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ATMOSPHERIC MOTION VECTORS AND IWWG MATTERS: REPORT FROM THE INTERNATIONAL WINDS WORKING GROUP

This paper summarizes the outcomes of the 12th International Winds Workshop (IWW12). The workshop was hosted by the University of Copenhagen and took place in Copenhagen, Denmark from 16-20 June 2014. There was a good cross-spectrum of attendance (65 participants) from a wide range of satellite producers, NWP centers, and research centers.

This paper:

i) recalls recommendations from CGMS-42 to IWW12
ii) highlights the outcomes and recommendations from IWW12

CGMS-43 is invited to discuss the outcomes and recommendations from IWW12.

Atmospheric Motion Vectors and IWWG Matters: Report from the International Winds Working Group

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1 INTRODUCTION

This paper summarises the outcomes of the 12th International Winds Workshop (IWW12) hosted by the University of Copenhagen in Copenhagen, Denmark from 16-20, June 2014.

Local Organising Committee	**Scientific Program Committee**
Dr. Aksel Hansen (Univ. of Copenhagen)	Dr. Mary Forsythe (Met Office, UK; IWWG Co-Chair)
Mr. Soren Granat (Univ. Of Copenhagen)	Mr. Jaime Daniels (NOAA/NESDIS, USA; IWWG Co-Chair)
	Dr. Regis Borde (EUMETSAT, Germany)

The workshop was very successful and provided a good opportunity to share results and discuss future work and collaborative opportunities.

The workshop included ten sessions, some of which included plenary discussions:

1. Operational Status
2. AMV Derivation
3. AMV Inter-comparison Project *(Plenary Discussion 1: AMV Inter-Comparison Study Results)*
4. Use of Satellite-Derived Winds in NWP
5. MISR, AATSR and Sentinel Winds
6. Boundary Layer
7. High Resolution Satellite-Derived Winds *(Plenary Discussion 2: Winds for High Resolution NWP)*
8. AMV Height Assignment and Treatment as Layers *(Plenary Discussion 3: Height assignment, treatment of AMVs over layers, and changes to BUFR format)*
9. Reprocessing activities
10. Doppler wind lidar

Two parallel working groups on Thursday pm:

WG1: Wind Extraction Methods
WG2: Data Assimilation

A splinter group discussion on scatterometer mesoscale Numerical Weather Prediction (NWP).

2 RECALLING ACTIONS AND RECOMMENDATIONS FROM THE CGMS TO IWW12

The actions and recommendations from CGMS-42 were introduced in the opening session of IWW12. Some specific items were discussed in the group discussions on key topics. The remainder were addressed in the Thursday afternoon working groups. Here we recall the CGMS Actions and Recommendations to IWW12 and provide a response to each.

Action 41.24: Co-Chairs of IWWG to provide a summary paper and lessons learnt to CGMS-42 from the second Atmospheric Motion Vector (AMV) derivation intercomparison project.

A CGMS IWWG working paper that provides a summary of the Second AMV Intercomparison Study has been prepared and will be submitted to the CGMS-43. A short synopsis of the outcomes of this study are included in Section 3 of this paper.

Action 41.25: IWWG co-chairs to i) organise a dedicated session at IWW12 on research, operational applications and benefits of high resolution AMVs and ii) to provide a corresponding report to the next CGMS meeting**.**

A dedicated session and plenary discussion on high resolution satellite-derived winds was held at IWW12 (see Section 3 below for further details). This topic is also the focus of an IWWG activity at: https://groups.ssec.wisc.edu/groups/iwwg/activities/high-resolution-winds-1/high-resolution-winds. The wiki pages were updated and circulated to the IWWG email list ahead of IWW12 to help stimulate discussion.

Action 41.28: NOAA to ensure that CIMSS/SSEC AMV reprocessing activity should be embedded into SCOPE-CM AMV project by a communication to the SCOPE-CM Secretariat.

NOAA has responded to this CGMS Action in CGMS-43 NOAA-WP02. For completeness, NOAA response is included here.

NOAA communicated with SCOPE-CM secretariat, Dr. Jorg Schulz, and he confirmed that CIMSS joined the SCOPE-CM project #10 (SCM-10) on AMV reprocessing. Mr. Toshiyuki Kurino (JMA) confirmed that this was briefed at the SCOPE-CM Executive Panel Meeting in 2014.

NOAA recommends closure of this action item.

Action 42.09: IWW12 and IPWG7 to respond to the updated HLPP and to provide feedback to cgmssec@eumetsat.int within 3 months after the working group meeting.

HLPP 3.2: Establish commonality in the derivation of satellite products for global users where appropriate (e.g., through sharing of prototype algorithms)

The Second AMV Intercomparison Study enables an understanding of differences between AMV products from different CGMS agencies and leads/encourages the use/development of better algorithms on the basis of common science. Further discussion of this topic can be found below in the response to CGMS Recommendation

HLPP 3.2.1: Infer guidance from the ongoing intercomparison of AMV products for the future developments towards consistent AMV products. Consider in the guidance the future perspective of having the geostationary ring populated with 16-channel imagers.

In the CGMS IWWG working paper that provides a summary of the Second AMV Intercomparison Study, a CGMS action is proposed that is directly relevant to HLPP 3.2.1. The proposed action is as follows:

A Third AMV Intercomparison study, optimally to take place in the 2018-2020 time frame, primarily to investigate the following:

- *The effect of using different QI processes and different target selection processes in the different AMV algorithms*

- *The effect of using imagery from the newest satellite series (Himawari 8/9 or GOES-R),with higher spatial resolution, higher temporal resolution, and more spectral channels in the AMV calculation.The new spectral channels will bear new information on cloud microphysics, especially the temporal changes (from slot to slot) will be useful to better understand the characteristics of the tracked cloud. Inter alia this will inform on the height assignment (for instance, a convective cloud with high temporal changes will most likely be a poor indicator of a 'wind' even when averaged over reasonably thick atmospheric layers).*

HLPP 3.3: Foster the continuous improvement of products through validation and inter-comparison through international working groups and SCOPE-type mechanisms

Recommend adding the following:

3.3.4 Encourage cross coordination of synergistic activities and information between the International Science Working Groups.

HLPP 3.5: Maintain, enhance and improve the methods to describe the error characteristics of satellite data and products;

Work related to this is undertaken by many centres. Notable contributions to this at IWW12 were a poster "Investigating AMV and NWP model errors using the NWP SAF monitoring" and several talks in the session on AMV height assignment and treatment as layers, which used both simulated imagery studies and lidar observations.

HLPP 3.5.2: Address the error characteristics of wind products at the next International Winds Workshop in 2014 and provide a set of guidelines to be considered at the operational centres.

This is work in progress. There was good discussion at IWW12 about types of information that could be provided from the derivation which may help to better represent the observation errors for AMVs. NOAA's new GOES-R AMV algorithm opens up new possibilities in NWP for improving the quality control and error characterisation of AMVs by providing extra information coming from the derivation process (nested tracking and ABI height algorithm).

It was recommended that AMV algorithm developers should identify what other diagnostic parameters could potentially be useful for AMV quality control. One example would be to provide information on the correlation surface to characterise how well-constrained the selected correlation peak is.

Recommendation 42.02: All ISWGs under CGMS (IPWG, ITWG, IWWG, IROWG, ICWG) to establish a formal interaction with Joint CEOS-CGMS Working Group on Climate.

This needs to be pursued in a coherent manner by all (five) ISWGs. We should define that approach at CGMS-43 taking into account what has been done so far.

Recommendation 42.03: CGMS recommends to CGMS members performing a reprocessing of AMVs to pursue future AMV reprocessing with their own algorithm and in addition with a common algorithm. IWW12 is invited to discuss the implications and derive guidance on the practical implementations.

There was good agreement at IWW12 about the importance of all operators reprocessing AMVs with their own best algorithm. There were several talks at the workshop summarising reprocessing activities at EUMETSAT, CIMSS, CMA, and JMA. It is clear that significant progress has been made in the provision of reprocessed AMVs. However, some significant practical implications of processing with a common retrieval algorithm were identified at IWW12 and are provided in Section 3.3 of this working paper. Consideration and discussion of this topic by the other CGMS ISWGs, re-analysis groups, and the SCOPE-CM executive panel is needed. Discussion of this topic at CGMS-43 is welcome.

3 IWW12 OUTCOMES

3.1 Some highlights from the talks and discussion

- Future satellite missions that will contribute to the generation of atmospheric wind observations: JMA's Himawari-8 (2014), ESA's Aeolus Wind LIDAR (2014), CMA's FY-2G (2014), NOAA's GOES-R Advanced Baseline Imager (2015), EUMETSAT's MSG-4 (June 2015), China's HY-2B (2015), JMA's Himawari-9 (2016), ISRO's

SCATSAT (2015), ISRO's Oceansat-3 scatterometer (2016), EUMETSAT's Metop-C (2018), EUMETSAT's MTG-I (2018), KMA's Kompsat (2018), and China's HY-2C (2019).

- New promising AMV derivation algorithms developed in advance of the next generation geostationary imagers were presented at IWW12. JMA presented its new AMV retrieval approach developed for its next generation Himawari-8/Advanced Baseline Imager (AHI). The newly developed feature tracking and height assignment algorithms are both based on Maximum Likelihood (MLE) theory and are designed to take advantage of the higher spatial and temporal resolution offered by the AHI. NOAA presented its new GOES-R AMV algorithm approach and showed its latest performance results. One of the strong

  points of the new GOES-R AMV algorithm is its direct use of some of the retrieved cloud products (ie., cloud-top pressure, cloud-top temperature) and the fact that it keeps track of a number of the retrieved cloud microphysical properties (ie., cloud type, cloud phase, optical depth, cloud particle size) for pixels that dominate the motion retrieval. NOAA/NCEP has been in the process of testing and preparing its data assimilation system for GOES-R by using GOES-R proxy AMVs derived from Meteoesat/SEVIRI observations. The International NWP Centers have requested that NESDIS provide them an offline test dataset of GOES-R proxy AMVs generated using Meteosat/SEVIRI so they can begin testing and preparing for GOES-R.

- Significant progress is being made by the satellite operators in the area of AMV reprocessing in support of SCOPE-CM efforts. UW-Madison/SSEC-CIMSS reported its successful reprocessing of AMVs from the GOES for the period 1995-2013. This success was noted and warmly received at IWW12. Reprocessed AMVs are now available from GOES, NOAA/AVHRR, Meteosat/SEVIRI, Metop-AVHRR, GMS, MTSAT, and FY satellites. Recommendation IWW12.11 strongly encourages NOAA to pursue and enable the reprocessing of GOES AMVs for the pre-1995 era.

- Results of the Second AMV inter-comparison study undertaken by the IWWG were presented and discussed. Seven operational satellite operators participated in the study. While numerous similarities in AMV product output were evident, notable differences still existed between the product datasets. The study results indicted some errors in two satellite operator's AMV retrieval codes. The IWW12 participants all agreed that future AMV inter-comparison studies should continue as they have been very informative, and useful to the satellite operators. These also provide an important mechanism towards achieving the use of common AMV algorithms among satellite operators.

- Given the importance of cloud height assignment to AMVs, the IWW12 co-chairs invited participation from a member of the International Cloud Working Group (ICWG) to discuss state of the art cloud retrieval algorithms and the activities of the ICWG members. This invitation was very timely and very well received by the IWWG members. The scientific discussions and interactions that centered on retrieval of cloud height and cloud microphysical properties were outstanding. Continued interaction between the two international science groups is planned. Strengthening the ties between the IWWG and the new ICWG will benefit both communities and ultimately the users of AMVs. It was

recommended that the ICWG work with the IWWG case study (used in the Second AMV Intercomparison Study). This would enable further study and analysis of differences observed between the height assignment methods. Future collaborative studies involving the IWWG and ICWG members could be undertaken. Dr. Andy Heidinger is currently serving as the liaison between the two groups for the near-term, subject to ICWG approval. It was recommended that at least one person from IWWG attend the next ICWG meeting (Lille, France, 2016).

- A NASA/JPL Terra/MISR near real-time winds product is planned to be in production by August 2014. About 90% of this product is expected to be made available to the NWP community within 2.5 hours via the Global Telecommunication System (GTS). NWP centers have shown strong interest in using this product within their operational NWP forecast/data assimilation systems.

- Dual use of overlapped AVHRR data from Metop-A and Metop-B (both in the same orbital plane) enable the generation of AMVs from the AVHRR instrument over the entire globe for the first time ever. These AMVs provide two key benefits to the Global Observing System (GOS). First, they fill existing coverage gaps between geostationary and polar AMVS, and second, they serve as an excellent tool for cross validating geostationary and polar AMVs.

- There was very good representation from Numerical Weather Prediction (NWP) centers at the workshop. NWP centers from the following organizations were represented at the workshop: CMC, DWD, ECMWF, JCSDA, JMA, KNMI, Meteo-France, Met Office (UK), NCEP.

- Very good representation from the scatterometer community at IWW12. A special boundary layer session was held to discuss the use of surface scatterometer winds and low level AMV products in the deep tropics to discern the existence of wind shear in the boundary layer that is associated with the occurrence of rainfall. Continued close collaboration between the IWWG and International Ocean Vector Winds Science Team (IOVWST) was recommended. A splinter group discussion on scatterometer mesoscale NWP was held at IWW12. A full report from this discussion can be found in Appendix-E. CGMS-43 is asked to consider and recognise the following:
  a) The full complementarity (no redundancy) of OSCAT and ASCAT at only 2.5 hours separation has been demonstrated at global NWP centres and confirms the need for improved temporal sampling. This is even more urgent for mesoscale modeling. Better revisit time and timeliness is needed for NWP throughout the day: the current 12 hour coverage should go down to 3 h. In this context, EUMETSAT and the SAFs agreed to continue efforts to obtain HY2A, RapidScat and ScatSat scattermeter wind services at SAF quality level.
  b) We moreover record Christophe Payan's statement about the current coverage limitations of ASCAT-A/B in the tropics, also made by Paul Chang in his presentation during the plenary.

The IWW12 proceedings are available on the EUMETSAT web site under www.eumetsat.int. These proceedings as well as the IWW12 presentations can be accessed via the IWWG web page (http://cimss.ssec.wisc.edu/iwwg/iwwg_meetings.html).

Details of the group discussion and working group discussions are provided in the appendices.

3.2 Update on winds for high resolution NWP

Development of high resolution winds and the assimilation strategy are important for improving forecasts of high impact weather events using high resolution models. But there are no stand-out solutions for either the derivation or assimilation of high resolution winds. The intention of the discussion at IWW12 and related IWWG wiki page is to enable greater community-wide discussion to guide developments. See:

https://groups.ssec.wisc.edu/groups/iwwg/activities/high-resolution-winds-1/high-resolution-winds

Current AMV products capture broad-scale to synoptic-scale flow. Looking at movie loops we can see information available on much smaller scales, this is only likely to improve as we move to next generation satellite systems with shorter image intervals and higher pixel resolution (e.g. Himawari-8. GOES-R, Meteosat Third Generation). Can we make use of this information to improve nowcasting and high resolution forecasting, particularly of high impact weather events?

There are a number of difficulties to overcome with both the AMV derivation and assimilation. In order to produce AMVs representative of smaller scale features of the flow we need to use smaller target boxes (probably 5-10 pixel in dimension) and shorter image intervals (5-10 min). However, the smaller number of pixels in the target makes it harder to find a unique solution and tends to result in a large number of invalid vectors. To address this, we need to focus on filtering out the poorly resolved cases (e.g. using information from the correlation surface) or using a clustering scheme (as applied in the GOES-R nested tracking, Bresky et al 2012) or finding another way to better constrain the tracking (e.g. Shimoji IWW12). Other considerations for the AMV derivation include: greater sensitivity to registration errors, inability to resolve the slower winds with shorter image intervals and the need to find alternatives to the current QIs, which tend to penalise spatially varying accelerating wind features.

For scatterometer winds there is a need for improved temporal sampling. Better revisit time and timeliness is needed for NWP throughout the day: the current 12 hour coverage should go down to 3 h.

For NWP there are additional considerations. 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 to alleviate problems from spatially and temporally correlated errors, data is thinned (or superobbed) and errors are inflated. But if we

thin too much, we will lose the mesoscale information of interest. Efforts continue in this area at a number of centres.

Recommendations:

- Observational requirements found in the WMO Observing Systems Capability Analysis and Review Tool (OSCAR) should be revisited and refined to meet the needs (ie., higher spatial and temporal resolution) of mesoscale NWP data assimilation systems.

- CGMS operators to work on the development of observing systems that serve the needs of the mesoscale modeling community. To initialize high resolution regional models, more independent observations from satellite operators are needed in both space (horizontal and vertical) and time. Wind observations from today's Global Observing System (GOS) cannot adequately support the evolution of wind motion scales in 4D.

- CGMS operators should take advantage of these updated requirements to better tailor AMV products for use in mesoscale modeling applications.

Mesoscale NWP modeling community should take these tailored AMV products and compare them against the model and independent observations, e.g., ModeS, wind quality, time and space characteristics.

3.3 AMV Reprocessing and the Use of Common Algorithms

The topic of AMV reprocessing was covered by talks and discussion at IWW12. There is a consensus among the scientific community for the need and benefits associated with satellite data and product reprocessing. A significant amount of progress has been made by the GSICS community that enables the intercalibration of a variety of satellite instruments – a critical first step for reprocessing products that include AMVs. IWW12 notes that a significant amount of progress has been made by many satellite operators to develop and build the infrastructure needed to reprocess AMVs. There were several talks at IWW12 summarizing AMV reprocessing activities at EUMETSAT, CIMSS, CMA, and JMA.

IWW12 WG1 agreed on the potential benefits of the AMV reprocessing for reanalysis, but also noted the utility and importance of reprocessed AMVs beyond reanalysis projects. For example, using reprocessed AMVs for scientific studies that provide insight into atmospheric circulation and its decadal variability, and into specific atmospheric processes (e.g. divergence fields from the tracking of AMVs from marine PBL clouds and inference of vertical subsidence) could be of great value for climatological studies (change of jet stream position for example).

Until now all satellite operators have reprocessed their own satellite data from their own data archive using a recent version of their own algorithm. This leads to the generation of consistent products among a satellite operator's historical satellites, but does not address differences in similar products reprocessed by other satellite operators.

There was a lot of discussion at IWW12 on the topic of using a "Common" algorithm in reprocessing activities. The idea is valid in concept, especially given the movement by CGMS satellite operators to acquire and use more consistent instrumentation. However, it was felt that greater consultation with scientists involved in reanalysis and climate was required before embarking on this complicated and expensive process. There was a general feeling that a higher priority should go to ensuring we have as complete a record as possible of reprocessed AMV datasets using the current framework, particularly from the earlier satellites.

Some of the practical concerns related to using a common algorithm were:

- All satellites are different (pixel resolution, temporal gaps between images, channels...etc) and algorithms have been designed, developed, and tuned to take advantage of the characteristics of the instrument. Application of a satellite operator's algorithm to another satellite operator's instrument may not be optimal.

- It would not be simple to construct or use a single algorithm that would accommodate the differences between the various instruments. We could decide to choose the most basic, older and simple algorithm that does not use the capabilities of the most recent sensors, but it does not make sense from a scientific point of view.

- There is presently no stand alone algorithm able to process all data. The NWC SAF algorithm has been designed to be portable, but is currently limited to MSG data over Europe. There are plans to adapt it to other satellites in the future (as part of EUMETSAT SAF CDOP3), but it will take several years. As far as we know there are no plans to adapt it for older generations of satellite instruments.

- AMVs come at the end of the processing chain, using other meteorological products that are derived upstream of the AMV algorithm (Cloud mask, Cloud analysis, Cloud Top Height, Radiative transfer calculations...etc.). This product dependency creates some practical difficulties/challenges that must be considered. For example, some satellite operators did not extract cloud products as part of their AMV reprocessing. It is also possible that a satellite operator's archive does not contain these needed products. This then, would require the cloud product to be reprocessed first before AMV reprocessing can commence. We should also consider using the same radiative transfer model and NWP background fields.

- A careful product validation process must be considered. The effort to properly validate the output products is labour intensive and time consuming. We would also need to validate any upstream products like clouds that would be needed for many of the newer AMV algorithms.

IWW12 discussed possible mitigation strategies to some of the above challenges:

- Reproject satellite imagery on to a common grid as a starting point for reanalysis efforts. It was agreed that this needs further discussion though.

- If a common wind retrieval system isn't feasible, there is benefit to utilizing algorithm components (e.g., a particular tracking method or a common quality indicator) that are deemed to be superior in some way by the community. Product intercomparisons studies are critical for determining the quality of various algorithm components. Having one or two groups work with each other's code and thoroughly examining the similarities and differences is a very useful exercise and is highly encouraged by the IWWG.

- Improving user understanding of the potential differences between products from different satellite operators e.g. due to different height assignment approaches.

- Encouraging all satellite operators to use a common approach when reprocessing data from all generations of their own satellites (allowing for some expected differences due to channel availability, resolution etc).

4 CONCLUSIONS

The 12th International Winds Workshop hosted by the University of Copenhagen in Copenhagen, Denmark continued the series of successful meetings. All recommendations from CGMS-42 were discussed, together with other key scientific issues, during the working group and plenary discussion sessions.

During the workshop a number of recommendations were proposed. The IWWG co-chairs would like to highlight for consideration at CGMS-43 the following key recommendations:

IWW12.1. **Producers and users to discuss and agree provision of further information characterising the AMV derivation for enhanced QC and error characterisation (e.g., height error estimates from pixel-based cloud schemes, information on the correlation surface, contrast, etc).**

IWW12.2. **Satellite operators to consider coordination of orbits for scatterometer instruments and to provide open and timely access to data in order to maximise independent coverage and benefits to nowcasting and NWP from assimilation of scatterometer wind data**

IWW12.3. **All producers to consider during design of future derivation systems for next generation satellites the ability to handle existing and where possible earlier generations of satellites (with some expected code modularity to reflect the different channel availability etc). This will remove the need to maintain more than one system, ensure more consistent and improved approaches are applied to all operational satellites and will greatly simplify the approach to reprocessing.**

IWW12.4. **IWWG community to agree a new standard BUFR template, which when rolled out should be adopted by all producers.**

IWW12.5. **IWWG co-chairs to check current requirements for satellite-derived winds in the GOS and to raise with CGMS (i) how best to increase**

visibility of AMVs as a driver for the design and operations of future satellite systems and (ii) how best to reflect the higher spatial and temporal resolution requirements of high resolution NWP and nowcasting.

IWW12.6. **Continue research into improved derivation and assimilation of high resolution winds for use in high resolution data assimilation and nowcasting.**

IWW12.7. **IWWG to undertake a 3rd AMV Intercomparison study in the 2018-2020 timeframe that will study the effect of using higher spatial, temporal, and spectral resolution imagery from the newest satellite series (Himawari 8/9 or GOES-R) on AMV derivation. The IWWG will coordinate with the ICWG in this study to gain an improved understanding of the cloud microphysics and its potential use for improving retrieved AMVs. Apply a NWP SAF analysis type approach to the results and dig deeper into differences observed by the various satellite operators in order to understand why some algorithms perform better in some situations than others.**

CGMS-43 is invited to consider additional recommendations from IWW12 shown in Appendix A.

The continued success of IWWG is greatly helped by the collaborative projects ongoing within the community. These are a very useful way to address a number of issues and we invite CGMS-43 to support continued collaboration by enabling specific studies and by providing funding for travel of scientists. We also continue to advocate that CGMS agencies provide support for future IWWG workshops including travel for its scientists to attend and participate in them.

As a final point to note, the current IWWG co-chairs would like to announce that Dr Régis Borde (EUMETSAT) and Mr. Steve Wanzong (University of Wisconsin/CIMSS) will be taking over the chairmanship of the IWWG at the completion of the Thirteenth International Winds Workshop (IWW13) planned in the summer of 2016 in Monterey, California.

APPENDICES:

APPENDIX-A: IWW12 Recommendations
APPENDIX-B: IWW12 Group discussion summaries
APPENDIX-C: IWW12 Working Group 1 Report
APPENDIX-D: IWW12 Working Group 2 Report
APPENDIX-E: IWW12 Scatterometer Mesoscale NWP Data Assimilation Splinter Discussion Report

APPENDIX A: IWW12 RECOMMEDATIONS

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IWW12.2. **Satellite operators to consider coordination of orbits for scatterometer instruments and to provide open and timely access to data in order to maximise independent coverage and benefits to nowcasting and NWP from assimilation of scatterometer wind data**

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IWW12.4. **IWWG community to agree a new standard BUFR template for satellite-derived atmospheric motion vectors, which when rolled out should be adopted by all producers.**

IWW12.5. **IWWG co-chairs to check current requirements for satellite-derived winds in the GOS and to raise with CGMS (i) how best to increase visibility of AMVs as a driver for the design and operations of future satellite systems and (ii) how best to reflect the higher spatial and temporal resolution requirements of high resolution NWP and nowcasting.**

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IWW12.8. Recognise increased usage of pixel-based cloud products by AMV

derivation schemes and benefits of discussion between experts in both areas. Attendance by ICWG Andrew Heidinger at IWW12 was very useful and recommend that this is repeated at future workshops with representative from IWWG also at ICWG meetings.

IWW12.9. MISR data to be made available in BUFR on the GTS (DONE). NWP Centres encouraged to undertake further evaluation and share results via the IWW NWP mailing list. Also to consider inclusion of monitoring online (e.g. via NWP SAF).

IWW12.10. Recommend for future workshops to encourage those presenting posters to bring along A4 print outs and one slide to introduce their work.

IWW12.11. Reprocessing of AMVs, and in particular funding of early GOES satellites and MODIS to be raised at joint CEOS-CGMS WG

IWW12.12. Encourage collaboration and sharing of software between producer centres to compare the methods and algorithm components. In particular AMV producers encouraged to provide a detailed description of their QI and cloud height methods. The IWW website could accommodate this information.

IWW12.13. All AMV producers to include a common QI using the same standard formulation.

IWW12.14. To help prepare for GOES-R: NESDIS to make available an offline test dataset of SEVIRI AMVs processed with the GOES-R algorithm in ASCII, including all available meta-data (from nested tracking and with information on cloud parameters), covering several months within the past year (two seasons). NWP centres to assess and provide feedback.

IWW12.15. To use the intercomparison dataset and the collocated lidar/AMV dataset to investigate in greater detail height assignment issues, in particular in the tropical region. Collaboration with the cloud retrieval community is encouraged.

IWW12.16. Participants encouraged to discuss with climate colleagues the potential of AMVs for climate applications both as direct measurements and through assimilation in reanalyses. Consider also whether there is a requirement for production using a common algorithm.

IWW12.17 Encourage continued support and collaboration between AMV producers and feedback from users to help improve the quality of AMV datasets, particularly with a view to securing long-term AMV provision over the Indian Ocean region.

APPENDIX B: IWW12 Group discussion summaries

Group Discussion 1: Results from the Second AMV Inter-Comparison Study

A key goal of this study was to learn and understand similarities and differences in AMVs produced at different operational centers, and ultimately, to improve the quality and consistency of the AMV products. A summary of this study and outcome is described in CGMS Working Paper IWWG-WP02 entitled , "Summary of the 2nd AMV Intercomparison Study"

As a reminder to CGMS 43 WGII, the following CGMS members participated in the study:

- Brazil Weather Forecast and Climatic Studies Center
- China Meteorological Administration (CMA)
- EUMETSAT (European Organization for the Exploitation of Meteorological Satellites)
- Japan Meteorological Agency (JMA)
- Korea Meteorological Administration (KMA)
- National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite Data and Information Service (NESDIS)
- NWC SAF (Satellite Application Facility on Support to Nowcasting & Very Short Range Forecasting)

Each member successfully generated and delivered the requested AMV product files to NWC SAF/AEMET. Details on the test datasets for the study and the prescribed instructions and configurations for how each AMV product dataset should be generated and what information should be output to the AMV product datasets is described on the following IWWG activities web page:

https://groups.ssec.wisc.edu/groups/iwwg/activities/amv-intercomparison-study

Four experiments were designed to test and compare different aspects of the AMV algorithms: target selection, tracking, cloud height assignment, and quality control.

Key Conclusions:

- With the exception of a couple, the various tracking algorithms used by the participants all perform well. For the two that did not, only simple modifications will resolve the problems. This is a basic outcome of such an intercomparison study and is evidence of the usefulness of a study like this.

- Significant differences exist in other processes of the AMV calculation for the different centers:

  - The variability in the target selection process, causing differences up to 500% in the amount of available AMVs, even in the case that a prescribed similar configuration is used for the AMV calculation.

- The variability in the height assignment techniques, which is the most likely reason to explain the differences in the validation statistics for the different centers.

- The variability in the AMV Quality Indicator (QI) values is likely caused by differences in the way the QI method is implemented. Centers should verify if they are using the method as defined by EUMETSAT or provide details on how and why the QI method is implemented differently.

The current AMV intercomparison study experiments were specifically designed to assess and verify the tracking and the height assignment algorithms used by the different centers.

The differences identified as part of this study clearly warrant the need and consideration for a Third AMV intercomparison study.

Group Discussion 2: Winds for High Resolution Numerical Weather Prediction (NWP)

Covered in Section 3.2

Group Discussion 3: Height Assignment, Treatment of AMVs over Layers, and Changes to BUFR Format

During the session "AMV height assignment and treatment as layers" there were several presentations describing studies that have explored the effects of interpreting AMVs as vertical averages of wind and/or reassigning AMVs to a lower height. These studies have explored different aspects, but on the whole there was a feeling that "the pieces fit together":

- AMVs do not seem to be really representative of the cloud layer top. They seem to be more representative of (i.e. more highly correlated with) the wind at a level below the cloud top.

- Apart from reassigning AMVs to a different level, it seems that interpreting AMVs as vertical averages also leads to improvements. However, there are some aspects of vertical averaging that are not well understood yet as shown in assimilation experiments of AMVs as layer averages.

The discussion that followed these presentations focused on height assignment and (mainly) possible corrections. There seems to be a good agreement about a few points:

- Continued interaction between the IWWG and the ICWG would be very beneficial. As experts in clouds, the ICWG members may develop or refine methods to extract information of interest for AMV height assignment.

- A height assignment correction may be beneficial, but it needs to be carefully considered and should not be too complicated.

- It would more appropriate that the height assignment correction is done at the user side (than at the producer side), for several reasons. Much more cloud information is required to do this.

- Information on cloud properties would be very valuable for users to develop their own height assignment corrections. This information should be included in AMV (BUFR) messages. Cloud type and optical depth were obvious candidates.

- Cloud top retrieval from NOAA's OE cloud-top height retrieval is really an "effective" cloud-top height meaning that it represents a height into the cloud (ie., below geometric cloud top) consistent with an optical depth of ~1. For example, the "effective" cloud-top for a thin cirrus cloud represents a height somewhere in the middle of this cloud. It is important that this information be communicated to the user community.

- Uncertainty estimates in cloud height retrieval is something the ICWG can/should provide for use by AMV producers and/or NWP users who assimilate AMVs. Optimal Estimation (OE) "cost" is a newly added output of the NOAA (and EUMETSAT?) cloud retrieval algorithms that indicate retrieval convergence. The OE "cost" is much higher for thin cirrus. The OE "cost" has the potential to be a good measure of cloud retrieval quality. AMV producers and NWP users need to evaluate this variable in order to determine its relationship to AMV quality.

- AMV BUFR Discussion Points

    - AMV producers will only provide u and v in AMV BUFR files and not speed and direction.
    - No need to include NWP vertical wind shear and temperature gradient. Remove from proposal.
    - Some of the information discussed as part of the new proposed wind BUFR sequence are not relevant to MISR. How do we deal with this? Kevin Mueller asked to provide IWWG co-chairs with a list of MISR relevant parameters that will need encoding.
    - A plan to transition from the current satellite winds BUFR sequence to a new one will be needed. This plan will need to consider the time it will take for users to transition to the updated sequence.
    - It is recommended that the following cloud parameters be included in the BUFR format rather than cloud type: emissivity, particle size, phase, height, single- or multi-layer.

APPENDIX-C: IWW12 Working Group 1 Report

REPORT FROM WORKING GROUP 1 (WG1): Methods

Chairs: Régis Borde (EUMETSAT) and Jeff Key (NOAA)

Consistent Products

The idea of a single wind retrieval algorithm for all satellites is valid in concept, but has a number of disadvantages. First, it may hinder innovation. Second, there are implementation issues such as the variety of software programming languages that are currently employed, architectural differences of the systems into which the code is integrated, and inadequate software and algorithm documentation. Therefore, additional and probably significant effort and resources would be required for most groups. The NWCSAF may be the exception in that they have people that can provide the necessary support if their software were adopted by others.

If a single wind retrieval system isn't feasible, there is certainly benefit to utilizing algorithm components (e.g., a particular tracking method or a common quality indicator) that are deemed to be superior in some way by the community. Product intercomparisons are critical to determining the quality of various algorithm components. Having one or two groups work with each other's code and thoroughly examining the similarities and differences is also a useful exercise.

The experience of the International Cloud Working Group (ICWG) is useful here. After years of Cloud Retrieval Evaluation Workshops (CREW), no single algorithm for generating global cloud properties has emerged as being superior to the others. It is therefore unlikely that a single algorithm will ever be used by all groups, even though many are deriving cloud products with the same satellite data.

However, the idea of a common algorithm for winds has a different motivation: there is a global user community in the numerical weather prediction (NWP) centers. A single winds algorithm for a given sensor type could emerge someday, particularly as imagers become more similar, for example, the ABI-like imagers on future geostationary satellites. In the near-term, however, it is likely that multiple algorithms will continue to evolve, though not independently.

IWW12-WG1 Recommendation 1: Encourage collaboration and sharing of software between producer centres to compare the methods and algorithms components.

Error Characterization

NWP centres are all familiar with the QI, though there are different ways of calculating this parameter. WG1 felt that it is important to separate tracking and height errors. The QI with and without the forecast should continue to be included in winds products.

The different product developers may include other error parameters in the data files, primarily for their own diagnostic use. Examples are cluster characteristics and multiple maxima and associated QI values.

IWW12-WG1 Recommendation 2: More discussion with wind product users (NWP centres) is recommented in order to determine the optimal error characteristic(s) that should be included in data products.

IWW12-WG1 Recommendation 3: There should be a common QI included by all data producers.

Reprocessing

The World Meteorological Organization (WMO) Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) has a project with the goal of reprocessing all wind products, both geostationary and polar-orbiting. To date, the project has proceeded with different centres reprocessing their own data using their own algorithm. So there is processing consistency for each satellite imager, but not necessarily consistency between satellites. The group agreed that it would be useful for one or more centres to reprocess all data (all satellites) with a single algorithm.

One recommendation was to reproject the imagery as a separate step and provide the reprojected imagery to all groups. This would provide a common starting point. Such a two-step approach was used by the Cooperative Institute for Meteorological Satellite Studies (CIMSS, University of Wisconsin-Madison, USA) for reprocessing of AVHRR polar winds, and by EUMETSAT for the reprocessing of Metop.

Besides the obvious use of reprocessed AMVs in reanalyses, other uses include the determination of error characteristics, climate studies such as changes in jet stream position and strength, changes in storm tracks, etc. Furthermore, the use of AMVs in reanalysis may help reveal errors in the AMV products.

IWW12-WG1 Recommendation 4: The challenges to reprocessing should be described in a short document for CGMS.

IWW Input to the CGMS Baseline

The WMO Integrated Global Observing System (WIGOS) is a framework for integrating all WMO observing systems under one umbrella. The *Manual on WIGOS* is an annex to the WMO Technical Regulations. The *Manual on GOS* (Global Observing System) is closely related to the *Manual on WIGOS* and its contents will progressively be moved into the the WIGOS manual.

The WIGOS manual describes common attributes of the space-based subsystem of the global observing system. It currently states that “This sub-system shall provide quantitative data enabling, independently or in conjunction with surface-based observations, the determination of the following variables: … Wind fields at the ocean surface and aloft”. It therefore clearly recognizes winds as an required variable to be observed from space.

It is less clear, however, to what extent winds are considered as a driver for the design and operation of new satellite systems and virtual constellations. Note that the overall architecture of the space component of WIGOS is defined and evolves in consultation with CGMS.

IWW12-WG1 Recommendation 5: The IWWG should investigate the role of winds in the design and operation of future satellite constellations, as described primarily in the *Manual on WIGOS*. Requirements for wind observations in WMO's Observing Systems Capability Analysis and Review Tool (OSCAR) should also be examined.

Intercomparison Study

The intercomparison study has been productive and informative so far. In addition to providing useful information on products and algorithms, it has helped identify problems with the intercomparison process itself. For example, tracking errors were revealed for two of the data producers.

Similar to the ICWG/CREW activity, the winds intercomparison will be done incrementally over a number of years. The next intercomparison phase will result in a more consistent and useful product. It should include improved cloud height assignment and a common quality assessment, perhaps a common QI. It is worth noting that the ICWG/CREW intercomparison project benefitted from a visiting scientist position to help with their website and database. No such resource is available to the IWWG.

It was suggested that the MISR cloud heights could be incorporated in the next winds intercomparison study.

IWW12-WG1 Recommendation 6: The participants of the intercomparison project should provide each other with a detailed description of their QI parameter and their cloud height methods. The IWW website should accommodate this information. Because of the resources involved, the next intercomparison study should be in four years.

High Resolution Winds

This topic has been discussed in plenary session. There were few additional comments by WG1. The group emphasized the importance of a spatial consistency check in the QI calculation, which may be a limitation to the retrieval of smaller scale information.

IWW12-WG1 Recommendation 7: Study quality indicators more appropriate to mesoscale AMV extraction.

BUFR Format

The new BUFR format was discussed at length during plenary. Only cloud parameters were discussed by the group. Cloud type, as suggested during plenary, may not provide sufficient

information for users who might want to adjust AMV heights based on cloud properties. More quantitative measures were suggested by the WG.

IWW12-WG1 Recommendation 8: It is recommended that the following cloud parameters be included in the BUFR format rather than cloud type: emissivity, particle size, phase, height, single- or multi-layer.

IWWG

Regarding the 12th International Winds Workshop itself, the only suggestion was that it would have been better to for everybody to be at the same hotel, or at hotels closer to each other. The group had positive comments about the poster session. There were only minor logistical issues.

There were no concerns about the IWWG website. The ICWG/CREW website is a wiki that has tools and datasets (password protected). The IWWG website could be expanded to include, or link to, some of its data, though WG1 interest in this idea was not uniform.

Regarding coordination between IWWG and ICWG, ICWG could work with the IWWG case study in their own intercomparison. This would identify differences between the height assignment methods. Andy Heidinger is part of the ICWG and is also on the IWWG mailing list. He will be the liaison between the two groups for the near-term, subject to ICWG approval. Back-to-back meetings might be difficult to arrange. It would be easier to work directly with the ICWG cloud height group. It was also recommended that at least one person from IWWG attend the next CREW meeting (Lille, France, 2016).

Methods

Tracking with hyperspectral data, i.e., tracking in moisture retrieval space rather than radiance space, was briefly discussed. One NASA-funded project is underway. EUMETSAT plans to revisit optical flow methods applied to moisture or temperature fields in the framework of MTG IRS.

AMV height assignment is recognized as an important aspect of wind retrieval that needs attention.

There was at least one recommendation during plenary to reduce the use of the model background wind field in search for tracers in tracking when possible. There was no strong opinion by the group as a whole on this topic, other than general agreement that using the background is important to polar winds derivation because of the large time interval between orbits.

IWW12-WG1 Recommendation 9: Further studies should be undertaken to assess the value of MISR or MISR-like instrumentation for global wind retrieval.

APPENDIX-D: IWW12 Working Group 2 Report

Report from Working Group 2 (WG2): Data Assimilation

Chairpersons: Niels Bormann[1], James Cotton[2]

[1]ECMWF, Reading, UK
[2]Met Office, Exeter, UK

Members: Niels Bormann (ECMWF), James Cotton (Met Office), Mary Forsythe (Met Office), Graeme Kelly (Met Office), Francis Warrick (Met Office), Christophe Payan (Météo France), Alexander Cress (DWD), Kevin Mueller (JPL), Sharon Nebuda (CIMSS), Michael Rennie (ECMWF), Kirsti Salonen (ECMWF), Angeles Hernandez (AEMET), Ad Stoffelen (KNMI), Stephane Laroche (MSC), Bjarne Amstrup (DMI), Mats Dahlbom (DMI), Koji Yamashita (JMA), Wei Han (CMA), Kathrin Folger (University of Munich), Dong Wu (NASA), Anne-Grete Straume-Lindner (ESA-ESTEC), Feng Lu (NSMC/CMA), Xiujuan Su (NCEP), Zhand Xiaohu (CMA), Jianmin Xu (CMA), Gert-Jan Marseille (KNMI), Teresa Valkonen (Met No), Julia Figa (EUMETSAT).

1. Introduction of GOES-R algorithm for current GOES AMVs

A significant upcoming change for the GOES AMVs is the plan to update the current data to use the algorithm developed for the future GOES-R satellite. The group noted from Hongming Qi's talk at the workshop that the new data would be available from October 2014, with operational implementation planned for July 2015. The long period of parallel dissemination was appreciated by the NWP centres present and this will allow sufficient time for testing in data assimilation systems and also to provide feedback to NESDIS. It was confirmed that the application of the algorithm for the current GOES data will include both the nested tracking and height assignment changes presented in various talks at the workshop. There was some uncertainty over the format in which the data would be provided, i.e. using the existing GOES BUFR sequence or the new proposed BUFR sequence as outlined by Jaime Daniels in the earlier plenary discussion (the latter still needs to undergo the official approval process). VIIRS data, which has recently been made available, also uses the full GOES-R algorithm (nested tracking and HA changes) and is disseminated in the existing BUFR format. It was felt by the group that this would also be the best approach for the GOES data. This avoids having to cope with multiple changes at the same time and also ensures that test data becomes available as soon as possible, without a possible delay due to the approval process for the new BUFR sequence.

The group therefore made the following recommendation:

Recommendation to NESDIS: To initially disseminate GOES AMVs derived with the GOES-R algorithm in the old BUFR sequence in order not to delay the parallel dissemination.

2. GOES-R algorithm and improved error characterisation

The GOES-R algorithm opens up new possibilities in NWP for improving the quality control and error characterisation of AMVs by providing extra information coming from the derivation process (nested tracking and ABI height algorithm). Sharon Nebuda had presented some results at the workshop on testing the quality control of proxy SEVIRI AMVs using parameters from the new algorithm e.g. cluster standard deviation and it was requested that these results be shared within the group in the form of a summary report.

Action on Sharon Nebuda: To make available results of the evaluation of the AMVs derived with the GOES-R algorithm through the NWP WG email list (iwwg-nwp@ssec.wisc.edu)

The question was asked as to whether some of the extra information planned for inclusion in the new AMV BUFR sequence could be disseminated earlier for testing purposes. It was confirmed that the proxy SEVIRI data as used for Sharon Nebuda's study are being produced by NESDIS in NRT and the group felt that it would be useful if this data could be made available e.g. offline period of several months. Providing this data in ASCII format would be suitable for all the NWP centres present. The group decided on the following action and recommendation:

Action on NESDIS: To make an offline test dataset of SEVIRI AMVs processed with the GOES-R algorithm available in ASCII, including all available meta-data (from nested tracking and with information on cloud parameters), covering several months within the past year (two seasons).

Recommendation on NWP centres: To evaluate the meta-data available from the GOES-R algorithm for QC and AMV error characterisation.

The group also discussed what other parameters could potentially be useful for QC, e.g. information on the correlation surface to characterise how well-constrained the correlation peak is. Although this was maybe more for discussion on the producer side, the group felt there was still something more to look at in this area. It was mentioned by Kevin Mueller that they make use of the image contrast (in the form of the normalised mean and standard deviation) in the MISR derivation and QC, but this doesn't form part of the height QC. At the end of the discussion the group made the following recommendation:

Recommendation on all winds producers: To make available further information characterising the AMV derivation for enhanced QC and error characterisation (e.g., information on the correlation surface, contrast, etc).

3. Representative level/layer for AMVs

Several studies presented at the workshop reported benefits from either shifting the assigned height of AMVs and/or treating the observations as layer averages. No generally applicable methodology has been established yet. It was noted that Kirsti Salonen's experiments with layer averaging gave a detrimental impact in the tropics and Mary Forsythe confirmed that the

Met Office had seen similar issues in their preliminary work. Generally there is a positive speed bias in the tropics at mid-high level and so spreading this signal out will only make the situation worse. Kirsti also confirmed that she is now running a further test with the new GOES hourly data.

It was suggested that it would be good to be able to dig in to the data sets used for the AMV inter-comparison study following a similar methodology as used for the NWP SAF analysis reports. Given the short period of study (one triplet of images) it was questioned whether there is enough data to perform a reliable comparison to model best-fit pressure and also uncertainty over how much convection was present in the scene. There is generally a need to look more carefully at height assignment in the tropics and it was noted that Kathrin Folger's data set collocating AMVs with lidar cloud tops could be useful for looking at statistics in the tropical region. The expertise of the cloud retrieval products community was also considered very valuable in this respect.

It was also recognised by the group that height attribution is affected by uncertainties/biases in cloud top pressure estimation as well as the "representative level/layer" concept. Summarising the discussion, the group made the following recommendations:

Recommendation to NWP centres: To further investigate what is the most representative layer/pressure for AMVs, using available data sources (incl. lidar, stereo heights, simulation studies, etc).

Recommendation to the Winds Working Group: To use the intercomparison dataset and the collocated lidar/AMV dataset to investigate in greater detail height assignment issues, in particular in the tropical region. Collaboration with the cloud retrieval community is encouraged in this respect.

4. MISR winds

With the imminent availability of a near-real-time MISR wind product in BUFR format, the group was keen to acknowledge the progress made by the MISR team regarding the provision of NRT data and also the test data sets made available to DWD and NRL. To ensure that the data is able to reach the widest possible audience the following recommendation was made:

Recommendation to JPL/NASA: To make the NRT MISR winds available on the GTS.

To ensure that the NWP community is able to learn as much as possible about the characteristics of the MISR data it was agreed that once centres begin to monitor the NRT data it would be good to share these results by making the monitoring statistics available externally, online. The NWP SAF AMV monitoring would be one such example. The group discussed plans for utilising MISR data at the various NWP centres represented. The Met Office primarily plan to focus on getting the data monitored (assimilation experiments are secondary). DWD are planning assimilation experiments and CMA indicated they would also like to do some impact studies. During the workshop Alexander Cress presented some monitoring and assimilation results utilising the offline test periods of MISR data and it was requested that these results, as well as the results of any other impact studies at other centres,

be distributed to the IWWG. It was also noted that the group should make better use of the IWWG NWP email list for sharing results and experiences with new data sets such as MISR.

Recommendation on NWP centres: To make routine monitoring statistics for the NRT MISR winds publically available online.

Action on centres working with MISR winds: To share results and experiences through the NWP WG email list.

5. New BUFR sequence

The group did not devote much time to discussing the proposed new AMV BUFR sequence. However there was consensus among the NWP centres present that there is no requirement (from this group) for information on the forecast data used in the processing to be included in BUFR (i.e. wind shear and temperature gradient).

6. Reprocessed AMVs

There were several talks at the workshop summarising reprocess activities at EUMETSAT, CIMSS and JMA and the group appreciated the progress that has been made in the provision of reprocessed AMVs. The topic of reprocessing with a common algorithm (as well as "own" algorithm) was briefly discussed but it was felt that consultation with re-analysis groups was required to judge whether this is desirable. Would data from this unified algorithm actually be used? The most important aspect is making sure that data get reprocessed.

7. Motion information from geostationary hyperspectral IR

The group noted that there was no work presented at the present workshop regarding extracting motion information from future hyperspectral IR sounders. Whilst MTG is not expected until 2021, FY-4A will be launched in 2016 and carries a hyperspectral sounder. The FY-4A sounder will have a spatial resolution of 16 km and may therefore be less suitable for wind tracking, but it nevertheless provides very interesting upcoming data that should be explored in this context. There is still an open question on whether radiance assimilation or using AMVs derived from humidity retrievals will be the best approach. The group was not aware of any on-going studies in this area (following on from Laura Stewart's work), and noted that more work may be required in the future. It was confirmed that CIMSS will produce winds derived from AIRS retrievals in near real time.

8. Scatterometer activities

There was a strong attendance from the scatterometer community at IWW12 with representation from most NWP centres, plus EUMETSAT and NOAA. The IWWG Workshops are seen as a complementary activity to the International Vector Winds Science Team meetings (most recently held in Brest, 2-4 June) and generally have more of a focus on NWP applications.

A separate meeting was held during IWW12 to discuss scatterometer related issues and further work was proposed on a number of topics:

- Several talks during the workshop noted problems with ambiguity removal using 3D Var assimilation systems due to the time miss-match between the model and observations in dynamic situations. Until the assimilation systems are upgraded to 4D Var (or move to more frequent cycling than 3-hourly) the best option may be to instead use the 2D Var solution provided by KNMI or restrict observations to data nearest analysis time. KNMI agreed to test the effect of using on/off-time background fields in ambiguity removal and to provide further guidance.

- In order to get a better handle on the spatial scale represented by the models the relevant tools (spatial variances/spectral) and an analysis resource will be hosted on the NWP SAF website.

- The wind speed scale of the Harmonie model is too high. KNMI will make the guidance document on scatterometer bias correction more prominent.

- The impact of observation thinning on ambiguity removal was discussed. KNMI will test the impact of reducing the weight given to observations.

- Benefit has been demonstrated from adding OSCAT data on top of ASCAT in NWP. With the recent failure of the Oceansat-2 instrument it was reiterated that data from other (current and planned) missions should be made available to the community in NRT.

The NWP WG emphasised the last point, by making the following recommendation:

Recommendation to relevant CGMS agencies: to make HY-2A and RapidScat scatterometer data available to the international community in NRT.

9. Aeolus winds

ECMWF have developed a level 2 processor which is available to download by interested centres. As Aeolus is a research mission, users are being encouraged to download the software themselves and experiment with it and several centres have plans to do this. Near real time L2 data may also get produced by KNMI following EUMETSAT support. Feedback on the format and dissemination of the L1B data was requested from NWP centres in the form of the following action:

Action on NWP centres: To provide feedback to Anne-Grete Straume-Lindner (ESA, anne.straume@esa.int) on their plans to process Aeolus data by end September 2014, considering the following points:

a) Whether they plan to process the level 1B data locally
b) What format they require for L1B (ESA format ok or need BUFR?)
c) Distribution is planned via the EO portal – do users also need access via the GTS/EUMETCast?

10. Feedback on Workshop organisation

The general feeling of the group was that had been a successful workshop with the discussion sessions again seen as being very useful. It was emphasized that there is a need to make sure that recommendations arising from discussions are included in the workshop report. A change to the format this year had been the introduction of poster sessions and this seemed to work well. It was suggested for next time that those presenting posters bring along A4 hand-outs for people to take away and read as well as making sure that electronic versions of posters (ppt/pdf) are available on the IWWG web-site. Having a representative from the cloud retrieval community at IWW12 was considered by the group to be very useful and this should be continued for future workshops.

APPENDIX-E: IWW12 Scatterometer Discussion

**Scatterometer mesoscale
NWP data assimilation -
IWW12 splinter discussion summary**

1 PARTICIPANTS

Ad Stoffelen (NWP SAF, lead), Julia Figa-Saldana (EUMETSAT, minutes), Alexander Cress (DWD),
James Cotton (Met Office), Giovanna de Chiara (ECMWF), Teresa Valkonen (Met No), Christophe Payan (Meteo France), Gert-Jan Marseille (KNMI).

2 PURPOSE AND RESULTS

To discuss status at different groups of scatterometer NWP data assimilation experiments, with particular focus on mesoscale models and extreme weather.
To assess the need for collaboration in

- providing guidelines for best practice scatterometer NWP data assimilation,
- exchanging methods, validation metrics and results.

In a broader context and prior to the meeting, following CGMS recommendations, the IWWg provided a description of mesoscale NWP data assimilation issues, which was used as input to the discussion, see https://groups.ssec.wisc.edu/groups/iwwg/activities/high-resolution-winds-1/.
The full complementarity (no redundancy) of OSCAT and ASCAT at only 2.5 hours separation has been demonstrated at global NWP centres and confirms the need for improved temporal sampling. This is even more urgent for mesoscale modelling. Better revisit time and timeliness is needed for NWP throughout the day: the current 12 hour coverage should go down to 3 h. In this context, EUMETSAT and the SAFs agreed to continue efforts to obtain HY2A, RapidScat and ScatSat scattermeter wind services at SAF quality level.
It would further be extremely helpful if this was also reported to and recognized at CGMS level, as we directly depend on agencies which in relevant cases are represented at the CGMS (e.g., SOA).
We moreover record Christophe Payan's statement about the current coverage limitations of ASCAT-A/B in the tropics, also made by Paul Chang in his presentation during the plenary. It would be relevant too to report this in the plenary mtg.
Following the discussions, as summarized below, the following actions were agreed:
All: Support improved temporal sampling, by selecting experimental periods with as many scatterometers as feasible: ASCAT, QSCAT, OSCAT, HY2A, RapidScat. KNMI will request (more) HY2A backscatter data from SOA/NSOAS.
All: Share experimental results among participants. Further experiments on timing errors, thinning, more aggressive QC in inner/outer loops and background error structure are encouraged.
NWP SAF (KNMI): Investigate 2DVar sensitivity to: timing errors, thinning, QC, background error structure, background (provided by participants) with the aim to provide guidance to NWP centres. Both for ASCAT and OSCAT type instruments.

NWP SAF: Make above points more prominent on web site: bias correction guidance, guidance, data and tools (as is) on spatial/spectral analyses and triple collocation.
EUMETSAT: Cater for RapidScat and HY2A satellite IDs for WMO BUFR; OSI SAF to draft BUFR template for wind product.
EUMETSAT/SAF: Continue efforts to obtain HY2A, RapidScat and ScatSat scattermeter wind services at SAF quality level.
NWP SAF: Organize NWP SAF workshop on scatterometer data assimilation.

3 AGENDA

After the presentations at the IWW12 of the different colleagues, a priority list for discussion was suggested by Ad Stoffelen:

- Observation timings
- Wind speed calibration
- Spatial representation of model and observations
- Temporal sampling
- Thinning
- QC
- Way forward
- AOB

4 OBSERVATION TIMING

The difference between observation and model verification time affects the success of the Ambiguity Removal (AR) as shown by several speakers. The problem is resolved with 4Dvar, but 4Dvar is not (yet) widely used (DWD and Harmonie use 3DVar).Tests with 4DVar Harmonie are ongoing at KNMI.
For 3Dvar, either global or regional, a good alternative is to move towards a rapid update configuration (1 h) or it would help to activate the choice of first guess at most appropriate time (FGAT), but the latter projects the time-wise correct observation increments to the central analysis verification time, which results in an analysis error contribution. It is noted that FGAT is no option in the Harmonie system. An alternative is to take the selected solution in the OSI SAF products, such that AR errors due to enhanced analysis error at 10m are avoided (see below), which may further corrupt the analysis (by the negative feedback).
At DWD, the implementation of the new non-hydrostatic ICON model will require to test/tune all the Scatterometer winds assimilation.
At MF, the regional model Aladin (for overseas applications) and the mesoscale NH model Arome (for France) would also require specific settings for scatterometer data assimilation.

5 CALIBRATION

Wind speed bias calibration is already active in Global NWP. For mesoscale initialization biases may be quite detrimental. Moreover, wind corrections brought by observations only last very short in the forecast cycle (1 hour). Biases at 10m are due to the physical surface layer closure. Every group needs to determine their own correction, according to their model

configuration. It is acknowledged that Harmonie has too high speeds for strong winds exceeding 15 m/s. A wind bias correction specific for it is necessary. The method to do this

was explained in the NWP training workshop at EUMETSAT in 2009, available in the NWP SAF page (http://nwpsaf.eu/deliverables/scatterometer/index.html). KNMI offers support in explaining methodology and sharing results.

As a side comment, Giovanna requested at least 4 weeks of s0 test data for s0 calibration updates. This will be taken into account, but it is very unlikely that any calibration change is necessary in either ASCAT-A nor –B in the short to medium term.

6 SPATIAL VARIABILITY

Spatial variability of wind in LAM models like Harmonie is generally not well known. It is necessary to evaluate this in order to define representativeness and ultimately the correct observation operator. Spectral analysis is difficult to implement and interpret for LAM. For complete evaluation, spatial variance analysis is best suited, also more robust.
KNMI to share the methods and all to apply. Then share results.
Christophe inquired what the influence of background/bck. error specifications is, used in the 2dVar AR? Is it consistent with that at the assimilation stage? NWP SAF tested effects of background and background error in the past and continues to do so. Perhaps guidance may be provided of how to interpret ASCAT AR differences between 2DVar and 3DVar or 4DVar. The NWP SAF will look into this, either providing guidance, a tool or testing other than ECMWF background fields.

7 TEMPORAL SAMPLING

The full complementarity (no redundancy) of OSCAT and ASCAT at only 2.5 hours separation well illustrates the need for improved temporal sampling. This will be even more urgent for mesoscale modelling. Better revisit time is needed for NWP through the day: current 12 hour coverage should go down to 3 h.
Revisit time improvements down from 3 h (such as current 50 min between ASCAT-A/B) useful to study convection processes (research) and improve physical parameterizations. Operational exploitation may follow subsequently.
PS: KNMI will request HY2A data for the period where also ASCAT (tandem) and OSCAT winds were available. Suggestions for particular time periods are welcome!

8 THINNING

A question is how spatial thinning affects the AR results, due to both diminished observation impact and provision of less spatial coherence to the AR. The NWP SAF will test this, so the other groups can benefit.
Temporal ASCAT A/B thinning effects are tested for global models (James) and conclusions for global NWP available (James to circulate the report). Since a global model would not take much benefit of the 50-minute ASCAT-A/B time separation, this temporal thinning experiment may be regarded mainly as a spatial thinning experiment, i.e., spatial oversampling of a very similar point in model state space.The global models take only small benefit of the 50-minutes ASCAT-A/B time separation, benefit probably thanks to a mixing between their 4DVar scheme and the fact that the swaths do not overlap entirely towards the poles. Various diagnostics (NWP index at MetO, FSO at ECMWF (A/B denial experiments)

and MF (periods comparison)) suggest that ASCAT-A impact is shared with ASCAT-B, when the latter is used in addition. An improved spatial separation should be more beneficial
An investigation for regional NWP is not available and optimal spatial processing and QC remain the main limiting factors in the use of the data that need further experimentation.

9 QUALITY CONTROL

A reduced MLE threshold: (more aggressive QC) may bring higher impact. Since MLE is a good proxy for local wind variability, it is strongly correlated with high o-b. Usually, unrepresentative observations are handled by a first guess check, but this depends on the highly variable quality of the background in such highly variable cases, which correspond to squall lines, gust fronts, etc. It is in principle more independent to do VarQC on the MLE than the O-B departures. NWP SAF will test this and will recommend new guidelines for scatterometer data assimilation.
QC in extreme weather: accepting more Scatterometer observations slightly improves sea level pressure, but not necessary the storm track forecast. It is thought more important/efficient to get the TC environment right, i.e., make sure that the TC is in the system (with Scatterometer hits on the developing system for up to 6 days in advance). The assimilation of high winds, moreover ambiguous in direction, at the heart of a storm, which usually correspond to high or extreme o-b, is complex since the (ad hoc) location of the observation with respect to the position and structure of the dynamical system is inherently unknown. Therefore, rather unrepresentative spatial background error correlation structure will be applied to the (large) increment. This applies to other storms too. This can be tested with a 10+ day experiment denying Scatterometer data at different stages. ECMWF will test this.
Having said that, the Hubert norm use has not been reviewed in a long time, and it is still useful to do so, since the method was tuned for a much lower model grid spacing.
It was noted that VarQC only works in 4DVar and that it will be tested in Harmonie when it migrates to 4DVar.

10 WAY FORWARD

Evaluate progress in a year, meet in association with the EUMETSAT conference, programme a NWP SAF workshop, perhaps linked to the European scatterometer conference on 3-5 Feb 2016.

11 AOB

Likelihood of accessing RapidSCAT and HY-2A data in NRT: technically possible, formal/programmatic issues are being worked on by EUMETSAT at high level and SAFs on working level.
No satellite ID exists for the WMO BUFR template for RapidSCAT ? Urgent need to start preparing this. HY-2A/ScatSat needed too!
HY-2A Current timeliness is 4-5 hours, would still be useful for global NWP. Improving that depends on SOA (Finland station). NSOAS plans to run the KNMI wind processor (PenWP), which may enable the OSI SAF to run high quality wind services.