Scene classification for Aeolus wind processing based on the EarthCARE feature mask

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Aeolus, ESA's wind mission, has provided almost five years' worth of global wind observations. The horizontal line-of-sight wind measurements from the world's first space-based Doppler wind lidar have provided positive impact by near-real-time assimilation in numerical weather prediction. To increase Aeolus's impact further, remaining errors should be identified.
Currently, measurements are grouped by a scene classification algorithm to use the best wind retrieval algorithm. It is expected that misclassification may negatively influence measurement error and bias. Recently, a feature mask algorithm developed for EarthCARE has been added to the Aeolus data processing chain to improve scene classification and as a pre-launch EarthCARE algorithm test.
In this work the current Aeolus clear/cloudy scene classification is compared to the new feature mask. The aim is to improve the classification and grouping of the Aeolus measurements to improve the retrieved winds, and to further test the feature mask algorithm for EarthCARE.

1. Introduction

Aeolus, ESA's wind mission, has provided almost five years' worth of global wind observations [1,2]. The horizontal line-of-sight wind measurements from the world's first space-based Doppler wind lidar have provided positive impact by near-real-time assimilation in numerical weather prediction (NWP) [3]. To increase the impact of Aeolus measurements in future assimilation of reprocessed data, remaining systematic differences (i.e., biases) between Aeolus winds and NWP model background winds should be identified and then corrected. In addition, wind processing of scenes with heterogeneous optical properties may be improved by segregating these scenes into more uniform classes.

In current data processing the measurements are grouped into 'clear' and 'cloudy' types by a scene classification algorithm to allow using the optimal wind retrieval algorithm. It is expected that misclassification may negatively influence measurement error and bias. Recently, a high-resolution feature mask algorithm developed for EarthCARE (known as A-FM) has been added to the Aeolus data processing chain to improve scene classification for Aeolus and as a pre-launch EarthCARE algorithm test [4,5].

In this work the current Aeolus clear/cloudy scene classification is compared to the new feature mask. The aim is to improve the classification and grouping of the Aeolus measurements to improve the retrieved winds as well as to further test the feature mask algorithm for EarthCARE.

2. Aeolus wind observations

Horizontal line-of-sight wind in the planetary boundary layer, troposphere, and lower stratosphere is measured with the Doppler wind lidar technique [6–8]. The Atmospheric LAser Doppler INstrument (ALADIN), operating at 355 nm, uses a variation of the High Spectral Resolution Lidar (HSRL) technique to detect the Doppler shift of the attenuated backscatter return signal, which is induced by atmospheric movements with respect to the satellite. The atmospheric backscatter, from air molecules and particles, is measured in two separate main detection channels, referred to as the (molecular) Rayleigh and (particulate) Mie channels. The Rayleigh channel consists of sequential Fabry-Pérot interferometers, utilized for applying a double-edge technique. Simply put, the two interferometers act as bandpass filters, each considering a wing of the thermally broadened molecular-backscatter return. The ratio of the filtered signals is used to determine the Doppler shift. Furthermore, in the Mie channel, the signal is detected by means of a Fizeau interferometer and relies on a fringe-imaging technique.

Wind retrieval is performed for an accumulation of measurements. The construction of accumulations of a certain ‘atmospheric class’ is one of the main features of the L2B processing. Currently, the atmospheric classes ‘clear’ and ‘cloudy’ are defined, which are determined for each measurement bin through a process referred to as scene classification. The atmospheric class is decided by the optical properties of the sensing volume: what is the contribution of particulate backscatter relative to molecular backscatter to the signals on ALADIN’s channels. The method and results discussed here are based on the fourth reprocessing campaign, which used processor algorithms on baseline 16. The scene classification of the Rayleigh channel is currently based on the Mie channel signal-to-noise ratio (SNR). Where altitude bins in the Rayleigh channel overlap with bins in the Mie channel, the following procedure is applied: Rayleigh altitude bins where Mie SNR exceeds a threshold of 10 are classified as cloudy. At higher altitudes, Rayleigh altitude bins are classified as clear (i.e., taking a Mie SNR of 0). The scene classification of the Mie channel currently causes all valid data to be classified as cloudy. Note that the classification ‘cloudy’ is intended to encompass all particulate scattering, including hydrometeors and aerosols, while ‘clear’ is intended to mean no particulate scattering, i.e., only molecular scattering.

3. Aeolus feature mask

The joint ESA-JAXA mission EarthCARE (Earth Cloud, Aerosol and Radiation Explorer) will utilize a cloud/aerosol lidar as one of its four measurement systems [9,10]. While being a HSRL system like ALADIN, ATLID (ATmospheric LIDar) is optimized exclusively for cloud and aerosol observations instead of wind measurements. To make accurate retrievals of cloud and aerosol extinction and backscatter, algorithms have been developed to address the low signal-to-noise ratio of the lidar signal by devising suitable data binning [5]. To this end the ATLID feature mask (A-FM) algorithm provides a probability mask whether a pixel contains clouds and/or aerosols. This mask is developed to help guide smoothing procedures performed in the ATLID profile retrieval algorithm (A-PRO), ensuring ‘strong’ and ‘weak’ signals are not mixed. Thus, making a distinction between i) strongly (optically thick regions of clouds and aerosols, and surface returns) and ii) weakly (optically thin aerosol regions and thin ice clouds) backscattering regions, and iii) clear sky regions.

A-FM defines coherent atmospheric structures (i.e., ‘features’) based on two complementary image processing techniques: the median hybrid method for strong features and a data-smoothing strategy based on a simplified maximum entropy method for the detection of weak features. For scene classification in the Aeolus wind processing, a version of the A-FM algorithm has been developed and implemented in the Aeolus L2A operational processor, named AEL-FM. The Aeolus data provides an opportunity for testing the feature mask algorithm before EarthCARE’s launch. The main difference between A-FM and AEL-FM is the need for oversampling the 24 Aeolus range bins to a higher vertical resolution to enable the A-FM procedure, and its consequent inversion, remapping the feature mask to the Aeolus measurement grid.

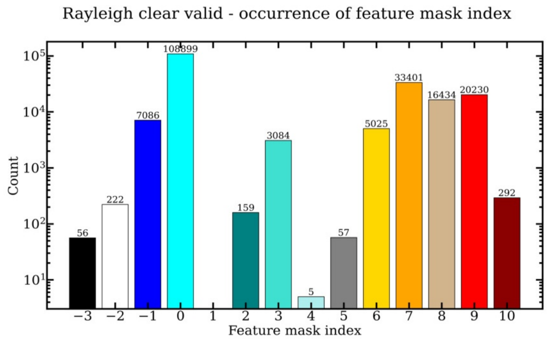

Figure 1. Occurrence of the feature mask index (on logarithmic scale) in a single-orbit Aeolus Rayleigh data subset classified as ‘clear’

4. First results

Firstly, the occurrence of features is investigated for wind data labeled with a certain scene classification. Remarkably, the first results for a single orbit indicate that features with high cloud or aerosol probabilities are present in the Rayleigh channel data classified as clear, as shown in Fig. 1. The histogram in Fig. 1, plotted with a logarithmic vertical axis, is based on the feature mask on measurement-level resolution. As expected, the largest feature mask index occurrence, for index 0, corresponds to clear sky. These measurements contain very low Mie signals, as expected for clear air. However, cloud features, marked by feature mask indices of 9 and 10, are also present rather prominently. In this case Mie signals are (very) strong and therefore most likely from cloud returns. Aerosol features, such as indices 6 and 7, are present in even slightly larger amount in this data subset classified as clear. More details on the definitions of the feature mask indices can be found in Van Zadelhoff et al. [5].

Moreover, as expected, data classified as cloudy seems to contain mostly features with high cloud probabilities. Based on single-orbit analysis this holds for both Rayleigh- and Mie-cloudy data. Clear sky features are very few in number (two orders of magnitude lower occurrence) and the occurrence of aerosol features is only one order of magnitude lower than the occurrence of cloud features.

Secondly, currently ongoing work aims to quantify the effect of these first results on wind bias between observation and background, and random error. Here, to compare the wind measurements and their bias with the feature mask, ways are being investigated to translate the feature mask from measurement-level resolution to accumulation-level resolution.

Lastly, future work will evaluate the possibilities of scene classification and thereby definition of accumulations, i.e., grouping, based on the feature mask output.

5. References

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