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TROPICAL AND EXTRATROPICAL TRANSITIONS AND PRECIPITATION WITH LANDFALLING HURRICANES

by

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1. OVERVIEW:

The tropical eastern Atlantic is a common breeding ground for classical Cape Verde hurricanes that originate from westward-moving African disturbances. Over the western Atlantic hurricane development is less classical and generally occurs poleward of 20°N. Many of the western Atlantic storms originate from remnant higher latitude cold-core upper-level baroclinic disturbances that penetrate equatorward into the subtropics. These baroclinic disturbances reach equatorward into the subtropics in the form of long potential vorticity (PV) tails that typically are oriented northeast-southwest. If ascent associated with these upper-level baroclinic disturbances can trigger organized deep convection over sufficiently warm seas surface temperatures the associated initial low-level cold-core disturbance can often transition into a warm-core hurricane by the tropical transition (TT) process (Davis and Bosart 2004), examples of which include Diana (1984), Michael (2000), Alex (2004) and Catarina (2004). An important operational aspect of hurricanes that form by the TT process is that their development and subsequent intensification is often poorly forecast by operational weather prediction models.

The baroclinic disturbance that became Diana (1984), an eventual Category 3 storm, formed along an old frontal boundary east of Florida. The initial development occurred ahead of an upstream PV anomaly over Florida that had fractured from the main PV reservoir to the north (Bosart and Bartlo 1991). Numerical simulations of the TT of Diana (1984) showed that the storm became warm-core storm in conjunction with the axisymmetrization and amalgamation of multiple convectively driven PV anomalies (Davis and Bosart 2001, 2002). Michael (2000) formed from a baroclinic disturbance to the southwest of Bermuda ahead of an upper-level PV anomaly, underwent TT and became a Category 3 storm, and the experienced an extratropical transition (ET) with devastating effect on Newfoundland (e.g., Davis and Bosart 2003; Abraham et al. 2004). Alex (2004) developed in a sheared environment northeast of the Bahamas as a westward-moving low-level disturbance interacted with two upper-level PV anomalies of midlatitude origin. Subsequent to the ensuing TT, Alex intensified over the Gulf Stream east of the Carolinas, brushed the Outer Banks with 40-45 m s^{-1} winds, and became a category 3 storm over the open waters of the Atlantic Ocean (Bosart et al. 2005). Alex was noteworthy for intensifying rapidly and unexpectedly within 100 km of the coast of North Carolina, a source of concern for forecasters and emergency managers alike.

Catarina (2004), the first-ever documented hurricane in the South Atlantic Ocean, also formed by the TT process (Levison et al. 2005; McTaggart-Cowan et al. 2005). A unique aspect of the Catarina development was that it formed in conjunction with a persistent Rex block (anticyclone poleward of a cyclone; Rex 1950a,b) just east of South America. Cyclogenesis was triggered by ordinary baroclinic cyclogenesis in conjunction with the cyclonic member of the Rex block. The baroclinic cyclone initially moved southeastward, stalled and then turned westward toward Brazil where it made landfall as a high Category 1 or low Category 2 storm. The combination of the Rex block and diabatically generated outflow from the storm resulted in

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enhanced upper-level ridging, a reduced shear environment and the development of an easterly steering current which caused Catarina to stall and then turn westward toward Brazil.

The opposite process, extratropical transition (ET), involves the transition of a warm-core hurricane into a cold-core disturbance (e.g., Harr et al. 2000; Harr and Elsberry 2000; Jones et al. 2003; Klein et al. 2000, 2002; Ritchie and Elsberry 2001, 2003). Notable Atlantic ET examples include Hazel (1954), Agnes (1972), Felix (1995), Iris (1995), Lili (1996), Earl (1998), Floyd (1999), and Irene (1999). Details on these ET storms can be found in Palmen (1958), DiMego and Bosart (1982a,b), Bosart and Dean (1991), Thorncroft and Jones (2000), Atallah and Bosart (2003, Colle (2003), Ma et al. (2003), Evans and Prater-Mayes (2004), McTaggart-Cowan et al. (2003, 2004), and Augusti-Panareda et al. (2005). In the Atlantic basin 40-50% of hurricanes recurving into higher latitudes experience some form of ET (Hart and Evans 2001). Methodology introduced by Hart (2003) and Evans and Hart (2003) has been very effective in helping to quantify the ET process.

ET storms, as well as non-transitioning (NT) storms, that make landfall or near landfall are frequently associated with significant mesoscale precipitation events that can lead to major inland flooding (e.g., Floyd 1999) or severe weather outbreaks (e.g., Frances 2004 or Ivan 2004). Distinguishing between ET and NT storms is important because of the capacity of the formewr category of storms to wreak havoc in populated areas. Work by Atallah and Bosart (2003) and Evans and Hart (2003) has established that the structure, size and orientation of midlatitudes troughs play an important role in determining whether an ET will occur. A separate question is, given an ET, will the storm reintensify significantly as an extratropical cyclone or gradually weaken and dissipate. The nature of the interaction and coupling between the upper-level PV anomalies and the transitioning cyclone is crucial in determining whether the ET process will be associated with significant storm reintensification (e.g., Thorncroft and Jones 2000).

In this presentation, TT and ET processes will be reviewed with an emphasis on important mesoscale signatures seen in both developments. During a TT, mesoscale deep convection acts to redistribute potential vorticity (PV) so that the PV associated with the triggering baroclinic disturbance is eroded with consequent reduction in the deep layer shear over the transitioning cyclone (Davis and Bosart 2004). Vortical convective hot towers appear to lead to low-level vorticity concentration and amalgamation during the TT process (Hendricks et al. 2004). During an ET, increasing baroclinicity and shear lead to a disruption of the quasi-symmetric hurricane circulation with the resulting shift of the precipitation shield to the left of the storm track as thermal advection develops. Mesoscale frontal circulations may develop with the resulting concentration of precipitation into banded structures with embedded convective elements (e.g., Atallah and Bosart 2003; Colle 2003). Orographic features may add further complexity to the mesoscale precipitation signature during an ET (e.g., Bosart and Dean 1991).

Examples of TT and ET will be shown to illustrate the characteristic behavior of Atlantic storms undergoing these processes. In the ET examples, where data is available over land, emphasis will be placed on documenting the observed mesoscale precipitation structure and explaining its distribution within the context of the evolving synoptic-scale circulation pattern. An example of a landfalling NT storm that produced a severe weather outbreak (Frances 2004) will be presented to contrast with ET events. Finally, mention will be made of a possible western Atlantic TT and genesis experiment (WATTAGE) to acquire critical mesoscale observations to quantify thermodynamic and dynamic processes critical to the TT problem. The conference presentation will be posted at:

http://www.atmos.albany.edu/student/tomjr/lb1link/abq_tt_et.html.

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