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# AWDP User Manual and Reference Guide

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KNMI, De Bilt, the Netherlands

<b>NWP SAF</b> <b>OSI SAF</b>	<b>AWDP User Manual and Reference Guide</b>	Doc ID : NWPSAF-KN-UD-005 Version : 3.3 Date : June 2020
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## AWDP User Manual and Reference Guide

KNMI, De Bilt, the Netherlands

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# 1 Introduction

This document is the User Manual (UM) of the ASCAT Wind Data Processor (AWDP) software package. The current introductory section gives general information about AWDP. Section 2 provides information on how to install, compile, and link the AWDP software. The use of AWDP is discussed in section 3.

More information about AWDP can be found in several other documents. The Product Specification (PS) [1] contains more details about the design of AWDP. Reading the UM and the PS should provide sufficient information to the user who wants to apply AWDP as a black box.

The Top Level Design (TLD) of the code and the Module Design (MD) of the AWDP code can be found in [2]. This document is of interest to developers and users who need more specific information on how the processing is done.

AWDP can be obtained through the NWP SAF website at <http://nwpsaf.eu>. Please note that any questions or problems regarding the installation or use of AWDP can be addressed at the OSI SAF helpdesk at <http://www.osi-saf.org/>.

## 1.1 Aims and scope

The ASCAT Wind Data Processor (AWDP) is a software package mainly written in Fortran 90 with some parts in C 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. [3] and [4] and information on the ESA and EUMETSAT web sites.

AWDP generates surface winds based on level 1b (L1b) or level 2 ASCAT and ERS data.

It has the ability to perform 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. The input of AWDP is Normalized Radar Cross Section (NRCS,  $\sigma^0$ ) data 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. Besides the nominal 25-km and 12.5-km products, AWDP also has the capability to generate a coastal wind product on 12.5-km or 6.25-km grids, where the backscatter data from the L1b files are replaced by box-averaged backscatter values from the full resolution level 1 ASCAT product (SZF data). This mode of operation produces winds that are closer to the coast than the winds from the nominal L1b data which contain backscatter values that are averaged using a Hamming filter, see [5]. EUMETSAT is planning to add a land fraction to their full resolution products which will help to improve wind coverage in coastal areas further once this is implemented. Although this new product version is not yet publicly available, test data have been received from EUMETSAT and the current AWDP version is able to handle the land fraction.

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Further tuning of the land flagging is still ongoing.

Apart from the ASCAT input data, 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.

AWDP is developed as code which can be run in an operational setting as is done by, e.g., the Ocean and Sea Ice Satellite Application Facility (OSI SAF). The coding is mainly in Fortran 90 with some parts in C and has followed the procedures specified for the NWP SAF. Special attention has been paid to robustness and readability. AWDP may be run on every modern Unix or Linux machine. AWDP can also be run on a Windows machine if a Linux environment like the Windows Installer for Ubuntu (Wubi) is installed or on a MacOS machine (Darwin).

## 1.2 Testing AWDP

Modules are tested by test programs. Many test programs are part of the modules themselves. Test programs can be compiled separately. For the AWDP program, the description of the test programs and the results of the testing are reported in [6].

## 1.3 Why use AWDP?

Scatterometers provide valuable observational data over the world's oceans. Therefore, successful assimilation of scatterometer data in numerical weather prediction systems generally improves weather forecasts. AWDP has been developed to fully exploit scatterometer data. It is meant to form the key component of the observation operator for surface winds in data assimilation systems, but it is also applicable for specific studies, in particular the 6.25-km and 5.7-km products.

The general scheme of AWDP (and any other wind scatterometer data processor) is given in figure 2.1. The input of AWDP is the EUMETSAT ASCAT L1b BUFR or PFS wind product (combined with ASCAT level 1 full resolution data in PFS in the case of coastal wind product processing) or the ESA ERS level 2 BUFR wind product. Besides this, GRIB input containing land-sea mask, sea surface temperature or soil temperature on level 0, and first guess winds over the globe is necessary. NWP data is not needed when AWDP is used on level 2 BUFR data which already contains model winds and ice flagging, or when ambiguity removal is omitted. See the description of the command line options in section 3.1 for more information on this.

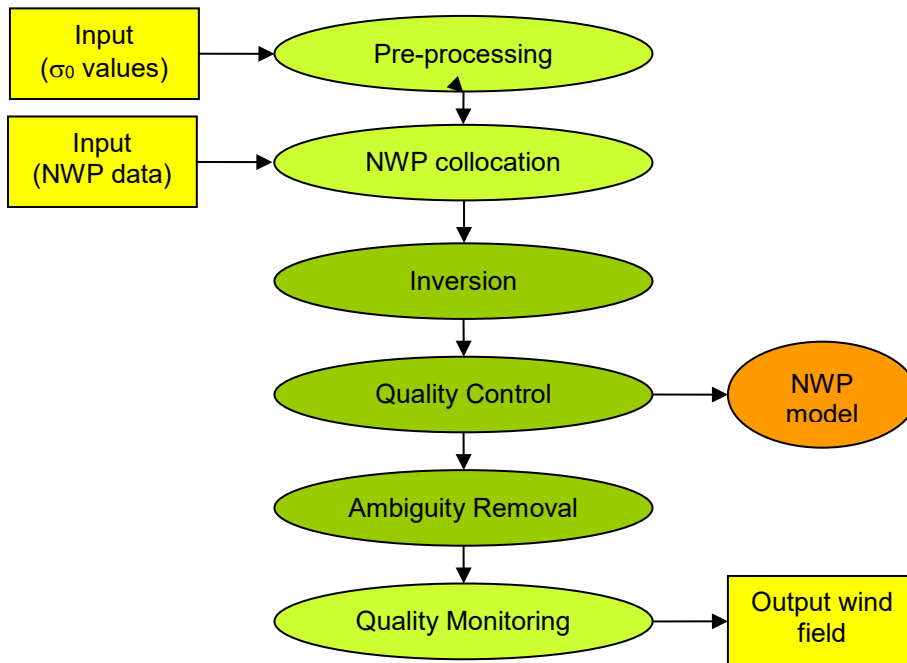
The AWDP processing chain contains several steps (see figure 2.1):

1. Pre-processing. The input file is decoded and the radar backscatter ( $\sigma^0$ ) values are written in the data structures of AWDP. In the case of coastal product processing (12.5-km, 6.25-km or 5.6-km grid), the full resolution (SZF) backscatter data are read and averaged. Some quality control on the input data is done.
2. Collocation with NWP data. The GRIB edition 1 or 2 files containing NWP data are read and the values for land fraction, sea surface temperature and first guess winds are interpolated and stored with the information of each WVC.
3. Inversion. The  $\sigma^0$  values are compared to the Geophysical Model Function (GMF) by means of a Maximum Likelihood Estimator (MLE). The wind vectors that give the best description of

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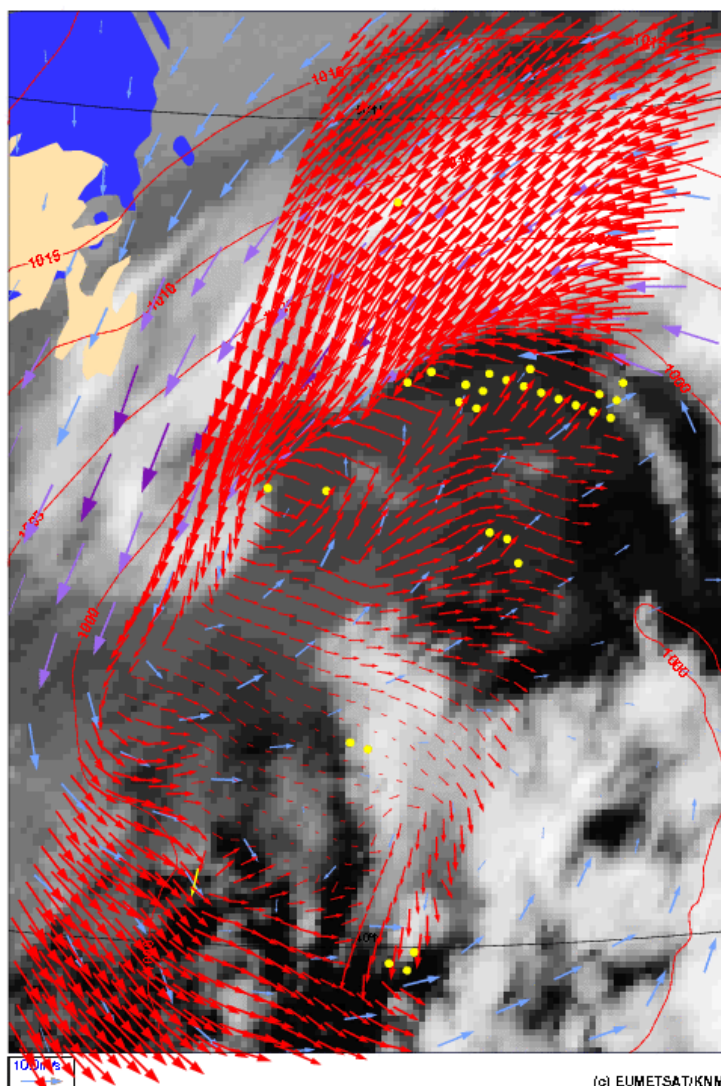
the  $\sigma^0$  values (the solutions) are retained. The MLE is also used to assign a probability to each wind vector. The normal scheme allows 4 solutions at most, but in the Multiple Solution Scheme (MSS) the maximum number of solutions is 144.

4. Quality Control. Solutions that lie far away from the GMF are likely to be contaminated by, e.g., sea ice or confused sea state. During Quality Control these solutions are identified and flagged.
5. Ambiguity Removal. This procedure identifies the most probable solution using some form of external information. AWDP uses a two-dimensional variational scheme (2DVAR) as default. A cost function is minimized that consists of a background wind field and all solutions with their probability, using meteorological balance, mass conservation and continuity as constraints.
6. Quality Monitoring. The last step is to output quality indicators to an ASCII monitoring file and to write the results in a BUFR format output file.



**Figure 2.1** AWDP processing scheme. The wind vectors and their probabilities after Quality Control may be fed directly in the Data Assimilation step of a Numerical Weather Prediction model.

Step 1, 2 and 6 of the processing chain are rather trivial; the real work is done in steps 3, 4, and 5. Note that an undesirable dependency arises if the output wind field is assimilated into a numerical weather prediction (NWP) model: in the 2DVAR Ambiguity Removal step (i) a background wind field is used and (ii) meteorological balance constraints causing spatially correlated error. Therefore it is recommended to feed the wind solutions and their probabilities directly into the NWP data assimilation step after Quality Control, as indicated in figure 2.1. If this is done, the Ambiguity Removal step can be skipped and consequently, no forecast winds are necessary in the NWP input. We are not aware of impact tests by assimilating AWDP outputs after ambiguity removal.



**Figure 2.2** AWDP wind field retrieved for 15 April 2007, approximately 13 h UTC, at 25 km cell spacing, near Newfoundland overlaid on a GOES IR satellite image. The yellow dots are rejected WVCs. The blue and violet arrows are a 6 hours forecast from the KNMI HIRLAM model.

As further detailed in [1], AWDP profits from developments in

- Inversion and output of the full probability density function of the vector wind (Multiple Solution Scheme, MSS).
- Quality Control (QC).
- Meteorologically balanced Ambiguity Removal (2DVAR) with the possibility of using numerical background error correlations and/or flow dependent errors.
- Quality monitoring.
- Capability to process ASCAT data on 25 km, 12.5 km, 6.25 km and 5.6 km cell spacing.

A complete specification of the AWDP software package can be found in the Product Specification [1]. The software is based on generic genscat routines. Genscat lies at the base of all



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scatterometer wind processors developed within NWP SAF. Genscat is a library of generic code suitable for all scatterometer instruments. It contains routines for e.g. wind inversion, ambiguity removal, reading and writing of files in BUFR, GRIB, and other formats. It also contains more low-level routines for e.g. date/time handling and numerical conversions. These routines are discussed in more detail in [1].

Genscat is owned by the NWP SAF. The code base is quite stable and most development work is done in the instrument-specific code that is built on top of genscat. For each new wind processor release, a dedicated genscat version is delivered which is tested by running the new configuration in parallel to the operational one and carefully comparing the outputs. Genscat is used as basis for all scatterometer wind data processors.

## 1.4 Modes of using AWDP

There are several modes to assimilate the ASCAT data in NWP models using AWDP. Anyway, the first thing to assure oneself of is the absence of biases by making scatter plots between ASCAT and NWP model first guess for at least wind speed, but wind direction and wind components would also be of interest to guarantee consistency.

The operational ASCAT wind product, available as a deliverable from the EUMETSAT OSI SAF project, could be the starting point for NWP assimilation:

1. The unique solution at every WVC may be assimilated as if it were buoy data. This is the fastest way and one exploits the data to a large extent. For a small advantage, AWDP could be installed to provide 2DVAR solutions based on the local first guess.
2. The AWDP software may be used to modify the 3DVAR or 4DVAR data assimilation system to work with the ambiguous wind solutions and their probabilities at every WVC. This represents some investment, but is applicable for all scatterometer data. The advantage with respect to option 1 in the ambiguity removal occurs only occasionally, but always in dynamic atmospheric cases (storms or cyclones) that are really relevant.

Both options can be based on AWDP in standard or MSS mode, and at various resolutions. MSS is somewhat more dependent on the first guess and balance constraints in 2DVAR than the standard AWDP, but much less noisy. A noticeable advantage is thus obtained by using option 2 and potentially the full hi-res benefit of the ASCAT data is achieved. The mode of using AWDP thus depends on the opportunities, experience, and time the user has to experiment with ASCAT data in the NWP system under consideration.

AWDP can, of course, also be used to create a stand-alone wind product, e.g., for nowcasting purposes. Such a stand-alone ASCAT wind product is a deliverable of the OSI SAF project. More information on this project can be found on <http://www.osi-saf.org/>. Note, however, that the OSI SAF does not deliver an ASCAT product on a 6.25 or 5.6 km grid. This product can only be generated by running AWDP yourself, see section 2.6.2 for some guidance.

## 1.5 Conventions

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

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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/>).

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## 2 Installing AWDP

The AWDP software package can be ordered from the NWP SAF website on <https://www.nwpsaf.eu/site/software/scatterometer/download/>. AWDP is written in Fortran 90 (with a few low level modules in C) and is designed to run on a modern computer system under Linux or Unix. AWDP needs a Fortran 90 compiler and a C compiler for installation. Also, CMake version 3.6 or higher (<https://cmake.org/>) is required in order to compile the ecCodes library. AWDP comes along with a complete make system for compilation. In some cases, the Makefiles call installation scripts which are written in Bourne shell to enhance portability. When compiled, AWDP requires about 100-150 Mb disk space. The package is intended to be installed in a user directory (e.g. the home directory) and sufficient disk space and write permissions should be available. If the executable is to be installed into a system directory like `/usr/bin`, generally root permissions are necessary.

AWDP has been successfully implemented on many different computer platforms and with many different compilers and compiler versions. Hence we can not specify exact requirements to compiler versions. For example, AWDP has been tested recently with the following compiler versions:

- GCC version 9.3.1 of 20200408
- GNU Fortran (gfortran) version 9.3.1 of 20200408
- Portland Fortran compiler version 11.10-0

In principle, AWDP may also run under Windows. However, it needs the BUFR and ecCodes libraries from ECMWF, and this poses some restrictions on the systems supported. Under Windows one must use a (free) Linux environment like Wubi (see <http://www.ubuntu.com/download/desktop/windows-installer> for more information and download).

To install AWDP, the following steps must be taken:

1. Copy the AWDP package (file `AWDP<version>.tar.gz`) to the directory from which AWDP will be applied, and unzip and untar it. This will create subdirectories `awdp` and `genscat` that contain all code needed (see section 2.1), and a script called `InstallAWDP` for easy compilation.
2. Unlike in older AWDP versions, it is not necessary anymore to download the BUFR and ecCodes libraries separately from the ECMWF website, they now fall under the Apache License, Version 2.0 and can be redistributed in combination with PenWP. You may obtain a copy of the License at <http://www.apache.org/licenses/LICENSE-2.0>.
3. Go to the top directory where the AWDP package (tar file) was copied to and run the `./InstallAWDP` script. The script will ask for the compiler used and it will invoke the

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make system for compilation and linking of the software (see also section 2.4).

AWDP is now ready for use, provided that the environment variables discussed in section 2.5 have the proper settings. See also sections 3.1 and 3.2 for directions on how to run AWDP.

## 2.1 Directories and files

All code for AWDP is stored in a file named `AWDP<version>.tar.gz` that is made available in the framework of the NWP SAF project. This file should be placed in the directory from which AWDP is to be run. After unzipping (with `gunzip AWDP<version>.tar.gz`) and untarring (with `tar -xf AWDP<version>.tar`), the AWDP package is extracted in subdirectories `awdp` and `genscat`, which are located in the directory where the tar file was located. Subdirectories `awdp` and `genscat` each contain a number of files and subdirectories. A copy of the release notes can also be found in the directory `awdp/doc`.

Tables 2.1 and 2.2 list the contents of directories `awdp` and `genscat`, respectively, together with the main contents of the various parts. Depending on the distribution, more directories may be present, but these are of less importance to the user.

<b>Name</b>	<b>Contents</b>
<code>doc</code>	Documentation, including this document
<code>execs</code>	Link to <code>awdp</code> executable, shell script for running AWDP
<code>src</code>	Source code for AWDP program and supporting routines
<code>tests</code>	Example BUFR and GRIB input files for testing purposes.

**Table 2.1** Contents of directory `awdp`.

Directories `awdp` and `genscat` and their subdirectories contain various file types:

- Fortran 90 source code, recognizable by the `.F90` extension;
- C source code, recognizable by the `.c` extension;
- Files and scripts that are part of the make system for compilation like `Makefile_thisdir`, `Makefile`, `use_`, `Objects.txt` and `Set_Makeoptions` (see 2.3.4 for more details);
- Scripts for the execution of AWDP in directory `awdp/execs`;
- Look-up tables and BUFR tables needed by AWDP;
- Files with information like `Readme.txt`.

After compilation, the subdirectories with the source code will also contain the object codes of the various modules and routines.

<b>Name</b>	<b>Contents</b>
<code>ambrem</code>	Ambiguity removal routines
<code>ambrem/twodvar</code>	KNMI 2DVAR ambiguity removal routines
<code>inversion</code>	Inversion and quality control routines
<code>support</code>	General purpose routines sorted in subdirectories

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Name	Contents
support/BFGS	Minimization routines needed in 2DVAR
support/bufr	BUFR tables (in subdirectory) and file handling routines
support/Compiler_Features	Compiler specific routines, mainly command line handling
support/convert	Conversion between wind speed/direction and $u$ and $v$
support/datetime	Date and time conversion routines
support/ErrorHandler	Error handling routines
support/file	File handling routines
support/eccodes	GRIB file handling routines
support/netcdf	NetCDF file handling routines
support/num	Numerical definitions and number handling routines
support/pfs	PFS file handling routines
support/singletonfft	FFT routines needed in minimization
support/singularity_analysis	Singularity exponent routines needed for flow-dependent errors in 2DVAR
support/sort	Sorting routines

**Table 2.2** Contents of directory `genscat`.

## 2.2 Installing the BUFR library

AWDP needs the ECMWF BUFR library for its input and output operations. The library tar file was downloaded from ECMWF and it is included in the AWDP software package. The package contains scripts for compilation and installation.

Directory `genscat/support/bufr` contains the shell script `make.bufr.lib`. It unzips, untars, and compiles the BUFR library file. This script is part of the `genscat` make system and it is automatically invoked when compiling `genscat`.

BUFR file handling at the lowest level is difficult to achieve. Therefore some routines were coded in C. These routines are collected in library `bufrio` (see also [2]). Its source code is located in file `bufrio.c` in subdirectory `genscat/support/bufr`. Compilation is done within the `genscat` make system and requires no further action from the user (see 2.4).

## 2.3 Installing the ecCodes library

AWDP needs the ECMWF ecCodes library for its input operations. The library tar file was downloaded from ECMWF and it is included in the AWDP software package. The package contains scripts for compilation and installation.

Directory `genscat/support/eccodes` contains a Makefile unzips, untars, and compiles the ecCodes library file. This Makefile is part of the `genscat` make system and it is automatically invoked when compiling `genscat`. Note that CMake version 3.6 or higher (<https://cmake.org/>) is required in order to compile the ecCodes library.

By default, the library for handling GRIB messages that are compressed using the JPEG algorithm, (as is done e.g. by NCEP) is not linked in the compilation process. This option can be activated by adding the link option `-lopenjpeg` to the `Makeoptions` file in directory `genscat`:

```
LINKFLAGS = $(LIB) -lopenjpeg
```

After this change, the software in directories `genscat/support/eccodes` and `awdp/src`

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needs to be recompiled using the commands `make clean` and `make`.

## 2.4 Manual compilation and linking

Compilation and linking of AWDP under Linux or Unix is done in three steps:

1. Set the compiler environment variables according to the choice entered on request. This can be done by running the appropriate `use_*` scripts in directory `genscat`.
2. Go to directory `genscat` and type `make`.
3. Go to directory `awdp` and type `make` to produce the executable `awdp` in directory `awdp/src`.

Before activating the `make` system, some environment variables identifying the compiler should be set. These variables are listed in table 2.4. The environment variables in table 2.4 can be set by using one of the `use_*` scripts located in directory `genscat`. Table 2.5 shows the properties of these scripts. The scripts are available in Bourne shell (extension `.bsh`) and in C shell (extension `.csh`). Note that if one of the environment variables is not set, the default `f90` and `cc` commands on the Unix platform will be invoked. Note that in the top directory a script called `InstallAWDP` is provided that asks the user which compiler he wants to use and invokes the appropriate `use_*` script (step 1 above), after which the compilation in the `genscat` and `awdp` directories is performed (steps 2 and 3 above).

Variable	Function
<code>\$GENSCAT_F77</code>	Reference to Fortran 77 compiler
<code>\$GENSCAT_F90</code>	Reference to Fortran 90 compiler
<code>\$GENSCAT_CC</code>	Reference to C compiler
<code>\$GENSCAT_LINK</code>	Reference to linker for Fortran objects
<code>\$GENSCAT_CLINK</code>	Reference to linker for C objects
<code>\$GENSCAT_SHLINK</code>	Reference to linker for shared objects

**Table 2.4** Environment variables for compilation and linking.

Script	Fortran compiler	C compiler	Remarks
<code>use_g95</code>	<code>g95</code>	<code>gcc</code>	GNU compilers by A. Vaught
<code>use_gfortran</code>	<code>gfortran</code>	<code>gcc</code>	GNU-GCC 4.0 compiler collection
<code>use_ifort</code>	<code>ifort</code>	<code>icc</code>	Intel Fortran and C compilers
<code>use_pgf90</code>	<code>pgf90</code>	<code>gcc</code>	Portland Fortran compiler

**Table 2.5** Properties of the `use_*` scripts.

Example: To select the GNU Gfortran compiler under Bourne, Bash or Korn shell type `“.use_gfortran.bsh”`, the dot being absolutely necessary in order to apply the compiler selection to the current shell. Under C shell the equivalent command reads `“source use_gfortran.csh”`.

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If the user wants to use a Fortran or C compiler not included in table 2.6, he can make his own version of the `use_*` script, or set the environment variables for compilation and linking manually.

AWDP is delivered with a complete make system for compilation and linking under Unix or Linux. The make system is designed as portable as possible, and system dependent features are avoided. As a consequence, some tasks must be transferred to shell scripts. The make system consists of two parts: one for AWDP and one for `genscat`. The `genscat` part should be run first. For compilation and linking of the `genscat` part, the user should move to the `genscat` directory and simply enter `make`.

The Makefile refers to each subdirectory of `genscat`, invoking execution of the local Makefile and, in cases where a subdirectory contains code as well as a subdirectory containing code, `Makefile_thisdir`. The settings for the compilers are located in file `Makeoptions` in directory `genscat`. This file is generated by the Bourne shell script `Set_Makeoptions` which is called automatically by the `genscat` make system. The local Makefile in subdirectory `genscat/support/bufr` calls the script `make.bufr.lib` for compilation of the BUFR library (see 2.2). It also contains the Fortran program `test_modules` that generates the binary BUFR tables B and D from the ASCII tables already present, and is executed automatically by the make system. Program `test_modules` can also be used to test the `genscat` BUFR module. The Makefile in subdirectory `genscat/support/bufr/bufr_tables` calls some shell scripts, which make symbolic links (using the `ln -s` command) of the generic binary BUFR tables B and D under different names. There are four different naming conventions in BUFR version 000240 to 000280, and binary files are generated for each of them. Further information on the make system is given in the inline comments in the scripts and Makefiles.

Compilation and linking of the AWDP part is done in a similar manner: go to the `awdp` directory and enter `make`. As with `genscat`, the make system will execute Makefiles in every subdirectory of `awdp`. The result is the executable `awdp` in directory `awdp/src` and a symbolic link to this executable in `awdp/execs`. AWDP is now ready for use. The make system of AWDP doesn't need any further files except the `genscat` file `Makeoptions`. This is the reason why `genscat` should be compiled first.

When recompiling (part of) AWDP or `genscat` with the make system, for instance when installing a new version of the BUFR library, one should be sure to enter `make clean` first. To recompile part of the software invoke the make system where needed. The compiler settings from file `Makeoptions` in directory `genscat` will be used again. If a change in these settings is necessary, type `make clean` in the `genscat` directory and `Makeoptions` will be removed. Don't forget to rerun the `use_*` commands to select the right compiler.

## 2.5 Environment variables

AWDP needs a number of environment variables to be set. These are listed in table 2.3 together with their possible values.

Name	Value
<code>\$BUFR TABLES</code>	<code>genscat/support/bufr/bufr_tables/</code>
<code>\$GRIB DEFINITION PATH</code>	<code>genscat/support/eccodes/definitions</code>

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\$INVERSION_LUTSDIR	genscat/inversion
\$LUT_FILENAME_C_VV	Any existing, writable path + file name
\$NBEC_FILE	/genscat/ambrem/nbec_ascat-a-coa_cos-auto-4000_tccal_obserrcorr.dat
\$AGGREGATION_FILE	awdp/data/aggregation table 1MXo-IandS.dat

**Table 2.3** Environment variables for AWDP.

The \$BUFR\_TABLES variable guides AWDP to the BUFR tables needed to read the input and write the output. The \$GRIB\_DEFINITION\_PATH variable is necessary for a proper functioning of the GRIB decoding software.

The variable \$INVERSION\_LUTSDIR should point to a directory containing some look up tables (extension .asc) that are used by the inversion software. The necessary tables are delivered with genscat.

The variable \$LUT\_FILENAME\_C\_VV points AWDP to the correct C band GMF lookup table at VV polarisation. It should contain a file name including a valid path. If the file does not exist, it will be created when the inversion is invoked for the first WVC, for CMOD versions lower than 7. In order to prevent confusion, it is advised to use standard file names <path>/cmod5.dat, <path>/cmod5\_5.dat, <path>/cmod5\_n.dat, or <path>/cmod6.dat, since the inversion software uses the file name to determine which CMOD version is used. For CMOD7, the GMF is delivered with AWDP as a table in directories awdp/data/little\_endian and awdp/data/big\_endian. The script awdp\_run in directory awdp/execs will automatically choose an appropriate value for the GMF filename.

Variable \$NBEC\_FILE points AWDP to the file containing the numerical background error correlations [7], Variable \$AGGREGATION\_FILE points AWDP to the aggregation table needed to generate averaged radar cross section triplets for the 5.6 km product [8].

It may happen that running AWDP results in an error message like ‘error while loading shared libraries: libzzz’. In such cases it may help to locate the specified shared object file on your system and to set the \$LD\_LIBRARY\_PATH variable to this directory.



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## 3 Processing details

### 3.1 Command line options

The AWDP main program is started from directory `awdp/execs` with the command

```
awdp [options/modes] -f <BUFR/PFS file> [-nwpfl <file>]
```

with `<>` indicating obligatory input, and `[]` indicating non-obligatory input. For normal AWDP operation we recommend to use the `awdp/execs/awdp_run` script which will call AWDP and pass its command line options to the AWDP executable. The following command line options are available.

**-f <input file>** Process a BUFR or PFS input file with name `input file`. AWDP detects if the input file is in BUFR format. If so, AWDP will produce output on the same grid as the input file. If not, it attempts to read the input as PFS file. If the PFS file contains 25 km or 12.5 km data, AWDP will generate output on the same grid. If the PFS file contains full resolution L1b data AWDP will generate a coastal product on a 12.5 km grid or on a 6.25 km grid if also the `-grid_size_0625` option is given (see below).

Example: `awdp -f ascat_20070426_test_250.11_buf` will process this file. The results will be written to a new BUFR file, see below in this section for the output file naming convention. It is possible to concatenate multiple BUFR input files into one using the Unix `cat` command, but PFS files must be processed one by one.

**-nwpfl <file>** Read a list of GRIB file names in the file named `file`. The files in the list are read and the GRIB edition 1 or 2 data are used in the wind processing. The most convenient way to construct a file list is to use the Unix command `ls -l GRIB file pattern > file`. Note that the `'-l'` contains the number `'1'` and not the character `'l'`. If no GRIB data are used, only the land masking which is present in the L1b beam information will be used. No ice screening will be performed (unless the `-icemodel` option is used). Ambiguity removal will be performed only if model winds are already present in the input BUFR file (i.e., in case of reprocessing of a level 2 file) or if the `-armeth 1strank` option is used (i.e., selection of the 1<sup>st</sup> rank wind solution). If level 2 data are reprocessed and no NWP data are read, the `qual_sigma0` flag which was set in the initial processing is evaluated and it will be used to determine if a WVC contains suitable backscatter data for wind inversion.

Several options for the processing can be invoked:

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- ignorelsm** Ignore the land-sea mask in the grib file list specified in the `-nwprfl` command.
- szffl <file>** Read a list of full resolution PFS file names in the file named `file`. The files in the list are read and the full resolution PFS data (SZF) are used to replace the 25-km/12.5-km/6.25-km beam data. This option is intended to produce a coastal wind product. The beam data ( $\sigma^0$  values, incidence and azimuth angles) which are read from the BUFR or PFS L1b input file, are replaced by average values of the data from the full resolution file which are located within a certain radius (7.5 km for a 6.25-km grid and 15 km for a 12.5-km grid) from the WVC location. See [2] for more information.
- grid\_size\_0625** Generate a coastal product on a 6.25 km grid. The input file (`-f` option) should be a full resolution L1b file [9].
- aggr** Generate a wind product on a 5.7 km grid with optimised radar sampling. The input file should be a full resolution L1b file [8].
- noinv** Switch off inversion (default is switched on). This option is useful to save processing time when wind inversion is already done in the input file, i.e., when an AWDP BUFR output file is reprocessed. For example, the NWP background winds can be replaced and the ambiguity removal performed in one run without repeating the wind inversion.
- icemodel <IM>** Choose ice screening method to be used: 0 (default), 1 or 2. The value 0 results in no ice screening, except when a GRIB file containing sea surface temperature is read. The value 1 invokes a simple (non-Bayesian) ice model which does not keep history of the water or ice state of each location. Value 2 invokes the Bayesian ice model which keeps the history of each location and uses this history to determine the sea or ice state of a WVC. The ice screening can be combined with the ice screening which is done in the GRIB collocation. In this case, the SST of the GRIB file will be used to assign a WVC as 'surely water' when the SST is above +5.0 °C, to support the Bayesian ice screening.
- noamb** Switch off ambiguity removal (default is switched on). This option is useful if the selection of the scatterometer wind solution is left to the data assimilation procedure of a Numerical Weather Prediction model. In other words: the NWP model is fed with a number of solutions and their probability, and finds the best value when comparing with other data sources.
- nowrite** Do not produce BUFR output (default is switched on).
- ignorellflags** Ignore the setting of L1b  $\sigma^0$  related flags in BUFR input. If this option is switched on, the value of the flags and quality indicators in the beam information, including the sigma0 usability and land fraction, is

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neglected.

- cmod <N>** Choose CMOD version 4, 5, 55, 5n, 6 or 7 (default).  
With this option, the user can choose between GMF version CMOD4, CMOD5, CMOD5.5 (CMOD5 + 0.5 m/s), CMOD5n (CMOD5 for neutral winds), CMOD6 or CMOD7. The GMF table is generated by the software and written to a binary file named `c-vv2.dat` in the current directory, if it does not yet exist for CMOD versions up to and including 6. Alternatively, the user may specify a file name (including path) in the environment variable `$LUT_FILENAME_C_VV`. If `$LUT_FILENAME_C_VV` is present, it will be used to store the GMF. A second file with the same name and extension `.zspace` is also generated. Note: the old GMF files need to be removed if new files need to be generated, i.e., if a different GMF version is requested. The script `awdp/execs/awdp_run` automatically chooses an appropriate GMF table filename.
- calval** Perform  $\sigma^0$  calibration (NWP Ocean Calibration, default is switched off). A calibration of the  $\sigma^0$  values is performed. See [10] for more details. Calibration coefficients are applied dependent on the satellite (Metop A or B), the GMF version and the level 1 data processing version.
- armeth <meth>** Choose ambiguity removal method.  
Valid methods are: `1strank` - the wind solution with the lowest distance to the GMF (residual) is selected, `bgclosest` - the wind solution closest to the background model wind is selected, `prescat` - see [2], `2dvar` - 2DVAR, see [2]. The default is `2dvar`.
- mss** Use the Multiple Solution Scheme for Ambiguity Removal.  
If the Multiple Solution Scheme (MSS) is switched on, AWDP internally works with 144 different solutions for the wind vector. If MSS is switched off, AWDP calculates four solutions at most. MSS is switched off as default.
- nbec** Use numerical background error correlations in 2DVAR [7].
- 2s1b** Process both ASCAT swaths in a single batch (speeds up ambiguity removal a bit).
- fde** Use flow-dependent errors for the scatterometer observations and the model background in 2DVAR. Default: use constant errors. See [7] for more details.
- binof <file>** Write selected data of each WVC to a binary output file.  
Data are written to a binary file `<file>`. This option is intended for research activities. More information on the file format can be found in the Fortran code of AWDP.
- writeall** Write all data to BUFR output, including level 2 input data.  
In the normal near-real time processing, a mixture of L1b and (recent)

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level 2 data is fed into AWDP in order to provide more data, which is beneficial for ambiguity removal. Only those data rows which were L1b input, are written to the level 2 output file. This option overrides this behaviour and writes all rows to the output file.

- handleall** Perform NWP collocation, inversion, ambiguity removal and output writing in all WVCs.  
By default, these steps are done only for WVCs which are L1b input, see the description at the `-writeall` option. This option is useful for reprocessing level 2 data.
- nws <N>** Write N wind solutions in BUFR output (default 4).  
The number of wind solutions to be written into the ASCAT BUFR format is flexible due to the use of the so-called delayed replication and can be chosen between 1 (providing only the selected wind solution) and 144 (providing all wind solutions in MSS processing).
- subc <SC>** Set id of sub-centre in each WVC of the BUFR output to SC.  
By default it is copied from input.
- mon** Switch on the monitoring function.  
The monitoring results are written in an ASCII file with the name `monitoring_report.txt`. By default, no monitoring file is produced.
- verbosity <L>** Set the verbosity level to L (default is 0).  
If the verbosity level is -1 or smaller, no output is written to the standard output except error messages. If the verbosity level equals 0 only some top level processing information is written to output. If the verbosity level is 1 or greater, also additional information is given.
- stressparam, -ana, -varqc, -ocf, -research, -orpm, -wpo, -wpos, -distance, -mlf, -kp, -grid\_size\_2dvar, -grid\_extent\_2dvar**  
Various options intended for research activities. More information can be found in the Fortran code of AWDP and genscat.

The normal mode of operation of AWDP is wind processing, i.e., a BUFR or PFS file is read and the various processing steps are performed. Note that by default, AWDP does not recalculate data that are already present in the input. For example, if a WVC already contains model winds then the GRIB collocation will not be done for this WVC; if a WVC already contains wind solutions then the wind inversion will not be performed. This behaviour is desired when near-real time processing is performed and a mixture of L1b and level 2 files is fed into AWDP. If one wants to perform reprocessing of level 2 files, the behaviour of AWDP can be changed by the command line options, e.g. the `-handleall` option.

Besides the wind processing, some other modes of operation are available. If one of the modes is invoked, AWDP internally sets some of the options in order to obtain the desired result. Note that these modes are always used in combination with the `-f <input file>` option.

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- mononly** Write the monitoring file without any processing.
- properties** Write some properties of the last row of the input file.  
The acquisition date and time and the sub-centre id are written to a small ASCII output file `properties.txt`.
- writeonly** Write all data to BUFR output without processing.  
This mode is useful to copy an input file to BUFR output without processing.

Running the command `awdp` without any command line options will display a list of all available command line options with a short explanation on the console. Running the command `awdp` with an illegal option will produce the same output, but preceded by an error message.

The output will be written into a BUFR file with the name

`INSTR_YYYYMMDD_HHMMSS_SAT_ORBIT_srv_o_SMPL(_CONT).l2_bufr,`

where

- `INSTR` is the instrument, `ascat` or `scatt`.
- `YYYYMMDD_HHMMSS` is the acquisition date and time (UTC) of the first data in the file.
- `SAT` is the satellite (6 characters), `ers1__`, `ers2__`, `metopa` or `metopb`.
- `ORBIT` is the orbit number (5 digits) of the first data in the file, `00000` for ERS data.
- `SMPL` is the WVC sampling (cell spacing), `250` for 25 km and `125` for 12.5 km.
- `_CONT` (contents) is omitted if the data contains both wind and soil moisture data. Otherwise it is set to `_ovw` (Ocean Vector Winds) or `_ssm` (Surface Soil Moisture).

Example: `ascat_20070426_095102_metopa_02681_srv_o_250_ovw.l2_bufr`

## 3.2 Scripts

Directory `awdp/execs` contains a Bourne shell script `awdp_run` for running `awdp` with the correct environment variables. The script can be invoked with all valid command line options for `awdp`. In the same directory, there is also a script `awdp_gui.py` available. This script provides a convenient graphical user interface and builds and runs an AWDP command line depending on settings of available radio buttons, check boxes et cetera. This script requires Python to be installed on your system. It may be necessary to change some of the environment variables set in the top part of the script.

Directory `awdp/tests/hires` contains a Python script `run_awdp-6.25.py` for processing ASCAT full resolution L1b data. See section 2.6.2 for more information.

## 3.3 Test data and test programs

### 3.3.1 AWDP tests

Directory `awdp/tests` contains two BUFR files for testing the AWDP executable. File `ascat_20070426_test_250.11_bufr` contains ASCAT L1b 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

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available in file `ascat_20070426_test_125.11_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
```

Note that the '-l' contains the number '1' and not the character 'l'. Then run AWDP on 25-km and 12.5-km cell spacing:

```
../execs/awdp_run -f ascat_20070426_test_250.11_bufr -mon -calval -nwpfl nwpflist
```

```
../execs/awdp_run -f ascat_20070426_test_125.11_bufr -mon -calval -nwpfl nwpflist
```

The result should be two ASCAT level 2 files in BUFR format, called

`ascat_20070426_095102_metopa_02681_srv_o_250_ovw.12_bufr`

and

`ascat_20070426_095100_metopa_02681_srv_o_125_ovw.12_bufr`, respectively.

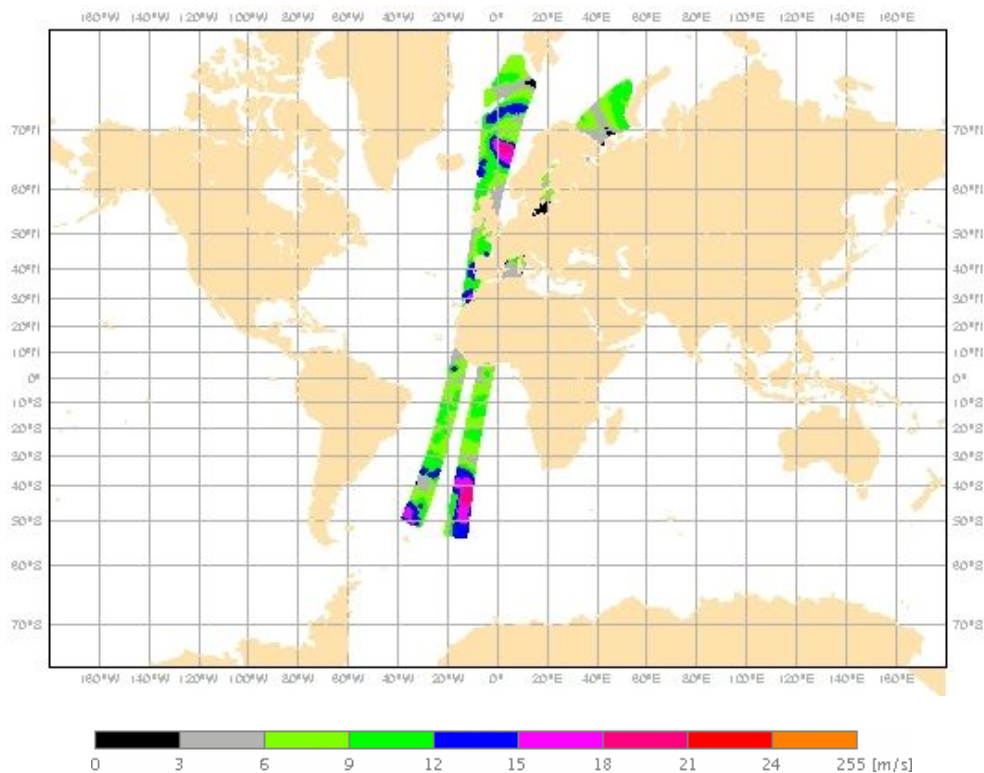
Figure 2.3 shows the global coverage of the test run on 25 km. The colours indicate the magnitude of the wind speed as indicated by the legend. The result on 12.5 km should be very similar to this.

Directory `awdp/tests` also contains an ERS BUFR file in ESA format, called `scatt_20070426_test_250.11_bufr` in ESA BUFR format. 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_250.11_bufr - mon -nwpfl nwpflist
```

The result should be an output file in ASCAT BUFR format, called `scatt_20070426_063627_ers2___00000_srv_o_250_ovw.12_bufr`.

Note that conversion software is delivered with AWDP to convert the BUFR output files into ASCII or NetCDF formats which are more convenient to visualise using publicly available software tools. These tools can be found in in directories `genscat/tools/bufr2asc` and `genscat/tools/bufr2nc` and are ready to use after compilation of AWDP. More information on the use of this software is available on [http://www.knmi.nl/scatterometer/bufr\\_reader/](http://www.knmi.nl/scatterometer/bufr_reader/).



**Figure 2.3** Global coverage of the test run. Wind speed results for the 25 km product are shown.

### 3.3.2 High resolution processing tests

Directory `awdp/tests` also contains subdirectory `hires`. This subdirectory contains a BUFR file named `ascat_A_20151027_164500_250_test.bufr` with three minutes of data and three consecutive L1b full resolution files with names starting with `ASCA_SZF_1B_M02`. Each file contains three minutes of data and the mid beam of the middle one covers the same area as the BUFR file. Further, `awdp/tests/hires` contains some ECMWF GRIB files (names starting with `ECMWF`), a list of full resolution L1b files named `szflist`, and a list of ECMWF GRIB files named `nwplist`.

Note that the first line in `nwplist` refers to a GRIB file in `genscat/support/eccodes` named `lsm_hires.grib`. This file contains a high resolution land-sea mask. The second file in `nwplist` also contains a land-sea mask (and sea surface temperature), but at a coarser resolution. AWDP will use the first land-sea mask it finds in the NWP file list, and for high resolution processing it is absolutely necessary that AWDP uses file `lsm_hires.grib` as land-sea mask. In particular, the tests described below may fail if an other land-sea mask is used.

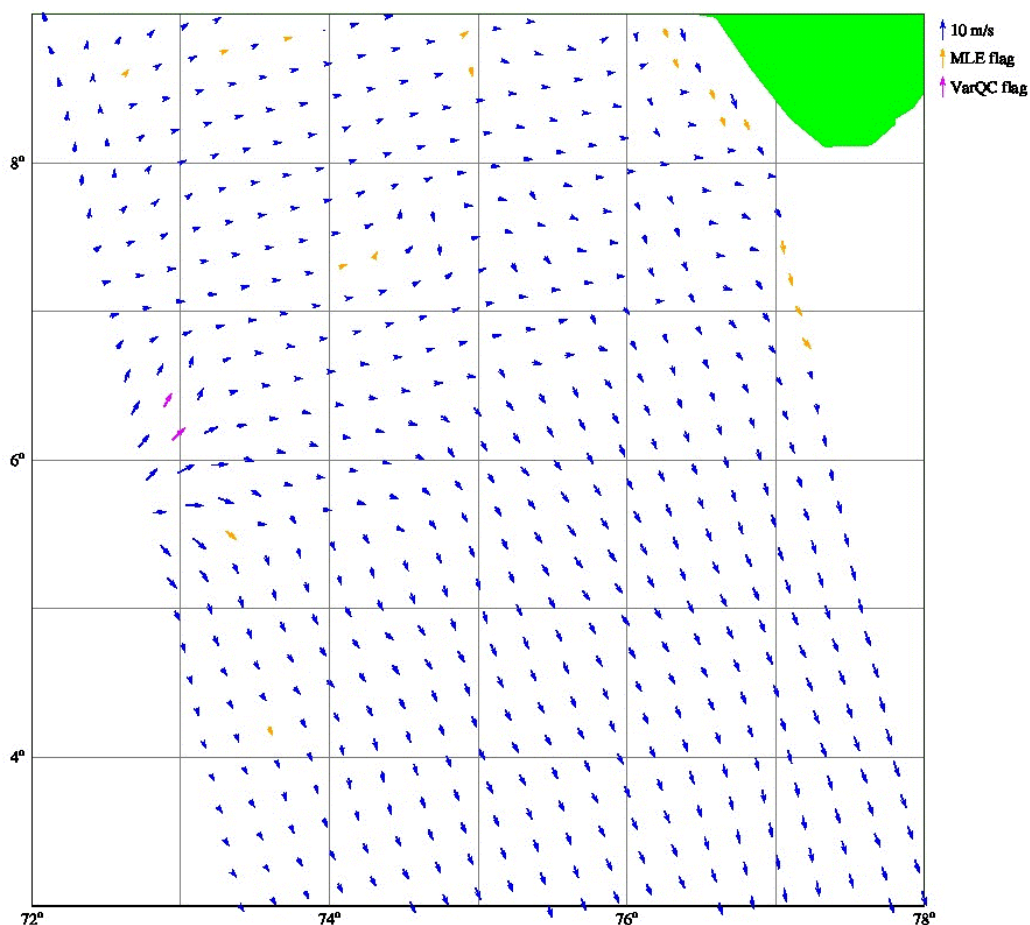


Figure 2.4 Detail of output on 25 km grid.

The command

```
../../execs/awdp_run -f ascat_A_20151027_164500_250_test.bufr  
-szffl szflist -nwplfl nwpllist -calval -handleall
```

will produce a BUFR output file named `ascat_20151027_164500_metopa_46811_srv_o_250_ovw.l2_bufr`. The input file, `ascat_A_20151027_164500_250_test.bufr`, is a BUFR file on a 25 km grid, so the output BUFR file is on the same grid. The command line option `-handleall` ensures that the model winds are recalculated from the GRIB files in `nwpllist`, and that the radar cross sections are recalculated from the L1b full resolution files in `szflist`. The input BUFR file has already been fully processed (it is output of a previous AWDP run), and without the `-handleall` option AWDP will consider processing completed. Figure 2.4 shows part of the output. A more detailed description can be found at the end of this paragraph.

The command

```
../../execs/awdp_run -f ASCA_SZF_1B_M02_20151027164500Z_  
20151027164759Z_N_O_20151027174103Z -szffl szflist -nwplfl nwpllist  
-calval
```



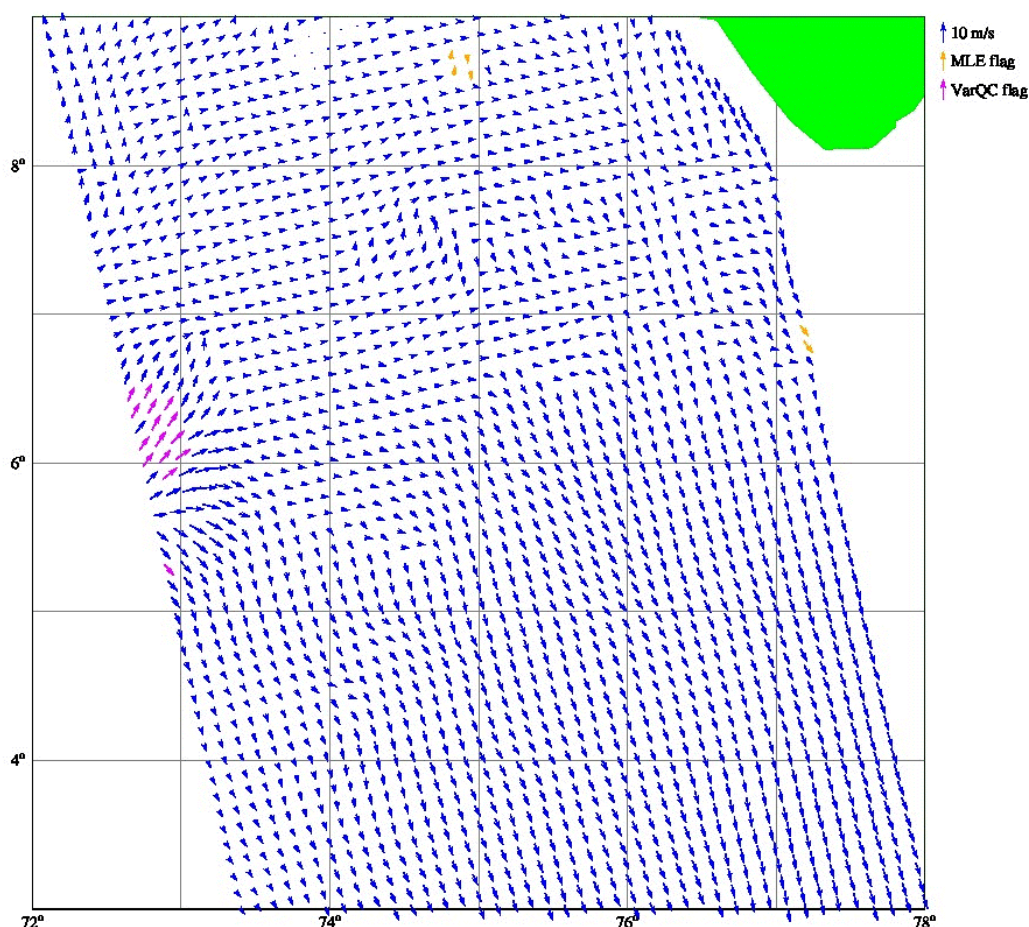
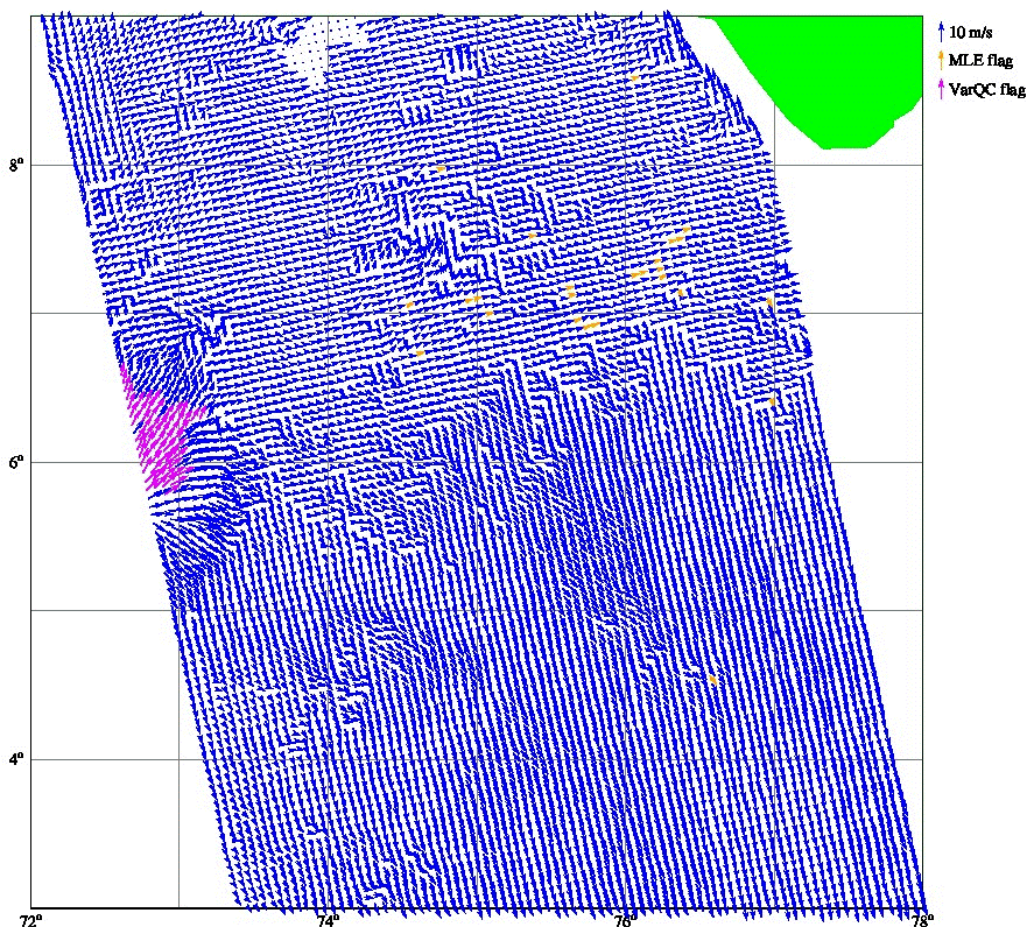


Figure 2.5 Detail of output on 12.5 km grid.

will produce output file `ascat_20151027_164500_metopa_46811_srv_o_125_ovw.12_buf.r`. Since the input file is a L1b full resolution file, processing starts from L1b. The output is on a 12.5 km grid, the model winds are calculated from the NWP file list, and the radar cross sections are calculated from the L1b data in the SZF file list. The `-handleall` option is not needed here to force these actions. Figure 2.5 shows part of the output for the same area as covered by figure 2.4.

Note that the input file, `ASCA_SZF_1B_M02_20151027164500Z_20151027164759Z_N_O_20151027174103Z`, is also present in the SZF file list. The logic behind this is that the SZF file list contains data for recalculating the radar cross sections, while the input file given with the `-f` option determines the area being processed and the grid size at which this will happen.

Note also that the SZF file list contains the files preceding and following `ASCA_SZF_1B_M02_20151027164500Z_20151027164759Z_N_O_20151027174103Z`. This is because the data in the full resolution L1b files is sorted by recording time. The preceding file is needed to complete the fore beam data in the area of interest, while the next file is needed to complete the aft beam data.



**Figure 2.6** Detail of output on 6.25 km grid.

The command

```
../../execs/awdp_run -f ASCA_SZF_1B_M02_20151027164500Z_  
20151027164759Z_N_O_20151027174103Z -szffl szflist -nwpfl nwplist  
-calval -grid_size_0625
```

will produce output file `ascat_20151027_164500_metopa_46811_srv_o_063_ovw.12_buf`. Processing is similar to the previous case, except that now a 6.25 km grid is forced by the `-grid_size_0625` command line option. Figure 2.6 shows part of the output for the same area as covered by figures 2.4 and 2.5. See also [9].

The command

```
../../execs/awdp_run -f ASCA_SZF_1B_M02_20151027164500Z_  
20151027164759Z_N_O_20151027174103Z -szffl szflist -nwpfl nwplist  
-calval -aggr
```

will produce output file `ascat_20151027_164500_metopa_46811_srv_o_057_ovw.12_buf`. The radar cross section triplets are obtained from the L1b full resolution data using an aggregation table that gives optimised radar sampling on a grid of 5.6 km in the along-track direction (actually the grid size is about 5.655 km). Figure 2.7 shows part of the output for the same area as covered by figures 2.4 - 2.6. See also [8].



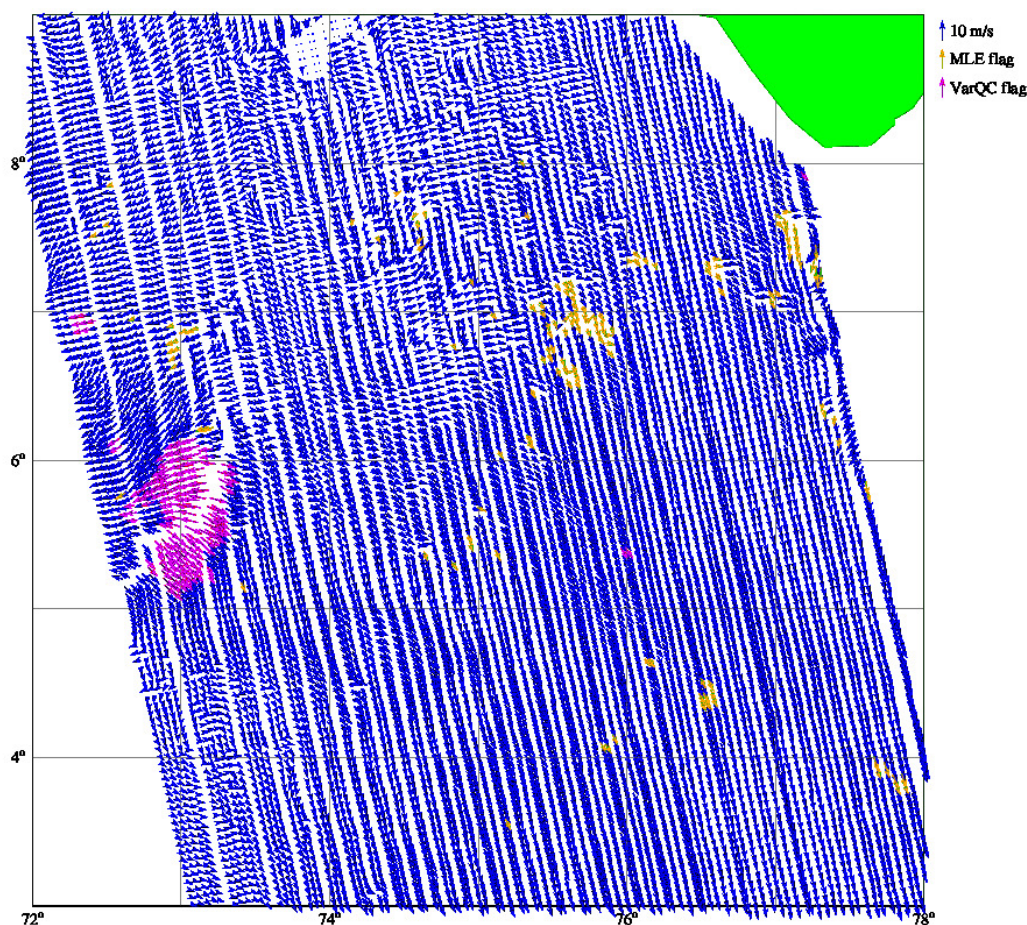


Figure 2.7 Detail of output on 5.6 km grid.

All BUFR output files from this paragraph cover two small strips in the Indian Ocean. Figures 2.4 - 2.7 show a part of the right hand strip close to the Indian subcontinent. The southern tip of India is visible in the upper right corner of each figure. Around 6°N 73°E a downburst is visible. When going to smaller grid sizes the downburst becomes better and better visible. The purple arrows indicate that the Variational Quality Control (VarQC) flag has been set, usually an indication of a large mismatch between scatterometer wind and model wind. In case of the downburst this is most likely due to the fact that the ECMWF predictions do not contain such mesoscale features.

The 5.6 km grid is synchronised with the ASCAT mid-beam antenna pattern. It has an along-track grid size of about 5.655 km and a varying cross-track grid size, see figure 2.7. The true spatial resolution of the ASCAT-5.6 km product (19 km) is slightly worse than that of the ASCAT 6.25 km product (17 km), but its quality is better.

One other point to note is the increase in output size: about 100 kB at 25 km, about 400 kB at 12.5 km, about 1.5 MB at 6.25 km, and about 2.1 MB at 5.6 km.

Directory `awdp/tests/hires` also contains a Python script named `run_awdp-6.25.py` for processing ASCAT full resolution L1b data. Users who want to do high resolution processing on a 6.25 km grid are encouraged to study this script carefully - it contains a lot of useful comments - and to use it as a starting point for their own processing chain.

**Important:** the full resolution L1b files needed for processing on a 6.25 km grid can be ordered

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online from the EUMETSAT Data Centre at [eoportal.eumetsat.int](http://eoportal.eumetsat.int). After registration, this site offers the possibility to select a geographical subset of the data, but the header information of L1b files produced in this way is not always compatible with their content. As a result, AWDP is not able to read those files and returns with an error message. It is therefore recommended to process only full orbit L1b files. From March 2014 onwards one should use archived NRT files (ASCAT GDS Level 1 Sigma0 at Full Sensor Resolution - Metop). For earlier dates one should use reprocessed Climate Data Record files (ASCAT L1 SZF Climate Data Record Release 2 - Metop). Do not use archived NRT files earlier than March 2014, because these do not have the right format for high-resolution processing in AWDP.

### 3.3.3 Other tests

Directory `genscat/support/bufr` contains a test program named `test_modules`. It is invoked by the `genscat` make system to construct the BUFR tables required by AWDP, but it can also be used to test the `genscat` BUFR module. The program is used as follows:

**test\_modules [BUFRinput]**

where `BUFRinput` is the BUFR input file.

If omitted, the program uses as default input the file `testreading.bufr` in directory `genscat/support/bufr`. The output is written to a BUFR file named `testwriting.bufr`. The directory also contains a shell script named `run_test_modules` that sets the environment variables required and executes the program. Further information can be found in the comment lines of the source code of `test_modules`.

Directory `genscat/support/eccodes` contains test programs named `test_read_GRIB1`, `test_read_GRIB2` and `test_read_GRIB3`. The programs can be run from the command line and read in the GRIB file `testfile.grib` in directory `genscat/support/eccodes`. Some properties of this file are written to ASCII output files. Note that the environment variable `$GRIB_DEFINITION_PATH` needs to be set to `directory(...)/genscat/support/eccodes/definitions`.

Subdirectory	Program name	Output file	Remarks
<code>bufr</code>	<code>test_modules</code>	<code>testwriting.bufr</code>	Part of make system
<code>eccodes</code>	<code>test_read_GRIB*</code>	several	GRIB handling
<code>Compiler_Features</code>	<code>TestCompiler_Features</code>	-	Command line handling
<code>convert</code>	<code>test_convert</code>	<code>test_convert.output</code>	Wind speed conversion
<code>ErrorHandler</code>	<code>TestErrorHandler</code>	-	Error handling
<code>singleonfft</code>	<code>TestSingleton</code>	-	Fast Fourier Transform
<code>file</code>	<code>TestLunManager</code>	<code>TestLunManager.output</code>	File management
<code>BFGS</code>	<code>Test_BFGS</code>	-	Minimization
<code>num</code>	<code>test_numerics</code>	<code>test_numerics.output</code>	Numerical issues
<code>pfs</code>	<code>test_pfs_ascat</code>	-	Read PFS file
<code>sort</code>	<code>SortModTest</code>	<code>SortModTest.output</code>	Array sorting
<code>datetime</code>	<code>TestDateTimeMod</code>	<code>TestDateTimeMod.output</code>	Date and time conversion

**Table 2.6** Test programs in `genscat/support`.

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Subdirectories `Compiler_Features`, `convert`, `ErrorHandler`, `singletonfft`, `file`, `BFGS`, `num`, `sort` and `datetime` of `genscat/support` contain test programs for the module in that subdirectory. The test programs write their result to the standard output. In some cases, a copy of the output is contained in the `.output` files for comparison. Table 2.6 gives an overview of the `genscat` test programs.

### 3.4 Documentation

Directory `awdp/doc` contains documentation on AWDP, including this document. Further information can be found in the `readme` text files, and in the comments in scripts, Makefiles and source code.

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## References

- [1] Verhoef, A., Vogelzang, J., Verspeek, J. and Stoffelen, A., 2020, *AWDP Product Specification*, Report NWPSAF-KN-DS-003, EUMETSAT.
- [2] Verhoef, A., Vogelzang, J., Verspeek, J. and Stoffelen, A., 2020, *AWDP Top Level Design*, Report NWPSAF-KN-DS-004, EUMETSAT.
- [3] Portabella, M., 2002, *Wind field retrieval from satellite radar systems*, PhD thesis, University of Barcelona. (Available on <http://www.knmi.nl/scatterometer/publications/>).
- [4] Stoffelen, A.C.M., 1998, *Scatterometry*, PhD thesis, University of Utrecht, ISBN 90-393-1708-9. (Available on <http://www.knmi.nl/scatterometer/publications/>).
- [5] Verhoef, A., M. Portabella and A. Stoffelen, 2012, *High-resolution ASCAT scatterometer winds near the coast*, IEEE Transactions on Geoscience and Remote Sensing, 2012, 50, 7, 2481-2487, doi:10.1109/TGRS.2011.2175001.
- [6] Verhoef, A., Vogelzang, J., Verspeek, J. and Stoffelen, A., 2013, *AWDP Test Report*, Report NWPSAF-KN-TV-005, UKMO, UK.
- [7] Vogelzang, J., and Stoffelen, A., 2016, *Developments in ASCAT ambiguity removal*, Report NWPSAF-KN-TR-026, EUMETSAT.
- [8] Vogelzang, J., 2016, *ASCAT winds on optimised grids*, Report NWPSAF-KN-TR-027, EUMETSAT.
- [9] Vogelzang, J., 2016, *ASCAT-6.25 validation*, Report NWPSAF-KN-TV-009, EUMETSAT.
- [10] Verspeek, J., A. Stoffelen, A. Verhoef and M. Portabella, 2012, *Improved ASCAT Wind Retrieval Using NWP Ocean Calibration*, IEEE Transactions on Geoscience and Remote Sensing, 2012, 50, 7, 2488-2494, doi:10.1109/TGRS.2011.2180730.

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## Appendix A: Acronyms

Name	Description
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
HIRLAM	High resolution Local Area Model
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
NCEP	United States National Centers for Environmental Prediction
NRCS	Normalized Radar Cross-Section ( $\sigma^0$ )
NWP	Numerical Weather Prediction
OSI	Ocean and Sea Ice
PFS	Product Format Specification (native Metop file format)
QC	Quality Control
SAF	Satellite Application Facility
SSM	Surface Soil Moisture
SST	Sea Surface Temperature
WVC	Wind Vector Cell, also called node or cell

**Table D.1** List of acronyms.

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## Appendix B: Development of AWDP

Software code for processing satellite data may become very complex. On the one hand, it consists of code related to the technical details of the satellite and instruments; on the other hand, the code drives complex algorithms to create the physical end products. Therefore, the EUMETSAT Satellite Application Facility (SAF) project for Numerical Weather Prediction (NWP) has included some explicit activities aiming at enhancing the modularity, readability and portability of the processing code.

For several years, the KNMI observation research group has been developing processing code to supply Near Real Time (NRT) level 2 surface wind products based on the ERS and SeaWinds Scatterometer L1b Normalized Radar Cross Section data ( $\sigma^0$ ). This work is coordinated and supervised by Ad Stoffelen. In the beginning only an adaptation of his ERS code existed. Later Marcos Portabella and Julia Figa added modifications and extensions to improve, e.g., the wind retrieval and quality control algorithms. In 2003, John de Vries finished the first official release of a processor within the NWP SAF. This processor was called the QuikSCAT Data Processor (QDP).

Meanwhile, Jos de Kloe has been updating the code for ERS scatterometer wind processing. For many parts of the process steps (e.g., the BUFR handling and part of the wind retrieval) a large overlap with SeaWinds Data processing coding exists. The KNMI Scatterometer Team is working towards generic NRT scatterometer processing. As a result, a new modular processing code for SeaWinds data was developed within the NWP SAF: the SeaWinds Data Processor (SDP) as successor of QDP.

Based on the generic code already available for SeaWinds and ERS processing, a new ASCAT Wind Data Processor (AWDP) was developed. This document is the corresponding reference manual. We hope this manual will strongly contribute to the comprehension of future developers and of users interested in the details of the processing.

Many persons contributed (directly or indirectly) to the development of the scatterometer software at KNMI: Hans Bonekamp, Jos de Kloe, Marcos Portabella, Ad Stoffelen, Anton Verhoef, Jeroen Verspeek, Jur Vogelzang and John de Vries are (in alphabetical order) the most important contributors.