Examining Vertical Velocities in the Dendritic Growth Zones of WRF Simulations of High Impact East Coast Winter Storms

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• Identifying Mesoscale Features to Improve Nor'easter Snow band Forecasts

• New Technique in Visualizing Vertical Velocities in the Dendritic Growth Zone

Background

The Complexities of Snow Bands

- Snow bands can be an intense period of moderate to heavy snowfall, accompanied by strong, gusty surface winds and possibly lightning. Often embedded in synoptic dynamics, they can lead to significant snow accumulation.[1]
- Numerical Weather Prediction (NWP) models often have diffculty simulating such events due to their rapid development and decay, localized impacts, and intricate vertical dynamics.
- Ingredients needed for snow band production are sufficient moisture, mid-atmospheric lift, and atmospheric instability.[1]

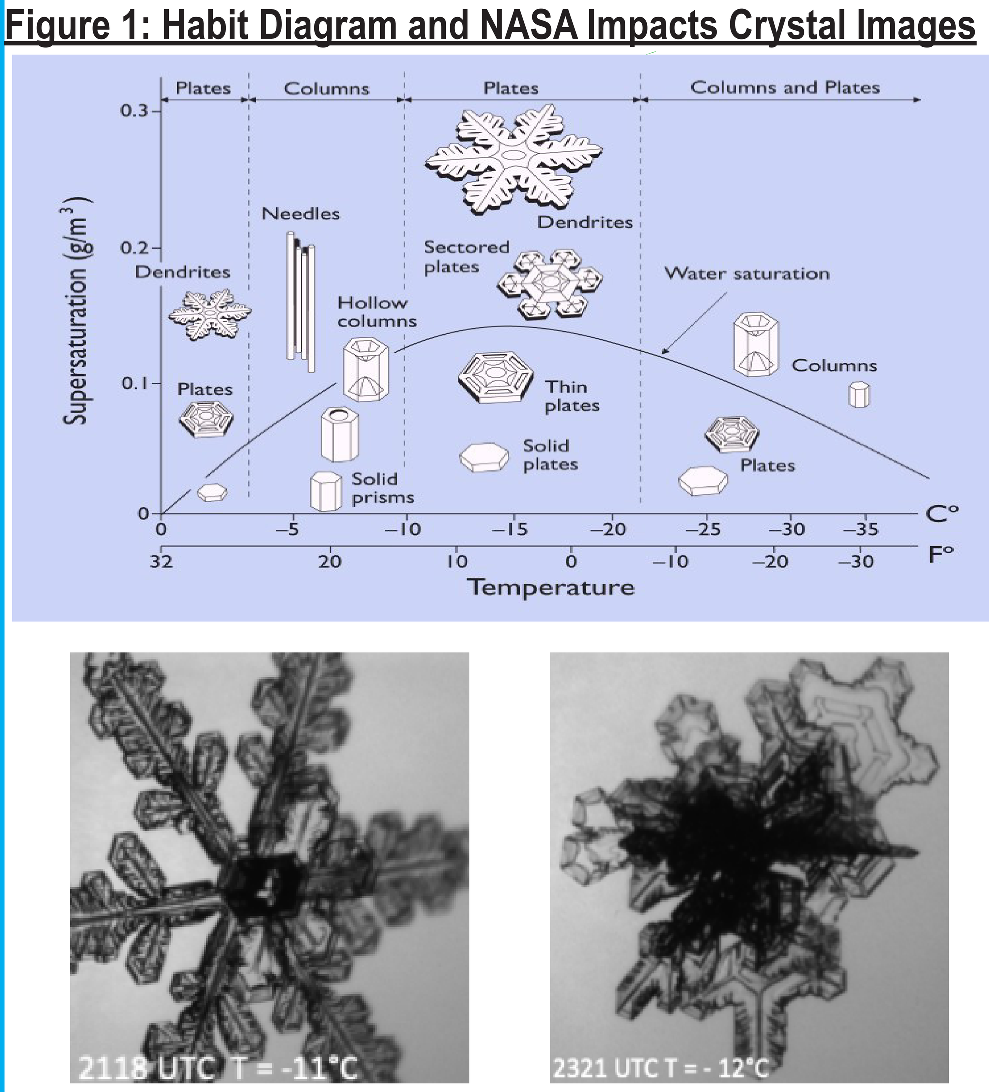
Dendritic Growth Zone Definition and Rationale

- The Dendritic Growth Zone (DGZ) is defined here as the vertical layer between -10°C to -20°C. Strong ascent and saturated conditions within the DGZ favors rapid growth of dendritic ice crystals, thus producing high snowfall rates.[2,3] For this study, the DGZ is deemed saturated when the dew point depression is less than 4°C. See Figure 1 for ice crystal shapes.
  - A wide DGZ temperature range is used to capture enough vertical levels within the Weather Reaserch and Forecasting Model (WRF).
- From an operational forecasting perspective, the growth of dendrites and their subsequent aggregation are important microphysical processes and should be identified in available observations.[4]

NASA Impacts Objectives

1. Providing observations critical to understanding the mechanisms of snowband formation, organization, and evolution
2. Examine how the microphysical characteristics and likely growth mechanisms of snow particles vary across snowbands
3. Improve snowfall remote sensing interpretation and modeling to advance predictive capabilities

Figure 1: Habit Diagram and NASA Impacts Crystal Images



Problem, Challenge, and Solution

Problem:

- Snow bands are high impact weather events
- It is difficult for a Numerical Weather Prediction Model to accuratly forecast the strength, position, and timing of these features

Challenge:

- Snow band forecasts involve mesoscale and synoptic scale dynamics (transcends scales)
- Vertical velocity and moisture measurements are needed to accurately depict dendritic growth

Solution:

- Create a 2D map of maximum vertical velocities within the DGZ to track mesoscale forcing
- Investigate strengths and weaknesses of individual members in forecasting the features

Case Study: January 29-30, 2022 Nor'easter

Description of Event[5]

- Rapidly deepening type A nor'easter
- Superpositioned between northern and southern jet streaks, allowing for strong divergence aloft.
- Secondary low developed, enhancing New England snow totals.

Figure 2: Surface Maps (12Z & 18Z, 29th)

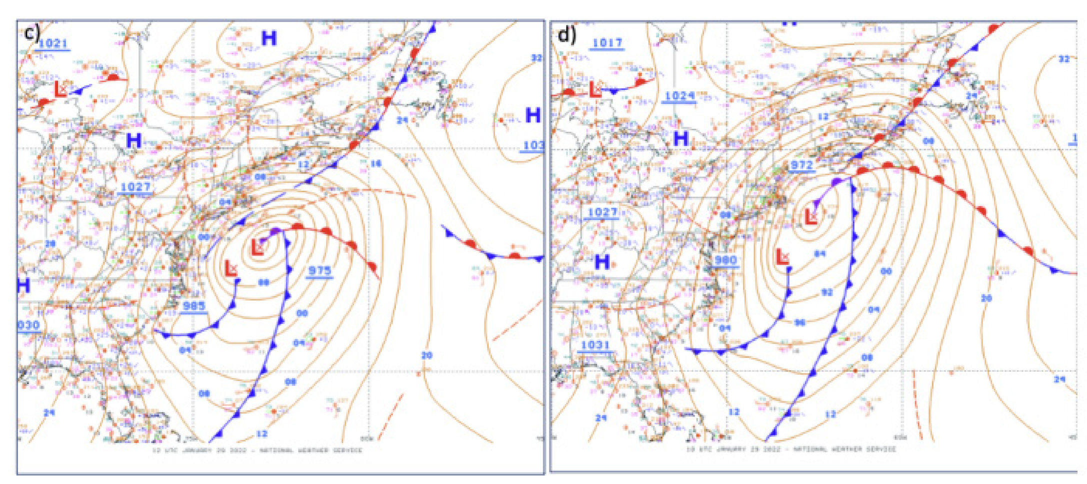


Figure 3: ER2 & P3 Flight Track

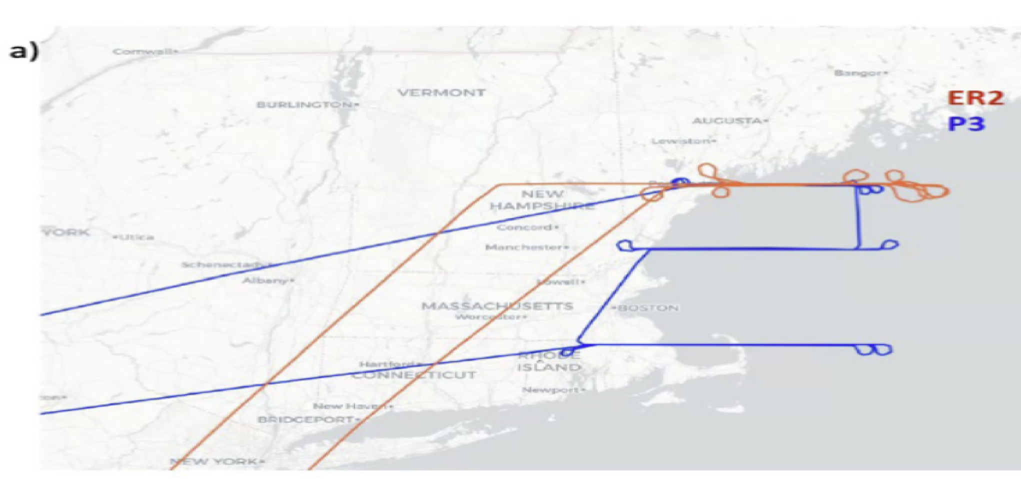
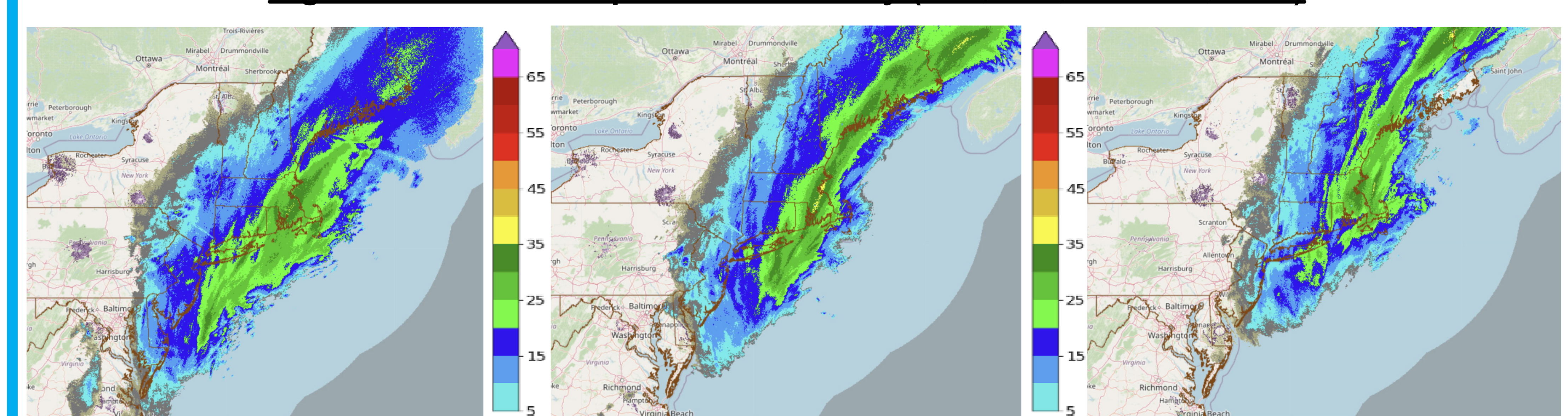


Figure 4: MRMS Composite Reflectivity (15Z, 18Z, and 21Z, 29th)



WRF Analysis Using Ensemble Data Assimilation

- Using the PSU EnKF system, we assimilated conventional observations to create an ensemble of WRF analyses at 3 km horizontal grid spacing
- Each ensemble member represents plausible atmospheric fields during the snowstorm

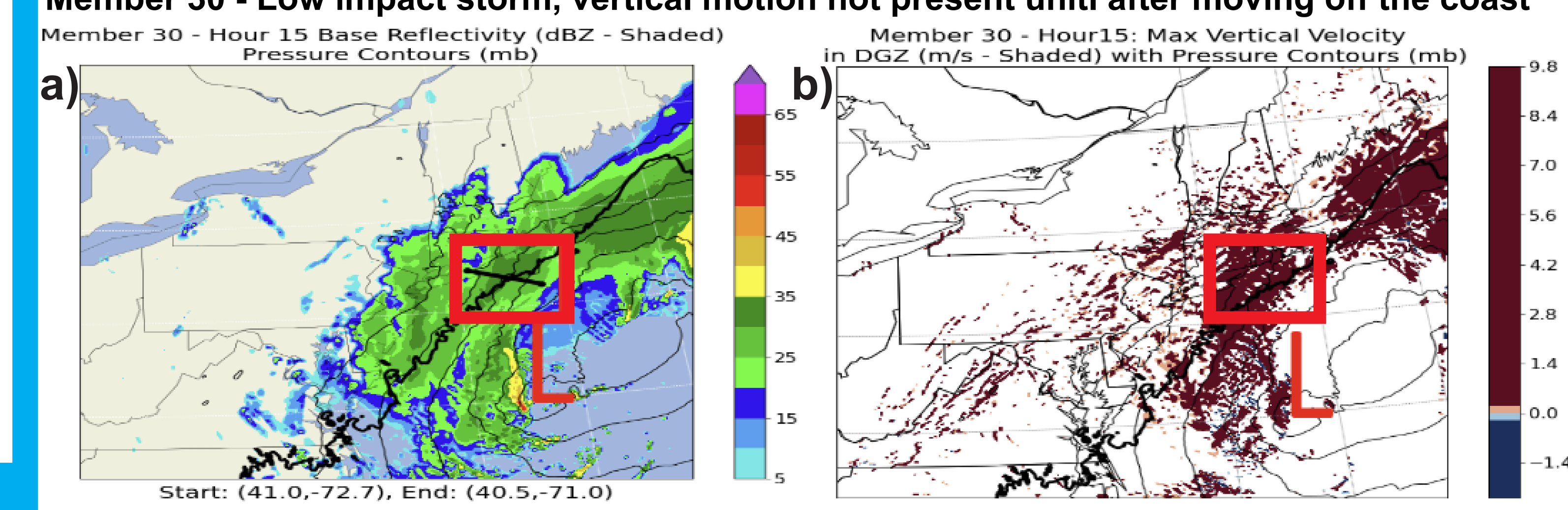
Process for Creating the 2D Map of Max Vertical Velocities within DGZ

1. Convert WRF Variables (e.g. perturbation pressure) to variables appropriate for the analysis
2. At each grid point, get a vertical profile of temperature
3. Find the -10°C and -20°C temps in the profile
4. Find the max vertical velocity within the layer
5. Where the max vertical velocity is found, retrieve the temperature and dew point
6. Calculate the dew point depression
7. If the dew point depression is >4°C, then mask the vertical velocity value on the graphic
8. The result is a 2D map of max vertical velocities within a saturated DGZ

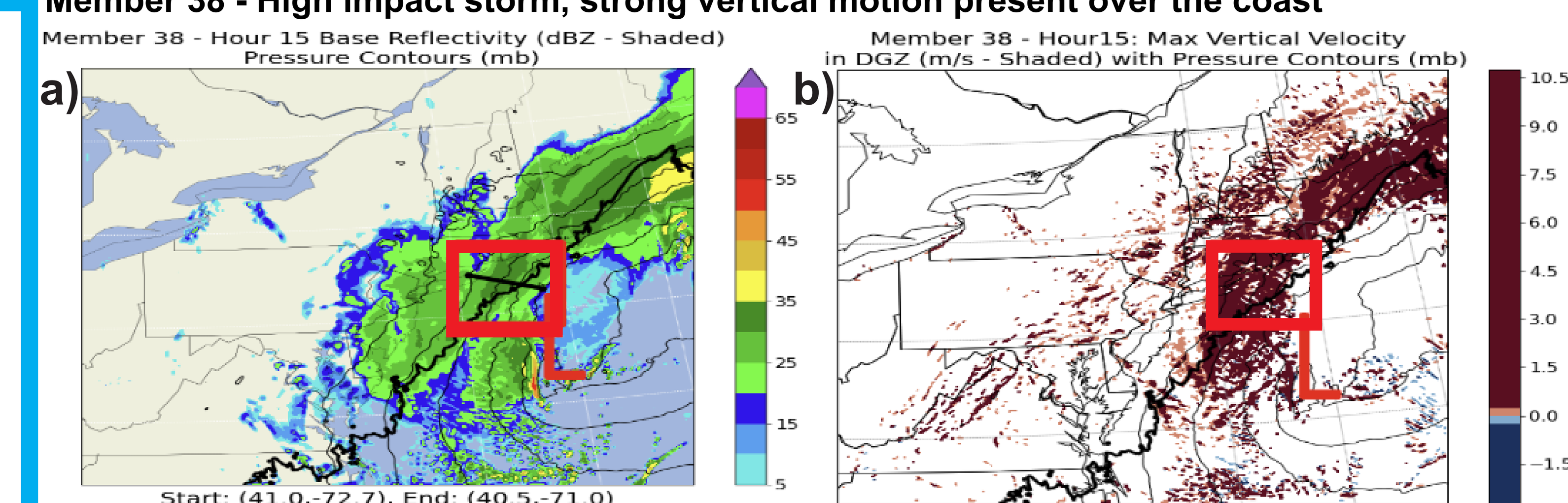
Figures 5-7: a) Radar reflectivity map with cross section line, 0°C isotherm, & isobars. b) 2D plot of maximum vertical velocity within a saturated DGZ. c) Cross section of vertical velocity with DGZ labeled.

15Z Figure 5

Member 30 - Low impact storm, vertical motion not present unitl after moving off the coast

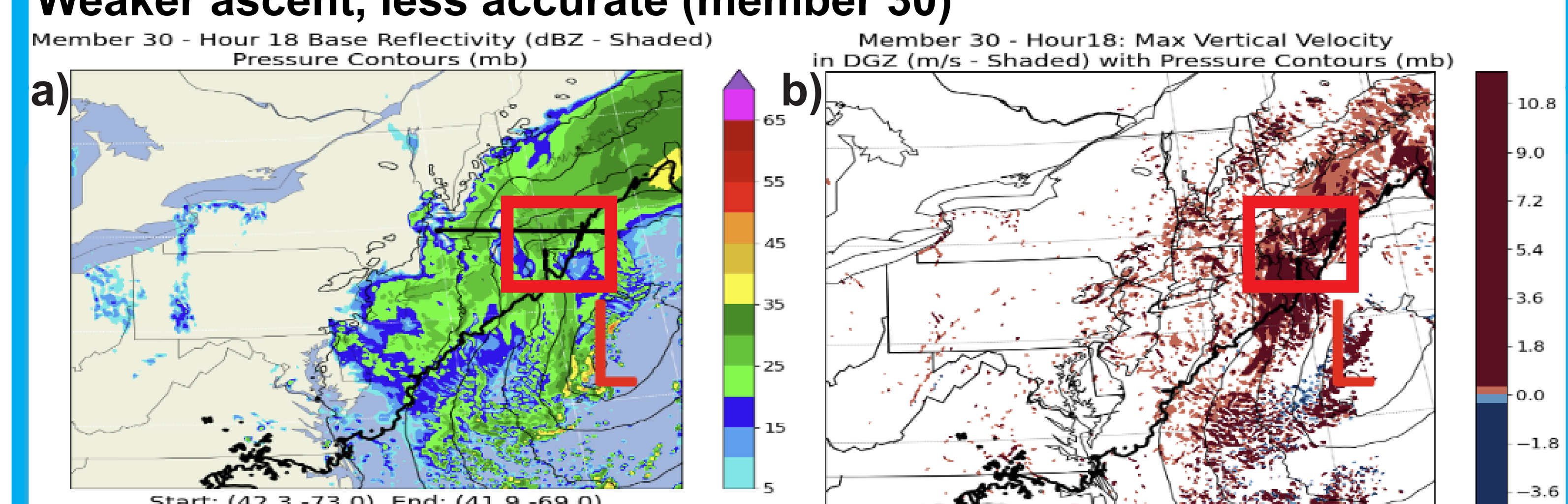


Member 38 - High impact storm, strong vertical motion present over the coast

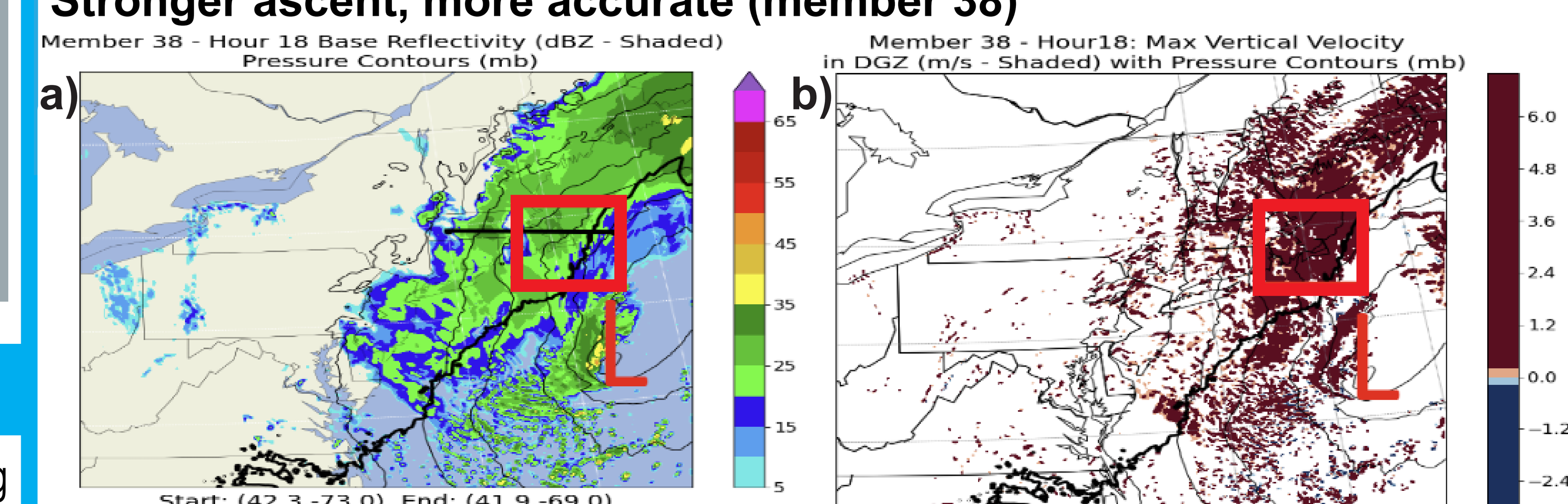


18Z (Also includes the Vertical Velocity Plots) Figure 6

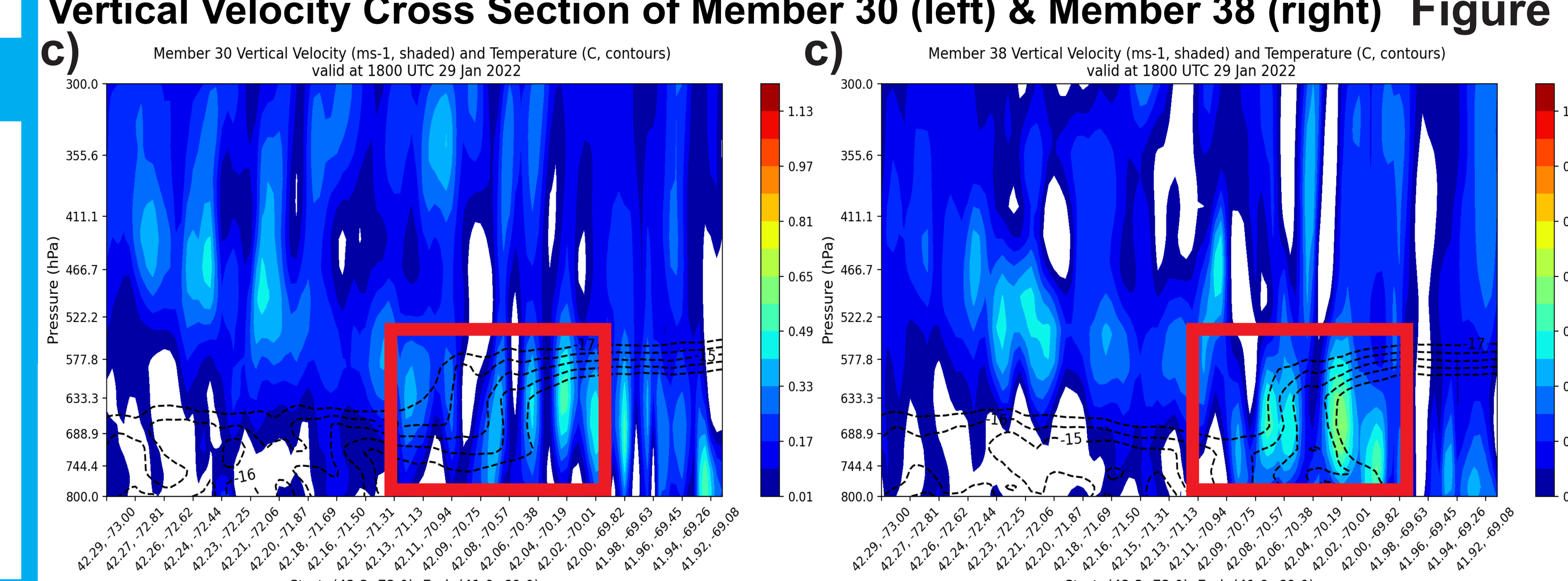
Weaker ascent, less accurate (member 30)



Stronger ascent, more accurate (member 38)



Vertical Velocity Cross Section of Member 30 (left) & Member 38 (right) Figure 7



Key Takeaways

1. At 15Z, the models had very similar solutions, however at 18Z, they disagreed.
2. At this time, the low impact member 30 had weak ascent, opposite of member 38.
3. Mem. 38 provided robust ascent in the red box, thus the snow band formed.
4. Mem. 30 failed to provide enough ascent in the DGZ, thus the snow band was weak

Works Cited: 1) The AMS Glossary 2) Bailey, M. P., and J. Hallett, 2009: A comprehensive habit diagram for atmospheric ice crystals: Confirmation from the laboratory, AIRS II, and other field studies. 3) Lamb, D., and J. Verlinde, 2011: Physics and Chemistry of Clouds. 4) Schrom et al., 2015: Polarimetric Radar Signatures of Dendritic Growth Zones within Colorado Winter Storms 5) Wagner et al., 2022, Impacts Science Summary for 29 January 2022: Departing Strong Nor'easter
Acknowledgements: The Nasa Impacts Team