Changes of TOA reflectance and cloud optical properties observed from space: Implications for Arctic climate change and feedback

B01

John P. Burrows, Marco Vountas
Luca Lelli, Linlu Mei, Narges Khosravi, Theofanis Stamoulis

1. Summary

This subproject has and had two foci : i) the development of **retrieval approaches** for **cloud identification**, **optical parameters**, and optimal statistical analysis methods, and ii) the preparation, analysis and interpretation of the trends in multi-sensor datasets of reflectance at the Top-Of-Atmosphere, **RTOA**, and Brightness temperature at TOA, **BTOA**, as a function of wavelength. In phase II we build on the heritage of the B01 phase I and have formulated the following key **research questions**:

Q1: What are the changes in the TOA reflectance in the solar spectral region and the retrieved cloud optical properties, observed from space over the past decades?

Q2: Are the predicted changes in surface and cloud properties in agreement with the identified changes?

2. Achievements phase I

Cloud research

Improvement of retrievals techniques for cloud parameters (Cloud Bottom Height, CBH, Cloud Top Height, CTH, Cloud Optical Thickness, COT, Cloud effective radius, CER and Cloud Phase, CP) over bright surfaces (further information in eight published papers).

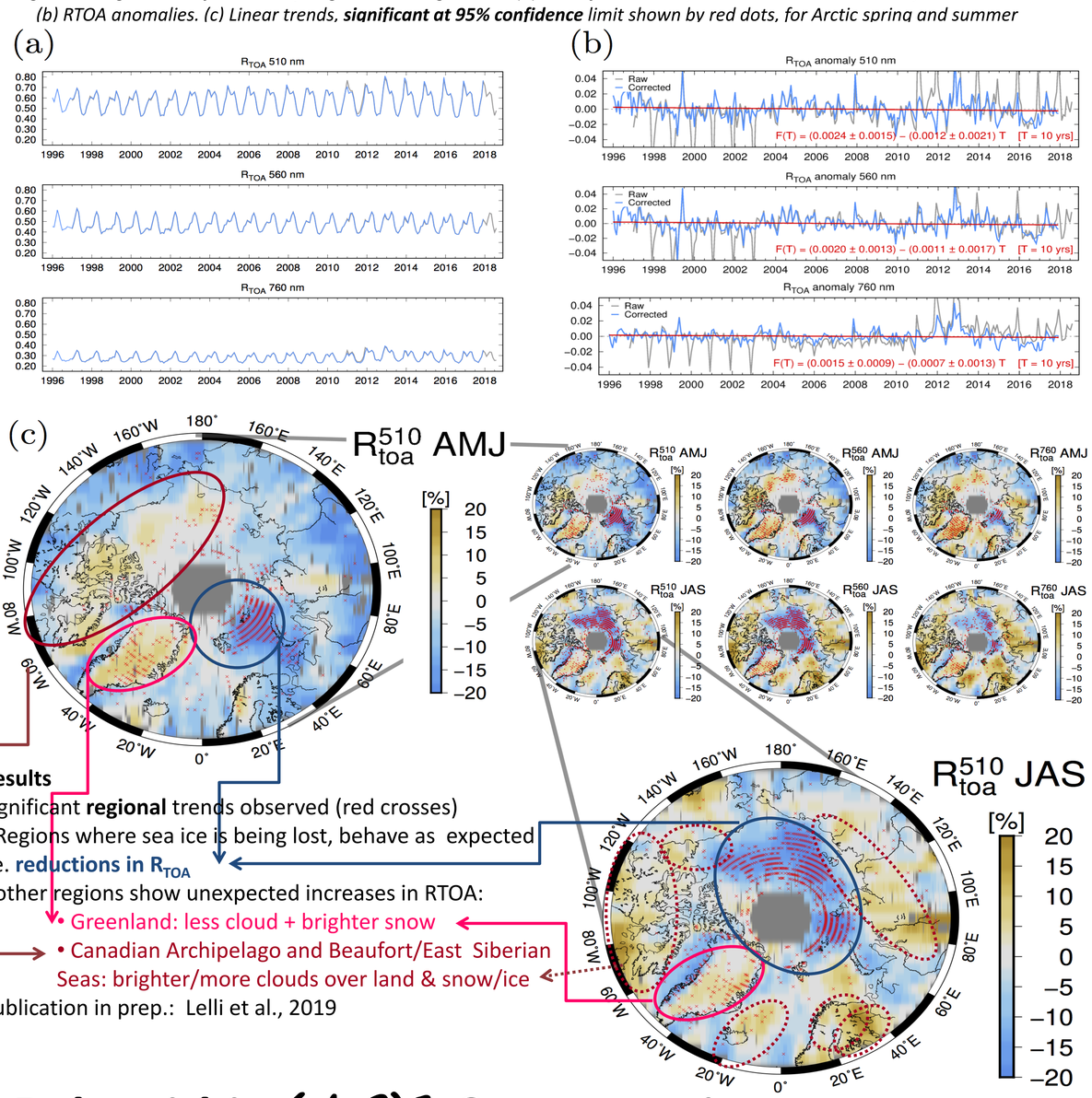
RTOA research

Changes in atmospheric or surface contribution to the spectral reflectance directly impacts on the reflectance at the top of the atmosphere, RTOA defined as

$$R_{toa} = \frac{\pi I(\lambda)}{\mu_0 I_0(\lambda)}$$

where I(λ) and I_0(λ) are the radiance (TOA) and the irradiance at wavelength λ. μ_0 is the cosine of the solar zenith angle. The R_{TOA} measured by the satellite instruments GOME (1996-2003), SCIAMACHY (2002-2012), and GOME-2 A/B (2007-present) are used.

*Fig. 1: Averaged values for latitude/longitude. 1°x1° grid cells. (a) RTOA from GOME, SCIAMACHY and GOME-2A, GOME-2B and (b) RTOA anomalies. (c) Linear trends, **siqnificant at 95% confidence** limit shown by red dots, for Arctic spring and summer*



Results

Significant **regional** trends observed (red crosses)

- Regions where sea ice is being lost, behave as expected i.e. **reductions in R_{TOA}**
- other regions show unexpected increases in RTOA:
  - Greenland: less cloud + brighter snow
  - Canadian Archipelago and Beaufort/East Siberian Seas: brighter/more clouds over land & snow/ice

Publication in prep.: Lelli et al., 2019

Hypothesis

The changes of top-of-atmosphere reflectance, brightness temperatures and cloud parameters provide unique knowledge to assess the impact of ice retreat and warming at high latitudes.

Summary of Achievements

- **Improvement** and adaption of **cloud retrieval** and identification **algorithms** for Arctic conditions: **eight peer-reviewed papers**
- **Creation** of a **23 years** time series of **RTOA**
- First **analysis** of **R_{TOA}** dataset and **determination** of 60-90°N and regional **trends**

3. Research plan phase II

→ **Harmonize** and **analyse** data set of Cloud parameters (**CBH,CTH, COT, CER, and CP**)

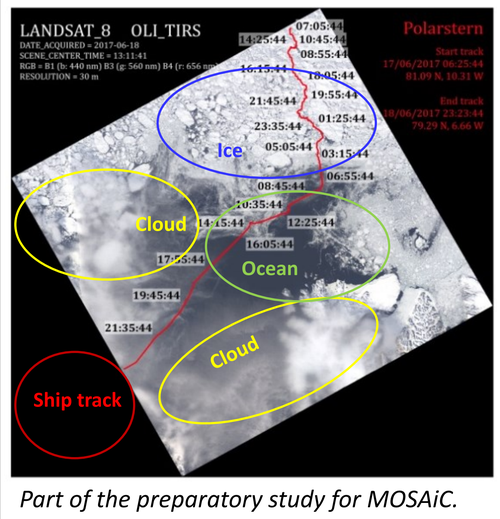
→ **Extension** of the **R_{TOA}** record w.r.t. time to 2023, spectral coverage and spatial resolution.

→ **Creation** of a **B_{TOA}** record

→ **Validation** of R_{TOA} & B_{TOA} dataset

→ Scientific exploitation of trend analyses and attribution of their origins

Fig.2: IUP/UB True colour composite around RV Polarstern during PASCAL (17. June 2017)



Part of the preparatory study for MOSAiC.

Project Plan

- **WP1:** RTOA & cloud identification/retrieval & temporal extension. Bringing together results from ASCIA/XBAER/SACURA and RTOA;
- **WP2:** Support for MOSAiC: assessment of RTOA and cloud retrievals in the region around RV Polarstern;
- **WP3:** RTOA improvement of spatial resolution including more satellite imagery (e.g. OLCI, MAIA & PACE);
- **WP4:** TIR studies using data from AVHRR but also ATSR-2, AATSR, SLSTR and IASI(-NG).

Year	2020				2021				2022				2023			
Quarter	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
WP1 Temporal extention																
WP2 MOSAiC																
WP3 Spatial resolution																
WP4 TIR measurements																

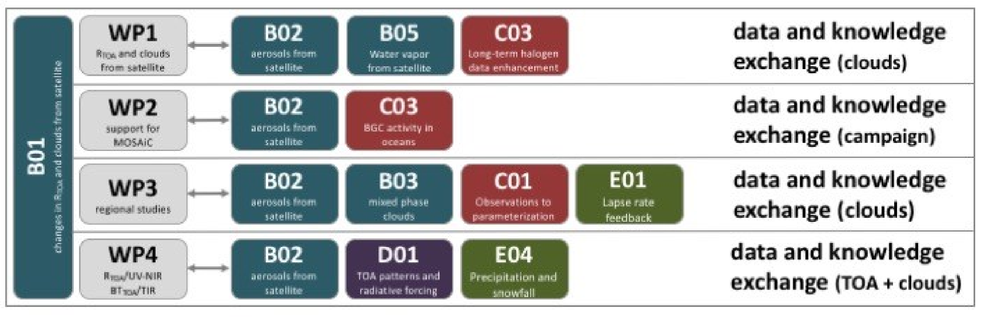
4. Role within (AC)³ & perspectives

Collaborations within (AC)³

Cluster B: **B02** continuation of close collaboration (aerosol and surface) + **B03** (clouds for energy fluxes in air transformations - CCA4 w/ aerosol, moisture, precipitation) + **B05** (clouds and R_{TOA} alignment w/ water vapour trends)

Cluster C: **C01** (cloud observations at regional scale leading to parameterizations) + **C03** (reactive gases and ocean colour data enhancement)

Cluster D: **D01** (R_{TOA}, B_{TOA} and clouds for pattern analysis and radiative forcing assessment)



Cluster E: **E01** (meridional energy transport, cloud retrievals for inversion and model constraints) + **E04** (surface w/ atmosphere: synthesis – precipitation and snowfall, analysis - processes, feedbacks, extremes)

Perspectives (2024- 2027) in a warming world:

- **Utilize/benefit from** the observations of upcoming satellite missions (e.g. Sentinel 3C/D, EarthCare, 3MI, etc).
- **Focus** on collaboration with model teams in cluster D and E to **s**upport the understanding of RTOA, BTOA and cloud changes.

TR 172 TRANSREGIONAL COLLABORATIVE RESEARCH CENTRE
(AC)³ ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms
COORDINATING UNIVERSITY
UNIVERSITÄT LEIPZIG
Universität Bremen
University of Cologne
ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG
TROPOS Leibniz Institute for Tropospheric Research