ABSTRACTS 2021 AEOLUS NWP IMPACT AND L2B PRODUCT QUALTY WORKING MEETING

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NWP monitoring of L2B product quality at ECMWF

by Michael Rennie, Fabian Weiler, Jos de Kloe, Gert-Jan Marseille, Saleh Abdalla and Oliver Reitebuch

This talk focusses on the Level-2B horizontal line of sight (HLOS) wind retrieval error characteristics as assessed with respect to the ECMWF global NWP model using the near-real-time (NRT) dataset.

Estimates of random and systematic error statistics were derived from observation minus background departure statistics and their evolution throughout the mission is assessed. The HLOS wind random error standard deviation varies over the range 4.0-6.5 m/s for the Rayleigh-clear and 2.8-3.5 m/s for the Mie-cloudy. For Rayleigh-clear this depends strongly on the atmospheric path signal levels which in turn depend on instrument performance, atmospheric backscatter properties (hence altitude) and the processing algorithm version. Due to the instrument degradation, the random errors increased over the course of the mission.

To help reduce the random errors closer to their initial level, an onboard accumulation of laser pulses (N-P settings) is currently under discussion. Such a change, which hopefully will be in operations by the time of the meeting, reduces the “measurement-scale” horizontal resolution (by factor 2) which improves the SNR for the benefit of the L2B processor classification algorithm (clear/cloudy). The improved classification leads to improved Rayleigh-clear random error by ~15%, whilst retaining the same “observation-scale” resolution (~87 km). The Mie-cloudy observations remain very similar in resolution and noise.

A variety of improvements in the systematic errors have been achieved in the ground processing chain during the mission as sources have been understood and corrected; however, some biases remain. An example is the Rayleigh-clear bias (~±1 m/s) which correlates with altitude and temperature. Investigations have provided some insight into how this bias relates to the Rayleigh-Brillouin calibration process — but it is not fully understood. Related investigations using special calibrations in off-nadir pointing (IRONICs) will be presented if time permits.

Another source of bias that is increasingly an issue for the Rayleigh-clear winds is caused by fluctuations in “hot” pixel dark current levels, which are becoming relatively more important as the atmospheric path signal level decreases. To try to mitigate this, the number of calibrations of dark current per day was doubled from four to eight in September-October 2021. Sporadic biases related to star-tracker moon-blinding and hence LOS pointing knowledge errors are now avoided in operations via a moon-blinding housekeeping flag, however this results in the absence of L2B winds in large areas of the tropics when the biases are not always present.

Sporadic and large Mie-cloudy O-B departures (>15 m/s HLOS wind) with respect to the ECMWF model are discussed. One such example over Australia is demonstrated to be very likely an issue in the ECMWF background winds and not due to Aeolus. This could be shown by comparing the ECMWF background with a reasonably close radiosonde wind profile.

Data quality of the Second Reprocessed Aeolus L2B Wind Data

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Reprocessing of Aeolus data products is an important task to provide a homogeneous data set processed using the latest processing baseline to provide the best quality products at the time. The first reprocessing campaign covered the early operation period of the second Flight Model laser (FM-B) over the period from June 24 to December 31, 2019. Processing baseline 10 was used for that campaign. The second reprocessing campaign covers the FM-B period from June 2019 to October 2020 and implements the October 2020 version of the processors (baseline 11). The third reprocessing campaign, which covers the FM-A period from August 2018 to June 2019, is ongoing.

Quality assessment of the of Level-2B horizontal line of sight (HLOS) wind product from the second reprocessing campaign, which was released in October 2021, was carried out. It was found out that the HLOS wind from Mie cloudy, Rayleigh clear and Rayleigh cloudy channels are, as expected, more homogeneous and of better quality than the corresponding products produced in NRT. Furthermore, the second reprocessed data sets were found to be better than those produced during the first campaign.

Results of the assessment study will be summarised in the talk. Some of the remaining issues, which are of minor nature, will be highlighted as well.

L2B processor evolution: next steps.

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Meeting topic: L2B product quality.

The L2B processing software, as part of the full chain of ground processors, is updated twice per year to reflect the latest insights in wind processing and calibration.

The last 2 releases, 3.50 and 3.60, included improvements in Mie-non-linearity correction (see abstract by G. J. Marseille), options to improve Rayleigh cloudy wind calibration, and added flexibility to flag winds possibly affected by ground echoes. In addition we had to add extra options to handle hardware problems, especially the fact that internal reference results became less reliable, but also to handle the issue with unreliable pointing when the startrackers are moon-blinded.

For the next release we are working on an option to do accumulation of signals before the classification is applied. Recent tests modifying the high resolution measurements (on-board N/P accumulation settings) have clearly shown that this can lead to improved wind quality, especially for decreasing signal levels as observed during the mission. Adding this to the software will hopefully also bring this improvement to next reprocessing results.

Also we aim to add an option to allow winds to be generated but flagged invalid during moon-blinding. Currently this flagging is rather conservative and throws away too much data. We hope this new option will allow us to tune the associated thresholds and allow more winds to be flagged valid around these events.

NWP calibration applied to Aeolus Mie channel winds

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Meeting topic: L2B product quality

Aeolus is the first Doppler wind lidar (DWL) in space to measure wind profiles. Aeolus is an ESA (European Space Agency) explorer mission with the objective to retrieve winds from the collected atmospheric return signal which is the result of Mie and Rayleigh scattering from the laser emitted light on atmospheric molecules and particulates. The focus of this contribution is on winds retrieved from instrument Mie channel collected data, i.e., originating from Mie scattering of atmospheric aerosols and clouds.

The use of simulated data from Numerical Weather Prediction (NWP) models is a widely accepted and proven concept for the monitoring of the performance of many meteorological instruments, including Aeolus. Continuous monitoring of Aeolus Mie channel winds against ECMWF model winds has revealed systematic errors in retrieved Mie winds. Following a reverse engineering approach the systematic errors could be traced back to imperfections of the data in the calibration tables which serve as input for the on-ground wind processing algorithms.

A new methodology, denoted NWP calibration, makes use of NWP model winds to generate an updated calibration table. It is shown that Mie winds retrieved by making use of the NWP based calibration tables show reduced systematic errors not only when compared to NWP model winds but also when compared to an independent dataset of very high resolution aircraft wind data. The latter gives high confidence that the NWP based calibration methodology does not introduce model related errors into retrieved Aeolus Mie winds. Based on the presented results in this paper the NWP based calibration table, as part of the level-2B wind processing, has become part of the operational processing chain since 1 July 2021.

Abstract for Presentation

3rd Aeolus NWP impact and L2B data quality meeting
1-3 December 2021

Project Title: Validation of Aeolus wind measurements on Cape Verde using radiosondes.

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Abstract:

As part of the Joint Aeolus Tropical Atlantic Campaign (JATAC), radiosondes were launched twice a day from Sal Airport in Cape Verde over a period of 26 days, from 04 to 30 September 2021. Among a total of 38 launches, 10 correspond to Aeolus nearby overpasses. The radiosonde data allow us to identify three different dust events as well as the passage of tropical cyclones. The radiosonde validation of the Aeolus winds revealed that the quality of the data is closely related to the atmospheric cloud and dust conditions, with the Rayleigh-clear wind values showing larger errors in the presence of aerosols or clouds which can possibly be attributed to the decreasing atmospheric path signal and attenuation effects of clouds/aerosols. Rayleigh winds have a systematic error (bias) of 0.71 m/s and a random deviation of 4.48 m/s (scaled Mean Absolute Deviation). Mie cloudy winds were more accurate with a systematic error of 0.71 m/s and a random deviation of 1.9 m/s. The statistics obtained from the radiosonde comparisons show lower systematic errors but similar random errors compared to other CAL/VAL studies.

Assessment of Aeolus L2B products with the LATMOS RALI airborne platform during the CADDIWA campaign in Cape Verde

L2B Quality product

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The CADDIWA (Cloud-Atmospheric Dynamics-Dust Interactions in West Africa) campaign that took place this fall (8 Sept. – 23 Sept. 2021) in Cape Verde aimed at sampling comprehensive measurements in situations involving strong interactions between the atmospheric dynamics, aerosols from the SAL (Saharan Aerosol Layer) and clouds, as are expected to occur in this region. To do so, the French SAFIRE Falcon 20 was equipped with a very complete payload including the French Radar-Lidar system RALI and dropsondes, as well as cloud and aerosol in-situ probes. A total of nine flights were performed, five of which were dedicated to Aeolus underpasses.

During these underpasses, flights were performed at the altitude of 10 km with the airborne 355 nm high spectral resolution Doppler lidar (HSRDL) LNG used in its cross-track 37° slant viewing mode (SVM). Taking advantage of the Mach Zehnder interferometer choice, backscattering, depolarization and extinction profiles were simultaneously retrieved at 355 nm, as well as HLOS wind measurement in aerosol and cloudy areas. The 95 GHz Doppler RASTA cloud radar was used in its 4-antenna (3 below aircraft and 1 zenith) viewing configuration to retrieve 3D-wind in cloudy areas (incl. precipitations). Several dropsondes (average number of 3 per underpass leg – beginning, middle and end of leg) were launched, and in situ wind measurements were made by the F20 at flight level.

We will present the first available comparisons between Aeolus L2B products and LNG+RASTA, in-situ F20 and dropsondes and analyze them with regards to the results obtained in 2019 with the same payload but in different atmospheric conditions.

Validation of Aeolus L2B Rayleigh wind product using Rayleigh Doppler lidar at La Reunion island within AboVE-2 campaign

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AboVE-Maido2 (Aeolus Validation Experient) is the second Aeolus Cal/Val campaign carried out at high-altitude Maido observatory on the tropical La Reunion island (21º S, 55º E) during 1 – 24 June 2021. The Maido observatory hosts an extensive park of high-performance lidars, including Rayleigh-Mie Doppler lidar (LiWind) based on double-edge FPI and capable of measuring horizontal wind components between 5 – 65 km with random error less than 1 m/s up to 28 km altitude. The location of ANX 4.5 ascending orbit with respect to LiWind eastward line-of-sight enabled spatial collocation of the measurements better than 10 km in the lower stratosphere every Wednesday.

The Cal/Val activities within AboVE-2 campaign included LiWind Doppler lidar operation from dusk till dawn to cover both ascending and descending overpasses as well as time-coordinated radiosondes ascents during and in between the overpasses. Overall, the campaign included 9 collocated measurements (4 ascending and 5 descending overpasses) using LiWind lidar and simultaneous radiosoundings. A specific Range Bin Setting (RBS) was applied to Aeolus within a 2º x 2º domain above La Reunion since 23 May 2021. With the highest bin centered at 28700 m, this RBS was conceived to evaluate ALADIN Rayleigh wind performance up to the maximum achievable altitude.

Here we present the results of point-by-point comparison between Aeolus, LiWind and radiosoundings and discuss ALADIN performance at different atmospheric conditions. A particular attention is given to ALADIN measurements in the uppermost bins.

3rd Aeolus NWP and L2B meeting 2021

Validation of Aeolus wind profiles over a tropical location (10.04^{o} N; & 76.9^{o} E) using 205 MHz wind profiler radar

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Meeting Topic: L2B product quality

This paper presents in detail the validation of Aeolus profiles over Cochin, India using the 205 MHz wind profile radar. A wind profiler at 205 MHz is operational at the Advanced Centre for Atmospheric Radar Research (ACARR), Cochin University of Science and Cochin, since 2017 and provides three-dimensional wind profiles across an altitude range of 315 m to 20 km. The Aeolus wind profiles have been validated for an altitude range of 1 to 20 km during the period June, 2019 to September, 2021. Aeolus Rayliegh wind for clear (Ray_clear) and Mie wind for cloudy (Mie_cloudy) show very good agreement with the radar wind profiles. The Pearson correlation coefficient between radar and Aeolus wind for Ray_clear and Mie_cloudy are 0.91 and 0.70, respectively. However, the Rayleigh wind for cloudy conditions and Mie wind for clear conditions show large errors in comparison to radar wind measurements. A detailed error characterisation of Aeolus wind profiles with respect to radar wind is presented in this study. The bias in Aeolus is provided in terms of observation altitude, seasons, different windy conditions and ascending/ descending orbits.

Inter-comparison of wind vectors derived from geostationary satellites with the Aeolus/ALADIN

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Wind information obtained from various means play an important role in data assimilation of numerical weather prediction. Atmospheric Motion Vector (AMV) obtained from the geostationary satellites provide a high spatio-temporal resolution wind information over the whole glove. On the other hand, Aeolus/Atmospheric Laser Doppler Instrument (ALADIN) data are very high horizontal and vertical resolution wind data and there is a limitation in observation time since it is a polar orbiting satellite. Therefore, if the advantages and disadvantages of the geostationary satellite AMV and the polar orbiting satellite ALADIN data can be complemented with each other, it is expected that the utilization wind observations on the numerical forecast can be improved. Data obtained from September 2019 to August 2020 are collocated with time and space criteria of ±15 minutes and 1.2 ° respectively and with the mandatory pressure levels. For the quality control, only AMV data with a Quality Index (QI) of 0.85 or higher are used. In case of the ALADIN data, quality control is performed using the observation type (clear or cloudy) and error estimation value of the ALADIN data. As a result of comparing AMV IR channel and ALADIN Mie channel data in 1 year, the correlation coefficients at the upper and middle layers (0.98) are larger than that at the lower layer (0.94). NRMS values in the upper, middle, and lower layers are 0.23, 0.26, and 0.33, respectively, and NRMS shows better statistics as the layer increases. As a result of comparing by latitude, for more detailed analysis, the correlation coefficient is 0.90 and NRMS is less than 0.3, therefore the two data are very consistent. Whereas the 15S-EQ latitude band shows the worst compatibility in the upper and middle layers in that NRMS is greater than 0.4. In the case of the lower layer, the compatibility of the 15S-30S latitude band is the worst. This specific latitude band is the same area where the cloud height assignment problem of AMV is frequently mentioned in previous studies. These characteristics are also shown in the results of comparison of ALADIN and Himawari-8. Therefore, the results of this study suggest that the accuracy of wind data is lower in the specific latitude band(the low-latitude band due to the AMV's height assignment problem in this region. It is expected that ALADIN can provide reliable wind data at low latitudes and in the south hemisphere and this would improve the accuracy of numerical forecasting skills.

Evaluation of the L2B winds at Punta Arenas, Southern Chile, using scanning Doppler cloud radar and radio soundings

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The LACROS facility of TROPOS is deployed at Punta Arenas, Southern South America, since November 2018 in the frame of the DACAPO-PESO campaign (dacapo.tropos.de).

Next to many other instruments, a scanning Doppler cloud radar is utilized. After intensive algorithm development, we want to show a first long-term statistics of the horizontal winds derived with the continues-measuring cloud radar compared to the Aeolus L2B winds during the two weekly overpasses. Naturally, the Mie winds are of most interest for that purpose, but a comparison with Rayleigh winds will be shown as well.

Furthermore, occasional radiosondes have been launched once a week since the beginning of 2020 for the direct evaluation of Aeolus winds. We will show dedicated case studies to show the potential but also current limitation (or features) of Aeolus and aim for a long-term statistic as well.

Abstract for the 3rd Aeolus NWP impact and L2B product quality working meeting, online, October 2021

Long-term validation of the Aeolus L2B product above Germany

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Meeting topic: L2B product quality

With Aeolus now more than 3 years in orbit, accompanied by several processor updates and already two successful reprocessing campaigns, a continuous validation as well as comparisons of different processing baselines are important. This is to capture not only the improvements due to data reprocessing, but also changes in systematic and random errors in the operational data due to system degradations.

With the radar wind profiler network of Deutscher Wetterdienst consisting of four UHF systems a continuous data set of wind measurements up to 16 km altitude with high accuracy in clear as well as in particle-laden air is available. These observations covering six Aeolus orbits over Germany per week provide sufficient data for an extensive validation of the Aeolus L2B wind product.

The presented work will focus on the long-term analysis of the Aeolus wind measurements above Germany. The analysis of systematic and random errors of the whole mission as well as comparisons between the operational and reprocessed data sets will be shown.

Evaluation of Aeolus L2B wind product with wind profiling radar measurements and ERA5 reanalysis dataset over Australia

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Meeting topic: L2B product quality

Abstract. Carrying an Atmospheric Laser Doppler Instrument, the Aeolus satellite was launched in 2018, becoming the first mission for wind profile measurements in space. Before utilising the Aeolus winds for different applications, evaluating its data quality is essential. This study aims to quantify the error information of Aeolus Level-2B11 horizontal line-of-sight winds during October 2020 – March 2021 over Australia. We first quantified the mean bias, scaled median absolute deviation (MAD) and correlation coefficient of Rayleigh-clear and Mie-cloudy winds by inter-comparison with ground-based wind profiling radar (WPR) measurements. The results indicate that both Rayleigh-clear winds and Mie-cloudy winds are in good agreement with the WPR measurements. Moreover, Mie-cloudy winds with smaller scaled MAD are shown to be more precise than Rayleigh-clear winds. Vertically, the Mie channel was found to be more capable of capturing the winds in the planetary boundary layer and between 7500 m and 12500 m in height. In addition to inter-comparison analysis, an attempt of triple collocation analysis was performed with the help of WPR measurements and ERA5 reanalysis dataset. Aeolus observations were found to have the largest error standard deviation, followed by WPR measurements and ERA5 reanalysis dataset. Overall, the findings of this study demonstrate the good performance of spaceborne Doppler lidar in wind profile detection over Australia and provide valuable information for data assimilation in numerical weather prediction.

Inter-comparison of wind measurements in the atmospheric boundary layer with Aeolus and a ground-based coherent Doppler lidar network over China

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Abstract. After the successful launch of Aeolus which is the first spaceborne wind lidar developed by the European Space Agency (ESA) on 22 August 2018, we deployed several ground-based coherent Doppler wind lidars (CDLs) to verify the wind observations from Aeolus. By the simultaneous wind measurements with CDLs at 17 stations over China, the Rayleigh-clear and Mie-cloudy horizontal-line-of-sight (HLOS) wind velocities from Aeolus in the atmospheric boundary layer are compared with that from CDLs. To ensure the quality of the measurement data from CDL and Aeolus, strict quality controls are applied in this study. Overall, 52 simultaneous Mie-cloudy comparison pairs and 387 Rayleigh-clear comparison pairs from this campaign are acquired. All of the Aeolus-produced L2B Mie-cloudy HLOS, Rayleigh-clear HLOS and CDL-produced HLOS are compared individually. For the inter-comparison result of Mie-cloudy HLOS wind and CDL-produced HLOS wind, the correlation coefficient, the standard deviation, the scaled MAD and the bias are 0.83, 3.15 $m \cdot s^{-1}$, 2.64 $m \cdot s^{-1}$ and -0.25 $m \cdot s^{-1}$ respectively, while the "y=ax" slope, the "y=ax+b" slope and the "y=ax+b" intercept are 0.93, 0.92 and -0.33 $m \cdot s^{-1}$. For the Rayleigh-clear HLOS wind, the correlation coefficient, the standard deviation, the scaled MAD and the bias are 0.62, 7.07 $m \cdot s^{-1}$, 5.77 $m \cdot s^{-1}$ and -1.15 $m \cdot s^{-1}$ respectively, while the "y=ax" slope, the "y=ax+b" slope and the "y=ax+b" intercept are 1.00, 0.96 and -1.2 $m \cdot s^{-1}$. It is found that the standard deviation, the scaled MAD and the bias on ascending tracks are lower than that on descending tracks. Moreover, to evaluate the accuracy of Aeolus HLOS wind measurements under different product baselines, the Aeolus L2B Mie-cloudy HLOS wind data and L2B Rayleigh-clear HLOS wind data under Baselines 07/08, Baselines 09/10, and Baseline 11 are compared against the CDL-retrieved HLOS wind data separately. From the comparison results, marked misfits between the wind data from Aeolus Baselines 07/08 and wind data from CDL in planetary boundary layer are found. With the continuous calibration and validation and product processor updates, the performances of Aeolus wind measurements under Baselines 09/10 and Baseline 11 are improved significantly. Considering the influence of turbulence and convection in the atmospheric boundary layers, higher values for the vertical velocity are common in this region. Hence, as a special note, the vertical velocity could impact the HLOS wind velocity retrieval from Aeolus.

Impact of Uncertainty in NWP Background T/P on L2B Retrieval of Rayleigh Winds

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NWP short-range forecast (background) has uncertainty in pressure and temperature, especially in observation-sparse regions. In this study, we explore impact of the uncertainty on Rayleigh wind retrieval. The pressure and temperature from both NOAA/FV3GFS and ECMWF model background are used in the ESA L2B processing package to derive Rayleigh winds. It is found that the pressure and temperature differences between the two NWP models can reach up to 6K and 1.5 hPa, respectively, in the lower stratosphere of the Southern hemisphere. The pressure and temperature uncertainty results in considerable difference in Rayleigh wind retrievals, up to 1 m/s. In addition, the Rayleigh wind differences show evident positive correlations to the pressure and temperature differences. These results suggest that the large uncertainty in NWP background pressure and temperature can lead to considerable uncertainty in L2B Rayleigh winds in the Southern hemisphere. The impact of this uncertainty on NOAA global forecast is being explored.

An Update on the Impact of Aeolus HLOS Winds in Numerical Weather Prediction at ECMWF

by Michael Rennie (ECMWF)

Aeolus was launched over three years ago and the L2B winds have been operationally assimilated at ECMWF for approaching two years.

The latest results on the assessment of the impact of L2B HLOS winds in ECMWF's global NWP Prediction system will be presented. In particular, the impact of the first and second reprocessed Aeolus data for the July-December 2019 period, during which Aeolus winds had their largest signal-to-noise ratio and hence largest positive impact. This early FM-B period helps to give an impression of what could be achieved with a potential operational EUMETSAT follow-on mission, in which significantly better SNR than Aeolus has achieved is sought.

In Observing System Experiments (OSEs) for several periods, Aeolus provides statistically significant improvement of a good magnitude in short-range forecasts as verified by observations sensitive to temperature, wind and humidity, peaking at ~200 hPa in the extratropics and ~150 hPa in the tropics. Longer forecast range verification shows positive impact strongest at the 2-3 day forecast range, e.g. ~2% improvement in root mean square error for vector wind and temperature in the tropical upper troposphere and lower stratosphere and polar troposphere. Positive impact of up to ten days is found in the tropical lower stratosphere wind and temperature. This impact appears to be larger with reprocessed data versus NRT. More recent impact experiments of variational QC modifications and a bias correction of the Rayleigh-clear winds as a function of temperature will be presented.

The operational Forecast Sensitivity Observation Impact (FSOI) metric shows that Aeolus is a useful contribution to the global observing system; with the Rayleigh-clear and Mie-cloudy winds providing similar overall short-range forecast impact in 2020-2021. Relative FSOI for the 2019 reprocessed dataset shows that Aeolus is amongst the most important satellite instruments, which is good result for a demonstration mission. Unfortunately, relative FSOI is closer to 2% in recent months versus 5% when the maximum atmospheric path signal was available in July 2019 (offline testing). Also, Aeolus winds have been absent for large fractions of 2020 and 2021 due to being flagged invalid (blocklisted). This occurred during periods of instrument testing (aimed at understanding/mitigating the signal loss) for which the L2B quality could have been compromised and also due to ALADIN entering Survival mode.

Validation and Impact assessment of Aeolus Doppler Wind Lidar Observations at the German Weather Service

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ABSTRACT

The first European Space Agency (ESA) Earth Explorer satellite mission Aeolus was launched successfully, in August 2018, providing for the first time, globally distributed profiles of horizontal line-of-side (HLOS) wind information. The Deutscher Wetterdienst (DWD), as part of the German project team EVVA (Experimental Validation and Assimilation of Aeolus data), investigated innovation statistics of the Aeolus winds relative to the global ICON model system of DWD, the observation error characteristic and bias behaviour of the HLOS winds, separated for the Mie and Rayleigh channels, for both Laser A and Laser B, on a routinely basis, run several impact studies and gave contributions to the CAL/VAL activities of ESA and for internal use in the data assimilation system of DWD. All the activities accumulated in the operational use of the Aeolus HLOS winds in May 2020, only one and a half year after the first arrival of the winds in our observation data base.

In my talk, I will give an overview of latest activities and impact assessments for summer 2020 (three months) and first impressions of the impact using reanalysed Aeolus HLOS winds for July 2019. Additionally, long term innovations statistics will be presented,

TITLE:
Separate the contributions from the Rayleigh and Mie channels of the AEOLUS HLOS winds in the Météo France global NWP model.

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NWP impact

ABSTRACT:
AEOLUS HLOS winds from both Rayleigh and Mie channels have been assimilated operationaly in the Météo France global NWP model (ARPEGE) since june 2020. Knowing the very different random errors of the winds provided by the two channels (standard deviation of ~3m/s for Mie versus ~5m/s for Rayleigh now), and the slow increase of these errors with time especially for the Rayleigh channel, the Mie channel could become the most reliable data source during the final phase of the AEOLUS mission. From that point of view, assessing the respective contributions of the Rayleigh and Mie channels of the AEOLUS HLOS winds in ARPEGE is of high interest to plan the AEOLUS life end in term of operational NWP use. A first assessment of the separate impacts of each channel was done using FSOi diagnostics on an experiment assimilating both channels but the work presented here uses another approach. Three OSE have been undertaken, the first one assimilating both channels, the second one assimilating Mie data only and the third one assimilating Rayleigh data only. The AEOLUS data used were taken from the first reprocessed dataset of the FM-B laser from july to december 2019.

This presentation will summarize the results obtained with these three OSE. Assessment of L2B wind products generated at ECMWF against model counterparts will be provided in terms of global and regional statistics. Results from assimilation experiments of AEOLUS winds in ARPEGE will be shown in terms of quality of enhanced analyses and resulting forecasts.

Operational impact and quality assessment of L2B HLOS winds from Aeolus at the Met Office

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The Met Office has been assimilating L2B Mie channel winds from Aeolus into its operational global NWP model since December 2020. Since this time Forecast Sensitivity to Observation Impact (FSOI) statistics have shown that per observation, the Mie channel winds had one of the highest impacts on the forecasts. In January 2021, assimilation of the L2B Rayleigh channel was accepted as a candidate change for the next implementation of an updated global model, expected to be made operational in early 2022. Rayleigh channel winds have been assimilated in the parallel run of the operational suite since the summer of 2021, alongside a large number of other changes, in preparation for operational implementation. FSOI statistics will be shown for this parallel run if available, and an assessment of the current quality of the winds using O-B statistics will be presented.

Abstract Title: Assessment of ADM-Aeolus HLOS Winds using NCMRWF Global Forecast System.

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Abstract:

At NCMRWF, the ADM-Aeolus data is received through EUMETCAST Terrestrial Reception System. The present study focuses on the assessment of these ADM-Aeolus Horizontal Line-Of-Sight (HLOS) wind observations using the Global Forecast System operational at NCMRWF. An observation system experiment is conducted for the period 01-30 November 2020 where the new observations are assimilated using GSI (Gridpoint Statistical Interpolation) Scheme in 3d-Var mode. Necessary modifications and updating of GSI code are done to assimilate the data. Data is thinned at a resolution of 80km and is being passed through various quality control checks to restrict the use of data of non-acceptable quality. Assimilation is done on a global scale in 6-hourly intermittent cycles. Only the Rayleigh clear and Mie cloudy observations are assimilated. The Observation minus Background diagnostics show bias values within ±1m/s. Analysis and background fit to temperature and humidity observations from radio-sonde shows bias close to zero except for humidity observations below 900hPa pressure level. 7-days global forecast is generated using analysis at every 00UTC. Significant impacts on upper atmospheric levels are observed over tropical regions for forecasts valid till day-6. Two case studies of very severe cyclonic storms Gati on the Arabian Sea and Nivar on Bay of Bengal regions show a reduction in Direct Positional Error and improvement in the analyzed fields of maximum 10m wind speed and minimum sea-level pressure.

Multi-year impact of Aeolus HLOS wind in a global NWP system

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Abstract

The multi-year impact of Aeolus satellite's Horizontal Line of Sight (HLOS) winds in Numerical Weather Prediction (NWP) is investigated in this study using the "Unified Model" based NCMRWF NWP system (NCUM). Aeolus Horizontal Line of Sight (HLOS) wind is being operationally assimilated in the Hybrid-4DVar data assimilation system of global NCUM since June, 2020. A yearlong impact of HLOS and seasonal (JJAS) impact for two years are discussed in this paper. The impact of each assimilated observations in NCUM are studied using adjoint based Forecast Sensitivity to Observation Impact (FSOI) method. A full year covering all seasons as well as multi-year seasonal FSOI statistics gives very useful information on the impact on global NWP model forecast of 12 km horizontal resolution. Significant impact of both Rayleigh-clear and Mie-cloudy HLOS winds observations on the NCUM forecast in comparison to other global observations is seen in our studies. Details of the height-wise impact are also interesting, which will also be presented in the conference.

Abstract for the 3rd Aeolus NWP impact and L2B data quality meeting

Impact of the Aeolus L2B HLOS winds in the ECCC global forecast system

Stéphane Laroche and Judy St-James

Environment and Climate Change Canada

A series of observing system experiments have been conducted over summer 2019 to assess the value of the near real-time (2B06) and reprocessed (2B10) L2B HLOS winds and their impact on the Environment and Climate Change Canada (ECCC) global forecasts. The impact of atmospheric motion vectors (AMVs) on forecasts is also examined and compared to the impact of HLOS winds. A dynamic bias correction based on observation minus background departures is applied to 2B06 dataset as initially proposed by ECMWF. The reprocessed data are of better quality and bias corrected using the telescope's primary mirror temperature variations as predictor.

The impacts of the near real-time and reprocessed HLOS winds on forecasts are generally positive for both temperature and wind. The impacts are largest in the troposphere over the tropics and polar regions. The positive impacts on forecasts are larger with the reprocessed data, particularly in the stratosphere where a significant degradation over the Southern Hemisphere is found from assimilating the near real-time data. The normalized forecast error reductions at days one and two for the wind are approximately 1.25 % over the tropics and Southern Hemisphere. The positive impact of the HLOS winds on forecasts is enhanced by approximately 40% when the AMVs are not assimilated in the control experiment. The forecast error reduction from assimilating AMVs is however two times larger than from assimilating HLOS winds in the extratropics. Conversely, the impact of HLOS winds on forecasts is generally larger in the tropics.

Impact of Aeolus HLOS winds in the Korean global model KIM

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The Korean Integrated Model (KIM) and hybrid 4-Dimensional Ensemble-Variational (4D-EnVar) data assimilation system were extended to assimilate the Horizontal Line-Of-Sight (HLOS) wind observations from the Aeolus satellite. Quality control procedures were developed to assess the HLOS wind data quality for assimilating. The variable transformation modules in 4D-EnVar data assimilation system were added to assimilate the new observation variables. In the global cycle on July 2020, additional assimilation of ALADIN observation shows globally significant benefits for 2.2% and 1.5% reductions of the zonal and meridional winds root-mean-square errors (RMSEs) against European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecast System (IFS) analysis. Additionally, the assimilation of ALADIN HLOS wind has a positive analysis impact on other mass variables such as temperature and humidity over the Tropics and Southern-Hemisphere. As a result, the positive forecast impacts for wind speed in the experiment assimilating ALADIN were shown in the 72-hour forecast fields as compared the IFS analysis.

Impact of Aeolus Winds on NOAA Global Forecast of 2019 Winter Storms over the US

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Recent efforts have focused on evaluation of the Aeolus Level 2B (L2B) wind data with ESA M1 bias correction and its impact on NOAA FV3GFS global forecast at synoptic and meso scales. The remaining biases between Aeolus and FV3GFS global model background is removed using a Total-Least-Square bias correction (taking account of noises in both Aeolus and NOAA/FV3GFS wind background) to optimize Aeolus assimilation with FV3GFS. In this study, we will present in detail the impact of Aeolus wind on FV3GFS forecast of the 2019 winter storms over the US. It is shown that Aeolus winds improve considerably the medium-range forecast of the locations of heavy snowfalls across the US. The mechanism of the Aeolus impact is also explored.

Impact of Aeolus L2B winds in the regional model Harmonie-Arome

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Meeting topic: NWP impact

Using the Harmonie-Arome regional model, we investigate the impact of assimilating the wind profiles from the Aeolus satellite over the Nordic region. We use 3DVar to assimilate the HLOS L2B winds for two different seasons. 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 will show 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.

Abstract for the 3rd Aeolus NWP impact and L2B data quality meeting

Tropical analysis and forecast uncertainties and Kelvin waves: what can be learnt from the Aeolus wind profiles?

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The tropics are the region with the largest uncertainties in the initial states for numerical weather prediction (analyses). Analysis uncertainties are largest in the tropical upper troposphere and the lower stratosphere (UTLS). One of the reasons is a lack of wind profiles which are more useful than temperature profiles in the tropics. This classical effect was described by Smagorinsky as "Not all data are equal in their information-yielding capacity. Some are more equal than others". Despite the relatively small number of Aeolus wind profiles and their relatively large random error, Aeolus winds have a positive impact on the quality of global weather forecasts, especially in the UTLS. Here we present one process contributing to the forecast improvements: the vertically-propagating Kelvin waves, which are a major contributor to tropical variability.

The studied period May-September 2020 was characterised by a weakening easterly phase of the quasi-biennial oscillation (QBO). Several case studies are presented using the ECMWF observing system experiment with and without Aeolus winds. The examples show that Aeolus wind profiles bring changes to the Kelvin wave structure in the layers with a significant vertical shear. We argue that improved ECMWF forecasts in the tropical tropopause layer are due to vertically-propagating Kelvin waves. Furthermore, we suggest that a stronger impact of Aeolus winds in May than later in summer was associated with the state of the QBO.

Reference: Žagar, N., M. Rennie and L. Isaksen, 2021: *Uncertainties in Kelvin waves in ECMWF analyses and forecasts: insights from Aeolus observing system experiments.* Geophy. Res. Let., 48, accepted.

3rd Aeolus NWP impact and L2B data quality meeting,
1 and 3 December 2021

The 2019/2020 QBO Disruption in Aeolus Wind Lidar Observations

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Meeting topic: NWP Impact *(Scientific Applications of Aeolus)*

Abstract:
The quasi-biennial oscillation (QBO) is a regular cycle of alternating winds which dominates the behaviour of the tropical stratosphere. It is extremely technically challenging to model, and for this reason wind observations are vital to understand it fully. Characterised by downward propagating easterly and westerly regimes, the QBO progressed uninterrupted for more than 60 years until a highly anomalous deviation from its normal pattern in 2016. During 2019/2020, a second disruption occurred. Here, we exploit novel data from Aeolus to study this disruption. As the first satellite able to observe winds at high resolution on a global scale, Aeolus is a uniquely capable platform for studying the evolution of the disruption and the broader circulation changes triggered by it. In this presentation, we use Aeolus to show the first direct wind observations of the QBO from space. We present results from the QBO2020 Aeolus range-bin setting implemented to observe this disruption, and compare with co-located radiosonde profiles and ERA5 reanalysis. Finally, we explore the large-scale wave activity before, during and after the disruption, and demonstrate how Aeolus and similar satellites can deepen our understanding of the QBO more generally.

Abstract for Presentation

3rd Aeolus NWP impact and L2B data quality meeting
1-3 December 2021

Project Title: The influence of Aeolus wind measurements on the representation of the West African Monsoon.

Author List: *Maurus Borne, KIT - Institute of Meteorology and Climate Research - Department Troposphere Research (IMK-TRO) ; Peter Knippertz (IMK-TRO); Martin Weissmann, University of Vienna - Department of Meteorology and Geophysics; Michael Rennie, European Centre for Medium-Range Weather Forecasts (ECMWF).*

Abstract:
This study investigates the quality and influence of Aeolus on the West African Monsoon (WAM) using radiosondes and NWP model equivalents. Two observing systems (OSEs) from ECMWF during the 2019 boreal summer (July-September) are analysed, with one OSE including a temperature-dependent bias correction in the Rayleigh channel. The first-guess departure statistics of radiosondes over West Africa show a reduction in the standard deviation for all levels when Aeolus is assimilated, and a further reduction when a temperature-dependent bias correction is included. This demonstrates the improvement of the ECMWF model background when Aeolus is assimilated and the further advantage of using the bias-correction.
However, despite this positive impact, first-guess departure statistics of Aeolus averaged over the same region reveals a small residual orbital and vertical-dependent bias in the Horizontal Line Of Sight (HLOS) wind observations for both Mie and Rayleigh channels. The influence on the African Easterly Jet (AEJ) and Tropical Easterly Jet (TEJ) in the analysis fields differs between the evening and the morning, corresponding to the ascending and descending orbits, respectively. Aeolus measurements have the effect of reducing the intensity of both AEJ and TEJ during the evening and the contribution of Mie data to this difference appears to be dominant, especially over the AEJ. The temperature-dependent bias correction appear to largely reduce the Rayleigh orbital bias and has the effect of reducing the analysis mean difference of wind between the morning and the evening. The apparent bias in the Mie-channel however, can be partially attributed to the wind diurnal cycle. The improvement of the wind representation over tropical West Africa at ECMWF enables further investigation on the propagation of the African Easter Waves (AEWS) and associated precipitation.