Remote Sensing of aerosols and their properties in the Arctic from satellite observations

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B02

1. Summary

The overarching objective in phase III is to further improve our understanding of the role of aerosols in climate change in the Arctic, during the period of Arctic amplification. Specifically this is achieved by a) extending the Aerosol Optical Thickness (AOT) datasets, retrieved from the radiance measurements, made by set of satellite instruments, b) assessing the changes and trends of the extended AOT time series, both regionally and averaged across the Arctic, and c) comparing measured AOT and that modelled by state of the art models and explaining geophysically the origin of the differences.

Hypothesis

The regional trends of Aerosol Optical Thickness in the Arctic are driven by changing emissions of aerosols and their precursors and by subarctic biomass burning during the period of Arctic amplification.

Research questions

Q1 Are the observed changes in AOT, retrieved from satellite observations, reproduced by atmospheric models?
Q2 Will the observed recent small positive trend in AOT above the ocean continue in the coming period and which mechanisms drive this increase?
Q3 How can the observed differences between modeled and observed AOT be explained during summer biomass burning episodes,
and is there a significant correlation between such episodes and phytoplankton dynamics in the Arctic?

Contribution to SQ1, SQ3

2. Achievements phase II

Study structure: Different AOT algorithms have been used and/or developed to determine AOT above the cryosphere, ocean, and land. This has required the improvements in the modelling of surface scattering and radiative transfer modelling.

AOT over the cryosphere: new Total AOT, its validation and trends

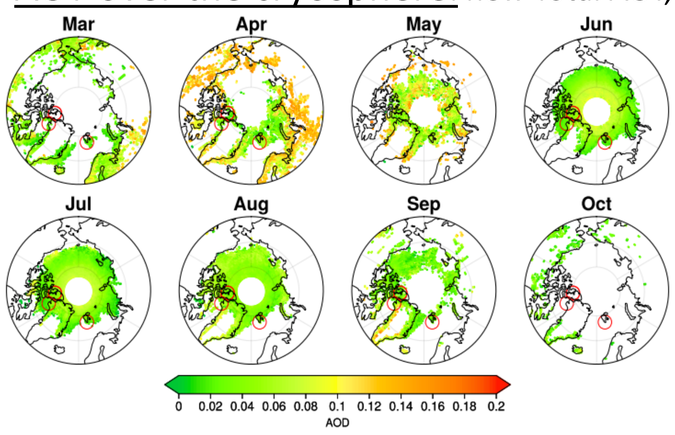

Fig. 1 (above) Total AOT over snow covered surfaces retrieved using an improved IUP-UB retrieval algorithm (AEROSNOW) using 9 years of AATSR satellite data.

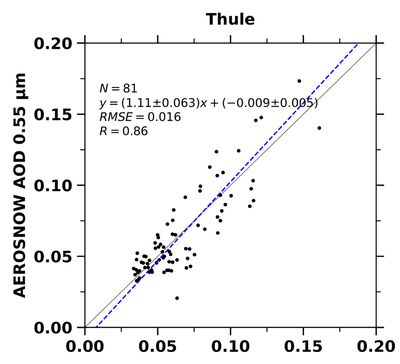

Fig. 2 (above) Validation of Total AOT from AEROSNOW by comparison with that total AOT from the AERONET measurement at Pearl, This is one of four stations, providing AOT in the high Arctic, see Fig 1: : Pearl, Opal Hornsund and Thule.

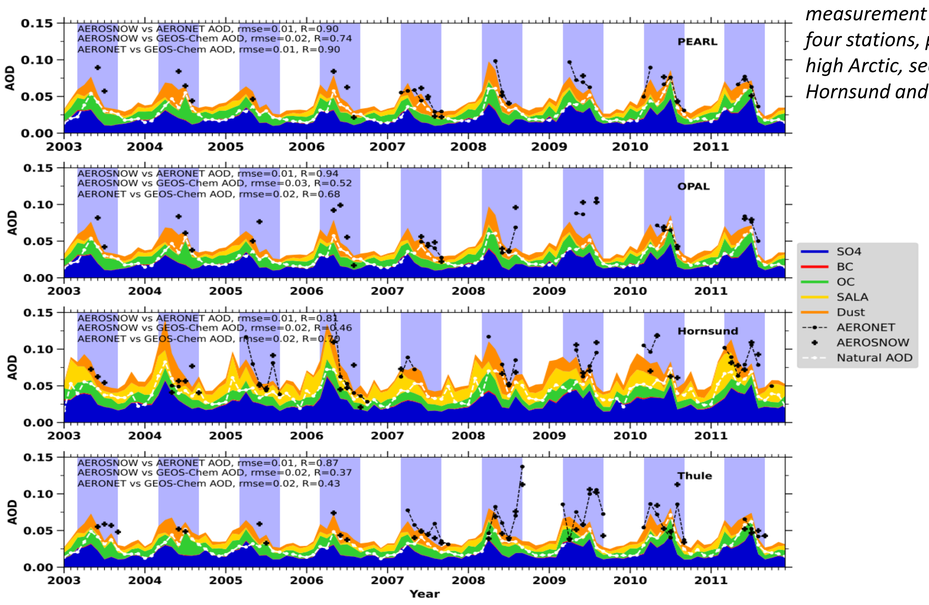

Fig. 3 (left) The comparisons of total AOT retrieved using AEROSNOW, AERONET and GEOS-Chem model, comparison and correlation coefficients for the four high Arctic AERONET stations.

Total and Tropospheric AOT over the ocean in the Arctic

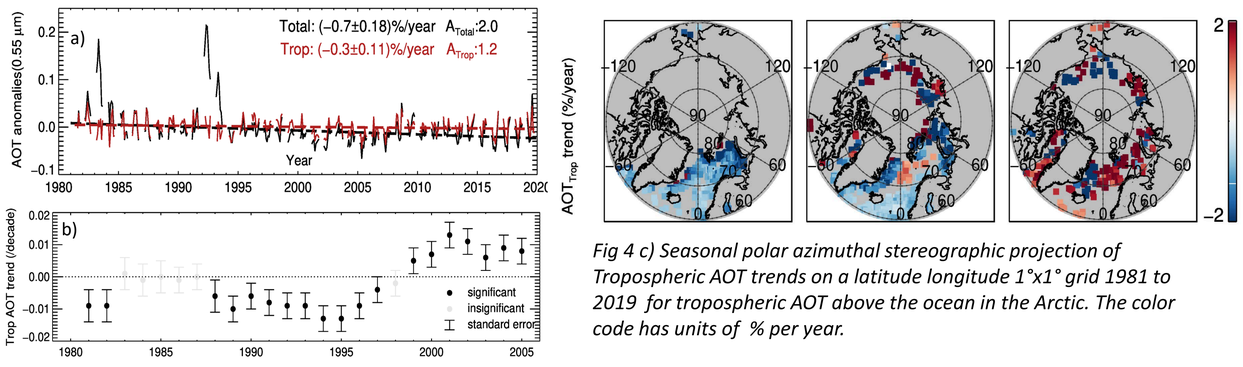

Fig. 4 a) Panarctic total and tropospheric AOT above the ocean in the Arctic and their linear trends, determined from AOT measurements made by NOAA AVHRR polar pathfinder level 2 from 1981 to 2019; b) Changing 15 year trends for tropospheric AOT, beginning in 1981 - solid symbols are 2 σ statistically significant. The color coded trends are in % per year.

Fig 4 c) Seasonal polar azimuthal stereographic projection of Tropospheric AOT trends on a latitude longitude 1°x1° grid 1981 to 2019 for tropospheric AOT above the ocean in the Arctic. The color code has units of % per year.

AOT over land/surface properties

Novel algorithms have been developed for the retrieval of AOT over.

The retrieval algorithms have been improved by using recent advances in radiative transfer modelling of the surface properties.

3. Research plan phase III

WP1 Aim is the temporal extension and harmonization of our studies of the AOT over the different surfaces (Q1).

The objective is to prepare a consolidated and consistent AOT dataset across all surfaces.

WP2 Assess & analyze trends (Q1, Q2 & SQ1, SQ3)

Comparisons with ground-based/campaign data to extend the validation (B04, E02).

AOT trends will be compared with model trends of AOT (D02).

The agreements and disagreements will be investigated and reasons for the disagreements analyzed and suggestions for model improvements derived.

WP3 Studies on oceanic biomass and the impact of aerosol from biomass burning (Q3 & SQ1, SQ3)

Changes in phytoplankton dynamics have been attributed to deposition on ocean of biomass burning aerosol (C03, D02, B04).

Occurrences of these phenomena will be identified and their significance assessed.

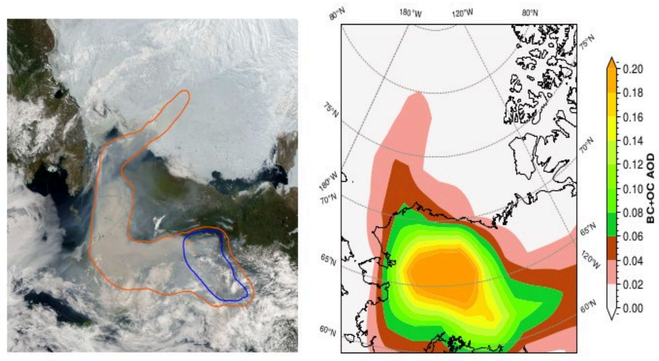

Fig. 5 Biomass burning plume as seen from MODIS true color imagery and that simulated by GEOS-Chem model.

4. Major expected results & Legacy

Major expected results within phase III

- Knowledge of the changes in AOT during Arctic amplification extends to 2025+.
- The answers to the questions whether the recent positive Arctic AOT trend continues.
- An assessment of where the AOT from satellite observations and current "state of the art" model agree or disagree and probable explanations → the importance of feedback between changes in AOT and climate change.
- Up to date knowledge of the changing amount of biomass burning in boreal regions from1995 to 2025+ and any impact on marine phytoplankton.

Project Legacy

The following data products from satellite observations will have been generated and made freely available:

a) The total, stratospheric and tropospheric AOT data products from satellite observations generated i) 1981-2025+ over the ocean and ii) over the cryosphere 1995 -2025+.

b) The changes and trends of these AOT data product time series.

The knowledge, gained from the AOT studies, will benefit the development of the EU/ESA/ EUMETSAT Copernicus satellite systems and the definition of the national and ESA and DLR climate change research programs exploiting space data products.

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