12D.1 OPERATIONAL FORECASTING OF EXTRATROPICAL TRANSITION

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1. INTRODUCTION

Every year during the late summer and autumn months, operational weather forecasters in eastern Canada are faced with the unique challenge of forecasting tropical storms undergoing extratropical transition (ET). A recent climatological study by Hart and Evans (2001) on ET in the Atlantic Basin shows a maximum frequency of their occurrence over the provinces of Nova Scotia and Newfoundland. In recent years, Canadian forecasters have been focussing more attention on these systems and ways to improve the forecasting of track and intensity changes. Examples of such efforts include the formation of the Canadian Hurricane Centre (CHC) in 1986 and the gathering of data from reconnaissance flights operated by Canada's Convair 580 research aircraft. This paper summarizes useful forecasting techniques based on the above work and other research.

2. IDENTIFYING PATTERNS

Given the lack of data over the ocean and shortcomings of numerical models in forecasting ET, the forecaster will benefit from knowledge of how the transition can be expected to evolve in various mid-latitude flow patterns. This may come from composite analyses, case studies or from a collection of individual storms readily available for reference.

Tropical cyclones (TC) moving into a large-scale ridging pattern (Fig. 1a) often dissipate over land or colder SSTs. If the TC moves into a zonally oriented baroclinic flow (Fig. 1b - similar to the Harr and Elsberry (2001) "northeast" pattern) the pressure center often deepens by 5 to 10 hPa after transition while tapping some energy from the mid-latitude temperature gradient.

Storms that recurve often do so in response to long-wave or short-wave troughs (Fig. 1c) approaching from the west. Long-wave patterns are often benign as far as ET is concerned because of broad scale northeasterly shear, but short waves can move in phase with the TC, resulting in significant intensification either before, during or after transition. These cases fit the "northwest" circulation pattern described by Harr and Elsberry (2001) where the short wave is described as a tongue of upper level potential vorticity to the northwest of the TC.

3. FORECASTING TRACK AND INTENSITY CHANGE

A basic approach to forecasting track and qualitative intensity change involves using 500-hPa height and vorticity prognostic charts. The forecaster first diagnoses the large-scale environment into which the TC is moving to determine which type of transition (if any) will occur: (a) dissipation without transition (b) transition to a weakening or moderately re-intensifying extratropical low or (c) transition to a strong re-intensifying extratropical low. The key is to track the motion of height and vorticity troughs on the 500-hPa charts, determine whether any troughs are likely to interact with the TC, and then advect the storm within the 500-hPa flow. The forecaster will determine when the TC encounters the mid-latitude stream by extrapolatiing the short-term motion of the storm.

It has been observed that storms tend to move at 75% (50%) of the 500-hPa geostrophic wind during the initial (latter) stage of transition. They typically move in line with the 500-hPa flow in the absence of significant deepening. This is often the case when the TC merges with a long-wave trough or zonal flow. On the other hand, if the TC merges with a digging short-wave trough, it will likely undergo significant deepening and move with a component toward lower heights at a typical angle of 20 to 30°. The onset of deepening usually occurs when the storm moves to within 5 degrees of latitude of the trough axis. Use of these techniques can significantly improve forecast results and can also be used as a check against numerical model forecasts.

4. RAINFALL, WIND AND WAVE FORECASTING

It is well understood that heavy rainfall is normally concentrated along quasi-stationary frontal zones well ahead of the transitioning storm and within 300 km to the left of the storm track (northern semicircle) in the "delta" rain region described by Klein et al. (2001). Conversely, rainfalls are frequently much less over areas right of the track owing to the intrusion of dry air wrapping around the southern part of the storm. In addition, meteorologists need to be aware of the potential for extreme precipitation resulting in flash floods caused by upslope flow in the vicinity of mountainous regions.

During ET, wind radii expand and maximum winds become displaced to the right of the storm track where they are typically twice as strong as winds experienced left-of-track. One may have to reduce the winds in the forecast to account for decoupling over the colder marine boundary layer. The degree to which decoupling occurs above the boundary layer is being investigated using dropsonde data from reconnaissance missions such as the Canadian Convair flights into Tropical Storm

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Karen in October 2001 and Hurricane Michael in October 2000.

Strong winds to the right of track blowing in the same direction as the storm motion can create very high seas where resonant wave growth occurs in "trapped-fetch" scenarios (MacAfee and Bowyer, 2000). As the storm accelerates and the wind field expands, the wave maximum becomes displaced further and further to the right. The wave maximum typically lags the passage of the storm by about 2 or 3 hours.

5. CLOUD STRUCTURE AND ASSOCIATED WEATHER

The appearance of the cloud shield of an ET cyclone varies considerably from case to case and on the stage of transition, but there are characteristics similar to most storms evident in satellite imagery. These features include loss of convection in the southern semicircle of the storm and an elongation of the cloud shield in the downshear direction (e.g. northeast). A strong warm frontal region often forms ahead of the storm or in the downshear region with a (usually weaker) cold frontal feature extending south of the low. A schematic of these features and associated weather at "mid-transition" are summarized in Figure 2.

6. REFERENCES

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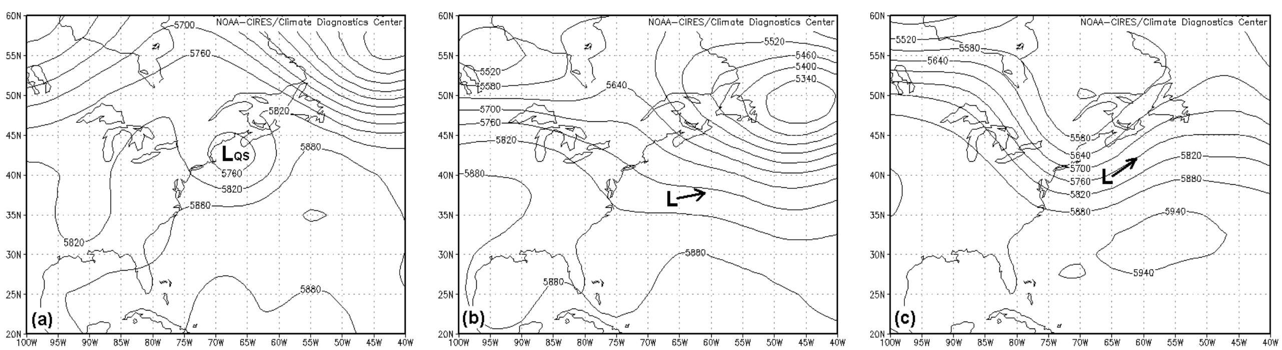

Fig. 1. Typical 500-hPa flow patterns for ETs in the northwest Atlantic: (a) ridging environment (Edouard 1996), (b) zonal baroclinic flow (Arthur 1996) and (c) short-wave trough / re-intensification (Earl 1998). Contour interval 60 m; surface low center denoted by "L" and storm motion by arrow.

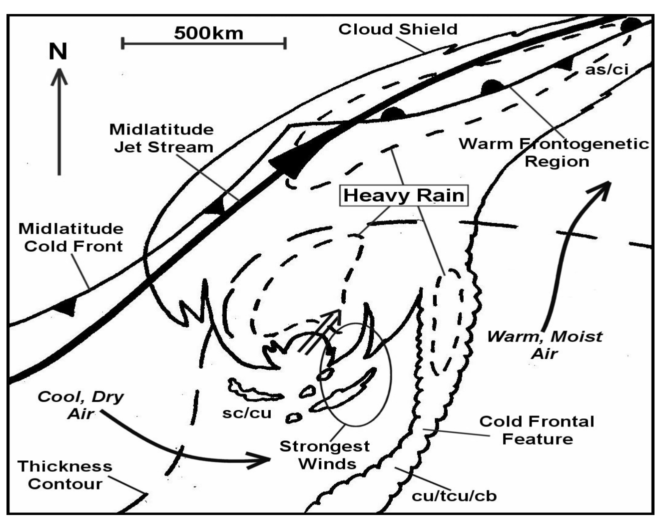

Fig. 2. Schematic of a weakening TC in "mid-transition" with associated weather and frontal features. Large figure available at http://www.geocities.com/novaweather/ET_schematic.html