Impact of observations on the AROME-Arctic regional model

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Acknowledgment: Niels Bormann & Heather Lawrence
Outline

1. Introduction of the NWP system
2. The OSE strategy
3. The available observations
4. Impact study: 2 Periods
5. Concluding remarks
The DA and NWP system

System setup: (Harmonie cycle 40h1.1.1)
-- AROME-Arctic
-- Model level definition: 65 level
-- Horizontal resolution 2.5 km
-- Non-hydrostatic dynamic
-- Physical parametrization: Harmonie-AROME
-- Data assimilation: 3D-VAR
  OI for surface
-- 3-hourly cycling
-- Lateral boundary conditions: ECMWF
-- Observations: Conventional, satellite
-- Satellite: AMSU-A, MHS, IASI, Scatterometer (L2), AMV
-- Blacklist of conventional observations: IFS decision

-- Large scale information taken into account using spectral mixing between first-guess and LBC
OSE experiments in Alertness

Alertness task 2.5: In frame of the APPLICATE project, ECMWF is running OSE experiments and sharing with us the results to be used as lateral boundary conditions (LBCs).

- They performed two series of Global OSE: Global and Arctic (lat >= 60) observations denial.

**LBC Options:**

- **LBC1:** Global Control
- **LBC2:** Global Arctic Obs Denial
- **LBC3:** Global Obs Denial

**Arctic Limited Area Model Assimilation Setups:**

- (a) LAM control
- (b) LAM Obs Denial

### Relative and Total Impact of Observations:

<table>
<thead>
<tr>
<th>Case</th>
<th>Global Control + LAM control</th>
<th>vs</th>
<th>Global Control + LAM Obs Denial</th>
<th>⇒</th>
<th>Impact of obs in Arctic LAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td>Global Control + LAM Obs Denial</td>
<td>vs</td>
<td>Global Arctic Obs Denial / Global Obs Denial + LAM Obs Denial</td>
<td>⇒</td>
<td>Impact of obs through LBC in Arctic LAM</td>
</tr>
<tr>
<td>Case 3</td>
<td>Global Control</td>
<td>vs</td>
<td>Global Arctic Obs Denial</td>
<td>⇒</td>
<td>Impact of non-Arctic observations on Arctic (LAM) NWP</td>
</tr>
<tr>
<td>Case 4</td>
<td>Global Control + LAM Control</td>
<td>vs</td>
<td>Global Arctic Obs Denial / Global Obs Denial + LAM Obs Denial</td>
<td>⇒</td>
<td>The Total impact of observations</td>
</tr>
</tbody>
</table>

The Total impact of observations = Impact of obs in Arctic LAM + Impact of obs through LBC in Arctic LAM

Global study: Bormann et al. 2019; Arctic study: Lawrence et al. 2019
### Lists of OSE Experiments

<table>
<thead>
<tr>
<th>Observations</th>
<th>Impact through LAM DA (Case 1)</th>
<th>Impact through LBC (Case 2)</th>
<th>Total impact (Case 4)</th>
<th>Impact of non-Arctic observation (Case 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave satellite radiances</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Microwave temperature sensitive radiances</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Microwave humidity sensitive radiances</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Infrared satellite radiances</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Atmospheric motion vectors (AMV)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional observations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Radiosonde observations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Surface pressure observations</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOP1 observations</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* X indicates tested for both SOP periods

### LBC Description

<table>
<thead>
<tr>
<th>LBC2: Arctic denial experiments</th>
<th>LBC3: Global denial experiments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All microwave satellite radiances</td>
<td>All microwave satellite radiances</td>
</tr>
<tr>
<td>All microwave temperature sensitive radiances</td>
<td>All microwave temperature sensitive radiances</td>
</tr>
<tr>
<td>All microwave humidity sensitive radiances</td>
<td>All microwave humidity sensitive radiances</td>
</tr>
<tr>
<td>All infrared satellite radiances</td>
<td>All infrared satellite radiances</td>
</tr>
<tr>
<td>All atmospheric motion vectors (AMV)</td>
<td>All atmospheric motion vectors (AMV)</td>
</tr>
<tr>
<td>All conventional observations</td>
<td>All conventional observations</td>
</tr>
<tr>
<td>All radiosonde observations</td>
<td>All radiosonde observations</td>
</tr>
<tr>
<td>All surface pressure observations</td>
<td>All surface pressure observations</td>
</tr>
<tr>
<td>All SOP1 observations</td>
<td>All SOP1 observations</td>
</tr>
</tbody>
</table>
OSE over SOP1 period

Experiments period: 10 February to 31 March 2018
10 - 14 February warming period

Some of the experiments were stopped with one month verification period due to lack computational

The denial experiments concern only the upper-air assimilation. The surface assimilation remained untouched

Concentrate mainly on upper-air impact due to presentation time constraint
Relative impact of microwave radiances on AROME-Arctic forecasts

**Impact through local DA (Case 1)**

Verification against radiosonde observations
RMSE of Relative Humidity (%) (OSE140MW - OSE140CM)
Period: 20180215 - 20180331

**Impact through LBC (Case 2)**

Verification against radiosonde observations
RMSE of Relative Humidity (%) (OSE140MMW - OSE140MW)
Period: 20180215 - 20180331

**Total impact (Case 4)**

Verification against radiosonde observations
RMSE of Relative Humidity (%) (OSE140MMW - OSE140CM)
Period: 20180215 - 20180331

- **Relative humidity**
  - RH T Geo
  - Significance Test

**Graphs**

- Normalized mean RMSE diff (60% conf) vs OSE140CM
  - Selection: ALL using 8 stations
  - Period: 20180215-20180331
  - Relative humidity 850hPa Hours: 00,12

- Normalized mean RMSE diff (60% conf) vs OSE140CM
  - Selection: ALL using 8 stations
  - Period: 20180215-20180331
  - Temperature 850hPa Hours: 00,12

- Normalized mean RMSE diff (60% conf) vs OSE140CM
  - Selection: ALL using 8 stations
  - Period: 20180215-20180331
  - Geopotential 850hPa Hours: 00,12
Relative impact of microwave radiances on AROME-Arctic forecasts (relative humidity at 850 hPa)

Impact of Local DA (CASE 1)

Local DA (Case 1) / Total Impact (Case 4) / LBC (Case 2)

Note the relatively shorter period – one month
Relative impact of satellite observations

IASI- LDA; IASI total impact; ATOVS- LDA; ATOVS total impact

Loc MW; Tot MW; Loc IASI; Tot IASI; Contr

Impact through LBC

**IASI:**
Positive impact on geopotential in lower troposphere and negative impact in upper-tropo and stratosphere.

**ATOVS:**
Positive impact on geopotential in lower troposphere and negative impact in upper-tropo and stratosphere.
### Impact through local DA:

**AMSU-A:**
- **Humidity:** Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Neutral Impact
- **Wind Speed:** Slightly Positive Impact

**MHS:**
- **Humidity:** Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Neutral Impact
- **Wind Speed:** Slightly positive impact on wind speed slightly negative impact in lower troposphere up to 12h forecast

**ATOVS:**
- **Humidity:** Positive Impact on humidity below 700 hPa, negative impact at 700 hPa up to 12h
- **Geopotential:** Neutral Impact
- **Temperature:** Positive to neutral impact.
- **Wind Speed:** Slightly Positive Impact

### Impact through LBC:

**AMSU-A:**
- **Humidity:** Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Neutral Impact
- **Wind Speed:** Slightly positive impact on upper-tropospheric and positive impact on lower-tropospheric

**MHS:**
- **Humidity:** Slightly Positive Impact
- **Geopotential:** Slightly Positive Impact
- **Temperature:** Slightly Positive Impact
- **Wind Speed:** Slightly Positive Impact

**ATOVS:**
- **Humidity:** Slightly Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Slightly Positive Impact
- **Wind Speed:** Slightly Positive Impact

### Total impact:

**AMSU-A:**
- **Humidity:** Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** negative impact on upper-troposphere and positive impact on lower-tropospheric
- **Wind Speed:** Positive - neutral impact

**MHS:**
- **Humidity:** Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Positive Impact - Neutral
- **Wind Speed:** Positive Impact, slightly negative impact in lower troposphere up to 12h forecast

**ATOVS:**
- **Humidity:** Slightly Positive Impact
- **Geopotential:** Neutral Impact
- **Temperature:** Slightly Positive Impact
- **Wind Speed:** Slightly Positive Impact
**IASI impact (SOP1):**

Through local DA:

- **Humidity:** Negative below 850 hPa, positive impact above 850 hPa
- **Geopotential:** Neutral Impact
- **Temperature:** Neutral Impact
- **Wind Speed:** Slightly negative impact in day 1

Through LBC:

- **Humidity:** Negative above 850 hPa, Positive impact below 850 hPa
- **Geopotential:** Negative above 850 hPa, Positive impact below 850 hPa
- **Temperature:** Negative above 500 hPa, Positive impact below 500 hPa
- **Wind Speed:** Slightly positive impact

**Total impact:**

- **Humidity:** Negative above 850 hPa, Positive impact below 850 hPa
- **Geopotential:** Negative above 850 hPa, Positive impact below 850 hPa
- **Temperature:** Negative above 500 hPa, Positive impact below 500 hPa
- **Wind Speed:** Slightly positive impact
OSE over SOP2 period

Experiments period: 1 July to 25 2018
1 - 4 July warming period

The denial experiments concern only the upper-air assimilation.
The surface assimilation remained untouched

Note the relatively short period due to lack of computational resource
<table>
<thead>
<tr>
<th>Impact through local DA:</th>
<th>Impact through LBC:</th>
<th>Total impact:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AMSU-A:</strong> Not checked</td>
<td><strong>AMSU-A:</strong> Not checked</td>
<td><strong>AMSU-A:</strong> Not checked</td>
</tr>
<tr>
<td><strong>MHS:</strong> Not checked</td>
<td><strong>MHS:</strong> Not checked</td>
<td><strong>MHS:</strong> Not checked</td>
</tr>
<tr>
<td><strong>ATOVS:</strong></td>
<td><strong>ATOVS:</strong></td>
<td><strong>ATOVS:</strong></td>
</tr>
<tr>
<td><strong>Humidity:</strong> negative impact up to 36h</td>
<td><strong>Humidity:</strong> Positive impact on humidity between 700 - 850 hPa and day-1 and on day-2</td>
<td><strong>Humidity:</strong> Negative impact for day 1, Positive impact for day 2</td>
</tr>
<tr>
<td><strong>Geopotential:</strong> Neutral Impact</td>
<td><strong>Geopotential:</strong> Negative impact on upper- tropospheric / stratospheric</td>
<td><strong>Geopotential:</strong> Slightly positive below 500 hPa and Negative impact above 500 hPa</td>
</tr>
<tr>
<td><strong>Temperature:</strong> Neutral Impact</td>
<td><strong>Temperature:</strong> Positive impact above 500 hPa and negative impact below 500 hPa</td>
<td><strong>Temperature:</strong> rather negative - neutral impact on lower troposphere</td>
</tr>
<tr>
<td><strong>Wind Speed:</strong> Positive impact</td>
<td><strong>Wind Speed:</strong> Negative impact on day-1 wind speed</td>
<td><strong>Wind Speed:</strong> Positive impact (except for day-1 below 700 hPa up to 24h forecast)</td>
</tr>
</tbody>
</table>
IASI impact (SOP2):

Through local DA:

Humidity: Negative impact below 700 hPa and positive impact above 700 hPa
Geopotential: Neutral Impact
Temperature: Neutral Impact
Wind Speed: Positive impact on day-1 and negative impact on day-2

Through LBC:

Humidity: Positive impact below 700 hPa and negative impact above 700 hPa
Geopotential: Negative impact between 100 & 200 hPa otherwise positive impact
Temperature: Negative - neutral impact
Wind Speed: Slightly positive impact

Total impact:

Humidity: Positive impact for day-1 below 700 hPa, otherwise negative impact
Geopotential: Positive impact below 500 hPa and negative impact above 500 hPa
Temperature: Positive impact below 500 hPa and negative impact above 500 hPa
Wind Speed: Slightly positive impact
Concluding remarks

- We just published (Randriamampianina et al., 2019) results of an OSE study, where each satellite radiance used in this study showed relative positive impact on the AROME-Arctic analysis and forecasts.

- The impact of the investigated satellite observations was slightly different during winter (SOP1) and summer (SOP2) periods. Negative and positive impacts were found through both local data assimilation and lateral boundary conditions.
  - Ex: not shown, but on top of was shown, the impact on surface parameters was found larger during SOP1 compared to that during SOP2.

- Total impact = impact through local DA + impact through LBC.
  - impact through LBC was not yet checked until now.

Thank you for your attention!
The available observations

Note the difference in scales in the plots

Case of March 30th, 2018
### Observations denial in both global and regional models

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Wind speed</th>
<th>Relative humidity</th>
<th>Geopotential height</th>
</tr>
</thead>
<tbody>
<tr>
<td>All conventional</td>
<td>All conventional</td>
<td>All conventional</td>
<td>All conventional</td>
</tr>
<tr>
<td>IR, MW</td>
<td>IR</td>
<td>MW</td>
<td>IR, MW</td>
</tr>
<tr>
<td>AMV</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Observation denial in regional model

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Wind speed</th>
<th>Relative humidity</th>
<th>Geopotential height</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOP1</td>
<td>SOP2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All conventional</td>
<td>All conventional</td>
<td>All conventional</td>
<td>All conventional</td>
</tr>
<tr>
<td>IR, MW</td>
<td>IR</td>
<td>AMV, MW</td>
<td>Up. Tr: AMV, IR (d2)</td>
</tr>
<tr>
<td>AMV</td>
<td>AMV</td>
<td>MW</td>
<td>MW</td>
</tr>
<tr>
<td></td>
<td>MW</td>
<td></td>
<td>Lo. Tr.: MW</td>
</tr>
<tr>
<td></td>
<td>AMV</td>
<td></td>
<td>AMV, IR (d1)</td>
</tr>
</tbody>
</table>

**Order of importance**

- **Upper-air forecast**
<table>
<thead>
<tr>
<th>Surface pressure</th>
<th>2m temperature</th>
<th>10m Wind speed</th>
<th>Total cloud cover</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Day-1</strong></td>
<td><strong>Day-2</strong></td>
<td><strong>0 - 12 hours</strong></td>
<td><strong>12 - 24 hours</strong></td>
</tr>
<tr>
<td>MCV, CV, PS, RS, MW, MMW, MRS AMV IR, MIR, MT S1N</td>
<td>MCV, MRS AMV IR, MMW, S1N RS, CV MW MT, MH</td>
<td>MCV CV PS MRS RS MW, MMW IR, MIR S1N MT, MH AMV</td>
<td>MCV CV MRS CV MRS PS, MW, MMW IR, MIR RS, S1N AMV MT, MH</td>
</tr>
<tr>
<td><strong>Day-2</strong></td>
<td><strong>0 - 12 hours</strong></td>
<td><strong>12 - 24 hours</strong></td>
<td><strong>Day-2</strong></td>
</tr>
<tr>
<td>2m relative humidity</td>
<td>2m Specific humidity</td>
<td>10m Wind speed</td>
<td>Total cloud cover</td>
</tr>
<tr>
<td><strong>Day-1</strong></td>
<td><strong>Day-2</strong></td>
<td><strong>0 - 12 hours</strong></td>
<td><strong>12 - 24 hours</strong></td>
</tr>
<tr>
<td>MH MMW, MW MRS, RS MT IR, MIR S1N, AMV MCV CV PS</td>
<td>MRS, MT MH, MIR, MCV MW MMW IR, S1N, RS, AMV CV PS</td>
<td>MCV CV MRS AMV MMW, MW, MH, RS MT, S1N, AMV MIR, IR, PS</td>
<td>MCV CV MRS, MIR MW, MT, RS, AMV PS, IR, S1N MH MMW</td>
</tr>
<tr>
<td><strong>Day-2</strong></td>
<td><strong>0 - 12 hours</strong></td>
<td><strong>12 - 24 hours</strong></td>
<td><strong>Day-2</strong></td>
</tr>
<tr>
<td>10m Wind speed</td>
<td>Total cloud cover</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0 - 12 hours</strong></td>
<td><strong>12 - 24 hours</strong></td>
<td><strong>Day-2</strong></td>
<td><strong>0 - 12 hours</strong></td>
</tr>
<tr>
<td>MCV CV RS, MRS MT, MH AMV, S1N, MMW IR, MIR PS, MW,</td>
<td>MCV CV MT MH MCV CV MRS, MIR MMW, MW MCV CV MRS, MIR MW, MMW MIR S1N IR MRS, CV</td>
<td>MCV CV PS, RS, MH, MT MRS, MW MMW, AMV MIR S1N IR MRS, CV</td>
<td>MCV MMW MRS, AMV MT, S1N CV, PS MH, IR, MIR, RS</td>
</tr>
</tbody>
</table>
Global denial experiments

**Experiments performed in Jan-Feb**

**Global denial (LBC)**, the following observations were taken out from the DA:
- All microwave satellite radiances
- All infrared satellite radiances
- All atmospheric motion vectors (AMV)
- All conventional observations
- GNSS RO

- **Control run using all observation is common in both global studies**

**Experiments performed in Feb-March**

**Arctic denial (LBC)**, the following observations were taken out from DA:
- All microwave satellite radiances
- All microwave temperature sensitive radiances
- All microwave humidity sensitive radiances
- All infrared satellite radiances
- All atmospheric motion vectors (AMV)
- All conventional observations
- All radiosonde observations
- All surface pressure observations
- All SOP1 observations

The experiments in blue were used in our study
Relative impact of microwave radiances on AROME-Arctic forecasts (Surface parameters – MSLP)

Note the relatively shorter period – one month
Relative impact of satellite observations

**IASI- LDA; IASI total impact; ATOVS- LDA; ATOVS total impact**

**Loc MW; Tot MW; Loc IASI; Tot IASI; Contr**

Impact through LBC

**IASI:**
Positive impact on geopotential (larger in lower troposphere and smaller in upper-tropo and stratosphere)

**ATOVS:**
Rather neutral impact on geopotential in lower-troposphere and negative impact on upper-troposphere / stratosphere.