NWP SAF: Science Plan for Deliverable 5.1

New and Improved Assimilation Procedures for Scatterometer Data from SCAT, ASCAT, NSCAT and SeaWinds

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 25 November 1998, between EUMETSAT and The Met. Office, UK, by one or more partners within the NWP SAF. The partners in the NWP SAF are The Met. Office, ECMWF, KNMI and Météo France.

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1. Rationale and outline description

1.1 Objective

SeaWinds on QuikSCAT provides great coverage over the oceans. However, rain contamination, wind direction noise characteristics, and wind direction ambiguity patterns need further study. Procedures to QC and assimilate NSCAT and SeaWinds measurements for NWP are developed. Procedures for the assimilation of SCAT and ASCAT measurements are further refined.

1.2 Situation at the start of development

ERS scatterometer winds have proven to be very useful for the forecasting of dynamic weather (Isaksen and Stoffelen, 2000; Atlas and Hoffman, 2000; Candy, 2001). Increased coverage, such as from tandem ERS-1 and ERS-2 measurements, clearly improve the situation (e.g., Stoffelen and Beukering, 1998; Le Meur et al, 1997). Improved coverage such as from the Ku-band scatterometers NSCAT and SeaWinds have thus great potential. Preliminary attempts to assimilate SeaWinds data were carried out with mixed success, and improved data characterisation was needed.

1.3 Deficiencies of the initial situation

The following four problem areas exist and continue to need further investigation

In contrast with C-band scatterometers such as on ERS and ASCAT, Ku-band scatterometers are sensitive to rain and procedures need to be developed to screen out rain-contaminated measurements.

SeaWinds data are nominally provided with a sampling of 25 km, whereas most NWP models use scatterometer data at a 100-km density. To reduce wind retrieval noise it is better to average backscatter measurements, s^0, to lower resolution before wind retrieval. For ERS and ASCAT observations the same applies, where it has been shown that averaged winds compare better to the HIRLAM first guess than thinned data (Stoffelen and Beukering, 1998).

NSCAT and SeaWinds use horizontal and vertical polarisation measurents, whereas ERS or ASCAT are solely based on vertical polarisation. This in combination with a varying measurement geometry results in a different wind direction ambiguity structure than for ERS or ASCAT. The near-nadir and far swath areas of SeaWinds are particularly difficult to QC and invert, due to poor sampling in azimuth.

Validation and monitoring of SeaWinds against conventional and model data has not been carried out for the products being developed in Europe.

1.4 Description of the deliverable

Concerning the problem areas noted in the previous section, the following respective developments are foreseen

Tailor-made SeaWinds QC has been developed and is being maintained (Portabella and Stoffelen, 2000, 2001). SeaWinds on ADEOS may profit from AMSR (Advanced Microwave Sounding Radiometer) for rain screening and effort will be directed into the development of improved QC using AMSR. However, note that AMSR data is only available within a 6 hour delivery time and at that point has not been collocated with SeaWinds. Application of AMSR for weather forecasting is thus limited to the medium range in general.

An ERS, ASCAT, NSCAT and SeaWinds backscatter data inversion module is being further developed and maintained. A procedure is being tested and incorporated to average backscatter measurements in a resolution cell of varying size. This procedure is applied before the wind inversion step. After testing for SeaWinds, the procedure will be incorporated and tested for ERS and ASCAT scatterometer data as well.

The ERS scatterometer cost function is being generalised to be able to cope with all scatterometer data. All scatterometer data can be characterised by multiple wind vector ambiguities that each have different probability and accuracy. A procedure is being developed that estimates this probability and accuracy and as such provides the input for a general scatterometer cost function. The cost function formulation takes into account the QC information and in fact relates solution probability to the normalised inversion residual, a by-product of the QC step. Moreover, for noisy data such as from SeaWinds we implement gross error occurrence as an additional wind ambiguity with a uniform (and low) probability. The working of the cost function for ambiguity removal is being tested and documented (Stoffelen, Voorrips, and de Vries, 2000).

Collocation files will be produced that contain the scatterometer data and model wind and wave data, but also conventional observations.

1.5 Means of distribution

A complete processing package for SeaWinds data decoding, consistency check, backscatter averaging, and inversion is being developed. The package is being complemented with a 2D-VAR ambiguity removal procedure (Stoffelen, de Vries, and Voorrips, 2001). Moreover, KNMI supplies a 100-km product (currently through an ftp site). The NWP SAF will provide user support for the maintenance and implementation of this software and for using the output data.

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2. Scientific approach, capabilities, and limitations

The scientific approach taken to deal with the respective problem areas noted above is

A quality control procedure is being developed for NSCAT and SeaWinds based on the QC methodology for the ERS scatterometer (Stoffelen and Anderson, 1997; Stoffelen, 1998). In addition to a screening similar to ERS, the procedure acts to remove rain contaminated points (Figa and Stoffelen, 2000). Tailor-made SeaWinds QC has been developed and is being maintained (Portabella and Stoffelen, 2000, 2001).

A limitation of this approach is obviously that anomalous geophysical conditions that are still compatible with the Geophysical Model Function (GMF) are not screened out, such as a few rain points that appear as 15 m/s winds. Such points should ideally be rejected by the QC procedures of NWP data assimilation systems. This is being tested in a 2D-VAR environment. Alternatively, one could
- use the backscatter polarisation ratio, but this has the same limitation and is more restricted (Wentz, 1999); or
- use the SeaWinds passive noise measurement to detect rain, though this has low accuracy (of 13 K; Jones, 1999).

Particularly in those parts of the SeaWinds swath where azimuth view diversity or polarisation coverage is lacking, notably around nadir and in the far swath, the wind vector may be underdetermined and QC by a consistency check, such as in the above-described methodology, impossible. The part of the swath where this occurs is limited fortunately, and will be indicated by a flag in the retrieval process product.

SeaWinds on ADEOS may profit from AMSR for rain screening but since AMSR is not available in near-real time no effort will be directed into the development of improved QC using AMSR. Checks on dynamical consistency and background wind for QC need to be tested before application of data in the nadir and outer swath areas.

Stoffelen (1998; chapter VI) describes the problem of the assimilation of variables that are related in a non-linear way to the NWP model variables, such as scatterometer backscatter measurements. As a practical solution, he suggests to assimilate retrieved scatterometer winds. This approach is further pursued here for SeaWinds scatterometer observations.

Radar backscatter, as measured by a scatterometer, is directly related to the anisotropic roughness of the ocean topography. The main direction of anisotropy aligns with the wind direction, while the amplitude of backscatter is a measure of the roughness. This direction and amplitude can be retrieved accurately by obtaining multiple samples of one scene as the satellite passes by, since backscatter noise is generally small for all scatterometer systems; backscatter-only noise results in a wind vector uncertainty of about 0.5 m/s. However, another error contribution exist in the interpretation of this amplitude and direction as a wind at 10m height. This much larger uncertainty, about 2 m/s, can be well modelled by a normal wind component error distribution. This dominating normally-distributed uncertainty in the wind domain corresponds to a skew error in the backscatter domain, which makes the assimilation of retrieved winds more attractive than the direct assimilation of backscatter measurements.

In the direct assimilation of backscatter observations, one transforms the first guess errors and the uncertainty in the GMF in a non-linear way to the backscatter space, resulting in a usually skew error distribution in this space. The precise form of the error distribution would depend on wind speed, wind direction, and view configuration. The maximum probability in a skew distribution generally does not overlap with the mean of the distribution, nor has the maximum symmetric properties. The optimal observation cost function is not a priori clear in such a case and requires considerable thought (Stoffelen, 1998, 2000). By the assimilation of retrieved winds this problem disappears.

The ERS scatterometer cost function is being generalised to be able to cope with all types of scatterometer data. All scatterometer data can be characterised by multiple, in particular, more than two, wind vector ambiguities that each have different probability and accuracy. This is in principle also true for those parts of the swath where the wind vector cannot be fully determined, because of limited azimuth or polarisation coverage, and where the ambiguity pattern can be of greater complexity. The complexity includes varying numbers of solutions, with varying probability and accuracy.

However, a limitation is that for some parts of the swath QC may be difficult and assimilation therefore more risky (see point 1. above).

By producing collocation files of scatterometer observations, conventional sea surface wind and ancillary observations, and NWP and wave model data, SeaWinds and (A)SCAT scatterometer data can be further validated and analysed, for example by the triple collocation methodology for wind error assessment and calibration, or for ocean backscatter calibration by NWP winds (see, e.g., Stoffelen, 1998), but for example also for the investigation of rain or sea state effects.

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3. Technical description of the deliverable

ESA and NOAA provide real-time scatterometer backscatter measurements and ancillary information through BUFR messages on the GTS for SCAT and SeaWinds respectively. In the Ocean and Sea Ice (OSI) SAF a procedure is developed for the inversion, ambiguity removal, and monitoring of ERS scatterometer measurements at the nominal sampling of 25 km in order to provide a wind product.

Within the NWP SAF a SeaWinds processing package is being developed that checks, spatially averages, and inverts backscatter data. After these steps a 2D-VAR-ambiguity routine can be run. This routine is used to investigate the ambiguity removal properties of the cost function and observation operator as proposed by the SAF. As such the SeaWinds processing package contains the modules that define the general scatterometer observation cost function. The processor provides a unique observed wind field that can be assimilated.

The software package will be obtainable from the NWP SAF, who will support and maintain it. Since the packages use look-up tables that define the GMF, the processing time is negligible. The RAM needed to store these look-up tables is moreover limited to a few Mbyte and not demanding.

4. Development strategy

4.1 Development phases.

The following planning is used for the development of the SeaWinds-related deliverables

- Specification of user requirements for data interfaces and format of QuikSCAT product (1999);
- Software for pre-processing and product validation (2000);
- Software for NSCAT and SeaWinds inversion and QC at varying resolution (2002); and
- Software modules incorporating the cost function and observation operator, based on a 2D-VAR implementation (2002);
- Improved QC software (2001).

In later years the scope of the packages will be modified to deal with SeaWinds on ADEOS-II and to improve the processing in the far and nadir-region swath (2003).

For (A)SCAT monitoring software will become available in 2002, and in later years a co-ordinated effort with the OSI SAF will result in modules for processing of smoothed data.

A module for collocation of SCAT or SeaWinds messages with conventional and model data will become available in 2004.

4.2 Validation plans

A common software coding practice has been defined within the NWP SAF leading to accessible code that eases software maintenance and support. Both general and specific performances of new code will be tested over a realistic set of geophysical data.

Developed modules are expected to be operationally implemented at several sites, but where a co-ordinated monitoring effort will be organised within the NWP SAF. This will act to validate the basic satellite data, but also the satellite data processing modules. If useful reference wind products are available, such as the NOAA products for SeaWinds and the ESA product for SCAT, regular comparison will be performed.

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