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Correlation Between Marine Aerosol Optical Properties and Wind Fields over Remote Oceans with Use of Aeolus Observations

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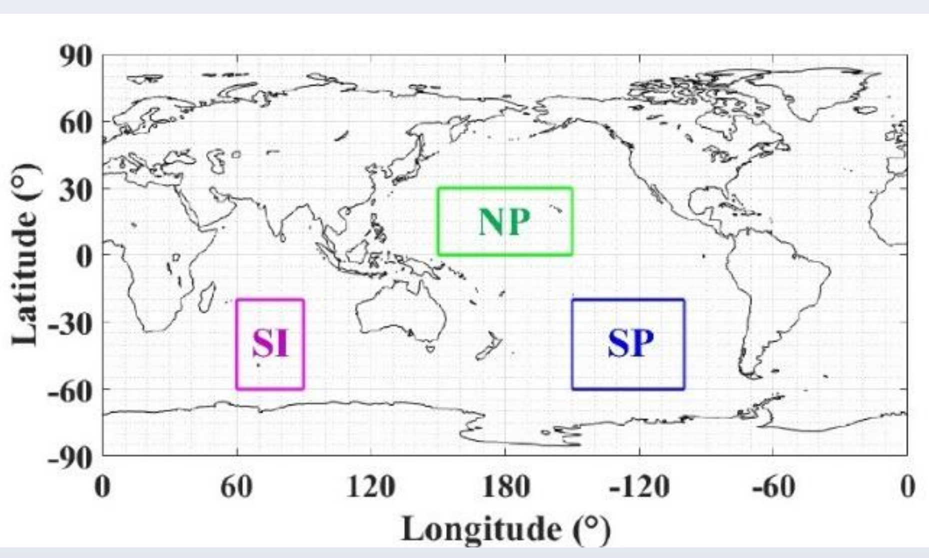
Abstract

Marine aerosol is mainly produced by wind, which is also a vital element impacting the transport, evolution and dissipation of marine aerosol. The understanding of the **accurate relationships between marine aerosol optical properties and wind speed** will improve the global aerosol transport models, the satellite-retrieved AODs, the atmospheric correction of ocean color and the study of biogeochemical cycles. **Aeolus**, the worldwide first ever wind detection lidar satellite, had the ability to measure **wind information and particulate optical properties simultaneously**, which provide the opportunity to explore the absolutely synchronous relationships between marine aerosol optical properties and wind speeds. Furthermore, thanks to the Aeolus measurement of vertical profiles, the relationships can be discussed in different vertical layers. In this paper, utilizing Aeolus data, **the relationships between the optical properties at 355 nm of marine aerosol and the corresponding instantaneous co-located wind speeds** of three remote ocean areas are explored and discussed at two sperate vertical atmospheric layers (0-1 km and 1-2 km, correspond to the heights **within and above marine atmospheric boundary layer (MABL)**), revealing the marine aerosol related atmospheric background states.

Research areas and data

Research areas



- NP: the North Pacific ocean area
- SP: the south Pacific ocean area
- SI: the south Indian ocean area

Data used

Instruments	Products
ALADIN /Aeolus	**L2A (Baseline 11-14)** Particle optical properties: ➢ extinction coefficient (α) ➢ backscatter coefficient (β) 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

Methods

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 ↓

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

↓ **Cloud screening**
Retain data with: Backscatter ratio < 2.5; RH < 94%

↓ **Backscatter coefficient correction**
Retain data with: RH > 50%
Correct with: Depolarization ratio = 1.13% of marine aerosol

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

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

↓ **Wind speed**

Step 3: Data analyses with marine aerosol optical properties and wind speed

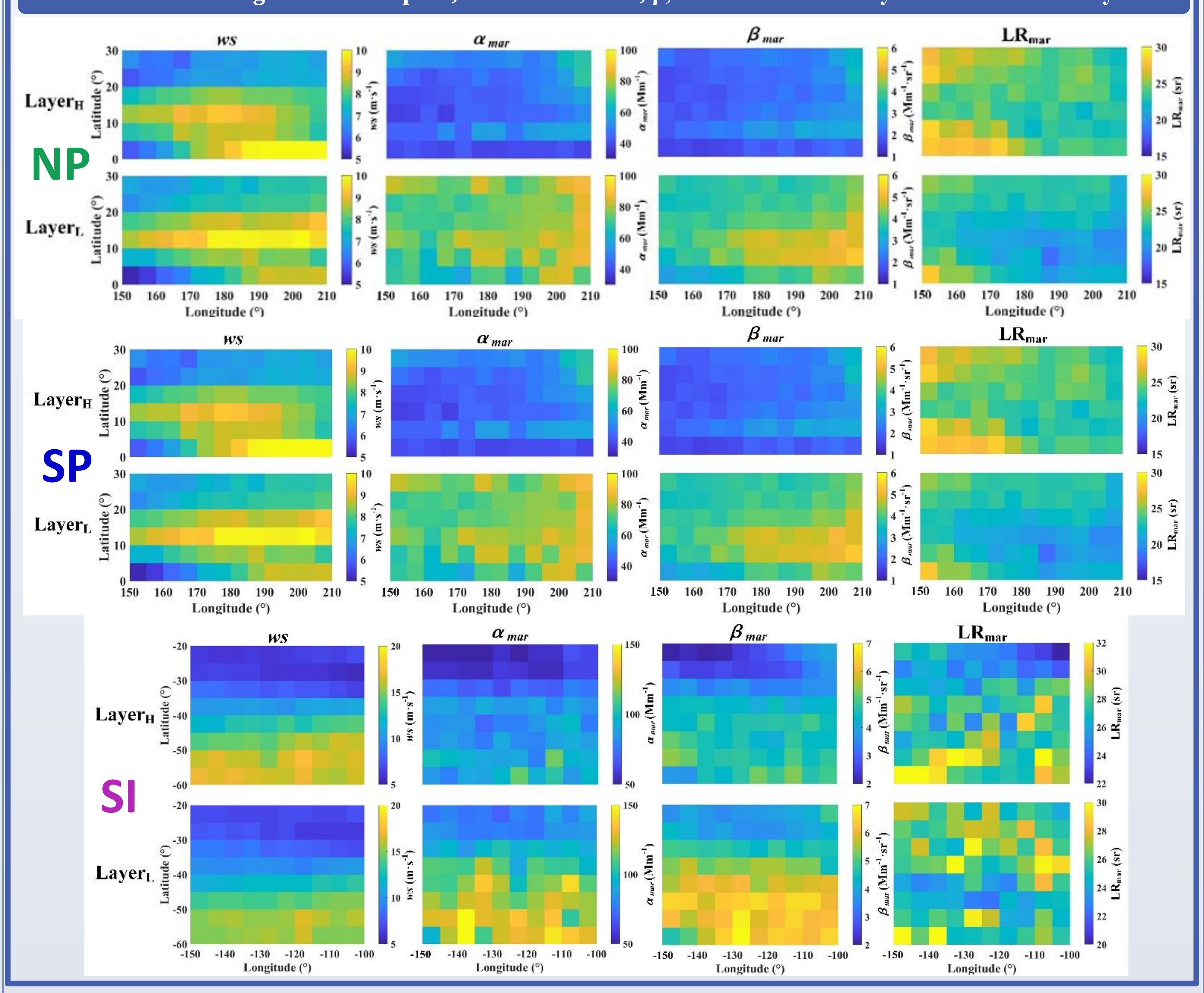
Distribution analyses of optical properties and wind speed
- At two vertical layers (ocean surface to 1 km; 1 km to 2 km)

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

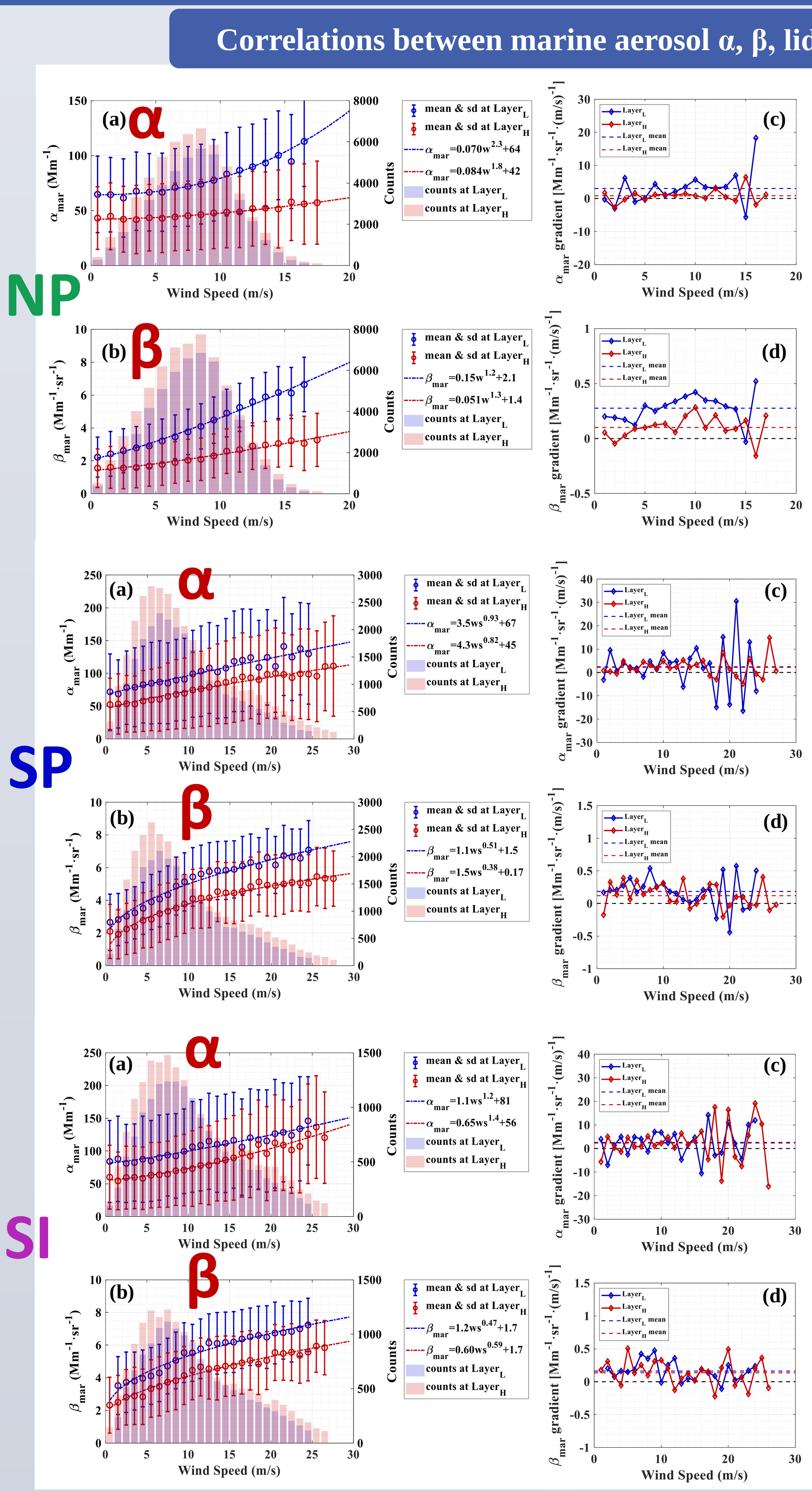
Derived aerosol optical properties analysis with wind speed
- AOD vs. wind speed
- Lidar ratio vs. wind speed

Results and discussion

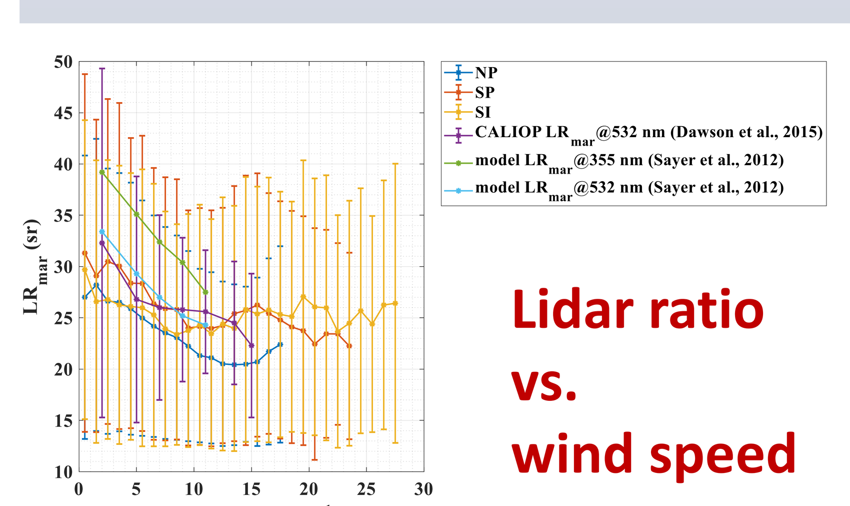
Distributions of background wind speed, marine aerosol α, β, lidar ratio at two layers above three study areas



Correlations between marine aerosol α, β, lidar ratio vs. wind speed



- The marine aerosol extinction/backscatter coefficients and the background wind speeds show positive relationships and they were fitted by **power law functions**, of which the corresponding R^2 are all higher than **0.9**.
- Both the MABL and the higher layer above the MABL will receive the marine aerosol produced and transported by the wind from the air-sea interface.
- The marine aerosol load at the lower layer (MABL) is stronger than at the higher layer. **The marine aerosol enhancements caused by the background wind are more intensive at the MABL.**
- The **gradient change points** of marine aerosol extinction/backscatter coefficients appear during the growth of them with wind speed, above which the growth rate becomes lower. It might illustrate that **the enhancement of marine aerosol driven by wind includes two phases**, among which one is **rapid growth phase** with high dependency of wind, and another is **slower growth phase** after the gradient change points.



Lidar ratio vs. wind speed

- Marine aerosol lidar ratio and its particle size have **negative relationship**.
- From the analysis from Aeolus data, marine aerosol lidar ratio variation with wind speed shows:
  - ➢ **downward trend at low wind speed**, indicating the increasing of particle size;
  - ➢ **upward trend at middle wind speed**, indicating the decreasing of particle size.
- The results at low wind speed fit well with previous works.

Reference

- Sun, K., Dai, G., Wu, S., Reitebuch, O., Baars, H., Liu, J., and Zhang, S.: Correlation between marine aerosol optical properties and wind fields over remote oceans with use of spaceborne lidar observations, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-433, 2023.