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Validation of ESA Aeolus wind observations using French ground-based Rayleigh Doppler lidars at midlatitude and tropical sites

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French Rayleigh Doppler wind lidars

Wind lidar systems deployed at **Haute-Provence** observatory (44°N) and **Maïdo** observatory (Reunion island, 21°S)

- Chanin, M.-L., Garnier, A., Hauchecorne A., Porteneuve J.: A Doppler lidar for measuring winds in the middle atmosphere, GRL, 1989
- Khaykin, S. M. et al.: Doppler lidar at Observatoire de Haute-Provence for wind profiling up to 75 km altitude: performance evaluation and observations, AMT, 2020.

Altitude coverage	5 – 75 km	
	$z < 30\text{km}$	$z > 50\text{ km}$
Vertical resolution	250 m	1-2 km
Accuracy	1 m/s	5 – 12 m/s
Temporal resolution	5 min	30 min

Observatoire de Haute Provence (OHP)

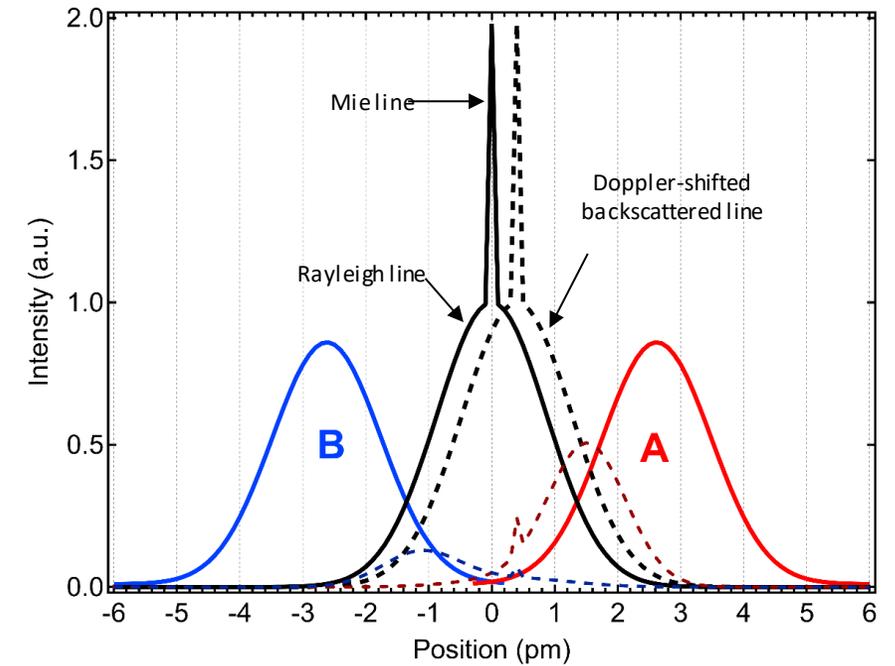


Maïdo Observatory (2158 m a.s.l.) Reunion island

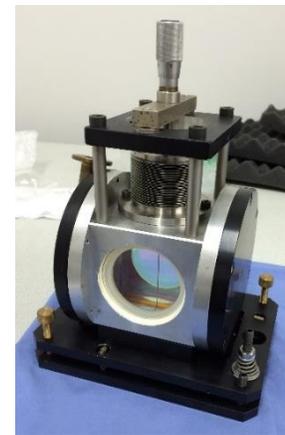
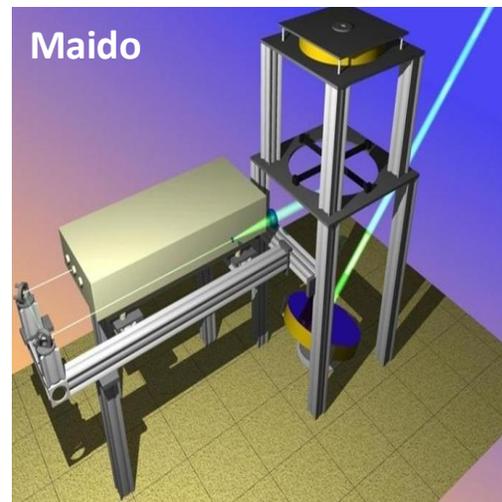
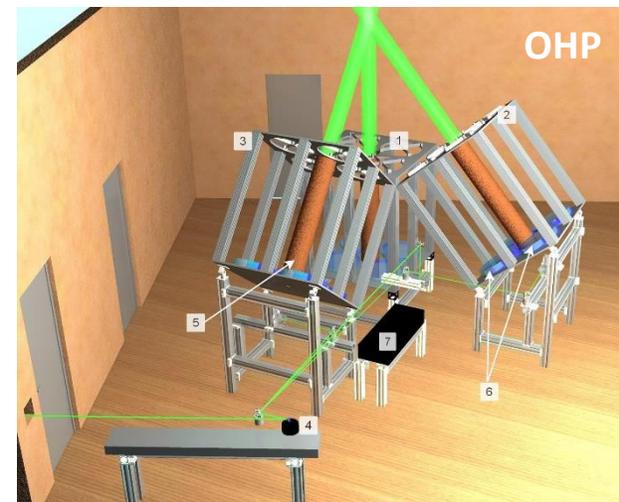


French Rayleigh Doppler wind lidars

- **Laser** : Nd-YAG injection-seeded, 532 nm, 800 mJ/pulse, 30 Hz
- **Telescope (OHP)**: 3 assemblies, 0.78 m² each (4 mirrors $\varnothing=500$ mm)
- **Telescope (Maido)**: Single rotating mirror ($\varnothing=600$ mm), 0.27 m²
- Lidar power (W·m²) comparable to Aeolus: 18.7 (OHP), 19.4 (Aeolus)
- **Doppler shift detection** : double-edge Fabry-Perot interferometer (same as Aeolus ALADIN Rayleigh channel)
- Laser beam is steered between 3 lines-of-sight
- Vertical pointing is used to obtain zero Doppler shift reference



Spectral shapes of the thermally-broadened Rayleigh backscatter line with the thin Mie line on top of it (solid black) and the FPI bandpasses A and B (solid red and blue). The Doppler-shifted backscatter line (corresponding to an imaginary wind speed of 175 m/s) is shown as black dashed curve. The signals transmitted through the A and B bandpasses for the Doppler-shifted backscattering are illustrated by the dashed red and blue curves.



Fabry-Perot interferometer
in a sealed pressure-
controlled housing

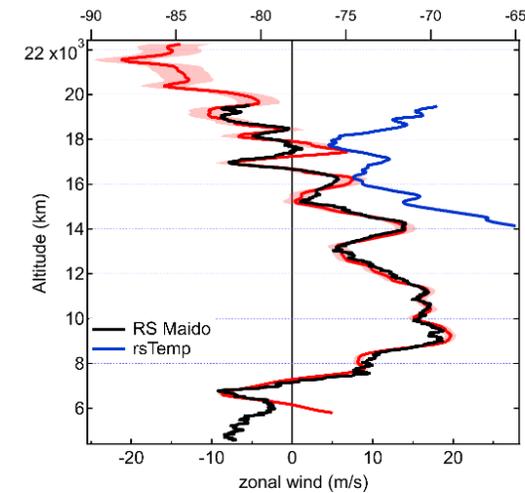
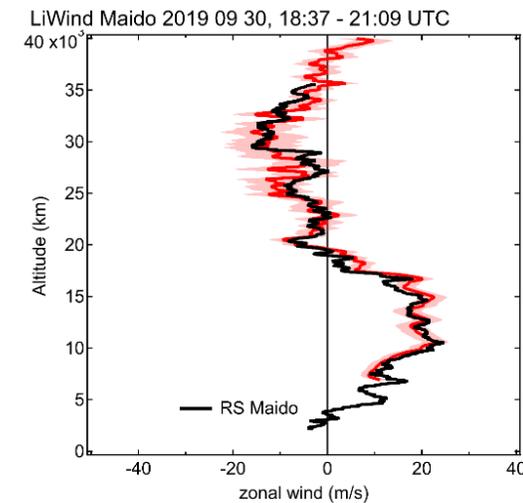
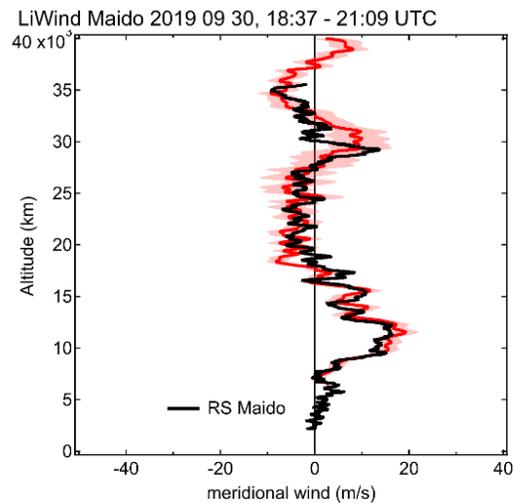
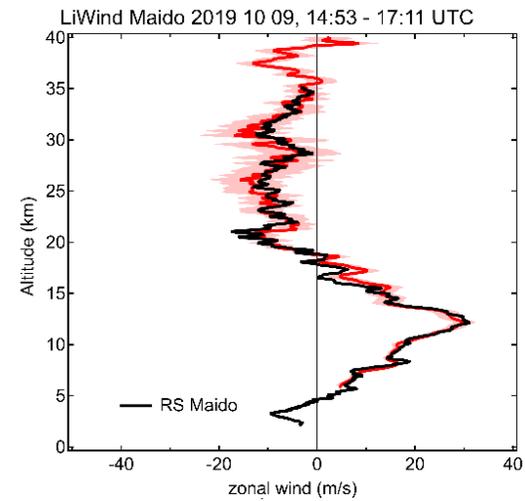
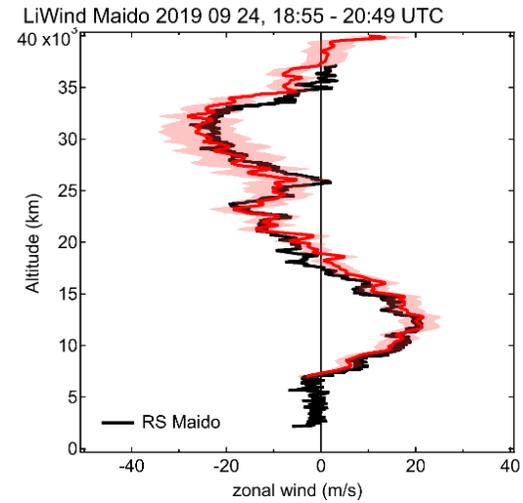
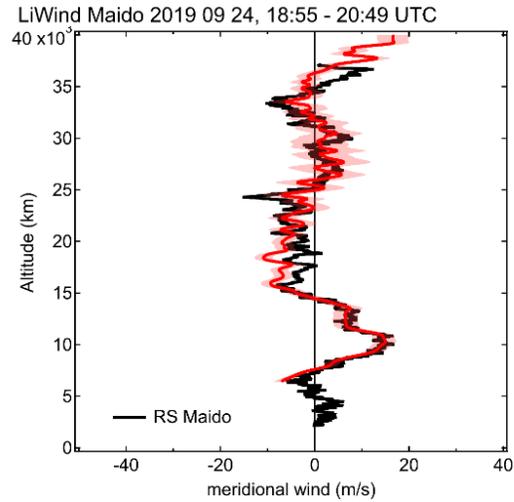
AboVE-Maido: Aeolus Validation Experiment at Maido

- 16 Sep – 11 Oct 2019, OPAR, Maido observatory
- 13 nights of lidar operation, 18 radiosoundings
- 100 h of LiWind lidar operation
- Minimum spatial offset with Aeolus: 10 km
- Ongoing time-collocated cal/val measurements once per month since November 2019



AboVE-Maido campaign: validation of LiWind lidar using radiosondes

- Based on 17 radiosonde ascents, the mean bias between RS and LiWind is less than 0.2 m/s

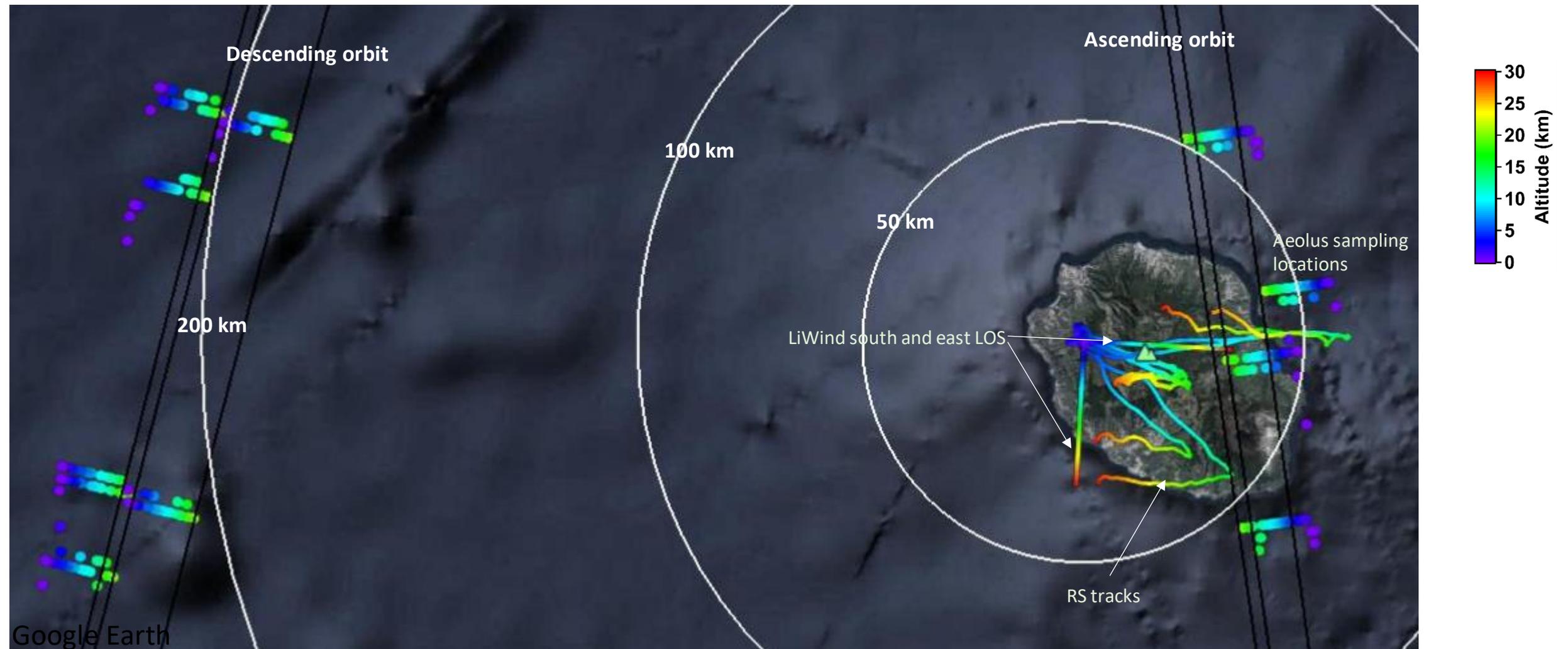


AboVE-Maido campaign: Aeolus validation using LiWind and radiosondes

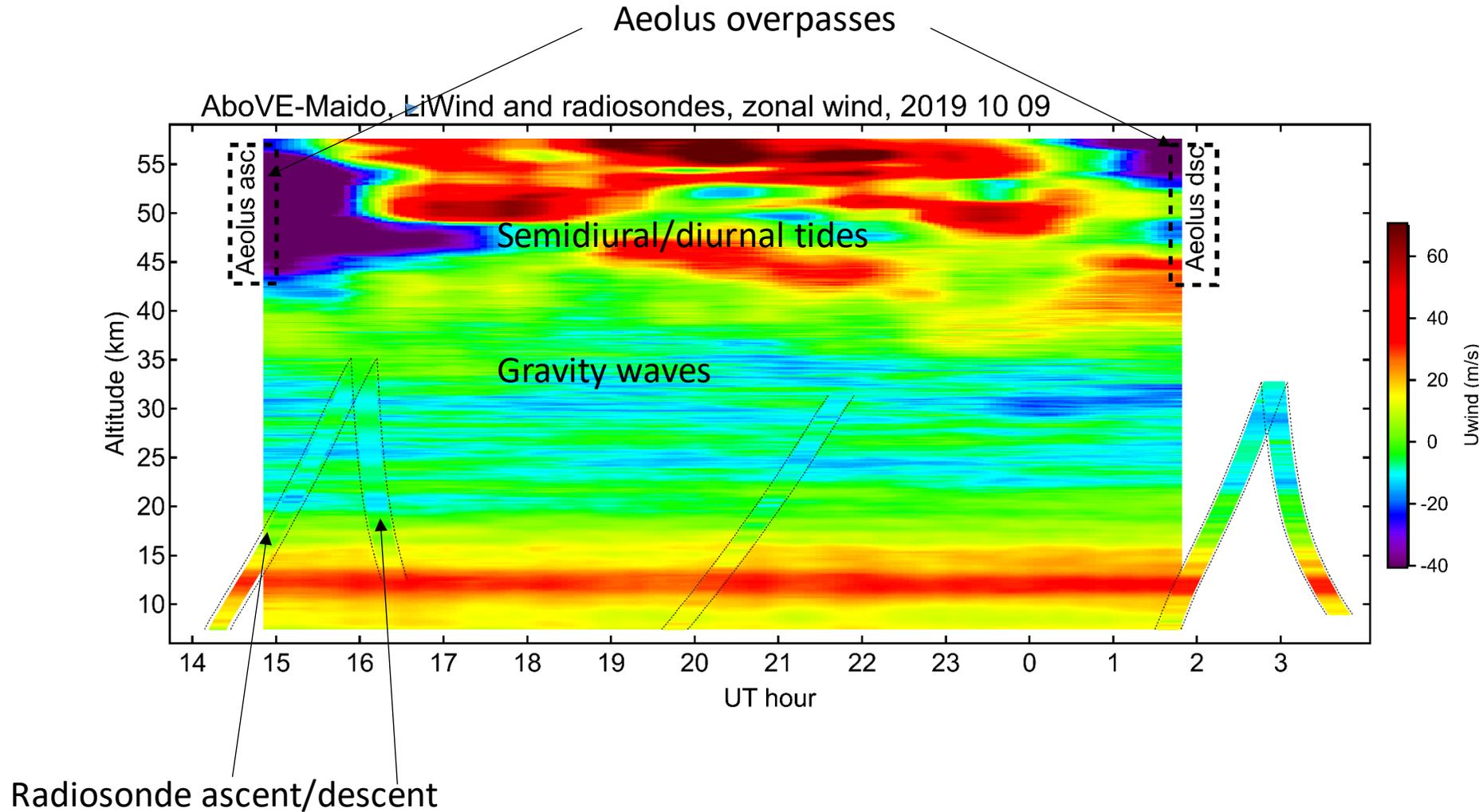
Aeolus satellite is in **sun-synchronous dusk/dawn orbit** passing close to La Reunion every week:

Wednesday at 14h40 UT (ascending orbit, 10-30 km away)

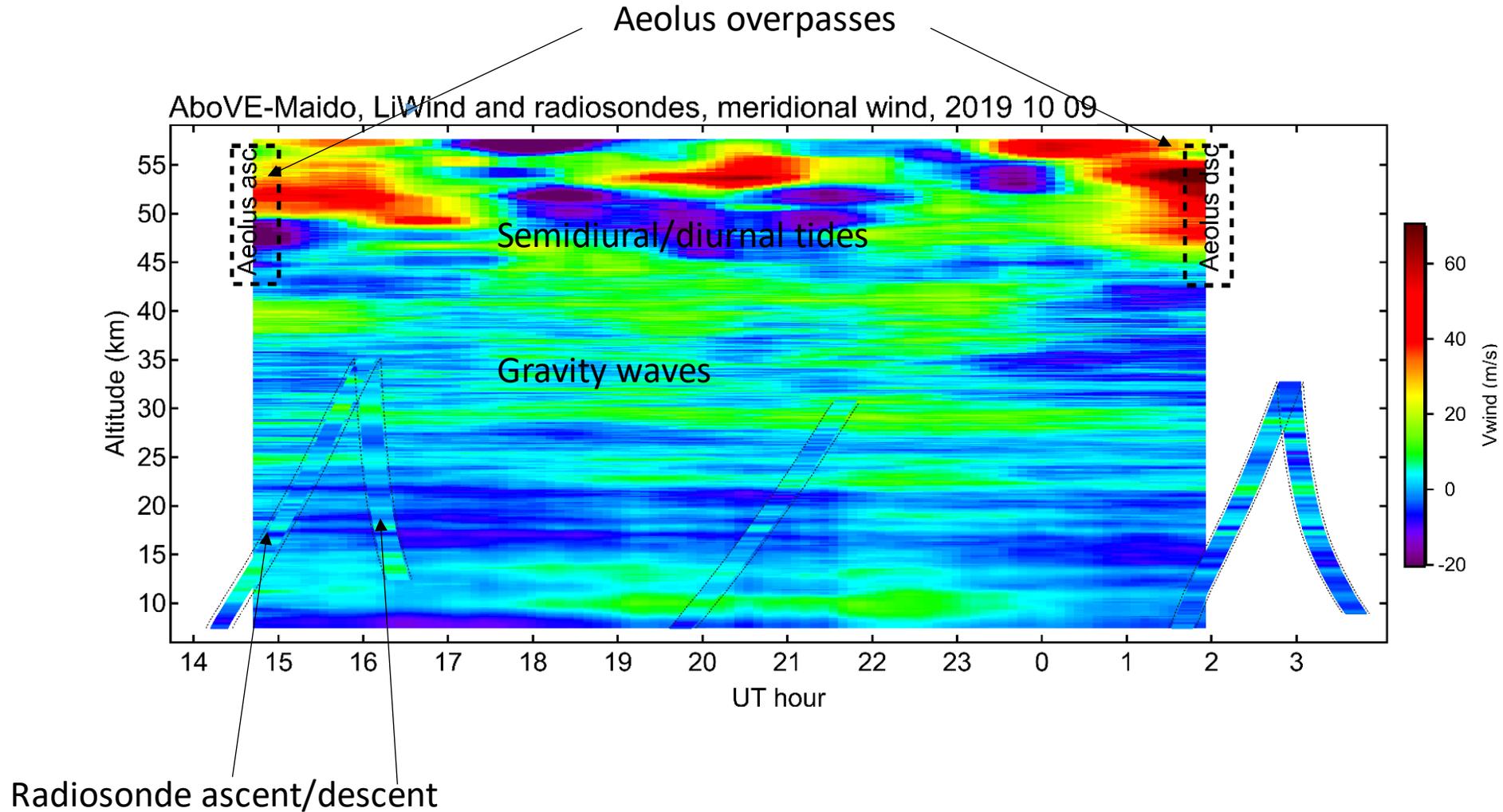
Thursday at 2h10 UT (descending orbit 200 km away)



Example of Cal/Val measurements with 3 radiosoundings and continuous LiWind operation from dusk till dawn: **zonal wind**



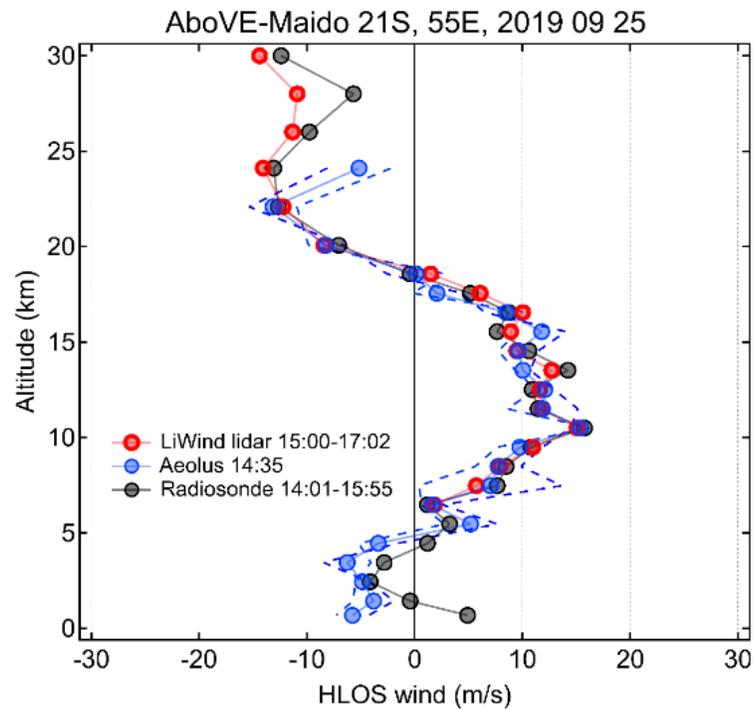
Example of Cal/Val measurements with 3 radiosoundings and continuous LiWind operation from dusk till dawn: **meridional wind**



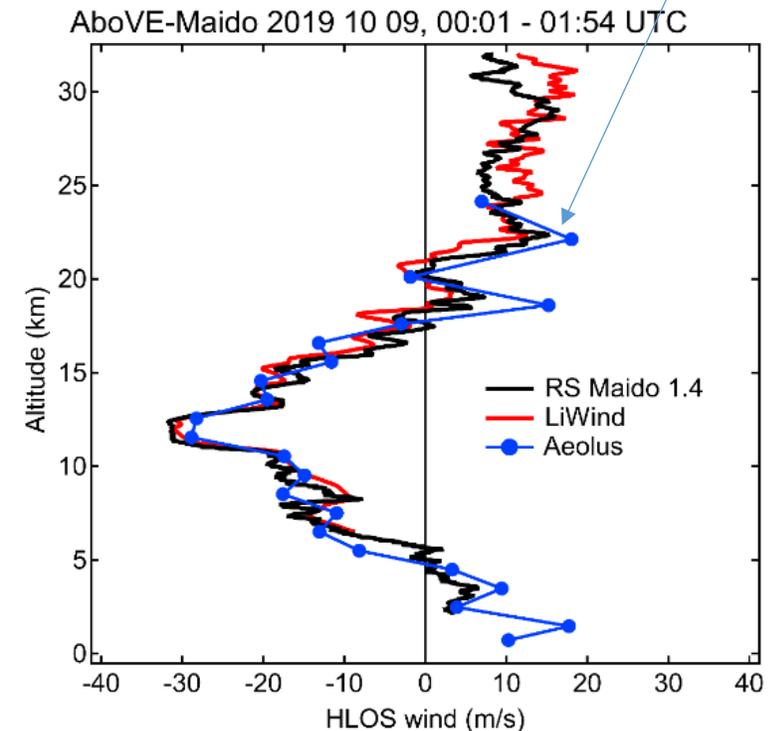
AboVE-Maido campaign: validation of Aeolus L2B Rayleigh-clear using LiWind and radiosondes

- During AboVE-Maido, 3 asc + 3 dsc Aeolus-collocated measurements have been done
- Perfect timing for the balloon launches and LiWind operation on Cal/Val nights
- Preliminary results of Cal/Val are very encouraging, Aeolus appears capable of reproducing vertical structures in the wind profile with scales comparable to its vertical resolution

Case#1 (asc): All data downsampled to Aeolus vertical resolution. Mean bias <1 m/s
Excellent agreement except for the uppermost bin
Figure selected for ESA quarterly report



Case#6 (dsc): Mean bias of + 1.5 m/s
Aeolus resolves gravity waves in the stratosphere

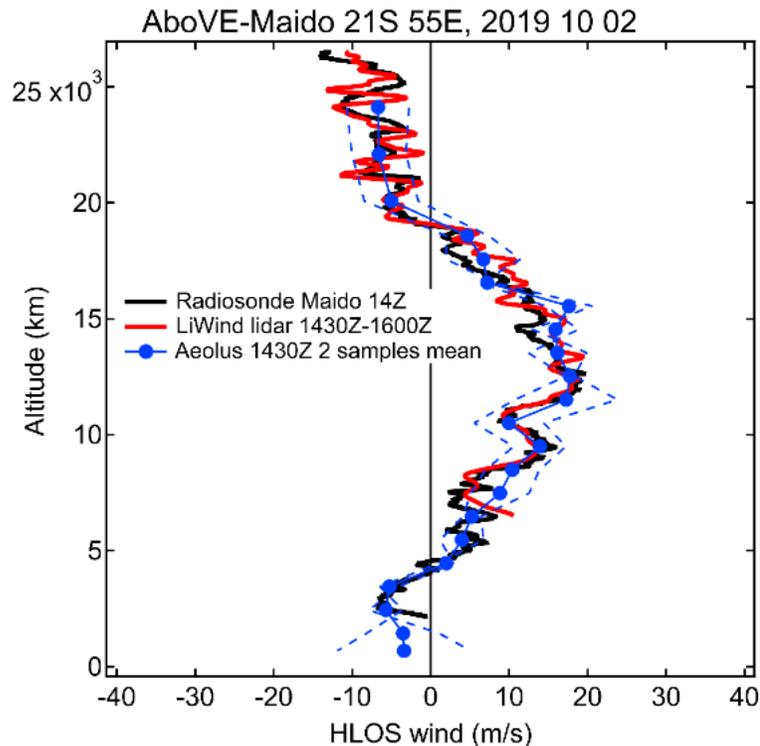


AboVE-Maido campaign: Aeolus validation using LiWind and radiosondes

- During AboVE-Maido, 3 asc + 3 dsc Aeolus-collocated measurements have been done
- Perfect timing for the balloon launches and LiWind operation on Cal/Val nights
- Preliminary results of Cal/Val are very encouraging, Aeolus appears capable of reproducing vertical structures in the wind profile with scales comparable to its vertical resolution

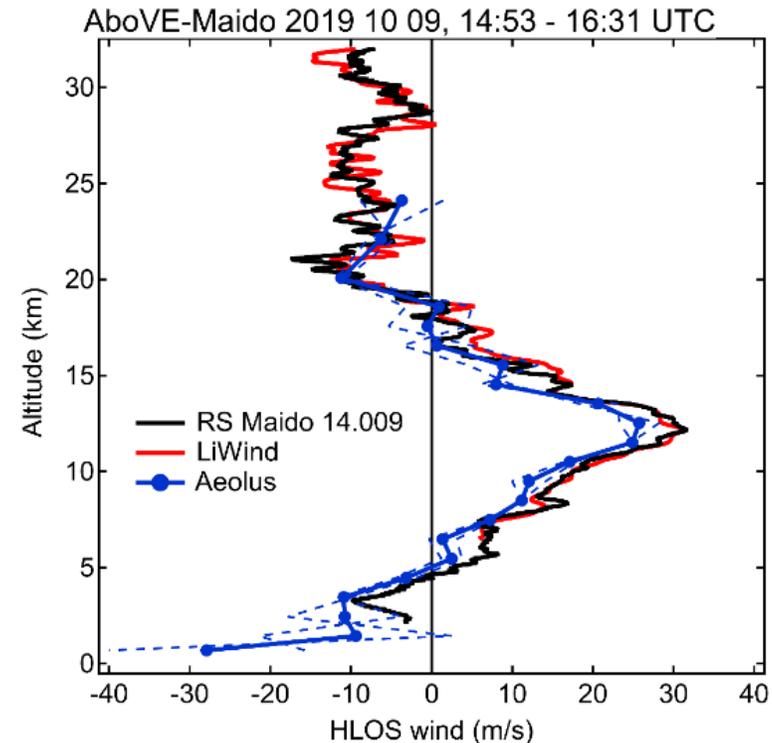
Case#3 (asc): Excellent agreement, mean bias < 1 m/s

Figure produced 1.5 hours after the satellite overpass (Cal/Val in near real time)



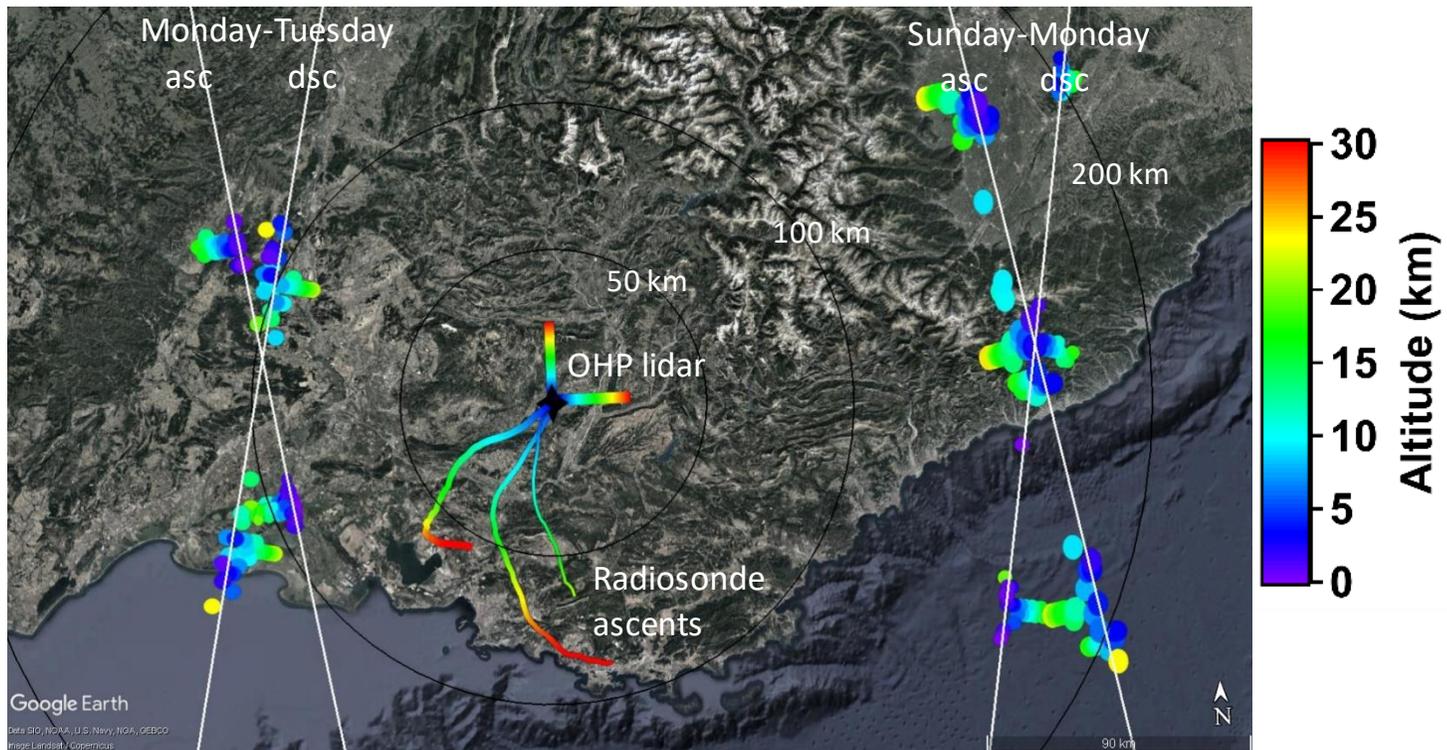
Case#5 (asc): Mean bias of -3.6 m/s

The bias in Aeolus wind product varies with time

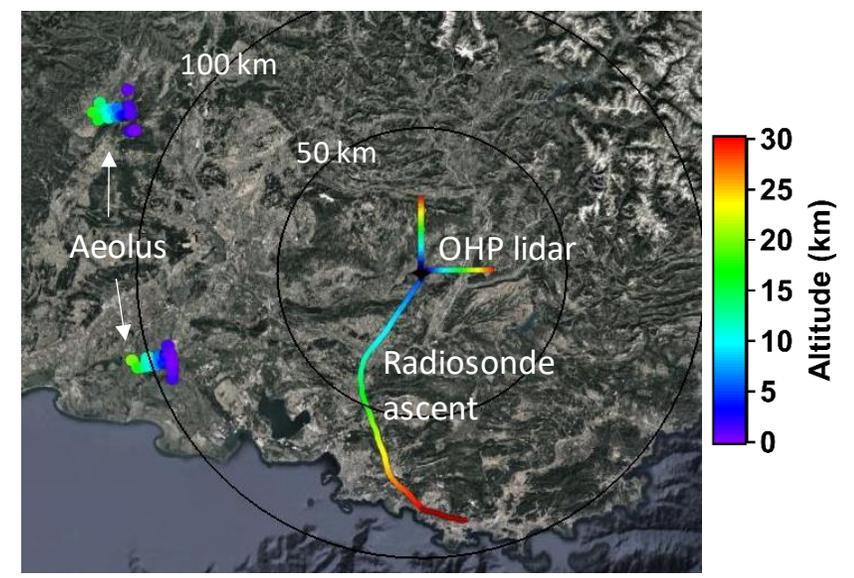
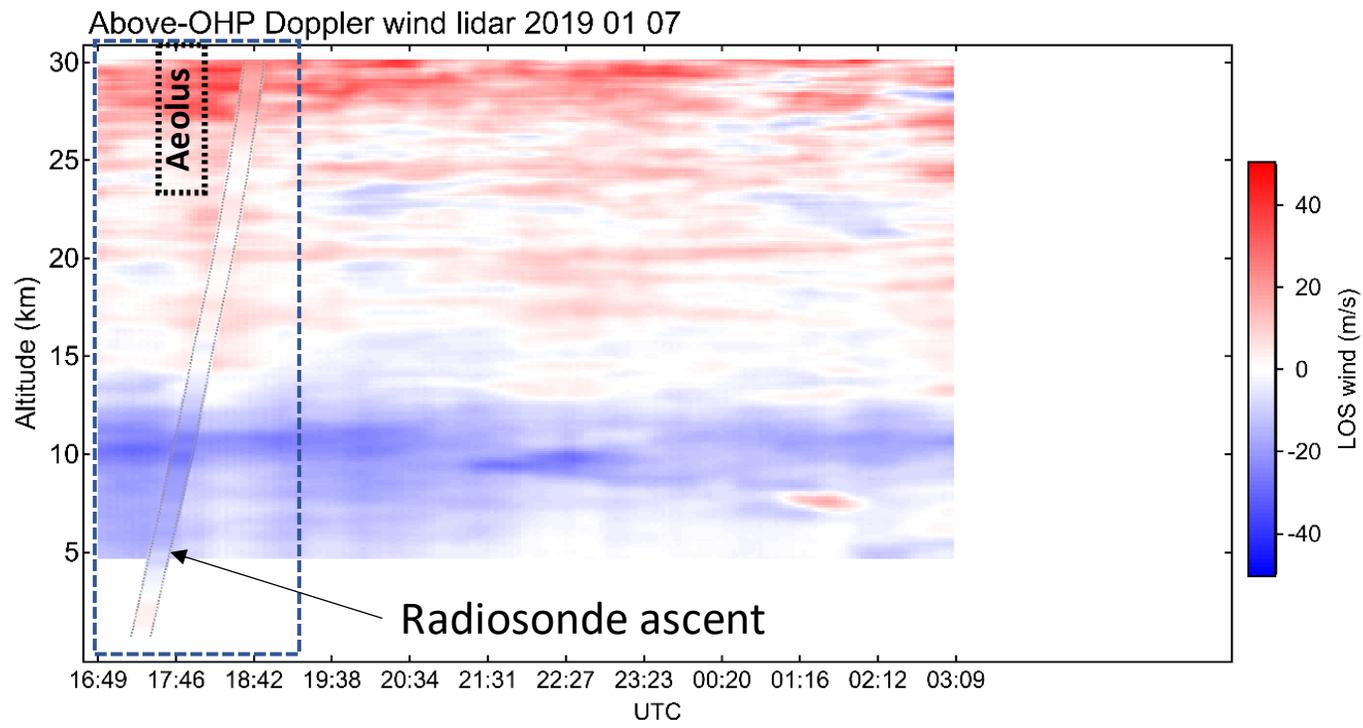


AboVE-OHP: Aeolus Validation Experiment at OHP

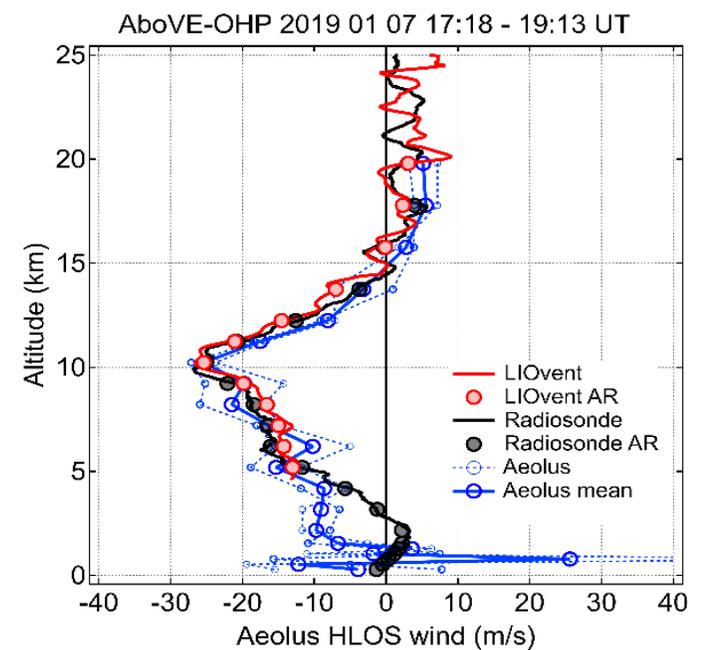
- 5 Jan – 5 Feb 2019, Observatoire de Haute Provence
- 21 nights of lidar operation, 3 radiosoundings
- 109 h of Wind lidar operation
- Aeolus in standby 13 Jan-21 Feb: missed 14 collocations
- 5 DWL - Aeolus collocations, 3 RS – Aeolus collocations
- Minimum spatial offset: 62 – 165 km



Collocation #3, evening 07 Jan: best case



Aeolus - OHPlidar		
Mean dif. / st. dev (m/s)	R correl.	Min. hor. distance (km)
+1.7 / 3.7	0.93	108



Summary and outlook

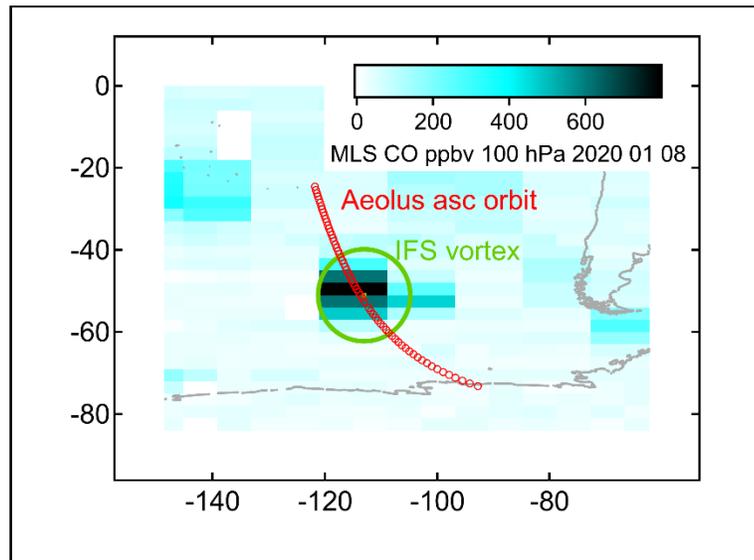
- Validation of Aeolus using its ground-based Rayleigh DWL predecessor at two French supersites
- Dedicated **AboVE** cal/val campaigns in **Haute-Provence** (Jan-Feb 2019) and **La Reunion** (Sep-Oct 2019)
- Validation of L2B Rayleigh-clear winds using ground-based lidar and radiosonde measurements precisely collocated in time with Aeolus overpasses
- Based on 17 collocated measurements at both sites, the mean bias varied between -3.6 m/s and 2.9 m/s with standard deviation between 3.1 m/s – 8.5 m/s. The bias is generally higher in the uppermost range bin. Correlation better than 0.8 for 96% of overpasses within 120 km / 3 hours
- The bias varies over time and appears consistent with the evolution of Aeolus biases with respect to ECMWF operational analysis (not shown)
- Aeolus wind profiling is capable of resolving gravity waves in the lower stratosphere: new global information on the kinetic energy of GW
- Validation activities are continued at both French supersites with 1 collocated measurements per month provided normal operation conditions

Remote sensing of wind using molecular scattering is challenging!

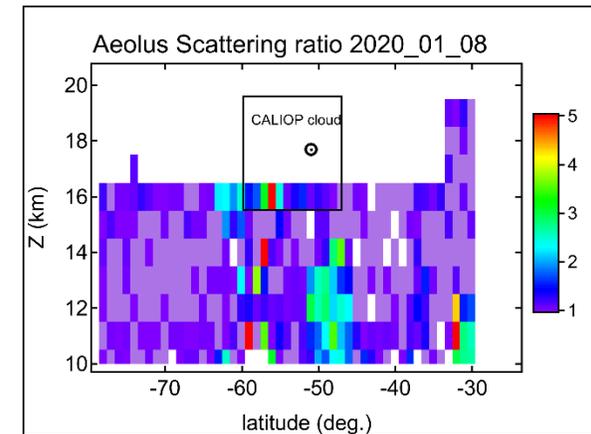
Aeolus captures a smoke-generated vortex in the stratosphere

- Extreme wildfires in Australia around New Year's eve 2020 generate pyroconvection injecting huge amount of combustion products into the stratosphere
- Solar heating of carbonaceous aerosol in an intense patch of smoke leads to formation of a confined anticyclone persisting for 3 months in the stratosphere
- Aeolus is the only one instrument on Earth to provide a cross-section of wind speed inside a new born-vortex above Southern Pacific

Aeolus sampling across a blob of CO-rich smoke seen by IFS as an isolated region of high vorticity



Aeolus sees the smoke in the stratosphere



Vortex centroid (IFS)

Aeolus captures the wind anomaly associated with the vortex

