An Assessment of the Impact of the Assimilation of NASA TERRA MISR Atmospheric Motion Vectors on the NRL Global Atmospheric Prediction System

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Second JCSDA Symposium
Atlanta, Georgia, 6 February 2014

* Thanks also to Ben Ruston, Tanya Maurer, and Tim Whitcomb

Outline

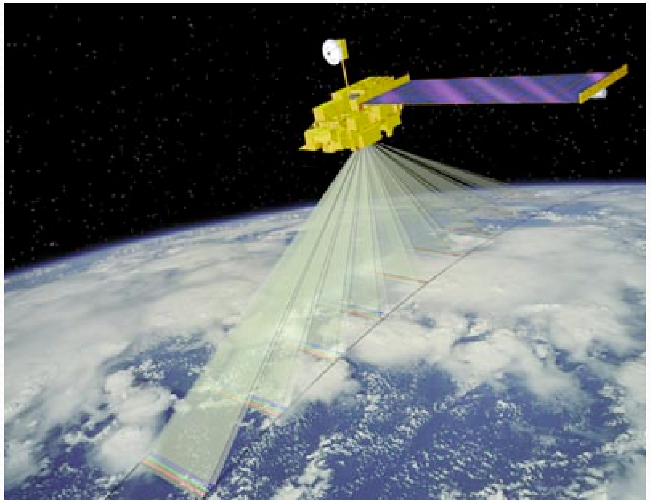
- Motivation
- MISR instrument
- Wind retrieval processing
- Experiment Design
- Forecast impact & Observation impact
- Summary and Future Work

Motivation

- **Evaluate TERRA MISR cloud motion vectors (CMV) impact on NWP**
  - The status of MISR CMV retrievals was presented at the 11^{th} International Winds Working Group meeting in Auckland, NZ.
  - We (NRL scientists) expressed an interest in assessing the value of these winds using our global NWP system
  - Since our global system already assimilates a large number of satellite AMVs, what additional benefit can be obtained from the MISR wind retrievals?
  - How are new observations complementary to the existing observations? Are they redundant, or do they fill a gap?

EOS TERRA MISR Instrument

- MISR: Multi-angle Imaging SpectroRadiometer
- On EOS-Terra, launched in 1999, sun-synchronous orbit
- Observations expected to continue until 2020
- Global coverage up to 85°, including traditional gap region between 50°-70° N/S for the sunlit pole
- Nine cameras for stereoscopic imaging and cloud pattern matching



MISR Cloud Motion Vectors

- Visible channel (670 nm)
- Parallax of stereoscopic images used to determine cloud top height
- Displacement in the 9 consecutive images is used to retrieve winds
- Retrievals are insensitive to atmospheric temperatures, radiometric calibration and complex surface types
- 17.6 km horizontal resolution, vertical resolution of ~500 m
- JPL provided a dataset that included only the highest quality CMVs (based on quality indicator and cloud confidence flags)
- CMVs with wind speed greater than 50 m/s were excluded
- Daytime only, no diurnal sampling
- Swath width ~ 400 km ➔longer revisit times (global coverage every 9 days)
- Anticipate latency could be < 3 hrs

Experiment Design

- **Forecast Model: NAVGEM v1.2.1 (planned spring 2014)**
  - T359L50, model top 0.04 hPa (around 70 km), horizontal resolution ~ 37 km
  - Semi-Lagrangian/Semi-Implicit dynamical core, forecast model, explicit clouds
- **Data Assimilation: NAVDAS-AR**
  - 4D-Var solved using accelerated representer technique
  - T359 outer loop, T119 (~ 111 km) inner loop resolution
  - Approximately 2.6 million obs/6 hrs (late data cut)
  - Radiance bias correction using variational bias correction approach
  - Began with zero bias coefficients (August 1, 2012)
- **Summer/Fall 2012 case : 15 August - 15 November, 2012**
  - 5-day forecasts at 00, 12 UTC
  - Observation impact computed every 6 hrs

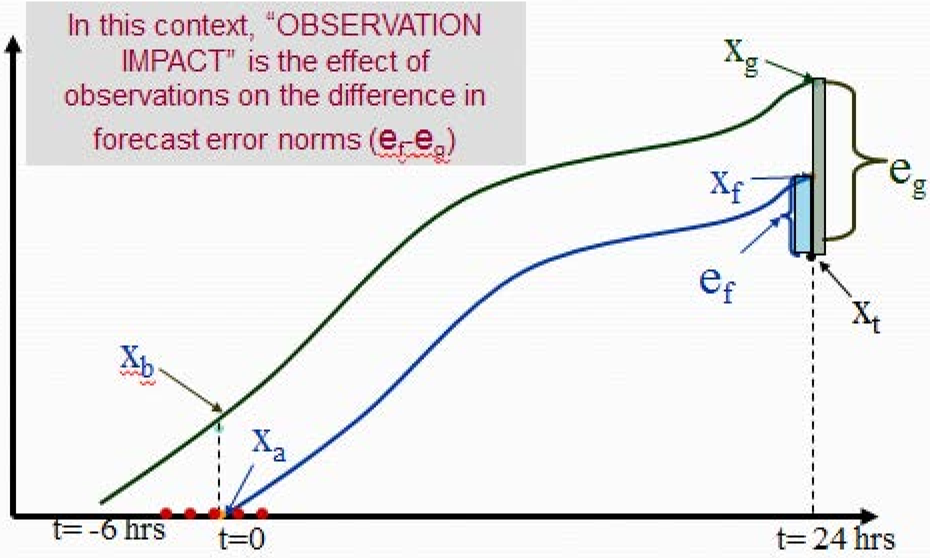
NAVDAS-AR: NRL Atmospheric Variational Data Assimilation System – Accelerated Representer
NAVGEM: Navy Global Environmental Model

NRL Processing of JPL MISR Winds

- Cloud top heights are converted to pressures using methods applied for pibals and airborne wind lidar
- Winds super-obs are generated using NRL method
- Assimilated winds up to 100 hPa
- Super-ob prism size was 1.0 degrees
- Vertical bin set to 50 hPa
- Default ob errors (same as for geostationary winds)
- Low wind speed threshold of 7.071 ms^{-1} applied

Observation Impact Methodology

- Mathematical technique using NAVDAS-AR and NOGAPS adjoint models
- Use a moist total energy error norm
- Observation impact products generated operationally 4x per day
- Results are used to refine observation usage
    - evaluate observation quality, satellite channel selection and tune observation reject lists



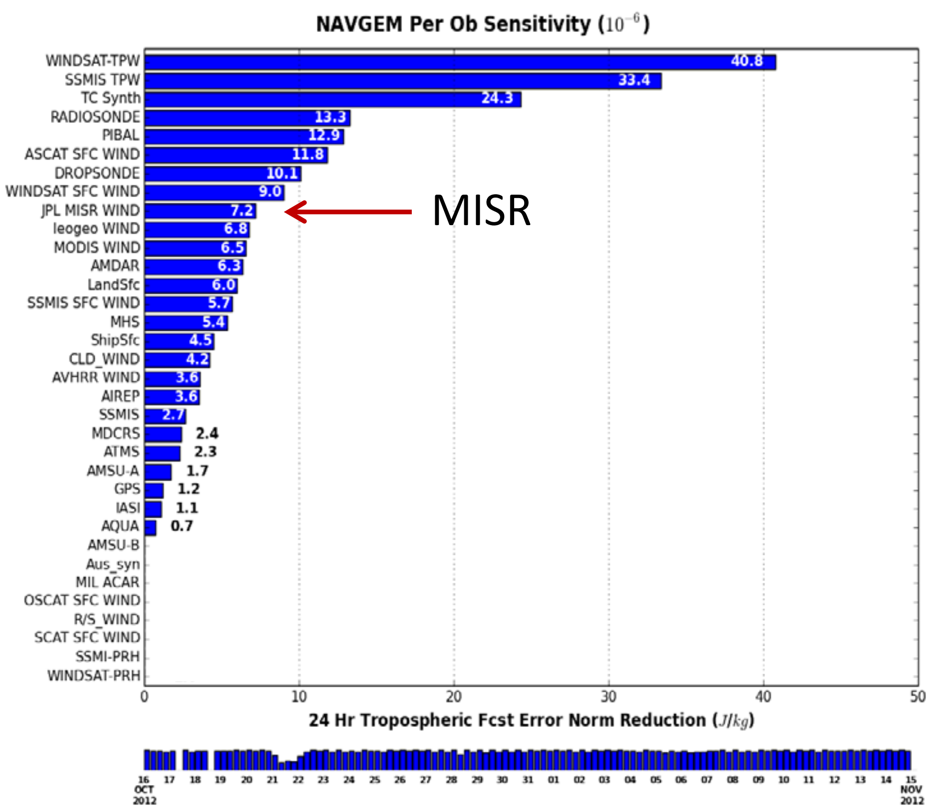
Observations move the model state from the "**background**" trajectory to the new "**analysis**" trajectory

The forecast error difference is due to the impact of all $e_{24} - e_{30}$ observations assimilated at 00UTC

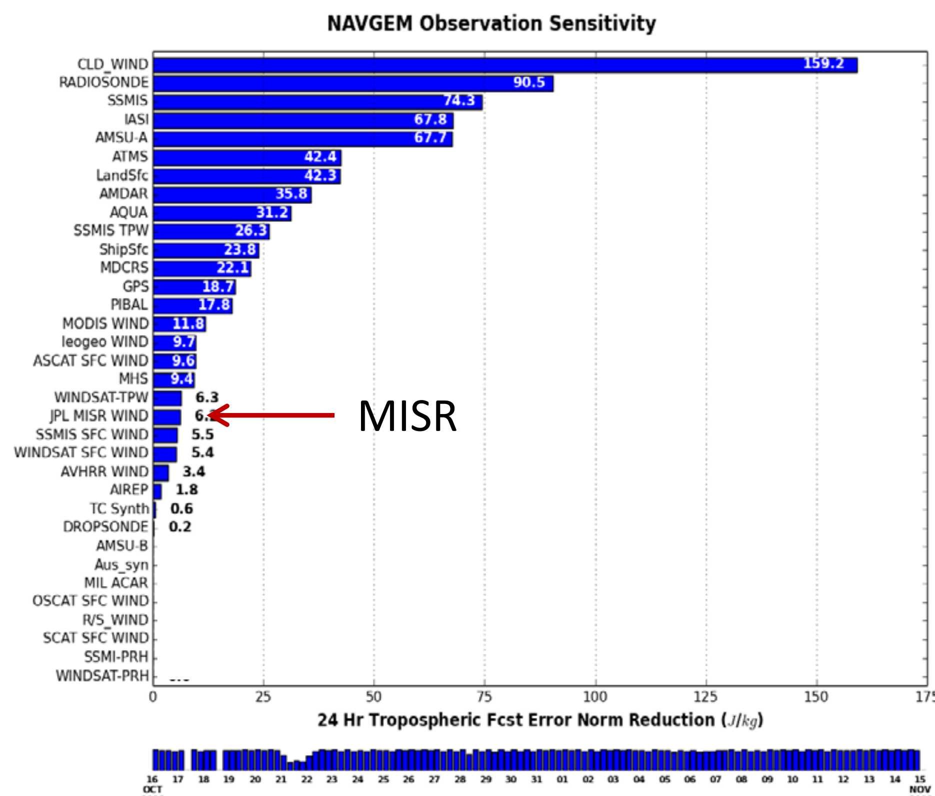
Baker and Daley (QJRMS, 2000); Langland and Baker (Tellus, 2004)

Sept 15th, 00 UTC through Nov 15th, 12 UTC
Percent Reduction in Moist Error Norm
Observation Impact computed every 6 hrs

MISR wind assimilation



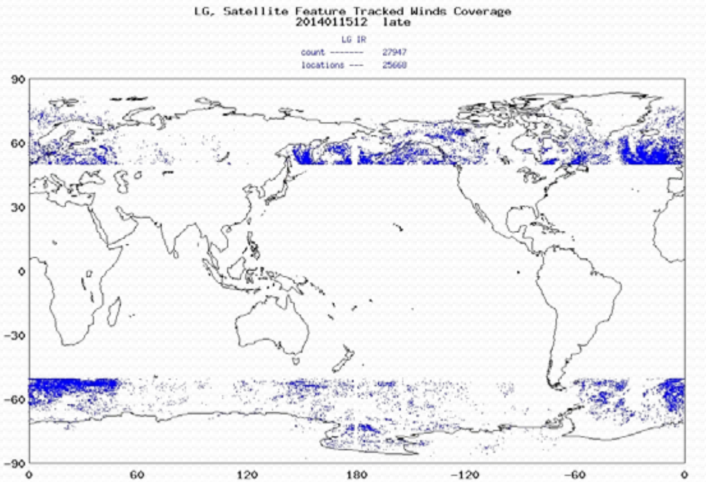
Per observation impact (J/kg)



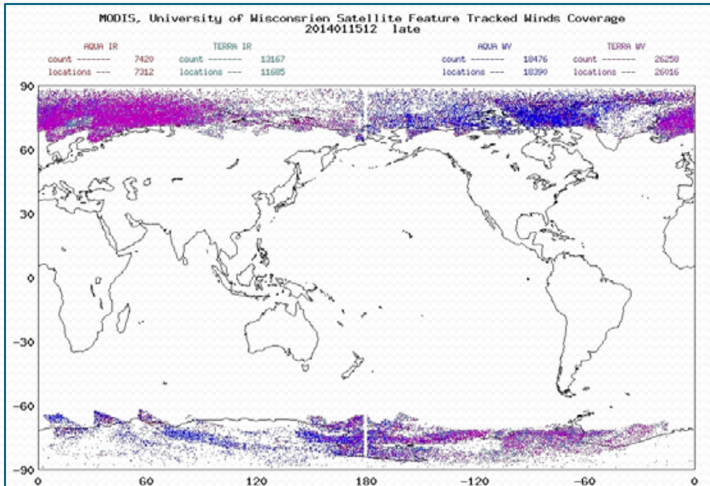
Percent reduction per observation type

CIMSS LEO-GEO/MODIS/GEO/MISR Winds

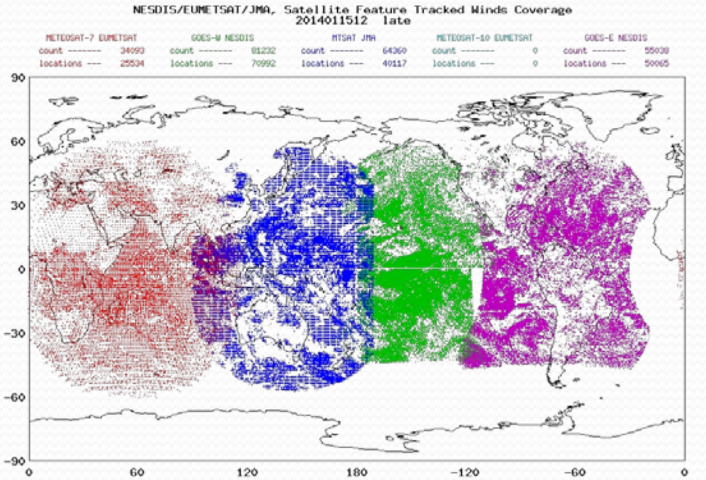
Coverage diagrams do not shown distribution in height and time



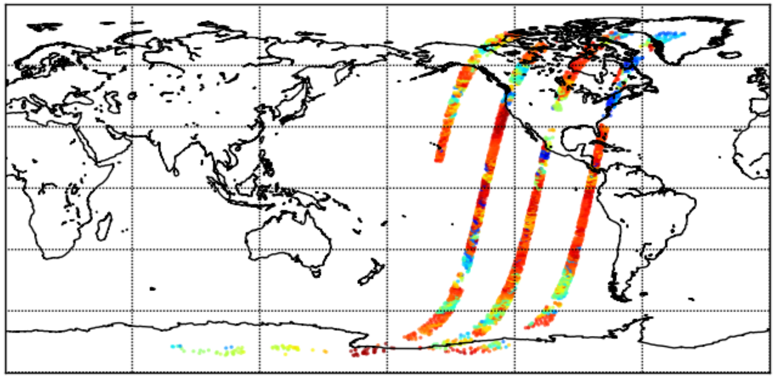
CIMSS Leo/Geo



CIMSS MODIS

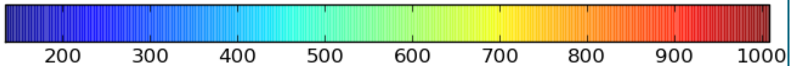


NESDIS/EUMETSAT/JMA Winds



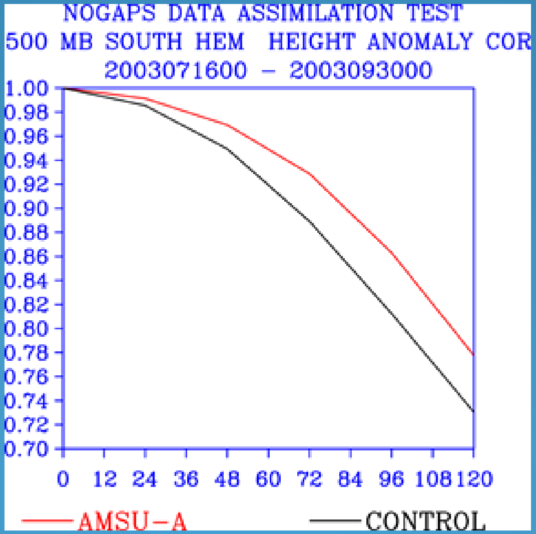
JPL MISR - 2012102818

Pressure



Results from MISR Assimilation Experiments

Unfortunately, these days are long gone …

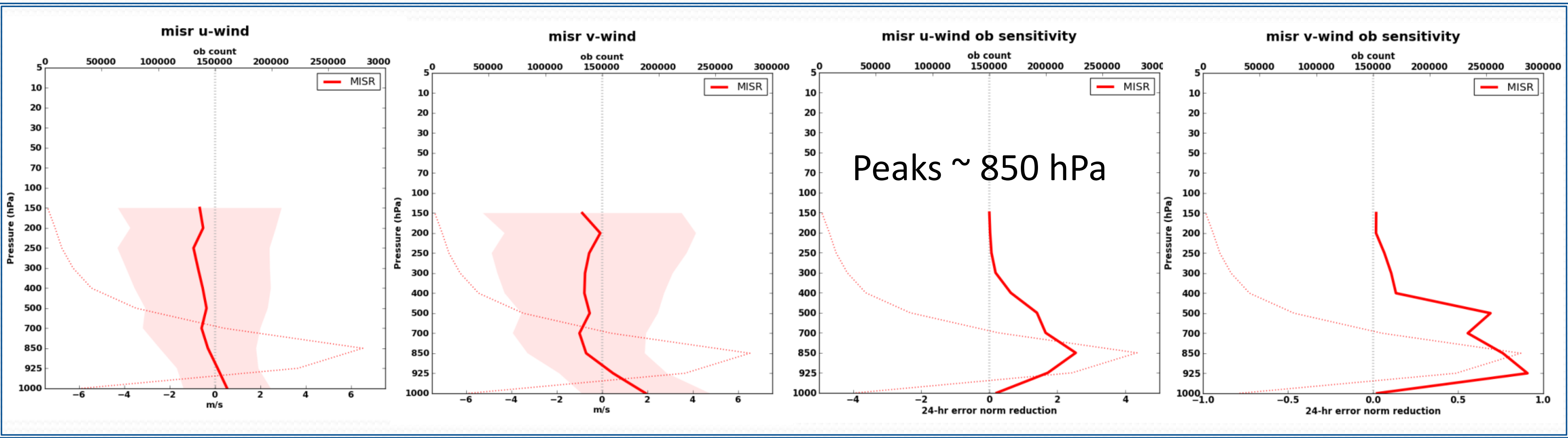


TERRA/MISR (top) and TERRA/MODIS (bottom)

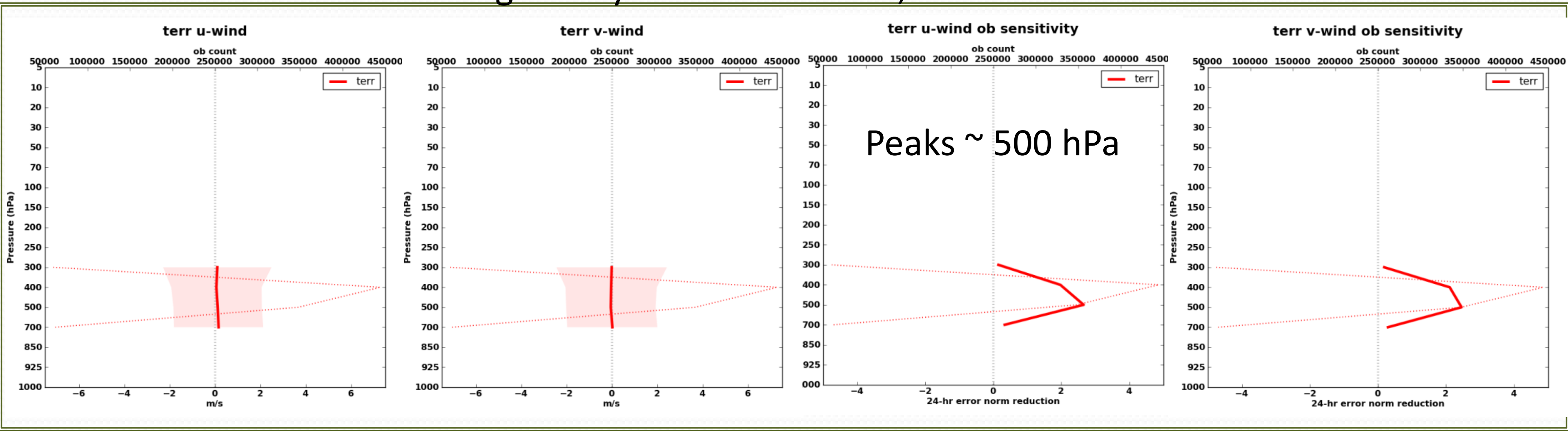
mean u and v wind innovations(ob-bk) (ms^{-1}) - left panels

total u and v ob impact (Jg^{-1}) - right panels

data for 2012091512 – 2012111512; ob counts dashed lines



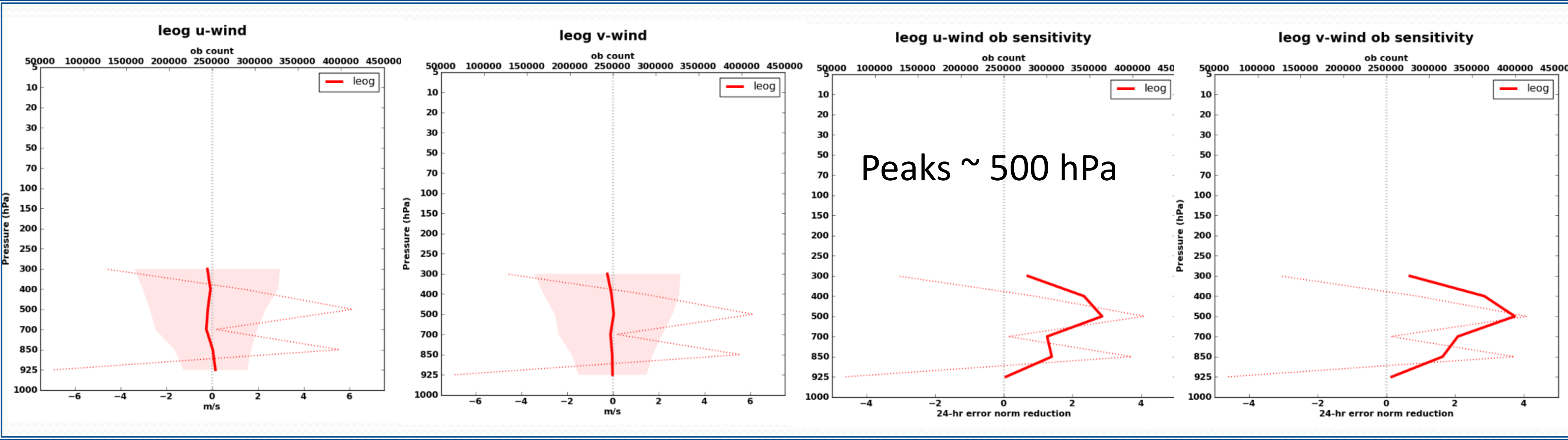
Observation counts are given by dashed red lines; note low data counts at some levels



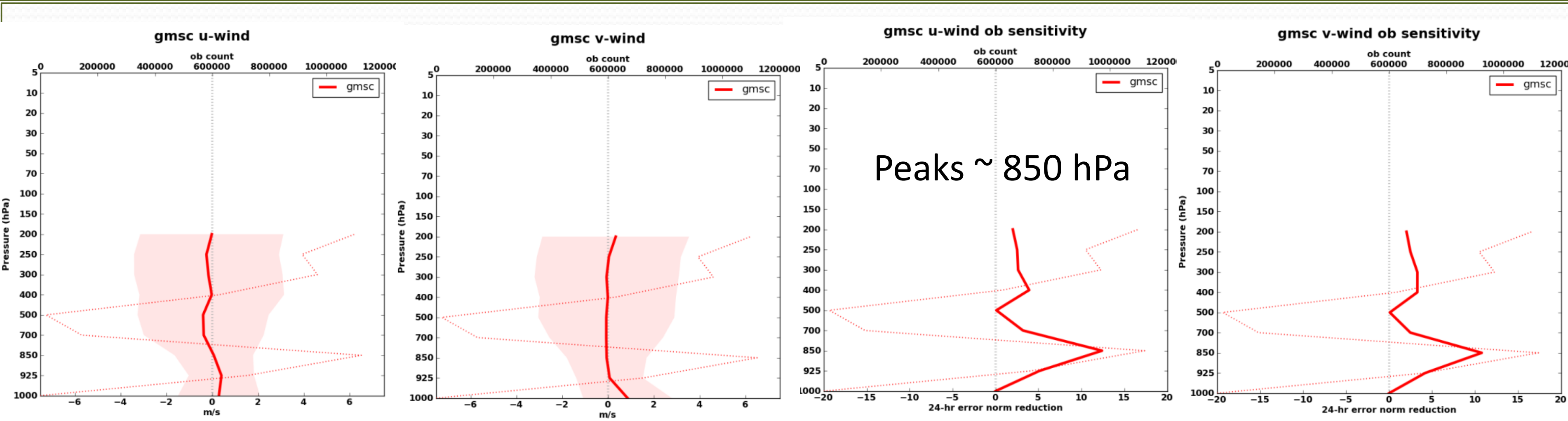
Mean u-wind innovation | Mean v-wind innovation | u-wind ob impact | v-wind ob impact

Leo/Geo (top) and MTSAT (bottom); from CIMSS

mean u and v wind innovations(ob-bk) (ms^{-1})
total u and v ob impact (Jg^{-1})
data for 2012091512 – 2012111512; ob counts dashed lines

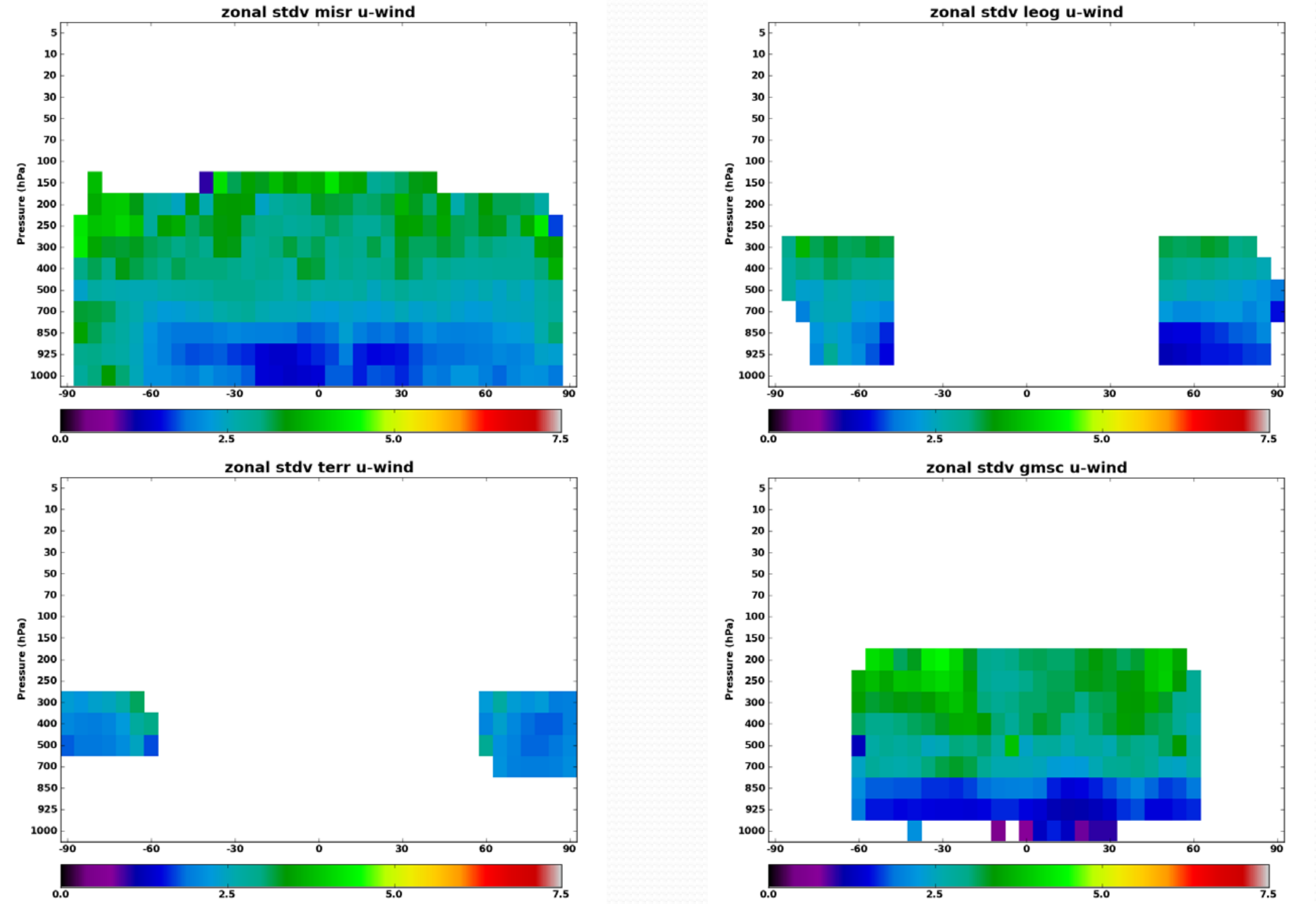


Observation counts are given by dashed red lines; note very low data counts at some levels

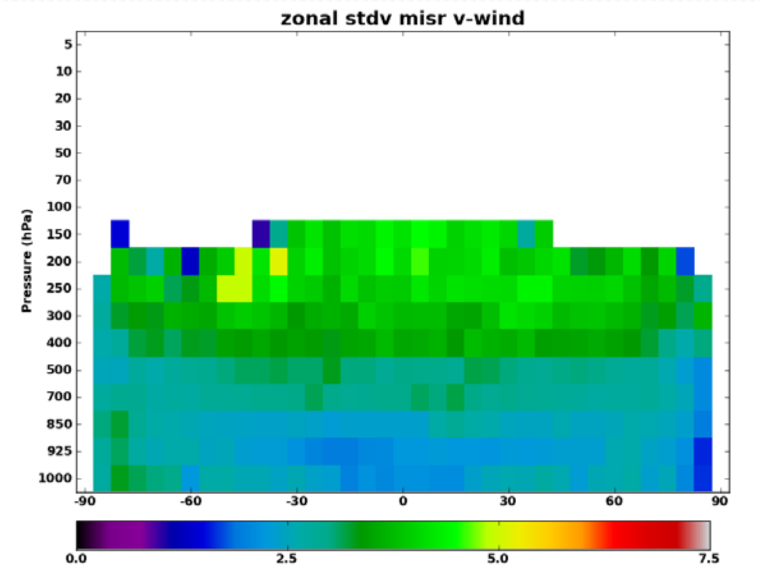


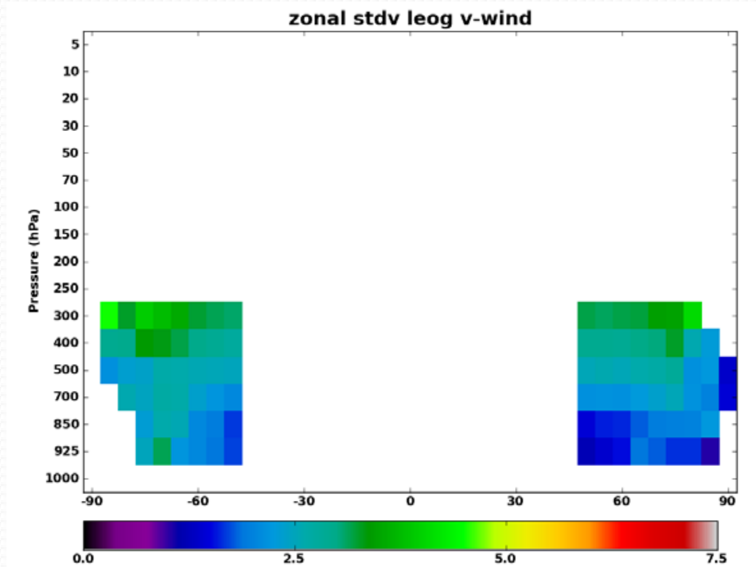
Mean u-wind innovation | Mean v-wind innovation | u-wind ob impact | v-wind ob impact

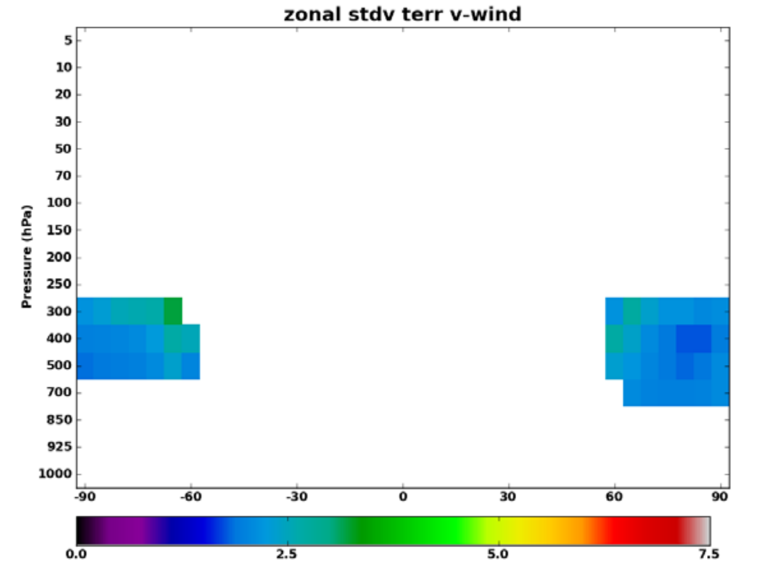
Innovation u-wind StDev(Sept. 15-Nov 15)

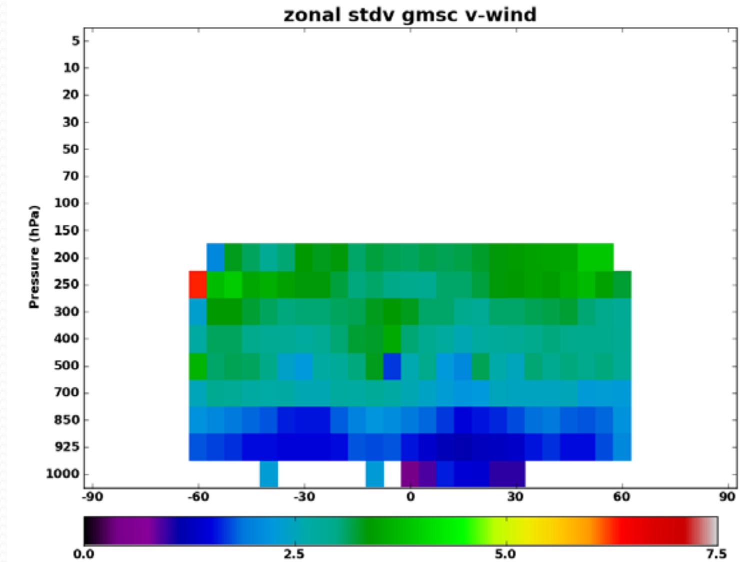


Innovation v-wind StDev (Sept. 15-Nov 15)





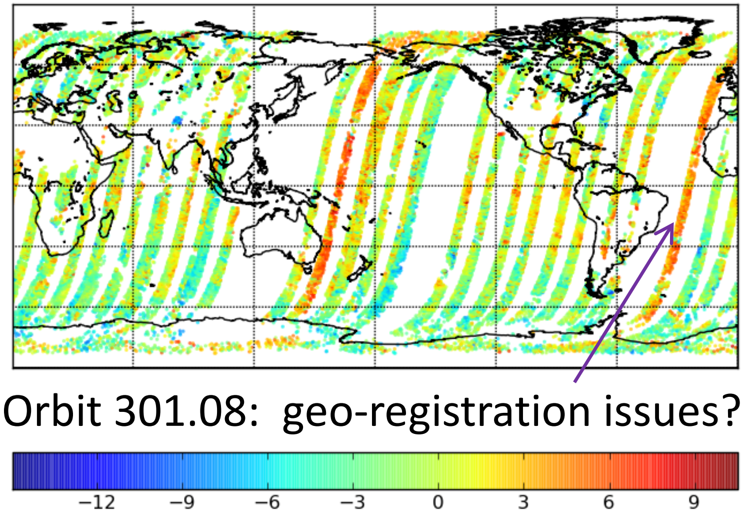




Conclusions and Future Work

- We see good overall impact from MISR winds
  - Low-level MISR winds appear to fill a data gap
  - Need to revisit quality control & assimilation procedures
  - Higher ob error variance for v-component winds
  - Carry JPL quality index along with the observation
  - Super-ob vs. thinning to capture MISR resolution
  - What is the optimum observation density?

MISR v-wind innovation
2012102700 - 2012102906



NASA ROSES-2013 award (PI: Dr. Junjie Liu, JPL)
Broader links to NOAA “Hurricane Sandy” sub-project (NOAA, NRL, NASA)

Acknowledgements

- NLB, PMP and RHL gratefully acknowledge support from the Naval Research Laboratory under program element 0601153N.

NAVGEM/NAVDAS-AR Data Summary

Conventional Data Types

- Radiosondes and Pibals
- Dropsondes
- Land, Ship and Buoy Surface Obs
- Aircraft Obs
  - AIREPS
  - AMDAR
  - MDCRS
- Synthetic Obs
  - TC Bogus

NOAA-15,16,18,19
METOP-A
AQUA, TERRA
GOES, MTSAT, METEOSAT
DMSP F16,17,18
WindSat
COSMIC 1-6, GRAS, GRACE-A,
SAC-C, CORISS, C/NOFS, Terra SAR-X

Satellite Data Types

- Surface Winds
  - Scatterometer, ASCAT
  - SSMI/SSMIS (4)
  - WindSat
- Feature Tracked Winds
  - Geostationary (5 satellites)
  - Polar Orbiters (AVHRR and MODIS)
  - Combined polar/geo winds (CIMSS)
- Total Water Vapor (TPW)
  - SSMI/SSMIS (4)
  - WindSat
- GPS Bending Angle (11)
- IR Sounding Radiances
  - IASI (T and WV) and AIRS
- MW Sounding Radiances
  - AMSU-A (Ch 4-14) (6)
  - SSMIS (Ch 2-7, 22-24) (3)
  - SSMIS/MHS 183 GHz (4)

Observation Impact Equation

$$\delta e_f^g = \left\langle (\mathbf{y} - \mathbf{H}\mathbf{x}_\mathrm{b}), \mathbf{K}^\mathrm{T} \left\{ \frac{\partial e_f}{\partial \mathbf{x}_\mathrm{a}} + \frac{\partial e_g}{\partial \mathbf{x}_\mathrm{b}} \right\} \right\rangle = \left\langle (\mathbf{y} - \mathbf{H}\mathbf{x}_\mathrm{b}), \left\{ \frac{\partial J_f^g}{\partial \mathbf{y}} \right\} \right\rangle$$

- The impact of observation subsets (e.g., separate channels, or separate satellites) can be easily quantified
- Computation always involves entire set of observations; changing properties of one observation changes the scalar measure for all other observations

$\delta e_f^g < 0.0$ the observation is BENEFICIAL

$\delta e_f^g > 0.0$ the observation is NON-BENEFICIAL