SMOS KO meeting 05-09-14

Joaquín Muñoz Sabater

- Part I: Technical work and deliverables

- Part II: SLV+ SMOS data assimilation experiments
  - Root-zone SMOS-DA soil moisture product,
  - SEKF components analysis for summer 2010 (diagnostic),
  - Soil moisture validation against in-situ data,
  - Atmospheric verification,

- Part III: Short experiments with different observation and background error scenarios
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Technical work done in IFS

List of issues

- ☑ RFI used in reprocessing
- ☑ AFOV flag used in preprocessing
- ☑ Change in monitoring over oceans; lsm introduced in general SQL
- ☑ Update links to new fields
- ☑ Add new CDF files and SMOS default op and rd configuration in hpsc
- ☑ Include binning option in prepIFS
- ☑ Adapt LESMOS switch in high-level routines, and cleaning unnecessary calls
- ☑ Use of npools instead of NPES_AN in bufr2odb
- ☑ Introduce SMOS MARS codes in CDF matching files
- ☑ Optimize CDF matching code for SMOS
- ☑ Merge monthly CDF matching files in a single grib
- ☑ Check the grib key needed to simplify CDF files
- ☑ Bugs for running expts in CRAY solved
- ☑ Bugs for angle averaging in shuffle_odb.F90 for cy40r3 solved

Contribution to cy40r3

- ☑ Solved bug assigning the same incidence angle to different obs in the same processor,
- ☑ IFS CMEM interface completed,
- ☑ Updated CMEM parameterisations with calibrated values following offline calibration study,
- ☑ Full specs of the obs managed by a single namelist, avoiding to edit each time F90 routines hard-coded for monitoring,
- ☑ Implementation of bias correction routines,
- ☑ Monitoring of SMOS data updated with 2m temp and snow depth masks
- ☑ Updated files to avoid calculation with RMDI values and feedback to ODB
- ☑ Implementation of angular binning per grid-point, incidence angle and polarisation

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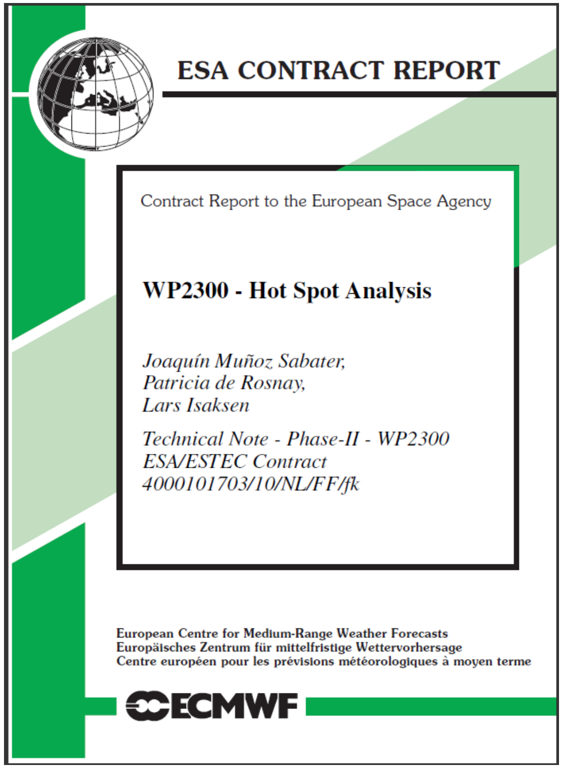
Deliverables since last PM


ESA CONTRACT REPORT

Contract Report to the European Space Agency

WP2300 - Hot Spot Analysis

Joaquín Muñoz Sabater,
Patricia de Rosnay,
Lars Isaksen

Technical Note - Phase-II - WP2300
ESA/ESTEC Contract
4000101703/10/NL/FF/fk

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen terme

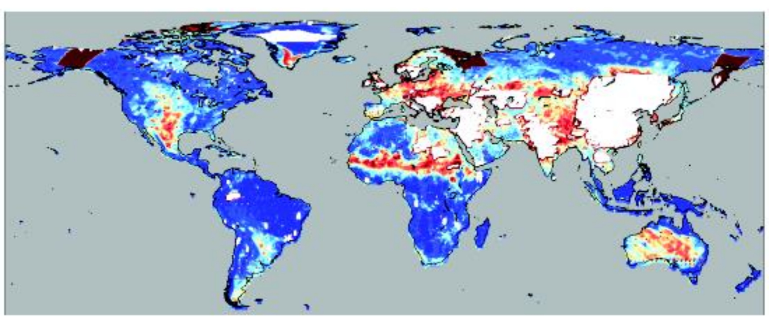
ECMWF

20.12.2013 - DL7(WP2300) :

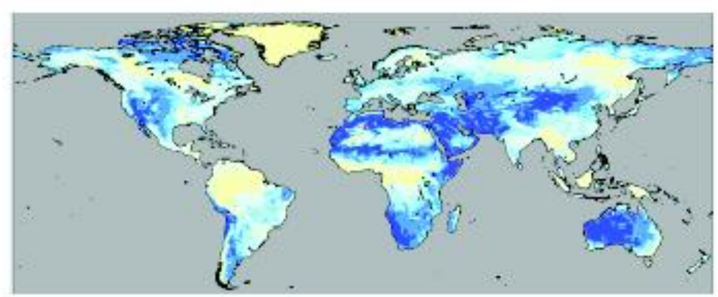
Hot spot analysis

- **Regions showing high dynamism of TBs,**
- **Equivalent model sensitivity,**
- **Promising for data assimilation impact**

$$J^{SMOS}_{(0-7cm)}(\alpha, p) = \frac{T'_B(\alpha, p) - T_B(\alpha, p)}{\delta\theta}$$

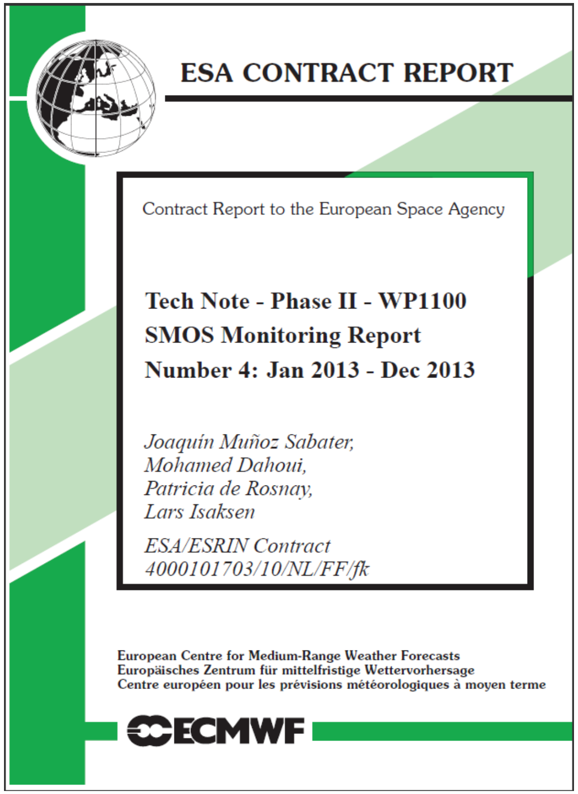


(b) July 2010



(b) July 2010

Deliverables since last PM


ESA CONTRACT REPORT

Contract Report to the European Space Agency

Tech Note - Phase II - WP1100
SMOS Monitoring Report
Number 4: Jan 2013 - Dec 2013

Joaquín Muñoz Sabater,
Mohamed Dahoui,
Patricia de Rosnay,
Lars Isaksen

ESA/ESRIN Contract
4000101703/10/NL/FF/fk

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
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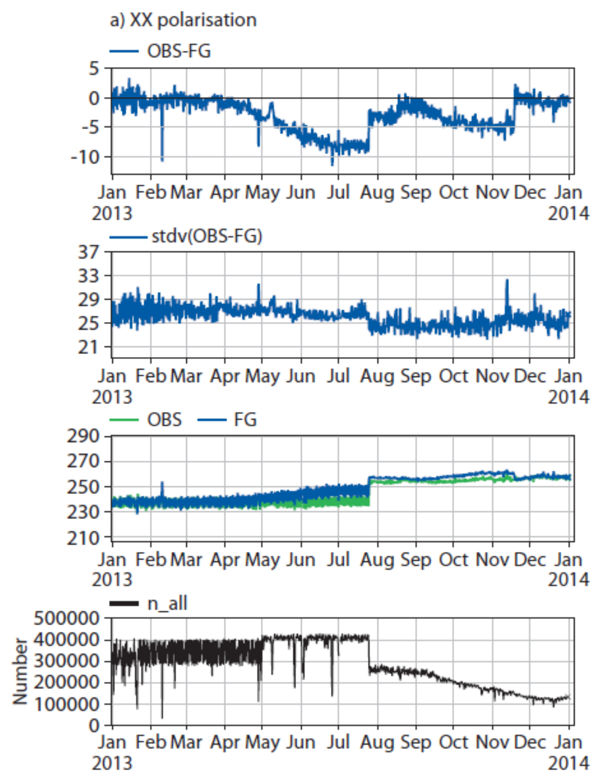
24.01.2014 - DL2 (WP3200):

Monitoring Report number 4

- **Year 2013,**
- **CMEM new calibration impacted the regionalized statistics,**
- **Bias are reduced**



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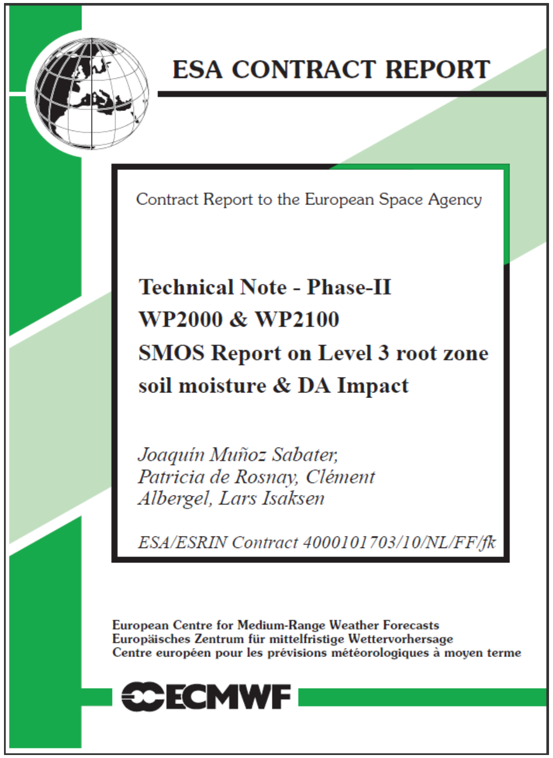
Deliverables since last PM


ESA CONTRACT REPORT

Contract Report to the European Space Agency

Technical Note - Phase-II
WP2000 & WP2100
SMOS Report on Level 3 root zone soil moisture & DA Impact

Joaquín Muñoz Sabater, Patricia de Rosnay, Clément Albergel, Lars Isaksen

ESA/ESRIN Contract 4000101703/10/NL/FF/fk

European Centre for Medium-Range Weather Forecasts
Europäisches Zentrum für mittelfristige Wettervorhersage
Centre européen pour les prévisions météorologiques à moyen terme

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28.02.2014 - DL5 (WP2000) & DL6 (WP2100):

SMOS report on Level-3 root zone soil mosture & DA impact

- **Root-zone algorithm and production chain → soil moisture product based on the assimilation of SMOS data**
- **Validation with in-situ data**
- **Atmospheric impact verification**

ECMWF

SMOS KO meeting 05-09-14

Joaquín Muñoz Sabater

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Root zone soil moisture SMOS-DA product

SMOS-DA : SM product based on assimilation of SMOS T_B in the antenna reference

- Global scale product, obtained at the ECMWF **T511** (~40 km) reduced Gaussian Grid.
- Period: **1 May 2010** 00UTC – **31 October 2012** 12UTC analysis.
- Observations configuration:
  - NRT T_B from **second reprocessed dataset 2010-2011** + NRT (v5.05) for 2012,
  - **30, 40, 50** degrees ± ΔT_B=0.5 K, **XX & YY** polarisations,
  - Only AF-FOV,
  - RFI flag used (BUFR info flag, bit-1)
  - Bias corrected using a point-wise CDF matching (based on yearly v_0 coefficients)
- CMEM configuration; best for R (Wang(DIEL), Wsimple(RGH), Wigneron(VEG))
- **Jacobians calibrated** ($\Delta\theta j$=0.01m^3m^{-3}, $/H^-_{max}/ = /H^+_{max}/$ =250 K/m^3m^{-3})
- **STD of observations error →** radiometric accuracy
- Full observational system used for the atmosphere,

✔ **Version 1**

- Interface and vegetation usage **bugs fixed**,
- 2-degrees **binned observations** at 30, 40, 50 degrees ± Δα=1, XX & YY polarisations,
- Observations bias corrected using **monthly CDF coefficients (v_2)**
- Physics of **cycle 38r2**

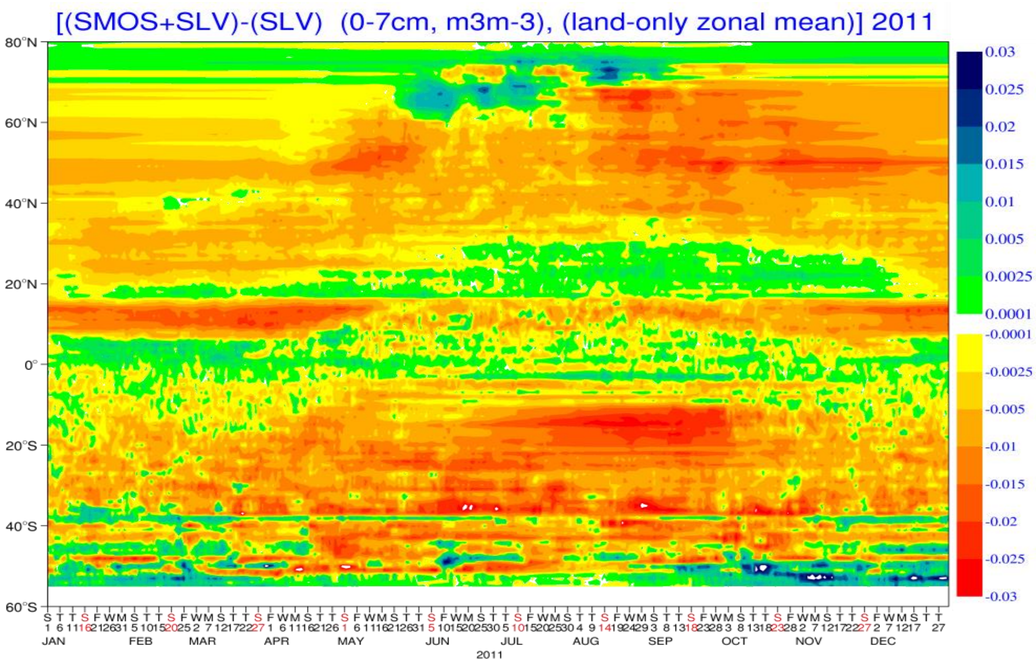
✔ **Version 2**

- Improved quality control check (fg check and Jacobians bounds revised. RFI prob occurrence maps?),
- 3D-error structures for B-matrix based on soil properties. Better definition of R matrix?
- Improved bias correction (CDF?, VARBC?, …)
- Larger use of incidence angles (25, 35, 45, 55)
- Physics of cycle 41

Version 3?

SMOS-DA SM product

- **Full year cycle (2011),**
- **Top layer,**
- **SM increment differences (SMOS-DA – CTRL),**



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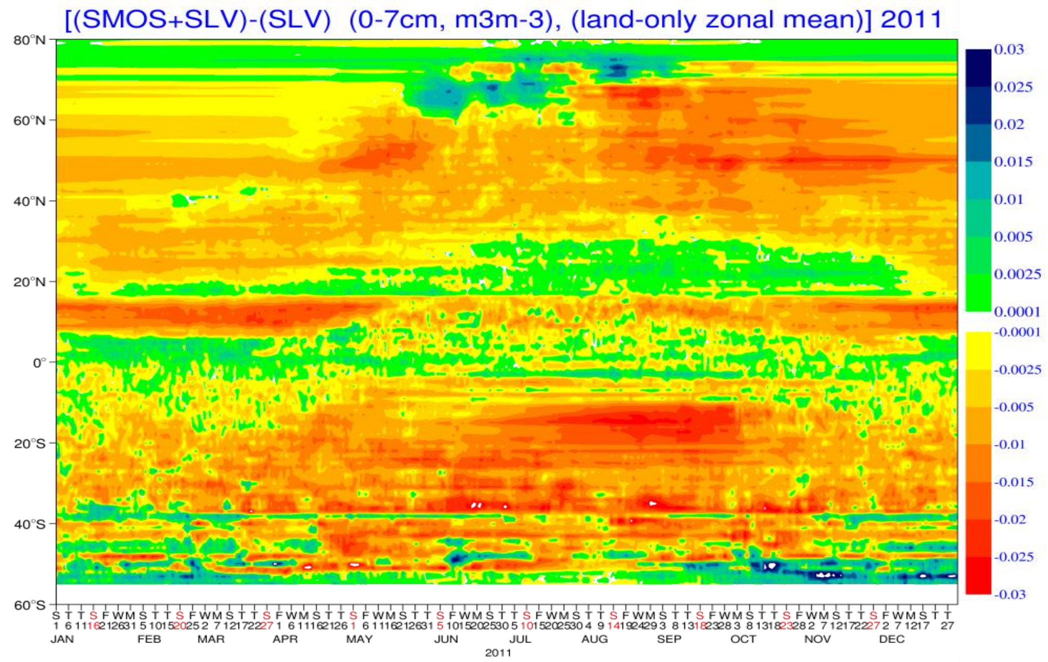
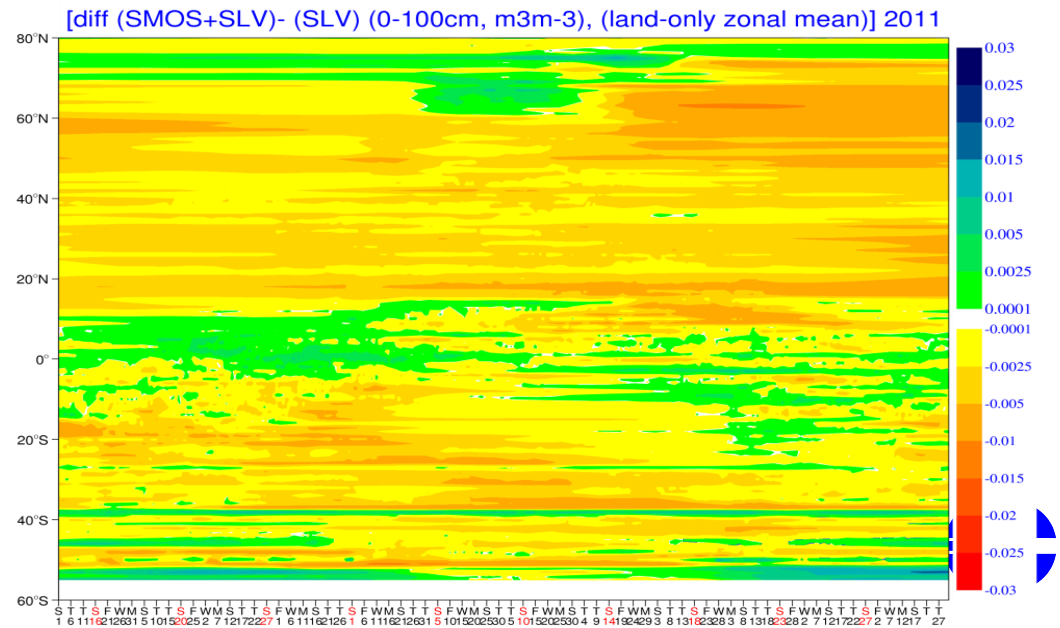
SMOS-DA SM product

- **Full year cycle (2011),**
- **Top layer,**
- **SM increment differences (SMOS-DA – CTRL),**



- **Full year cycle(2011),**
- **Deep layer,**
- **SM increment differences (SMOS-DA – CTRL),**



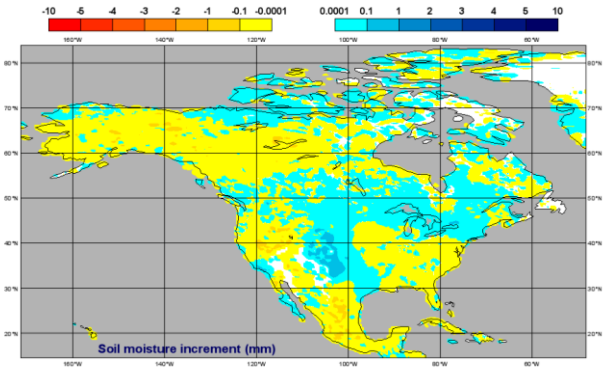
Assimilation experiments comparison

<u>Assimilation experiments:</u>

- Only SLV (T^{2m} and RH^{2m})
- Only SMOS TB
- SLV + SMOS TB

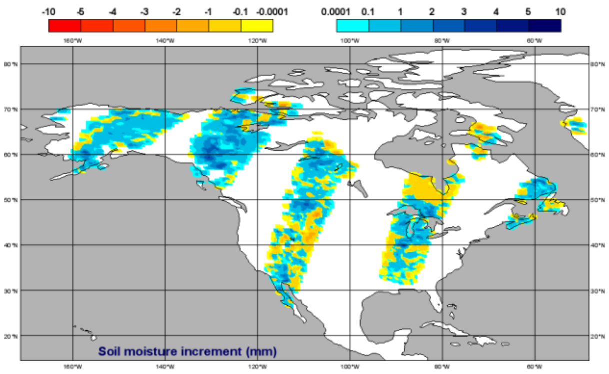
- Period: **1 June 2010** 00UTC – **31 August 2010** 12UTC analysis (1 month spin-up) → Boreal summer
- same specs that SMOS-DA experiment

Assimil T^{2m} & RH^{2m}



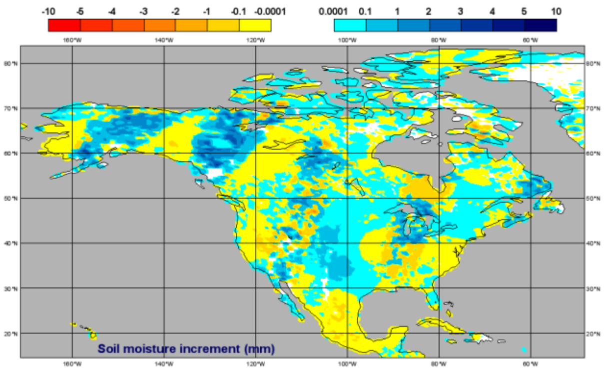
min=-0.45 mm; max=0.44 mm; mean=-0.01mm

Assimil SMOS T_B



min=-3.98 mm; max=3.62 mm; mean=-0.32mm

Assimil T^{2m}, RH^{2m} & SMOS T_B



min=-3.66 mm; max=4.26 mm; mean=0.12mm

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Assimilation experiments analysis

Analysis of the different components of the SEKF in these expts:

- First-guess departures
- Jacobians of the observator operator
- Gain matrix components
- Quality control
- Soil moisture increments
- Point-scale time series analysis
- Global time series analysis

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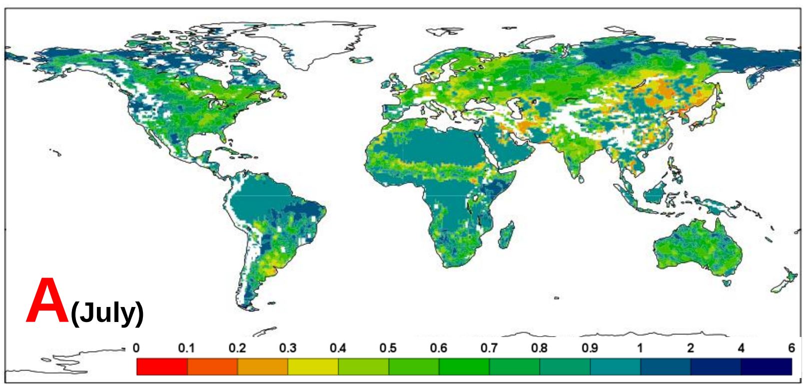
Bias correction

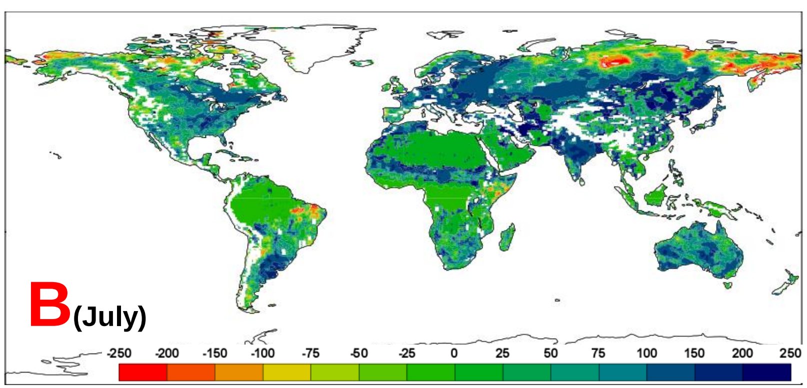
CDF-matching → matches mean and variance of two distributions

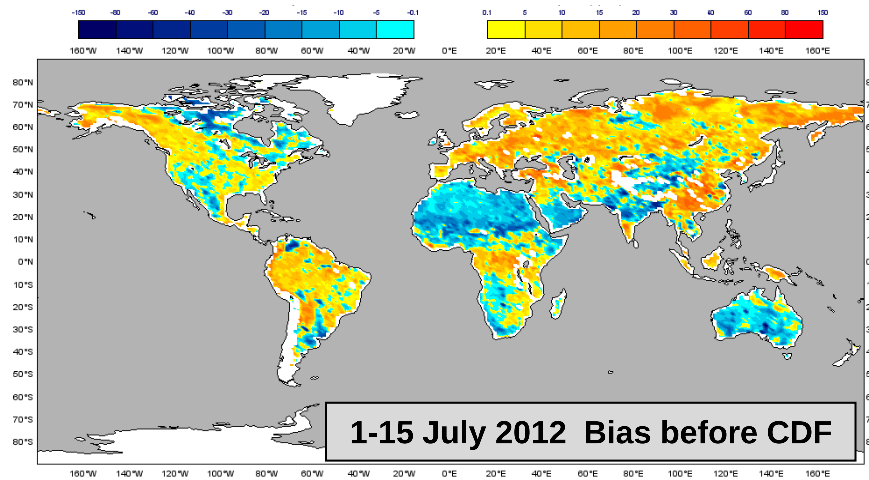
$$\boxed{T_B(BC) = \mathbf{A} * T_B^{SMOS} + \mathbf{B}}$$

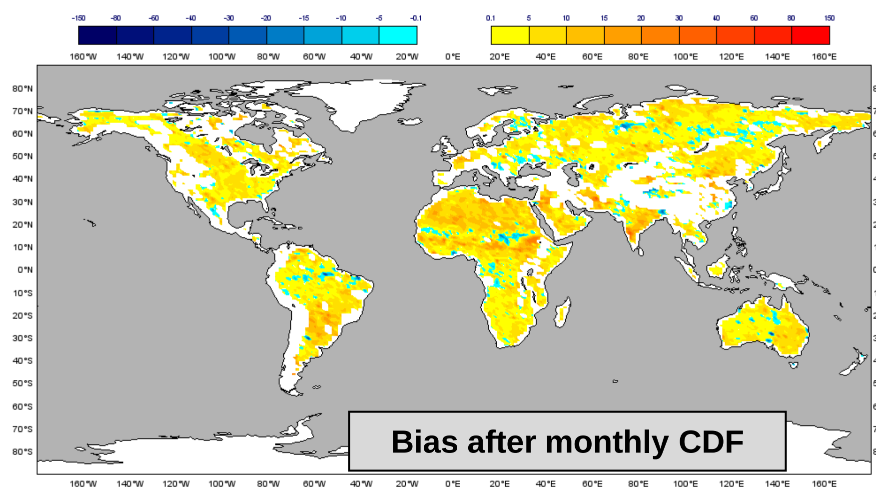
$A = \sigma_{CMEM} / \sigma_{SMOS}$

$B = T_B^{CMEM} - T_B^{SMOS} * (\sigma_{CMEM} / \sigma_{SMOS})$





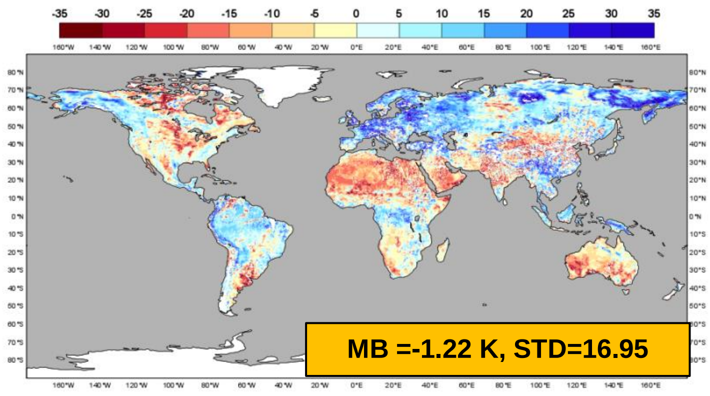




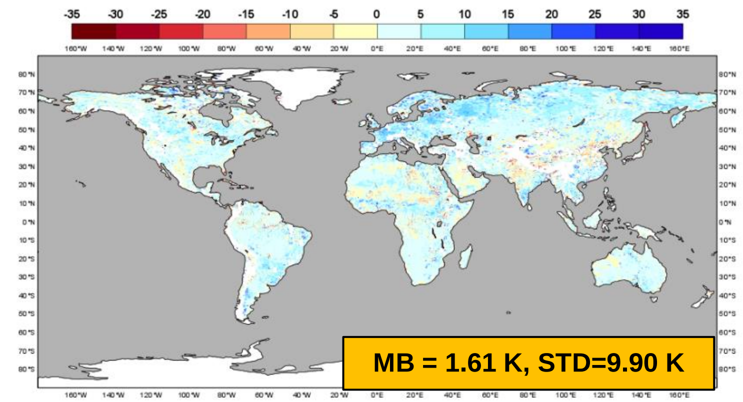
CDF matching and fg_departures (OBS-MODEL)

June 2010

SMOS T_B -40XX



After CDF-matching



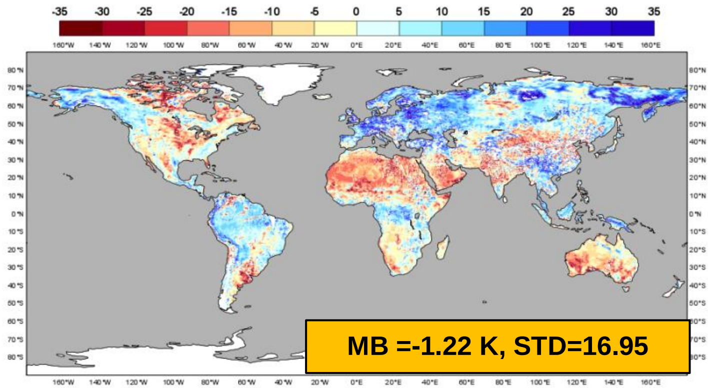
- **The shown bias are very consistent with the statistical monitoring plots**
- **Strong regional bias in XX polarisation**
- **CDF-matching reduces greatly the mean absolute bias and their STD**

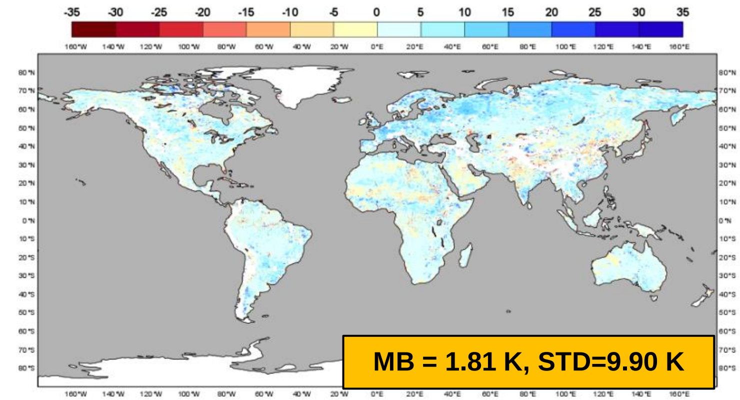
	Before	After
40XX MAB	17.38	9.68
40YY MAB	15.99	9.82

CDF matching and fg_departures (OBS-MODEL)

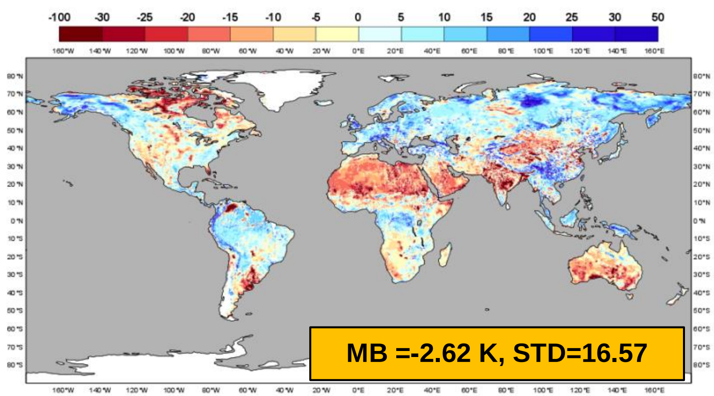
SMOS T_B -40XX | **After CDF-matching**

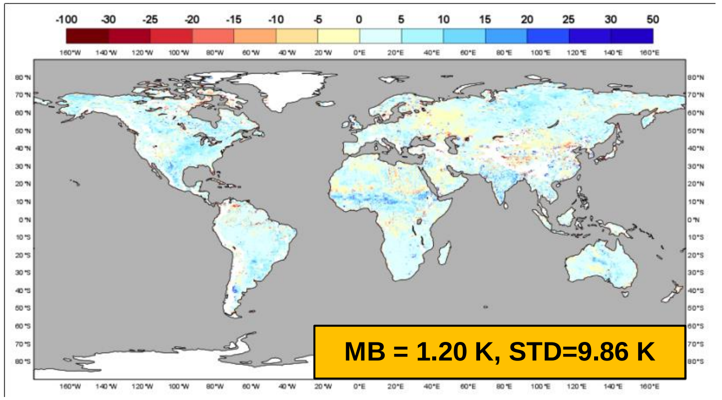
June 2010





July 2010





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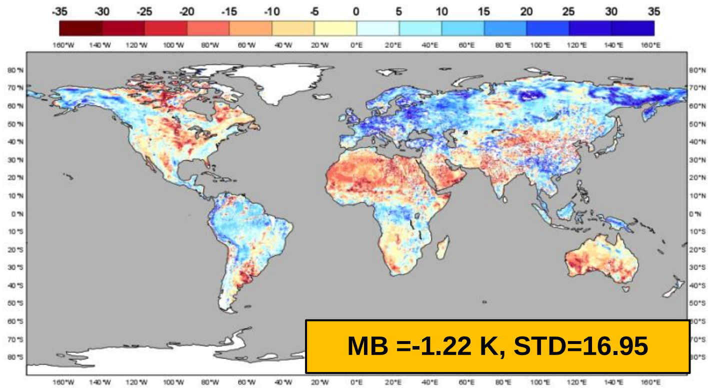
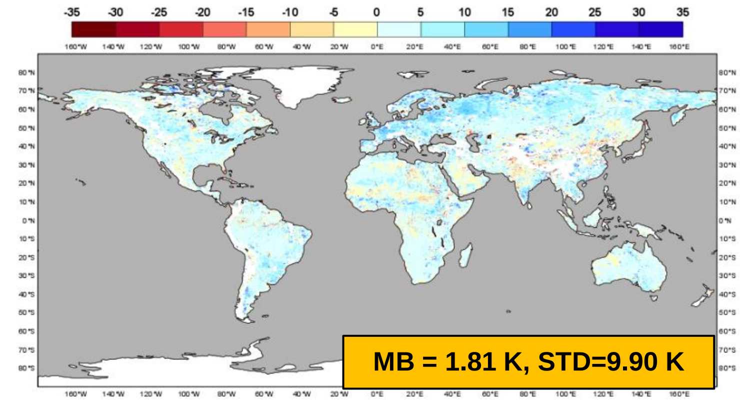
CDF matching and fg_departures (OBS-MODEL)

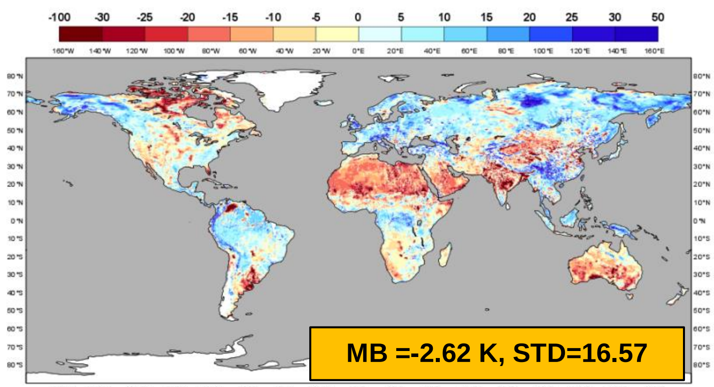
SMOS T_B -40XX | **After CDF-matching**

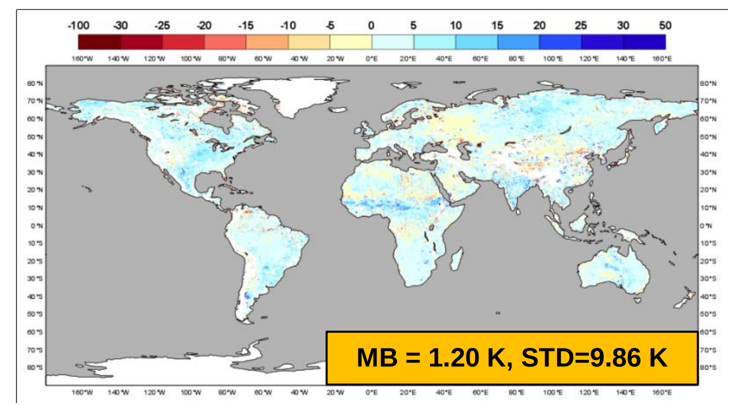
June 2010



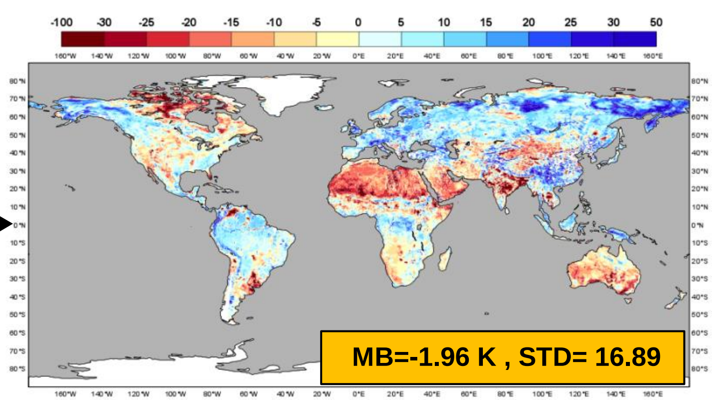


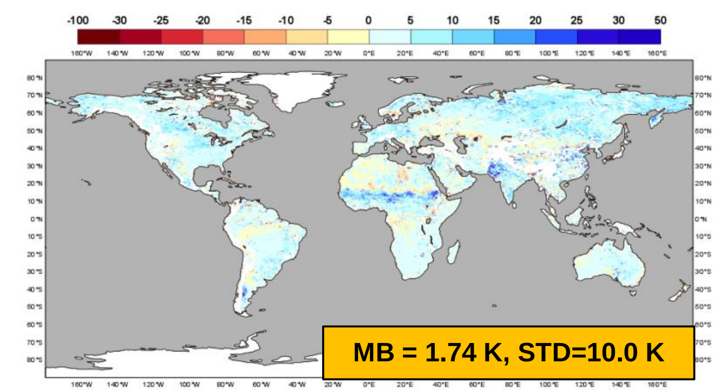
July 2010





August 2010

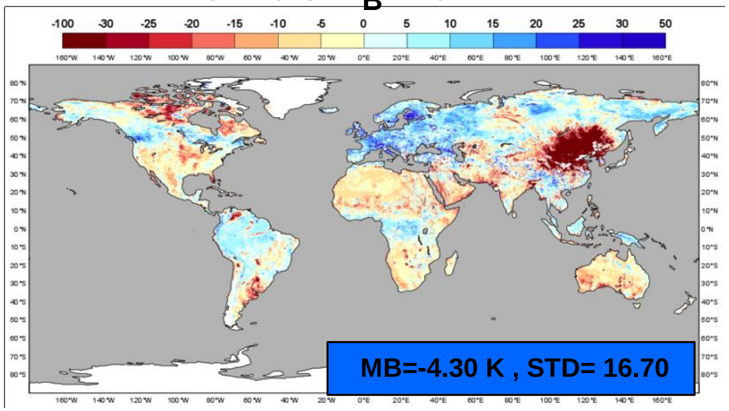


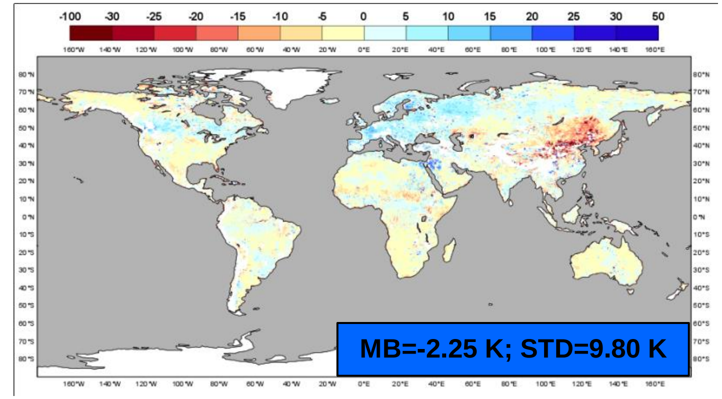


CDF matching and fg_departures (OBS-MODEL)

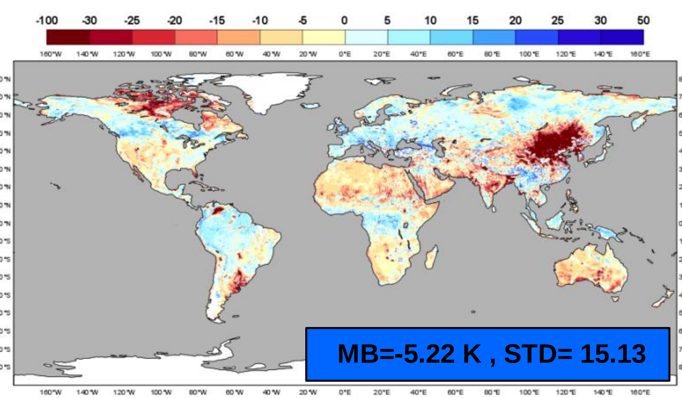
SMOS T_B -40YY | **After CDF-matching**

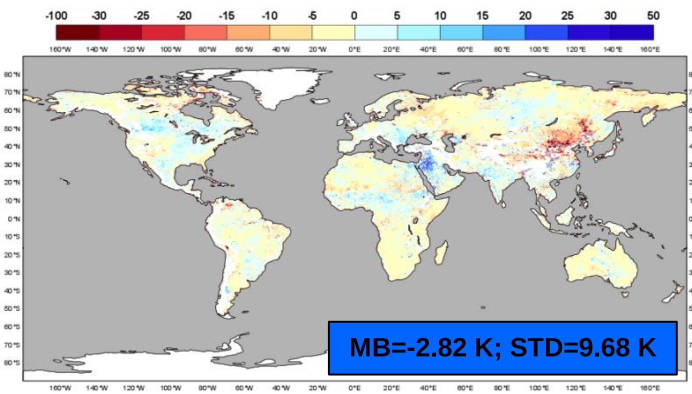
June 2010





July 2010





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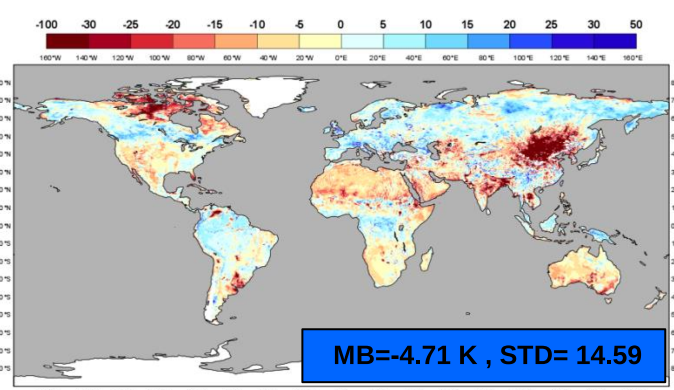
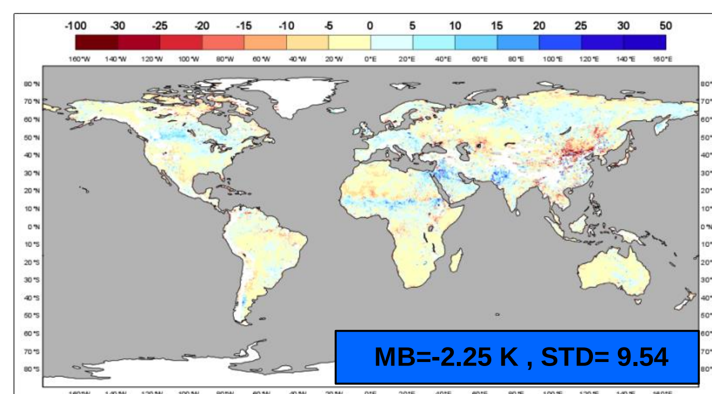
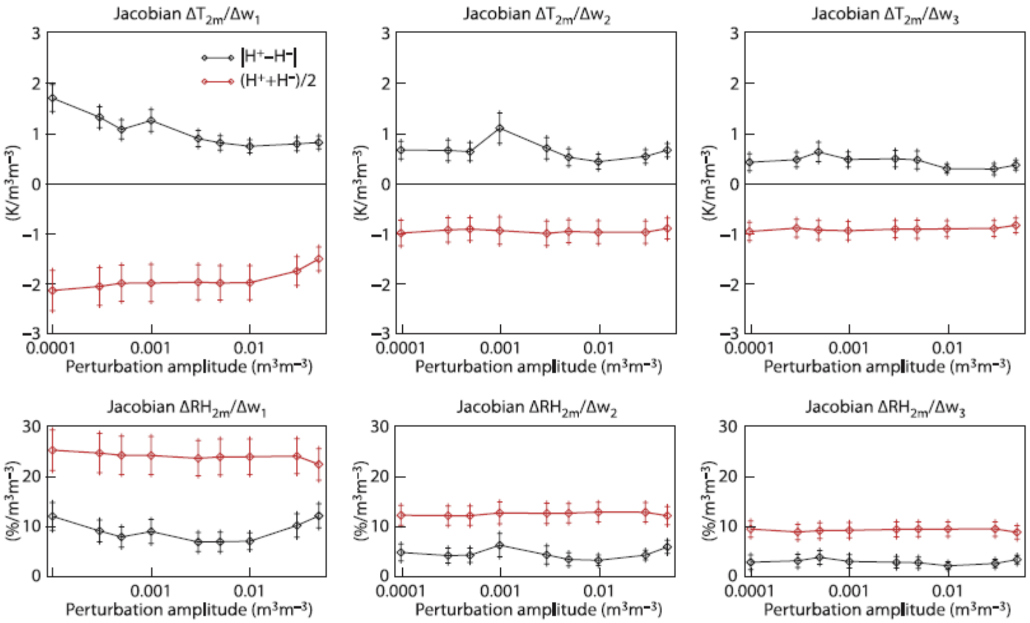




Jacobians of the observation operator

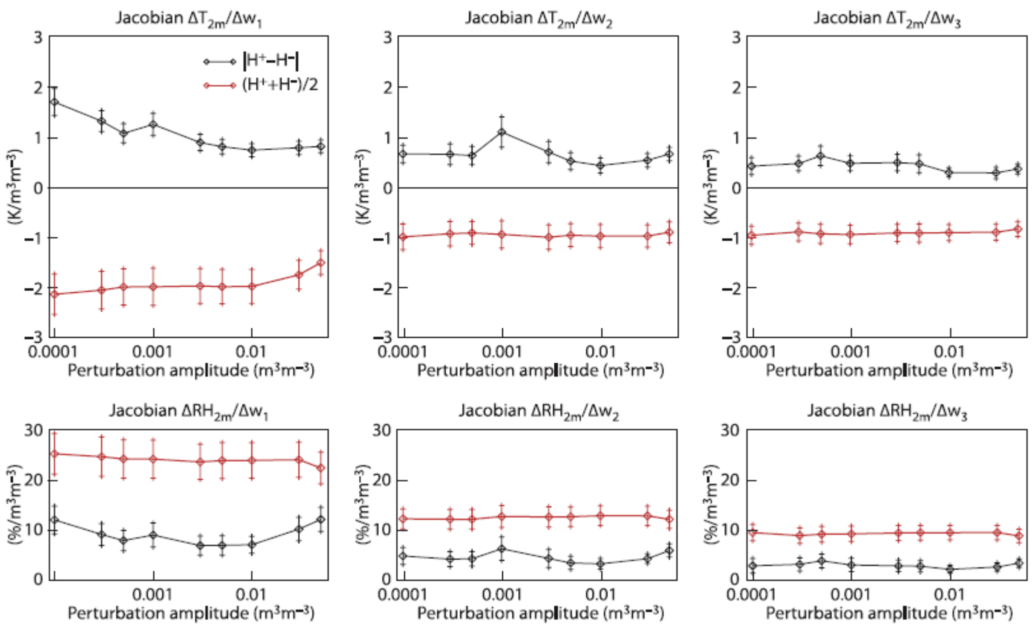


Drusch et al., 2009 (JHM)

- T2m sensitivity to soil moisture is negative
- RH2m sensitivity to soil moisture is positive
- Larger sensitivity of top layer

- The best perturbed value of soil moisture is 0.01 m3m-3

Jacobians of the observation operator



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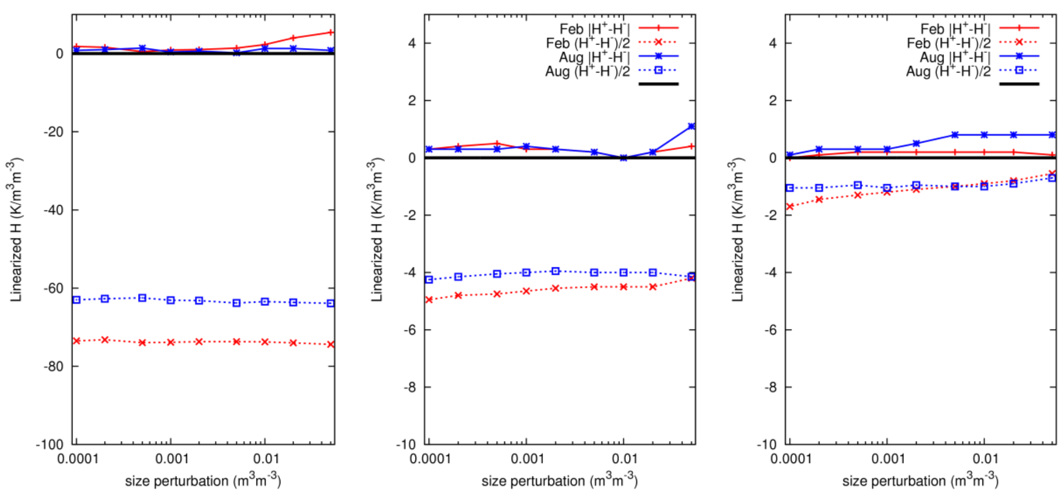


- TB sensitivity to soil moisture is negative

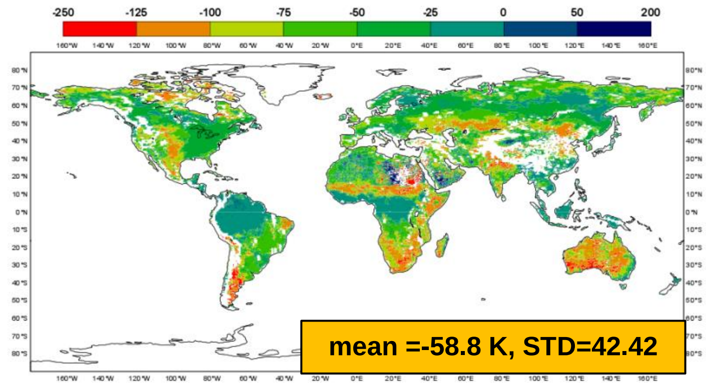
- Much larger sensitivity of the top layer → the correction of the top layer will be more effective in order to fit the observations

- Best values between 0.001 and 0.01 m3m-3 → for consistency with screen temp and humdity, 0.01 m3m-3 selected

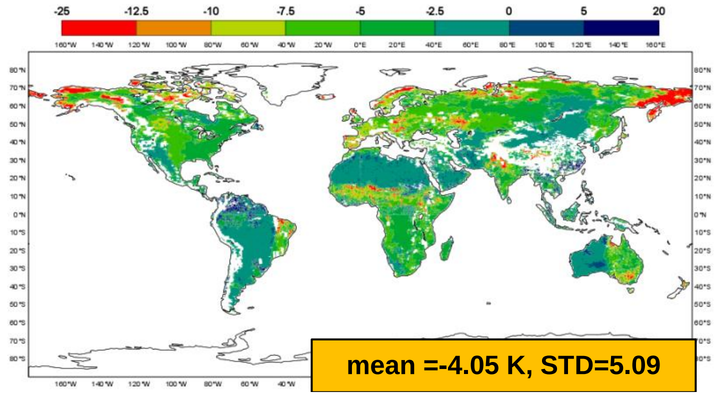
SMOS components of the Jacobians (SMOS expt)

SMOS T_B -40XX (June average)

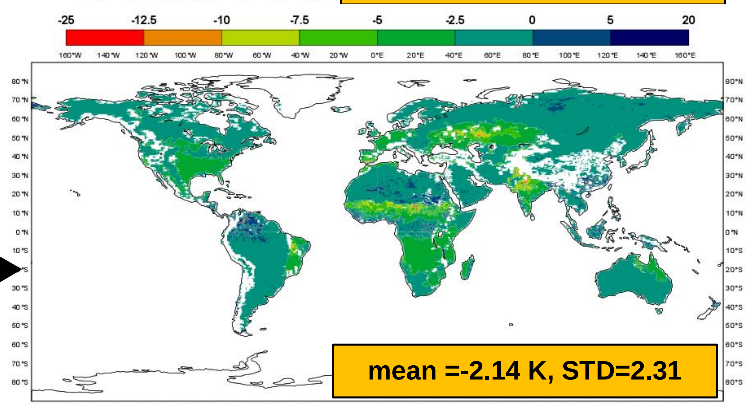
L1 (0-7 cm)



L2 (7-28 cm)



L3 (28-100 cm)



- Consistent values with calibration expts,
- Some dependence found as a function of the incidence angle and polarisation (also with averaged month), but the patterns are the same
- Main sensitivity found in transition zones (hot-spots),
- SMOS+SLV & SMOS expts have similar jacobians range of values

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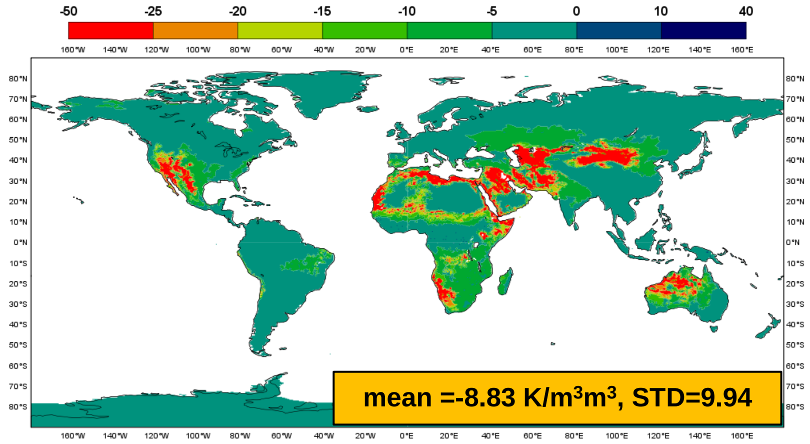
T2m and RH2m components of the Jacobians (SLV expt)

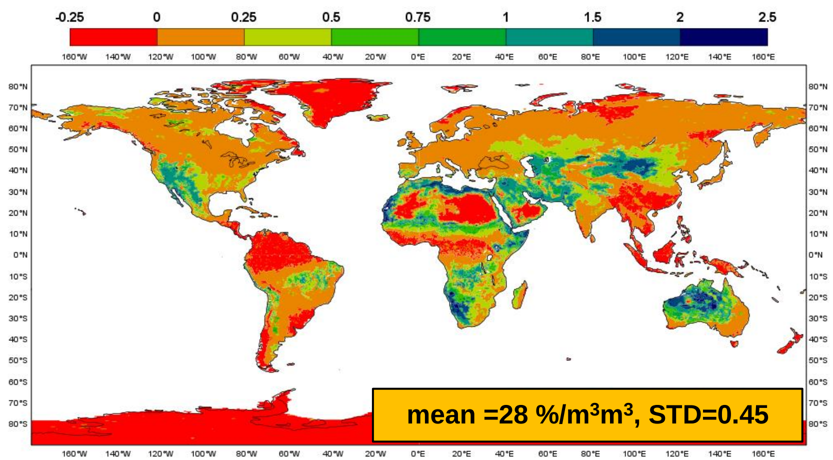
T^{2m} (00 & 12UTC June average)

(0-7 cm)



RH^{2m} (00 & 12UTC June average)

(0-7 cm)



- A soil moisture increase, reduces T2m, Whereas increases mostly RH2m.
- Jacobians for 2nd and 3rd layer are smaller.

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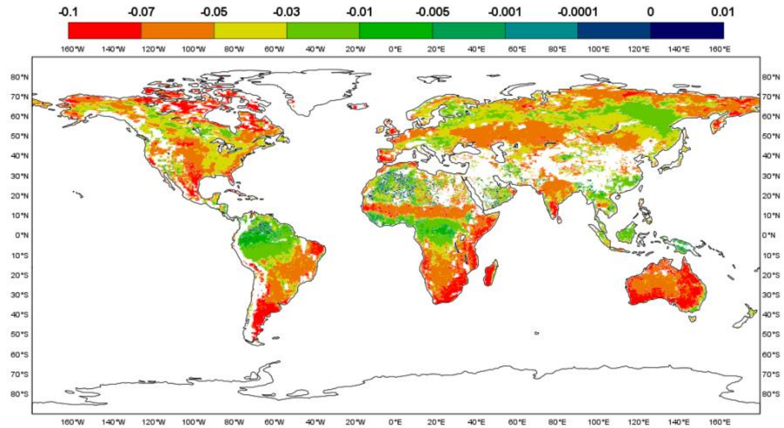
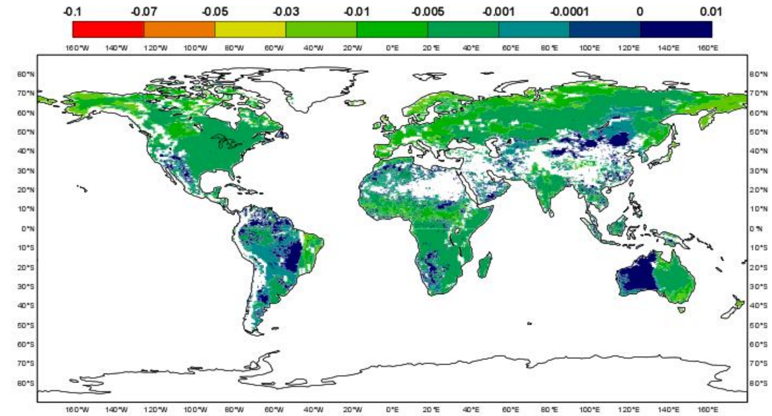
Gain components (SMOS + SLV expt)

SMOS T_B - 50XX (June average) – [0-7]cm

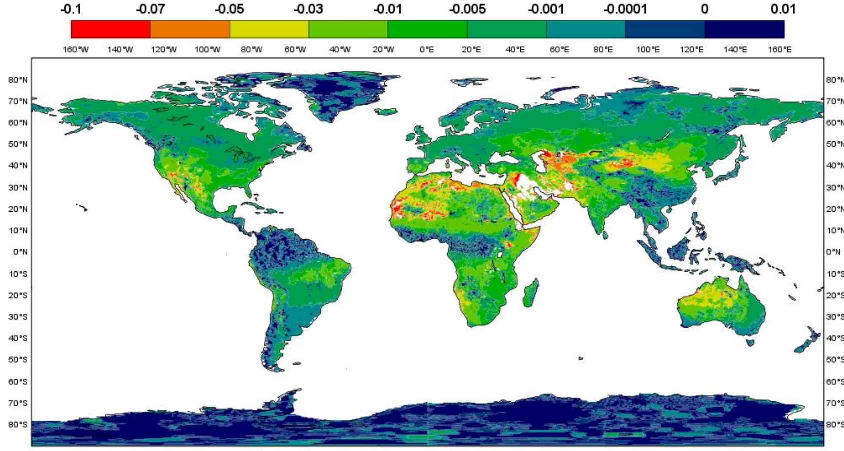


SMOS T_B - 50XX (June average) – [7-28] cm

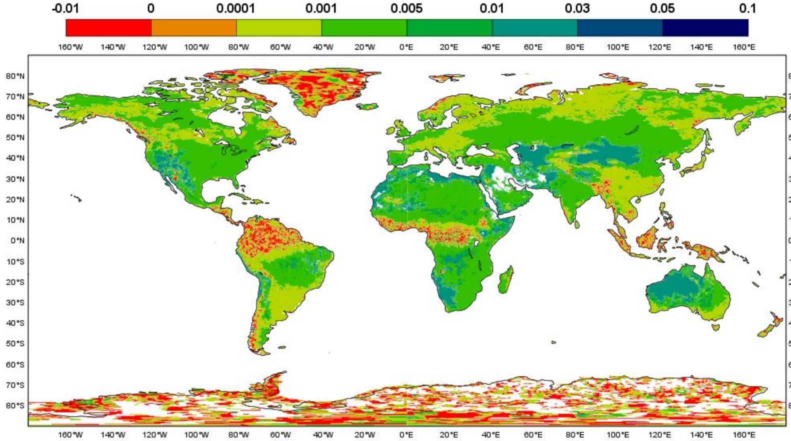


- SMOS gain components are negative for the top layer
- They follow well the Jacobians maps
- Remarkable reduction for the 2nd and 3rd layer

T^{2m} 00 & 12UTC (June average)



RH^{2m} 00 & 12UTC (June average)



- Similar patterns for 2nd and 3rd layer, but the gain reduction is less noticeable

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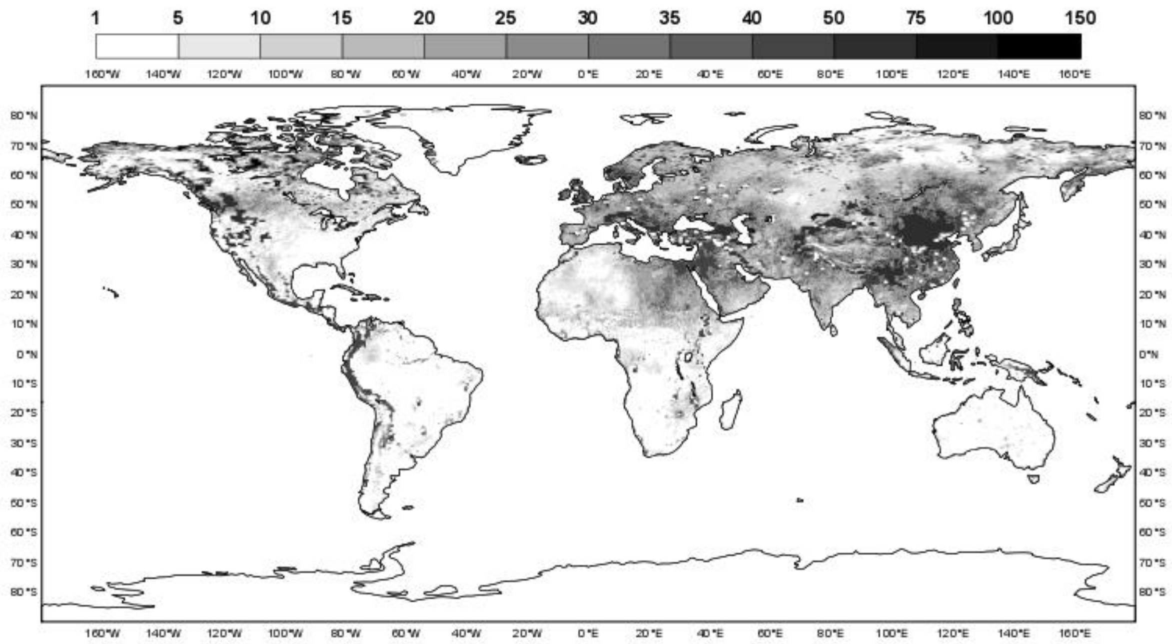
Quality control

- **Quality control in the SEKF for these experiments:**
  - **Number of observations,**
  - **First-guess check (5 K, 20, 20 K)**
  - **Jacobian check (50 K/m^3m^{-3}, 500%/m^3m^{-3}, 250 K/ m^3m^{-3})**
  - **Soil moisture increment check (Δ>0.1 m^3m^{-3})**

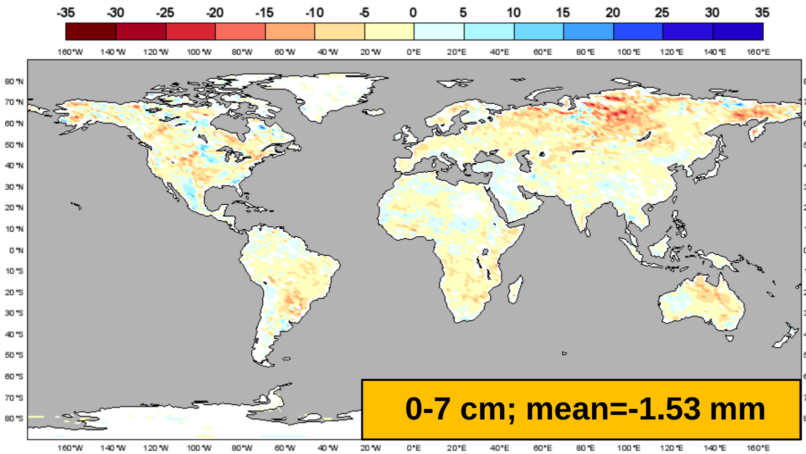


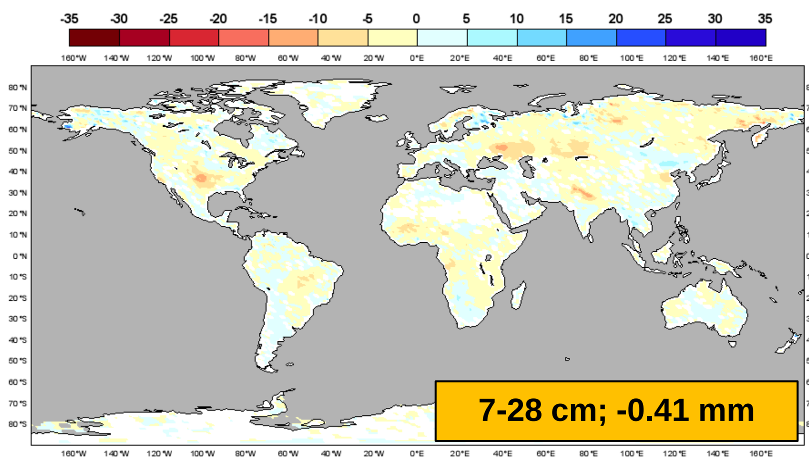
ECMWF

Accumulated soil moisture increments differences (mm)

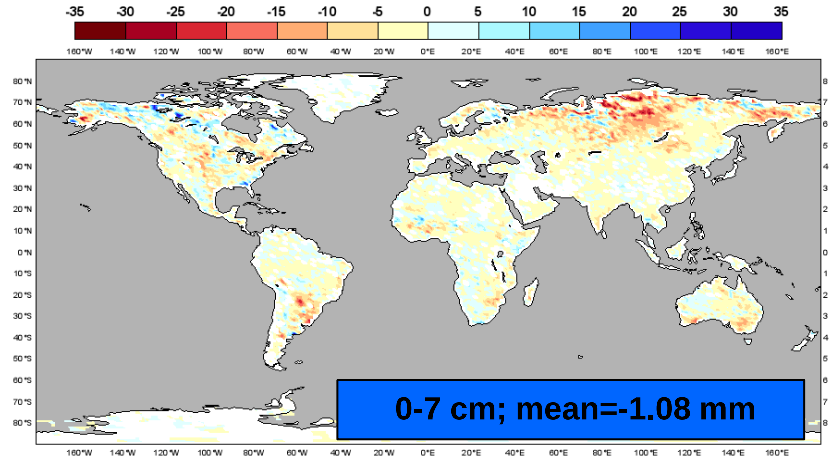
June 2010

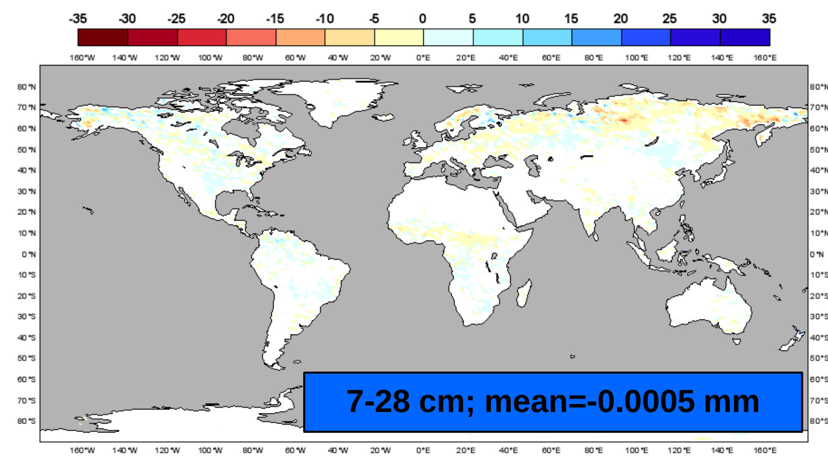
SMOS T^B – SLV





[SMOS T^B , T^{2m}, RH^{2m}] – SLV



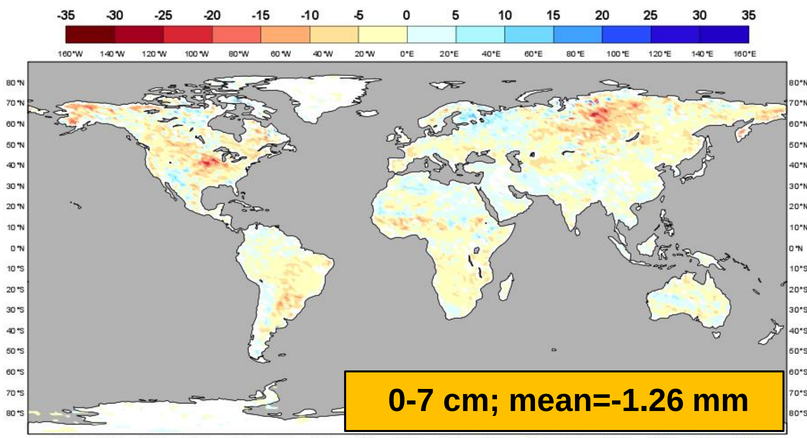


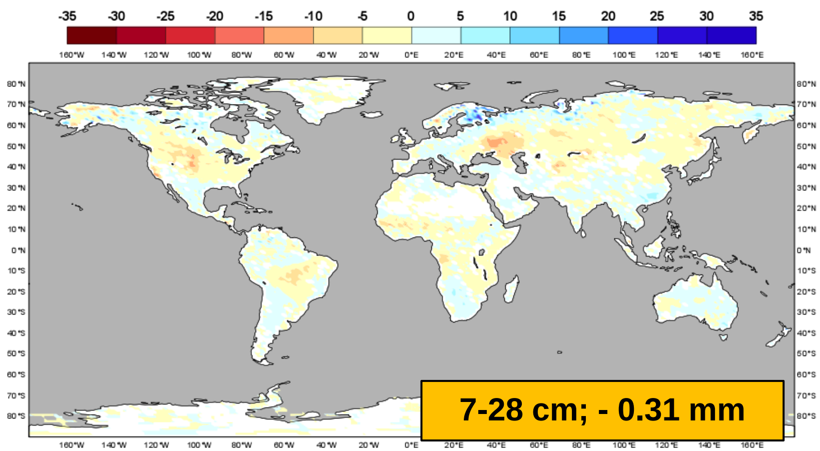
- Soil moisture increments differences seem to be dominated by SMOS instead of screen level variables, as increments are stronger. → Patters for top soil layer are quite similar for both configurations.
- The second soil layer is more affected if only SMOS TBs are assimilated

Accumulated soil moisture increments differences (mm)

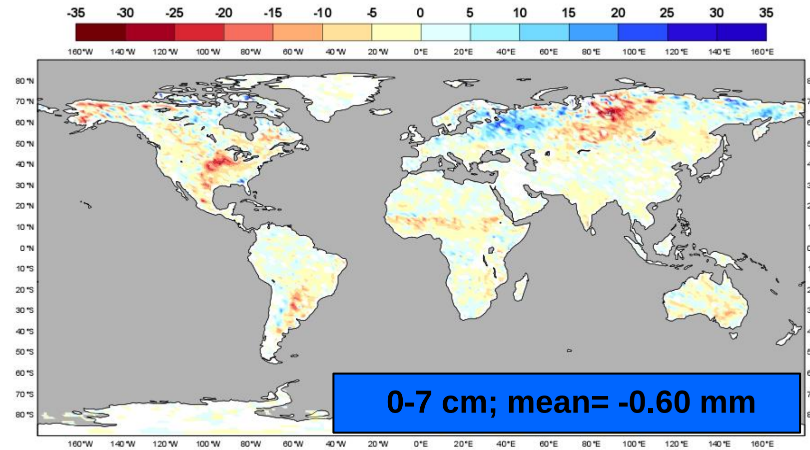
July 2010

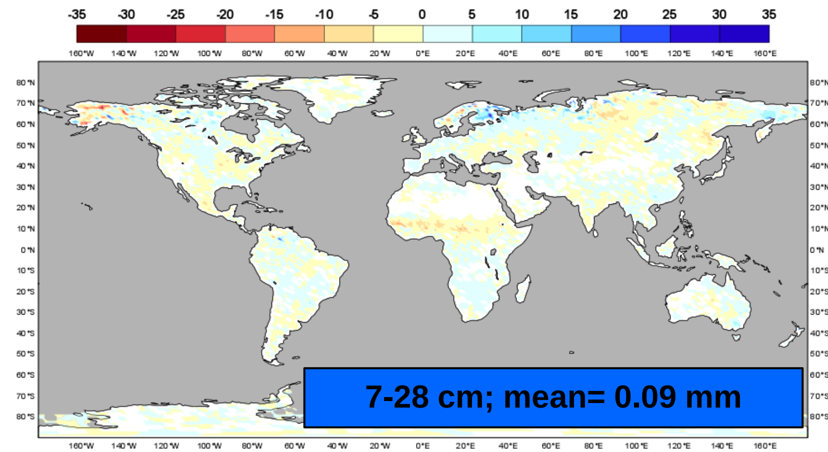
SMOS T^B – CTRL (SV)





[SMOS T^B, T^{2m}, RH^{2m}] – CTRL (SV)





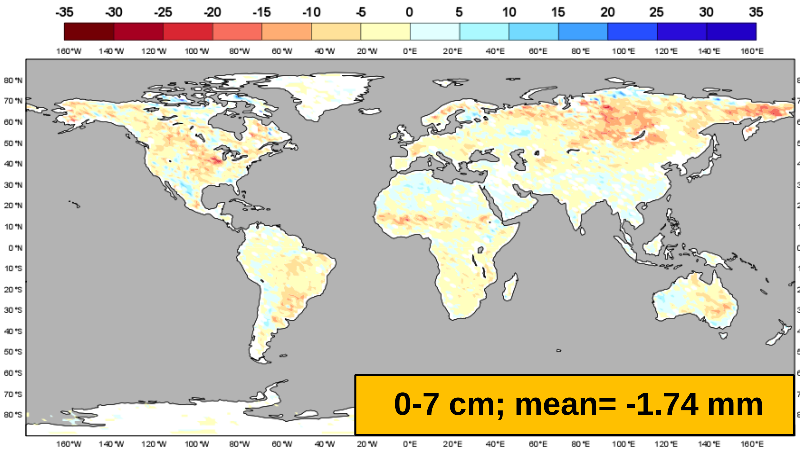
ECMWF

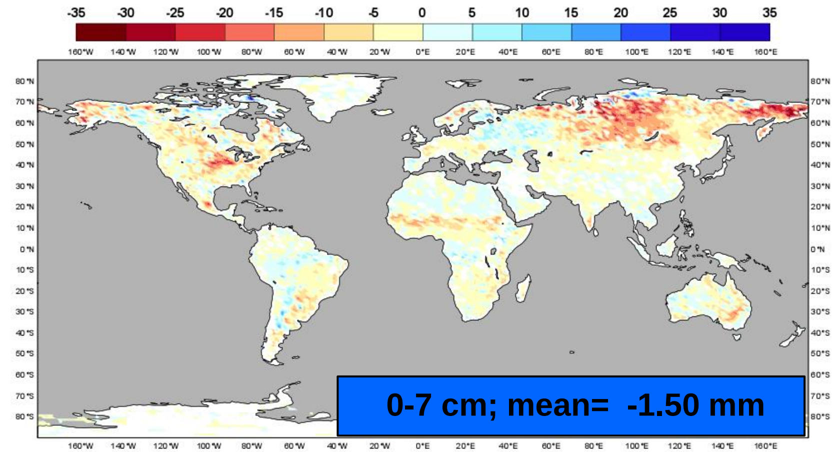
Accumulated soil moisture increments differences (mm)

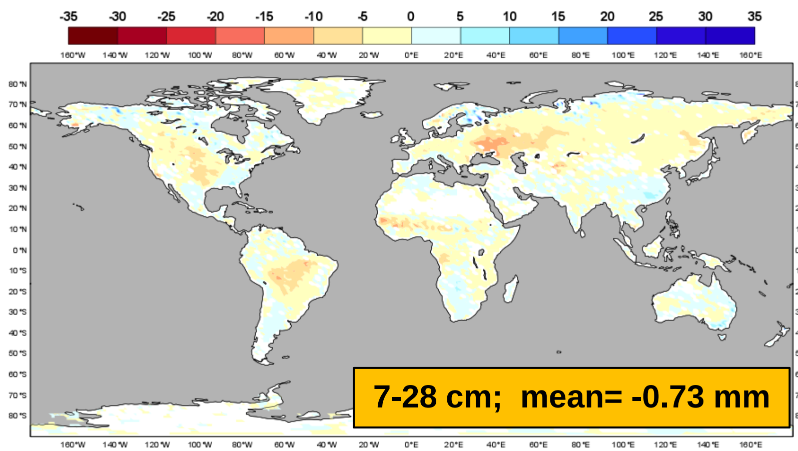
August 2010

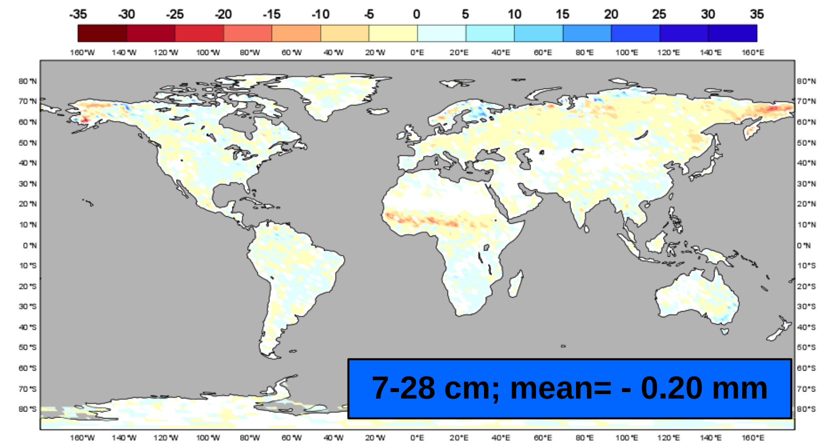
SMOS T^B – CTRL (SV)

[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)







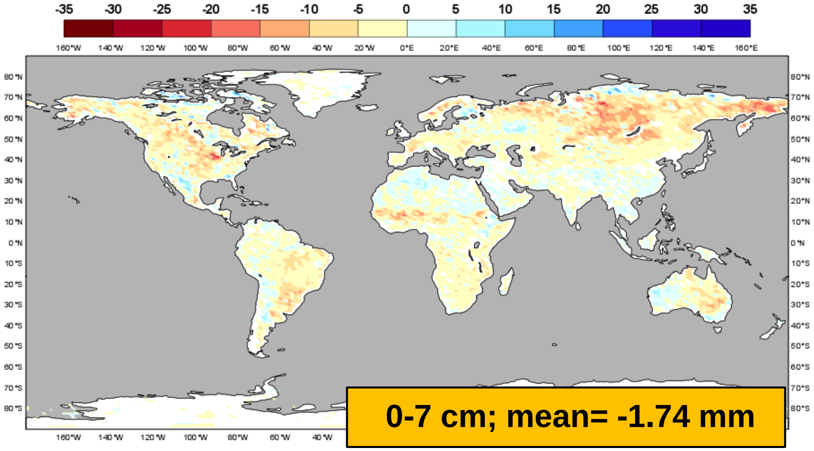


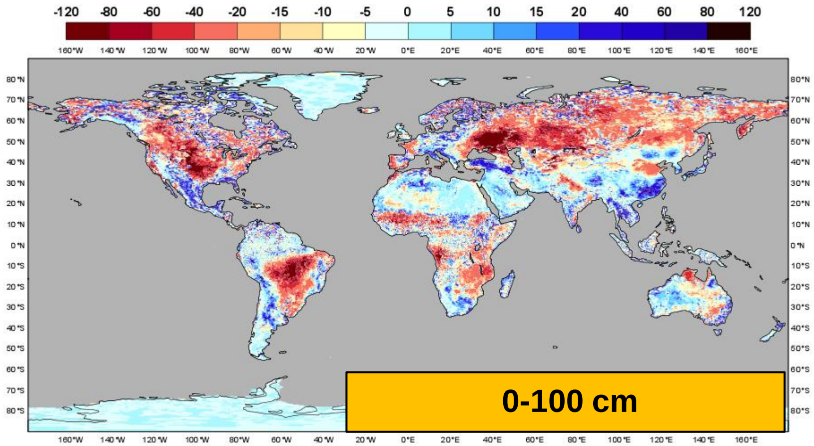
ECMWF

Accumulated soil moisture increments differences (mm)

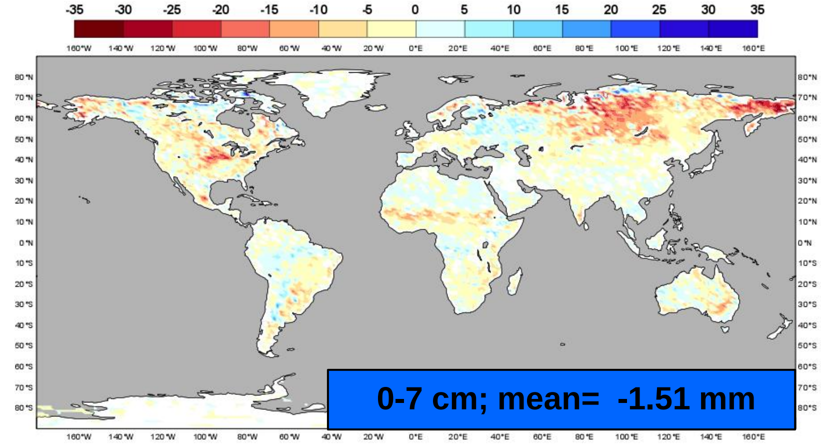
JJA - 2010

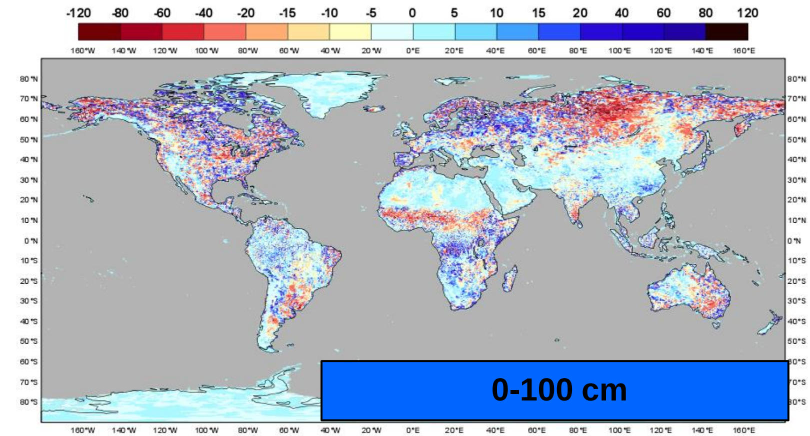
SMOS T^B – CTRL (SV)





[SMOS T^B, T^{2m}, RH^{2m}] – CTRL (SV)





Accumulated soil moisture increments

JJA - 2010

Mean absolute increments

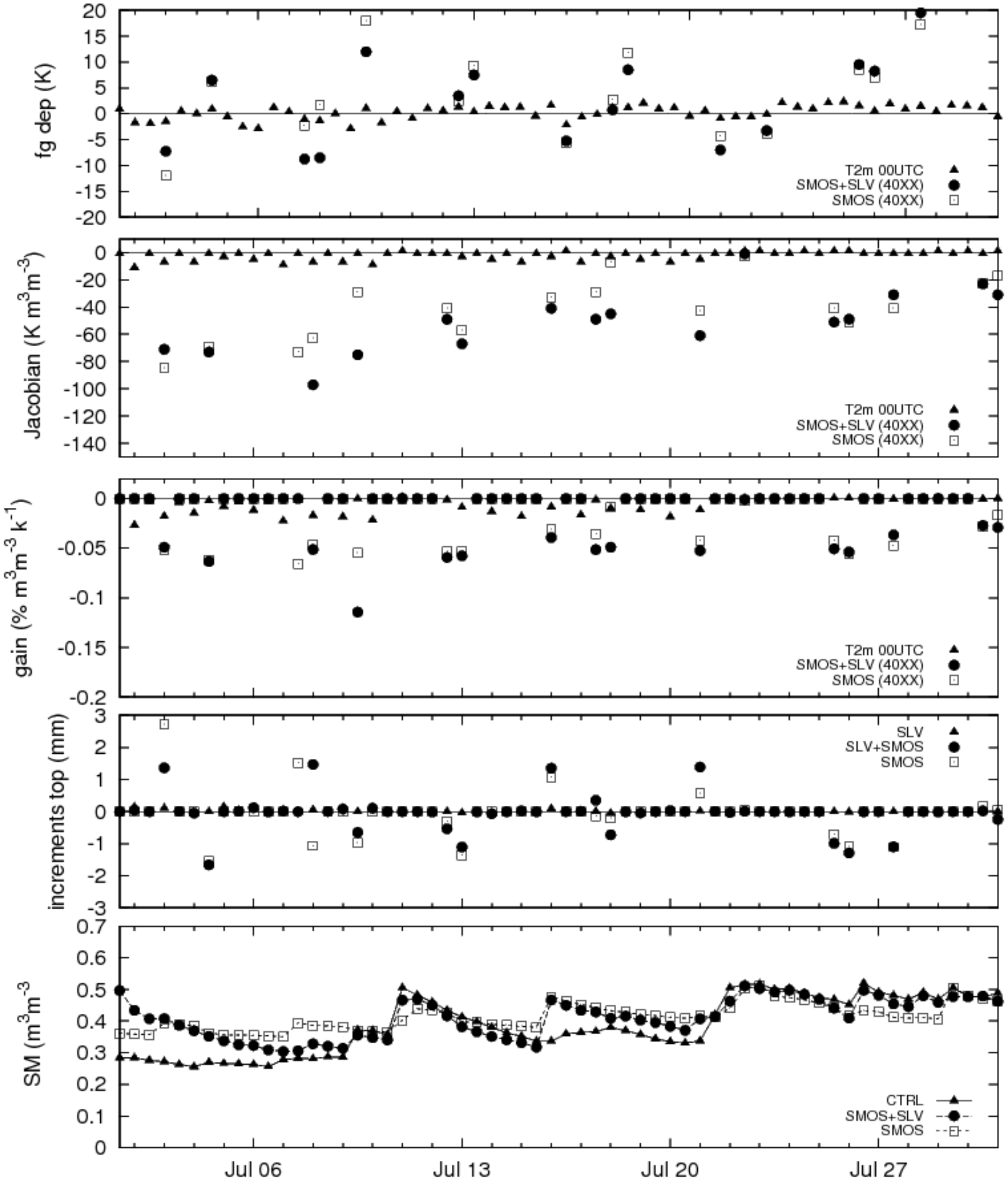
	SLV	SLV+SMOS	SMOS
(0-7cm) MAInc (mm)	0.03	0.15	0.16
1^{st} meter MAinc (mm)	0.16	0.31	0.23
1^{st} meter STD	0.14	0.25	0.18

Total absolute increments

	SLV	SLV+SMOS	SMOS
(0-7cm) TAInc (mm)	0.99	6.66	6.15
1^{st} meter TAinc (mm)	7.84	15.43	9.13
1^{st} meter STD	18.52	34.34	23.27

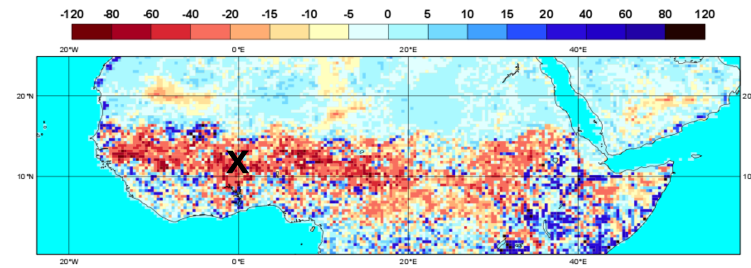
ECMWF

Point-scale diagnostic – layer 1

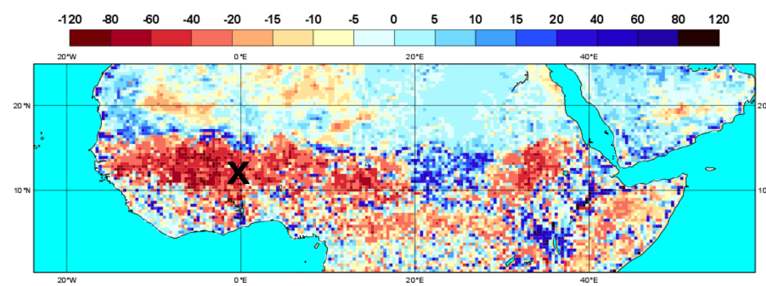


JJA - 2010

[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)



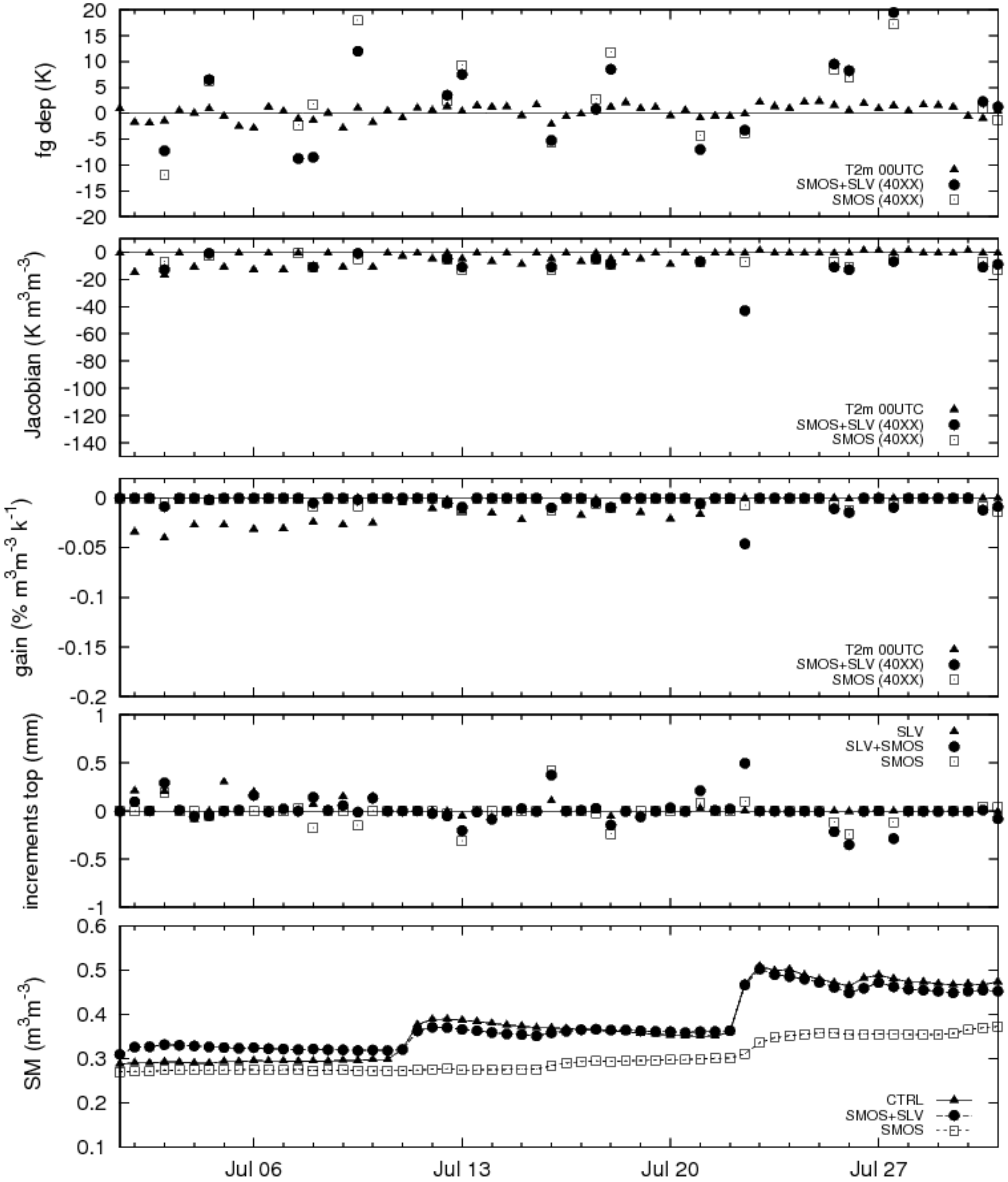
SMOS T^B – CTRL (SV)



[lat=11.77, lon=0]

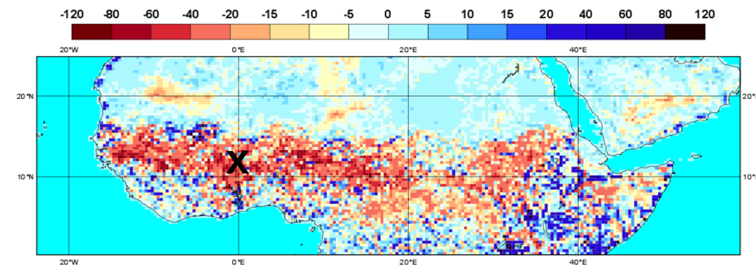
ECMWF

Point-scale diagnostic – layer 2

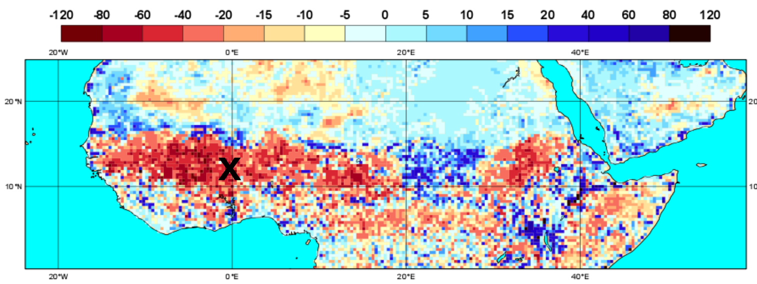


JJA - 2010

[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)



SMOS T^B – CTRL (SV)



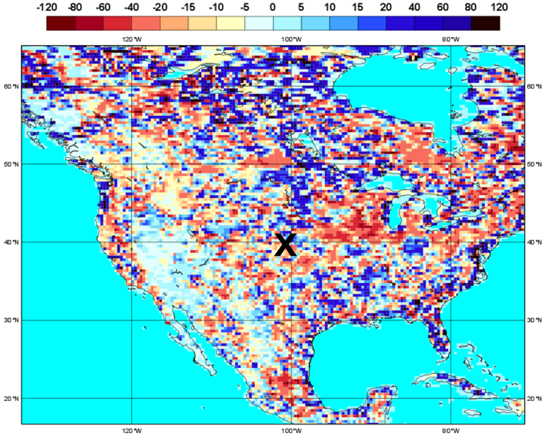
[lat=11.77, lon=0]

ECMWF

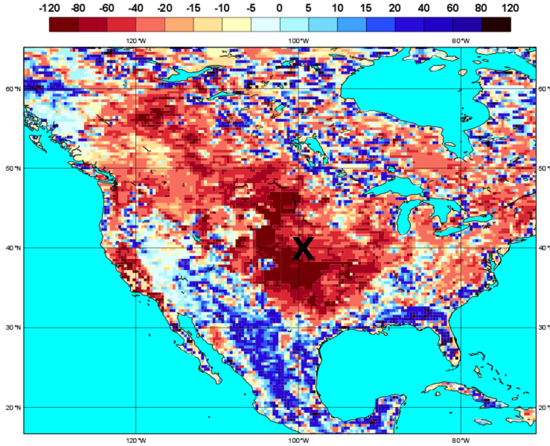
Point-scale diagnostic – layer 1

JJA - 2010

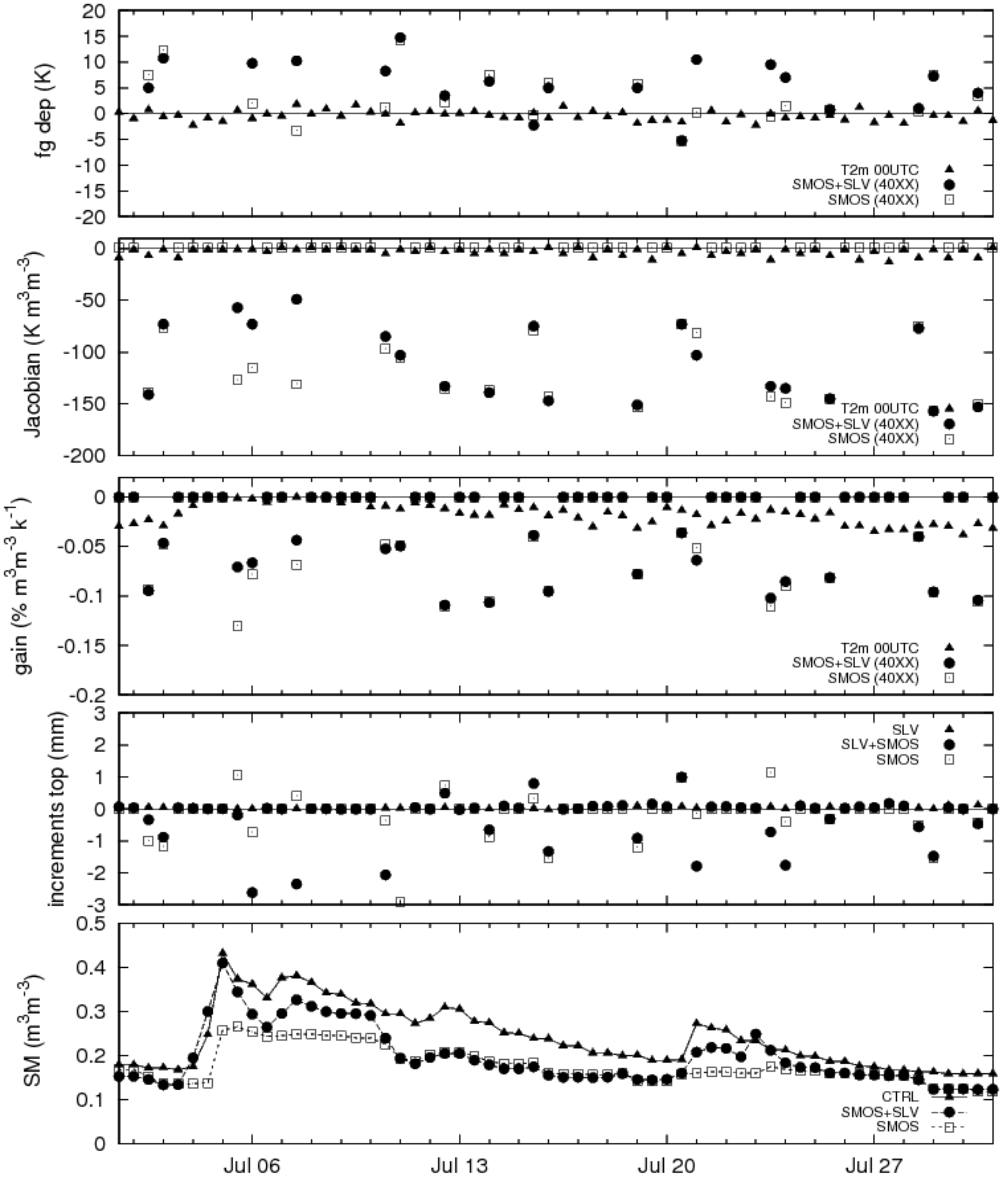
[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)



SMOS T^B – CTRL (SV)



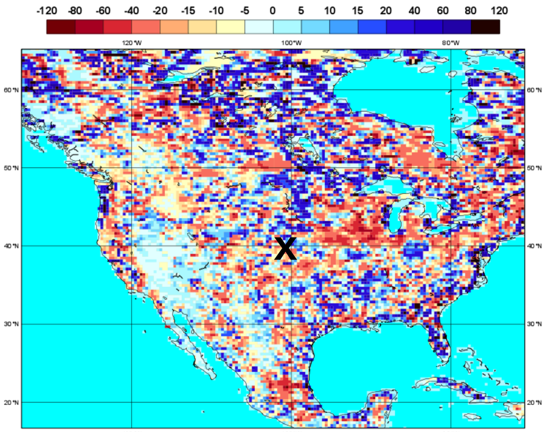
[lat=37.05N, lon=99.85W]



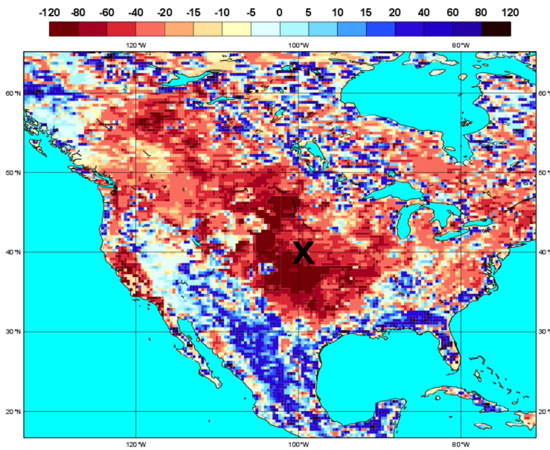
Point-scale diagnostic – layer 2

JJA - 2010

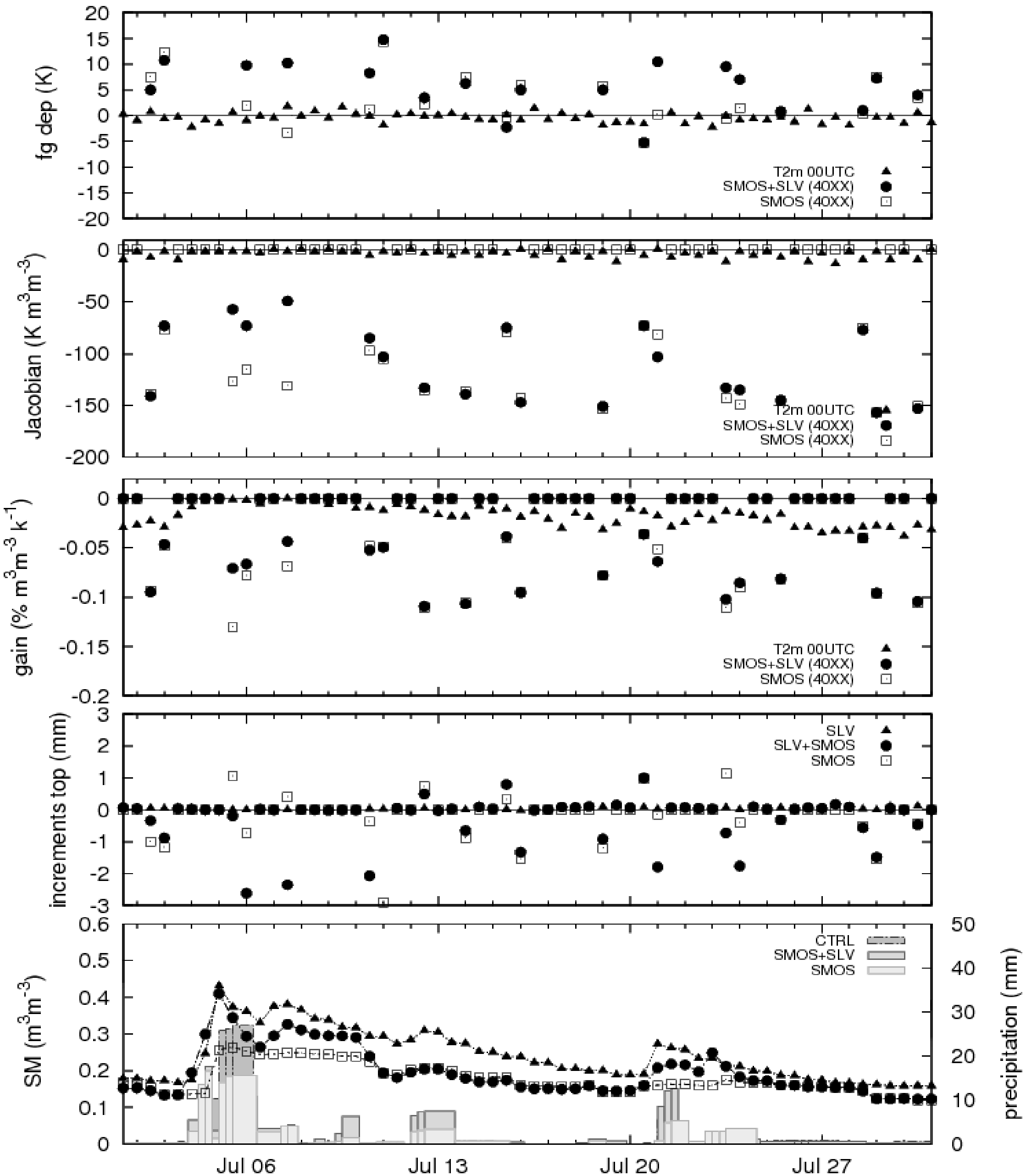
[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)



SMOS T^B – CTRL (SV)



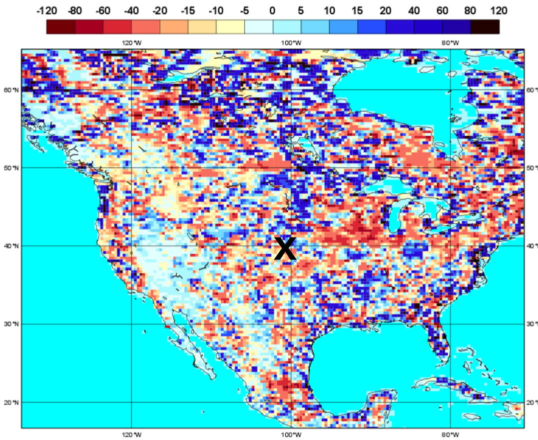
[lat=37.05N, lon=99.85W]



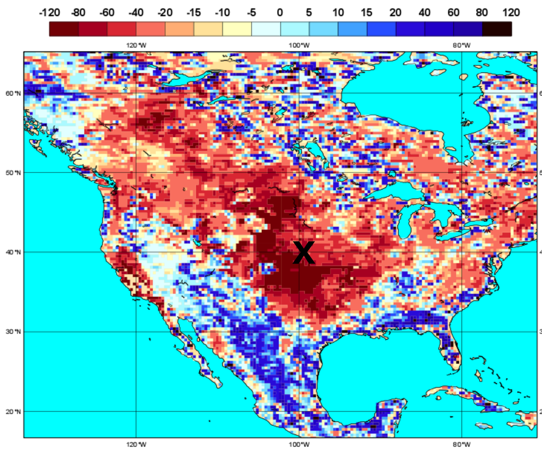
Point-scale diagnostic – layer 2

JJA - 2010

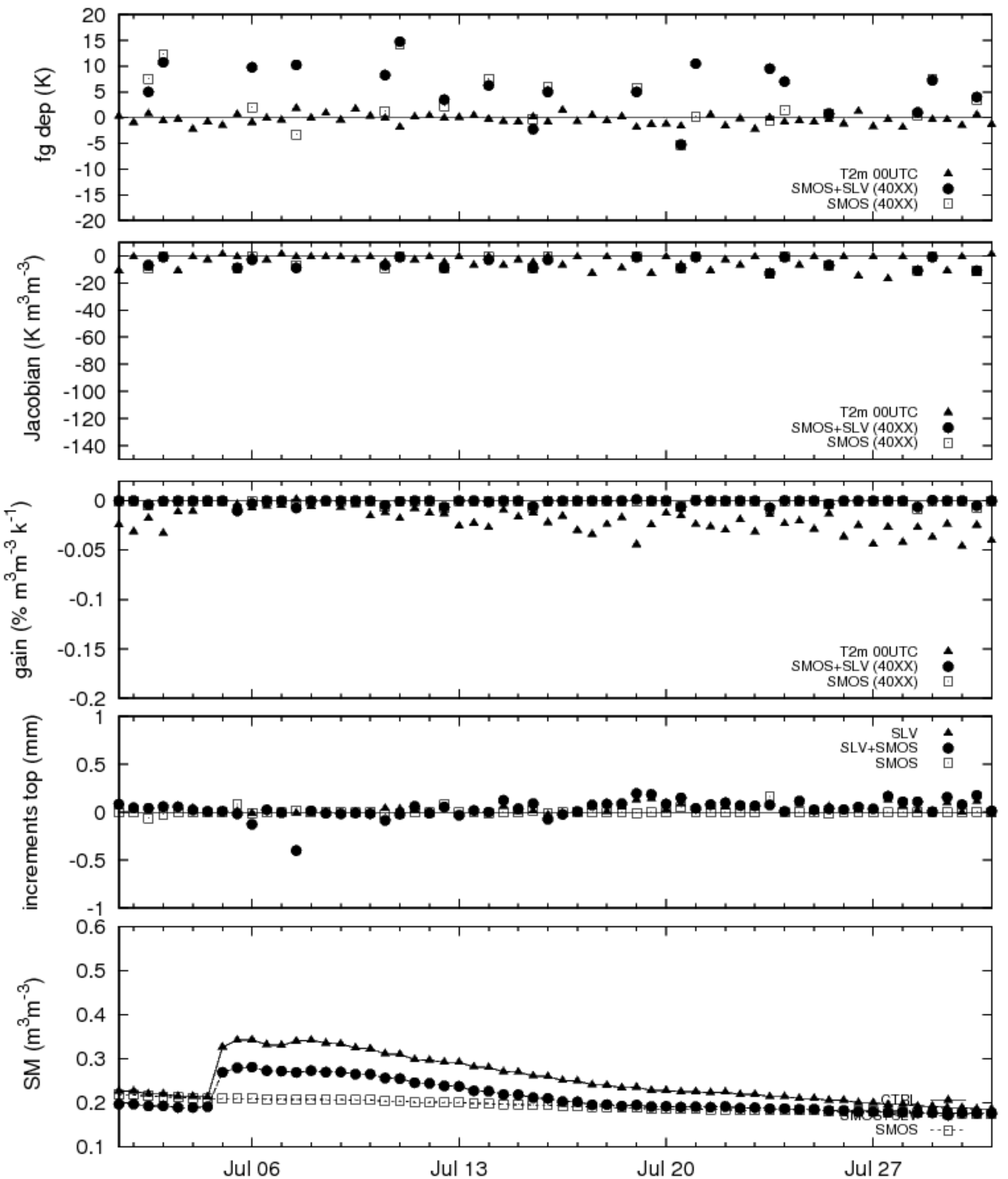
[SMOS T^B , T^{2m}, RH^{2m}] – CTRL (SV)



SMOS T^B – CTRL (SV)

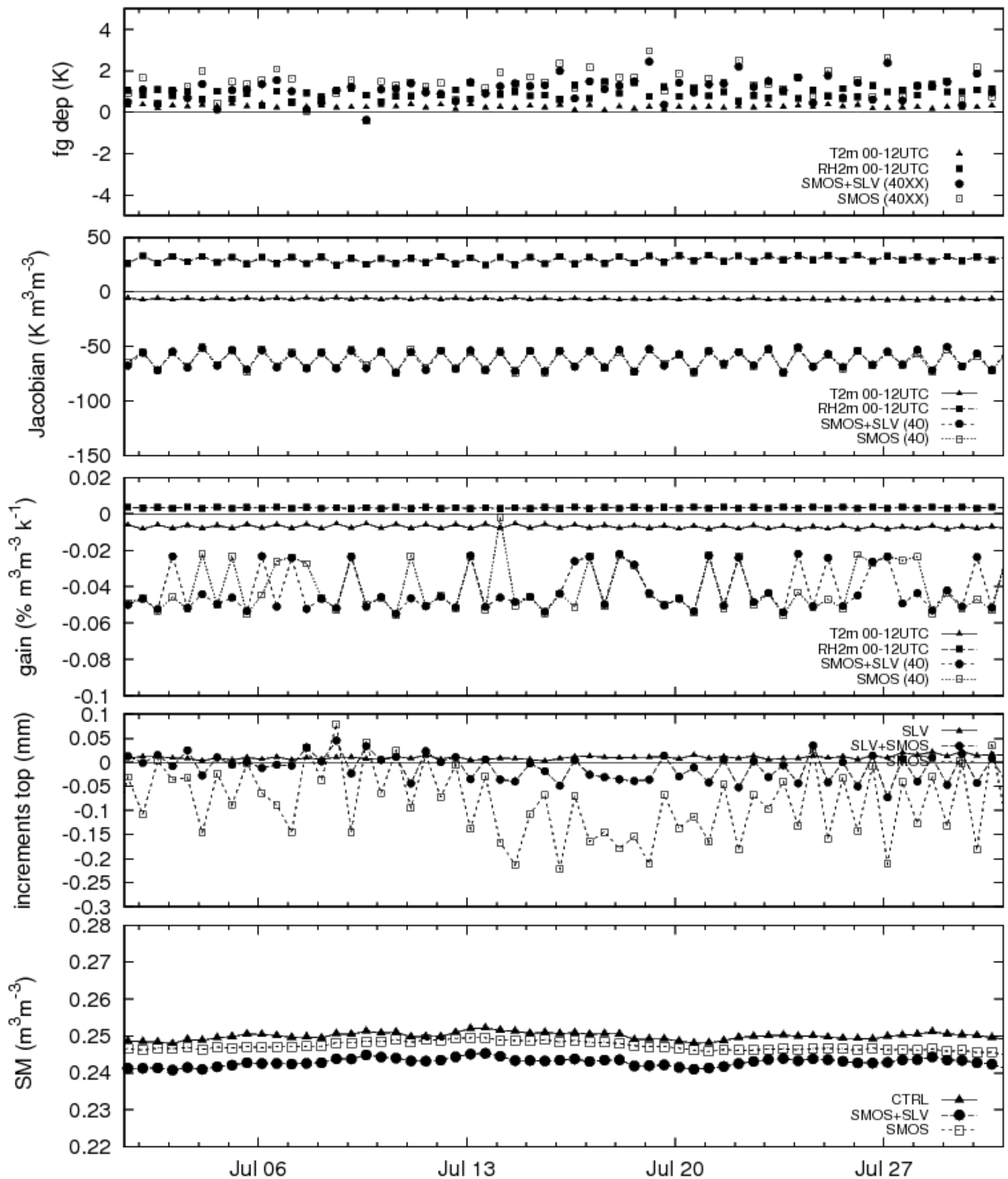


[lat=37.05N, lon=99.85W]



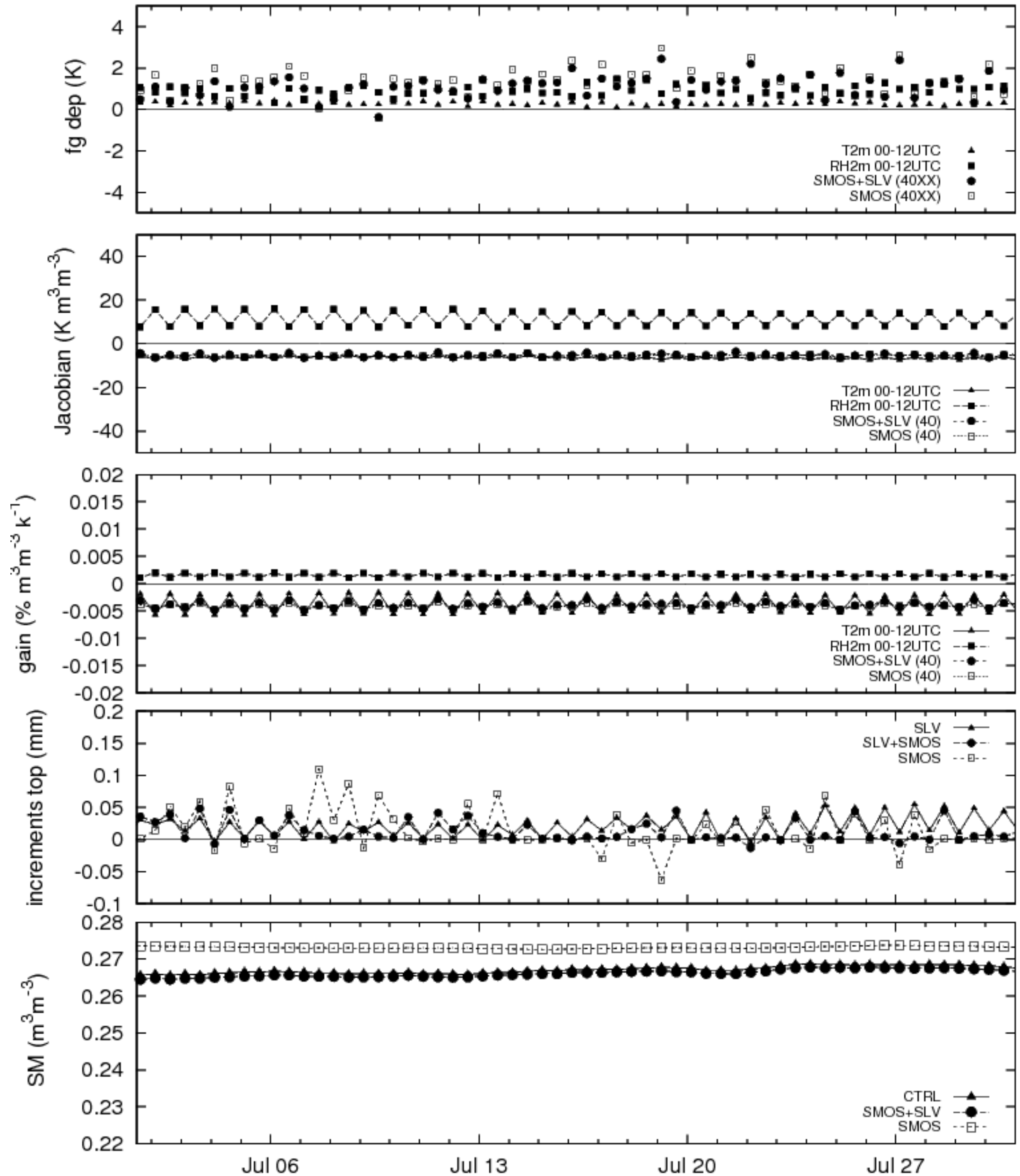
Global diagnostic – layer 1

Daily global averaged fields; (0-7 cm)



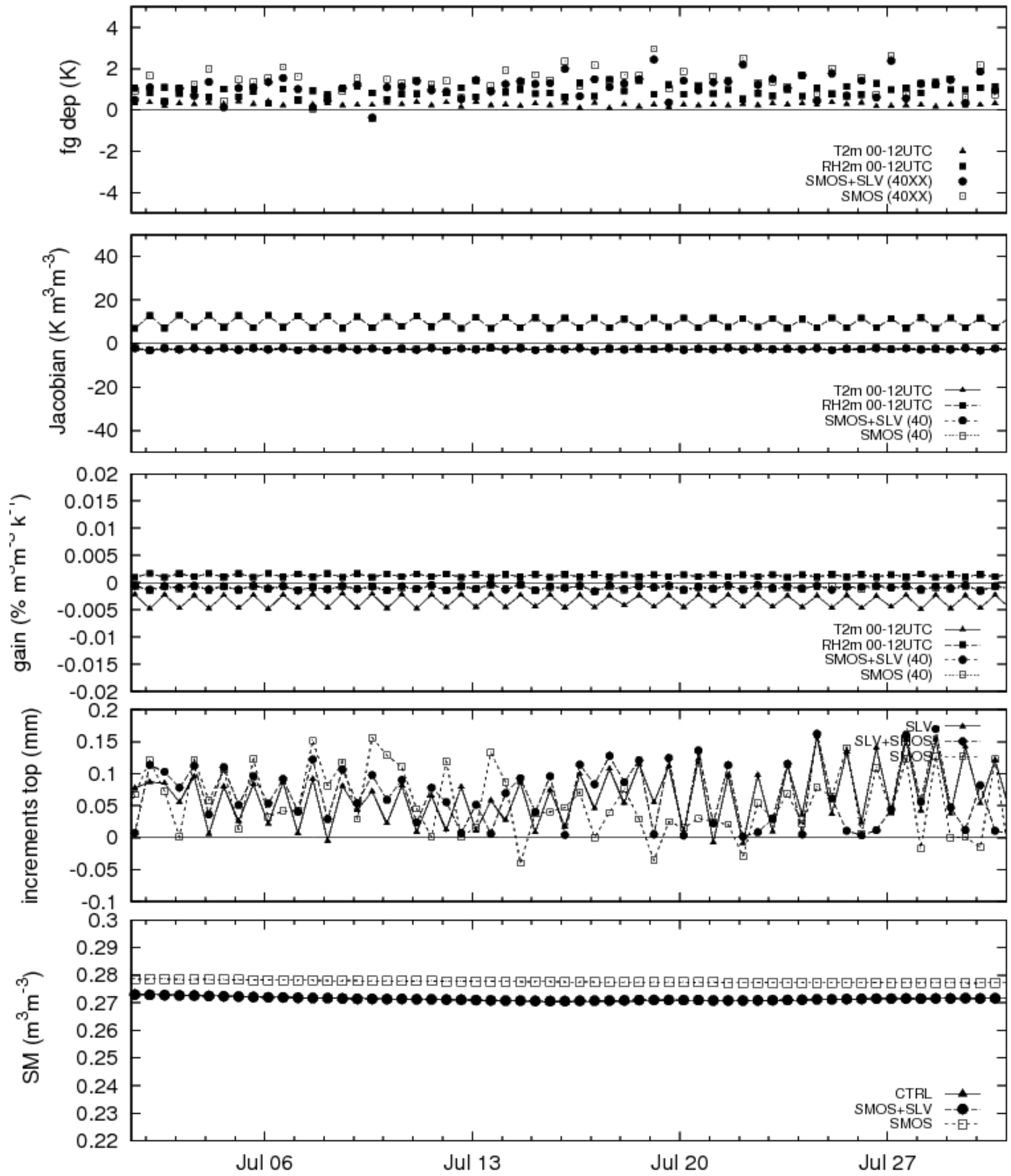
Global diagnostic – layer 2

Daily global averaged fields; (7-28 cm)



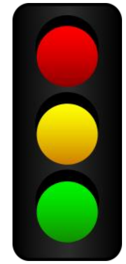
Global diagnostic – layer 3

Daily global averaged fields; (28-100 cm)



SM validation summer (JJA) 2010 - top layer

- **CTRL:** assimilation of T^{2m}, RH^{2m}
- **SMOS**: assimilation of only SMOS T_B CDF corrected
- **SMOS+SLV**: assimilation of T^{2m}, RH^{2m} and SMOS T_B CDF
- Validation undertaken over significant stations (p-value<0.05) in 8 countries



→ The worst among the 3 expt.

→ Neither the best nor the worse

→ The best among the 3 expt.

	CTRL			SMOS			SMOS + SLV			
Network	Bias	RMSD	R	Bias	RMSD	R	Bias	RMSD	R	N
SMOSMANIA	-0.017	0.067	0.77	-0.043	0.085	0.71	-0.015	0.064	0.78	9
TWENTE	0.024	0.097	0.77	-0.013	0.099	0.71	0.005	0.095	0.76	18
SCAN	-0.088	0.137	0.55	-0.076	0.132	0.55	-0.082	0.135	0.57	98
USCRN	-0.079	0.115	0.67	-0.072	0.116	0.64	-0.074	0.115	0.69	61
MAQU	0.027	0.067	0.75	0.064	0.089	0.79	0.026	0.067	0.74	16
SWATMEX	-0.080	0.095	0.80	-0.126	0.138	0.74	-0.082	0.098	0.79	8
VAS	-0.082	0.105	0.48	-0.072	0.079	0.53	-0.085	0.099	0.59	1
OZNET	-0.104	0.122	0.69	-0.098	0.118	0.72	-0.104	0.122	0.71	30
REMEDHUS	-0.065	0.093	0.57	-0.058	0.080	0.73	-0.068	0.092	0.61	17
UMBRIA	-0.153	0.159	0.65	-0.207	0.210	0.47	-0.153	0.159	0.67	2
HOBE	-0.052	0.076	0.70	-0.031	0.066	0.57	-0.033	0.067	0.69	30

Bias (m^3m^{-3}); RMSD (m^3m^{-3})

Root-zone SM validation summer 2010 (JJA)

- **CTRL:** assimilation of T^{2m}, RH^{2m}
- **SMOS**: assimilation of only SMOS T_B CDF corrected
- **SMOS+SLV**: assimilation of T^{2m}, RH^{2m} and SMOS T_B CDF corrected

➢ Validation undertaken over 77 (SCAN) and 50 (USCRN) stations (p-value<0.05)
➢ Observations are averaged over 5, 10, 20, 50 cm (and 100 cm also for USCRN)
➢ Model SM is averaged over the three layers (7, 28, 100 cm)

CTRL

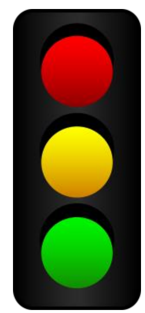
Network	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SCAN	-0.041	0.113	0.72	77
USCRN	-0.072	0.111	0.66	50

SMOS

Network	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SCAN	-0.027	0.119	0.72	77
USCRN	-0.064	0.106	0.70	50

SMOS + SLV

Network	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SCAN	-0.040	0.115	0.73	77
USCRN	-0.066	0.109	0.69	50



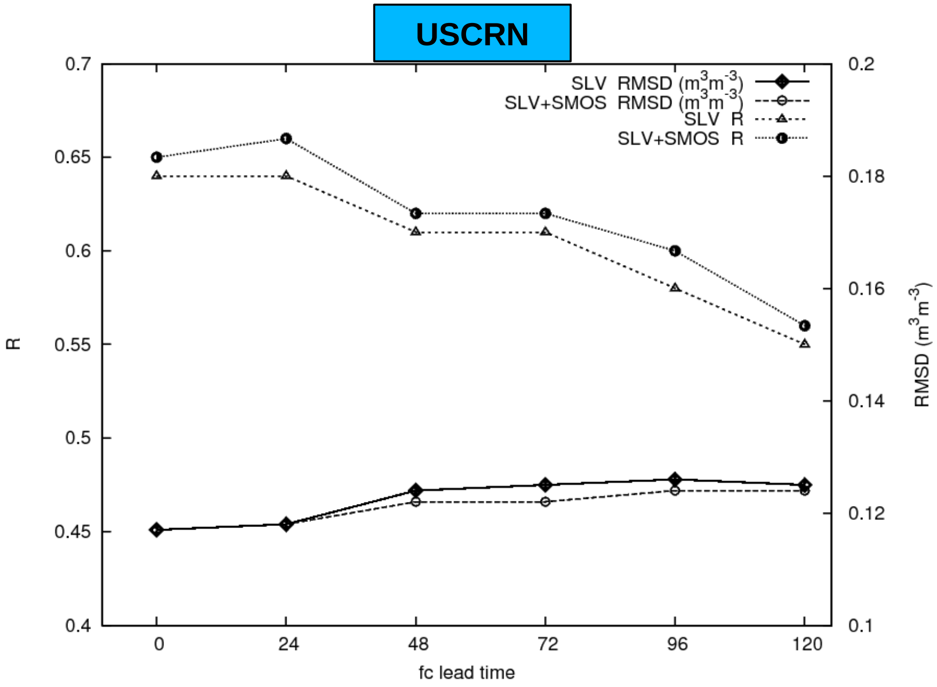
→ **The worst among the 3 expt.**

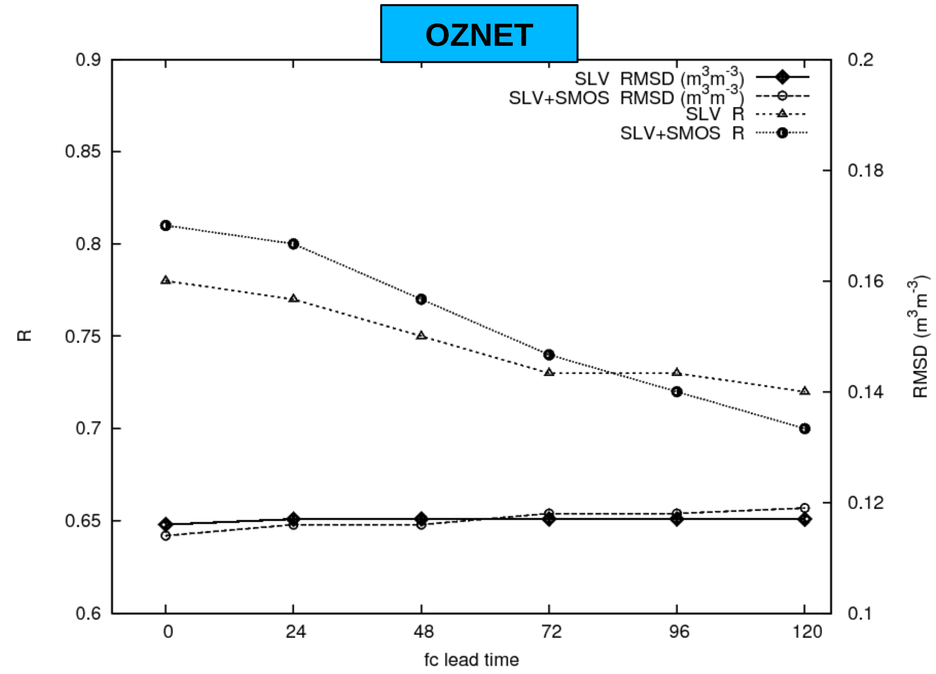
→ **Neither the best nor the worse**

→ **The best among the 3 expt.**

ECMWF

validation of the soil moisture forecasts





- **The correlation coefficient (R) decreases with fc lead time, and RMSD increases slightly.**
- **Skill in the forecast of soil moisture with SMOS+SLV is superior to SLV at least up to 72h (5 days for USCRN)**

ECMWF

Summary of main points & conclusions

• In average, the assimilation of only SMOS T_B dries more the top layer than a combination of both, SMOS T_B and screen-level variables.

• SMOS T_B have much more sensitivity to soil moisture variations than screen temperature and humidity → SMOS components of the Jacobian of the observation operator are larger → expected larger correction of the top layer due to SMOS observations.

• Gain is larger for SMOS components; combined with local large departures for SMOS TBs (especially very variable in areas with strong dynamic) → top increments for only SMOS assimilation are much larger. The smaller gain components of SLV module the large increments of SMOS in the SMOS+SLV experiment.

• Do we want smaller Gain for the SMOS components? Probably yes in order to obtain more stable increments → How?

a) Increasing the error of SMOS TB (assuming screen errors are constant)
b) Decreasing the error of the background state variables

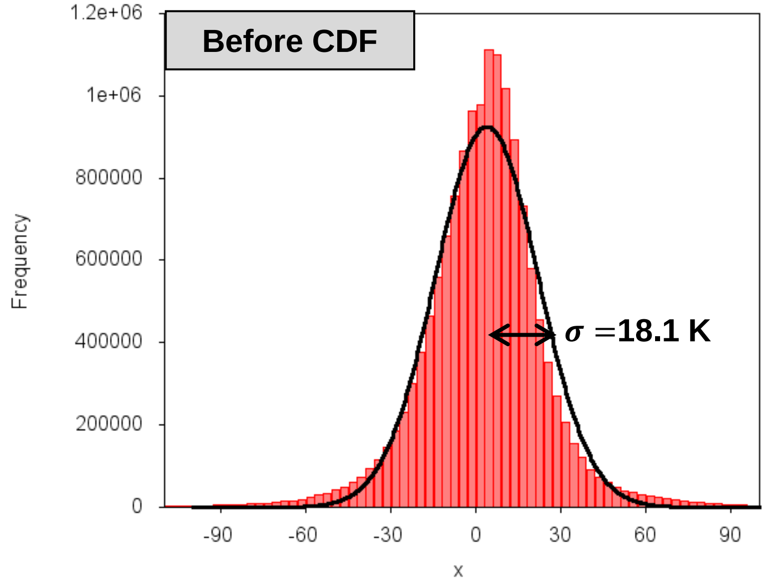
c) Decreasing fg-departures would also reduce SMOS increments → challenging for bias correction, or decreasing fg_check threshold.

ECMWF

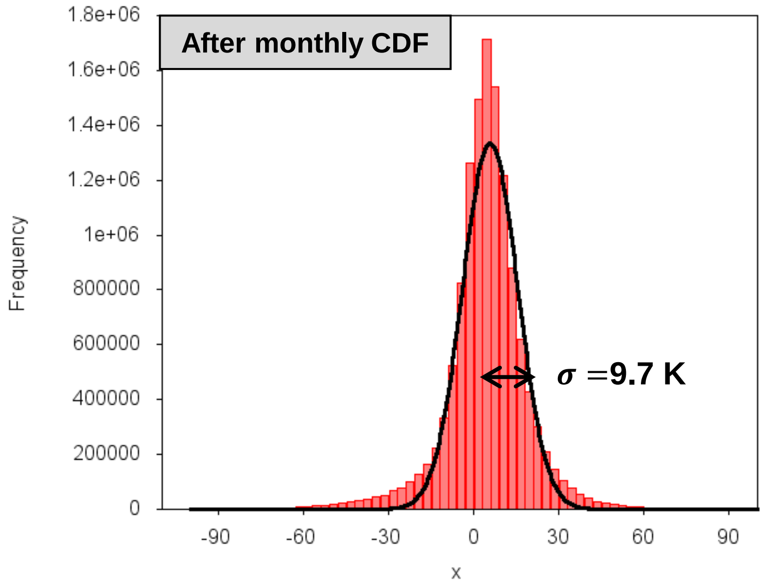
- First-guess departures (01-15 July 2012)
- Data already screened (snow, ice, sea, hard_RFI),
- Angles: 30, 40, 50, Polarisations: XX, YY
- More than 14 million observations

Histograms of departures fitted to a normal distribution:

$$N(x) = \frac{A}{\sigma\sqrt{2\pi}} \cdot exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$



- Current abs(FG_CHECK)< 20K effective at eliminating observations contaminated by RFI.



- abs(FG_CHECK)<10 rejects also observations in areas of great potential.

  An experiment with 10 K fg_check exists already.

ECMWF

Summary of main points & conclusions

• In nearly all cases (with or without screen-level variables), the introduction of SMOS T_B in the observation vector is beneficial for soil moisture analysis and forecasts.

• In general, SLV increments are slightly positive as a response to compensate for model errors (and of contrary sign to SMOS increments). These results into a model wet bias. Assimilating only SMOS data produces a drier soil and less precipitation in certain regions.

• The complementarity of SLV and SMOS TB obtains the best results against in-situ soil moisture.

• However, those networks located in semi-arid climates, with stronger seasonal cycle, the assimilation of only SMOS T_B is the best to match in-situ data (REMEDHUS, VAS, Oznet).

• The worst results by assimilating only SMOS T_B is for temperate-humid climates (South-France, central Italy) or in average over a variety of different climates (USCRN, SCAN).

• Assimilating SMOS information seems not being beneficial in areas strongly affected by RFI in 2010 (Holland, Denmark) → Quality control important!

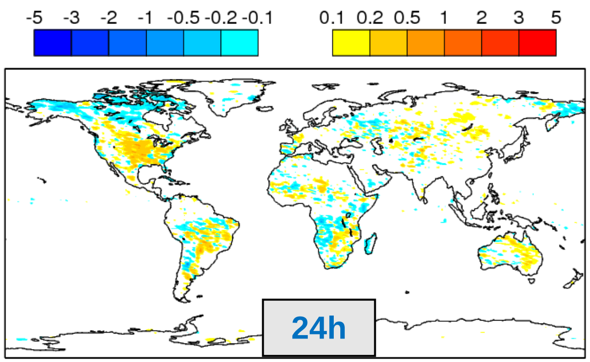
• For the root-zone, the information provided by only SMOS data is the most beneficial, having a positive impact when compared to in-situ data

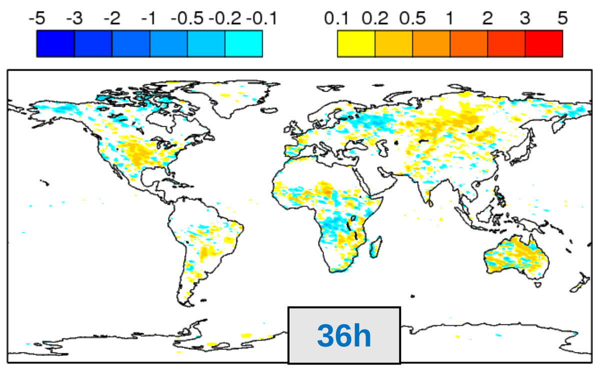
• Complementary observational systems (high spatio-temporal resolution but with poor coverage and representativity with low spatio-temporal with great coverage and good representativity of large areas) is the best option!

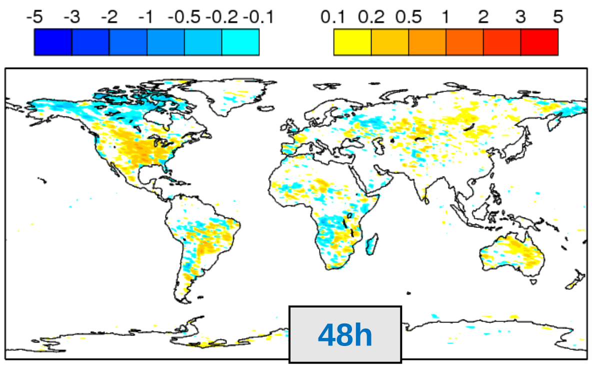
Impact on T^{2m} – JJA → (SMOS+SLV) - SLV

- In total, these plots show the average of 92 forecast started at 00UTC
- Verification is against own analysis

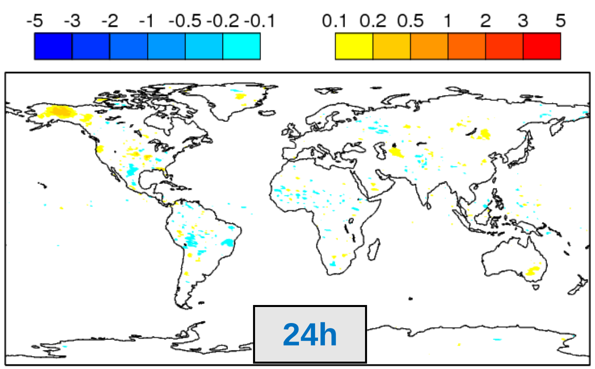
- Blue → air temp is colder
- Red → air temp is warmer

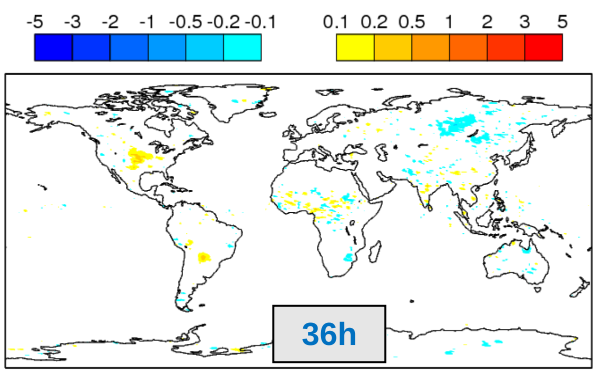


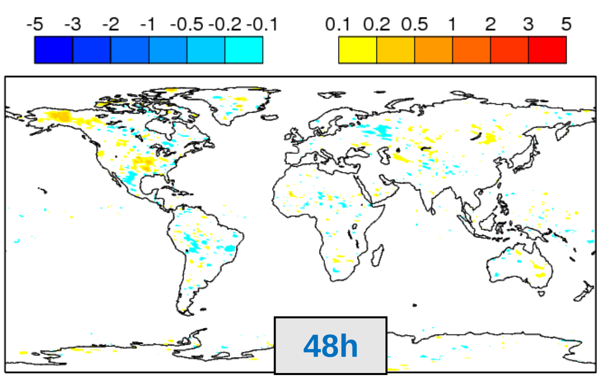




- Blue → mean abs error reduced
- Red → mean abs error increased



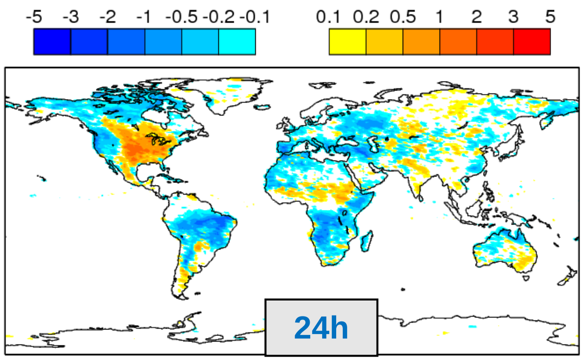


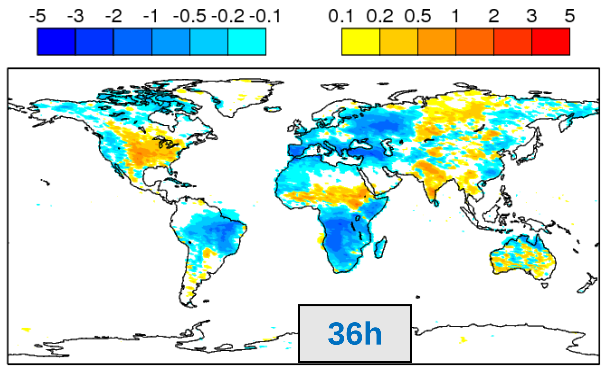


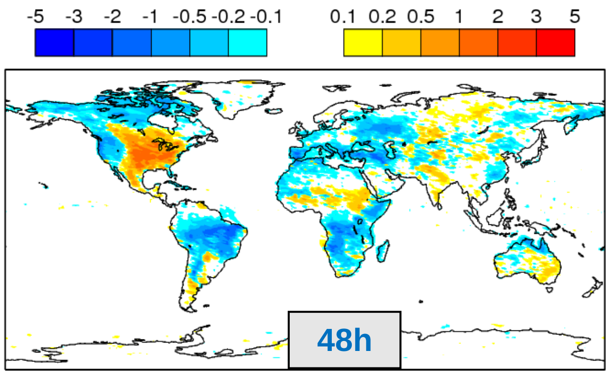
ECMWF

Impact on T^{2m} – JJA → SMOS - SLV

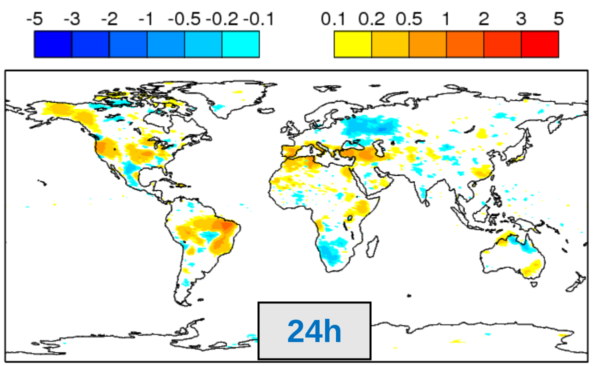
- Blue → air temp is colder
- Red → air temp is warmer

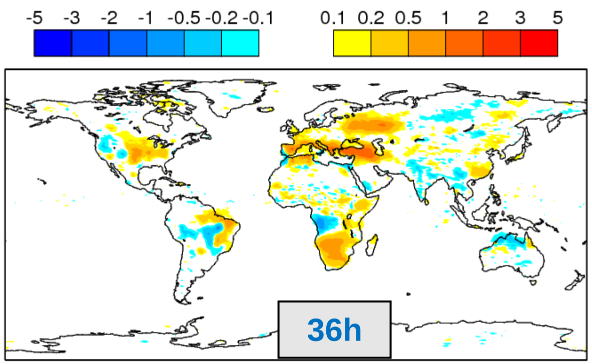


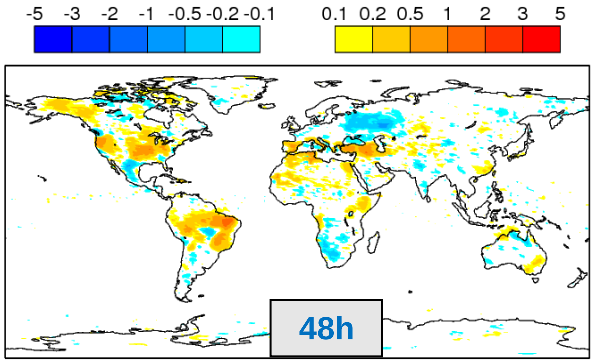




- Blue → mean abs error reduced
- Red → mean abs error increased

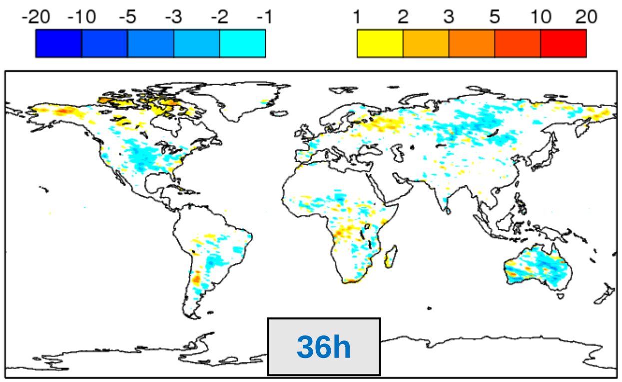


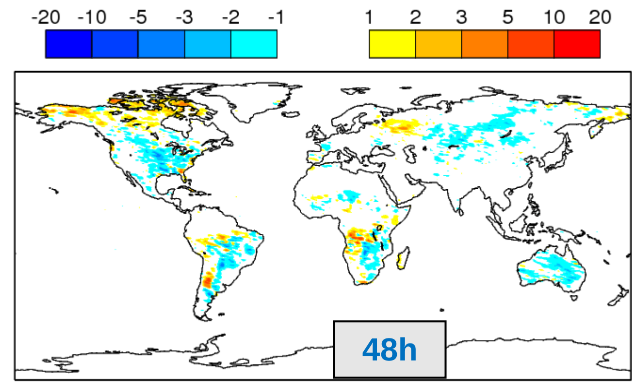




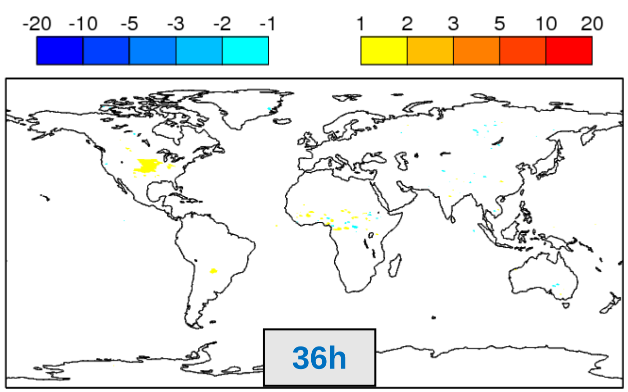
Impact on RH^{2m} – JJA → (SMOS+SLV) - SLV

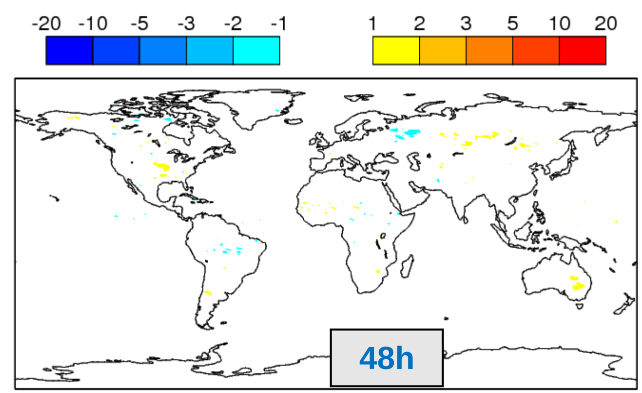
- Blue → air is drier
- Red → air is more humid





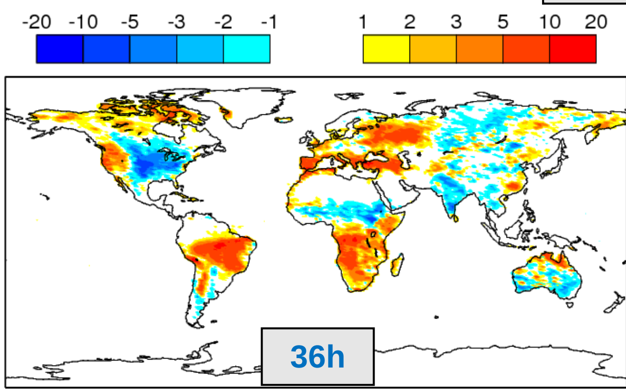
- Blue → mean abs error reduced
- Red → mean abs error increased

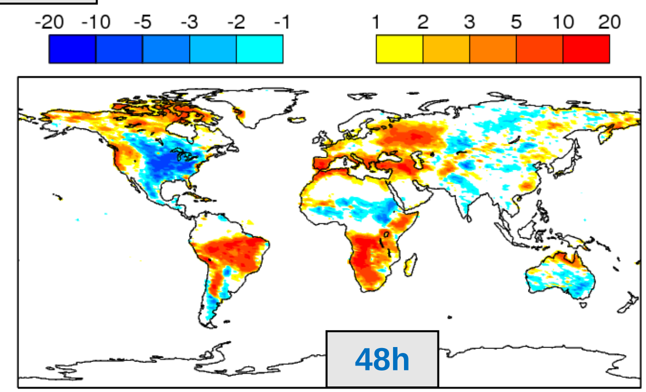




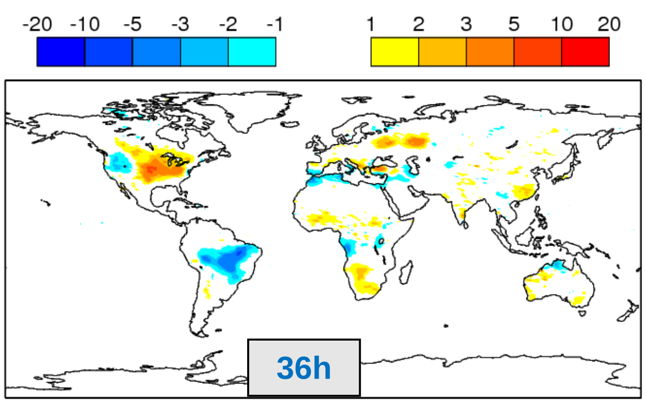
Impact on RH^{2m} – JJA → SMOS - SLV

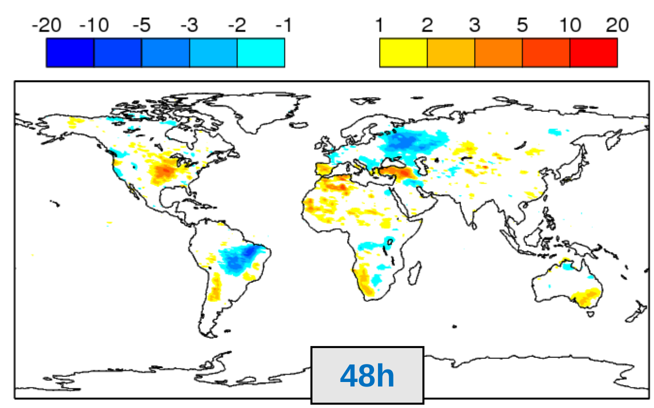
- Blue → air is drier
- Red → air is more humid



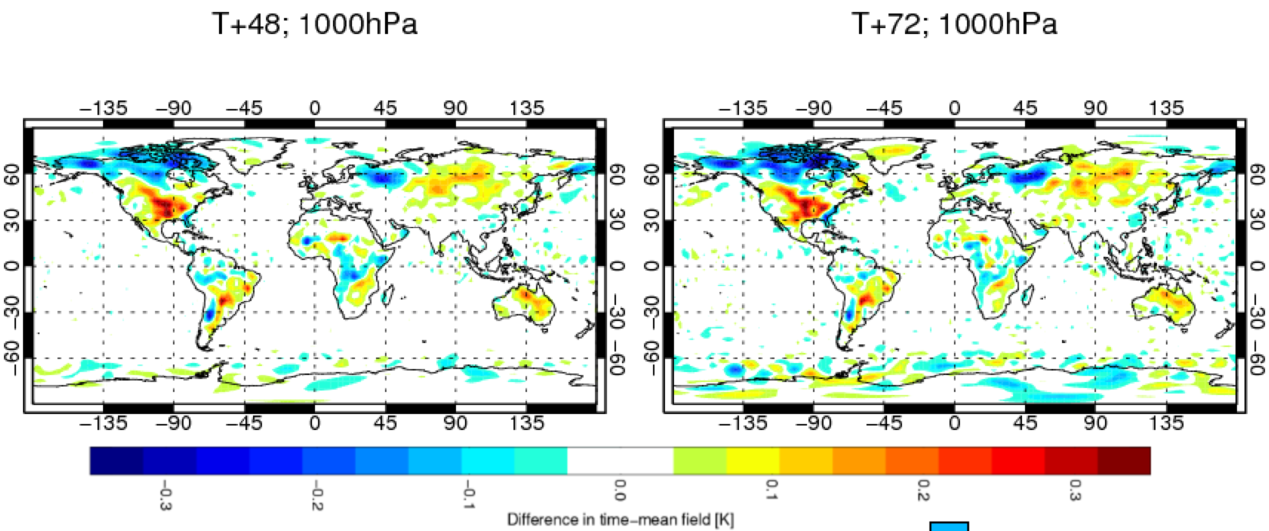


- Blue → mean abs error reduced
- Red → mean abs error increased



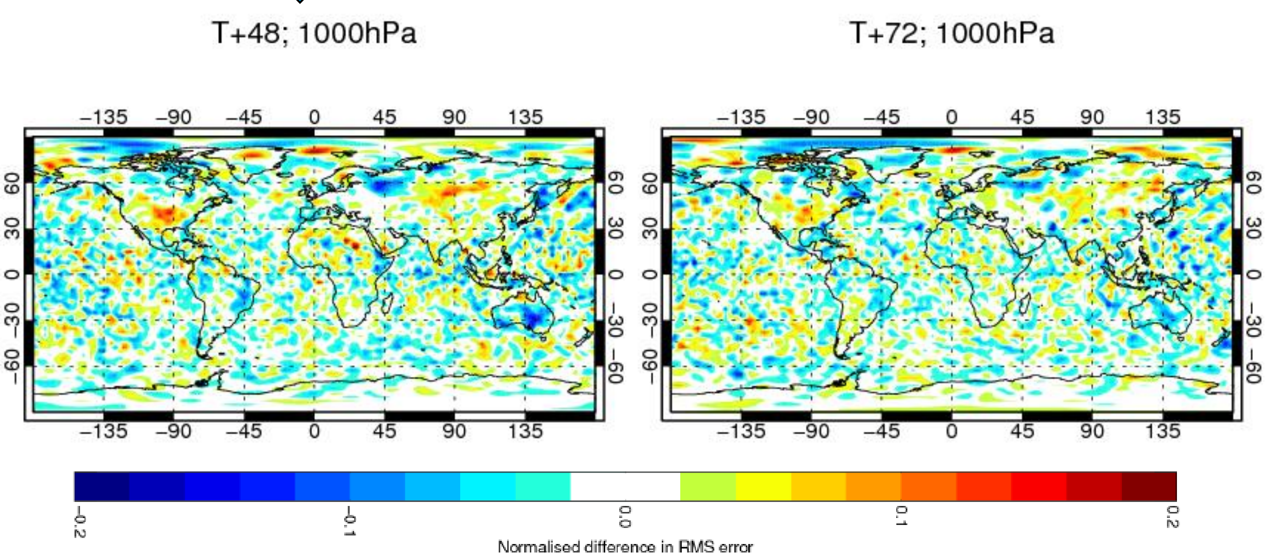


Impact and RMS air temperature forecast error - JJA



(SMOS+SLV) - CTRL

- Blue → air temp is colder
- Red → air temp is warmer

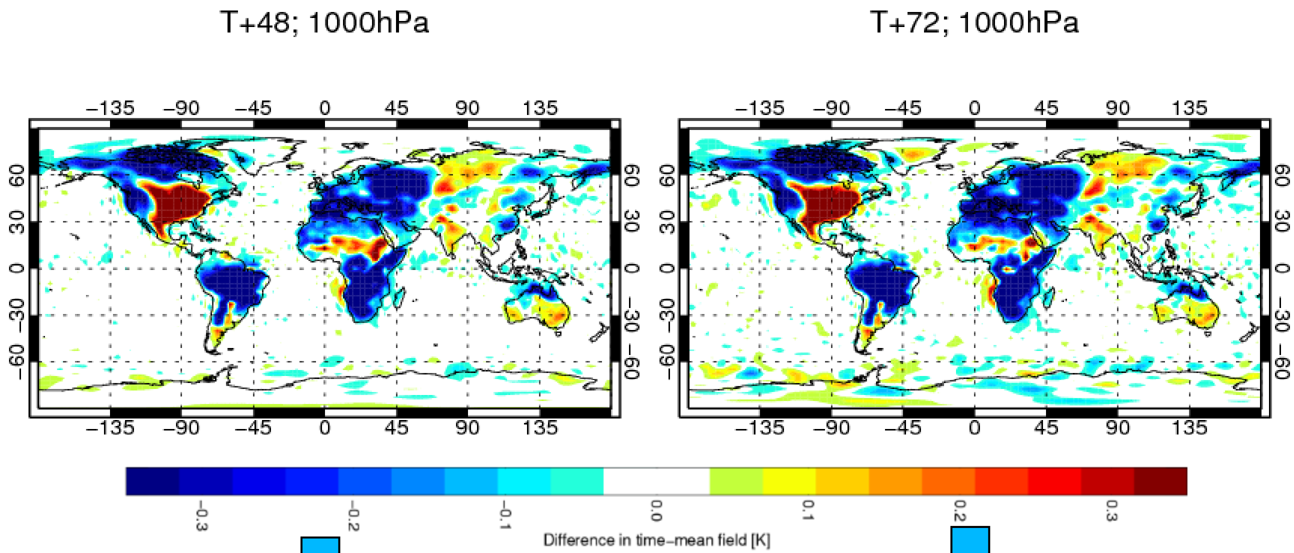


- Blue → error reduced
- Red → error increased

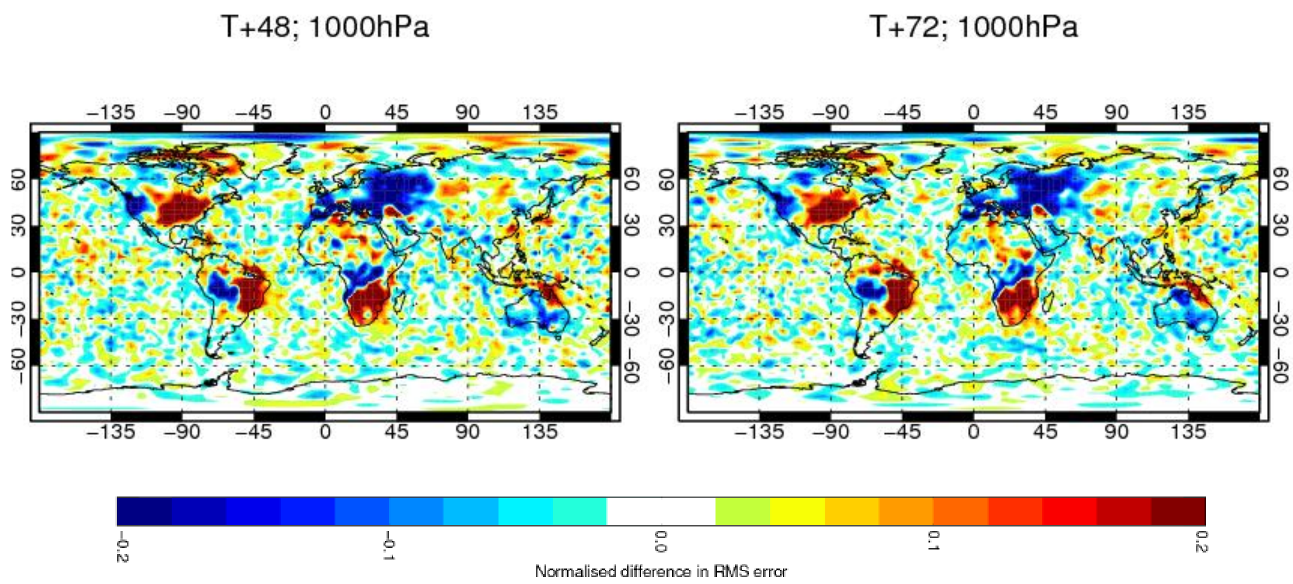
ECMWF

Impact and RMS air temperature forecast error - JJA

SMOS - CTRL

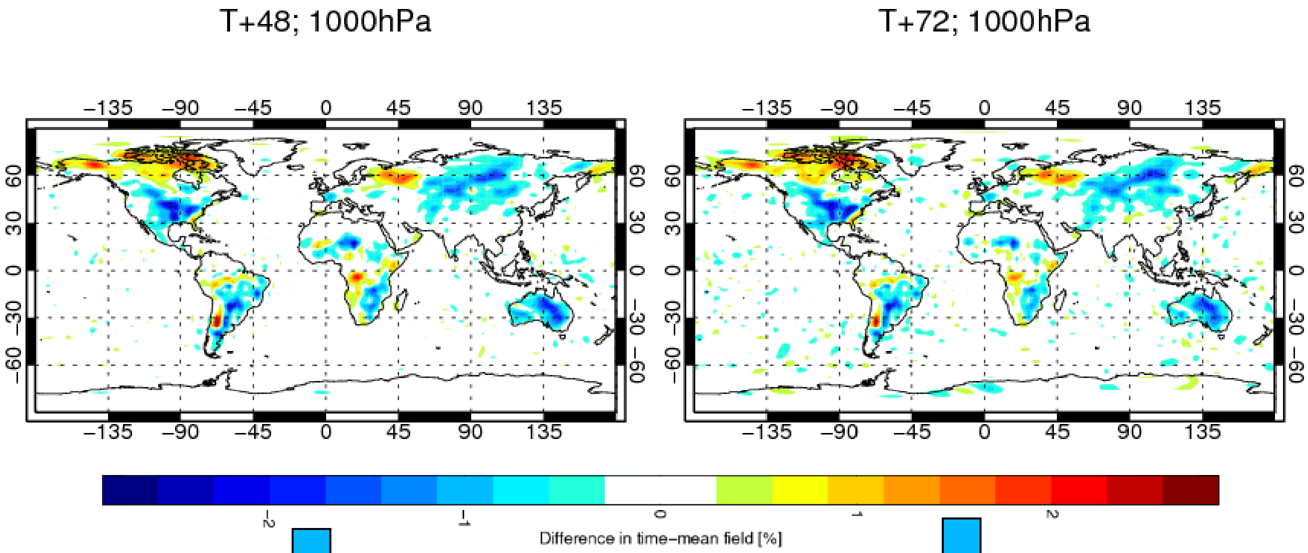


- **Blue → air temp is colder**
- **Red → air temp is warmer**



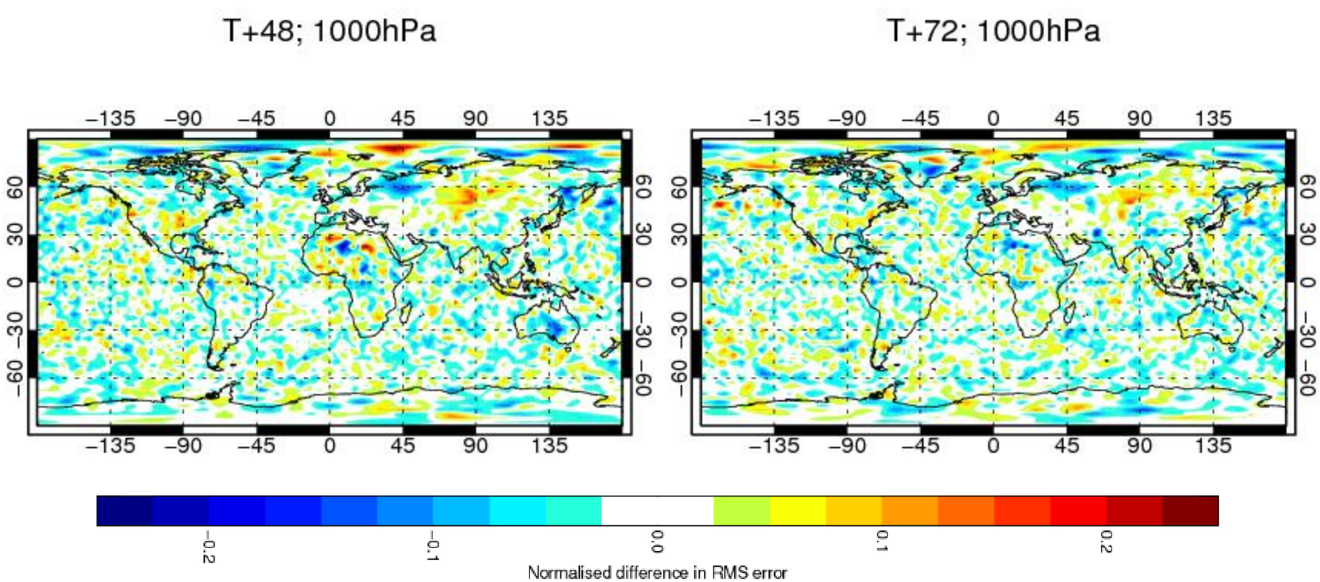
- **Blue → error reduced**
- **Red → error increased**

Impact and RMS air humidity forecast error - JJA



(SMOS+SLV) - CTRL

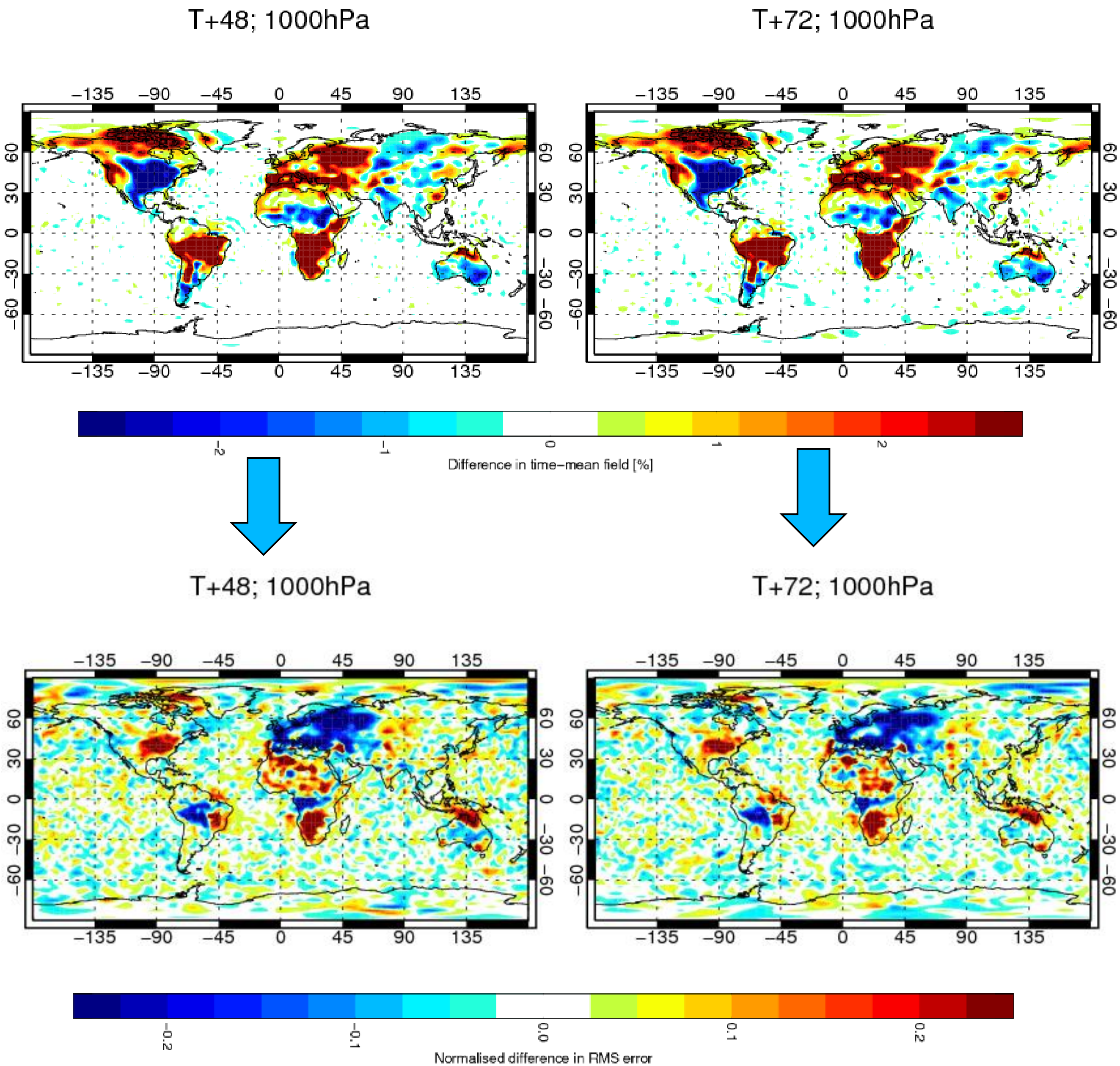
- **Blue → air is drier**
- **Red → air is more humid**



- **Blue → error reduced**
- **Red → error increased**

ECMWF

Impact and RMS air humidity forecast error - JJA



SMOS - CTRL

- **Blue → air is drier**
- **Red → air is more humid**

- **Blue → error reduced**
- **Red → error increased**

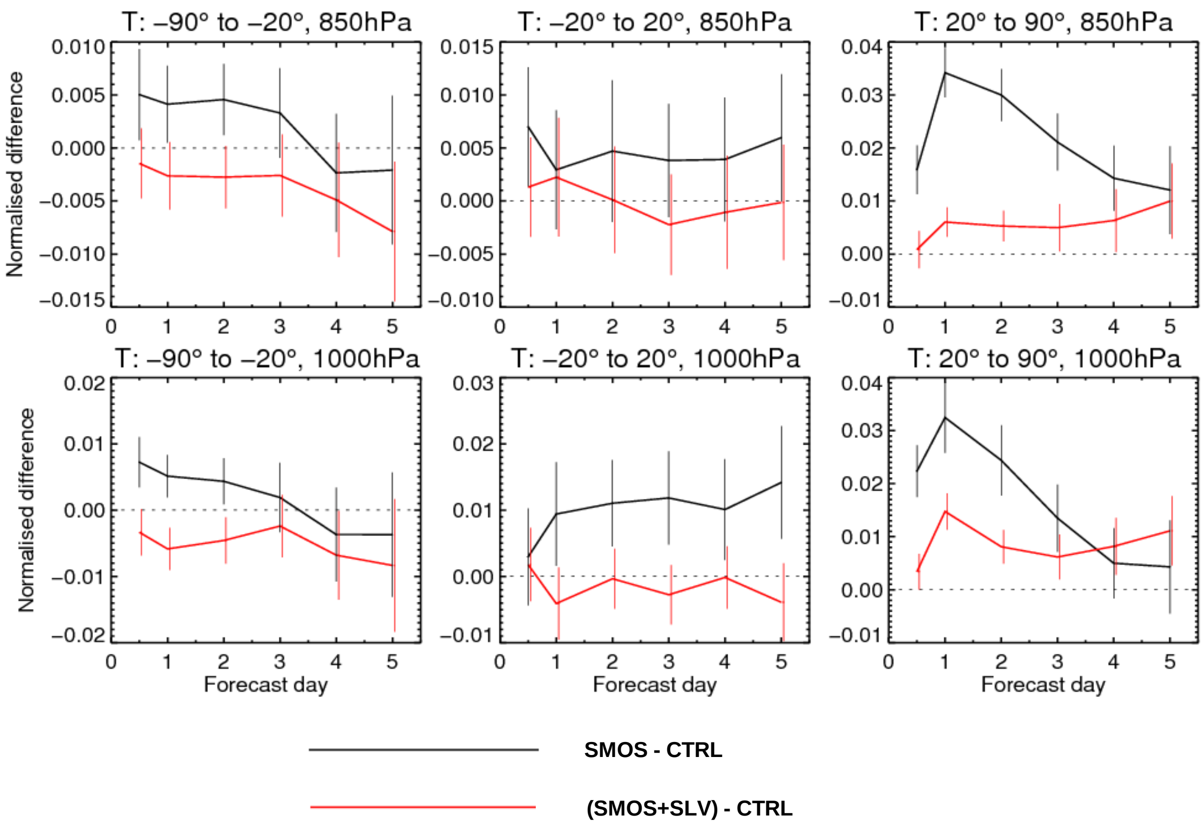
ECMWF

Forecast scores air temperature (JJA-2010)

$$\text{NRMS}=\frac{RMS(e^{SMOS})-RMS(e^{CTRL})}{RMS(e^{CTRL})}$$

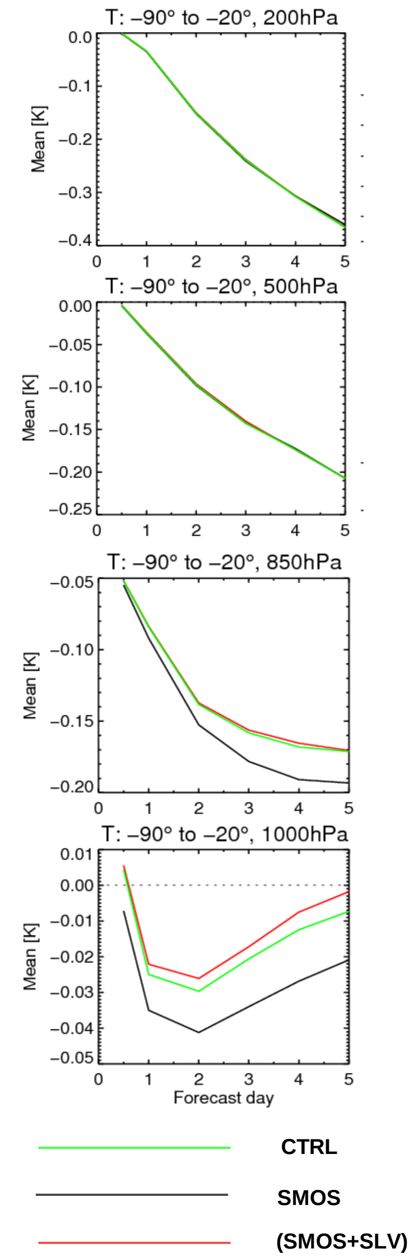
$$e^{expt} = fc^{EXPT} - an^{EXPT}$$

$$e^{CTRL} = fc^{CTRL} - an^{CTRL}$$



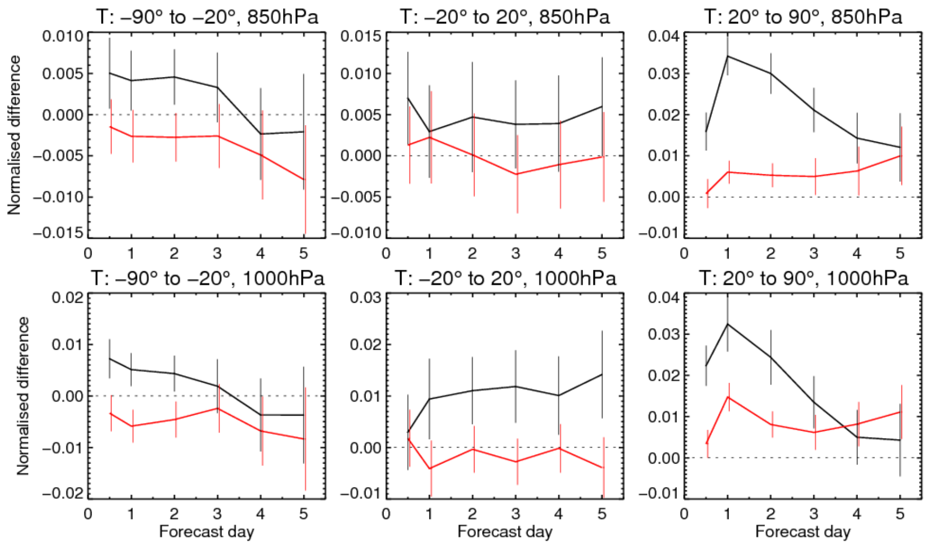
NMRS>0 → expt increases error

NMRS<0 → expt decreases error

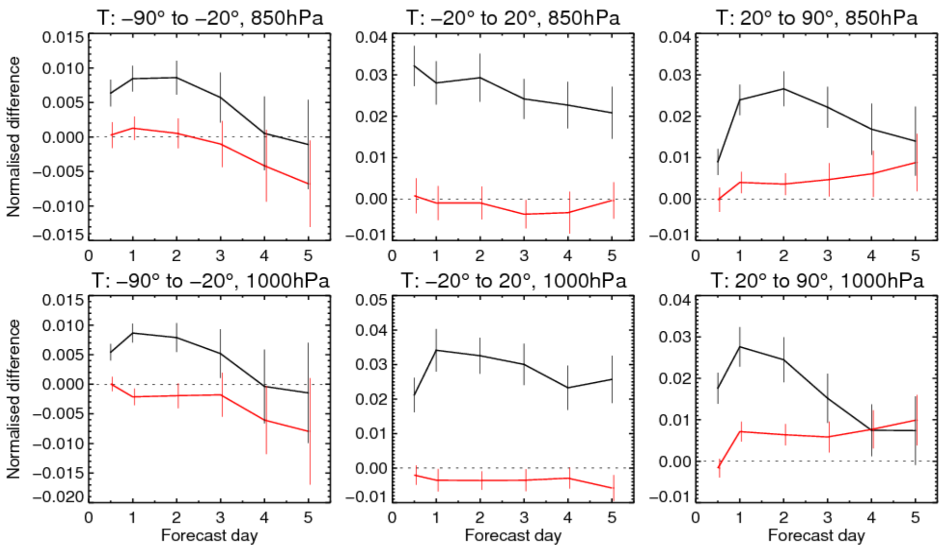


Forecast scores air temperature (JJA-2010)

Against own an



Against oper



SMOS - CTRL

(SMOS+SLV) - CTRL

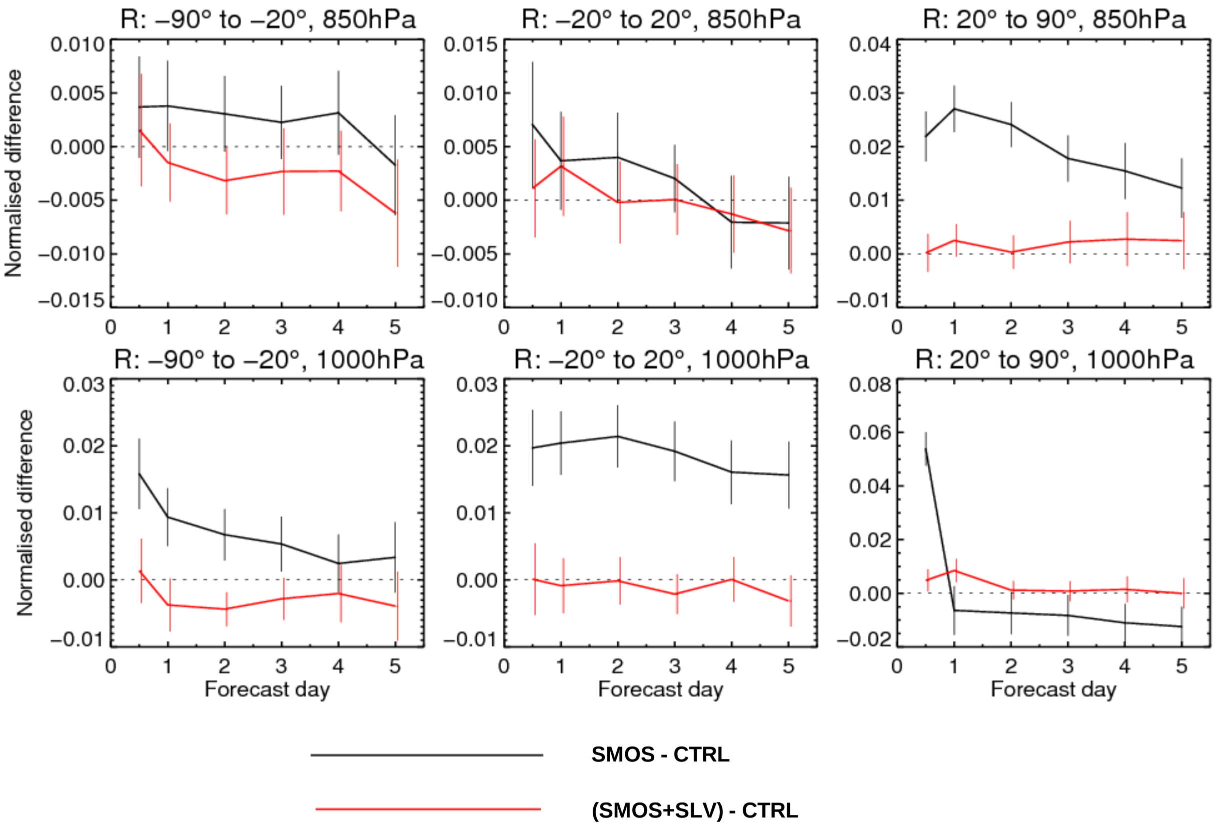
ECMWF

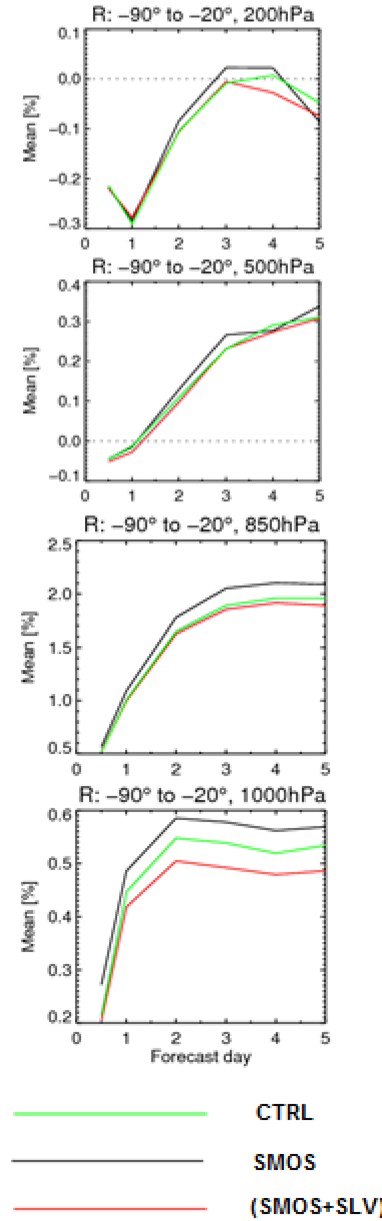
Forecast scores air humidity (JJA-2010)

$$\text{NRMS}=\frac{RMS(e^{SMOS})-RMS(e^{CTRL})}{RMS(e^{CTRL})}$$

$$e^{expt} = fc^{EXPT} - an^{EXPT}$$

$$e^{CTRL} = fc^{CTRL} - an^{CTRL}$$





NMRS>0 → expt increases error

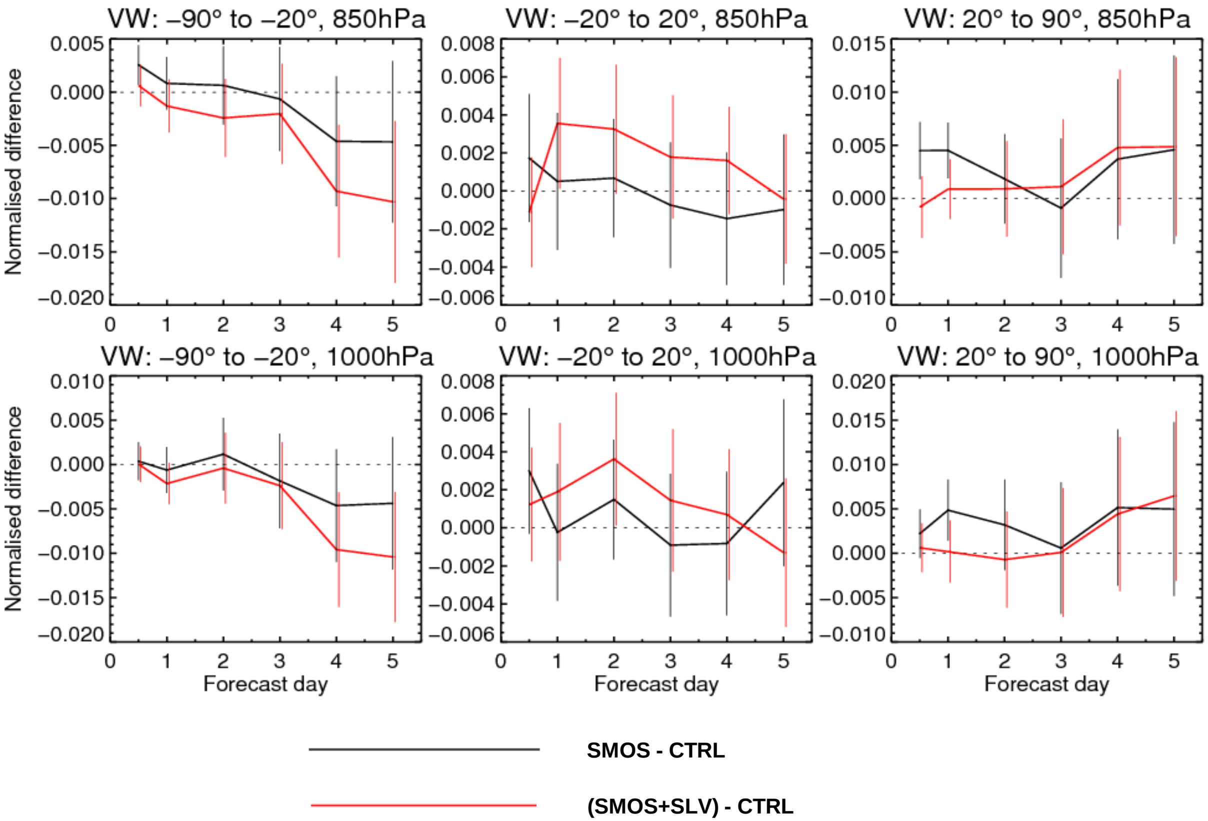
NMRS<0 → expt decreases error

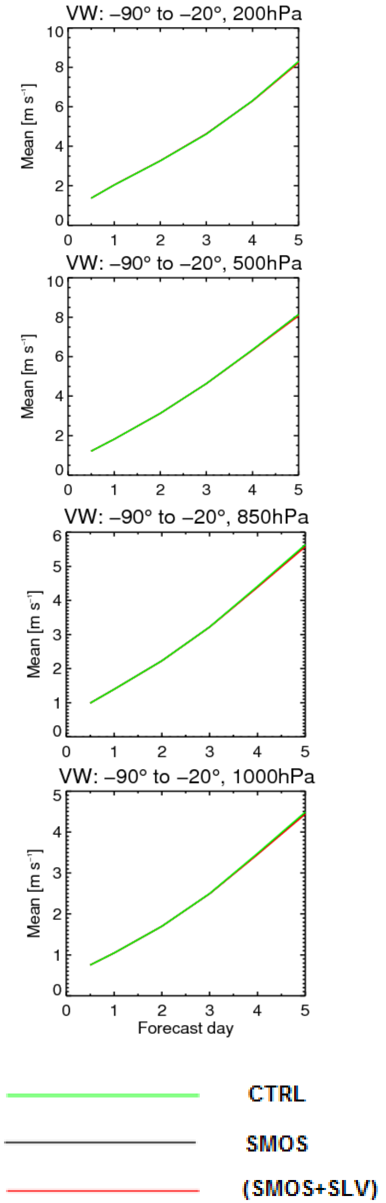
Forecast scores wind speed (JJA-2010)

$$\text{NRMS}=\frac{RMS(e^{SMOS})-RMS(e^{CTRL})}{RMS(e^{CTRL})}$$

$$e^{expt} = fc^{EXPT} - an^{EXPT}$$

$$e^{CTRL} = fc^{CTRL} - an^{CTRL}$$





NMRS>0 → expt increases error

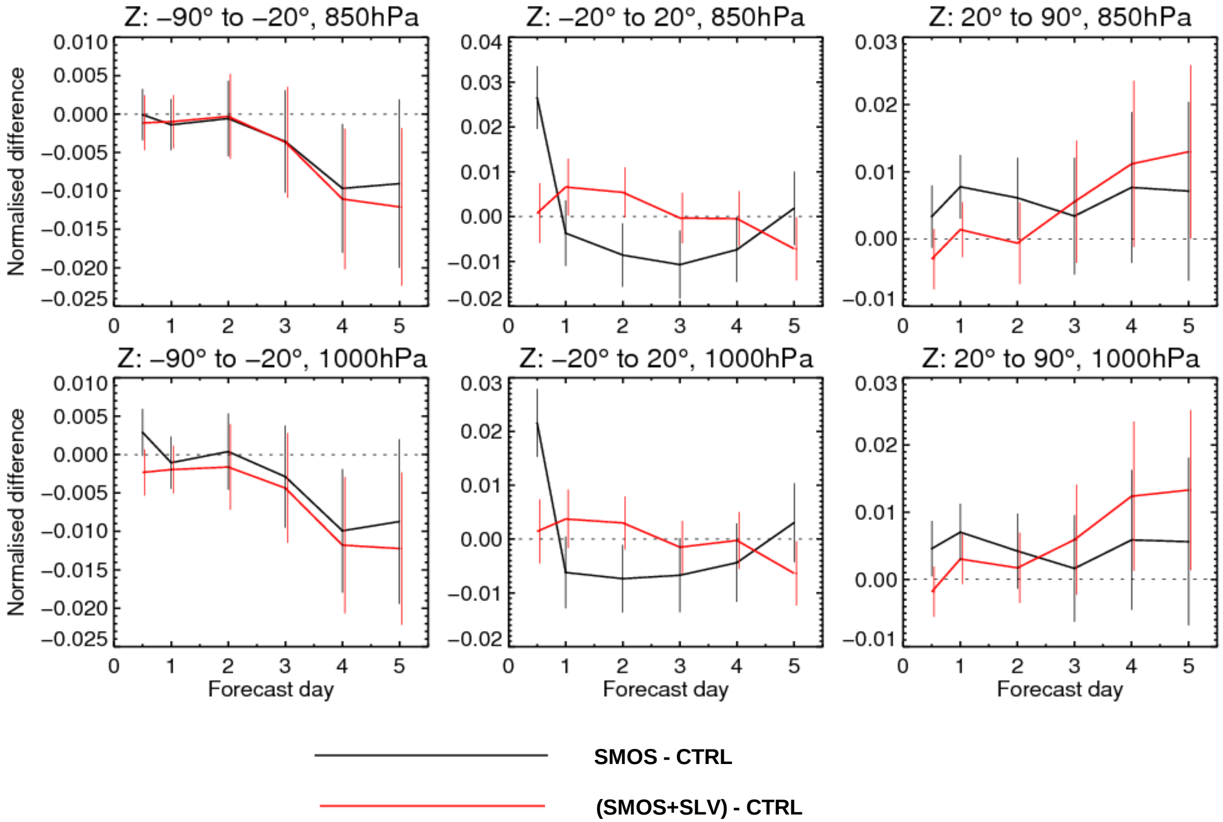
NMRS<0 → expt decreases error

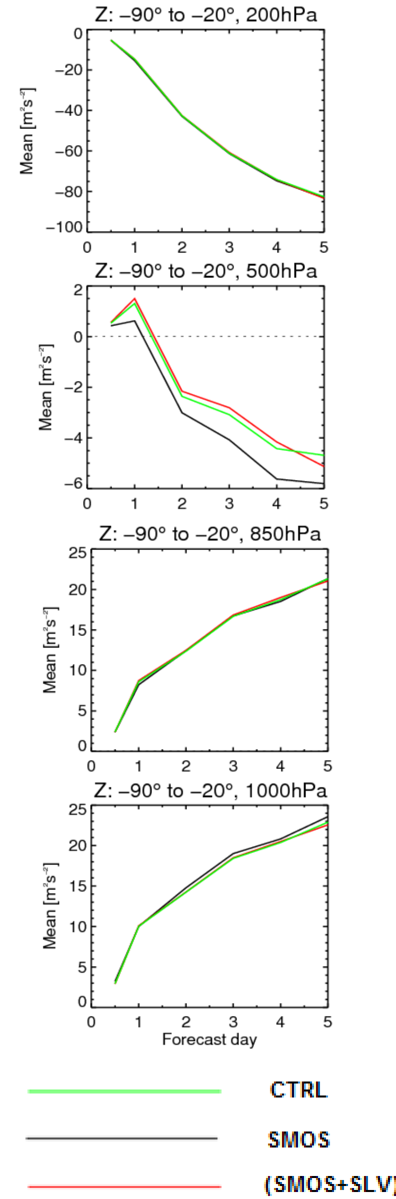
Forecast scores geopotential (JJA-2010)

$$\text{NRMS}=\frac{RMS\left(e^{SMOS}\right)-RMS\left(e^{CTRL}\right)}{RMS\left(e^{CTRL}\right)}$$

$$e^{expt} = fc^{EXPT} - an^{EXPT}$$

$$e^{CTRL} = fc^{CTRL} - an^{CTRL}$$

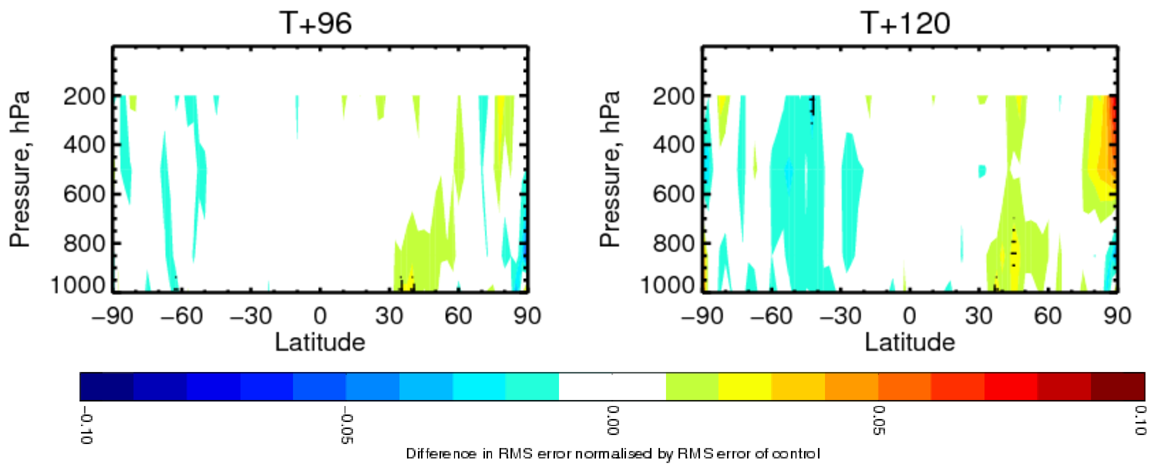




NMRS>0 → expt increases error

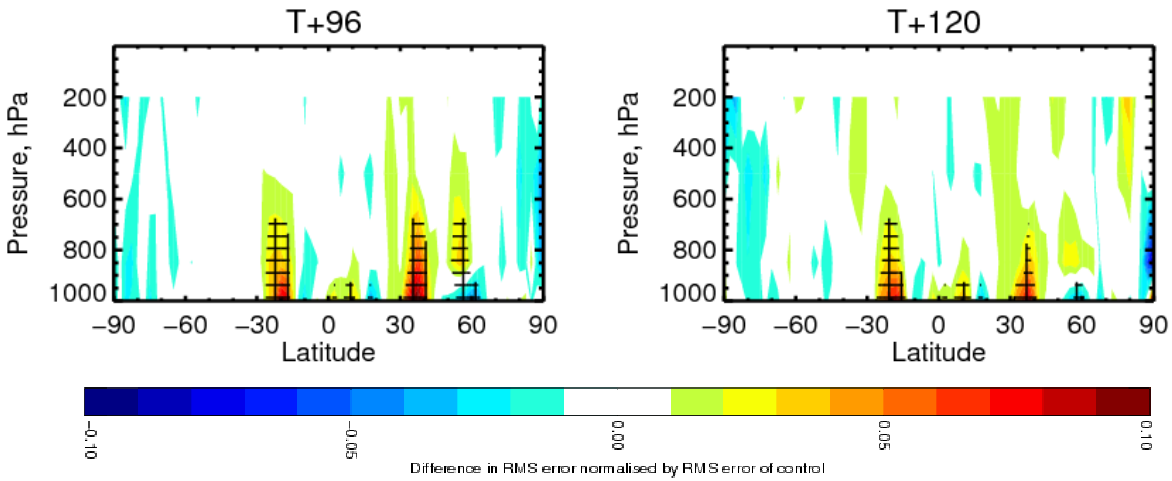
NMRS<0 → expt decreases error

Forecast scores air temperature (JJA-2010)



(SMOS+SLV) - CTRL

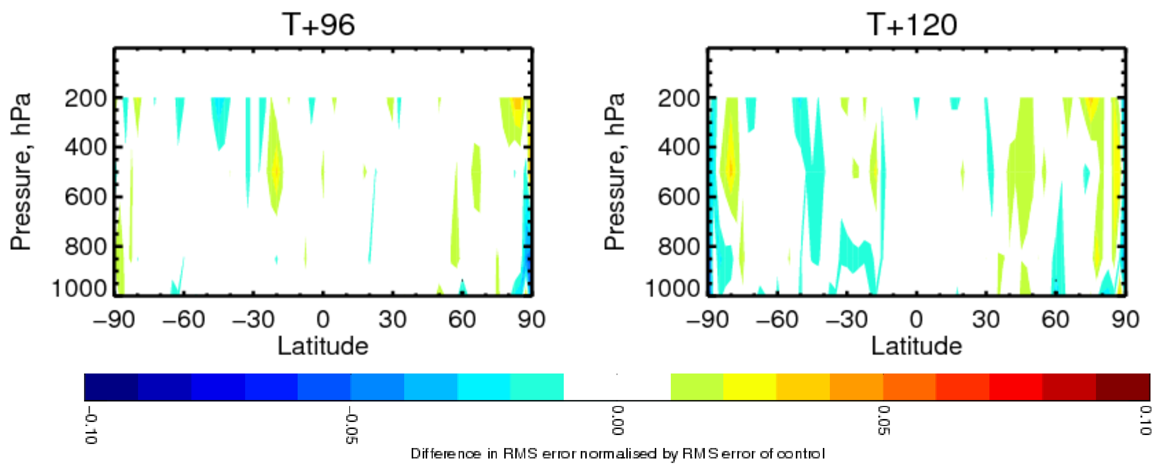
- **Blue → error forecast decreases**
- **Red → error forecast increases**



SMOS - CTRL

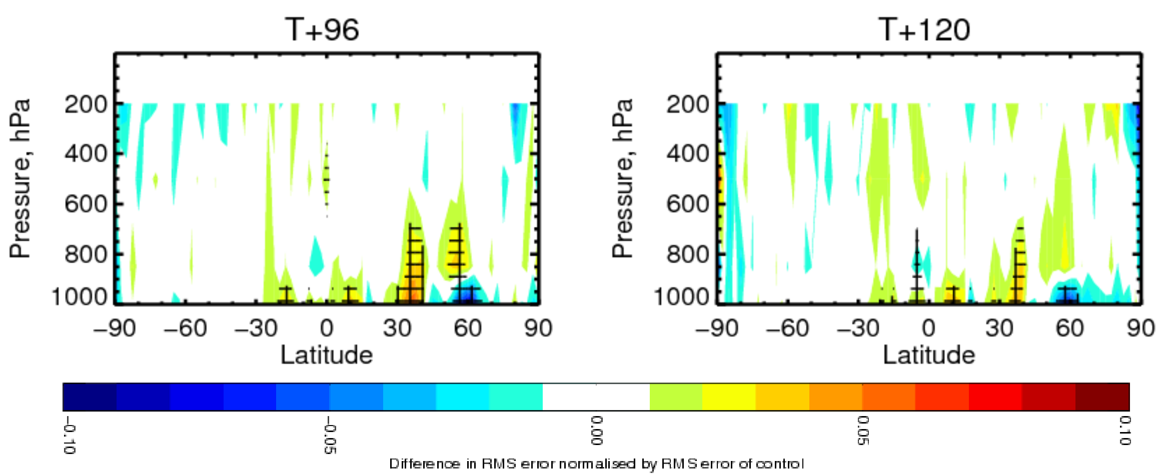
ECMWF

Forecast scores air humidity (JJA-2010)



(SMOS+SLV) - CTRL

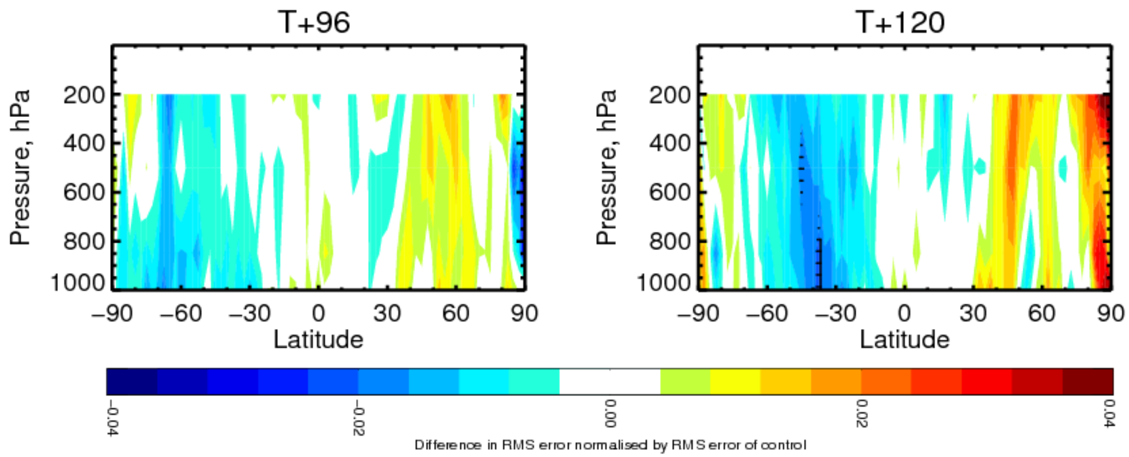
- **Blue → error forecast decreases**
- **Red → error forecast increases**



SMOS - CTRL

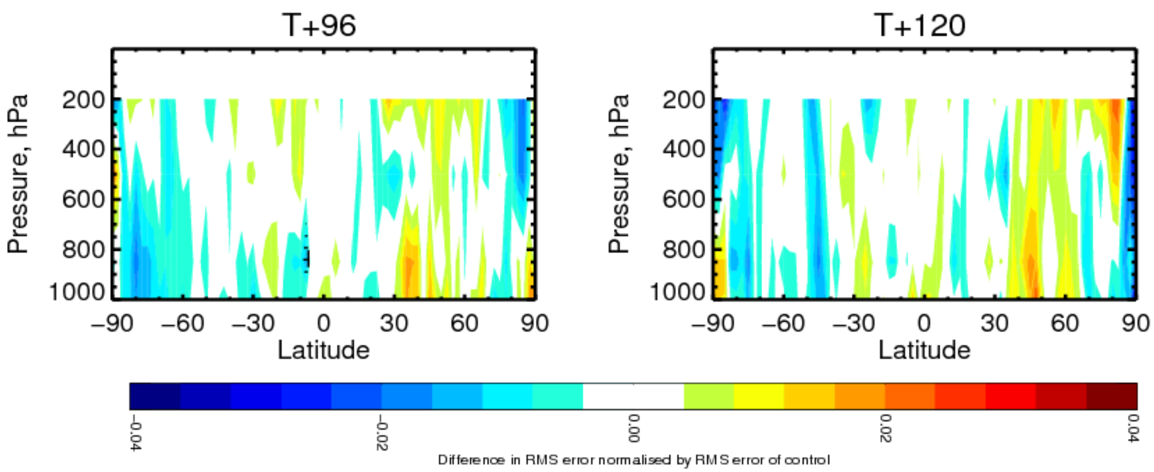
ECMWF

Forecast scores vector wind speed (JJA-2010)



(SMOS+SLV) - CTRL

- **Blue → error forecast decreases**
- **Red → error forecast increases**

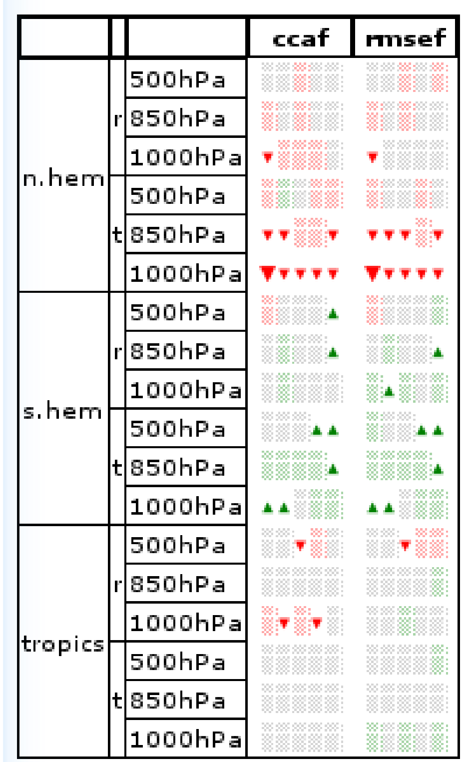


SMOS - CTRL

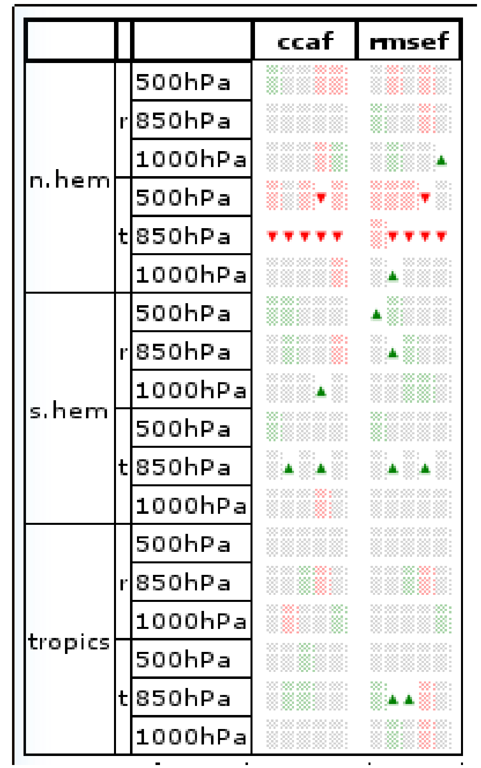
ECMWF

Forecast scores (analysis vs observations)

JJA – 2010 (summer) → against own analysis



JJA – 2010 (summer) → against observations

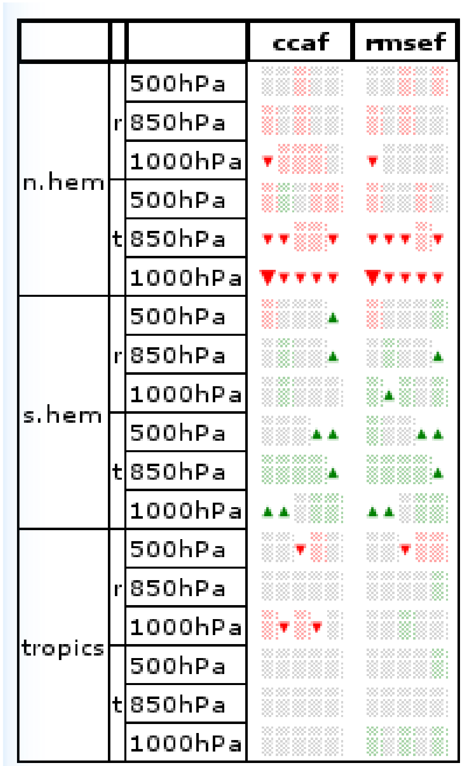


(SMOS+SLV) - SLV

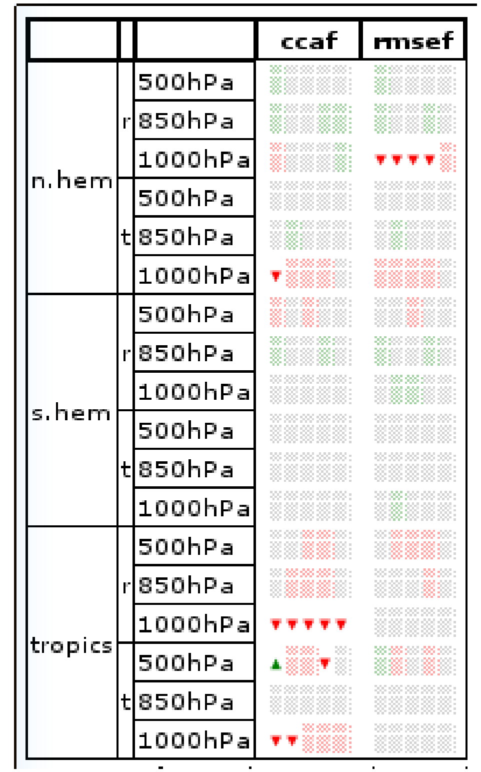
ECMWF

Forecast scores (against own analysis)

JJA – 2010 (summer)



SON- 2010 (Autumn)



(SMOS+SLV) - SLV

ECMWF

Summary and conclusions on the atmospheric impact

• The impact of assimilating only SMOS TBs in the SEKF is larger than used in combination with SLV, which is due to stronger SM increments. The influence is primarily close to the surface, whereas it is very weak in the upper troposphere.

• For boreal summer of 2010, SMOS increments produce a warmer and drier atmosphere in the center of US, but also in the Sahel, South of Africa and Australia → hot spot study identified these areas as potentially significant for NWP impact. Some cooling and more humid atmosphere is produced in Northern Canada and North of Europe.

• How is the previous impact in regards to the RMS forecast error? The forecast error of air temperature and humidity in SMOS+SLV is small, slight degradations are found in center of US and some small improvements in the South Hemisphere. The impact in the skill is larger if only SMOS TBs are assimilated, but with mixed signs: generally the skill in the centre of US is degraded, whereas it has a diurnal cycle in Europe and South of Africa.

SMOS KO meeting 05-09-14

Joaquín Muñoz Sabater

- Part I: Technical work and deliverables

- Part II: SLV+ SMOS data assimilation experiments
  - Root-zone SMOS-DA soil moisture product,
  - SEKF components analysis for summer 2010 (diagnostic),
  - Soil moisture validation against in-situ data,
  - Atmospheric verification,

- Part III: Short experiments with different observation and background error scenarios
  - Validation against in-situ and SYNOP data,
  - Atmospheric verification

ECMWF

Sensitivity to the error specification

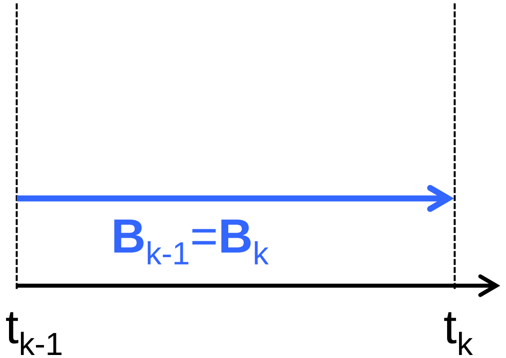
Investigate the effect of various observation (**R**) and background error (**B**) specification in the soil moisture analysis.

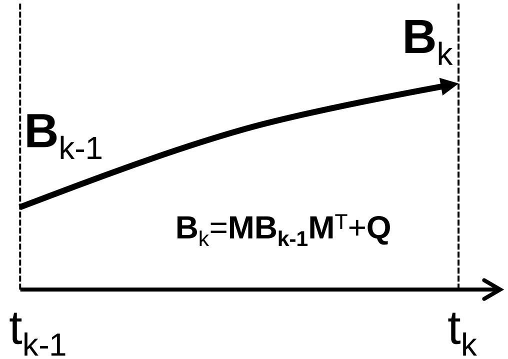
- USA → best place for availability of observations and “cheaper” experiments,
- Period: 15 Sept- 14 Oct 2012 → recharge period, good variability of soil moisture,
- 3 angles (30, 40, 50), 2 polarisations (XX, YY), AF-FOV, RFI flag,
- Physics of cy40r1,
- Only ATOVS, GBRAD and NEXRAD observations used to limit number of observations, and still reasonable atmospheric constrain

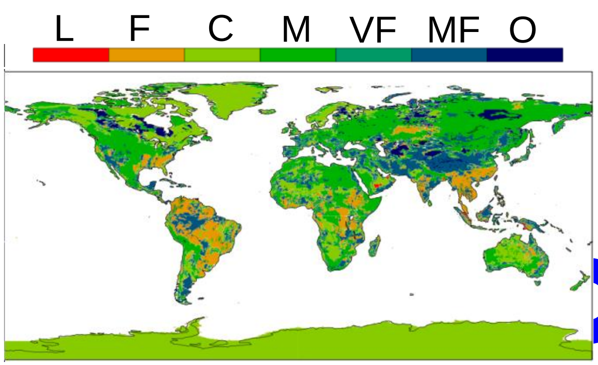
Sensitivity to the error specification

<u>Experiment types:</u>

- **CTRL →** no soil moisture analysis (SLV and all the other surface variables are still analysed)
- **SLV →** assimilation of only T^{2m}, RH^{2m} (simulate surface operational conditions)
- **SLV+SMOS →** assimilation of T^{2m}, RH^{2m} and SMOS T_B with **B** static
- **SMOS B-fix →** assimilation of only SMOS T_B with **B** static
- **SMOS B-prop →** assimilation of only SMOS T_B with **B** propagated between two cycles. Background errors grow as a function of the model error along the assimilation window
- **SMOS PDI →** pseudo direct-insertion of SMOS T_B . SEKF filters still apply to increments and departures
- **SMOS 2R →** assimilation of only SMOS T_B, doubling the observation error (2**R**),
- **SMOS B-text →** assimilation of only SMOS T_B; background error is defined as a proportion of the water holding capacity (WHC). 10% of WHC is equivalent to doubling background error (0.02 m3/m-3), or 20 mm for the 1st meter of soil.
- **SMOS 3DB →** Top layer more affected by short-scale variability and more sensitive to precipitation errors → larger error: 0.04 m3/m-3, approximately equal to 0.2(wfcp-wwp), 2nd layer 0.1(wfcp-wwp) and 3rd layer more stable 0.05(wfcp-wwp)







Sensitivity to the error specification

Four groups of experiments type have been investigated:

- [CTRL, SLV, SMOS+SLV, SMOS] → investigate type of assimilated observation
- [SMOS PDI, SMOS, SMOS 2R] → Investigated different weights to SMOS observations
- [SMOS B-fix, SMOS B-prop, SMOS B-text, SMOS 3DB] → Investigate different configurations of the B-matrix
- [SMOS B-fix, SMOS B-prop, SMOS B-text, SMOS 2R] → Investigate different configurations of the B-matrix and observation error

Validation and verification:

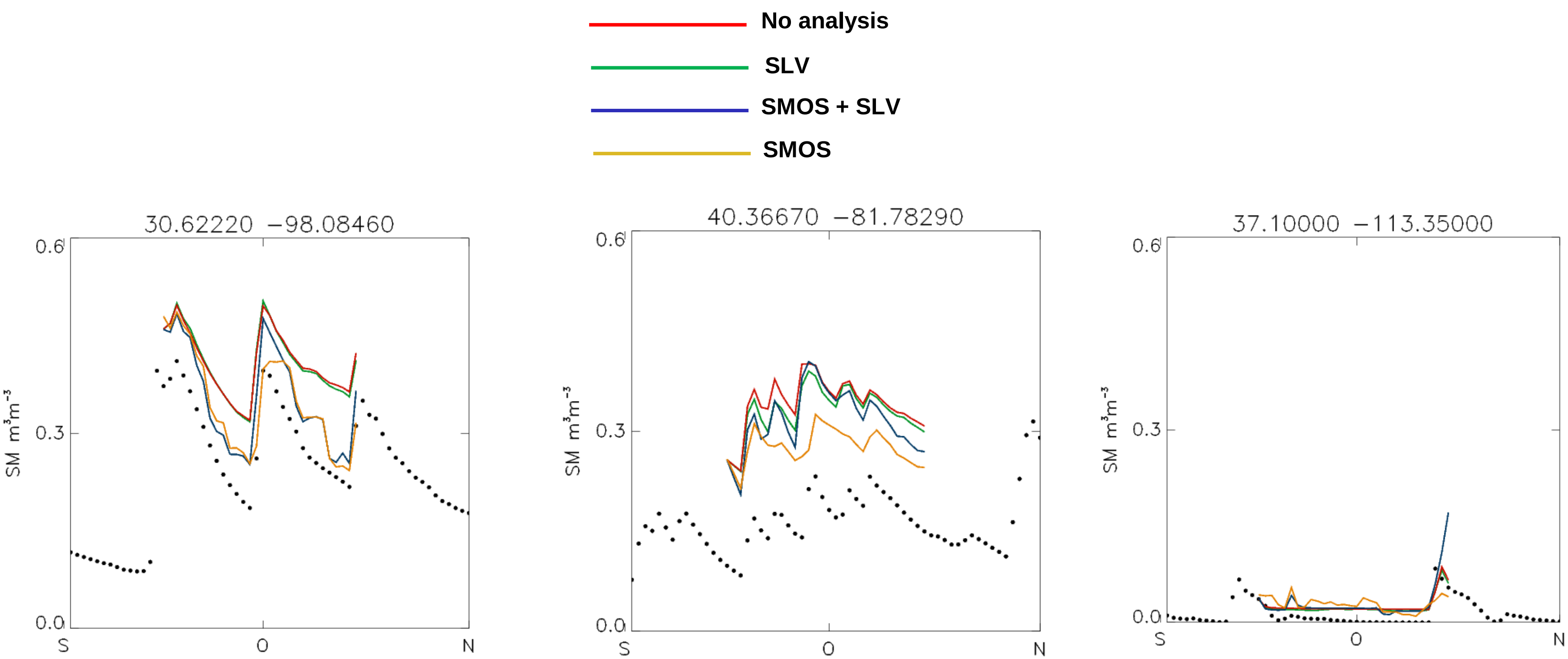
- Validation against in-situ data of two independent networks: SCAN and USCRN
- Comparison against T2m and Dew point temperature observations from the SYNOP network
- Atmospheric verification using a North-America mask

ECMWF

Validation against in-situ data (top layer)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.115	0.130	0.75	60
SLV	-0.115	0.130	0.75	60
SMOS+SLV	-0.097	0.121	0.76	60
SMOS	-0.089	0.115	0.67	60

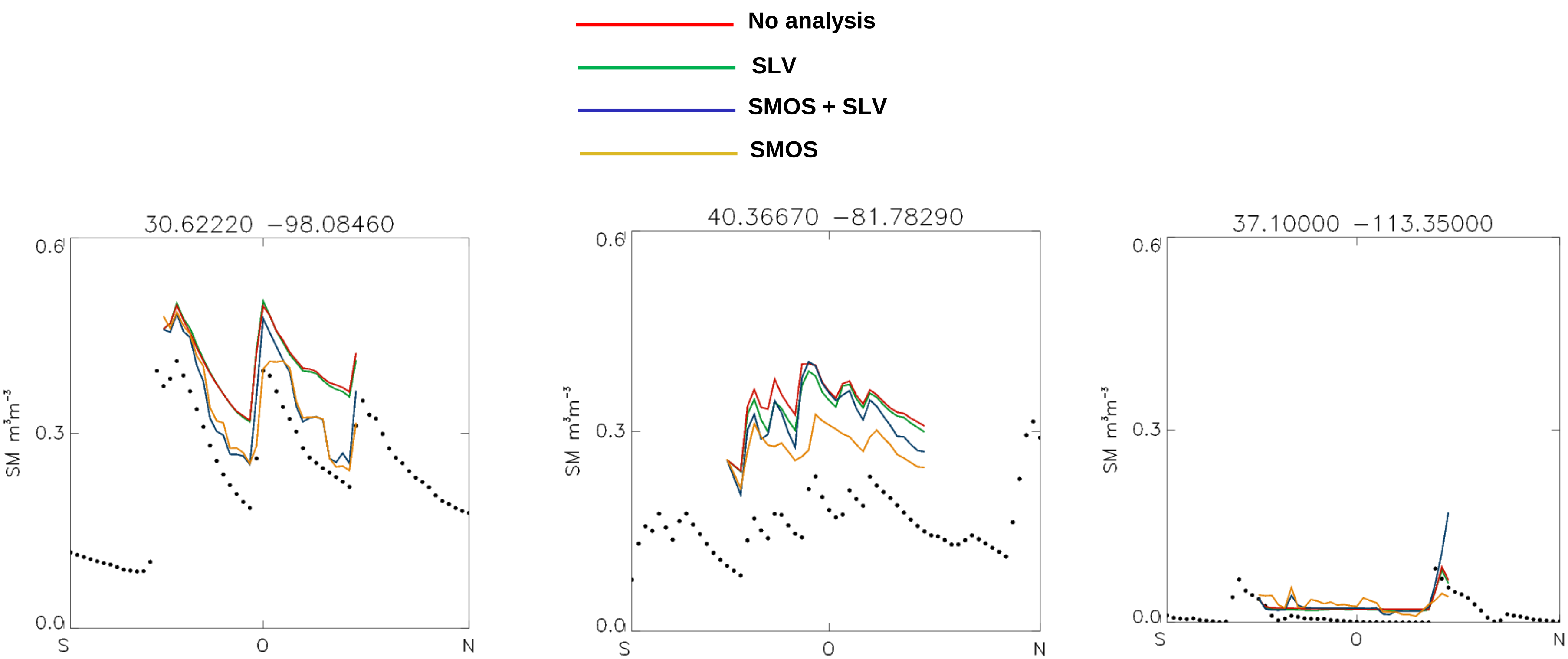
SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.062	0.104	0.74	86
SLV	-0.061	0.104	0.74	86
SMOS+SLV	-0.048	0.101	0.75	86
SMOS	-0.035	0.101	0.68	86



Validation against in-situ data (top layer) – last 15 days

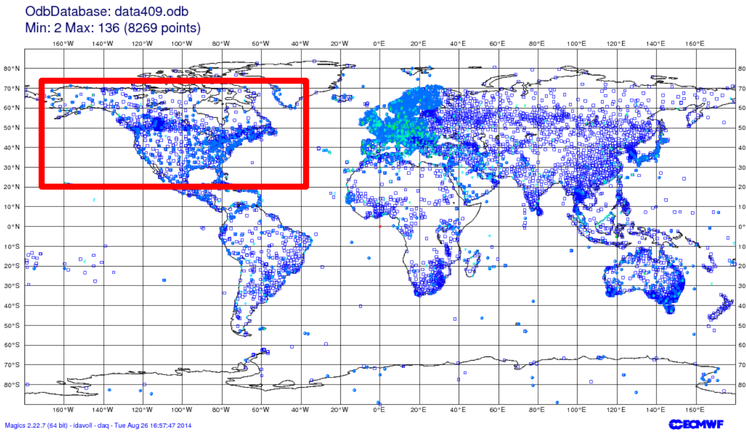
USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.102	0.115	0.77	52
SLV	-0.103	0.115	0.78	52
SMOS+SLV	-0.087	0.107	0.76	52
SMOS	-0.073	0.094	0.69	52

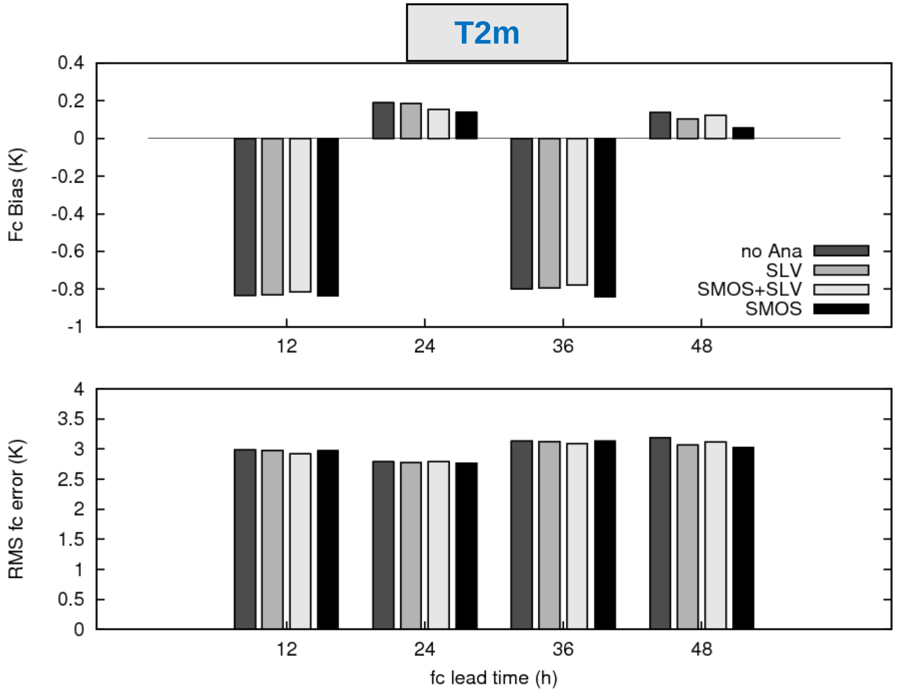
SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.061	0.110	0.83	60
SLV	-0.060	0.110	0.85	60
SMOS+SLV	-0.052	0.108	0.82	60
SMOS	-0.033	0.108	0.76	60

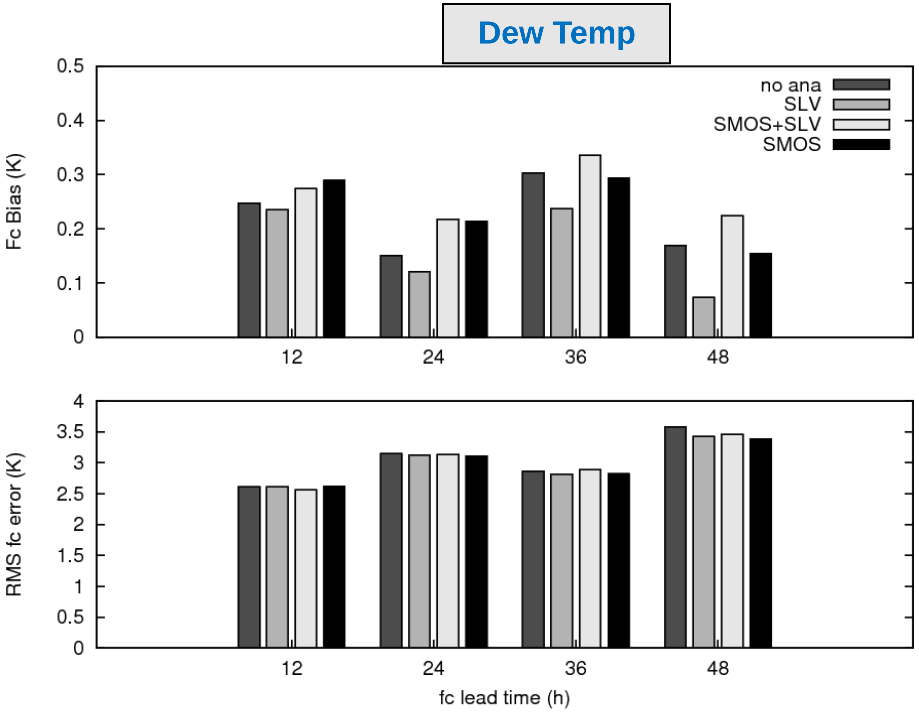


T2m and Dew point temperature forecast impact

- **Validation against T2m and Dew Temp of the SYNOP network**



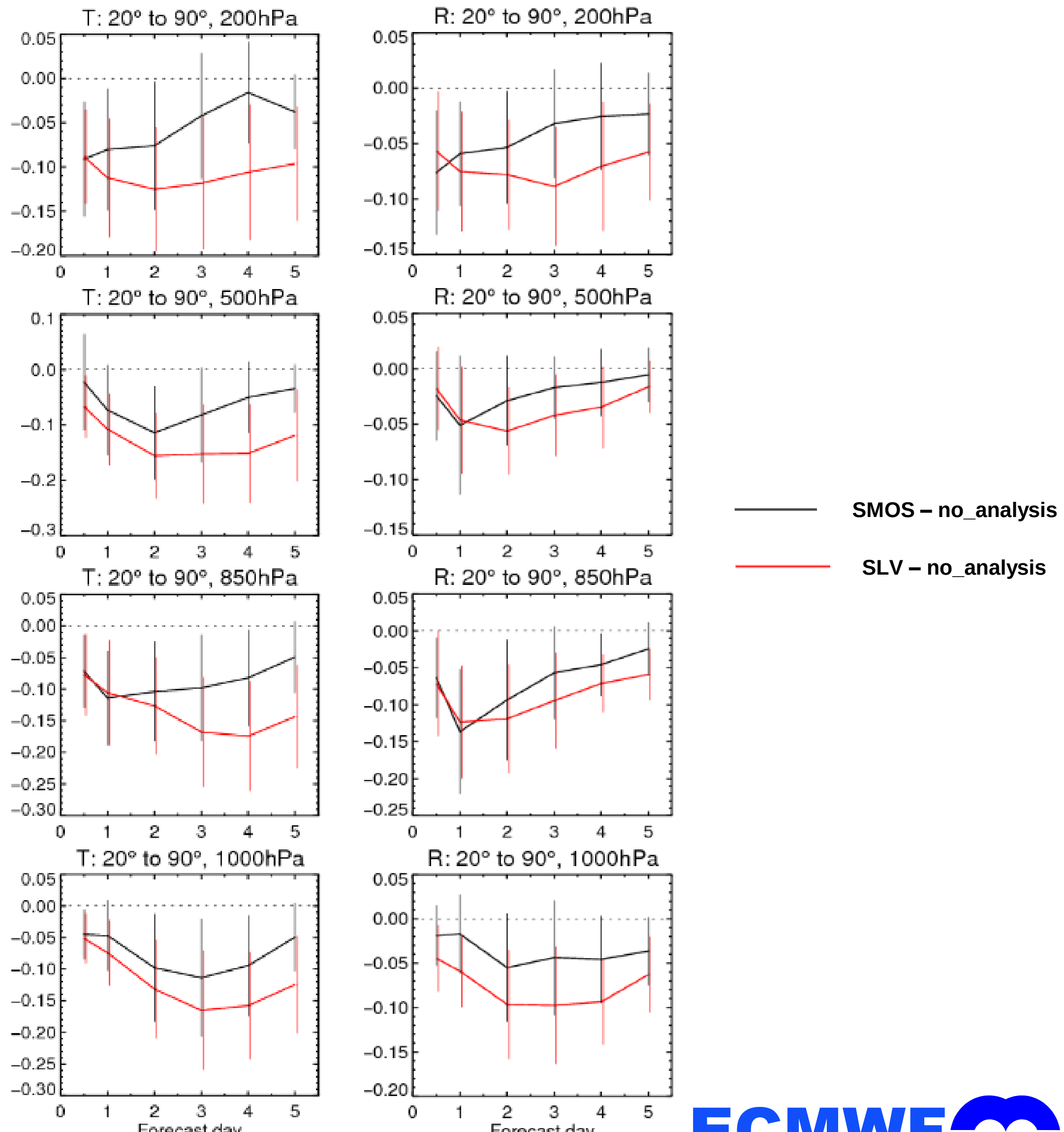




Air temperature and humidity verification

- **Normalized RMS forecast error**
- **For each lead forecast time, average of 30 forecasts started at 00UTC**
- **Verification is against operational analysis:**

These experiments are run under a degraded observing system, implying a very poor analysis. The significance of the scores against their own analysis is probably less significant than using the operational analysis (of higher quality).

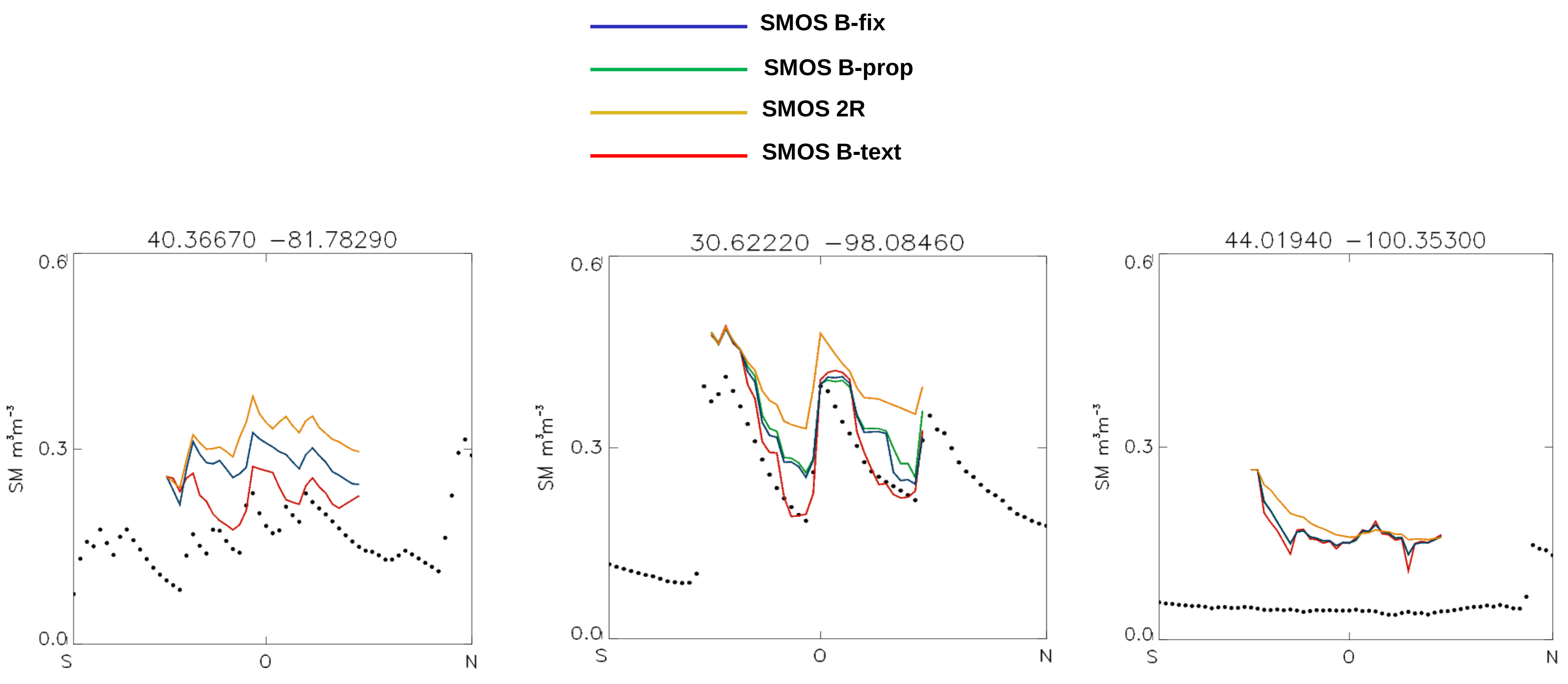


ECMWF

Validation against in-situ data (top layer)

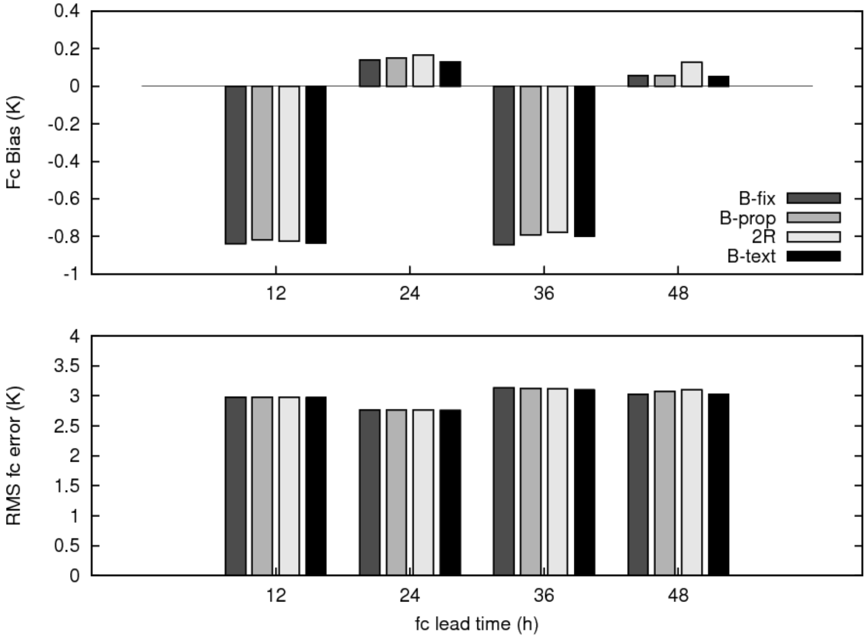
USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS B-fix	-0.087	0.111	0.68	65
SMOS B-prop	-0.090	0.114	0.67	65
SMOS 2R	-0.096	0.115	0.71	65
SMOS B-text	-0.075	0.107	0.64	65

SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS B-fix	-0.021	0.093	0.70	76
SMOS B-prop	-0.024	0.093	0.71	76
SMOS 2R	-0.033	0.095	0.71	76
SMOS B-text	-0.014	0.093	0.65	76

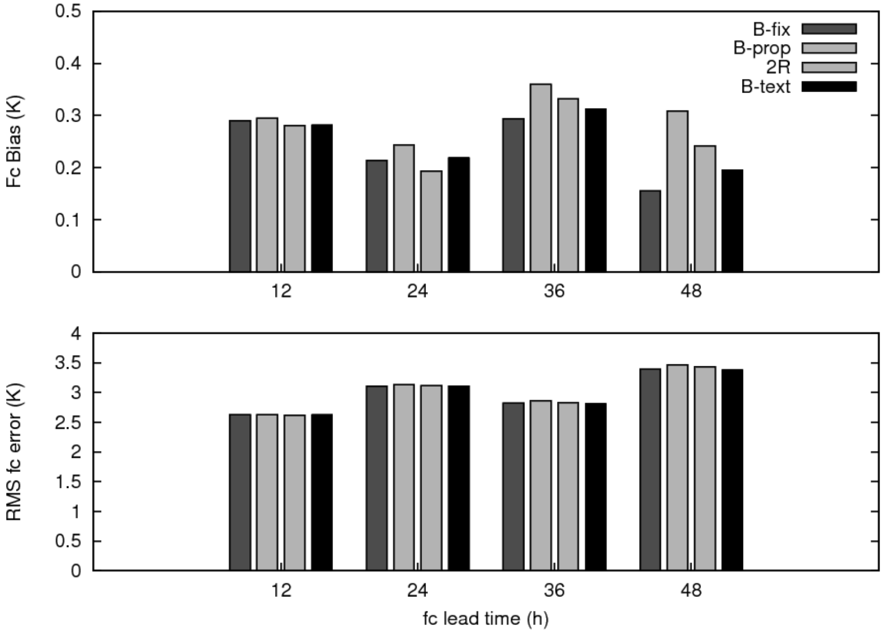


T2m and Dp Temperature forecast impact

T2m



Dew Temp



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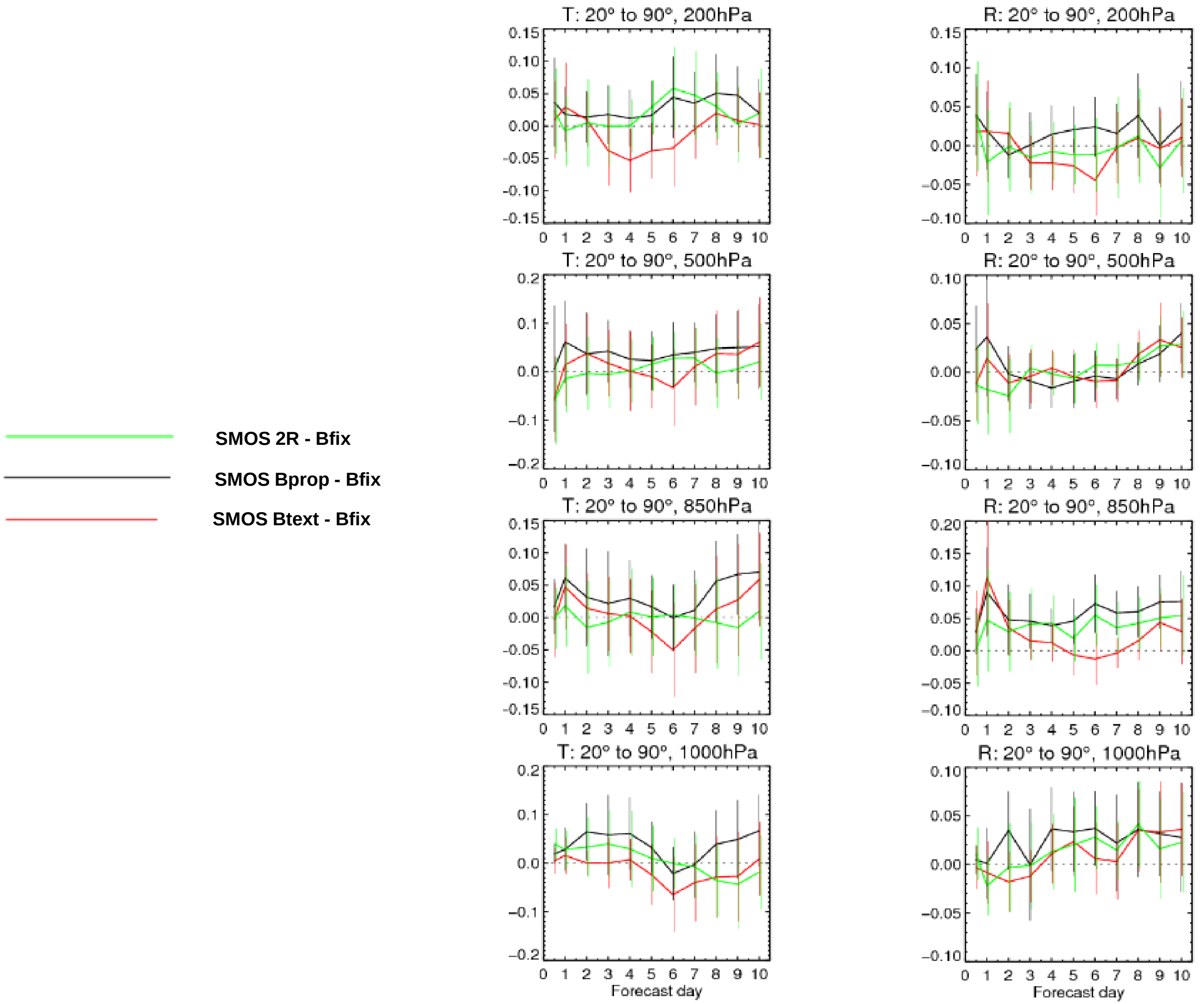
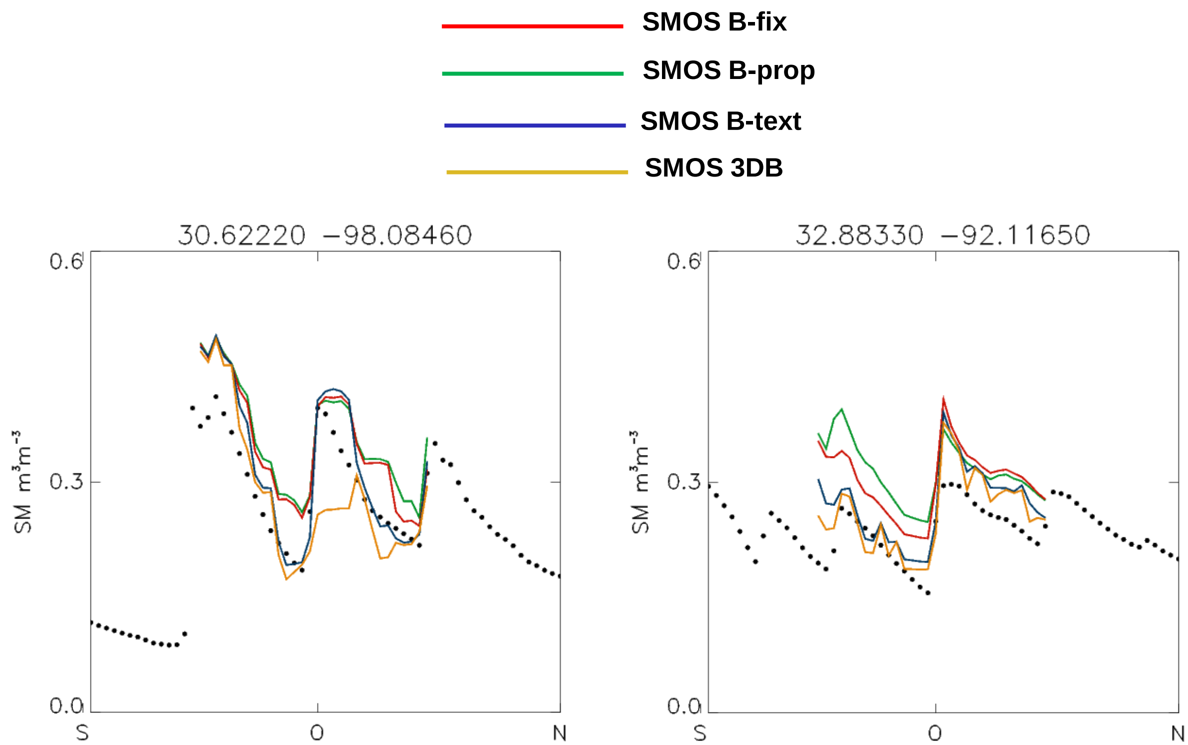
Air temperature and humidity verification



Validation against in-situ data (top layer)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS B-fix	-0.085	0.109	0.70	64
SMOS B-prop	-0.088	0.111	0.69	64
SMOS Btext	-0.074	0.104	0.67	64
SMOS + 3DB	-0.071	0.102	0.65	64

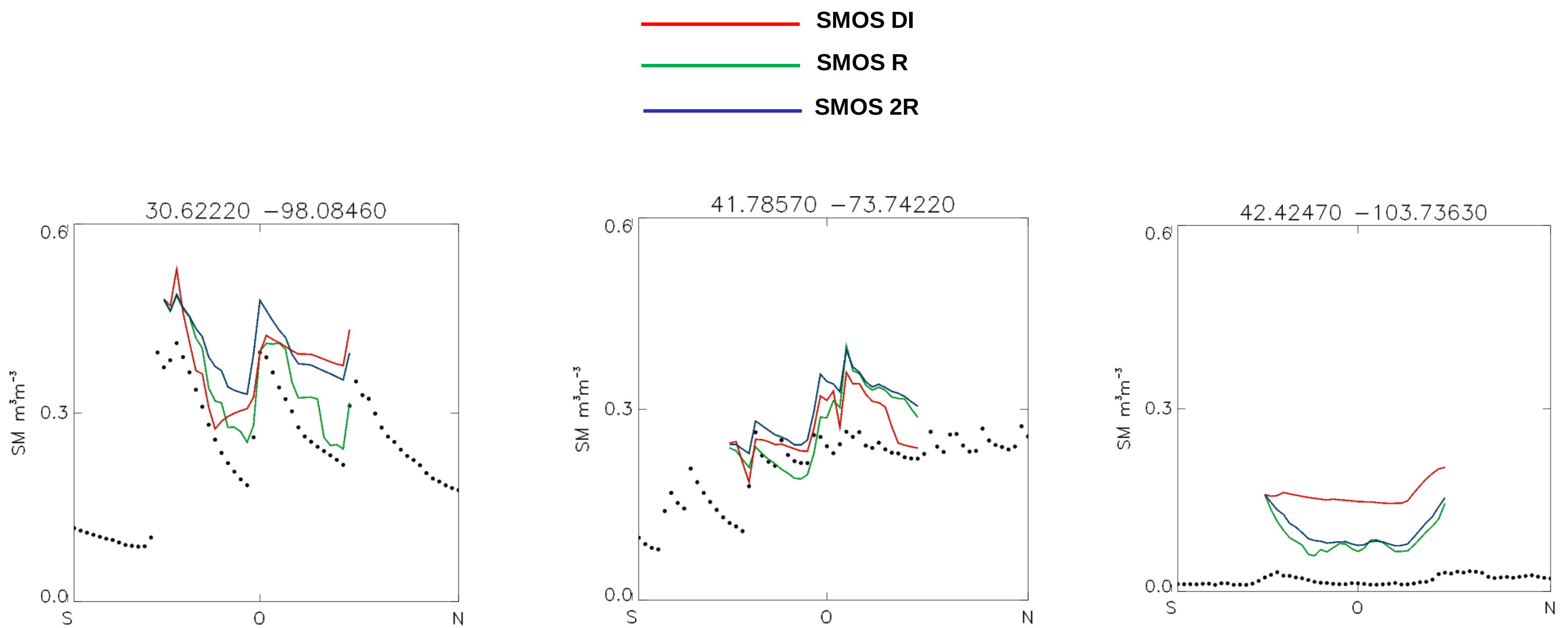
SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS B-fix	-0.022	0.095	0.70	77
SMOS B-prop	-0.025	0.095	0.70	77
SMOS Btext	-0.015	0.094	0.66	77
SMOS + 3DB	-0.016	0.094	0.64	77



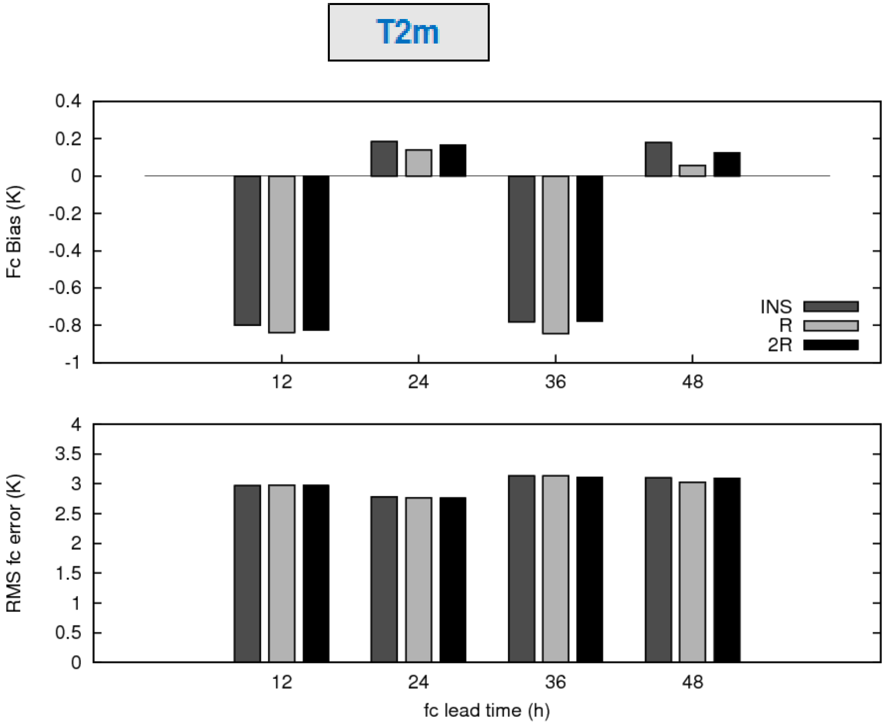
Validation against in-situ data (top layer)

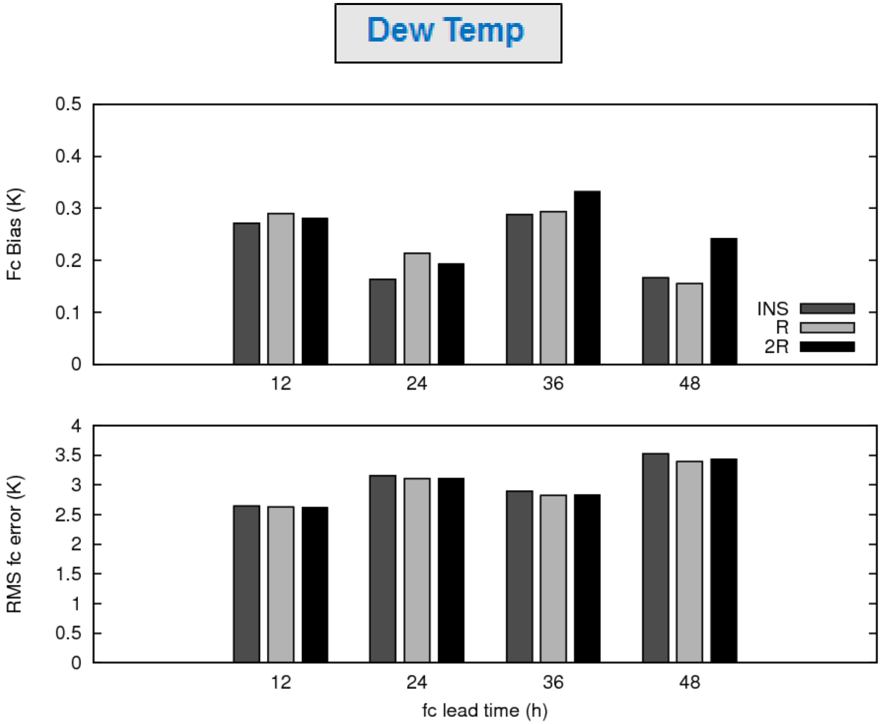
USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
Direct Ins	-0.099	0.116	0.71	58
SMOS + R	-0.086	0.113	0.69	58
SMOS+2R	-0.096	0.117	0.74	58

SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
Direct Ins	-0.051	0.106	0.68	83
SMOS + R	-0.032	0.101	0.69	83
SMOS+2R	-0.044	0.104	0.72	83



T2m and dew point temperature forecast impact





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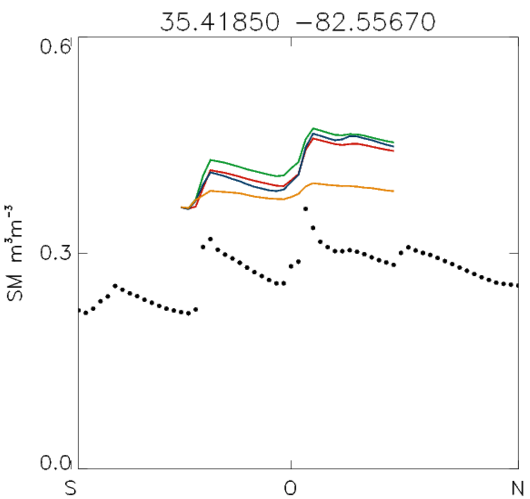
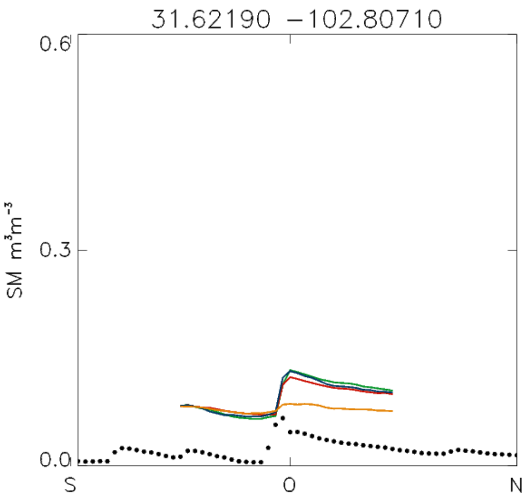
Validation against in-situ data (1st meter)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.089	0.096	0.74	37
SLV	-0.089	0.096	0.72	37
SMOS+SLV	-0.087	0.095	0.72	37
SMOS	-0.080	0.089	0.61	37

SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
No an	-0.032	0.096	0.74	56
SLV	-0.031	0.096	0.70	56
SMOS+SLV	-0.030	0.096	0.72	56
SMOS	-0.024	0.099	0.61	56

No analysis
SLV
SMOS + SLV
SMOS





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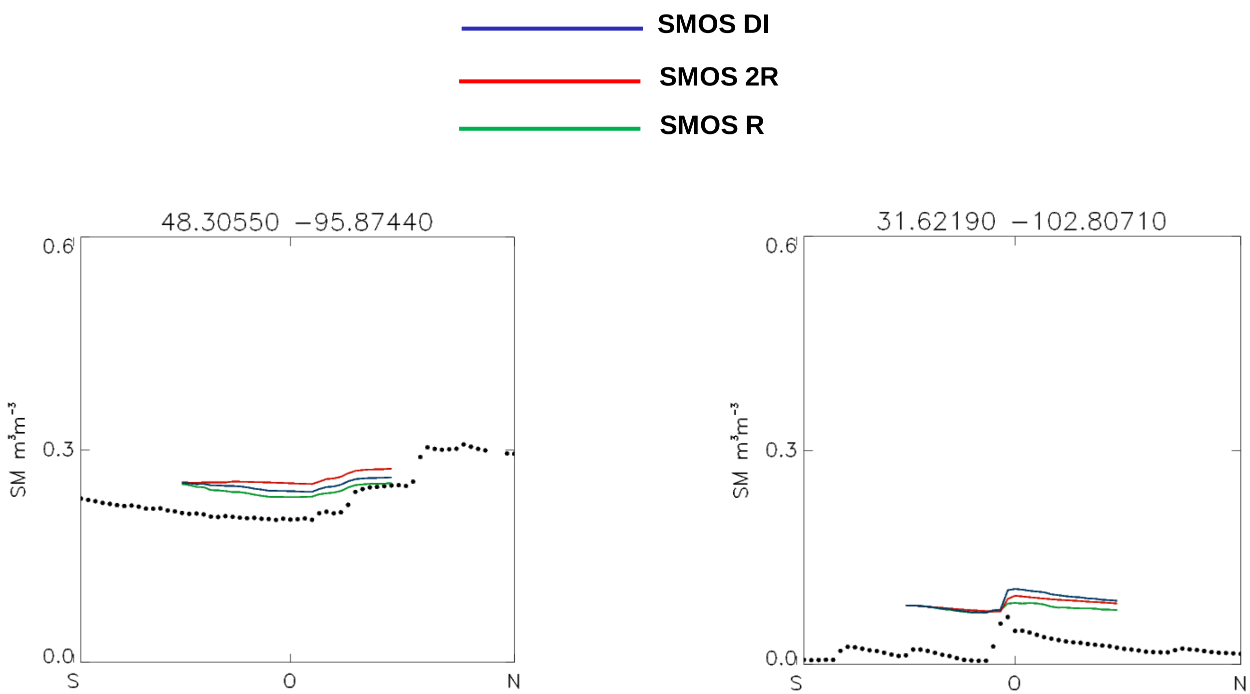
Validation against in-situ data (1st meter)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
Direct Ins	-0.082	0.092	0.70	38
SMOS + R	-0.081	0.091	0.63	38
SMOS+2R	-0.081	0.091	0.70	38

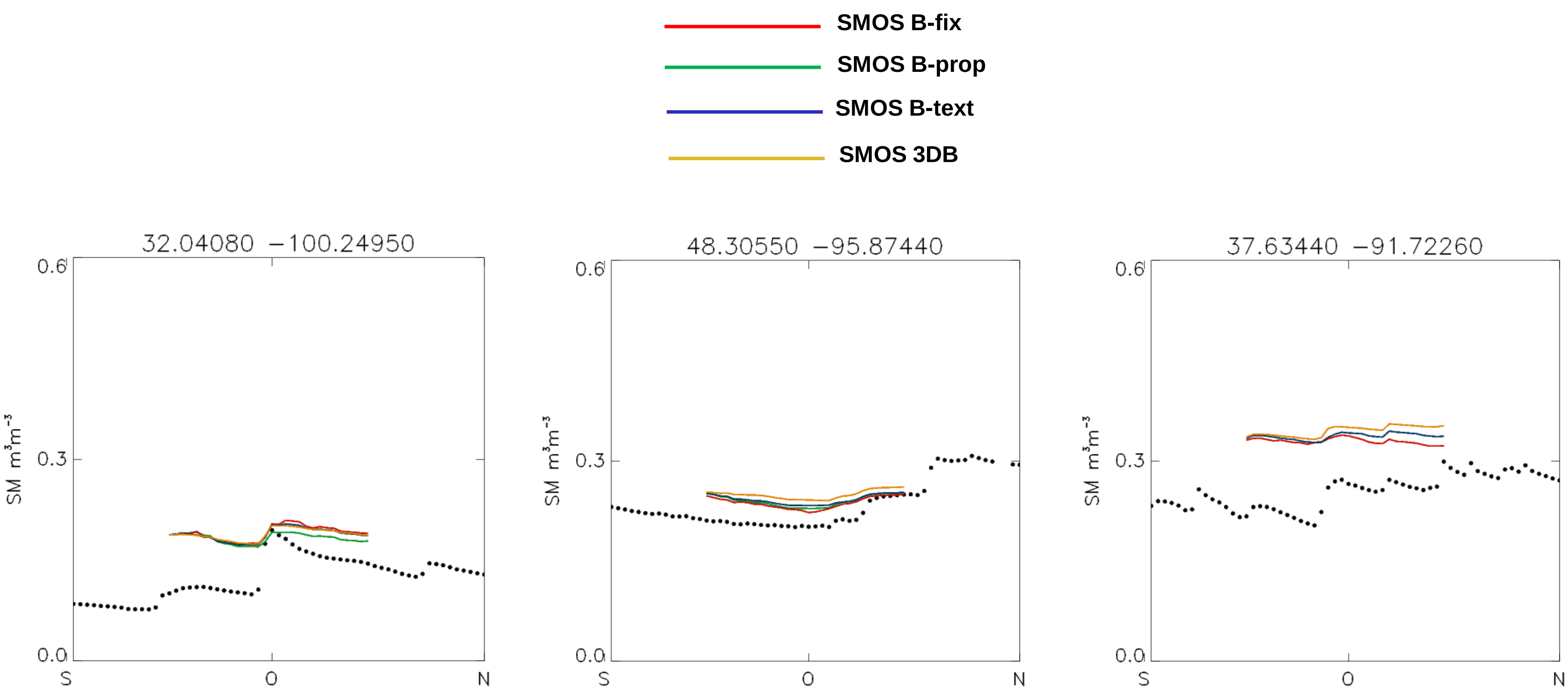
SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
Direct Ins	-0.029	0.095	0.67	62
SMOS + R	-0.025	0.095	0.58	62
SMOS+2R	-0.027	0.095	0.65	62



Validation against in-situ data (1st meter)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS Bfix	-0.077	0.093	0.63	30
SMOS Bprop	-0.076	0.091	0.65	30
SMOS Btext	-0.077	0.092	0.66	30
SMOS + 3DB	-0.076	0.092	0.71	30

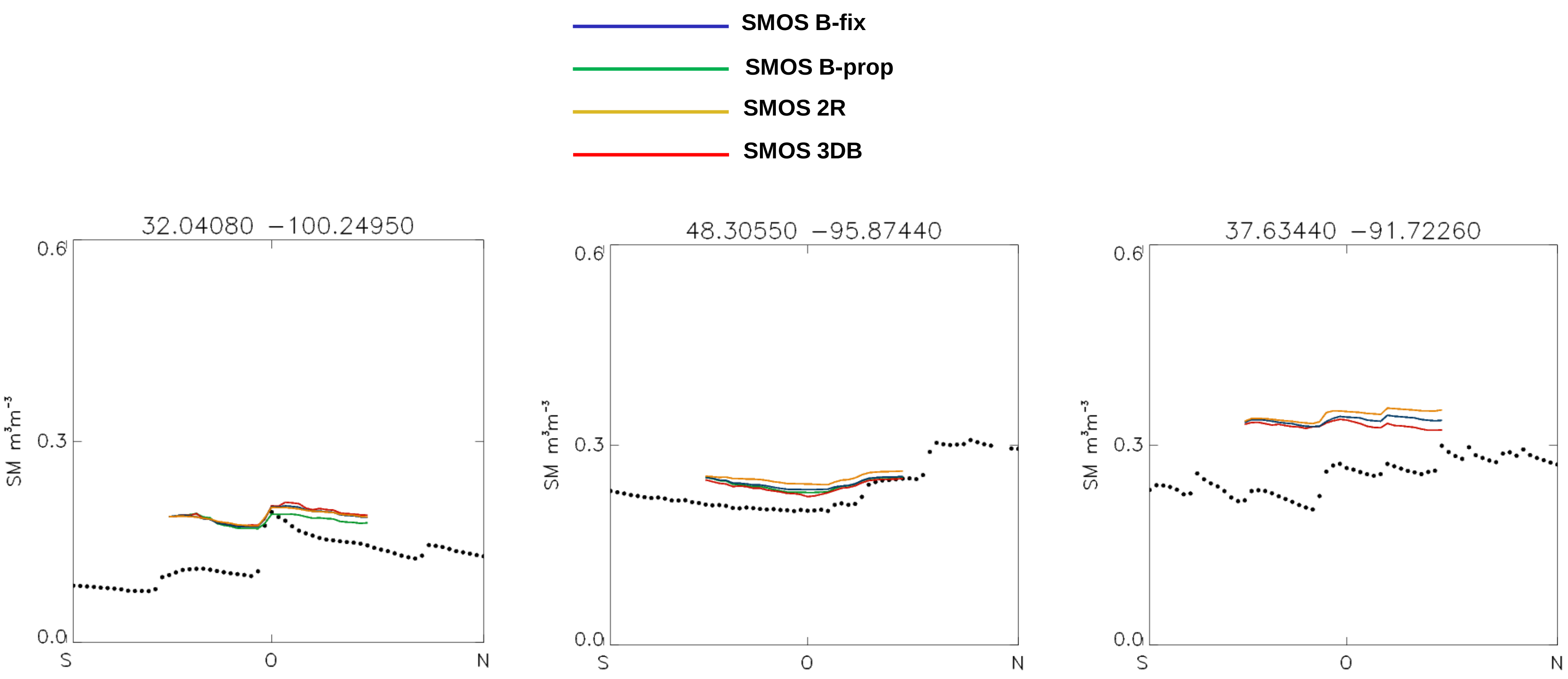
SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS Bfix	-0.013	0.090	0.64	48
SMOS Bprop	-0.012	0.090	0.65	48
SMOS Btext	-0.012	0.090	0.64	48
SMOS + 3DB	-0.012	0.089	0.65	48



Validation against in-situ data (1st meter)

USCRN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS Bfix	-0.074	0.088	0.63	28
SMOS Bprop	-0.073	0.087	0.62	28
SMOS + 2R	-0.074	0.089	0.59	28
SMOS + 3DB	-0.072	0.087	0.57	28

SCAN	Bias (m^3m^{-3})	RMSD (m^3m^{-3})	R	N
SMOS Bfix	-0.020	0.092	0.61	53
SMOS Bprop	-0.020	0.092	0.62	53
SMOS + 2R	-0.022	0.092	0.66	53
SMOS + 3DB	-0.019	0.091	0.60	53



Conclusions

• A series of several 1-month experiments have been run to study:

a) The effect of different type of observations in the soil moisture analyses,
b) The effect of different configurations of the B-matrix,
c) The effect of different weights given to SMOS observations in the SEKF,

a) Compared to a free run, assimilating screen-level variables is neutral for soil moisture analysis. However, it benefits the forecast of air temperature and humidity, up to 10%.
In contrast, the assimilation of SMOS observations reduces bias and RMSD against in-situ data, for both, top layer and root-zone. The correlation coefficient is penalized for the larger variability introduced by the increments and for just one month. The atmospheric impact is still positive compared to the free run, but not as much as for SLV assimilation.

b) Redefining the B-matrix as a function of the soil texture (B-text or 3D-B experiments) obtains the best results in terms of Bias and RMSD against in-situ data for the top layer. However, the variability of the increments can affect the correlation over short time scales. Among these experiments, the atmospheric impact was found to be neutral.

c) The current weight given to SMOS observations obtain closest analysis to in-situ data. However, doubling the SMOS observation error will reduce the variability of the increments (lower gain) and that improves the correlation against in-situ.

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Discussion

- For future implementation in operations, consider:
  - Doubling or tripling SMOS error → smaller gain and more stable increments,
  - B matrix defined as a function of soil texture (B-text or 3D-B) → reduces bias and RMSD,
  - Reduce first-guess check? Adaptive to the location?
  - Improve quality control of observations.

Caveats

- Experimentation:
  - ECMWF uses a large diversity of satellites and data from different sources to constrain the atmospheric system → impact of a new observing system is difficult.
  - Degrading the observations system would be a way to observe stronger impact of SMOS (for example without using conventional data),
  - The operational system is rather conservative as the background error is relatively small in comparison to the observation error → an investigation over the error matrices can optimize the weight given to the observations.

- Verification,
  - Verification is a science itself.
  - The introduction of a new observing system can produce bad scores over variables which are dominated by small scale structures and in areas with small number of observations. This is because when comparing against the own analysis, the increments might be stronger when introducing the new system, compared to the control, and for the few 2-3 days obtain apparent bad scores. For example, this would be the case for RH in Australia.

Caveats

- SMOS impact:
  - The primary objective, improving soil moisture, is achieved.
  - Atmospheric impact is not strong but is
    - Slightly positive over South Hemisphere,
    - Negative over North Hemisphere
  - What happen? This is the first time we use an spatialized direct observations of soil moisture in our model and the trend is to dry out, but still overestimating water in soil → Consequence: less evapotranspiration into the atmosphere and lower amount of water to produce clouds. Our model finds it easier to remove clouds than creating new clouds and adding more moisture is beneficial for the atmosphere in this case. The vertical transport is also quite strong and the model needs of additional moisture to compensate for these errors. Before we use to modify soil moisture to compensate for errors in 2m temp and relative humidity. Indeed, the hypothesis was that screen level errors was related to errors in soil moisture and this is not always the case. Therefore, the sm value was updated to produce the fluxes to decrease 2m t and rh errors. The other schemes (convection…) where tuned in consequence. C-TESSEL is pointing towards the same problem. They improve surface fluxes but degrades atmospheric scores and therefore cannot be put into operations. It also could be a problem of a relatively think root-zone layer (1m) → if too thin, and in US starts drying until no much water left, then no more evaporation to produce clouds
  - SMOS, as an Earth Explorer, as being able to point towards a very complex problem in a very complicated system → this involves a close collaboration of data assimilation team with physical aspects to solve this problem.

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