Spatiotemporal Analysis of Top of the Atmosphere Reflectance using the GOME-2 Scanning Spectrometer

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Abstract (I)

- Global Ozone Monitoring Experiment-2 (GOME-2) A, B and C, onboard Meteorological Operational (MetOp) satellites A, B and C, respectively, are used to measure reflectance at the top of the atmosphere (R^{TOA})
- Through a spatiotemporal analysis across multiple spectral bands, we identify the trends and minima in the GOME-2 R^{TOA} time series over Greenland and dissect the causes behind them using complementary higher level satellite and reanalysis data

Hypothesis (II)

GOME-2 R^{TOA}, as a purely measured quantity with no retrieval model assumptions, can be used to better assess anomalous conditions over Greenland with the help of other higher level data products

Formulation (III)

We define the R^{TOA} as follows:

$$R_{\lambda}^{\text{TOA}} = \frac{\pi \, I_{\lambda}}{\cos(\theta_0)\, E_{\lambda}^{0}}$$

where

- λ corresponds the wavelength for which the the spectral reflectance is measured
- E_{λ}^{0} is the unpolarized downwelling solar irradiance (in units of photons × s^{-1} × cm^{-2} × nm^{-1})
- Θ_0 is the solar zenith angle in degrees
- I_{λ} is the upwelling scalar radiance measured at TOA (in units of photons × s^{-1} × cm^{-2} × nm^{-1} × sr^{-1})

Such that E_{λ}^{0}, Θ_0 and I_{λ} are all taken from GOME-2 measurements and Θ_0 values greater than 90° are filtered out.

Greenland Summer R^{TOA} Trends (IV)

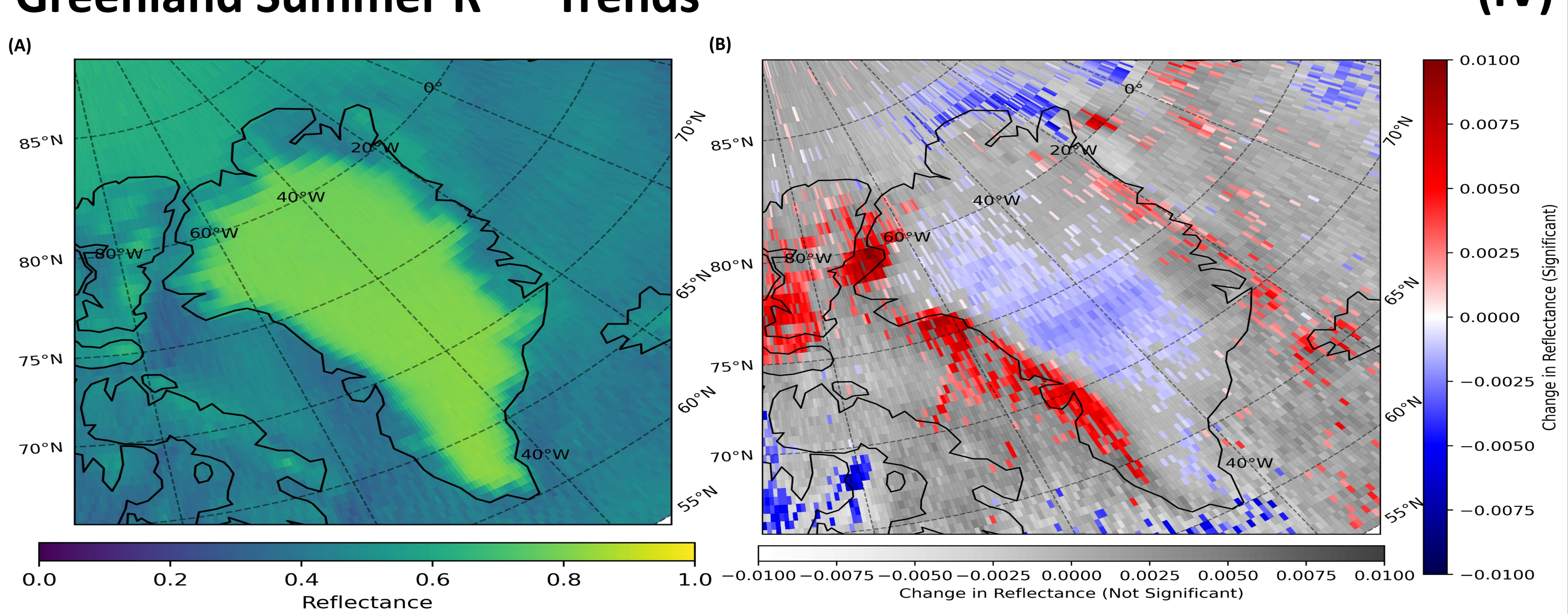

Fig. 1: (A) 2024 Summer GOME2 576-790nm Reflectance (B) 2007-2024 GOME2 576-790nm Reflectance Trends (grid cells with trends that are statistically significant at the 95% confidence level use the diverging blue-red colorbar whereas those that are not use the grayscale colorbar)

Greenland Summer R^{TOA} and CERES CAF (V)

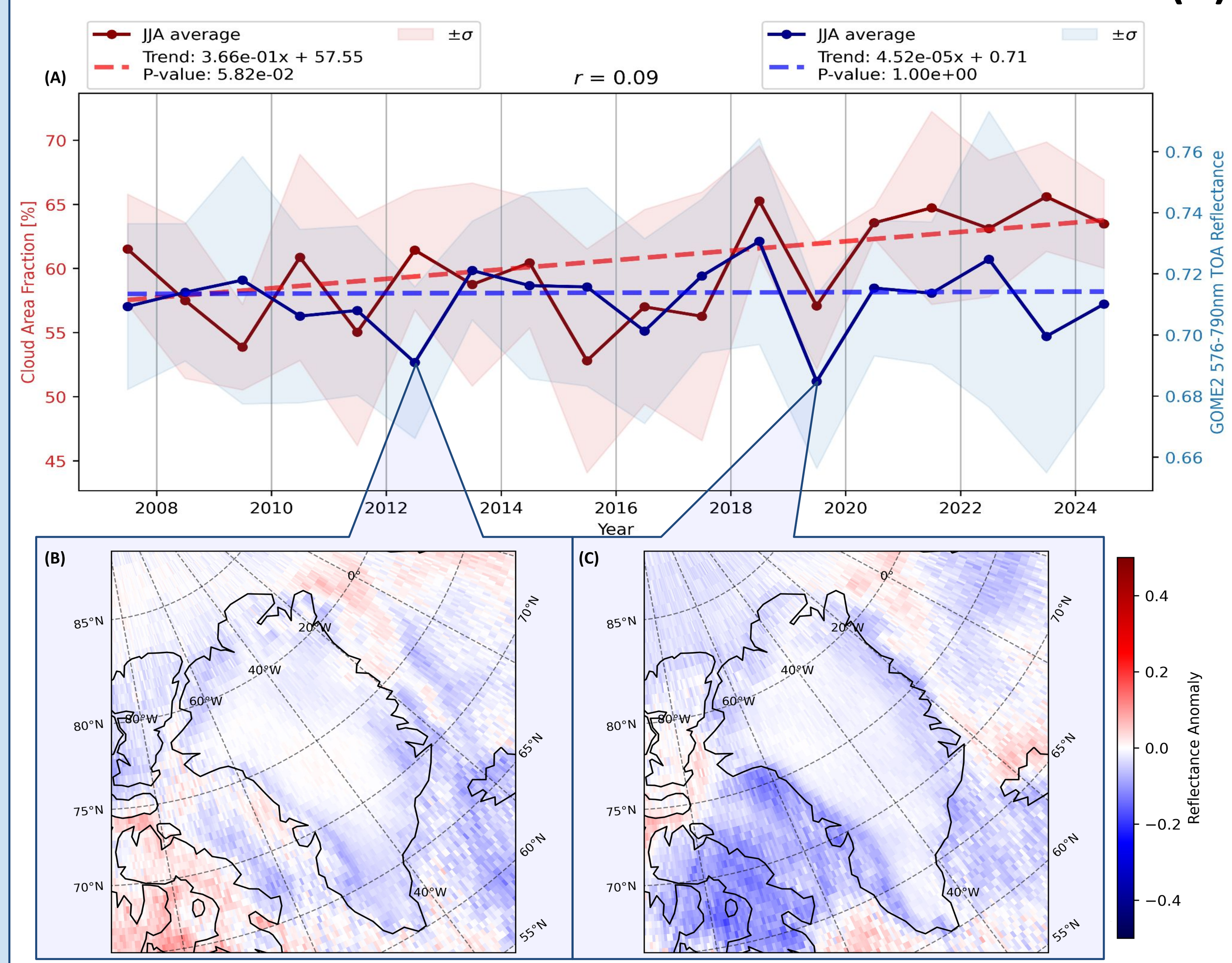

Fig. 2: GOME2 576-790nm Reflectance and CERES cloud area fraction (CAF) JJA averages over Greenland, (B) 2012 JJA Reflectance anomaly, (C) 2019 JJA Reflectance anomaly (where an anomaly is defined as a given summer average subtracted from the average of all summers in the 2007-2024 period)

Greenland Summer R^{TOA} and ERA5 GBI (VI)

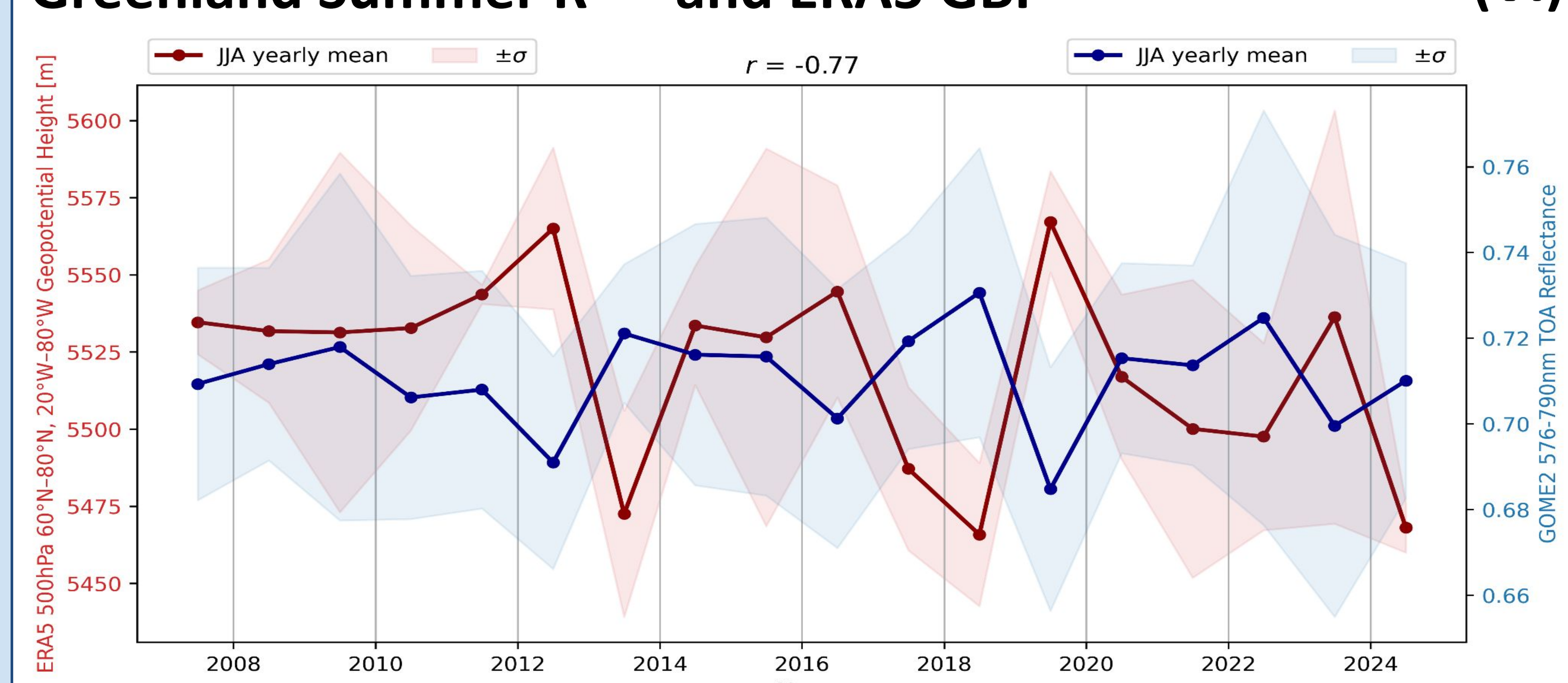

Fig. 3: GOME2 576-790nm reflectance over Greenland and ERA5 500 hPa 60°N–80°N, 20°W–80°W geopotential height, i.e.the Greenland Blocking Index (GBI), JJA averages (where 500 hPa geopotential height corresponds to the height of the 500 hPa pressure level adjusted to account for variation in gravity, altitude and latitude)

Conclusions (VII)

- A large part of central Greenland has **negative** R^{TOA} trends which are statistically significant at the 95% confidence level, as seen in **Fig. 1**
  - Western coast has strong and **positive** trends (at 95% confidence)
- High regional correlation (***r* > 0.8**) between summer R^{TOA} and CERES cloud area fraction trends for certain Arctic regions (e.g. Baffin Bay and Greenland Sea; not shown) but **NOT** for Greenland, as seen in **Fig. 2**
  - R^{TOA} response to clouds over Greenland likely depends on a combination of surface and cloud properties **in addition** to cloud fraction
- R^{TOA} minima in the summer average time series linked to atmospheric blocking over Greenland (***r* < -0.7**), as seen in **Fig. 3**
  - Both 2012 (Bennartz et al., 2013) and 2019 (Tedesco et al., 2020) anomalously strong summer melt events occurred during strong blocks
  - Cloud conditions during blocks depend on atmospheric properties of the air mass caught in the block

Outlook

- Future projections of GBI can be used to better predict Greenland ice sheet melting
  - Air mass trajectory analysis can help identify the type and intensity of melt
- GOME-2 R^{TOA} offers a unique look at Greenland that does not suffer from the inaccuracies introduced through retrieval model assumptions
  - On the one hand, higher level data products can help dissect the GOME-2 R^{TOA} signal, on the other, GOME-2 R^{TOA} can help validate retrievals of quantities that are known to affect reflectance

References

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