AMSR-E Science Team Meeting

La Jolla, CA

Sep. 6-8, 2006

Data assimilation of AMSR-E soil moisture and comparison with SMMR results

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3 – SAIC

4 – JPL

Outline

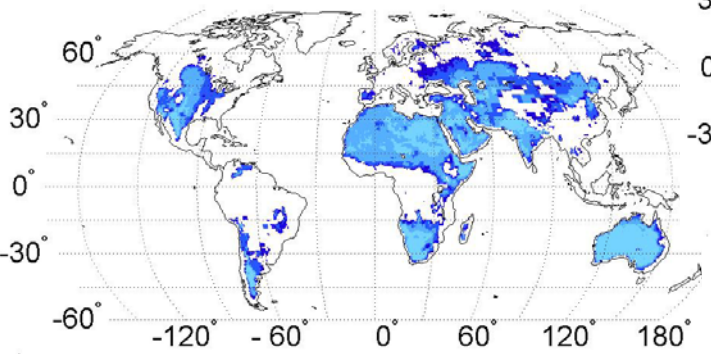
Biases
Assimilation

Global soil moisture data sets

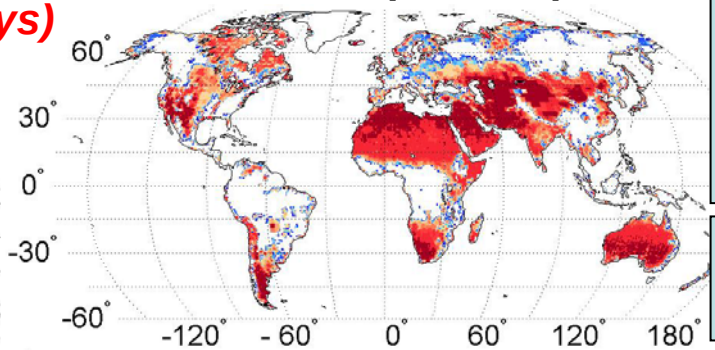
1. Satellite retrievals

(upper 1.25cm, 50-140km, 1-3 days)

SMMR (1979-87)



AMSR-E (2002-06)



Number of data per month

Soil moisture retrievals **not** available under dense vegetation, near open water, in frozen soil.

More AMSR-E data than SMMR data.

2. Model data

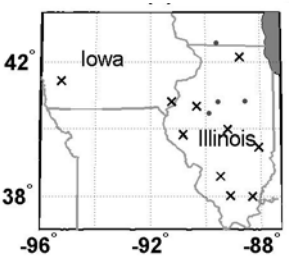
NASA Catchment Model (CLSM) forced w/ observation-corrected meteorological data.

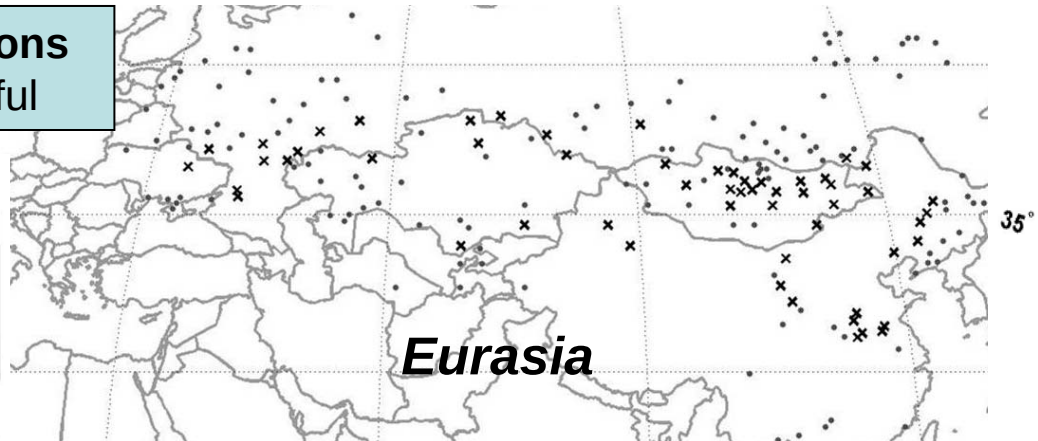
(upper 2cm, ~40…150km, 3-6h)

3. In situ data

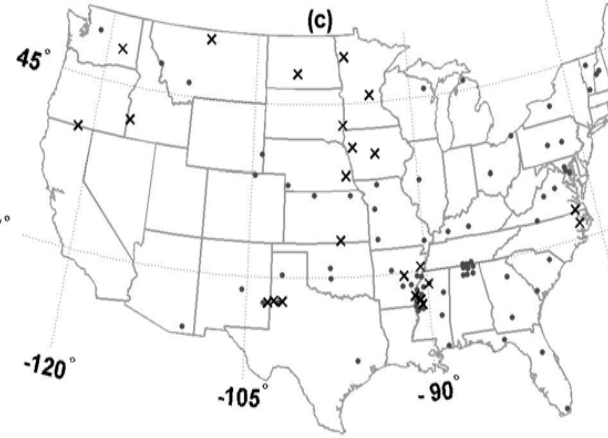
(upper 5…10cm and profile, point scale, hourly - 10 days)

GSMDB stations
66 of 200 useful





USDA SCAN stations
23 of 103 useful

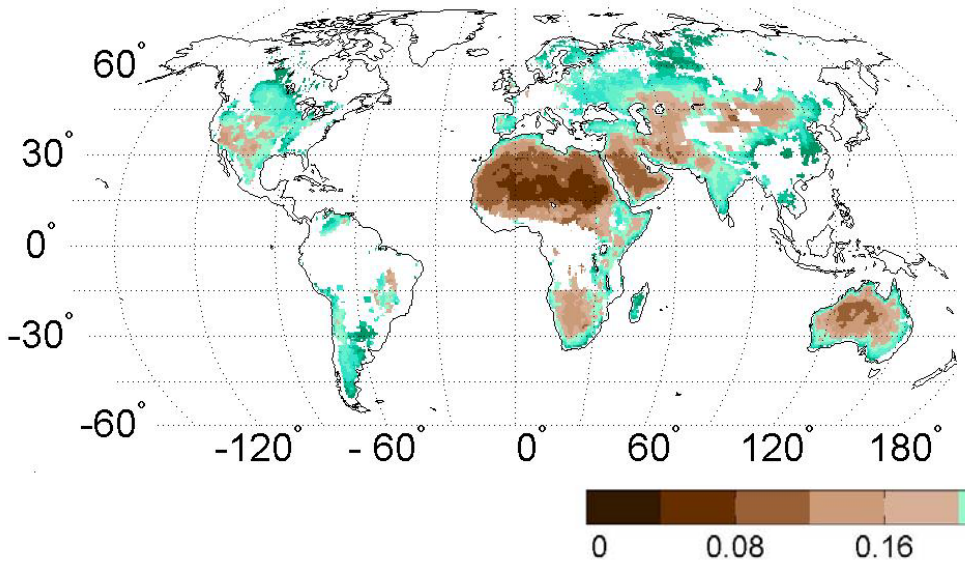


Data sources

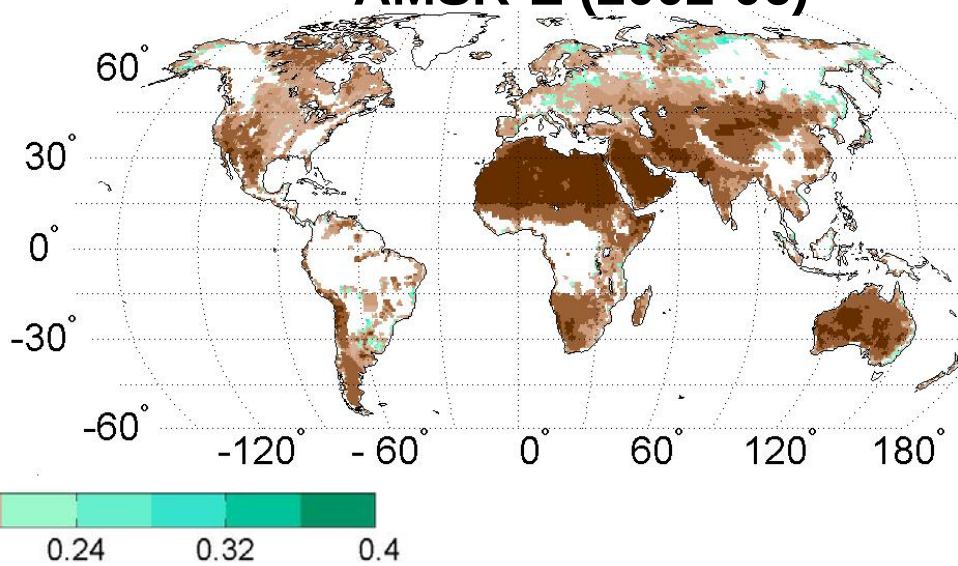
		"SMMR period" 1979-87 (~8.5 years)	*"AMSR-E period" 2002-06 (~4 years)*
Soil moisture retrievals	*Sensor*	SMMR (Nimbus 7)	AMSR-E (Aqua)
	Frequency	C-Band (6.6 GHz)	X-Band (10.7 GHz)
	Sampling depth	~1.25 cm	~1 cm
	Horiz. Resolution	~150 km	~40 km
	Equator crossing	12 am/pm	1:30 am/pm
	Algorithm	Owe et al., 2001	Njoku et al. (http://nsidc.org)
Land surface model		NASA Catchment (~0.5°)	(same w/ minor updates)
Meteorol. forcing data (obs.-based)	*Author*	Berg et al., 2005	GLDAS
	Baseline	Re-analysis (ERA-15)	NASA GEOS NWP analysis
	Observations	Monthly	Daily/pentad
	Precipitation	GPCP satellite/gauge	CMAP (5-day)
	Radiation	SRB (1983-87 only)	AGRMET daily
	Air temp./humid.	CRU	(None)
	Horiz. resolution	~2 deg	~2 deg
In situ data		GSMDB	USDA SCAN

Satellite vs. satellite bias (time avg. soil moisture)

SMMR (1979-87)

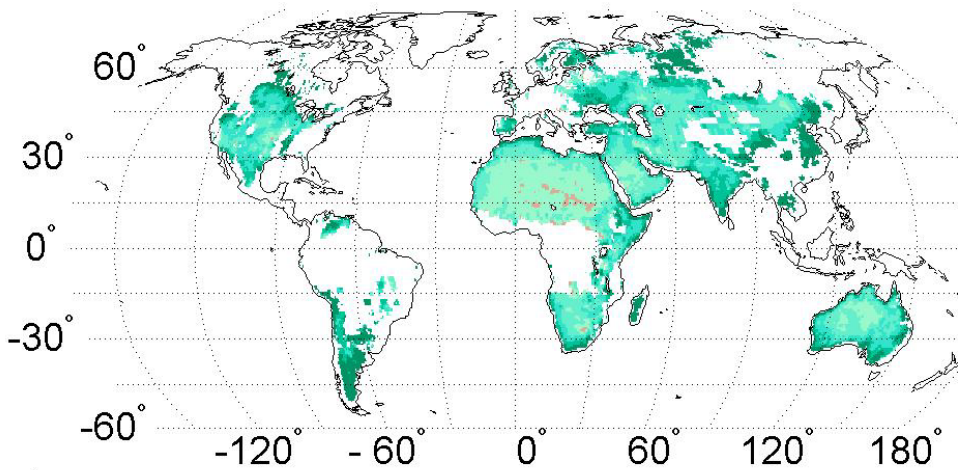


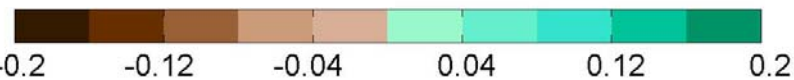
AMSR-E (2002-06)



Soil moisture [m³/m³]

SMMR minus AMSR-E



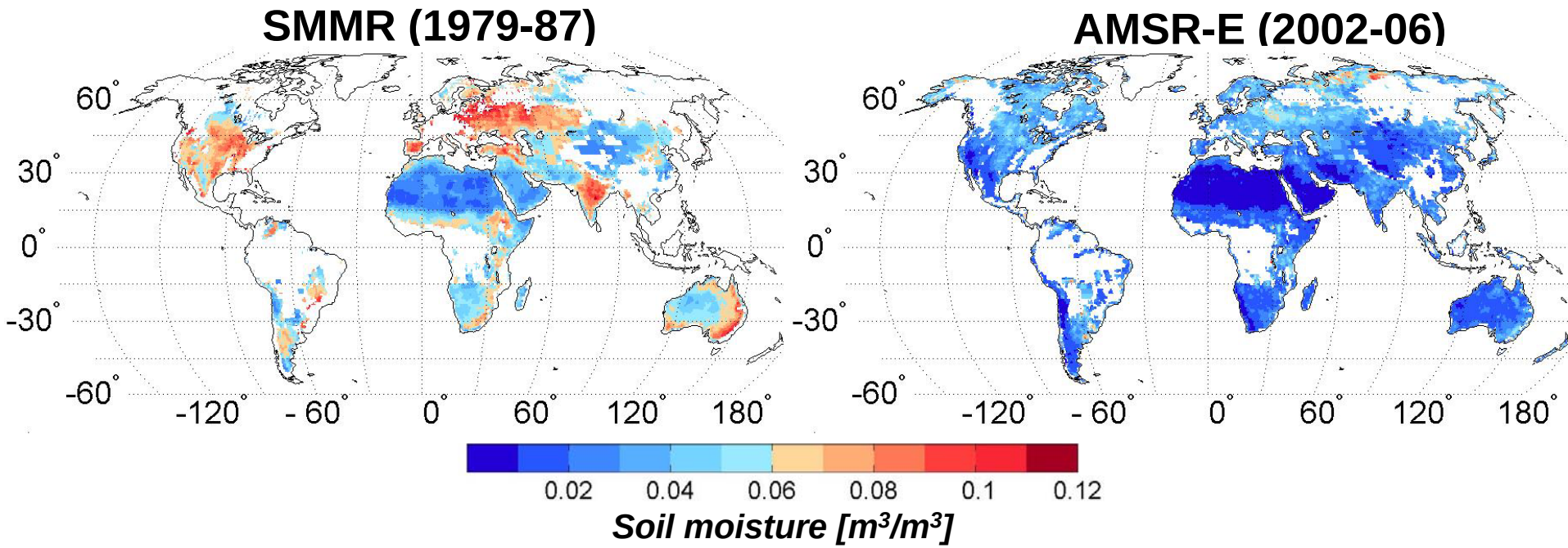


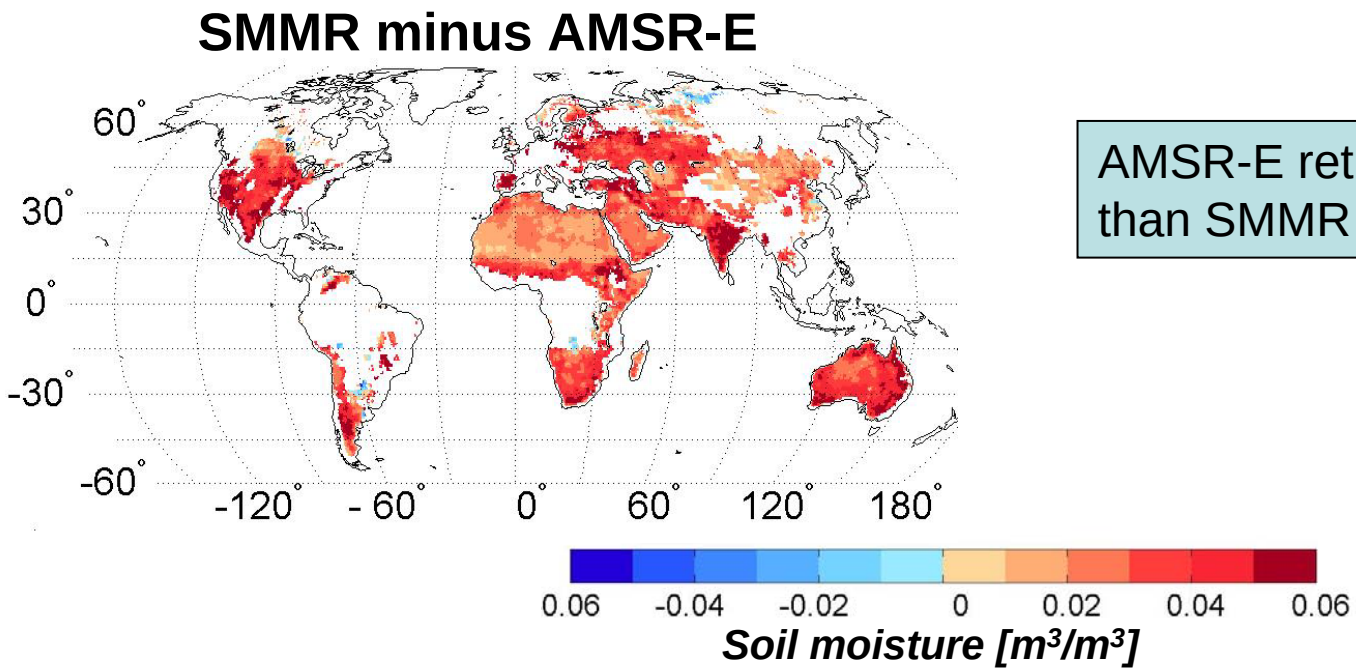
Soil moisture [m³/m³]

AMSR-E retrievals **much** drier than SMMR retrievals.

Magnitude of differences comparable to dynamic range.

Satellite vs. satellite bias (time avg. soil moisture)





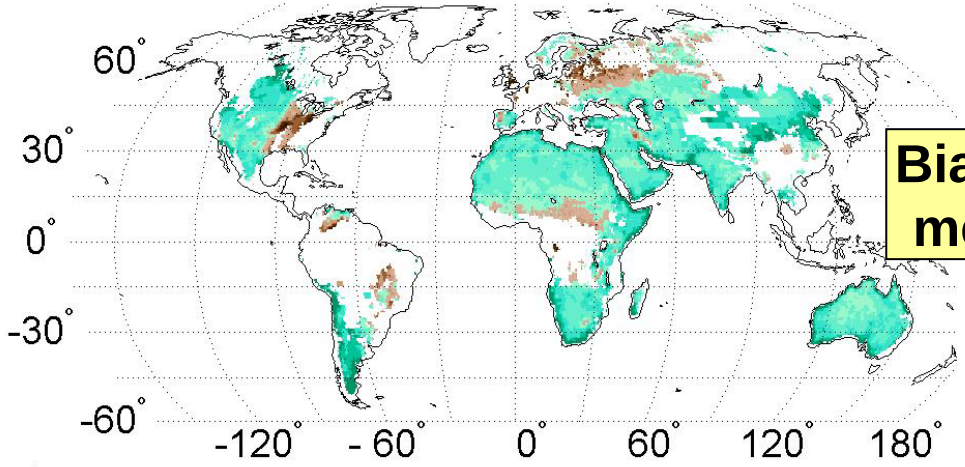
AMSR-E retrievals **much** less variable than SMMR retrievals.

We found strong biases between AMSR-E and SMMR.

For assimilation, we are really interested in **satellite vs. model** biases.

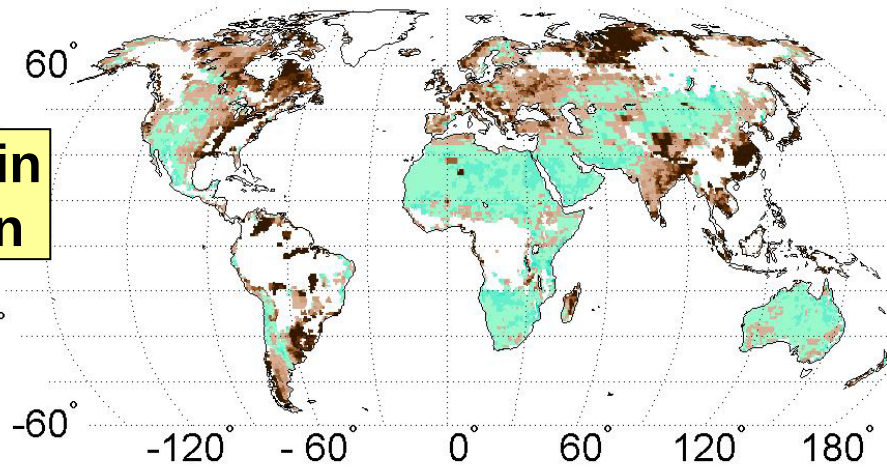
Satellite vs. model bias

SMMR minus model (1979-87)



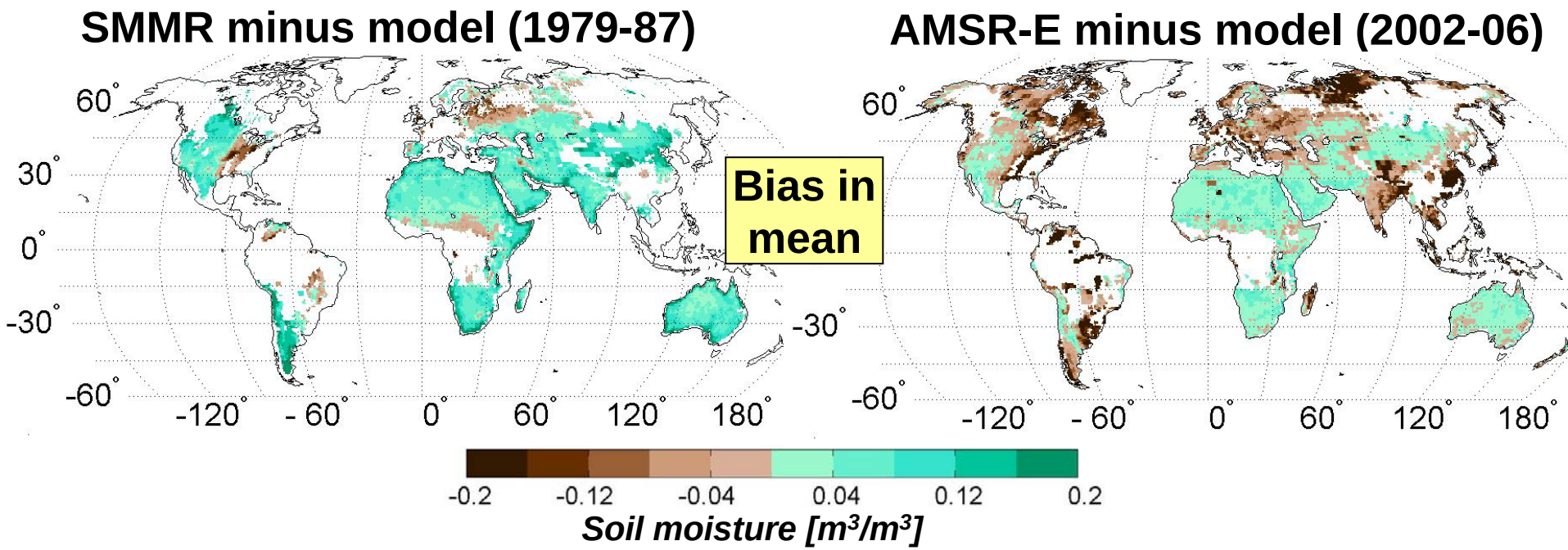
Bias in mean

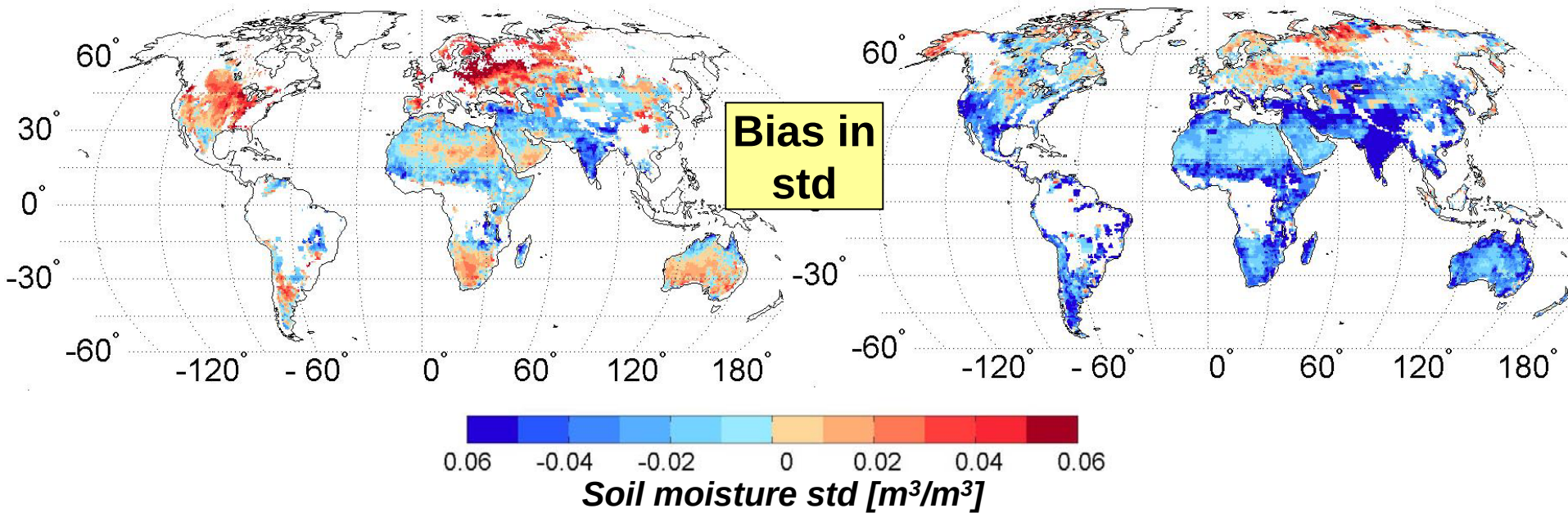
AMSR-E minus model (2002-06)



Soil moisture [m³/m³]

Satellite vs. model bias





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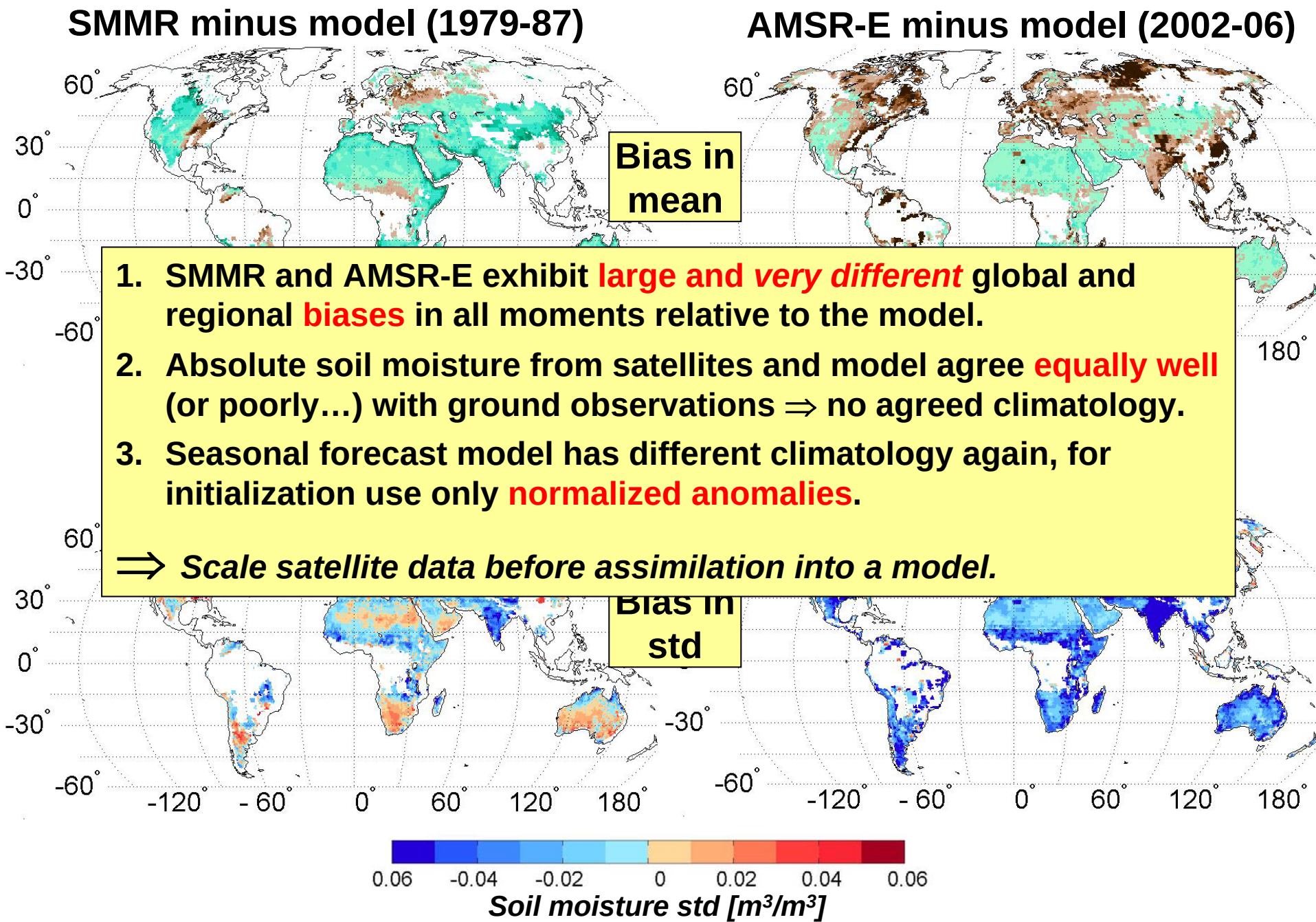
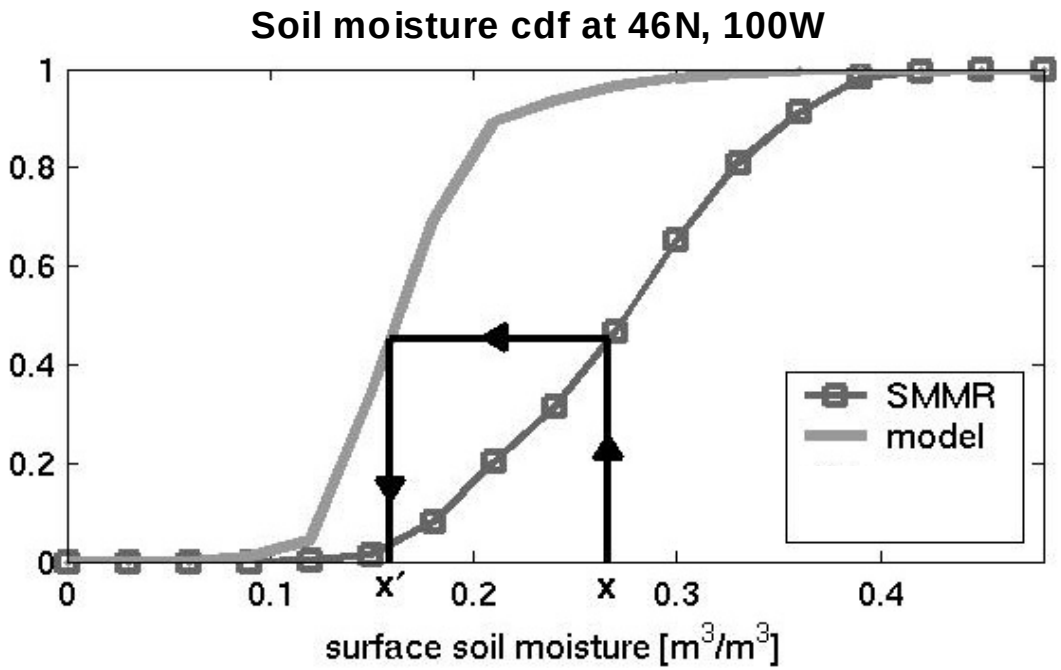


1. SMMR and AMSR-E exhibit large and *very different* global and regional biases in all moments relative to the model.
2. Absolute soil moisture from satellites and model agree equally well (or poorly…) with ground observations ⇒ no agreed climatology.
3. Seasonal forecast model has different climatology again, for initialization use only normalized anomalies.

⇒ ***Scale satellite data before assimilation into a model.***

Soil moisture scaling for data assimilation



Assimilate percentiles.

Global soil moisture data sets

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ASSIMILATE

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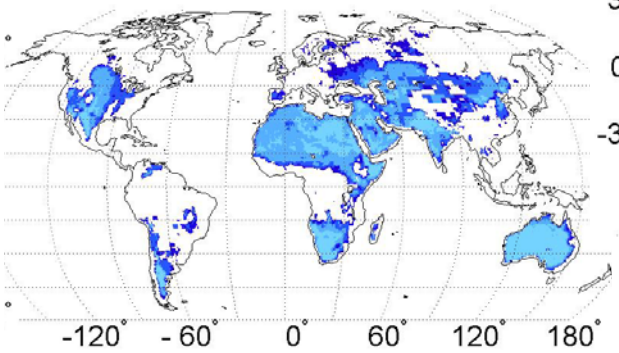
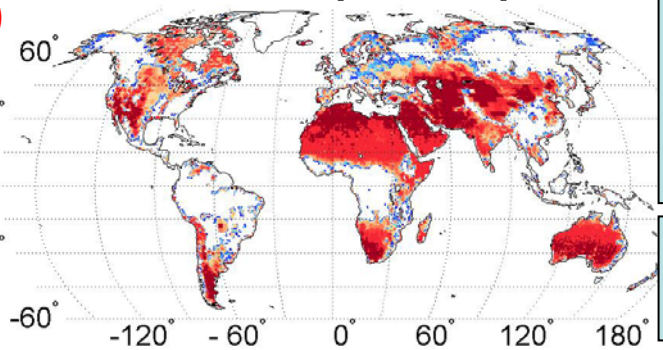


AMSR-E (2002-06)



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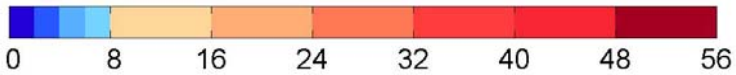

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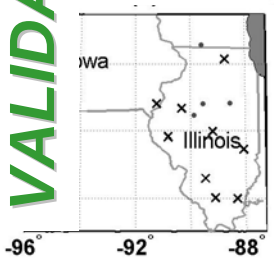
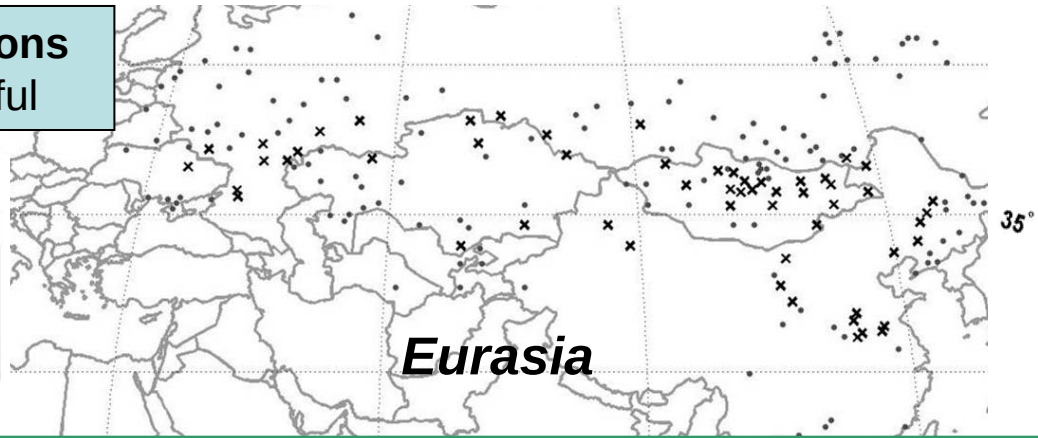
VALIDATE

MDB stations
f 200 useful





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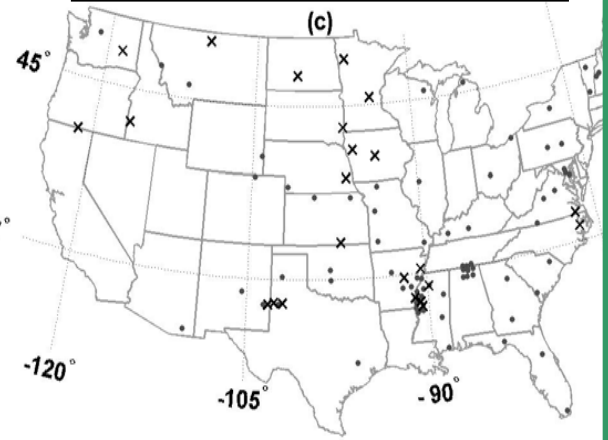
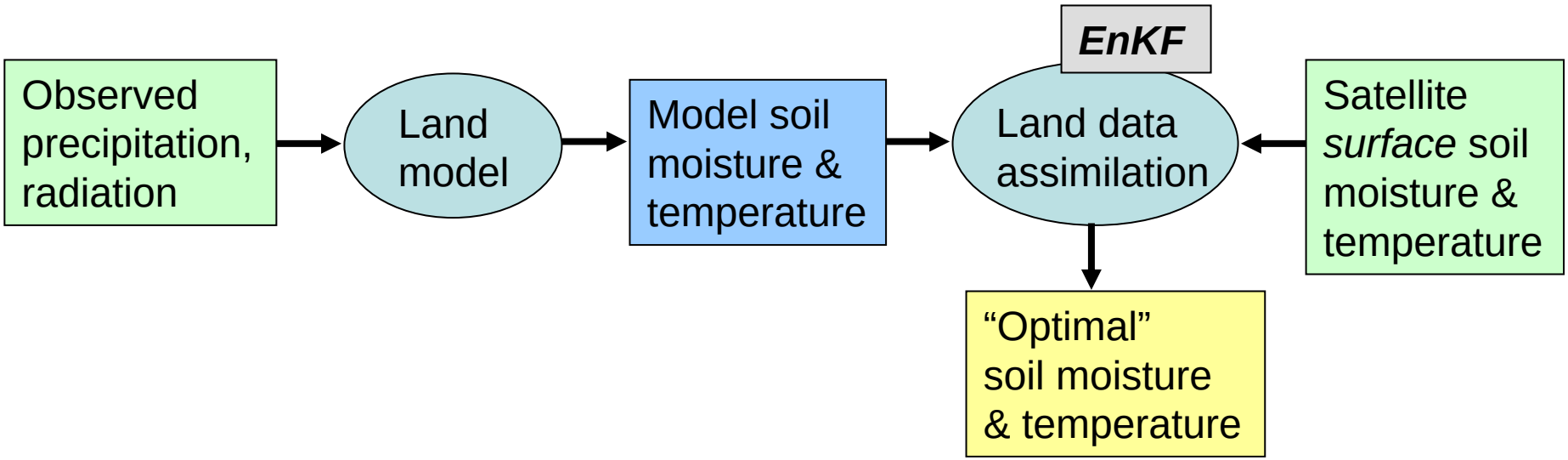


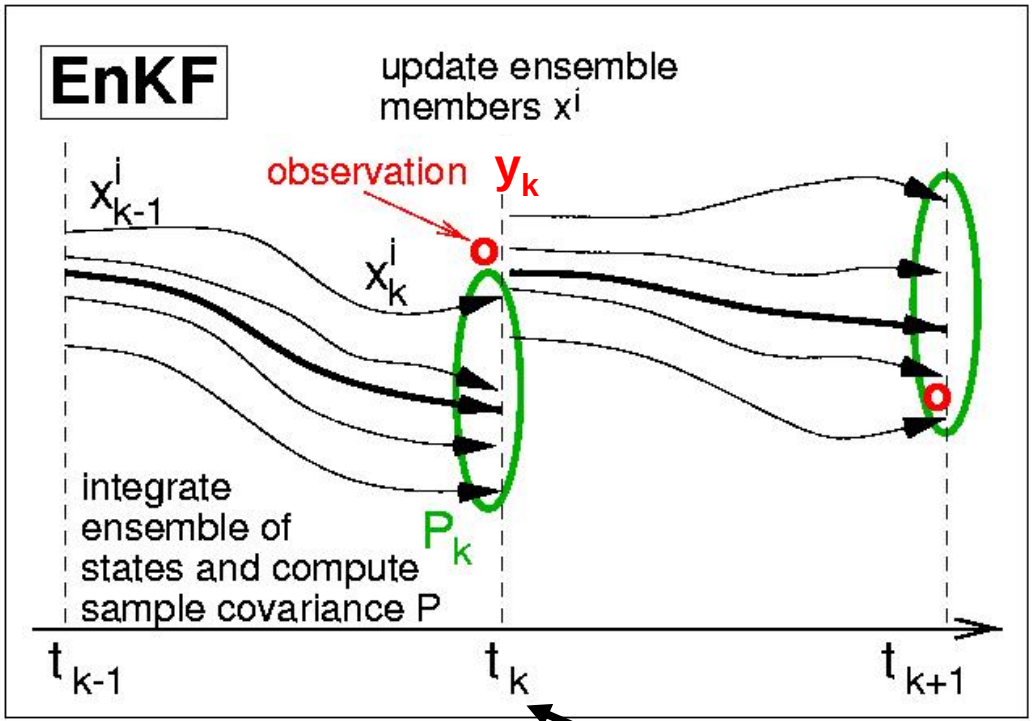
Land data assimilation



Data assimilation with the Ensemble Kalman filter (EnKF):

Consider relative uncertainties in modeled and observed soil moisture.

Soil moisture assimilation



$\mathbf{x_k^i}$ state vector (eg soil moisture)

$\mathbf{P_k}$ state error covariance

$\mathbf{R_k}$ observation error covariance

Propagation $\mathbf{t_{k-1}}$ to $\mathbf{t_k}$:

$$\mathbf{x_k^{i-} = f(x_{k-1}^{i+}) + w_k^i}$$

w = model error

Update at $\mathbf{t_k}$:

$$\mathbf{x_k^{i+} = x_k^{i-} + K_k(y_k^i - x_k^{i-})}$$

for each ensemble member i=1…N

$$\mathbf{K_k = P_k (P_k + R_k)^{-1}}$$

with $\mathbf{P_k}$ computed from ensemble spread

Validation against in situ data

SMMR: *Reichle & Koster, GRL 2005* AMSR-E: *Reichle et al., in prep. 2006*			Anomaly time series correlation coeff. with in situ data [-] (with 95% confidence interval)			Confidence levels: Improvement of assimilation over	
		N	**Satellite**	**Model**	**Assim.**	**Satellite**	**Model**
AMSR-E (*daily*)	Surface	23	**.38±.02**	**.43±.02**	**.50±.02**	**>99.99%**	**>99.99%**
	Root zone	22	**n/a**	**.40±.02**	**.46±.02**	**n/a**	**>99.99%**

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AMSR-E (*monthly*)	Surface	12	**.41±.08**	**.50±.09**	**.57±.08**	**99.7%**	**91.1%**
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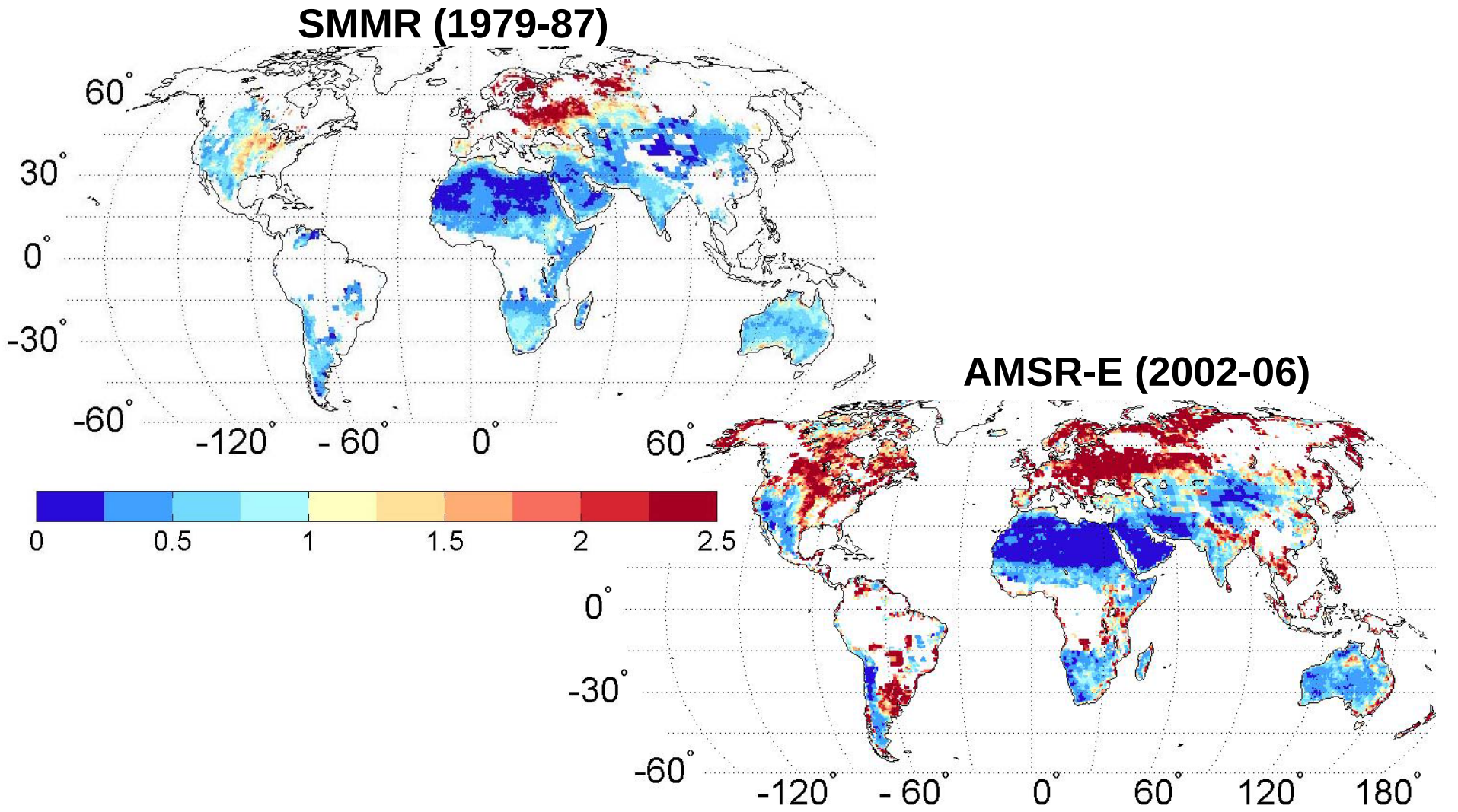
	Root zone	11	**n/a**	**.42±.10**	**.54±.08**	**n/a**	**97.9%**
SMMR (*monthly*)	Surface	66	**.32±.03**	**.36±.03**	**.43±.03**	**99.9%**	**99.9%**
	Root zone	33	**n/a**	**.32±.05**	**.35±.05**	**n/a**	**80%**

Assimilation product agrees better with ground data than satellite or model alone.

Modest increase may be close to maximum possible with *imperfect* in situ data.

Variance of normalized innovations



Variance deficiency in dry climates, excess variance in wetter climates.

Potential for improvement by (adaptively) tuning model error parameters.

Conclusions

No agreed *global* climatology of (absolute) surface soil moisture.

Scaling needed for assimilation.

Assimilation of AMSR-E data improves soil moisture estimates.

Future tasks:

Improve data assimilation:

- Quality control.
- Spatially variable model and observation error parameters.
- Adaptive tuning of model and observation error parameters.

Operations and future directions:

- **Implement operational land initialization for seasonal prediction (AMSR-E).**
- **Do improved land initial conditions lead to better seasonal forecasts?**
- **Multi-variate soil moisture, snow, and surface temperature assimilation.**
- **Land assimilation in coupled land-atmosphere system!!!**

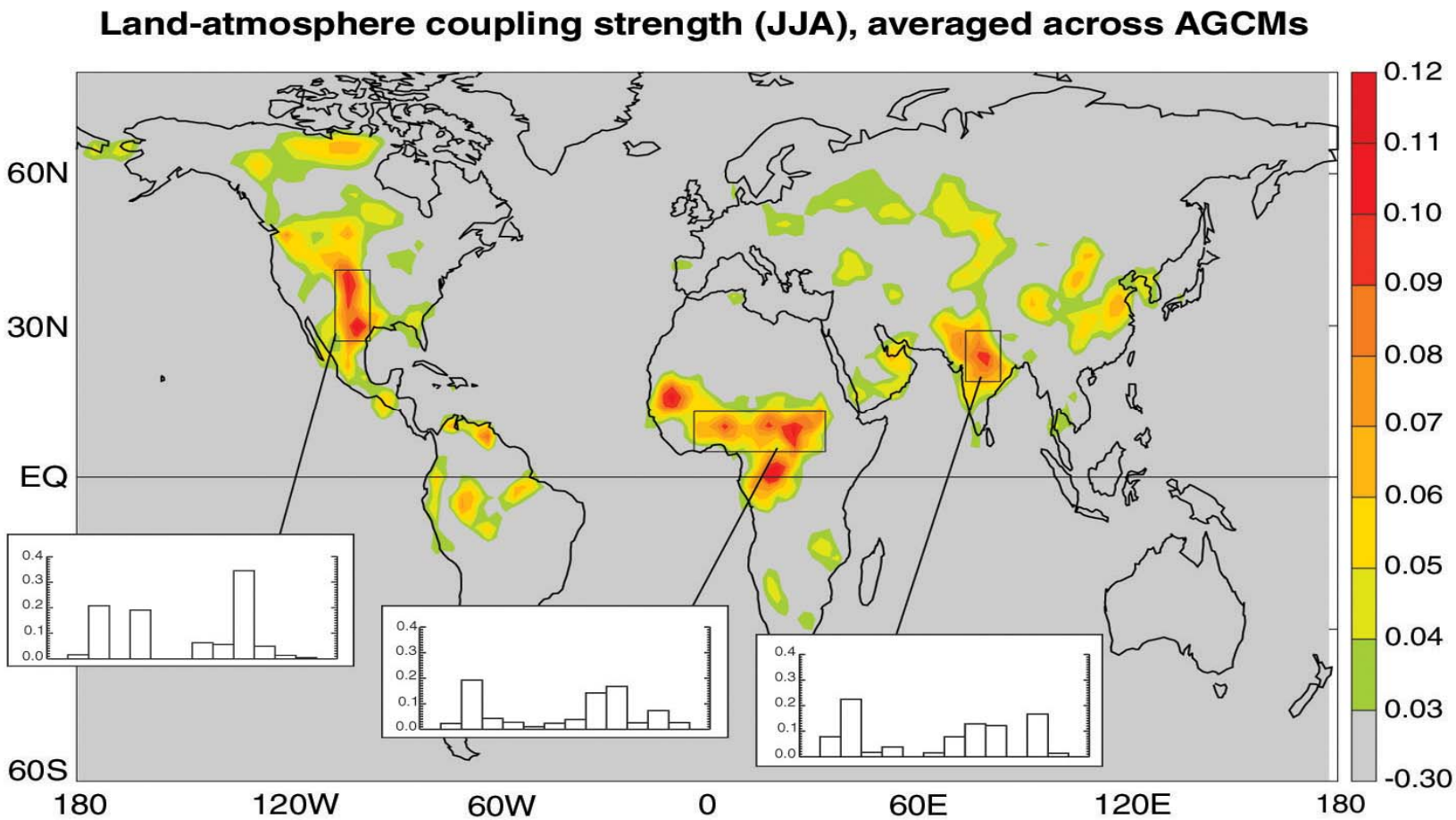
THE END.

Extra slides

Outline

Method	Ensemble Kalman filter
Soil Moisture	Data, biases, and assimilation
Soil Temperature	Data, biases, and assimilation

Soil moisture memory and "hot spots"



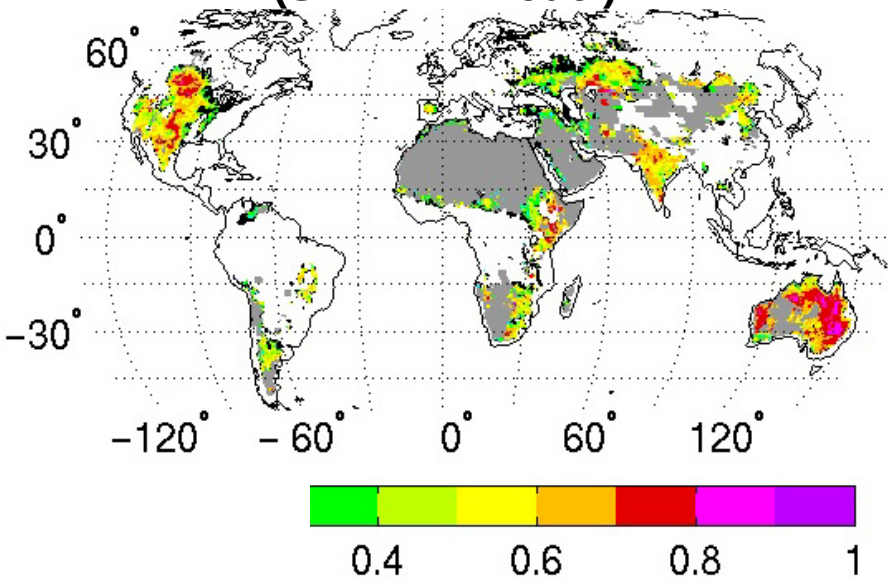
Koster et. al, *Science*, 2004

"Hot spots" where soil moisture changes can affect summer rainfall (multi-model consensus).

Land data assimilation may help with accurate seasonal forecast initialization.

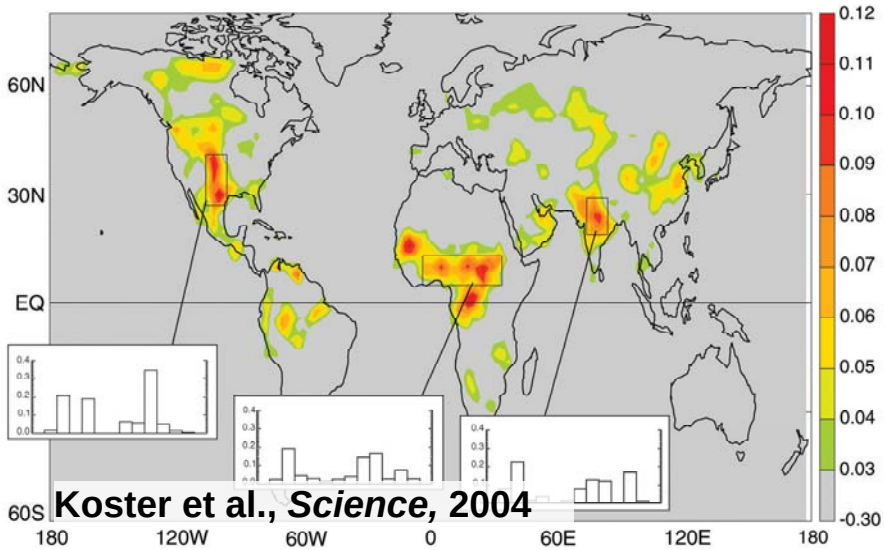
Anomaly time series

Anomaly time series correlation (SMMR v. model)



White: *insufficient data*
Grey: *variability < noise*
Black: *zero at 5% stat. significance*

"Hot spots" where soil moisture can affect rainfall

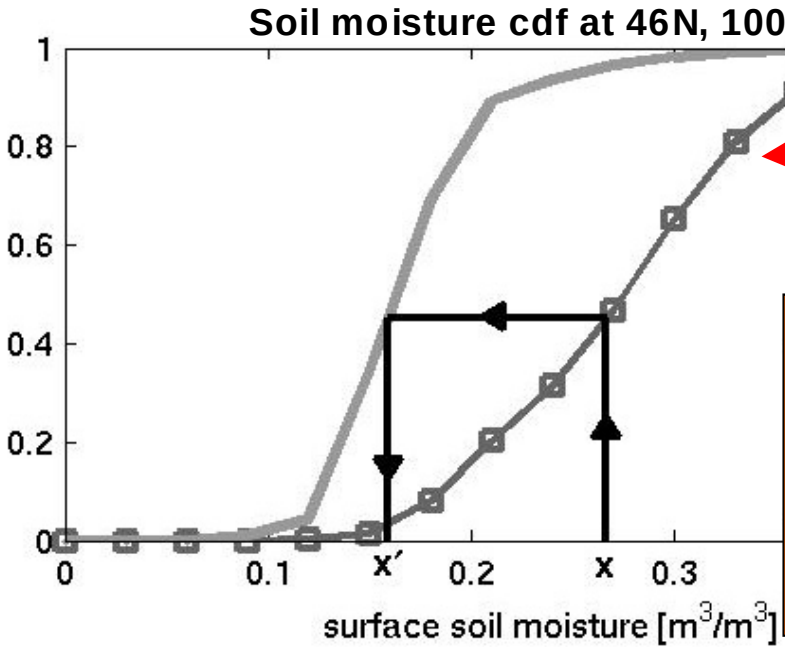


Koster et al., *Science*, 2004

Reichle et al., JHM, 2004, also showed that…

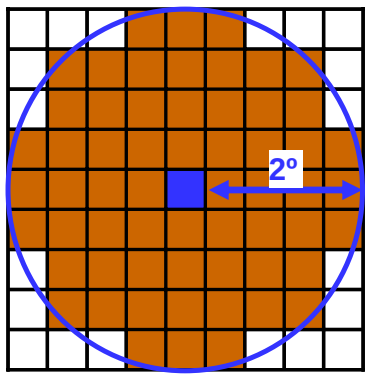
…satellite and model anomalies agree where soil moisture is important for seasonal forecasts!

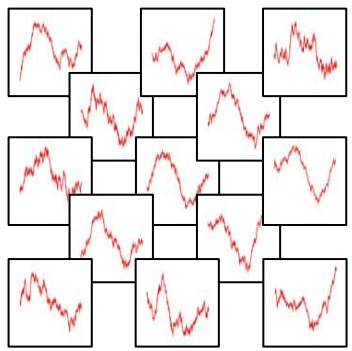
Soil moisture scaling for data assimilation



For "new" sensors:
- cannot use time series from historic satellites,
- long time series not immediately available!

Solution:
Approximate CDF from many 1-year time series at grid points within some distance from point of interest.

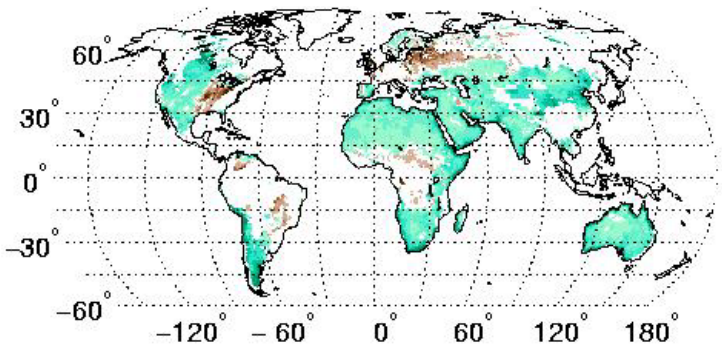




Soil moisture scaling for data assimilation (mean)

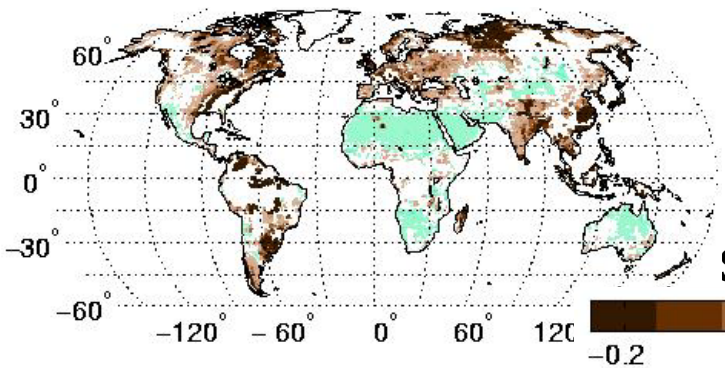
ORIGINAL multi-year data sets
(Satellite minus model)

SMMR

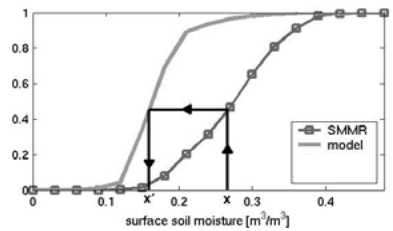


Reichle et al. *JHM* 2004

AMSR-E

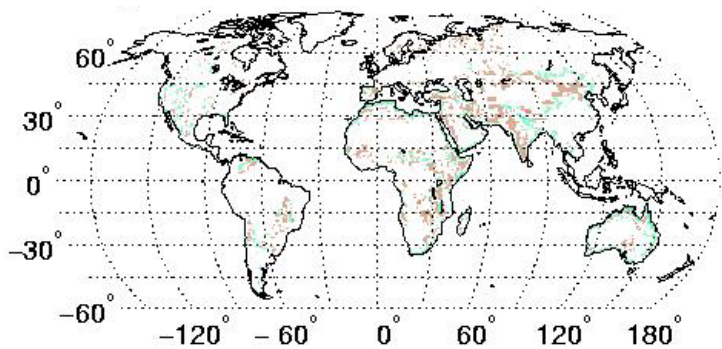


CDF scaling based on **1 year** of satellite data



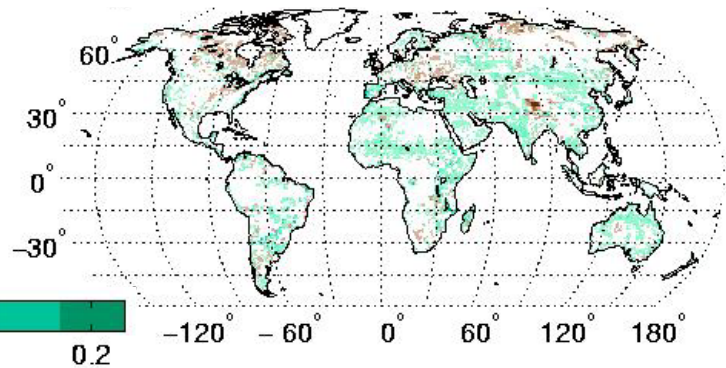
SCALED multi-year data sets
(Satellite minus model)

SMMR

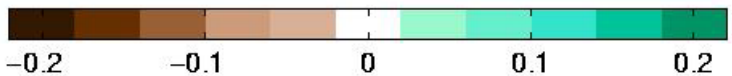


Reichle & Koster *GRL* 2004

AMSR-E



Soil moisture [m³/m³]

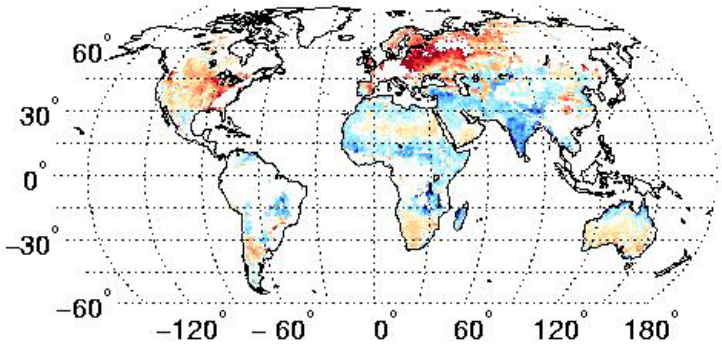


1 year of satellite data sufficient for considerable reduction in long-term bias.

Soil moisture scaling for data assimilation (std)

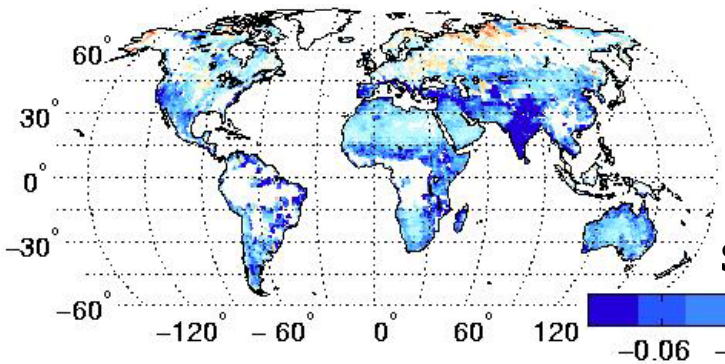
ORIGINAL multi-year data sets
(Satellite std minus model std)

SMMR

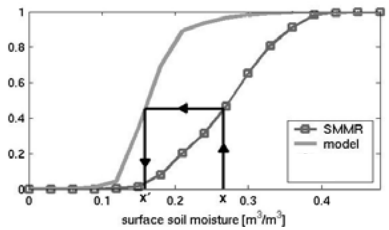


Reichle et al. *JHM* 2004

AMSR-E

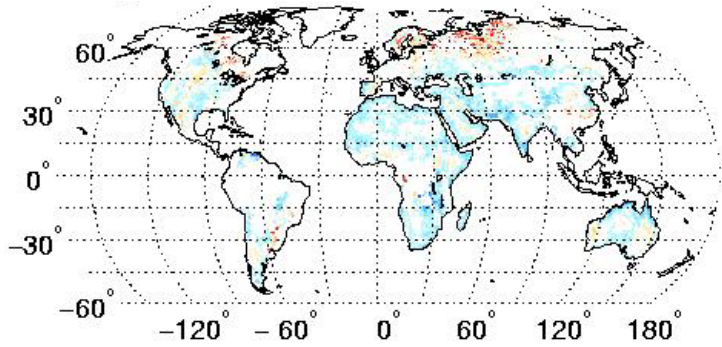


CDF scaling based on **1 year** of satellite data



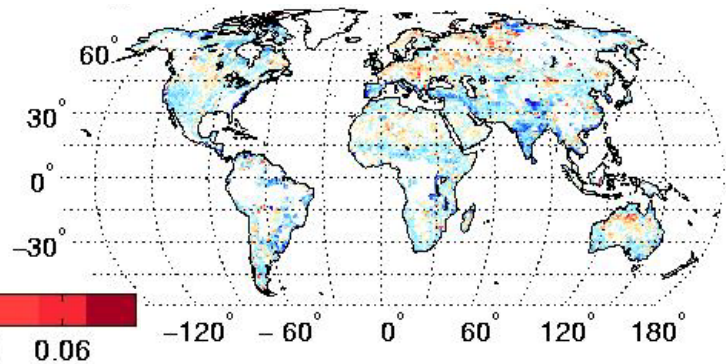
SCALED multi-year data sets
(Satellite std minus model std)

SMMR

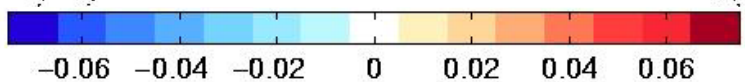


Reichle & Koster *GRL* 2004

AMSR-E



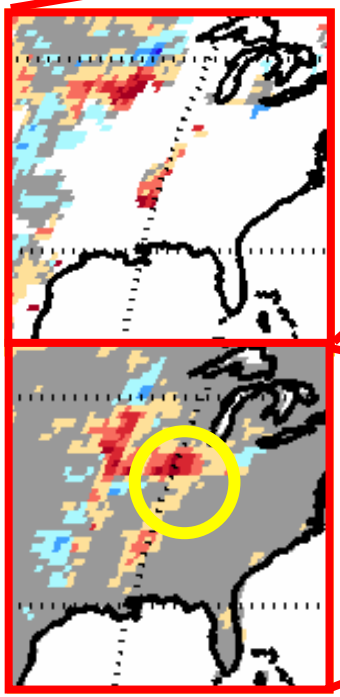
Soil moisture std [m³/m³]

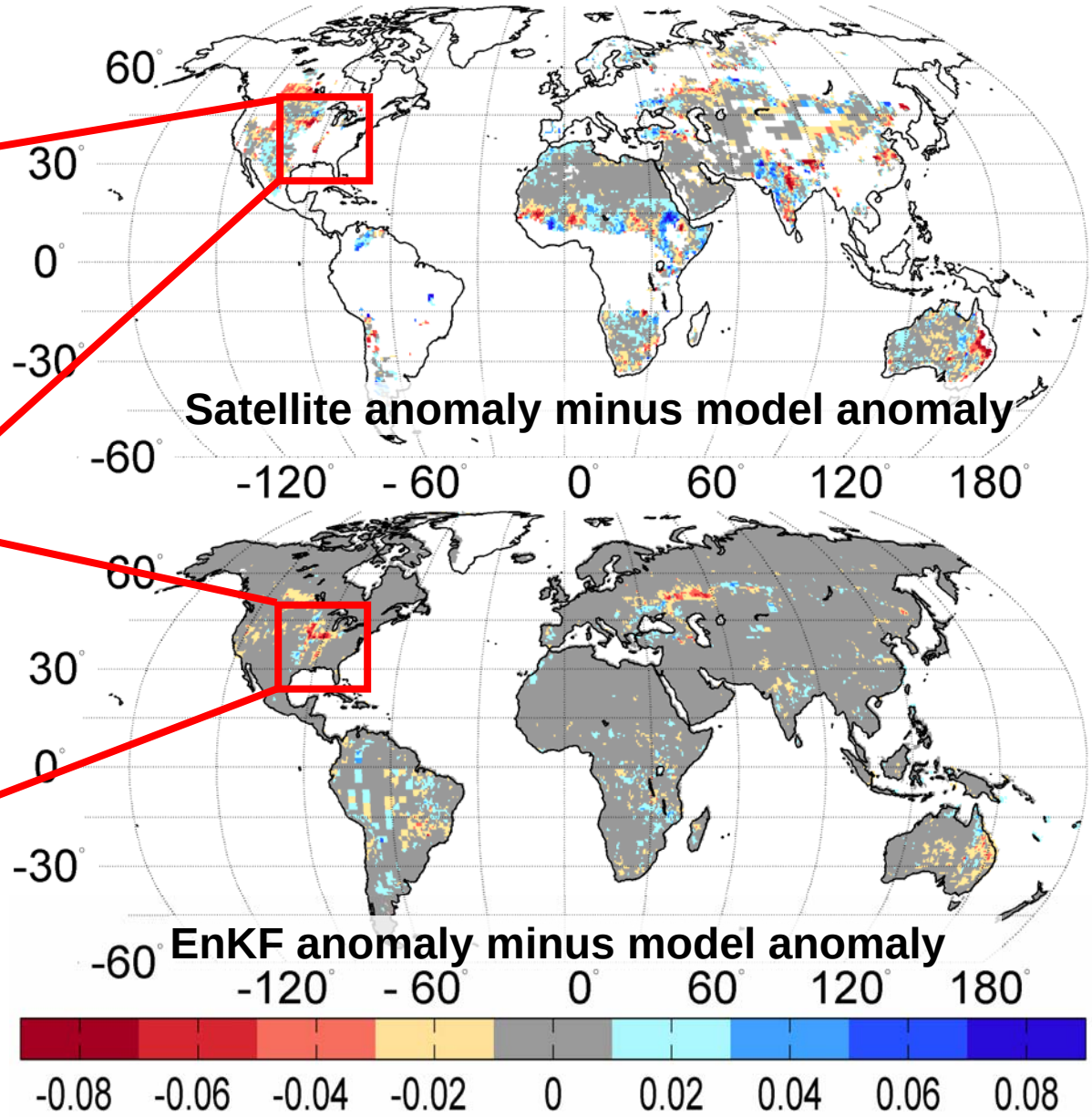


1 year of satellite data sufficient for considerable reduction in long-term bias.

Impact of SMMR assimilation – July 1982

Assimilation product lies "between" SMMR and model.

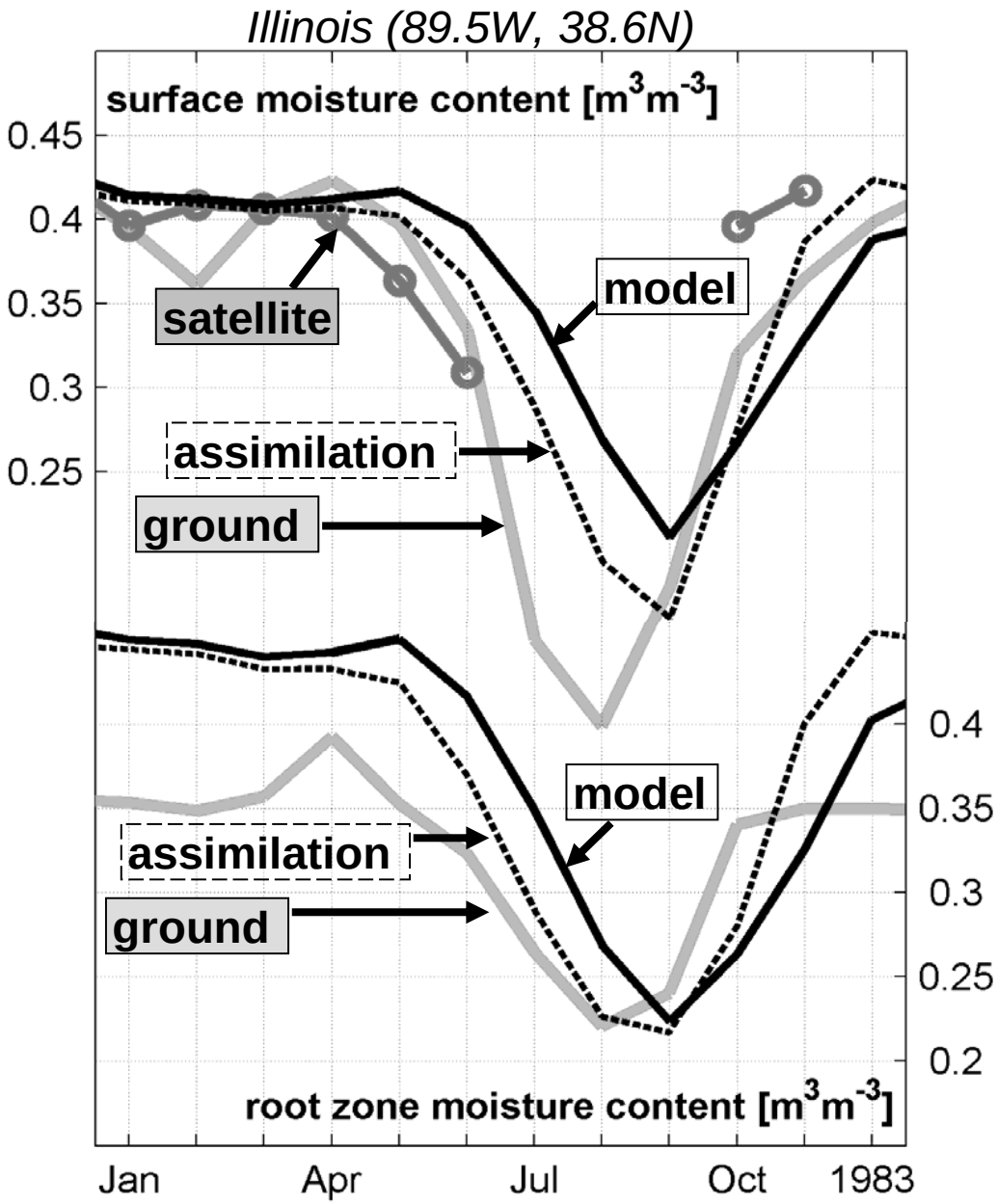




There are interesting dynamical effects.

Reichle & Koster, GRL 2005

Validation against in situ data



Assimilation product has improved phase of annual cycle.

Reichle & Koster, GRL 2005

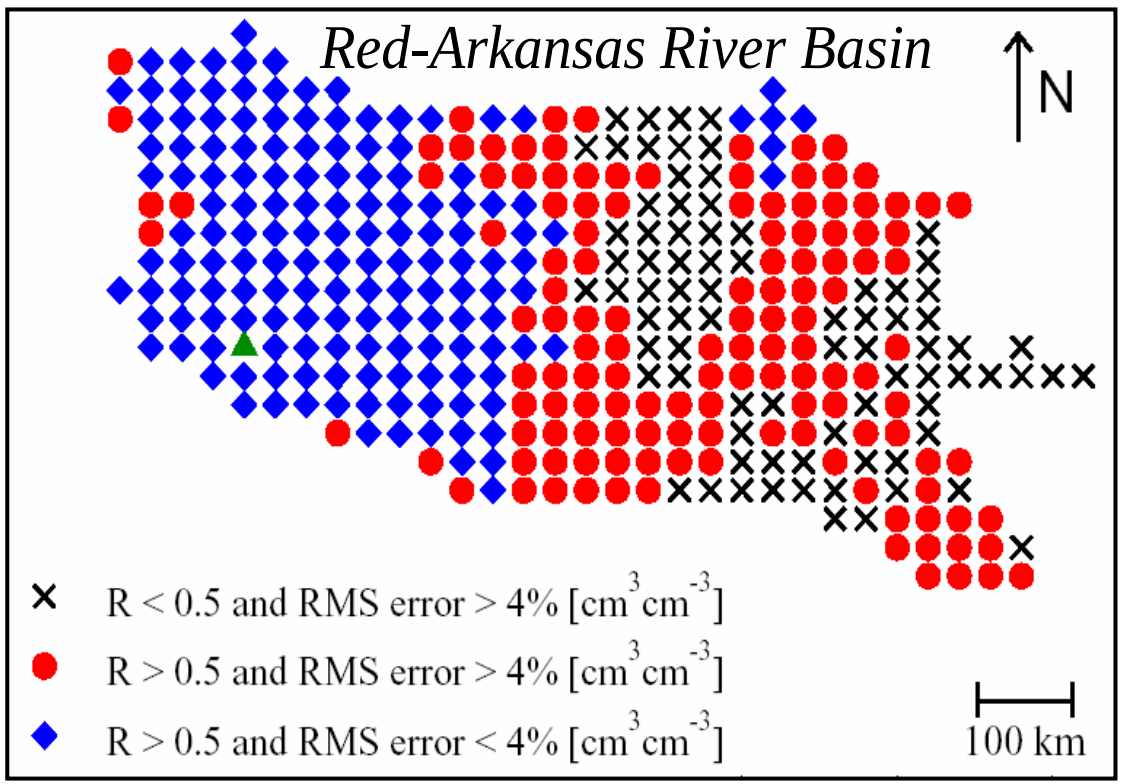
Soil moisture mission planning

Commonly, soil moisture mission planners require a measurement accuracy of ~0.04 m^3/m^3 ("4%") in absolute soil moisture.

Time-invariant errors contribute to RMSE but do not affect anomaly estimates.

Observing System Simulation Experiment (OSSE) result:

For a large part of the Red-Arkansas river basin, satellite retrievals might be useful (R>0.5) even though their absolute errors exceed 0.04 m^3/m^3.



For modeling and forecasting applications, satellite retrievals might be more useful than previously assumed.

Crow et al., GRL 2005