ASSIMILATION OF SCATTEROMETER WINDS AT ECMWF

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Abstract

At the European Centre for Medium-Range Weather Forecasts (ECMWF) scatterometer winds have been assimilated in the operational Integrated Forecast System (IFS) from 30 January 1996 onwards. After the failure of QuikSCAT and the recent permanent switch-off of the ERS-2 satellite, currently only data from the ASCAT instrument on the METOP-A platform are actively assimilated. Scatterometer data are also routinely monitored and inter-compared. A description of the wind assimilation will be presented.

Analysis experiments have been performed in order to assimilate data from the Scatterometer onboard OCEANSAT-2 satellite, launched in September 2009. OSCAT data is currently only passively monitored and not yet actively assimilated. Results of these experiments will be also discussed.

INTRODUCTION

Space borne scatterometers provide accurate observations of near surface winds. Accurate knowledge of ocean surface wind fields are important information for a wide range of applications, for instance the computation of reliable air/sea heat fluxes, assimilation into Numerical Weather Prediction (NWP) models, ocean models and surface-wave models, as well as climate studies.

The assimilation of Scatterometer winds at ECMWF started in January 1996 with data from the ERS-1 and ERS-2 missions. ERS-2 Scatterometer provided data until the end of the mission in July 2011 (excluding a suspension of about 3 years from 2001 to 2004). Data from Seawinds, onboard QuikSCAT satellite, were assimilated from January 2002 onwards. The data dissemination was interrupted in November 2009 after a failure occurred to the satellite's antennae.

Currently only Scatterometer winds from the METOP-A ASCAT sensor are assimilated into the IFS. Surface winds from ASCAT were introduced into the operational suite on 12 June 2007. Both the METOP-A ASCAT Global and EARS streams disseminated by EUMETSAT are received and used. Research activities have been performed in order to analyse OCEANSAT-2 Scatterometer (OSCAT) products disseminated by the Ocean and Sea Ice Satellite Application Facility (OSI SAF). Wind fields have been compared to collocated ECMWF First-Guess winds. Studies have been carried out to assess the configuration of OSCAT wind processing in the assimilation scheme.

The objective of this paper is to describe the status of the operational assimilation of Scatterometer winds into the 4D-Var component of the Integrated Forecast System at ECMWF. A description of the ASCAT products assimilated and experiments on OSCAT winds are shown. Also results from a NWP impact study of Scatterometer winds during the Atlantic Hurricane season are discussed.

METOP-A ASCAT PRODUCTS

At ECMWF the METOP-A ASCAT products at 50 km horizontal resolution (oversampled on a 25 km grid) are presented to IFS. These products contain observations from the two ASCAT swaths each gridded into 21 Wind Vector Cells (WVCs or nodes) resulting in 42 WVCs. Scatterometer winds are obtained by applying an "in-house" wind inversion by means of a geophysical model function (GMF) that describes the relation between the backscatter measurements, triplets in case of ASCAT, and the u and v wind components. Since November 2010, scatterometer winds are assimilated as neutral winds rather than 10 m winds, in order to take account for variations in stability. The CMOD5.N (Hersbach, 2010) GMF is used. For each backscatter triplets 2 wind solutions are retrieved. A bias correction is applied to ASCAT measurements both in terms of backscatter (sigma nought) before the

inversion, and wind speed, after the inversion. This is important in order to compensate for any changes in the instrument calibration and to guarantee consistency between the retrieved and the model winds. Both corrections are WVC dependent. The wind speed correction is also dependent on the wind speed itself.
A quality control is applied before and after the wind inversion. The first check is done on the land fraction in the product which must be zero. A conservative sea-ice check is also applied. ASCAT data is rejected when the model sea-ice cover exceeds 1% or if the SST is below 273.15 K. Data are also discarded when the ASCAT and collocated model winds are stronger than 35 m/s. Finally the average backscatter residual of the wind inversion, also called normalized distance to the cone, is checked. This helps in recognizing anomalous data.
Not all the observations that pass QC are actively assimilated. A thinning is applied such that only one observation out of four is assimilated. Across swath WVC's 1, 5, 9, 13, 17, 21, 22, 26, 30, 34, 38, 42 are selected resulting in a horizontal resolution of about 100 km. In 4D-var two ASCAT wind solutions are considered. The most appropriate is dynamically determined (de-aliasing) by comparison with the ECMWF model winds. For the selected solution, in 4D-var an observation error of 1.5 m/s is assigned to both U and V components through the cost function.
Scatterometer winds are routinely monitored. The mean observation values, first guess (FG) and analysis departures and their standard deviations are monitored daily on global and regional scales. Results are available on the ECMWF web site: http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/wind/scatt/ASCAT/.
In Figure 1 scatter plots of ASCAT versus ECMWF FG winds are shown for wind speed (left) and direction (right) for September and October 2011. ASCAT winds are on a global average very close to the ECMWF FG winds with a bias close to zero and a standard deviation of about 1.25 m/s. The wind direction standard deviation is about 14 degrees. The performance of the data is quite stable in time with small differences ranging within the seasonal variability.

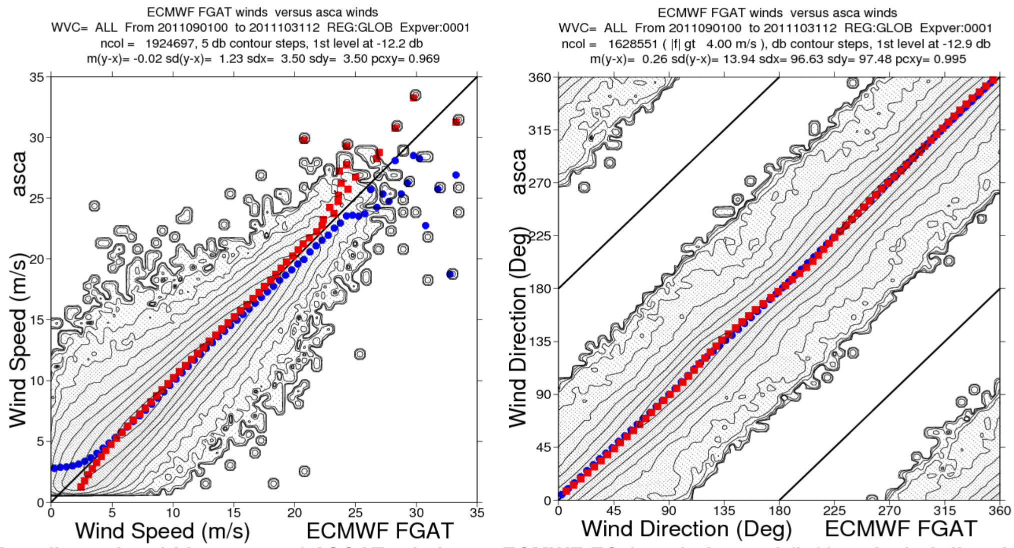

Figure 1: Two-dimensional histogram of ASCAT relative to ECMWF FG for wind speed (left) and wind direction (right) from 1 September to 31 October 2011. Blue circles denote average for bins in the x-direction; red squares averages for bins in the y-direction.

OCEANSAT-2 SCATTEROMETER PRODUCTS

OCEANSAT-2 was launched in September 2009 by ISRO (Indian Space Research Organisation). It carries on board a Ku-band Pencil Beam Scatterometer (OSCAT) providing backscatter measurements on a ground resolution cell of 50 km. In the framework of the NWP SAF and Ocean and Sea Ice (OSI) SAF, KNMI developed the OSCAT Wind Data Processor (OWDP) to process L1B ISRO products and to generate L2B wind data with the same BUFR format as Seawinds. OWDP inverts the WVC backscatter data to ambiguous wind solutions using the NSCAT2 Geophysical Model Function (GMF). No winds have yet been computed in the outer parts of the swath where only VV-polarised outer beam data are available, i.e. WVC numbers 1-4 and 33-36 (Stoffelen et al., 2011).

A quality control step is performed after wind inversion. OSCAT products contain land/sea ice fraction flags and rain contamination flags. Also all WVCs in which the wind solution closest to the NWP background wind has a Maximum Likelihood Estimator (MLE) value above a certain threshold are rejected.

ECMWF receives the experimental OSI SAF L2B products as generated in NRT at KNMI. A first QC is based on the KNMI product flags related to the land/sea fraction, rain contamination, and data quality. On top of the KNMI QC, the land-sea fraction and sea-ice fraction (together with the SST check) are verified applying the same thresholds as used for ASCAT winds. Due to the lower grid spacing (50 km) no thinning is applied to OSCAT winds. However in order to have the same weight as ASCAT data, which are assimilated every 100 km, in 4D-Var a weight of 0.25 is applied to the 50 km OSCAT winds.

Since the beginning of the experimental NRT dissemination, in March 2011, three different datasets have been delivered that reflect differences in the ISRO processor configuration and the subsequent update of KNMI OWDP. To verify the OSCAT products and assess their impact on the ECMWF 4D-Var scheme, analysis experiments have been conducted. The first set of experiments was based on the period from 26 March 2011 to 25 May 2011. Comparison between OSCAT and collocated ECMWF FG winds are shown in Figure 2. On average OSCAT winds are lower than FG winds with a speed bias of about 0.25 m/s. The wind speed standard deviation is around 1.25 m/s. However discrepancy for high wind speeds can be noticed. Also for this data version, winds are cut off below 2 m/s. No major issues are shown on the wind direction whose standard deviation is around 12.5 degrees.

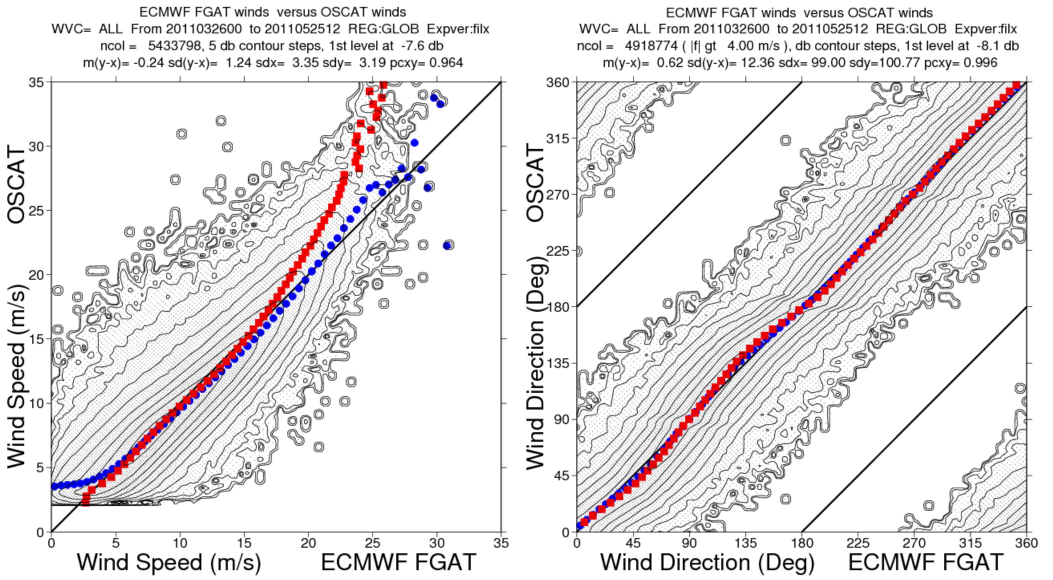

Figure 2: Two-dimensional histogram of OSCAT relative to ECMWF FG for wind speed (left) and wind direction (right) from 26 March 2011 to 25 May 2011. Blue circles denote average for bins in the x-direction; red squares averages for bins in the y-direction.

A wind speed bias correction, WVC-dependent, has been calculated to have consistency between OSCAT and model winds. Based on the hypothesis that OSCAT and FG winds have comparable random errors, for each WVC the bias correction has been computed as the average between OSCAT wind and FG wind biases (computed as the distance of respectively the blue circles and red squares from the 45 degrees diagonal). Since the wind speed bias would lead to unrealistically large corrections at high speed values, a wind speed threshold of 25 m/s is applied to the data so that winds above this value are discarded.

The comparison between bias corrected OSCAT winds and ECMWF FG winds is shown in Figure 3. As expected the wind speed bias is now almost zero. Also, it is shown that this correction does not affect the wind direction, whose bias and standard deviation are not changed.

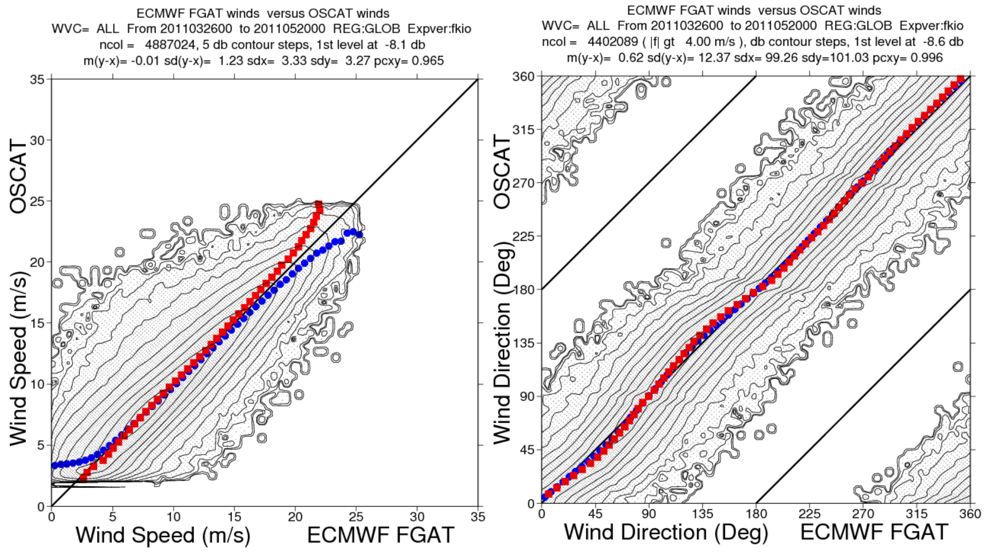

Figure 3: Two-dimensional histogram of bias corrected OSCAT winds relative to ECMWF FG for wind speed (left) and wind direction (right) from 26 March 2011 to 25 May 2011. Blue circles denote average for bins in the x-direction; red squares averages for bins in the y-direction.

The neutral impact of OSCAT data on ASCAT data has been verified. By comparing the performance of ASCAT winds in two experiments differing only for the assimilation of OSCAT data it has been verified that the assimilation of OSCAT winds does not affect the assimilation performances of ASCAT observations. Indeed the bias and the standard deviation of the differences between ASCAT and ECMWF FG winds are almost the same (not shown here).

In August 2011 and December 2011 two upgrades of respectively KNMI OWDP and ISRO processor lead to changes in the data. In Figure 4 results for the comparison between OSCAT and ECMWF FG winds are presented for the period from 29 August 2011 to 28 September 2011. Within this configuration OSCAT winds are lower than ECMWF FG winds. The speed bias is around 0.53 m/s, the standard deviation is around 1.22 m/s. Although the wind speed bias being larger than the one computed for the first dataset (March-May 2011), the discrepancy for high wind speed is lower. With this processor configuration, also winds below 2 m/s are computed. Wind direction standard deviation is around 11 degrees.

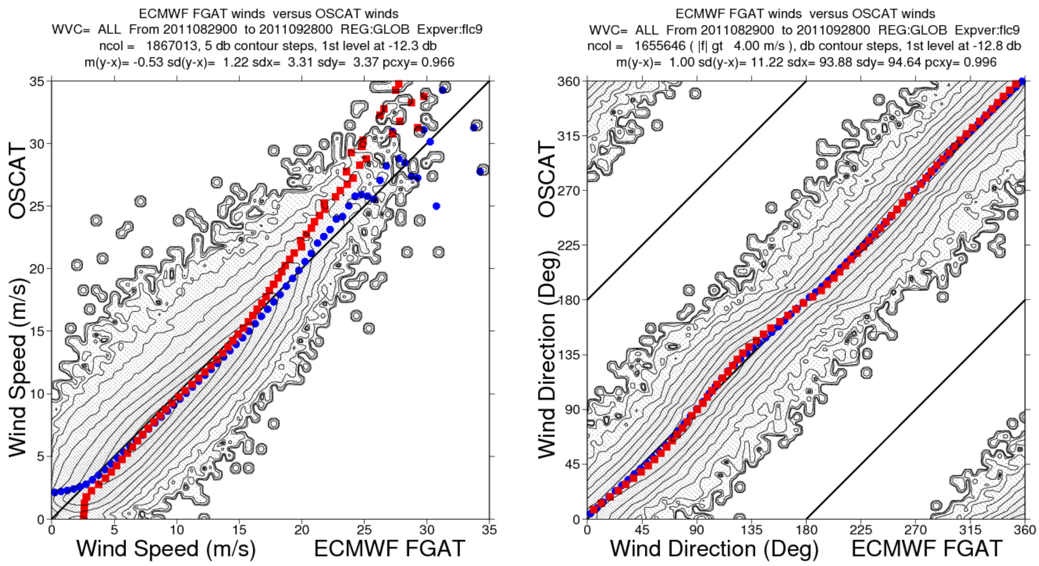

Figure 4: Two-dimensional histogram of bias corrected OSCAT winds relative to ECMWF FG for wind speed (left) and wind direction (right) from 29 August 2011 to 28 October 2011. Blue circles denote average for bins in the x-direction; red squares averages for bins in the y-direction.

The same analysis has also been done for the third, and current data configuration (data from December 2011 onwards) as show in Figure 6. For this last version OSCAT winds are still smaller that ECMWF FG winds showing however a smaller bias, that is around 0.1 m/s. The discrepancy for high wind speeds is a bit higher than the second datasets. No major issues resulted for wind direction.

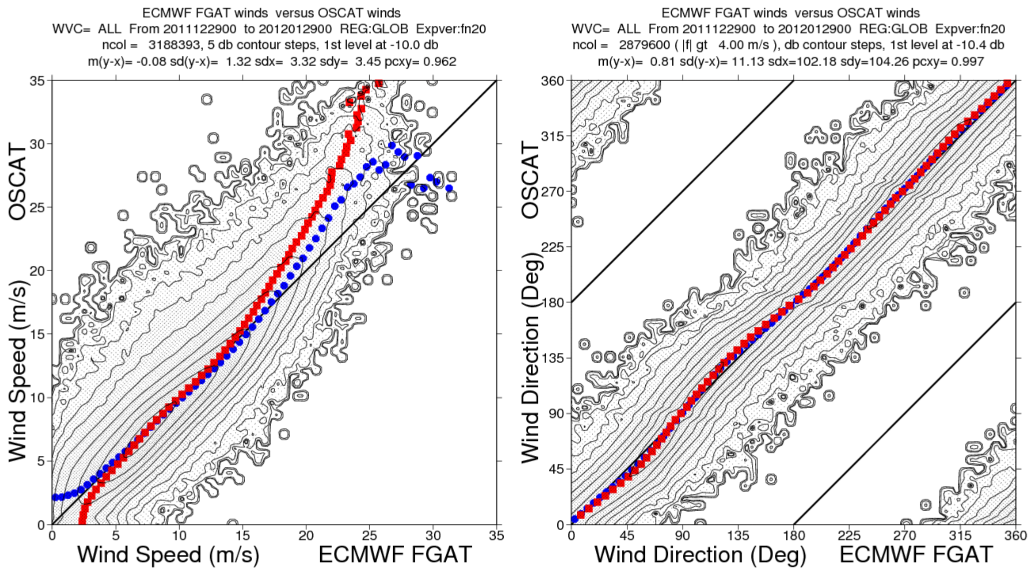

Figure 5: Two-dimensional histogram of bias corrected OSCAT winds relative to ECMWF FG for wind speed (left) and wind direction (right) from 29 December 2011 to 29 January 2012. Blue circles denote average for bins in the x-direction; red squares averages for bins in the y-direction.

As for the first dataset (March-May 2011), starting from the comparison with the ECMWF FG winds, the wind speed bias correction for each configuration has been computed for each WVC and applied to OSCAT winds to verify the impact in the IFS.

Currently, speed bias corrected OSCAT winds are monitored and only passively assimilated. The bias correction needs to be updated every time a configuration change is performed. To summarize, the QC is based on KNMI product flags. Also, checks based on ECMWF land/sea fraction, sea-ice fraction and SST are applied. Wind speeds above 25 m/s are discarded. Due to the lower grid spacing no thinning is performed and a weight of 0.25 is applied.
Active assimilation of OSCAT winds is planned for Summer 2012.

CONTRIBUTION TO NWP WINDS IMPACT STUDY

In the framework of a NWP winds impact study initiated by the International Winds Working Group, ECMWF performed a Scatterometer denial experiment over the selected period 15 August - 30 September 2010, i.e. the Atlantic Hurricane season. The experiment was run at a spatial resolution of T799 (~15 km). For the same period also an AMVs denial experiment has been conducted (Bormann et al., 2012).

Figure 6 shows the vector wind difference of mean wind analysis between the Scatterometer denial experiment and the control at 1000 hPa geopotential height for the period selected. The mean differences are generally within 0.5 m/s and mainly in the tropical area.

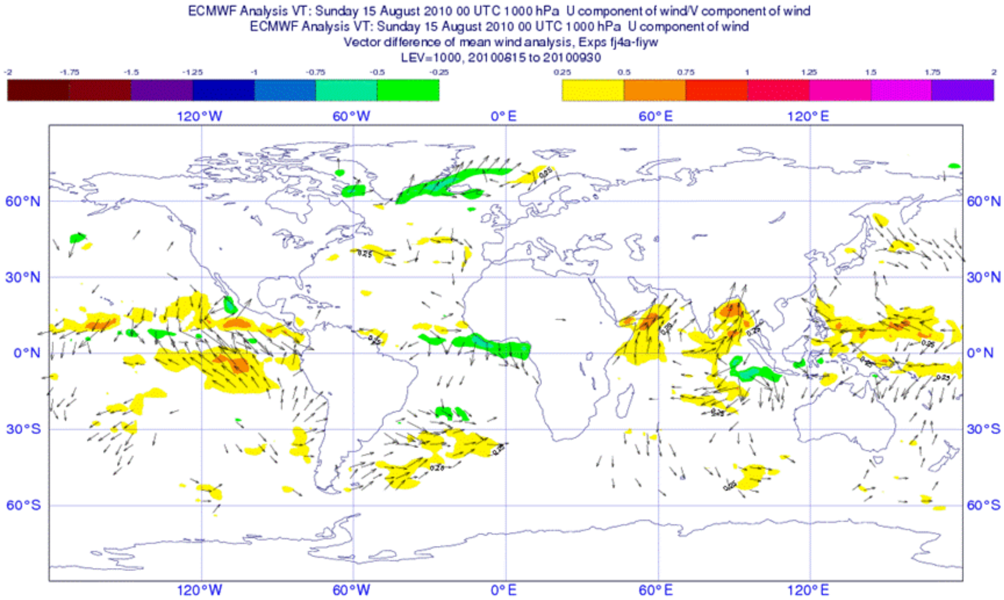

Figure 6: Difference in the mean wind analysis at 1000 hPa between the SCAT denial experiment and the Control. Shading indicates the difference in mean wind speed [m/s]. The considered period is 15 August - 30 September 2010.

Figure 7 shows the difference between the Scatterometer denial experiment and the control for the 1000 hPa geopotential height 48 hour forecasts RMS error. Both experiments are verified against their own analysis. Blue areas denote a positive impact of Scatterometer winds. The general impression is that on average the Scatterometer winds have a positive impact. This is more evident in the Central Atlantic and on the North West Pacific, areas of formation of Tropical Cyclones. Also the typical track of tropical cyclones is quite evident mainly in the Atlantic region. This suggests that Scatterometer winds have a good impact in the analysis and forecast of tropical storms. Similar results are also found for the upper levels (not shown).

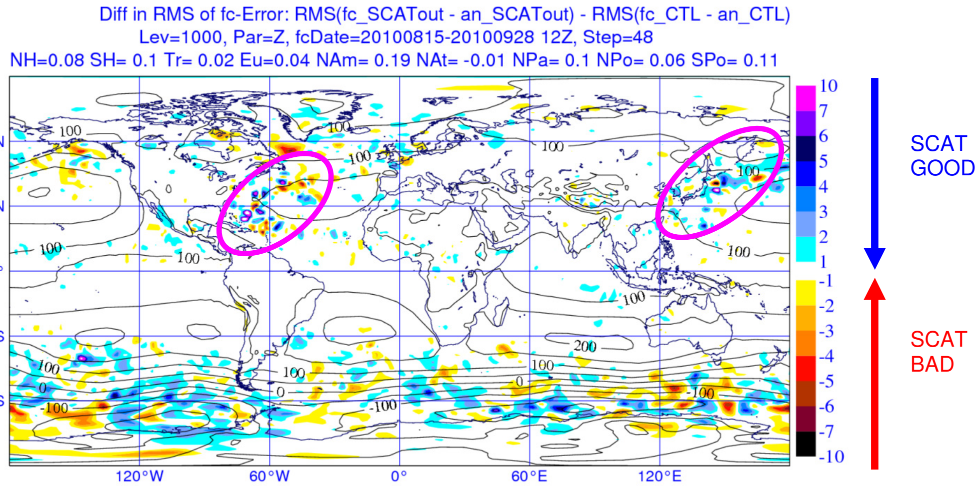

Figure 7: Difference in the root mean square error of the 1000 hPa geopotential [gpm] for the 48 h forecast, with each experiment verified against its own analysis. Positive values suggest an improvement from using the Scatterometer winds. The period is 15 August – 30 September 2010.

Vitart et al. (1997) developed a procedure to detect model tropical storms from ECMWF model fields. The algorithm detects the center of a tropical storm and the related Sea Level Pressure (SLP). To evaluate how Scatterometer and AMVs observations can improve the representation of these storms in the model, the algorithm has been run for the Control, AMVs denial and Scatterometer denial experiments. For each day the position and the minimum SLP for each tropical cyclone have been detected both in the analysis and in the forecasts. For each storm and forecast step, the position of the storm center and the SLP center have then been compared to the available observation values. The observed cyclone location and depth are received from the Regional Specialized Meteorological Centers (RSMC) recognized by WMO: they are the National Hurricane Center (NHC) for the North Atlantic region and the Japan Meteorological Agency (JMA) for the West Pacific Region. To compute the mean errors, only the storms detected in all the experiments have been used. The number of cases used to compute the statistics ranges from 56 (12h forecast range) to 32 (4 days forecast range). Beyond the 4 day forecast range, the number of cases is considered too small to make any significant statistics. In Figure 9 and Figure 8 the mean error in the localization of the minimum SLP and of the storm center are shown, respectively.

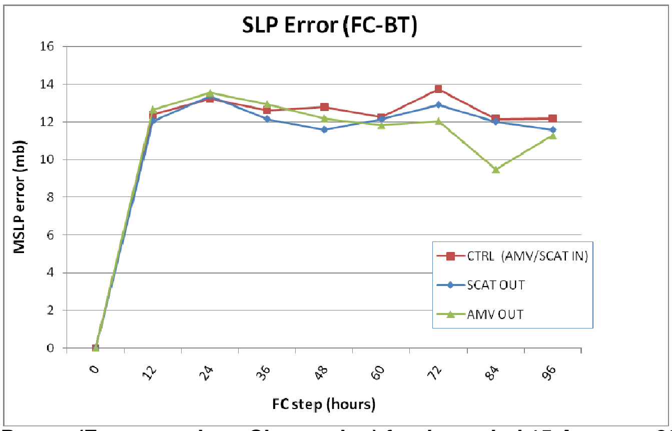

Figure 8: Mean SLP error (Forecast minus Observation) for the period 15 August – 30 September 2010.

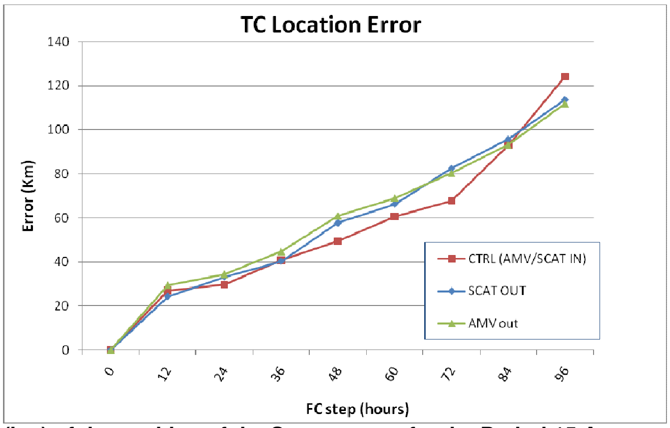

Figure 9: Mean error (km) of the position of the Storm centre for the Period 15 August – 30 September 2010.

Results show that for the estimation of the minimum SLP the impact of Scatterometer and AMVs winds seems quite neutral for the first 96 hours (Figure 8). The assimilation of both Scatterometer and AMVs observations seems to have a positive impact in the localitation of the TC centre. However to draw a more robust conclusion on the AMVs and Scatterometer impact a higher number of cases would be needed.

CONCLUSIONS

METOP-A ASCAT observations provide stable and good quality wind fields. Data is actively assimilated and routinely monitored. The IFS has been prepared to assimilate METOP-B data, whose launch is now planned for July 2012.

The quality of OSCAT winds is promising. Comparison of wind fields with ECMWF FG winds showed a quite large difference for high speed values. To compensate for such discrepancy, a wind speed bias correction is applied. OSCAT data is still under passive monitoring. All the technical modifications to IFS have been performed to assimilate bias corrected winds. Active assimilation is planned for the summer 2012.
Scatterometer data contribute positively to skill in the ECMWF assimilation system, especially in tropical storm areas. The impact of Scatterometer and AMVs winds on forecast of tropical cyclones seems to be neutral on the SLP while small improvements in terms of the location of the cyclone centre are shown. However, since the number of analyzed cases is not really high, further studies are needed to draw more robust conclusions.

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