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 ones 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°x1° 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.
of Michael than for the ST. For the ST, the motion of the lower-tropospheric vorticity center
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 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