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The CM SAF CLARA-A3 Climate Data Record - Surface Albedo

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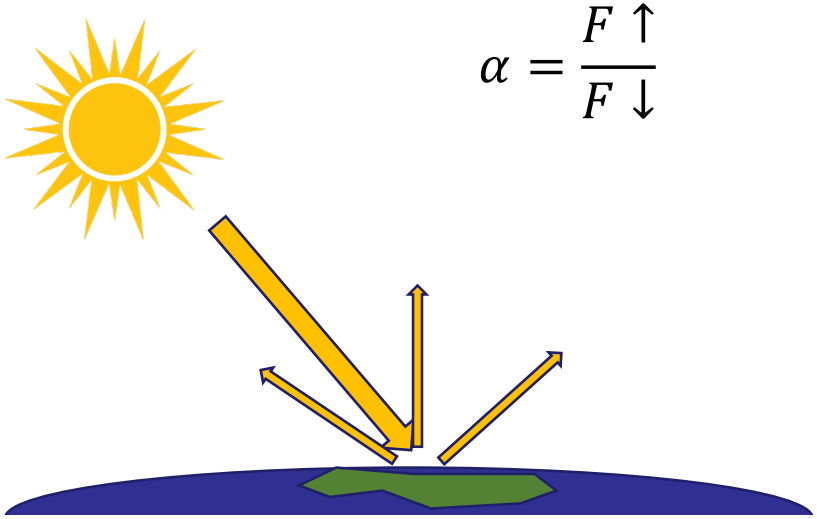
EUMETSAT
CM SAF
CLIMATE MONITORING

Background: surface albedo, the intuitive physical variable

$$\alpha = \frac{F\uparrow}{F\downarrow}$$



The animation shows the directional-hemispherical reflectance, or black-sky surface albedo.

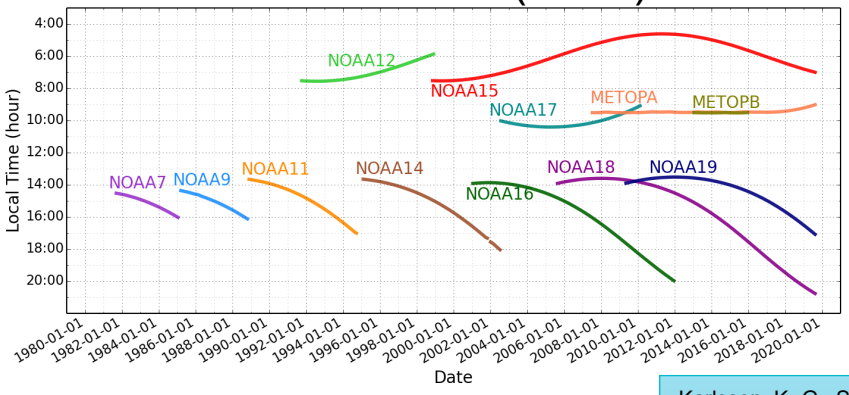
- Everyone has a surface albedo sensor: The MK I Eyeball
- While we are pretty good at qualitative albedo estimation (fresh snow > melting snow > grassland > asphalt), analyzing the Earth's energy budget requires quantitative estimates
- A useful note on terminology: *albedo = hemispherical reflectance,* but both our eyes and our satellites observe *directional reflectance*.
- A useful note on terminology #2: *planetary albedo != surface albedo*

The CLARA records – a brief history

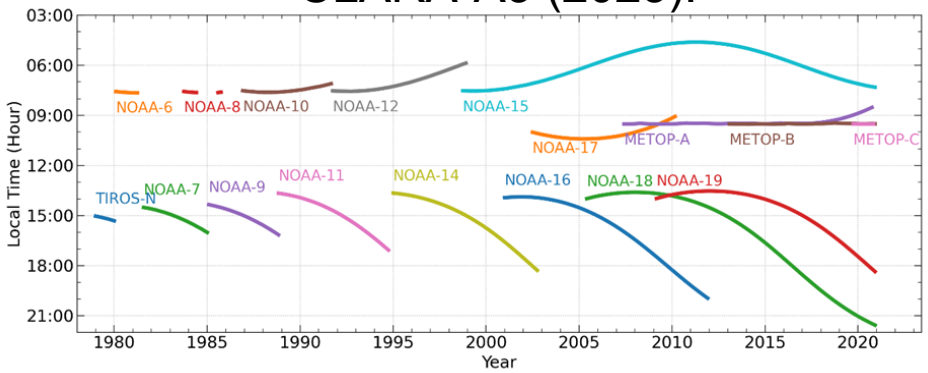
- CLARA: **C**M SAF c**L**ouds, **A**lbedo and **RA**diation
- Global scale climate data records of cloud and energy cycle from the AVHRR optical imager family

- CLARA-A1 released in 2012
- CLARA-A2 released in 2017, extended in 2020
- CLARA-A3 released in 2023

CLARA-A2 (2017):



CLARA-A3 (2023):



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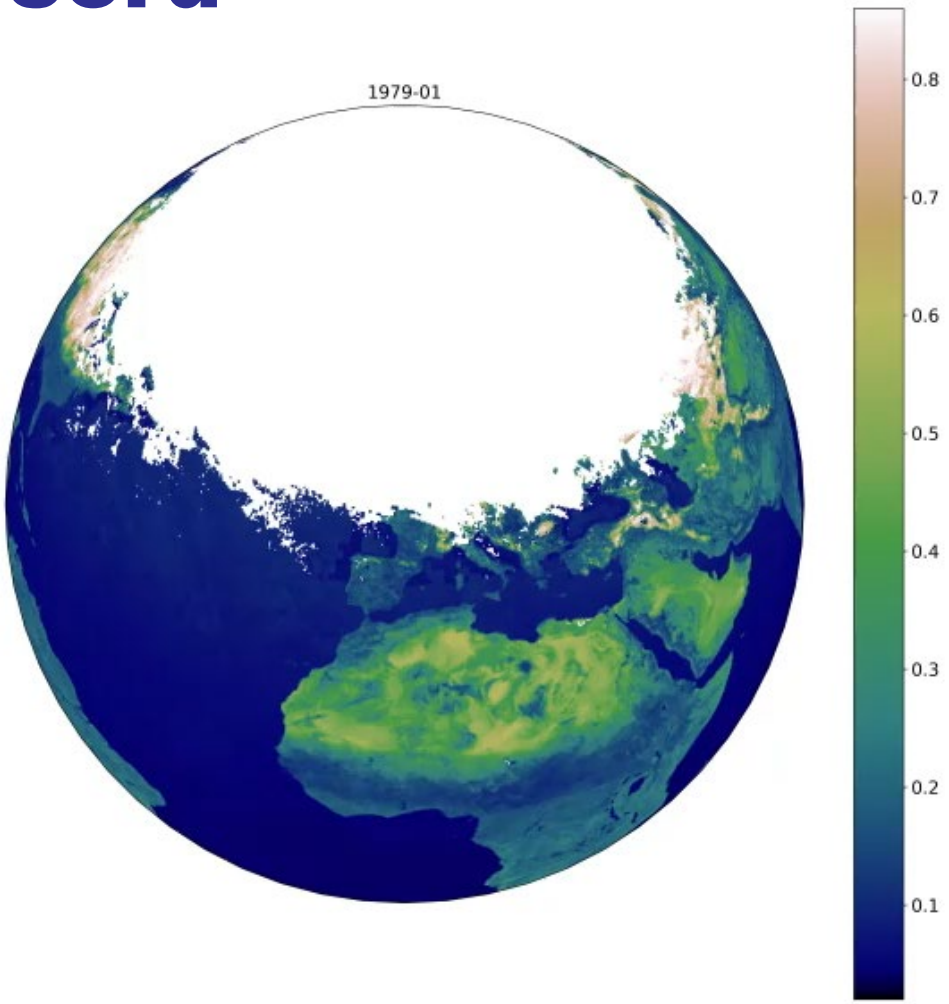
Karlsson, K.-G., Stengel, M., Meirink, J. F., Riihelä, A., Trentmann, J., Akkermans, T., Stein, D., Devasthale, A., Eliasson, S., Johansson, E., Håkansson, N., Solodovnik, I., Benas, N., Clerbaux, N., Selbach, N., Schröder, M., and Hollmann, R.: CLARA-A3: The third edition of the AVHRR-based CM SAF climate data record on clouds, radiation and surface albedo covering the period 1979 to 2023, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2023-133, in review, 2023.

The CLARA-A3 global surface albedo data record

- For the first time in CLARA editions, we provide
  - Black-sky albedo (DHR)
  - White-sky albedo (BHR_{ISO})
  - Blue-sky albedo (BHR)
- Global coverage between **1979-2020**, continues with an Interim Climate Data Record until **2023+**
- Available as pentad (5-day) and monthly means
- Spatial resolution of 0.25 degrees, polar subsets available in 25-km EASE2-grid
- Core algorithms consistent with predecessors (for black-sky albedo), but with e.g. improved cloud screening.



Variability of surface albedo

Albedo depends on:

1. Wavelength (snow is black in the near infrared at 1.6μm)

2. Illumination geometry (ever looked at a snowpack when the Sun is low?)

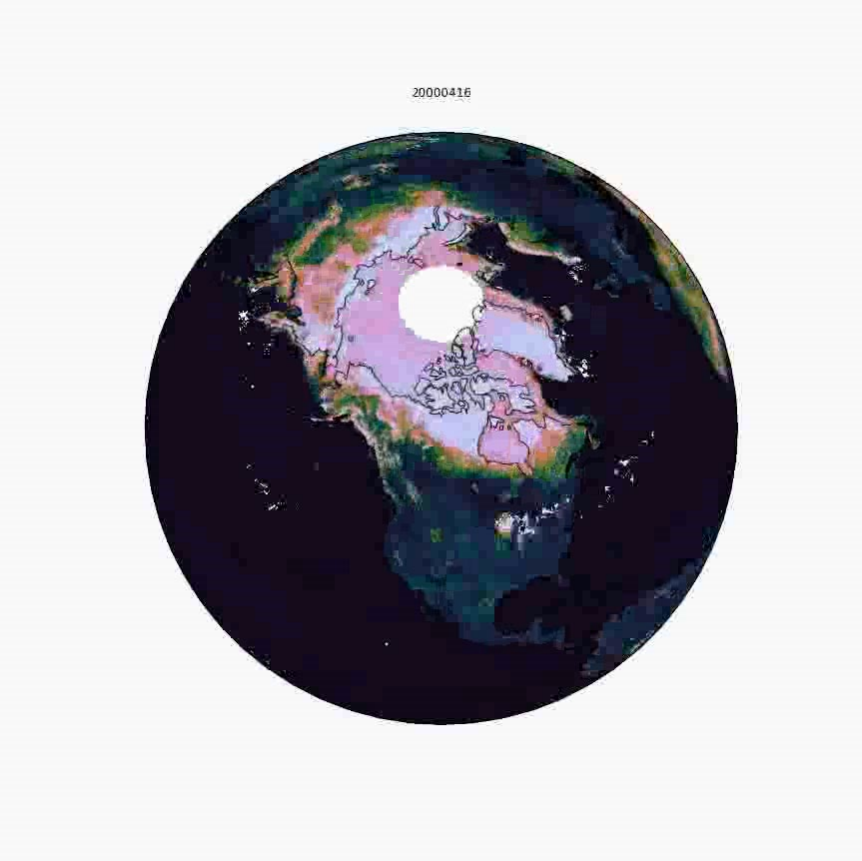
3. Surface material (think of melt ponds on sea ice)

4. 3D structure of said surface (vegetation canopies, snow micro/macrostructure)

5. For blue-sky albedo, atmospheric properties matter

The most essential thing driving albedo variability is the availability of snow/sea ice cover!

Satellite-based optical remote sensing of surface albedo



Critical challenges and boundary conditions:

1. **No observations** possible under **clouds** or with **insufficient solar illumination**

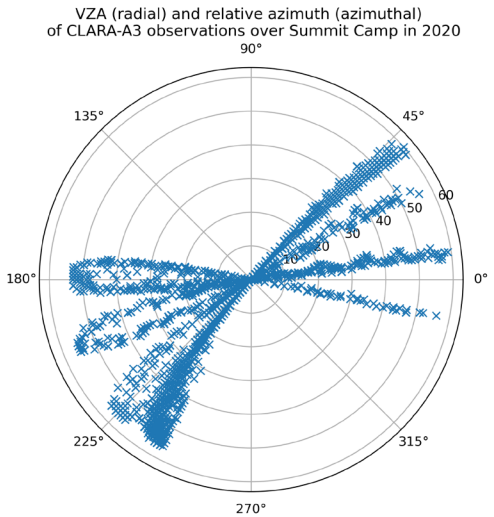
2. The satellite observes the surface from **one (variable) direction at a time**, and **the atmosphere can strongly affect** the measurement.

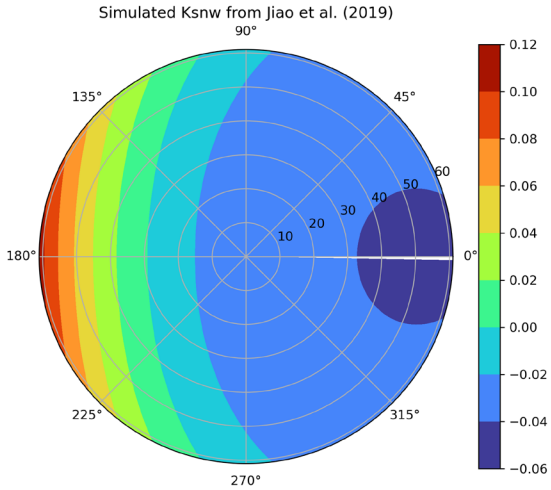
3. Albedo depends on the **land surface** types of the observed scence, which are **not smoothly varying**.

4. **Satellites observe only discrete parts of the shortwave solar spectrum**, yet the full broadband albedo is needed for many applications.

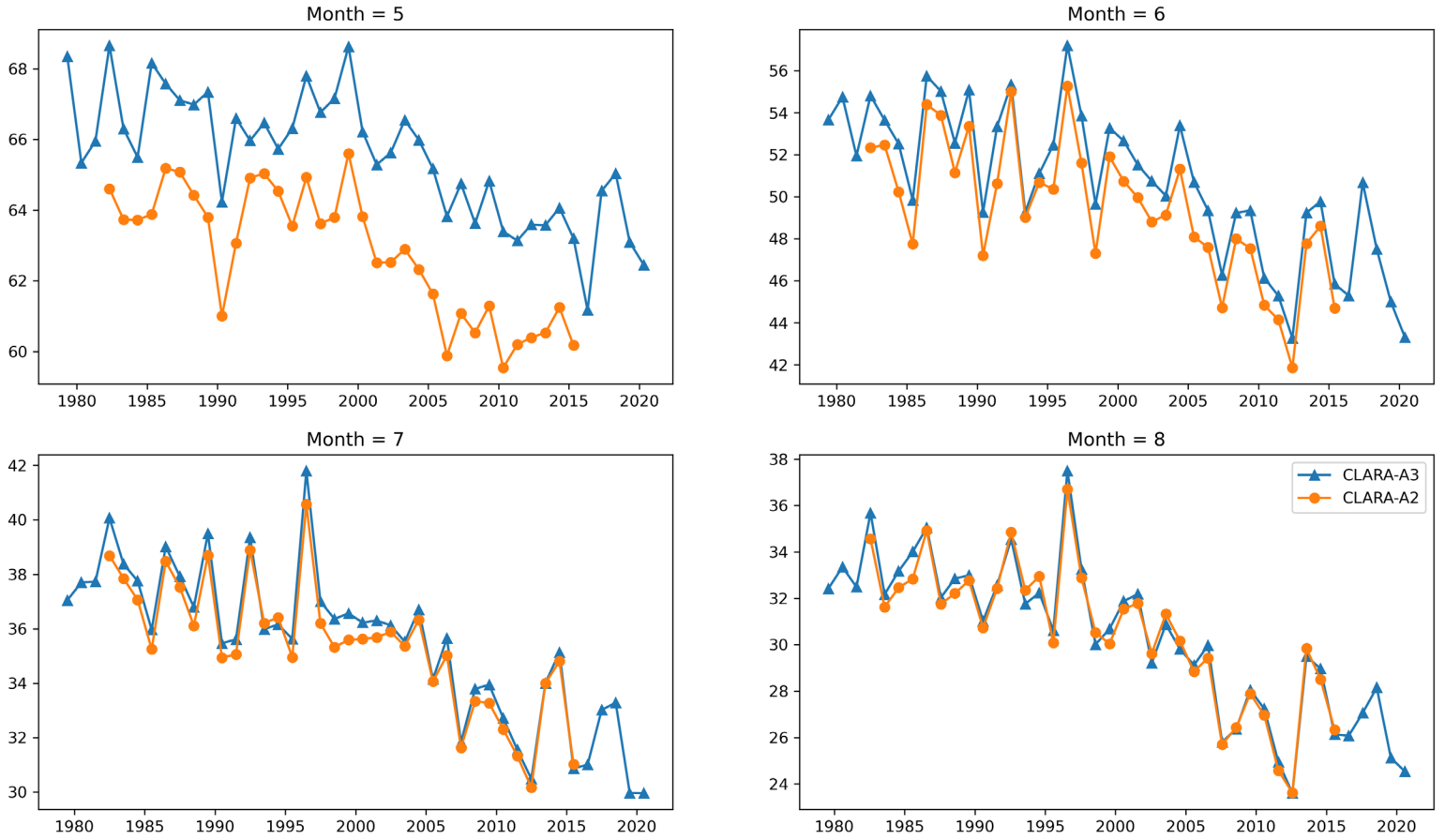
Retrieval algorithm in 30 seconds…

Cloud and illumination screening → Topography correction → Atmospheric correction → Angular reflectance (BRDF) correction → Narrow-to-broadband conversion

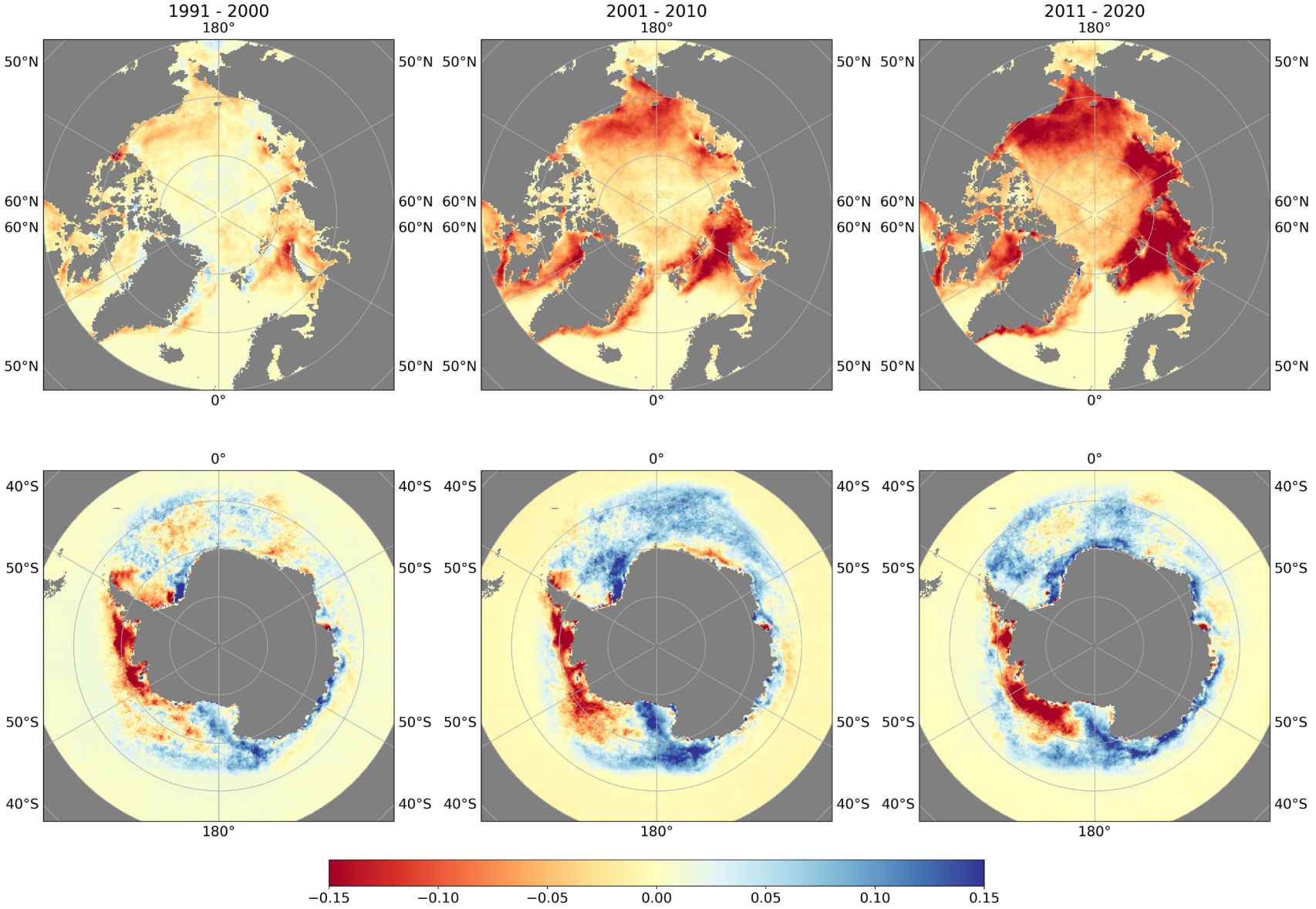




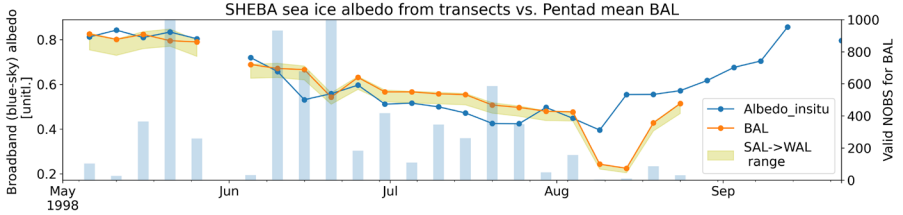
CLARA-A3 vs CLARA-A2, monthly mean Arctic black-sky albedos for lat>70 deg.

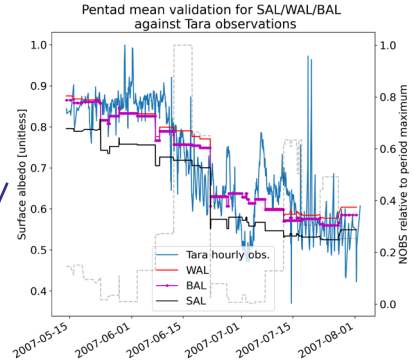


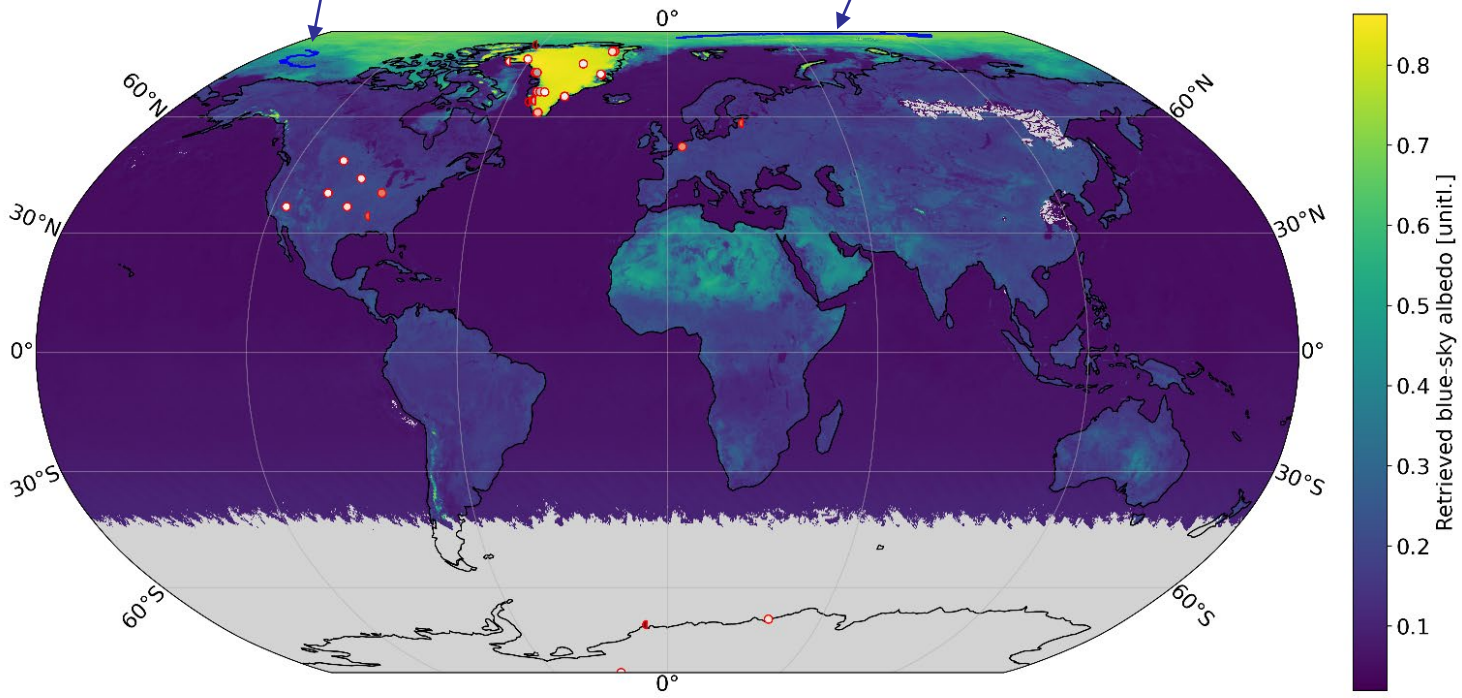
Polar sea ice: Decadal summer blue-sky albedo difference to 1979-1990



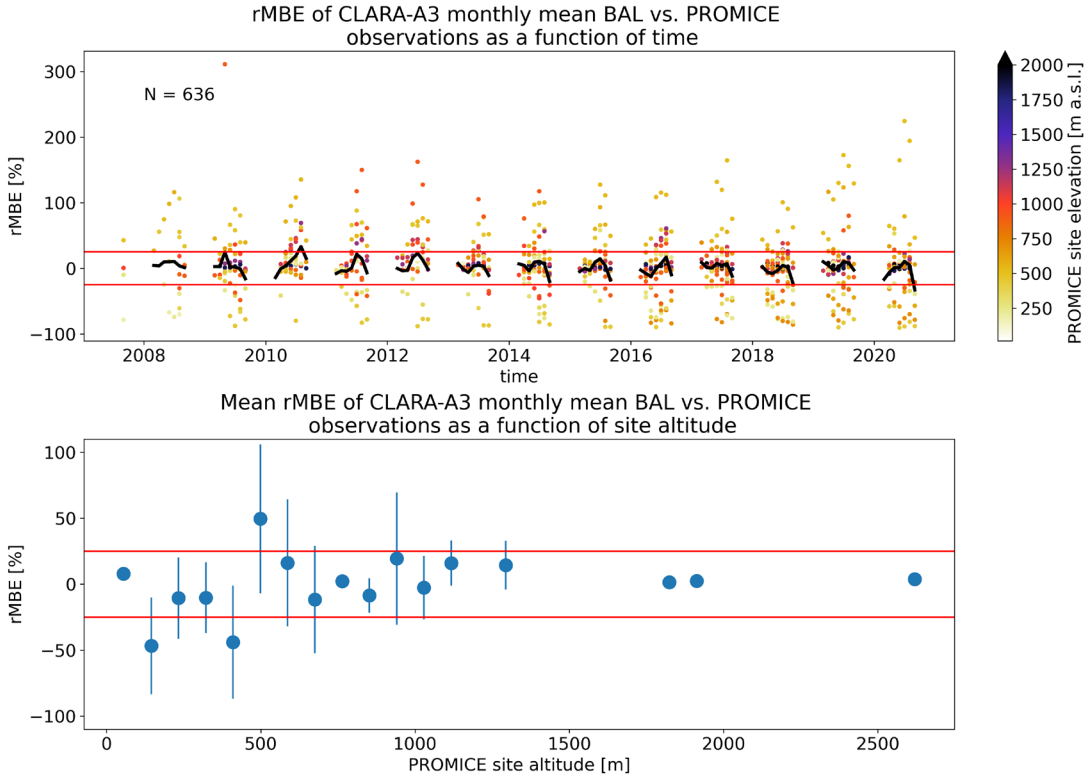
Evaluation of data record quality

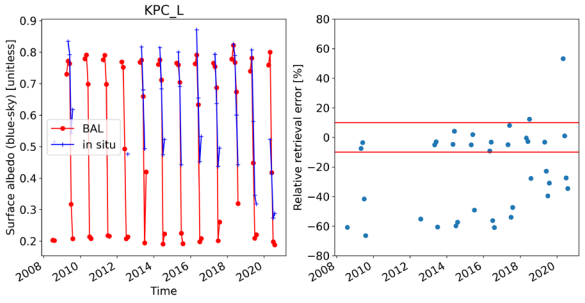


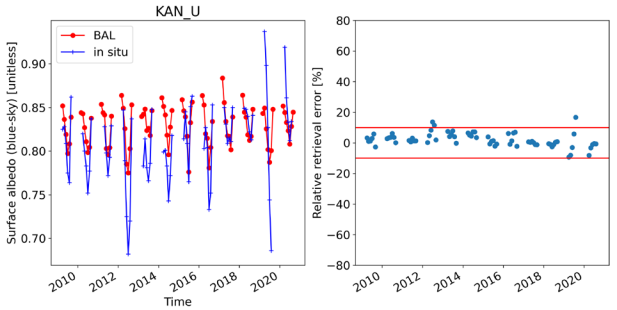




Retrieval bias vs PROMICE





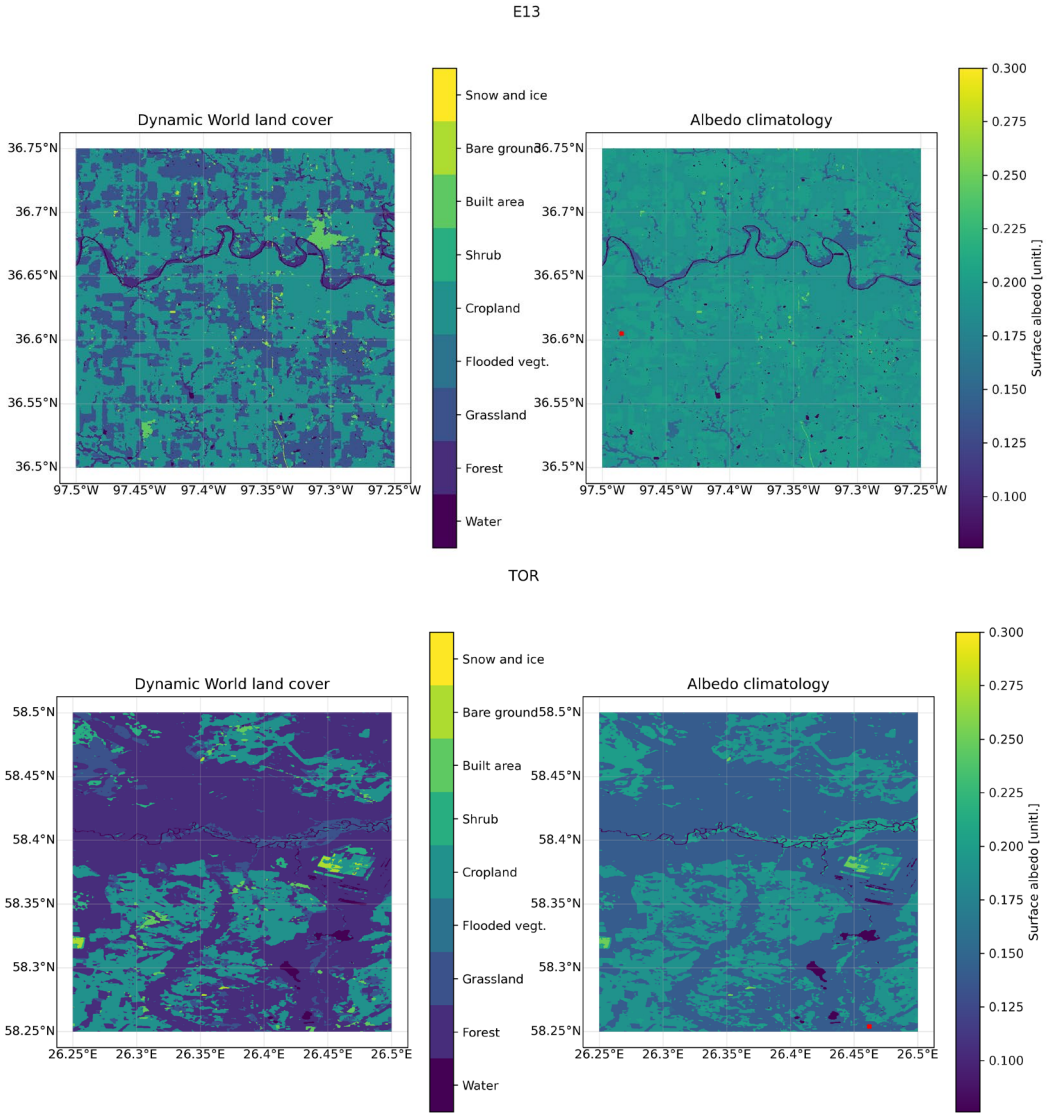


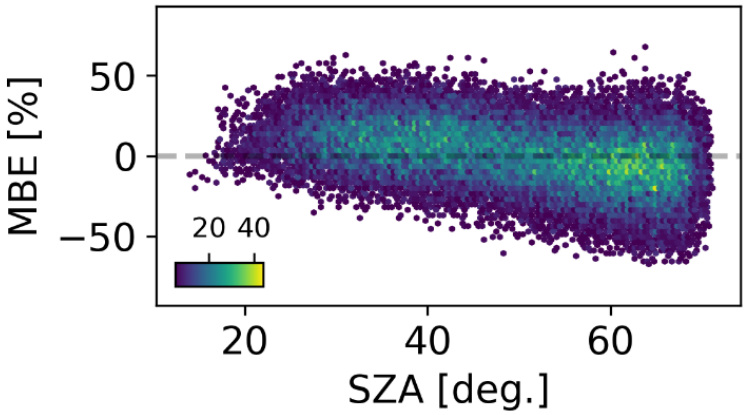
The point-to-pixel problem

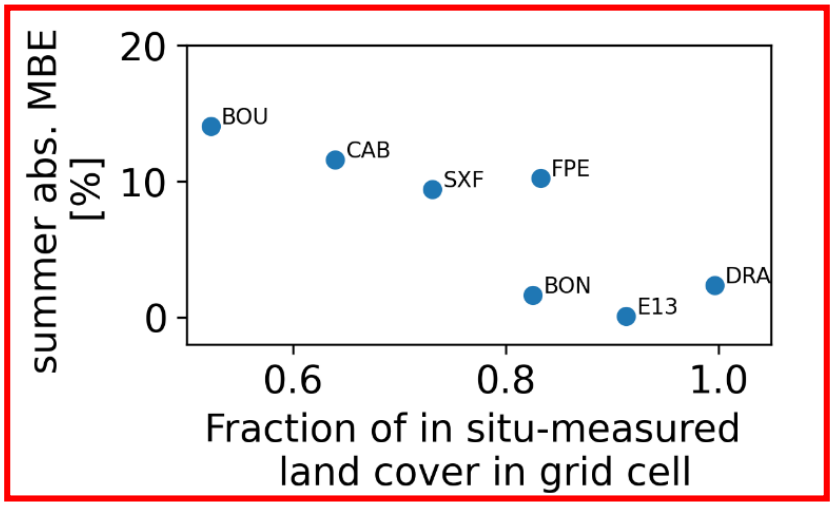
Pyranometer footprint is some hundreds of sq.m, AVHRR footprint is some square kilometers. Is observed low bias between CLARA and reference any indication of actual retrieval quality?

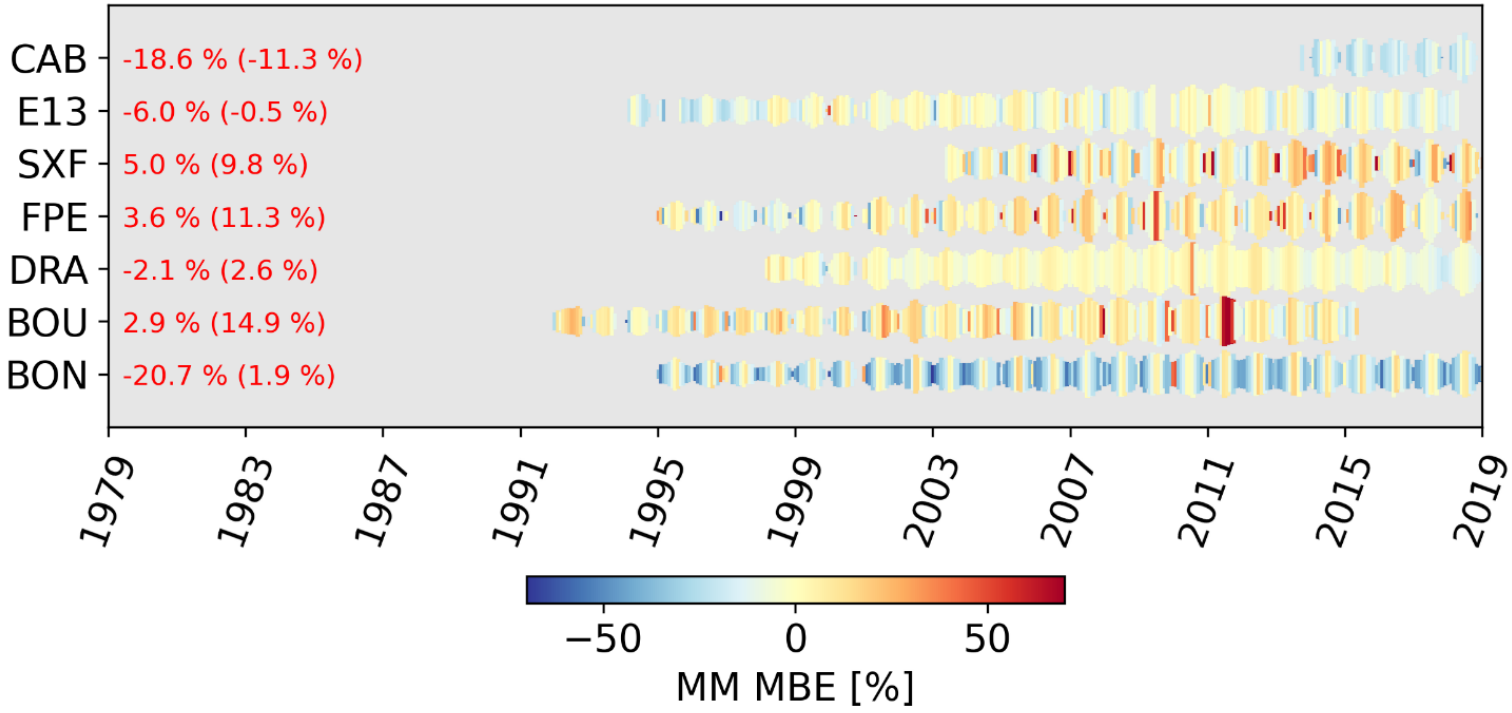
-> Enter Google Dynamic World land cover, nominal resolution ~30 meters

-> Compute 'expected' surface albedo at CLARA grid cell scale to identify where large biases are to be expected




MBE [%]
50
0
−50
20 40
20
40
60
SZA [deg.]


summer abs. MBE [%]
20
10
0
BOU
CAB
SXF
FPE
BON
E13
DRA
0.6
0.8
1.0
Fraction of in situ-measured land cover in grid cell


CAB
E13
SXF
FPE
DRA
BOU
BON
-18.6 % (-11.3 %)
-6.0 % (-0.5 %)
5.0 % (9.8 %)
3.6 % (11.3 %)
-2.1 % (2.6 %)
2.9 % (14.9 %)
-20.7 % (1.9 %)
1979
1983
1987
1991
1995
1999
2003
2007
2011
2015
2019
−50
0
50
MM MBE [%]

Strengths, weaknesses, artefacts?

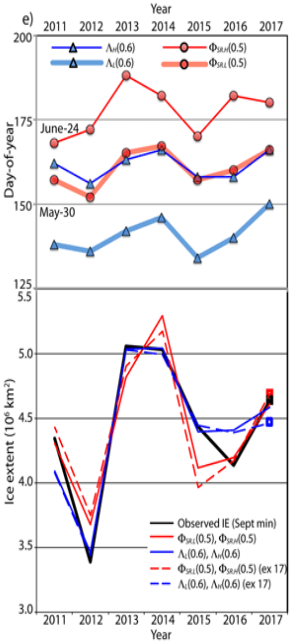
- Predecessors have a proven track record for cryospheric albedo studies. CLARA-A3 is expected to continue that with extended coverage and new flavours of data available to users
- Bias against reference observations is low, matches or improves upon previous CLARA albedo estimates

- Algorithm designed for low bias (esp. over cryosphere), the tradeoff being low precision (meaning large scatter about the low mean bias)
- Spatiotemporal resolution remains coarse

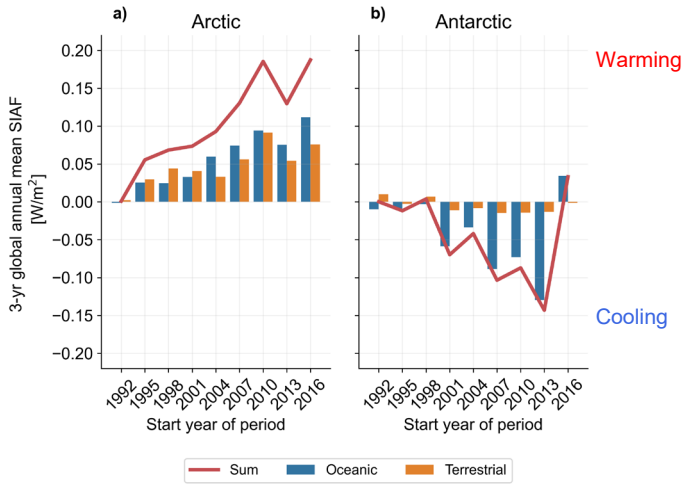
- Some [technical] artefacts have been found:
  - Individual retrievals in polar night, resulting from corrupted data
  - Transient artefacts at dateline crossing for the polar subsets
  - Antarctic sea ice is somewhat dimmer than in CLARA-A2; investigation to follow on the plausibility of the change

You may be interested in the record if you are…

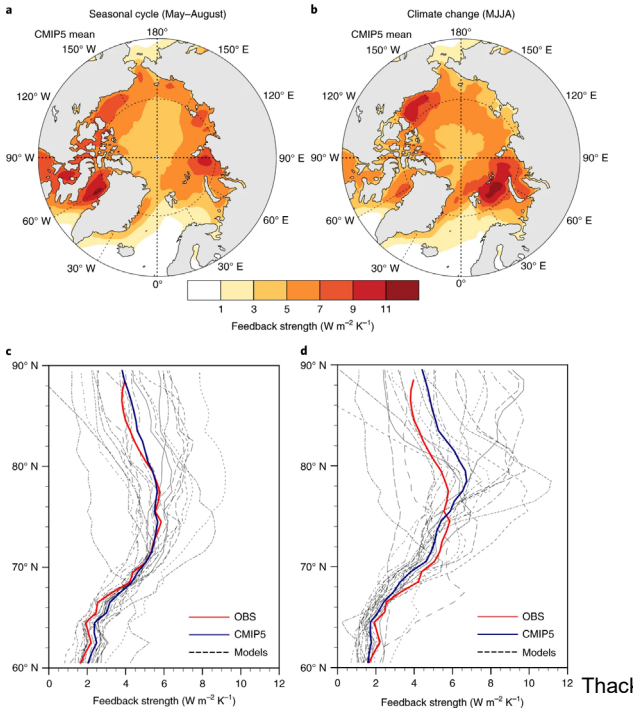
- Working on large-scale climate analysis
- Interested in the properties of and changes in the global snow and ice cover
- Interested in examining the global radiative energy budget



Kwok et al., 2018



Riihelä et al., 2021



Thackeray & Hall, 2019

Thank you!