Regional reanalysis

Harald Schyberg
Norwegian Meteorological Institute
harald.schyberg@met.no

… thanks to many colleagues in the CARRA and CERRA teams

Climate Change

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute

Climate Change

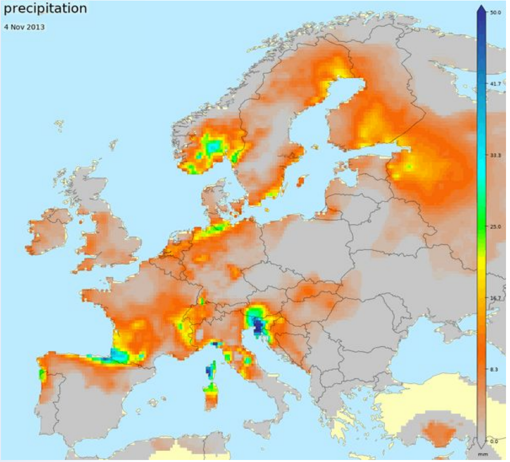
Outline - overview of reanalysis activities: Regional reanalysis

- Introduction
  - Regional gridded climate data: Geostatistics vs dynamical downscaling vs reanalysis
  - Overview of existing regional reanalysis systems
  - The experience from operational regional NWP
- Data assimilation schemes and host model forcing
- Challenges with adapting input data for regional reanalysis
  - Satellite observations
  - Conventional observations
  - Surface fields
- What value is added by regional reanalysis (examples vs global reanalysis)
  - Overall verification against independent observations
  - Case examples for high-impact weather
  - Climate statistics
- Final remarks

Regional climate grids: Gridding vs dynamical downscaling vs reanalysis

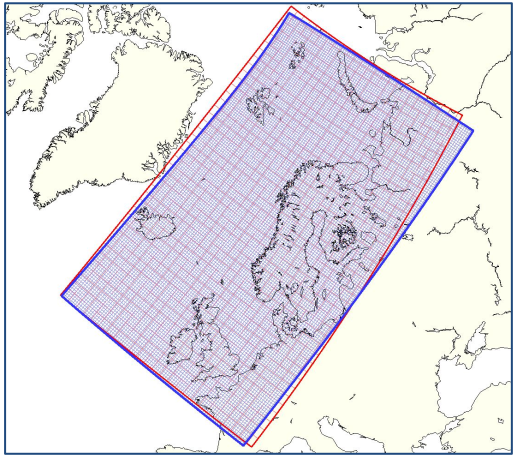
Climate Change

Example gridded observations: E-OBS



E-OBS: A grid providing a set of main observed surface variables at 0.1° x 0.1° and 0.25° x 0.25°, daily from 1950. Available in CDS.

Example regional downscaling: NORA3



NORA3: A 3km grid downscaling of ERA5 providing full NWP fields (using HARMONIE-AROME system) on 3 km grid, hourly from 1995. Available on https://thredds.met.no/thredds/projects/nora3.html .

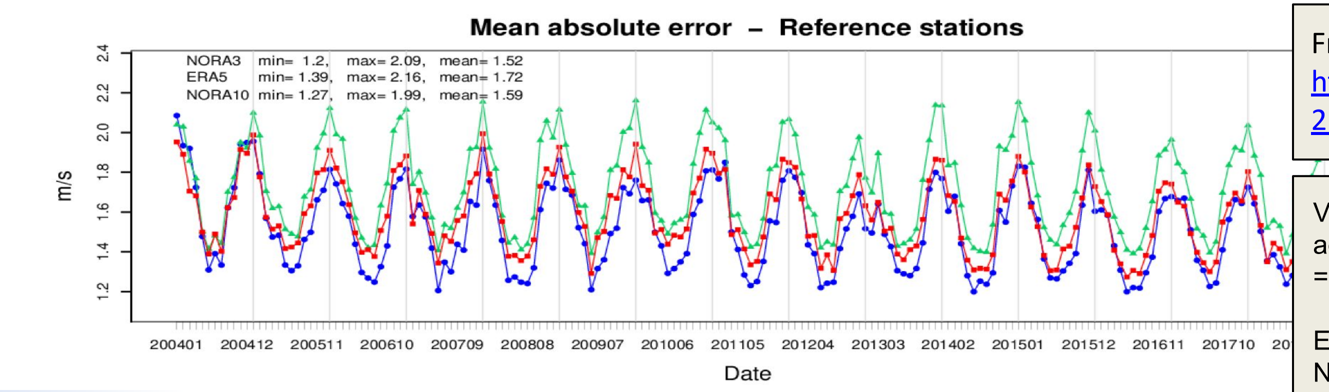
Gridding: Available where dense observation network only, often fit observations exactly

Dynamical downscaling (hindcast): Global reanalysis on lateral boundaries, no additional observation usage

Regional reanalysis: Downscaling of global reanalysis, with its own data assimilation cycling

Climate Change

Dynamical downscaling: Example added value by resolution



From Haakenstad et al, 2021, https://doi.org/10.1175/JAMC-D-21-0029.1

Verification of NORA3 wind speeds against observing stations with MAE $= 1/n \left(\sum | f_i - o_i | \right)$

ERA5 (green)
NORA10 (10 km downscaling, red)
NORA3 (blue)

- ➢ Downscaling ERA5 from ~32 km to 3 km already adds quality (no upper-air assimilation)

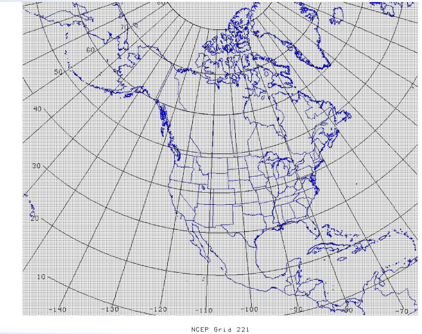
Regional reanalysis: Assimilation gives *additional* improvements

- ➢ But costs more: manpower effort in observation collection/preparation and computation resources in assimilation

Climate Change

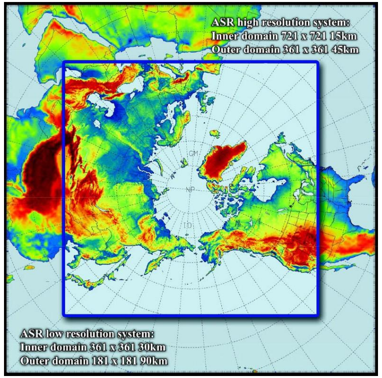
Regional reanalyses: Examples on several continents

NARR
(North American Regional Reanalysis)



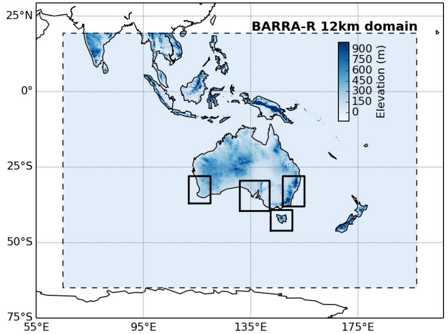
NCEP,
32 km, 1979-2014

ASR
(Arctic System Reanalysis)



Univ. Ohio,
45 (outer) /15 (inner) km,
15km dataset 2000-

BARRA
(Bureau's Atmospheric high-resolution Regional Reanalysis for Australia)

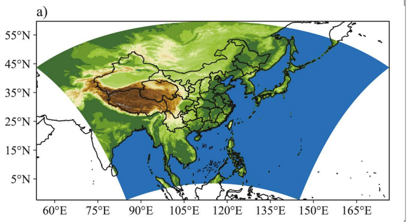


BoM,
12 km, 1990-2019
(+1.5 km sub-areas)

Climate Change

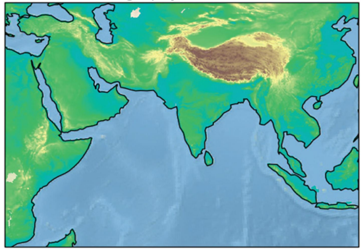
Regional reanalyses: Examples on several continents (II)

CNRR
(Chinese Regional Reanalysis)



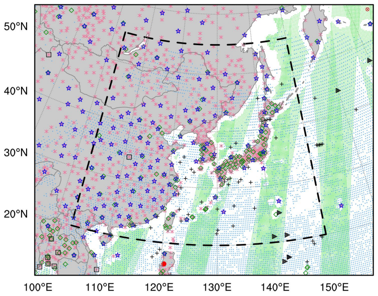
Nanjing Univ (WRF),
18 km, 1998–2009

IMDAA
(Indian Monsoon Data Assimilation and Analysis)



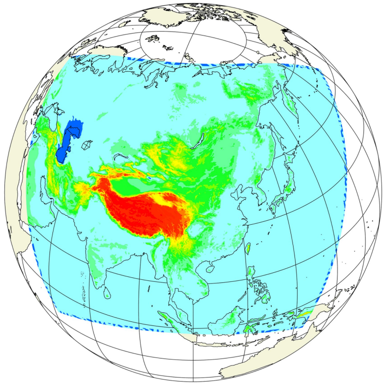
Met Office, NCMRWF, IMD,
12 km, 1979-2018

EARR
(East Asia Regional Reanalysis)



Yonsei Univ (WRF),
12 km, 2010–2019

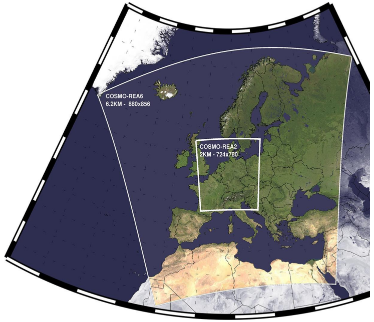
EARS
(East Asia Reanalysis System)



CMA (WRF),
12 km, 1980–2018

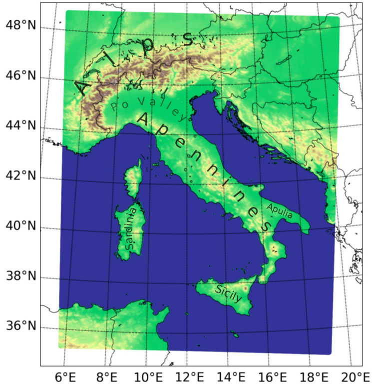
Regional reanalyses: Examples recent European production

COSMO-REA's



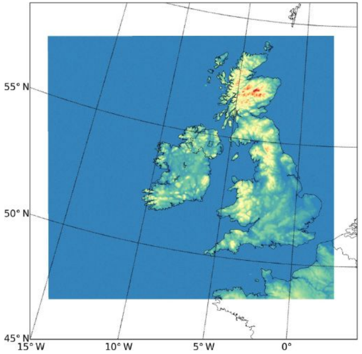
DWD/Universities:
COSMO-REA2 - Central Europe, 2km, 2007-2016
COSMO-REA6 - European continent 6 km, 1995-2019
COSMO-ENS-REA12 - European continent at 12km, 2006-2010.

SPHERA
(High Resolution REAnalysis over Italy)



Arpae-Emilia Romagna (COSMO),
2.2 km, 1995-2020

MÉRA
(Met Éireann Reanalysis)



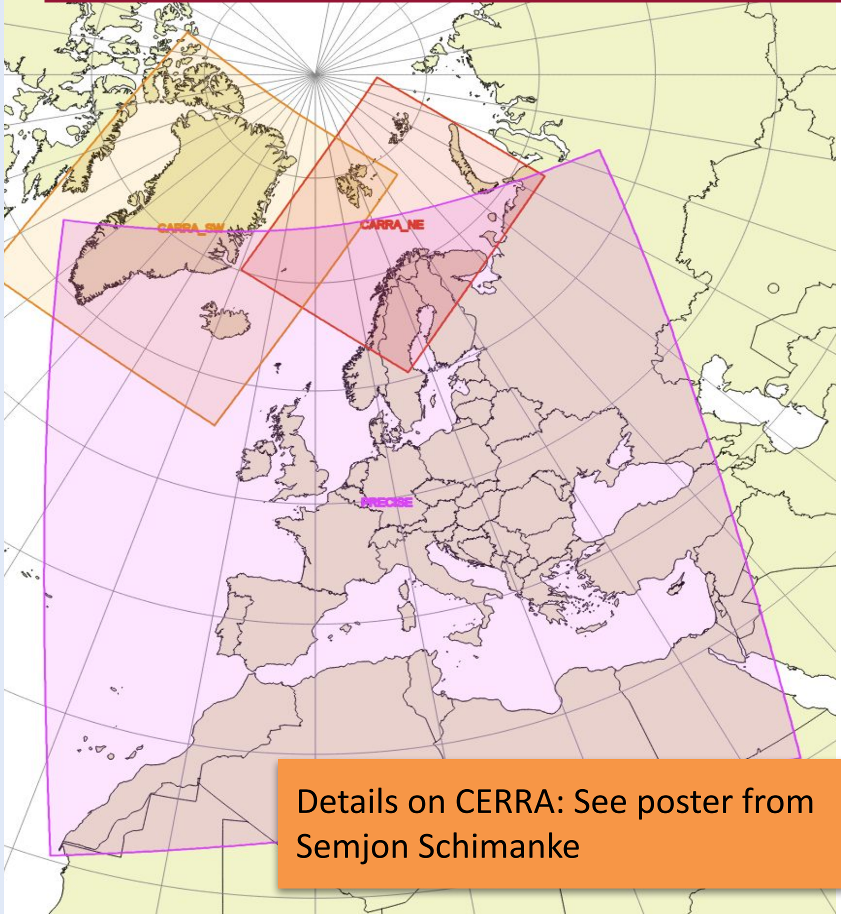
Met Éireann (HARMONIE–AROME),
2.5 km, 1981–2015

DANRA
(DANish ReAnalysis)

DMI (HARMONIE-AROME),
2.5 km, 1990-2020 under production

Climate Change

Copernicus Climate Change Service (C3S):
The Copernicus *Arctic* and *European* regional reanalyses: CARRA and CERRA



Implemented in Copernicus phase 1 (completed):

- CERRA: 5,5 km resolution, 1983-2021
  - Lead by SMHI
  - Legacy in Euro4M and UERRA European research projects
- CARRA: Two domains, 2.5 km horizontal resolution, available time period 1991-present
  - Lead by MET Norway

Updating of these systems in Copernicus phase 2:

- CERRA: Timely updating and back extension planned
- CARRA: regular (monthly) updating to present time ongoing

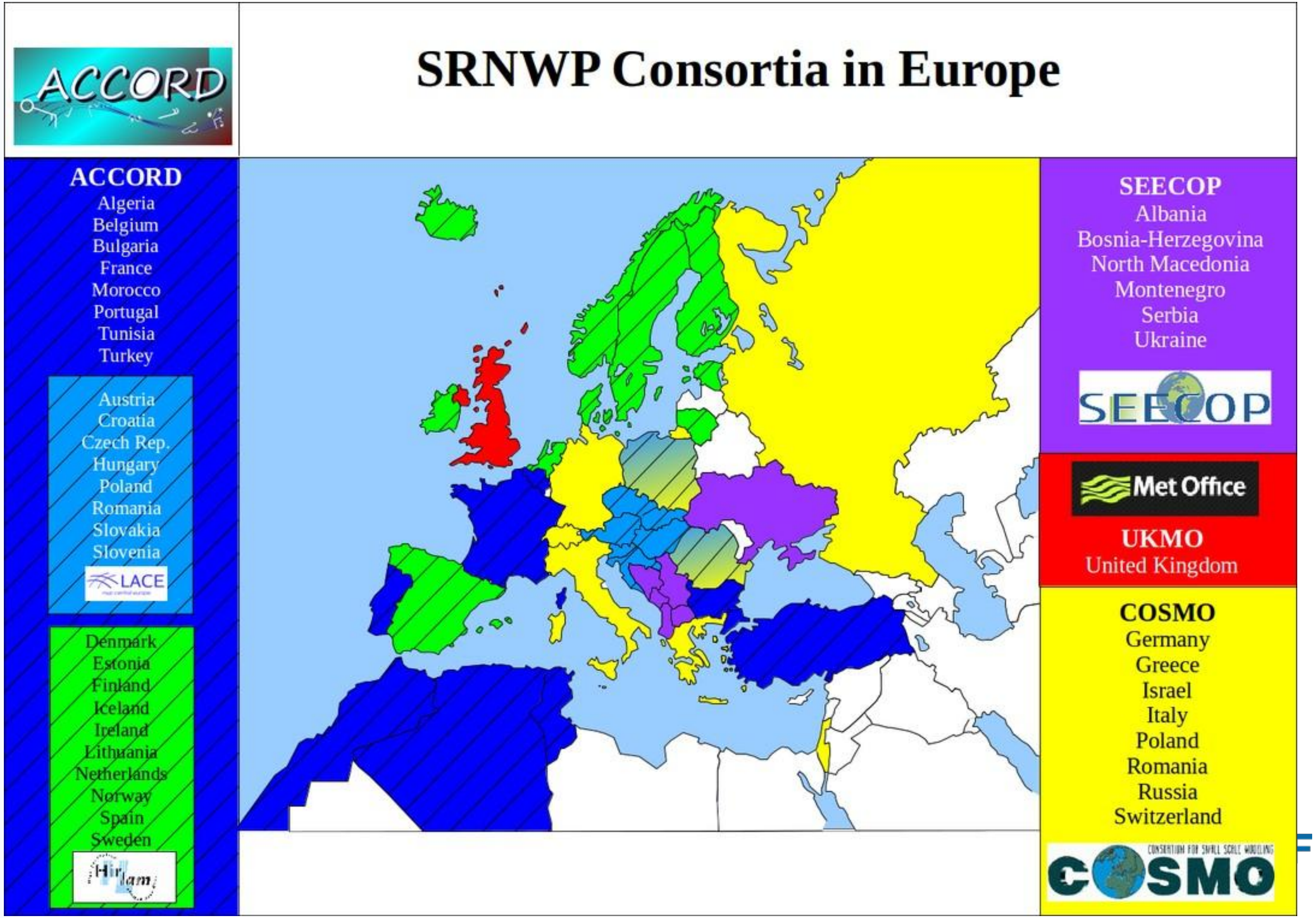
Norwegian Meteorological Institute   DMI   SMHI
METEO FRANCE   Icelandic Met Office   FMI

Details on CERRA: See poster from Semjon Schimanke

PROGRAMME OF THE EUROPEAN UNION   Copernicus Europe's eyes on Earth   IMPLEMENTED BY ECMWF   Norwegian Meteorological Institute

Climate Change

Regional reanalysis building on the experiences from operational regional NWP



Norwegian Meteorological Institute

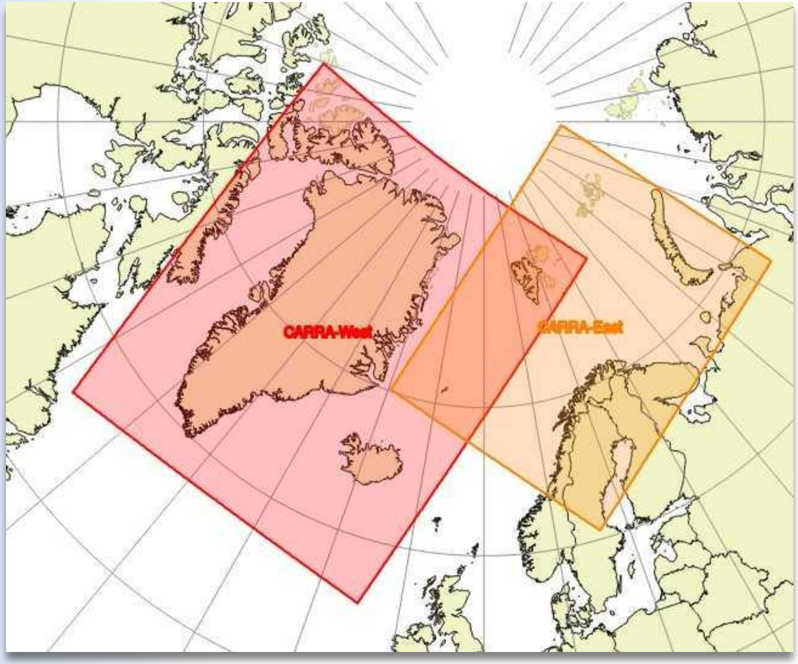
Climate Change

Experiences from regional operational NWP are also relevant for regional reanalysis

- ❖ Regional forecasting generally benefit from higher model resolution than global systems
- ❖ Observation impacts: Regional systems already benefit from assimilation in the global forecast model used as “host model”
  - ➢ More limited observation impact seen than in global systems (increasing with domain size, decreasing with forecast range)
- ❖ Operational forecasting NWP systems are are quality assured through their evolution and testing → **Strong benefit from reusing as far as possible.**

Climate Change

Copernicus Arctic Regional ReAnalysis - The CARRA system and data set



- Benefits from the experience from operational Arctic weather forecasting systems in Denmark (DMI) and Norway (MET Norway)
- Coverage in two domains, main areas of interest in the European sector of the Arctic
- Reanalysis using the HARMONIE-AROME NWP system v40h.1.1 , 2.5 km horizontal resolution
- Many extensions for reanalysis and Arctic application
- Non-hydrostatic, convection permitting model
- 3-hourly cycling with 3D-Var, hourly output
- Long forecasts (up to +30h) from 00 and 12

Data availability: Open and free in C3S Climate Data Store (CDS):

- 1991- end June 2023 now available, quasi-real-time monthly updating (within two months after end produced month)

PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF
Norwegian Meteorological Institute

Data assimilation and uncertainty estimation in CARRA and CERRA

Climate Change

CARRA employs a 3D-Var scheme:

$$J(\mathbf{x}) = \tfrac{1}{2}(\mathbf{x}-\mathbf{x}_b)^T \mathbf{B}^{-1} (\mathbf{x}-\mathbf{x}_b) + \tfrac{1}{2}(\mathbf{y}-H(\mathbf{x}))^T \mathbf{R}^{-1} (\mathbf{y}-H(\mathbf{x}))$$

Seasonal variation of B-matrix (same B for each year in reanalysis):

$$\mathbf{B}(day) = w(day)*\mathbf{B}_{winter} + (1-w(day))*\mathbf{B}_{summer}$$

B generated from downscaled ERA5 EDA ensembles over a few time periods. Two methods tested:

- **"BRAND" - perturbations of fields** (chosen)
- "EDA" - perturbation of observations

Surface assimilation: SURFEX + OI scheme (CANARI)

3-hours cycling frequency

CARRA uncertainty estimation:

- Based on the downscaled ensembles used for computing B matrix
- Scaled with observation departures, method by Bojarova et al

Gives climatological uncertainty (depending on variable, height and East/West domain)

Data assimilation in **CERRA** shares many elements with CARRA, but :

- uses CERRA-EDA: A 10 member ensemble data assimilation system with 11 km resolution
- CERRA-EDA runs a few days ahead of the deterministic system (5.5 km resolution) to be used for background error estimation

Forcing from host model (ERA5) in CARRA: Not only on lateral boundaries

Climate Change

The large-scale model (here ERA5) has some advantages in representing the large scale:

- More efficient use of satellite observations, for example due to a higher model top, use of more satellites, …
- more advanced data assimilation method
- lateral boundary schemes (flow relaxation) are non-perfect solutions

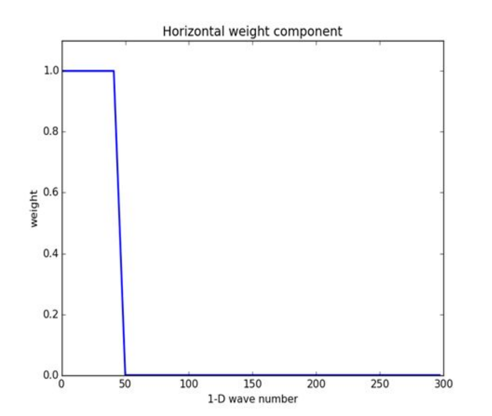
→ **Forcing from the global model is also used in inner domain**

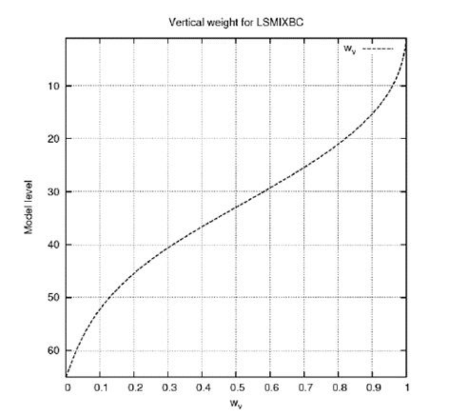
The "LSMIXBC" scheme

Scale dependent "blending" with the global model fields:

$$\widehat{X_b^{ls}}(m,n,lev) = w_{ls}\widehat{X_{ls}}(m,n,lev) + (1 - w_{ls})\widehat{X_b}(m,n,lev)$$

Weights depend on heigh and wave number:





Alternative method adding a **term J_k** (Guidard and Fischer, 2008) to the 3D-Var cost function was also implemented and tested:

- Allows going towards a statistically optimized weighting
- Promising results, also adjusts moisture
- Was not chosen due to limited long-term monitoring experience

BY ECMWF

Norwegian Meteorological Institute

Climate Change

Upper-air satellite observations in CERRA and CARRA

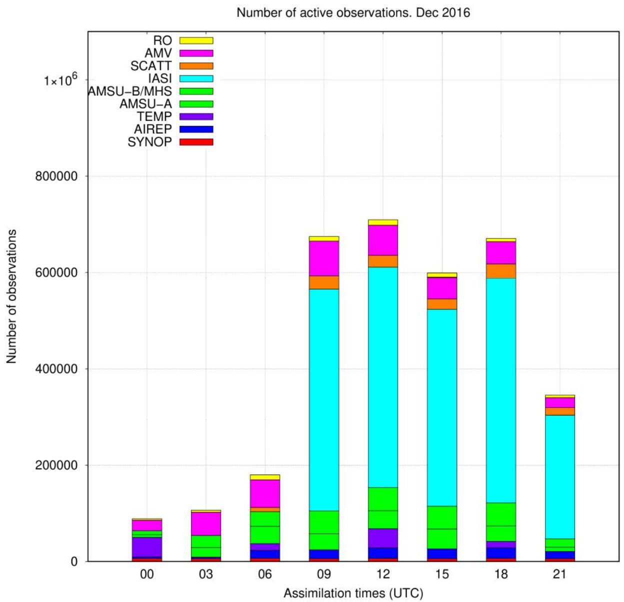
Benefits from historical blacklisting in ERA5 and the MARS archive

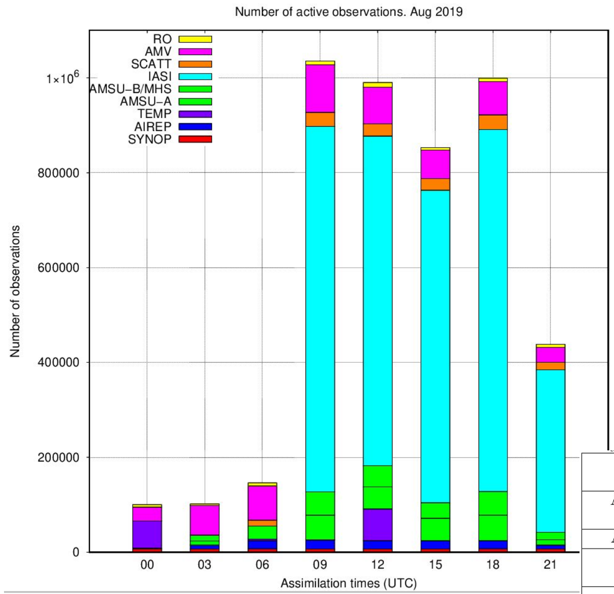
Satellite (based) Observations		
Instrument	**Satellites**	**Location / Origin**
Advanced Microwave Sounding Unit –A (AMSU-A)	NOAA – 15, 16, 18, 19 MetOp-A, B, C	MARS Archive, ECFS
Advanced Microwave Sounding Unit –B (AMSU-B) and Microwave Humidity Sensor (MHS)	NOAA – 16, 17, 18, 19 MetOp – A, B, C	MARS Archive, ECFS
Microwave Sounding Unit (MSU)	NOAA-6, 7, 8, 9, 10,11,12,14	MARS Archive
Infrared Atmospheric Sounding Interferometer (IASI)	MetOp – A, B,C	EUMETCast, Reprocessed, ECFS
Atmospheric Motion Vectors (AMV)	NOAA, MetOp – A, B,C, METEOSAT	MARS Archive
Scatterometer	NSCAT– ERS2, Seawinds – QuickSCAT, OceanSat2 - OceanSCAT, Metop - A, B, C – ASCAT	EUMETSAT Data Center
GPS Radio Occultation (GPS-RO)	Metop, COSMIC, CHAMP, GRACE	Reprocessed Climate Data Records
Ground - Based GNSS - ZTD (GPS-ZTD)	GPS and GLONASS	Reprocessed data

GPS-RO and GPS-ZTD used in CERRA only

Example: Observation usage, CARRA-East - variation in time

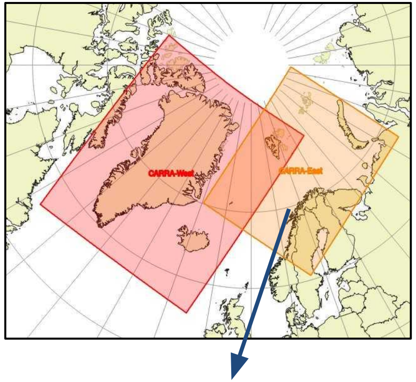
Climate Change





December 2016

August 2019



Instrument	Satellites, December 2016	Satellites, August 2019
ATOVS AMSU-A	NOAA-15,18,19 METOP-1,2	NOAA-15,18,19 METOP-1,2,3
ATOVS AMSU-B	NOAA-18	
ATOVS MHS	NOAA-19 METOP-1,2	NOAA-19 METOP-1,2,3
IASI	METOP-1,2	METOP-1,2
SCATT	METOP-1,2	METOP-1,2,3
AMV	NOAA-15,18,19 NPP AQUA METOP-2	NOAA-15,18,19 NPP AQUA METOP-1,2 Dual-METOP
RO	METOP-1,2 GRACE-A COSMIC-1,6	METOP-1,2,3

These and following figures from Per Dahlgren, ITSC-24/manuscript in prep.

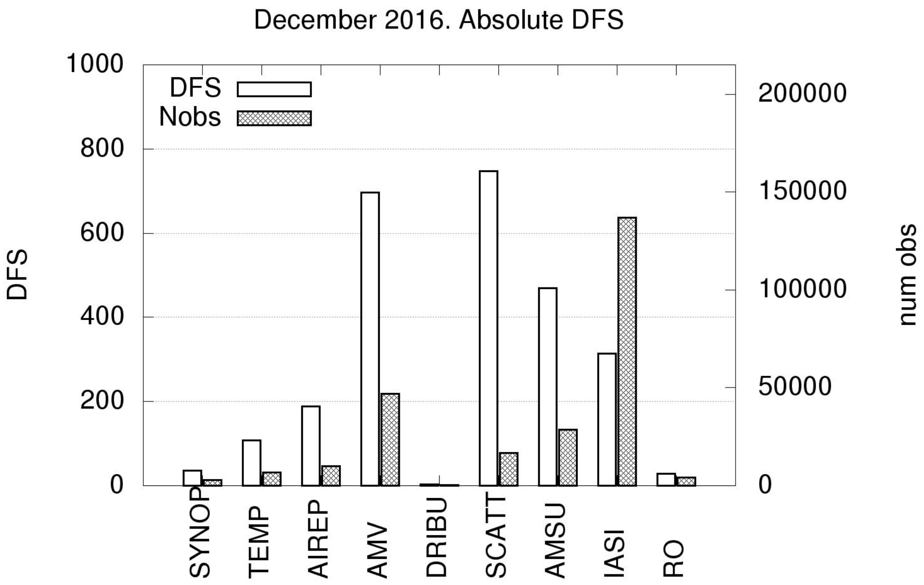
Observation impact on the analyzed atmospheric state - CARRA-East
Degrees of Freedom for Signal (DFS)

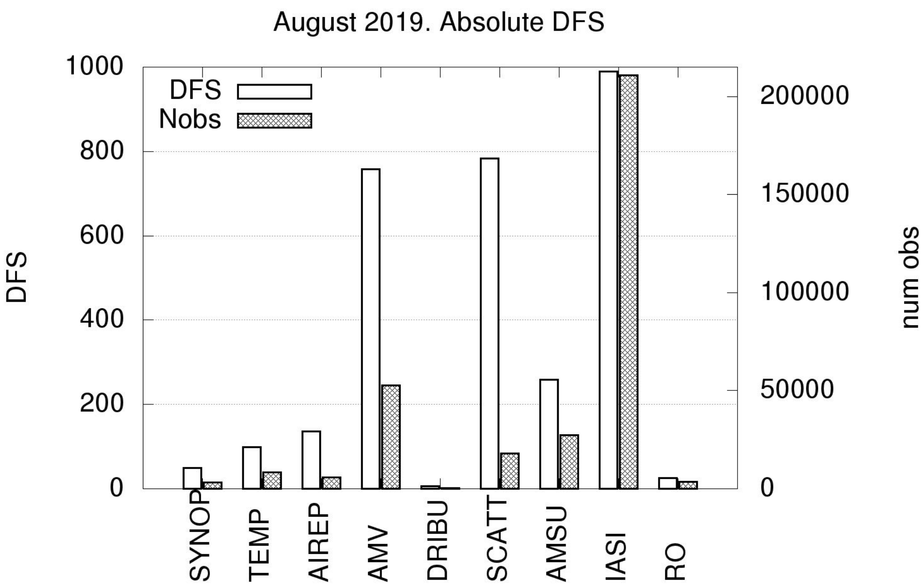
Climate Change

Radiances, and other satellite based observations, all have large influence on the analyzed atmospheric state

AMSU/MHS larger impact than IASI in winter

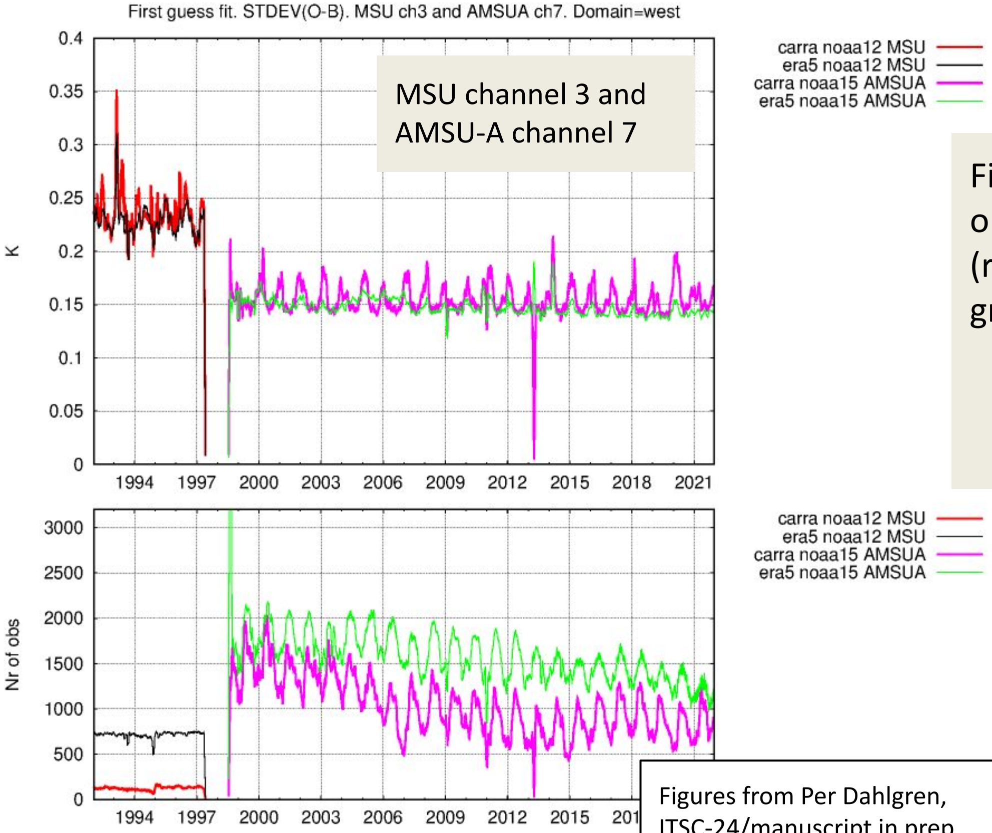
...and vice versa in summer





Climate Change

Upper-air satellite data for regional reanalysis: Example microwave brightness temperatures fit CARRA-East vs ERA5



First guess fit (top figures) and number of observations used (bottom figures) of ERA5 (red and magenta) and CARRA (black and green).

- ERA5 has a slightly better first guess fit and CARRA has a very large seasonal variation (top figure).

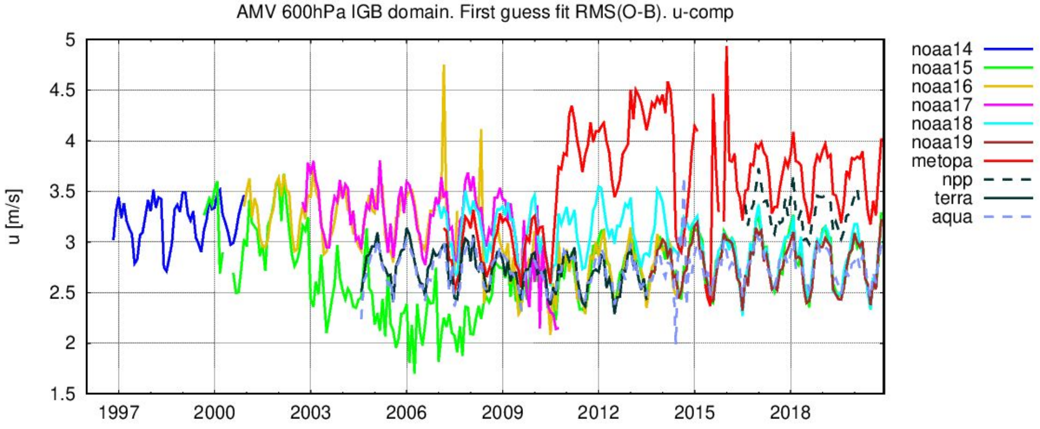
Figures from Per Dahlgren, ITSC-24/manuscript in prep.

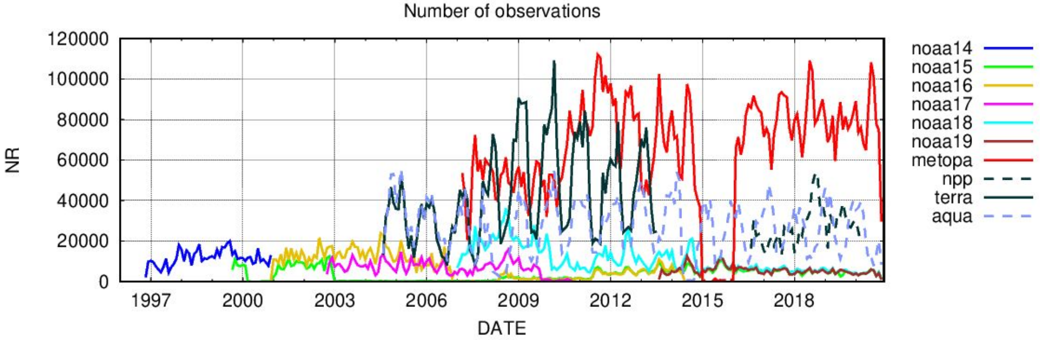
IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute

Climate Change

Atmospheric motion vector data for CARRA-West domain: Use of polar orbiting wind data





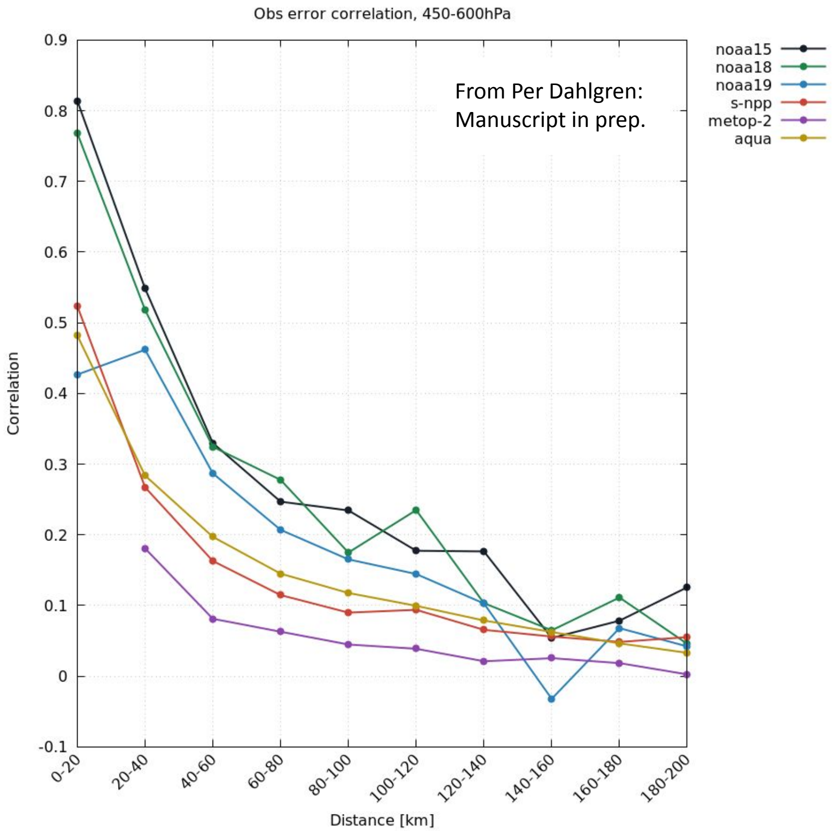
Statistics (monthly values) showing the AMV data actively assimilated in the CARRA-West domain.

Top: First guess departures for AMV u-wind component
Bottom: number of observations

Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF
Norwegian Meteorological Institute

Climate Change

Atmospheric motion vector data for CARRA: For high resolution horizontal error correlations are an issue



Applying Desroziers method: Estimated horizontal error correlations for various AMV products

Statistics from December 2015, CARRA-East domain

IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute

Climate Change

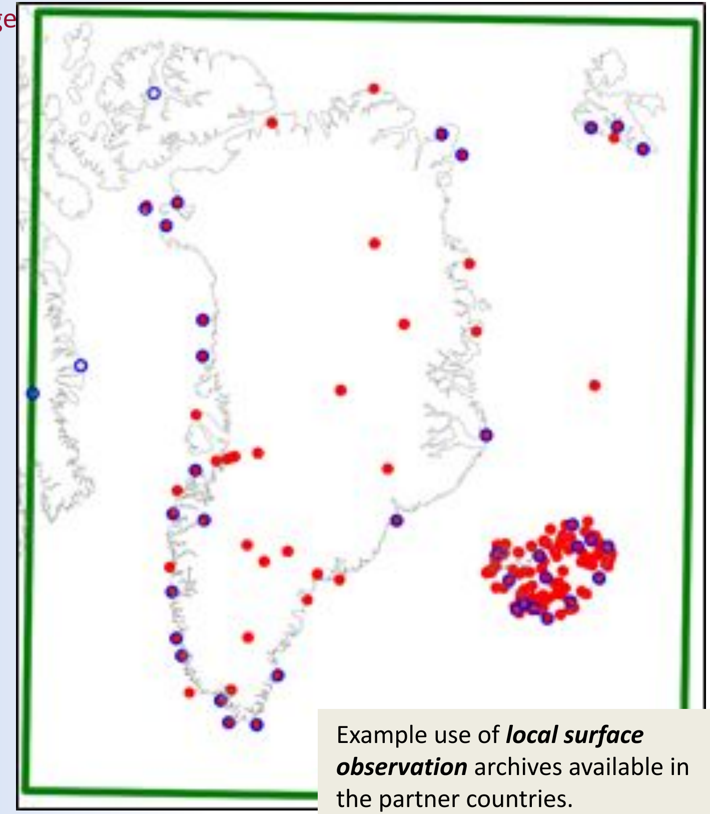
Upper-air satellite data for regional reanalysis: Challenges needing attention

- Satellite data important in conventional-observation-sparse areas (oceans, the Arctic)
- Upper air observations have smaller impact in limited-area domains, taking the forcing from host model into account
- Limited domains: Some hours have limited satellite coverage
  - Smaller data sets for variational bias correction
- Observation thinning distances/horizontal error correlations require consideration
- Observing system changes in time, increase in satellite data

- Optimizing the usage of all satellite obs. systems in regional reanalysis requires considerable effort

Conventional observations for regional reanalysis

Climate Change



Example use of ***local surface observation*** archives available in the partner countries.

Blue: Obs in ERA5

Red: Extra local obs in CARRA

High-density data more relevant in regional/high-resolution reanalysis.

In CARRA use of delayed-mode data sets not transmitted in real-time from weather services and measurement programmes

- *ASIAQ*, *GCNet* and *PROMICE:* Greenland automatic weather station programmes
- Delayed-mode quality controlled automatic surface observations from national weather centres and their partners

PROGRAMME OF THE EUROPEAN UNION · Copernicus Europe's eyes on Earth · IMPLEMENTED BY ECMWF · Norwegian Meteorological Institute

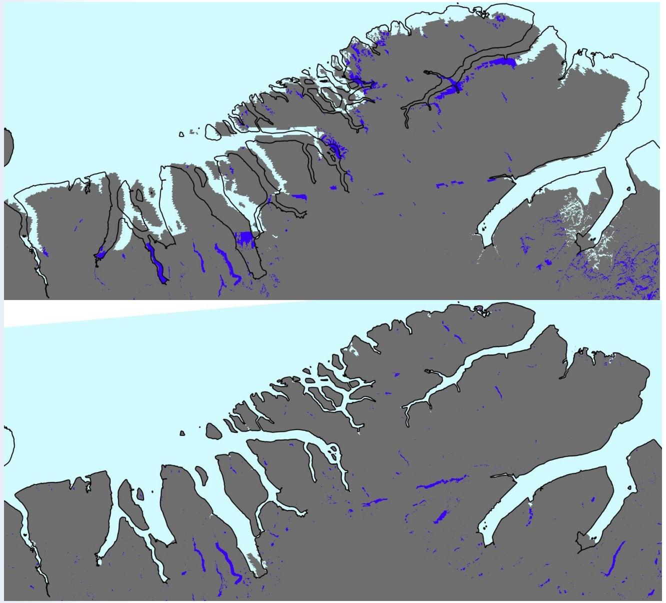
Climate Change

Conventional observations for regional reanalysis (2)

- Benefit from historical non-real-time, well quality-controlled automatic weather station data
  - Allows describing small scales better and filling gaps
- Potential for benefitting further from data rescue efforts
- Issue with quasi-real time timely updating: Need to wait for delivery and quality control (often more than 1 month, but will evolve?)

Climate Change

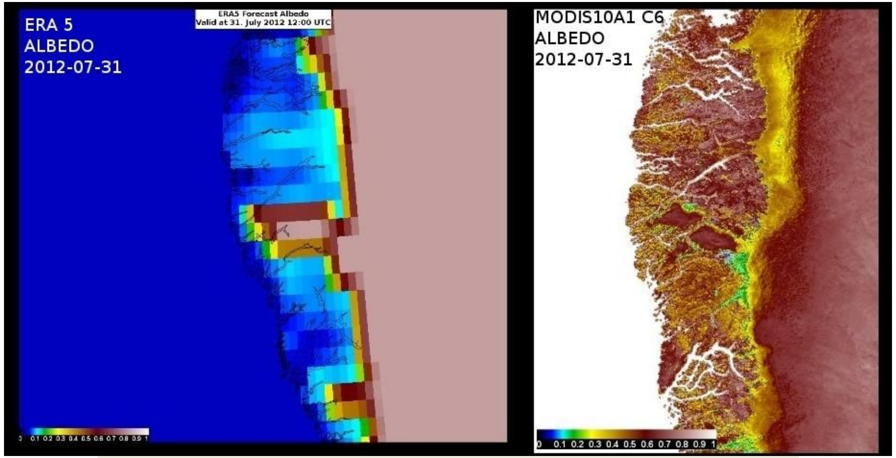
Attention to surface representation: Examples



North Greenland physiography:

Upper: Uncorrected Ecoclimap physiography

Lower: Corrected physiography using sat. data.



West Greenland albedo representation:

Left: ERA5 glacier albedo

Right: Albedo derived from MODIS

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute

Climate Change

Surface representation: Sea ice concentration for CARRA

- ERA5 uses OSI SAF SIC (1979 -> NRT), based on coarse resolution SSMIS;
- For CARRA, we used higher resolution SIC, from AMSR-E and AMSR2:
  - AMSR-E (June 2002 - Oct 2011) and AMSR2 (July 2012 - 2019);
  - SSMIS (OSI SAF) in the Oct 2011 - July 2012 period.
- The AMSR-E + AMSR2 data came from ESA CCI (until May 2017) and a special extension was processed at MET Norway for CARRA.

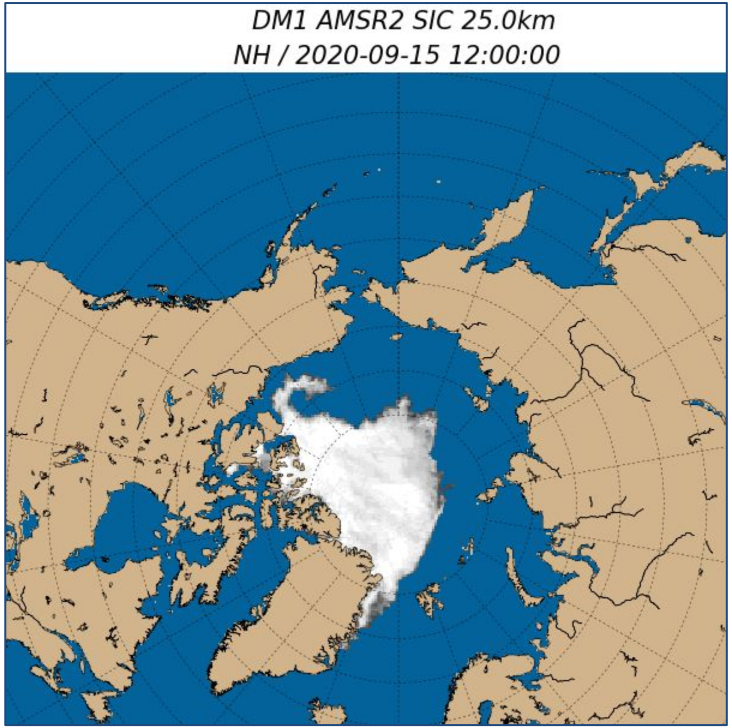


Figure: Higher resolution from AMSR2 (used in CARRA) than from SSMIS (used in ERA5).

CARRA Sea Surface Temperature and Sea Ice Concentration input grids

Climate Change

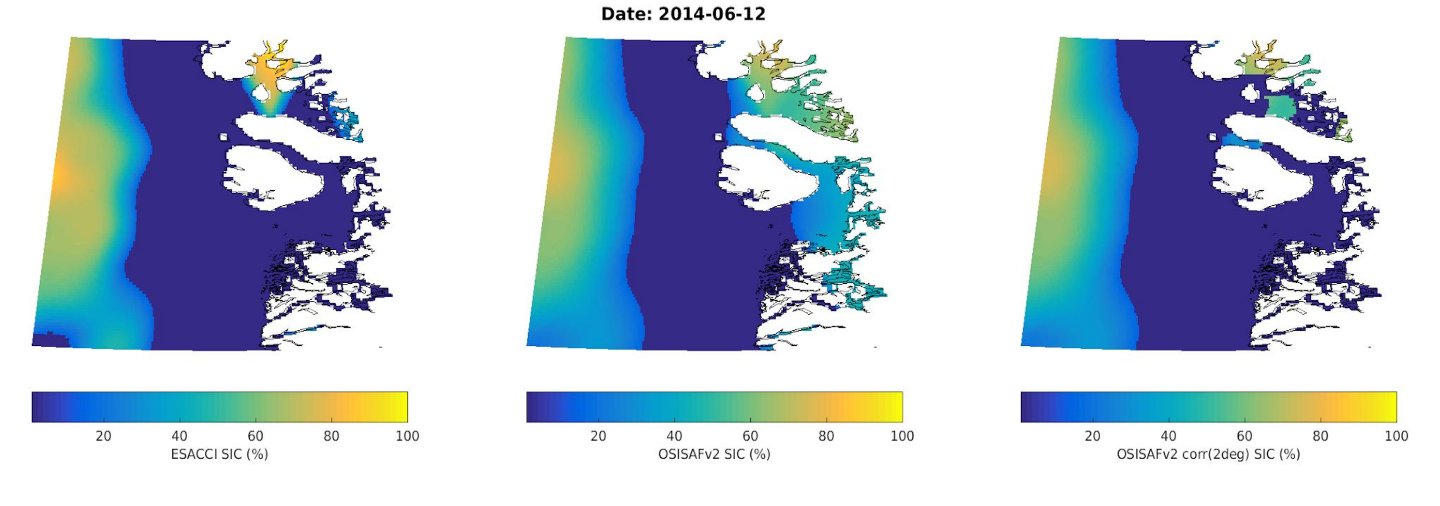
Existing products adjusted for consistency and regridded to grid.

Sea ice:

- ESA CCI 25 km product (2002-11, 2012-20, **AMSR** based)
- OSISAF 25 km product (1979–2015, **SSMI+SSMI/S** based) used when AMSR not available (coarser)
- Baltic sea 3km (BAL_REP) and 2km (BAL_NRT) analysis charts from national ice services

SST:

- ESA CCI SST 5 km (1991-2010, **IR**, many satellites)
- OSTIA 5 km (2007-, many satellites+in-situ obs) used after 2010.
- Baltic sea 3km (BAL_REP) and 3km (BAL_NRT) analysis charts



Left: Example adjustment of OSISAF Sea Ice Concentration data for consistency with ESA CCI (West Greenland Coast)

ECMWF

Norwegian Meteorological Institute

Climate Change

Snow input for higher resolution


NR Norsk Regnesentral NORWEGIAN COMPUTING CENTER

Meteorologisk institutt

Note

Advancement of global snow mapping in CryoClim

Sentinel4CryoClim Phase 1, Deliverables 1-6

Note no.	SAMBA/10/17
Authors	Rune Solberg, Øystein Rudjord, Arnt-Børre Salberg (NR) Mari Anne Killie, Steinar Eastwood, Lars-Anders Breivik (MET)
Date	28 March 2017

CryoClim 1982-

- Global, optical snow product, CryoClim 1982 -
- 5 km resolution
- based on historical optical and infrared AVHRR data (A2 FCDR, will update to use more recent reprocessed input)
- Bayes approach, extensive, manual collection of training data
- near-real-time production set up

(Suitable off-the-shelf products at high resolution were not available)

PROGRAMME OF THE EUROPEAN UNION · Copernicus Europe's eyes on Earth · IMPLEMENTED BY ECMWF · Norwegian Meteorological Institute

Climate Change

Remarks - surface fields for regional reanalysis

Benefit from higher-resolution surface descriptions than some of those used for global reanalysis and some “off-the-shelf” products

- Sea ice maps, sea surface temperature
- Snow mapping
- Surface albedo maps
- Physiography corrections for high resolution

Issues:

- Quasi-real time updating: Some good climate consistent high-resolution products not timely updated

Climate Change

Improvements of regional NWP simulations from horizontal resolution?

- More detailed structures in free atmospheric circulations, but small scales are not necessarily predictable and well represented

  (Climatology could be right, but the cloud or shower could be at the wrong place at a given time)

- Forced structures: More details of the surface/physiography forcing can be represented with higher horizontal resolution.

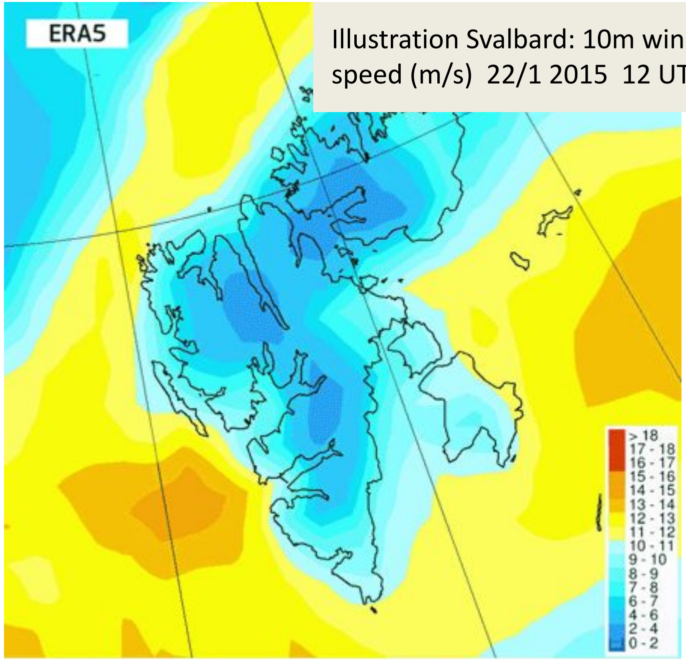
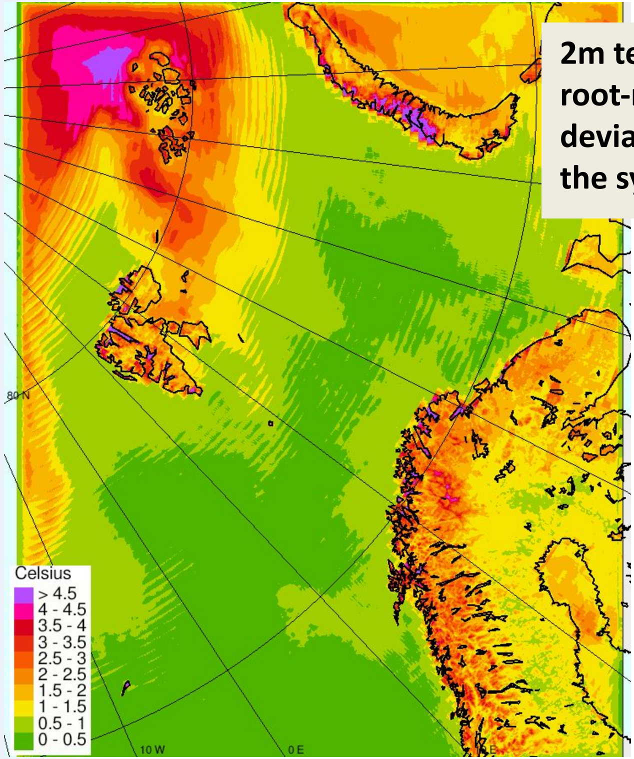


Illustration Svalbard: 10m wind speed (m/s) 22/1 2015 12 UTC

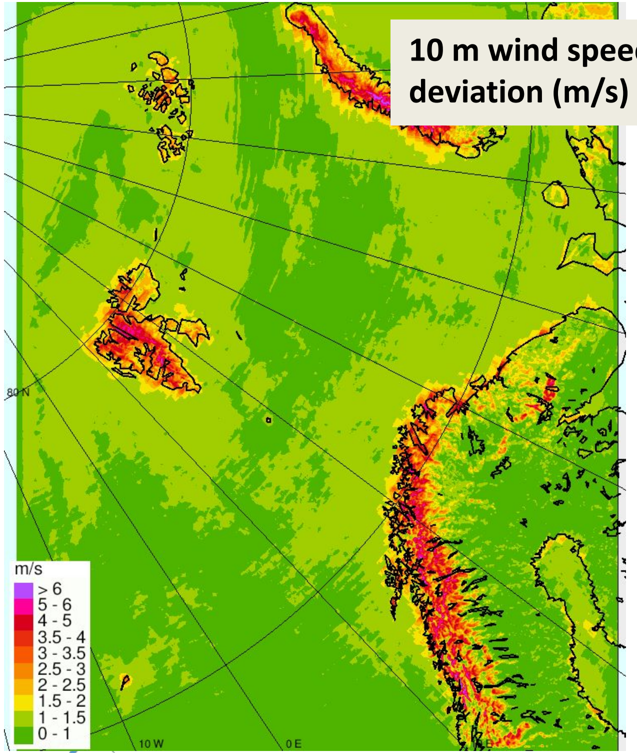
Climate Change

Example overall differences: CARRA-East vs ERA5 for February-March 2018

2m temperature root-mean-square deviations between the systems (^{0}C)



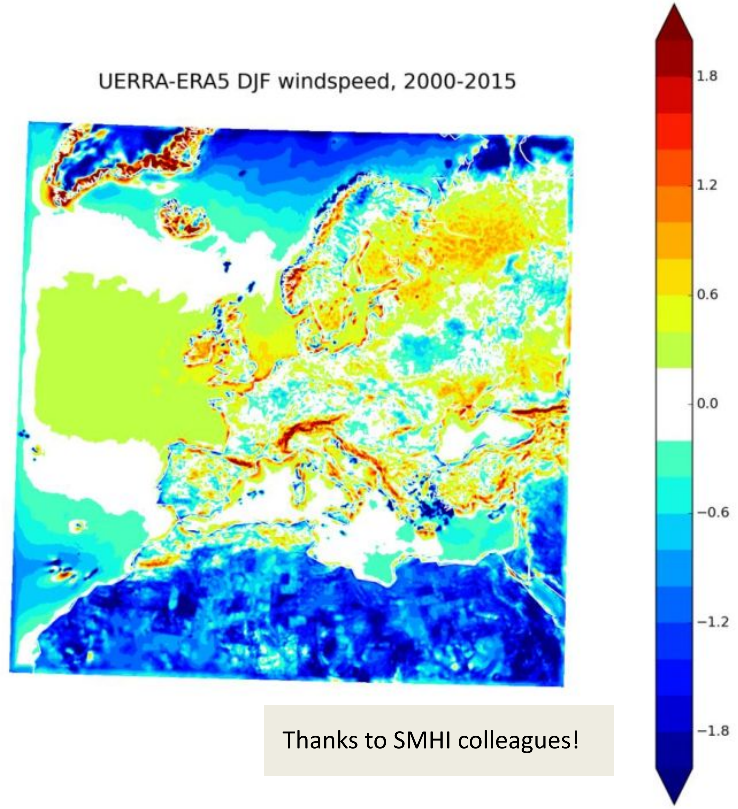
10 m wind speed RMS deviation (m/s)



PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
ECMWF
Norwegian Meteorological Institute

Climate Change

Example: biases in wind speeds in regional reanalysis vs ERA5

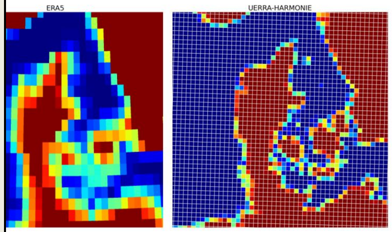


Thanks to SMHI colleagues!

Example from **UERRA reanalysis vs ERA5**

UERRA is an 11 km reanalysis, 1961-2019, using HARMONIE-ALARO NWP system, precursor to CERRA

- Mean wind differences in m/s
- Biases mainly < 1 m/s, much related to coastlines/topography



~31km 11km

Verification against 24 Swedish coastal stations

	UERRA	ERA5	ERA-int
Mean bias	-0.02	0.01	Not checked
Correlation	0.85	0.85	0.79
RMSE	1.83	1.97	2.36

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute

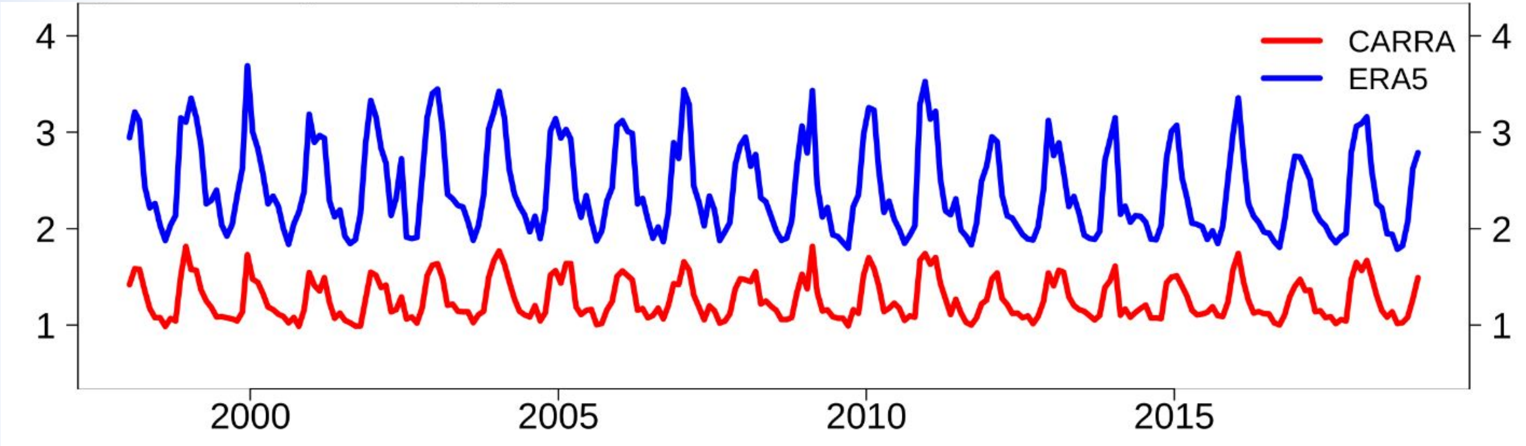
Added value vs global reanalysis: Example: CARRA

We see differences but:
Do we add value vs ERA5, if so how much?

- Overall verification statistics vs observations
- Capturing of extremes (example: polar lows)
- Local climate statistics
- Climate trends

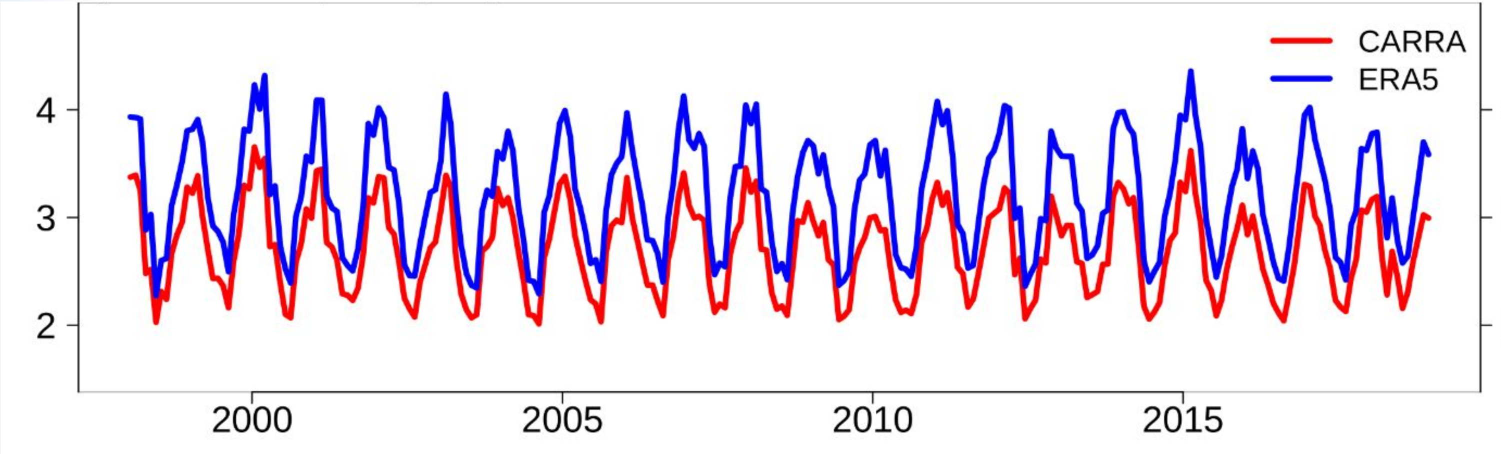
Some examples on following slides…

Verification examples of CARRA and ERA5: Temperature



2m temperature time series verification statistics for CARRA and ERA5.
Root mean square of errors (degr. C) both West and East domains.
Stations which made observations through the entire 1998-2018 period are included.

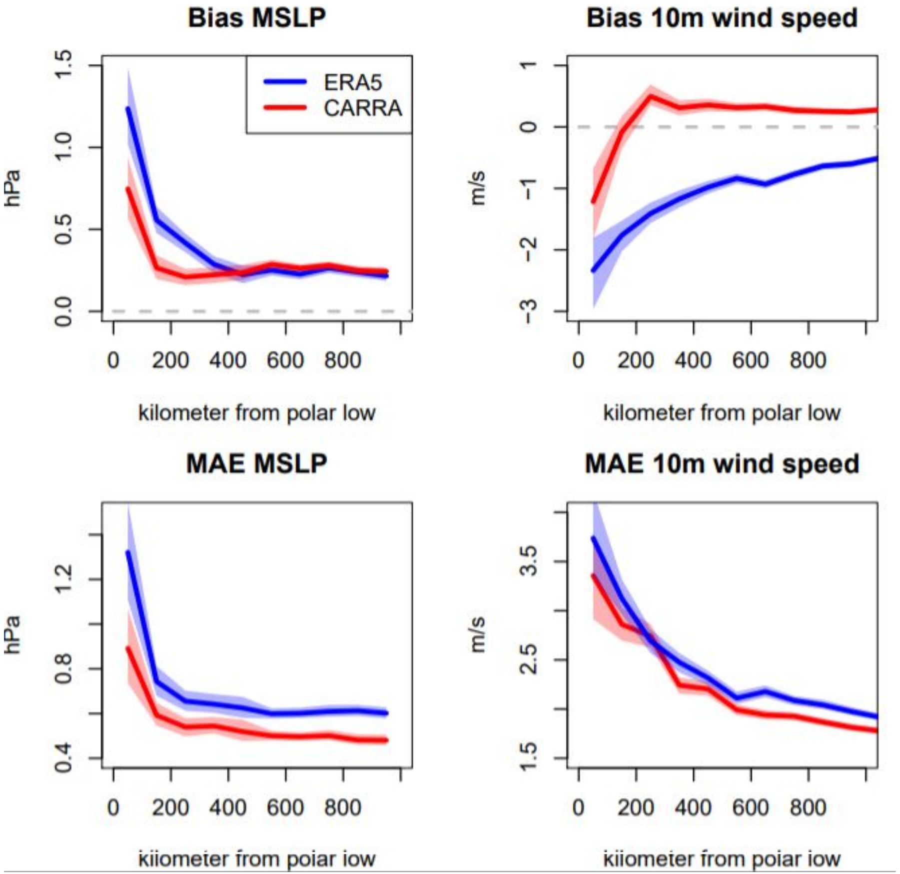
Verification examples of CARRA and ERA5: Wind

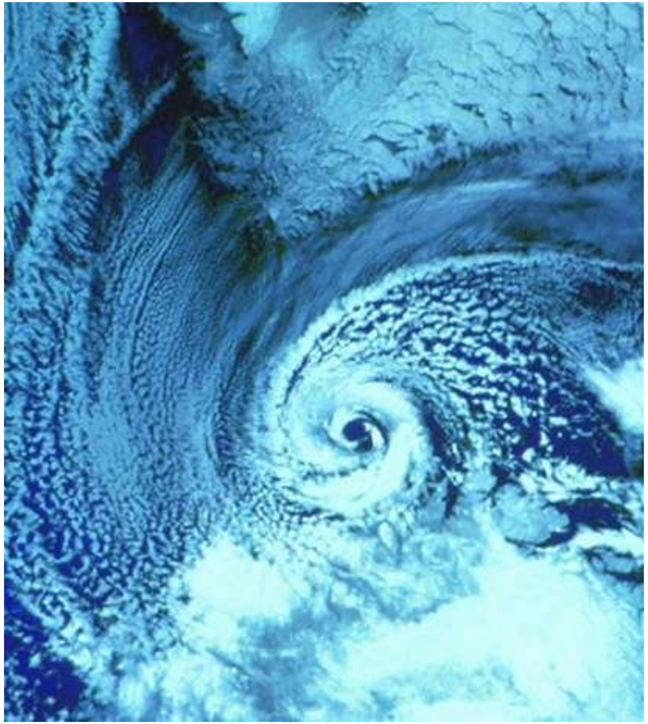


10m wind speed time series verification statistics for CARRA and ERA5.
Root mean square of errors (m/s) versus surface observing stations (both West and East domains). Stations which were available for the entire 1998-2018 period.

Climate Change

Polar lows 1999-2019

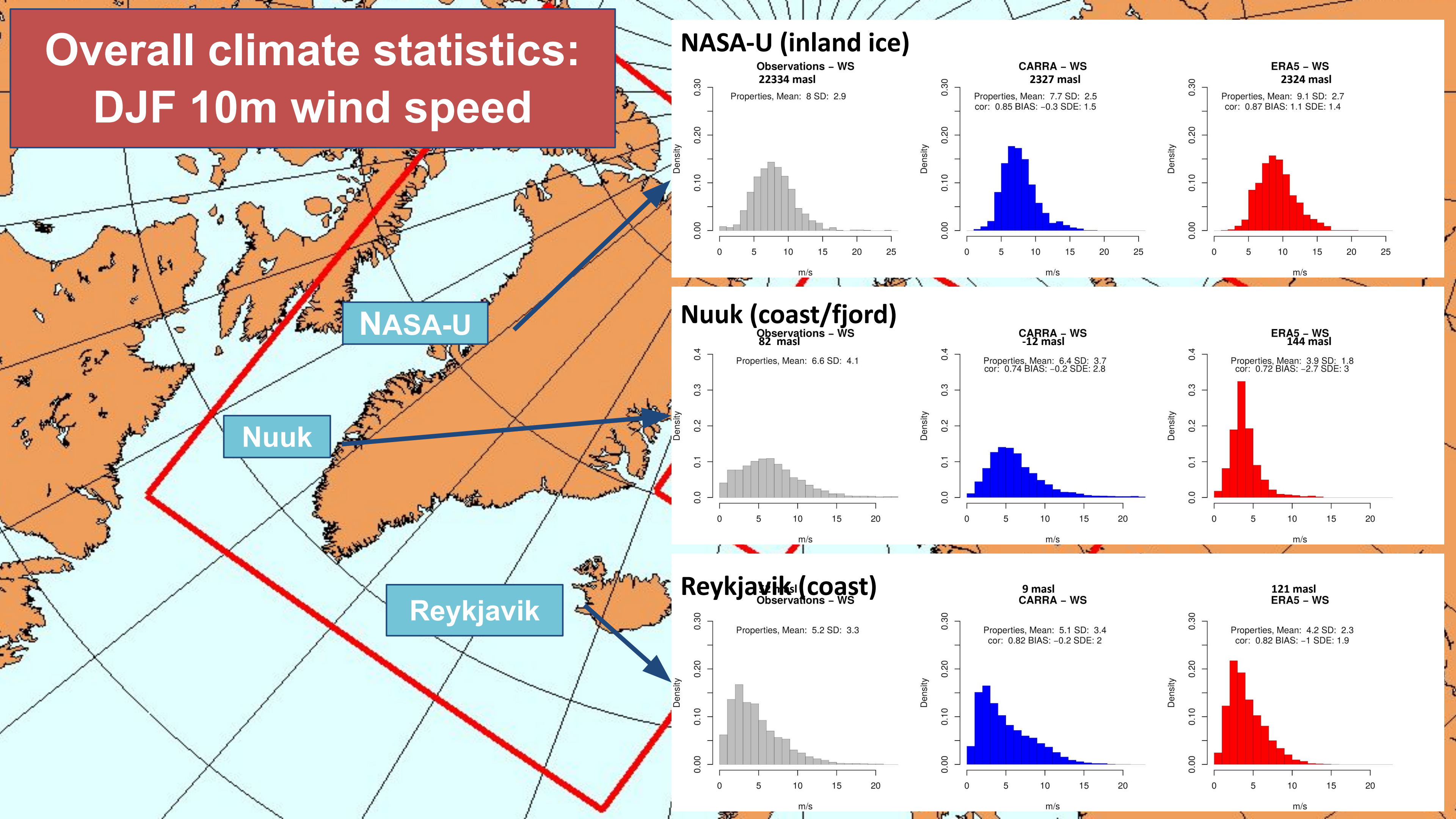




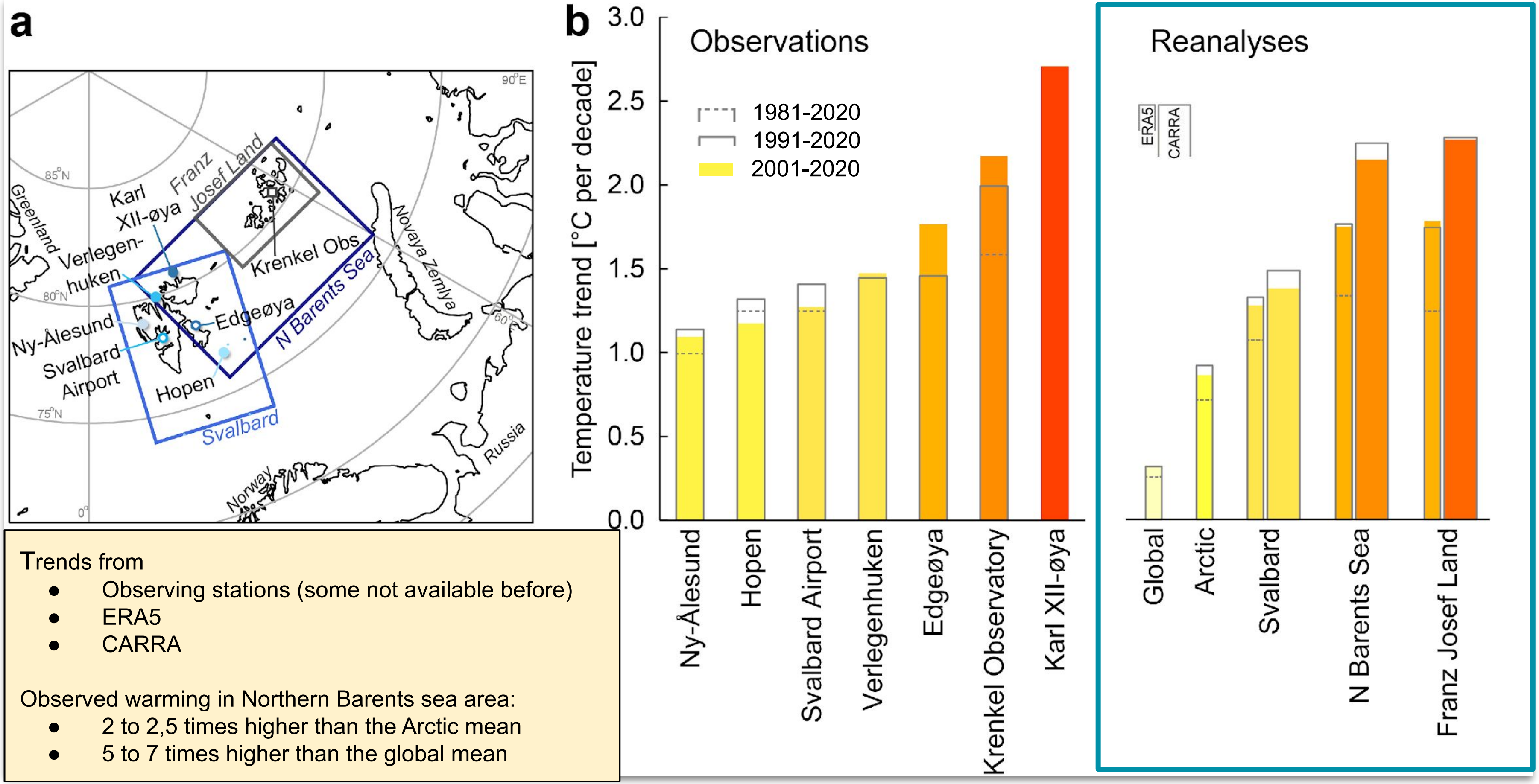
Polar low data set:
Rojo, Maxence; Noer, Gunnar; Claud, Chantal (2019):
Polar Low tracks in the Norwegian Sea and the Barents Sea from 1999 until 2019. *PANGAEA*, https://doi.org/10.1594/PANGAEA.903058,

Figures by Morten Køltzow, MET Norway: Verification for observations around polar low landfall.

ECMWF opernicus Europe's eyes on Earth European Commission


Overall climate statistics:
DJF 10m wind speed
NASA-U
Nuuk
Reykjavik
NASA-U (inland ice)
Observations – WS
22334 masl
Properties, Mean: 8 SD: 2.9
CARRA – WS
2327 masl
Properties, Mean: 7.7 SD: 2.5
cor: 0.85 BIAS: −0.3 SDE: 1.5
ERA5 – WS
2324 masl
Properties, Mean: 9.1 SD: 2.7
cor: 0.87 BIAS: 1.1 SDE: 1.4
Density
m/s
Nuuk (coast/fjord)
Observations – WS
82 masl
Properties, Mean: 6.6 SD: 4.1
CARRA – WS
-12 masl
Properties, Mean: 6.4 SD: 3.7
cor: 0.74 BIAS: −0.2 SDE: 2.8
ERA5 – WS
144 masl
Properties, Mean: 3.9 SD: 1.8
cor: 0.72 BIAS: −2.7 SDE: 3
Density
m/s
Reykjavik (coast)
Observations – WS
Properties, Mean: 5.2 SD: 3.3
9 masl
CARRA – WS
Properties, Mean: 5.1 SD: 3.4
cor: 0.82 BIAS: −0.2 SDE: 2
121 masl
ERA5 – WS
Properties, Mean: 4.2 SD: 2.3
cor: 0.82 BIAS: −1 SDE: 1.9
Density
m/s

Isaksen et al: Exceptional warming over the Barents area (Nature Scientific Reports, June 2022)



Trends from

- Observing stations (some not available before)
- ERA5
- CARRA

Observed warming in Northern Barents sea area:

- 2 to 2,5 times higher than the Arctic mean
- 5 to 7 times higher than the global mean

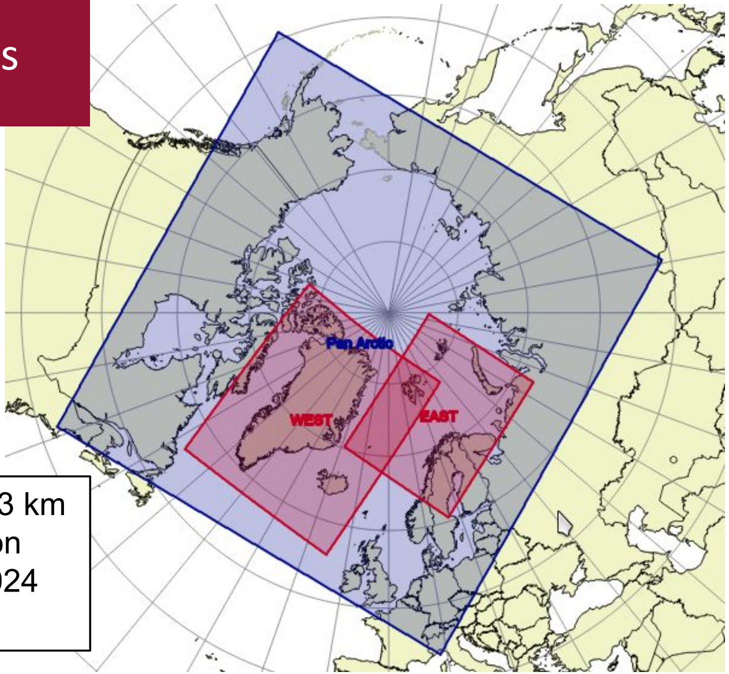
Example added value vs host model/global reanalysis: Verification of CARRA

Do we add value vs ERA5?

- ➢ Overall verification statistics vs observations ✓
- ➢ Capturing of extremes (example: polar lows) ✓
- ➢ Local climate statistics ✓
- ➢ Climate trends (?)

Climate
Change

Overview: Future of Copernicus regional reanalysis



- **CARRA-Timely Updates**: Monthly quasi-real-time updates of the CARRA1 system operational since March and to be provided throughout the coming 3-4 years
- **CERRA-Timely Updates**: The same for the European reanalysis system: Under implementation

- **CARRA2**: Next generation pan-Arctic reanalysis, resolution 3 km or better, covering at least from 1991 to 2025. Implementation kicked off in September 2022. Will start production March 2024

- **CERISE**: "CopERnIcus climate change Service Evolution" - Research project under the "Copernicus evolution" call started this year.
  Prepare methods and demonstrate candidate regional reanalysis systems to become part of C3S after 2027

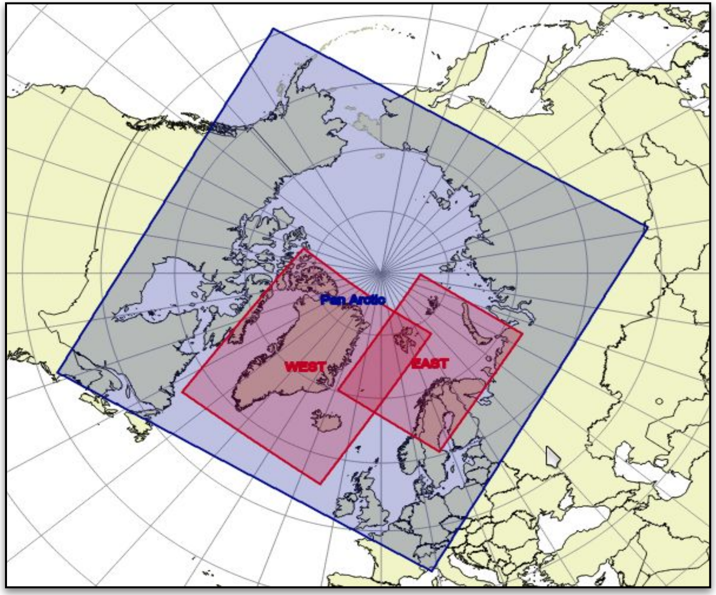
ian
logical
Institute

Climate Change

The development of the CARRA2 system

Under development: Next generation Arctic reanalysis, **CARRA2**:

- a much larger domain (pan-Arctic) targeted at 2.5 km horizontal resolution (adjustments depending on computation cost)
- data series up to present time, starting 1991 or earlier
- significant updates in surface scheme, both in physics and assimilation
- machine-learning based uncertainty estimation
- contract runs 2022-26
- production scheduled to start next spring



Climate Change

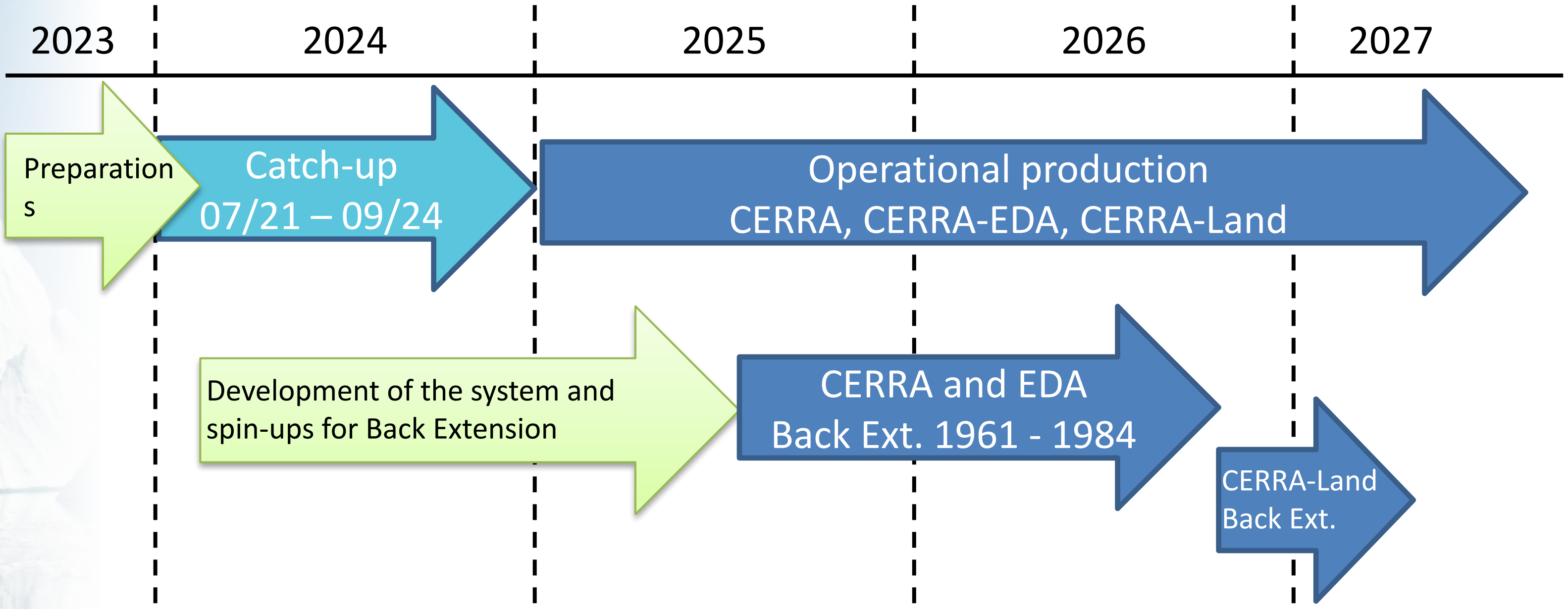
CARRA User Workshop on Teams Thursday 21 September 09:30-15:00 CEST

Information and registration on
https://climate.copernicus.eu/copernicus-arctic-regional-reanalysis-carra-user-workshop
(or google “CARRA user workshop”)

PROGRAMME OF THE EUROPEAN UNION Copernicus Europe's eyes on Earth IMPLEMENTED BY ECMWF Norwegian Meteorological Institute

Climate Change

Time line of the continuation of **CERRA** service



Preparations for the operational production include porting to ATOS as well as updating the observing system (Metop-C, Mode-S and ATMS from NOAA-20 and NPP).

Development needed for the Back Extension include handling of new input data, which is currently prepared for ERA6, and retuning of the model systems.

Details on CERRA: See poster from Semjon Schimanke

Climate Change

Plans and ongoing work in CERISE: Building reanalysis demonstrators - candidates for post-2027 C3S service

- Reanalysis assimilation methods: Towards more use of ensemble methods
- Evolution on surface assimilation and use of surface sensitive satellite observations
- Unification of Arctic and European reanalysis systems for C3S

Final remark

Offline / Land-surface regional reanalysis systems not covered here (sorry!)

Climate Change

Thank you!

...

PROGRAMME OF THE EUROPEAN UNION

IMPLEMENTED BY ECMWF

Norwegian Meteorological Institute