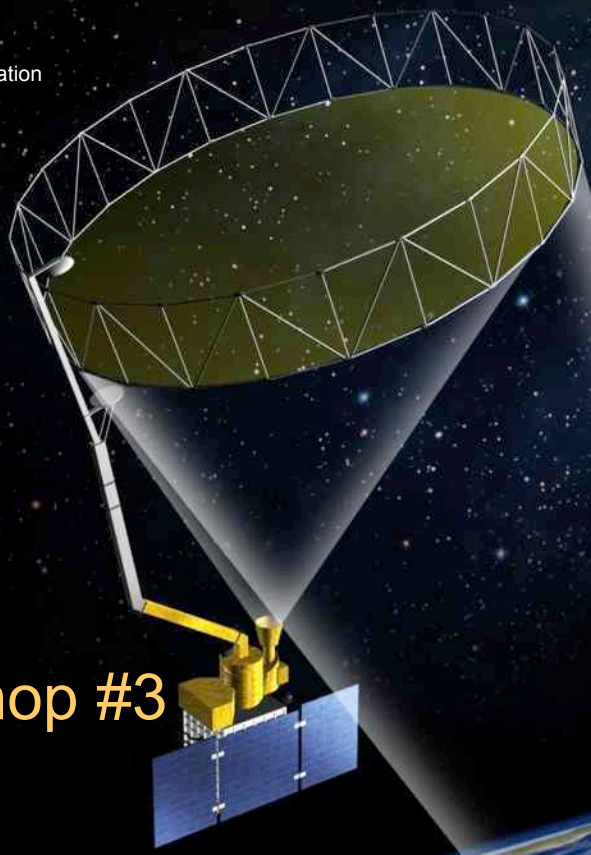
National Aeronautics and Space Administration



Soil Moisture
Active Passive
Mission

SMAP

Cal/Val Workshop #3

Nov. 14-16, 2012
Oxnard, CA

Model Products and Data Assimilation in Validation

Rolf Reichle (NASA/GSFC)
Wade Crow (USDA/ARS)
Patricia de Rosnay (ECWMF)
Clara Draper (NASA/GSFC)
and many others!

Outline

Direct comparisons vs. model products

- Classical metrics
  - Bias, RMSD, R
- Triple colocation

Validation within data assimilation systems

- Monitoring
  - Observations-minus-forecast residuals and other stats
- Improvements from data assimilation
  - Use of related observations (vegetation, precipitation, …)

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Direct Comparisons: Classical Metrics

Model products are **not** "truth".

However, NWP-type "model" products are based on many millions of atmospheric observations each day.

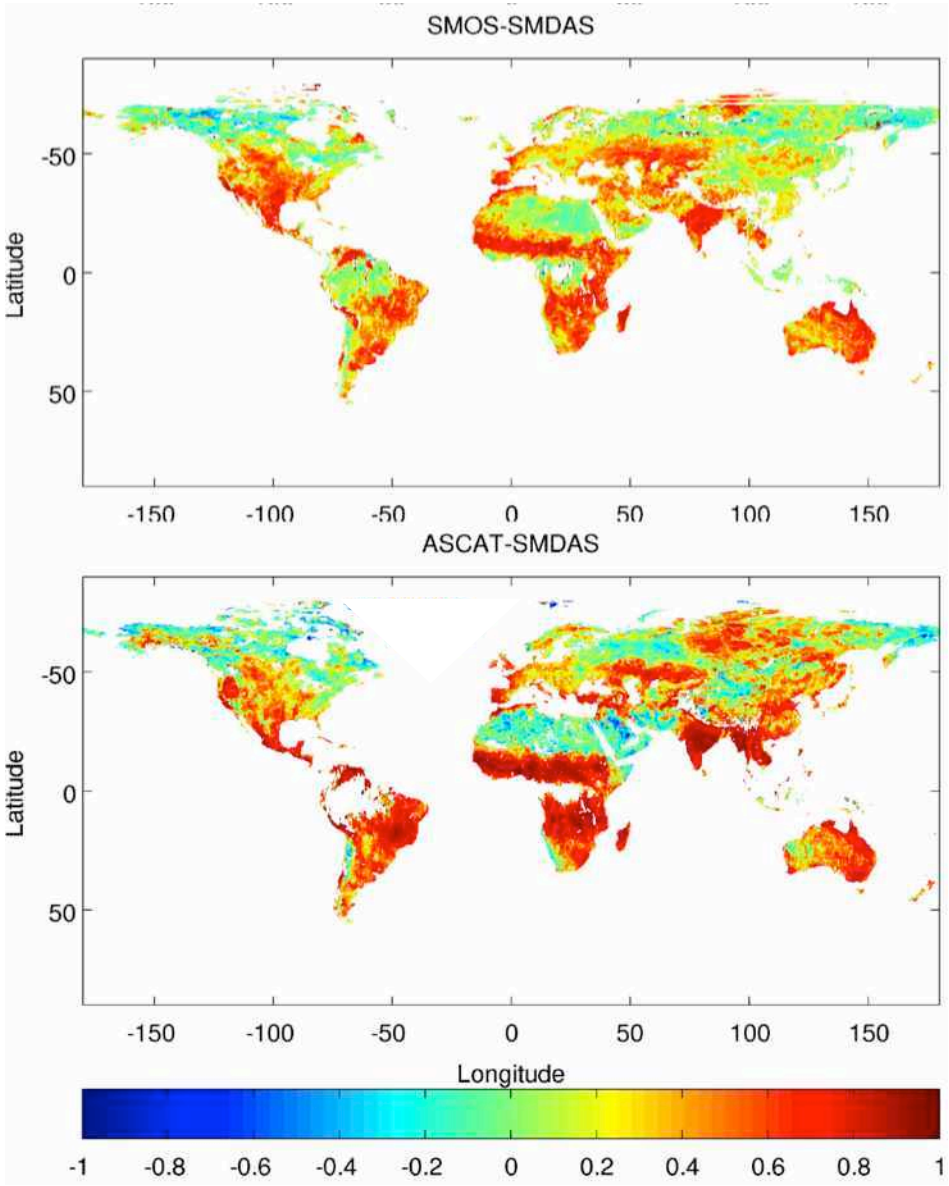
Skill of "model" soil moisture products is often comparable to or even better than that of satellite retrievals.

Skill vs. ~200 *in situ* sites	ECMWF	ASCAT	SMOS
Correlation	0.70	0.53	0.54
Bias (index)	-0.05	-0.07	0.12
RMSD (index)	0.24	0.26	0.24

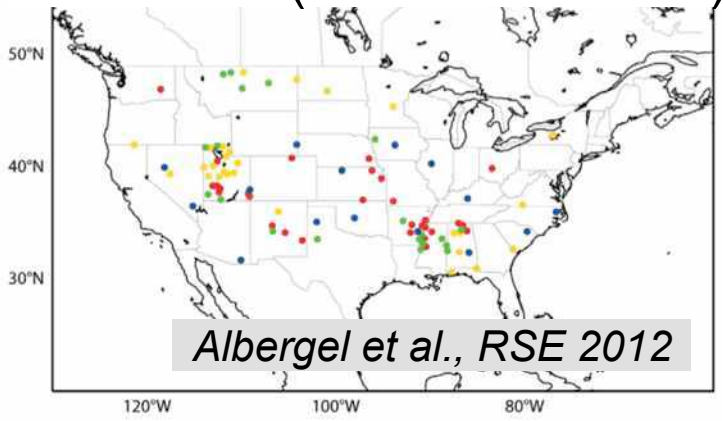
Albergel et al., RSE 2012

Caveat: Early results!

Direct Comparisons: Classical Metrics



Corr. coeff. (SMOS vs. SCAN)



Benefit:
Global assessment vs. independent estimates (as opposed to a handful of locations)

Gruhier et al, H-SAF VS11_02:
http://www.ecmwf.int/research/EUMETSAT_projects/SAF/HSAF/ecmwf-hsaf/index.html

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Direct Comparisons:Triple Colocation

Triple Colocation (TC) is a method to estimate RMS errors in data products.

TC requires three independent estimates.

Model products can be used for TC.

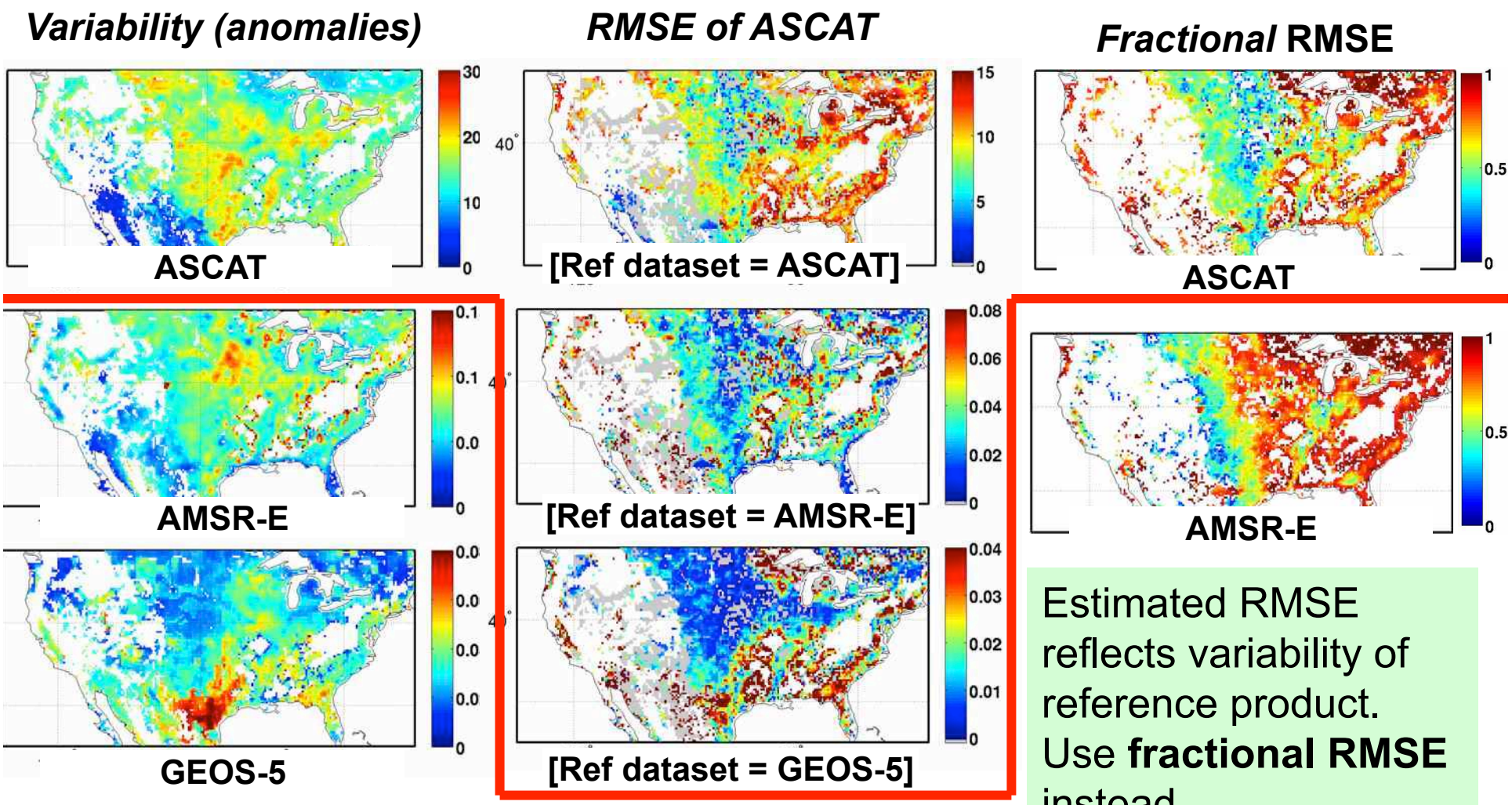
NOTE:

1.) TC cannot provide absolute RMS errors.

2.) TC is sensitive to the climatology of the reference data set.

3.) Error correlations between data sets result in biased RMSE estimates.

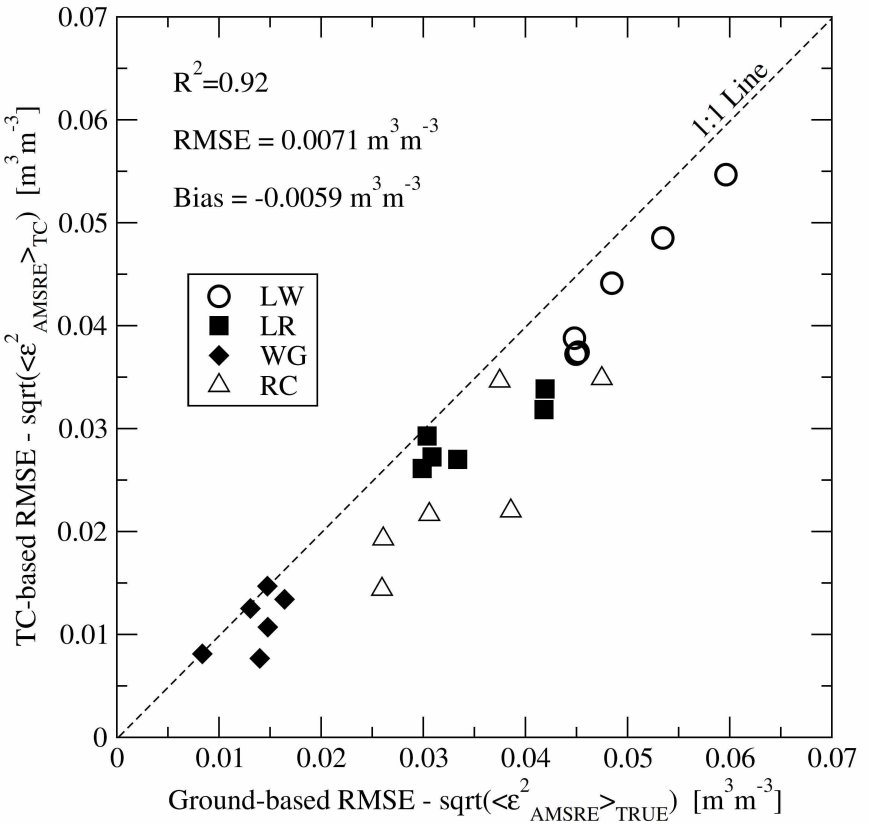
Direct Comparisons:Triple Colocation

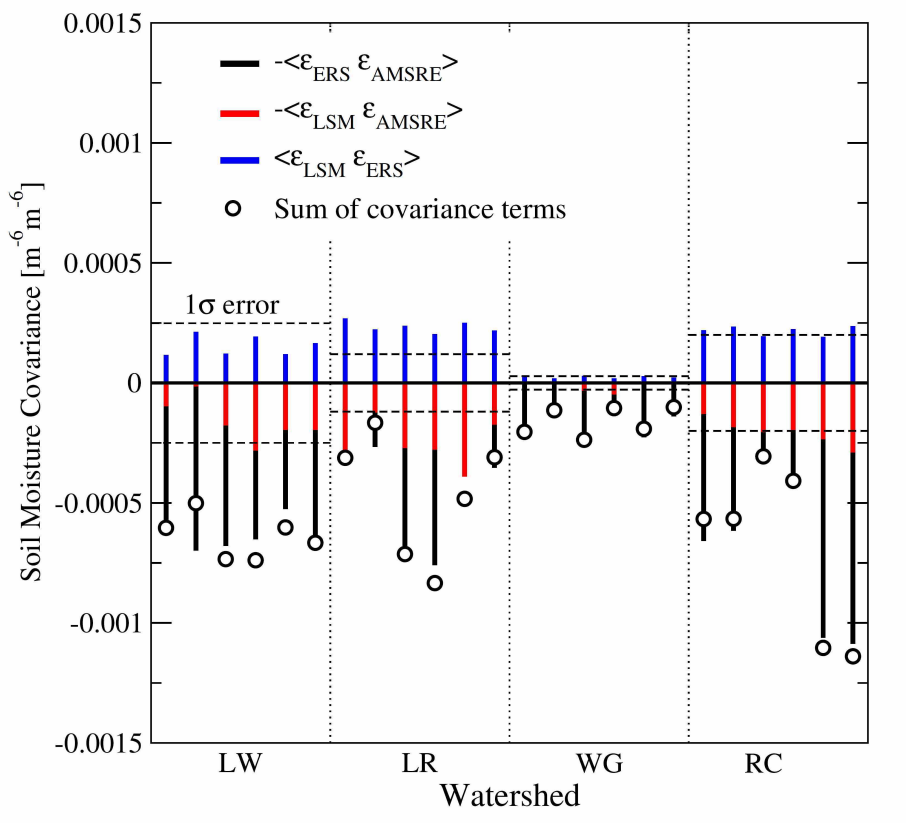


Estimated RMSE reflects variability of reference product. Use **fractional RMSE** instead.

Draper et al. 2012 in prep.

Direct Comparisons:Triple Colocation



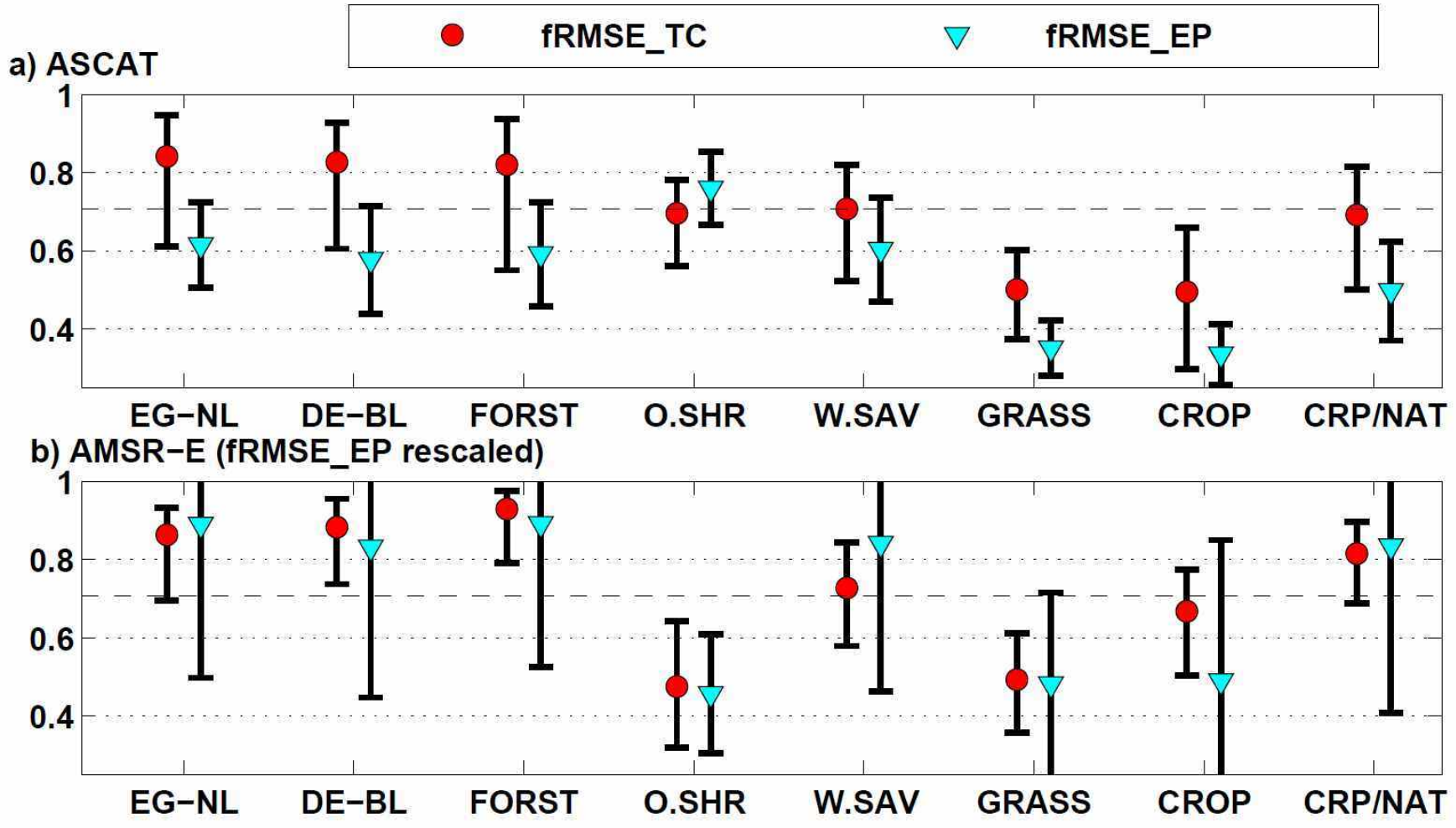


TC-based estimates match core-site based estimates of RMSE.

Bias between RMSE estimates is related to error correlations between data products.

Crow et al. 2012 IAHS Red Book #352

Direct Comparisons:Triple Colocation



TC-based fRMSE estimates are consistent with:
- fRMSE from error propagation and
- expectations (vegetation classes).

Draper et al. 2012 in prep.

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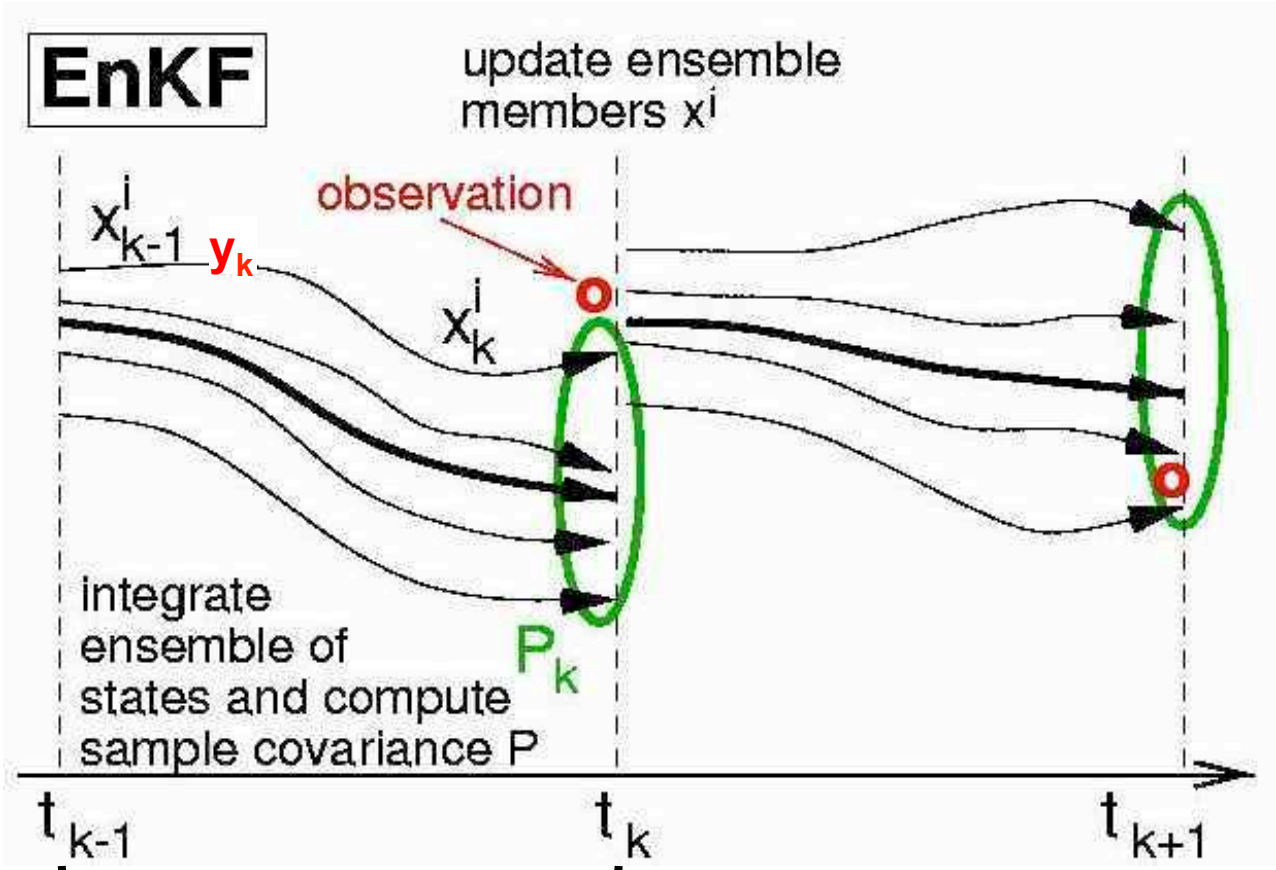
Ensemble Kalman filter (EnKF)



model propagation step

update step

Diagnostics of filter performance

Filter update: $x^+ = x^- + K(y - x^-)$

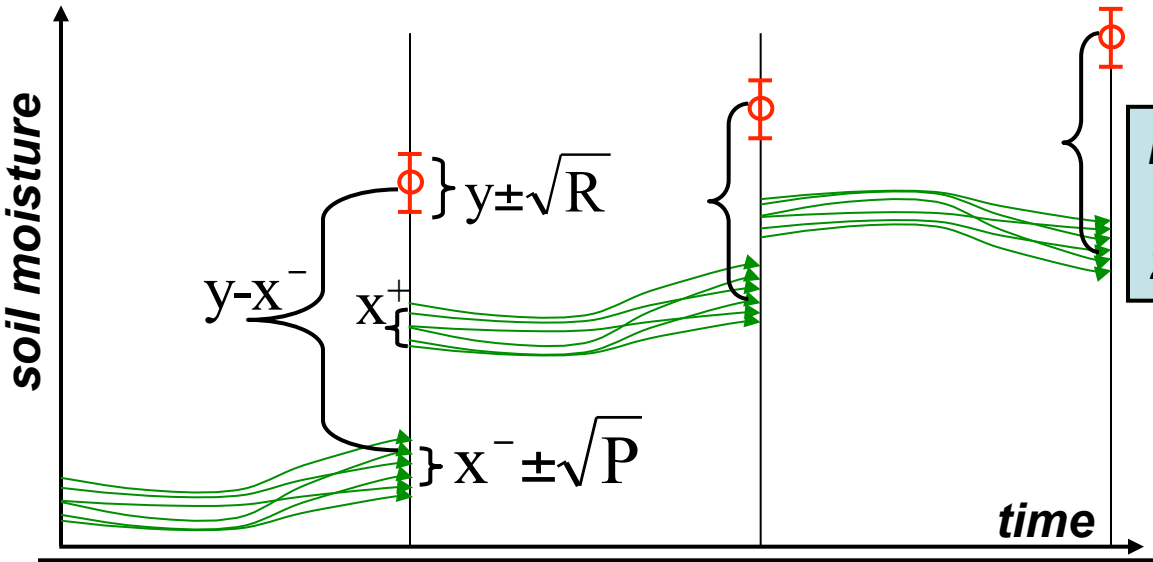
$K = P\,(P + R)^{-1}$ = **Kalman gain**

Diagnostic: $E[(y - x^-)\,(y - x^-)^T] = P + R$

x^- = model forecast
x^+ = "analysis"
y = observation

innovations ≡ obs – model prediction (internal diagnostic)

state err cov + obs err cov (controlled by inputs)



Example:
1) Bias.
2) Input uncertainties too small.

Innovations diagnostics are ALWAYS available within assimilation system.

- Mean of innovations should equal zero. ***Otherwise have bias!***
- Normalize innovations with sqrt(P+R) → std-dev should equal one.

Otherwise (input) model and obs error parameters are inconsistent!

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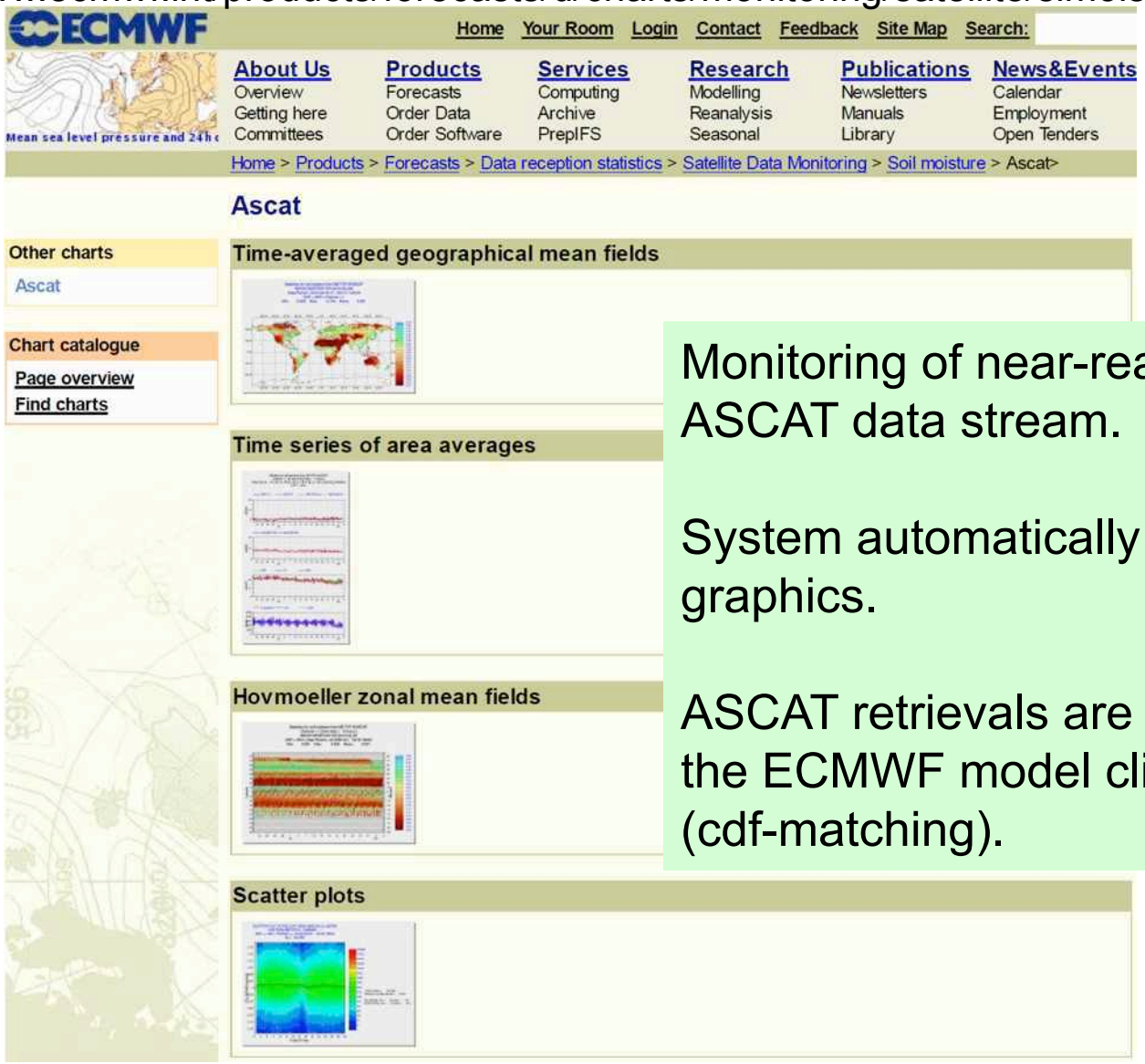
ASCAT Monitoring (Soil Moisture)

http://www.ecmwf.int/products/forecasts/d/charts/monitoring/satellite/slmoist/ascat/



Monitoring of near-real time ASCAT data stream.

System automatically generates graphics.

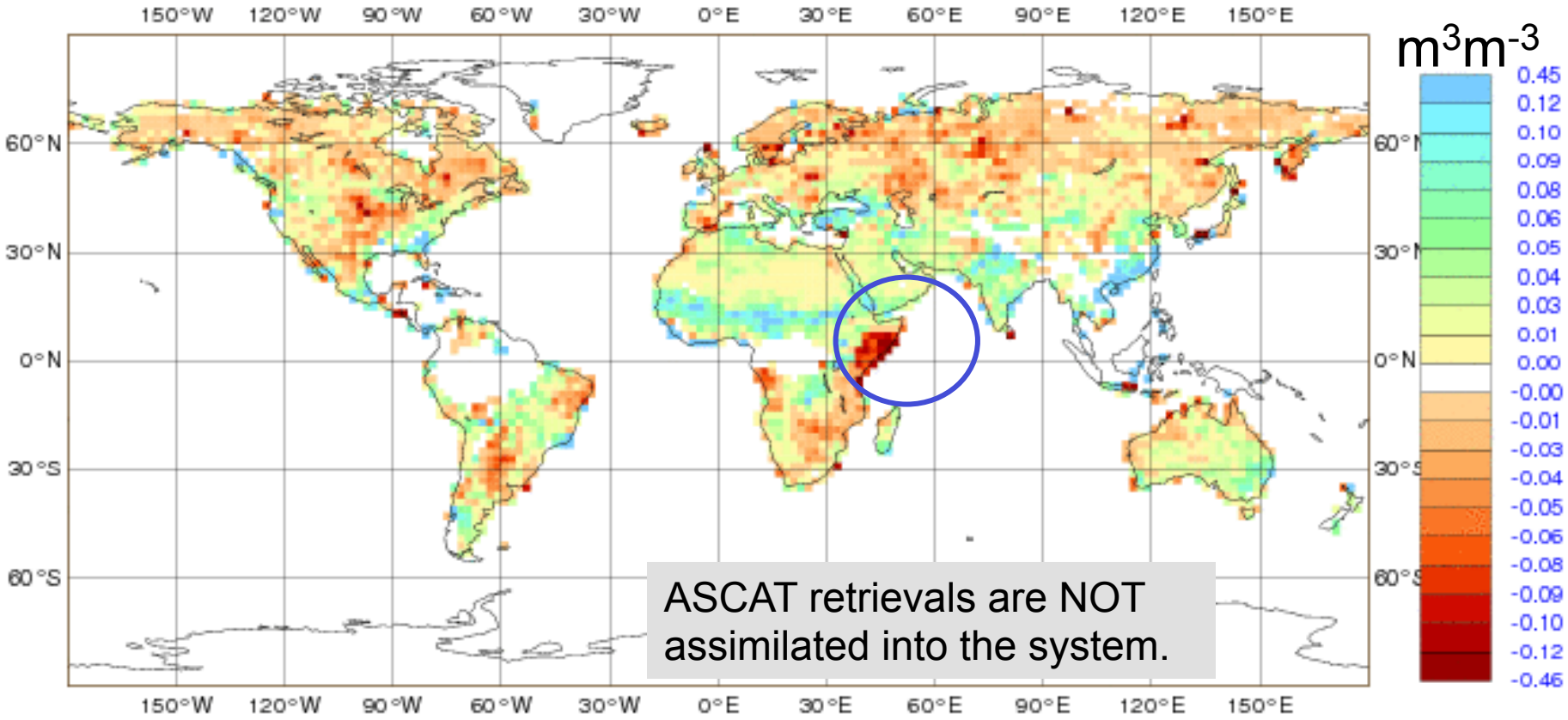
ASCAT retrievals are scaled to the ECMWF model climatology (cdf-matching).

ASCAT Monitoring (Soil Moisture)

innovations = first-guess departures = observations-minus-forecast residuals

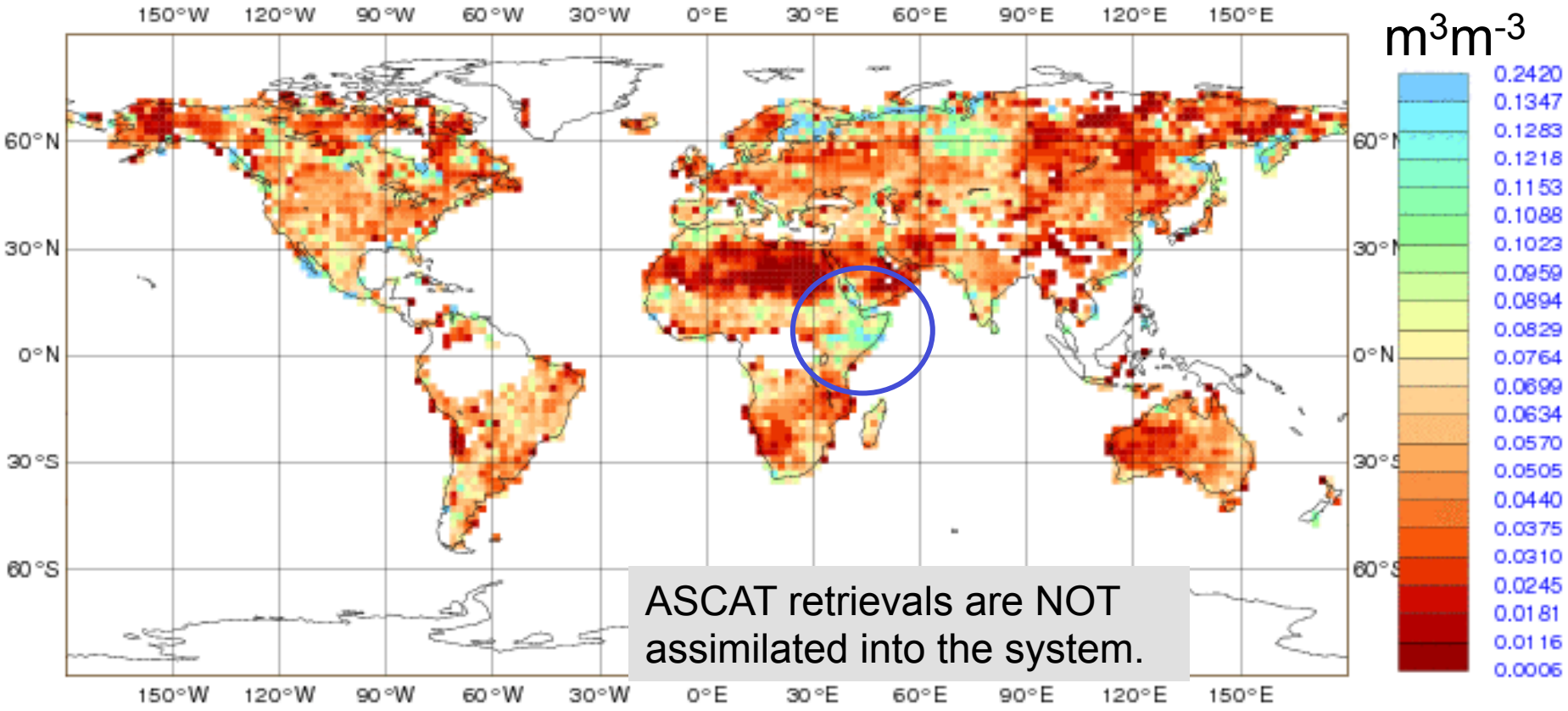
Mean of innovations: 27 Sep to 27 Oct 2012

(ASCAT minus ECMWF surface soil moisture)



ASCAT Monitoring (Soil Moisture)

Std-dev of innovations: 27 Sep to 27 Oct 2012

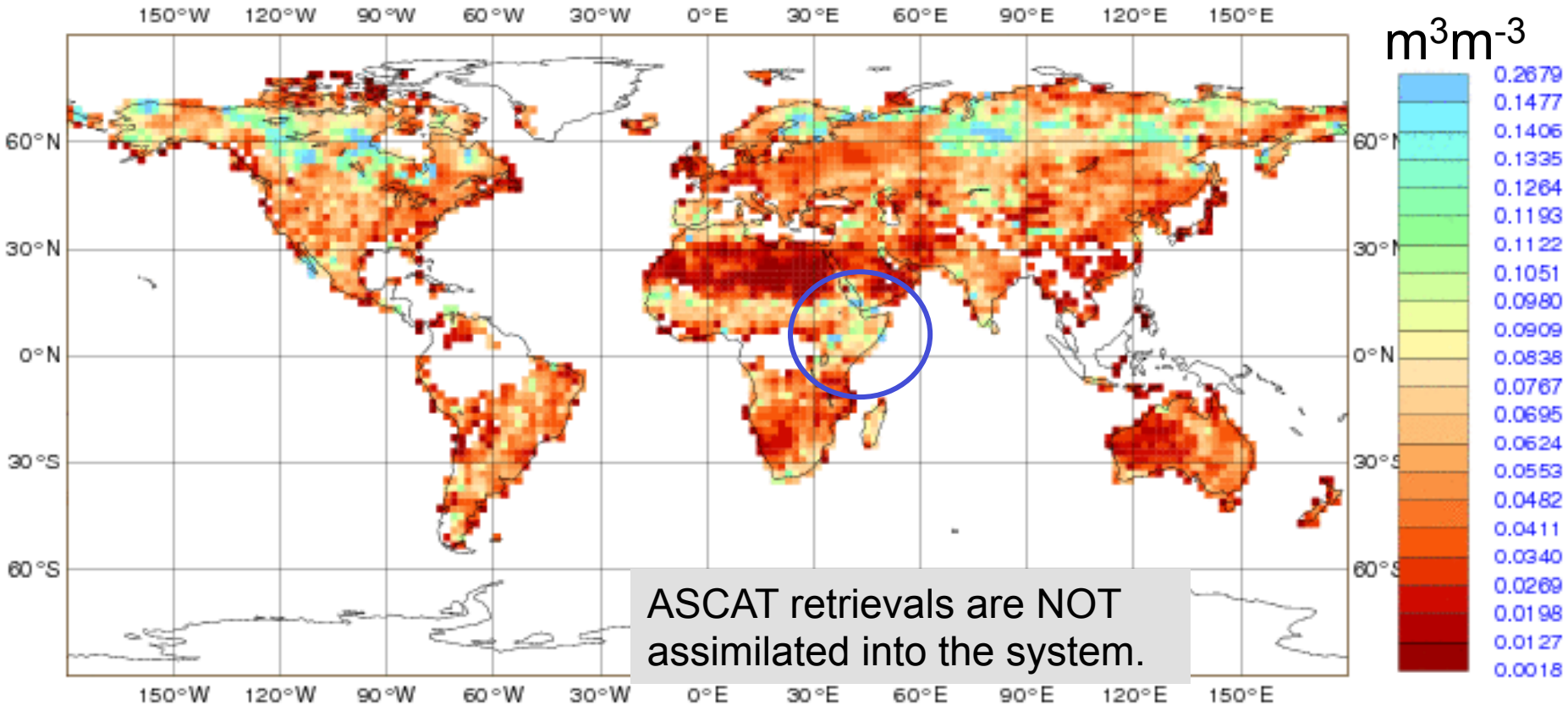


ECMWF

ASCAT Monitoring (Soil Moisture)

Std-dev of ***observations***: 27 Sep to 27 Oct 2012

→ Issue most likely related to observations.

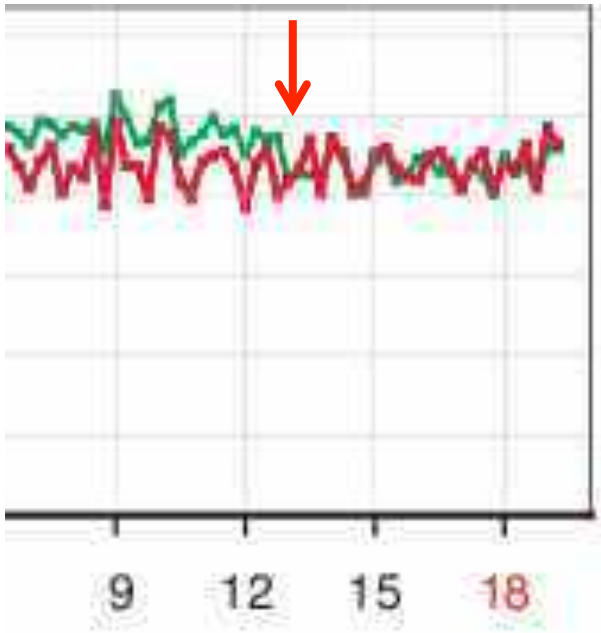


ECMWF

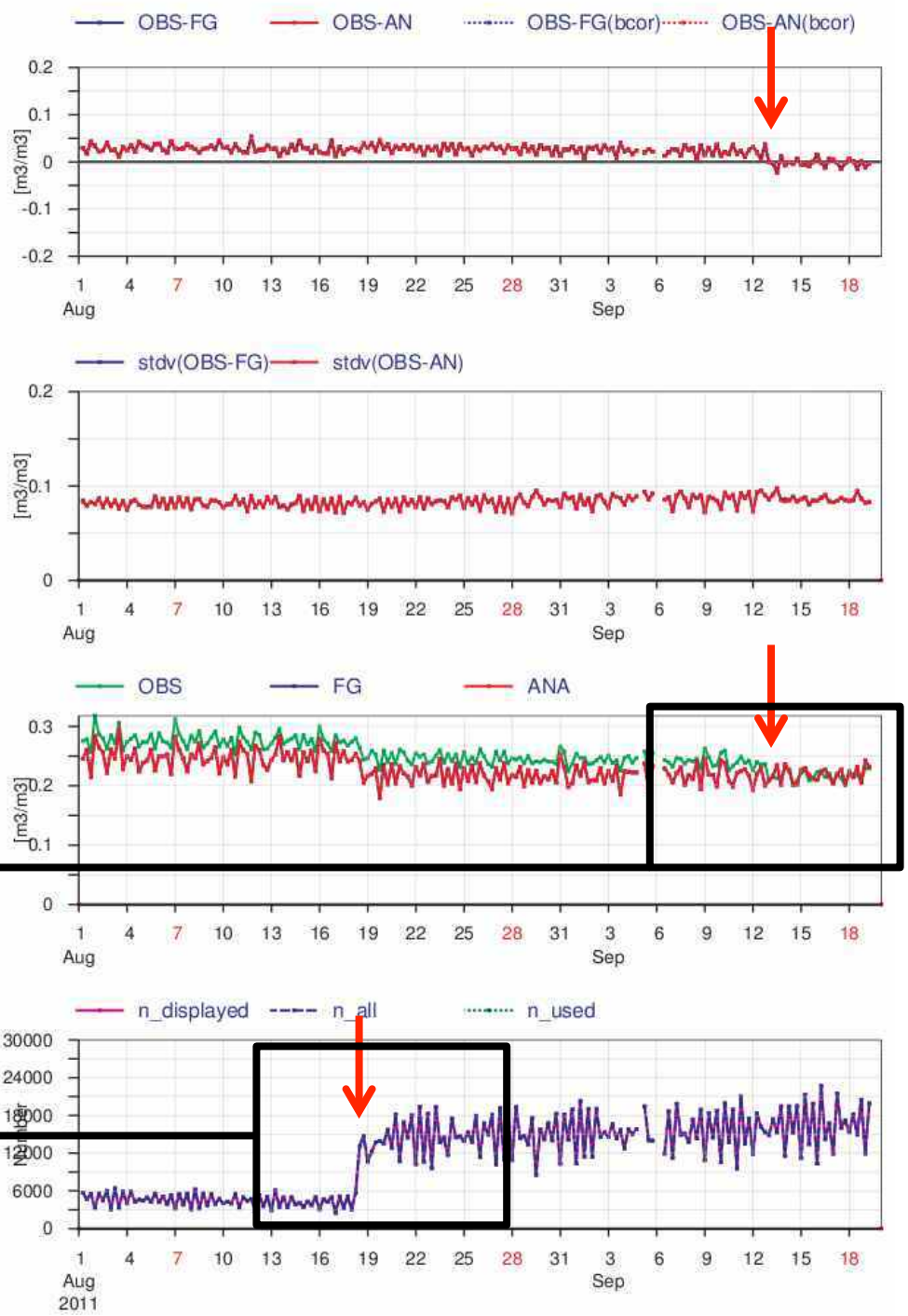
ASCAT Monitoring

Global scale statistics

13 September 2011:
Revised cdf-matching.



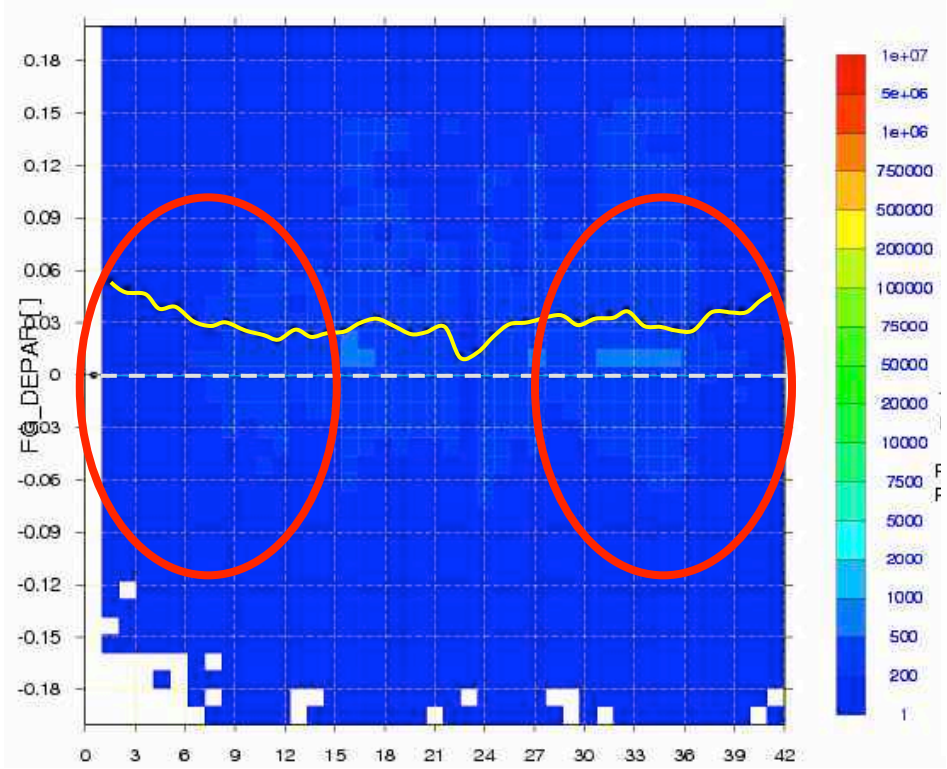
18 August 2011:
Improved ASCAT product, more data pass QC for monitoring.



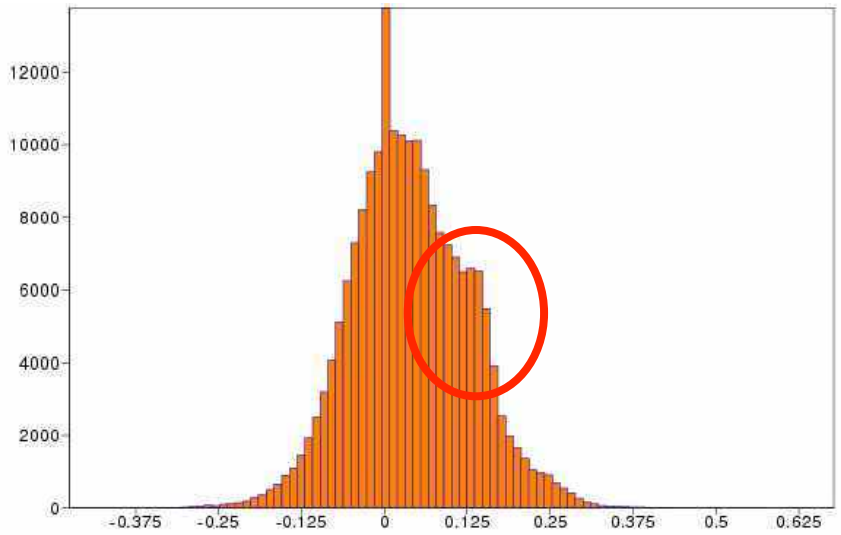
ASCAT Monitoring (Soil Moisture)

April 2011 stats w/ **old** L2 processor and **old** cdf-matching.

First guess departures exhibit:
- *Angular dependency (problem: ASCAT product).*
- *Positive bias (problem: cdf-matching).*



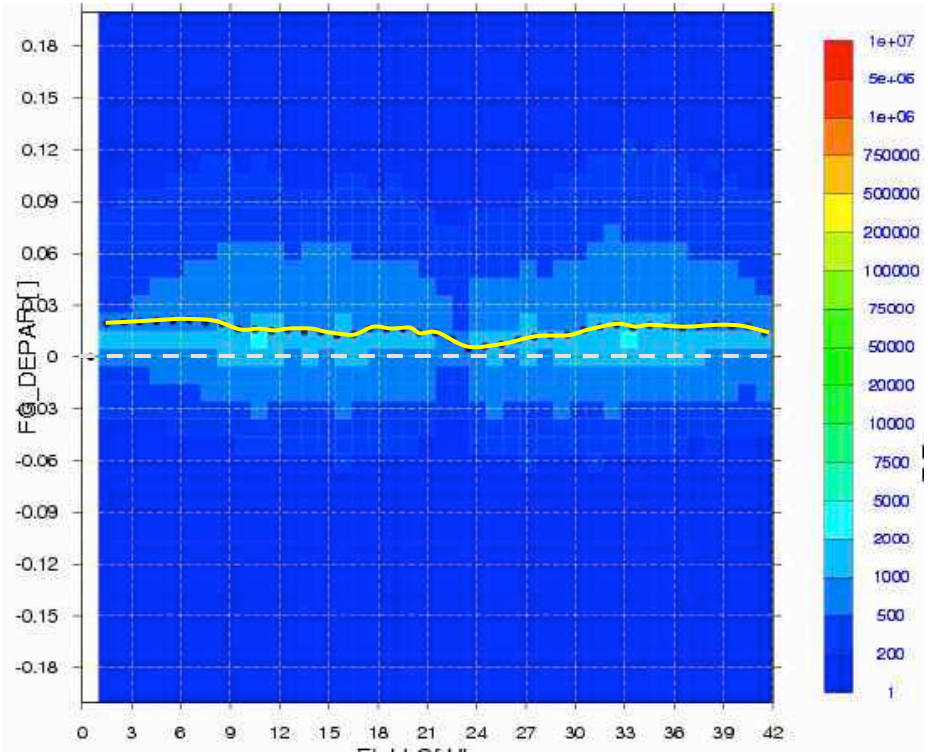
mean = 0.033 m^3m^{-3}
std-dev = 0.090 m^3m^{-3}

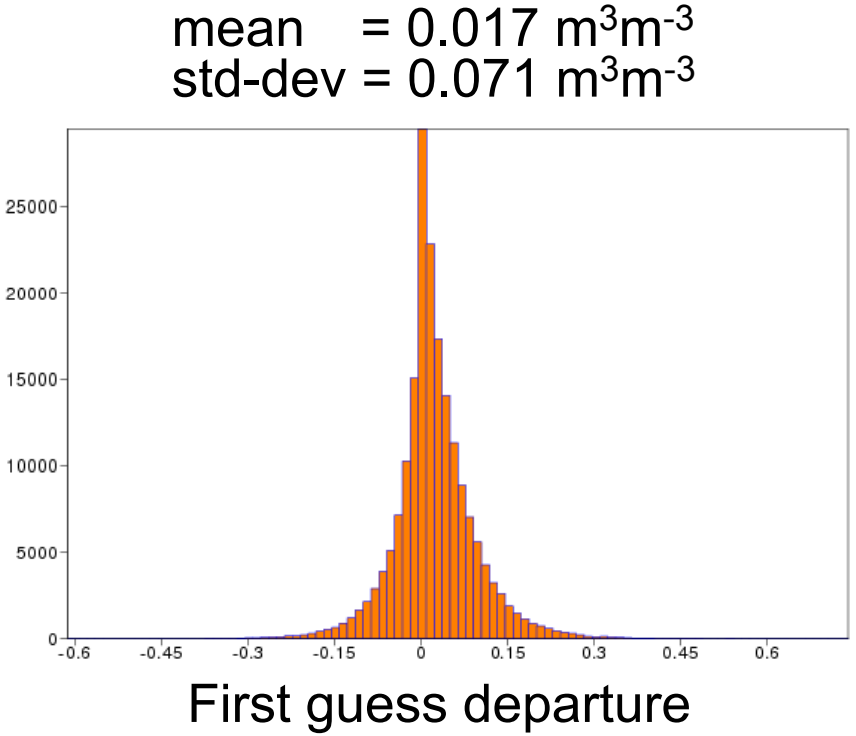


ASCAT Monitoring (Soil Moisture)

April 2011 stats w/ **new** L2 processor and **new** cdf-matching.

First guess departures exhibit:
- *Improved angular signature.*
- *Improved mean innovations.*



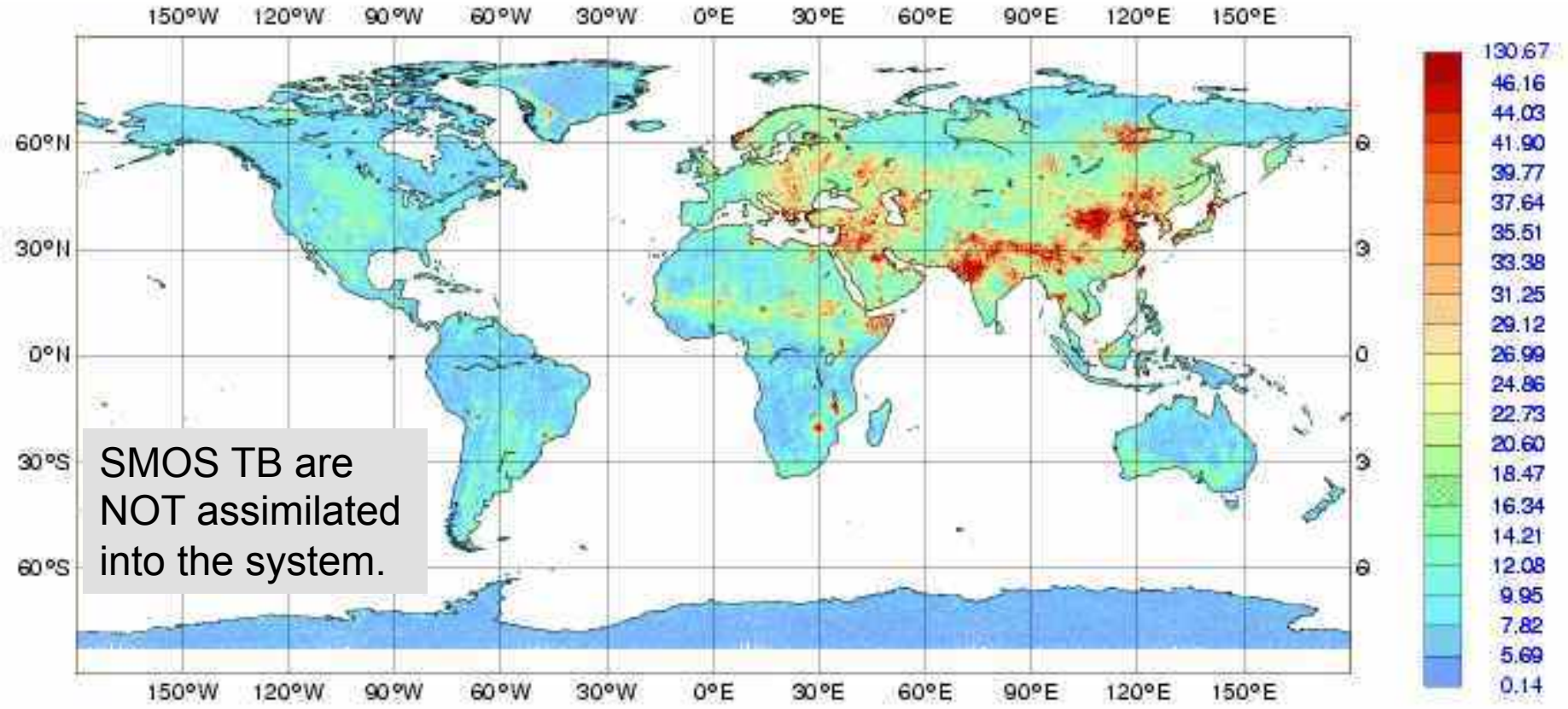


SMOS Monitoring (Brightness Temperature)

Std-dev of innovations: July/August 2012

Monitoring illustrates Radio Frequency Interference (RFI) issues.

Many RFI sources switched off in Europe, still an important issue in Asia.



Muñoz Sabater et al., 2011

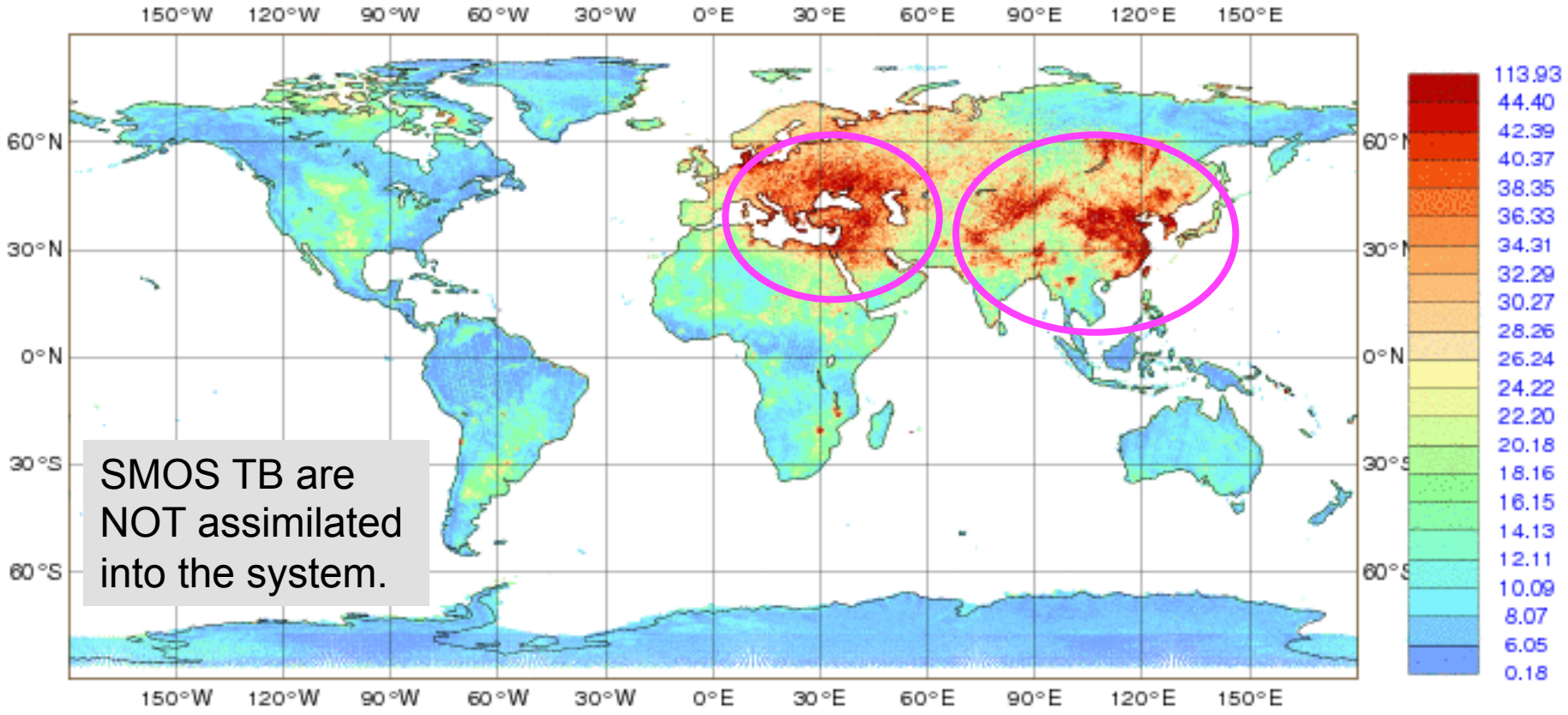
ECMWF

SMOS Monitoring (Brightness Temperature)

Std-dev of innovations: ***Sept/Oct*** 2012

New RFI sources over Poland impacting Europe.

More info at http://www.cesbio.ups-tlse.fr/SMOS_blog/



Muñoz Sabater et al., 2011

ECMWF

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Data Assimilation

Assimilating satellite retrievals into the model provides additional evaluation options:

1.) Validate assimilation product vs. soil moisture in situ obs.

2.) Validate assimilation product vs. related observations.

3.) Evaluate innovations and increments (incl. "R-value" approach).

Data assimilation

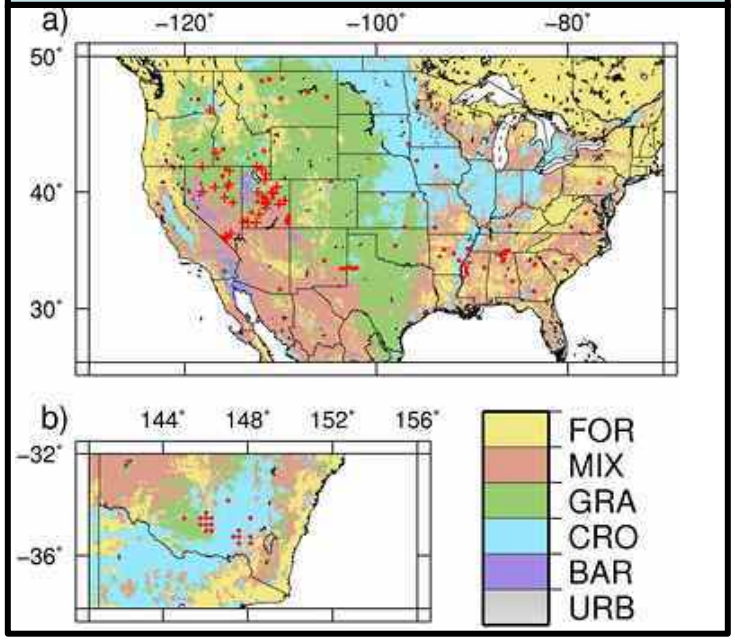
Skill increases significantly through data assimilation.

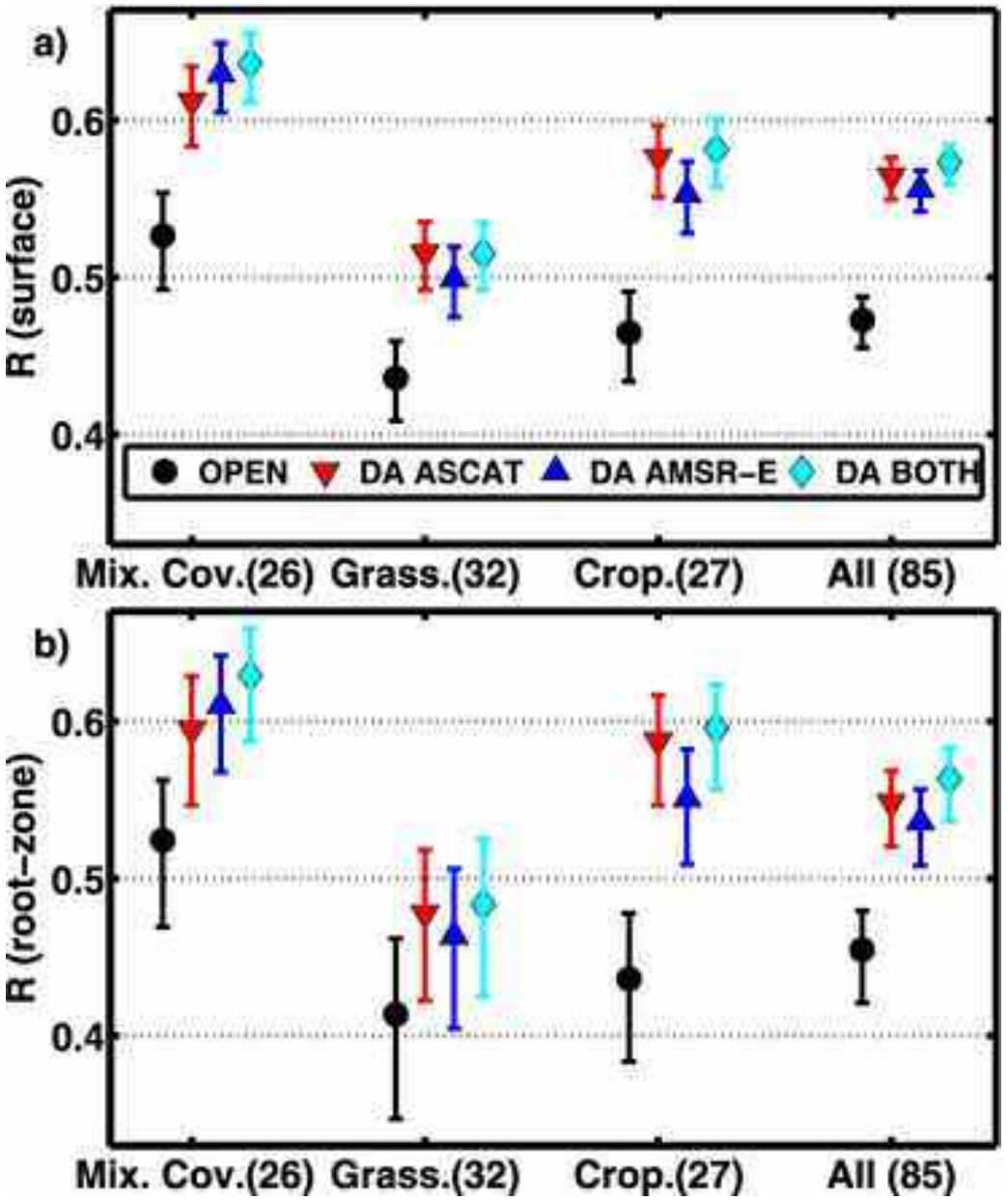
Similar improvements from AMSR-E and ASCAT.

Metric: Anom. time series corr. coeff.

Anomalies ≡ mean seasonal cycle removed

Validated with in situ data

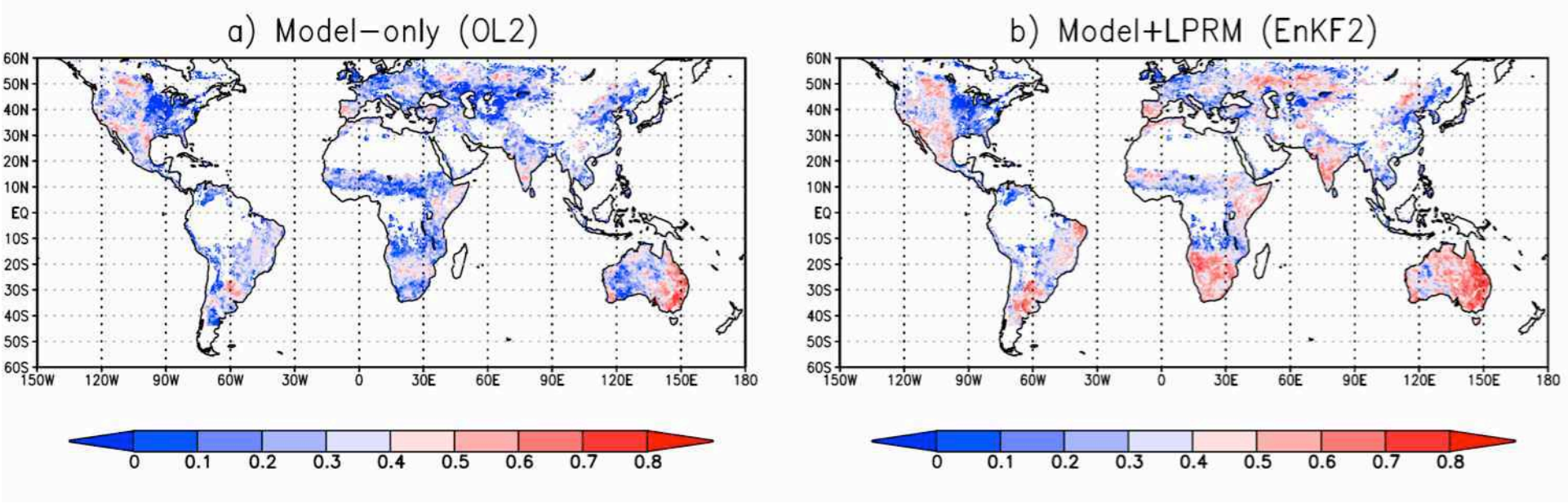


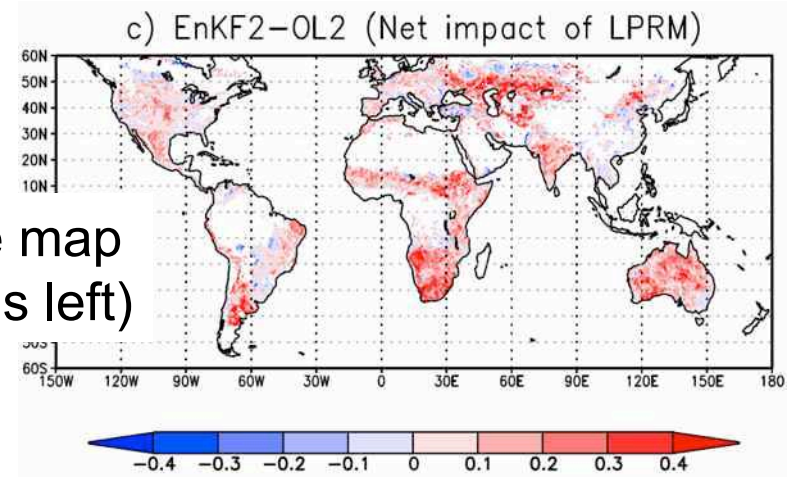


Draper et al. (2012), GRL, doi:10.1029/2011GL050655.

Data assimilation

Rank correlations between soil moisture and NDVI (one-month lag) (left) without and (right) with assimilation of satellite soil moisture.





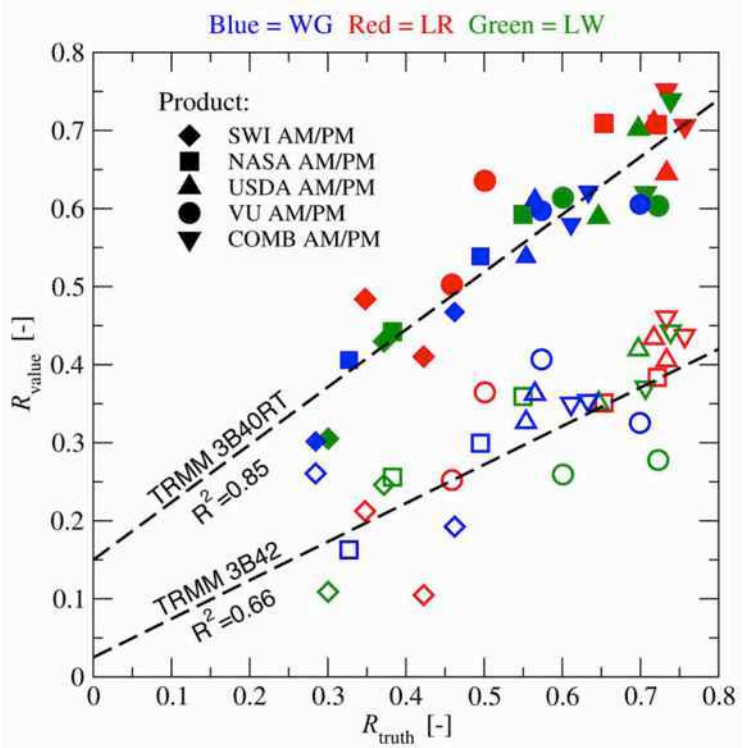
Difference map (right minus left)

Large added value in areas with poor precipitation obs.

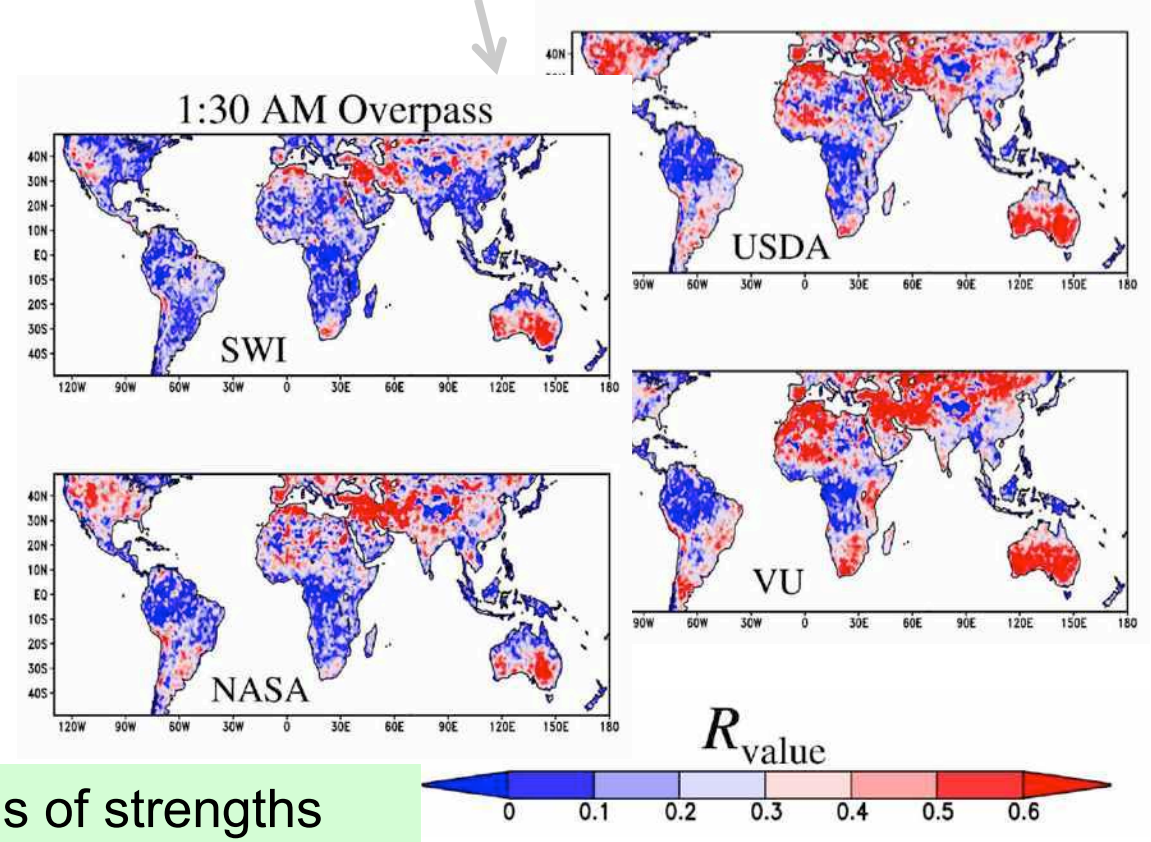
Bolten and Crow (2012), GRL, doi:10.1029/2012GL053470.

Data assimilation

"R-value" = (anti-)**correlation between**
(i) analysis increments (from an assimilation system using standard precip.) and
(ii) errors in precipitation (vs. high-quality estimates)



"R-values" for 4 different AMSR-E soil moisture products



"R-values" agree with skill assessed vs. in situ obs.

Quantitative analysis of strengths and weaknesses of a given satellite product vs. other products.

Crow et al. (2010), TGARS, doi:10.1109/TGRS.2010.2040481

Model products and assimilation for SMAP validation

JPL/SDS:

- Assessment of L2/L3 products vs. model products.

GMAO/SDS:

- Monitoring of L4_SM.
- Assessment of L4_C.

Early Adopter projects (examples):

- ECMWF: Monitoring of L1C_TB and L2_SM_A.
- Environment Canada: Impact of SMAP assimilation on NWP.
- Army: Impact on SMAP assimilation on mobility estimates.
- …

Summary

Satellite products can be evaluated directly against model products (incl. **Triple Colocation**).

Satellite products can be evaluated within data assimilation systems (incl. **Monitoring** and **R-value approach**).

Model products and data assimilation methods enable:

- **near-global** evaluation,
- **continuous and near-real time** assessment,
- evaluation at the **appropriate scale**, and
- use of **additional observations** (e.g. precipitation, vegetation).

Model products and assimilation systems are not perfect. Their use in evaluation **only supplements core-site validation!**

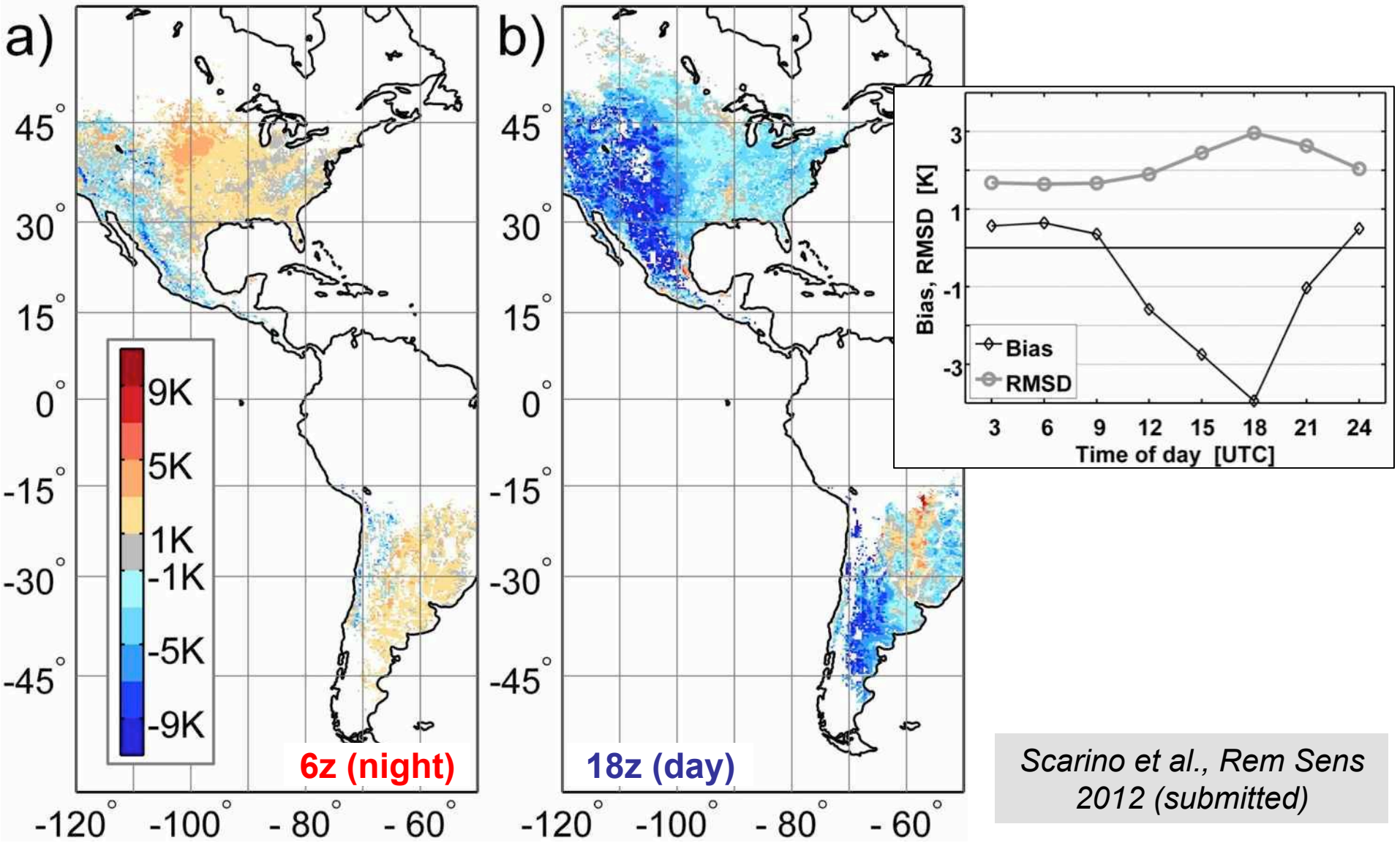
Thank you for your attention.

Questions?

Back-Up Slides

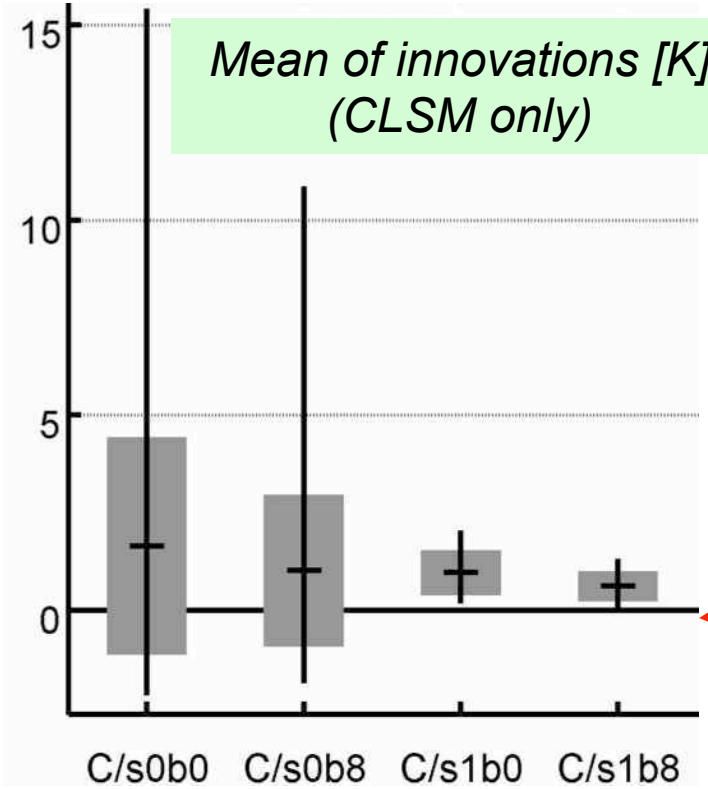
Direct Comparisons: Classical Metrics

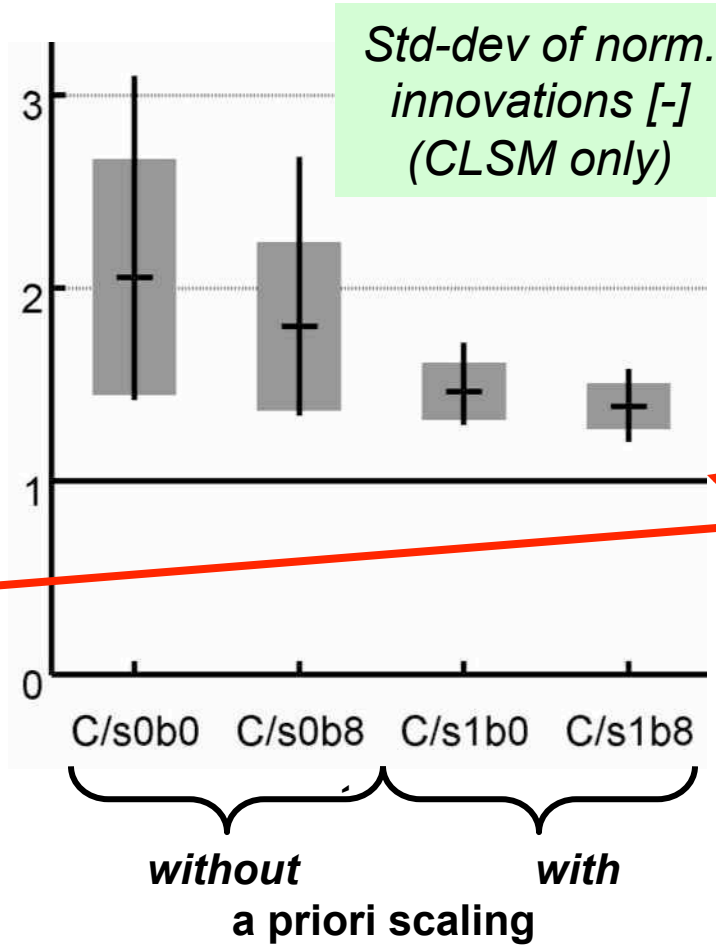
Tskin mean difference: GEOS-5 minus GOES-13



Scarino et al., Rem Sens 2012 (submitted)

Land surface temperature (LST) assimilation: Interpreting innovations





b0, b8: without/with dyn bias corr

Without a priori scaling, strong bias remains.

Input model and/or obs error std-dev are too small.

Reichle et al. (2010), JHM, doi:10.1175/2010JHM1262.1.