17D.1 THE IMPACT OF EXTRATROPICAL TRANSITION ON HURRICANE RISK IN THE NORTHEAST US

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1. INTRODUCTION

There has been debate as to the constraints on the minimum pressure of tropical cyclones (TCs) (e.g. Bister and Emanuel, 1998) when modeling the risk from extreme hurricanes in the Northeast US. However, it has always been intriguing that the most intense hurricane to have impacted the region in the 20th Century, the New England Sept 21st 1938 hurricane, had a frontal structure at landfall and was itself the first TC recognized as undergoing extratropical transition (ET). It is now clear that this was not fortuitous and that there is an intrinsic connection between the severity of a storm in the Northeast and the probability that it is undergoing ET. This connection has implications for all assessments of hurricane risk in this region.

2. EXTRATROPICAL TRANSITION

The work of Hart and Evans (2001), Darr (2002), and Hart and Evans (2003) to identify the status of all Atlantic hurricanes since 1979 has provided the basis for determining the probabilities and geographical variability in the ET of Atlantic hurricanes. Overall, slightly more than 40% of all tropical cyclones in this basin undergo ET, which typically takes 18-48 hrs to be completed.

The proportion of tropical cyclones in which ET has been initiated increases away from the tropics, being absent in southern Florida, while affecting about 15% of all hurricanes around the Gulf coast. In passing to higher latitudes along the Atlantic coast this proportion is around 25% in South Carolina, rising to 75% in southern New England. Probabilities rise for hurricanes that occur later in the season, when the majority of hurricanes making landfall in the Gulf in November are likely to have initiated ET.

ET is found to be driven by proximity to the weather systems associated with the midlatitude jet stream. From the analysis of track data, a strong relationship is found between forward speed (and acceleration) with the initiation of ET. This relationship runs across all central pressure ranges, latitudes and regions. A storm moving at 20mph has a 20% chance of having initiated ET, while for a storm of 40mph forward speed this has risen to 75% and at 60mph is close to 95%. In fact, once a storm is moving at 40mph, ET has either started, or begins within the following twelve hours.

3. INTENSE HURRICANES IN THE NORTHEAST US

North of Cape Hatteras, SSTs are always insufficient to sustain a tropical cyclone (TC) circulation. Hence, for a TC to make landfall along the southern coast of Long Island and New England (the LINE coast) it has to have arrived from far to the south, where SSTs are above the critical 27°C threshold. Once other factors such as outflow temperature are taken into consideration (Bister and Emanuel, 1998), a general relationship can be established linking SSTs with minimum TC pressures. For a central pressure of 920hPa (i.e. the pressure threshold of a Cat 5 Hurricane) the minimum sustaining SST is at least 28°C.

September is the warmest month for SSTs along the Atlantic margin. The shortest distance between the LINE coast and the northernmost edge of the September 27°C isotherm is about 600km while the 28°C isotherm is about 900km away. The 29°C isotherm, where a 900hPA TC could be sustained, is about 1200km to the south of the LINE coast.

For any TC with a central pressure deeper than the SST over which it is travelling, the storm will fill and weaken. This filling rate accelerates where the SSTs fall below 27°C, to the north of Cape Hatteras. On average, the longer it takes the TC to travel north, the more it will have filled prior to landfall. To get an intense TC making landfall on the LINE coast, it therefore has to have moved very rapidly. In considering maximum forward speeds, distance travelled and filling rates, based on this analysis, it can be shown that it is not possible to get a CAT 5 central pressure TC to landfall at the LINE coast.

More generally, however, the deeper the storm at landfall the faster it has to have travelled to sustain its deep central pressure. However, as already discussed, the faster the storm moves the more likely it is to have

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started to undergo ET. In consequence, ET and the depth of the central pressure at landfall in the Northeast are strongly correlated.

Mean and Standard Deviation hourly filling rates have been derived from the full population of historical hurricanes, moving through this region (sampled and smoothed over a 2x2 degree grid), and these have been employed in a stochastic hurricane track and pressure simulation model, that includes the linkage between the probabilities of initiating ET and forward speeds. Results from this model indicate that the probability that a storm has begun transitioning prior to landfall in the Northeast is greater than 90% for a Cat 4 central pressure, and more than 70% for the Cat 3 range of central pressures.

4. HISTORICAL HURRICANES IN THE NORTHEAST US

A principal test of these conclusions comes from reviewing the ET status of all the major hurricanes to have made landfall along the LINE coast. The Sept 21st 1938 Hurricane, (deep Cat 3: 946hPa central pressure, and a forward speed approaching 60mph) was well advanced through ET at landfall in Long Island. The 1938 ‘Hurricane’ highlights the characteristics of a well advanced ET windfield, with all inland damage located over a broad region to the right hand (east) side of the track, the axis of which tended to diverge from the low pressure track of the storm as it moved inland. Overall the windfield has more in common with that of an intense ETC storm, such as Dec 26th 1999 Windstorm Lothar in France than that of a classic intense TC windfield.

Before 1938, the previous deep Cat 3 hurricane to make landfall on the LINE coast was that of Sept 23rd 1815. Re-examination and interpretation of all the original accounts of this storm, show that it was similar, if a little weaker, to that of 1938, with a similarly advanced ET windfield in which all the inland damage was located to the east of the track of the storm (as reconstructed from the hourly wind direction observations), along with a forward speed of around 50mph. The only other deep Cat 3 intensity storm, that of September 8th 1869, also had clear ET windfield characteristics.

During the 20th Century other hurricanes that made landfall on the LINE coast as weak Cat 3 or deep Cat 2 storms, including the Great Atlantic Hurricane of 1944, 1954 Carol, 1960 Donna and 1985 Gloria had initiated ET at or prior to landfall on the LINE coast. Only 1991 Bob maintained a TC circulation after landfall, although it began ET soon after exiting east Massachusetts. The historical record confirms that the large majority of intense storms on the LINE coast have initiated ET at landfall.

5. IMPLICATIONS FOR HURRICANE RISK

The recognition that the most intense storms of hurricane origin to affect the Northeast are most unlikely to have hurricane windfields, has major significance for consideration of all forms of hurricane risk in the Northeast US. The windfields of ET storms differ from those of TCs in two principal ways. First the maximum windspeeds of ET storms are reduced on average 20-30%, relative to Hurricanes. Second, for fast moving storms and once ET is underway for a few hours, the damaging windfields tend to be broader distributed mostly to the right of the track.

The implications of employing ET rather than TC windfields for the large majority of the deepest storms in a probabilistic risk analysis model, means that risk tends to be reduced at the western end of the LINE coast, as around New York City, while remaining more consistent with (or even a little higher than) a TC windfield model out to the east around SE Massachusetts. This means that design windspeeds and storm surge heights previously developed for New York City using TC windfield models are likely to be overestimated, given that the city will be on the left hand side of ET storm tracks making landfall on the LINE coast. This deficit is not compensated by rarer TC or ET tracks making landfall on the New Jersey coast, as these will have become weakened overland before the peak windspeeds, out to the right of the track, affect the city. For catastrophe loss modeling of hurricanes for the insurance industry, the broader but weaker ET windfields, tend overall to reduce losses by on average 30-40% relative to TC windfields, although this result can be very sensitive to the geographic disposition of the exposure relative to the track of the storm. Also, for modeling the damage to electricity transmission and distribution systems, the broader windfields of ET storms may cause more damage and disruption than when modeled by TC windfields.

6. REFERENCES

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