Analyzing Error in Balloon-Based Wind Measurements due to Spatial Separation Using the North American Regional Reanalysis

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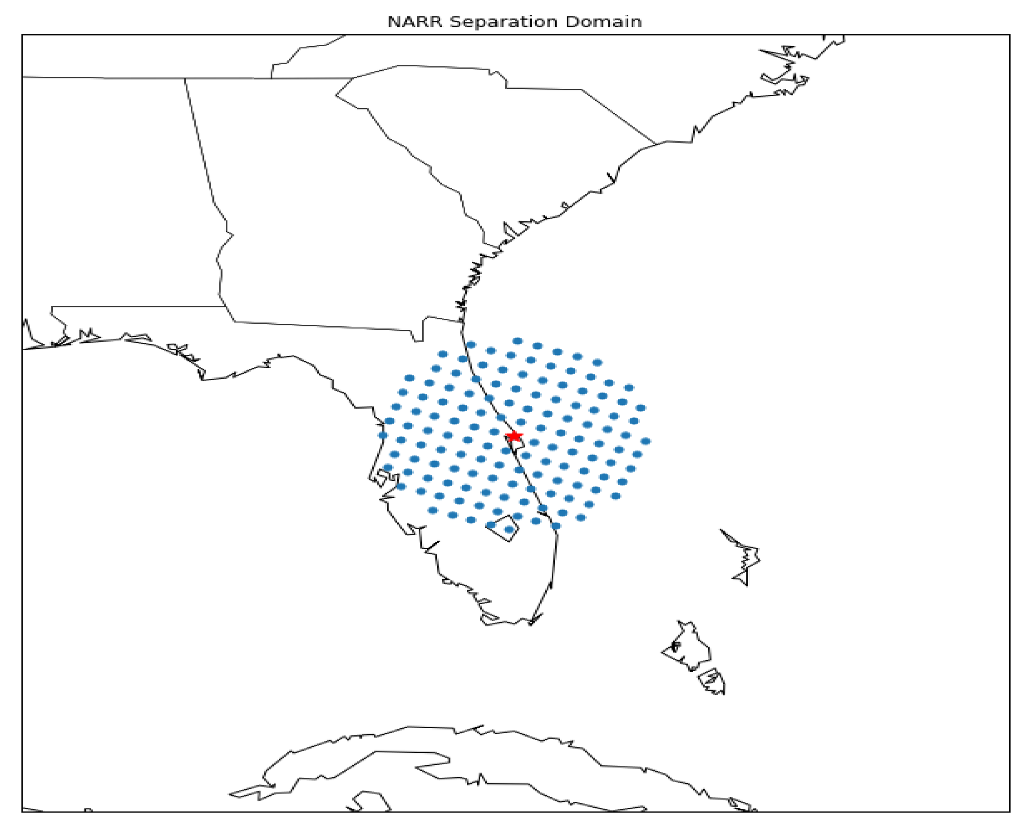
Introduction:

Weather balloons have been a longstanding asset to NASA and Aerospace meteorology. Balloons are used from launch vehicle design to day-of-launch operations. One of the most valuable assets from these balloons is wind data from the surface up to 30 km. Due to aloft winds, the balloons may drift downrange of the launch site and vehicle flight path. A 2017 study found balloons at Kennedy Space Center (KSC) can drift as far as 200 km from the launch site (Decker 2017). To obtain robust launch vehicle wind assessments, it is highly desirable to characterize the wind environment along the flight path. This study looks into the errors associated with spatial separation of wind measurements using the North American Regional Reanalysis (NARR).

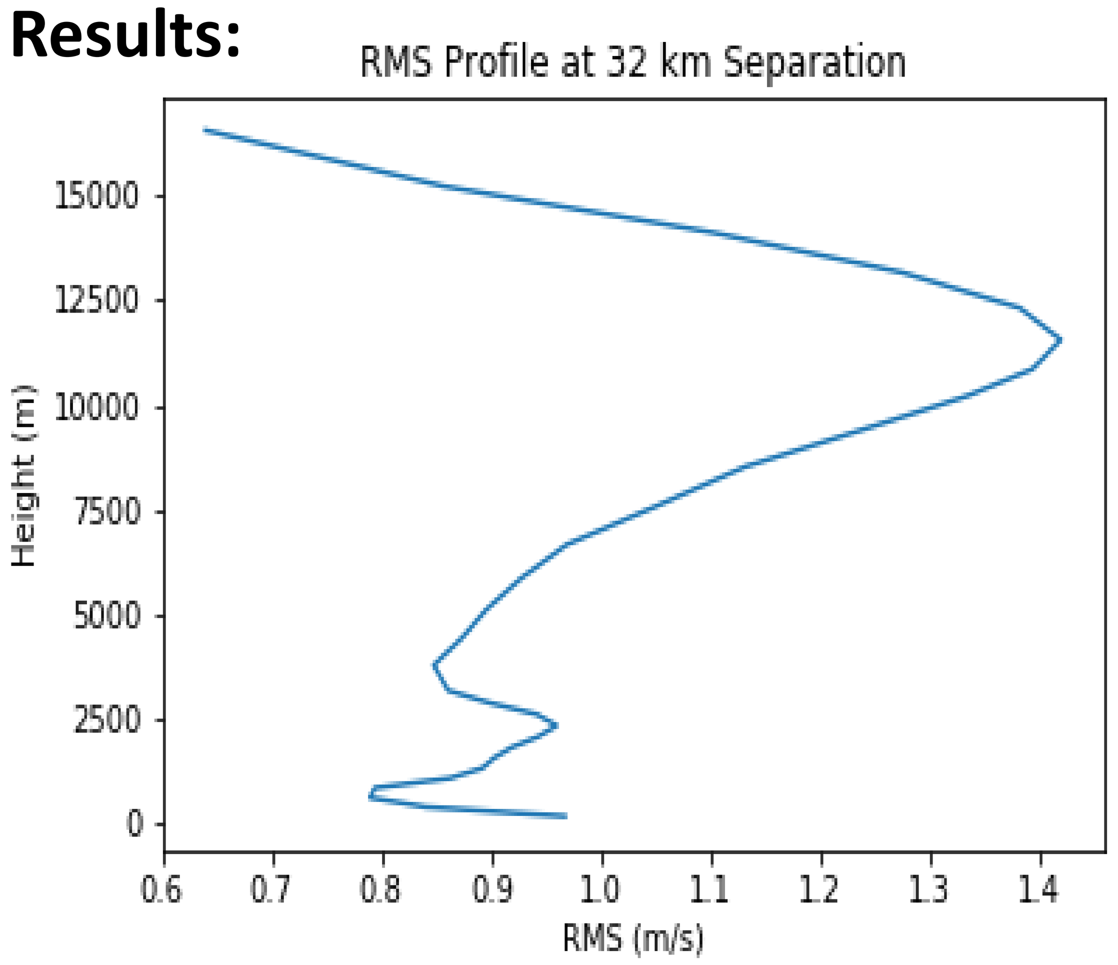


Data & Methods:

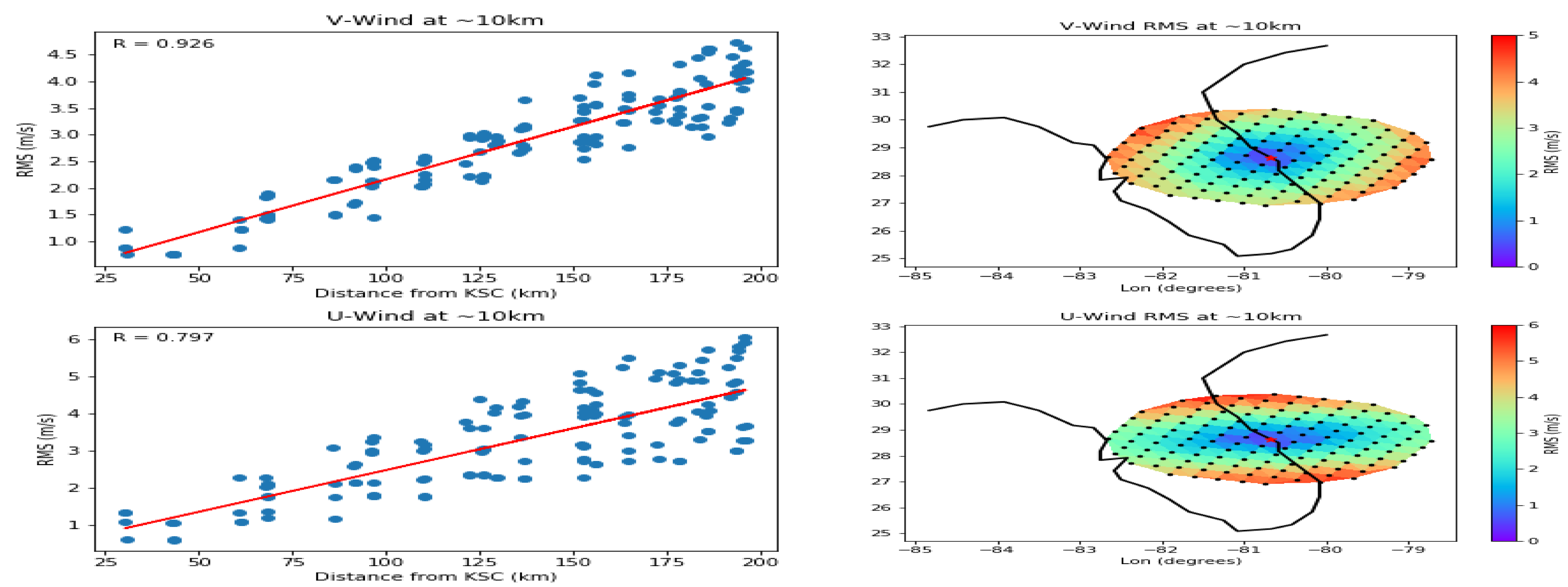
- NARR grid points within 200 km radius of KSC are used
- 32 km grid spacing, 29 pressure levels from 1000 mb to 10 mb, POR Jan 1979 – Apr 2018
- Distance between each point and KSC is calculated via Vincent ellipsoid method
- Direction difference calculated via compass bearings
- RMS deltas calculated between concurrent wind profiles from KSC and each grid point for entire POR
- RMS deltas separated by distance and direction

$$X_{RMS} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2}{n}} \left[\frac{m}{s}\right]$$

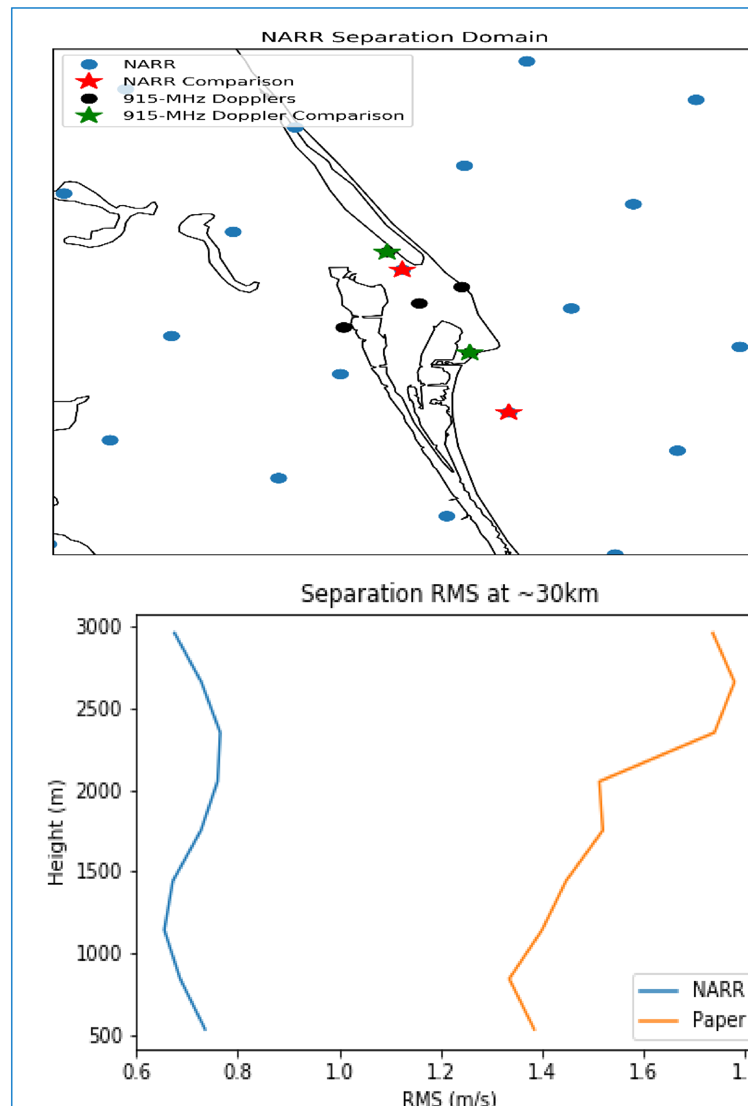
Results:



Profiles of RMS errors with height calculated at each grid point



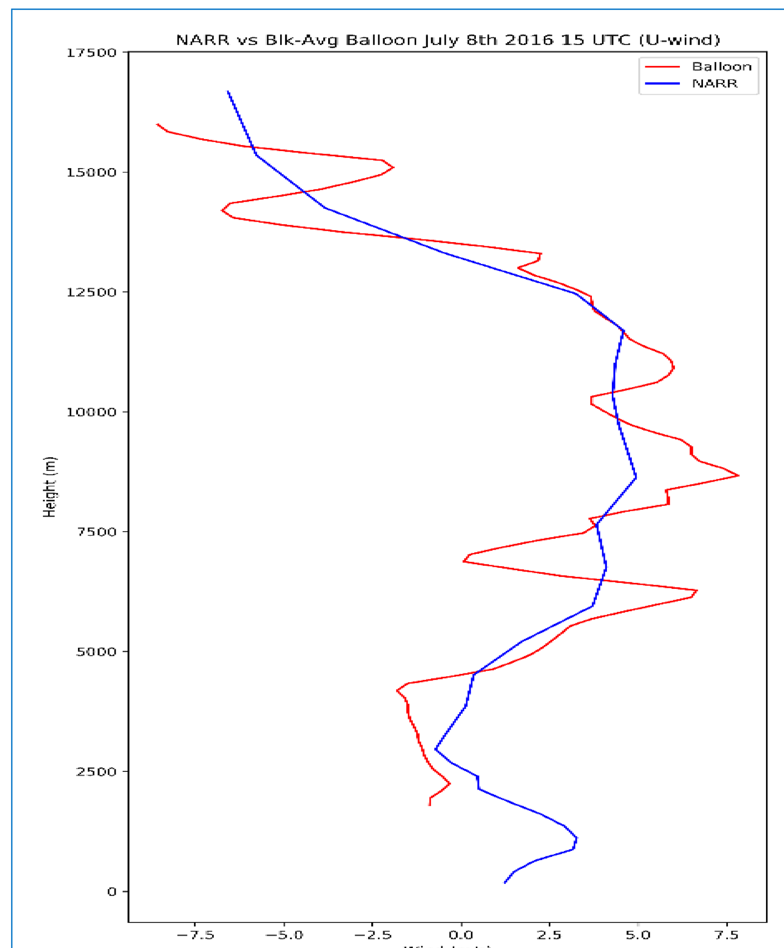
Linear regression and heat map plots showing changes in distance at a single height slice (10 km). RMS errors increase with distance. V-wind (U-wind) errors maximized in the East and West (North and South).

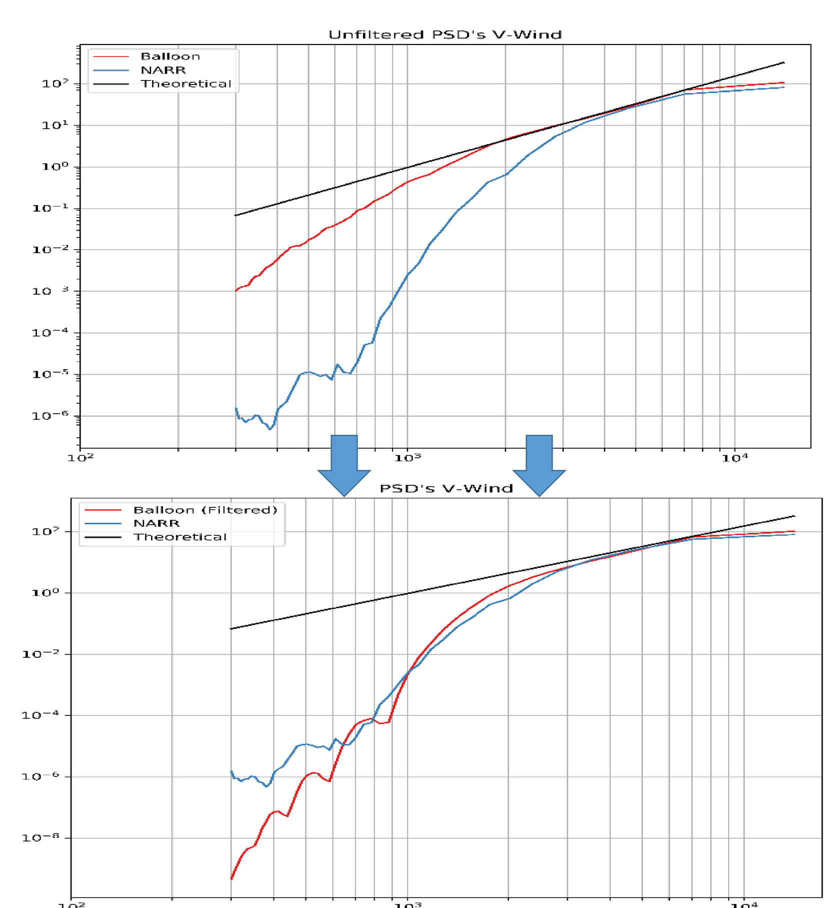


Results of similar points are compared to previous study by Merceret and Ward (2006):

- Structure functions created based on separation of 915 MHz doppler radars
- Square root of the structure functions give RMS deltas
- Largest separation distance was roughly 30 km

Errors found in this study are roughly 50% of those found in Merceret and Ward (2006)





Spectral Analyses of NARR vs balloon data shows NARR does not resolve the small wavelength wind features captured by the balloon system, due to the coarse nature of the NARR data. Total difference between NARR and balloon data is likely a combination of spatial differences and small scale winds. Corrections for small scale winds can be found via the following:

- Low-pass filter measured data to obtain matching or similar spectral content to NARR data
- Take the difference between the original measured data and the new filtered measured data
- The difference between the two should yield the errors caused by using a coarse/smoothed data set

This process can be replicated for any measurement system

Conclusions:

- Overall spatial separation RMS deltas (when not accounting for small scale features) range between 0.5 m/s to 6.3 m/s for separations between 30 km and 200 km
- The highest RMS deltas occur at a height of around 10 km
- In general, the larger the separation, the higher the RMS deltas
- Comparing results to a previous study (Merceret and Ward, 2006) show the RMS deltas obtained here are about half of what was previously found
- Including the small scale correction of the NARR with these numbers will likely yield results closer to reality
- If desired for launch vehicle wind assessments, results from this study can be used to account for wind uncertainty due to spatial separation between the measurement location and the vehicle flight path