Royal Netherlands Meteorological Institute
Ministry of Infrastructure and the Environment

aeolus because wind matters

The performance of Aeolus in heterogeneous atmospheric conditions

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A major challenge for the ESA Aeolus mission is to retrieve high quality winds in heterogeneous atmospheric conditions, i.e., where both the atmospheric dynamics and optical properties vary strongly within the sampling volume. Such conditions induce height assignment errors and subsequent errors in retrieved winds, in particular for scenes with large wind shear. Over the years atmospheric databases (from ECMWF-CALIPSO/LITE and high-resolution radiosondes) were built and used together with simulation tools to test Aeolus performance in realistic atmospheric scenes.

1. Introduction

The European Space Agency Aeolus mission aims to measure wind profiles from space. A major challenge is to retrieve high quality winds in heterogeneous atmospheric conditions, i.e., where both the atmospheric dynamics and optical properties vary strongly within the sampling volume. In preparation for launch we aim to quantify the expected error of retrieved winds from atmospheric heterogeneity, particularly in the vertical, and develop algorithms for wind error correction, as part of the level-2B processor (L2Bp). The Aeolus lidar is operated at 355 nm laser wavelength thus measuring on both particles (aerosols, cloud droplets) and molecules and potentially yielding two wind solutions for the sampled volume, from the Mie and Rayleigh channel signals, respectively.

2. Particle-free atmosphere

The non-uniform distribution of molecules in the measurement bin introduces height assignment errors in Rayleigh channel winds up to 2.5% of the measurement bin size in the stratosphere which translates to 0.5 ms^{-1} bias for typical atmospheric conditions, if not corrected.

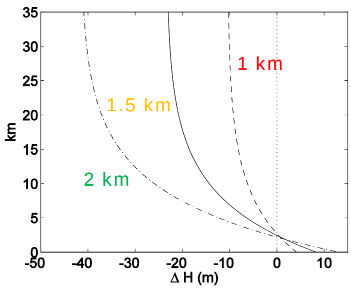

Figure 1 *Rayleigh channel height assignment error as a function of bin size.*

3. Clouds and aerosols

Atmospheric databases including aerosol and cloud backscatter and extinction (from CALIPSO/LITE) and co-located wind, temperature and humidity (from ECMWF/UKMO) were used as input for the simulation tool LIPAS to assess Aeolus' coverage and quality (Figure 2). Strong wind shear above the cirrus cloud in figure 3 induces large errors in Rayleigh channel winds around 25 km (figure 4). The cirrus cloud is not centred in the measurement bin, inducing height assignment errors, hence large errors in Mie channel winds.

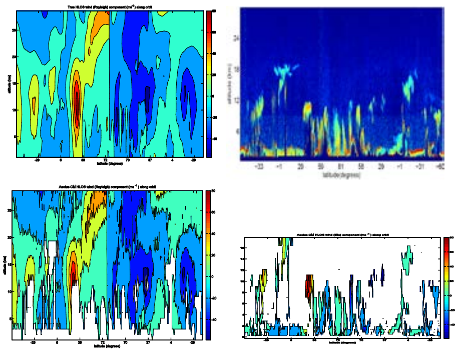

Figure 2 *Top: true HLOS wind (UKMO) and attenuated backscatter (CALIPSO). Bottom: Aeolus Rayleigh and Mie channel HLOS winds.*

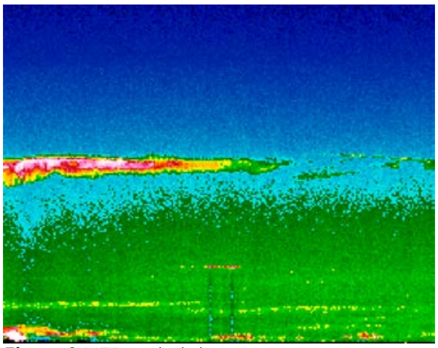

Figure 3 *LITE tropical cirrus scene*

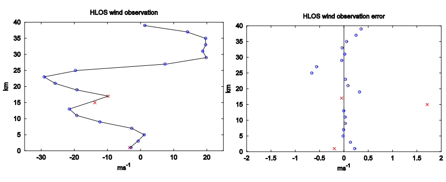

Figure 4 *Left: ECMWF wind profile valid for figure 2. Right: HLOS wind error. Blue/red symbols correspond to Rayleigh/Mie winds. Bin size is 2 km.*

4. High-resolution radiosondes

NWP models underestimate wind variability (fig.5). Radiosondes sample the atmosphere at 2s (~10m along track) resolution.

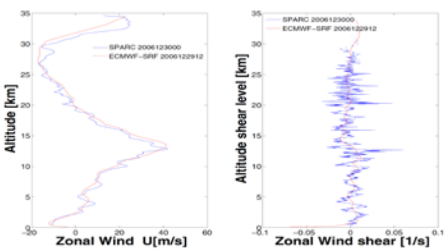

Figure 5 *Radiosonde (blue) and ECMWF model (red) zonal wind profile (left) and wind shear.*

Clouds along the radiosonde path can be detected from measured temperature and humidity.

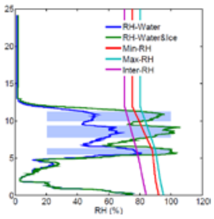

Figure 6 *Cloud detection along radiosonde path*

From the resulting radiosonde database it was concluded that the presence of cloud or aerosol layers in the measurement bin yields biases in Mie channel winds which cannot be easily corrected and mostly exceed the mission requirement of 0.4 ms^{-1}. The collocated Rayleigh channel wind solution is generally preferred because of smaller biases, in particular for transparent cloud and aerosol layers with one-way transmission above 0.8.

5. Laser jitter

Laser pulse-to-pulse frequency variation (jitter) is expected in the order of 5-10 MHz. This can be corrected in principle at measurement level with the internal reference signal, albeit only for homogeneous atmospheric scenes. Otherwise, laser jitter may induce correlated errors at measurement level in the order of meters per second for Mie and Rayleigh winds.

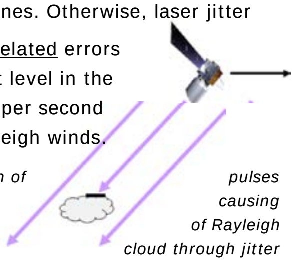

Figure 7 *A fraction of pulses encounter cloud, causing correlated errors of Rayleigh winds below the cloud through jitter*

Laser induced errors at observation level are in the order of tenths of ms^{-1}. However, correlated errors are known to be detrimental for NWP if not taken into account.

6. Conclusion

This poster addresses the challenges for Aeolus wind retrieval in heterogeneous atmospheric conditions. In particular, Mie winds are prone to height assignment errors that cannot be corrected and should be treated with great care in NWP. Experience from the simulation studies is used to improve level-2B wind processing.

More information is found on www.knmi.nl/~marseill