



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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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 11th 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





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)



NAVGEM Per Ob Sensitivity (10⁻⁶)

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



MISR wind assimilation

40.8 WINDSAT-TPV CLD WIND SSMIS TPW 33.4 RADIOSOND 90.5 TC Synth SSMI3 74.3 RADIOSONDE IAS 67.8 PIBAL AMSU-A 67.7 SCAT SFC WIND ATM DROPSONDE LandSf WINDSAT SFC WIND AMDAR MISR IPL MISR WIND AQUA leogeo WIND SSMIS TPV MODIS WIND ShipSf AMDAR MDCRS LandSfo GP SSMIS SFC WIND PIBAI MHS MODIS WIND ShipSfo leogeo WIND CLD_WIND ASCAT SFC WIND AVHRR WIND AIREP MISR SSMI 6.1 MDCE SSMIS SEC WIND 5.5 WINDSAT SEC WIND 5.4 AVHRR WIND 3.4 TC Synth 0.6 DROPSOND 0.2 MSIL. AMSU-Aus sv Aus svi MIL ACAR MIL ACAL SFC WIND OSCAT SFC WINE R/S WIND R/S WIND SCAT SFC WIND SCAT SFC WINE SSMI-PRH SSMI-PRH WINDSAT-PRE WINDSAT-PRI 10 20 30 50 25 75 100 125 150 175 24 Hr Tropospheric Fcst Error Norm Reduction (J/kg) 24 Hr Tropospheric Fcst Error Norm Reduction (J/kg) 16 OCT 2012 21 24 2012 Per observation impact (J/kg) Percent reduction per observation type

NAVGEM Observation Sensitivity

CIMSS LEO-GEO/MODIS/GEO/MISR Winds

Coverage diagrams do not shown distribution in height and time



NESDIS/EUMETSAT/JMA, Satellite Feature Tracked Winds Coverage 2014011512 late











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



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





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 vcomponent 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





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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)