COST HarmoSnow albedo workshop
24-25 August 2016, FMI

Michele Citterio
GEUS

Automated in situ albedo observations: PROMICE status and opportunities

a research and advisory institution in the ***Ministry of Climate and Energy***

KLIMA-, ENERGI- OG BYGNINGSMINISTERIET

GEUS

PROMICE

Programme for Monitoring of the Greenland Ice Sheet

Programme for Monitoring of the Greenland Ice Sheet

PROMICE goals

- **Provide a consistent long-term data set of observations from the Greenland ice sheet**
- **Calculate mass loss**
- **Understand the mass loss**

Established: *2007 – 2010*

Operational*: 2011 – onwards*

All our data is public from day 1, see www.promice.org

PROMICE

Programme for Monitoring of the Greenland Ice Sheet

Monitoring of:

- **surface energy balance** (SEB)
- **surface mass balance** (SMB)
- **dynamic loss** (icebergs)

Largest energy source during melt season: <u>solar radiation</u>

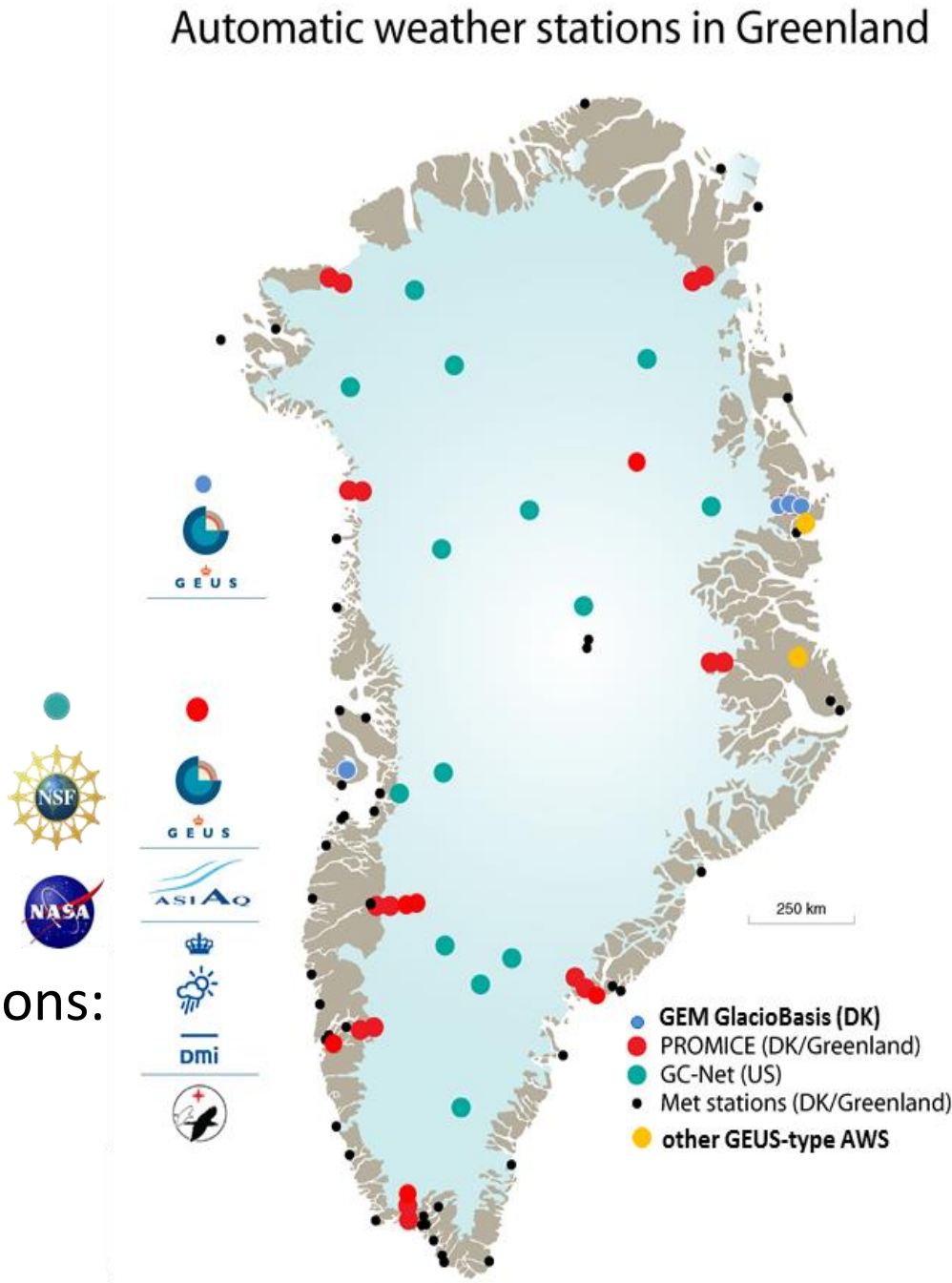
albedo is enough for SEB at the point of the station

... but ...

we work at the Greenland scale

To link with space-based observations:

- **narrow- vs. broadband**
- **BRDF**
- **surface roughness**



Obsevationally based melt products

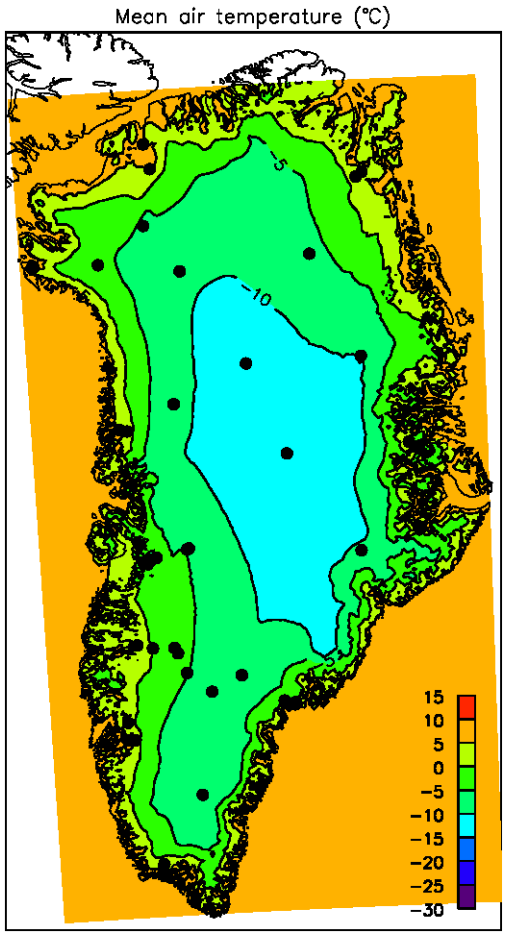


Figure 1: Average near-surface air temperature for days 178-182 in 2011.

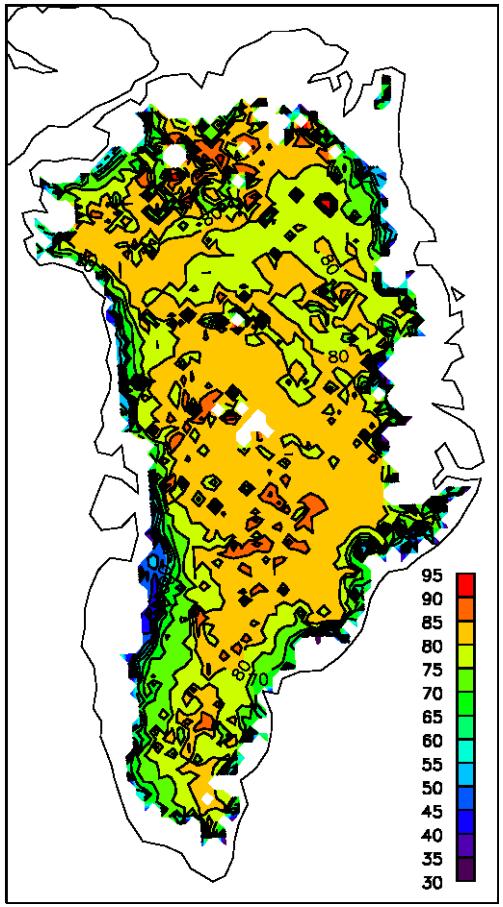


Figure 2. MODIS albedo

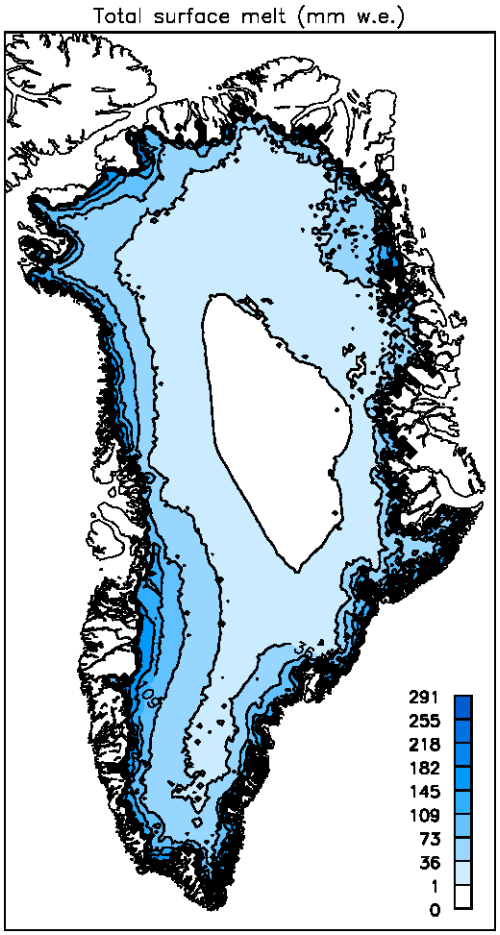


Figure 3. Surface meltwater locally generated on the Greenland ice sheet for days 178-182 in 2011.

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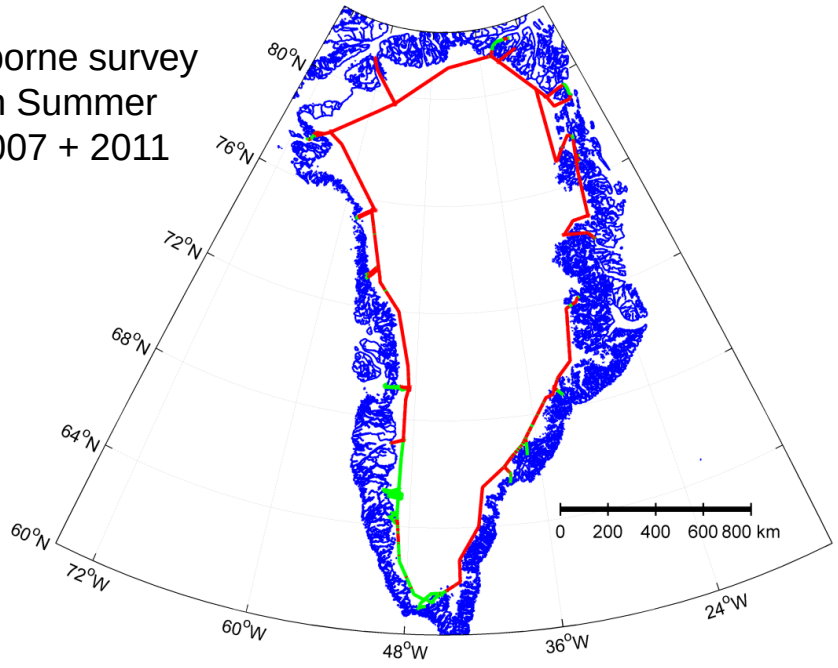
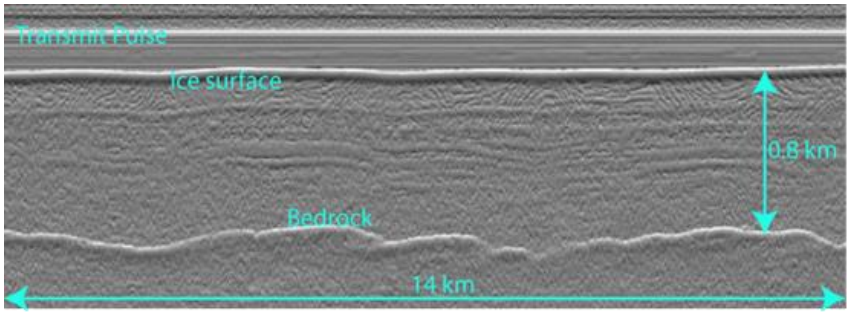
Airborne surveys of flux gates, and...

Airborne survey in Summer 2007 + 2011





DTU | DTU Space
National Space Institute

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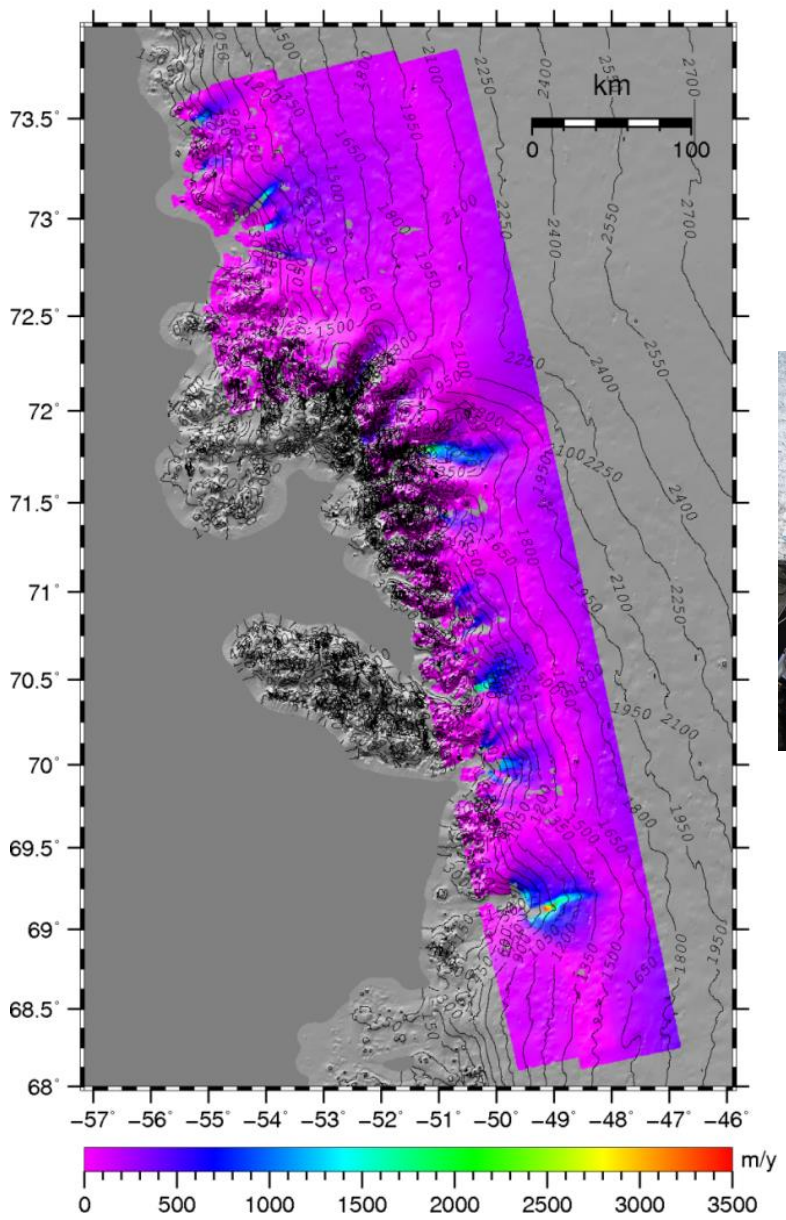
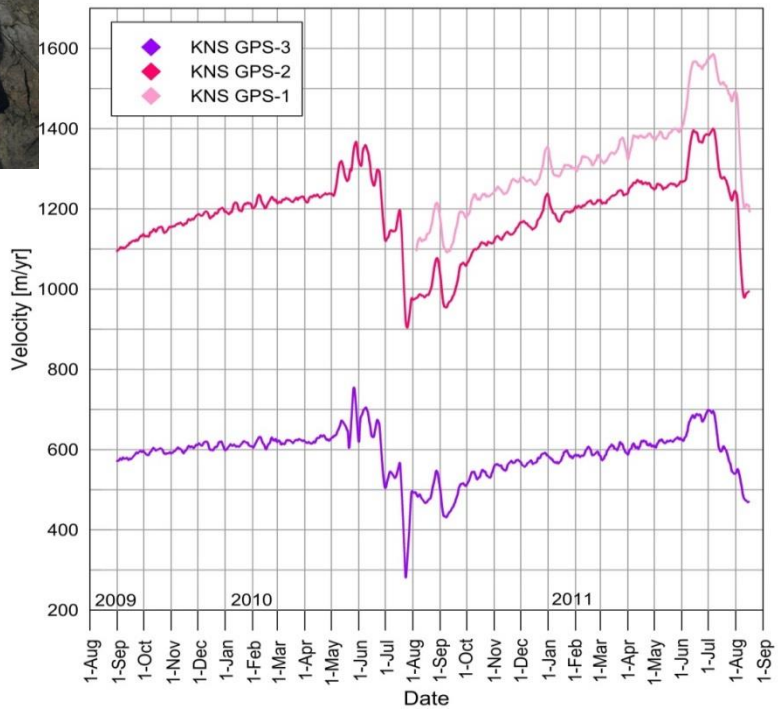
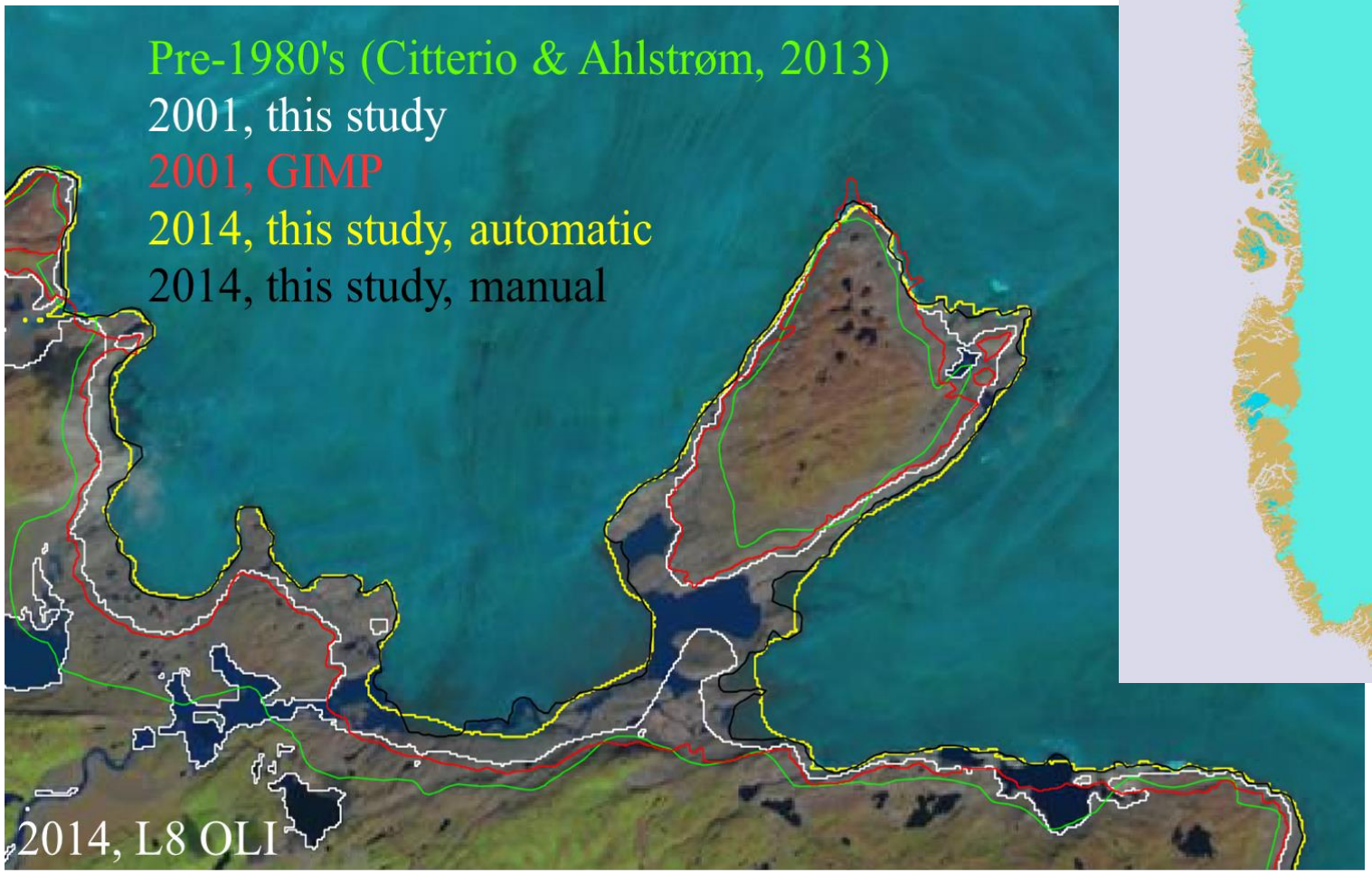
…flow velocities → dynamic mass loss

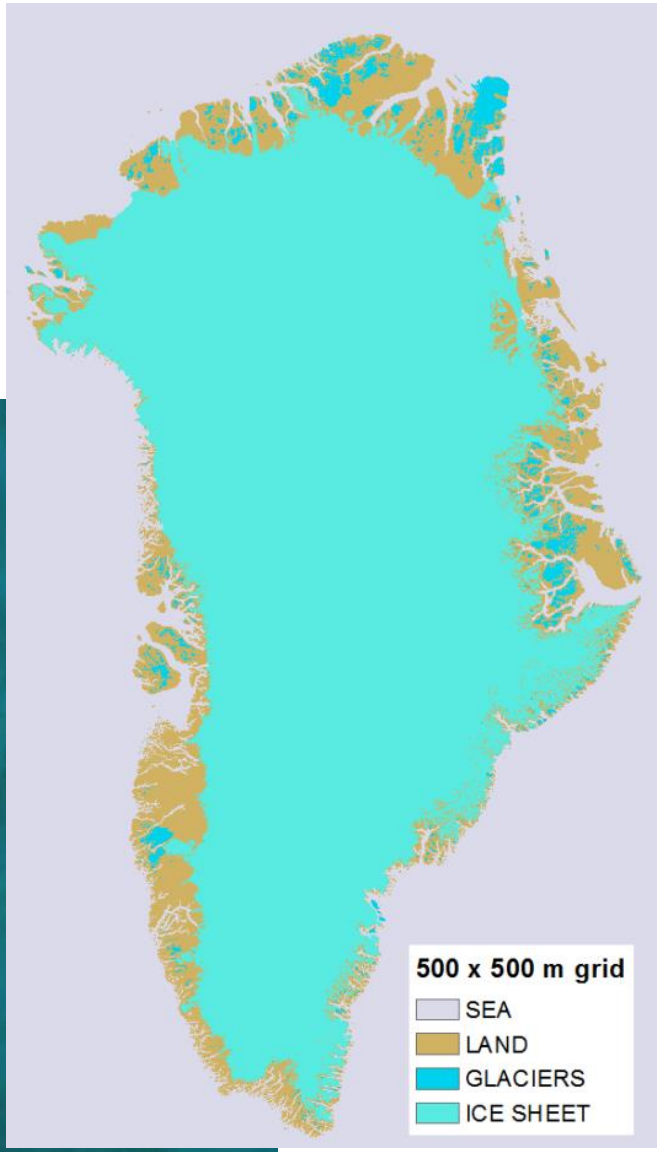




Mapping glacier margin fluctuations, and…

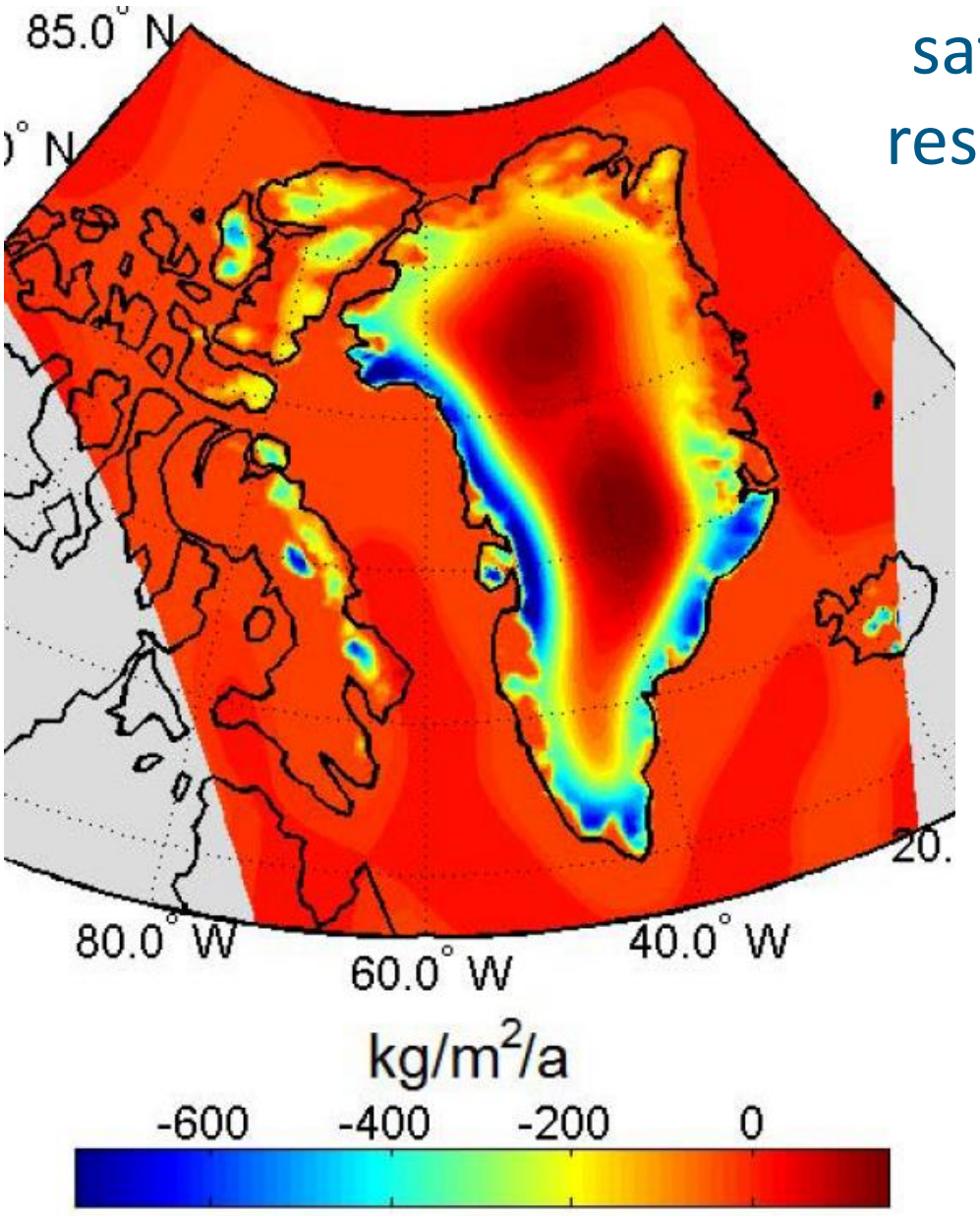
- ice sheet
- 10^5 glaciers separated from the ice sheet
- 10 - 30 m change (Sentinel 2 – Landsat pixel)





(Citterio & Ahlstrøm, TC, 2013)

… regional mass change from satellite gravimetry → high resolution total mass change



- Partition mass loss between ice sheet and local glaciers

- Avoids double counting

- No mixing of fast (glaciers) and slow (ice sheet) response time ice masses

Between December 2003 to December 2010:

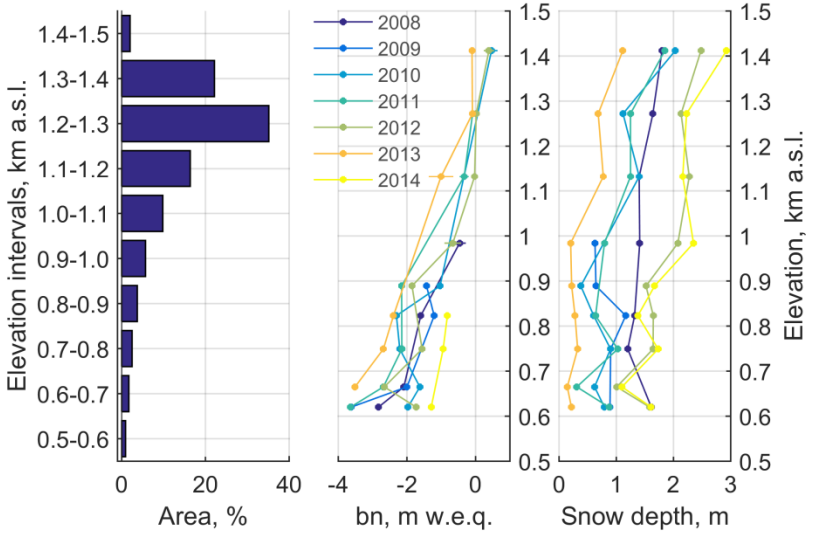
218 ± 20 Gt / yr from the ice sheet proper,

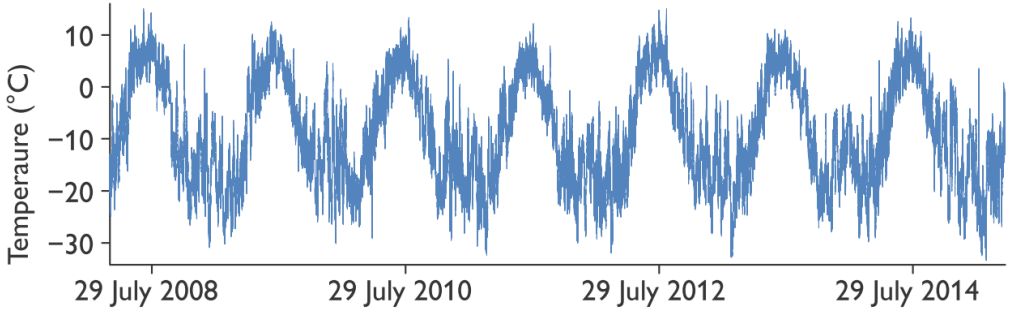
34 ± 5 Gt / yr (or 14%) from Greenland peripheral glaciers and ice caps

Colgan et al.,
Rem. Sens. Env. 2015

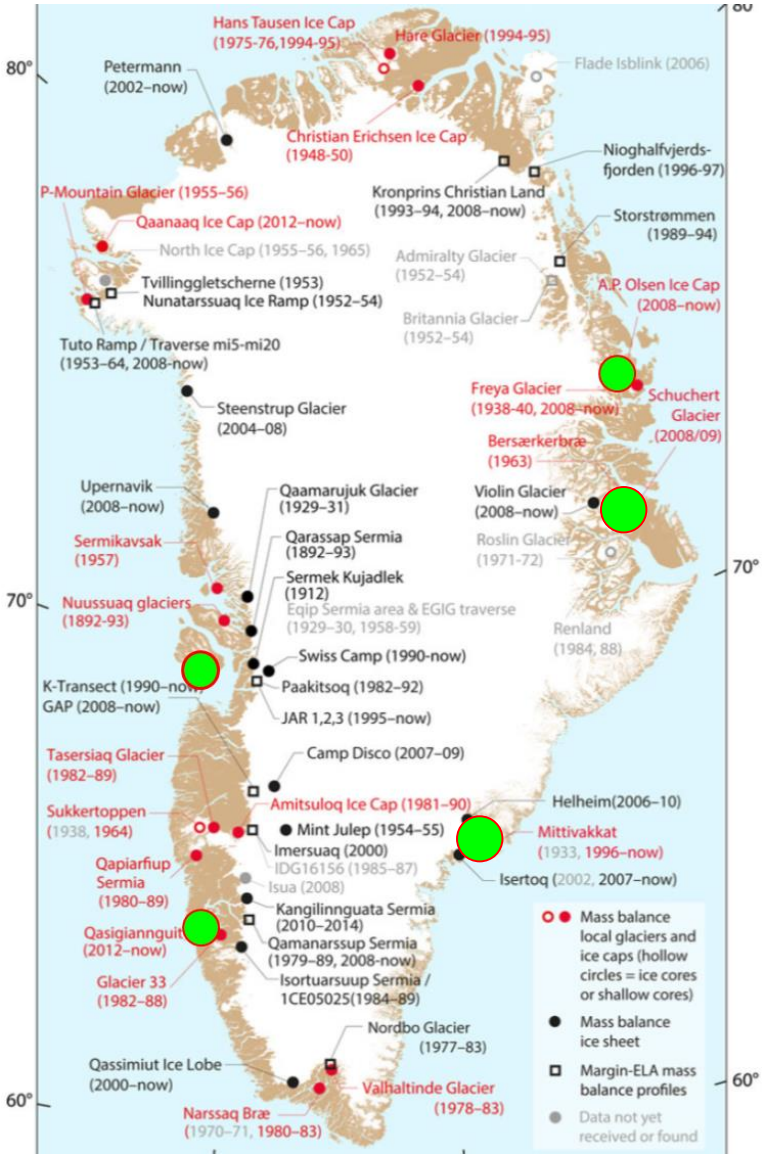
Monitoring of local glaciers

- A.P. Olsen ice cap (GEM, GEUS)
- Qasigiannguit glacier (GEM, Asiaq)
- Chamberlin glacier (GEM, GEUS)
- Mittivakkat glacier (KU and PROMICE, GEUS)
- Schuchert glacier (mining, GEUS)



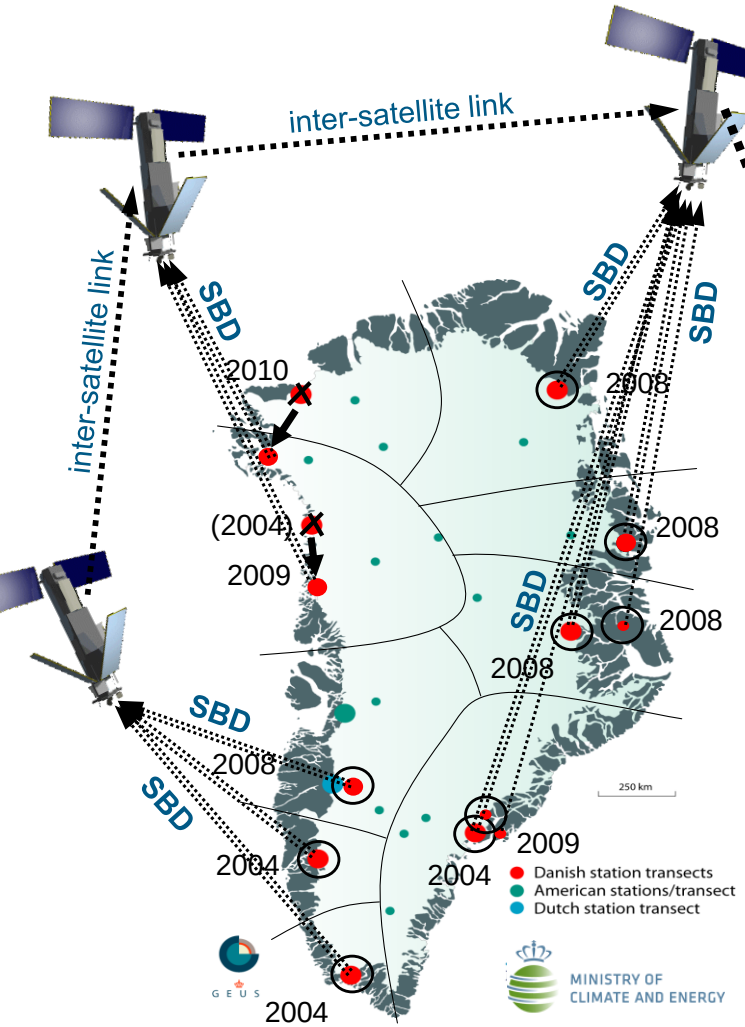


APO-1 AWS

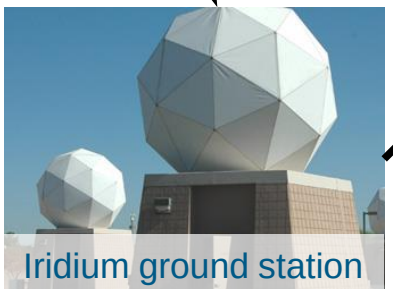


Machguth et al., 2016

PROMICE as a component of GCW CryoNet



downlink



e-mail

DMI

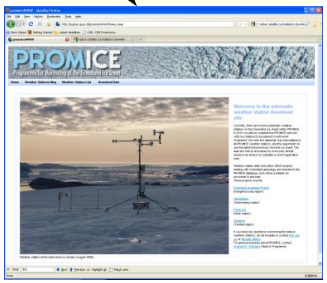
WMO

realtime

GCW
Global Cryosphere Watch

G E U S
PROMICE
database

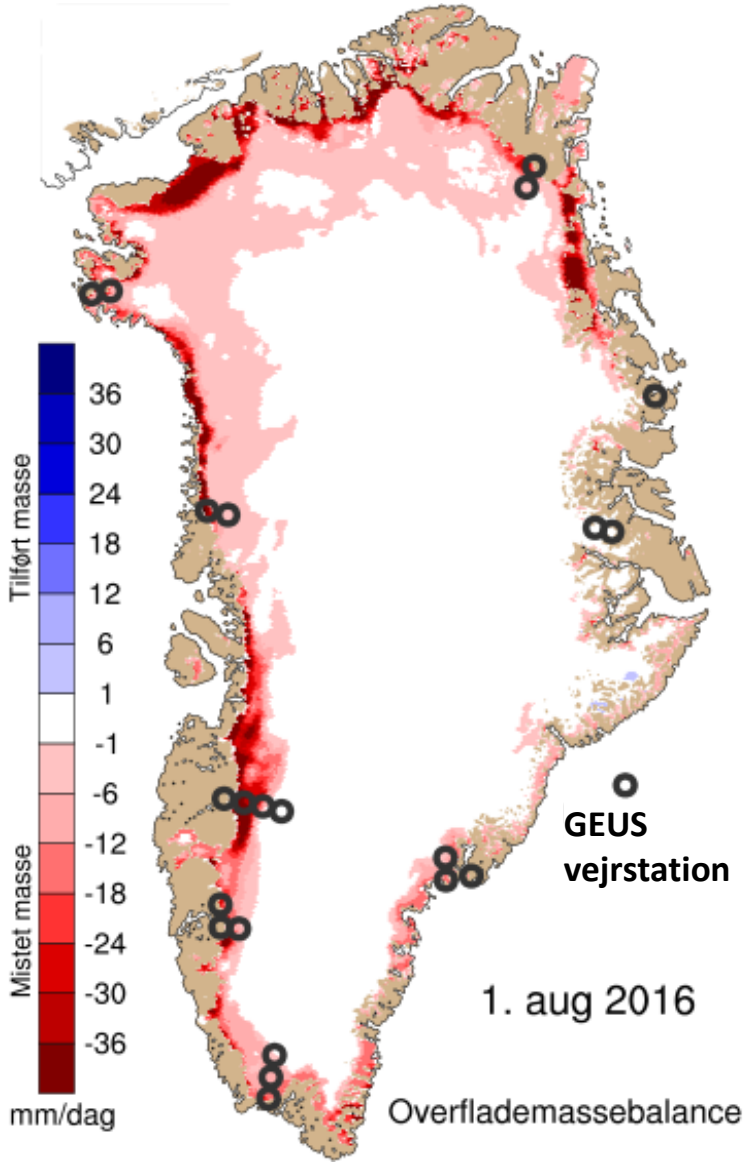
timeseries,
metadata

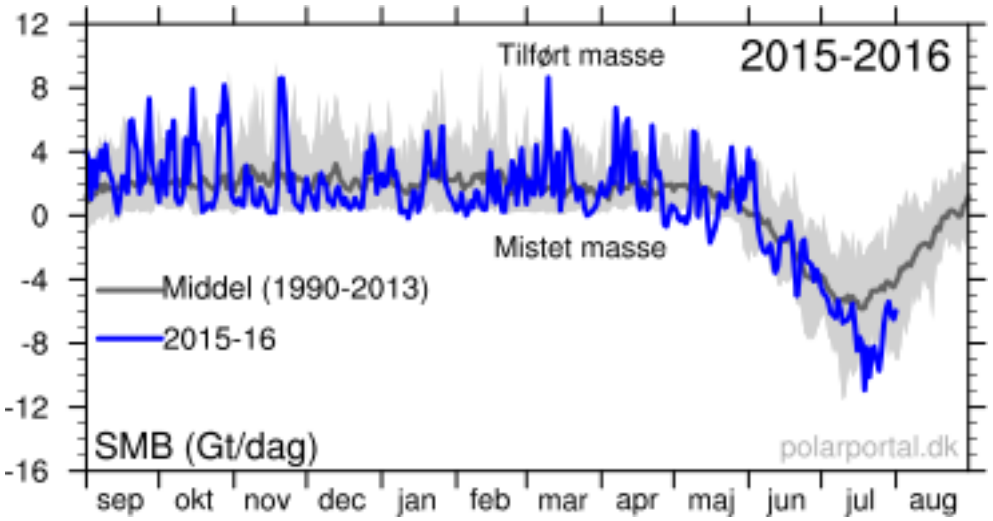


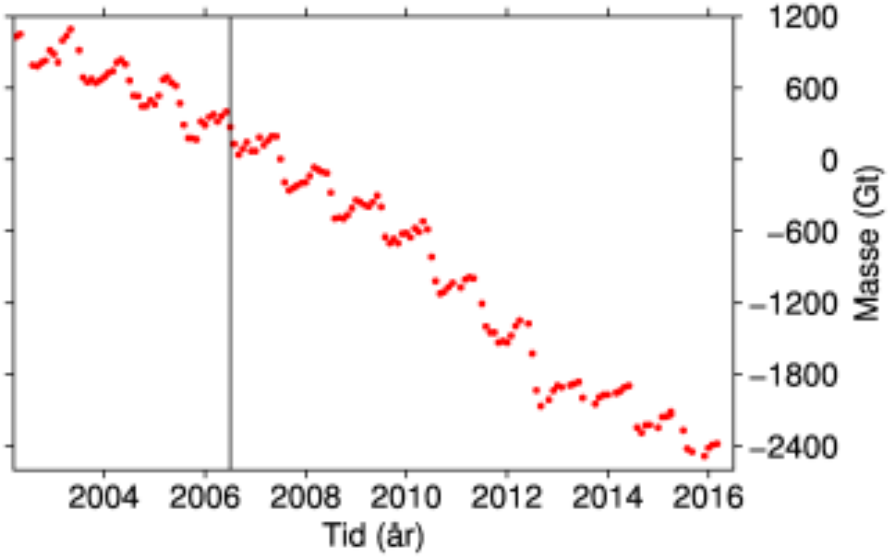
Free full online data access: www.promice.org

M. Citterio - mcit@geus.dk

Near real time mass balance estimate and public outreach







from www.polarportal.dk, daily updated state of Greenland cryosphere by DMI, GEUS & DTU

PROMICE

Programme for Monitoring of the Greenland Ice Sheet

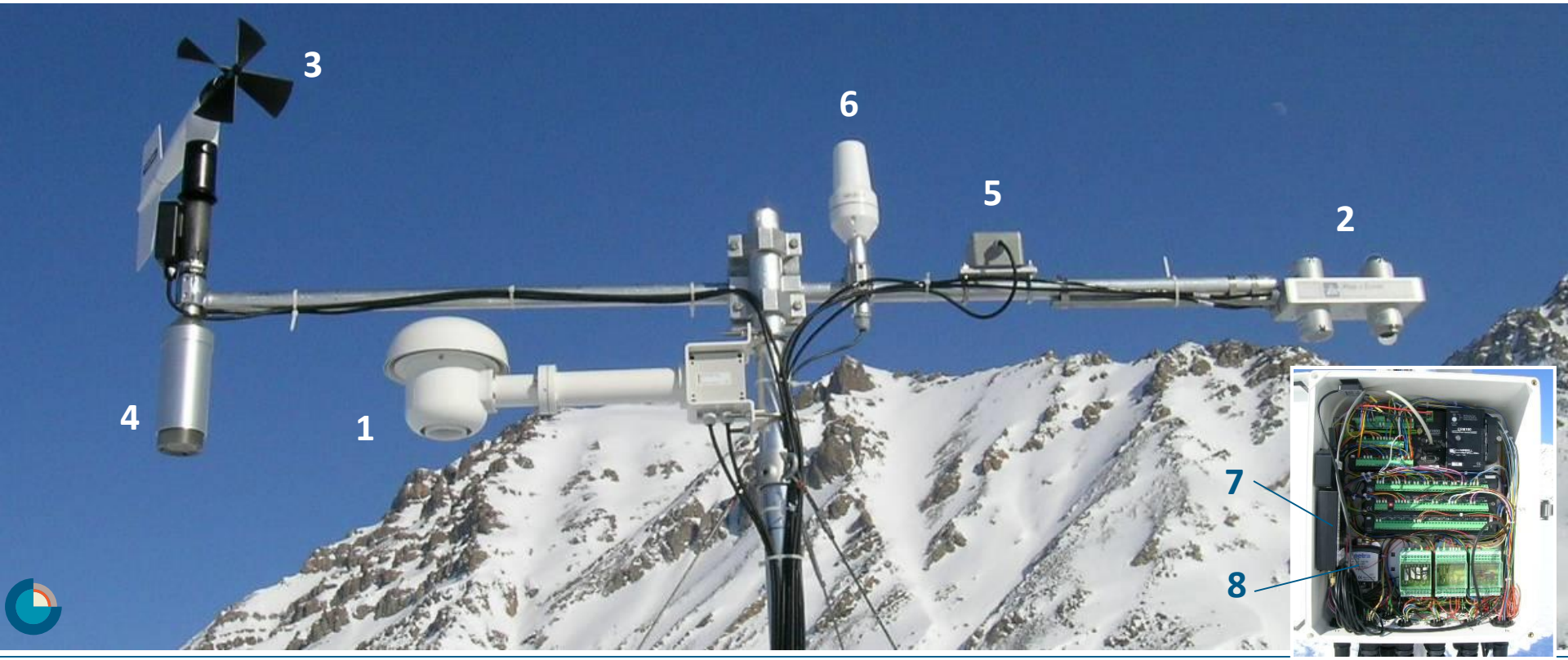
Sensors on the mast and boom

Sensors mounted on the tripode:

1. air temperature and humidity (aspirated)
2. SW↓, LW↓, SW↑, LW↑ radiation
3. wind speed and direction
4. snow surface level
5. two-axes tilt meter
6. Iridium satellite antenna
7. GPS receiver and Iridium modem
8. barometric pressure

Other sensors:

ice surface level (sonic ranger on drilled stakes)
8-levels thermistors string (GEUS)
hydraulic ablation meter (GEUS)



mcit@geus.dk

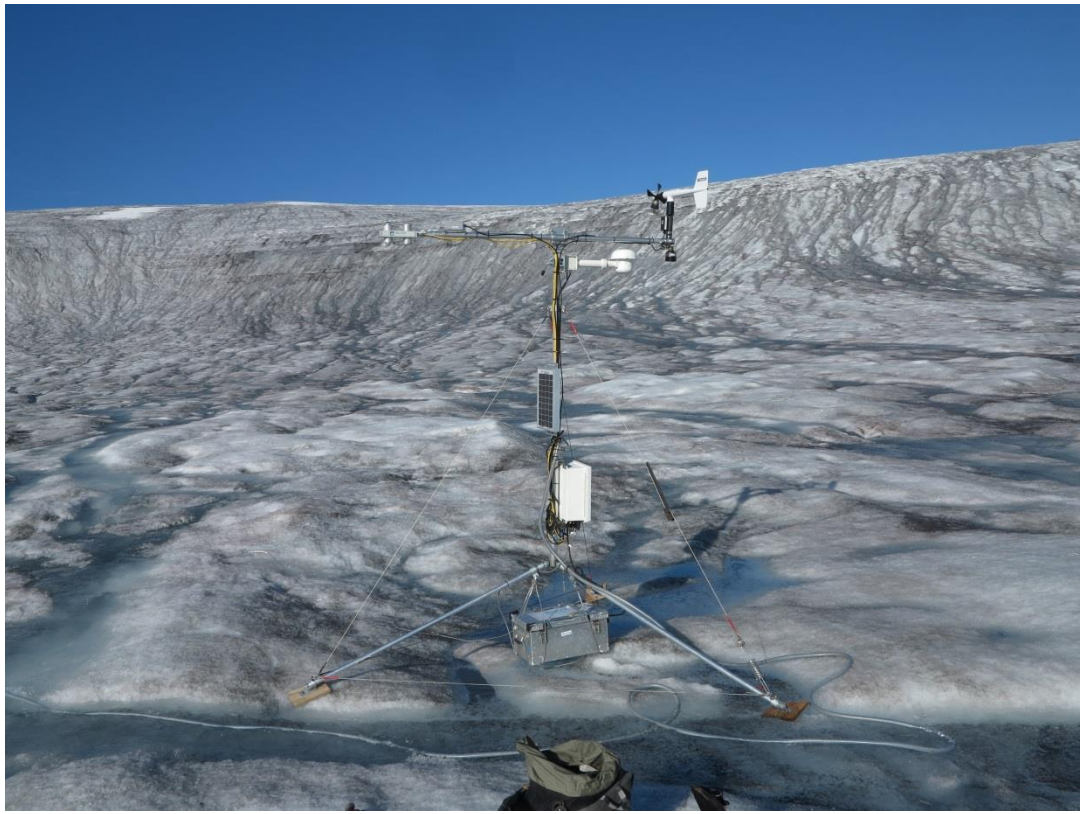
GEUS glaciological AWS (Citterio et al., 2015)

mcit@geus.dk

Surface melt conditions

Monitoring of surface energy balance (SEB) and surface mass balance (SMB)

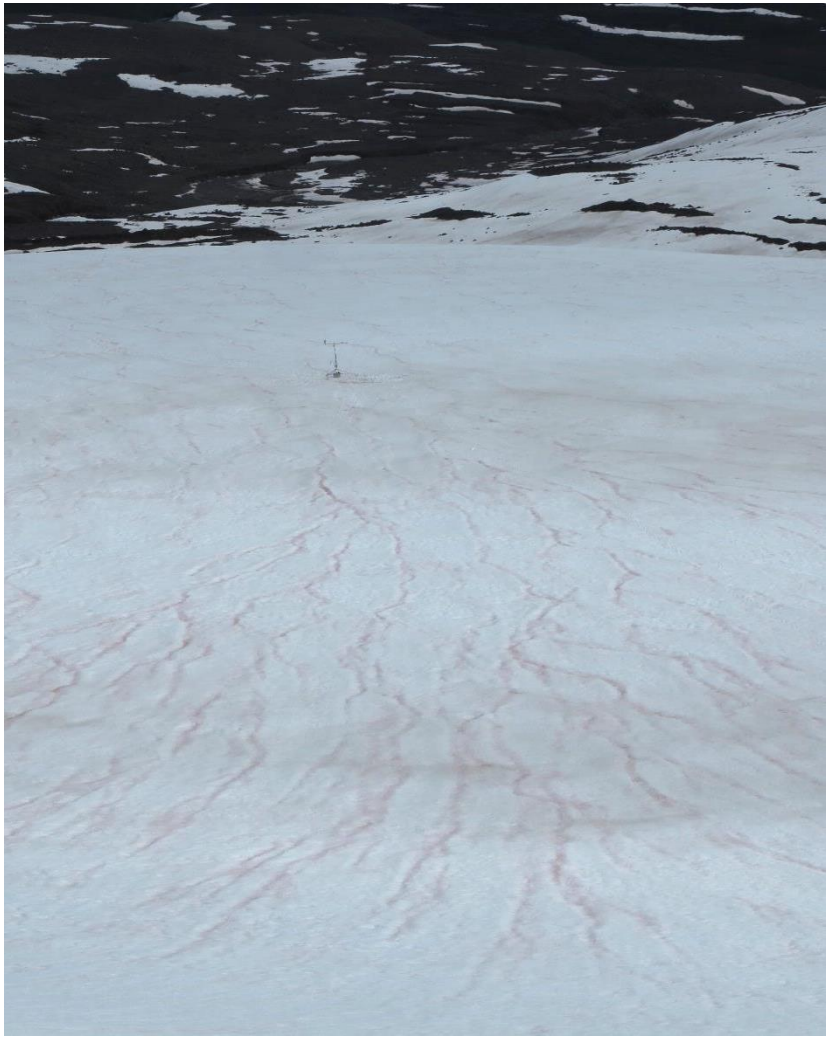
- Ice vs. firn vs. Snow albedo
- Surface roughness
- ‘dirt’
- meltwater ponds and streams
- crevasses

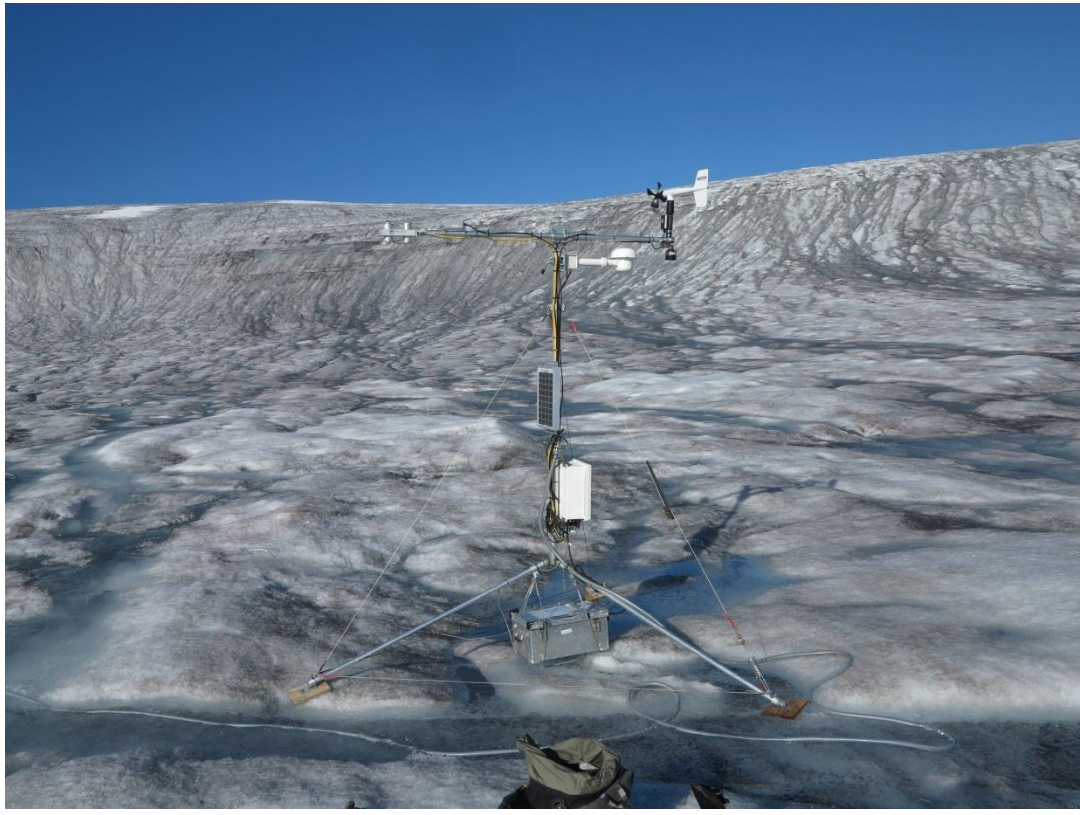


Surface melt conditions

Monitoring of surface energy balance (SEB) and surface mass balance (SMB)

- Microbiology (algae, bacteria)

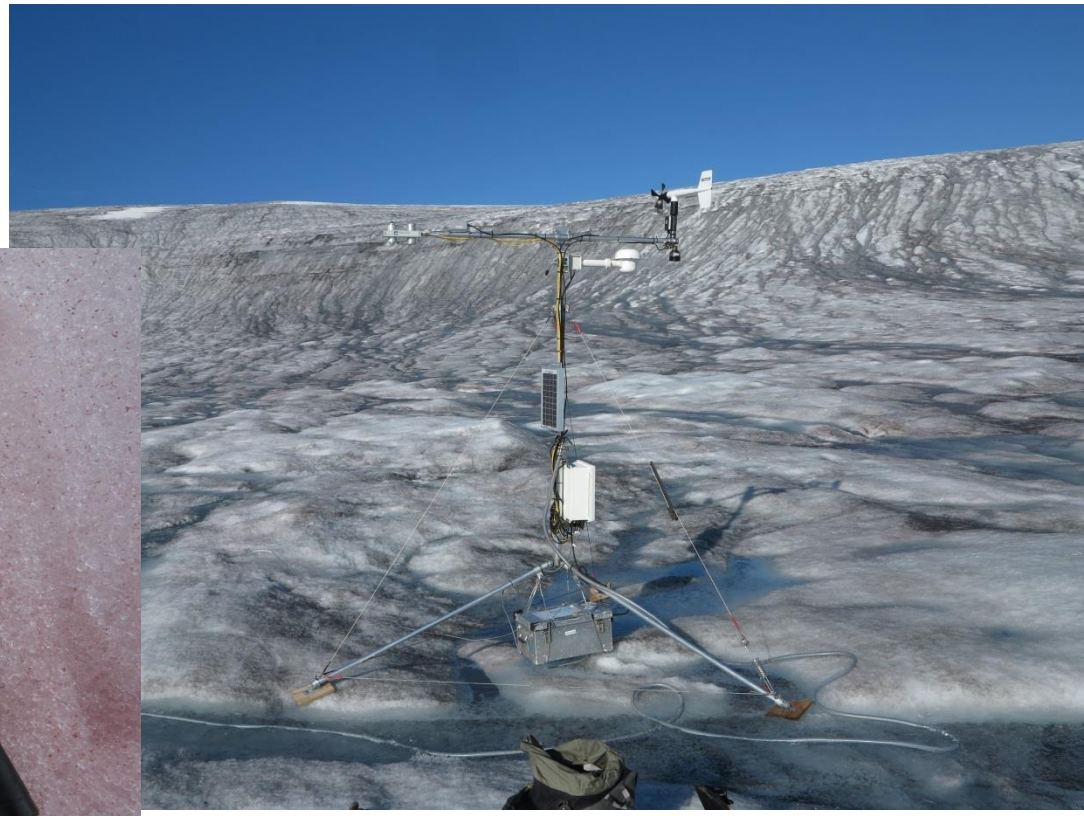




Surface melt conditions

Monitoring of surface energy balance (SEB) and surface mass balance (SMB)

- ...
- Microbiology (algae, bacteria):
  → albedo change?
  → timing?

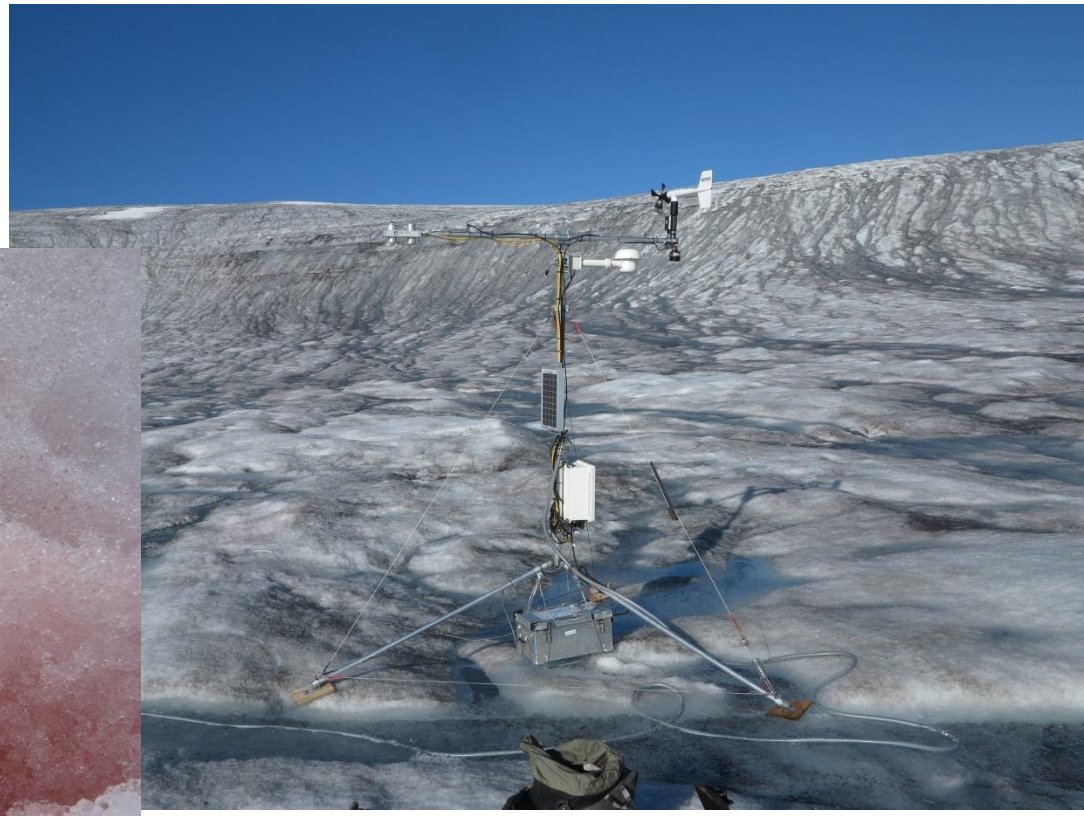


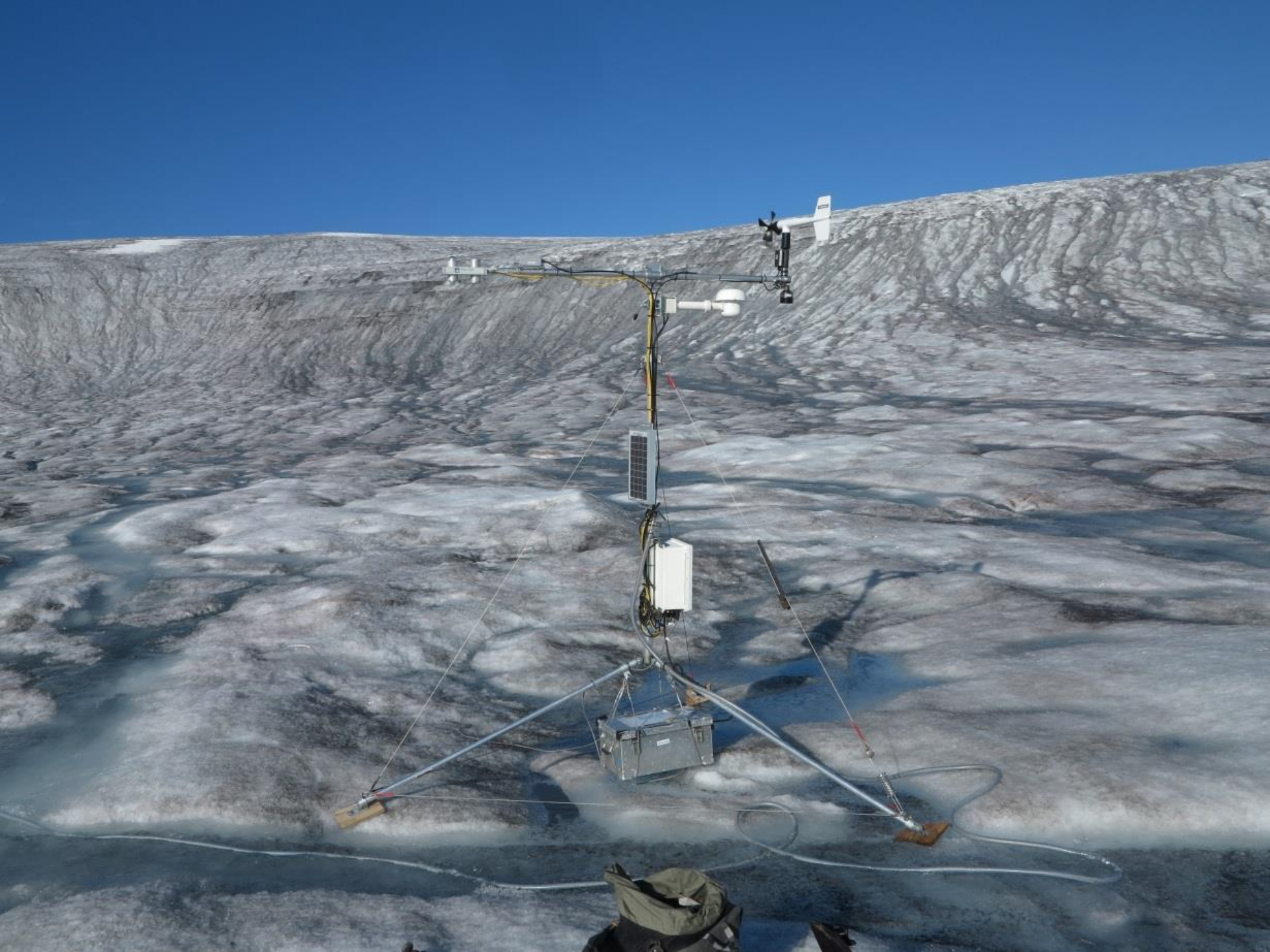
Surface melt conditions

Monitoring of surface energy balance (SEB) and surface mass balance (SMB)

- ...
- Microbiology (algae, bacteria):
  → albedo change?
  → timing?
  → not only at the surface

13% lower albedo (Lutz et al 2016)

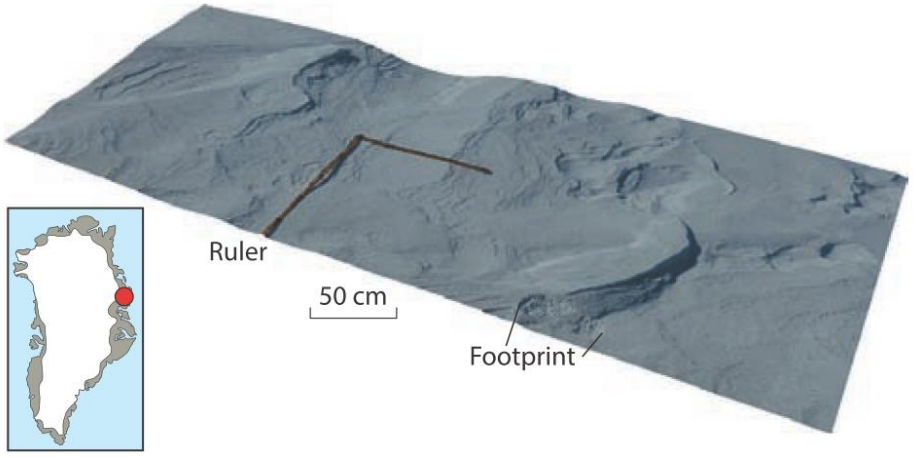


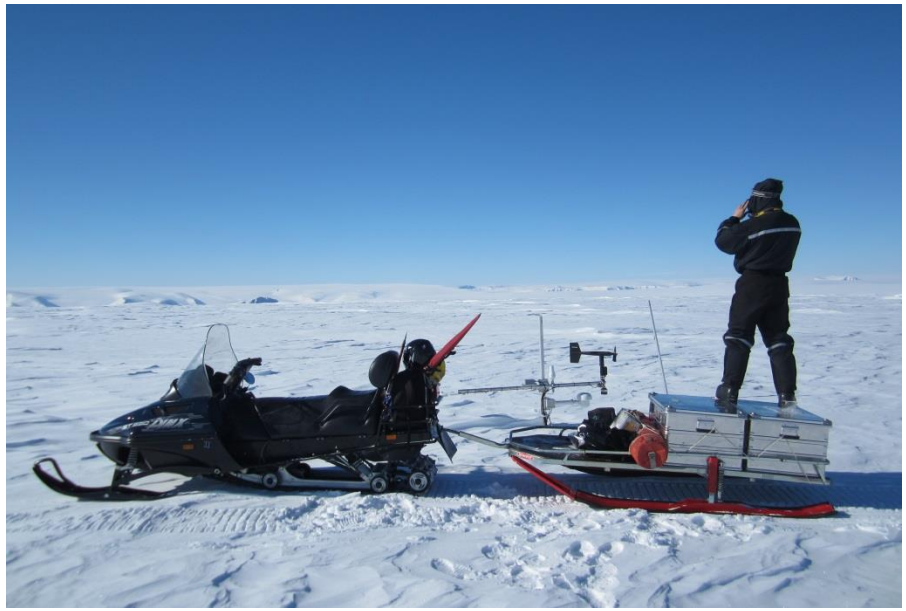


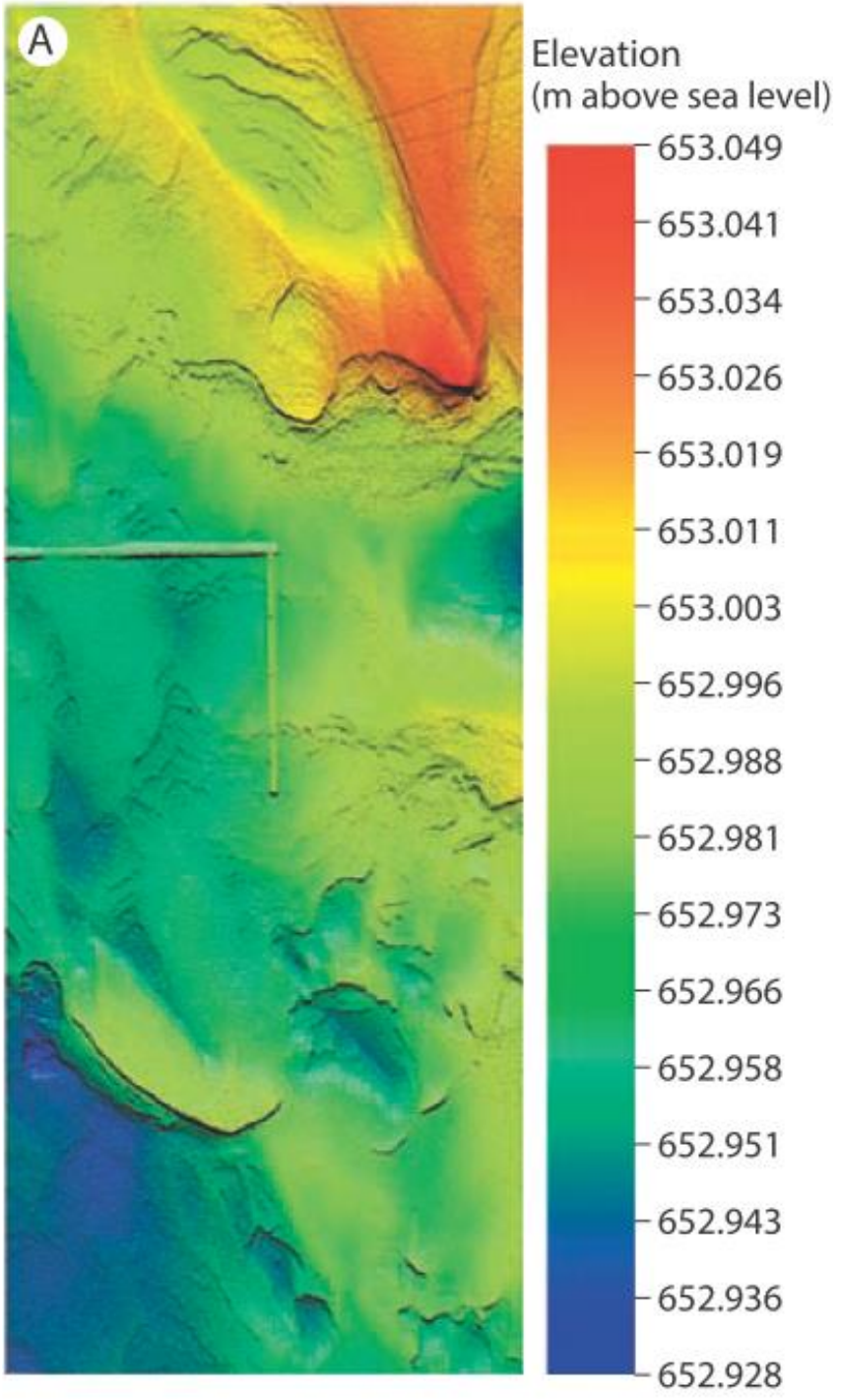

YOUNG


YOUNG

Surface microtopography from close range stereo-photogrammetry

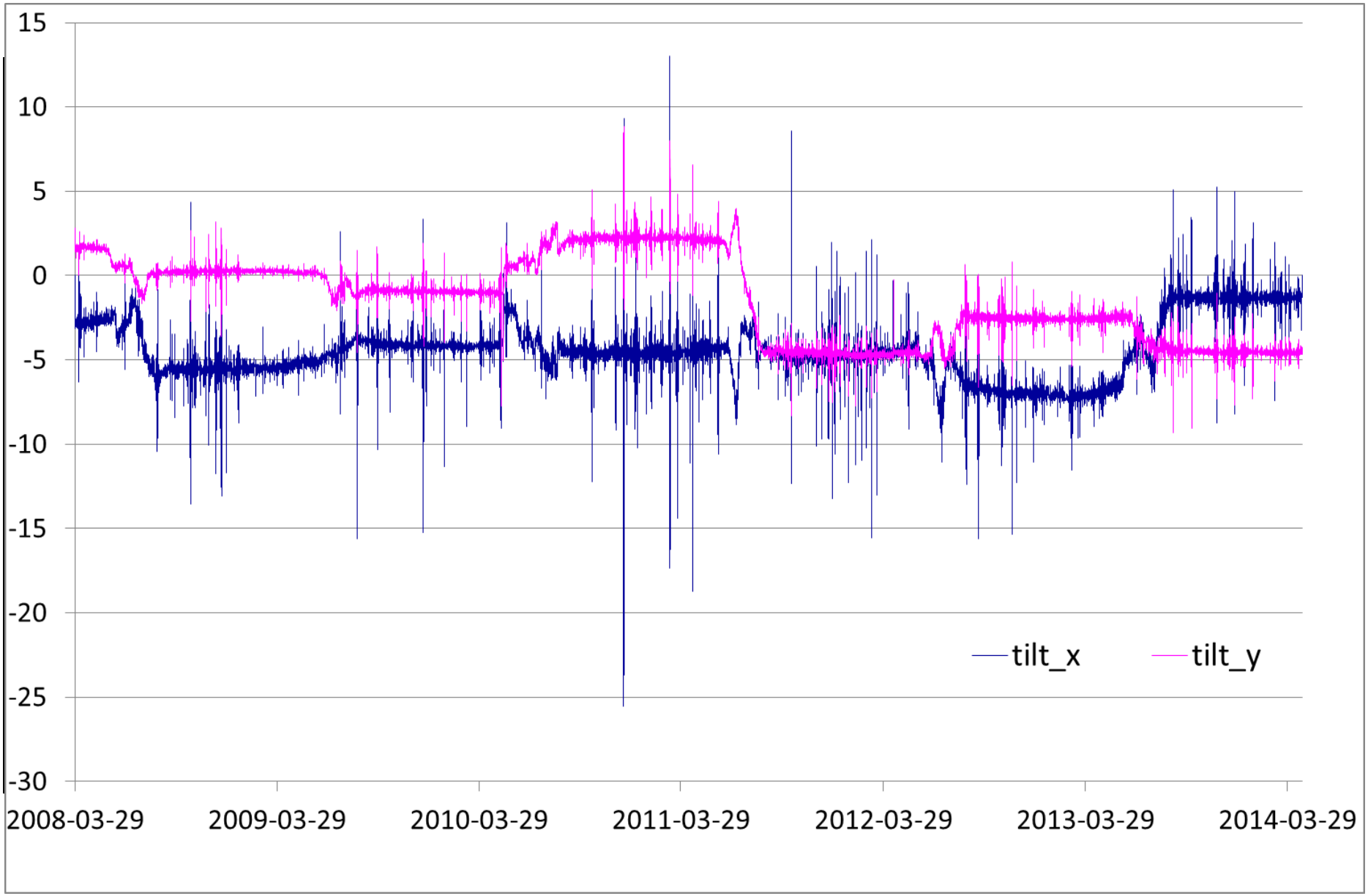






Sørensen, Bjærger & Citterio, 2015

Station tilt



ablation stake South Greenland.mp4

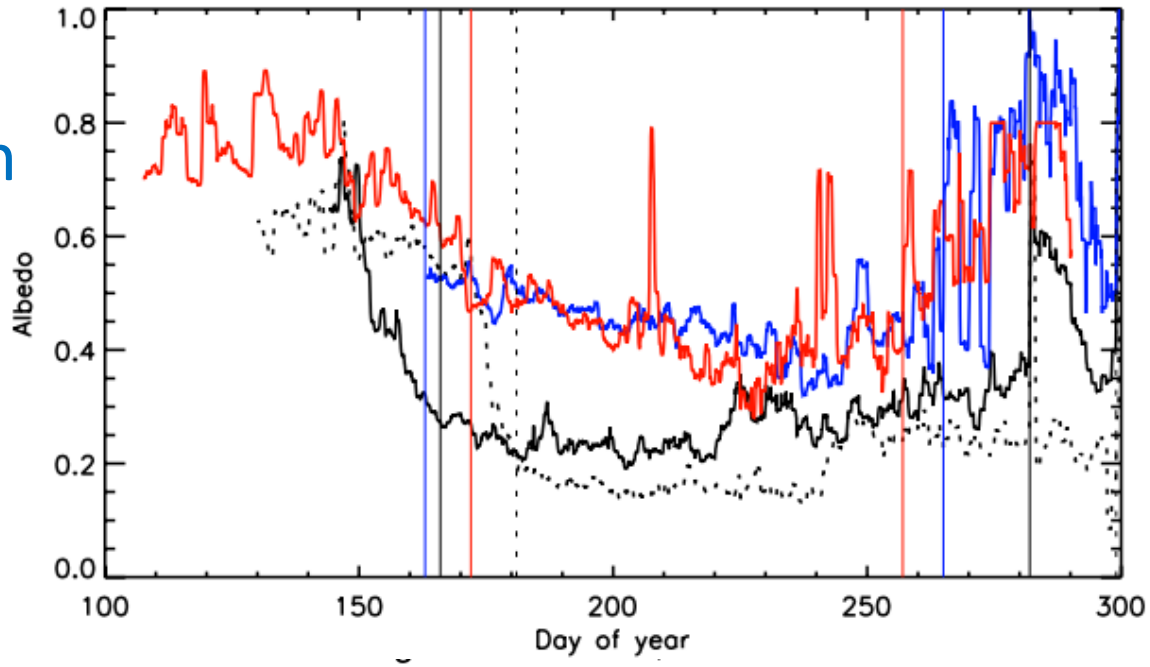
Surface melt aws.mp4

Animation of a PROMICE weather station with ablation sensor.mp4

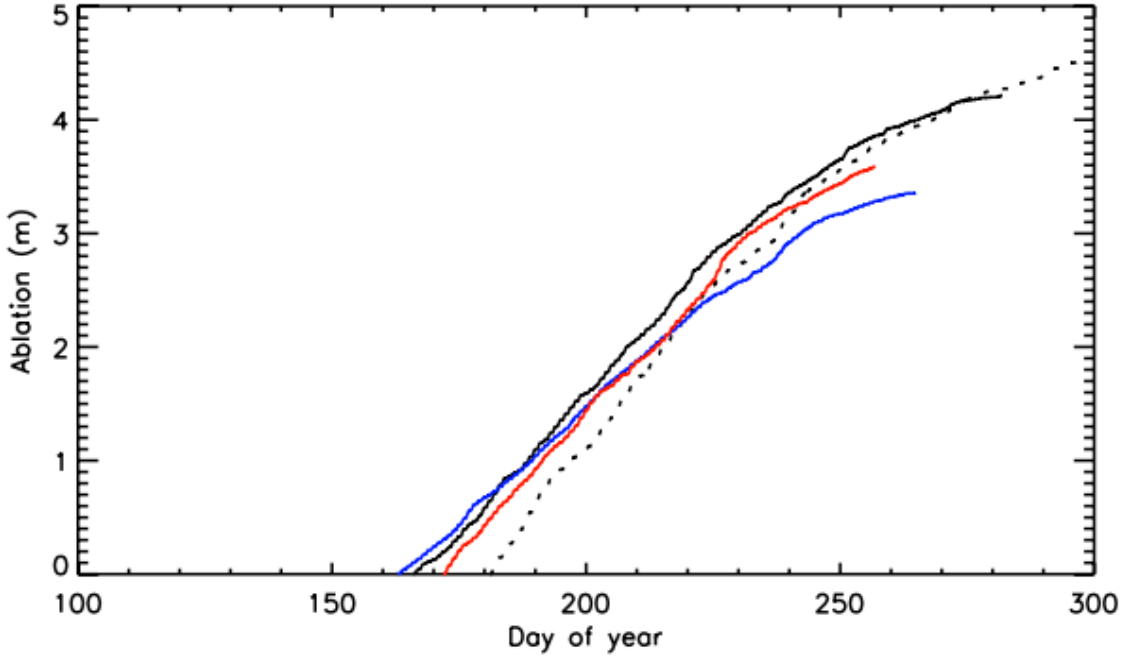
Albedo after tilt correction for radiation on a horiz. surface

Correction based on **measured** 2-axes tilt of the radiometers

Up- and down facing radiometers known to be exactly aligned (are both part of the same instrument)



St71 (black), Nuuk2 (blue), and Tas1 (red)



van As et al., 2009

Retrospective tilt correction

Wang et al., 2016

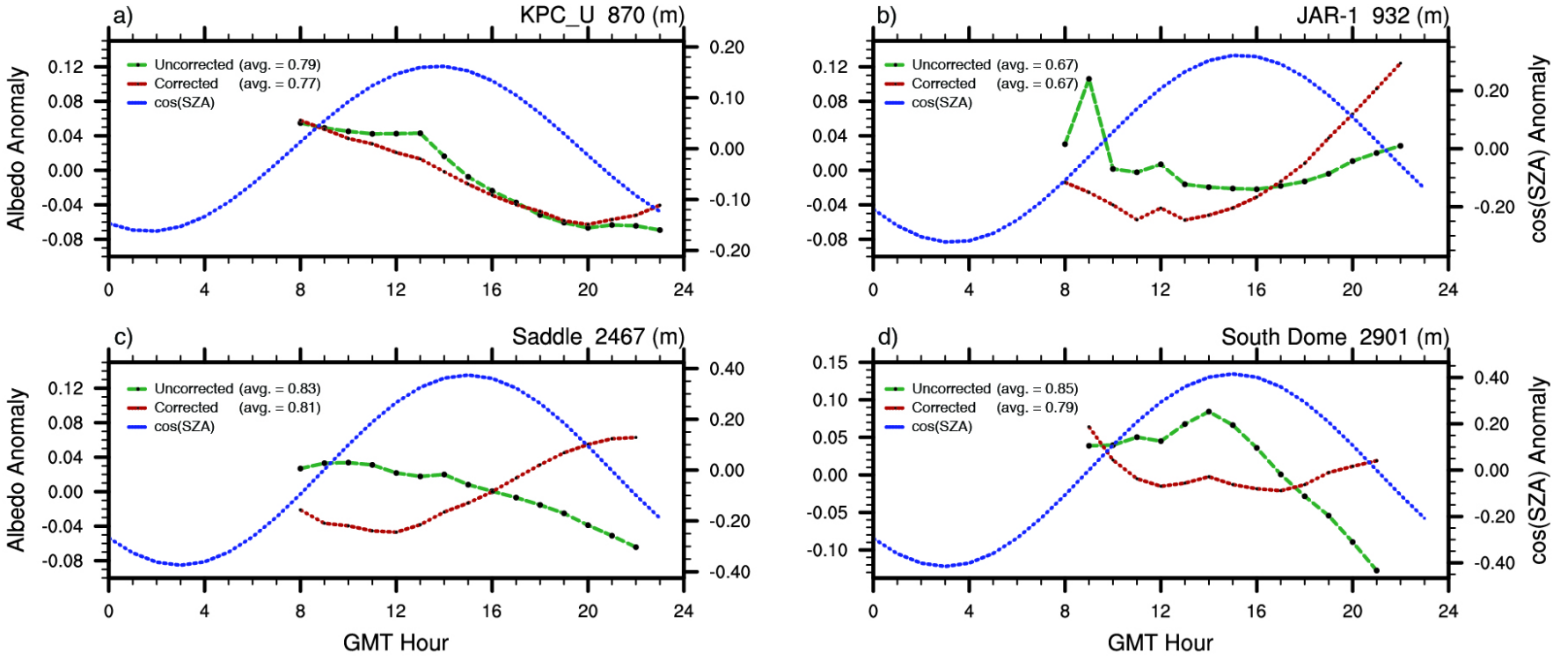
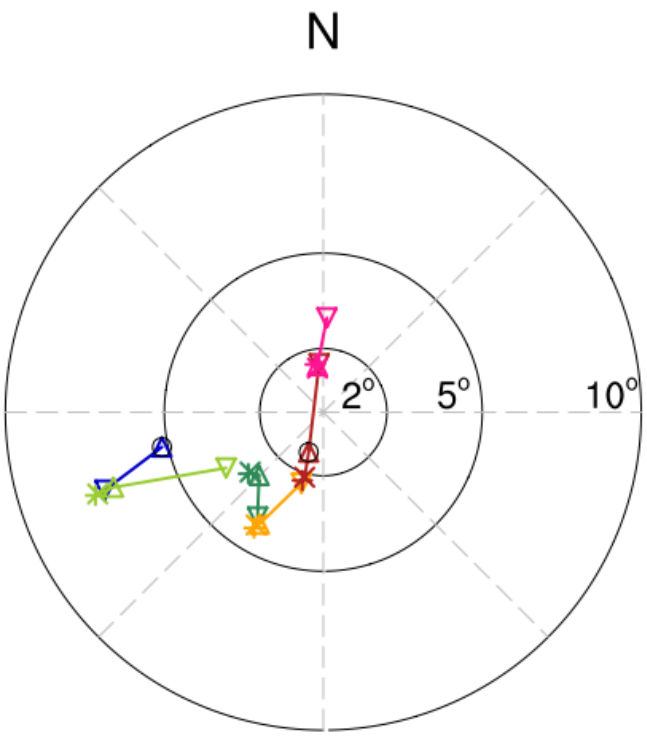
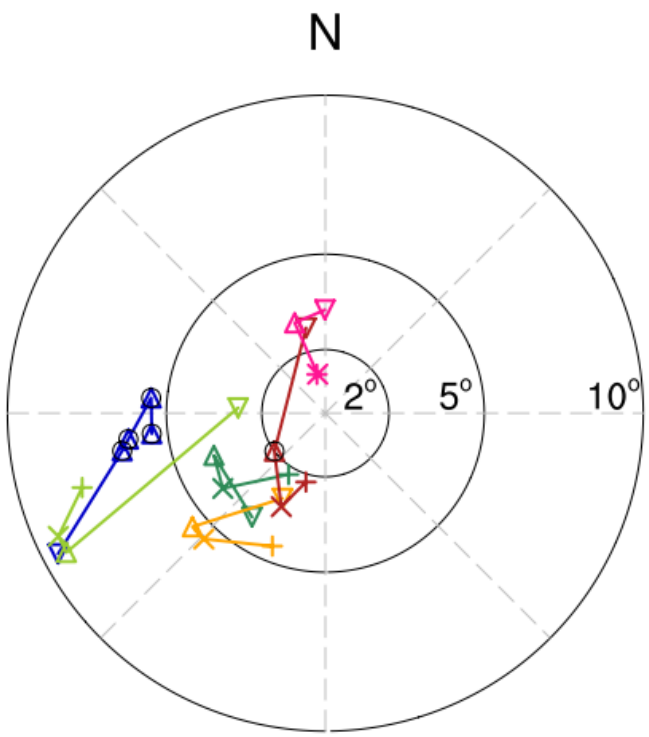


Figure 1. Diurnal variability of albedo with SZA less than 75° in June 2013 at a) KPC_U; b) JAR-1; c) Saddle; d) South Dome.

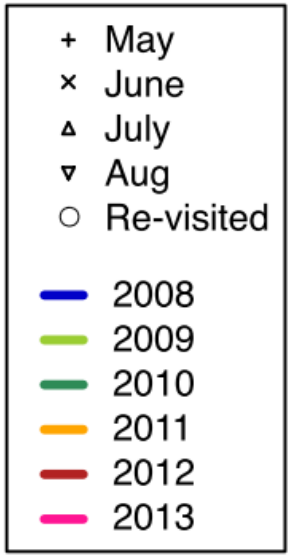
Measured vs. estimated tilt angle and tilt direction at the KPC_U station



Measured

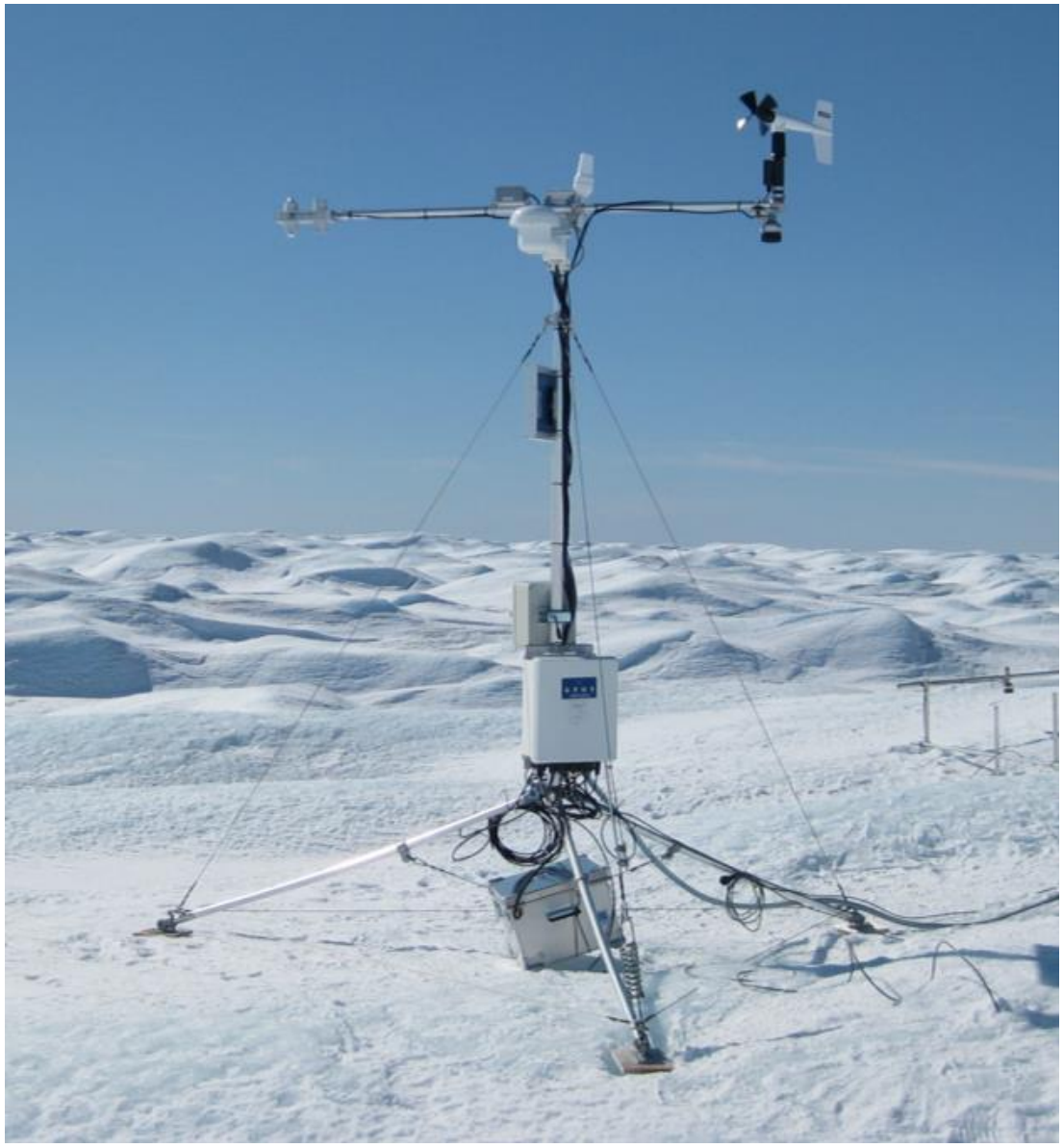


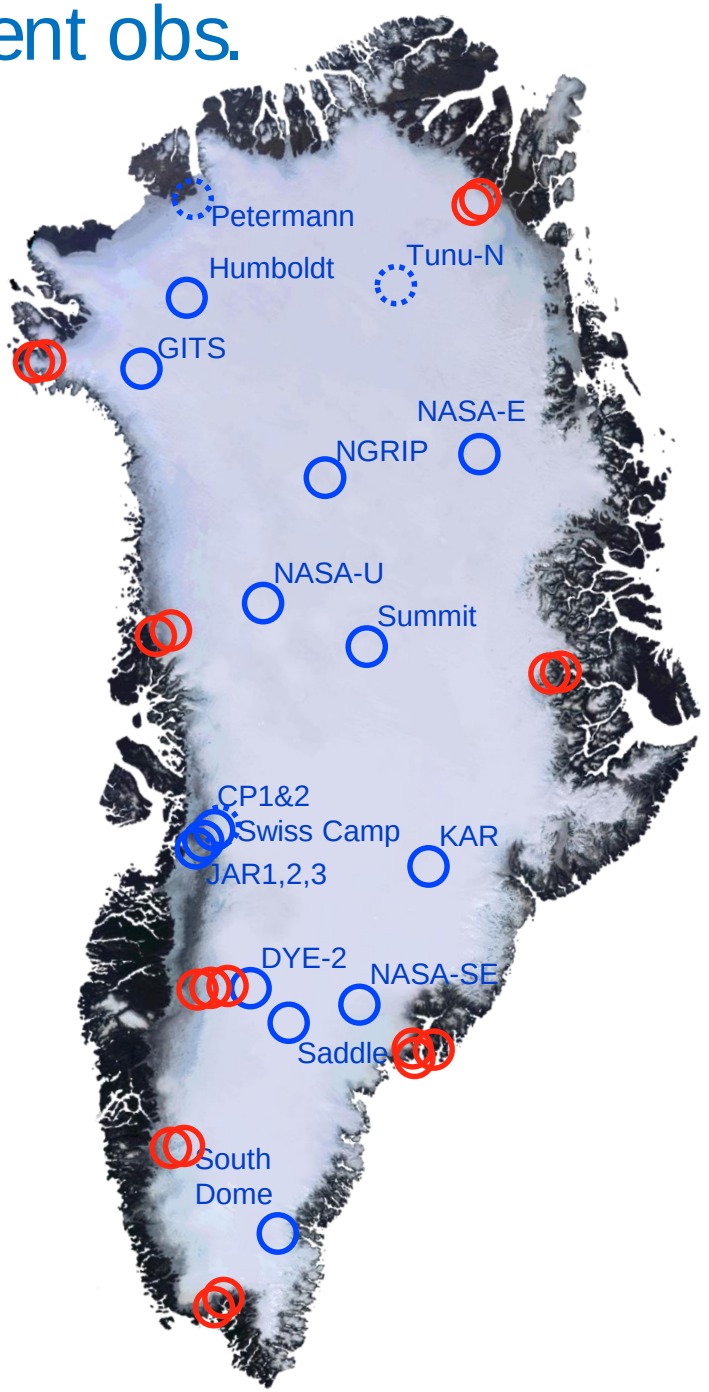
Estimated



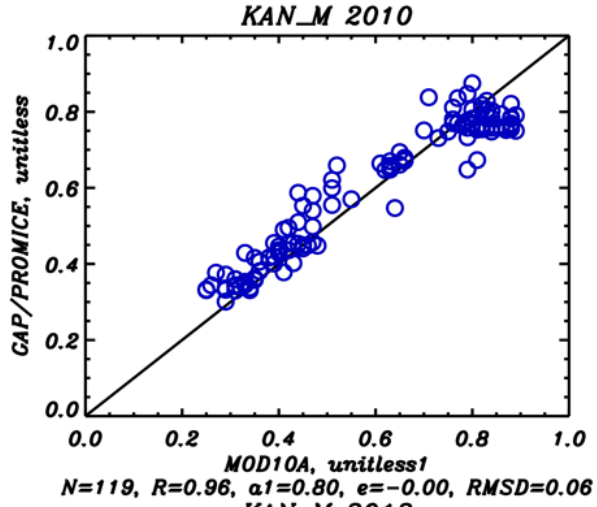
RIGB (Wang et al., 2016)

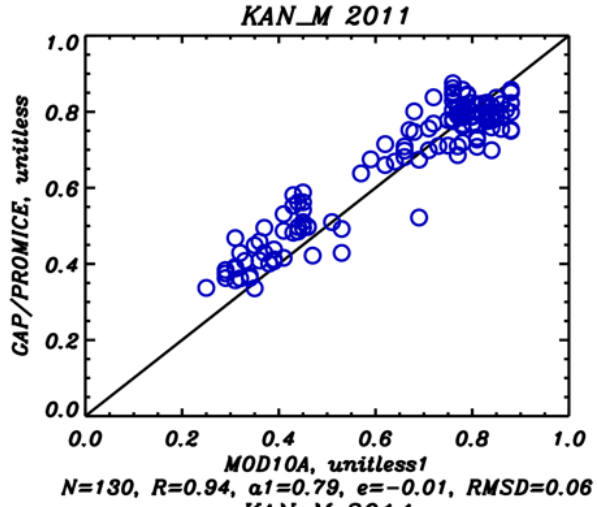
PROMICE homogeneous 2007-present obs.

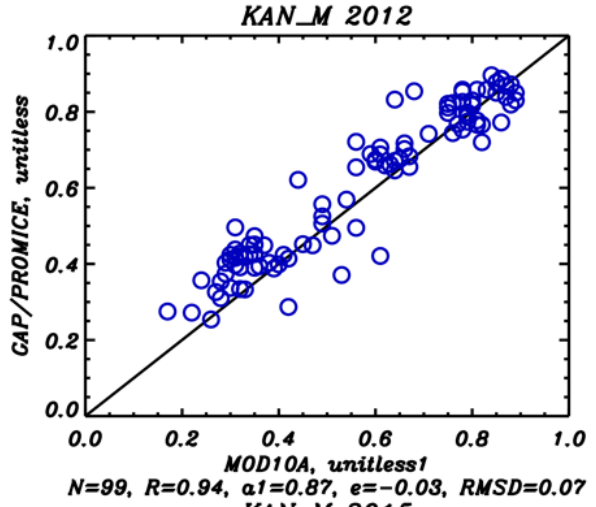


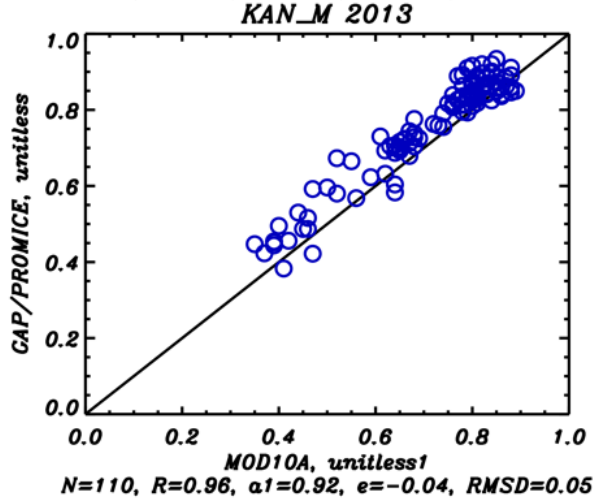


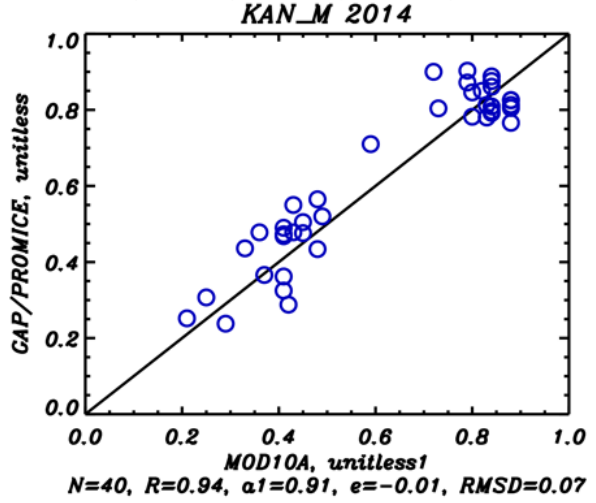
MOD10 Albedo vs. PROMICE in situ

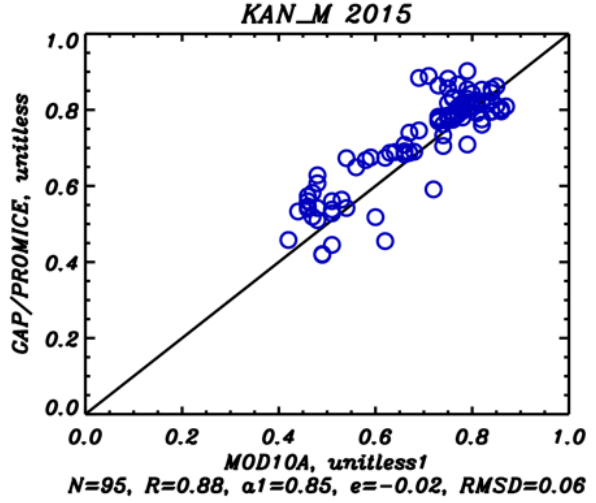












Box, unpublished

The way ahead

Improve tilt measurement (improve SEB):

→ smaller 2-axes tilt sensor built under the CNR-4 shield to guarantee exact alignment

→ integrate a solid state compass to address change of azimuth

Characterize and if possible compensate for CNR-1 / CNR-4 error sources (improve SEB):

→ long term sensitivity drift, temperature coefficient, cosine response

Add spectral information (assist with linking to satellite albedo):

→ as soon as a practical (low power, low cost and low maintenance ... possibly)

Add surface roughness information (assist with linking to satellite albedo):

→ stereophotogrammetry


Thank you