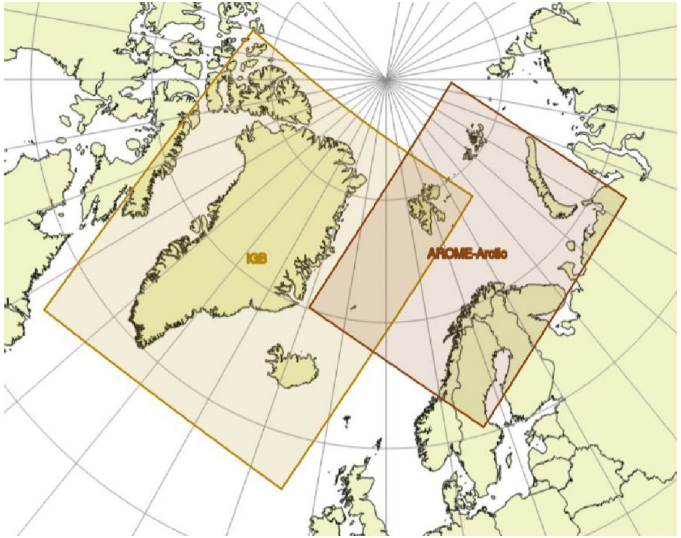
Climate Change

Extending Harmonie-arome for regional re-analysis



"C3S 322 Lot2"
-- CARRA
(1997-2021)

Xiaohua Yang
with acknowledgement to CARRA team

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Outlines

- What is CARRA
- Scientific perspectives and links to Harmonie-arome
  - Input data, assimilation and model aspects
  - Configuration, monitoring and evaluation
- Status and plan

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

C3S 322 Lot2
Copernicus Arctic Regional ReAnalysis (CARRA)

Fact sheets

- A **high resolution** and **consistent** reanalysis dataset (1997-2021)
- Approach: adapt from operational Harmonie-arome at 2.5 km with SW & NE domains
- aimed to have added values over global reanalysis ERA5
- project period 2017-2021 for current phase
- run at ECMWF HPC
- (a sister project to PRECISE, --- for European domain at 5
- a production infrastructure, with a view on continuity
  - extended domain, periods
  - near real time update

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

Danish Meteorological Institute

Climate Change

Scientific perspectives: NWP system adapted for reanalysis

- Focus on analysis of atmospheric states (0h, except for precip: +6 -> +18h)
- Focus on temporal consistency: fixed model version & care on evolution of observation
- Extended use of observation: satellite data (radiance, RO, wind measurement)
- Focus on reduced systematic error
- Uncertainty information
- Verification and monitoring with longer-term perspectives
- Use of enhanced input data (PGD, observation, global re-analysis LBC)

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth European Commission

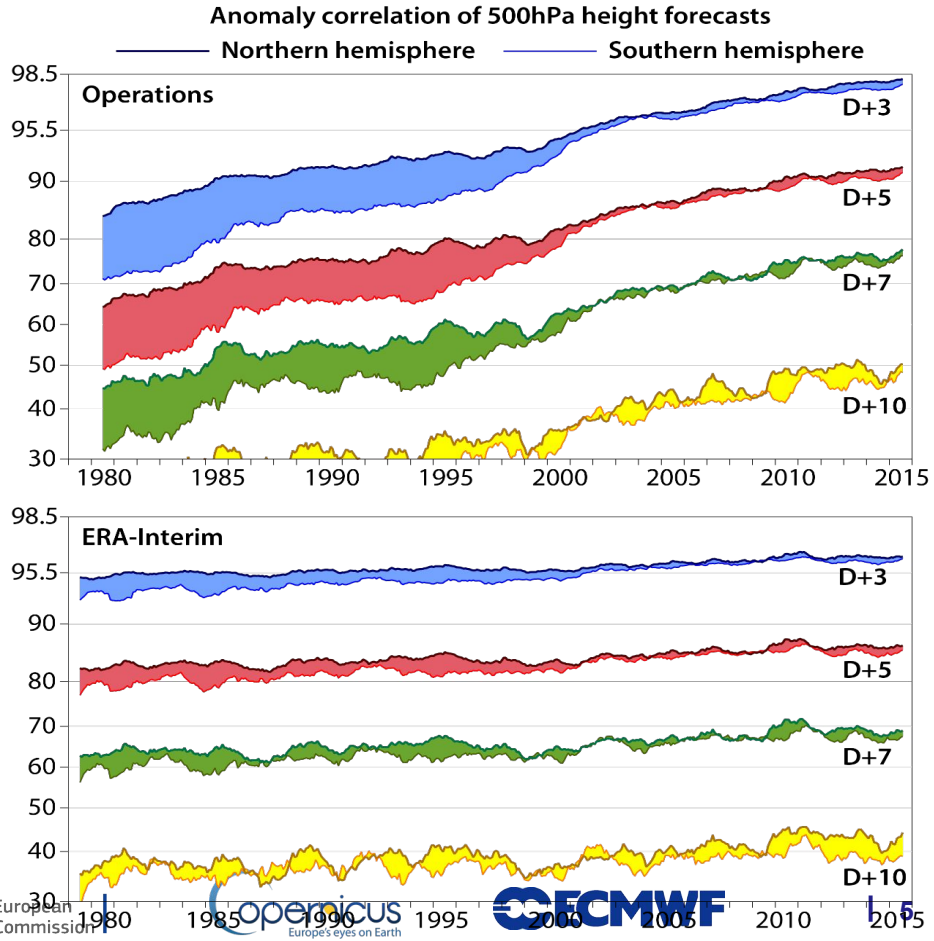
The key aspect of reanalysis: consistency

(Courtesy Horanyi et al, 2017)

Consistent reconstruction of the atmosphere, waves (and ocean):

- merge observations into ***global fields,***
- using the ***laws of physics***
- and appropriate ***bias correction*** scheme
- maintain the ***same up-to-date system*** over the entire reanalysis period.

At lower resolution to ***keep affordable***



European Commission

Copernicus Europe's eyes on Earth

ECMWF

Climate Change

Scientific perspectives: CARRA reanalysis: features and challenges

- Handling of glacier especially for melting (snow scheme and use of external albedo)
  - D95 scheme or explicit snow scheme?
  - use of external albedo dataset for glacier ice and sea ice?
  - snow assimilation or not?
- Assimilation for a data sparse area
  - added focus on remote sensing
  - focus on surface process; MESCAN
- LBC with ERA5 analysis and ERA5-EDA in error statistics
- Enhanced PGD database (orography, glacier mask, albedo, LAI, soil)
- Sea state input (High-res SST/ICE)
- Non-Lambert projection for Pan-arctic domain (rotated Mercator? Polar-stereographic?

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth European Commission

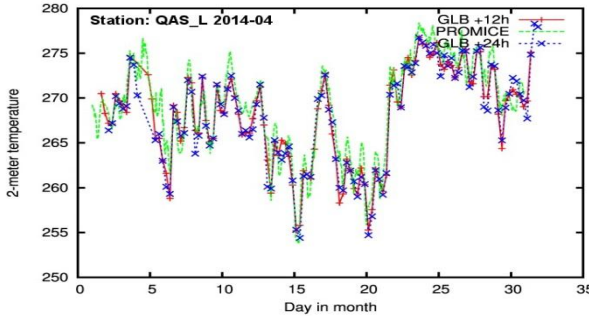
Danmarks Meteorologiske Institut

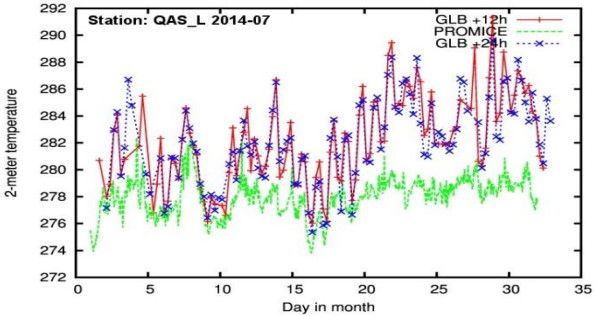
Need for model Improvement: what shall be target and approach

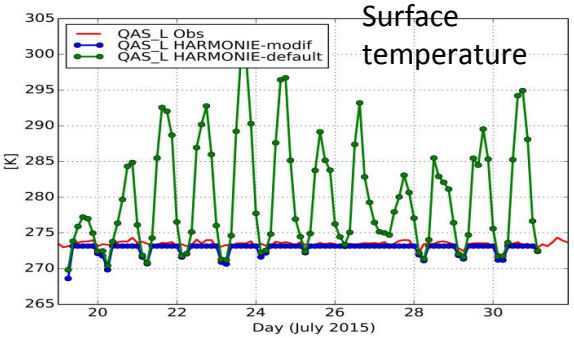
Glacier modelling

Veðurstofa Íslands

Currently no glacier land type in HARMONIE so when the snow melts we have seen large drift in HARMONIE output, for example HARMONIE T2m compared to the QAS_L AWS (PROMICE) on the Greenland ice sheet







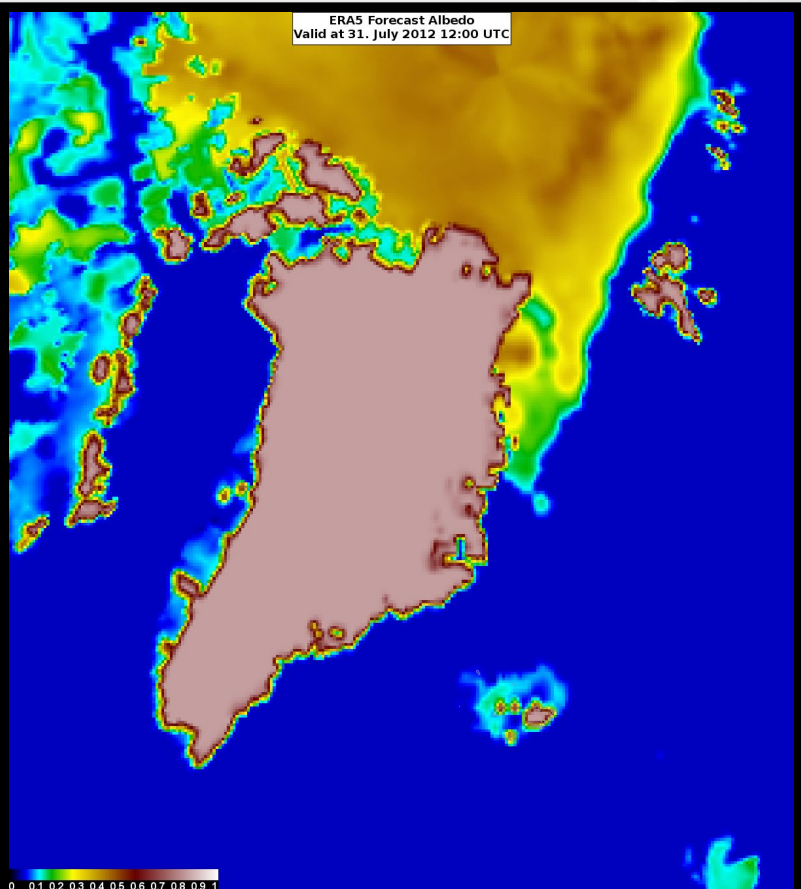
(Ruth Mottram, Emily Gleeson@MetEireann, Kristian P Nielsen)

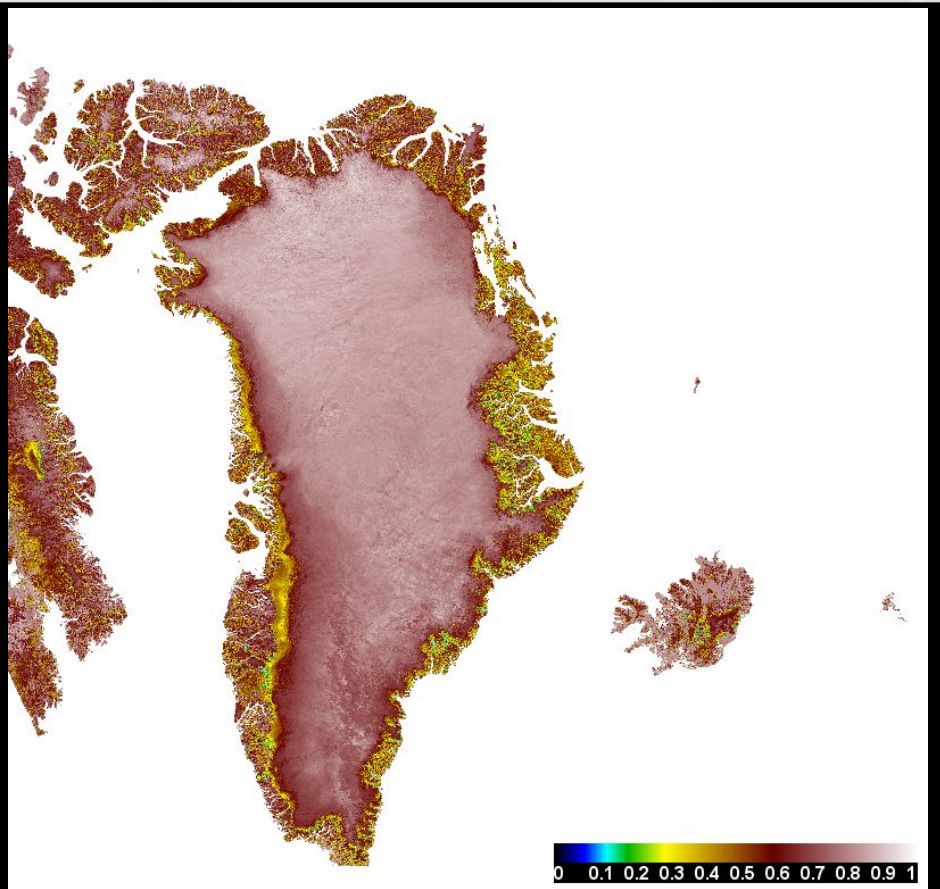
As remedy, test has been done to prevent surface (skin) temperature rising above 0°C when glacier ice is exposed, and the energy is then used to melt glacier ice.

Albedo issue. In winter, glaciers are bright white and covered in snow, when bare ice is exposed in summer the surface is highly variable. This poses some challenges. E.g., issues with albedo in western Greenland in Summer.

Albedo comparison

Figures by Bolli Palmason (IMO)



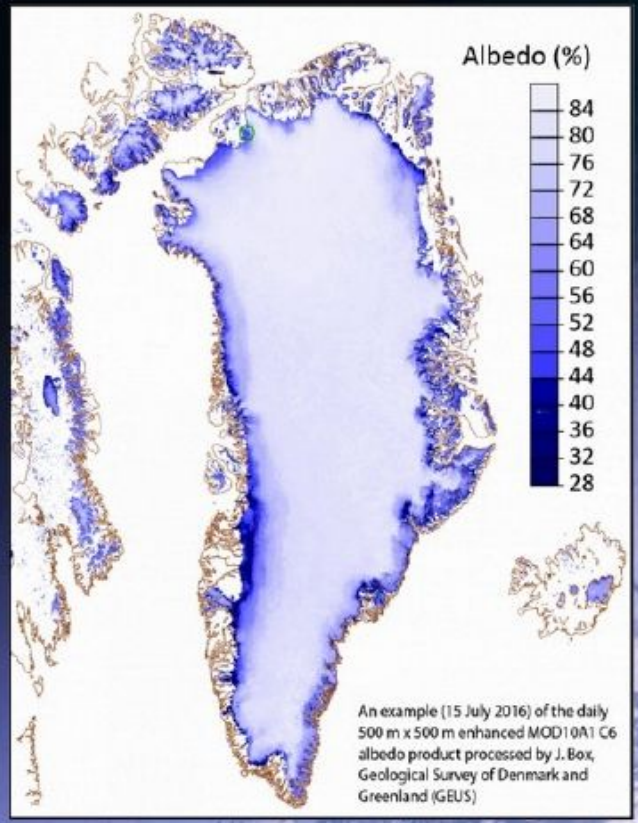


Climate Change

Albedo datasets for arctic glacier

data source: MODIS

- MOD10A1 C6 product
- timespan
  - 2000-2017
- temporal resolution
  - daily
- native resolution
  - 500 m



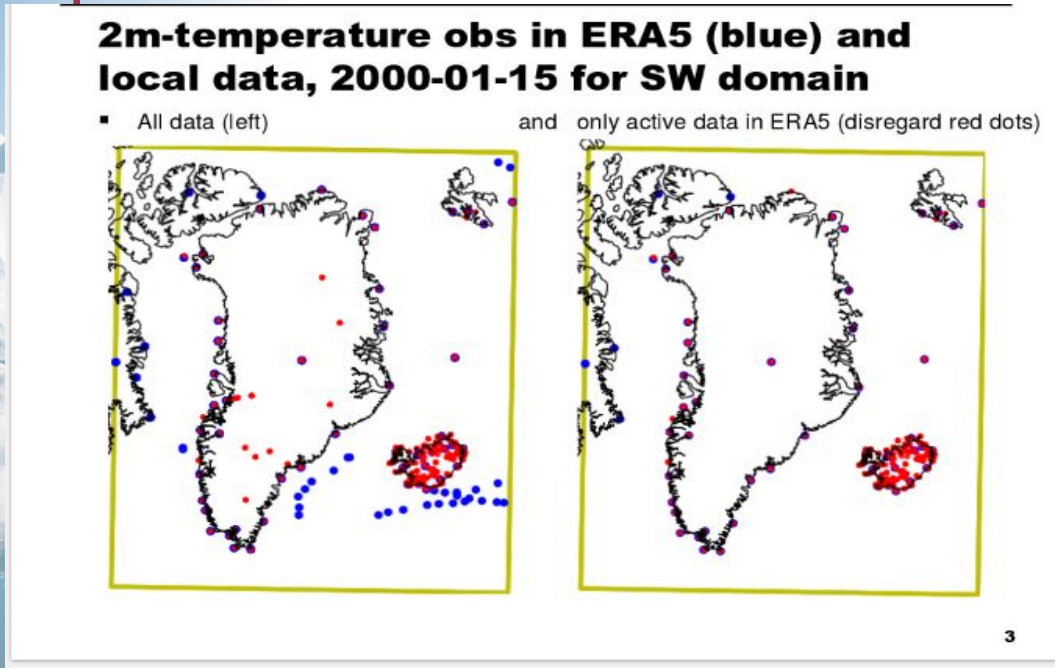
Box, J.E., D. van As, K. Steffen, 2017. **Greenland, Canadian and Icelandic land ice albedo grids (2000-2016)**, Geological Survey of Denmark and Greenland Bulletin, 38, 53-56. link

Box, J. E., X. Fettweis, J.C. Stroeve, M. Tedesco, D.K. Hall, and K. Steffen. 2012. **Greenland ice sheet albedo feedback: thermodynamics and atmospheric drivers**, The Cryosphere, 6, 821-839. doi:10.5194/tc-6-821-2012

(Courtesy K P Nielsen)

Climate Change

Arctic area is extremely data sparse. Efforts to use more obs



- Very limited stations, especially few about moist parameters. no snow depth obs over Greenland
- Mostly coastal stations
- Significant portion of obs not sent to GTS
- Collect and use more surface data
  - Iceland, Greenland SYNOP
  - snow depth data form non-GTS
  - use better quality checked data
- Use more satellite data
  - Radiance, RO, AMV, Scatterometer

ECMWF Copernicus Europe's eyes on Earth European Commission

The evolving observing system

Satellite	Duration	Instruments to use
NOAA-09	12 Dec 1984 – 31 Dec 1997	MSU
NOAA-10	17 Sep 1986 – 31 Dec 1997	MSU
NOAA-11	**24 Sep 1988 – 30 Sep 2004**	**MSU**
NOAA-14	**30 Dec 1994 – 31 Dec 2005**	**MSU**
NOAA-15	**01 May 1998 – Dec 2016**	**AMSU-A/B**
NOAA-16	**21 Sep 2000 – 09 June 2014**	**AMSU-A/B**
NOAA-17	24 June 2002 – 10 Apr 2013	AMSU-B
NOAA-18	20 May 2005 –	AMSU-A/MHS
NOAA-19	6 Feb 2009 –	AMSU-A/MHS
NPP	28 Oct 2011 –	ATMS
Metop-A	19 Oct 2006 –	AMSU-A/MHS/IASI
Metop-B	17 Sep 2012 –	AMSU-A/MHS/IASI
Metop-A/B/C	19 Oct 2006 –	GRAS
COSMIC	2006 –	IGOR
Jason-CS/ Sentinel-6	Lauch: TBD	TriG
CHAMP	Sep 2001 - 2008	BlackJack
GRACE-A/B	2005 –	BlackJack
Retrieval observations		
EUMETSAT AMV – polar winds	1982 –	
QuikSCAT wind	20 June 1999 – 21 Nov 2009	
ERS1 wind	5 Aug 1991 – 2June 1996 (2001?)	
OSCAT wind	23 Sep 2009 – Feb 2014	
ASCAT wind	2007 –	

Courtesy: ECMWF

Climate Change

Current status
Evolution of CARRA System

- CARRA Alpha (Baseline) adapted from reference Harmonie-arome (~40h1.2)
  - Technically and meteorologically validated
- CARRA Beta currently in preparation (Sept 2018)
  - Build-up of a Harmonie re-analysis system infrastructure
    - input data stream, monitoring, output stream
    - individual components separately validated based on CARRA-alpha
  - Essential feature enhancement
    - value-added input data
    - Assimilation algorithm. Large scale constraint and time evolving structure function adapted to observation
    - improvement upon critical and known model deficiency
    - development of monitoring and verification setup
- Final CARRA re-analysis system (May 2019)
  - Many simultaneous developments to be checked!

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth

European Commission

Climate Change

System & Configuration

Lead Xiaohua Yang

- System configuration, testing
  (lead: Xiaohua Yang)
- Large scale constraint and background errors, uncertainty estimation
  (lead: Jelena Bojarova)
  - Jk vs LSMIX; time varying B
- Verification (lead: Morten Køltzow)
- Development of monitoring system for reanalysis production
- (Proof-of-concept) extended Pan-Arctic reanalysis
  - need for non-lambert projection

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Input & algorithm/handling

Lead Heiner Kørnich

- ECOCLIMAP II + soil update. (lead: Kristian P Nielsen)
  - DMI/IMO/MET collection
- Albedo over glacier and sea ice (lead: Kristian P Nielsen)
  - GEUS data over glacier; FMI data over sea ice
  - experiments about snow scheme (albedo, ...)
- SST and sea ice (lead Jacob Høyer)
  - Use of 5 km OSI-SAF SST re-analysis and 10 km SIC re-analysis
- Snow (lead: Mariken Homleid)
  - climate station data
  - assimilation issue: satellite data?
- SYNOP data (lead: Magnus Lindskog)
  - local data from Greenland, Iceland, Norway ...
- Remote sensing data and assimilation, (lead: Roger Randriamiapianina)
  - Microwave radiance data since 1997
  - RO data since 2006 (ROMSAF reprocessed); IASI data since 2006
  - AMV, Scatterometer data

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

CARRA developers during preparation phase (2017- 2019)

Core working group for the system development:

Xiaohua Yang (DMI)
Ole Vignes (MET)
Kristian Pagh Nielsen (DMI)
Patrick Le Moigne (M-F, surface part)
Eric Bazile (M-F, model physics)
Roger Randriamampianina (MET)
Roel Stappers (MET)
Mariken Homleid (MET)
Jelena Bojarova (SMHI)
Bolli Pálmason (IMO)
Sigurdur Thorsteinsson (IMO)
Laura Rontu (FMI)
Per Dahlgren (MET)
Susanne Hagelin (SMHI)

Group on local datasets:

Heiner Körnich (SMHI)
Mariken Homleid (MET)
Patrick Samuelsson/Esbjörn Olsson (SMHI)
Bjarne Amstrup (DMI)
Patrick Le Moigne (M-F)
Tryggvi Hjörvar (IMO)
Markku Kangas (FMI)
Jacob Høyer (DMI)
Mats Dahlbom (DMI)
Eivind Støylen (MET)
Morten A. Ødegaard Køltzow (MET)
Teresa Valkonen (MET)

(Updated from list by H Schyberg, Jan 2018)

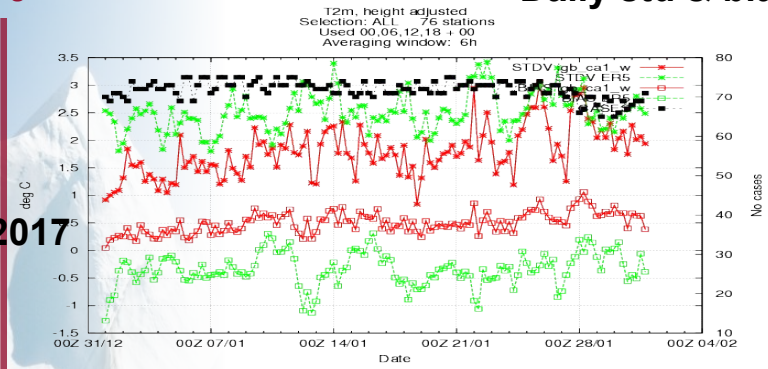
ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

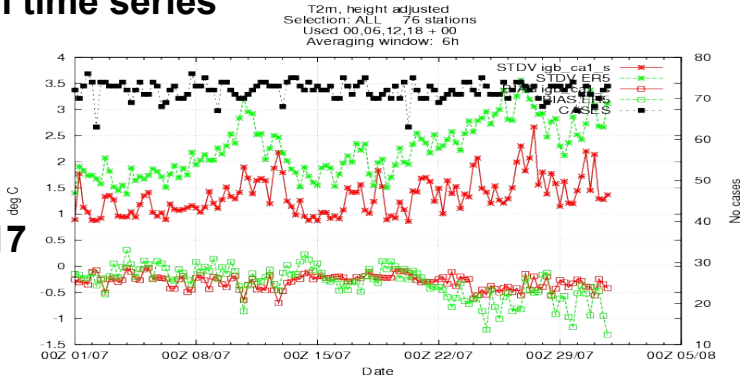
Quality Preview with for CARRA-SW, T2m

Daily std & bias of T2m time series

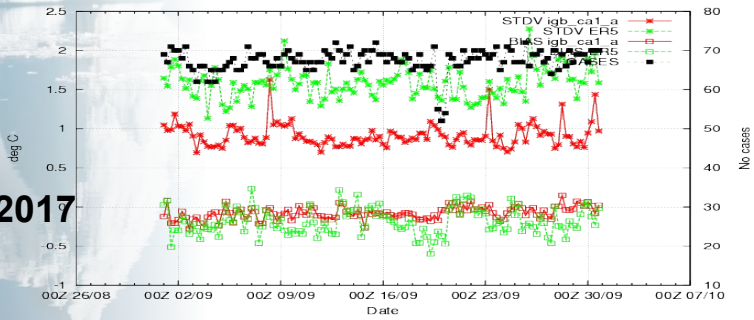
Jan 2017



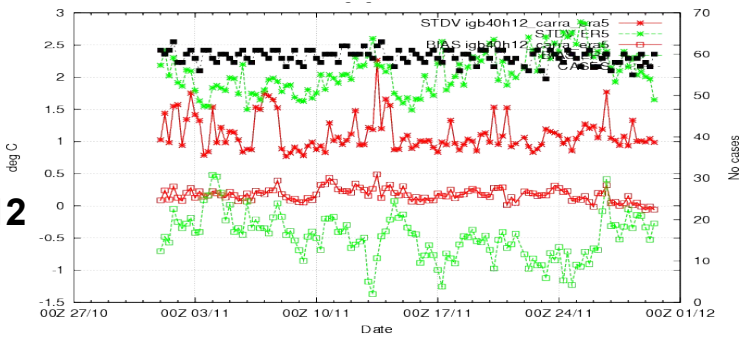
Jul 2017



Sep 2017



Nov 2012



CARRA-SW vs ERA5

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth

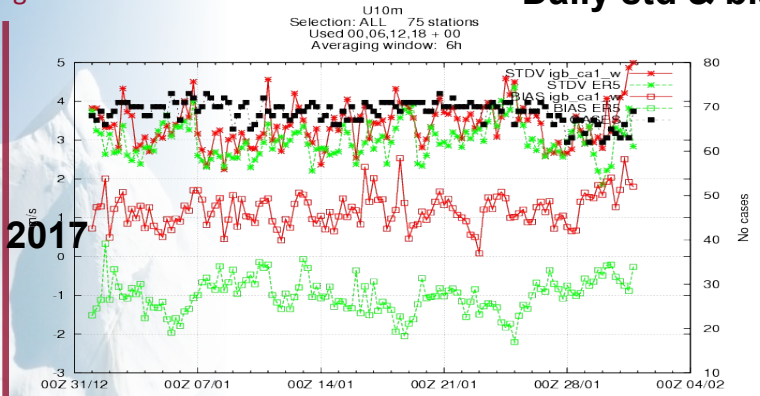
European Commission

Climate Change

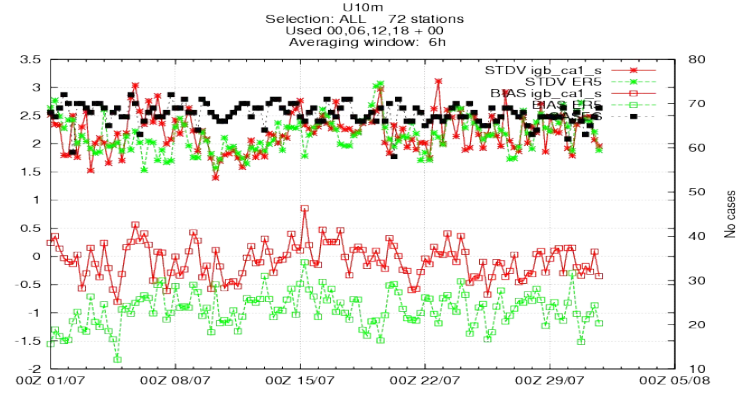
Quality Preview with CARRA-SW, W10m

Daily std & bias of W10m time series

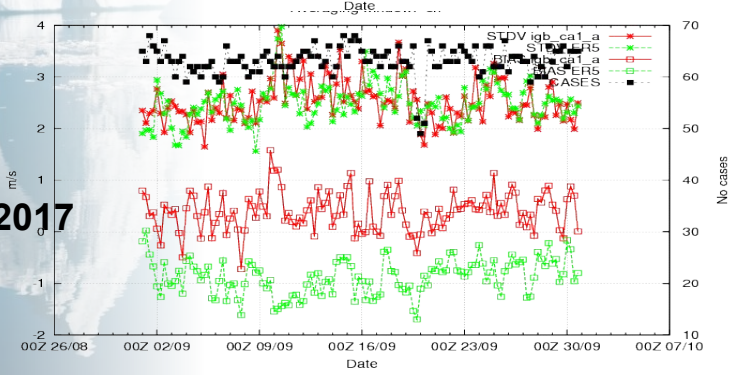
Jan 2017



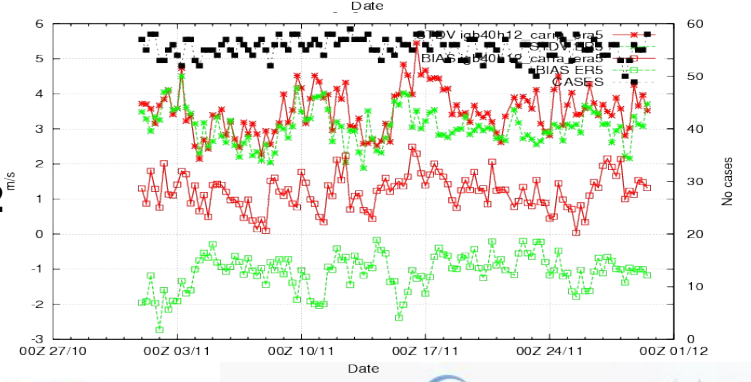
Jul 2017



Sep 2017



Nov 2012



CARRA-SW vs ERA5

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth

European Commission

Climate Change

Summary
CARRA re-analysis, an extention of Harmonie-arome system

Many exciting development & deviation & challenges!!

- Handling of snow and glacier (snow scheme & assimilation, albedo insertion over glacier and ice
- LBC with ERA5
- Use of non-Lambert projection (rotated mercator? polarstereographic)
- Enhanced PGD database (orography, ecoclimap II,soil)
  - Large scale constraint (Jk or LSMIX)
  - Time evolution of B
  - Uncertainty information
  - MESCAN
  - Enhanced local synoptic data, wider use of remote sensing
  - Sea state input (Highres SST/ICE)
  - postprocessing products especially for ECVs
  - Monitoring system for production on ECMWF
  - Verification for multi-year products

A multi-phase project. Analysis system will evolve with Harmonie-arome system

Danish Meteorological Institute

ECMWF Copernicus Europe's eyes on Earth European Commission

FIN

ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Work on B

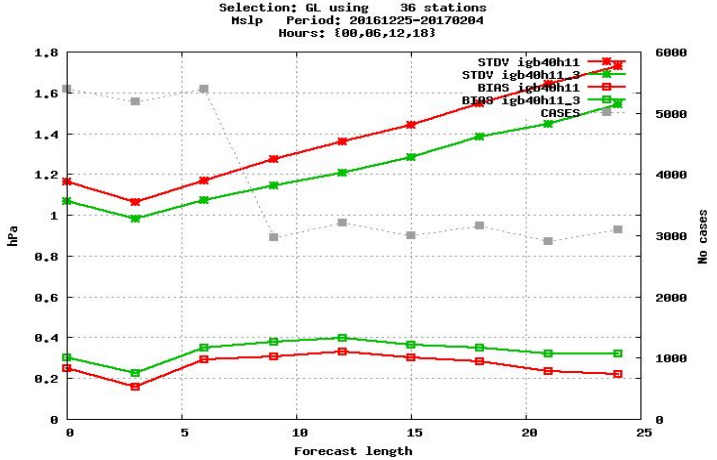
- Derive Jb statistics using ERA5 ensemble forecast.
- Test of BRAND approach
- Seasonal and diurnal structure function and their smooth transition
- Investigate impact of spin-up issues and agree on EPS forecast lead time (3h?,6h?,9h?)
- IAU

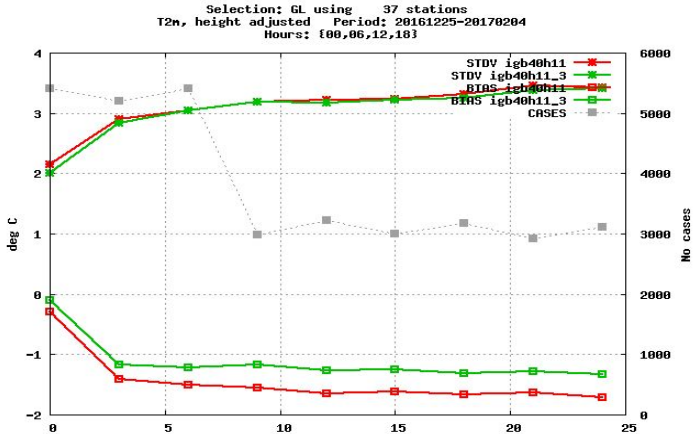
Climate Change

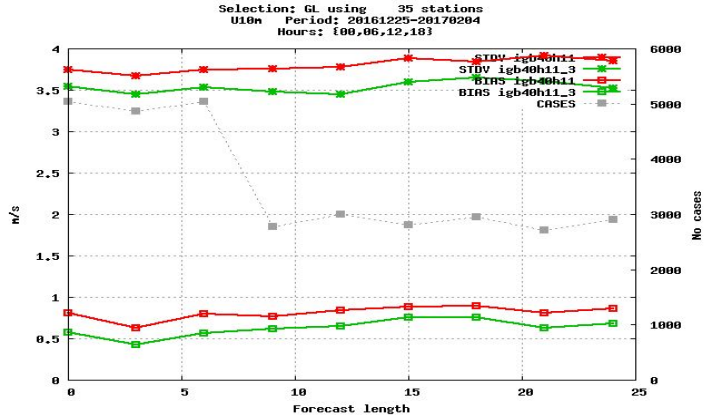
Estimate of uncertainty: some ideas

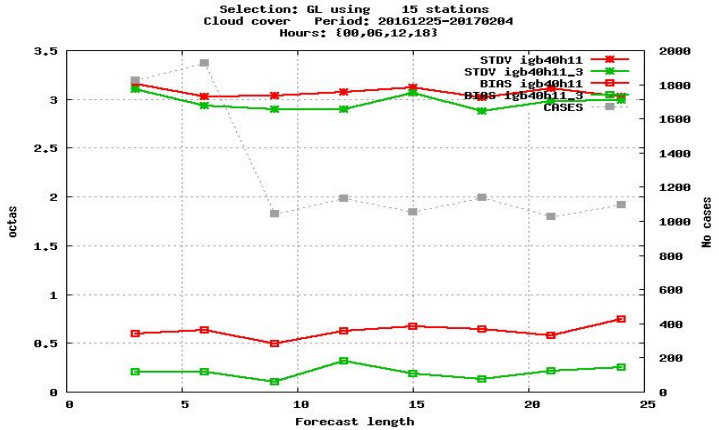
- Estimation of short range uncertainty from time sliced EDA
- Diagnosis from seasonal and diurnal variability as reflected in structure functions
- Indirect posterior diagnostics (ob-fg/ob-an) for estimation of uncertainty
- Extention of verification especially from spatial verification

Orographic data resolution and glacier mask correction









old oro database/glacier mask

new oro database/glacier mask

Greenland stations