Monitoring SMOS data at ECMWF,

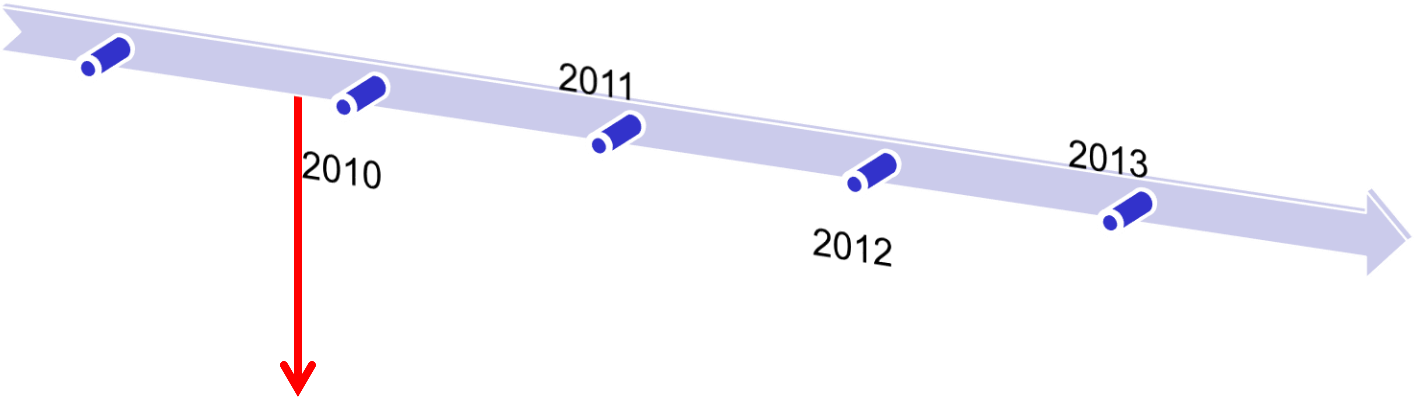
“a chronological review”

Joaquin Muñoz-Sabater

but with invaluable help from A. Fouilloux, P. de Rosnay, C. Albergel,
M. Dahoui, L. Isaksen, G. Balsamo, M. Drusch, I. Mallas
and many others…

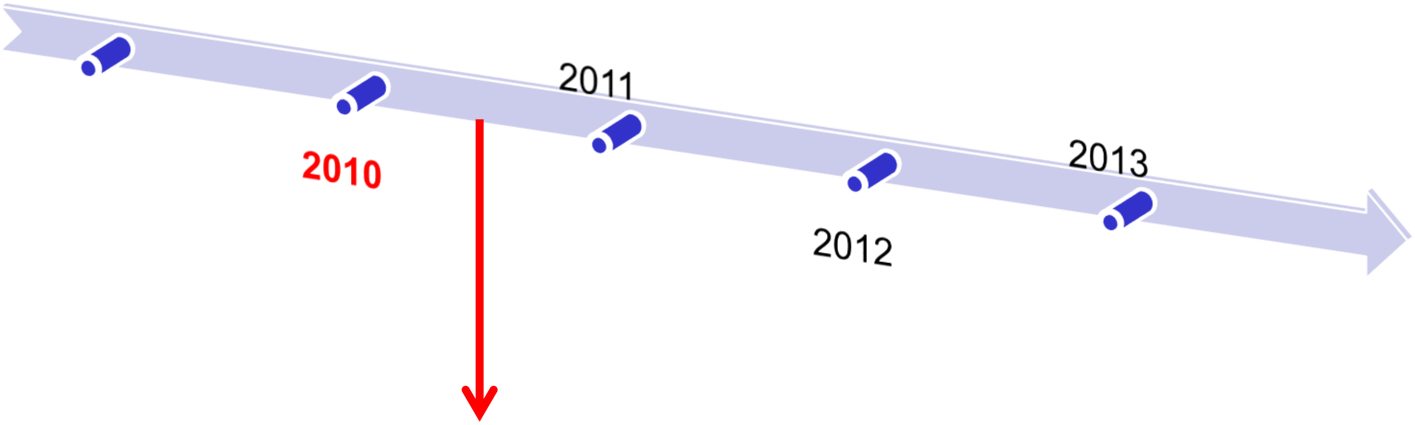
ECMWF

Monitoring Suite –> a chronological review



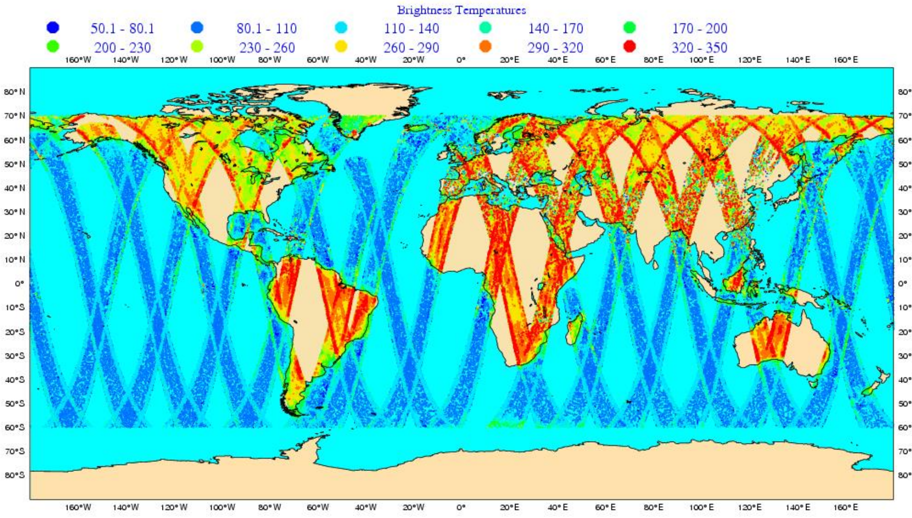
- Starting to prepare the introduction of a completely new type of data in the IFS,
- 2 November 2009 → SMOS is successfully launched from Plesetsk, Russia

Monitoring Suite –> a chronological review

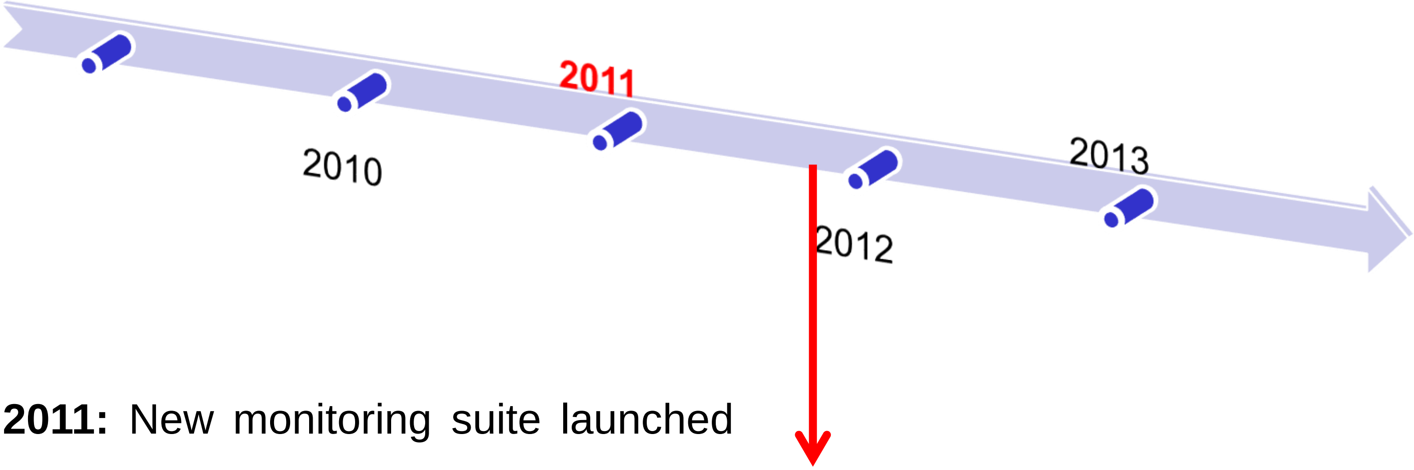


- ECMWF starts using the first batch of data,
- First maps of brightness temperatures are produced and published online at the ECMWF SMOS webpage. Maps are manually update every 1-2 weeks,
- ECMWF keeps an offline suite, however is not in Near Real Time (NRT),
- **4 November 2010** → Memory problems partially solved. A new suite is launched (cy36r4) which monitors the data in NRT and produces more than a 1000 plots per day.

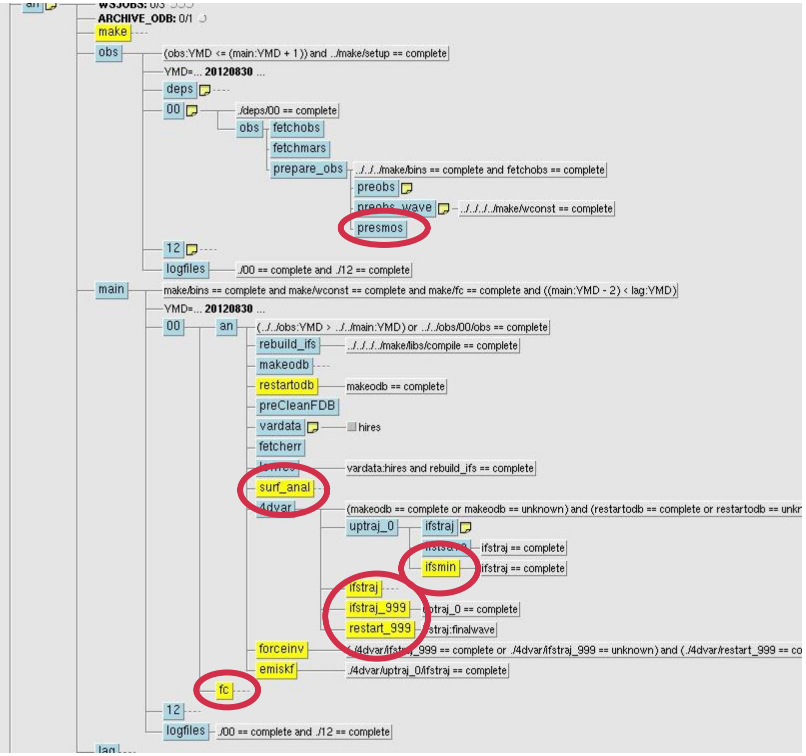
28-11-2009



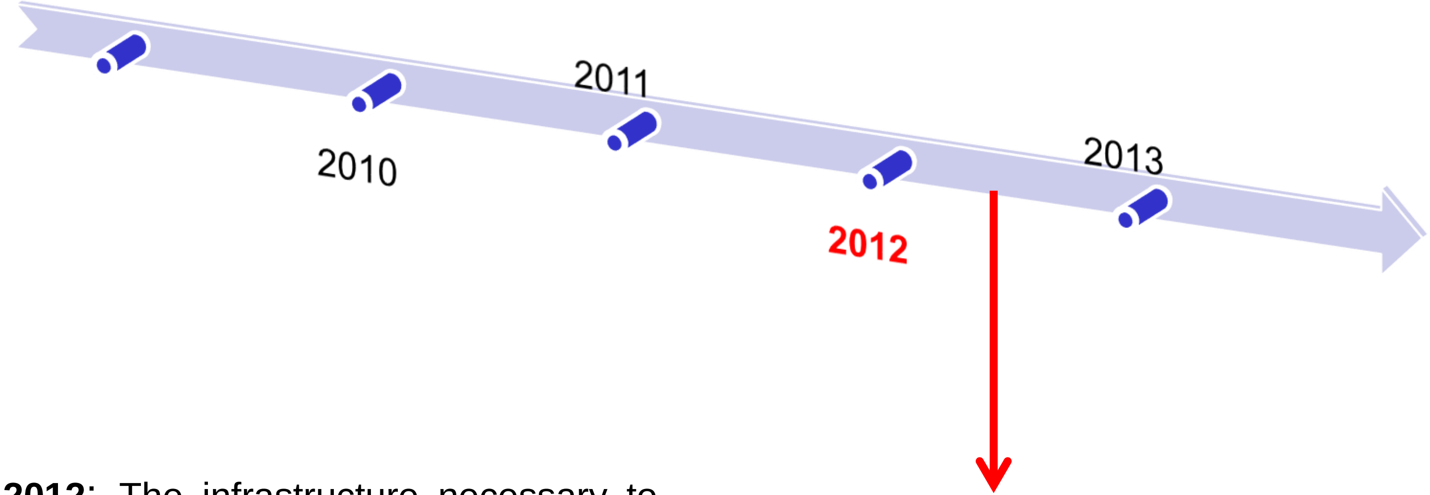
Monitoring Suite –> a chronological review



- **15 Nov 2011:** New monitoring suite launched in cy37r3,
- Smoothly transition between old and new suite. Scripts were synchronized with the aim of not affecting the statistics since it happened in the middle of a month,
- New suite running only in monitoring mode and only with SMOS data → only first model trajectory is run, no minimizations or surface analysis is produced → computing resources are drastically reduced and suite runs much faster. The new suite rapidly caught up the NRT and it does not need extra resources or priority,
- Monitoring is added to some cal/val sites. Only satellite at ECMWF doing this.

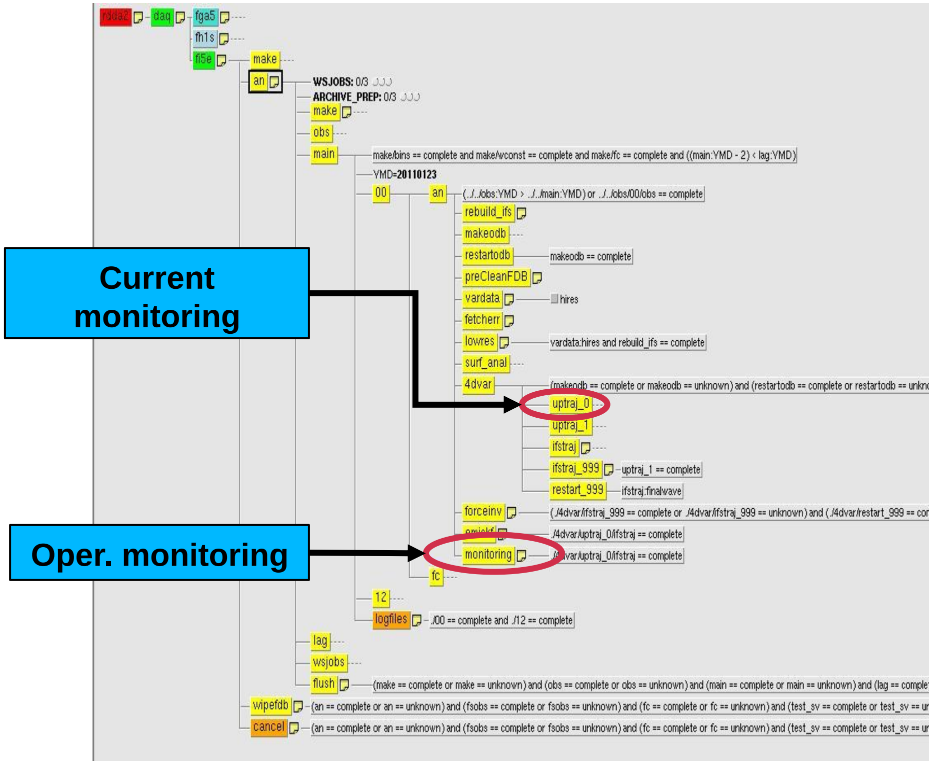


Monitoring Suite –> a chronological review



- **15 June 2012**: The infrastructure necessary to make SMOS operational is submitted to cy38r2 → first operational contribution to COPE project.
  - Advantage, supported by operations,
  - Only in areas where data assimilated,
  - New version v4.1 of CMEM introduced,
  - CMEM parameterisation calibrated for R,
  - RFI flag will be used,
  - Operational in summer 2013

- **14 Dec 2012:** Migration of suite from c1a to c2a



```
rdda2 - daq - fga5 ----
              fh1s ----
              fi5e --- make ----
                       an --- WSJOBS: 0/3
                              ARCHIVE_PREP: 0/3
                              make ----
                              obs ----
                              main --- make/bins == complete and make/wconst == complete and make/fc == complete and ((main:YMD - 2) < lag:YMD)
                                       YMD=20110123
                                       00 --- an --- (../../obs:YMD > ../../main:YMD) or ../../obs/00/obs == complete
                                                     rebuild_ifs
                                                     makeodb ----
                                                     restartodb --- makeodb == complete
                                                     preCleanFDB
                                                     vardata --- hires
                                                     fetcherr
                                                     lowres --- vardata:hires and rebuild_ifs == complete
                                                     surf_anal ----
                                                     4dvar --- (makeodb == complete or makeodb == unknown) and (restartodb == complete or restartodb == unkn
                                                               uptraj_0 ----
                                                               uptraj_1 ----
                                                               ifstraj ----
                                                               ifstraj_999 - uptraj_1 == complete
                                                               restart_999 - ifstraj:finalwave
                                                     forceinv --- (./4dvar/ifstraj_999 == complete or ./4dvar/ifstraj_999 == unknown) and (./4dvar/restart_999 == cor
                                                     ./4dvar/uptraj_0/ifstraj == complete
                                                     monitoring --- ./4dvar/uptraj_0/ifstraj == complete
                                              fc ----
                                       12 ----
                                       logfiles - ./00 == complete and ./12 == complete
                              lag ----
                              wsjobs ----
                              flush --- (make == complete or make == unknown) and (obs == complete or obs == unknown) and (main == complete or main == unknown) and (lag == comple
                       wipefdb - (an == complete or an == unknown) and (fsobs == complete or fsobs == unknown) and (fc == complete or fc == unknown) and (test_sv == complete or test_sv == ur
                       cancel - (an == complete or an == unknown) and (fsobs == complete or fsobs == unknown) and (fc == complete or fc == unknown) and (test_sv == complete or test_sv == ur
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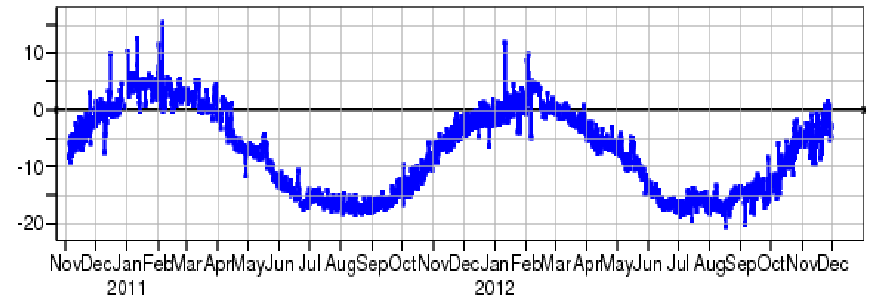
Bias

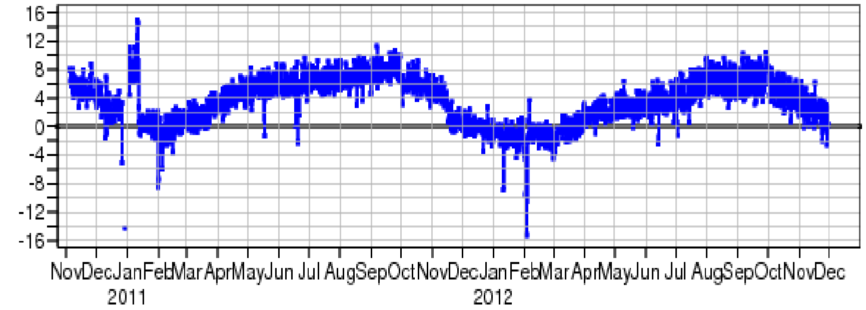
40 degrees incidence angle
Period: Nov-2010-Nov 2012

XX polarisation

Mean Bias North-hemisphere

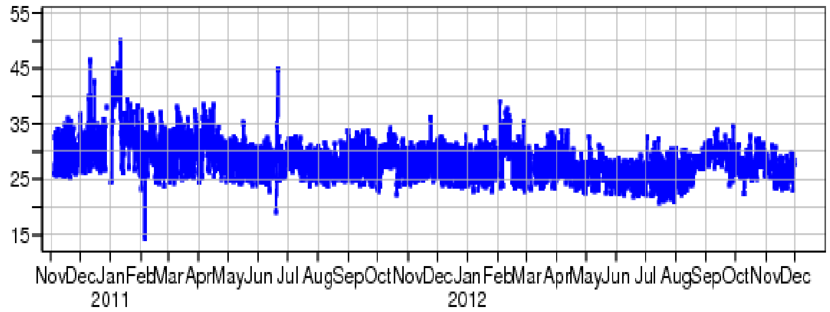


Mean Bias South-hemisphere

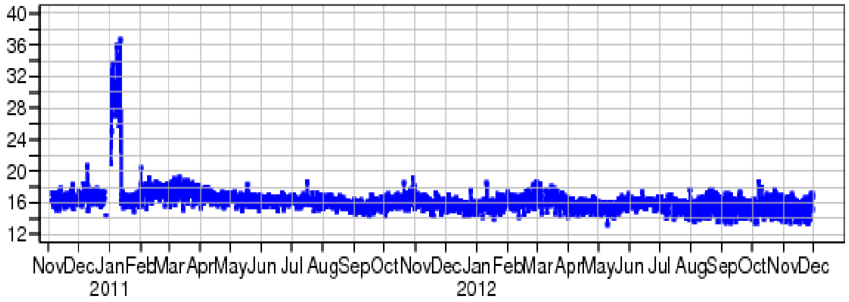


YY polarisation

std(obs) North-hemisphere

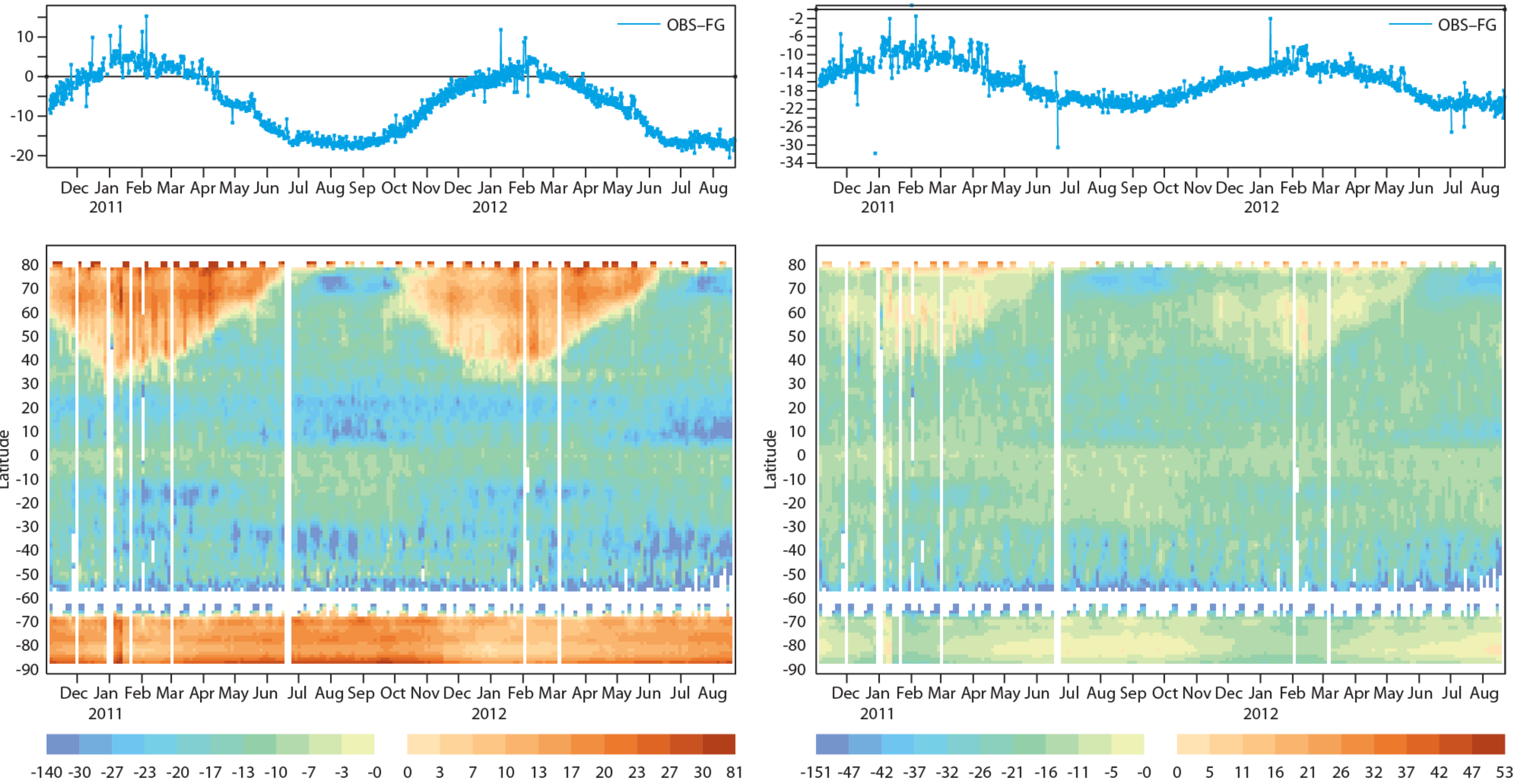


std(obs) South-hemisphere



Bias

40 degrees incidence angle
Period: Nov-2010-August 2012

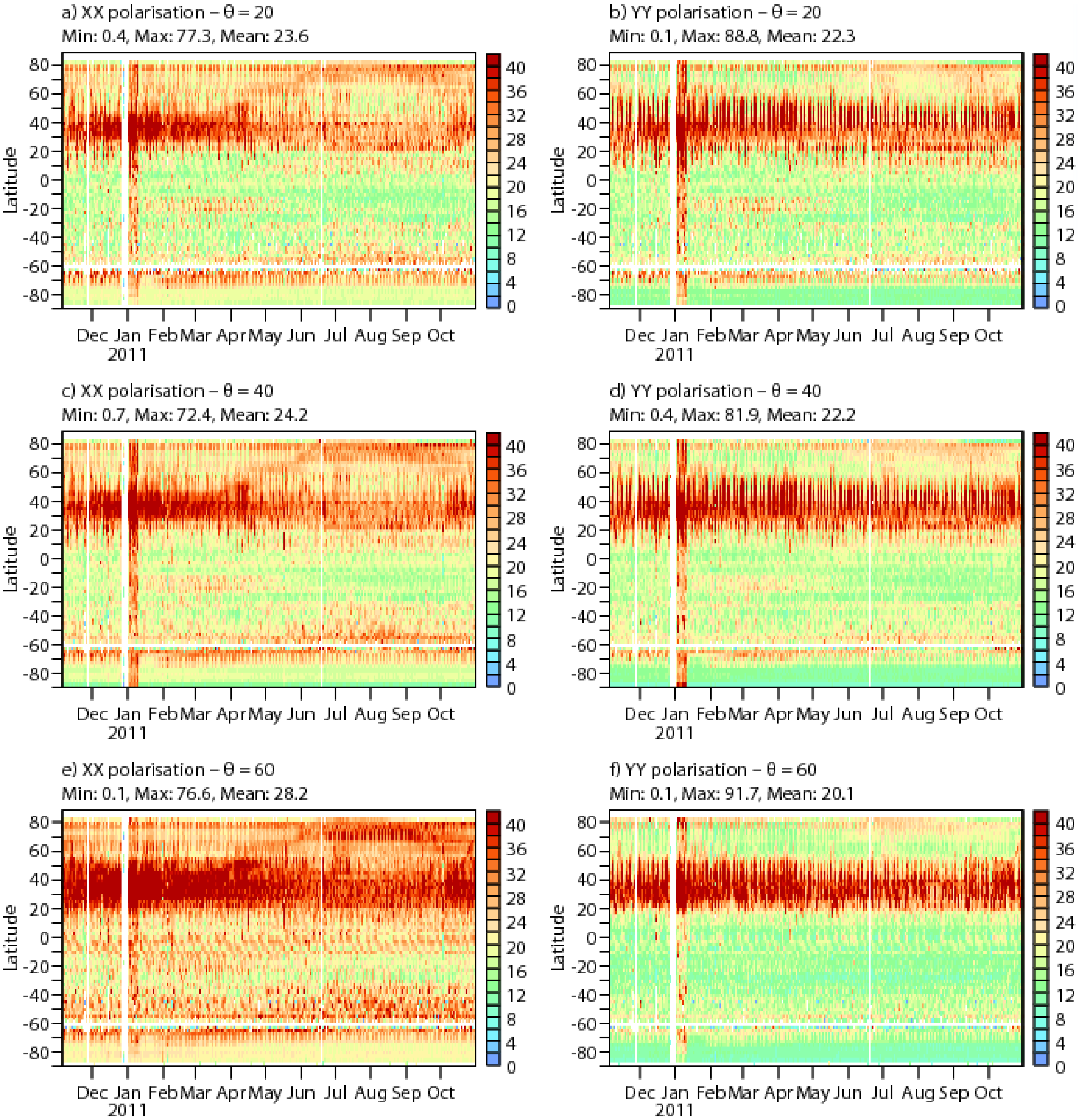


NH-XX polarisation

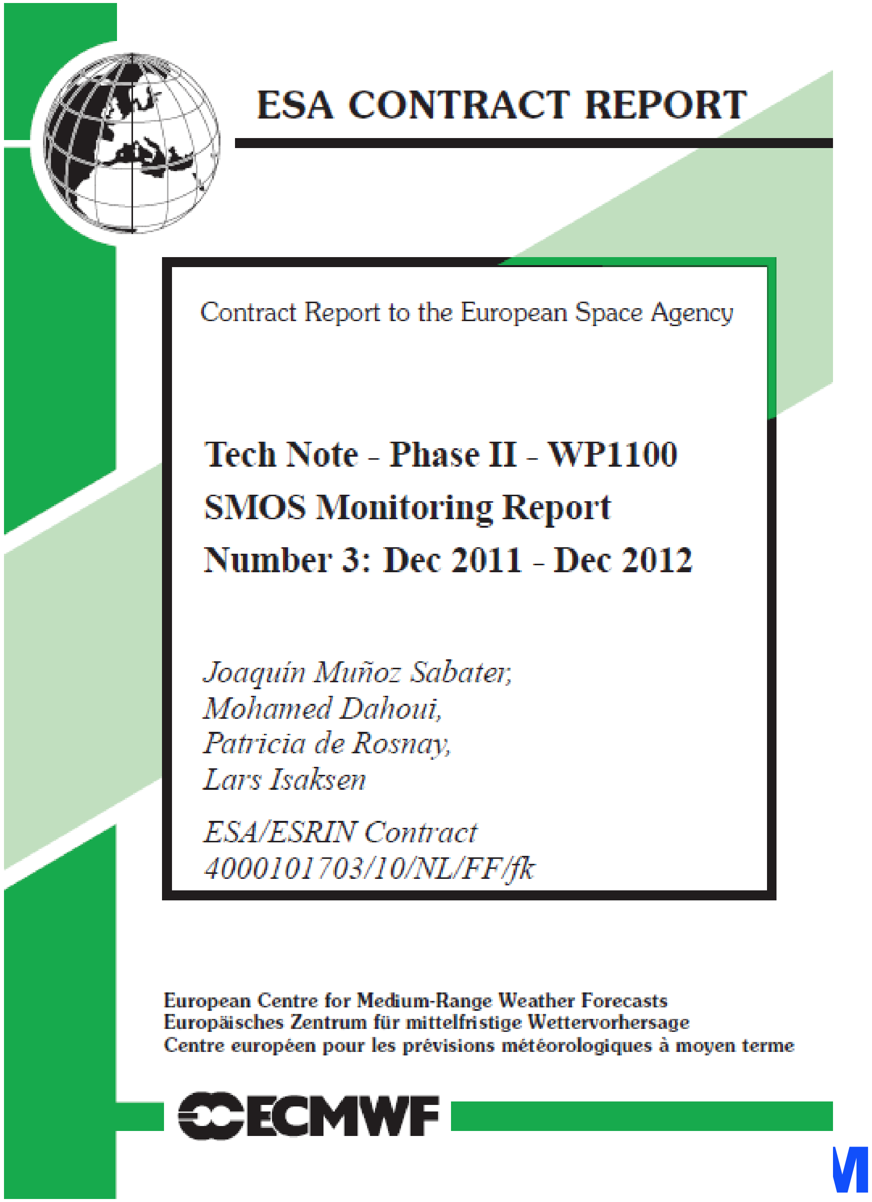
NH-YY polarisation

ECMWF

- Hovmoeller plots
- Period: Nov-2010
  Sept 2011
- std(fg departures)



Monitoring Report number 3



ESA CONTRACT REPORT

Contract Report to the European Space Agency

Tech Note - Phase II - WP1100
SMOS Monitoring Report
Number 3: Dec 2011 - Dec 2012

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
Centre européen pour les prévisions météorologiques à moyen terme

ECMWF

Full report at…

SMOS data assimilation study at ECMWF

- Technical implementation and experimentation,
- Jacobians and SEKF calibration,
- DA impact experiments (OSEs),
- SMOS-DA-v1.0

Assimilation of SMOS T_B study → current status

- Preparation activities for the assimilation:
  - Thinning scheme,
    - cy36r1: Pseudorandom thinning scheme,
    - cy36r4: Angular thinning scheme,
    - cy37r1: Flexible thinning scheme,
    - Other approaches explored,
    - cy38r1: Introduction of SMOS light product,
  - Noise filtering → angular binning in bins of up to 2 degrees reduces noise of observations in 2-3 K.
  - CMEM sensitivity to different parameterisations and CDF matching parameters,
- Implementation of SMOS data within the SEKF completed → lot of time devoted to technical work,
- "Technical" experiments,
- Jacobians calibration,
- DA impact experiments,
- Production of a Level-3 soil moisture product,
- Hot spot analysis

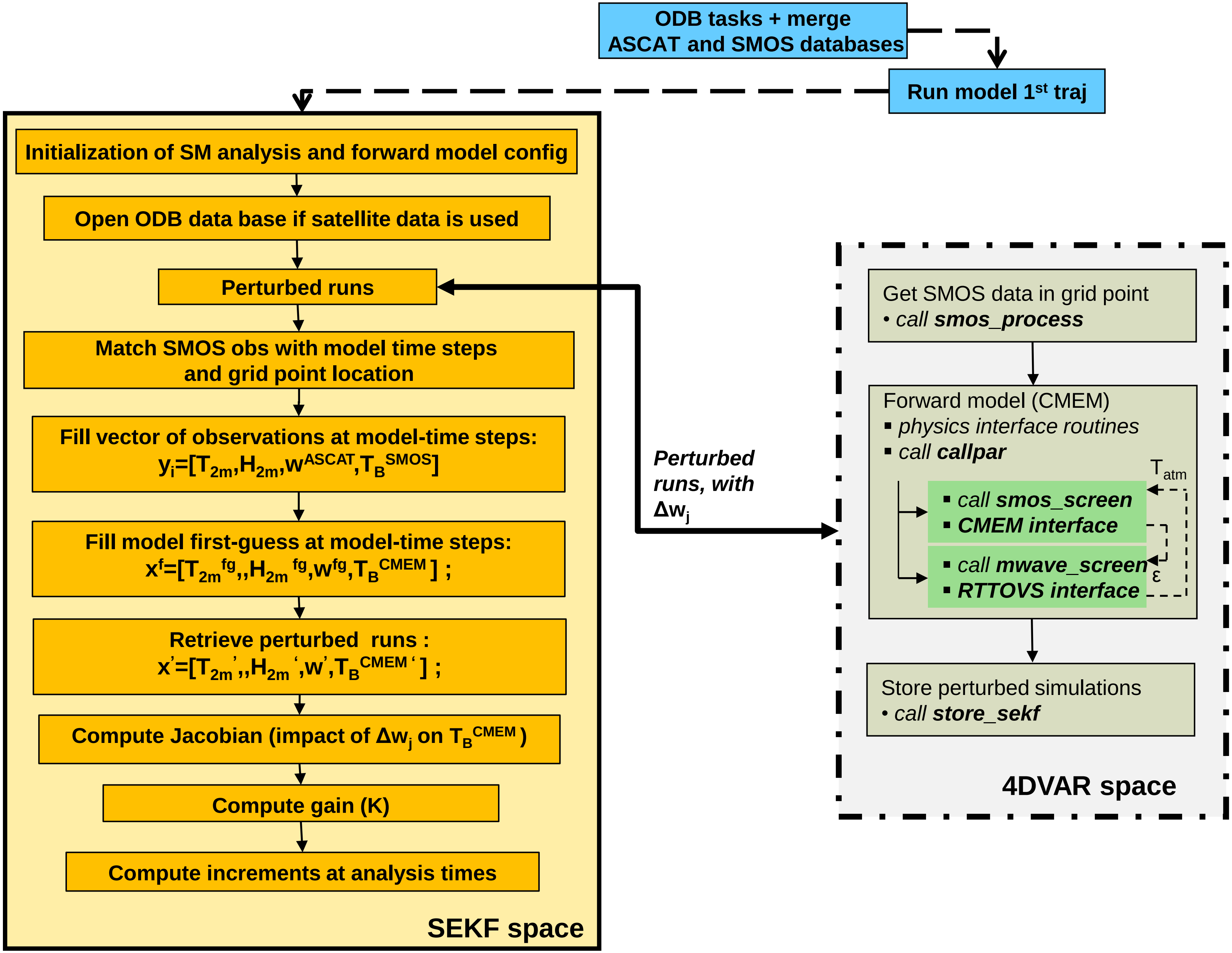
ECMWF

Implementation of SMOS data in the SEKF

▶ Objective:

- Develop structure necessary to accommodate SMOS data in the ECMWF version of the SEKF, and make it compatible with the monitoring suite and other data used for soil moisture analysis (remote sensed and screen level variables),

- This was a very technical task, which demonstrated to be also very challenging and more complex than expected,
- Most of the technical changes were explained in the previous progress meeting.
- Some part of the SEKF code were revised. Several changes were proposed:
  - Many 'active' observations were missing within the SEKF → The current operational SEKF for SM analysis is only active if SM>0.01 m^3m^{-3}. In this way a chess-like perturbation for perturbed runs avoids negative values of SM if the size of perturbation is larger than 0.01 m^3m^{-3} when SM <= 0.01 m^3m^{-3}. → Substitution of this condition by a land-sea mask condition (if LSM> 50% then is considered land).
  - The size of the perturbation should be strictly the same for all grid-points and equal to the value specified in a namelist. This was not strictly true for the current implementation, and some small differences were observed. In order to get the right size of the perturbation, the unperturbed and perturbed forecasted soil moisture for the first model time step is retrieved from the SEKF and the difference associated to the size of the perturbation.
  - Some improvement have permitted to quality control SMOS data with grib files.



ODB tasks + merge ASCAT and SMOS databases

Run model 1st traj

Initialization of SM analysis and forward model config

Open ODB data base if satellite data is used

Perturbed runs

Match SMOS obs with model time steps and grid point location

Fill vector of observations at model-time steps: $y_i=[T_{2m},H_{2m},w^{ASCAT},T_B^{SMOS}]$

Fill model first-guess at model-time steps: $x^f=[T_{2m}^{fg},,H_{2m}^{fg},w^{fg},T_B^{CMEM}]$;

Retrieve perturbed runs : $x'=[T_{2m}',,H_{2m}',w',T_B^{CMEM}{}']$;

Compute Jacobian (impact of Δw_j on T_B^{CMEM})

Compute gain (K)

Compute increments at analysis times

SEKF space

Perturbed runs, with Δw_j

Get SMOS data in grid point
- *call **smos_process***

Forward model (CMEM)
- *physics interface routines*
- *call **callpar***

- *call **smos_screen***
- ***CMEM interface***
- *call **mwave_screen***
- ***RTTOVS interface***

Store perturbed simulations
- *call **store_sekf***

4DVAR space

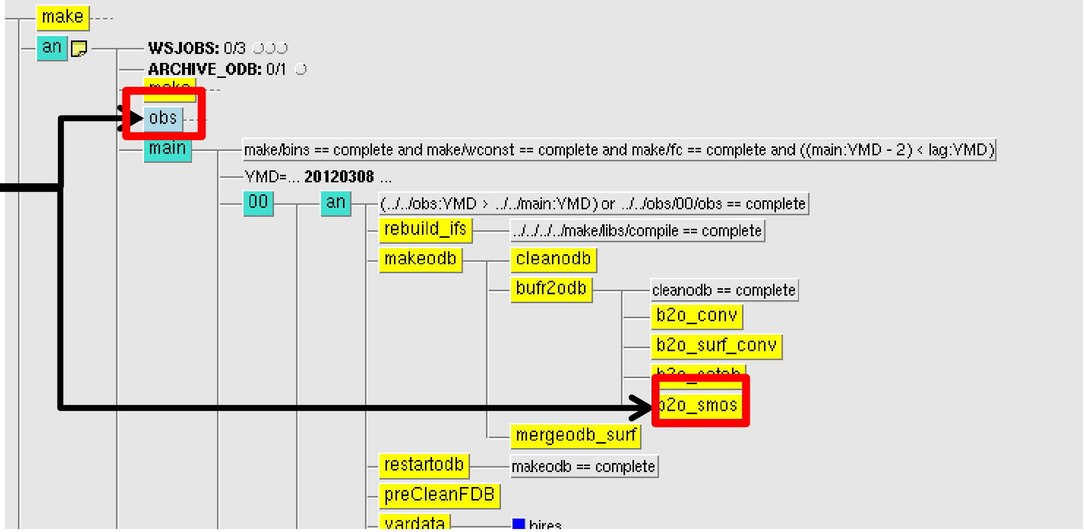
ECMWF

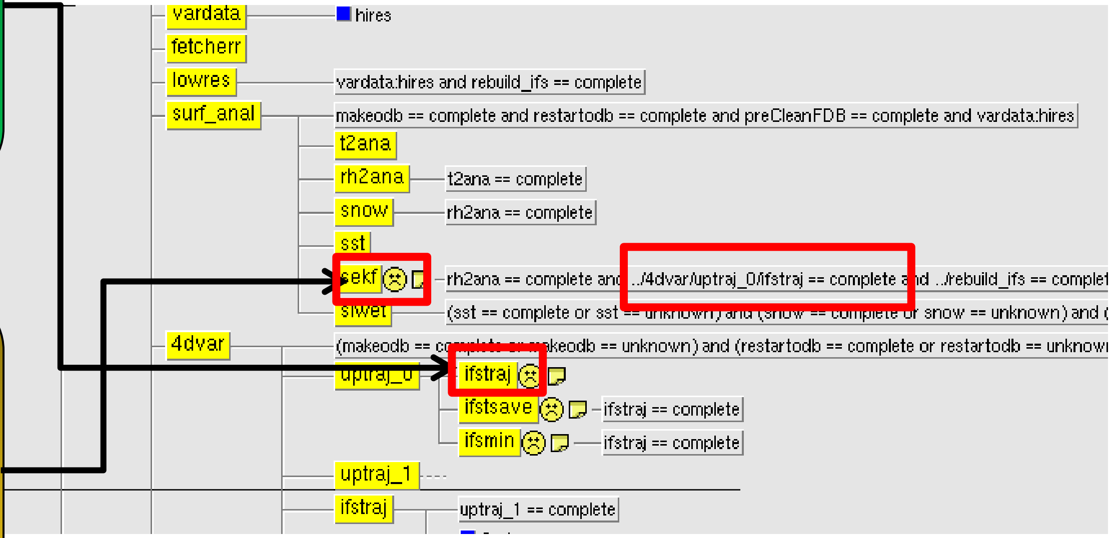
XCDP view of main SMOS tasks in the SEKF

BUFR & ODB spaces: quality checks, thinning, setup of SMOS monitoring and CMEM configuration, creation of internal database for SMOS, distribution of observations per processor and time slots, merging of remote sensing data in a single database for surface analysis, etc.

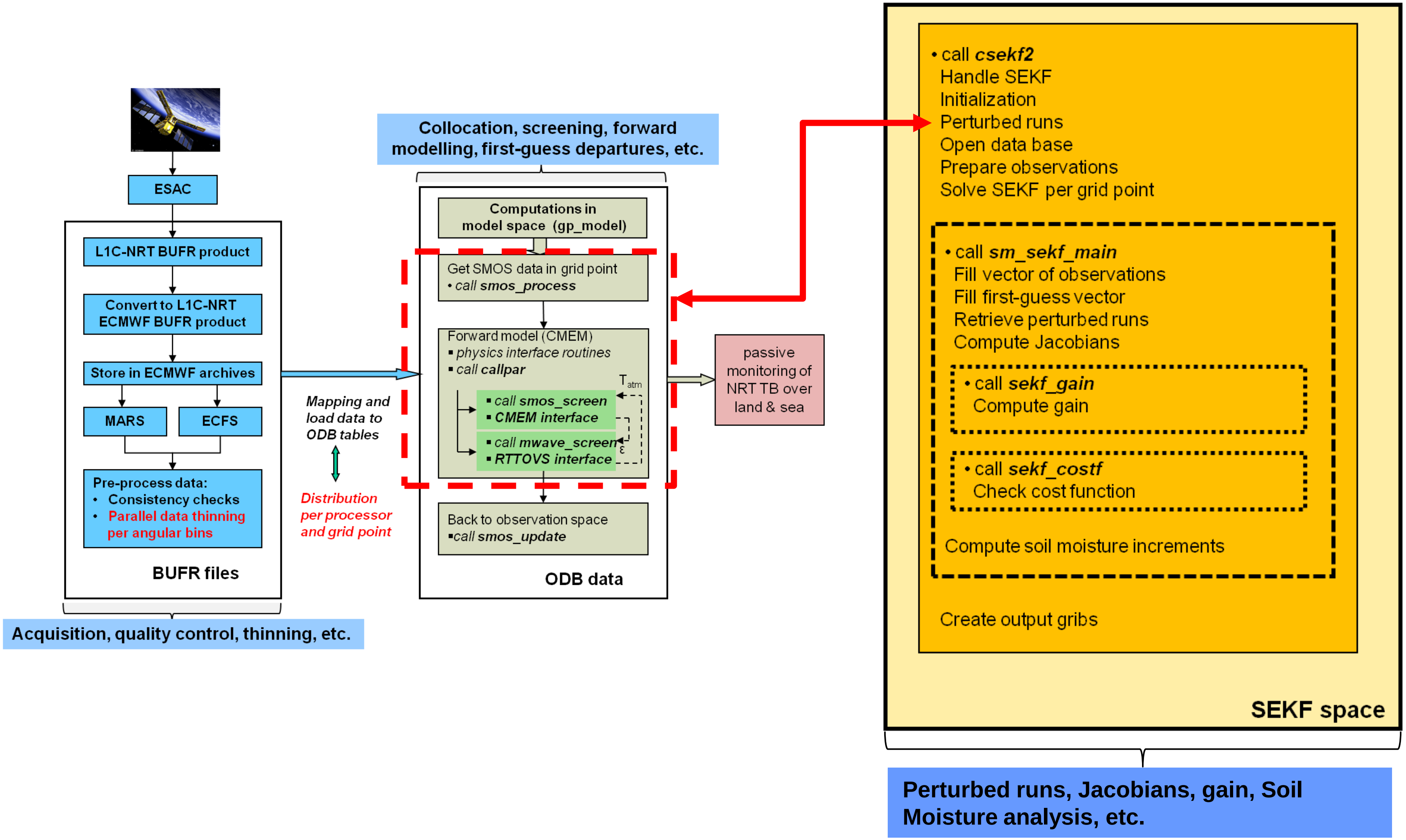
4DVAR space: collocation of observations with model grid, screening and flagging of each observation, forward model computation, feedback to ODB database, first-guess departures, monitoring statistics ,etc.

SEKF space: retrieval of observations to assimilate and matching with modelled equivalents for same model time step and location, perturbed runs and storing of perturbed T_B, innovation vector and soil moisture increment computation, etc.





Implementation of SMOS data in the IFS



ESAC

L1C-NRT BUFR product

Convert to L1C-NRT ECMWF BUFR product

Store in ECMWF archives

MARS

ECFS

Pre-process data:
- **Consistency checks**
- **Parallel data thinning per angular bins**

BUFR files

Acquisition, quality control, thinning, etc.

Mapping and load data to ODB tables

Distribution per processor and grid point

Collocation, screening, forward modelling, first-guess departures, etc.

Computations in model space (gp_model)

Get SMOS data in grid point
- *call **smos_process***

Forward model (CMEM)
- *physics interface routines*
- *call **callpar***

T_{atm}

- *call **smos_screen***
- ***CMEM interface***

- *call **mwave_screen***
- ***RTTOVS interface***

ε

Back to observation space
- *call **smos_update***

ODB data

passive monitoring of NRT TB over land & sea

- call ***csekf2***

Handle SEKF
Initialization
Perturbed runs
Open data base
Prepare observations
Solve SEKF per grid point

- call ***sm_sekf_main***

Fill vector of observations
Fill first-guess vector
Retrieve perturbed runs
Compute Jacobians

- call ***sekf_gain***

Compute gain

- call ***sekf_costf***

Check cost function

Compute soil moisture increments

Create output gribs

SEKF space

Perturbed runs, Jacobians, gain, Soil Moisture analysis, etc.

ECMWF

Implementation of SMOS data in the SEKF

▸ Main problems encountered in the implementation (not the only ones):

- Development of SMOS TB assimilation in SEKF was started in cy36r4. All routines were transferred to cy37s to use latest versions of IFS → Systematic failure of experiments and difficult to trace back.

- A new column had to be constructed in SMOS ODB, containing information of the model time step at which the observations belong. This is necessary for the Jacobian and model first-guess computation.

- Computation of observation time step in SEKF was not accurate and resulted in observations with a wrong model equivalent, often a missing value.

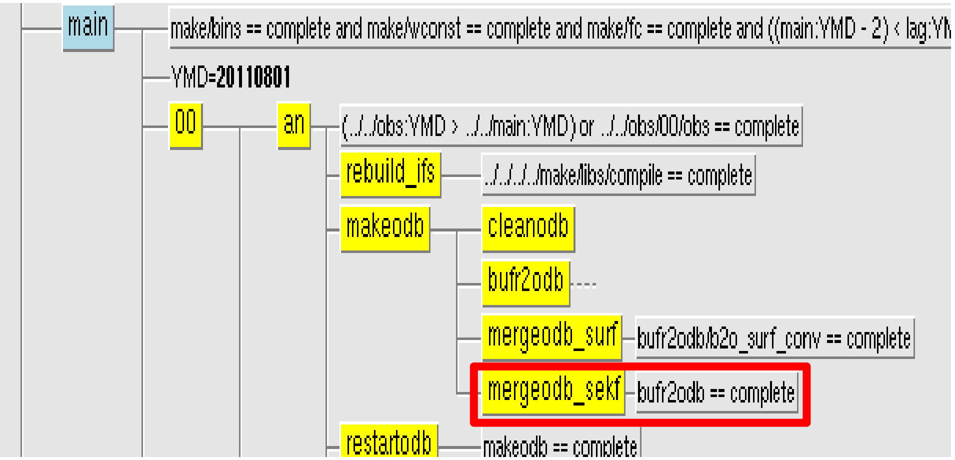
- A bug in the ODB software was found, which made the observations corresponding to the first model time step missing.

- Last but not least → previous tasks have involved lot of testing and debugging, which is slow and requires lot of expt (queue time, priorities, running time, etc.)

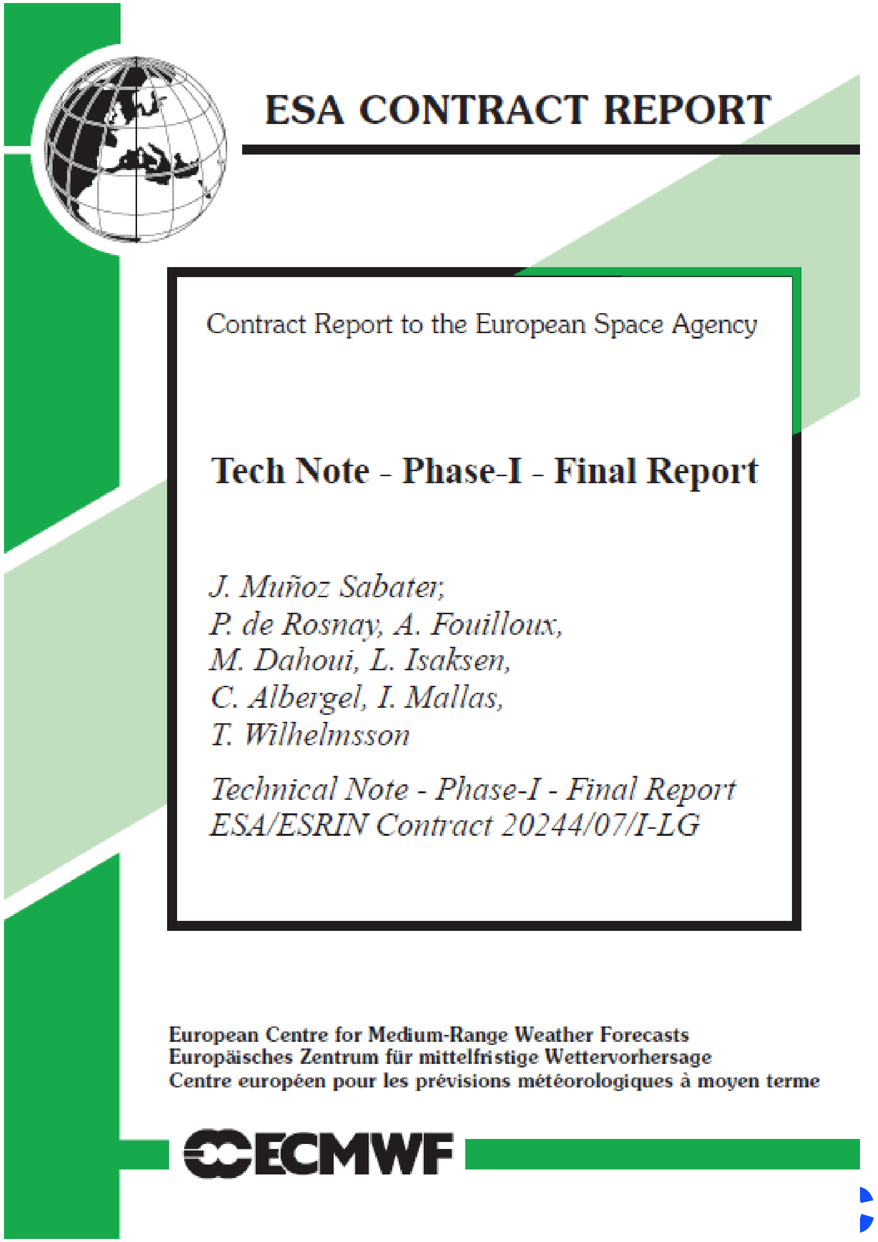
Implementation of SMOS data in the SEKF

What can I do now in the SEKF?

- All possible combinations of screen level variables and satellite data (ASCAT, SMOS) can now be assimilated for the analysis of soil moisture,
- A new surf_sekf database is created for remote sensing data for SM analysis (throughout symbolic links, so no more memory involved), implying opening (expensive) only once the observational database. → door is open to accommodate future satellite data sensitive to SM (SMAP).
- Configuration of SMOS data assimilation experiment (and monitoring) is user friendly → everything is controlled by an unique namelist, including the use of the SMOS light product.
- CMEM parameterisation can be controlled ‘on the fly’,



Final Report



ESA CONTRACT REPORT

Contract Report to the European Space Agency

Tech Note - Phase-I - Final Report

J. Muñoz Sabater,
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C. Albergel, I. Mallas,
T. Wilhelmsson

Technical Note - Phase-I - Final Report
ESA/ESRIN Contract 20244/07/I-LG

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

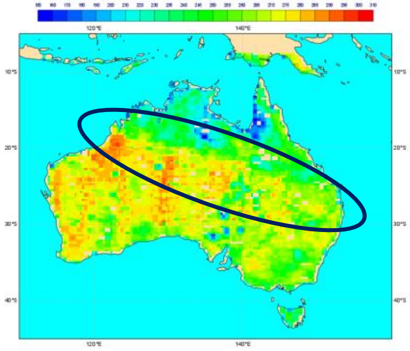
More at…

Experimentation in CY37R3 & CY38R1

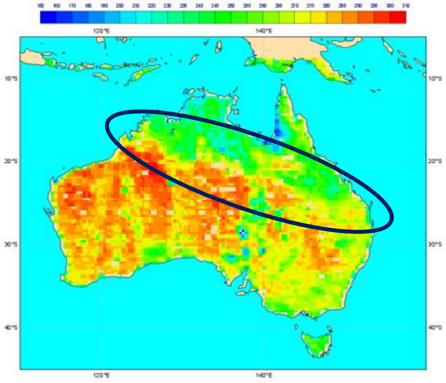
EXPT	PERIOD	DATA	REGION	BC	OBJECTIVE
A	4-10 Apr 2011	T^{2m},RH^{2m} (SYNP)	NA	-	Technical
B	4-10 Apr 2011	SYNP, T_B(40XX,40YY)	NA	T_B(bc)=T_B+avg(bias)	Technical
C	4-10 Apr 2011	SYNP	Australia	-	Technical
D	4-10 Apr 2011	SYNP, T_B(40XX,40YY)	Australia	T_B(bc)=T_B+avg(bias)	Technical
E	April 2011	SYNP	Australia	-	Technical + cal
F	April 2011	SYNP, T_B(40XX,40YY)	Australia	T_B(bc)=T_B+avg(bias)	Technical + cal
G	April 2011	SYNP, T_B(20XX,50XX)	Australia	T_B(bc)=T_B+avg(bias)	Technical + cal
H	July 2011	SYNP	NA and SA	-	DA- impact
I	July 2011	SYNP, T_B(20XX,50XX)	NA and SA	T_B(bc)=T_B+avg(bias)	Technical + cal
J	July 2011	SYNP, T_B(30-40-50-XX-YY)	NA and SA	T_B(bc)=T_B+avg(bias)	Test CONV
K	July 2011	SYNP, T_B(30-40-50-XX-YY)	NA and SA	T_B(bc)=T_B+avg(bias)	DA- impact
L	July 2011	SYNP, T_B(30-40-50-XX-YY)	NA and SA	CDF-matching	DA- impact
M	Feb 2011	SYNP	Australia	-	DA- impact
N	Feb 2011	SYNP, T_B(30-40-50-XX-YY)	Australia	T_B(bc)=T_B+avg(bias)	DA- impact
O	Feb 2011	SYNP, T_B(30-40-50-XX-YY)	Australia	CDF-matching	DA- impact
P	May10- Oct12	SYNP	Global	-	SMOS-DA-v1.0
Q	May10- Oct12	SYNP, T_B(30-40-50-XX-YY)	Global	CDF-matching	SMOS-DA-v1.0

Quality control for C and D – T_B average 1-3 April

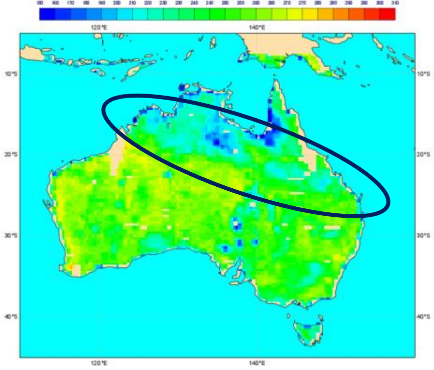
40XX



40YY



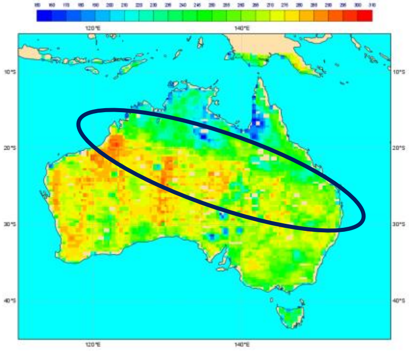
20XX



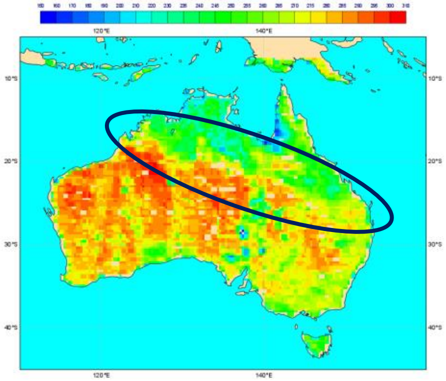
- Strange behaviour of T_B at all incidence angles and polarisations?

Quality control for C and D – T_B average 1-3 April

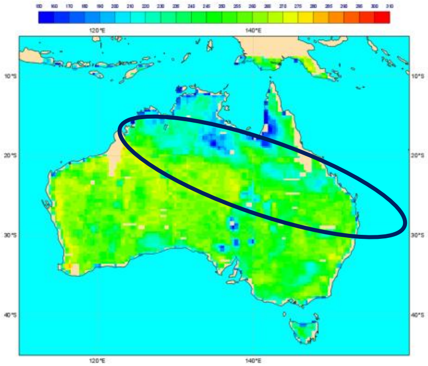
40XX



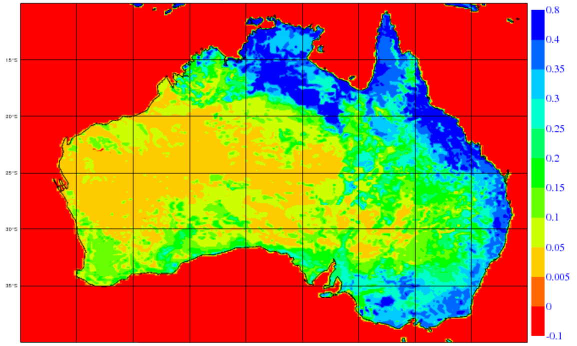
40YY



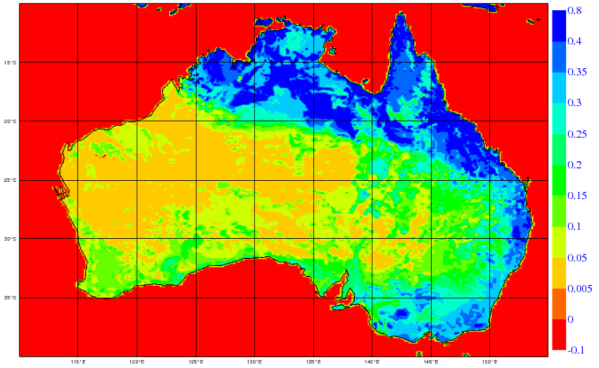
20XX



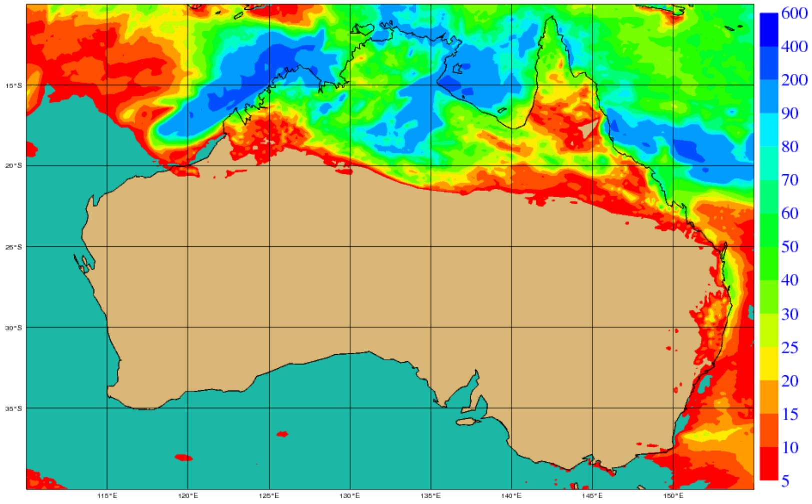
Soil Moisture (layer-1) in m3/m3 20110401 at 00UTC



Soil Moisture (layer-1) in m3/m3 20110403 at 00UTC



Total Precipitation in mm 20110401 at 00UTC, Step96

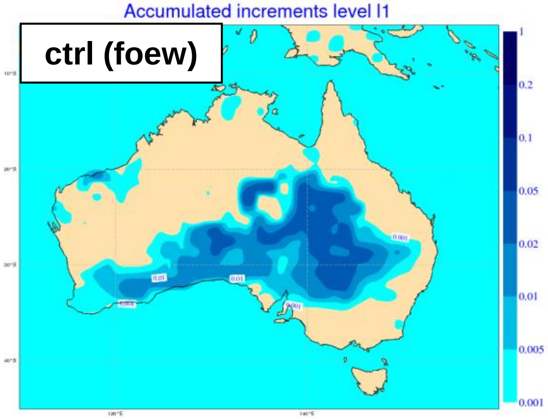


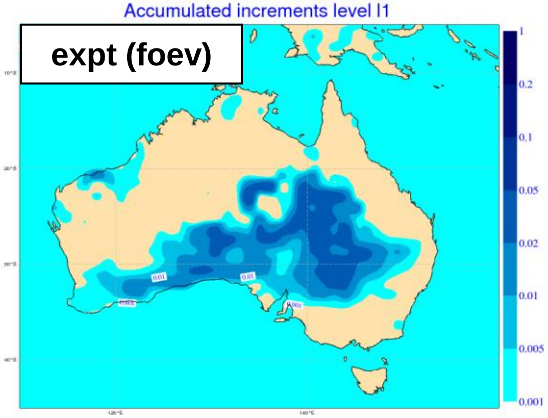
- Very good ability of SMOS to capture precipitation events.

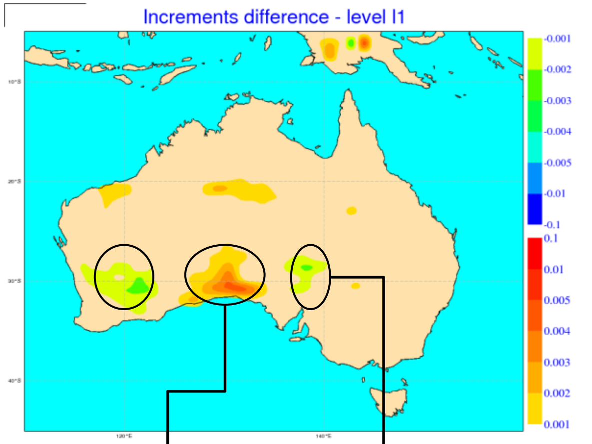
- Assimilation of SMOS T_B in the antenna reference frame, two preliminary case studies:
  - Period: 04 April 2011 00UTC – 10 April 2011 12UTC analysis, T159 (~125 km)
  - Observations: NRT brightness temperatures (standard product), 40 degrees ± ΔT_B=0.5 K, XX & YY polarisations,

CASE a) Australia (no RFI, soil water recharge period)
- **expt-foew**: assimilation T2m, RH2m (CTRL)
- **expt-foev**: assimilation T2m, RH2m, SMOS T_B

CASE b) North-America (start of drying period)
- **expt-foeu**: assimilation T2m, RH2m (CTRL)
- **expt-foeq**: assimilation T2m, RH2m, SMOS T_B

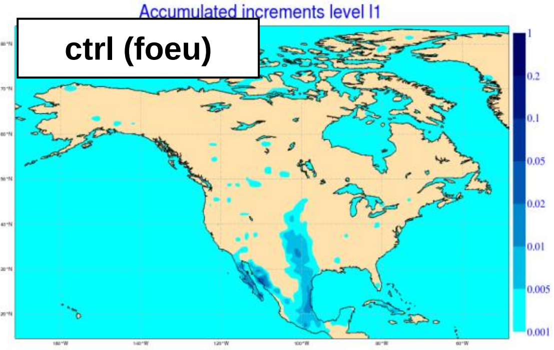


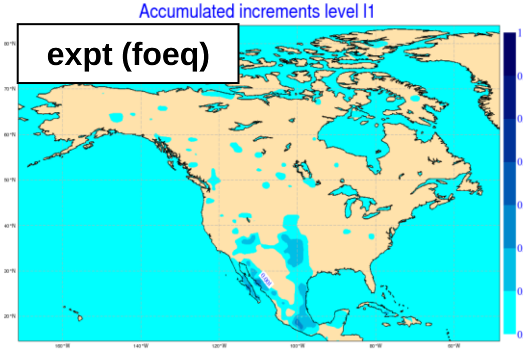


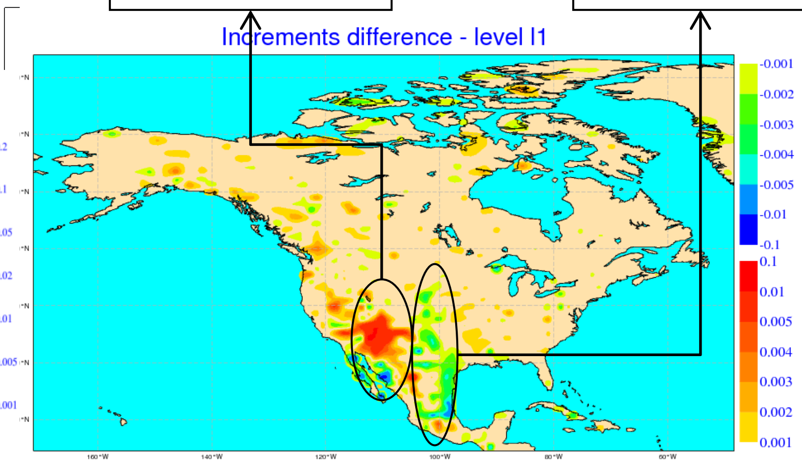


add water

remove water







SMOS data assimilation study at ECMWF

- Technical implementation and experimentation,
- Jacobians and SEKF calibration,
- DA impact experiments,
- SMOS-DA-v1.0

Calibration of Jacobians: perturbation size

- Jacobians computation:
  - Several experiments were launched for different sizes of the soil moisture perturbation of the three layers (in m^3m^{-3}): 0.0001, 0.0002, 0.0005, 0.001, 0.002, 0.005, 0.01, 0.02 and 0.05.
  - Same experiments with same perturbation size but with initial negative value and for a week in February (22-28 Feb 2012) and one in August (25-31 Aug 2011) → total 36-weeks experiments.
  - Resolution T159, snow and frozen soil masks based on forecast fields of snow depth and 2m temp were applied too.
  - Only six incidence angles were used (10, 20, 30, 40, 50, 60 ± 0.5).
  - No RFI or FOV filtering was processed, as it is only the model who intervenes here.
  - Jacobians were bounded between [-10000, 10000] to avoid extreme and unrealistic sensitivity. This value was chosen add-hoc but large enough to also investigate where too unrealistic large sensitivities take place.

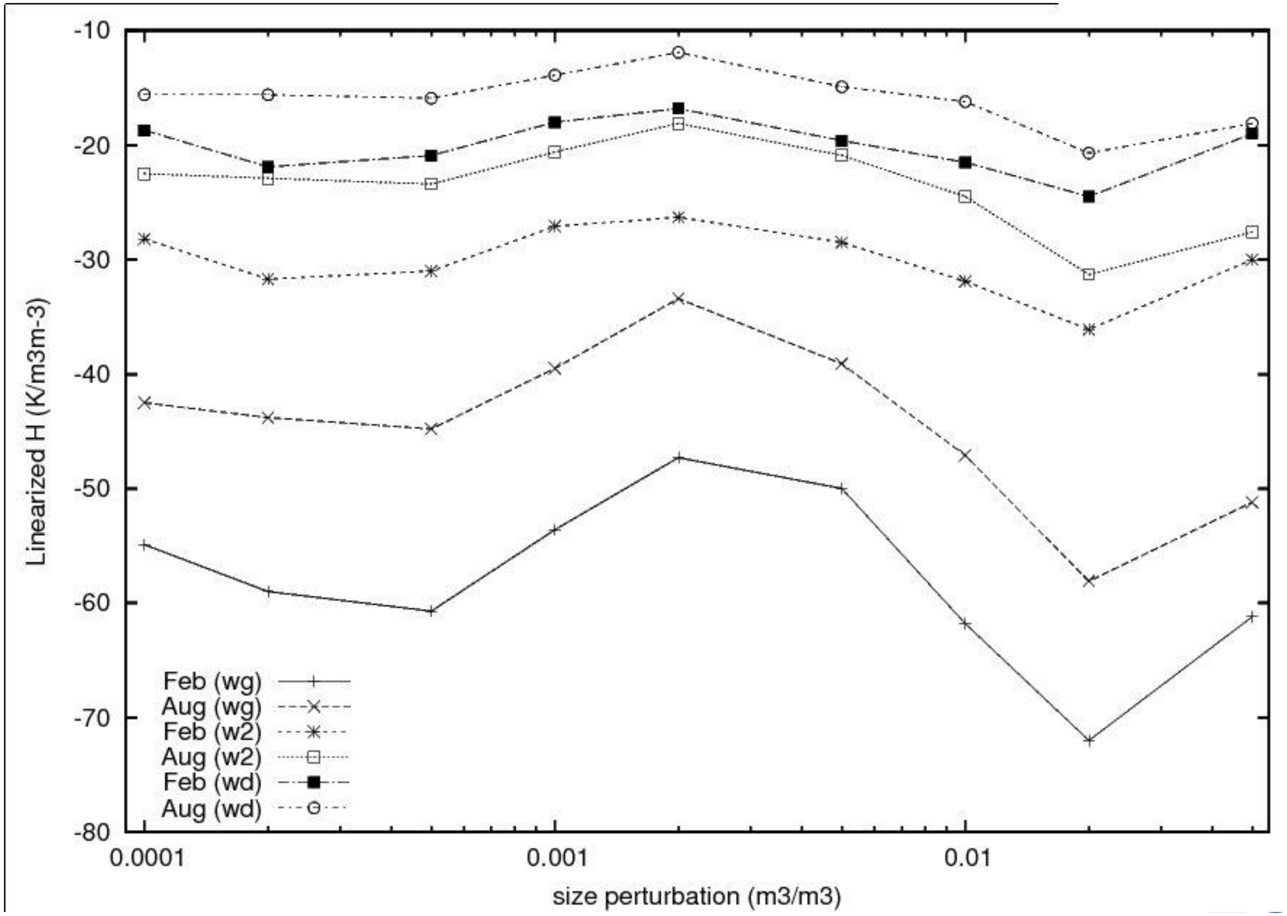
Calibration of Jacobians: perturbation size

- Jacobians computation at saturation/near saturation level:
  - In case SM is at saturation level, then a positive perturbation will result in perturbed SM at the same level that the non-perturbed, as SM cannot be higher than saturation. The exceeding water will run off. Therefore there won't be any sensitivity in the Jacobians, which will be zero (this is hardcoded).
  - However, if the non-perturbed value of SM is very close to saturation (but not at saturation point), then the perturbed SM will be at saturation point (with enough perturbation size). In practice this might mean study the sensitivity to very tiny perturbations of SM, and therefore a likely much weaker sensitivity (or unrealistic numerical high sensitivity).
  - The previous bulleted points happened in quite a non-negligible number of pixels if the perturbed variable is the surface SM, while is lower for the root-zone SM and it never happened for the third layer.

Jacobians as a function of positive perturbation size

- Jacobians computation (through histo_accmulatd.sh): computed as an averaged value per soil level,

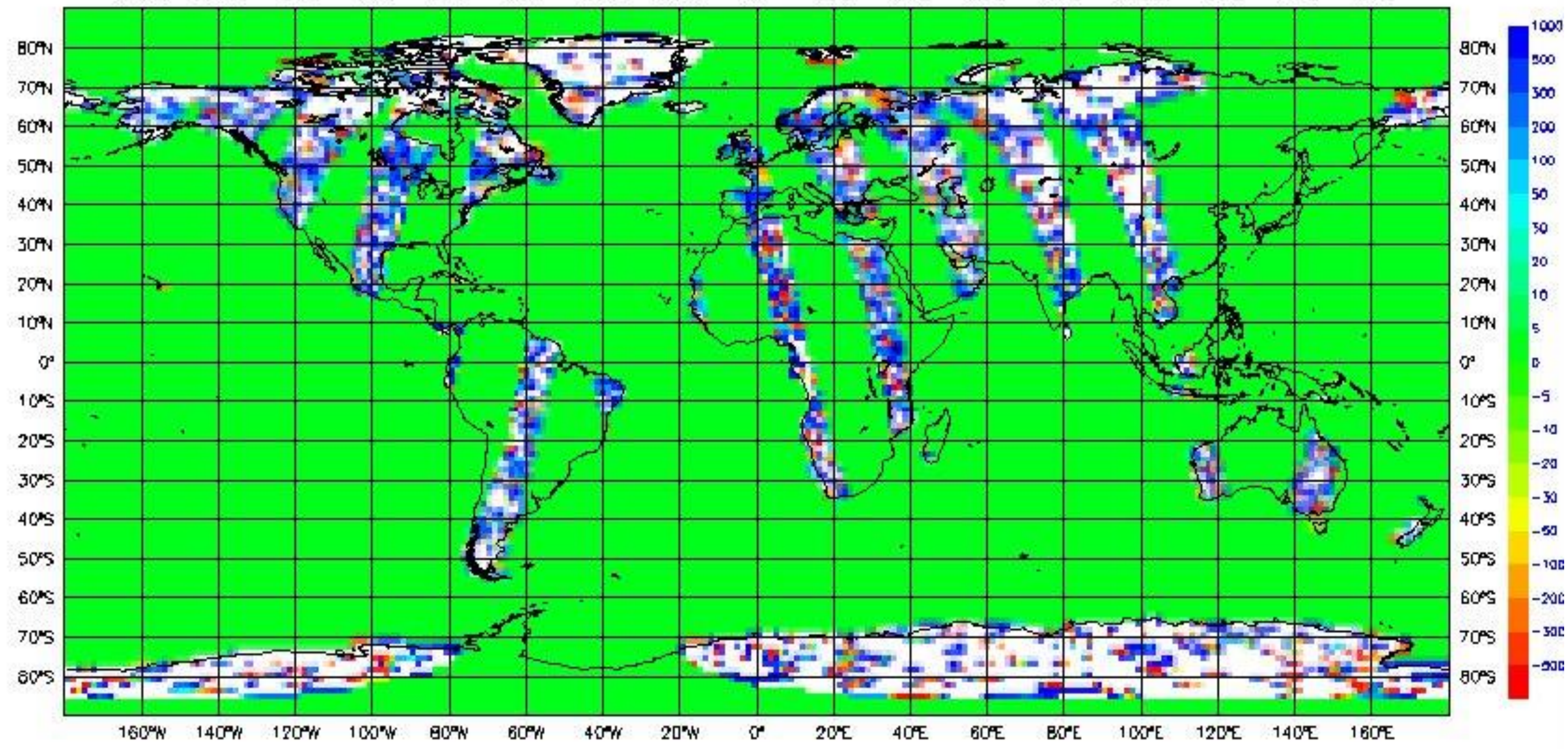
- This figure shows the Jacobian average per one week in February and August. It shows that largest sensitivity is for the top level and the lowest for the deepest level, as it should be. However it seems it depends on the perturbation size, with no clear trend. February shows larger sensitivities than August.



Jacobians in IFS

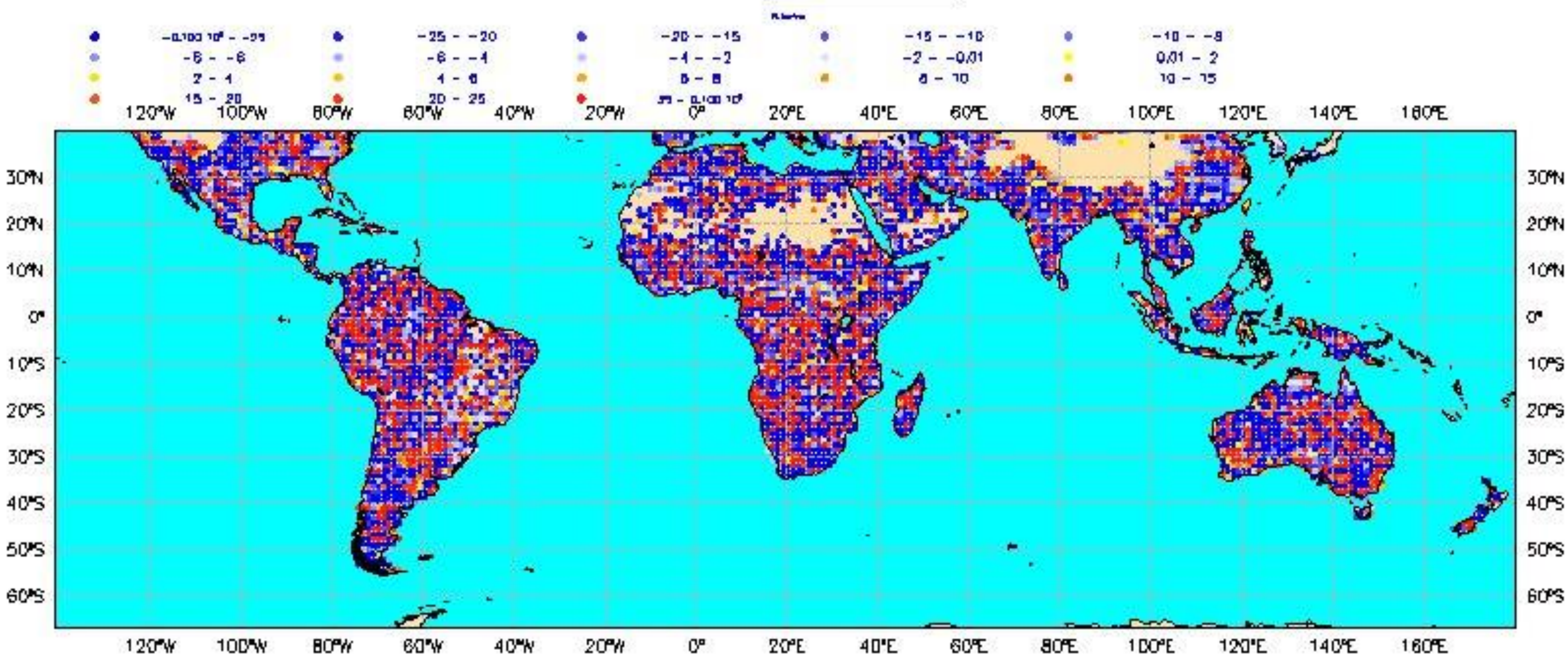
- Histograms of Jacobian values looked very noised, there is no structure at all!
- Many very large values are found.

Jacobians at θ=40 and XX pol, first soil level, 2012022200 cycle, $\Delta w=0.01\ m^3/m^3$



Jacobians in IFS

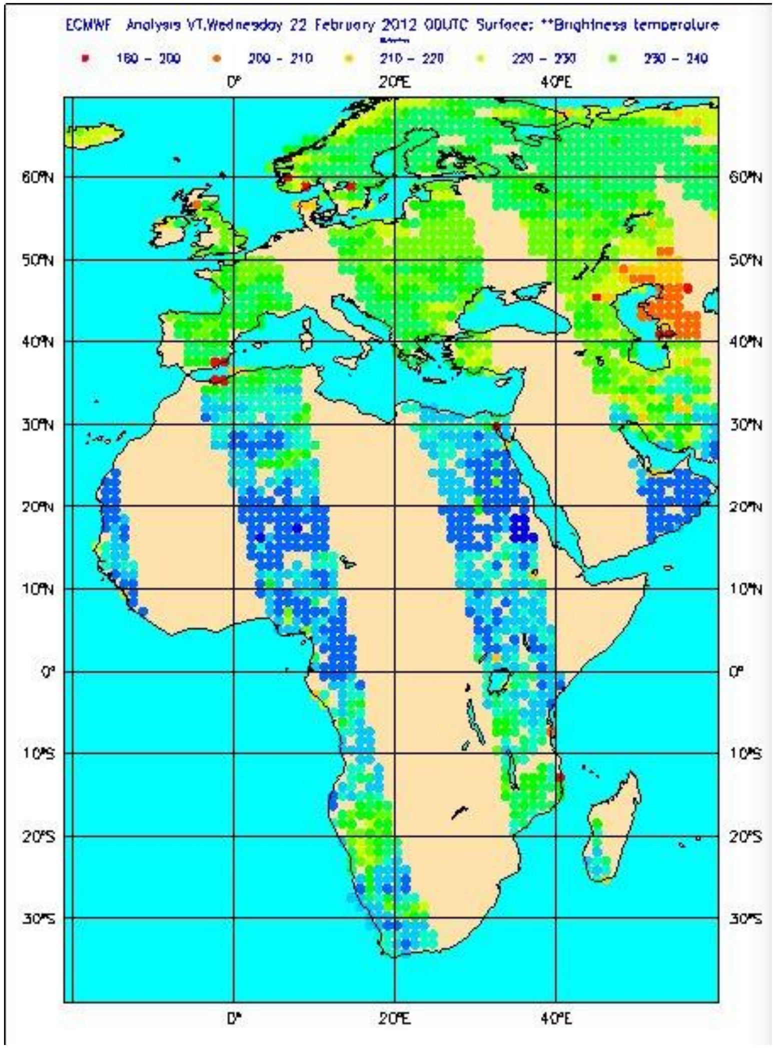
Jacobians at θ=40 and XX pol, first soil level, averaged over 20120222-20120228, $\Delta w=0.01 m^3/m^3$



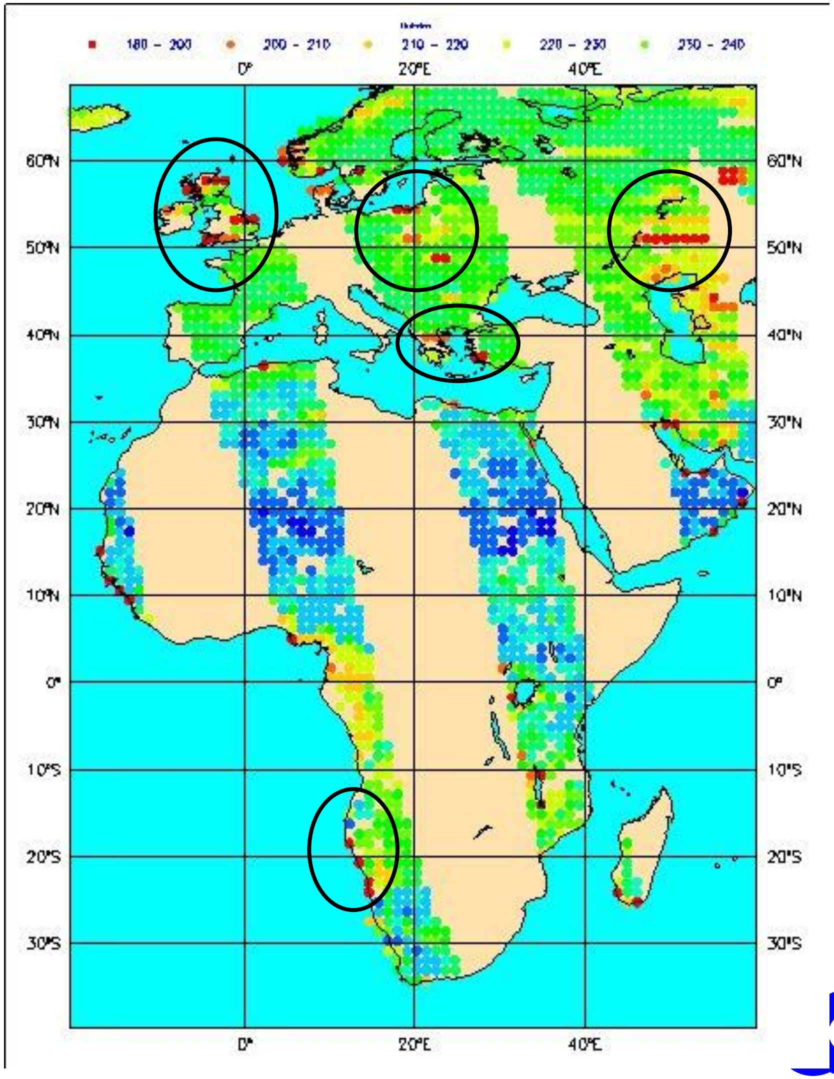
Very noisy, with some exceptions lacking of any structure !!!

Jacobians computation

Modelled T_B θ=50 and XX pol, 2012022200 (offline CMEM v4.1)

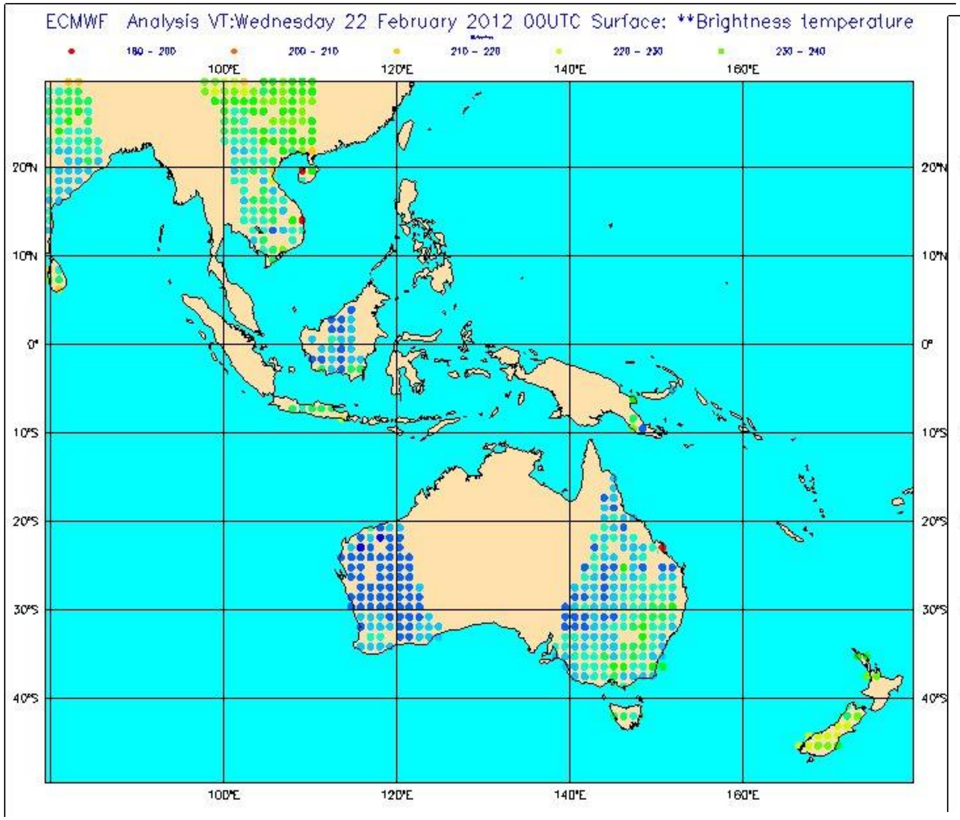


Modelled T_B θ=50 and XX pol, 2012022200 (CMEM IFS v4.1)

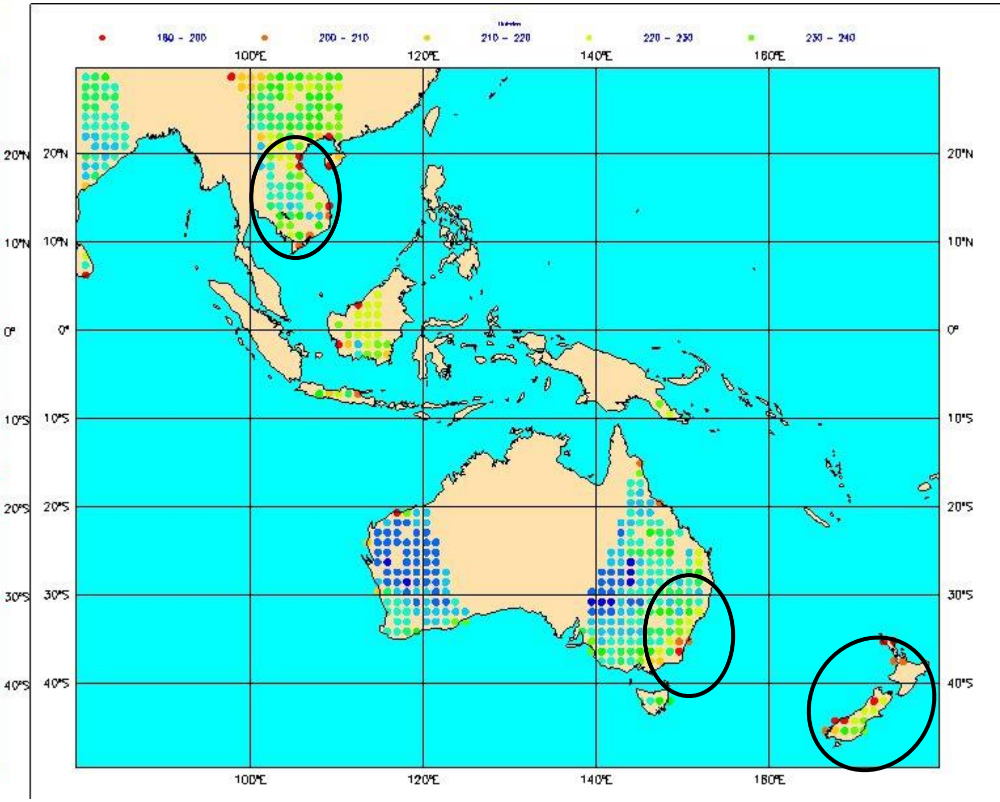


Jacobians computation

Modelled T_B $\theta=50$ and XX pol, 2012022200 (offline CMEM v4.1)



Modelled T_B $\theta=50$ and XX pol, 2012022200 (CMEM IFS v4.1)



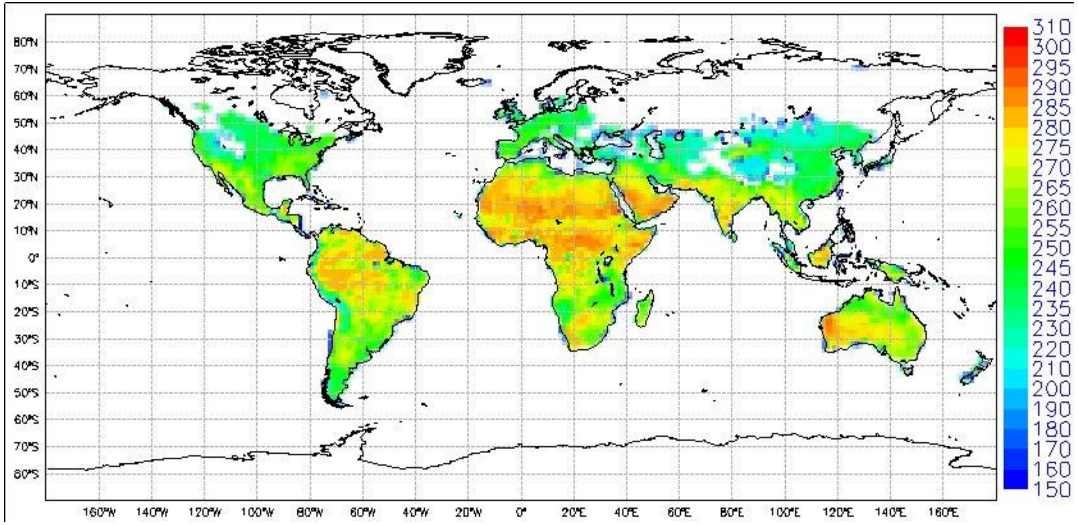
Origin of the problem

➢ Why for certain grid-points strong differences were found with the offline version? Although the general patterns of the perturbed runs of simulated T_B looked fine, many points produced unrealistic sensitivities to small perturbations of soil moisture. The consequence is that the jacobians were too noisy, with strong disagreements with the offline version of CMEM.

- The variable producing the error was the incidence angle of the observations →declared in a global module as in the offline version, and then shared between different grid points (one for each OPEN-MP process) belonging to the same MPI-task.
- Hence, grid-points for which the modelled T_B is very sensitive to the incidence angle (depending on the soil conditions), had differences between the non and perturbed runs of more than 20K for tiny perturbations! (for example if the non-perturbed run uses 10 degrees and the perturbed 50 degrees)
- Running twice the same experiment produced different results!!
- The **bug fix** consists at removing the incidence angle as a constant variable in the module of constant parameters of CMEM and integrate it as a field within the CMEM structure of fields, thus declaring it local for each OPEN-MP processor and not sharing this information with other processors.

Modelled T_B (CMEM v4.1 - θ=40, average [2012022200-2012022800])

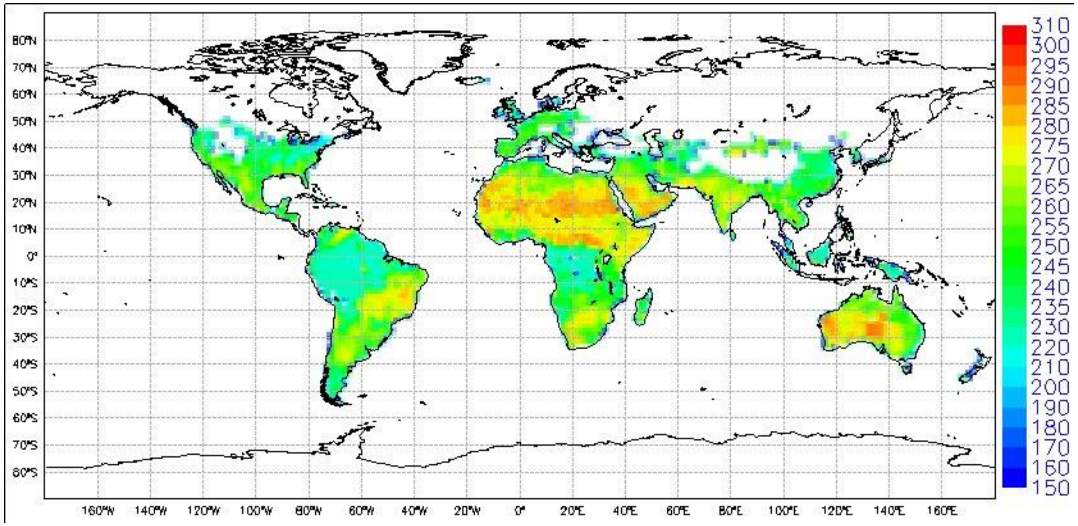
Offline CMEM - XX pol



Offline CMEM

- Run for 00UTC and 12UTC,
- Forced with operational analysis fields,
- Every run global coverage,
- Average is over 7x2 values per grid point if there isn't snow according to analysed snow cover field.

IFS CMEM - XX pol



CMEM in IFS

- SMOS TBs are assimilated with no control over quality of analysis,
- Analysis increments feedback next cycle,
- For a given day, only if SMOS overpasses this grid-point, a value is available.

Perturbed modelled T_B (CMEM v4.1 - θ=40, 2012022200-2012022800)

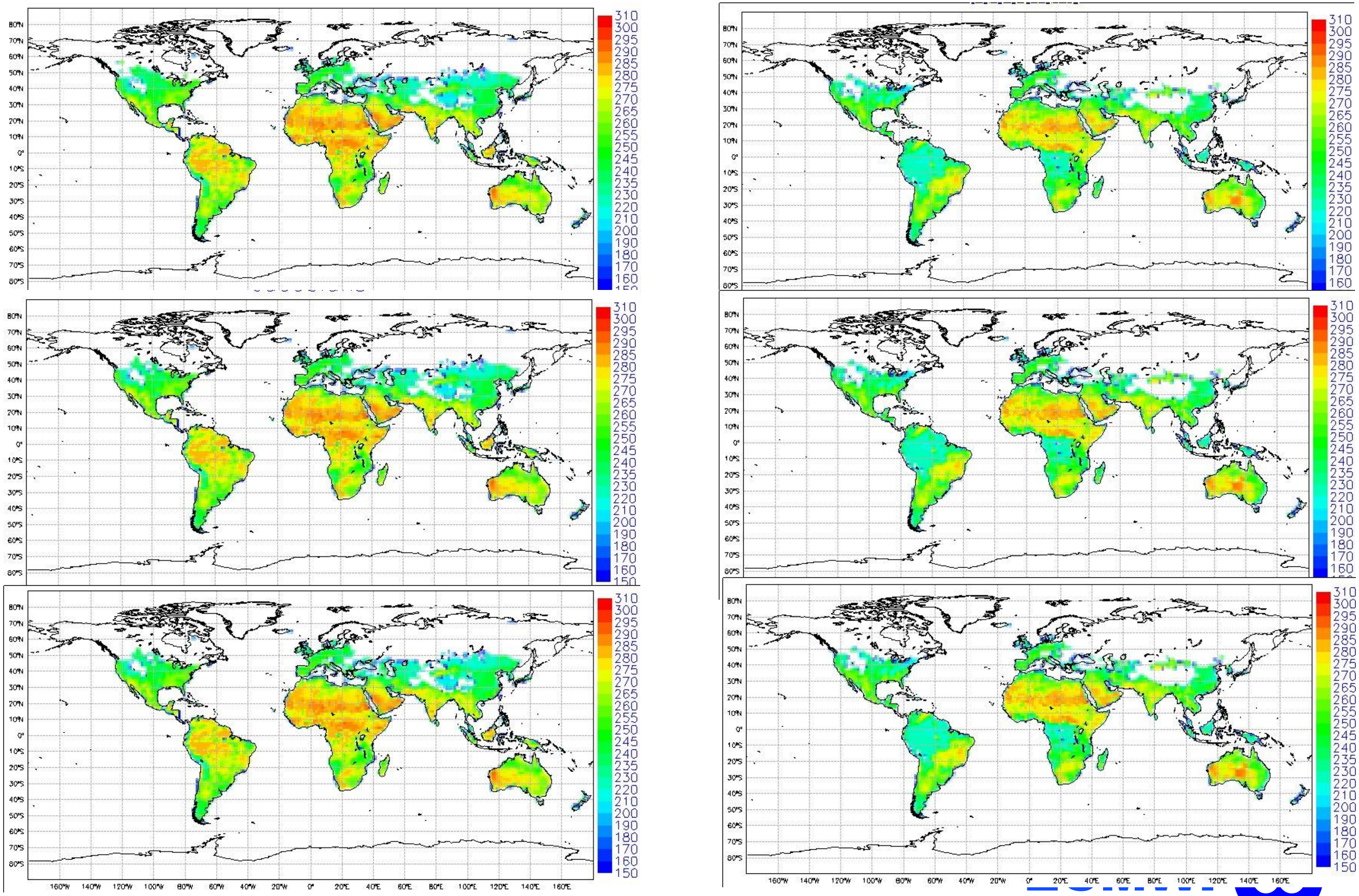
Offline CMEM - XX pol

IFS CMEM - XX pol

Layer 1
Δw=0.01 m³/m³

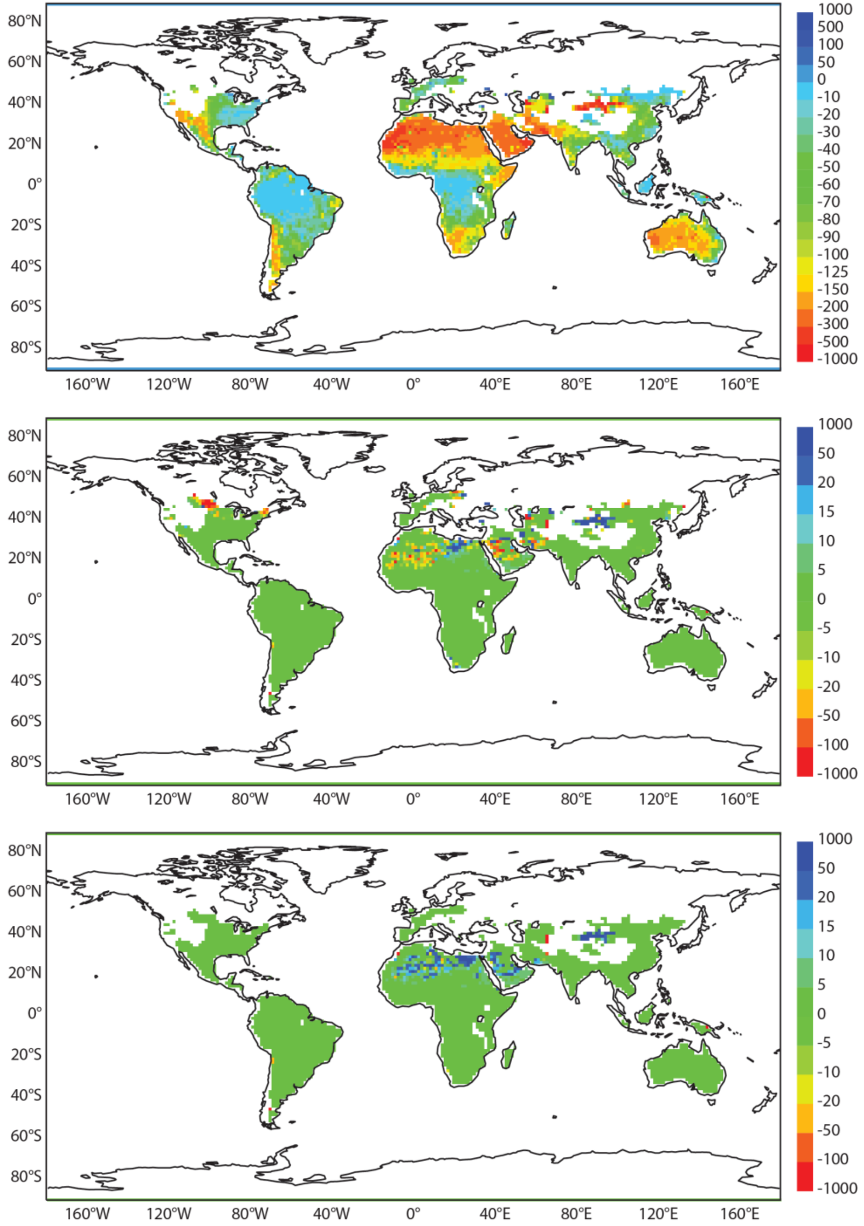
Layer 2
Δw=0.01 m³/m³

Layer 3
Δw=0.01 m³/m³

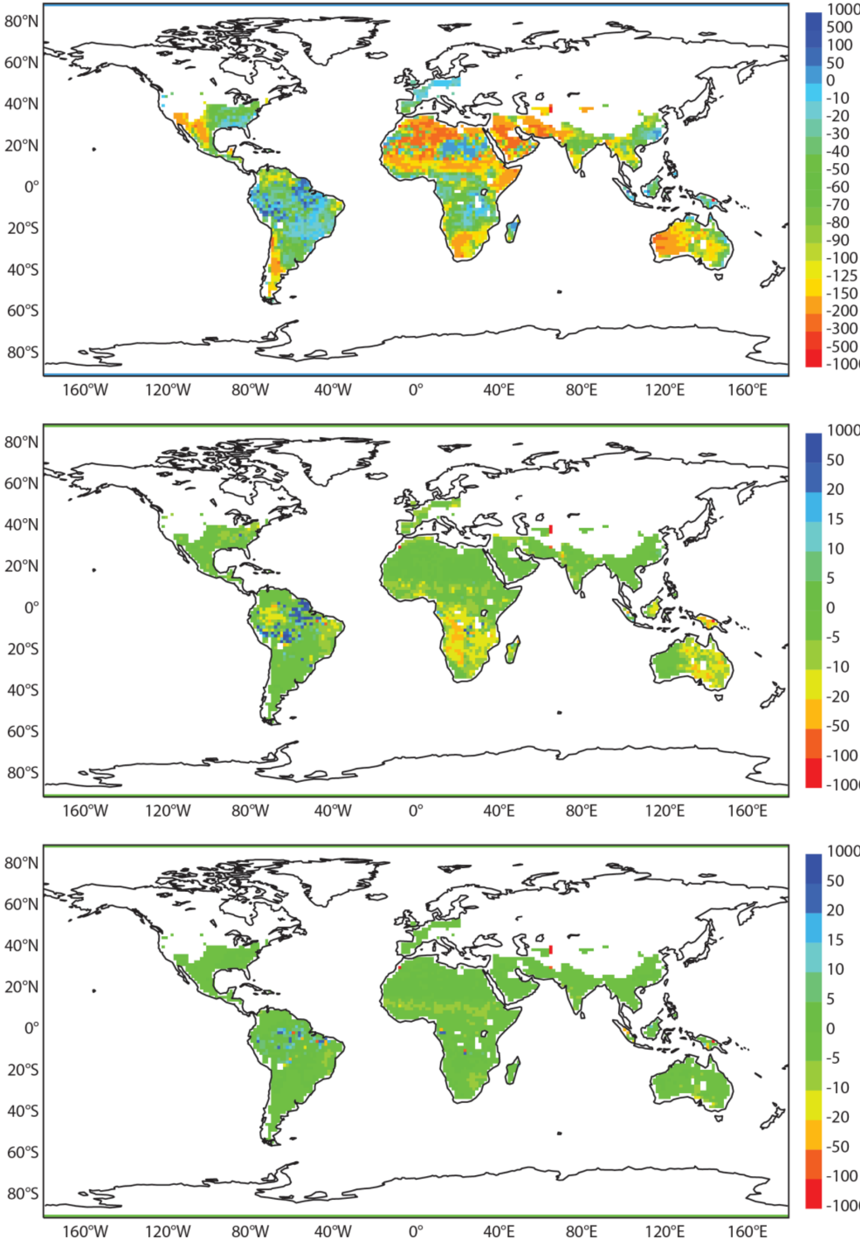


Jacobians (CMEM v4.1 - θ=40, 2012022200-2012022800, Δw=0.01 m^3/m^3)

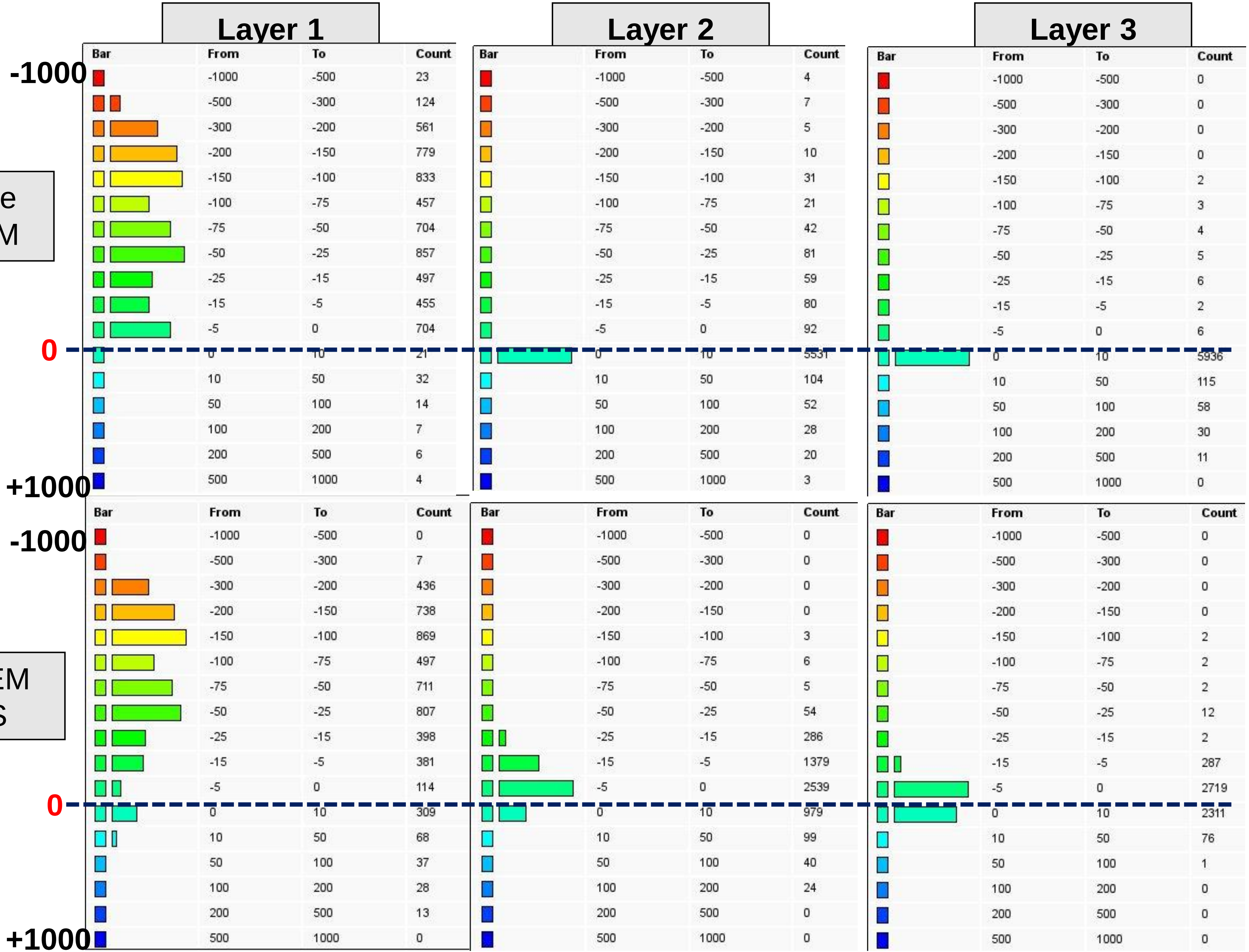
offline CMEM – XX pol



IFS CMEM – XX pol



Histograms of averaged jacobians 2012022200-2012022812 ($\Delta w=0.01\ m^3/m^3$ - $\theta=40$, XX pol)



Layer 1 | Layer 2 | Layer 3

Offline CMEM

Layer 1

Bar	From	To	Count
🟥	-1000	-500	23
🟧	-500	-300	124
🟧	-300	-200	561
🟧	-200	-150	779
🟨	-150	-100	833
🟩	-100	-75	457
🟩	-75	-50	704
🟩	-50	-25	857
🟩	-25	-15	497
🟩	-15	-5	455
🟩	-5	0	704
🟩	0	10	21
🟦	10	50	32
🟦	50	100	14
🟦	100	200	7
🟦	200	500	6
🟦	500	1000	4

Layer 2

Bar	From	To	Count
🟥	-1000	-500	4
🟧	-500	-300	7
🟧	-300	-200	5
🟧	-200	-150	10
🟨	-150	-100	31
🟩	-100	-75	21
🟩	-75	-50	42
🟩	-50	-25	81
🟩	-25	-15	59
🟩	-15	-5	80
🟩	-5	0	92
🟩	0	10	5531
🟦	10	50	104
🟦	50	100	52
🟦	100	200	28
🟦	200	500	20
🟦	500	1000	3

Layer 3

Bar	From	To	Count
🟥	-1000	-500	0
🟧	-500	-300	0
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	2
🟩	-100	-75	3
🟩	-75	-50	4
🟩	-50	-25	5
🟩	-25	-15	6
🟩	-15	-5	2
🟩	-5	0	6
🟩	0	10	5936
🟦	10	50	115
🟦	50	100	58
🟦	100	200	30
🟦	200	500	11
🟦	500	1000	0

CMEM IFS

Layer 1

Bar	From	To	Count
🟥	-1000	-500	0
🟧	-500	-300	7
🟧	-300	-200	436
🟧	-200	-150	738
🟨	-150	-100	869
🟩	-100	-75	497
🟩	-75	-50	711
🟩	-50	-25	807
🟩	-25	-15	398
🟩	-15	-5	381
🟩	-5	0	114
🟩	0	10	309
🟦	10	50	68
🟦	50	100	37
🟦	100	200	28
🟦	200	500	13
🟦	500	1000	0

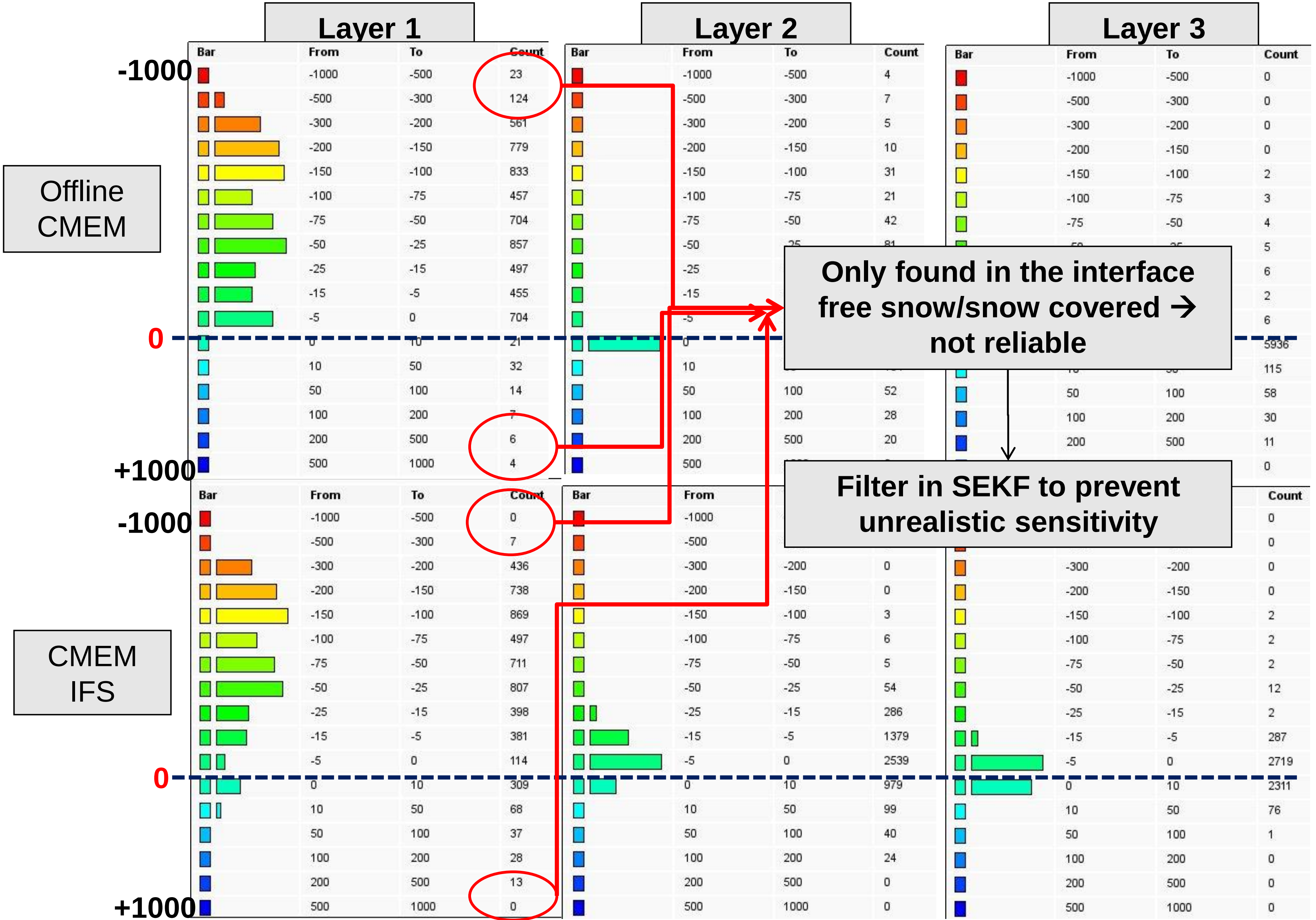
Layer 2

Bar	From	To	Count
🟥	-1000	-500	0
🟧	-500	-300	0
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	3
🟩	-100	-75	6
🟩	-75	-50	5
🟩	-50	-25	54
🟩	-25	-15	286
🟩	-15	-5	1379
🟩	-5	0	2539
🟩	0	10	979
🟦	10	50	99
🟦	50	100	40
🟦	100	200	24
🟦	200	500	0
🟦	500	1000	0

Layer 3

Bar	From	To	Count
🟥	-1000	-500	0
🟧	-500	-300	0
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	2
🟩	-100	-75	2
🟩	-75	-50	2
🟩	-50	-25	12
🟩	-25	-15	2
🟩	-15	-5	287
🟩	-5	0	2719
🟩	0	10	2311
🟦	10	50	76
🟦	50	100	1
🟦	100	200	0
🟦	200	500	0
🟦	500	1000	0

Histograms of averaged jacobians 2012022200-2012022812 (Δw=0.01 m³/m³ - θ=40, XX pol)



Only found in the interface free snow/snow covered → not reliable

Filter in SEKF to prevent unrealistic sensitivity

Offline CMEM

Layer 1

Bar	From	To	Count
🟥	-1000	-500	23
🟥	-500	-300	124
🟧	-300	-200	561
🟧	-200	-150	779
🟨	-150	-100	833
🟩	-100	-75	457
🟩	-75	-50	704
🟩	-50	-25	857
🟩	-25	-15	497
🟩	-15	-5	455
🟩	-5	0	704
🟦	0	10	21
🟦	10	50	32
🟦	50	100	14
🟦	100	200	7
🟦	200	500	6
🟦	500	1000	4

Layer 2

Bar	From	To	Count
🟥	-1000	-500	4
🟥	-500	-300	7
🟧	-300	-200	5
🟧	-200	-150	10
🟨	-150	-100	31
🟩	-100	-75	21
🟩	-75	-50	42
🟩	-50	-25	81
🟩	-25		
🟩	-15		
🟩	-5		
🟦	0		
🟦	10		
🟦	50	100	52
🟦	100	200	28
🟦	200	500	20
🟦	500		

Layer 3

Bar	From	To	Count
🟥	-1000	-500	0
🟥	-500	-300	0
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	2
🟩	-100	-75	3
🟩	-75	-50	4
🟩			5
			6
			2
			6
			5936
🟦			115
🟦	50	100	58
🟦	100	200	30
🟦	200	500	11
			0

CMEM IFS

Layer 1

Bar	From	To	Count
🟥	-1000	-500	0
🟥	-500	-300	7
🟧	-300	-200	436
🟧	-200	-150	738
🟨	-150	-100	869
🟩	-100	-75	497
🟩	-75	-50	711
🟩	-50	-25	807
🟩	-25	-15	398
🟩	-15	-5	381
🟩	-5	0	114
🟦	0	10	309
🟦	10	50	68
🟦	50	100	37
🟦	100	200	28
🟦	200	500	13
🟦	500	1000	0

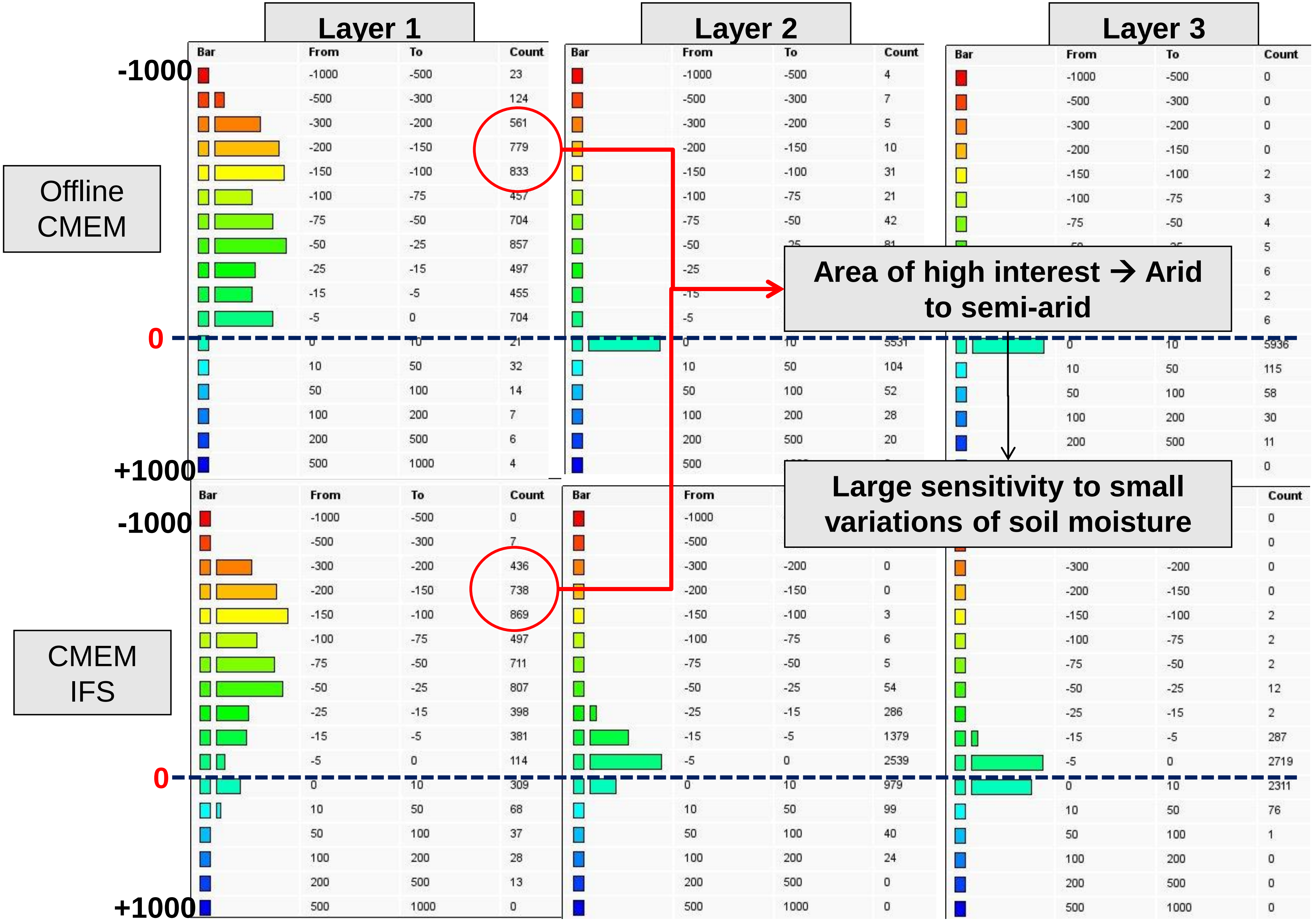
Layer 2

Bar	From	To	Count
🟥	-1000		
🟥	-500		
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	3
🟩	-100	-75	6
🟩	-75	-50	5
🟩	-50	-25	54
🟩	-25	-15	286
🟩	-15	-5	1379
🟩	-5	0	2539
🟦	0	10	979
🟦	10	50	99
🟦	50	100	40
🟦	100	200	24
🟦	200	500	0
🟦	500	1000	0

Layer 3

Bar	From	To	Count
			0
🟥			0
🟧	-300	-200	0
🟧	-200	-150	0
🟨	-150	-100	2
🟩	-100	-75	2
🟩	-75	-50	2
🟩	-50	-25	12
🟩	-25	-15	2
🟩	-15	-5	287
🟩	-5	0	2719
🟦	0	10	2311
🟦	10	50	76
🟦	50	100	1
🟦	100	200	0
🟦	200	500	0
🟦	500	1000	0

Histograms of averaged jacobians 2012022200-2012022812 (Δw=0.01 m³/m³ - θ=40, XX pol)



Area of high interest → Arid to semi-arid

Large sensitivity to small variations of soil moisture

Offline CMEM – Layer 1

Bar	From	To	Count
■	-1000	-500	23
■	-500	-300	124
■	-300	-200	561
■	-200	-150	779
■	-150	-100	833
■	-100	-75	457
■	-75	-50	704
■	-50	-25	857
■	-25	-15	497
■	-15	-5	455
■	-5	0	704
■	0	10	21
■	10	50	32
■	50	100	14
■	100	200	7
■	200	500	6
■	500	1000	4

Offline CMEM – Layer 2

Bar	From	To	Count
■	-1000	-500	4
■	-500	-300	7
■	-300	-200	5
■	-200	-150	10
■	-150	-100	31
■	-100	-75	21
■	-75	-50	42
■	-50	-25	81
■	-25		
■	-15		
■	-5		
■	0	10	5531
■	10	50	104
■	50	100	52
■	100	200	28
■	200	500	20
■	500	1000	0

Offline CMEM – Layer 3

Bar	From	To	Count
■	-1000	-500	0
■	-500	-300	0
■	-300	-200	0
■	-200	-150	0
■	-150	-100	2
■	-100	-75	3
■	-75	-50	4
■	-50	-25	5
			6
			2
			6
■	0	10	5936
■	10	50	115
■	50	100	58
■	100	200	30
■	200	500	11
			0

CMEM IFS – Layer 1

Bar	From	To	Count
■	-1000	-500	0
■	-500	-300	7
■	-300	-200	436
■	-200	-150	738
■	-150	-100	869
■	-100	-75	497
■	-75	-50	711
■	-50	-25	807
■	-25	-15	398
■	-15	-5	381
■	-5	0	114
■	0	10	309
■	10	50	68
■	50	100	37
■	100	200	28
■	200	500	13
■	500	1000	0

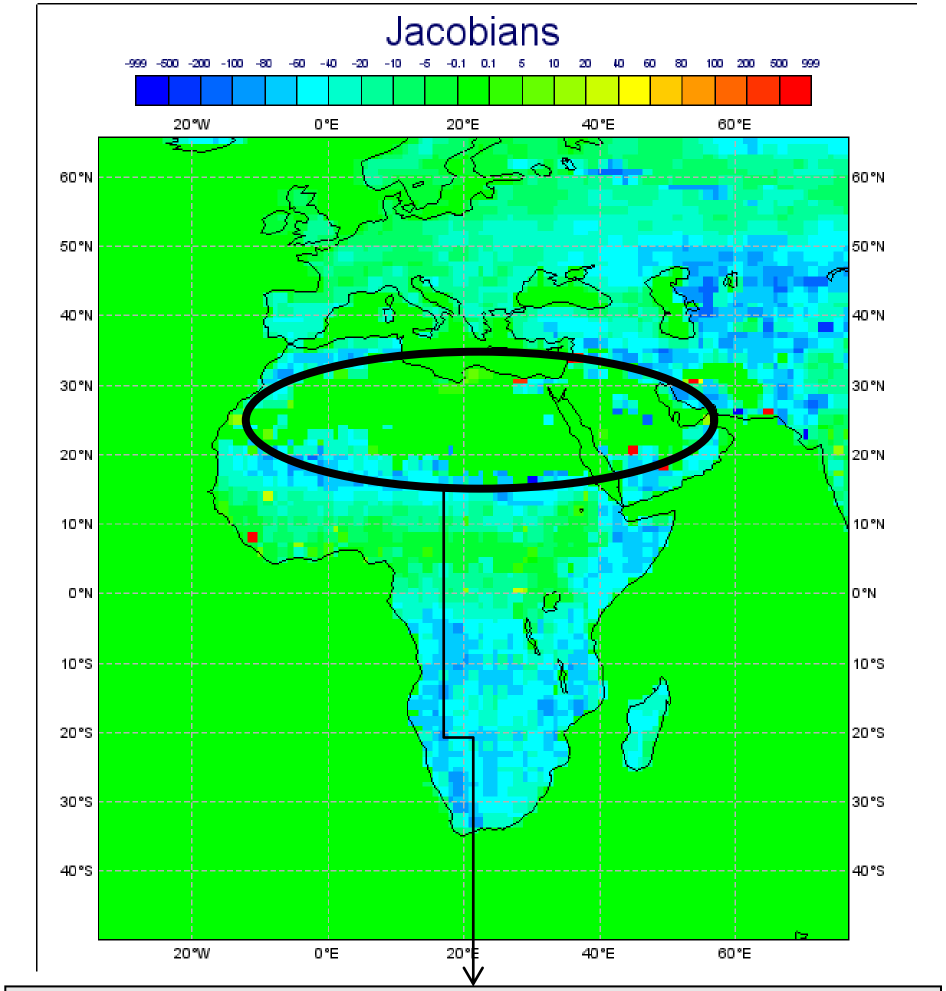
CMEM IFS – Layer 2

Bar	From		
■	-1000		
■	-500		
■	-300	-200	0
■	-200	-150	0
■	-150	-100	3
■	-100	-75	6
■	-75	-50	5
■	-50	-25	54
■	-25	-15	286
■	-15	-5	1379
■	-5	0	2539
■	0	10	979
■	10	50	99
■	50	100	40
■	100	200	24
■	200	500	0
■	500	1000	0

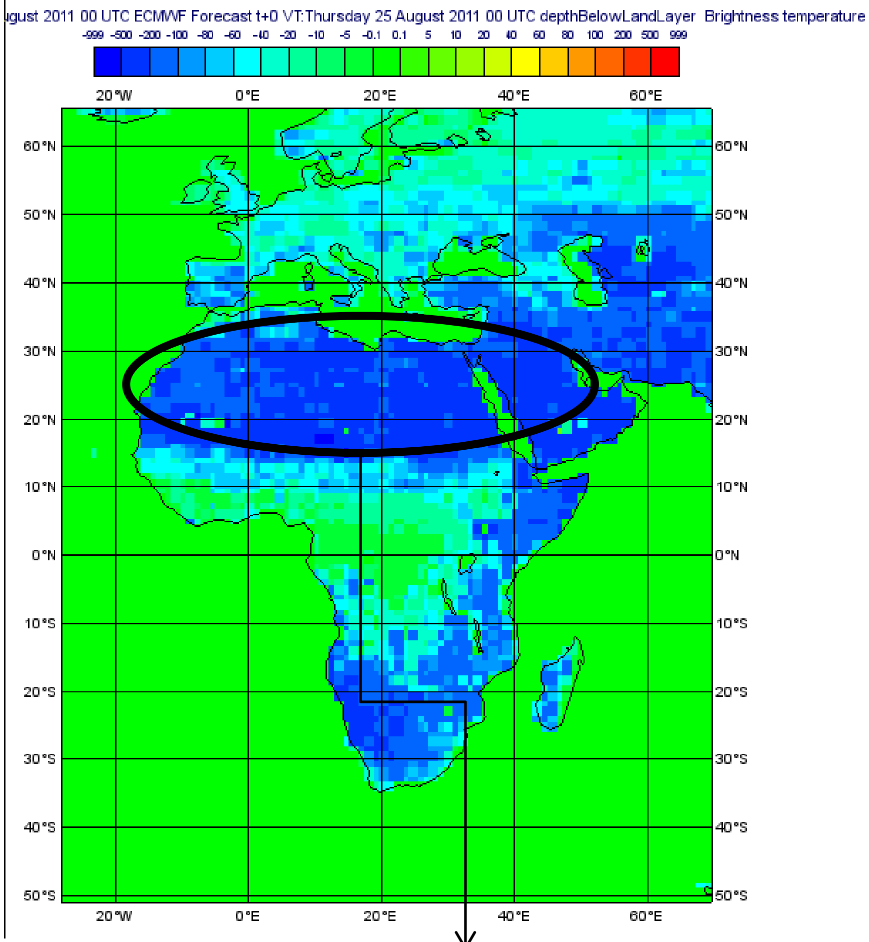
CMEM IFS – Layer 3

			Count
			0
			0
■	-300	-200	0
■	-200	-150	0
■	-150	-100	2
■	-100	-75	2
■	-75	-50	2
■	-50	-25	12
■	-25	-15	2
■	-15	-5	287
■	-5	0	2719
■	0	10	2311
■	10	50	76
■	50	100	1
■	100	200	0
■	200	500	0
■	500	1000	0

Jacobians during dry season (θ=40, XX pol, 2011082500-2011083112, Δw=0.05 m³/m³)



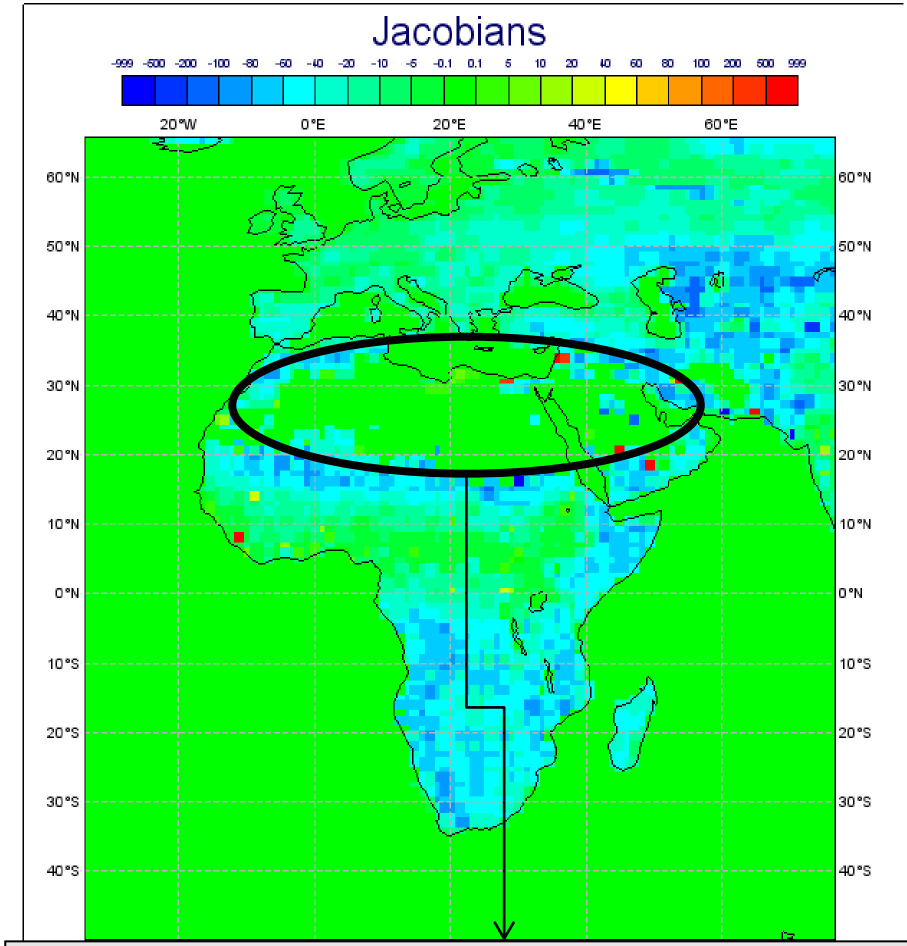
Offline CMEM, LOMASK_AUTO=.FALSE.



Area of large sensitivity → Jacobians are zero, which means observations won't have any influence in the analysis!

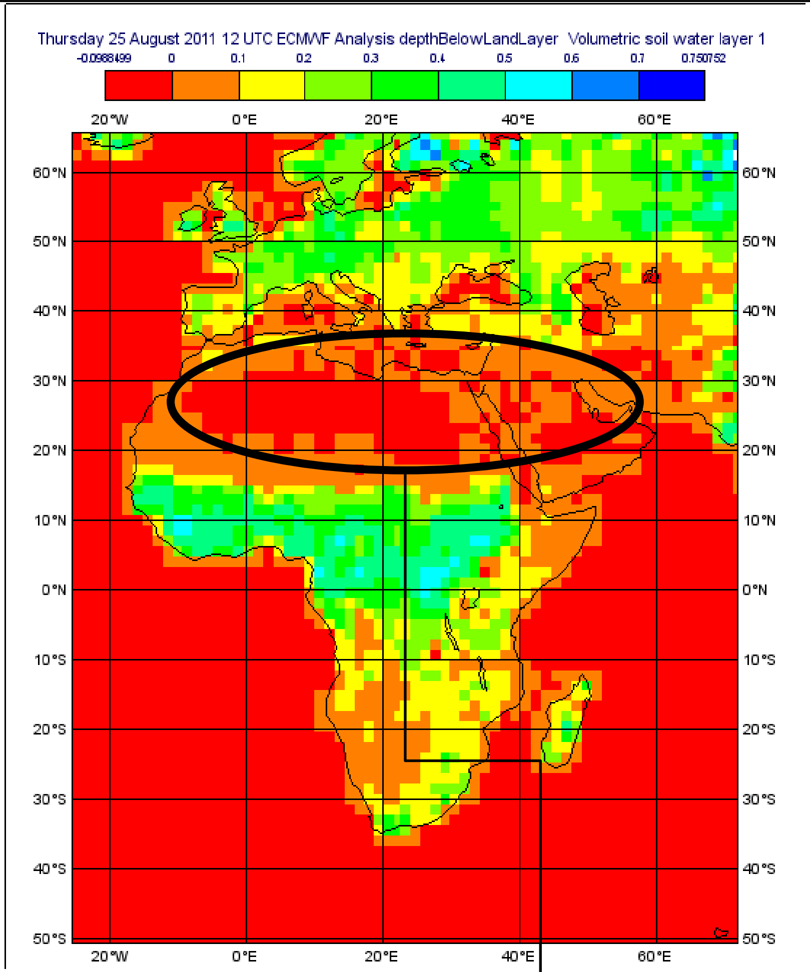
However, by using the LOMASK_AUTO option equal to false, strong sensitivity is found

Jacobians during dry season (θ=40, XX pol, 2011082500-2011083112, Δw=0.01 m^3/m^3)



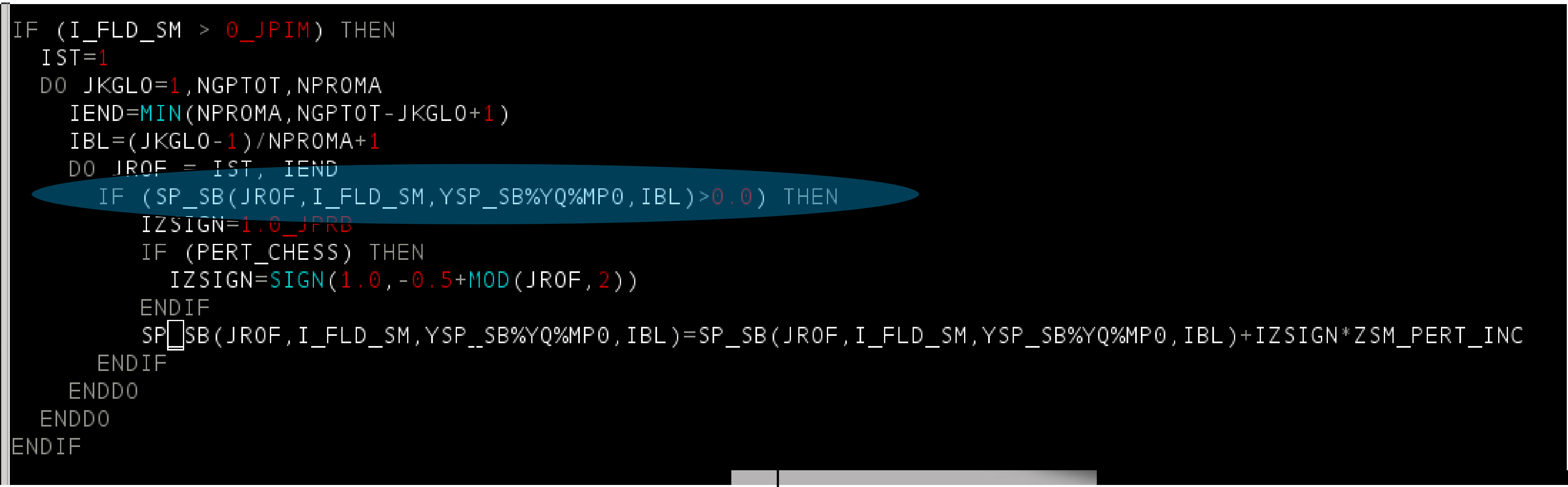
Filters implemented avoiding analysis are hard RFI, freezing soil, snow covered, no active grid-point, no observation, too large departure or too large increment or too large sensitivity (in blue are deactivated for calibration)!

Operational fc sm, level-1



Values of SM are a negative epsilon or zero.

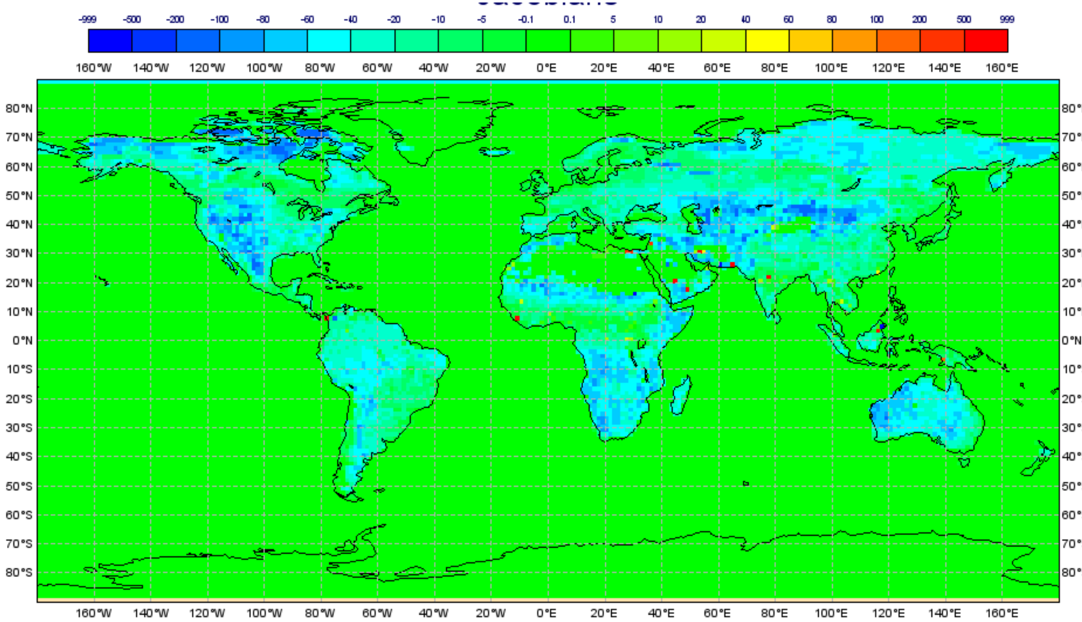
Jacobians during dry season (θ=40, XX pol, 2011082500-2011083112, Δw=0.01 m^3/m^3)



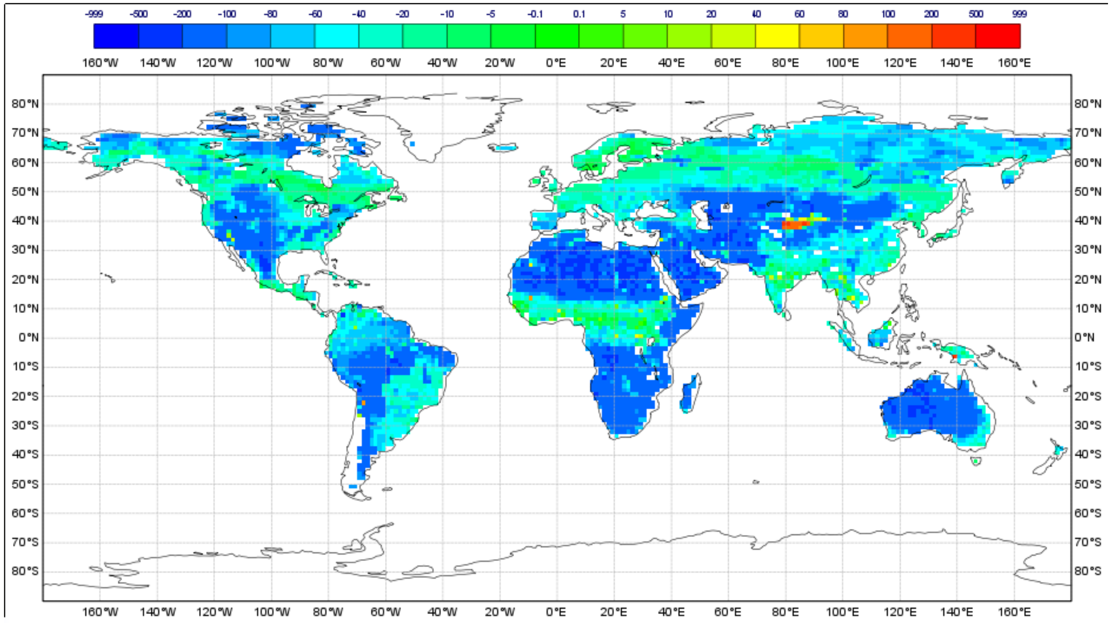
```
IF (I_FLD_SM > 0_JPIM) THEN
  IST=1
  DO JKGLO=1,NGPTOT,NPROMA
    IEND=MIN(NPROMA,NGPTOT-JKGLO+1)
    IBL=(JKGLO-1)/NPROMA+1
    DO JROF = IST, IEND
      IF (SP_SB(JROF,I_FLD_SM,YSP_SB%YQ%MP0,IBL)>0.0) THEN
         IZSIGN=1.0_JPRB
         IF (PERT_CHESS) THEN
           IZSIGN=SIGN(1.0,-0.5+MOD(JROF,2))
         ENDIF
         SP_SB(JROF,I_FLD_SM,YSP_SB%YQ%MP0,IBL)=SP_SB(JROF,I_FLD_SM,YSP_SB%YQ%MP0,IBL)+IZSIGN*ZSM_PERT_INC
      ENDIF
    ENDDO
  ENDDO
ENDIF
```

Perturbations are only allowed if SM>0 ! → needs to allow perturbation if soil is completely dry → fine if SM is corrected only through screen variables as they provide indirect information of SM, and because in Africa there wasn't any observation. But if satellite data (specially passive microwaves) is used needs to be modified!

If perturbation is allowed in arid regions → mean value over a week in August



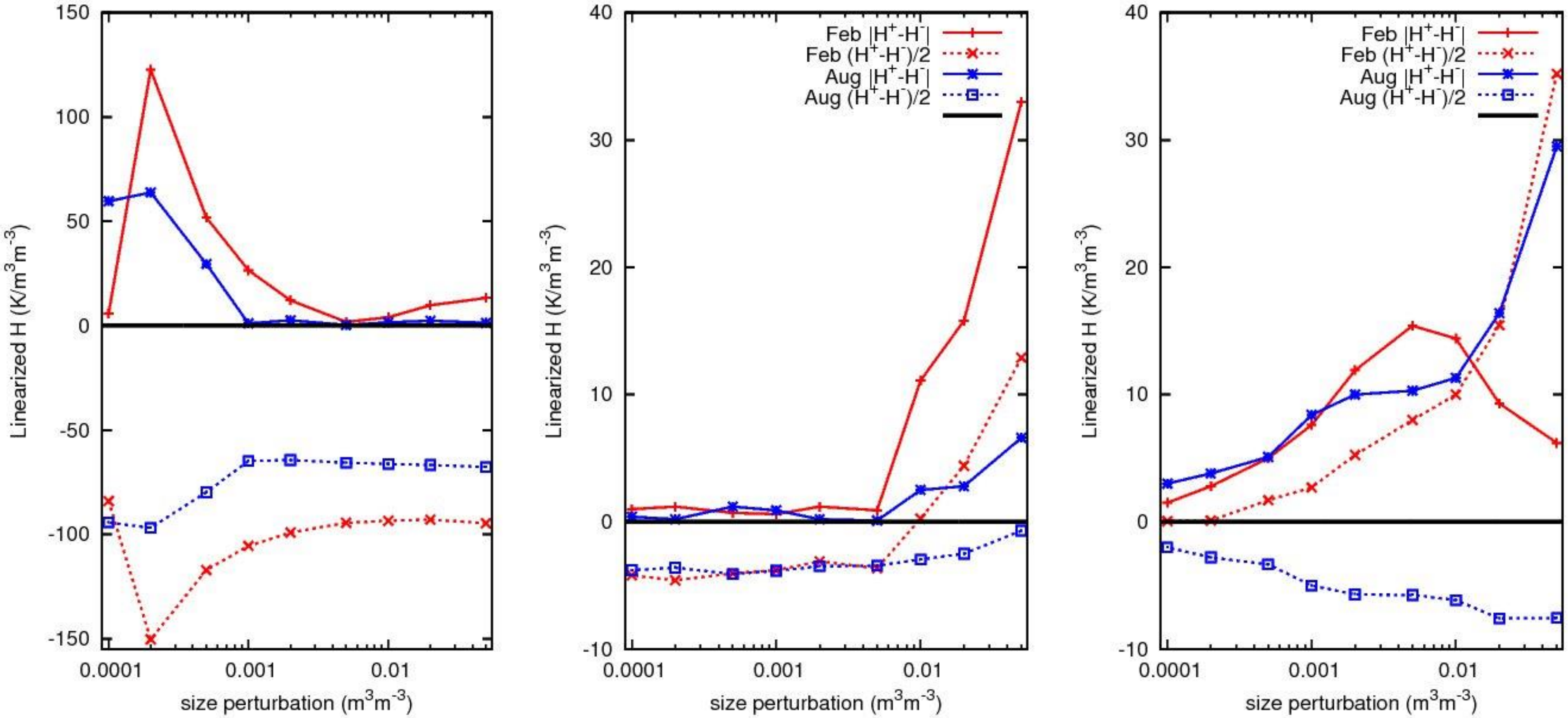
Values of SM can be negative epsilon or zero → lack of sensitivity of the Jacobians in certain areas



By allowing SM perturbations to be produced if SM=0 (negative values moved to zero), then larger sensitivity of Jacobians are found.

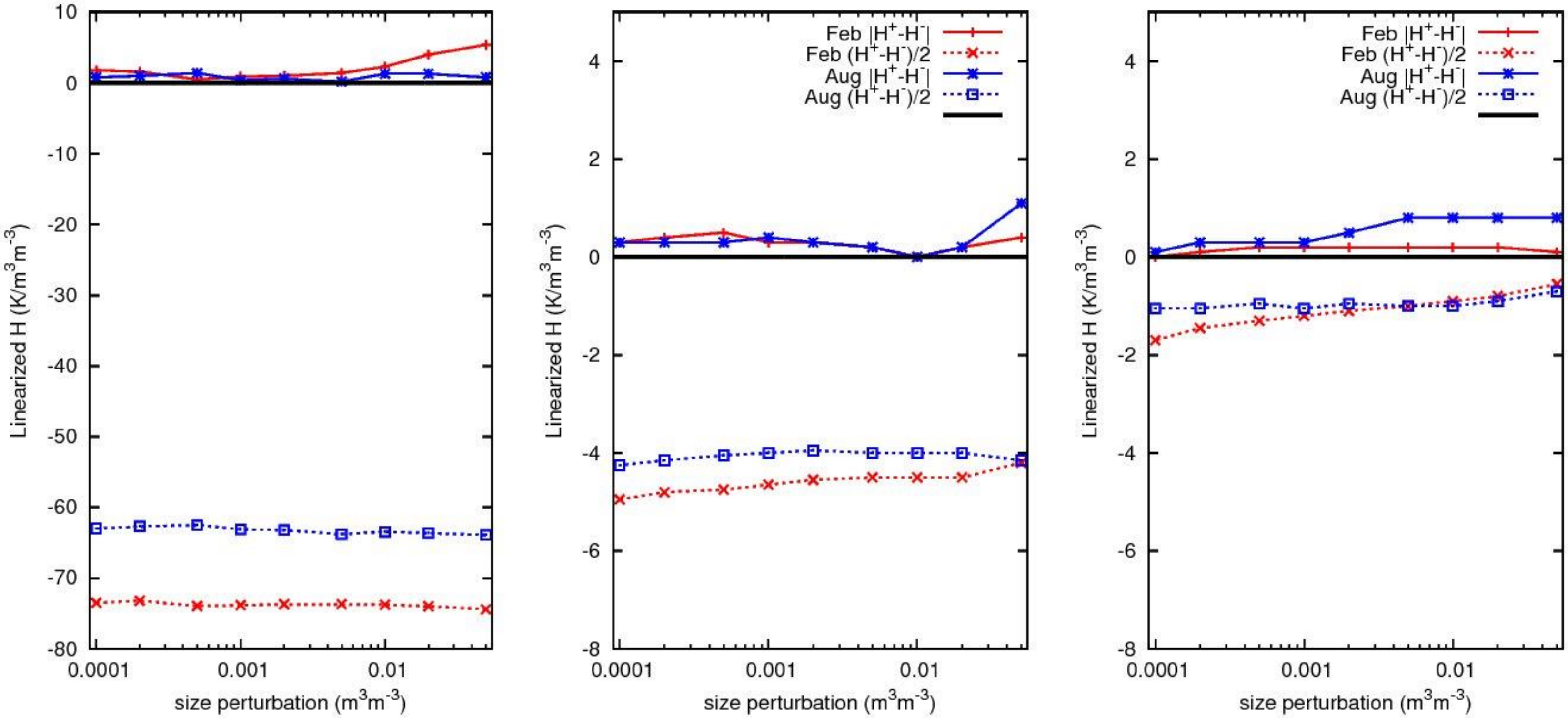
ECMWF

Mean jacobians (non filtered values)



- **Numerical instabilities produce large jacobians for very small perturbations in the first layer**
- **Non-linear effects are also evident for large perturbations, specially for the second and third soil layers.**

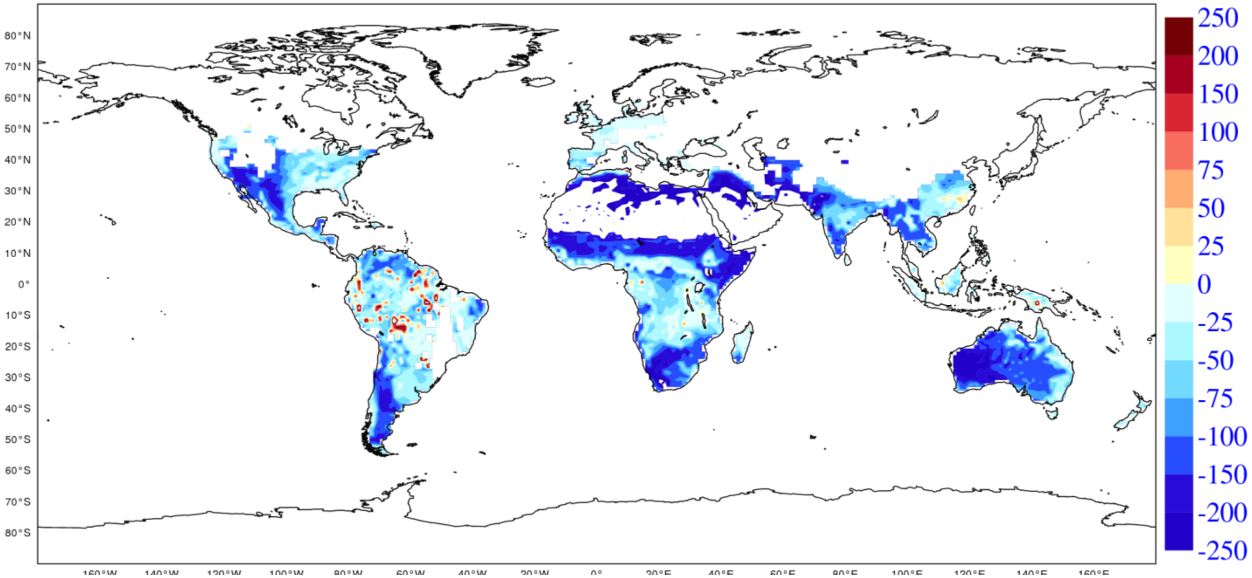
Mean jacobians (filtered values)



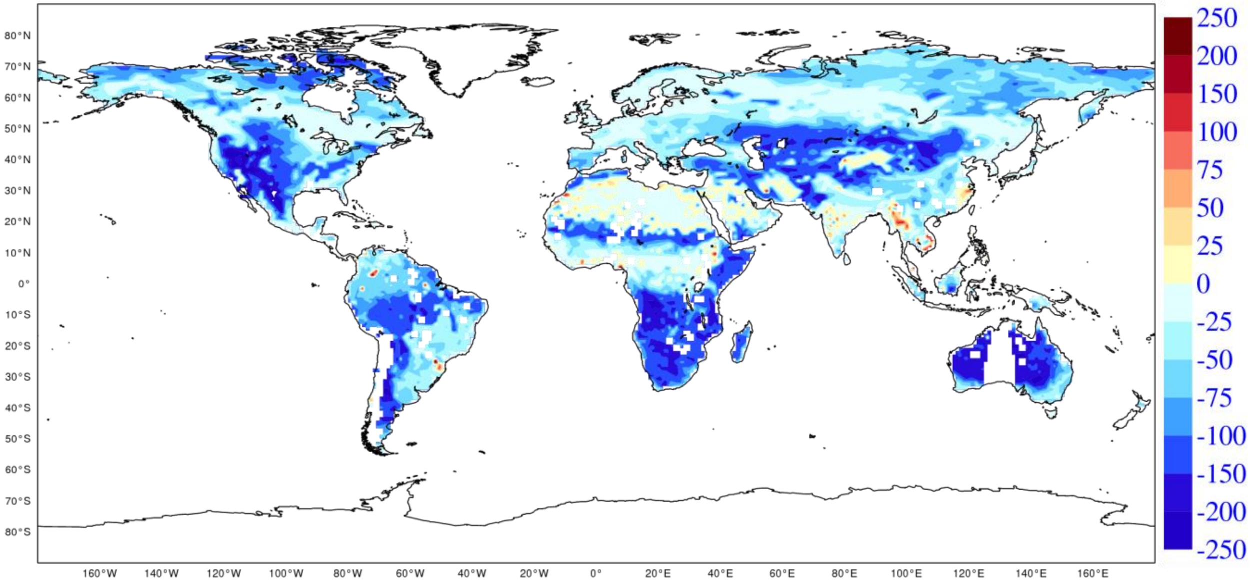
- **Larger sensitivity for first soil layer → It is expected larger correction of first layer of SM to correct towards SMOS observations.**
- **Sensitivity of T_B to SM is negative.**
- **The optimal perturbation value is between 0.005 m^3m^{-3} and 0.01 m^3m^{-3}. For consistency with T^{2m} and RH^{2m}, 0.01 m^3m^{-3} will be used.**

Jacobians after calibration

February - morning Jacobian SMOS 40XX (K/m3m-3)

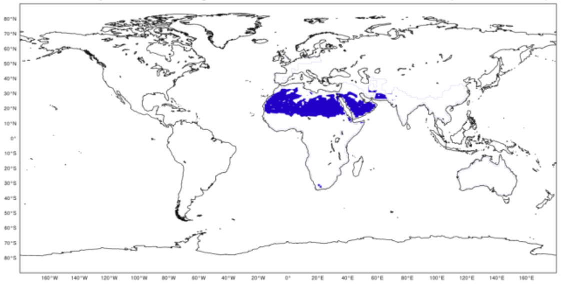


August - evening Jacobian SMOS 40XX (K/m3m-3)



Rejected data

February - morning Jacobian SMOS 40XX (K/m3m-3)



SMOS data assimilation study at ECMWF

- Technical implementation and experimentation,
- Jacobians and SEKF calibration,
- DA impact experiments,
- SMOS-DA-v1.0

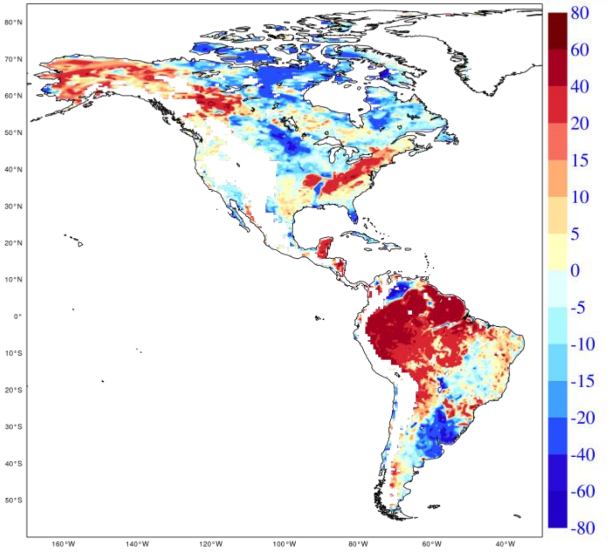
OSE – North & South America case study

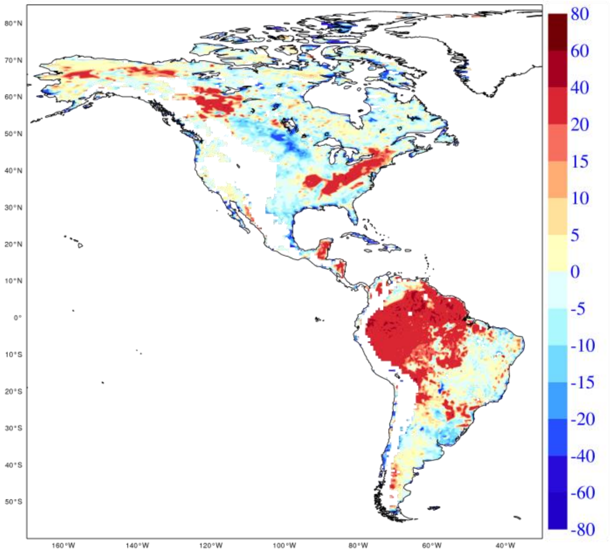
- Assimilation of SMOS T_B (SEKF) in the antenna reference frame
  - July 2011
  - Resolution: **T511** (~40 km)
  - Observations:
    - NRT brightness temperatures,
    - **30, 40, 50** degrees $\pm \Delta T_B = 0.5$ K
    - **XX & YY** polarisations
    - Only AF-FOV
  - CMEM configuration; best for R (Wang(DIEL), Wsimple(RGH), Wigneron(VEG))
  - **Jacobians calibrated** ($\delta\theta_j = 0.01 m^3m^{-3}$, $|H^-_{max}| = |H^+_{max}| = 250\ K/m^3m^{-3}$)
  - **STD of observations error →** radiometric accuracy
  - Degraded observational system for the atmosphere → only conventional and geostationary data sensitive to winds,

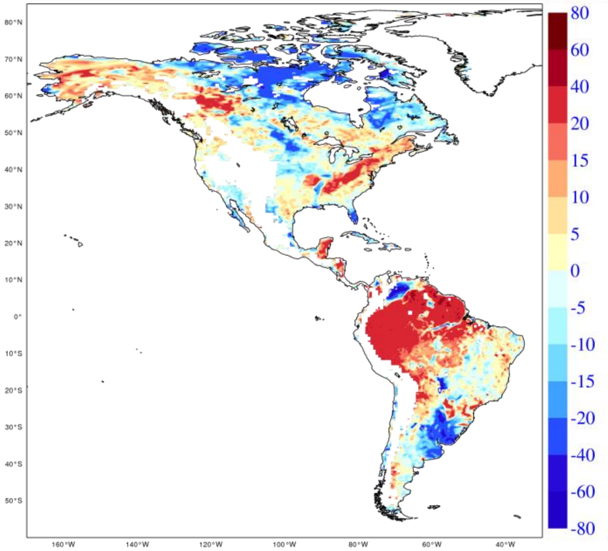
- **CTRL:** assimilation of T^{2m}, RH^{2m}
- **EXPT-1:** assimilation of T^{2m}, RH^{2m} + SMOS T_B (~BC)
- **EXPT-2:** assimilation of T^{2m}, RH^{2m} + SMOS T_B CDF

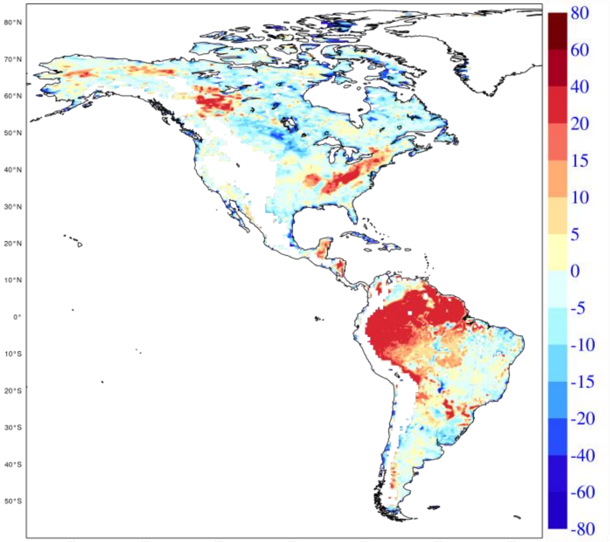
ECMWF

Bias correction (30 degrees, XX&YY polarisations)

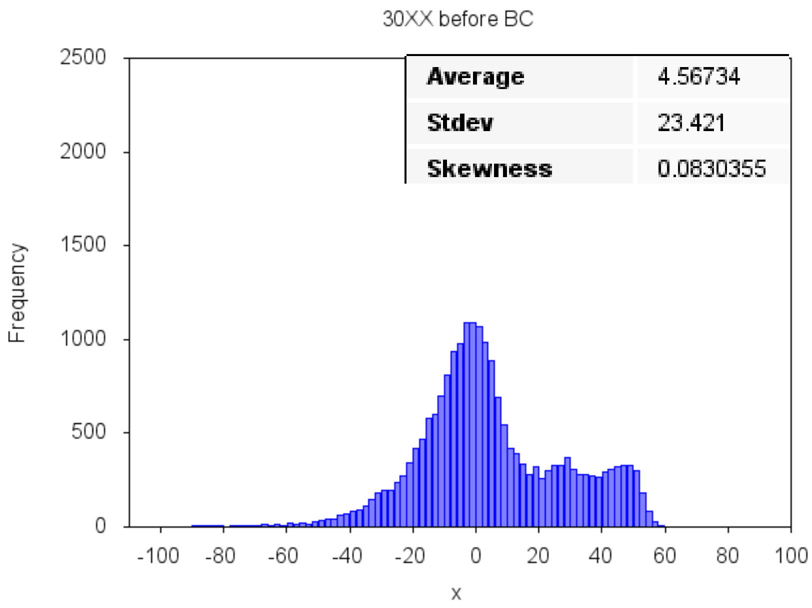

30XX - before BC


30XX - after BC

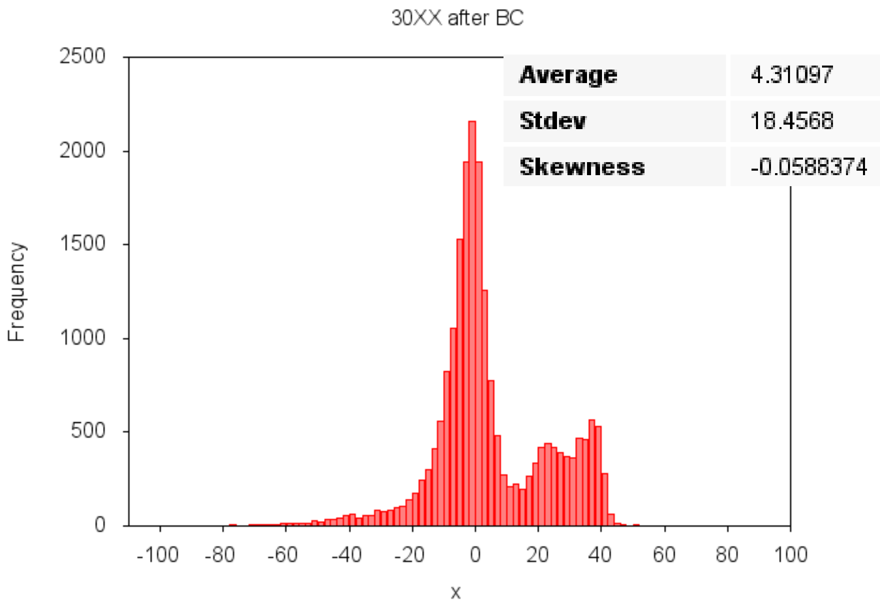

30YY - before BC


30YY - after BC

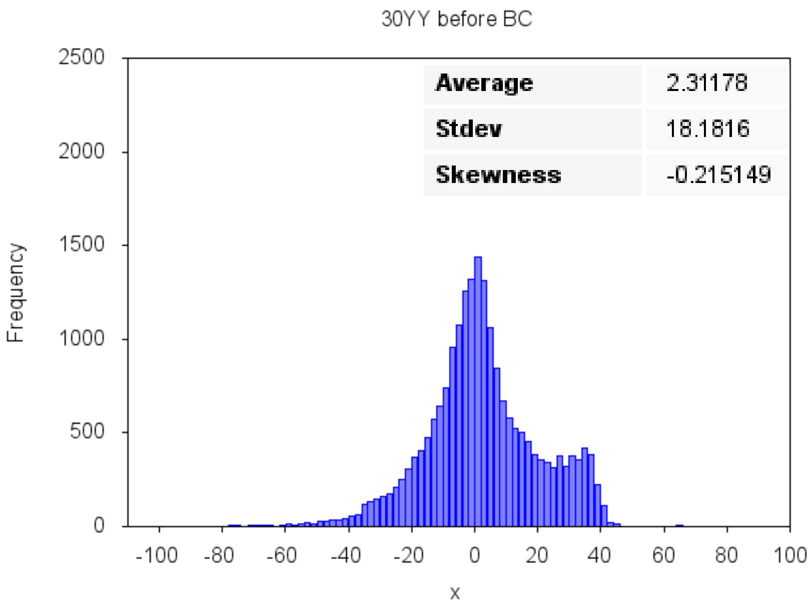
Bias correction (30 degrees, XX&YY polarisations)


30XX before BC

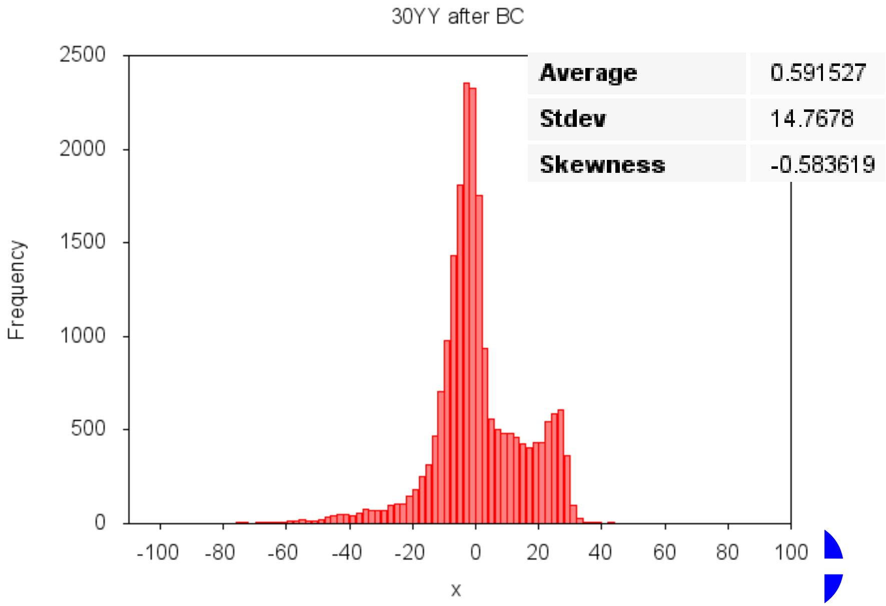
Average	4.56734
Stdev	23.421
Skewness	0.0830355


30XX after BC

Average	4.31097
Stdev	18.4568
Skewness	-0.0588374

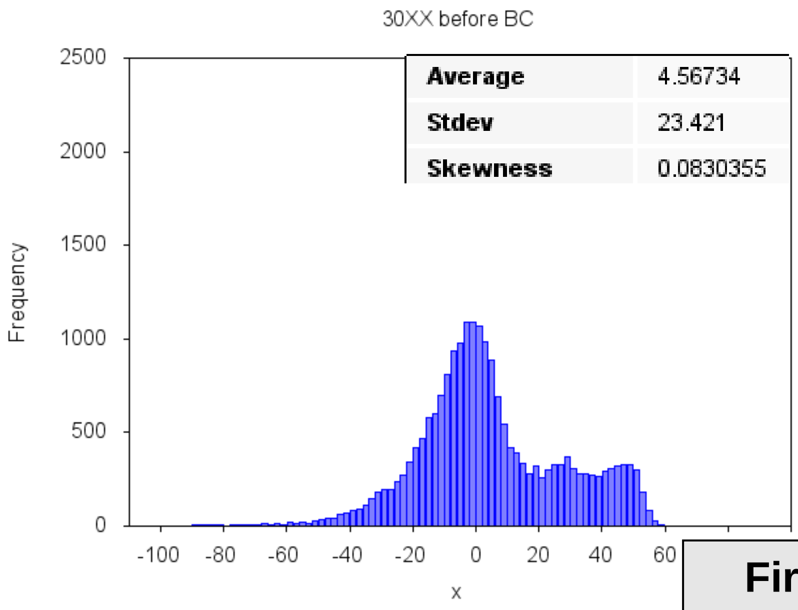

30YY before BC

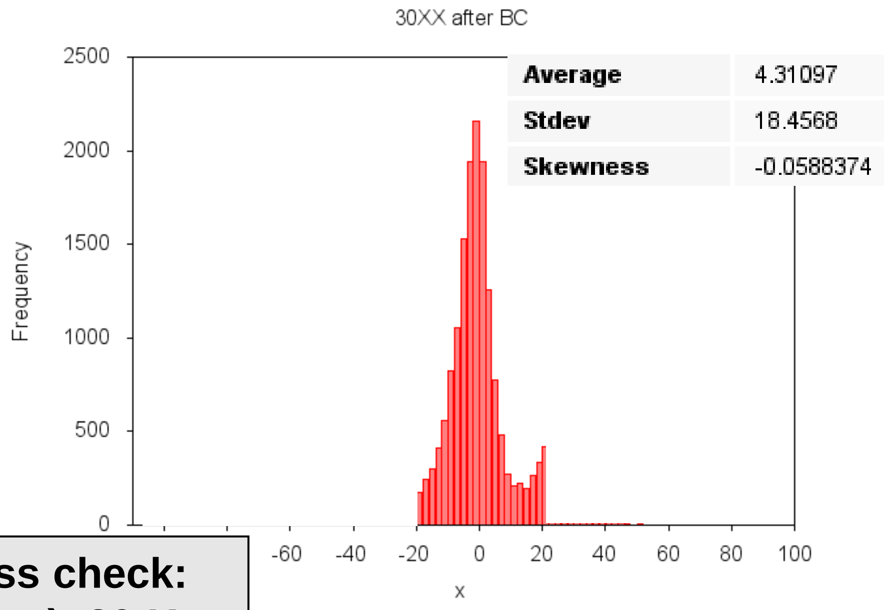
Average	2.31178
Stdev	18.1816
Skewness	-0.215149


30YY after BC

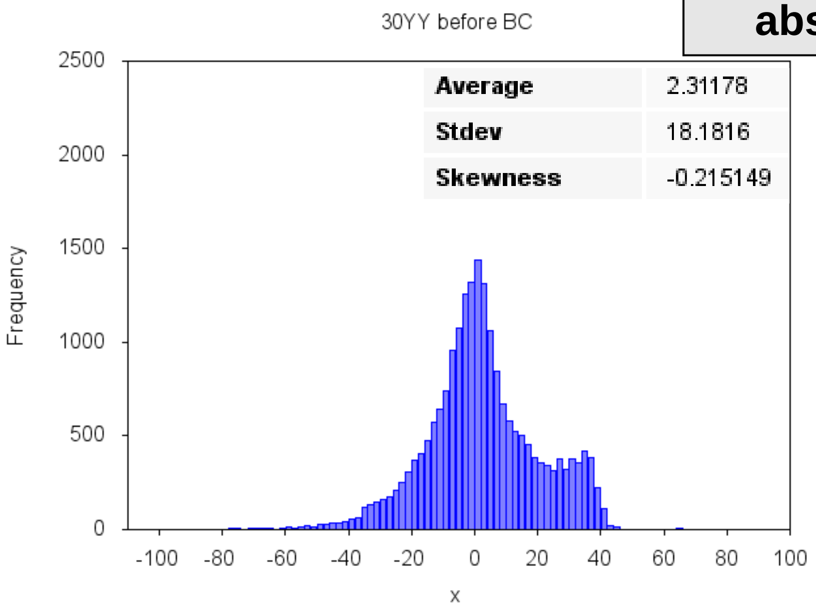
Average	0.591527
Stdev	14.7678
Skewness	-0.583619

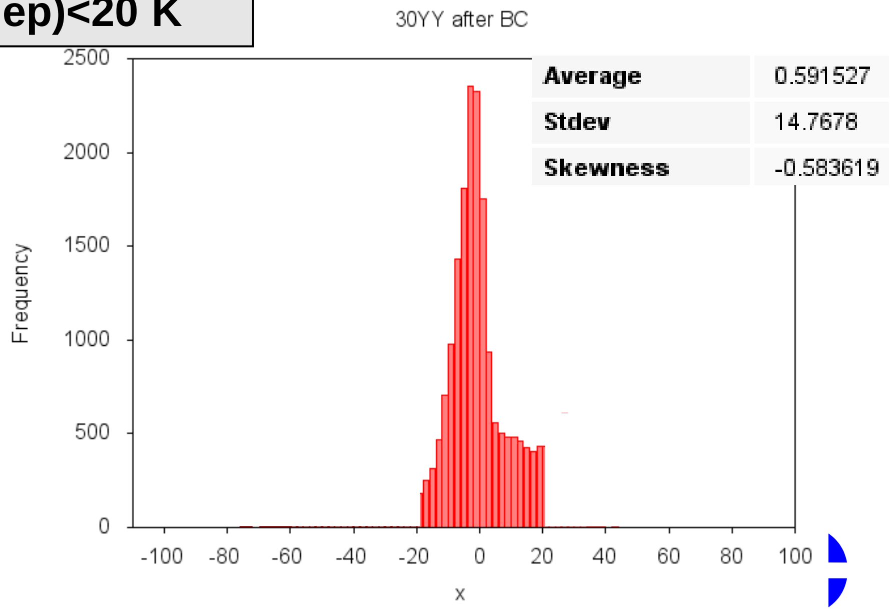
Bias correction (30 degrees, XX&YY polarisations)



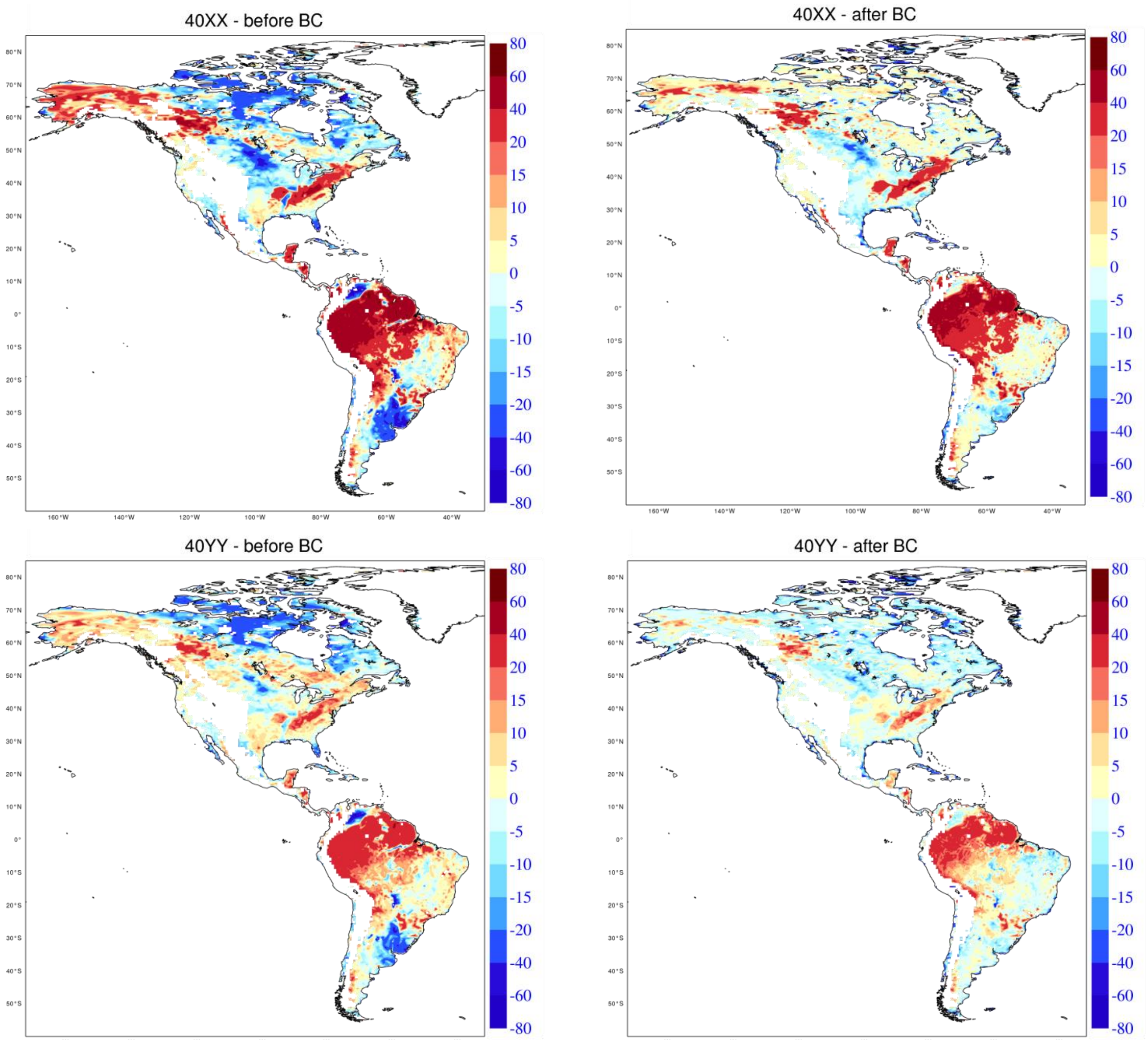


First-guess check: abs(fg_dep)<20 K

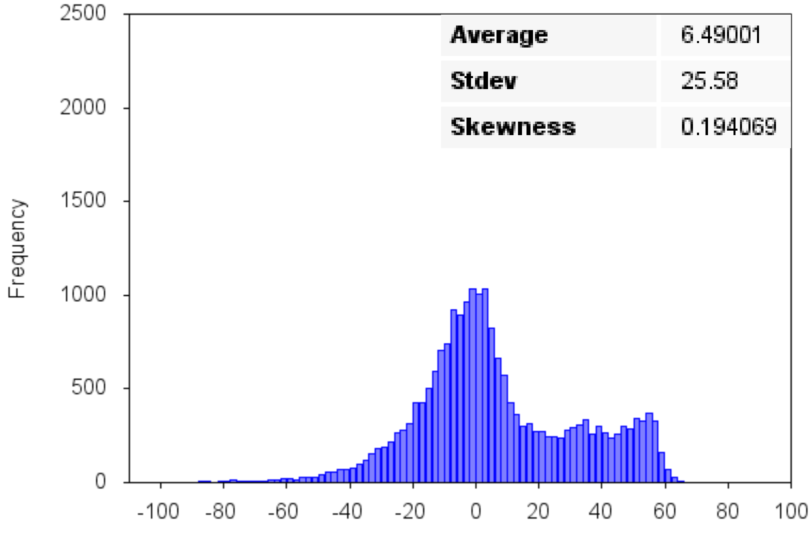




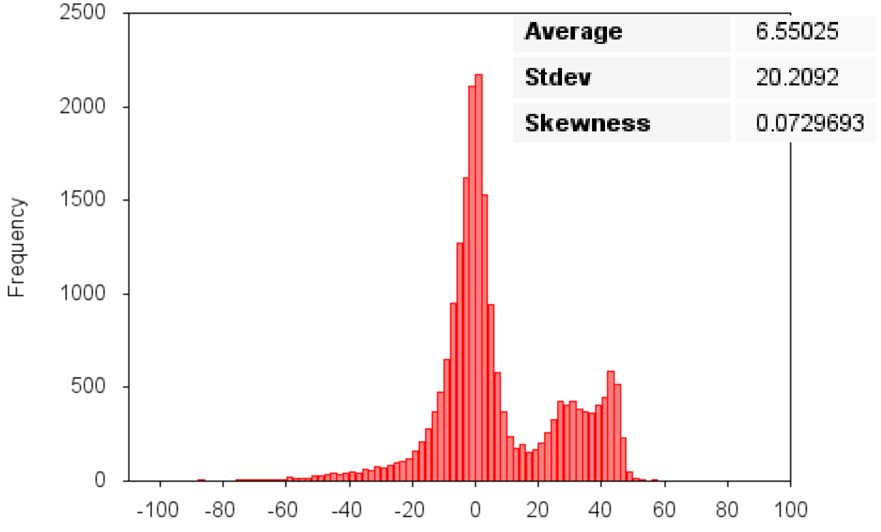
Bias correction (40 degrees, XX&YY polarisations)



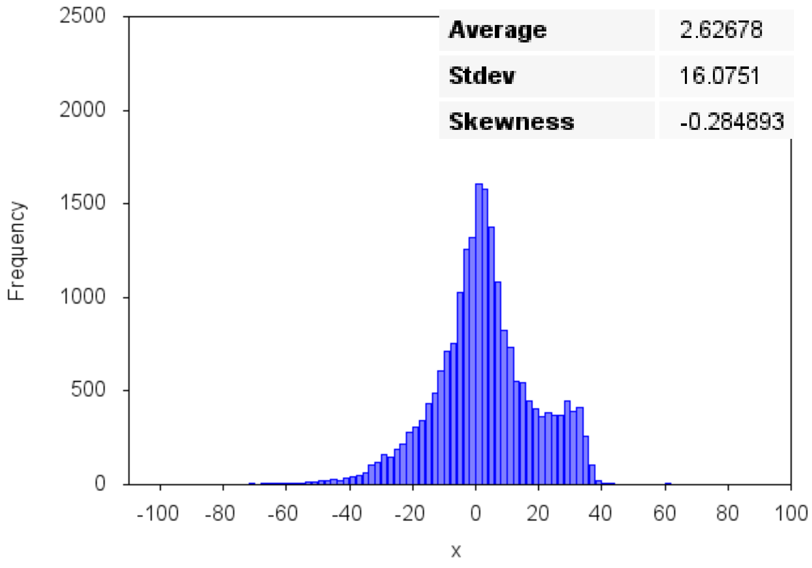
Bias correction (40 degrees, XX&YY polarisations)


40XX before BC

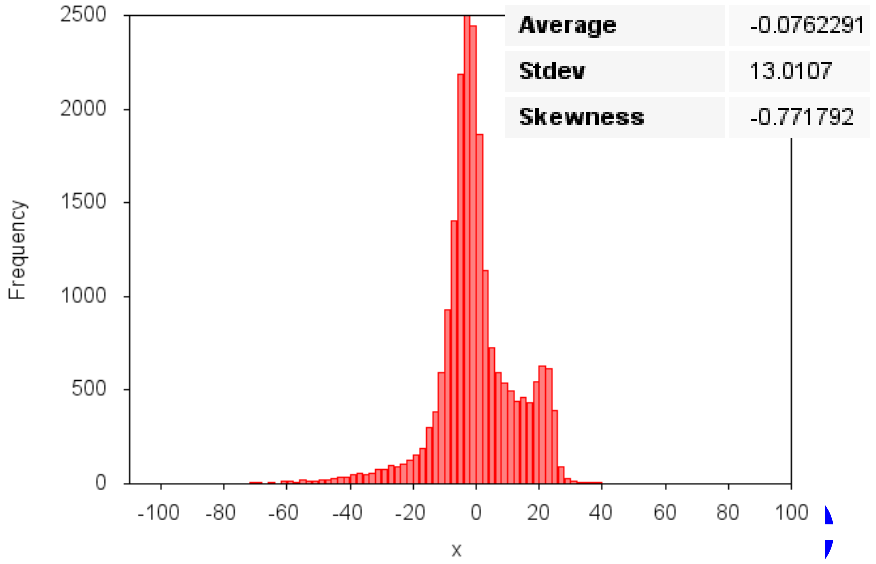
Average	6.49001
Stdev	25.58
Skewness	0.194069


40XX after BC

Average	6.55025
Stdev	20.2092
Skewness	0.0729693

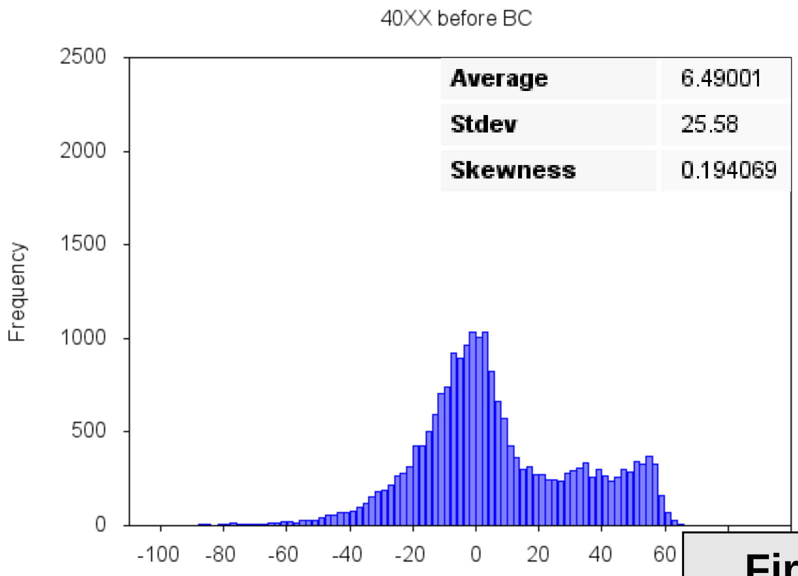

40YY before BC

Average	2.62678
Stdev	16.0751
Skewness	-0.284893

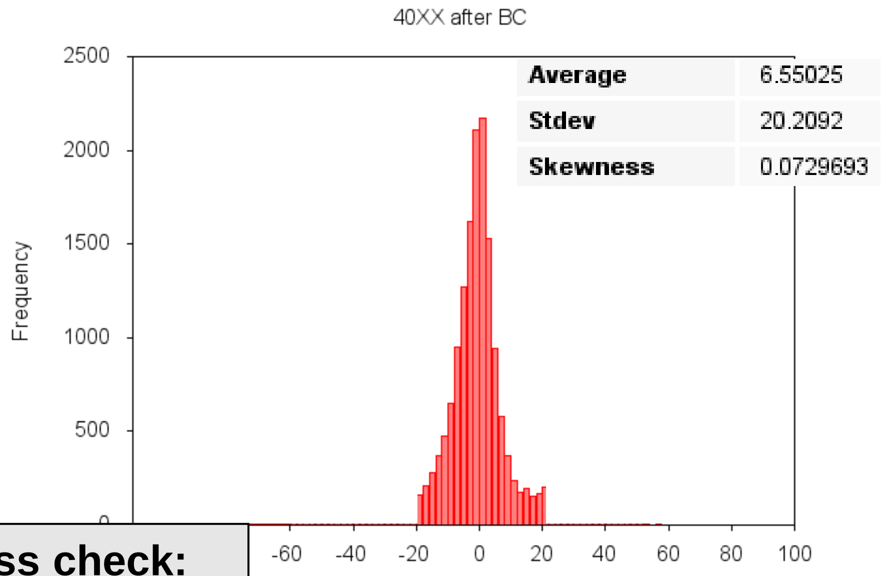

40YY after BC

Average	-0.0762291
Stdev	13.0107
Skewness	-0.771792

Bias correction (40 degrees, XX&YY polarisations)

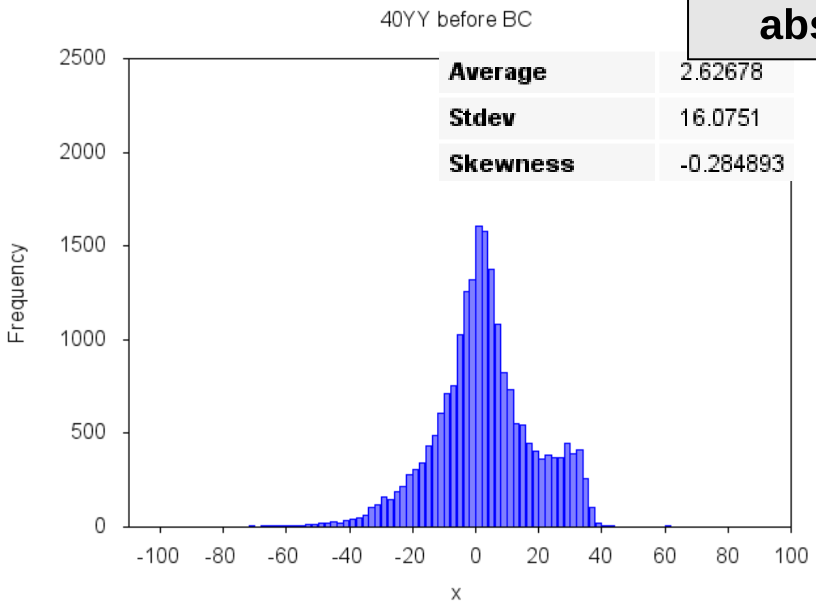

40XX before BC

Average	6.49001
Stdev	25.58
Skewness	0.194069

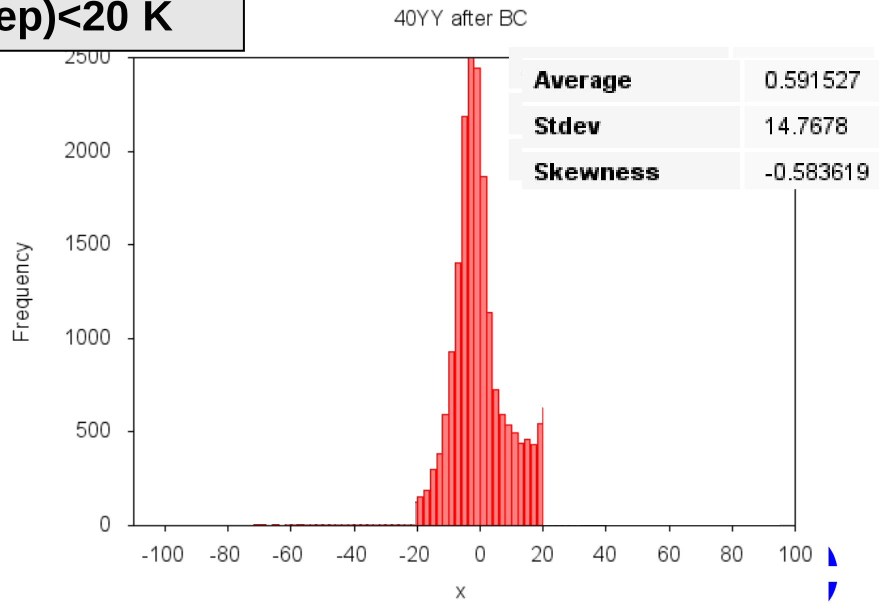

40XX after BC

Average	6.55025
Stdev	20.2092
Skewness	0.0729693

First-guess check: abs(fg_dep)<20 K


40YY before BC

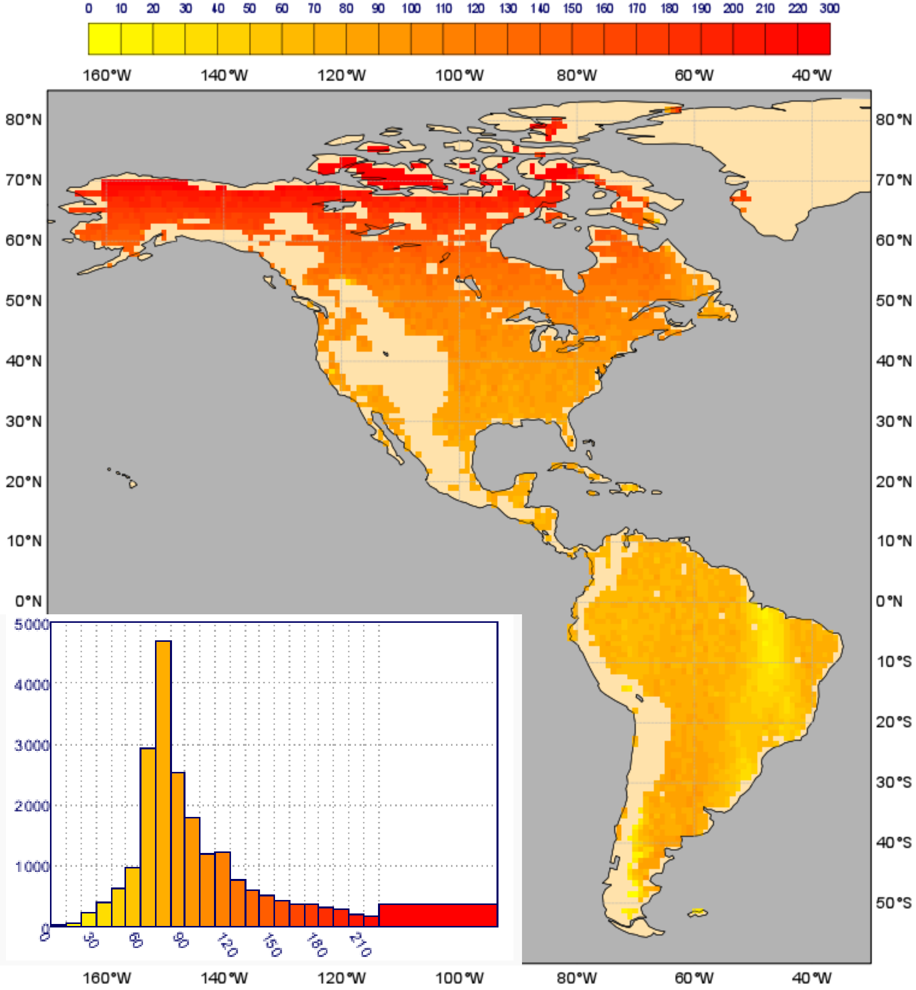
Average	2.62678
Stdev	16.0751
Skewness	-0.284893


40YY after BC

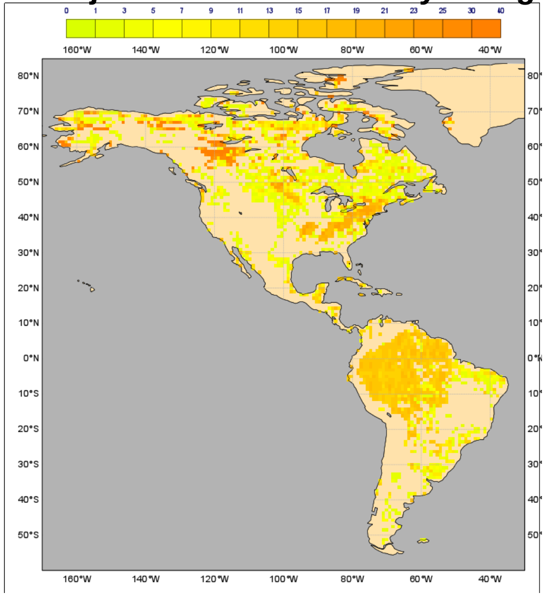
Average	0.591527
Stdev	14.7678
Skewness	-0.583619

Quality control – potential number of assimilated observations

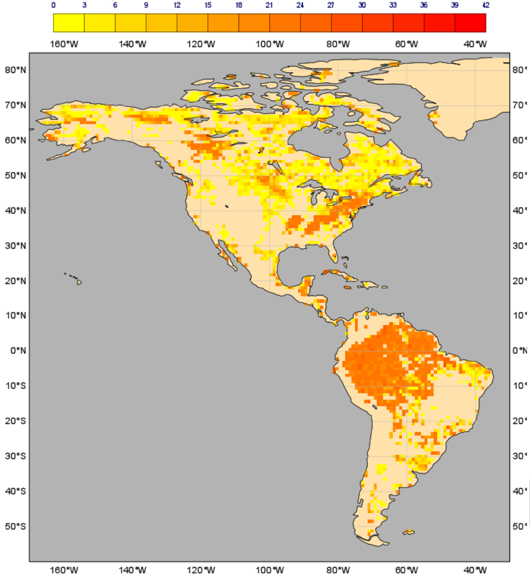
Potential number of assimilated observations



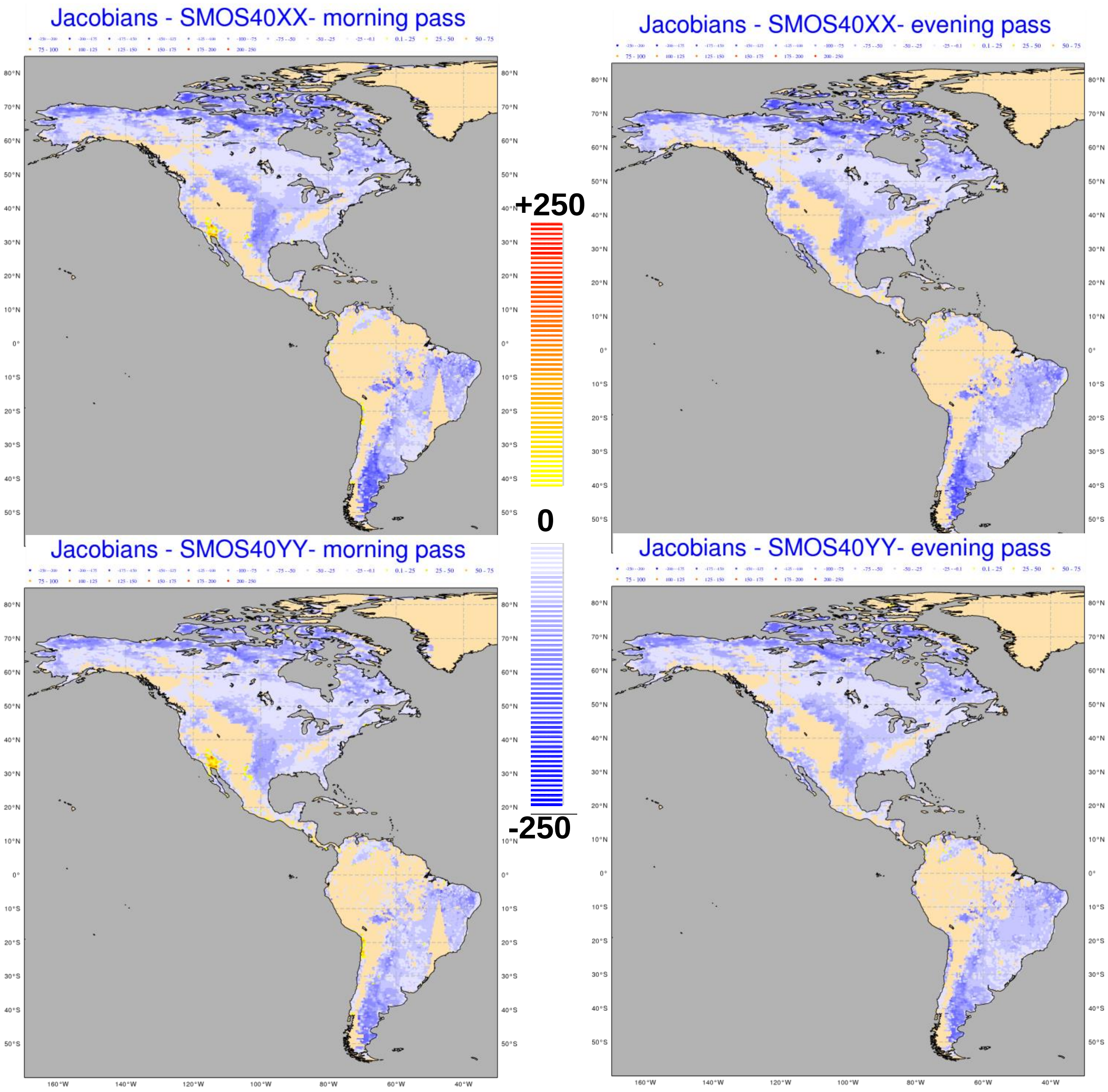
Number of rejected observations by first-guess check



Percentage of rejected observations (%)



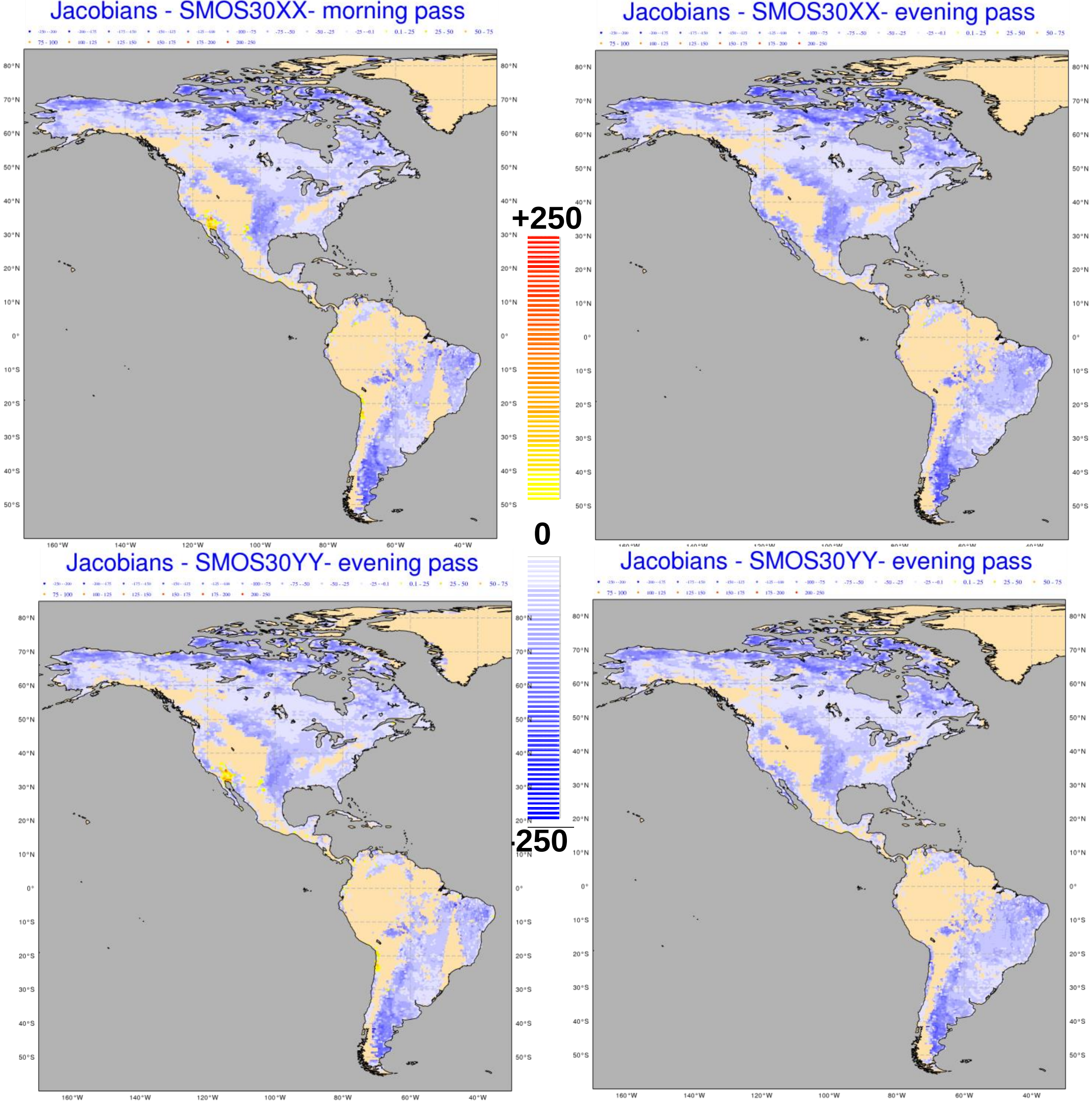
Sensitivity of T_B to soil moisture perturbations



- Θ=40 degrees
- First soil layer (7cm)
- $\delta w_1 = 0.01\ m^3m^{-3}$

- Larger sensitivity of XX-pol
- Equivalent sensitivity morning-evening cycles
- Larger sensitivity North-Canada, Central US and South of S.America

Sensitivity of T_B to soil moisture perturbations



Jacobians - SMOS30XX- morning pass

Jacobians - SMOS30XX- evening pass

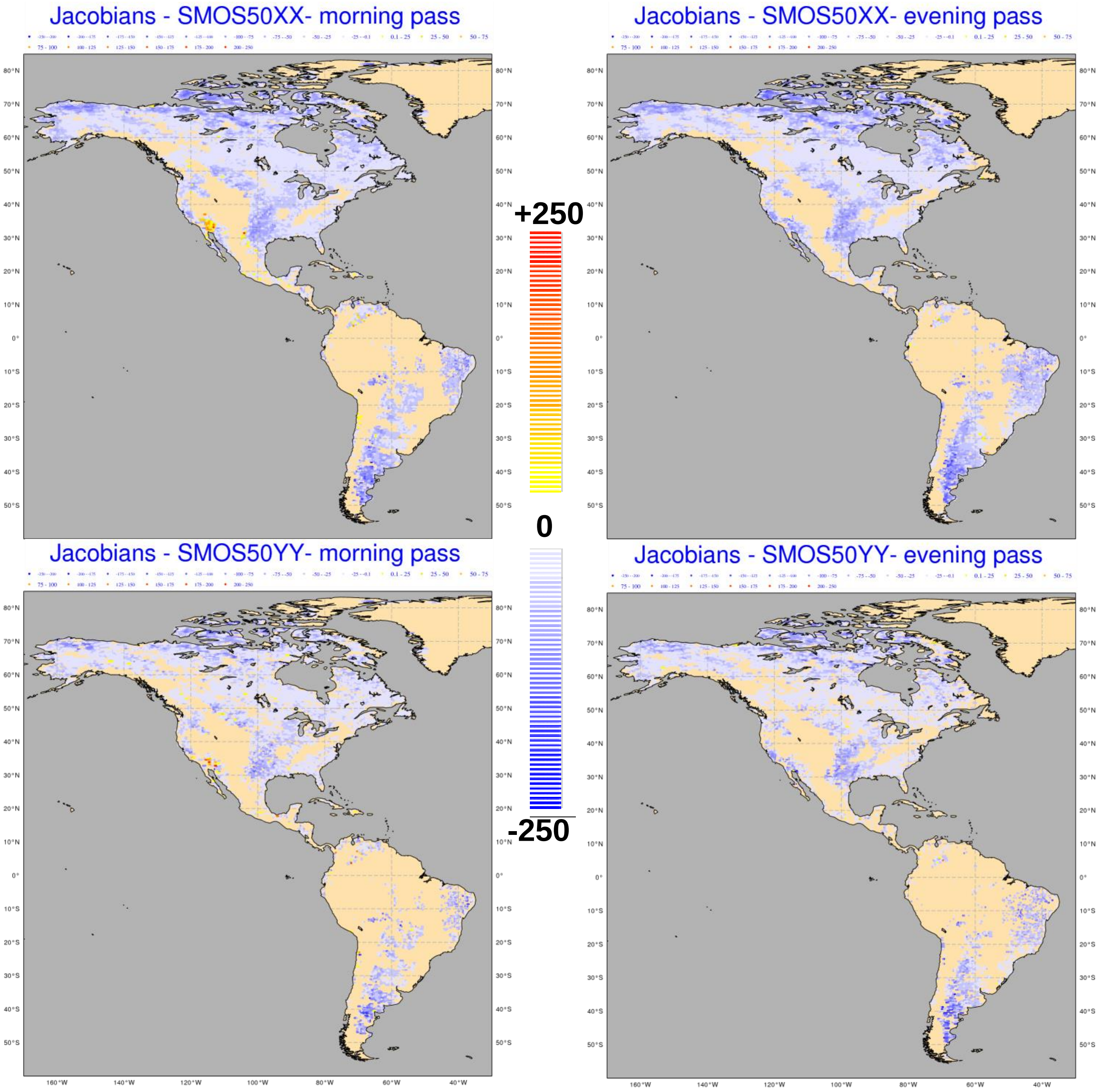
Jacobians - SMOS30YY- evening pass

Jacobians - SMOS30YY- evening pass

- Θ=30 degrees
- First soil layer (7cm)
- $\delta w_1 = 0.01\ m^3m^{-3}$

- Equivalent patterns than for 40 degrees.
- Same order of sensitivity for morning-evening cycle as at 40 degrees

Sensitivity of T_B to soil moisture perturbations


Jacobians - SMOS50XX- morning pass

Jacobians - SMOS50XX- evening pass

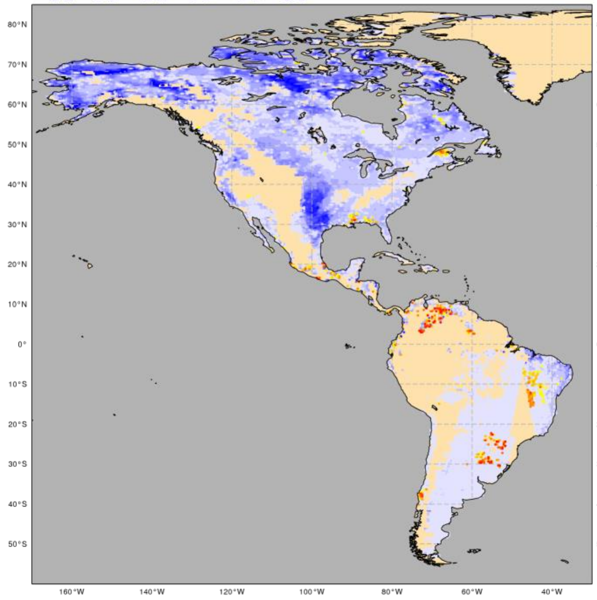
Jacobians - SMOS50YY- morning pass

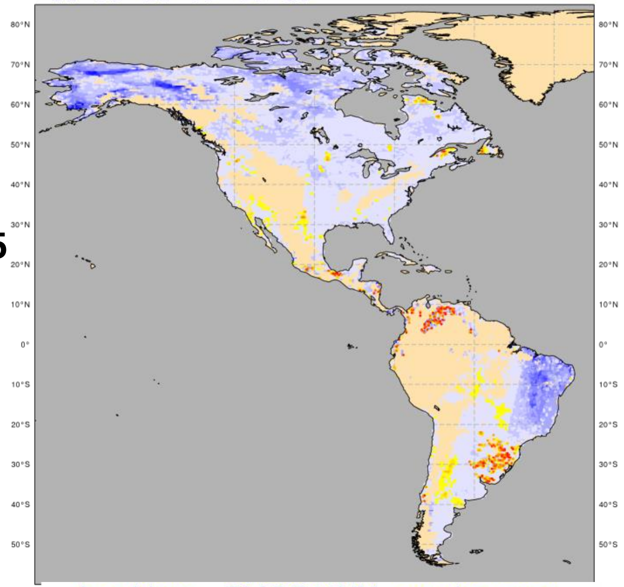
Jacobians - SMOS50YY- evening pass

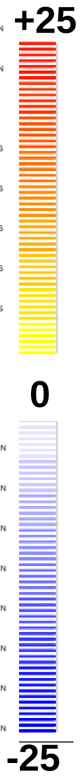
- Θ=50 degrees
- First soil layer (7cm)
- $\delta w_1 = 0.01\ m^3m^{-3}$

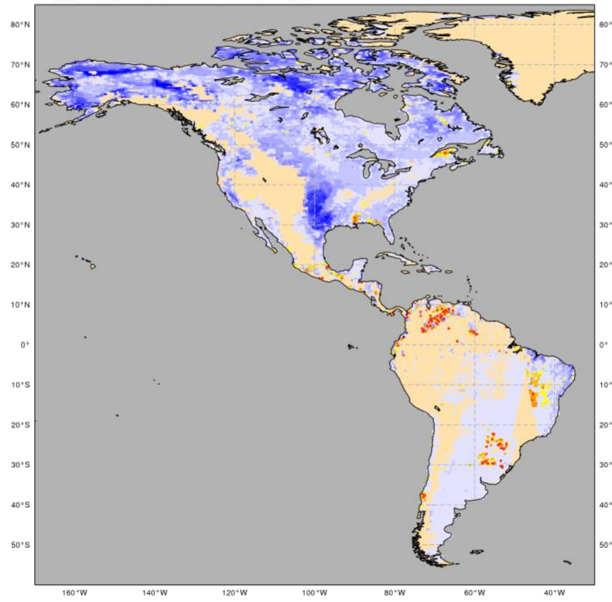
- Less data passes the quality controls
- Lower sensitivity for morning-evening cycles than 30-40 degrees

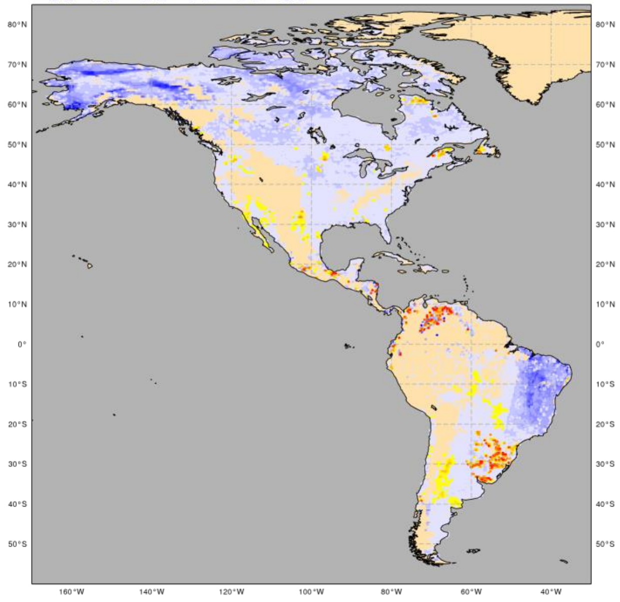
Sensitivity of T_B to soil moisture perturbations


Jacobians - SMOS40XX- morning pass


Jacobians - SMOS40XX- evening pass



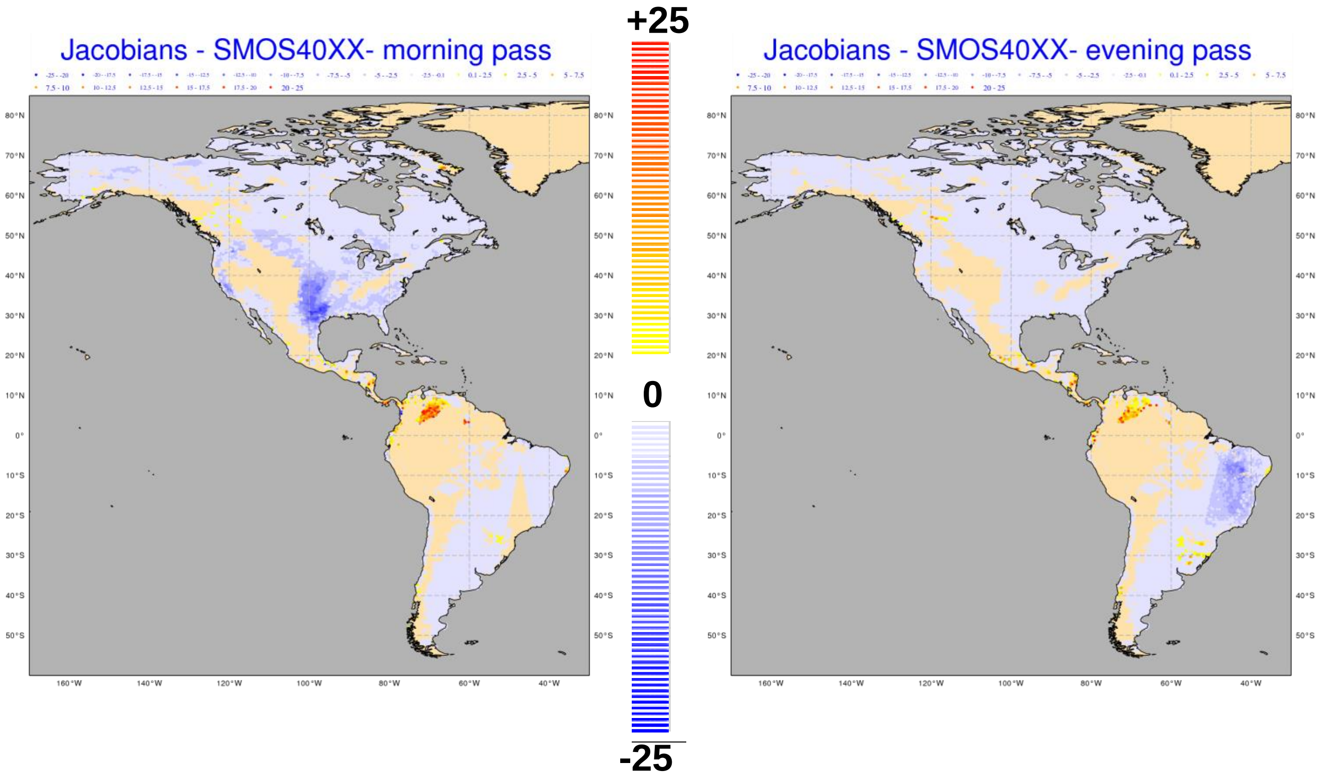

Jacobians - SMOS40YY- morning pass


Jacobians - SMOS40YY- evening pass

- Θ=40 degrees
- Second soil layer (7-28 cm)
- $\delta w_2 = 0.01\ m^3m^{-3}$
- Equivalent patterns for morning-evening, but stronger morning than evening
- Closer sensitivity between XX-YY
- For S. America, some increase of T^B with increasing SM

ECMWF

Sensitivity of T_B to soil moisture perturbations

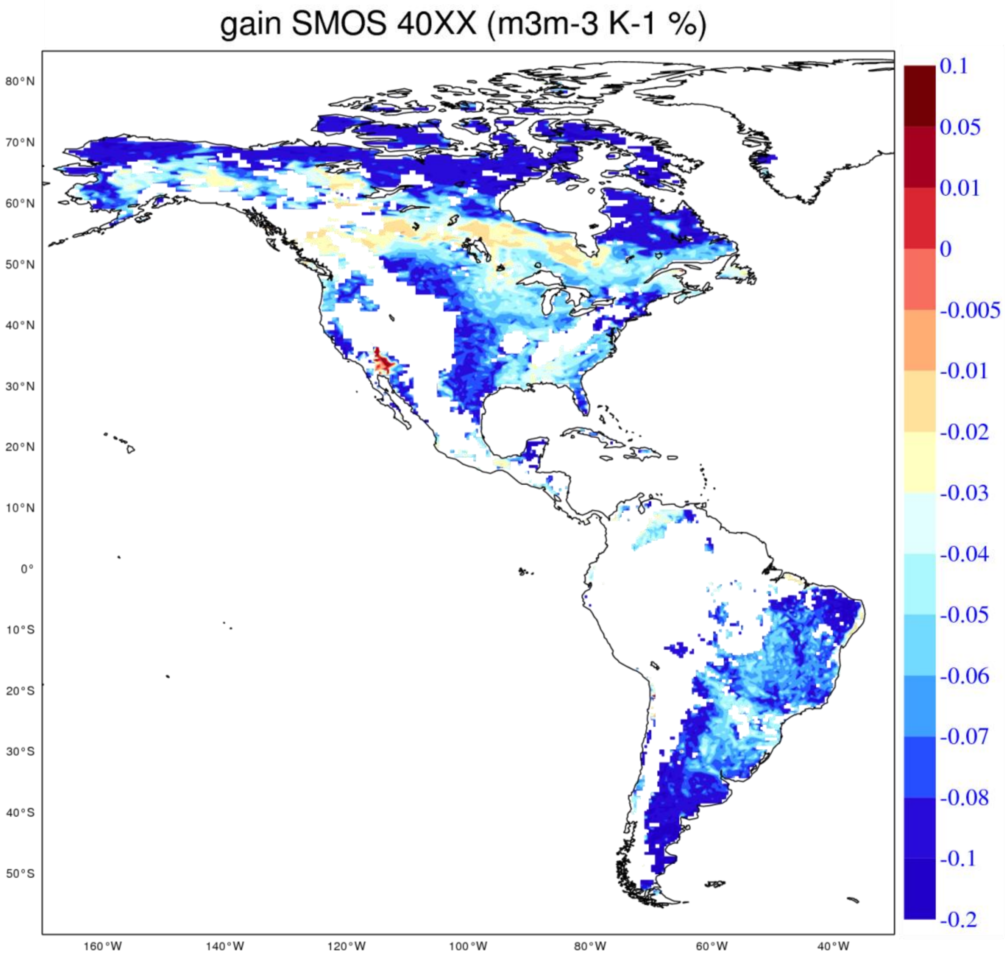


Jacobians - SMOS40XX- morning pass

Jacobians - SMOS40XX- evening pass

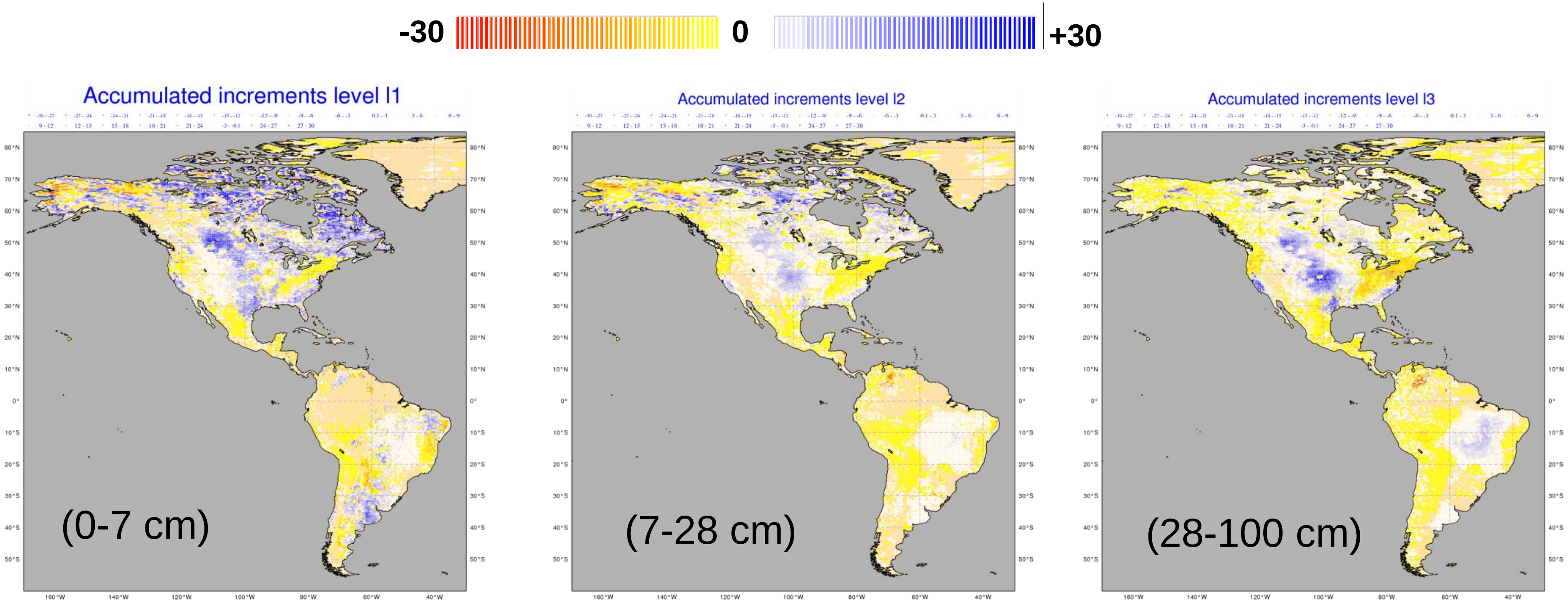
- $\Theta=40$ degrees
- Third layer (28-100 cm)
- $\delta w_3 = 0.01$ m^3m^{-3}
- Similar sensitivity XX-YY
- Lower sensitivity than for previous two layers.
- Stronger sensitivity in central US in the morning, and in West of S. America in the evening.

Gain Matrix



- Θ=40 degrees
- First soil layer (0-7 cm)
- $\delta w_1 = 0.01\ m^3m^{-3}$
- Similar for YY

Accumulated soil moisture increments in mm



- Despite first layer thinner, it has the strongest increments
- Strong increment in center of US for deepest layer
- Coherent with Jacobians and Gain matrix

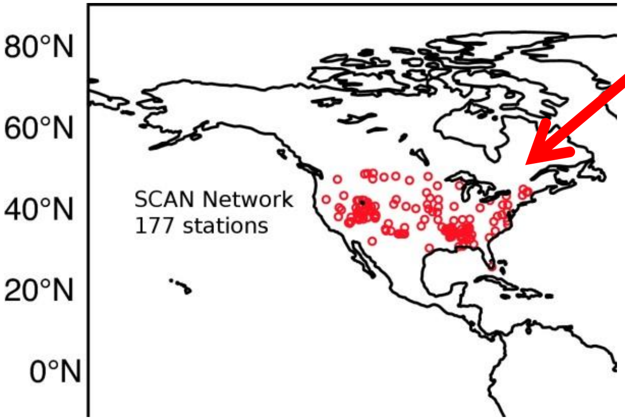
Validation with SCAN network observations; Layer 1 (0-7 cm) vs. in-situ (~5cm)

- Only same stations are used for the comparison

	CTRL	SMOS + ~BC	SMOS + CDF
R	0.550	0.561	0.562
RMSD	0.126	0.125	0.129
Bias	-0.074	-0.076	-0.079

p-value < 0.05 → N=59

59 stations with significant R (p-value <0.05) in July - 2011



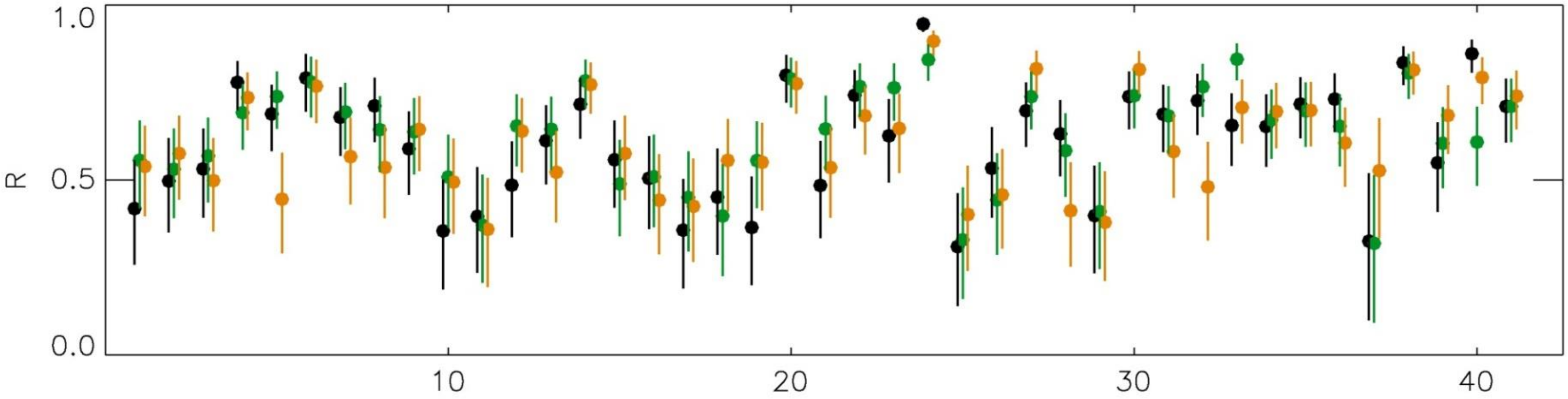
- Little quality control applied to measurements from NRCS-SCAN !
- *Dharssi et al. (2011)*; reject if $R<0.3$, $RMSD>0.2$ m^3m^{-3} and $SD>0.1$ m^3m^{-3}

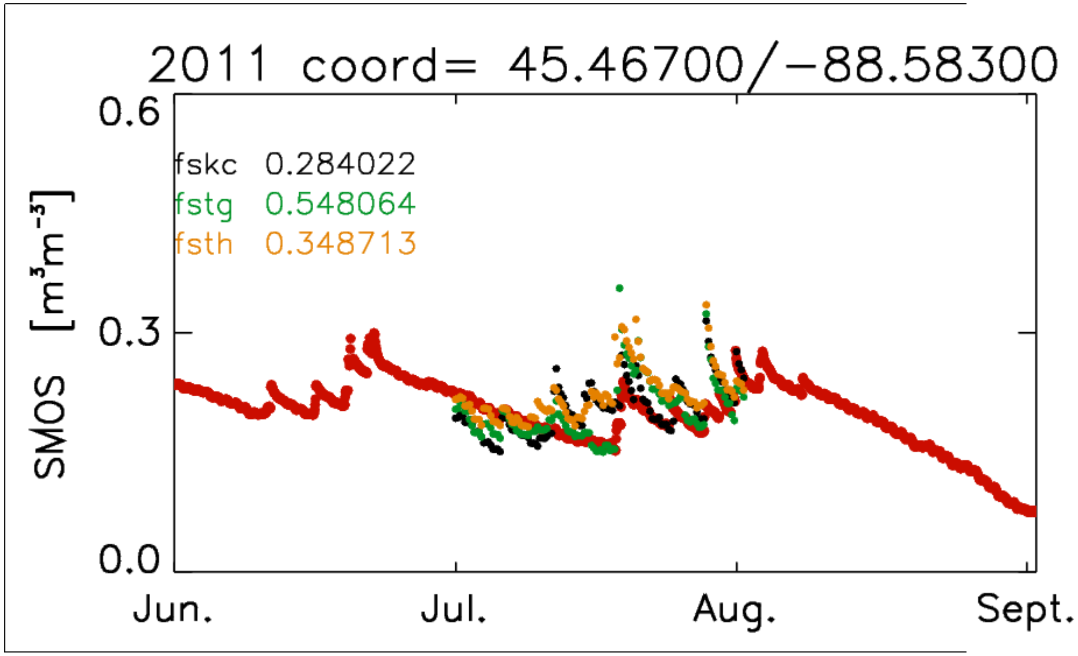
	CTRL	SMOS + ~BC	SMOS + CDF
R	0.638	0.631	0.653
RMSD	0.082	0.082	0.084
Bias	-0.029	-0.033	-0.033

p-value < 0.05 & R>0.3 & RMSD<0.2 → N=40

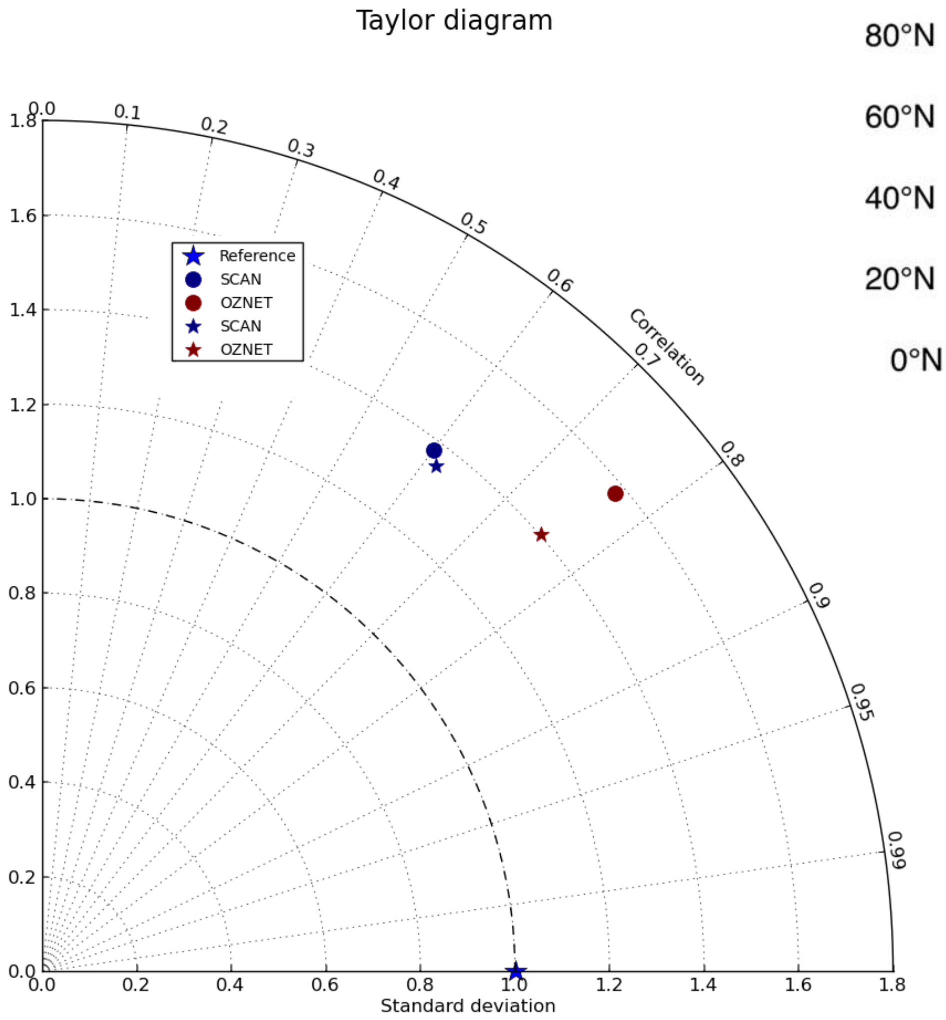
SCAN network: Layer 1 (0-7 cm) vs. in-situ (~5cm)

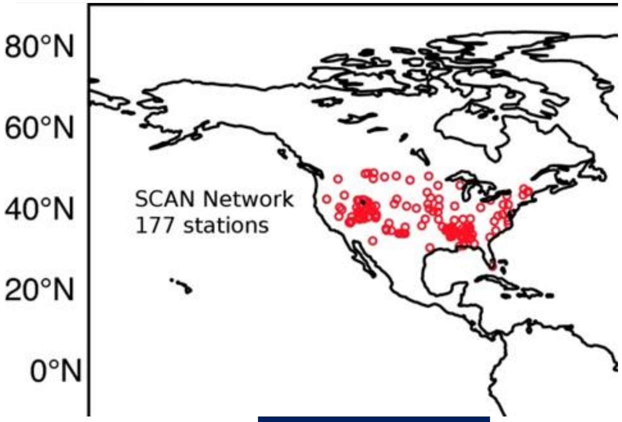
- For each R estimate a 95% Confidence Interval (CI) was calculated using a Fisher Z transform
- Small sample (1 month) ➔ large CI



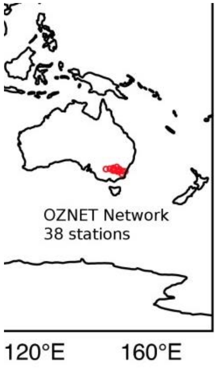


OSEs – validation against SCAN (America) and OZNET (Australia)





SCAN



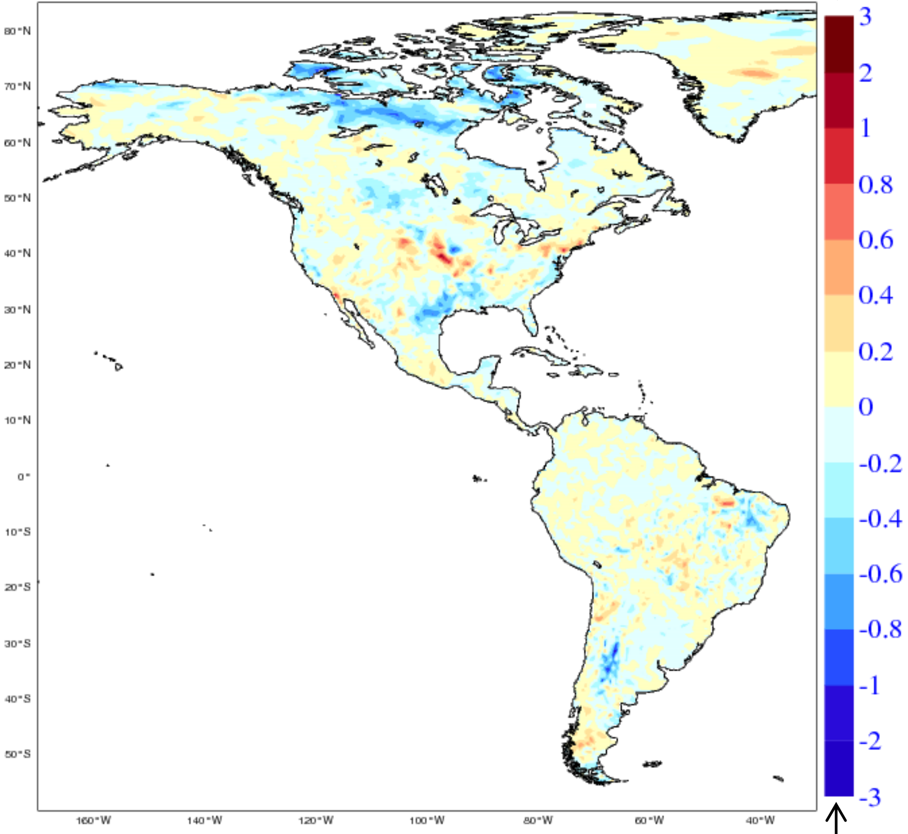
OZNET

ECMWF

24h T^{2m} and RH^{2m} forecast sensitivity

Heat up (K)

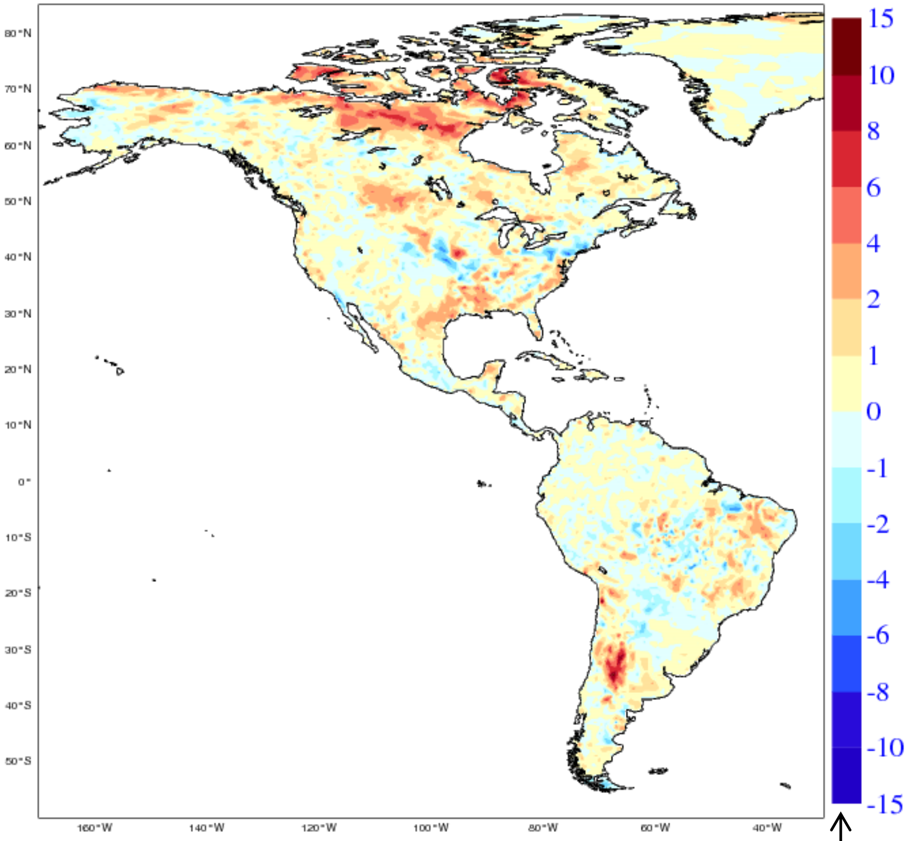
Friday 1 July 2011 00UTC ECMWF Forecast t+24 VT: Saturday 2 July 2011 00UTC Surface: **2 metre temperature
diff_mean_fc_err_T



Cool down (K)

Reduce moist (%)

Friday 1 July 2011 00UTC ECMWF Forecast t+24 VT: Saturday 2 July 2011 00UTC Surface: **2 metre dewpoint temperature
diff_mean_fc_err_RH

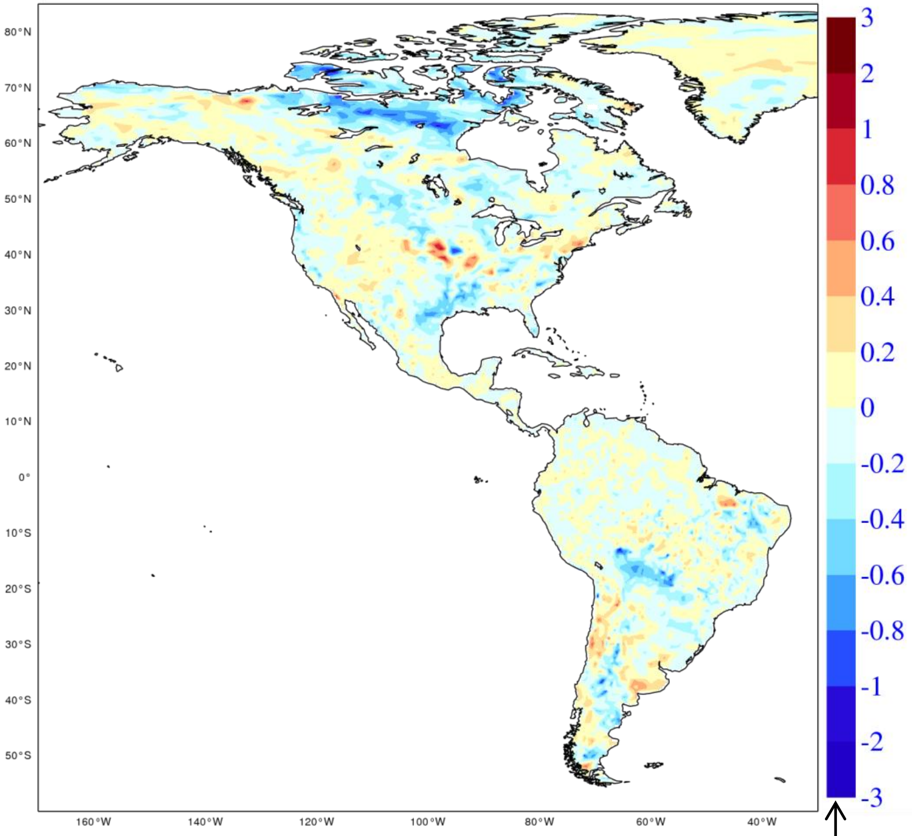


Increase moist (%)

48h T^{2m} and RH^{2m} forecast sensitivity

Heat up (K)

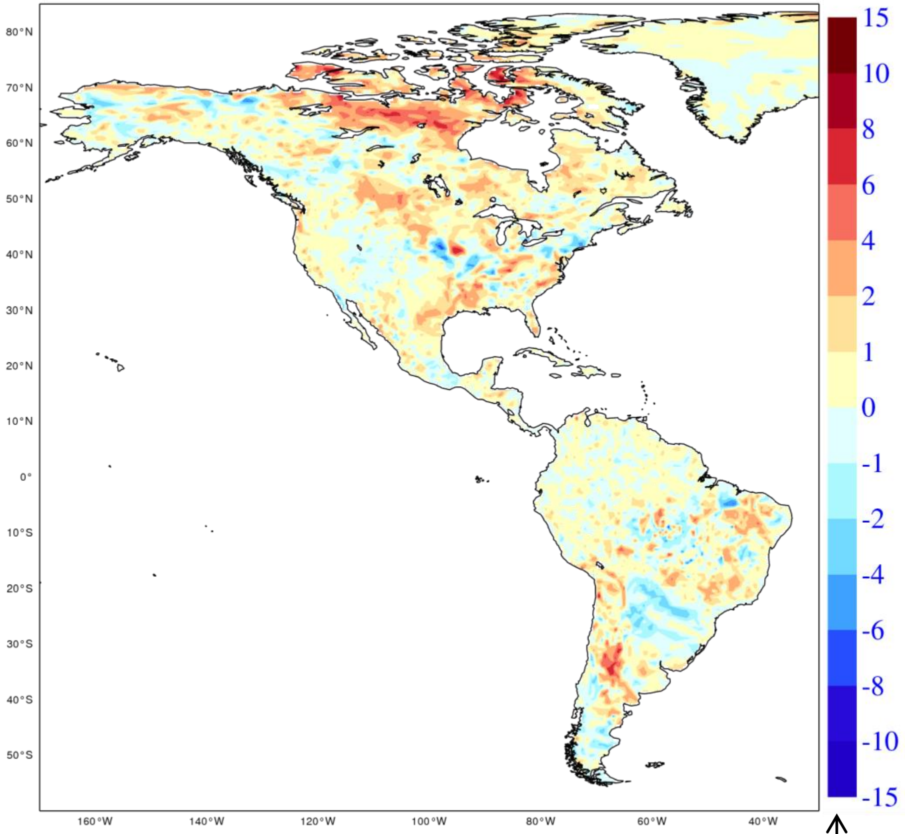
Friday 1 July 2011 00UTC ECMWF Forecast t+48 VT: Sunday 3 July 2011 00UTC Surface: **2 metre temperature
diff_mean_fc_err_T48



Cool down (K)

Reduce moist (%)

Friday 1 July 2011 00UTC ECMWF Forecast t+48 VT: Sunday 3 July 2011 00UTC Surface: **2 metre dewpoint temperature
diff_mean_fc_err_RH48



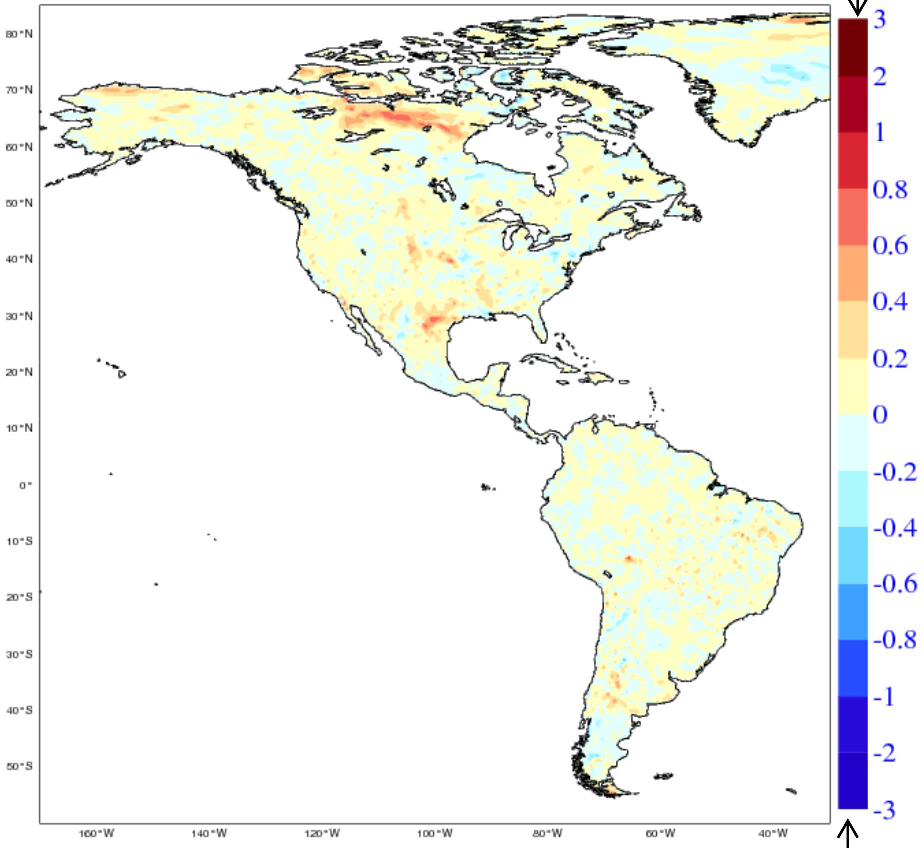
Increase moist (%)

ECMWF

24h T^{2m} and RH^{2m} forecast errors

Degrade (K)

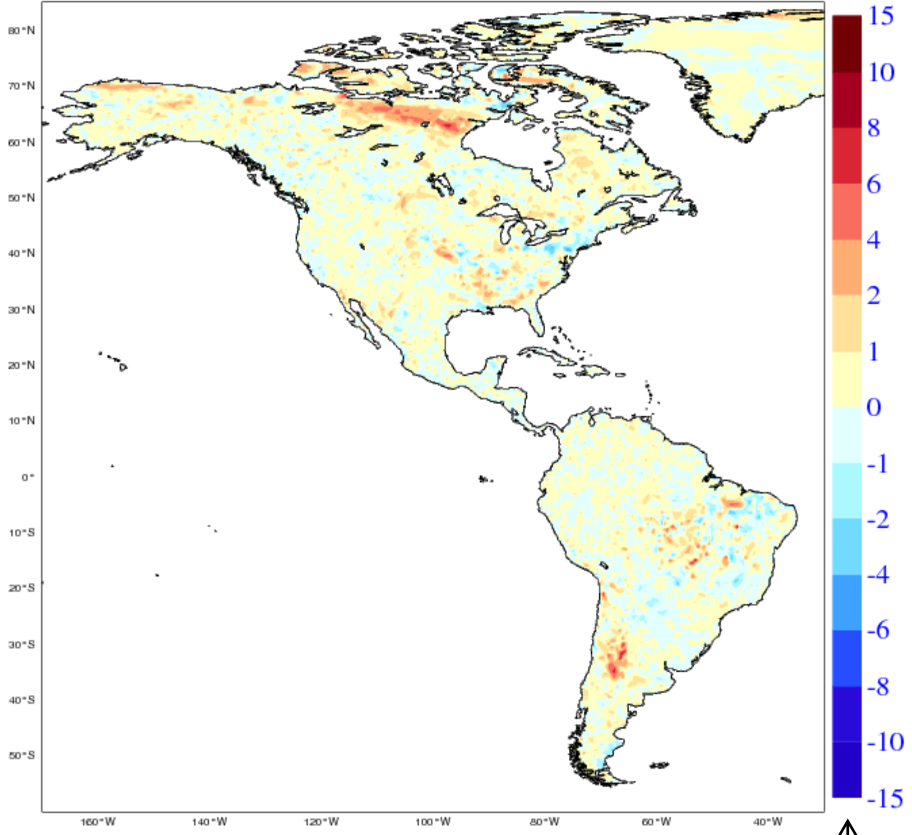
Friday 1 July 2011 00UTC ECMWF Forecast t+24 VT: Saturday 2 July 2011 00UTC Surface: **2 metre temperature
diff_meanabs_fc_err_T



Improve (K)

Degrade (%)

Friday 1 July 2011 00UTC ECMWF Forecast t+24 VT: Saturday 2 July 2011 00UTC Surface: **2 metre dewpoint temperature
diff_meanabs_fc_err_RH

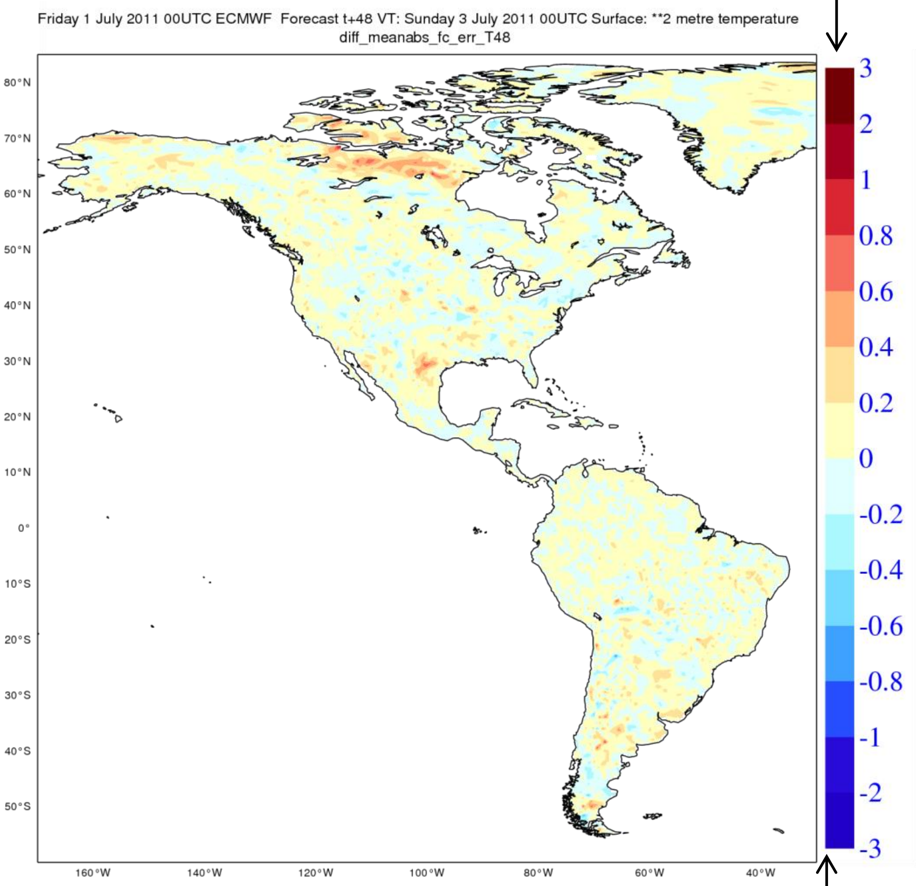


Improve (%)

ECMWF

48h T^{2m} and RH^{2m} forecast errors

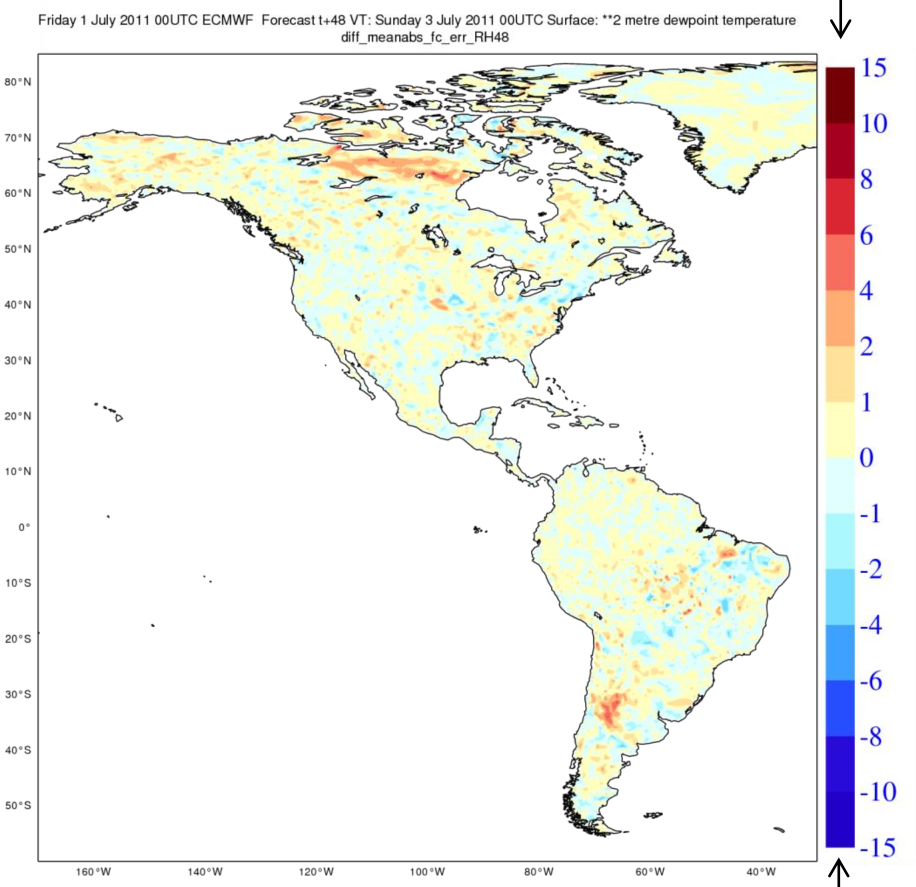
Degrade (K)



Friday 1 July 2011 00UTC ECMWF Forecast t+48 VT: Sunday 3 July 2011 00UTC Surface: **2 metre temperature
diff_meanabs_fc_err_T48

Improve (K)

Degrade (%)



Friday 1 July 2011 00UTC ECMWF Forecast t+48 VT: Sunday 3 July 2011 00UTC Surface: **2 metre dewpoint temperature
diff_meanabs_fc_err_RH48

Improve (%)

ECMWF

SMOS data assimilation study at ECMWF

- Technical implementation and experimentation,
- Jacobians and SEKF calibration,
- DA impact experiments,
- SMOS-DA-v1.0

SMOS–DA–v1.0

- Assimilation of SMOS T_B in the antenna reference frame at **global** scale (SEKF)
  - Period: **1 May 2010** 00UTC – **31 October 2012** 12UTC analysis
  - Resolution: **T511** (~40 km)
  - Observations:
    - NRT brightness temperatures (**Second reprocessed dataset 2010-2011**),
    - **30, 40, 50** degrees $\pm \Delta T_B$=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
  - CMEM configuration; best for R (Wang(DIEL), Wsimple(RGH), Wigneron(VEG))
  - **Jacobians calibrated** ($\Delta\theta j=0.01 m^3m^{-3}$, $/H^-_{max}/ = /H^+_{max}/ = 250\ K/m^3m^{-3}$)
  - **STD of observations error →** radiometric accuracy
  - Full observational system used for the atmosphere,

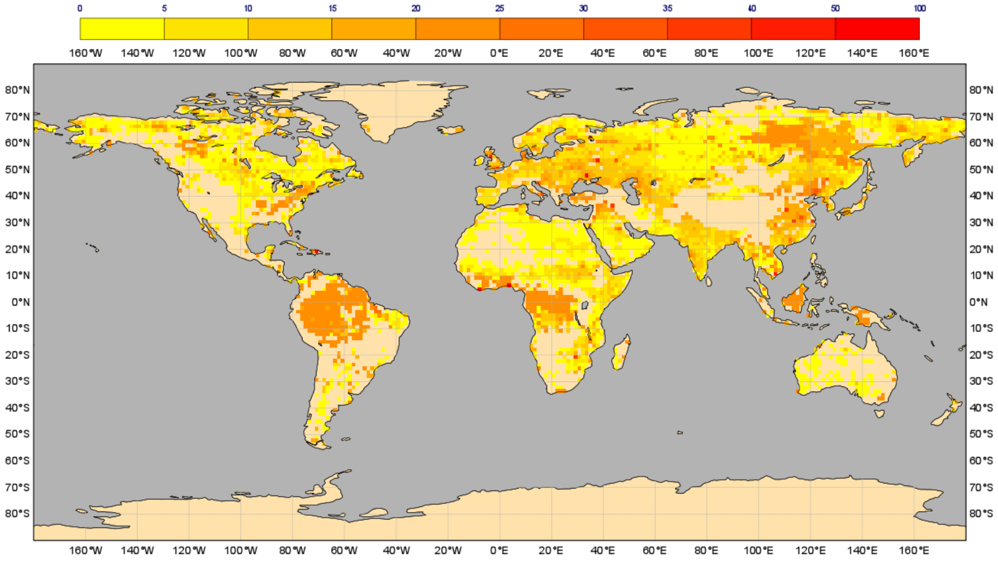
- **CTRL:** assimilation of T^{2m}, RH^{2m}
- **SMOS-DA-v1.0**: assimilation of T^{2m}, RH^{2m} + SMOS T_B CDF

ECMWF

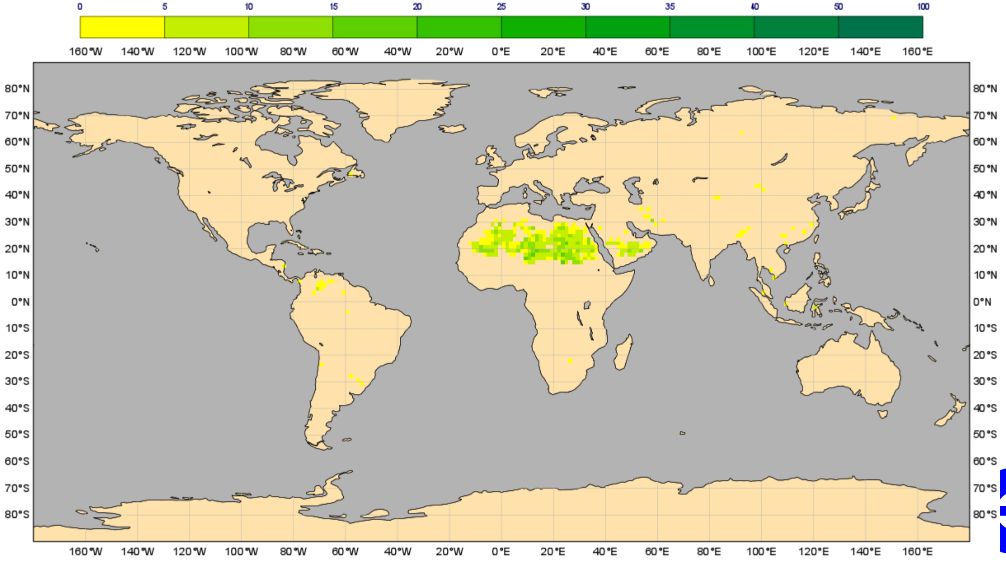
SMOS–DA–v1.0 - Quality Control

- Quality control for **May-June 2010**.
- Most of the rejections are produced by the first-guess check.
- Large bias remaining in tropical forests, East Asia, East US and some part of Middle East
- Only a few observations rejected by large too large sensitivity, but keeping good sensitivity in other very responsive regions.

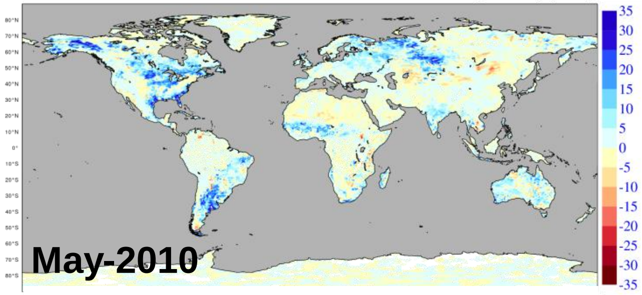
Percentage of rejected observations by first-guess check

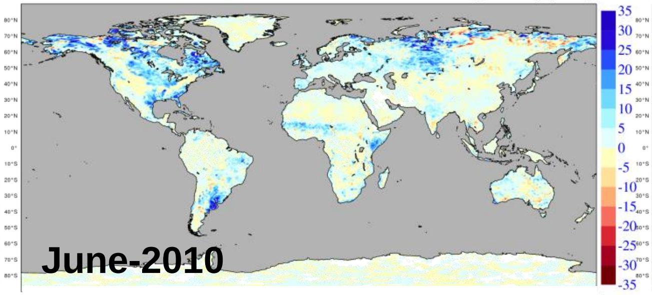


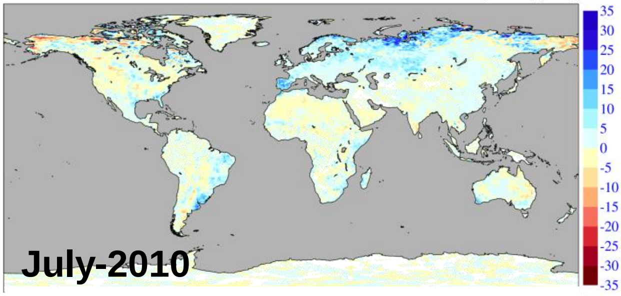
Number of rejected observations by too large sensitivity

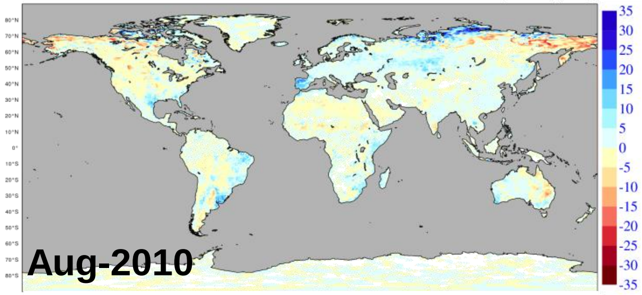


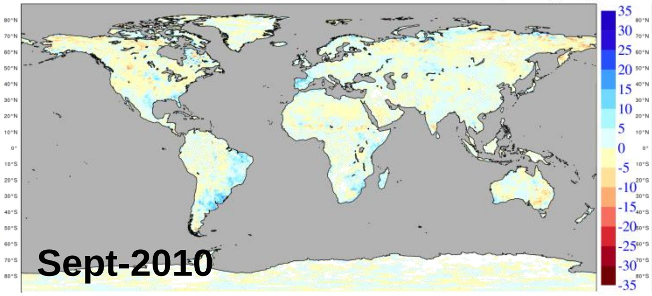
SMOS–DA–v1.0 - difference between accumulated SM increments SMOS-CTRL (0-7cm)

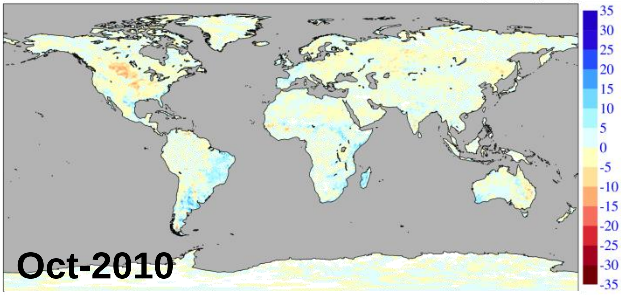

Month 05 2010 - difference accumulated increments (0-7cm) (mm)

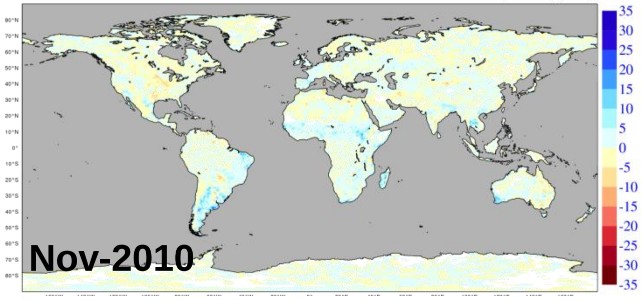

Month 06 2010 - difference accumulated increments (0-7cm) (mm)

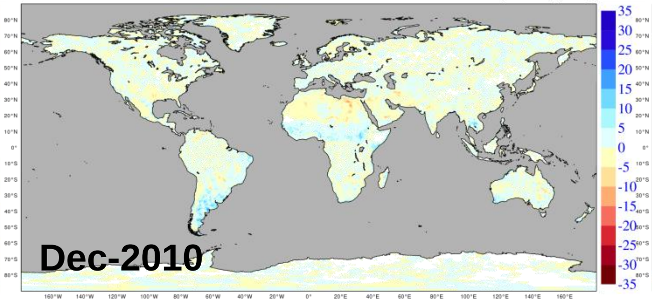

Month 07 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)

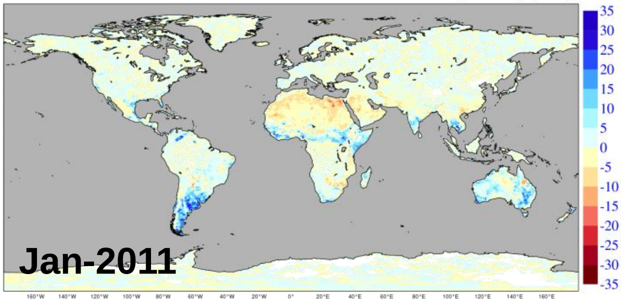

Month 08 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)

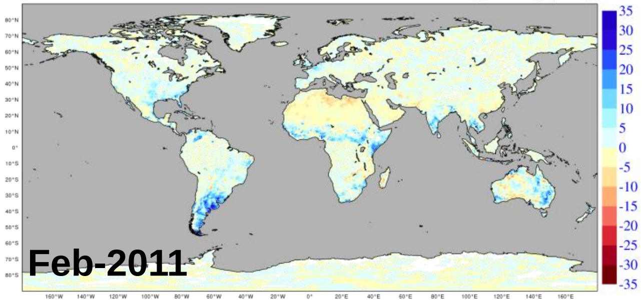

Month 09 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)


Month 10 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)


Month 11 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)


Month 12 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)

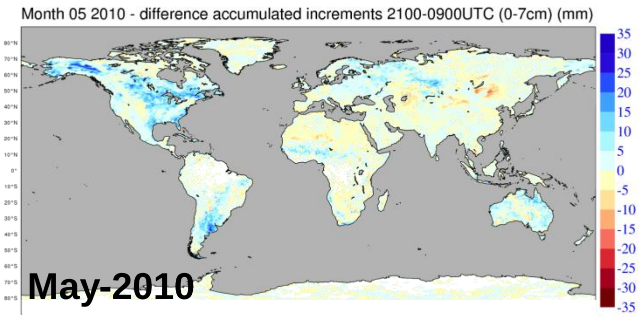

Month 01 2011 - difference accumulated increments (0-7cm) (mm)

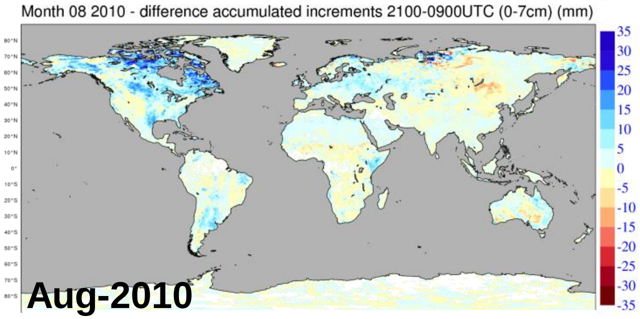

Month 02 2011 - difference accumulated increments (0-7cm) (mm)

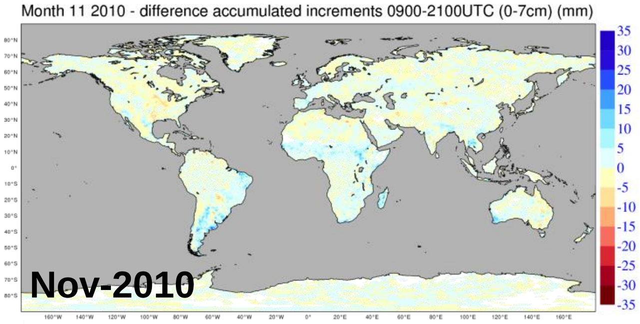
ECMWF

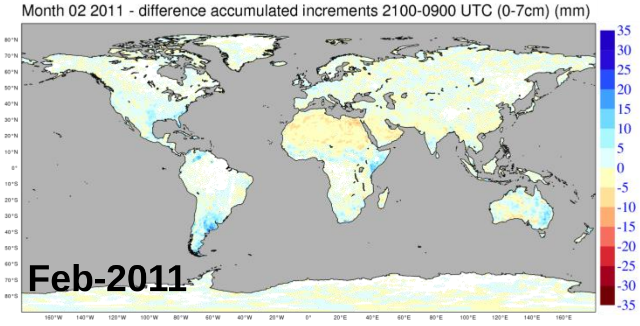
SMOS–DA–v1.0 - difference between accumulated SM increments SMOS-CTRL (0-7cm)

2100-0900 UTC increments

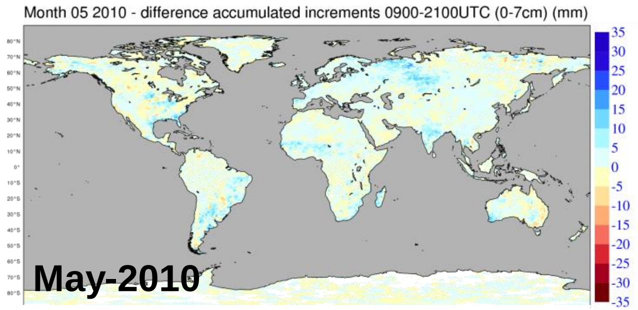

Month 05 2010 - difference accumulated increments 2100-0900UTC (0-7cm) (mm)

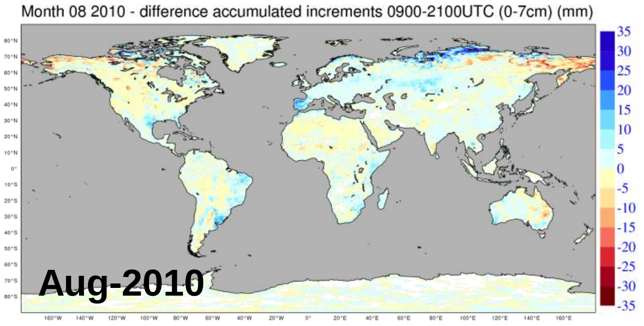

Month 08 2010 - difference accumulated increments 2100-0900UTC (0-7cm) (mm)

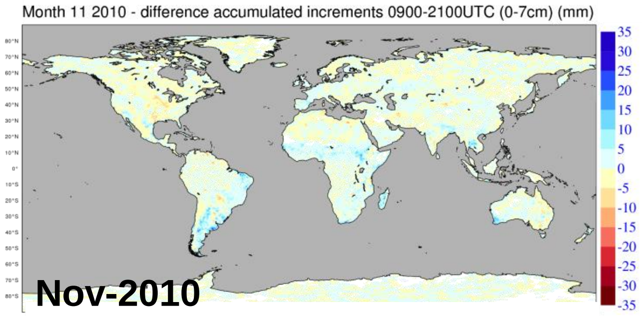

Month 11 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)

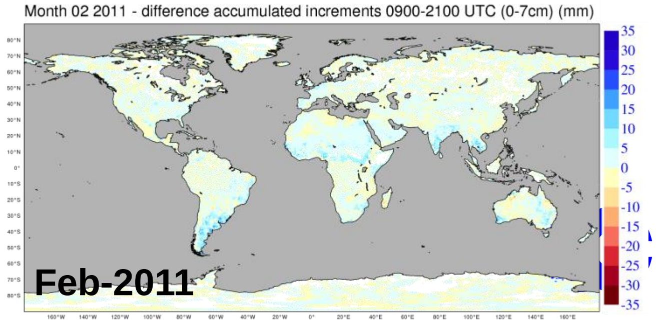

Month 02 2011 - difference accumulated increments 2100-0900 UTC (0-7cm) (mm)

0900-2100 UTC increments

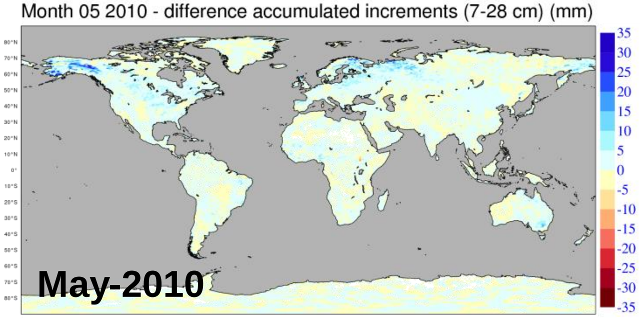

Month 05 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)


Month 08 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)

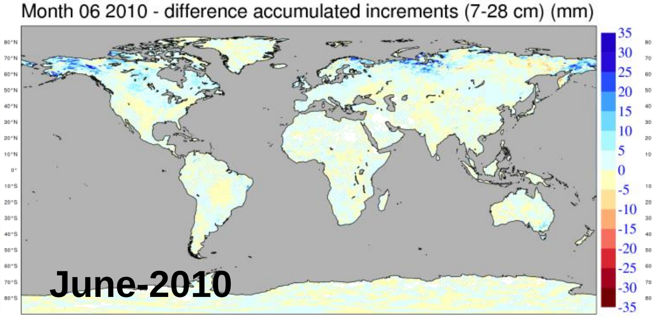

Month 11 2010 - difference accumulated increments 0900-2100UTC (0-7cm) (mm)


Month 02 2011 - difference accumulated increments 0900-2100 UTC (0-7cm) (mm)

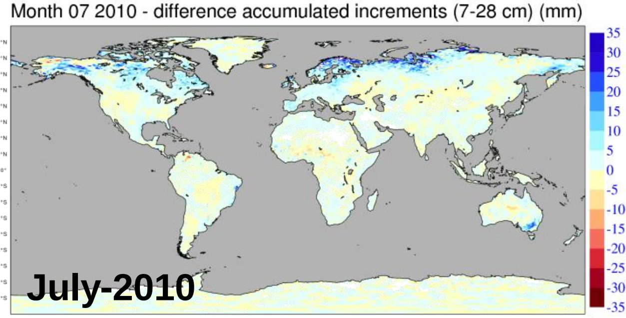
SMOS–DA–v1.0 - difference between accumulated SM increments SMOS-CTRL (7-28cm)


Month 05 2010 - difference accumulated increments (7-28 cm) (mm)

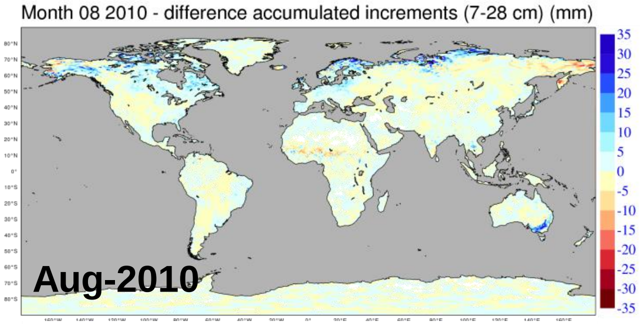
May-2010


Month 06 2010 - difference accumulated increments (7-28 cm) (mm)

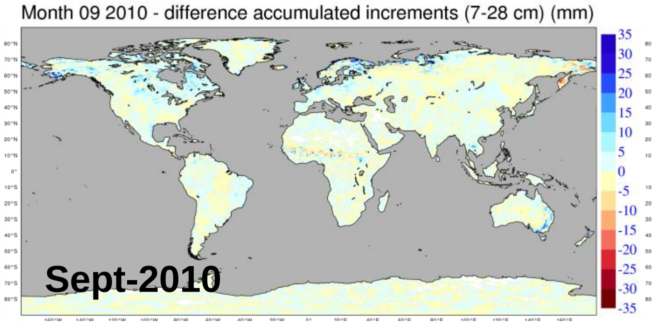
June-2010


Month 07 2010 - difference accumulated increments (7-28 cm) (mm)

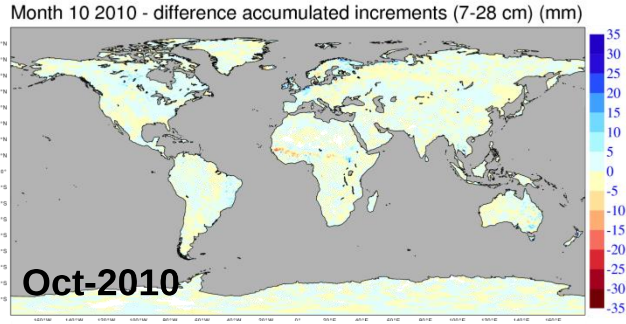
July-2010


Month 08 2010 - difference accumulated increments (7-28 cm) (mm)

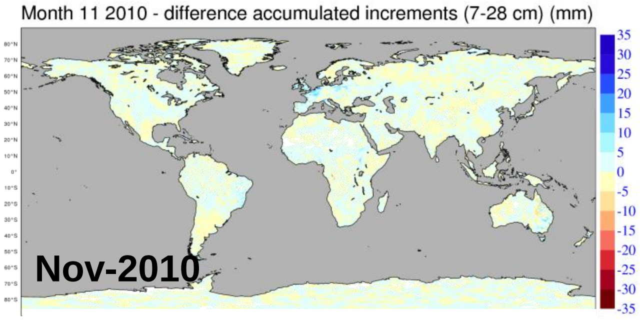
Aug-2010


Month 09 2010 - difference accumulated increments (7-28 cm) (mm)

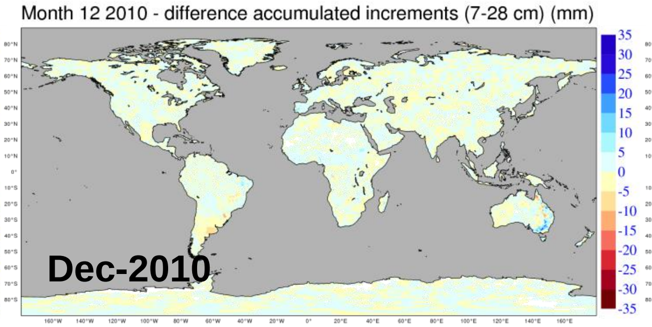
Sept-2010


Month 10 2010 - difference accumulated increments (7-28 cm) (mm)

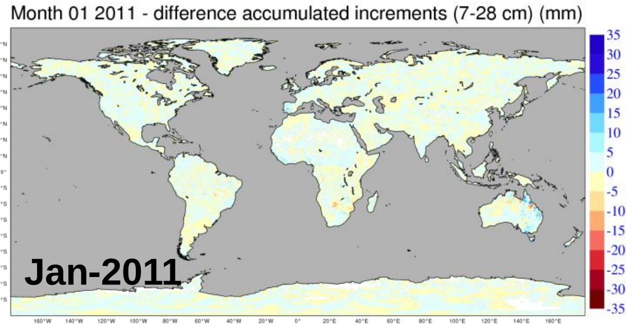
Oct-2010


Month 11 2010 - difference accumulated increments (7-28 cm) (mm)

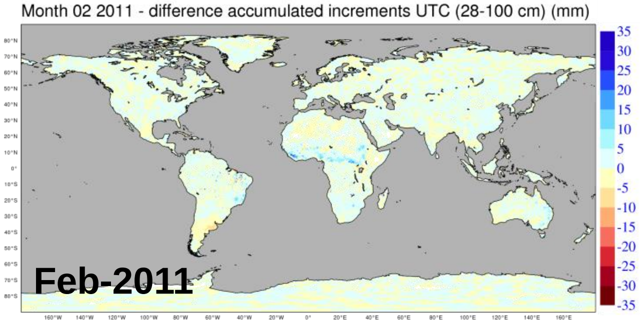
Nov-2010


Month 12 2010 - difference accumulated increments (7-28 cm) (mm)

Dec-2010


Month 01 2011 - difference accumulated increments (7-28 cm) (mm)

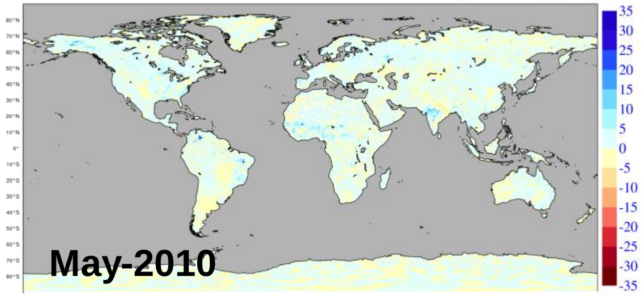
Jan-2011


Month 02 2011 - difference accumulated increments UTC (28-100 cm) (mm)

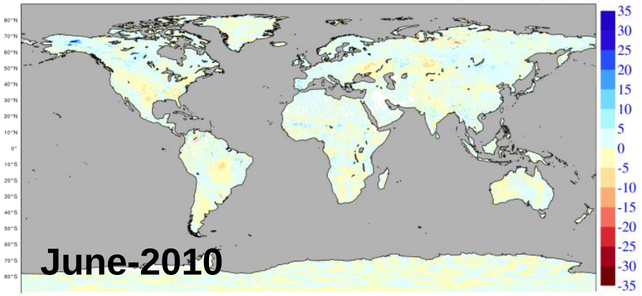
Feb-2011

SMOS–DA–v1.0 - difference between accumulated SM increments SMOS-CTRL (28-100cm)

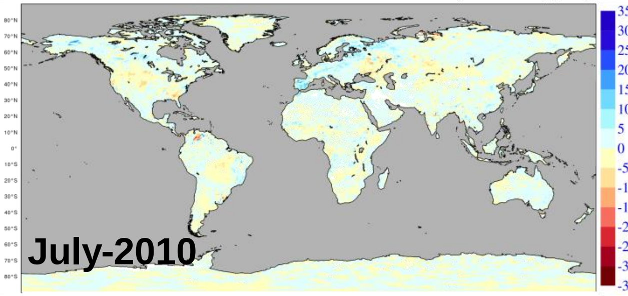
Month 05 2010 - difference accumulated increments UTC (28-100 cm) (mm)



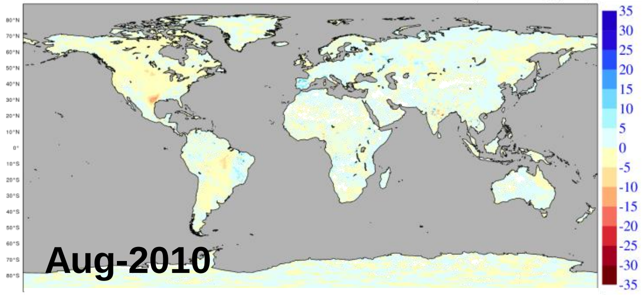
Month 06 2010 - difference accumulated increments UTC (28-100 cm) (mm)



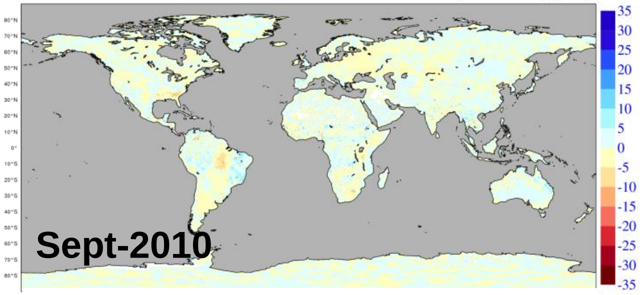
Month 07 2010 - difference accumulated increments UTC (28-100 cm) (mm)



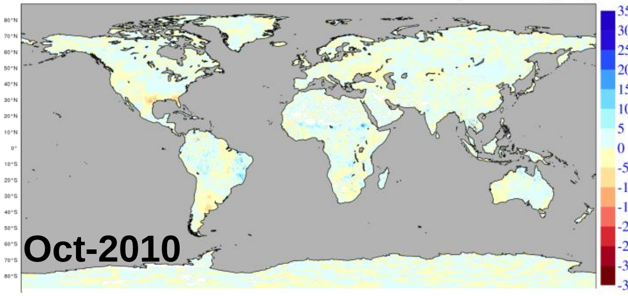
Month 08 2010 - difference accumulated increments 0900-2100 UTC (28-100 cm) (mm)



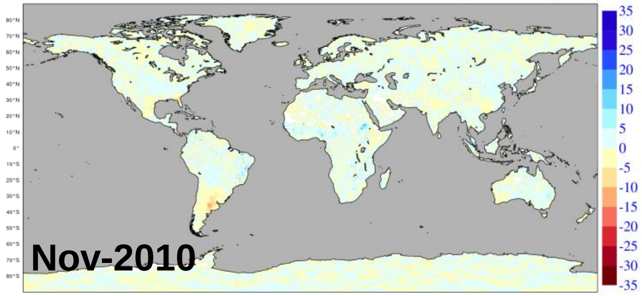
Month 09 2010 - difference accumulated increments UTC (28-100 cm) (mm)



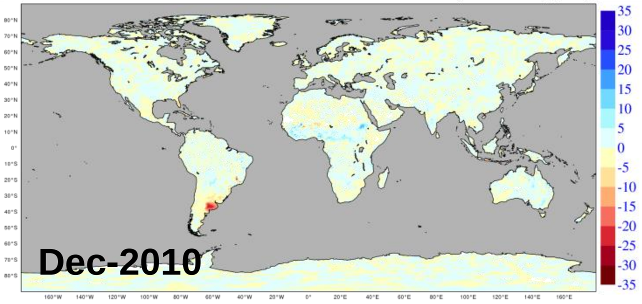
Month 10 2010 - difference accumulated increments UTC (28-100 cm) (mm)



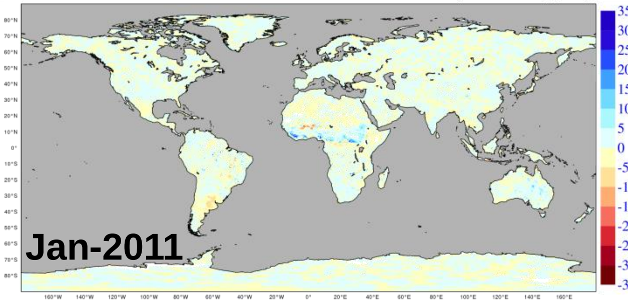
Month 11 2010 - difference accumulated increments UTC (28-100 cm) (mm)



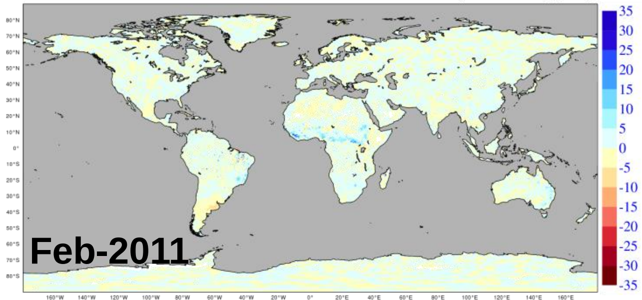
Month 12 2010 - difference accumulated increments UTC (28-100 cm) (mm)



Month 01 2011 - difference accumulated increments UTC (28-100 cm) (mm)

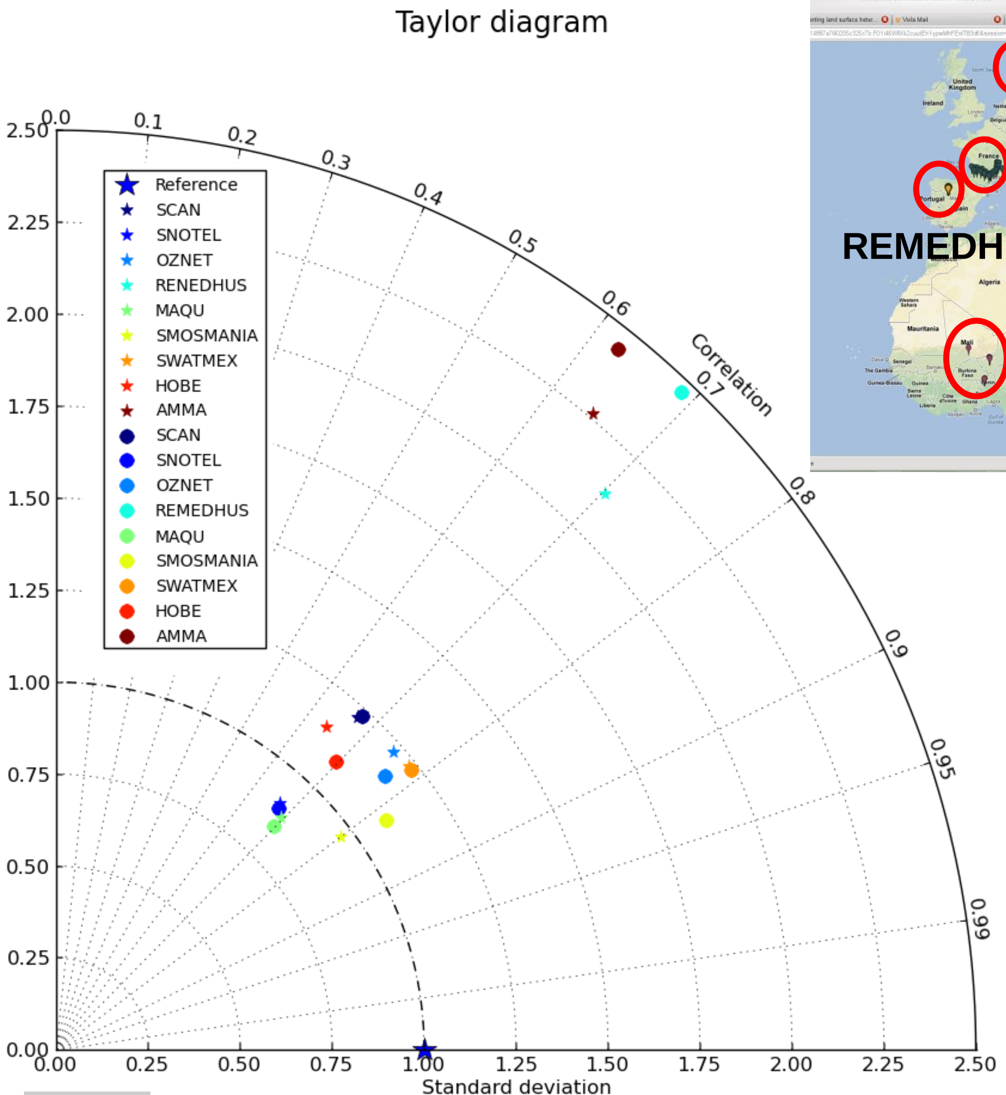


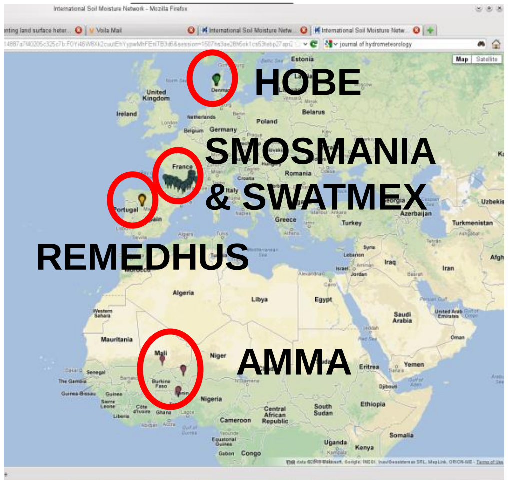
Month 02 2011 - difference accumulated increments UTC (28-100 cm) (mm)

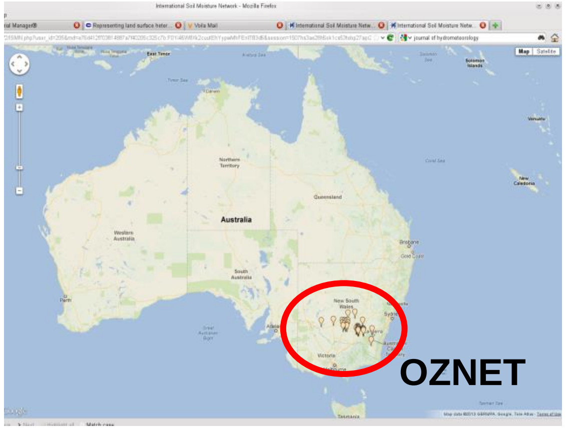


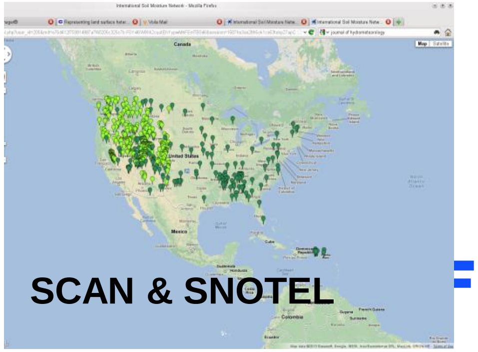
ECMWF

SMOS–DA–v1.0 - Validation





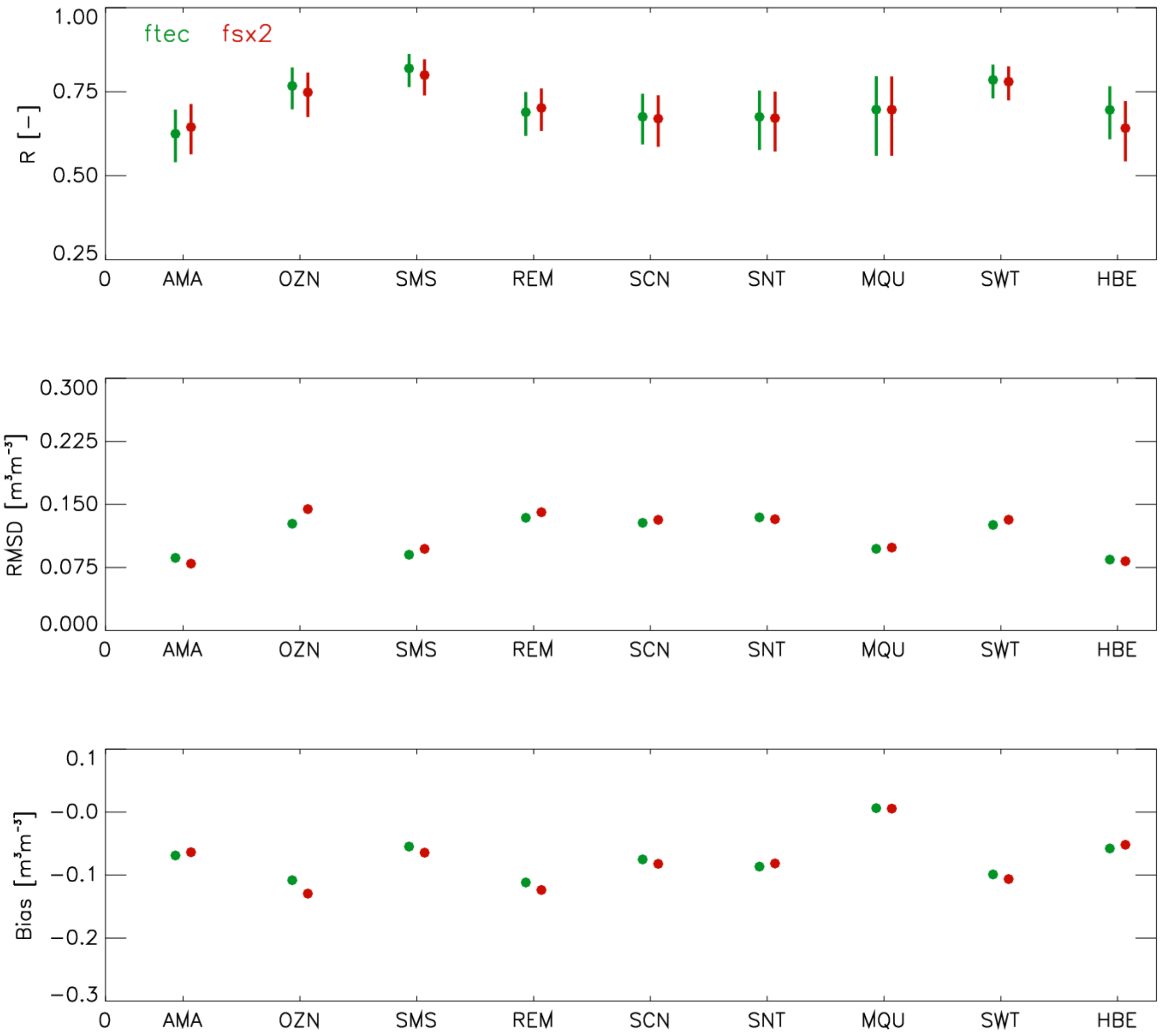




★ **SMOS exp analysis against observations**

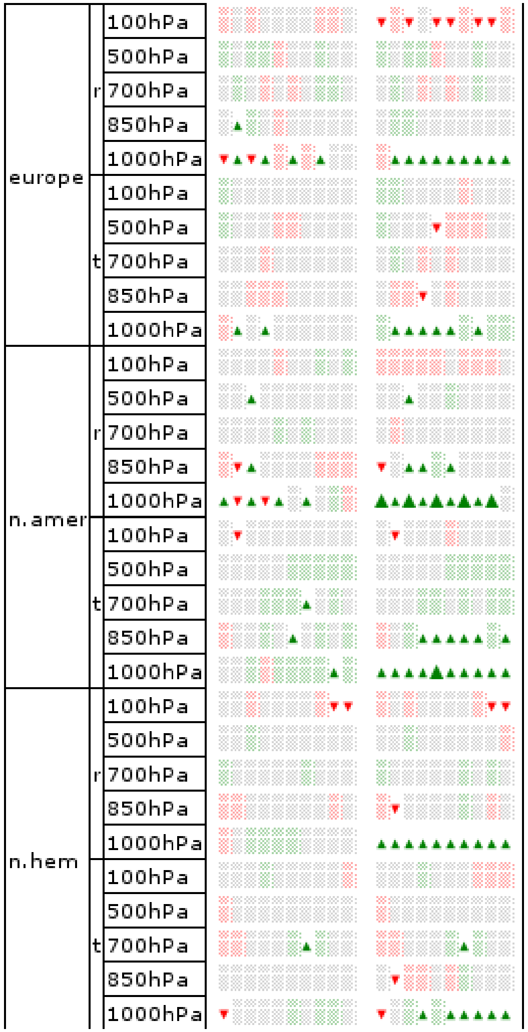
● **Control analysis against observations**

SMOS–DA–v1.0 - Validation

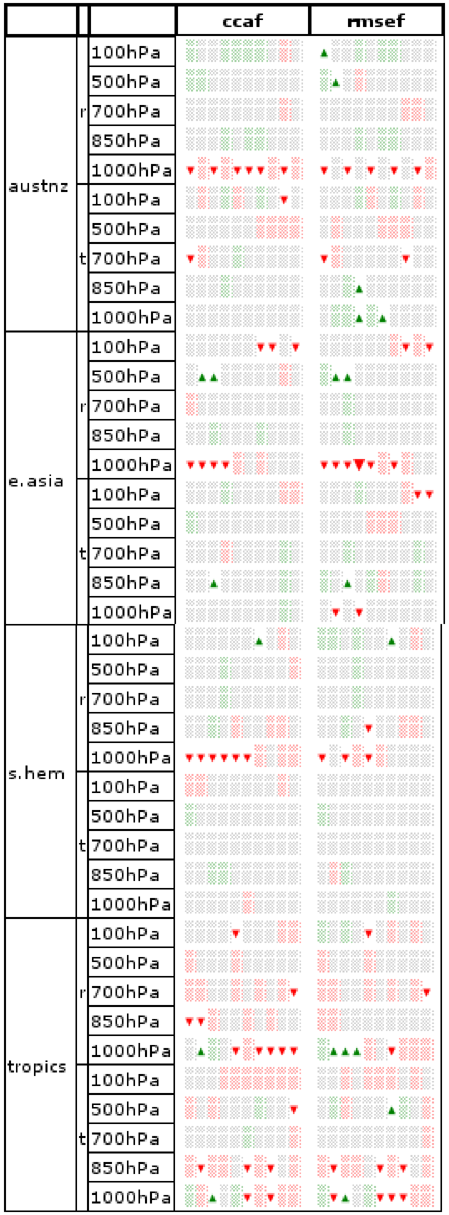


SMOS–DA–v1.0 - Score cards May–Oct 2010

Rather positive impact in…



Rather negative impact in…



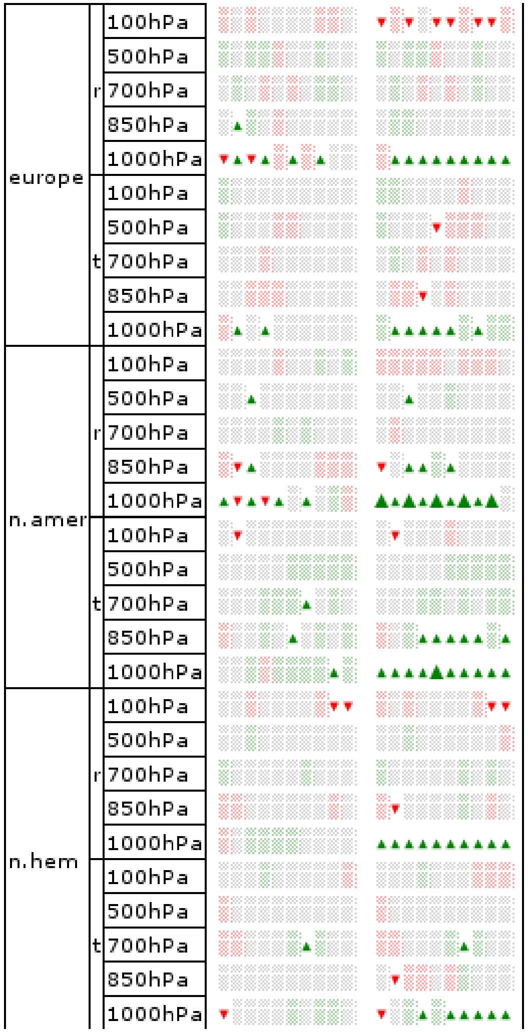
Includes China, Japan and Mongolia → RFI!!

Rather small impact compared to NH → less data?

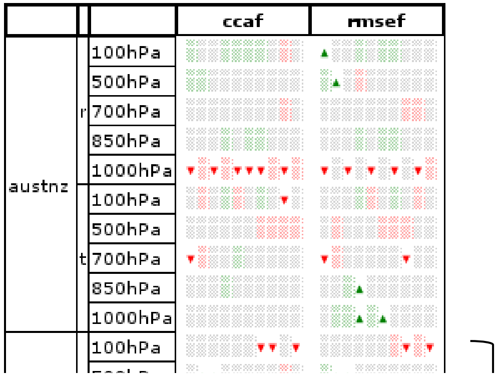
Strong bias remaining?

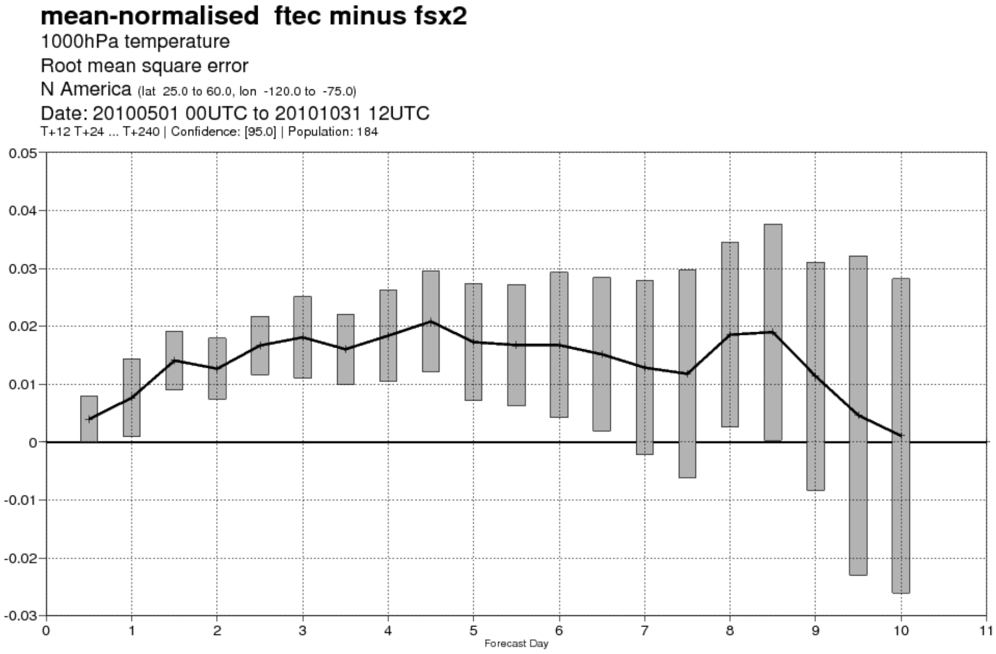
SMOS–DA–v1.0 - Score cards May–Oct 2010

Rather positive impact in…



Rather negative impact in…




mean-normalised ftec minus fsx2

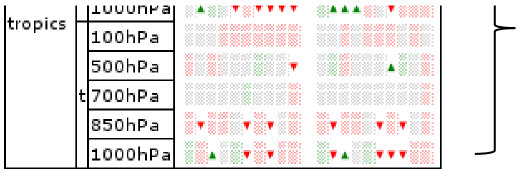
1000hPa temperature

Root mean square error

N America (lat 25.0 to 60.0, lon -120.0 to -75.0)

Date: 20100501 00UTC to 20101031 12UTC

T+12 T+24 ... T+240 | Confidence: [95.0] | Population: 184



Strong bias remaining?

Summary / Conclusions

- SMOS is now part of the ECMWF SEKF and can be used synergetically with ASCAT data and screen level variables,
- Some elements of the SEKF have been calibrated:
    - Linearised jacobians → the optimal perturbation of soil moisture is between 0.005 m^3m^{-3} and 0.01 m^3m^{-3}.
    - For that soil perturbation, the largest sensitivity allowed is 250 K/m^3m^{-3}.
    - The SMOS elements of the R matrix are equal to the radiometric sensitivity of each individual observation.
- Several OSEs have been run;
    - For America strong sensitivity is found for the Northern and Southernmost regions. Also for center US, but likely produced by different physical processes,
    - Validation against in situ data of the SCAN network shows slightly positive impact of SMOS data on soil moisture,
    - Slight degradation against OZNET observations in terms of R, but better in the amplitude of the SM variations,
    - The assimilation of SMOS data in US suggests some cooling of the lowest atmosphere, and viceversa for the relative humidity

Summary / Conclusions

- Production of Level3 SM product,
    - Nearly a year of product processed (approx 4 processed months per month)
    - Validation against in-situ data shows quite neutral behaviour,
    - Significant positive impact is found for T and RH in the North Hemisphere (extratropics),
    - Rather negative impact for the Tropics and for RH in Australia

Way forward

- Suggested improvements/areas of further research
  - There are still concerns with bias → more work needed on bias correction,
  - Other elements of the SEKF need tuning/calibration,
  - Some land improvements could be very beneficial to reduce bias (lakes, better soil texture maps, etc.) → sensitivity studies
  - B-matrix cycling impact,
  - More experimentation and analysis would be beneficial (together with ASCAT data and without any other data),
- Further verification of the atmospheric impact;
  - Information content study of each incidence angle,
  - Sensitivity of the forecast to SMOS data (and each incidence angle)