Hydrology Research with the North American Land Data Assimilation System (NLDAS) Datasets at the NASA GES DISC using Giovanni

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Former NASA NLDAS participants: Brian Cosgrove and Charles Alonge

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Presentation Outline

- Introduction of the North American Land Data Assimilation System (NLDAS) datasets
  - ➔ Phase 1 (1996 – 2007) and Phase 2 (1979 – present)
- Images and stories from NLDAS datasets using Giovanni at the NASA GES DISC
  - ➔ A look at the 29 Jun 2012 U.S. derecho and Hurricane Isaac, along with stories on previous tropical systems, winter snow, etc.
- What's coming soon with NLDAS datasets
  - ➔ Monthly and climatological NLDAS datasets
  - ➔ Additional NLDAS land-surface model (LSM) datasets
- The next phase of NLDAS
  - ➔ Assimilation of remotely-sensed soil moisture and snow

NLDAS Phase 1 and Phase 2

- NLDAS Phase 1 datasets extend from 1 Aug 1996 to 31 Dec 2007
- NLDAS Phase 2 datasets extend from 1 Jan 1979 to present
- All NLDAS datasets are hourly and on an 1/8th deg. resolution (approximately 12km) over a CONUS domain, including parts of Canada/Mexico (25-53 °N; 125-67 °W)
- Both phases of NLDAS use a best-available blend of observations and reanalyses to create a land-surface model (LSM) forcing dataset to drive separate LSMs to produce output of soil moisture, fluxes, snow, soil temperatures, runoff, etc.
- Phase 2 (Xia et al., 2012, JGR) is the current real-time system, and includes improvements to the surface forcing and to the LSMs over the initial Phase 1 system (Mitchell et al., 2004, JGR)
- Phase 2 datasets are updated daily with a typical four-day lag

NLDAS Phase 2 Forcing Data

- The model-based fields are derived from the NCEP North American Regional Reanalysis (NARR) analysis fields:
  - NARR surface data used as base (3 hourly, 32km, Jan 1979 – present)
  - Elevation correction for temperature, pressure, humidity, and longwave
  - Includes 21 standard surface/2m/10m and lowest model layer forcing fields
  - NARR also has a real-time continuation product known as the Regional Climate Data Assimilation System (R-CDAS) from 2003 to present
- The observation fields used as part of NLDAS-2 include:
  - NARR's surface-based downward shortwave radiation (SWdown) is bias-corrected using GOES UMD SRB SW data
  - Hourly NLDAS precipitation based on CPC daily PRISM-corrected gauge data, hourly Stage II Doppler radar data, half-hourly CMORPH, hourly HPD data, and 3-hourly NARR model data (depending on location and availability)

NLDAS Phase 2 Forcing Data

- List of Earth Observations in the NLDAS-2 forcing along with coverage dates and temporal and spatial resolutions of the data:

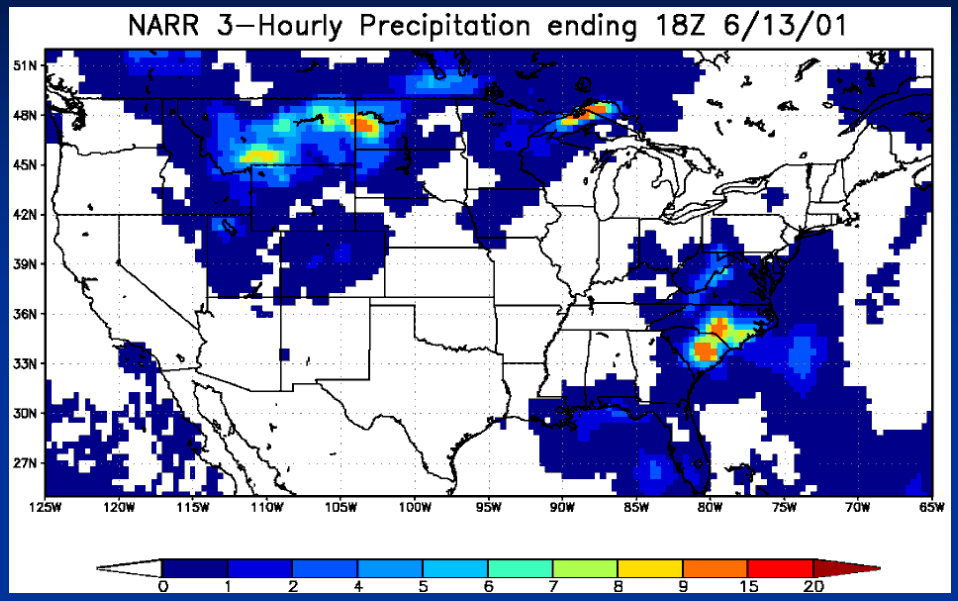
Forcing	Coverage	Temporal Resolution	Spatial Resolution	Notes
NARR Model	1979-2003	3 Hourly	32km	
R-CDAS Model	2003-Present	3 Hourly	32km	Realtime version of NARR
GOES Radiation	1996-2000	Hourly	1/8th degree	Used to bias correct NARR
CPC PRISM Gauge	1979-Present	Daily	1/8th degree	Used over CONUS, Mexico
CPC Gauge	1979-Present	Hourly	2 X 2.5 degree	Used over CONUS
CMORPH Precip	2002-Present	1/2 Hourly	8km	Used over CONUS, Mexico
Stage II Precip	1996-Present	Hourly	4km	Used over CONUS

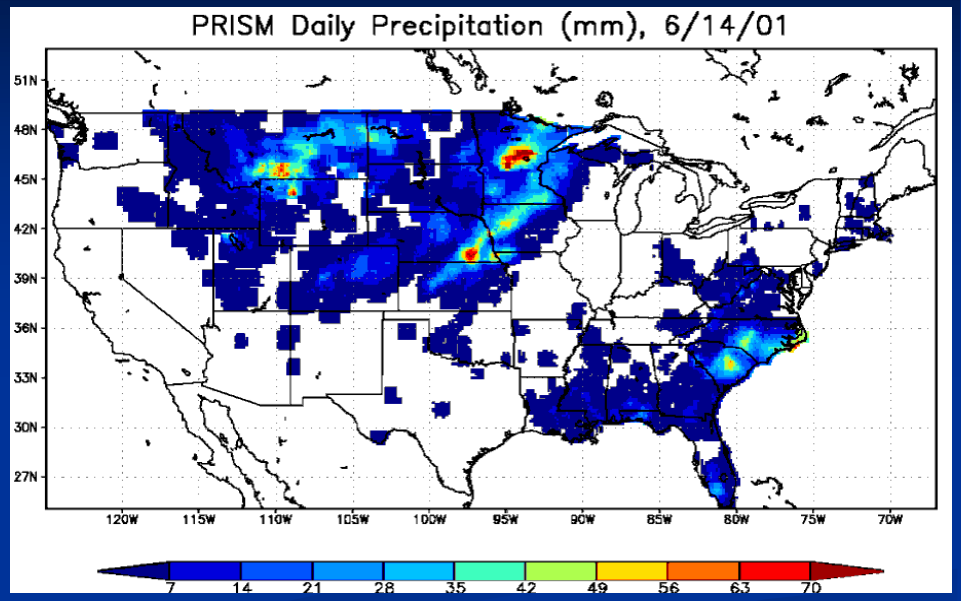
- An important point to keep in mind is that the CPC PRISM-corrected gauge-based daily 1/8th-degree precipitation analysis is used as the forcing in NLDAS-2, and the other datasets are used to temporally disaggregate the daily values into hourly amounts
- Additional details on the products used for this disaggregation depending on location within the domain and data availability are found in the following slide

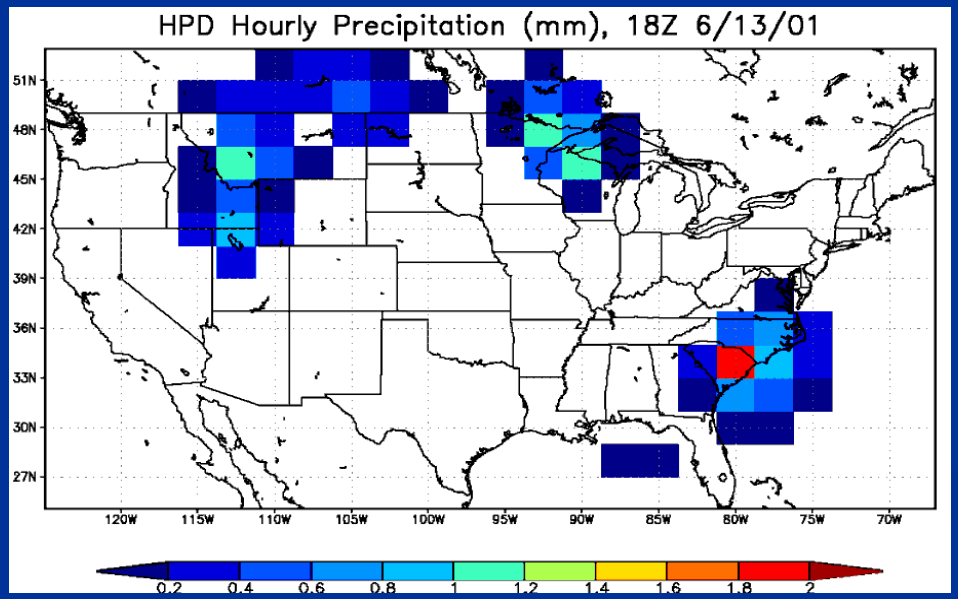
Generation of NLDAS-2 precipitation

Dataset	Years	CONUS	Mexico	Canada
CPC daily gauge analysis	1979 – present	**1/8th-degree PRISM-adjusted analysis**	**1/4th-degree (before 2001, 1-degree) analysis**	Not used
Stage II Doppler hourly 4-km radar data	1996 – present	**1st choice** to temporally disaggregate	Not used	Not used
CMORPH satellite-retrieved half-hourly 8-km analysis	2002 – present	**2nd choice** to temporally disaggregate	**1st choice** to temporally disaggregate	Not used
CPC HPD 2x2.5-degree hourly analysis	1979 – present	**3rd choice** to temporally disaggregate	**2nd choice** to temporally disaggregate	Not used
NARR/R-CDAS 3-hourly 32km model-simulated precipitation	1979 – present	**4th choice** to temporally disaggregate	**3rd choice** to temporally disaggregate	**Used for all precip over Canada areas; a 1-degree blend near U.S.-Canada border is done.**

Generation of NLDAS-2 precipitation

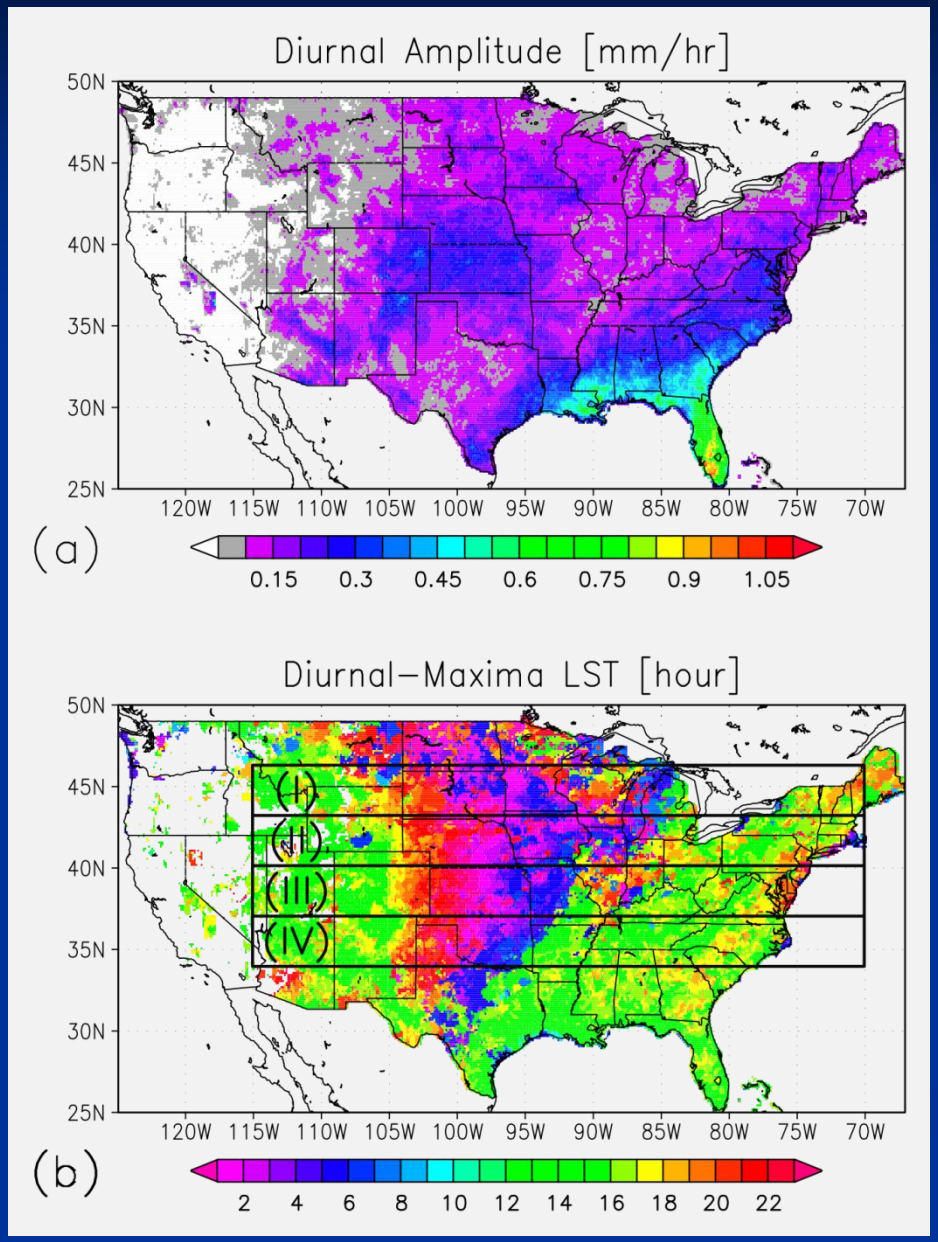


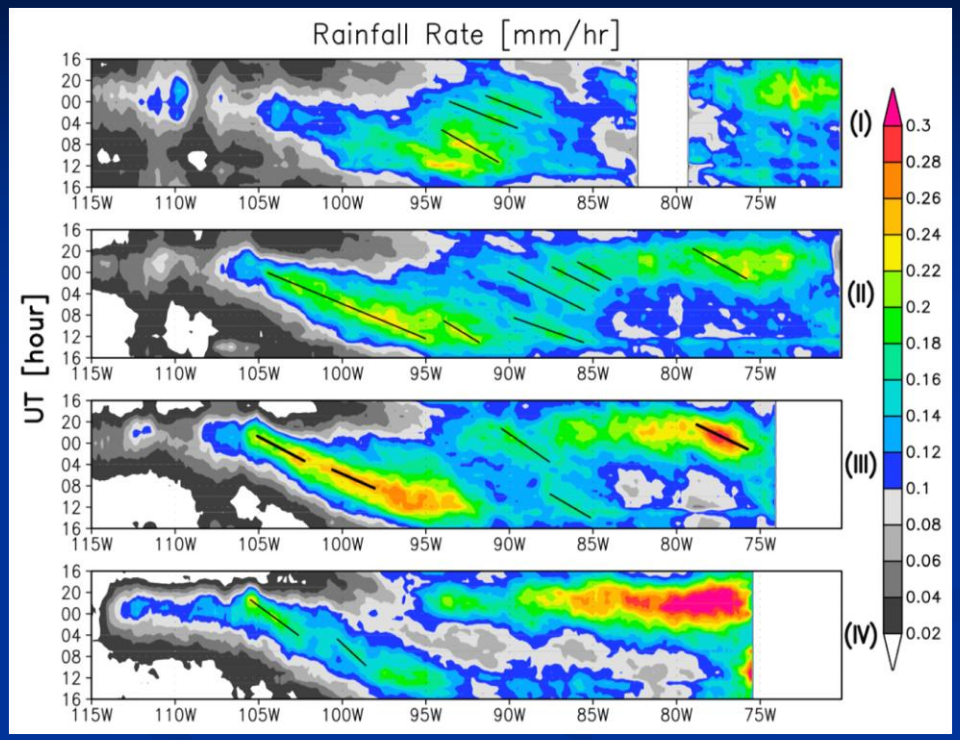




Over CONUS, CPC PRISM-adjusted daily gauge analyses are temporally disaggregated to hourly, primarily using Stage II Doppler radar data. If the radar data is unavailable, the following datasets are used instead, in order of availability: CMORPH analyses, CPC HPD hourly analysis, and then NARR model-simulated precipitation. Different data/methods used over Canada/Mexico.

NLDAS-2 precipitation diurnal cycle





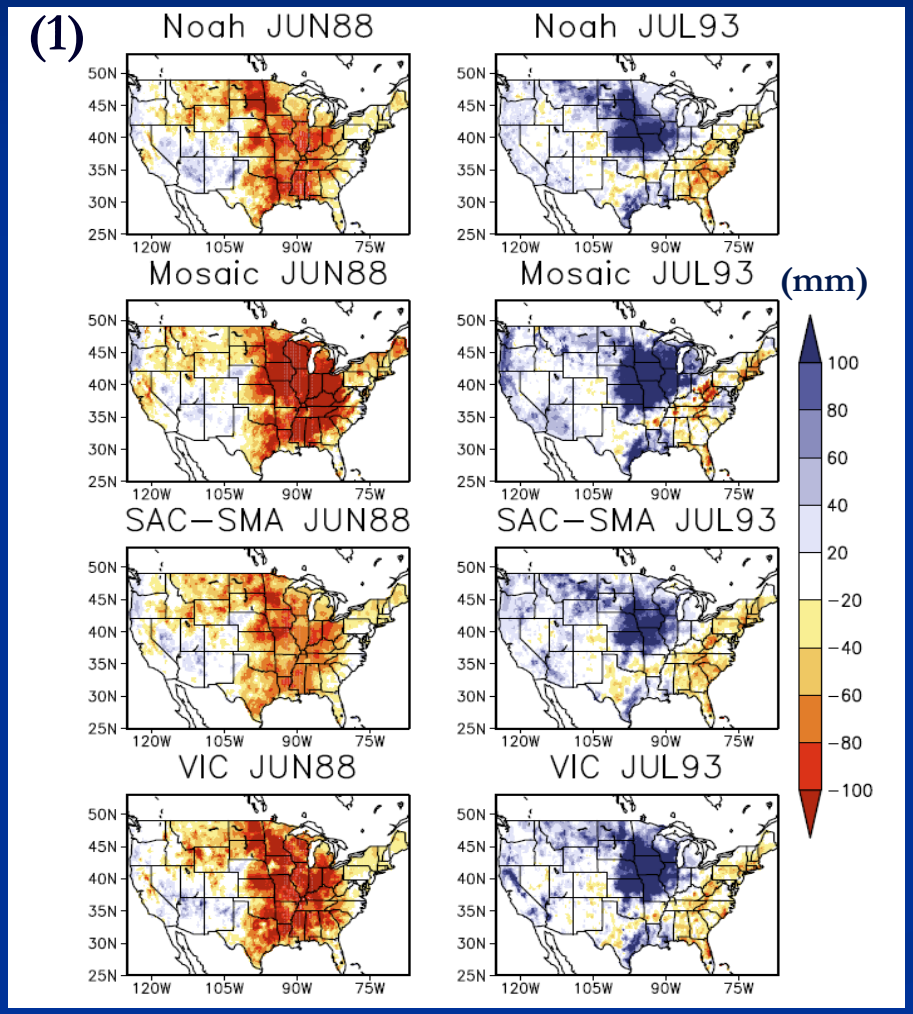
Matsui et al. (2010) examined the diurnal cycle of summertime precipitation in NLDAS over CONUS. Zonal phase speeds of the precipitation were estimated and compared to background zonal wind speeds from the MERRA reanalysis.

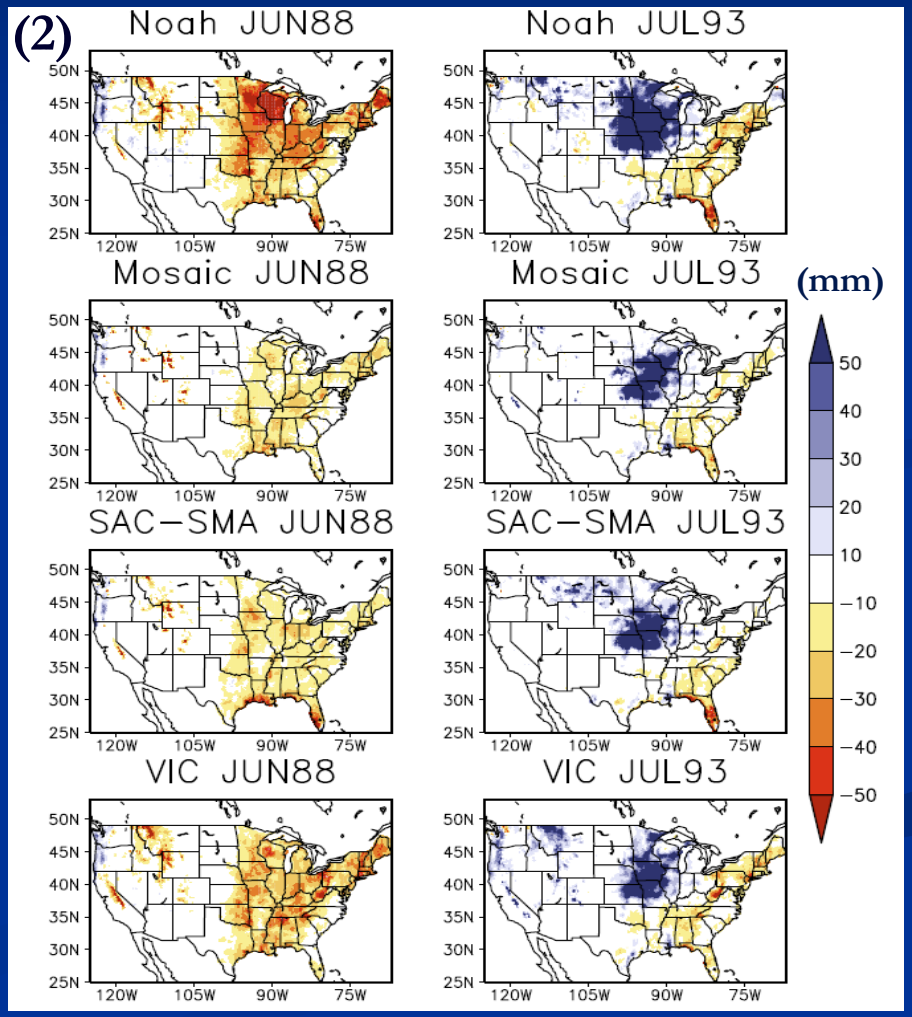
NLDAS-2 Land Surface Model (LSM) Reanalysis Datasets

- NLDAS-2 surface meteorological forcing is used to drive a suite of four LSMs, from both the meteorological (Noah and Mosaic) and hydrological (VIC and Sacramento) communities
- Common model parameters are used with these models, such as:
  - Land mask/cover datasets from AVHRR
  - Albedo, greenness, and LAI/SAI climatologies
  - STATSGO (for CONUS) and FAO (outside CONUS) soil info
  - GTOPO-30 ~1-km elevation dataset
- The LSMs produce hourly outputs of soil moistures/temperatures, snow, runoff, evapotranspiration, fluxes. Streamflow values are also calculated from routing the runoff (Lohmann et al., 2004, JGR)
- A near real-time NLDAS Drought Monitor webpage is updated daily using a long-term climatology for each NLDAS-2 LSM

Evaluating NLDAS-2 LSM Results

- (1) Top 2m soil moisture and (2) runoff anomalies for both the 1988 drought (left panels) and 1993 wet (right panels) years for the four NLDAS LSMs

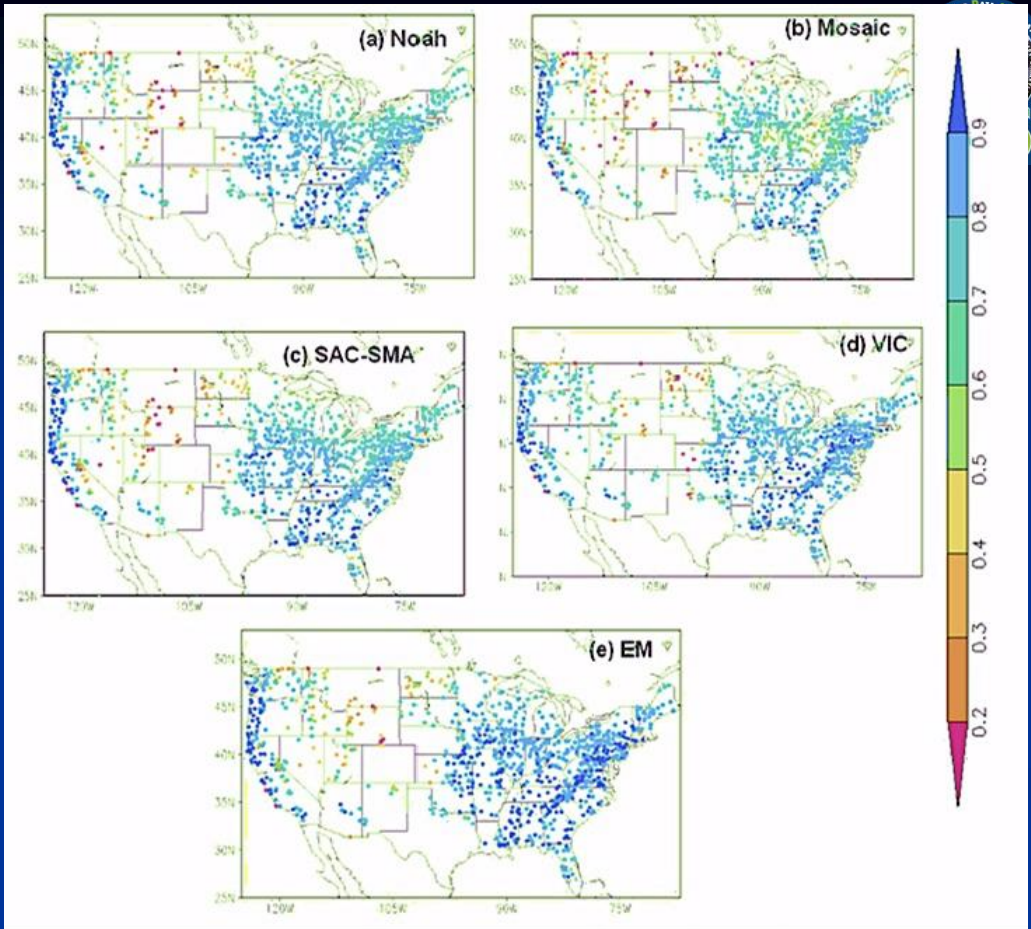


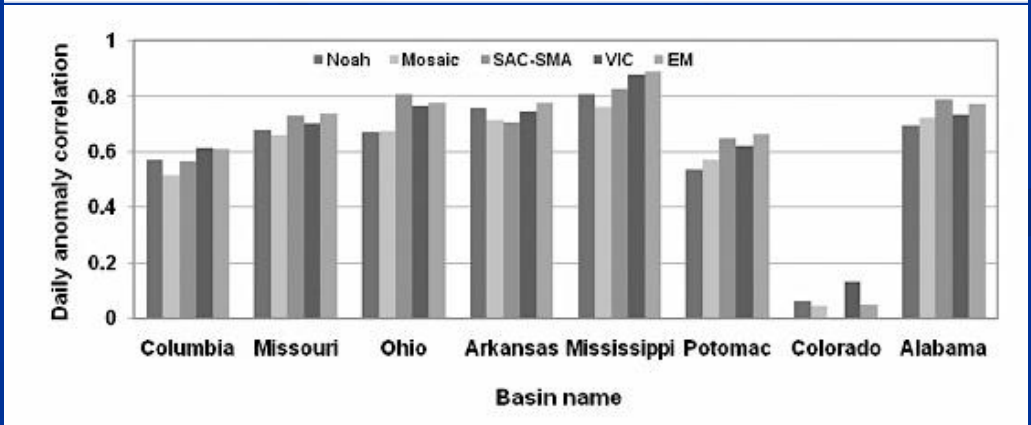


Xia et al. (2012): Part 1, JGR-Atmos.

Streamflow Comparisons

- **Correlation coefficients** between mean observed and simulated streamflow anomalies for the four models and their multi-model ensemble mean (EM) for years, 1979-2008
- Top figure: For monthly means (961 basins)
- Bottom figure: For daily means for 8 major U.S. river basins

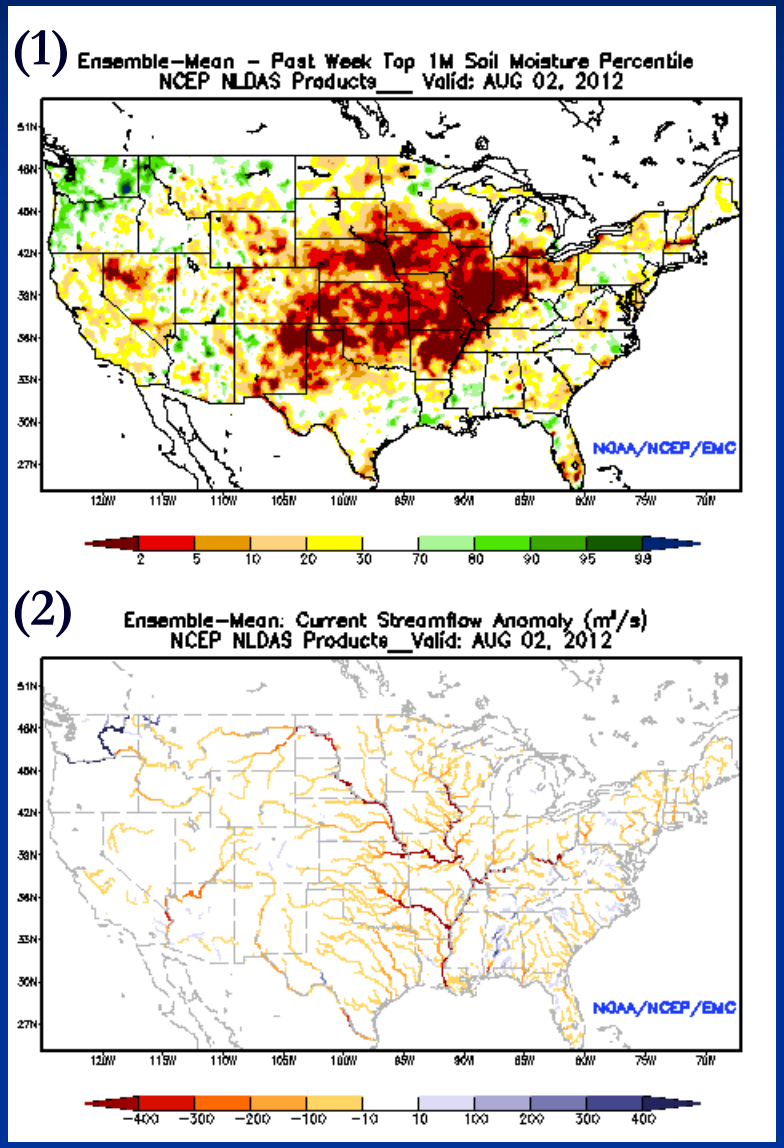




Xia et al. (2012): Part 2, JGR-Atmos.

NLDAS-2 Drought Monitor

-- http://www.emc.ncep.noaa.gov/mmb/nldas/drought/



- NLDAS-2 model data are also used in a near-real-time **drought monitor** (with anomalies/percentiles against 1980-2007 NLDAS-2 climatologies).

Examples of (1) soil moisture percentiles and (2) streamflow anomalies from the NLDAS Drought Monitor is shown to the right.

- Anomalies (based on a 28-year mean value for the DOY) and percentiles (with a 5-day moving window) are calculated as current, past week, and past month values

NLDAS data/services at the GES DISC

- Hydrology DISC (HDISC)
  http://disc.gsfc.nasa.gov/hydrology/
- GrADS Data Server (GDS)
  http://hydro1.sci.gsfc.nasa.gov/dods/

32+ years of hourly NLDAS datasets available at the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC)

Data Type (Short Name)	Description	FTP	GDS	Mirador		Giovanni *
				Navigation	Search	(Visualization)
NLDAS-1, 0.125 degree, North America (NLDAS-1 README Document)						
NLDAS_FOR0125_H.001	Hourly forcing	✓	✓	✓	✓	✓
NLDAS-2, 0.125 degree, North America (NLDAS-2 README Document)						
NLDAS_FORA0125_H.002	Hourly primary forcing	✓	✓	✓	✓	✓
NLDAS_FORB0125_H.002	Hourly secondary forcing	✓	✓	✓	✓	✓
NLDAS_MOS0125_H.002	Hourly Mosaic	✓	✓	✓	✓	✓
NLDAS_NOAH0125_H.002	Hourly Noah	✓	✓	✓	✓	✓
GLDAS-2, 1.0 degree. Global (GLDAS-2 README Document)						
GLDAS_NOAH10_3H_E1.002	3 hourly Noah experiment 1	✓	✓	✓	✓	✓
GLDAS_NOAH10_M_E1.002	Monthly Noah experiment 1	✓	✓	✓	✓	✓
GLDAS-1, 0.25 degree, Global (GLDAS-1 README Document)						
GLDAS_NOAH025SUBP_3H	3 hourly Noah	✓	✓	✓	✓	
GLDAS_NOAH025_M	Monthly Noah	✓	✓	✓	✓	
GLDAS-1, 1.0 degree, Global (GLDAS-1 README Document)						
GLDAS_CLM10SUBP_3H	3 hourly CLM	✓	✓	✓	✓	✓
GLDAS_CLM10_M	Monthly CLM	✓	✓	✓	✓	✓
GLDAS_MOS10SUBP_3H	3 hourly Mosaic	✓	✓	✓	✓	✓
GLDAS_MOS10_M	Monthly Mosaic	✓	✓	✓	✓	✓
GLDAS_NOAH10SUBP_3H	3 hourly Noah	✓	✓	✓	✓	✓
GLDAS_NOAH10_M	Monthly Noah	✓	✓	✓	✓	✓
GLDAS_VIC10_3H	3 hourly VIC	✓	✓	✓	✓	✓
GLDAS_VIC10_M	Monthly VIC	✓	✓	✓	✓	✓
LPRM-based Soil Moisture						
LPRM_AMSRE_SOILM2.002	Swath	✓		✓	✓	
LPRM_AMSRE_A_SOILM3.002	Daily 0.25 degree	✓		✓	✓	
LPRM_AMSRE_D_SOILM3.002	Daily 0.25 degree	✓		✓	✓	
LPRM_TMI_DY_SOILM3.001	Daily 0.25 degree	✓		✓	✓	
LPRM_TMI_NT_SOILM3.001	Daily 0.25 degree	✓		✓	✓	
LPRM_TMI_SOILM2.001	Swath	✓		✓	✓	

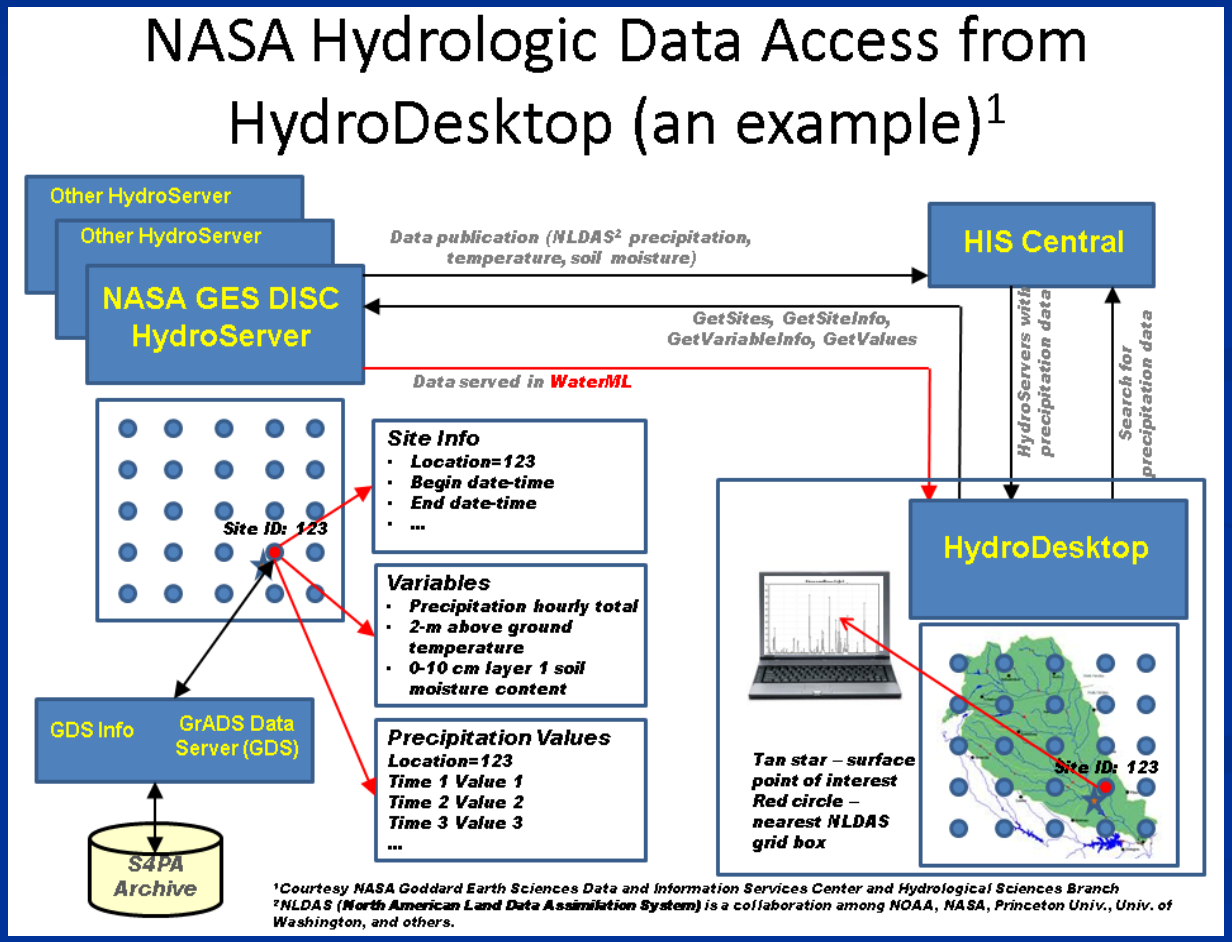
Data is available via 4 methods:

1) Mirador searching, subsetting, and downloading
2) Giovanni online visualization and analysis
3) anonymous ftp
4) a GDS.

Currently, NLDAS-1 forcing as well as NLDAS-2 forcing and Mosaic and Noah model output datasets are available.

LDAS Datasets Added to CUAHSI

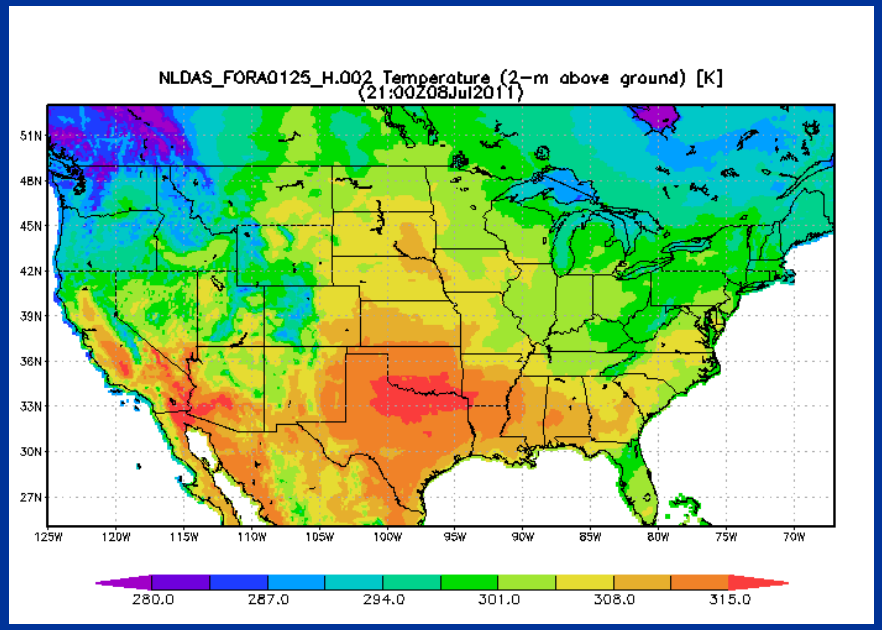
- The GES DISC has integrated NLDAS & GLDAS data into the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) Hydrologic Information System (HIS):

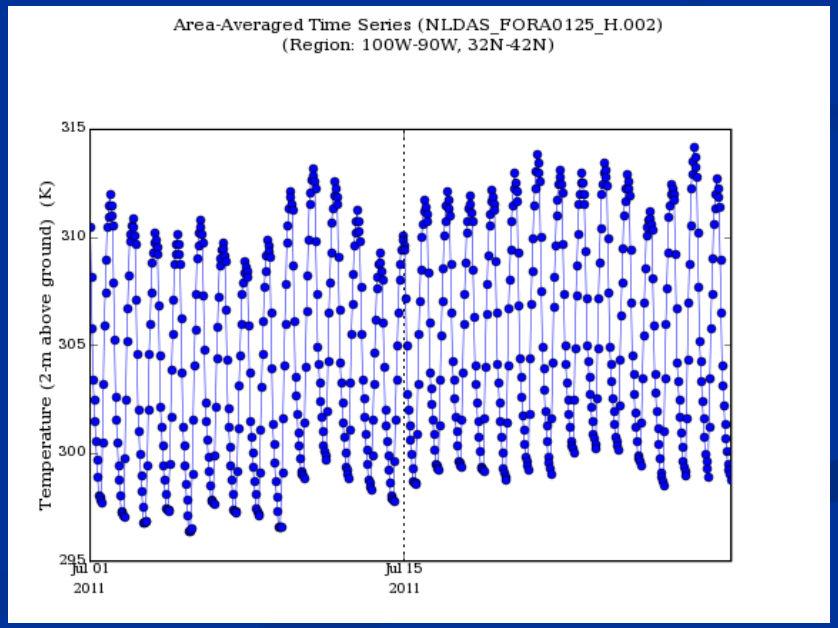


- A Web Service that provides the data as a time series along with corresponding metadata in WaterML
- Schematic on left shows data access using the CUAHSI HIS client HydroDesktop; the data can be searched, retrieved, and analyzed along with hydrological data from other sources available via HIS.

NLDAS Giovanni: Heat Wave 2011

- A significant heat wave occurred over Texas and Oklahoma during July and August 2011
- Giovanni created images of (left) a snapshot from an animation of hourly temperatures and (right) an area-average time-series of the 2-m above ground air temperature from the NLDAS-2 forcing

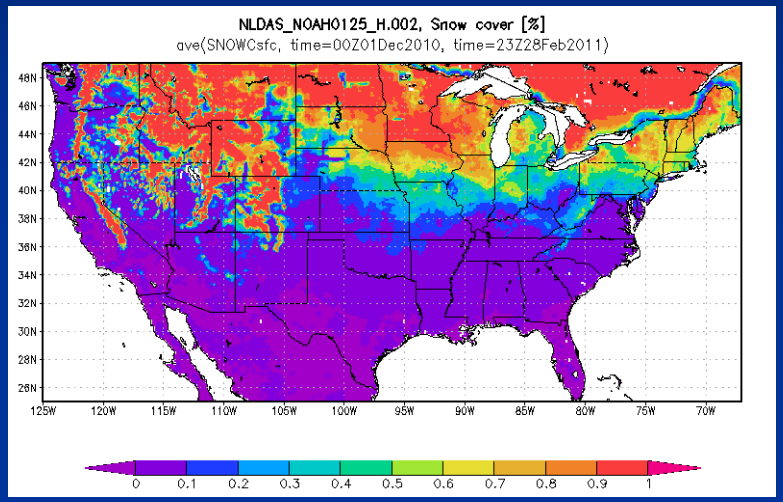


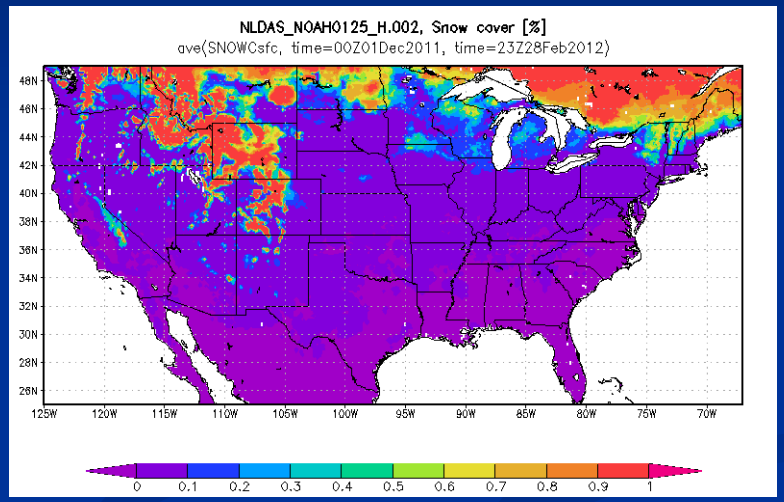


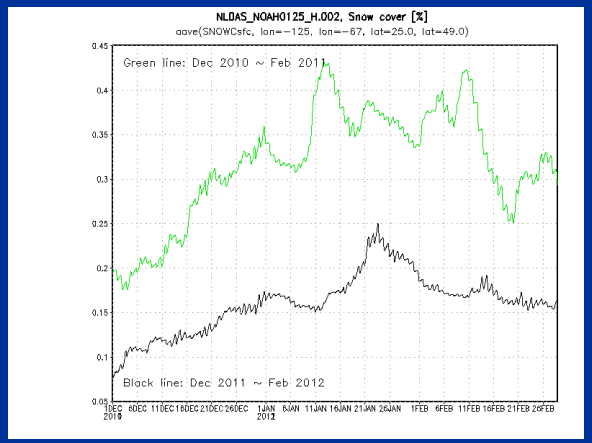
http://disc.sci.gsfc.nasa.gov/gesNews/steamy_heat_on_plains

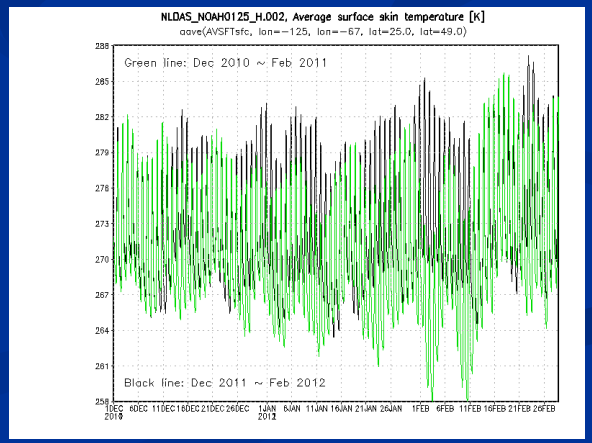
NLDAS Giovanni: Snow Cover

- These figures show differences in winter snow cover and temperatures for DJF 2011 (snowy) and 2012 (not snowy)





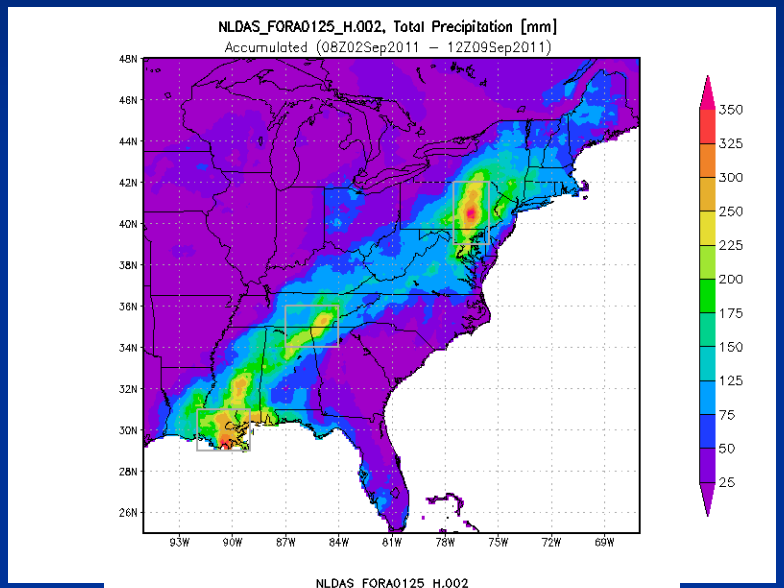


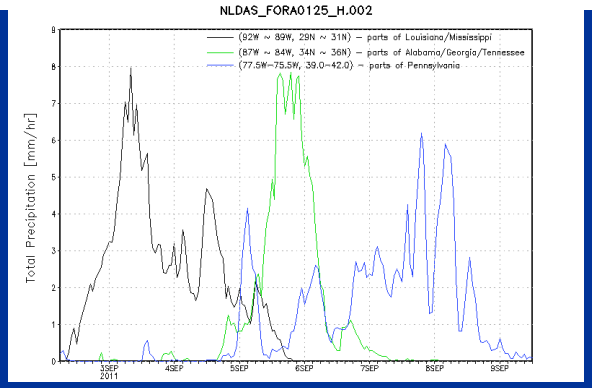


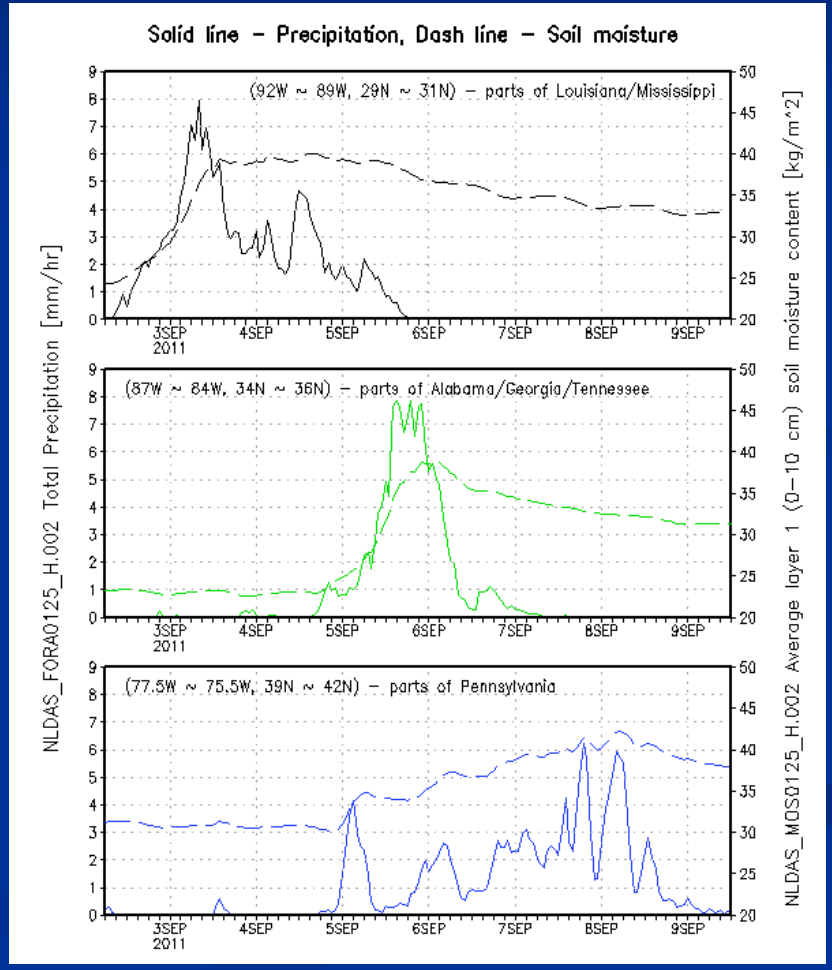
http://disc.sci.gsfc.nasa.gov/gesNews/nldas_warm_winter_part_2

NLDAS Giovanni: T.S. Lee

- Tropical Storm Lee made landfall on the Gulf Coast and brought rainfall and increased soil moisture to the East



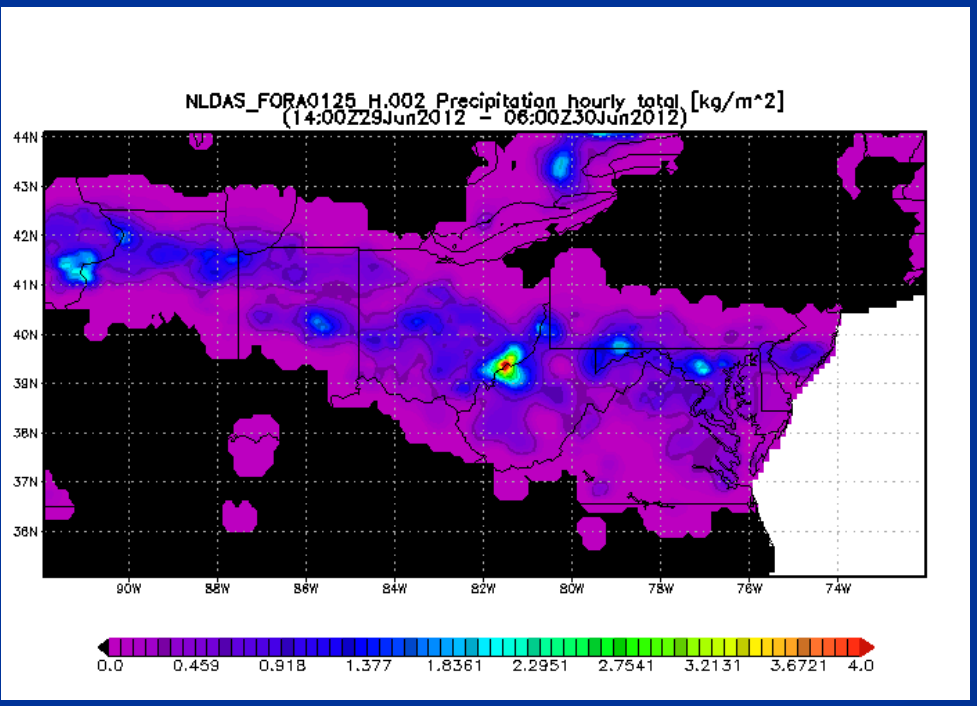


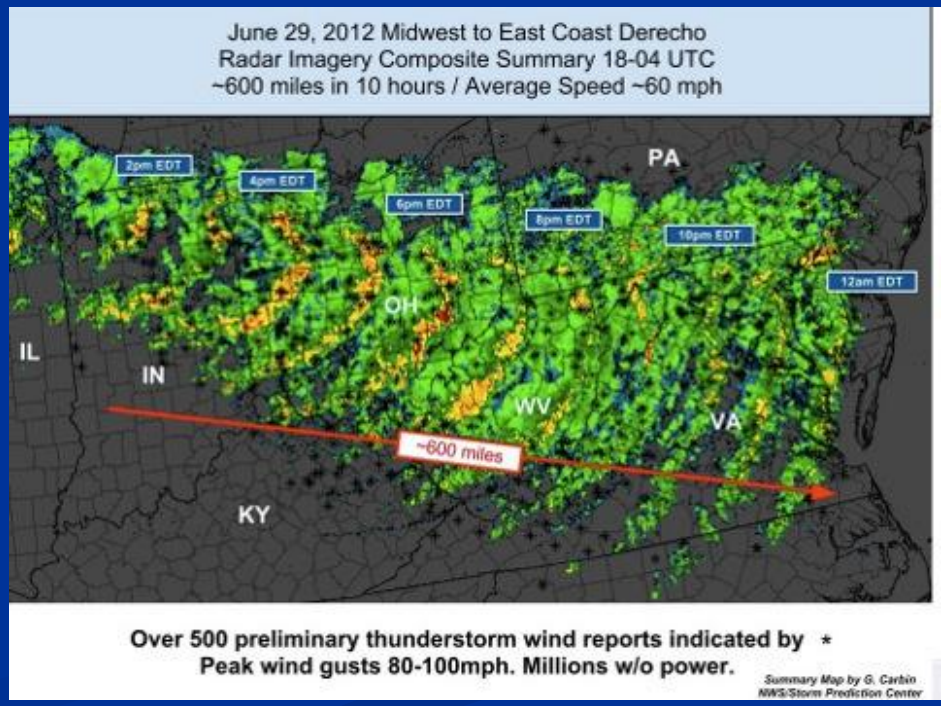


http://disc.sci.gsfc.nasa.gov/gesNews/nldas_views_ts_lee

NLDAS Giovanni: 29 Jun 2012 derecho

- A severe derecho traveled from Iowa/Illinois through to the Mid-Atlantic on 29 Jun 2012. Heavy precipitation and strong winds resulted in widespread power outages. The left figure is from Giovanni and the right figure is from the National Weather Service.

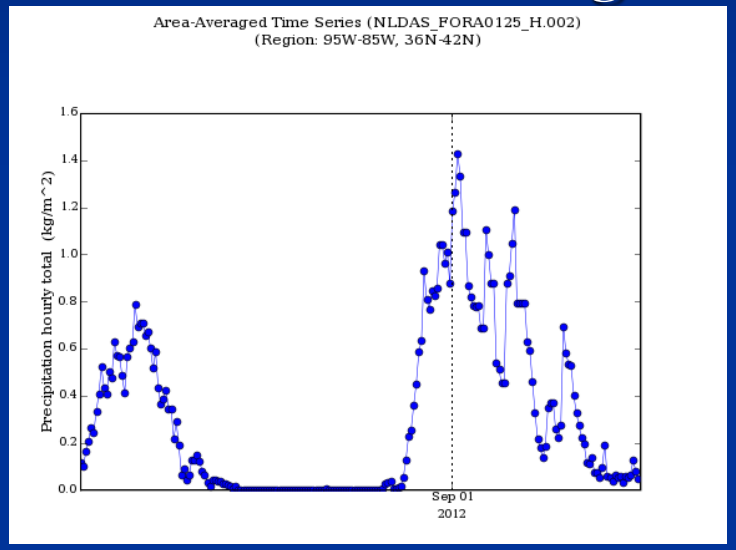


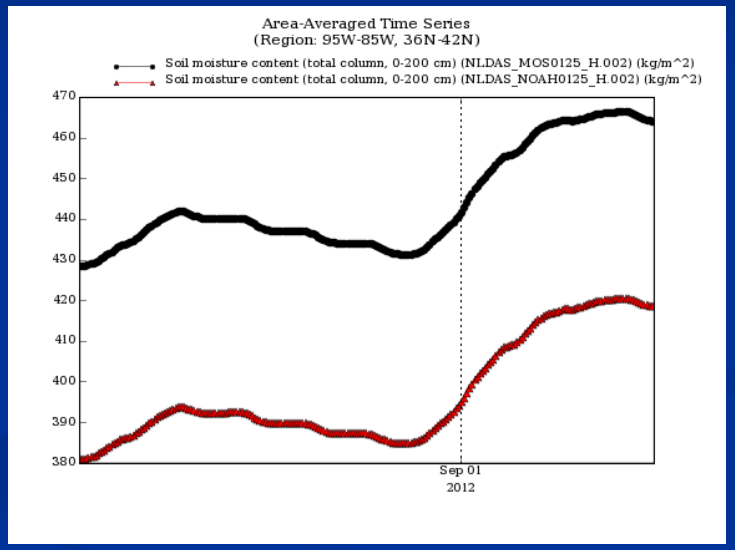


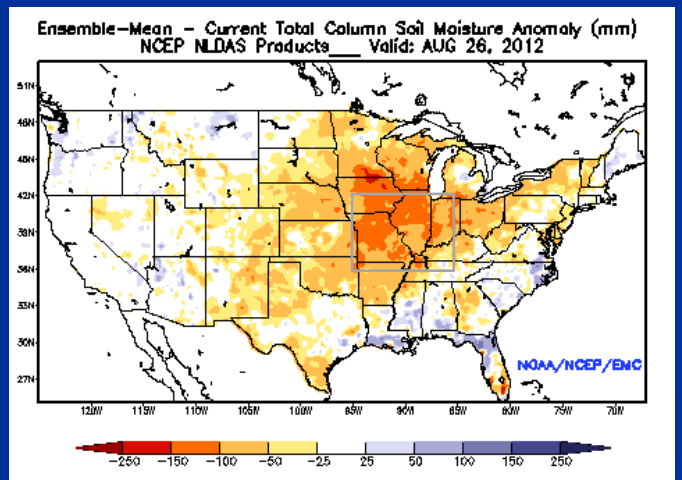
http://disc.sci.gsfc.nasa.gov/giovanni/giovanni_user_images#derecho

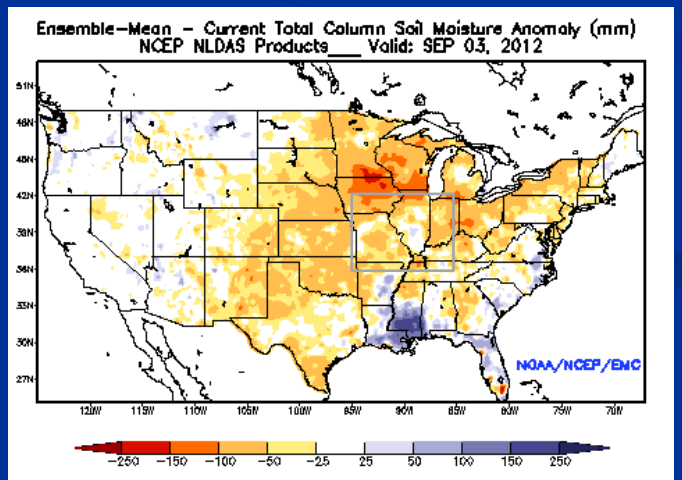
NLDAS Giovanni: Hurricane Isaac

- Hurricane Isaac made landfall in Louisiana and brought intense rainfall. Before and after soil moisture anomalies from the NLDAS Drought Monitor are also shown.







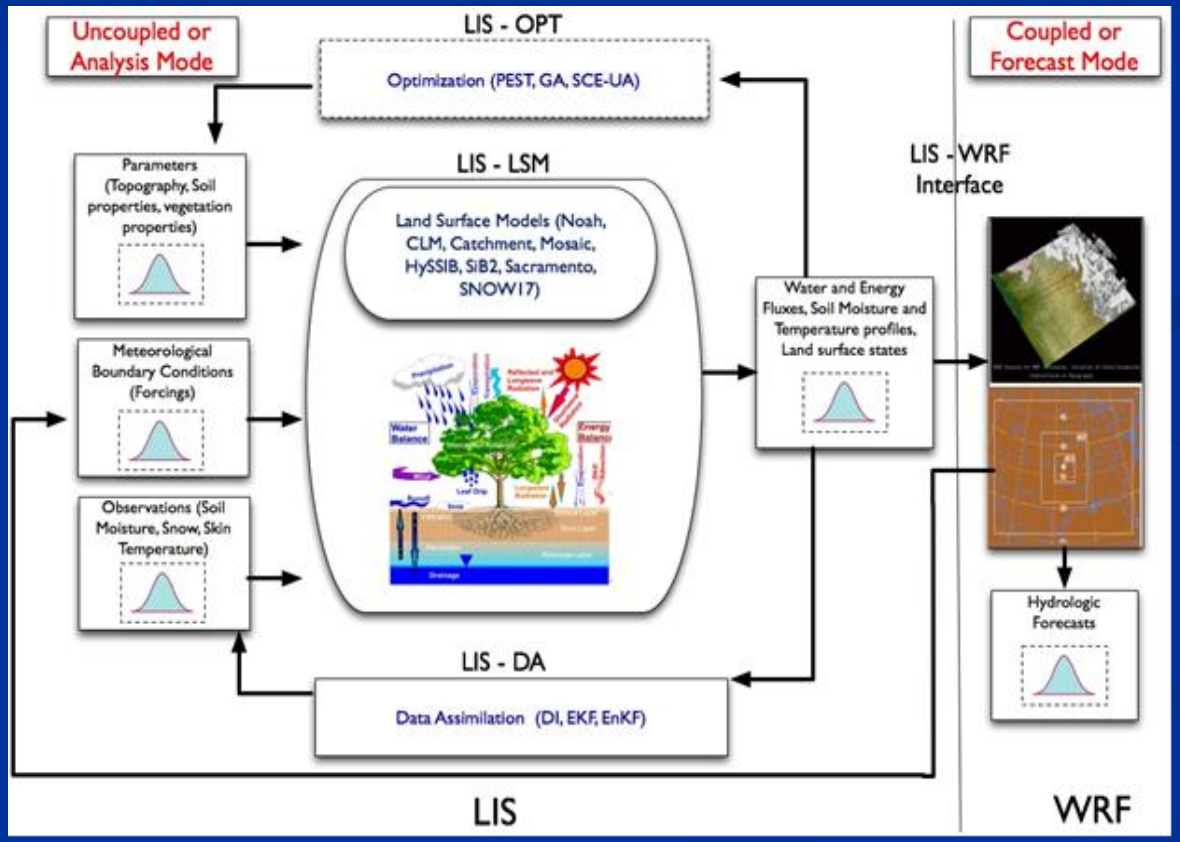


Future NLDAS Datasets/Products

- Coming soon: NLDAS monthly and climatology datasets for Phase 1 and Phase 2
  - Monthly-mean fields (from the current hourly datasets) for the forcing and the LSM outputs will be released at the GES DISC
  - Monthly climatological fields will also be provided
- Coming soon: NLDAS Phase 2 VIC and Sacramento LSM hourly datasets
  - VIC and Sacramento currently available at NOAA/EMC only via ftp, but will be brought to the GES DISC and made available in Giovanni
- A year or two from now: next phase of NLDAS
  - The next phase of NLDAS will include new and upgraded LSMs and include data assimilation of remotely-sensed soil moisture and snow
  - The NASA-developed Land Information System (LIS) will be used as the software framework

The Land Information System (LIS)

- LIS is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observational data products with land-surface models



- LIS can use different LSMs, forcings, parameter datasets, observations, and includes modules for data assimilation and parameter optimization techniques.
- In addition to being run in an offline/uncoupled mode, LIS can also run coupled to the WRF forecast model.

LSMs and Data Assimilation in LIS

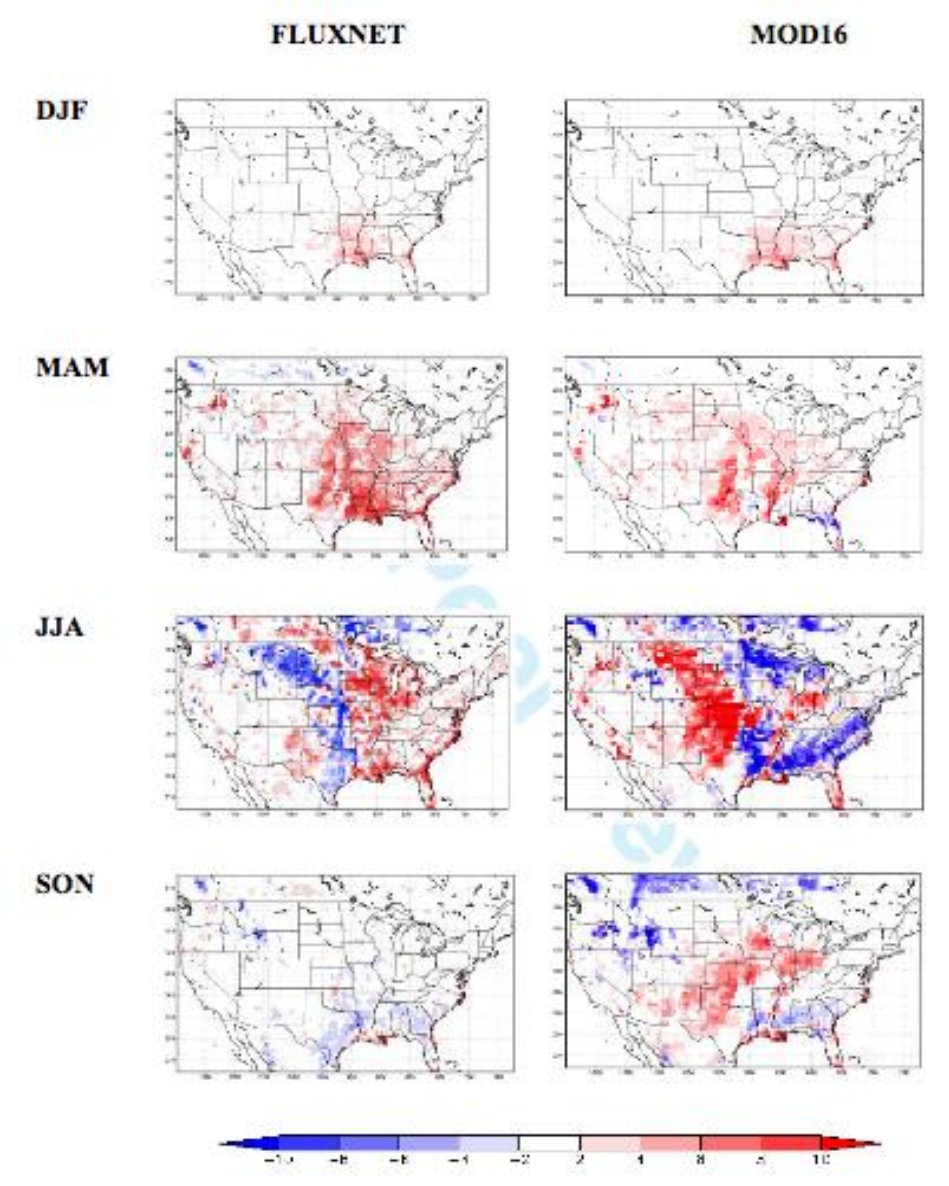
- The next phase of NLDAS is currently in development, and will include new and upgraded LSMs using the Land Information System (LIS) software framework; LIS was developed within the Hydrological Sciences Laboratory (HSL) at NASA/GSFC
- The LIS framework will allow data assimilation of soil moisture and snow products to help improve drought diagnosis using NLDAS
- Outputs will be extensively evaluated against numerous observations using the NASA/HSL's Land surface Verification Toolkit (LVT)
- List of parameters, resolution, and satellite sensors of data to be used:

Parameters	**Spatial Resolution**	**Satellite Sensors**
Snow covered area (SCA)	500m	Terra/Aqua MODIS
Snow water equivalent	25-km	Aqua AMSR-E
SCA & SWE	25-km	ANSA
Soil moisture	25-km	Aqua AMSR-E

Soil moisture data assimilation to improve ET

- How does soil moisture data assimilation improve (ET) evapotranspiration estimates?
- Assimilation of LPRM retrievals of AMSR-E soil moisture into Noah LSM
- ET estimates are evaluated against FLUXNET and MODIS-based datasets
- Panels show improvement metrics in red [RMSE diffs]

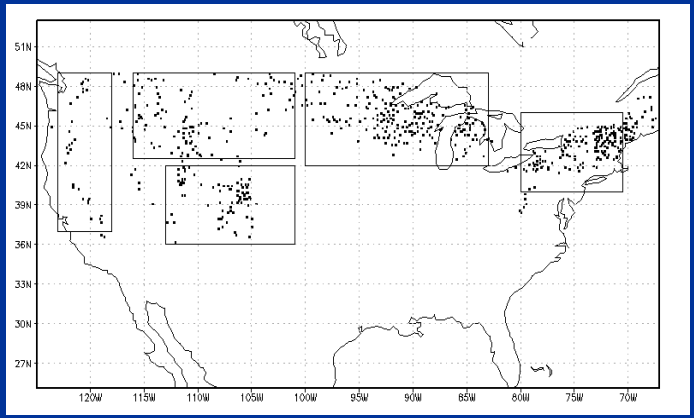
Noah v3.2 Qle	FLUXNET (W m^{-2})		MOD16 (W m^{-2})	
	RMSE	Bias	RMSE	Bias
Open-loop	27.6 ± 0.3	12.9 ± 0.4	22.7 ± 0.2	11.2 ± 0.3
LPRM DA	**25.6 ± 0.3**	**10.9 ± 0.3**	**21.9 ± 0.3**	**9.2 ± 0.3**

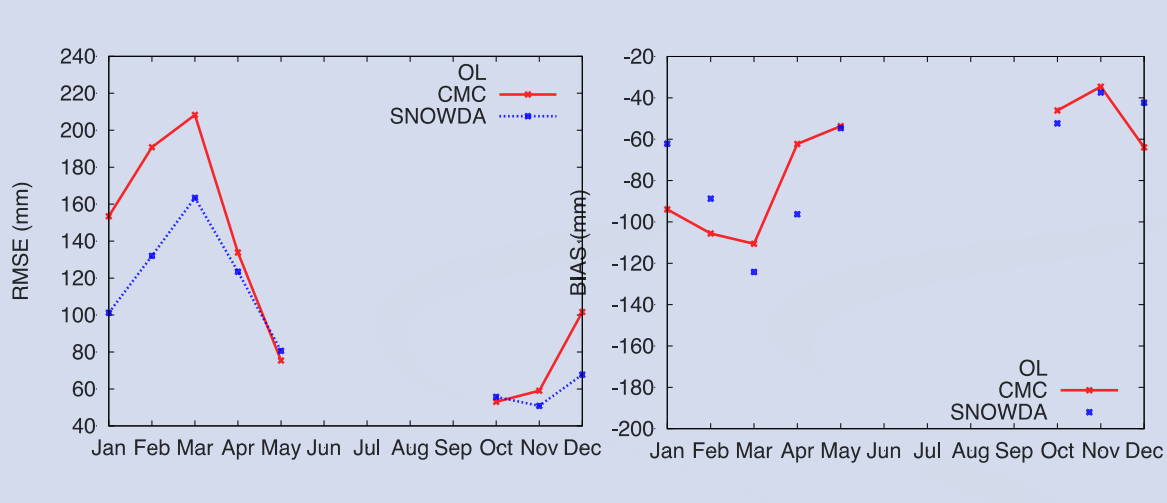


Peters-Lidard et al. (2011): Estimating evapotranspiration with land data assimilation systems, Hydrological Processes

Evaluating Snow Assimilation Results

- Non-assimilated open-loop ("OL") simulations compared with assimilated ("SNOWDA") and observations ("CMC"), which are included for an independent evaluation of the simulations.
- Validation performed with the U. S. NOAA/NWS COOP stations





	RMSE (mm)	Bias (mm)	R
OL	212 +/- 10.7	-130.0 +/- 11	0.63 +/- 0.01
CMC	197 +/- 8.0	-85.9 +/- 8.0	0.70 +/- 0.01
SNOWDA	152 +/- 8.5	-77.6 +/- 8.19	0.77 +/- 0.01

Summary

- NLDAS is a successful collaboration project that's produced over 32 years of hourly 1/8th-degree surface forcing and land-surface model output over CONUS and parts of Canada/Mexico
- NLDAS integrates many different Earth Observations in the creation of the surface forcing as well as in the LSMs to produce model output of soil moisture, evaporation, snow pack, runoff, and surface fluxes
- The NASA GES DISC provides many NLDAS datasets/services; Giovanni-created images and stories have examined numerous tropical storms, the 29 Jun 2012 derecho, winter snow, heat waves
- NLDAS monthly, climatological, and VIC/Sacramento dataset will soon be added to the NASA GES DISC
- The next-generation of NLDAS will include upgraded LSMs as well as data assimilation of soil moisture and snow products towards improved diagnosis of drought and initial conditions for forecasts

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  - Collaborations with AquaTerra and CUAHSI

NLDAS & LIS websites

- NLDAS at NASA:
  http://ldas.gsfc.nasa.gov/nldas/
- NLDAS datasets at the NASA GES DISC:
  http://disc.gsfc.nasa.gov/hydrology/
- NLDAS at NOAA/NCEP/EMC:
  http://www.emc.ncep.noaa.gov/mmb/nldas/
- LIS website at NASA:
  http://lis.gsfc.nasa.gov/

Please sign up for the LDAS mailing list!