Goddard Space Flight Center

Land Information System

The Impact of Soil Moisture and Snow Assimilation on Noah LSM Evaporation and Streamflow

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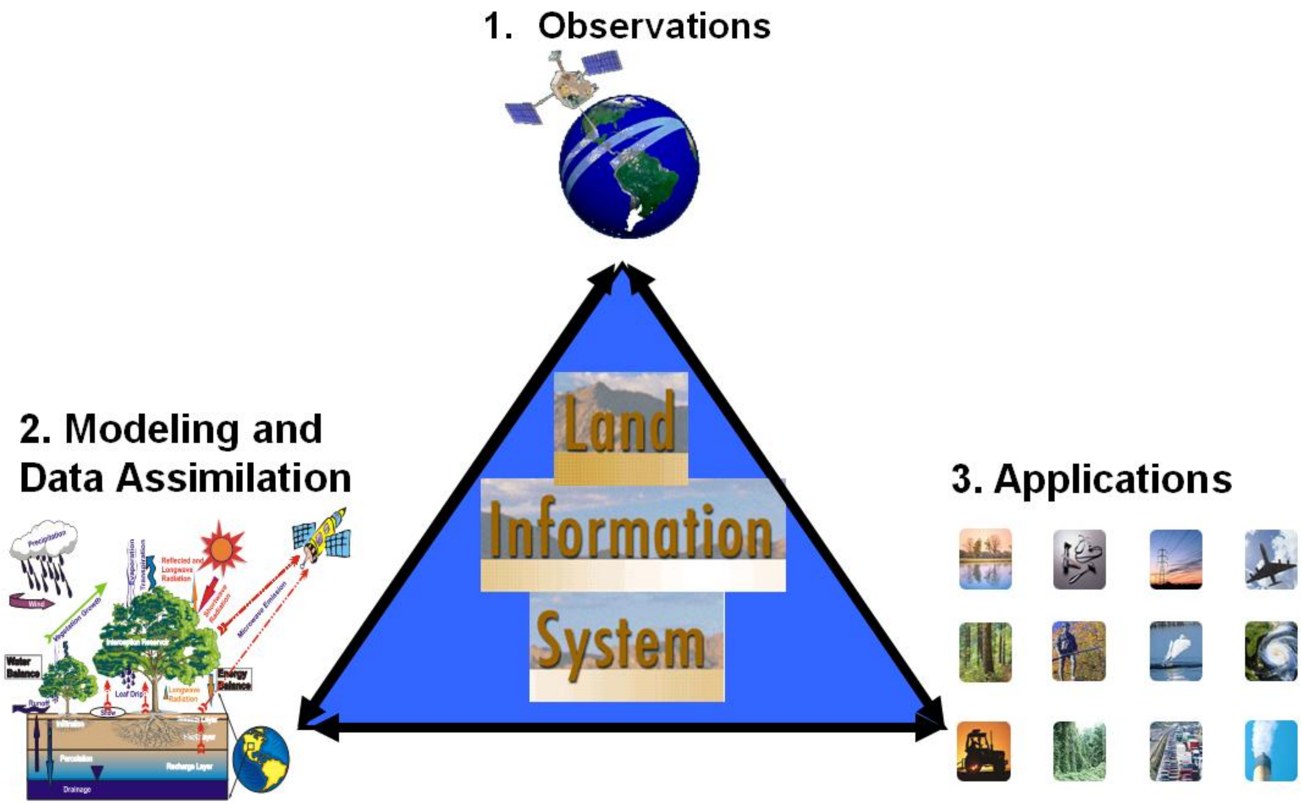
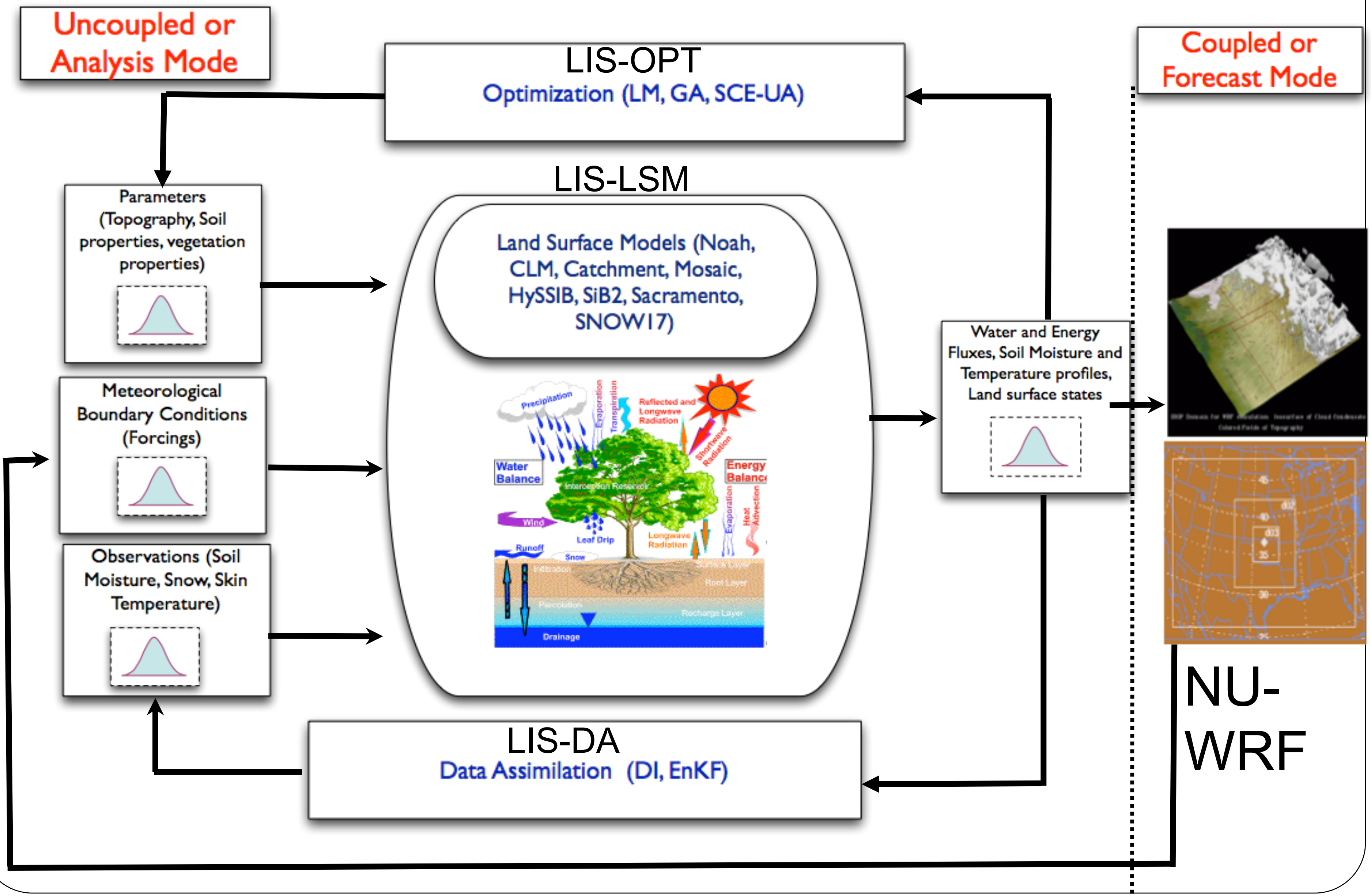
The Land Information System (LIS; http://lis.gsfc.nasa.gov) is a common land data assimilation infrastructure for NASA/DoD/NOAA



Kumar, S. V., C. D. Peters-Lidard, Y. Tian, P. R. Houser, J. Geiger, S. Olden, L. Lighty, J. L. Eastman, B. Doty, P. Dirmeyer, J. Adams, K. Mitchell, E. F. Wood and J. Sheffield, 2006. Land Information System - An Interoperable Framework for High Resolution Land Surface Modeling. *Environmental Modelling & Software,* Vol. 21, 1402-1415.

Peters-Lidard , C.D., P.R. Houser, Y. Tian, S.V. Kumar, J. Geiger, S. Olden, L. Lighty, B. Doty, P. Dirmeyer, J. Adams, K. Mitchell, E.F. Wood and J. Sheffield, 2007: High-performance Earth system modeling with NASA/GSFC's Land Information System. *Innovations in Systems and Software Engineering.* 3(3), 157-165. DOI:10.1007/s11334-007-0028-x

LIS Subsystems



Land Data Assimilation Objectives

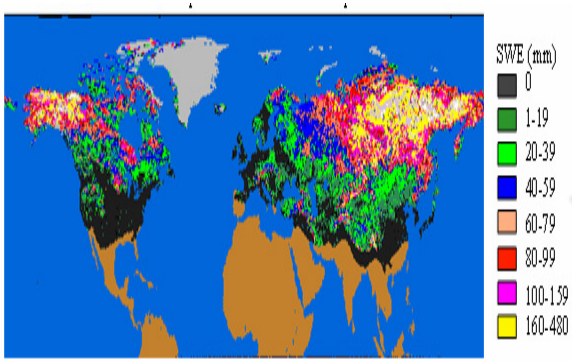
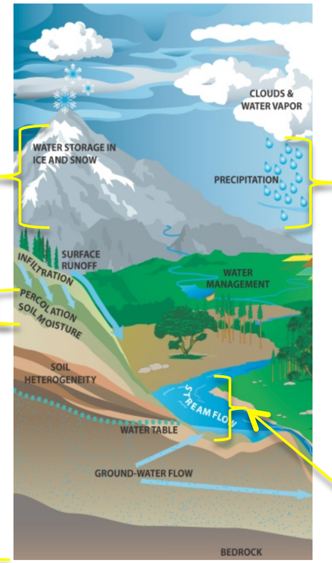


Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/ VIIRS and DWSS/MIS.



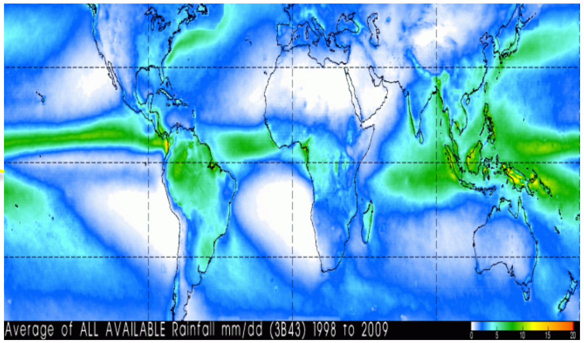


Figure 2: Annual average precipitation from 1998 to 2009 based on TRMM satellite observations. Future observations will be provided by GPM.

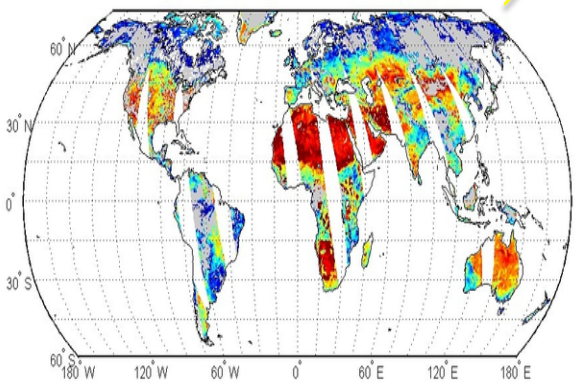


Figure 3: Daily soil moisture based on Aqua/ AMSR-E. Future observations will be provided by SMAP.

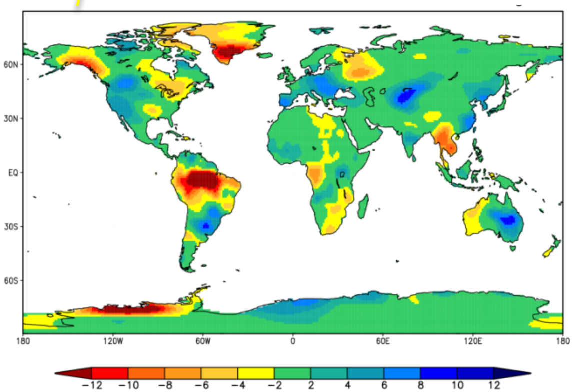


Figure 4: Changes in annual-average terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) between 2009 and 2010, based on GRACE satellite observations. Future observations will be provided by GRACE-II.

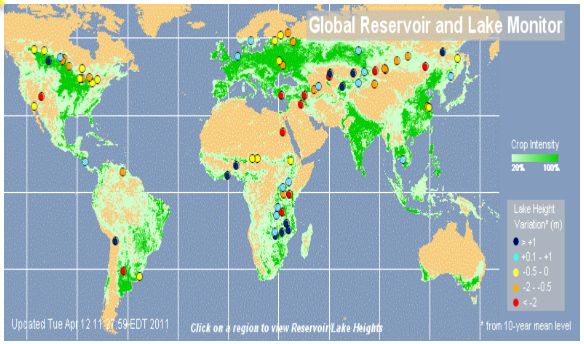
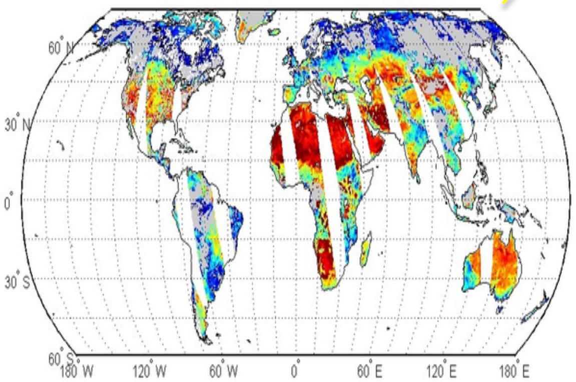


Figure 5: Current lakes and reservoirs monitored by OSTM/Jason-2. Shown are current height variations relative to 10-year average levels. Future observations will be provided by SWOT.

Soil Moisture Data Assimilation



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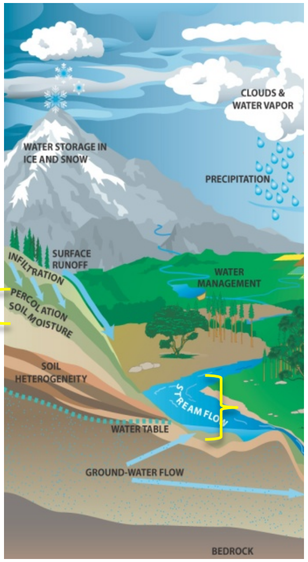


Impact Assessment:

- Drought

Variables Analyzed:

- Soil Moisture
- Evapotranspiration
- Steamflow

Experimental Setup:

- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 2002-01 to 2010-01
- Forcing: NLDASII
- LSM: Noah 3.2

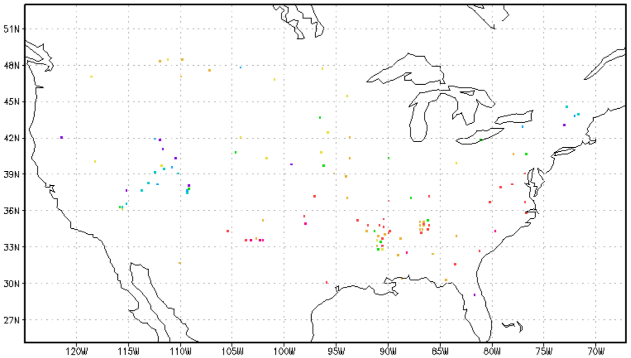
Data Assimilation:

- AMSR-E LPRM soil moisture
- AMSR-E NASA soil moisture

Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

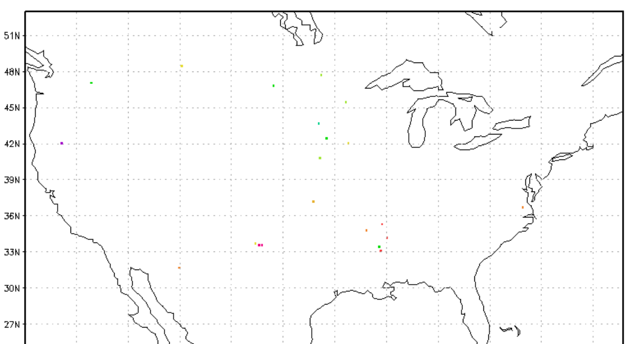
Soil moisture Assimilation -> Soil moisture (Evaluation vs SCAN)

ALL available stations (179)



Anomaly correlation	OL	NASA-DA	LPRM-DA
Surface soil moisture (10cm)	0.55 +/- 0.01	0.49 +/- 0.01	0.56 +/- 0.01
Root zone soil moisture (1m)	0.17 +/- 0.01	0.13 +/- 0.01	0.19 +/- 0.01

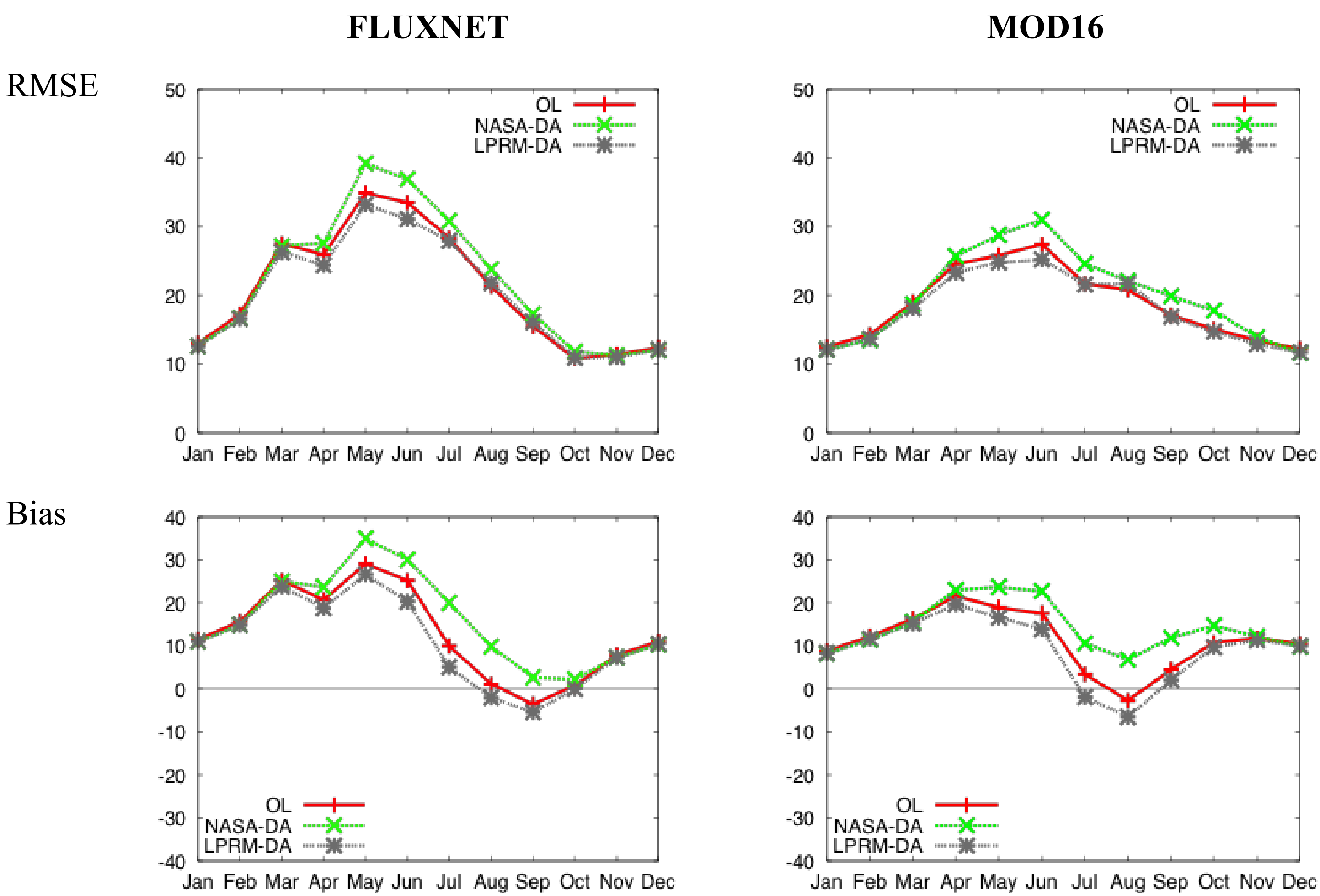
(21) Stations listed in Reichle et al.



Anomaly correlation	OL	NASA-DA	LPRM-DA
Surface soil moisture (10cm)	0.62 +/- 0.05	0.53 +/- 0.05	0.62 +/- 0.05
Root zone soil moisture (1m)	0.16 +/- 0.05	0.13 +/- 0.05	0.19 +/- 0.05

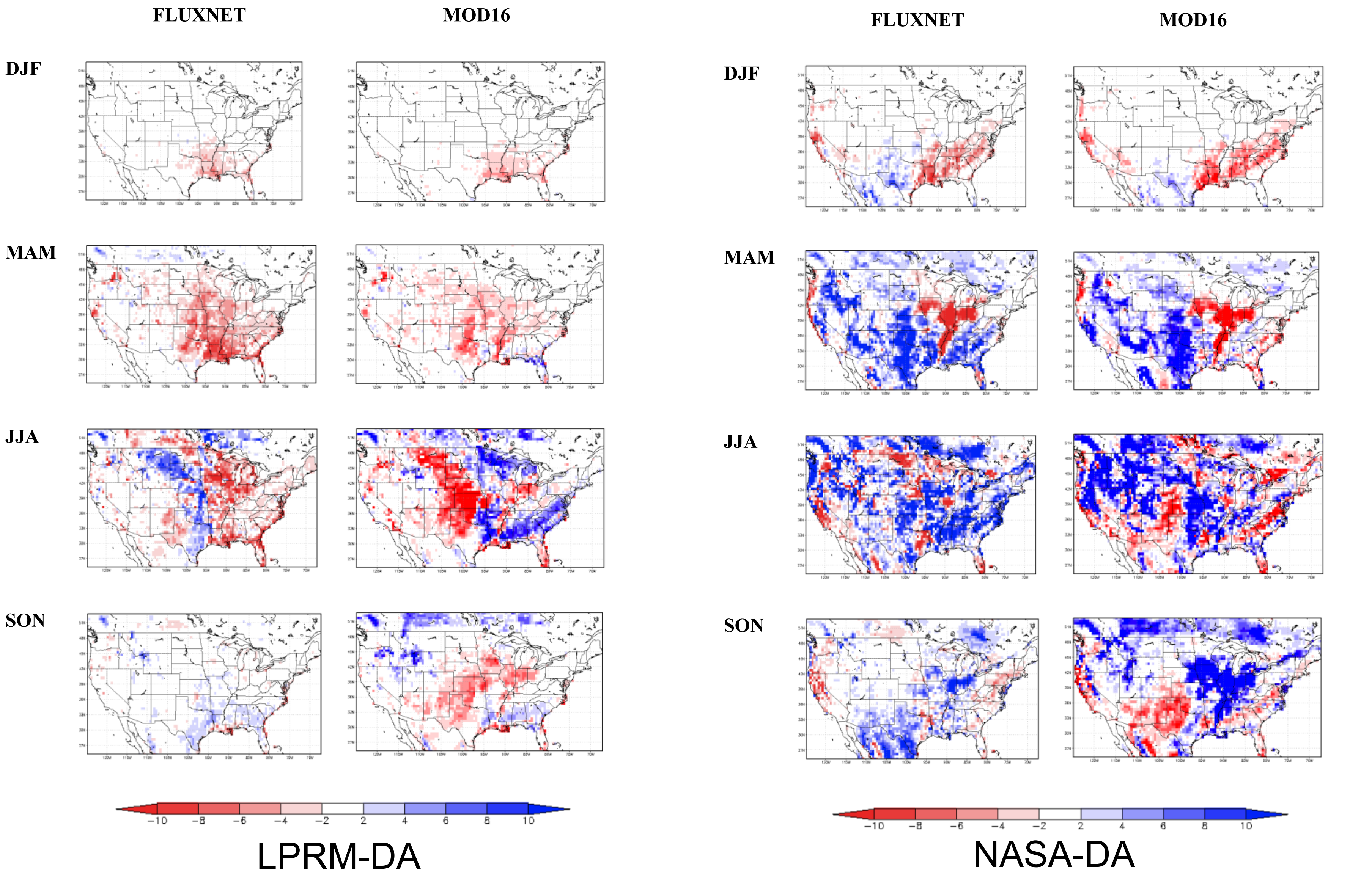
Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

Soil Moisture Assimilation -> Latent Heat Flux



Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

Where Does Soil Moisture Assimilation Help Improve Qle (i.e. Reduce RMSE) ?



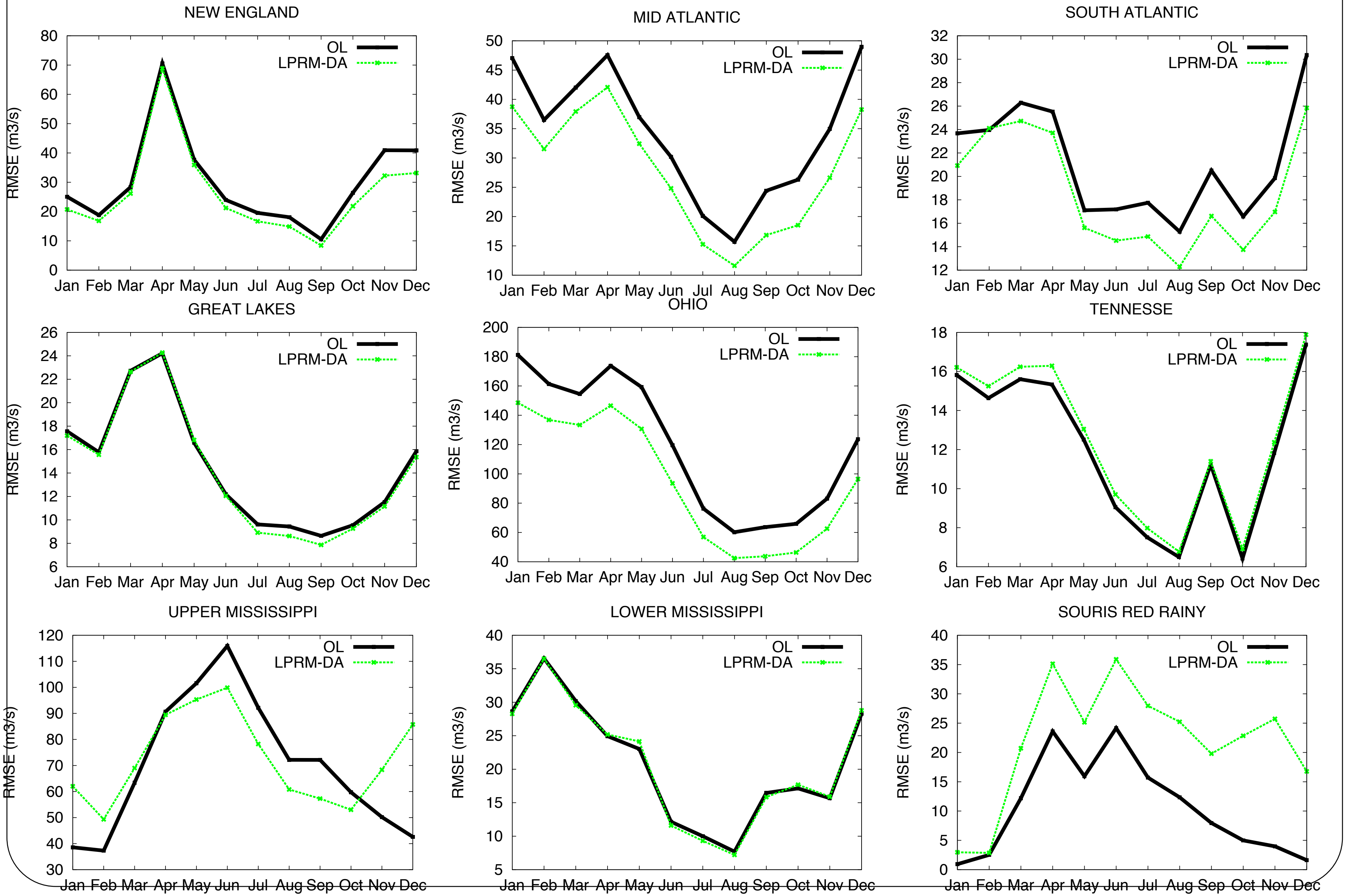
Where Does Soil Moisture Assimilation Help Improve Qle (i.e. Reduce RMSE) ?

Qle RMSE % Difference (DA-OL)	FLUXNET		MOD16	
Landcover type	NASA-DA (Wm^{-2})	LPRM-DA (Wm^{-2})	NASA-DA (Wm^{-2})	LPRM-DA (Wm^{-2})
Evergreen needleleaf forest	17.6	7.9	10.5	-3.6
Deciduous broadleaf forest	3.2	12.7	0.3	0.7
Mixed forest	1.8	8.0	-0.7	-0.9
Woodlands	16.4	18.9	11.5	-5.9
Wooded grassland	8.8	-0.5	9.6	0.3
Closed shrubland	7.3	3.4	2.5	8.9
Open shrubland	9.0	7.4	3.6	12.1
Grassland	23.9	7.1	32.9	46.4
Cropland	12.3	34.7	30.9	40.8
Bare soil	-0.1	0.6	-0.8	1.4
Urban	-0.1	-0.1	-0.2	-0.3

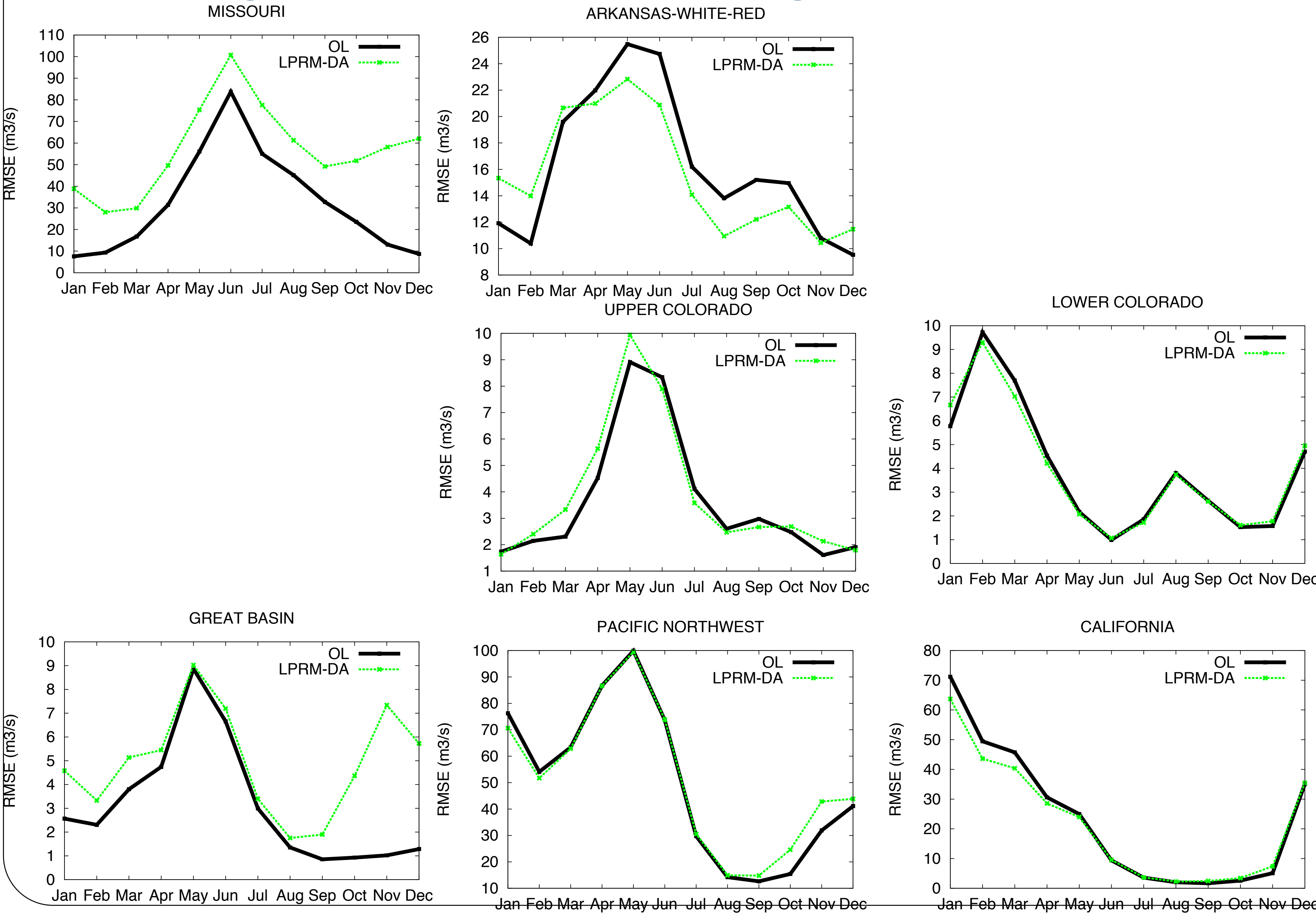
Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

Soil Moisture Assimilation -> Streamflow Evaluation vs. USGS gauges – by major basins

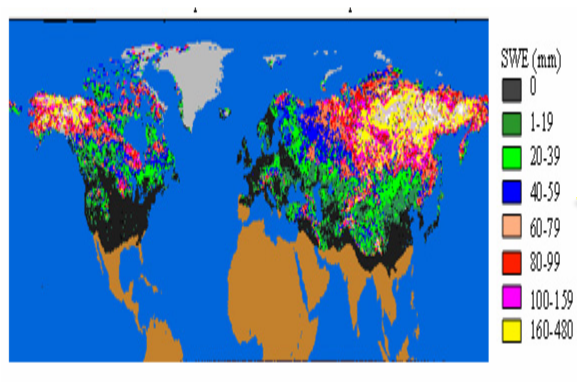
Soil Moisture Assimilation -> Streamflow
(average seasonal cycles of RMSE– using Xia et al. (2011) stations)



Soil Moisture Assimilation -> Streamflow
(average seasonal cycles of RMSE– using Xia et al. (2011) stations)



Snow Data Assimilation



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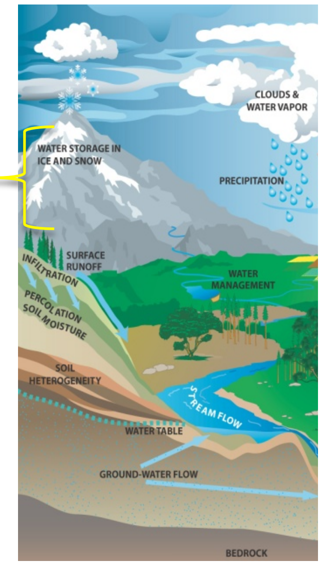


Impact Assessment:

- Floods

Variables Analyzed:

- Snow Depth
- Steamflow

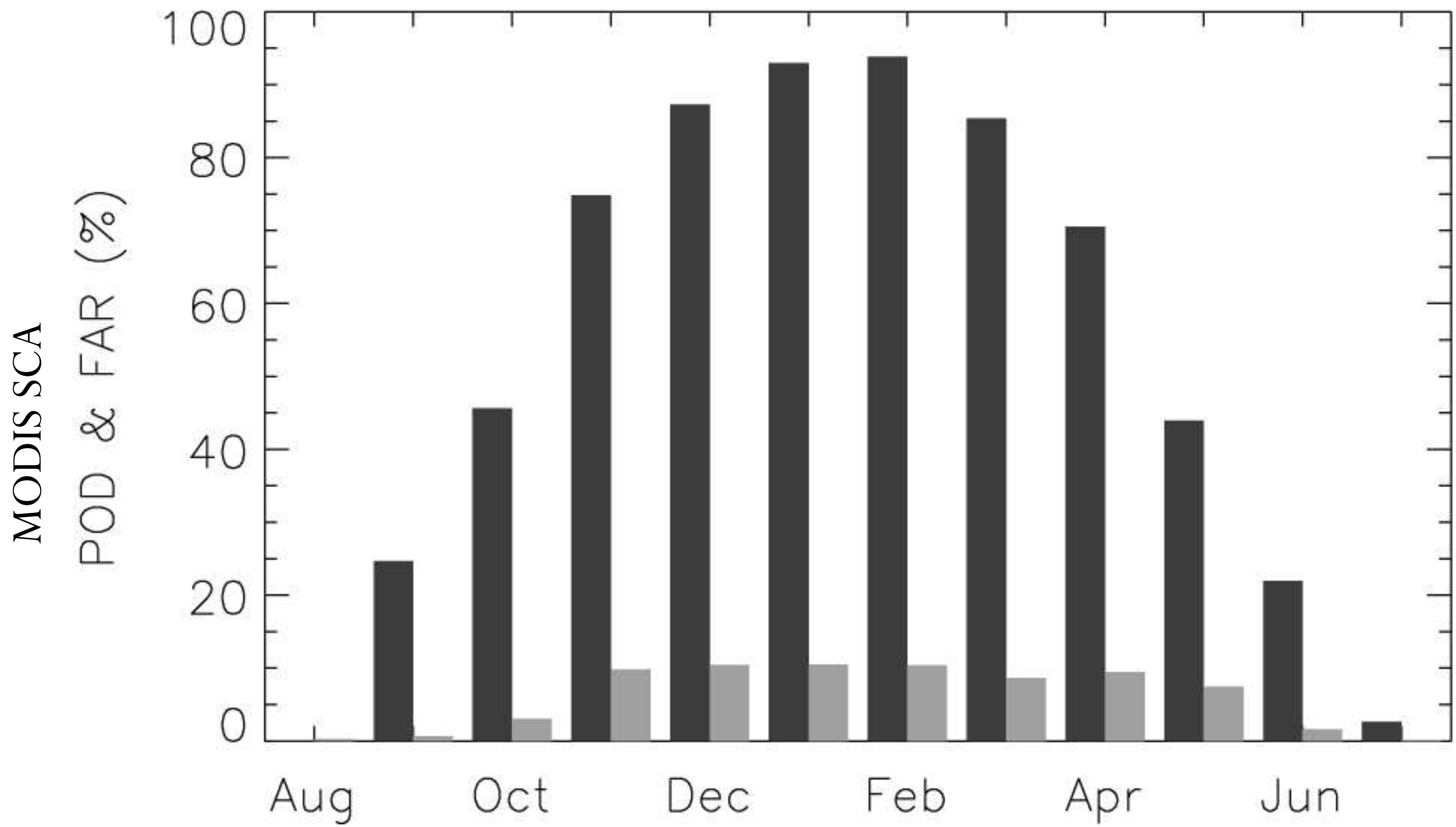
Experimental Setup:

- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 2002-01 to 2010-01
- Forcings: NLDASII
- LSM: Noah 3.2

Data Assimilation:

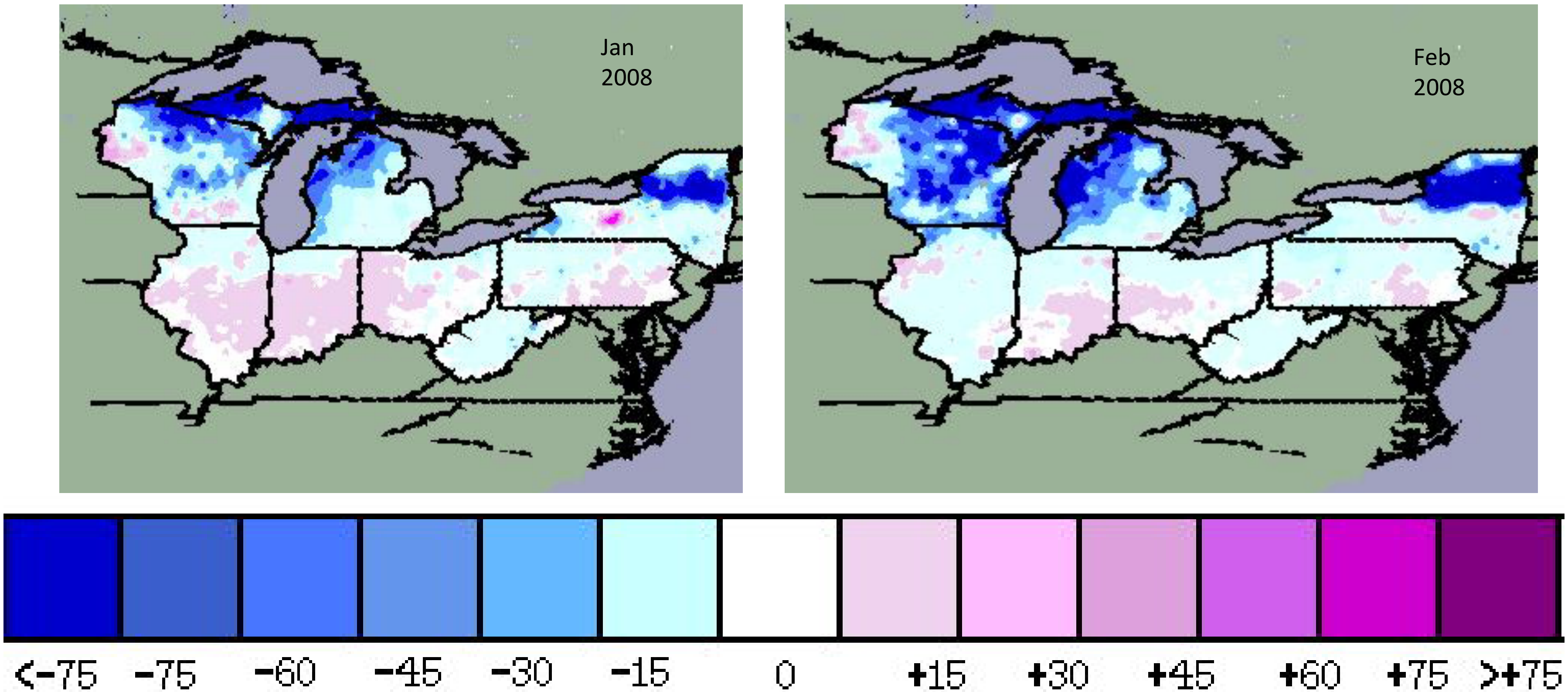
- MODIS snow covered area
- AMSR-E snow depth
- AMSR-E bias corrected
- snow depth

Accuracy of Remotely Sensed Snow Data MODIS SCA (2000-2005)



Dong; Jiarui and Christa Peters-Lidard, 2010: On the Relationship Between Temperature and MODIS Snow Cover Retrieval Errors in the Western U.S., IEEE J. Selected Topics in Applied Earth Observations and Remote Sensing, 3(1), 132-140, doi: 10.1109/JSTARS.2009.2039698.

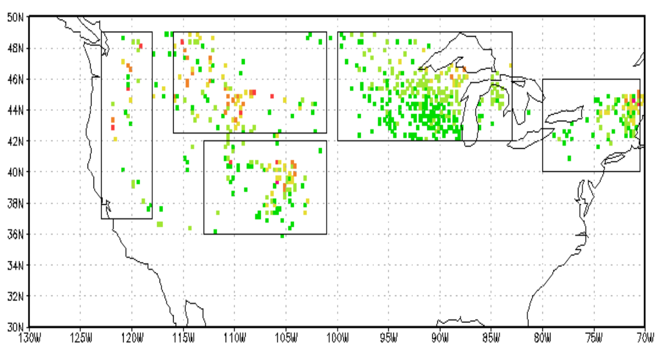
Accuracy of Remotely Sensed Snow Data
AMSR-E SWE Bias (Jan-Feb 2008)



Mean difference between AMSR-E SWE vs. COOP data (mm)

The good news:
Snow physics improvements in Noah LSM
(Noah 2.7.1 vs Noah 3.1)

- Evaluation against the NWS COOP station data (2002-2010) using the LIS Verification Toolkit (LVT)
- Noah 3.1 performs consistently better than Noah 2.7.1

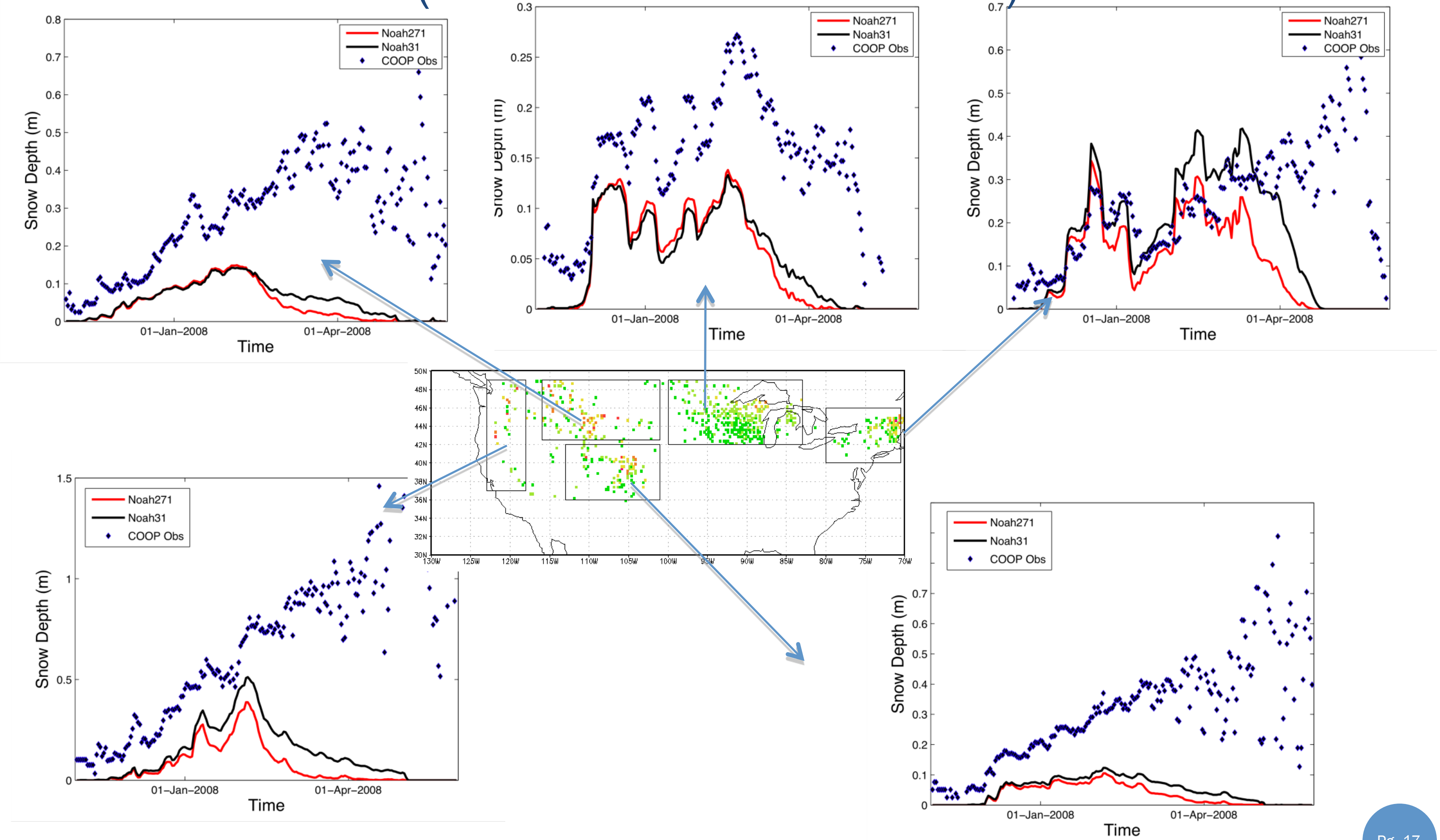


RMSE (mm)	CONUS	High Plains	West Coast	SGP	Midwest	North East
Noah 2.7.1	251.0	288	451	353	217	206
Noah 3.1	220.0	263	393	322	191	164

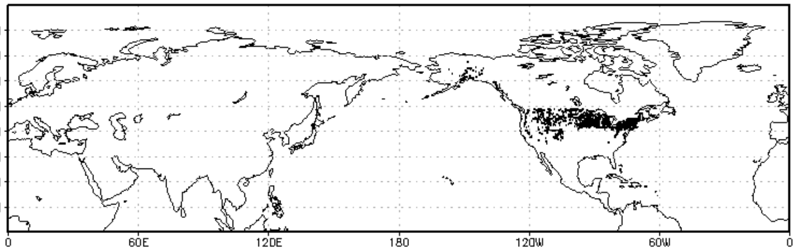
Bias (mm)	CONUS	High Plains	West Coast	SGP	Midwest	North East
Noah 2.7.1	-182	-208	-301	-267	-163	-138
Noah 3.1	-139	-170	-197	-223	-135	-68

R	CONUS	High Plains	West Coast	SGP	Midwest	North East
Noah 2.7.1	0.46	0.38	0.50	0.26	0.49	0.56
Noah 3.1	0.57	0.47	0.66	0.37	0.62	0.70

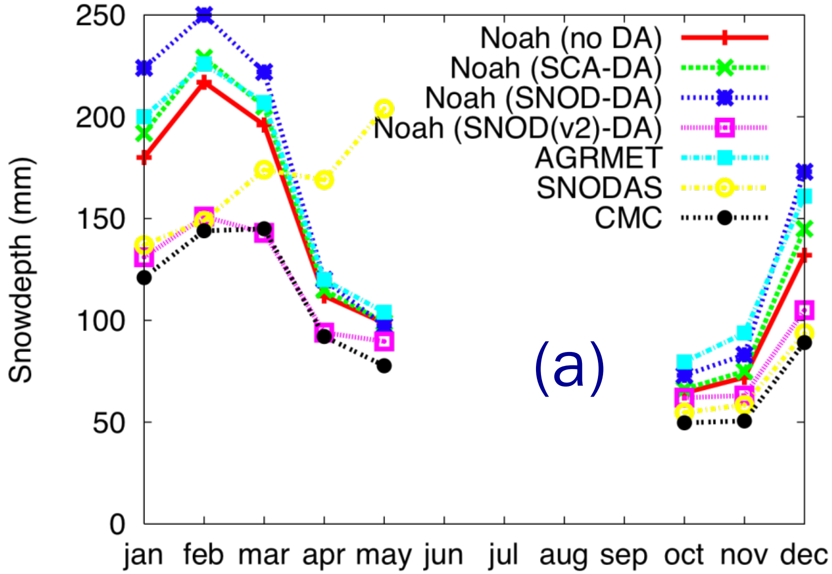
But:
Large biases in snow depth remain
(Noah 2.7.1 vs Noah 3.1)

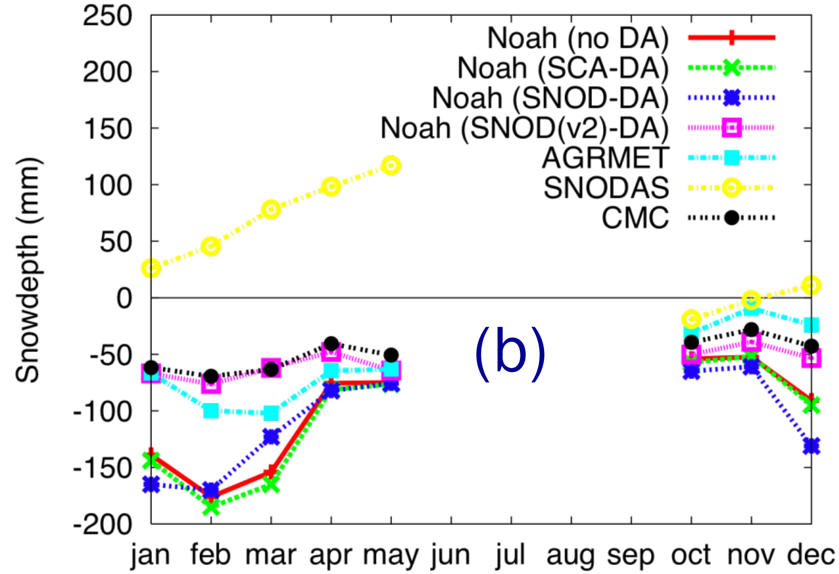


MODIS SCA and AMSR-E SNOD Snow Assimilation vs. COOP Stations



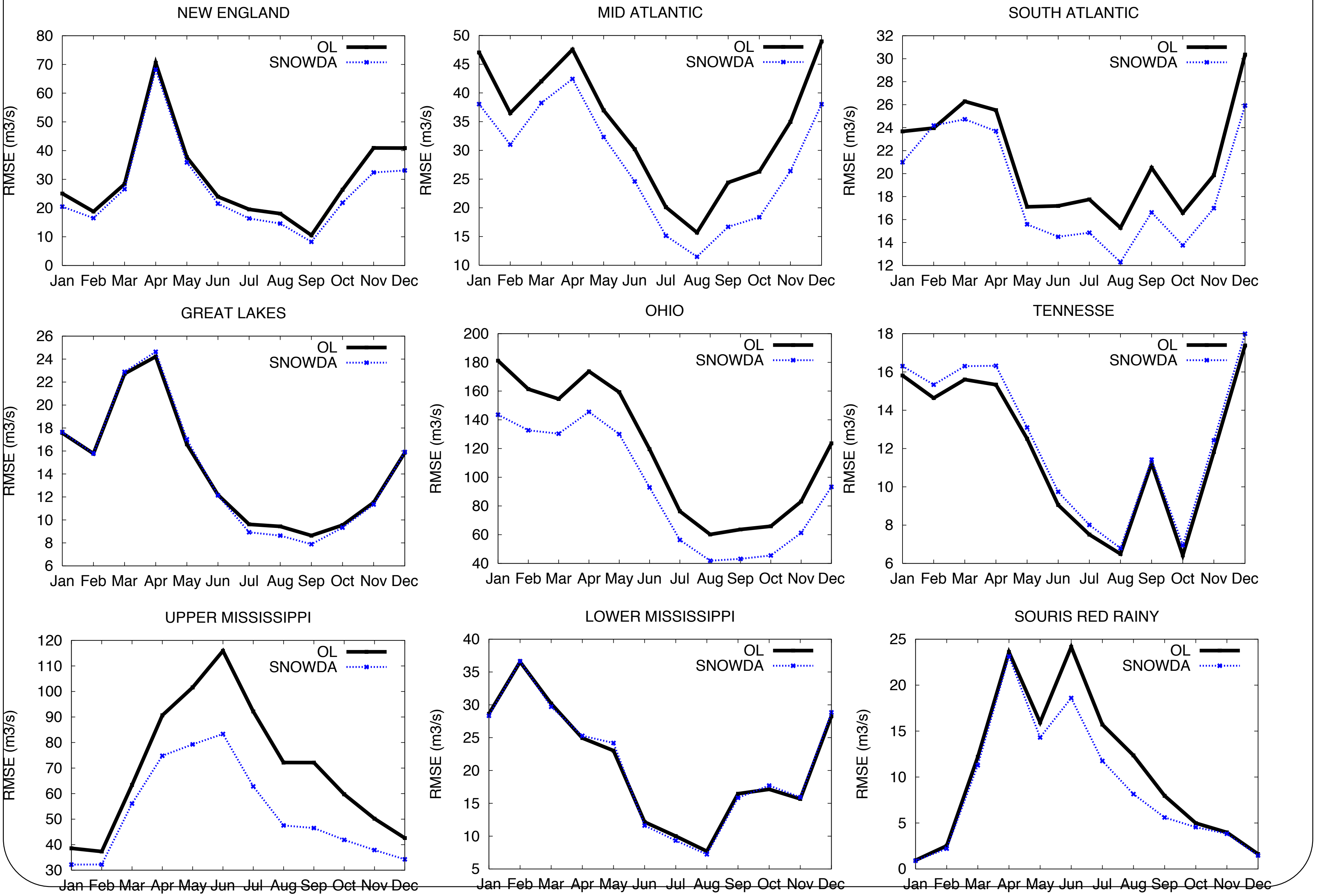
Average seasonal cycle of (a) RMSE and (b) Bias





	RMSE (mm)	Bias (mm)	R
Noah (no DA)	220.0	-139.0	0.57
Noah (SCA-DA)	232.0	-148.0	0.44
Noah (SNOD-DA)	257.0	-151.0	0.25
Noah (SNOD(v2)-DA)	156.0	-67.3	0.78
AGRMET	235.0	-81.7	0.51
SNODAS	173.0	42.4	0.68
CMC	147.0	-60.7	0.70

Snow Assimilation -> Streamflow
(average seasonal cycles of RMSE– using Xia et al. (2011) stations)



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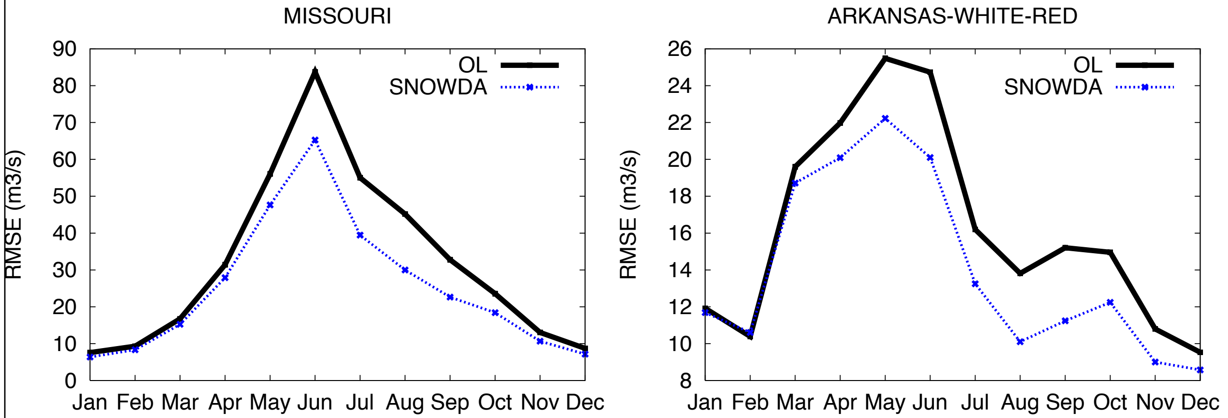
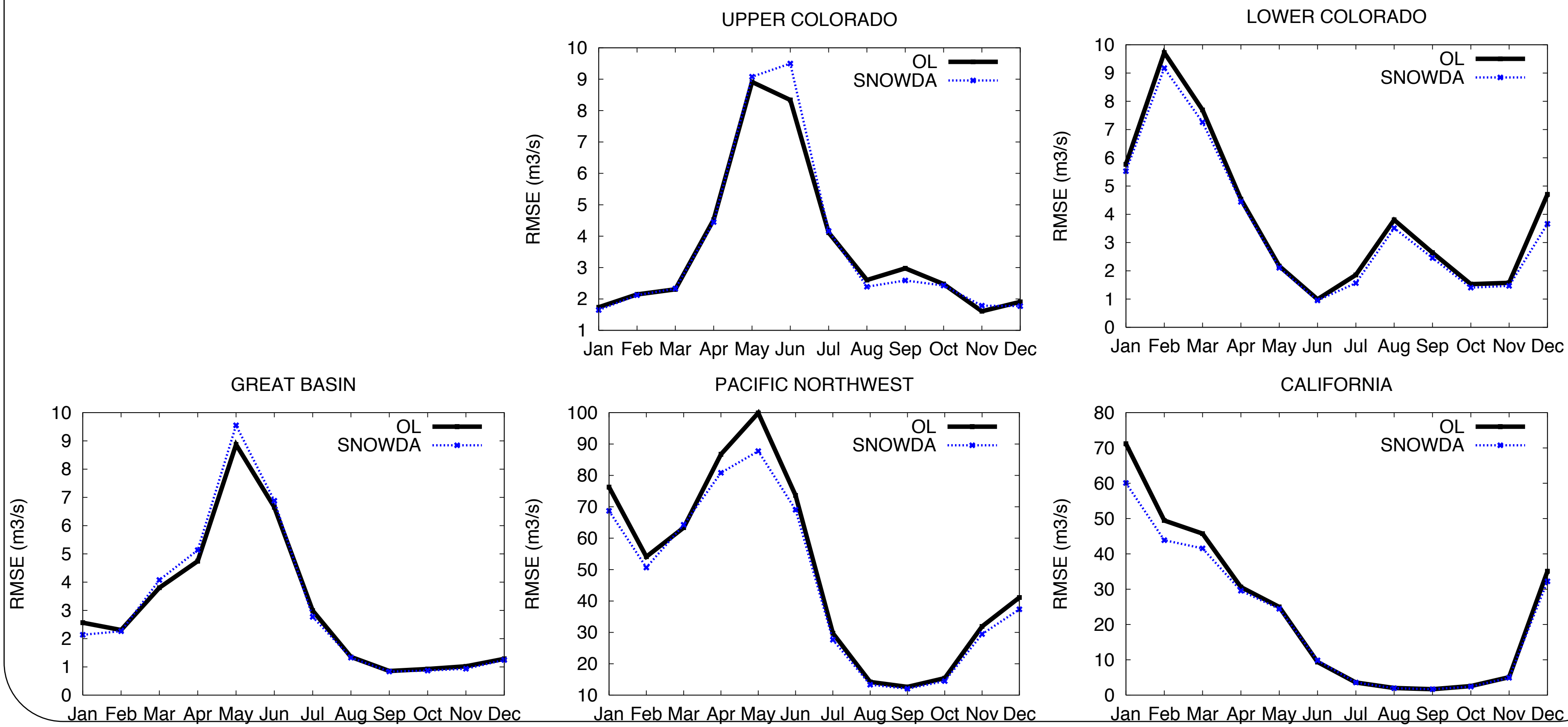


Snow DA shows improvements during the melt periods
-E.g., New England, Upper Mississippi, Souris Red Rainy, Missouri, Arkansas



Summary

- LPRM AMSR-E Soil moisture assimilation can improve soil moisture, streamflow and evapotranspiration -> Critical for Drought, NWP
  - Recommendation: Soil Moisture
    - AMSR-E is no longer functional, ASCAT, SMOS and GCOM-W/AMSR-2 are now orbiting, and SMAP will be launched in 2014. JCSDA needs reliable LandEM forward models for C,X-band and L-band with land surface-based evaluation and metrics
- Bias-corrected AMSR-E Snow depth assimilation improves snow depth and streamflow. Other results (not shown) show some potential for MODIS/SCA, especially in snow transition regions or spring snowmelt.
  - Recommendation: Snow
    - Bias-corrected snow depth from AMSR-2, along with SCA from MODIS/VIIRS. Snow RT model in LandEM not mature and snowpack RT highly uncertain, so product-based approach best for near-term.

Additional References

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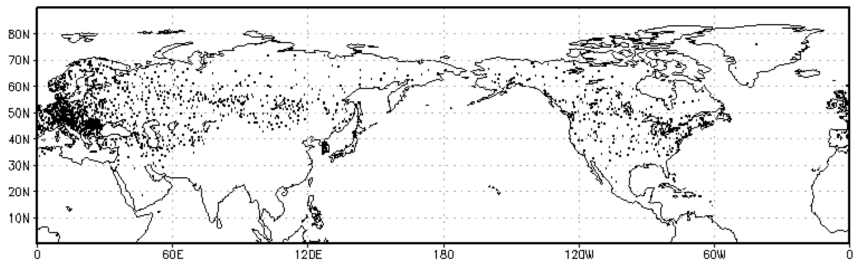
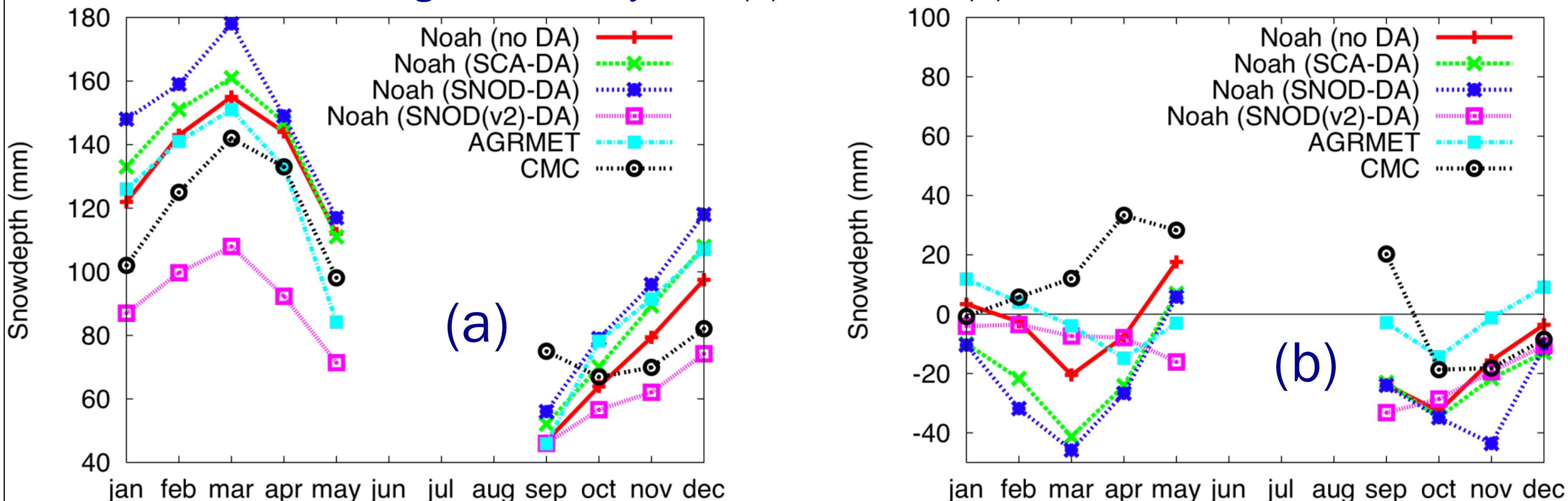
MODIS SCA and AMSR-E SNOD Snow Assimilation vs. WMO Stations

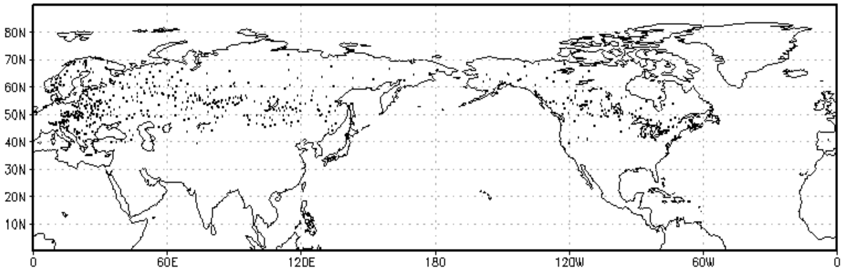


Average seasonal cycle of (a) RMSE and (b) Bias



	RMSE (mm)	Bias (mm)	R
Noah (no DA)	154.0	-10.9	0.63
Noah (SCA-DA)	162.0	-25.5	0.52
Noah (SNOD-DA)	170.0	-28.9	0.40
Noah (SNOD(v2)-DA)	112.0	-14.0	0.70
AGRMET	154.0	11.60	0.62
CMC	140.0	-1.59	0.72

MODIS SCA and AMSR-E SNOD Snow Assimilation vs. GSOD Stations



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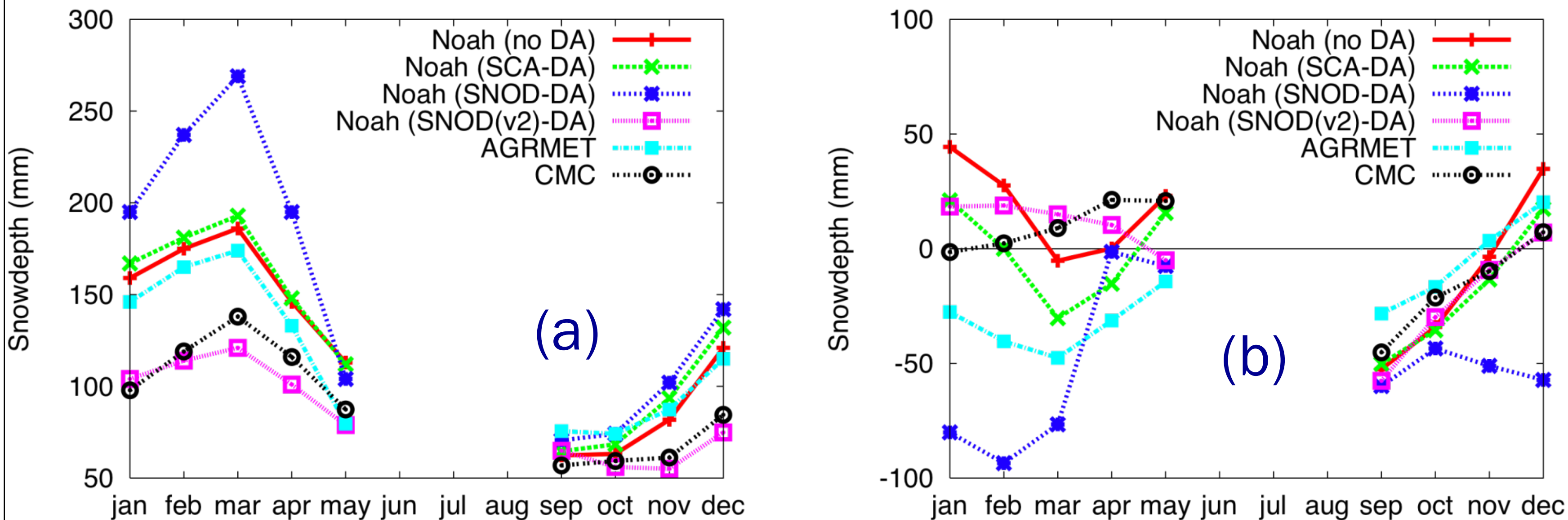

	RMSE (mm)	Bias (mm)	R
Noah (no DA)	182.0	17.0	0.64
Noah (SCA-DA)	190.0	-4.0	0.57
Noah (SNOD-DA)	228.0	-66.8	0.40
Noah (SNOD(v2)-DA)	131.0	13.1	0.75
AGRMET	181.0	-24.3	0.59
CMC	132.0	4.8	0.81