Investigation of Multi-bands in the Comma Head of the 26–27 December 2010 Northeast U.S. Winter Storm

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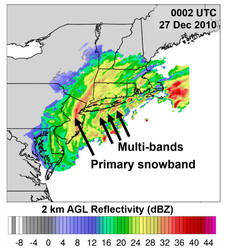
1. Introduction

Multi-bands are defined as ≥ 2 snowbands with lengths ≤ 200 km with a similar orientation and movement that can occur in the presence of a primary band, or larger snowband with a length > 200 km. Individual multi-bands have been observed to have shorter lifetimes than primary snowbands.

The case of 26–27 Dec 2010 or the "Boxing Day Blizzard of 2010" is an exemplary case of both a primary band and multi-bands forming and maturing in the comma head of a Northeast U.S. winter storm or nor'easter.

This case study explores the following mechanisms that may be responsible for the genesis of these multi-bands

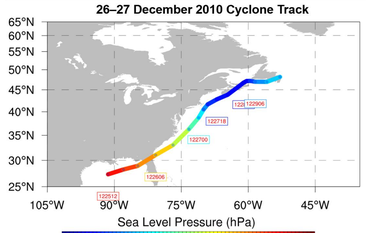
- Frontogenetical forcing
- Shear-induced circulations
- Gravity waves



2. Case Background

A series of snowbands produced 12 - 32 inches (30.5 - 81.2 cm) of storm total snowfall with rates approaching 3 in h^{-1} (7.62 cm h^{-1}) and wind gusts up to 70 mph (60.8 kts) in the NYC metropolitan area from 26–27 Dec 2010.

The associated low pressure system developed in the Gulf of Mexico and matured as it moved up the Eastern Seaboard deepening to 964 hPa off the coast of Cape Cod by 1200 UTC 27 Dec.



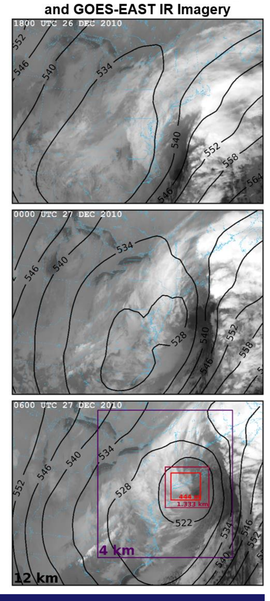

Snow Keeps City at Standstill

THE WALL STREET JOURNAL.
DEC. 27, 2010

December Blizzard Will Cost Over $68 Million

The New York Times
JAN. 24, 2011

CFSR 500-hPa Geopotential Height and GOES-EAST IR Imagery

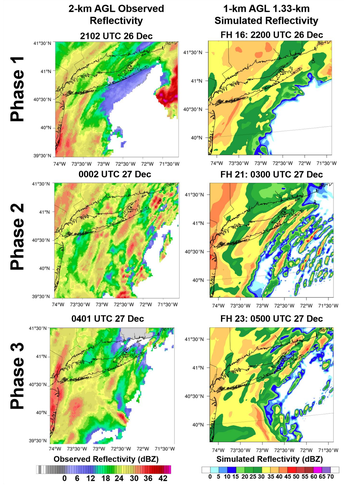


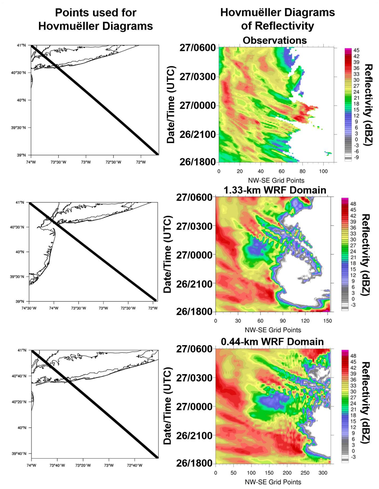
3. WRF Model Setup

The Weather Research and Forecasting (WRF-ARW) v. 3.6.1 was used to simulate the 26–27 Dec 2010 case. Dozens of experiments were conducted to test which configuration produced the most realistic results. The North American Regional Reanalysis (NARR) combined with Yonsei University (YSU) planetary boundary layer (PBL) scheme and Morrison double-moment microphysical parameterization scheme yielded higher fidelity of simulated multi-bands compared to observations.

Initial / Lateral Boundary Conditions	NARR
Simulation Times	0600 - 0600 UTC 26 – 27 Dec 2010
Microphysics Scheme	Morrison 2-moment
Planetary Boundary Layer Scheme	YSU
Horizontal Grid Spacing	12, 4, 1.33, 0.44 km
Number of vertical levels	40
Time steps	36, 12, 4, 1 s
Cumulus Parameterization Scheme	BMJ, none, none, none
Longwave Radiation Scheme	RRTM
Shortwave Radiation Scheme	Dudhia
Land surface scheme	Noah-MP

4. Observed & Simulated Multi-bands



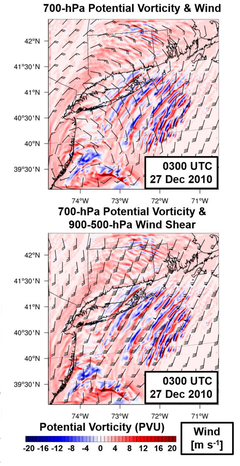


Snowbands were observed in 3 distinct phases related to primary and multi-band genesis and maturity provided in the table below. These phases were reproduced within the model simulation with a ~2 h timing error.

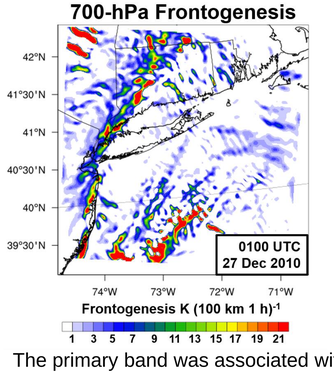
Phase	Description	Observed Times	Simulated Times
1	Primary band genesis and pivot	15 – 21 UTC 26 Dec	FH 11-17 17 – 23 UTC 26 Dec
2	Primary band maturity and multi-band genesis and maturity	21 – 03 UTC 26–27 Dec	FH 17-23 23 – 05 UTC 26-27 Dec
3	Band decay	03 – 06 UTC 27 Dec	FH 23-24 05 – 06 UTC 27 Dec

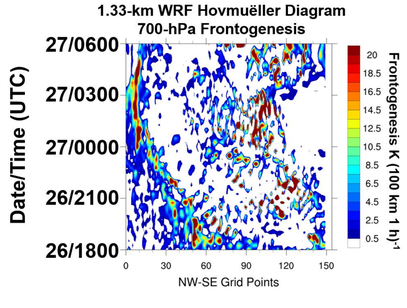
Multi-bands formed as cells offshore and became organized into bands that moved towards the NW and aggregated with the primary band.

Multi-bands coincided with potential vorticity (PV) dipoles implying consistent upward motion in the model-resolved bands. These features were oriented parallel to the 900-500-hPa wind shear and moved in the same direction as the 700-hPa wind.



5. Genesis Mechanism I: Frontogenesis?



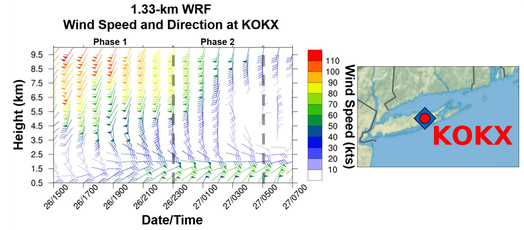


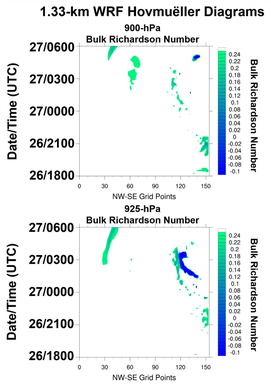
The primary band was associated with a region of strong 700-hPa frontogenesis.

During multi-band genesis between 2300 – 0100 UTC, there were no distinct frontogenesis maxima collocated with the multi-bands, but rather a broad area of higher values offshore.

Therefore these multi-bands were not forced by a constant frontogenetical circulation.

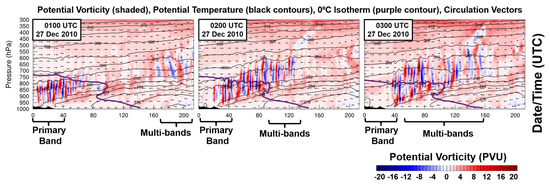
6. Genesis Mechanism II: Shear-induced Circulations?

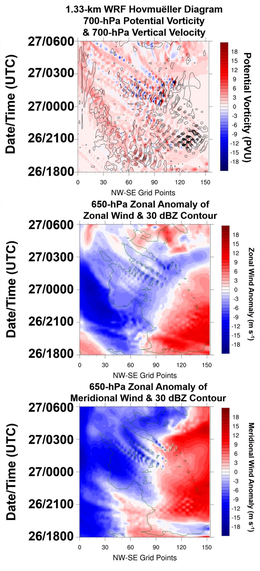




The multi-bands formed during a time of enhanced directional and speed wind shear. This shear may produce vertical circulations given that the Bulk Richardson Number, an estimate of dynamic instability, was less than the critical value (0.25) in the multi-band genesis region at two lower atmospheric pressure levels.

7. Genesis Mechanism III: Gravity Waves?





The multi-bands were associated with PV dipoles that perturbed the isentropes as they traveled from southeast to northwest.

The multi-bands originated near wave-like perturbations as evident in the PV field with overlaid vertical motion and zonal anomalies of each wind component.

The perturbations were most pronounced near the temperature inversion along a sloping frontal boundary which might suggest gravity waves were traveling along that interface.

8. Summary & Future Work

- Multi-bands (multiple snowbands with lengths ≤ 200 km) occurred east of a primary band (length > 200 km) in the comma head of the mature Northeast U.S. 26–27 Dec 2010 extratropical cyclone
- Multi-bands were not associated with frontogenetical forcing but the primary band coincided with a consistent frontogenesis maximum.
- Multi-bands were associated with PV dipoles that were oriented parallel to the 900-500-hPa wind shear and traveled following the 700-hPa wind.
- Multi-bands formed in an environment of enhanced vertical wind shear which could produce vertical circulations resulting in the formation of the incipient bands offshore.
- There appeared to be wave activity during the genesis stage of the multi-bands before they traveled to the northwest in a region of a frontal inversion.
- Future work will further explore waves as a multi-band genesis mechanism.

Acknowledgement:
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Recommended Observations:
More frequent thermodynamic profiles from more locations are needed to provide insight into the complex banding environments within winter storms.