Changes of Top-of-Atmosphere reflectance and cloud properties in the Arctic from 1995 to present using satellite data

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John P. Burrows, Marco Vountas,
Luca Lelli, Linlu Mei, Vladimir V. Rozanov

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UNIVERSITÄT LEIPZIG | Universität Bremen | University of Cologne | TROPOS Leibniz Institute for Tropospheric Research | AWI

1 Summary

- Over the Arctic **Clouds** play large role in determining the **solar spectral reflectance at the top of the atmosphere, R_{TOA}**
- Retrieval algorithms for application with hyperspectral and multispectral data from spaced based instrumentation available since 1995
- Production and validation of unique long term data sets for R_{TOA} and cloud parameters
- Statistical analyses to assess **the origins and evolution of Arctic Amplification**

Hypothesis

Long-term changes of solar spectral reflectance top of the atmosphere, R_{TOA} provide early warning of Arctic climate change at the surface.


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2 Research rationale

- **Accurate knowledge of the absorption, scattering and emission** by cloud, surface (ocean land or ice), aerosol and water vapour **to quantify the Arctic energy budget** and **assess the origins of Arctic Amplification**
- Changes in R_{TOA} depend significantly on cloud parameters and surface conditions at higher latitudes
- Ground-based measurements above the Arctic are sparse and in disagreement (**Figure 1** and **Table 1;** from Eastman & Warren, 2010)

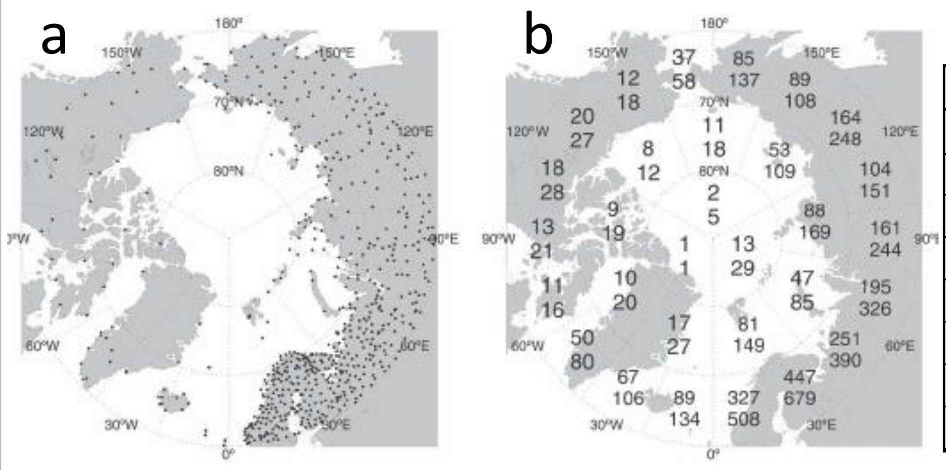


Fig. 1: a) the distribution of ground based stations; b) the average number in hundreds per year of cloud during dark seasons.

	Satellite	Satellite	Ground	Ground
Instrument	AVHRR (a)	TOVS-P (b)	Synoptic (c)	Synoptic (d)
Time span	1982–1999	1908–2001	1971–1996	1954–2007
	Day + Night	Day + Night	Day	Day + Night
Surface	Land + Ocean	Ocean	Land	Land + Ocean
Winter (DJF)	−6.0	−4.1	+2.9	+0.3
Spring (MAM)	+3.2	+4.8	+2.1	+0.2
Summer (JJA)	+1.6	+0.4	−0.4	+0.2
Autumn (SON)	−1.6	+0.4	−0.8	+0.5

Table 1 : comparison of seasonal trends for total cloud covered in % per decade over the Arctic.

- **Starting in 1995**, spectrally and radiometrically calibrated spectrometers (**GOME and ATSR-2** onboard ERS-2, **SCIAMACHY, MERIS and AATSR** on-board ENVISAT and **GOME-2 and AVHRR-3** on the MetOp-A and MetOp-B) provide hyperspectral and multispectral radiance at TOA and extra-terrestrial irradiance
- **Retrieval algorithms** for R_{TOA} and **cloud properties (cloud cover (CC) cloud optical thickness (or spectral albedo) COT, the altitude of cloud boundaries, i.e., cloud top height (CTH) and cloud bottom height (CBH) and the profiles of Cloud effective radius (CER)** are to be adapted and optimized for use with the above data
- Consolidated data products for **R_{TOA} and Cloud parameter**s will be generated and investigated from **60°N and 90°N**
- **Statistical analyses** yield **Trends and Correlations** with surface conditions to assess their relationships and feedback, the value of **R_{TOA} and cloud parameters as early warnings of the evolution of Arctic Amplification**

3 Research plan

Work packages (WP): 1) The derivation of **R_{TOA}** -WP1; 2) The derivation of **Cloud parameters** - WP2; 3) **Validation** WP3; 4) **Trends** and statistical analyses WP4

Year	2016				2017				2018				2019			
Quarter	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
WP1 (UNI–B)	■	■	■	■											■	■
WP2 (UNI–B)					■	■	■	■	■							
WP3 (UNI–B)				■		■	■	■	■	■					■	■
WP4 (UNI–B)				■	■						■	■	■	■	■	■

Table 2: WP Iterative Timeline

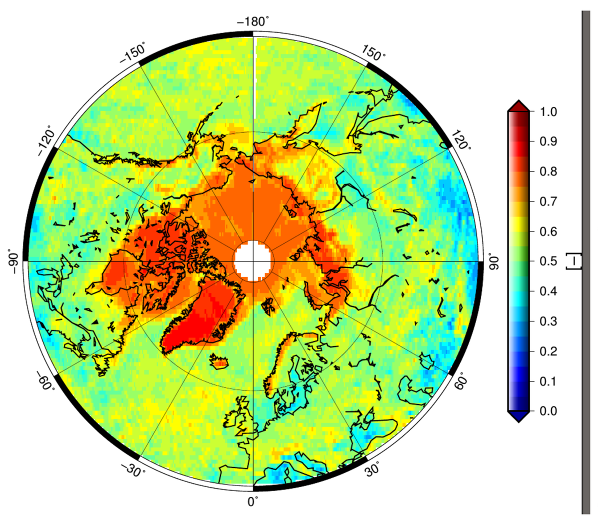


Fig. 2: R_{TOA} from SCIAMACHY MAM 2008

WP1: - Literature survey, data collection and generation of consolidated and consistent **R_{TOA}**
- Observed R_{TOA} will be compared to radiative transfer model (SCIATRAN)

WP2: - Retrieval of cloud Parameters **CC, COT, CF, CTH, CPI and CER** using Semi-Analytical CloUd Retrieval Algorithm, SACURA, and related algorithms adapted to the Arctic conditions

WP3: - **Validation/Comparisons** of cloud parameters with ground-based and satellite-borne measurements, as well as those collected from campaigns & other subprojects of (AC)³

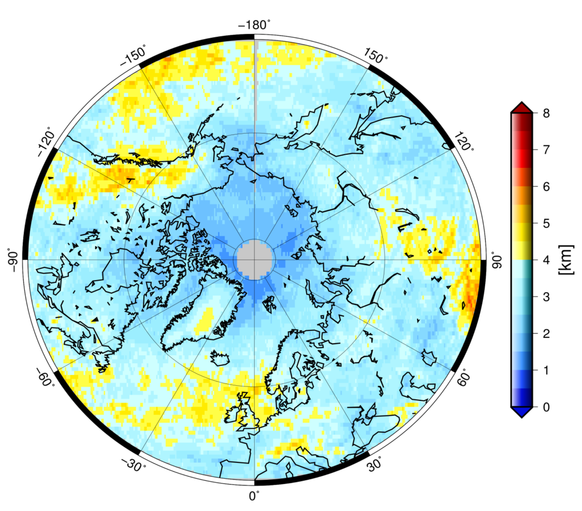


Fig. 3: CTH SCIAMACHY 2008

WP4: - **Statistical analyses** for trends and correlations of R_{TOA}, cloud parameters, surface conditions and comparisons to model results

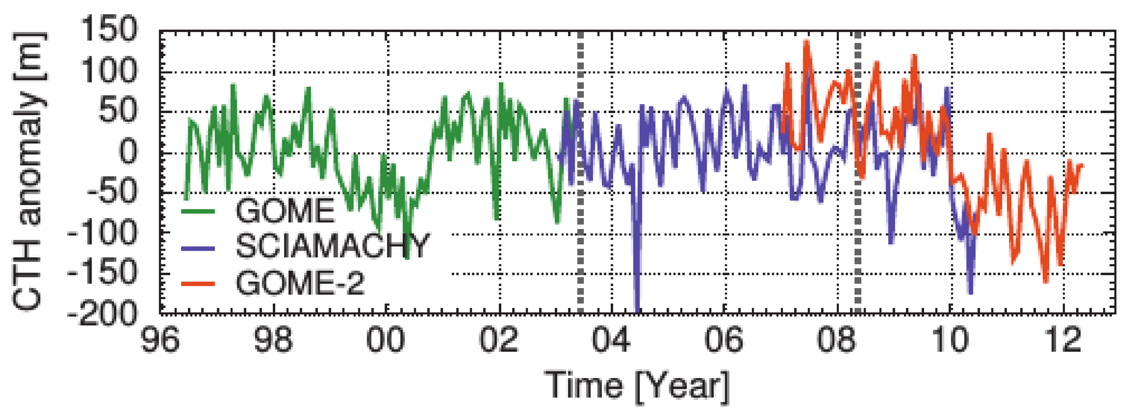
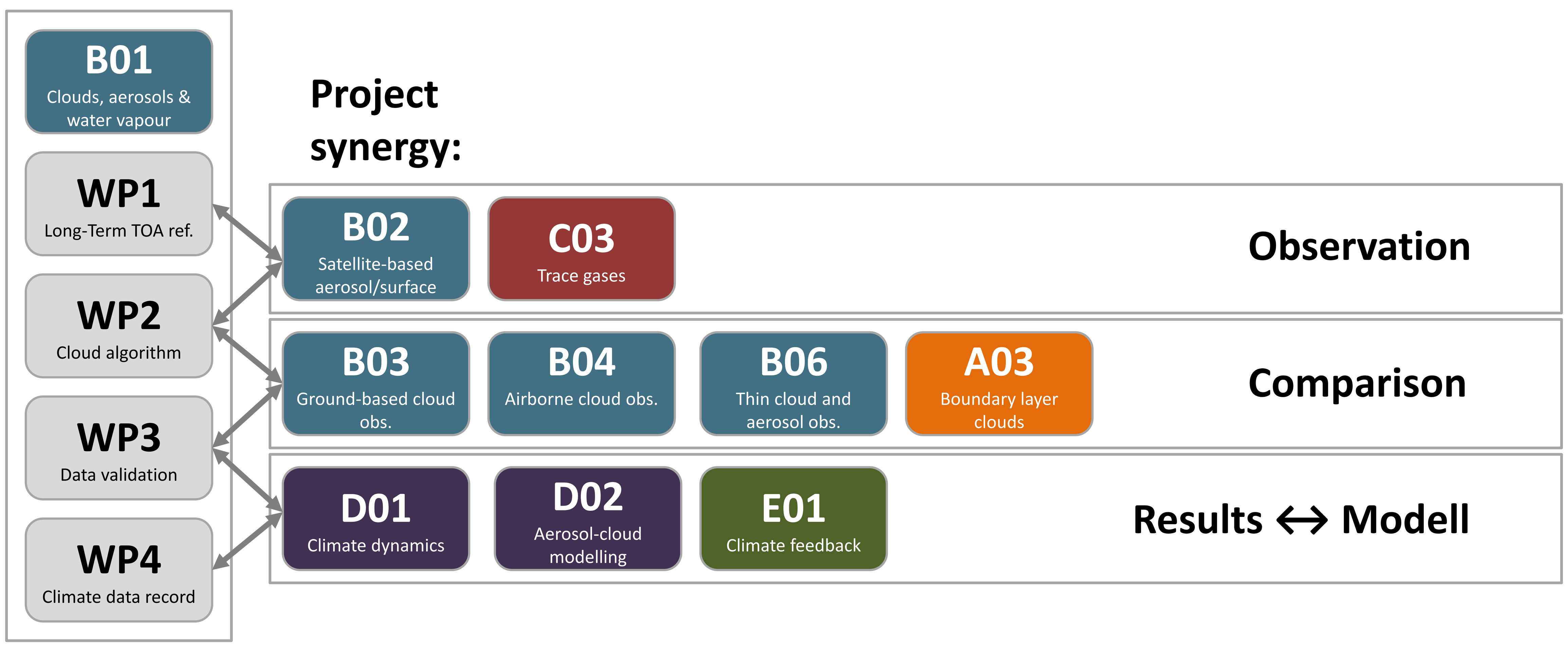


Fig. 4: SCIAMACHY CTH Trends 60°N-60°S

4 Role within (AC)³ & perspectives



Collaboration within (AC)³

- Algorithm development
- Comparison/validation
- Assessment of models

Perspectives

Following optimization of the retrieval and analysis techniques in the first phase of (AC)³:

- Evolution of goals using "the lessons learned"
- Extension of long-term record of data products using next generation of space-based data, e.g. from multispectral **SLSTR and OLCI on ESA Sentinel 3** and hyperspectral data from **Sentinel 5P** and **Sentinel 5, 3MI, IASI NG, Metimage,** on Metop Second generation from 2021 onwards
- Synergistic use of data and models to assess anthropogenic and natural origins of change

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