Set of demonstrative experiments to assimilate SMOS T_B in the ECMWF SEKF

Joaquin Munoz Sabater

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

CASE b) Australia (clean of RFI, soil water recharge period)

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

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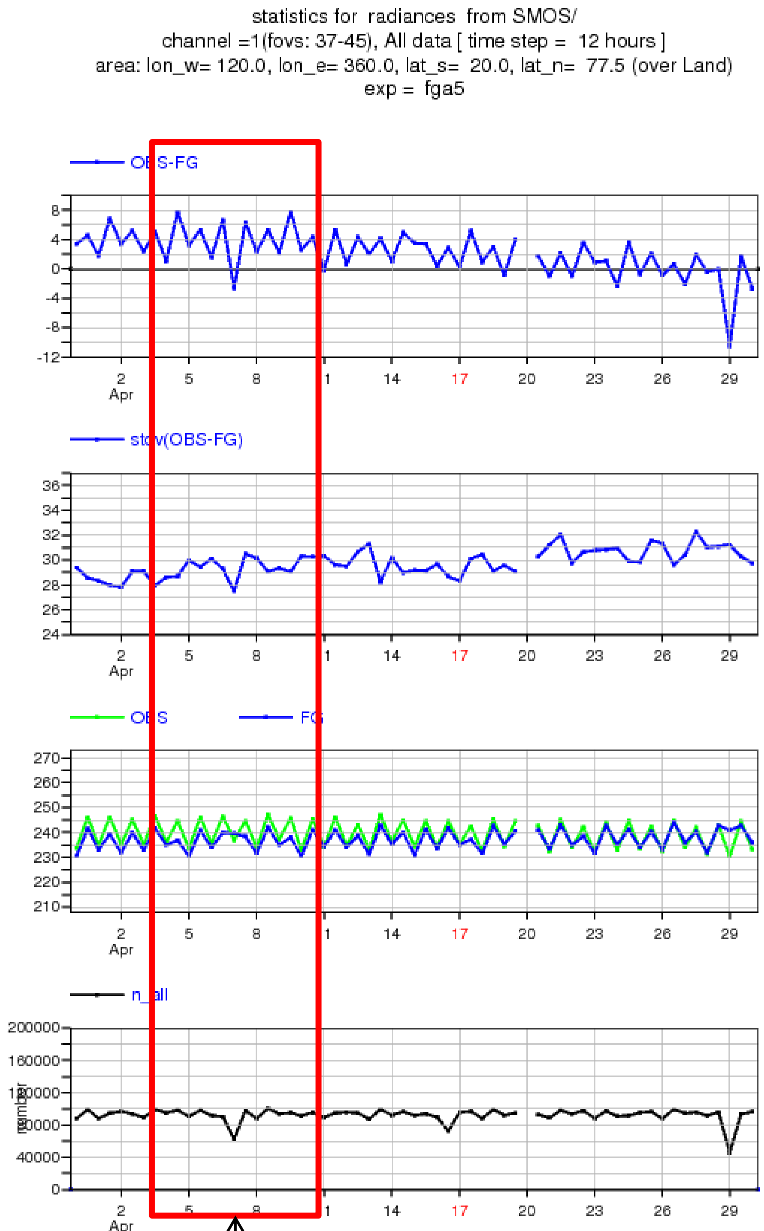
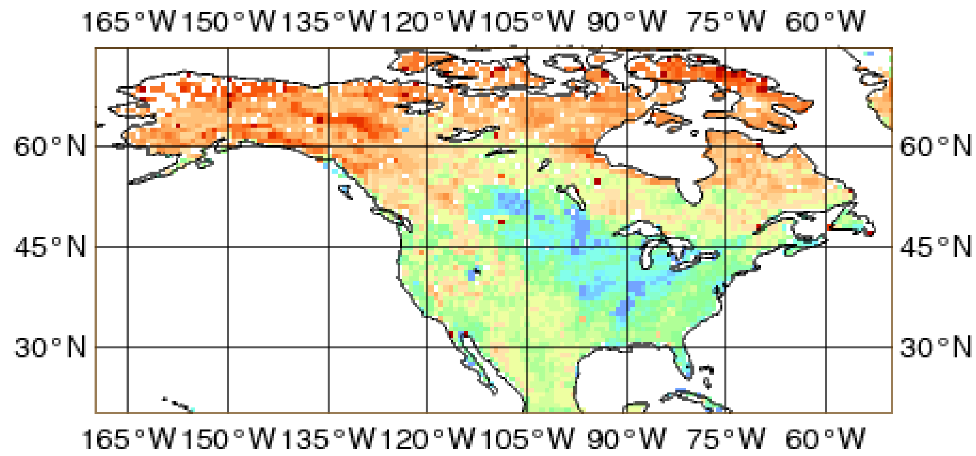
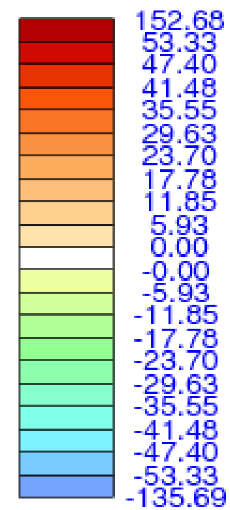
North America – XX polarisation



Assimilation window

Mean bias (6-20 April)





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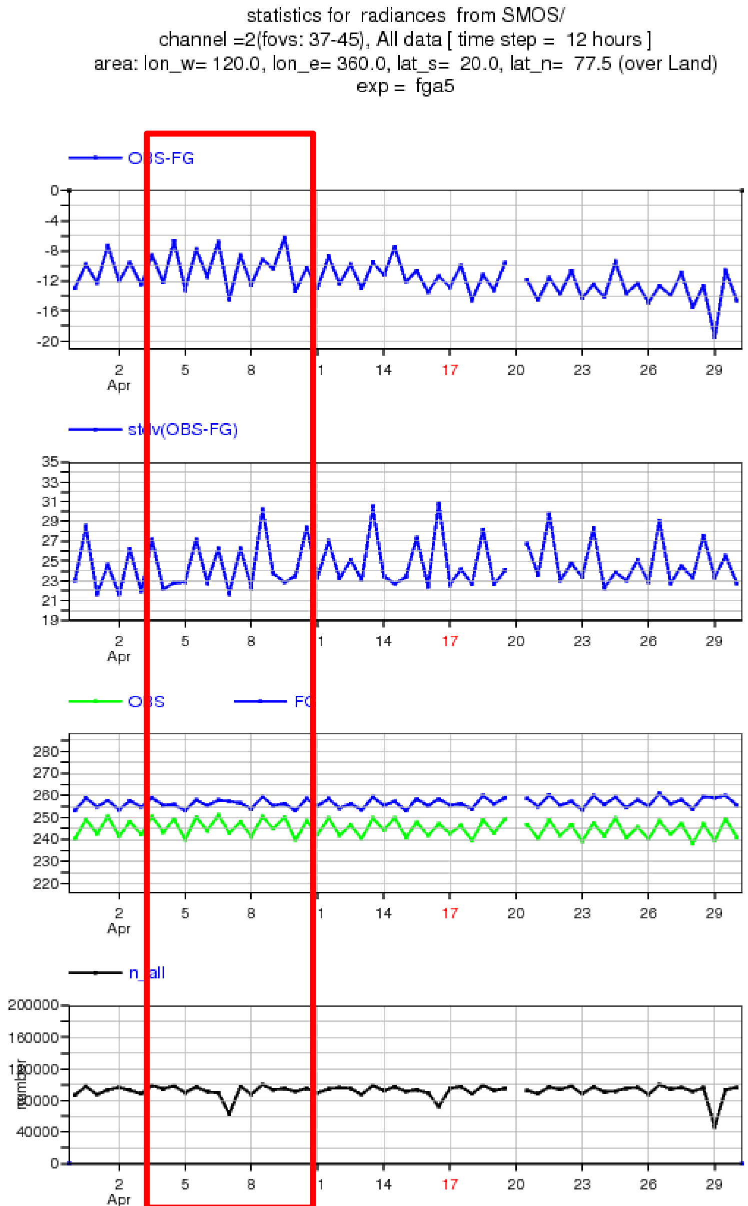
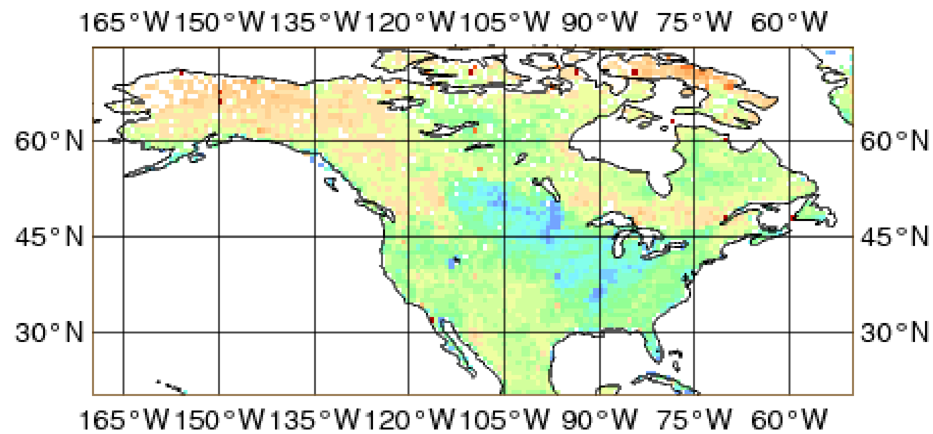
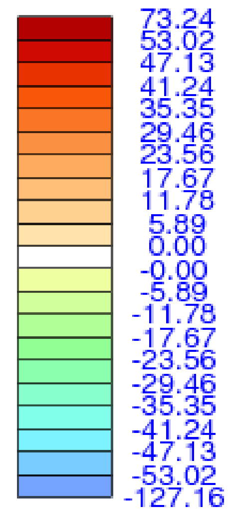
North America – YY polarisation



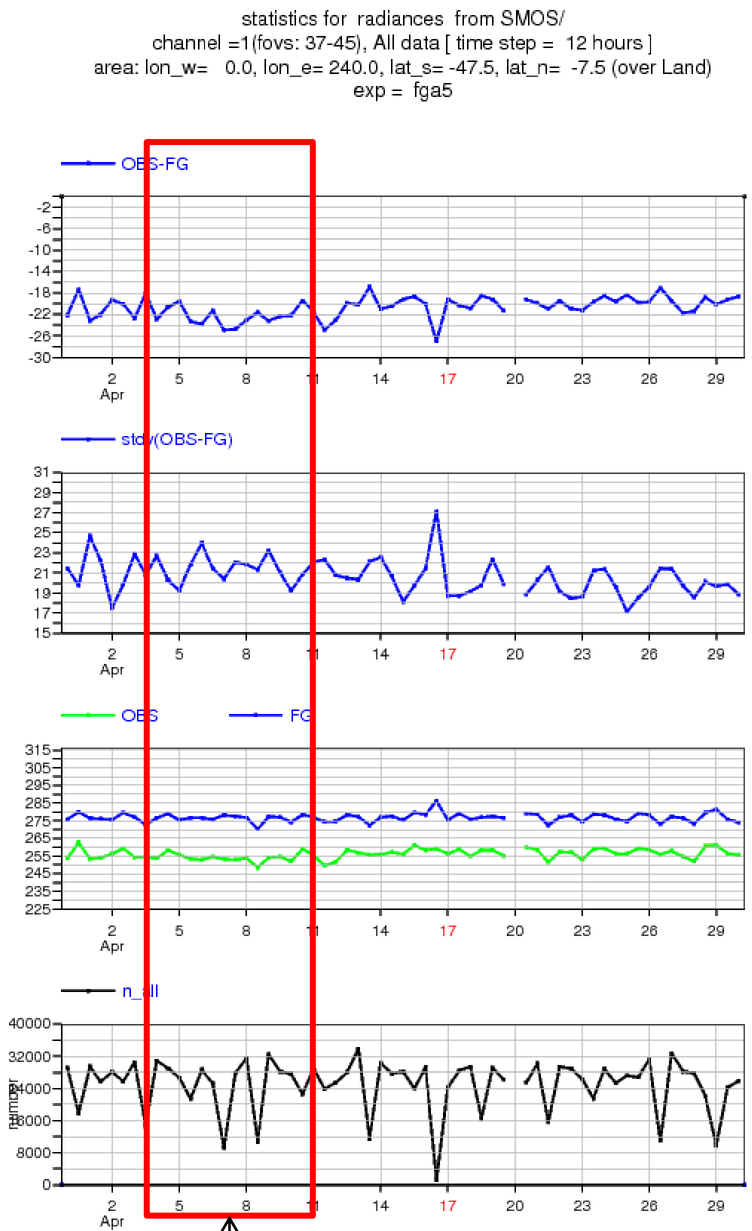
Assimilation window

Mean bias (6-20 April)



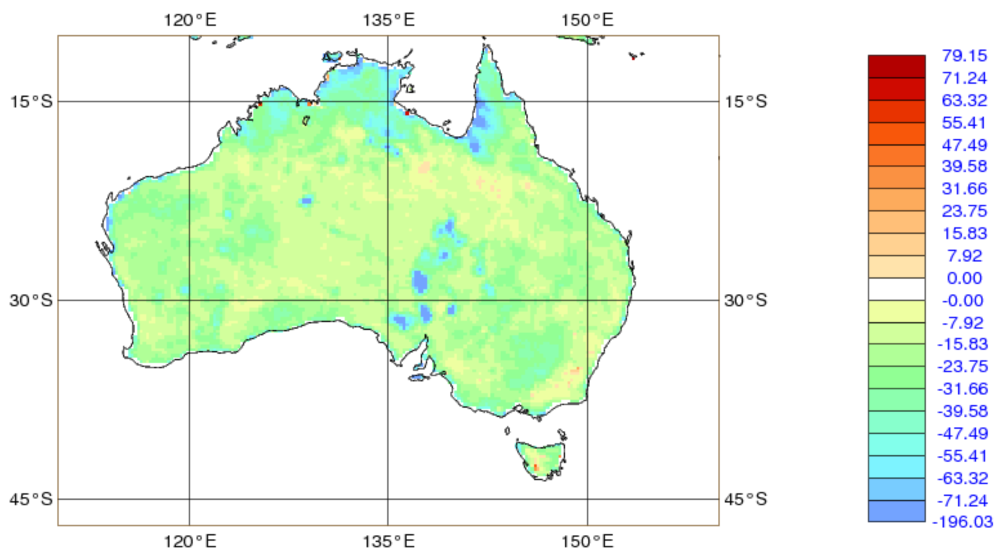


Australia – XX polarisation



Assimilation window

Mean bias (6-20 April)



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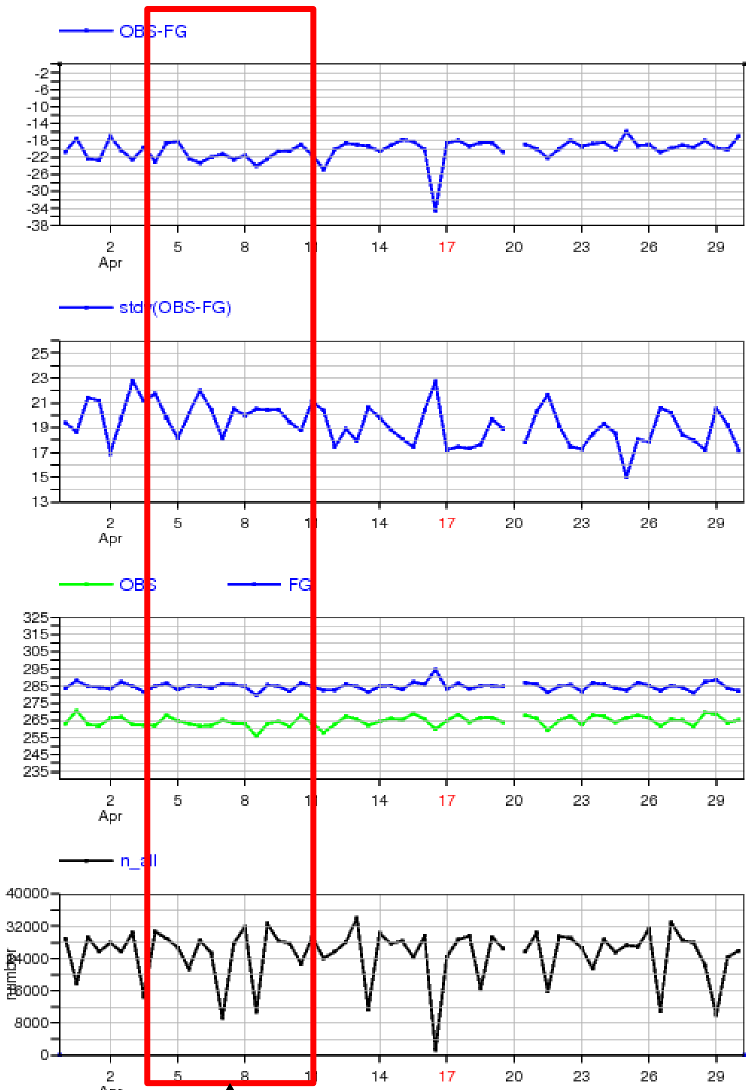
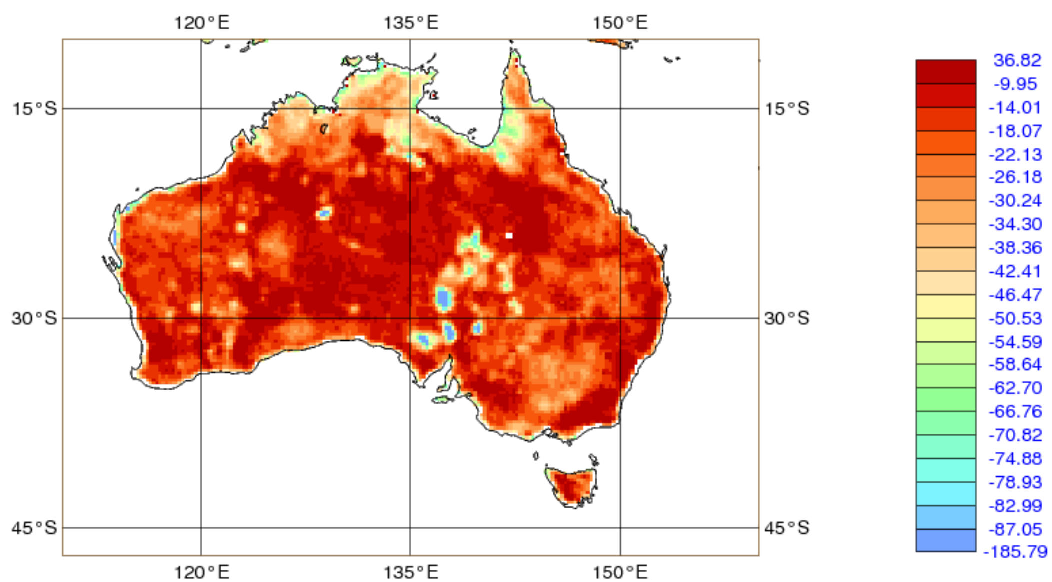
Australia – XX polarisation

statistics for radiances from SMOS/
channel =2(fovs: 37-45), All data [time step = 12 hours]
area: lon_w= 0.0, lon_e= 240.0, lat_s= -47.5, lat_n= -7.5 (over Land)
exp = fga5



Assimilation window

Mean bias(6-20 April)



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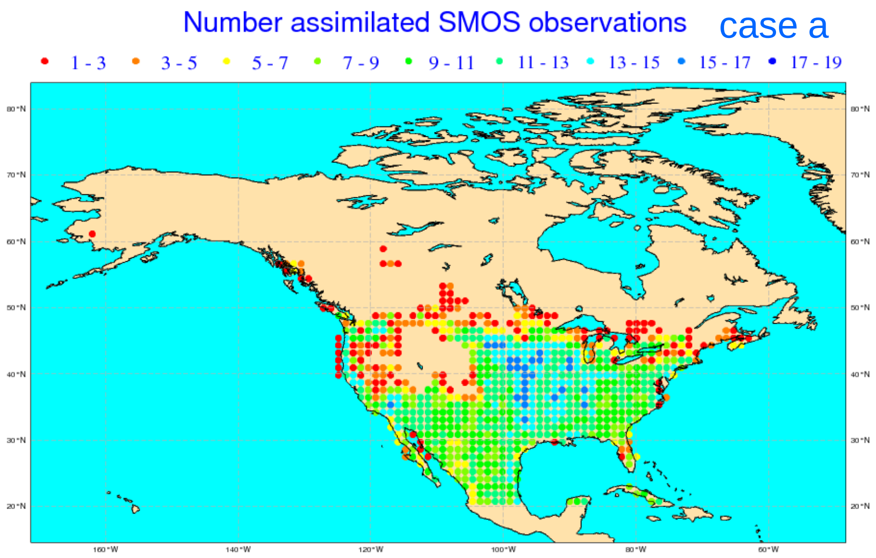
Quality control & bias correction

- 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



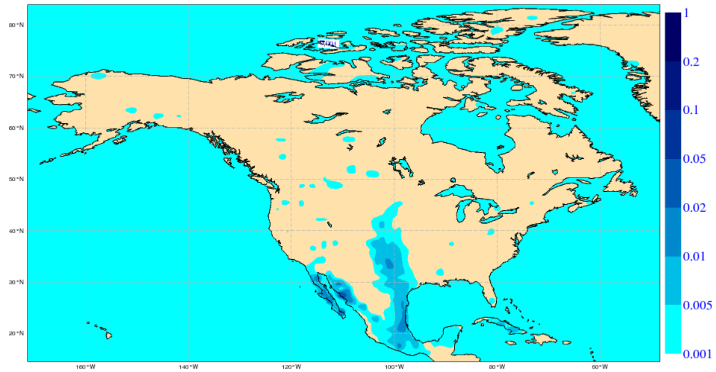
- ‘Crude’ bias correction:
  - Hypothesis: Bias are stationary over the assimilation week period
  - Bias = *f*(polarisation, region, angle)
  - $T_B\,(bc) = T_B + \overline{\text{bias}}$ (6 Apr to 20 Apr)

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

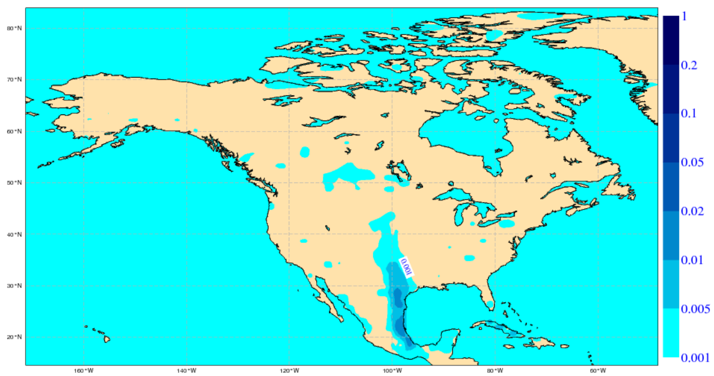
Accumulated soil moisture increments → case a)

ctrl (foeu)

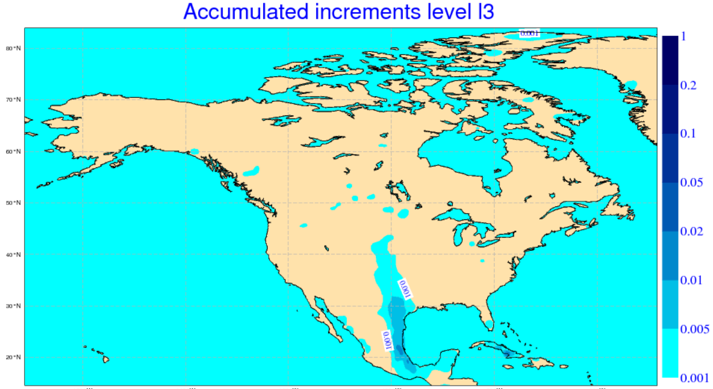
Accumulated increments level l1



Accumulated increments level l2

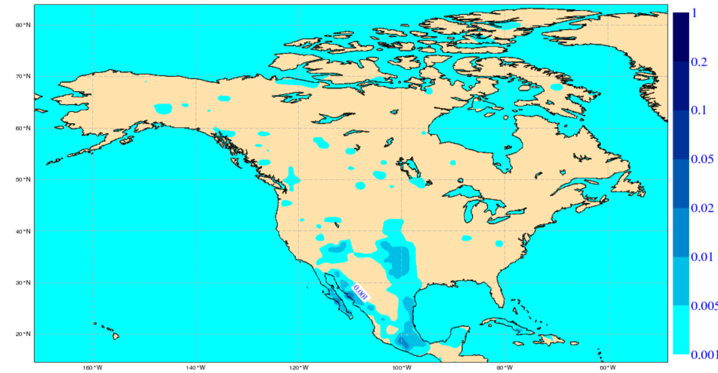


Accumulated increments level l3

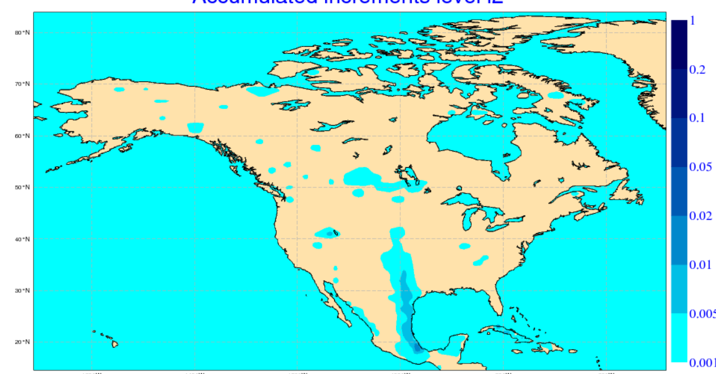


expt (foeq)

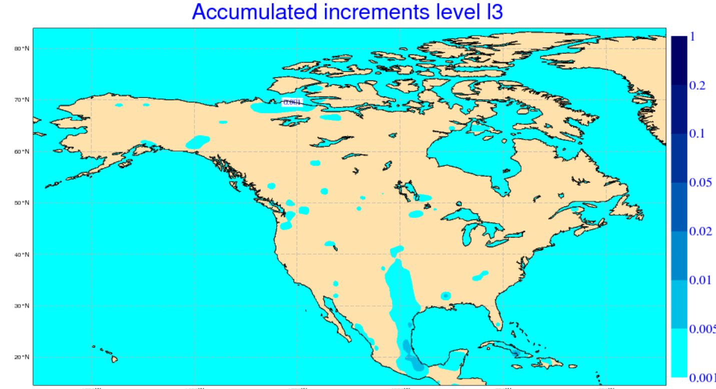
Accumulated increments level l1



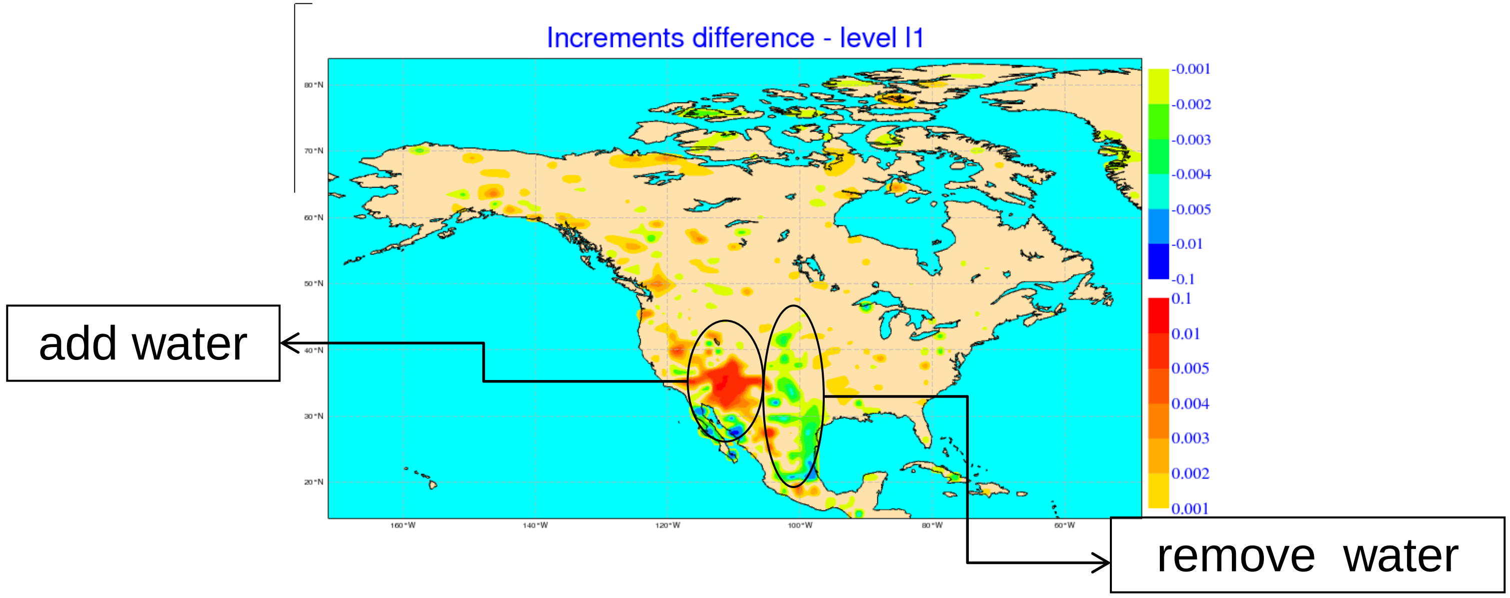
Accumulated increments level l2

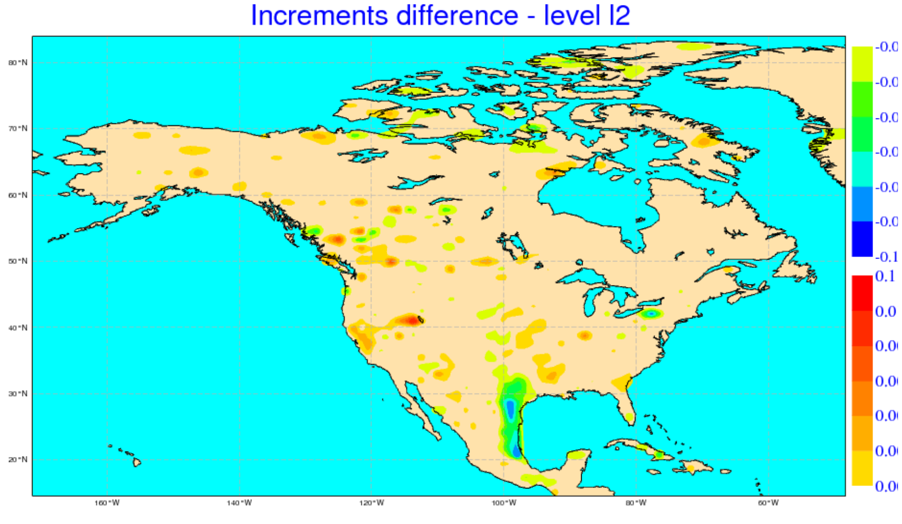


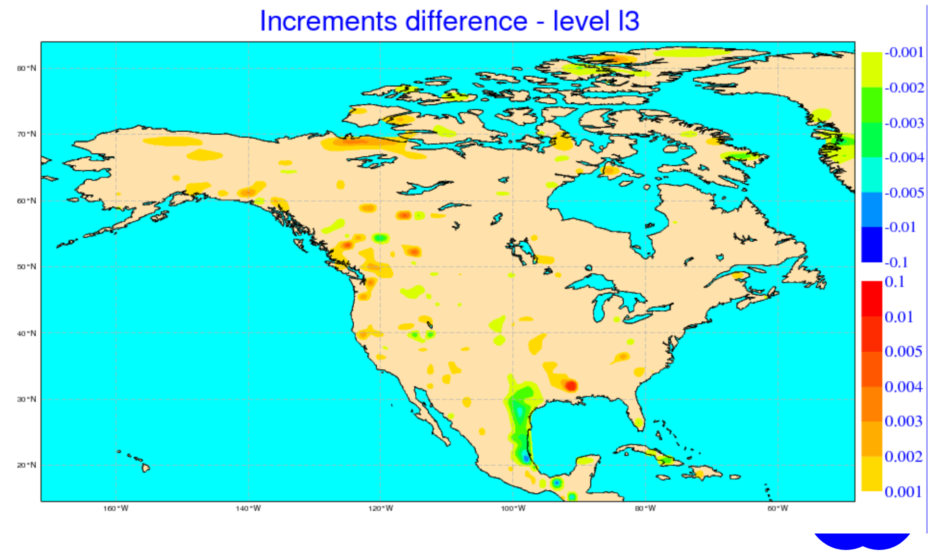
Accumulated increments level l3



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

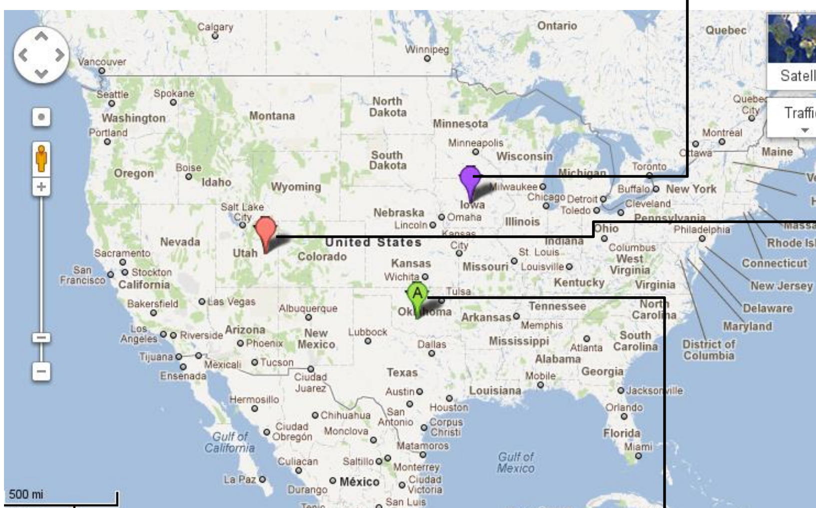


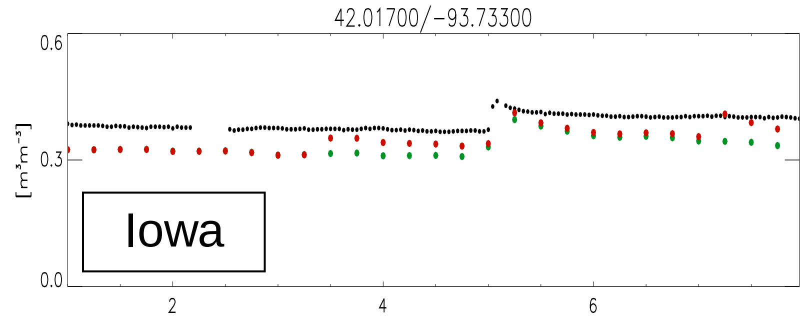


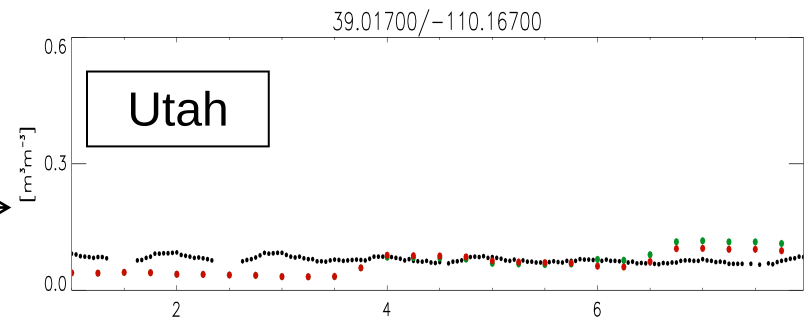


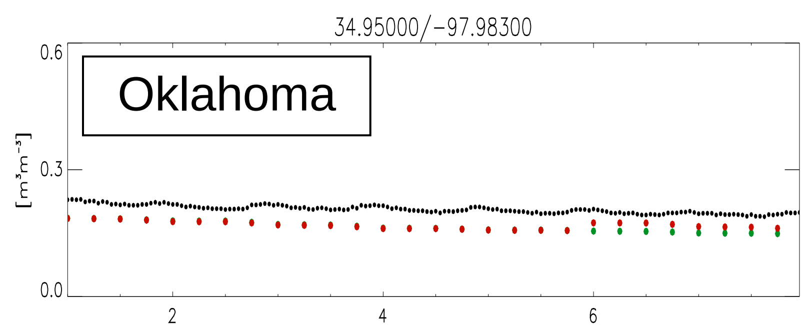
Validation (using the closest model grid point)

Legend:
Black → observations
Green → ctrl
Red → expt









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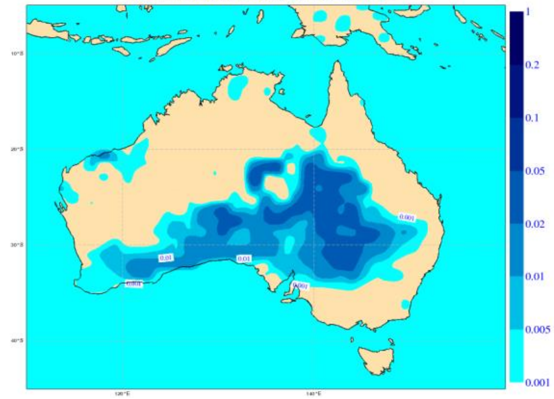
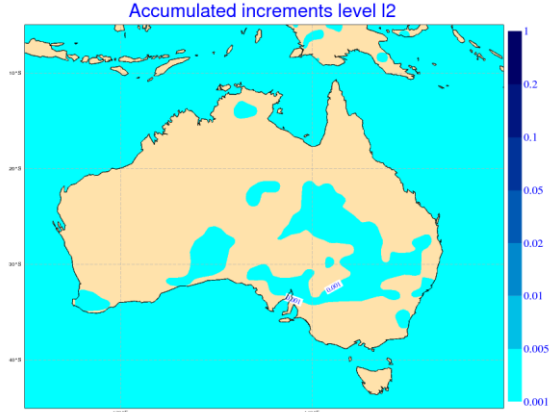
Accumulated soil moisture increments → case b)

ctrl (foew)

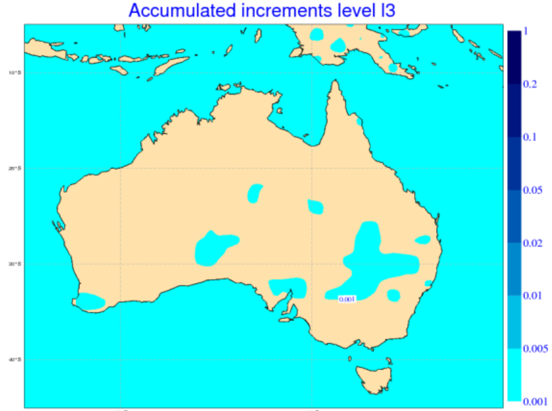
Accumulated increments level l1



Accumulated increments level l2

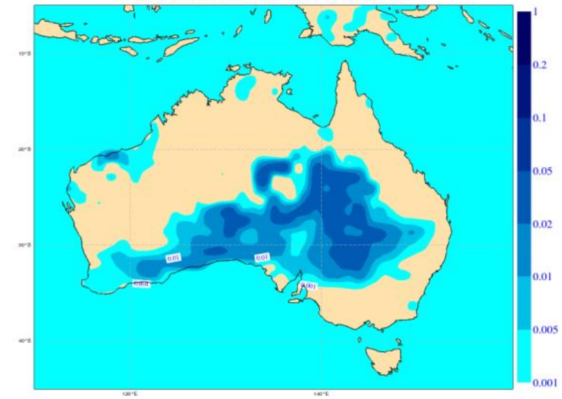


Accumulated increments level l3

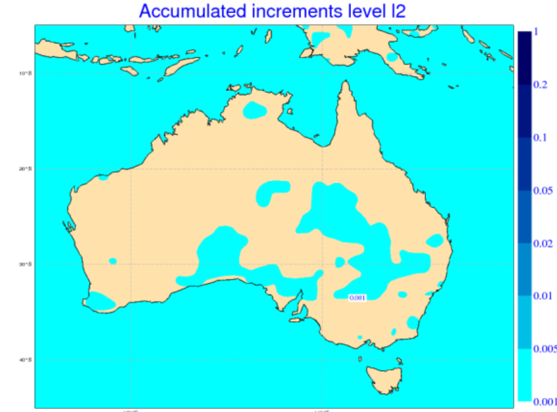


expt (foev)

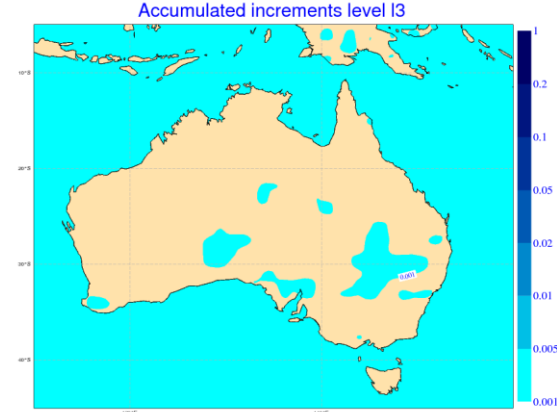
Accumulated increments level l1



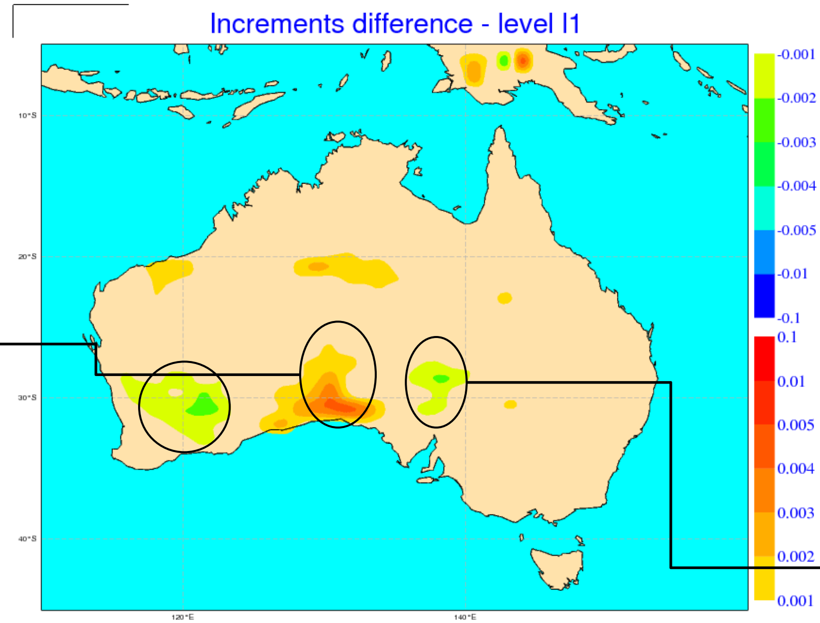
Accumulated increments level l2



Accumulated increments level l3

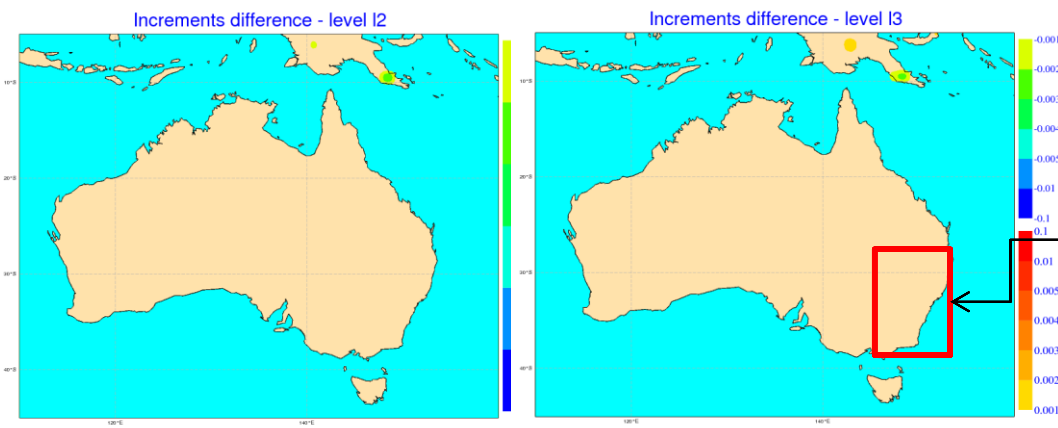


Accumulated soil moisture increments difference expt–ctrl → (SMOS T_B contribution to SM correction)



add water

remove water



Very small impact

No impact on OZNET validation sites

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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.
  -
- Caveats
  - CMEM current configuration produces strong bias (most of cases overestimates the

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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,

  - Although very small, 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),

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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.

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Second set of experiments to assimilate SMOS T_B in the ECMWF SEKF

Joaquin Munoz Sabater

ECMWF

- Assimilation of SMOS T_B in the antenna reference frame. Experimental setup:
  - Period: **01 April 2011** 00UTC – **30 April 2011** 12UTC analysis
  - Resolution: **T511** (~40 km ~ SMOS resolution)
  - Observations:
    - NRT brightness temperatures (standard product),
    - expt-frm1: 40 degrees ± 0.5 K, XX & YY polarisations → (40XX, 40YY),
    - expt-frmx: 20,50 degrees ± 0.5 K, XX polarisation → (20XX, 50XX)
  - CMEM configuration as in SMOS suite (not calibrated at global scale)
  - **Jacobians calibrated** ($\Delta\theta j$=1%, $/H^{-}_{max}/ = /H^{+}_{max}/$ =250 K/m3m-3)
  - **STD of observations error** → radiometric accuracy
  - Degraded observational system → show better the impact of SMOS on the fc skill (only conventional and SATOB data used on top of T2m,RH2m and SMOS data.)

- Assimilation expts: Australia (clean of RFI, soil water recharge period)
- **expt-frjm**: assimilation of T2m, RH2m → default configuration (CTRL)
- **expt-frm1**: assimilation of T2m, RH2m, SMOS T_B (40XX,40YY)
- **expt-frmx**: assimilation of T2m, RH2m, SMOS T_B (20XX,50XX)

- *Preliminary impact of assimilating SMOS TB on SM fields.*

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Quality control & bias correction

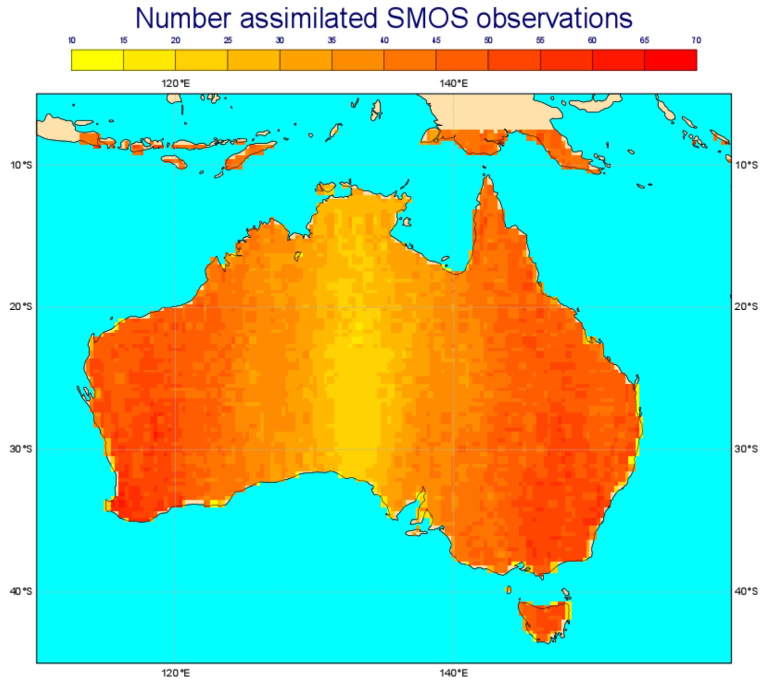
- Quality control & data thinning:
  - Routine checks for each observation,
  - RFI hard filtering: $50 < T_B < 350$ K
  - ‘Own light product’ applied at T511 (very small dataset),
  - Snow and frozen masks applied based on snow depth and T^{2m} forecasted fields.
  - First-guess departure limit set up to 16 K (~4% of SM error?)
  - Too large sensitivity of Jacobians rejected: **abs**(H_{SMOS})=250 K/m^{3}m^{-3}

- ‘Crude’ bias correction:
  - Hypothesis: Bias are stationary over April in Australia
  - Bias = *f*(polarisation, angle), but also *f*(location) accounted in CDF matching.
  - T_B (bc) = $T_B + \overline{\text{bias}}$ (Apr-2011)

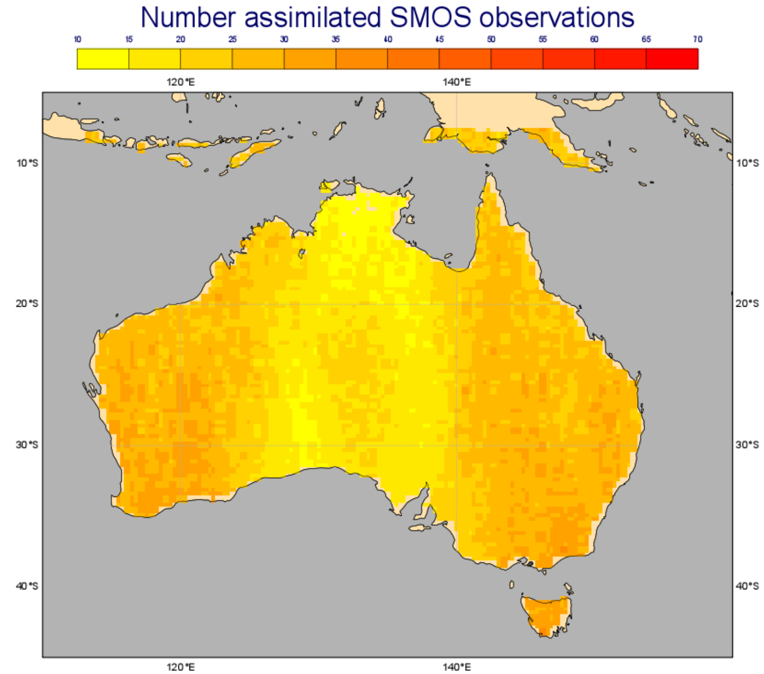
MEAN BIAS	***XX***	***YY***
frm1 (40XX,YY)	-20 K	-20 K
frmx (20,50XX)	-15 K	-32 K

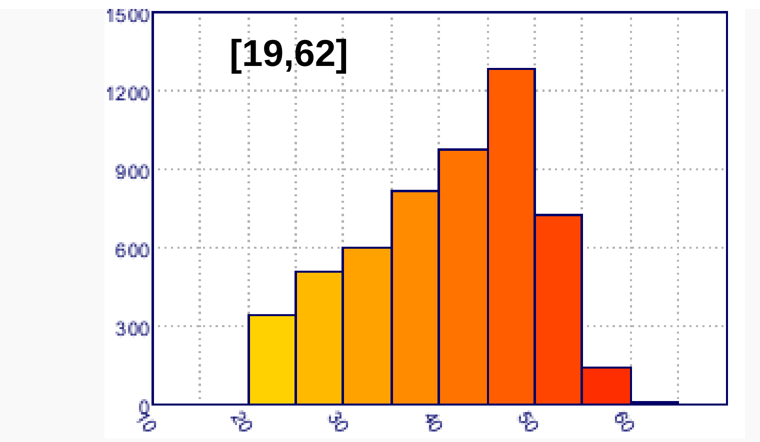
Quality control – potential number of assimilated observations

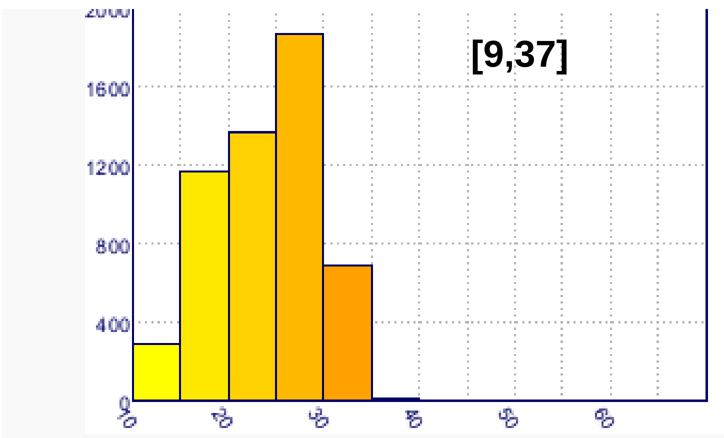
40XX,YY



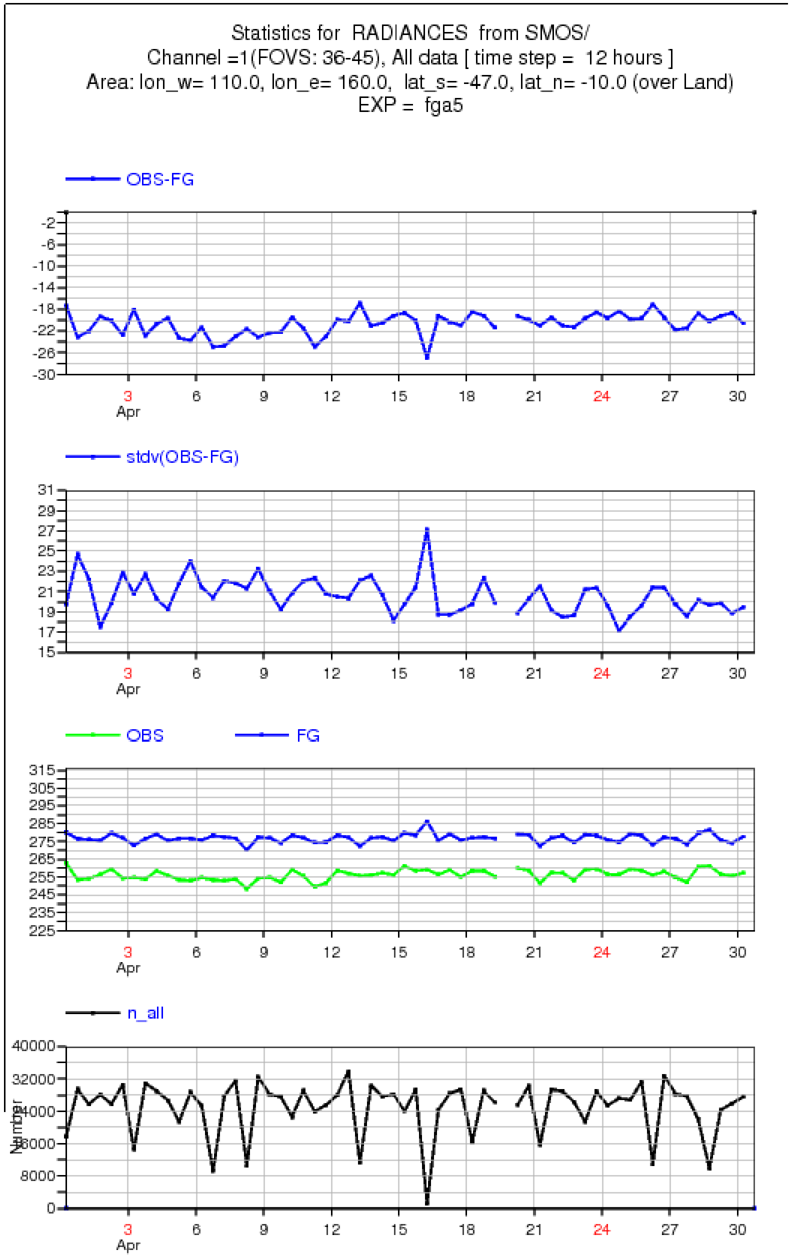
20,50XX

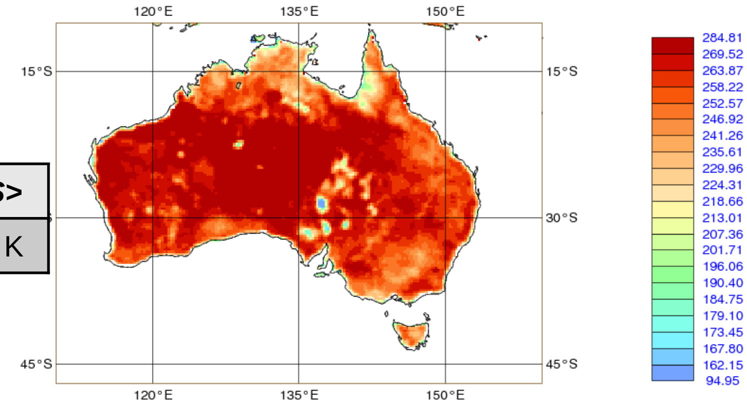






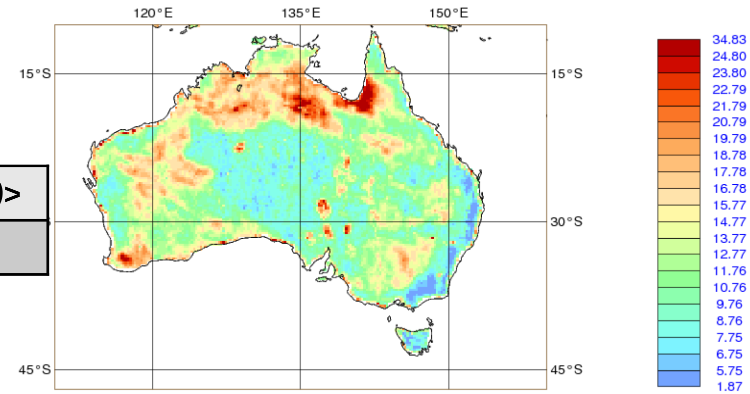
Australia – bias 40XX polarisation – April 2011





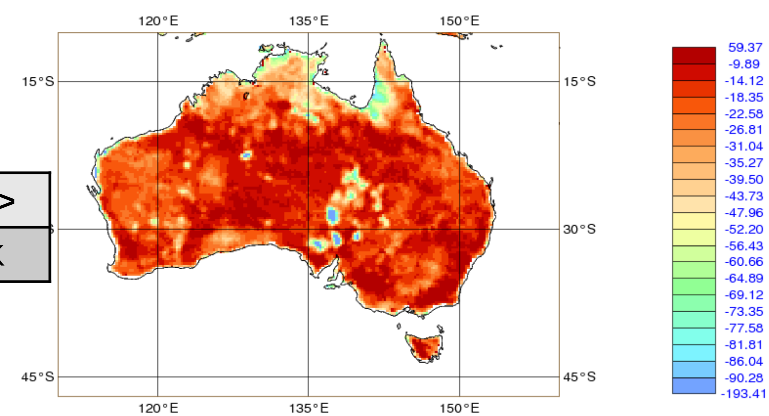
<OBS>

259.3 K



<σ(OBS)>

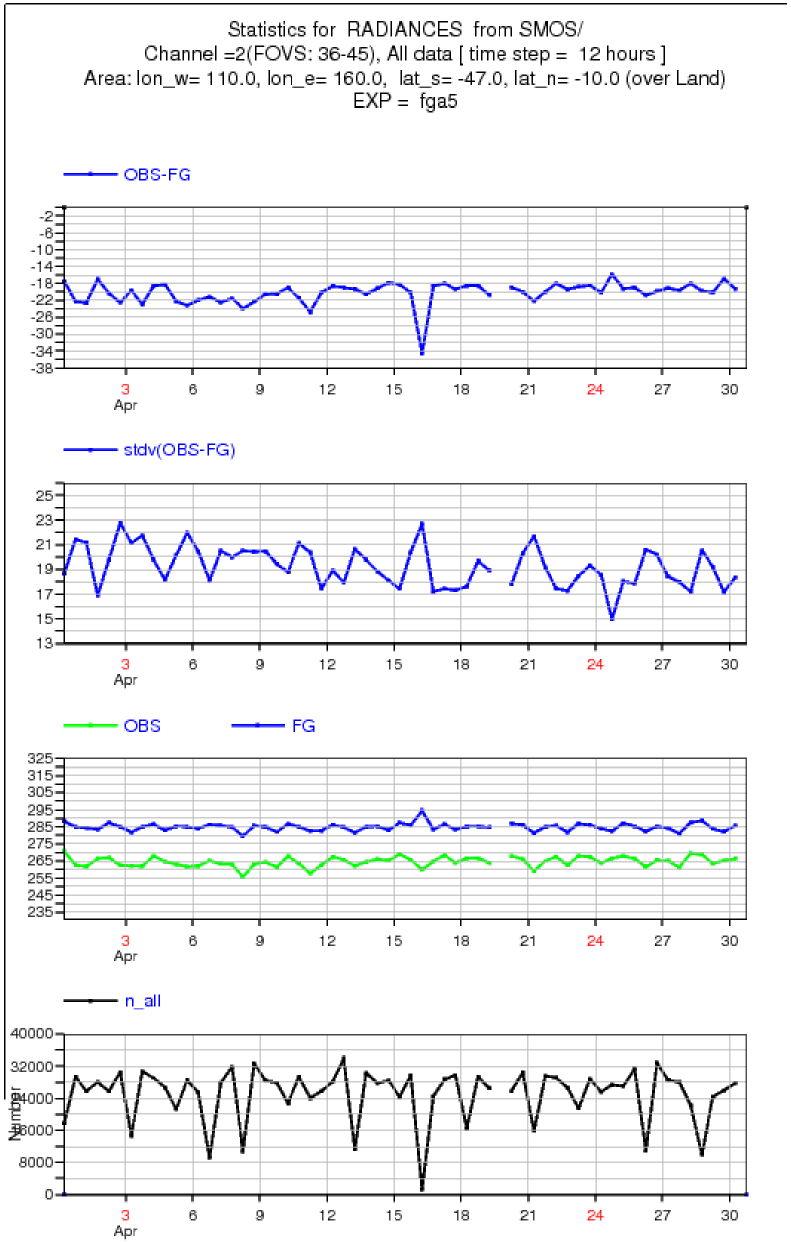
12.8 K

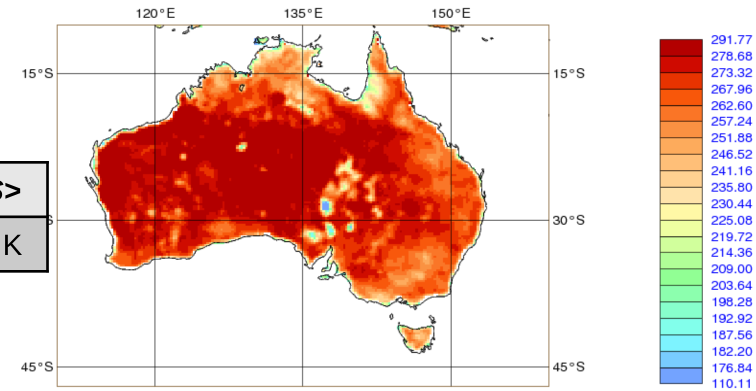


<fgdep>

-21.2 K

Australia – bias 40YY polarisation – April 2011





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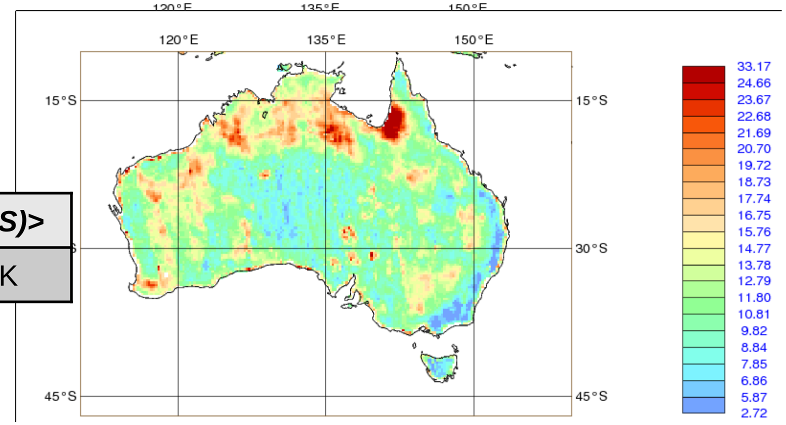
268.5 K



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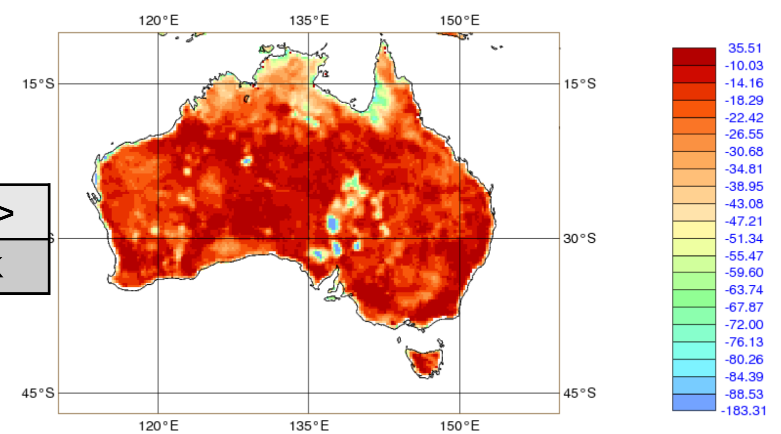
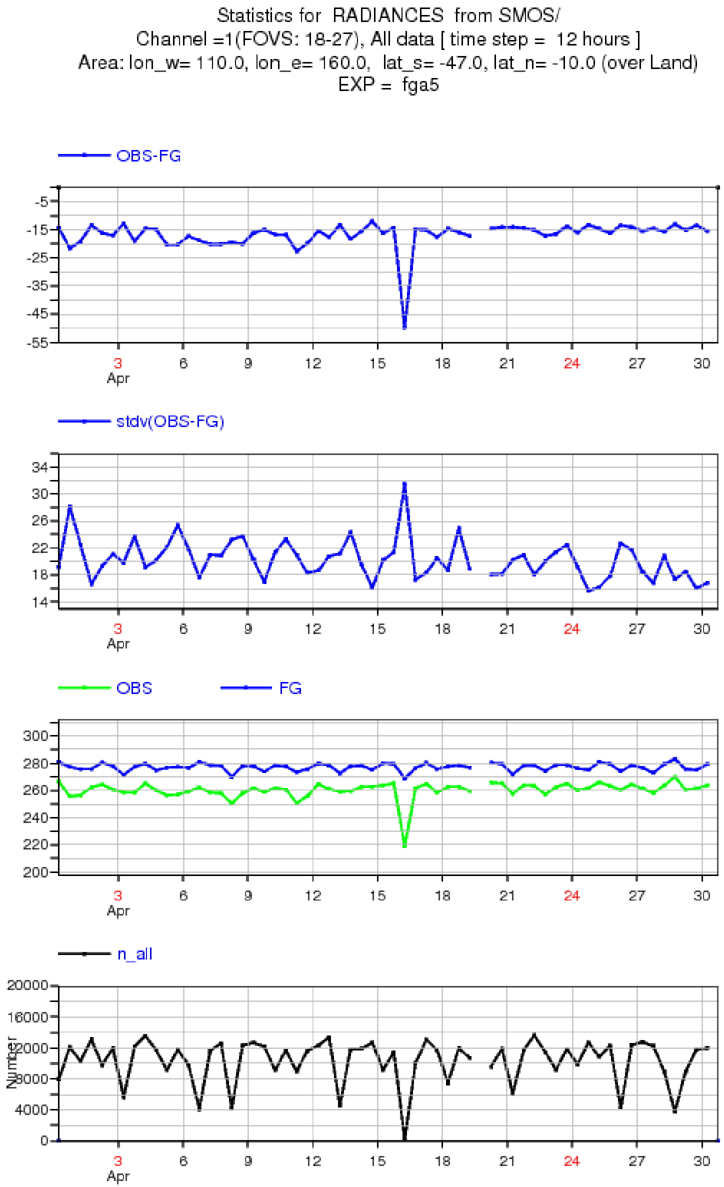
12.3 K



<fgdep>

-19.5 K

Australia – bias 20XX polarisation – April 2011



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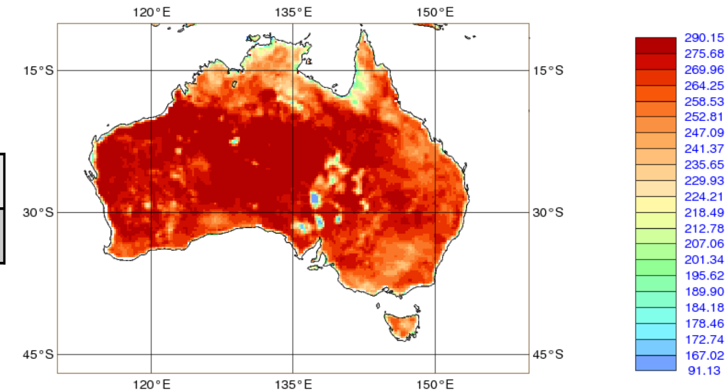
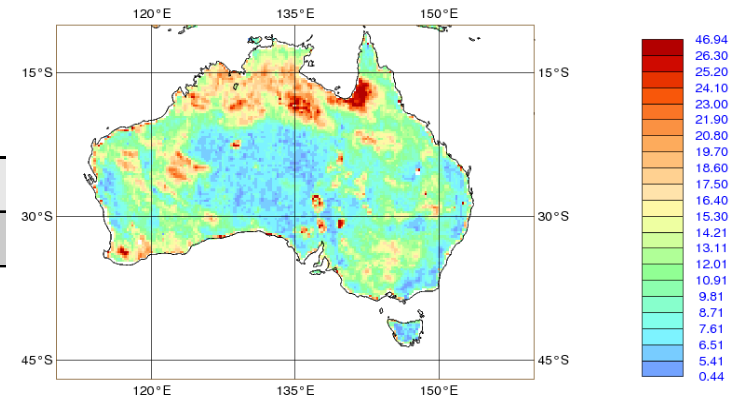
264.9 K



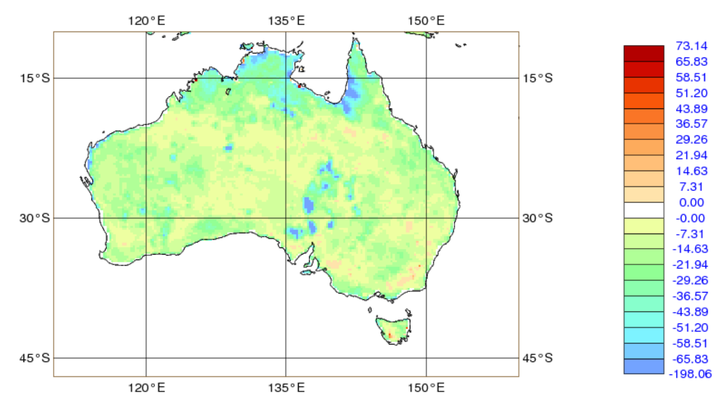
<σ(OBS)>

-11.8 K

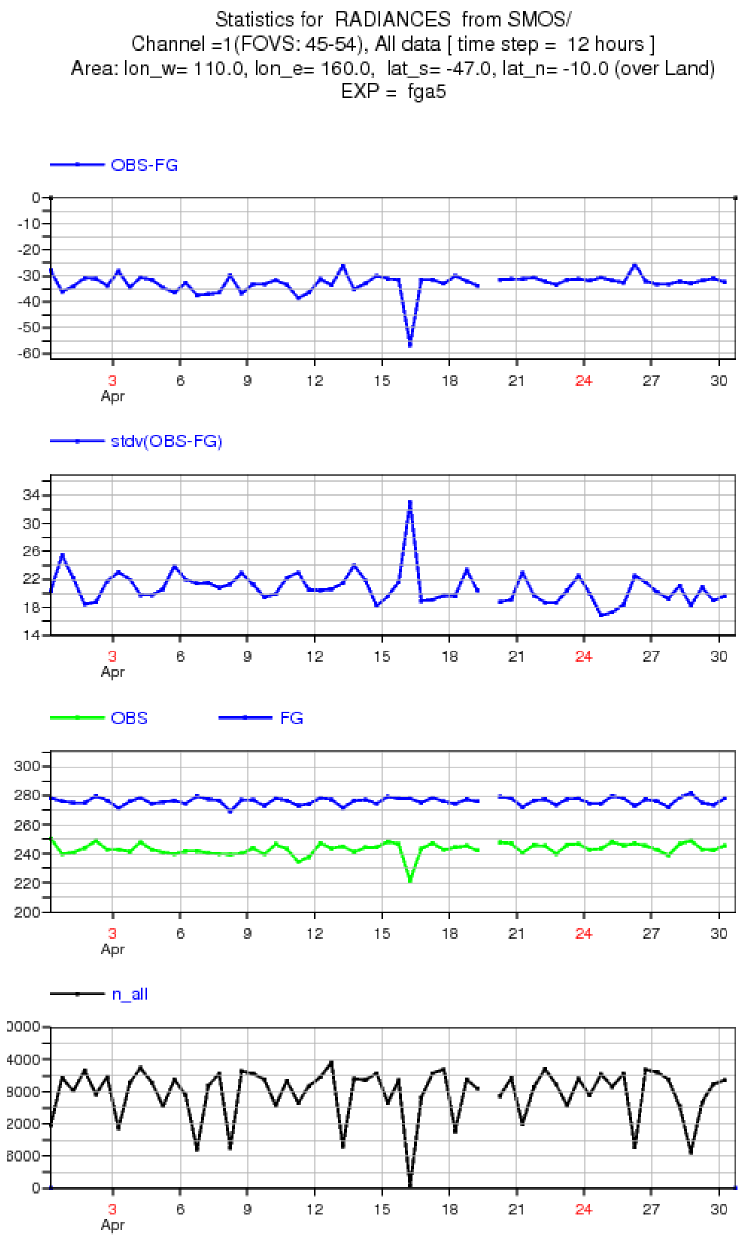


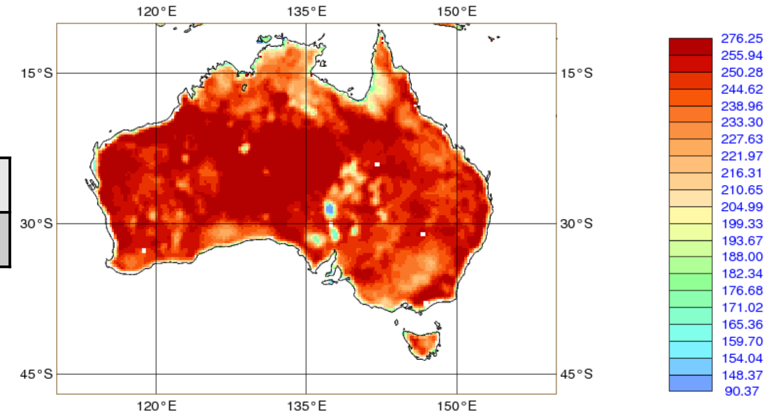
<fgdep>

-16.2 K



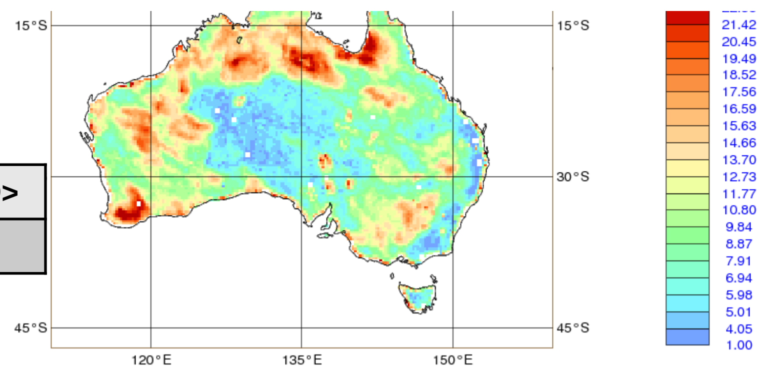
Australia – bias 50XX polarisation – April 2011





<OBS>

245.6 K



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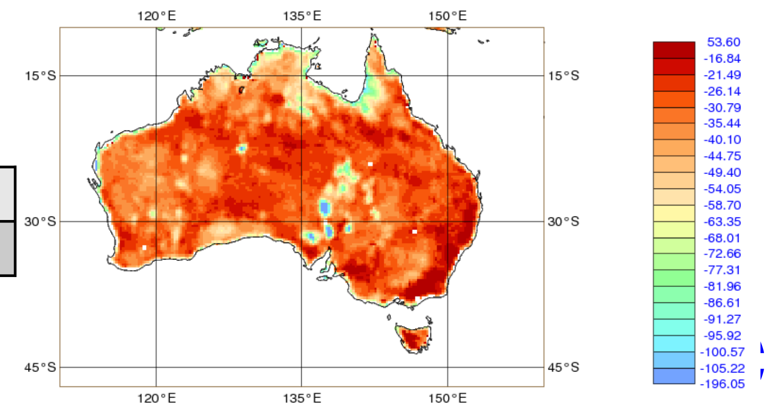
10.8 K

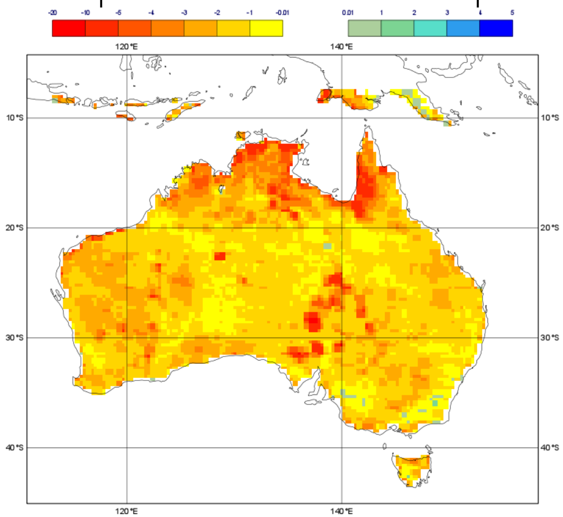


<fgdep>

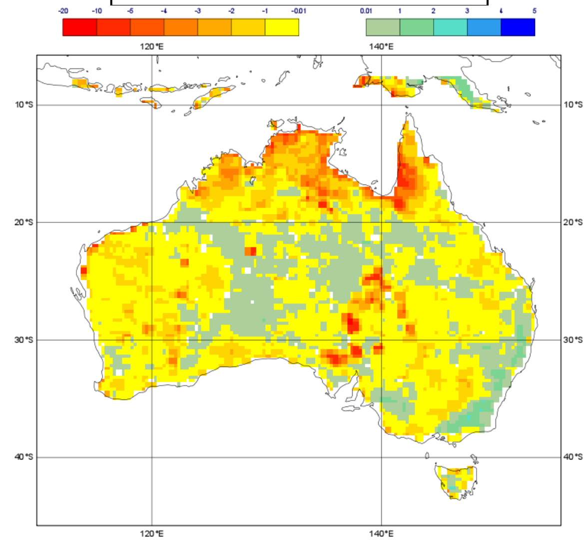
-34.4 K

Mean bias april and bias corrected (frm1)

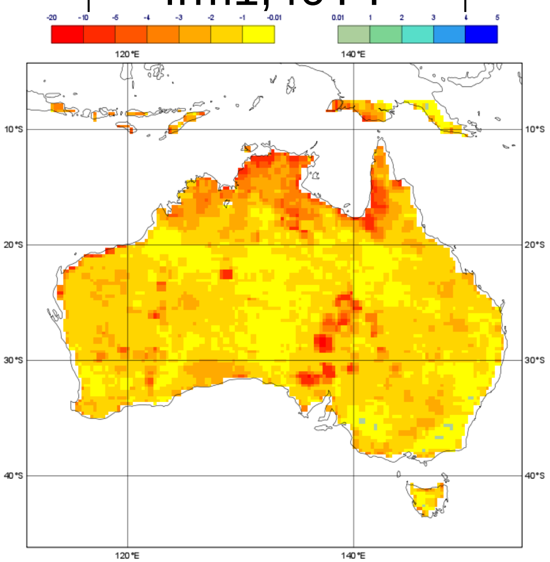
frm1, 40XX



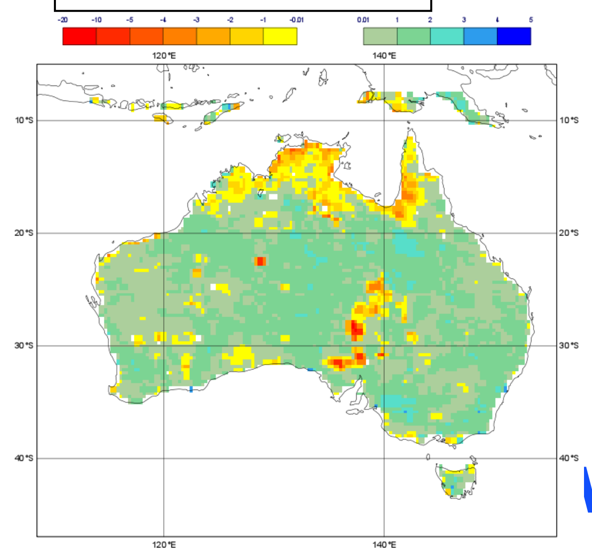
frm1,40XX BC



frm1,40YY

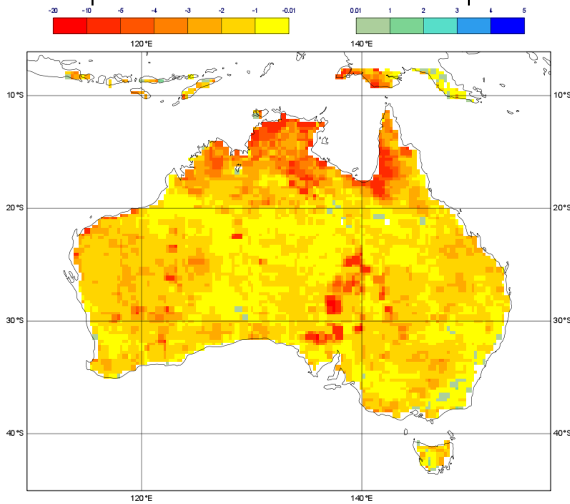


frm1,40YY BC

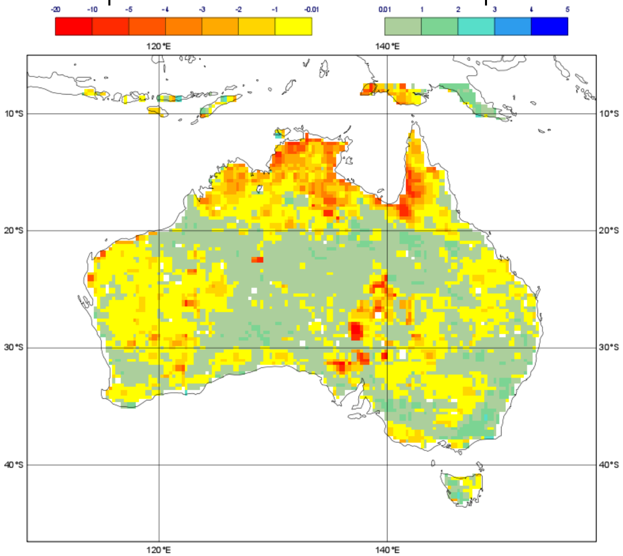


Mean bias april and bias corrected (frmx)

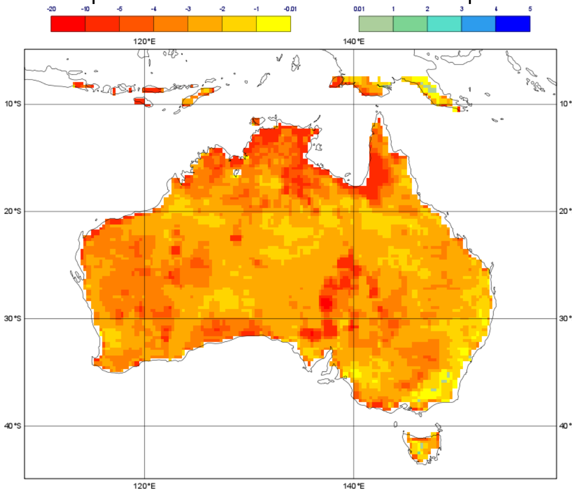
frmx, 20xx pol



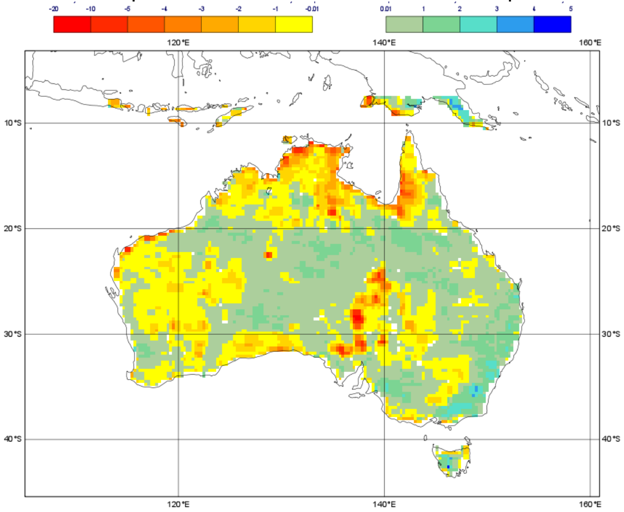
frmx,20XX BC



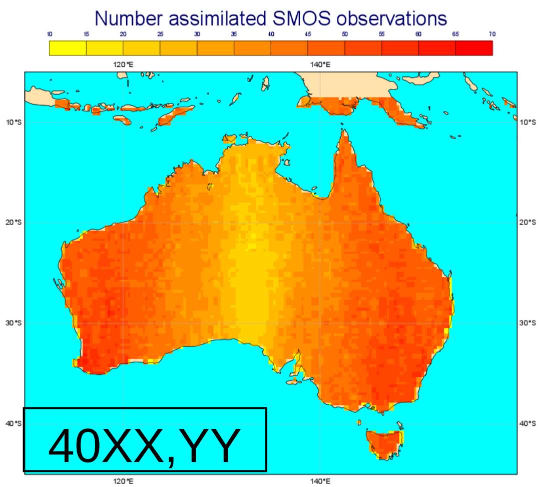
frmx,50xx pol

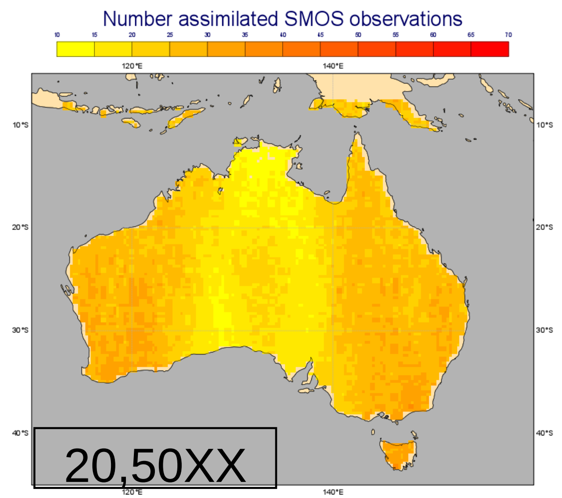


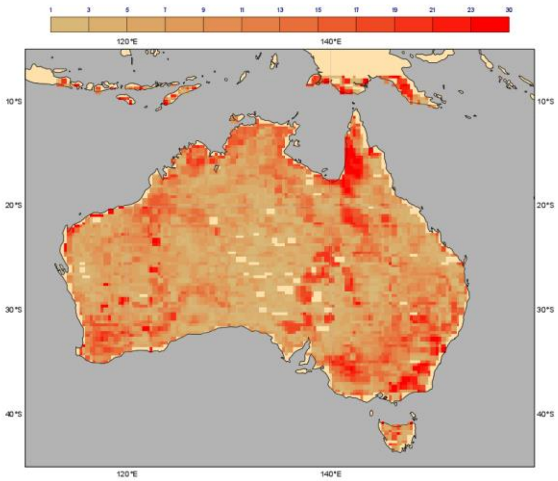
frmx,50XX BC

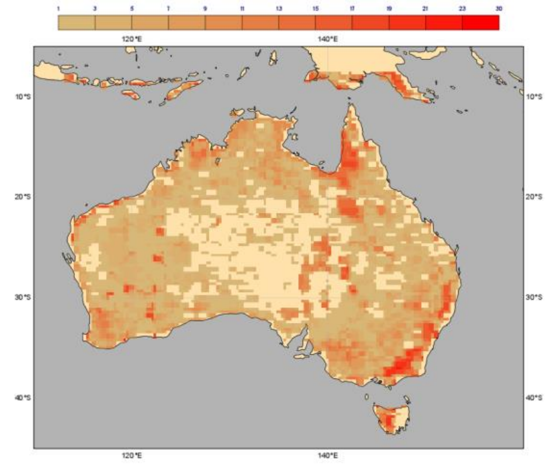


Quality control – fg_depar check





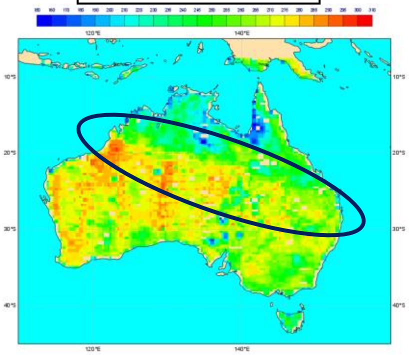




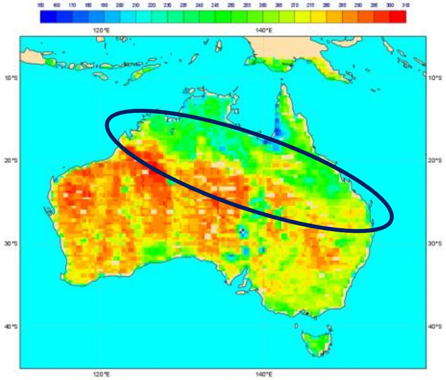
- Areas with strong variability of the obs have been removed by fg check.
- Almost no observations were rejected by Jacobian check.

Quality control – T_B average 1-3 April

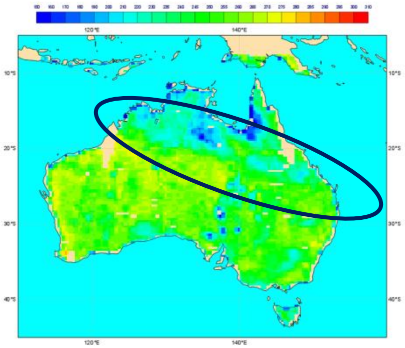
40XX



40YY



20XX

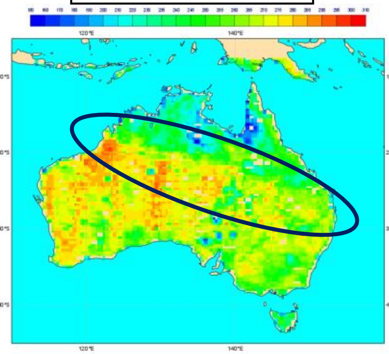


- Strange behaviour of TB at all incidence angles?

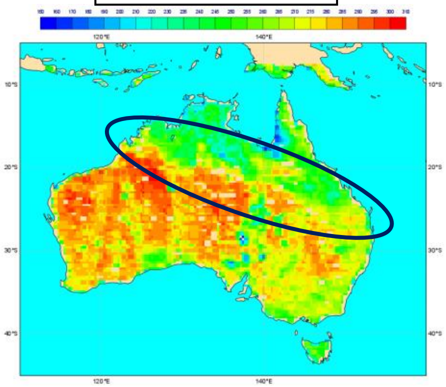
ECMWF

Quality control

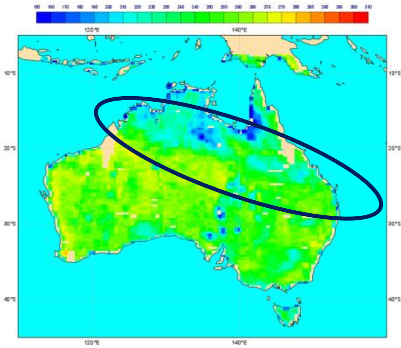
40XX



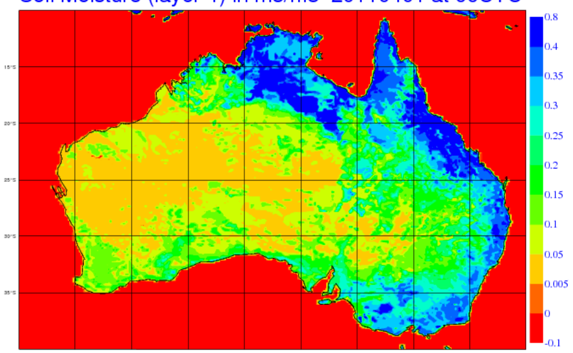
40YY



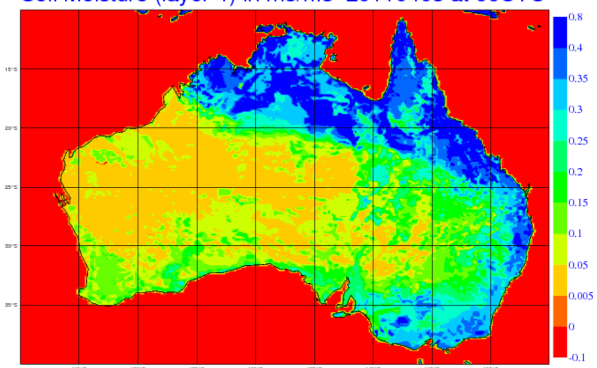
20XX



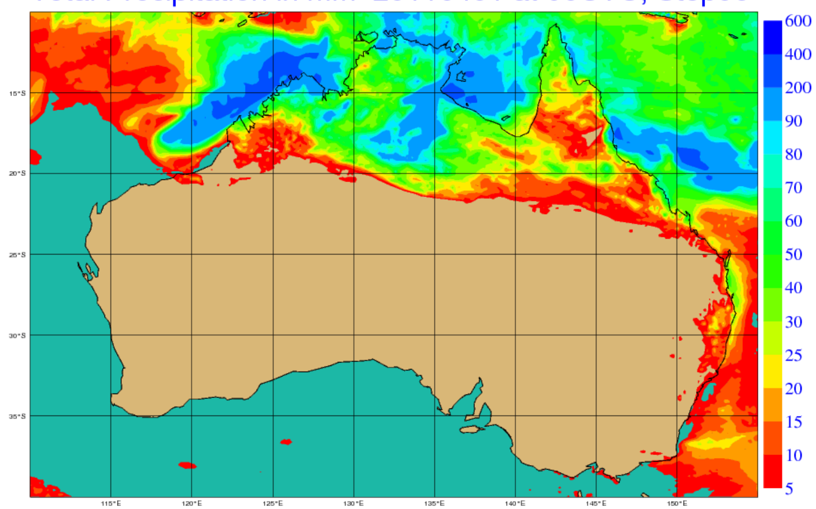
Soil Moisture (layer-1) in m3/m3 20110401 at 00UTC



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



Total Precipitation in mm 20110401 at 00UTC, Step96

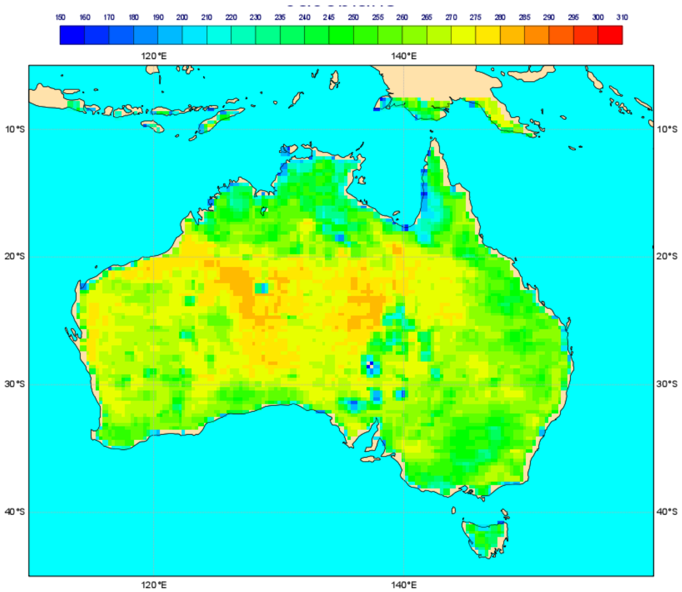


- Very good ability of SMOS to capture precipitation events.

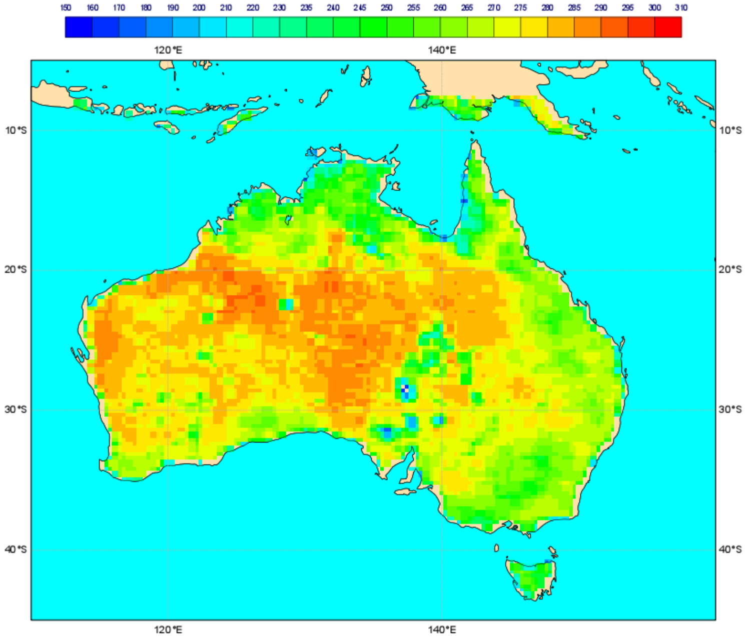
ECMWF

Tb average april → relation with jacobians

frm1, 40xx pol

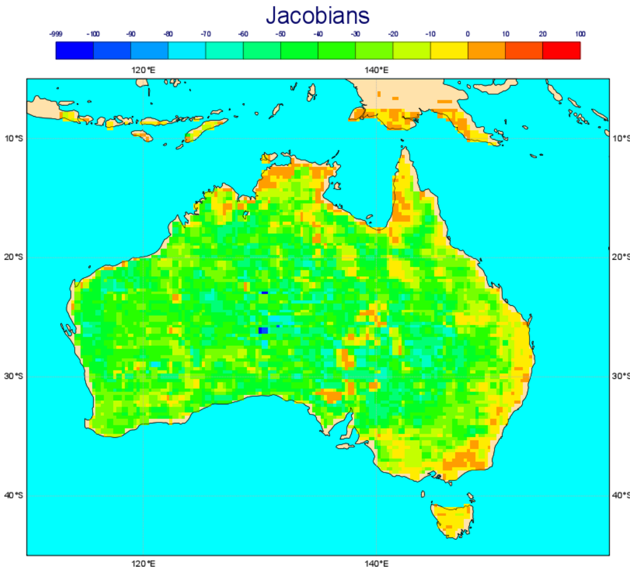


frm1,40yy pol

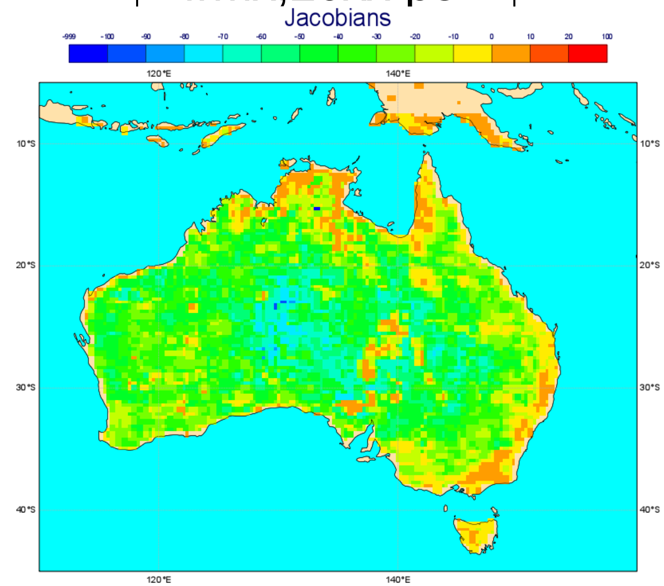


Averaged jacobians top layer – expected sensitivity

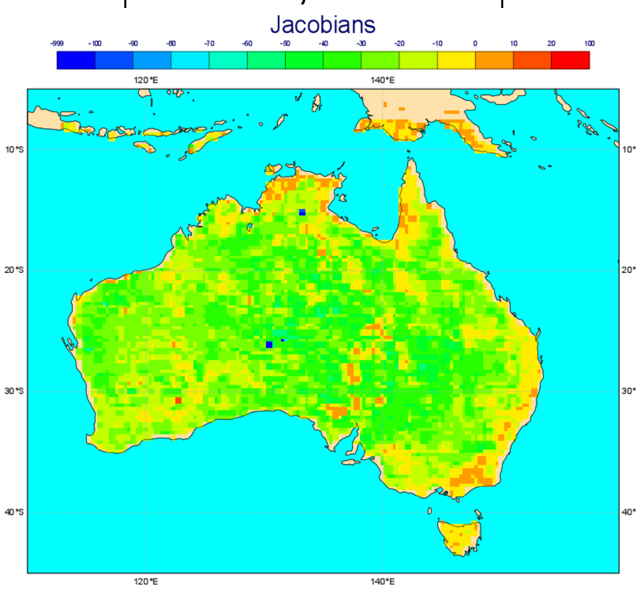
frm1,40XX



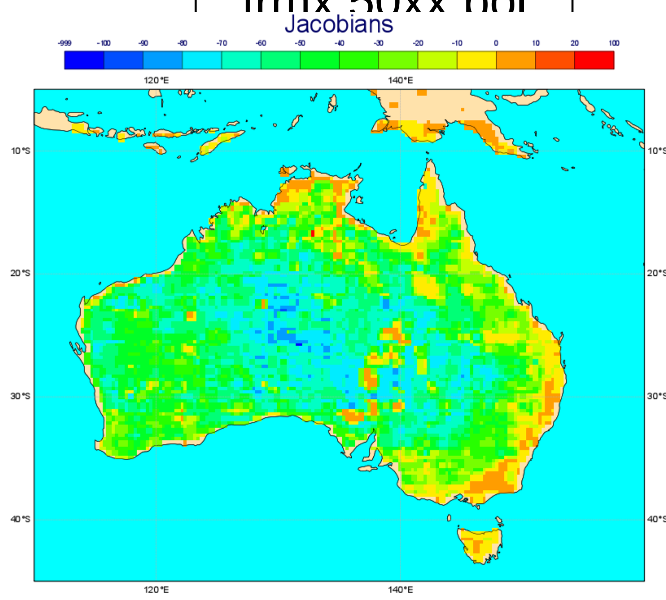
frmx,20xx pol



frm1,40YY



frmx,50xx pol



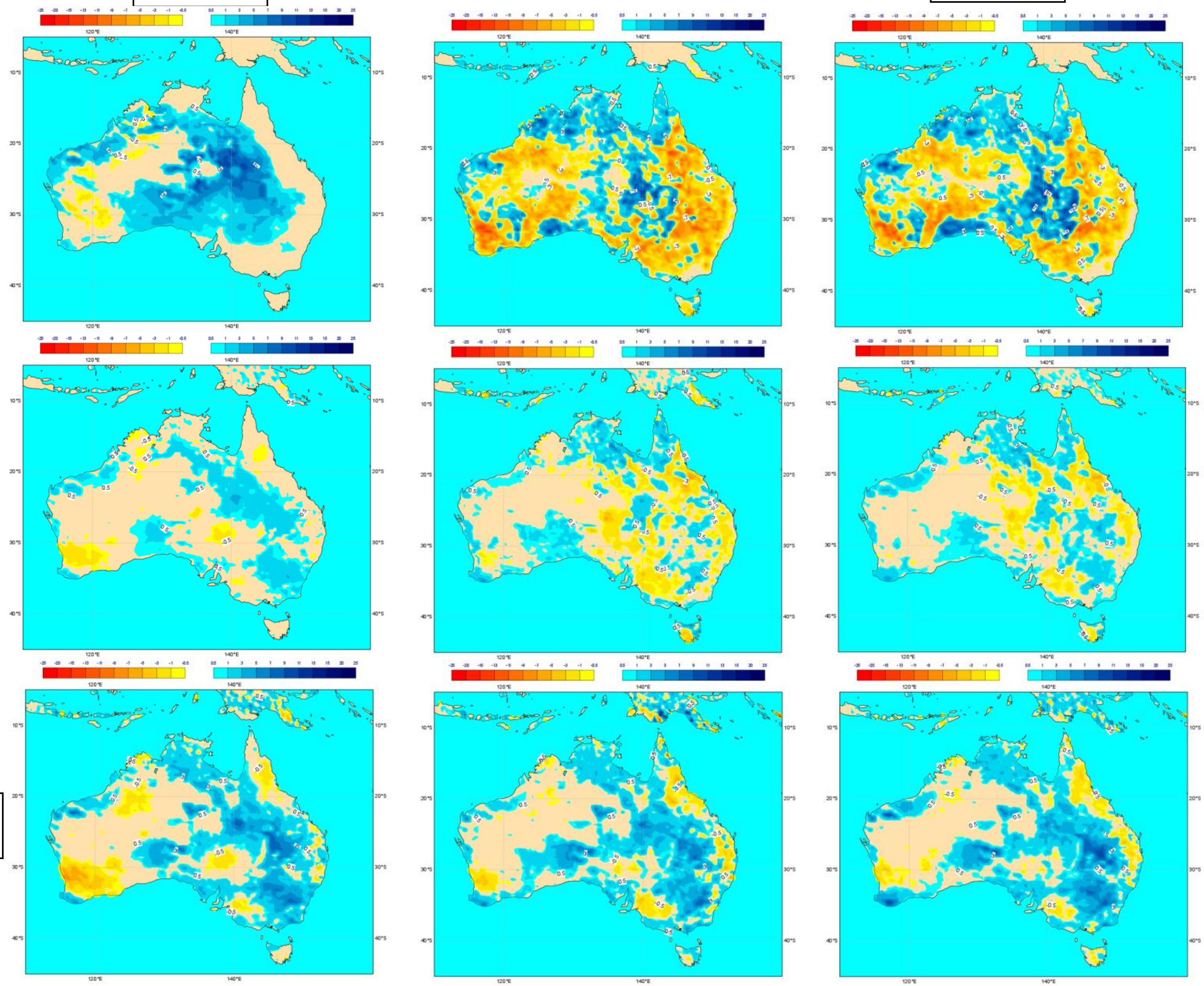
Accumulated SM increments (mm)

frjm | frm1 | frmx

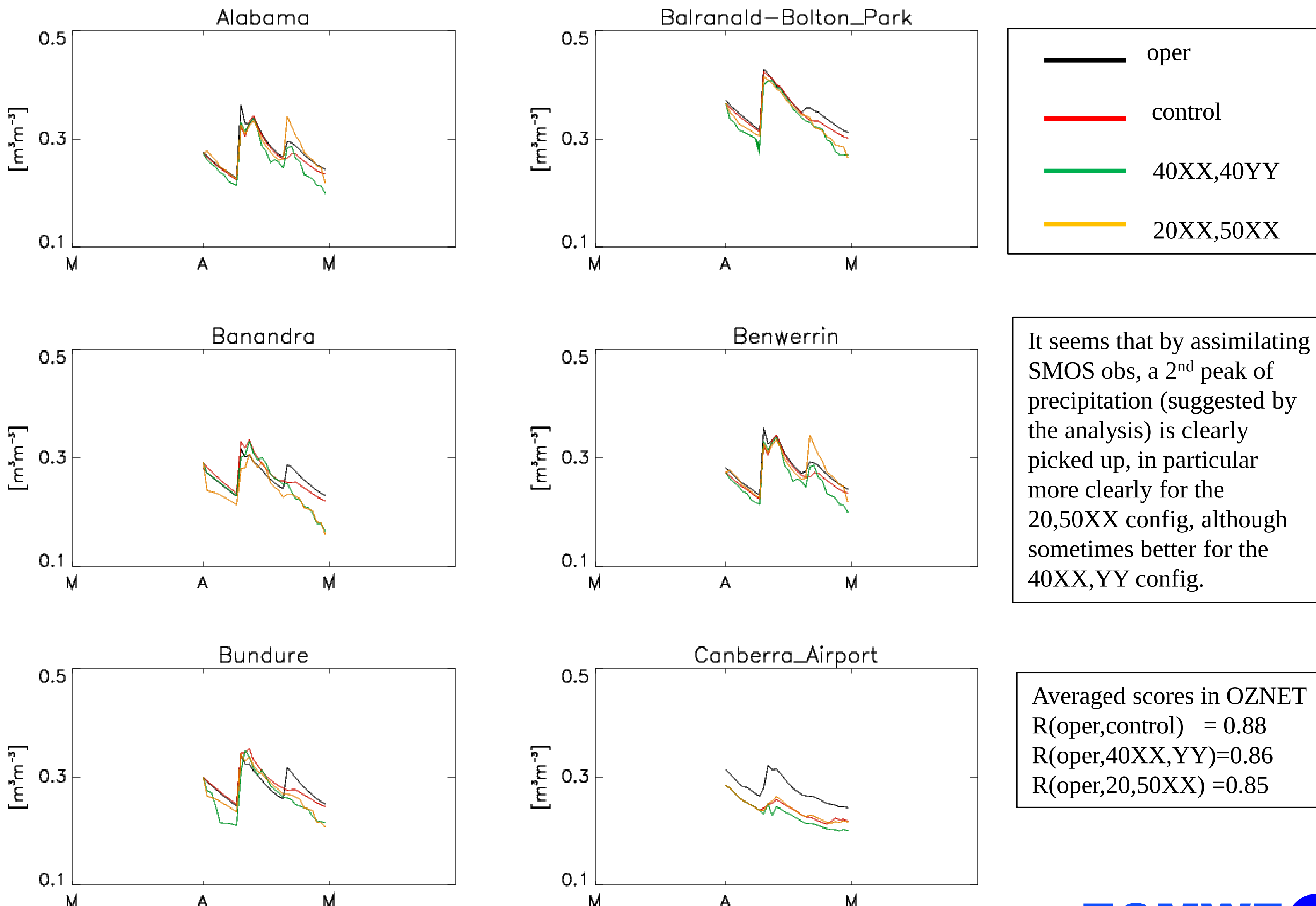
∫ 0-7cm

∫ 7-28cm

∫ 28-100cm



Validation against operational analysis (OZNET locations)

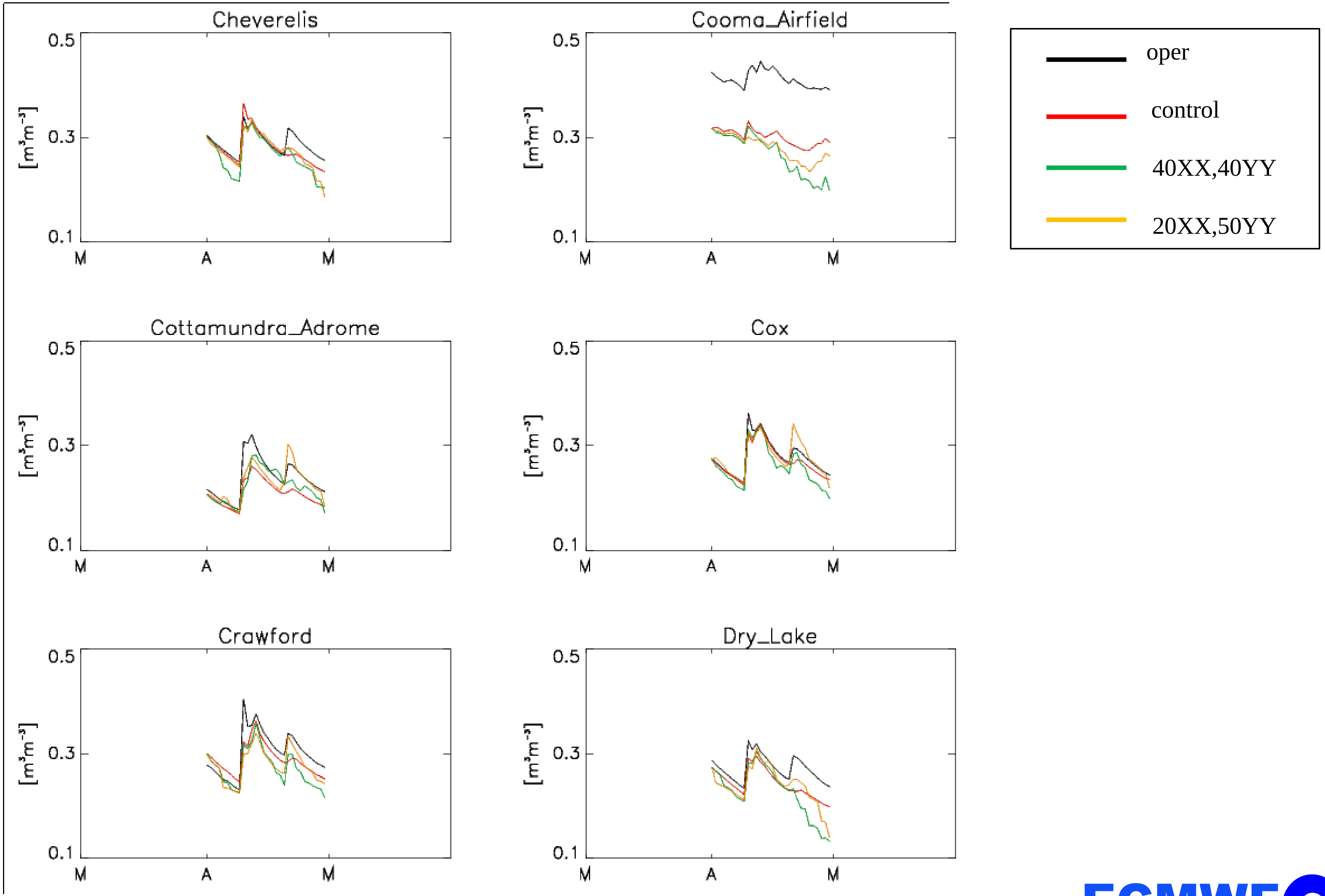


It seems that by assimilating SMOS obs, a 2nd peak of precipitation (suggested by the analysis) is clearly picked up, in particular more clearly for the 20,50XX config, although sometimes better for the 40XX,YY config.

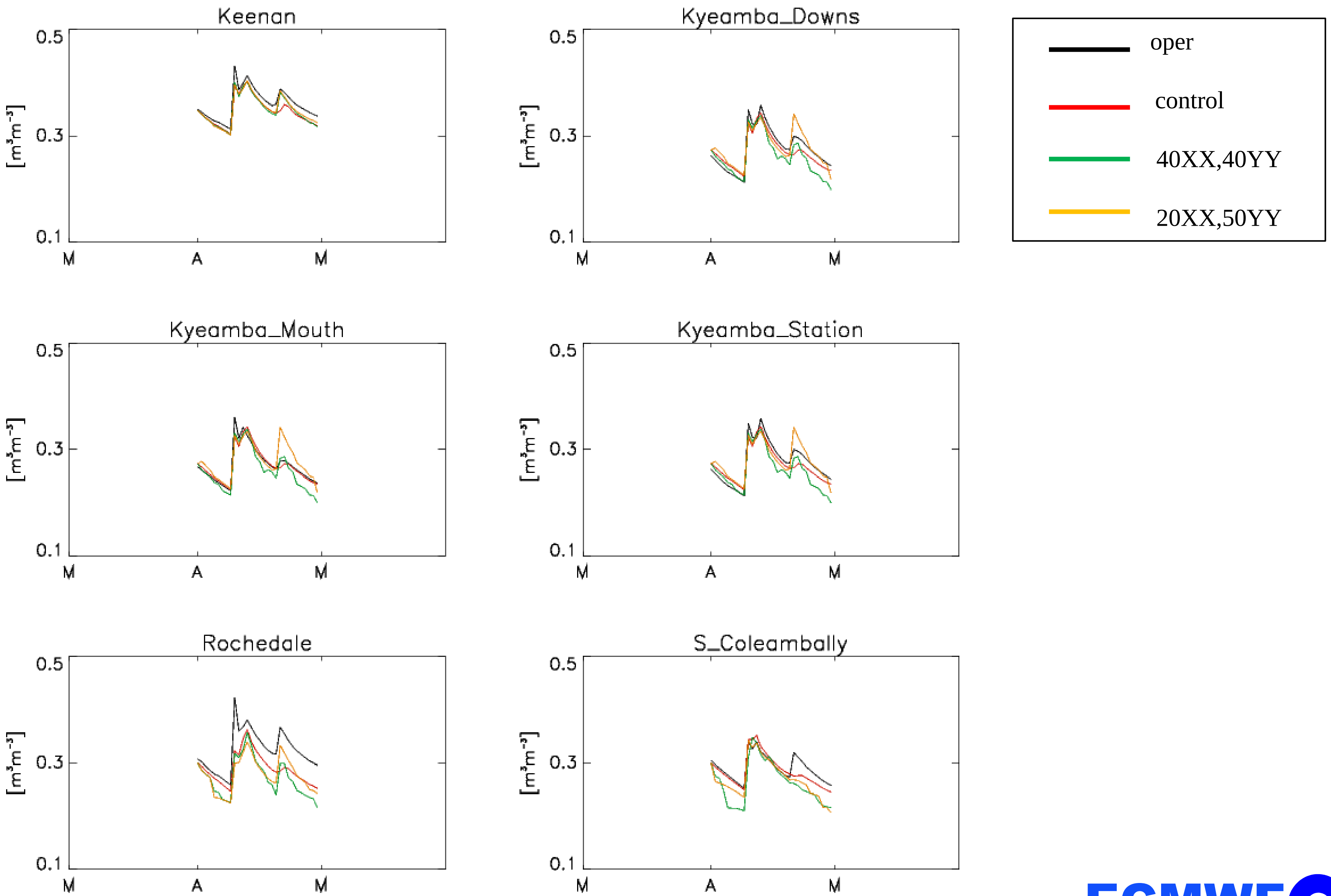
Averaged scores in OZNET
R(oper,control) = 0.88
R(oper,40XX,YY)=0.86
R(oper,20,50XX) =0.85

ECMWF

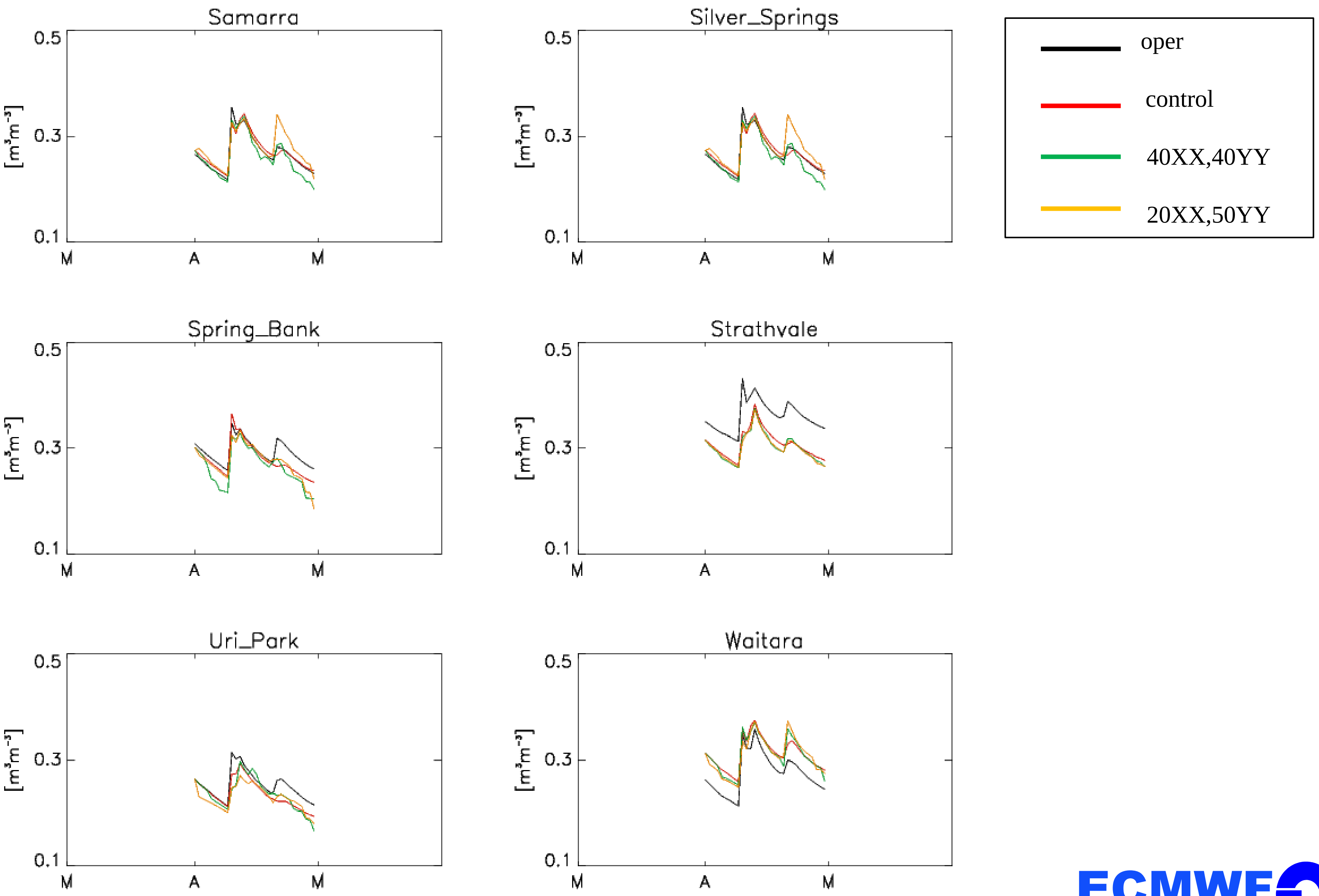
Validation against operational analysis (OZNET locations)



Validation against operational analysis (OZNET locations)



Validation against operational analysis (OZNET locations)



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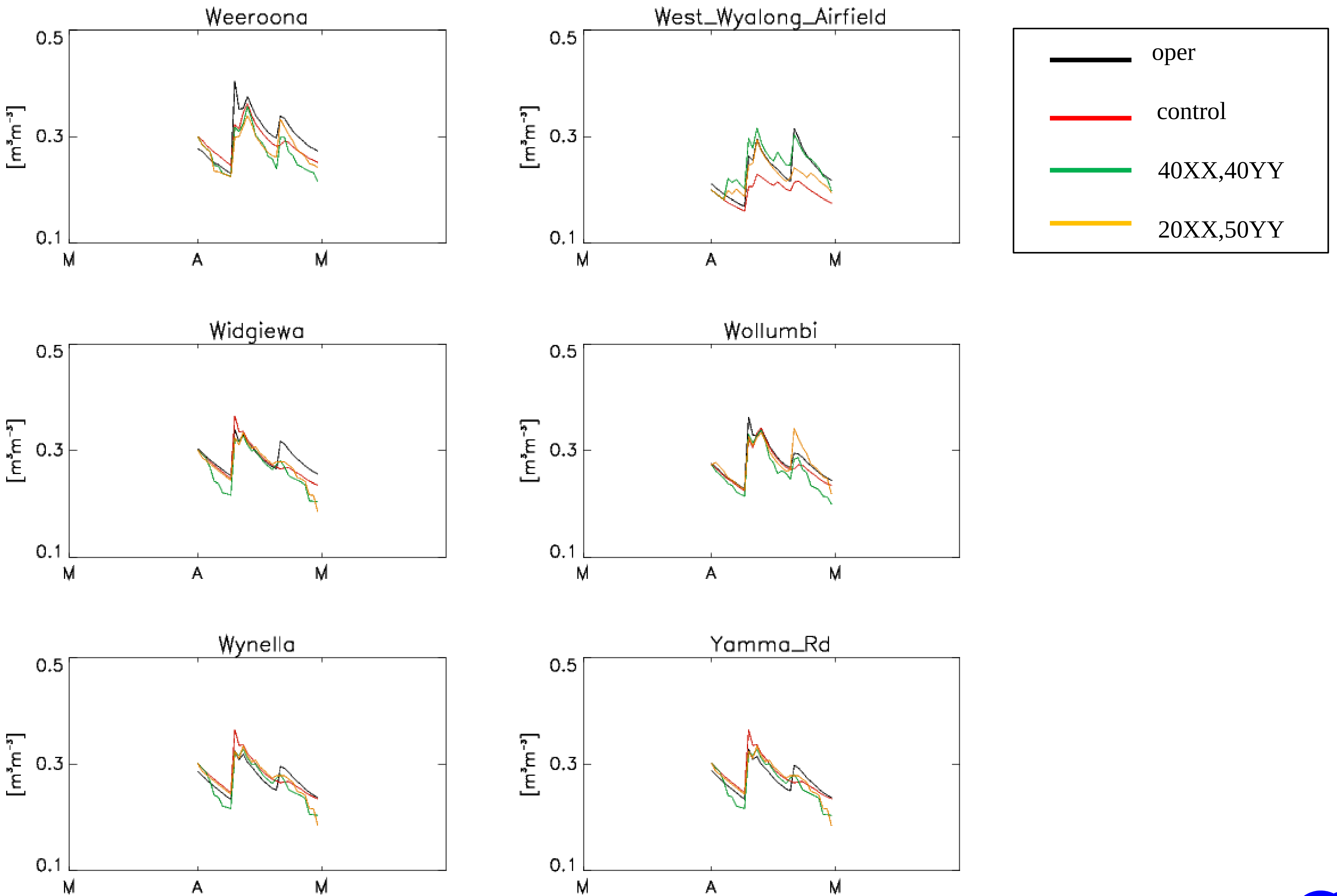
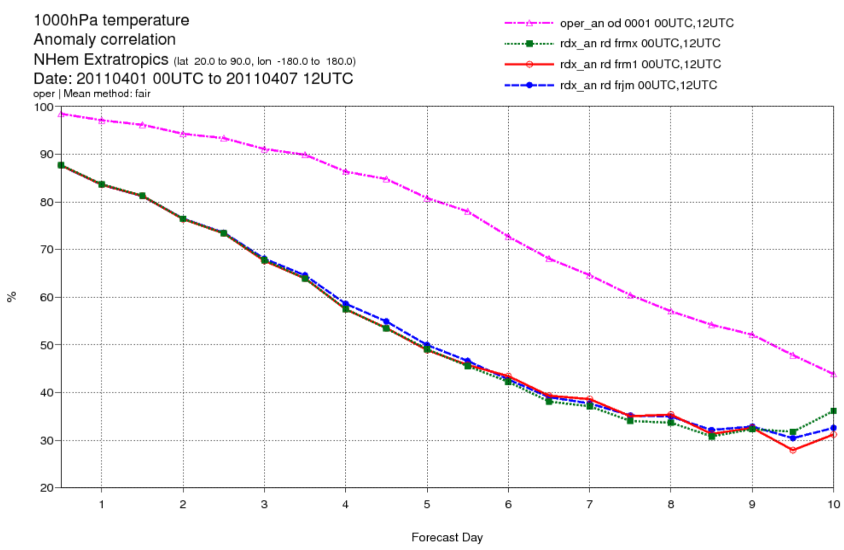
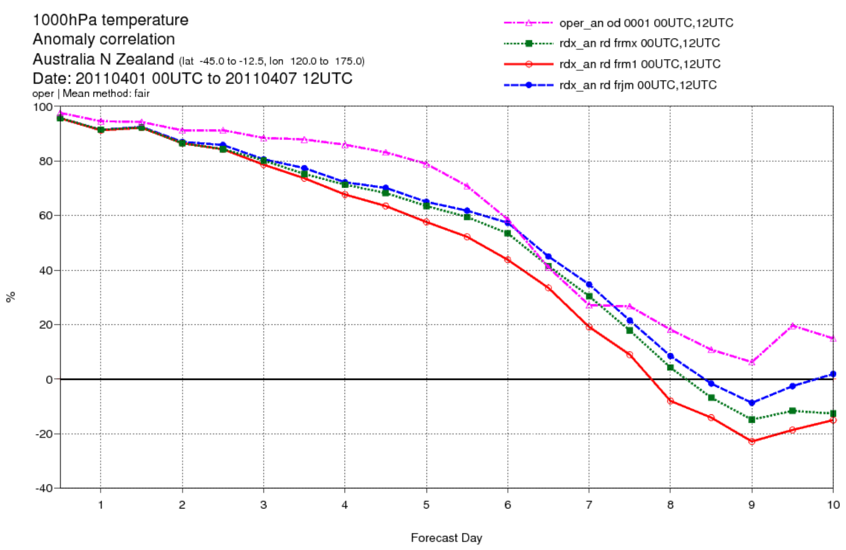
Validation against operational analysis (OZNET locations)

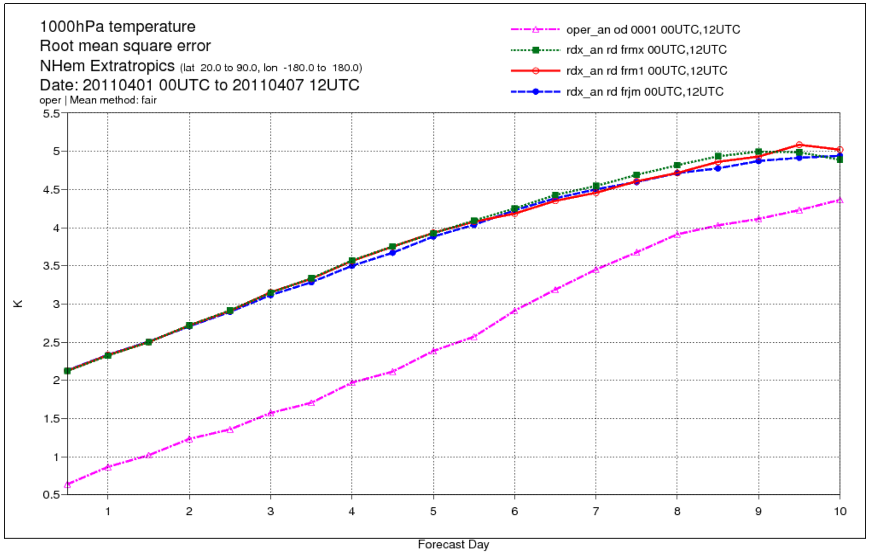


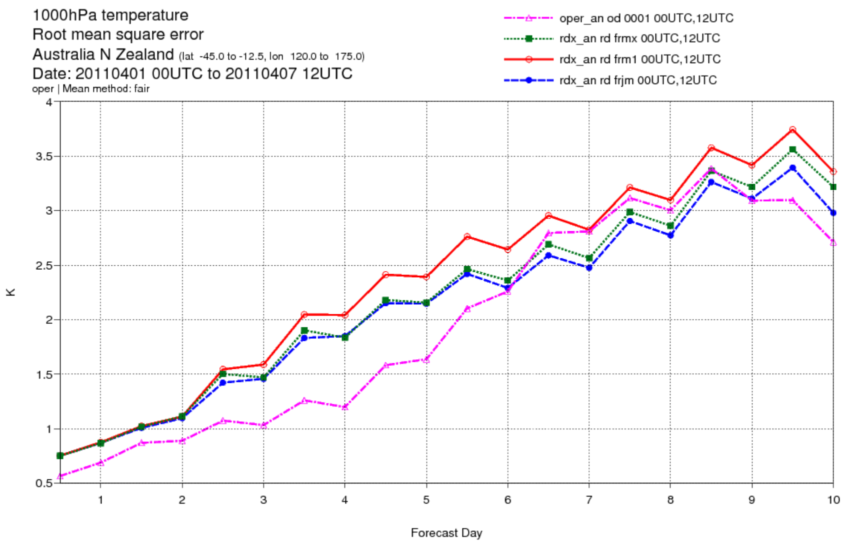
ECMWF

Impact on the forecast skill









Quality control, verification and validation

- SEKF quality control flag extended for SMOS,
- Mean Jacobian fields,
- Analysis increments,
- Gain fields,
- Forecast skill plots against the control. As reference the operational analysis is used,
- Validation of analysis against the OZNET sites,
- Validation against flux towers sites in Australia?
- Impact on the T2m and RH2m, using as reference the operational analysis,

- Assimilation of SMOS T_B in the antenna reference frame. Experimental setup:
  - Period: **01 July 2011** 00UTC – **31 July 2011** 12UTC analysis
  - Resolution: **T511** (~40 km ~ SMOS resolution)
  - Observations:
    - NRT brightness temperatures (standard product),
    - **expt-frm1**: 40 (± 0.5) degrees, XX & YY polarisations → (40XX, 40YY),
    - **expt-frmx**: 20, 50 (± 0.5) degrees, XX polarisation → (20XX, 50XX),
  - CMEM configuration calibrated according to RMSE metric.
  - **Jacobians calibrated** ($\Delta\theta j$=0.01m^3m^{-3}, $/H^-_{max}/ = /H^+_{max}/$ =250 K/m^3m^{-3})
  - **STD of observations error** → radiometric accuracy
  - Degraded observational system → expt run faster and shows better the impact of SMOS on the SM fields and fc skill (only conventional data at global scale is used to constrain atmospheric analysis),

- Assimilation expts: North and South America (few RFI, dry period North America)
- **ctrl-fskc**: assimilation of T^{2m}, RH^{2m} → default configuration (CTRL)
- **expt-fska**: assimilation of T^{2m}, RH^{2m}, SMOS T_B (20XX,50XX)

ECMWF

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 T511 (very small dataset),
  - Snow and frozen masks applied based on snow depth and T^{2m} forecasted fields.
  - First-guess departure limit set up to 20 K
  - Too large sensitivity of Jacobians rejected: max(**abs**(H_{SMOS}))=250 K/m^3m^{-3}

- 'Crude' bias correction:
  - Hypothesis: Bias are approximately stationary over July in America
  - Bias = *f*(polarisation, angle), but also *f*(location) accounted for in CDF matching.
  - $T_B\,(bc) = T_B + \overline{\text{bias}}$ (Apr-2011)

MEAN BIAS	***20***	***50***
fska (20XX,50XX)	28.4 K	31.2 K

ECMWF