Opportunities and Challenges in Land Data Assimilation

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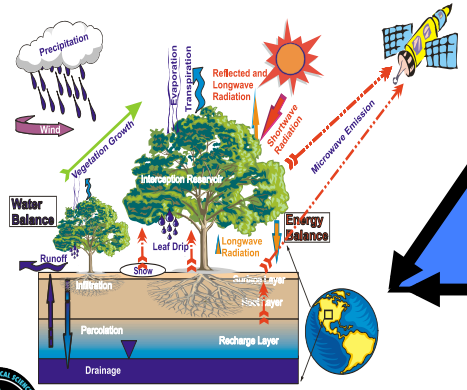
ESS@ 20
June 23, 2009

Land Data Assimilation: Maximizing Mission Science and Applications Return

1. Observations

2. Modeling and Data Assimilation



3. Applications & Decisions

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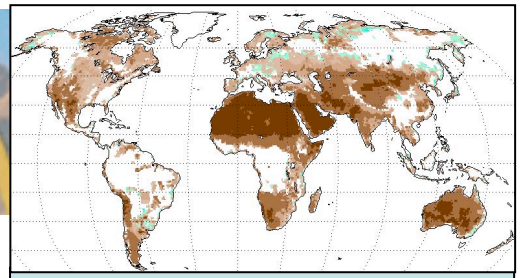
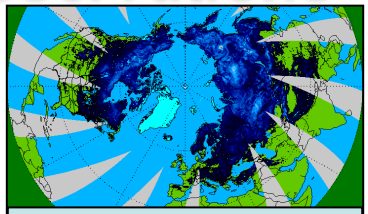
June 23, 2009

Land Surface Observations

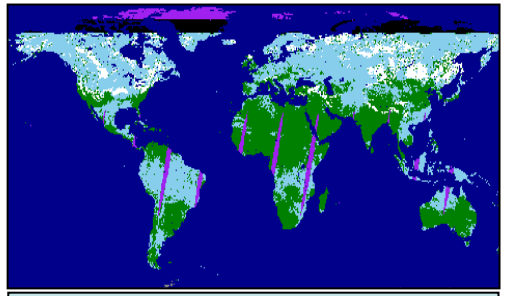
Vegetation/Carbon
(Landsat, AVHRR, MODIS, *DESDynI, ICESat-II, HyspIRI, LIST, ASCENDS*)



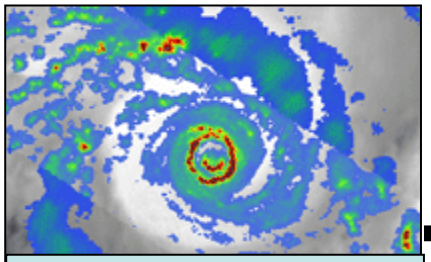
Surface soil moisture
(SMMR, TRMM, AMSR-E, *SMOS, Aquarius, SMAP*)



Snow water equivalent
(AMSR-E, SSM/I, *SCLP, GCOM-W, MIS*)

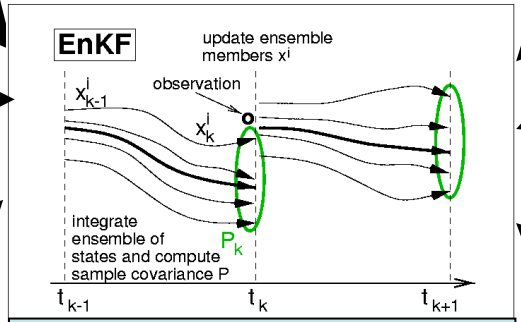


Snow cover fraction
(MODIS, *VIIRS, MIS*)

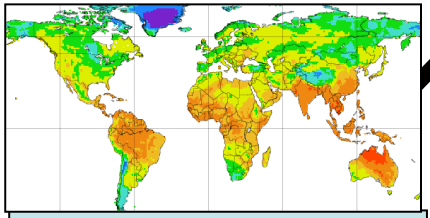


Precipitation
(TRMM, *GPM*)

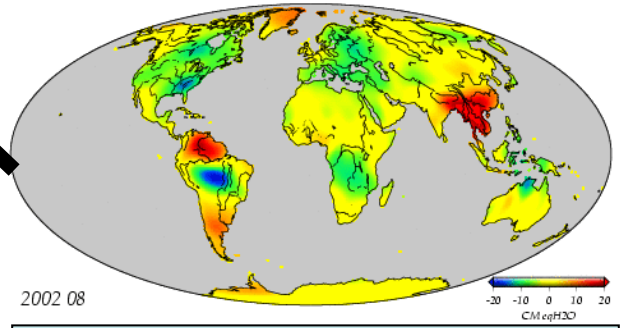
Water surface elevation
(Jason-2, *SWOT*)



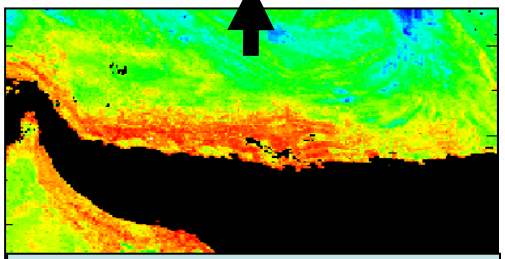
Ensemble-based land data assimilation system



Radiation
(CERES, *CLARREO*)



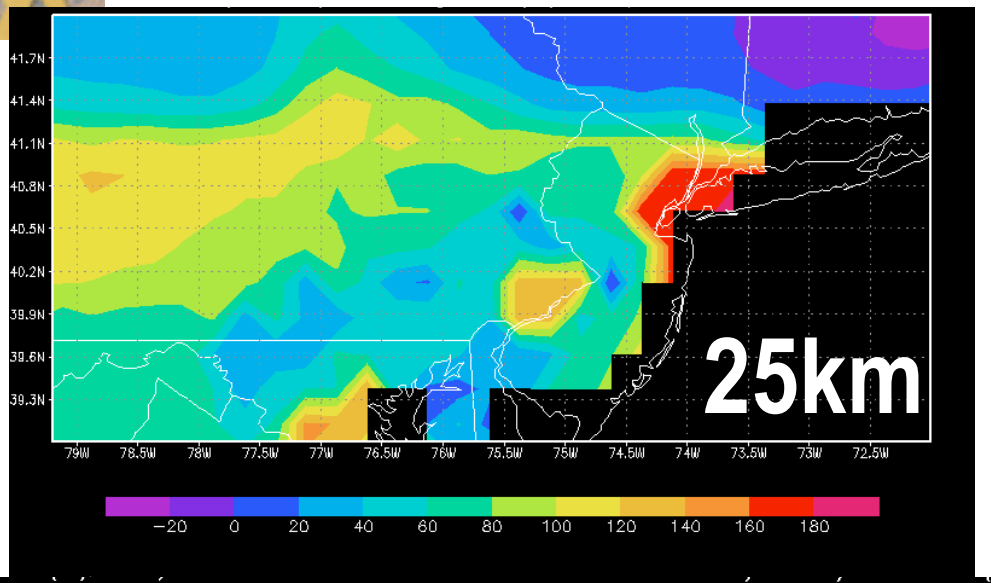
Terrestrial water storage
(GRACE,*GRACEII*)

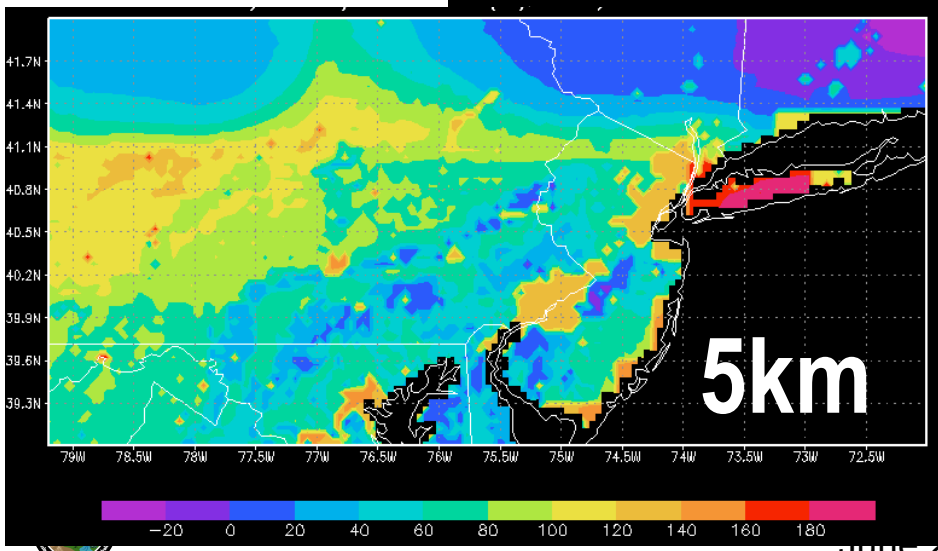


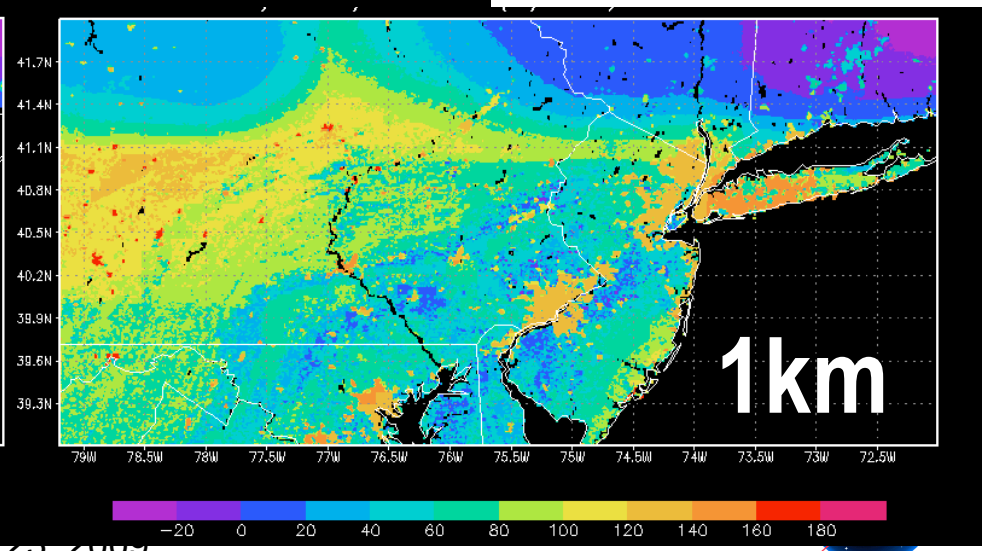
Land surface temperature
(MODIS, AVHRR,GOES,…)

First generation LDA:

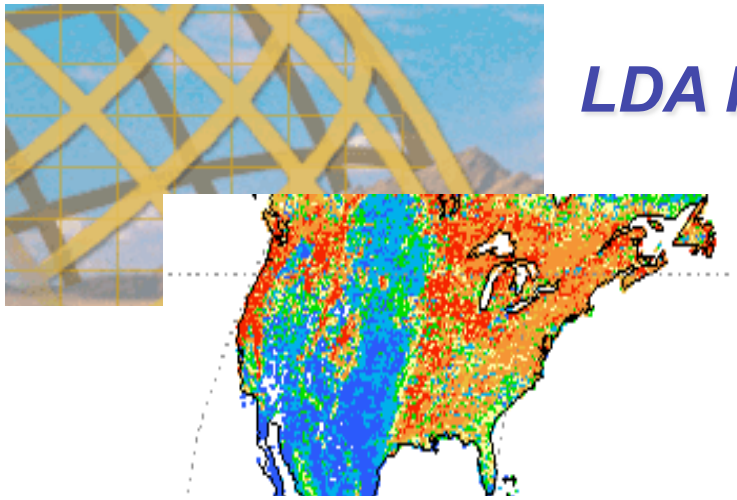
Moderate resolution (e.g., MODIS)

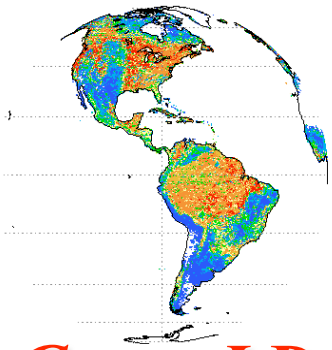






LDA Frameworks: NLDAS, GLDAS, LIS





North American LDAS

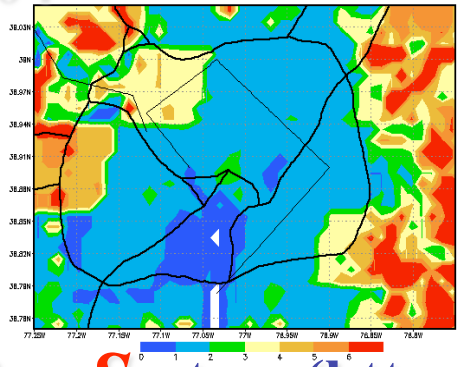
1/8 Degree Resolution

Mitchell et al., JGR, 2004

Global LDAS

1/4 Degree Resolution

Rodell et al., BAMS, 2004

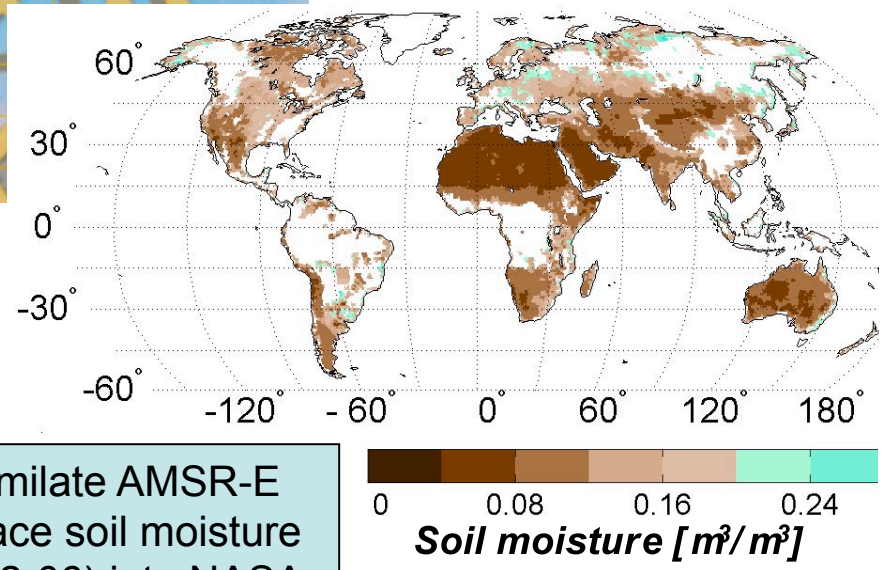


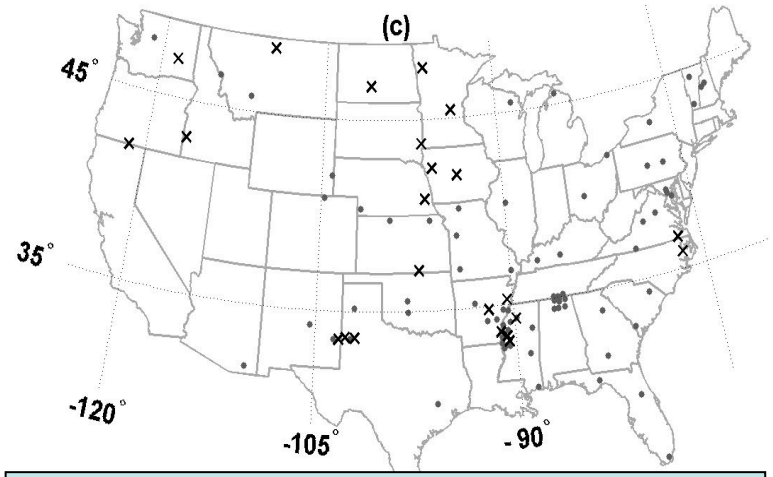
Land Information System (http://lis.gsfc.nasa.gov)

Multi-Resolution Ensemble LDAS Software Framework

Kumar et al., EMS, 2006

LDA Science: AMSR-E Soil moisture





Assimilate AMSR-E surface soil moisture (2002-06) into NASA Catchment model

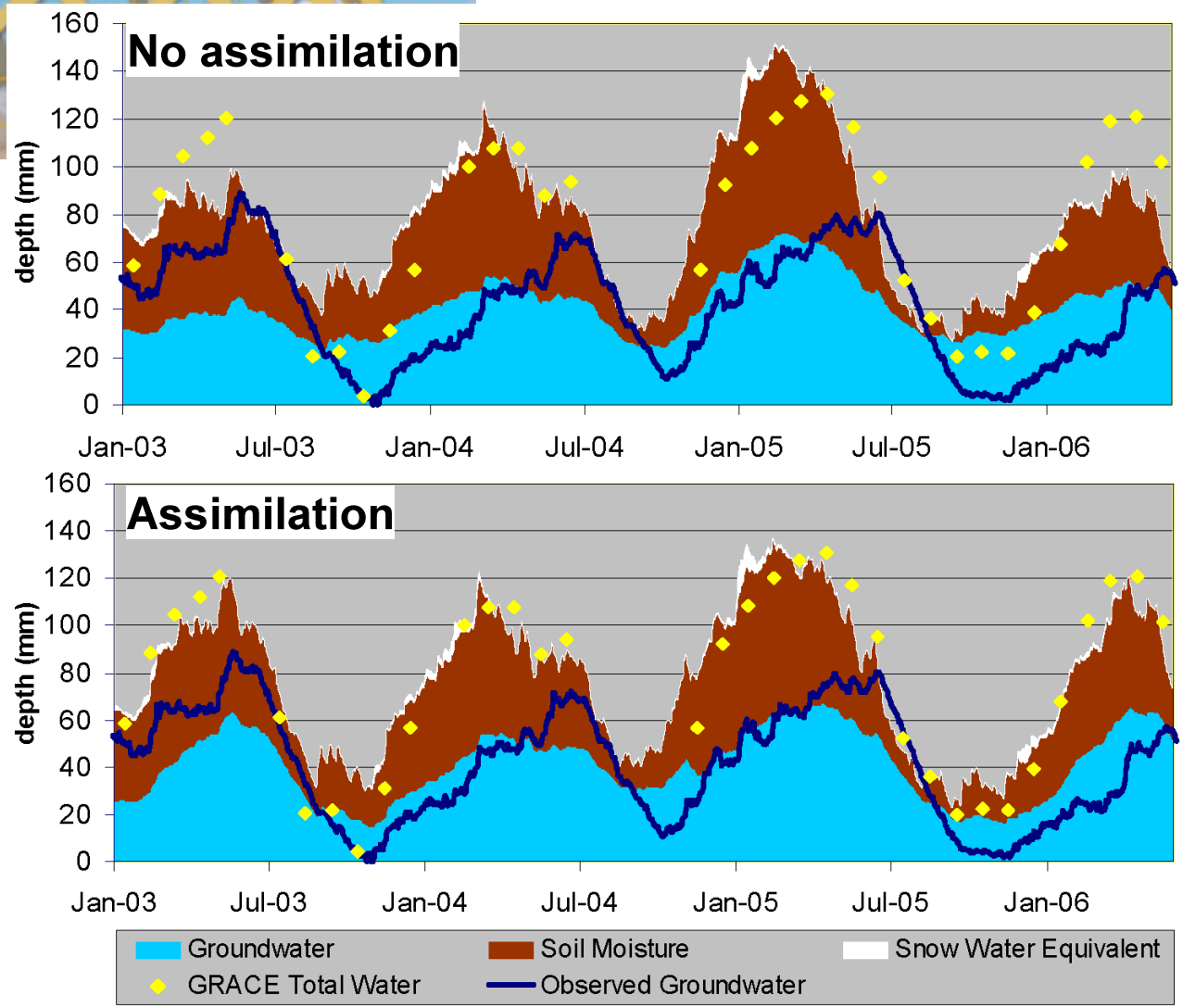
Validate with USDA SCAN stations (only 23 of 103 suitable for validation)

		Skill (anomaly time series correlation coeff. with in situ data with 95% confidence interval)		
	N	**Satellite**	**Model**	**Assim.**
Surface soil moisture	23	**.38±.02**	**.43±.02**	**.50±.02**
Root zone soil moisture	22	**n/a**	**.40±.02**	**.46±.02**

- **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.
- Use data assimilation for generation of SMAP "Level 4" product.

Reichle et al. (2007) *J Geophys Res*, doi:10.1029/2006JD008033.

LDA Science: GRACE terrestrial water storage



Validation against observed groundwater:

RMSE = 23.5 mm

R^2 = 0.35

RMSE = 18.5 mm

R^2 = 0.49

Assimilation disaggregates GRACE data into snow, soil moisture, and groundwater.

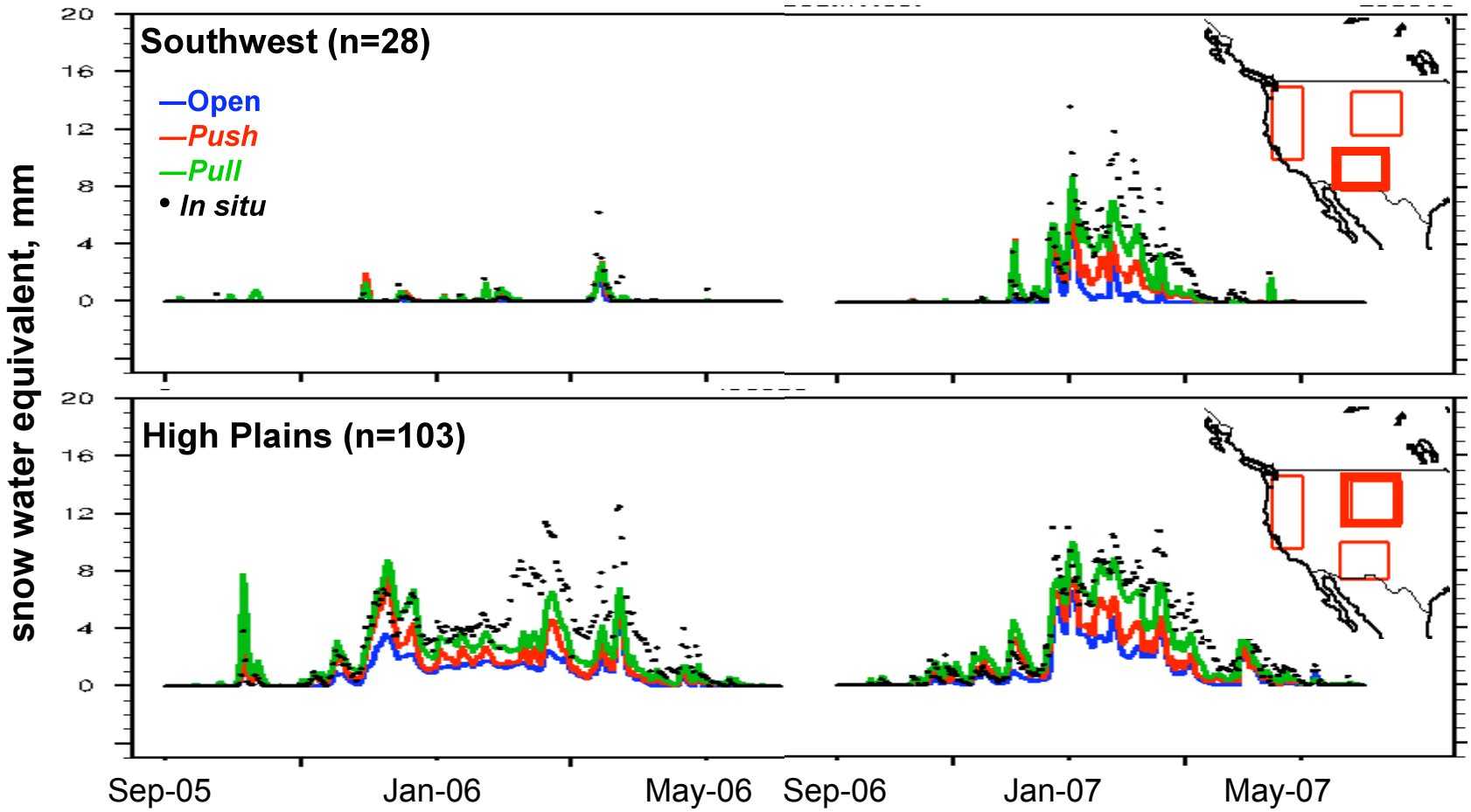
Assimilation estimates of groundwater better than model estimates.

Zaitchik, Rodell, and Reichle (2008) *J. Hydrometeorol.*, doi:10.1175/2007JHM951.1

LDA Science: MODIS snow covered area

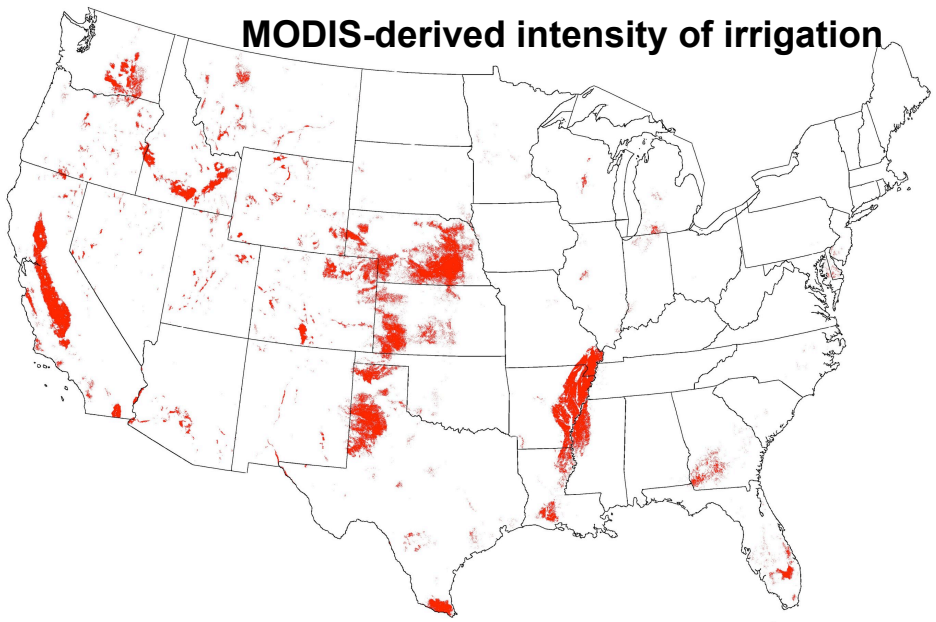
Forward-looking "pull" algorithm (smoother):

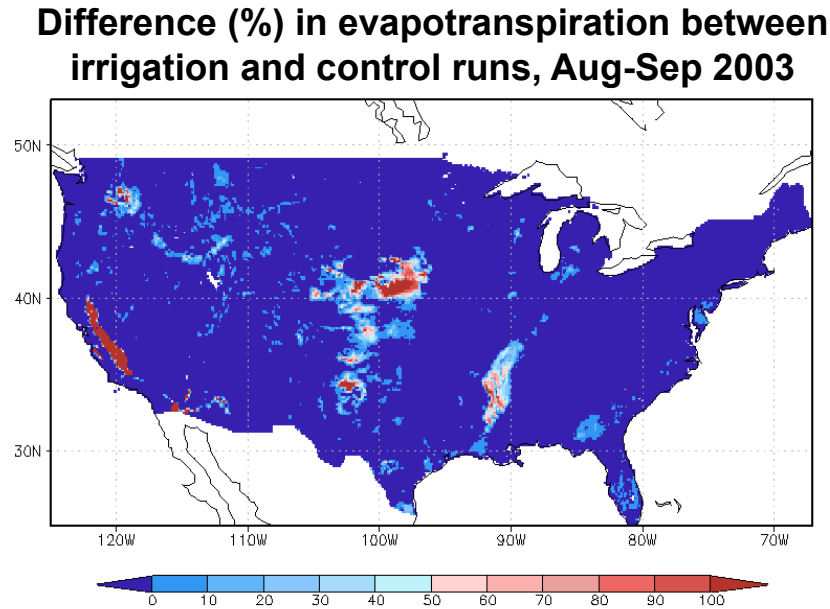
- Assess MODIS snow cover 24-72 hours ahead
- Adjust air temperature (rain v. snowfall, snow melting v. frozen)

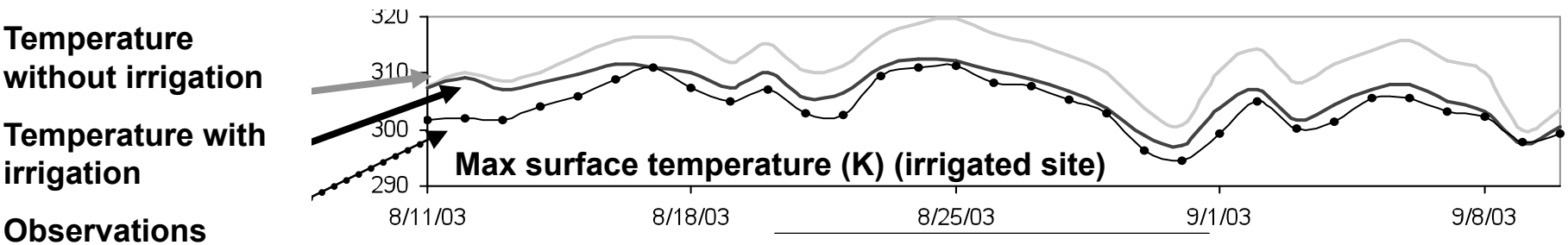


Zaitchik and Rodell, J. Hydromet., doi:10.1175/2008JHM1042.1, in press.

LDA Science: MODIS-based irrigation intensity





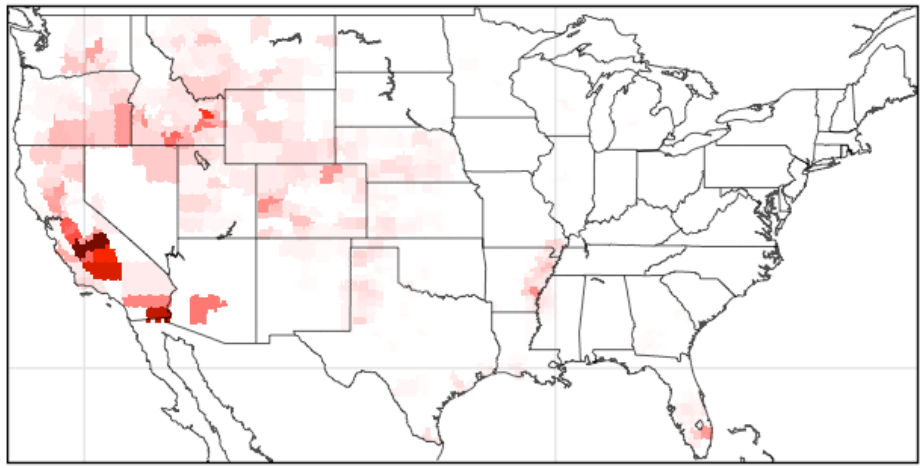


Ozdogan and Gutman (2008) *Remote Sens Environ*
Ozdogan, Rodell, and Kato (2009) *J Hydrometeorol,*

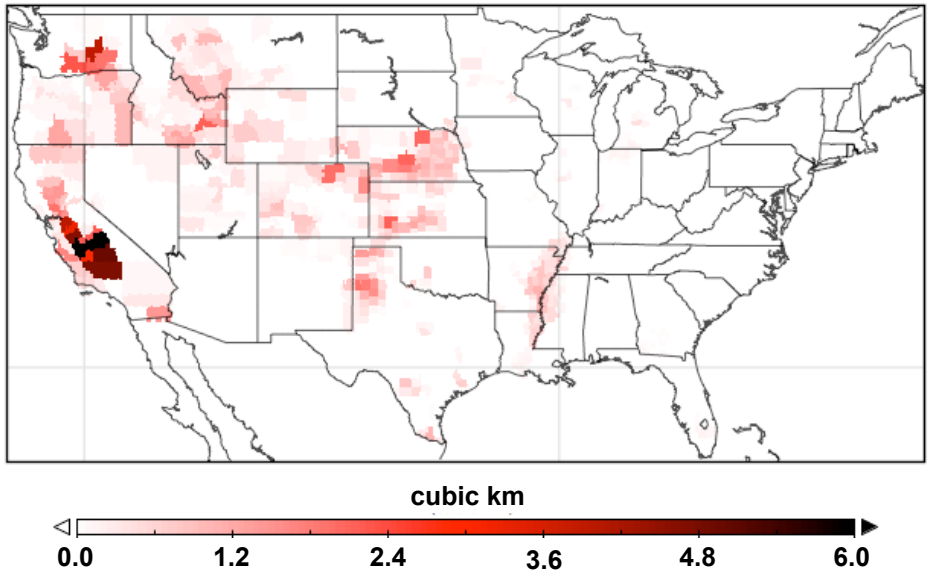
LDA Science: MODIS-based irrigation intensity

2003 county irrigation totals

Reported by USGS

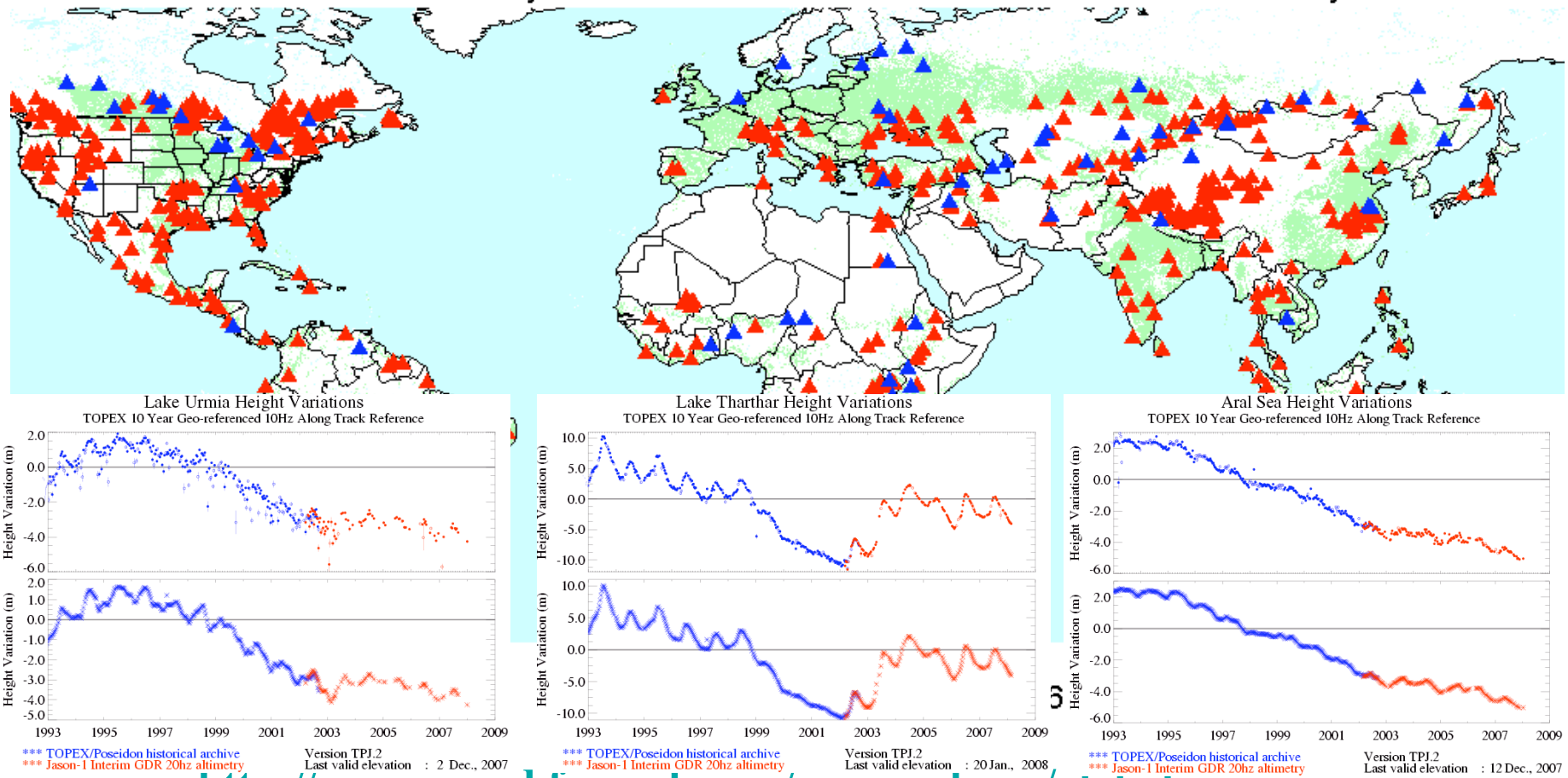


Modeled in this study



LDA Opportunity 1: Surface Water Level Assimilation (Jason & SWOT)

Current Lakes Monitored by Jason-1 and Potential Lakes Monitored by ENVISAT



http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir

LDA Opportunity 2: Multi-agency level-4 soil moisture products from SMAP+GPM (the "W-Train") using LIS

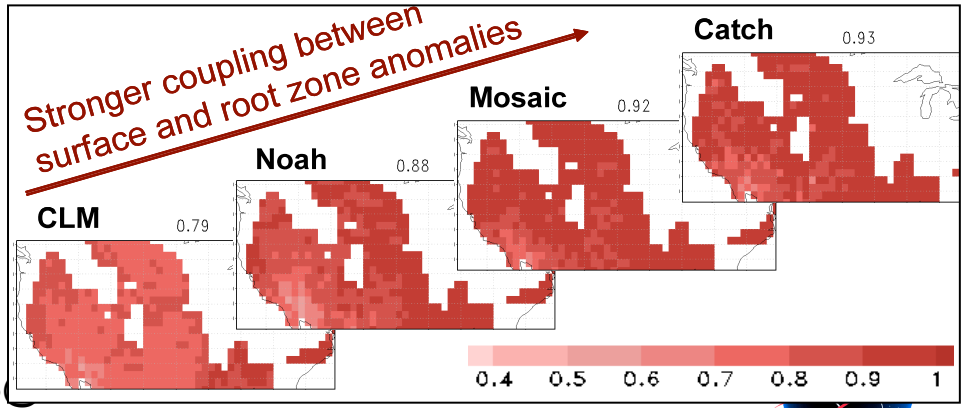
Normalized ROOT ZONE soil moisture improvement from assimilation of surface soil moisture

		Synthetic observations from				Avg
		Catch	Mos	Noa	CLM	
Model	Catch	0.71	0.54	0.36	0.38	**0.50**
	Mos	0.55	0.69	0.31	0.33	**0.47**
	Noa	0.43	0.43	0.36	0.26	**0.37**
	CLM	0.11	0.21	0.10	0.45	**0.22**
Avg		**0.45**	**0.47**	**0.28**	**0.36**	**0.39**

Catchment and Mosaic work better for assimilation than Noah or CLM.

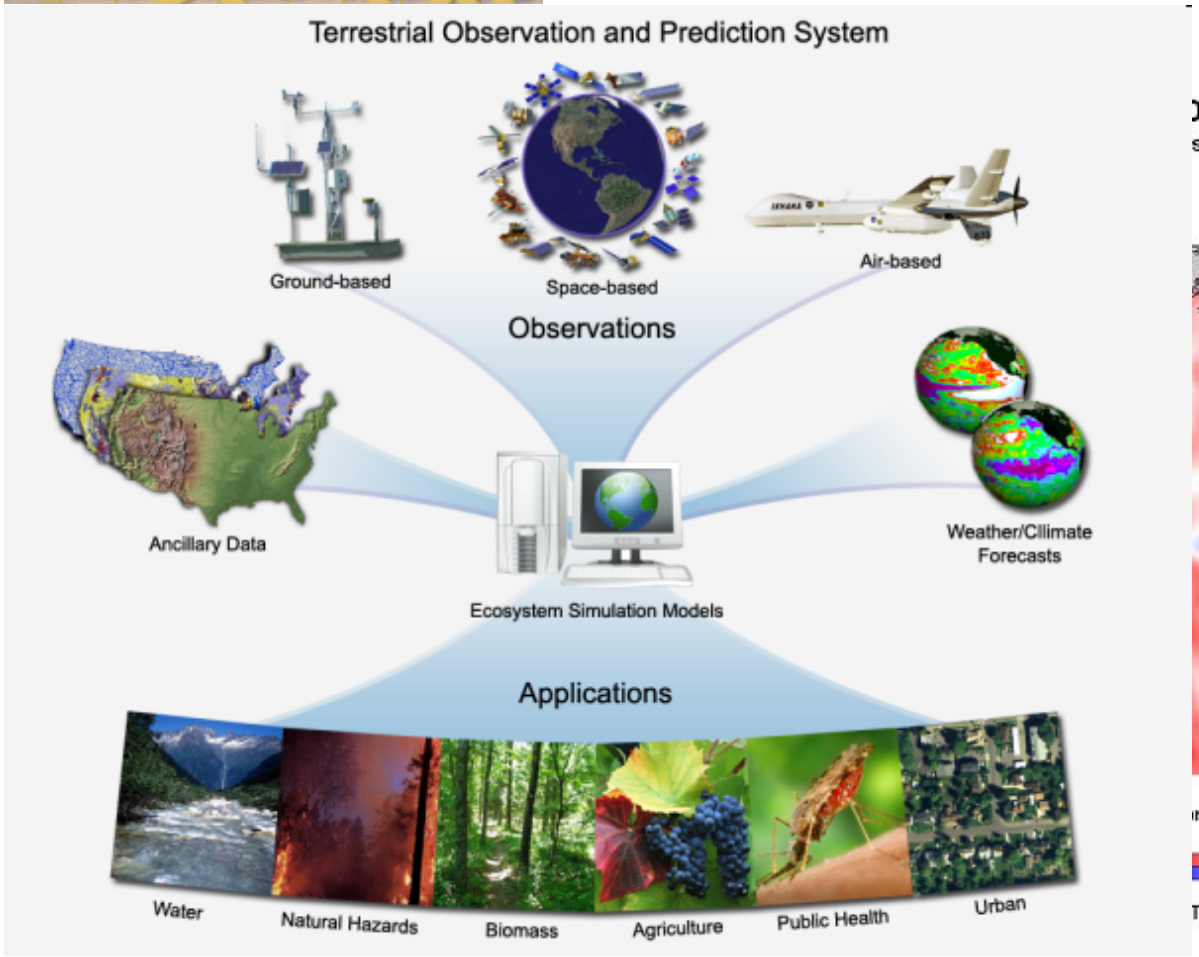
Catchment or MOSAIC "truth" easier to estimate than Noah or CLM "truth".

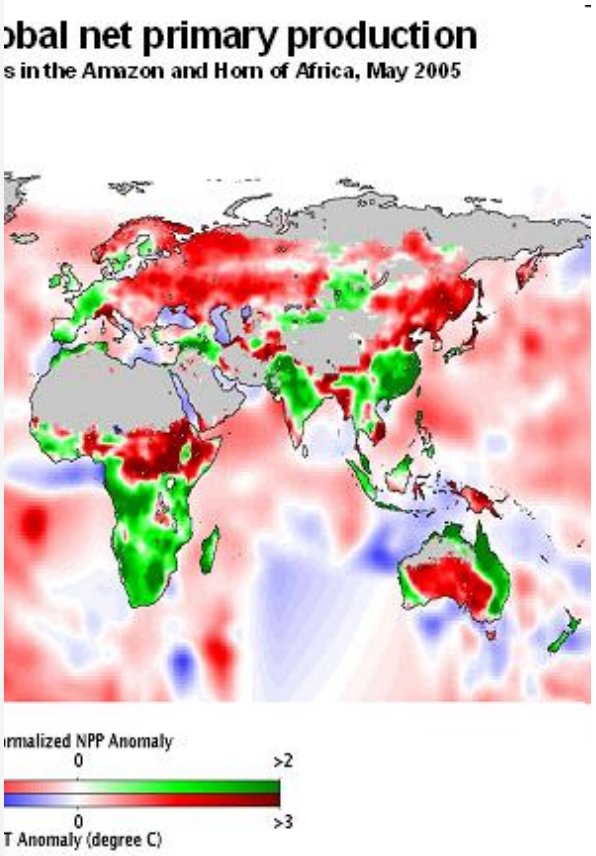
Stronger coupling between surface and root zone provides more "efficient" assimilation of surface observations.



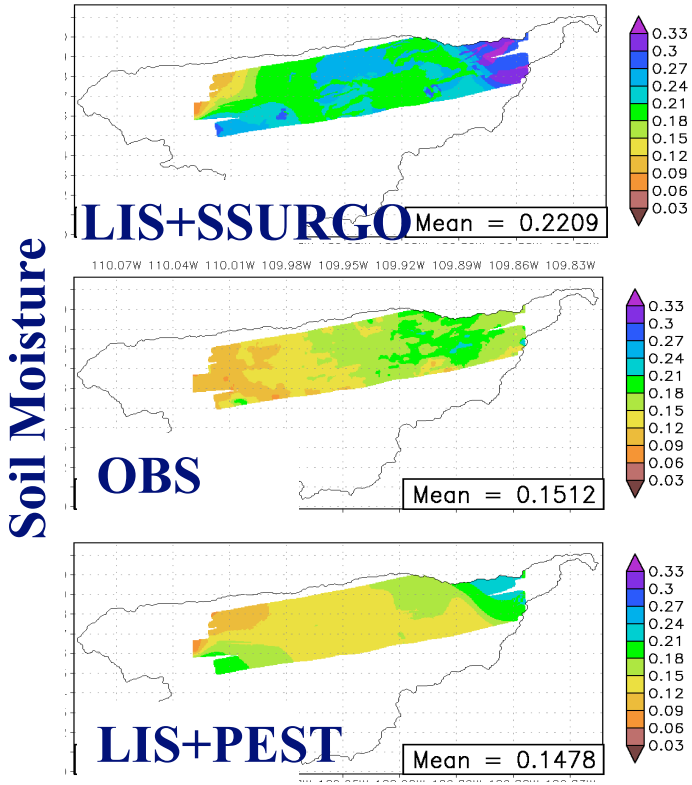
Kumar et al. (2009) *J. Hydromet, in review.*

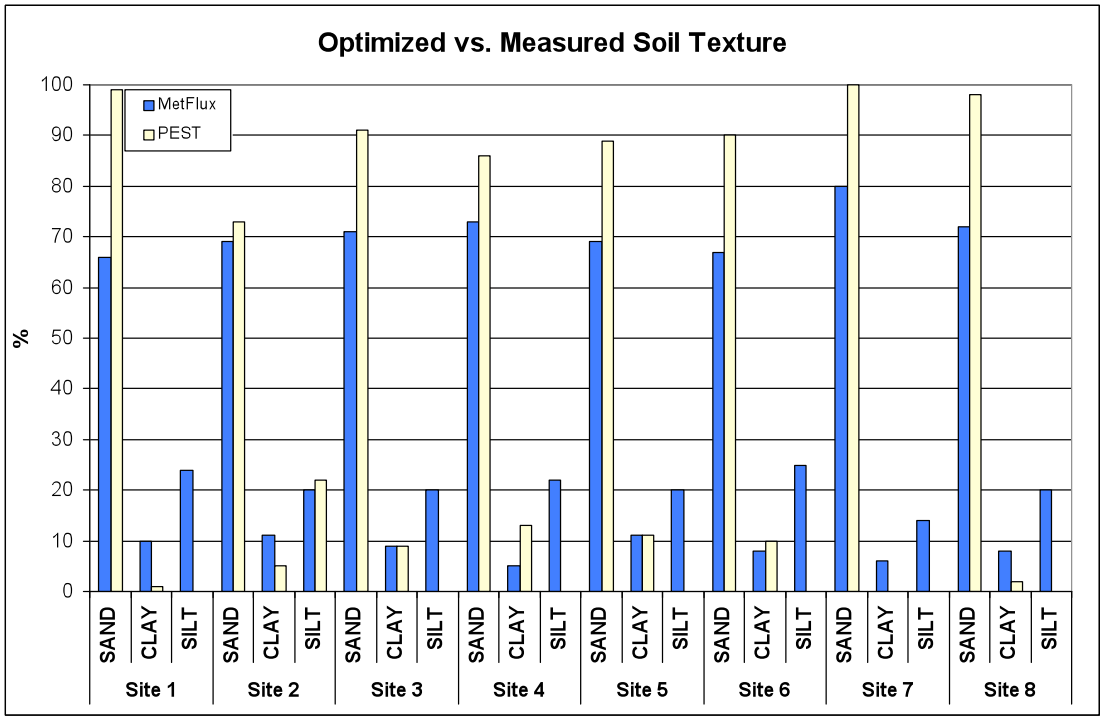
LDA Opportunity 3: Integrated biophysical and ecological analysis (LIS+TOPS)





LDA Opportunity 4: Integrated data assimilation and parameter estimation (example: soil texture estimation)

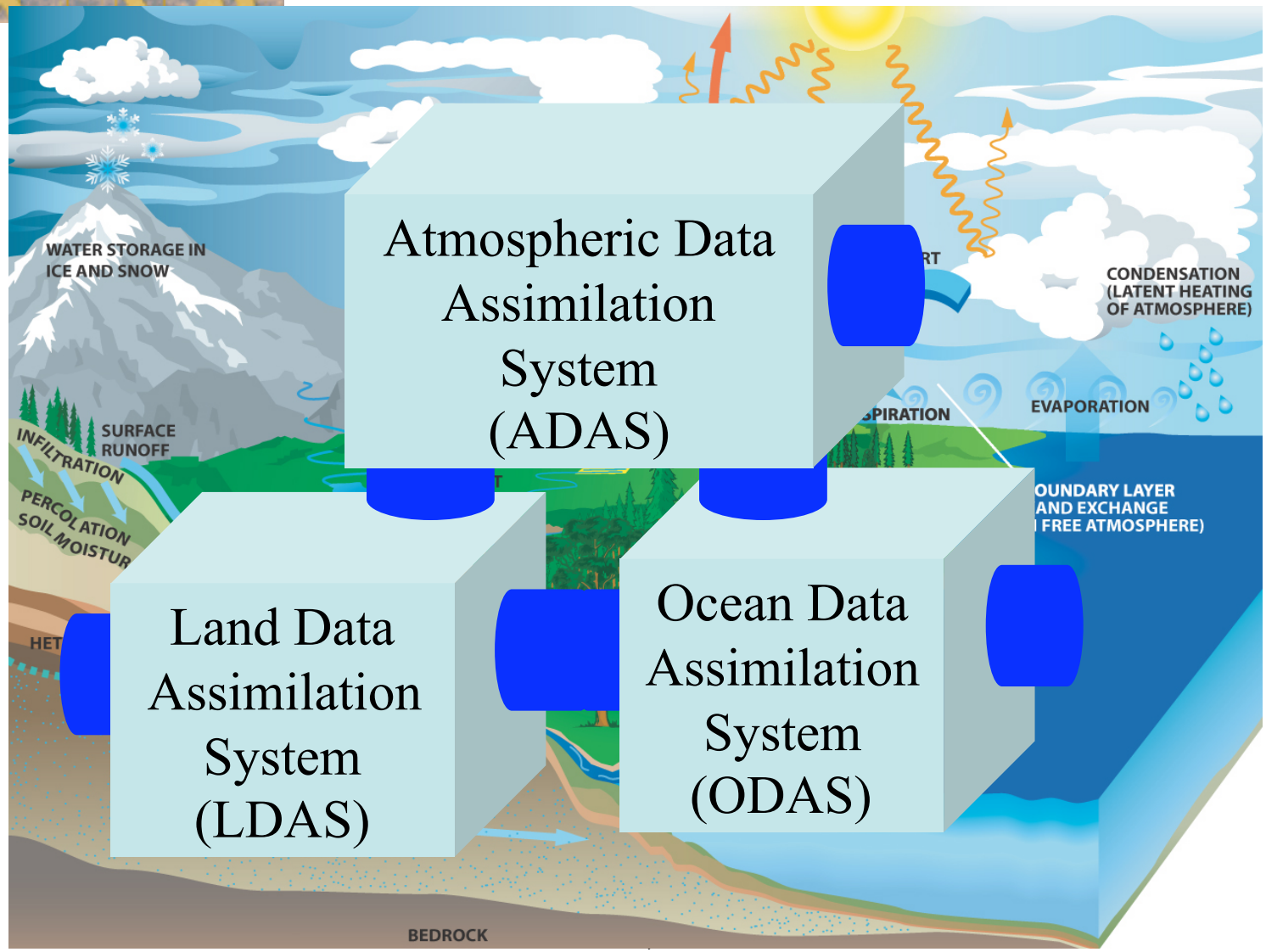




Peters-Lidard C. D., D. M. Mocko, M. Garcia, J. A. Santanello Jr., M. A. Tischler, M. S. Moran, Y. Wu (2008), Role of precipitation uncertainty in the estimation of hydrologic soil properties using remotely sensed soil moisture in a semiarid environment, Water Resour. Res., 44, W05S18, doi:10.1029/2007WR005884.

Santanello, J.A., Jr., C. D. Peters-Lidard, M. Garcia, D. Mocko, M. Tischler, MS. Moran, and D.P. Thoma, 2007: Using Remotely-Sensed Estimates of Soil Moisture to Infer Soil Texture and Hydraulic Properties across a Semi-arid Watershed, Remote Sensing of Environment, 110(1), 79-97, DOI=http://dx.doi.org/10.1016/j.rse.2007.02.007.

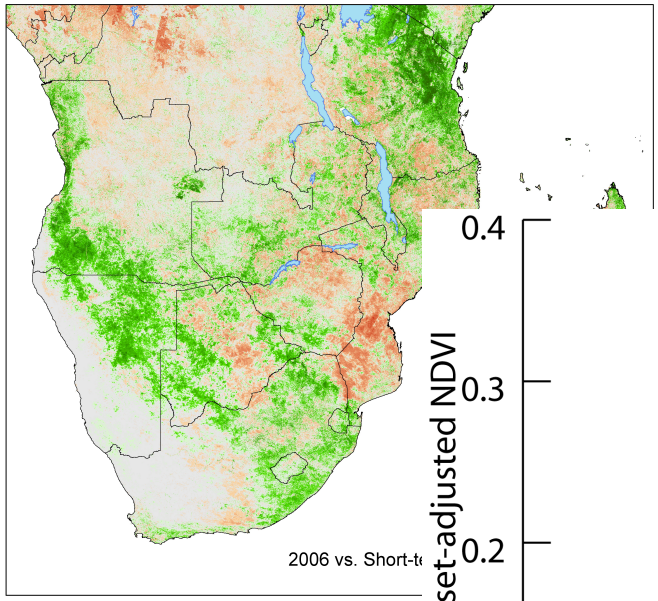
LDA Challenge 1: Integrated Earth System Analysis

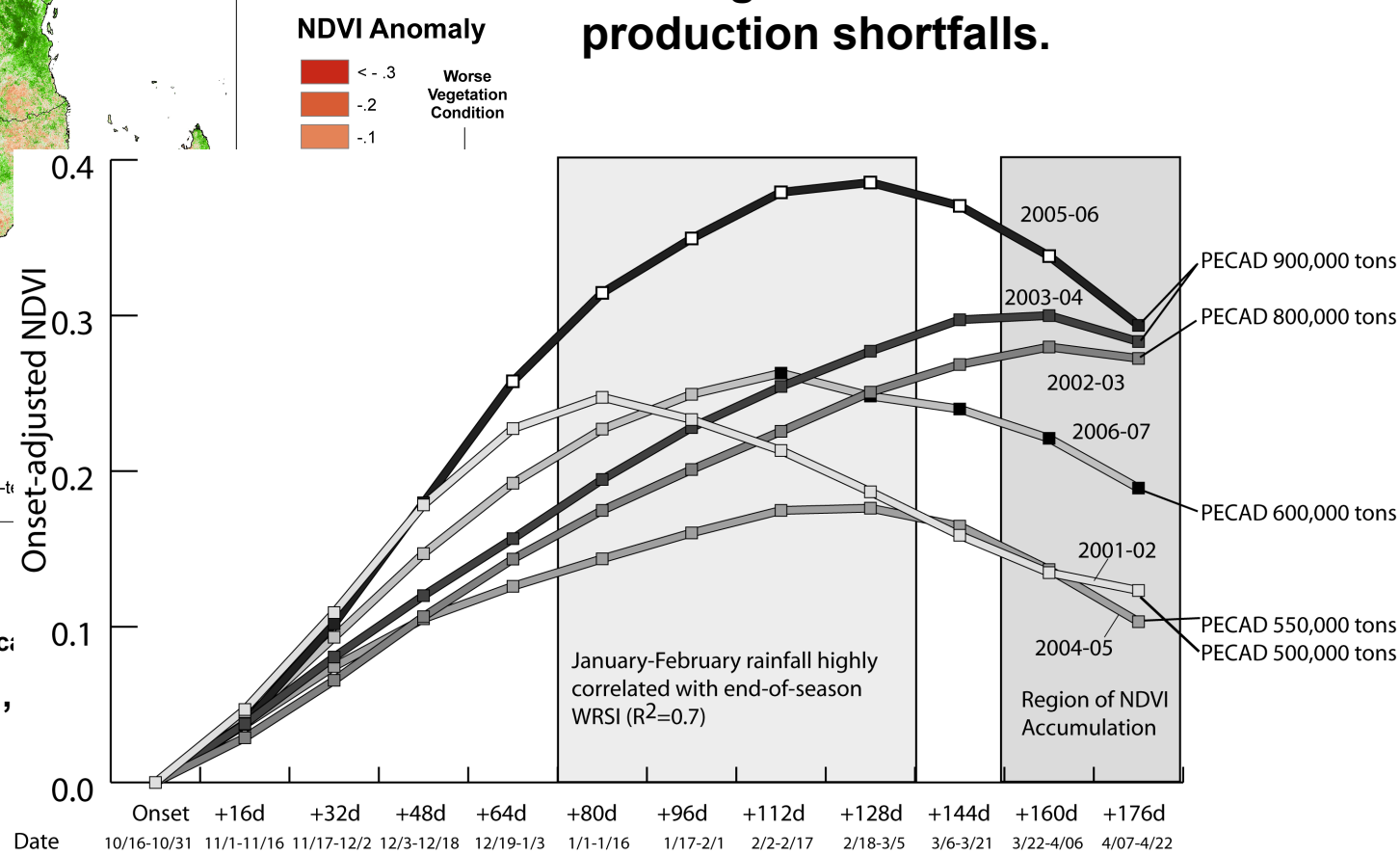


LDA Challenge 2: Custom Analyses for Partner Applications

FEWS NET
FAMINE EARLY WARNING SYSTEMS NETWORK

Projecting MODIS NDVI data 4 months ahead will give advance warning to food and fodder production shortfalls.





Southern Afric

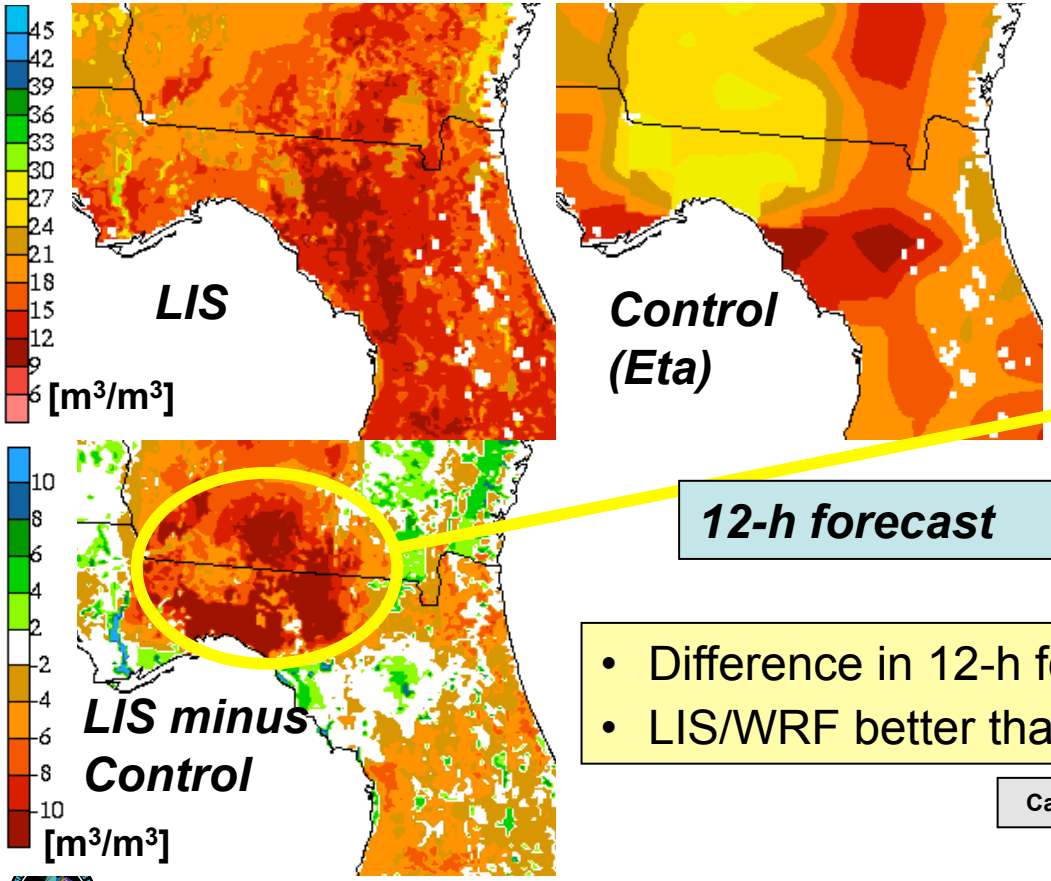
Funk and Brown,

Summary

- LDA Technology
  - LIS as a framework for LDA--“LDAS in a box”
- LDA Science
  - AMSR-E soil moisture
  - GRACE terrestrial water storage (groundwater)
  - MODIS snow covered area
  - MODIS irrigation intensity
- LDA Opportunities
  - Surface water level assimilation (Jason & SWOT)
  - Multi-agency level-4 soil moisture products from SMAP+GPM (+SWOT+GRACEII+SCLP=“W-Train”)
  - Integrated biophysical and ecological analysis (LIS+TOPS)
  - Integrated data assimilation and parameter estimation
- LDA Challenges
  - Integrated Earth system analysis
  - Custom analyses for partner applications

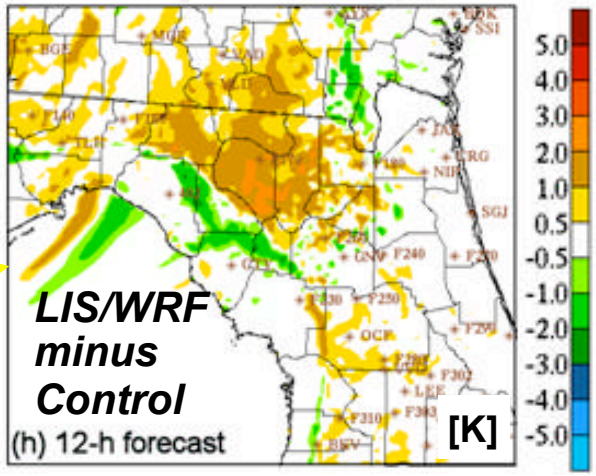
Regional LDA for Weather Forecasting

0-10cm soil moisture initial condition (6 May 2004 12z)



12-h forecast

12-hour forecast: 2m air temp. difference (valid 7 May 2004 0z)



- Difference in 12-h forecast of 2m air temp. (sea breeze)
- LIS/WRF better than control (independent validation)

Case et al. (2008) *J. Hydrometeorol.*, doi: 10.1175/2008JHM990.1, in press.