On the derivation of zonal and meridional wind components from Aeolus horizontal line-of-sight wind

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Abstract

Aeolus measures the wind component along its horizontal line-of-sight, but for the analysis and interpretation of atmospheric dynamics, zonal and/or meridional wind components are most useful.

Here, we introduce and compare three different methods to derive zonal and meridional wind components from the Aeolus wind measurements.

We find that the most promising method involves combining Aeolus measurements during ascending and descending orbits. Using this method, we derive global estimates of the zonal wind in the latitude range 79.7° S to 84.5° N with errors of less than 5 ms^{-1} (at the 2-sigma level).

Due to the orbit geometry of Aeolus, the estimation of meridional wind in the tropics and at midlatitudes is more challenging and the quality is less reliable. However, we find that it is possible to derive meridional winds poleward of 70° latitude with absolute errors typically below ±5 ms^{-1} (at the 2-sigma level).

Aeolus measurement principle

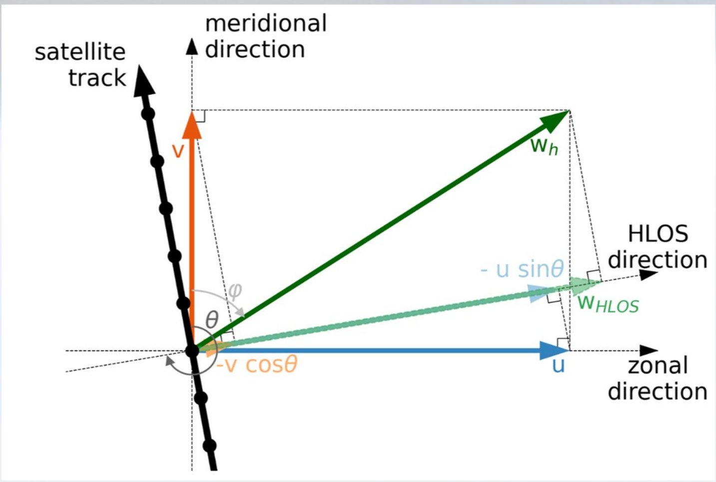
Aeolus measures the wind along its line-of-sight (LOS), which is at an angle of 35° off-nadir perpendicular to the satellite flight direction. The LOS wind w_{LOS} contains contributions from both the horizontal and the vertical wind:

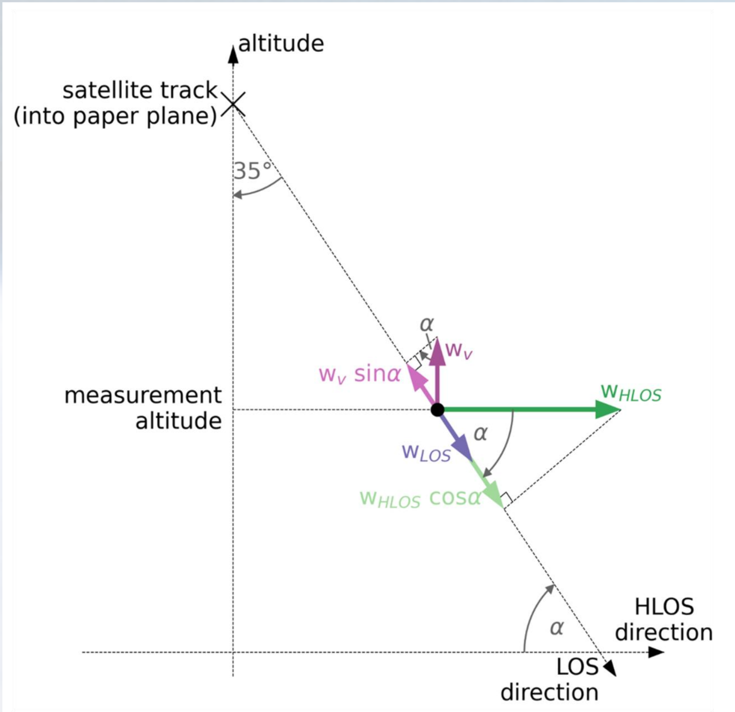
$$w_{LOS} = w_{HLOS} \cos\alpha + w_v \sin\alpha\,.$$

The horizontal wind along the LOS w_{HLOS} consists of a meridional and a zonal component:

$$w_{HLOS} = -u \sin\theta - v \cos\theta\,.$$

The standard Aeolus L2B wind product is the wind along HLOS (w_{HLOS}).

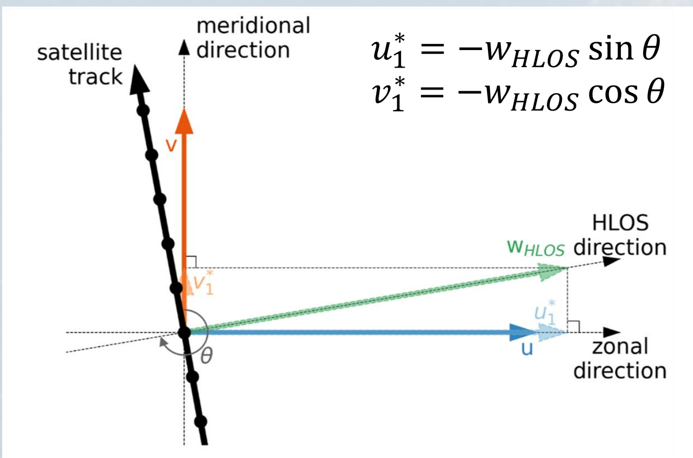




Methods to estimate zonal and meridional wind components

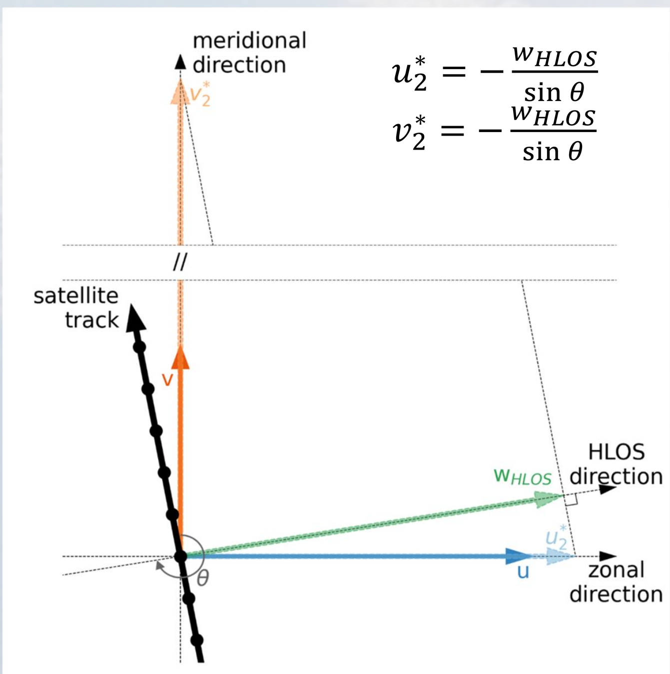
The first method to convert Aeolus w_{HLOS} into zonal and meridional wind components is a simple projection onto the zonal and meridional axis direction. The second method uses the assumption of zero meridional (zonal) wind for determining the zonal (meridional) wind component. The third method is inspired by the velocity–azimuth display (VAD) technique for single ground-based or airborne radar or lidar instruments and uses the geometrical differences between ascending and descending orbits.

Method 1: Simple projection of HLOS wind to cardinal axes

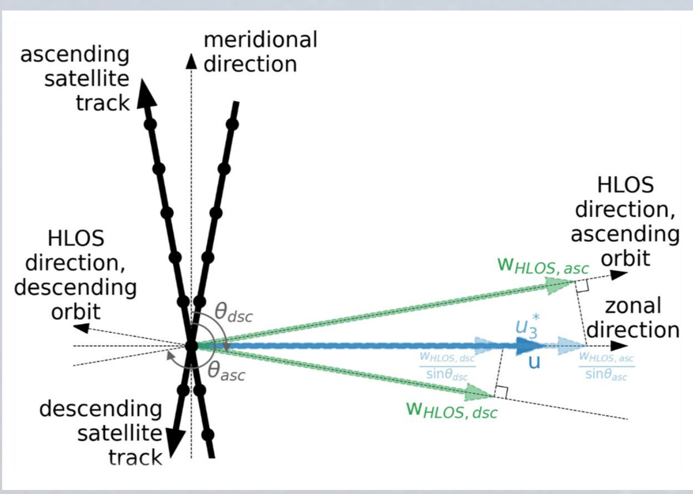


$$u_1^* = -w_{HLOS} \sin\theta$$
$$v_1^* = -w_{HLOS} \cos\theta$$

Method 2: Assumption of zero meridional (zonal) wind



$$u_2^* = -\frac{w_{HLOS}}{\sin\theta}$$
$$v_2^* = -\frac{w_{HLOS}}{\sin\theta}$$

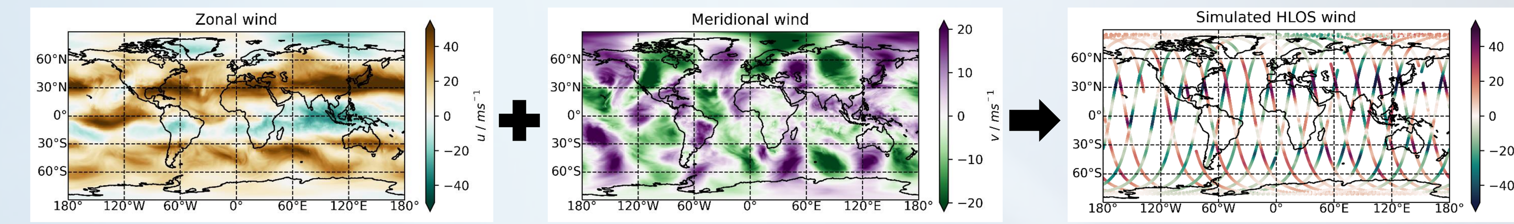


Method 3: Use of ascending and descending orbits

$$u_3^* = -0.5 \cdot \left(\frac{w_{HLOS,asc}}{\sin\theta_{asc}} + \frac{w_{HLOS,dsc}}{\sin\theta_{dsc}}\right)$$
$$v_3^* = -0.5 \cdot \left(\frac{w_{HLOS,asc}}{\cos\theta_{asc}} + \frac{w_{HLOS,dsc}}{\cos\theta_{dsc}}\right)$$

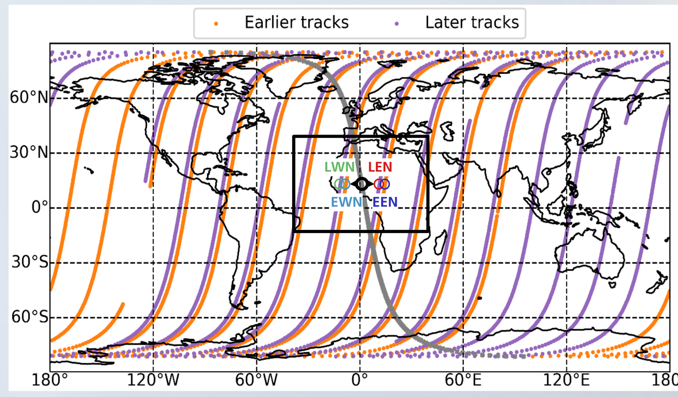
Simulating Aeolus observations from ERA5

Aeolus-like HLOS wind measurements are constructed by sampling ERA5 data on real Aeolus Rayleigh clear measurement locations (time, longitude, latitude, altitude and azimuth angle) for the whole month of January 2021.

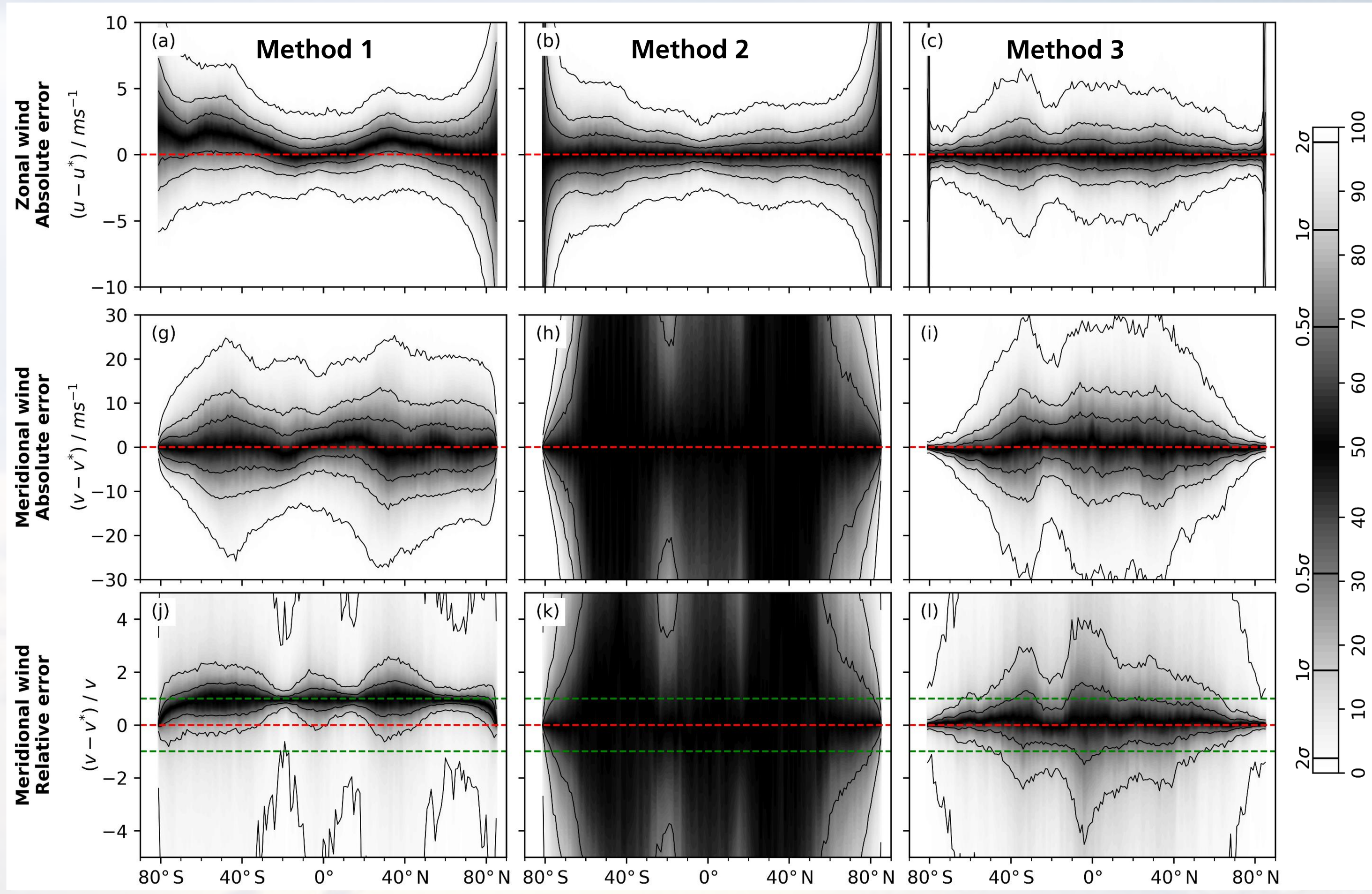


Colocation of ascending and descending measurements for Method 3

For each individual measurement, the nearest neighbours in longitude (one east and one west) but with different orbit phase (ascending vs. descending) are identified within the time period from 24 hours before to 24 hours after the measurement time. In this way, four nearest neighbours are determined: the earlier west neighbour (EWN), the earlier east neighbour (EEN), the later west neighbour (LWN), and the later east neighbour (LEN). The two early and two late nearest neighbours are then linearly interpolated in space onto the original measurement location and afterwards interpolated linearly in time.



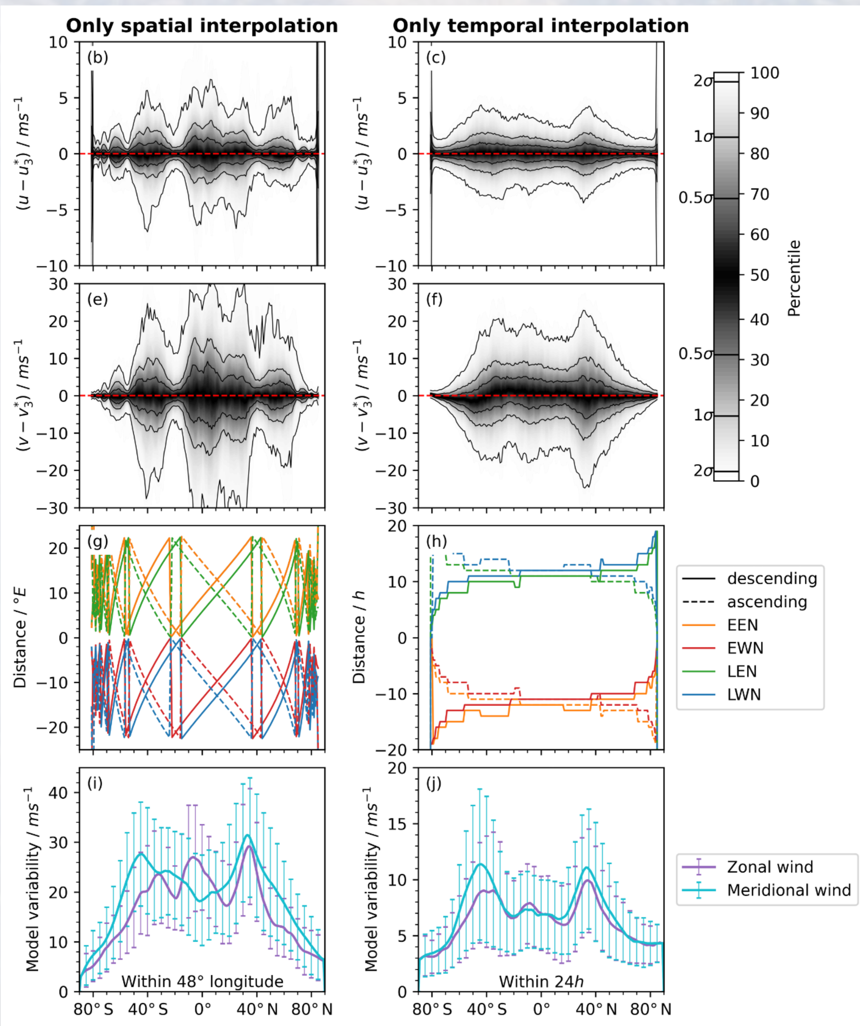
Statistical error assessment



All three methods produce reliable zonal wind estimates between 70°S and 70°N with absolute errors typically below 5 ms^{-1}. Poleward of 70° latitude, the zonal wind errors of Method 1 & 2 increase strongly, whereas the errors of Method 3 remain at a low level.

Method 3 is the only method able to produce reliable meridional winds at all latitudes. Especially poleward of 70° latitude the derivation of the meridional wind is reasonable with absolute errors usually below ±5 ms^{-1}.

Influence of spatial and temporal interpolation for Method 3



Method 3 relies on temporal and spatial interpolation of measurement data taken at different locations and at different points in time. This interpolation is the main error source of this method.

The errors due to both temporal as well as spatial interpolation strongly depend on the distance to the nearest neighbour: The closer in time or space the nearest neighbour is, the smaller is the error.

In addition to this dependence on the distance to the nearest neighbours, the absolute errors are also correlated with the variability of the wind speeds.

Reference

Krisch, I., Hindley, N. P., Reitebuch, O., and Wright, C. J.: On the derivation of zonal and meridional wind components from Aeolus horizontal line-of-sight wind, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2021-381, in review, 2021.