Impact of the Local Roughness on 2DVAR Wind Analyses During Hurricane Sandy

Steven M. Lazarus[1], *slazarus@fit.edu*, (321)431-3705
Michael E. Splitt[1], John D. Horel[2], Xia Dong[2]
[1]Florida Institute of Technology; [2]University of Utah

INTRODUCTION:

The utility of surface winds in operational data assimilation/analysis systems is often limited due to relatively high rejection rates (e.g., Pondeca et al. 2011). To a large extent, the wind observations are rejected a priori – automatically flagged as a result of residing within one of a number of 'black lists' or having been identified as problematic with respect to a particular assimilation system (e.g., Benjamin et al. 2010). The surface wind observations that survive these *initial* quality control measures are typically compared to the first- guess (background) wind field. For surface analyses, the background winds are often diagnosed by bringing the 'forecast' winds down (from the lowest model level) to the surface (10 m) via the application of Monin-Obukhov (M-O) theory. Even in the absence of observation and model error, this process can introduce discrepancies between forecast and observed winds due to differences in 1) atmospheric stability, and 2) surface roughness. Here we focus on the latter in which model (observed) roughness is given as a bulk (local) quantity that is independent of (dependent on) wind direction.

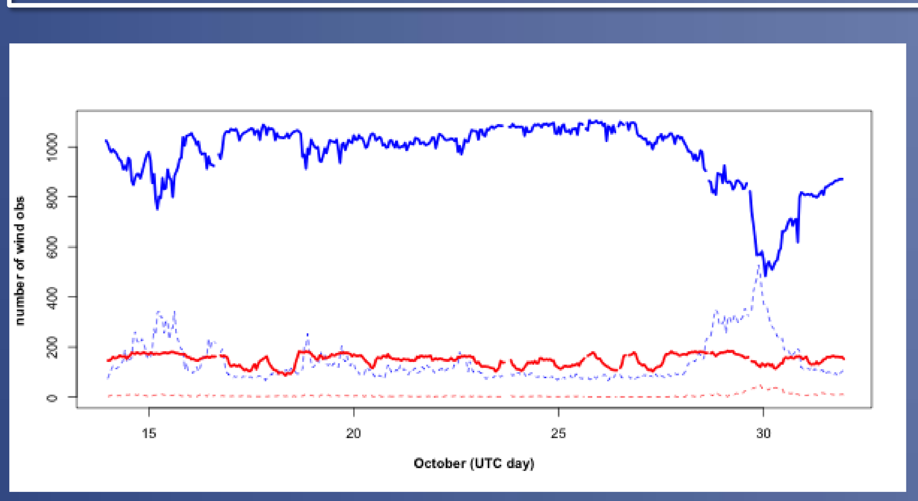

Fig. 1. Time series of the number of analysis observations for ALL (solid blue), and adjusted (YAD, red solid line) experiments. Also shown are the number of corresponding rejected observations (colored dashed lines).

UU2DVAR:

This work employs the University of Utah Variational Surface Analysis (UU2DVAR) – a two-dimensional data assimilation system that analyzes 2 m air temperature and dew point, 10 m winds (u and v components) and wind speed, and surface pressure (Tyndall and Horel 2013). For computational purposes, the analysis is formulated in observation space significantly lowering the order of the matrix inversions. The innovation vector (LHS, Eq. 1) is expressed as

$$\mathbf{y}_o - \mathbf{H}(\mathbf{x}_b) = (\mathbf{HBH}^T + \mathbf{R})(\mathbf{BH}^T)^{-1}(\mathbf{x}_a - \mathbf{x}_b), \quad (1)$$

where $\mathbf{y}_o$ is the observation vector, **H** is a forward operator, **B** and **R** are the background and observation error covariance, and $\mathbf{x}_a$ and $\mathbf{x}_b$ are the analysis and background. By setting $\eta = (\mathbf{BH}^T)^{-1}(\mathbf{x}_a - \mathbf{x}_b)$, the analysis vector is given by

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{BH}^T\eta \quad (2)$$

η is computed iteratively by solving Eq. (1), and the analysis is subsequently obtained via Eq. (2). A *background bias correction* is defined by a first order auto-regressive model (AR1) whereby the current analysis bias (b_k) depends on the previous day's bias (i.e., 24 h prior – b_{k-1}) and weighted (α = 0.15) analysis increment [d**x** = K($\mathbf{y}_o$ – **H**($\mathbf{x}_b$)), where K is an error covariance-dependent weight].

$$b_k = b_{k-1} - \alpha d\mathbf{x}. \quad (3)$$

DATA:

The background wind field is obtained from downscaled (from 13 km-to-5 km, Benjamin et al. 2007) 1 h Rapid Refresh (RR) forecasts. Observations consist of those that reside within the MesoWest database – augmented by 131 WeatherFlow stations located within the coastal zone in the northeast US (see Fig. 2). The WeatherFlow data include direction-dependent (22.5° bins) *local* surface roughness (z_0) that are used to 'adjust' the 10 m winds by bringing them up to a 60 m blending height using the *local* (observed/estimated) roughness and then back down to 10 m using the bulk (model) roughness (*see companion poster #638 by Splitt et al.*).

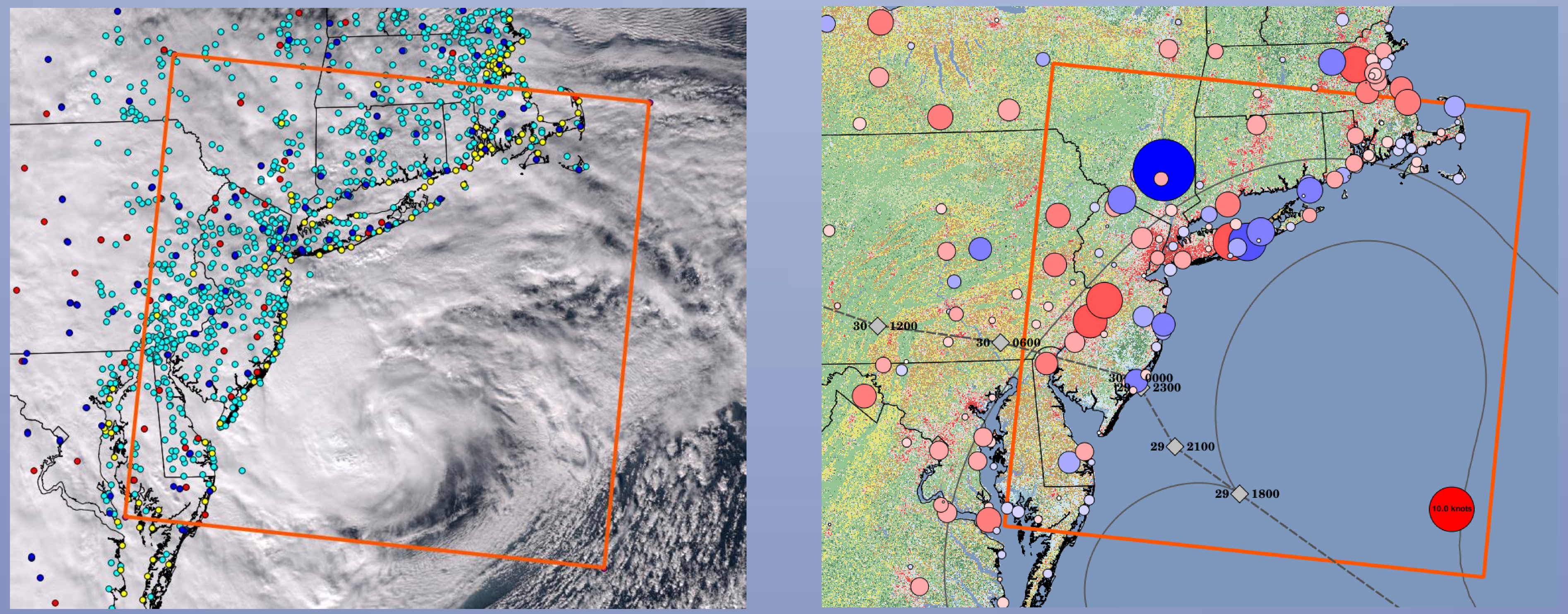

Fig. 2. LEFT: Analysis observation locations by network – RAWS (filled red circles), NWS (filled blue circles), WxFlow (filled yellow circles), and 'other' (cyan filled circles). For the RAWS, NWS, and WxFlow stations a z_0 wind adjustment is possible. Also shown is a GOES visible image valid 1735 UTC October 29 2012. RIGHT: Wind adjustments (kt) valid 23 UTC 29 October 2012. The red (blue) circles indicate negative (positive) wind speed adjustments for which the observed wind speed is reduced (increased) based on differences between the local and bulk roughness. Also shown: NLCD 2006 land cover, and the NHC's Best Track storm position (dashed gray line) and wind radii (50 and 64 kt, solid gray lines).

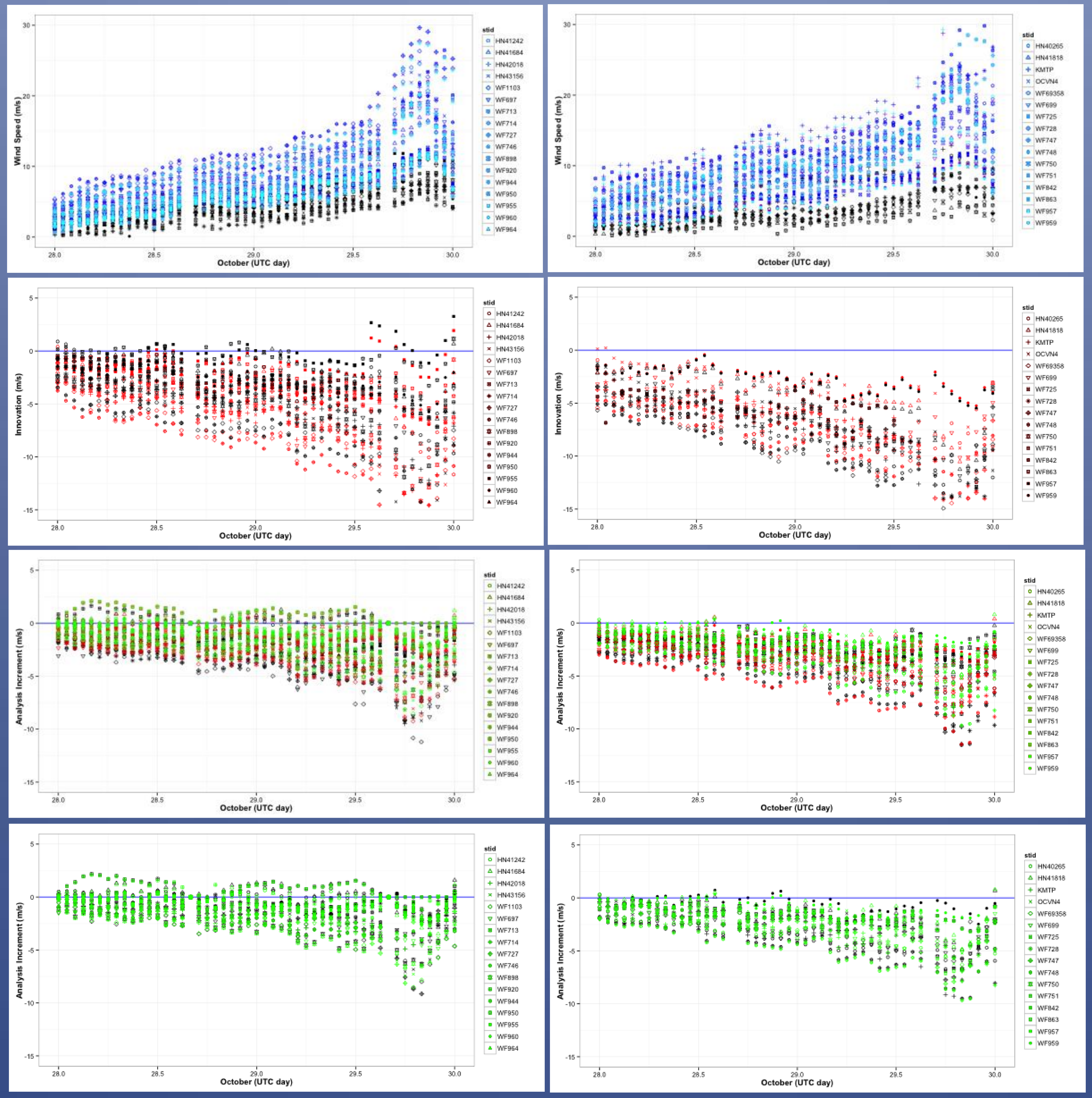

Fig. 3. LEFT (RIGHT): Stations with 'large' negative (positive) z_0 differences compared to the bulk roughness i.e., bulk roughness > (<) the local (northeast flow) z_0. TOP: observed (black symbols) and background wind speed (m/s) for NAD_SUB_NBC (blue), NAD_SUB_YBC (purple), and YAD_SUB_YBC (cyan). ROW 2: Wind speed innovations (m/s) for NAD_SUB_NBC (black) and YAD_SUB_NBC (red). ROW 3: Wind speed increments (m/s) for YAD_ALL_NBC (black), YAD_SUB_NBC (red), and YAD_SUB_YBC (green). BOTTOM: Wind speed increments (m/s) for NAD_SUB_YBC (black) and YAD_SUB_YBC (green).

Table 1. The eight experiments. N(Y)AD – no (yes) wind adjustment, ALL (SUB) – all (subset) of observations are ingested , N(Y)BC – no (yes) bias correction.

Exp. Name	AD	ALL	BC
NAD_ALL_NBC		x	
NAD_ALL_YBC		x	x
YAD_ALL_NBC	x	x	
YAD_SUB_NBC	x		
NAD_SUB_NBC			
YAD_ALL_YBC	x	x	x
YAD_SUB_YBC	x		x
NAD_SUB_YBC			x

ANALYSES:

A modified (new) version of the UU2DVAR is implemented here. This version allows for the creation of a smaller (subset) analysis domain from within that of the CONUS region used by Tyndall and Horel (see their Fig. 1, 2013). The subdomain used here is delineated by the orange box in Fig. 2. A one degree lat/lon observation buffer is applied around the analysis subdomain to avoid spurious 'edge' effects. With the exception of the horizontal decorrelation length scale (see Eq. 4 Tyndall and Horel 2013), which is set to 20 km here, all other analysis parameters are set to their 'operational' values. A series of *8 distinct experiments* (3456 analyses) are performed for which the UU2DVAR is run hourly for 18 days (October 14-31 2012) on the 'Sandy' subdomain (see Table 1).

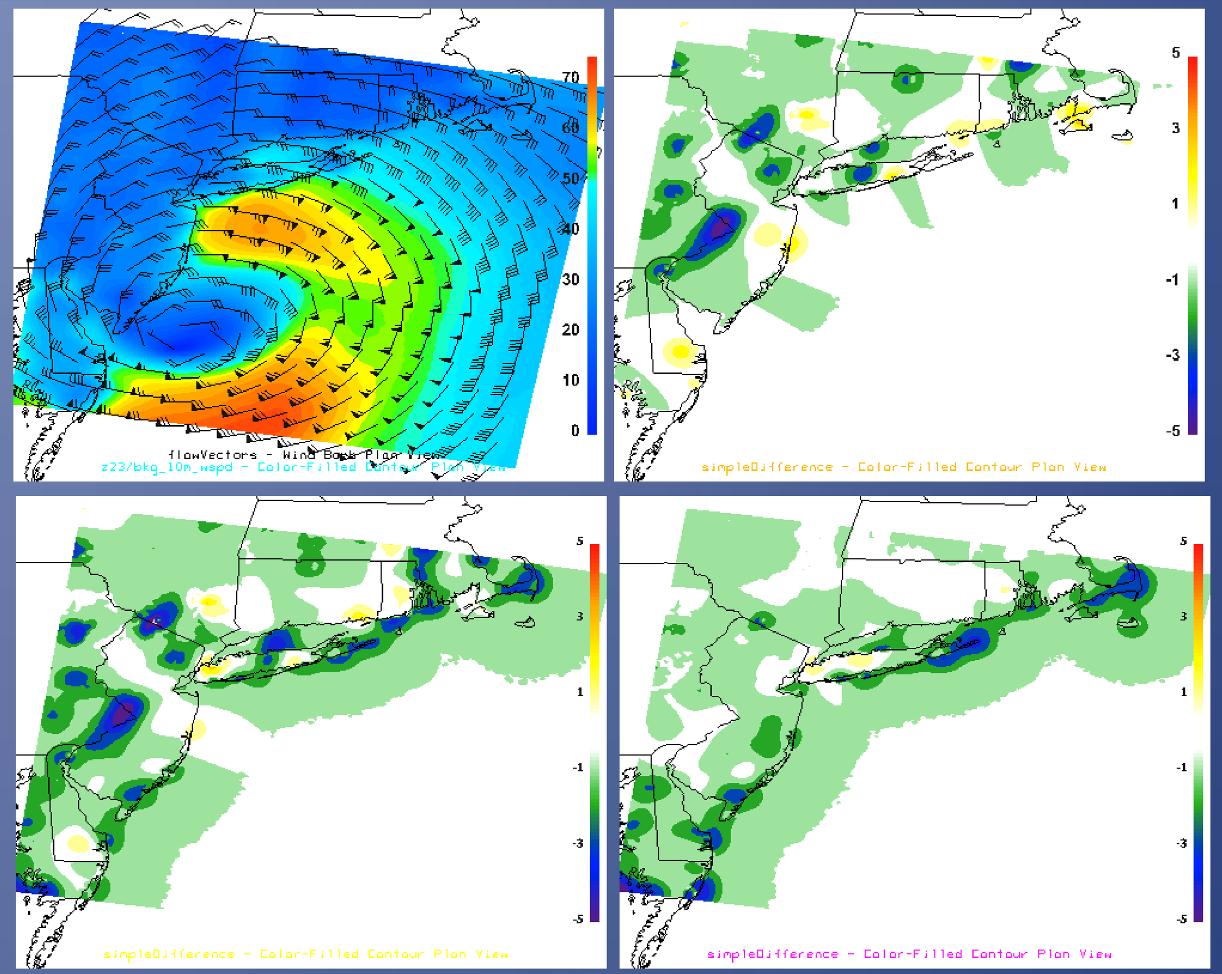

Fig. 4. TOP LEFT: RR background wind speed (2 kt contour interval, shaded color) and wind barbs (kt). UU2DVAR analysis wind speed differences (1 kt interval) from the <u>same</u> 'baseline' experiment (i.e., NAD_SUB_NBC). TOP RIGHT: YAD_SUB_NBC, BOTTOM LEFT: YAD_SUB_YBC, BOTTOM RIGHT: NAD_SUB_YBC. Analyses valid 23 UTC 29 October 2012.

HIGHLIGHTS:

- *Bias correction improves* with use of adjusted winds (TOP Fig. 3)
- *Innovation response differs* between the two z_0 subsets. When the bulk z_0 is greater than the local (LHS Fig. 3) the adjusted wind speed decreases and the innovations increase (and vice versa).
- *Increment response differs* between the two z_0 subsets. When the bulk z_0 is less than the local (RHS Fig. 3), the adjusted wind speed increases and the increments become less negative (and vice versa).
- For both z_0 subsets, the *bias correction reduces the analysis increment*.
- Background winds are biased high (over land, TOP row Fig. 3, black symbols). If the only error present was in the z_0 specification, both roughness subsets should show improvements.
- The 'true' model bias may actually be higher in some locations (and wind directions).

REFERENCES & ACKNOWLEDGEMENTS:

- Benjamin, S. G., B. D. Jamison, W. R. Moninger, S. R. Sahm, B. E. Schwartz, and T. W. Schlatter, 2010: Relative Short-Range Forecast Impact from Aircraft, Profiler, Radiosonde, VAD, GPS-PW, METAR, and Mesonet Observations via the RUC Hourly Assimilation Cycle. *Mon. Wea. Rev.*, **138**, 1319–1343.
- Benjamin, S. G., J. M. Brown, G. Manikin, and G. Mann, 2007: The RTMA Background – Hourly Downscaling of RUC Data to 5 km detail. *23rd Conference on IIPS*, AMS. January 2007, San Antonio, TX.
- De Pondeca, M., and Coauthors, 2011: The Real-Time Mesoscale Analysis at NOAA's National Centers for Environmental Prediction: Current Status and Development. *Wea. Forecasting*, **26**, 593–612.
- Tyndall, D. P. and J. D. Horel, 2013: Impacts of Mesonet Observations on Meteorological Surface Analyses. *Wea. Forecasting*, **28**, 254–269.

This research was sponsored by the NWS National Mesonet Program and NOAA-NCEP/IMSG Grant # DG133W-10-CN-0111. The WeatherFlow data were provided by Bill Thorson of WeatherFlow Inc.