Copernicus Arctic Regional Reanalysis

Climate Change

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Danish Meteorological Institute

on behalf of the **DMI**, **IMO** and **C3S D322 Lot 2** teams:

Harald Schyberg (MET), Xiaohua Yang (DMI), Heiner Körnich (SMHI), Roger Randriamampianina (MET), Bjarne Amstrup (DMI), Pia Nielsen-Englyst (DMI), Bolli Palmason (IMO), Patrick Samuelsson (SMHI), Morten Køltzow (MET), Jason Box (GEUS), Ken Mankoff (GEUS) *and many others*

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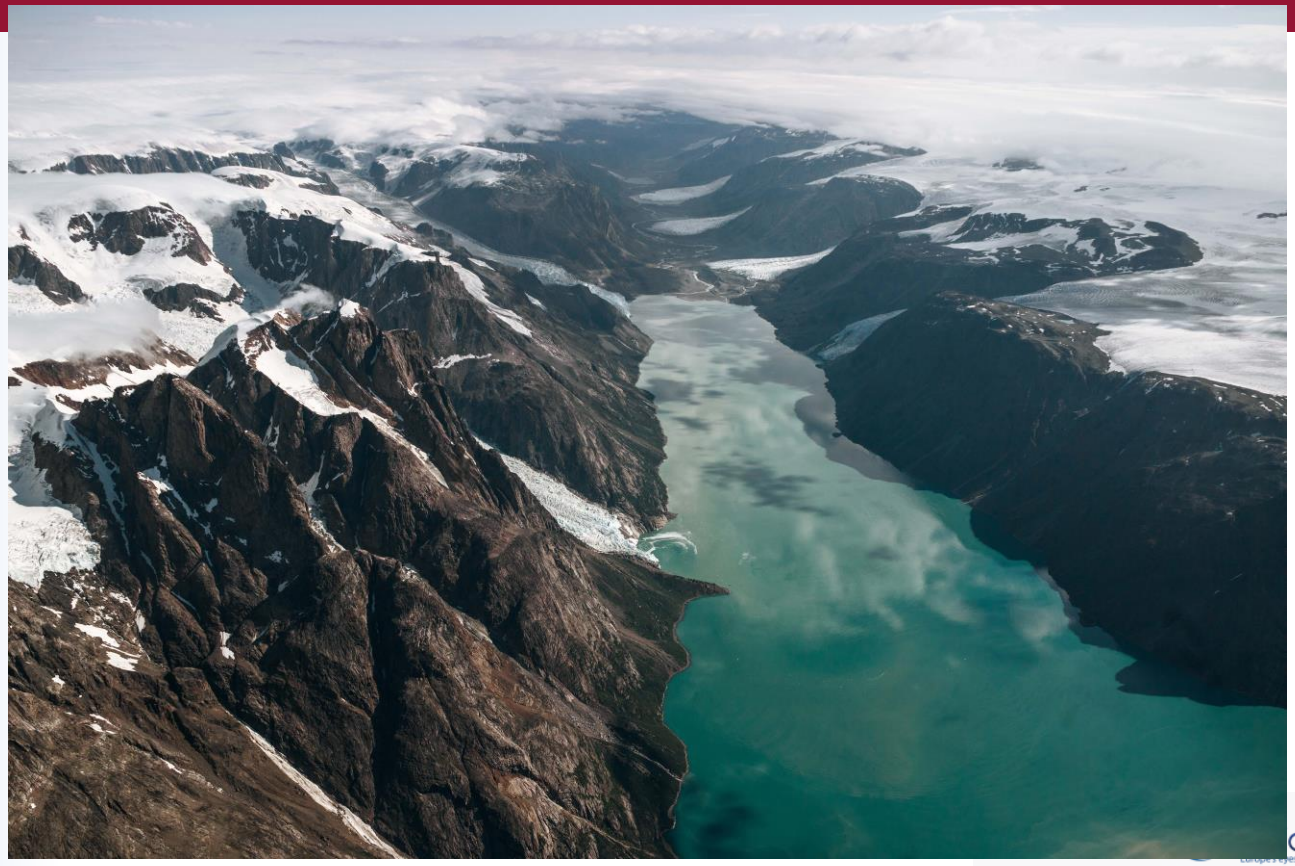
Why perform an Arctic regional reanalysis?



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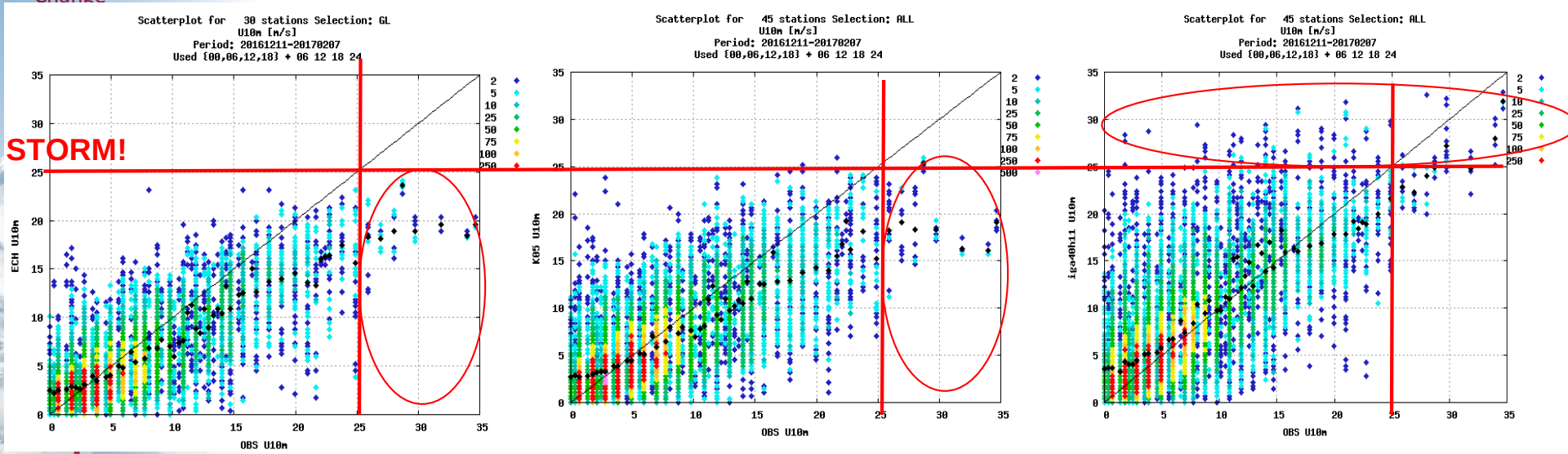
Why high resolution? It is crucial to represent critical processes



ECMWF HiRes
9 km

HIRLAM-K05
5 km

Harmonie-IGA
2.5 km

Surface wind verification for Greenland, Dec 2016 - Feb 2017

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C3S - Copernicus Arctic Regional Reanalysis

Official motivation

- Warming in the Arctic (observational records and future scenarios) roughly twice as high as global trends
- Need for understanding and management of change processes
- Increased economic activity in the region

(Animated gif: NASA)

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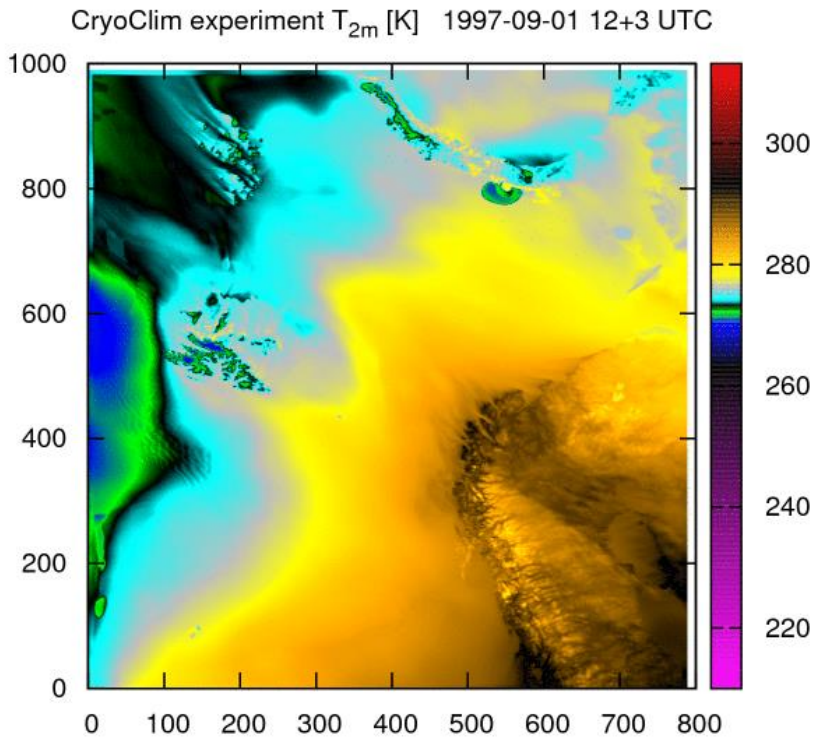
C3S - Copernicus Arctic Regional Reanalysis



- **Regional reanalysis datasets for July 1997-(June 2021)**
- Very high resolution regional model Harmonie-AROME (2.5 km, 65 layers)
- **Two domains, main areas of interest in the European sector of the Arctic; One year proof-of-concept reanalysis for a pan-arctic domain**
- **3D-VAR with extensive use of satellite data and use of local surface observation available in the partner countries**
- Special emphasis on NWP schemes and observations for the handling of "*cold surfaces*": Snow, sea ice, glaciers

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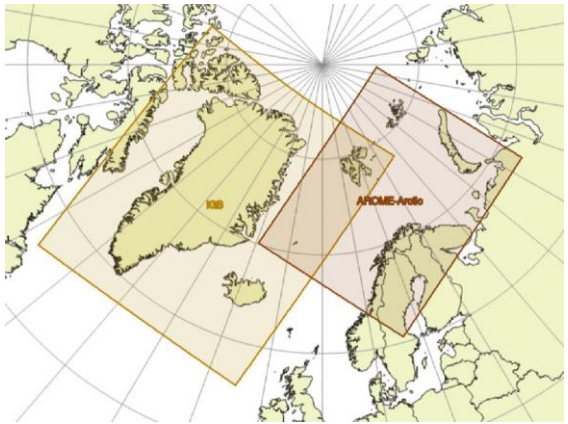
System Configuration

- System: based on the operational Harmonie-AROME 40h1.1.1 at DMI/IMO and met.no
  - **Two domains with Greenland/Iceland, Svalbard/Northern Scandinavia**
  - 2.5 km grid, 65 levels below 10 hPa
  - 3D-VAR with enhanced observation input
    - 8 cycles/day, 30h forecast at 00/12
    - Reprocessed AMV/Scatterometer/RO
    - High resolution sea state data



- Main adaptations: ERA5, extra input data
  - hourly LBC from ERA5 4DVAR

- Computations on ECMWF HPC
  - Production starts in April 2019
  - 3x 9-yr time slicings
  - Data will be available via Copernicus CDS by 2021

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Schedule for production of the C3S Arctic reanalysis

September 2017:
Project start

September 2018:
System beta

April 2019:
Final system,
and
production start

June 2021:
Production end;
complete dataset
released

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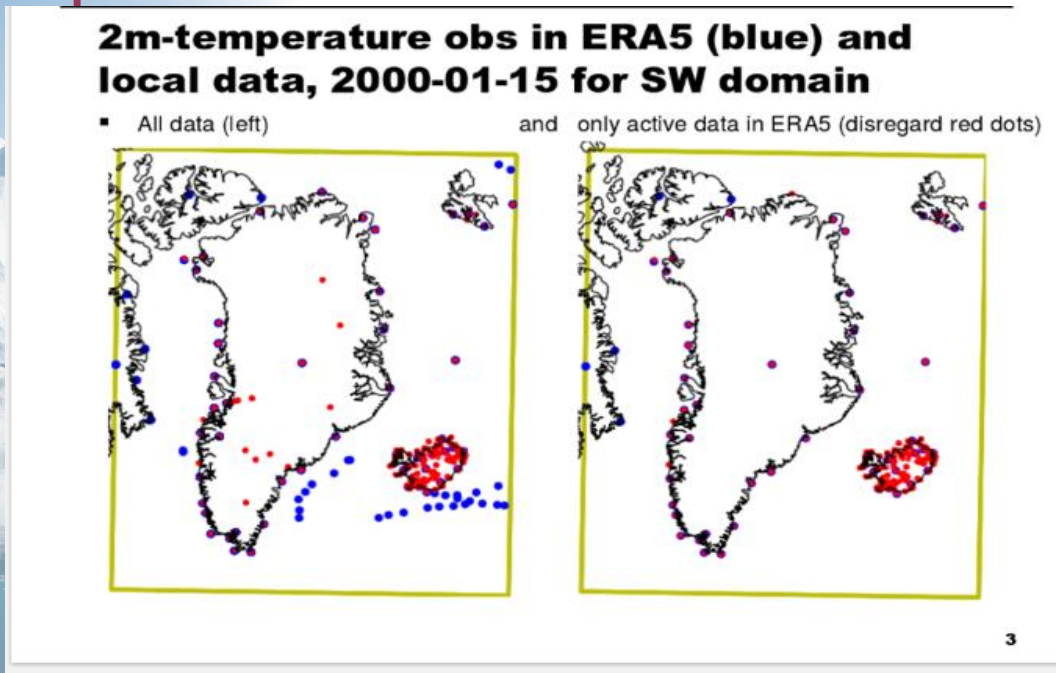
Arctic area is extremely data sparse!



- **Very limited number of stations, especially few about moist parameters.**
- No snow depth obs over Greenland
- **Mostly coastal stations**
- **Significant portion of obs not on GTS**
- Collect and use more surface data
  - Iceland, Greenland SYNOP
  - snow depth data form non-GTS
  - use better quality-checked data
  - PROMICE/GCNET/ASIAQ data
- **Use more satellite data**
  - **Radiance, RO, AMV, Scatterometer**

(Magnus Lindskog et al)

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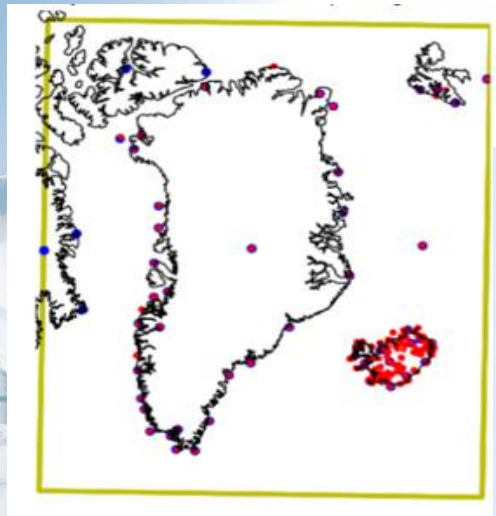
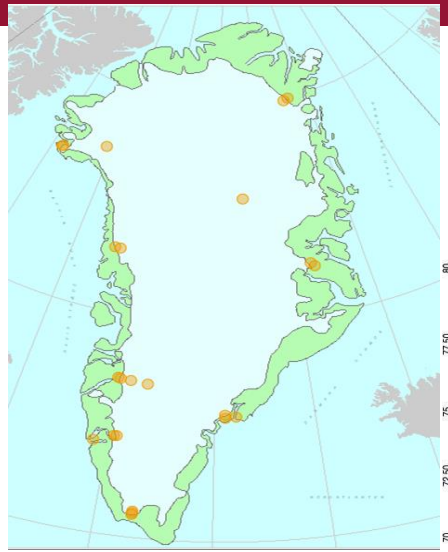
Enhanced surface observation data



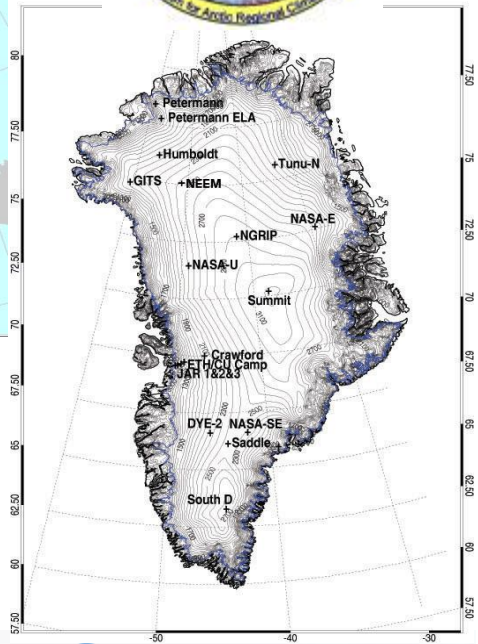
ERA-5 (GTS)

(Bjarne Amstrup et al)



PROMICE

(2008-)



ASIAQ GREENLAND SURVEY · Danish Meteorological Institute · Mittarfeqarfiit Grønlands Lufthavne | Greenland Airports · GEM Greenland Ecosystem Monitoring

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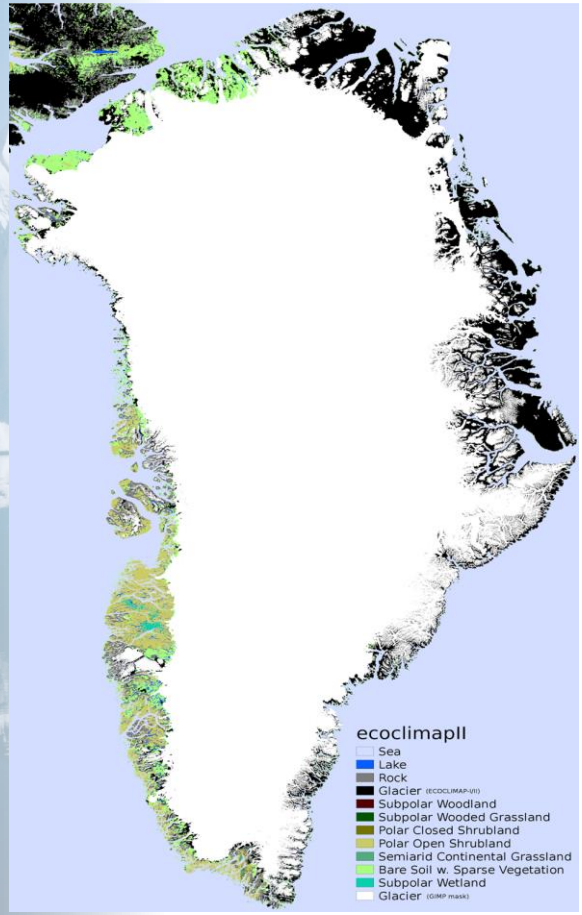
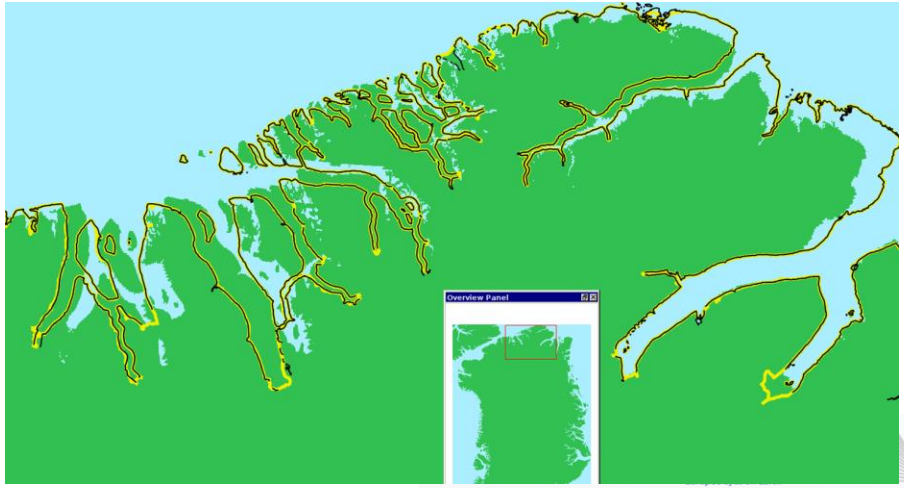
Corrections of physiographic data (PGD)



- **Svalbard icesheet/glacier extents corrected**
- Clay and sand extents from Soilgrid used
- **Topography improved with better DEM datasets**
- Coastline errors corrected with coastlines from the Danish mapping authorities and other sources.

(Bolli Palmason, Teresa Valkonen Matti Horttonainen, Ekaterina Khoreva)



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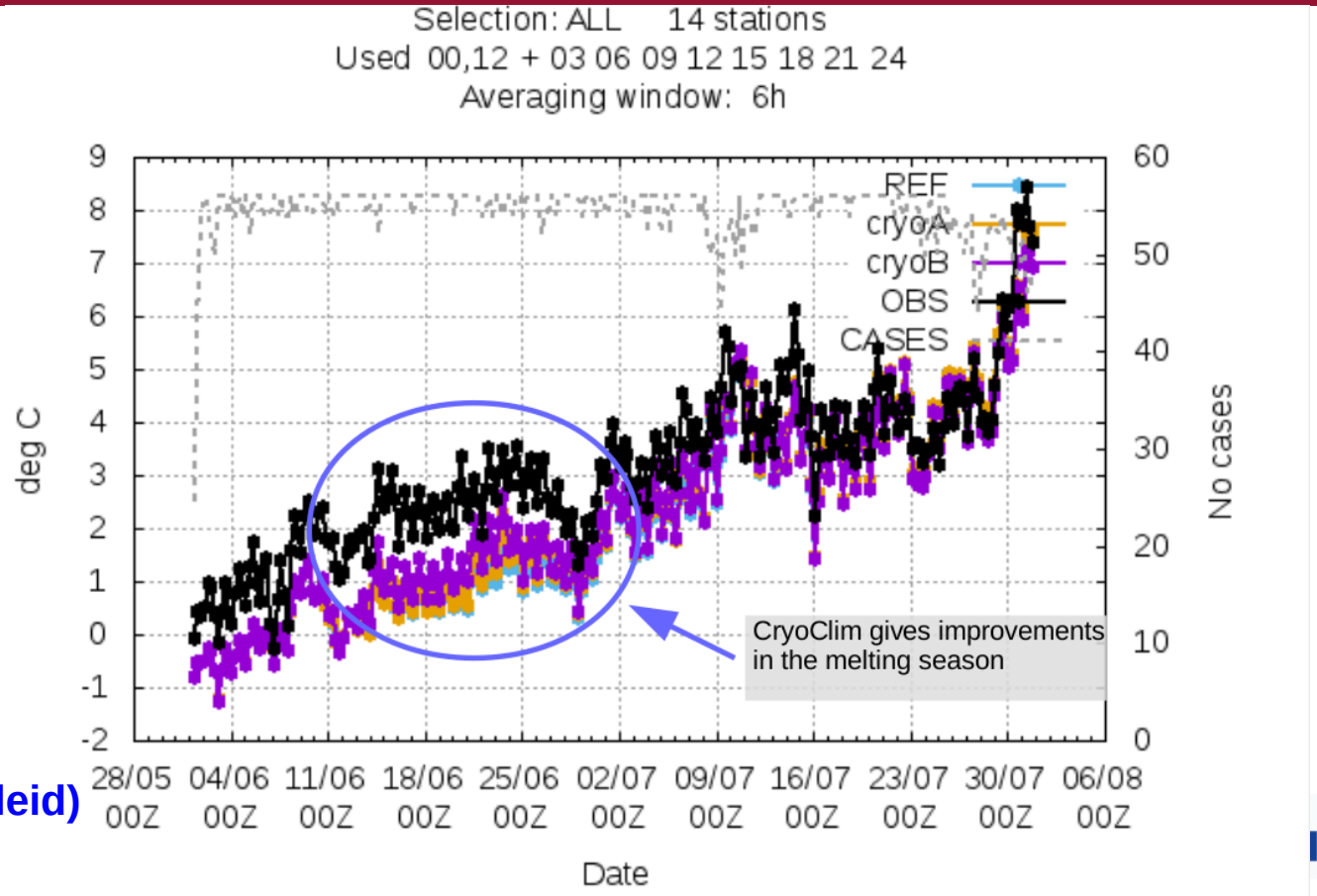
Assimilation of Cryoclim satellite snow (5 km)

Summer 2015
Svalbard



(Mariken Homleid)

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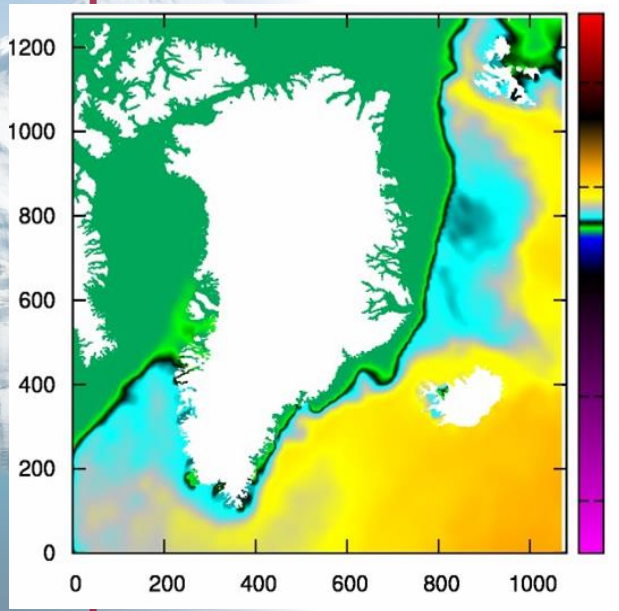
High resolution SST (~5km) & Ice cover (~10 km)

A seamless product tailor made for C3S Arctic (Pia Nielsen-Englyst et al.)

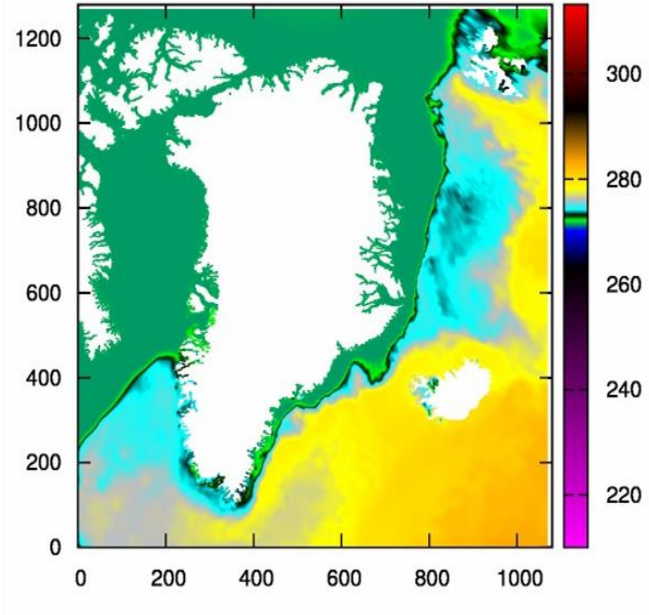
Sea Ice : ESA CCI SICCI and Eumetsat OSI-SAF Sea ice CDR

SST: Eumetsat OSISAF Level 4 + ESA CCI CMC L4

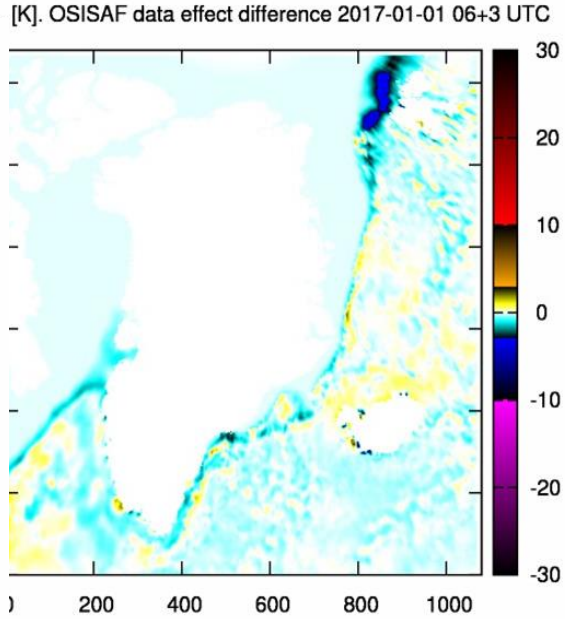
2017-01-01-09 UTC



ERA 5 SST



OSI SAF-CCI SST



SST difference

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Satellite data

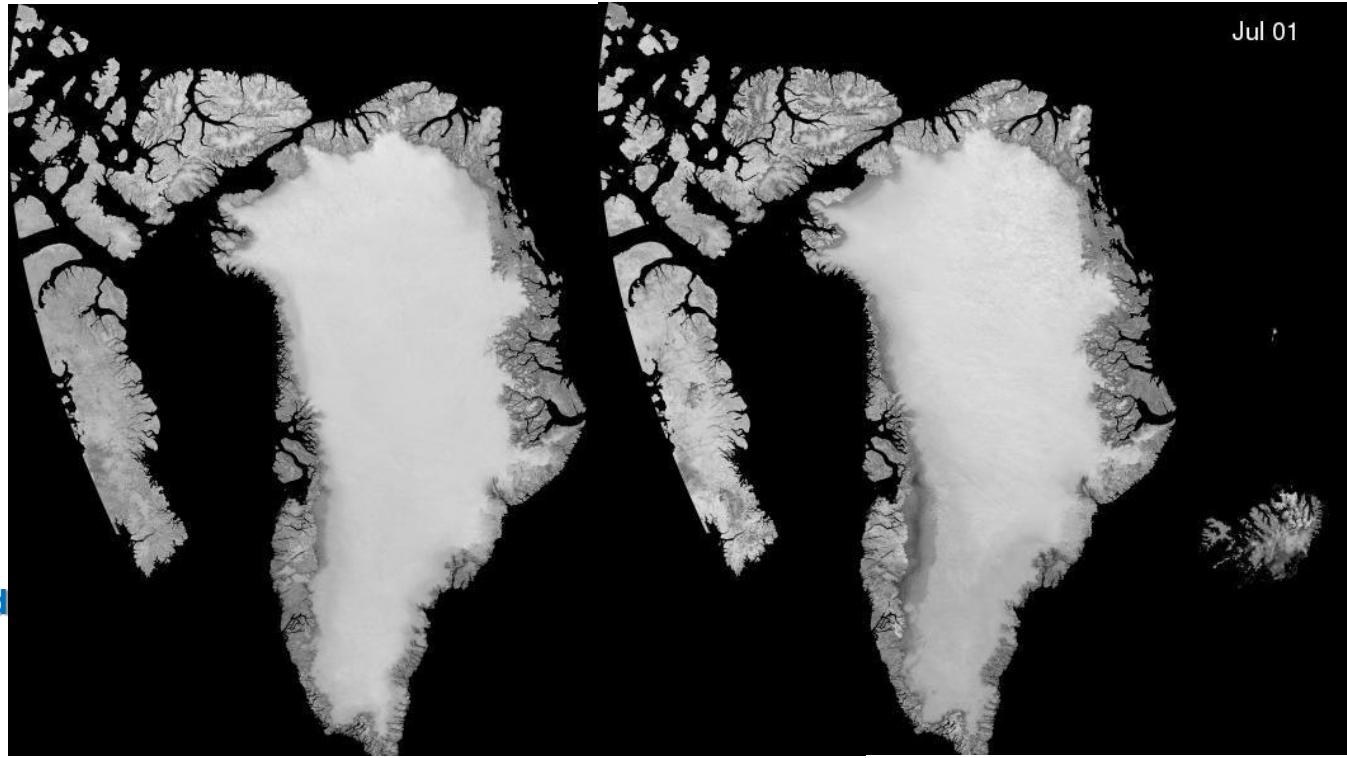
Daily albedo grids

+ MODIS-Terra
+ 2000-present
+ denoised
+ gap-filled
+ validated 0.05 RMSE

Box, J.E., D. van As, K. Steffen, 2017. **Greenland, Canadian and Icelandic land ice albedo grids (2000-2016)**, Geological Survey of Denmark and Greenland Bulletin, 38, 53-56.

July 2000

July 2012



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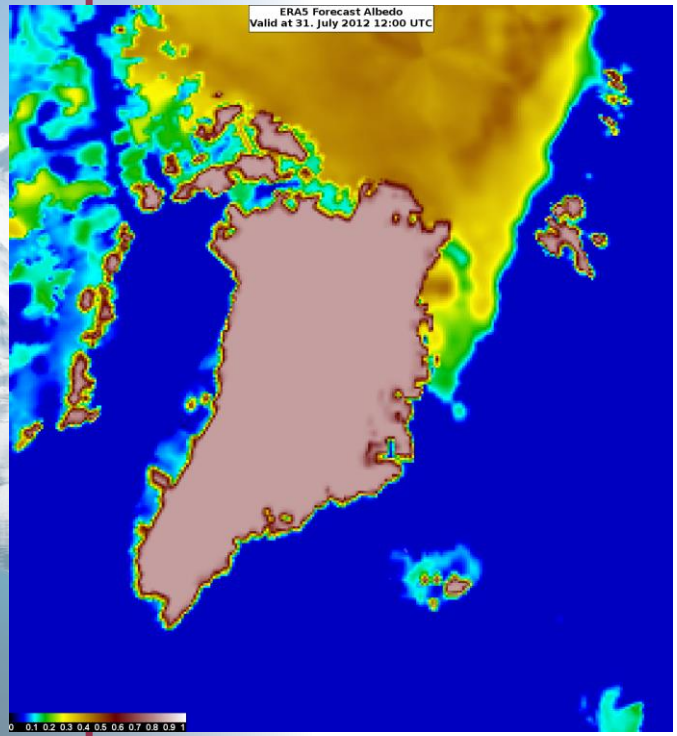
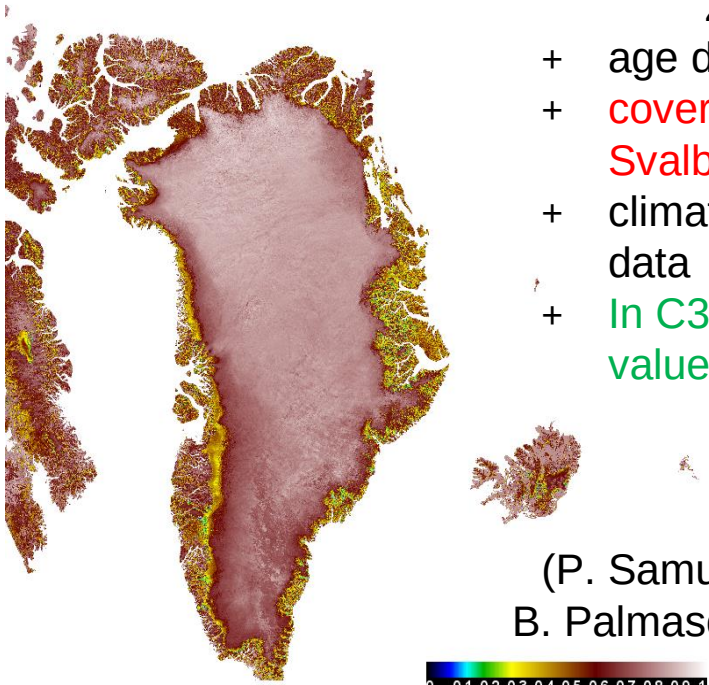
Albedo over arctic glaciers

ERA5



GEUS (Box et al)



MOD10A1 C6 product
2000-2017, daily, 500m

+ age data
+ covering Greenland, Iceland Svalbard & adjacent areas
+ climatologies using 2000-2006 data
+ In C3S Arctic, external albedo values will be assimilated

(P. Samuelsson, B. Palmason & K. P. Nielsen)

Figures by Bolli Palmason (IMO)

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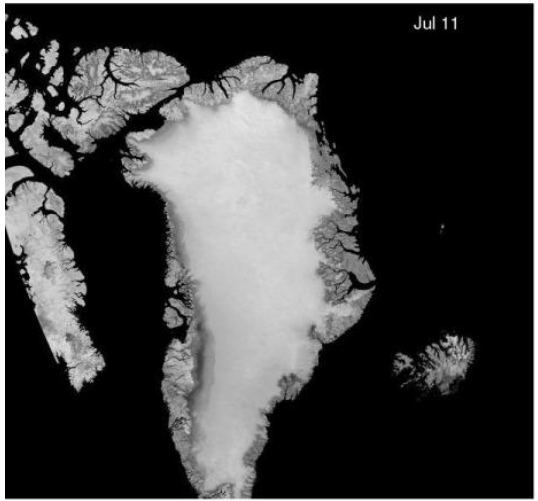

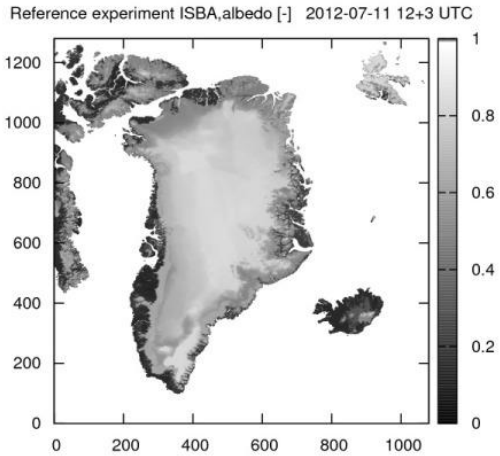

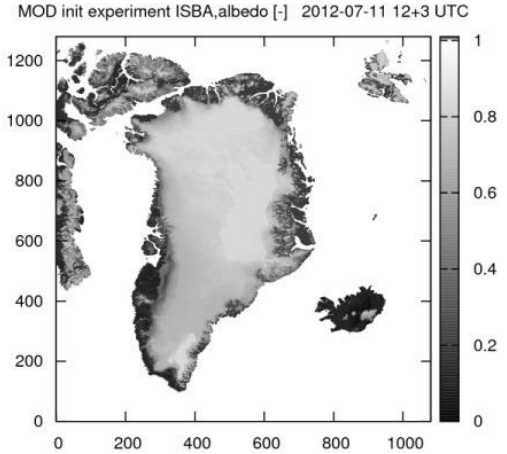

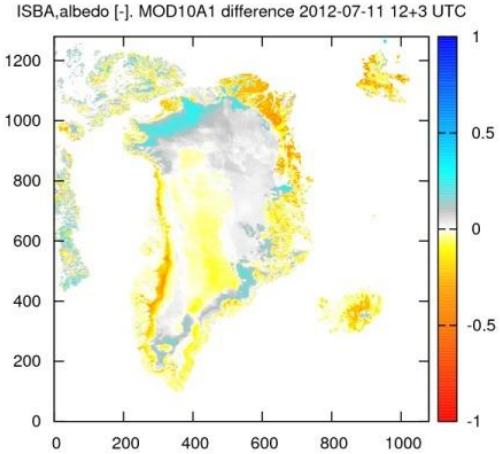

Assimilation of the daily gap-filled GEUS MOD10A1 C6 snow and glacier albedo dataset as provided by Box & Mankoff

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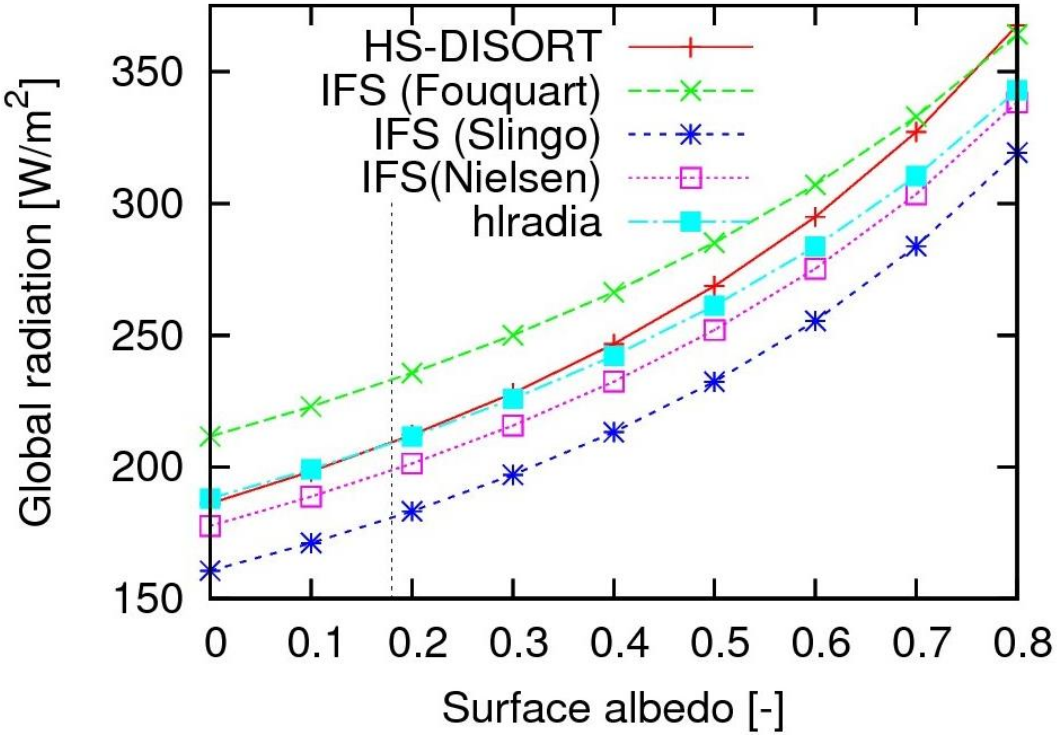
The effect of multiple reflections underneath clouds



Simulations for a cloud with
100 g/m^2 cloud water load and
10 µm effective radius.

From (Nielsen, Gleeson & Rontu 2014; GMD)

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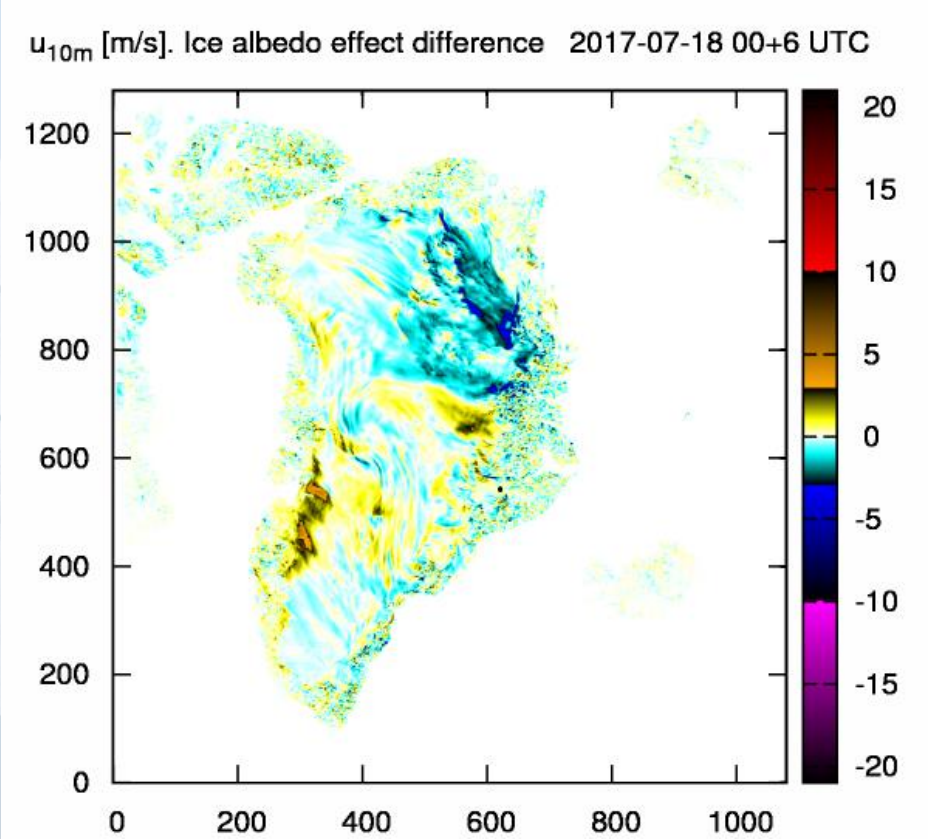
Atmospheric effects of albedo changes



When the surface physical parameters are changed, this changes the atmospheric state as well.

This shows the importance of coupled modelling!

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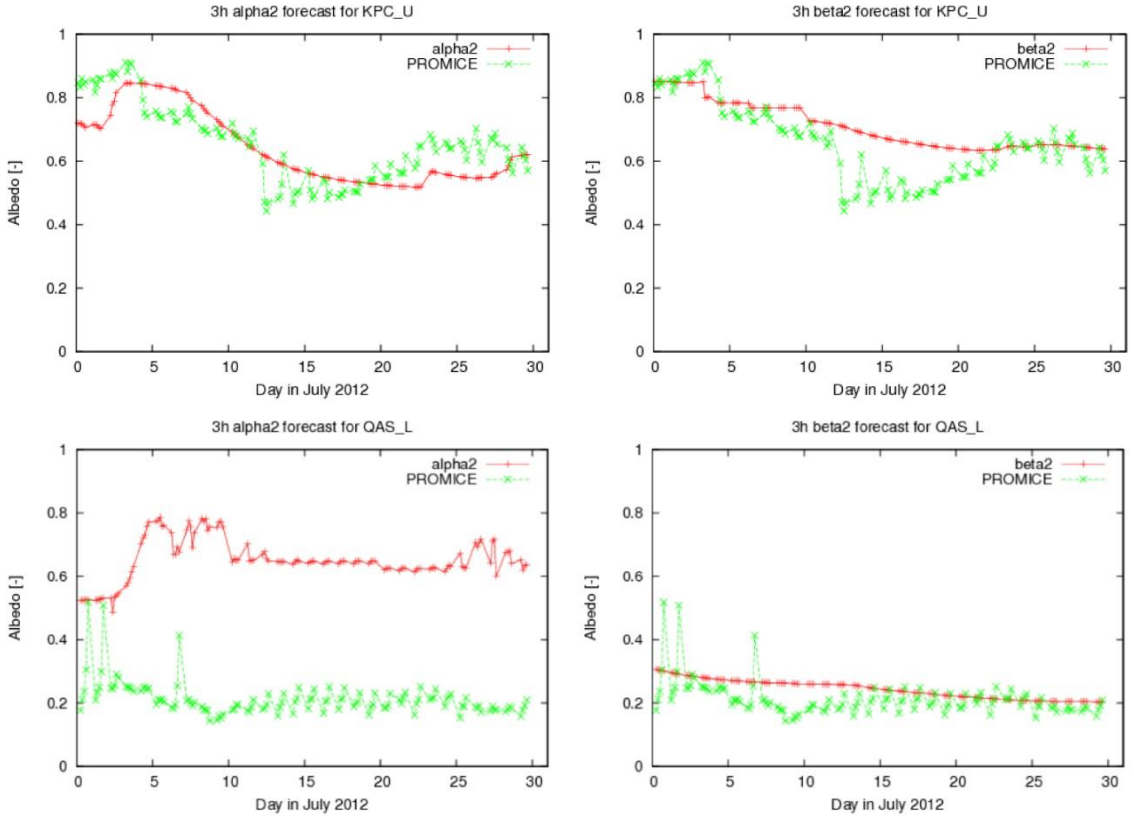
Impact of satellite-derived albedos



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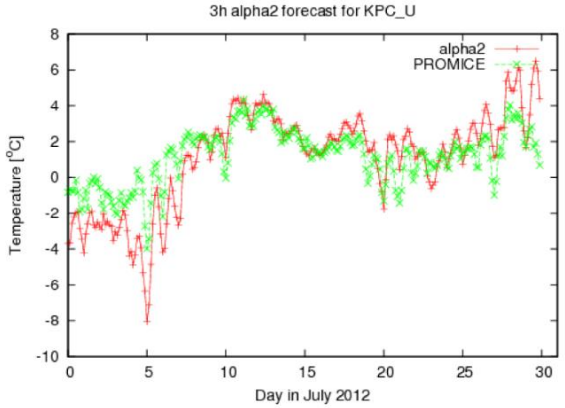
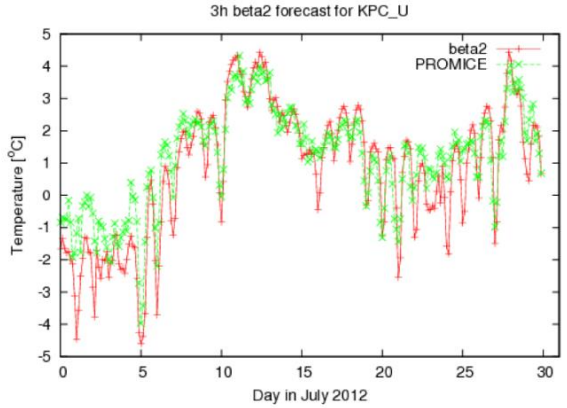
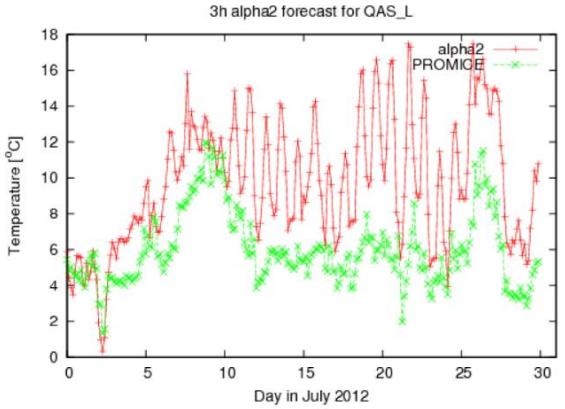
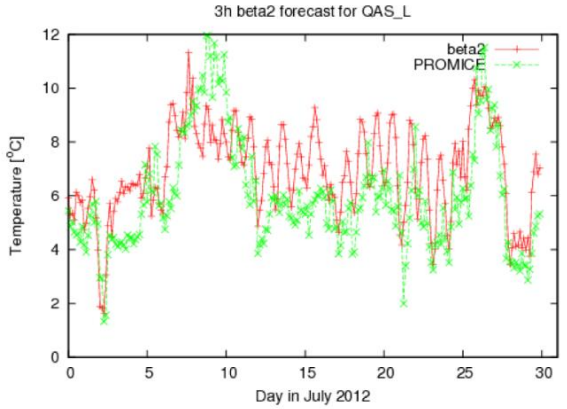
Impact of satellite-derived albedos









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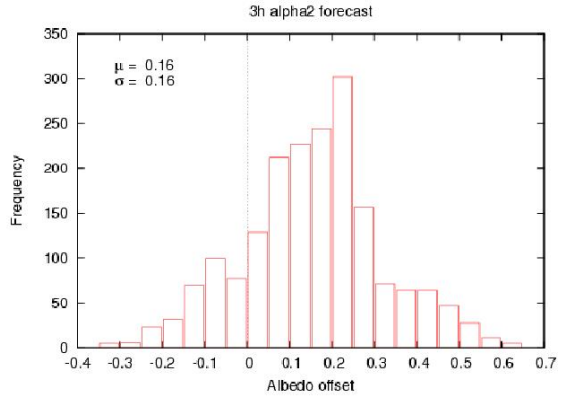
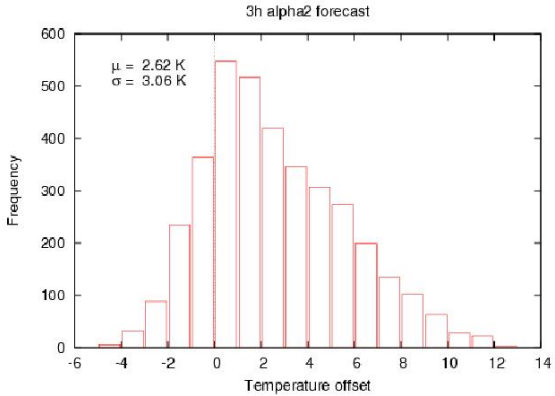
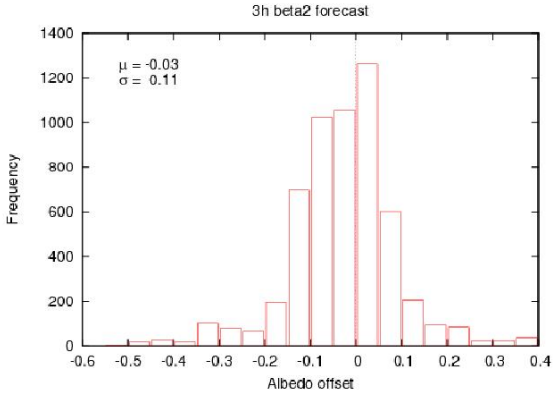
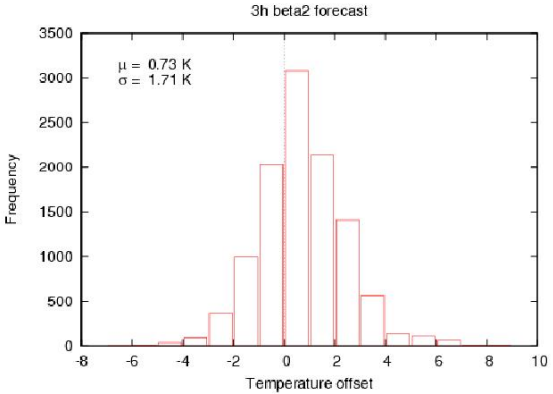
Impact of satellite-derived albedos









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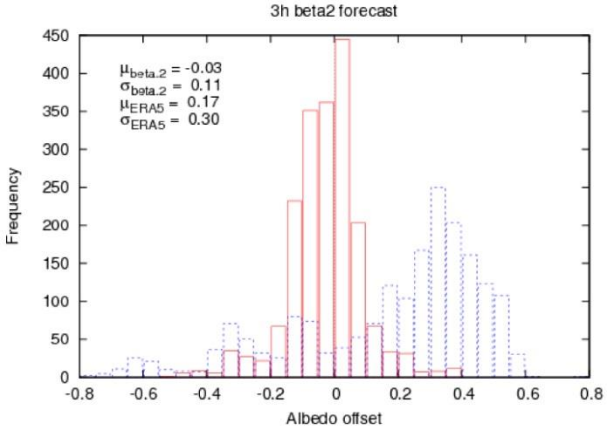
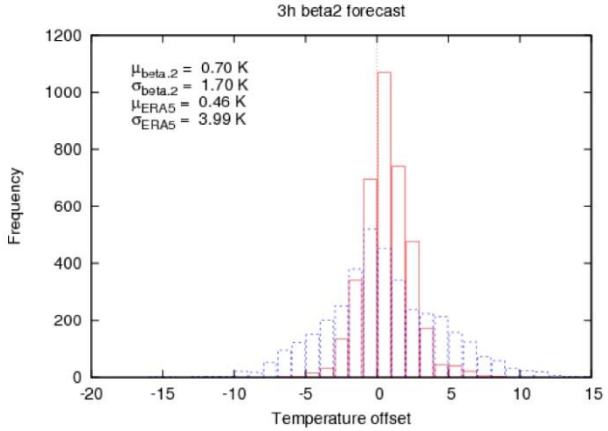
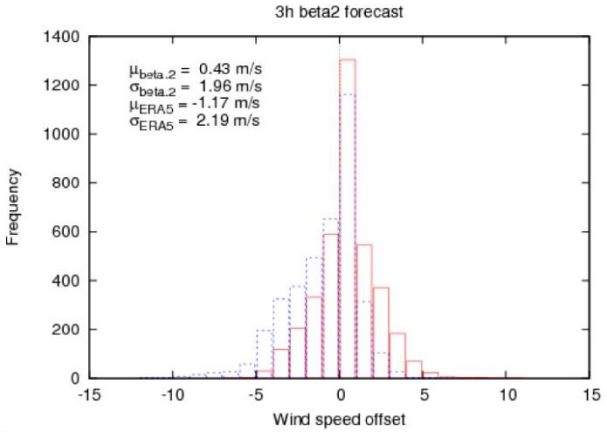
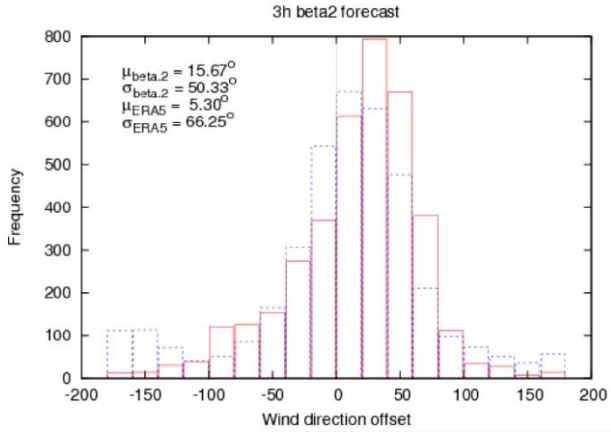
Comparison with ERA-5

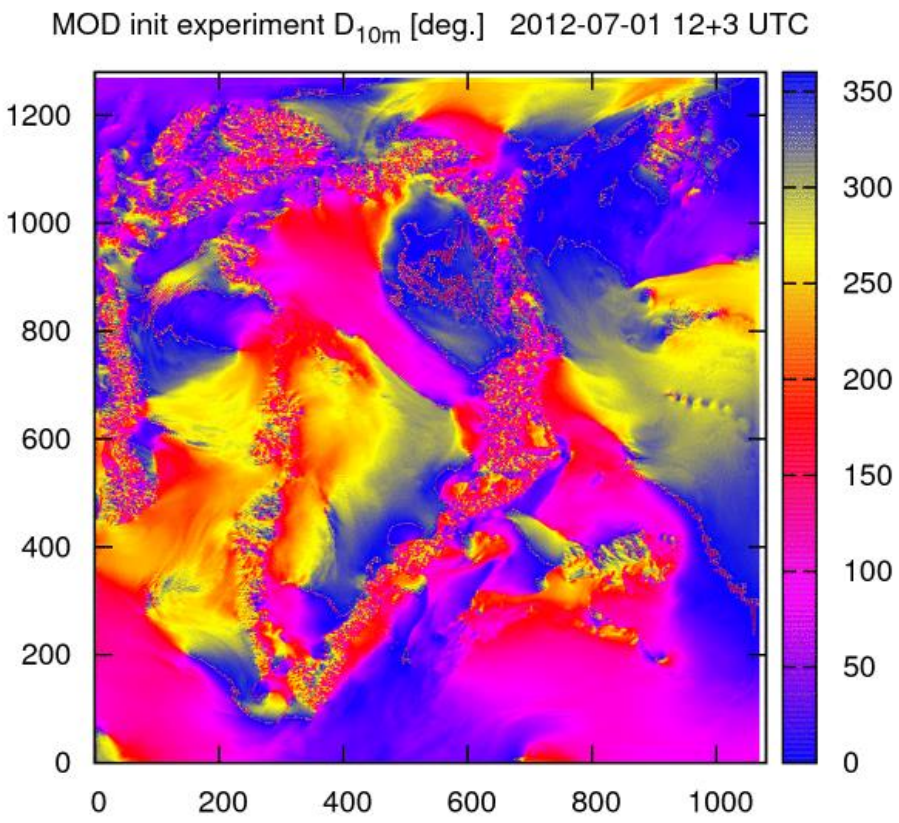


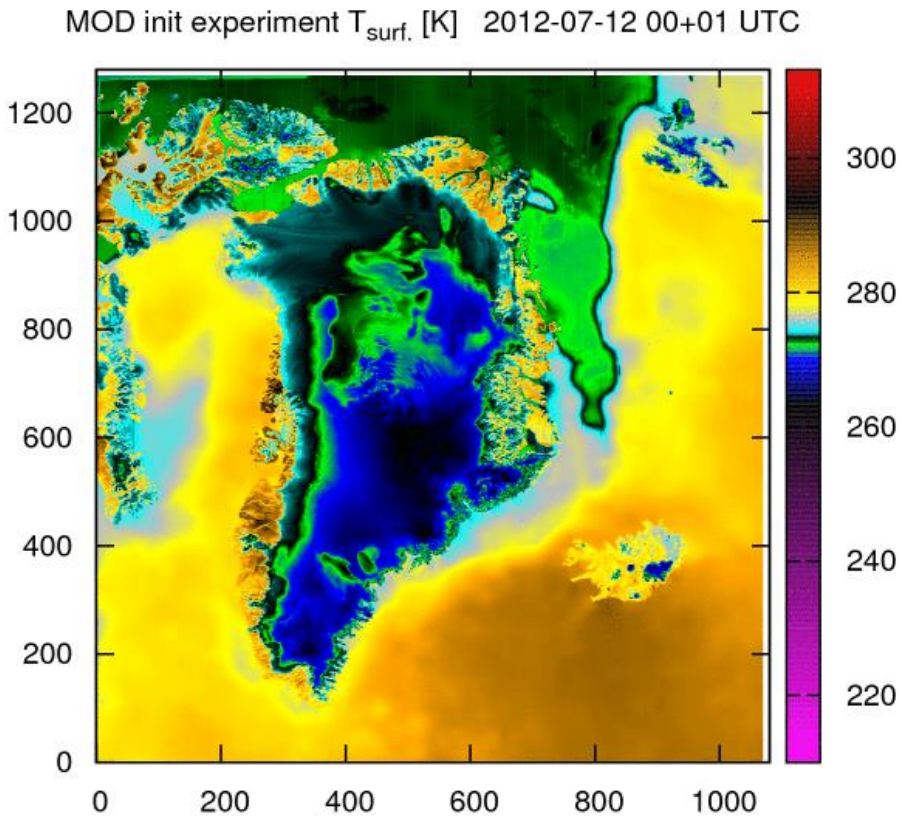






Statistics for 16 PROMICE stations


MOD init experiment D_{10m} [deg.] 2012-07-01 12+3 UTC
0
200
400
600
800
1000
1200
0
50
100
150
200
250
300
350


MOD init experiment $T_{surf.}$ [K] 2012-07-12 00+01 UTC
0
200
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220
240
260
280
300

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THANK YOU FOR YOUR ATTENTION!

Summary:

C3S Arctic is a ***very high resolution*** 24-year regional re-analysis for arctic regions. Preparation phase features major efforts to address 1) cold surface processes and 2) sparse observation:

- enhanced handling of ***snow and arctic glaciers***
- enhanced model description about ***surface features***
- ***enhanced observation data input*** with local synoptic, reprocessed satellite, and sea states data
- also, some measures of uncertainty e.g. through EDA on time slicing
- Technical and meteorological baseline in good shape; provisional C3S datasets confirm added value over ERA5
- C3S production starts in ***May 2019***

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