# COMPARATIVE IMPACT OF OCEAN SURFACE WIND VECTORS AND OCEAN SURFACE WIND SPEED FOR GLOBAL NWP

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ABSTRACT

In this study, we compare the impact of ocean surface vector winds (OSWV) to ocean surface wind speed (OSWS) observations for global data assimilation and numerical weather prediction. Currently, OSWV are provided by scatterometers (ASCAT) and polarimetric microwave imagers (WindSat), while OSWS are provided by microwave imagers (e.g. SSMIS and AMSR-2) or GNSS-R (future research NASA CYGNSS). Forecast sensitivity observation impact (FSOI) statistics for NAVGEM (NAVy Global Environmental Model) indicate that, on average, ASCAT and WindSat wind vectors (OSVW) have slightly more than twice the impact of SSMIS wind speed observations. This result is expected, as wind vectors provide two observations, whereas wind speed provides only one.

However, this comparison does not take into account differences due sensor quality and resolution (and averaging), ability to retrieve winds in precipitating regions, and effective data coverage relative to other observing platforms. As such, it gives limited insight into the additional value provided by wind direction observations. To examine these questions in more detail, we have modified our global NAVGEM system to assimilate ASCAT wind vectors as wind speed observations. The wind vectors are processed through the same data selection and quality control algorithms, and then only the wind speed is retained. The 4DVar satellite wind processing software generates superobs for SSMIS wind speeds. Preliminary results indicate that the ASCAT wind speed observations have similar FSOI per observation as SSMIS wind speed observations.

We will present detailed results from two multi-month NAVGEM assimilation runs. The baseline run assimilates ASCAT wind vectors while the test run assimilates the ASCAT wind speed. Comparisons will include the fit of analyses and forecasts with in-situ observations and analyses from other NWP centers (e.g. ECMWF and GFS).

**STATUS OF TWO SATELLITE WINDS MISSIONS UNDER STUDY IN JAPAN: A DOPPLER LIDAR FOR TROPOSPHERIC MEASUREMENTS AND SMILES-2 FOR MIDDLE ATMOSPHERE.**

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ABSTRACT

Two satellite missions with winds measurement capability are studied in Japan. One is designed for measuring winds in the troposphere using a coherent Doppler Wind Lidar (DWL) at infrared wavelength. The mission definition is based on the technological developments realized by JAXA (laser at 1.6 µm, super low orbit satellite platform) and NICT (laser at 2 µm). Simulations are being performed in order to estimate the measurement performances and to create data for an Observing System Simulation Experiment (OSSE). The latter allows us to quantitatively assess the impacts of the measurements on atmospheric models and to define an efficient observation strategy. The second study is on the 2nd generation of the Sub-Millimetre wave Limb-Emission Sounder (SMILES-2) whose aim is to provide data on the chemistry and dynamics of the middle-upper atmosphere. If realized, it will be the first mission designed for profiling the horizontal wind vector from 30 km to more than 120 km. It will inherit the 4-K cooled heterodyne technology tested with SMILES from the International Space Station (2009-2010). It has been demonstrated using SMILES data that the line-of-sight winds can be retrieved in the stratosphere from the small Doppler shift in the measured molecular lines. In this presentation, we will introduce these missions with a special focus on the first results from the DWL simulations and OSSE.

[1] S. Ishii et al.: *"Measurement performance assessment of future space-borne Doppler Wind Lidar for Numerical Weather Prediction"*, SOLA, 12, 55-59, doi:10.2151/sola.216-012, 2016
[2] M. Suzuki et al.: *"Sensitivity study of SMILES-2 for chemical species"*, Proc. SPIE, 96390M, doi:10.1117/12.2194832, 2015
[3] P. Baron et al.: *"Measurement of stratospheric and mesospheric winds with a submillimeter wave limb sounder: Results from JEM/SMILES and simulation study for SMILES-2",* Proc. SPIE, 9639, doi:10.1117/12.2194741, 2015

# CURRENT STATUS OF EUMETSAT OPERATIONAL AMV PRODUCTS

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ABSTRACT

EUMETSAT is deriving Atmospheric Motion Vectors (AMV) operationally from the Meteosat geostationary satellites as well as from the EUMETSAT Polar System satellite Metop. Recent research activities have led to important changes in the EUMETSAT operational AMV algorithms. The last MSG MPEF release 2.2 includes the use of the new Optimal Cloud Analysis (OCA) product to set AMV altitude, together with implementation of a new method which set the altitude of Clear Sky Water Vapour winds.

A new global AVHRR winds product derived from a pair of Metop-A and Metop-B images has been developed and has become operational in January 2015. The global coverage results in a homogeneous retrieval over the whole globe and helps to fill gaps between 50 to 70° latitude north and south, where few wind observations are available for assimilation. Finally a new triplet mode AVHRR wind product has been developed using 3 consecutives images taken by the two Metop satellites. This new product is derived over polar regions, and has become operational in December 2015.

This paper will give an overview of these recent developments, together with information on long-term perspectives. This mainly concerns the preparation of AMV prototype algorithms for the future MTG FCI and EPS-SG METimage instruments, and the EUMETSAT operational plans for Meteosat 8 and Metop A.

# USING DATA FROM THE ADVANCED HIMAWARI IMAGER (AHI) AS A PROXY TO ASSESS THE PERFORMANCE OF THE GOES-R DERIVED MOTION WINDS ALGORITHM

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ABSTRACT

In preparation for the launch of the GOES-R satellite later this year, the Derived Motion Winds algorithm is undergoing final testing and validation using proxy data from the Japan Meteorological Agency's Himawari-8 satellite which was launched in October 2014 and carries the 16-channel Advanced Himawari Imager (AHI) that is nearly identical to the Advanced Baseline Imager (ABI) to be flown on the GOES-R satellite. Access to data from Himawari-8 gives GOES-R algorithm developers an unprecedented glimpse of how their algorithms should perform once the ABI data is available. It also prepares potential users of GOES-R imagery and derived products for the substantial increase in the volume of information that will be available to the user community.

This poster is an extension of the oral talk given by J. Daniels during the operational status session of the conference and will focus on the lessons learned from applying the new GOES-R nested tracking algorithm to Himawari-8 imagery. In particular, the poster will highlight the challenges presented by tracking cloud features with the high spatial resolution visible band and suggest possible improvements to the algorithm to maximize the quality of the derived motion product.

# GENERATION OF HIMAWARI-8 AMVs USING THE FUTURE MTG AMV PROCESSOR.

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ABSTRACT

The Meteosat Third Generation (MTG) programme is intended to provide meteorological data from the geostationary orbit as a continuation of the Meteosat Second Generation (MSG) services at least until the late 2030s. The first MTG satellite is scheduled for a launch around 2019. The programme consists of a twin satellite concept, based on three-axis stabilised platforms: four imaging satellites (MTG-I) and two sounding satellites (MTG-S). Images from the Flexible Combined Imager (FCI) instrument on board the MTG-I satellites will be used to derive Atmospheric Motion Vectors (AMVs) in a wide range of frequencies, from visible to infrared.

In preparation for the upcoming launches, the MSG AMV processor has been adapted to Himawari-8 as a first step towards adapting it to MTG. Himawari-8 was launched in October 2014 and provides operational services since July 2015. The Advanced Himawari Imager (AHI) instrument on board Himawari-8 is a 16 channel multispectral imager, and has similar spectral and spatial characteristics to the aforementioned MTG-I FCI instrument. In this paper, preliminary results of the MTG AMV processor using Himawari-8 data are presented.

# TOWARDS IMPROVED HEIGHT ASSIGNMENT AND QUALITY CONTROL OF AMVS IN MET OFFICE NWP

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ABSTRACT

Atmospheric motion vectors (AMVs) derived from polar, geostationary and mixed satellite imagery are an important input to numerical weather prediction (NWP) analyses. The height assignment step remains the dominant source of error in AMV derivation schemes. At the Met Office AMVs are treated as single-level point observations of the wind at cloud-top or cloud-base. The current approaches to handling height errors are: 1) *a-priori* blacklisting of known problem areas with large systematic errors, 2) down-weighting observations through specification of situation-dependent observation errors, 3) bias correcting mean height errors. This presentation summarises efforts to further improve the handling of height errors in the assimilation.

For winds tracking low level clouds it is important that they are assigned heights within the boundary layer, since variations in the wind vector can increase rapidly above a capping inversion. Although most AMV producers try to account for this via an inversion correction, there are residual errors e.g. due to the use of a limited number of vertical model levels which fail to resolve the inversion correctly. Performing a separate inversion correction within the assimilation system itself has a number of advantages, including the use of the full vertical model resolution within the boundary layer. RMS vector differences for inversion height corrected winds are found to be reduced by 16%, with the largest improvements observed for GOES-13 and MTSAT-2. For MSG results are slightly more mixed. Preliminary impact studies applying the low-level inversion correction show a small positive impact on NWP forecast scores.

AMVs are derived from tracking cloud and WV features and so they should not be assigned heights in parts of the model that are very dry. Even if the model is in error, and not the observation, it still may be best to reject the AMV to avoid possible spurious results in the analysis. Collocated model background relative humidity (RH) is found to be a good quality indicator for IR and WV winds. Applying a RH threshold to remove AMVs assigned in 'dry' regions of the model is almost universally beneficial in improving biases (some very significant) for geostationary winds, but this must be weighted against the number of observations rejected. Model best-fit pressure can also be used as a tool to estimate when AMVs are thought to have been assigned to the wrong 'moist' layer of the model. Assimilation experiments have so far shown a fairly mixed impact from testing these new quality control methods.

# UPDATE ON OCEAN SURFACE WIND ASSIMILATION AT THE MET OFFICE

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ABSTRACT

Ocean surface wind vectors from scatterometers and passive microwave radiometers have been assimilated in Met Office numerical weather prediction (NWP) models for many years.

The Met Office global atmospheric NWP model has a horizontal resolution of N768 (17-km in mid latitudes), 70 vertical levels and runs a 4D-Var assimilation system four times per day (00,06,12,18Z) to produce an analysis of the current atmospheric state. Surface winds are operationally assimilated from ASCAT on Metop-A/B, WindSat and now also from RapidScat on the International Space Station. The scatterometer winds are assimilated as ambiguous U and V wind components (up to 4 wind solutions allowed to influence the analysis). RapidScat data were introduced to operations on 15 September 2015 helping to improve the coverage of winds in the tropics and mid-latitudes. Assimilation experiments have shown a largely neutral impact on global NWP scores but an improvement in the background (short-range forecast) fit to the observations. The experiments covered a period when there were many active storms in the Australian basin and the addition of RapidScat led to an overall reduction in tropical cyclone forecast track errors.

The ESA funded SMOS+STORM project aims to demonstrate the performance, utility and impact of SMOS L-band measurements at high wind speeds over the ocean during tropical and extra-tropical storm conditions. The Met Office has been assessing the potential for SMOS measurements of high wind speeds to improve NWP analyses and in particular for tropical cyclones which are generally found to be too weak in intensity. Case studies have shown the assimilation of SMOS wind speeds to be successful in increasing the analysed intensity of a tropical cyclone and the first results from full assimilation experiments will be presented.

# IMPROVING THE USE OF SATELLITE WINDS AT THE GERMAN WEATHER SERVICE

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ABSTRACT

Geostationary and polar-orbiting satellites provide spatially and temporally highly resolved wind observations which are widely used operationally by global and regional NWP centers. Various impact studies demonstrate the positive benefit of AMV and scatterometer wind products in the data assimilation system of the German Weather Service (DWD). Currently, the DWD uses AMV wind data from 5 geostationary satellites (GOES 13/15, METEOSAT 7/10, Himawari-8) and several polar-orbiting satellites (MODIS from TERRA and AQUA; AVHRR winds from the NOAA satellites and Metop). Additionally, scatterometer wind observations derived from the ASCAT instrument onboard of Metop A and Metop B are used routinely.

Monitoring of AMV wind vectors, product upgrades and the evaluation of new wind products which have the potential to improve the quality of analyses and forecasts, are an ongoing task at DWD. This presentation will give an overview of recent progress in the assimilation of AMV and scatterometer data. Since the last wind workshop, several new and upgrade AMV wind products become available. Thereby, the main focus was on the use of Himawari-8, Dual-Metop AMVs and polar winds derived from the VIIRS instrument on the NPP satellite. Monitoring and impact results will be presented. Additionally, results of an impact study, using MISR cloud tracked winds for a summer period in 2015 will be presented.

Based on investigations initiated by the University of Munich height assignment correction functions using cloud top heights derived from lidar measurements onboard of Calispo will be presented including first impact study results.

Additionally, impact studies using scatterometer data from five different instrumens (two C-band scatterometer onboard of Meteop-A and Meteop-B; a Ku-band scatterometer at Oceansat -2, a Ku-Band scattometer onboard of HY-2A and another Ku-band scatterometer onboard the ISS), all processed by KNMI, will be presented confirming the high quality and usefulness of scaterometer data in our global data assimilation system.

**USE OF GOES-R ADVANCED BASELINE IMAGER (ABI) PROXY DATA TO ASSESS THE PERFORMANCE OF THE GOES-R WINDS ALGORITHM**

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ABSTRACT

A new Atmospheric Motion Vector (AMV) nested tracking algorithm has been developed for the Advanced Baseline Imager (ABI) to be flown on NOAA's future GOES-R satellite which is scheduled to be launched in October 2016. GOES-N/O/P, Meteosat SEVERI, and NPP/VIIRS imagery have served as GOES-R ABI proxy data sources for the continued development, testing, and validation of the GOES-R AMV algorithms. Himawari-8 was successfully launched October 7, 2014 and carries the Advanced Himawari Imager (AHI) which is an almost identical instrument to the ABI. The availability of AHI datasets brings an unprecedented opportunity to exercise and test the GOES-R AMV algorithm.

This talk will focus on the outcome of our work to assess the performance of the nested tracking algorithm using H-8/AHI imagery as well as the other proxy data sources noted above. We will share what we have learned since developing the baseline algorithm and discuss algorithm improvements we have made and tested. Finally, we will highlight some of the AMV user readiness activities we are involved in to help prepare our user community for GOES-R.

**ATMOSPHERIC MOTION VECTORS FROM INSAT-3D: ISRO STATUS**

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ABSTRACT

At Space Applications Centre (SAC), Ahmedabad, the operational derivation of atmospheric motion vectors (AMVs) from Indian geostationary meteorological satellites started since 2007 using the data from Kalpana-1 and INSAT-3A under INSAT Meteorological Data Processing System (IMDPS) project. Later many improvements in the operational retrieval algorithm have taken place with the advancement in the retrieval techniques. The most recent advanced Indian geostationary meteorological satellite INSAT-3D was launched on 26 July 2013 and placed at $82^0$E over the Indian Ocean region. The data from an improved six channel imager and nineteen channels sounder on-board INSAT-3D has enhanced the scope for better understanding of the different tropical atmospheric processes over this region. The retrieval techniques and accuracy of atmospheric motion vectors (AMVs) has improved significantly with the availability of improved spatial resolution data along with more options of spectral channels in the INSAT-3D imager. The present study, a brief summary of the INSAT-3D data and operational AMV retrieval algorithm using four different spectral channels (visible, infrared, mid-infrared and water vapour channels) of INSAT-3D at 4 km spatial resolution are discussed. The long-term quality assessment of INSAT-3D AMVs with different other observations viz. radiosonde winds, model analysis winds and other available AMVs over this region are also presented. To demonstrate the initial application, INSAT-3D AMVs are also assimilated into numerical model to assess the impact for forecast improvement for few case studies. The validation results and impact assessment from this study will provide some guidance to the international operational agencies for implementation of this new AMV dataset for future applications in the Numerical Weather Prediction (NWP) over the south Asia region.

# SCATTEROMETER WINDS ACTIVITIES AT ECMWF

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ABSTRACT

Scatterometer wind vectors have been assimilated in the ECMWF 4D-Var Integrated Forecasting System (IFS) for more than 20 years, giving a positive impact on the analysis and forecasts.

Scatterometer wind data from the ASCAT sensors on-board the European METOP-A and METOP-B satellites are currently operationally assimilated. Data from the RapidSCAT sensor on-board the International Space Station (ISS) are also available; their assessment together with the evaluation of their impact on IFS are ongoing.

Recent scatterometer impact studies performed at ECMWF confirm the positive impact of ASCAT data on the IFS. The benefit was also shown for extreme events such as the case of tropical cyclones. Other research activities are ongoing in order to further improve the impact of Scatterometers winds and several aspects need to be taken into account to maximize the benefit of using EPS-Second Generation Scatterometer sensors. These will provide high winds with a better representation and a higher spatial resolution. Regarding the high wind speeds, we are testing a different quality control of such observations that uses the Huber Norm. The atmospheric model resolution is soon going to increase and a review of the observation sampling is also under investigation by testing different thinning strategies and observation errors.

This presentation gives an overview of the status of scatterometer winds operational and research activities at ECMWF.

# EXTENDING THE LEGACY OF MISR CLOUD MOTION VECTORS TO TANDEM SPACECRAFT

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## ABSTRACT

The Multi-angle Imaging SpectroRadiometer (MISR) instrument on NASA's Terra mission has been generating cloud motion vector winds since February 2000. MISR uses multiple pushbroom cameras to retrieve cloud-top heights (CTH) and cloud-top winds (CTW) across a 400-km swath. The disparities (horizontal offsets) between cloud features are obtained by pattern matching of images acquired at different look angles or times. Vector winds are generated at 17.6 km resolution, while CTH and cross-track winds are generated on a 1.1 km grid. Diagnostics imply an uncertainty in the along-track wind component of 2-3 m $s^{-1}$, while the cross-track component has smaller uncertainty (1 m $s^{-1}$). The reason for this difference is that from a single spacecraft, uncertainties in the along-track component of CTW from MISR are highly correlated with uncertainties in CTH. The MISR approach also requires the assumption of zero vertical wind.

Reduction in wind uncertainties in both the cross-track and along-track directions is feasible by flying identical multi-angle imagers on tandem satellites in the same orbit plane, separated by about 8 minutes in overpass time. By acquiring images at the same view angle from two separate satellites, it is possible to determine CTW independent of stereoscopic parallax, allowing unambiguous and accurate correction for cloud advection of CTH from each spacecraft. With this approach, instantaneous wind uncertainties are estimated to be ±0.3 m $s^{-1}$ for both the cross-track and along-track components. For rapidly convecting clouds, the technique also provides sensitivity to vertical wind speed.

We have developed an instrument concept known as the Multiangle Stereo and Time-lapse Imager (MSTI), which would enable acquisition of pushbroom images at 8 discrete along-track view angles. As with MISR, CTH and CTW retrievals are independent of instrument absolute radiometric calibration or atmospheric thermal structure. By taking advantage of advances in detector technology, MSTI would acquire multiangle imagery over a 1000-km swath, yielding 3-day global coverage (compared to 9 days with MISR), and have a mass of only 17 kg (compared to 150 kg for MISR). An Earth Venture mission concept, known as the Spaceborne Atmospheric Boundary Layer Explorer (SABLE), has been proposed that would implement identical MSTI instruments on a pair of microsatellites. In addition to providing data of value for improving models of numerical weather prediction and storm dynamical processes, a key objective of SABLE is determination of cloud-top entrainment rate (ER). Entrainment—the mixing of relatively dry air into regions of moister air through turbulent processes—is one of the least well understood processes controlling low cloud formation. The lack of quantitative measurements of ER has impeded progress in climate model development for more than two decades.

This poster will provide an overview of the MSTI and SABLE concepts, and provide a quantitative comparison of the CTH, CTW, and entrainment rate uncertainties expected from the tandem satellite approach with current MISR capabilities.

# REPROCESSING OF ATMOPHERIC MOTION VECTORS AT EUMETSAT

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ABSTRACT

Imagers have been flying onboard polar and geostationary orbiting satellites for more than 30 years providing a suitable data source for climate research. The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) participates in the second European Re-Analysis of the global CLIMate system (ERA-CLIM2) project. The project contribution is dedicated to the "Preparation of satellite observations, boundary conditions, and forcing data" with the aim to improve the available observational record for the 20th century and to prepare data sets and assimilation tools needed for global reanalysis. One of EUMETSAT's contributions within the ERA-CLIM2 project is the generation Atmospheric Motion Vectors (AMVs) from polar and geostationary satellites. The polar AMVs are reprocessed using data from AVHRR instruments and derived from two independent algorithms. The first algorithm is the EUMETSAT operational algorithm and the second one is the algorithm developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS). The geostationary AMVs are reprocessed using MVIRI and SEVIRI images respectively onboard METEOSAT first and second generation satellites. The current operational algorithm run at EUMETSAT is used for the reprocessing.
The reprocessed products are validated through a comparison against radiosonde and NWP model analysis data. This paper will present the AMV dataset and detail the AMV reprocessing plans at EUMETSAT.

**AMVS: PAST PROGRESS, FUTURE CHALLENGES**

Mary Forsythe, James Cotton, Francis Warrick

Met Office

ABSTRACT

Atmospheric motion vectors (AMVs) are produced by tracking clouds or areas of water vapour in consecutive satellite images and have been assimilated in Numerical Weather Prediction (NWP) models since the 1980s. In recent years there have been several developments including: improved coverage (areal and temporal), new derivation approaches, introduction of situation-dependent error schemes and evaluation of new observation operators.

Forecast Sensitivity to Observations Impact (FSOI) show beneficial impact from AMVs at many NWP centres. In recent years, the Met Office has seen an increasing contribution from AMVs towards reducing 24-hr forecast errors. AMVs are now ranked third behind hyperspectral IR and microwave radiances, ahead of the conventional observations including radiosondes and aircraft.

Looking ahead, what are the main challenges? As forecasts and observing systems continue to improve, it is critical we continue to improve the quality of the AMV products. To achieve this we need to understand more about the AMV data and sources of error so we can improve the AMV derivation, quality control and representation. In recent years there has been a move towards direct use of pixel-based cloud schemes developed by the cloud community. Many of these schemes provide estimates of height error and cost which can highlight where height assignment is more problematic and could be used for blacklisting and adjusting observation errors in NWP.

Current AMV products capture broad-scale to synoptic-scale flow. Looking at movie loops we can see information available on much smaller scales. Can we use this information to improve nowcasting and high resolution models, particularly for the forecasting of high impact weather events? Aside from the challenges of generating AMVs using smaller target boxes, there are additional considerations for NWP. In NWP smaller scales tend to change fast and represent only modest energy conversion. The quantity and coverage of observations required to initialise and evolve these scales is a daunting challenge. Inadequate coverage could compromise the analysis of the larger scales. Also AMVs have correlated errors in space and time. To alleviate problems, data is thinned (or superobbed) and errors are inflated. But if we thin too much, we will lose the mesoscale information of interest.

In this talk we will highlight some of the key developments, review results from Forecast Sensitivity to Observations Impact (FSOI) and look ahead to some of the future challenges, many of which will benefit from continued collaboration between AMV producers and users.

# NWC SAF/HIGH RESOLUTION WINDS AMV SOFTWARE VERSION 2016

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ABSTRACT

The "High Resolution Winds (HRW)" product, developed inside the "Satellite Application Facility on support to Nowcasting and very short range forecasting (NWC SAF)" stand alone "software package for geostationary satellites (NWC/GEO)", provides a detailed calculation of Atmospheric Motion Vectors and Trajectories locally and in real time by its users.

A new version of NWC/GEO software package is being released in 2016, with following main new elements for HRW product: the inclusion in "CCC height assignment method" of a pressure level correction physically based on the cloud depth, considering new parameters provided by NWC/GEO Cloud Microphysics product, and its extension to the processing of images coming from GOES-N satellite series (GOES-13, GOES-14 and GOES-15).

Common tools and libraries used by all NWC/GEO products have also been prepared to easily process later on additional geostationary satellite series, through the conversion of satellite input data to a common NetCDF format. A detailed documentation of all HRW code has also been included, with the support of Doxygen tool and through comments inside its C/Fortran code, which helps NWC SAF users to understand every single step of HRW algorithm.

The validation of HRW version 2016 for MSG satellite AMVs, compared to previous version 2013, shows an increase in the amount of valid AMVs of about a 20%, and a reduction in all validation statistics, up to about a 20% in the case of the BIAS. The validation for GOES-N satellite AMVs shows equivalent validation statistics than for MSG satellite AMVs.

Because of its characteristics and its ease to be obtained, understood and run locally, HRW product had been proposed as option for "Stand alone AMV calculation software", available to all AMV researchers and users. The good validation results obtained by HRW product, one of the two best AMVs algorithms in the 2014 AMV Intercomparison study, with the additional improvements in validation shown by version 2016, should be enough to convince any AMV researcher about the use of NWC/GEO HRW product.

**ON IMPORVING THE USE OF AMV AT NCEP GSI**

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ABSTRACT

Satellite winds are changing for multiple reasons – new imaging instruments are launched, novel retrieval algorithms are implemented, more AMV producers are joining the Global Observing System. Simultaneously NWP models evolve as well.

NCEP GSI is now ready to assimilate GOES-R and HIMAWARI-8 winds. We will present the preparatory work for these two data streams, and results from re-evaluating and improving the AMVs Observation operator in NCEP GSI, addressing changes in the AMV products.

We will also present a study focusing on the complimentary nature of AMVs and Doppler lidar winds, in anticipation of the JMA and ESA's Doppler winds lidar space instruments.

**MISR WIND STRUCTURE ALONG THE EQUATOR DURING EL NINO AND LA NINA IN 2000-2016**

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ABSTRACT

MISR monthly averaged wind vectors over the ocean along the equator appear to be sufficient in quantity to draw conclusions about the upper-troposphere limb of the Walker Circulation during El Nino and La Nina events since March 2000, when MISR data were first recorded. In the Pacific Ocean where the Walker Circulation was first defined by Jacob Bjerknes, the zonal wind directions would be westward at the surface and eastward in the upper troposphere. In the central Pacific Ocean at 170-130 °W, the MISR climatological-mean zonal wind component in 2-km layers from 1-19 km averaged from January 2001 to December 2014 reversed direction at about 7-km height. In the central Pacific, maximum westward (eastward) wind speeds occurred at 0-m (14-km) height. At 14-km height, the speed of the eastward wind in El Nino was 10 m $s^{-1}$ less than in La Nina. This condition produced a much weaker vertical wind shear in El Nino to enable formation, growth and maintenance of tropical storms, which was consistent with observations, e.g., the northern hemisphere summer in 2015 had a large number of typhoons originating in the tropical west Pacific. In the super El Nino event of March 2015 – January 2016, which continues at the time of preparation of the abstract and additional data will be available in the analysis presented at IWW13, MISR winds at 14 km were similar, to within about ± 3 m $s^{-1}$, to the average zonal wind speed during the previous four El Nino events. Also, the influence of El Nino and La Nina events on surface and upper-troposphere winds over the equatorial Atlantic and Indian oceans will be discussed.

# EVALUATION OF FY2E REPROCESSED WINDS IN GRAPES

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ABSTRACT

The quality of FY-2E AMVs has improved significantly during past years and the FY-2E AMVs are reprocessed in the period of 2010-2015. In the recent two years, various studies for evaluation of the reprocessed AMVs are conducted in the Global/Regional Assimilation PrEdiction System (GRAPES) at CMA, including quality control, the height assignment correction using best fit pressure, optimal spatial thinning and observation error tuning using Desroziers diagnostic method and the observation error model considering wind vertical shear and height uncertainty. This presentation will give an overview of recent progress in the evaluation of the FY-2E old and reprocessed AMVs at Chinese Meteorological Administration (CMA).

**DERIVATION OF WIND VECTORS FROM METOP AVHRR AT EUMETSAT.**

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ABSTRACT

EUMETSAT is currently deriving Atmospheric Motion Vectors (AMV) operationally from the EUMETSAT Polar System satellite Metop. The launch of *Metop-B* in 2012 permitted to double the product frequency extracting AMVs from both *Metop-A* and *Metop-B* satellite data over the Polar Regions. The tandem configuration with two satellites on the same orbital plane, but with a phase difference provided an interesting opportunity to create global AMVs from satellites with a significant overlap in imagery data. Therefore EUMETSAT has developed a new Global AVHRR winds product derived from a pair of *Metop-A* and *Metop-B* images that have a temporal gap about 50 minutes between the two images. The tandem configuration provides also the possibility to derive wind vectors over polar areas using a triplet of AVHRR images, keeping the same time period necessary to derive Single Metop polar wind product, but allowing a temporal consistency check in the calculation of the AMV quality index. Three different AMV products are extracted from AVHRR imagery at EUMETSAT, using two or three images taken by one or two satellites, having different coverage and time integration.

This paper describes the scientific concept of the AVHRR wind extraction algorithm developed at EUMETSAT and presents the performances of the various AVHRR wind products against the corresponding forecast fields. Intercomparisons of these different products highlight the role of the temporal gap between the images used to extract the wind and the impact of the consistency check on the calculation of the quality index.

# EXTRACTION OF 3D WIND PROFILES FROM IASI LEVEL2 PRODUCTS.

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ABSTRACT

Atmospheric Motion Vectors (AMVs) derived from satellite imagery constitute a significant part of the observation data assimilated in Numerical Weather Prediction (NWP) models because they are the only upper wind observations with good global coverage for the tropic, mid-latitudes and polar regions. AMVs are routinely extracted from the Meteosat geostationary satellites at EUMETSAT as well as from the EUMETSAT low orbit Polar System satellite Metop AVHRR instrument.

The AMVs commonly extracted from imagers provide information of cloud motions at a single level in the troposphere, and do not allow to getting the whole wind profiles. Such wind profiles may theoretically be estimated from temperature and humidity profiles retrieved from hyperspectral sounding, for which the height information is already available together with the retrievals. Time sequences of retrieved water vapour fields become in this approach the “imagery” for tracking winds and the corresponding AMV heights can be directly inferred from the profile heights information.
Studies involving novel methods to extract AMVs from humidity fields have been realised by EUMETSAT in the past. Results of these studies illustrated the potential benefits of using optical flow methods on smooth water vapour fields, but they also pointed important limitations of these methods. The 2D framework of the tested methods did not allow to manage correctly the frequent multilayer situations for example, or to consider properly the convection in cloudy areas. Such limitations may be potentially reduced by considering the 3D optical flow algorithm (Heas and Mémin, 2008) recently developed at INRIA/IRISA, which is fed with several horizontal layers of atmospheric fields to extract dense wind fields for all the considered layers.

This last algorithm has been adapted to ingest IASI level 2 temperature and humidity fields, and to extract dense wind fields from a pair of IASI data taken consecutively by Metop A and Metop B satellite over high latitudes areas. This paper will present the method and the preliminary results of this new development, highlighting the feasibility of wind profile extraction from IASI level 2 data, and discussing the short-term perspective of this project at EUMETSAT.

**INTERCOMPARISON OF CLOUD HEIGHTS FOR AMV GENERATION**

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ABSTRACT

Atmospheric Motion Vectors (AMVs) are an important source of satellite data for assimilation into Numerical Weather Prediction (NWP) models. A large driver of the accuracy of AMVs are the heights assigned to each vector. In recent years, AMV applications are relying more and more on the cloud heights generated from external cloud height algorithms, including those participating in the International Cloud Working Group (ICWG). AMV applications provide a direct link to the cloud height products and the NWP community.

While cloud height comparisons have been a common activity in the past Cloud Retrieval and Evaluation Workshops (CREW), the AMV application only uses a sub-set of cloud heights. This subset usually consists of cloud edges and other features that are identifiable targets in the AMV tracking schemes.

To make a relevant analysis, we will use an AMV algorithm to select pixels which would serve as AMV targets and restrict our analysis to those pixels. We will use the NOAA/CIMSS AMV software and use 1DVAR heights from NOAA (ACHA) and EUMETSAT (OCA). Our goal will be to compare the cloud height performance for the AMV-relevant pixels. Another aspect of this work is to compare the cloud height uncertainty estimates and other meta-data. We intend to collaborate with the International Winds Working Group (IWWG) and work towards standard and relevant definitions of our products and their meta-data.

# USE OF ATMOSPHERIC MOTION VECTORS IN THE REGIONAL MESOSCALE MODEL HARMONIE IN AEMET

A. Hernandez

AEMET

ABSTRACT

AMVs are widely used by NWP assimilation systems, as they can provide information about atmospheric wind in areas not well covered by other observation systems. In regional mesoscale NWP, assimilation-forecast cycles are carried out frequently (typically every three hours, but often hourly or even sub-hourly), and the cut-off time for observations is short (typically 1 to 2 hours, but it can be as short as 20 minutes). Therefore one of the problems faced is the lack of observation sources that combine a high frequency with a short latency. AMVs from Meteosat-10 currently represent such a source over Southern Europe.

However, AMVs are not simple point observations of wind, but the result of a complex derivation process. It is well known that AMV errors are large and complex, and that their characteristics vary with e.g. height assignment method or geographical area. In recent years several AMV studies have been carried out to improve the knowledge about error characteristics and vertical representativity, to explore alternative interpretations, or to design suitable height corrections, following different approaches. From the perspective of mesoscale NWP, there is also the issue of the horizontal scale represented by AMVs, partly related to the size of the tracer boxes, and partly to the quality index used to filter AMVs for the assimilation, as this index is essentially a measure of spatial and temporal consistency.

This contribution will present the work in progress in AEMET (Spain National Meteorological Service), part of the HIRLAM consortium, to assimilate Meteosat-10 AMVs in HARMONIE, a mesoscale regional NWP model with a default horizontal resolution of 2.5 km. A key tool in this work is the NWC/GEO software, produced by the EUMETSAT SAF on support to Nowcasting.

# EVALUATION OF DUAL-MODE METOP AMVS

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ABSTRACT

The METOP-A and METOP-B satellites form the space segment of the EUMETSAT Polar System. EUMETSAT has recently introduced a novel dual-mode atmospheric motion vector (AMV or "wind") retrieval technique, taking advantage of the swath overlap between the satellite tandem that flies in the same orbital plane but with a half orbit separation. These dual-mode AMVs are extracted by tracking cloud features in a pair of 10.8-µm images obtained ~50 minutes apart, allowing global wind retrievals from AVHRR for the first time. The increased coverage of the product helps filling the 55°-70° AMV data gap between the coverage areas of geostationary and polar sensors.

We present a comprehensive evaluation of METOP AMVs against GOES-13/15, METEOSAT-7/10, MTSAT-2, and HIMAWARI-8 geostationary winds, MODIS polar winds, MISR stereo winds as well as radiosonde observations and ERA-Interim model winds. Comparison statistics are derived for the globe and separately for large climatological areas (polar regions, mid-latitudes, tropics). Emphasis is put on investigating height assignment errors; therefore, validation results are stratified according to height assignment technique (equivalent blackbody temperature, IASI $CO_2$-slicing, low-level temperature inversion correction). Some of the geostationary satellite-derived winds are available from several independent producers (CIMSS, EUMETSAT, JMA). Comparison of AMVs derived from the same imagery enables identification of differences caused by algorithm specifics and confirms the advantage of METOP AMVs, which represent a globally homogeneous dataset.

# POLAR WINDS FROM NEAR-INFRARED BAND CLOUD TRACKING

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ABSTRACT

Polar clouds are notoriously difficult to detect and characterize with satellite imagers because of the similarities between their temperature and reflectance properties and those of the underlying snow and ice surface. Ubiquitous lower-tropospheric temperature inversions in winter and nearly isothermal temperature profiles in summer result in a very small temperature contrast between low, stratiform clouds – the most common cloud type over much of the Arctic Ocean – and the surface. In the visible portion of the electromagnetic spectrum clouds and snow/ice are equally bright, again creating a situation of very low contrast between the two. This lack of contrast impacts cloud tracking and the derivation of wind information because there are fewer good features to track.

In the near-infrared, however, the scattering properties of liquid-phase clouds and snow/ice are significantly different, and therefore the contrast between low clouds and the surface is large. This is particularly true at 1.6 and 3.7 µm, a fact that has been exploited in polar cloud detection at least since the early 1990s. The Advanced Very High Resolution Radiometer, the Moderate Resolution Imaging Spectroradiometer (MODIS), and the Visible Infrared Imaging Radiometer Suite (VIIRS) all have bands at these wavelengths. In theory, near-infrared data will provide more good features for cloud tracking and atmospheric motion vector derivation during the "daytime", especially for low clouds.

Polar winds from the MODIS 1.6 µm band are now routinely produced for the Arctic and Antarctic as a research product (http://stratus.ssec.wisc.edu/products/rtpolarwinds/, labelled as "Terra-SW" and "Aqua-SW"). Height assignment is done using the infrared window channel (11 µm). There are fewer wind vectors than for the infrared window cloud-track winds, primarily because at the time of this writing (February) there is little daylight in the Arctic, and low, liquid clouds over the Antarctic continent are not common. Nevertheless, it is expected that the near-infrared cloud track winds will be a valuable complement to current polar winds products. Statistics for the accuracy of the MODIS near-infrared winds relative to radiosonde and model background winds are being compiled and will be presented.

# AMV QUALITY CONTROL METHOD FOR THE NEXT GENERATION GEOSTATIONARY SATELLITE OF KOREA

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ABSTRACT

The second generation geostationary satellite of Korea (Geo-KOMPSAT 2A; GK-2A) will be launched in 2018. The Advanced Meteorological Imager (AMI) on GK-2A will have sixteen spectral bands with 0.5-2 km spatial resolution and will scan every 10 minutes for the Full Disk. It will provide four times more spatial and time resolution, and three times more for spectral information compared to COMS MI. Therefore, the new meteorological data processing system for the AMI is developing.

Atmospheric Motion Vector (AMV) is very important data for numerical weather prediction (NWP) models as it provides valuable wind information, especially where no ground measurement exist. To obtain qualitative information from each AMV product, Quality Control (QC) is required to verify the quality of the product. GK-2A AMV QC is performed in two ways. The first one is Quality Indicator (QI) (Holmlund, 1988) and the second way is Expected Error (EE) (Le Marshall, 2004; Berger, 2008). The statically-based QI is a simple scheme which consists of five vector consistency tests, which are emphasized on spatial and temporal consistency. The EE is essentially an extension of the QI, but it is based on regression between the difference of AMV and rawinsonde wind with respect to the five QI tests results and AMV's speed, pressure, NWP model vertical temperature gradient, and wind shear. We have performed two QC methods on the AMV derived from Current Korean geostationary satellite (COMS). The analysis shows when QI is applied, a significant portions of slow wind vectors where are located in low altitude are eliminated. On the contrary, when EE is applied, relatively strong wind in high altitude is eliminated whereas slow wind in low altitude is selected. The combined QI and EE have provided improved AMV performance in selecting qualitative wind vectors both in low and high altitude. Along with this traditional QC method, we have performed additional approach by applying median filter and categorizing wind vector clustering to overcome the reduction in the number of wind vectors and cyclonic wind with high curvature such as typhoon after QC.

# THE STATUS OF DEVELOPMENT FOR AMV ALGORITHM OF GEO-KOMPSAT 2A

Tae-Myung Kim, Sung-Rae Chung, Byung-il Lee, Seonkyun Baek

NMSC/KMA

ABSTRACT

Atmospheric Motion Vector(AMV) algorithm for Geo-KOMPSAT 2A has been developed since 2014. The second geostationary meteorological satellite (Geo-KOMPSAT 2A; here after GK-2A) of Korea will launch in 2018. The AMI, flown on the GK-2A has sixteen spectral bands(like GOES-R/ABI and Himawari-8/AHI). In preparation for the launch of the GK-2A, NMSC/KMA has plan to develop a lot of meteorological products using GK-2A/AMI data. These products include scene analysis, cloud, wind, atmospheric condition, radiation and surface parameters. The Atmospheric Motion Vector(AMV) is one of fifty-two products to support numerical weather prediction and weather forecasting.

The AMVs algorithm for GK-2A consists of four steps such as target selection, vector tracking, height assignment and quality control. In this paper, an overview of AMV algorithm developed for GK-2A and the preliminary results will be presented.

**FORECAST SENSITIVITY AND OBSERVATION IMPACT (FSOI)**
**INTER-COMPARISON EXPERIMENT**

Rolf Langland, Nancy Baker

Naval Research Laboratory, Monterey, CA
With Thomas Auligné (JCSDA) and additional co-authors to be included

ABSTRACT

Forecast Sensitivity and Observation Impact (FSOI) techniques provide a practical means to estimate the forecast impact of all assimilated observations for NWP systems. In this presentation, we describe direct comparisons of FSOI quantities between different NWP systems. A common "baseline" set of FSOI experimental parameters are applied for the time period December-February (DJF) 2014/2015. An adjoint-based FSOI approach is applied for the NWP systems at the Naval Research, NASA/GMAO, and the UK Met Office; whereas an ensemble-based FSOI approach is applied at the National Centers for Environmental Prediction (NCEP). The Japan Meteorological Agency (JMA) applies both the adjoint-based and ensemble-based FSOI capabilities, enabling a direct comparison of the two techniques.

Given the aforementioned experiment, we plan to describe the differences in aggregated FSOI quantities between NWP systems for the relevant observing systems. Additionally, NWP system inter-comparisons of FSOI quantities for common observation subsets within the 3-month period will be presented. The relative impact of wind observation in various operational forecast systems will be compared, along with discussion of gaps in the current global observation system.

Note: this presentation will be an updated version of a talk to be presented by Thomas Auligné (JCSDA) at the WMO 6$^{th}$ Workshop on the Impact of Various Observing Systems, Shanghai, China, May 13-16, 2016.

# RECENT WORK ON AMV AND OPERATIONAL IMPLEMENTATION OF SATELLITE WIND PRODUCTS AT THE METEOROLOGICAL SERVICE OF CANADA

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ABSTRACT

New AMV products from the operational satellites Himawari-8 and Suomi NPP have been implemented in the MSC data assimilation system in early 2016. The passive monitoring of the S-NPP VIIRS polar winds against the background from the global forecast system (i.e O-B) shows that the RMS vector differences (RMSVD) are generally smaller than the RMSVD for corresponding AVHRR polar winds from the NOAA satellites. This is especially true above 400 hPa where the RMSVD are 20% smaller. The inclusion of the S-NPP winds increases the number of polar winds assimilated by 20 %, and provides a small but positive impact on forecasts over the polar regions. AMV products from Himawari-8 became available on July 2015 in replacement of MTSAT-2. The volume of AMVs from Himawari-8 is roughly five times larger than that from MTSAT-2 and the data coverage is much greater. In an operational context, this represents a challenge in terms of data continuity. In order to assimilate a number of AMV as comparable to MTSAT-2, only one out of three water vapor channels is used and only AMV with a QI greater than 97 are assimilated. We found that the quality of the AMV from Himawari-8 is much better. The RMSVD of O-B for Himawari-8 are 15% smaller than those of MTSAT-2.

The situation dependent observation error algorithm developed at the UK Met-Office was tested for summer 2011. Overall, the impact on forecasts for this period is neutral. Another trial for the autumn 2015 period is currently carried out and the results will be presented at the workshop.
The RapidScat wind product is both similar and complementary to ASCAT wind retrievals, which are already assimilated operationally at MSC and are known to improve the quality of analyses over the oceans. Assimilation experiments with and without assimilation of RapidScat data were performed using the global forecast system for a one-month period in January 2015. The impact on forecasts is mixed, but positive in the northern extratropics.

# AMV RESEARCH ACTIVITIES AND PROGRESS AT ECMWF

Katie Lean, Kirsti Salonen and Niels Bormann

ECMWF

ABSTRACT

This presentation gives an overview of recent research activities and the status of the operational assimilation of Atmospheric Motion Vectors (AMVs) at ECMWF. We will focus particularly on efforts to close the gap in AMV coverage between polar and geostationary satellites and continued efforts to improve the height attribution for AMVs.

Recent enhancements in the set of available AMVs have provided the opportunity to close the long-standing gap in AMV coverage at higher mid-latitudes between geostationary and polar AMVs. This has been achieved through two developments: firstly, the allowed zenith angle for geostationary satellites has been increased from 60˚ to 64˚. Secondly, we introduced new AMVs from the polar orbiting Metop satellite. The Metop data used are a combination of the Dual product (deriving AMVs from image pairs using both satellites) in mid-latitudes (40˚-60˚) and the Single winds product (using image pairs from the same satellite) for the Polar regions (>60˚). The two upgrades lead to a significant positive forecast impact at mid-latitudes.

Improving the height assignment and better understanding the errors associated with the process has also been an ongoing challenge. Recently, a new development is the use of Optimal Cloud Analysis (OCA) to obtain the cloud parameters needed for the AMV height assignment. OCA uses a one dimensional optimal estimation approach and also tests for multi-layer cloud situations allowing estimates for single or two layers where appropriate. Meteosat Second Generation (MSG) data are being provided with this new height assignment technique alongside the previous Cross-Correlation Contribution (CCC) method. The impact of using the OCA product in the MSG AMV data is assessed.

# ASSESSMENT OF AMVS FROM HIMAWARI-8 AND VIIRS

Katie Lean, Kirsti Salonen and Niels Bormann

ECMWF

## ABSTRACT

The recent launches of several satellites has meant that many new Atmospheric Motion Vectors (AMVs) have become available. In particular, detailed analysis has been carried out for the Advanced Himawari Imager (AHI) instrument on Himawari-8 and the Visible Infrared Imager Radiometer Suite (VIIRS) instrument on the polar orbiting Suomi National Polar-orbiting Partnership (SNPP) satellite.

Himawari-8 has replaced Multifunction Transport Satellite - 2 (MTSAT-2) in geostationary orbit. Compared to its predecessor, this new instrument has better resolution (up to two times higher) and completes a full disk scan in 10 minutes reduced from 24 minutes. An increase in the number of channels from 5 to 16 allows AMVs to be derived from five channels (three water vapour, one infrared and one visible). A new tracking technique for calculating the wind vector and new height assignment method have also been developed. In preparation for operational use, AMVs from Himawari-8 have been assessed at ECMWF through first guess departure statistics with comparison to the performance of MTSAT-2. Assimilation experiments have been conducted to investigate the impact of the new data on the forecast system.

VIIRS will be the successor of the Advanced Very High Resolution Radiometer (AVHRR), used to generate polar AMVs. The constrained pixel growth on VIIRS means that compared to other instruments such as AVHRR, the resolution is higher at the swath edges. The swath width is also wider than the Moderate Resolution Imaging Spectroradiometer (MODIS). AMV derivation from VIIRS uses a method developed for the Geostationary Operational Environmental Satellite - R (GOES-R) which employs a new nested tracking algorithm and height assignment using externally generated cloud information. AMVs from VIIRS have been similarly assessed using first guess departure statistics and assimilation experiments.

# IMPACT STUDIES OF HIGHER RESOLUTION COMS AMV IN THE OPERATIONAL KMA NWP SYSTEM

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NIMS/Korea Meteorological Administration

ABSTRACT

A new algorithm to retrieve higher resolution AMV (the target size is about 64 km at nadir, and uses optimal target method for target selection) was developed by National Meteorological Satellite Center (NMSC) in Korea. Currently, the operational KMA global NWP system uses COMS AMV, whose target size is about 96 km at nadir, with other AMVs from Meteosat, GOES, MTSAT and polar orbit satellites. The higher resolution AMV data seem to have better quality compared with sonde observation relieving the slow bias in winter jet region. Also the number of data is increased as four times as previous one. Assimilation of higher resolution COMS AMV made wind analysis fields stronger in winter jet region improving forecast verification score in winter hemisphere. However, the forecast impact wasn't good in summer hemisphere, and so detailed analysis on AMV error characteristics had been done for optimized use of the new data.

In this study, newly developed AMV data were assimilated in the operational KMA global NWP system replacing previous COMS AMV data. Then, different strategies of blacklisting have been tested because the current blacklisting strategy is very strict, and so only small amount of AMV can be assimilated. It was shown that more data were assimilated and the forecasting impact was more positive when weaker blacklisting strategy was applied. Also, error profiles for each channel were calculated, and its impact was evaluated. The variation of spatial thinning strategy has been tested since the spatial resolution of AMV data changed. However, the thinning impact wasn't that good than we expected. In the conference, detailed explanation about the new AMV data, blacklisting and thinning strategies, and error profile will be presented, and the forecasting impact will be shown.

# IMPACTS OF SPATIAL OBSERVATION ERROR CORRELATION IN ATMOSPHERIC MOTION VECTORS ON DATA ASSIMILATION

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## ABSTRACT

This study investigates spatial error correlations in the Atmospheric Motion Vectors (AMVs) derived from geostationary satellite imagery. A good characterization for the random and systematic errors of observation is essential in order to extract information from the observation during an assimilation process in a near-optimal way (Bormann et al., 2014). The spatial structure of the AMV error correlations is identified based on monthly datasets of AMVs and radiosonde observations collocated for July and August in 2015. We use the AMVs with a quality indicator (QI) threshold of 80% to filter out poor-quality data, and remove outliers by three-sigma. Results for AMVs from infrared (IR; 10.8 µm), water vapour (6.7 µm), and visible (0.67 µm) channels of the Multifunction Transport Satellite (MTSAT-2) and the Korean geostationary Communication, Ocean and Meteorological Satellite (COMS) are presented. Winds from two datasets show statistically significant spatial error correlations depending on distance with little difference between satellites, channels, and vertical levels. With regard to this AMV error correlation structure, we plan to present impacts of different thinning resolution for AMVs on the KIAPS data assimilation system.

## HIMAWARI-8 DERIVED MOTION WINDS - GENERATION AND ASSIMILATION

John Le Marshall[1], David Howard[1], Yi Xiao[1], Jamie Daniels[2], Steve Wanzong[2], Jim Jung[3], Wayne Bresky[2], Andrew Bailey[2], Chris Tingwell[1], Paul Gregory[1], Tan Le[1] ,Tim Morrow[4] and Denis Margetic[1]

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ABSTRACT

In October 2014 the Japanese Meteorological Agency (JMA) launched the new generation Geostationary satellite Himawari-8. This satellite provides 10 minute interval imagery in sixteen different wavebands over the Asian and Australasian region. At the Bureau of Meteorology the imagery has been navigated, calibrated and subsequently used to generate Derived Motion Winds (DMVs) over the full earth disk viewed from the satellite. Each vector has been error characterised and assigned an expected error. In preparation for the operational assimilation of 10 minute data from the full disk footprint of Himawari-8, 10 minute high temporal and spatial resolution data generated over the Australian region from Himawari-6 (during the High Ice Water Experiment) and from Himawari-8 after July 2014 were combined with the Australian Bureau of Meteorology operational database to provide forecasts using the next generation operational regional forecast model ACCESS APS2. Results from these tests indicate the Himawari-8 10 minute wind data have the potential to produce high density, high quality AMVs which are able to improve model initialisation and forecasts. The forecasts undertaken include cases associated with extreme weather. The results have also provided the appropriate times, data selection and application methods for the effective use of these high temporal resolution data.

# BIAS ASSESSMENT OF MODIS/MISR CLOUD MOTION WIND

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National Satellite Meteorological Center, CMA

ABSTRACT

Three-years MODIS/MISR satellite retrieval polar wind records from 2013 to 2015 were selected for studying the bias distribution by comparing to ECMWF reanalysis and radiosonde. The temporal and spatial matching window for collocation the wind records were set to 300 seconds and 50 km.

The inter-comparison between MODIS/MISR and reanalysis winds in north hemisphere reveals that Modis IR winds speed agree with reanalysis within 0.5m/s in most cases. and MISR winds have a systematic bias of -0.5m/s along zonal, and +0.5m/s along meridional. The inter-comparison between MODIS/MISR and reanalysis in southern hemisphere shows the MODIS wind distribution have the similar pattern as in north hemisphere, while the MISR wind speed bias increase with the height. This comparison also reveals that the MISR wind provide much more wind information within boundary layers than the other, which suggest MISR wind may be useful in improving the boundary layer forecast.

**MISTiC WINDS, A MICRO-SATELLITE CONSTELLATION APPROACH TO HIGH RESOLUTION OBSERVATIONS OF THE ATMOSPHERE USING INFRARED SOUNDING AND 3D WINDS MEASUREMENTS**

Kevin R. Maschhoff

BAE Systems

ABSTRACT

MISTiC$^{TM}$ Winds is an approach to improve short-term weather forecasting based on a miniature high resolution, wide field, thermal emission spectrometry instrument that will provide global tropospheric vertical profiles of atmospheric temperature and humidity at high (3-4 km) horizontal and vertical ( 1 km) spatial resolution. MISTiC's extraordinarily small size, payload mass of less than 15 kg, and minimal cooling requirements can be accommodated aboard a 27U-class CubeSat or an ESPA-Class micro-satellite. Low fabrication and launch costs enable a LEO sun-synchronous sounding constellation that would collectively provide frequent IR vertical profiles and *vertically resolved* atmospheric motion vector wind observations in the troposphere. These observations are highly complementary to present and emerging environmental observing systems, and would provide a combination of high vertical and horizontal resolution not provided by any other environmental observing system currently in operation. The spectral measurements that would be provided by MISTiC Winds are similar to those of NASA's Atmospheric Infrared Sounder that was built by BAE Systems and operates aboard the AQUA satellite. These new observations, when assimilated into high resolution numerical weather models, would revolutionize short-term and severe weather forecasting, save lives, and support key economic decisions in the energy, air transport, and agriculture arenas–at much lower cost than providing these observations from geostationary orbit. In addition, this observation capability would be a critical tool for the study of transport processes for water vapor, clouds, pollution, and aerosols. Key technical risks are being reduced through laboratory and airborne testing under NASA's Instrument Incubator Program.

**FORECAST IMPACT OF MISR CMV IN GEOS-5**

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ABSTRACT

We have conducted a number of experiments exploring the positive forecast impact of assimilating cloud motion vectors (CMVs) derived from the Multi-angle Imaging SpectroRadiometer (MISR) instrument into the Goddard Earth Observing System Model Version 5 (GEOS-5) Data Assimilation System (DAS). From aboard the polar-orbiting Terra satellite, MISR exploits stereo imagery captured over the 7 minute duration of an overpass from multiple camera angles to jointly resolve geometric cloud height and motion, avoiding known issues with AMV assigned heights determined by radiometric techniques. MISR CMV are available at high latitudes and at low levels where there are current deficiencies in the sampling of satellite atmospheric motion vectors. They are publicly available in near real time (NRT), with under 2.5 hour latency, and are archived with a nearly continuous global record dating back to early 2000, and expected to continue until at least 2020.

MISR CMV provided consistent reduction of 24-hour forecast errors when assimilated in the GEOS-5 DAS at at 0.5° x 0.6° resolution in conjunction with standard Modern-Era Retrospective analysis for Research and Applications (MERRA) observational inputs. Using the adjoint method, the relative contribution of MISR CMV to error reduction was consistently greater than 0.02 J/kg per 6-hour time step, a magnitude representing 10-15% of the total benefit from all other satellite winds. The greatest benefits were apparent over the Southern Ocean at all levels. The most optimal assimilation approach assigned greater uncertainty to the component of MISR retrieved cloud motion oriented along the ground-track, which is less accurate because of the need to differentiate real cloud motion from apparent cloud motion due to parallax. This optimal approach was more consistent and provided much greater mean benefit than assigning error to the northward and eastward components uniformly. Further experiments found the standard NRT CMV products to deliver lesser, but comparable benefit relative to the standard CMV product, due primarily to lesser sampling. Forecast benefit was also found to be consistent for different time periods.

# MISRLITE - A CONVOY MISSION FOR SENTINEL-3 FOR VERTICAL UPDRAFT MEASUREMENT OF CONVECTIVE SYSTEMS AND PRELIMINARY RESULTS FROM AIRMISRLITE

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ABSTRACT

Clouds and their interactions with aerosols (ACI) represent one of the greatest uncertainties in climate forecasting. For example, estimates of the climate forcing by ACI range from close to zero to -1.3 W $m^{-2}$, in contrast to forcing by Carbon Dioxide of 1.7±0.4 W $m^{-2}$ (2011 relative to 1750) [1,2]. Clouds and ACI, in turn, are governed by vertical velocity (updraft speeds) and the impact of different updraft speeds and associated mass flux, entrainment and mixing processes on the formation of cloud liquid and ice and their drop size and number concentrations, which in turn determine cloud extent, optical properties, rainfall, downdrafts, but also the vertical transport of mass, energy and momentum [1].

MISRlite (Multi-angle Infrared Stereo Radiometer) aims to address the retrieval of the 3D wind-field (u,v,w) along with brightness temperatures in the thermal IR using space-qualified European uncooled microbolometer arrays operating in Time Delay Integration (TDI) mode on two spacecraft (a tandem) positioned 60 seconds ahead and 60 seconds behind Sentinel-3 (S3). The synergy between the cloud [3] and aerosol retrieval of microphysical properties from SLSTR (Sea Land Surface Temperature Radiometer) and OLCI (Ocean Land Colour Imager) on S3 and the extremely accurate temperature calibration of SLSTR to cross-calibrate the MISRlite cameras will allow atmospheric dynamics to be coupled to cloud thermodynamics and microphysics, including particle concentrations, for the first time ever. MISRlite will allow geometric cloud-top heights to be retrieved from stereo machine vision alongside cloud-top advective winds and by observing the time variation of CTHs (Cloud-Top Heights), the vertical velocity can be retrieved alongside the change in temperature of the cloud-tops at resolutions from 150m. MISRlite will also exploit recent advances in super-resolution sub-pixel matching [4] to achieve the necessary accuracy. We will show examples of the aircraft MISRlite prototype as well as cloud-top height results using optical flow compared against simultaneous scanning laser altimetry.

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# ASSIMILATION OF GOES CLEAR AIR WATER VAPOR ATMOSPHERIC MOTION VECTORS IN THE NCEP GLOBAL FORECAST SYSTEM

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ABSTRACT

The tropics consistently have the greatest wind errors, both in the NCEP Global Forecast System (GFS) model as well as atmospheric motion vectors (AMVs) derived from cloud motion attributed in part to the impact of deep convection. Motion vectors derived from tracking clear air water vapor fields avoid these areas of complex cloud dynamics as well as provide wind data in locations with limited operational wind data. The desire to improve the performance of the GFS Data Assimilation System in the tropics has motivated this research to perform a new evaluation of the clear air water vapor AMVs. Implementation of the GOES-13 & 15 clear air water vapor AMVs in the GFS will be discussed as well as results from two seasons to show the impact of this data on the analysis state and forecast skill.

**STATUS OF THE OPERATIONAL SATELLITE WINDS PRODUCTION AT CPTEC/INPE AND ITS USAGE IN REGIONAL DATA ASSIMILATION OVER SOUTH AMERICA**

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ABSTRACT

Tropospheric winds are estimated using satellite imagery since late 60's and today they are a very important source of information for numerical weather forecasts. The CPTEC/INPE has being producing AMV, operationally, since early 2000's, using GOES satellites. The typical spatial coverage is the South America and surrounding oceans covered by the GOES satellites. Nowadays, the wind extraction at CPTEC/INPE is done using the visible, near infrared (3.9 µm) water vapor absorption (6.7 µm) and window infrared (10.2 µm) channels. This algorithm makes use of triplets of successive GOES images with at least 30 minutes between each pair, which allow having a new wind field each at least half hour. The quality control applied to the wind fields is based on that one developed at EUMETSAT where each AMV receive a quality indicator and the final user can choose what level is more suitable to their application. The wind estimates produced are disseminated on the World Meteorological Organization's Global Telecommunications System (GTS) in the BUFR format. Recently, CPTEC/INPE has started its rapid data assimilation cycle with convective scale regional models over South America and some selected locations over Brazil. During this experimental stage, high resolution model using nested domains were implemented. In order to minimize the latency of the availability information, important issue in this activity, the AMV produced by CPTEC have been used and the first results have been obtained. This work shows the actual status of the AMV production at CPTEC/INPE, its validation, the applications for regional data assimilation and the preparation for use of the future GOES-R images.

# ESTIMATION OF THE SEA SURFACE WIND IN THE VICINITY OF TYPHOON USING HIMAWARI-8 LOW-LEVEL AMVS

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ABSTRACT

Conventional surface wind data and sea surface wind product retrieved from polar orbiting satellite using microwave scatterometers has not enough spatial and temporal resolution respectively. This lack of surface wind data over the ocean makes it difficult for forecasters to estimate accurate surface winds around a typhoon.

The Meteorological Satellite Center of the Japan Meteorological Agency (JMA/MSC) is currently developing a monitoring product using Atmospheric Motion Vectors (AMVs) for tropical cyclone analysis and forecast. JMA operational satellite Himawari-8 is now observing typhoon area using its super-rapid scan function. Imagery data obtained by this function every 2.5 minutes enable us to derive more AMVs than before.

JMA/MSC is investigating relationship between wind speed of low-level AMVs computed from Himawari-8 observation data and that of collocated ASCAT winds in a period from May 2015 to December 2015 over western North Pacific area. As a result of regression analysis, the relationship between ASCAT and AMVs shows simple linearity around typhoons. Sea surface winds retrieved from AMVs by multiplying a coefficient and ASCAT winds show good consistency within 1.5m/s error range.

This presentation shows the result of this collocation study and a plan to introduce the AMV-derived sea surface winds to JMA’s operational tropical cyclone monitoring system.

# ASSIMILATION EXPERIMENTS OF HIMAWARI-8 RAPID SCAN ATMOSPHERIC MOTION VECTORS

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ABSTRACT

Himawari-8 has been operating rapid scan observations over Japan and the neighbouring area every 2.5 minutes. Rapid Scan Atmospheric Motion Vectors (RS-AMV) are derived from the rapid scan imagery with the improved retrieval algorithm involving newly developed tracking and height assignment methods (Shimoji 2014). Because RS-AMVs are expected to capture smaller scale airflows than ordinary AMVs, they can be useful in mesoscale data assimilation. This study aims to investigate the impact of RS-AMVs on the prediction of mesoscale phenomena such as local heavy rainfalls.

First, the data quality and the characteristics of observation errors of RS-AMVs were examined using the statistics of differences from JMA mesoscale analyses, radiosonde observations and NHM (JMA non-hydrostatic model) forecasts. In order to make full use of these high resolution data and to avoid observation error correlations in space and time, the strategies for quality control, data thinning or formation of super observations were considered based on the results of the statistics. Next, data assimilation experiments using NHM-LETKF (Kunii 2014) on heavy rainfall events in summer of 2015 were conducted. Some cases brought promising results showing a positive impact on precipitation forecasts, though we need further investigation about how to utilize RS-AMVs in our data assimilation system more effectively.

# THE USE OF SATELLITE-DERIVED WINDS IN NAVGEM: OVERVIEW AND COMING UPDATES

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ABSTRACT

Satellite-derived winds of various types continue to be one of the most important data categories in the U.S. Navy's global numerical weather prediction model, NAVGEM (Navy Global Environmental Model). This presentation will examine the current status of the assimilation of satellite-derived winds in NAVGEM, including the use of superobs in NAVGEM, which wind datasets are operationally assimilated, and their forecast sensitivity observation impact. The discussion will also include quality control and data usage (e.g., which channels are used, vertical limits and land masking, etc.) A summary of prospective changes to the assimilation of satellite-derived winds will also be presented.

# THE SATELLITE WINDS IN THE OPERATIONAL NWP SYSTEM AT MÉTÉO-FRANCE

Christophe Payan

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ABSTRACT

The presentation will give some informations on the last global model upgrade done in April 2015 in term of resolution and the use of an ensemble assimilation.

The activity about the satellite winds has recently focused on the assimilation of the oceanic surface winds from the scatterometer instrument RapidSCAT, installed by NASA on the ISS in September 2014, after the loss of OSCAT some months before. The evaluation of data provided by the KNMI in the frame of the EUMETSAT Ocean and Sea Ice Application Facility showed statistics of departure against the model background similar to statistics with the other instruments as ASCAT. The assimilation of this data, in an optimized configuration, improves the global forecast scores and the tracking of the tropical cyclones, allowing to mitigate the shutdown of OSCAT.

Side AMVs, the replacement of MTSAT-2 by the new Japanese satellite Himawari 8, of third generation, with the AHI imager and 16 channels, was prepared. The use of this new AMV product broadcasted by JMA allows to increase the number of assimilated AMVs, with a better agreement with the model background. An assimilation experiment of this data showed a neutral impact on the forecast scores with respect to the use of MTSAT-2 AMVs only, and a clear improvement in the southern hemisphere when no Japanese AMVs are used in the control.

**OPERATIONAL WIND PRODUCTS AT NOAA/NESDIS: A STATUS UPDATE**

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ABSTRACT

This paper summarizes the status of the operational and new improved wind products at NOAA/NESDIS. Recent improvement, new additions, processing changes and monitors, future plans of the Atmospheric Motion Vector (AMV) product suite will be discussed. The current satellite constellation for operational AMV winds processing includes GOES-13 (eastern operational geostationary satellite), GOES-15 (western operational geostationary satellite), VIIRS from S-NPP, AVHRR from NOAA and MetOp series, and MODIS from Terra and Aqua. Besides the currently operational AMV products, several improvements in NOAA/NESDIS AMV products have been implemented. These improvements include current GOES, Himawari-8, MODIS and AVHRR AMV products by using GOES-R/VIIRS AMV algorithms. Updates on the status of these operational AMV products, new wind processing system, data access policy, and other future plans will be presented. In addition, an overview of the operational ASCAT ocean surface wind products at NOAA/NESDIS is also presented.

# ASSESSMENT AND USE OF GEOSTATIONARY AND POLAR ATMOSPHERIC MOTION VECTORS AT MET NORWAY

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NMI, Norway

ABSTRACT

The Norwegian Space Centre supports the assessment and exploitation of the atmospheric motion vectors (AMV) at MET Norway (SAWIRA project JOP.07.15.2). Today we run two non-hydrostatic mesoscale operational models with the AROME physics (AROME-MetCoOp and AROME-Arctic) with domains over Scandinavia and Arctic, respectively. We are interested in both geostationary and polar orbiting satellite based Atmospheric Motion Vectors (AMV), called respectively geowind and polar wind hereafter. Our investigation showed that, while it is easy to find suitable operational access to geowinds data within acceptable latency, we needed to deal with issues of availability and latency for the polar winds. Our operational systems use three-dimensional variational assimilation technique with 3-hour cycling and cut-off time of 1 hour 45 minutes. We are also developing a hourly non-cycling assimilation system with 15 minutes cut-off time for nowcasting purposes. The geowind data are tested in both assimilation systems, while the polar winds are tested only with the 3-h cycling system due to the latency constraint.

Polar winds retrieved from Metop satellites are the most appropriate products for our Arctic model. As consequence, we do not have access in due timeliness to polar winds at early morning (00 – 06 UTC) assimilation times. Local production of polar winds using other satellites, including NPP and NOAA-19, can be a solution for this issue. We have been considering to port the EUMETSAT processing package, but found out that long-term use can be better supported by CIMSS' processing package.

We found very promising impact of assimilating test datasets of both geowinds and polar winds in our mesocale models. Our presentation will report about more detailed impact studies, which will be conducted after some refinement in both AMV data processing and its assimilation technique.

# COMPARISON OF AMV HEIGHT ASSIGNMENT BIAS ESTIMATES FROM MODEL BEST-FIT PRESSURE AND LIDAR CORRECTIONS

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ABSTRACT

The traditional interpretation of an atmospheric motion vector (AMV) observation is a single-level point estimate of wind at the assigned height. Recent studies indicate benefits from interpreting AMVs as layer averages, or as single-level wind estimates but within the cloud instead of the cloud-top or cloud base.

Long-term model best-fit pressure statistics give valuable information about the height assignment uncertainties for AMVs and can be used to estimate systematic height assignment errors. An alternative source of information to estimate the systematic height assignment errors are space born lidars which provide independent cloud height information. The lidar observations have been shown to have great potential to correct the systematic errors in AMV height assignment.

In this poster the two approaches to estimate the magnitude of the systematic height assignment errors for AMVs are compared. The results indicate that the two methods generally support each other. For IR and VIS AMVs the magnitudes of the systematic height error estimates are comparable especially at low levels. For WV winds and for high level IR winds some differences are seen in the magnitude. Shifts of 20-60 hPa are seen between the methods and typically the lidar correction is indicating more pronounced negative values, i.e. AMVs assigned too high in the atmosphere, than the best-fit pressure statistics.

# FEATURE-TRACKED 3D WINDS FROM SATELLITE SOUNDERS: DERIVATION AND IMPACT IN GLOBAL MODELS

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## ABSTRACT

The global measurement of 3D winds is recognized as an important dataset to improve medium- to long-range weather forecasts. At this time, vertical wind profiles through the troposphere are primarily from rawinsondes and aircraft ascents/descents, and are mostly confined to land areas. Wind information over mid- and low-latitude oceanic regions is limited to Atmospheric Motion Vectors (AMVs) from cloud and water vapor feature tracking using imagers on geostationary satellites. A similar technique is used with imagery from polar orbiting satellites over high-latitude regions. However, these geostationary and polar satellite-derived AMVs provide only single-level wind information at a particular geographic location.

To attain a 3D distribution of wind information, an AMV product is being developed based on tracking water vapor features retrieved from satellite sounders. The retrievals produce spatial maps of humidity on pressure surfaces in clear sky and above clouds. The initial AMV product, available in near real-time, is based on retrievals from the Aqua Atmospheric Infrared Sounder (AIRS) and is being evaluated by several Numerical Weather Prediction (NWP) centers. Moreover, a two-month case of AMVs has been generated from Advanced Technology Microwave Sounder (ATMS) and Infrared Atmospheric Sounding Interferometer (IASI) retrievals.

The status of the project will be reported, along with a discussion on: (a) The 3D wind derivation technique as applied to AIRS, ATMS, and IASI; (b) assimilation statistics from the Gridpoint Statistical Interpolation (GSI) system; (c) and, the forecast impact in the Global Forecast System (GFS).

# ASSIMILATION AND FORECAST IMPACT OF THE LEO/GEO AMVs IN THE GDAS/GFS

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ABSTRACT

Deriving Atmospheric Motion Vectors (AMV) from satellite images has been done successfully for many years from both geostationary and polar orbiting platforms. The spatial coverage of satellite-derived AMVs is generally equatorward of 60° latitude for geostationary satellites and poleward of 70° latitude for the polar satellites. This coverage results in a 10° gap, which has been noted as a potential problem by numerical weather prediction (NWP) centers. Specifically, the dynamically active polar jet stream can be located in this latitudinal zone and improper model initialization may lead to errors in the forecasts.

A novel technique was developed to fill this AMV-void gap using an advanced image compositing technique designed to blend the data from the many polar (e.g., NOAA AVHRR, Metop AVHRR, Terra/Aqua MODIS) and geostationary (e.g., GOES, Meteosat, Himawari 8) weather satellites. We are currently producing in real-time these composite images and deriving AMVs (known as Leo/Geo winds). Several NWP centers are incorporating these winds into their operational global models.

We will report on our latest assimilation and forecast experiments of the Leo/Geo winds using NCEP's GDAS/GFS (Global Data Assimilation System/ Global Forecast System) and their use at other NWP centers.

# SSMIS WIND SPEED NEURAL NETWORK ALGORITHM AND GENERAL PURPOSE OSWV VALIDATION TOOL BOX

Philip Shen

Navy Reasearch Laboratory, DeVine Consulting

ABSTRACT

The Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS) brightness temperatures are used to produce an Ocean Surface Wind Speed (OSWS) product. The Navy's current operational algorithm performs poorly in modeling high wind speeds (above 15m/s) and retrieving wind speeds in areas of high atmospheric scattering. Neural networks have been used by other organizations to determine wind speed and appear to be an ideal approach to capture the linear and nonlinear intricacies of the brightness temperature-wind speed relationship. The new SSMIS algorithm is comprised of two neural networks: one for clear scenes and one for high scatter scenes. The 37 GHz polarization ratio is used to determine which algorithm is applied. The new neural network algorithm produces retrievals with more high wind speeds, increased coverage in high scatter areas, and a better overall accuracy. As part of the Weather Satellite Follow-on (WSF) initiative, the DMSP Cal/Val group is working to develop a General Purpose Ocean Surface Wind Vector (OSWV) Validation Tool Box. Analysis tools developed for the SSMIS Cal/Val program will be utilized in performing validation for SSMIS, Advanced Scatterometer (ASCAT), WindSat, Compact Ocean Wind Vector Radiometer (COWVR), RapidScat, Advanced Microwave Scanning Radiometer-2 (AMSR-2), and GMI OSWS and OSWV products. Wind speed products will be validated using observations, such as global ship and buoy reports, and Numerical Weather Prediction (NWP) model outputs, in addition to cross-validation between satellite sensor products.

**CURRENT STATUS OF OPERATIONAL WIND PRODUCT IN JMA/MSC**

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ABSTRACT

The Japan Meteorological Agency (JMA) has started operation of Himawari-8 Atmospheric Motion Vectors (AMVs) from July 7th 2015. AMV computed from Himawari-8 has been disseminated to NWP centers via Global Telecommunication System (GTS) in BUFR format every 60 minutes. And the agency plans to launch Himawari-9 as a backup for Himawari-8 in 2016.

The agency has started operation of high-density AMVs for JMA's meso-scale Numerical Weather Prediction (NWP) system since August 2015. The high-density winds from Himawari-8 are generated around Japan area.

The observing function of Advanced Himawari Imager (AHI) is significantly enhanced from those of MTSAT-2; multispectral capacity (16 bands), high spatial resolution (0.5 – 1.0 km for visible and 1 – 2 km for infrared), fast imaging (within 10 minutes for full disk), and rapid scanning with flexible area selection and scheduling. These upgrades of imager enabled to retrieve more AMVs with more accuracy than before.

JMA/MSC has a plan to start operation of Himawari-8 rapid scan AMVs for monitoring, nowcasting and short-range NWP systems in 2016.

This presentation introduces JMA's plans for operation of Himawari-8 and -9 AMVs and show statistical, characteristic and quality difference between Himawari-8 and MTSAT AMVs. In addition, ongoing developments for derivation and application of rapid scan AMVs at JMA/MSC is also presented.

# AEOLUS QRT SERVICES FOR ATMOSPHERIC DYNAMICS

Ad Stoffelen

KNMI

ABSTRACT

ESA is currently implementing the Doppler Wind Lidar (DWL) mission 'Aeolus', being part of its Living Planet Programme. ESA's Aeolus mission is the first space mission to acquire profiles of the wind on a global scale. The mission is a demonstrator for future operational missions, providing vertical profiles of the tropospheric and lower stratospheric wind field for the improvement of numerical weather prediction (NWP) and atmospheric research. The largest improvement is expected in the tropics, over the oceans and in polar areas, where it much improves atmospheric sampling in the vertical. In addition, Aeolus will provide valuable profile information on aerosol and cloud layer optical properties. Although weather forecasts have advanced considerably in recent years, meteorologists urgently need reliable wind-profile data to further improve accuracy. ESA's Aeolus wind mission will demonstrate that measuring global wind-profiles from space, using laser technology, can meet this requirement. NWP centres will assimilate these wind data into numerical prediction models and the key output will be improved weather forecasts and a better understanding of atmospheric dynamics to the benefit of climate research. Moreover, vertically-resolved clouds and aerosol Level 2 data products will be generated, providing continuity to a series of space-borne lidar missions (CALIPSO, CATS, EarthCare). ESA met many challenges in developing the space hardware to obtain, for the first time, wind profile information from space and is now ready for a launch in 2017. The mission plans on cal/val and processing and monitoring in the ground segment will be presented at the workshop. The presentation will further discuss processing near clouds and optimal spatial sampling and processing of the Aeolus data for the benefit of meteorological analyses. Global, but also regional NWP users will be able to use the data, due to the development of a fast processing track in quasi real time (QRT), as proposed by KNMI to EUMETSAT and this will be presented.

# MESOSCALE ASSIMILATION OF SCATTEROMETER WINDS

Ad Stoffelen

KNMI

ABSTRACT

Data assimilation has proven beneficial for numerical weather prediction (NWP) in global and limited area hydrostatic models. However, demonstrating positive impact from assimilating observations (both conventional and from satellites) in non-hydrostatic mesoscale models, like HARMONIE, appears quite a challenge. A dense network of observations in all four dimensions is needed to correctly initiate the evolution of rapidly evolving small-scale weather phenomena. Lacking observation density on spatial scales that the model resolves and on time scales of, e.g., convective processes, induces phase errors, i.e., incorrect positioning of weather systems. Additional errors are introduced by the discrepancy between observation time and analysis time for satellite observations, but also aircraft observations, which is inherent for 3D-VAR and more acute for the rapidly evolving mesoscale systems.

Observing System Experiments (OSE) have been conducted with the high-resolution limited area model HARMONIE, which is operational at KNMI and most other weather centres which are part of the European HIRLAM consortium. Assimilating scatterometer winds may potentially improve the initial mesoscale model state of the turbulent flow near the ocean surface and in subsequent forecasts. Scatterometer winds used include the ASCAT instrument on board the European Metop-A satellite, Seawinds on board the US QuikSCAT satellite and OSCAT on board the Indian OceanSat-2 satellite. Focus was on past extreme weather events with strong winds, causing disruption over the Netherlands. The latest results from the scatterometer impact experiments will be presented. Challenges of mesoscale data assimilation will be highlighted and possible directions for solutions discussed.

Moreover, 2DVAR experiments will be discussed that improve the analysis wind fields against independent buoy winds and add variability to the ECMWF background spectrum by improved background error structure functions and increased weight of the scatterometer observations. In this case, no forecasts are run. In addition, scatterometer QC indicators, associated with local wind variability, are compared with the (independent) ECMWF background errors and found to be strongly correlated. This suggests that the scatterometer spatial structure of the QC variables can help predict the background error covariance structure and the QC parameters are thus further compared to the ECMWF ensemble background spatial error covariances for verification. The encouraging results will be presented at the workshop.

# COMPARISON AND IMPACT OF NEWLY AVAILABLE ATMOSPHERIC MOTION VECTORS IN NAVGEM

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ABSTRACT

Atmospheric motion vectors (AMVs) from COMS-1 (Republic of Korea's geostationary Communication, Oceanography and Meteorology Satellite – 1), Global AVHRR (the Advanced Very High Resolution Radiometer 3 onboard Europe's polar orbiting Meteorological Operational Satellites A and B), Himawari-8 (Japan's geostationary meteorological satellite), INSAT-3D (the geostationary Indian National Satellite – 3D), and MISR (the United States' National Aeronautics and Space Administration's sun-synchronous Earth Observing System Terra satellite) have recently become available. Since satellite-derived winds are one of the most beneficial data categories in the U.S. Navy's global numerical weather prediction model, these newly available data are evaluated for inclusion in the NAVGEM (Navy Global Environmental Model) operational suite. AMVs from Global AVHRR and MISR are of particular interest because they are the first near-polar orbiting satellites to provide non-surface winds over the mid-latitudes and tropics. This presentation will examine AMVs from the newly available sources, and will compare data characteristics among the two low earth orbit satellites and the three newly available geosynchronous satellites. The discussion will also include their forecast sensitivity observation impact and various data handling and quality control measures that have been applied.

**ESA'S ADM-AEOLUS WIND LIDAR MISSION - GETTING READY FOR LAUNCH**

Anne Grete Straume-Lindner, Anders Elfving, Denny Wernham, Frank de Bruin, Thomas Kanitz, Dirk Schuettemeyer, Jonas Von Bismarck

ESA

ABSTRACT

The European Space Agency (ESA)'s wind mission, ADM-Aeolus, is getting ready for launch in spring 2017. The Doppler wind lidar, ALADIN, will enter the Instrument Full Functional Performance test in February 2016, which will be followed by the integration on the satellite platform. The lidar shall deliver horizontally projected single line-of-sight wind observations from ~30 km down to the Earth's surface, or down to optically thick clouds. The vertical sampling will be 500 m in the planetary boundary layer (PBL), 1 km in the troposphere, and 2 km in the stratosphere. The horizontal observation resolution is ~85 km. The required accuracy of the wind measurements is 2 m/s in the PBL, 2-3 m/s in the free troposphere, and 3-5 m/s in the lower stratosphere. Spin-off products are extinction and backscatter profiles. The satellite will fly in a polar dusk/dawn orbit, measuring at 6 am/pm local time. The global coverage is ~16 orbits per day. The wind and optical properties products will be delivered near-real-time (NRT) for direct ingestion by operational numerical weather prediction (NWP) and air quality models.

At the 5$^{th}$ WMO Workshop on Observing Systems Impact in 2012, it was concluded that direct wind observations, such as AMVs, are very highly ranked when it comes to NWP impact per observation. This emphasizes the large potential for further global direct wind observation systems. During the first months after launch the ALADIN instrument will be carefully characterized and calibrated, and the data products will be extensively validated by collocated observations and monitored by NWP models. In this talk, the planned validation techniques and their contribution to the product verification and quality assessment will be presented. Also, the status of the Aeolus mission will be presented together with results from pre-launch campaigns with the Aeolus Airborne Demonstrator (A2D).

# THE IMPACTS OF FOUR DIMENSIONAL THINNING ON EUMETSAT AND JMA AMVS

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ABSTRACT

Hourly AMV products are produced operationally at EUMETSAT, NESDIS, AMVs from Himawari is also hourly too. The hourly AMV products provide important system evolution information, especially for the four dimensional (4D) variational data assimilation system. However the thinning scheme for AMV products in NECP data assimilation system is three dimensional (3D), which will filter out system temporal evolution information. With four dimensional (4D) hybrid data assimilation system will be implemented soon, the temporal thinning scheme added to current operational 3D thinning is tested on EUMETSAT and JMA AMVs. The results of parallel experiments with 4D thinning show significant positive impacts on global wind forecast, it also shows slight improvement on rawinsonde wind observation fits.

# THE ATHENA-OAWL MISSION CONCEPT AND THE GREEN-OAWL (GROAWL) AIRBORNE DEMONSTRATOR

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ABSTRACT

Sparse sampling and representational inaccuracies in global wind observations, particularly over the oceans, southern hemisphere, and the tropics, are known to limit weather and air quality forecast accuracy. The National Research Council 2007 Earth Science Decadal Survey recognized this and described tropospheric winds as the "number one unmet measurement objective for improving weather forecasts" and thus called for a Doppler wind lidar mission (3D-Winds). Now in 2016 the Earth Science community works on the second Decadal Survey, and as Numerical Weather Prediction (NWP) models become more sophisticated and require more data, the need for global wind profiles is even greater. Implementation of a space-based wind lidar mission in the US to address this data need has faced multiple challenges over the last few decades, mainly in the areas of technology readiness, cost, and political priority. To address some of these challenges, Ball Aerospace, with support from the NASA Earth Science Technology Office, has built and demonstrated the Optical Autocovariance Wind Lidar (OAWL) in ground and aircraft-based validation tests. The OAWL approach uses a modified Mach Zehnder interferometer technique that can be configured to measure Doppler shifts from aerosols and/or molecules, and can operate at different laser wavelengths including those already demonstrated in space and those that are currently in the space-qualification phase. The direct detection OAWL approach leverages experience, technology, and heritage from the CALIPSO lidar system on orbit since 2006.

Working with a science team from multiple institutions across all sectors, we developed the ATHENA-OAWL mission concept, proposed to NASA's Earth Venture Instrument call in 2013. Recognizing the importance of the winds measurements, the team was awarded technology development funding to further demonstrate and validate the OAWL approach for a future Earth Venture mission proposal or Decadal Survey mission. The Green-OAWL (GrOAWL) system is a two-look airborne demonstrator for the ATHENA OAWL mission, currently being built at Ball. GrOAWL operates at the 532 nm wavelength and is designed to measure simultaneous line-of-sight (LOS) winds from two azimuthally orthogonal directions to provide u and v component information for horizontal winds.

We will provide a brief overview and history of space-based Doppler wind lidar activities and mission concepts in the US and Europe, review some of the challenges faced, briefly outline the ATHENA-OAWL mission, and present preliminary results from the GrOAWL airborne flight demonstration tests planned for April/May of 2016.

# DEVELOPMENT AND OPTIMIZATION OF MESOSCALE ATMOSPHERIC MOTION VECTORS (AMVS) USING NOVEL GOES-R PROCESSING ALGORITHMS ON 1-5 MIN. SRSO PROXY DATA, AND DEMONSTRATION OF READINESS FOR GOES-R APPLICATIONS VIA IMPACT STUDIES IN MESOSCALE/HURRICANE DATA ASSIMILATION AND NWP SYSTEMS

David Stettner, Christopher Velden, Will Lewis, Wayne Bresky, Jaime Daniels, Steve Wanzong

ABSTRACT:

One of the principle benefits expected from GOES-R is the improvement in temporal sampling of images from the ABI. The rapid refresh (1-5 min.) should allow for quantitative improvements in derived products such as AMVs, which have long stood as an important contributor of tropospheric wind information to analyses on the global scale (Velden et al. 2005). GOES-R will allow superior cloud-tracking and AMV generation on time scales not only useful for global applications, but for mesoscale applications (e.g., severe storms, hurricanes) as well.

The reasons we are optimistic that GOES-R AMVs can be an important contributor to mesoscale analyses are a result from recent and ongoing studies using GOES-R proxy datasets (Bedka and Mecikalski, 2005; Velden et al. 2013; Rabin et al. 2013; Wu and Velden, 2013, 2015). In this study, we build on these pioneering efforts and take advantage of expected GOES-R capabilities and new AMV derivation methods (Bresky et al. 2012). Then apply these to the production of mesoscale AMV datasets with the goal of extracting wind information that benefits short-term forecasts and operational NWP. First results will be presented here from model impact studies of cases involving hurricanes and severe weather events.

# THE REPROCESSED FY-2E ATMOSPHERIC MOTION VECTOR'S APPLICAITON IN GRAPES

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ABSTRACT:

Atmospheric Motion Vectors (AMVs) can supply plenty of useful information for numerical weather prediction. With the improvements in the image navigation, data calibration and derivation algorithm, the quality of FY-2E is expected to be improved. Therefore it is necessary to evaluate the improvement of FY-2E AMVs for the analysis field and precipitation forecast in GRAPES (Global/Regional Assimilation Prediction System) at CMA. In this study, the old and the reprocessed FY-2E AMVs are used to analyse the characteristics of their horizontal and vertical structures and apply to GRAPES-3DVAR Regional Assimilation Prediction System to compare their differences on the assimilation and prediction. The experiments using the data of August in 2013 show some encouraging results, which show neutral to positive impact on wind analysis field, especially in mid and low levels. Furthermore, due to the improvement of the initial fields for the model prediction, the performance score for regional precipitation forecast increased. Especially the assimilation of the reprocessed FY-2E WV have more positive impact on the wind analysis and forecast in heavy rainfall level than the old, which need a further investigation and utilization. Conclusively, the reprocessed FY-2E AMVs have more positive impact on wind assimilation and forecast improvements of GRAPES.

# UPDATE ON AMV ACTIVITIES AT THE MET OFFICE

Francis Warrick, James Cotton, Mary Forsythe

Met Office, UK

ABSTRACT

AMVs are an important observation type in global numerical weather prediction (NWP) models. This talk will include an update on new AMV data sets trialled in the Met Office global model, and results from using information from the GOES-R derivation scheme for AMV quality control.

To fill the coverage gap between polar and geostationary AMVs, LeoGeo and EUMETSAT Single-Metop AMVs were trialled, found to be beneficial and approved for operational use. Himawari-8 AMVs have replaced MTSAT-2 AMVs using similar quality control. Other assimilation trials have included VIIRS, expanded use of Himawari-8 AMVs, Dual-Metop, and GOES visible and shortwave infrared AMVs.

As AMV derivation schemes have been developed in recent years, particularly the increasing use of pixel-based cloud schemes, new information is becoming available which may be useful for NWP centres to help with quality control and observation error setting. One example of this is the information available from the GOES-R derivation scheme.

AMVs derived using the nested tracking scheme developed for the upcoming GOES-R satellite have been analysed at the Met Office. Test data was provided using Meteosat-10 imagery.  The test data included cloud and cluster properties from the derivation. The potential of these properties for situation-dependent quality control was explored and results will be presented. The application of a cloud top pressure filter improves the overall quality and bias of the AMV dataset without loss of the higher speed winds or appreciable loss of coverage.  Filtering by the median cloud optical depth also showed promise.

# STUDYING AMV ERRORS WITH THE NWP SAF MONITORING WEBSITE

Francis Warrick, James Cotton, Mary Forsythe

Met Office, UK

ABSTRACT

The NWP SAF (Satellite Application Facility for Numerical Weather Prediction) is a EUMETSAT-funded activity that exists to co-ordinate research and development efforts among the SAF partners to improve the interface between satellite data and NWP for the benefit of EUMETSAT member states.

The AMV monitoring activities of the NWP SAF are there to help identify and understand errors in the AMV data. This understanding can be useful to inform improvements both to the AMVs' derivation and to the way they are used in NWP. The monitoring includes an archive of observation-minus-background (O-B) statistics, which compare the AMVs to short-range NWP forecasts. The O-Bs are calculated against both Met Office and ECMWF backgrounds. This helps us to see whether the source of the O-B difference is due to model or AMV problems.

To make sense of the large amount of monitoring information held on the website, every two years an Analysis Report is produced. These assess whether features seen in the monitoring statistics have improved or worsened, and identify any new features which have appeared since the previous report. Ideally, the cause of the feature is investigated using more O-B statistics, height assignment differences (between the AMVs, model best-fit pressures and cloud-top height products), model fields and satellite imagery. This poster will explain some interesting features from the 7$^{th}$ Analysis Report published in early 2016.

# AMV HEIGHT RETRIEVALS FROM STEREO AND IR TECHNIQUES

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ABSTRACT

Height assignment of satellite winds is one of the major error sources of atmospheric motion vector (AMV) measurements. MISR stereo cloud motion vector (CMV) and height retrievals are used to compare with GOES and Himawari-8 AMV heights derived from various methods (WIN, WINV, BASE, HIST, H2O, and CO2). The WIN method has overall better performance than other methods for optically thick clouds at all levels and latitude bins. For high clouds the H2O method has a generally better skill than the HIST and CO2 in producing a consistent height with MISR. For low clouds, the WINV and BASE methods produce little consistency with the stereo heights. In addition, we will also discuss comparisons between MISR CMVs and airborne lidar winds during the PolarWind experiment, a joint NASA and ESA campaign near Greenland in May 2015.

# ASSIMILATION OF HIMAWARI-8 ATMOSPHERIC MOTION VECTORS INTO THE NUMERICAL WEATHER PREDICTION SYSTEMS OF JAPAN METEOROLOGICAL AGENCY

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ABSTRACT

The Meteorological Satellite Center of Japan Meteorological Agency (JMA) has been producing operational Himawari-8 Atmospheric Motion Vectors (AMVs) since July 7th, 2015. The AMVs are produced using three sequential satellite images with time interval of 10 minutes, while MTSAT-2 AMVs are using 30~60 minutes interval images.

Himawari-8 AMVs will be assimilated with JMA's operational global and regional Numerical Weather Prediction (NWP) Systems as replacement of MTSAT-2 AMVs.
For the effective use of Himawari-8 AMVs, the pre-processing system for AMVs was updated mainly in the following three points:
Firstly, the quality indicator (QI, Holmlund 1998) thresholds for rejecting low quality AMVs were revised considering the characteristics of Himawari-8 AMVs. Secondly, the climatological check was revised to use more AMVs in the middle troposphere. Thirdly, a super-observation technique was introduced over Japan for the JMA’s operational global NWP system.
To investigate the impact of Himawari-8 AMVs with the revised pre-processing system comparing with the impact of MTSAT-2 AMVs, observing system experiments (OSEs) using the JMA’s operational NWP systems were performed in approximately two months of summer and a month of winter 2015.

The OSEs using the global NWP system revealed that wind forecast errors over the Himawari-8 observation area, especially around Japan, were reduced and mean positional errors for ten typhoons in summer were also reduced from 24-hour to 48-hour and from 90-hour to 120-hour forecast lead time. The reduction rate was about 6 % from 24-hour to 48-hour forecast lead time. The OSEs using the JMA’s regional NWP systems brought the improvement of rain forecasts as well.
The Himawari-8 AMVs with the revised pre-processing system are planned to be introduced in the JMA’s operational NWP systems in March 2016 when Himawari-8 AMVs are started to be used as replacement of MTSAT-2 AMVs.

I will give a presentation and discuss about these details at the IWW13.

# STATUS OF OPERATIONAL AMVS FROM FENGYUN-2 SATELLITES

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ABSTRACT

This paper briefly introduces status of AMVs operations at NSMC. Since the 12th International Winds Workshop (IWW12) held in June 2014, CMA continues AMVs operations and services. At present, FY-2G (105°E) and FY-2E (86.5°E) are both in operation. AMVs derivations are performed for both FY-2G and FY-2E. For FY-2G, AMVs are provided at 00 06 12 18 UTC, while FY-2E at 03 09 15 21 UTC. The wind derivation scopes are in the regions of satellite zenith angle less than 60 degrees.

There are several changes at the Fengyun-2 operational AMVs derivation system in the last two years. The algorithms mentioned last workshop, such as "second tracking", had been operational in the past two years. The BUFR encoder had been updated from BUFR edition 3 to 4. The QI without NWP had been added to Fengyun-2 AMVs.

Furthermore, the progress of Fengyun-2 AMVs historical dataset reprocessing and Fengyun-4 AMVs will be mentioned.