Aeolus L2B products validation with ground-based CDLs net over China and products application on aerosol observation

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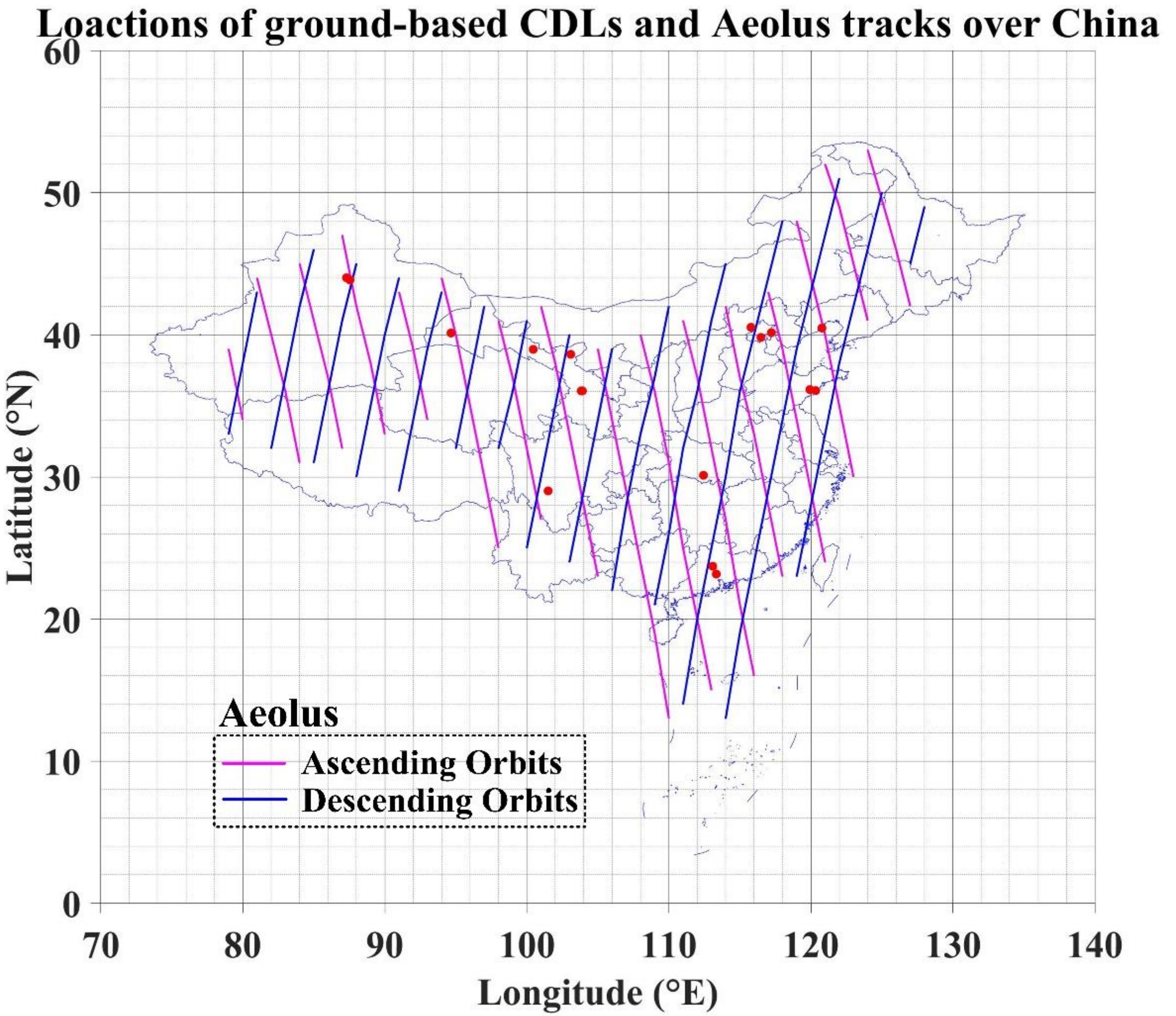
CONTENT

- **Validation of ALADIN:**
  - **L2B products validation with ground-based CDLs over China**
- **Science exploration with ALADIN:**
  - **1/2 Sahara dust aerosol transport observation**
  - **2/2 Correlation between marine aerosol and wind**

Validation: Aeolus L2B products with CDL network

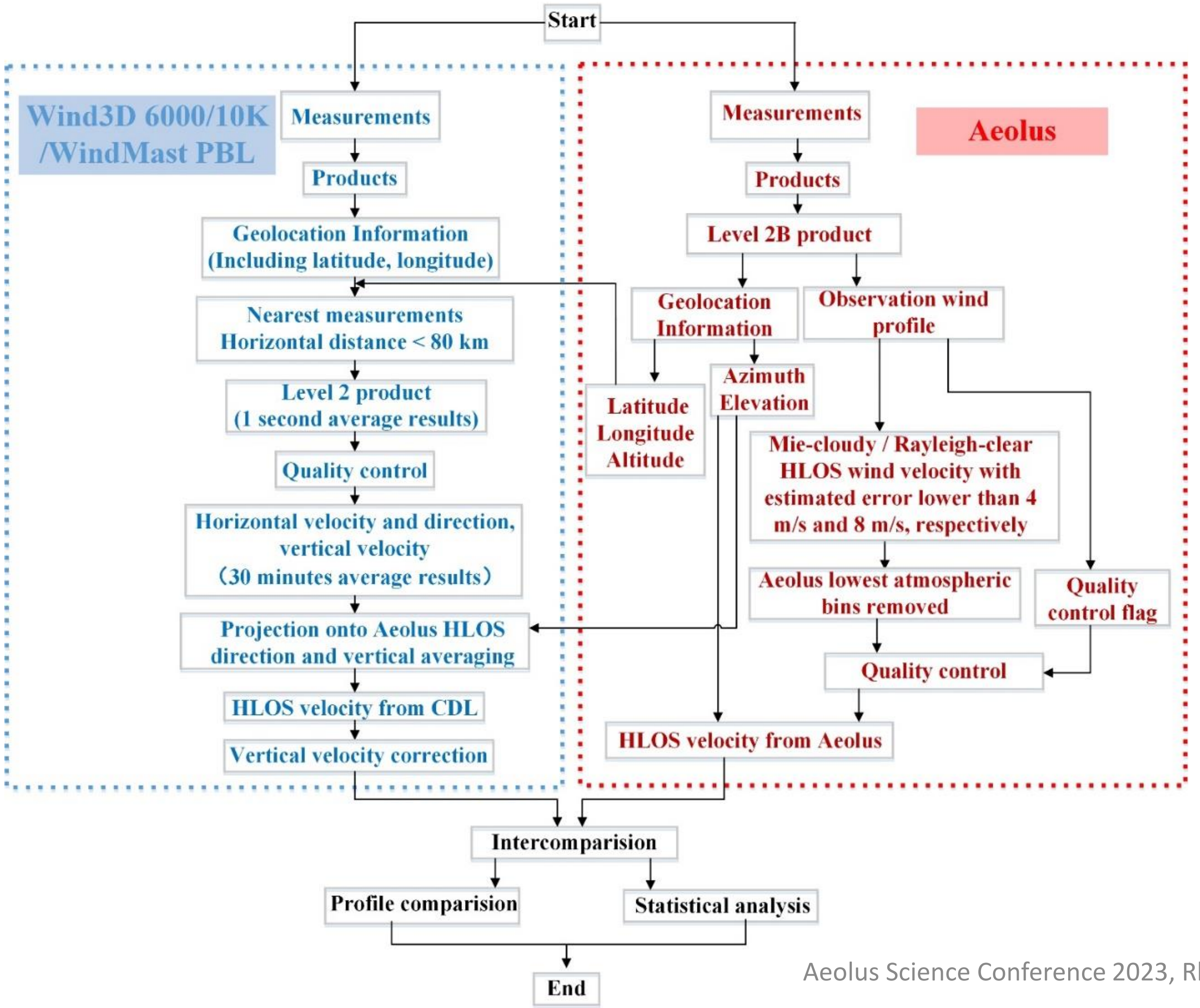
Qualification	Specifications	
	Wind3D 6000	WindMast PBL
Wavelength	1550 nm	1550 nm
Repetition rate	10 kHz	10 kHz
Pulse energy	160 μJ	100 μJ
Pulse width	100 ns to 400 ns	100 ns to 400 ns
Detection range	**80 m to 6000 m**	**30 m to 4000 m**
Data update rate	4 Hz	4 Hz
Range resolution	15 m to 60 m	15 m to 30 m
Wind speed accuracy	**≤0.1 m/s**	**≤0.1 m/s**
Wind speed range	**±75 m/s**	**±75 m/s**
Wind direction accuracy	0.1°	0.1°

mainly measure wind profiles in atmospheric/planet boundary layer (PBL) and lower troposphere



Ground-based CDL observation sites of the VAL-OUC campaign from January to December 2020

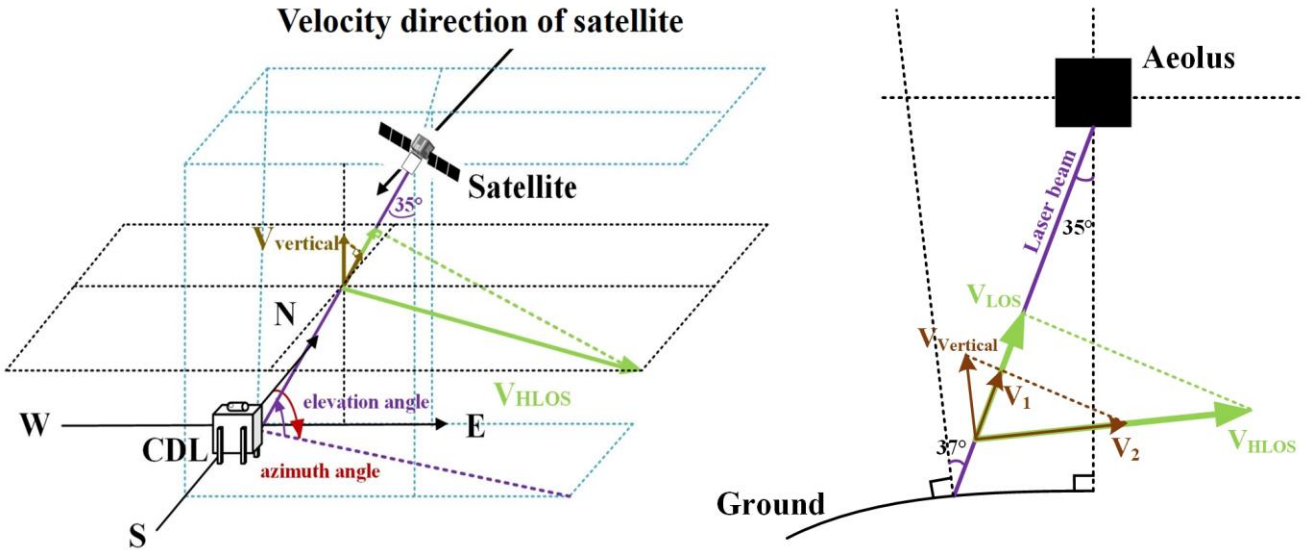
Intercomparison strategy



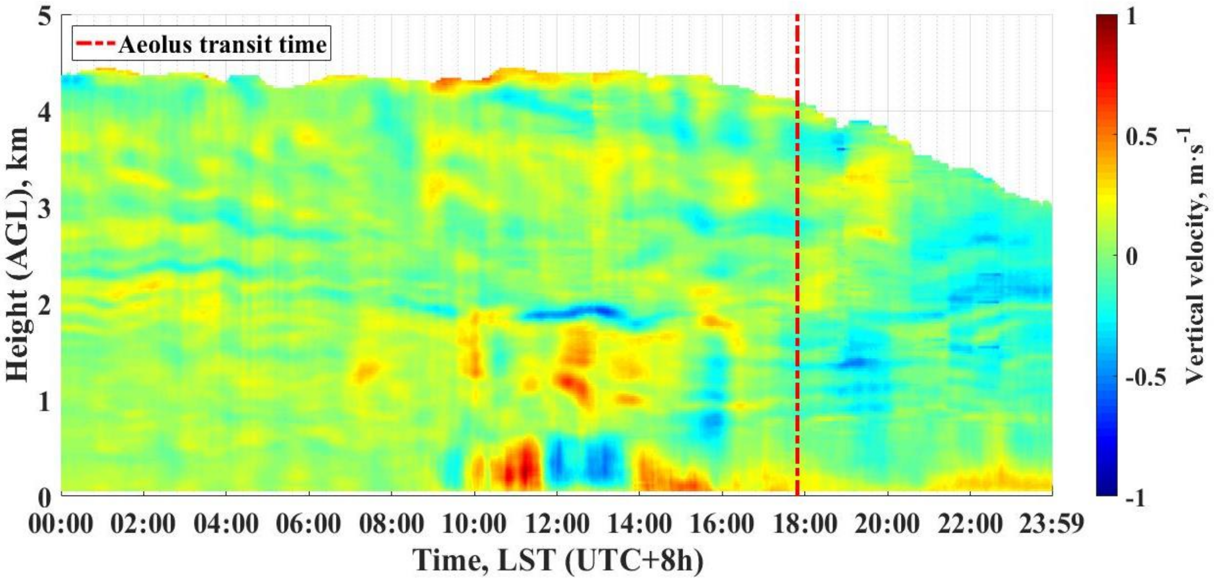
- Profiles match
- Quality control
- Average of CDL wind profiles (time and vertical)
- CDL wind switching to HLOS wind
- Profile comparison and statistical analysis

Validation: Aeolus L2B products with CDL network

Influence of vertical velocity on V_{HLOS}



The influence of $V_{vertical}$ on V_{HLOS} is V_2 = Vvertical $\cdot \cos 37° / \sin 37°$, i.e. V_2 = Vvertical $\cdot \cot 37°$.

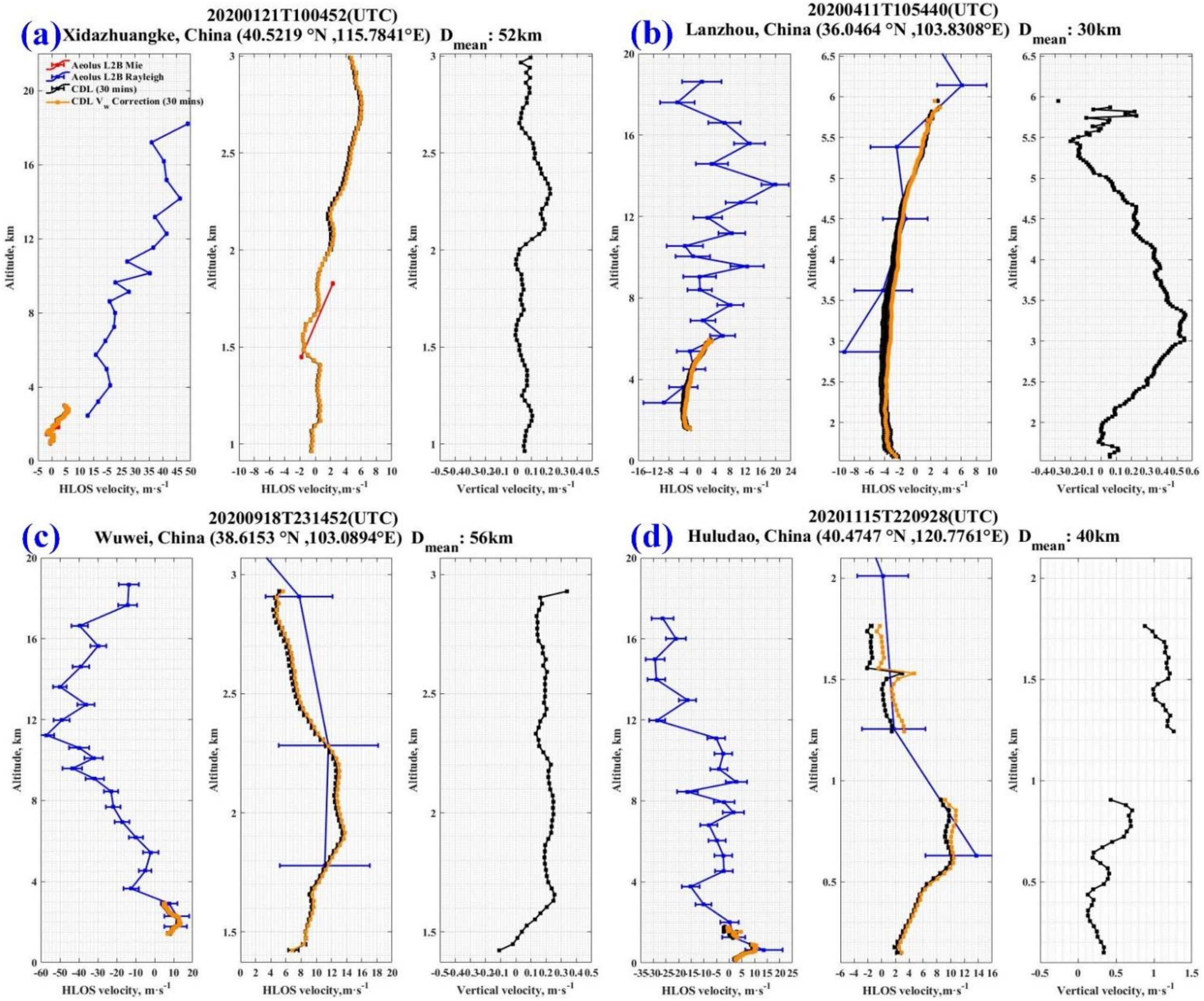


Vertical wind measurement case by CDL with a moving average of 30 minutes, in Qingdao China, on 16 November 2020.

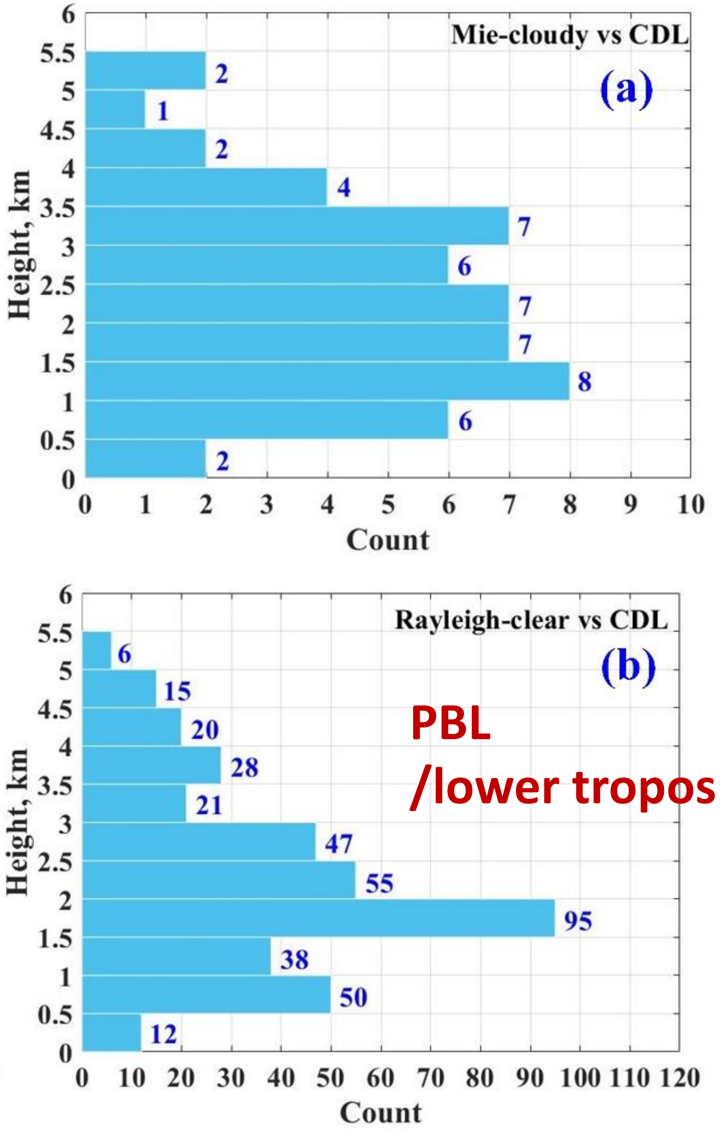
typical vertical velocity: **0 m/s to ±0.40 m/s**	HLOS retrieved difference: **±0.53 m/s**
Maximum/minimum vertical velocity: **around 1 m/s / -1 m/s**	**±1.33 m/s**

- In the atmospheric boundary layers, where the Vertical convections are common, the influence of vertical velocity on HLOS wind retrieval can not be ignored.
- The vertical velocity correction of CDL-HLOS is only used in the profiles analysis for the method discussion and the corrected CDL HLOS results are not used in the statistical comparison.

Validation: Aeolus L2B products with CDL network

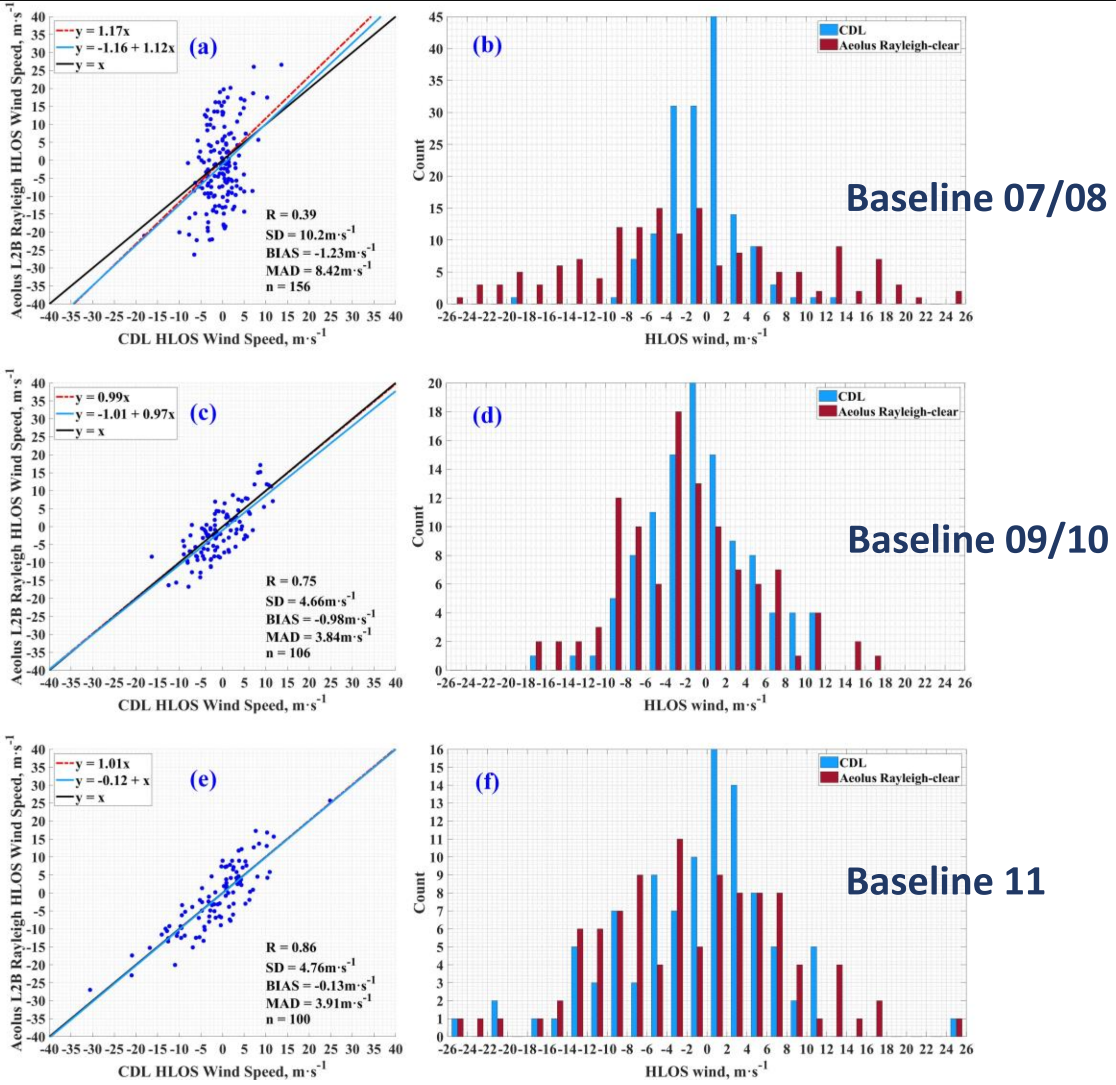


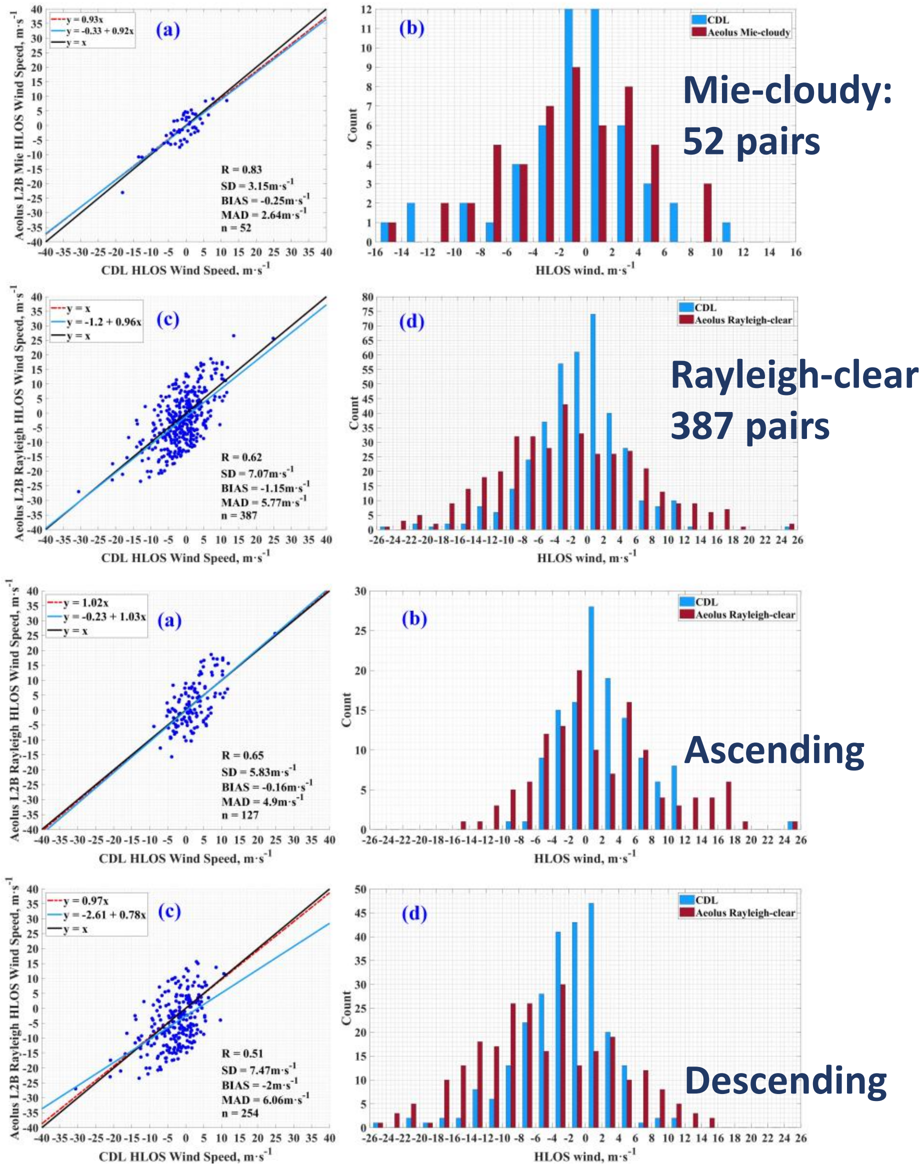
- Red lines: Aeolus L2B Mie-cloudy HLOS profiles;
- Blue lines: Aeolus L2B Rayleigh-clear HLOS profiles;
- Black lines: CDL-retrieved HLOS profiles；
- Yellow lines: CDL-retrieved HLOS profiles after vertical velocity correction.



Counts of data pairs at different height ranges

Validation: Aeolus L2B products with CDL network





Statistical comparison analyses by **Baselines, Mie/Rayleigh channels and ascending/descending** using the data of 2020

Conclusion and outlook

✓ The **influence of vertical velocity on V_{HLOS}** in the wind retrieval should be considered.

✓ As **the Baseline updating**, the Aeolus L2B HLOS winds (both Mie-cloudy and Rayleigh-clear, mainly in the PBL and the lower troposphere) fitting with the CDL HLOS winds **becomes better**.

✓ In the PBL and the lower troposphere, Aeolus **L2B Rayleigh-clear channel** can also provide reasonable HLOS wind.

➢ The CDL network in China has been being developed since 2018. The wind profiles from 2018 to 2023 all over China can still be reliable of Aeolus for the validation of FM-A/FM-B/FM-A reprocessing data baselines.

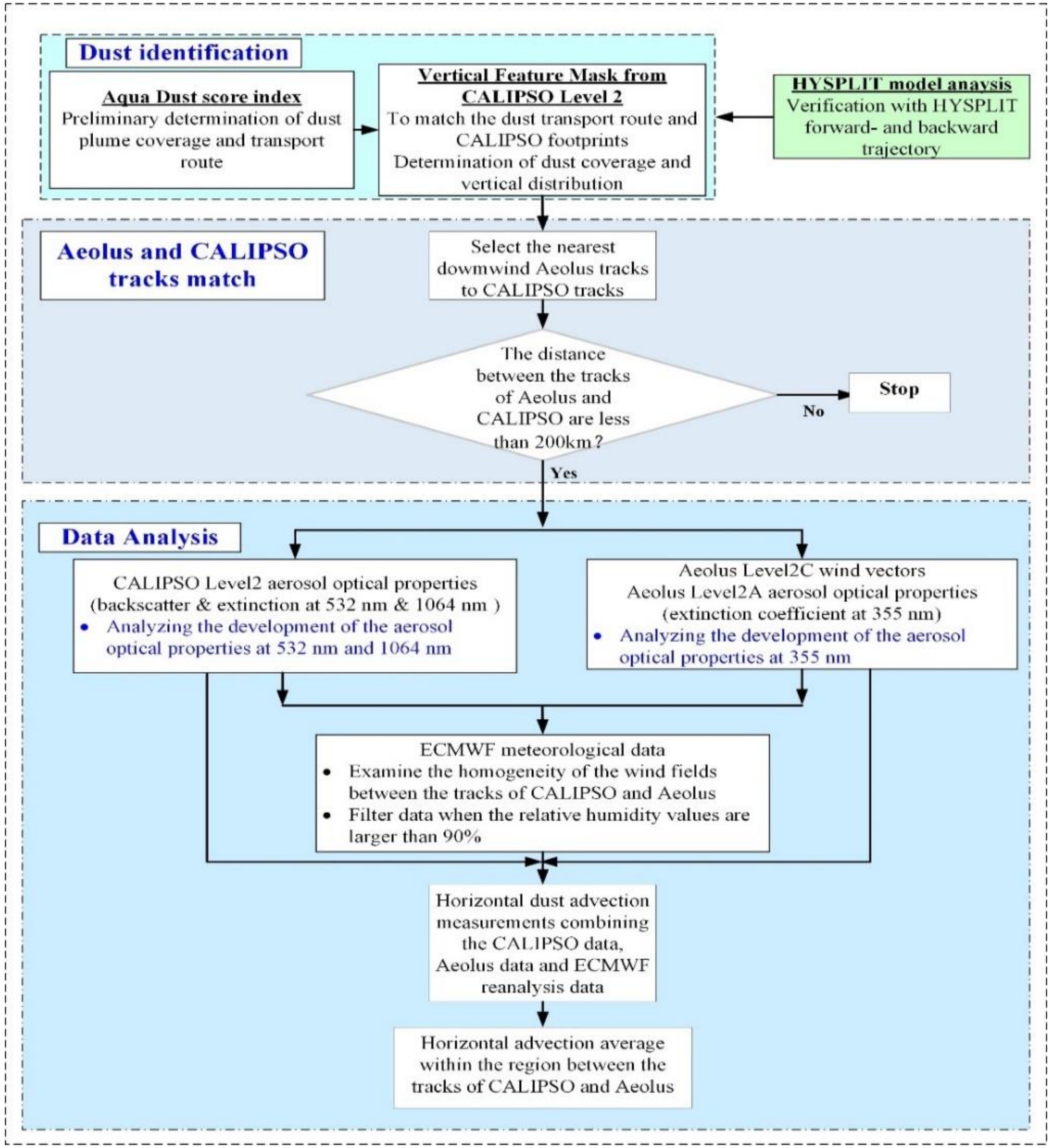
*Ref.: Wu, S., Sun, K., Dai, G., et al., **Inter-comparison of wind measurements in the atmospheric boundary layer and the lower troposphere with Aeolus and a ground-based coherent Doppler lidar network over China, AMT**, 2022, Special issue: Aeolus data and their application*

Science exploration: 1/2 Sahara dust aerosol transport observation

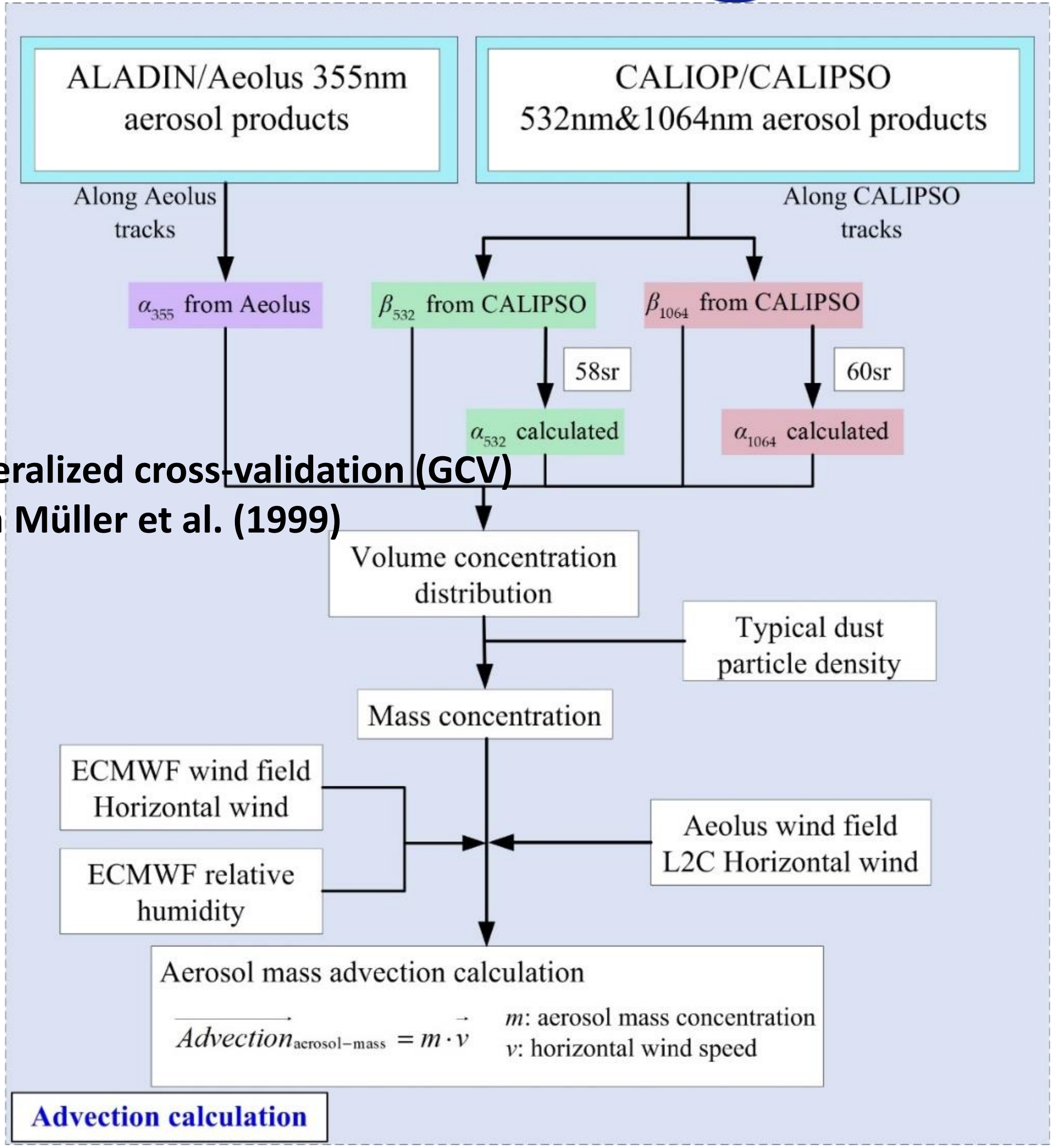
Data/models used

<table>
<tr><th>Instruments
/Models</th><th>Products</th></tr>
<tr><td>ALADIN
/Aeolus</td><td>L2A (baseline 10)
Particle optical properties:
➢ <u>extinction coefficient@355nm</u>
L2C (baseline 10)
➢ <u>Reanalysis wind vector profiles assimilated with L2B HLOS wind</u></td></tr>
<tr><td>CALIOP
/CALIPSO</td><td>L2 Aerosol profile
➢ <u>Extinction coefficient @532nm/1064nm</u>
➢ <u>Backscatter coefficient @ 532nm/1064nm</u>
L2 Vertical Feature Mask
➢ <u>Aerosol type</u></td></tr>
<tr><td>ERA5
/ECMWF</td><td>0.25°×0.25°, hourly, 37 pressure levels
➢ <u>Wind vector</u>
➢ <u>Relative humidity</u></td></tr>
<tr><td colspan="2">The Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model</td></tr>
</table>

Science exploration: 1/2 Sahara dust aerosol transport observation



Dust identification, Aeolus and CALIPSO tracks match and data procedures

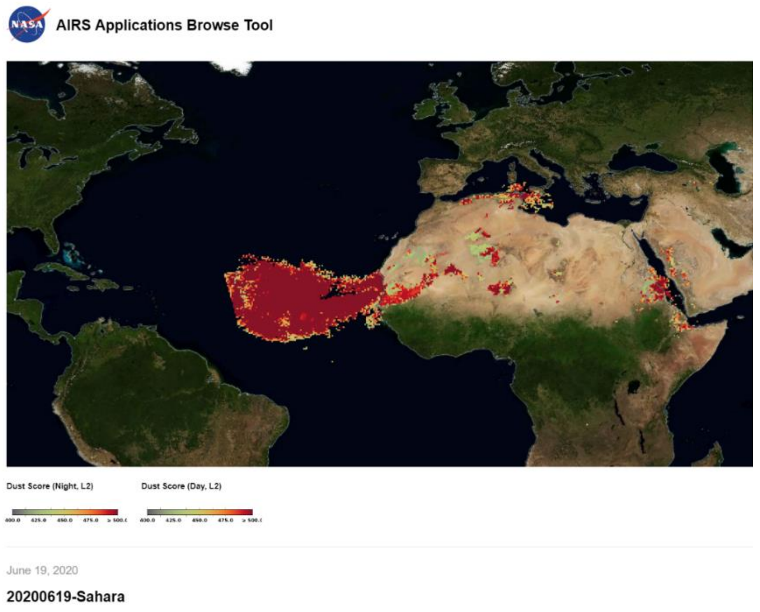


Generalized cross-validation (GCV) from Müller et al. (1999)

The flowchart of the dust mass advection calculation procedure

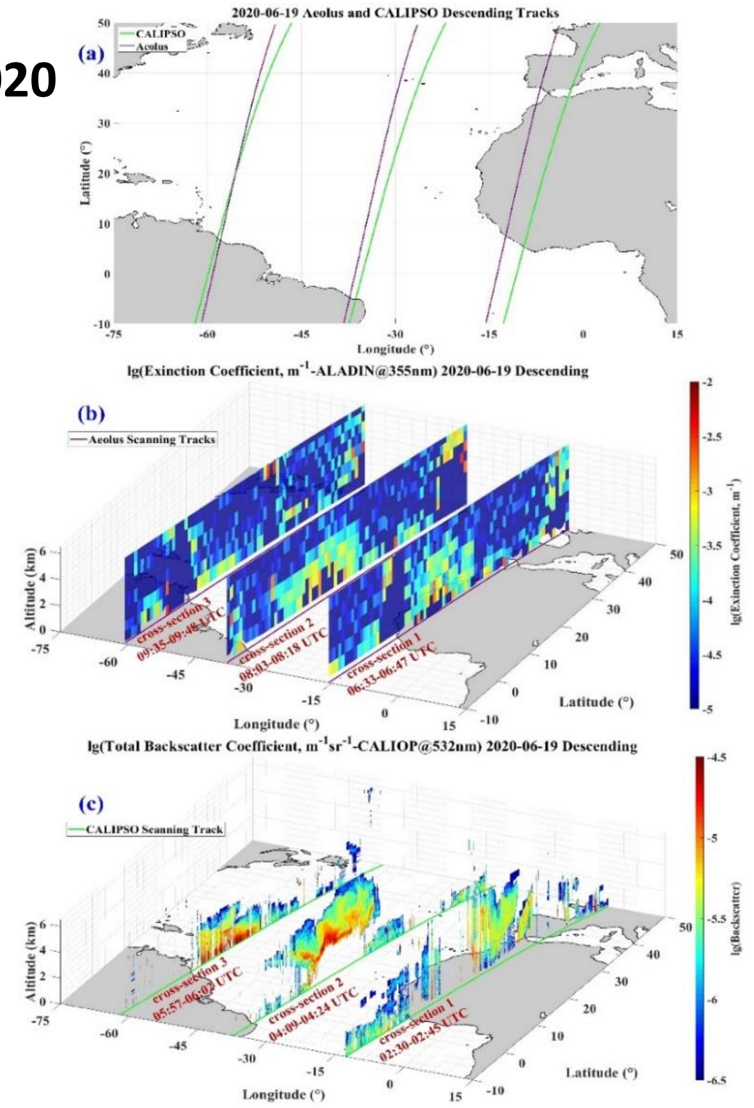
Science exploration: 1/2 Sahara dust aerosol transport observation

CASE 1: Observation snapshot on 19 June 2020

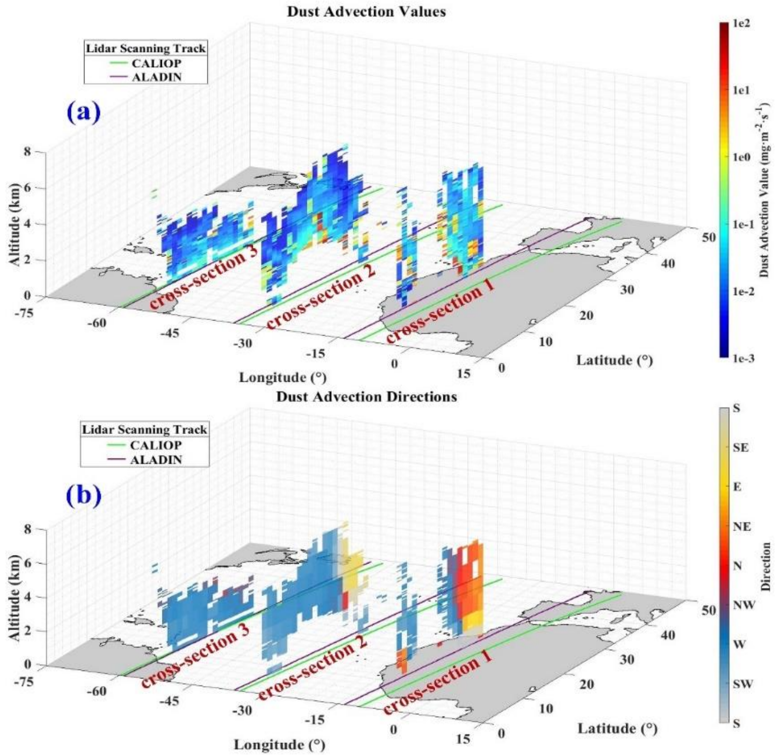


The Dust Score Index provided by AIRS/Aqua on 19 June 2020

- From the measurement results on 19 June 2020, the dust plumes are captured over the emission region (Western Sahara), the transport region (middle Atlantic) and the deposition region (western Atlantic).
- Indicating that the dust plume area over the Atlantic on this day is quite enormous and that this dust transport event is massive and extensive.



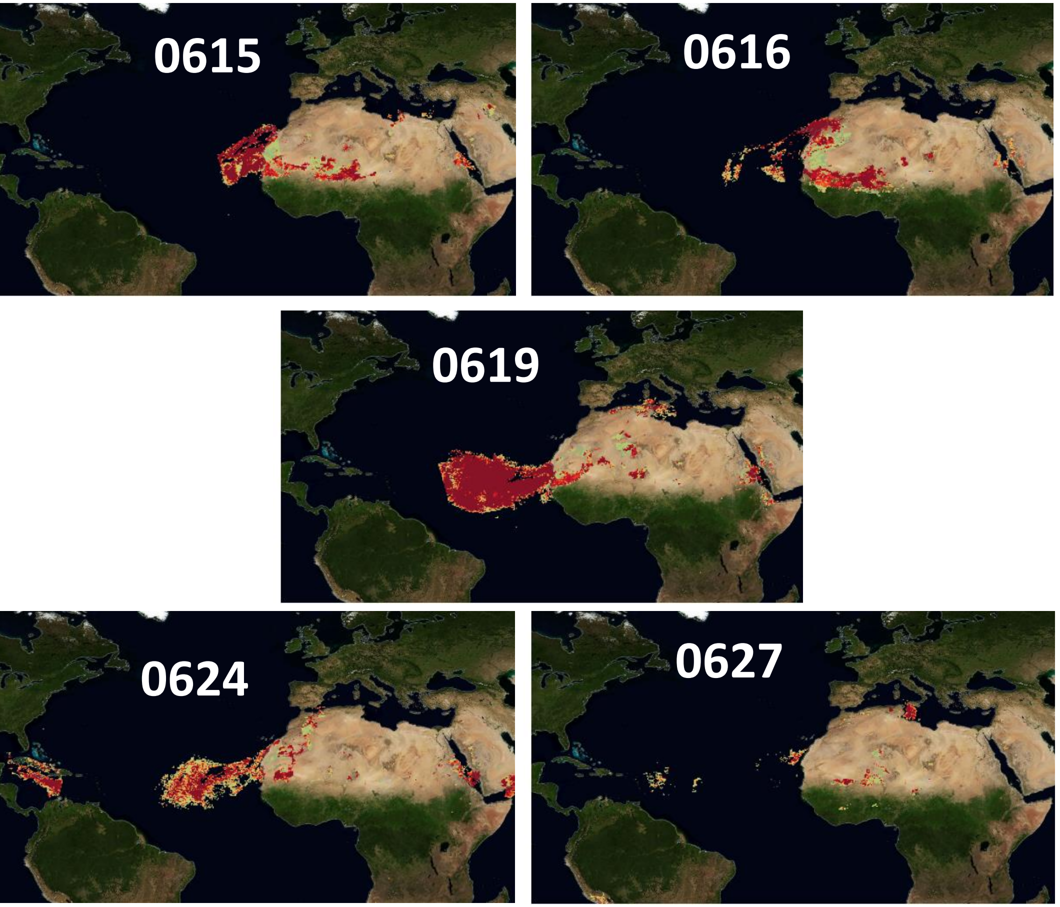
Observation cross-sections of Aeolus and CALIPSO on 19 June 2020



The dust advection calculated with data from ALADIN, CALIOP

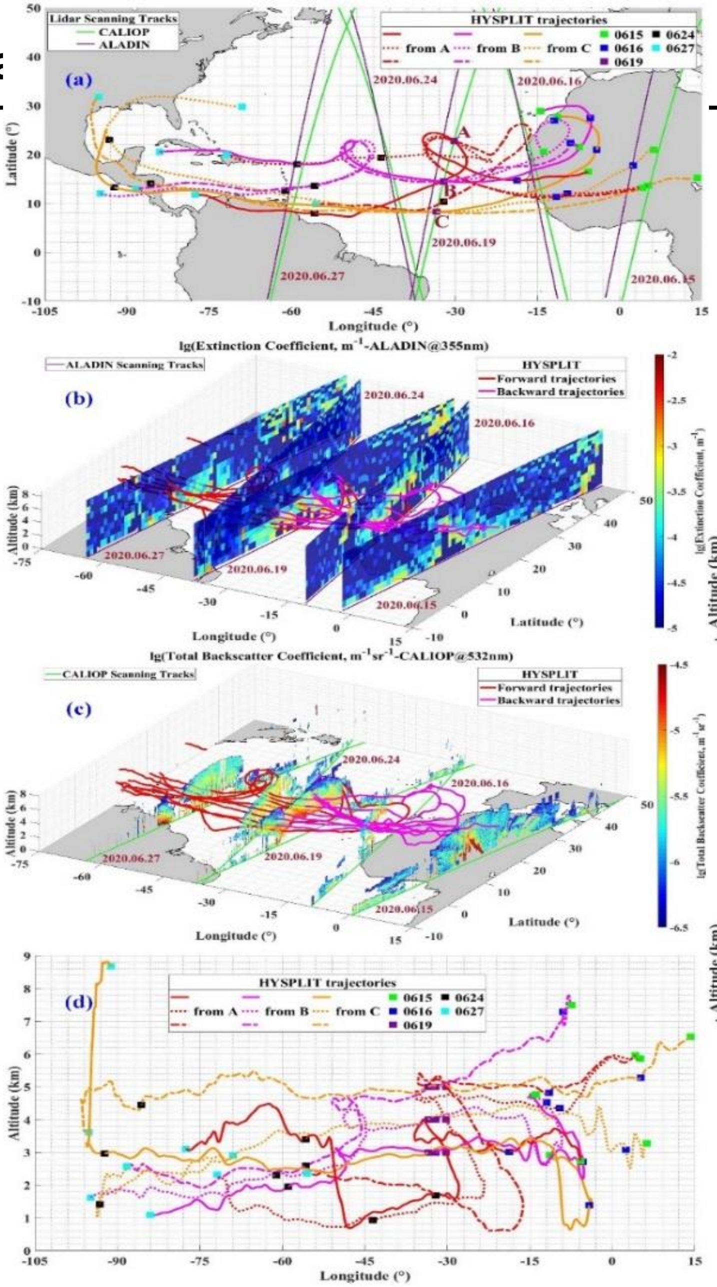
Science exploration: 1/2 Sahara dust aerosol tra

CASE 2: whole transport of "Godzilla" event

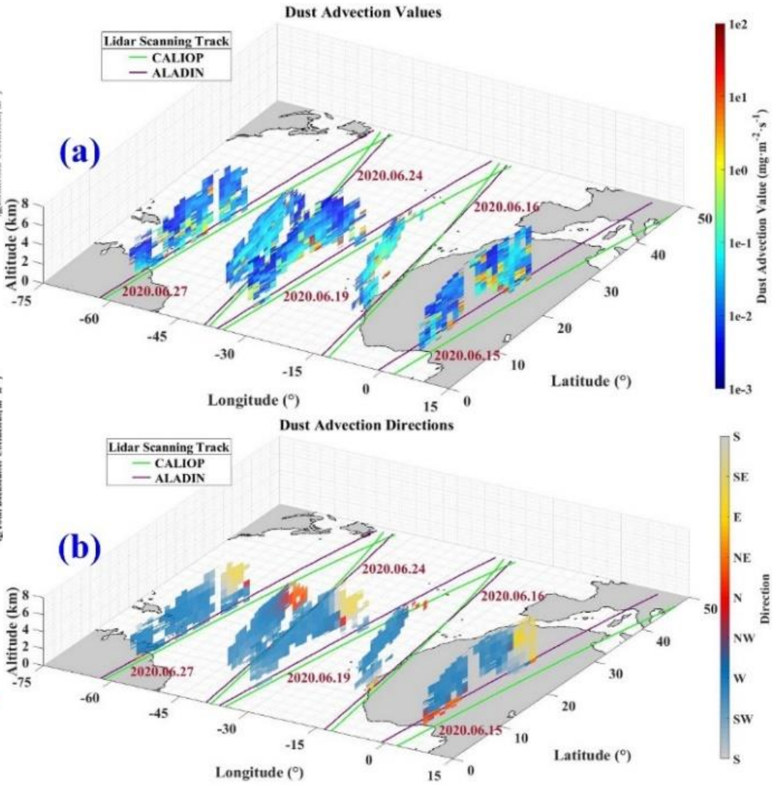


The Dust Score Index provided by AIRS/Aqua at different stages, including emission, transport, dispersion and deposition

The ALALIN cross-sections and the CALIOP cross-sections correspond well to the dust score and HYSPLIT trajectories, temporally and spatially.



Observation of dust event during 15 and 27 June 2020 with ALADIN and CALIOP and HYSPLIT trajectories



The dust advection calculated with data from ALADIN, CALIOP

Summary and Conclusion

✓ ALADIN has the ability

- on the observations of dust optical properties and wind fields
- on tracking the dust events
- calculating the dust mass advection with the combination of satellite and model data.

✓ The huge dust plumes were trapped and transported in the northeasterly trade-wind zone between latitudes of 5◦ and 30◦ N and altitudes of 0 and 6 km.

✓ Aeolus provided the observations of the dynamics of this dust transport event in the Saharan Air Layer.

Ref. : Dai, G., Sun, K., Wang, X., Wu, S. et al., ***Dust transport and advection measurement with spaceborne lidars ALADIN and CALIOP and model reanalysis data, ACP****, 2022, Special issue: Aeolus data and their application*

Science exploration: 2/2 Correlation between marine aerosol and wind

Background

Ref. : http://www.oceansinc.org/2013/04/biological-activity-alters-ability-of.html

marine aerosol/sea spray aerosol

- Interaction with solar radiation
- Impact on retrieval of spaceborne ocean color lidar

…

Wind is the primary driver of the emission of marine aerosol

Correlation between **marine aerosol optical properties** and **wind speed**

Data used

Instruments	Products
ALADIN /Aeolus	**L2A (Baseline 11-14)** Particle optical properties: ➢ extinction coefficient ➢ backscatter coefficient NWP: ➢ Relative Humidity (RH) ➢ Molecular backscatter coefficient **L2C (Baseline 09-14)** ➢ Reanalysis wind vector profiles assimilated with L2B HLOS wind
CALIOP /CALIPSO	**L2 Vertical Feature Mask** ➢ Aerosol type

Time range of the data： April 2020 to June 2022

Science exploration: 2/2

Step 1: Selection of study areas with CALIOP

Select Ocean areas far from land
Reduce the influence of terrestrial aerosols

CALIOP VFM products
Statistical analysis of aerosol types in the selected area

Marine aerosol dominates? No → **stop**

Yes

Select areas dominated with marine aerosol

Step 2: Data processing of Aeolus products

Level 2A product
- **Extinction coefficient at 355 nm**
- **Backscatter coefficient at 355 nm**

Quality control
- Valid data selection with QC flags
- Outliers elimination with Tukey's test

NWP model parameters from Level 2A product
- Relative humidity (RH)
- Molecular backscatter coefficient

Cloud screening
Retain data with: RH < 94%; backscatter ratio < 2.5

Backscatter coefficient correction
Correct with: Depolarization ratio = 2% of marine aerosol

NWP model winds from Level 2C product
- U component of wind vectors
- V component of wind vectors

Wind speed

Pure marine aerosol α and β

Step 3: Data analyses

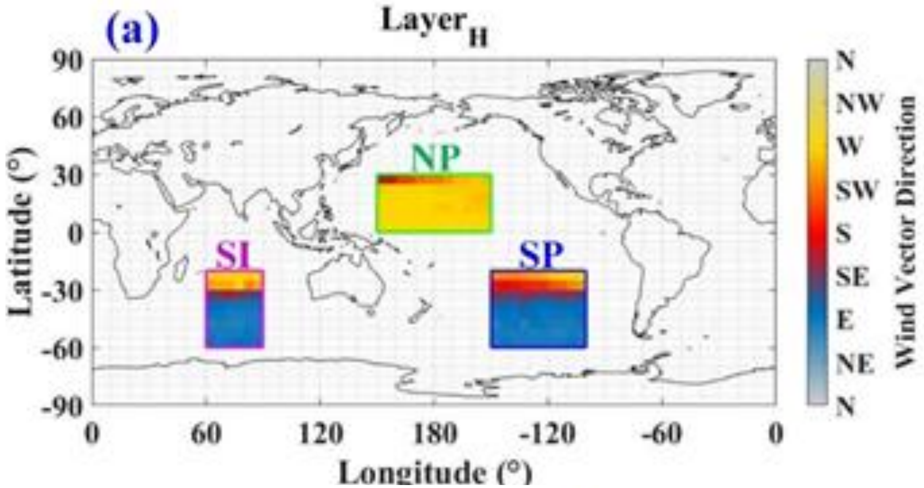
Optical properties and wind speeds distribution analyses
At two sperate vertical layers (ocean surface to 1 km; 1 km to 2 km) over selected ocean areas

Correlation analysis between optical properties and wind speed
- Averaging of optical properties along the wind speed grid of 1 $m \cdot s^{-1}$
- Parametric curve fitting of the optical mean properties vs. wind speed

Derived aerosol optical properties analysis with wind speed
- Aerosol optical depth vs. wind speed
- Lidar ratio vs. wind speed

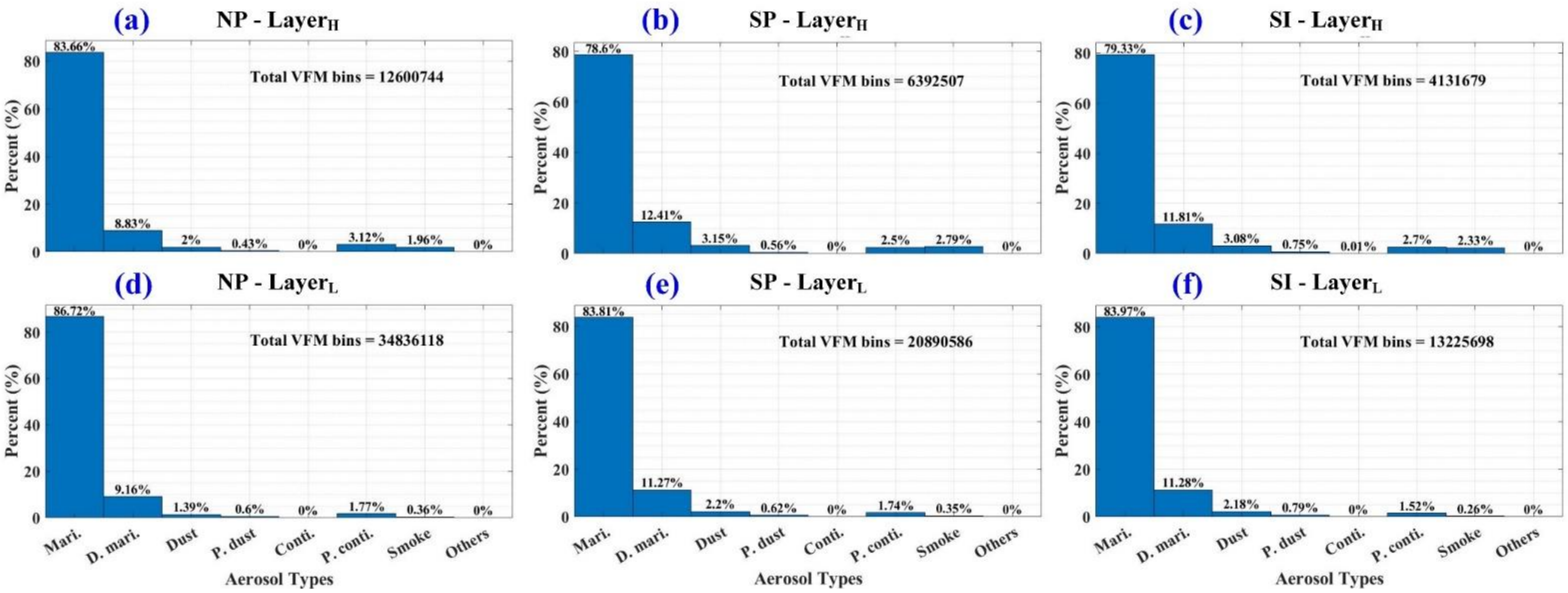
0-1 km layer ($Layer_L$): corresponding to the marine atmospheric boundary layer (MABL)
1-2 km layer ($Layer_H$): above the MABL
*The lowest bins of L2A products are absent to avoid the ground return signals' contamination

Science exploration: 2/2 Correlation between marine aerosol and wind



Study areas:

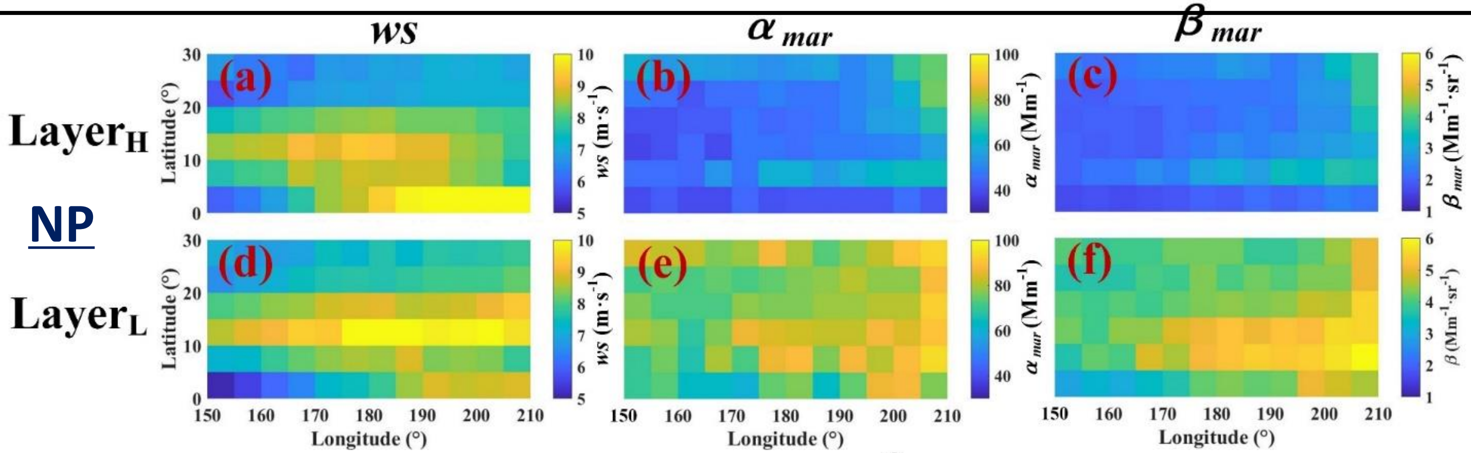
The north pacific area (NP)
The south pacific area (SP)
The south India area (SI)

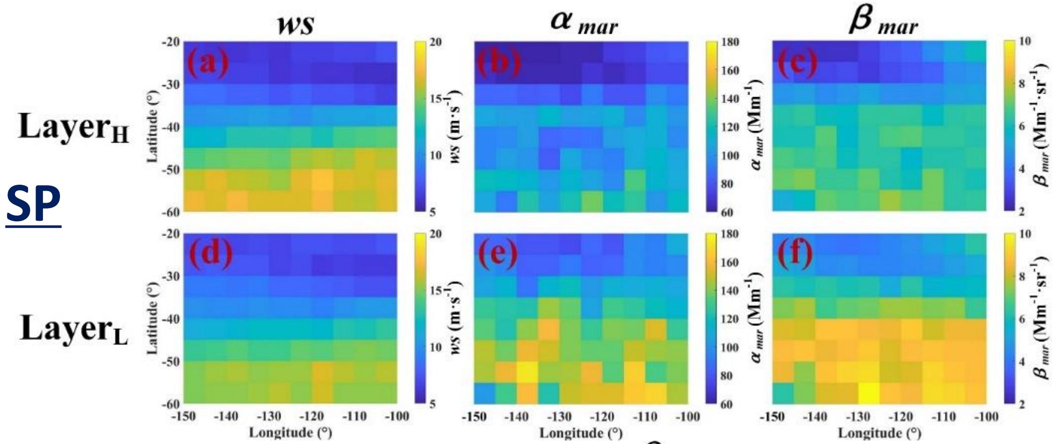


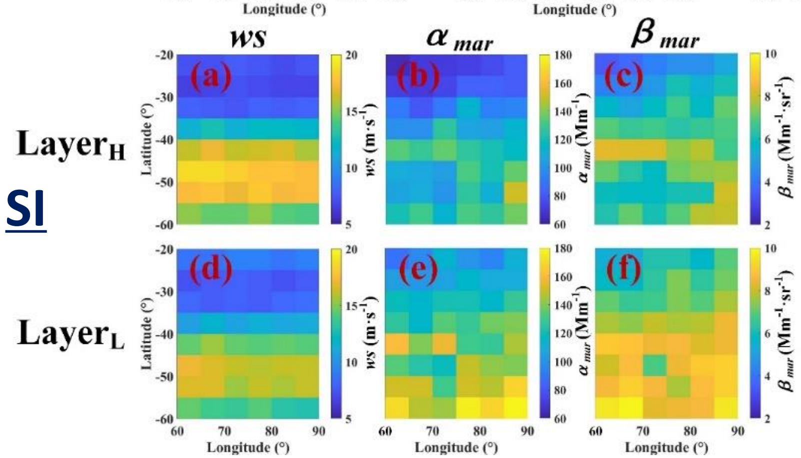
marine aerosol > 75%
marine+dusty marine aerosol > 90%

→ **marine aerosol dominates in three study areas**

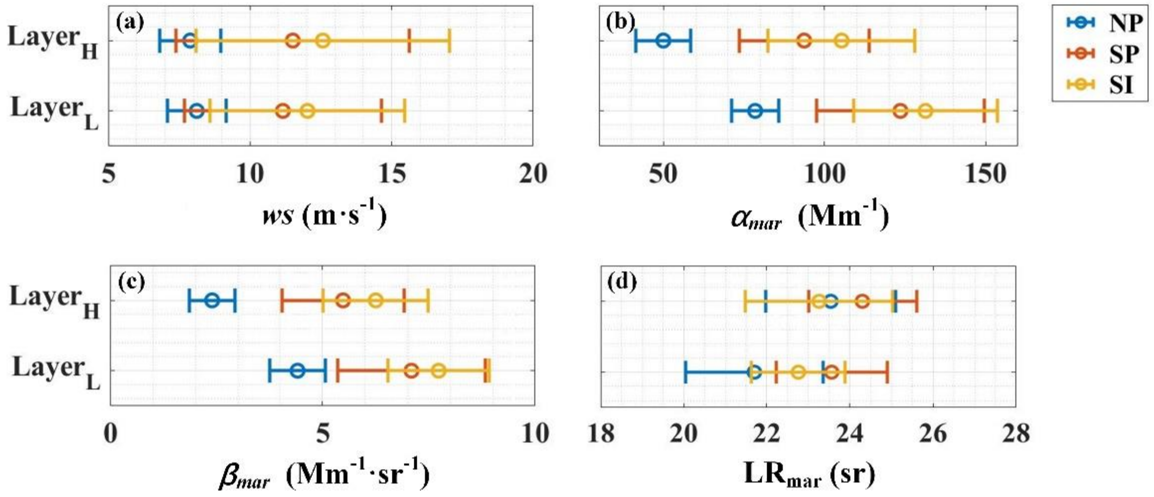
Science exploration: 2/2 Correlation between marine aerosol and wind







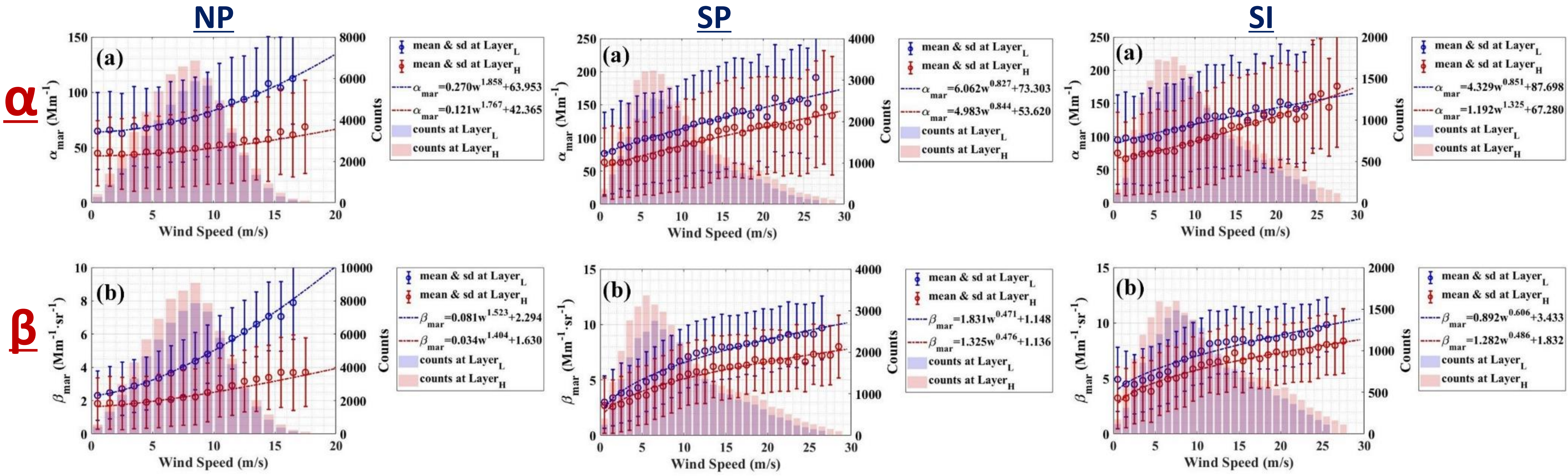
The spatial distribution shows **positive relationship** between marine aerosol optical properties and wind speed at both layers.



Typical ranges of marine aerosol optical properties at 355 nm (Prijith et al., 2014; Kiliyanpilakkil and Meskhidze, 2011; Floutsi et al., 2022): **α: 47 to 180 Mm-1**

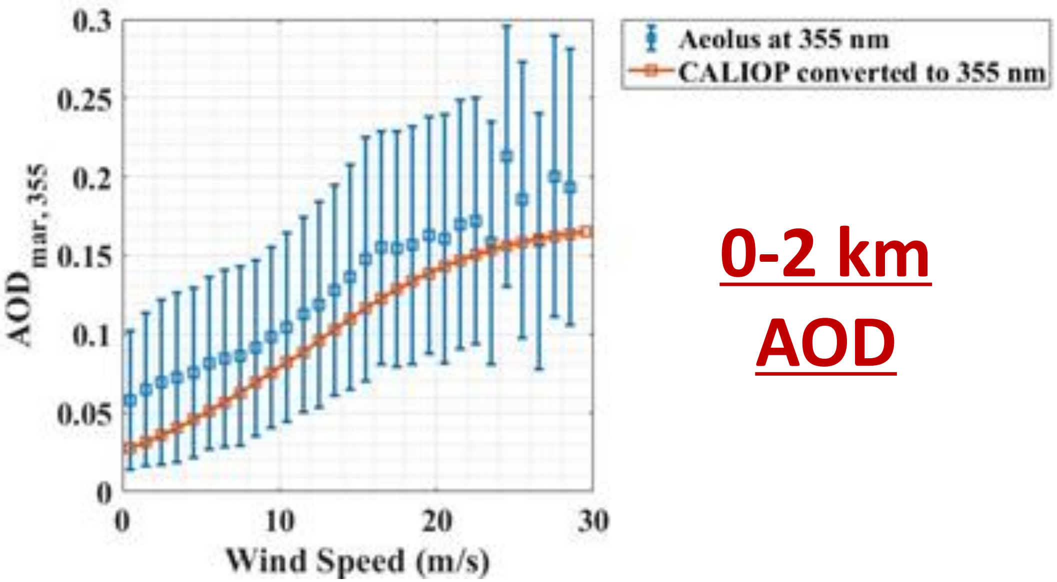
β: 1.3 to 7.2 Mm-1·sr-1

Science exploration: 2/2 Correlation between marine aerosol and wind



- In the same wind speed bins, the marine aerosol optical properties at $Layer_L$ are larger than those at $Layer_H$.
- The gradients at $Layer_L$ are larger than at $Layer_H$ for the same wind speed.
- The α/β-wind speed relationships can be fitted quite well by power law functions in all cases.
- The SP, SI area (mid-latitude areas)’s α/β-wind speed relationships are similar, but different from the NP (low-latitude area)’s.

Science exploration: 2/2 Correlation between marine aerosol and wind

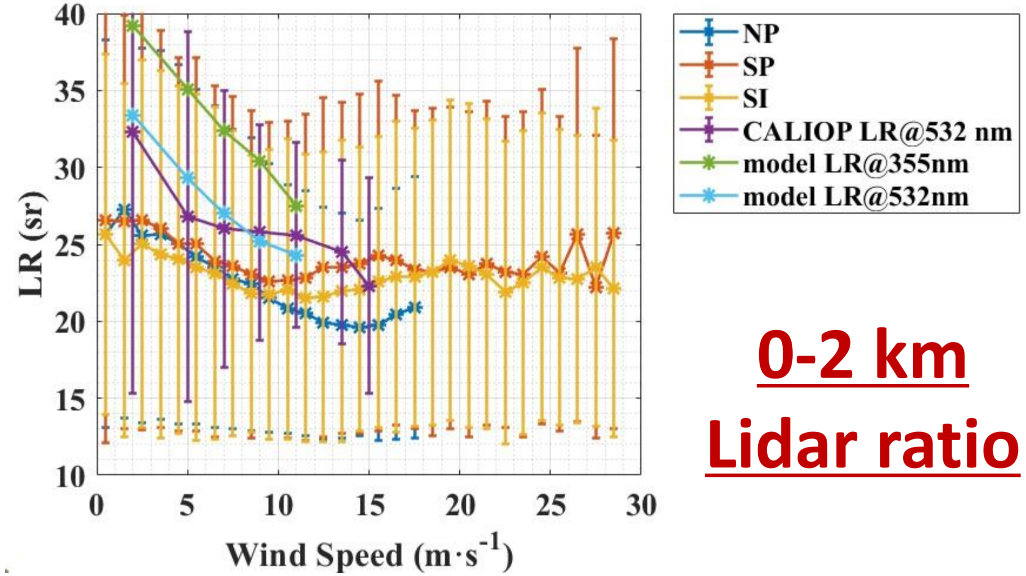


0-2 km AOD

- Comparison between **CALIOP converted AOD at 355 nm (using Ångström exponent)** and **Aeolus AOD at 355 nm** along wind speed.

*CALIOP AOD (532 nm)-wind speed relationship from Kiliyanpilakkil and Meskhidze (2011)

*Ångström exponent from Sayer et al. (2012)



0-2 km Lidar ratio

- Marine aerosol lidar ratio and its particle size have negative relationship (Masonis et al., 2003; Haarig et al., 2017)
- the marine aerosol LR-wind speed relationship from Aeolus:
  - •downward trend at relatively low wind speed
  - •upward trend at the middle wind speed
  - •stable at the very high wind speed
- Comparison with the LR-wind speed relations from CALIOP (Dawson et al., 2015) , from model simulation(Sayer et al., 2012)

Summary and Conclusion

- ✓ First ever deriving pure marine aerosol optical properties from Aeolus products.
- ✓ Acquiring the spatiotemporally synchronous relationship with the aerosol optical properties and the instantaneous wind speeds, which could indicate the background atmosphere states within and above the MABL over remote ocean.
- ✓ Conducting analysis at two separate height layers above ocean surface to explore the vertical differences.

*Ref.: Sun, K., Dai, G., Wu, S., et al., **Correlation between marine aerosol optical properties and wind fields over remote oceans with use of spaceborne lidar observations**, **ACPD**, Special issue: Aeolus data and their application*

THANK YOU!