Recent satellite wind impact studies at the German Weather Service

A. Cress, C. Köpken, H.W. Bitzer

Deutscher Wetterdienst, P.O. Box 106465, 63004 Offenbach am Main

Abstract

Global wind measurements are essential to improve our knowledge of atmospheric dynamics and to describe atmospheric transport processes of energy, water, airbourne particles and trace elements. Atmospheric motion vector (AMV) winds derived from tracking clouds and water vapour image sequences are the only global tropospheric wind information for numerical weather prediction models and therefore make an important contribution to the global observing system, particularly over the oceans and in polar areas, were there are either no other or only very few conventional wind data. Additionally, space-borne scatterometer data provide near surface wind observations over the global oceans with high temporal and spatial resolution under most weather conditions. The German weather service, DWD, has been using AMVs operationally in its global data assimilation system since 1990s, with consistently positive impacts. Recent work has been focused on the replacement of Meteosat-7 data by the new wind products of Meteosat-8 and Meteosat-9, the switch from GOES 10 to GOES 11 and from Meteosat-5 to Meteosat-7 and the successfully inclusion of AMV's from the MTSAT-1R satellite derived by the Meteorological Satellite Center of JMA. Further impact studies have been carried out with Bufr formatted MODIS winds derived by NOAA/NESDIS.

Results of different impact studies demonstrate the positive benefit of using AMV wind products in the NWP system of the DWD. After extensive monitoring and careful QI selection, the winds from Meteosat-8/9 show a slightly positive impact on both hemispheres and Europe. No substantial negative impact results from replacing GOES 10 and Meteosat-5 winds by AMV winds derived from GOES 11 and Meteosat-7, respectively. After the implantation of an improved height assignment scheme, the quality and impact of winds from MTSAT-1R improved substantially. Using quality information in the selection process of MODIS winds lead to a substantial improvement of the polar analysis and increased forecast quality over both hemispheres. Additionally, direct broadcast winds have the potential to increase forecast quality even further. First results indicate a higher forecast quality over the Southern Hemisphere.

The assimilation of scatterometer wind data requires careful data selection with regard to rain and ice contamination. Near surface winds measured by the new ASCAT scatterometer onboard the Metop satellite, required the setup of a new processing chain. Using the scatterometer data leads to improved analyses, visible especially in cases of tropical cyclones or deep extra-tropical systems, the forecast impact is, however small.

I Introduction

Atmospheric motion vector wind observations are derived from the changing positions of typical structures (automatic pattern recognition) in three consecutive images made by geostationary or polar orbiting satellites in the infrared, visible and water vapour channels within a certain time period. The so derived wind vectors are assigned an altitude based on radiation temperature of the cloud measured by selective channels. Finally, each wind is assigned a quality index which supplies information regarding the spatial and temporal consistency of winds and to a background field (usually a short-range forecast).

Errors can occur not only in pattern recognition but also in height assignment. Such errors substantially reduce the quality of the wind data and their usefulness in data assimilation. Winds in a large area are sometimes subject to the same or similar errors, and similar errors can remain uncorrected over a long time period. When this happens, the AMV winds contain spatially and temporally correlated errors, which, as yet, can not be accounted for in modern data assimilation systems. Additionally, redundant wind measurements are produced by observing the same tracer in different spectral channels. Consequently, the winds are usually thinned out spatially and temporally before they are used. In addition, winds with an inadequate quality index (QI) are not used at all. Also the assumption, that clouds were conservative randomly distributed within and floating with the airflow, to estimate a unbiased AMV wind is certainly only a first approximation to the real physical behaviour of clouds and depict a serious limitation of using AMV wind fields in NWP systems.

Space-borne scatterometer date provide accurate near surface wind observations (both wind speed and direction) over the global oceans with high temporal and spatial resolution under most weather conditions. With an intensification of satellite data usage at the DWD, the implementation of wind observations from the Seawinds scatterometer aboard the QuikScat satellite and from the ASCAT scatterometer aboard the Metop satellite is being worked on. Whereas the Seawinds scatterometer, which operates at KU-band frequency, is very sensitive to rain and ice contamination and makes a careful elimination of poor quality data necessary, the C-band ASCAT scatterometer wind measurements are relatively independent of rain conditions and only ice contamination has to be eliminated. Therefore a whole new processing chain for both scatterometer data has to be setup at the DWD.

II Experiment design

Using the global assimilation and forecasting system of the DWD several impact studies for different time periods (winter and summer) were conducted to estimate the potential benefit of AMV wind observations, to test the impact of new wind producing satellites, the replacement of satellites by new modern ones (Meteosat-7 to Meteosat-8/9) and to investigate the potential impact of the scatterometer wind data from QuikScat and ASCAT. All experiments were compared to the operational forecasts (Control) – in general not using the wind data tested in the experiment – using a verity of conventional (synops, radiosonde , aircraft, buoy) and satellite (AMSU-A form the NOAA Satellites, Metop and Aqua) observations. In general, the DWD uses AMV wind observations only over sea and at synoptic times (00, 06, 12, 18 UTC), with the exception of polar Modis winds (every 3 hours and also over land). Winds derived from the visible channel are used only below 700 hPa and winds from the water vapour cloudy channel only above 400 hPa. AMVs tracked from clear-sky atmospheric motions in the water vapour channel are not used at all. The assimilation processing chain of AMVs at DWD consists of several steps. First a static filtering is conducted through QI thresholds, separately for channels, tropospheric layers and geographical regions and only wind data which exceed the QI thresholds are remain active. Second a thinning step is used in order to take into account the high spatial correlation of the AMV winds. To accommodate the various horizontal resolutions and spatial correlations of the extra-polar and polar AMV wind measurements, two different thinning box widths, ~180 km and ~60 km, were introduced into the processing steps of the assimilation procedure.

In the following, quality and impact of different AMV wind products from different satellite processing centres will be described in more detail. Additionally, monitoring and impact results of scatterometer wind observations will be discussed.

III Analyse and forecast impact of AMV wind observations

Before using observation data in any assimilation scheme the quality of the data has to be estimate in order to eliminate possible data biases or major shortcomings of the data by identifying and filtering out bad data. One major tool to estimate the quality of measurements is by comparing the data with other independent measurements or model results. In case of AMVs, the quality is assessed by com-

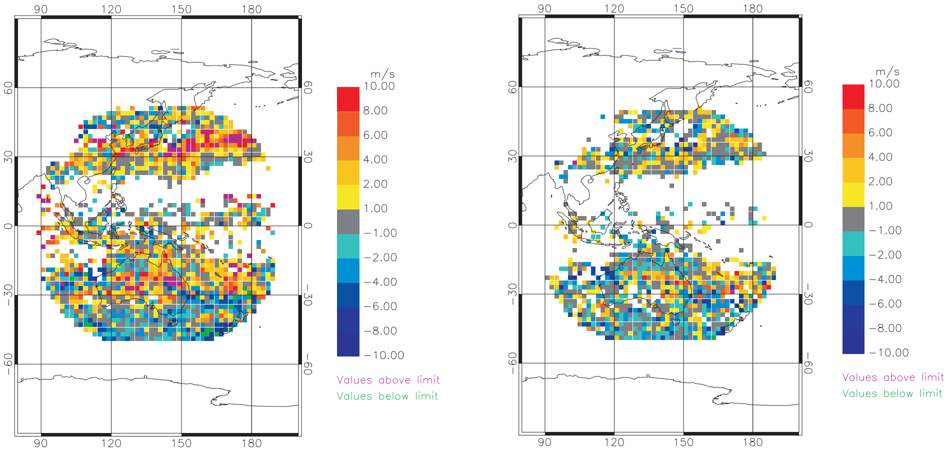

Figure 1: Observation minus First Guess speed bias statistics for MTSAT-1R infrared mid level (400 – 700 hPa) winds for QI > 80 (left) and QI > 90 (right) compared with the DWD global model First Guess wind field for July 2007.

paring the wind data to a 3 hour model forecast (First Guess). An example is shown in Figure 1, where the regional innovation statistics (observation minus first guess) for the MTSAT-1R infrared mid level winds with QI values larger than 80 (Fig.1, left) and QI values larger than 90 (Fig.1, right) are depicted. Obviously, the data with lower QI values show large differences in the Pacific area east of Japan and in the southern part of the Pacific ocean. By using only wind data with higher QI values the wind data with large innovation errors could be eliminated almost totally from the data set. Therefore, a careful selection of AMV wind measurements against QI thresholds is essential before using them in any assimilation system.

A good correspondence was found between the quality of the GOES 11/12 AMV wind statistics and similar statistics for METEOSAT 7/9 for a winter period in 2008 (Fig. 2). There is a positive bias between AMV winds and the corresponding model results (model to slow), which is more pronounced in Atlantic ocean area (GOES 12 and Meteosat-9) than in the Pacific and Indian Ocean areas (GOES 11 and Meteosat-5). This could be connected to a higher baroclinic activity over the Atlantic region compared to the Pacific and Indian Ocean areas. Obviously, the variational quality control, which is a integrated part of the 3DVAR assimilation scheme at DWD, is able to reduce the bias and RMS of all different AMV wind data considerably. Additionally, no significant outliners could be found, which indicates that the QI threshold filtering and the thinning processes are successful to eliminate the majority of bad data.

The impact of AMV wind vectors on the quality of the analyses is illustrated in Fig. 3. Here, the mean difference between the Control analysis and an experiment without using AMV wind data for a winter period (12. Dec. 2007 – 12. Jan. 2008, left panels) and the corresponding RMS differences of the increments (right panels) for the wind speed in 300 hPa (upper panels) and 850 hPa (lower panels) are shown. The maximum changes in the wind speed analysis occur at 300 hPa in the tropical and southern parts of the Pacific Ocean. The eastward zonal flow is decelerated considerably over the tropical Pacific in a narrow band about 4500 km wide. At the same time the RMS wind speed increments are decreased by a considerable amount over large regions in the tropical and southern parts of the Pacific and Atlantic Ocean.

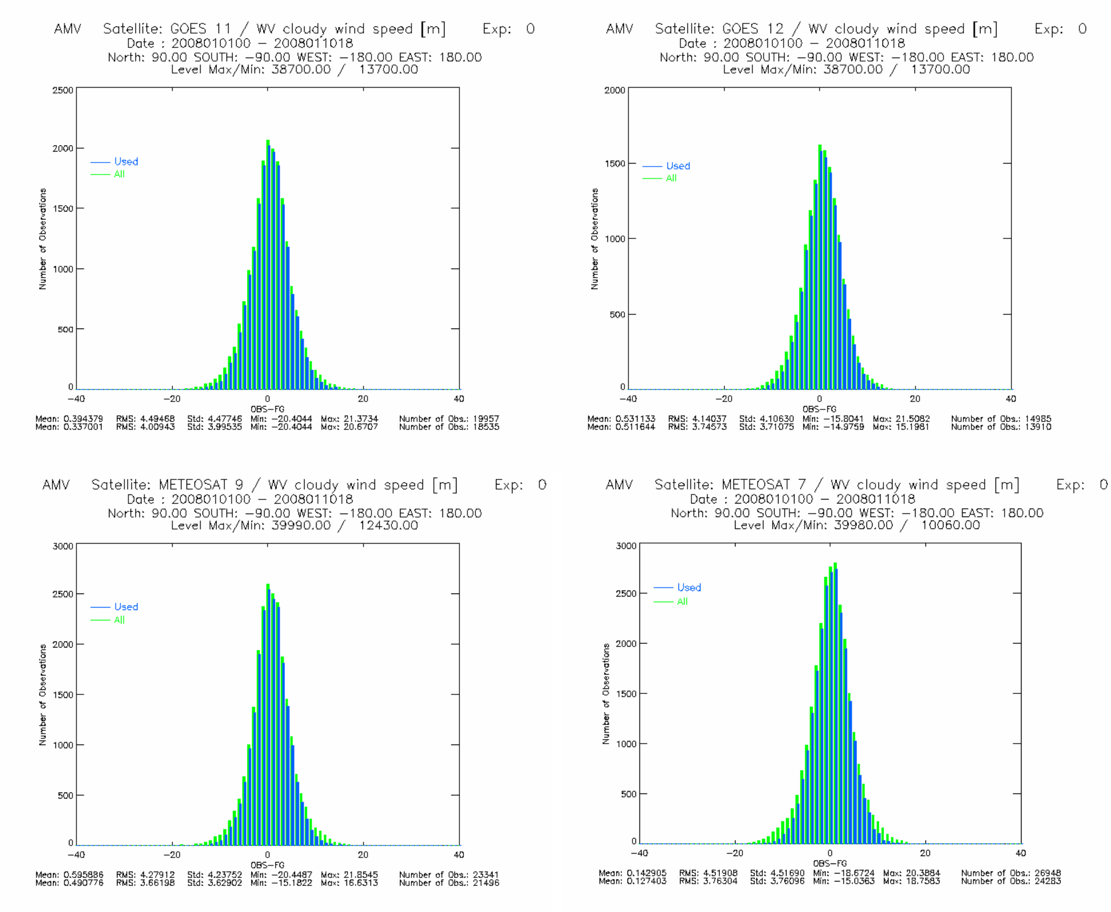

Figure 2: Frequency distribution of upper level WVcloudy AMV wind speed innovations for GOES 11 (upper left), GOES 12 (upper right), METEOSAT-9 (lower left) and METEOSAT-7 (lower right) for all (green) and used (after first guess check and variational quality control, blue) wind data for a 20 day period in January 2008.

AMV's are able to alter the model background significantly over large parts of the tropical and subtropical ocean areas. At 850 hPa, the striking patterns of decreased wind speed analysis can be found in the stratocumulus inversion regions over the Pacific and Atlantic oceans, in tropical regions of the Pacific and to a smaller amount also over the Atlantic Ocean. The main RMS differences at 850 hPa is mainly limited over the Pacific Ocean, where almost no other low level wind observations exist.

Fig. 4 compares the forecast impact of an experiment not using any AMV wind vectors to Control forecasts using all available observations. This No-AMV experiment shows a small, but fairly consistent degradation in forecast quality for the tropical atmosphere and on the Southern Hemisphere, whereas the forecast impact on the Northern Hemisphere is smaller, due to a better observation density, especially conventional (radiosonde, aircraft) data, on the Northern Hemisphere which mask the potential impact of AMV wind vectors considerably. In the absence of other satellite date, the AMV wind data show a much bigger benefit. Obviously, impact experiments using AMV wind vectors from new satellites or replacing one satellite with a new, modern one in general show much smaller positive benefit on the forecast quality and can occasionally even show small negative impacts depending on chosen periods and areas. One example of impacts on the forecast quality by using additionally the wind vectors derived from the MTSAT-1R satellite is depicted in Fig. 5. In this case using the MTSAT-1R leads to a small but positive impact on both Hemispheres and Europe.

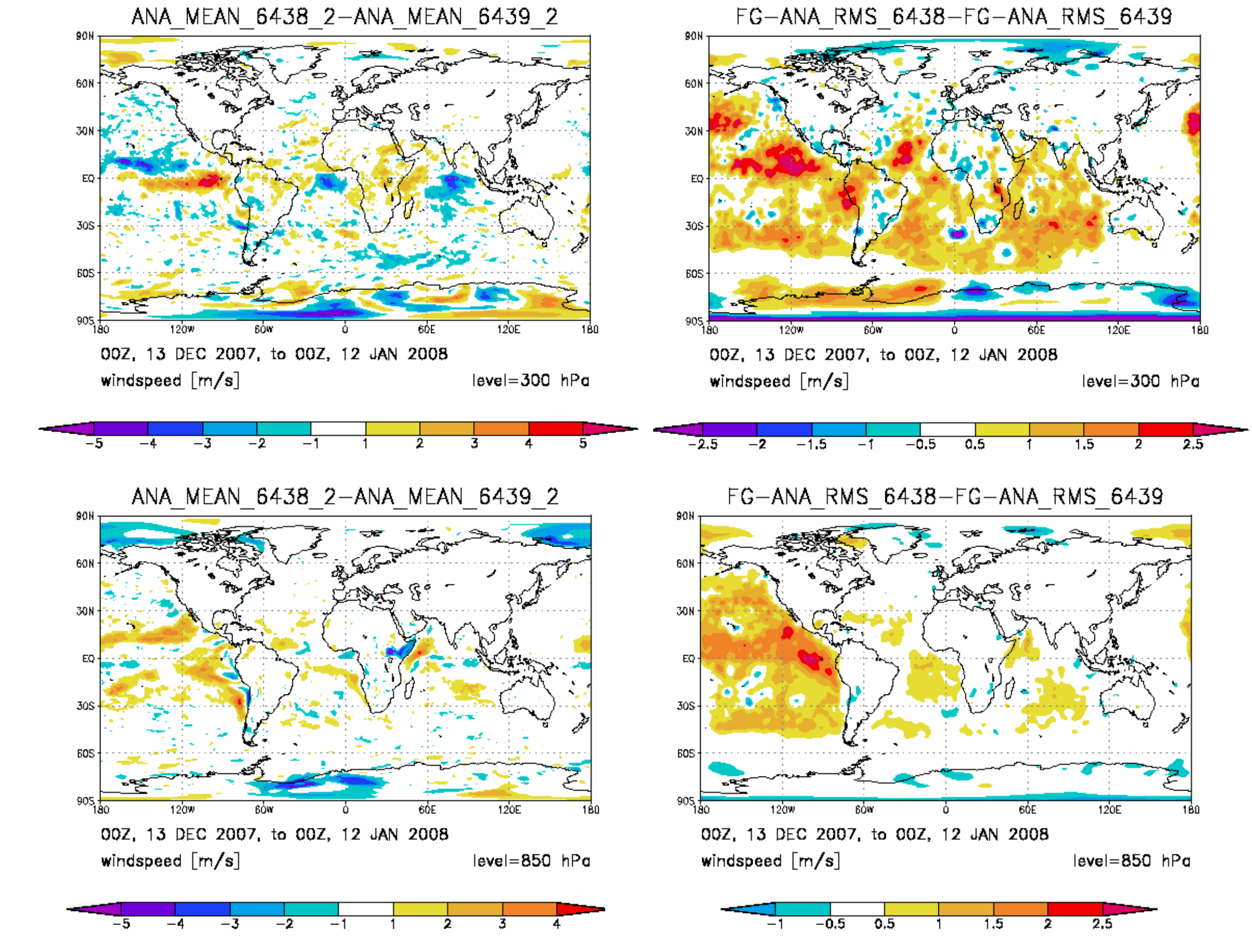

Figure 3: Mean Difference between the analyses of the Control and an experiment without using AMV wind data (left) and the RMS of the First Guess minus analysis (right) for 300 hPA (upper pictures) and 850 hPa (lower pictures) for the time period 12.12.2007 – 12.01. 2008.

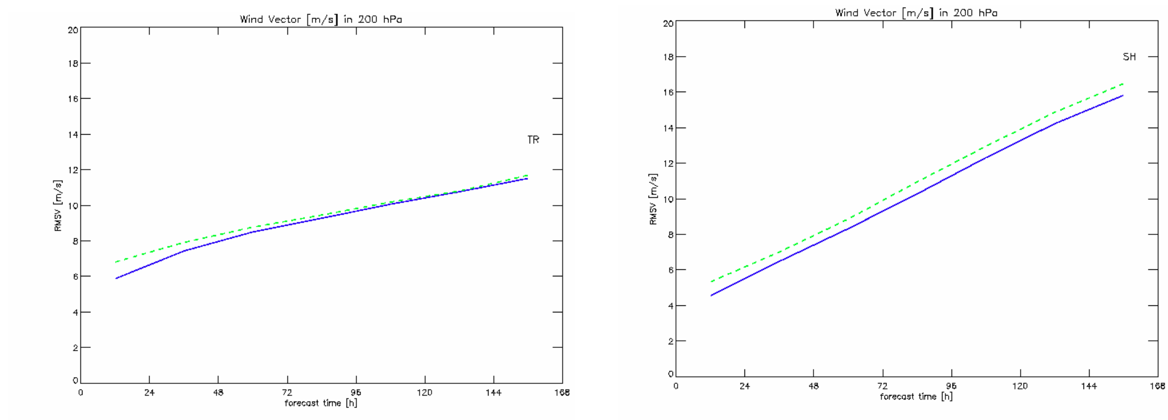

Figure 4: Mean RMS wind vector scores in the Tropics (left) and on the Southern Hemisphere (right) at 200 hPa for the AMV denial experiment (green) and the Control (blue) for the period 12 Dec. 2007 – 12 Jan. 2008.

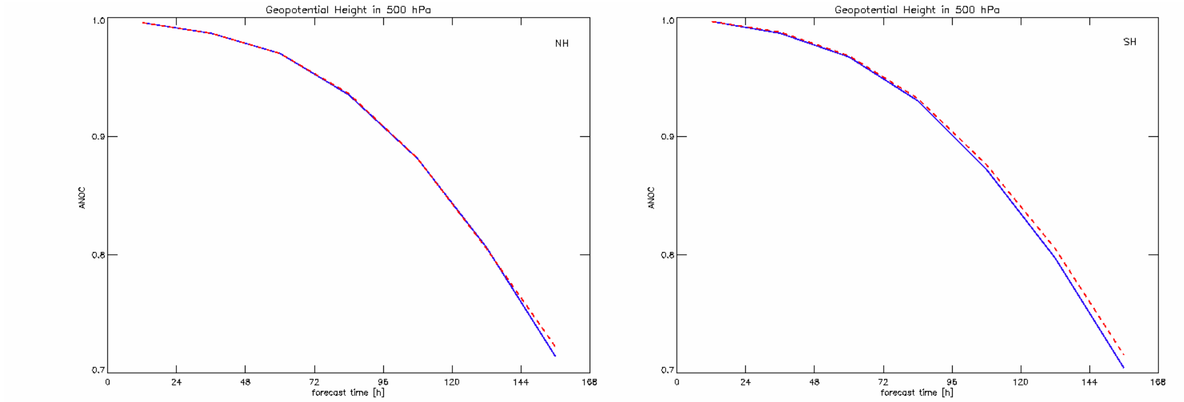

Figure 5: Mean anomaly correlation coefficient for an experiment using wind vectors derived from MTSAT-1R (red) and a Control (blue) for the Northern Hemisphere (left) and the Southern Hemisphere (right) and the period: 10.06 – 10.07 2007

IV Analyse and forecast impact of scatterometer data

The German Weather Service uses wind observations in 10 meters height from the Seawinds scatterometer aboard the QuikScat satellite and from the ASCAT scatterometer aboard the Metop satellite. In the following, quality control and forecast results will be focussed on experiments using the newer ASCAT scatterometer 10 meter wind data derived by the OSI SAF facilities at KNMI. As the assimilation scheme at DWD currently can only handle one wind solution, we select the most likely wind vector solution from the two ambiguity wind solutions of the ASCAT scatterometer. Since the ASCAT scatterometer operates in C-band frequencies, there is no sensitivity to rain contamination and the data can be used in all weather situations. Only a careful elimination of winds over land/ice has to implemented. As Fig. 4 illustrates, the quality of ASCAT derived wind vectors compared to collocated model wind vectors is very good. Using the quality flags, developed by the OSI SAF team at KNMI and inherit in the Bufr coded winds, the quality of the ASCAT wind vectors increases substantially (Fig. 6b) leaving a small positive bias of up to 0.2 m/s, which is comparable to wind measurements from buoys. Obviously, high scatterometer winds at the upper left part of the scatter plot, which do not correspond to corresponding model winds can be successfully eliminated by using the wind vector cell quality flag.

The assimilation of 10 meter wind vectors derived from ASCAT has a positive impact on the analyses and forecast performance of the numerical prediction system at DWD (the same is valid for using QSCAT wind data) mainly on the Southern Hemisphere and for deep baroclinc systems (tropical storms, deep low pressure system), where small positive corrections in position and intensity can be obtained. As an example, Fig. 7 shows a time series of anomaly correlation coefficients for Europe for the Control run and an experiment using additionally ASCAT wind vectors for a 3-day forecast. The time dependent anomaly correlations for both, the Control and the experiment exhibit strong similarities except for the 29th of Jun 2007, where a substantial increase of the anomaly correlation can be found in case of the experiment including ASCAT wind vectors, caused by a better forecast of a strong low pressure system off the coast of Ireland (both position and intensity).

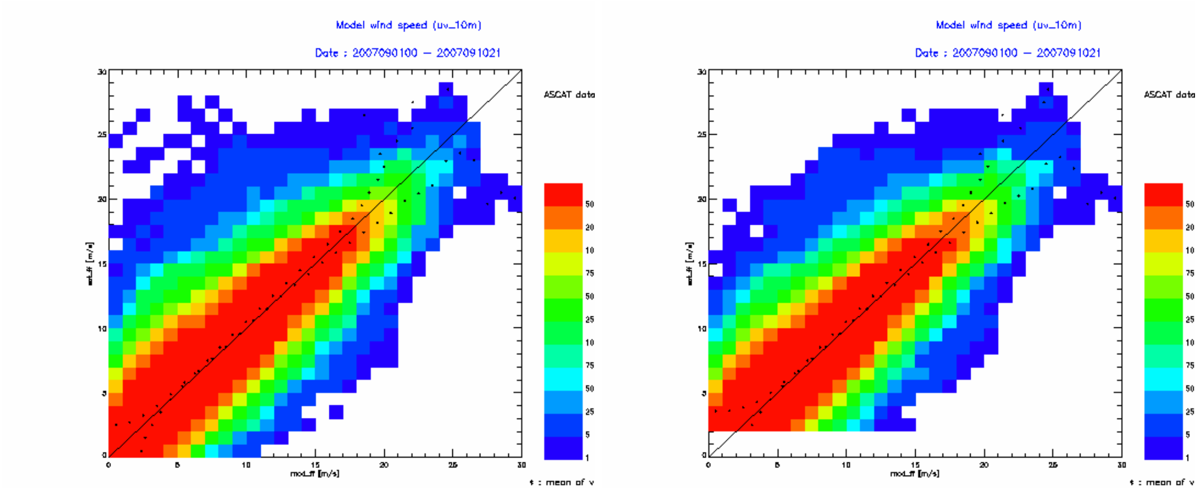

Figure 6: Scatter plot between ASCAT wind speed observations and collocated GME first guess wind speeds for all data (left) and for data after using the wind vector cell quality flag (right) for a 10 day period in September 2007.

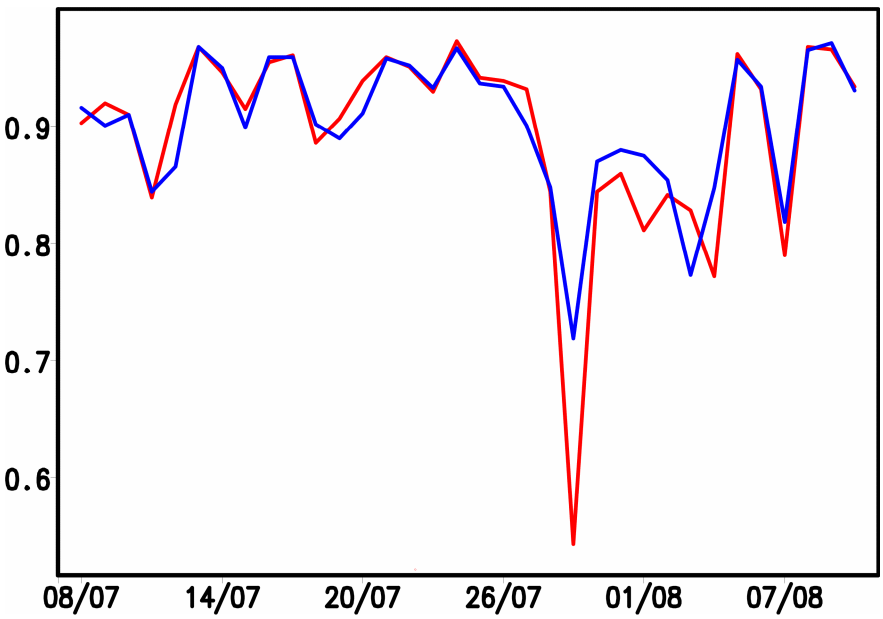

Figure 7: Time series of anomaly correlation coefficients for 72 hour forecast of sea level pressure over Europe for the Control run (red) and an experiment including ASCAT wind vector measurements (blue) for the time period 9^{th} July – 9^{th} August 2007.