Inner Core Structure of Hurricane Patricia Observed during TCI-2015

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TCI-2015
Tropical Cyclone Intensity Experiment

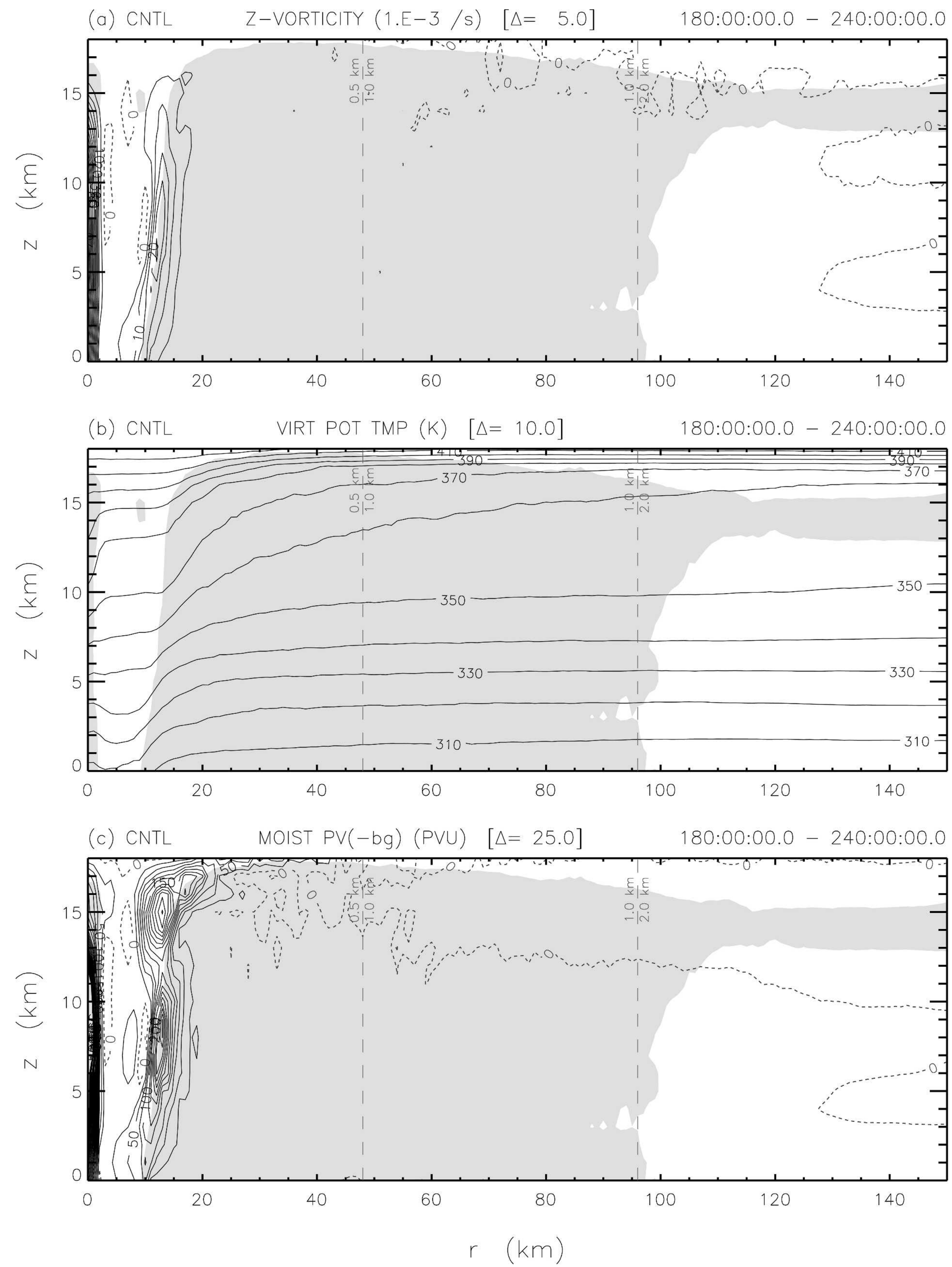
Acknowledgments: ONR TCI-DRI Award N00011410118

$$P = \frac{1}{\rho}\left[\left(\frac{-\partial v}{\partial z}\right)\left(\frac{\partial \theta}{\partial r}\right) + \left(f + \frac{\partial (rv)}{r\,\partial r}\right)\left(\frac{\partial \theta}{\partial z}\right)\right]$$

- Potential Vorticity is a fundamental quantity for highly vortical fluid flows

- Describes the balanced part of the flow, and is materially conserved in the absence of friction and heating

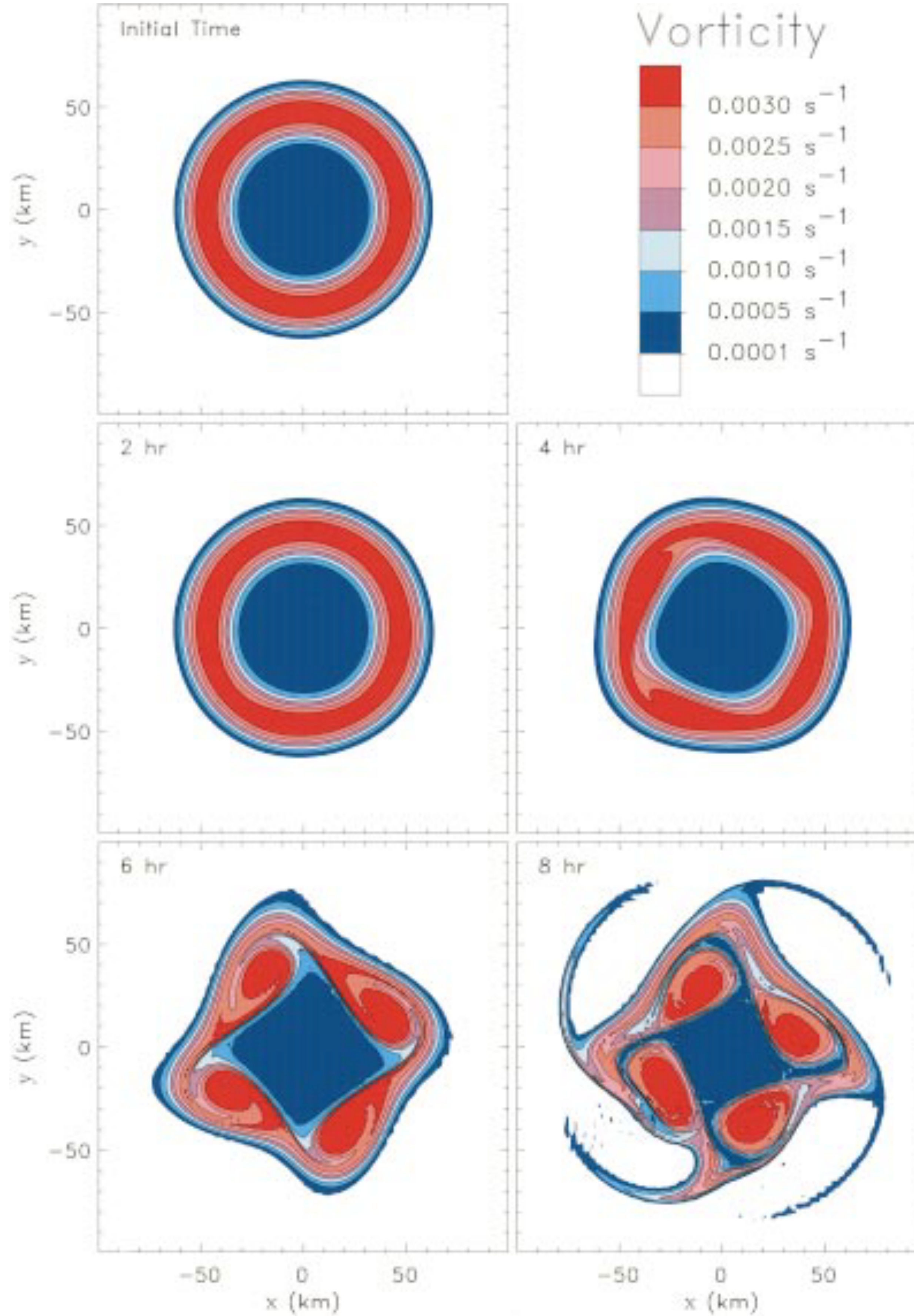
- PV cannot be measured directly as it depends on gradients of the flow



Hausman et al. 2006

$$P = \frac{1}{\rho}\left[\left(\frac{-\partial v}{\partial z}\right)\left(\frac{\partial \theta}{\partial r}\right) + \left(f + \frac{\partial (rv)}{r\partial r}\right)\left(\frac{\partial \theta}{\partial z}\right)\right]$$

- A ring of PV can satisfy the condition for barotropic instability
- Stability depends on width and intensity of diabatic heating, with thinner rings more unstable (Hendricks et al. 2014)



Schubert et al. 1999

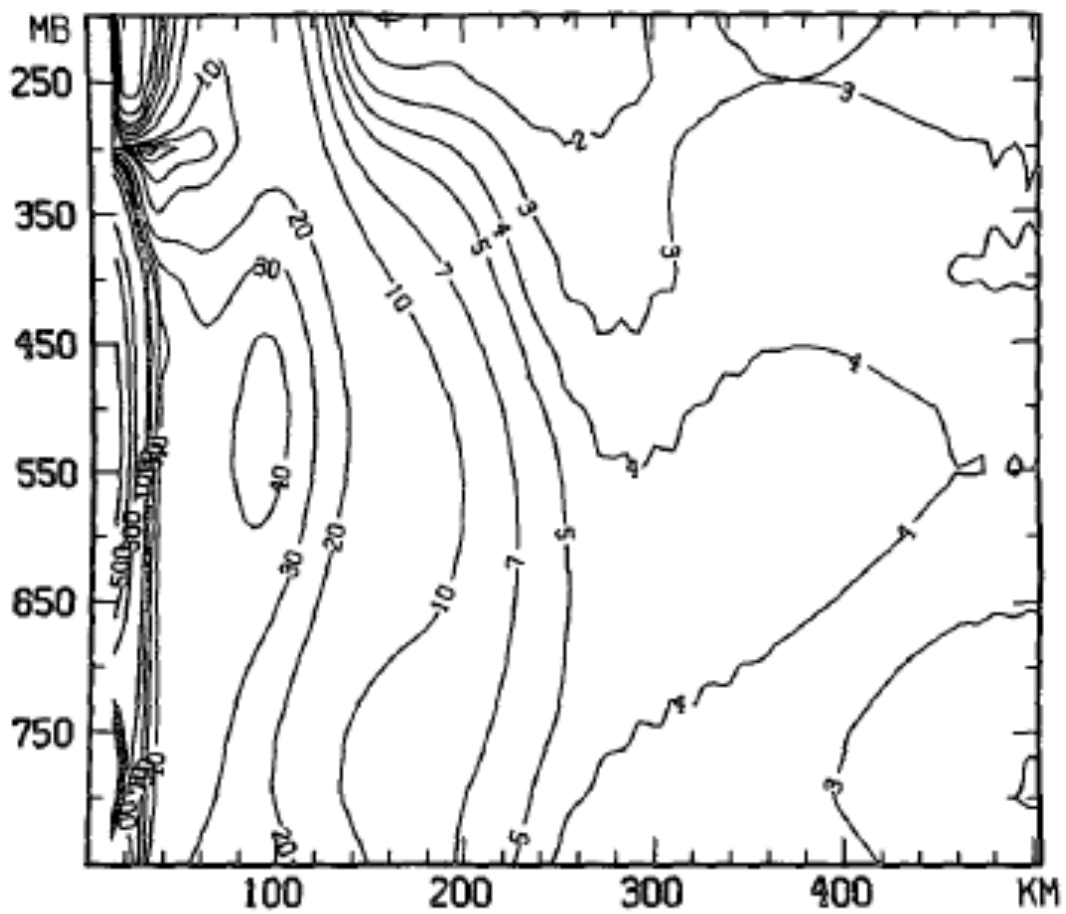
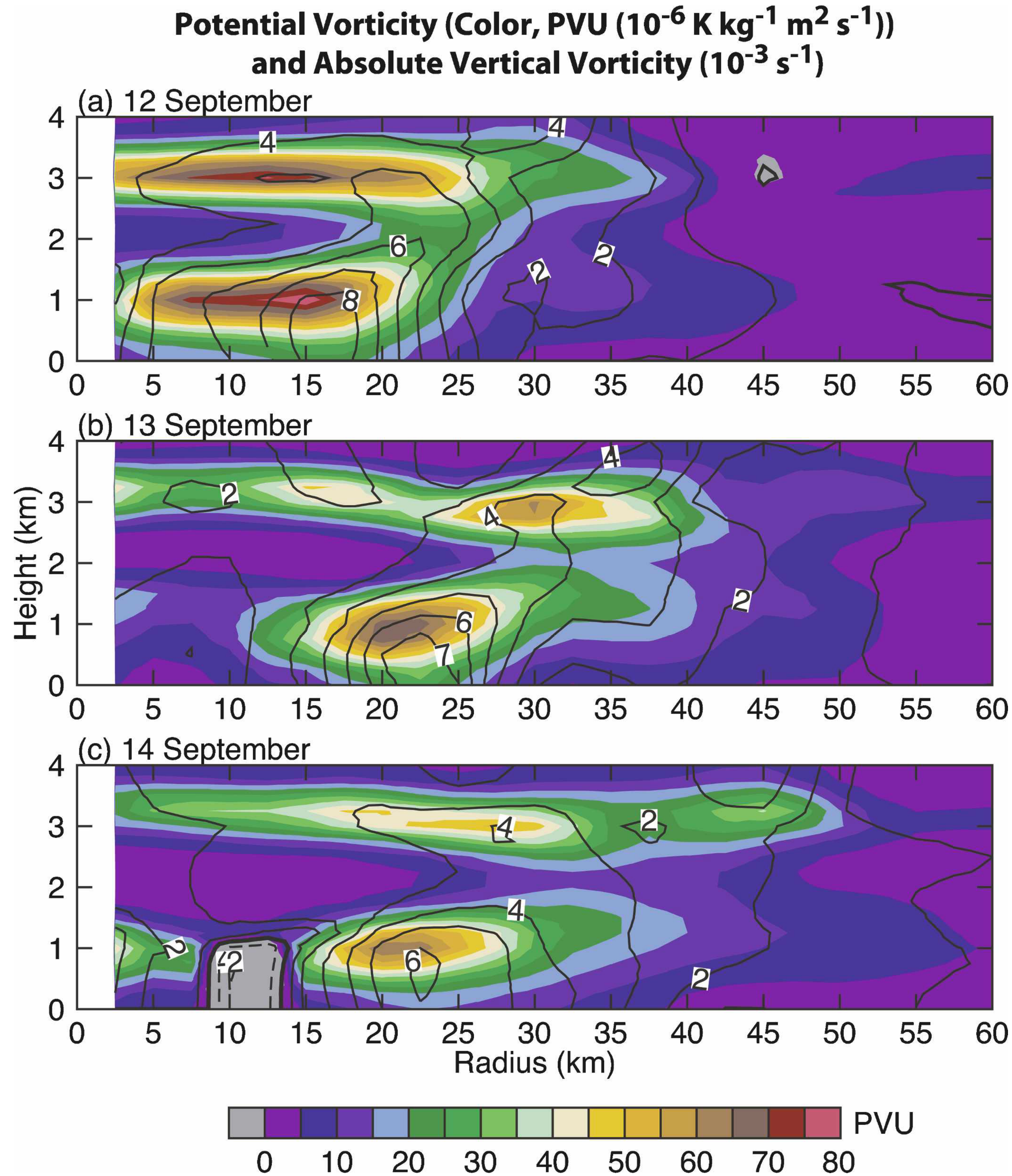


FIG. 11. Radial–height cross section of symmetric PV. Contours are 2, 3, 4, 5, 7, 10, 20, 30, 40, 50, 70, 100, 300, 500, 1000 × 10^{-7} $m^2\ s^{-1}\ K\ kg^{-1}$. Values in data-sparse region, within 13 km of vortex center, are not displayed.

Mass field in inner-core derived from gradient wind balance



Shapiro and Franklin 1995

Bell and Montgomery 2008

- ***Hypothesis***: Exponential increase in potential vorticity during the rapid intensification of Patricia led to thin tower of PV that became unstable in the presence of vertical shear and reduced inflow from secondary eyewall

$$\frac{DP}{DT} \approx P\left(\frac{\partial \dot{\theta}}{\partial \theta}\right)$$

- ***Tool:*** SAMURAI analyses combining HDSS dropsondes and P-3 Doppler radar for integrated thermodynamic and kinematic fields to calculate PV

- ***Goal:*** Resolve ***axisymmetric*** flow field and strong gradients to provide new insights into the rapid intensification process

Datasets

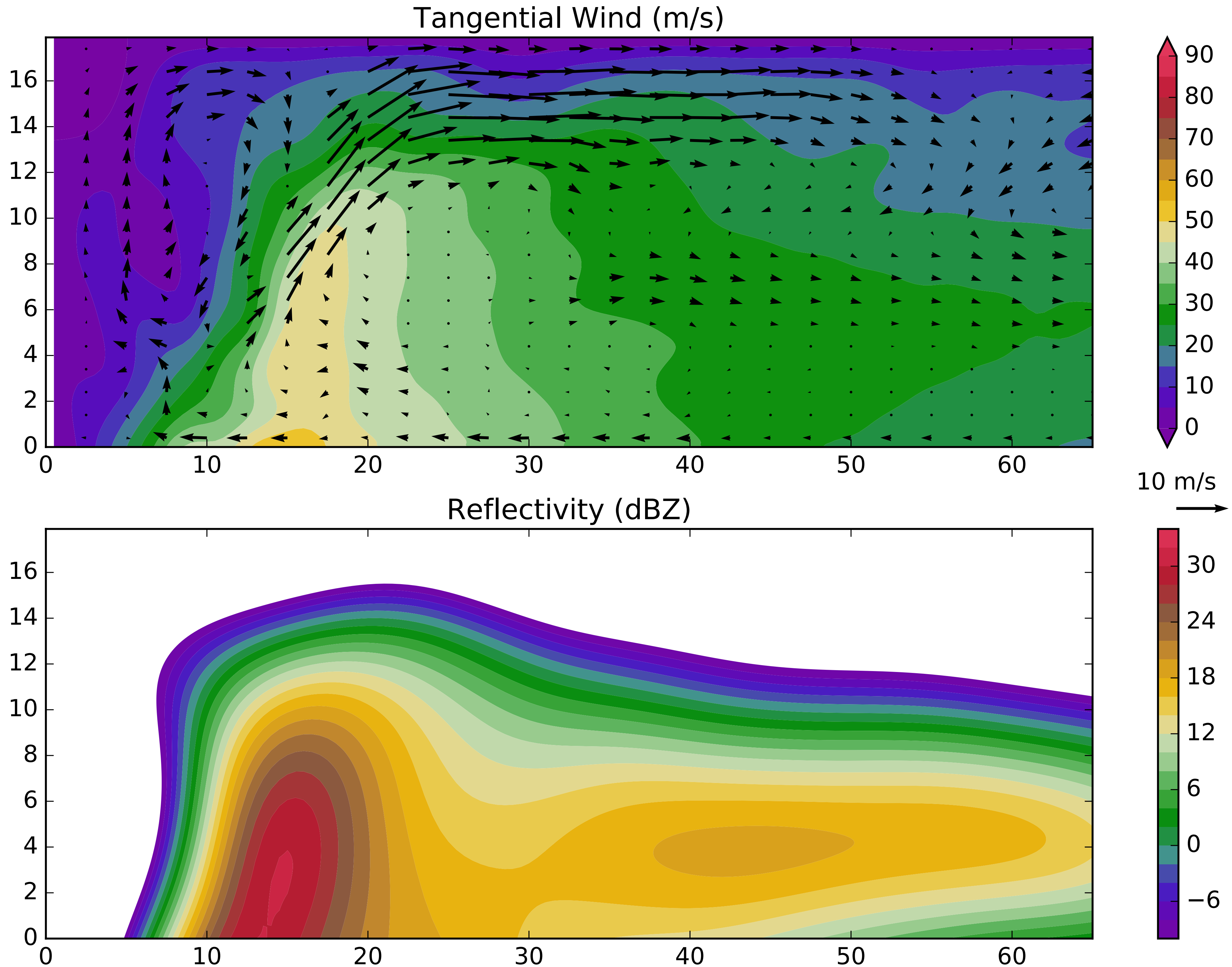
- Quality controlled HDSS dropsondes and NOAA P3 dropsondes
- Airborne Doppler radar and flight level data from NOAA P3
- Hourly Atmospheric Motion Vectors

Date	# of Sondes
20-Oct	13
21-Oct	77
22-Oct	83
23-Oct	84

Analysis Methodology

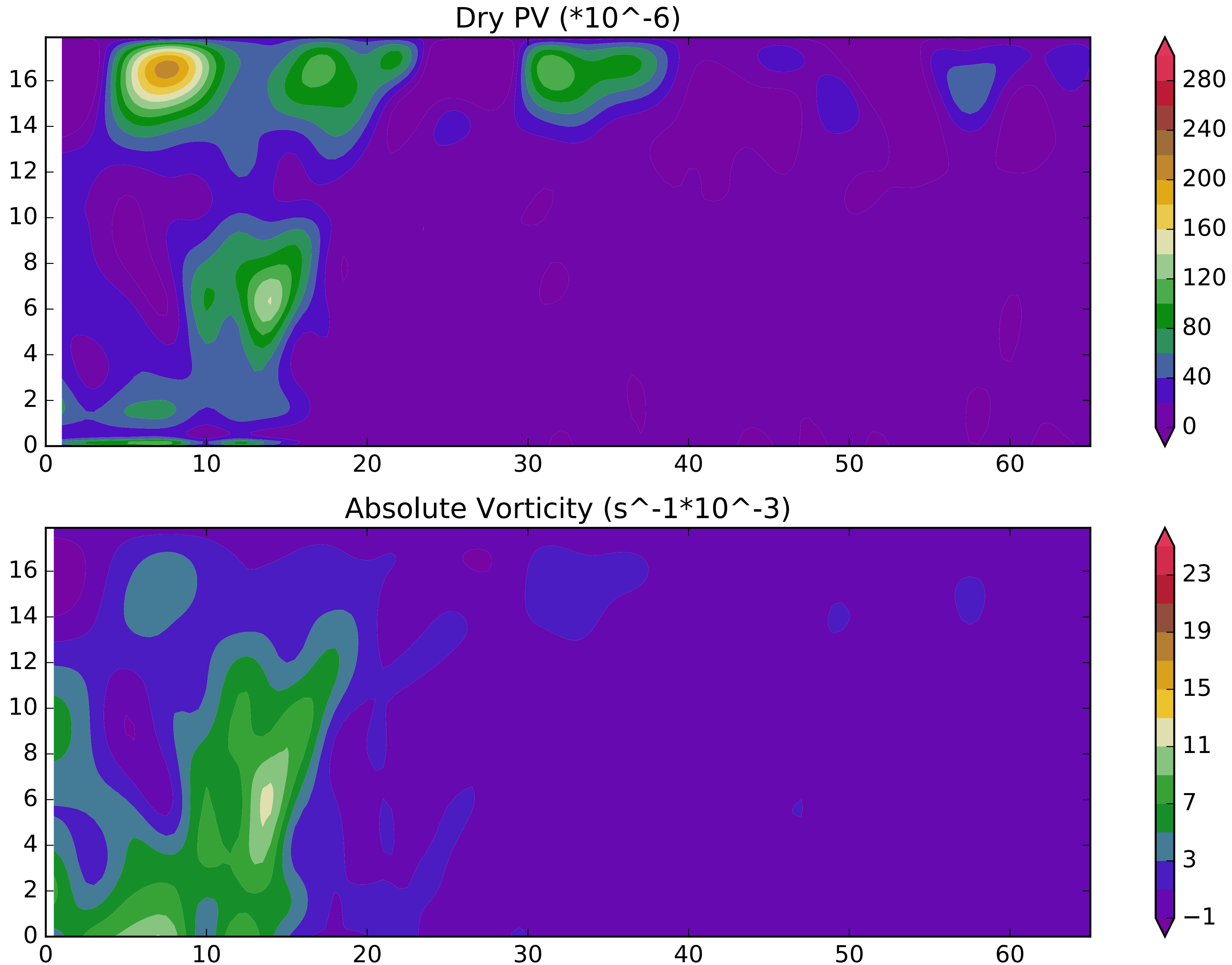
- SAMURAI 3DVAR analysis (Bell et al. 2012)
- Thermodynamic analysis averaged over whole WB-57 flight
- Kinematic analysis for each NOAA P3 penetration

1715-1800 UTC 22 October



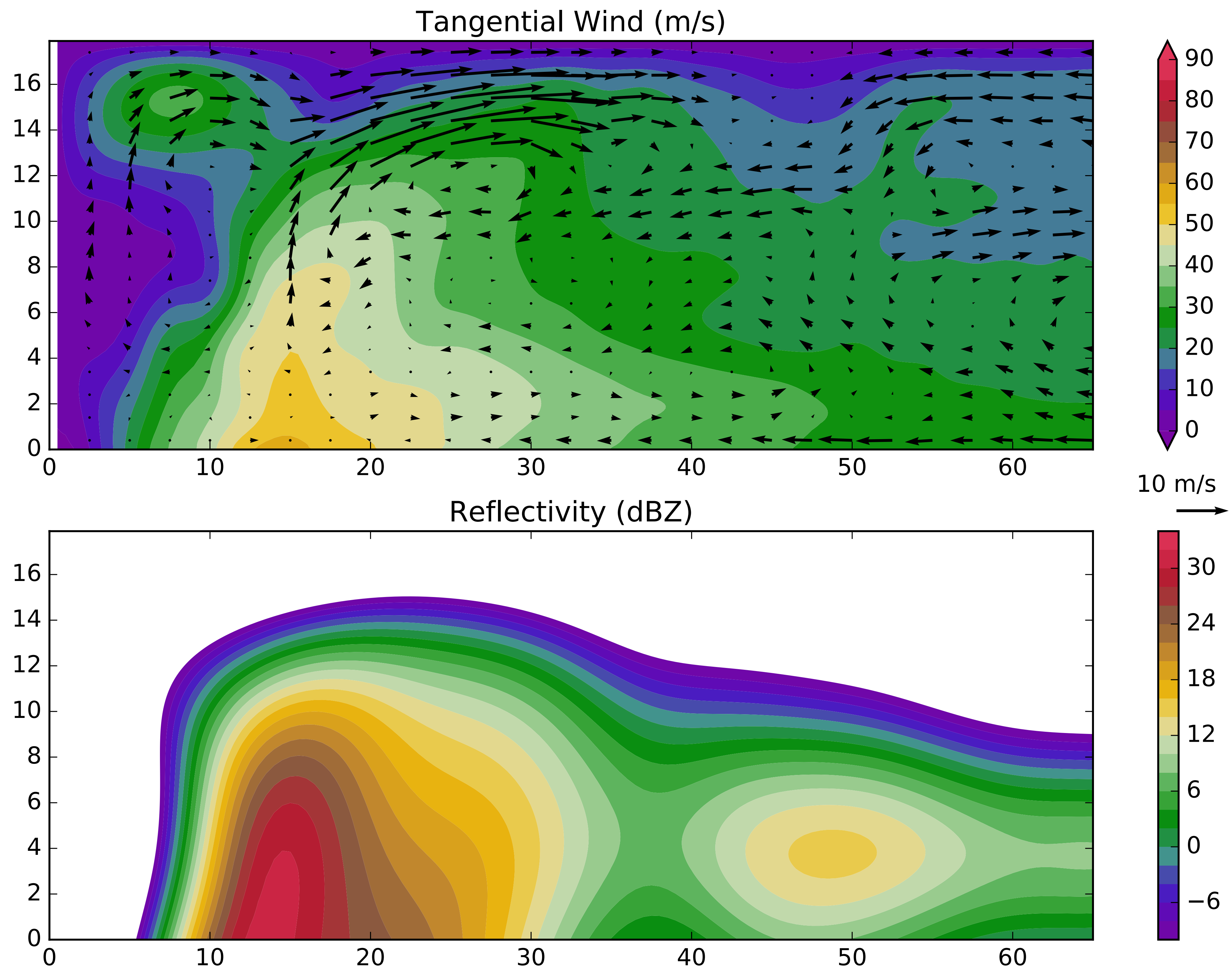
Preliminary Analysis

1715-1800 UTC 22 October



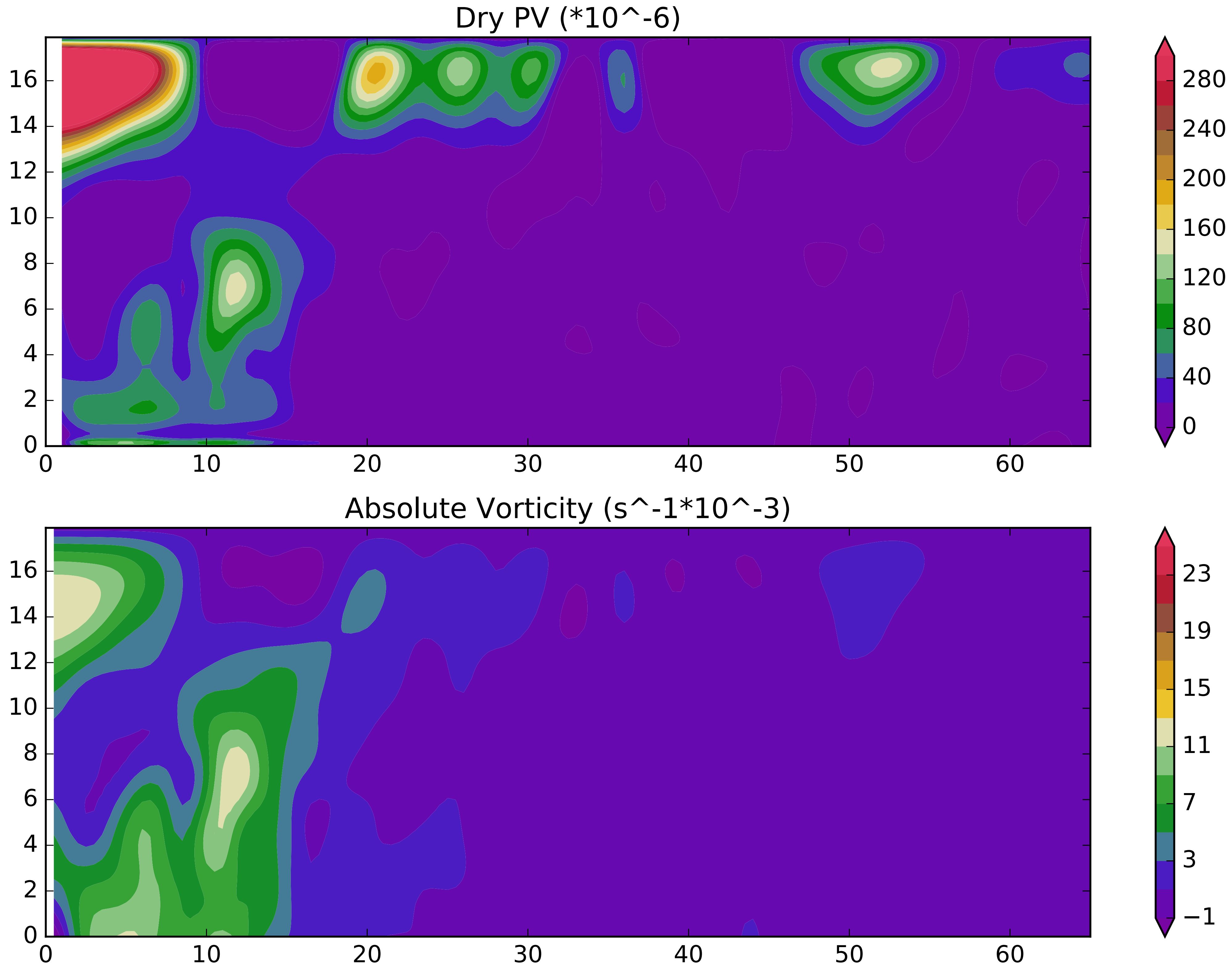
Preliminary Analysis

1800-1915 UTC 22 October



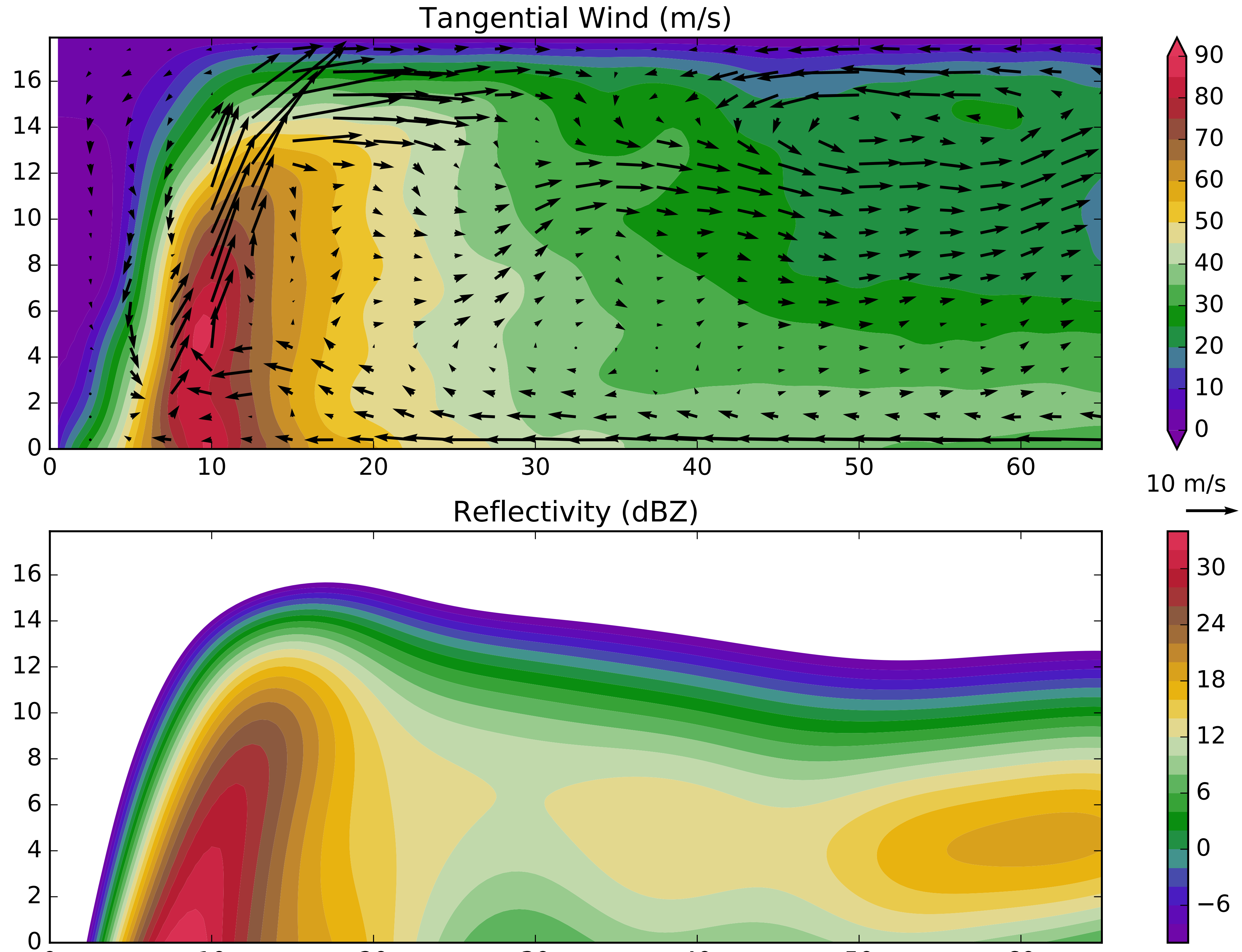
Preliminary Analysis

1800-1915 UTC 22 October



Preliminary Analysis

1700-1800 UTC 23 October



Preliminary Analysis

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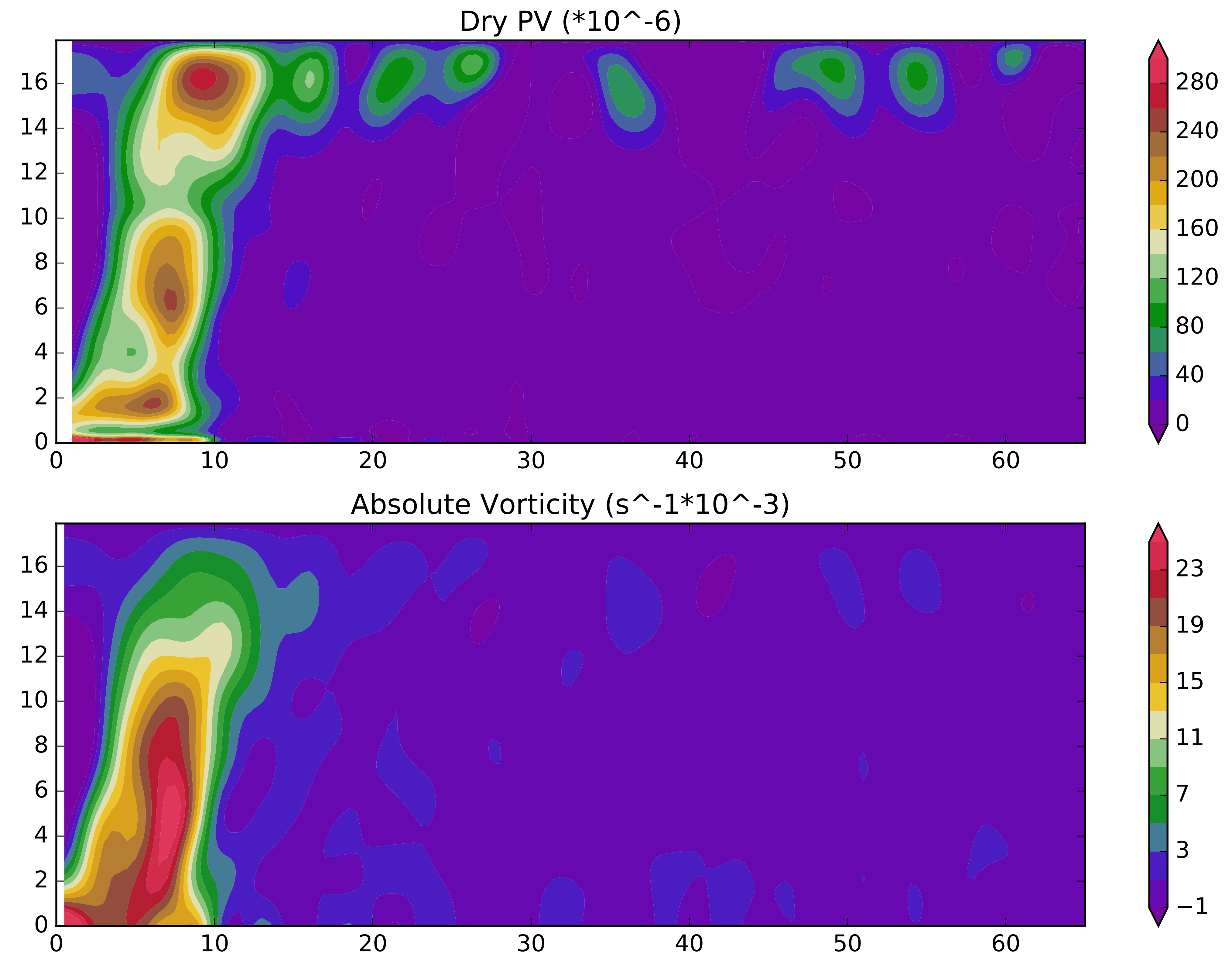
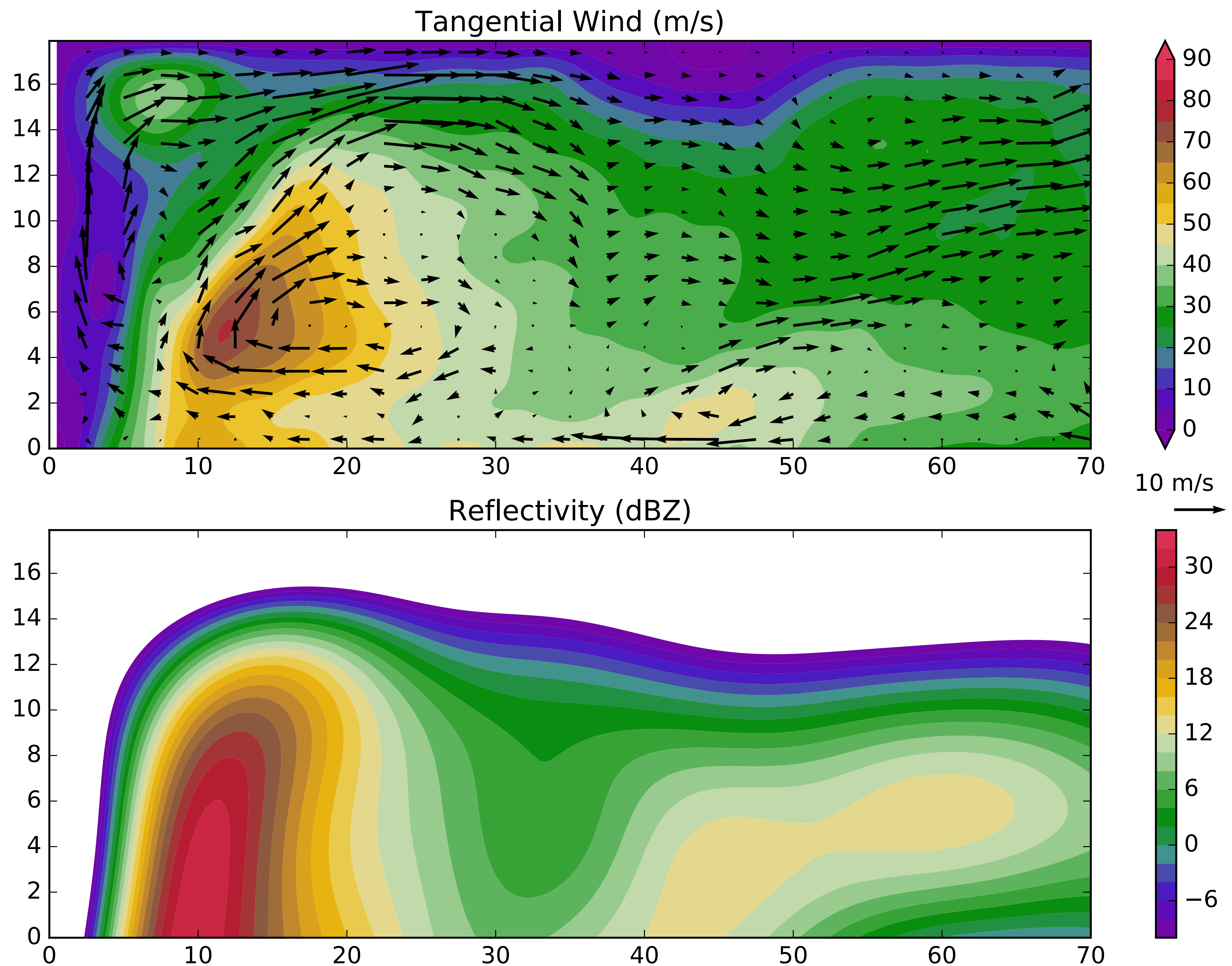


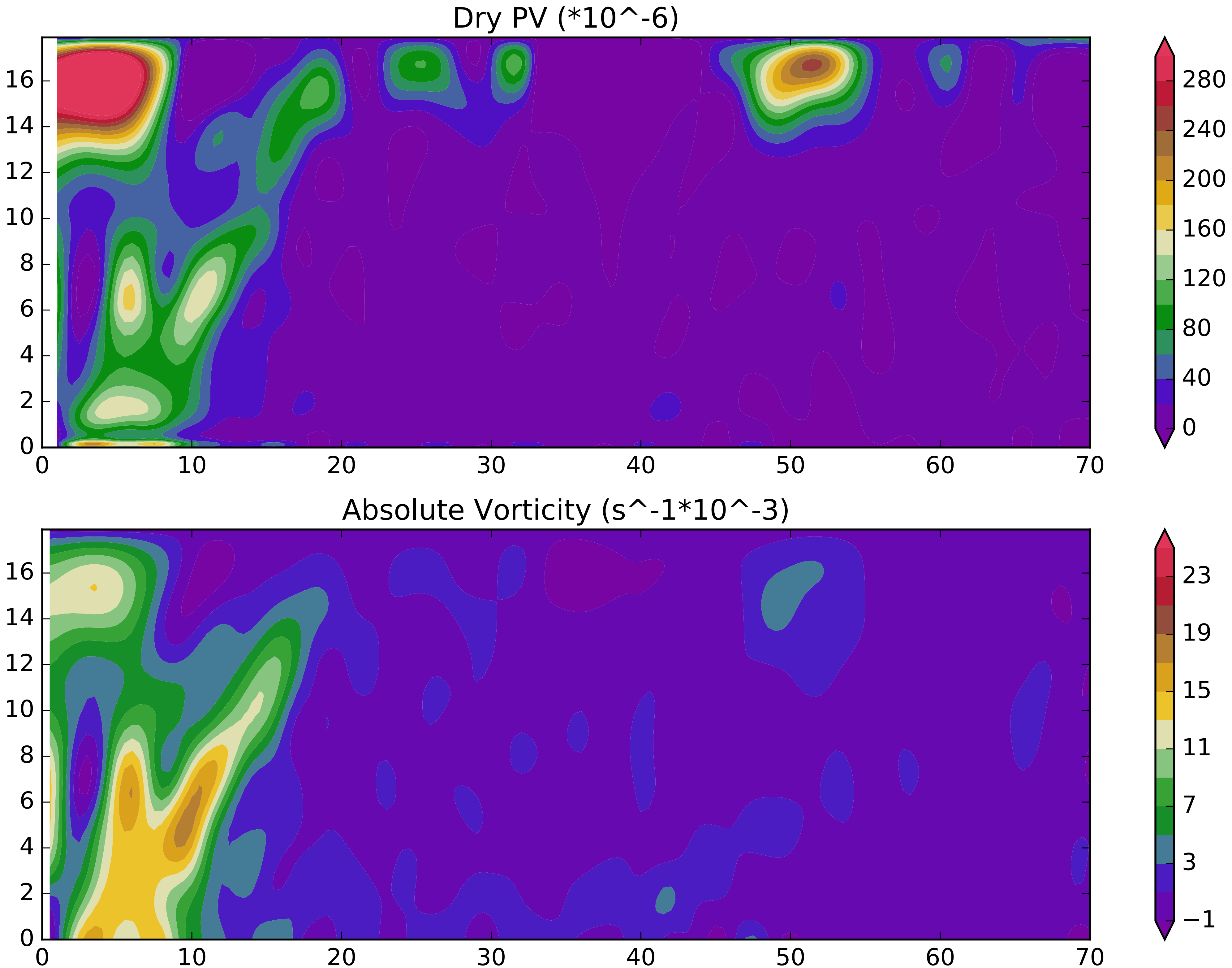
Preliminary Analysis

1950-2100 UTC 23 October



Preliminary Analysis

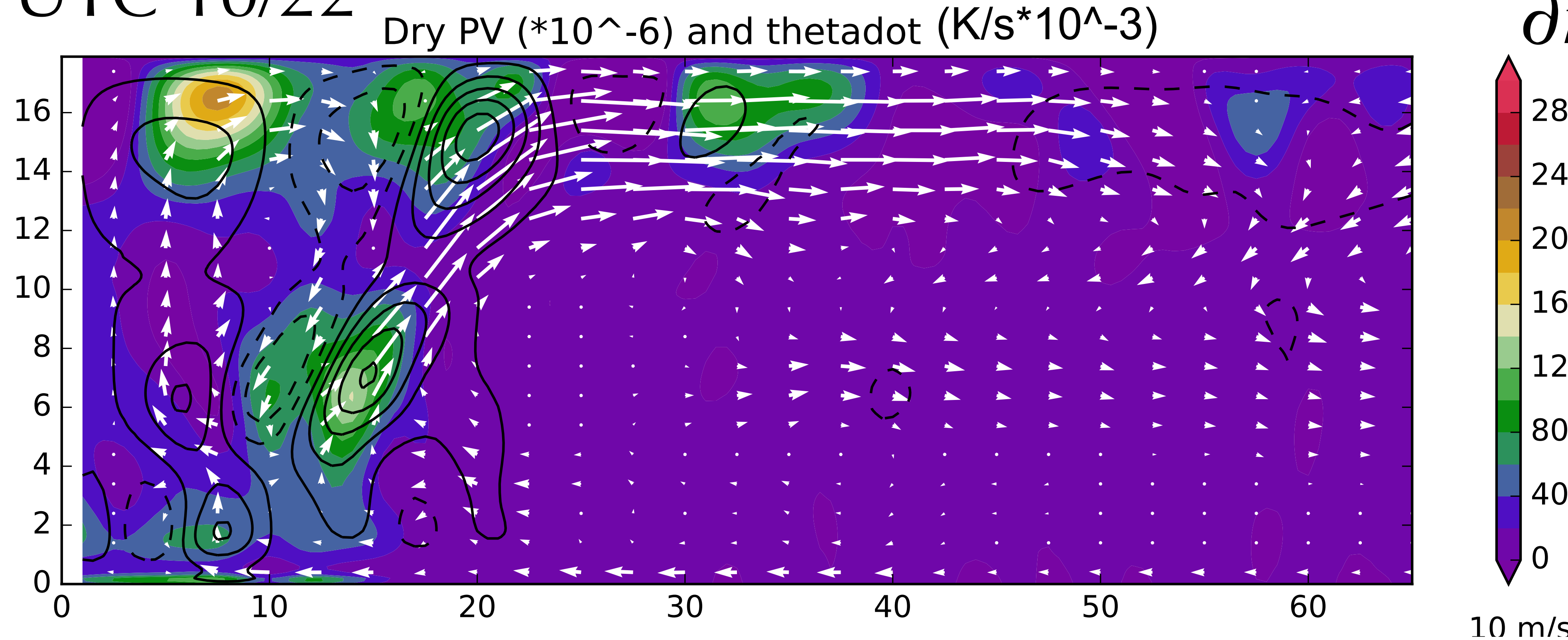
1950-2100 UTC 23 October



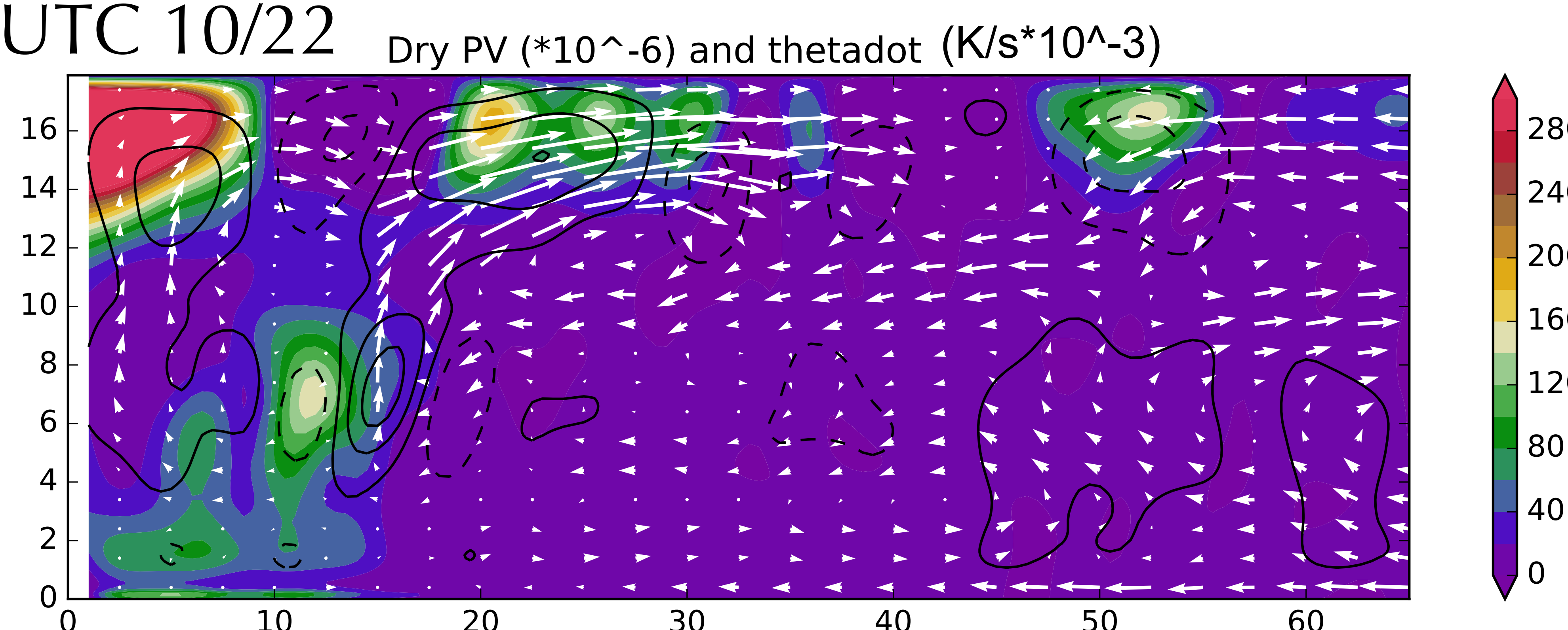
Preliminary Analysis

$$\dot{\theta} \approx u\frac{\partial \theta}{\partial r} + w\frac{\partial \theta}{\partial z}$$

~1740 UTC 10/22



~1840 UTC 10/22

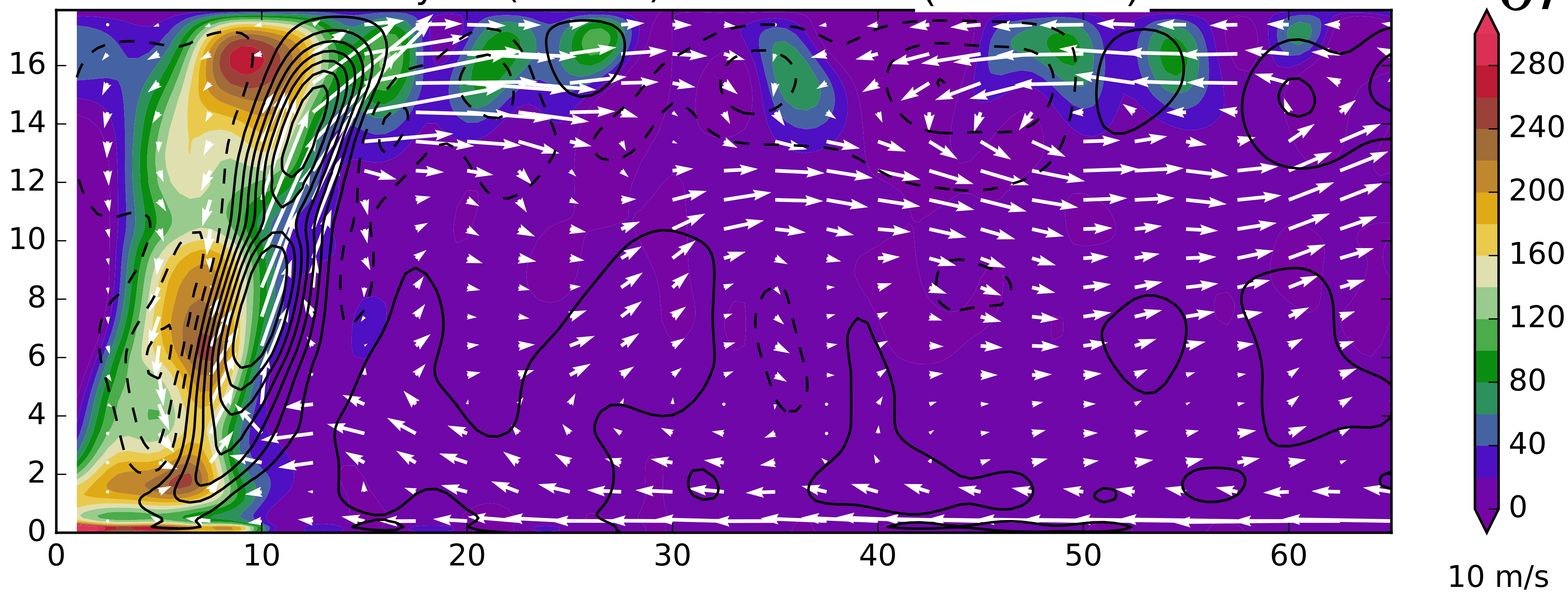


Preliminary Analysis

$$\dot{\theta} \approx u\frac{\partial\theta}{\partial r} + w\frac{\partial\theta}{\partial z}$$

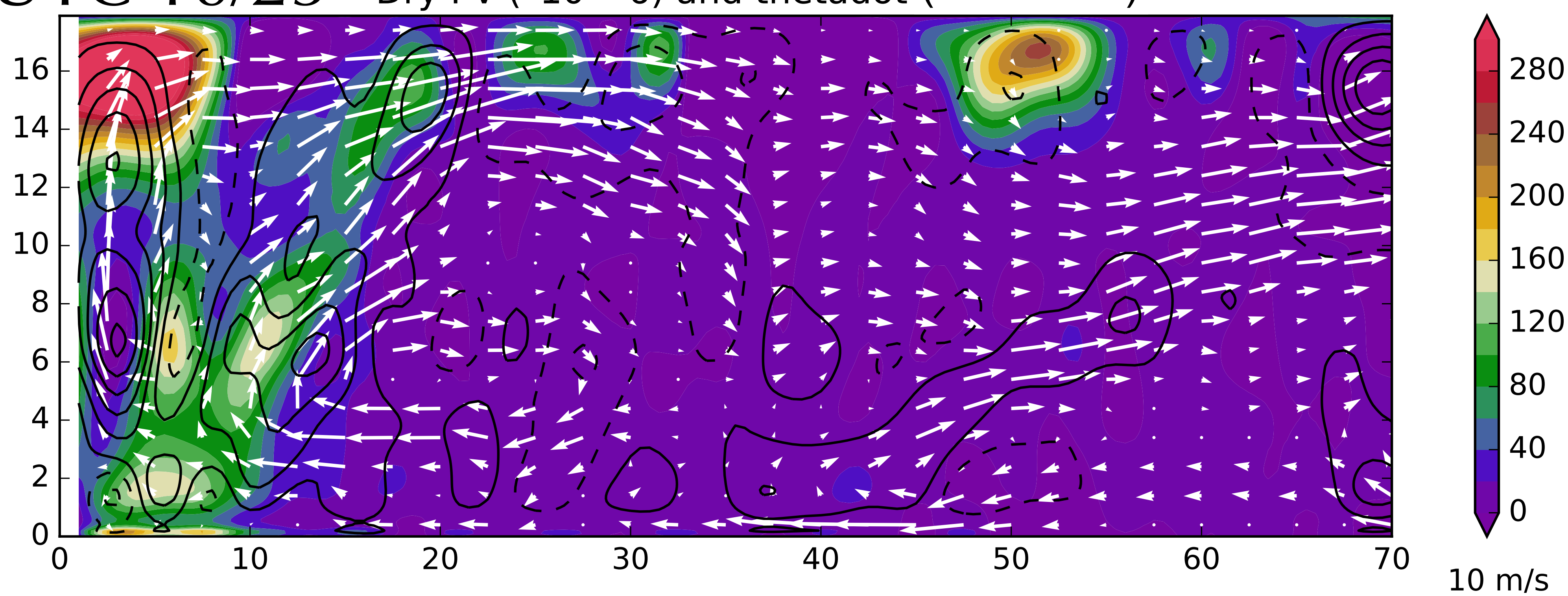
~1730 UTC 10/23

Dry PV (*10^-6) and thetadot (K/s*10^-3)



~2130 UTC 10/23

Dry PV (*10^-6) and thetadot (K/s*10^-3)



Preliminary Analysis

Summary and Conclusions

- HDSS soundings and NOAA P3 tail radar data allow for calculation of full-tropospheric PV in Hurricane Patricia during rapid intensification and weakening
- Analyses suggest that a mid-level max migrated inward and became aligned with lower max associated with eye inversion and upper-level max associated with tropopause at peak intensity, resulting in impressive ~250 PVU tower
  - Hausman et al. 2006 simulation not that unrealistic!
- Rapid breakdown of thin PV tower appears to have occurred shortly after maximum intensity, due in part to reduced heating associated with vertical shear and developing secondary eyewall
  - Results broadly consistent with Hendricks et al. 2014

Future Work and Collaboration

- Analyses are nearing final stages
  - Gradients and vertical motion are sensitive to data gaps and filtering, especially inside eye and dropsonde gaps
- Further calculation of PV tendencies, Richardson number, and other quantities is ongoing
- Barotropic stability analysis of PV structure
- 3D PV calculation much more difficult and requires thermodynamic retrieval
- Collaborations welcome! Willing to share SAMURAI analyses once they are final