"The Balanced Wind, Mass, and Potential Vorticity Structure of Warm-Ring Tropical Cyclones"

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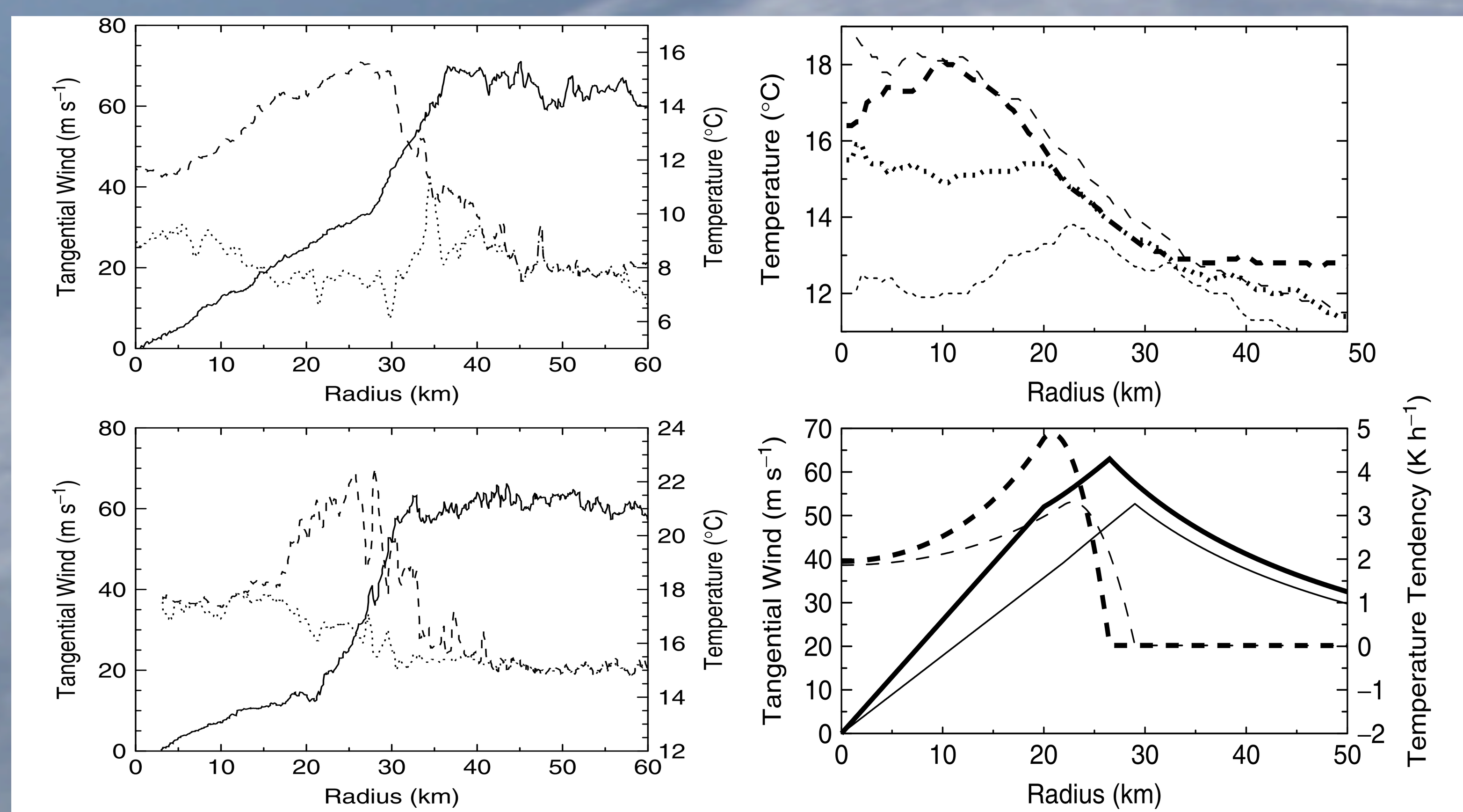
Observations



The figure on the left are radial profiles of flight-level tangential wind (solid lines), temperature (dashed lines) ad dew-point (dotted lines) from Hurricane Isabel on 13 September 2003 at 3.7km (top) altitude from 1948 UTC to 1956 UTC and 2.1km (bottom) from 1922 UTC to 1931 UTC. The figure on the right shows radial profiles from Hurricane Guillermo of time-averaged temperature and dew-point (top, light dashed and dotted lines respectively) on 2 August and 3 August (top, heavy dashed and dotted lines respectively). The corresponding three-region model's estimate of Guillermo's 700hPa tangential wind and temperature tendency on 2 August (bottom, light solid and dashed lines respectively) and 3 August (bottom, heavy solid and dashed lines respectively).

Warm-rings are present from these figures from two different tropical cyclones, where we can clearly see an actual rise in temperature outward from the center of the vortex. .

Methods

The thermal wind equation is

$$\left(f + \frac{2v(z)}{r}\right)\frac{\partial v(z)}{\partial z} = \frac{g}{T_0}\frac{\partial T'}{\partial r},$$

The spatial structure of the idealized baroclinic vortex

$$v(r,z) = v_m(z)\left\{\frac{n\left(\frac{r}{r_m(z)}\right)^{n-1}}{1+(n-1)\left(\frac{r}{r_m(z)}\right)^{n}}\right\}$$

Where,

$$v_m(z) = v_B - (v_B - v_T)\left(\frac{z}{z_T}\right)^2\left(3 - 2\frac{z}{z_T}\right),$$

And,

$$r_m(z) = r_B - (r_B - v_T)\left(\frac{z}{z_T}\right)^2\left(3 - 2\frac{z}{z_T}\right)$$

Abolute angular momentum is defined

$$R(r,z) = \left(r^2 + \frac{2rv}{f}\right)^{\frac{1}{2}}$$

Given $\theta = T(p_0/p)^\kappa$ where $p_0/p = e^{\frac{z}{H}}$, This gives our potential temperature equation

$$\theta = (\bar{T} + T')\exp\left[\frac{\kappa z}{H}\right]$$

Potential vorticity is defined as

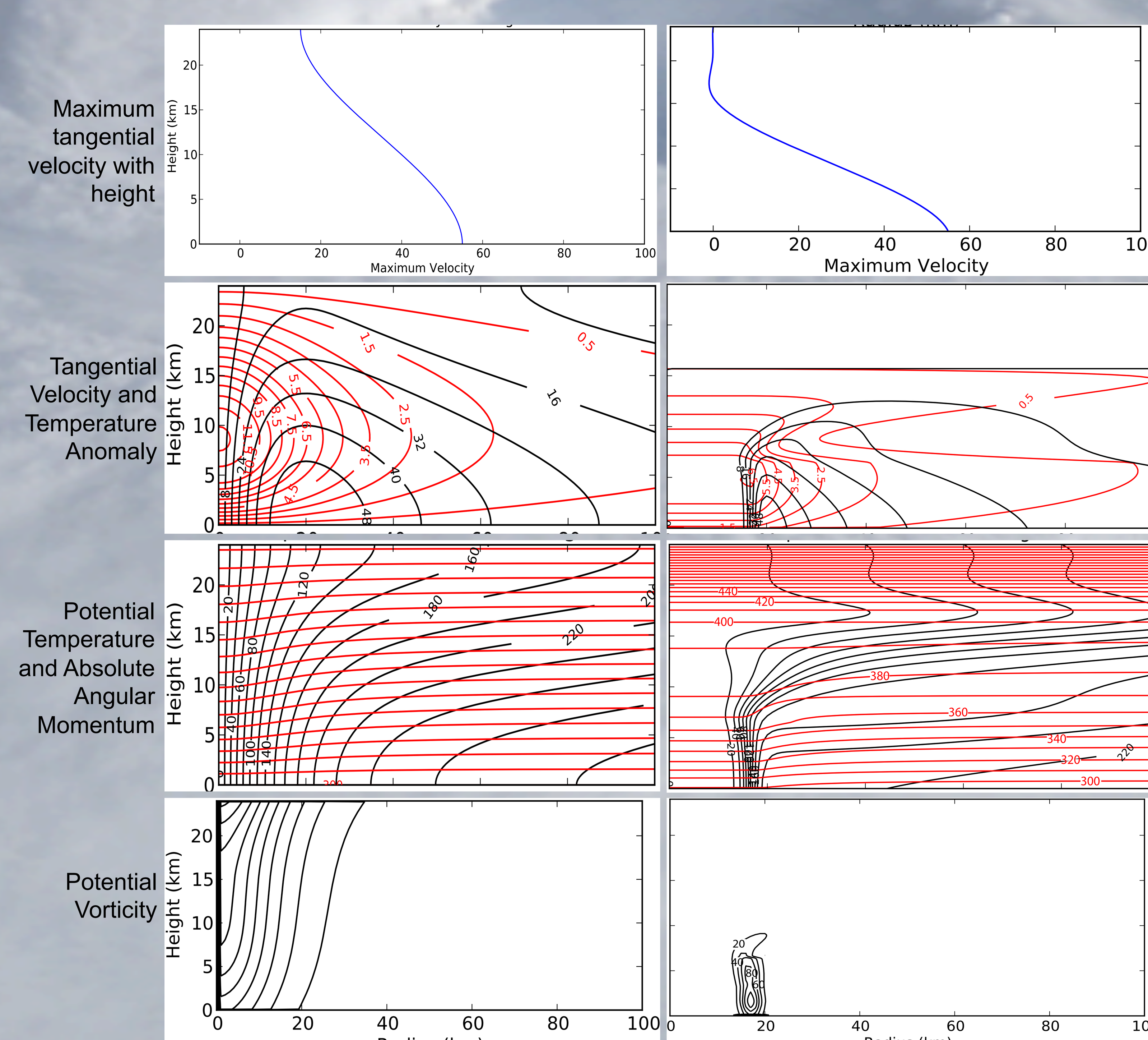
$$P = \left(\frac{1}{\rho_0 \exp\left[\frac{-z}{H}\right]}\right)\left[-\frac{\partial v}{\partial z}\frac{\partial \theta}{\partial r} + \left(f + \frac{\partial (rv)}{r\partial r}\right)\frac{\partial \theta}{\partial z}\right]$$

Beginning with the gradient wind, hydrostatic and thermal wind, we model the structures of the tangential wind, temperature, absolute angular momentum, potential temperature and potential vorticity of an vertically sheared tropical cyclone with an outward tilting radius of maximum wind and a U-shaped wind profile.

Introduction

In general, tropical cyclones have been thought to have a warm-core structure; that is, the largest temperature anomalies occur at the center. It has been observed on more than one occasion however, that large temperature anomalies can occur on the inner edge of the eyewall. This warm-ring structure is observed in the lower troposphere of strong tropical cyclones. The presence of a warm-ring structure has been linked to the existence of a hub-cloud in the center of the eye, cascading pileus in the upper troposphere at the edge of the eye and a clear inner moat in the lower troposphere of the outer edge of the eye, all of which are associated with strong inertial stability in an eye of relatively large radius (Schubert, WH, Rozoff, CM, Vigh, JL, McNoldy, BD, Kossin, JP. 2007).

Results



•On the left, we show a case of the most basic warm-core structure. This plot does not include a varying radius of maximum wind, or a U-shaped wind.

•A plot showing a warm-ring temperature structure is shown on the right. Values from a read-in GATE profile were used to plot the maximum velocites with height, as well as the values for temperature in our theta and temperature anomaly equations (Fulton, S. R. and W. H. Schubert, 1985). Also, the radius of maximum wind is set to begin tilting at 6.5km above the surface and the variable functions of changing U-shaped winds and radius of maximum wind are restricted to 15 km.

Conclusions and Future Work

- By modifying equations and variables in thermal wind balance, a plot showing warm-rings was obtained. It was obtained for a reasonably strong tropical cyclone, indicating that modeling the warm-ring structure is possible, and with reasonable parameters.
- There is much work to be done in refining the model and showing more warm ring plots for different parameters. Once these phenomena can be replicated more regularly within the model, we may begin to speculate more on the implications a warm-ring structure has on a tropical cyclone and what brings them about. There will also be an effort to find more documented examples of a warm-ring structure through flight-data.

Acknowledgements

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