Validation of OSCAT observations

Jana Čampa, Benedikt Strajnar

Slovenian Environment Agency

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Introduction

Winds change on relatively small scales in the atmosphere but the number of observations available for data assimilation is still too low. Scatterometers on board polar orbiting satellites fill the gap in data sparse regions over the oceans. They provide information on winds near the sea surface on the basis of signal scattering on the wavy sea surface.

ASCAT scatterometer wind observations have been widely used in NWP models. OSCAT offers complementary information to that from ASCAT for data assimilation. This report investigates the impact of OSCAT observations on the analysis and the forecast in the ALADIN/SI model.

Model configuration and OSCAT observations

ALADIN model configuration

We used the latest operational version of ALADIN/SI model for this evaluation, using the following configuration:

- ALADIN model cycle cy43t2 (ALARO-v1b package of physical parametrizations)
- 432 x 432 grid points, 4.4 km resolution
- 87 vertical levels
- Three-dimensional variational data assimilation (3D-Var) for upper-air observations, optimal interpolation (OI) for soil assimilation
- B-matrix for assimilation based on ECMWF ensemble data assimilation model version cy40
- 3-hourly assimilation cycle
- ECMWF lateral boundary conditions
- Conventional and satellite observations: SYNOP, AMDAR, AMV, HR-AMV, TEMP, AMSU&MHS, SEVIRI, IASI, Mode-S MRAR/EHS, ASCAT, OSCAT (subject of experimentation)

OSCAT data

OSCAT is a scatterometer instrument on board ScatSat-1 satellite [1]. It provides near surface wind vector observations. The data are available over ocean surfaces with the horizontal resolution of approx. 25km. Most of the data used in this investigation is included into the analysis over the Mediterranean Sea, however a small number of observations is also assimilated over the North Sea between England and the Netherlands.

The satellites carrying ASCAT (Metop B and C) and OSCAT (ScatSat-1) scatterometers overpass Europe twice daily in a time interval of less than one hour. Therefore, both datasets are assimilated in the same assimilation run. At the moment, overpass times are not optimal for the use in NWP – the data is mostly available for the 09 and 21 UTC runs whereas longer forecasts are usually calculated at typical synoptic times. All three satellites are a part of an international effort to improve spatial and temporal coverage of sea surface winds. ScatSat-1 started in a close orbit to Metop-B for calibration purposes and has gradually drifted to its final Equator crossing time at 8:00 UTC [1], [2].

The satellite retrieval process results in 2-4 possible solutions for near surface wind vectors. All available solutions are read and one solution is chosen during the assimilation process. According to the literature the retrieved data is less reliable above 25 m/s. [1]

Experimental setup

The experimental setup consists of four experiments: an operational-like reference suite (REF) and an experimental suite including OSCAT data (OSCAT), and two similar experiments without ASCAT data. Since ASCAT and OSCAT offer complementary information the purpose of the last two was to isolate the impact of OSCAT alone. The reference suite includes all data that is operationally assimilated in ALADIN/SI. The experiments were initiated on 1 December 2019 0 UTC and 24h forecasts were computed over one month (experiments including ASCAT) or 10 days (experiments excluding ASCAT). The experiments without ASCAT data were performed to test the possible redundancy effect. Namely, ASCAT and OSCAT provide the same type of information at approximately the same time. Each of them might have a very positive effect on the analysis, however including OSCAT might reduce the positive effect of ASCAT data. Besides, Wang et al. (2019) point some inconsistencies in retrieved wind fields from different scatterometers. However, since ASCAT data already belongs to the standard in data assimilation, most of this study is performed with this data set.

Including OSCAT data into the data assimilation process in ALADIN/SI model requires a new entry in the aldnml_param_bator.cfg namelist, since the data files are organized differently than other previously used data. Following lines need to be added:

```
BEGIN kuscat
1 1 1 11
codage     1  312028
control    1       4  nb vents
offset     1       5
values    15  005002  LATITUDE
values    16  006002  LONGITUDE
values     9  004001  YEAR
values     1  001007  SATELLITE IDENTIFIER
values    20  006034  CROSS TRACK CELL NUMBER
values    21  021109  SEAWINDS WIND VECTOR CELL QUALITY
values    24  021101  NUMBER OF VECTOR AMBIGUITIES
values    31  011012  WIND SPEED AT 10 M
values    33  011011  WIND DIRECTION AT 10 M
values    34  011053  FORMAL UNCERTAINTY IN WIND DIRECTION
values    35  021104  LIKELIHOOD COMPUTED FOR SOLUTION
END kuscat
```

“kuscat” is ALADIN internal name for routines dealing with OSCAT data, number 4 (second line, “control”) stands for the number of possible solutions from the retrieval, and the number 5 (third line, “offset”) for the offset between the messages in the grib files that include the wind solutions.

Results

Impact on the analysis

We investigated the impact of the newly assimilated wind data on the model analysis. First, we compare the data to the model first guess, i.e. a 3-hour model forecast interpolated to observation location, in order to identify potential biases. Figure 1 (left panel) presents a 2D histogram of OSCAT wind and the model wind first guess. The points are distributed evenly on both sides of the diagonal, which implies no significant bias for the larger part of the data. However, the tails of the distribution are not on the diagonal. The values are consistently lower in the model than in the data for winds over 15m/s. This can be due to underestimation in the model or overestimation in the OSCAT retrieval. The product documentation reports overestimation of OSCAT winds, though subsequently addressed with corrections in the retrieval process [3], [4].

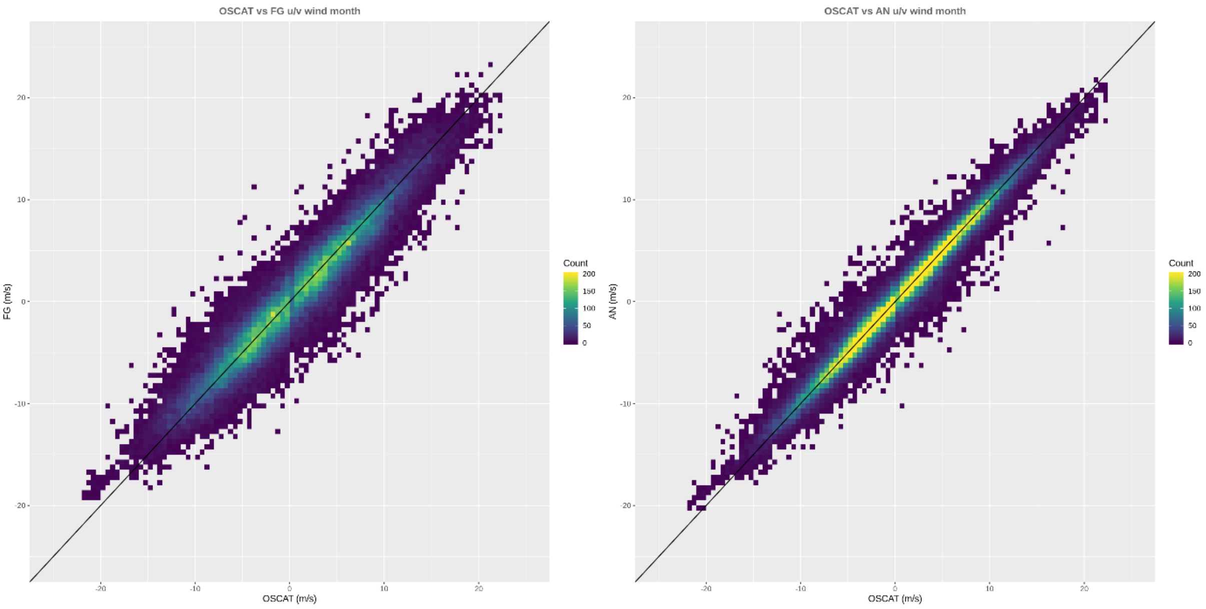

Figure 1: 2D histogram of OSCAT wind observations and model first guess (left) and analysis (right) of the same variable (both u and v wind). Included are all model runs and data between 1 December 00 UTC and 31 December 12 UTC.

The right panel in Figure 1 presents a similar histogram between the observations and the analysis resulting after the assimilation. The points are concentrated closer to the diagonal, a sign for the analysis coming closer to OSCAT observations. This is confirmed in Figure 2. Here, the mean and standard deviation of OMG (first guess departure or obs-minus-guess; blueish points) and AMG (analysis departure or obs-minus-analysis; reddish points) for OSCAT data are presented over the period of one month. Each point represents the mean or the standard deviation of all observations in one assimilation cycle. It can be seen that the analysis is typically closer to OSCAT data than the first guess, even though a few exceptions are present. The figure does not confirm that this effect comes entirely from OSCAT data, but OSCAT data plays an important role as seen in Figure 1.

When new observations are included into the assimilation process, the impact of other observations usually changes. This is also the case here, as presented in Figure 3. The blue columns represent the departure of the first guess (OMG) from the observations and the orange columns the departure of the analysis (OMA) from the observations for different observation types due to OSCAT data. In the left panel simulations including ASCAT wind scatterometer data are presented and in the right panel ASCAT was excluded.

As expected, the figure shows the largest changes of OMA and OMG for wind observations (var 3, 4, 124, 125) from surface stations (type 1), atmospheric motion vectors (type 3) and ASCAT (type 9). There is almost no change in wind observations from the aircraft (type 2) or radiosondes (type 5).

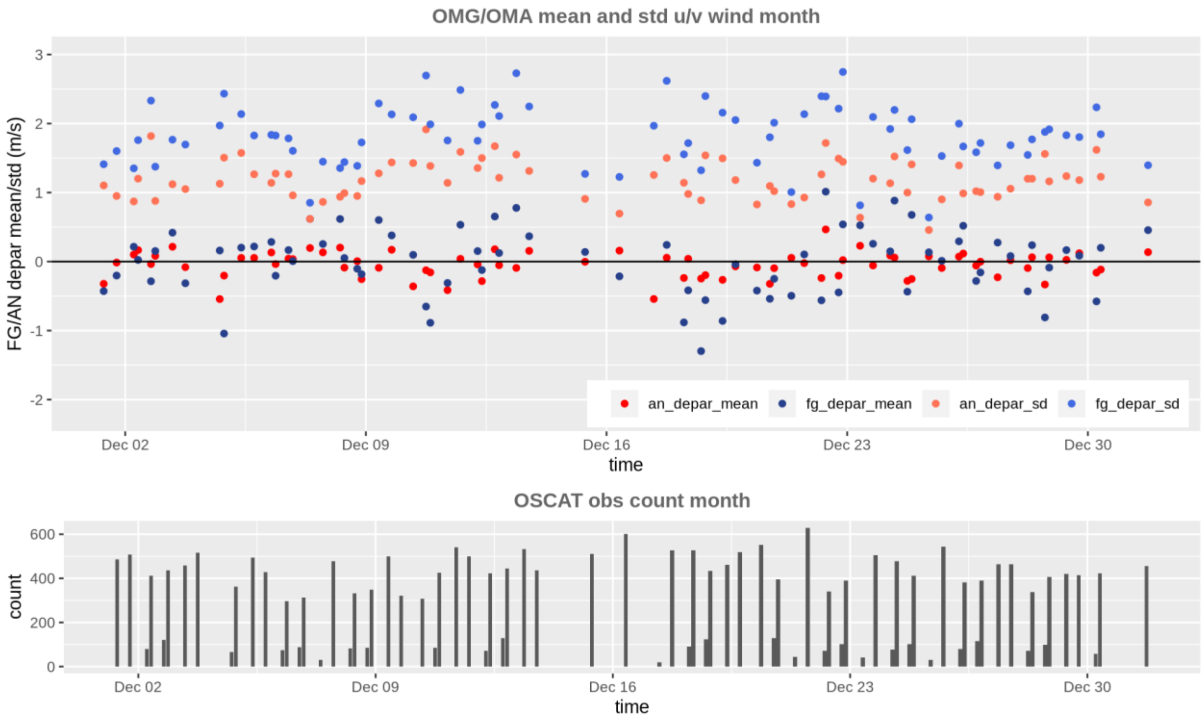

Figure 2: Mean and standard deviation of OMG and OMA for OSCAT data over the experimentation period. OMG in blueish shades, OMA in redish shades. Lower panel: Number of included observations in each assimilation cycle.

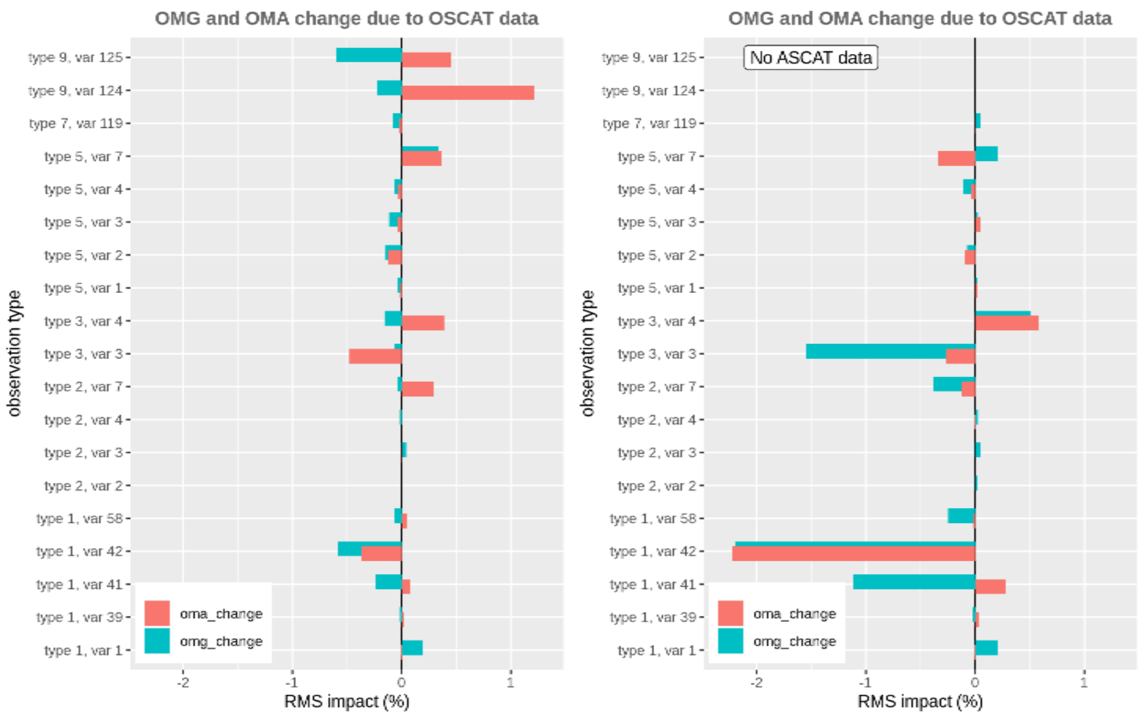

Figure 3: OMG and OMA change due to OSCAT data for all assimilated observations for the selected experimantation period. Left panel: with ASCAT data, right panel: without ASCAT data.

Interestingly, sometimes the effect is different for u and v component of the wind. When no ASCAT data is included in the analysis (right panel), the effect of OSCAT data is much larger. Again the largest changes can be seen for surface stations and atmospheric motion vectors.

The orange columns show that the inclusion of OSCAT data also brings the model analysis closer to ASCAT data. Bhowmick et al. [5] found a similar result for the UK Met Office model. This is also true for humidity measurements (var 7) when both scatterometer datasets are included (left panel). For other measurements the effect is more ambiguous.

Impact on forecast

To measure the impact of OSCAT observations on the forecast, standard verification scores were calculated using the verification package *harp*. 24h forecasts were computed at 00 and 12 UTC from initial conditions with and without OSCAT data. Most of OSCAT observations were assimilated into 09 and 21 UTC forecasts, however, longer forecasts are usually not produced at these times. Therefore, only the impact on the forecasts at standard times was investigated. The simulations here include ASCAT data.

The impact was calculated for the stations around the Mediterranean, as we expect less impact further away from the measurements. The selected stations are shown in the upper panels in Figure 4. As OSCAT only provides wind measurements close to the ocean surface, the upper-air verification (comparison with radiosonde measurements) was omitted.

Left panels in Figure 4 show very small to neutral impact on the forecast for 2m temperature, 2m specific humidity, 10m wind speed and total cloud cover for all Mediterranean stations in the region covered by Aladin/SI model. In fact, the impact cannot be seen from the figures as the values in the REF and OSCAT experiment differ in the range of ca. 1‰. The impact is similarly small for other variables. We have experimented with different verification areas. With larger areas the impact on the forecast is even smaller. A noticeable impact can be seen for smaller areas in the Mediterranean region and single coastal stations, as presented here for the region around Corsica and Sardinia (right panels). The impact is the largest, but still very small, for the total cloud cover and specific humidity.

A smaller number of OSCAT observations is also assimilated at 06 UTC and in fact a slightly larger differences between the REF and OSCAT experiments were found in some regions at that forecast time. However, the impact was not large and the forecasts were not affected in the same direction.

The missing impact on the forecast is contradictory to the fact that there is a change in OMG (observations minus first guess). The first guess can only be different if the 3-hour forecast is changed. A very likely explanation is that OMG is calculated at the observation locations (over the sea) and the impact on forecast at the locations of surface stations (mainly over land) where the impact of these observations is smaller. The verification results for a selected number of coastal stations confirm this.

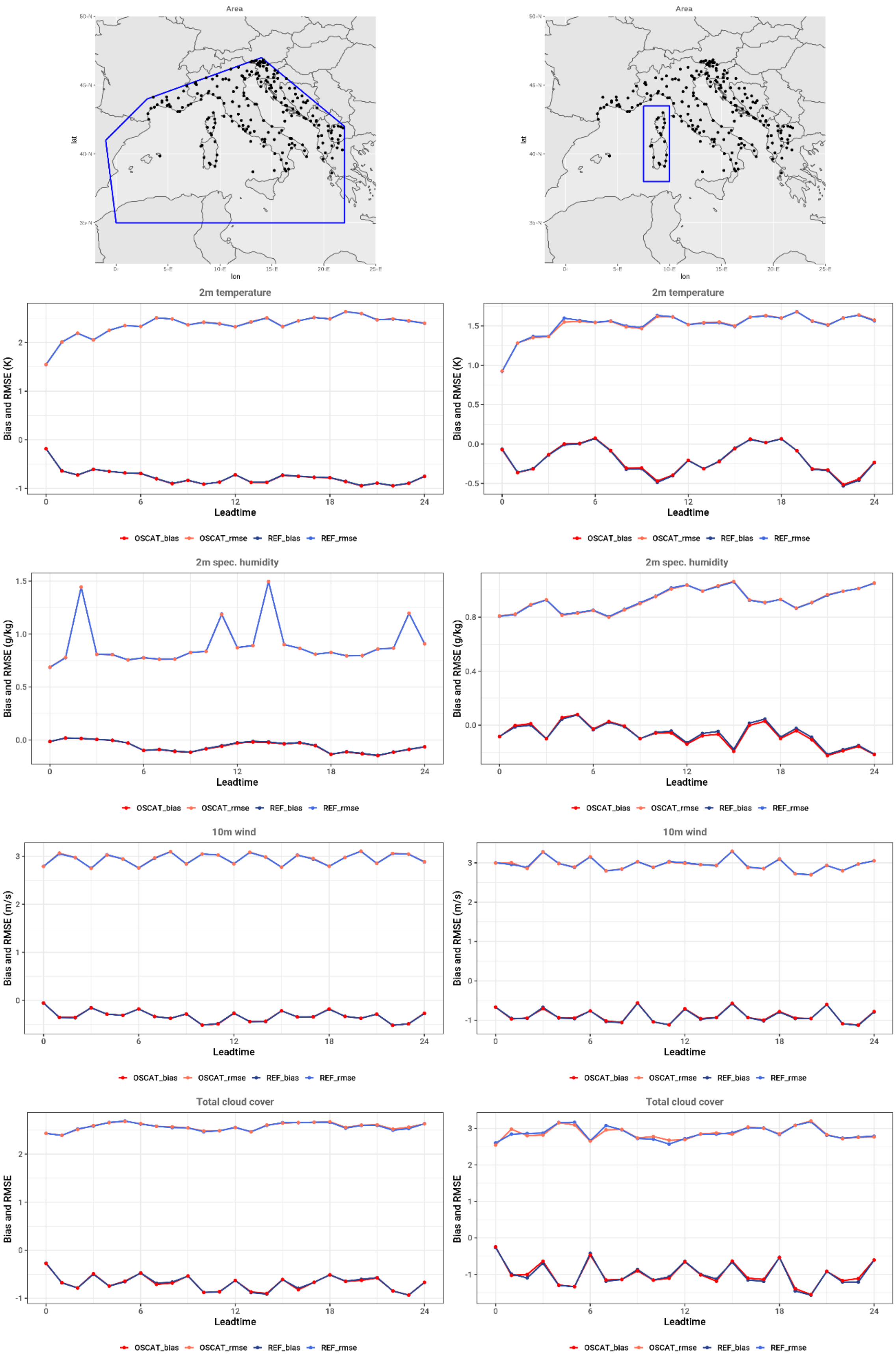

Figure 4: Verification of 2m temperature, 2m specific. Humidity, 10m wind speed and total cloud cover against surface stations. Mean and RMS error for experiments REF and OSCAT, forecasts were initiated at 00 or 12 UTC. Selected surface stations are depicted in the upper panels.

Summary and conclusions

The impact of OSCAT wind observations in ALADIN/SI NWP model was investigated over a period of one month. The majority of the data was available for assimilation at 09 and 21 UTC and therefore had little impact on forecasts at typical synoptic times. OMG/OMA investigation showed an impact of OSCAT data on the analysis, however, the impact on the forecast at some distance from the observations was largely neutral.

OSCAT data represent a complementary dataset to the more widely used ASCAT data. As both cover data sparse regions over the seas and oceans they represent a valuable source of information for NWP. When both are assimilated OSCAT reduces the impact of ASCAT data and causes the problem of redundancy. Still, this does not cause any negative impact on the forecast. As we expect OSCAT to be able to fill the gap in case of ASCAT failure or other problems, it should be beneficial to include OSCAT data into the operational analysis.

References

[1] OSI SAF, ScatSat-1 wind Product User Manual, SAF/OSI/CDOP2/KNMI/TEC/MA/287, 2018

[2] Wang, Z., A. Stoffelen, B. Zhang, Y. He, L. Xiuzhong. Inconsistencies in scatterometer wind products based on ASCAT and OSCAT-2 collocations. *Remote Sensing of Environment*. Vol 225. DOI: 10.1016/j.rse.2019.03.005, 2019.

[3] OSI SAF, Algorithm Theoretical Basis Document for the OSI SAF wind products, SAF/OSI/CDOP2/KNMI/SCI/MA/197, 2018

[4] OSI SAF, ScatSat-1 wind validation report, SAF/OSI/CDOP3/KNMI/TEC/RP/324, 2018

[5] Bhowmick, S. A., J. Cotton, A. G. Fore, R. Kumar, C. Payan, E. Rodríguez, A. Sharma, B. W. Stiles, A. Stoffelen and A. Verhoef. An assessment of the performance of ISRO's SCATSAT-1 Scatterometer. *Current science*. Vol. 117, Nr. 6. DOI: 10.18520/cs/v117/i6/959-972, 2019.