# Developments in Surface analysis at DWD

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# Outline

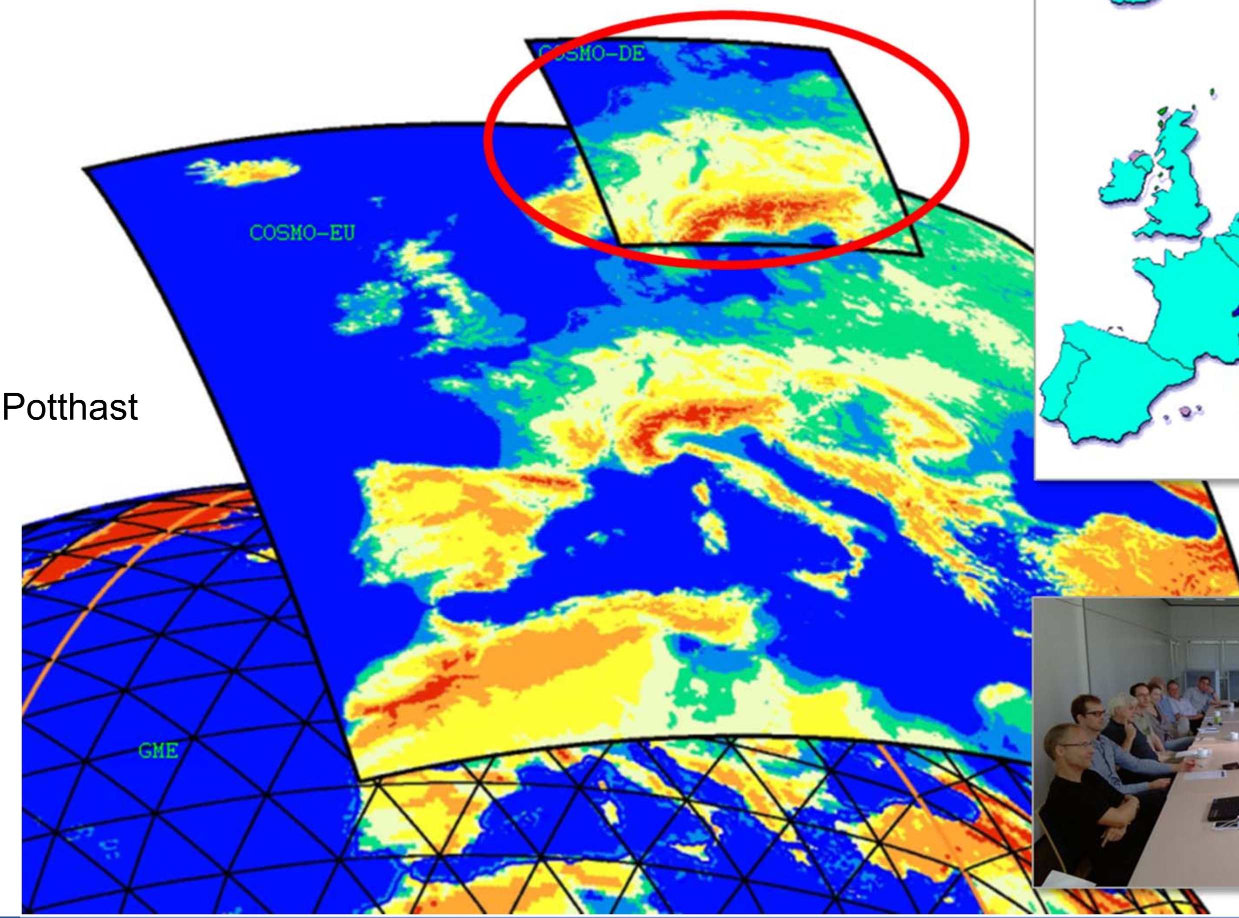
- Short overview NWV model suite at DWD and surface analysis schemes
- SMA
  - Present and future schemes
  - First test with SMA-Enkf
- SST and Snow analysis
  - Problems with Snow analysis in data sparse regions.
  - Blacklisting of „bad“ ship observations
- Summary

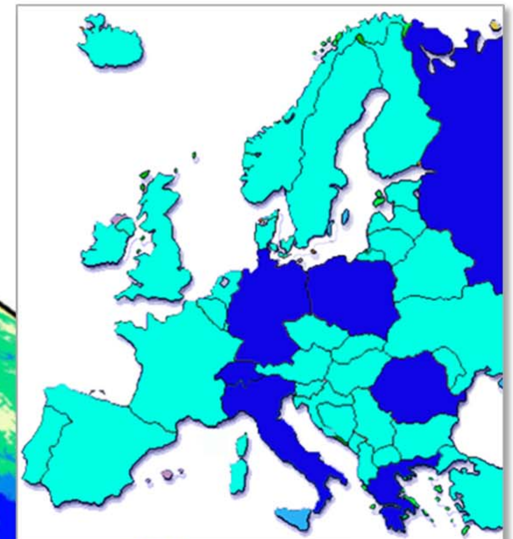
# Regional modelling in COSMO framework



**02-24 Hours**

**High Resolution Modelling**



Courtesy R. Potthast

# Modelsystem present and next

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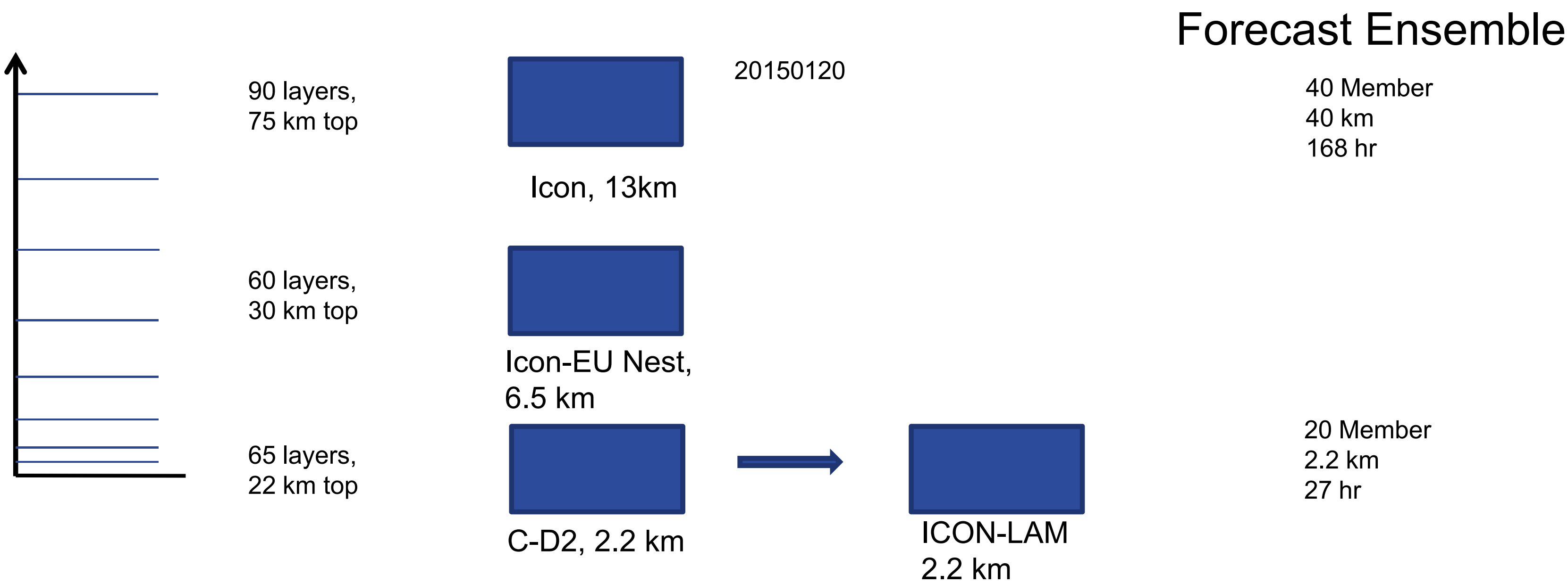
Wetter und Klima aus einer Hand




| Model / domain | Spatial resolution | Replaced by | Spatial resolution | Operational implementation at DWD |
|---|---|---|---|---|
| ICON / global | 13 km | | | January 2015 |
| ICON-Nest Europe extended | 6.5 km 60 layers | | | 2015 |
| COSMO-2 Germany extended to west | 2.2 km, 65 layers | ICON-LAM | 2.2 km, 65 layers | End 2020 |

# TEMP-Verification Geopot 500 hPa

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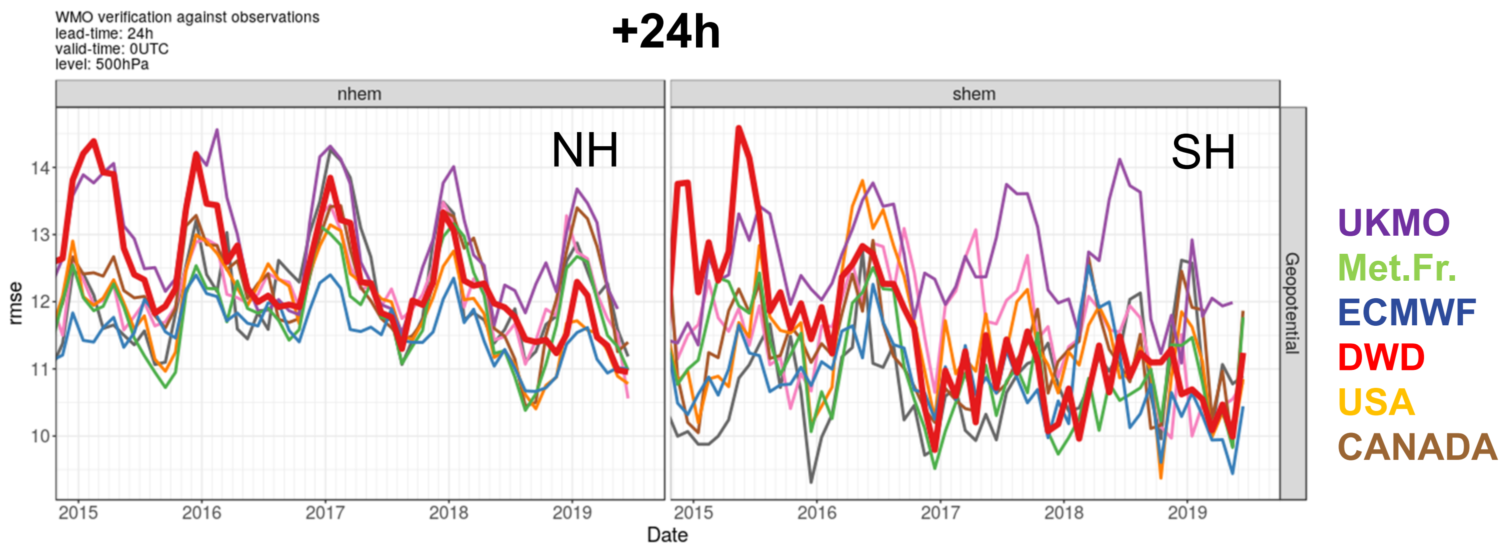
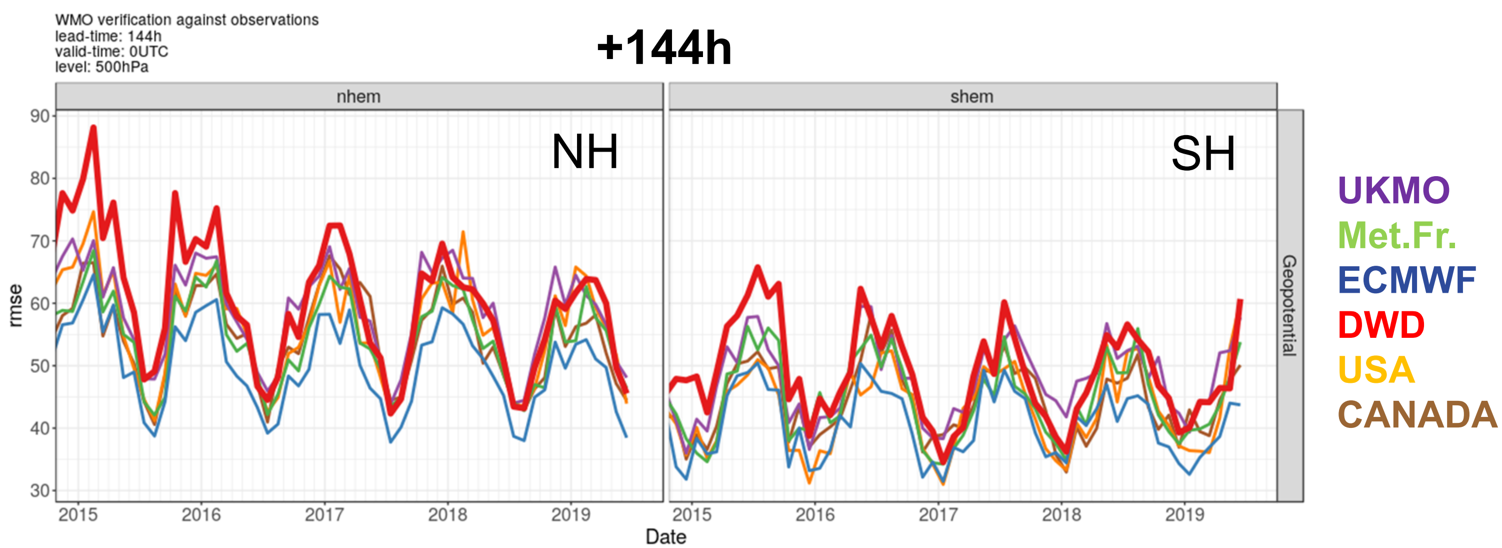


# Present surface analysis schemes

- Soil moisture analysis - 2d-Var
- Screen level analysis T2m, Rh2m - OI
- Snow analysis - Cressman
- SST and sea ice analysis – External analysis (Ostia) as bg, combined with Cressman

# Soil moisture analysis

# 2d var (z,t) soil moisture analysis

Cost function penalizes deviations from observations and initial soil moisture content

$$J = (w - w_b)^T B^{-1} (w - w_b) + (T_{2m} - T_{2m}{}^{obs})^T O^{-1} (T_{2m} - T_{2m}{}^{obs})$$

$$\nabla J = 0$$

Analysed soil moisture depends on T2m forecast error and sensitivity ∂T2m/∂w

$$w_{ana} = w_b + (\Gamma_{T2m}{}^T O^{-1} \Gamma_{T2m} + B^{-1})^{-1} \Gamma_{T2m}{}^T O^{-1} \underbrace{(T_{2m}{}^{obs} - T_{2m}(w_b))}_{T2m\ fc\ error}$$

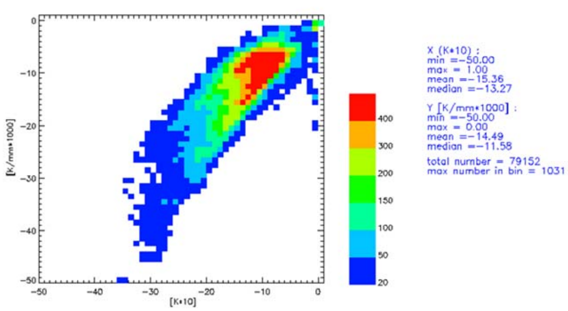
$$\Gamma_{T2m} = \frac{\partial T_{2m}(12:00, 15:00)}{\partial w(0:00)}$$

# Parameterisation for Sensitivity dT2m/dw

In previous SMA for regional model sensitivity was calculated by two extra model forecast runs
In ICON it is derived from Surface energy balance and Penman type equation

$$\frac{\partial T_{2m}}{\partial w_k} = \frac{\overline{r_a}}{\rho c_p}\left(\frac{\alpha}{1-\alpha}\right)\frac{Lhfl}{(r_a + r_f)}\frac{1}{f_{LAI}}\left(1-\frac{r_s}{r_{s,\max}}\right)\frac{r_s}{w_{root} - w_{pwp}}\frac{dz_{k,root}}{z_{root}}$$

dT2m/dw
Param / explicit variation




**No further need for additional model runs!**

- Present global SMA has been introduced as efficient alternative to the 2d var analysis scheme in COSMO-EU

- However it depends on modifications of the transfer scheme, and it suffers to be limited to the use of conventional observations and does not allow complex forward operators.

- Satellite derived soil moisture products are available, which can be used but those are generally based on different model system (e.g. SMOS neural network soil moisture is based on ECMWF auxiliary data)

- For direct use of satellite radiances the assimilation scheme has to be replaced.

- Solution: Devlopment of Ensemble based SMA

# Development Ensemble based SMA for deterministic run

Analysis update equation

$$x^a = x^b + \underbrace{\mathbf{B}H^T[H\mathbf{B}H^T + \mathbf{O}]^{-1}}_{\mathbf{K}}(y - H[x^b])$$

Approximation of covariances with ensemble covariances

$$\mathbf{B_{i,j}} = \overline{(x_i^b - x_i^t)(x_j^b - x_j^t)}$$
$$= \frac{1}{N_{ens} - 1} \sum_{m=1}^{N_{ens}} (x_{i,m}^b - \overline{x_i^b})(x_{j,m}^b - \overline{x_j^b})$$

HBH$^T$ derived from ensemble covariance of obs equivalents

$$HBH^T = \overline{H(x^b - \overline{x^b})(H(x^b - \overline{x^b}))^T}$$
$$= \overline{(y^b - \overline{y^b})(y^b - \overline{y^b})^T}$$

Algorithm computational efficient

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Analogue

$$\begin{aligned} \mathbf{B}H^T &= \overline{(x^b - \overline{x^b})(H(x^b - \overline{x^b}))^T} \\ &= \overline{(x^b - \overline{x^b})(y^b - \overline{y^b})^T} \end{aligned}$$

- No horizontal correllations in SMA,
- R diagonal
- Sparse matrices to invert

⇒ Kalman gain can be calculated simply from ensemble forecast at affordable cost.

Upscaling of K from ensemble resolution to the deterministic grid using soil moisture index for scaling between different soil types.

Calculation of increments on deterministic grid

$$x^a - x^b = \mathbf{K}(y - H[x^b])$$

EnKF don‘t need linear or adjoint model and no backward integration in time.
So it is easy to implement and therefore it is so popular!

SMA is coded, first tests are under investigation

First test analysis 2019040200

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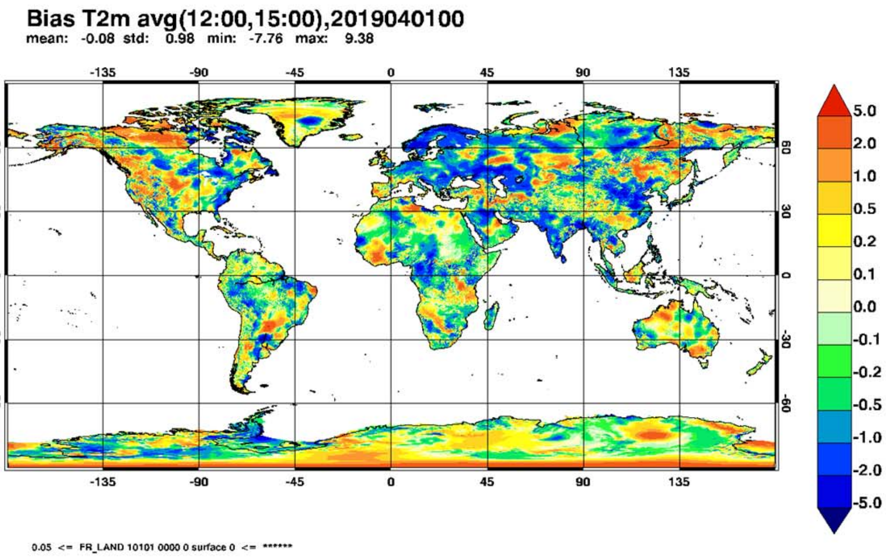


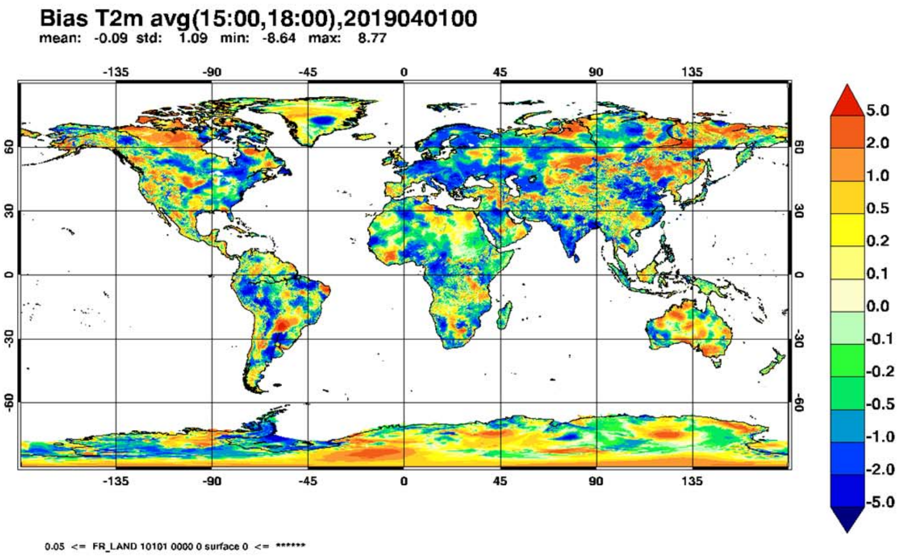


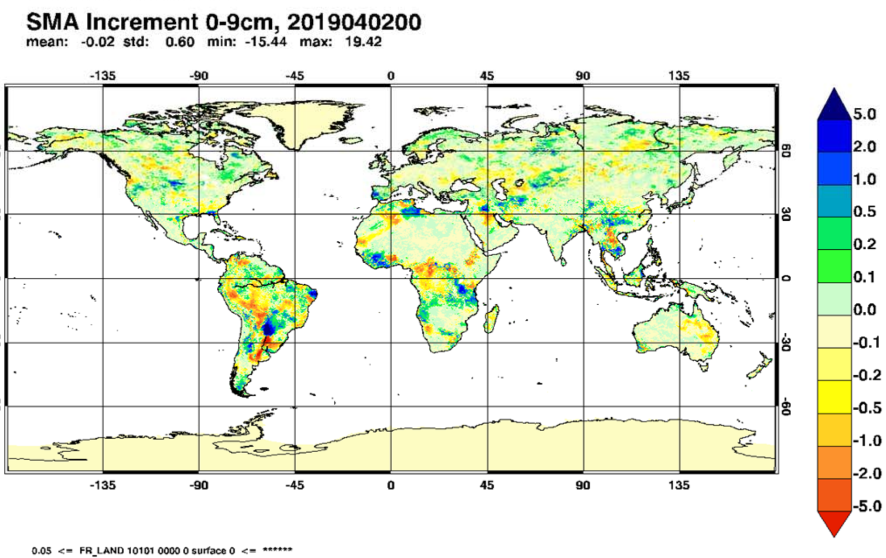


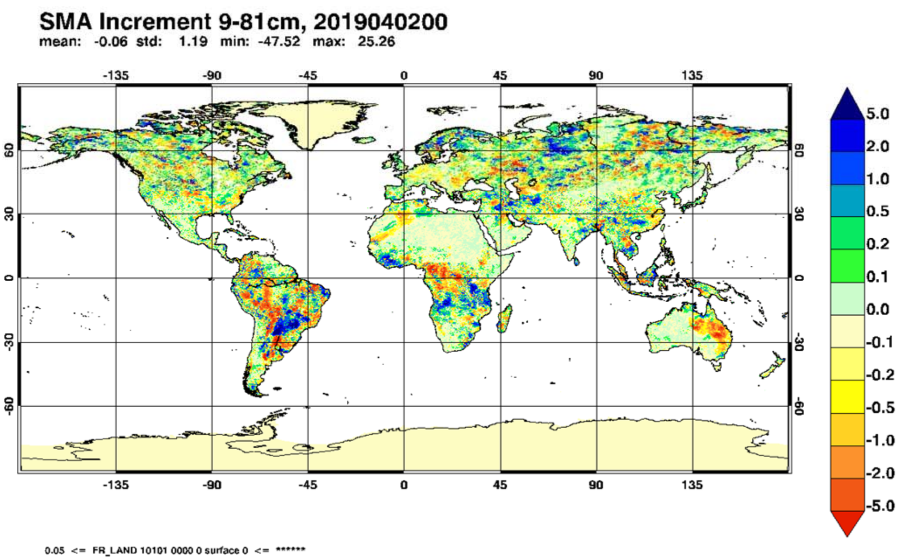

## Relative spread scaled with soil moisture content decreases strong in deeper layers

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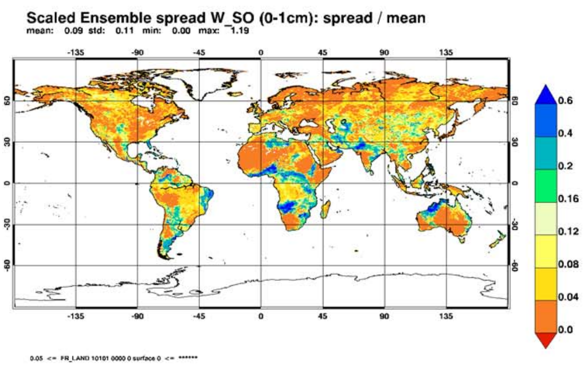
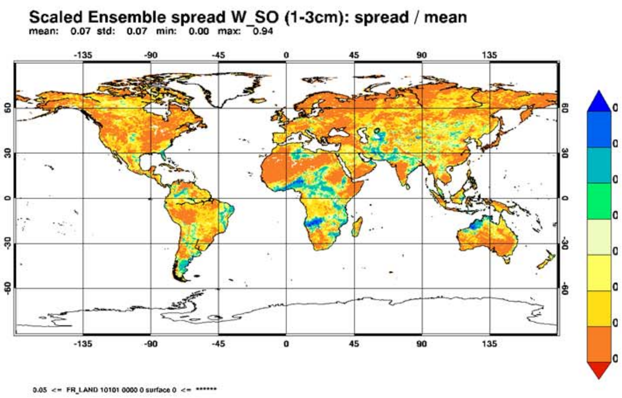
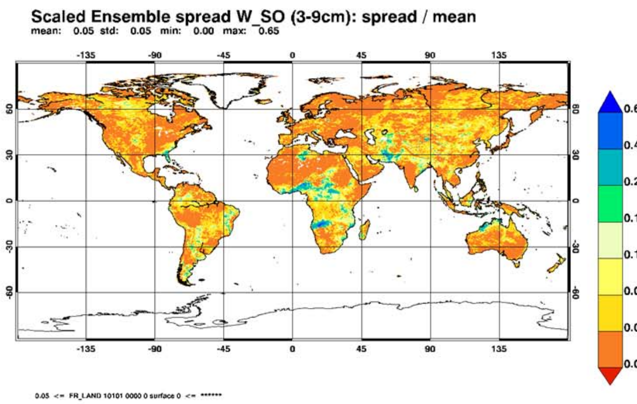
0-1 cm



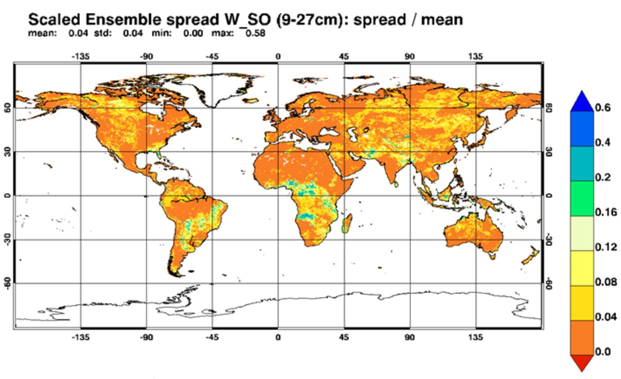

1-3 cm



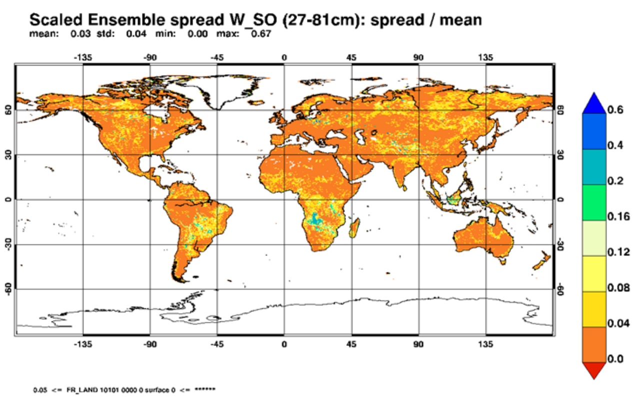

3-9 cm




9-27 cm




27-81 cm



# Covariance inflation f=2.5
# Larger increments in deep layers

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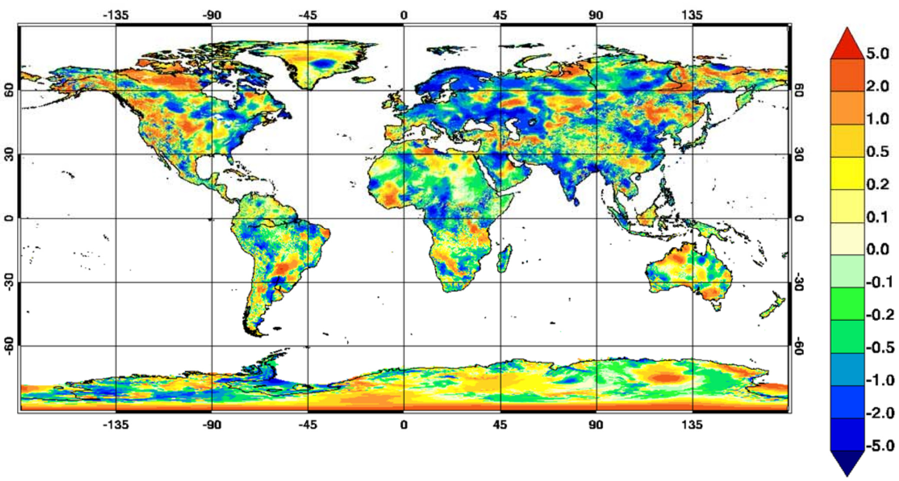
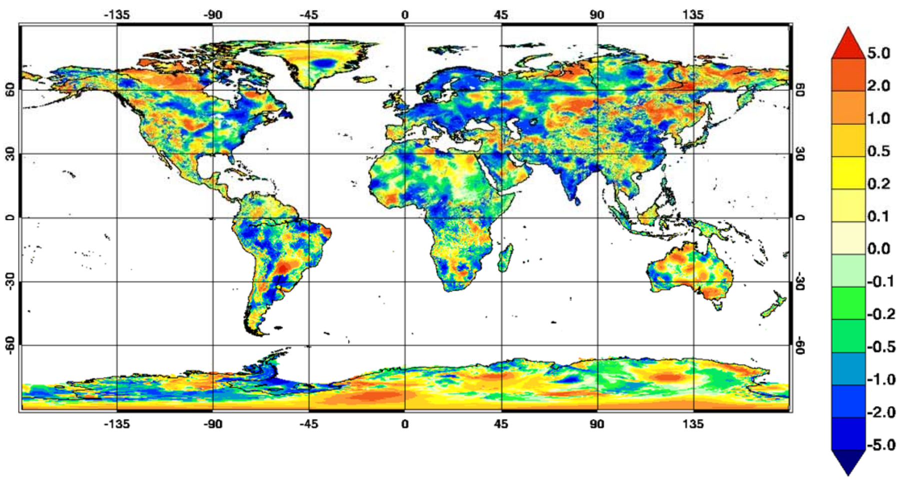
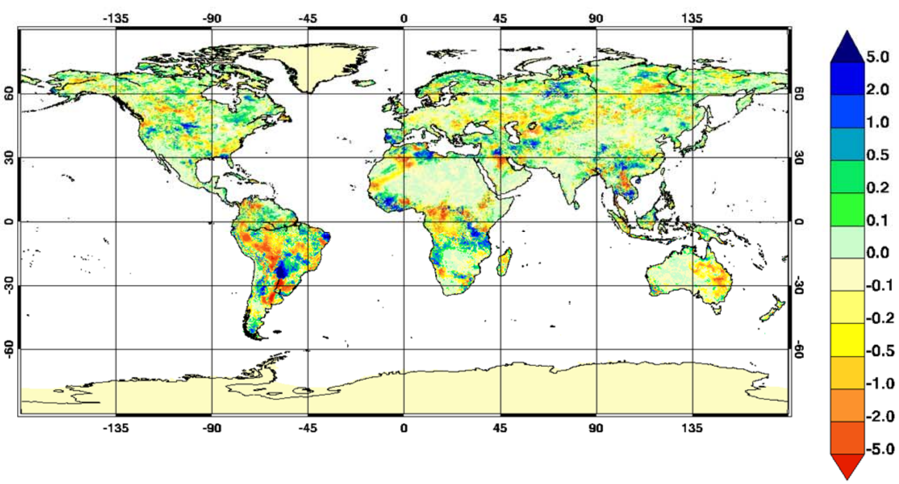
**Bias T2m avg(12:00,15:00),2019040100**
mean: -0.08 std: 0.98 min: -7.76 max: 9.38



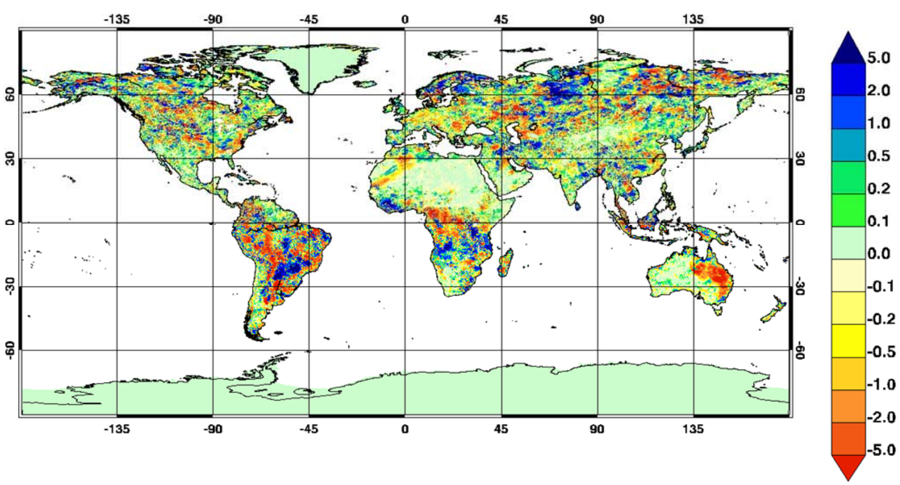

**Bias T2m avg(15:00,18:00),2019040100**
mean: -0.09 std: 1.09 min: -8.64 max: 8.77

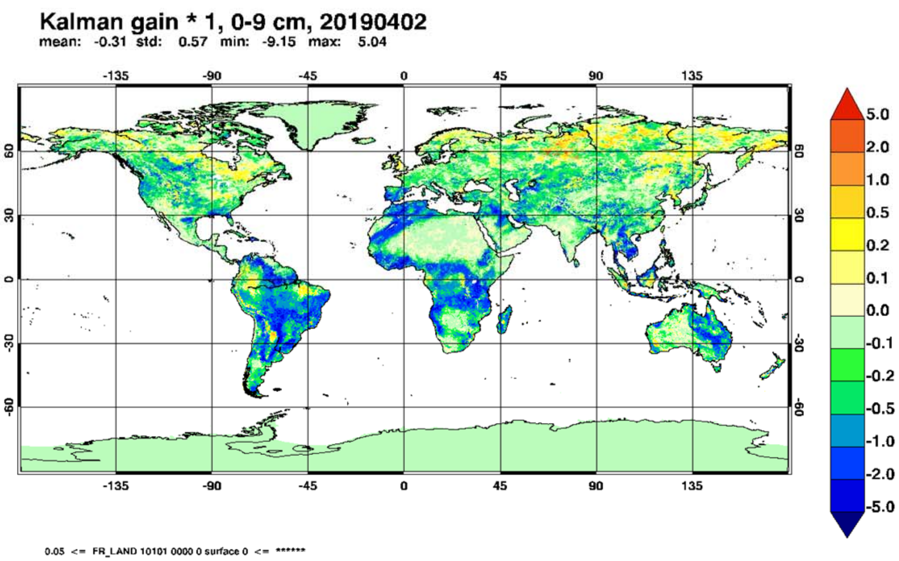


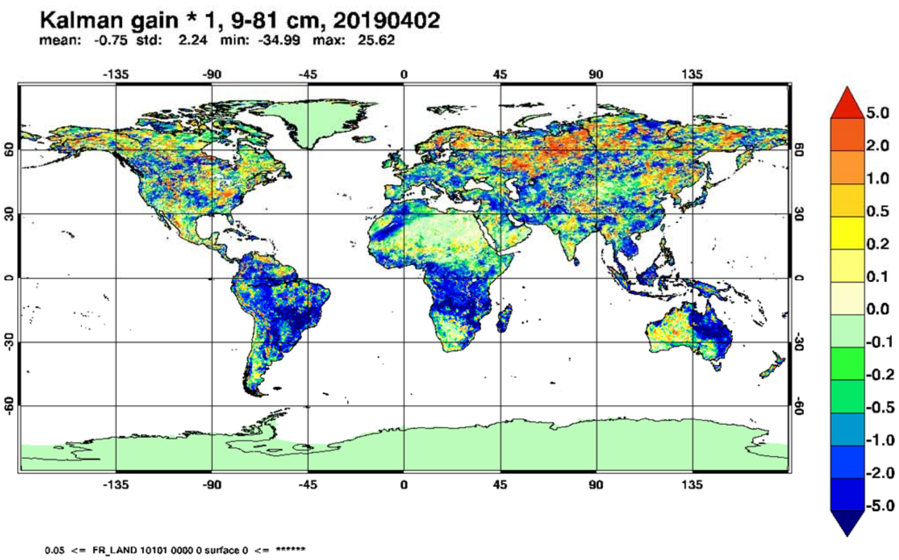

**SMA Increment 0-9 cm, 20190402, f_inflat=2.5,**
mean: -0.05 std: 0.82 min: -18.56 max: 22.11




**SMA Increment 9-81 cm, 20190402, f_inflat=2.5,**
mean: -0.13 std: 2.17 min: -69.40 max: 42.89






Correlations in northern regions not flux controlled, soil moisture and temperature should be negative correlated

## Summary SMA - EnKF

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- Increments have correct sign as expected almost drying for cold bias and moistening for warm bias. SMA seems to work correctly.

- Increments are relative small, to increase impact B-matrix needs to be increased.

- Two possible solutions considered:
  - Covariance inflation
    Effect in deeper layers as desired
  - Increase initial perturbation of soil moisture
    more spread should improve signal/noise ratio
    probably strong impact on ensemble (retuning, adjust mean w_so?)

- Correlations in northern regions not surface flux controlled, Increments should be reduced when surface – atmosphere coupling is small!

# Snow analysis

- Analysis scheme
- Issues with snow analysis in regions with isolated observations

# Snow data used in Snow analysis

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**Conventional observations:**

- Snow height reports from synop stations,
- If not available 3-6 hourly precipitation sums in combination with screen level temperature.
- If not reported information from ww (observer reports presence of snow) is extracted and converted to snow depth obs

**Additional information from external data sources**

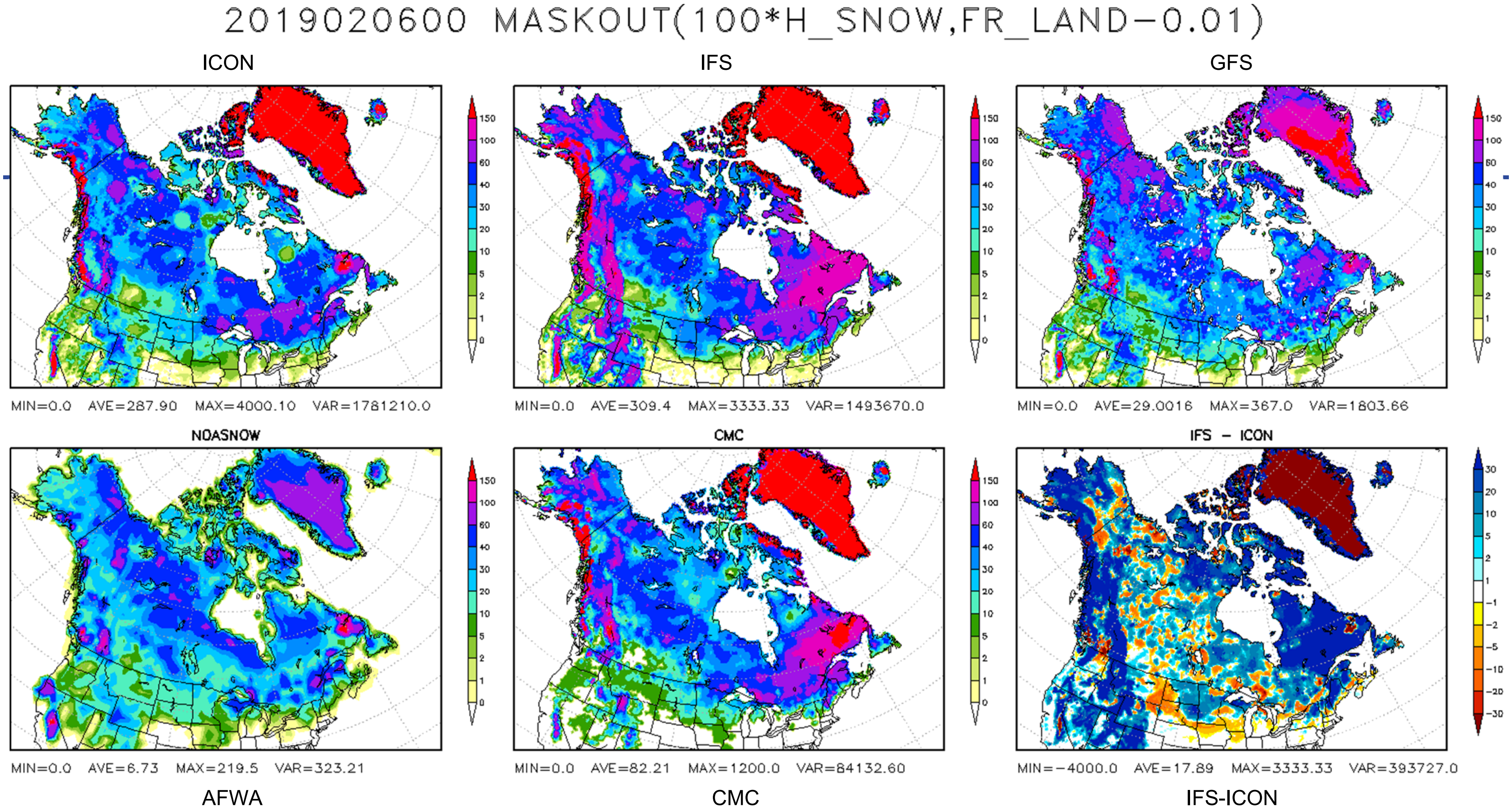
- Indirect use of satellite information through NOAA IMS snow cover and NOAA snow depth over data sparse areas in northern hemisphere.
- Where missing snow climatology from ERA Interim is used.

**Fixed snow depth over permanent glaciers**

Over permanent glaciers fixed snow depth of 40 m, snow density 200 kg/m2.

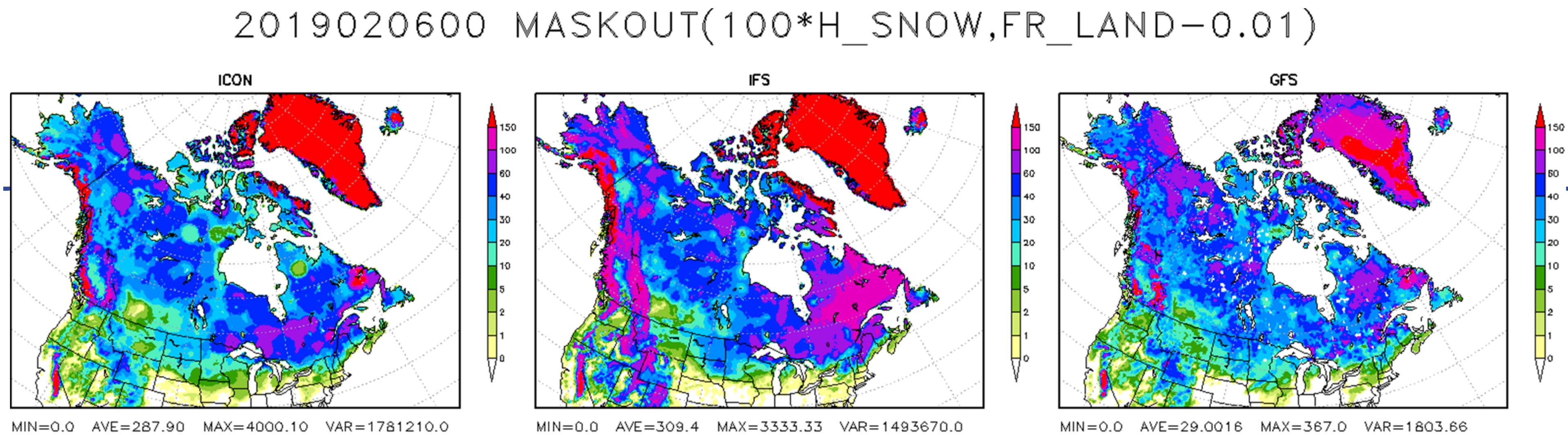
# Snow analysis

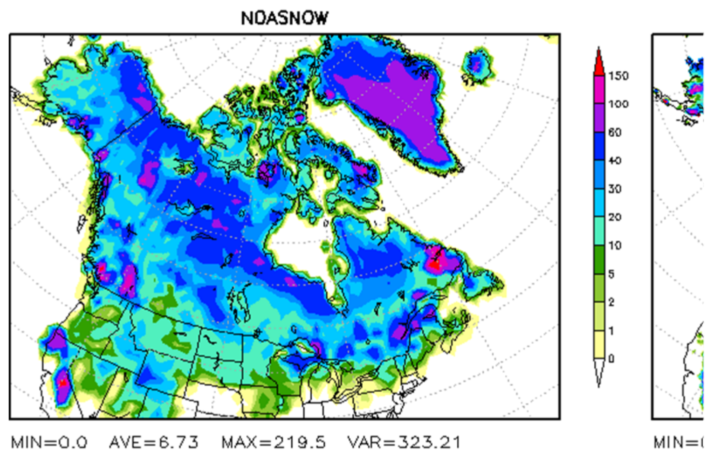
- Issues with snow analysis in regions with isolated observations

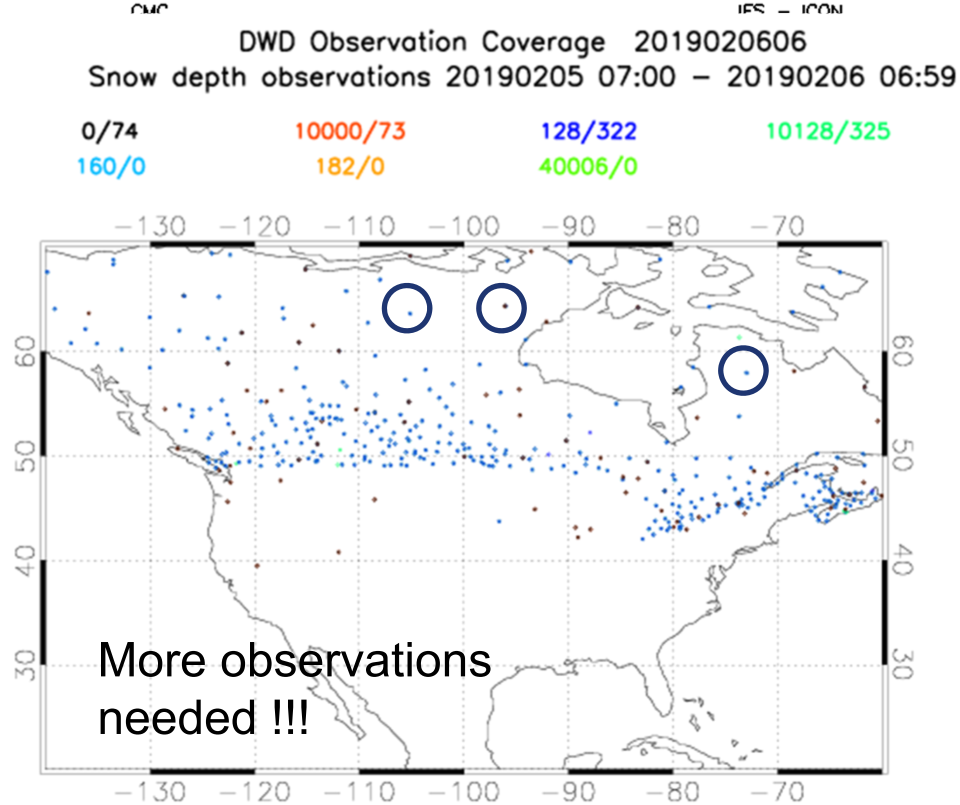



Large snow depth at east and west coast for IFS and CMC, small snow depht for ICON and smallest for american analysis

Circle like structures with ICON in regions with few observations. Too sharp structure function, too much weight given to single observations.
More observations needed !!!




More observations needed !!!

Large snow depth at east and w
and smallest for american analy

Circle like structures with ICON

# Observation thinning in SST analysis

- Single ship observations lead to spurious patterns in the analysis.
- Blacklisting removes the „visible ship routes“ from the analysis

Obs – fg (Ostia)

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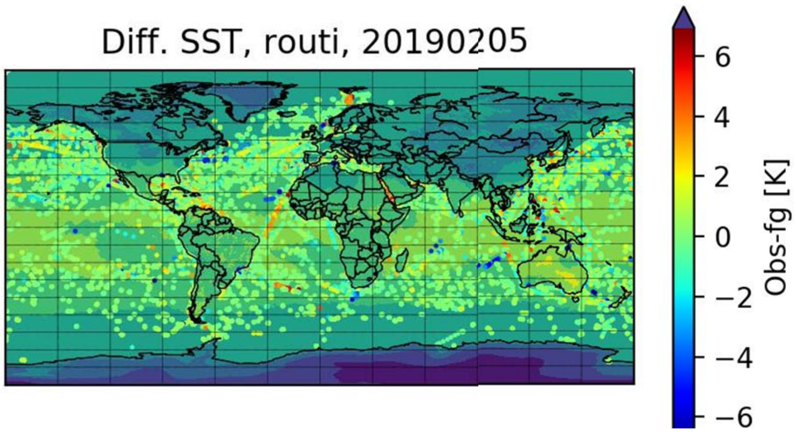
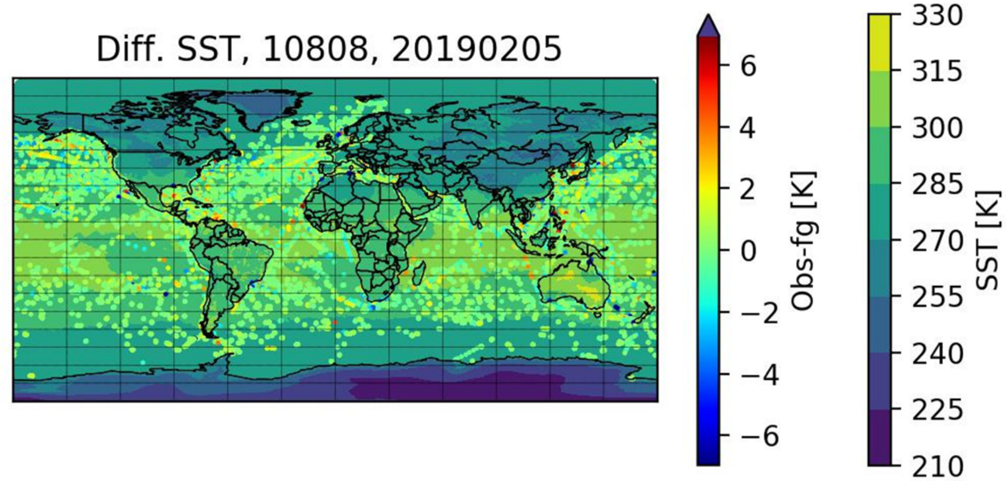
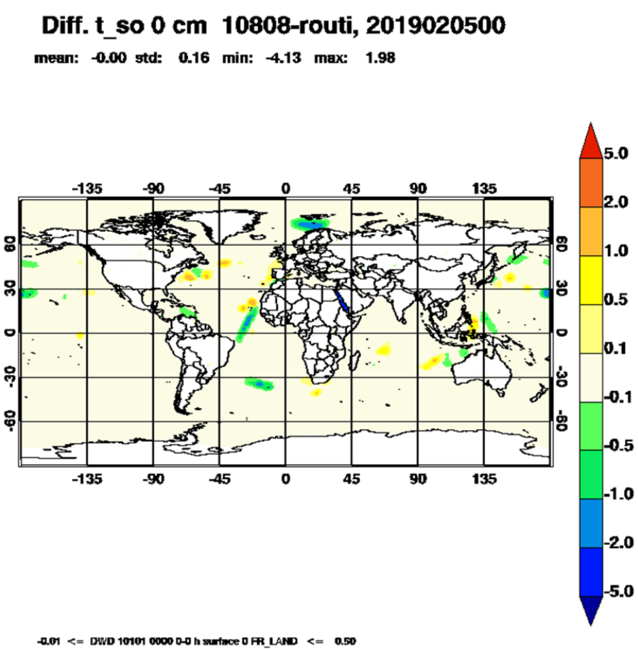



Impact on
SST analysis



# Summary

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SMA

- Development of Ensemble based SMA EnKF, Interpolation of 40km Ensemble gain to deterministic grid. Increments small in first tests, covariance inflation helps. Next step towards soil moisture perturbations to increase spread.

Snow

- Problems in regions with isolated snow depth observations.
- Better snow reporting practice highly desired, Hopefully GCW activities help to improve the snow reporting from U.S. regional snow networks to GTS.

SST

- Blacklisting of ships and buoys has been introduced to remove spurious patterns from the SST analysis

Future

- Review of Cressman based Snow and SST analysis in the next years. Use of more “modern” assimilation method i.e. 2d Var.

# Fin