P 1.39 DIAGNOSING TROPICAL CYCLONES AND DEEP CONVECTION USING UPPER TROPOSPHERIC INERTIAL STABILITY AND CLOUD-MOTION WIND VECTORS

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1 MOTIVATION

The purpose of this note (complemented by the accompanying poster) is to introduce derived products which combine geostationary (infrared and water vapor) satellite data and derived "cloud drift" wind vectors (Velden et al. 1998), upper tropospheric potential vorticity (PV), and quantities that diagnose the lateral outflow potential from the anvils of deep convection (Mecikalski and Tripoli 1998; Sui and Yanai 1986). Isentropic levels between 340 and 365 K are analyzed using products designed for the purpose of evaluating the correlations between cloud motion-derived winds, low inertial stability and intensity changes of tropical convection and tropical cyclones.

Low upper-tropospheric inertial stability has been shown to be important for determining the intensity of convective systems (Molinari et al. 1997; Dickinson and Molinari 2000). Convection should grow most readily into regions of lowest inertial (or symmetric) stability (Emanuel 1979). Observational and numerical modeling work by Blanchard et al. (1998) positively correlates regions of weak inertial stability with mesoscale convective complex development over the central US.

In the upper troposphere, surrounding deep convection, low inertial stability would result in a tendency for air parcels, exiting the top of the convective clouds, to spread outward from the updraft (at the parcel's equilibrium level) with relative ease. In contrast, should air parcels exiting deep convection encounter high inertial stability, the rate of horizontal mass transport away from storm top may be significantly limited. Given two deep convective clouds in similar shear and thermodynamic environments, the one extending into the less inertially stable upper troposphere would perform less work on its environment (through forced compensating subsidence) and thus should persist longer and achieve greater intensity compared to the convection encountering high inertial stability aloft.

Although the work of Blanchard et al. (1998) demonstrates that deep convection preferentially forms in conditions of low upper tropospheric (above about 30.0 kPa) PV, an unanswered question is: How self-serving is low PV to enhancing the convection that may generate it? Given that low upper tropospheric PV is a known prerequisite to the development (or invigoration) of deep convection, how does the production and redistribution of this low PV influence the long-term behavior of mesoscale convection? Can "outflow corridors" be established via the perpetual generation of low PV aloft, or must low upper tropospheric PV be present prior to the establishment of such an outflow pathway?

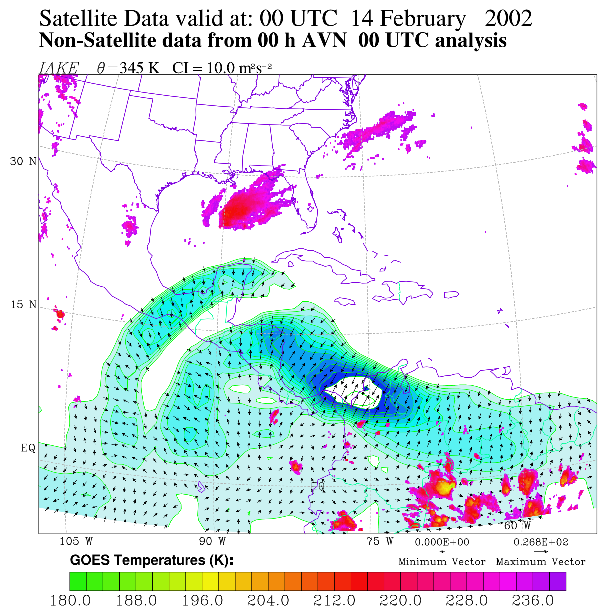

Figure 1: A product that combines enhanced GOES-8 data (shading with accompanying scale on bottom denoting cloud temperatures, K), and IAKE (see below) to show the direction of convective outflow based on the lowest inertial stability on the 345 K isentrope. Date of image is 14 February 2002.

These questions may best be answered by combining the above data sets. In particular, cloud motion vectors can provide information about the inherently un-(geostrophically) balanced flows exiting the anvils of thunderstorms, tropospheric levels that are in fact well

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sampled by cloud motion vectors. By combining the PV-related products, computed from routinely available global analyses, with the cloud drift wind data, realtime diagnostics and short-range (0-6 h) forecasts are provided. Three to twelve hour convection-intensity forecasts can be made using the PV-derived products alone. Diagnostic products are computed for three oceanic basins: the Eastern Pacific, the Western Atlantic and the Eastern Atlantic to the African coast. These products are currently available in realtime via the internet (http://its.ssec.wisc.edu/~johnm/trmm_istc.html), and are being developed in collaboration with the Tropical Cyclone Research Team (headed by C. Velden of CIMSS) to assist forecasters in tropical cyclone and convection prediction.

2 DERIVED CONVECTION-OUTFLOW DIAGNOSTICS

Figure 1 presents one product that shows the location of deep convection (enhanced, colored clouds) and the most favored direction for outflow based on inertial stability along the 345 K isentrope (shaded inertial available kinetic energy, IAKE; Mecikalski and Tripoli 1998). By spring 2002, about a dozen outflow-related products will be available through the CIMSS Tropical Cyclones homepage (as well as through URL above).

The following list describes the general types of the products available through 2002:

- Combined enhanced-satellite (identifying the most active, growing thunderstorms and tropical cyclones), IAKE and cloud drift winds to diagnose low-PV—convective outflow correlations. IAKE is in effect the horizontal (along-line) integration of PV in units of energy (m^2s^{-2});
- Vector differences between measured cloud drift winds and IAKE vectors across isentropic convective outflow layers, used to determined whether convection, in fact, seeks the path of least horizontal resistance for its outflow;
- Combined IAKE, PV and cloud drift winds to determine whether pre-existing low upper-tropospheric PV causes convective enhancements, and the role convectively-generated low upper-tropospheric PV plays in invigorating new or existing convection;
- Products that identify potential outflow corridors with respect to regions of active convection.

Figure 2 shows a product that combines enhanced GOES-8 imagery, contoured IAKE and cloud drift winds. Note the correspondence between active convection (shading) within the intertropical convergence zone, centered on about 8-10° N and positive IAKE (low inertial stability). The correlation between low inertial stability and active convection suggests that the convection in this region is ventilating its anvil-level outflow more easily than otherwise, and will persist longer and reach greater intensity than otherwise.

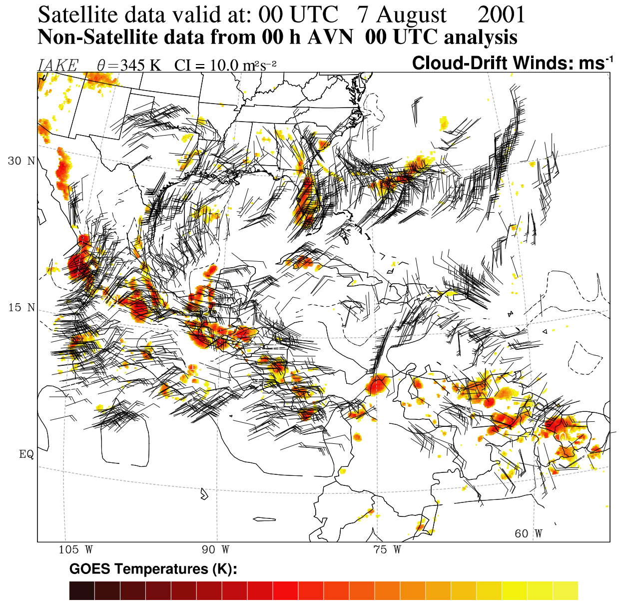

Figure 2: A composite of contoured IAKE (no vectors), enhanced GOES-8 data (shading with accompanying scale on bottom denoting cloud temperatures, K), and GOES-derived cloud motion vectors for 00 UTC 7 August 2001.

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3 BIBLIOGRAPHY

Blanchard, D. O., W. R. Cotton, and J. M. Brown 1998: Mesoscale circulation growth under conditions of weak inertial instability. *Mon. Wea. Rev.*, **126**, 118–140.

Dickinson, M., and J. Molinari, 2000: Climatology of sign reversals of the meridional potential vorticity gradient over Africa and Australia. *Mon. Wea. Rev.*, **128**, 3890–3900.

Emanuel, K. A. 1979: Inertial instability and mesoscale convective systems. Part I: Linear theory of inertial instability in rotating viscous fluids. *J. Atmos. Sci.*, **36**, 2425–2449.

Molinari, J., D. Knight, M. Dickinson, D. Vollaro, and S. Skubis, 1997: Potential vorticity, easterly waves, and Eastern Pacific tropical cyclogensis. *Mon. Wea. Rev.*, **125**, 2699–2708.

Mecikalski, J. R. and G. J. Tripoli 1998: Inertial available kinetic energy and the dynamics of tropical plume formation. *Mon. Wea. Rev.*, **126**, 2200–2216.

Velden, C. S., T. L. Olander, and S. Wanzong, 1998, The impact of multispectral GOES-8 wind information on Atlantic tropical cyclone track forecasts in 1995. Part I: Dataset methodology, description, and case analysis. *Mon. Wea. Rev.*, **126**, 1202–1218.