THE SEAWINDS DATA PROCESSOR

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Abstract

SeaWinds on board QuikSCAT is a rotating beam Ku-band scatterometer, operational since 1999. The SeaWinds Data Processor (SDP) reprocesses the level 2 BUFR product. SDP has a number of advanced features, in particular the Multiple Solution Scheme (MSS) and Two Dimensional Variational Ambiguity Removal (2DVAR). The current operational version, SDP 1.5, is reviewed in this paper. It is shown that 2DVAR in combination with MSS is effective in removing observational noise in the SeaWinds observations in the nadir part of the swath. Before the end of 2008 version 2.0 of SDP will be released. It includes processing of the outer swath and improved variational quality control. In this paper some examples of SDP wind products will be shown and their quality will be assessed.

1. INTRODUCTION

SeaWinds on board QuikSCAT is a scatterometer operated by the National Oceanic & Atmospheric Administration (NOAA) from 1999 onwards. It is a rotating beam scatterometer operated at Ku-band, so both its observation geometry and its operating frequency differ greatly from that of the Advanced Scatterometer (ASCAT) carried by MetOp A. The advantage of SeaWinds over ASCAT is its large swath width of 1800 km, but its disadvantages are an unfavorable observation geometry in the nadir part of the swath and increased sensitivity to rain.

The SeaWinds Data Processor (SDP) reprocesses NOAA’s level 2 BUFR product. SDP has been developed at KNMI in the framework of the Satellite Application Facility for Numerical Weather Prediction (NWPSAF) sponsored by the European METeorological SATellite organisation (EUMETSAT). The SDP source code can be obtained without charge from the NWP SAF web site [www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer](http://www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer). At the moment there are about 80 registered users. The current operational version is 1.5.

The wind products generated with SDP can be found on the Ocean and Sea Ice (OSI) SAF web site [www.knmi.nl/scatterometer](http://www.knmi.nl/scatterometer). Figure 1 shows a detailed view of an observation on 2 September 2008 taken from this site. The scatterometer winds (red arrows) are drawn over an IR image in black-and-white. Yellow dots denote cells rejected by the quality control procedure; yellow arrows are flagged by the variational quality control. The blue arrows are HIRLAM model predictions. The black lines represent the parallel 40°N and the meridian 60°W, so the scene is in the Northern Atlantic near the east coast of the USA. The OSI SAF site also contains the most recent ASCAT wind products as well as information on buoy comparisons.

The general scheme of SDP is shown in figure 2. The basic input data are the radar cross sections of the ocean surface measured by the scatterometer. In the inversion step these data are compared to a Geophysical Model Function (GMF), an empirical function that gives the radar cross section as a function of wind speed and wind direction, observation geometry and radar frequency and polarization. In general, the inversion step returns more than one solution. These so-called ambiguities have almost the same wind speed but different wind direction. In the traditional approach the ambiguities are points on the GMF with (local) minimum distance to the observation point. For SeaWinds in the nadir swath these minima become very broad as function of the wind direction and the minimum is no longer a good representation of the ambiguity.
The Multiple Solution Scheme (MSS) takes all possible wind directions into account in bins of 2.5°, leading to 144 ambiguities. After quality control (detection and removal of cells contaminated by rain, sea ice, etc.), the ambiguities and their a priori probabilities can be fed into the data assimilation part of a Numerical Weather Prediction (NWP) model.
If the SDP output is to be used as a stand alone product for nowcasting or oceanographic applications, the most likely solution must be found in the Ambiguity Removal step. SDP uses a variational approach called Two Dimensional Variational Ambiguity Removal (2DVAR). 2DVAR makes an analysis from the scatterometer observations and a background wind field, taking the a priori probabilities and physical laws into account. Next, the ambiguity closest to the analysis is selected as solution. In this way, 2DVAR leads to both statistically and physically consistent wind fields (Portabella and Stoffelen, 2004; Vogelzang, 2007).

2. QUALITY OF SDP 1.5 WIND PRODUCTS

The quality of the SDP wind fields has been tested in various ways. The observation noise in high resolution SeaWinds data can be effectively removed by application of 2DVAR with MSS (Portabella and Stoffelen, 2004; Vogelzang et al., 2007, 2008). Figure 1 shows an example. The wind field is smooth, but small scale features are still visible.

Table 1 shows that indeed 2DVAR retains small scale information. SDP was run for all observations from January 2008 with MSS and 2DVAR, using ECMWF model predictions as background. The zonal and meridional wind components, u and v, respectively, were compared with the ECMWF background and buoy measurements. The results of this comparison are shown in table 1. When going to coarser resolution, the standard deviation of the difference with the ECMWF model decreases. This is because small scale variations that are not present in the ECMWF background are averaged out. The buoy observations, on the other hand, do contain small scale information, and therefore the agreement with them is better for the SDP wind product at 25 km.

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<th>SDP at 25 km</th>
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<tr>
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<td>$\sigma_u$ (m/s)</td>
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<td>ECMWF</td>
<td>1.87</td>
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<td>Buoys</td>
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Table 1: Comparison of the SDP wind fields at 25 km and 100 km with the ECMWF background and buoy observations for January 2008.

Figure 3: Seawinds observation of an extratropical hurricane in the northern Pacific on December 30, 2004 with variational quality control (left) and without (right). Arrow colors indicate wind speed: 0-10 m/s (yellow); 10-20 m/s (green); 20-30 m/s (light blue); 30-40 m/s (dark blue). Black arrows indicate cells with an observation cost function larger than 12.
Variational Quality Control (VQC) is a widely accepted technique in data assimilation for giving less weight to observations that differ much from the background. VQC is also implemented in 2DVAR. A possible drawback may be increased influence of the background in extreme situations where scatterometer observations and model predictions disagree.

As an example of this, figure 3 shows SDP results of an extratropical hurricane in the Northern Pacific on 30 December 2004. The left hand panel of figure 3 is with VQC, the right hand panel without. Arrow colors indicate the wind speed, while black arrows indicate cells with an observation cost function exceeding a threshold value of 12. The black arrows in the left hand panel of figure 3 are rejected by VQC. In these cases there is a large difference between the scatterometer observations and the background. Because of VQC the observations have reduced weight and 2DVAR selects an ambiguity close to the background. If VQC is omitted, as in the right hand panel of figure 3, the observations retain their weight, no matter how much they differ from the background. As a result, 2DVAR selects ambiguities that have larger a priori probability and fit better in the overall circulation pattern.

Note that without VQC more cells have an observation cost larger than 12, because 2DVAR now is able to find solutions that differ more from the background. In other words, 2DVAR now gives more weight to the observations and less to the background. More information on the quality of SDP 1.5 wind products can be found on www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer and in (Vogelzang et al., 2008).

3. NEW FEATURES IN SDP 2.0

December 2007 NOAA changed its level 2 SeaWinds BUFR product (Jelenak and Chang, 2007). The most important changes were less strict quality control (in particular rain flagging) and generation of four cross sections in the outer swath (wind vector cells 1-9 and 67-76). In order to provide continuity in the quality of KNMI's SDP wind products the quality control procedure was retuned. With the new NOAA BUFR product as input, SDP flags off as much wind vector cells as with the old product.

Figure 4: Standard deviation of the difference between the SDP 2.0 winds and ECMWF model predictions. SDP 2.0 was run with and without MSS for 25 km resolution (left) and 100 km resolution (right) for all data from January 2008.
An advantage of the new NOAA BUFR product is the easy calculation of wind solutions in the outer swath, because the outer swath now contains two pairs of radar cross sections. However, the radar cross sections in each pair differ very little in azimuth angle, so noise problems similar to those in the nadir swath may be expected. In order to assess the quality of the outer swath winds, SDP 2.0 was run for all data of January 2008 with and without MSS, at 25 km and 100 km resolution. 2DVAR was applied with the NCEP model prediction as background. The results were compared with ECMWF model predictions.

Figure 4 shows the standard deviation of the differences in the zonal and meridional wind components, $u$ and $v$, respectively as a function of Wind Vector Cell (WVC) number. At 25 km resolution (left hand panel of figure 4) the standard deviation without MSS (red curves) peaks at nadir (around WVC 38) and in the outer swath. In these regions one expects to find the highest observation noise level. As expected, application of MSS (black curves) reduces the noise and the differences between observed and NWP wind fields become almost independent of the WVC number. There is only a slight increase in difference at nadir and in the outer swath. This shows that the quality of the outer swath results is comparable to those in the nadir part of the swath.

The same holds at 100 km resolution (right hand panel of figure 4), though the effect of MSS is less pronounced than at 25 km resolution. Nevertheless, this figure shows that even at 100 km application of MSS leads to more uniform differences between observed and modeled winds along the SeaWinds swath.

Figure 5 shows the frequency of rain flag setting as a function of WVC number for all SeaWinds data of January 2008 processed with SDP 2.0 at 25 km resolution. In the sweet swath and the nadir swath, WVC 10-66, the rain flagging frequency varies between 7% and 8%. In the outer swath, however, the flagging frequency drops to about 5%. As a consequence, the SDP 2.0 outer swath wind solutions may be contaminated by rain. Therefore the outer swath winds are not recommended for assimilation into NWP models as long as the quality control procedure in the outer swath is not retuned. For nowcasting applications, however, the outer swath results can be used.

![Figure 5: Frequency of rain flag setting by SDP 2.0 as a function of WVC number.](image)
4. CONCLUSIONS

The SeaWinds Data Processor (SDP) proves effective in removing the observation noise in the nadir and outer swath of SeaWinds when applying 2DVAR in combination with MSS. Small scale features in the observations are retained by the structure functions in 2DVAR. The effect of the background is diminished by switching off variational quality control.

The current operational version is SDP 1.5. It can be obtained free of charge from the NWP SAF web site www.metoffice.gov.uk/research/interproj/nwpsaf/scatterometer. At this moment (September 2008) there are about 80 registered users worldwide.

In the end of 2008 SDP 2.0 will become the new operational version. SDP 2.0 features outer swath processing and continuity in wind product quality, despite recent changes in the NOAA BUFR input product. The outer swath winds can be used for nowcasting purposes but are not recommended for assimilation in NWP models because the rain detection algorithm needs retuning in the outer swath.

REFERENCES


