Two novel, general purpose algorithms for unfolding Doppler velocities

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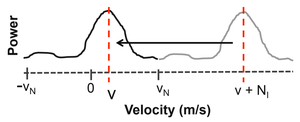
Introduction

Radial Doppler velocities measured by weather radars are limited in range due to the phase based nature of the measurement. When the velocities of the scattering particles are outside of this range, the values measured are folded or aliased into this limited range.



Various algorithms have been designed to unfold or dealias the measured velocities to determine the true atmospheric velocities. Most algorithms are designed to unfold velocities from a single scan type (PPI, RHI or vertical pointing) and perform best at specific radar frequencies and Nyquist velocities. Here we present two novel algorithms which can unfold velocities from data collected at various wavelengths, Nyquist velocities and scan types.

Algorithm Description

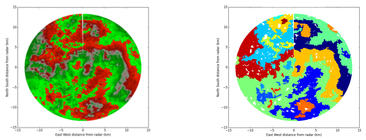
Multi-dimensional phase unwrapping

The multi-dimensional phase unwrapping algorithm uses a technique originally developed for unfolding phases in the analysis of optical fringe-patterns [1, 2]. Doppler velocities are first converted into phase measurements and then placed in a rectangular grid. A reliability value is calculated for each point and edge in this grid. The grid is then unwrapped edge-by-edge by minimizing the difference between the two phases with any correction being applied to the smaller group of points. Edges with highest reliability are unwrapped first.

Region based dealiasing

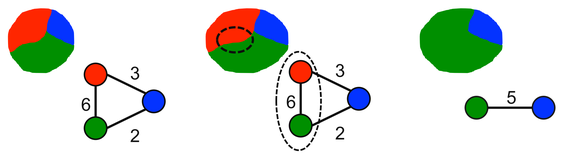
The region based dealiasing algorithm unfolds Doppler velocities in a manner similar to what a human would do when performing hand-dealiasing. Similar methods have been previously proposed [3, 4]. First regions of similar velocities are identified in the radar sweep.

Raw Velocities **Segmented Regions**

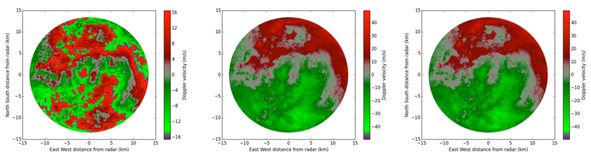


Raw and segmented velocities from the ARM CSAPR radar in the SGP. Data is from the first 150 gates of a PPI scan at the highest elevation (42°) collected at 10:47 UTC on May 20, 2011

These regions are then unwrapped against each other by minimizing the velocity differences between all bordering gates. Regions with the largest number of shared edges are unwrapped fist. This step is accomplished by modeling the regions and edges as a dynamic network graph.



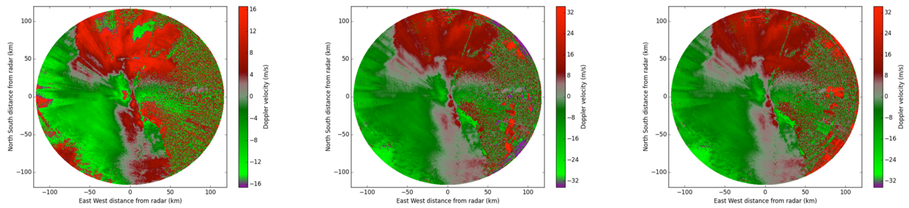
Raw Velocities **Phase Unfolded** **Region Unfolded**



Results from ARM Scanning Precipitation Radars

CSAPR

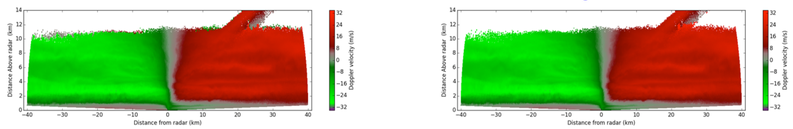
Raw Velocities **Phase Unfolded** **Region Unfolded**



Doppler velocities from the ARM CSAPR radar at the SGP site corrected multi-dimensional phase unwrapping, and the region based dealiasing algorithms. Data is from the lowest PPI scan with an elevation of 0.75° collected at 10:47 UTC on May 20, 2011.

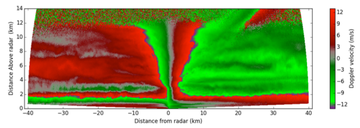
XSAPR

Phase Unfolded **Region Unfolded**



Doppler velocities from the ARM XSAPR at the SGP I5 site collected at 11:36 UTC on May 20, 2011. Data is from an RHI scan. Gates with reflectivity below -5 dbZ were excluded when unfolding.

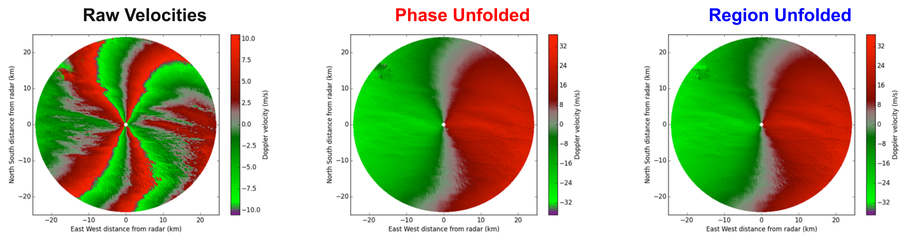
Raw Velocities



Results from ARM Scanning Cloud Radars

KaSACR

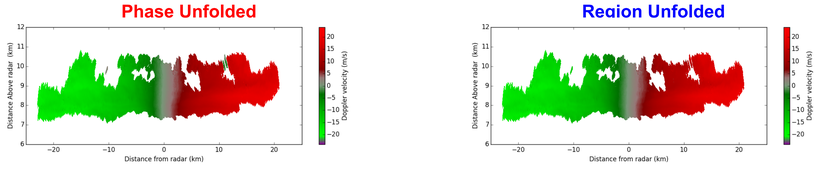
Raw Velocities **Phase Unfolded** **Region Unfolded**



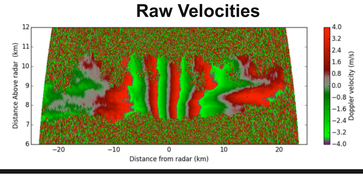
Doppler velocities from a PPI scan of the KaSACR instrument at the NSA collected at 13:21 UTC on January 14, 2014. Data is from the 1° elevation scan, no gates were excluded when unfolding.

WSACR

Phase Unfolded **Region Unfolded**



Raw Velocities

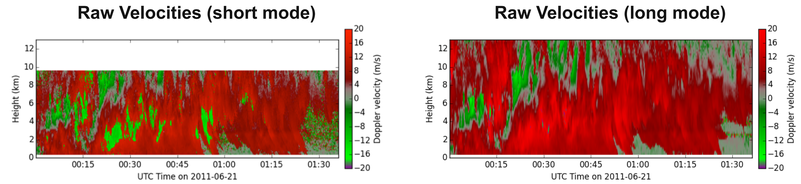


Doppler velocities of a cross wind RHI scan of the WSACR instrument in the SGP collected at 20:40 UTC on August, 20, 2012. A feature mask from the currently in-development SACRCOR VAP was used to select gates and suppress returns from noise, clutter and insects.

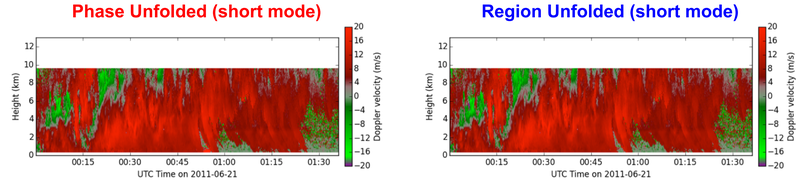
Results from a Zenith pointing ARM radar (915MHz RWP)

These dealiasing algorithms can also be used to unfold velocities measured by zenith pointing radars. In this example, velocities from the precipitation mode short pulse of the ARM 915 MHz RWP at the SGP central facility are unfolded using the two algorithms. The unfolded velocities agree well with the long pulse velocities collected with a larger Nyquist velocity (20.1 vs. 14.6 m/s). Data from June 21, 2011.

Raw Velocities (short mode) **Raw Velocities (long mode)**



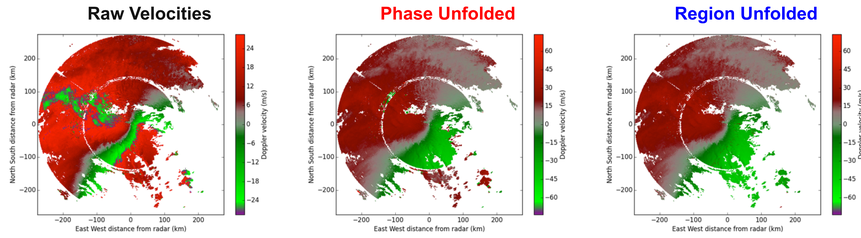
Phase Unfolded (short mode) **Region Unfolded (short mode)**



Results from NEXRAD Radars

These new dealiasing algorithms can also be applied to NEXRAD and other non-ARM radars. In the example below, data from the S-band NEXRAD (WSR-88D) radar located in Upton, NY (KOKX) is unfolded using both techniques. Data is from 0.5° elevation PPI scan taken on August, 28th 2011 at 7:21 UTC during which Hurrican Irene was making landfall producing winds in excess of 100 km/h.

Raw Velocities **Phase Unfolded** **Region Unfolded**



Additional information and References

The multi-dimensional phase unwrapping and region based unfolding algorithms are available in the Python ARM Radar Toolkit (Py-ART). Py-ART is an open source project which is distributed under a BSD license and available for free on GitHub. Please try out these algorithms on your data.

Fork me on GitHub

https://github.com/ARM-DOE/pyart

See the Lang *et al poster* (Session 3) for a statistical evaluation of these algorithms and the FourDD algorithm [5] on data from the NASA TOGA C-band radar.

References:

[1] Herráez, M. A., D. R. Burton, M. J. Lalor, and M. A. Gdeisat. *Applied Optics* 41, (2002): 7437–44.
[2] Hussein, A., M. Gdeisat, D. Burton, and M. Lalor. *Opt. Meas. Sys. for Ind. Inspection IV* 5856:32–40, 2005
[3] Bergen, W. R., and S. C. Albers. *Journal of Atmospheric and Oceanic Technology* 5, (1988): 305–19.
[4] Zhongqi, J., and G. Wiener. *Journal of Atmospheric and Oceanic Technology* 10, (1993): 798–808.
[5] James, C. N., and R. A. Houze Jr. *Journal of Atmospheric and Oceanic Technology* 18, (2001): 1674–83.

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