Rayleigh-cloudy winds

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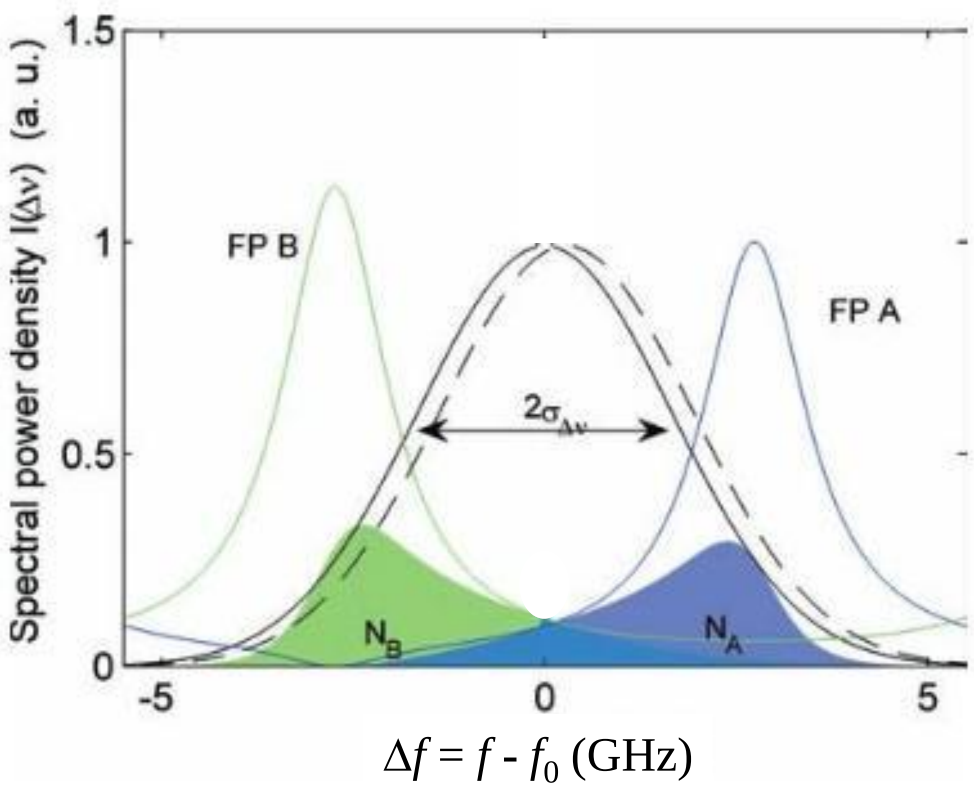
Overview

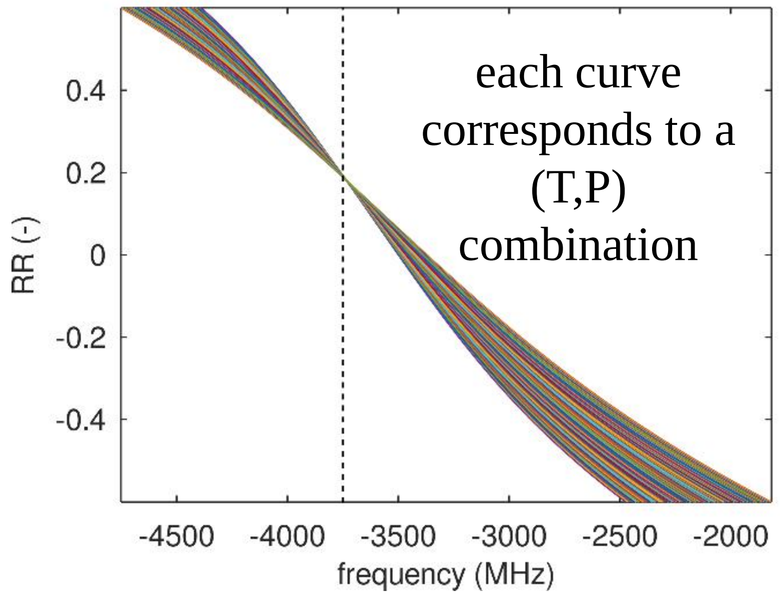
- Motivation
  - Until recently we have not been able to produce a high quality Rayleigh-cloudy wind product
- Introduction on Rayleigh channel winds in clear air conditions – Rayleigh-clear
- Procedure to retrieve high quality Rayleigh-cloudy winds
- Rayleigh-cloudy winds statistics
- Conclusions

Rayleigh winds in clear air conditions



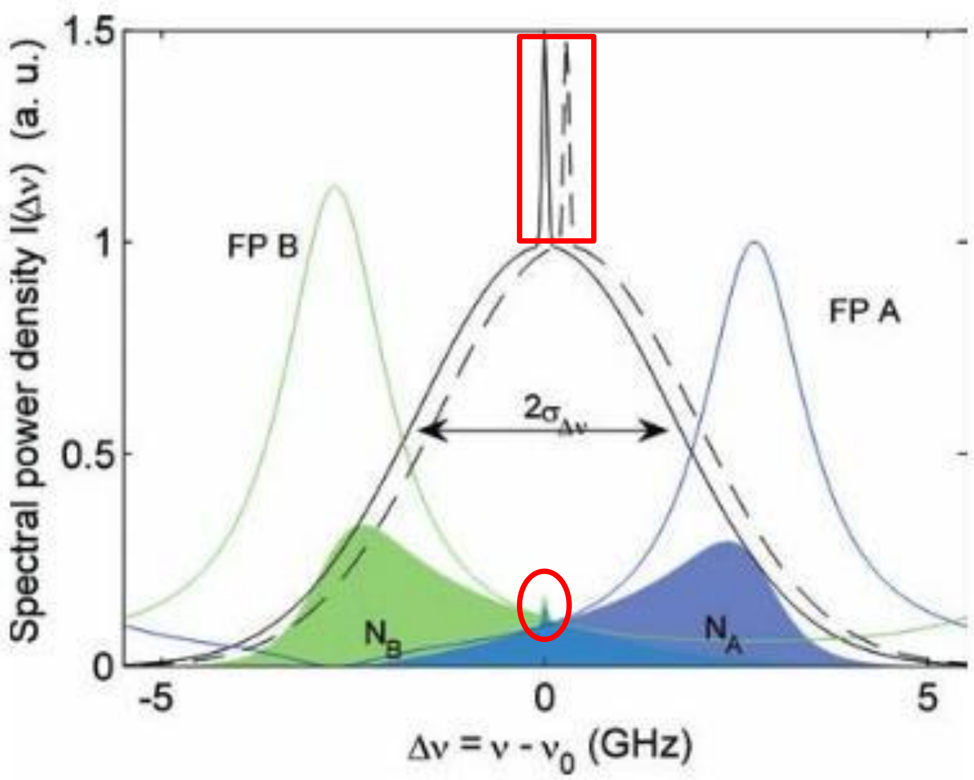
- Rayleigh Response $RR_0 = \dfrac{N_A - N_B}{N_A + N_B}$

- The Rayleigh Response value is a function of temperature, pressure and the Doppler shifted frequency: $RR_0 = RR_0(T,P,\Delta f)$



Available as a 3-dimensional table

Rayleigh winds in cloudy/aerosol conditions



- Rayleigh Response $RR = \dfrac{N_A + n_A - N_B - n_B}{N_A + n_A + N_B + n_B}$

- RR = RR(T,P,Δυ,ρ); the scattering ratio, ρ, is a measure of Mie scattering relative to Rayleigh scattering in the atmosphere:

$$\rho = \frac{\beta_m + \beta_p}{\beta_m}$$

- This would require a 4-dimensional table
- Instead: alternative approach (next slide)

Impact of Mie return on Rayleigh Response

Make use of NWP data

$$H_{NWP}(u,v) = -u\sin(\psi) - v\cos(\psi)$$
$$v_{LOS} = H_{NWP}(u,v)\sin(\theta)$$
$$\Delta f_{NWP} = v_{LOS}/(-\lambda/2)$$

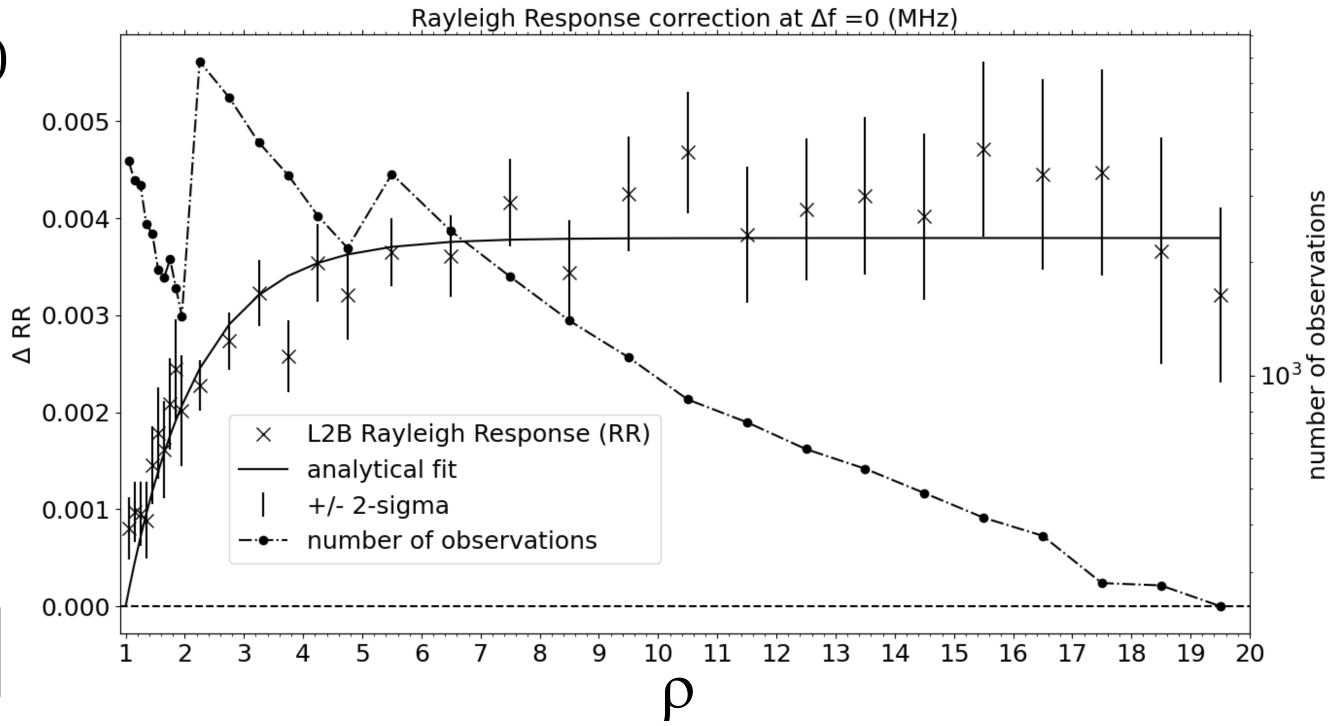
ψ is the azimuth angle
ϕ is the incidence angle
λ is the laser wavelength

(P,T) from NWP
⇩

- $HLOS_{NWP}$ => Δf_{NWP} => RR_0 (clear air conditions)
- $\Delta RR = RR_{meas} - RR_0$

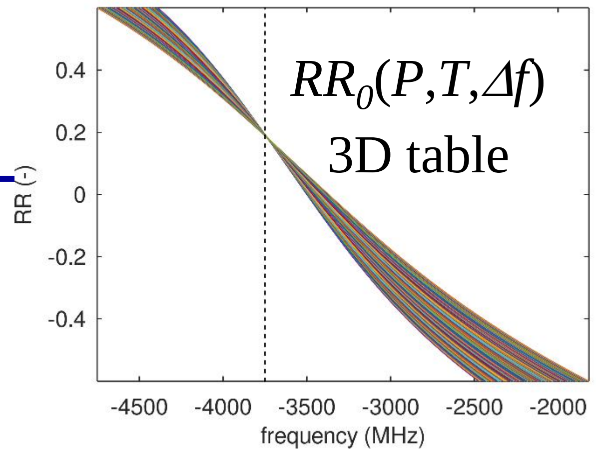
- ΔRR is a combination of (i) Mie contribution, (ii) instrument noise and (iii) NWP model error
- ➢ Averaging over a long time period reduces noise and model error contribution
- ➢ What is left is Mie contribution => curve fitting

$$\Delta RR(\rho) = a\left(1 - e^{-b_0(\rho-1)}\right)$$



Retrieving Rayleigh-cloudy winds

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat



It turned out that parameter a is a function of the Doppler shifted frequency:

$$a = a_0 + a_1 \Delta f$$

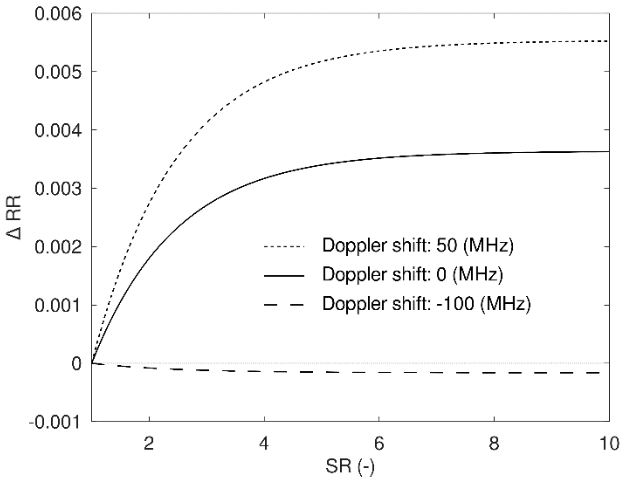
Rayleigh Response model, including Mie contribution

$$RR(P,T,f_0+\Delta f,\rho) = RR_0(P,T,f_0+\Delta f) + \Delta RR(\rho,\Delta f)$$

3D RR_0 table (assuming ρ=1)

with $\Delta RR(\rho,\Delta f) = (a_0 + a_1 \Delta f)(1 - e^{-b_0(\rho-1)})$

(parameters a_0, a_1, b_0 are obtained with the use of NWP model data)



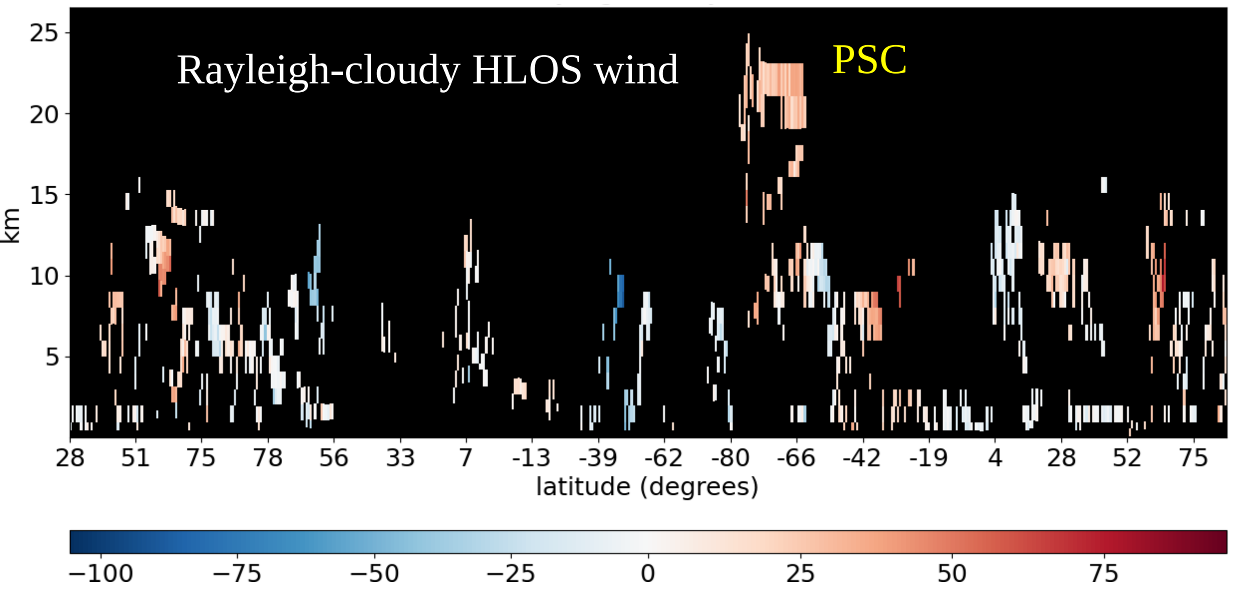
- solve Δf from $RR(P,T,f_0+\Delta f,\rho) = RR_{meas}$
  (by linearizing RR_0)

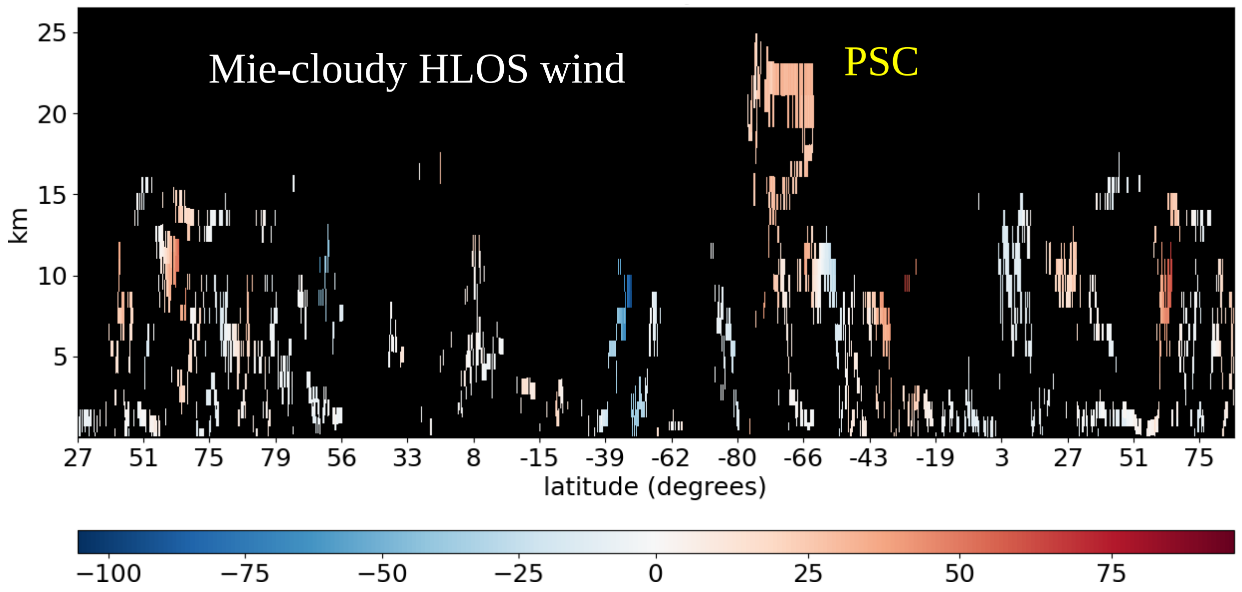
Aeolus Rayleigh-channel winds in cloudy conditions

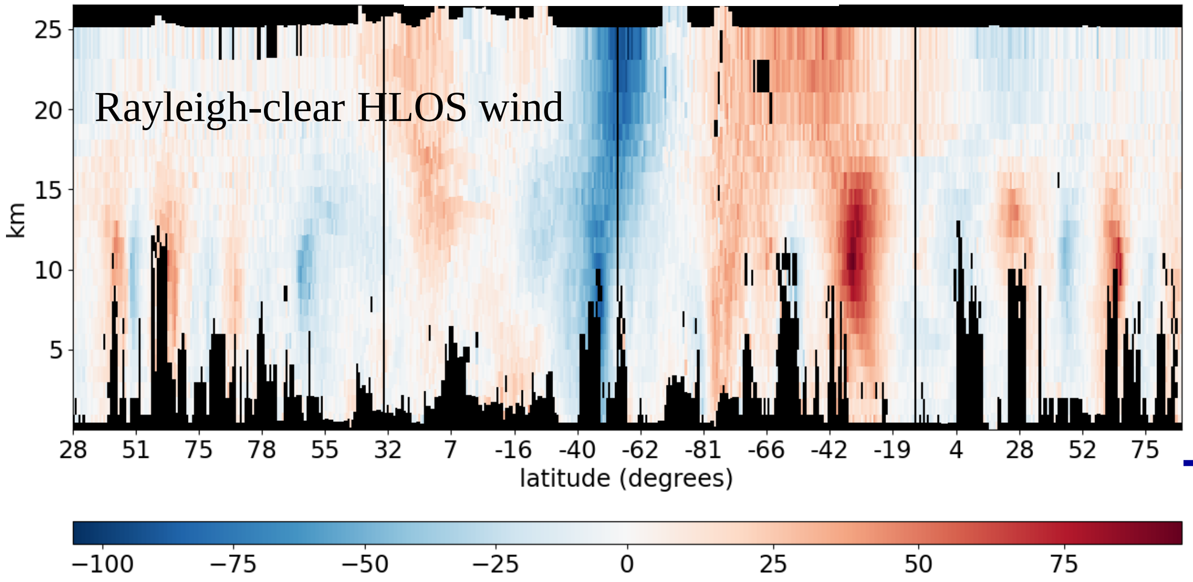
Gert-Jan Marseille[1] | Jos de Kloe[1] | Alain Dabas[2] | Thomas Flament[2,3] | Michael Rennie[4]

submitted to QJRMS

Aeolus data coverage - 15 August 2019 ~02:53 UTC

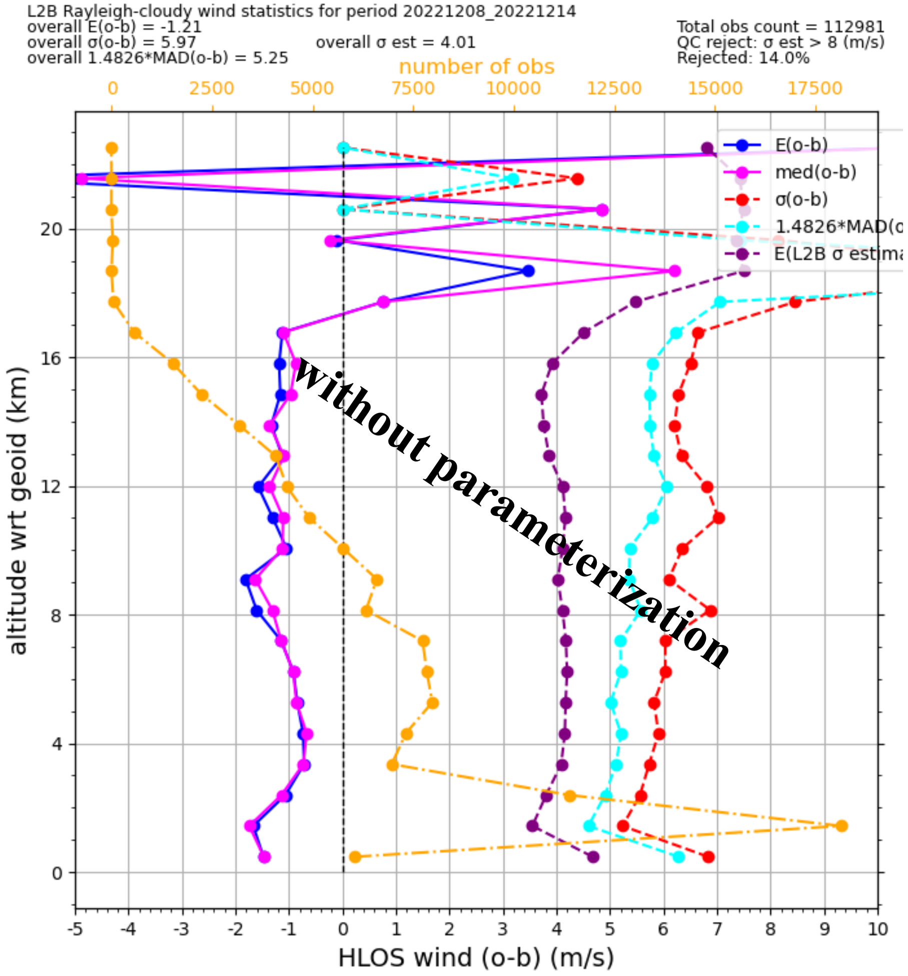


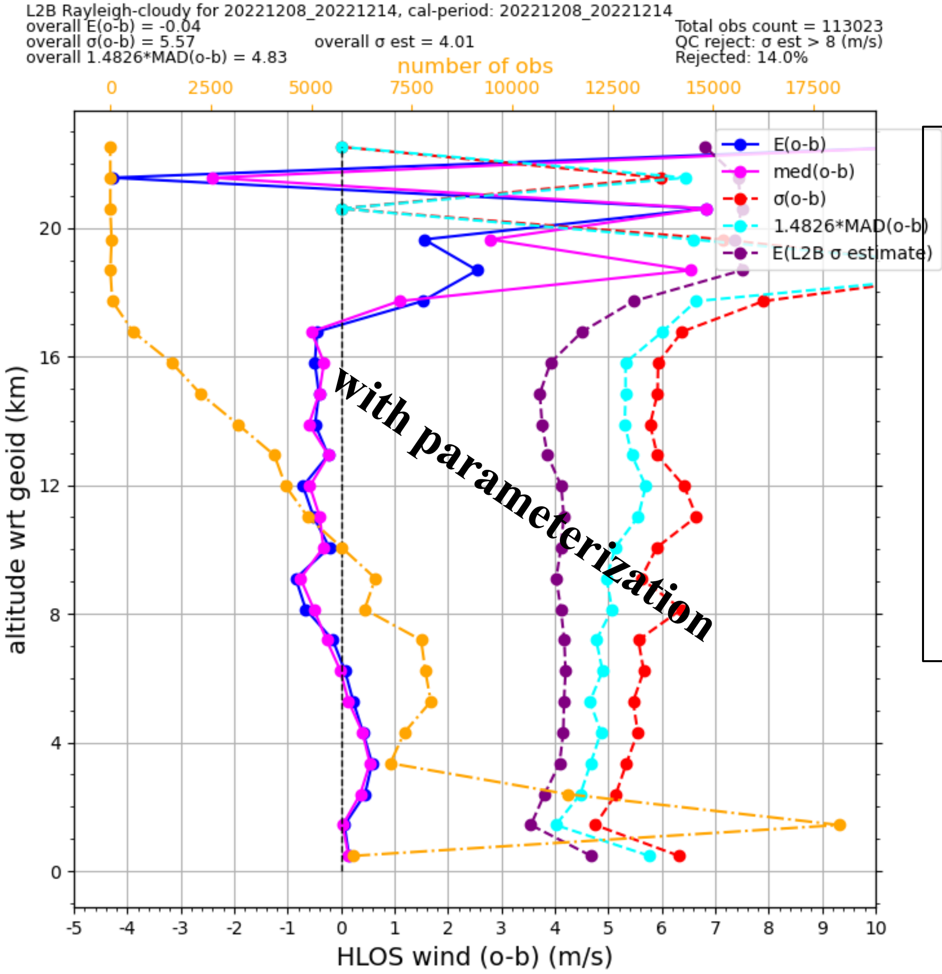




- Rayleigh-cloudy winds are similar to Mie-cloudy winds (visually)
- Rayleigh-cloudy winds have lower resolution, but are more representative to model winds (resolution)
- Both winds are complementary for NWP

Rayleigh-cloudy winds statistics – FM-A period

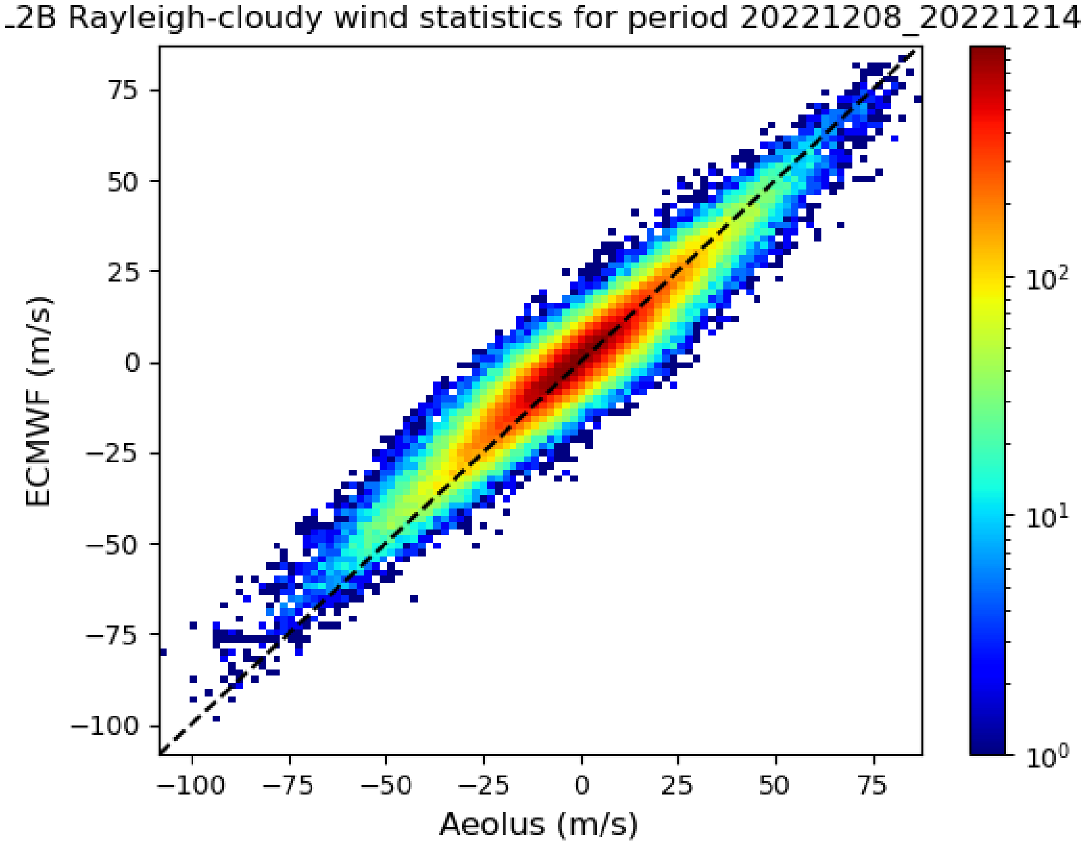




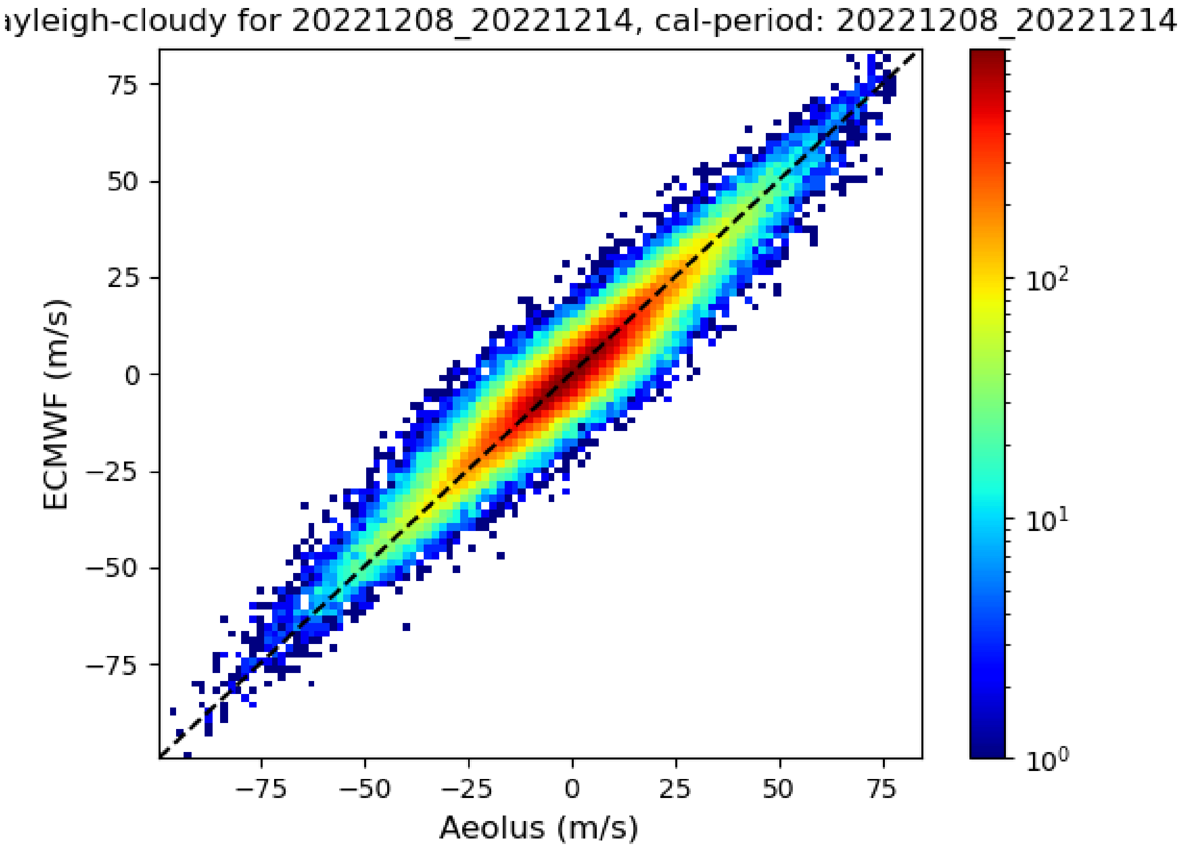
- 8-14 Dec. 2022
- Bias from -1.21 m/s to -0.04 m/s
- SMAD from 5.25 m/s to 4.83 m/s (9% reduction)

Rayleigh-cloudy winds statistics (ctd.)

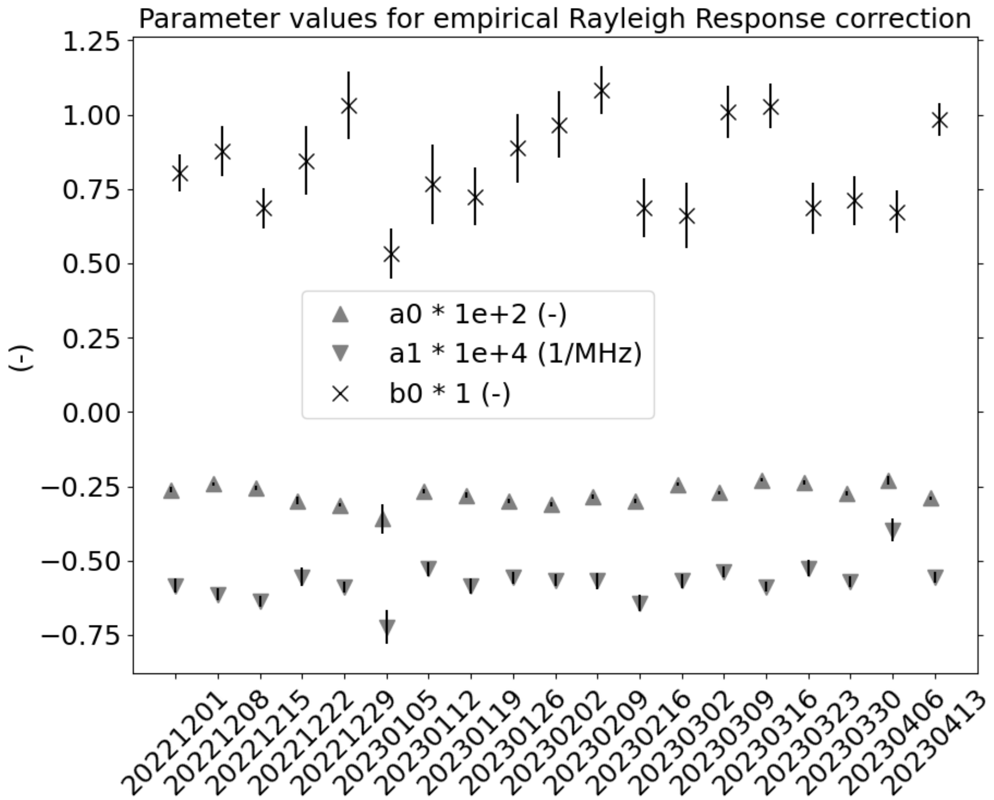
without parameterization

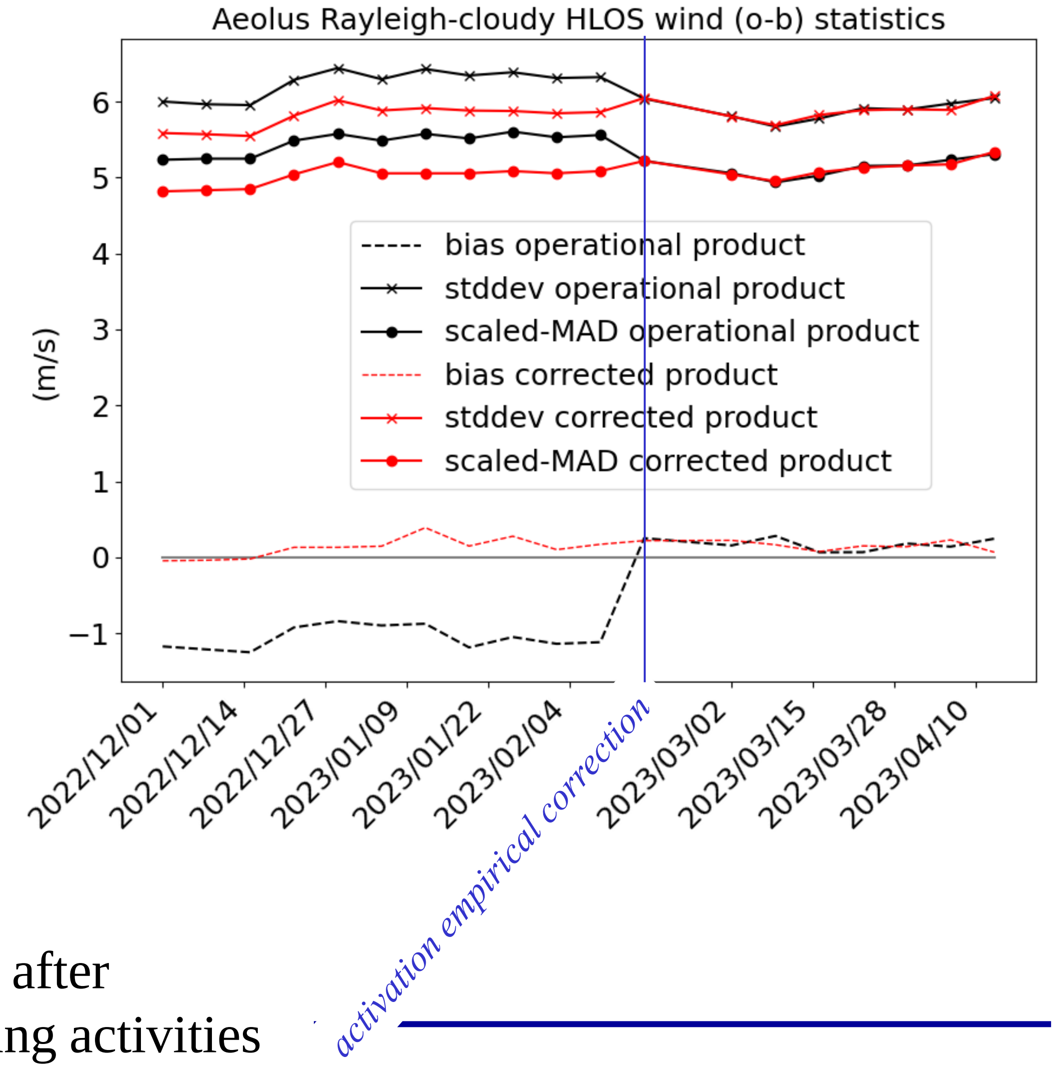


with parameterization



Rayleigh-cloudy monitoring; FM-A period





- Parameters estimated on a weekly base; stable!
- Overall biases of Rayleigh-cloudy winds are very small after 16 February 2023 and will be in forthcoming reprocessing activities

Conclusions

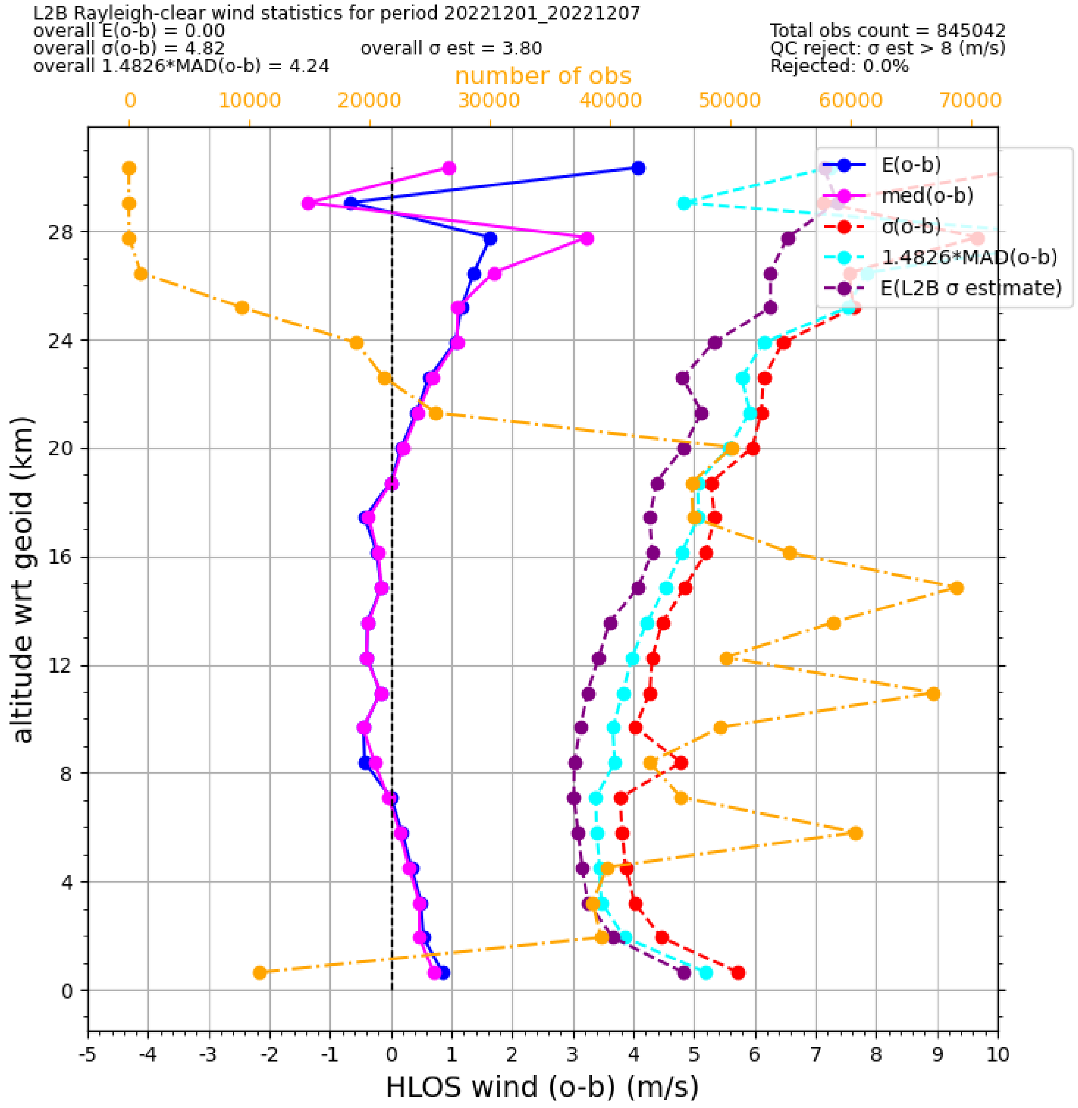
- We have a procedure in place to retrieve good quality Rayleigh-cloudy winds
  - Bias-free with a random error slightly larger than for Rayleigh-clear winds

- Improved Rayleigh-cloudy winds are available in the operational data set since 16 Febuary 2023 and will come available for the complete mission in forthcoming reprocessing activities

- The impact of Rayleigh-cloudy winds for NWP is to be assessed; first results will be presented by Michael Rennie

backup

Standard Rayleigh-clear statistics



- 1-7 Dec. 2022
- (o-b) bias: 0.00 m/s
- (o-b) SMAD/STDEV: 4.24/4.82 m/s

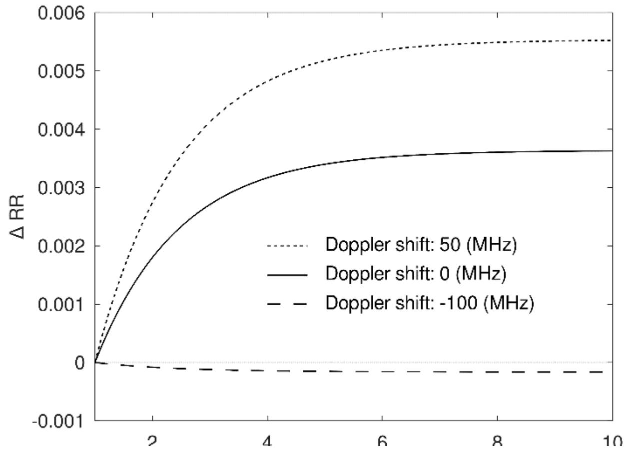
➢ Better than Rayleigh-all (as expected, because Rayleigh-cloudy is worse than Rayleigh-clear)

➢ But note the different sample (510K vs. 845K observations)

Rayleigh-cloudy winds

$$RR(P,T,f_0+\Delta f,\rho) = RR_0(P,T,f_0+\Delta f) + \Delta RR(\rho,\Delta f)$$

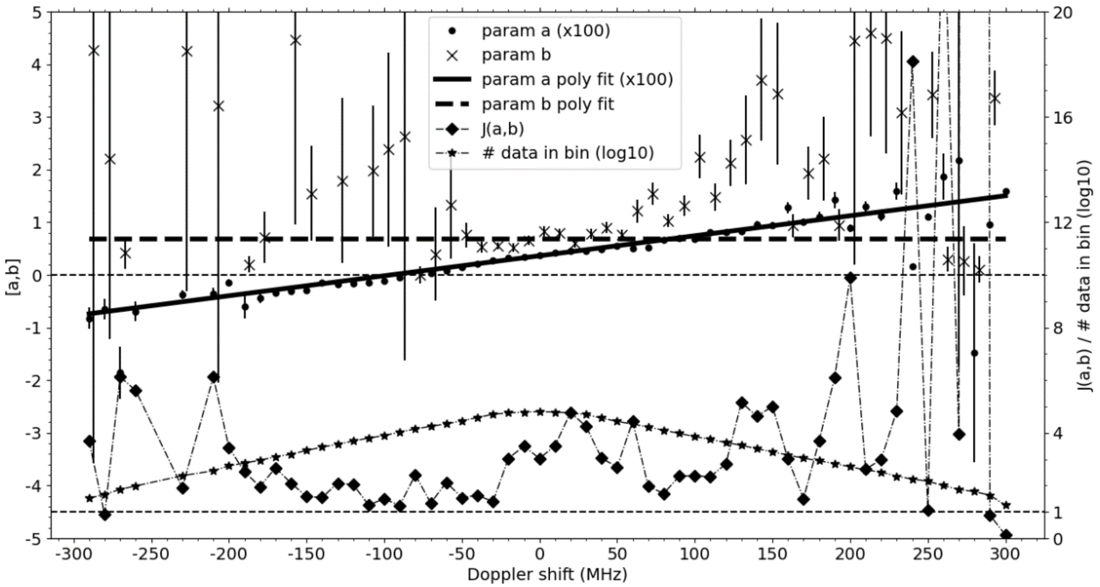
AUX_RBC (assuming ρ=1)



curves derived by making use of NWP data

$$\Delta RR(\rho,\Delta f) = (a_0 + a_1\Delta f)(1 - e^{-b_0(\rho-1)})$$

a_0, a_1, b_0



- solve Δf from $RR(P,T,f_0+\Delta f,\rho) = RR_{meas}$ through linearization

Parameter estimation of Mie contribution using NWP

$$\Delta RR(\rho, \Delta f) = (a_0 + a_1 \Delta f)(1 - e^{-b_0(\rho - 1)})$$

(*P*,*T*) from NWP

⇩

- $HLOS_{NWP}$ => Δf_{NWP} => RR_0
- $\Delta RR = RR_{meas} - RR_0$

- ΔRR is a combination of
  - Mie contribution
  - Instrument noise
  - NWP model error

➢ Averaging over a long time period reduces noise and model error contribution

➢ What is left is Mie contribution => curve fitting