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Ice Surface temperatures, status and utility

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Outline

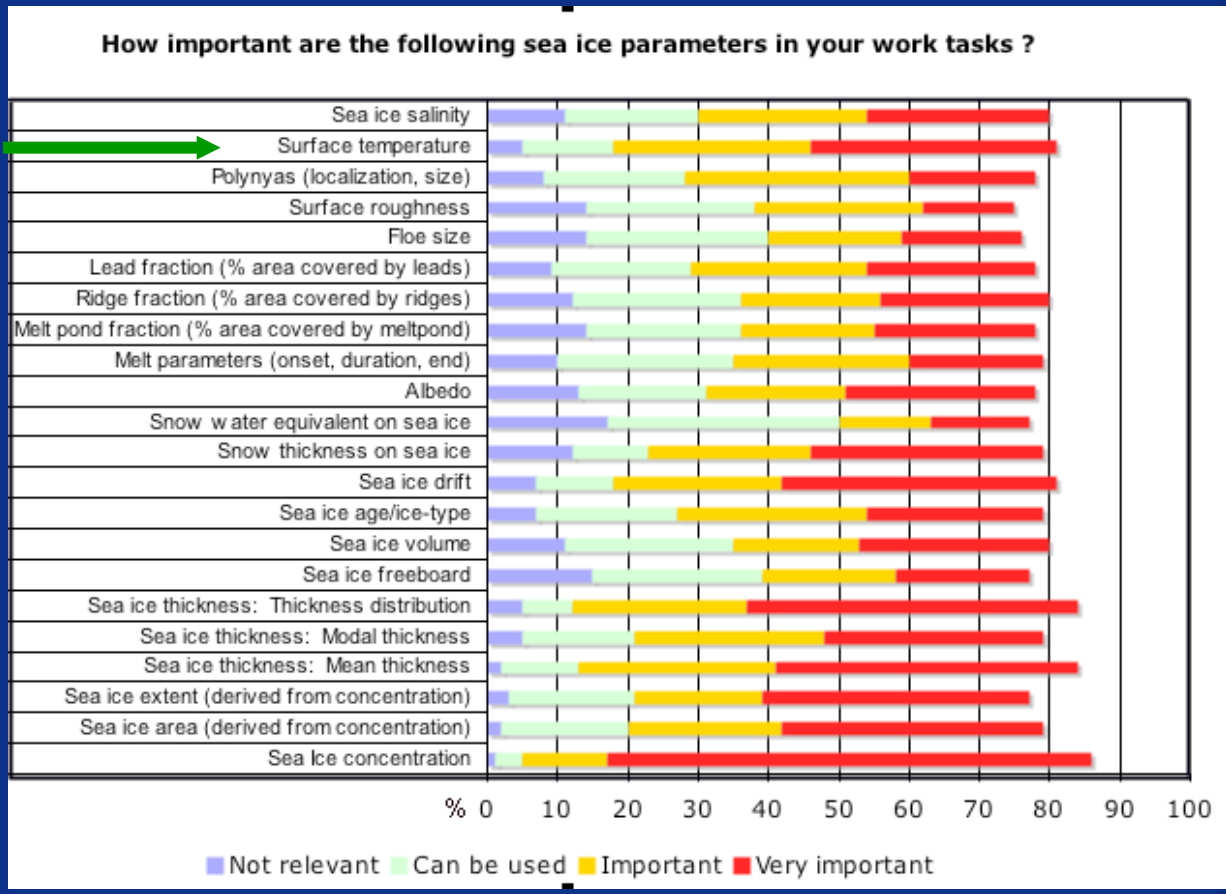
- **Motivation for IST data production**
- **IST from satellite**
  - Infrared
  - Passive microwave
- **IST from in situ**
  - Examples
  - Comparison with satellites
- **Challenges for users**
  - Representativeness
- **Examples of applications**
- **Summary**

Why ?

Requested by the sea ice user community

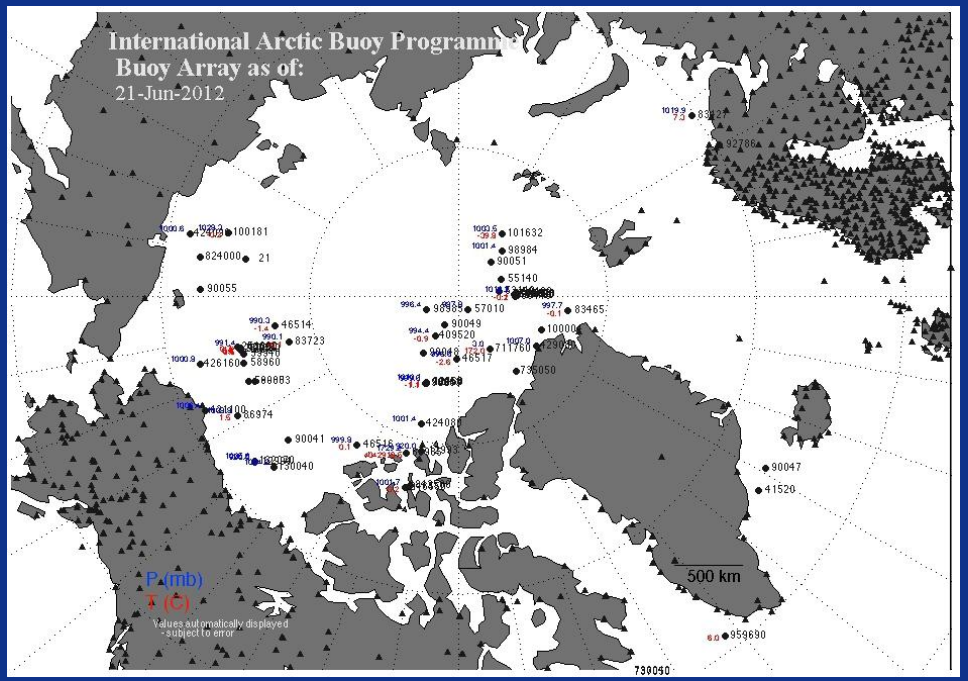
- ESA CCI project on Sea Ice
  - User survey
- 91 respondents

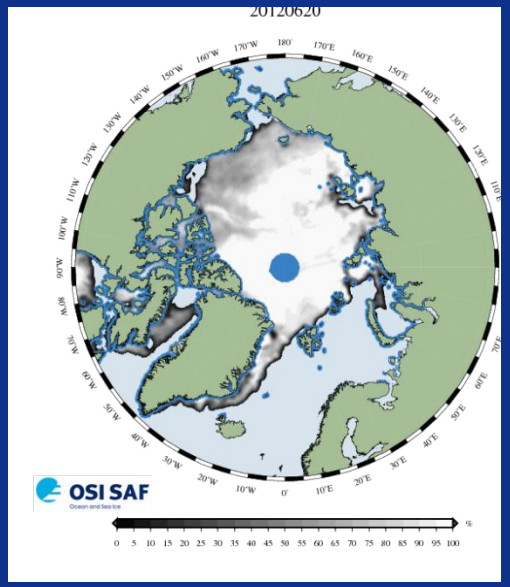
- IST ranking 4 out of 22 parameters.



Existing operational temperature observations

- Very few near real time observations
  - Arctic Sea Ice
  - Greenland Ice sheet

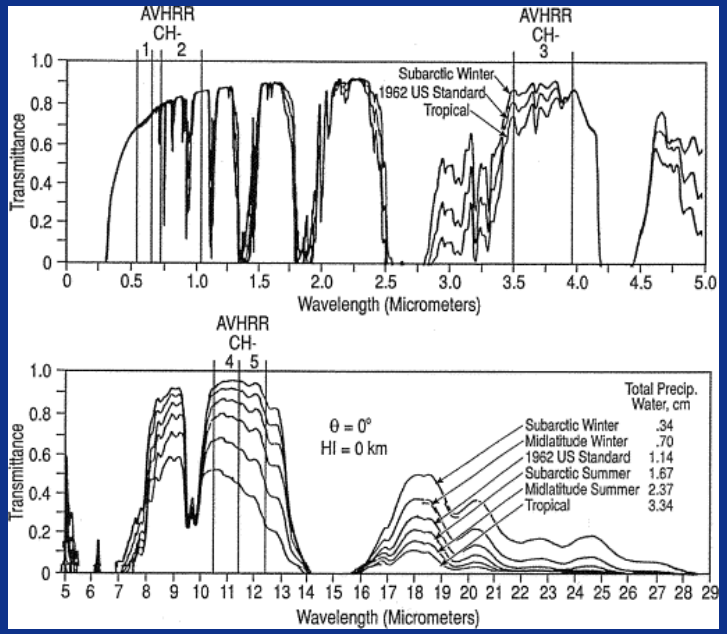




Satellite IST

IR Algorithm description

- Typical IR algorithms use the traditional split window algorithm:
  - $Tice = a + bT_{11} + d(T_{11}-T_{12})\sec(\theta)$
- Developed by Key and Haefliger, 1992
- Coefficients determined by fitting to in situ observations or using radiative transfer models
- Typically very transparent atmosphere in high latitudes and cold conditions.



Existing IST products

- Modis Aqua and Terra
- AVHRR Polar Pathfinder dataset
- Metop_A
- ATSR
- AMSR-E
- VIIRS
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)
- IASI
- Enhanced Thematic Mapper Plus (ETM+)

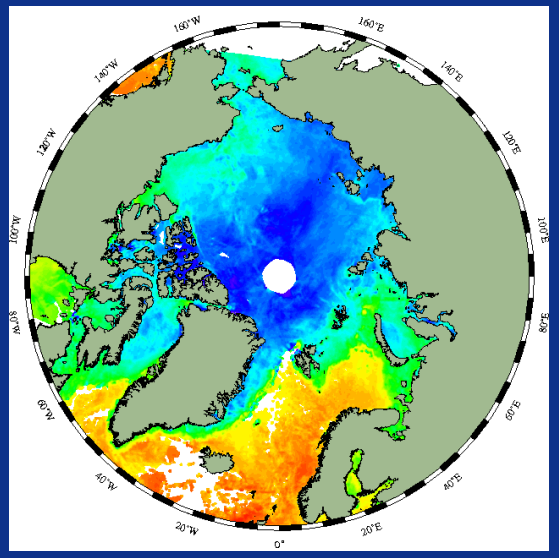
Modis IST observations

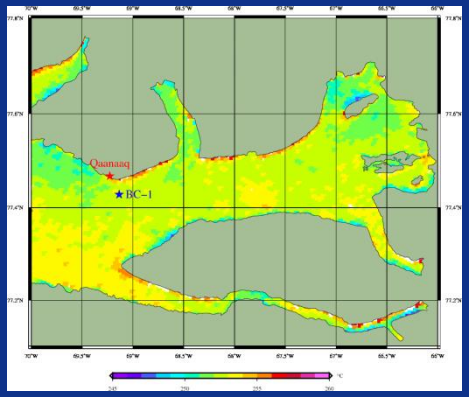
- Produced by NSIDC
- 1 km spatial resolution
- Aqua and Terra
- Using Modis cloud mask
- Data available since 2000

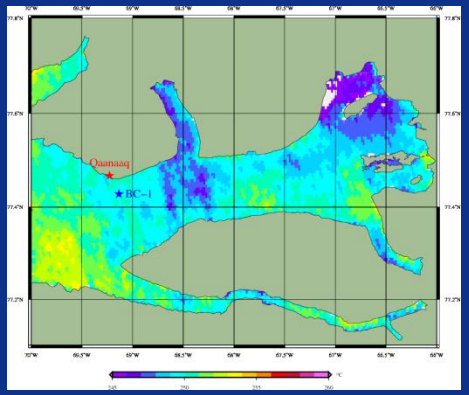
Hall, D. K., J. Key, K. A. Casey, G. A. Riggs, and D. J. Cavalieri (2004), Sea ice surface temperature product from MODIS, IEEE Trans. Geosci. Remote Sens., 42, 1076–1087, doi:10.1109/TGRS.2004.825587

OSI-SAF Metop-A IST product

- 3 minute granules of 1 km AVHRR data from the NWC SAF PPS software.
- Integrated HL SST, IST and Marginal Ice Zone Temperature product, based on Metop AVHRR
- SST for HL
  - **Regional algorithm coefficients (separate day/night)**
- IST
  - As Key et al., 1992, compared with buoys
- MIZ
  - Scaled linearly between IST and SST, using T4
  - Vincent et al., 2008



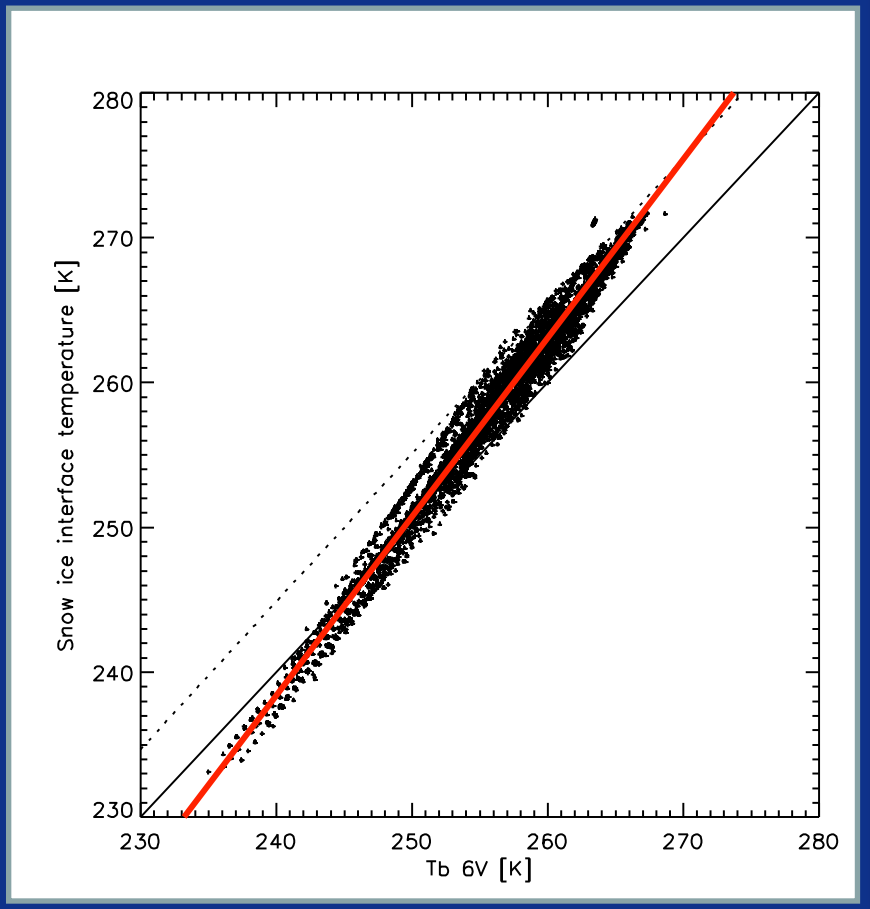




Passive microwave IST

- Not limited by cloud cover.
- Long record
- Usually the 6 GHz observations used for IST.
- Not Skin IST and difficult to blend with IR observations
- Combined thermodynamic and MW emission model showed good agreement between Tb in 6 GHz and snow-ice interface temperature (Tonboe et. Al., 2011)

$T_{Snow\text{-}ice}$ vs. TB_{6GHz} , Model

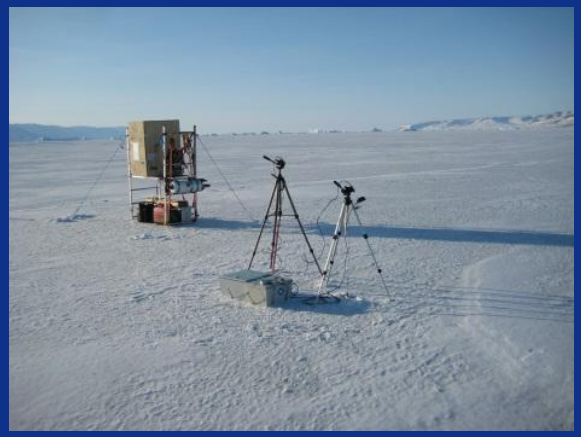


Tonboe, R.T., Dybkjær, G., and Høyer, Tellus, 63A, 1028-1037, 2011.

In situ IST and validation

In situ observations

- **Challenging to obtain a good coverage of accurate validation data.**
  - Infrared radiometers (broad band, narrow band, sky correcting or not)
  - Drifting buoys
  - Thermocrons
  - Ice mass balance buoy (thermistor string)
  - AWS (T2m + skin)
- **Each type of observations has specific sampling characteristics**



Comparison, Satellite vs in situ

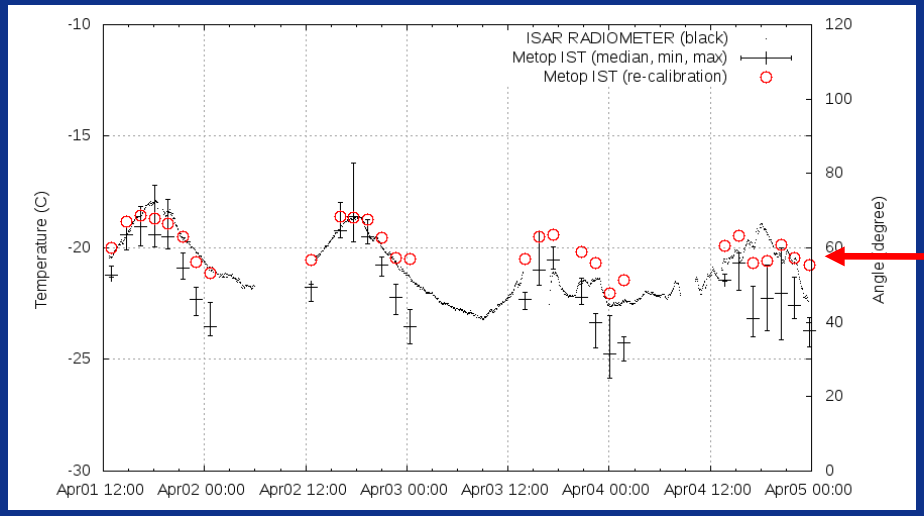
- **Validation studies carried out**
  - Modis: Hall et al., 2004, 2012 + Scambos et al., 2006
  - AVHRR: Key and Haefliger, 1992, Key et al., 1997, Scambos et al., 2006,
  - Metop_A: Dybkjær and Høyer, 2012, Dybkjær et al., 2012

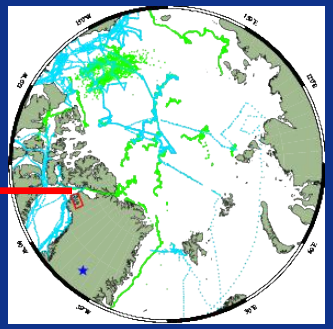
- **Compared to AWS stations + drifting ice buoys:**
  - Typical cold bias in the IST products: 1-3 ^{o}C
  - Typical standard deviations: 1-3 ^{o}C

- **Improved results obtained with:**
  - Infrared radiometers (Scambos et al, 2006, Dybkjær et al., 2012)
  - Multisatellite intercomparisons (Modis vs. ASTER vs. ETM+) (Hall et al., 2008)
  - Additional cloud masking (Dybkjær et al., 2012)

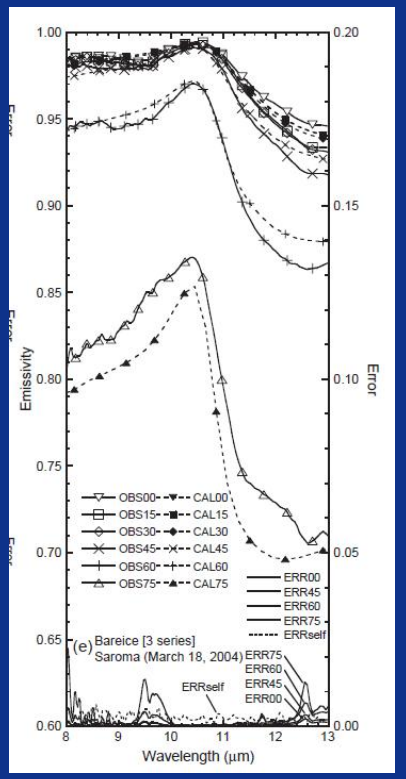
Infrared Radiometer observations

- Radiometers deployed on ships, ice stations & AWS on land
- Validation results significantly better than temperature sensors and T2m
- Very cold sky temperature (173 K in Qaanaaq) results in underestimation of up to 1.3 K if no skycorrection is performed
- Tskin = (TBice – (1-ε)*TBsky)/ε





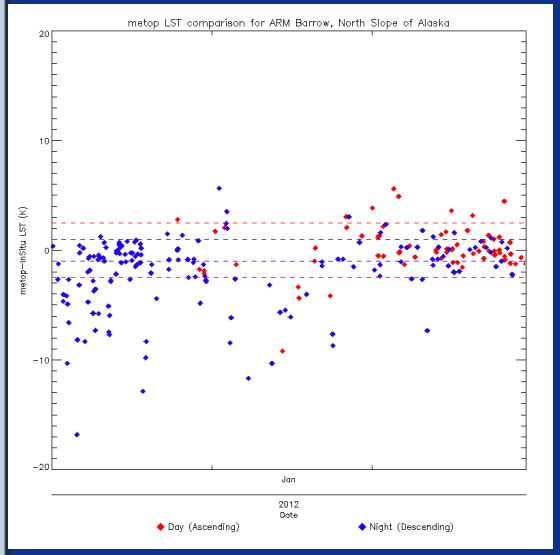
Directional emmissivity



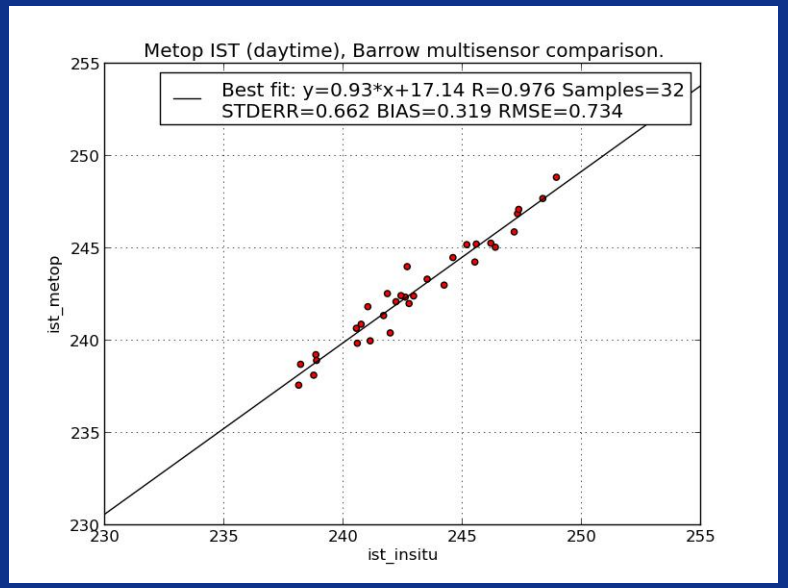
Hori et al., 2006

Multisensor Match-up dataset

- Very useful to explore strength and weaknesses in the different data set
- Until now only one point for 3 months. Sea ice and Ice sheet MDs needed.
- Ensure right data is put in and extracted !



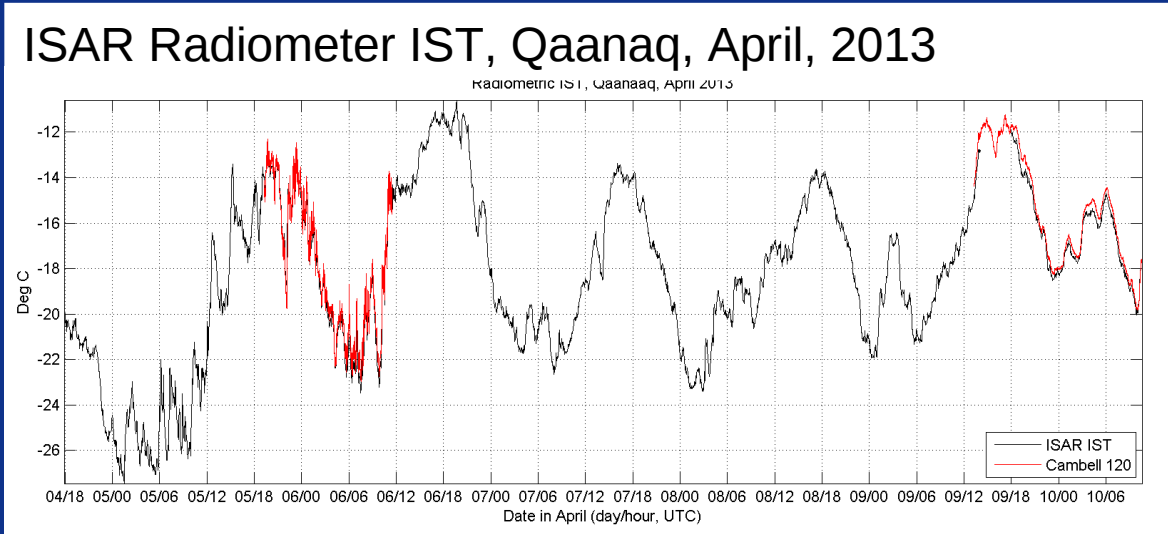
Same MD, correct use of cloud flags



Challenges for users

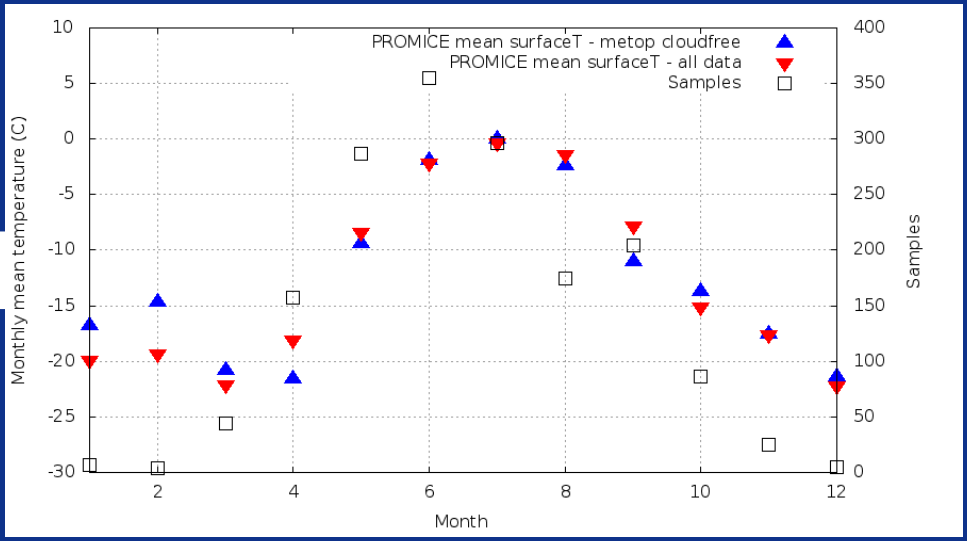
Representativeness

- Large diurnal variation, even on hourly scale
- Uneven sampling with large diurnal and hourly IST variations
- Clear sky bias

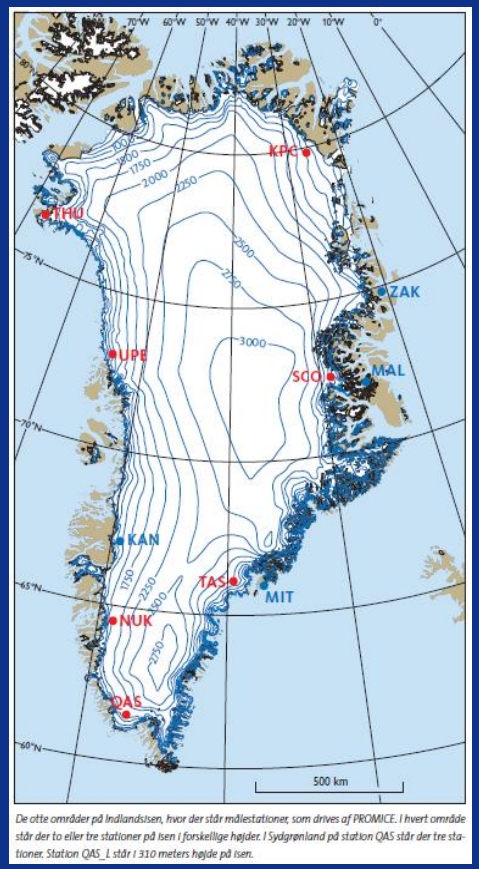


Representativeness

- **Clear sky bias from satellite ?**
- **Promice monthly mean surface temperature**
  - All observations
  - Subsampled to Metop_A clear sky
- **Needs more attention**



www.promice.org

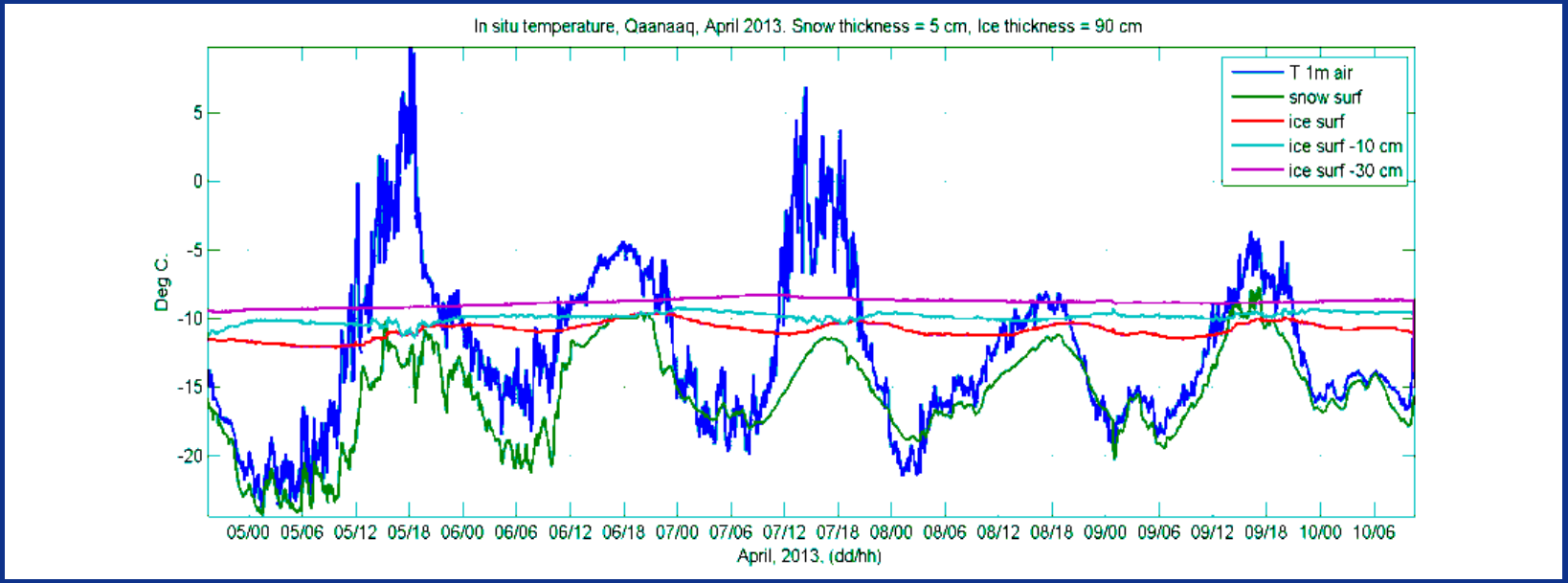


De otte områder på Indlandsisen, hvor der står målestationer, som drives af PROMICE. I hvert område står der to eller tre stationer på isen i forskellige højder. I Sydgrønland på station QAS står der tre stationer. Station QAS_L står i 310 meters højde på isen.

Vertical Temperature variability

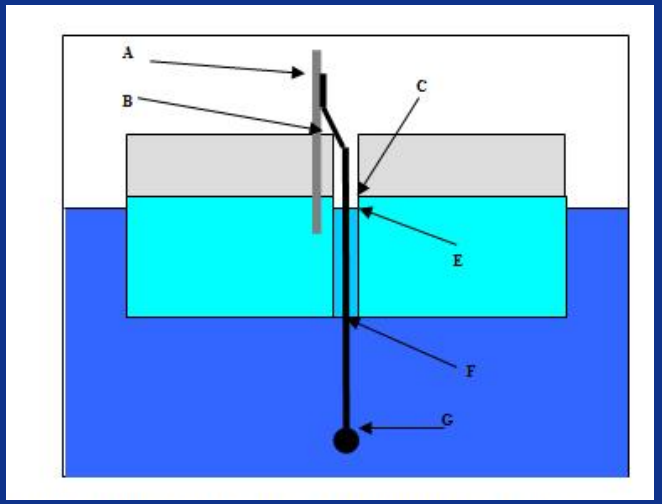
- **Large gradients within snow and sea ice**
- **T2m often used as proxy for IST**
- **Snow very effective insulator**

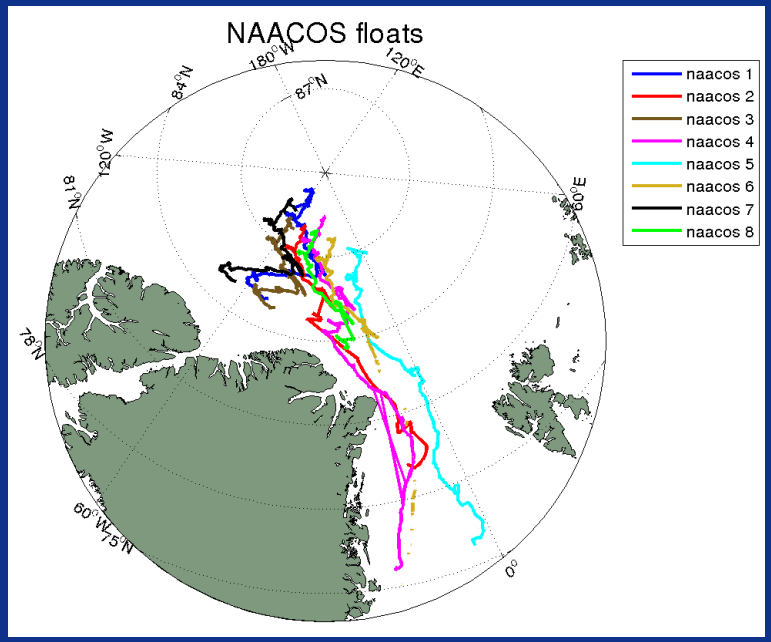
In situ temperature at different levels



Ice mass balance buoys

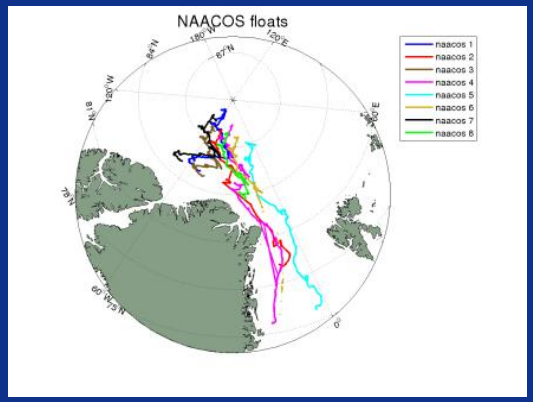
- 8 ice mass balance buoys deployed North of Greenland, summer 2012 (2-3 still alive)
- SAMS IMBs
- Sensor interval: 2 cm
- Observation: water, ice, snow and air
- Transmit data in NRT

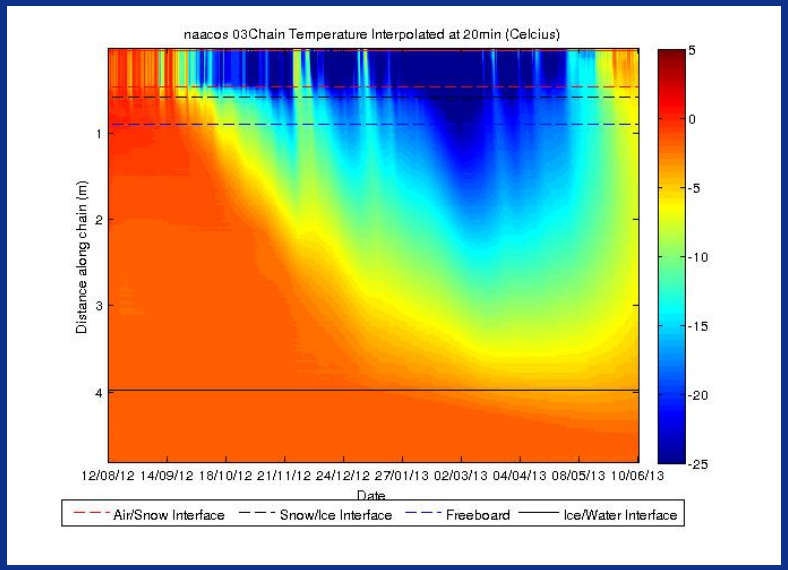


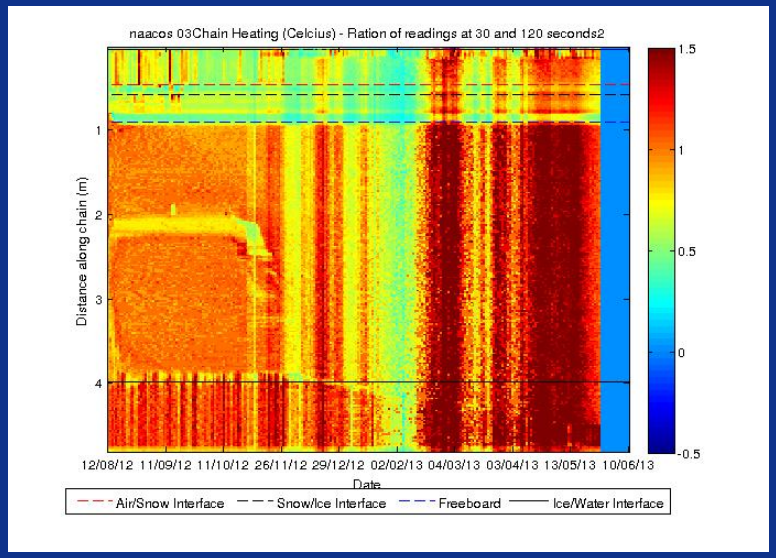


Vertical Temperature variability

- **Temperature observations from Multiyear ice floe**
- **10 months data**
- **Initial conditions**
  - ice thickness: 3.4 meters
  - 12 cm snow
  - 45 cm air

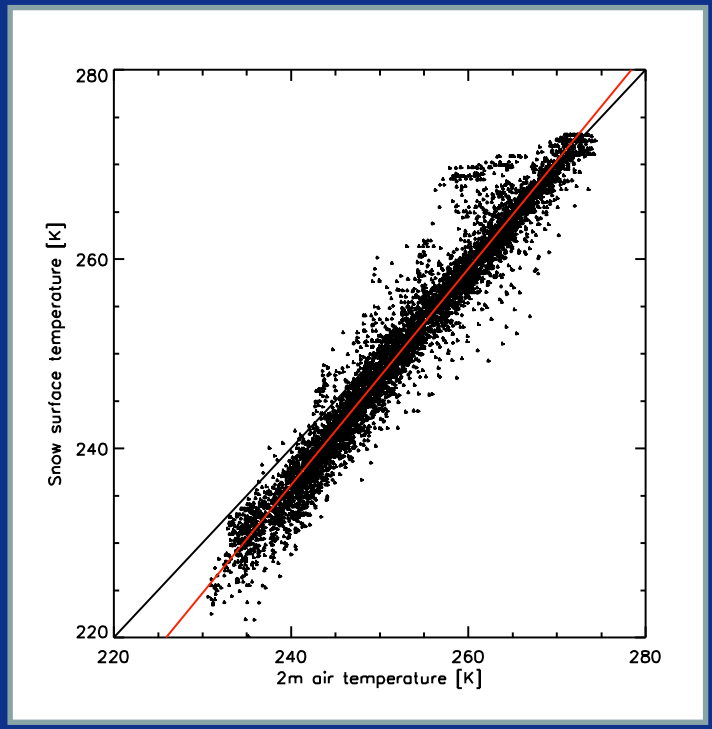






Relation, air/snow/ice/water temperature – modelling

- Thermodynamic modelling of sea ice generation.
- Relation ship, T2m and snow surface (Tonboe et al., 2011)
- Cold bias for cold temperatures

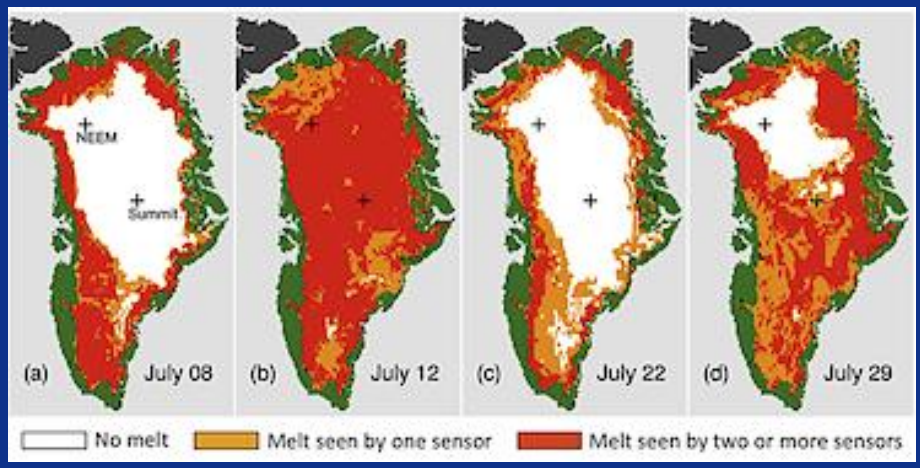


Examples of applications

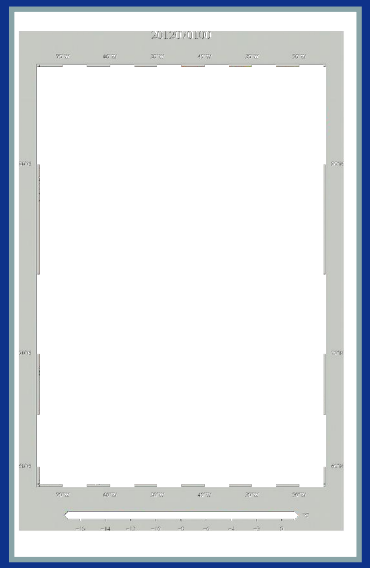
Greenland Melt event in 2012

- Extremely warm temperatures in July 2012
- 97 % of surface melted
- Previous events in year 1889 and ~ 1300

Hall et al., 2012



Metop_A 2-daily averages

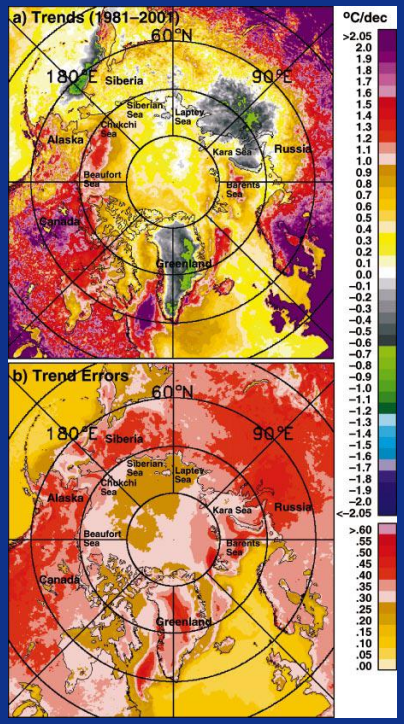


Nghiem, S. V., D. K. Hall, T. L. Mote, M. Tedesco, M. R. Albert, K. Keegan, C. A. Shuman, N. E. DiGirolamo, and G. Neumann (2012), The extreme melt across the Greenland ice sheet in 2012, Geophys. Res. Lett., 39, L20502, doi:10.1029/2012GL053611.

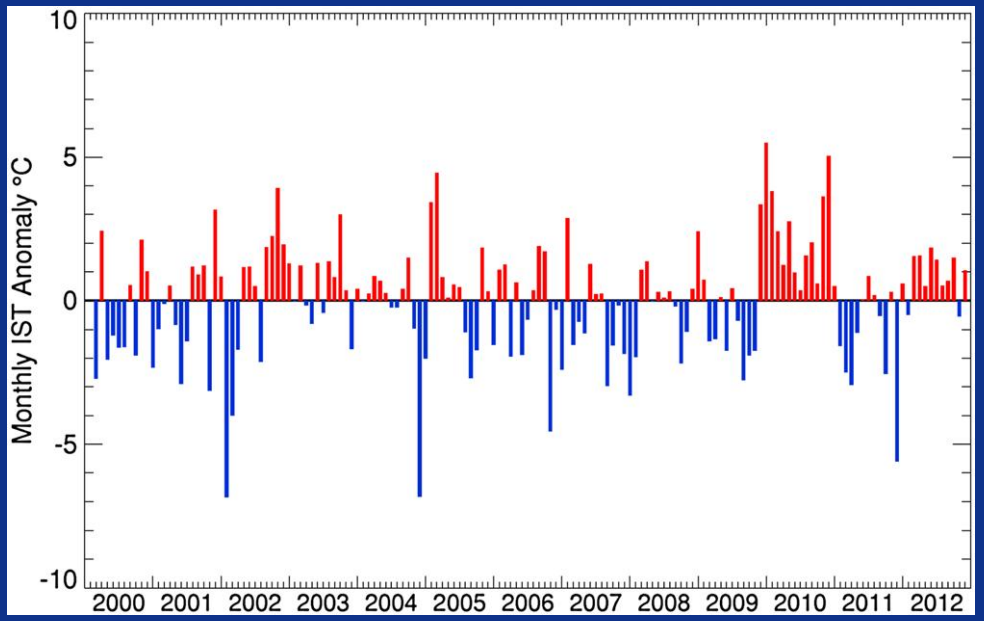
Climate data series

- Greenland Ice sheet IST from Modis
- Warming trend: 0.5 degC/decade, largest in northwestern Greenland
- Surface melt events in 2002 and 2012

Trends 1981-2002, Comiso et al., 2003



Monthly IST anomalies for the Greenland ice Sheet. From Hall et al., 2013.



DMI
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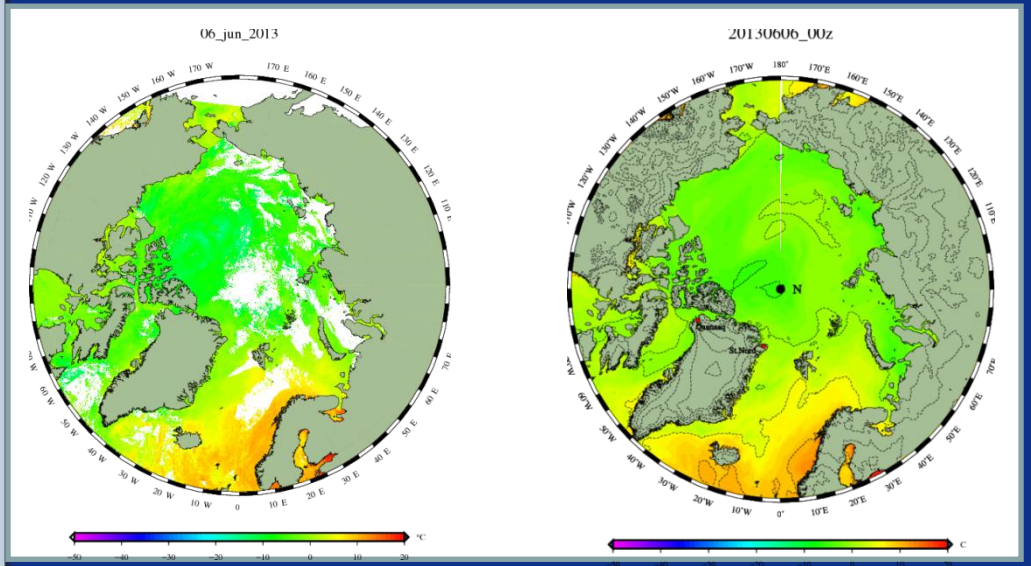
Daily monitoring of Arctic surface temperatures

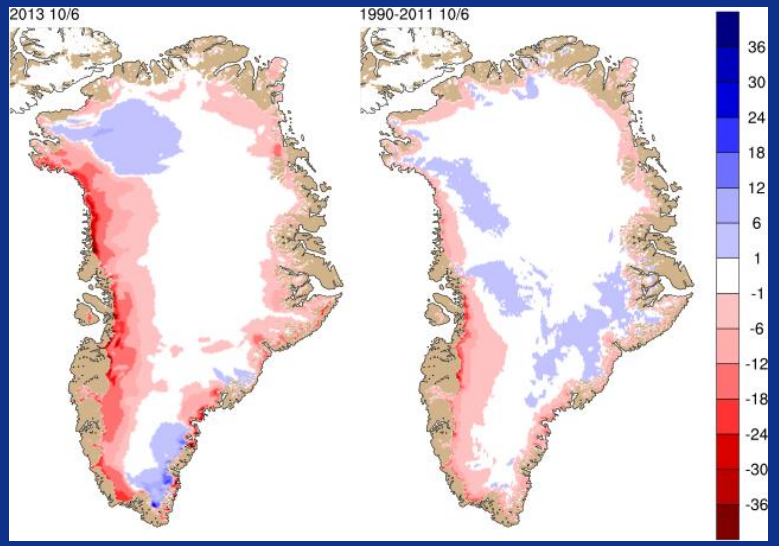
- **At: ocean.dmi.dk and dmi.dk**
- **Figures updated every day**
- **New website available 21st June: polarportal.dk**

Metop_A surface temp



ECMWF T 2m

Ice sheet mass balance (climate model)



Summary

- Several IST products out there (IR + PMW)
- Challenging to use the observations due to measurement uncertainty and sampling characteristics
- Validation results depend upon in situ observations
- Need for proper validation and intercomparisons
- Large potential for inclusion in models and reaanalysis but sampling characteristics complicate assimilation