Evaluation of Aeolus L2B wind product using triple collocation analysis

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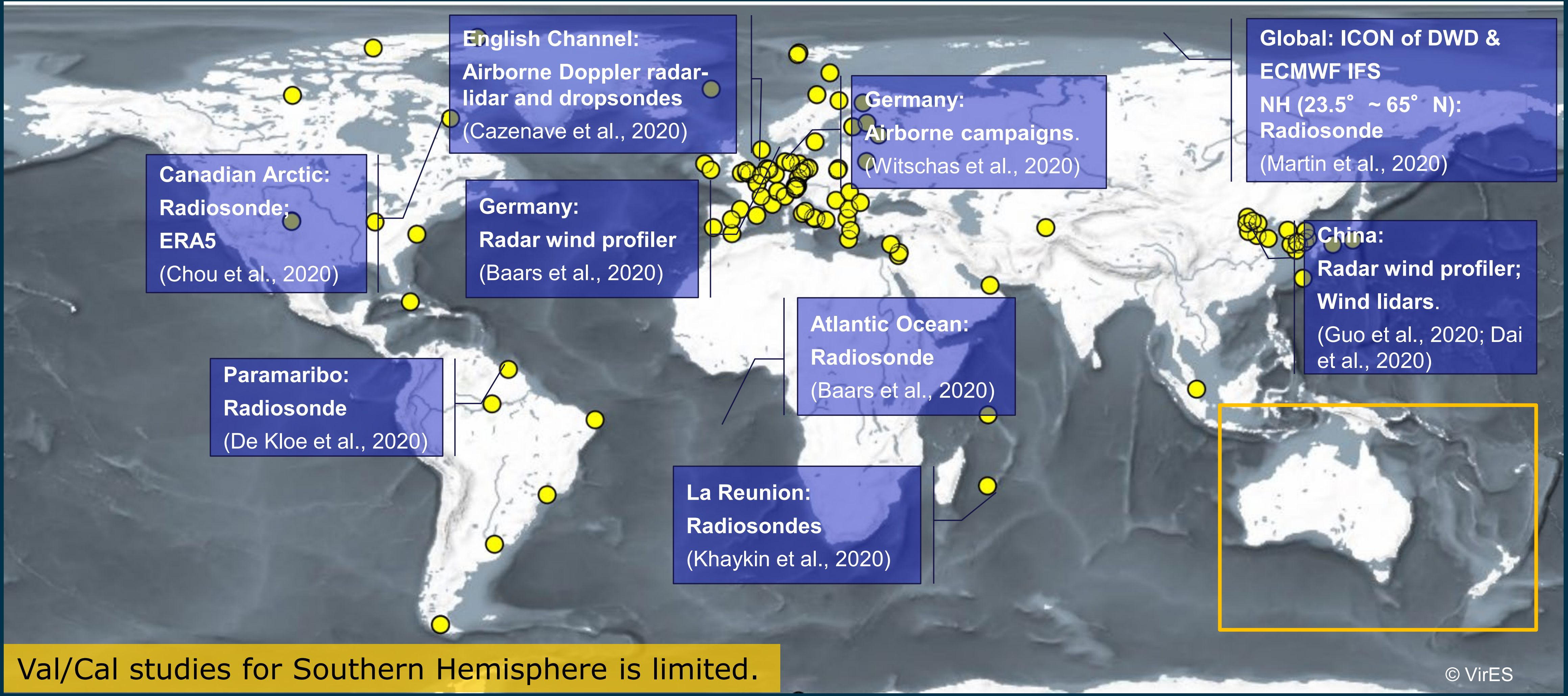
Objectives of the L2B product quality assessment

- To evaluate Level 2B11 winds over Australia using triple collocation analysis

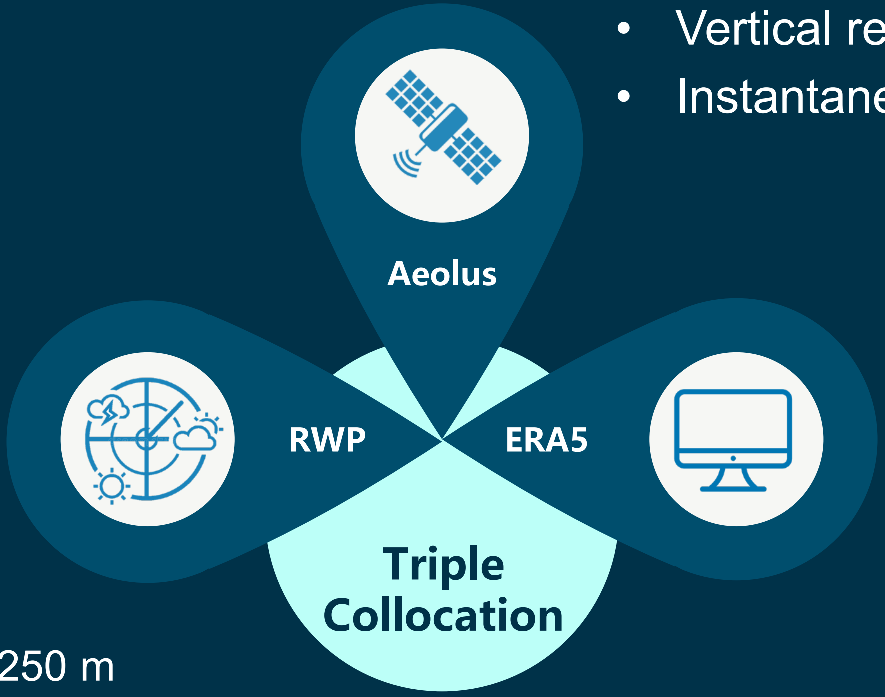


Experimental method applied

- Datasets

Aeolus Level-2B11 HLOS winds (ESA)

- Horizontal resolution: 87 km (Rayleigh-clear); 14 km (Mie-cloudy)
- Vertical resolution: from 250 m to 2 km
- Instantaneous



Wind profiling radar (WPR) (Met Office, 2008)

- Point measurement
- Sampling intervals :
  - Stratospheric Tropospheric Profilers: 100 m/500 m
  - Boundary Layer Profilers: 100 m/250 m
- 30-minute averaged winds

ERA5 reanalysis dataset (Hersbach et al., 2018)

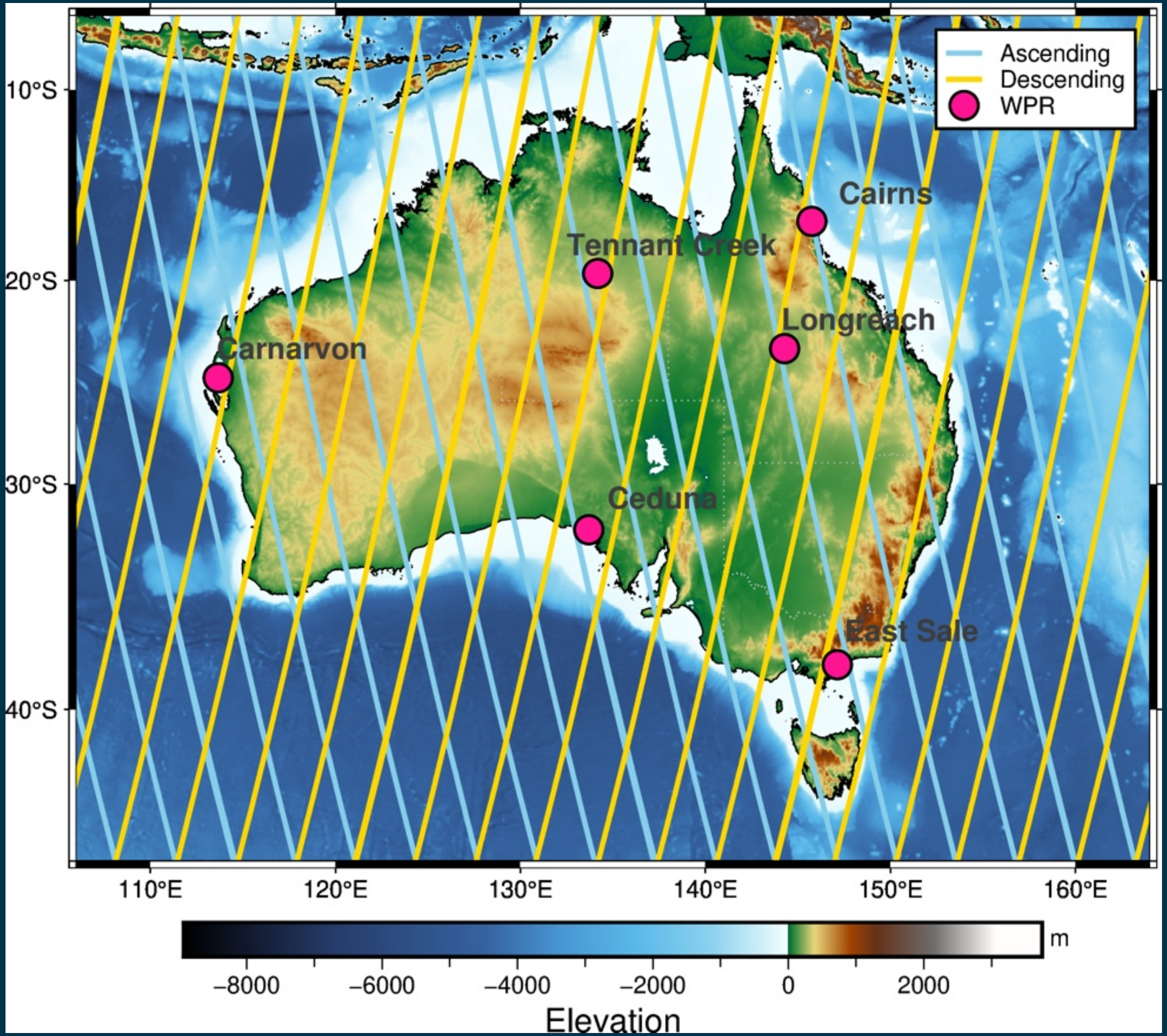
- Horizontal resolution: 0.25°×0.25°
- 37 pressure levels
- Hourly

Study period: October 2020 – March 2021 (Summer half year of Australia)

Experimental method applied

- Collocation criteria
  - WPR: < 75 km
  - ERA5: nearest grid
  - Temporal difference < 30 min
- Quality control
  - Rayleigh-clear winds: estimated error < 7 m/s
  - Mie-cloudy winds: estimated error < 5 m/s

(Guo et al., 2021; Zhang et al., 2016)



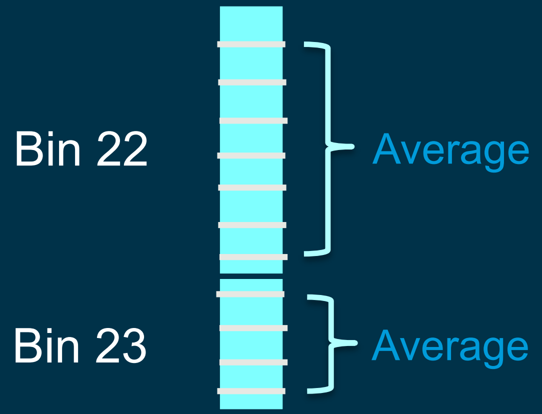
Experimental method applied

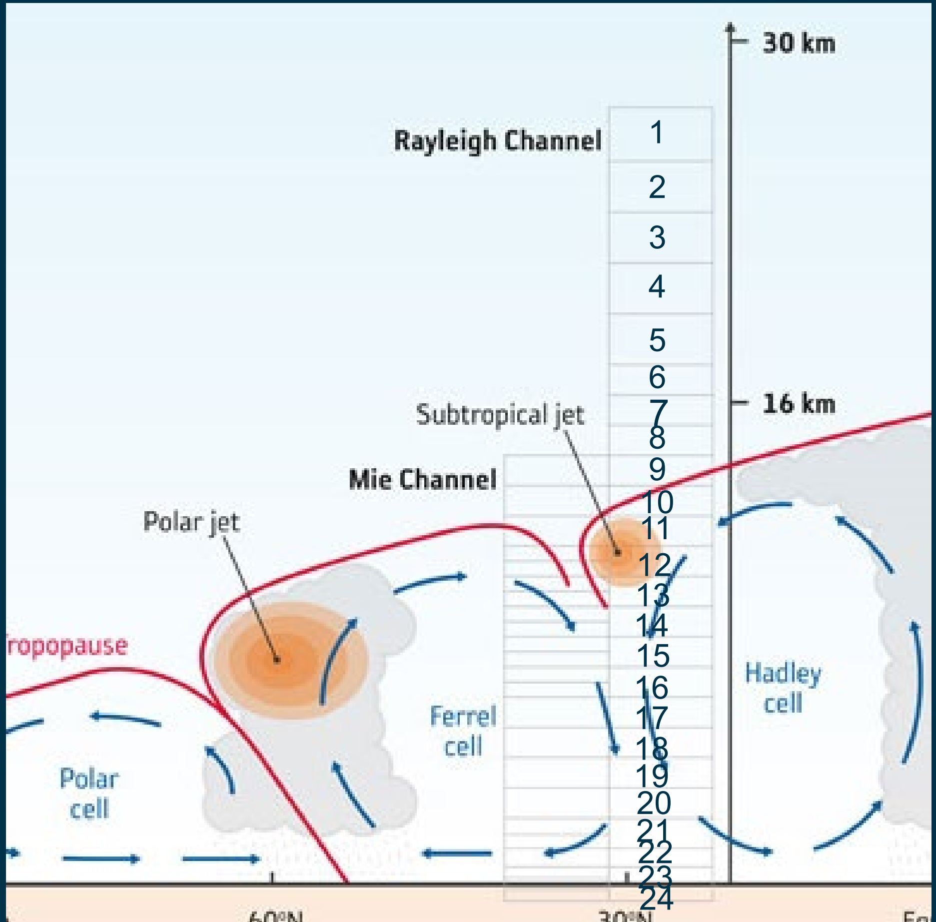
- Wind vectors from WPR and ERA5 were converted to

$$HLOS = -u \cdot \sin\varphi - v \cdot \cos\varphi$$

Azimuth angle (~100°/259° for descending/ascending)

- Conversion: WPR, ERA5 -> Aeolus range bins





Credit: ESA

Experimental method applied

- Model of Triple Collocation

Three different measurement systems:

$$HLOS_1 = T + e_1$$
$$HLOS_2 = a_2 + b_2 T + e_2$$
$$HLOS_3 = a_3 + b_3 T + e_3$$

Where:

T - the true value;

a_i -offset of the calibration;

b_i - slope of the calibration;

e_i - the random error of each system;

$HLOS_i$ - horizontal line-of-sight wind speed.

Assume $HLOS_1$ is the reference.

After derivation, the error variances are:

$$\sigma_1^2 = \langle e_1^2 \rangle = C_{11} - \frac{(C_{12} - \langle e_1 e_2 \rangle)(C_{13} - \langle e_1 e_3 \rangle)}{C_{23} - \langle e_2 e_3 \rangle}$$
$$\sigma_2^2 = \langle e_2^2 \rangle = C_{22} - \frac{(C_{12} - \langle e_1 e_2 \rangle)(C_{23} - \langle e_2 e_3 \rangle)}{C_{13} - \langle e_1 e_3 \rangle}$$
$$\sigma_3^2 = \langle e_3^2 \rangle = C_{33} - \frac{(C_{23} - \langle e_2 e_3 \rangle)(C_{13} - \langle e_1 e_3 \rangle)}{C_{12} - \langle e_1 e_2 \rangle}$$

Where:

C_{ii} - the variance of each system

C_{ij} - the covariance between the system i and j;

$\langle \quad \rangle$ - the statistical averaging.

Assume the true measurement errors are independent, then $\langle e_i e_j \rangle = 0$.

(Vogelzang and Stoffelen,2012; Ribal and Young, 2020)

Experimental method applied

- Algorithm of Triple Collocation

The error standard deviation:

$$\sigma_1 = \sqrt{C_{11} - \frac{C_{12}\,C_{13}}{C_{23}}}$$

$$\sigma_2 = \sqrt{C_{22} - \frac{C_{12}C_{23}}{C_{13}}}$$

$$\sigma_3 = \sqrt{C_{33} - \frac{C_{23}C_{13}}{C_{12}}}$$

Calibration coefficients and relations (assume $HLOS_1$-WPR is the reference):

$$b_2 = \frac{C_{23}}{C_{13}}$$

$$b_3 = \frac{C_{23}}{C_{12}}$$

$$a_2 = \langle HLOS_2 \rangle - b_2 \langle HLOS_1 \rangle$$

$$a_3 = \langle HLOS_3 \rangle - b_3 \langle HLOS_1 \rangle$$

$$HLOS_2^* = \frac{HLOS_2}{b_2} - \frac{a_2}{b_2}$$

$$HLOS_3^* = \frac{HLOS_3}{b_3} - \frac{a_3}{b_3}$$

(Vogelzang and Stoffelen,2012; Ribal and Young, 2020)

Main results from L2B product quality analysis

Standard deviation error (SDE) of three different systems [ms^{-1}]

	1: WPR	2: Aeolus	3: ERA5	N
Rayleigh-clear	1.79	**5.43**	0.95	883
Mie-cloudy	2.11	**4.42**	1.52	226

- ERA5 is the most precise wind product, followed by ground-based radar and Aeolus product;
- Mie channel has better performance than Rayleigh channel;
- The SDE of both Rayleigh-clear and Mie-cloudy winds are large than Aeolus Mission Requirements.

Main results from L2B product quality analysis

If considering spatial representation error:

	1: WPR	2: Aeolus	3: ERA5	N
Rayleigh-clear	1.79	5.43	0.95	883
Mie-cloudy	2.11 ⇧	4.42 ⇧	1.52 ⇩	226

WPR, Rayleigh-clear winds and ERA5:

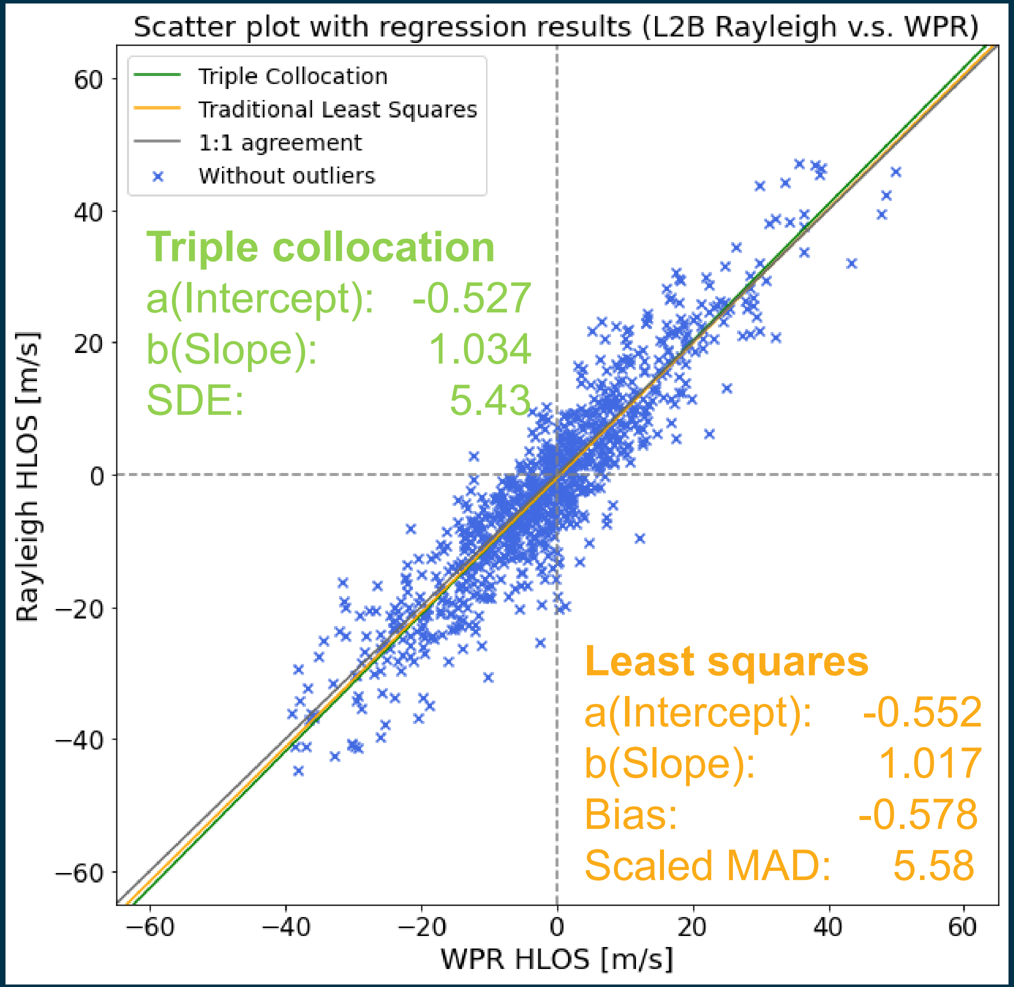
- The effective horizontal resolution of ERA5 is about 150 km (Stoffelen et al., 2020);
- Small common variance of the coarse Rayleigh winds and WPR;
- Small impact from representativeness error.

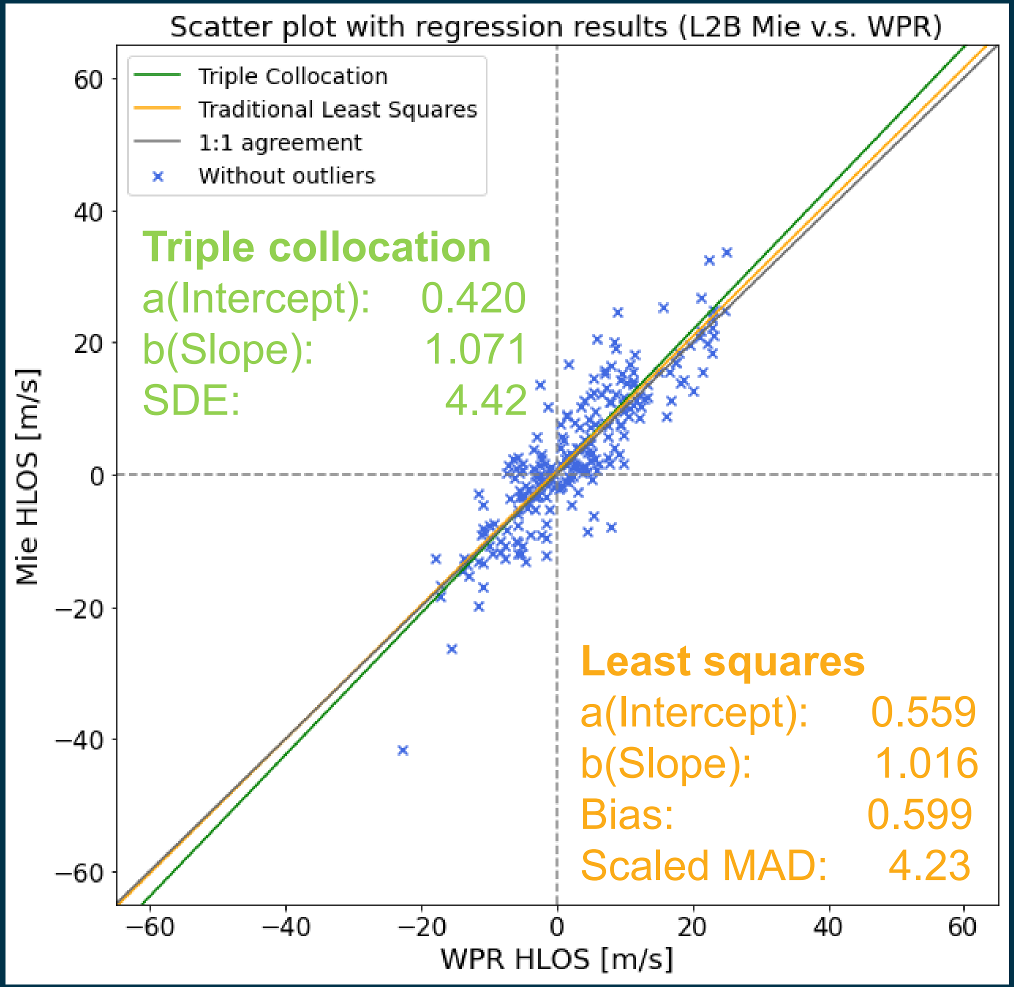
WPR, Mie-cloudy winds and ERA5:

- Common variance between the moderate-resolution Mie winds and WPR is not resolved by ERA5;
- SDEs of ground-based radar and Mie-cloudy winds should become larger;
- The higher value of SDEs may be caused by relatively high variability conditions of Mie-cloudy winds.

Main results from L2B product quality analysis

- Comparison with intercomparison analysis





Summary and recommendations for Aeolus-2

- **Summary:**
  - Overall, both Rayleigh-clear winds and Mie-cloudy winds are with sufficient accuracy of systematic error < 0.6 m/s;
  - Mie-cloudy winds are shown to be more precise than Rayleigh-clear winds;
  - The results from triple collocation and intercomparison analysis are comparable.

- **Future work:**
  - Investigate the wind variability during Rayleigh and Mie winds sampling;
  - Assess data quality for Australia winter (April 2020 – September 2020)

Thank You!
Any Questions?

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