

NWP SAF

Satellite Application Facility for Numerical Weather Prediction

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AWDP Test Plan and Test Report

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KNMI, De Bilt, the Netherlands

The EUMETSAT
Network of
Satellite Application
Facilities



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AWDP Test Report

KNMI, De Bilt, the Netherlands

This documentation was developed within the context of the EUMETSAT Satellite Application Facility on Numerical Weather Prediction (NWP SAF), under the Cooperation Agreement dated 29 June, 2011, 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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Preface

This document is the test plan and test report for the ASCAT Wind Data Processor (AWDP) software package. It is set up according to the guidelines of the NWP SAF; see the NWP SAF Development Procedures for Software Deliverables. Parts of the AWDP developments are in fact genscat developments. The tests for genscat modules are also included in this document. Part of the test plan is a traceability matrix to show how requirements as described in the Product Specification (Chapter 3 of the AWDP User Manual and Reference Guide [*Verhoef et. al.*, 2014]) are related to the tests in this document.

Most of the module tests described in this document have been developed and performed for older versions of AWDP and SDP (the SeaWinds Data Processor, a large part of the code in genscat is shared between AWDP and SDP). For this new AWDP version, all module tests have been repeated.

Anton Verhoef, February 2014

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Chapter 1

Introduction

1.1 Aims and scope

The ASCAT Wind Data Processor (AWDP) is a software package written in Fortran 90 for handling data from the Advanced Scatterometer (ASCAT) and European Remote Sensing satellite (ERS) scatterometer instruments. Details of these instruments can be found on several web sites and in several other documents, see e.g. [Portabella, 2002; Stoffelen, 1998] and information on the ESA and EUMETSAT web sites.

AWDP generates surface winds based on ASCAT and ERS data. It allows performing the ambiguity removal with the Two-dimensional Variational Ambiguity Removal (2DVAR) method and it supports the Multiple Solution Scheme (MSS). The output of AWDP consists of wind vectors which represent surface winds within the ground swath of the scatterometer. Input of AWDP is Normalized Radar Cross Section (NRCS, σ^0) data. These data may be real-time. The input files of AWDP are in BUFR or Product Format Specification (PFS, native Metop) format. BUFR input may be provided using the BUFR templates for ERS or ASCAT; output is always written using the ASCAT BUFR template. Moreover, AWDP needs Numerical Weather Prediction (NWP) model winds as a first guess for the Ambiguity Removal step. These data need to be provided in GRIB edition 1 or 2.

1.2 Development of AWDP

AWDP is developed within the Numerical Weather Prediction Satellite Application Facility (NWP SAF) and Ocean and Sea Ice Satellite Application Facility (OSI SAF) programs as code which can be run in an operational setting. The coding is in Fortran 90 and has followed the procedures specified for the NWP SAF. Special attention has been paid on robustness and readability. AWDP may be run on every modern Unix or Linux machine. In principle, AWDP can also be run on a Windows machine if a Linux environment like the Windows Installer for Ubuntu (Wubi) is installed. Details on the AWDP package can be found in [Verhoef *et. al.*, 2014].

The AWDP code is based on code developed for the ERS, NSCAT and SeaWinds scatterometers, and the simulations of the ESA Rotating Fan beam Scatterometer (RFSCAT). The common code of these projects is consolidated in the generic scatterometer (genscat) layer. In each development step, following from the heritage, the output of the code developments has been compared to the output of the original code. Moreover, KNMI runs an experimental suite in the framework of the

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OSI SAF, where AWDP, in different modes, is routinely compared to the operational OSI SAF suite at <http://www.knmi.nl/scatterometer/>. This comparison is both field-wise and statistical.

Several developers work with and on AWDP at KNMI, and even more with the genscat layer for SeaWinds, ERS, OSCAT or ASCAT projects. Improvements to the code follow the test procedures as described in this document. The effort of maintaining a unique reference code greatly improves robustness and reliability of the code, i.e., sharing results and enjoying the benefits.

1.3 Testing AWDP, traceability matrix

This section describes the Test Plan of the AWDP deliverable. Tests have been carried out in all stages of the development of AWDP. The inversion module is not tested for the AWDP package, because such a test has already been made for the QuikSCAT Data Processor (QDP) development. AWDP contains several methods for Ambiguity Removal within module *ambrem* and its sub modules. Only modules needed for the KNMI 2DVAR scheme for Ambiguity Removal are tested within this project.

Compilation is done on several platforms (operating systems) and with different Fortran 90 compilers. The integration and validation tests were done on both a Linux work station and a SUN machine.

Chapter 2 contains the tests for a number of individual modules. In general, modules are tested with the associated test programs that are located in the folder containing the module under consideration. The output of the test programs is always the standard output (screen) which may be redirected to any test log file or to some output files which are stored in the associated folders. Chapter 3 describes the AWDP integration test. A test folder containing some sample data is provided with AWDP and some of the resulting wind fields from these data are shown. Chapter 4 discusses the validation tests. AWDP has been compared with the Prescat wind processing software using ERS data, and the results of both processors have been compared for identical output. AWDP ASCAT winds have also been compared with ECMWF model winds in the scope of this report; buoy validations are performed in the scope of the OSI SAF. Chapter 4 also contains a technical check of the ice screening algorithm. Chapter 5 describes the portability tests. It contains an overview of platform/operating systems and Fortran compilers for which AWDP is supported. Finally, Chapter 6 is devoted to testing the user documentation.

The table below is the traceability matrix. It shows the requirements in the User Manual and Reference Guide [Verhoef et. al., 2014], Chapter 3, how they are tested and where in this report these tests are described.

Requirement	Section of UM & RG	Testing method	Test plan reference (section)	Comment
AWDP generates surface winds	3.1, 3.5.6, 3.5.8	Process L1B file in awdp/test folder and inspect output	3.1	
AWDP generates BUFR output	3.1, 3.5.1	Process L1B file in awdp/test folder and	3.1	

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Requirement	Section of UM & RG	Testing method	Test plan reference (section)	Comment
		inspect output		
AWDP generates 25 or 12.5 km Wind Vector Cells	3.2, 3.5.2	Process L1B files in awdp/test folder and inspect output	3.1	
AWDP output contains latitude, longitude and other parameters	3.2	Process L1B file in awdp/test folder and inspect output	3.1	
AWDP can use either L1B ASCAT data or L2 ERS BUFR data as input	3.3	Process ASCAT and ERS data in awdp/test folder	3.1, 3.2	PFS ASCAT data are not tested in the scope of this document
AWDP reads GRIB data containing LSM, SST and forecast winds	3.3	Process L1B file in awdp/test folder and check that a consistent wind field is obtained	3.1	
AWDP will compile and run on different Linux and Unix platforms	3.4	Compile and run AWDP on different platforms	5	
AWDP can ingest full resolution ASCAT data and build a coastal wind product	3.5.3	Process 12.5 km L1B file in combination with full resolution data		Not tested in the scope of this document
WVCs with high MLEs must be rejected by Quality Control	3.5.5	Process L1B file in awdp/test folder and check if QC flag is set for high MLE values	3.1	
Bayesian ice screening is implemented	3.5.7	Process a few days of L1B data and inspect ice maps	4.3	
A product monitoring flag is implemented	3.5.9	Not tested since there are no data with anomalous instrument performance available	-	
AWDP can process data within reasonable CPU time.	3.6	Process L1B file in awdp/test folder and check processing time.	3.1	

Table 1.1 Traceability matrix.

1.4 Test folders

The Test folder of the AWDP software package is located in subdirectory `awdp/tests`. This subdirectory contains several input files for AWDP that are discussed in more detail in Chapter 3. The scripts for executing these tests are located in directory `awdp/execs`. It is recommended to use these scripts (or a modified version) also for normal AWDP operation, as the environment variables needed by AWDP are set in these scripts.

As stated before, most test programs are located in the same directory as the module to be tested. See Chapter 2 for detailed information.

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1.5 Conventions

Names of physical quantities (e.g., wind speed components u and v), modules (e.g. *BufrMod*), subroutines and identifiers are printed italic.

Names of directories and subdirectories (e.g. `awdp/src`), files (e.g. `awdp.F90`), and commands (e.g. `awdp -f input`) are printed in Courier. Software systems in general are addressed using the normal font (e.g. AWDP, genscat).

Hyperlinks are printed in blue and underlined (e.g. <http://www.knmi.nl/scatterometer/>).

References are in square brackets with the name of the author italic (e.g. [*Stoffelen*, 1998]).

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Chapter 2

Module tests

In this chapter the various tests to individual modules within AWDP are presented. The tests are listed alphabetically in the module name. Table 2.1 gives an overview of the modules tested, their location and the name of the associated test programs.

Module tests have been included in AWDP if the following conditions were satisfied:

1. The test does not require additional software.
2. The output of the test program is self explanatory enough to judge the outcome of the test.

Module name	Location	Test program
<i>awdp_data</i>	<i>awdp/src</i>	<i>awdp_data_test</i>
<i>BFGSMod</i>	<i>genscat/support/BFGS</i>	<i>Test_BFGS</i>
<i>BufrMod</i>	<i>genscat/support/bufr</i>	<i>test_modules</i>
<i>convert</i>	<i>genscat/support/convert</i>	<i>test_convert</i>
<i>CostFunction</i>	<i>genscat/ambrem/twodvar</i>	<i>Test_SOS</i>
<i>StrucFunc</i>	<i>genscat/ambrem/twodvar</i>	<i>Test_SOS</i>
<i>DateTimeMod</i>	<i>genscat/support/datetime</i>	<i>TestDateTimeMod</i>
<i>ErrorHandler</i>	<i>genscat/support/ErrorHandler</i>	<i>TestErrorHandler</i>
<i>gribio_module</i>	<i>genscat/support/grib</i>	<i>test_read_GRIB1, test_read_GRIB2,</i> <i>test_read_GRIB3</i>
<i>LunManager</i>	<i>genscat/support/file</i>	<i>TestLunManager</i>
<i>numerics</i>	<i>genscat/support/num</i>	<i>test_numerics</i>
<i>pfs_ascat</i>	<i>genscat/support/pfs</i>	<i>test_pfs_ascat</i>
<i>SingletonFFT</i>	<i>genscat/support/singletonfft</i>	<i>TestSingleton</i>
<i>SortMod</i>	<i>genscat/support/sort</i>	<i>SortModTest</i>

Table 2.1 Overview of module tests.

2.1 Module *awdp_data*

Module *awdp_data.F90* in directory *awdp/src* contains the data structure definitions for the AWDP software. It is tested by program *awdp_data_test*, the output of which is listed in table 2.2.

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```

=== CELL INFO: Level 1b data ===
Originating centre: 2147483647
Origin sub-centre: 2147483647
Software id: 2147483647
Satellite id: 2147483647
Satellite instr: 2147483647
Dir of motion: 1.7000000E+38
Year:***** month:**** day:****
Hour:***** min:**** sec:****
Latitude: 1.7000000E+38
Longitude: 1.7000000E+38
Pixel size on hor: 1.7000000E+38
Orbit number: 2147483647
Node number: 2147483647
Height of atmosph: 1.7000000E+38
Loss per unit len: 1.7000000E+38
Beam collocation: missing
Beam colloc value: 2147483647

```

```

BEAM nr. 1
Identifier: 2147483647
Incidence angle: 1.7000000E+38
Azimuth angle: 1.7000000E+38
Sigma0: 1.7000000E+38
Noise value: 1.7000000E+38
Kp estimate qual: missing
Kp est qual value: 2147483647
Sigma0 usability: 2147483647
Synt data quantity: 1.7000000E+38
Synt data quality: 1.7000000E+38
Orbit quality: 1.7000000E+38
Solar refl contam: 1.7000000E+38
Telemetry pres/qua: 1.7000000E+38
Extrapol ref pres: 1.7000000E+38
Land fraction 1.7000000E+38

```

```

BEAM nr. 2
Identifier: 2147483647
Incidence angle: 1.7000000E+38
Azimuth angle: 1.7000000E+38
Sigma0: 1.7000000E+38
Noise value: 1.7000000E+38
Kp estimate qual: missing
Kp est qual value: 2147483647
Sigma0 usability: 2147483647
Synt data quantity: 1.7000000E+38
Synt data quality: 1.7000000E+38
Orbit quality: 1.7000000E+38
Solar refl contam: 1.7000000E+38
Telemetry pres/qua: 1.7000000E+38
Extrapol ref pres: 1.7000000E+38
Land fraction 1.7000000E+38

```

```

BEAM nr. 3
Identifier: 2147483647
Incidence angle: 1.7000000E+38
Azimuth angle: 1.7000000E+38
Sigma0: 1.7000000E+38
Noise value: 1.7000000E+38
Kp estimate qual: missing
Kp est qual value: 2147483647
Sigma0 usability: 2147483647
Synt data quantity: 1.7000000E+38
Synt data quality: 1.7000000E+38
Orbit quality: 1.7000000E+38
Solar refl contam: 1.7000000E+38
Telemetry pres/qua: 1.7000000E+38
Extrapol ref pres: 1.7000000E+38
Land fraction 1.7000000E+38

```

```

=== CELL INFO: Level 2 soil moisture data ===
Software id: 2147483647
Database id: 2147483647
Surf soil moisture: 1.7000000E+38

```

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Error in surface sm: 1.7000000E+38
Sigma0 at 40 deg: 1.7000000E+38
Error in sigma0_40: 1.7000000E+38
Slope at 40 deg: 1.7000000E+38
Error in slope_40: 1.7000000E+38
Sm sensitivity: 1.7000000E+38
Dry backscatter: 1.7000000E+38
Wet backscatter: 1.7000000E+38
Mean surface sm: 1.7000000E+38
Rain fall detection: 1.7000000E+38
Sm correction flag: 2147483647
Sm processing flag: 2147483647
Sm quality: 1.7000000E+38
Snow cover fraction: 1.7000000E+38
Frozen land frac: 1.7000000E+38
Inundat/wetland fr: 1.7000000E+38
Topogr complexity: 1.7000000E+38

=== CELL INFO: Level 2 wind data ===

Software id: 2147483647
Generating appl: 2147483647
MODEL WIND
Wind speed: 1.7000000E+38
Wind direction: 1.7000000E+38
Ice probability: 1.7000000E+38
Ice age A-param: 1.7000000E+38
WVC QUALITY
WVC quality: missing
WVC quality value: 2147483647
Num of ambiguities: 0
Index of sel wind: 2147483647
Skill for AR: 1.7000000E+38

=== CELL INFO: Process information ===

Process flag: POOR satellite id
Process flag: POOR satellite instrument
Process flag: POOR satellite dir of motion
Process flag: POOR time
Process flag: POOR lat/lon
Process flag: POOR pixel size on horizontal
Process flag: POOR node number
Process flag: POOR beam 1
Process flag: POOR beam 2
Process flag: POOR beam 3
Process flag: POOR model wind
Process flag: POOR ambiguity
Process flag: POOR selection
Level 1/2 of input: 2147483647
Analysis speed : 1.7000000E+38
Analysis direction: 1.7000000E+38
Observation cost : 1.7000000E+38

=== CELL INFO: Level 1b data ===

Originating centre: 99
Origin sub-centre: 5
Software id: 1
Satellite id: 3
Satellite instr: 100
Dir of motion: 180.0000
Year: 2005 month: 10 day: 6
Hour: 10 min: 3 sec: 33
Latitude: 50.00000
Longitude: 12.00000
Pixel size on hor: 25000.00
Orbit number: 12345
Node number: 4
Height of atmosph: 5000.000
Loss per unit len: 9.9999997E-06
Beam collocation: T
Beam colloc value: 1

BEAM nr. 1
Identifier: 1
Incidence angle: 40.00000

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Azimuth angle: 45.00000
 Sigma0: -10.00000
 Noise value: 5.000000
 Kp est. qual. flag: F
 Kp est qual value: 0
 Sigma0 usability: 0
 Synt data quantity: 0.1000000
 Synt data quality: 0.2000000
 Orbit quality: 0.3000000
 Solar refl contam: 0.4000000
 Telemetry pres/qua: 0.5000000
 Extrapol ref pres: 0.6000000
 Land fraction 0.7000000

BEAM nr. 2
 Identifier: 2
 Incidence angle: 30.00000
 Azimuth angle: 90.00000
 Sigma0: -7.000000
 Noise value: 2.000000
 Kp est. qual. flag: T
 Kp est qual value: 1
 Sigma0 usability: 1
 Synt data quantity: 0.2000000
 Synt data quality: 0.3000000
 Orbit quality: 0.4000000
 Solar refl contam: 0.5000000
 Telemetry pres/qua: 0.6000000
 Extrapol ref pres: 0.7000000
 Land fraction 0.8000000

BEAM nr. 3
 Identifier: 2
 Incidence angle: 40.00000
 Azimuth angle: 135.0000
 Sigma0: -10.00000
 Noise value: 5.000000
 Kp est. qual. flag: F
 Kp est qual value: 0
 Sigma0 usability: 0
 Synt data quantity: 0.3000000
 Synt data quality: 0.4000000
 Orbit quality: 0.5000000
 Solar refl contam: 0.6000000
 Telemetry pres/qua: 0.7000000
 Extrapol ref pres: 0.8000000
 Land fraction 0.9000000

=== CELL INFO: Level 2 soil moisture data ===

Software id: 2
 Database id: 15
 Surf soil moisture: 12.30000
 Error in surface sm: 4.500000
 Sigma0 at 40 deg: -12.34000
 Error in sigma0_40: 4.560000
 Slope at 40 deg: -0.2300000
 Error in slope_40: -0.1200000
 Sm sensitivity: 6.780000
 Dry backscatter: 7.890000
 Wet backscatter: 8.900000
 Mean surface sm: 45.60000
 Rain fall detection: 78.90000
 Sm correction flag: 1
 Sm processing flag: 5
 Sm quality: 34.50000
 Snow cover fraction: 1.230000
 Frozen land frac: 2.340000
 Inundat/wetland fr: 3.450000
 Topogr complexity: 5.670000

=== CELL INFO: Level 2 wind data ===

Software id: 3
 Generating appl: 99
 MODEL WIND

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```

Wind speed:          5.000000
Wind direction:      234.0000
Ice probability:      0.100000
Ice age A-param:     10.00000
WVC QUALITY
WVC quality: KNMI Quality Control fails
WVC quality: some portion of WVC over land
WVC quality value:    163840
Num of ambiguities:   2
Index of sel wind:    1
Skill for AR:         1.7000000E+38

```

```

    AMBIGUITY nr.    1
Wind speed:          6.000000
Wind direction:      222.0000
Probability:          0.900000
Cone distance:        0.100000

```

```

    AMBIGUITY nr.    2
Wind speed:          5.000000
Wind direction:      15.00000
Probability:          0.100000
Cone distance:        0.200000

```

```

=== CELL INFO: Process information ===
Process flag: OK satellite id
Process flag: OK satellite instrument
Process flag: OK satellite dir of motion
Process flag: OK time
Process flag: OK lat/lon
Process flag: OK pixel size on horizontal
Process flag: OK node number
Process flag: OK beam          1
Process flag: OK beam          2
Process flag: OK beam          3
Process flag: OK model wind
Process flag: OK ambiguity
Process flag: OK selection
Level 1/2 of input:           2
Analysis speed   : 1.7000000E+38
Analysis direction: 1.7000000E+38
Observation cost : 1.7000000E+38

```

Table 2.2 Output of program *awdp_data_test*.

2.2 Module *BFGSMod*

Directory `genscat/support/BFGS` contains program `Test_BFGS`. This program tests the minimization routine `LBFGS` and its associated routines in module *BFGSMod*. The routines in *BFGSMod* are slightly modified versions of the freeware routine `LBFGS` and its subroutines. `LBFGS` was written by J. Nocedal, see [Liu and Nocedal 1989].

Program `Test_BFGS` finds the minimum of the function

$$f(x) = \sum_{i=1}^{100000} (x - i)^4$$

The minimum is the point (1, 2, ..., 100000). The search starts at the origin. The typical output is shown in table 2.3.

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Program Test_BFGS testing routine LBFGS

Behaviour of cost function:

Iter Cost

0 0.20001E+25
1 0.19527E+25
2 0.17724E+25

...

84 0.29492E-15
85 0.95608E-16
86 0.30995E-16

Routine LBFGS completed succesfully

Number of iterations : 87
Dimension of problem : 100000
Number of corrections in BFGS update : 5
Cost function at start : 0.20001D+25
Cost function at end : 0.30995D-16
Precision required : 0.10D-19
Norm of final X : 0.18258D+08
Norm of final G : 0.97625D-13
Minimum and Maximum error in solution : 0.000003 0.000005
Time needed : 0.460 seconds

Program Test_BFGS completed succesfully.

Table 2.3 Output of program Test_BFGS.

2.3 Module *BufrMod*

Directory genscat/support/bufr contains program *test_modules*. This program is compiled and called automatically by the genscat make system, since it is needed to translate the ASCII BUFR tables to binary form. It will also read in a small BUFR test file, decode it, encode the data again and write them to an output BUFR file. Hence, the program can be used to check the BUFR library. Table 2.4 shows the output generated by *test_modules*. The program can be invoked by calling the shell script *run_test_modules*, which sets the environment variable \$BUFR_TABLES and calls *test_modules*.

```

nr of BUFR messages in this file is:      1
      ECMWF

      BUFR DECODING SOFTWARE VERSION - 7.2
      1 APRIL 2007.

Your path for bufr tables is :
./bufr_tables/
BUFR TABLES TO BE LOADED B0000000000210000001.TXT,D0000000000210000001.TXT
tbd%nelements =          44
pos_lat =              25
pos_lon =              26
latitude range:      -3.630000          1.260000
longitude range:      2.850000          7.690000
      ECMWF

      BUFR ENCODING SOFTWARE VERSION - 7.2
      1 April 2007.

Your path for bufr tables is :
./bufr_tables/
BUFR TABLES TO BE LOADED B0000000000210000001.TXT,D0000000000210000001.TXT

```

Table 2.4 Output of program *test_modules*.

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2.4 Module *convert*

Directory `genscat/support/convert` contains module *convert.F90*, a number of routines for the conversion of meteorological and geographical quantities. Its associated test program is *test_convert*, and part of its output is listed in table 2.5. Program *test_convert* produces quite a lot of output.

It starts with checking some conversions between different wind vector representations and transformations between different geographical coordinate systems, followed by a check of the transformation from orbit angles ($p, a, \text{rot}(z)$) to three-dimensional position (x, y, z).

Only the results for $p = 0^\circ$ and 90° are (partly) shown in table 2.5; those for $p = 10^\circ, 45^\circ$, and 70° are omitted. Program *test_convert* ends with some trigonometric calculations on a sphere.

```
=====
u =      5.000000      v =     -7.000000
uv_to_speed, uv_to_dir ==> sp =      8.602325      dir =      324.4623
=====
sp =      8.602325      dir =      324.4623
speeddir_to_u, speeddir_to_v ==> u =      5.000002      v =     -6.999999
=====
met2uv: sp =      10.00000      dir =      135.0000
met2uv: ==> u =     -7.071068      v =      7.071068
uv2met: u =     -7.071068      v =      7.071068
uv2met: ==> sp =      10.00000      dir =      135.0000
=====
lat, lon =      55.00000      5.000000
latlon2xyz: ==> x, y, z =      0.5713938      4.9990479E-02      0.8191521
x, y, z =      0.5713938      4.9990479E-02      0.8191521
xyz2latlon: ==> lat, lon =      55.00000      5.000000
=====
      p      a      rot_z      x      y      z      a1      rot_z1      a2      rot_z2
0.00000 -90.00000  0.00000  0.00000  0.00000 -1.00000 -90.00000 106.16298 270.00000  0.00000
0.00000 -90.00000 15.00000  0.00000  0.00000 -1.00000 -90.00000 105.59795 270.00000  9.72975
0.00000 -90.00000 30.00000  0.00000  0.00000 -1.00000 -90.00000 103.95005 270.00000 27.91061
0.00000 -90.00000 45.00000  0.00000  0.00000 -1.00000 -90.00000 101.35209 270.00000 43.81981
0.00000 -90.00000 60.00000  0.00000  0.00000 -1.00000 -90.00000  98.00070 270.00000 59.32336
0.00000 -10.00000  0.00000  0.98481  0.00000 -0.17365 -10.00000  0.00000 190.00000 180.00000
0.00000 -10.00000 15.00000  0.95125  0.25489 -0.17365 -10.00000 15.00000 190.00000 -164.99998
0.00000 -10.00000 30.00000  0.85287  0.49240 -0.17365 -10.00000 30.00000 190.00000 -149.99998
...
90.00000 45.00000 30.00000  0.25882  0.96593  0.00000  74.99999  0.00000 105.00000  0.00000
90.00000 45.00000 45.00000  0.00000  1.00000  0.00000  90.00000  0.00000  90.00000  0.00000
90.00000 45.00000 60.00000 -0.25882  0.96593  0.00000  74.99999  0.00000 105.00000  0.00000
90.00000 90.00000  0.00000  0.00000  1.00000  0.00000  90.00000  0.00000  90.00000  0.00000
90.00000 90.00000 15.00000 -0.25882  0.96593  0.00000  74.99999  0.00000 105.00000  0.00000
90.00000 90.00000 30.00000 -0.50000  0.86603  0.00000  59.99999  0.00000 120.00000  0.00000
90.00000 90.00000 45.00000 -0.70711  0.70711  0.00000  45.00000  0.00000 135.00000  0.00000
90.00000 90.00000 60.00000 -0.86603  0.50000  0.00000  30.00000  0.00000 149.99998  0.00000
=====
latlon1 =      5.000000      5.000000      latlon2 =      6.000000
5.000000
angle distance =      1.000000
km distance =      111.3188
latlon1 =      55.00000      5.000000      latlon2 =      56.00000
5.000000
angle distance =      1.000000
km distance =      111.3188
latlon1 =      85.00000      5.000000      latlon2 =      86.00000
5.000000
angle distance =      1.000000
km distance =      111.3188
=====
latlon1 =      5.000000      5.000000      latlon2 =      5.000000
6.000000
angle distance =      0.9961947
km distance =      110.8952
=====
```

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```

latlon1 = 55.00000 5.000000 latlon2 = 55.00000
6.000000
angle distance = 0.5735765
km distance = 63.84987
latlon1 = 85.00000 5.000000 latlon2 = 85.00000
6.000000
angle distance = 8.7155804E-02
km distance = 9.702084
=====

Test WVC_Orientation
WVC1 coordinates (Lam1,Phi1) = -115.2000 -18.61000
WVC2 coordinates (Lam2,Phi2) = -123.6500 -17.52000
WVC1 orientation Alfa1 = 173.5995 (Should equal 173.5994720)
WVC2 orientation Alfa2 = 170.9747 (Should equal 170.9747467)
=====

```

Table 2.5 Output of program *test_convert*

2.5 Modules *CostFunction* and *StrucFunc*

Module *CostFunc.F90* in directory *genscat/ambrem/twodvar* contains the cost function definition of the 2DVAR method. Module *StrucFunc* in the same directory contains the error covariance model of the background field. Large parts of these modules are tested in the single observation solution test implemented in program *Test_SOS*. Table 2.6 lists its output.

The main idea behind this test is that the 2DVAR analysis increment can be calculated analytically in case of one single observation with unit probability. Starting with zero background increment and an observation increment (t_o, l_o) on the 2DVAR grid at the position with indices (1,1), the initial total cost function equals

$$J_t^{init} = \frac{t_o^2 + l_o^2}{\varepsilon^2}$$

where ε stands for the standard deviation of the observation error, which is set to 1.8 in *Test_SOS*. The 2DVAR problem now reduces to a simple optimal interpolation problem. If the standard deviation of the background error is set to the same value as that of the observation error, the final solution has $J_t^{fin} = J_o^{fin} + J_b^{fin} = \frac{1}{2} J_t^{init}$ with $J_b^{fin} = J_o^{fin}$. This allows construction of the final solution and its gradient, see *Vogelzang* [2007] for more detailed information and a complete description of the 2DVAR method.

Program *Test_SOS* reads the observation increment and the structure function parameters from an input file with default name *Test_SOS.inp*, see below. The Helmholtz transformation coefficients are set according to option JV, which is the default option standing for sampled continuum (the other option is for periodic boundary conditions but these do not reproduce the correct scaling, see *Vogelzang* [2007] for more details. The program copies the structure function parameters into the *SF*-struct, and the observation increments in the *TwoDvarObs*-struct. The structure function parameters are printed by routine *PrnStrucFuncPars*.

The error covariances are calculated numerically in module *StrucFunc*. For Gaussian structure functions, they can also be calculated analytically. The two methods are compared and the relative precision is printed. In table 2.6 it is 0.00345 for the stream function ψ and 0.0 for the velocity potential χ , since the latter quantity is identically zero in this example. The precision of the

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covariances depends on the correlation lengths R_ψ and R_χ .

The total cost function and its gradient is evaluated by routine *JoScat* in module *CostFunction*. From this the cost function components and gradients at the final solution are calculated and checked against their analytical value. The (absolute) precision is printed. Finally, *Test_SOS* checks the packing and unpacking routines of the control vector in both directions.

As stated before, program *Test_SOS* reads its input from an input file. The name (and path) of that file must be given as command line argument of *Test_SOS*. When omitted, the program assumes *Test_SOS.inp* as input file. Table 2.7 gives the structure and contents of the input file. It is in free format.

```
=====
PROGRAM Test_SOS - Single Observation Solution Check
=====
```

```
Input read from file      : Test_SOS.inp
Helmholz coefficients type : JV
2DVAR:
2DVAR: Parameters inside the StructFunc module:
2DVAR: Grid size in position domain      : 100000.0      m
2DVAR: Grid dimensions                  : 32 by 32
2DVAR: Free edge size                    : 5 points
2DVAR: Structure function type           : Gaus
2DVAR: Northern hemisphere:
2DVAR: Error standard deviation in psi   : 2.000000      m/s
2DVAR: Error standard deviation in chi   : 2.000000      m/s
2DVAR: Rotation/divergence ratio         : 0.100000
2DVAR: Range parameter for psi           : 300000.0
2DVAR: Range parameter for chi           : 300000.0
2DVAR: Tropics:
2DVAR: Error standard deviation in psi   : 1.800000      m/s
2DVAR: Error standard deviation in chi   : 1.800000      m/s
2DVAR: Rotation/divergence ratio         : 1.000000
2DVAR: Range parameter for psi           : 300000.0
2DVAR: Range parameter for chi           : 300000.0
2DVAR: Southern hemisphere:
2DVAR: Error standard deviation in psi   : 2.000000      m/s
2DVAR: Error standard deviation in chi   : 2.000000      m/s
2DVAR: Rotation/divergence ratio         : 0.100000
2DVAR: Range parameter for psi           : 300000.0
2DVAR: Range parameter for chi           : 300000.0
```

```
CheckCovMat - checking precision of Covariances
Relative precision in covariances of psi: 0.000000
Relative precision in covariances of chi: 3.1197767E-04
```

```
Number of observations      : 1
Number of control variables : 2046
```

```
Obs2dvar after initialization:
i j Namb u v Jo gu gv
-----
1 1 1 1.0 0.0 0.77160E-01 -0.30864E+00 0.00000E+00
```

The gradient velocity fields duo and dvo (nonzero components only):

```
i j duo dvo
-----
1 1 -0.30864E+00 0.00000E+00
```

The cost function of the solution:

```
Observation part : 7.7160493E-02
Background part : 7.7160530E-02 precision 3.7252903E-08
```

The background velocity field:

```
u(1,1) : 0.5000000
Expected value : 0.5000000 precision 2.9802322E-08
v(1,1) : 3.1561567E-20
```

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Expected value : 0.000000 precision 3.1561567E-20

Check background cost function

Direct calculation from psi and chi : 7.7160530E-02
Calculation by Jb from control vector : 7.7160537E-02 precision
7.4505806E-09

Check observation cost function

Expected value : 7.7160493E-02
Calculation by Jo from control vector : 7.7160463E-02 precision
2.9802322E-08
Precision in gradients better than 1.9753901E-10

Check packing/unpacking:

Precision in packing/unpacking of xi 0.000000
Precision in packing/unpacking of psi 0.000000
Precision in packing/unpacking of chi 0.000000

Program Test_SOS completed.

=====

Table 2.6 Output of the single observation solution test.

Record	Item nr.	Name	Meaning
1	1	u0_ini	Initial observation increment in transversal direction (m/s)
1	2	v0_ini	Initial observation increment in longitudinal direction (m/s)
2	1	lparameter	Logical parameter indicating if 2DVAR parameters should be read from file
3	1	TDVParameterFile	Name of 2DVAR parameter file

Table 2.7 Input file for *Test_SOS*.

2.6 Module *DateTimeMod*

Module *DateTimeMod.F90* in directory *genscat/support/datetime* contains general purpose date and time help functions. These are tested by program *TestDateTimeMod*, the output of which is listed in table 2.8.

```
time-tests
time: 14:22:03.70
time_real      = 51723.70
time_real + 77.2 = 51800.90
time: 14:23:20.90
time2 is valid
time1 =
time: 14:22:03.70
time2 =
time: 14:23:20.90
time 1 .ne. time2
date-tests
date: 15-12-1999
date_int =      19991215
date_int + 1 =    19991216
date: 16-12-1999
date2 is valid
date1 =
date: 15-12-1999
date2 =
date: 16-12-1999
date 1 .ne. date2
date-stepping-tests
ERROR: The date      21000101 is outside the range
19000101...20991231, this is not implemented at this time
ERROR: Julian routines differ from my own routines
date: 31-12-2099
```

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```

next_date_int =      2147483647
date: 01-01-2100
next_julian_date_int =      21000101
all OK
before:
time: 23:59:57.70
date: 31-12-1999
after incrementing by:  5.22 seconds
time: 00:00:02.92
date: 01-01-2000
valid time
test of function date2string: 19991231
test of function date2string_sep: 1999-12-31
test of function time2string: 235957
test of function time2string_sep: 23:59:57
before convert_to_derived_datetime:
date: 28-02-2005
time: 52:00:00.00
after convert_to_derived_datetime:
date: 02-03-2005
time: 04:00:00.00
Current date and time:
date: 10-02-2014
time: 14:44:18.52

```

Table 2.8 Output of program *TestDateTimeMod*.

2.7 Module *ErrorHandler*

Module *ErrorHandler.F90* in directory `genscat/support/ErrorHandler` contains routines for handling errors during program execution. The module is tested by program *TestErrorHandler*, the output of which is listed in table 2.9.

```

The Error Handler program_abort routine is set to
return after each error,
in order to try and resume the program...
testing: report_error
an error was reported from within subroutine: dummy_module_name1
error while allocating memory
testing: program_abort (with abort_on_error = .false.)
an error was reported from within subroutine: dummy_module_name2
error while allocating memory
==> trying to resume the program ...
The Error Handler program_abort routine is set to
abort on first error...
testing: program_abort (with abort_on_error = .true.)
an error was reported from within subroutine: dummy_module_name2
error while allocating memory

```

Table 2.9 Output of program *TestErrorHandler*.

2.8 Module *gribio_module*

Module *gribio_module.F90* in directory `genscat/support/grib` contains routines for reading and decoding GRIB files. The module is tested by programs *test_read_GRIB1*, *test_read_GRIB2* and *test_read_GRIB3*, the output of which is listed in tables 2.10 to 2.12. The test programs read in two small GRIB files (*testfile.grib* in GRIB edition 1 format and *testfile.grib2* in GRIB edition 2 format) present in this directory and print some of their contents to the standard output. The environment variable `$GRIB_DEFINITION_PATH` needs to be set and has to point to the directory containing GRIB definition tables. These are available in

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(...)/genscat/support/grib/definitions.

```

open GRIB edition 1 file
file name = ./testfile.grib
date of grib field =          20031111
time of grib field =          24
derived date of grib field =   20031112
derived time of grib field =    0

```

lat	lon	10u	10v	speed
54.00	4.00	-4.576	8.006	9.221
54.00	4.50	-5.143	7.764	9.313
54.00	5.00	-5.034	7.520	9.050
54.00	5.50	-4.925	7.276	8.786
54.50	4.00	-4.849	8.455	9.747
54.50	4.50	-5.139	8.315	9.775
54.50	5.00	-5.200	8.426	9.902
54.50	5.50	-5.261	8.537	10.028
55.00	4.00	-5.267	8.577	10.065
55.00	4.50	-5.398	8.454	10.031
55.00	5.00	-5.416	8.620	10.180
55.00	5.50	-5.434	8.786	10.330
55.50	4.00	-5.686	8.699	10.392
55.50	4.50	-5.657	8.594	10.289
55.50	5.00	-5.632	8.814	10.459
55.50	5.50	-5.606	9.034	10.632

```

open GRIB edition 2 file
file name = ./testfile.grib2
date of grib field =          20031111
time of grib field =          24

```

End of tests

Table 2.10 Output of program *test_read_GRIB1*.

```

retrieve grib field par_id_t
lat of first gridpoint = 89.142
lat step                = -1.121
number of lat points    = 160
lon of first gridpoint = 0.000
lon step                = 1.125
number of lon points    = 320

```

i	j	field(i,j)
80	160	302.663
80	161	302.445
80	162	302.148
80	163	301.560
81	160	301.999
81	161	302.298
81	162	301.808
81	163	301.708
82	160	302.056
82	161	302.117
82	162	301.490
82	163	301.888
83	160	302.214
83	161	302.001
83	162	301.796
83	163	302.361

Table 2.11 Output of program *test_read_GRIB2*.

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```

retrieve grib field par_id_10u
date of grib field = 20031111
time of grib field = 24
WARNING: latitude dimension of field is too small to contain
WARNING: the read data; truncating the array !!!!!
original: nr_lat_points = 160
truncated: nr_lat_points = 50
WARNING: longitude dimension of field is too small to contain
WARNING: the read data; truncating the array !!!!!
original: nr_lon_points = 320
truncated: nr_lon_points = 50

  i   j   field(i,j)
48  48   -0.414
48  49    0.477
48  50   -0.111
49  48    3.330
49  49    2.899
49  50    3.252
50  48    3.503
50  49    2.408
50  50    3.212

```

Table 2.12 Output of program *test_read_GRIB3*.

2.9 Module *LunManager*

Module *LunManager.F90* in directory *genscat/support/file* contains routines for file unit management. It is tested by program *TestLunManager*, the output of which is listed in table 2.13.

```

Starting fileunit test program
===== lun_manager =====
fileunit: 31 was not in use !!!
free_lun returns without freeing any fileunit
fileunit: 88 was not in the range that is handled
by this module ! ( 30 - 39 )
free_lun returns without freeing any fileunit
fileunit: 88 was not in the range that is handled
by this module ! ( 30 - 39 )
enable_lun returns without enabling any fileunit
fileunit: 88 was not in the range that is handled
by this module ! ( 30 - 39 )
disable_lun returns without disabling any fileunit
fileunit: 21 was not in the range that is handled
by this module ! ( 30 - 39 )
disable_lun returns without disabling any fileunit
unit: 31 is used?: F
unit: 31 is used?: T
start of inspect_luns
  lun 0 is open
  lun 0 has a name: stderr
  lun 5 is open
  lun 5 has a name: stdin
  lun 6 is open
  lun 6 has a name: stdout
  lun 31 is open
  lun 31 has a name: TestLunManager.F90
end of inspect_luns
fileunit: 31 is still in use !
disabling it is only possible if it is not used !
disable_lun returns without disabling any fileunit
fileunit: 30 is in use
fileunit: 31 is in use
fileunit: 32 is still available
fileunit: 33 is still available
fileunit: 34 is still available
fileunit: 35 is still available
fileunit: 36 is still available

```

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```

fileunit:          37  is still available
fileunit:          38  is still available
fileunit:          39  is still available
fileunit:          21  was not in the range that is handled
by this module ! (      30  -      39  )
enable_lun returns without enabling any fileunit
fileunit:          22  was not in the range that is handled
by this module ! (      30  -      39  )
enable_lun returns without enabling any fileunit

```

Table 2.13 Output of program *TestLunManager*.

2.10 Module *Numerics*

Module *numerics.F90* in directory `genscat/support/num` contains routines for checking and handling numerical issues like variable sizes and ranges. These are tested by program *test_numerics*, the output of which is listed in Table 2.14.

```

Starting numerics test program
===== representation tests =====
REALACC(6)
r4: digits          24
r4: epsilon         1.1920929E-07
r4: huge            3.4028235E+38
r4: minexponent     -125
r4: maxexponent      128
r4: precision        6
r4: radix           2
r4: range            37
r4: tiny            1.1754944E-38
ENDREALACC
REALACC(12)
r8: digits          53
r8: epsilon         2.2204460492503131E-016
r8: huge            1.7976931348623167E+308
r8: minexponent     -1021
r8: maxexponent     1024
r8: precision       15
r8: radix           2
r8: range           307
r8: tiny            2.2250738585072010E-308
ENDREALACC
===== numerics tests =====
int1 = 127
int2 = 32767
int4 = 2147483647
int8 = 9223372036854775807
huge(int1) = 127
huge(int2) = 32767
huge(int4) = 2147483647
huge(int8) = 9223372036854775807
REALACC(6) r4 = 1.7000000E+38 ENDREALACC
REALACC(12) r8 = 1.7000000000000000E+038 ENDREALACC
===== check variable sizes =====
Variable sizes are as expected
===== detect and print variable sizes =====
var_type nr_of_words range precision
i         4         9
i1_       1         2
i2_       2         4
i4_       4         9
i8_       8        18
dr        4        37         6
s_        4        37         6
l_        4        37         6
r_        4        37         6

```

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```

r4_      4      37      6
r8_      8     307     15
===== dB conversion test =====
REALACC(6)
input test number:          1.2300001E-04
converted to dB:            -39.10095
converted back to a real:    1.2299998E-04
ENDREALACC
===== done =====

```

Table 2.14 Output of program *test_mumerics*.

2.11 Module *pfs_ascat*

Module *pfs_ascat* in directory `genscat/support/pfs` contains routines for reading and decoding files in the Product Format Specification (PFS, native Metop) format. The associated test program is *test_pfs_ascat* which reads a small sample file present in this directory. Its output is shown in table 2.16.

```

file: ./ascat_1b.szo
nrecords      161
nnodes        21
swath         2 node          1
date/time of first record 2002 08 08 20 05 02
mean s0 fore beam -4.83118844324852      dB
mean s0 mid beam  -5.020170888184862      dB
mean s0 aft beam   -4.390880841944516      dB

```

Table 2.15 Output of program *test_pfs_ascat*

2.12 Module *SingletonFFT*

Module *SingletonFFT* in directory `genscat/support/singletonfft` contains routines for Fast Fourier Transforms. The associated test program is *TestSingleton*. Part of its output is shown in table 2.16.

```

=====
PROGRAM TestSingleton
Test of SingletonFFT routines by comparing with analytical FT
=====

Spreading times grid size in dimension 1:  0.1000000      (should be ~ 0.1)
Spreading times grid size in dimension 2:  0.1000000      (should be ~ 0.1)
=====

1D
  F O R W A R D      B A C K W A R D
P r e c i s i o n    P r e c i s i o n
N1      Real        Imag      Real        Imag
-----
32  0.83631E-06  0.10286E-04  0.11921E-06  0.69247E-07
34  0.61329E-06  0.78932E-05  0.11921E-06  0.11285E-07
36  0.94782E-06  0.12215E-04  0.11921E-06  0.11036E-06
38  0.27877E-06  0.20358E-05  0.17881E-06  0.22604E-07
40  0.83631E-06  0.12143E-04  0.11921E-06  0.54017E-07
42  0.44603E-06  0.56252E-05  0.77824E-07  0.92940E-07
44  0.12900E-06  0.27819E-06  0.17881E-06  0.14948E-06
46  0.94782E-06  0.13554E-04  0.35763E-06  0.34905E-07
48  0.94782E-06  0.14143E-04  0.23842E-06  0.12666E-06
50  0.50178E-06  0.66967E-05  0.17881E-06  0.10431E-06
=====

2D      F O R W A R D   F F T      B A C K W A R D   F F T

```

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P r e c i s i o n					P r e c i s i o n				
N1	N2	Real	Imag	Time	Real	Imag	Time		
32	32	0.11995E-05	0.20572E-04	0.0000	0.17881E-06	0.10663E-06	0.0000		
32	34	0.10952E-05	0.18179E-04	0.0001	0.11921E-06	0.63061E-07	0.0000		
32	36	0.12516E-05	0.22501E-04	0.0000	0.11921E-06	0.11339E-06	0.0000		
32	38	0.88658E-06	0.82503E-05	0.0001	0.17881E-06	0.66826E-07	0.0001		
32	40	0.12516E-05	0.22430E-04	0.0000	0.17881E-06	0.95745E-07	0.0000		
32	42	0.99089E-06	0.15911E-04	0.0000	0.11921E-06	0.12151E-06	0.0000		
32	44	0.88658E-06	0.10286E-04	0.0001	0.29802E-06	0.17938E-06	0.0001		
32	46	0.11473E-05	0.23840E-04	0.0001	0.35763E-06	0.63112E-07	0.0001		
32	48	0.12516E-05	0.24430E-04	0.0000	0.27816E-06	0.12973E-06	0.0000		
32	50	0.10430E-05	0.16983E-04	0.0000	0.17881E-06	0.11206E-06	0.0000		
34	32	0.11473E-05	0.18179E-04	0.0001	0.11921E-06	0.78046E-07	0.0001		
...									
48	50	0.10952E-05	0.20840E-04	0.0001	0.30120E-06	0.12803E-06	0.0001		
50	32	0.99089E-06	0.16983E-04	0.0000	0.17881E-06	0.11192E-06	0.0000		
50	34	0.83443E-06	0.14590E-04	0.0001	0.17881E-06	0.10692E-06	0.0001		
50	36	0.10430E-05	0.18912E-04	0.0001	0.23842E-06	0.11300E-06	0.0001		
50	38	0.46937E-06	0.47101E-05	0.0001	0.17881E-06	0.10619E-06	0.0001		
50	40	0.93873E-06	0.18840E-04	0.0001	0.35763E-06	0.11030E-06	0.0001		
50	42	0.62582E-06	0.12322E-04	0.0001	0.29802E-06	0.11184E-06	0.0001		
50	44	0.46937E-06	0.66967E-05	0.0001	0.29802E-06	0.14250E-06	0.0001		
50	46	0.99089E-06	0.20251E-04	0.0001	0.23842E-06	0.10202E-06	0.0001		
50	48	0.10430E-05	0.20840E-04	0.0001	0.29802E-06	0.15117E-06	0.0001		
50	50	0.57367E-06	0.13393E-04	0.0001	0.35763E-06	0.11255E-06	0.0001		
=====									
Program TestSingleton: Resume									
Worst case accuracies									
F O R W A R D					B A C K W A R D				
		Real	Imag		Real		Imag		

1D		0.94782E-06	0.14143E-04	0.35763E-06		0.14948E-06			
2D		0.13559E-05	0.28287E-04	0.77486E-06		0.28650E-06			
Program TestSingleton: Normal termination.									
=====									

Table 2.16 Output of program *TestSingleton*

2.13 Module *SortMod*

Module *SortMod* in directory `genscat/support/sort` contains two routines for sorting the wind vector solutions found in the inversion step to their probability. The associated test program is *SortModTest*. Its output is shown in table 2.17.

Test program for the SortMod module									
Unsorted array									
10.0	9.0	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0
After GetSortIndex									
1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Sorted array, after SortWithIndex									
1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0

Table 2.17 Output of program *SortModTest*

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Chapter 3

AWDP integration test

Directory `awdp/tests` contains two ASCAT BUFR files to test the AWDP executable. File `ascat_20070426_test_250.l1_bufr` contains ASCAT level 1b data from 26 April 2007, 9:51 to 10:29 UTC with 25 km cell spacing. The same data, but on 12.5 km cell spacing, is available in file `ascat_20070426_test_125.l1_bufr`. The files `ECMWF*.grib` contain the necessary NWP data (SST, land-sea mask and wind forecasts) to perform the NWP collocation step.

The user can test the proper functioning of AWDP using the files in the `awdp/tests` directory. To do this, first create a small file containing a list of NWP files:

```
ls -l ECMWF_200704260000_0* > nwpflist
```

Then run AWDP on 25 km and 12.5 km cell spacing:

```
../execs/awdp_run -f ascat_20070426_test_250.l1_bufr -nwpfl  
nwpflist -mon -calval
```

```
../execs/awdp_run -f ascat_20070426_test_125.l1_bufr -nwpfl  
nwpflist -mon -calval
```

The result should be two ASCAT level 2 files in BUFR format, called `ascat_20070426_095102_metopa_02681_srv_o_250_ovw.l2_bufr` and `ascat_20070426_095100_metopa_02681_srv_o_125_ovw.l2_bufr`, respectively.

Directory `awdp/tests` also contains an ERS file in ESA BUFR format, called `scatt_20070426_test_250.l1_bufr`. The data are from the same date as the ASCAT data in this directory and they can be processed using the same ECMWF files.

```
../execs/awdp_run -f scatt_20070426_test_250.l1_bufr -nwpfl  
nwpflist -mon
```

The result should be an output file in ASCAT BUFR format, called `scatt_20070426_063627_ers2_000000_srv_o_250_ovw.l2_bufr`

Note that by default, the winds will be calculated using the CMOD5.n GMF will be used which results in equivalent neutral 10m winds.

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3.1 ASCAT test data

Figure 3.1 shows the global coverage of the ASCAT test run on 25 km. The colours show the magnitude of the wind speed as indicated by the legend. The result on 12.5 km should be very similar to this. The figures 3.2 and 3.3 show detailed wind vector plots over the Atlantic near the UK, with 25 km and 12.5 km cell spacing, respectively. In the detail plots, a magenta marker on top of the wind arrow denotes land presence. Yellow wind arrows indicate that the Variational Quality Control flag is set, i.e. the Wind Vector Cell is spatially inconsistent. A yellow dot means that the KNMI Quality Control Flag is set.

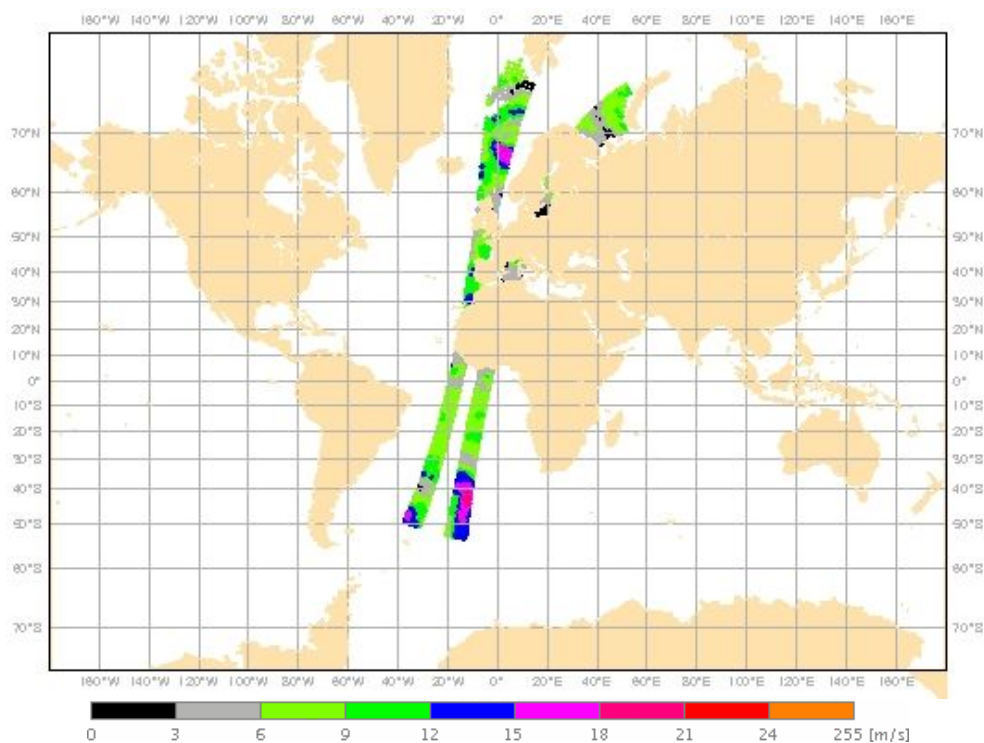


Figure 3.1 Global coverage of the ASCAT test run. Wind speed results for the 25 km product are shown.

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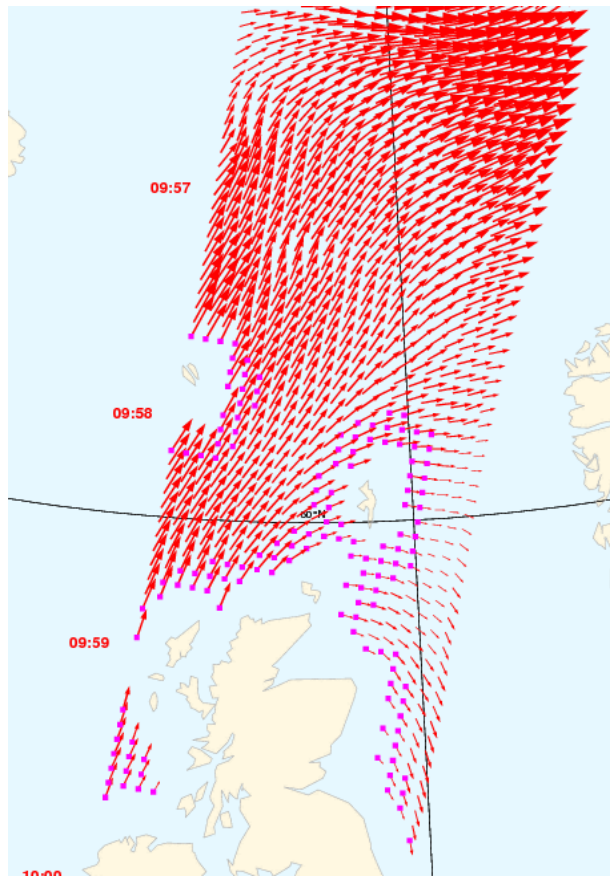


Figure 3.2 Detail plot of the ASCAT test run. Wind vectors for the 25 km product are shown.

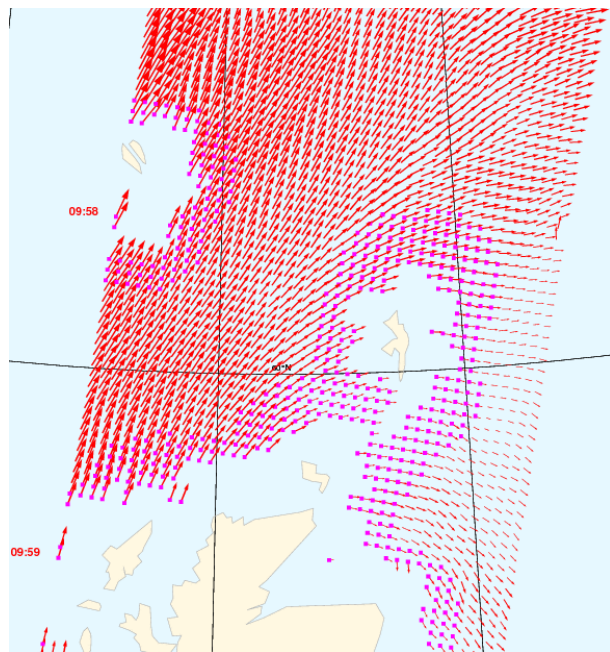


Figure 3.3 Detail plot of the ASCAT test run. Wind vectors for the 12.5 km product are shown.

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1	IDENTIFICATION OF ORIGIN	99.0000	CODE TABLE 1033
2	IDENTIFICATION OF ORIGIN	0.0000	CODE TABLE 1034
3	SOFTWARE IDENTIFICATION (	0.0000	NUMERIC
4	SATELLITE IDENTIFIER	4.0000	CODE TABLE 1007
5	SATELLITE INSTRUMENTS	190.0000	CODE TABLE 2019
6	DIRECTION OF MOTION OF MO	229.0000	DEGREE TRUE
7	YEAR	2007.0000	YEAR
8	MONTH	4.0000	MONTH
9	DAY	26.0000	DAY
10	HOUR	9.0000	HOUR
11	MINUTE	51.0000	MINUTE
12	SECOND	58.0000	SECOND
13	LATITUDE (HIGH ACCURACY)	75.7223	DEGREE
14	LONGITUDE (HIGH ACCURACY)	52.1184	DEGREE
15	PIXEL SIZE ON HORIZONTAL	25000.0000	M
16	ORBIT NUMBER	2681.0000	NUMERIC
17	CROSS-TRACK CELL NUMBER	21.0000	NUMERIC
18	HEIGHT OF ATMOSPHERE USED	12500.0000	M
19	LOSS PER UNIT LENGTH OF A	0.0000	dB/M
20	BEAM COLLOCATION	1.0000	CODE TABLE 21150
21	BEAM IDENTIFIER	1.0000	CODE TABLE 8085
22	RADAR INCIDENCE ANGLE	36.8700	DEGREE
23	ANTENNA BEAM AZIMUTH	13.0900	DEGREE
24	BACKSCATTER	-14.1700	dB
25	RADIOMETRIC RESOLUTION (N	1.5000	%
26	ASCAT KP ESTIMATE QUALITY	0.0000	CODE TABLE 21158
27	ASCAT SIGMA-0 USABILITY	2.0000	CODE TABLE 21159
28	ASCAT USE OF SYNTHETIC DA	0.0000	NUMERIC
29	ASCAT SYNTHETIC DATA QUAL	0.0000	NUMERIC
30	ASCAT SATELLITE ORBIT AND	1.0000	NUMERIC
31	ASCAT SOLAR ARRAY REFLECT	0.0000	NUMERIC
32	ASCAT TELEMETRY PRESENCE	1.0000	NUMERIC
33	ASCAT EXTRAPOLATED REFERE	0.0000	NUMERIC
34	ASCAT LAND FRACTION	0.0000	NUMERIC
35	BEAM IDENTIFIER	2.0000	CODE TABLE 8085
36	RADAR INCIDENCE ANGLE	27.6300	DEGREE
37	ANTENNA BEAM AZIMUTH	328.4400	DEGREE
38	BACKSCATTER	-8.0800	dB
39	RADIOMETRIC RESOLUTION (N	2.0000	%
40	ASCAT KP ESTIMATE QUALITY	0.0000	CODE TABLE 21158
41	ASCAT SIGMA-0 USABILITY	2.0000	CODE TABLE 21159
42	ASCAT USE OF SYNTHETIC DA	0.0000	NUMERIC
43	ASCAT SYNTHETIC DATA QUAL	0.0000	NUMERIC
44	ASCAT SATELLITE ORBIT AND	1.0000	NUMERIC
45	ASCAT SOLAR ARRAY REFLECT	0.0000	NUMERIC
46	ASCAT TELEMETRY PRESENCE	1.0000	NUMERIC
47	ASCAT EXTRAPOLATED REFERE	0.0000	NUMERIC
48	ASCAT LAND FRACTION	0.0000	NUMERIC
49	BEAM IDENTIFIER	3.0000	CODE TABLE 8085
50	RADAR INCIDENCE ANGLE	36.8600	DEGREE
51	ANTENNA BEAM AZIMUTH	283.4600	DEGREE
52	BACKSCATTER	-15.4100	dB
53	RADIOMETRIC RESOLUTION (N	2.0000	%
54	ASCAT KP ESTIMATE QUALITY	0.0000	CODE TABLE 21158
55	ASCAT SIGMA-0 USABILITY	2.0000	CODE TABLE 21159
56	ASCAT USE OF SYNTHETIC DA	0.0000	NUMERIC
57	ASCAT SYNTHETIC DATA QUAL	0.0000	NUMERIC
58	ASCAT SATELLITE ORBIT AND	1.0000	NUMERIC
59	ASCAT SOLAR ARRAY REFLECT	0.0000	NUMERIC
60	ASCAT TELEMETRY PRESENCE	1.0000	NUMERIC
61	ASCAT EXTRAPOLATED REFERE	0.0000	NUMERIC
62	ASCAT LAND FRACTION	0.0000	NUMERIC
63	SOFTWARE IDENTIFICATION (	MISSING	NUMERIC
64	DATABASE IDENTIFICATION	MISSING	NUMERIC
65	SURFACE SOIL MOISTURE (MS	MISSING	%
66	ESTIMATED ERROR IN SURFAC	MISSING	%
67	BACKSCATTER	MISSING	dB
68	ESTIMATED ERROR IN SIGMA0	MISSING	dB
69	SLOPE AT 40DEG INCIDENCE	MISSING	dB/DEG
70	ESTIMATED ERROR IN SLOPE	MISSING	dB/DEG
71	SOIL MOISTURE SENSITIVITY	MISSING	dB
72	BACKSCATTER	MISSING	dB
73	WET BACKSCATTER	MISSING	dB

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74 MEAN SURFACE SOIL MOISTUR	MISSING NUMERIC
75 RAIN FALL DETECTION	MISSING NUMERIC
76 SOIL MOISTURE CORRECTION	MISSING FLAG TABLE 40005
77 SOIL MOISTURE PROCESSING	MISSING FLAG TABLE 40006
78 SOIL MOISTURE QUALITY	MISSING %
79 SNOW COVER (SEE NOTE 4)	MISSING %
80 FROZEN LAND SURFACE FRACT	MISSING %
81 INUNDATION AND WETLAND FR	MISSING %
82 TOPOGRAPHIC COMPLEXITY	MISSING %
83 SOFTWARE IDENTIFICATION (	2201.0000 NUMERIC
84 GENERATING APPLICATION	91.0000 CODE TABLE 1032
85 MODEL WIND SPEED AT 10M	7.8500 M/S
86 MODEL WIND DIRECTION AT 1	341.7600 DEGREE TRUE
87 ICE PROBABILITY	MISSING NUMERIC
88 ICE AGE ("A" PARAMETER)	MISSING dB
89 WIND VECTOR CELL QUALITY	0.0000 FLAG TABLE 21155
90 NUMBER OF VECTOR AMBIGUIT	2.0000 NUMERIC
91 INDEX OF SELECTED WIND VE	1.0000 NUMERIC
92 DELAYED DESCRIPTOR REPLIC	4.0000 NUMERIC
93 WIND SPEED AT 10 M	9.2500 M/S
94 WIND DIRECTION AT 10 M	338.8000 DEGREE TRUE
95 BACKSCATTER DISTANCE	0.7000 NUMERIC
96 LIKELIHOOD COMPUTED FOR S	-0.2560 NUMERIC
97 WIND SPEED AT 10 M	8.9100 M/S
98 WIND DIRECTION AT 10 M	156.5000 DEGREE TRUE
99 BACKSCATTER DISTANCE	-1.0000 NUMERIC
100 LIKELIHOOD COMPUTED FOR S	-0.3520 NUMERIC
101 WIND SPEED AT 10 M	MISSING M/S
102 WIND DIRECTION AT 10 M	MISSING DEGREE TRUE
103 BACKSCATTER DISTANCE	MISSING NUMERIC
104 LIKELIHOOD COMPUTED FOR S	MISSING NUMERIC
105 WIND SPEED AT 10 M	MISSING M/S
106 WIND DIRECTION AT 10 M	MISSING DEGREE TRUE
107 BACKSCATTER DISTANCE	MISSING NUMERIC
108 LIKELIHOOD COMPUTED FOR S	MISSING NUMERIC

Table 3.1 Wind Vector Cell in BUFR format

Table 3.1 shows one decoded Wind Vector Cell of the resulting output file in BUFR format.

From the plots and table in this section it is clear that:

- Output is provided in BUFR format.
- The Wind Vector Cell spacing is 25 km in this case, see field 15 in the BUFR outputs and figure 3.2. With 12.5 km input, the output is also on 12.5 km WVC spacing, see figure 3.3.
- The output contains latitude, longitude, time, orbit and node numbers, NWP background wind vector, WVC quality flag, and information on the radar backscatter including σ^0 and K_p data.
- AWDP can process ASCAT input data.
- A consistent wind field is obtained which proves that both BUFR and GRIB data are read successfully.

Table 3.3 shows what happens when the MLE value exceeds a threshold for Quality Control. The MLE of the first wind solution (the one closest to the model wind) is contained in field 95 and has a value of 25.3. This is above the threshold value of 19.8 for node number 23. The Wind Vector Cell Quality (field 89) has an integer value of 139328, i.e., Fortran bits 6, 13 and 17 are set, corresponding to the flags for ‘Distance to GMF too large’, ‘Wind inversion not successful’ and ‘KNMI Quality Control’.

83 SOFTWARE IDENTIFICATION (	2201.0000 NUMERIC
84 GENERATING APPLICATION	91.0000 CODE TABLE 1032

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85 MODEL WIND SPEED AT 10M	8.9000	M/S
86 MODEL WIND DIRECTION AT 1	14.9900	DEGREE TRUE
87 ICE PROBABILITY	MISSING	NUMERIC
88 ICE AGE ("A" PARAMETER)	MISSING	dB
89 WIND VECTOR CELL QUALITY	139328.0000	FLAG TABLE 21155
90 NUMBER OF VECTOR AMBIGUIT	4.0000	NUMERIC
91 INDEX OF SELECTED WIND VE	1.0000	NUMERIC
92 DELAYED DESCRIPTOR REPLIC	4.0000	NUMERIC
93 WIND SPEED AT 10 M	9.5200	M/S
94 WIND DIRECTION AT 10 M	25.6000	DEGREE TRUE
95 BACKSCATTER DISTANCE	25.3000	NUMERIC
96 LIKELIHOOD COMPUTED FOR S	-0.0650	NUMERIC
97 WIND SPEED AT 10 M	7.3000	M/S
98 WIND DIRECTION AT 10 M	274.3000	DEGREE TRUE
99 BACKSCATTER DISTANCE	28.5000	NUMERIC
100 LIKELIHOOD COMPUTED FOR S	-0.9350	NUMERIC
101 WIND SPEED AT 10 M	9.5800	M/S
102 WIND DIRECTION AT 10 M	187.5000	DEGREE TRUE
103 BACKSCATTER DISTANCE	30.8000	NUMERIC
104 LIKELIHOOD COMPUTED FOR S	-1.6320	NUMERIC
105 WIND SPEED AT 10 M	7.7300	M/S
106 WIND DIRECTION AT 10 M	84.2000	DEGREE TRUE
107 BACKSCATTER DISTANCE	41.7000	NUMERIC
108 LIKELIHOOD COMPUTED FOR S	-4.8390	NUMERIC

Table 3.3 Part of Wind Vector Cell, rejected by Quality Control

The processing of the 25 km test file (approximately half an orbit) takes ~6 seconds on a Linux workstation and the processing of the corresponding 12.5 km test file takes ~18 seconds. Hence the ASCAT wind processing can be done easily in near-real time on an affordable computer system.

3.2 ERS test data

Figure 3.4 shows the coverage of the ERS test run (winds computed with AWDP) on 25 km. The colours show the magnitude of the wind speed as indicated by the legend. Since the ERS data were only available when the satellite was in sight of a ground station, only a limited spatial coverage is obtained. Figure 3.5 shows detailed wind vector plots over the Pacific near the US west coast. In the detail plots, a magenta marker on top of the wind arrow denotes land presence. Yellow wind arrows indicate that the Variational Quality Control flag is set, i.e. the Wind Vector Cell is spatially inconsistent. A yellow dot means that the KNMI Quality Control Flag is set.

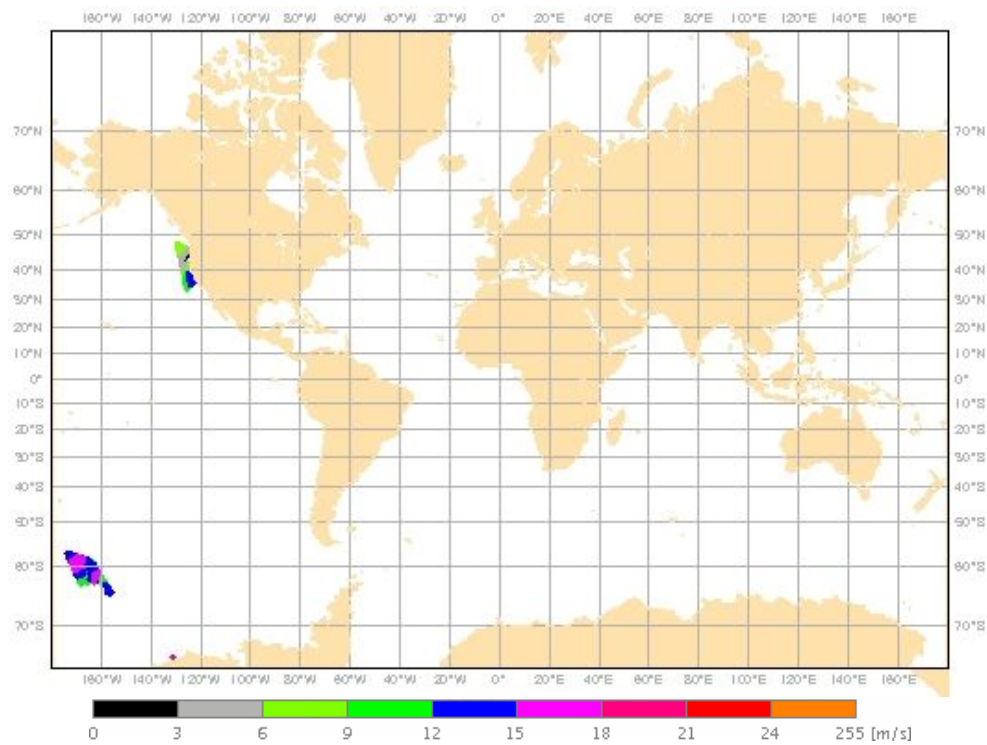


Figure 3.4 Global coverage of the ERS test run with AWDP.

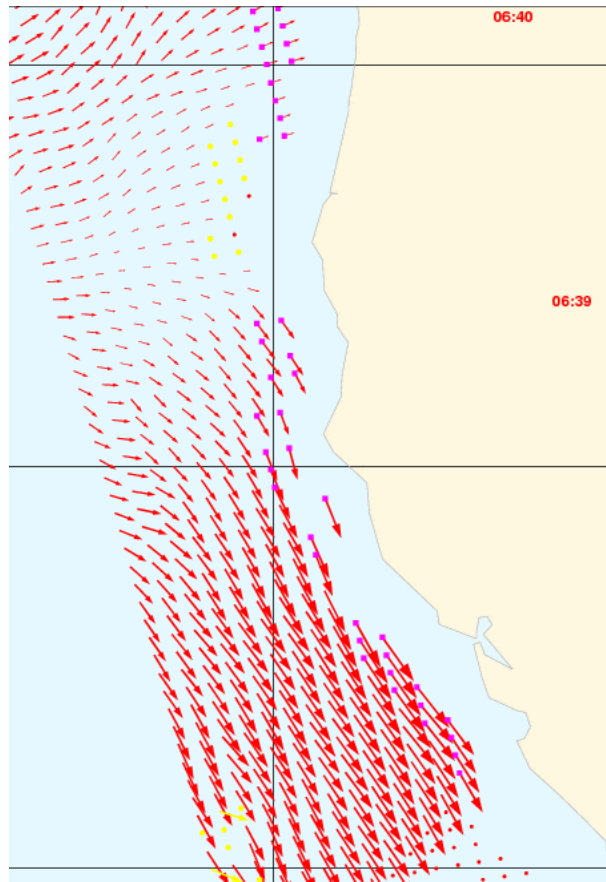


Figure 3.5 Detail plot of the ERS test run.

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Chapter 4

Validation tests

There is no other wind processing software available for ASCAT data so it is not possible to compare ASCAT winds from AWDP with ASCAT winds from other sources. On the other hand, there is ERS wind processing software available: the Prescat package [*Stoffelen*, 1998] has been used to routinely process ERS winds at KNMI for many years. In the next section we compare ERS winds computed with Prescat with those computed by AWDP.

ASCAT winds from AWDP are routinely compared with NWP and buoy data in the OSI SAF project. See <http://www.knmi.nl/scatterometer/osisaf/> for more information. In the scope of this Test Report, we show the results of a validation study of AWDP winds versus model wind forecasts from the ECMWF model, see section 4.2.

4.1 AWDP versus Prescat

Figure 4.1 shows the collocations of the ERS winds computed by Prescat and those computed by AWDP. Contoured histograms are shown for wind speed, wind direction and u and v wind components. In the wind direction plots, only those wind vectors where the Prescat wind speed is at least 4 m/s are taken into account. The bin sizes for the histograms are 0.5 m/s for wind speed, u and v , and 5° for wind direction.

The ERS data are those from 26 April 2007 which are also used in the previous section. It is clear from the plots that the results are almost spot on and no biases are discernable. Although a limited data set is used in this experiment, it is obvious that the AWDP winds are equivalent to the Prescat winds.

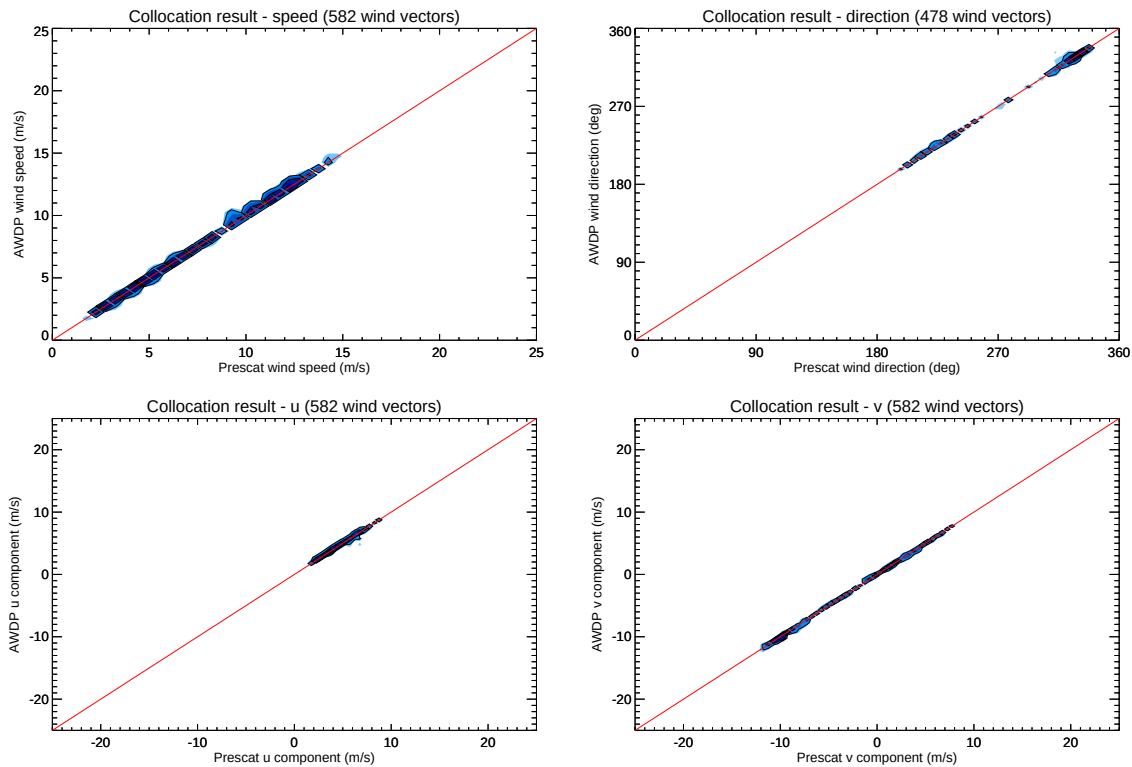


Figure 4.1 Collocation results of ERS winds from Prescat and AWDP.

4.2 AWDP winds versus ECMWF winds

We compared the ASCAT winds from AWDP with ECMWF forecast winds from the operational model (+3 to +21 hours forecasts from the 00 UTC and 12 UTC runs). The ASCAT data are 25 km Metop-A and Metop-B level 1b data from 1 and 2 November 2012 (28 orbits from both satellites).

Figure 4.2 shows the collocations of the ASCAT and ECMWF winds. Contoured histograms are shown for wind speed, wind direction and u and v wind components and after rejection of Quality Controlled (KNMI QC flagged) wind vectors. Note that the ECMWF winds are real 10m winds, whereas the scatterometer winds are equivalent neutral 10m winds, which are on average 0.2 m/s higher. In the wind direction plots, only those wind vectors where the model wind speed is at least 4 m/s are taken into account. The bin sizes for the histograms are 0.5 m/s for wind speed, u and v , and 2.5° for wind direction.

From the contour plots it is clear that biases are generally low. We obtain wind component standard deviations of 1.44 in u and 1.49 in v directions, both for Metop-A and Metop-B.

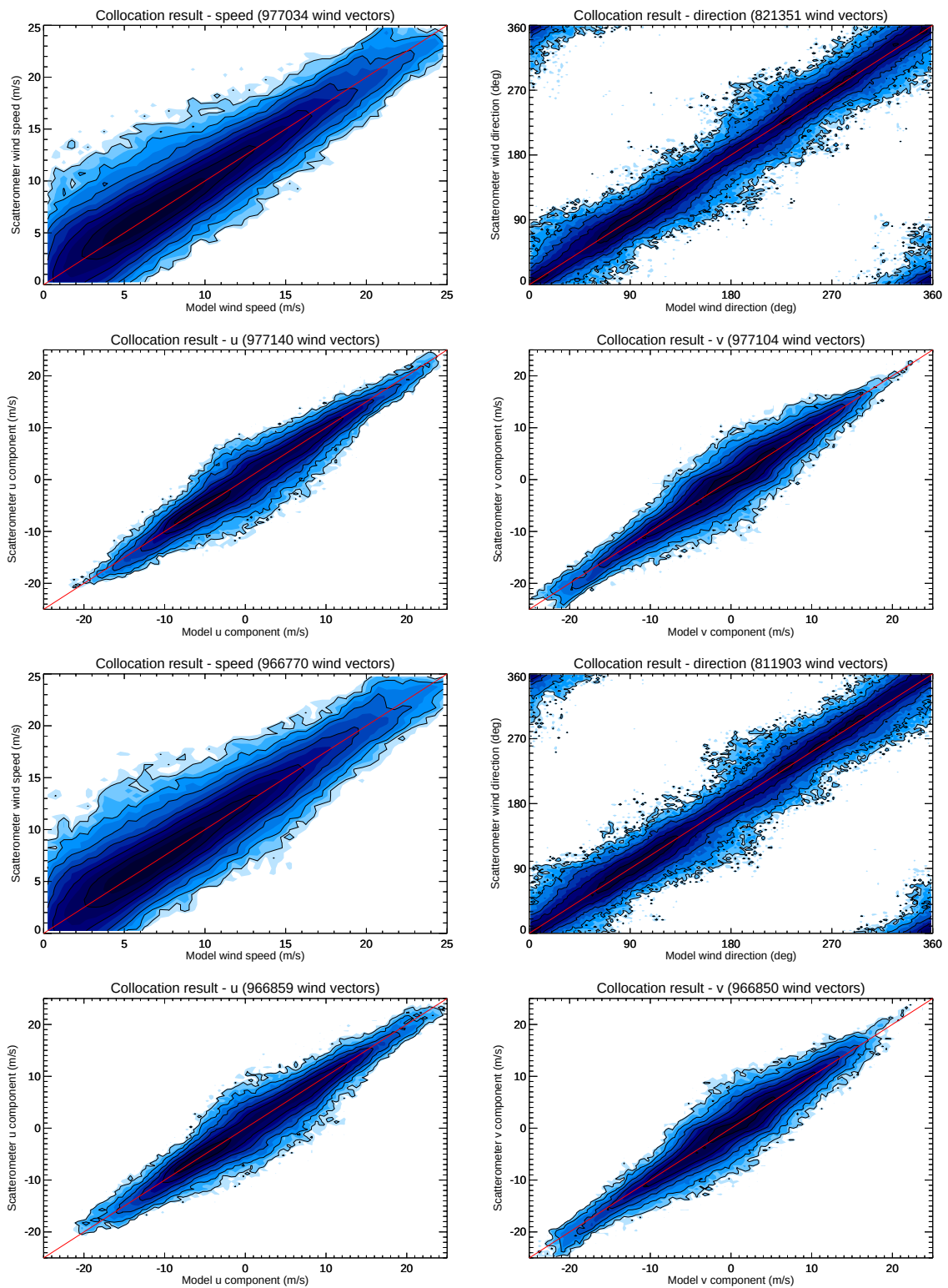


Figure 4.2 Collocation results of ASCAT winds from Metop-A (top) and Metop-B (bottom) versus ECMWF forecast winds.

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4.3 Ice screening test

Figure 4.3 shows the ice maps for North and South poles after processing three days of data. The test data are from 1 to 3 November 2012 (25 km Metop-A data only). Ice maps of the North Pole and South Pole are provided. The blue parts in the maps indicate open water; the black parts correspond to land areas or areas not visited within these three days. The gray scale is a measure of the ice A-parameter (albedo). Multi year ice has in general a higher albedo than first year ice, so lighter areas correspond to older ice. In the scope of this report we did not verify the ice extent in detail with other measurements. More information about the ice screening algorithm can be found in [Belmonte *et al.*, 2011].

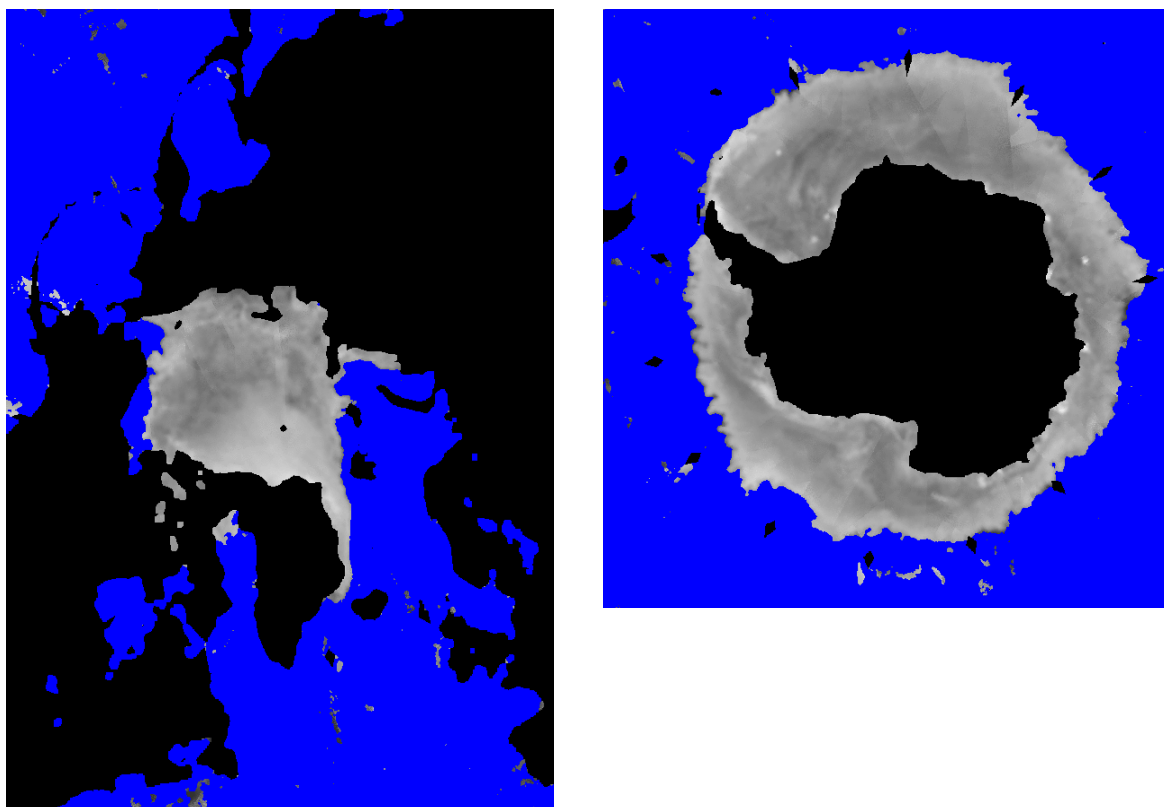


Figure 4.3 AWDP ice maps for North Pole (left) and South Pole (right).

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Chapter 5

Portability tests

The AWDP software package inherits its portability by using strict Fortran 90 code (with a few low level routines for reading and writing binary in C). AWDP is delivered with a complete make system. The Makeoptions include file of genscat takes care of the different settings needed under various platforms. This Makeoptions file is also used for the SeaWinds scatterometer wind processor SDP and the OSCAT scatterometer wind processor OWDP.

The default platform for development is a Linux work station. Different Fortran 90 compilers were used to compile both genscat and AWDP. Table 5.1 provides an overview of the platforms and compilers on which AWDP was tested successfully.

Platform	Operating system	Fortran compiler
Intel-based workstation	Fedora Linux	GNU g95, Portland f90, gfortran, Intel Fortran
SUN	SUN OS UNIX	Sun Fortran

Table 5.1 Supported platforms and compilers for AWDP.

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Chapter 6

User documentation tests

The user documentation (readme files within the software package and the AWDP User Manual and Reference Guide, [Verhoef *et. al.*, 2014]) has been will be provided to beta testers for review. The beta tester's comments have been implemented in the user documentation. User feedback on the documentation will also be implemented in future versions of the documentation.

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Appendix A

Acronyms

Name	Description
AMI	Active Microwave Instrument, scatterometer on ERS-1 and ERS-2 satellites
AR	Ambiguity Removal
ASCAT	Advanced SCATterometer on Metop
BUFR	Binary Universal Form for the Representation of data
C-band	Radar wavelength at about 5 cm
ERS	European Remote Sensing satellites
ECMWF	European Centre for Medium-range Weather Forecasts
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
genscat	generic scatterometer software routines
GMF	Geophysical model function
KNMI	Koninklijk Nederlands Meteorologisch Instituut (Royal Netherlands Meteorological Institute)
Ku-band	Radar wavelength at about 2 cm
L1b	Level 1b product
LSM	Land Sea Mask
LUT	Look up table
Metop	Meteorological Operational Satellite
MLE	Maximum Likelihood Estimator
MSS	Multiple Solution Scheme
NRCS	Normalized Radar Cross-Section (σ^0)
NWP	Numerical Weather Prediction
OSI	Ocean and Sea Ice
OSCAT	Scatterometer onboard of the Indian Oceansat-2 satellite
PFS	Product Format Specification (native Metop file format)
QC	Quality Control
RFSCAT	Rotating Fan beam Scatterometer
RMS	Root Mean Square
SAF	Satellite Application Facility
SSM	Surface Soil Moisture
SST	Sea Surface Temperature
WVC	Wind Vector Cell, also called node or cell

Table A.1 List of acronyms.