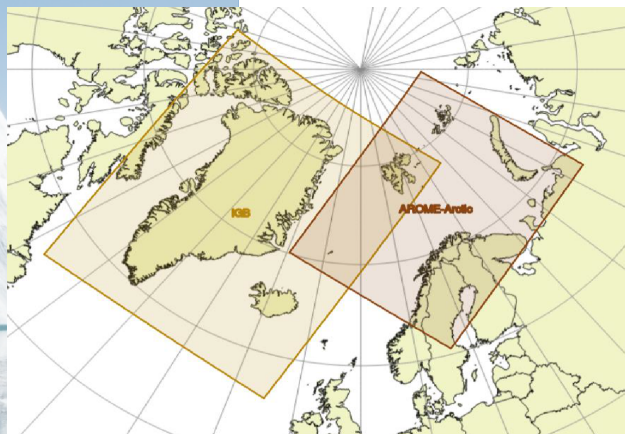# Copernicus Arctic Regional ReAnalysis
--- Achievements so far

Climate Change

CARRA reanalysis with
Harmonie@2.5 km
(1997-2021)
    +   1 yr demonstration reanalysis for pan-arctic area

Partners: *MET, DMI/GEUS, SMHI, MF, IMO, FMI*
Coordinator: Harald Schyberg(MET)

Xiaohua Yang, DMI

- CARRA system and status
- Achievements and links to operational applications
  - Input, assimilation and model aspects
- Summary

acknowledgement to the CARRA team

Climate Change

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth

European Commission

Scientific perspectives:
A NWP forecast system adapted for re-analysis

A **high resolution** and **consistent** reanalysis dataset (1997-2021)
- A reanalysis system adapted from operational Harmonie-arome at 2.5 km
- Focus on **analysis** of atmospheric states (0h, except for precip: +6 -> +18h)
  - analysis boundary
- Focus on temporal **consistency:** fixed model version & care on evolution of observation
- Enhanced **input** data
  - improved surface database, sea states, non-GTS data, satellite data
- Focus on reduced **systematic error**: glacier/snow handling
- Uncertainty information
- Verification and monitoring with long-term perspectives

Components development in the CARRA reanalysis

- **Reanalysis system**
  - **ERA 5 boundary**; configuration harmonisation between domains; Output stream; **Production logistics**
- Improvements on top of Harmonie-40h1.1.1
  - **Forecast model**
    - use of satellite derived glacier albedo data
    - improved surface states: orography (ARCDEM), PGD
    - improved snow/ice parameterisation and snow initialisation
    - use of high resolution sea states (reprocessed ESA-CCI/OSISAF data)
    - quadratic grids
  - **Use of observation**
    - significantly increased surface observation data for assimilation and verification
    - significantly increased use of satellite data
  - **Assimilation algorithm**
    - large scale constraint: LSMIX or Jk
    - EDA with observation perturbation or Brand
    - Implementation of IAU
    - Error estimation approach for deterministic reanalysis product

Norwegian Meteorological Institute ECMWF opernicus Europe's eyes on Earth European Commission

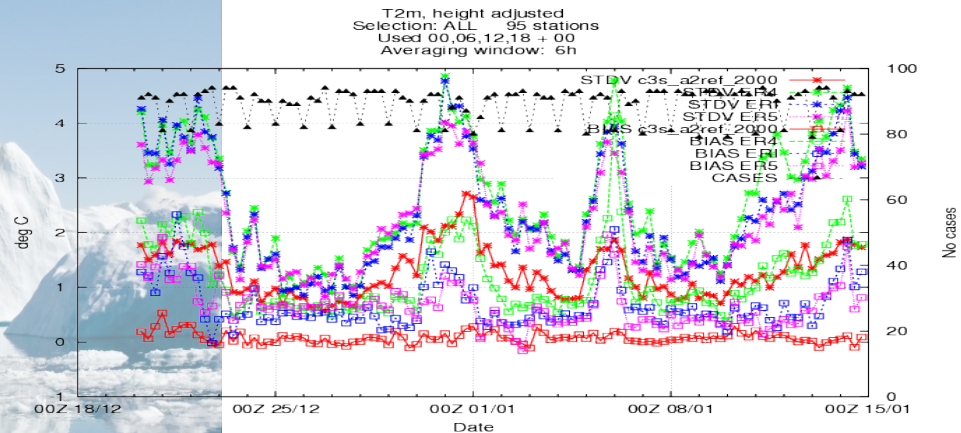# Evolution of the CARRA reanalysis system

- **alpha 1 Nov 2017 (baseline):** 40h1.1.1
- **alpha 2 July 2018**
  - + ERA 5 boundary; harmonised domain configuration (quadratic grid, LOCND2)
  - + improved PGD, reprocessed ESA cci/osisaf sea states
- **beta 1 Oct 2018**
  - + satellite derived glacier albedo, glacier snow initialisation
  - + reprocessed GPS RO, scatterometer, PROMICE/GCnet
- **beta 2 Dec 2018**
  - + PGD/ECCOCLIMAP II update (glacier mask, coast line, LAI, cover type)
  - + atovs, AMV-polar wind, ASIAQ,satellite derived snow cover
- **rc 1 8 March 2019; rc2 22 March 2019**
  - ARCDEM data, satellite snow, non-GTS station data, MSU,ERS wind, IASI, RO AMSU-A with dynamic emissivity, snow roughness
- **CARRA 1.0 April 30 2019**

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Climate
Change

T2m std/bias

T2m, height adjusted
Selection: ALL   95 stations
Used 00,06,12,18 + 00
Averaging window: 6h

STDV c3s_a2ref_2000
STDV ER4
STDV ER1
STDV ER5
BIAS c3s_a2ref_2000
BIAS ER4
BIAS ER1
BIAS ER5
CASES

Dec 20 1999 - Jan 2000, North Scandinavia, Svalbard

ERA 40 125 km
ERA Interim 80 km
ERA5   31 km

CARRA 2.5 km

Climate Change
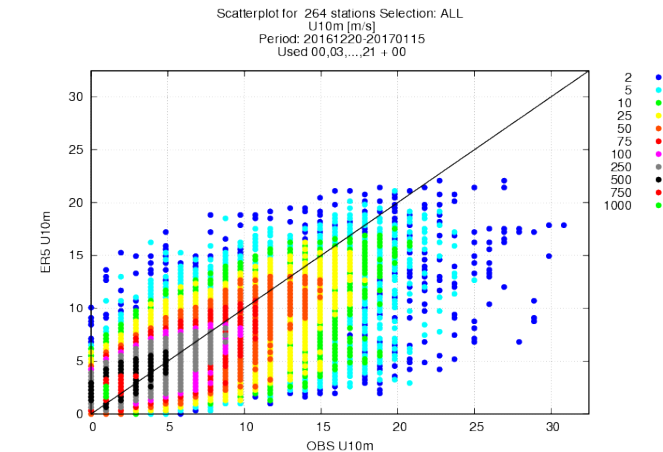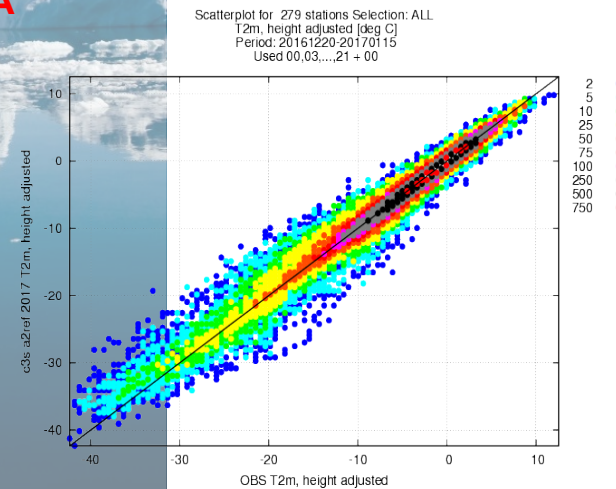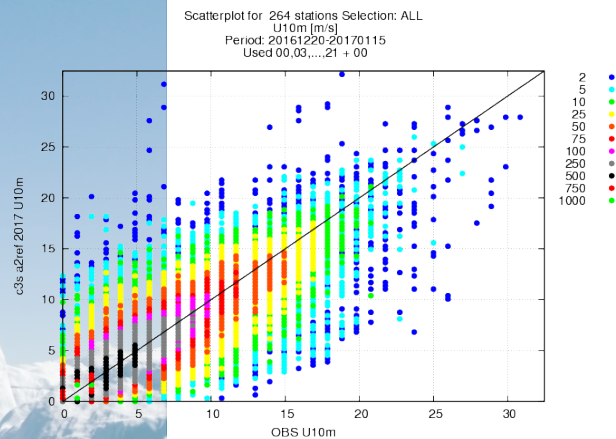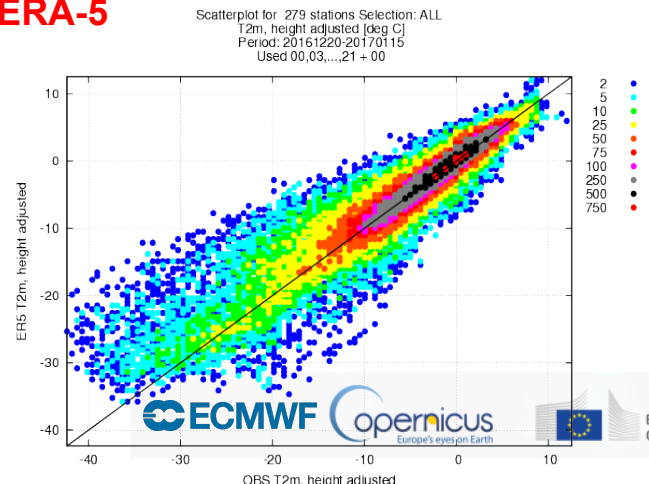
Wind

CARRA

ERA-5

T2m
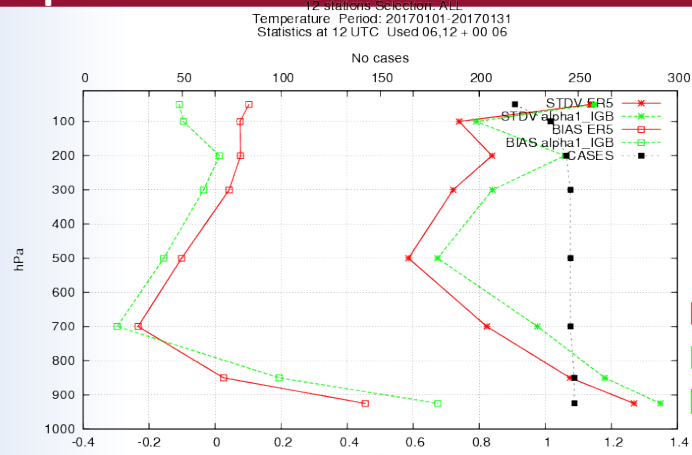
Climate Change

ECMWF ERA 5
HARMONIE with lagged boundary
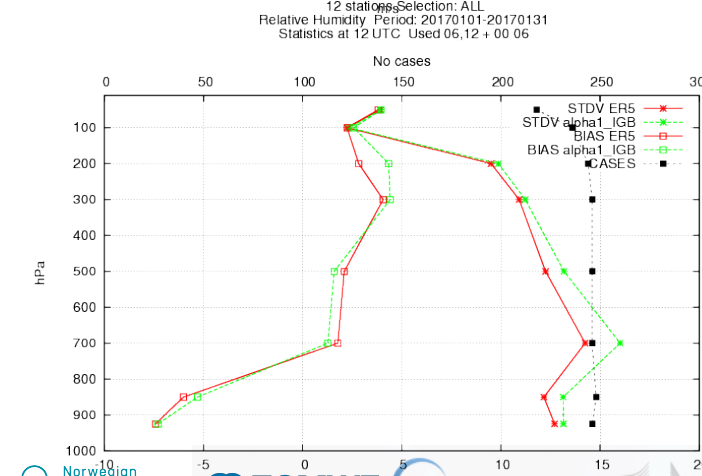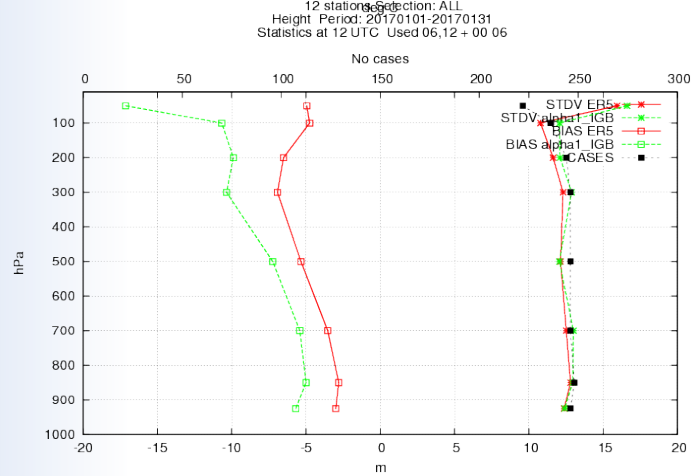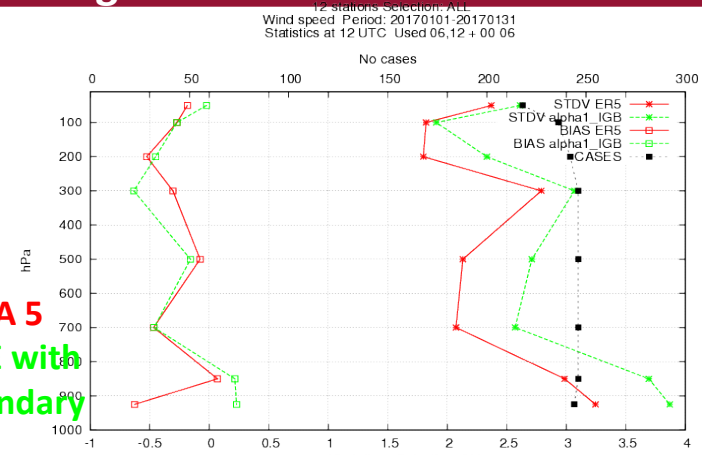
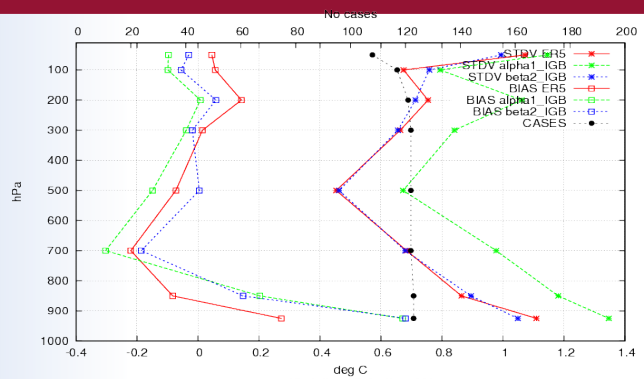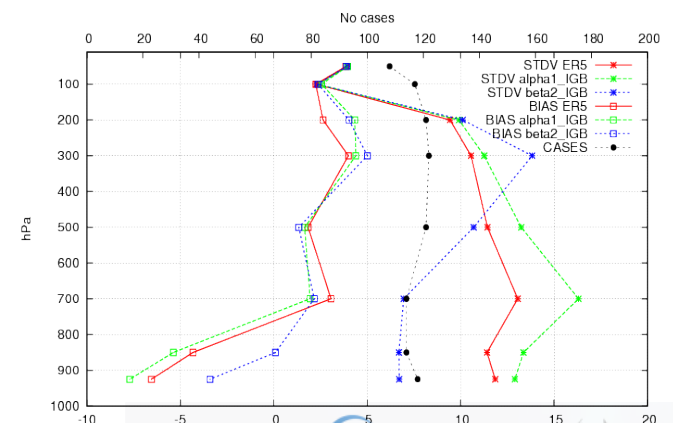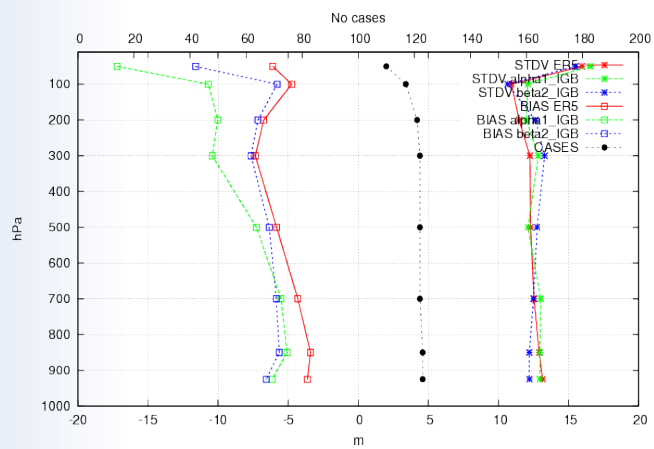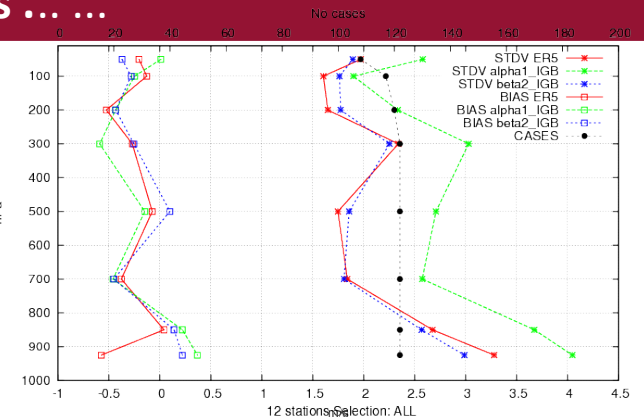**Without using lagged forecast boundary, HARMONIE reveals its true competitive skills also for large scale parameters … …**

Climate Change

ECMWF ERA 5
HARMONIE with lagged boundary
CARRA, analysis boundary

- Glacier mask error corrections (reductions) performed by Bolli Palmason (IMO) for Greenland and Teresa Valkonen (Met Norway) for the Norwegian AROME-Arctic domain.
- New PGD data for the uncovered area added for Greenland (Bolli) and rocks added for the AROME-Arctic domain.

Improvement in surface data base: orography and PGD (Palmason, Nielsen et al)
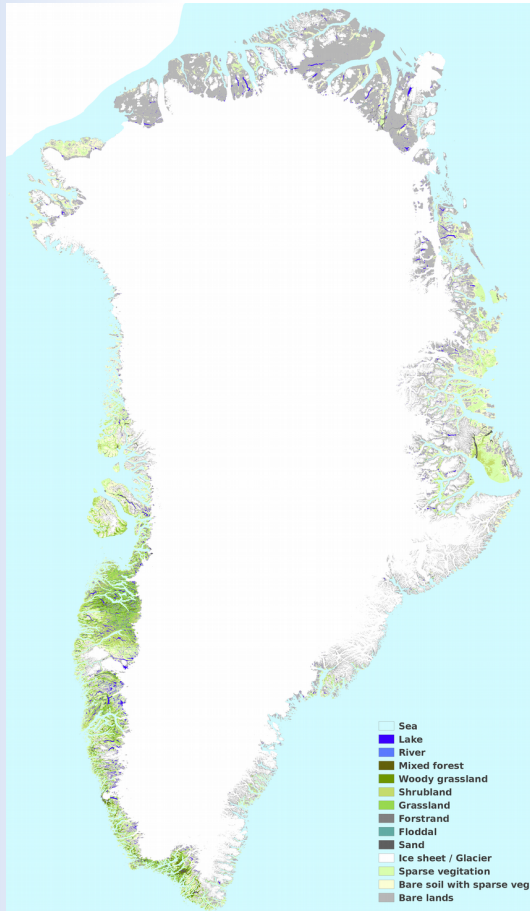

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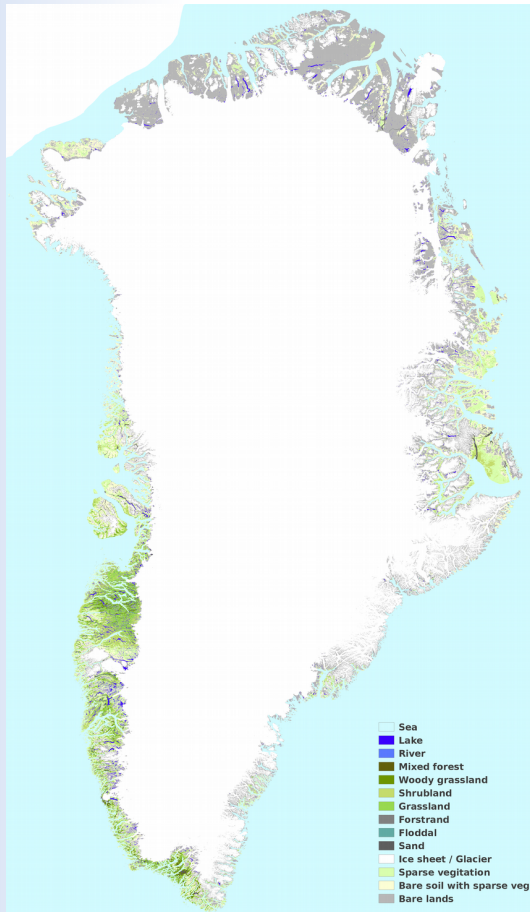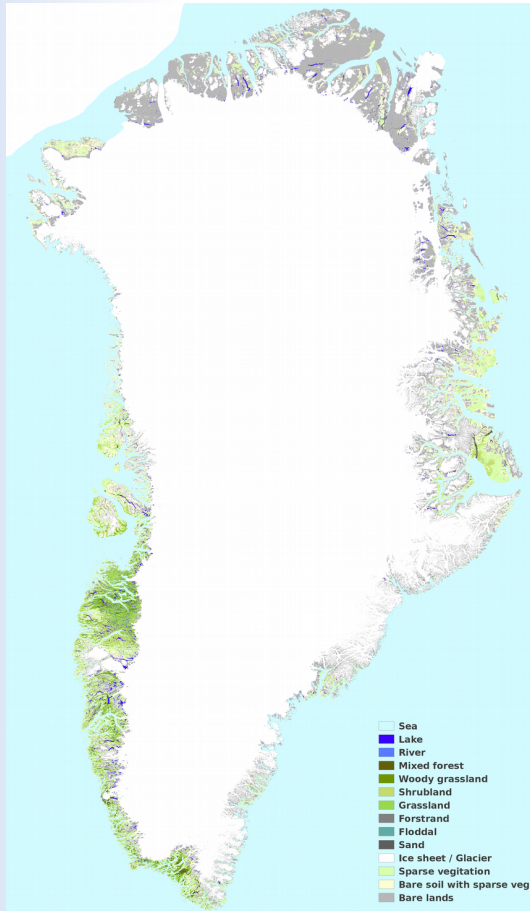

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- SoilGrids sand and clay fractions replace the FAO HWSD 1 km data (Bolli). For Iceland (and Denmark) local data are used!

Legend:
- Sea
- Lake
- River
- Mixed forest
- Woody grassland
- Shrubland
- Grassland
- Forstrand
- Floddal
- Sand
- Ice sheet / Glacier
- Sparse vegetation
- Bare soil with sparse veg
- Bare lands

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ECMWF   Copernicus   European Commission
Europe's eyes on Earth
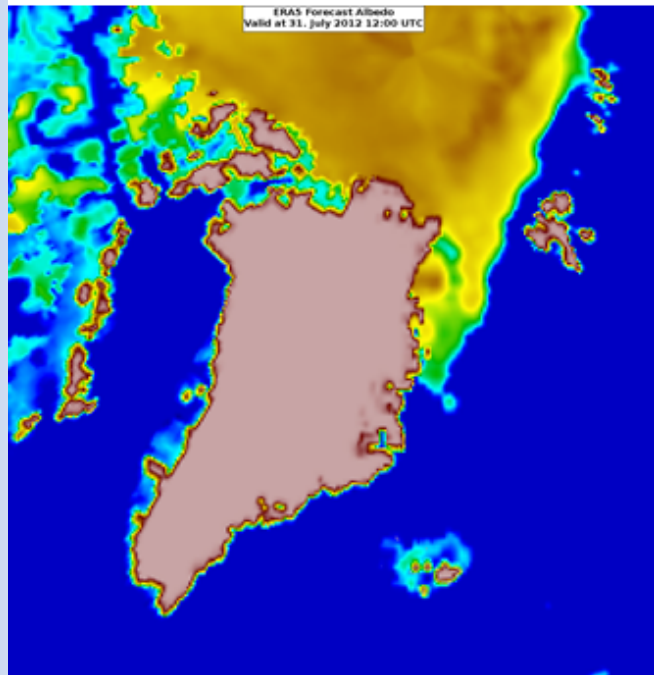
Climate Change

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- SoilGrids sand and clay fractions replace the FAO HWSD 1 km data (Bolli). For Iceland (and Denmark) local data are used!
- **Outreach: The corrected Greenland glacier mask has been shared with ECMWF.**
- **To do: Harmonise clay/sand data with the 300 m FMI SoilGrids data & the extended cover types with ECOCLIMAP-II/2nd gen.**
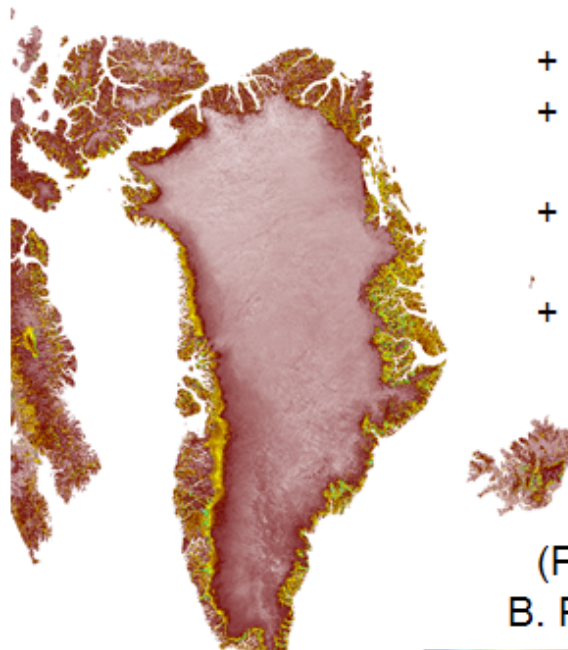
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European Commission

Improvement in handling of glacier snow and albedos

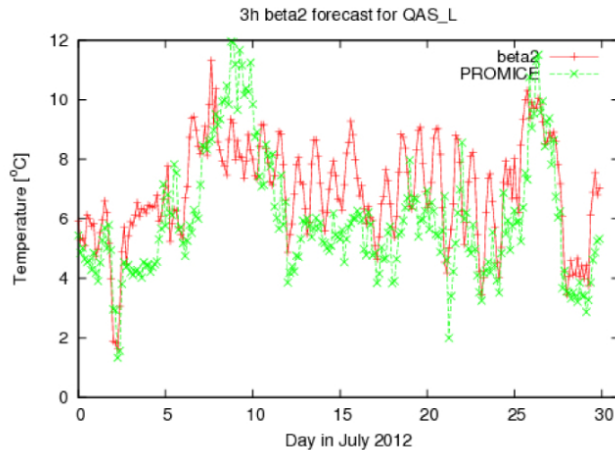

ERA5

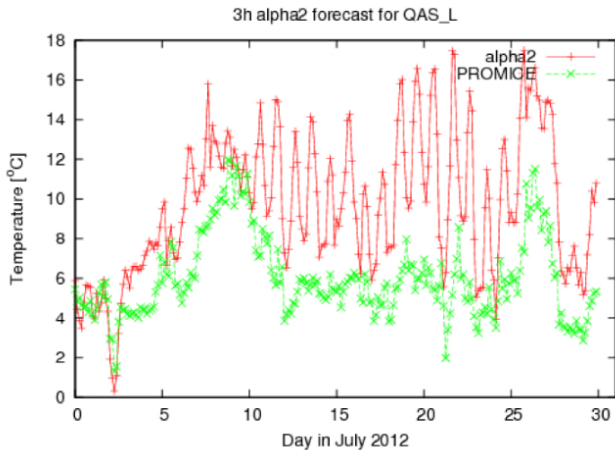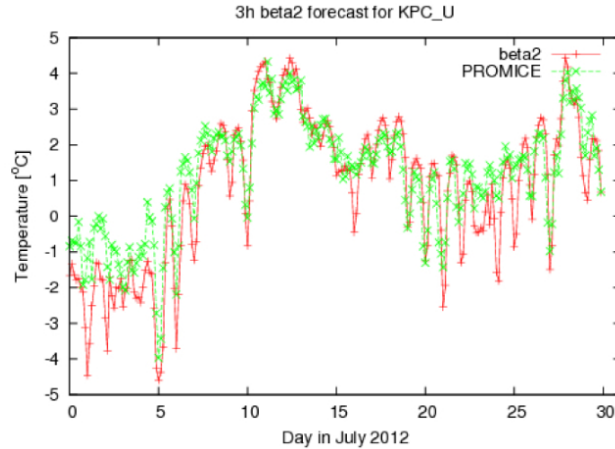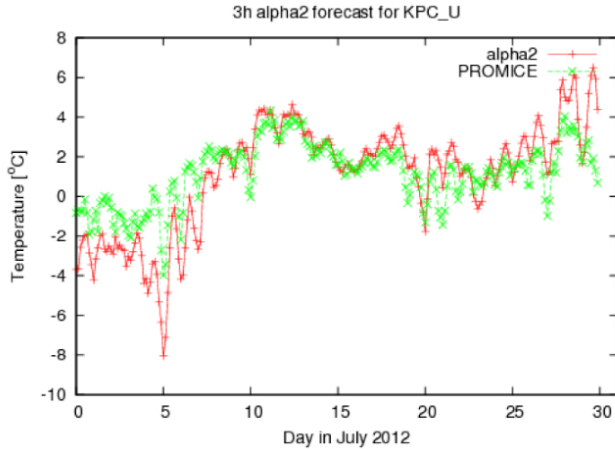GEUS (Box et al)

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)

Improvement in handling of glacier snow and albedos

Clear improvements are seen when the satellite albedos are assimilated!

NWP version
CARRA versions

(K. P. Nielsen)

Extensive test to improve use of observation

Upper air

- **Local Non-GTS** pressure observations
- **IASI** (Zhengqi W, Roger)
- **Scatterometer** (ERS, QSCAT, OSCAT, ASCAT) (Teresa V.)
- Reprocessed **AMV** data (Per D.)
- Assimilation of **GPC RO** data (Mats D.)
- AMSU-A data with **dynamic emissivity** (Sigurdue T and Roger R.)
- **MSU** (Susanna H. and Per D)
- Adaptation of ECMWF blacklist data (Per D.)
- Radio sonde bias correction (Per D.)

Surface

- Local surface observation, glacier stations
- Satellite snow cover (Mariken H.)
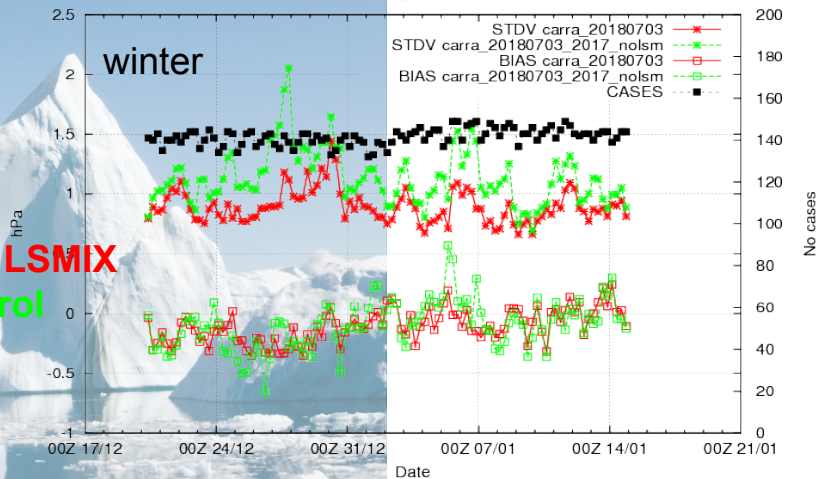- High resolution sea states (OSISAF)
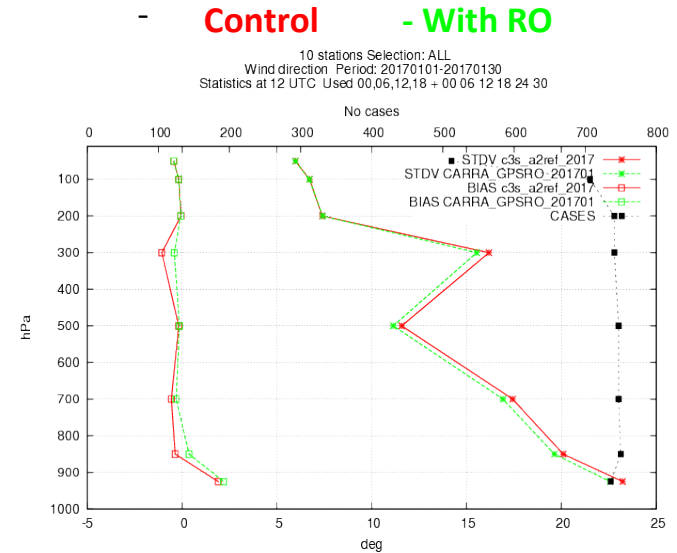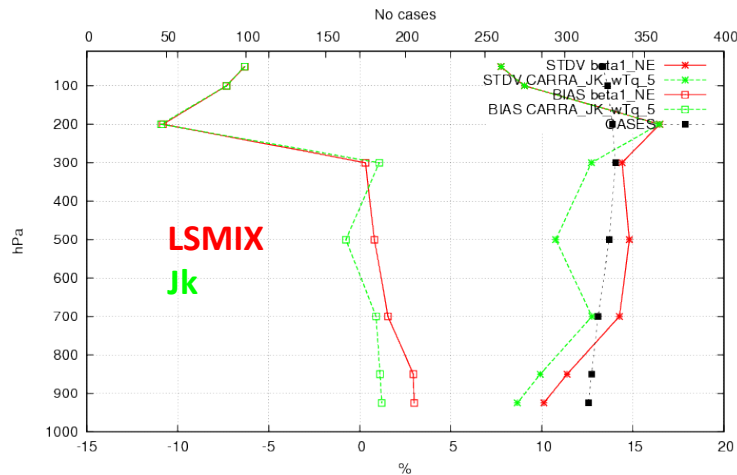

Impact of RO data in CARRA

Climate
Change

winter

with LSMIX
control

(Xiaohua Y and Ole V.)

LSMIX
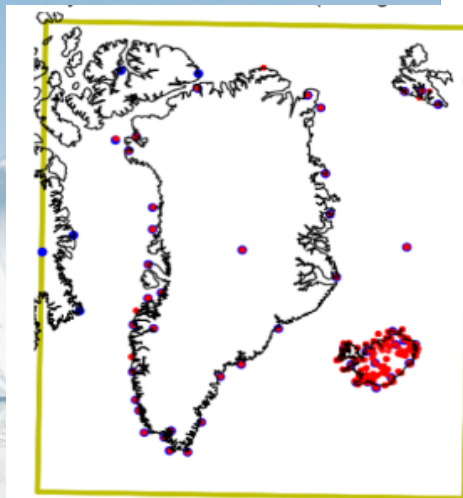Jk

(Jelena B. and Mats D.)

Two alternative schemes, LSMIX and Jk, have been evaluated in their capability to extract from global model (ERA5) the large scale information into CARRA via 3DVAR

LSMIX is the default scheme in HARMONIE-arome.
Earlier implementation flaw with Jk corrected
Tests show Jk with comparable skill as LSMIX,
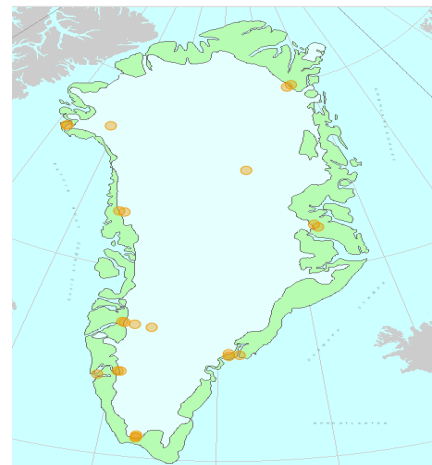sometimes better (for humidity parameters)

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Climate
Change

DMI+ASIAQ
ASIAQ: 11
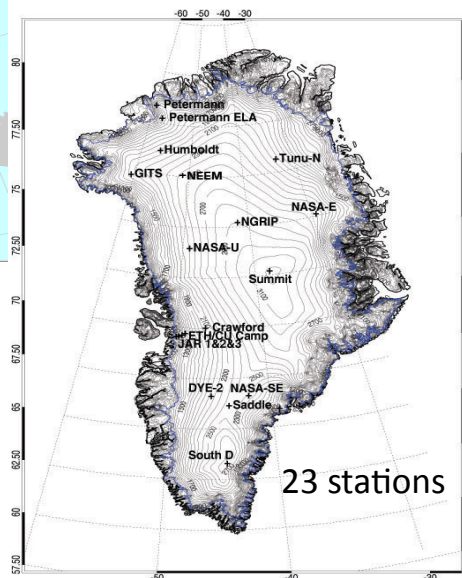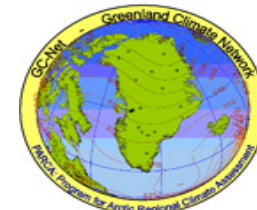
ERA-5 (GTS/mars)
Greenland 40

(2008-, 25 stations)

23 stations

West domain (Greenland+iceland+) , ~80 -> 400

East domain (Svalbard+north scandinavia) , ~100 -> ~ 300

Quality assurance of observation data

4330 T2m for 199711
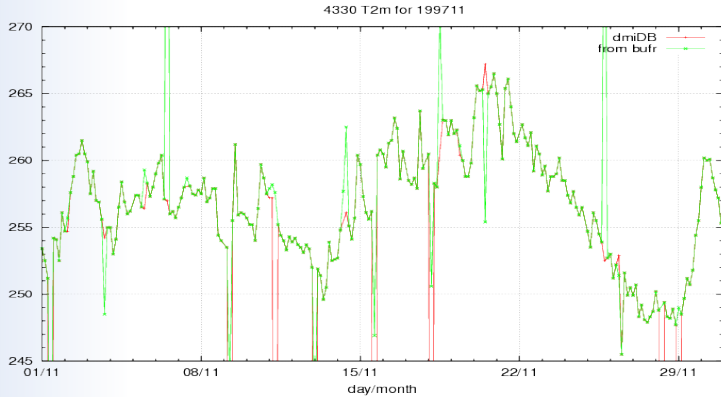
data on GTS
DMI observation database
DMI surface pressure observation

(B. Amstrup)

Observation data needs quality assurance!

Example with station **Daneborg**
- Occasionally inconsistent between GTS bufr and local database
  - neither are consistently better!
  - combination necessary
- assimilate surface pressure instead of MSLP?
  - it has problem too.
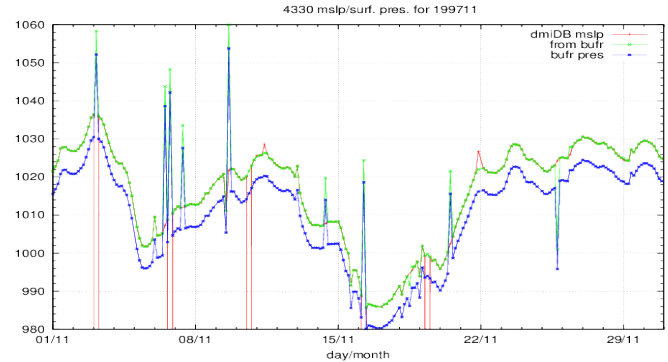
4330 mslp/surf. pres. for 199711

Climate
Change

Production at ECMWF HPC

6 simultaneous streams, 3 8-year time slicing for each domains
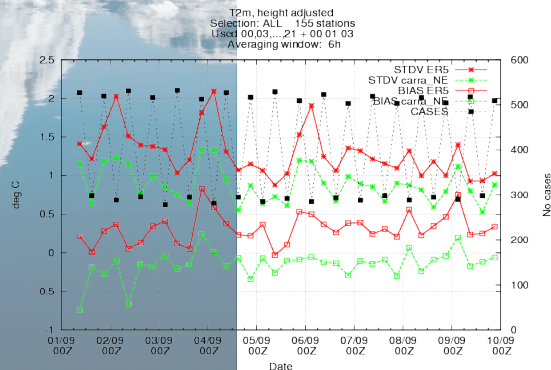
currently in 1-year warm-up phase

targeted throughput 6-7 days/day/stream

Production team by met.no and DMI

(Eivind S, Per D, Åsmund B, Xiaohua Y, Carlos P, Bjarne A)

weekly video meeting and on-duty shift

monitoring facility on the web

Regular monitoring

Time series of observation data use

Time series of o-b, o-a

Verification Intercomparison to ERA-5
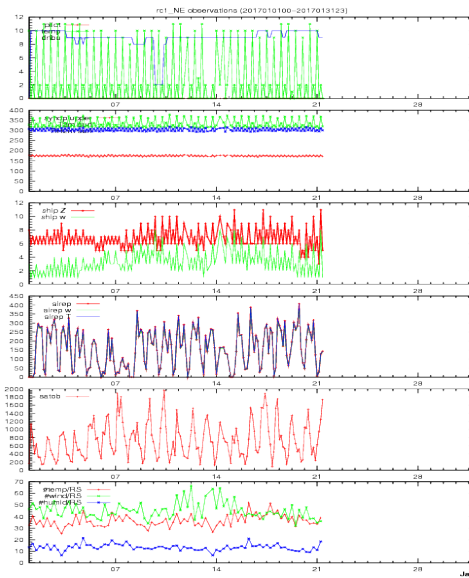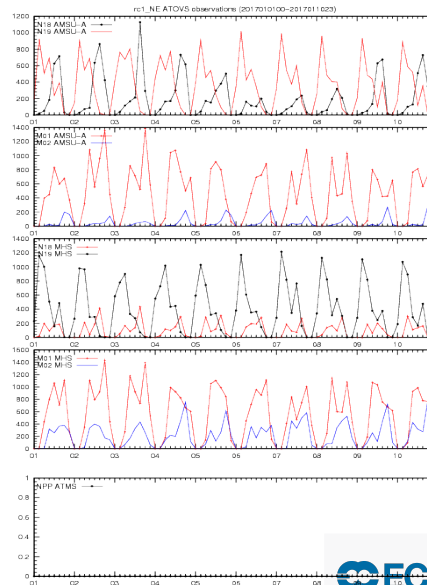
Summary: achievements and applications

Numerous scientific and technical achievements from CARRA so far

- A regional reanalysis system infrastructure extended from Harmonie-arome for high-resolution applications
- A high quality dataset with a clear added values over global re-analysis
  - also including large scale parameters
- Successful implementation of many desirable features through extensive validation, many with direct applicability to operational HARMONIE
  - use of improved and harmonised orography, PGD data
  - significantly improved glacier modelling and glacier snow initialisation
  - investigation and progresses on lsmix/Jk, BRAND and IAU approach
  - assimilation of IASI, ASCAT, Polar AMV and AMSU-A dynamic emissivity
  - assimilation of satellite snow observation
  - use of high resolution sea states data

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