Royal Netherlands
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ASCAT ASSIMILATION in HIRLAM REPORT

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Executive summary

The data of the space-born radar ASCAT provides global wind information over water surfaces, including data sparse oceans. The use of these data in global numerical weather prediction (NWP) models leads to improved forecasts. In regional NWP the ASCAT data is less frequently used. This study focuses on the assimilation of ASCAT data in the regional HIRLAM model. The results show a modest positive to neutral impact on the forecast up to 6 hours.

Acknowledgement

The author would like to thank John de Vries for his invaluable input. John offered the base for this study and delivered updates of the software. Due to other obligations he could not contribute to the writing of this report.
The author acknowledges the excellent support of the Hirlam-Ecmwf group by Ulf Andrea, Dominique Lucas, and Xiaohua Yang. Next to other support they supplied frozen versions of the HIRLAM software versions, and validation software necessary to bring the study forward.
Colleagues at KNMI contributed with their appreciated knowledge to the project and to this report: Anton Verhoef, Toon Moene, Siebren de Haan, and Gert-Jan Marseille.

1 Introduction

Assimilation of observations is essential to ensure that numerical weather prediction (NWP) models analyses will be in close agreement with the actual state of the atmosphere. There is a large amount of observations, surface based, ship-based, airborne and space-born. Despite this large number still only a relative small part of the atmosphere is sampled. Any extension of assimilated observations in a NWP model can therefore have a beneficial impact on NWP analyses and resulting forecasts. In this report we describe the impact of derived ocean surface winds from the advanced scatterometer (ASCAT) observations on the forecasts of the High Resolution Limited Area Model (HIRLAM), version 7.4 beta 1 with 3D-Var. Simultaneously an assimilation study is performed on the operational Royal Netherlands Meteorological Office (KNMI) HIRLAM setting (Unden 2002). The findings of the latter study has been accepted for publishing, De Haan et al 2013. As this study has a close resemblance with the study of De Haan et al, 2013.

Scatterometers, which are space born radar systems, can provide wind information over the data sparse oceans, De Haan et al, 2013. The most significant impact of scatterometer observations on NWP forecasts is expected over sea and near coastal regions, close to where the observations are made.

Previous studies of the impact of scatterometer winds on NWP forecasts were done and for global NWP there is a positive impact shown (Hersbach, 2007). For Limited Area Models (LAM) the master thesis of Ollinaho, 2010 indicates a positive to neutral impact on the forecasts. The impact of ASCAT assimilation in the latter thesis is predominantly assessed with stations over land.

To assess the impact of observing systems in a NWP model is generally determined by denial experiments; that is, by comparing analyses and forecasts of a control experiment using all observations in the analysis with a similar experiment denying the observing system under investigation. As the experiments are performed over a period in the past data latency is not relevant opposed to the study of De Haan et al, 2013, which focusses on an operational environment. For an operational implementation in regional NWP models data latency is a relevant factor, more than in global operational NWP models which have larger assimilation windows.

This experiments discussed in this report are in close agreement with the article of De Haan et al, 2013. This report describes in section 2 the scatterometers used during the development of the software. Section 3 briefly describes the assimilation followed by the time path of the implementation in section 4. Section 5 describes the experiments and the obtained results followed by the conclusions in section 6.

2 Scatterometers

The Seawinds scatterometer is a space born radar system on the Quikscat satellite that observes the ocean surface in the microwave part of the electromagnetic spectrum, (http://winds.jpl.nasa.gov/). A rotating dish antenna emits two beams with 6 degrees of separation. From the collected reflected radar energy near-surface wind speed and direction can be derived, see below. The swath width is 1800 km.

The ASCAT scatterometer was launched in October 2006 on board of the Metop-A (meteorological polar orbiting satellite) (www.eumetsat.int) , and became operational in early 2007. Scatterometer data continuity was guaranteed by the availability of ASCAT at the moment that the Seawinds system failed on November 23, 2009.

Two sets of three antennas of ASCAT measure the resultant electromagnetic backscatter from the wind-roughened ocean surface in two 500 km wide swaths, on each side of the satellite ground track. The three antennas on each side are oriented to broadside and ± 45° of broadside, and so make sequential observations of the backscattering coefficient of any location within view from three directions. The three directions are needed to resolve the wind direction ambiguity. (http://www.eumetsat.int/Home/Main/Satellites/Metop/Instruments/SP_2010053161611647?l=en) The backscatter over water surfaces depends on the capillary waves amplitude and their direction. The backscattering properties are well known and are dependent on both the wind speed and the direction of the wind with respect to the observation platform position. The three radar measurements can then be applied to the backscatter/wind velocity model (Stoffelen et al 1997) to deduce the wind speed and direction at the 10 meter level above mean sea level, which is the commonly used level of wind speed and direction observations in meteorology. The wind result consists of two to four ambiguous vector solutions.

For this study the ASCAT wind product is used (see http://www.knmi.nl/scatterometer) in Binary Universal Form for the Representation of Meteorological Data (BUFR) and Network Common DataForm (NetCDF) formats. Used ASCAT products include wind speed and direction information at 25 km spacing. The 25-km product has an accuracy of 1.3 m/s in wind speed and 16 degrees in wind direction when compared to collocated ECMWF model winds (Verspeek et al. 2010; Vogelzang et al. 2011).

On board of the Indian satellite Oceansat-2 there is a rotating Ku band scatterometer mounted. The data appear to have sufficient quality and have become available in 2013.

In 2012 the Metop-B was launched, also carrying an ASCAT instrument thus doubling the observation frequency of ASCAT observations.

A more frequent availability of scatterometer data from various satellites will ensure timeliness for the assimilation windows of regional NWP and the opportunity to further evaluate the impact of ASCAT assimilation on NWP forecasts by using scatterometer observations from other platforms.

3 Assimilation

At the start of the study a Seawinds data assimilation software application within HIRLAM was available. It was decided to extend this application in order to cope with ASCAT data. This decision was made when the development of a separate ASCAT assimilation software package was not successful.

The chosen approach of Seawinds extension ensured that the consecutive steps of the assimilation software chain could remain the same. The developed software is able to cope with Seawinds and ASCAT data separately and simultaneously by using different logicals for ASCAT and Seawinds. As ASCAT and Seawinds have different data structures the reading routines had to be adapted. ASCAT provides information in more wind vector cells, 42, compared to Seawinds, 19, so array sizes had to be adaptable. Once the wind vector cells information is ingested the consecutive steps for ASCAT and Seawinds data assimilation are similar.

The ASCAT observations give to two to four ambiguous vector solutions per wind vector cell. This is essentially different from other in situ wind observations, which provide only one vector solution. The wind ambiguities, solution probabilities, and prior information from the ECMWF model 10-m background winds are used in a 2D variational ambiguity removal procedure to produce an analysed surface wind field (Vogelzang et al. 2009). This wind field is then used to select the wind vector ambiguity in each Wind Vector Cell (WVC) that is closest to the HIRLAM analysis, based on vector difference, as the solution for the observed surface wind. So within the analysis itself the best wind solution fitting to the atmospheric state is chosen.

This characteristic of ASCAT ambiguous winds hampers the determination of the error characteristics. With “*o*” the observation, “*b*” the back ground (short-term forecast) wind, and `*a*` the analysed wind, the differences between *o-b*, and *o-a* can only be assessed when the observed ASCAT wind is known. The “o-b” is not known a-priori, but results from the analysis. So only after the analysis the *o-b* can be determined. This is different from *o-b* determination for more typical non-ambiguous wind measurements.

The HIRLAM implementation of ASCAT winds is designed to assimilate the components of the wind vector ambiguities. Before ASCAT observations are admitted to the analysis, they first have to undergo a screening procedure. The screening of ASCAT observations consists of a location check for each WVC against the HIRLAM domain and a check on the observation time for each across-track row of WVC´s against the observation time window of a given assimilation cycle. In addition, a threshold check is performed for the presence of sea ice and land. Finally, the WVC quality flag from the ASCAT wind product is used to ensure the use of winds based on high-quality and complete backscatter measurements and a successful inversion. Because the ASCAT wind information consists of wind ambiguities, no first-guess check is carried out and, in the analysis, variational quality control is not active for ASCAT data.

In 3DVAR, the cost function

$$J = J_b + J_o \tag{1}$$

is minimized. The component terms in (1) are quadratic forms expressing the ‘‘distance’’ between the analysis state and the prior or background state and the observations, respectively. The cost function *Jo* comprises the contributions of individual observation types:

$$J_o = J_{o\,synop} + J_{o\,ASCAT} + .. \tag{2}$$

For ASCAT, the cost function is defined as

$$J_{o\,ASCAT}=\sum_{j}^{N_{obs}}\left(\sum_{i=1}^{N_i} J_i^{-p}\right)^{-1/p} \tag{3}$$

where

$$J_i=\left(\frac{u-u_i}{\sigma_{o\,ASCAT}}\right)^2+\left(\frac{v-v_i}{\sigma_{o\,ASCAT}}\right)^2-2\ln \mathrm{P}_i \tag{4}$$

is the cost of the i^{th} ambiguity; Nj is the number of ambiguities in observation j; (u, v) and (u_i, v_j) are the analysis and ASCAT wind vector ambiguity components, respectively; so, σ_{0ASCAT} is the expected standard deviation of the error in the ASCAT wind components with a value of 1.8 m s^{-1} (Vogelzang et al. 2009); Pi is the a priori solution probability (Portabella and Stoffelen 2004); and p is an empirical weight factor for the ambiguities, which currently has the value of four. This weight factor emphasizes the discrimination between the ambiguities and makes the expression for the cost function behave more as an ‘‘if’’ statement.

4 Time path of the development.

HIRLAM

The goal of the study was to asses the impact of the assimilation of ASCAT wind ambiguities into the HIRLAM model. The first choice was to use the trunk version of HIRLAM on ECMWF. This choice was unfortunate. Due to unforeseen changes in the trunk version implementation problems occurred. Fortunately the HIRLAM system managers provided several frozen versions for the development of the ASCAT software implementation. More than one frozen version was required as the project team members could not work continuously on the project. Due to limited available time the project progress was slow. Therefore the software was implemented in (frozen) versions of 7.2, and 7.3. In the latter version all issues were resolved. In early 2011 it was decided to wait for the release of version 7.4. It took a while before a stable frozen version 7.4 (beta1) became available, which is used for the results shown in this study.

Additional Time delay causes

In the period of the project there were other unforeseen changes, which hampered the study on the implementation of ASCAT assimilation. These included:

- The ASCAT Bufr format changed.
- a difference was found between the MARS ECMWF ASCAT archive files and the KNMI archived files. It took a while to recognize the difference and to develop a software solution to ensure a correct handling of the two file versions.
- platform changes at ECMW, requiring a new frozen version which was not always instantly available.
- Part of the verification software intended for data interpretation did not incorporate sea stations.

5 Experiments and Results

To asses the impact of ASCAT assimilation a parallel experiment with two runs is performed. One run with an active assimilation of ASCAT observations and another with passive assimilation of ASCAT observations. Passive denotes the run with the denial of observations under study. The results of these parallel experiments are compared in this section.

In the passive run the “minobstype” for ASCAT observations is set from “true” to “false” in the script $EXP/scripts/VARinput, with $EXP being the name of the experiment directory in the directory $HOME/hl_home. This causes the minimization matrix to be calculated while neglecting the ASCAT observations.

Two periods were selected for comparison between active and passive assimilation of ASCAT wind ambiguities. A summer case from July 1 until 16, 2010 and a winter case of December 9 until 26, 2010. This choice ensured the selection of two different wind climatology periods. In winter time the wind speeds over sea are likely to be higher than in the summer due to a higher occurrence frequency of low pressure systems. At the time of the decision this choice appeared to contribute to the study by introducing different climatologies. Unfortunately, in hindsight, the decision to limit the two study periods to approximately a fortnight, introduced too short experiment periods. For an impact assessment a minimum period of six weeks is appropriate. This short coming was only recognized towards the end of the experiment, and there were no resources to extend the experiment. Table 1 summarises the observations used in the experiments.

		Parameter	Assimilated
Surface	synop	Pressure	y
	Synop ships/moored buoys	Wind vector pressure	N Y
	Drifting buoys	pressure	Y
Upper air	Radio sondes	Wind vector humidity temperature	Y Y Y
	Airep/Amdar/Pilot reports	Wind vector temperature	Y Y
	Atovs	Brightness temperature	Y

Table 1. Observations used in the experiments. N(o) and Y(es) indicates whether the observations were assimilated in the experiments.

Following the approach of De Haan et al, 2013, the shown results are derived by comparison to other observations on sea, including ASCAT observations, and observations from moored buoys and ships. For the studied periods the bias and the standard deviation of the model minus observed 10 m winds are calculated as a function of forecast time, see Figure 1. In the figure also the relative change in the standard deviation is included.

For the summer period the assimilation of ASCAT ambiguities have a small impact on the analyses. Only close to the moment of assimilation a modest positive impact can be seen for the standard deviation of approximately 1 percent up to six hours in the comparison

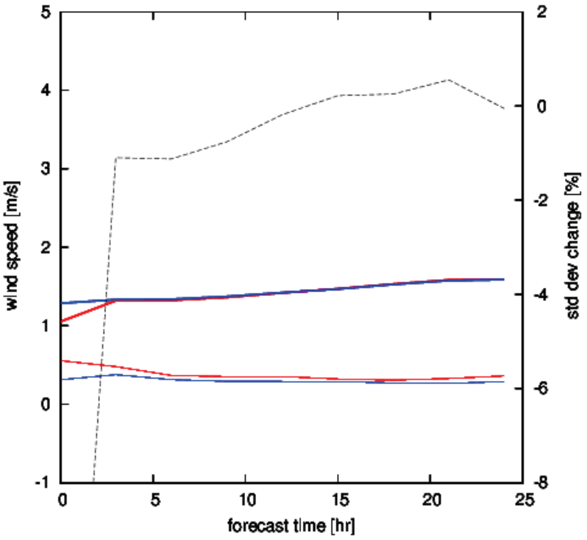

Figure 1. The ASCAT observation minus forecast bias (thin lines) and standard deviation (thick lines) as a function of forecast times for the summer study period for the active ASCAT assimilation (red) and passive ASCAT assimilation (blue). The relative change in the standard deviation is denoted by the black line and right axis, a negative value indicates a positive impact on the standard deviation.

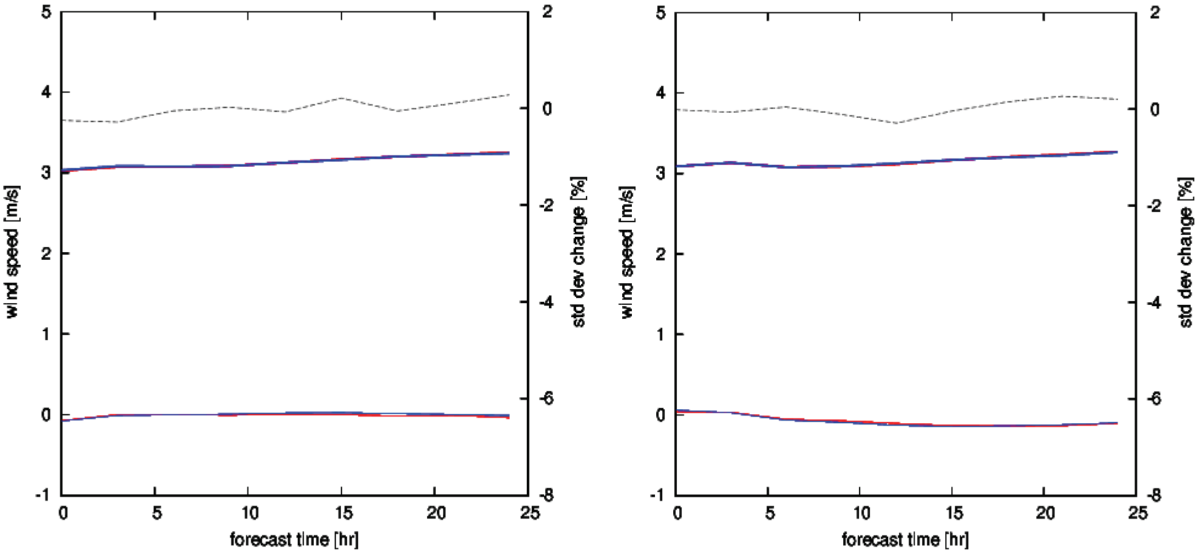

Figure 2. As Figure 1 but for ships and moored buoys easterly (left side) and northerly (right side) wind observations.

between observed and analysed ASCAT winds, after six hours this impact becomes negligible. The bias increases when assimilating ASCAT winds. Assimilating ASCAT winds has no significant impact on observation minus model statistics for wind and pressure observations from ships and moored buoys, see Figure 2 and 3. This differs from the results from De Haan et al, 2013 where a positive impact on both standard deviation and bias is shown. They consider a longer period of ten weeks, opposed to the two weeks used in this study. This might explain the difference. The obtained poor results of this study support the hypothesis that the two weeks period is too short, as already mentioned above.

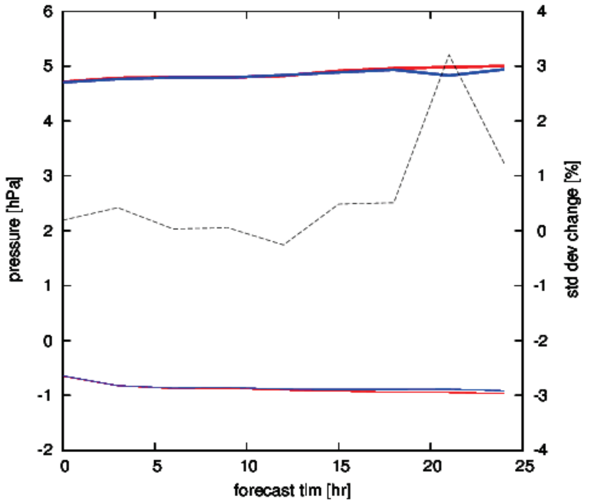

Figure 3. As Figure 1 but for ships and moored buoys pressure observations.

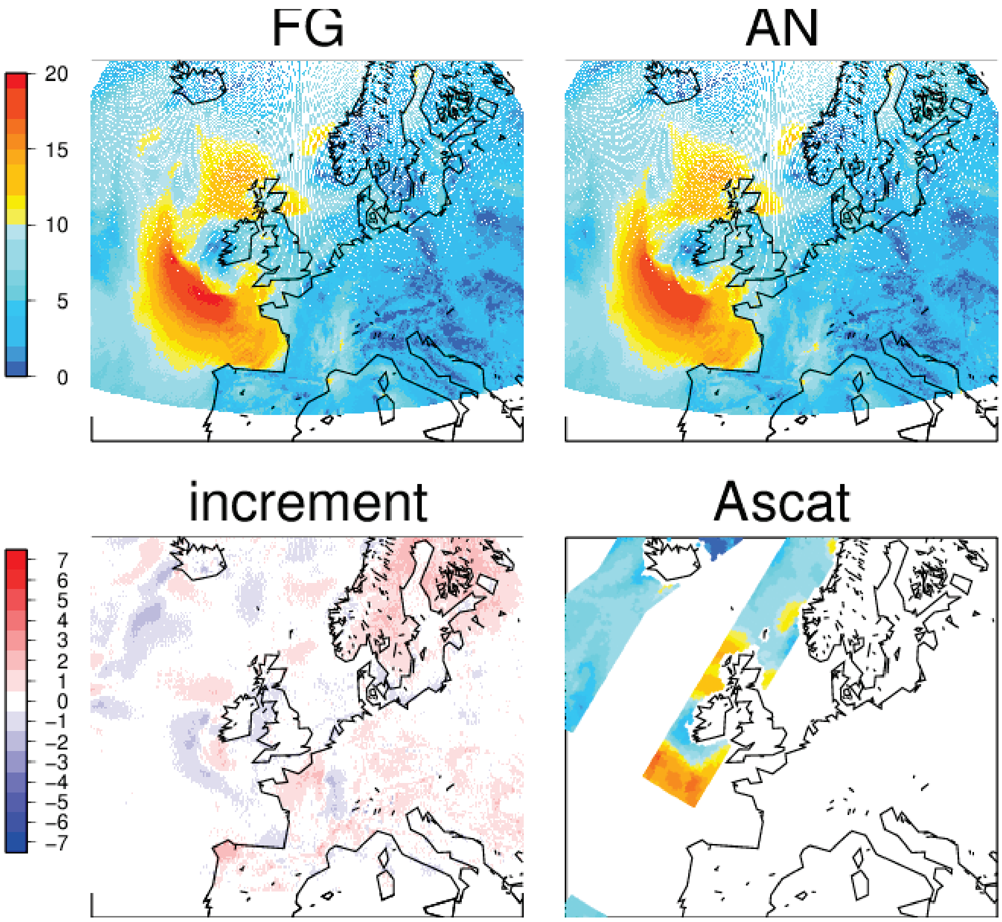

Figure 4. The wind speed valid for 12:00 hr GMT at 14-07-2010 for the first guess, FG, (forecast of 09:00 GMT + 3 hours) upper left, the analyses, AN upper right, including assimilated ASCAT observations, shown bottom right,. The bottom left panels shows the increment (AN-FG).

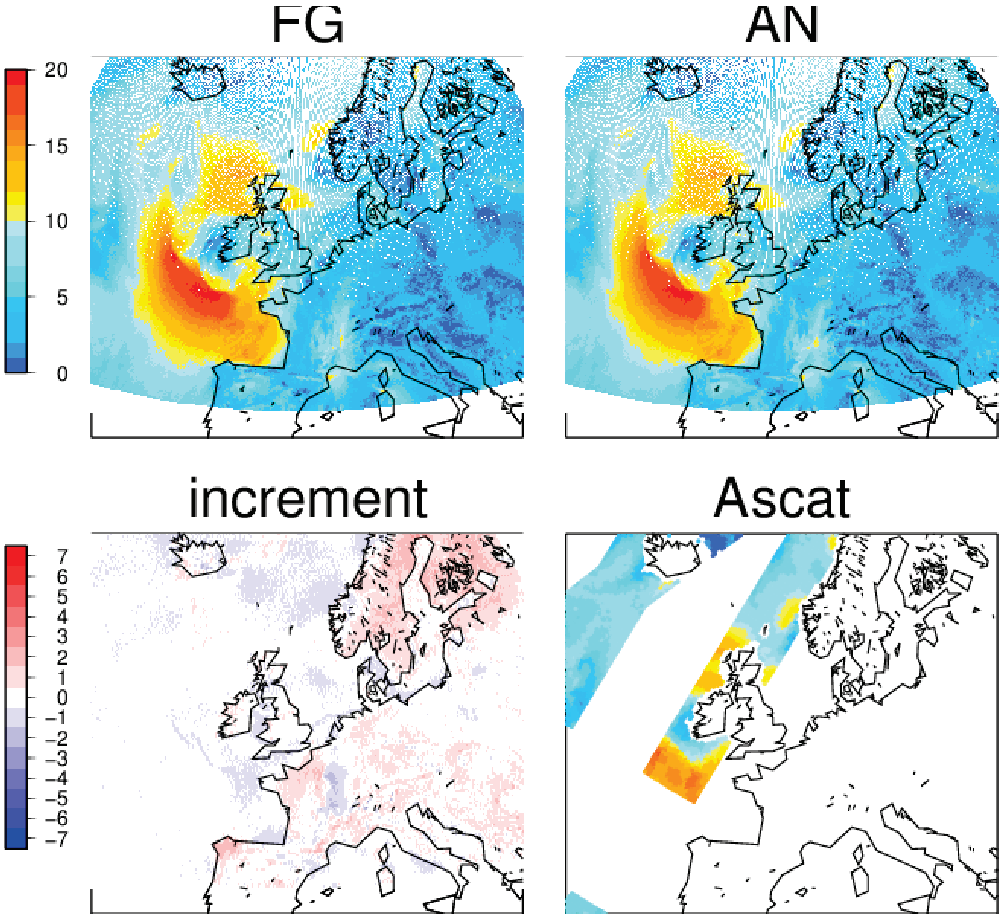

Figure 5 as Figure 4 but for the passive experiment, i.e., ASCAT observations were not assimilated.

The summer case partly overlaps with the period of the local implementation at KNMI of ASCAT assimilation. It comprises an extreme thunderstorm event in the Netherlands on July 14, around 18:00 GMT, known as the "Vethuizen thunderstorm case" where victims had to be deplored. This thunderstorm developed over the main land of France, and Belgium and explains the neutral impact of ASCAT assimilation for this development.

However a modest impact of the ASCAT assimilation for this particular case is visible over sea, around 12:00 when comparing the increment distribution over the area in Figure 4 for active and Figure 5 for passive assimilation. The convective development itself caused a major adaptation of the analysed field over Belgium and Northern France at 15:00, see Figure 7 occurring in both the passive and active run, the latter hints that other than ASCAT observations cause this adaptation. For the active run the ASCAT assimilation in the previous assimilation steps leads to increments over sea, less visible in the passive assimilation.

The time scale of the development is relative small. In Figure 6 the increments at 12:00 for the active and passive are shown together with the resulting increments (active minus passive) between the three hour forecast fc+3 and the six hour forecast fc+6. Over land there is no significant increment for both the forecasts nor in the active mode nor in the passive mode. Over sea the patterns of the active assimilation remain partly visible.

There is no ASCAT overpass near 15:00 nor at 18:00 hence no impact on the forecast of the thunderstorm event with strong wind gusts can be expected from ASCAT assimilation.

There is a difference in averaged observed winds between the summer and winter period for coastal and sea stations. In figure 8 and 9 the averaged wind speeds for a selected number of stations are given, for summer and winter respectively. The spatial distribution of these stations is given in Figures 10 and 12 in which the standard deviation for summer and winter respectively are given at the location of the stations. As the most significant impact of ASCAT winds is on sea, ships and coastal stations were selected.

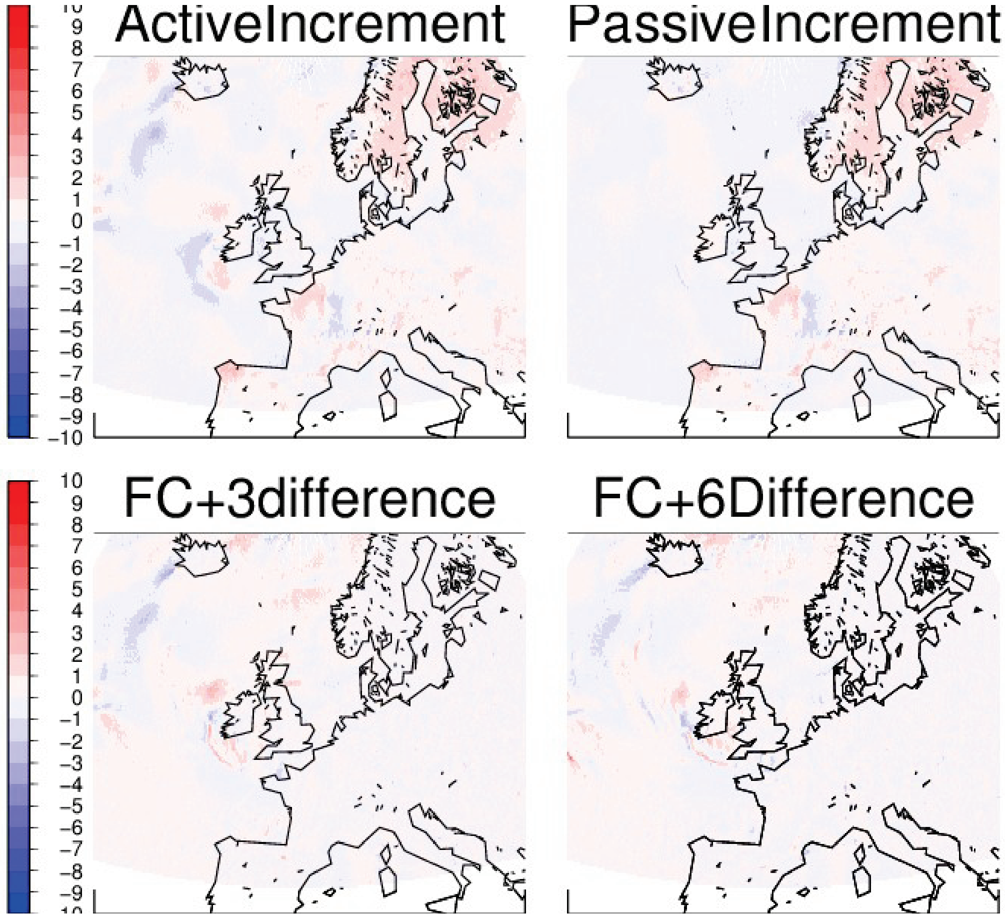

Figure 6 The increments of figure 4 upper left and 5 upper right and the forecast increments active – passive for the forecast of 3 and 6 hours, lower left and right respectively.

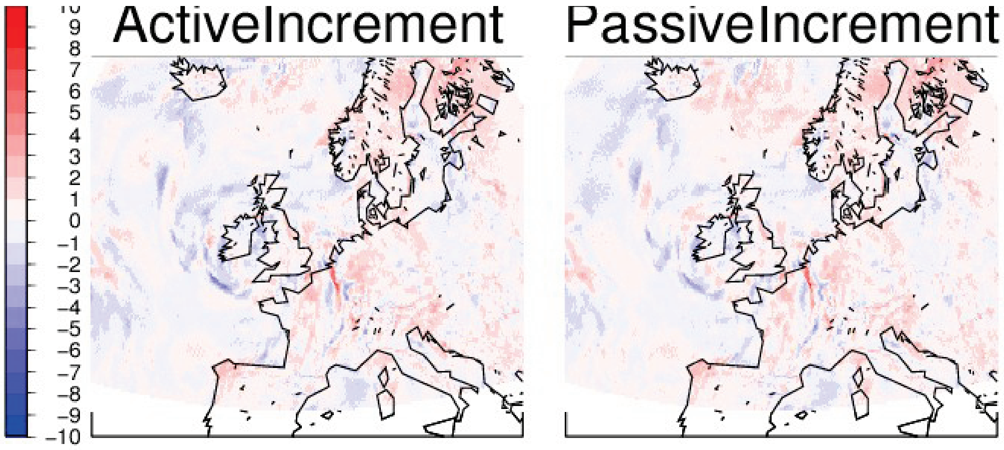

Figure 7 As the upper part of Figure 6 but for 15:00 hr GMT of 14-07-2010.

In Figure 9 significant unexplained differences occur in winter time between (stations) observed wind speeds and the ASCAT winds, both from active and passive assimilation. These differences are negligible in the summer period, Figure 8. Also the occurring wind speeds are higher in winter than in summer. The latter supports the assumption that the wind speeds in winter time are affected by a higher frequency of occurrence of low pressure systems, resulting in higher wind speeds. From this graphs no impact difference can be assessed directly between active and passive assimilation of ASCAT.

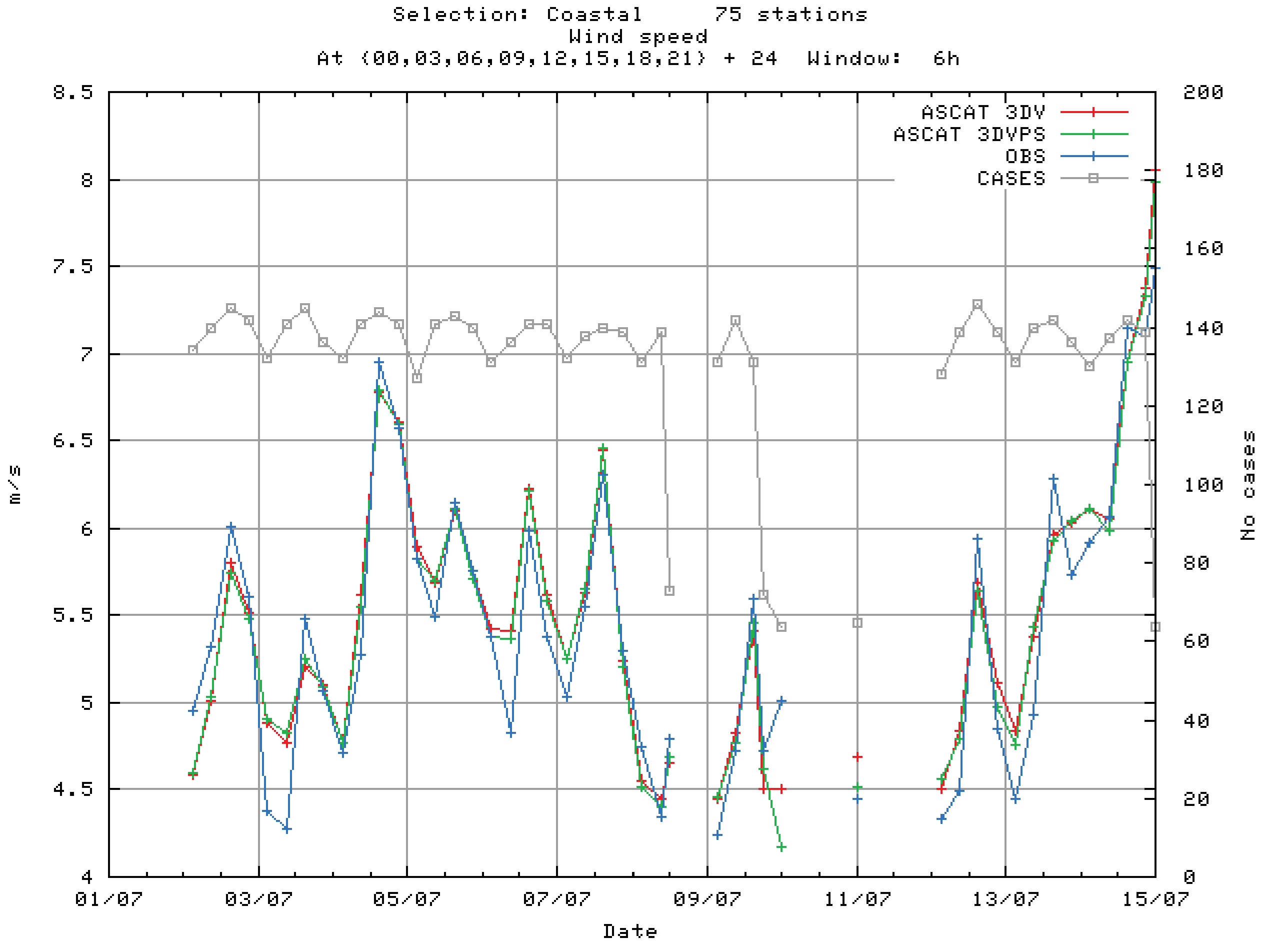

Figure 8. Averaged wind speeds as function of time for the summer study period for the different experiments and station observations.

The biases and standard deviation for the winter time period are compared for the active and passive assimilation as function of the forecast time are shown in Figures 14 till 16 They comprise the results for the ASCAT wind speed, the ships or moored buoys easterly and northerly wind components and the ships or moored buoys surface pressure. All the figures show a positive impact of the active ASCAT assimilation both in bias and decreased standard deviation. Although the pressure only shows a positive impact in a lower standard deviation up to a forecast time of 6 hours.

The most significant improvement occurs when the ASCAT winds are used for the comparison with a decrease of standard deviation of 6 % at fc+3, Figure 14. The specified observation error for both wind components is 1.8ms^{-1}, De Haan et al, 2013. For the comparison to ships and moored buoys the standard deviation is in summer 3 ms^{-1} and in winter 3.5 ms^{-1} for non-ASCAT wind observations for the two parallel experiments. These values correspond to the standard deviation determined for the coastal stations in figures 11 and 13.

Figure 9 shows that 17-12-2010 is a day with high wind speeds at the coastal stations and moored buoys. To study the impact of an ASCAT assimilation the results of this day are discussed in more detail.

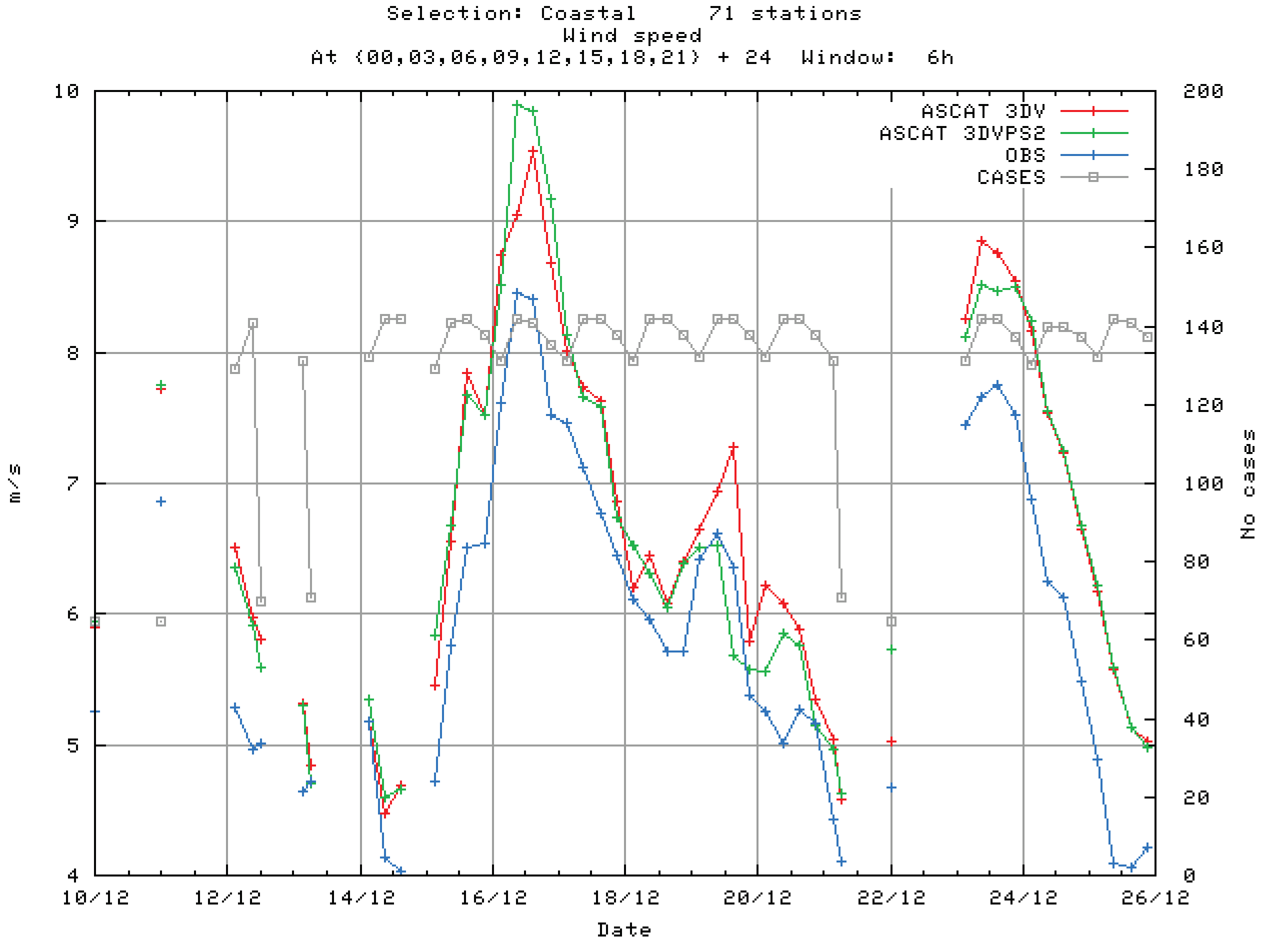

Figure 9. As figure 8 but for the winter study period.

In Figure 17 and 18 at 20101217_12 the impact of the ASCAT assimilation is shown. The first guess field (Forecast + 3hr) the analysed field, the increment (a-f) and the ASCAT observations are given. For comparison the same results are given for the passive assimilation run. At noon there is a system with high wind speeds south of Iceland, which is covered well by the ASCAT observations. Also around the UK areas with high wind speeds occur. Within these areas a large number of the ships and coastal stations are located see Figure 20 where the coverage of ASCAT is combined with the location of reporting ships and moored buoys. This explains the high wind speeds in Figure 9.

Comparing the increments between the active and passive experiment results in Figure 19 it is clearly visible that the ASCAT assimilation impact occurs predominantly over sea. The impact over land is hardly noticeable in comparison to the impact over sea. This corresponds to the results of Ollinaho 2010.

In Figure 19 lower part the increment of the active run (a-f) , of passive run and of the forecast +3 and +6 between active and passive runs are compared. The comparison between active and passive increments shows that ASCAT winds lead to significant increments over sea. The figure shows that within the forecasts there are also increments over land. The area with increments deviating from zero over land increases with forecast time. This is conform the expectations that the increments are transported downstream by the wind.

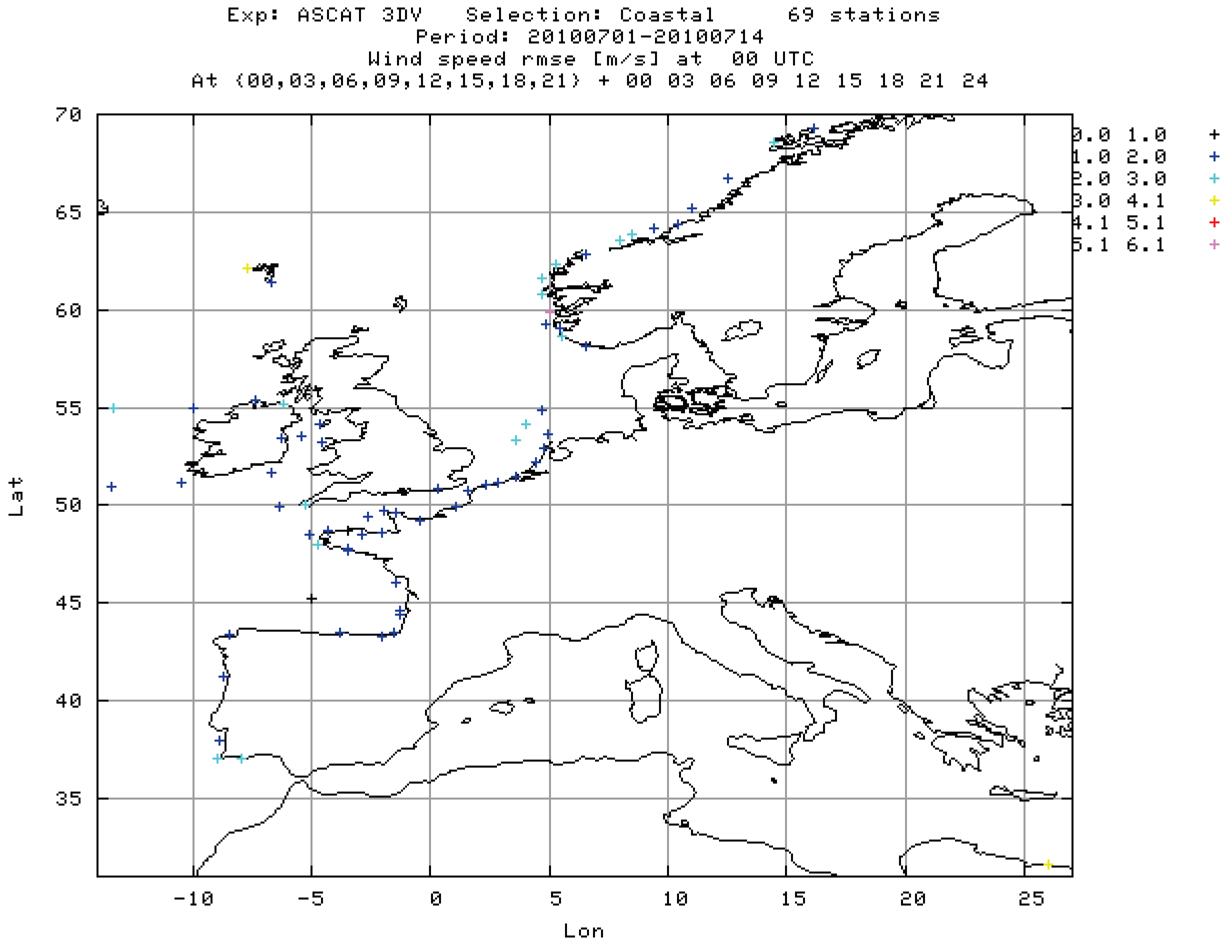

Figure 10. Wind speed rms given at the station location for the summer period active assimilation.

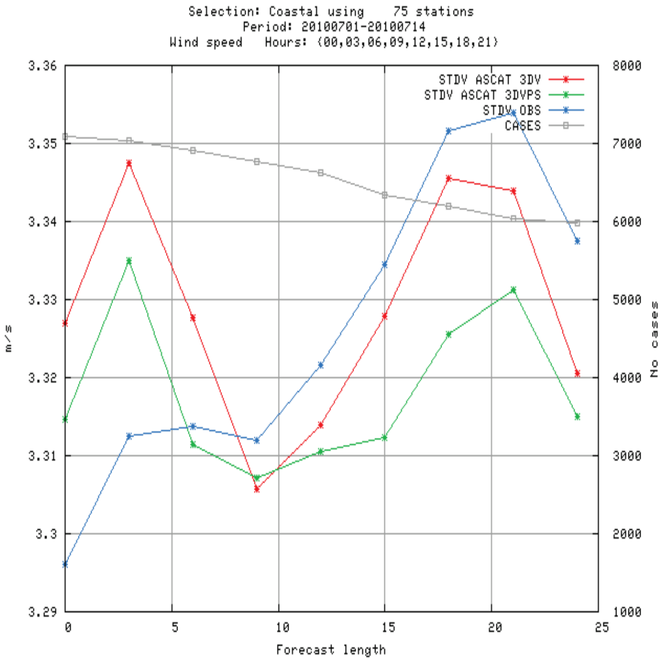

Figure 11. The standard deviation of the wind observations at the stations shown in figure 10 as function of forecast time.

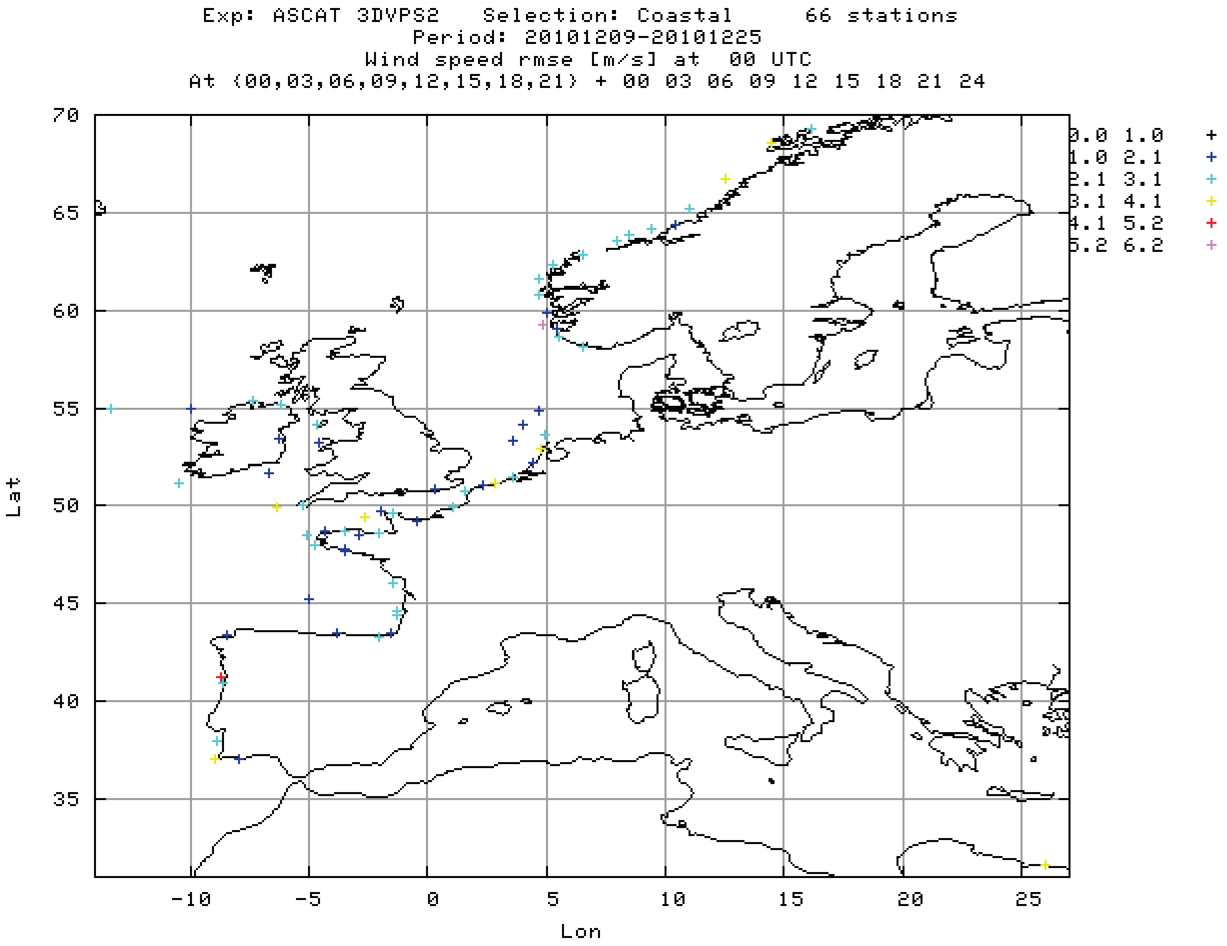

Figure 12. As Figure 10 but for the winter period.

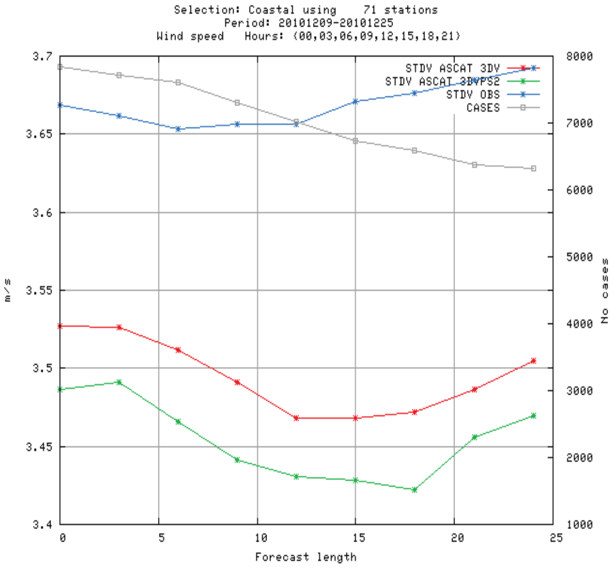

Figure 13. As figure 11 but for stations given in figure 12.

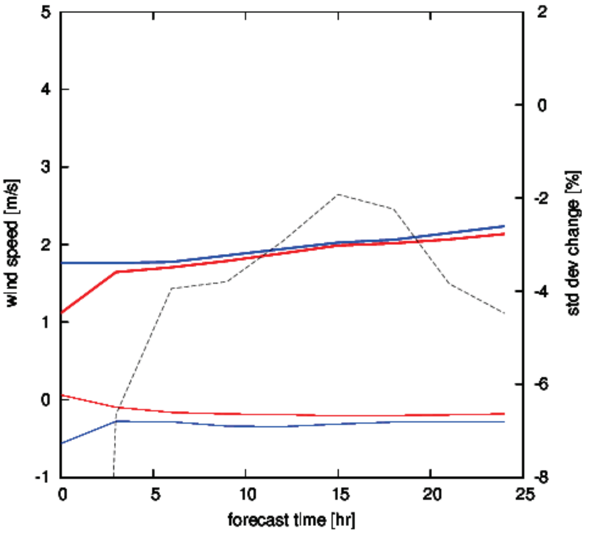

Figure 14. As figure 1 but for the winter study period.

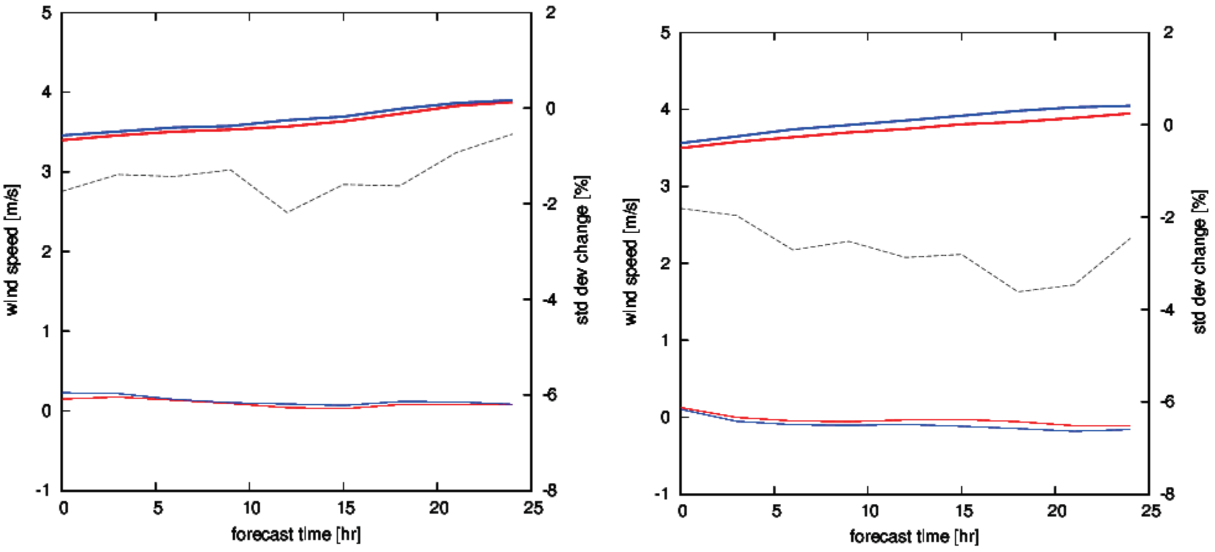

Figure 15. As Figure 2 but for the winter period.

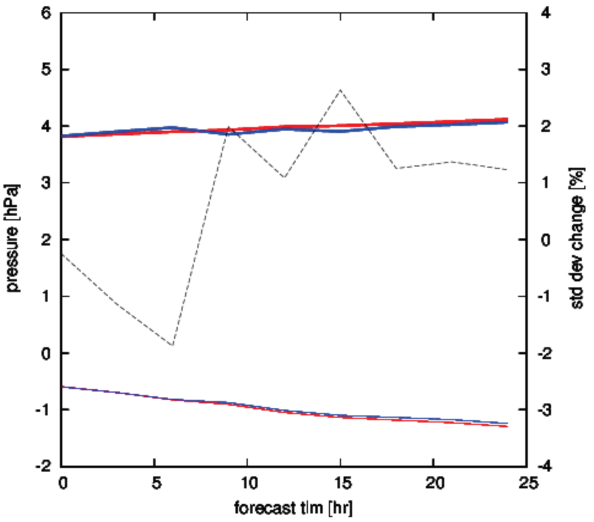

Figure 16. As Figure 3 but for the winter period.

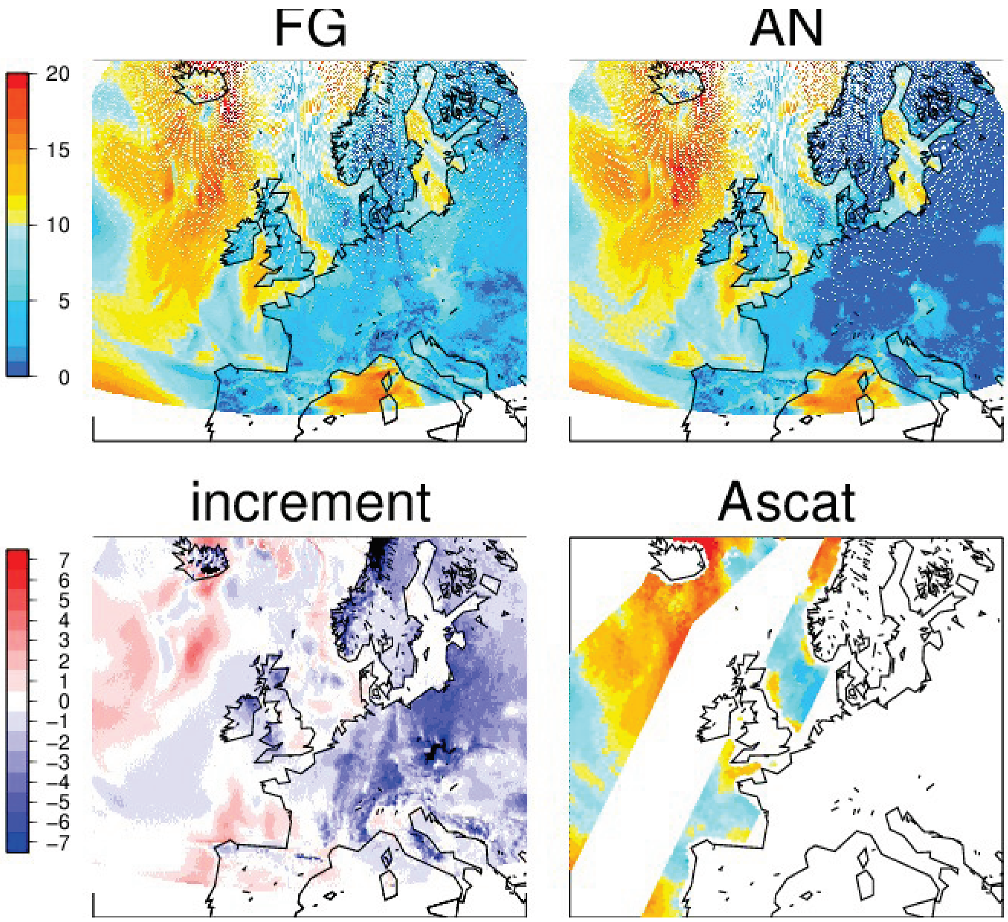

Figure 17. As Figure 4 but for 12:00 17-12-2010

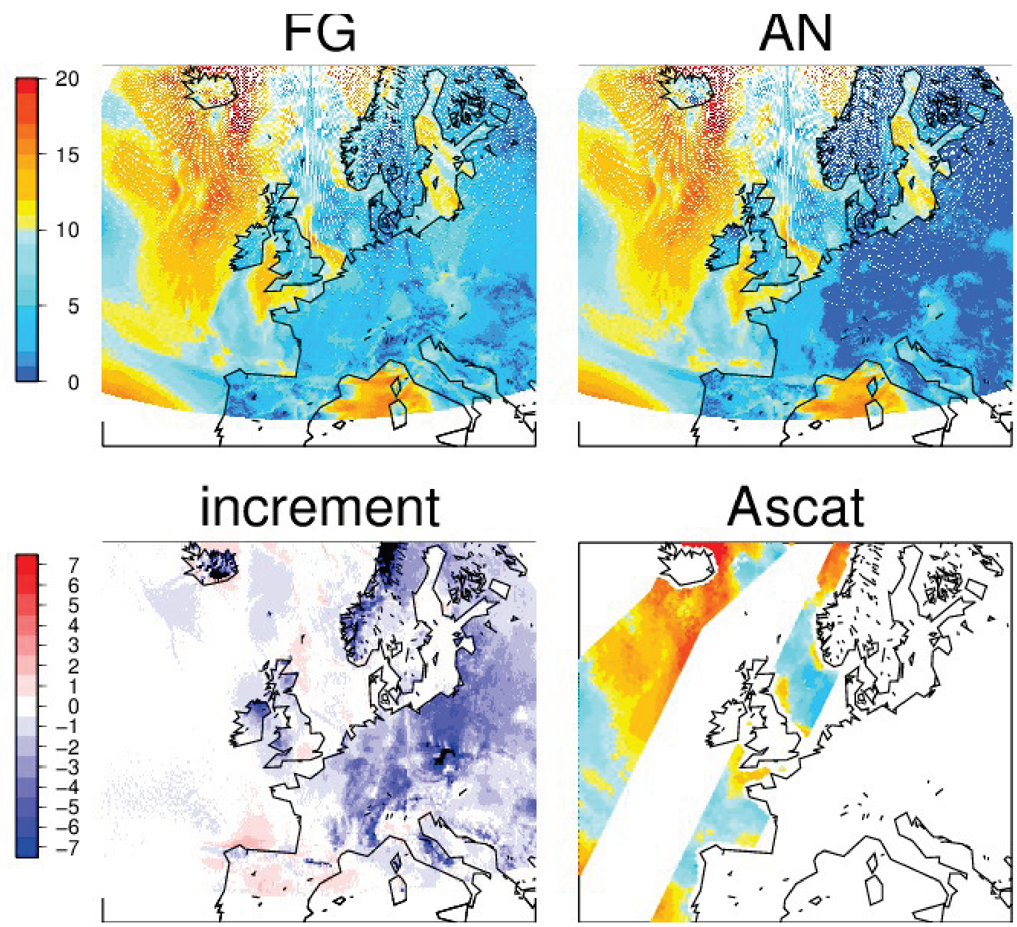

Figure 18. As Figure 5 but for 12:00 17-12-2010

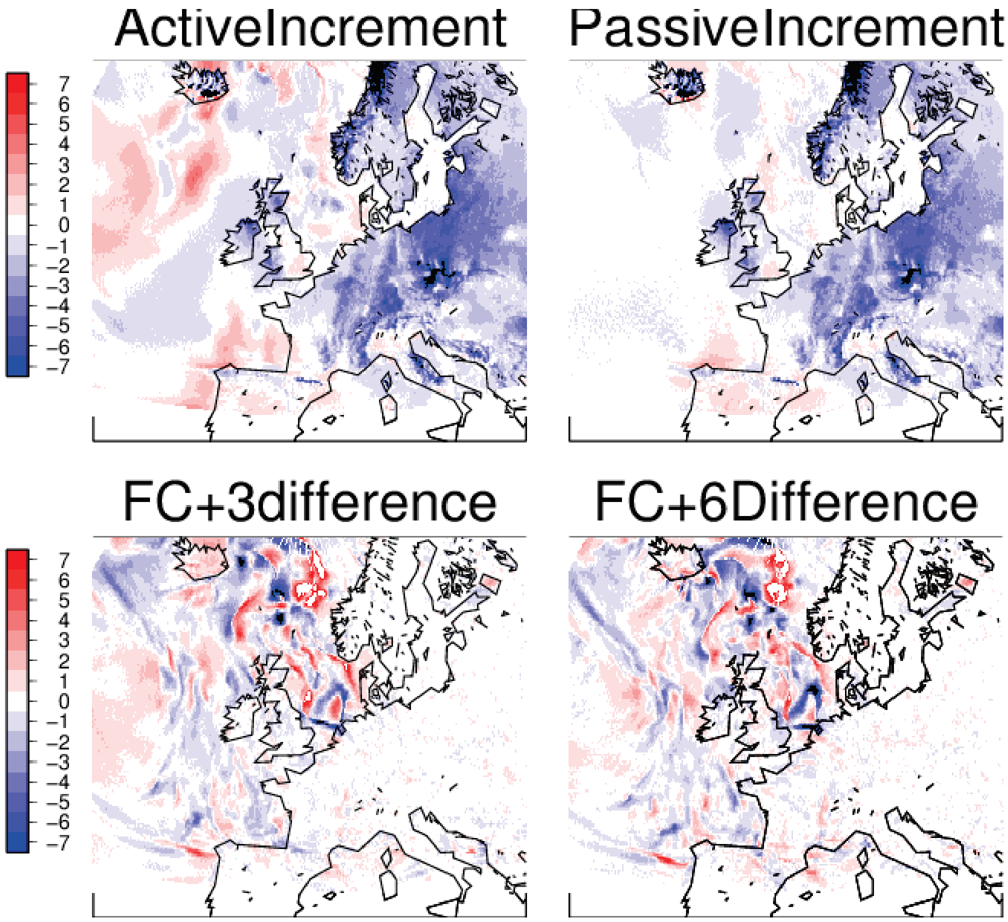

Figure 19. As Figure 6 but for 12:00 17-12-2010

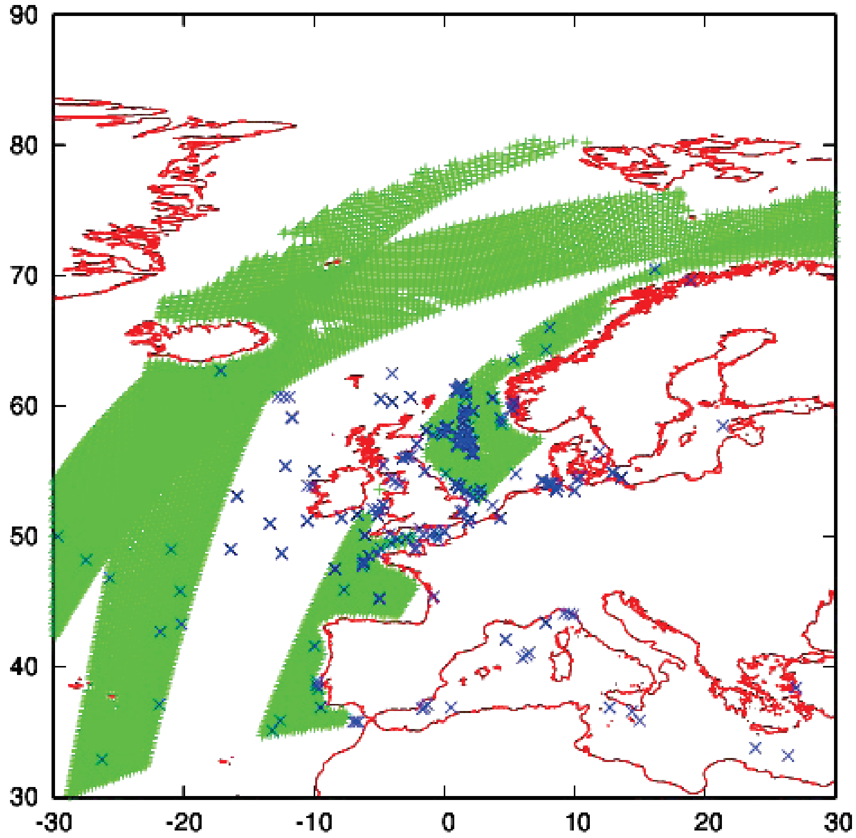

Figure 20. The spatial distribution of assimilated observations for 12:00 17-12-2010, green points denote ASCAT, blue crosses the ships, moored buoys and coastal stations.

6 Conclusions

To assess the impact of ASCAT wind ambiguities assimilated in a HIRLAM version of release 7.4 an observing system experiment (OSE) was performed. This includes a parallel experiment, one including (the so-called active experiment) and one excluding (also denoted passive or control experiment) the assimilation of ASCAT observations. Two OSEs were conducted, for two different periods in 2010, a fortnight in summer and a fortnight in winter. Passive assimilation consists of neglecting the ASCAT assimilation in the minimization matrices of the HIRLAM calculation. In this way the ASCAT observations do not contribute to the forecast calculation. OSE is also referred to as denial experiment.

The results of the active and the passive assimilation are compared. The comparison shows a negligible effect in the summer and a positive impact on the results in winter reflected in a lower standard deviation and lower bias. The best result in this study is a 6% decrease in standard deviation for ASCAT winds assimilation at the 3 hour forecast in winter time see Figure 14. The positive impact of ASCAT observation assimilation is predominantly over sea and at the coast. Remote from the sea over land the impact is negligible.

Within this study no additional effort is invested to optimize the use of ASCAT data within the assimilation method. No data thinning is applied nor is error inflation applied. Optimal data usage is expected to improve upon the results.

The selected periods are too short to demonstrate statistical significant impact of ASCAT observation for the HIRLAM model. Nevertheless, De Haan, et al 2013 showed the positive impact over a 10 week period of assimilation of ASCAT data in Hirlam (albeit in version 7.2cis). Based on the results and on the results of De Haan et al, 2013, the authors are confident to encourage the use of ASCAT data, especially for forecasts at sea and coastal regions. It is expected that the use of ASCAT data will lead to improved forecasts. In the near future the availability of ASCAT observations will improve with the METOP-B ASCAT instrument and the upcoming Indian and Chinese scatterometers. This will increase the forecast skill as more ASCAT data can be assimilated.

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Short manual for ASCAT implementation

Summary

This is a short description for the use of ASCAT in the assimilation of HIRLAM.
For an explanation of ASCAT data we refer to www.knmi.nl/scatterometer
This manual highlights the changes in the code for the ASCAT assimilation.
Special attention should be for the script RetrieveASCAT which ensures that the ASCAT data is available for assimilation.
The ASCAT observations can be downloaded from the KNMI ftp server or via the EUMETSAT EARS service. Their time delay at the time of writing is approximately 2 hours, but it is foreseen that the time delay will decrease in the future.

Read the latest information on www.knmi.nl/scat

Disclaimer:

The present (2013) code is only tested in 3DVARan in HIRLAM version 7.4beta1.

ASCAT implementation

To see where ASCAT related code is introduced in the software we suggest to use the unix command within the HIRLAM experiment directory under hl_home:

```
grep -in ASCAT */*
grep -in ASCAT */*/*
grep -in ASCAT */*/*/*
```

The ASCAT data is introduced into the model in a similar manner as Seawinds data. Therefore ASCAT assimilation is also related to the logical “llsws” (llSeawinds) in the script VARinput.
Also a number of routines containing ASCAT calls and references still contain “Seawinds” references. (see listing below). To assure that all related software is visualised we also recommend to perform a “grep -in SWS” in the unix command given above.

To assimilate ASCAT actively in a HIRLAM experiment $EXP one should set in hl-home/$EXP/scripts/Env_expdesc:

```
ASCAT=yes           # use ASCAT
```

The ASCAT data are collected by
scripts/RetrieveASCAT
[The option for reading operational ASCAT data from the ECMWF MARS archive has to be included and the paths have to be changed accordingly. Please also note that the instrument bufr coding for ASCAT is different in the KNMI bufr distribution (122) versus ECMWF (139)]. The present code however can handle this difference.

RetrieveASCAT is called from

```
scripts/MakeCMA:#========================= get ASCAT data
```

Changes are introduced in the following scripts and source codes, behind the name a classification of change ranging from minor to major is given:

Scripts:
3DVARan

MakeCMA (Major)
RetrieveASCAT [called by CMAstat]
VER_create_fld (minor, mainly forecast times)
VER_create_obs [called by CMAstat]
The VER_create_fld and VER_create_obs scripts and related software had to be adapted to include the sea surface observations.
Verify.sms (minor,only added VER_create_obs)

Code:
src/cmatoobs/cmatoobsmod.F (major)
src/cmatoobs/cmatoSeawinds.F (major)
src/cmatoobs/Seawinds_qc.F (does not occur in 7.3)
src/hlbufr/putSeawinds.F (large difference)
src/obscompress/compress_Seawinds.F (additions for ASCAT and Seawinds)

src/obsproc/HIRLAM: scanSeawinds.F90 (major)

To evaluate the impact of the ASCAT assimilation extra output files are created: scat_list.dat and scat_all.dat. They do not obey the “OBST” output file format used for the other observations. Their format description is given in the appendix, last part.
These files are archived combined with other observations in the file:
OBSTccyymmdd_hh.tar.gz

Ensure that you archive the desired output by creating and adapting
scripts/Archive.pl
In this scripts the user prescribes the files stored for evaluation.

Historical path

This section describes the chronological development of the software creation. It includes next to the successful steps, also the hurdles we experienced. The hurdles are included to create awareness for those who will update or create new software for the caveats HIRLAM (or any other NWP software package) developments may bring.

The project started at the end of 2007.
In the initial stage of the project the aim was the creation of a dedicated program for ASCAT observations based on existing Seawinds software. During the first six months of the study it appeared that the original Seawinds code worked for HIRLAM version cis but not for HIRLAM version 7.2rc nor for 7.1.3 or 7.1.4. It took time to establish the cause of the occurring errors. The HIRLAM versions on ECMWF are frequently updated as are the hardware computer platforms. The renewal to newer platforms and updates of HIRLAM are good developments. The caveat is that a piece of software which worked previously can produce error messages as it wasn't updated to comply with a newer platform, or software environment.
To circumvent this the ECMWF helpdesk can provide “frozen versions” of the code.
For the ASCAT assimilation a frozen HIRLAM version of cis, called cis080424 was made available. The previous developed Seawinds software could cope with the cis version.

After several improvements and new developments the approach to create a separate ASCAT software package was abandoned in September 2008. It appeared too complicated to embed the new code in the existing HIRLAM structure.

The Seawinds software part within HIRLAM cis was modified to encompass both the Seawinds and ASCAT observations. The advantage of this approach was that the consecutive parts of software dealing with Seawinds/ASCAT only needed modest modifications. The software was written to assimilate both Seawinds and ASCAT simultaneously. It took time to get this software faultless.
During the study the platform hpce was replaced by hpcf on ECMWF. The frozen cis080424 was not updated on the hpcf. It took a while to realize the impact of this omission. The ECMWF helpdesk made the cis080424 version available on the hpcf.

Unexplainable errors occurred. It appeared that they were caused by invisible characters. Only by changing to a different editing environment it became visible that there were unprintable characters which caused the scripts to falter.
Unfortunately scripts which were not updated for the ASCAT assimilation experiment played an unforeseen crucial role for successful runs. They had to be adapted to ensure ASCAT assimilation.

Before the summer of 2009 a successful run was made.
After the summer at ECMWF the hpcf platform was replaced by the c1a platform. On the new platform the software could not read the atovs data any more. Inactivation of the atovs assimilation enabled successful runs. But the intention of the experiment was to show the added value of the assimilation of ASCAT observations on the complete HIRLAM system including atovs. Still in order to proceed the software is run without atovs data. At the end of 2009 so-called vfld and vobs files were created. These files are necessary for the analysis of the impact of ASCAT observations assimilation.

November 2009 the Seawinds instrument failed.
In early 2010 the bufr version of ASCAT was changed to Bufr 4.

In April 2010 the eruption of the Eyjafjallejökull changed the priorities in work temporarily. In the Summer of 2010 a software version was written for HIRLAM version 7.3rc2. The new version worked and includes both the atovs data and the ASCAT data.
In early September 2010 there was a ECMWF system upgrade. The system upgrade caused rare IO problems between MARS and ECFS systems. Due to these reading/writing hiccups the HIRLAM runs were aborted at unpredictable moments. In October 2010 the cause of these hiccups was recognized and a remedy was provided by the ECMWF helpdesk.

In November and December 2010 successful runs are made, producing results for a comparison study. The runs progressed slowly due to communication problems on ECMWF between ECFS and MARS.

In February 2011 all runs with HIRLAM version 7.3rc2 were completed successfully. KNMI would like to have the ASCAT implementation in the newest/latest version 7.4 as a default option. To comply with this the project had to pause in the project until the availability of the version 7.4rc2.

From the obtained results with version 7.3rc2 it appeared that the output of the script VER_create_vfld and VER_create_vobs did not contain any sea surface observations, this included the moored buoys observations. It is foreseen that a significant impact of ASCAT assimilation will be over and near the sea. It is desirable to include sea surface observations into the evaluation. The incorporation of the moored buoys into the results required some effort as part of the verification code needed to be changed.

The ASCAT identifier differs between the KNMI ASCAT archive and the ECMWF MARS archive. In June 2011 the software was updated to cope with the two identifiers 122 (KNMI) and 139 (ECMWF).

The requirement to implement ASCAT assimilation in the latest version of HIRLAM 7.4 has been brought to version 7.4beta 1. The runs required much time due to large climate files. Due to limited resources this lasted long. In 2012 the experiments were performed which are discussed in this paper. In Early 2013 there was time to wrap these result up into this report.

A short explanation of the used Software Fortran programs

In the directory hl_home/$EXPERIMENT/scripts
the script
MAKECMA
calls RETRIEVE_SWS
and uses it to convert ASCAT and Seawinds scatterometer data into a CMA format.
The CMA format serves as input to HIRLAMVDA

HirVDA *HIRVDA* – HIRLAM Variational Data Assimilation tool is the program that actual reads all the observations. In order to be able to read the ASCAT and Seawinds data a bufr routine scanSeawinds is adapted to cope with either Seawinds or ASCAT or a combination of the two.

HIRLAMVDA has :

to read the ASCAT dat,
to screen the ASCAT data
to interpret the monitor flag
to compress the essential contributing ASCAT data
to control the data quality
to minimize the cost and J function. Here a flag should enable the omission of the ASCAT data to assess the added value through O-A and O-B statistics. (Probably O-F)
to decompress the data structure

to create a feedback file providing sufficient information.

HIRLAMVDA uses

scanSeawinds.F90 converts the bufr content to cma
Seawindsbody.F90 fills the cma body content called from scanSeawinds.F90
in directories: hl_home/ASCAT/obsproc/HIRLAM/

to read both the ASCAT data and/or the Seawinds data
to screen the ASCAT data
to interpret the monitor flag
called from src/obsproc/make_cma/mkcmasin.F90

It uses obscompress / decompress

to (de)compress the essential contributing ASCAT (Seawinds) data
to control the data quality
called from src/obscompress/(de)compress_obsmod.F

it uses putSeawinds

Write out Seawinds monitoring and ascii feedback information
to create a feedback file providing sufficient information for evaluation.
Called from src/hlvar/hirvda.F

(de)alloc_Seawinds

Allocate and deallocate are required to allocate memory space.
Called from src/cmatoobs/cmatoobsmod.F
src/cmatoobs/obsmodtocma.F
src/obscompress/(de)compress_obsmod.F

Cmatoobsmod

Adapted to cope with ASCAT only through obs subtype number: obstyp and obscode

cmatoSeawinds
Called from src/cmatoobs/cmatoobsmod.F

obsmodtocma
Master routine to copy data from observation modules back to cma
Called from src/hlvar/putcmaobs.F which is called from src/hlvar/hirvda.F

Seawindstocma
called from src/cmatoobs/obsmodtocma.F
put content of Seawinds/ASCAT to cma

Seawindsdata.F90
Seawindsmindata.F90
Defines the Seawinds(min)data
Called from several routines

Manual

This manual is intended for non-experienced users starting to work with HIRLAM. The HIRLAM code is huge and complex. It is not easy to understand all the direct dependencies and indirect dependencies. It is also a still evolving program. This means that a step forward in the evolution can have impact on the study which the “fresh” user is doing. While performing our study we realised that there is no “simple” manual to get acquainted with HIRLAM software nor with the scripting or hardware structure. To fill this gap and to facilitate the introduction to HIRLAM this manual is written. It only describes the experience we gained with data assimilation, so we barely scratched the surface of the HIRLAM structure.

We also refer to the HIRLAM website as a support tool.
https://HIRLAM.org/trac/wiki/ReleaseNotes7.?

We performed an assimilation study of ASCAT data in HIRLAM.
We experienced the Assimilation of data in HIRLAM is a challenging exercise. The choice to do this in a continuous developing environment on ECMWF makes it even more challenging.

Although this may seem obvious it is stressed here that before performing any run on the ECMWF it is very recommendable to check the differences between the developed or changed software and the latest version of this software of the HIRLAM release used. Especially for studies lasting over long time periods this approach minimizes the unforeseen errors. Do not hesitate to contact the helpdesk at ECMWF when unforeseen errors occur. They give a good support.

The manual describes the basic structure of the ECMWF environment, the structure of HIRLAM code which is relevant for assimilation, and basic commands. The used commands are summarised at the end of the manual. A basic knowledge of UNIX is assumed.

ECMWF structures

The ECMWF environment consists of several computers. The computers change in course of time. One accesses the ECMWF via ecaccces [see section commands].
The user is prompted to access one of the computers. Normally one accesses the “ecgate” platform. On the “ecgate” the {$USER} disposes of two directories a $HOME and a $SCRATCH (or “/scratch/ml/nl/nkq”).
Normally one enters in a “borne shell”. To work in another more user friendly shell one can for example use the “tcsh” command.
As soon as one performs runs with HIRLAM software the results are stored on another platform, an archive environment referred to as ec.[see commands for access]. One can directly access this archive environment using “rlogin c1a”. Please note that:
-c1a will change in time.
-in the archive platform one disposes of the borne shell only.

HIRLAM structures

HIRLAM consists of Fortran coded software and (Born shell) scripts. Both need to be adapted when new software is developed. The Fortran coding can occur in different

versions, F90 and others.
HIRLAM prescribes a directory structure to perform runs or experiments. The software created in this {$USER} directories is nested into the HIRLAM directory structure when an experiment is started. This is done by insertion or replacement of the {$USER} created or changed files where appropriate in the original HIRLAM directory tree.

The prescribed directory is $HOME/hl_home/$EXPERIMENT.
The $EXPERIMENT name is created by the {$USER}.

Any HIRLAM run has to be started from the directory: $HOME/hl_home/$EXPERIMENT. The system will come with an error message when this requirement is not fulfilled.
There are several versions of HIRLAM available. If the {$USER} has chosen one version the {$USER} has to setup the associated HIRLAM environment. [see commands]. Please note that a version can become obsolete in course of time. The support for this version can become a problem. If the study takes to much time one should be aware of the necessity to port to a newer version.

Once HIRLAM is initiated and run it will create a directory
ec:/nkq/HIRLAM/ASCAT/ccyy/mm/dd/HH with HH the start time.
the directory contains [only prefixes are given]

log files	Hl*Cycle*, Make Cycle*
Analysis and Observations	ACMA (! relevant for interpretation)
OF	for verification
an	analysis
fb	file in ascii containing feedback data for interpretation
ve	verification data (prefix) or verification fields (suffix)
his	NWP-SAF monitoring files for Seawinds
hist	history file
ob	observation files (prefix)

The content of the archive is prescribed by the script:
scripts/Archive.pl

The method applied and the data used are prescribed by the script:
scripts/Env_expdesc
The latter script also prescribes where the data are stored in archive: ec or ectmp. Please note that both are used. One will be used to store the minimalisation results the other for the archive.

Commands

This includes the most common commands used during the experiment.

Login ssh {$USER}@ecacces.ecmwf.int
use your identity key to access the system.

archive “ec”

ec:/{$USER}	permanent storage
ectmp:/{$USER}	temporary storage e.g. ectmp:/{$USER}/HIRLAM/ASCAT/ccyy/mm/dd/HH
ec:/HIRLAM/	contains the HIRLAM archive
ec:/HIRLAM/cis/obs/	contains the observation files for HIRLAM version “cis”

els;ecp;emkdir;ermdir;erm are commands to manipulate and study the archive files.

Setup and run HIRLAM

The person responsible for the implementation of Hirlam at the time of writing is Xiaohua Yang, identified by {$USER} identity “nhz”. So “~nhz” will frequently appear on the command line.
To benefit from the software developed by other HIRLAM users the new user should be part of the “HIRLAM” group. This has to be requested to the HIRLAM support, X. Yang.

First steps:
Compilation of self developed software.
For first trial compilation on small parts of software it is recommendable to use the “xlf90” command.
Xlf90 without arguments invokes a help page.
Commonly applied calls are (preferable in a separate directory [I.e not in hl_home]:

```
xlf90 -c -qsuffix=F90 {$USER}_DEVELOPED_SOFTWARE.F90 -I ~nll/hl_home/CIS1TMP
xlf90 -c -WF,-DMPI
```

Use UNIX grep and diff commands to see the difference between the developed software and the original software.
Very recommendable is to compare scripts or software with the original HIRLAM software. It can reveal version differences or other inconsistencies.
e.g.

```
diff scripts/VER_create_vfld ~/nhz/HIRLAM_release/7.3rc/scripts/ VER_create_vfld
```

To study dependencies one can use:

```
grep  VER_create_vfld */* or ~/nhz/HIRLAM_release/7.3rc/*/*
```

When the compilation is successful the software can be copied to the appropriate location the HIRLAM directory structure. Do not copy the object files!

Check if the (new) scripts have an execute permission “rwx” instead of “rw-” witjh “ls -l” command.

To setup your experiment with a particular version of the reference system (e.g. 7.2,cis)

```
        ~nhz/HIRLAM setup -r cis
```

To checkout a particular script or file from the version control system

```
        ~nhz/HIRLAM co scripts/MakeCMA
```

A cold start run with the reference system for 48 hr forecast (minimal 6 hr)

```
        ~nhz/HIRLAM  start DTG=2007120712 DTGEND=2007120912 LL=48 LLMAIN=48
```

Continuation of a model run (no cold start)

```
        ~nhz/HIRLAM  prod DTGEND=2007121112 LL=48 LLMAIN=48
```

remove all data for new experiments on the ecgate :

```
rm -rf $SCRATCH/hl_home/$EXPERIMENT/*
```

on the platform c1a

```
rm -rf /c1a/tmp/ms/nl/nkq/hl_home/$EXPERIMENT/*
```

To monitor and kill runs on c1a

```
rsh c1a -l nkq llq -u nkq
rsh c1a -l nkq llcancel
```

Contents of scatt_all

The content of the observation file of scat_all differs from the format of other observation files. Hence the writing used to generate the scatt_all is given. The next lines are used to generate scat_all output files:

```
write(100+mype,fmt)
   $    nint(buf(icount+ 1)), ! Seawinds_obstype
   $    nint(buf(icount+ 2)), ! Seawinds_obssubtype
   $    nint(buf(icount+ 3)), ! Seawinds_orbit
   $    nint(buf(icount+ 4)), ! Seawinds_row
   $    nint(buf(icount+ 5)), ! Seawinds_wvc
   $    buf(icount+ 6),       ! Seawinds_lat
   $    buf(icount+ 7),       ! Seawinds_lon
   $    nint(buf(icount+ 8)), ! Seawinds_date
   $    nint(buf(icount+ 9)), ! Seawinds_time
   $    nint(buf(icount+10)), ! Seawinds_repevent1
   $    nint(buf(icount+11)), ! Seawinds_repstat
   $    nint(buf(icount+13)), ! Seawinds_noambi
   $    nint(buf(icount+12)), ! Seawinds_ambisel
   $    nint(buf(icount1+1)), ! Seawinds_selected
   $    (solprob(j),          ! Seawinds_ambiprob
   $      spdc(j),            ! Seawinds_ambiwspdobs
   $      dirc(j),            ! Seawinds_ambiwdirobs
   $      j=1,4),
   $    buf(icount1+2),       ! Seawinds_anaspeed
   $    buf(icount1+3),       ! Seawinds_anadir
   $    buf(icount1+4),       ! Seawinds_bgspeed
   $    buf(icount1+5),       ! Seawinds_bgdir
   $    buf(icount1+6),       ! Seawinds_cost
   $    buf(icount1+7)        ! Seawinds_ppg
```

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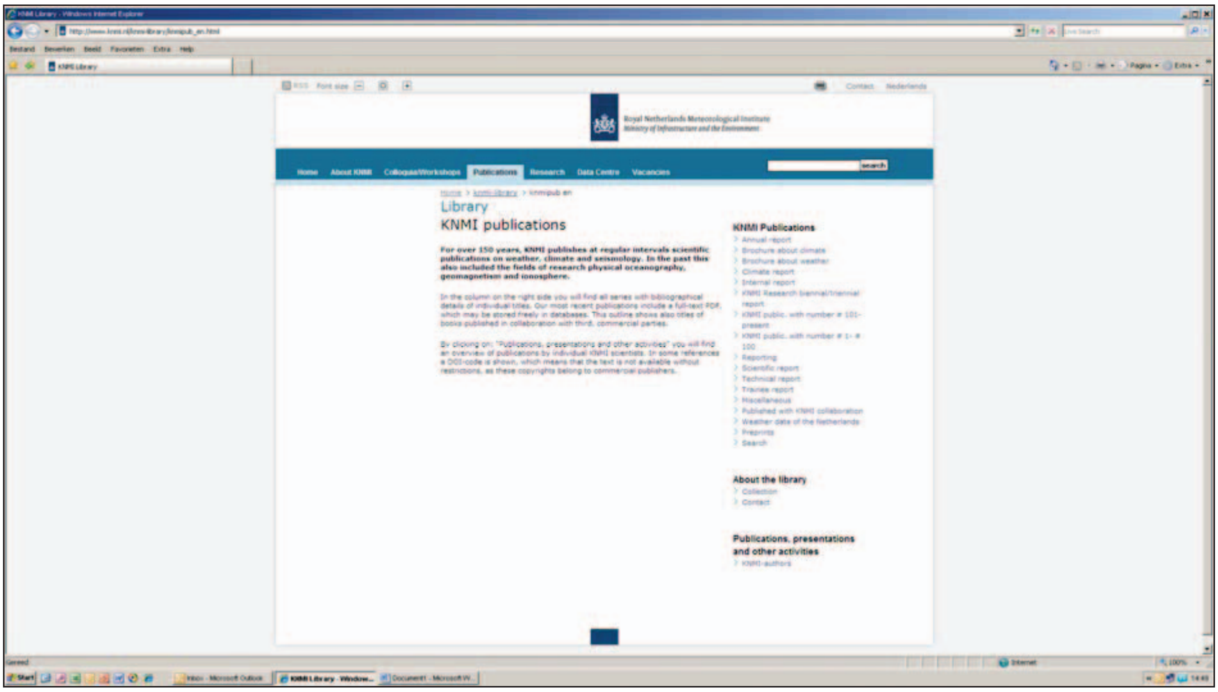

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