Influence of Aeolus data assimilation on the representation of gravity waves in ECMWF analysis fields

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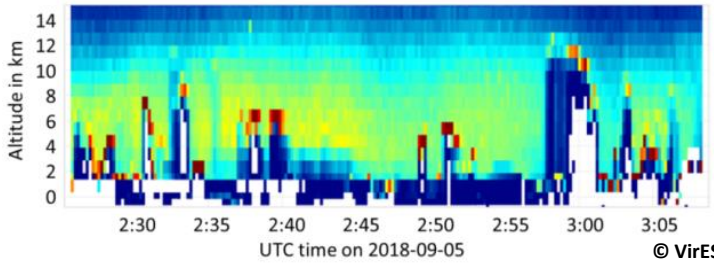
Outline

1. What is Aeolus and how does it measure wind?
2. Can we see gravity waves in Aeolus observations?
3. How does the assimilation of Aeolus winds impact gravity waves in ECMWF?

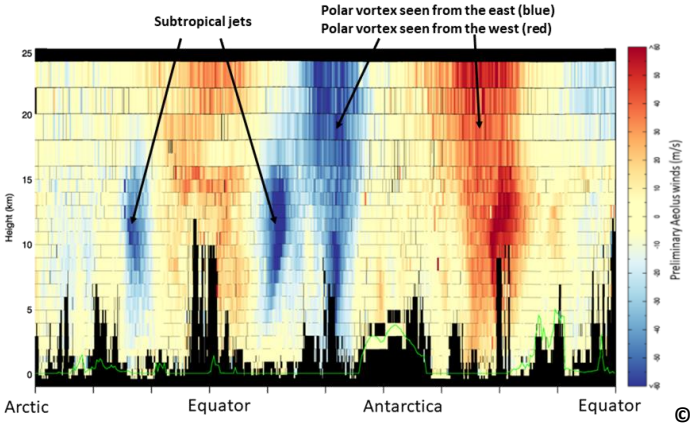
Aeolus Wind Observations

First Rayleigh backscatter signals from 5 Sep 2018



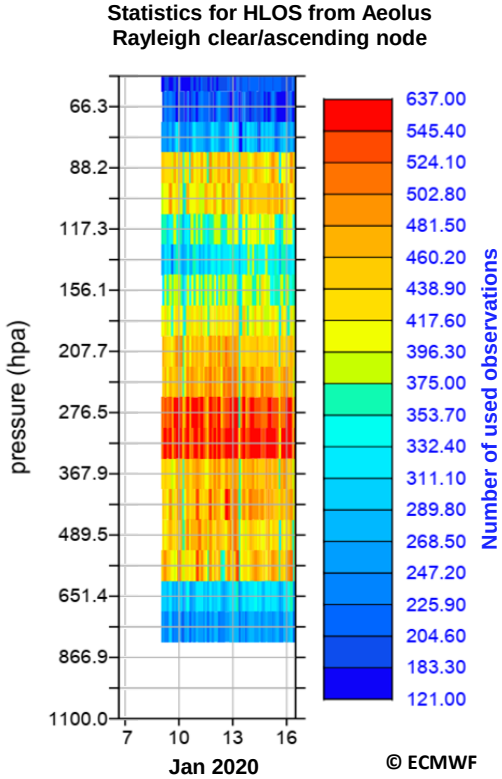
© VirES for Aeolus

First wind data published on ESA website on 12 Sep 2018



© VirES for Aeolus

Aeolus measurements are actively assimilated in ECMWF since 9 Jan 2020



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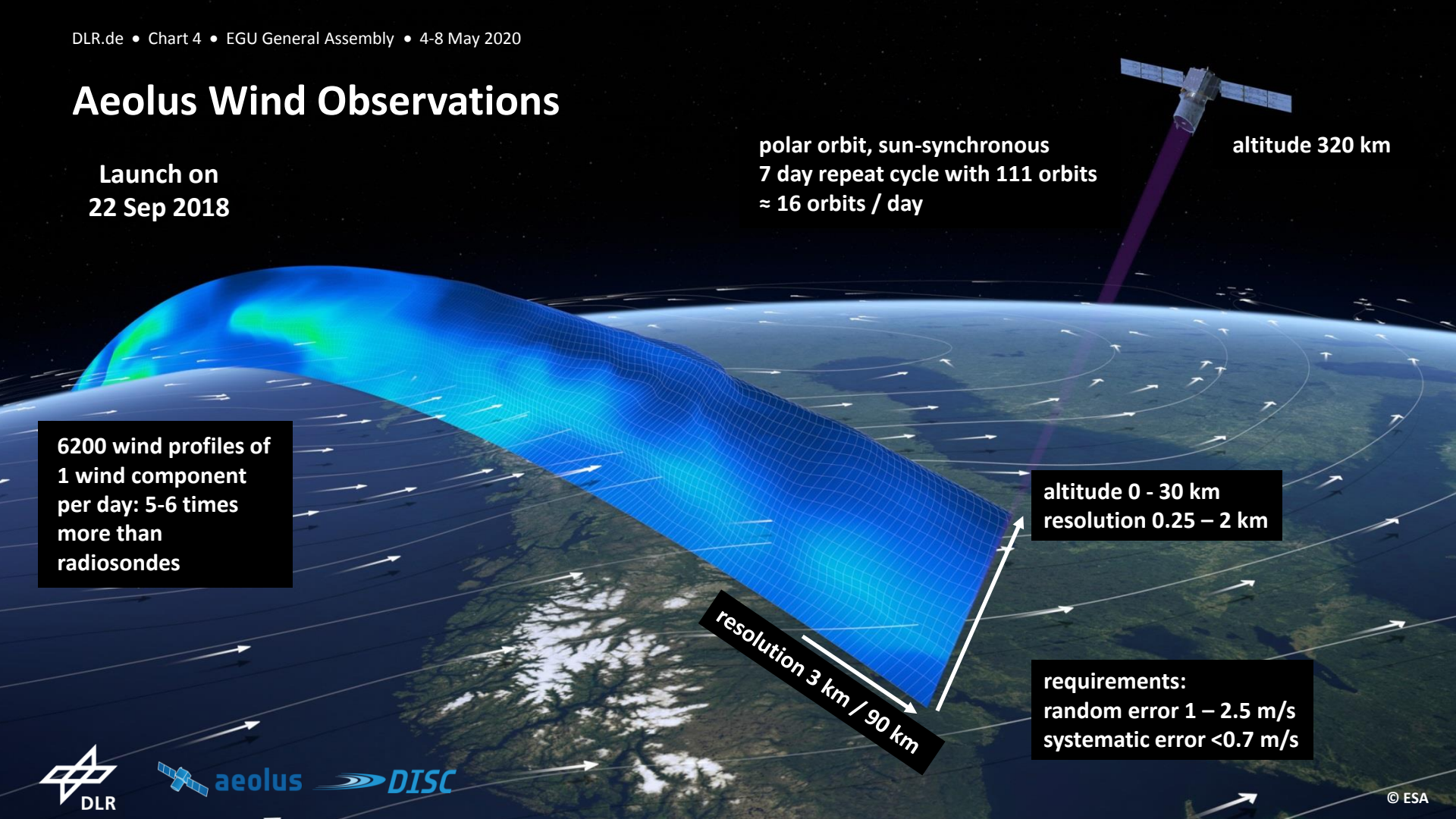
Aeolus Wind Observations

Launch on
22 Sep 2018

polar orbit, sun-synchronous
7 day repeat cycle with 111 orbits
≈ 16 orbits / day

altitude 320 km



6200 wind profiles of 1 wind component per day: 5-6 times more than radiosondes

altitude 0 - 30 km
resolution 0.25 – 2 km

resolution 3 km / 90 km

requirements:
random error 1 – 2.5 m/s
systematic error <0.7 m/s

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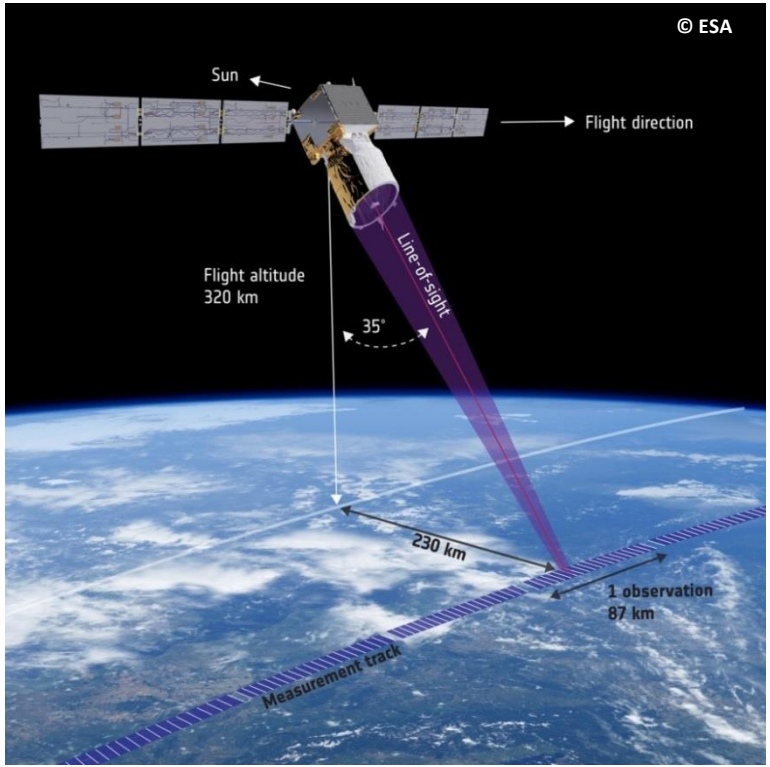
Aeolus Measurement Principle



- **ALADIN: A**tmospheric **LA**ser **D**oppler **In**strument
- Measurements of winds => use **Doppler effect**

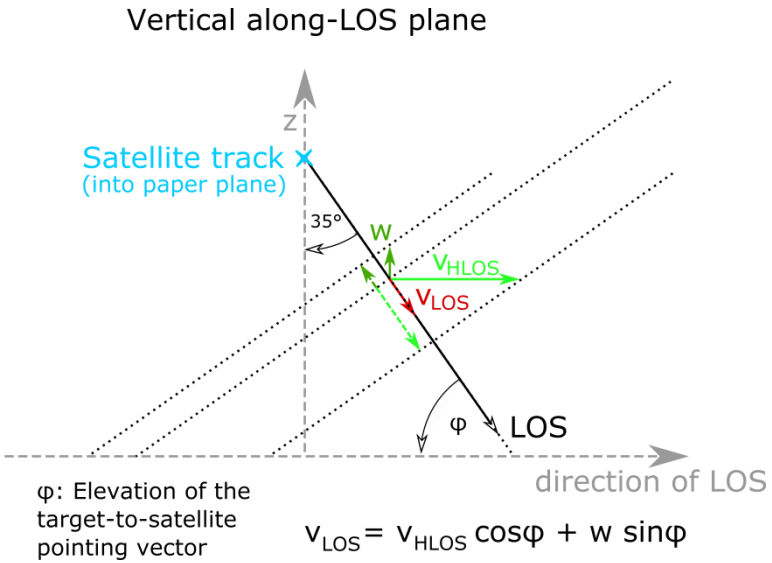
Doppler-Equation: $\Delta f = 2 f_0 \frac{v_{LOS}}{c}$

relative Doppler shift $\Delta f/f_0 \approx 10^{-8}$ for 1 m/s

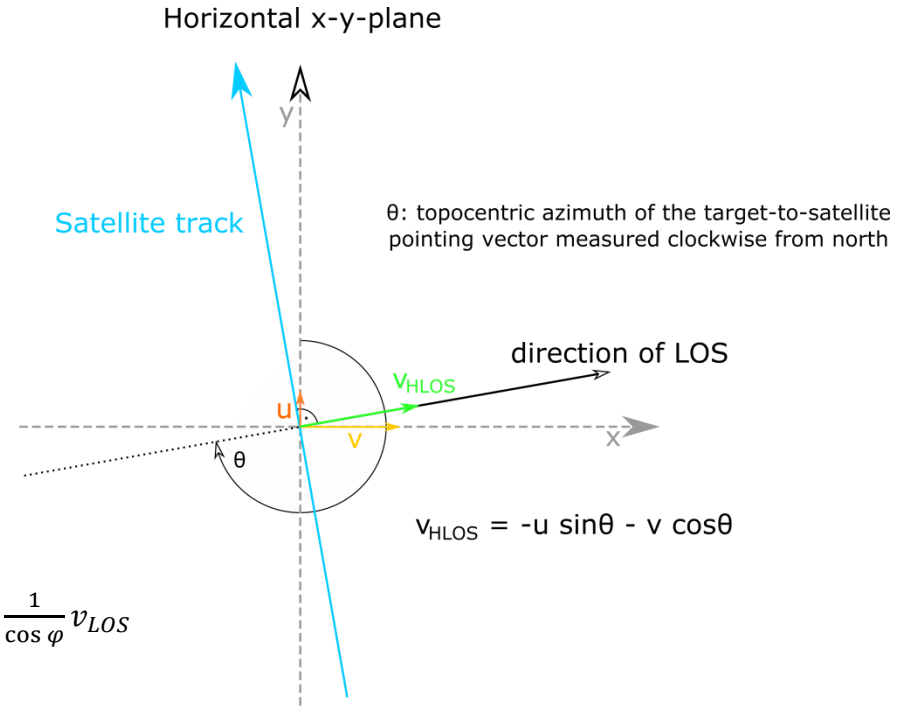
1 m/s (LOS) ⇔ 5.64 MHz ⇔ 2.37 fm
size H-atom 50 pm, H-nucleus 1.2 fm

- For clear-air conditions: molecular Rayleigh backscatter
- ultraviolet (UV) **wavelength at 355 nm** ($\beta_{mol} \approx \lambda^{-4}$)
- 2nd spectrometer for Mie backscatter in aerosol & clouds

Aeolus Measurement Geometry



For comparison with (u, v)-measurements (e.g. models)



Conversion in L2B processor (assuming zero vertical wind): $v_{HLOS} = \frac{1}{\cos\varphi} v_{LOS}$

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2. **Can we see gravity waves in Aeolus observations?**
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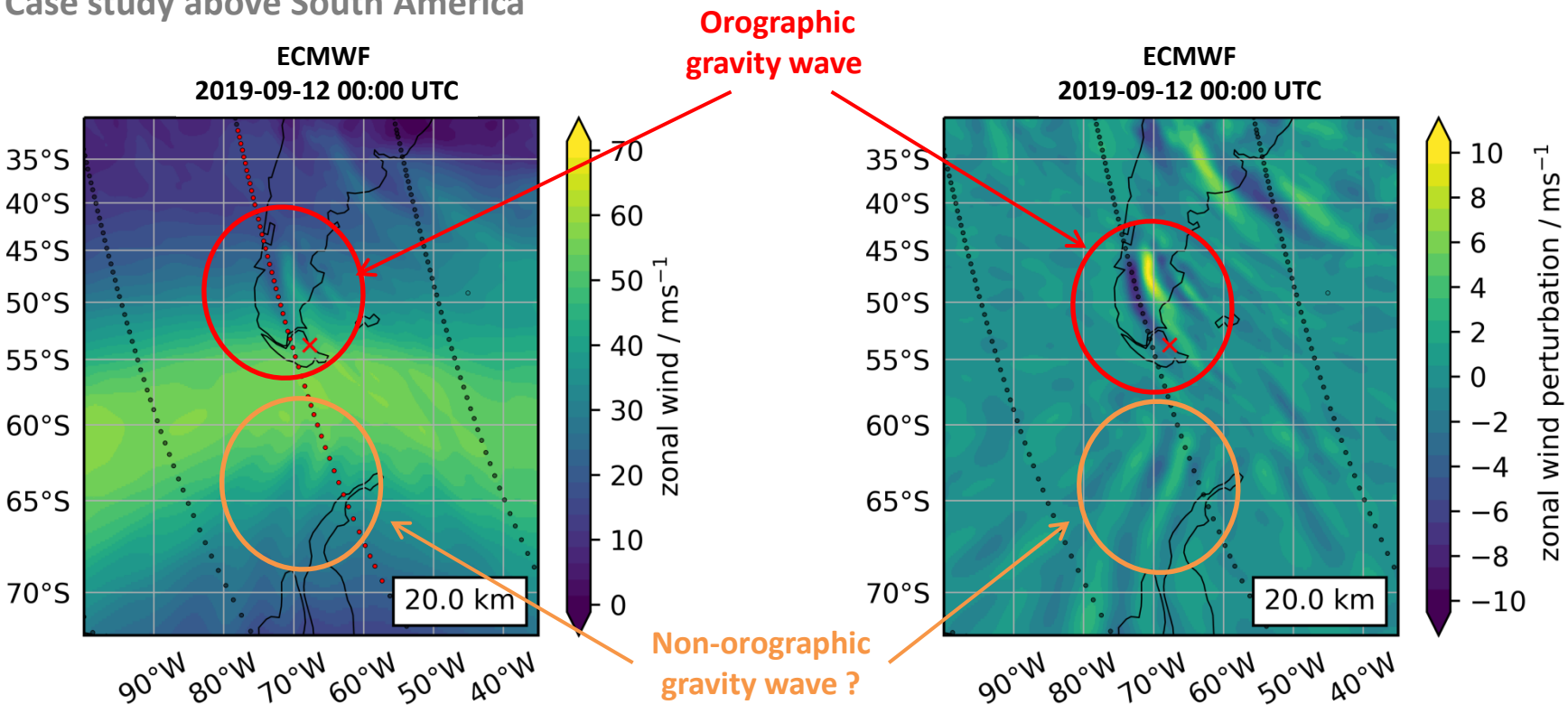
Can we see gravity waves in Aeolus observations?

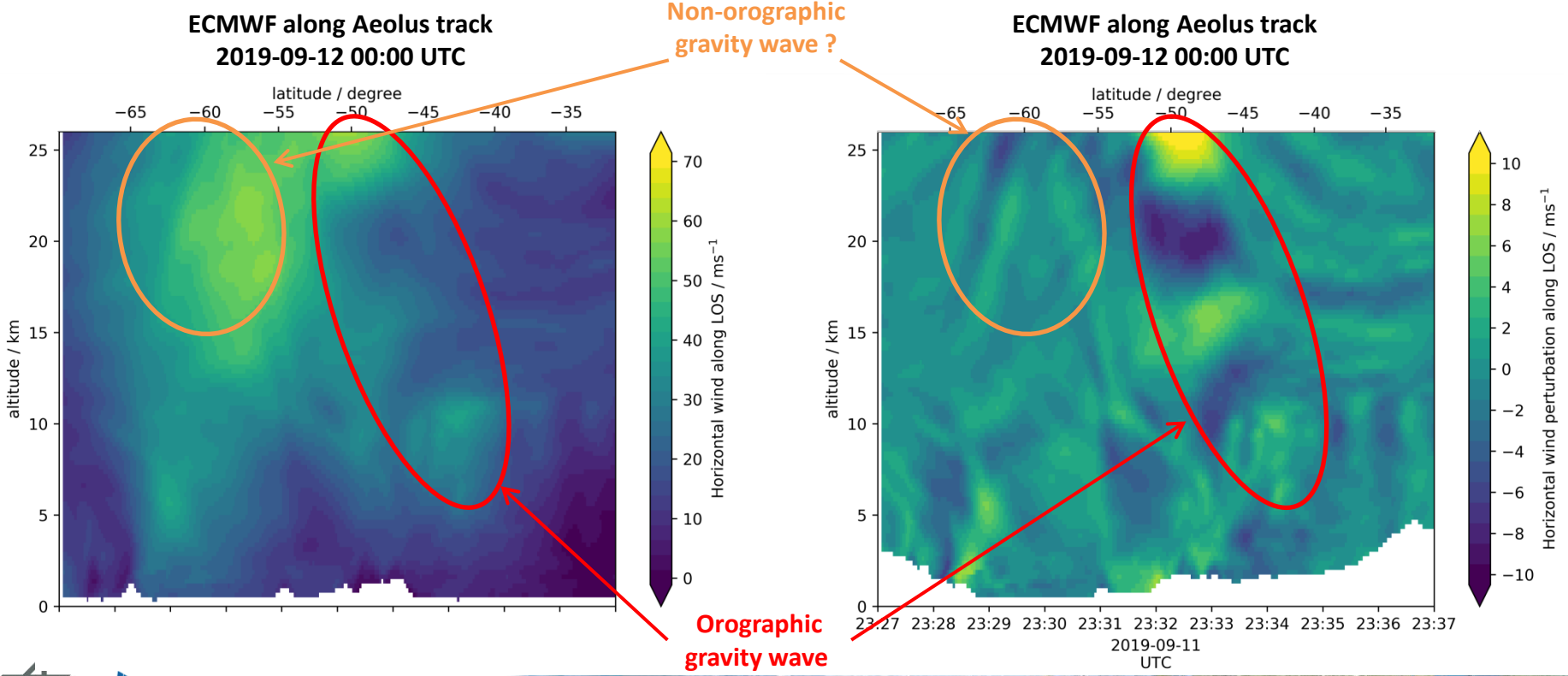
Case study above South America



x Rio Grande (base of airborne & ground-based GW campaign *SOUTHTRAC*)

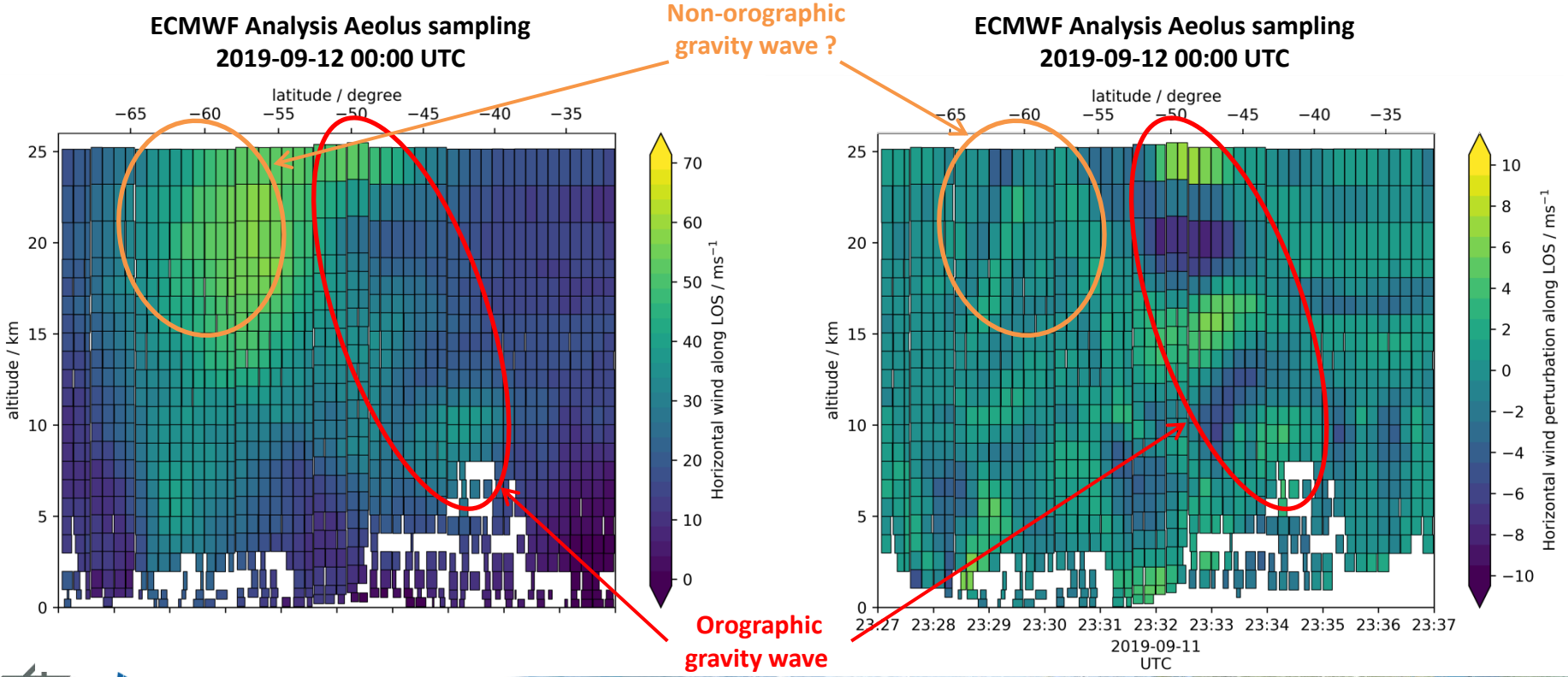
Can we see gravity waves in Aeolus observations?

Case study above South America



Can we see gravity waves in Aeolus observations?

Case study above South America



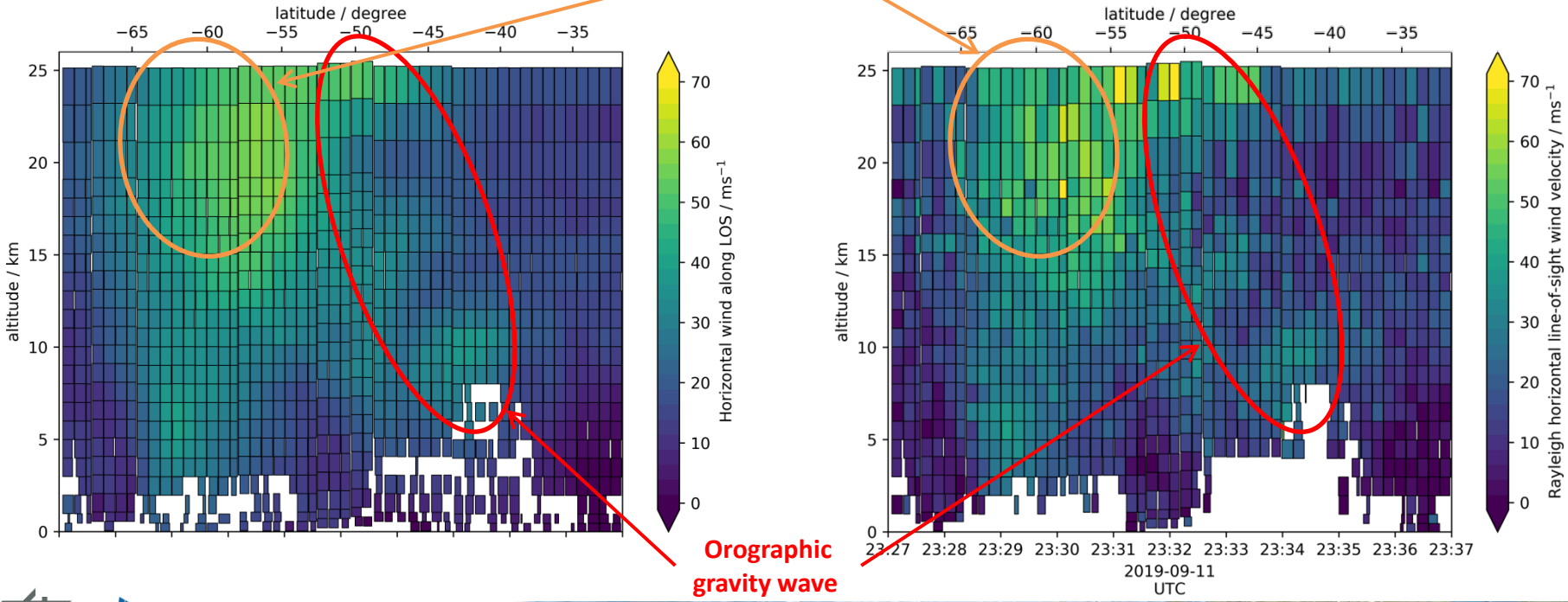
Can we see gravity waves in Aeolus observations?

Case study above South America

* The used Aeolus data is preliminary (not fully calibrated/validated and not yet publicly released). Further data quality improvements, including in particular a significant product bias reduction, will be achieved before the public data release.

ECMWF Aeolus sampling
2019-09-12 00:00 UTC

Aeolus HLOS measurements*



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Can we see gravity waves in Aeolus observations?

Case study above South America

* The used Aeolus data is preliminary (not fully calibrated/validated and not yet publicly released). Further data quality improvements, including in particular a significant product bias reduction, will be achieved before the public data release.

Summary:

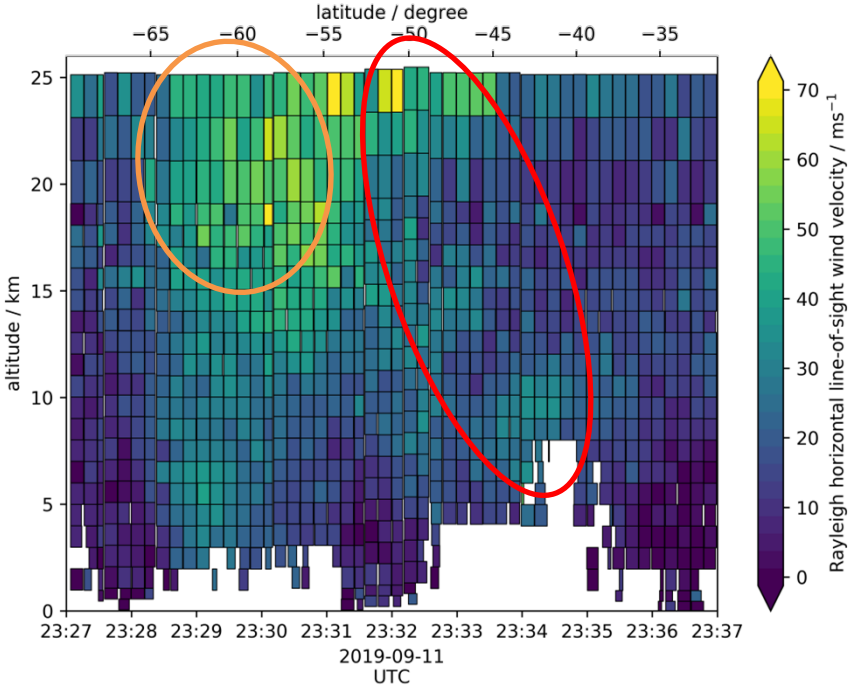
- The **orographic wave structure** above South America is **clearly visible in Aeolus HLOS measurements**.
- The **non-orographic wave structure** above the Arctic Ocean **should** also **be detectable** with Aeolus. However, a **separation of background wind and wave structure** would be **required** to properly see this wave in the Aeolus measurements.

➢ **Yes, we can see gravity waves in Aeolus observations! ☺**

Outlook:

- Develop method to separate background wind and wave structure in Aeolus measurements
- Determine wave parameters

Aeolus HLOS measurements*



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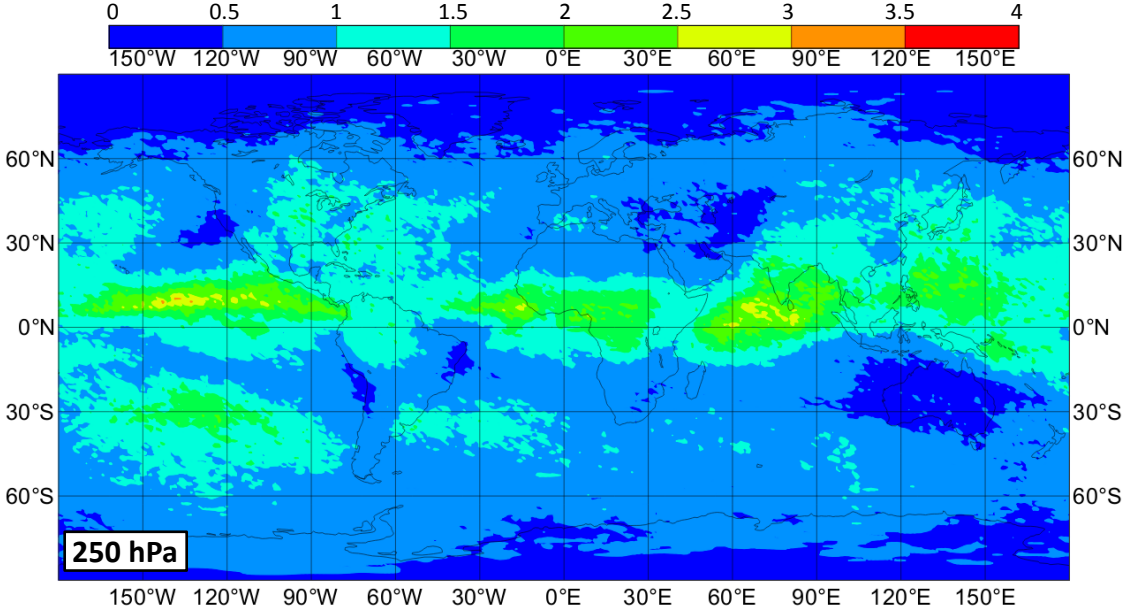
How does the assimilation of Aeolus winds impact GWs in ECMWF?

Global wind patterns change due to Aeolus assimilation

Standard deviation of the **differences of u-wind component** (m/s) at **250 hPa** between the analysis using Aeolus and the control not using Aeolus HLOS winds



See also **EGU2020-5340**: *An Assessment of the Impact of Aeolus Doppler Wind Lidar Observations for Use in Numerical Weather Prediction at ECMWF* by **M. Rennie and L. Isaksen**

Assimilation experiment for the period of 2 Aug. – 26 Oct. 2019

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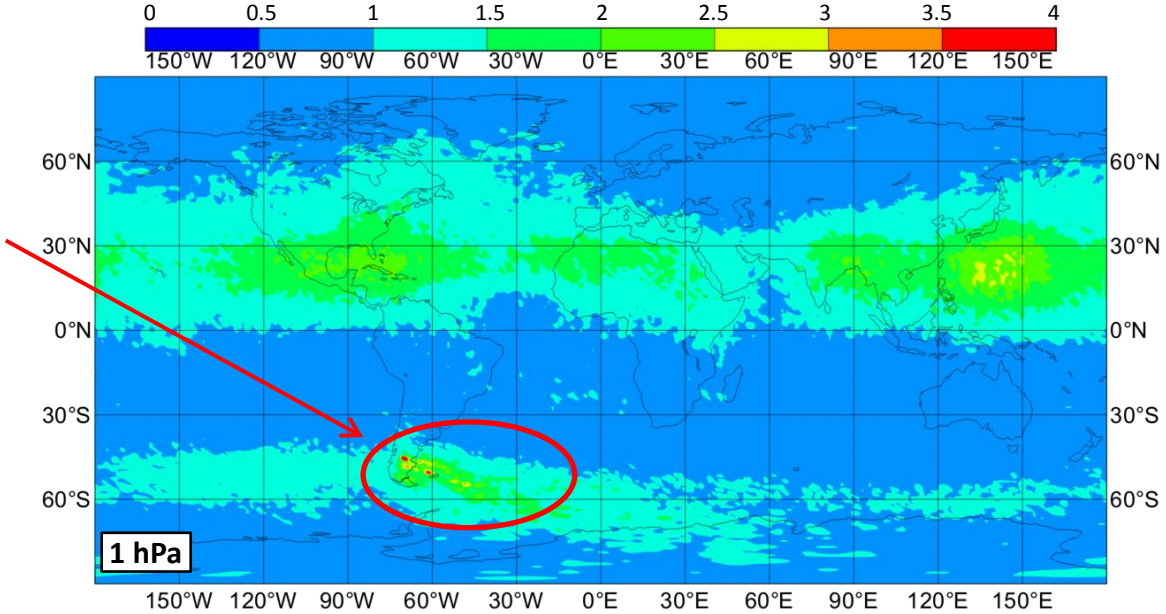
How does the assimilation of Aeolus winds impact GWs in ECMWF?

Global wind patterns change due to Aeolus assimilation

Standard deviation of the **differences of u-wind component** (m/s) at **1 hPa** between the analysis using Aeolus and the control not using Aeolus HLOS winds



Caused by gravity waves?

Assimilation experiment for the period of 2 Aug. – 26 Oct. 2019

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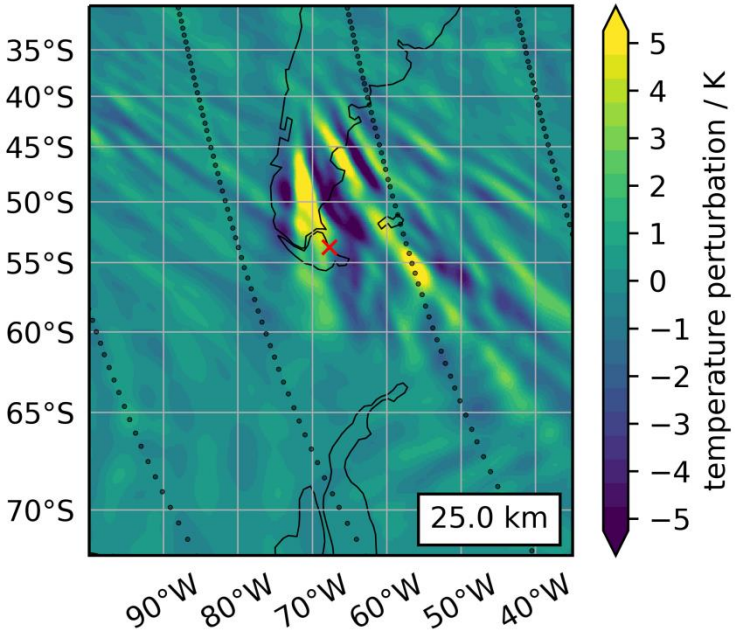
*LIDAR data provided by B. Kaifler, DLR.

How does the assimilation of Aeolus winds impact GWs in ECMWF?

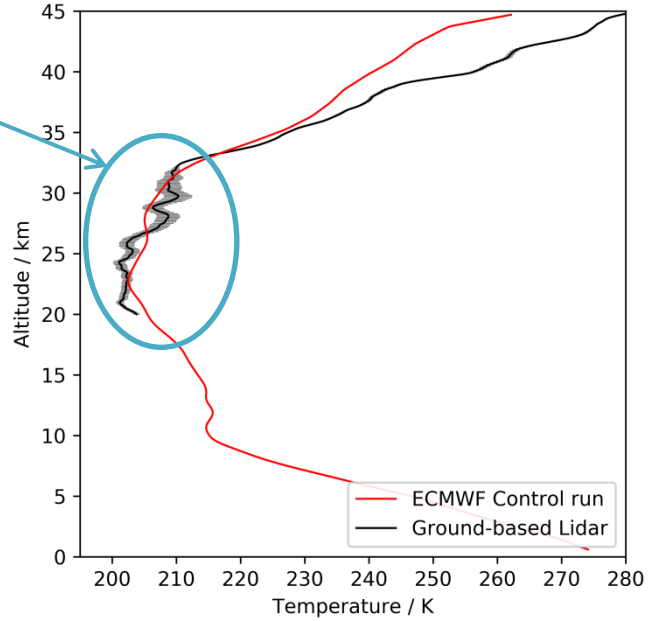
Case study on 04 August 2019, 00:00 UTC, above Rio Grande, Tierra del Fuego

ECMWF control run*



Comparison of ECMWF control run with ground-based LIDAR* in Rio Grande (x in left plot)

Gravity wave perturbation much stronger in LIDAR measurements!



* ECMWF control run is a set-up similar to ECMWF operational analysis however with lower horizontal resolution (TCo399 ≈29km grid spacing) without assimilation of Aeolus data

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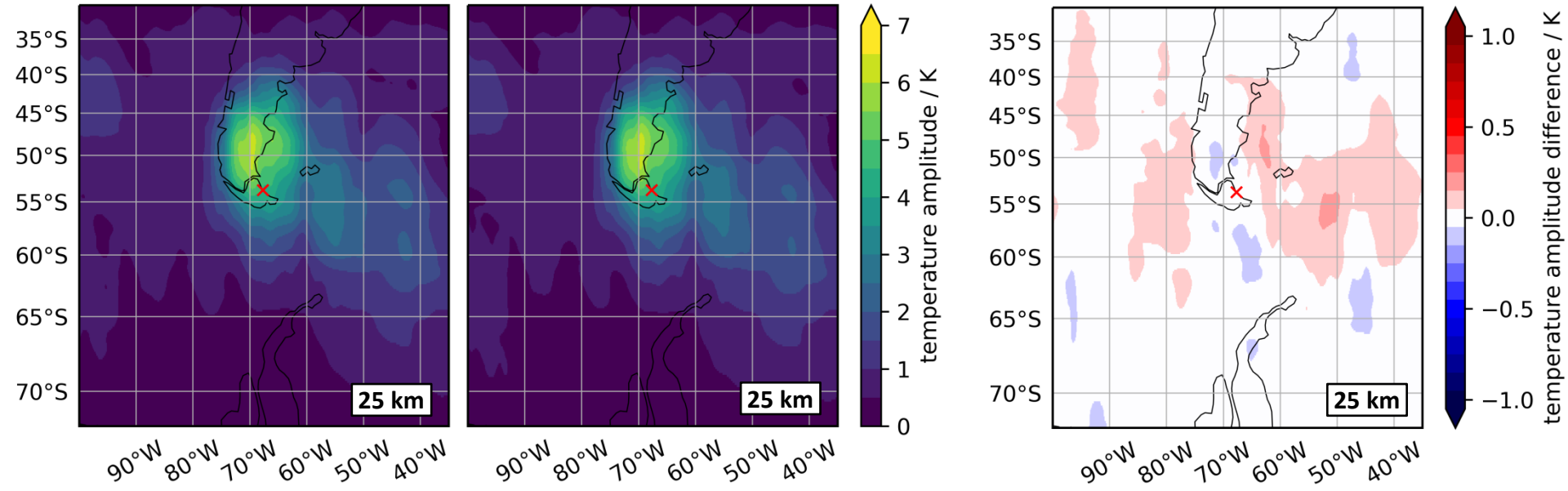
How does the assimilation of Aeolus winds impact GWs in ECMWF?

Case study on 04 August 2019, 00:00 UTC, above Rio Grande, Tierra del Fuego

ECMWF control run | **ECMWF Aeolus assimilation** | **Control run - Aeolus assimilation**

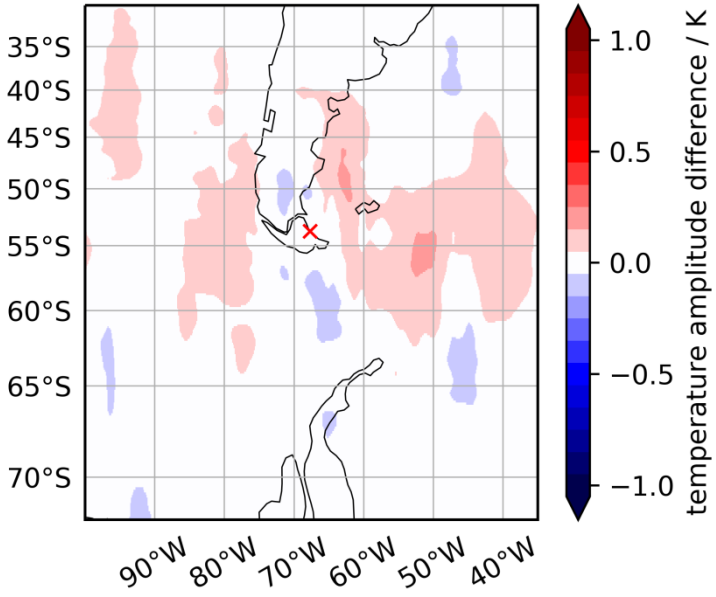


LIDAR data provided by B. Kaifler, DLR.

How does the assimilation of Aeolus winds impact GWs in ECMWF?

Case study on 04 August 2019, 00:00 UTC, above Rio Grande, Tierra del Fuego

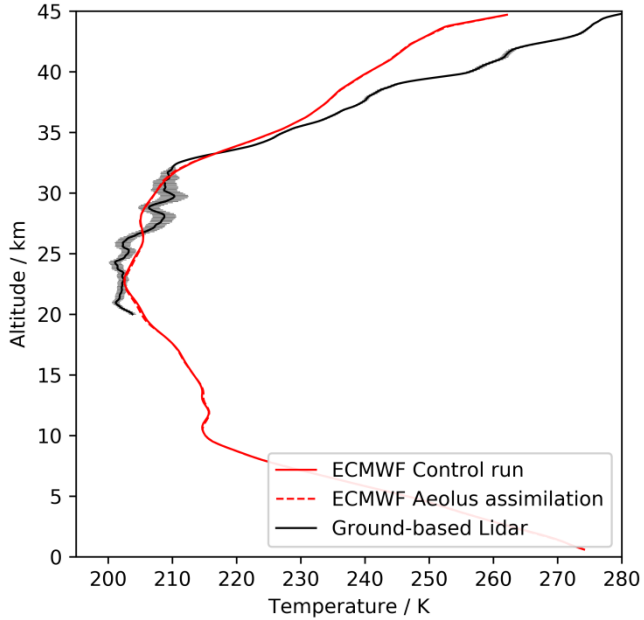
Control run - Aeolus assimilation



Assimilation of Aeolus data barely changes the strength of this gravity wave. ☹

Due to instrument problems only measurements up to 13 Aug. 2019 and after 02 Oct. 2019 are available. All available comparisons in August show a similar picture. Later Lidar measurements still need to be analyzed.

Comparison of ECMWF with ground-based LIDAR in Rio Grande

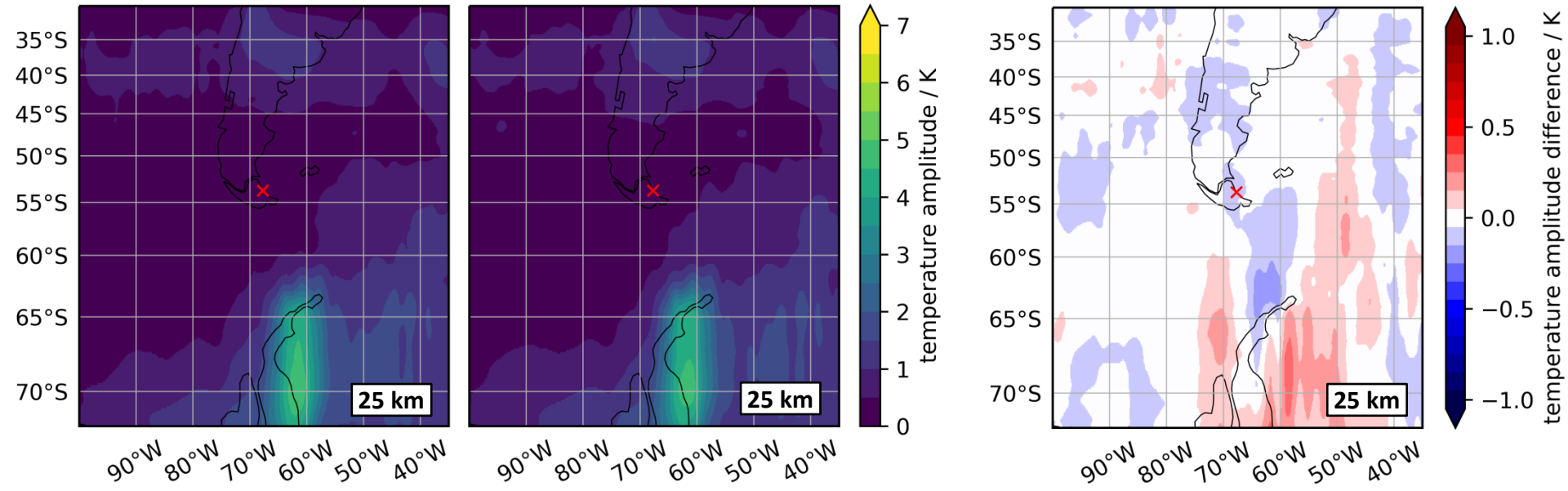


DLR aeolus DISC

How does the assimilation of Aeolus winds impact GWs in ECMWF?

Case study on 20 August 2019, 00:00 UTC, above Antarctic Peninsula

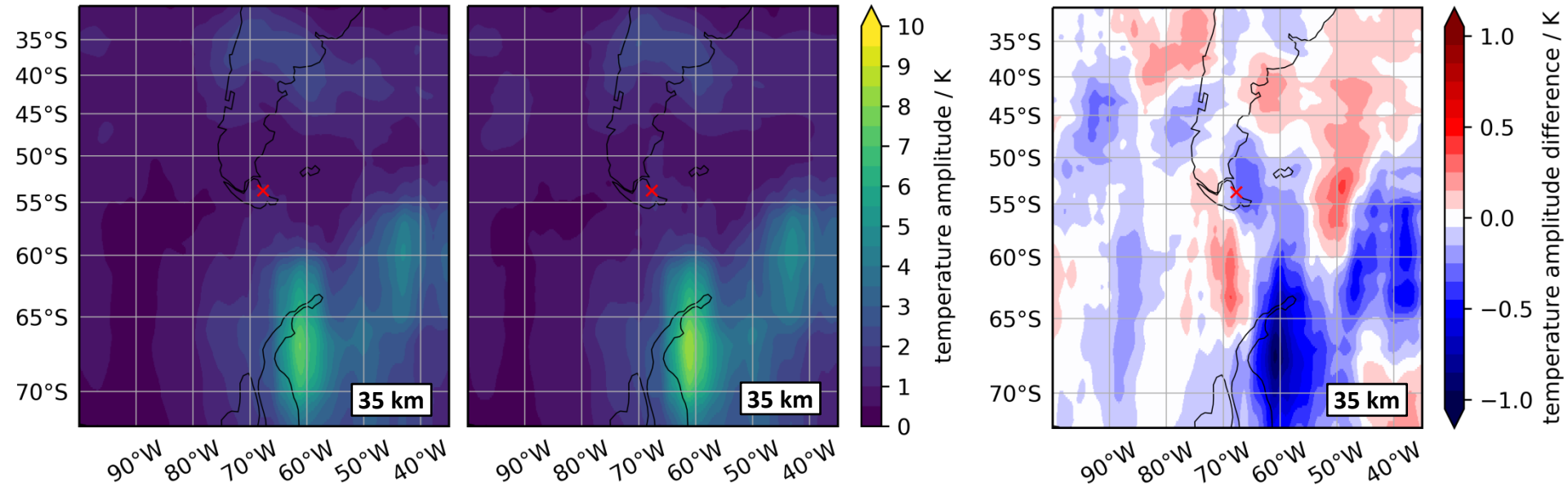
ECMWF control run | **ECMWF Aeolus assimilation** | **Control run - Aeolus assimilation**



How does the assimilation of Aeolus winds impact GWs in ECMWF?

Case study on 20 August 2019, 00:00 UTC, above Antarctic Peninsula

ECMWF control run | **ECMWF Aeolus assimilation** | **Control run - Aeolus assimilation**

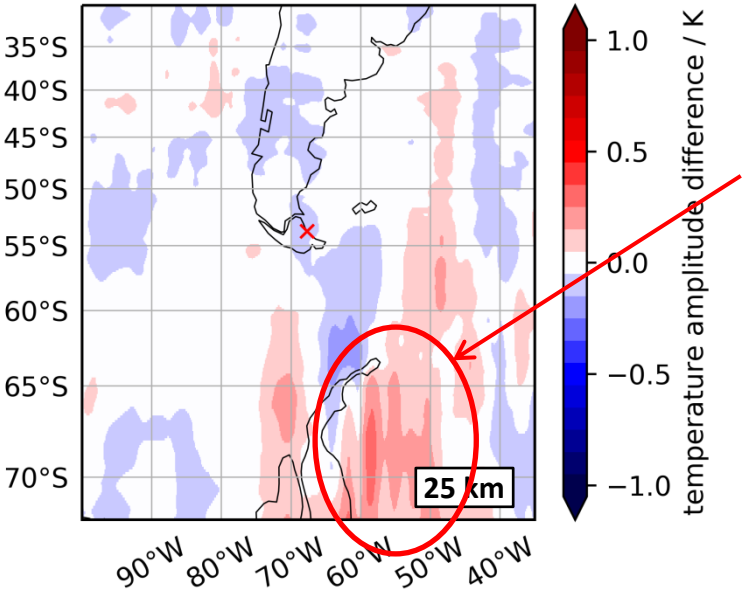


DLR aeolus DISC

How does the assimilation of Aeolus winds impact GWs in ECMWF?

Case study on 20 August 2019, 00:00 UTC, above Antarctic Peninsula

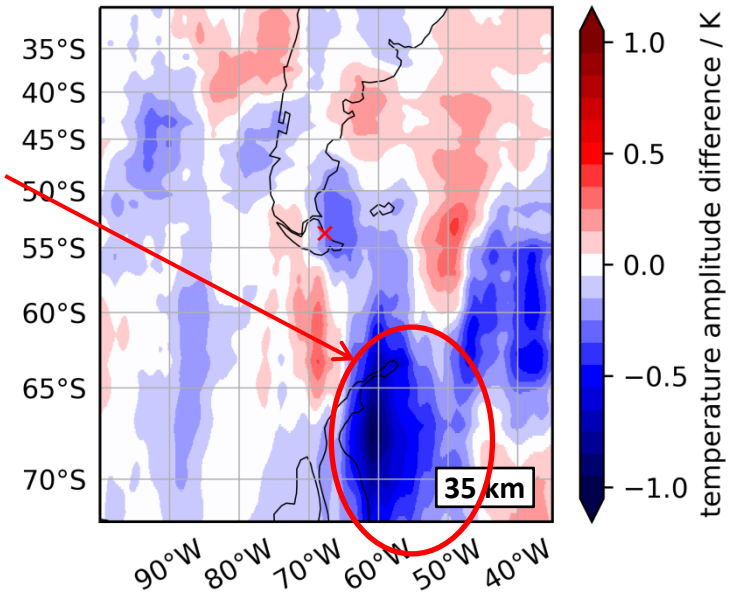
Control run - Aeolus assimilation



What happens between 25km and 35km (above Aeolus measurement altitude)?

-> Further investigation needed!

Control run - Aeolus assimilation



How does the assimilation of Aeolus winds impact GWs in ECMWF?

Summary:

- The assimilation Aeolus in ECMWF changes the gravity wave representation.
- Both amplifications as well as reductions can be observed.
- **This is still work in progress: Please check back on status for Aeolus Cal/Val workshop in November!**

Outlook:

- Expand comparisons to October ground-based lidar data. And compare to aircraft observations, which were taken above South America and the Drake passage in September.
- Investigate further the changes observed for the Antarctica case (20/08/2019) between 25km and 35km altitude, e.g. with respect to background wind patterns?
- Do statistical analyses on whole assimilation experiment (2 Aug. – 26 Oct. 2019).