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
Outlines

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

acknowledgement to the CARRA team

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
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**
  - ARCDDEM 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**
Grid resolution crucial for realism in surface quantities

T2m std/bias

Dec 20 1999 - Jan 2000, North Scandinavia, Svalbard

ERA40 125 km
ERA Interim 80 km
ERA5 31 km
CARRA 2.5 km
CARRA vs ERA-5 for Greenland & Iceland

Climate Change

Wind

CARRA

T2m

ERA-5
Operational HARMONIE often shows inferior large scale scores than ECMWF.

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

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.
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- Greenland topography update first to GIMP DEM and next to ArcticDEM v7 (Bolli).
Climate Change

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Climate Change

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- 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.
Improvement in handling of glacier snow and albedos

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
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).
Collection of non-GTS surface observation

DMI+ASIAQ
ASIAQ: 11

(2008-, 25 stations)

ERA-5 (GTS/mars)
Greenland 40

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

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

23 stations
Quality assurance of observation data

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.

data on GTS
DMI observation database
DMI surface pressure observation
(B. Amstrup)

Observation data needs quality assurance!
CARRA in production phase (May 2019 - June 2021)

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 Ismix/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