Wave Structure Along a Frontal Boundary: Effects on Microphysics and Surface Precipitation; *Focus on 13 February 2020 Research Flight*

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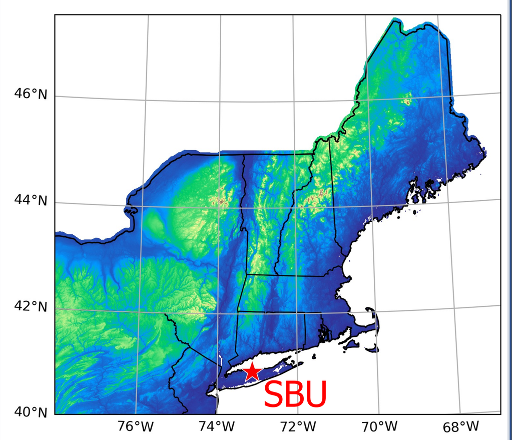
IMPACTS

Overarching goals

- Improve our understanding of the origin and evolution of snowbands that are frequently observed in the eastern United States
- Understand microphysical growth processes of precipitation within banded snowfall
- Advance remote sensing interpretation of snowfall

Motivation for this study

- Explore cellular and periodic features in precipitating radar echo that coincided with periodic variability in rainfall intensity
- How does the cellular cloud structure aloft develop?
- How do in situ microphysics vary within these cellular features and how do these variations alter surface precipitation?



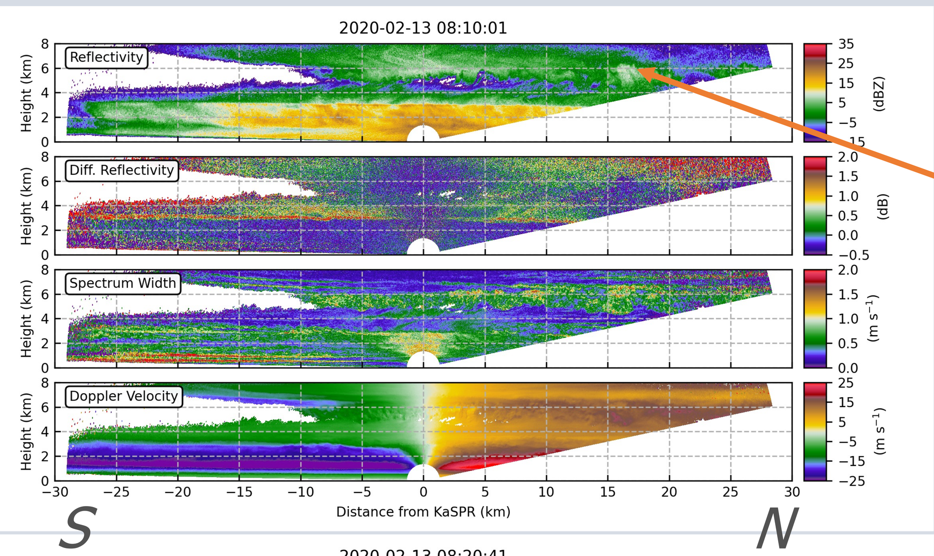
Data sources for this study

- GOES-16 10.3µm infrared channel
- P-3 aircraft, in situ instrumentation
- Ground-based radar
  - WSR-88D, S-band radar PPI (0.5° elevation) at Upton, NY (KOKX)
  - KaSPR, Ka-band radar RHIs (0°-180° orientation) at Stony Brook University, NY (SBU)
  - MRR, Micro Rain Radar, K-band vertically pointing radar at SBU
- Atmospheric soundings launched at SBU

Ground-Based Radar

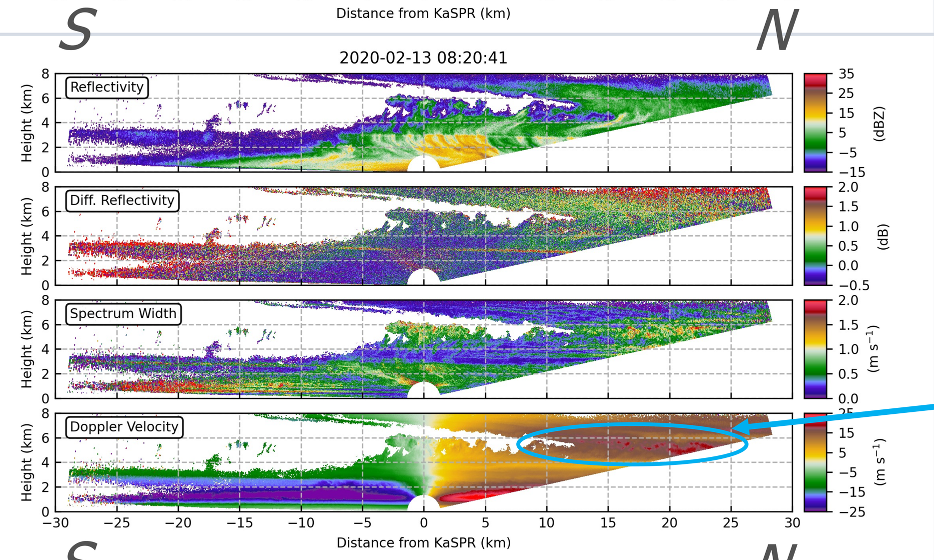
13 Feb 2020
KaSPR RHIs (SBU site)

What did the observed cellular cloud structure look like?



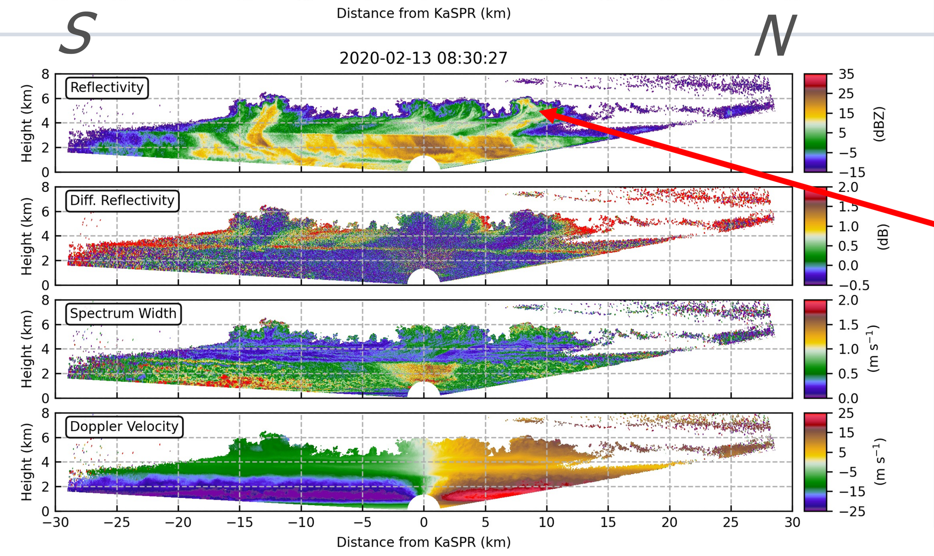
0810 UTC

- Bright band melt level ~3 km AGL
- Initially: Dry layer aloft capped by nearly uniform elevated reflectivity maximum at ~6 km AGL
- Positive differential reflectivity aloft, suggestive of dendritic/plate-like particles
- Horizontal velocity shear with collocated spectrum width maximum, indicating turbulence



0820 UTC

- Break up of elevated reflectivity maximum layer
- Heads of cellular features developed near sheared, turbulent layer
- Wave-like pattern was evident in radial velocity ~1 to 3 km above melting level (~4 to 6 km AGL)

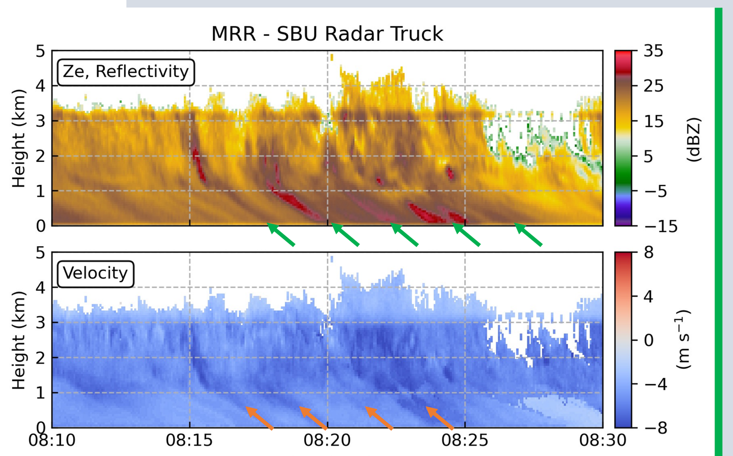


0830 UTC

- Distinct, elevated convective cells formed above melting level
- High reflectivity cells collocated with regions of low differential reflectivity (nearby regions of high differential reflectivity)

Micro Rain Radar, Vertical (SBU site)
0810-0830 UTC

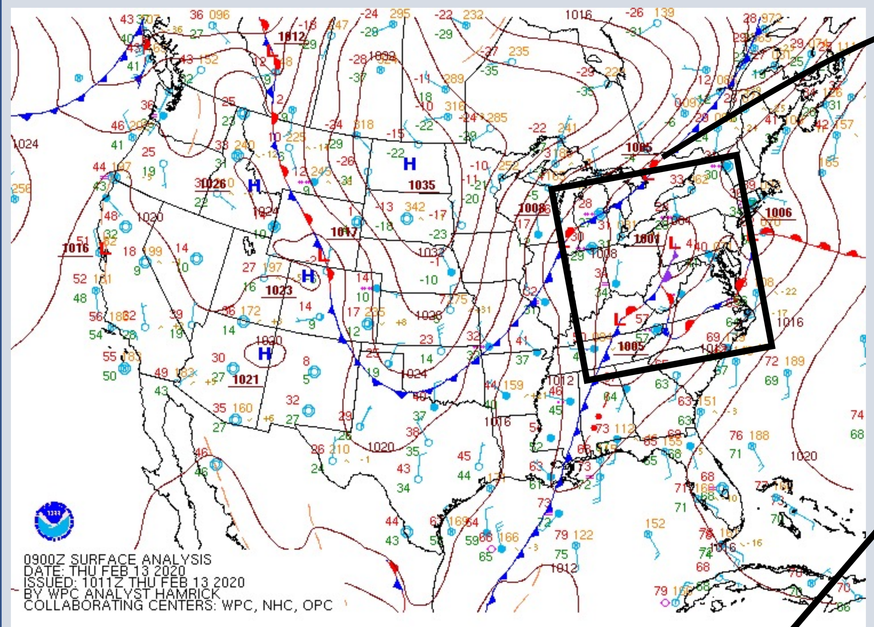
- Reflectivity: Vertically-pointing radar indicated steady rainfall but with several semi-regular, isolated periods of stronger intensity (green arrows)
- Velocity: Larger fall speeds possibly an indication of larger particles formed aloft, contributing to increased precipitation (orange arrows)



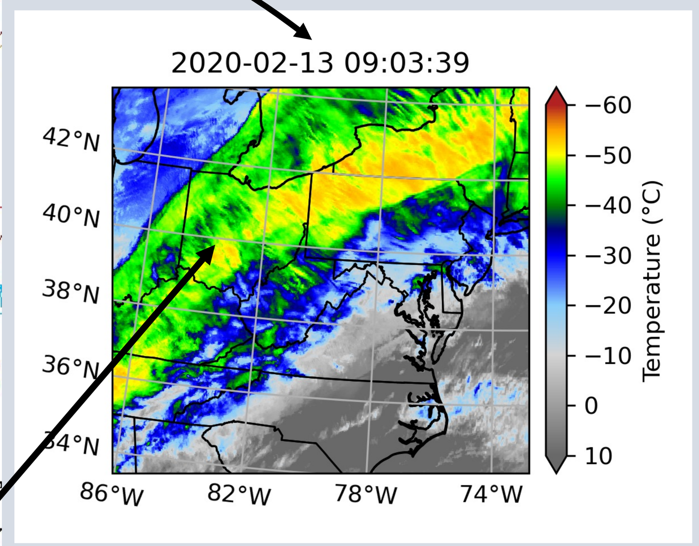
Synoptic-Scale Observations

13 Feb 2020

What was the broad scale context of these cellular features?



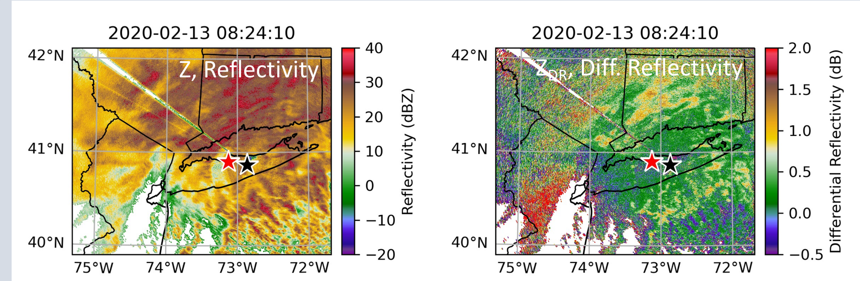
0900 UTC Surface Analysis



0903 UTC GOES-16 10.3µm Infrared

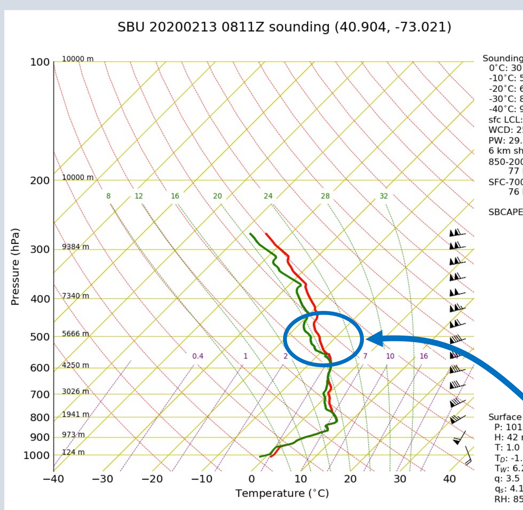
- Parallel slow-moving cold fronts over NE region, weak surface low pressure
- Broad cloud band between frontal boundaries, numerous wave structures in GOES-16 infrared imagery
- Waves typically oriented orthogonal to frontal boundary

WSR-88D (0.5° PPI) Upton, NY (KOKX) (★); SBU (★)



Below melting level (near Long Island, NY)

- To north: deep clouds, possibly ~E/W organized regions of high Z, Z_{DR}
- To south: shallower clouds, ~NW/SE organized high-frequency wave structure evident in Z, Z_{DR}



0811 UTC, SBU

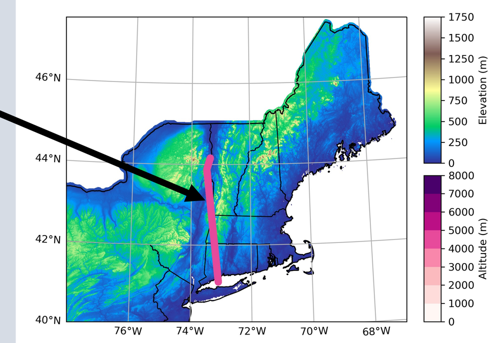
- At SBU (★), ahead of warm front: low-level stable layer with strong frontal inversion to ~ 800 hPa
- Near freezing at surface, significantly warmer aloft
- Shallow, elevated, potential instability near 5 km height (similar height to turbulent layer indicated by high spectrum width in KaSPR RHIs, at left)

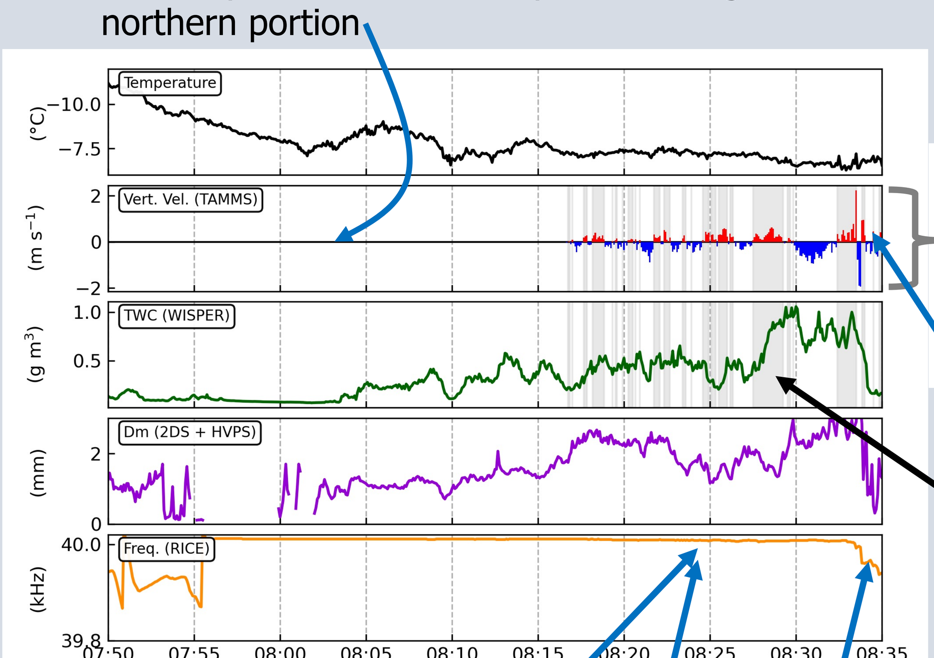
In Situ Observations (P-3 aircraft)

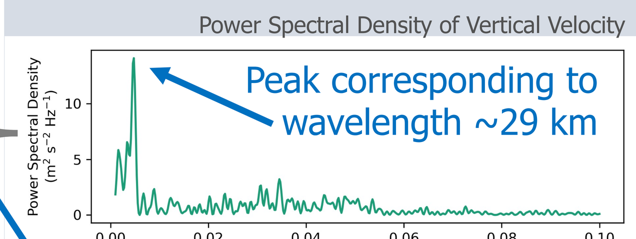
What are the microphysical characteristics of these cellular features?

13 Feb 2020 'Flight Leg 2', 0750 - 0835 UTC

- North to south (north of warm front)
- ~ 4550 m constant altitude (~ -6°C to -8°C)
- Turbulence reported by flight scientists during southern portion of flight leg
- *Currently* no vertical velocity data during northern portion

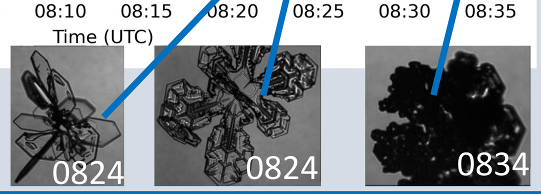






- Wave structure in vertical velocity
- Upward vertical motion (shaded gray regions) typically correspond to periods of increasing total water content
- Poor association between vertical motion and change in particle size
- No supercooled liquid water indicated by RICE instrument (except southern end near SBU)

Cloud Particle Imager (CPI) Images; Observation time in UTC

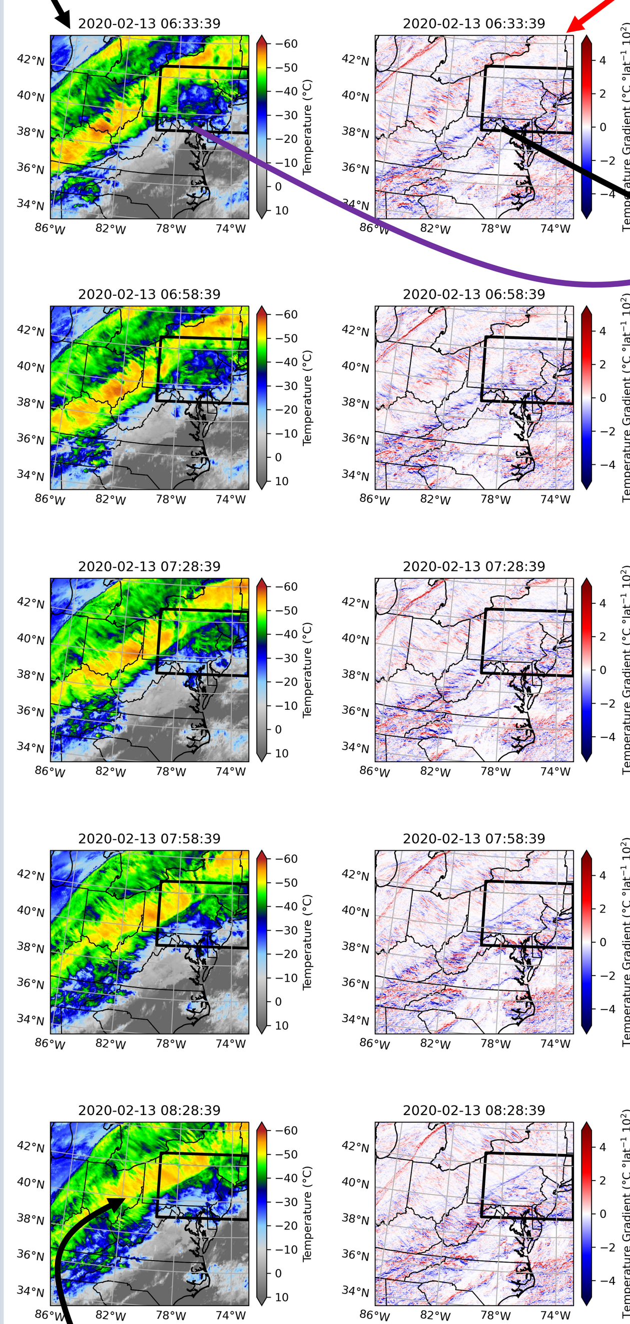


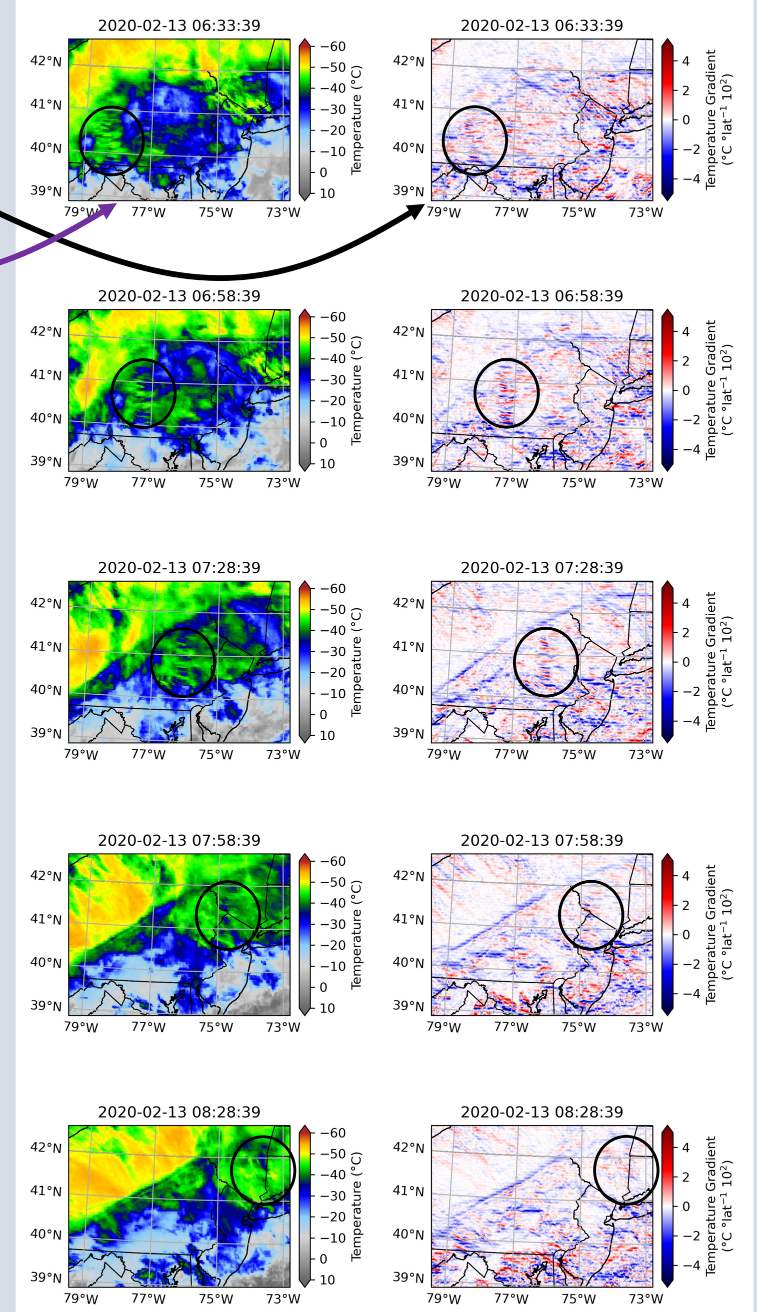
Hypothesis: Within ascending waves, water content increases and may imply growth by deposition or increased number concentration. At flight level (~ -7°C), riming does not appear to be a primary contributor during most of this time period.

Wave Packet Movement

Where does the wave structure observed near Stony Brook, NY originate?

GOES-16 IR 0630-0830 UTC — Gradient in cloud-top temperature along latitude orientation





- Wave-like pattern widely evident at cloud top in GOES-16 IR imagery
- Waves generally appear along cold frontal boundary, typically oriented orthogonal to front
- Waves sampled by P-3 aircraft seen as a small-scale wave packet oriented ~E/W and progressed along frontal boundary (circled in black, zoomed in panels in right column)
- Origin of small-scale wave packets near West Virginia suggest possible orographic influence from Appalachian Mountains because the low-level flow appears to be in a cross-barrier orientation (not shown).

Discussion and Future Work

- Elevated convective cells near SBU appear to form within a layer of high wind shear and turbulence, near a layer of potential instability
- In situ observations nearly collocated with SBU ground radar indicate a wave-like pattern in vertical velocity measurements, likely an isolated small-scale gravity wave packet within a broader wave field
- Power spectrum analysis of vertical motion indicates a horizontal wavelength in the wave packet of ~30 km, generally smaller than northeast US gravity waves more commonly described in the literature (~100-200 km; e.g., Bosart et al. 1998 , Zhang et al. 2001)
- Wave packet rapidly propagates along frontal boundary; phase speed should be determined
- Although scale is small, individual waves within the packet appear to affect ice microphysical growth processes, suggested by increases in total water content within and decreases in Z_{DR} within ascending waves
- Surface precipitation appears to be enhanced on a semi-regular frequency following the wave cycle aloft; can surface precipitation contribution from wave activity be estimated?

References

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