Multi-Sensor Snow Data Assimilation

Matt Rodell[1], Zhong-Liang Yang[2], Ben Zaitchik[3], Ed Kim[1], and Rolf Reichle[1]

[1]NASA Goddard Space Flight Center
[2]The University of Texas at Austin
[3]Johns Hopkins University

Project Summary

Title: Multi-Sensor Snow Data Assimilation

Problem Statement: MODIS, AMSR-E, and GRACE all provide observations that are relevant to snow water equivalent mapping, each with significant advantages and disadvantages.

Hypothesis: Global fields of SWE can be produced with greater accuracy than previously seen by simultaneously assimilating MODIS snow cover, AMSR-E SWE, and GRACE terrestrial water storage observations within a sophisticated land surface model.

Team:

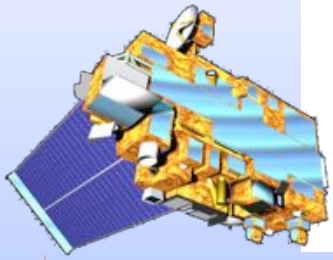
- NASA/GSFC: Matt Rodell (PI), Ed Kim, Rolf Reichle
- U. Texas: Liang Yang (Co-PI)
- Johns Hopkins: Ben Zaitchik

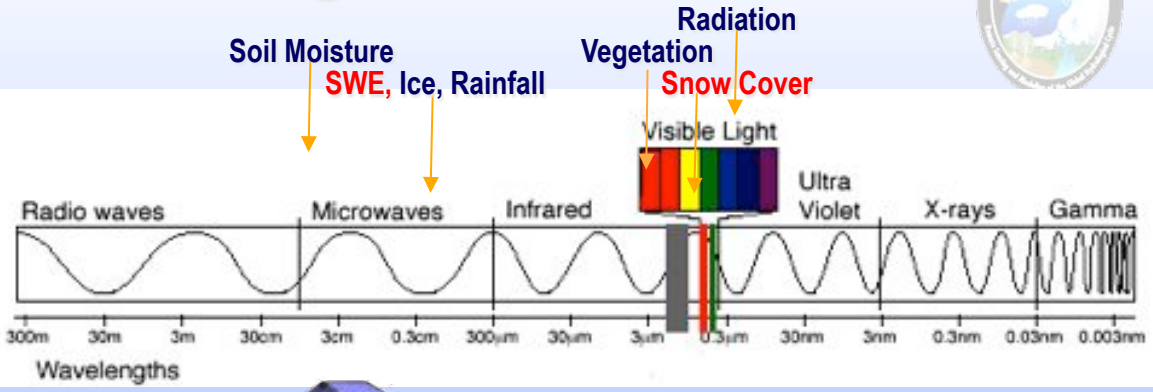
Timeline: Just getting started

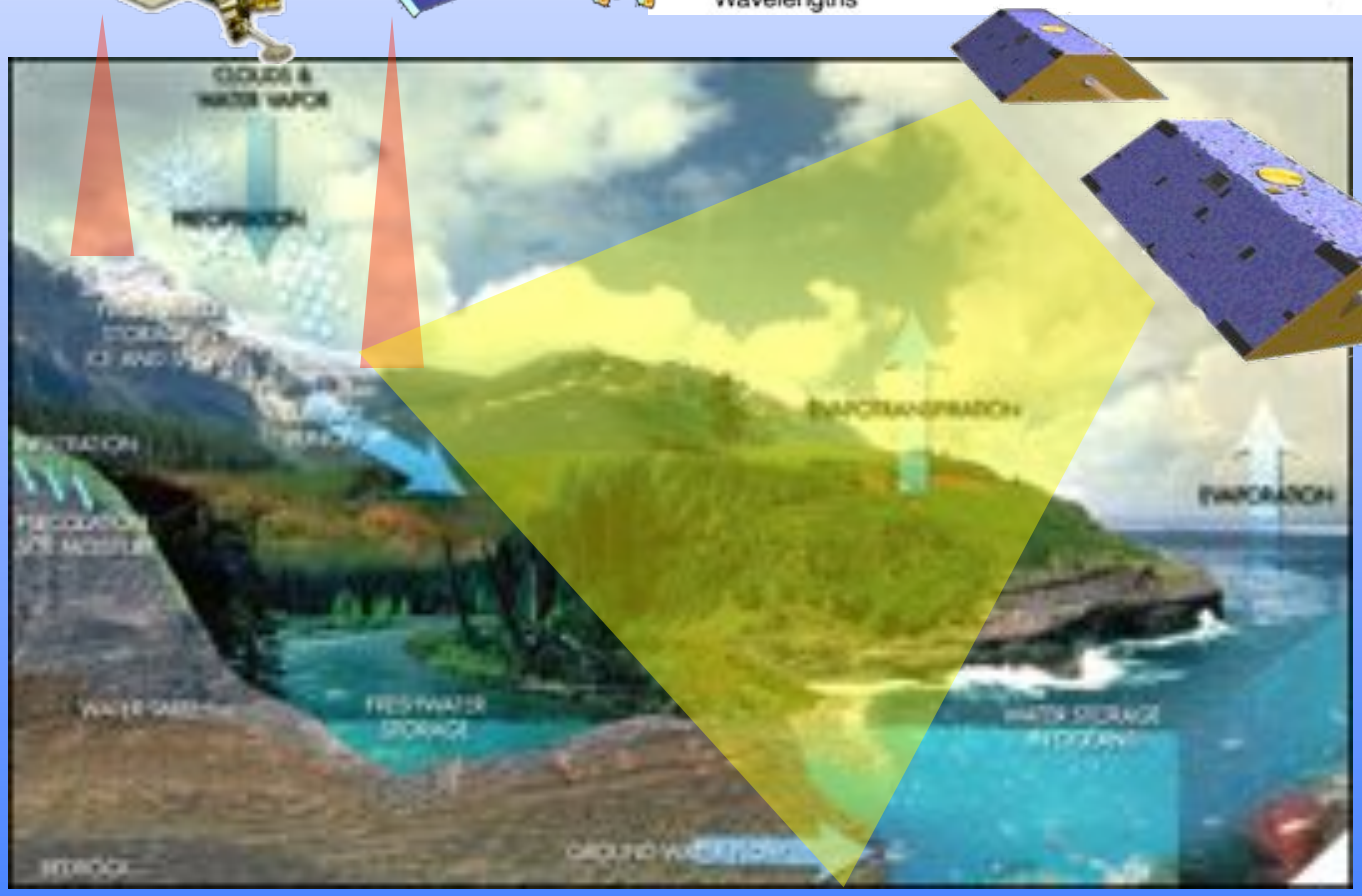
Remote Sensing of Snow

Aqua:
MODIS,
AMSR-E

Terra:
MODIS







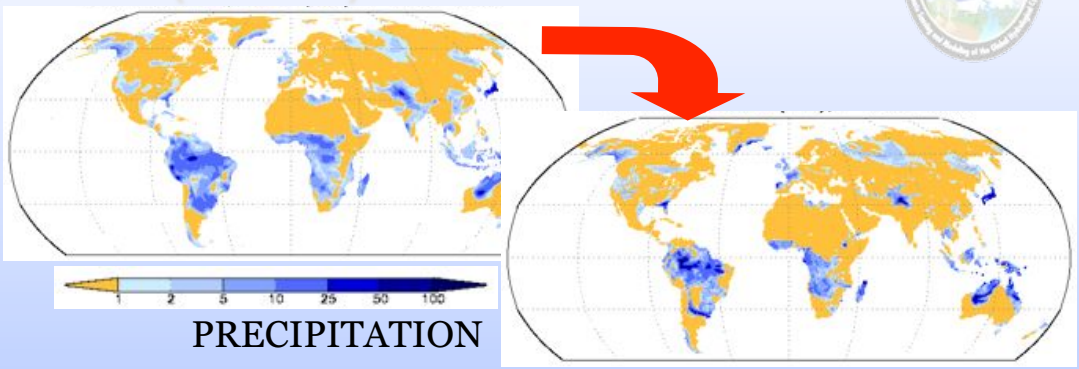
GRACE
GRACE provides changes in total water storage, which are dominated by SWE at high latitudes and deep or wet altitudes, but at very coarse resolution

MODIS provides high resolution snow cover data but not SWE; AMSR-E provides SWE data but with significant errors where snow is

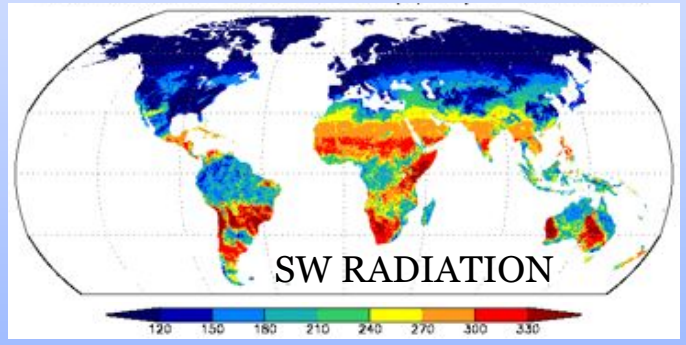
Matt Rodell
NASA GSFC

Data Integration within a Land Data Assimilation System (LDAS)

INTERCOMPARISON and OPTIMAL MERGING of global data fields



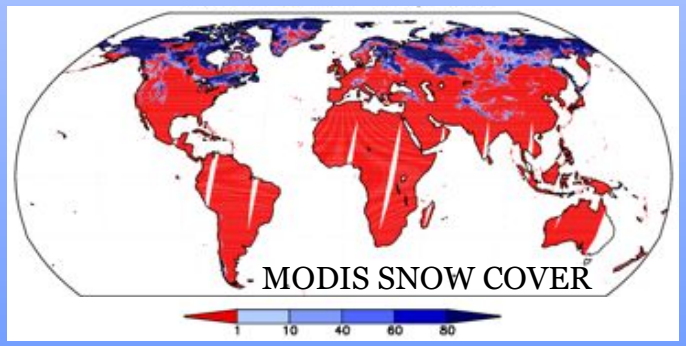
PRECIPITATION



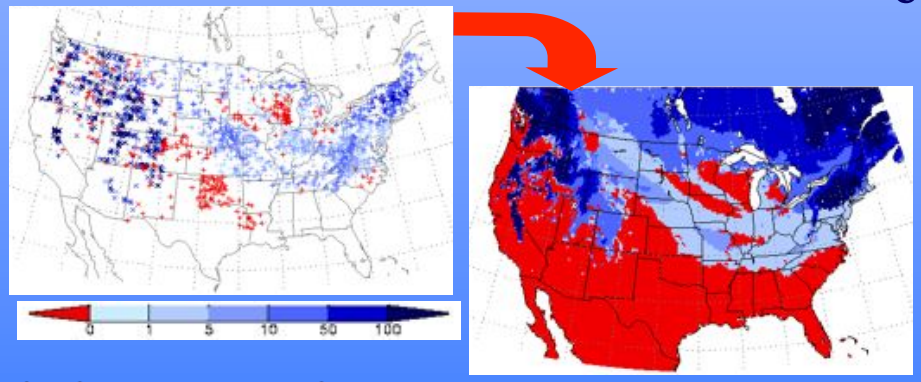
SW RADIATION

Satellite data products used to PARAMETERIZE and FORCE land surface models within LIS

ASSIMILATION of satellite based land surface state fields (snow, soil moisture, etc.)



MODIS SNOW COVER



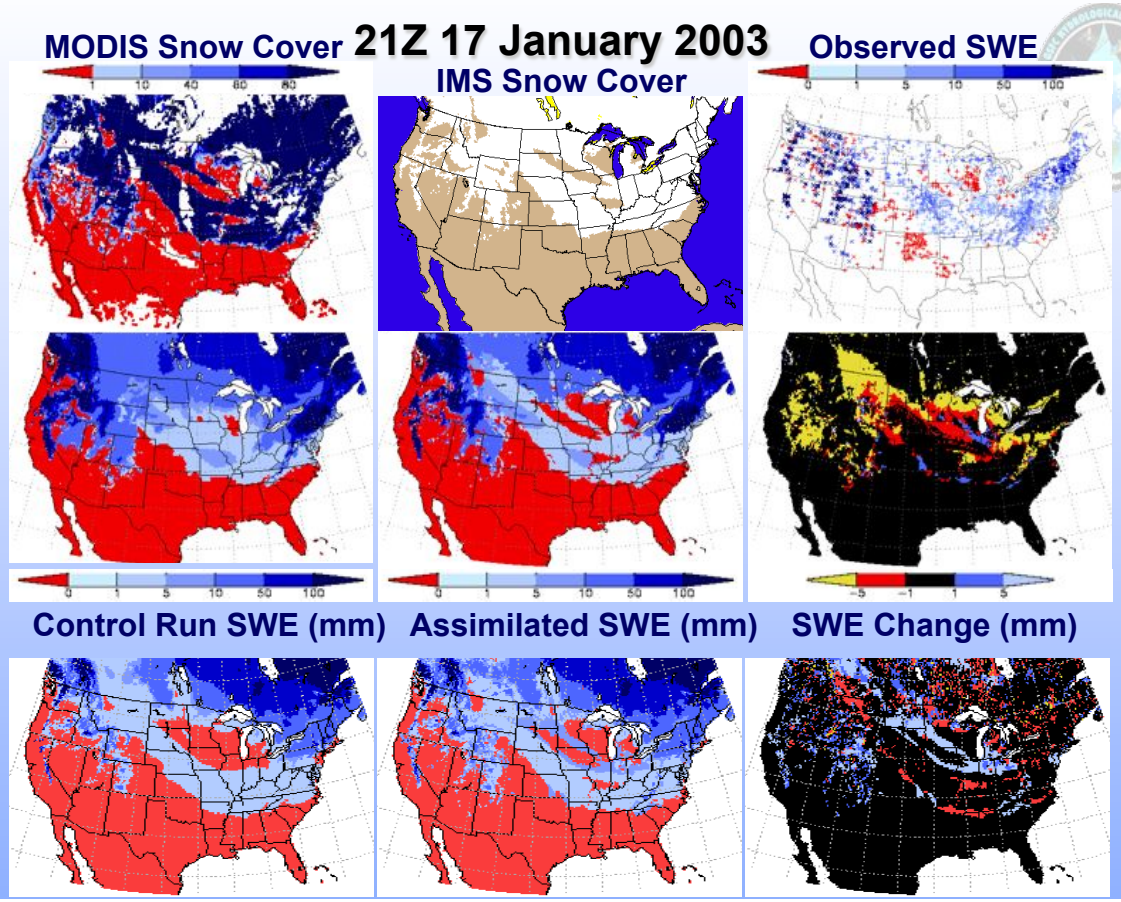
SNOW WATER EQUIVALENT

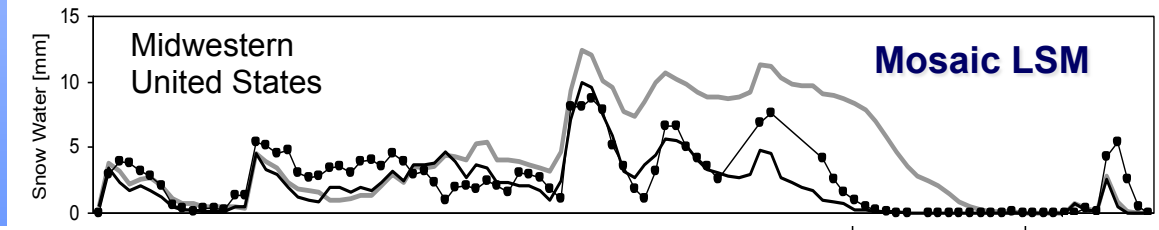
Ground-based observations used to EVALUATE model output

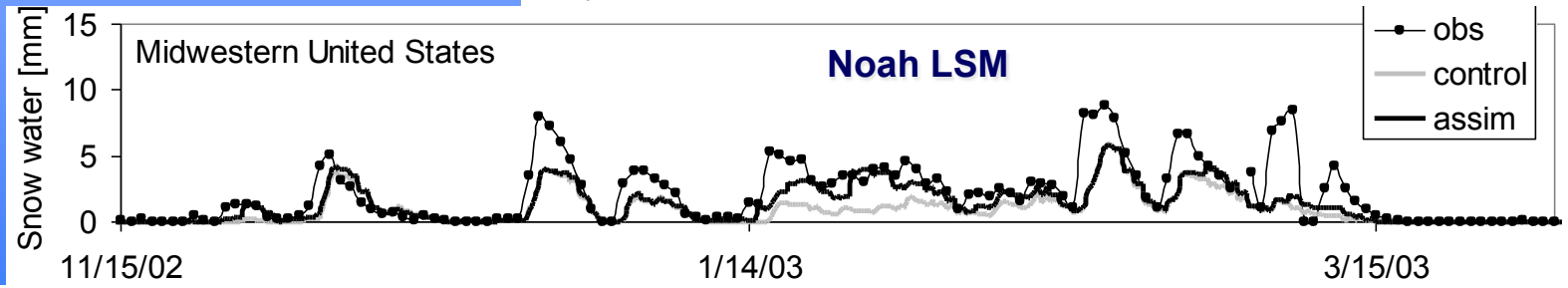
Matt Rodell
NASA GSFC

MODIS Snow Cover Assimilation

- MODIS snow cover fields used to update the Mosaic and Noah LSMs within GLDAS/LIS
- Models fill spatial and temporal gaps in data, provide continuity and quality control
- Assimilated output agrees more closely with IMS snow cover fields (top middle) and ground observations (top right, bottom)
- Assimilated output contains more information (~hourly SWE) than MODIS (~daily snow cover)







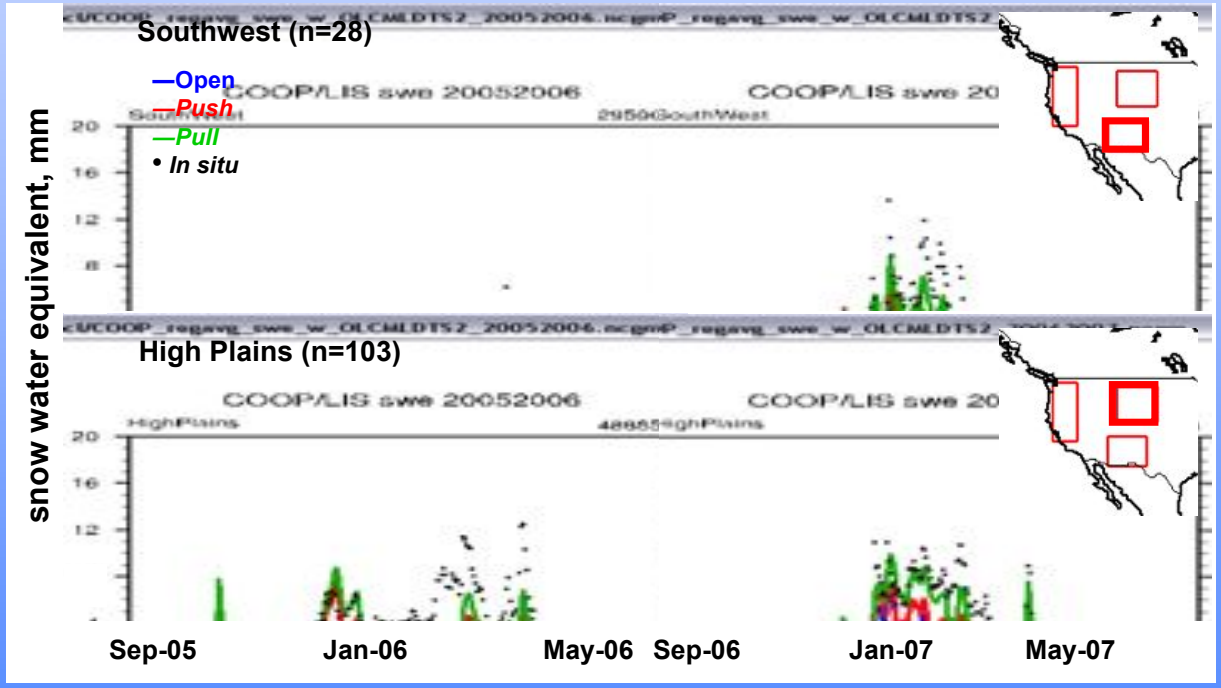
Based on *Rodell and Houser, J. Hydromet., 2004.*

Matt Rodell
NASA GSFC

Advanced Rule-Based MODIS Snow Cover Assimilation

Foreward-looking "pull" algorithm

- Assesses MODIS snow cover observation 24-72 hours ahead
- Adjusts temperature to steer the simulation towards the observation
- Generates additional snowfall if necessary
- Improves accuracy while minimizing water imbalance



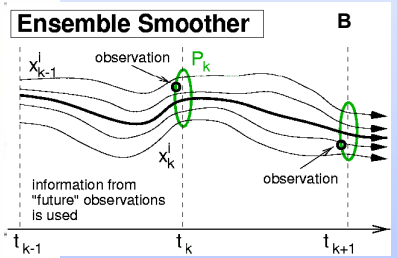
Zaitchik and Rodell, J. Hydromet., 2009

Matt Rodell
NASA GSFC

GRACE Data Assimilation

GRACE water storage, mm
January-December 2003 loop

Model assimilated water storage, mm
January-December 2003 loop



Monthly anomalies (deviations from the 2003 mean) of terrestrial water storage (sum of groundwater, soil moisture, snow, and surface water) as an equivalent layer of water. Updated from *Zaitchik, Rodell, and Reichle, J. Hydromet., 2008.*

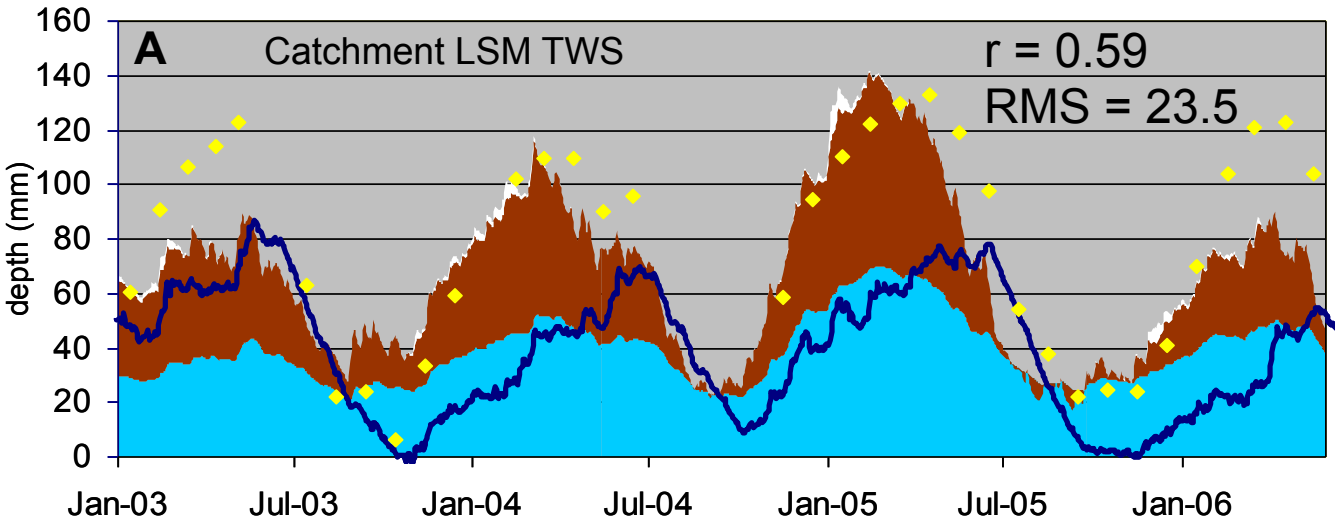
From scales useful for water cycle and climate studies…

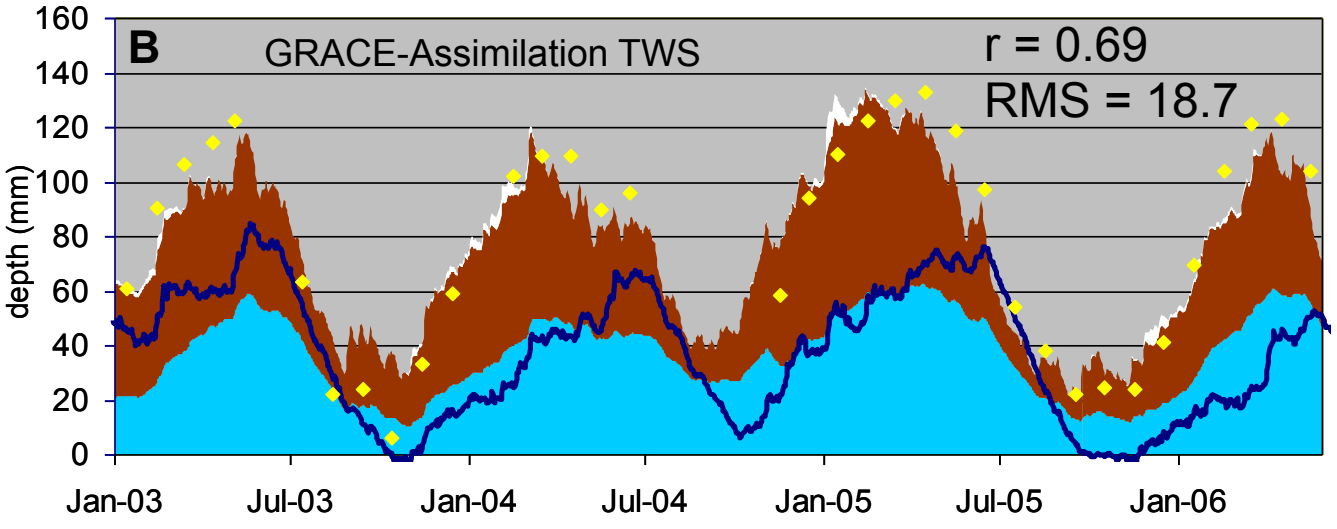
To scales needed for water resources and agricultural applications

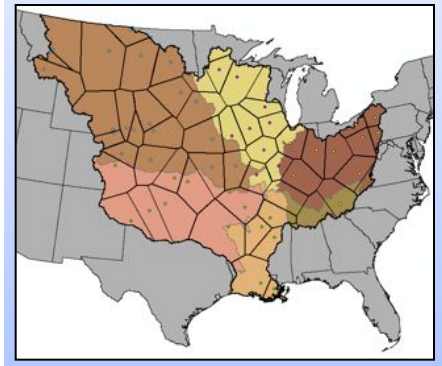
Matt Rodell
NASA GSFC

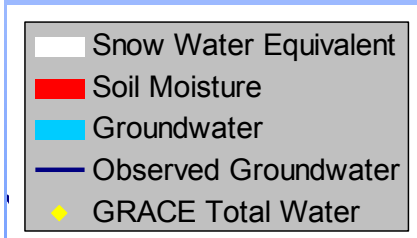
GRACE Data Assimilation

Model separates SWE, soil moisture, and groundwater; GRACE ensures accuracy.





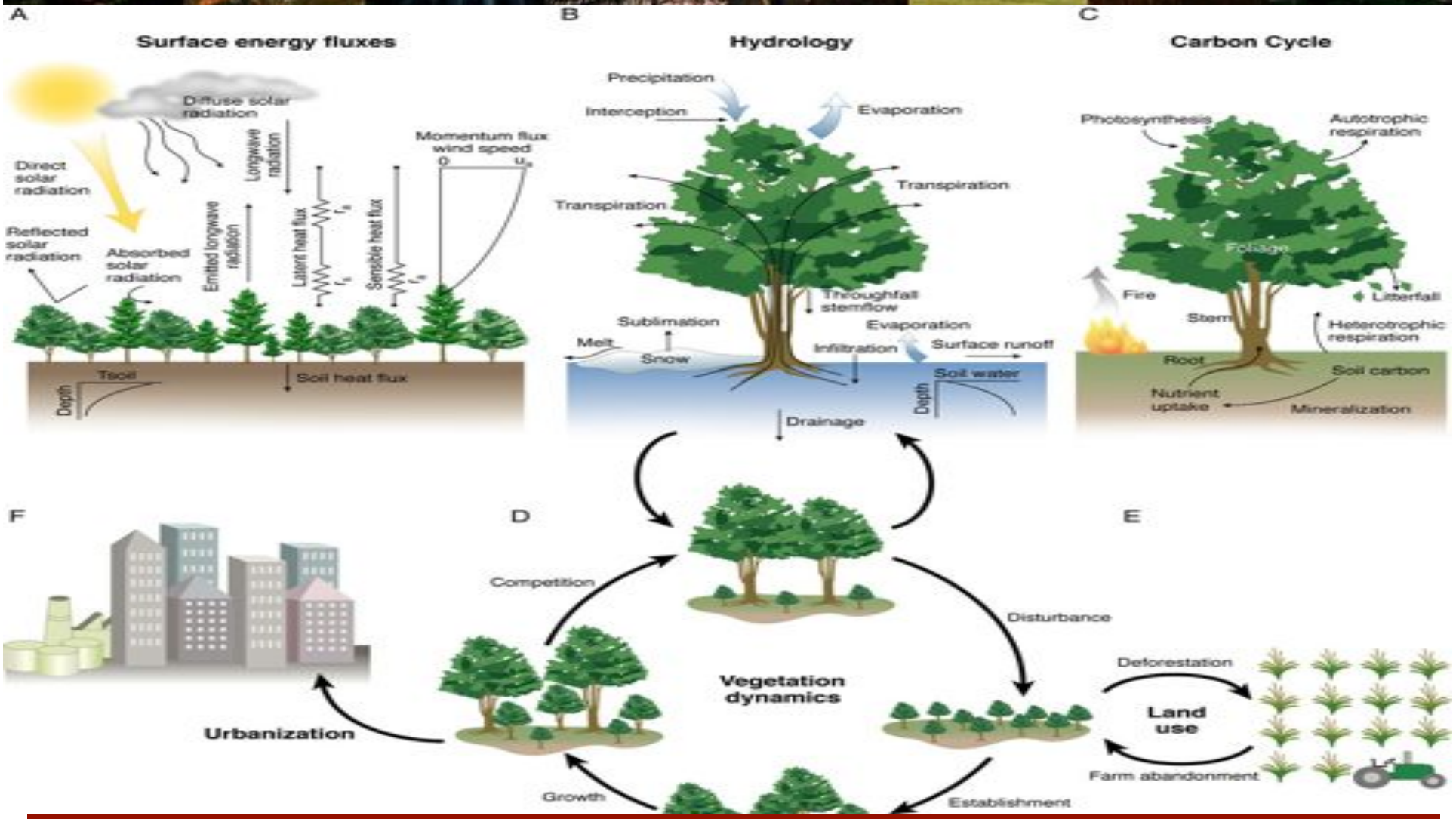




Zaitchik, Rodell, and Reichle, J. Hydrometeorology, 2008.

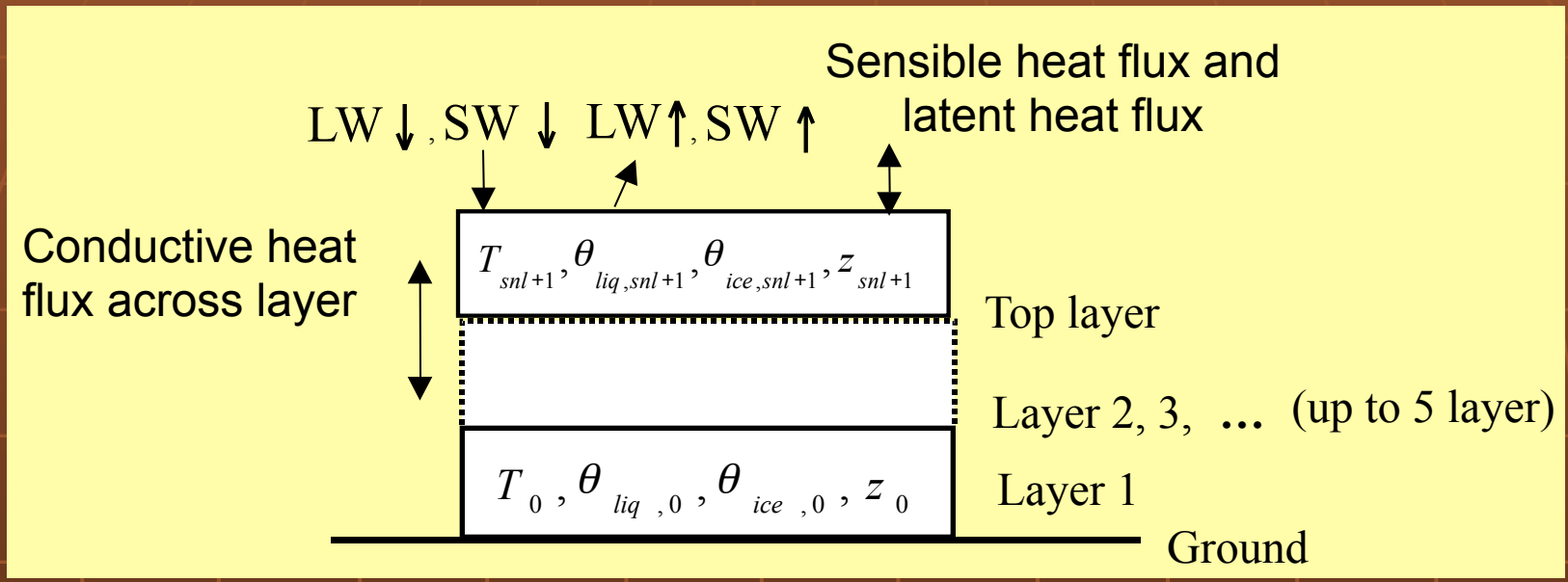
From a global, integrated observation
To application-specific water storage components

NCAR Community Land Model (CLM4)



Co-Chairs: David Lawrence (NCAR), Zong-Liang Yang (Univ of Texas at Austin)

Multi-layer Snow Model in Community Land Model



$$C\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}(\lambda \frac{\partial T}{\partial z}) + \rho_{ice} L_f \frac{\partial \theta_{ice}}{\partial t} + S$$

Snowpack heat diffusion

$$G + LH + SH = LW_g + SW_g$$

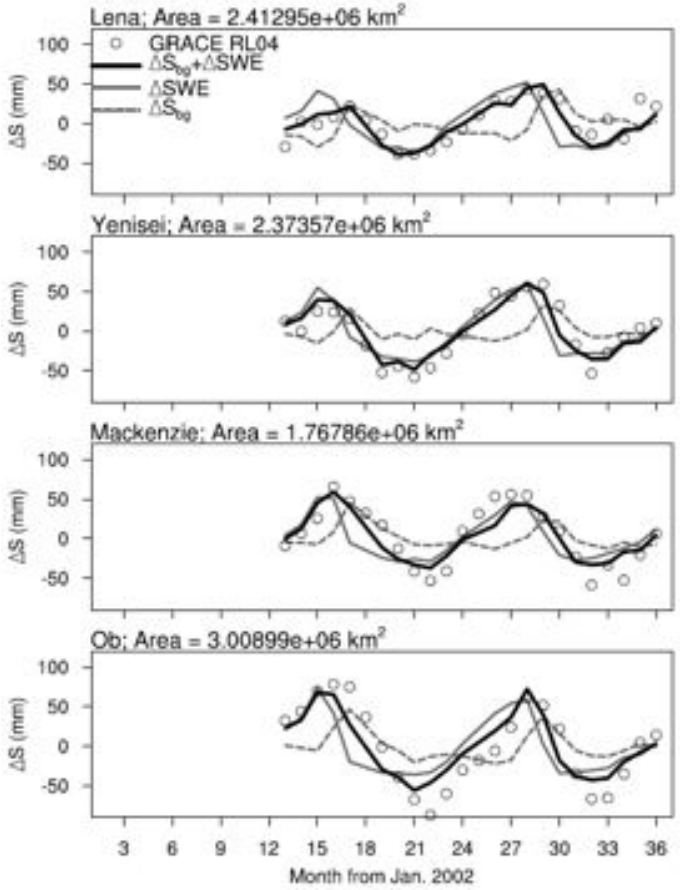
Surface energy balance

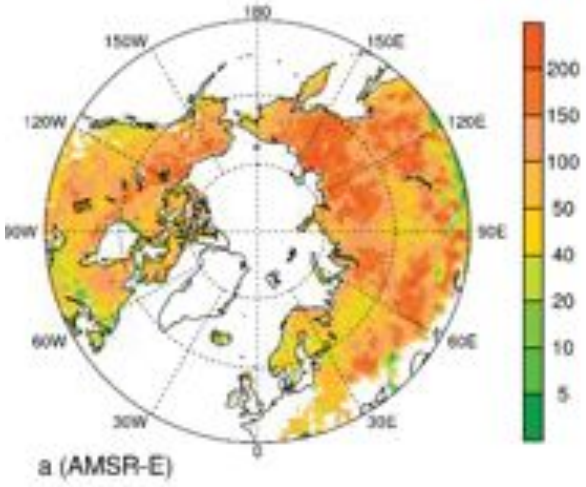
$$X_{SWE,t} = X_{SWE,t-1} + P_t - Q_t - E_t$$

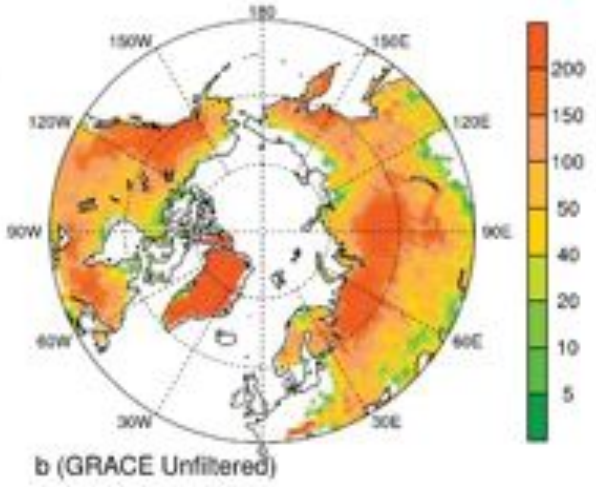
System function

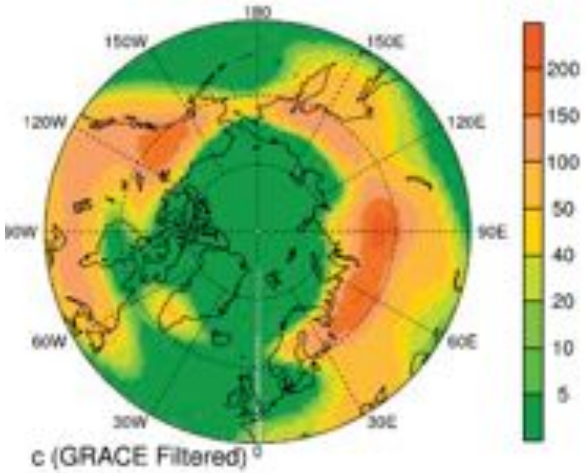
Retrieving Snow Mass Using GRACE & CLM

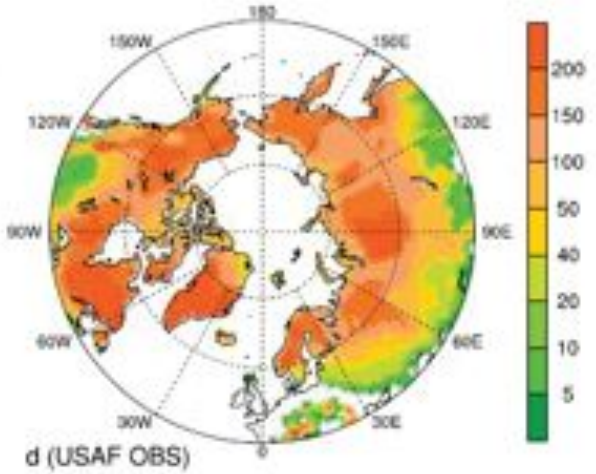
$$\Delta SWE = \Delta S - \Delta S_{bg}$$









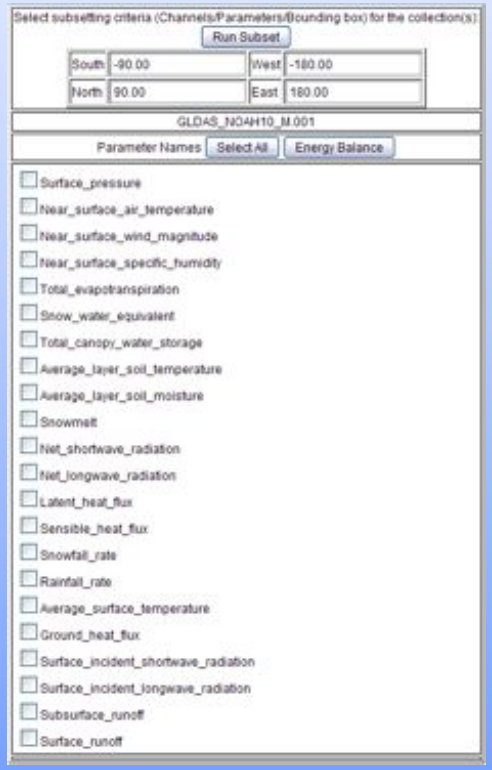


Niu, Seo, Yang, et al., 2007, GRL

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

Data Distribution from GES DISC

http://disc.gsfc.nasa.gov/hydrology



- Data available in GRIB and NetCDF formats
- Supports on-the-fly subsetting (right)
- Full documentation
- Quick look maps soon to be available
- **Supports a growing number of national and international hydrometeorological investigations and water resources applications**

Matt Rodell
NASA GSFC

Project Summary

Title: Multi-Sensor Snow Data Assimilation

Problem Statement: MODIS, AMSR-E, and GRACE all provide observations that are relevant to snow water equivalent mapping, each with significant advantages and disadvantages.

Hypothesis: Global fields of SWE can be produced with greater accuracy than previously seen by simultaneously assimilating MODIS snow cover, AMSR-E SWE, and GRACE terrestrial water storage observations within a sophisticated land surface model.

Team:

- NASA/GSFC: Matt Rodell (PI), Ed Kim, Rolf Reichle
- U. Texas: Liang Yang (Co-PI)
- Johns Hopkins: Ben Zaitchik

Timeline: Just getting started