

HIGH RESOLUTION SCATTEROMETER WIND PROCESSING

Jur Vogelzang, Ad Stoffelen, Marcos Portabella, Anton Verhoef, Jeroen Verspeek

KNMI
P.O. Box 201, 3730 AE De Bilt, The Netherlands

Abstract

The launch of the Advanced Scatterometer ASCAT on MetOp-A is planned on 17 July 2006. Development of scatterometer products in Europe is organised through the EUMETSAT Satellite Application Facilities. Product developments are focussed on using the data for Numerical Weather Prediction and short-range weather forecasting. The former is well suited by the SeaWinds products as currently produced at KNMI at 100-km resolution (see <http://www.knmi.nl/scatterometer>) in preparation of the operational ASCAT production suite. For short-range forecasting or in semi-enclosed sea areas such as the Mediterranean, however, higher resolution is desirable, and both an experimental 25-km SeaWinds product and the Early Advanced Retransmission Service, EARS, ERS-2 product are available. The European Space Agency ERS-2 scatterometer KNMI product provides quasi real-time winds in the North Atlantic and European seas. It is currently provided in the ASCAT BUFR format to facilitate the development of ASCAT user interfaces. KNMI attempts to improve the spatial filtering properties of the wind retrieval by using prior information on the expected meteorological balance, e.g., favouring rotational structures in high-latitude regions. Moreover, solutions in all wind directions, weighted by their inherent probability, are retained in the processing, the so-called Multi Solution Scheme. The 2D-VAR method has the advanced filtering properties needed for maintaining small-scale meteorological information in SeaWinds, while reducing noise. This is shown by comparing the autocorrelation of the KNMI products, with those of the NOAA SeaWinds product, and, for reference, those of the NCEP model. It is shown that scatterometer wind fields at high resolution contain noise, but that this noise is effectively removed in the Multi Solution Scheme. These findings will help KNMI to develop a 12.5-km ASCAT scatterometer wind product in the coastal zone in the next phase of the SAF project.

INTRODUCTION

The all-weather capability of a scatterometer provides unique wind field products of the most intense and often cloud-covered wind phenomena, such as tropical cyclones (for example, see figure 1). As such, it has been demonstrated that scatterometer winds are useful in the prediction of tropical cyclones, e.g., Isaksen and Stoffelen (2000), and extra-tropical cyclones (Stoffelen and Beukering, 1997). At the moment the ESA ERS-2 and the NASA SeaWinds scatterometer on QuikScat provide respectively a regional real-time and a global near-real time data stream. In 2006 EUMETSAT will continue the global scatterometer mission with the ASCAT scatterometer on EPS/METOP, and will start a regional real-time ASCAT dissemination. As such, continuity of both services is likely provided to the operational meteorological community for another period of 15 years.

EUMETSAT set up Satellite Application Facilities (SAF) providing software and data products and services. KNMI is involved in the scatterometer activities of the following SAFs in preparation for ASCAT:

- Numerical Weather Prediction SAF for scatterometer software products;
- Ocean and Sea Ice SAF for scatterometer wind products; and Scatterometer Ocean Stress (SOS) products.

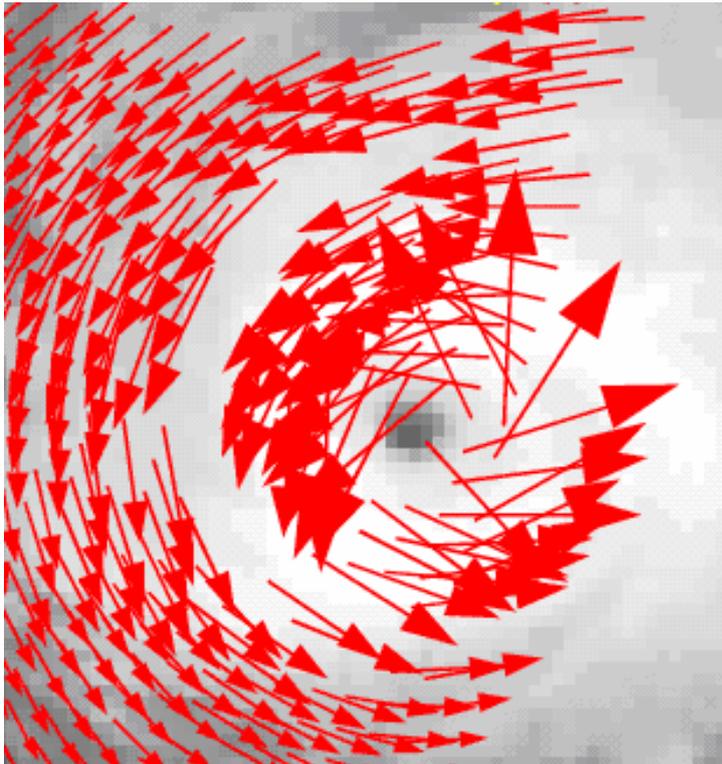


Figure 1: QuikScat 25-km wind product generated at KNMI for tropical cyclone Rita (2005), raging in the Caribbean. GOES IR cloud imagery is provided underneath for reference.

In Figure 2 an overview of the scatterometer wind processing package is given. Scatterometer sea surface wind research and development lies at the basis of wind product innovation:

- Input product consistency checks, quality control, rain (for SeaWinds) and ice (for ERS) screening;
- Simultaneous processing of multiple ERS-2 ground station acquisitions in order to
 - provide unique processing at all wind vector cells (WVC), i.e., avoid duplicates;
 - complete backscatter triplets by combining acquisitions of all available ground stations at each WVC;
- Spatial averaging methodologies to reduce noise and enhance quality of SeaWinds products; Inversion: computation of optimal wind solutions and associated probabilities from measurement information;
- Determination of information content; definition of observation operator; ambiguity removal (spatial filter to determine a unique wind vector field);
- Processors for real-time and archive scatterometer wind and stress products;
- Active monitoring and quality assurance methodologies (of instrument and processing); and
- Web site (visualisation) and product distribution;

Product enhancement as well as preparation of wind production and user services for ASCAT on METOP are the main goals of this R&D. KNMI currently processes a global OSI SAF QuikScat 100-km product, an experimental SeaWinds 25-km product, and a North- Atlantic ERS-2 25-km product, and distributes it to the international meteorological community. Moreover, KNMI-processed ERS-2 scatterometer winds are made available in quasi real-time through the ASCAT Early Advanced Retransmission Service (EARS). Moreover, at <http://www.knmi.nl/scatterometer> links to the visual presentation of these products are provided, both in vector and flag presentation. Global maps of wind speed are provided over the last 22 hours (as in Figure 3), segregated in ascending and descending orbit tracks. By mouse clicks on these maps more detailed regional plots become available (as in figure 1). The link also provides documentation, papers, and software products.

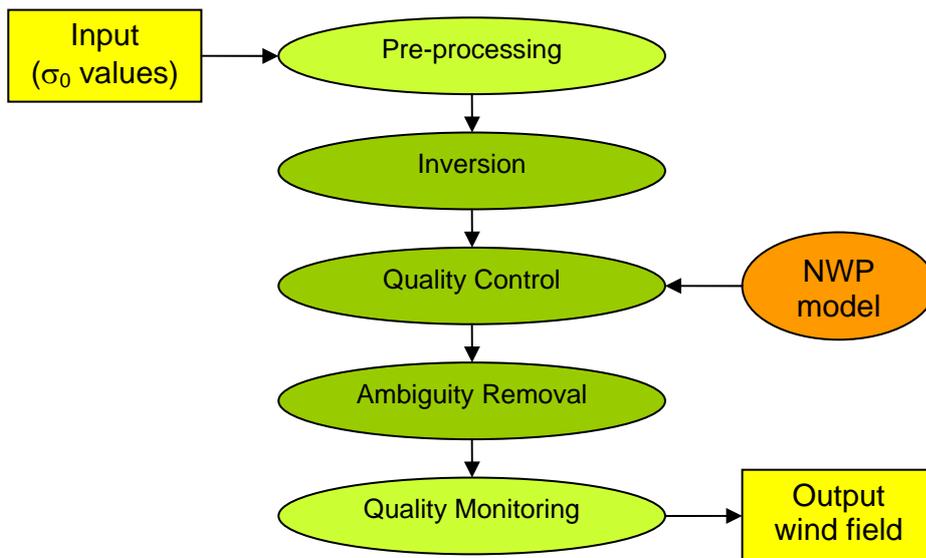


Figure 2: Schematic view of KNMI scatterometer wind processing software

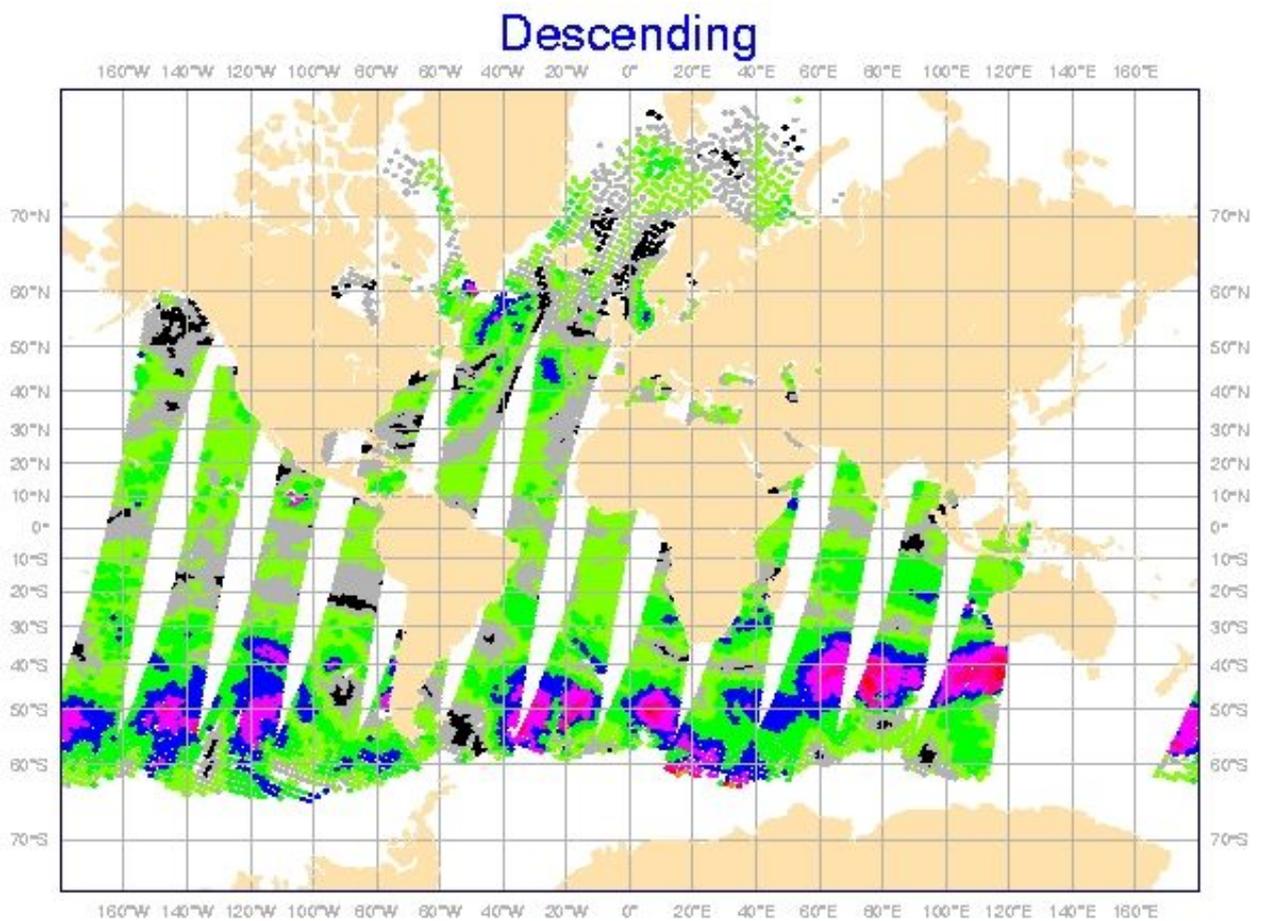


Figure 3: Overview of QuikScat SeaWinds 100-km wind speeds (coloured) as generated at KNMI.

QUIKSCAT PRODUCTS

The standard KNMI 100-km QuikScat product has been developed for NWP assimilation and it is verified to compare better with independent ECMWF NWP winds and is thus suitable for NWP assimilation (Portabella, 2002). At lower resolutions more random wind noise is expected from SeaWinds. The use of the KNMI 100-km product in NWP provides generally positive or neutral impact, depending on the study period. Further noise reduction and QC is believed to be beneficial for NWP impact and further progress is being made by implementing the so-called Multiple Solution Scheme (MSS) IWW. The improvement is brought by using wind vector probability information in combination with the 2D-VAR background constraints on rotation and divergence (Portabella and Stoffelen, 2003). We further note that the improved verification of MSS is mainly due to the reduction of occasional erratic noise; coherent mesoscale structures remain present and become more visible due to the noise reduction.

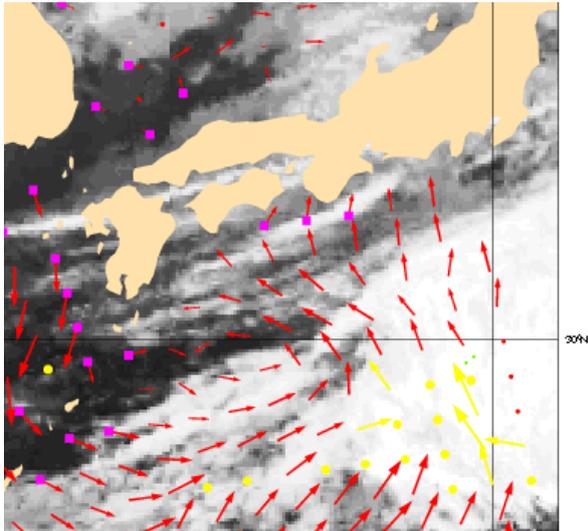


Figure 4: QuikScat 100-km wind product generated at KNMI. GOES IR cloud imagery is provided underneath for reference.

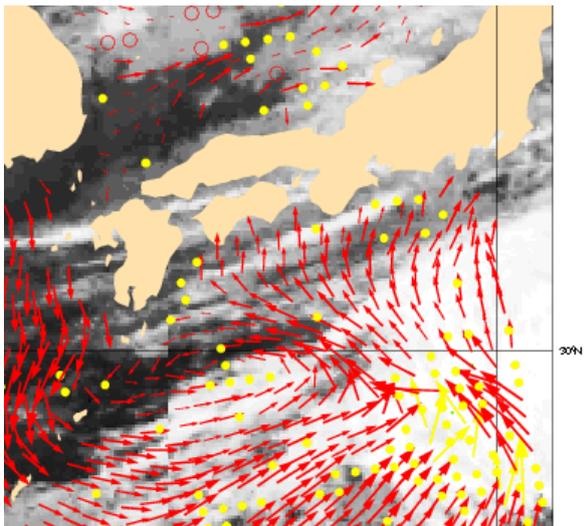


Figure 5: As figure 4, but now for the 25-km QuikScat wind product.

Based on this experience a 25-km MSS SeaWinds product was developed and is now operated experimentally at KNMI (see www.knmi.nl/scatterometer). Figures 4 and 5 show the the MSS product at 100 km and 25 km resolution, respectively. It is clear that important mesoscale details, potentially useful for short range weather forecasting and nowcasting, are added. The finding at 100-km resolution for MSS that the 2D-VAR NWP background winds, NCEP winds at 1000 mb, have a relatively small influence on the product appears also valid at 25 km. This needs to be further validated however.

INCREASED SPATIAL RESOLUTION AND NOISE

Figure 6 shows the autocorrelation for the zonal wind component, u , of the 25-km QuikScat wind product. The curves are based on all available data from December 2004 and are averaged over all wind nodes. The QuikScat winds, either with or without MSS, show slightly less correlation than the NCEP model winds. This indicates that the QuikScat winds have more variability at short distances.

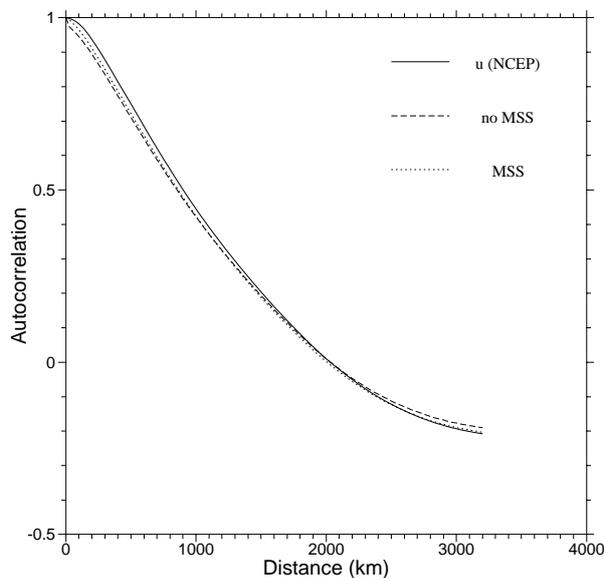


Figure 6: Autocorrelation of the zonal wind component u obtained from the NCEP model (solid curve) and from the QuikScat measurements with and without MSS (dotted and dashed curve, respectively).

Figure 7 shows an enlargement near the origin of figure 6. The autocorrelations of the model wind and the QuikScat wind obtained with MSS approach smoothly the value 1 which the autocorrelation should have at zero distance. The QuikScat wind without MSS, however, shows a clear discontinuity (note that the autocorrelation is given every 25 km and that the curves are drawn to guide the eye). This is caused by a white noise component in the wind field. It adds to the total variance of the wind, but does not give any contribution to the correlation between different wind cells.

It is easily shown that the noise variance is proportional to the height of the discontinuity in the autocorrelation at zero distance, the constant of proportionality being equal to the total variance in the wind. Various extrapolations to the origin were tested to estimate the height of this discontinuity, and a quadratic fit yields a plausible extrapolation. Figure 8 shows the height of the discontinuity as a function of wind vector cell (WVC) number. The same quadratic extrapolation was also applied to the autocorrelations of the NCEP model wind and the QuikScat wind obtained with MSS

Figure 9 shows the variance of the noise component in the wind fields. For the QuikScat wind obtained without MSS the noise variance depends strongly on the wind vector cell number. The highest values are in the centre of the swath around cell 40. This is the so-called azimuth part of the swath where the observation geometry is less favorable for wind extraction. As a consequence, retrieved winds contain more noise, to a level of 1.4 m/s r.m.s

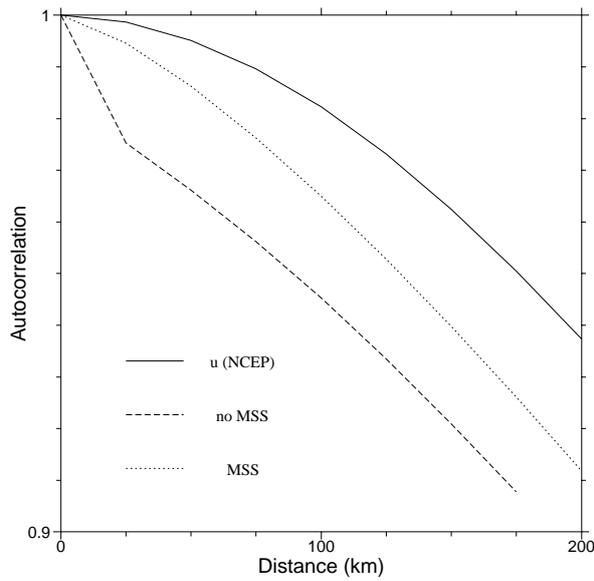


Figure 7: Enlargement of figure 6 near the origin. Note that autocorrelation values are given at each horizontal tick.

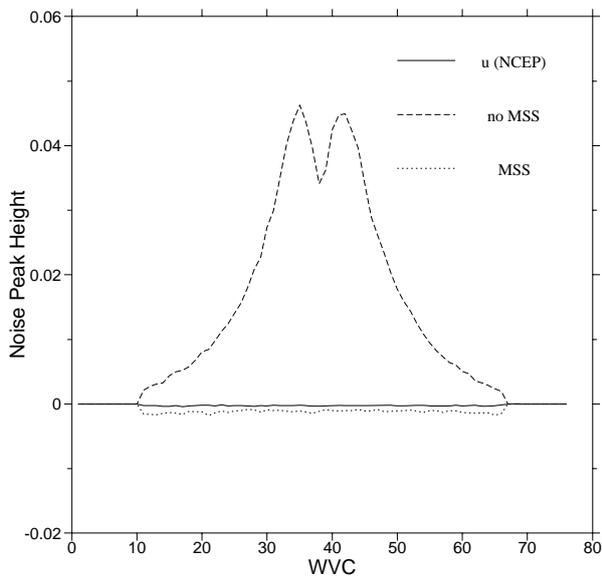


Figure 8: Noise peak height as a function of wind vector cell number. Curves as in figure 6.

The noise variances for the NCEP model winds and the QuikScat wind obtained with MSS are slightly negative, because the extrapolated autocorrelation is exceeding one. Such variances are not significant but their absolute value gives an indication of the error in the noise variance. Figure 9 shows that the noise is effectively reduced when using the MSS.

Figure 10 shows the effect of resolution. The solid curve gives the noise variance in the QuikScat winds at 25 km resolution obtained without MSS and is identical to the dashed curve in figure 8. As expected, the noise variance decreases at 50 km resolution (dashed curve) and becomes insignificant at 100 km (dotted curve). Therefore it is save to use 100 km QuikScat winds in NWP as far as the noise level is concerned.

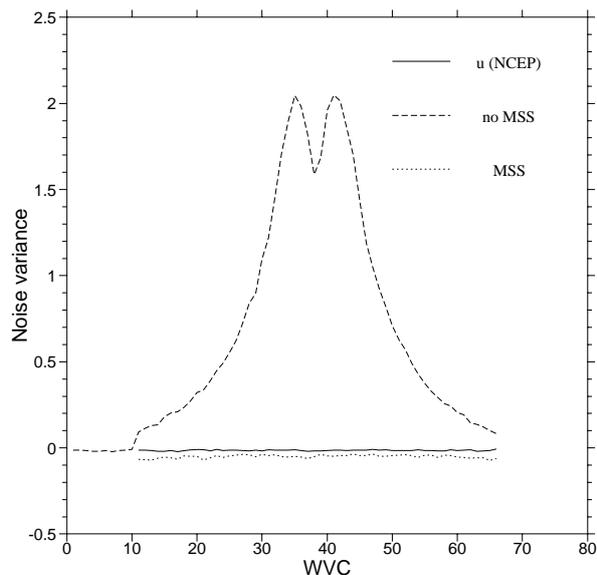


Figure 9: Variance of the noise contribution as a function of wind vector cell number. Curves as in figure 6.

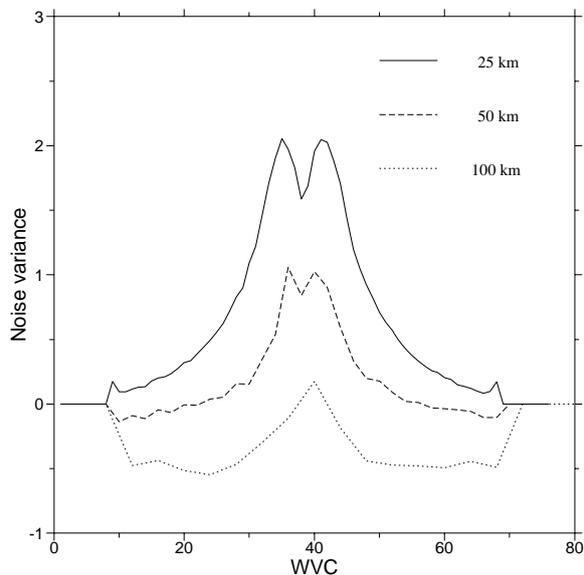


Figure 10: Noise variance along the swath for various resolutions.

OUTLOOK

KNMI developed a spatial filtering method that fully exploits the information obtained by scatterometer wind retrieval (Portabella and Stoffelen, 2003) and which is meteorologically balanced, called MSS. Given the beneficial working of MSS, an increase in the resolution of the QuikScat wind retrieval is being experimented. It will be verified spatially by correlation analyses and against in situ observations. KNMI welcomes potential users and testers of this product, whom should contact the authors.

Scatterometers provide accurate and spatially consistent near-surface wind information. Hardware permitting, there will be a continuous series of scatterometers with at times ideal coverage of the ocean surface wind for the first two decades of this century. EUMETSAT provides user services in collaboration with KNMI, where these are now being set up and freely available at <http://www.knmi.nl/scatterometer> for the QuikScat and ERS-2 scatterometers. Near-real time FTP

products or software can be obtained after registration. Moreover, a visiting scientist scheme is funded in order to support the development programme and the use of the KNMI services. Again, the authors will provide more information on request.

EUMETSAT's ASCAT is planned for launch on the 17th of July. KNMI is making plans for the EUMETSAT SAFs to provide wind and wind stress products with main innovations in spatial resolution and in the coastal zone. Extended calibration and validation activities will be ongoing.

REFERENCES

Atlas, R., and Hoffman, R.N. (2000) The Use of Satellite Surface Wind Data to Improve Weather Analysis and Forecasting. in *Satellites, Oceanography, and Society*, edited by D. Halpern, Elsevier Oceanography Series 63, Elsevier Science, Amsterdam, the Netherlands, ISBN 0-444-50501-6.

ECMWF (2004) European Centre for Medium-range Weather Forecast, <http://www.ecmwf.int>

EUMETSAT Satellite Application Facilities (SAF) (2004), <http://www.eumetsat.de/saf>

HIRLAM (2004) High-Resolution Limited Area Model, <http://hirlam.knmi.nl>

Isaksen, L and Stoffelen, A (2000) ERS-Scatterometer Wind Data Impact on ECMWF's Tropical Cyclone Forecasts. *IEEE-Transactions on Geoscience and Remote Sensing* (special issue on Emerging Scatterometer Applications) **38** (4), pp. 1885-1892

KNMI (2004) <http://www.knmi.nl/scatterometer>

Portabella, M. and Stoffelen, A (2001) Rain detection and quality control of SeaWinds. *J. Atm. and Ocean Techn.* **18** (7), pp. 1171-1183

Portabella, M. and Stoffelen, A. (2003) A probabilistic approach for SeaWinds data assimilation. *Quart. J. R. Met. Soc.* **130**, pp. 127-159

SeaWinds (2004)

Instrument: <http://winds.jpl.nasa.gov/missions/quikscat/quikindex.html>

Archive data: <http://podaac.jpl.nasa.gov/quikscat>

Near-real time data: <http://manati.wwb.noaa.gov/quikscat>

Stoffelen, A. (2000) A generic approach for assimilating scatterometer winds. Proc. ECMWF seminar 4-8 Sept. 2000, available from http://www.knmi.nl/scatterometer/seawinds/pdf/ECMWF_seminar00.pdf.

Stoffelen, A., Voorrips, A., and de Vries, J. (2000) Towards the Real-Time Use of QuikScat Winds. BCRS project report, available from KNMI.

Stoffelen, A. and van Beukering, P. (1997) The impact of improved scatterometer winds on HIRLAM analyses and forecasts. BCRS study contract 1.1OP-04, report published by BCRS, Delft, The Netherlands, and HIRLAM technical report #31, published by IMET, Dublin, Ireland. Available from KNMI.