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polar regions and beyond

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# Impact of Microwave Data Assimilation in the HARMONIE-AROME Forecast System

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Irina Sandu, Morten A Ø Køltzow, Zheng Qi Wang

RFI workshop Virtual | 14-18 February 2022 - ECMWF

# Outline

- Context
- Observing System Experiments design:
  - Total impact
  - Adding instruments
  - Adding one channel
- => Impact on the HARMONIE-AROME:
  - surface forecasts
  - upper-air forecasts
- Summary

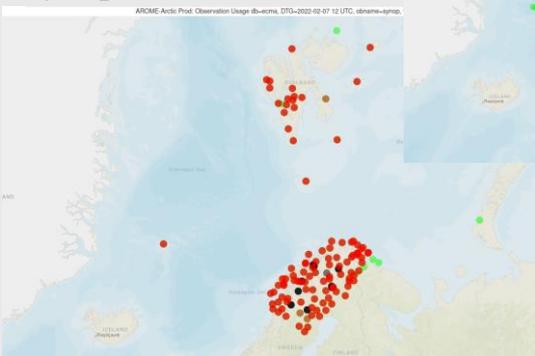
# Context

## Observation data assimilation

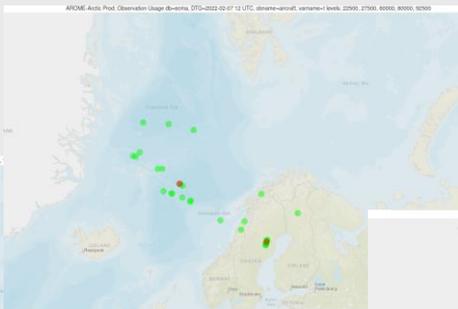
Data assimilation combines observational and model information to provide an estimate of the most likely state and its uncertainty for the atmosphere // finding the right balance between both.

Problem: Sparse network of conventional data over high latitudes to constrain the model

Synop

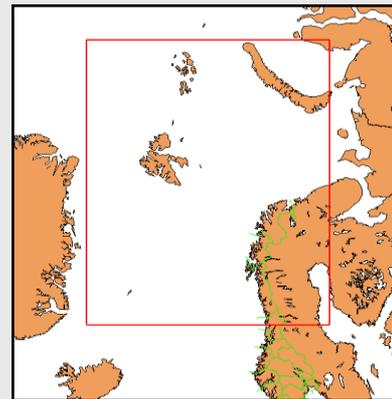
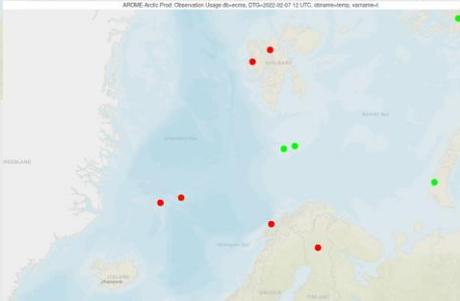


Aircraft



*Example for Arctic domain  
(07/02/2022 - 12UTC)*

Radiosondes



# Context

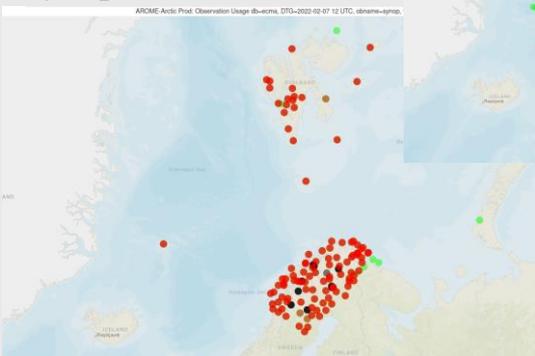
## Observation data assimilation

Data assimilation combines observational and model information to provide an estimate of the most likely state and its uncertainty for the atmosphere // finding the right balance between both.

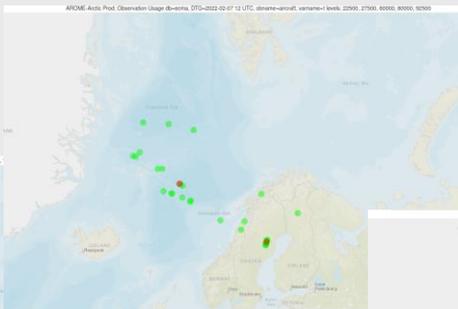
Problem: Sparse network of conventional data over high latitudes

=> regions benefit from a high-density coverage of satellite observations

Synop

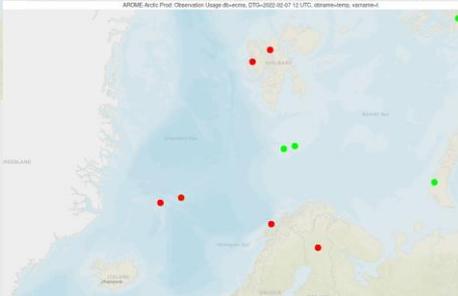


Aircraft



*Example for Arctic domain  
(07/02/2022 - 12UTC)*

Radiosondes



MW satellite data



# Context

## Forecast systems

### AROME-Arctic

- Model upper-air physics:
- Model surface physics:
- Domain:
- Upper-air assimilation:
- Surface assimilation:
- Update strategy:  
(00, 03, 06, 09, 12, 15, 18, 21 UTC)
- Lateral boundary condition: ECMWF  
(in this study every 3 hour)
- Used model version: 40h1.2
- Forecast lengths: Long forecast (48 h)  
twice a day (00, 12 UTC) for verification purposes
- Winter period : 10 February - 31 Ma
- Summer period : 1 - 25 July 2018
- Observations: IASI, AMSU, MHS, Polar wind AMV, ASCAT, synop,  
radiosondes,

aircraft

HARMONIE-AROME  
SURFEX

Arctic

3D-Var  
Optimum interpolation  
3 hourly cycling

(00, 03, 06, 09, 12, 15, 18, 21 UTC)

ECMWF

(in this study every 3 hour)

40h1.2

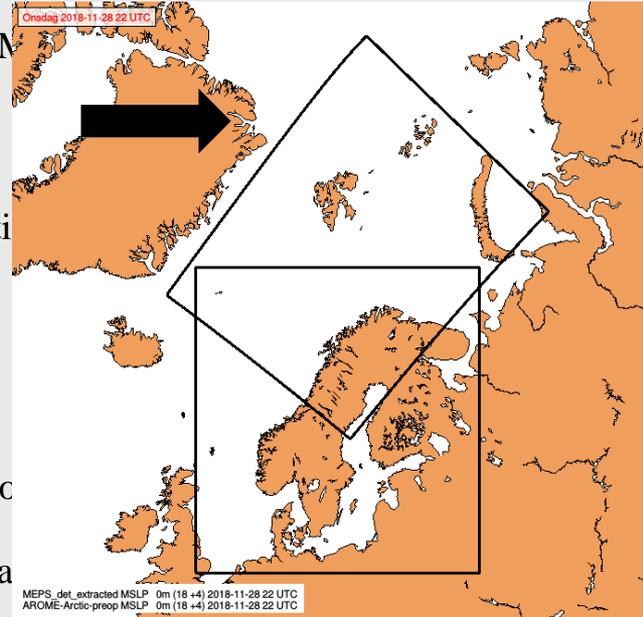
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# Context

## Forecast systems

### MEPS

- Model upper-air physics:
- Model surface physics:
- **Domain:**
- Upper-air assimilation:
- Surface assimilation:
- Update strategy:
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- Observations:  
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HARMONIE-AROME  
SURFEX

Scandinavia

3D-Var  
Optimum interpolation  
3 hourly cycling

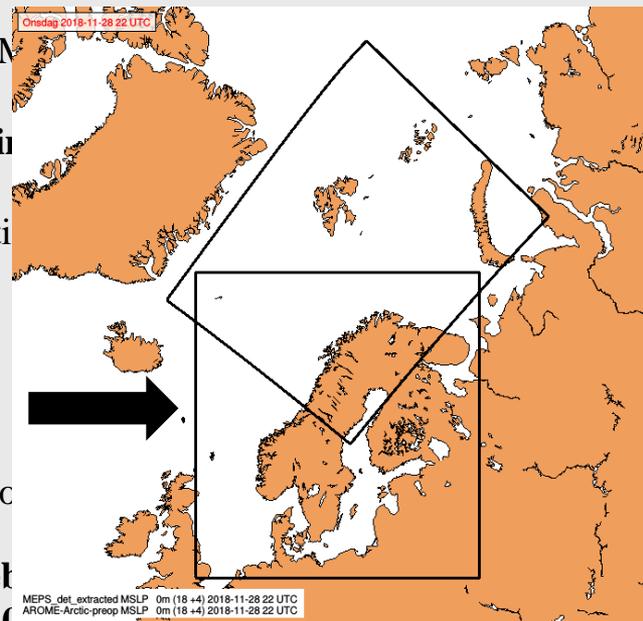
(00, 03, 06, 09, 12, 15, 18, 21 UTC)  
ECMWF  
(in this study every 3 hour)

**43h2.1**  
Long forecast (48 h)

**01 January - 20 February**

**01 June - 20 July 2021**

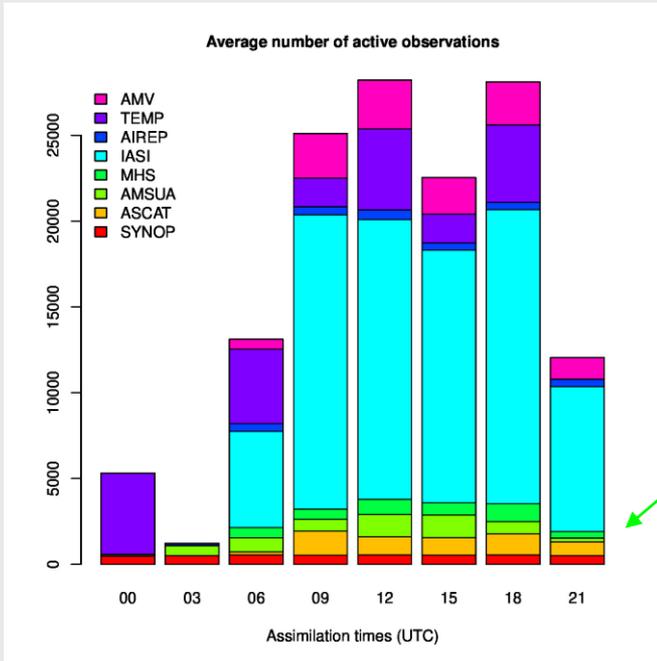
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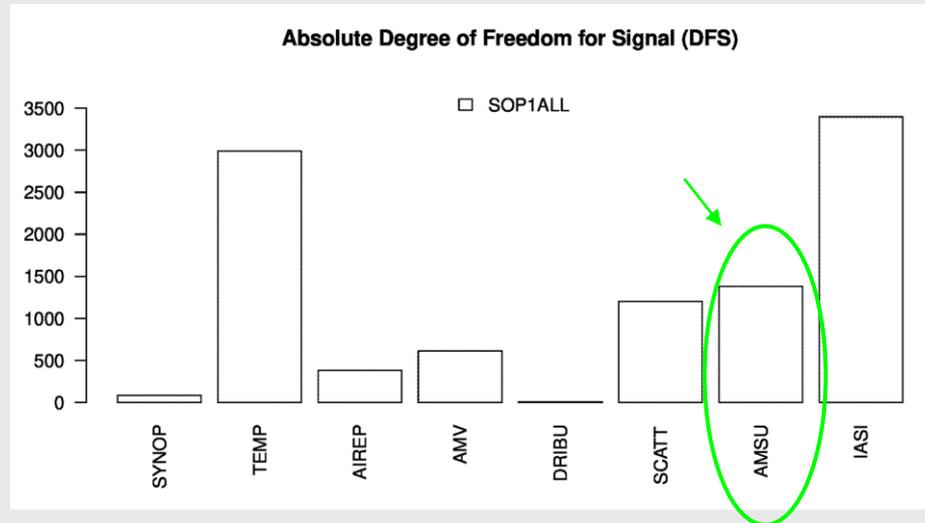
# Context

## General Impact of Observations in R-DA

*A 10-day averaged number of assimilated observations per observation type*



*Averaged DFS over four distant assimilation times*



$\Rightarrow$  **MW data** among leading contributors to today's forecast skills at regional scale despite a small amount of active data

# Observing System Experiments

To measure the impacts of observations an OSE, consists in running experiments in which observations are removed from (or added to) a data assimilation system. The resulting forecasts is compared against ones produced using a control set (e.g., Kelly et al. 2007).

- 1) Total Impact (denial): MW data
- 2) Adding MW instruments: ATMS and MWHS-2
- 3) Adding one channel: Channel 5 from AMSU-A (over land)

# Observing System Experiments

## 1) Total Impact of MW data

=> Regional systems (AROME-Arctic) are very sensitive to lateral boundary conditions, especially to the data that were assimilated in it ...

Question: Impacts on regional forecast model if we have lots of RFI (data loss) at a global scale ?

CTL	“Gall/Rall”	All OBS in Global (LBC)	&	All OBS Regional
Exp 1	“Gall/RnoMW”	All OBS in Global (LBC)	&	No MW Regional
Exp 2	“GnoMW/RnoMW”	No MW in Global (LBC)	&	No MW Regional

- 1) Adding MW instruments: ATMS and MWHS-2
- 2) Adding one channel: Channel 5 from AMSU-A (over land)

# Observing System Experiments

## Total impact

Impacts on the surface fields:

=> The **total** impacts of MW observations are dominated by **regional DA**

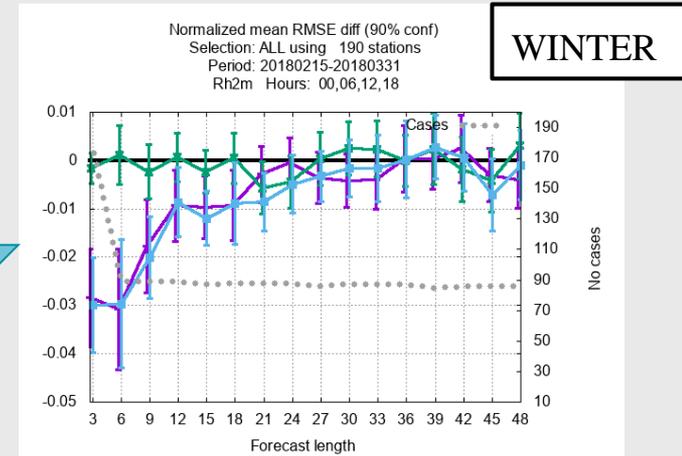
Exemple:

Normalized mean RMSE diff of Rh2m shows **some impacts** on the forecast up to 24h coming from the assimilation of MW in **regional DA**

However, if No MW data are assimilated in the **LBCs**, the effect is **neutral** for surface fields

**The relative impacts of MW data:**

- Through the Region DA
- Through the LBCs
- Total



# Observing System Experiments

## Total impact

### The relative impacts of MW data:

- Through LBCs
- Through Arctic data in LBCs
- Through the Regional
- Total

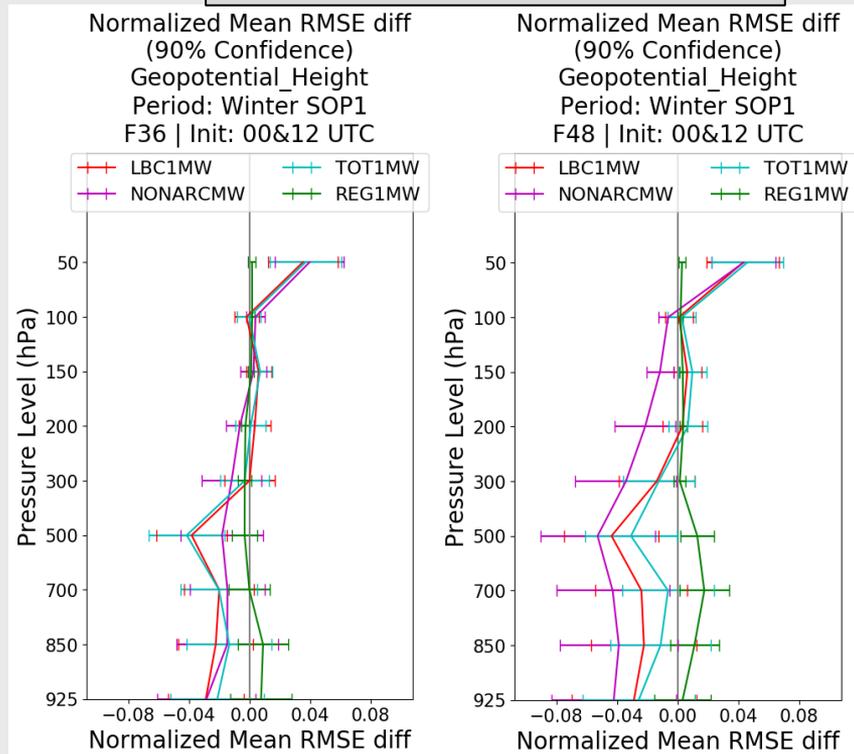
Impacts on the upper-air fields:

=> The **total** impacts of MW observations dominated by **LBCs**

Exemple:

Profiles of normalized mean RMSE diff of Geopotential Height show **impacts** on the forecast from LBCs at 36h and arctic MW LBCs at 48h.

However, the impact is neutral through **regional DA**.



# Observing System Experiments



- 1) Total Impact
- 2) Adding MW instruments: ATMS and MWHS-2

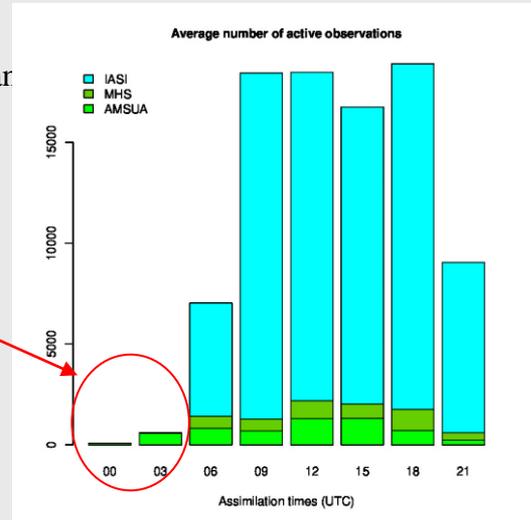
Question: What if lots of RFI affect all channels from the same instrument ?

CTL

All OBS (including AMSU, MHS and

Exp 1 “EXP-ATMS” CTL + ATMS

Exp 2 “EXP-MWHS-2” CTL + MWHS-2



# Observing System Experiments



- 1) Total Impact
- 2) Adding MW instruments: ATMS and MWHS-2

Question: What if lots of RFI affects all channels from the same instrument ?

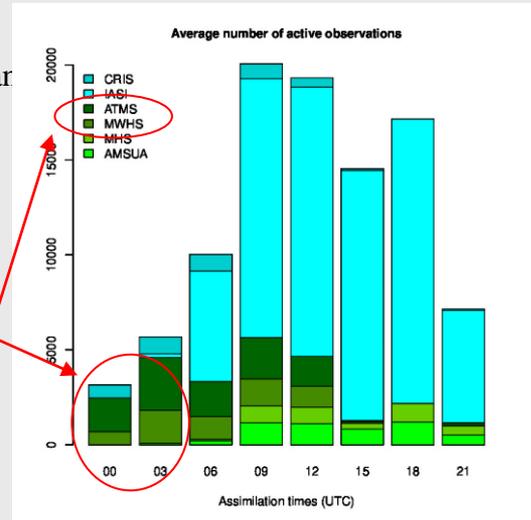
CTL

All OBS (including AMSU, MHS and

Exp 1 “EXP-ATMS” CTL + ATMS

Exp 2 “EXP-MWHS-2” CTL + MWHS-2

Gap  
closed



# Observing System Experiments

## Adding MW instruments

Frequencies of assimilated channels:

On top of AMSU-A and MHS,

- 5 channels from ATMS for **Temperature** sounding:  
=> ~ 53.5 to 57.3 GHz
- 5 channels from ATMS for **Humidity** sounding:  
=> ~ 183.3 GHz

- 5 channels from MWHS-2 for **Humidity** sounding:  
=> ~ 183 GHz

	AMSU-A		MHS		ATMS		MWHS-2	
	1	23.8			1	23.8		
	2	31.4			2	31.4		
	3	50.3			3	50.3		
	4	52.8			4	51.76		
	5	53.596 ± 0.115			5	52.8		
Active T	6	54.4			6	53.596 ± 0.115		
	7	54.94			7	54.4		
	8	55.5			8	54.94		
	9	f0 = 57.290344			9	55.5		
	10	f0 ± 0.217			10	f0 = 57.290344		
	11	f0 ± 0.3222 ± 0.048			11	f0 ± 0.217		
	12	f0 ± 0.3222 ± 0.022			12	f0 ± 0.3222 ± 0.048		
	13	f0 ± 0.3222 ± 0.010			13	f0 ± 0.3222 ± 0.022		
	14	f0 ± 0.3222 ± 0.0045			14	f0 ± 0.3222 ± 0.010		
	15	89	1	89	15	f0 ± 0.3222 ± 0.0045		
					16	89.5		
							10	150
			2	157				
					17	165.5		
					18	183.31 ± 7.0	15	183±7
					19	183.31 ± 4.5	14	183±4.5
			4	183.31 ± 3.0	20	183.31 ± 3.0	13	183±3
					21	183.31 ± 1.8	12	183±1.8
			3	183.31 ± 1.0	22	183.31 ± 1.0	11	183±1
			5	190.311				

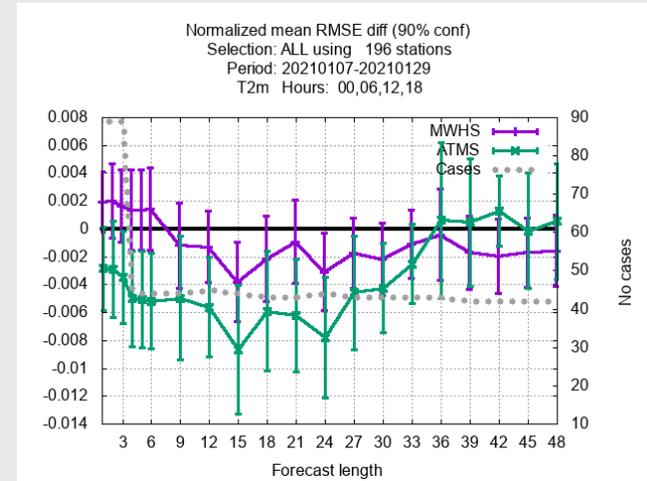
Active Q

# Observing System Experiments

## Adding MW instruments

Impact on surface fields:

- Clear positive impact of ATMS data on surface fields was observed
- Rather positive than neutral impact of MWHS2 data on surface fields was observed



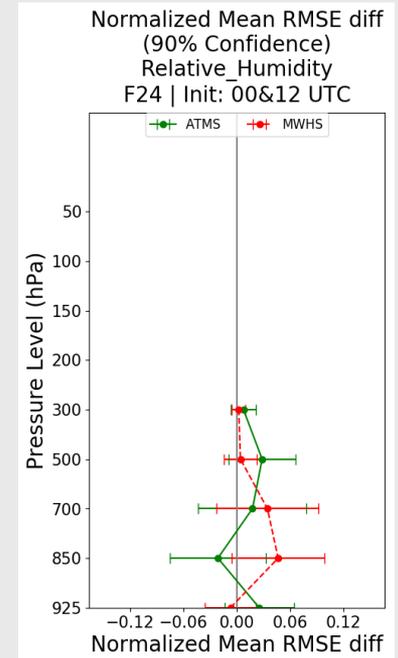
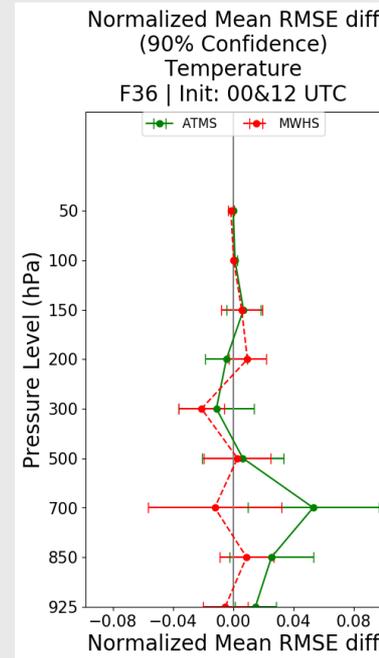
# Observing System Experiments

## Adding MW instruments

### Impact on upper-air:

- Expected promising impact of both ATMS and MWHS2 data on upper-air forecasts was found

=> Lack of observations for verification  
(only 2 radiosondes from November till March 2021)  
The results are still questionable



# Observing System Experiments

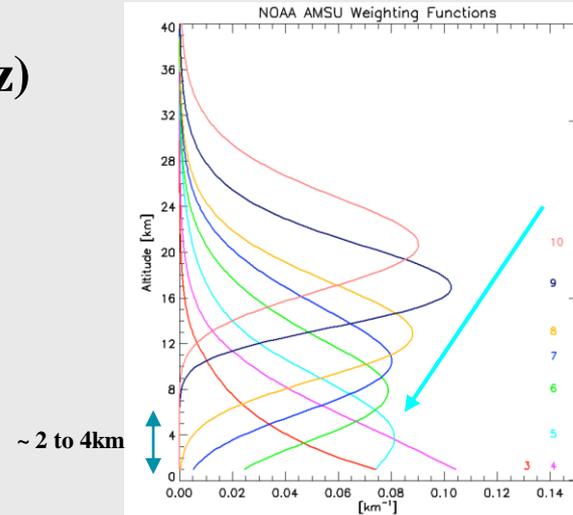
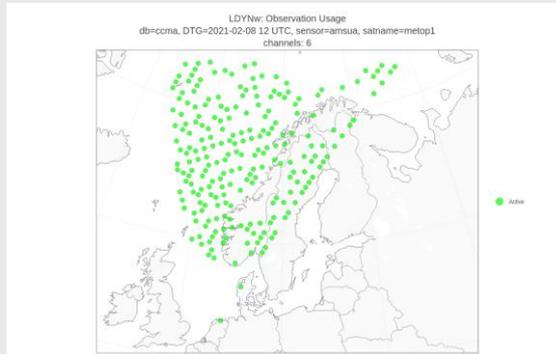
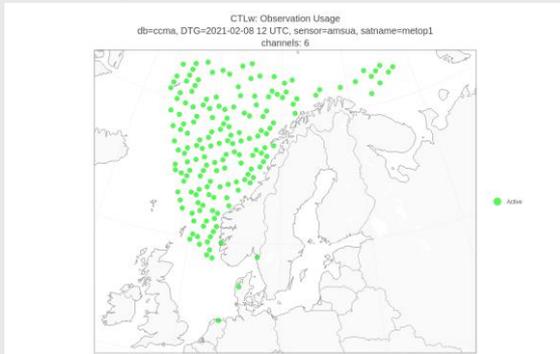
- 1) Total Impact
- 2) Adding MW instruments: ATMS and MWHS-2
- 3) **Adding one channel: Channel 5 from AMSU-A (over land)**

METCOOP25D  
Domain  
(Scandinavia)

Question: What if lots of RFI affect one channel on a single instrument ?

**CONTROL**  
**Chan 5 blacklisted**

**EXP : CTL + chan5 (53.6 GHz)**  
**(with new surface scheme)**



# Observing System Experiments

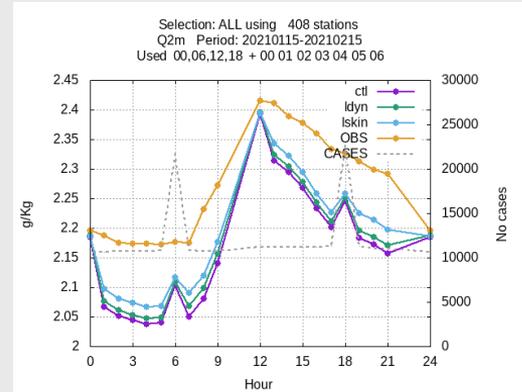
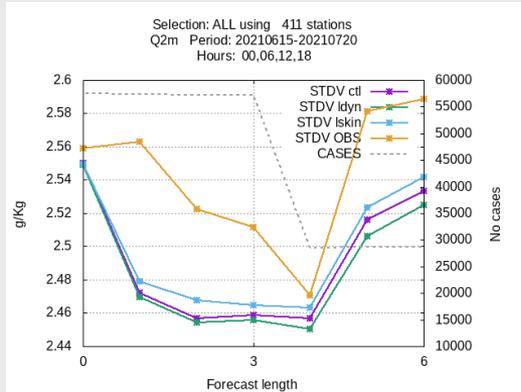
## Adding 1 MW channel (53.6 GHz)

Impact on the surface:

=> positive impact on the humidity on short range forecast up to 6h forecast length

Same results for wind speed

Neutral for geopotential and temperature



Daily variation of the forecast skills



# Summary

- High latitude regions benefit from a high-density coverage of satellite observations
- The **total** impacts of MW observations on the surface fields are dominated by the impacts through **regional DA** while upper-air impacts are dominated by the **LBCs**.
- Adding one MW instrument has a positive impact on surface fields but it was difficult to conclude about upper-air impact because of the lack of verification data.
- Adding one MW channel (over land) brought positive impact from the surface to 700 hPa and up to 24h forecast length.

=> Very important to deal with RFI to optimize the use of MW satellite data and compensate for the sparse network of conventional data over polar regions !

# Thank you for your attention