IMPACT OF AEOLUS L2B WINDS IN THE REGIONAL MODEL HARMONIE-AROME

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ABSTRACT

We investigate the impact of assimilating the wind profiles from the Aeolus satellite in the regional model Harmonie-Arome. In this study we use 3DVar to assimilate the HLOS L2B winds for two different seasons over the Nordic region. The autumn period (Sept-Oct 2018) is using laser A and the spring period (Apr-May 2020) is using laser B data. We will show the impact of both Rayleigh and Mie winds in the regional model for the two periods and present the impact on the analysis and the forecasts. We see that the quality of the Aeolus observations has degraded between the first and second experiment period over our domain. However, observations from Aeolus, in particular the Mie winds, have a clear impact on the analysis of the regional model for both periods, whereas the impact on the forecasts is neutral. We will also show some early results highlighting the potential improvement in using 4DVar, which generates flow-dependent analysis increments, instead of 3DVar when assimilating Aeolus wind profiles.

INTRODUCTION

The Aeolus L2B winds are here assimilated in the Harmonie-Arome model over the MetCoOp domain, which is also the operational weather forecast system for Norway, Sweden, Finland and Estonia. In this study we investigate the impact of adding Aeolus HLOS winds to the data assimilation for two periods, 14 Sept – 14 October 2018 (early laser A period) and 20 April – 19 May 2020 (laser B period, when the mirror temperature bias correction became operational). Boundary and initial conditions are provided by the IFS from ECMWF. The experiments run a forecast eight times per day, every third hour with shorter catch-up runs for the intermediate cycles and longer forecasts during the synoptic hours.

For both periods, we investigated the impact of all Aeolus data as well as the impact of the Rayleigh and the Mie observations separately. We start by investigating the quality of the Aeolus observations. Fig. 2 shows the bias and standard deviation (SD) for Aeolus Rayleigh and Mie observations compared to radiosonde and aircraft data. For the laser A period, the Mie observations show a comparable quality to that seen in the aircraft and radiosonde observation and the Rayleigh observations having somewhat lower quality. For the laser B period, the Aeolus data quality has degraded.

DATA COVERAGE

On average we have two or three Aeolus overpasses per day over the MetCoOp domain, descending orbits at 03 and 06 UTC and ascending orbits at 15 and 18 UTC. During the laser A period (autumn 2018), the satellite coverage is more varied from cycle to cycle than it is for the laser B period (spring 2020).

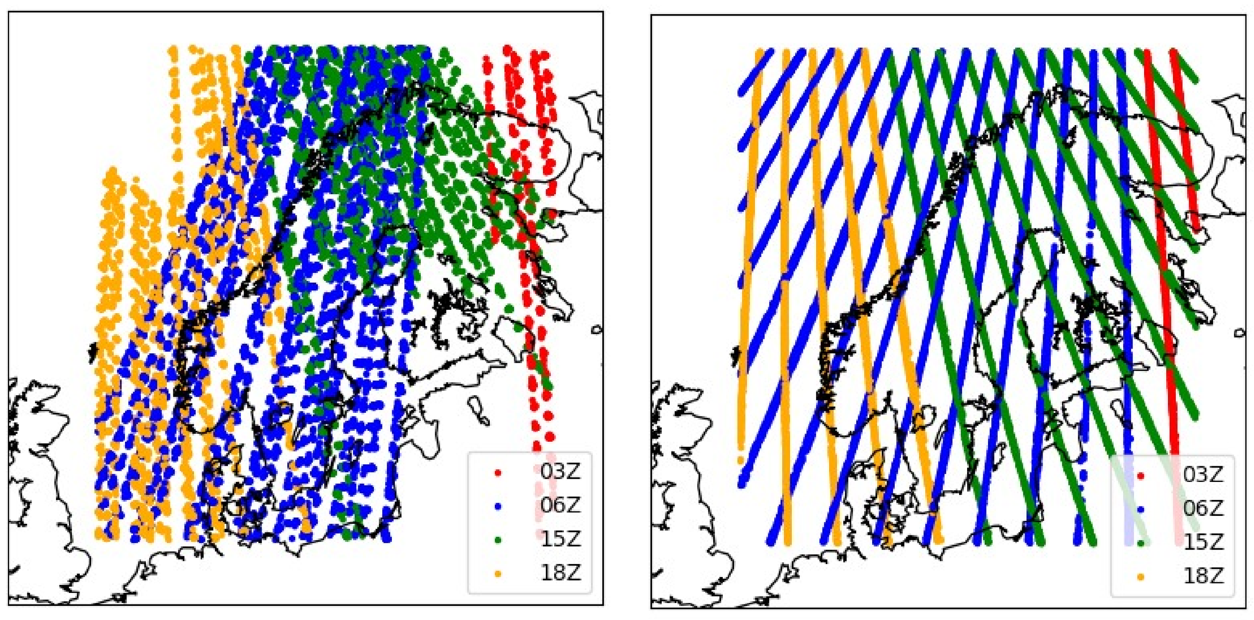

Fig. 1: Coverage of Aeolus overpasses over the MetCoOp domain for the two periods.

FORECAST IMPACT

The forecast impact is evaluated against radiosonde data. As there are only radiosonde data available at 00 and 12 UTC, we can only evaluate the impact of Aeolus data on the 6 h forecasts from 06 and 18 UTC, which are valid at the time there are both radiosonde data available and Aeolus data has been used in the data assimilation. There are some small differences in the standard deviation and bias for wind speed and direction, at different heights, but overall we see that the forecast impact of the Aeolus HLOS winds is neutral.

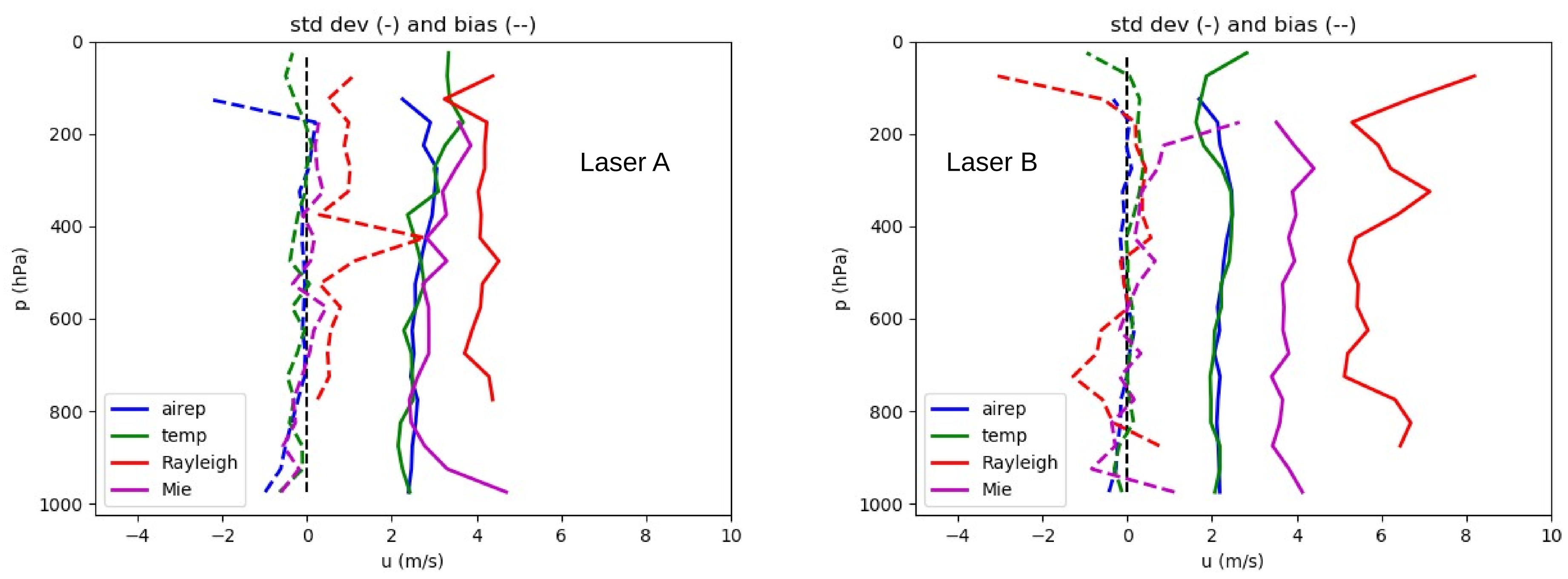

Fig. 2: Standard deviation and bias of O-B for Aeolus Mie (purple lines) and Rayleigh (red lines) HLOS winds compared to radiosondes (green lines) and aircraft data (blue lines).

OPTIMIZING THE EXPLOITATION OF AEOLUS WINDS IN REGIONAL NWP – A NEW ESA PROJECT BY SMHI, MET NORWAY AND KNMI

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In this project, which will start later this year, we will investigate the impact of reprocessed Aeolus L2B wind observations in the Harmonie-Arome model. We plan to use 4DVar data assimilation over two domains (UWC-West (red) and AROME-Arctic (orange) and focus on cases with strong winds, polar lows for the Arctic domain and wind storms for the UWC-West domain.

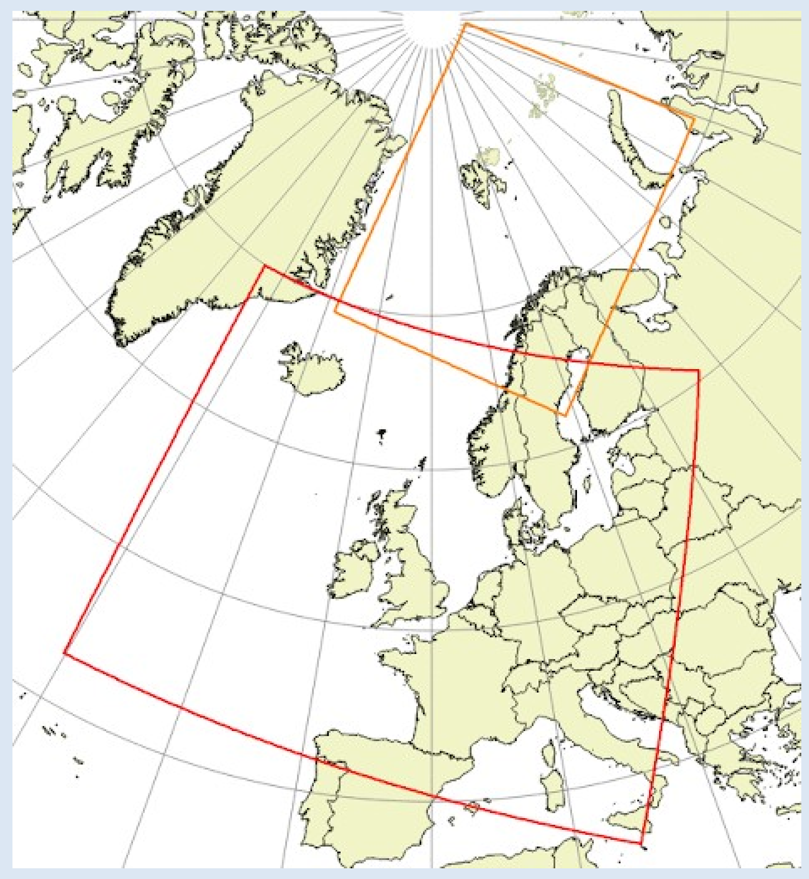

Fig. 6: The AROME-Arctic (orange) and UWC-West (red) domains.

The advantage of the AROME-Arctic domain is the high number of Aeolus overpasses which should mean that the use Aeolus observations in the data assimilation will have a large impact on both the analysis and the forecast. The advantage of the UWC-West domain is the higher availability of other observations to use for verification and that it is more representative of a typical mid-latitude domain.

PRELIMINARY RESULTS WITH 4DVAR

Aeolus observations can successfully be used in 4DVar in Harmonie-Arome. For the MetCoOp domain, the difference in the impact of Aeolus observations between 3DVar and 4DVar can be seen in the analysis increments of the u component of the wind speed in the example below. The figures below show the difference in the analysis increments, with one experiment using Aeolus observations in the data assimilation and a control experiment without Aeolus data for 10 June 2021 at 06 UTC, for 3DVar (left) and 4DVar (right).

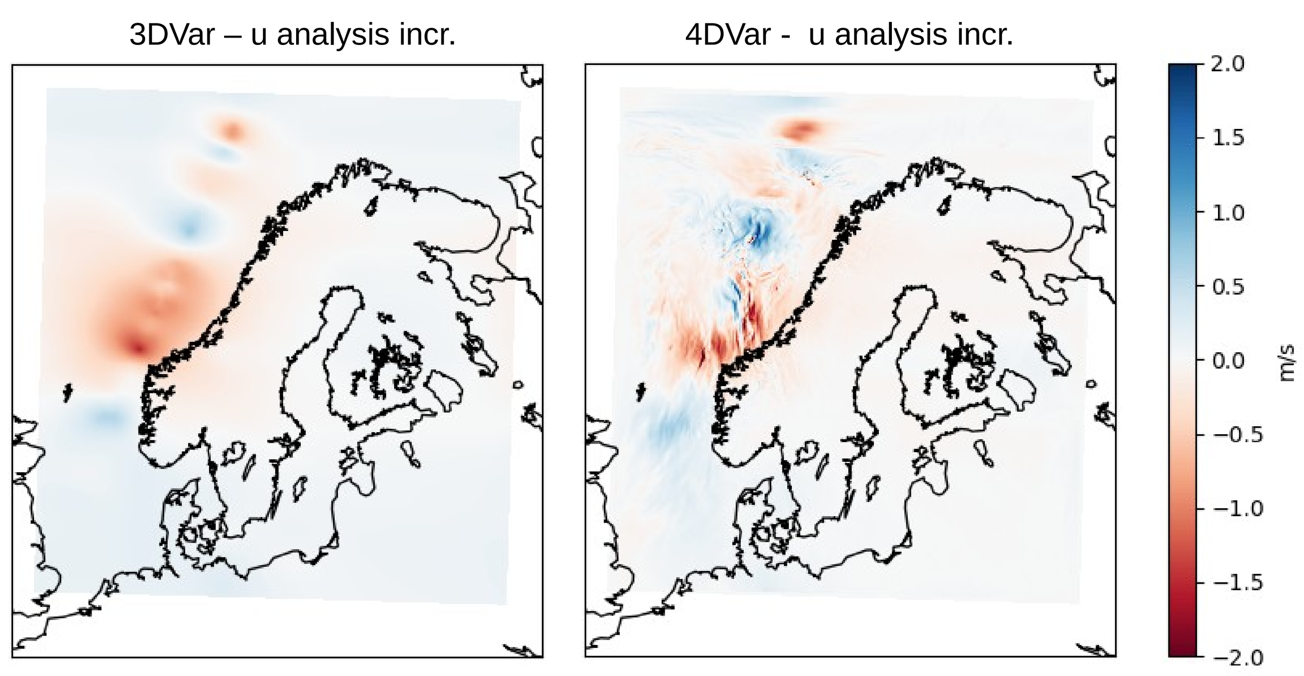

Fig. 5: Difference in analysis increments of u, with and without Aeolus winds in the data assimilation. Plot valid at 2021-06-10 06 UTC.

ANALYSIS IMPACT

Looking at the O-B (Observation minus Background) and the O-A (Observation minus Analysis) for the two periods, top panels of fig. 3, it is clear that both the Mie and the Rayleigh data have an impact on the analysis, since the O-A values (dashed lines) are lower than the O-B values (solid lines). This is seen in both the Rayleigh (red) and Mie (blue) data, though the impact is larger for the Mie data. The corresponding observation errors and background errors are shown in the bottom panels. Given that the observation error is lower for the Mie data, it is as expected that the Mie data also have a larger impact on the analysis than the Rayleigh data.

Another way to investigate the impact of Aeolus data is to calculate the degree of freedom of signal (DFS). This is a method where to compare the impact of different observation types where the absolute DFS shows the weight per observation type on the analysis system and the relative DFS show the weight per observation. The DFS for wind observations are shown in fig. 4 for the laser B period. The absolute DFS is shown both for all cycles and for only the cycles where there are Aeolus observations. The relative DFS is only shown for all cycles as the results are very similar to the relative DFS for the cycles with Aeolus data.

The DFS scores indicate that the Aeolus observations have an absolute impact on the analysis which is comparable to that from the SYNOP observations. It is also clear that the Mie data has a larger relative impact than the Rayleigh data. The relative DFS for the Mie observations is the largest of the four observation types, whereas it's the smallest of the four types for the Rayleigh observations.

We also studied the impact of adjusting the observation errors for the laser A period using the Desroziers method, which recommended an increase in both the observation and the background error. The recommended increase for the observation error was larger than for the background error. However, tuning the observation and background errors in line with the recommendations from the Desroziers method gave a neutral impact.

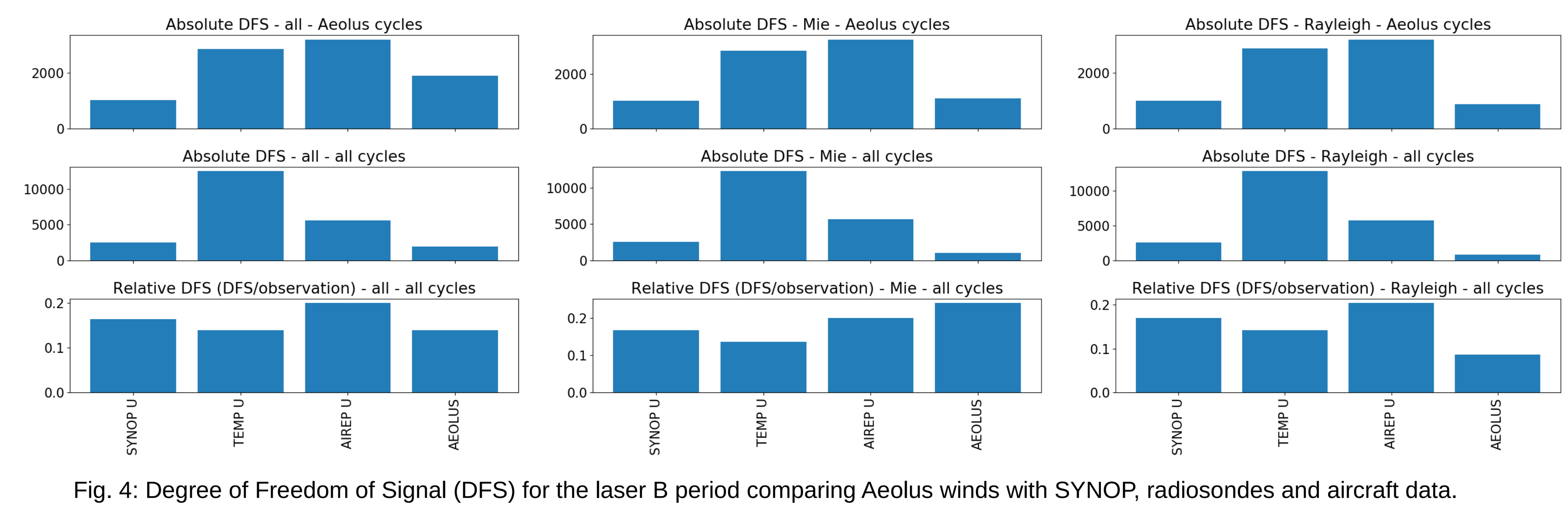

Fig. 4: Degree of Freedom of Signal (DFS) for the laser B period comparing Aeolus winds with SYNOP, radiosondes and aircraft data.

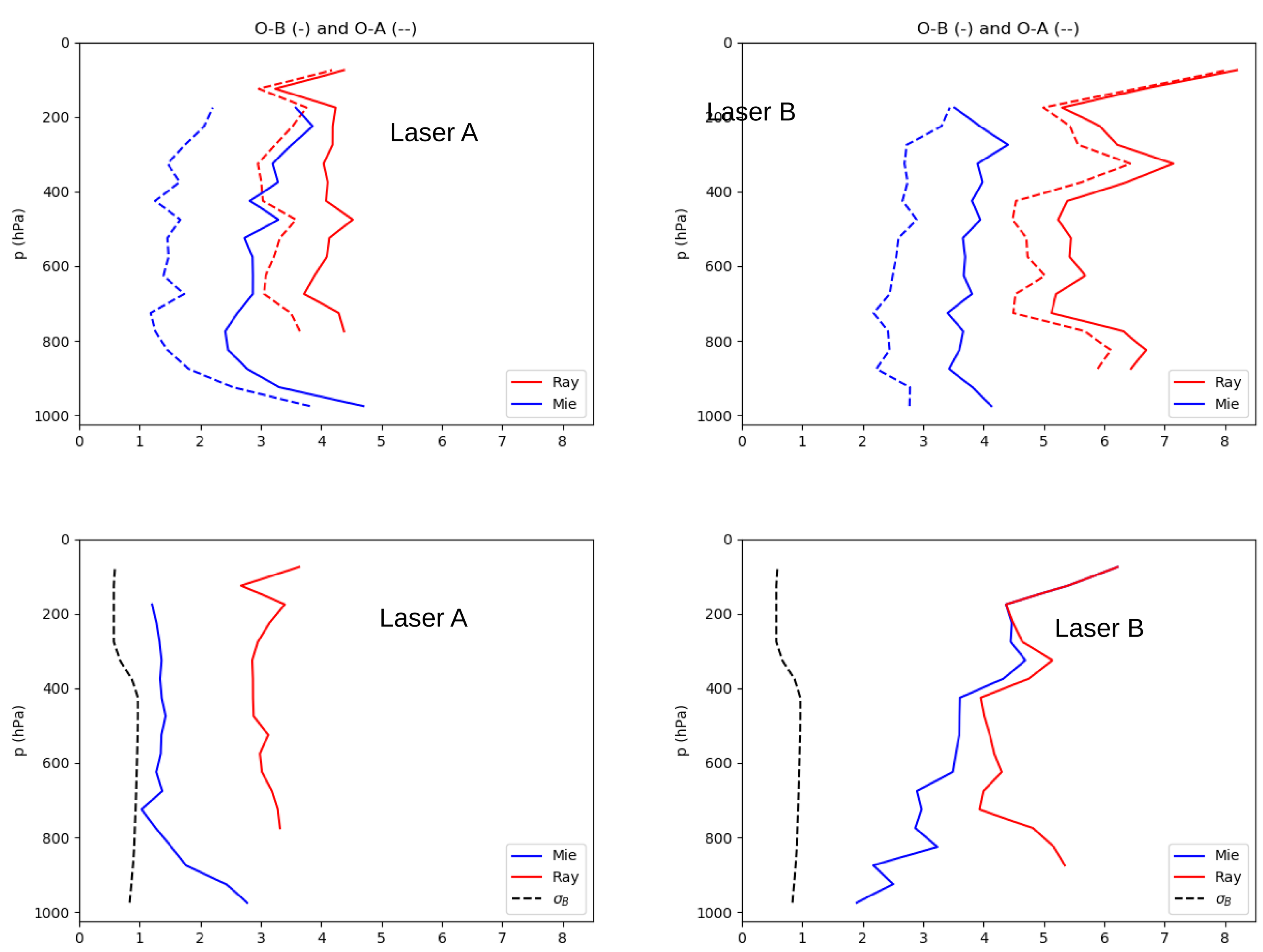

Fig. 3: Top row: standard deviation and bias of O-B and O-A for Rayleigh (red lines) and Mie (blue lines).
Bottom row: Mean observation error and background error.

CONCLUSION AND OUTLOOK

We have successfully assimilated Aeolus data from both laser A and laser B period in the regional NWP model Harmonie-Arome using 3DVar data assimilation. The impact of the Aeolus L2B winds were investigated both for all Aeolus observations, and separately for the Mie and Rayleigh data. We found that the Mie data, with its smaller observation error, had a larger impact on the analysis than the Rayleigh data despite the fact that there were more Rayleigh observations available. The forecast impact was neutral.

Early results indicate that using 4DVar instead of 3DVar, in order to account for the observation time and use the forecast model itself in the assimilation process, can be a better way to assimilate Aeolus HLOS winds in the Harmonie-Arome model.

In a new project we will investigate the impact of Aeolus winds on different domains using 4DVar data assimilation and reprocessed Aeolus observations during cases with strong winds.

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Reference: Evaluating the use of Aeolus satellite observations in the regional NWP model Harmonie-Arome
Susanna Hagelin, Roohollah Azad, Magnus Lindskog, Harald Schyberg and Heiner Körnich,
2021, Atmos. Meas. Tech., volume 14, pages 5925-5938, https://doi.org/10.5194/amt-14-5925-2021

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