9C2

BAROCLINIC TROPICAL CYCLOGENESIS: DEVELOPING AND NON-DEVELOPING CASES

Christopher A. Davis
National Center for Atmospheric Research*
Boulder, Colorado

Lance F. Bosart
University at Albany, SUNY
Albany, New York

1. INTRODUCTION

While the conditions favoring tropical cyclogenesis over the tropical Atlantic Ocean are relatively well known (Gray 1968, DeMaria et al. 2001), conditions favoring tropical cyclogenesis at higher latitudes have received relatively less attention. Bracken and Bosart (2000) demonstrated that deep, upward motion exists on the sub-synoptic scale over Western Caribbean intensifying disturbances, consistent with differential vorticity advection with an upper-tropospheric trough-ridge environment in the presence of westerly shear. As remarked in that paper, nontrivial vertical shear is essential to the development of these higher latitude storms (and probably the lower latitude storms as well) because the persistent upward motion that helps organize the convection depends on it. However, there appears to be an upper limit of vertical shear around 15 m s^{-1} between 850 and 200 hPa beyond which development is unlikely (DeMaria et al 2001). Typically, any disturbance growing by baroclinic conversion of available potential energy exists in an environment where the vertical shear exceeds this threshold. How, then, does tropical cyclogenesis occur in such cases?

2. CASE COMPARISON

The case of Hurricane Michael (2000) and a successor, sub-tropical storm (ST) are examined herein to better understand how tropical cyclogenesis might be anticipated. Both storms occurred during October, 2000 and developed in about the same area east of Florida and over similar sea surface temperatures (SSTs), at least in their baroclinic phases. We use the global analyses produced by the National Centers for Environmental Prediction (NCEP) on a $1^o x 1^o$ grid. The storm center in both cases is defined as the maximum relative vorticity at 900 hPa. Centered on the storm, we compute vertical wind shear and thermodynamic profiles averaged over squares of varying sizes. Roughly similar results are obtained from different averaging domains; here we focus on a 10-degree square box and compute the mean vertical shear between 200 hPa and 900 hPa. Figure 1 displays a time series of this, as well as SST beneath the storm center. Michael forms in a lower-shear environment than the ST, although the shear in both cases decreases markedly during the baroclinic phase of the life cycle. Michael also sits over water of greater SST and particularly when the vertical shear is weak than the ST. Furthermore, the weak-shear, high-SST state persists much longer in the case

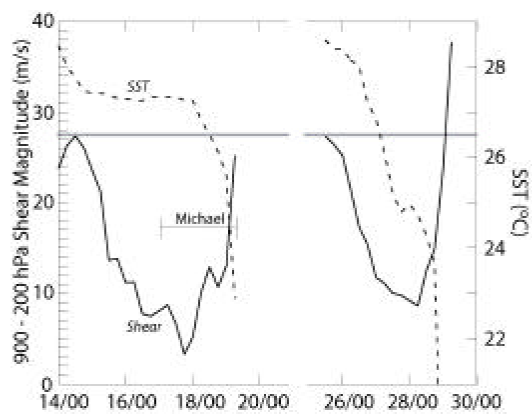

Figure 1. Time series of storm-centered, 900-200 hPa wind shear and SST for the pre-Michael disturbance and Hurricane Michael (left) and the sub-tropical storm (right). The tropical phase of Michael is indicated.

* The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Corresponding author address: Christopher A. Davis, MMM Division, NCAR, P.O. Box 3000, Boulder, CO 80307-3000
Email: *cdavis@ucar.edu*

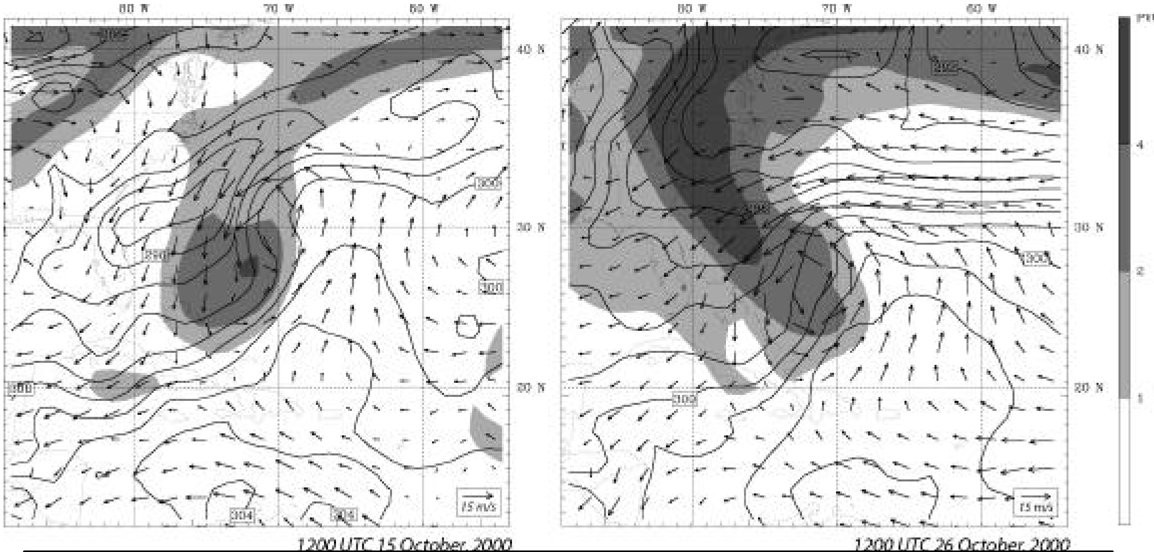

Figure 2. PV on 340 K surface (PVU, shaded), 900 hpa potential temperature (K) and 900 hpa wind vectors (alternate grid points) from AVN analyses prior to Michael (left) and during the ST development (right).

of Michael than for the ST. For the ST, the shear does not weaken until the storm moves over colder water. Lower-tropospheric relative humidity and the strength of the initial, baroclinic disturbance were comparable among the two cases.

As summarized in Fig. 2, the synoptic-scale flow prior to the development of Michael features anticyclonic wave breaking at tropopause level, PV filamentation and the development of a cut-off low in the subtropics. For the ST, the upper-level trough never detaches from the stratospheric reservoir and there is cyclonic wrapping of positive and negative PV anomalies. The distinction in the two cases amounts to the distinction between development in anticyclonic versus cyclonic barotropic shear (LC1 and LC2, respectively, of Thorncroft et al. 1993; see also Wernli et al. 1998).

3. SYNTHESIS

We note that Hurricane Diana (1984) developed in a manner similar to Michael, in that a trough fracture, or LC1-type evolution of the synoptic-scale, led to a cut-off low in the upper troposphere that initiated weak development along a baroclinic zone (Bosart and Bartlo 1991). In both cases the cut-off low was eroded by diabatic heating and redistribution of PV. This, coupled with the motion of the lower-tropospheric vorticity center underneath the decaying upper low, decreased the deep-layer shear. In the ST case, the differing upper-level evolution resulted in a PV anomaly connected to the stratospheric reservoir. It was therefore more difficult for diabatic heating to erode the upper trough and therefore and the vertical shear was maintained longer.

Further research, to be reported at the conference, will utilize numerical simulations to demonstrate differences in the organization of deep convection between the two cases. These simulations will show how deep convection forms near the center of the pre-Michael disturbance and leads to a warm-core vortex, and why convection remains displaced from the center in the ST case.

References

Bosart, L. F., and J. Bartlo, 1991: *Mon. Wea. Rev.*, **119**., 1979–2013.

Bracken, E., and L. F. Bosart, 2000: *Mon. Wea. Rev.*, **128**, 353–376.

DeMaria, M., J. A. Knaff, and B. H. Conell, 2001: *Wea. and Forecasting*, **16**, 219-233.

Gray, W. M., 1968: *Mon. Wea. Rev.*, **96**, 669-700.

Thorncroft, C. D., B. J. Hoskins, and M. E. McIntyre, 1993: *Quart. J. Roy. Meteor. Soc.*, **119**, 17–56.

Wernli, H., R. Felhmann, and D. Luthi, 1998: *J. Atmos. Sci.*, **55**, 2080-2094.