



# Report from the International Winds Working Group Chairs: A Coordinated Study of Atmospheric Motion Vector (AMV) Impact on NWP and Other Satellite Wind Highlights

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# Outline

- **International Winds Working Group (IWWG)**
  - Introduction to group
  - Collaborative projects underway
- **Coordinated NWP study to assess AMV impact**
  - Brief description of study, participants, goals
  - Key highlights/findings
- **Satellite Wind Highlights Captured at IWW11**
  - Satellite wind sources: Now and in the future
  - New/emerging approaches to AMV derivation
  - High resolution (spatial and temporal) AMVs



# International Winds Working Group (IWWG)

- Established in 1991 and became a formal working group of the Coordination Group for Meteorological Satellites (CGMS) in 1994. Currently about 50-60 active members.
- Provides a forum to discuss and coordinate research and developments in data production, verification/validation procedures, and assimilation techniques.
- Focus on derivation and applications of atmospheric winds derived from
  - Geostationary and polar imagery (clouds and water vapor)
  - Radar backscatter & conical microwave radiometers (ocean surface winds)
  - Research instruments (ie., MISR)
  - Future instruments (advanced imagers, space-borne LIDAR, Geo-Hyperspectral)
- Biennial Workshops, with the most recent (IWW11) held February 20-24, 2012 in Auckland, New Zealand
  - NWP centers from the following organizations were represented at the workshop: NCEP, NASA, JCSDA, ECMWF, UK Met Office, Dwd, Meteo-France, FNMOC, NRL, JMA, and KMA.

Web page: <http://cimss.ssec.wisc.edu/iwwg/iwwg.html>



# IWWG Web Page

## *A Collaborative Tool...*

- Product information
- Training Links
- Wiki Sections
  - Information
  - Collaborative Activities
- IWWG Workshops

International Winds Working Group (IWWG) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://cimss.ssec.wisc.edu/iwwg/iwwg.html

International Winds Working Grou...

**INTERNATIONAL WINDS WORKING GROUP**


HOME ABOUT US **INFORMATION** (wiki) **ACTIVITIES** (wiki) WORKSHOPS LINKS CONTACT US

Welcome to the **International Winds Working Group** website

The International Winds Working Group (IWWG) was established in 1991 and became a formal working group of the Coordination Group for Meteorological Satellites (CGMS) in 1994.

IWWG was initially established to focus on cloud track winds from geostationary data. As the satellite observing system has developed, the IWWG has broadened its interest to cover the range of wind datasets derived from current and future satellite missions. The main focus remains the atmospheric motion vectors produced by tracking features (clouds and water vapour) in geostationary and polar imagery sequences. Other winds datasets addressed by the group include: (i) ocean surface winds derived from radar backscatter and conical-scanning microwave radiometers (ii) data from research missions (e.g. MISR winds) and (iii) future datasets including wind profile information from space-borne lidar and 3-D wind fields derived from tracking features in clear sky moisture fields produced from future geostationary hyperspectral infrared sounders.

IWWG provides a forum to discuss and coordinate research and developments in data production, verification/validation procedures and assimilation techniques.

General Announcements	Latest News
<p><b>11th INTERNATIONAL WINDS WORKSHOP</b> 20-24 Feb 2012, University of Auckland, New Zealand</p>  <p>Courtesy of IrNZ/Flickr.com</p>	<p>For older news items see the <a href="#">news archive</a></p> <p><b>Feb 12:</b> Release of the 5th analysis report of the NWP SAF AMV monitoring - see the <a href="#">NWP SAF AMV analysis reports web page</a> for further information.</p> <p><b>Feb 12:</b> Update to IWWG web pages including introduction of new wiki pages.</p> <p><b>Jan 11:</b> Proceedings of IWW3 available online - follow the workshops link.</p> <p><b>Dec 10:</b> Régis Borde standing in as co-chair for IWWG while Mary Forsythe is on maternity leave during 2011 (Régis will also co-chair IWW11 in Feb 2012).</p>

HOME ABOUT US **INFORMATION** (wiki) **ACTIVITIES** (wiki) WORKSHOPS LINKS CONTACT US

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Web page: <http://cimss.ssec.wisc.edu/iwwg/iwwg.html>



# IWWG Key Collaborative Projects

- NWP SAF analysis reports of monthly O-B monitoring (every 2 years)
- NWP winds impact study (undertaken in 2011-12)
- Inter-comparison of AMV derivation schemes (first study in 2006, second phase 2012-13)
- Simulated data studies (ECMWF - 2011-12, University of Reading – ongoing)
- Access to portable AMV derivation software (via NWC SAF) to support research efforts

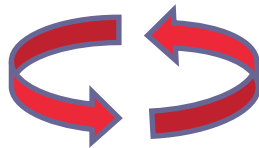


# NWP Satellite Applications Facility (SAF) AMV Monitoring

## Aims

- Provision of rolling 3 year archive of monthly O-B monitoring plots (UKMO and ECMWF)
- Producing analysis reports every 2 years to coincide with the IWWs – core is a record of features identified in the O-B monitoring

Understand



Improve

- Improve understanding of AMV error characteristics in order to enable improvements to the AMV derivation and their treatment in NWP models

The screenshot shows the NWP SAF AMV Monitoring website. The main content area is titled 'NWP SAF AMV Monitoring' and includes a navigation menu with tabs for 'Introduction', 'Monthly Monitoring', 'Analysis Reports', 'Investigations', 'NWP', 'Real-time Monitoring', and 'Action List'. Below this, there are sections for 'Types of plots' and 'Monitoring Plots'. The 'Types of plots' section describes four types of plots: Speed bias density plots, Zonal plots, Map plots, and Vector plots. The 'Monitoring Plots' section includes a calendar grid for selecting a month and year from 2009 to 2012. The website also features logos for the Met Office, ECMWF, and METEO FRANCE.

The image shows the cover of the 5th Analysis report. The cover features the NWP SAF logo at the top. Below the logo, it states 'Document NWPSAF-MO-TR-027', 'Version 1.0', and '09/10/12'. The main title is 'Fifth analysis of the data displayed on the NWP SAF AMV monitoring website' with a URL: [http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind\\_report/](http://research.metoffice.gov.uk/research/interproj/nwpsaf/satwind_report/). The author is listed as 'James Cotton UK Met Office'. At the bottom, there are logos for the Met Office, ECMWF, and METEO FRANCE.

5th Analysis report released Feb 2012





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# Coordinated Study of AMV Impact *Background...*

From Lars Peter Riishojgaard's talk at IWW10 (2010):

- Diminished relative impact of AMVs in some global NWP systems as recorded in the last WMO sponsored impact workshop (Geneva, May 2008)
- However, some adjoint sensitivity studies show very significant impacts, especially on a per observation basis
- Inconsistencies among assessments of AMV impact

To address this:

**IWW10.1** NWP centers to coordinate a joint AMV and scatterometer denial study, also looking at adjoint sensitivity statistics where available. Aim to summarise in a report to the WMO GOS impact workshop and IWW11.

**CGMS-A39.30** The co-chairs of IWWG and rapporteur requested to discuss the results from NWP impact studies at IWW11 and to synthesize general observations on performance.





# Coordinated Study of AMV Impact *Study Details...*

Expand on an earlier preliminary study from 2008/09 by **selecting two longer trial seasons** (6 weeks) and **coordinating a more consistent approach** to producing verification results.

**Period 1:** 15 Aug – 30 Sep 2010, **NH summer period**, captures all major Atlantic hurricanes

**Period 2:** 1 Dec 2010 – 15 Jan 2011, **NH winter period**

## Test options:

1. **AMV denial\*** (Periods 1 and 2)
2. Scatterometer denial (Period 1)
3. Polar AMV denial (Period 2)
4. Sensitivity study (Period 1)

Results from 8 NWP centers

Here we focus on AMV results

Synthesis report in draft stage

	No AMV	No Scat	No Polar	Sensitivity
DWD	✓ ✓	✓	✓	
ECMWF	✓ ✓	✓	✓	✓
GMAO				✓
JMA	✓ ✓	✓	✓	✓
KMA	✓ ✓			
MF	✓ ✓		✓	✓
NRL	✓ ✓	✓	✓	✓
UKMO	✓ ✓	✓		✓



# Coordinated Study of AMV Impact *Analysis...*

## Identified a number of plots to be produced in agreed form to enable easier comparison:

- Impact on 200/250 hPa analysis wind field
- Fit of first guess and analysis to radiosonde winds (profile plots)
- Impact on T+48 RMS forecast error for 500 hPa geopotential height
- Time series of T+24 mean and RMS wind error at 850 and 200/250 hPa
- Forecast Sensitivity
  - Bar charts of forecast sensitivity to all observation types
  - Break down of forecast sensitivity for AMVs by satellite-channel
  - Maps of mean impact/sensitivity by level

## Differences in:

1. NWP configurations (resolution, 3D-Var/4D-Var etc)
2. AMV types assimilated and QC
3. Other observation usage



# Coordinated Study of AMV Impact Highlights...

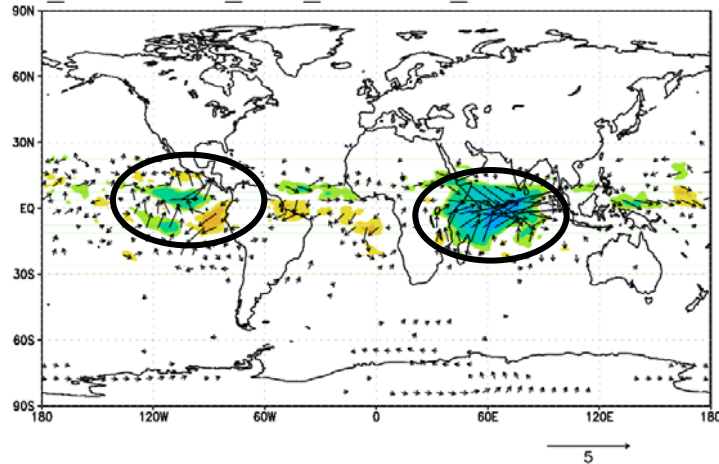
## Impact on mean wind analysis at 200/250 hPa:

- Concentrated in tropics, particularly (i) Eastern Pacific and (ii) Indian Ocean
- Impact not consistent between centers e.g.

During Period 1 there is a predominantly Easterly mean flow in the tropics.

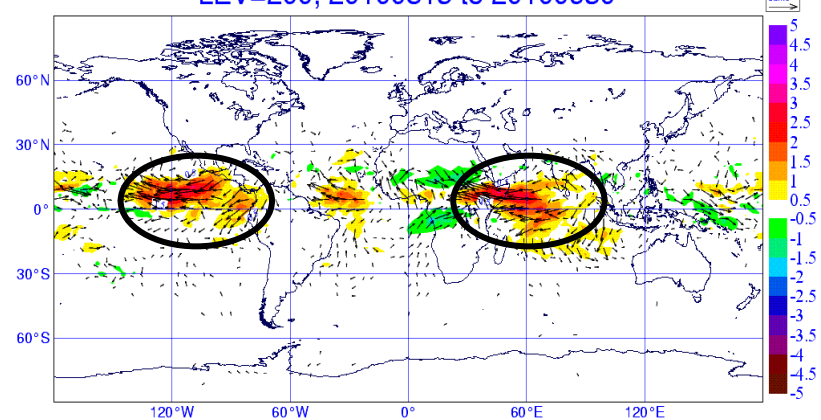
The inclusion of the AMVs tends to enhance the strength of the easterly flow at **DWD, JMA and NRL**, but reduce it at **ECMWF and MF**

G016\_TEST1-G016\_CNTL\_20100815\_20100930 on 200 hPa



JMA

Vector difference of mean wind analysis, Exps AMVout-CTL  
LEV=200, 20100815 to 20100930



ECMWF

**Denial –Control:** green/blue represent where the analysis is faster as a result of assimilating AMVs

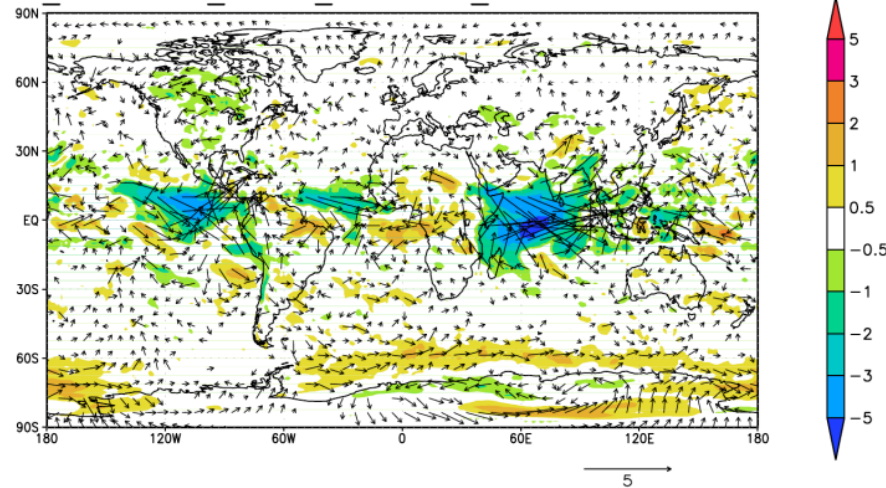


# Coordinated Study of AMV Impact Highlights...

## Can we explain the different impacts in tropics?

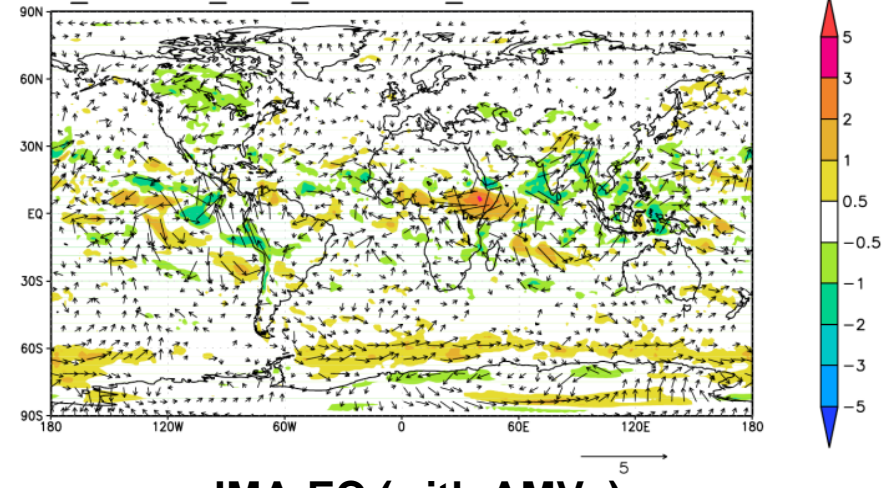
- Compare JMA and ECMWF wind analyses with and without AMVs

JMA\_NOAMV-EC\_NOAMV\_20100815\_20100930 on 200 hPa



**JMA-EC (no AMVs)**

JMA\_CNTL-EC\_CNTL\_20100815\_20100930 on 200 hPa



**JMA-EC (with AMVs)**

- Overall differences between ECMWF and JMA are significantly smaller in the experiments with AMVs than in the denial experiments
- The differences seen in the AMV denials are likely due to differences in the climatology of the forecast models of the centers
- AMVs act to bring the two systems in better agreement

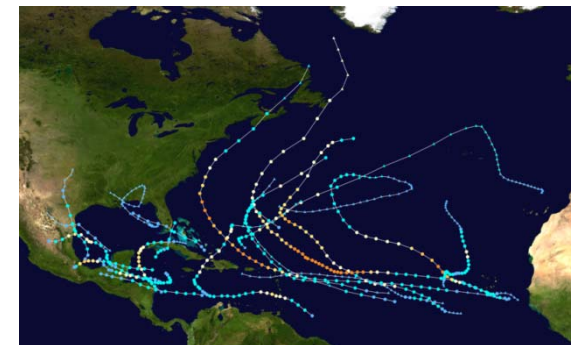
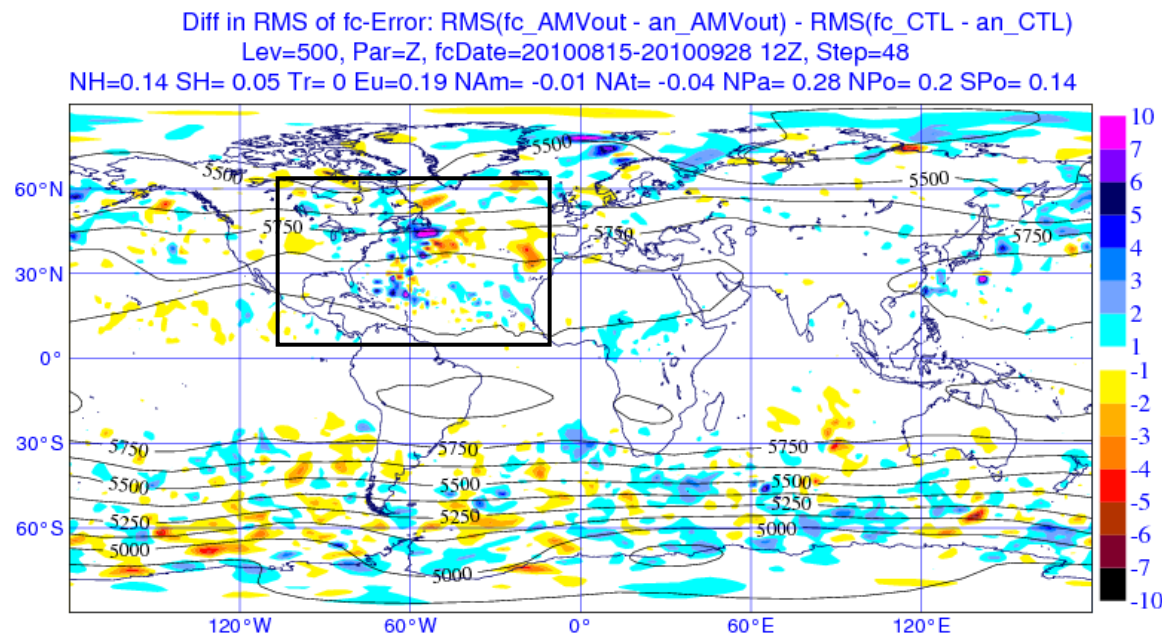




# Coordinated Study of AMV Impact *Highlights...*

## Impact on 500 hPa Geopotential Height T+48 forecast error (RMS)

- Overall impact rather positive
- Most widespread reductions in RMS found in the extra-tropics and polar-regions in particular (verification against own analysis)
- Several centers (ECMWF, MF, DWD, JMA, UKMO) in period 1 show a largely positive impact on Z500 in region of North Atlantic storm tracks e.g.



**ECMWF**

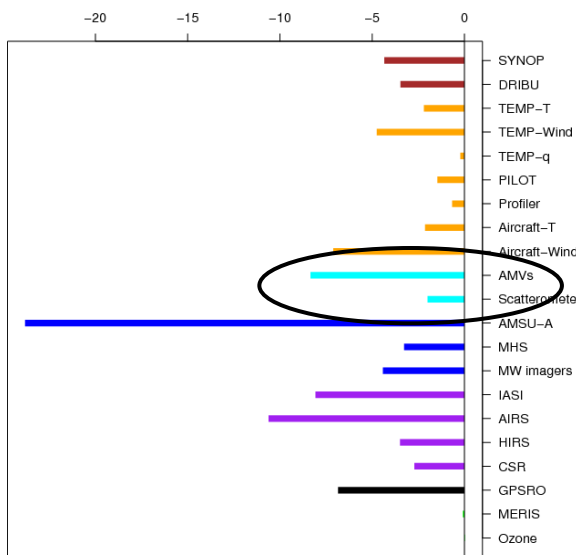
**Blue/purple colours** represent where the forecast RMS in the reference experiment (containing the AMVs) is smaller than in the denial experiment i.e. **positive impact**



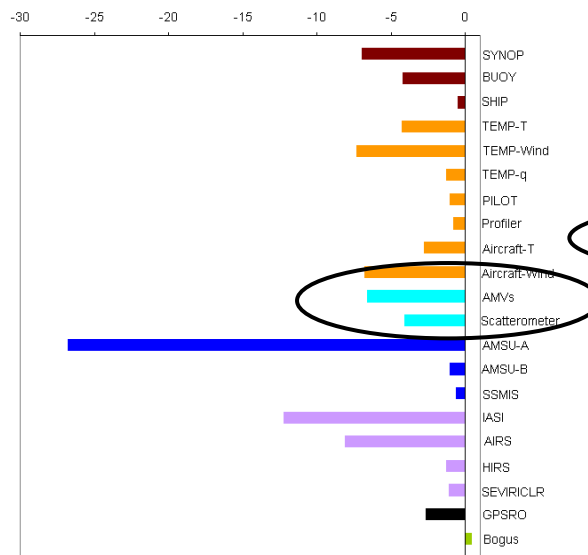
# Coordinated Study of AMV Impact Highlights...

## Forecast Sensitivity to Observations (FSO)

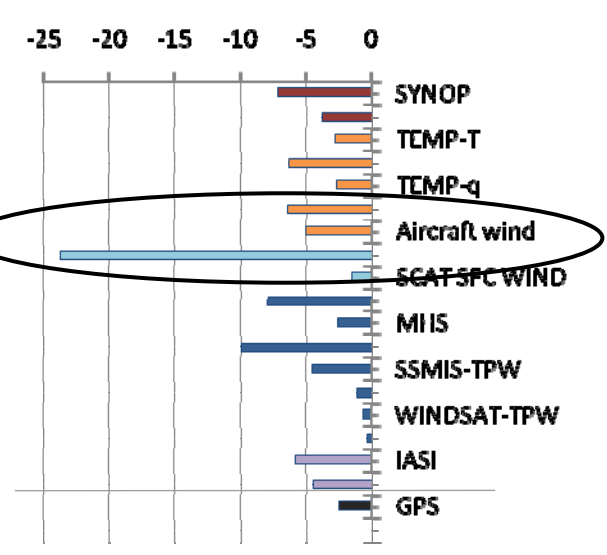
- Adjoint-based FSO method gives estimate of the contribution of each observation towards reducing the 24-hour forecast error
- Top level results agree fairly well for ECMWF, Met Office, MF – **AMV FSO of 7-11%**. **Scatterometer FSO small, but consistent positive impact**
- Markedly different for NRL – AMV FSO of 23%. Due to differences in AMV assimilation (e.g. superobs) or is the NAVDAS system able to extract wind information more effectively than temperature information?



ECMWF



Met Office



NRL

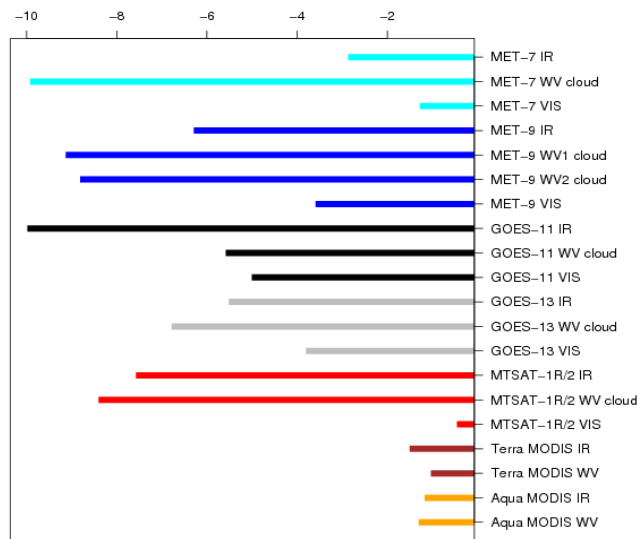


# Coordinated Study of AMV Impact Highlights...

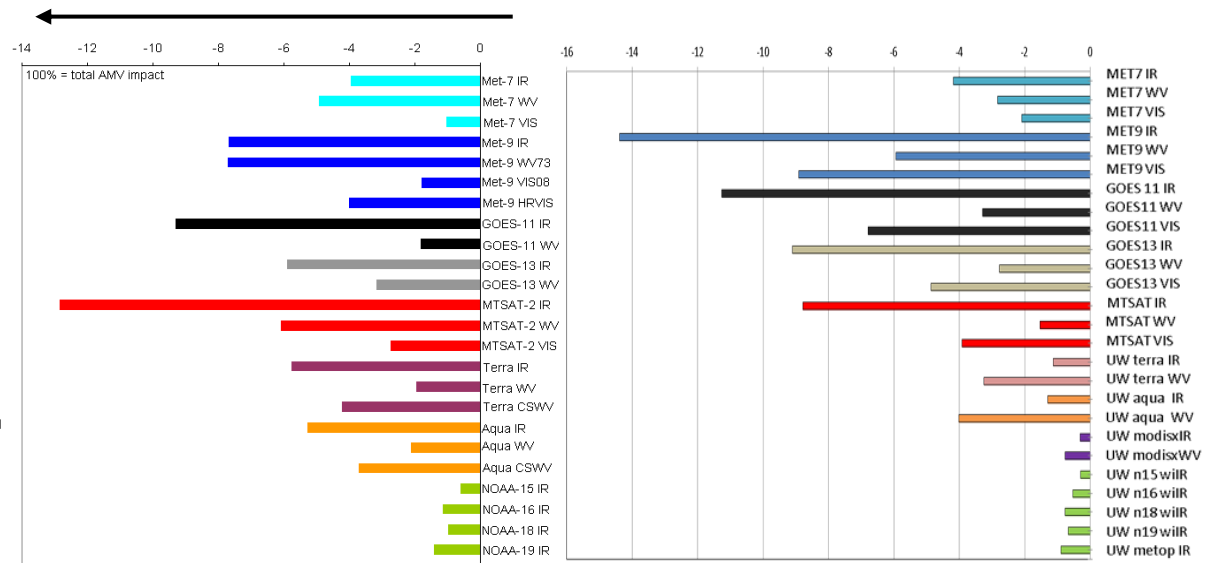
## Total AMV FSO by satellite/channel combination

- All combinations contribute positively
- Total impacts closely related to the number of observation assimilated
- Difference in impact from geostationary WV winds: largest contributions for ECMWF, smallest for NRL

reduction in forecast error



ECMWF



Met Office

NRL





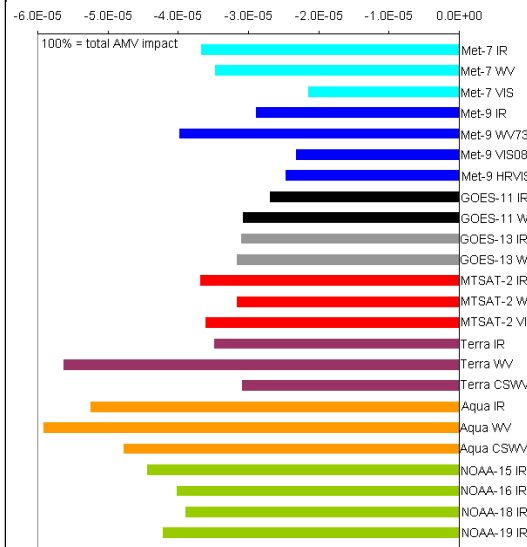
# Coordinated Study of AMV Impact Highlights...

## Mean FSO per observation

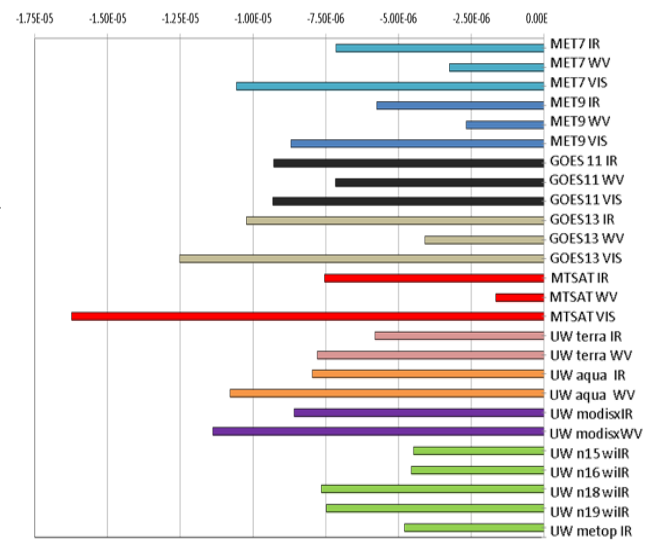
- Met Office shows more uniform impact per observation
- For ECMWF the largest contribution per observation comes from the geostationary cloudy WV winds, smallest tends to be from visible
- Opposite tends to be true for NRL - largest impact per geostationary superob is from the visible winds and the smallest from the WV
- Polar wind differences: Met Office shows strong impact, small impact for ECMWF



ECMWF



Met Office



NRL



# Coordinated Study of AMV Impact *Conclusions...*

- Positive forecast impact is seen from AMVs across all NWP centers – especially in upper troposphere and this is demonstrated by the fit to radiosonde profiles, the time series of forecast error and FSO results.
- Nearly all centers see a strong impact on the tropical mean wind analysis
- Larger impact often seen for centers who use 3DVAR or fewer other observations, and for NRL whose FSO statistics suggest quite a different impact from the various components of the observing system
- No geographical regions where the AMVs are performing consistently poorly among several centers. Suggests regions of negative impact are mainly system- dependent (QC, thinning, assimilation scheme, forecast model, etc), rather than AMV- dependent
- In addition to the classic denial study, the FSO stats further indicate significant relative importance of the AMVs in the global observing system context

***Final report is being prepared...***



# Outline

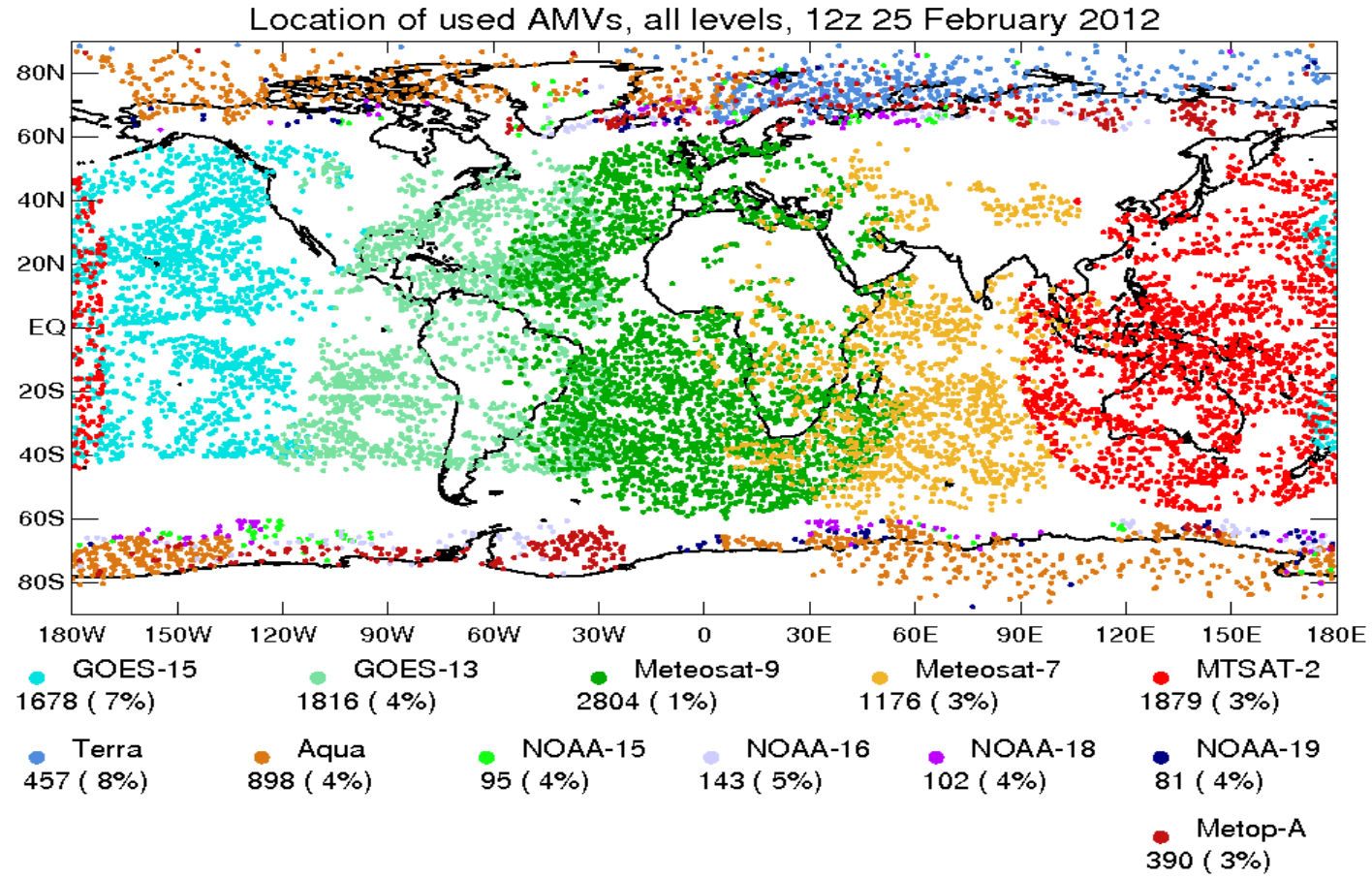
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# Today's Satellite Wind Observations

## *Where we are now... AMVs*

Met Office using data from 5 geostationary and 7 polar platforms



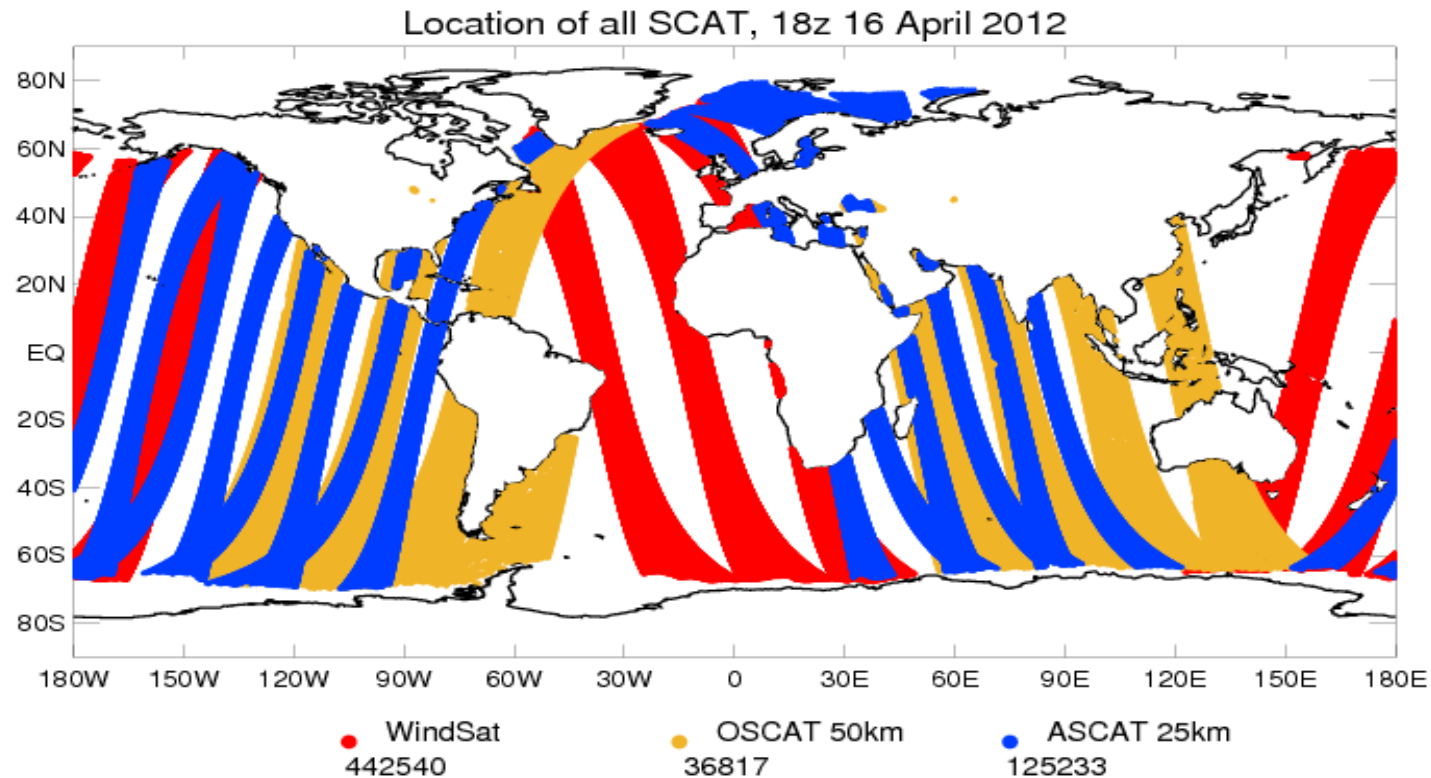
- Data gaps around 60N/S, but otherwise good spatial coverage.
- Improving temporal coverage - most geostationary AMVs available hourly.



# Today's Satellite Wind Observations

## *Where we are now...SCAT winds*

### Surface winds



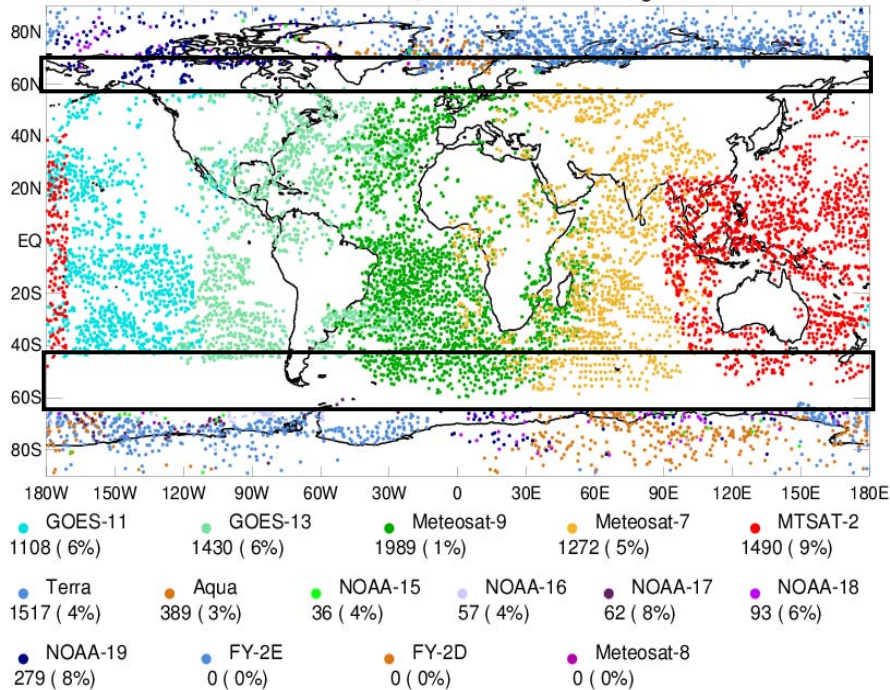
**The first winds from China's HY-2A satellite have been produced. These will provide complementary coverage to ASCAT and OSCAT observations**



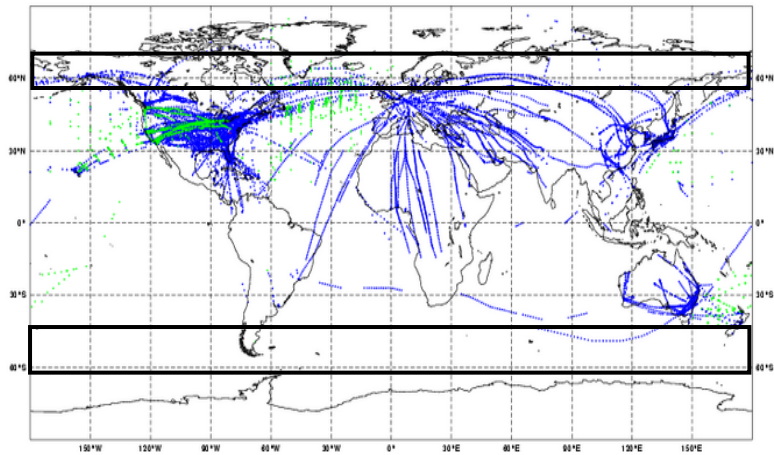


# Closing the Gap...

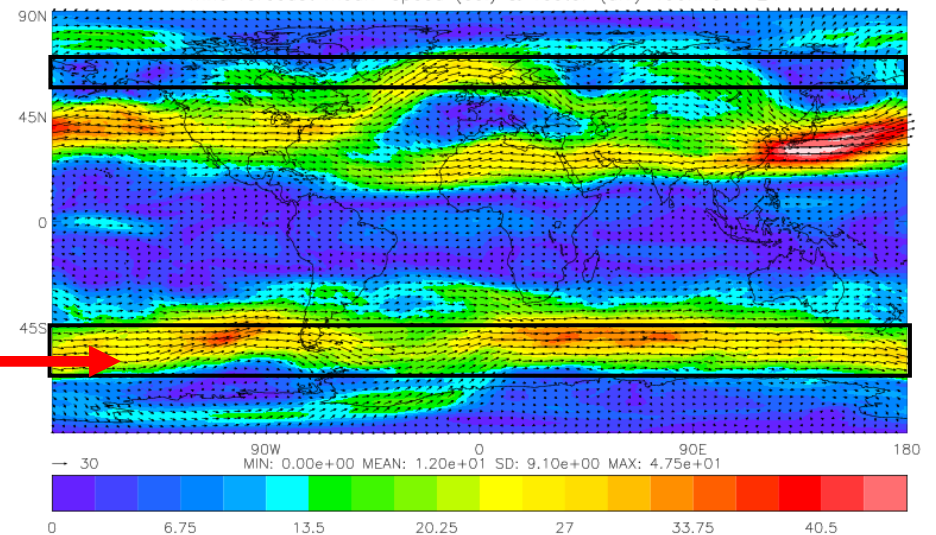
Location of used AMVs, all levels, 12z 25 August 2010



Aircraft



Met Office QG00 March 2011  
Wind forecast mean-speed (col) & vector (arr) 400hPa T+24



- Key baroclinic areas void of wind observations
- Lack of other wind data in AMV data voids
- Useful for constraining polar front jets

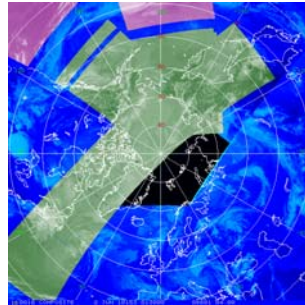


# Closing the Gap

## *Datasets that could help...*

- **Multi-Satellite AMVs**

- LEO/GEO (GOES, Meteosat, FY-2, MTSAT, AVHRR, MODIS)
- LEO/LEO
  - Metop-A/B (AVHRR)
  - Terra/Aqua (MODIS)
  - NOAA-15/16/18/19 (AVHRR)



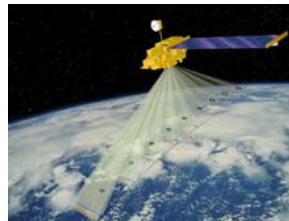
- **Polar Communications & Weather (PCW)**

- Canadian mission for 2 satellites in highly elliptical orbit



- **MISR Winds**

- Terra; potential for follow-on missions

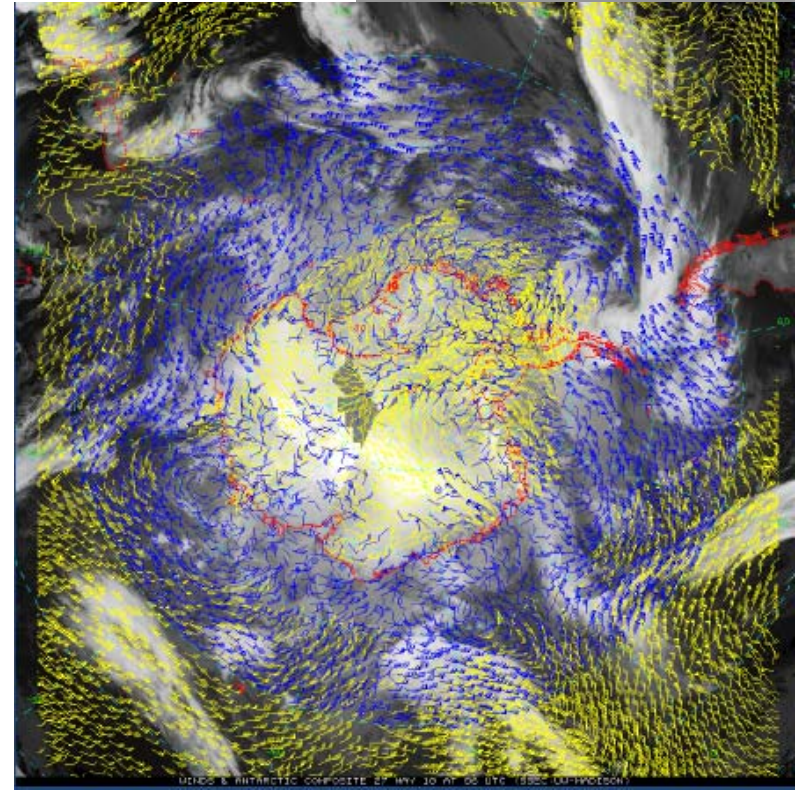


- **ADM-Aeolus**

- Global vertical wind profiles (*cross-track component*)



 LeoGeo winds  
 Existing AMVs



**LeoGeo AMVs** – Experimental product developed at U/W CIMSS with aim to fill the “gap”

Derived from composites of geostationary and polar orbiting imagery.





# Improving Satellite Winds

*Where the efforts are focused...*

- **Improving coverage** (spatially & temporally)
  - Multi-satellite winds (LEO/GEO, LEO/LEO)
  - Higher resolution products (more on this later)
  - Higher refresh rate (ie., hourly GEO winds)
- **New/emerging wind derivation schemes**
  - Nested tracking algorithm (NOAA), Cross Correlation Contribution (CCC)+Optimal Cloud Analysis (OCA) Algorithm (EUMETSAT)
    - Better feature tracking
    - Use improved pixel-based cloud-top heights computed via optimal estimation approach
    - Enable determination of height error estimates/uncertainty
    - Improve the link between pixels used in feature tracking and height assignment



# Improving Satellite Winds

*Where the efforts are focused...*

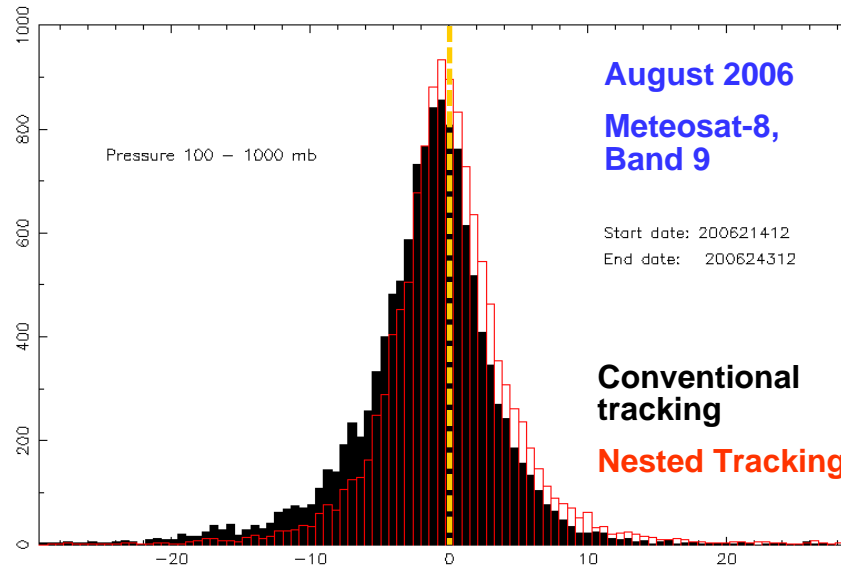
- New/emerging wind derivation schemes (*cont'd*)
  - LEO/LEO Winds: Preparations for global wind derivation from Metop-A/Metop-B (EUMETSAT)
  - Synergistic use of hyperspectral instruments for LEO wind height assignment (EUMETSAT)
  - MISR cloud motion vector algorithm (JPL)
  - Higher resolution scatterometer winds
- Improving understanding and characterization of AMV height assignment errors
  - Comparisons to model best-fit pressure
  - Comparisons to CALIPSO data/cloud heights
  - Simulation studies



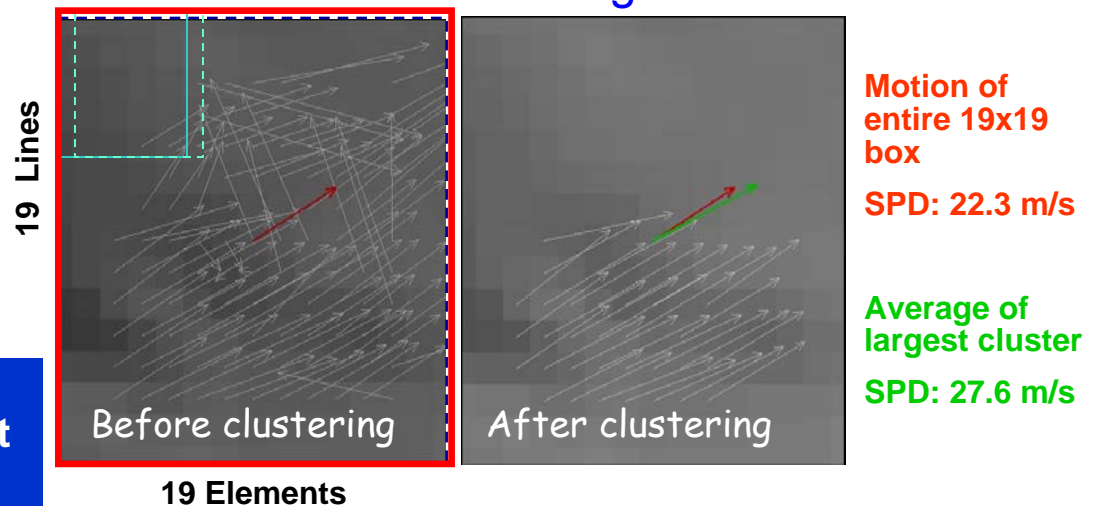
# NOAA's GOES-R Nested Tracking Algorithm

- Designed to minimize observed slow speed bias of satellite winds using heritage winds algorithm; a significant concern for NWP
- Computes local motions (*nested*) within a larger target scene, together with a clustering algorithm, to arrive at a superior motion solution
- Capable of extracting motion at different levels and/or different scales within each target scene being tracked
- Uses pixel level cloud heights (optimal estimation) to assign a representative height

AMV – RAOB Wind Speeds (m/s)



Nested Tracking

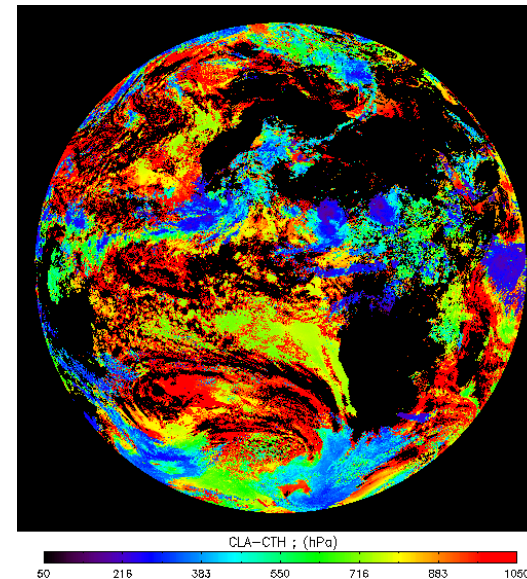
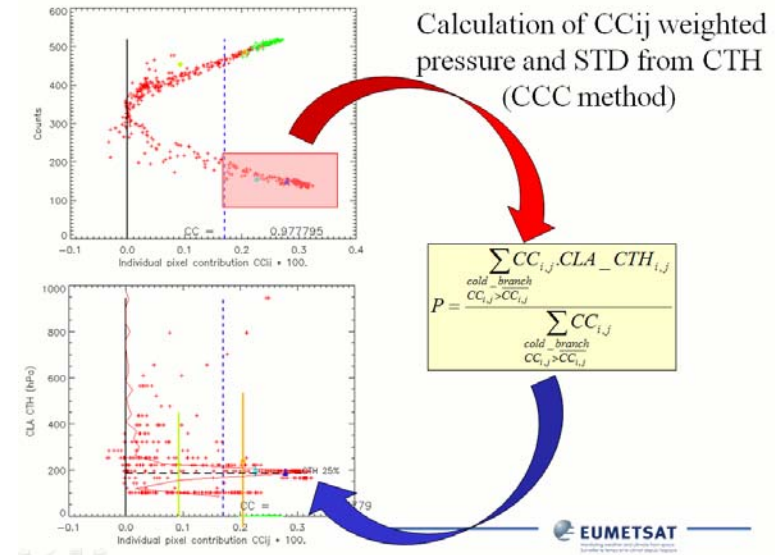


Being tested in NCEP GFS;  
Other NWP centers encouraged to test  
this approach



# EUMETSAT's Cross-Correlation Contribution (CCC) Algorithm

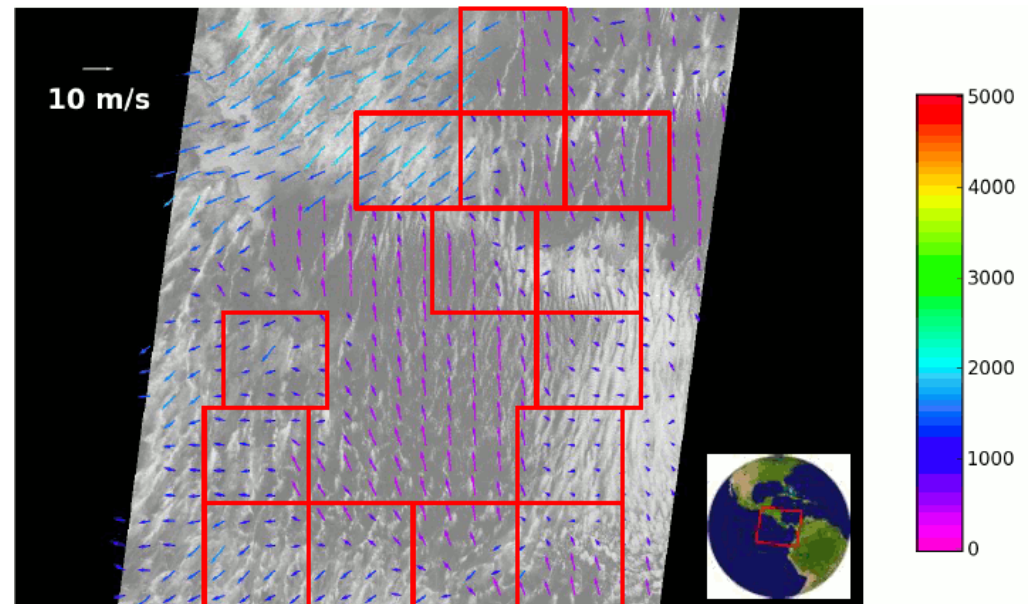
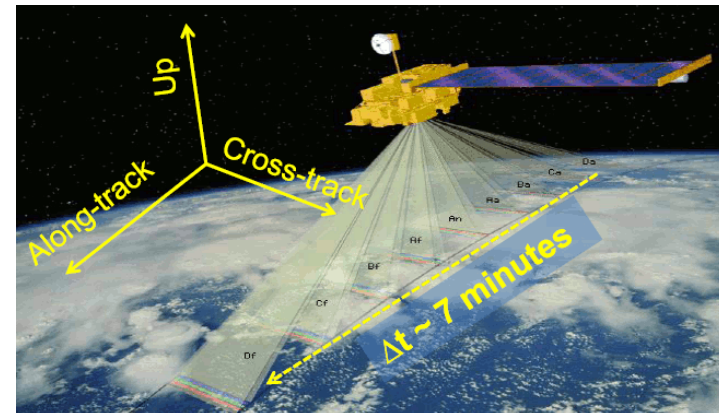
- Pixel contribution to the cross correlation coefficient, CCij, is used to select the pixels that contribute the most to the tracking
- Subset of selected pixels used to compute height assignment
  - Establishes strong link between pixels driving motion and height assignment
- Use of optimal cloud analysis product (optimal estimation) being evaluated in preparation for future MTG





# New MISR Cloud Motion Vector Product

- 17.6 km resolution (vs 70.4 km)
- 3x coverage
- Better agreement with RAOB, GOES, and MODIS winds
- Added Quality Indicator (QI) (follows EUMETSAT methodology)
- 5 Hour Latency Possible (From Sensing to Data Availability)

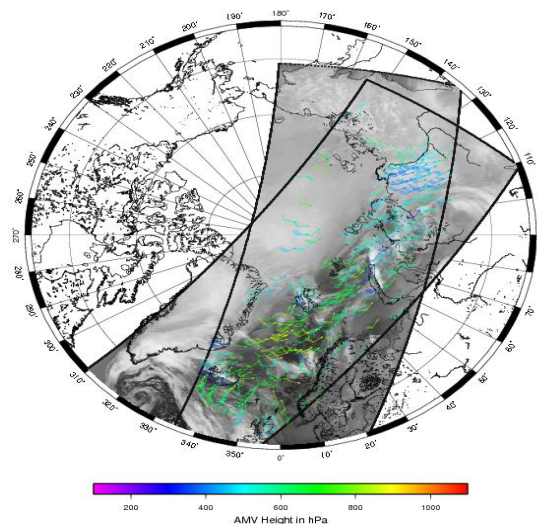
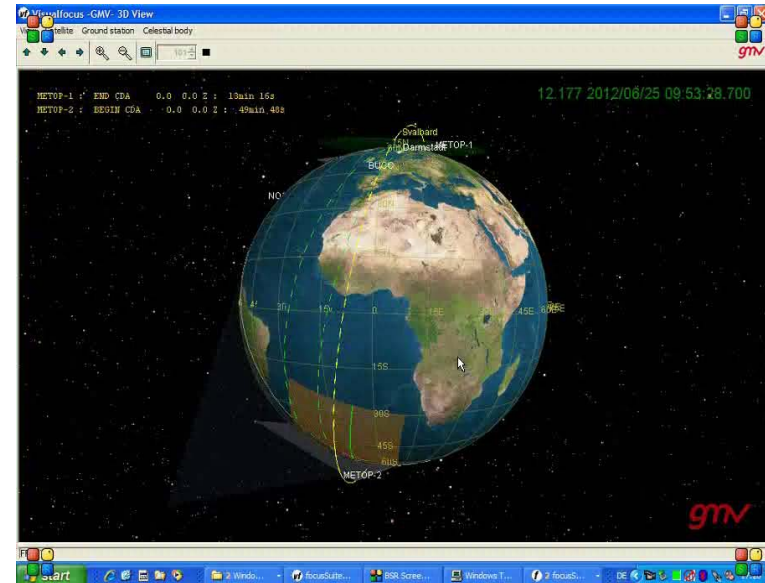






# EUMETSAT Preparations for Deriving Winds from Metop-A/B

- Significant overlap in AVHRR swaths between Metop-A and Metop-B will enable AMVs to be generated **globally**
- IASI measurements to assign AMV heights
- Use cross-correlation contribution (CCC) method
- Parallax correction

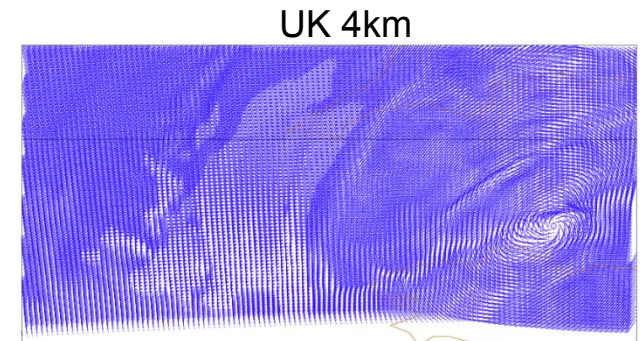
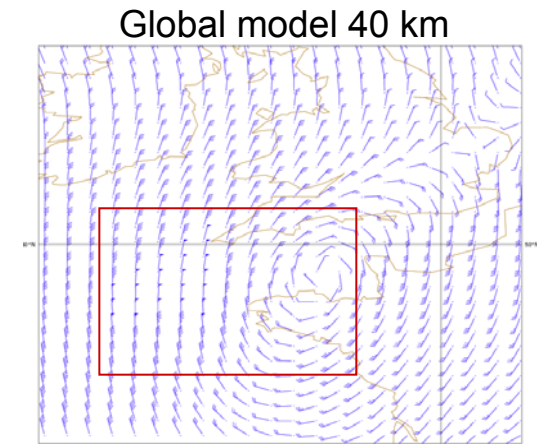


Metop-A  
AVHRR  
Winds



# High Resolution (Space and Time) AMVs

- Current AMV products generally designed to capture broad-scale to synoptic scale flow.
- However, NWP is moving to higher spatial resolution and more frequent assimilation cycles.
- There is information available on smaller scales in the geo satellite imagery (i.e. **clearly evident in rapid-scan animations**)
- Future instruments (GOES-R ABI, Himawari-8, etc) will bring improved spectral, spatial, and temporal resolution, all of which will enable the generation of higher resolution AMV products
- **Can we derive more useful AMV information for nowcasting and mesoscale assimilation in high resolution models? Particularly to help with forecasting high impact weather events.**



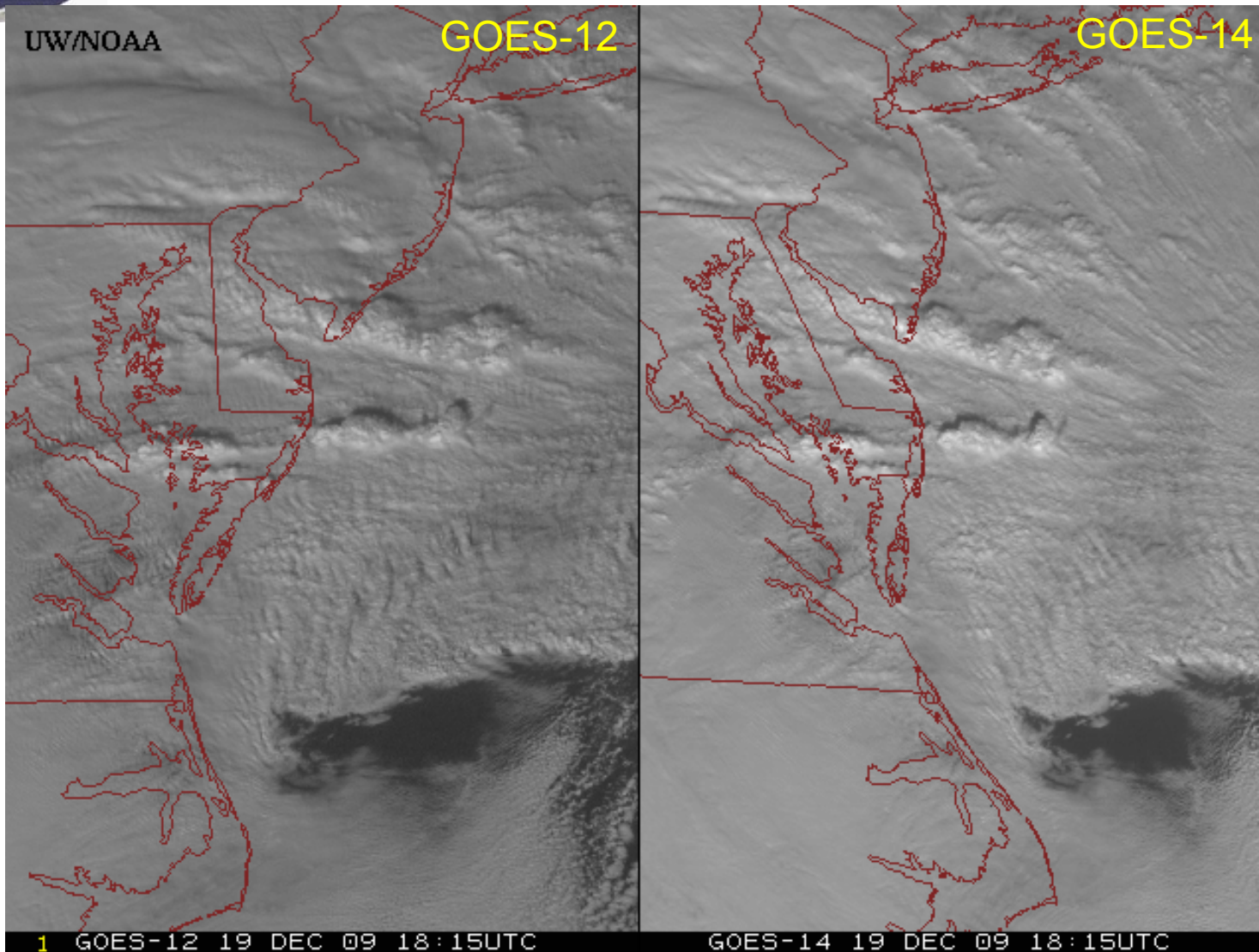
Examples of wind field resolution from Met Office models operational in 2010





# GOES-14: Sample "1-min" imagery

*A hint of what GOES-R will routinely provide...*



**Visible data from the GOES-14 NOAA Science Test**



# High Resolution (Space and Time) AMVs

## **Some challenges:**

1. More sensitive to satellite image registration errors. However, imager navigation systems are greatly improving.
2. Need to revisit approach to quality control (QI tuned to large-scales, penalizes spatially varying, accelerating wind features)
3. How to handle correlated errors, both space and time? Are these as important to mesoscale model applications? If thinned too much, will we lose the mesoscale information of interest?

## **IWWG plan of attack:**

1. Recognized as one of the key new areas to focus on
2. Studies underway (e.g. Majumdar and Velden), but results preliminary
3. Wiki page on IWWG web page to foster collaborations

Asking for input from NWP community



# Influence of Assimilating High-resolution Satellite-Derived Data on Analyses and Forecasts of Tropical Cyclone Track and Structure

Christopher S. Velden<sup>1</sup>, Sharanya J. Majumdar<sup>2</sup>,  
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University of Wisconsin, CIMSS<sup>1</sup> University of Miami, RSMAS<sup>2</sup> National Center for Atmospheric Research<sup>3</sup>

**Goals:** Use **multiple** and **integrated** satellite data sets at their highest resolution to build an advanced analysis/forecast system for tropical cyclones; seek an optimal assimilation strategy for integrated satellite data in a mesoscale framework (WRF-DART EnKF, NRL-COAMPS 4DVAR).

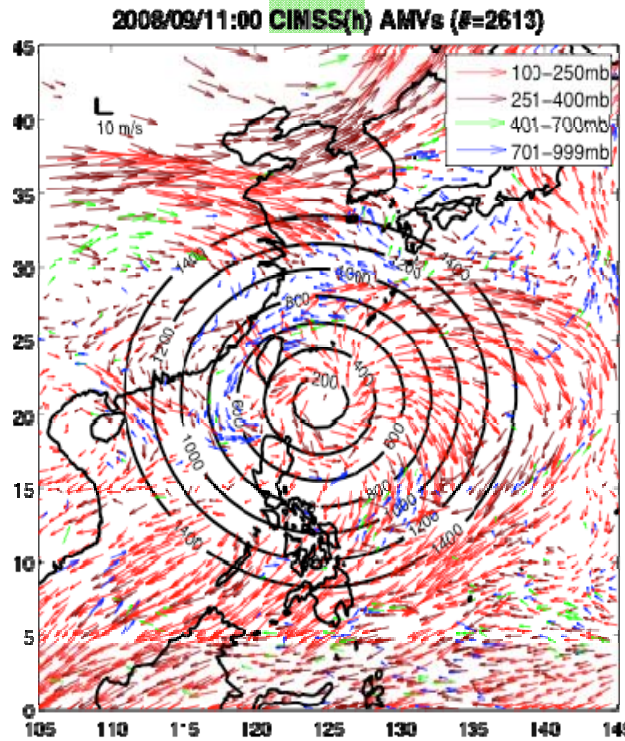
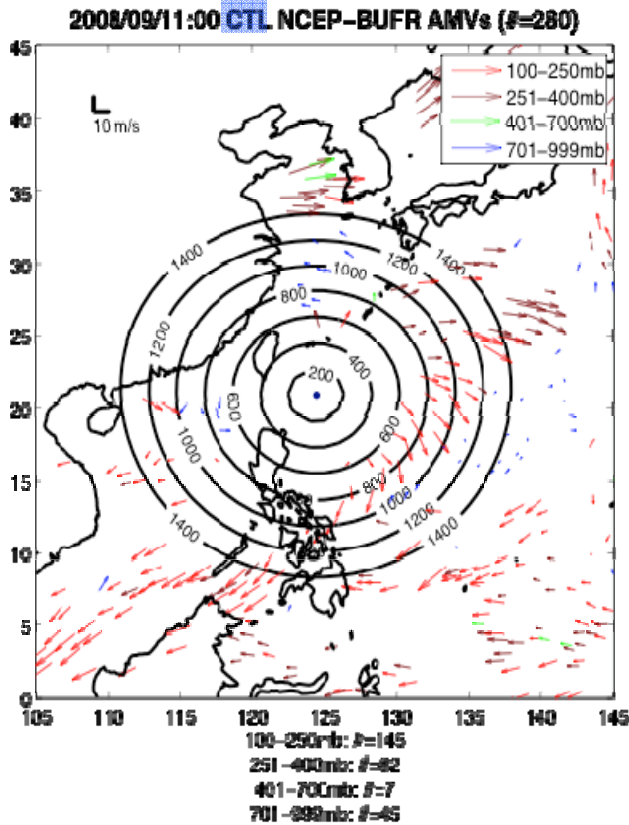
Dynamic variables: **Atmospheric Motion Vectors (AMVs)**, ASCAT surface wind

Thermodynamic variables: Temperature and moisture soundings, Total Precipitable Water (TPW)

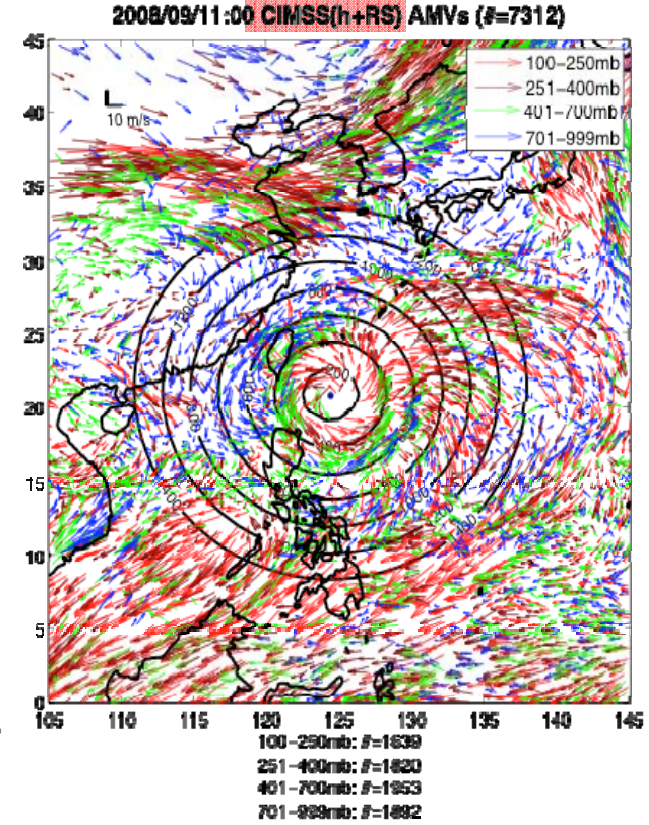




# Example: AMV Density



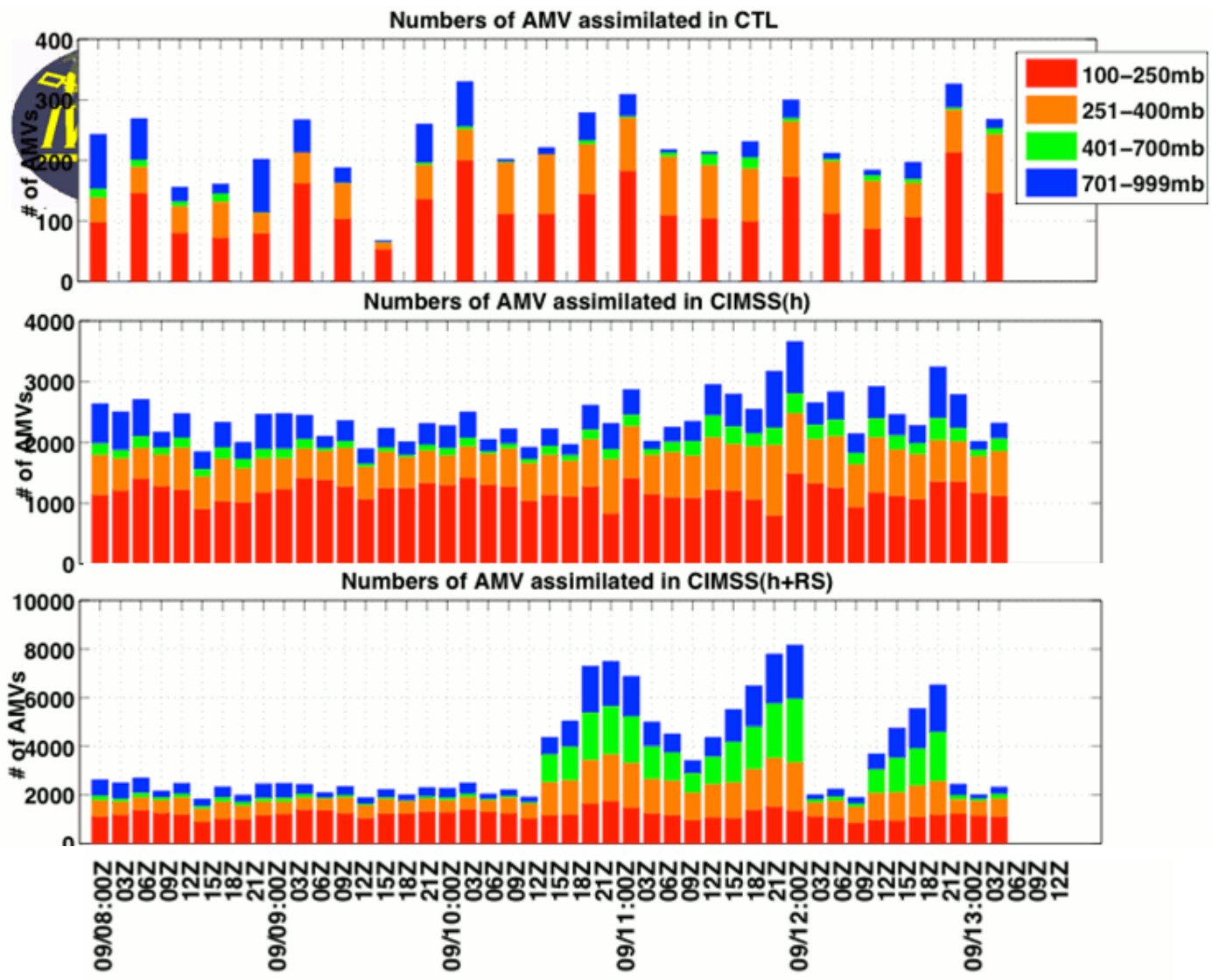
Analysis domain centered on selected typhoon (Sinlanku) (contour every 200km)



Increasing AMV coverage

When increasing AMV refresh rate (hourly)

Taking advantage of rapid-scan imagery



CTL = Operational AMVs

CIMSS (h) = Hourly AMVs produced at CIMSS

CIMSS (h+RS) = Hourly plus Rapid-Scan AMVs produced at CIMSS





# Summary

- **International Winds Working Group**
  - Well established, broad, and active membership
  - Well focused and poised to address issues related to satellite winds; achieved through collaborative projects
- **Coordinated study of AMV impact on NWP**
  - Demonstrated a consistent level of positive forecast impact from AMVs across all NWP centers
  - In addition to the classic denial study, the FSO stats further indicate significant relative importance of the AMVs in the global observing system context
- **Promising future**
  - NWP model/data assimilation improvements
  - Future satellites, new instruments, and new approaches for deriving atmospheric winds



# Backup Slides



## Winds from Current Satellite Missions

- **EUMETSAT:**

**GEO:** Meteosat-7/8/9 (imager)  
**LEO:** Metop-A (AVHRR/3, IASI, ASCAT-scatterometer)

- **NOAA:**

**GEO:** GOES-13/15 (imager)  
**LEO:** NOAA-15/16/18/19 (AVHRR)  
NPP (VIIRS)

- **US Navy:**

**LEO:** Coriolis (Windsat- MW radiometer)

- **NASA:**

**LEO:** Terra (imager), Aqua (imager, MISR)

- **JMA:**

**GEO:** MTSAT1/2 (imager)

- **CMA:**

**GEO:** FY2-C/D/E (imager)  
**LEO:** HY-2A (scatterometer)

- **KMA:**

**GEO:** COMS (imager)

- **IMD:**

**KALPANA-1** (imager)

- **ISRO:**

**LEO:** OceanSat2 (OSCAT- scatterometer)



# Winds from Future Satellite Missions

- **EUMETSAT:**

**GEO:**

MSG-3/4 (advanced imagers) - **2012/2014**

MTG (advanced image/hyperspectral  
sounder) - **2020/2022**

**LEO:**

Metop-B (AVHRR/3, IASI,

ASCAT - **2012**

EPS-SG - **2020**

- **NOAA:**

**GEO:**

GOES-R/S (advanced imager) - **2015/2017**

**LEO:**

JPSS-1 (VIIRS imager, hyperspectral  
sounder) - **2016**

- **JMA:**

**GEO:**

Himawari-8 (advanced imager) - **2014**

- **CMA:**

**GEO:**

FY2-F/G/H (imager) - **2012/2014/2015**

FY4-A/B (advanced imager; hyperspectral  
sounder) - **2015/2017**

**LEO:**

HY-2A (scatterometer) - **2012**

- **KMA:**

**GEO:**

GeoKompsat-2A (advanced imager) - **2017**

- **ESA:**

**LEO:**

ADM/Aeolus (LIDAR) - **2014**