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A land data assimilation system for NWP initial conditions and hydrometeorological forecasting

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Background: The H2O project

Earth system approach in NWP

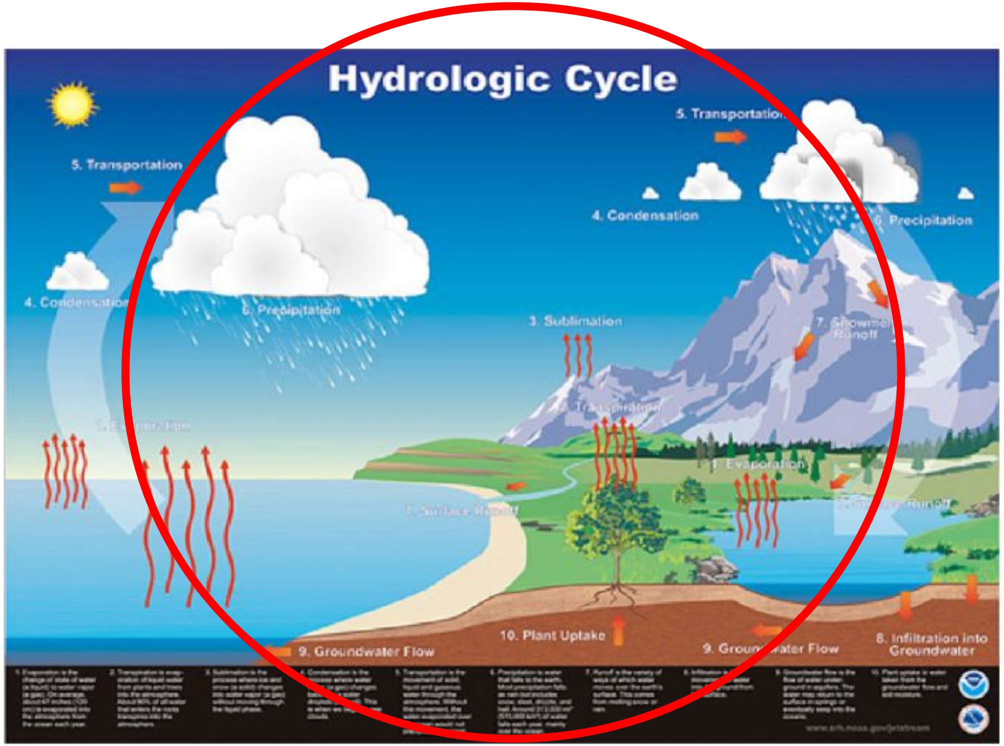
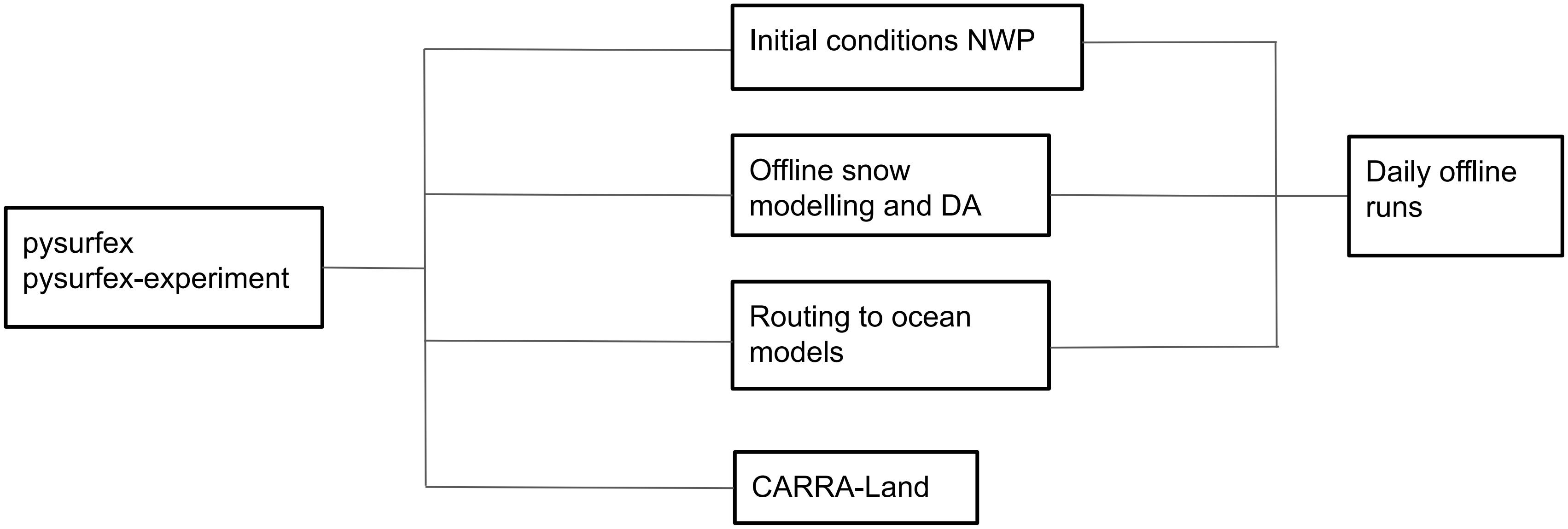


Figure 1: Source: NOAA, Dirmeyer et al., WWOSC 2015, WMO

Meaning:

- snow and land processes
- re-distribution of precipitation
- Earth observation system
- coupling towards lakes, ocean and the environment

Project time-period 2020 - 2024



pysurfex
pysurfex-experiment
Initial conditions NWP
Offline snow modelling and DA
Routing to ocean models
CARRA-Land
Daily offline runs

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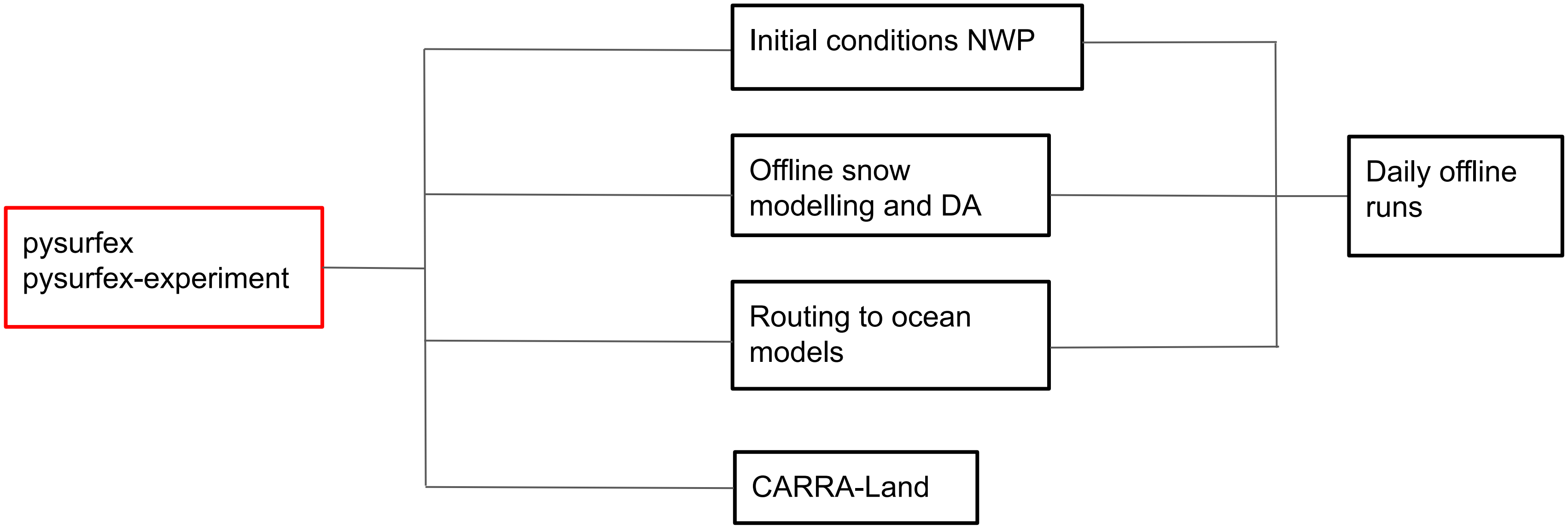

pysurfex and pysurfex-experiment

pysurfex: https://github.com/metno/pysurfex

- Quality control of observations: titanlib
- Horizontal optimal interpolation (OI): gridPP
- Create forcing
- Conversion of bufr observations to json
- Post processing, convert increments etc to SQLite database

pysurfex-experiment: https://github.com/metno/pysurfex-experiment

- ecFlow scheduler
- Easy compilation of code
- Easy handling of operational runs

Figure 2: view of ecFlow scheduler for an offline pysurfex-experiment setup

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pysurfex and pysurfex-experiment

pysurfex: https://github.com/metno/pysurfex

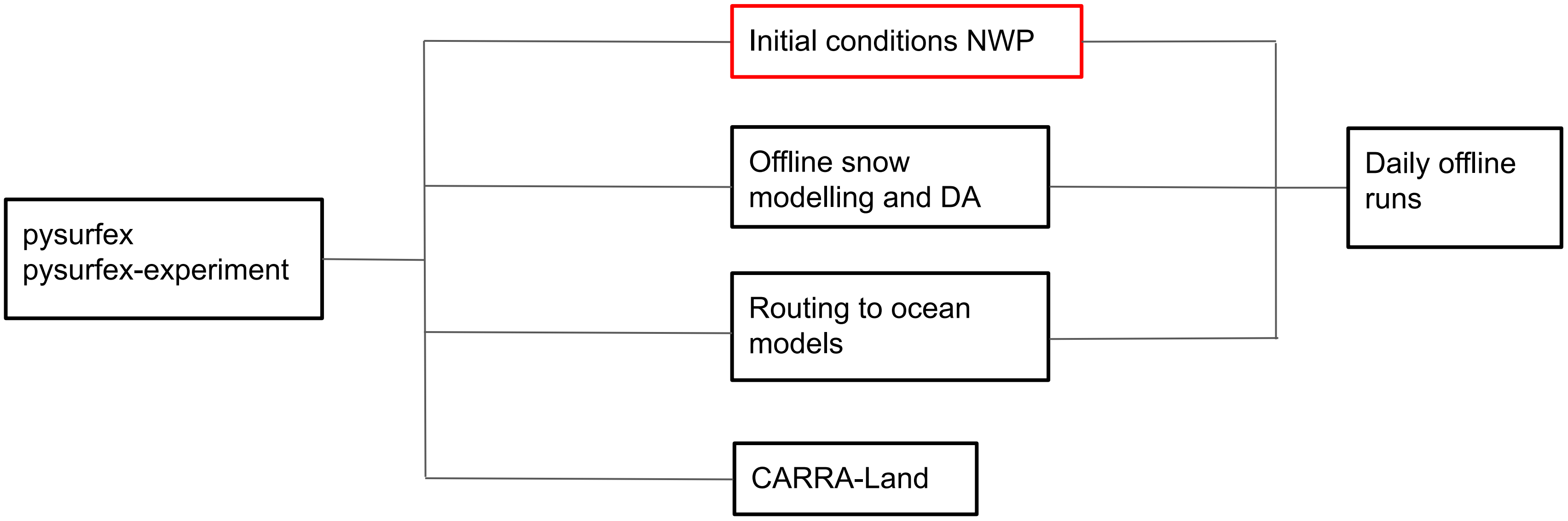
In operations:

- MetCoOp nowcasting suite, running hourly with 12h forecast
  - Quality control (QC) of T2m and RH2m
  - Horizontal OI of T2m and RH2m

- AROME-Arctic preop2
  - Create forcing for offline SEKF runs (land data assimilation)
  - QC of T2m, RH2m and snow depth
  - Horizontal OI of T2m, RH2m and snow depth

- CARRA2 pan-Arctic
  - Regional high-resolution re-analysis
  - Similar setup as in AROME-Arctic preop2

Figure 3: view of ecFlow scheduler for an offline pysurfex-experiment setup



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Offline system as initial surface conditions in NWP

Courtesy of Åsmund Bakketun

- Land surface model (LSM) performance depend on input data (atmospheric forcing)
- In NWP, errors (precipitation) are remembered by the LSM and might degrade following forecasts.
- To reduce this issue we rerun LSM with analysed forcing (MET Nordic analysis) data eventually providing improved initial conditions for the next atmospheric forecast
- The proposed method improved short range forecasts of 2m temperature and humidity at in situ stations, and increased the spatial accuracy in forecasting a convective precipitation event
- See: https://doi.org/10.1175/WAF-D-22-0184.1

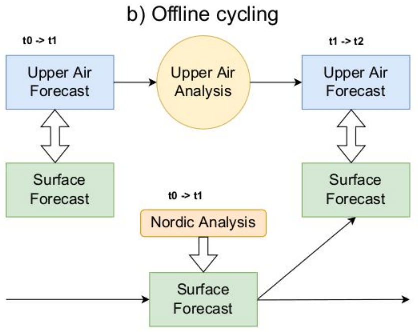
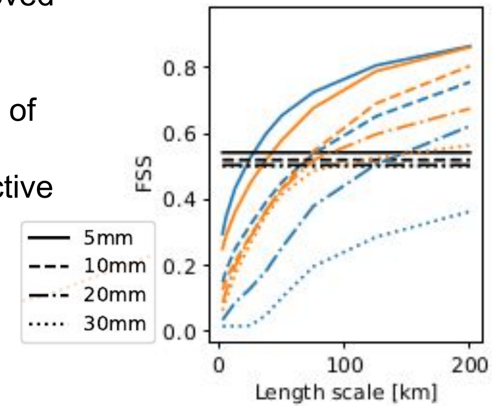


Figure 4: Schematics of the initialization strategy



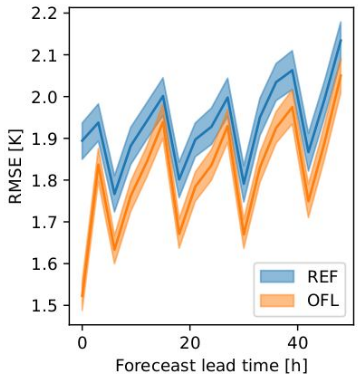


Figure 5: Fraction skill score (NEW orange vs OLD blue) (left), 2m temperature RMSE vs forecast lead time (right)

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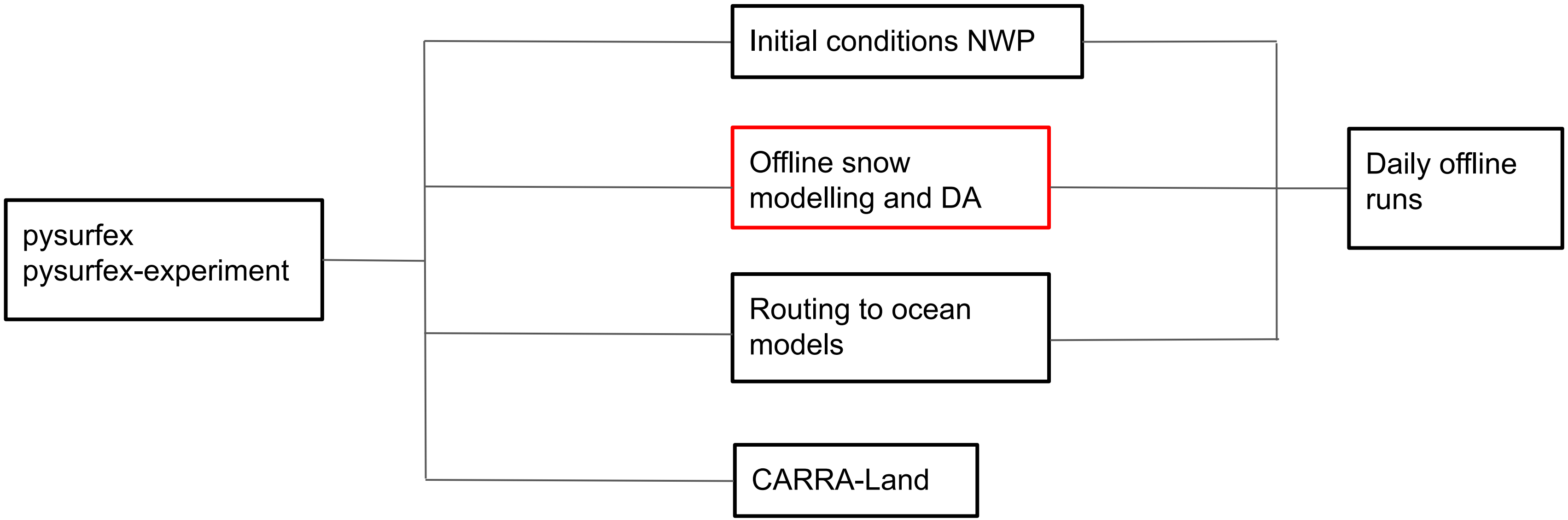

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Ongoing research activities on **snow modelling** and DA

Courtesy of Helene B. Erlandsen

Exp.:	**FRD95**	**FRe3**	**FRe12**	**De3p2**	**De12p12**	**De12p2m**	**De12p12 m**	**De12p12 ms**	**De12p12 mh**	**De12p12 mfs**
Soil w&T	FR	FR	FR	DIFF (D)	DIFF	DIFF	DIFF	DIFF	DIFF	DIFF
Snow	D95, 1 layer	ES, 3 layers (e3)	ES, 12 layers (e12)	ES, 3 layers	ES, 12 layers	ES, 12 layers	ES, 12 layers	ES, 12 layers	ES, 12 layers	ES, 12 layers
Patches	-			2 (p2)	12 (p12)	2	12	12	12	12
MEB	-	-	-	-	-	MEB (m)	MEB	MEB	MEB	MEB
Snow frac.	fs	fs	fs	fs	fs	1|0	1|0	1|0	1|0	fs
misc.								SOC (s)	hortonian flow (h)	

Table 1: Different offline model configurations tested, FRD95 close to current operational setting, De12p2m close to the new multi-layer physics setup

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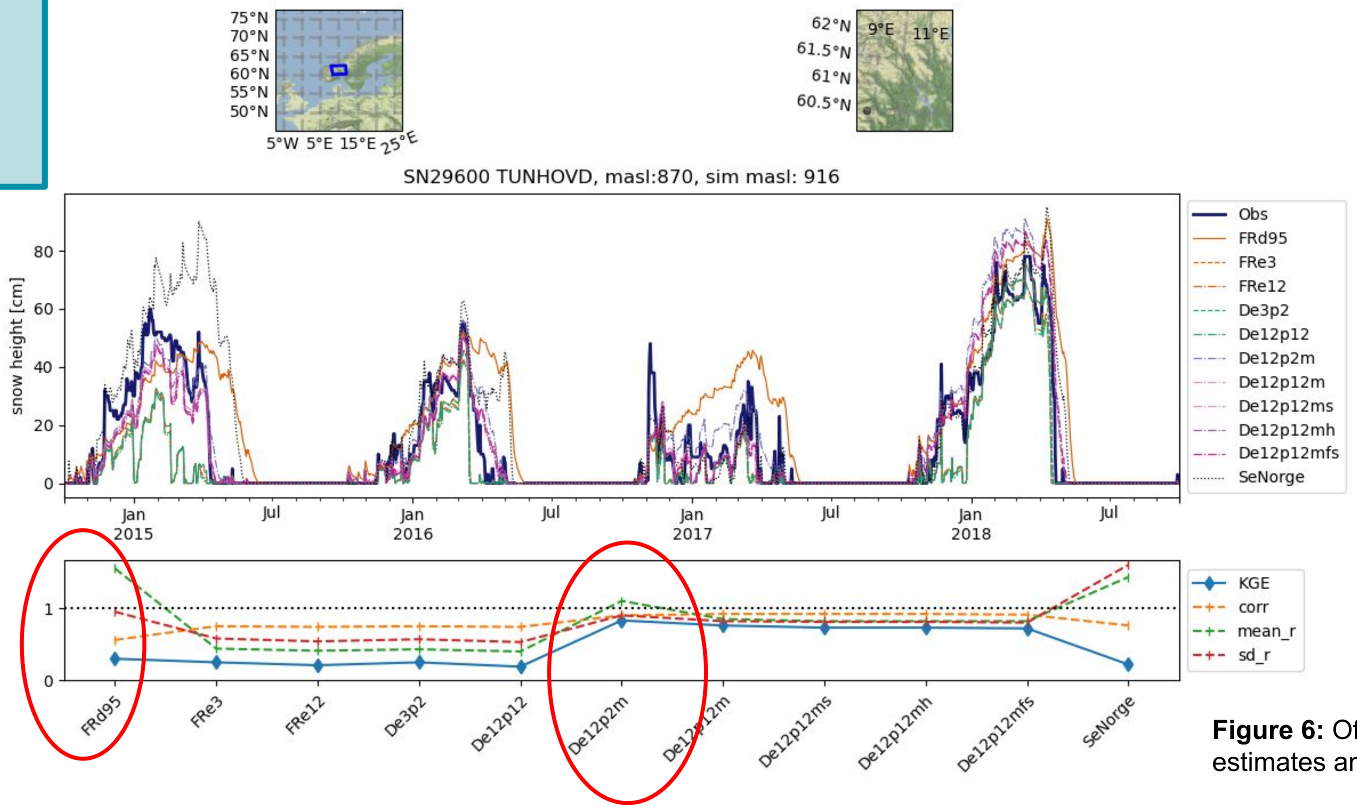
Ongoing research activities on **snow modelling** and DA

Courtesy of Helene B. Erlandsen

Improved scores for advanced physics option



xgeo 2022

Figure 6: Offline snow depth estimates and summary scores

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Ongoing research activities on snow modelling and **DA**

Quantify the difference between open-loop and snow DA:

- Offline experiments using pysurfex-experiment and pysurfex

- Period: 2022.10.01 - 2023.03.01

- Assimilation of bufr snow depth data over southern Norway (06 cycle)

- Create a blacklist of stations for validation, see figure to the right.

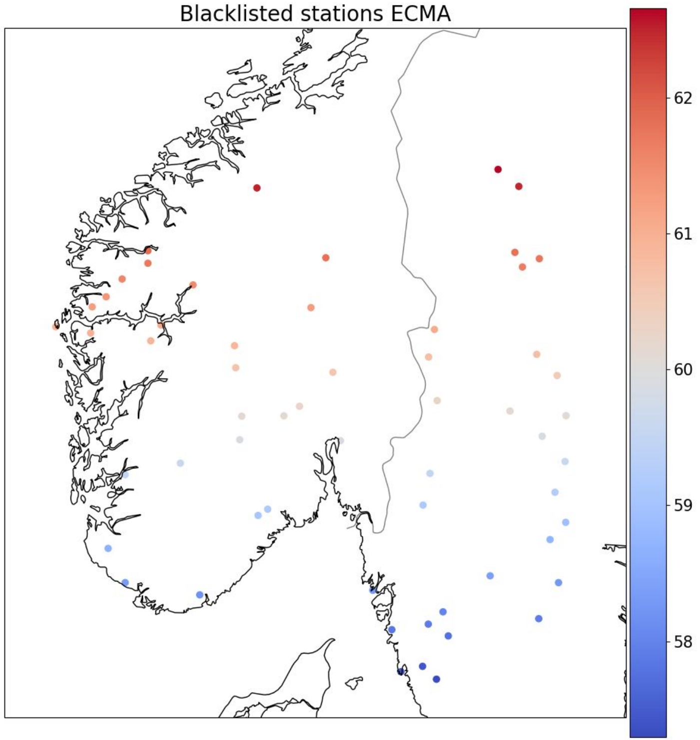
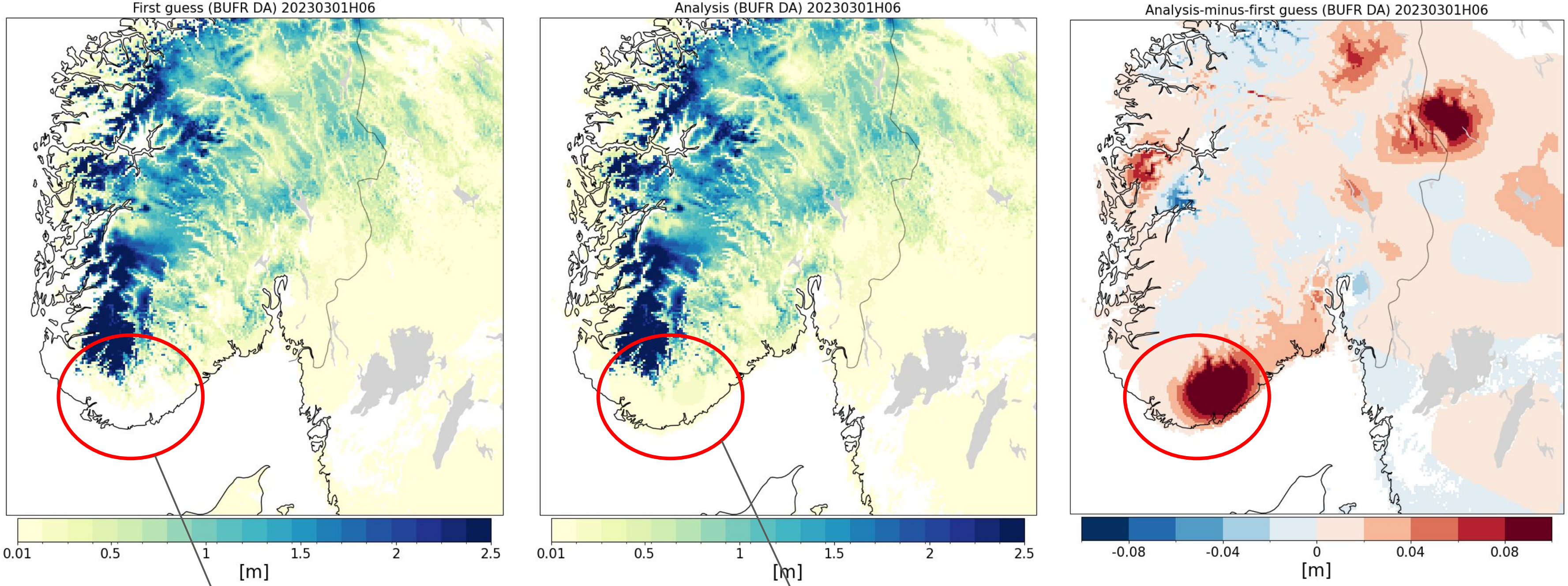


Figure 7: Position of blacklisted stations used for cross-validation in the snow data assimilation

Ongoing research activities on snow modelling and **DA**

Offline snow depth fields over south Norway and the horizontal OI



No snow if FG

Adds snow in the analysis

Analysis-minus-FG

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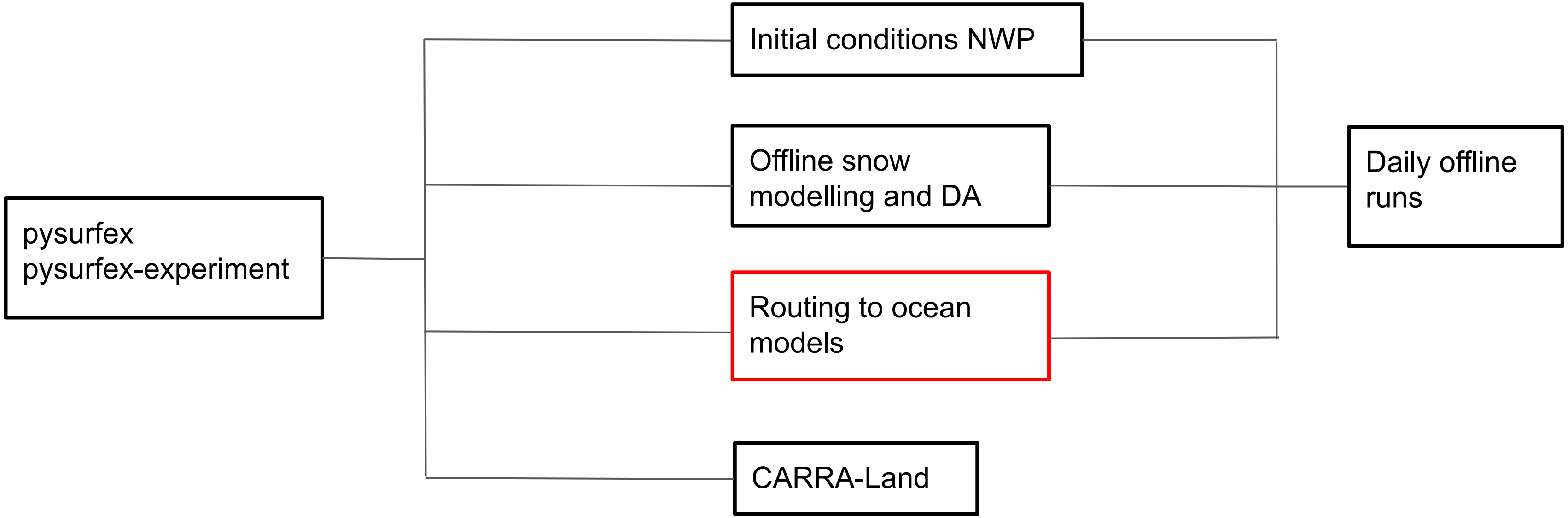
Ongoing research activities on snow modelling and **DA**

Summary statistics:

- Improvement in all metrics when averaged over all blacklisted stations.
- The open-loop run has too little snow (obs-minus-model) this is reduced with snow assimilation.
- The snow DA (most likely) compensates for underestimated solid precipitation.

Table 2: Summary scores for the different snow DA tests

Exp name	**Bias (#59) [m]**	**mse (#59) [-]**	**rmse (#59) [m]**	**nse (#59) [-]**
OL	0.053	0.0245	0.108	0.32
SWE (eps=0.8)	0.024	0.0147	0.088	0.45
SD (eps=0.8)	0.019	**0.0129**	**0.082**	**0.49**
EPS (eps=0.5)	**0.018**	**0.0129**	**0.082**	0.48
OL (snowsoilflux)	0.052	0.024	0.108	0.33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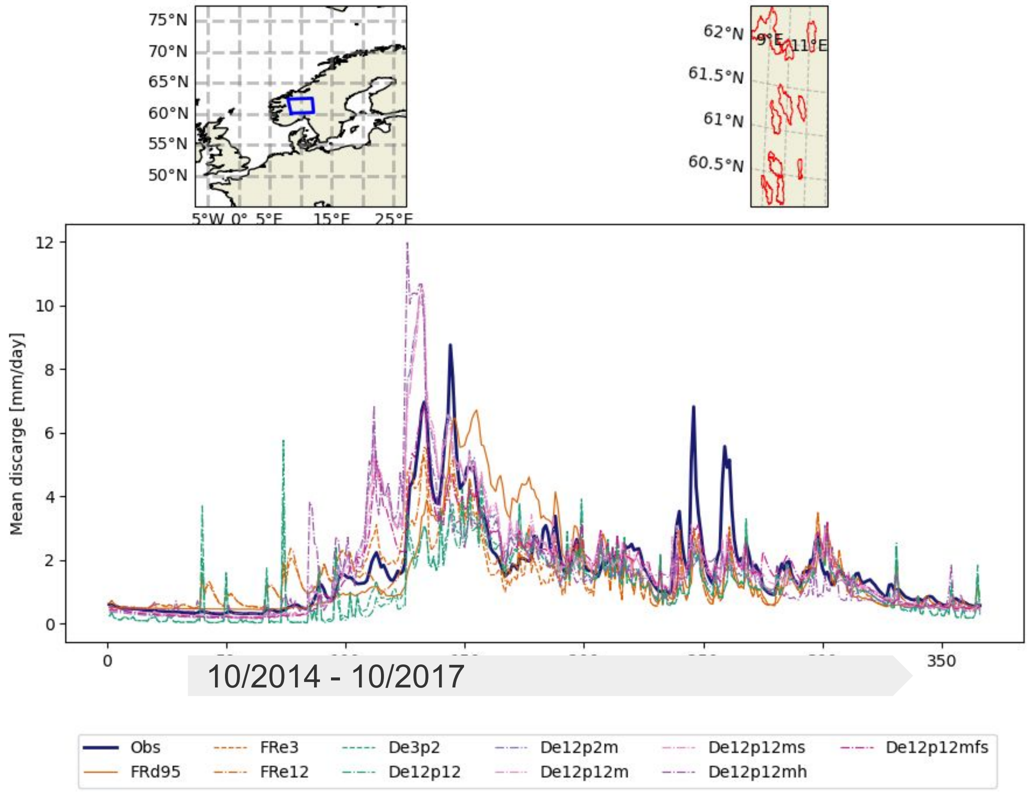
How does different model configurations affect river discharge

Courtesy of Helene B. Erlandsen



Grid cell runoff & drainage weighted in, given basin overlap (xESMF)

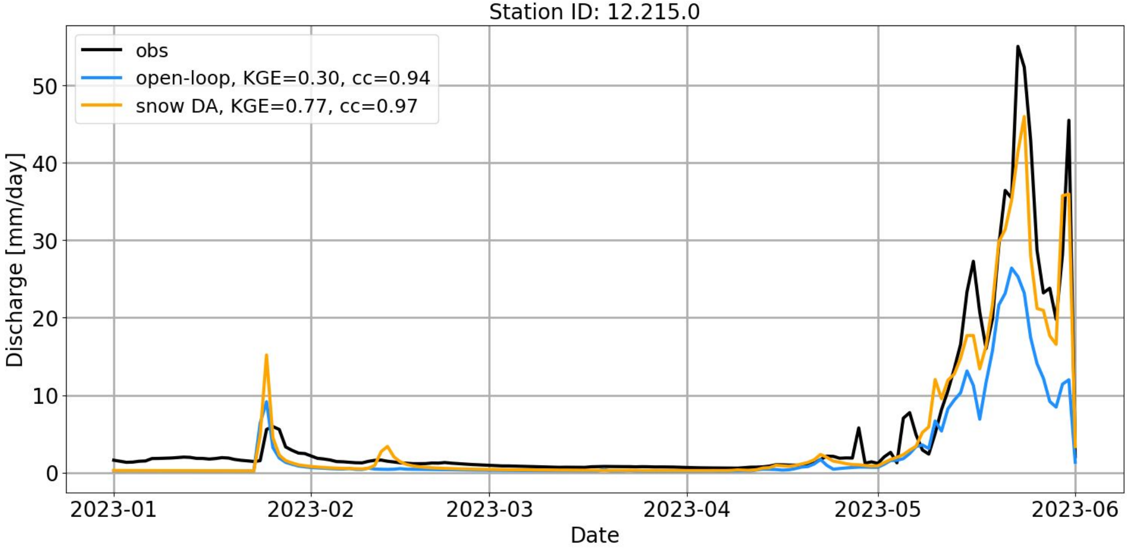
Discharge mean catchment KGE scores:

De12p12mfs	0.56
De12p2m	0.54
De12p12m	0.54
De12p12ms	0.51
FRe12	0.49
FRd95	0.47
FRe3	0.47
De12p12mh	0.35
De3p2	0.34
De12p12	0.32

Figure 8: (Left) Discharge time-series for the different model configurations. (Right) Mean catchment KGE scores for the different model configurations.

Downstream effects of snow DA

Runoff and drainage production and comparison with NVE observations



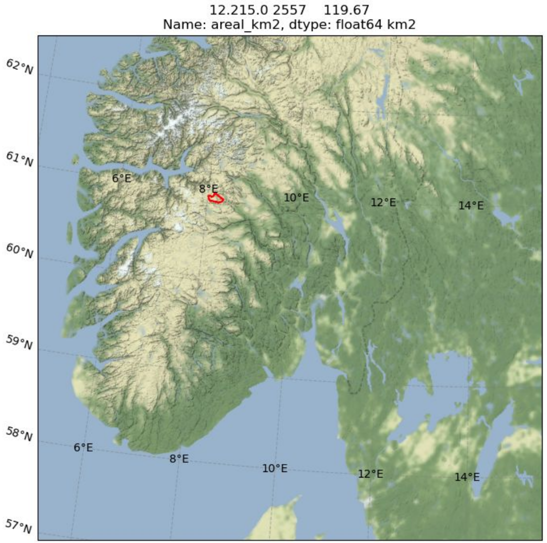


Figure 9: Example discharge time-series for Storeskar (Hemsedal)

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Downstream effects of snow DA

Summary verification scores:

- Increase in Kling-Gupta efficiency (KGE) scores
- Increase in correlation coefficient (R)
- No filtering for larger catchments (where our method has limitations)

Table 3: Summary scores for no snow DA (open-loop) and with snow DA

N=83	KGE	R	Bias (mm/day)
open-loop	-0.05	0.6	6.7
snow DA	0.22	0.68	4.8

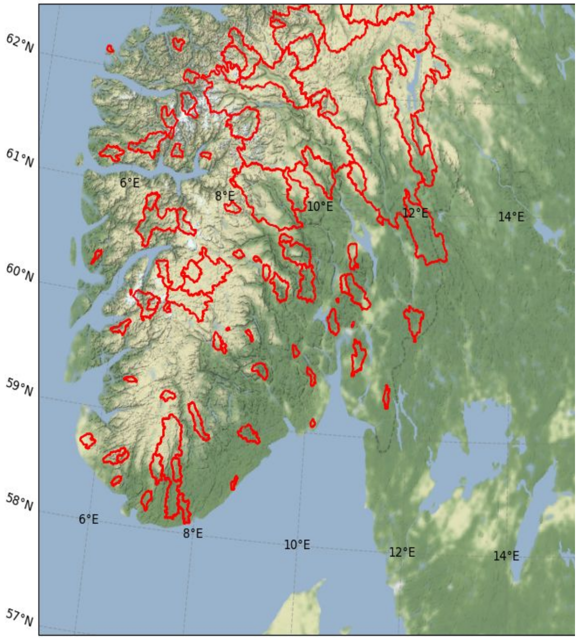
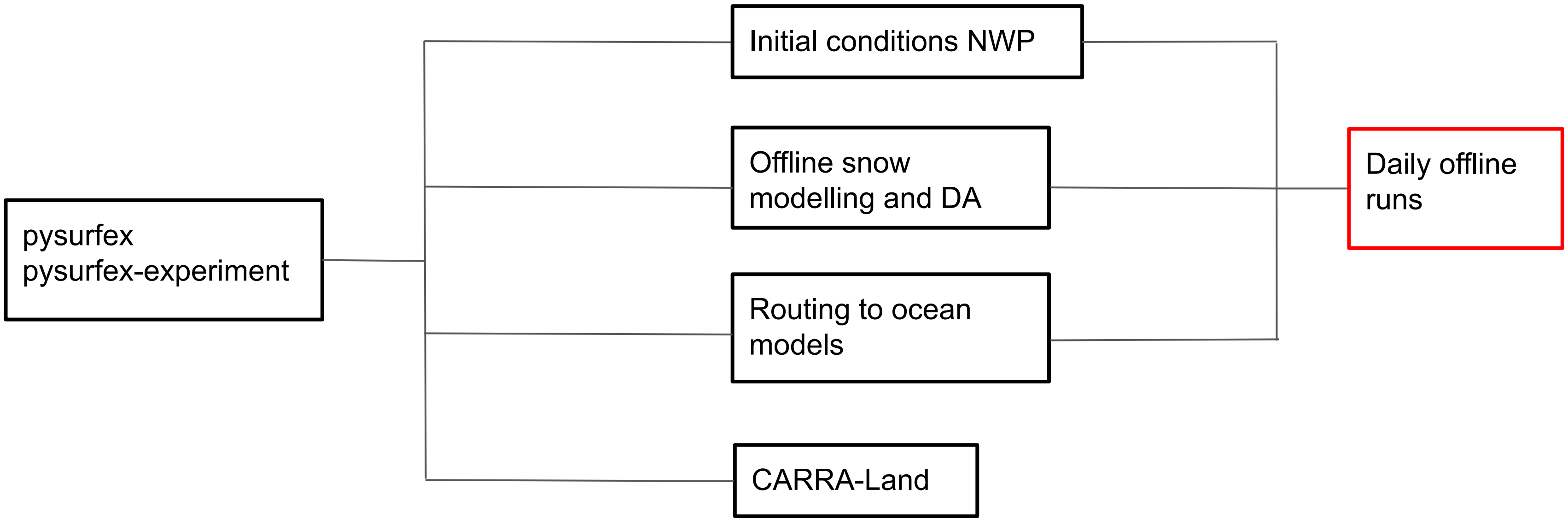


Figure 10: Catchments used in the summary statistics.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Daily offline runs

- MET-Nordic operational real-time:
  - Availability: last 3 days
  - Analyses and forecasts runs every hour
- MET-Nordic operational archive:
  - Availability: 2018.03.01 - now
  - Analyses available for every hour, forecasts available at 00Z, 06Z, 12Z, and 18Z.
- MET-Nordic rerun archive version 3:
  - Released January 2023.
  - Availability: 2012.09.01 - 2023.01.31
  - Includes analyses only
- 1 km resolution

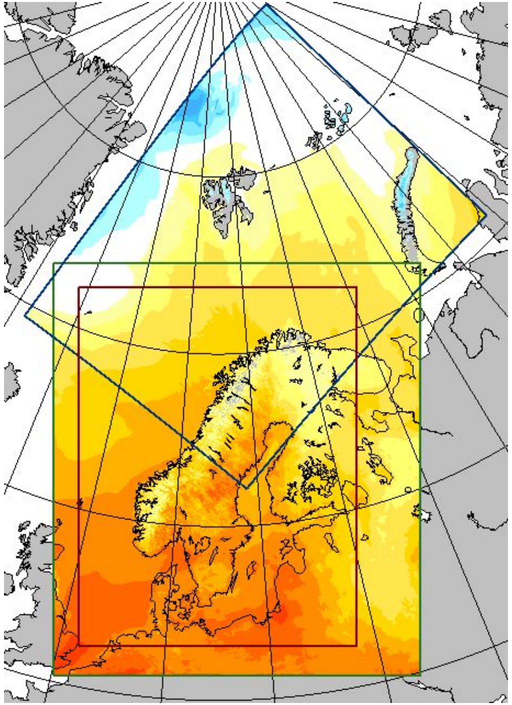

Figure 11: AROME-Arctic (blue box), MetCoOp (green box) and MET Nordic (red box)

https://github.com/metno/NWPdocs/wiki/MET-Nordic-dataset

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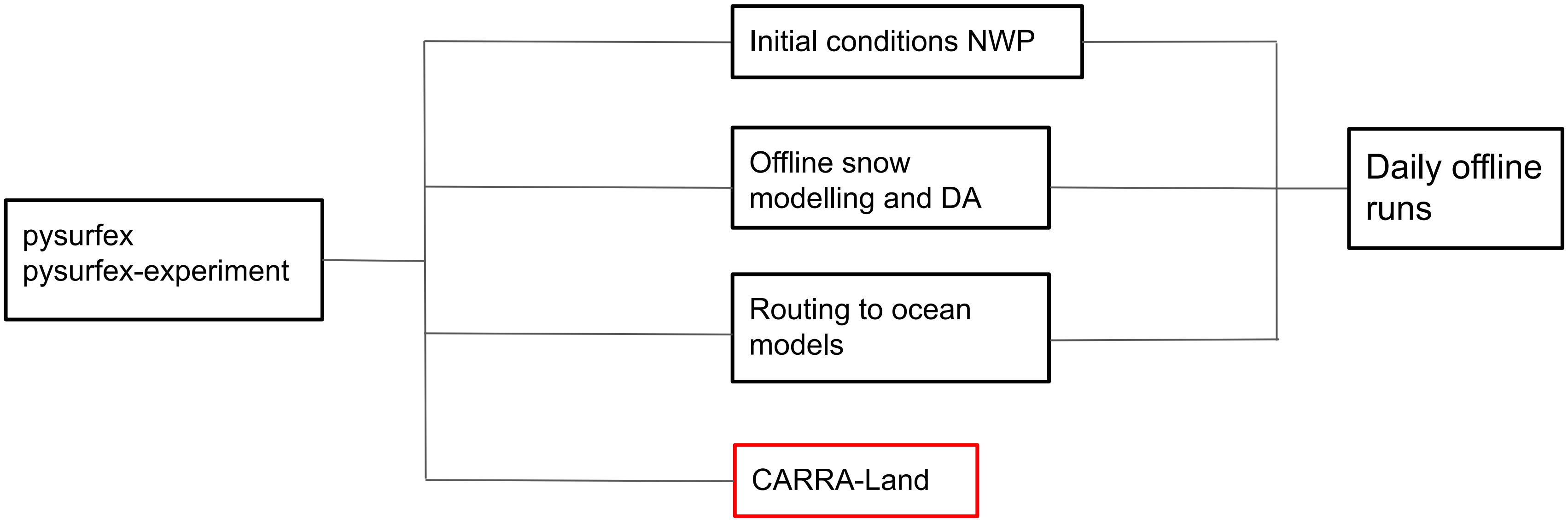

CARRA2 and CARRA-Land

- CARRA2: ISBA-DF, MEB, ES + pysurfex (gridPP + titan)
- 1991 - present
- Cryoclim and BUFR snow depth assimilation
- CARRA-Land: Working on next generation reanalysis; CERISE
- Unified land DA, i.e., screen level DA + more satellite observations
- Forcing from CARRA2 PA
- Land demonstrator

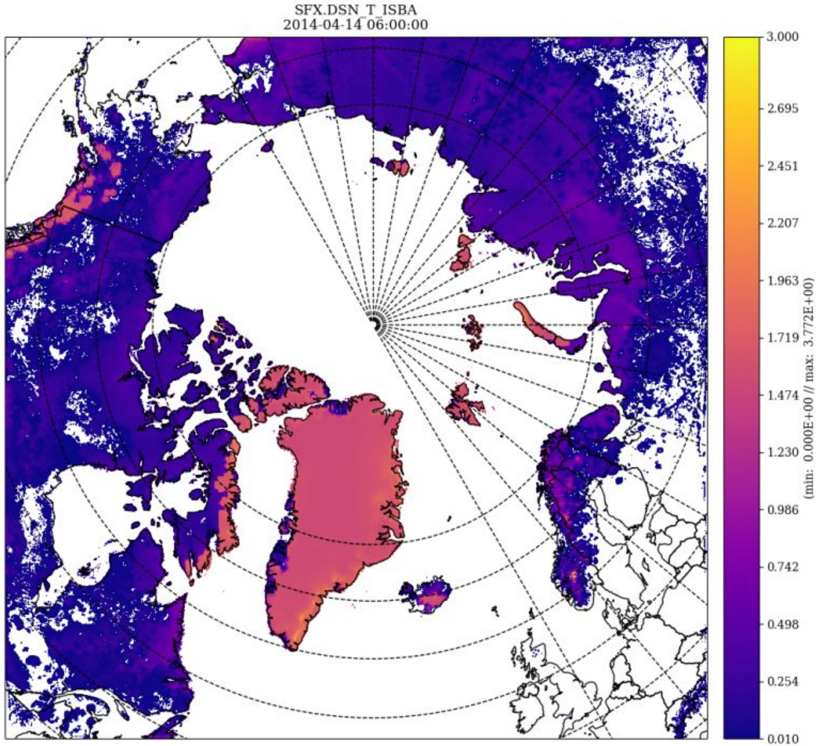

Figure 12: Illustration of the CARRA2 pan-Arctic domain

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Summary

- Developed tools to simplify offline SURFEX runs (pysurfex and pysurfex-experiment), important for potential new operational land surface product.
- We have demonstrated the usefulness of such a system in initializing short term NWP forecasts.
- Promising offline tests for the new multi-layer physics option (in terms of snow depth and runoff).
- The new setup for snow data assimilation titan + gridPP improves the snow depth estimates and the runoff when compared to open-loop.
- These model and data assimilation developments are planned to be implemented in a offline system running daily covering the MET-Nordic domain.