Detecting Waves in Doppler Radial Velocity Observations

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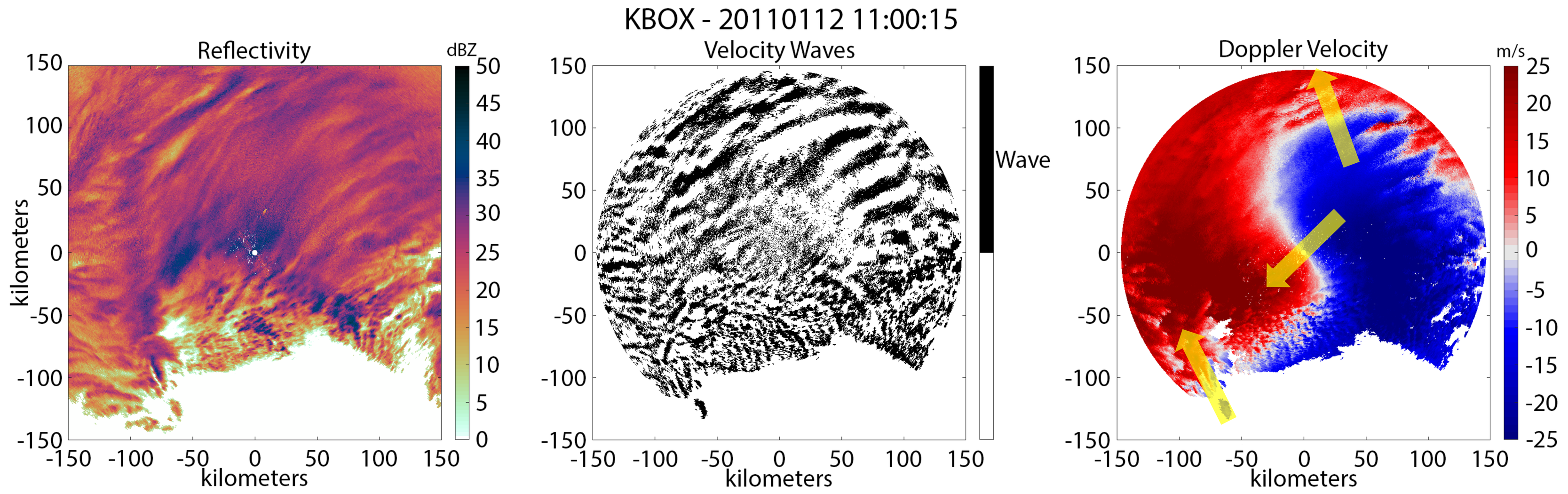
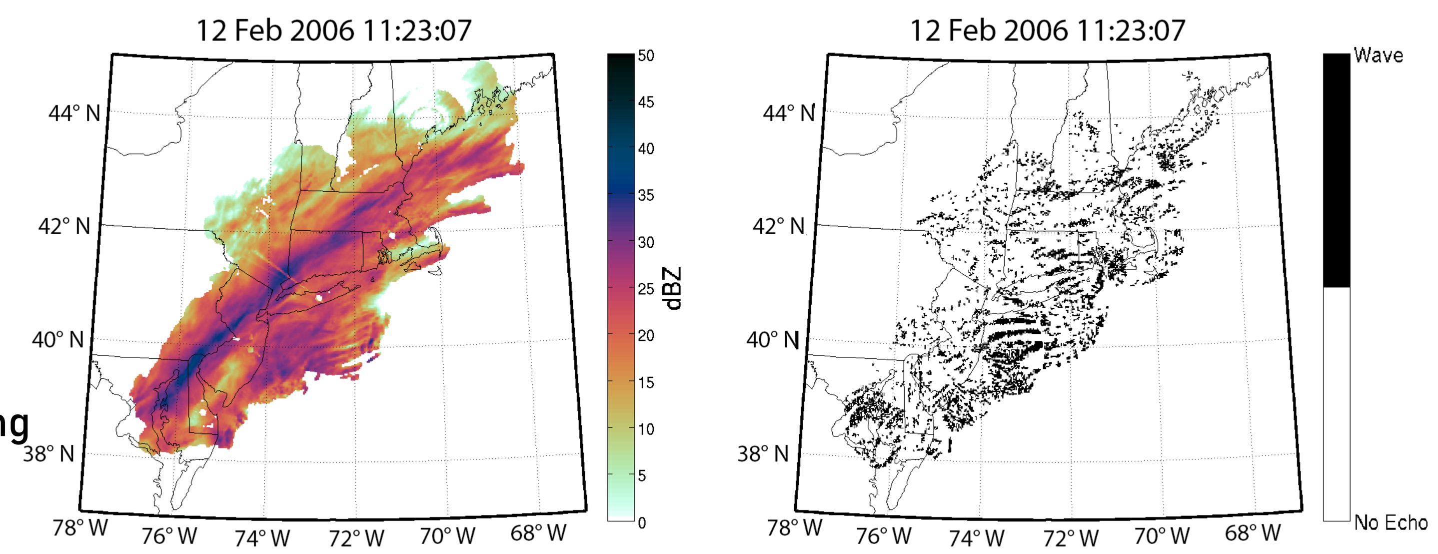
ENVIRONMENT ANALYTICS

Winter Storms and Waves

Precipitation accumulation in winter storms in the northeast United States is sensitive to the occurrence, intensity, and propagation of mesoscale bands of locally higher precipitation (Novak et al. 2004; Novak et al. 2008; Novak and Colle 2012; Ganetis et al. 2018). Investigation of Doppler radial velocity data for these storms has shown the frequent occurrence of transient, banded velocity perturbations that move off-axis with respect to the mean flow in a wave-like pattern. To determine if these velocity waves are relevant to the precipitation banding, they must be identified and quantified.



Radar reflectivity, wave detection, and Doppler velocity for the KBOX radar near Boston, MA on 12 January 2010 at 11:00 UTC (left). A set of coherent plane waves are moving towards the NNE. These waves are denoted by striations in the radial velocity field and coincide with, but move independently of, banded precipitation features. Yellow arrows denote wind direction at different ranges.

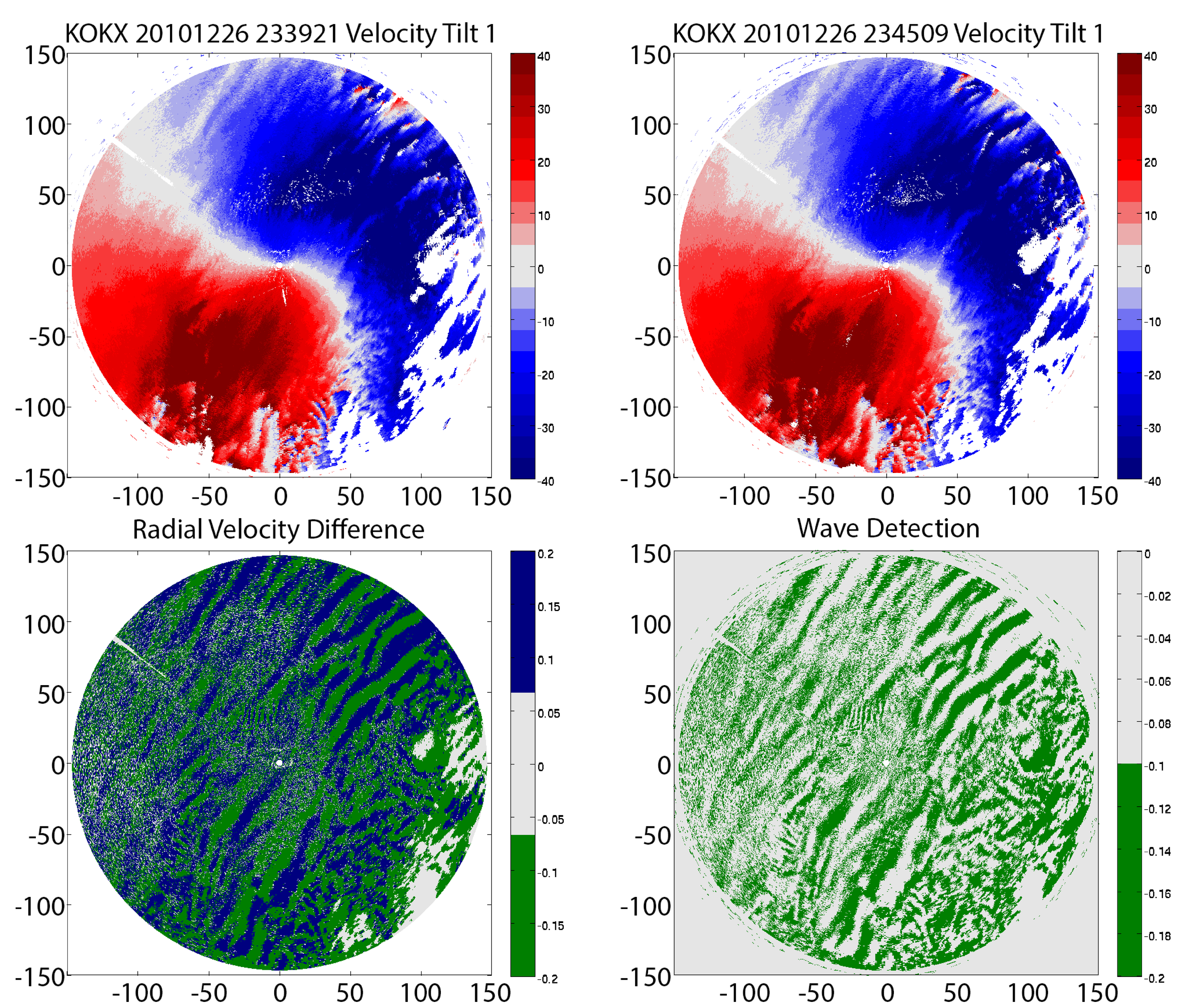


Radar reflectivity and wave detection for data stitched together from six radars in the NE US for 12 February 2006 at 11:23 UTC (right). The radar reflectivity features a large band of higher precipitation associated with a front spanning from MD across the New York City Area and just west of Boston. There are also sets of smaller banded precipitation features over the ocean south of Long Island. The wave detection data shows sets of moving velocity perturbations that are coherent and span multiple radar domains. These waves move with a different speed and direction than the smaller bands.

Detecting Waves

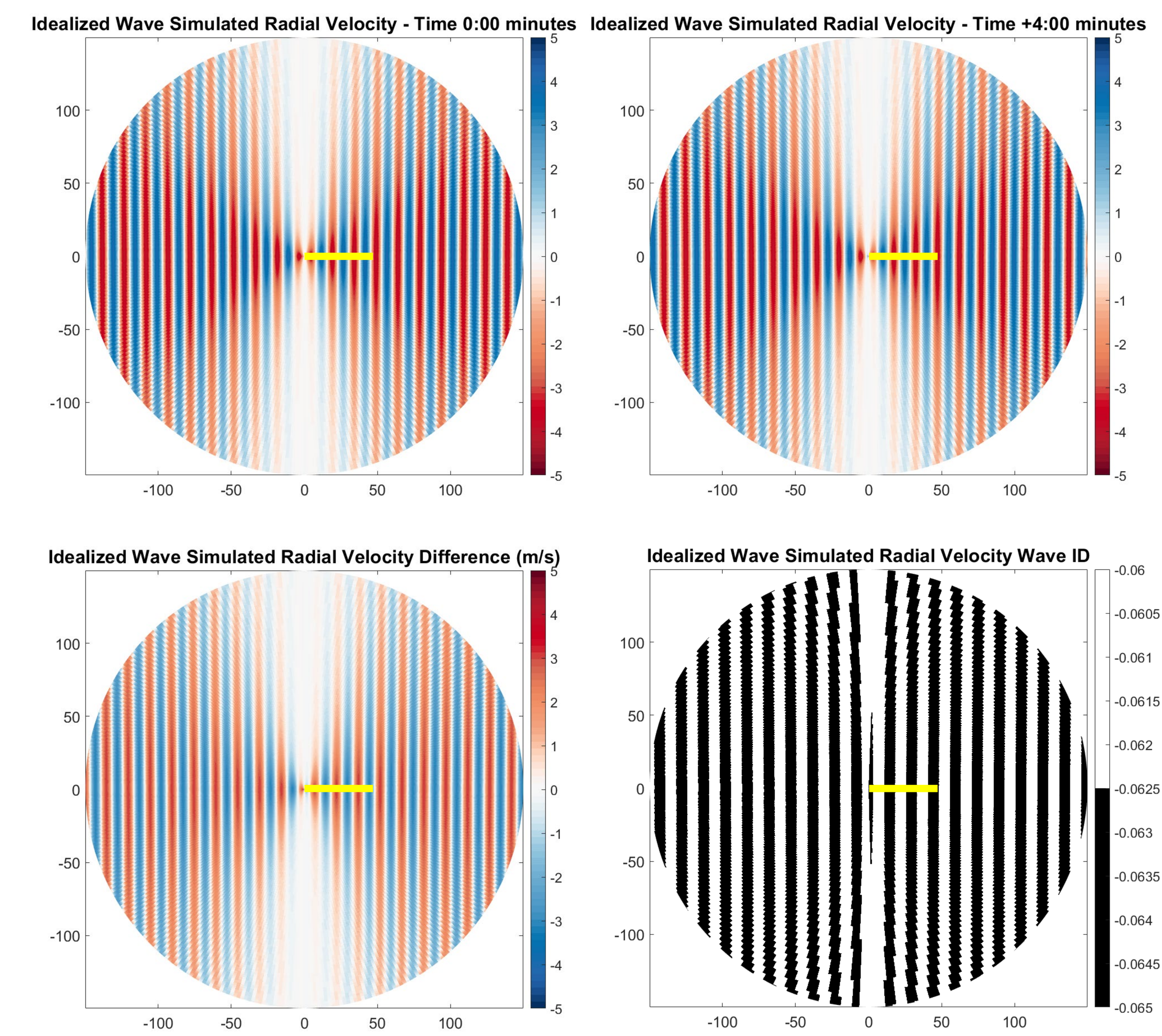
To isolate waves seen visually in animated sequences of radial velocity plots, we subtract two sequential radial velocity fields to get a difference field. The difference field contains linearly banded features with both negative and positive values that represent a temporal change in the radial velocity field. The difference field is converted to a binary field. The portions of the difference field with radial velocity values less than 0.06 m/s are given a value of one, and the remaining, largely positive portion of the field is given a value of zero. The binary threshold is set a small distance from zero to reduce noise.

The positive and negative changes in the radial velocity difference fields represent local accelerations and decelerations of the radial velocities, respectively. Positive values of radial velocity acceleration (*i.e.* time-2 radial velocity > time-1 radial velocity) represent areas of divergence and inferred downward motion ,and negative values represent areas of deceleration and associated convergence and inferred upward motion. We choose to use the negative portion of the radial velocity difference field in order to focus on the convergence and inferred upward motion associated with the velocity waves.

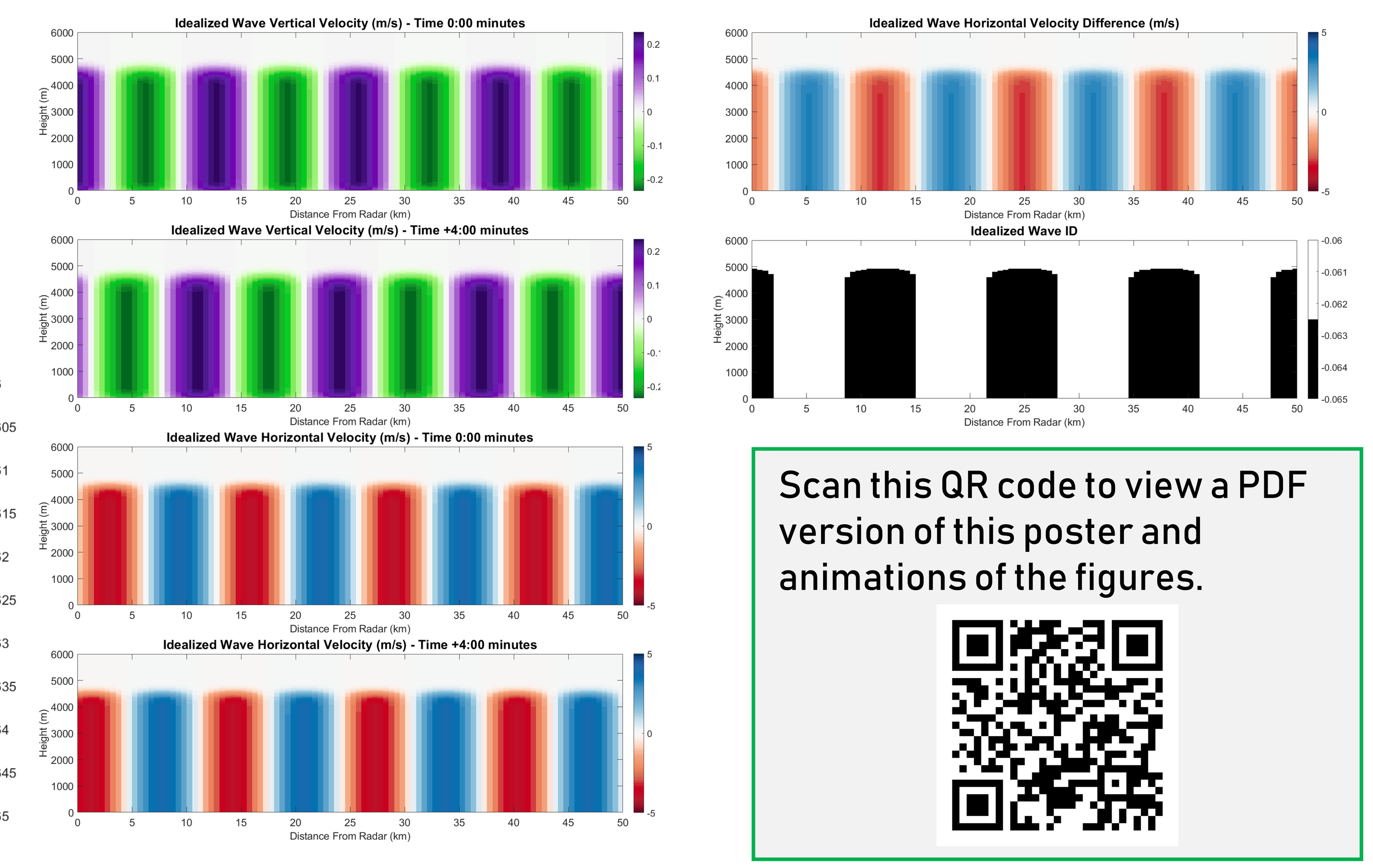


Testing with Idealized Waves

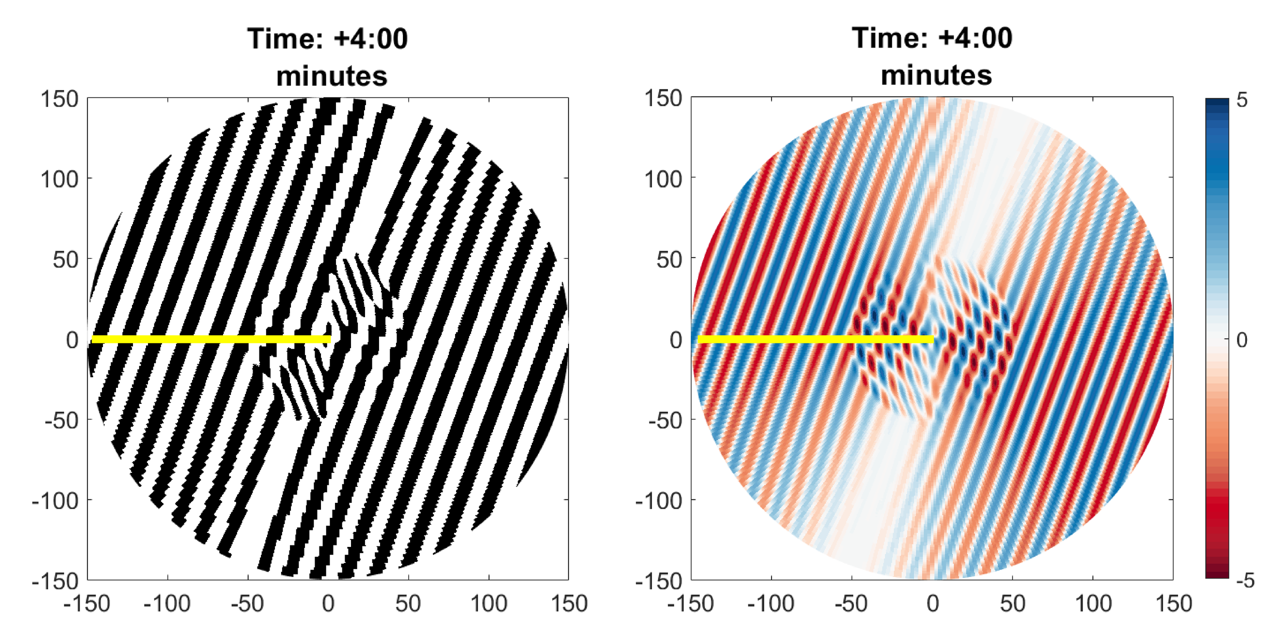
We test the algorithm using an idealized plane wave. This allows us to verify that the algorithm correctly estimates wavelength, speed, direction, and depth. The simulated radar images represent a radar with a beam width of 1°, a range of 150 km, a gate spacing of 250 m, a scan elevation of 0.5°, and a volume repeat time of 4 minutes. The yellow lines in the plan view images denote the location of the vertical cross sections.



Wave Length	Direction	Speed	Wave Depth	Max. Horiz. Velocity	Max. Vertical Velocity
15 km	270°	8 m/s	4500 m	4 m/s	0.22 m/s



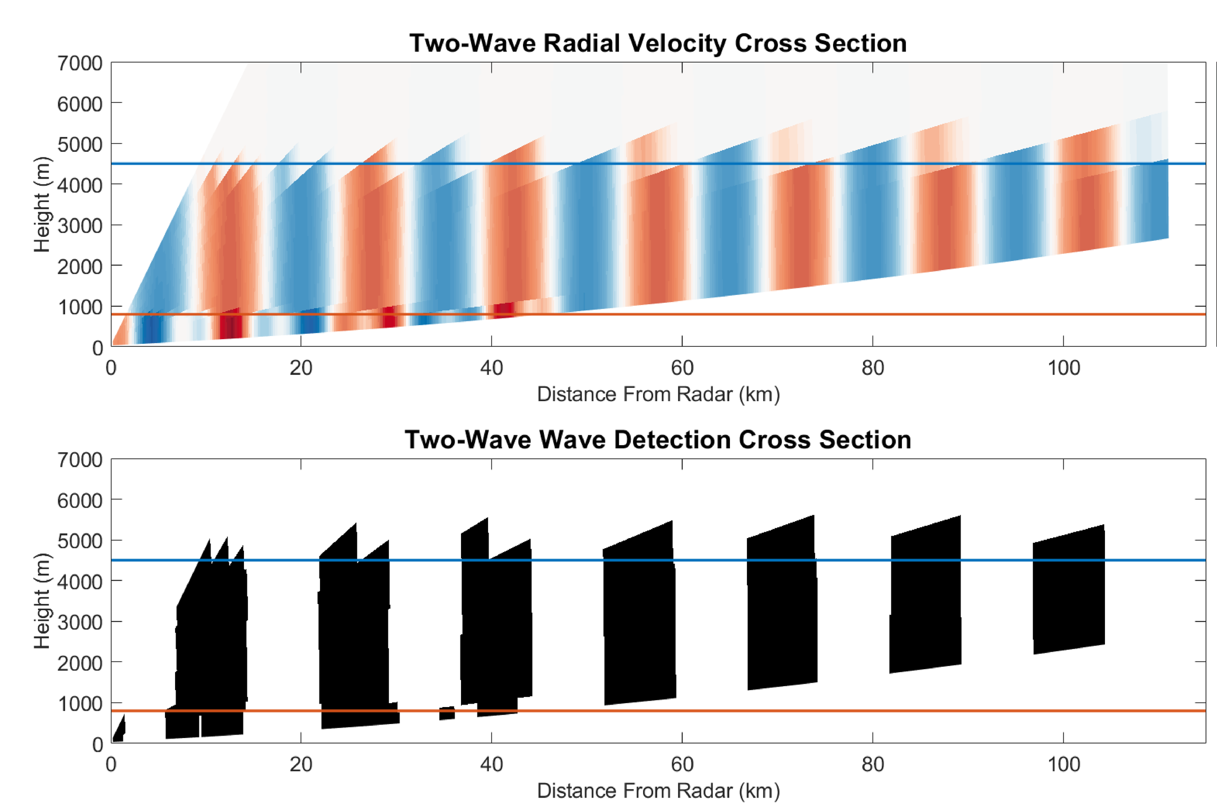
Scan this QR code to view a PDF version of this poster and animations of the figures.



Idealized Two-Wave Example

The figures to the left illustrate an example with different idealized waves superimposed in the same domain. The two waves in this example have differing wavelengths, orientations, depths ,and velocity perturbations. The wave identification method for this case captures a pattern similar to those seen in real-world data, suggesting that waves with a structure similar to the idealized waves occur in winter storms.

Wave Length	Direction	Speed
15 km	290°	15 m/s
4.5 km	250°	8 m/s
Wave Depth	**Max. Horizontal Velocity**	**Max. Vertical Velocity**
4500 m	4 m/s	0.22 m/s
900 m	3 m/s	0.40 m/s



Depth Estimates from PPI

The figures to the left illustrate a cross section of the data constructed from a National Weather Service VCP12-like pattern along the ray towards 270° azimuth, which is between the two idealized waves' orientations. The lines in the figure denote the heights of the two waves (800 m and 4500 m). The wave detection technique is capable of accurately estimating the tops of wave trains where they are sufficiently resolved. Estimates are most accurate close to the radar where different elevation radar beams are packed closer together and provide greater effective vertical resolution.

Conclusions

- Idealized waves yield radial velocity patterns similar to those observed in winter storms
- These are characteristic of gravity waves, and they are observed as sets of moving, linear perturbations in Doppler radial velocity observations
- These wave have depths on the order of several km and move with speed and direction different from mean flow
- Radial velocity difference fields can be used to identify waves and quantify wavelength, speed, direction, and depth
- Identifying waves and quantifying their characteristics using radial velocity data is useful for investigating their relationship to banded precipitation structures in NE US winter storms

Other References

Hoban, N. P. (2016). *Observed Characteristics of Mesoscale Banding in Coastal Northeast U.S. Snow Storms* (master's thesis). North Carolina State University.

Acknowledgements

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