ECMWF update

- Bias correction,
- Technical implementation of SMOS data in the ECMWF SEKF
- Use of the RFI flag

Bias correction

- Assimilation of SMOS data within the ECMWF SEKF relies on spatial-temporal agreement between simulated and observed brightness temperatures.
    - In general, strong bias are observed for most incidence angles and geographical areas,

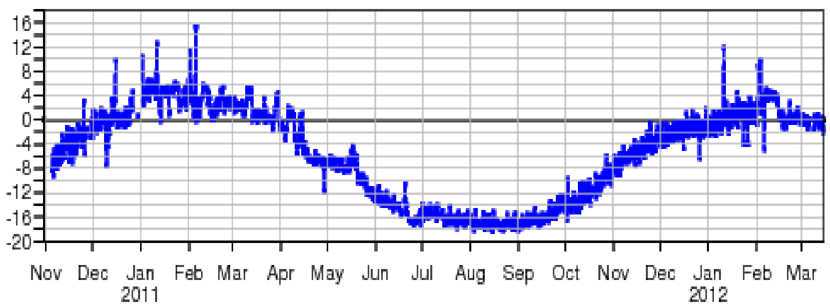
Monitoring results

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

XX polarisation	YY polarisation

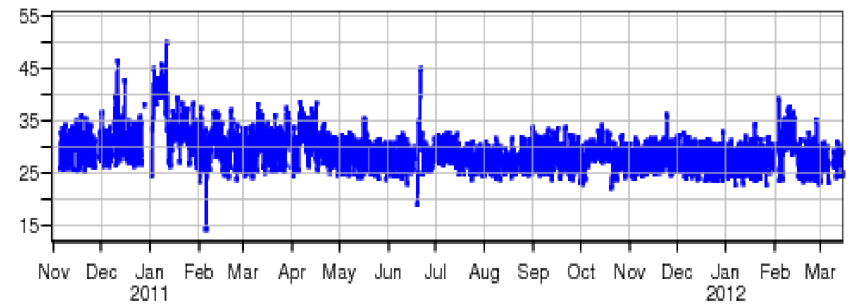
Mean Bias North-hemisphere

OBS-FG



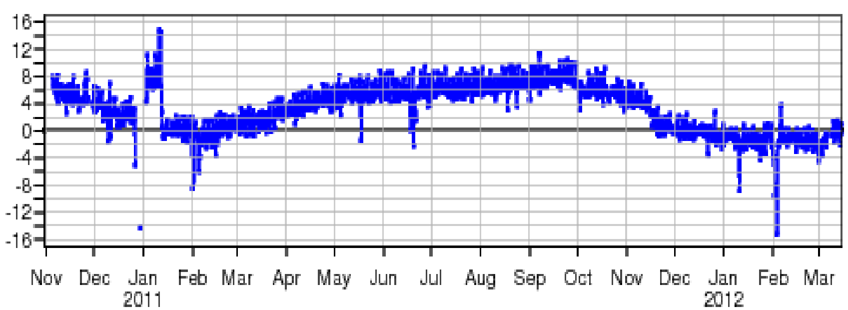
std(obs) North-hemisphere

stdv(OBS-FG)



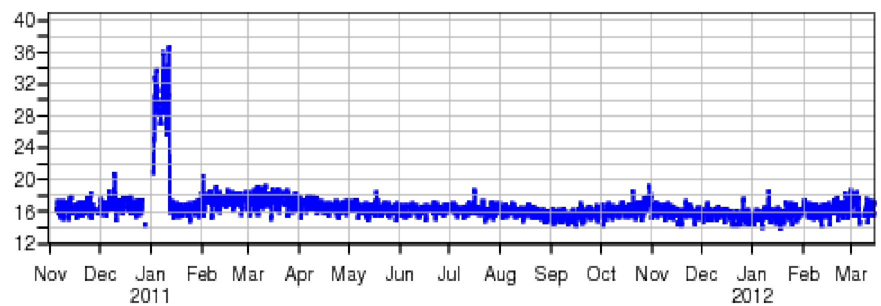
Mean Bias South-hemisphere

OBS-FG



std(obs) South-hemisphere

stdv(OBS-FG)



Bias correction

- Assimilation of SMOS data within the ECMWF SEKF relies on spatial-temporal agreement between simulated and observed brightness temperatures.
  - In general, strong bias are observed for most incidence angles and geographical areas,
  - If simulations of T_B are used as the reference, SMOS observations need to be unbiased before assimilation → a bias correction method is necessary,
  - CDF-matching aims to match the pdf of two data sets, ideally to a climatology issued of a long time series.
  - SMOS pdf of T_B is matched to that simulated by CMEM for the year 2010.

Bias correction

- First step to unbiased SMOS data;
  - Produce grib-files from BUFR files → drastically reduce data volume. Both, data and model need to be in the same grid.
  - Defines the spatial averaging requested when interpolating BUFR grid points to a regular lat-lon grid. Also any other filters can be requested (big slope, wetlands, field of view, etc.),
  - Bufr_to_grib made available to community at ECMWF SMOS website:

    http:/www.ecmwf.int/research/ESA_projects/SMOS/tools/smos_tools.html
  - At T799 for a 6h period, from 2.14 GB in BUFR for all angles to 0.4 MB per file and polarisation → a very light product available for research purposes.

ECMWF

Bias correction

➢ Second step; Calibrate CMEM (calibration based on comparison against global observed T_B),

CMEM parameterizations:

- **Soil dielectric mixing model**
  (Wang & Schmugge / Dobson / Mironov)?
- **Effective temperature model**
  (Choudhurry / Wigneron / Holmes)?
- **Smooth surface emissivity model**
  (Fresnel / Wilheit)?
- **Soil roughness model**
  (None = Smooth / Choudhury / Wegmuller / Wigneron 01/07)
- **Vegetation opacity model**
  (None / Kirdyashev / Wegmuller / Wigneron / Jackson)?
- **Atmospheric radiative transfer model**
  (None / Pellarin / Liebe / Ulaby)?

SOIL

VEGETATION

ATMOSPHERE

- Equivalent to L-MEB when options in red are chosen

ECMWF

Bias correction

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SOIL

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VEGETATION

- **Atmospheric radiative transfer model**
  (None / Pellarin / Liebe / Ulaby)?

ATMOSPHERE

- Equivalent to L-MEB when options in red are chosen

Current SMOS monitoring suite based on:

- Wang (diel)
- Choudhury (roughness)
- Kirdyashev (vegetation)

References:

- Drusch et al., 2009
- de Rosnay et al., 2009
- Sabater et al., 2012

ECMWF

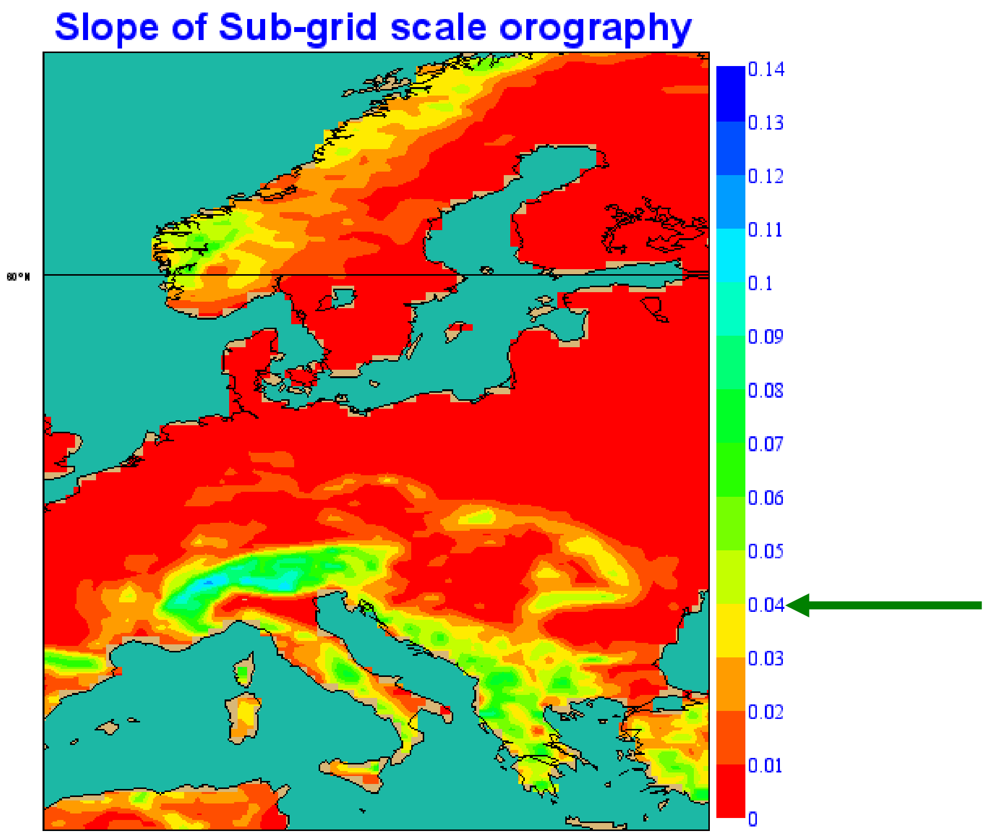
Bias correction

- ➢ Second step: calibrate CMEM (calibration based on comparison against global observed TBs),

  - ➢ Global (computationally affordable) calibration based on the key components:
    - Dielectric Model
    - Roughness Model
    - Vegetation Opacity

  - ➢ 18 years of offline CMEM simulations at 40 degrees incidence angle:
    - Atmospheric forcing comes from ERA-Interim
    - Last version of HTESSEL is used (includes new evaporation scheme over bare soil and LAI cycle),

  - ➢ For both calibration and CDF matching, filter as:
    - Slope index larger than 4% (using ECMWF slope index parameter)
    - Snow covered areas
    - Freezing temperature areas.



ECMWF

Bias correction

• Annual mean bias between SMOS T_B (recalibrated data set in 2010) and CMEM offline simulations, at 40 degrees. Data between 3 and 9 AM.

TBXX (K)

	Wang	Dobson	Mironov	Ro
Jackson	-21.5 13.1	-20.6 17.6	-21.8 11.5	**Ch** **Wi**
Wigneron	-20.0 22.2	-19.0 25.2	-20.2 20.6	**Ch** **Wi**
Kirdyashev	-21.0 23.5	-19.8 29.3	-21.2 22.1	**Ch** **Wi**

TBYY (K)

	Wang	Dobson	Mironov	Ro
Jackson	-10.8 8.5	-10.1 12.3	-10.9 7.9	**Ch** **Wi**
Wigneron	-9.9 14.34	-9.1 18.8	-10.1 13.8	**Ch** **Wi**
Kirdyashev	-11.1 14.6	-10.2 19.6	-11.2 14.2	**Ch** **Wi**

ECMWF

Bias correction

- Revised configuration of operational CMEM based on global comparison of SMOS reprocessed TB and CMEM offline simulation in 2010, at 40 degrees.
- Previous (preliminary) results suggest moving from Wang-Choudhury-Kirdyashev to Mironov-Wigneron-Jackson → lower bias and better correlation.

- Next step:
  - On-going CDF-matching → a & b monthly correction parameters (seasonal correction), independent for XX and YY polarisation, and 30, 40, 50 degrees,
  - Implementation in IFS.

Implementation of SMOS data in the SEKF

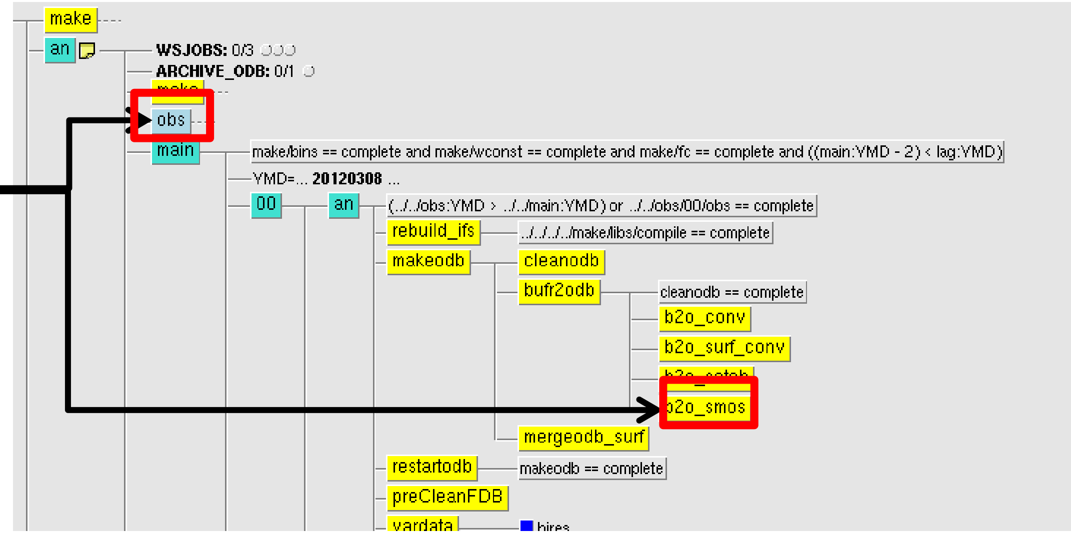
- Objective:
  - Develop structure necessary to accommodate SMOS data in the ECMWF version of the SEKF, and make it compatible with the monitoring suite and other data used for SM analysis (remote sensed and screen level variables)

- This is a very technical task, which has demonstrated to be also challenging and more complex than expected,
- Implementing SMOS data in the SEKF involves interacting and make compatible two spaces which are nearly independent (atmospheric 4DVAR space and SEKF space)

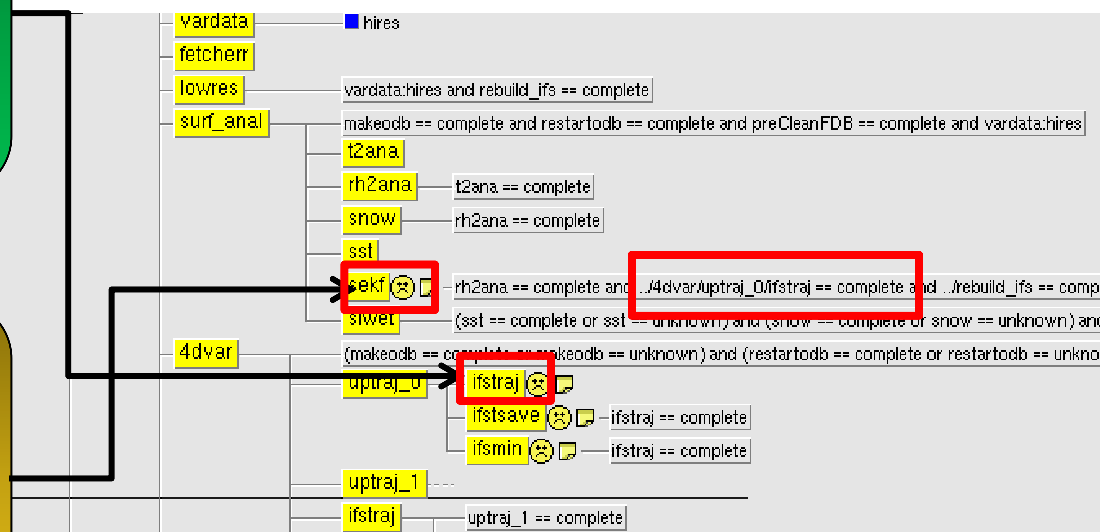
ECMWF

Implementation of SMOS data 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.

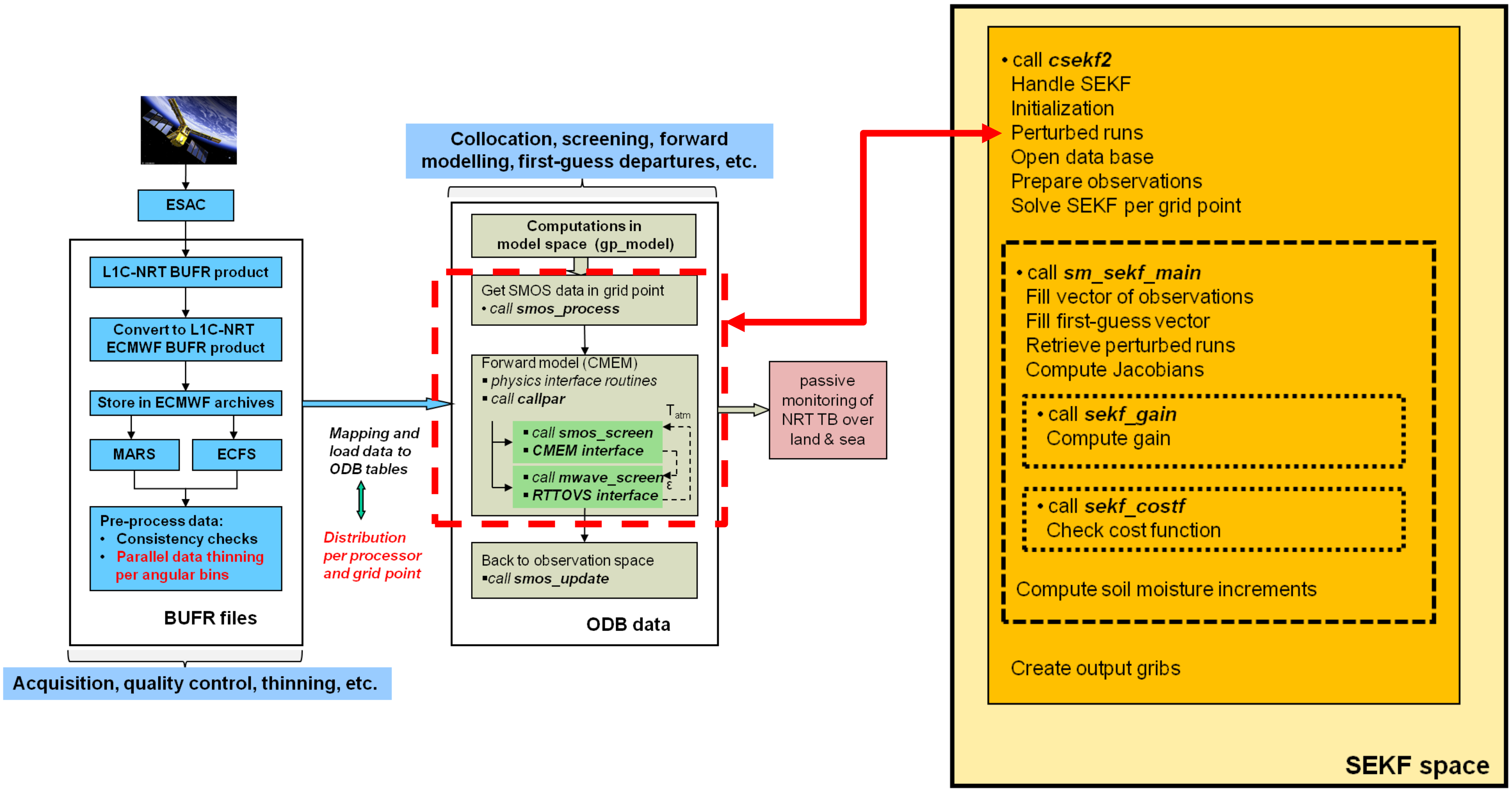


4DVAR space: collocation of observations with model grid, screening and flagging of each observation, forward model computation, feedback to ODB database, first-guess departures, monitoring statistics ,etc.



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.

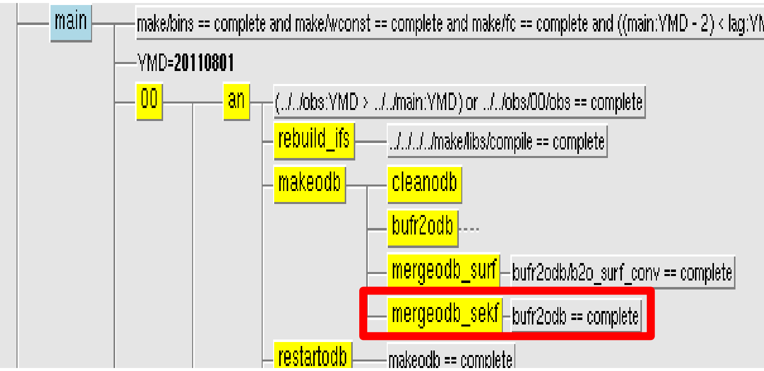
Implementation of SMOS data in the IFS



ECMWF

Implementation of SMOS data in the SEKF

- New features of SEKF:
  - SEKF can now assimilate:
    - only screen level variables,
    - screen level variables and (ASCAT OR SMOS) data.
    - screen level variables and (ASCAT AND SMOS) data,
    - only ASCAT soil moisture index,
    - only SMOS brightness temperatures,
    - only ASCAT and SMOS data.



  - 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).
  - memory used by SMOS reduced to a minimum, (still room for optimization),
  - CMEM configuration in SEKF independent of monitoring,
  - Configuration of assimilated observations controlled by name list,

ECMWF

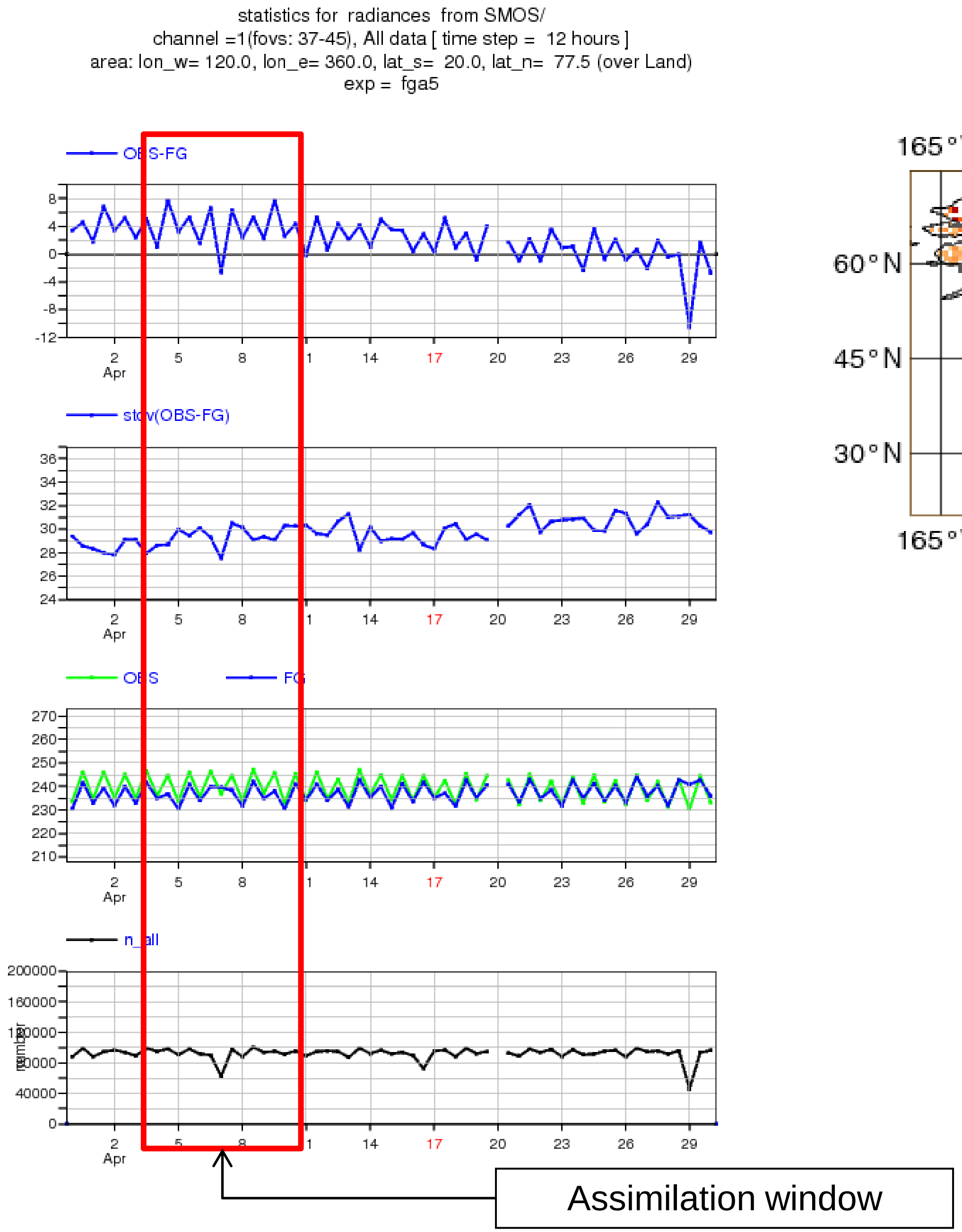
- Assimilation of SMOS T_B in the antenna reference frame, two preliminary case studies:
  - Period: 04 April 2011 00UTC – 10 April 2011 12UTC analysis
  - Resolution: T159 (~125 km)
  - Observations:
    - NRT brightness temperatures (standard product),
    - 40 degrees ± ΔT_B=0.5 K
    - XX & YY polarisations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

CASE a) North-America (low bias for XX-pol, start of the drying period)

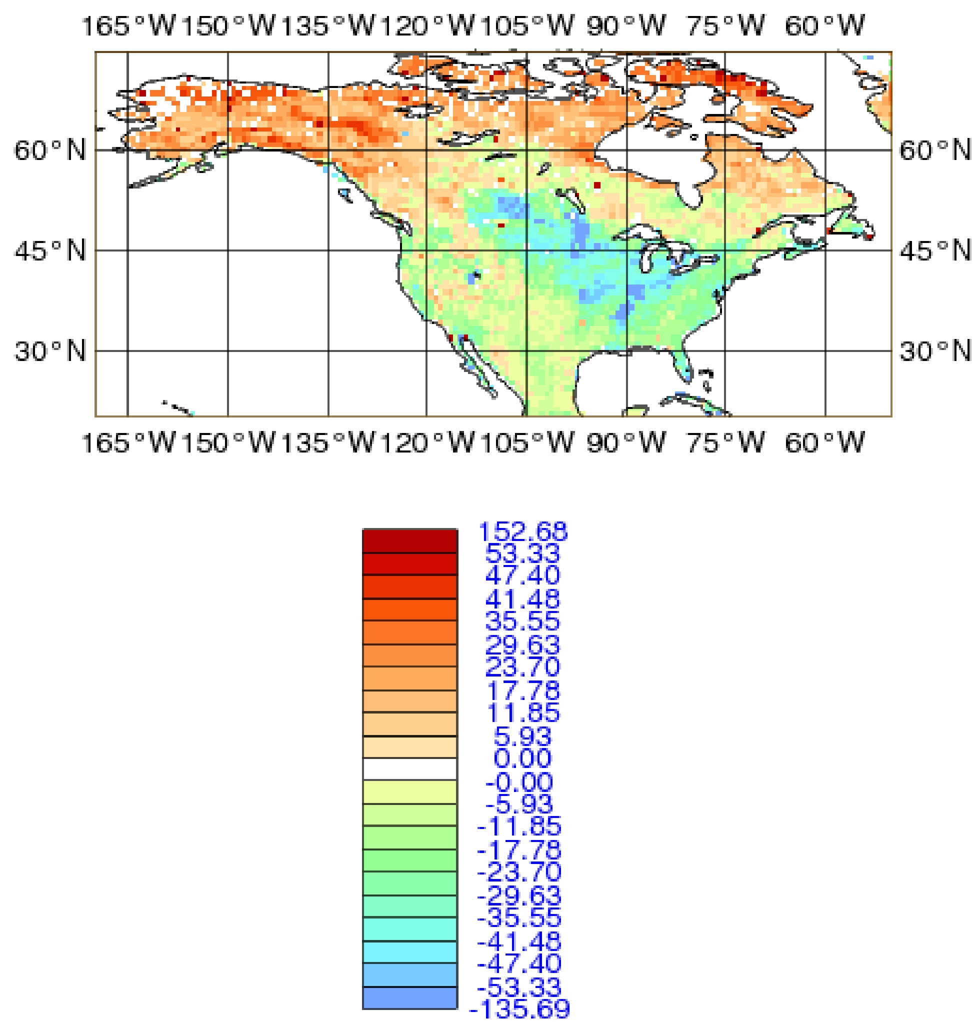
- **expt-foeu**: assimilation of T2m, RH2m → default configuration (CTRL)
- **expt-foeq**: assimilation of T2m, RH2m, SMOS T_B

ECMWF

North America – XX polarisation

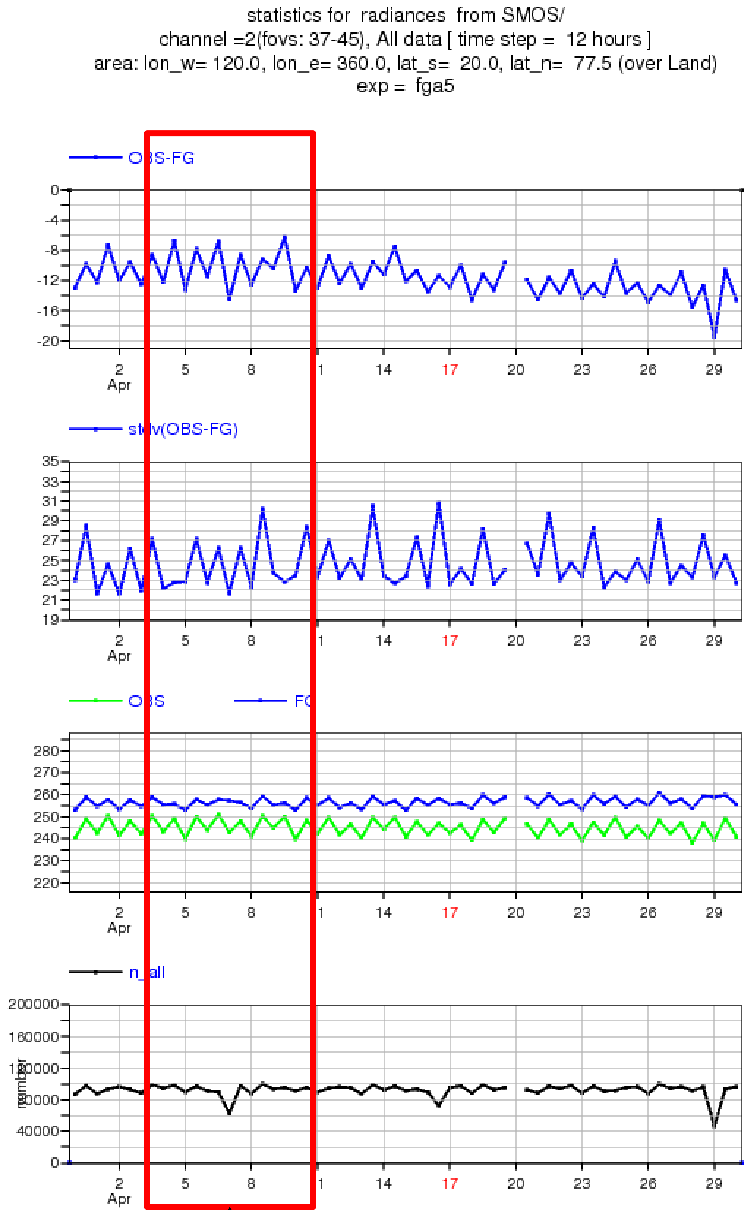


Mean bias (6-20 April)

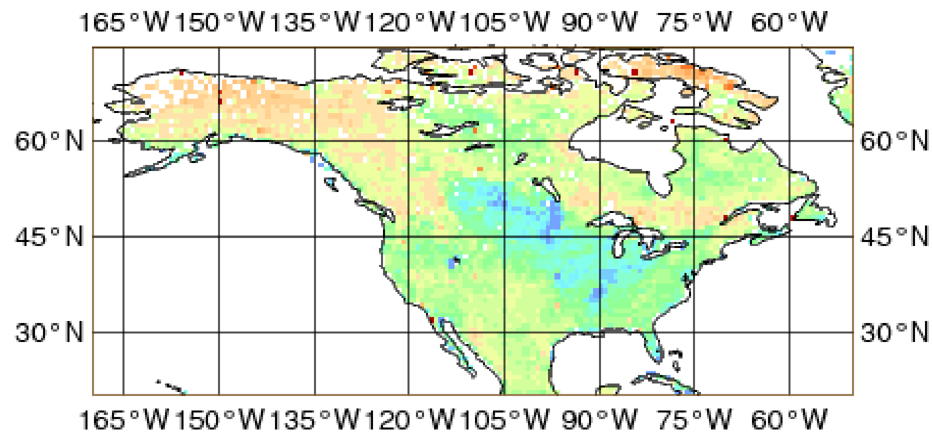


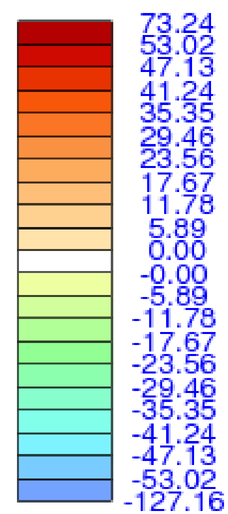
ECMWF

North America – YY polarisation



Mean bias (6-20 April)

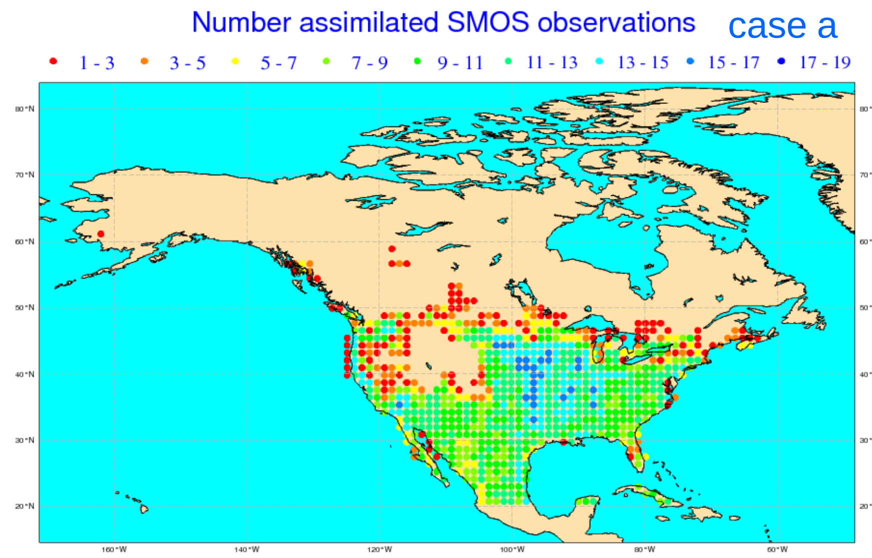




Assimilation window

Quality control & bias correction

- Quality control & data thinning:
  - Routine checks for each observation
  - RFI hard filtering: $50 < T_B < 350$ K
  - 'Own light product' applied at T159 (very small dataset)
  - 'Simple' snow mask applied based on snow depth forecasted field



- 'Crude' bias correction:
  - Hypothesis: Bias are stationary over the assimilation week period
  - Bias = *f*(polarisation, region, angle)
  - $T_B\,(bc) = T_B + \overline{bias}$ (6 Apr to 20 Apr)

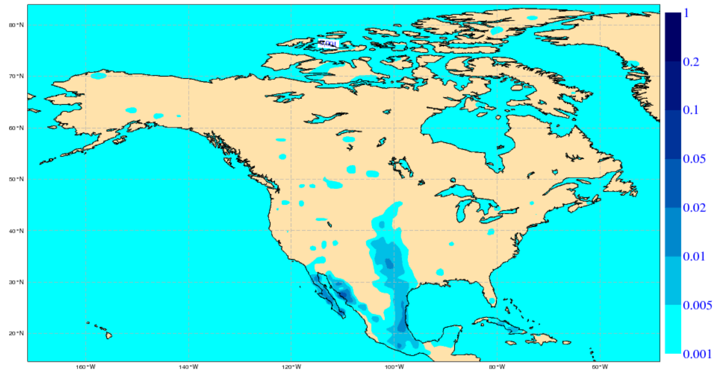
MEAN BIAS	*XX*	*YY*
North America	0.5	-11.0
Australia	-21.6	-19.7

CMWF

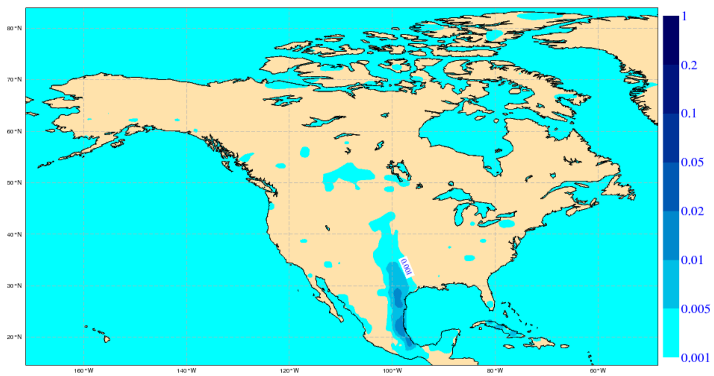
Accumulated soil moisture increments → case a)

ctrl (foeu)

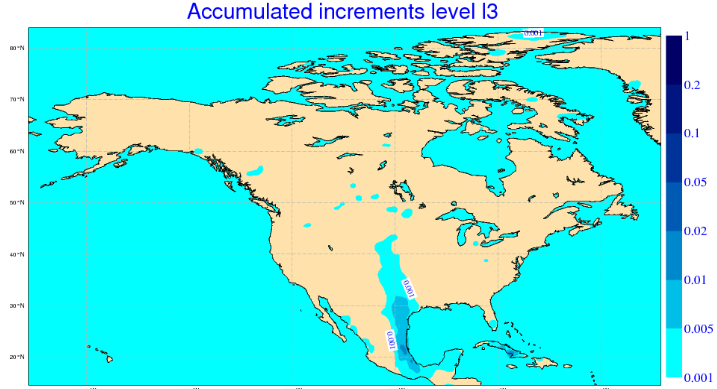
Accumulated increments level l1



Accumulated increments level l2

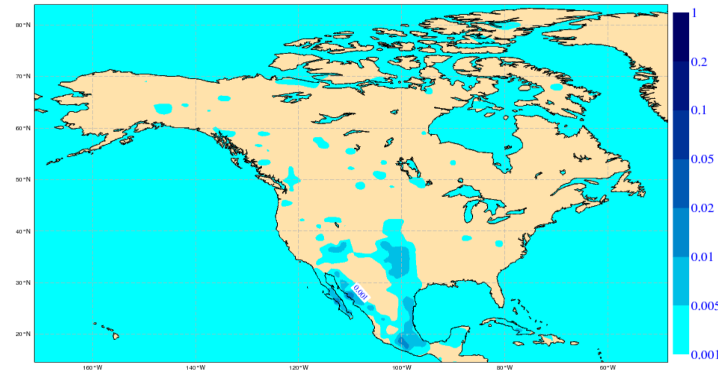


Accumulated increments level l3

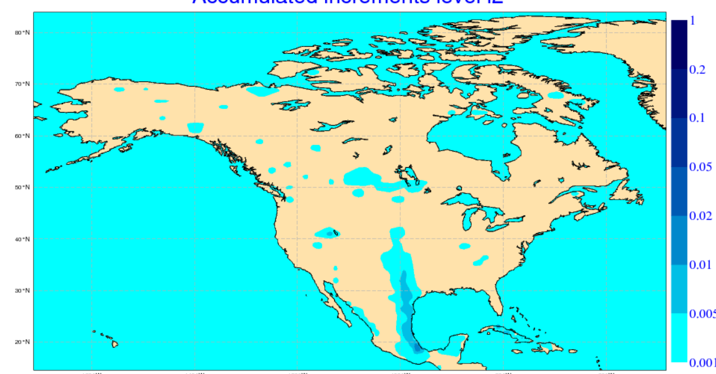


expt (foeq)

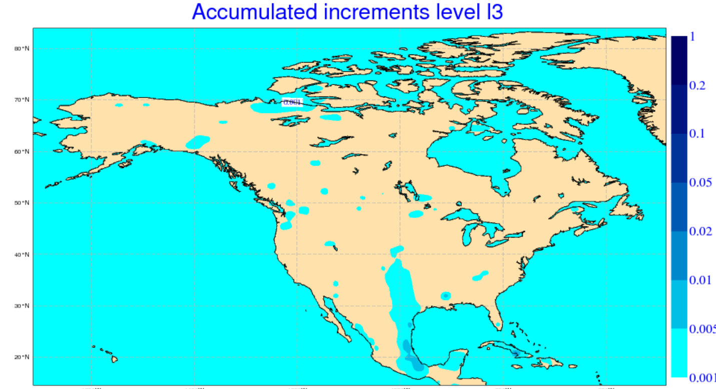
Accumulated increments level l1



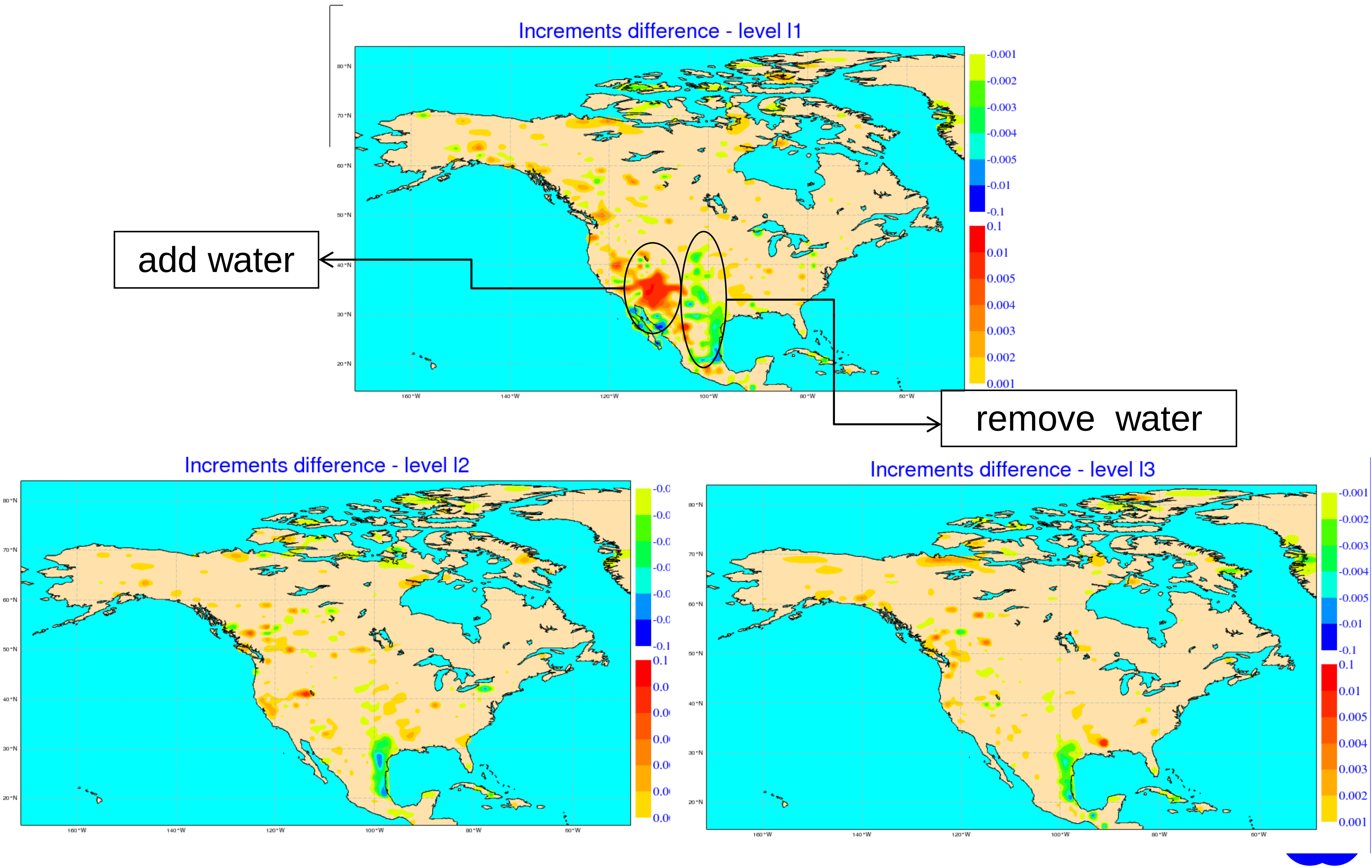
Accumulated increments level l2



Accumulated increments level l3

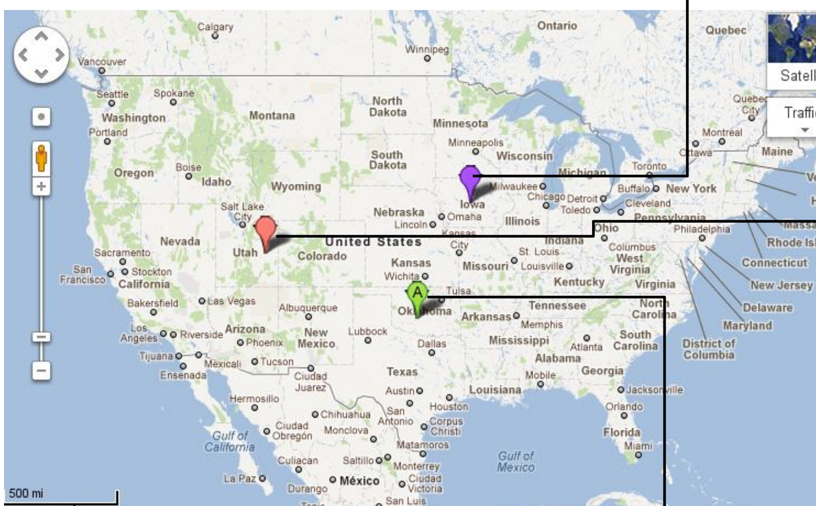


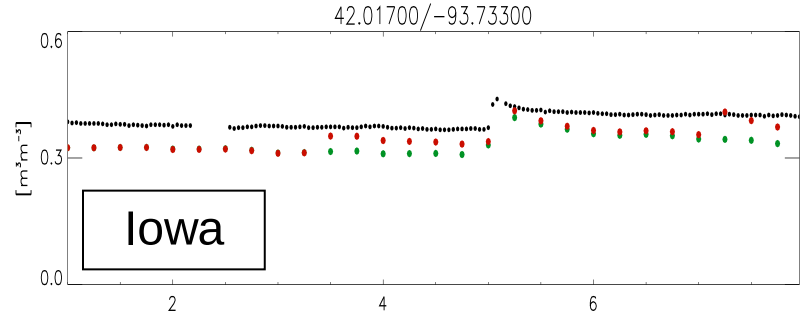
Accumulated soil moisture increments difference expt–ctrl → (SMOS T_B contribution to SM correction)

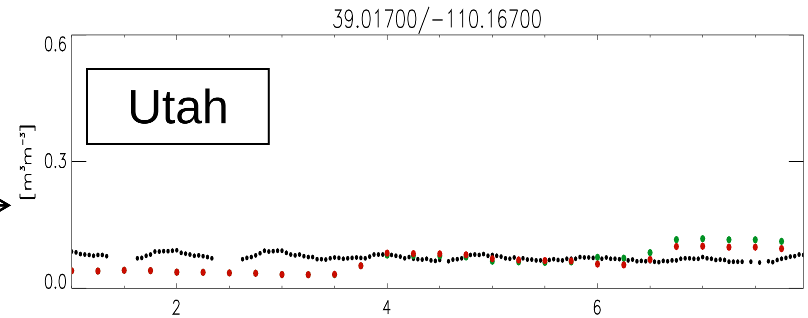


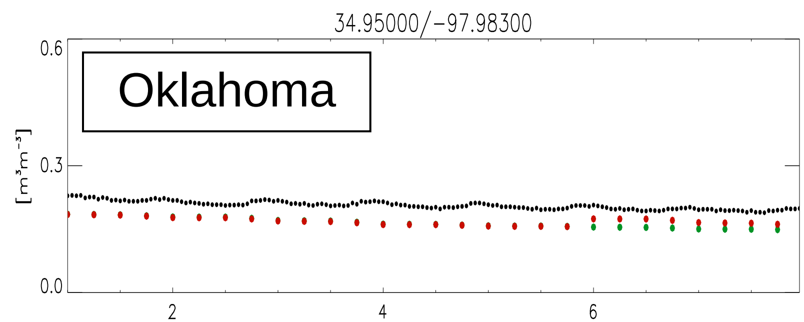
Validation (using the closest model grid point)

Legend:
Black → observations
Green → ctrl
Red → expt









ECMWF

Impact of using a better resolution

- Conclusions:
  - The same experiments were run at T511 (only case a) and producing two-daily 10 days forecasts at 00UTC and 12UTC analysis.

Meteorological impact

- Conclusions:
  - All previous experiments were run using a degraded observational system. Only ATOVS raw-1C radiances (HIRS, MSU, SSU, AMSU-A, AMSU-B, MHS) and SMOS radiances were used.

Conclusions and caveats

- Conclusions:
  - T159 + own light product produces a cheap experiment, both in terms of memory and computational time.
  - The SMOS data configuration used for assimilation in the ECMWF SEKF is flexible,
  - There is an impact of assimilating SMOS observations in the soil moisture analysis, mainly in the top surface layer for the two week-period case studied here.

- Caveats
  - CMEM current configuration produces strong bias (most of cases overestimates the observations) → the bias correction used in these experiments still produces strong residual biases. A future CDF matching (using calibrated CMEM configuration) will bring observations and modelled T_B values more in agreement.
  - **H** is not optimized (a perturbed value of 1% is used for each layer for the Jacobians computation),

ECMWF

Conclusions and caveats

- Caveats

  - **R** and **B** matrices not optimized and are fixed in these experiments. All SMOS observations share the same variance. Also the **B** matrix is not cycled.

  - Only one angle is assimilated per grid point (only two observations can be assimilated per cycle and grid point),

  - AFOV less biased, in these experiments the EAFOV was also used.

  - no binning done,

  - resolution used in these experiments is very coarse (the closest grid point to a validation site can be far away).

  - RFI still present in some areas of North-America (for this period the RFI flag in BUFR was not available),

  - Product used is the standard one, not reprocessed data here.

  - **These experiments are very preliminary. They are mainly setup to demonstrate that the technical assimilation approach is working → lot of room for improvement!**

  - Next, the meteorological impact in following experiments will also be evaluated,

  - A quality analysis flag for SMOS will be available too.

ECMWF

RFI flag in BUFR product

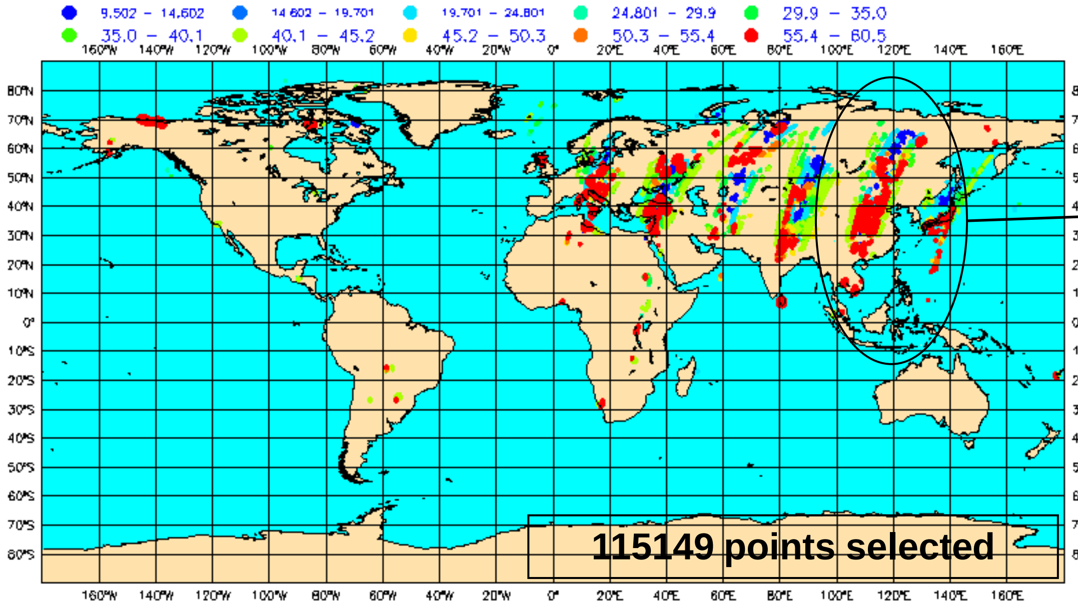
- Use of RFI flag at ECMWF:
  - RFI flag information in BUFR since deployment of NRT v5.05 the 7 March 2012.
  - Also RFI flag info available in the last reprocessing (2010-2011),
  - BUFR product, SMOS information flag, two bits interesting for ECMWF:
    - Bit-1: Pixel is affected by RFI effects as identified in the AUX_RFILST or it has exceeded the BT thresholds
    - Bit-4:Measurement is affected by the tails of a point source RFI as identified in the AUX RFI list (tail width is dependant on the RFI expected BT defined in the AUX RFILST. → no RFI information was found here.

ECMWF

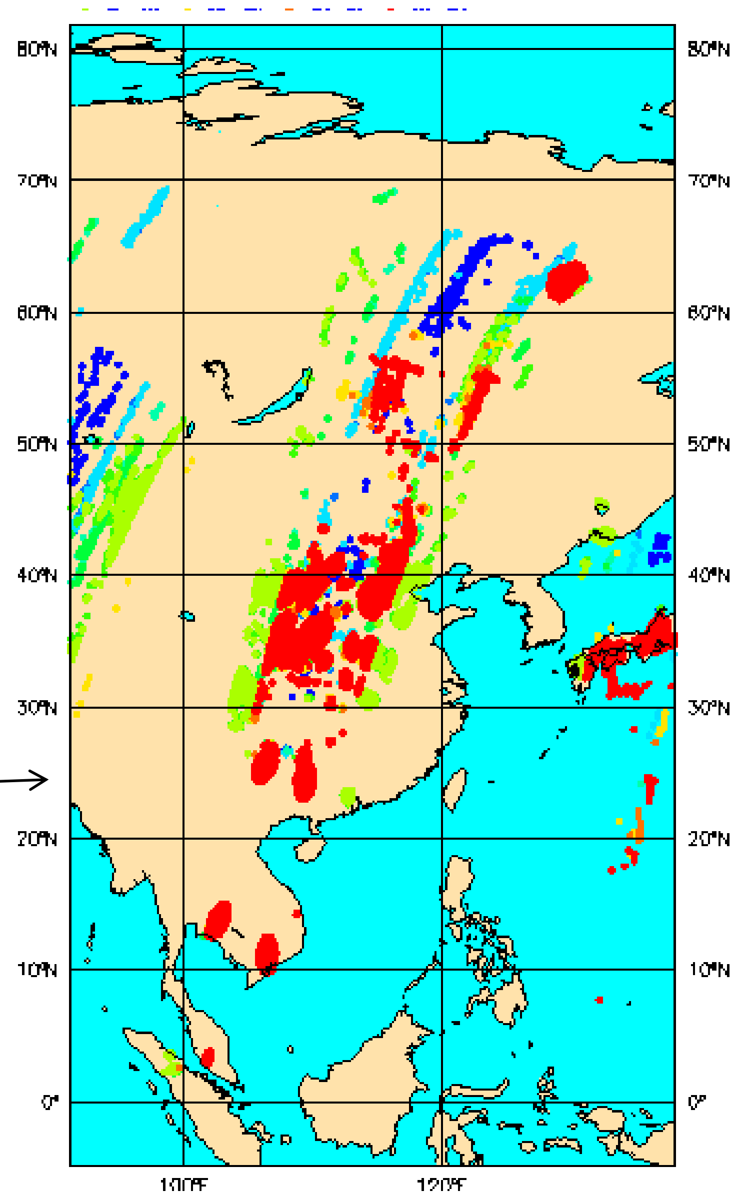
SMOS info flag (bit-1) – all data

- SMOS database in IFS the 9 May 2012 (data from 2100UTC to 0900UTC) with current monitoring suite.
  - Basic quality control,
  - Selected angles: 10, 20, 30, 40, 50, 60 (± 0.5),
  - Selected polarisations: XX, YY

Incidence angle



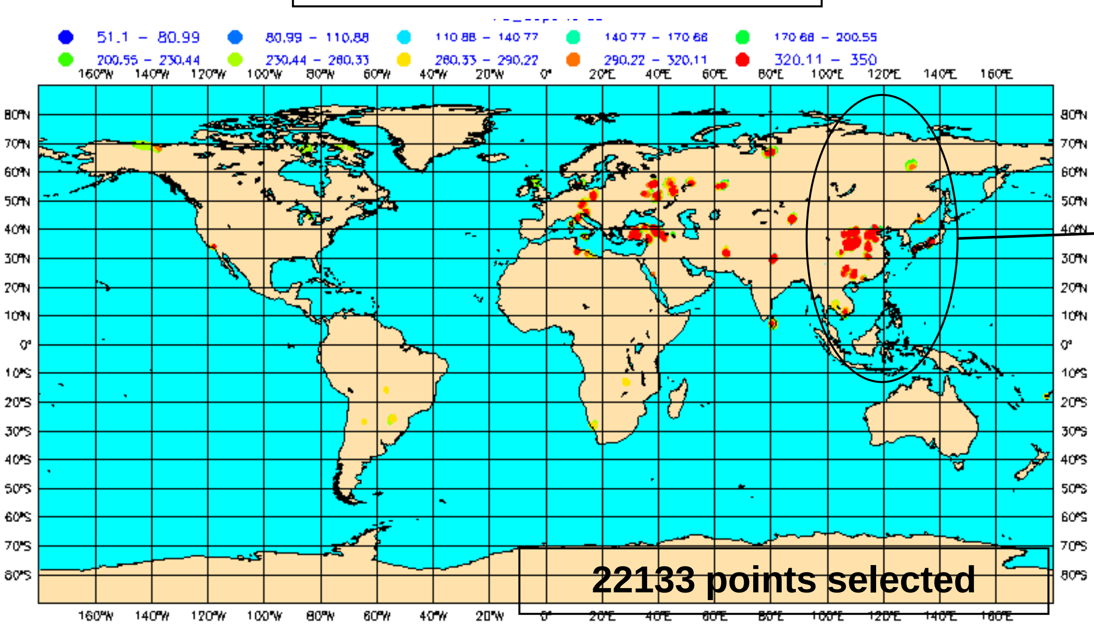
EAFOV



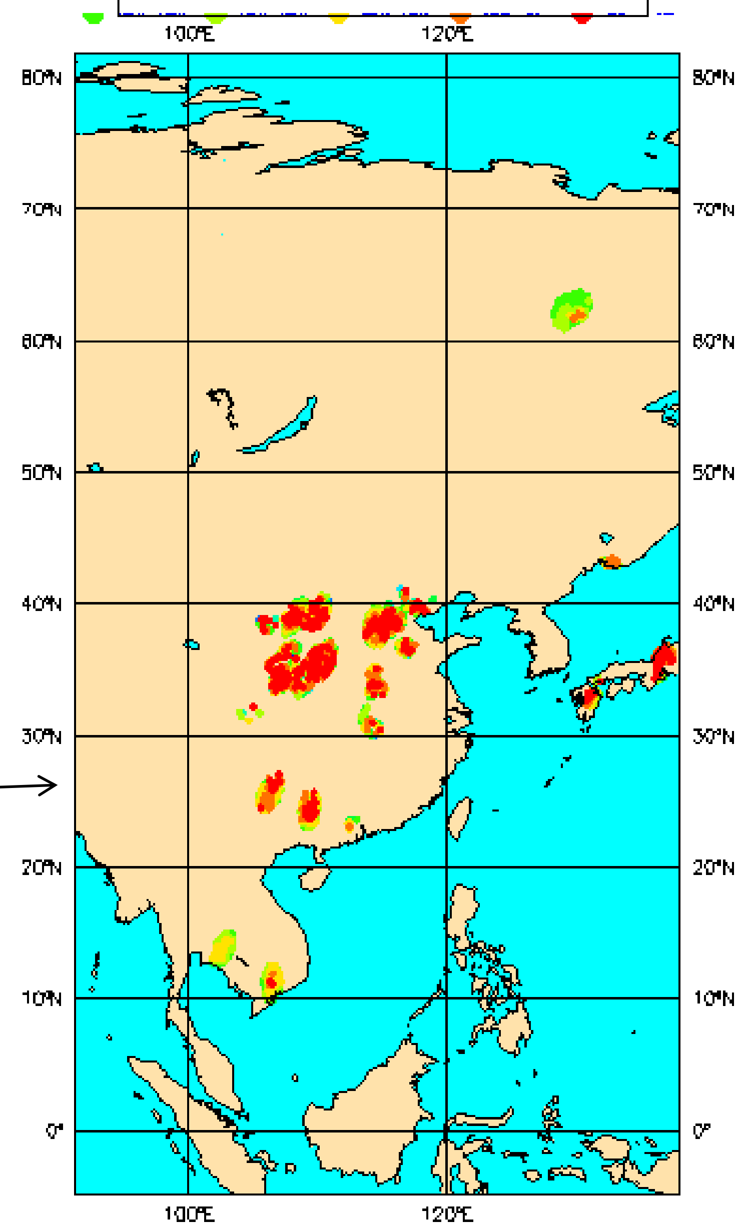
SMOS info flag (bit-1) – active data

- On top of previous thinning/screening, only active data will be assimilated → guarantee to pick only the nearest observation to the model grid (per angular bin), where the analysis are carried out.
- RFI flagged areas are dramatically reduced → keeps only the most heavily contaminated areas?

Incidence angle



EAFOV

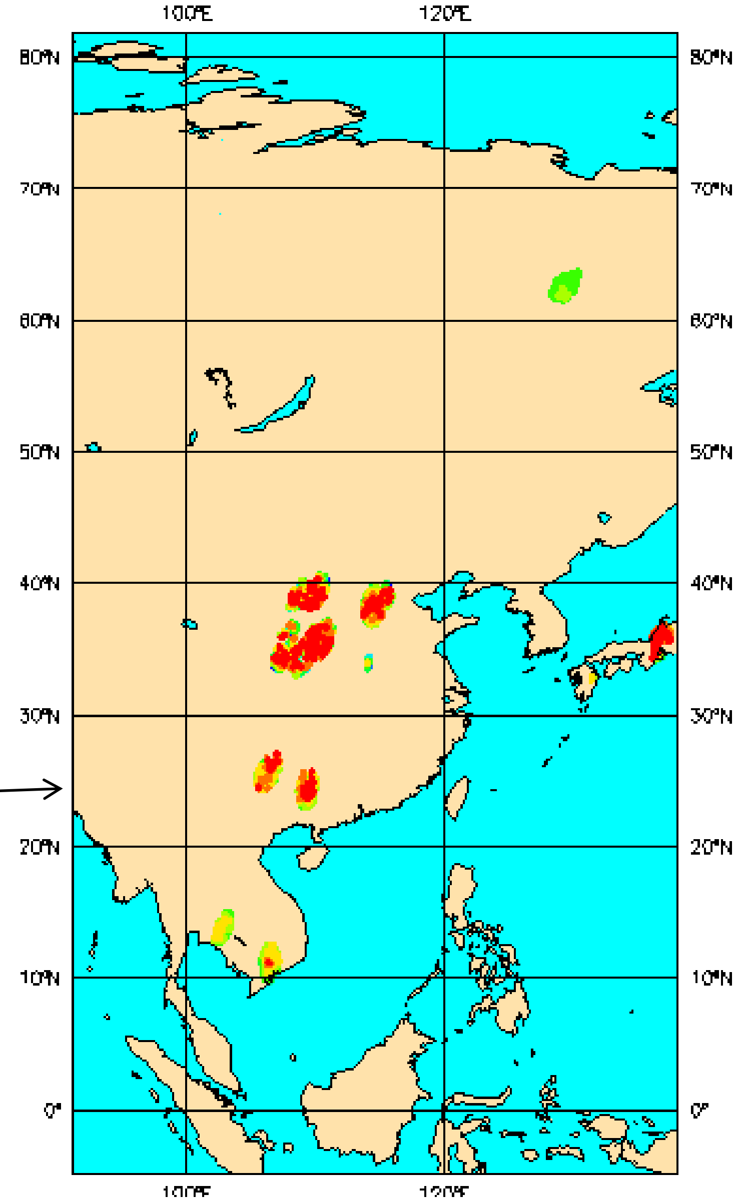


SMOS info flag (bit-1) – active data + AFOV

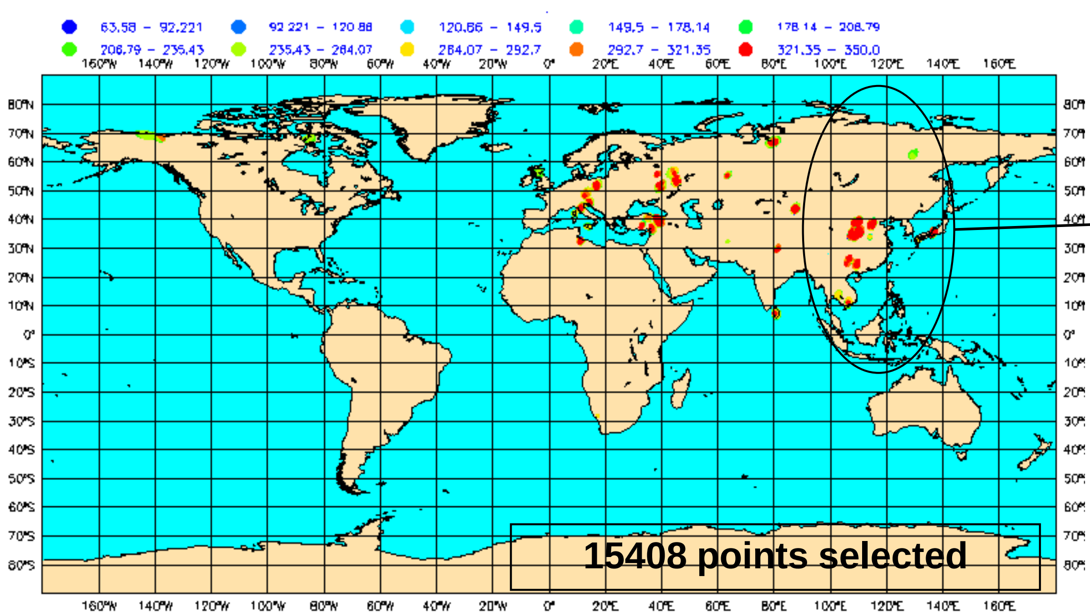
- For assimilation purposes, better assimilate data in the AFOV → further, modest, reduction of data.

- Based on this filter, which data is still left to be assimilated?

AFOV

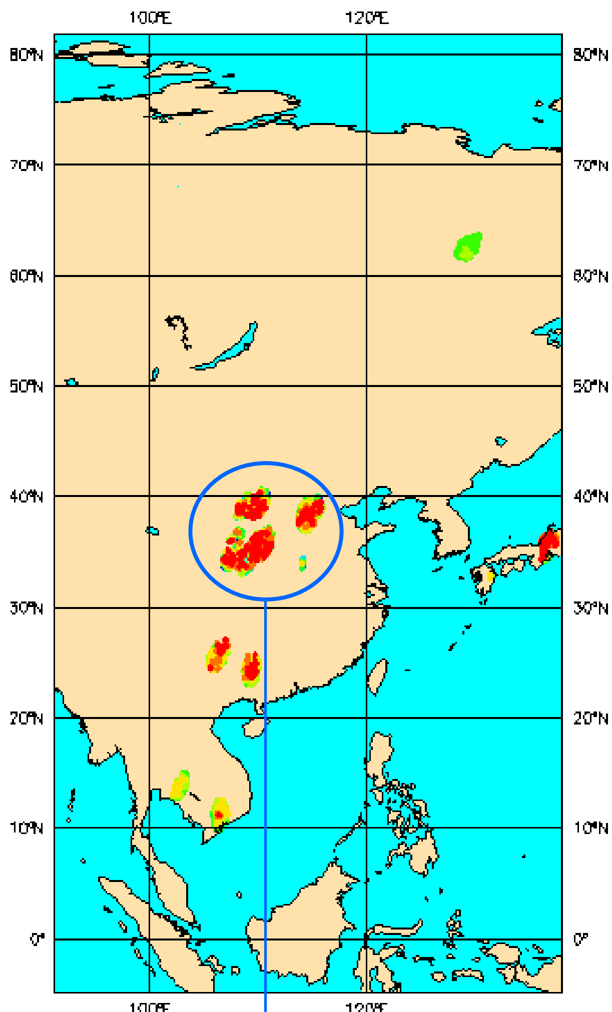


Incidence angle

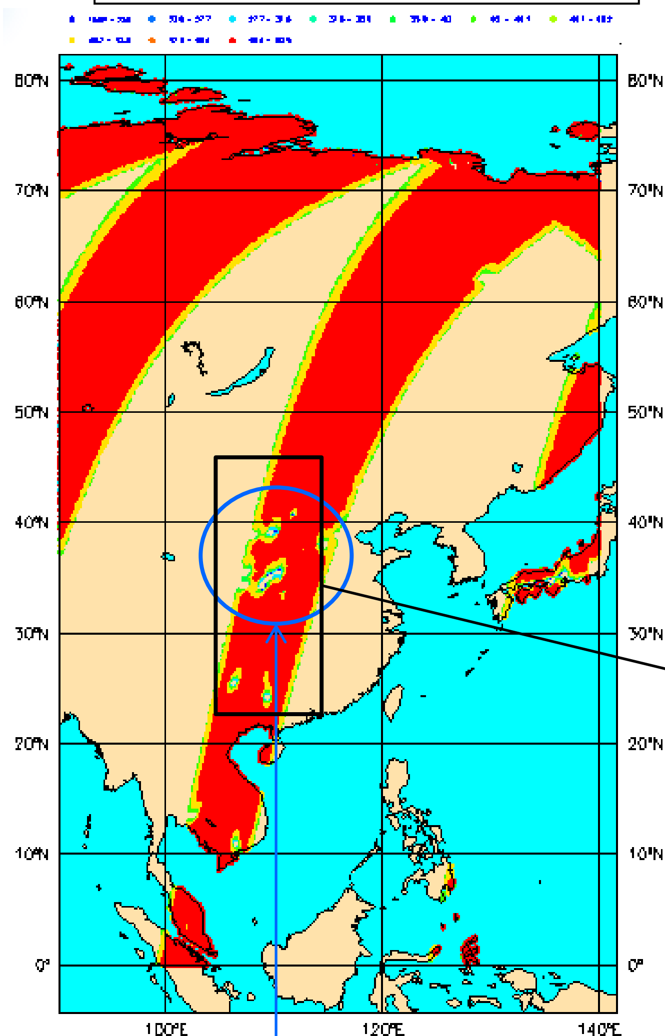


SMOS info flag (bit-1)

Active data at T1279 filtered based on thinning, screening, SMOS flag and radiometric accuracy



Active data at T1279 still available to be assimilated



Data which potentially could be assimilated still in areas suspicious of being contaminated (perhaps SMOS flag not effective yet to filter data contaminated by tails of the source?) → further filters are required for assimilation

Data filtered

ECMWF

Conclusions and caveats

- Caveats

  - **R** and **B** matrices not optimized and are fixed in these experiments. All SMOS observations share the same variance. Also the **B** matrix is not cycled.

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  - Next, the meteorological impact in following experiments will also be evaluated,

  - A quality analysis flag for SMOS will be available too.

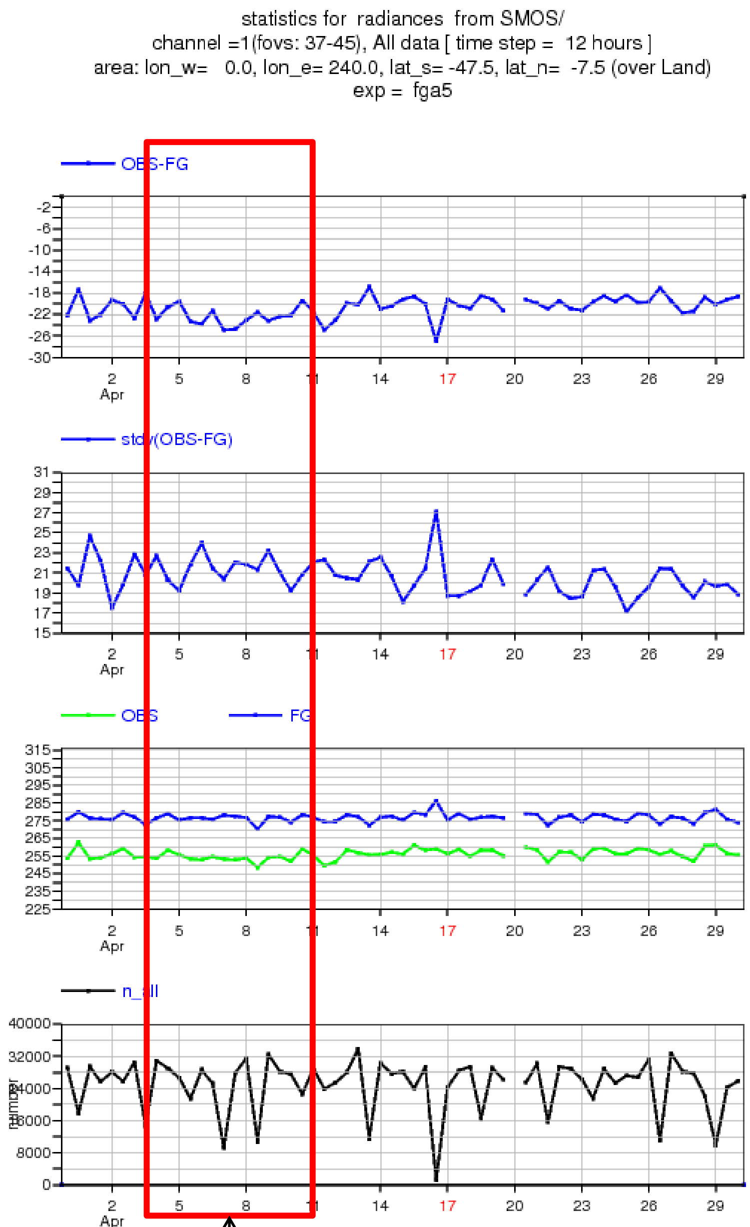
Conclusions

- Bias correction:
  - Revised configuration of operational CMEM based on global comparison of SMOS reprocessed TB and CMEM offline simulation in 2010, at 40 degrees.
  - Results suggest moving from Wang-Choudhury-Kirdyashev to Mironov-Wigneron-Jackson → lower bias and better correlation.
  - On-going CDF-matching → a & b correction parameters, independent for XX and YY polarisation, and 10, 20, 30, 40, 50.
  - Implementation in IFS almost completed.
- Implementation of SMOS data in SEKF:
  - Implementation is completed, although still lot of parameters to tune up.
  -

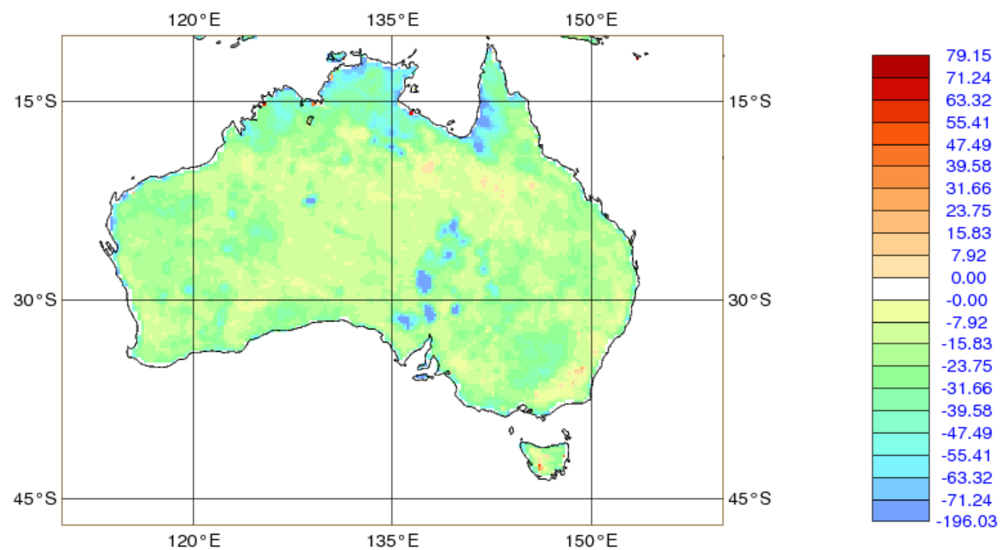
ECMWF

Extra

Australia – XX polarisation



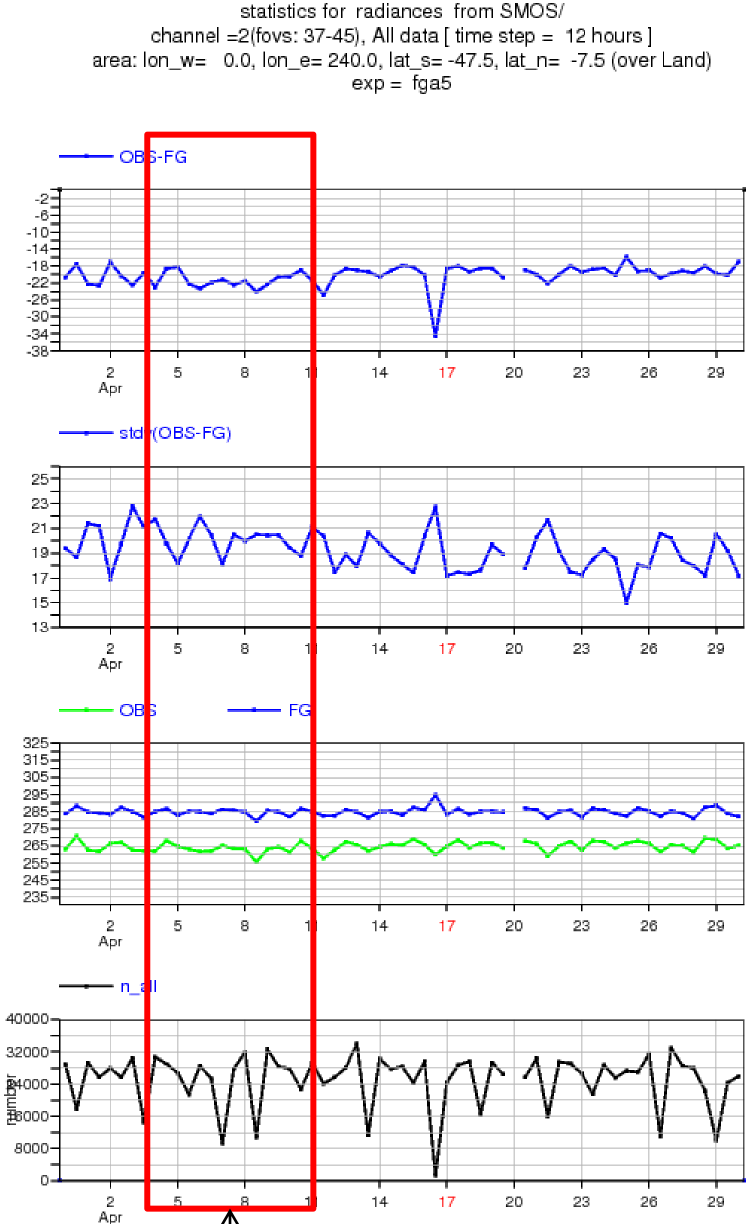
Mean bias (6-20 April)



Assimilation window

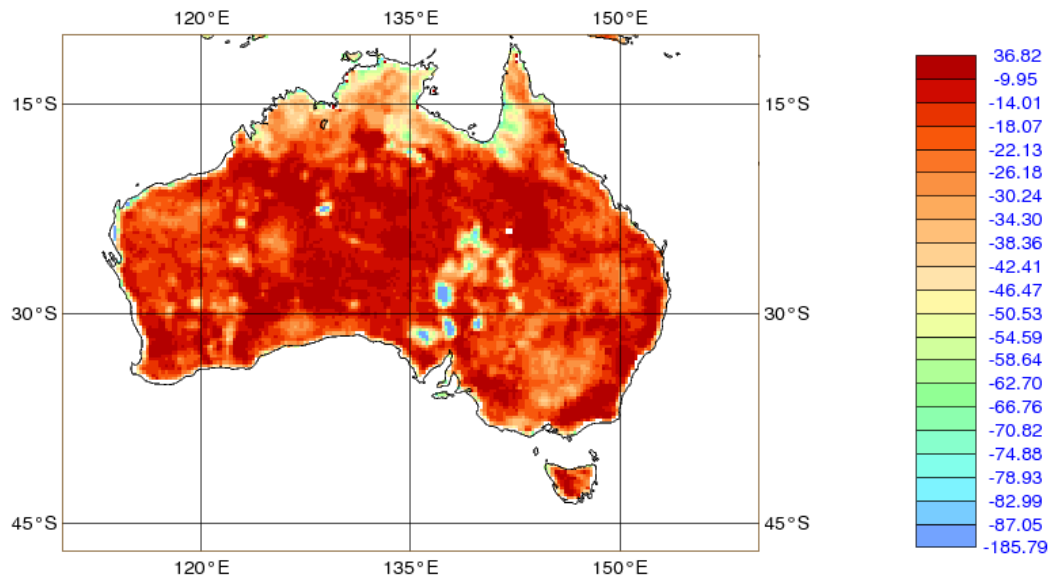
ECMWF

Australia – XX polarisation



Assimilation window

Mean bias(6-20 April)



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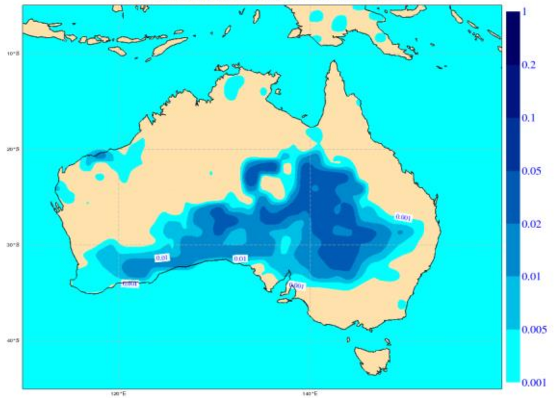
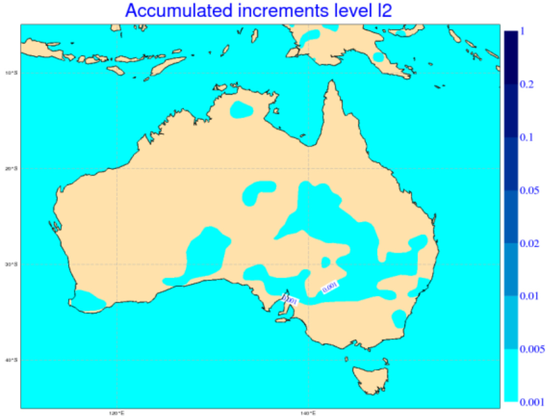
Accumulated soil moisture increments → case b)

ctrl (foew)

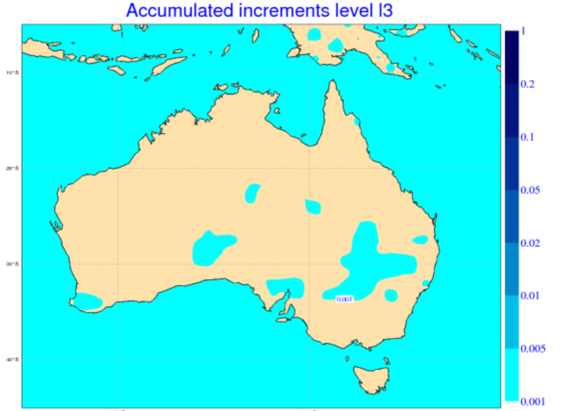
Accumulated increments level l1



Accumulated increments level l2

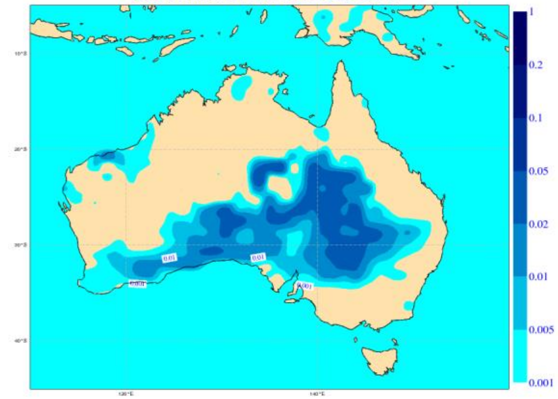


Accumulated increments level l3

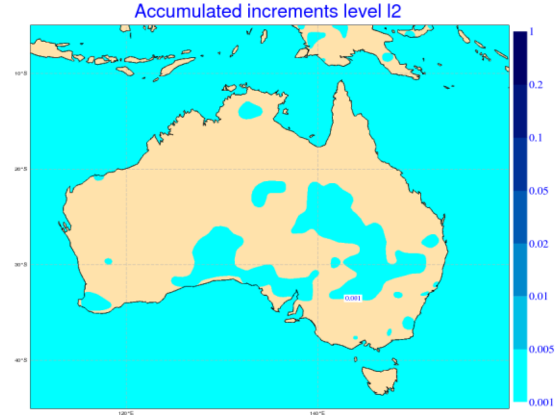


expt (foev)

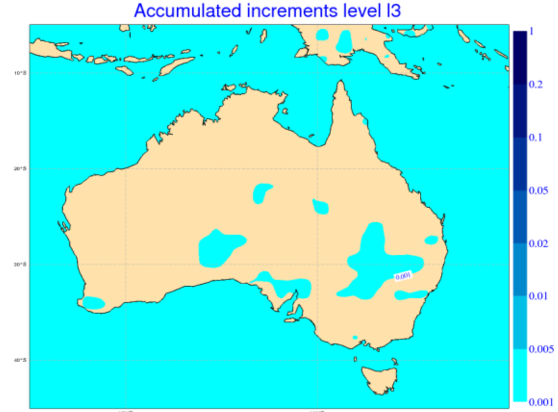
Accumulated increments level l1



Accumulated increments level l2

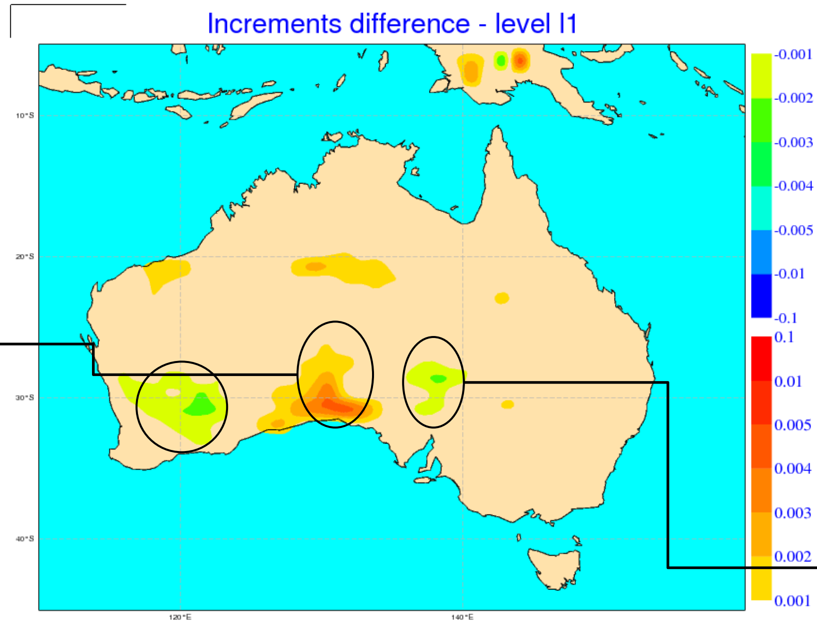


Accumulated increments level l3



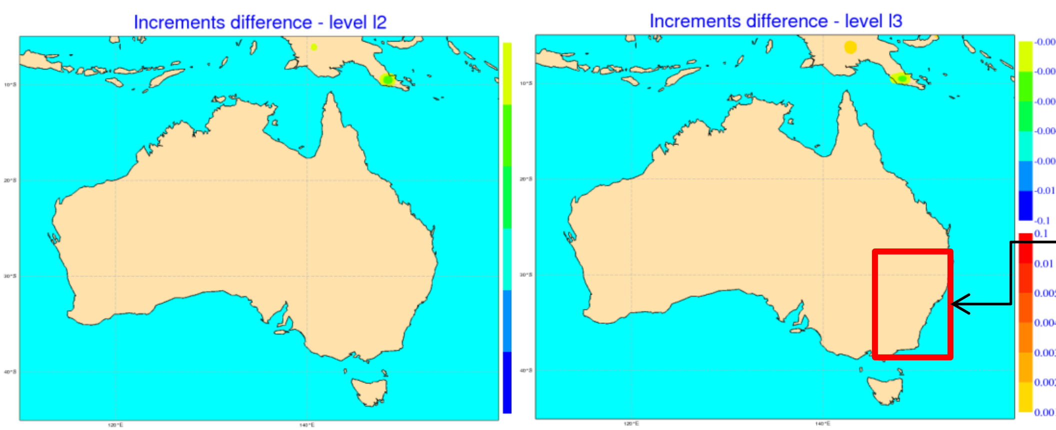
Accumulated soil moisture increments difference expt–ctrl → (SMOS T_B contribution to SM correction)

add water



remove water

Very small impact



No impact on OZNET validation sites

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