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Triple collocation analysis of 4D wind observations

Federico Cossu[1], Marcos Portabella[1], Wenming Lin[2], Ad Stoffelen[3], Jur Vogelzang[3], Gert-Jan Marseille[3], Siebren de Haan[3]

[1] Barcelona Expert Centre, Institute of Marine Sciences (ICM-CSIC), Barcelona, Spain
[2] Nanjing University of Information Science & Technology (NUIST), Nanjing, China
[3] Royal Netherlands Meteorological Institute (KNMI), De Bilt, The Netherlands

cossu@icm.csic.es

1. Introduction

Surface wind observations from insitu and remote instruments (buoys and scatterometers) are characterized by different scales and measurement errors, which can be estimated with the triple collocation method (Stoffelen, 1998). In a previous study we assessed the errors of the different wind products using collocations of buoys, scatterometer and ECMWF model output (Cossu et al., 2021). In this study, we extend the triple collocation analysis to tropospheric winds (4D winds) using collocations of aircraft observations (Mode-S), vertical wind profiles from the Aeolus satellite mission (**Fig. 1**) and ECMWF model output.

2. Data

- **Mode-S EHS observations**: aircraft-derived meteorological data (de Haan, 2011).
- **Aeolus observations**: vertical wind profiles from the Rayleigh (sensitive to atmospheric molecules) and Mie (sensitive to clouds and aerosols) channels of the horizontal line of sight (HLOS) wind component.
- **ECMWF IFS model** (interpolated to Aeolus locations/times).

Time period: 28 June 2019 to 26 December 2019.

4. Results

Collocations distribution (**Fig. 3**)

- The distribution is characterized by an almost uniform number of collocations from 5th bin onwards (distances > 40 km).
- Collocations with a small (large) horizontal distance have a smaller (bigger) collocation error.

Error variances (**Fig. 4**)

- We used a representativeness error of r^2=0 m²/s², as a more precise estimation of this value is still in progress.
- The common true variance (grey triangles) decreases with the horizontal distance.
- Mode-S error (blue circles) increases with the horizontal distance.
- Aeolus error (red squares) is almost constant if compared with Mode-S, although it is slightly increasing in the Mie channel (filled squares).
- The error variance for Rayleigh (empty squares), as expected, is higher than for Mie.
- For ECMWF (green diamonds) the error is always lower than the other two systems and it is decreasing with the horizontal distance.
- Irregular behavior of the first four points (distances < 40 km) caused by irregular sampling (see Fig. 3).

5. Conclusions

- Triple collocation analysis was applied to 4D wind observations.
- Error variances strongly depend on collocation distance, and therefore on the collocation error.
- Aeolus Rayleigh error > Aeolus Mie error (consistent with previous estimates).
- Sampling strategy affects the results (important for calibration and validation).
- Future work will focus on the estimation of the representativeness error, which will in turn lead to more accurate error variance estimates.

Acknowledgements

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References

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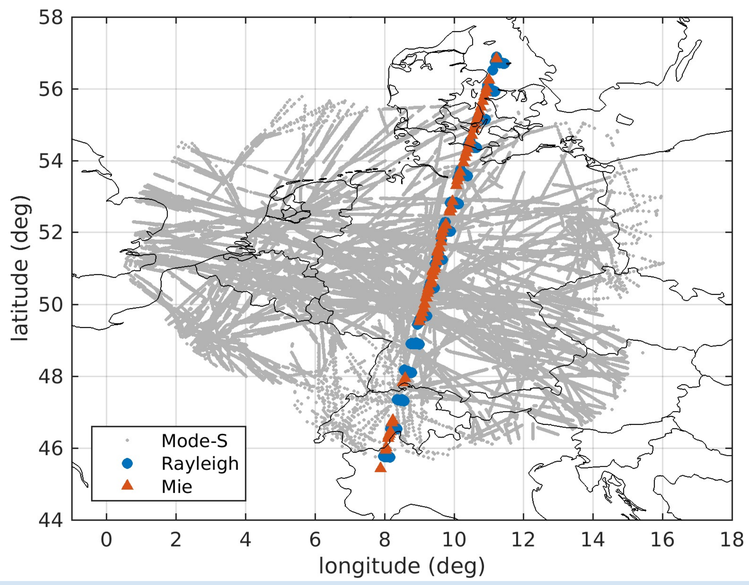

Fig. 1: horizontal locations of Aeolus observations (blue dots and red triangles) and Mode-S observations (gray dots) within ±15 minutes from Aeolus pass, which occurs on 01-07-2019 from 05:40:35 UTC to 05:43:30 UTC.

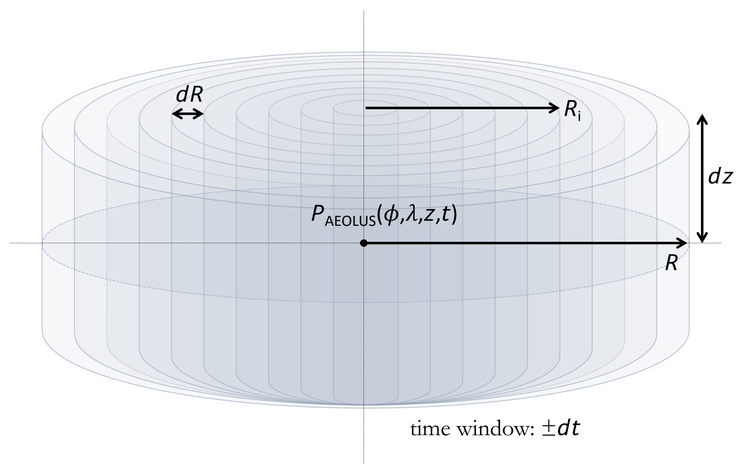

Fig. 2: collocation box built around each Aeolus observation, with concentric rings of increasing radius. Each cylinder has dimensions dz=±75 m, dt=±15 min and radius R_i varying from 10 km to 200 km at steps of dR=10 km.

3. Methods

Collocation strategy

- We use a collocation box around each Aeolus observation, with rings of increasing radius (**Fig. 2**).
- We select Mode-S observations with the following minimum normalized distance:

$$D = \sqrt{(\Delta R)^2 + (100\,\Delta z)^2 + (1000\,\Delta t)^2}$$

where ΔR (m) is the horizontal distance, Δz (m) is the vertical distance and Δt (min) is the temporal distance of Mode-S from Aeolus.

- We accept only the cases with at least 16 rings filled with Mode-S observations.

Triple collocation analysis

According to Vogelzang et al. (2021), the error variances for each system *i=1,2,3* are:

$$\sigma_1^2 = \frac{C_{11}}{a_1^2} - T + \left(\frac{C_{13}}{C_{23}} - 1\right) r^2$$

$$\sigma_2^2 = \frac{C_{22}}{a_2^2} - T + \frac{C_{13}}{C_{23}}\left(1 - \frac{C_{13}}{C_{23}}\right) r^2$$

$$\sigma_3^2 = \frac{C_{33}}{a_3^2} - T + \left(\frac{C_{13}}{C_{23}} - 2\frac{C_{12}C_{33}}{C_{23}^2}\right) r^2 + \frac{C_{33}}{C_{23}^2} r^4$$

where Mode-S is system 1, Aeolus is system 2, ECMWF is system 3, a_i are the calibration scaling coefficients, C_{ij} are the covariances, $T = \frac{C_{12}C_{13}}{C_{23}}$ is the common true variance and r^2 is the representativeness error, which is the variance common to systems 1 and 2 that cannot be resolved by system 3.

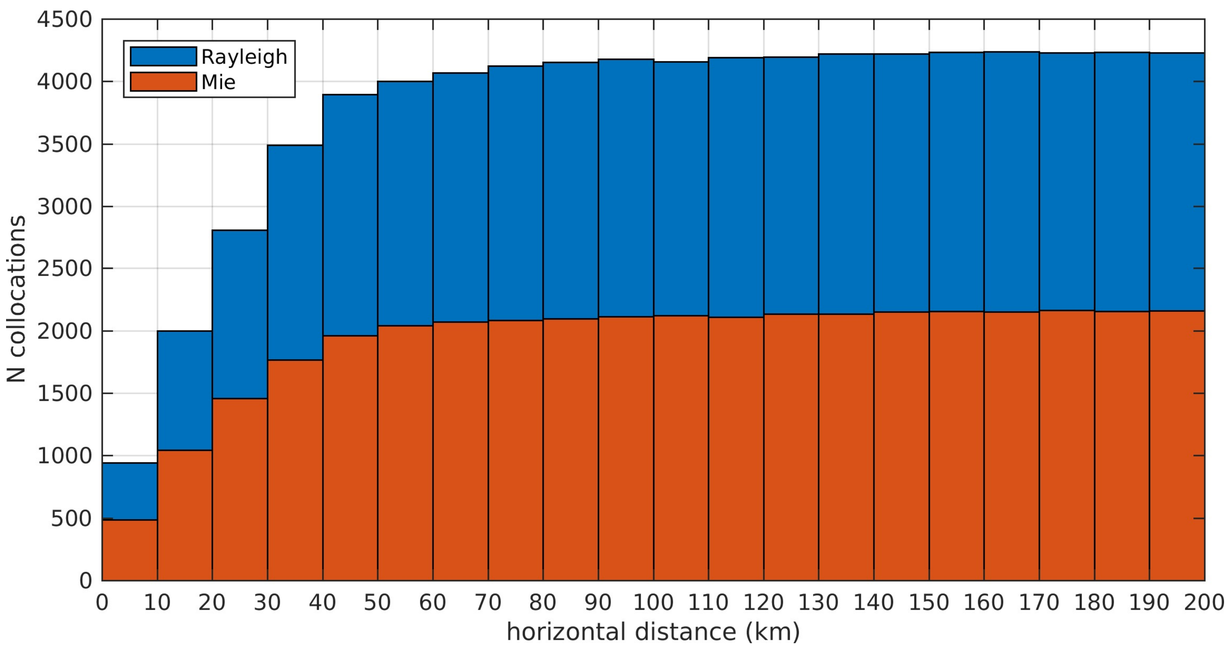

Fig. 3: distribution of the number of collocations as a function of the horizontal distance from Mode-S to Aeolus for the Rayleigh channel (blue) and for the Mie channel (red).

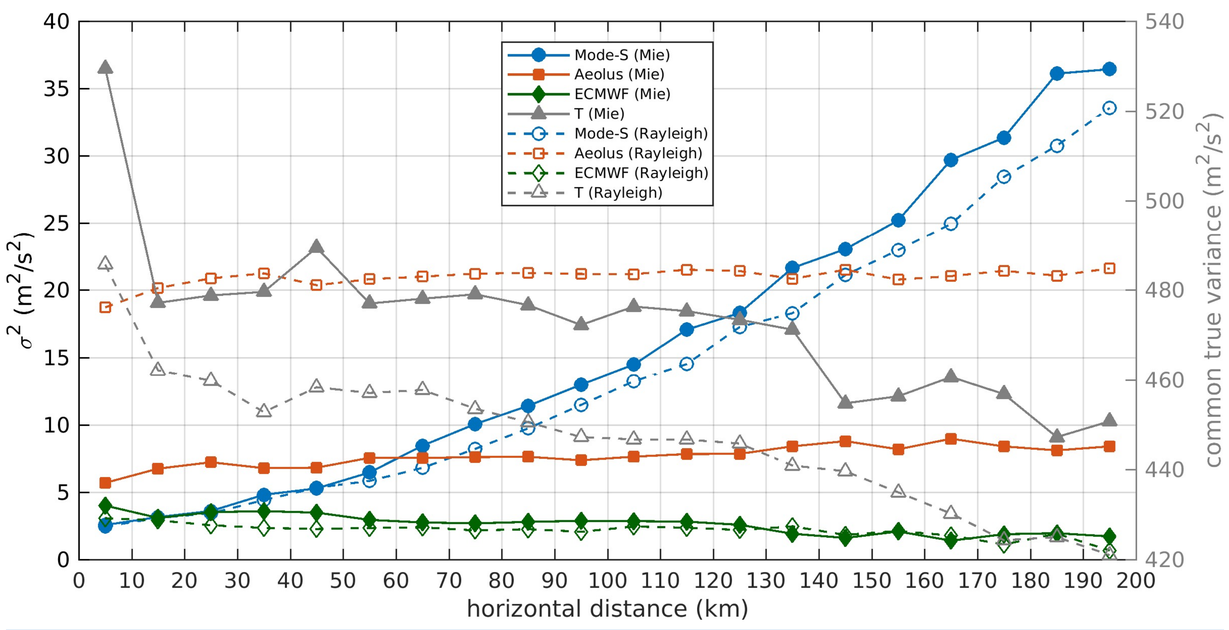

Fig. 4: error variances estimated with the triple collocation analysis for Mode-S (blue), Aeolus (red) and ECMWF (green) collocations as a function of the horizontal distance between Mode-S and Aeolus. The common true variance is shown in grey. The filled solid lines are for the Mie channel, while the empty dashed lines are for the Rayleigh channel.