Using a reanalysis-driven land surface model for initialization of a numerical weather prediction system and its applications

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The joint 28th ALADIN Wk & HIRLAM ASM Toulouse 2018

- How to initialize the soil when going to more advanced soil schemes?
  - Coffee break discussions with Eric Bazile

What about re-running offline with best possible forcing and use it as initial values?

Bakketun et.al 2023

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Introduction

- NWP models need realistic boundary conditions (initial, lateral and lower) to provide accurate weather forecasts
- land surface is not chaotic, but could have long memory
- land-atmosphere interactions impact the weather throughout the simulation -> potential to consistently force the model in the wrong direction

Hypothesis and Research questions

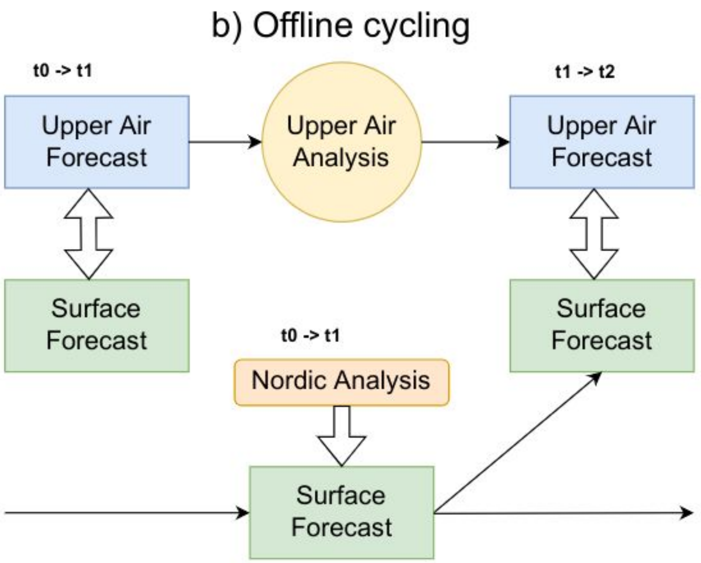
The current state of the land surface is a product of past weather (forcing).
+ A reanalysis should have smaller errors than a forecast for the same period.
=> Using the reanalysis to force and rerun the surface model will give a more accurate estimate of the current state.

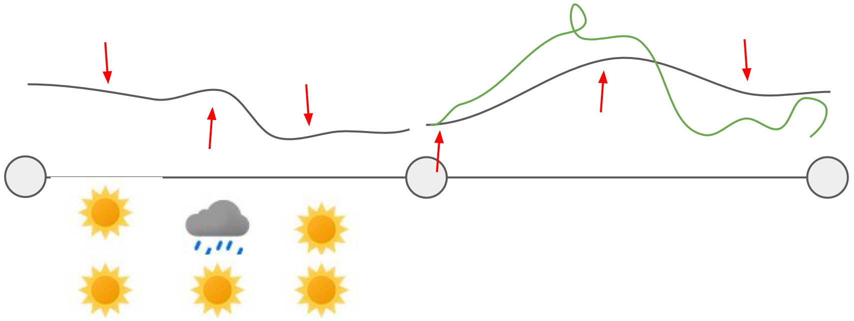
1. Are NWP forecasts over the Nordic countries sensitive to the land surface initial condition, in particular during convective precipitation?
2. Can we, by correcting forcing data for the land surface model with screen level observations, improve the surface analysis relative to a sequential DA method and potentially reduce the forecast errors?

Offline cycling

Use the best forcing data available and rerun the surface model.

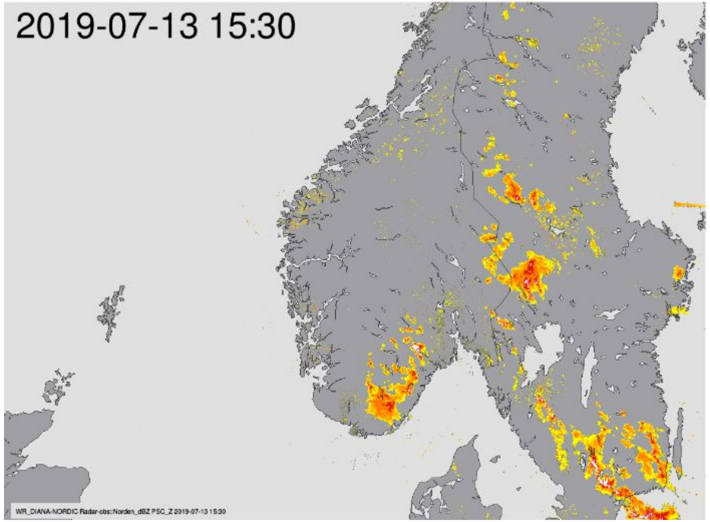
1. include much more observational data (netatmo and radar etc)
2. correct the full trajectory not only the state at analysis time
3. avoid the assumptions of the sequential DA schemes

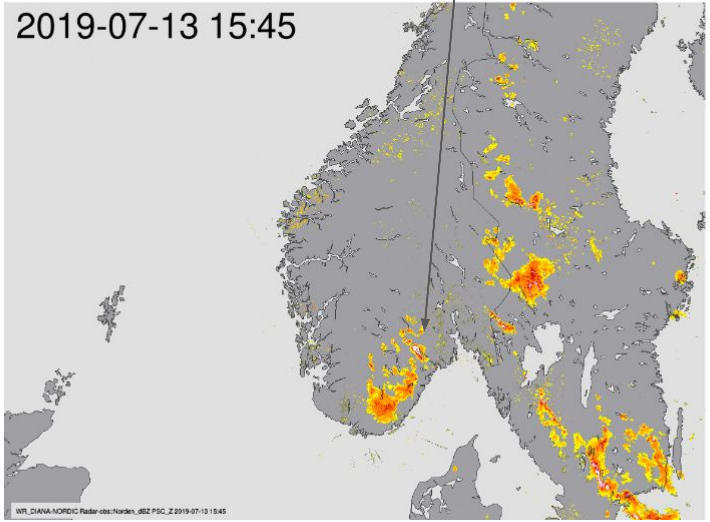




13 July 2019

- well forecasted
- not extreme amounts
- weak synoptic forcing -> perfect for testing the impact of surface conditions



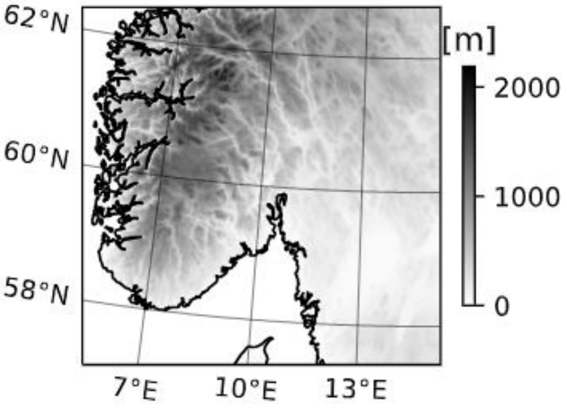


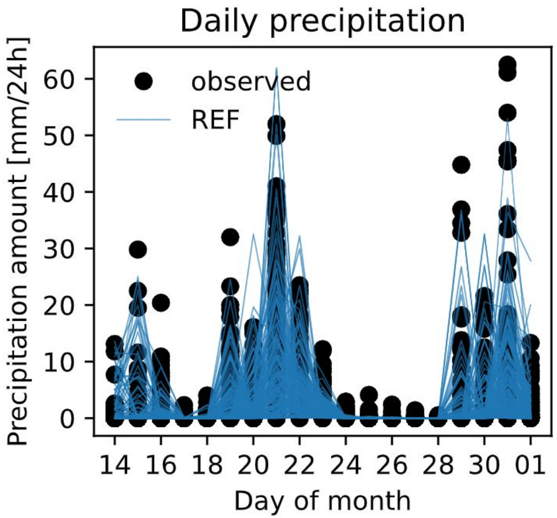
Experimental setup

July 2019
- includes a convective precipitation event and two low pressure systems

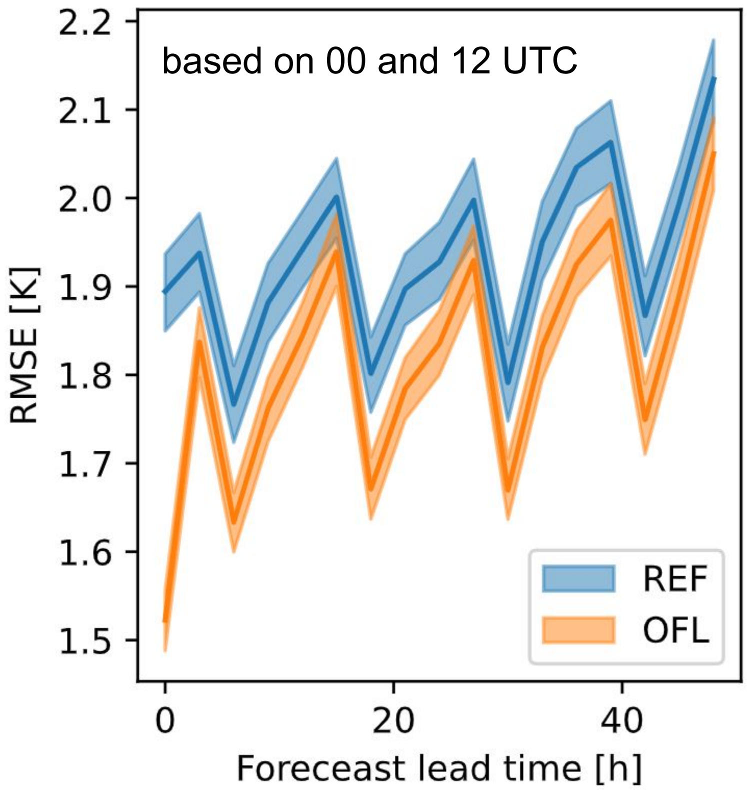
- reference simulation using SEKF for land surface analysis (REF)
- experiment using offline cycling and Nordic Analysis (OFL) https://github.com/metno/NWPdocs/wiki/MET-Nordic-dataset

results include
1. model comparison
2. validation of forecast variables (t2m, q2m)
3. spatial validation of precipitation (FSS) against nordic analysis

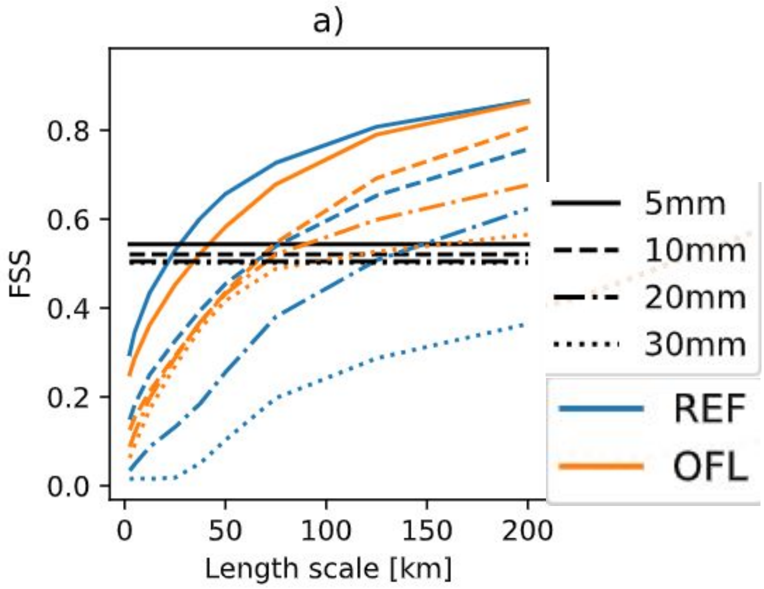




Validation of screen level variables (synop stations)



Convective precipitation event 13 July



Fractions Skill Score (FSS)

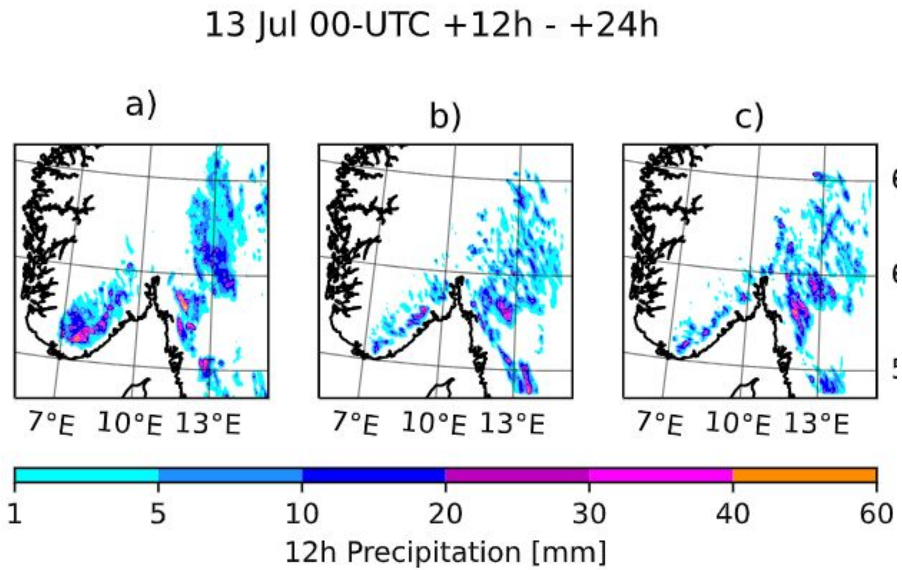


Fig.9 12h accumulated precipitation during 12-24 UTC on 13 July 2019. Nordic analysis product (a), REF (b), and OFL (c)

Conclusion from paper

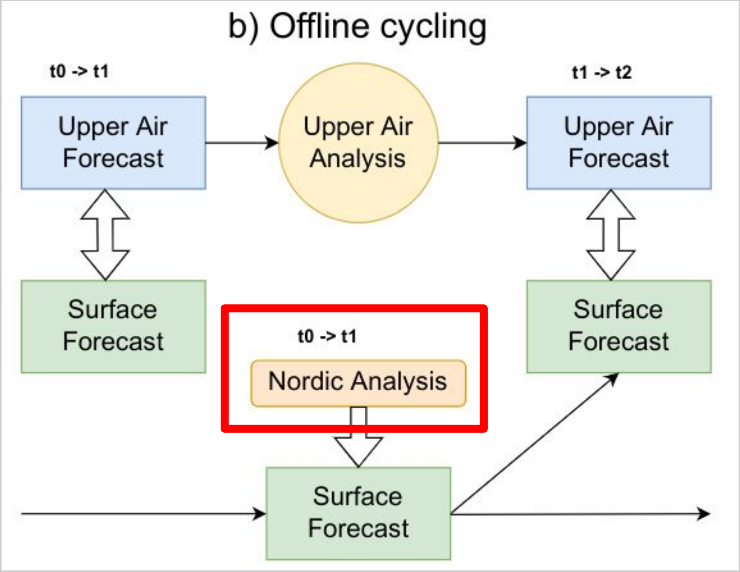
1. Short range weather forecasts **can be sensitive** to the land surface initial conditions, particularly during convective events with weak synoptic forcing.
2. By using high quality reanalysis product to drive the land surface model between forecast cycles, we achieve modified initial conditions, which show **consistent improvement of short range forecasts** in terms of T2m, Q2m and spatial precipitation pattern.

What if we don’t have a re-analysis?

- Create our own analysis!
  - T2M, RH2m (precipitation) [radiation]
  - QC of observations
    - titanlib (https://github.com/metno/titanlib)
  - Horizontal OI
    - gridpp (https://github.com/metno/gridpp)

Implemented in pysurfex

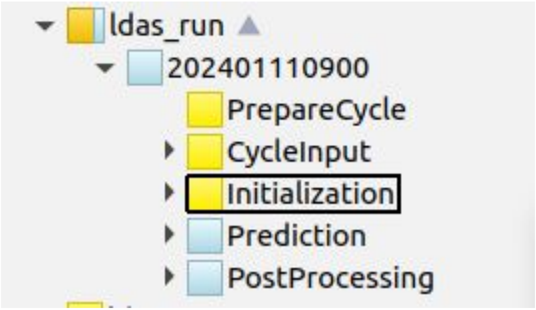
(https://github.com/metno/pysurfex)

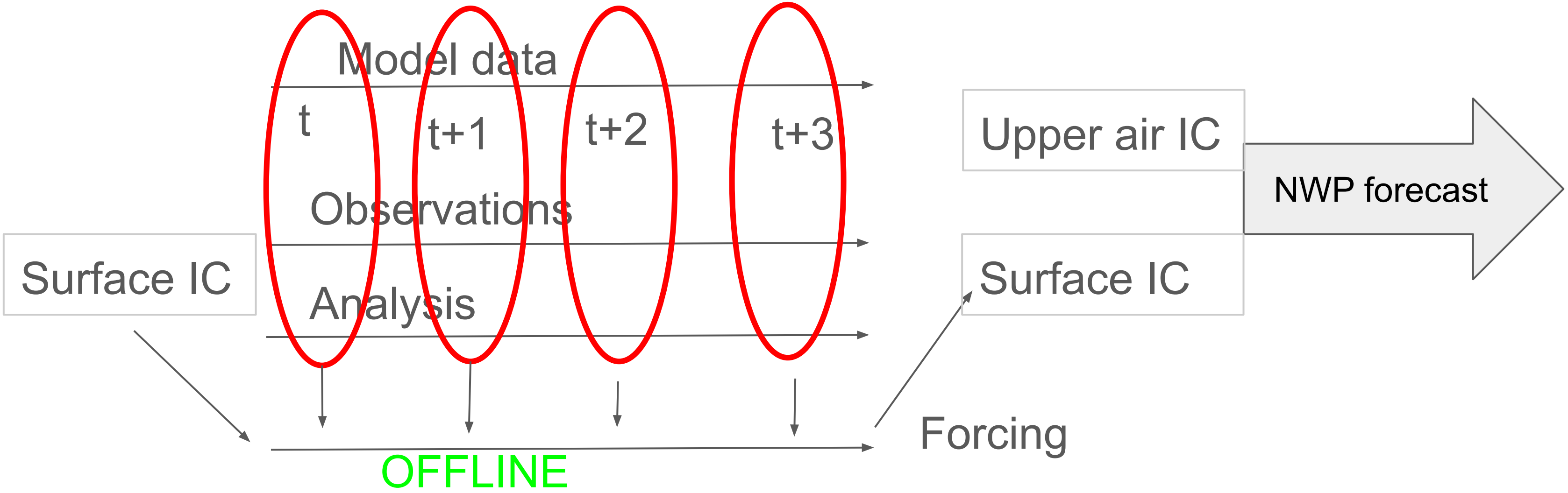


Wouldn’t it be nice if we also had a scheduler system for such offline runs?

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

- developed in the MET-Norway H2O project
- daily LDAS system to start production in 2024
    - Could re-use MET-Nordic re-analysis
- Creation of re-analysed forcing needed for other applications





DEODE prototype vs pysurfex experiment

- jointly developed
- latest pysurfex-experiment is now a plug-in to DEODE prototype (still a PR)!
    - sharing the “engine”
    - extending the suites and scheduler tasks
        - user defined suites and tasks
    - Could be applied to other applications? ACCORD?

Future plans:

- Analysed forcing as input to DEODE extremes on demand (planned 2025)
    - offline Pan-European system analysing forcing from global Digital Twin (DT)
- Replace SEKF in AROME-Arctic pre-operational run at MET-Norway with reanalyis driven land surface model
    - Harmonie script system using pysurfex

Thank you for the attention!

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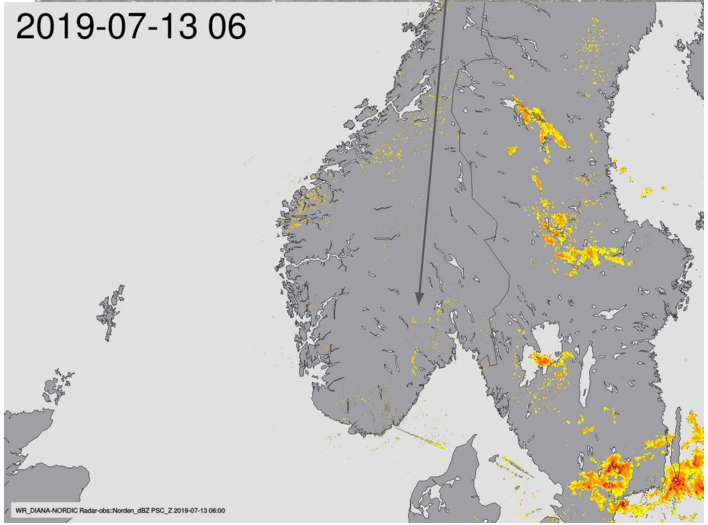
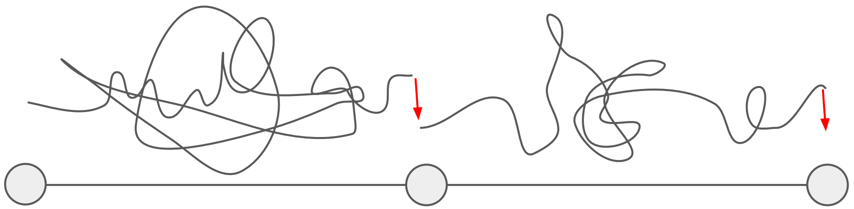
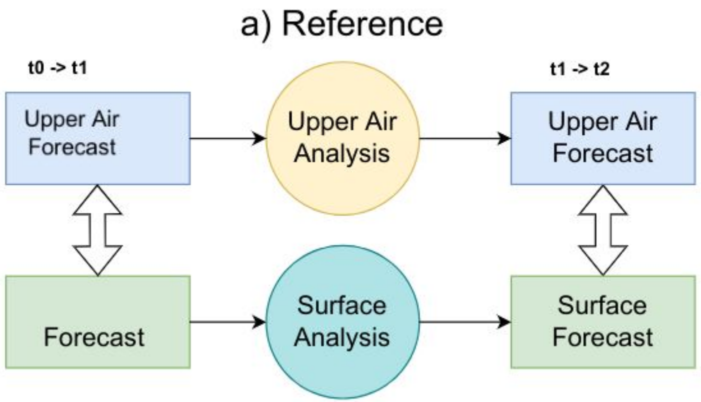


Sequential data assimilation

More accurate initial conditions are usually obtained through sequential DA schemes like OI, EKF or EnKF.

They correct prognostic state variables based on some observed quantity. Usually not the same variable, but somehow related.





$$\boldsymbol{x}_{\mathrm{a}}(t_i) = \boldsymbol{x}_{\mathrm{f}}(t_i) + \mathbf{K}_i\left(\boldsymbol{y}_{\mathrm{o}}(t_i) - h_i[\boldsymbol{x}_{\mathrm{f}}]\right)$$

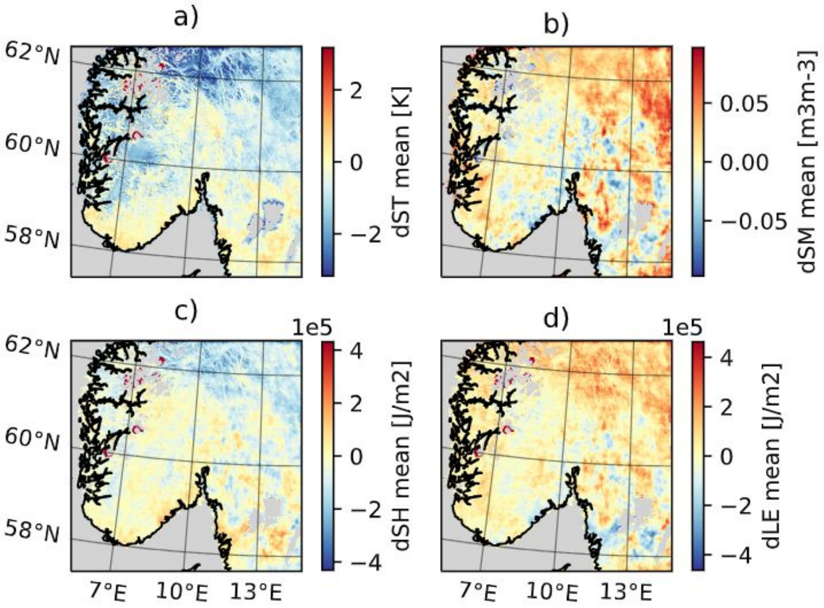
$$\mathbf{K}_i = \mathbf{B}\mathbf{H}^T\left(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}\right)^{-1}$$

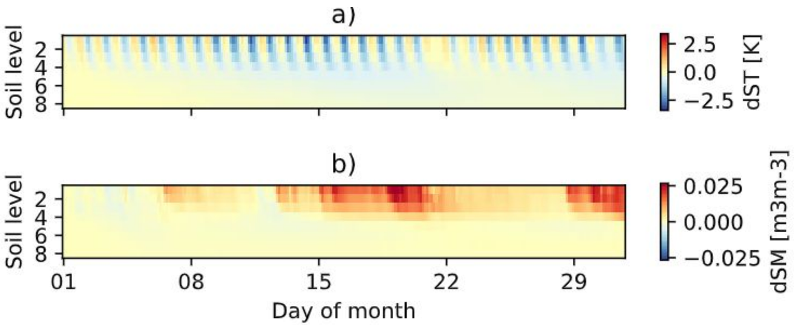
Model comparison

monthly mean differences

- soil temperature (ST): differences following topography (resolution and height correction of reanalysis)
- soil moisture (SM): patterns related to precipitation event early in the period (13 July)

Latent and sensible heat flux are consistent with state variables



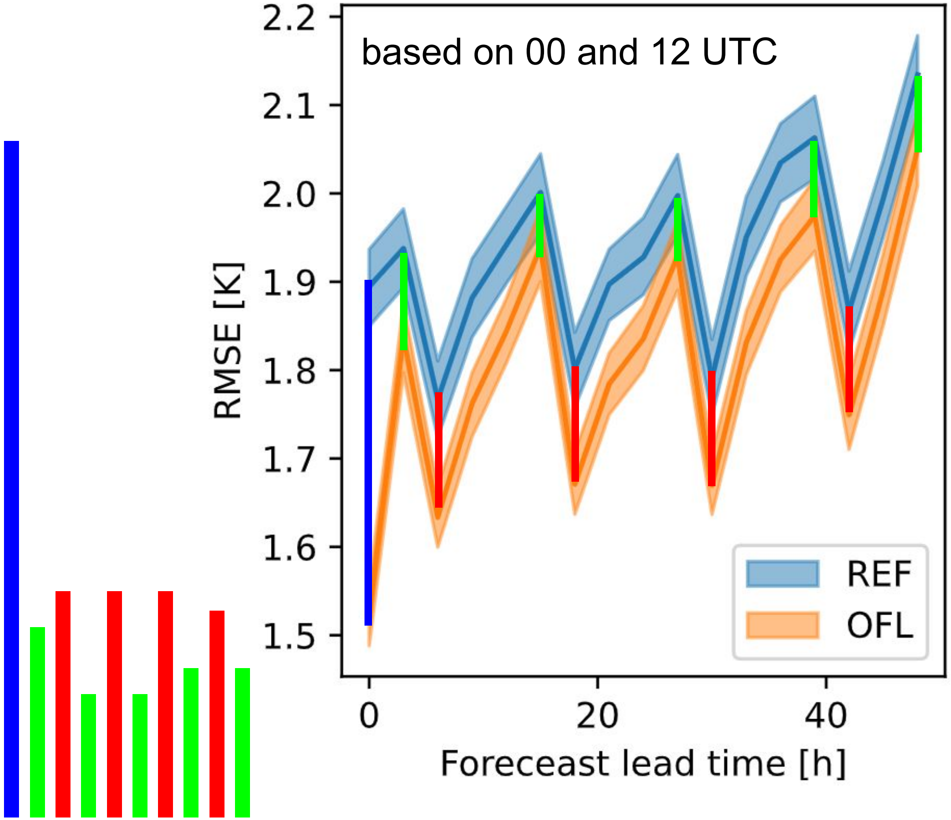


Validation of screen level variables (synop stations)

- Improved t2m and q2m up to +48h
- RMSE max at 15 UTC

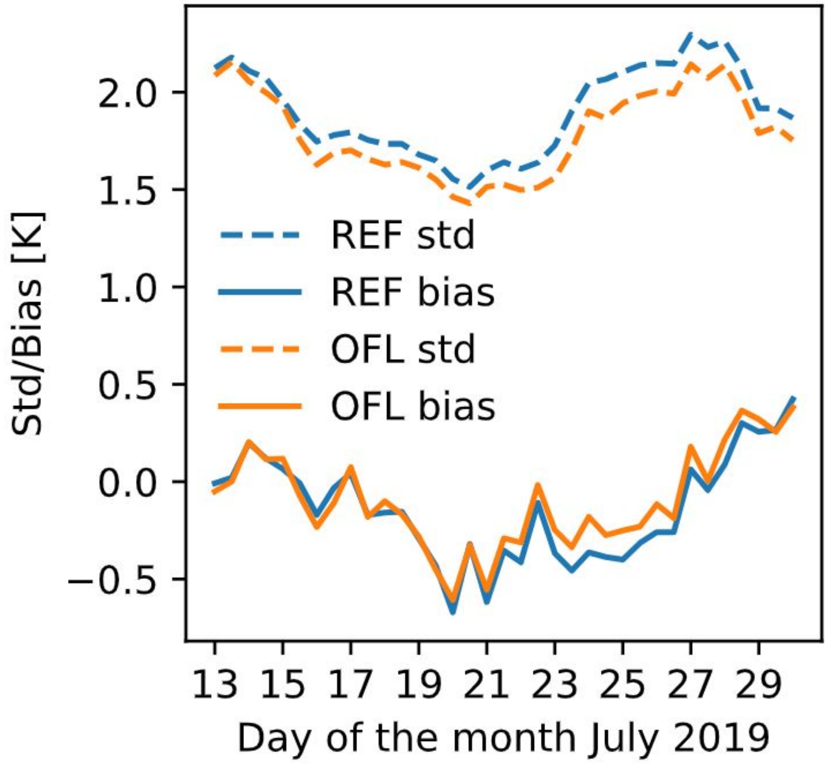
  RMSE min at 06 UTC

- during night soil temperature has more impact on air temperature
- more nonlinear processes during day, and soil moisture is a key component
- model error dominates at 15 UTC, require development of model processes

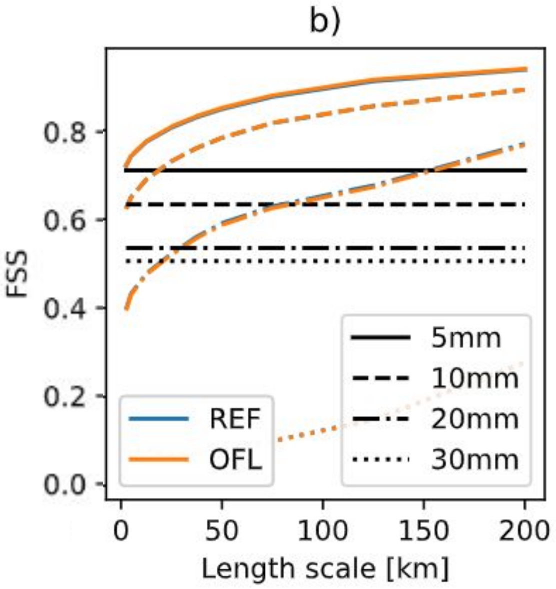


Validation of screen level variables (synop stations)

- weather dependent errors
-



Large scale precipitation event 20 July



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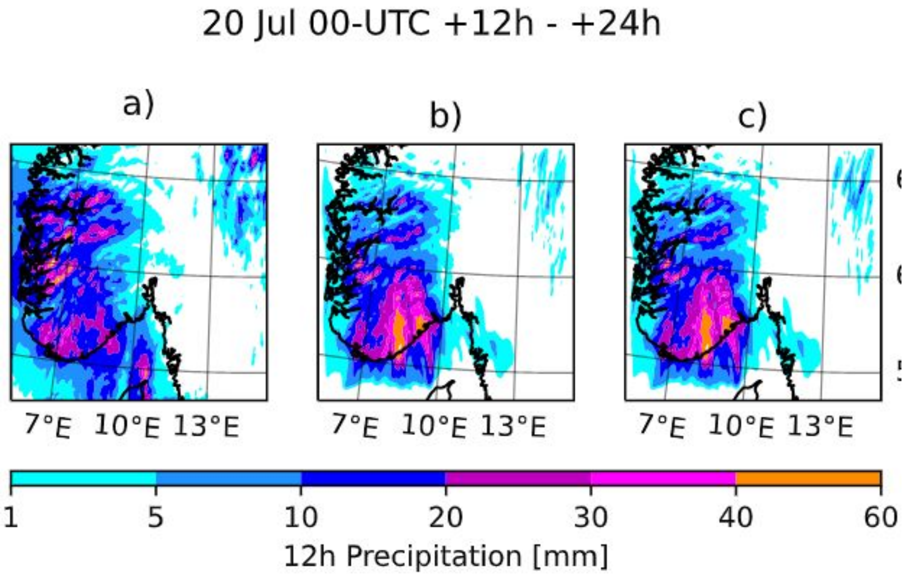
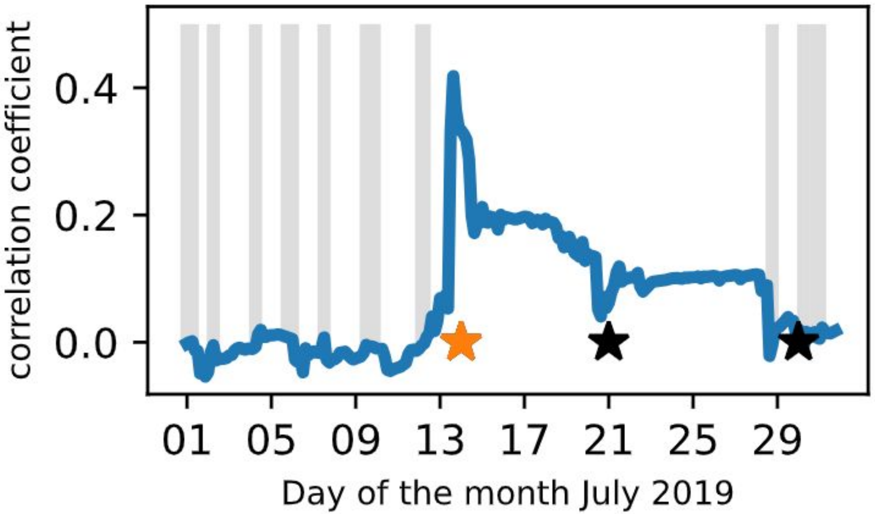


Fig.9 12h accumulated precipitation during 12-24 UTC on 13 July 2019. Nordic analysis product (a), REF (b), and OFL (c)

Memory of precipitation errors

The spatial correlation between ΔP_event and ΔSM(t) is elevated for two weeks and even “surviving” a large scale precipitation event.

Demonstrates the importance of keeping the correct memory



$$R(t) = corr(\Delta P(t_e), \Delta SM(t))$$