Representation of land surface physics in AROME-Arctic: Utilizing the multi-layer soil, snow and vegetation options

Å. Bakketun, J. Blyverket, P. Samuelsson, M. Müller
Mainly sea

Land surface processes at high latitudes are challenging because of
- snow cover
- snow interacting with vegetation
- polar night with strong inversions
- freeze/thaw of soil water
Multi-Layer surface physics

**Force-restore (operational AROME-Arctic setup)**

- **ISBA-3L** 3 layer soil (top, root, deep)
- **D95** bulk snow scheme
- **OI** surface analysis

**Multi-layer physics**

- **ISBA-DIF** 14 layer soil (0.01m, ..., 12m)
- **ISBA-ES** 12 layer explicit snow scheme
- **MEB** Multi Energy Balance for vegetation
- **SEKF** Simplified Extended Kalman Filter for surface analysis (constant $B$)
Model setup

code: git@hirlam.org:users/metno/Harmonie arome_arctic_cy43

multi-layer physics:
  - ISBA-DIF (Decharme et al. 2011)
  - ISBA-ES (Decharme et al. 2016)
  - MEB (Boone et al. 2017)

surface analysis: SEKF (Bakketun in prep.) (t2m,rh2m -> wg6, ..., wg2, tg2, tg1)

experiment: start at 2019-09-01, 3h cycling for one year. 48-67 hour forecast in validation periods, Dec 2019, April - June 2020 and Dec 2020.

reference: Similar experiment with ISBA-Force Restore (FR), D95, MEB deactivated and OI surface analysis (CANARI)
## Experiment timeline

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>c</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>AA_AP (SEKF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>AA_FR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AA_AP (open loop)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Period of interest, snow melting season**

Cold start from IFS, 3h cycling, long forecasts for validation. X initialised from y.
All station summary time series +00
Spring validation period April - July 2020

AROME-Arctic-AP T2M 2020.04-2020.07

AROME-Arctic-AP Q 2020.04-2020.07
Spring validation period April - July 2020

AROME-Arctic-AP T2M 2020.04-2020.07

AROME-Arctic-AP RH2M 2020.04-2020.07
Spring validation period April - July 2020

leadtimes = 6

T2M

RMSE(SEKF) - RMSE(OL)
RMSE(SEKF) - RMSE(FR)
Reference has cold bias at inland stations

Dot size and colour indicate MAE and bias in T2M respectively
Reference has cold bias at inland stations

Dot size and colour indicate MAE and bias in T2M respectively.

Reduced cold bias with multi-layer surface physics.

Dot size and colour indicate MAE and bias in T2M respectively.
Reference struggles with warming event

T2M
obs

T2M bias
Multi-layer
Ref
Multi-layer physics

Snow depth

Snow depth 2020-05-15 00:00:00

Snow depth 2020-06-06 00:00:00

reference
Snow

T2M obs

T2M bias

Multi-layer

Ref

median snow depth

DSN_T-ISBA DIF

DSN_T-ISBA FR
Challenges

- Dramatic changes to model system -> difficult to isolate impact of each scheme

- Compensating errors could show up, retuning of the system required

- The current operational system has a very effective surface analysis, acts as a sink for errors in the atmospheric model. Such large increments should be avoided for the multi-layer models.

- A realistic model should be provided realistic input data.