Validation of Aeolus wind products over the tropical Atlantic using radiosondes

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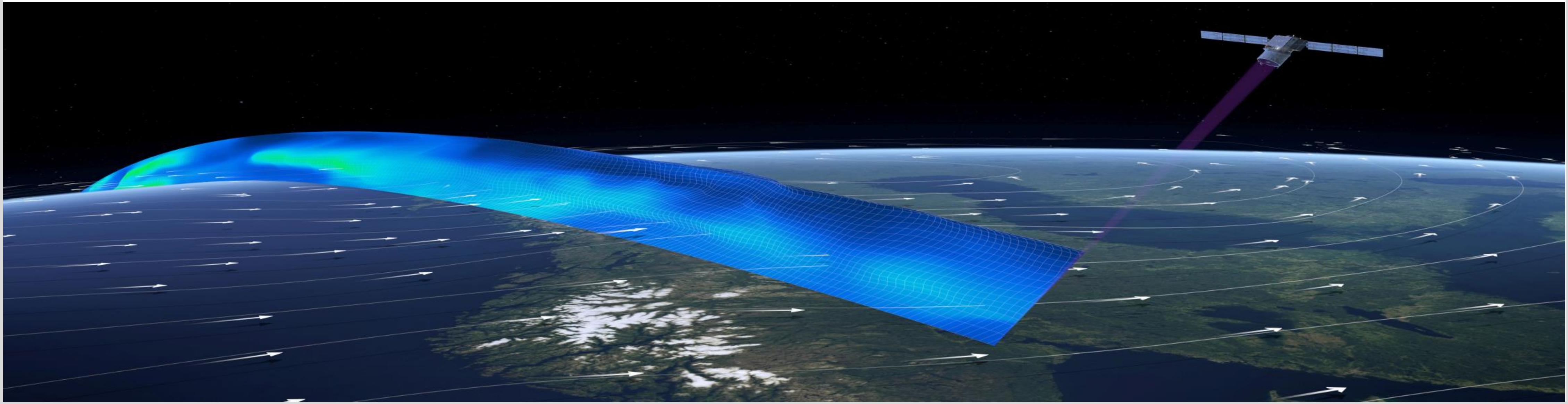

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Motivation

- **What is the quality of Aeolus L2B wind products in the tropics** in terms of systematic and random errors?
- **What are the error** dependencies of Rayleigh-clear and Mie-cloudy wind observations **with respect to the presence of clouds and dust?**

Tropical Atlantic during boreal summer

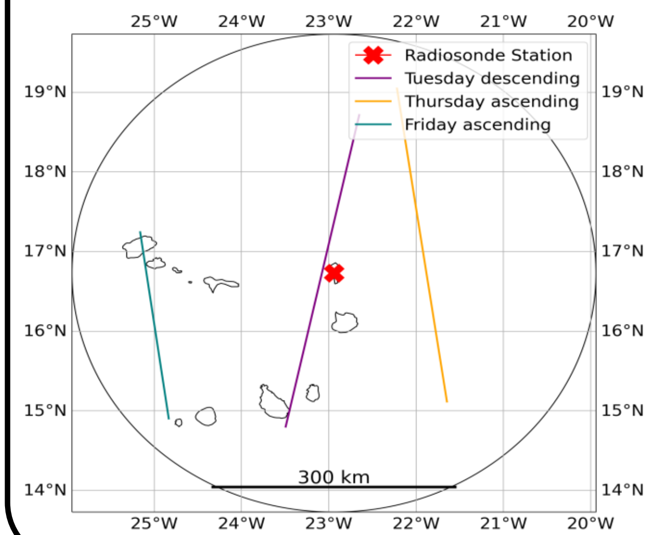
- Validation of Aeolus using radiosondes launched in West Africa (Sal) and in the Caribbean (Saint Croix & Puerto Rico), JATAC in Aug.-Sept. 2021
- Atmospheric aerosols: Saharan dust aerosols, sea salt aerosols, biomass combustion aerosols..
- Convective cloud types associated with the West African Monsoon (WAM) circulation and the Inter Tropical Convergence Zone (ITCZ)

Radiosonde component of JATAC

- During JATAC, **radiosondes** were launched **from three different sites**

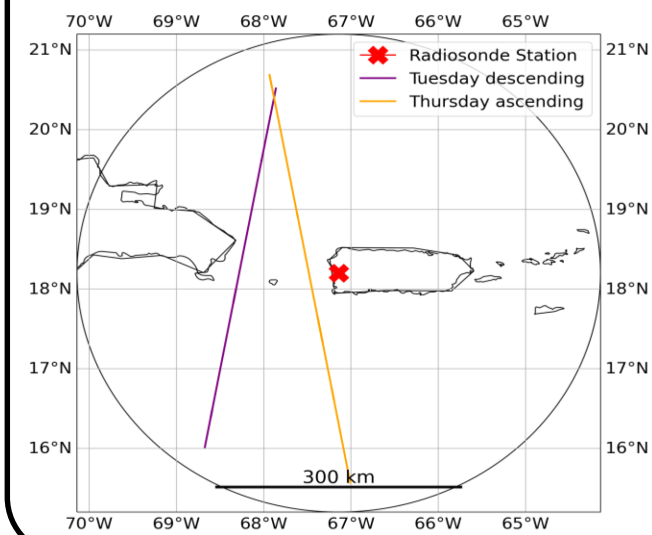
Sal Island (Cape Verde)

37 (9 corresponding to Aeolus overpass)
Period: 07/09/2021 – 28/09/2021
From: KIT



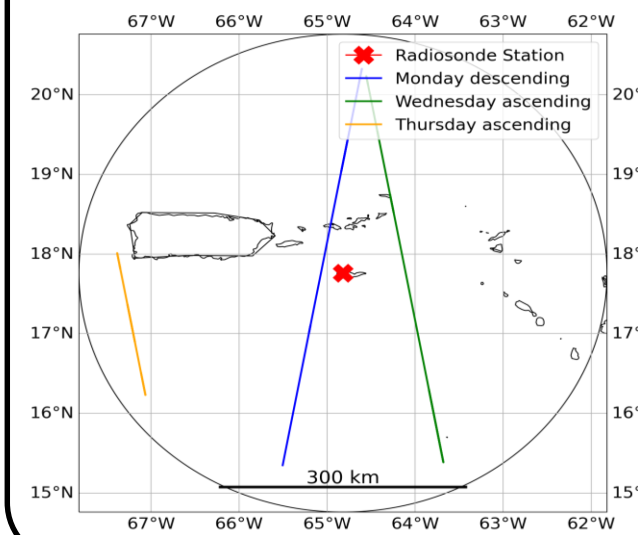
Puerto Rico (Mayagüez)

32 (4 corresponding to Aeolus overpass)
Period: 24/08/2021 – 28/09/2021
From: Univ. of Oklahoma (NASA CPEX-AW)



Saint Croix (Carambola)

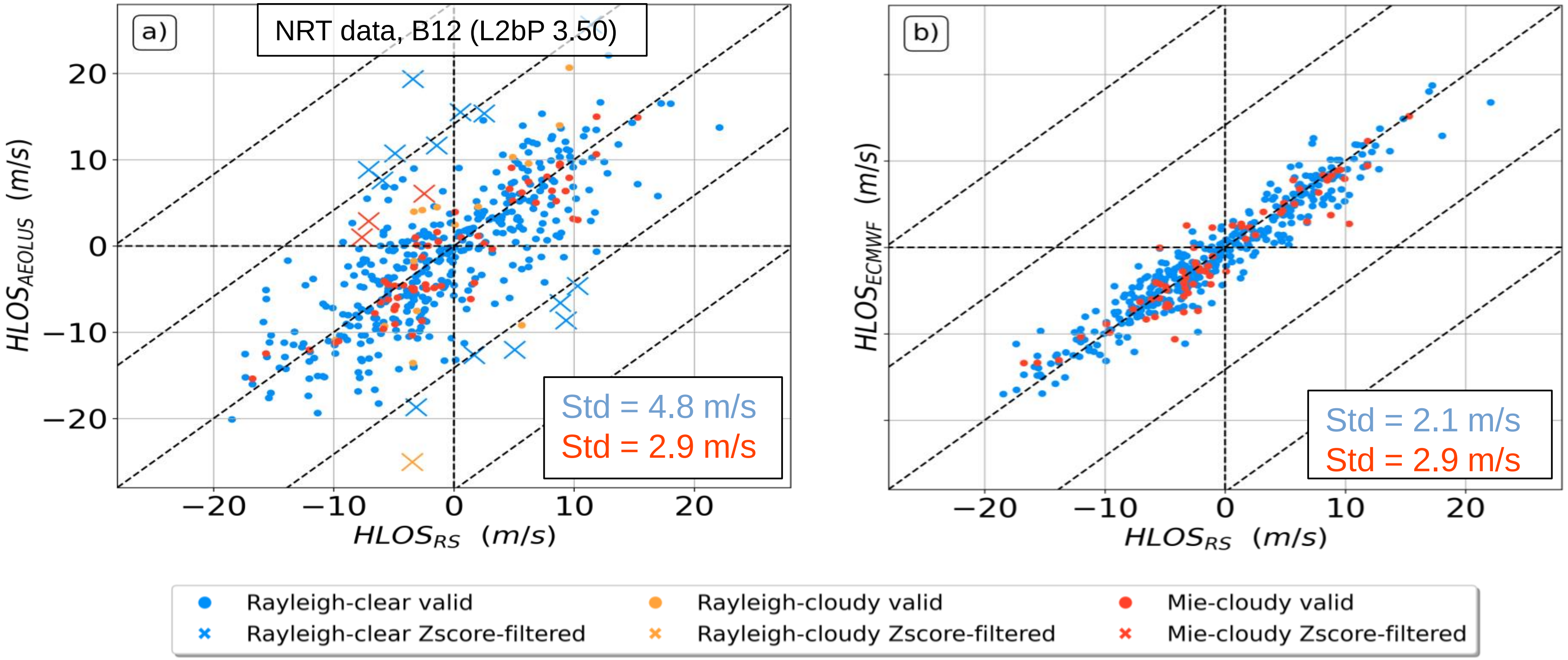
73 (7 corresponding to Aeolus overpass)
Period: 19/08/2021 – 14/09/2021
From: Univ. of Utah (NASA CPEX-AW)



- A total of **20 radiosonde profiles** (12 ascending / 8 descending, co-location radius 50 km to 340 km)
- Radiosondes launched between **19/08 and 28/09 2021**
- Bin-to-bin comparisons: Rayleigh-clear (**#384**), Mie-cloudy (**#59**) and Rayleigh-cloudy (**#16**)

Comparative analysis with Aeolus L2B and ECMWF model equivalents

- Comparison of RS HLOS winds with Aeolus L2B (left) and ECMWF model equivalents (right)



QC

- Validity flag = 1, EE of 8 m/s (Ray) and 4 m/s (Mie)
- Modified Z-score with threshold = 3

Model equivalents:

- Good agreement with RS
- Co-location parameters are appropriate

Systematic and random errors

Aeolus random error:

$$\sigma_{\text{Aeolus}} = \sqrt{\sigma_{\text{tot}}^2 - \sigma_{\text{RS}}^2 - \sigma_{\text{rep}}^2}$$

Radiosonde error:

$$\sigma_{RS} = 0.7\, m/s$$

Representativeness error:

$$\sigma_{rep} = 1.5 - 2.5\, m/s$$

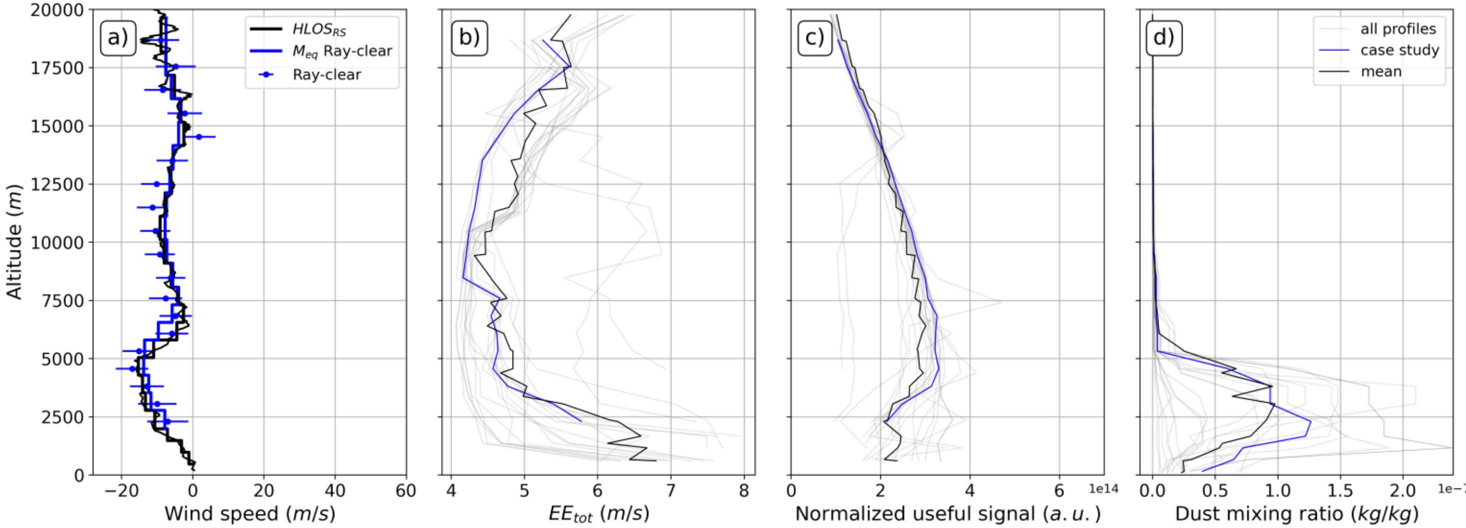
See Martin et al. (2021)

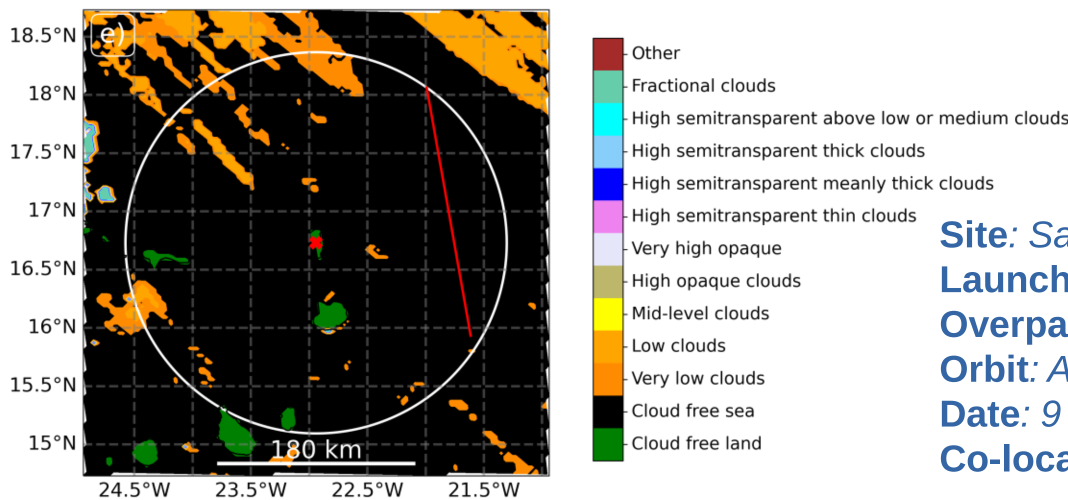
	Rayleigh-clear			Mie-cloudy	
	σ_{Aeolus} 2–16km	σ_{Aeolus} 16–20km	μ	σ_{Aeolus} 2–16km	μ
Ascending	3.4 – 3.9	4.0 – 4.4	-0.2±0.3	1.1 – 2.3	-0.8±0.6
Descending	4.3 – 4.7	4.4 – 4.9	-0.9±0.4	0.5 – 2.1	-1.1±0.4
All	3.8 – 4.3	4.3 – 4.8	-0.5±0.2	1.1 – 2.3	-0.9±0.3
ESA	2.5	3	0.7	2.5	0.7

- **Systematic error** meets mission requirements (0.7 m/s) for both, **Rayleigh** and **Mie**
- **Random error** larger for Rayleigh (lower signal levels) and within specs for Mie
- **Hint of orbital dependent bias** (ascending/descending) for Rayleigh winds.

NRT data, B12 (L2bP 3.50)

Case study 1: Clear-sky





Site: *Sal Airport*
Launch: *18:45 UTC*
Overpass: *19:24 UTC*
Orbit: *Ascending*
Date: *9 September 2021*
Co-location radius: *180 km*

- **Low dust concentration** (CAMS)
- Cloud type (NWSAF): **Mostly cloud-free** with some low-level clouds

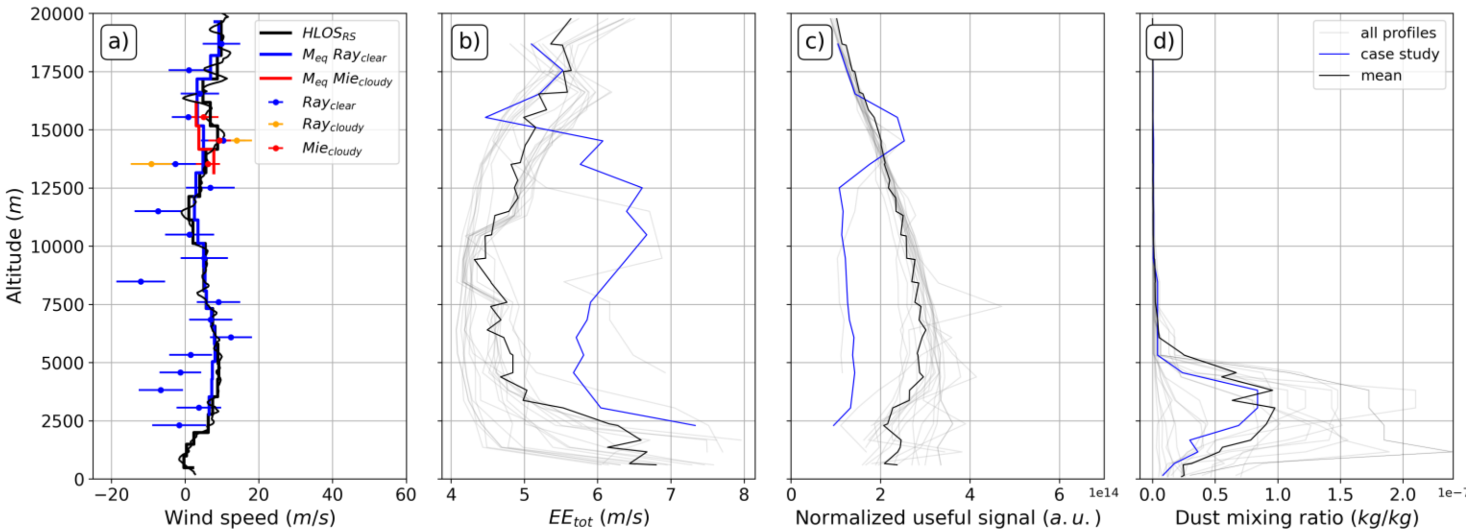
➢ **Good agreement** between Rayleigh-clear and Radiosonde HLOS

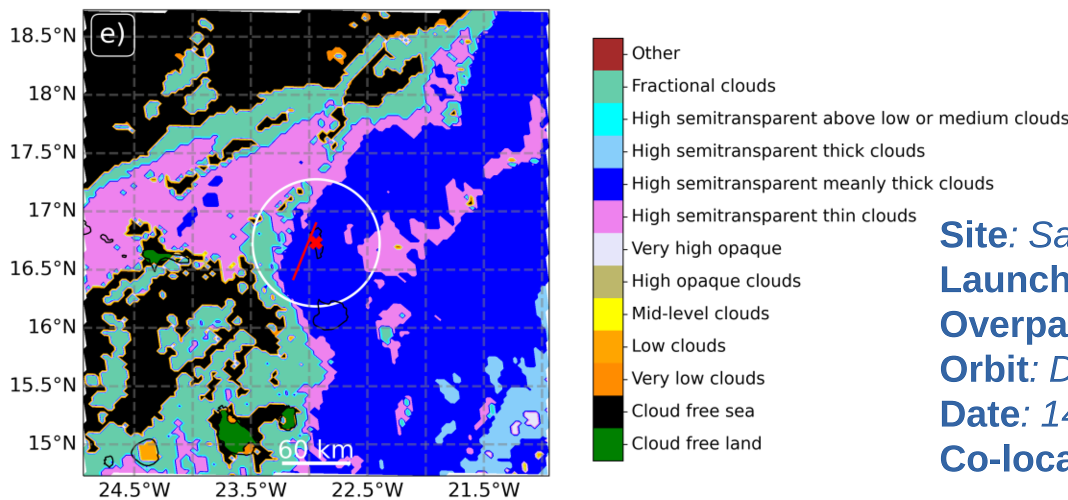
➢ EE larger at the upper and lower troposphere (**SAL**)

➢ Useful signal inversely proportional to EE

NRT data, B12 (L2bP 3.50)

Case study 2: Cloudy sky





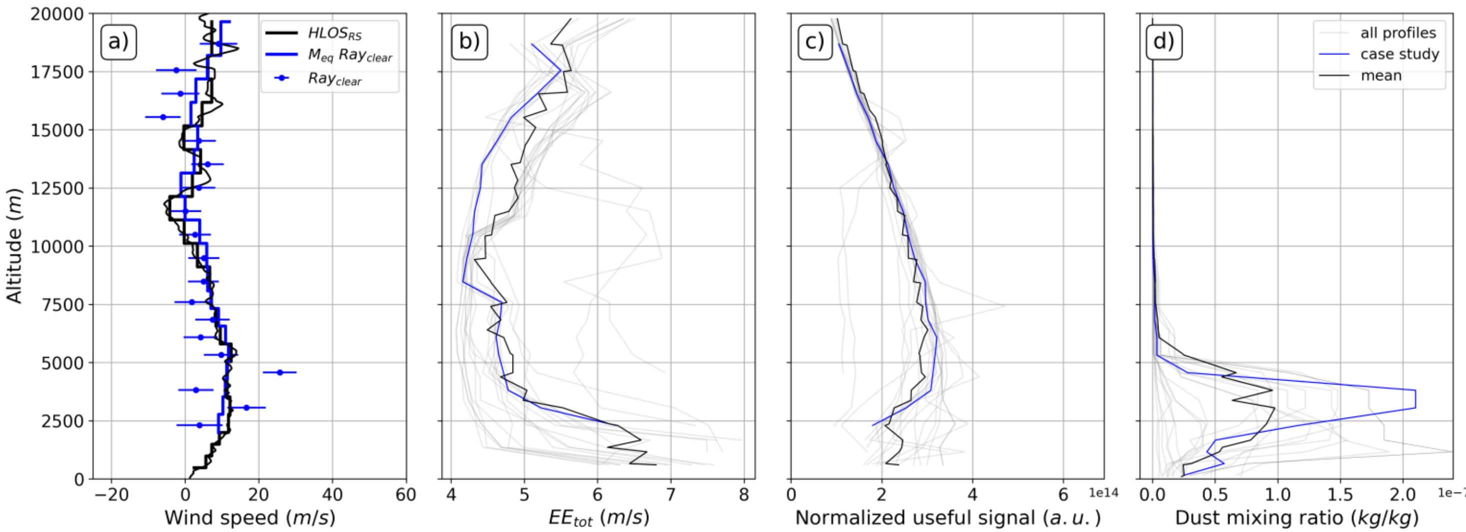
Site: *Sal Airport*
Launch: *07:00 UTC*
Overpass: *07:28 UTC*
Orbit: *Descending*
Date: *14 September 2021*
Co-location radius: *60 km*

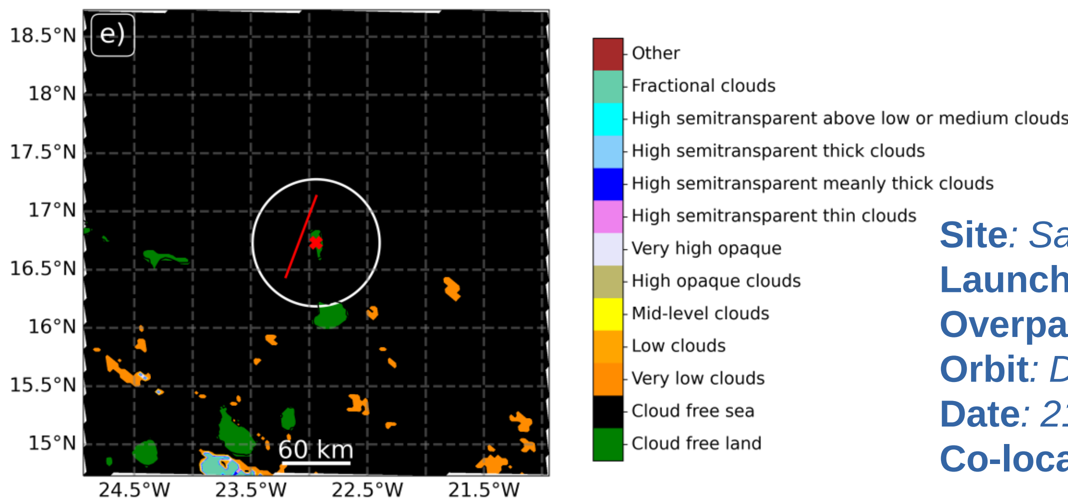
- **Low dust concentration** (CAMS)
- Cloud type (NWSAF): **Mostly high semitransparent clouds**

- ➢ **Below cloud base** (13km), Rayleigh-clear follows an **irregular pattern**
- ➢ Below the cloud base**, EE is larger** (~6 m/s) – lower signal levels
- ➢ Large EE at cloud top, and lower below cloud base

NRT data, B12 (L2bP 3.50)

Case study 3: Dusty conditions





Site: *Sal Airport*
Launch: *06:50 UTC*
Overpass: *07:28 UTC*
Orbit: *Descending*
Date: *21 September 2021*
Co-location radius: *60 km*

- **High dust concentration** (CAMS)
- Cloud type (NWSAF): **Mostly cloud-free** with some low level clouds

- Rayleigh-clear **outliers below 5 km** (SAL) could be linked to a cross-talk. **No Mie-winds** available **in dust layer**
- EE larger at the upper troposphere and the SAL
- Useful signal inversely proportional to EE

NRT data, B12 (L2bP 3.50)

Error dependency of Rayleigh-clear with Cloud/Dust concentration

	Cloud < 50 %		Cloud > 50 %		Cloud > 75 %	
	$Dust_{NO}$	$Dust^{*}$	$Dust_{NO}$	$Dust^{*}$	$Dust_{NO}$	$Dust^{*}$
EE_{tot}	4.8	5.4	5.0	5.6	5.3	5.8
STD	4.3	5.0	5.1	5.9	5.6	6.4
COUNT	234	28	64	52	38	24

* Threshold for „dust“ = 10^{-7} kg/kg

- Reported EE is larger than the STD in clear sky conditions and is becoming gradually too low with the increasing presence of clouds and dust (Possibly owing to lower signal levels or to a cross-talk)

NRT data, B12 (L2bP 3.50)

Error dependency of Mie-cloudy with Cloud/Dust concentration

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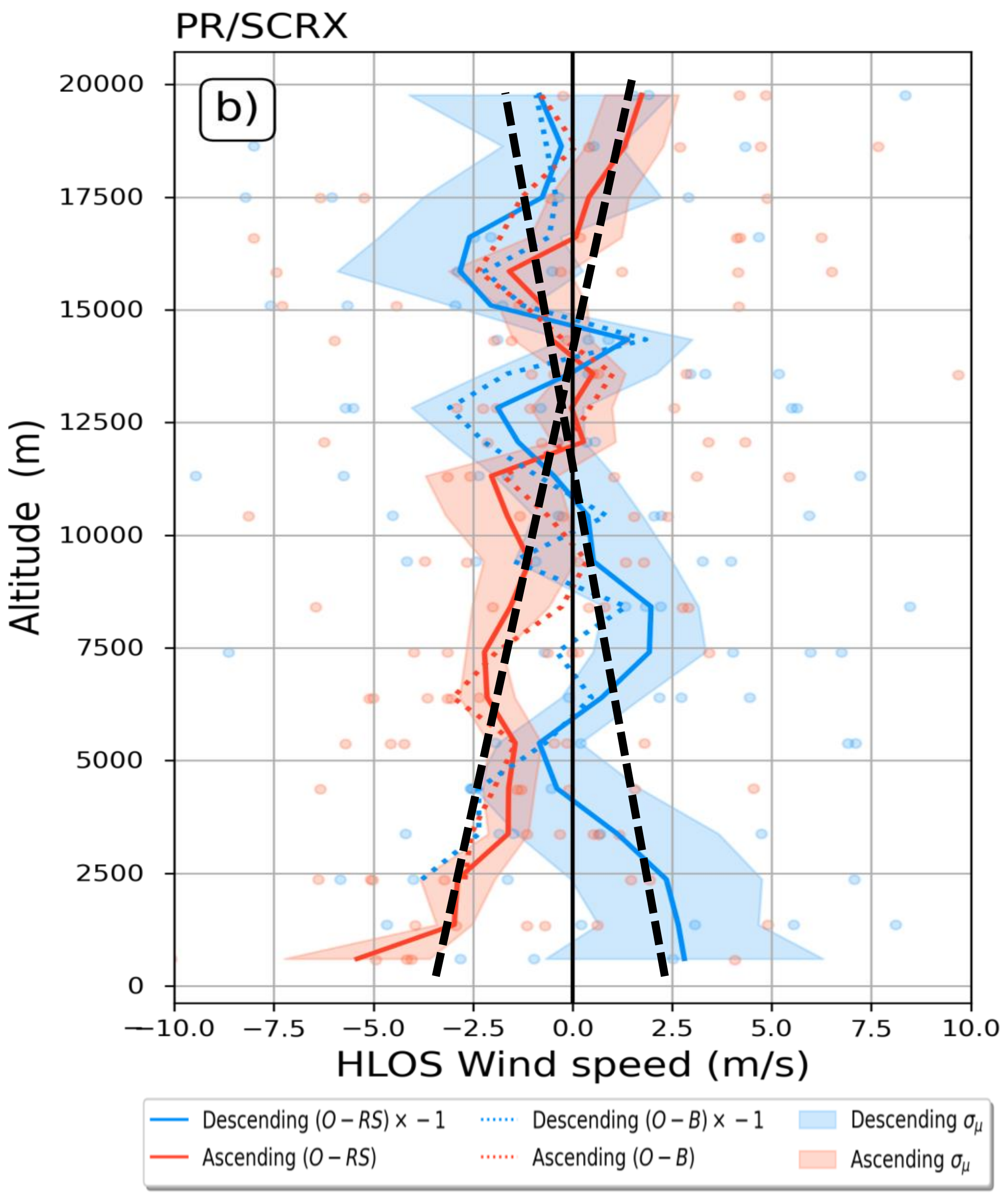
	Cloud < 50 %		Cloud > 50 %		Cloud > 75 %	
	$Dust_{NO}$	$Dust^*$	$Dust_{NO}$	$Dust^*$	$Dust_{NO}$	$Dust^*$
EE_{tot}	3.7	3.6	3.4	3.5	3.2	3.4
STD	2.96	1.53	1.89 ⟷	2.95	1.68 ⟷	3.18
COUNT	11	9	16	23	8	13

* Threshold for „dust“ = 10^{-9} kg/kg

- The obtained **STD is generally smaller than the EE** reported in the data product
- **Clear sky: Random error with dust, smaller than without dust** → dust return strong enough to obtain “good measurements (as from clouds)
- **Cloudy conditions (>50%): Random error with dust, larger than without dust** → Attenuation by dust weakens the backscatter return from clouds and hence reduces the quality of Mie return

Orbital-dependant Bias in Rayleigh-clear channel



- **Height-dependent bias** visible with respect to both radiosondes and ECMWF model equivalents (see also Borne et al, 2023 – West Africa based on model equivalents)
- **Underlying cause for this bias remains unknown** (could be related to an instrument calibration)

NRT data, B12 (L2bP 3.50)

Conclusions

In the framework of **JATAC**, 20 radiosondes launched from Sal, Saint Croix and Puerto Rico were used to validate Aeolus over the **tropical Atlantic** during **August-September 2021**.

Rayleigh-clear (NRT data, B12 - L2bP 3.50):

NRT data, B12 (L2bP 3.50)

- Random error: **3.8 – 4.3 m/s (2-16 km) and 4.3 – 4.8 m/s (16-20 km)**
- Systematic errors: **-0.5 ± 0.2 m/s** (within specs)
- **Below clouds and within dust layers**, the quality of **Rayleigh-clear is degraded** when the useful signal is reduced; associated with underestimation of L2B EE (cross-talk?)
- **Gross outliers** (large departures and low EE) are found **at all altitudes** and under **all environmental conditions**; statistical nature of the error distribution
- Observational confirmation of **height (and orbital)-dependent bias** (root-cause unknown)

Mie-cloudy (NRT data, B12 - L2bP 3.50):

- Random error: **1.1 – 2.3 m/s** (2-16 km)
- Systematic errors: **-0.9 ± 0.3 m/s**
- **Mie-cloudy does not sample within dust layers:** rejected by QC, weak backscatter of dust
- Mie errors decrease with cloud cover, while increases in the presence of dust

Borne et al. "Validation of Aeolus L2B products over the tropical Atlantic using radiosondes." EGUsphere 2023 (Submitted)