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Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat

Aeolus impact in limited area model Harmonie

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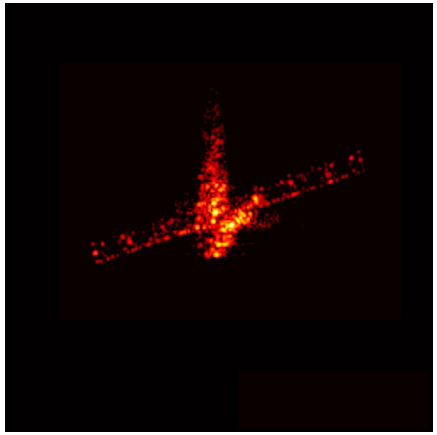
SMHI

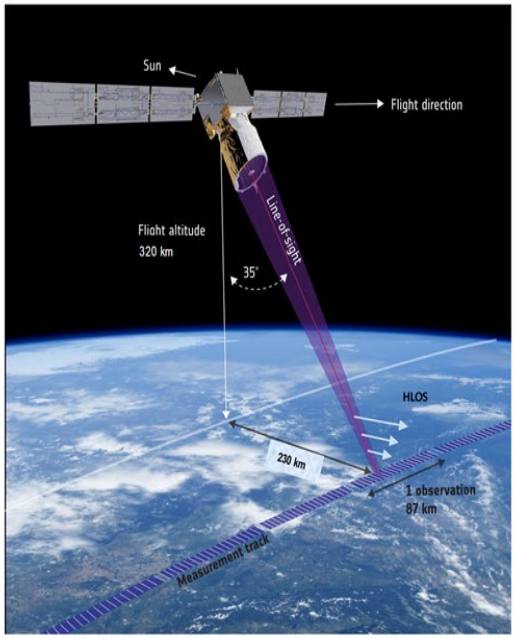
Norwegian
Meteorological
Institute

Aeolus – winds from space

- Launch: 22 August 2018
- First European lidar in space
- First Doppler wind lidar in space – worldwide unique mission



Final images of Aeolus
from radar antenna in Germany
28 July 2023
~18:20 CEST



- UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in continuous mode, with 2 receiver channels (HSRL):
  - Mie receiver (aerosol & cloud backscatter)
  - Rayleigh receiver (molecular backscatter)
- The line-of-sight is pointing 35° from nadir to derive horizontal wind component
- The line-of-sight is pointing orthogonal to the ground track velocity vector to avoid contribution from the satellite velocity
- Spacecraft regularly pointed to nadir for calibration

European Space Agency

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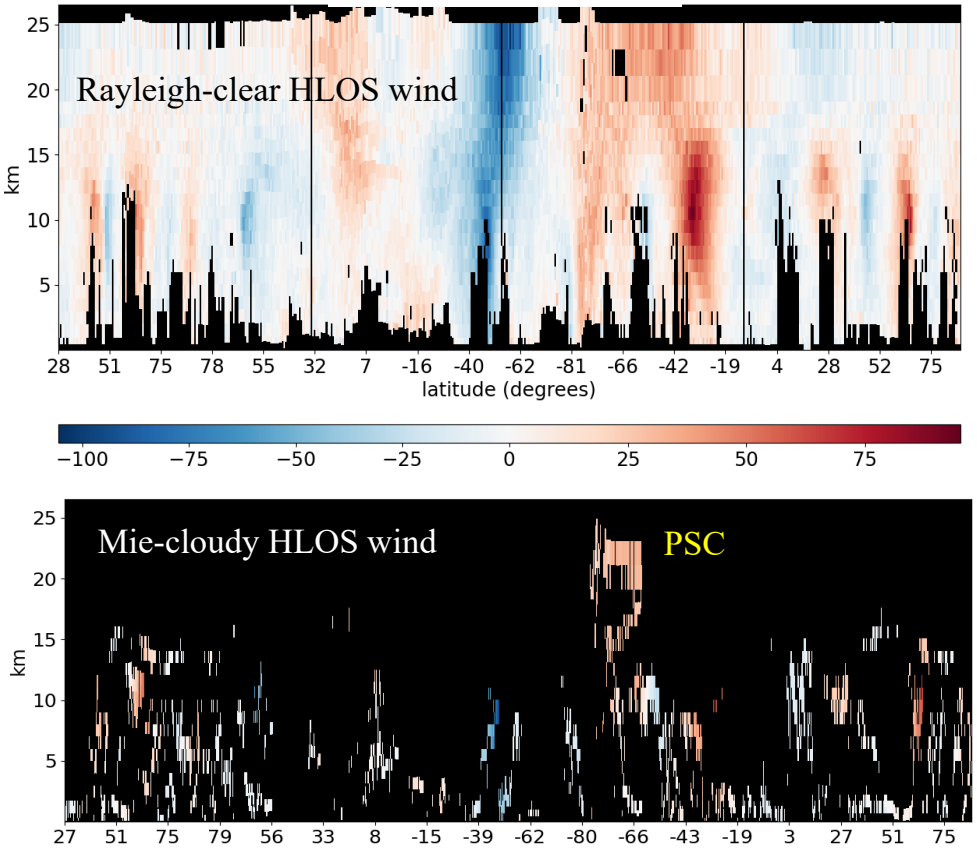
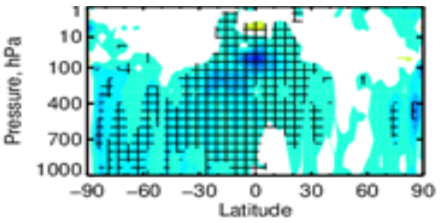
Aeolus success in global models

Two main products: Rayleigh-clear and Mie-cloudy

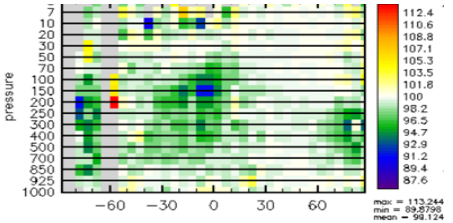


Positive impact in all global models

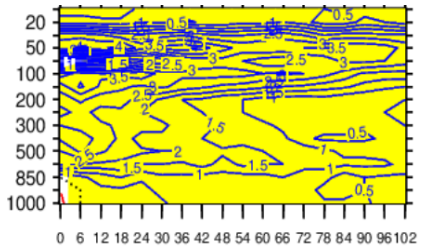
ECMWF: v t+72 h



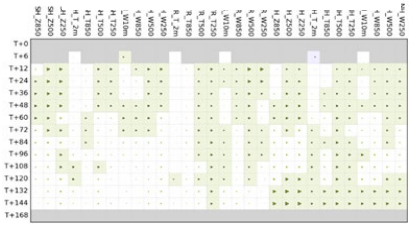
DWD: u radiosonde – f (t+6h)

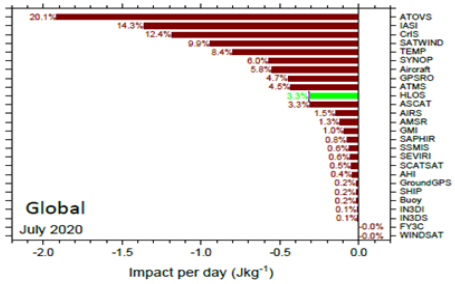


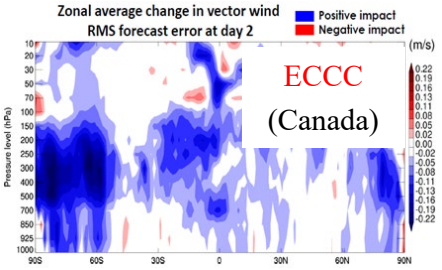
Meteo France: ΔRMS(o-f) in %



UKMO ΔRMS(o-f)







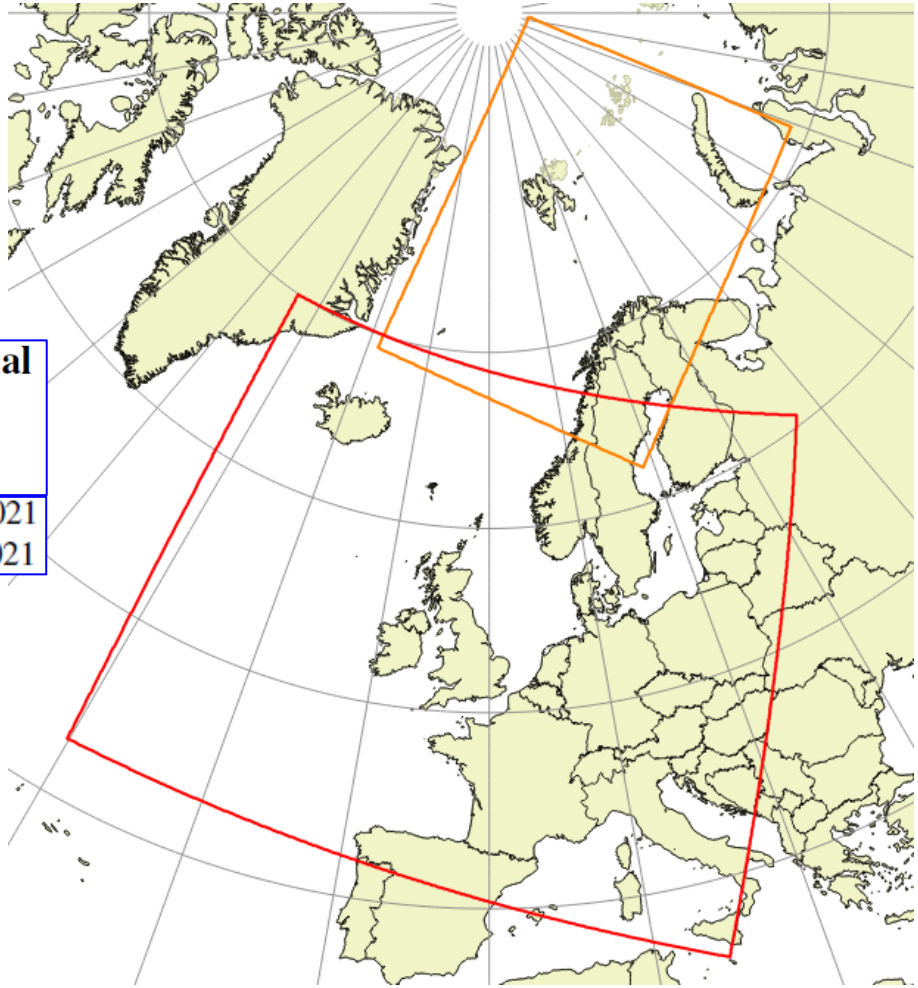
Motivation

- Aeolus shows positive impact in all global models
- However, the impact is neutral in limited area models (LAM)

Evaluating the use of Aeolus satellite observations in the regional numerical weather prediction (NWP) model Harmonie–Arome

Susanna Hagelin[1], Roohollah Azad[2], Magnus Lindskog[1], Harald Schyberg[2], and Heiner Körnich[1]

Atmos. Meas. Tech., 14, 5925–5938, 2021
https://doi.org/10.5194/amt-14-5925-2021



- ESA issued an ITT with the aim to define recommendations for the use of Aeolus data in LAM

- Study proposal of SMHI/met.no/KNMI was selected

UWC-West domain

- New future operational KNMI domain
  - DINI consortium; DINI = Denmark, Iceland, Netherlands, Ireland
- Model cycle: cy43h2.2.1
- 2 km grid size
- 90 vertical levels (surface – 10 hPa)
- Non-hydrostatic model
- Boundary conditions from ECMWF

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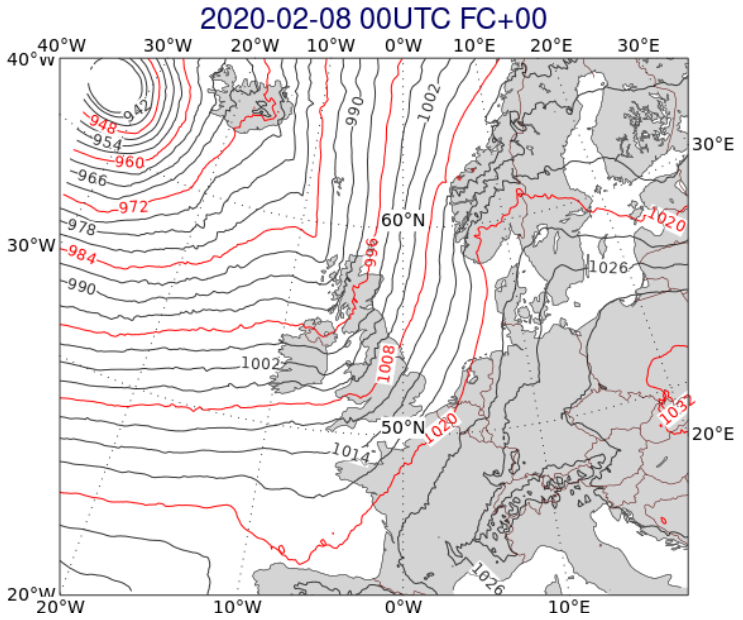
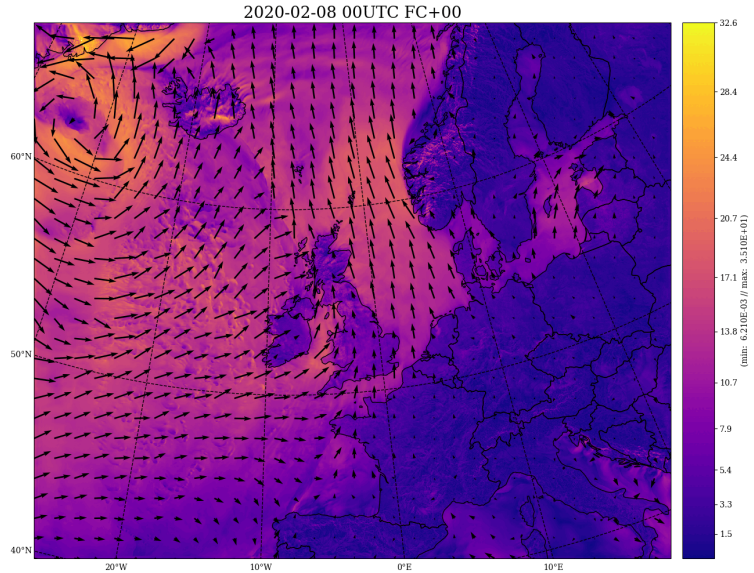
OSE experimental setup

- Experimental period: 20 Jan. – 10 March 2020
  - Capturing two storms: Ciara (7-10 Feb.) and Dennis (13-16 Feb.)
- 4DVar data assimilation
- 3-hr cycling
  - (10-13 UTC, 13-16 UTC, etc.)
- Four experiments:
  - Control, using all existing observations, denoted
  - Aeolus-Mie: Control + Aeolus Mie-cloudy observations
  - Aeolus-Mie + error inflation
  - Aeolus-Rayleigh: Control + Aeolus Rayleigh-clear observations





OSE

Aeolus Mie winds only

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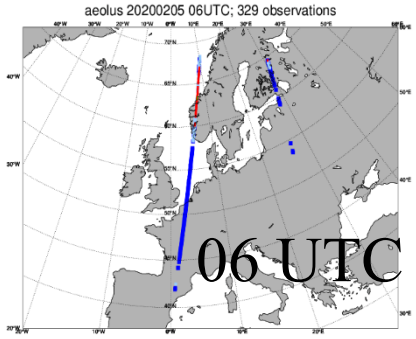
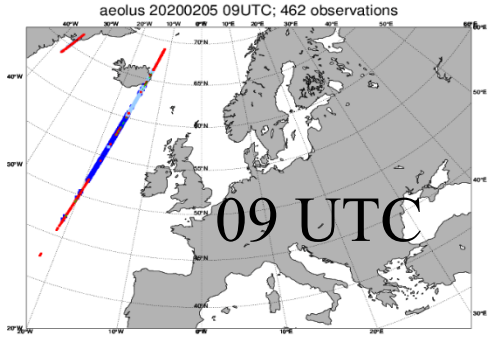
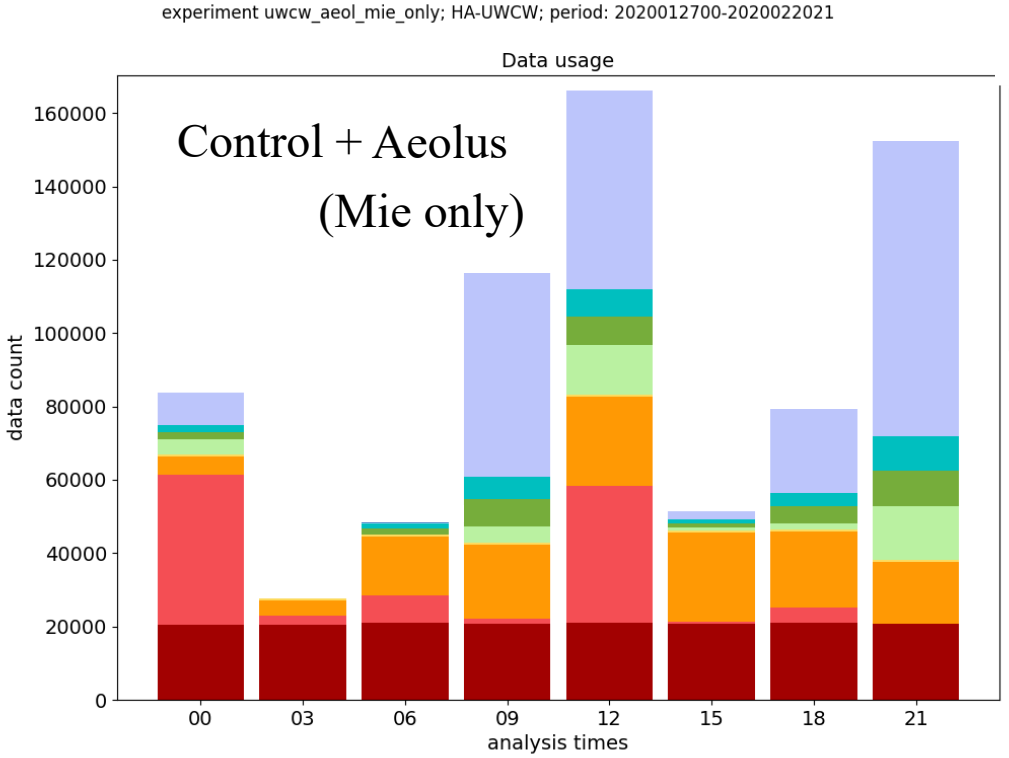
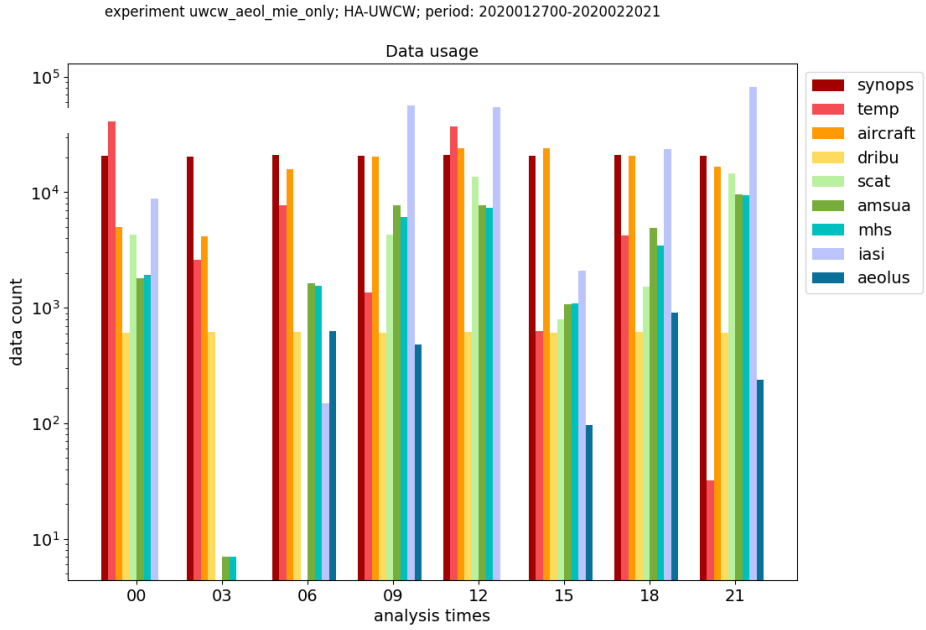
Data usage



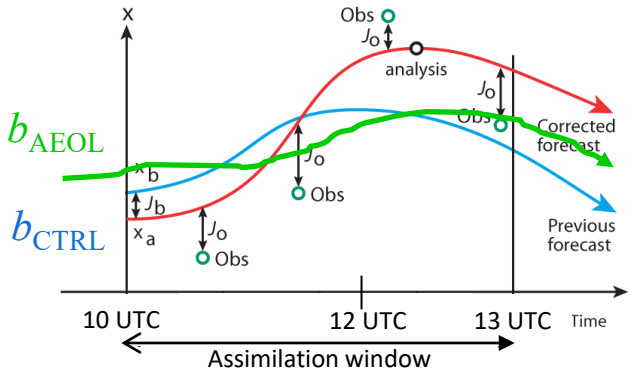




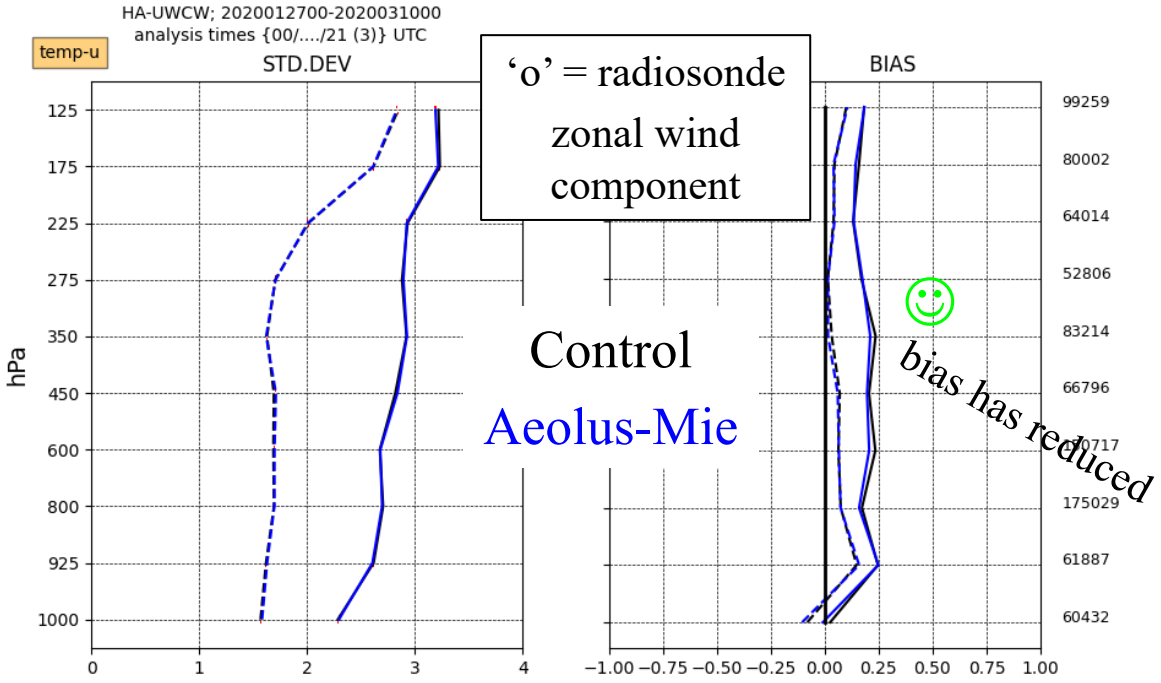


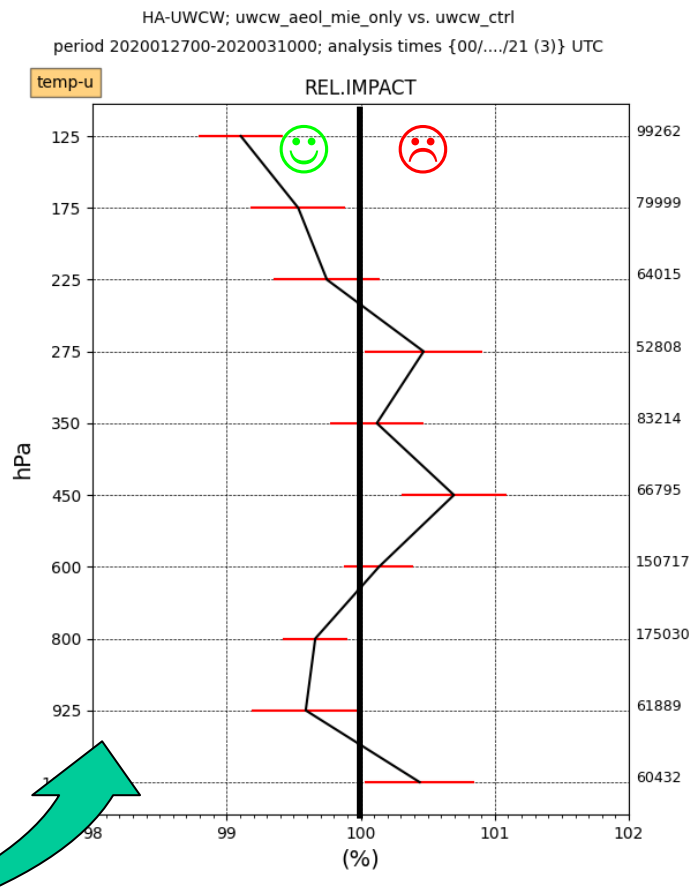
- Mean data usage per assimilation cycle
  - ➢ The number of Aeolus Mie-cloudy winds is relatively very small

Aeolus impact – on short forecast range



- Compare first-guess innovations (o-b) of the Control and Aeolus-Mie experiments





$$I = \frac{\langle o - b_{AEOL} \rangle}{\langle o - b_{CTRL} \rangle} \text{ x } 100\%$$

Aeolus impact on short-term forecasts
(period: 27/1 – 10/3 2020)

- Integrate Aeolus impact in the vertical

Positive Aeolus impact in LAM for the first time!

except for humidity (temp-q)

(I come back to that later)

OSE

Aeolus Mie winds only + error inflation

Relative impact of error inflation versus no inflation (period: 27/1 – 28/2 2020)

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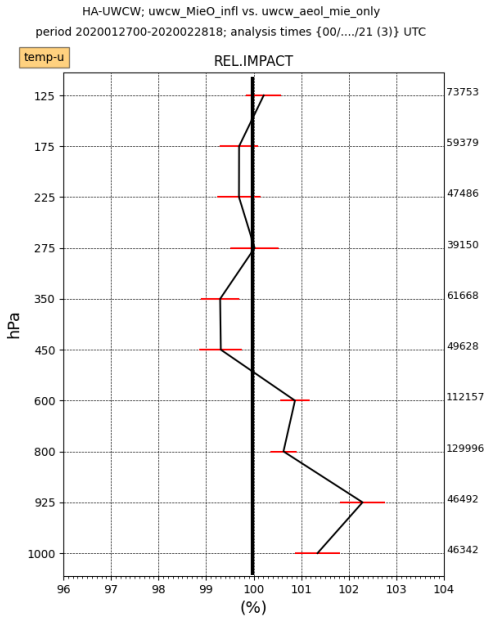


temp-u

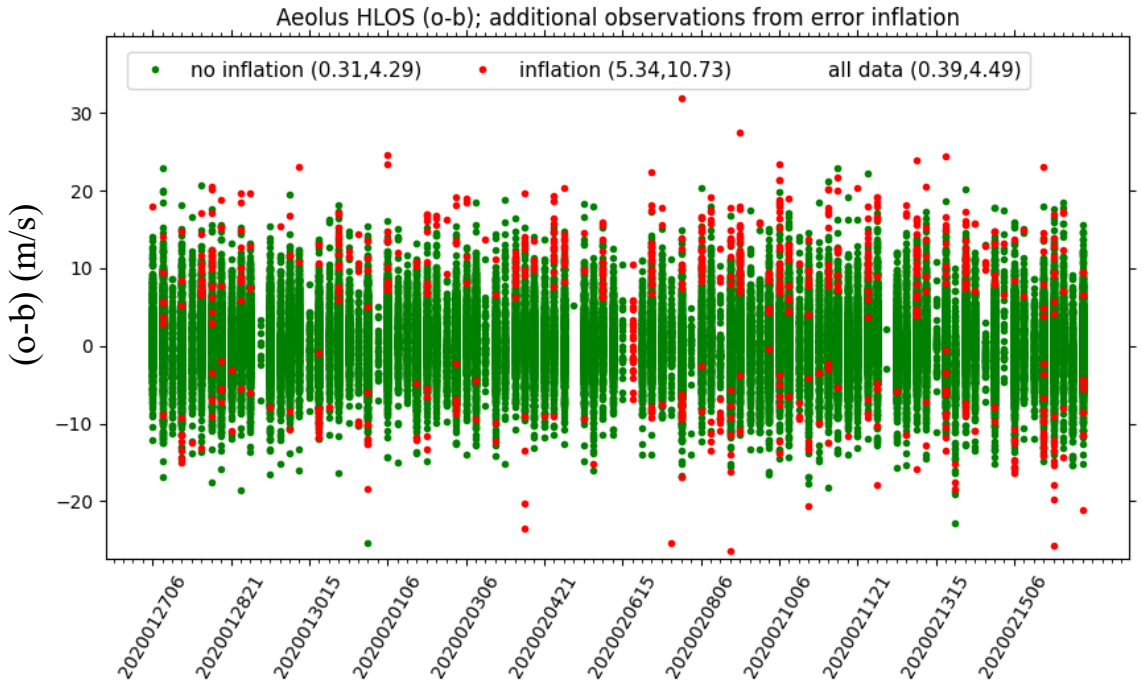
- Error inflation makes Aeolus impact worse

  Except for humidity (temp-q)

Mie wind error inflation

- Error inflation has the side effect of effecting (or better affecting) Quality Control as part of the data screening in data assimilation (we did not realise before)

Red dots denote additional Aeolus winds when doing error inflation



IFS does implement error inflation NOT in the correct way

First-guess check:

$|(o-b)| < \alpha\sigma$, $\alpha=\{3,4,5\}$

- with σ the assigned observation error
- inflating σ relaxes to first-guess check!
- More low-quality winds are allowed in the analysis

➢ Undesired!

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Aeolus Rayleigh winds only

Aeolus Rayleigh-clear impact on short-term forecasts (period: 27/1 – 28/2 2020)

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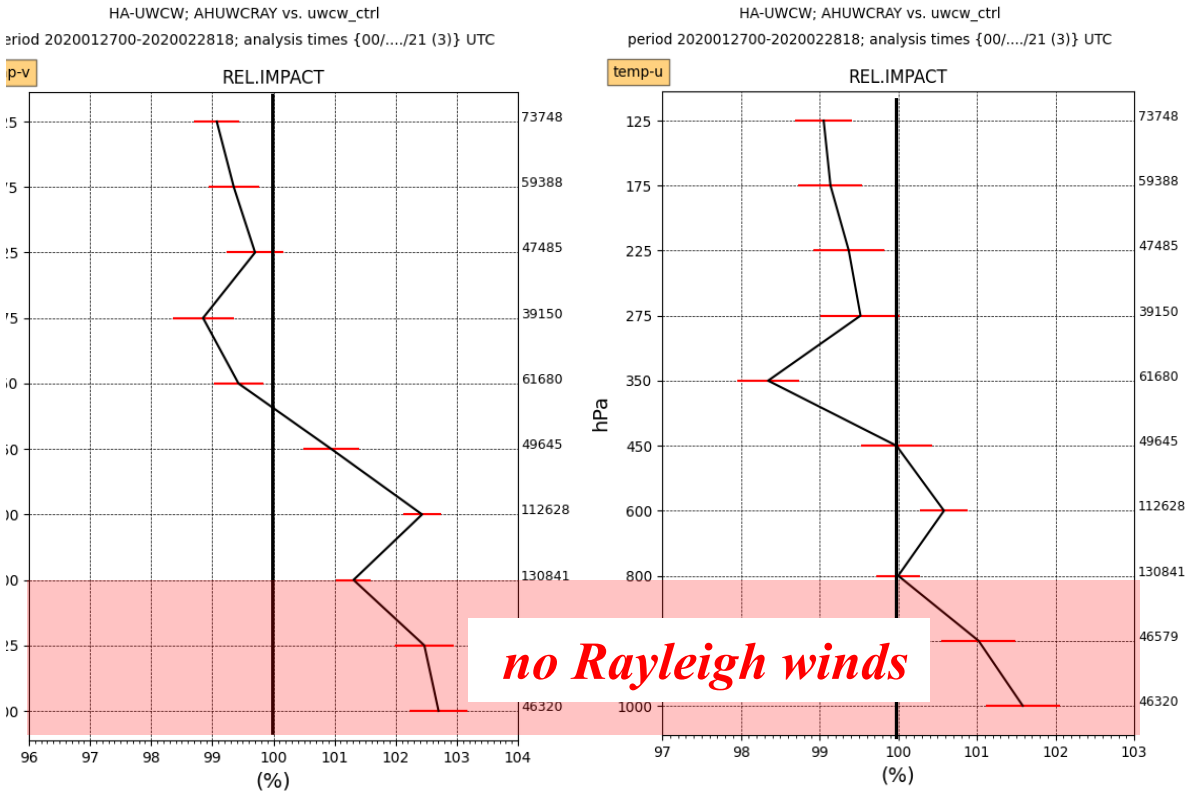
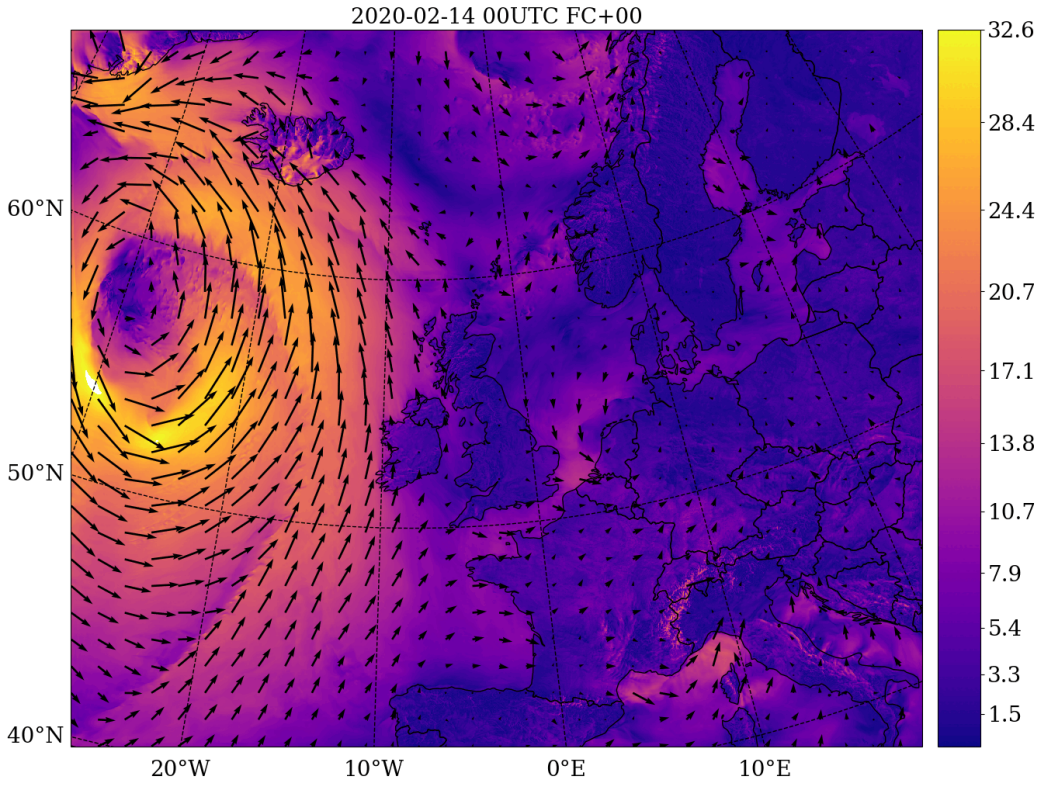


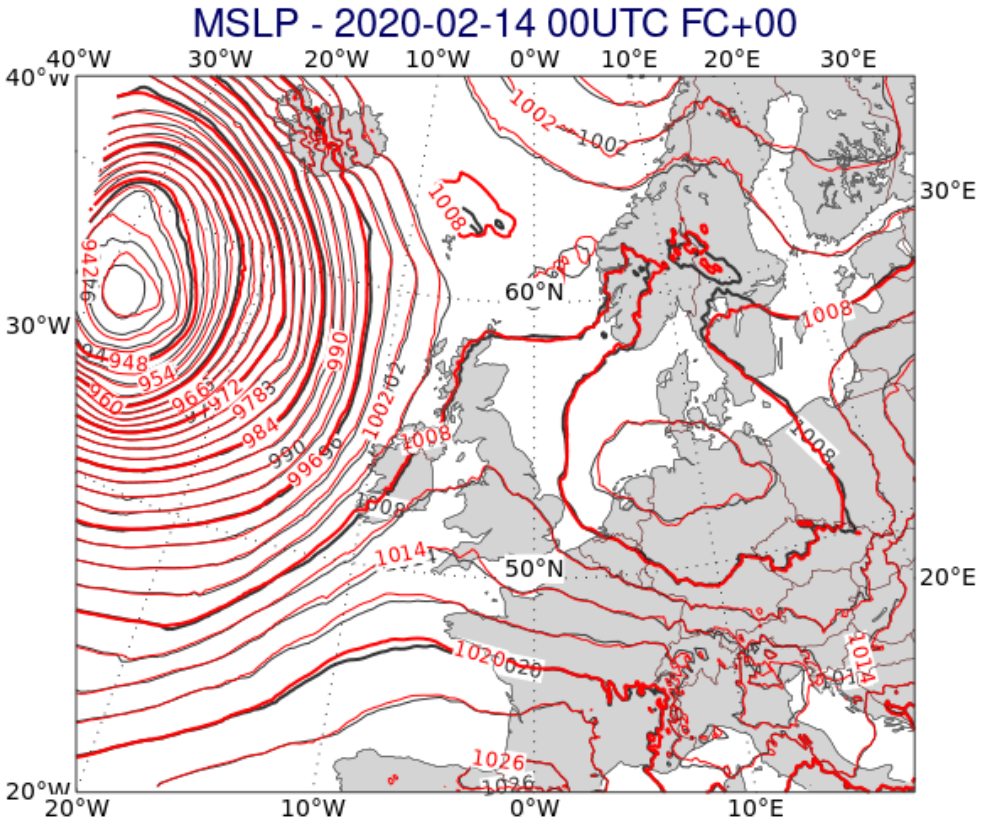
Negative impact is mainly in the (lower) troposphere, where no Rayleigh winds are assimilated

Storm Dennis – February 2020

- Period 14-18 February 2020

Control experiment / Aeolus-Rayleigh experiment





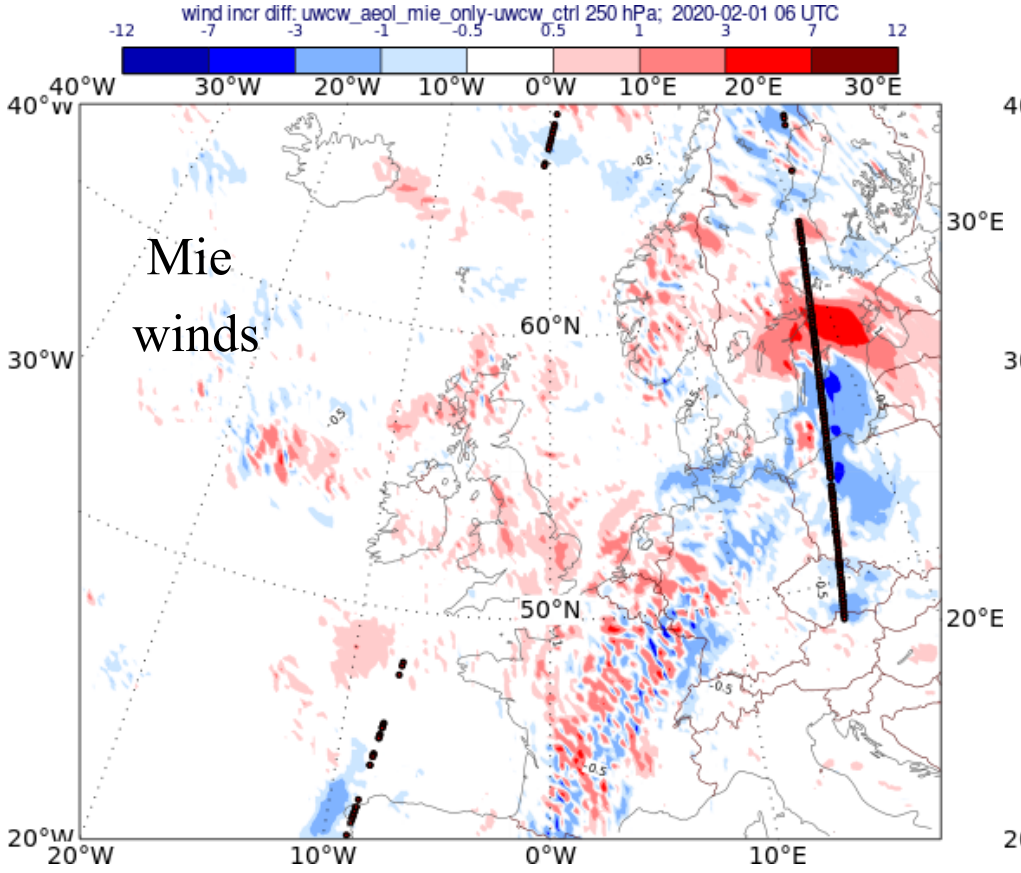
Conclusions

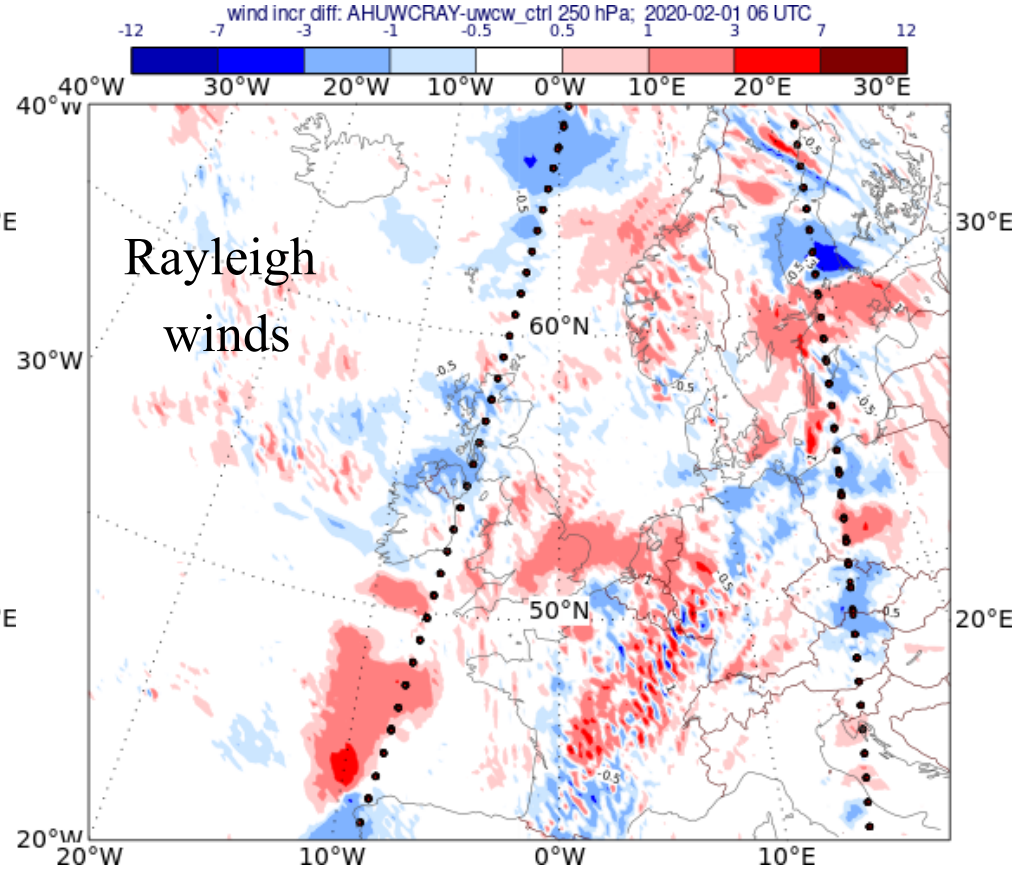
- For the first time we see positive Aeolus impact in a limited area model !!
- Aeolus is only a very small extension to the existing data coverage
- Aeolus wind biases compensate for ascending and descending orbits
  - Recommendation 1: consider bias correction as part of VARBC (most global NWP weather centers already do so)
- Error inflation has the side-effect of allowing more poor-quality data in the analysis
  - Recommendation 2: Improve use of first-guess-check when assessing error inflation (also ECMWF did not realize before)
- Recommendation3: use exactly the same observational dataset for verification of the different experiments in OSE (this is not always done! …. and than you cannot conclude anything)

- Why does the verification score of q behaves opposite to (u,v,T)??

Backup slides

Increments at 250 hPa of Aeolus experiment





- Aeolus increments at 250 hPa more substantial from Rayleigh winds

Aeolus winds along tracks on previous slide

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