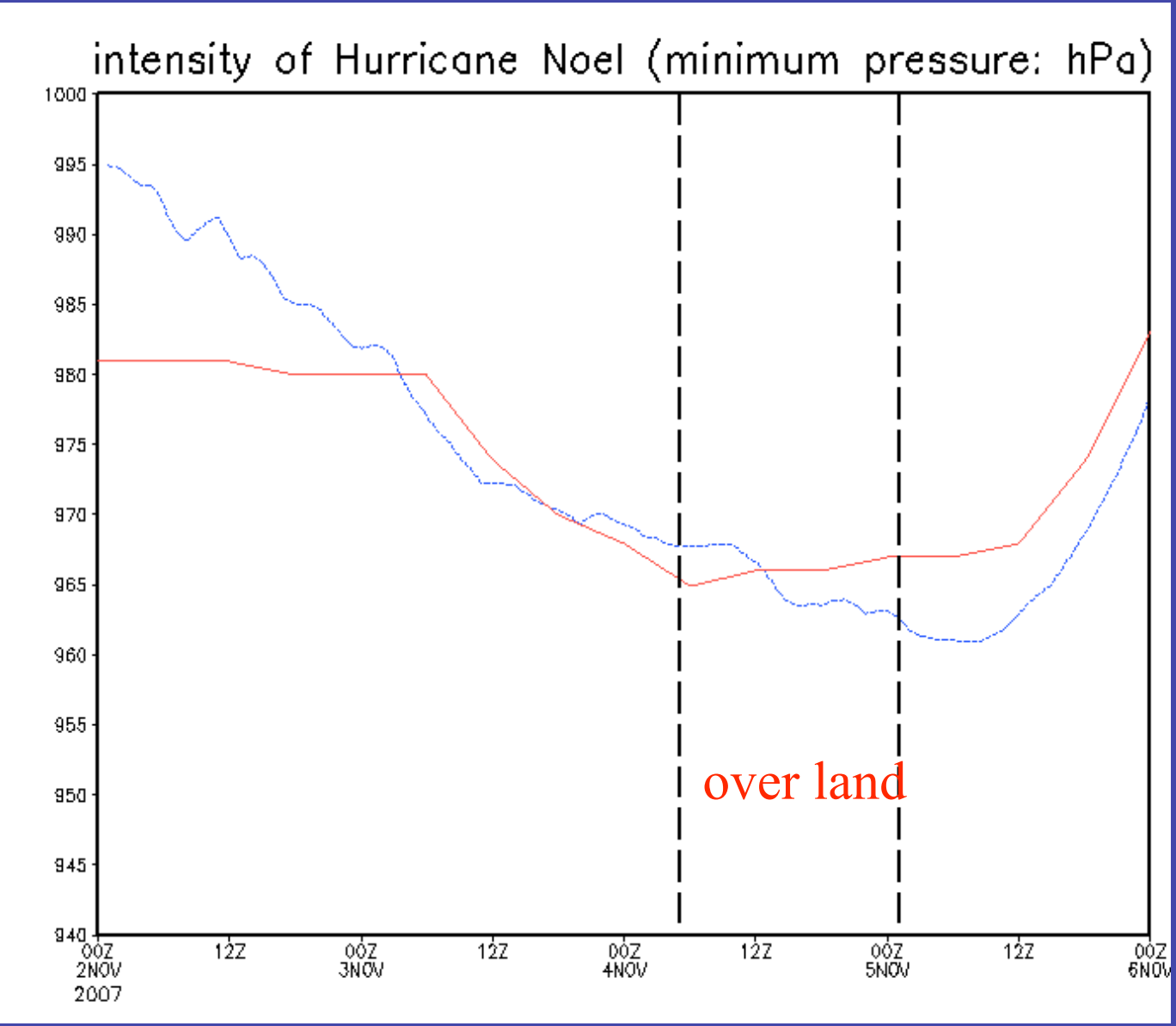
- To document the stages associated with the extratropical transition of Noel.

- To study the reintensification of Noel using PV framework.

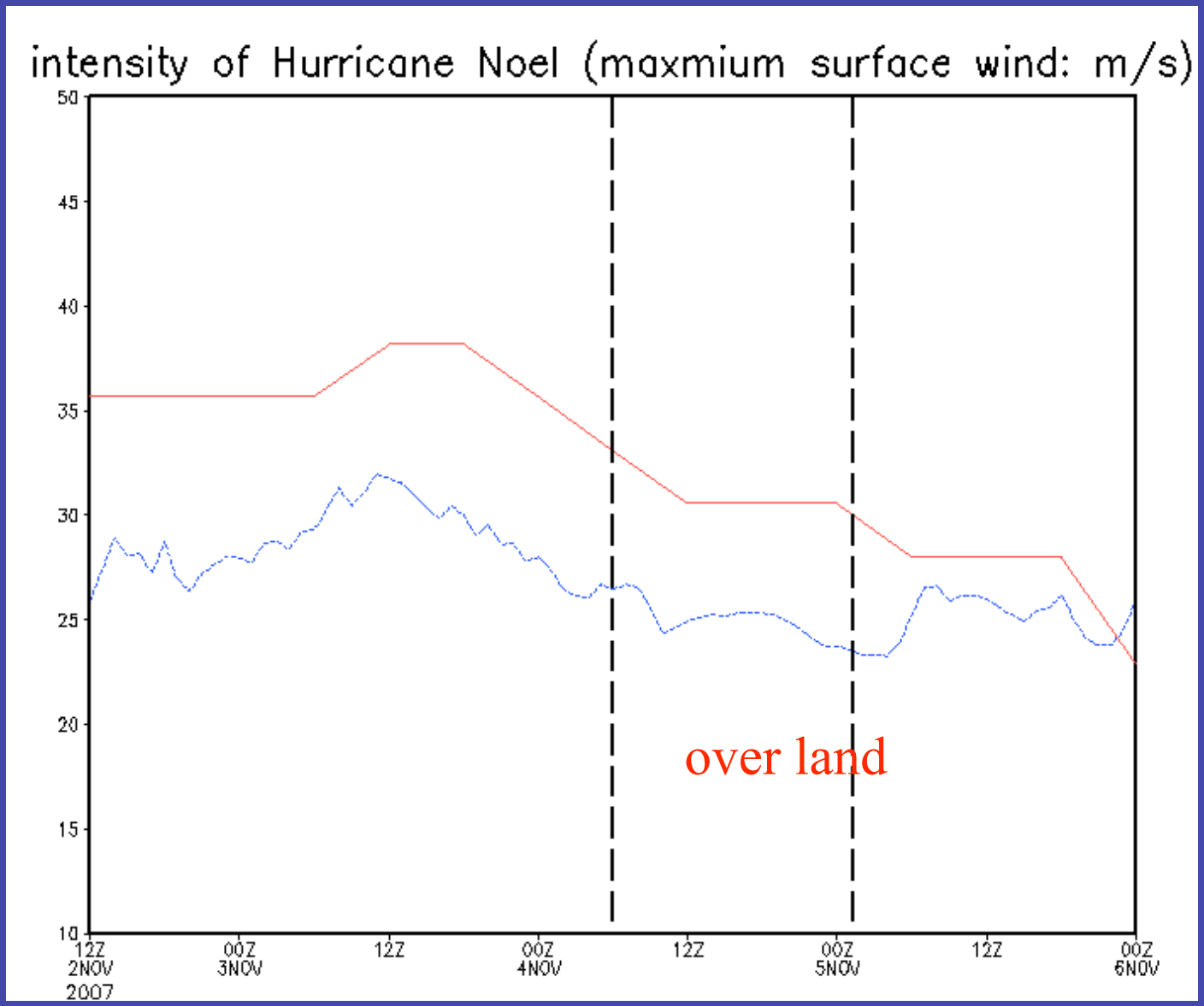
Model Verification



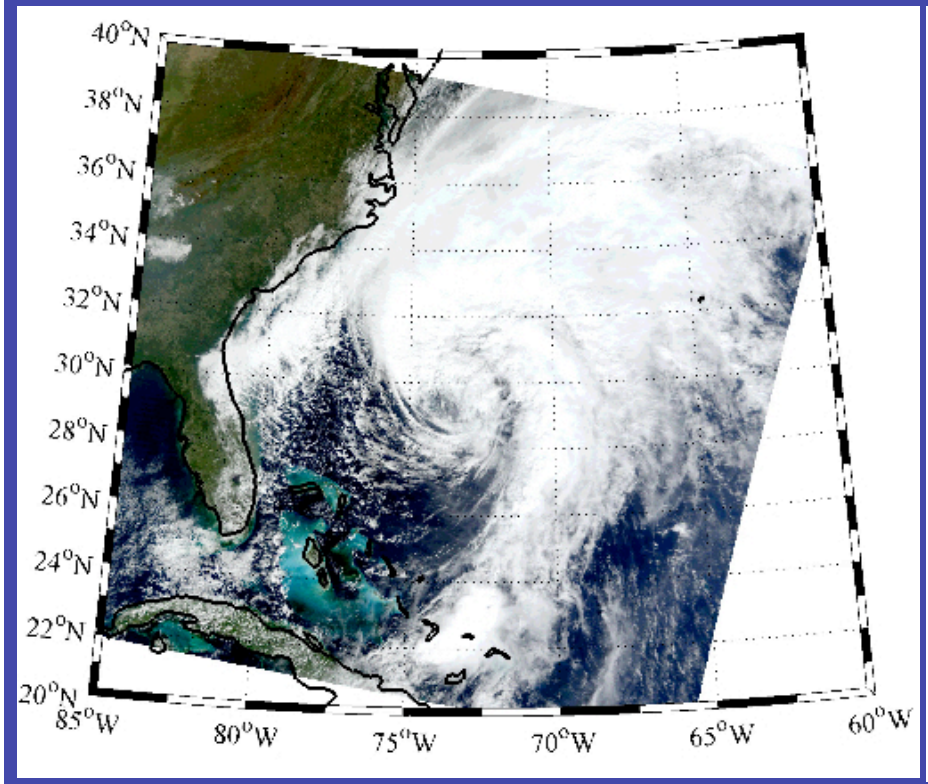
MM5 domains, Sea surface temperature (SST), Sea ice concentration and observed (red) and simulated (blue) best track

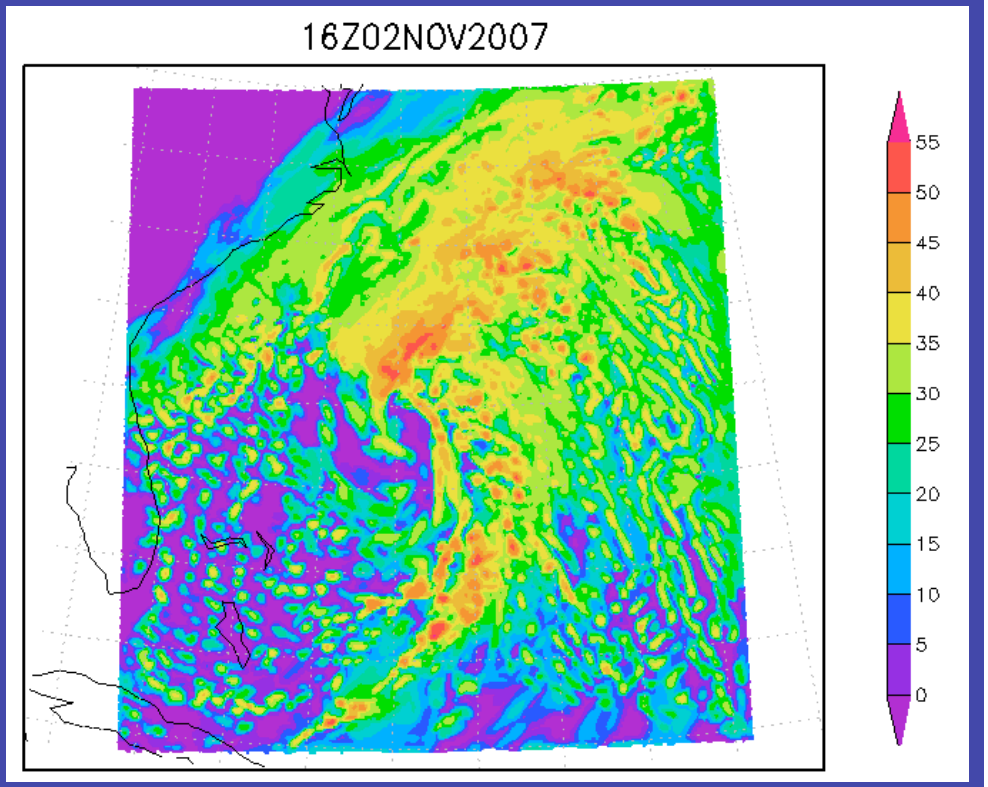


Observed (red) and simulated (blue) minimum central pressure

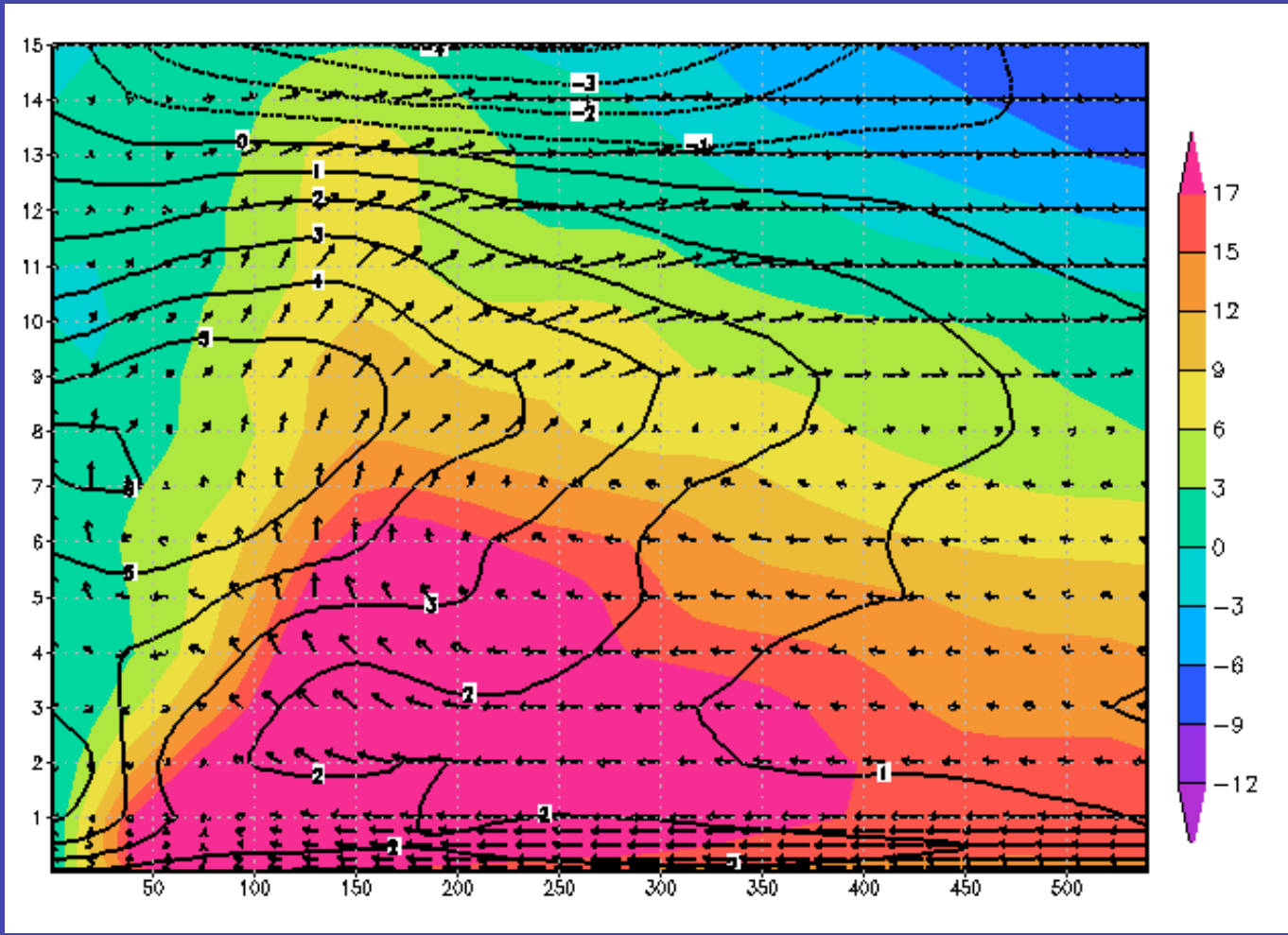


Observed (red) and simulated (blue) maximum surface wind speed

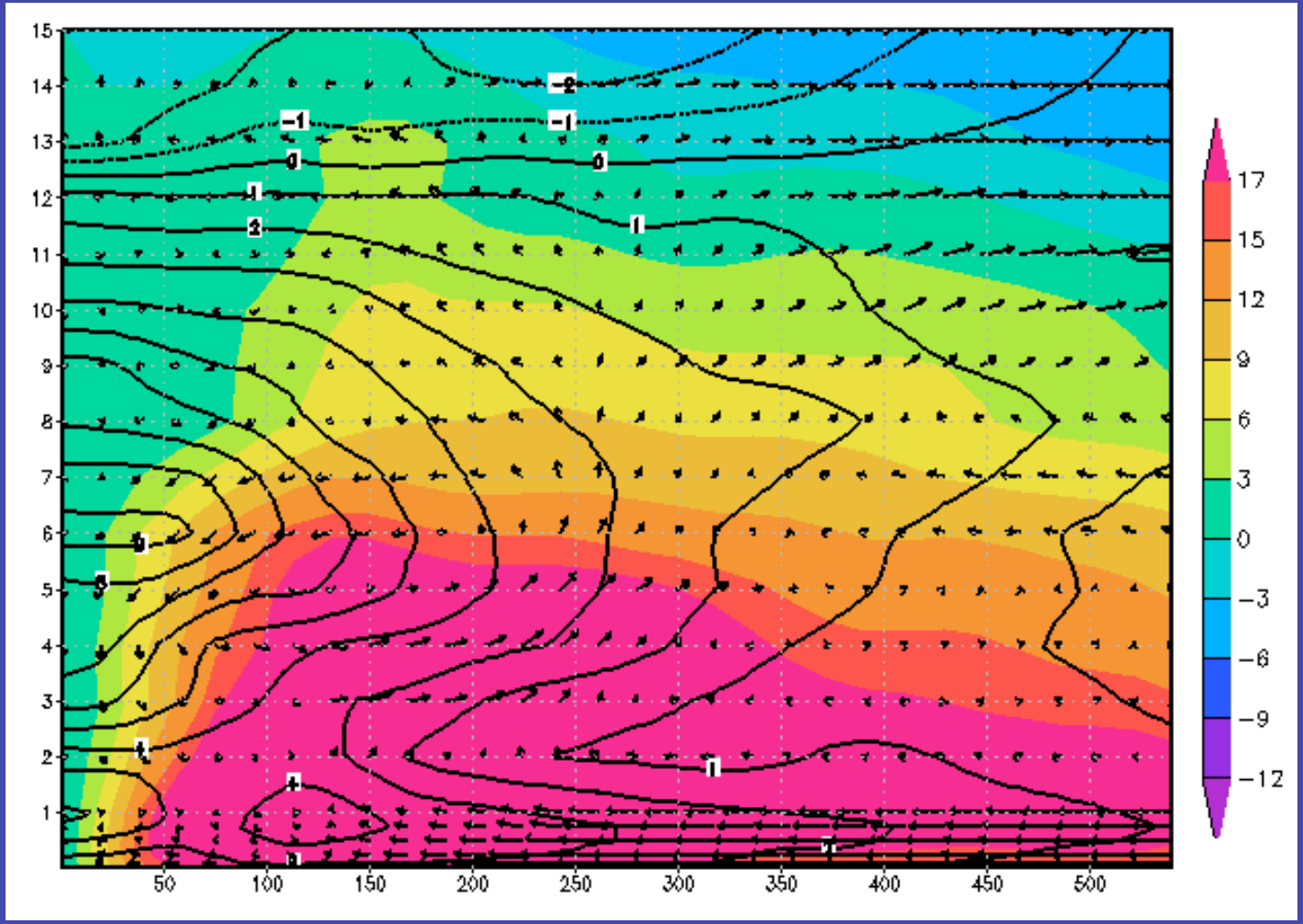




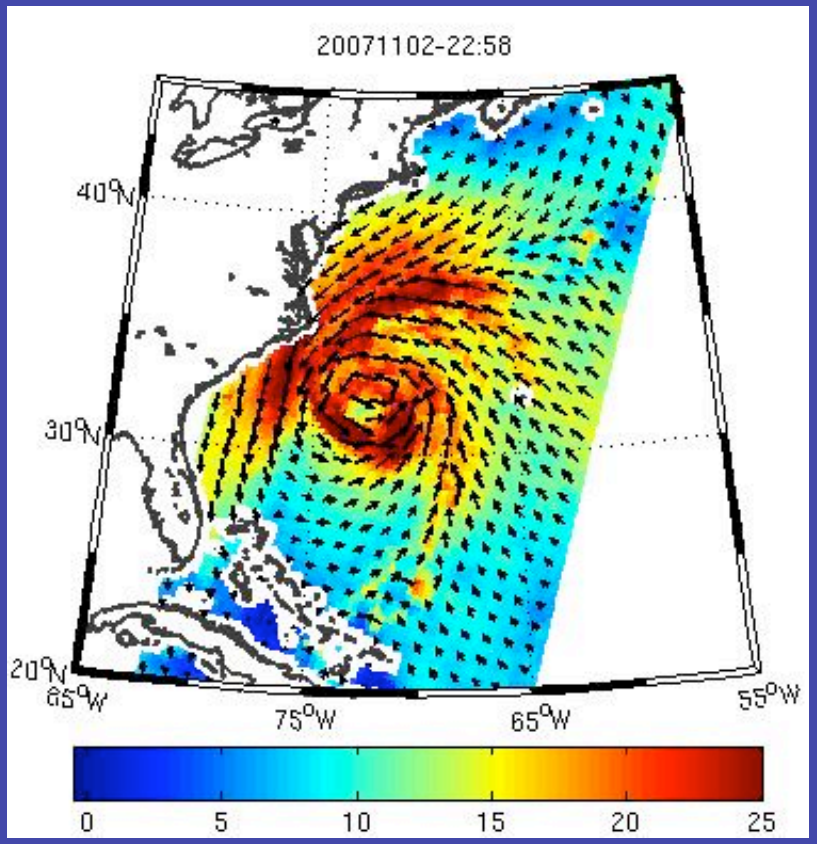
Visible imagery (left) and simulated reflectivity (right) at 1600 UTC 2 Nov 2007

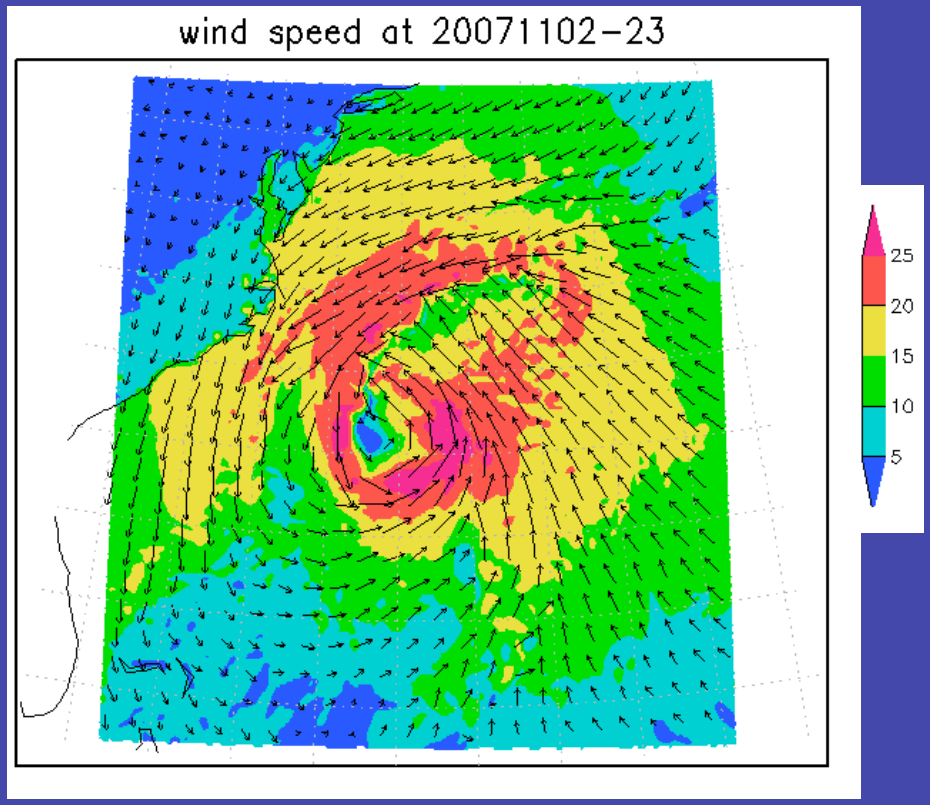


Height-radius cross section of azimuthally averaged tangential winds (shading), temperature deviation (contours) and flow vectors at 12 UTC 2 Nov 2007



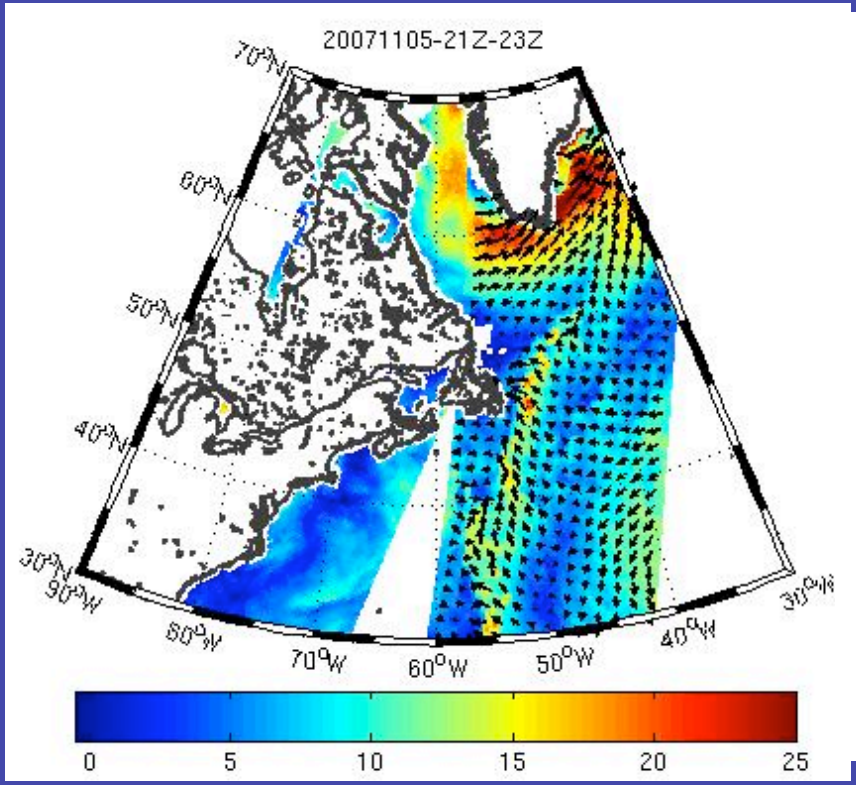
Radius-height cross section of azimuthally averaged tangential winds (shading), temperature deviation (contours) and flow vectors at 20 UTC 2 Nov 2007

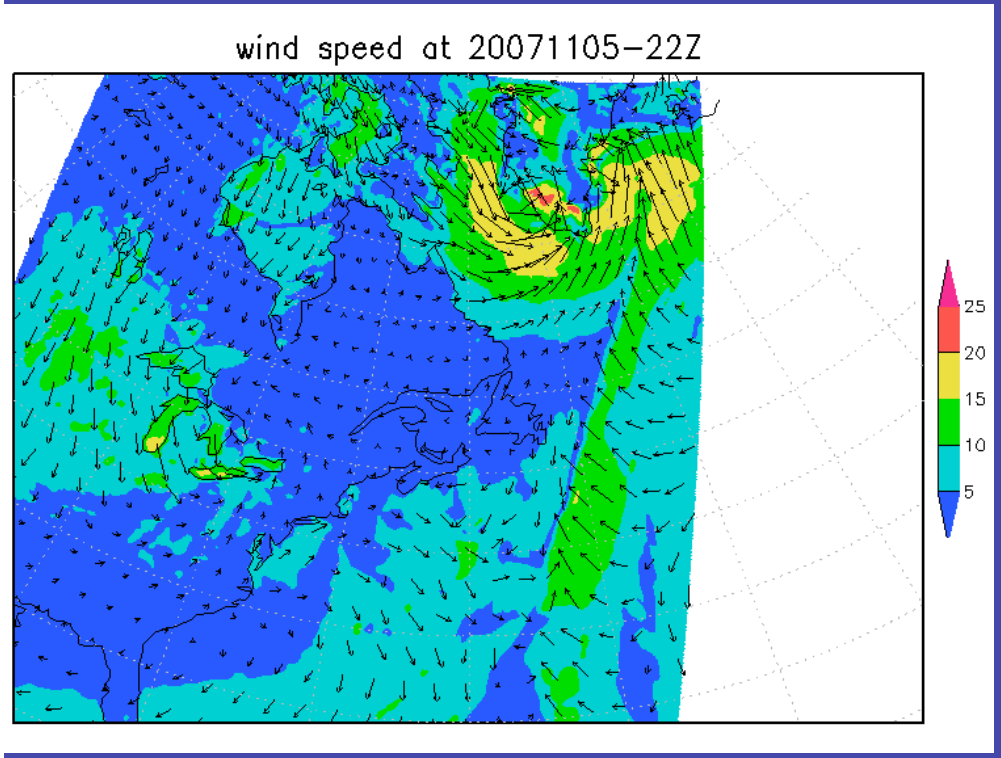




Observed (left) and simulated surface wind (right) at

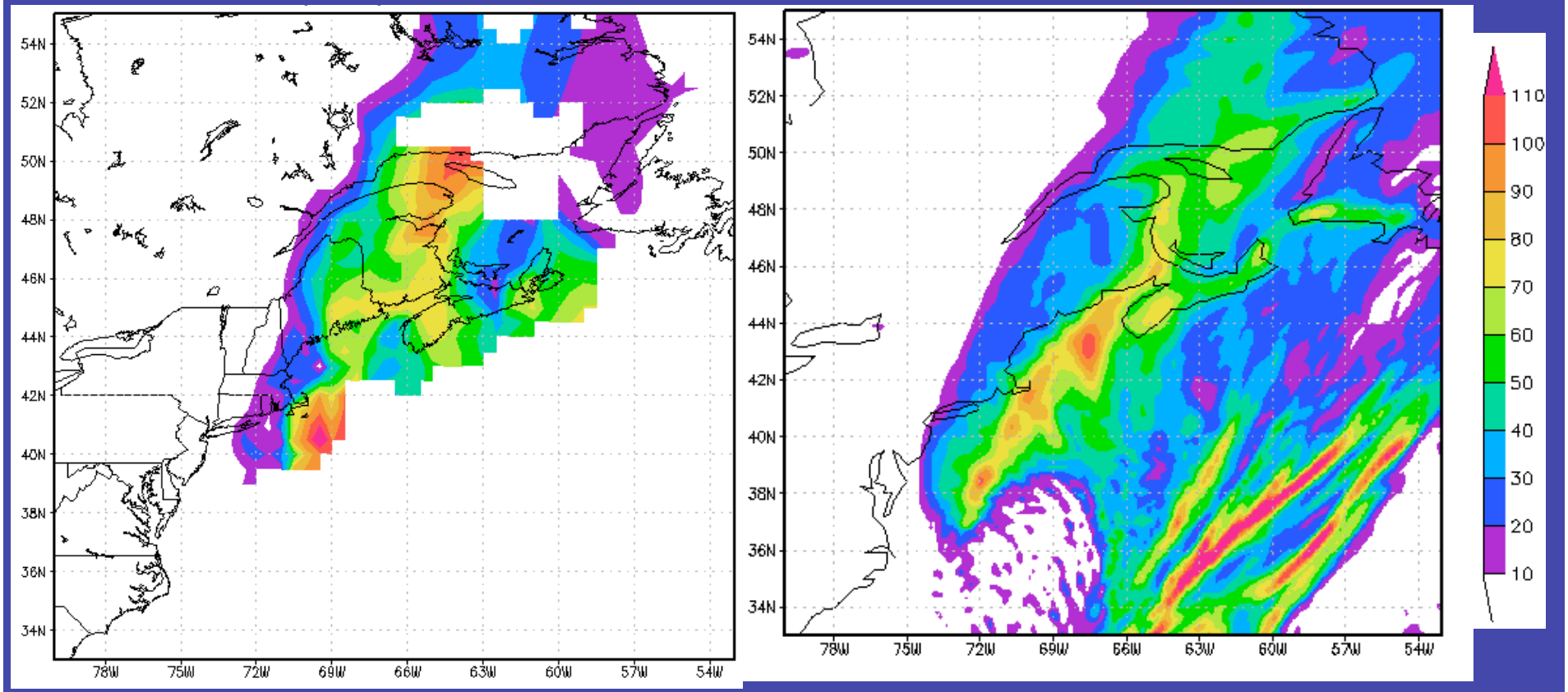
2300 UTC Nov 2 2007



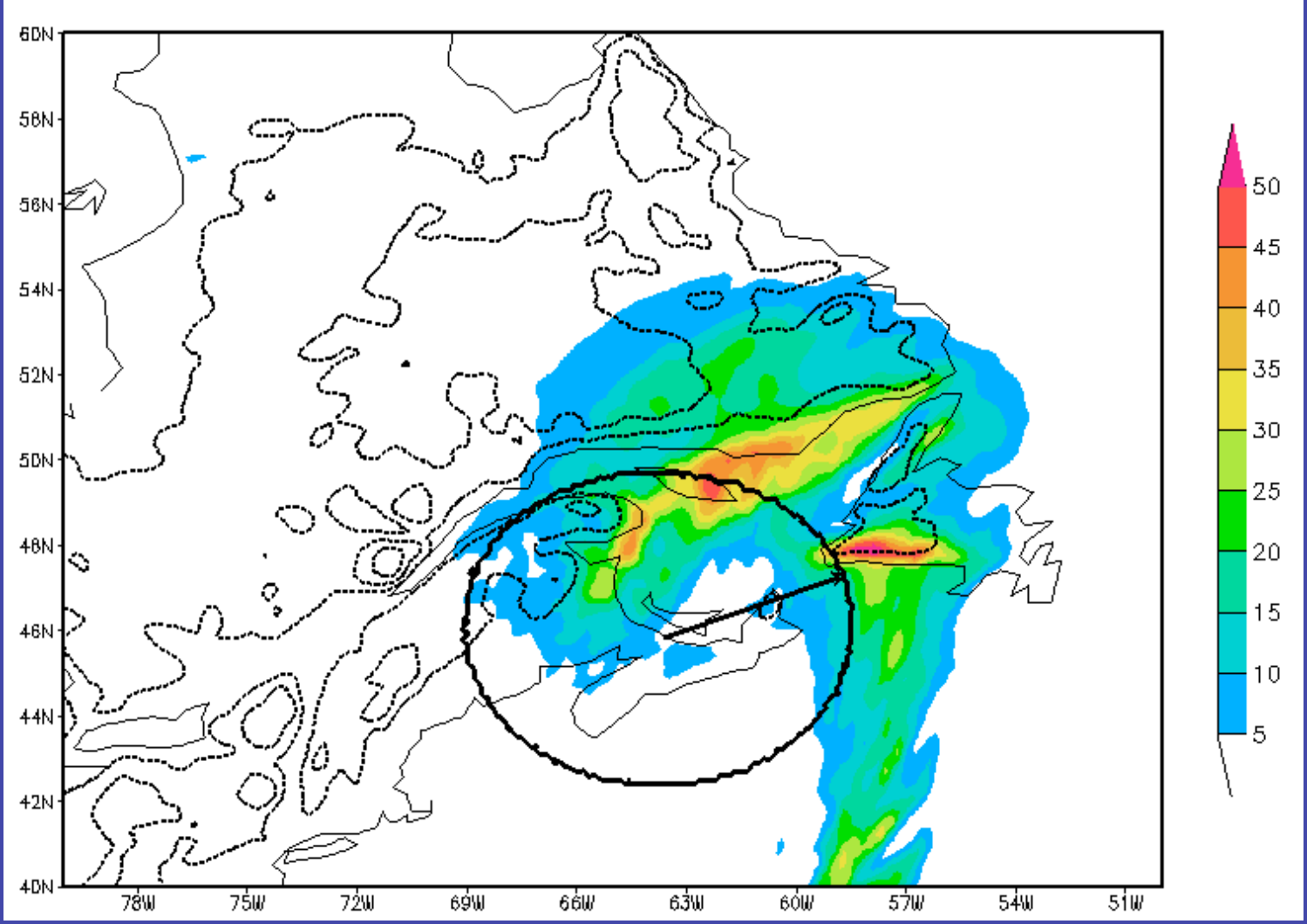


Observed (left) and simulated surface wind (right) at

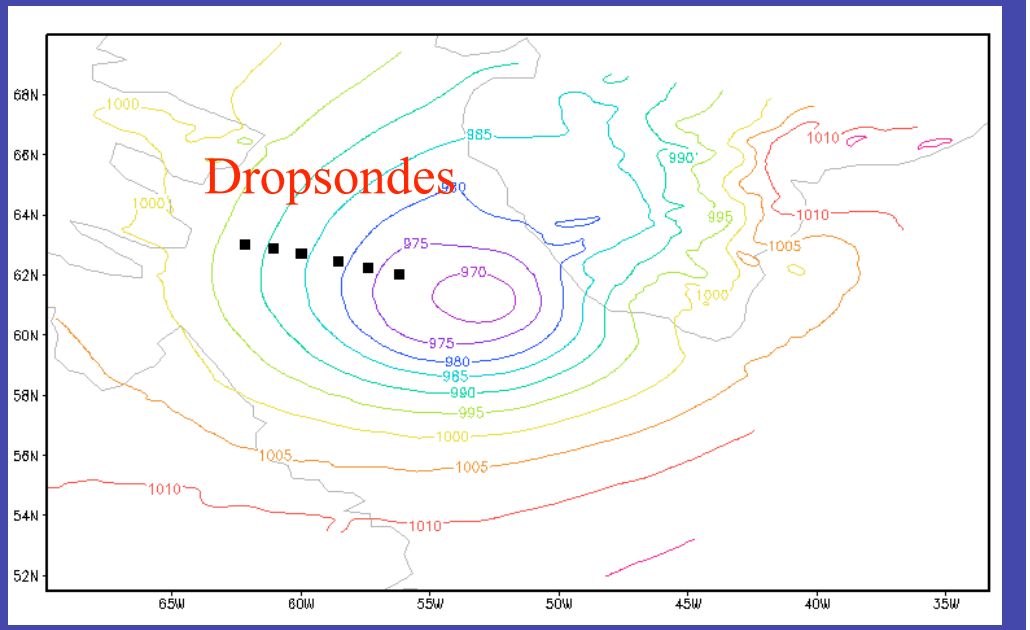
2200 UTC Nov 5 2007

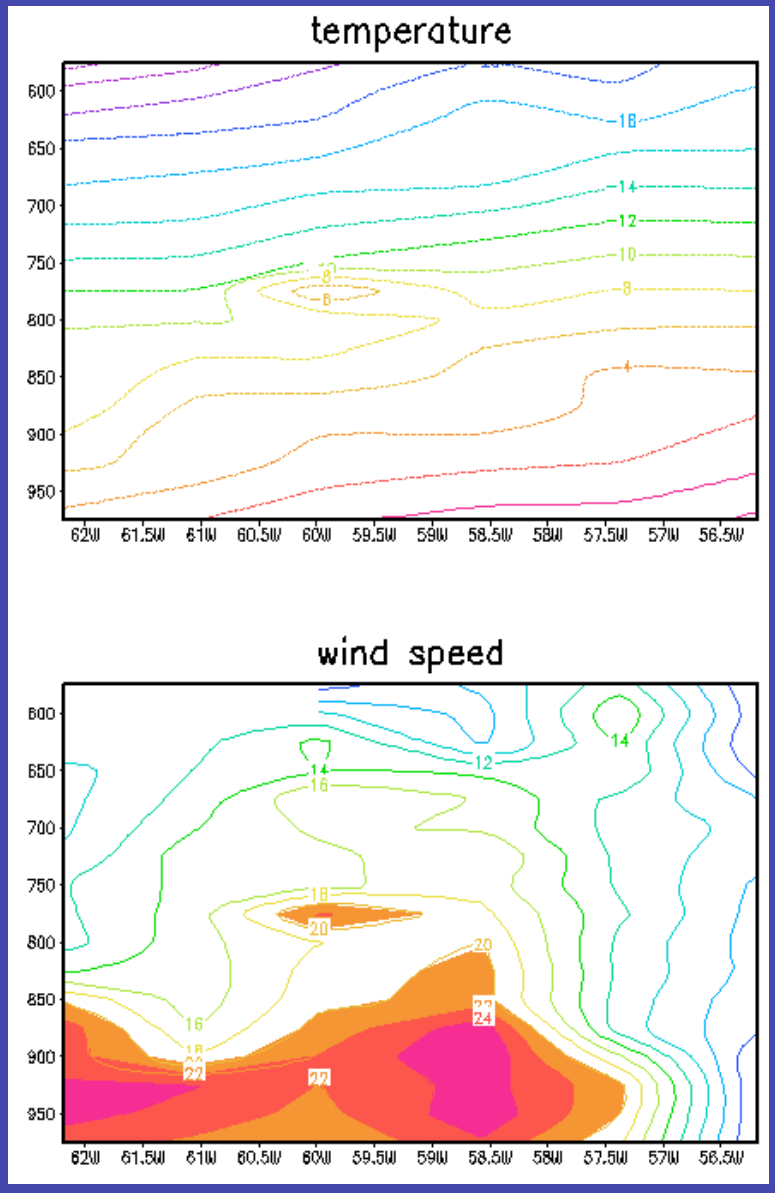


Observed (left) and simulated (right) 2-day precipitation (mm)

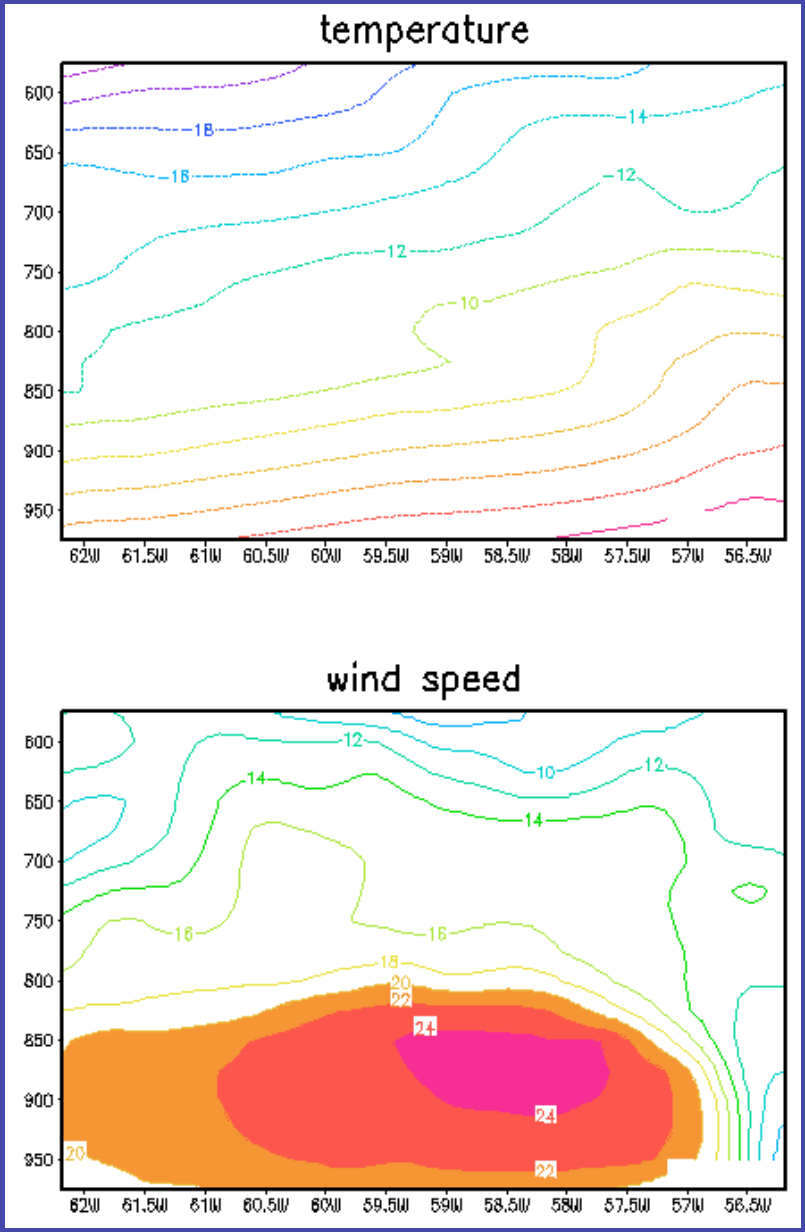


6-h precipitation (shading) superposed with radius of maximum wind (RMW) and wind shear





Height-longitude cross sections of observed temperature and wind speed (right) from STAR field experiment



Height-longitude cross section of simulated temperature and wind speed

Extratropical Transition (ET) of Hurricane Noel

Definition of Extratropical Transition (ET)

Evans and Hart (2003)

Storm-motion-relative thickness asymmetry (B)

$$B = h(\overline{Z_{600\ \mathrm{hPa}} - Z_{900\ \mathrm{hPa}}}\,|_R - \overline{Z_{600\ \mathrm{hPa}} - Z_{900\ \mathrm{hPa}}}\,|_L),$$

B>= 10 Nontropic thermal gradient

900-600-hPa thermal wind ($-|V_T^L|$)

$$\left.\frac{\partial(\Delta Z)}{\partial \ln p}\right|_{900\ \text{hPa}}^{600\ \text{hPa}} = -|V_T^L|$$

900-600-hPa thermal wind ($-|V_T^U|$)

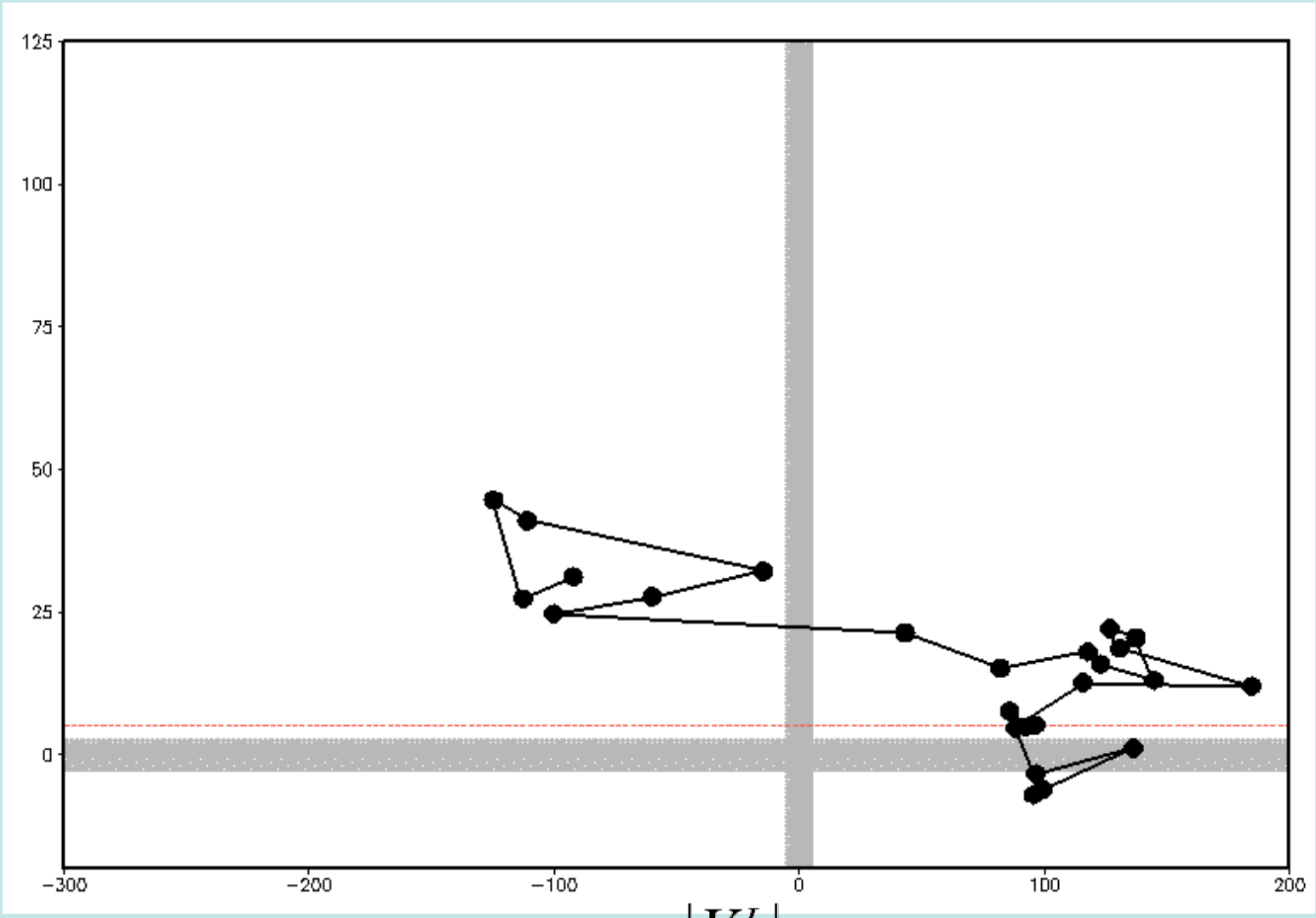
$$\left.\frac{\partial(\Delta Z)}{\partial \ln p}\right|_{600\ \text{hPa}}^{300\ \text{hPa}} = -|V_T^U|$$

Eliassen-Palm (E-P) flux

$$\mathbf{F} \equiv \left[-r\overline{(\sigma u_L)' v_L'}, \; \overline{p' \frac{\partial \Psi'}{\partial \lambda}} \right]$$

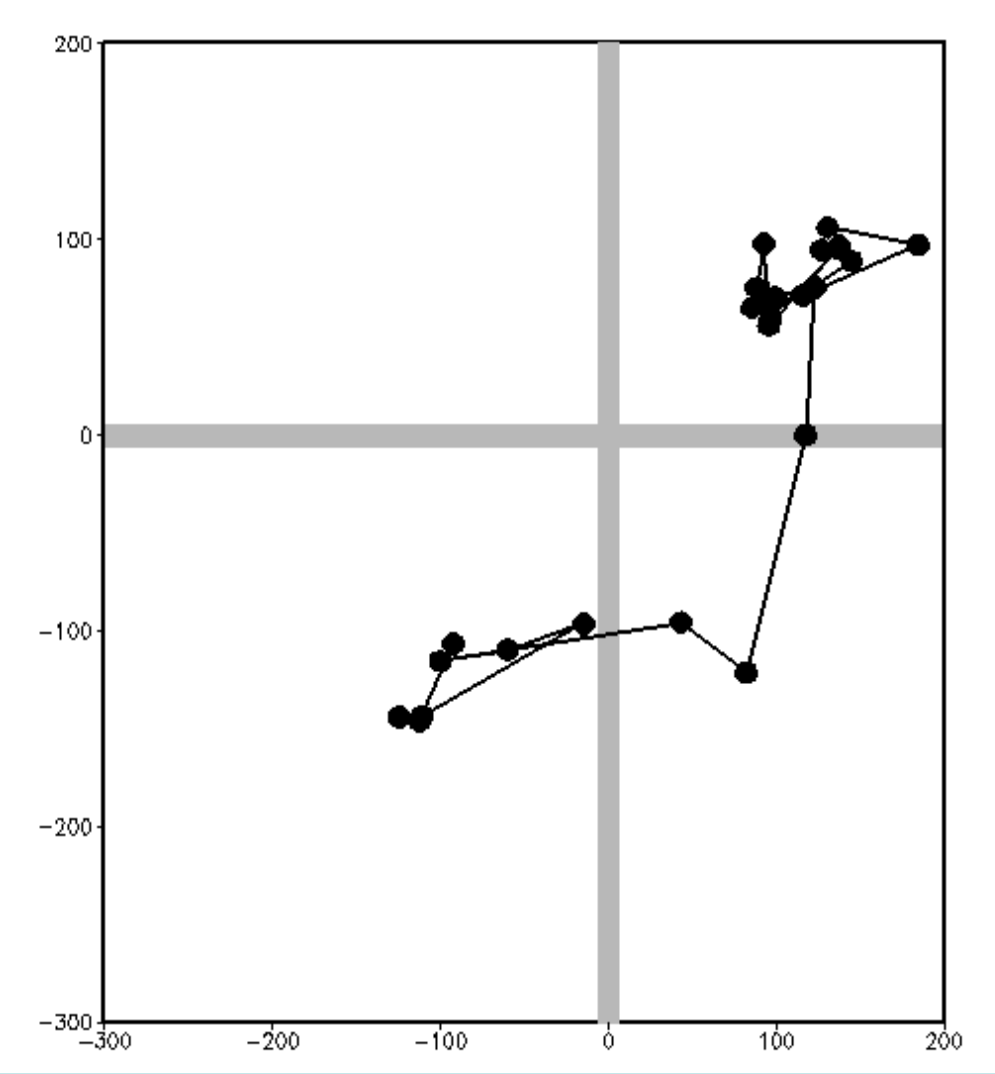
Divergence of E-P flux

$$\nabla \cdot \mathbf{F} = -\frac{1}{r}\frac{\partial}{\partial r} r^2 \overline{(\sigma u_L)' v_L'} + \frac{\partial}{\partial \theta} \overline{p' \frac{\partial \Psi'}{\partial \lambda}},$$



B vs $-|V_T^L|$

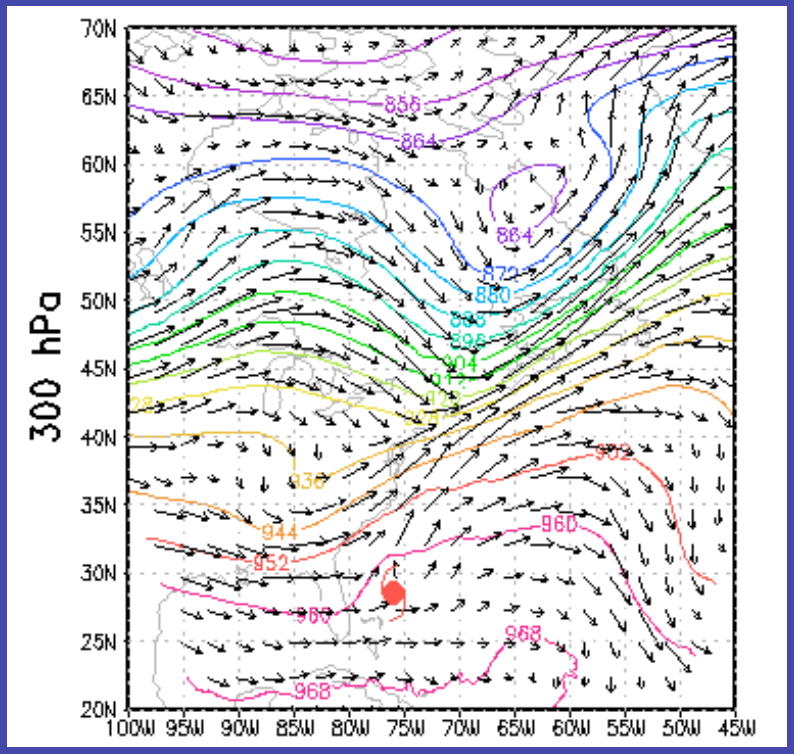
$-|V_T^U|$

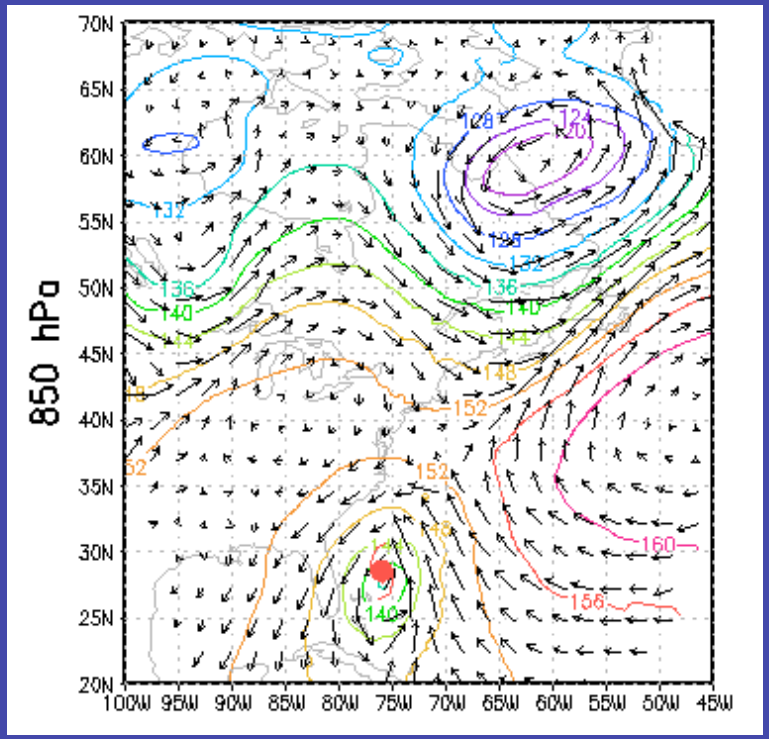


$-|V_T^L|$

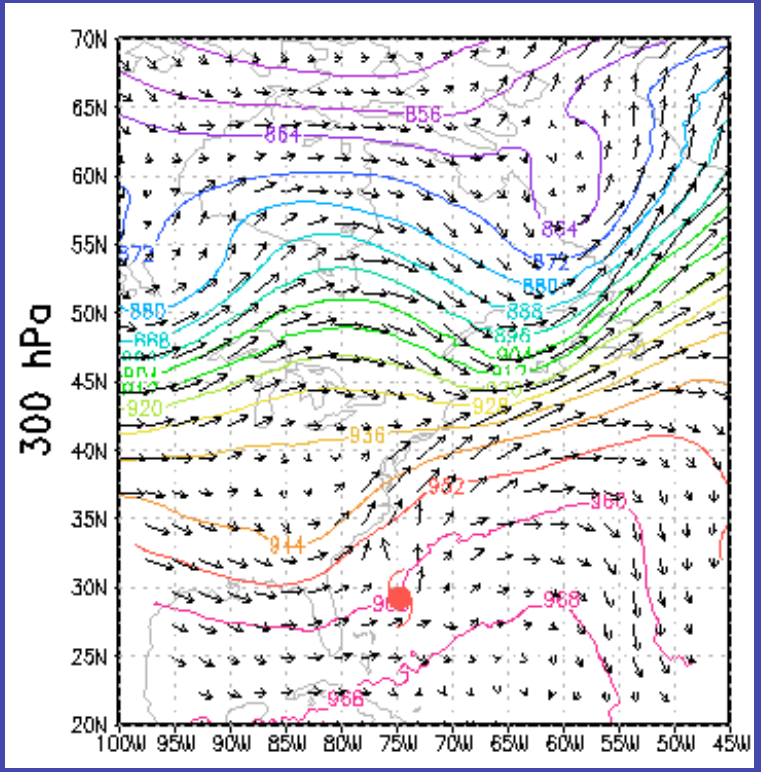
$-|V_T^L|$ vs $-|V_T^U|$

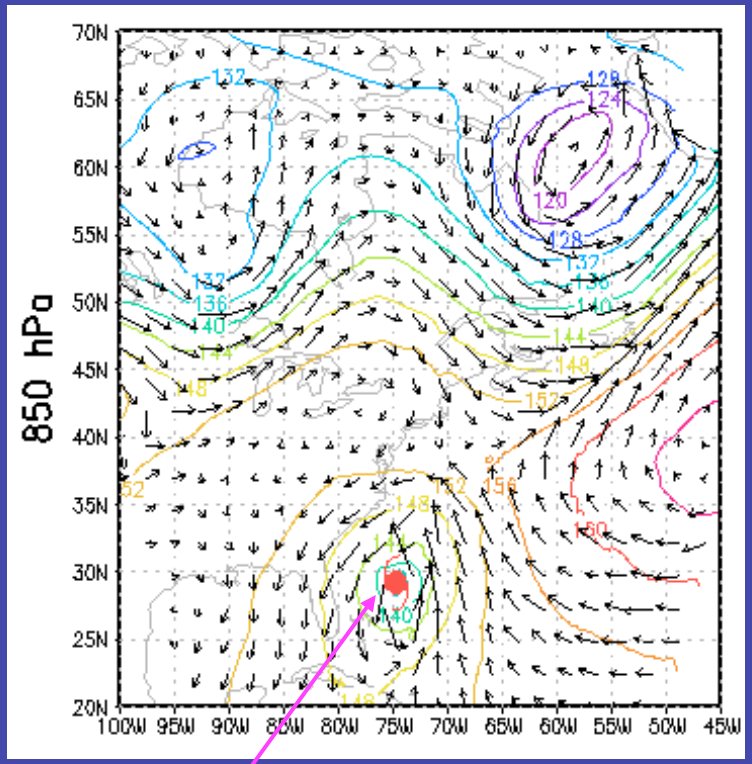
850 hPa (right) and 300 hPa (left) geopotential height and wind vectors at 0600 UTC Nov. 2 2007



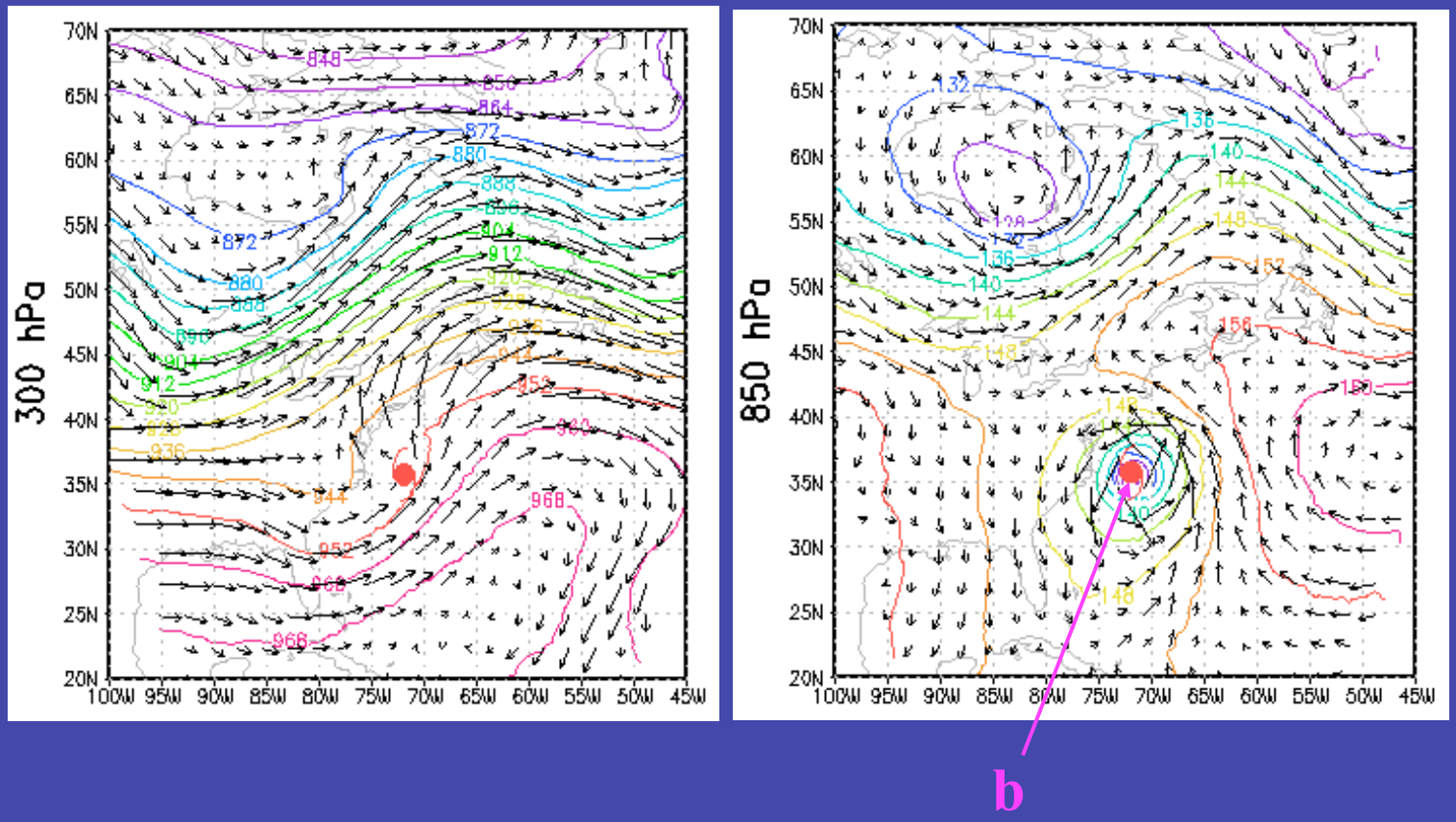


850 hPa (right) and 300 hPa (left) geopotential height and wind vectors at 1200 UTC Nov. 2 2007

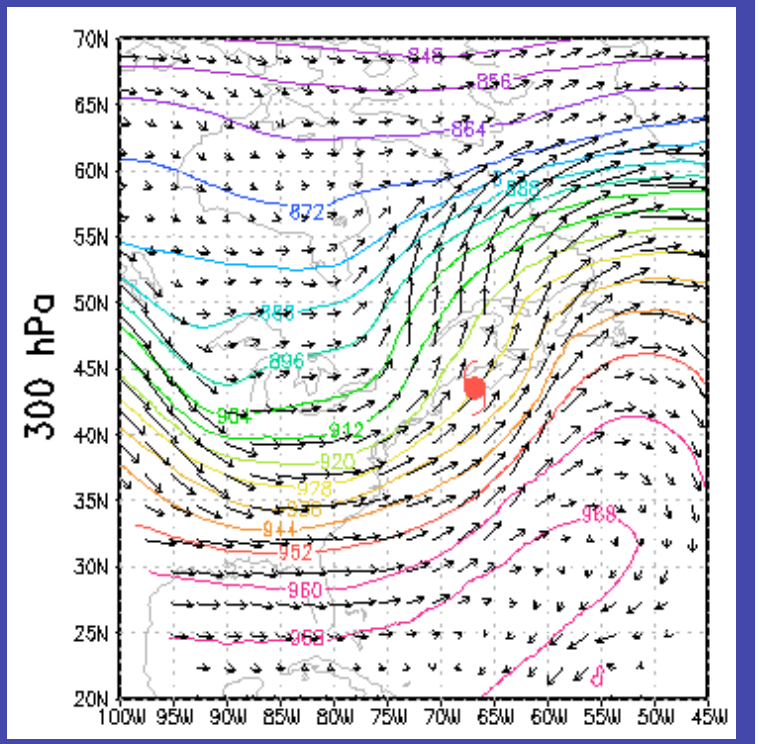


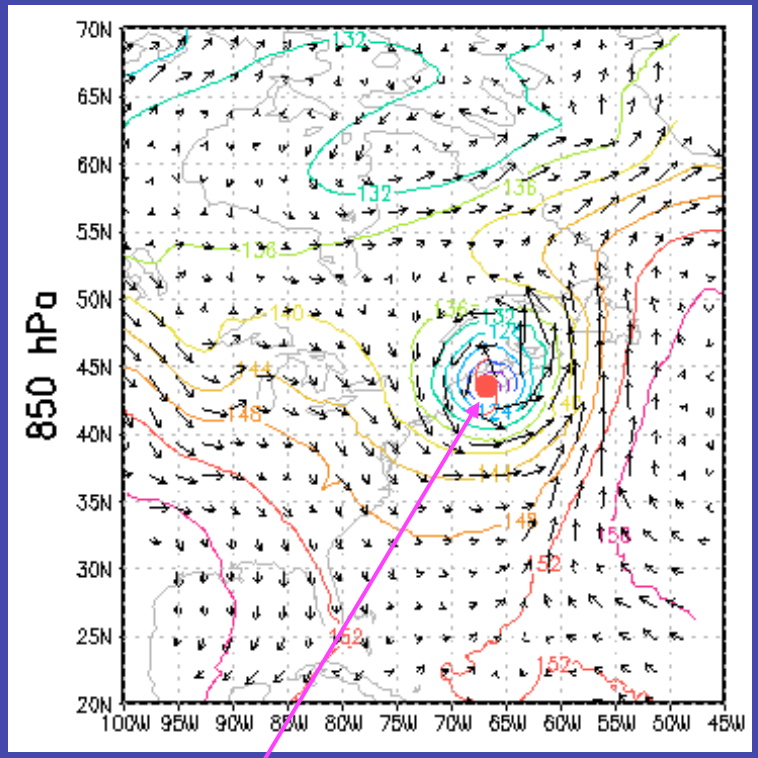


850 hPa (right) and 300 hPa (left) geopotential height and wind vectors at 0600 UTC Nov. 3 2007



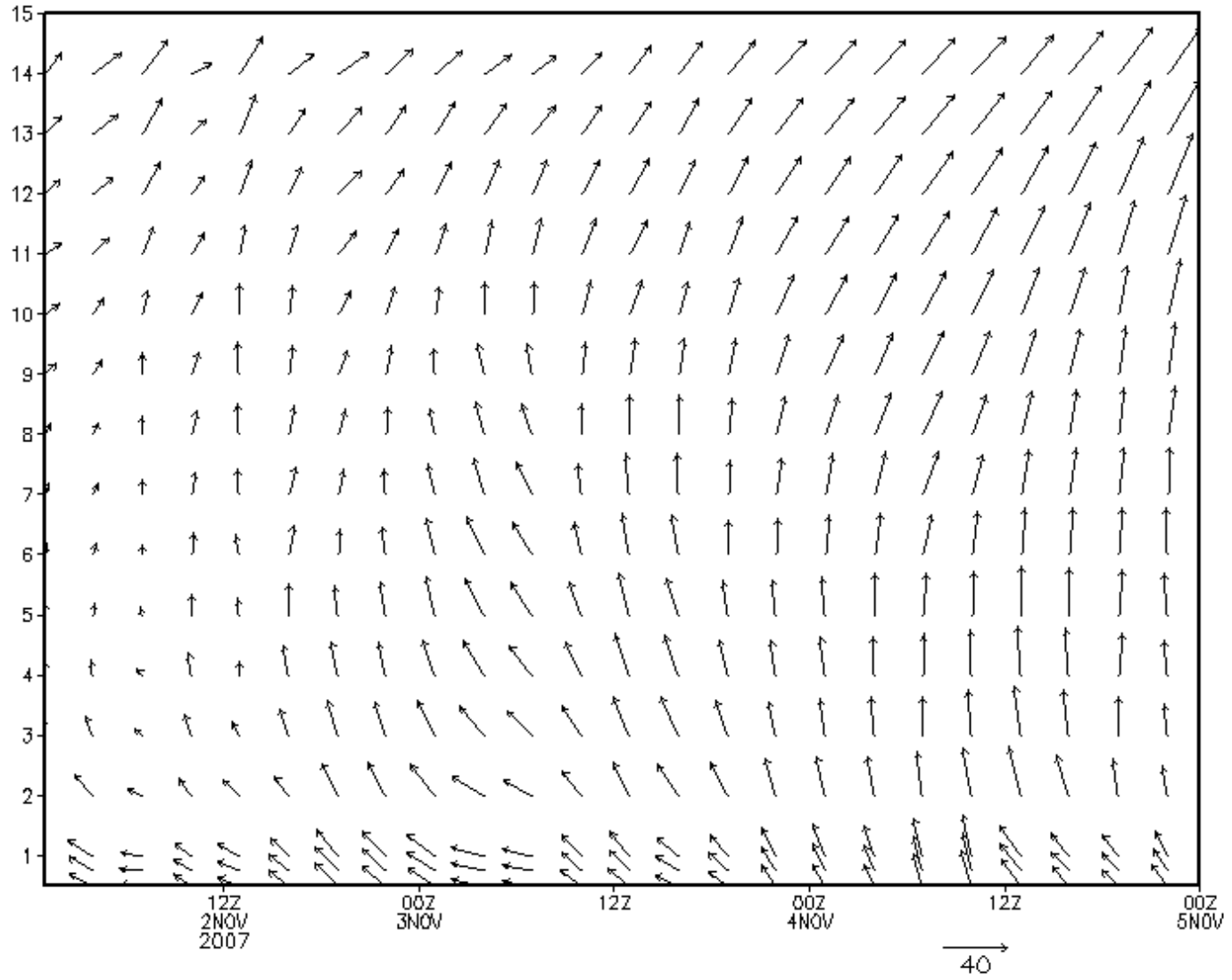
850 hPa (left) and 300 hPa (right) geopotential height and wind vectors at 0400 UTC Nov. 4 2007



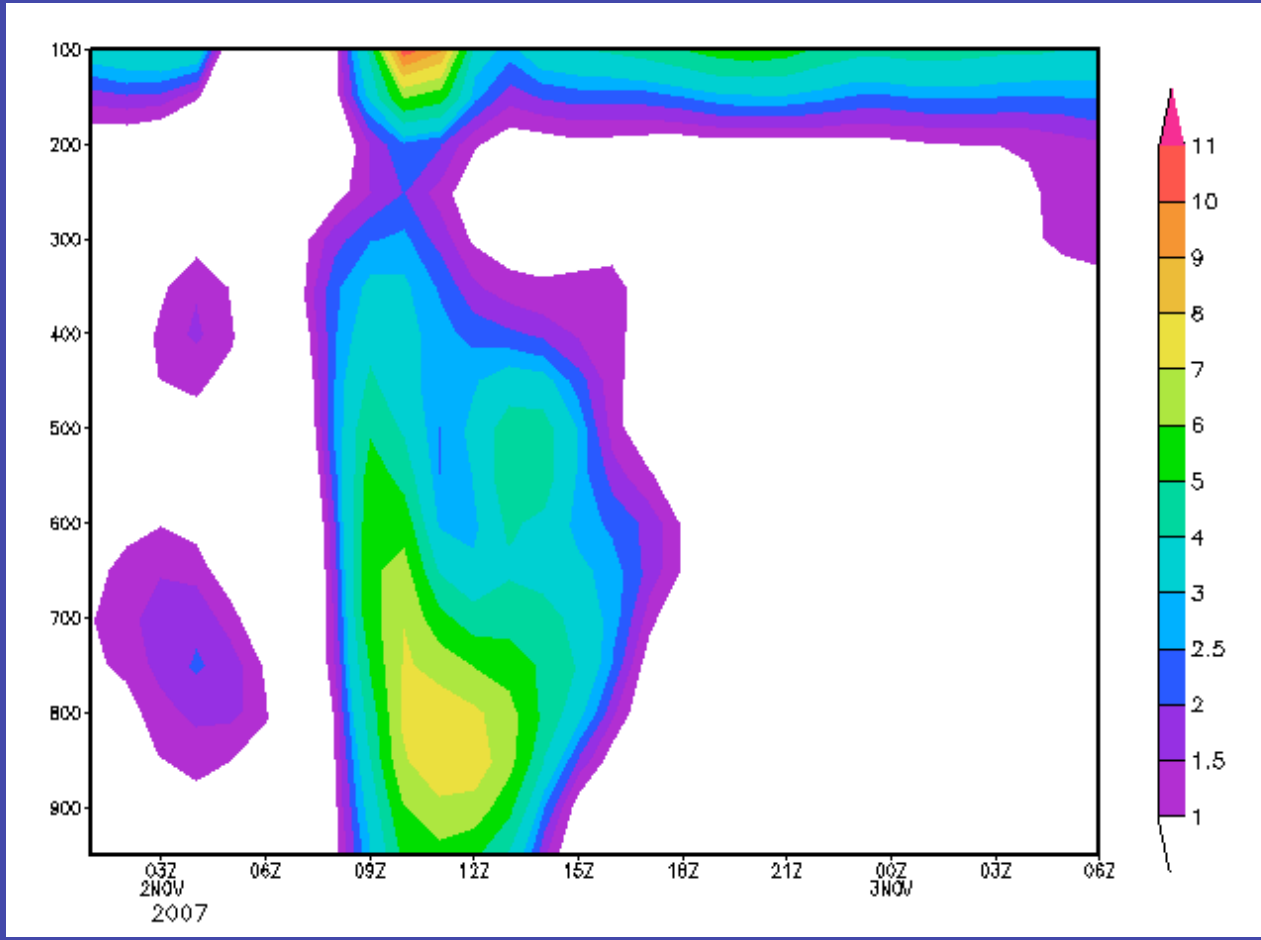


c

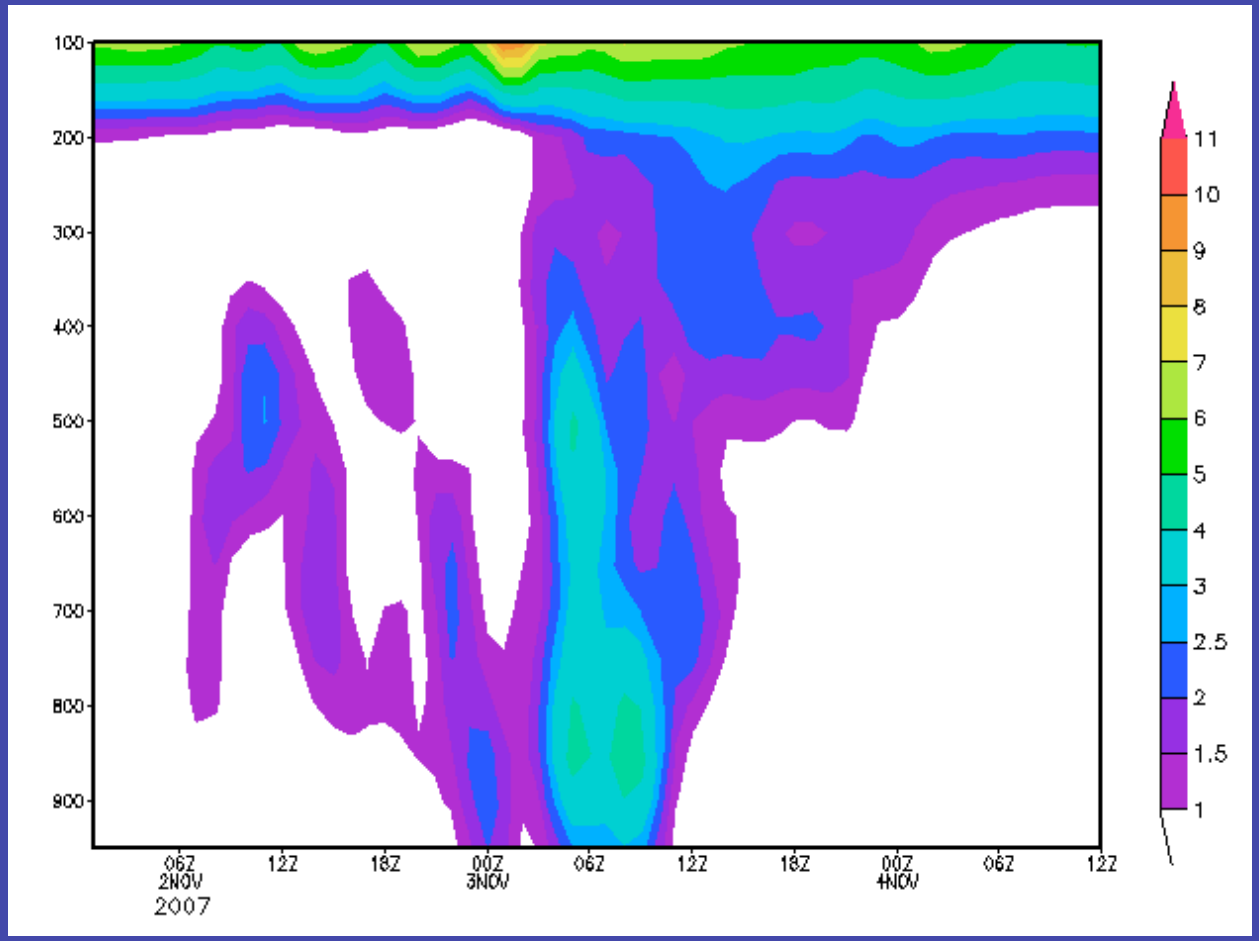
Height-time cross section of wind vectors



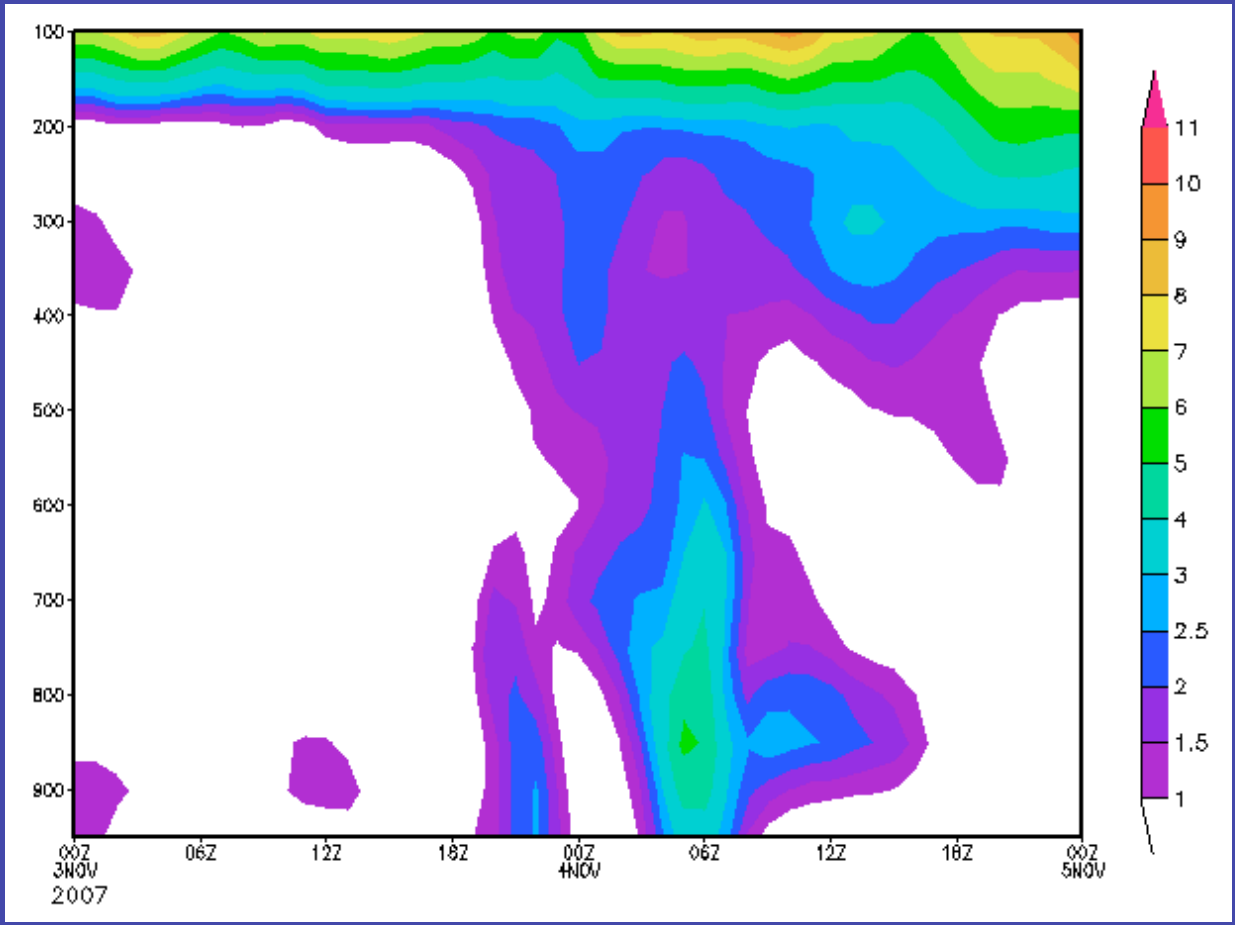
Height-time cross section of PV at location a



Height-time cross section of PV at location b

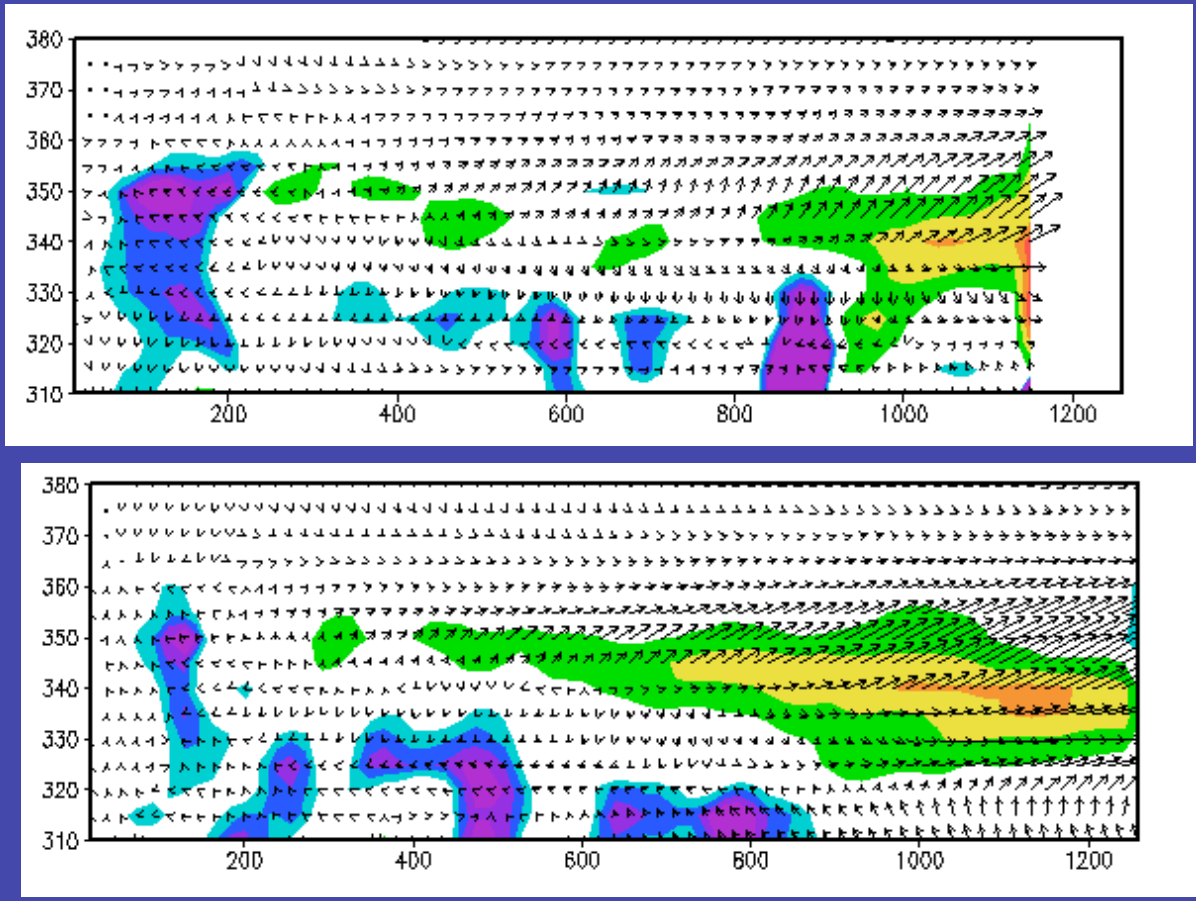


Height-time cross section of PV at location c

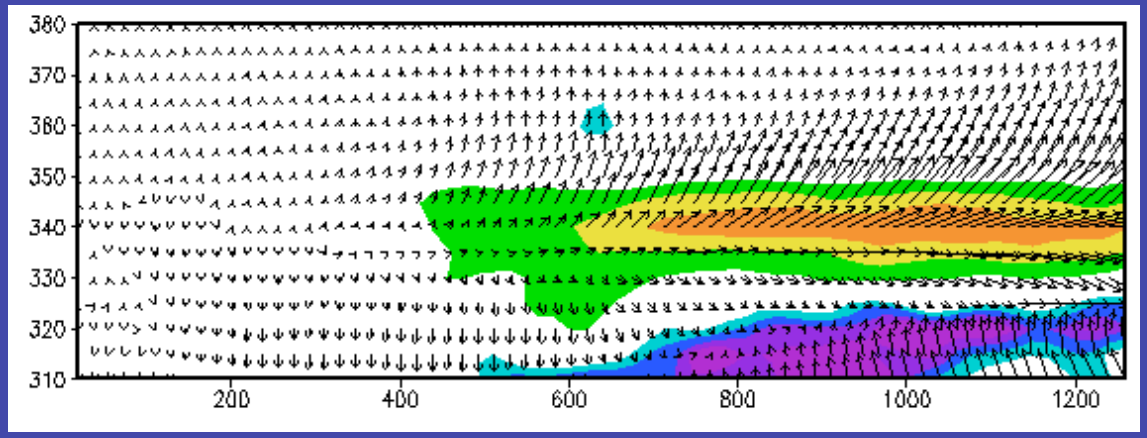


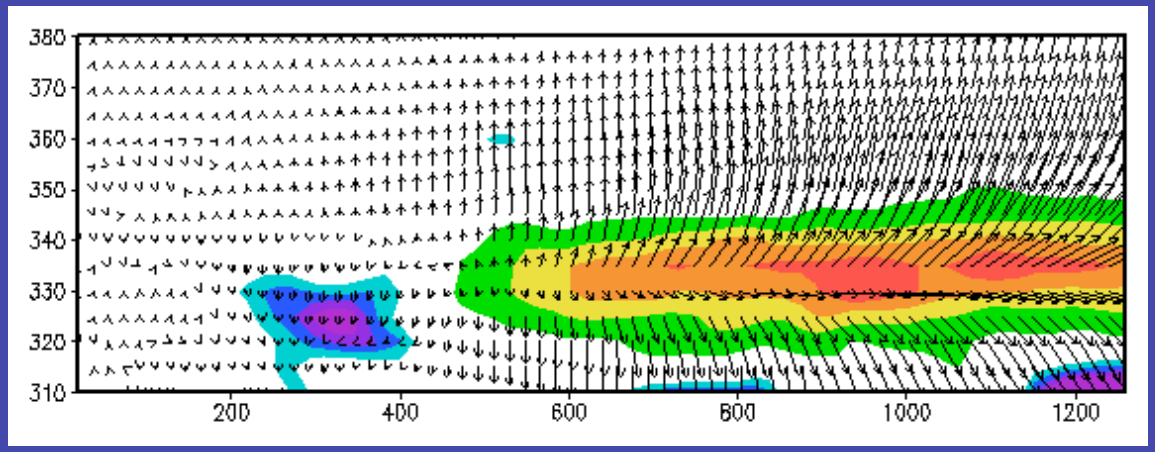
Latitude-time cross sections of temperature advection (shading) and geopotential height (thick contours)

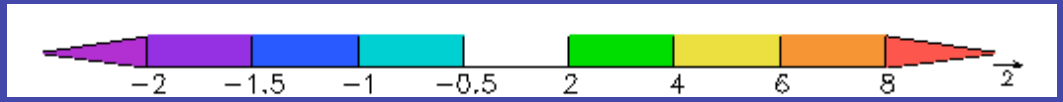
Potential temperature (θ)-radius (r) cross sections of E-P flux and E-P flux divergence at 0700 UTC (upper) and 1200 UTC (lower) 2 Nov. 2007



Potential temperature (θ)-radius (r) cross sections of E-P flux and E-P flux divergence at 1200 UTC (upper) 3 Nov. and 0400 UTC (lower) 4 Nov. 2007







Conclutions

- The model reproduced Noel's evolution throughout its lifecycle.
- The ET began around 1200 UTC November 2 2007 when Hurricane Noel became significantly asymmetric. Right after Noel made landfall over eastern Canada, the cold core of cyclone developed at lower-troposphere, indicating the completion of the ET.
- Noel started intensifying 18 hours after the beginning of ET when it interacted with the southern portion of an approaching upper-level middle latitude trough.

Conclutions—cont.

- During each interaction between the upper level trough and Noel, potential vorticity (PV) was transferred downward from the upper troposphere to the lower troposphere, resulting in the intensification of cyclone.
- As the cyclone intensifies, the upper-level eddy momentum forcing is more important than the upper-level eddy heat forcing.