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Added values with the regional atmospheric reanalyses

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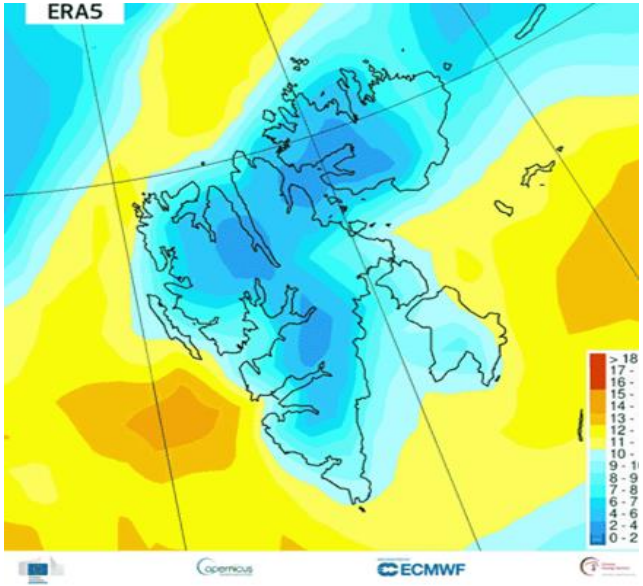
&
Copernicus CARRA team
DMI DANRA team



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Outlines

- **Harmonie-NWP based reanalyses**
  - CARRA and DANRA
- **Where comes the added values**
  - Added values with regional NWP
  - High fidelity climate reanalysis
- **Further findings**
  - Is LAM intrinsically inferior to global model for large scale properties?
  - Is hydrostatics approximation still acceptable at 2.5 km grid resolution?
  - Cases with analysis bust
- **Outlooks**

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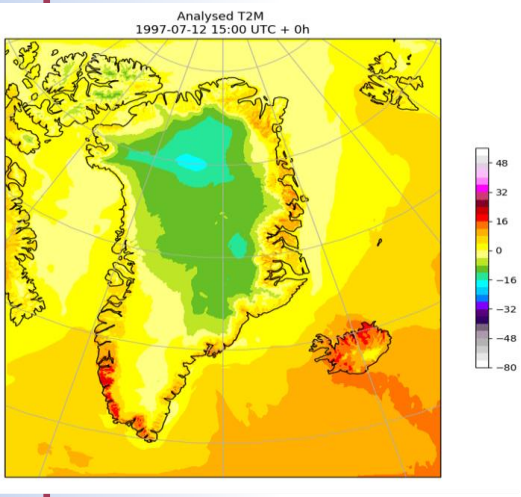
Harmonie-based regional reanalysis

Xiaohua Yang, Nordic Meteorologists Meeting 2022, Helsingki, 15 June 2022

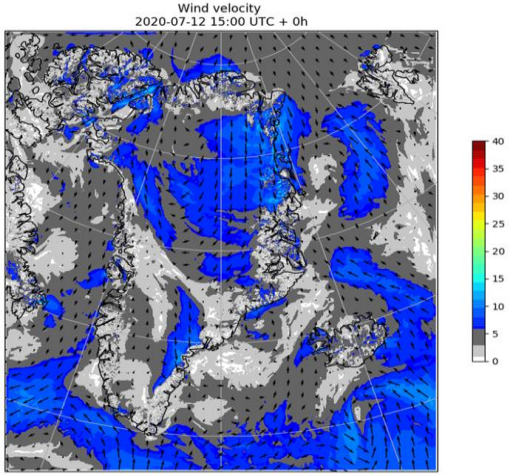
Climate Change

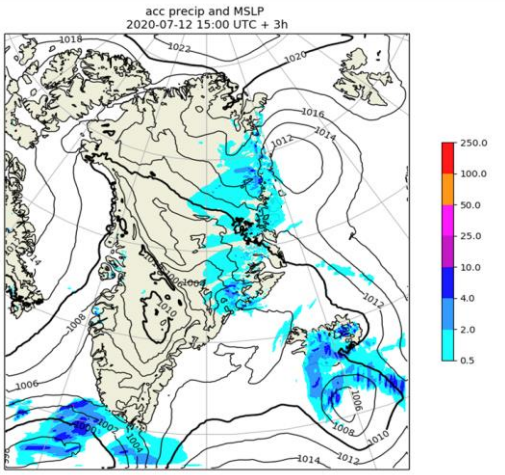
Climate reanalysis: past weather hour by hour

- Gridded climate dataset produced by state of art weather model and data assimilation
- fixed model version + maximum utilisation of observation: high fidelity dataset
- combination of assimilation and forecast with focus on analysis and short range



temperature on 12 July each year (note the warm 2012)





Reanalysis provides gap-free, high fidelity, gridded and coherent climate time series

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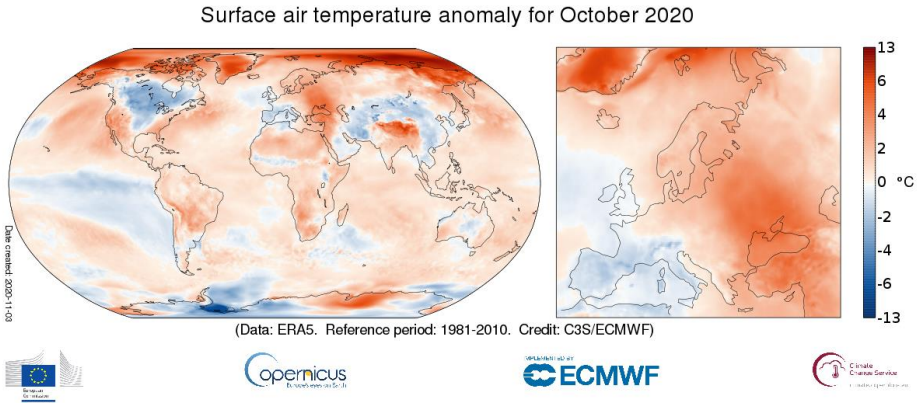
Climate Change

C3S global and regional reanalyses for the Arctic region

ERA5: Global reanalysis

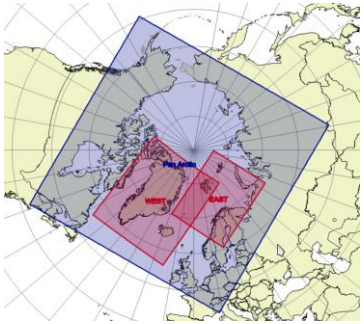


Available in the CDS (> 35,000 users): @ 25 (31 native) km
Atmosphere, land, ocean waves.

- From **1979 to 5 days ago**
- Preliminary back extension (1950-1978) made available recently; for the Arctic the final release will be similar.

Conducted at ECMWF

CARRA: Arctic reanalysis



CARRA1: (red domains)
January 1991 – Dec 2021 @ 2.5km

Proof of concept: (grey domain)
1-year pan-Arctic reanalysis, Sep 2017/18 @ 3.75km

Met Norway, DMI, SMHI, FMI, IMO, Météo-France

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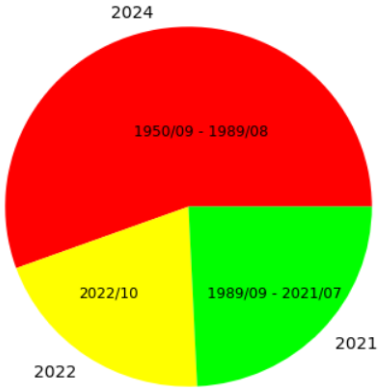
DANish ReAnalysis (DANRA)

NCKF (Danish National Center for Climate Research) DANRA

- CARRA reanalysis-adapted
- lateral boundary conditions from ERA5
- maintain close to real time afterwards



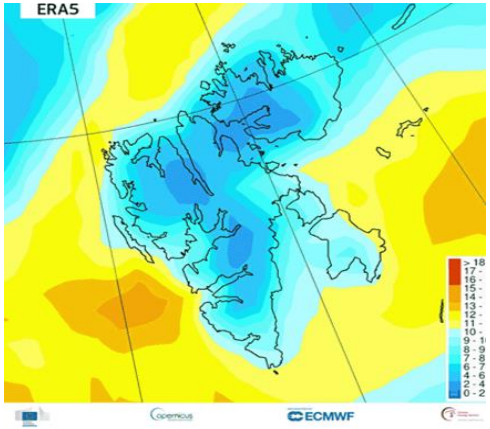
DANRA

2023, 30+ year DANRA 2.5 km (1991-2021)

2025, full 70-year DANRA 2.5 km (1951-2020)

Xiaohua Yang, Bjarne Amstrup, Carlos Peralta Aros, Kasper Hintz, Søren Borg Nielsen, Flemming Vejen

Regional reanalyses, magnifying glasses to ERA5

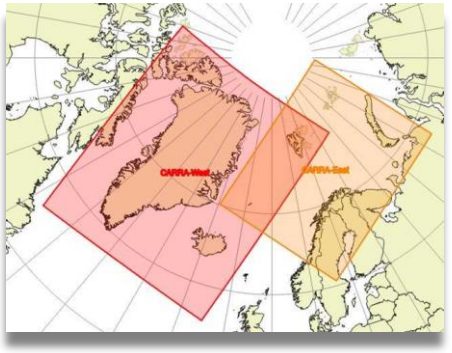


Global Reanalysis:

Copernicus ERA5, 31 km

Regional Reanalysis:

Copernicus CARRA, 2.5 km
DANRA, DMI, 2.5 km



Harmonie Climate Reanalysis System

Adapted from operational NWP Harmonie-arome CY40

Using ERA5 hourly boundary
3-hourly 3DVAR assimilation with up to 30h fcst

Enhanced representation of high-resolution features through input data and improved surface modelling: local surface observation, satellites data, satellite **snow**, **glacier albedo**, high resolution sea states, and also improved **physiography**

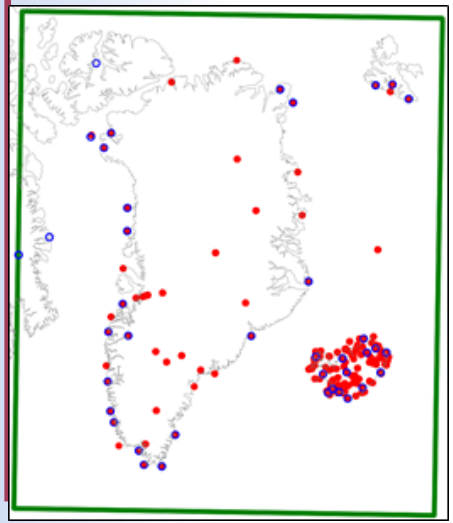
Climate Change

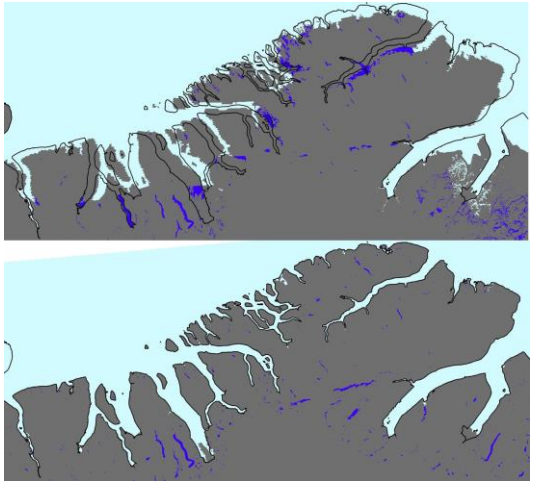
Enhanced surface representation: database and characteristics

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

Blue: Obs in ERA5

Red: Extra local obs in CARRA (e.g. PROMICE, GC-NET, ASIAQ)

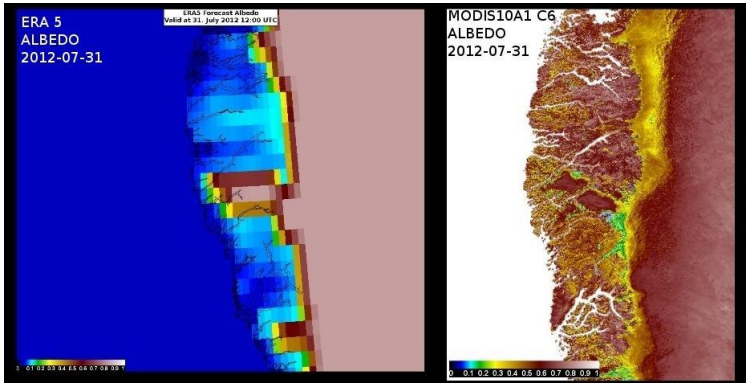




North Greenland physiography:

Upper: Uncorrected Ecoclimap physiography

Lower: Corrected physiography using sat. data.



West Greenland albedo representation:

Left: ERA5 glacier albedo

Right: Albedo derived from MODIS

Also use of 5 km resolution historical satellite (AVHRR) based data set for snow cover (CryoClim)

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Manifestation of added values

Xiaohua Yang, Nordic Meteorologists Meeting 2022, Helsingki, 15 June 2022

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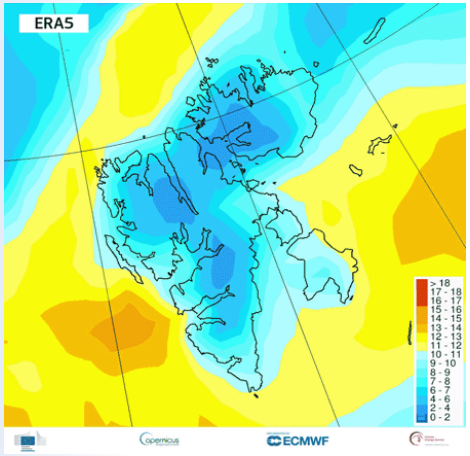
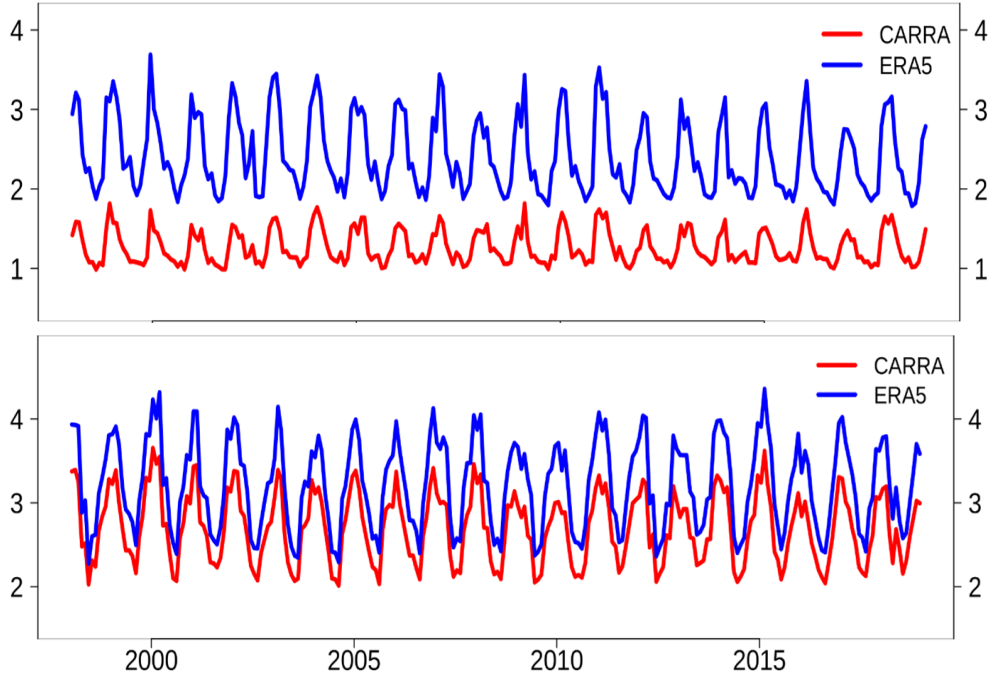
General verification intercomparison clearly in favor of CARRA





T2/W10 error time series for CARRA and ERA5.

Added values with the km-scale CARRA data

- higher data resolution
- improved fidelity for ECVs
- better representation of extreme features and small scale climatology

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opernicus
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European Commission

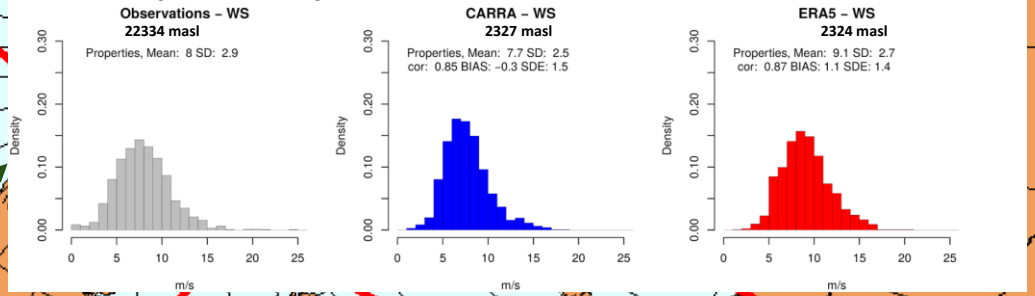
Overall climate statistics: DJF 10m wind speed

NASA-U (4443)

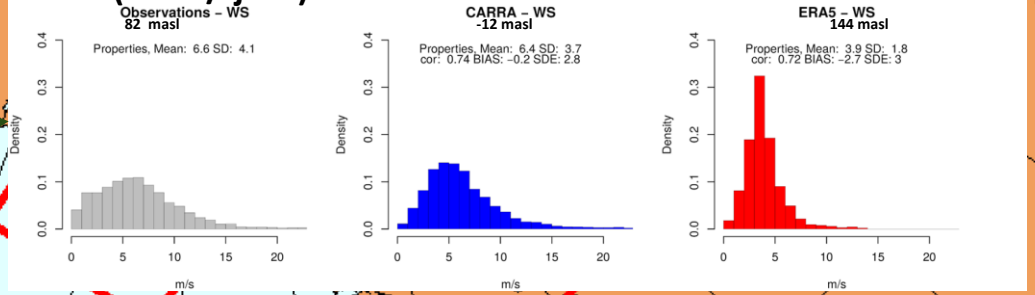
Nuuk (4249)

Reykjavik (4030)

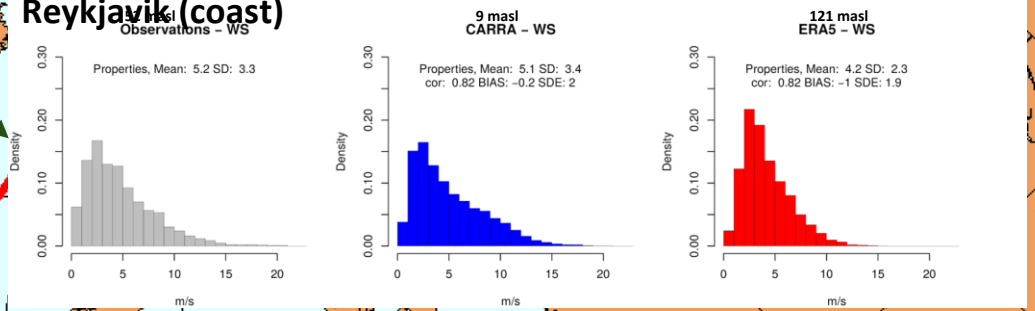
NASA-U (inland ice)



Nuuk (coast/fjord)

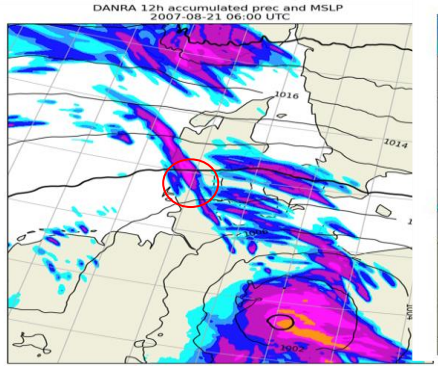


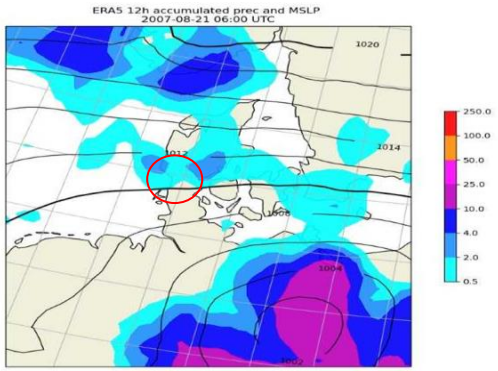
Reykjavik (coast)



KM-scale reanalysis resolves major flashfloods

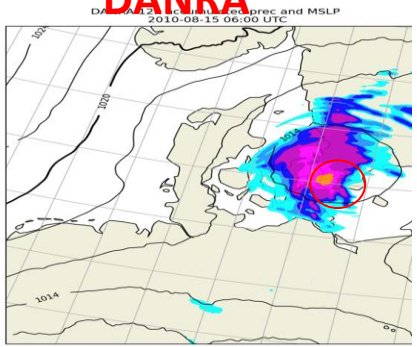
20070820

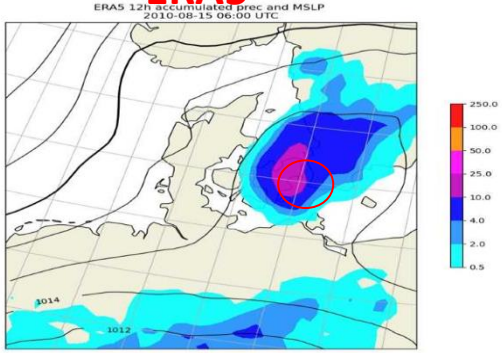




DANRA

ERA5





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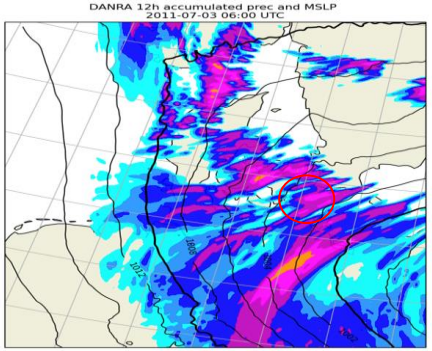
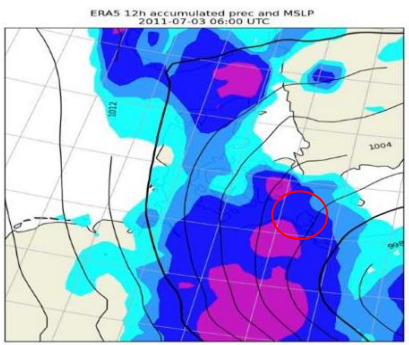
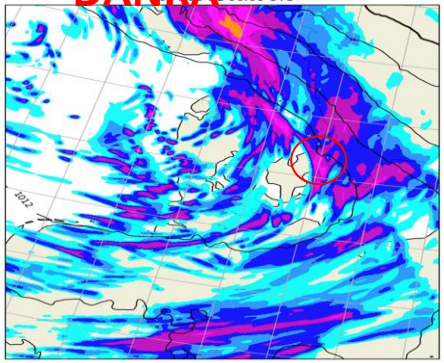
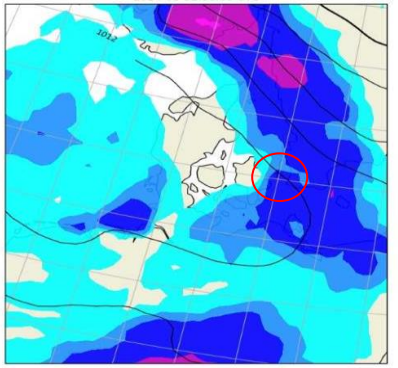




DANRA

ERA5





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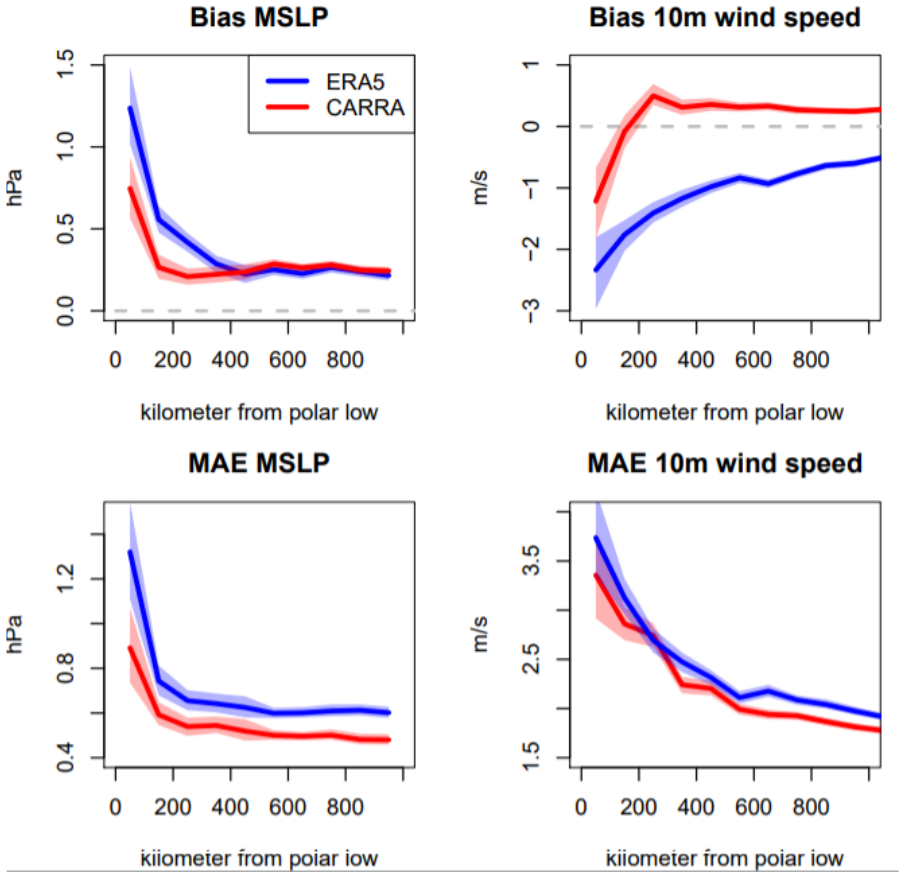
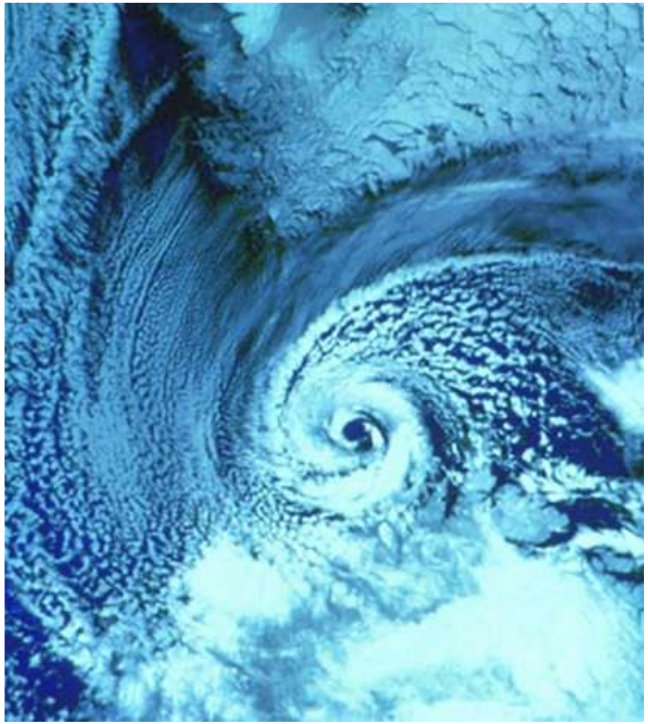
Climate Change

Polar lows 1999-2019





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.

Danmarks Meteorologiske Institut

Better replica of historical Danish storms

Danish category 4 storms	Wind Speed Maxima [m/s]		
	OBSERVED	DANRA	ERA5
1981-11-24	35.0	28.5	26.2
1983-01-18	31.4	27.4	23.2
1990-02-26	31.0	28.6	23.6
1991-01-09	33.0	29.9	24.5
1999-12-03	41.2	39.5	27.5
2013-10-28 "Alan"	38.0	33.7	23.6
2013-12-05 "Bodil"	31.4	31.2	25.8

Peak mean wind as observed and simulated in the Danish (DANRA) and global reanalysis (ERA5) for hurricane events in the last three decades.

Climate Change

Summary: Added values due to resolution, observations, model representations

Improved fidelity and capability manifested through

- case-to-case and near-surface quantities
- high-impact situations (polar lows/storms, convective events, winter warming events)
- local climate statistics in presence of physiographic features
- MSLP and large scale properties no exceptions!

Added value from combination of

- model set-ups which benefit from state of art operational configuration with experiences
- extended use of observations data in data assimilation including local data
- higher horizontal model resolution and enhanced description about forcing
  - physiography
  - sea surface temperature; sea ice
  - snow cover
  - glacier albedo

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Further findings

For years it has been a common experience that LAM models (HARMONIE...), while outperforming those of the global models (ECMWF) in screen level quantities (T2, W10m... ...) thanks to better resolved surfaces, the skill scores on ‘large scale weather parameters’ (surface pressure, upper air quantities) usually lag behind those of ECMWF.

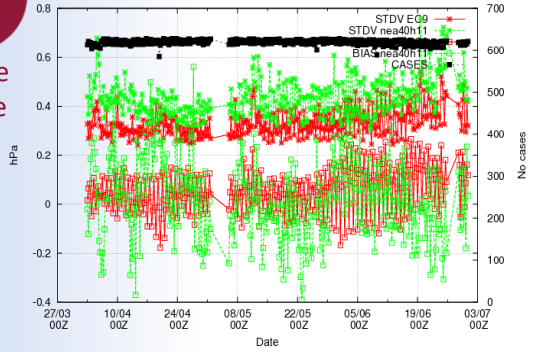
Why?

Shortcomings in data assimilation algorithm and capability??

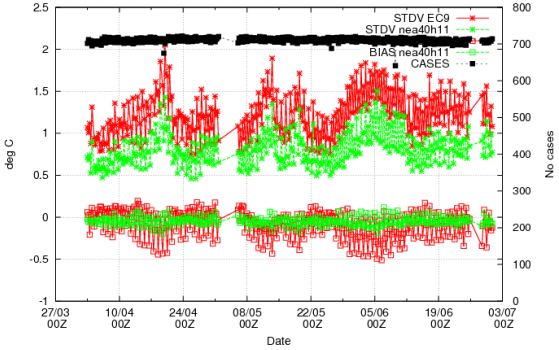
Limited model domain to take into account important observations outside??

Climate Change

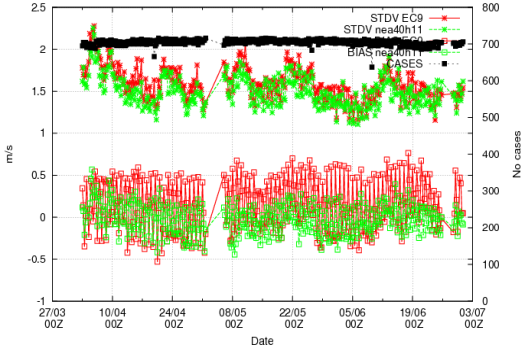
Pressure



T2m

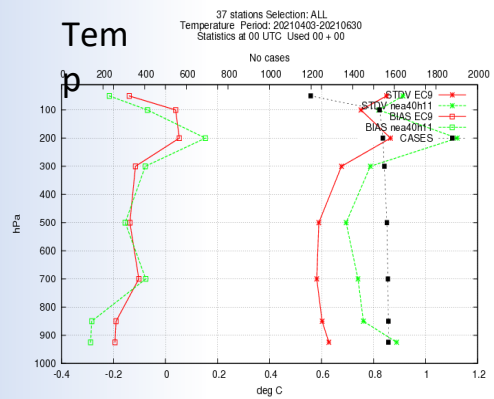


W10m

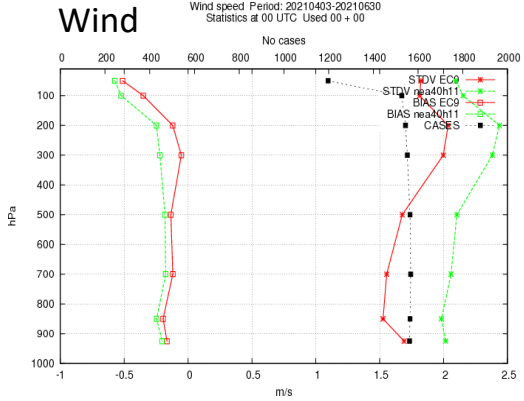


Daily error time series of MSLP, T2m and W10m forecasts comparing ECMWF and DMI-HARMONIE, March-May 2021

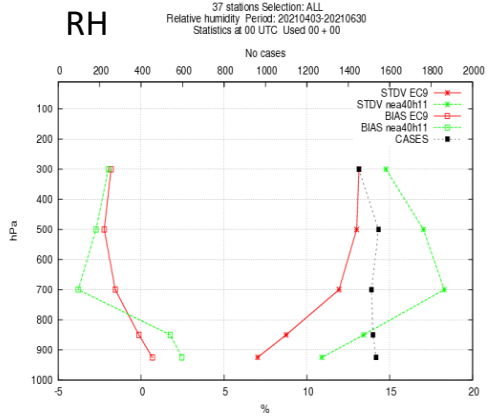
Tem p



Wind



RH



Averaged errors with T, W and RH along pressure levels ECMWF and DMI-HARMONIE, March-May 2021

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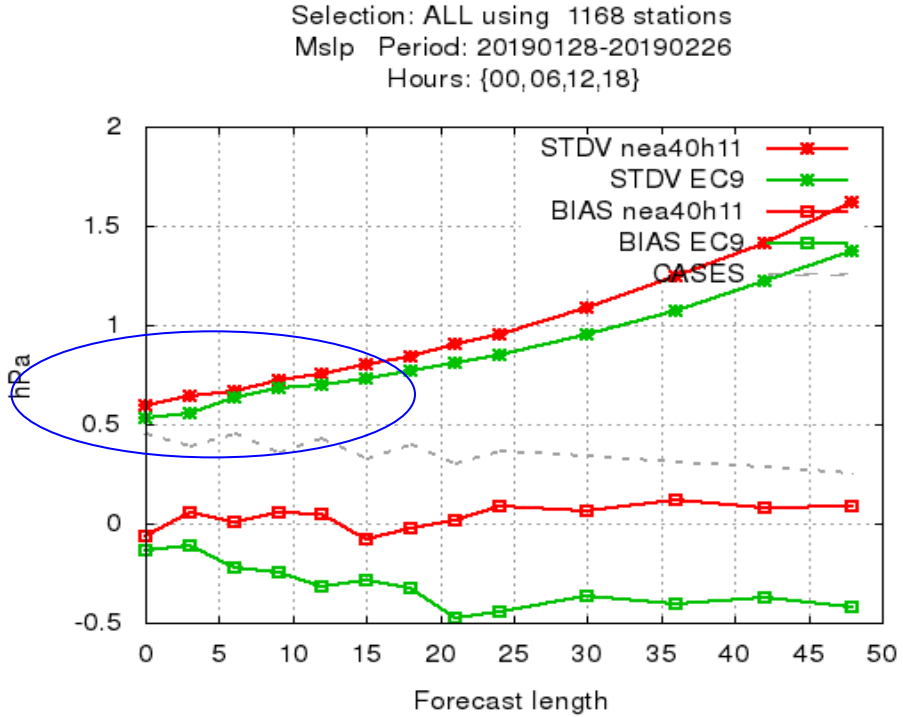
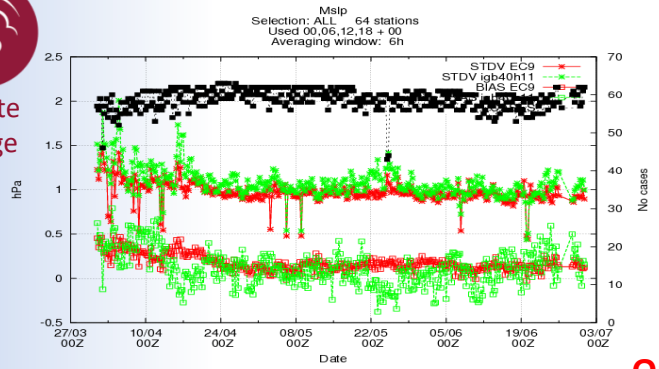


DMI-HARMONIE

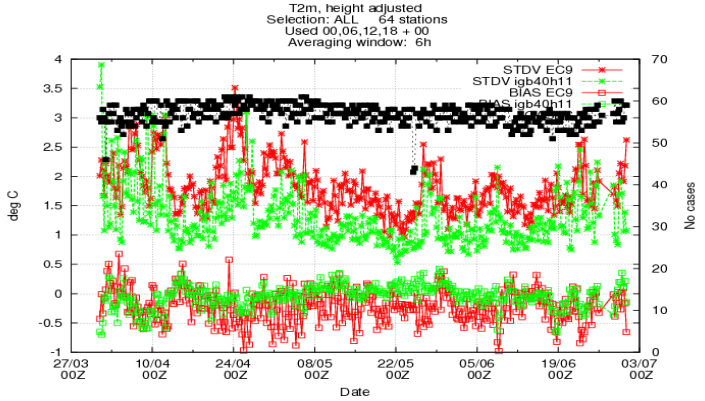
ECMWF HRES

ECMWF HRES normaly verifies better in MSLP than DMI-NEA. Note the latter is driven by a 6h older forecast. ECMWF-HRES delivers 3 to 9 h later than DMI-NEA. Taking into account delivery time, NEA could be better!!!
..... Delivery time is a quality indicator.

Climate Change



Greenland-Iceland

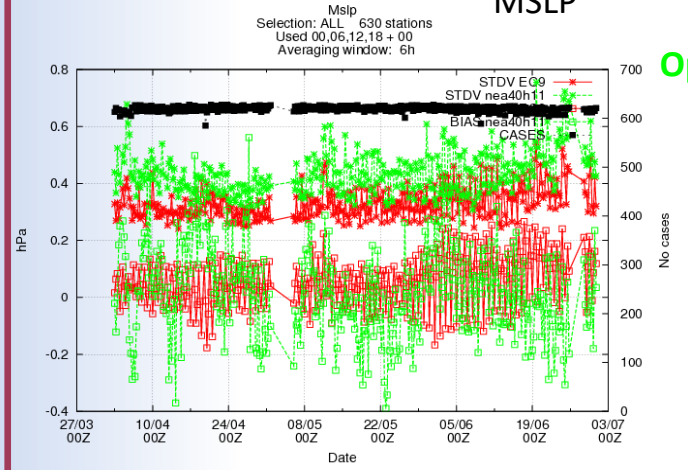


Operational ECMWF

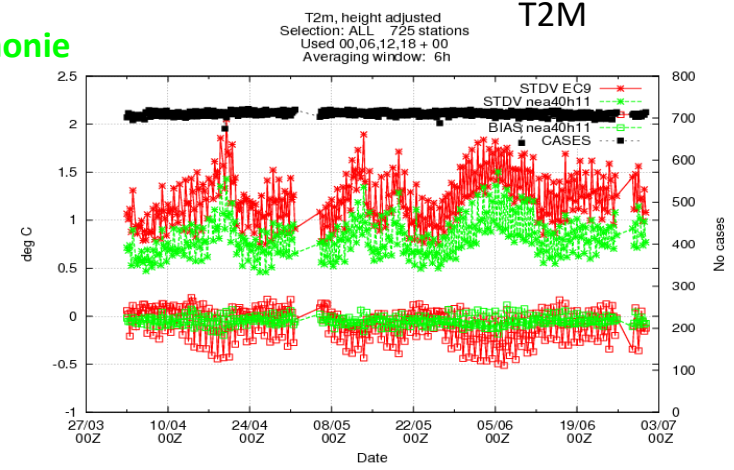
MSLP

T2M

Operational DMI-Harmonie



Nordic stations



March-May 2021

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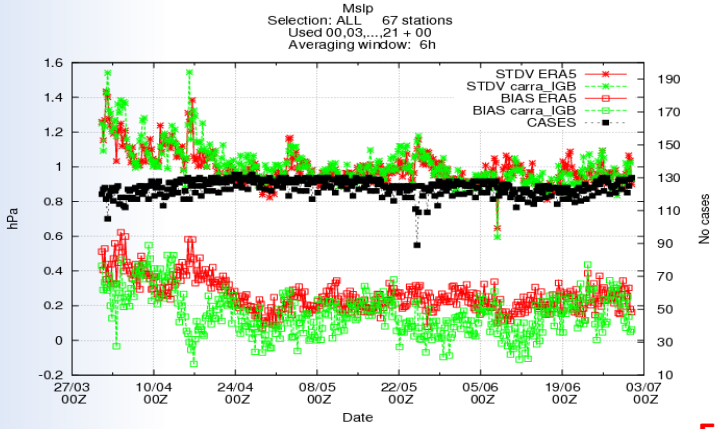
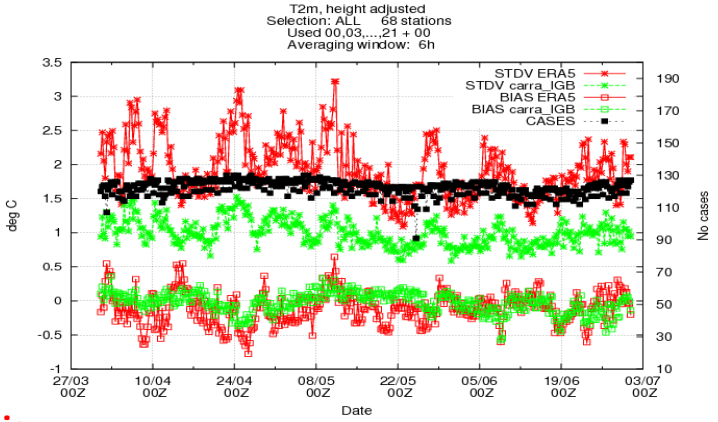


Greenland -Iceland

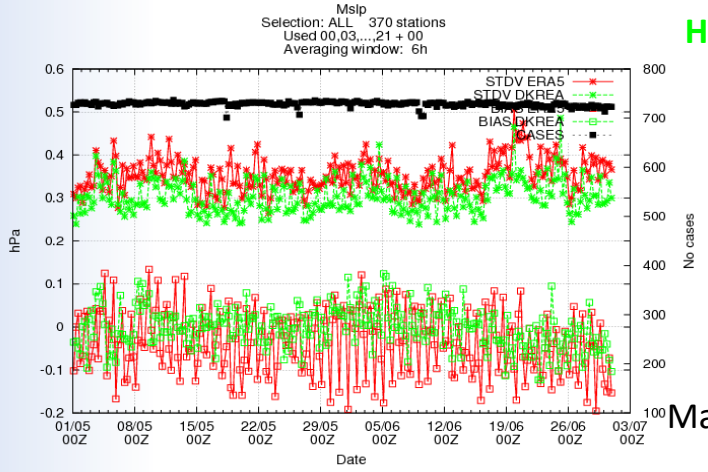


ERA5 reanalysis

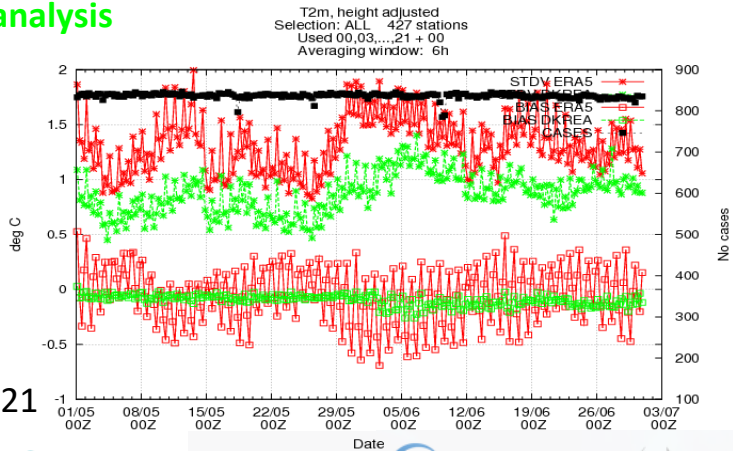
MSLP

T2m

Harmonie reanalysis



Nordic stations



March-May 2021

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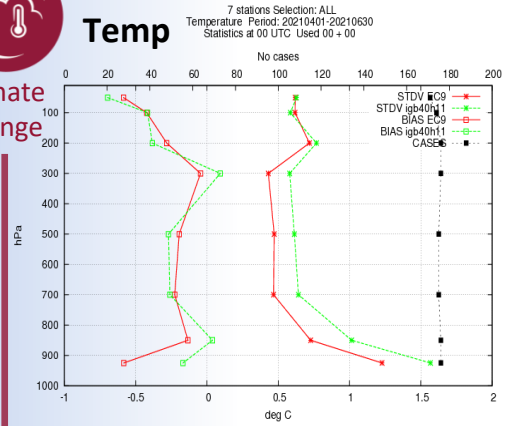
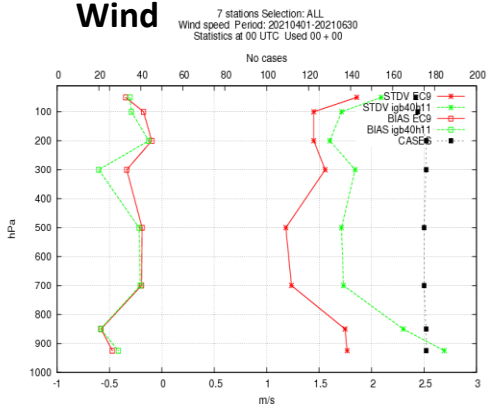
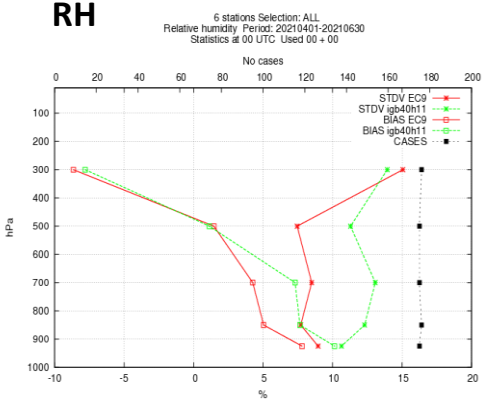
Temp



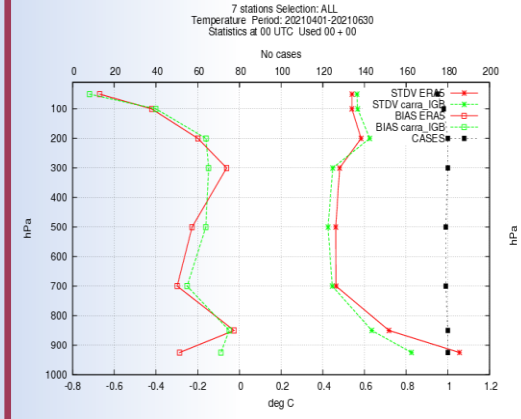
Wind

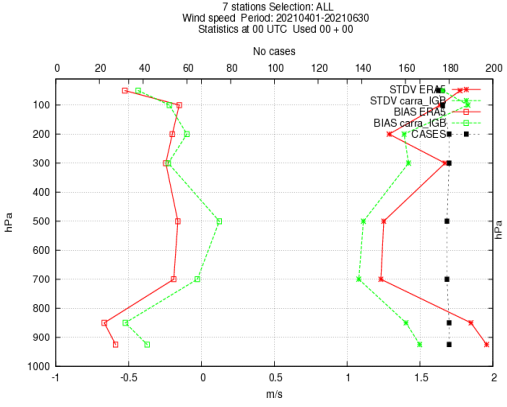


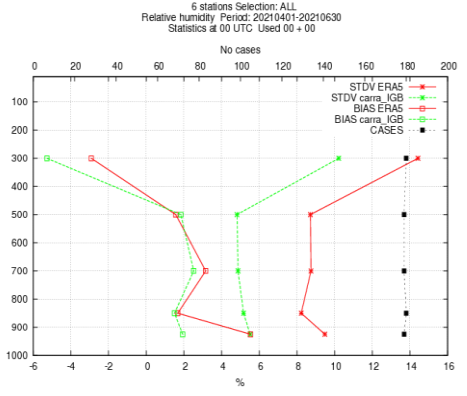
RH



Operational







Reanalyses

Greenland-Iceland stations, March-May 2021

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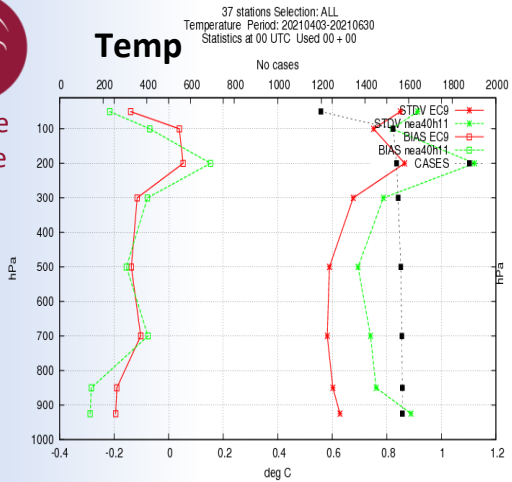
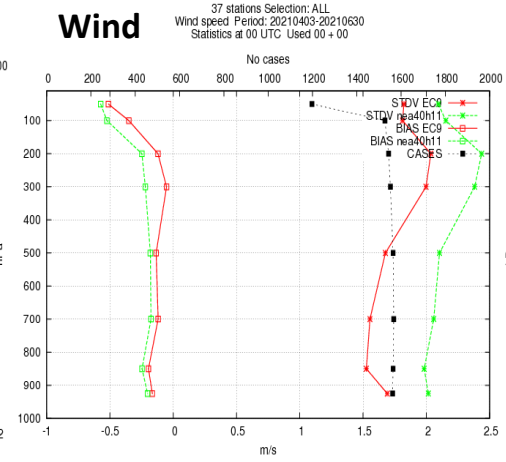
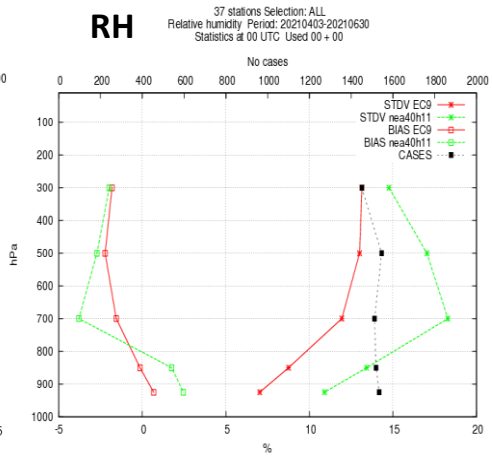
Temp



Wind



RH



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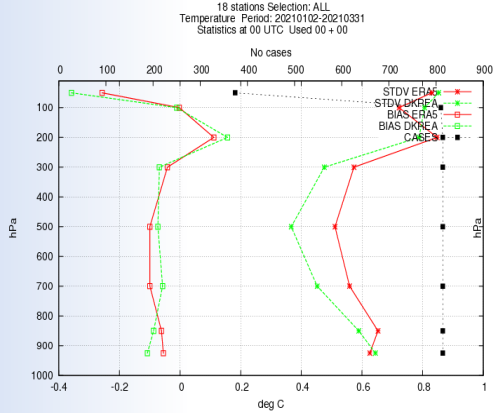

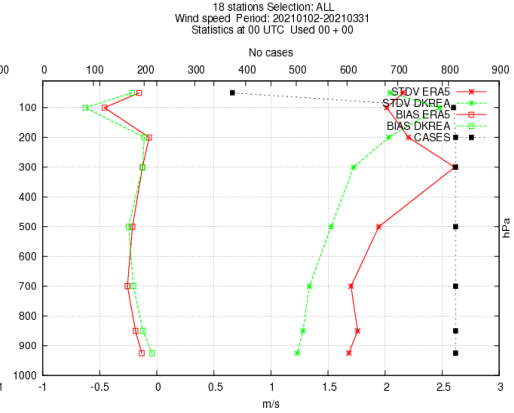

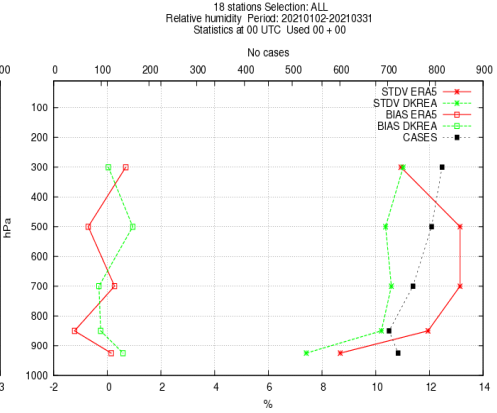

Reanalyses

Nordic stations, March-May 2021

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For years it has been a common experience that LAM models (HARMONIE...), while outperforming those of the global models (ECMWF) in screen level quantities (T2, W10m... ...) due to better resolved surfaces, the skill scores on 'large scale weather parameters' (surface pressure, upper air quantities) usually lag behind those of ECMWF.

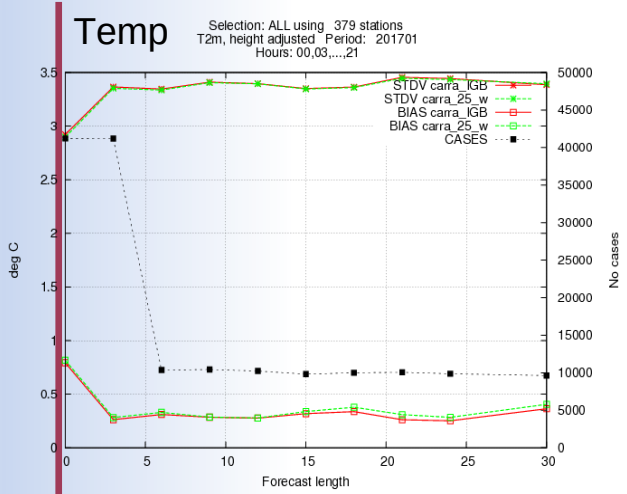
Why?

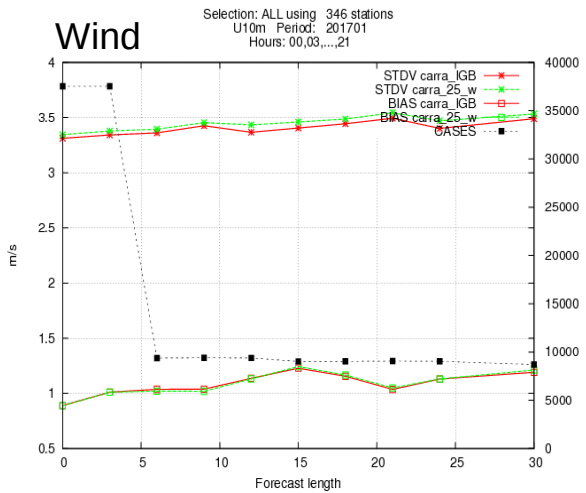
Actually, a quite fundamental deficiency in the LAM forecast is associated with time lagging of lateral forecast boundaries from global model (> 6h time lagging). ***In reanalysis scenario, as the lateral boundary is with analysis, the deficiency is gone. LAM parameters for large scale become competitive!***

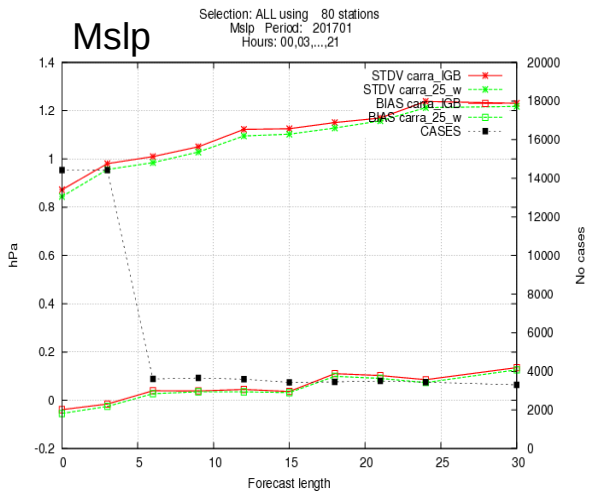
Thus, LAM model is not intrinsically inferior to global models on predictability of the large scale properties!

Climate Change

nonhydrostatic effects at 2.5 km?







nonhydrostatic configuration vs hydrostatic configurations @ 2.5 km

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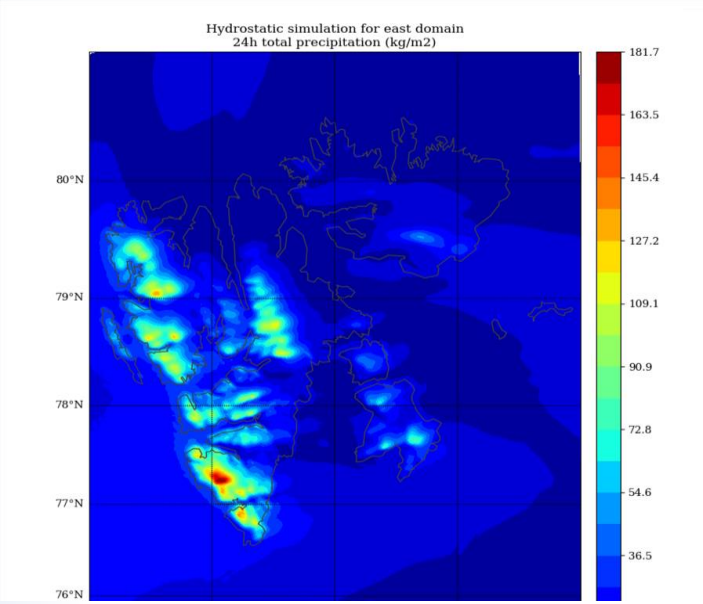
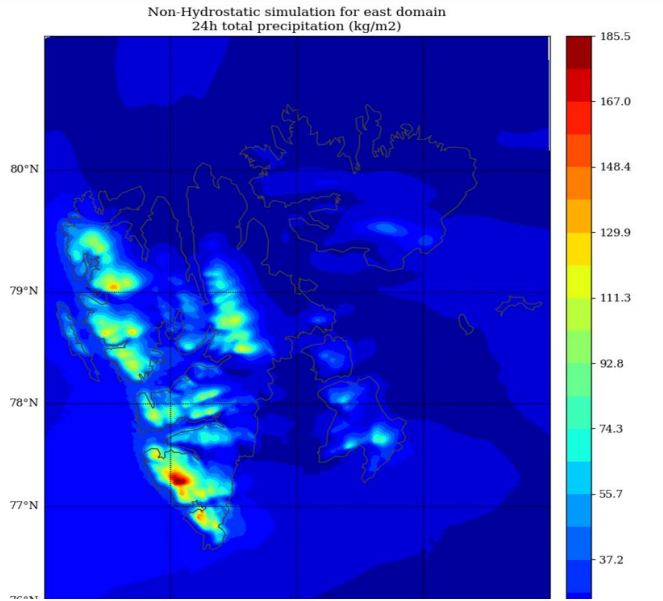
nonhydrostatic effects at 2.5 km?

Hydrostatic



Non-Hydrostatic



CARRA-simulated extreme rainfall event in Svalbard Nov 8 2016, 06 UTC, 24h accumulated

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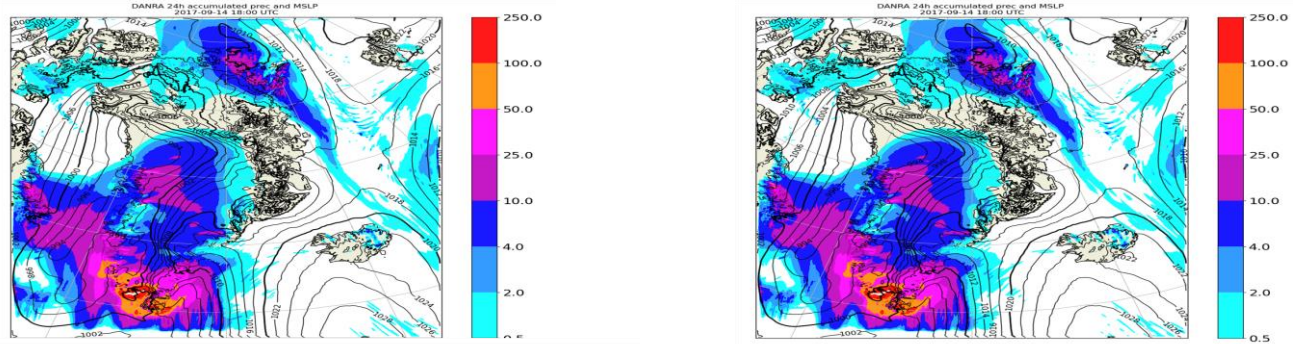
nonhydrostatic effects at 2.5 km?

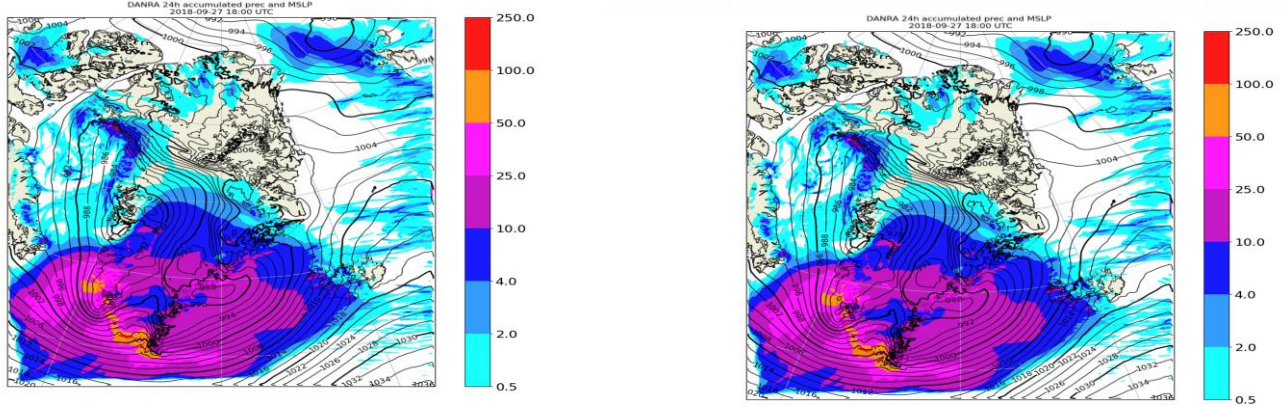
Climate Change

Hydrostatic | **Non-Hydrostatic**

20170913



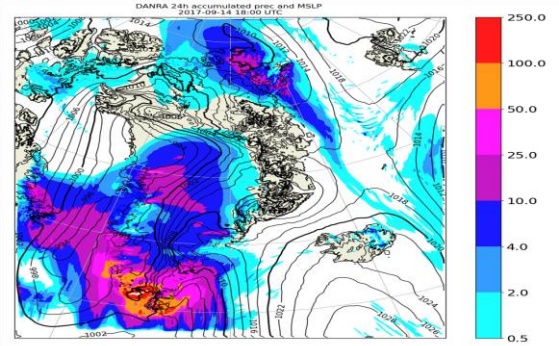
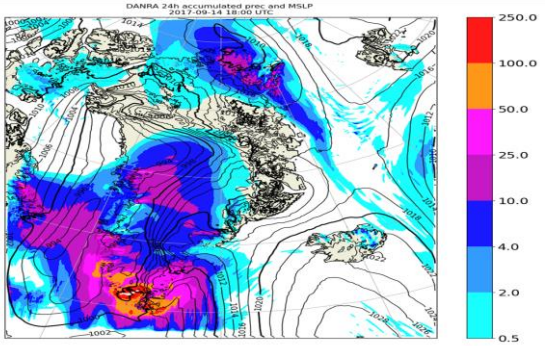
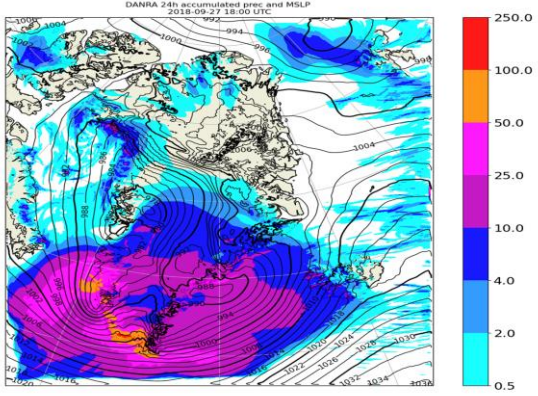
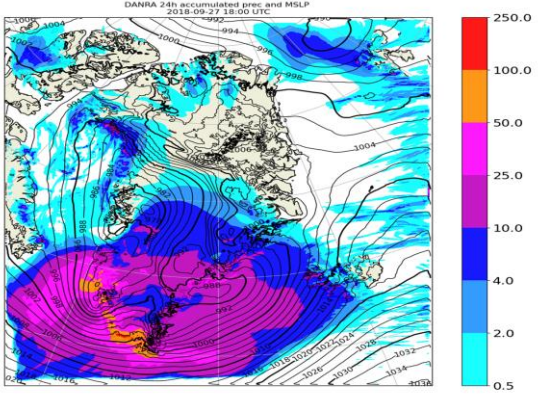
20180927



CARRA simulated extreme rainfall events in south Greenland, 24h accumulated

Climate Change

nonhydrostatic effects at 2.5 km?

	Hydrostatic	Non-Hydrostatic
20170913		
20180927		

at 2.5 km, a nonhydrostatic configuration does not appear to add value to hydrostatic!

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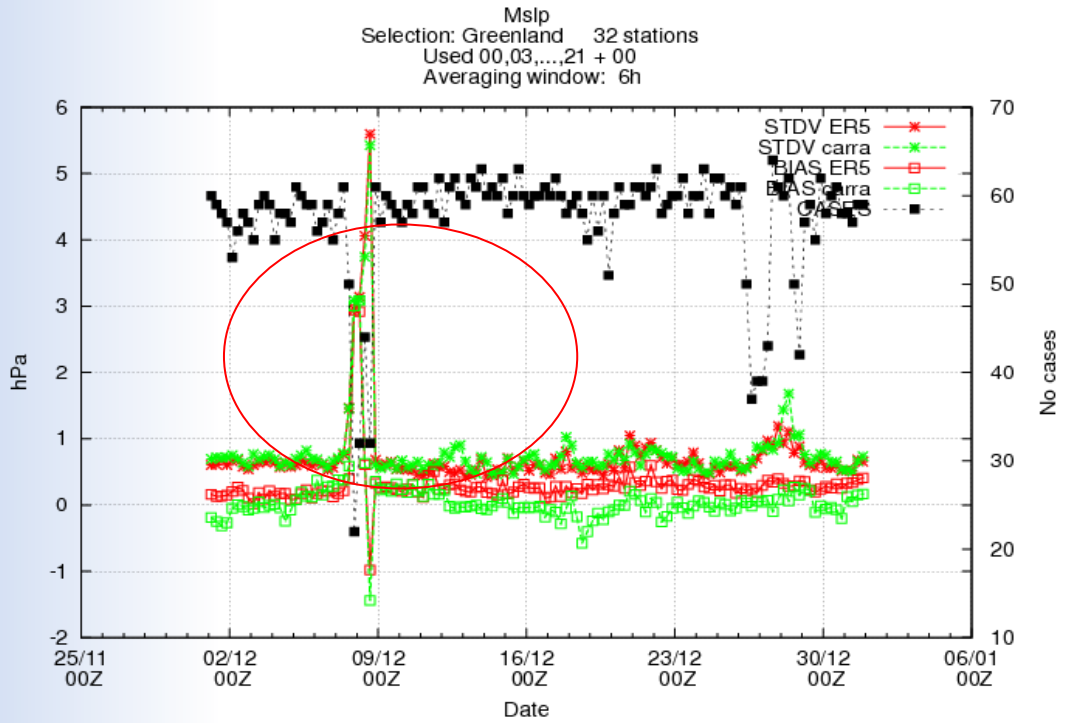
Known deficiency: analysis bust cases



CARRA data series contain occasionally cases with large deviation to the verifying observations for key parameters (analysis bust cases), where substantial amount of good observation data got rejected due to large model error.

Future phase of CARRA reanalyses shall hopefully improve

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Outlook: CARRA2, DANRA-70

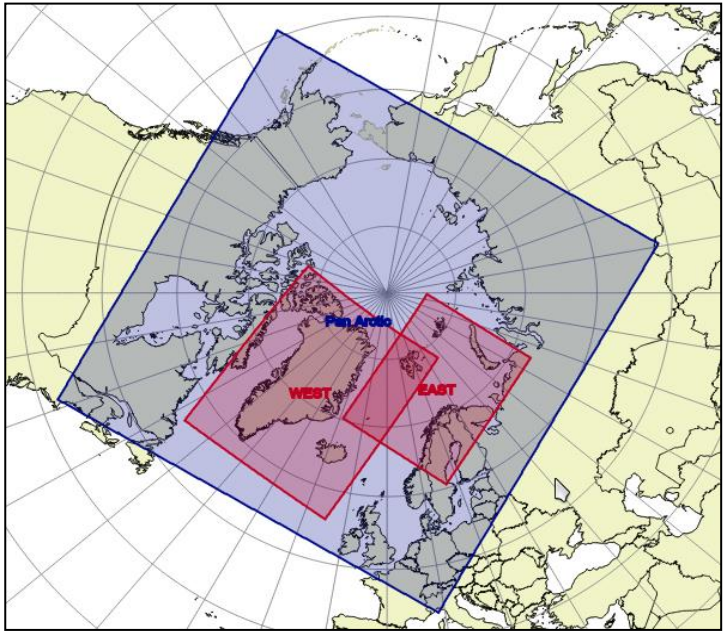
DANRA-30 year will be extended to 70 years by 2025.

In response to C3S call for next generation Arctic reanalysis, a CARRA2 configuration is currently in preparation, which is for an extended Pan-arctic domain.
Likely configuration

- 2.5 km resolution on Pan-arctic domain
- Possibly an extended reanalysis period with 40+ years
- statistical means produced along production
- Significant updates in surface scheme

Projected production start early 2024, to be complete in 2026

User feedback welcome!



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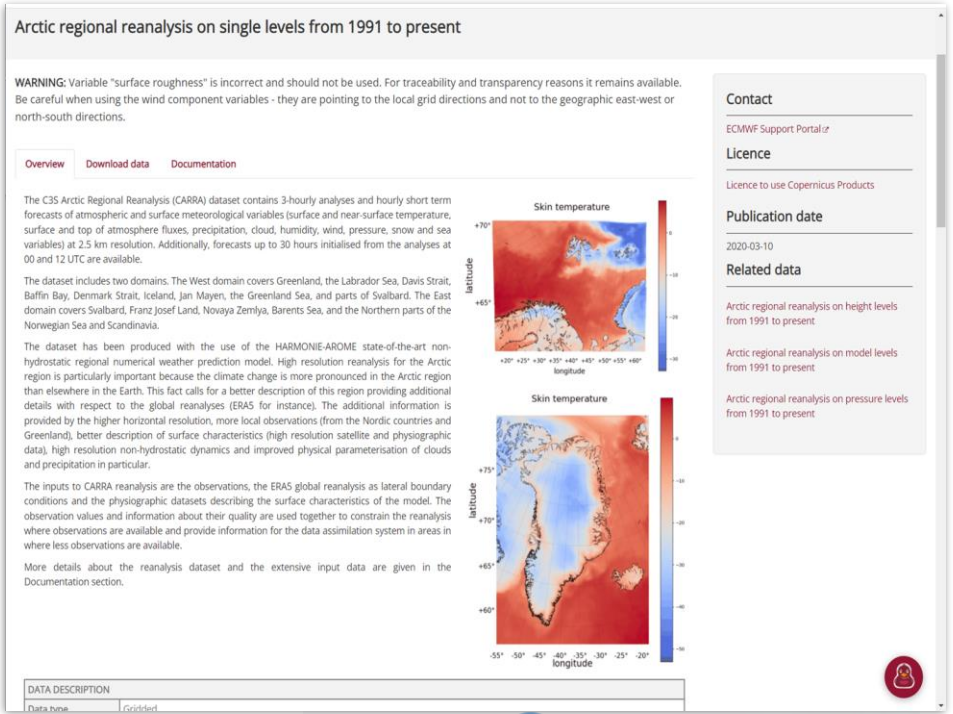
Where can I get the data?

CARRA

C3S web page, including links to *Climate Data Store* download pages:
https://climate.copernicus.eu/copernicus-arctic-regional-reanalysis-service

DANRA

https://dmidk.github.io/danra-docs/fields.html



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The Danish Meteorological Institute

Thank you!