Quantifying Spatial Separation Error in Tropospheric Wind Measurements

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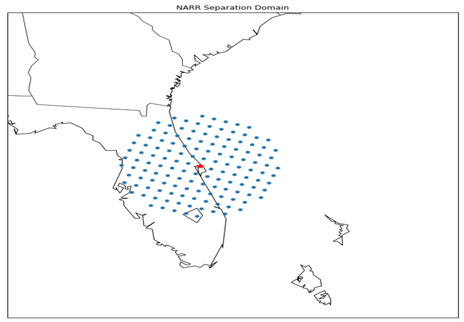
Introduction:

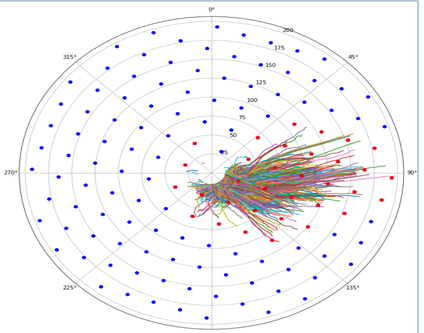
Wind measurements from the surface through the troposphere are an important asset for both range and Day of Launch (DOL) operations. Weather balloons have long been used to fulfill this operational need. Decker (2017) found balloons at Kennedy Space Center (KSC) can drift as far as 200 km from the launch site. Curtis et al. (2019) found Root Mean Square (RMS) wind deltas between 0.5 m/s and 6.3 m/s for separations between 30 km and 200 km from KSC using the North American Regional Reanalysis (NARR) model. The purpose of this study is to validate the model-based results found in Curtis et al. (2019) with observed wind and separation deltas calculated between the NASA Tropospheric Doppler Radar Wind Profiler (TDRWP) and weather balloons.



All NARR grid points within 200 km of KSC (blue) and the grid point representing KSC (red)

Data & Methods:

- NARR, Balloon, and TDRWP data taken from 1 June 2016 to 30 June 2017.
- Balloon vs TDRWP comparisons binned into nearest NARR grid point.
- Binning is done via a vector difference nearest neighbor algorithm comparing balloon tracks to initially selected group of grid points within 200 km of KSC.
- Only balloon separations of 16 km or greater considered.
- Each grid point must have at least 10 samples at any given altitude to be considered.
- Observed and NARR RMS deltas calculated for each chosen point.

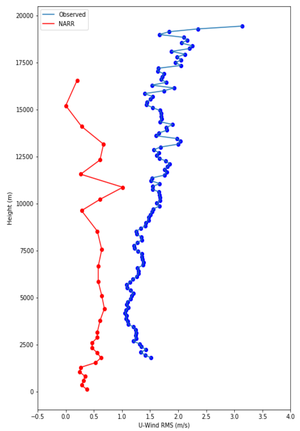


Balloon ground tracks (lines), NARR grid points (blue), and chosen NARR grid points (red)

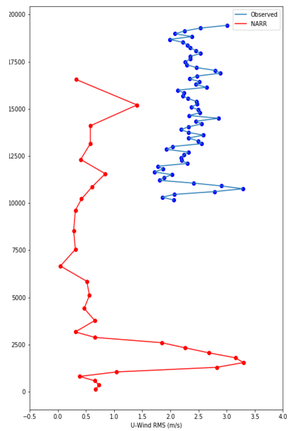
Results:

The below figures show RMS deltas for the NARR and observed data at selected grid points, as well as RMS values across all points, for both u- and v-wind.

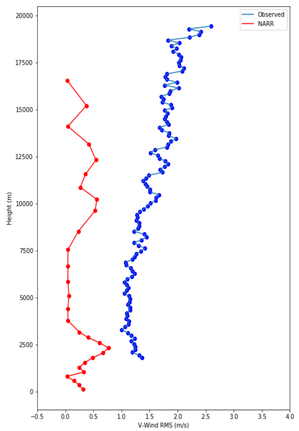
30 km U



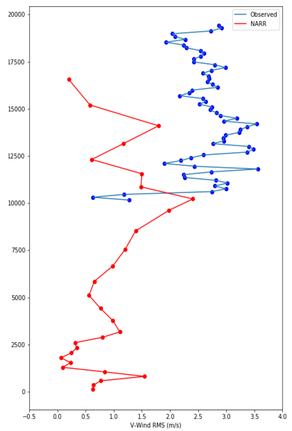
70 km U



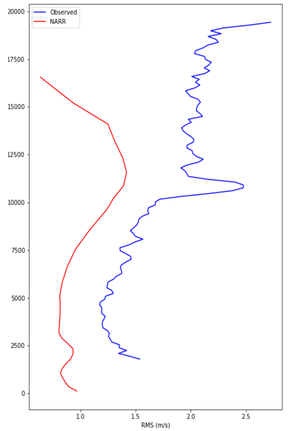
30 km V



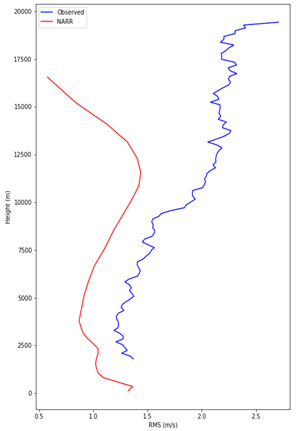
70 km V



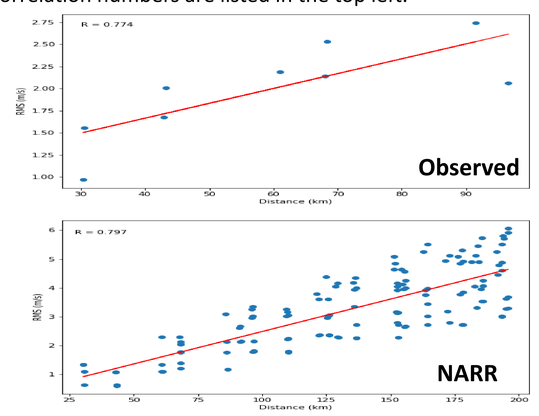
All U

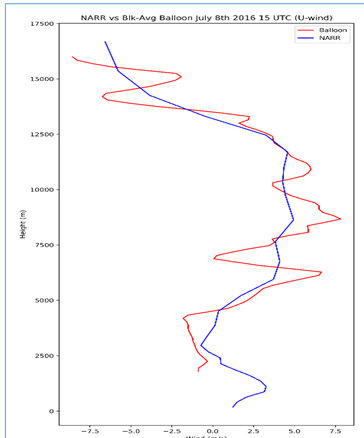


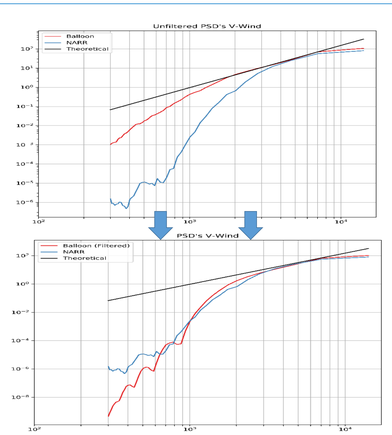
All V



The following two plots are scatter plots and linear regression lines of RMS values against distance for u-wind at an altitude of 10 km for observed data (top) and NARR (bottom). Pearson correlation numbers are listed in the top left.







A caveat noted from Curtis et al. (2019):

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 could account for the differences noted in the RMS wind delta comparisons.

This process can be replicated for any measurement system.

Conclusions:

- Errors due to spatial separation are almost always under-represented using the NARR dataset compared to observed data between the TDRWP and weather balloons.
- In the NARR dataset the RMS deltas begin to decrease after approximately a 10 km height while in the observed dataset they are increasing throughout most of the vertical profile.
- Linear regression and Pearson correlations between distance and RMS deltas are similar between the two datasets indicating a similar increasing relationship between spatial separation and wind error.
- The results from this study can be used to adjust balloon wind data by accounting for uncertainty due to spatial separation.
- Future work includes adding in the small scale correction as noted in the caveat from Curtis et al. (2019) and continuing to add more data to the observed database.