Hurricane Force Winds in Extratropical Cyclones: a Modeling and Observational Study

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Introduction

• Earlier wind observations were primarily from the sparse network of volunteer observing ships. Based on NASA QuikSCAT data, we know that extreme winds occur in the rapid deepening to mature phase of the life cycle, typically, on the cold side of the bent back portion of the occluded front.
• Because of the rapid intensification, the development of dangerous conditions, and inability of global numerical models to accurately predict the timing, structure and intensity of these storms, it is necessary to better understand the evolution of these storms and diagnose the causes of extreme winds.
• A NOAA WP-3D N43RF flew within the storm from 1605-1851 UTC on February 1 during rapid intensification and sampled hurricane force winds via the Stepped Frequency Microwave Radiometer (SFMR) and GPS dropsondes.

Methods

• The Weather Research and Forecast Environmental Modeling System (WRF EMS) version 3.1 was used to model the evolution of the cyclone.
• Model ran for 48 hours from 12 Z 1/31/2011 to 12 Z 2/2/2011.
• NCEP Global Forecast System (GFS) model data at every three hours and one degree resolution was used for input.
• Output from the WRF EMS was hourly at 12 km resolution.

Results

• WRF model output successfully generates hurricane force winds.
• Evidence of bent-back front formation begins around 0400 Z 2/1/2011.
• Hurricane force winds observed three different times throughout the life cycle of the cyclone at:
  • 1000 Z 2/1/2011 – 1600 Z 2/1/2011 on the cold side of the bent-back but downstream of warm frontogensis within the "inverted-T" region.
  • 1800 Z 2/1/2011 – 0000 Z 2/2/2011 after the bent-back front re-intensifies.
  • 1100 Z 2/2/2011 – 1200 Z 2/2/2011 as an extension of the Greenland tip jet.
• Satellite evidence shows the bent-back comma region strengthen and weaken three separate times.
• Based on ASCAT readings, the model's wind features are displaced north and west of actual observations.

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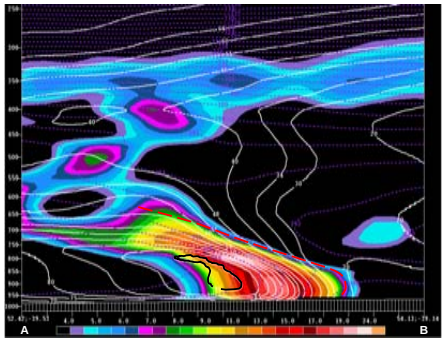
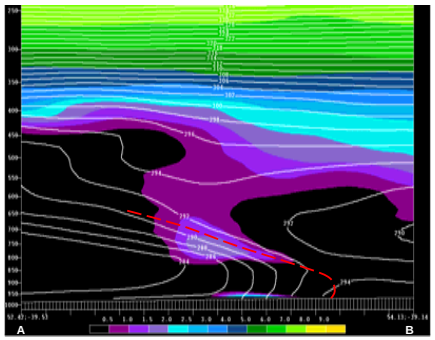
Case Study: February 1, 2011 North Atlantic Storm

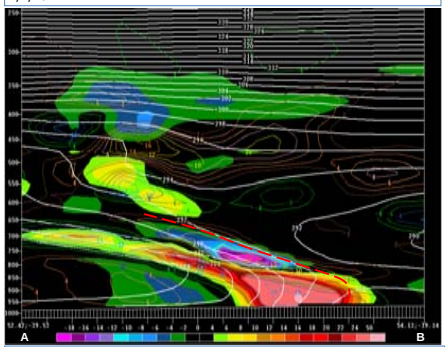
• The storm started as a 1007 hPa low at 1200 Z on January 31, 2011.
• It rapidly deepened to 966 hPa at 1200 Z on February 1, 2011, a 41 hPa drop in 24 hours.
• 70.7% of the deepening that occurred during the storm happened in the first 24 hours.



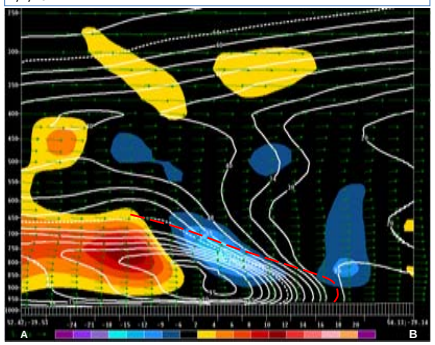
Cross section showing theta-E gradient (shaded) and isotachs (kts) at 12 Z 2/1/2011.



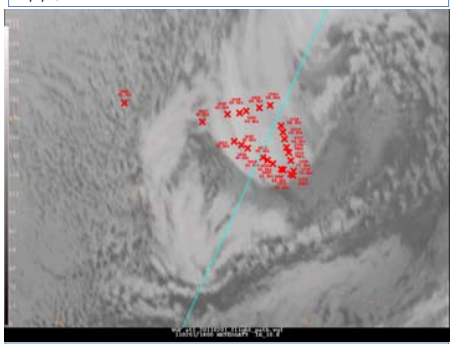
Cross section showing potential vorticity and theta-E contours at 12 Z 2/1/2011.



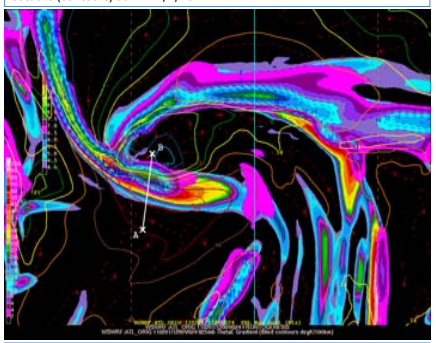
Cross section showing frontogenesis (shaded) and divergence (contours) at 12 Z 2/1/2011.



Cross section showing omega (shaded), wind circulation (arrows) and isotachs (contours) at 12 Z 2/1/2011.

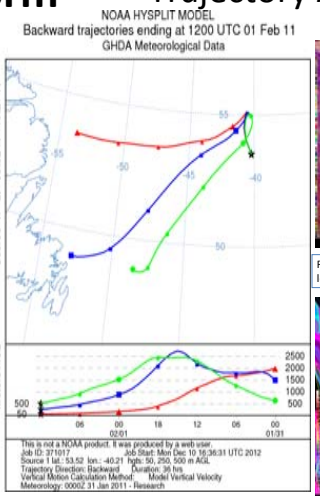


The flight path of the NOAA WP-3D N43RF overlaid on IR image at 18 Z 2/1/2011.

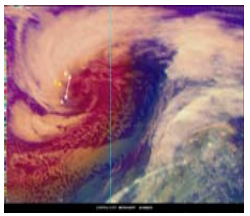


Path of cross section taken at 12 Z 2/1/2011. Fields depict model derived 925 mb theta-E gradient, frontogensis, and winds.

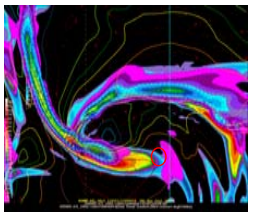
Trajectory Analysis



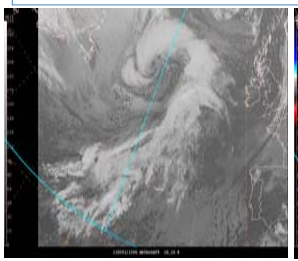
36 hour backwards trajectory for 12 Z 2/1/2011 at 53.52 N, -40.21 W at 50 m, 250 m, and 500 m. Trajectories based on half-degree GFS, native hybrid levels.



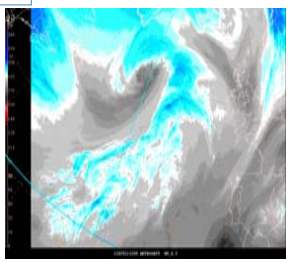
RGB image taken at 1157 Z on 2/1/2011 showing locations of cross section and trajectory.



Location of trajectory based on model derived fields of frontogensis, 925 mb theta-E gradient, and winds at 12 Z 2/1/2011.



Infrared image of the storm at 12 Z 2/1/2011.



Water vapor image of the storm at 12 Z 2/1/2011.

Future Work

• Sensitivity tests to determine which physical parameters in the WRF EMS model give the best, most realistic representation of storm.
• Continued trajectory analysis on the airflow through the low level jet and bent back front to try and determine the origin and evolution of the flow.
• Try to integrate the aircraft data into the WRF EMS model.
• Use different initial conditions in future model runs.
• Develop dynamic diagnostic tools that will be applied to the storm and bent back front region in an effort to understand the forcing and resultant evolution.