12D.4 EXTRATROPICAL TRANSITION OF HURRICANES MICHAEL AND KAREN: STORM RECONNAISSANCE WITH THE CANADIAN CONVAIR 580 AIRCRAFT

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1. INTRODUCTION

Extratropical transition (ET) has been raised as a forecast challenge by meteorologists from all ocean basins affected by tropical cyclones, where the poleward movement of a tropical cyclone (TC) into the midlatitudes is normally associated with the weakening or decaying stage of its lifecycle. Typical problems in all these regions that experience ET include accurately predicting their track, intensity, and impacts. The most challenging issues are associated with the potential large amounts of precipitation, continued high wind speeds, and the generation of large ocean surface waves and swell. Furthermore, the forward speed of these storms often accelerates from a typical 5 m/s in the tropics to in excess of 25 m/s in the midlatitudes.

Given the ET forecast challenge to Canada, the Meteorological Research Branch and the Canadian Hurricane Centre of the Meteorological Service of Canada (MSC) agreed to consider a modest ET field study. One aspect of this program would be the use of the National Research Council's (NRC) Convair 580 to conduct meteorological and microphysical investigations of ETs passing offshore Atlantic Canada. During the period 17-20 October 2000, Hurricane Michael provided this opportunity, and a flight was conducted on the afternoon of the 19th. A follow-up flight was conducted nearly one year later on 15 October 2001 into Tropical Storm Karen.

2. SYNOPTIC HISTORY OF HURRICANE MICHAEL

On the morning of 17 October 2000, tropical storm Michael evolved from a subtropical type weather system to the southwest of Bermuda. Michael subsequently reached hurricane strength by late afternoon on 17 October. After remaining quasi-stationary for several days, Michael began to accelerate northeastward early on 19 October. At this point Michael's forward speed was near 17 m/s, into the region ahead of a negatively tilted trough over the U.S. Northeast.

During the afternoon of 19 October, a remarkable interaction occurring between the trough and Michael resulted in explosive deepening off the coast of Nova Scotia. It is estimated that the deepening was equivalent to a rate of 14 hPa in the six hours between 1200 UTC and 1800 UTC 19 October. A ship (call sign 3EHR6) located just east of the center at 1700 UTC reported a sea level pressure of 965.5 hPa and a sustained southerly wind of 41 m/s. At the time, Michael was racing northeastward near 30 m/s.

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As the storm tracked towards the south coast of Newfoundland, frontal structures became apparent. A frontal wave to the northwest—a legacy of a baroclinic low off Nova Scotia—was maintaining heavy convection, while a warm occlusion process appeared to be forming in the vicinity of the hurricane. A cold front with significant convection extended southward and an apparent occluded front extended eastward. This "hybrid" storm reached the south coast of Newfoundland just west of Harbour Breton around 8:00 pm local time (2230 UTC).

3. SYNOPTIC HISTORY OF HURRICANE KAREN

Like Michael, Karen was born from a subtropical disturbance that formed near Bermuda on 10 and 11 October 2001. Karen reached hurricane status late on 13 October then moved erratically northward during the next 36 hours. By the afternoon of 14 October, Karen's winds dropped to tropical storm force when it moved over cooler waters. By that time Karen acquired a steady north-northwestward heading, putting it on a beeline toward southern Nova Scotia. The center reached the coast at 1115 UTC 15 October at Western Head, Nova Scotia. Maximum sustained winds at the time were estimated to be near 22 m/s, mainly over water. Karen moved north-northeastward into the Gulf of St. Lawrence later that day while merging with a cold front approaching from Quebec.

4. CONVAIR 580 RESEARCH FLIGHTS

The Convair 580 (CV580) aircraft has been highly instrumented for storm research, especially cloud microphysics. It is equipped with a 4-channel NCAR GPS dropsonde system, a 35 GHz radar (fixed up and down antennae providing simultaneous up and down cross-sections), up to 10 locations for cloud particle measurement probes, 4 hot-wire liquid and total water content probes, a SPEC cloud particle imager, and a wind/gust measurement system. The flight duration is typically 4.5 to 5 hours. A team of MSC and NRC meteorologists and researchers participated in the reconnaissance flights into Hurricane Michael and Tropical Storm Karen.

The CV580's inaugural ET flight was into Hurricane Michael on 19 October 2000. The purpose of this flight was two-fold: to collect meteorological data from a rapidly transitioning TC and to determine the suitability of the CV580 for ET hurricane missions. A summary of performance related issues for this flight are discussed by Wolde et al. (2001).

After departing from Greenwood, Nova Scotia at 1521 UTC, the aircraft climbed to an altitude of 7000 m and headed toward the southeast. After updating the storm's position, the flight track was adjusted to the east (at 1635 UTC) in order to intercept the hurricane center.

The flight path came to within approximately 40 km of Michael's surface center at an altitude of 6500 m, which was maintained throughout the observation period. Between 1645 UTC and 1740 UTC the CV580 sampled the storm's eastern quadrant and in the westbound leg (after 1745 UTC), sampled mainly the southwest sector of the storm.

In the case of Tropical Storm Karen, the CV580 left Halifax international airport before sunrise (just after 7:00 am local time), initially heading southwest toward the Atlantic Ocean. Once over the water it paralleled the south coast of Nova Scotia, intersecting the storm center very near landfall at a flight level near 6500m. Several dropsondes were deployed along this leg while radar and cloud microphysical properties were continuously being monitored. The crew then flew eastward to a position approximately 200 km south of the storm center before heading due north along a line back toward the center, which was by this time over land. Some moderate icing (but little turbulence) was experienced while over mainland Nova Scotia around 6000 m. The final dropsonde was over the Bay of Fundy, in the northwestern part of the storm. From there the CV580 headed south again, collecting cloud microphysical data while spiraling down to 1200 m.

Around 1330 UTC, the crew began heading back to Halifax above what was mostly low-level cloud southeast of the center. The pilot was challenged by strong low-level wind shear at a time when the airport was receiving the strongest winds from Karen, and was forced to abort the landing. The crew was then diverted to an alternate airport in Quebec City (650 km away), ending the four and-a-half-hour flight.

5. METEOROLOGICAL OBSERVATIONS

An abundance of very unique meteorological data (including cloud microphysical) was collected during the two flights - more than can be summarized in this article. Large amounts of moisture, indicative of the tropical nature of these storms, were measured by the CV580. In a broad area of stratiform precipitation west of the storm center of Michael, very high concentrations of small ice particles were observed; amounts similar to those measured in previous studies into cumulonimbus anvil clouds over land.

Of particular interest were the wind measurements observed by the dropsondes. The most remarkable example is the one released less than 100 km east of Michael's center (Figure 1), which showed a deep layer of maximum winds up to 72 m/s, between 500 and 2500 m.

In the case of Karen, which was just beginning to interact with the mid-latitude baroclinic zone, low-level jets were observed on both the west and east sides of the storm. Figure 2 displays a cross section comprised from 10 dropsondes through the center of Karen. To the east of the center a low level jet of 27 m/s near 500 m is where one would expect it to be in a TC (Franklin et al., 2000). However, to the west of the center, the jet occurs at approximately 1600 m (assuming this is the same feature). In addition, a weaker marine boundary layer jet appears near 100 m on the western side.

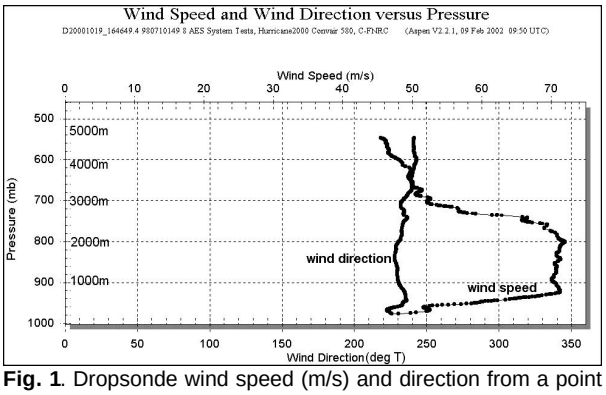

Fig. 1. Dropsonde wind speed (m/s) and direction from a point less than 100 km east of the center of Michael.

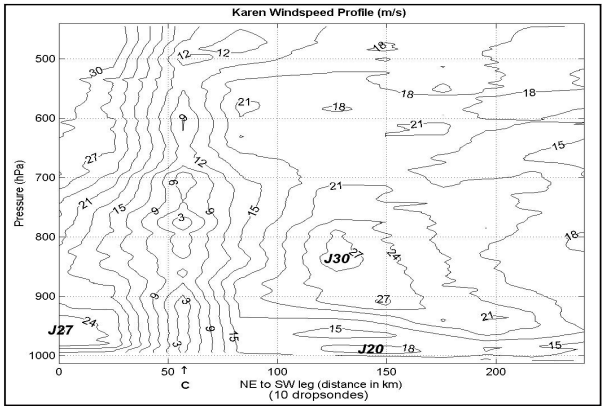

Fig. 2. Profile of winds (m/s) derived from 10 dropsondes through "Karen". Contours every 3 m/s; "C" denotes the storm center; "J" denotes a jet with the magnitude labeled.

6. CONCLUSIONS

In this paper, we provide a brief overview of the details of research flights into two distinct tropical cyclones undergoing extratropical transition near Nova Scotia. This preliminary data set shows substantial asymmetries in moisture and winds associated with these ET systems. Their capacity to maintain large moisture contents while interacting with midlatitude baroclinicity poses a threat of intense rainfall while their rapid translational speeds can create very high winds east of their tracks, endangering the lives of mariners.

Further analyses of this data, including comparisons with model simulations and inclusion of additional oceanographic data are planned. These results are also being used to justify a collaborative atmospheric-oceanographic ET field experiment being considered in the 2003 hurricane season.

7. REFERENCES

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