Recent progress from LIS-NLDAS

David M. Mocko[1,2], Sujay V. Kumar[1,2], Kristi Arsenault[1,2],
Shugong Wang[1,2], Christa D. Peters-Lidard[1],
Youlong Xia[3,4], Michael B. Ek[3], Jiarui Dong[3,4]

The **North American Land Data Assimilation System (NLDAS)** is a collaborative project between NOAA/NCEP, NASA/GSFC, Princeton Univ., Univ. of Washington, and NOAA/OHD, and is supported by the NOAA Climate Program Office's Modeling Analysis, Predictions, and Projections (MAPP) Program.

Acknowledgements: Brian Cosgrove[5], Yuqiong Liu[1,5], Grey Nearing[1,2], Augusto Getirana[1,6], Sarith Mahanama[1,7], Benjamin Zaitchik[8], Jim Geiger[1], Michael Jasinski[1] , Bailing Li[1,6], Hualan Rui[1,9], Bill Teng[1,9], Bruce Vollmer[1], and numerous members of both the NLDAS and LIS teams over the last 15+ years

1 – NASA/GSFC; 2 – SAIC; 3 – NOAA/NCEP/EMC; 4 – IMSG; 5 – OHD; 6 – Univ. MD; 7 – SSAI; 8 – Johns Hopkins Univ.; 9 - ADNET

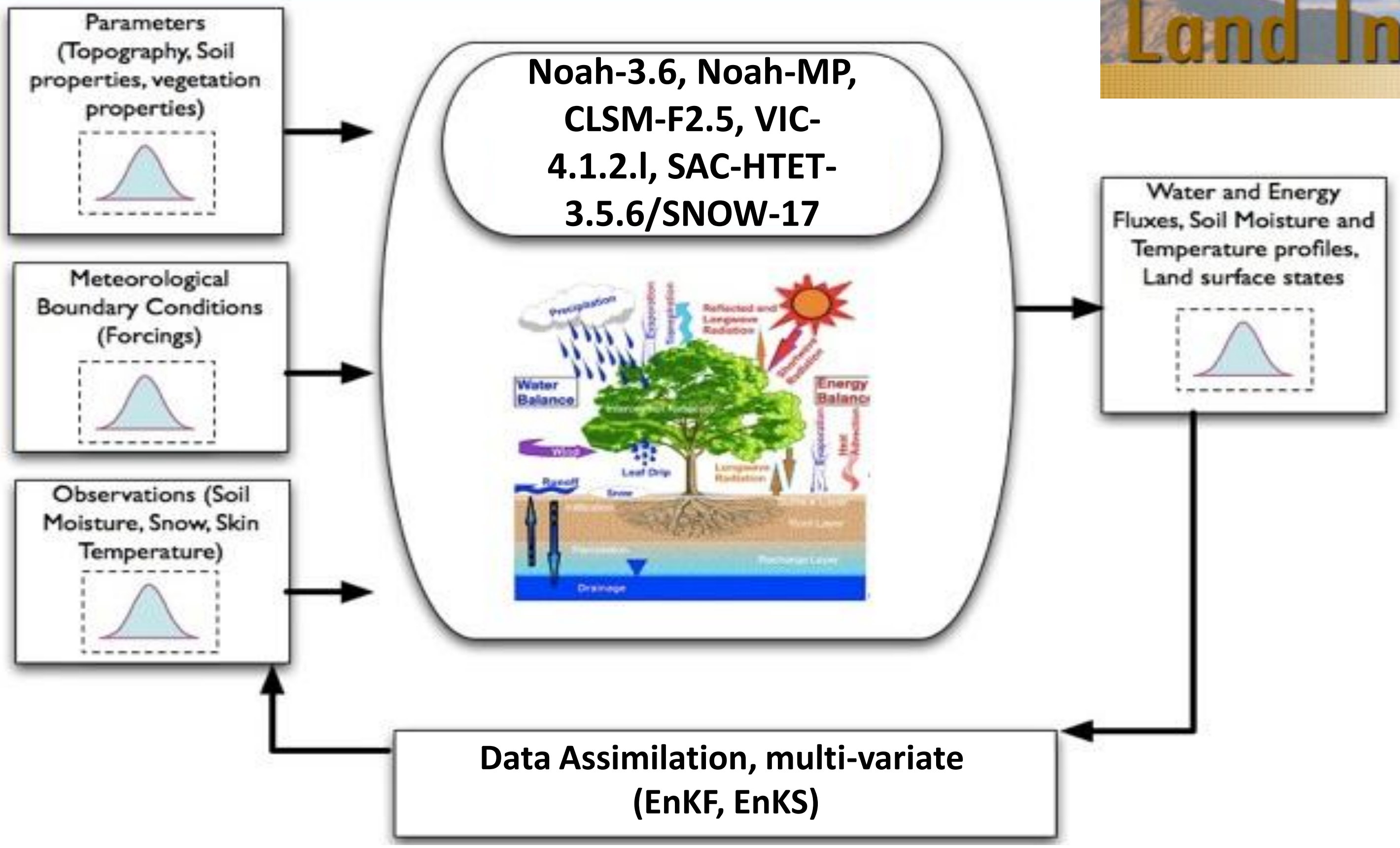
The next phase of NLDAS will use updated models and data assimilation using NASA's Land Information System

LIS-based next phase of NLDAS

1979 – Present Updated w/ Larger Domain Forcings and Parameters at 4-km

Satellite EDRs*

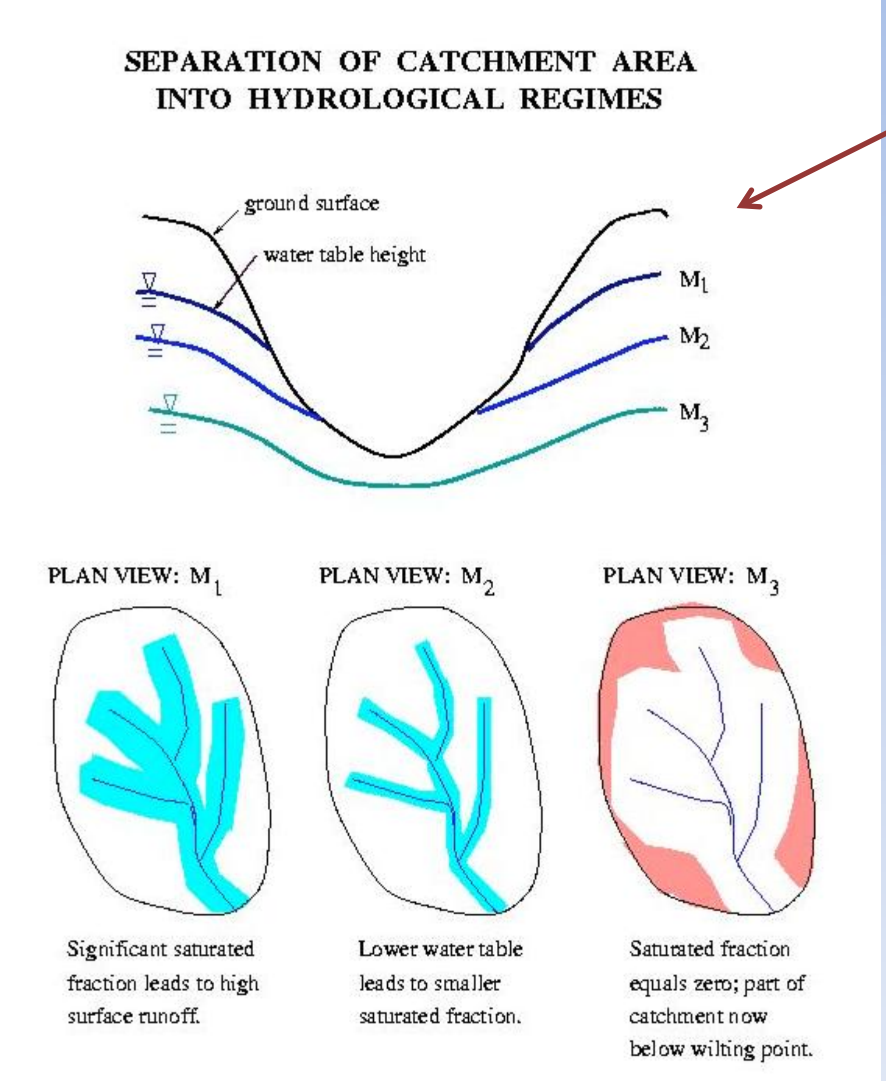
SM, SCA, SWE, TWS, and II



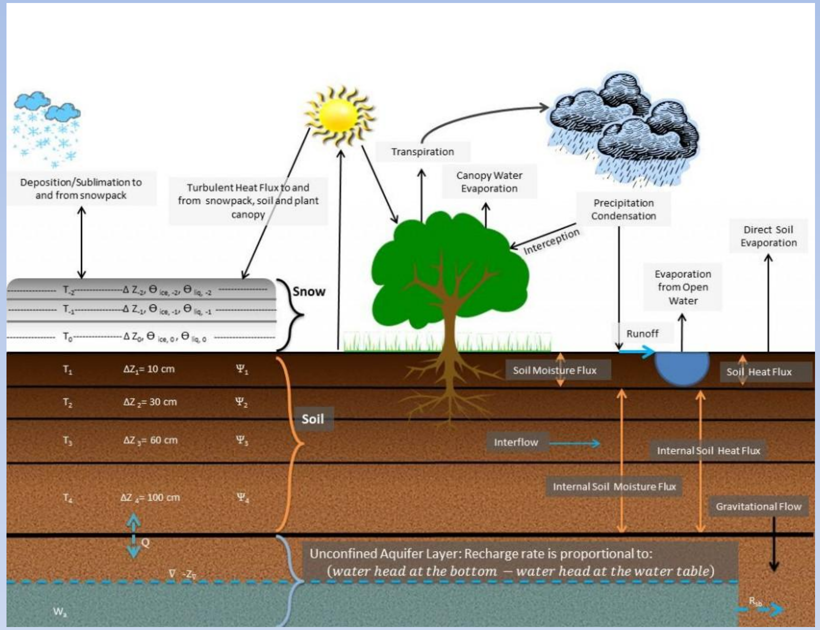
* Satellite-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), & irrigation intensity (II)

The **Land Information System (LIS)** is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observed data products with land-surface models.

NASA GMAO’s Catchment LSM is being added to the NLDAS suite, and other LSMs are being upgraded to later versions



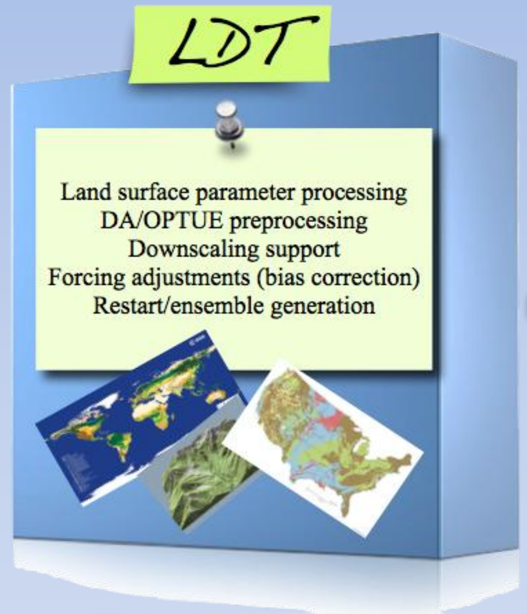
The **Catchment land-surface model (CLSM)** is developed by the NASA Global Modeling and Assimilation Office (GMAO), and is the land-surface component of the NASA GEOS-5 GCM.



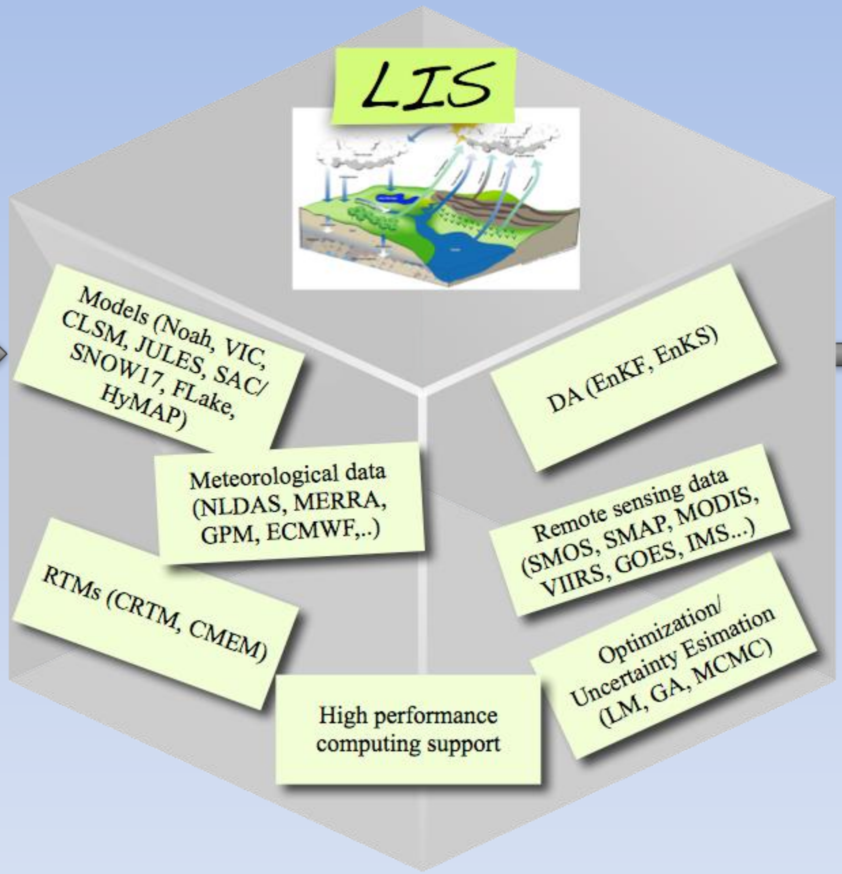
Noah-MP is a LSM option within WRF, with Multiple Physics options, including for dynamic vegetation.

VIC-4.1.2.l, SAC-HTET-3.5.6, and Noah-3.6 have also been implemented in LIS and contain numerous upgrades, such as to soil temperatures, vegetation, and snow-physics.

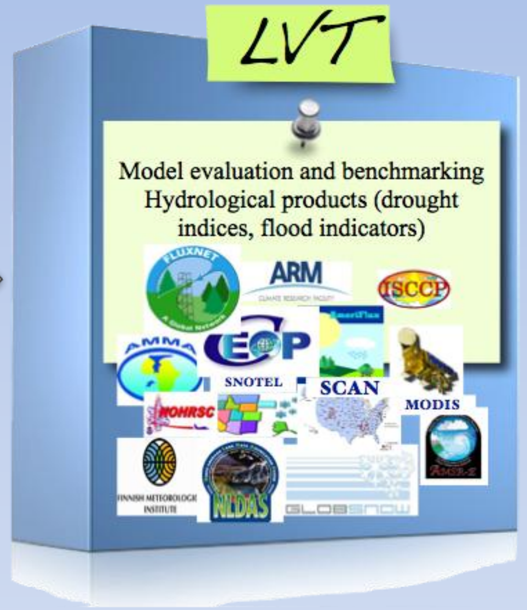
The LIS modeling suite



Land surface Data Toolkit (LDT)



Land Information System (LIS)



Land surface Verification Toolkit (LVT)

LVT Tutorial

On 1-2 September 2015, several members of the NASA/GSFC Hydrological Sciences Laboratory (617) provided a workshop on the NASA Land surface Verification Toolkit (LVT).

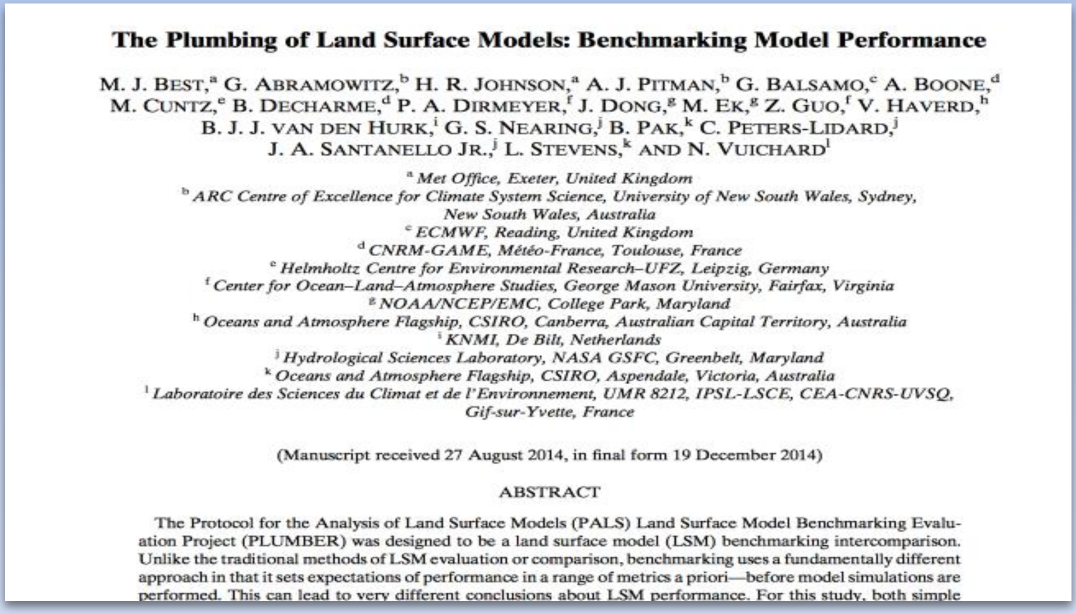
LVT is a comprehensive tool for land surface model verification and benchmarking and includes the support for a wide range of in-situ, remotely-sensed, and model/reanalysis products.

The participants at the tutorial included users from NASA/GSFC, NASA/MSFC, USAF 557th weather wing, NCAR, NRL, NOAA NCEP, UK met office, University of Reading, US Army Cold Regions Research and Engineering Lab (CRREL), International Center for Biosaline Agriculture (ICBA), Johns Hopkins University, USGS EROS, University of California Santa Barbara (UCSB), and the University of Delaware.

NASA personnel that led the tutorial included Sujay Kumar (SAIC/617), David Mocko (SAIC/617 & 610.1), Kristi Arsenault (SAIC/617), Jim Geiger (587), and Amy McNally (ESSIC/617).

LVT definitions

LVT functions both as a verification and benchmarking environment



The Plumbing of Land Surface Models: Benchmarking Model Performance

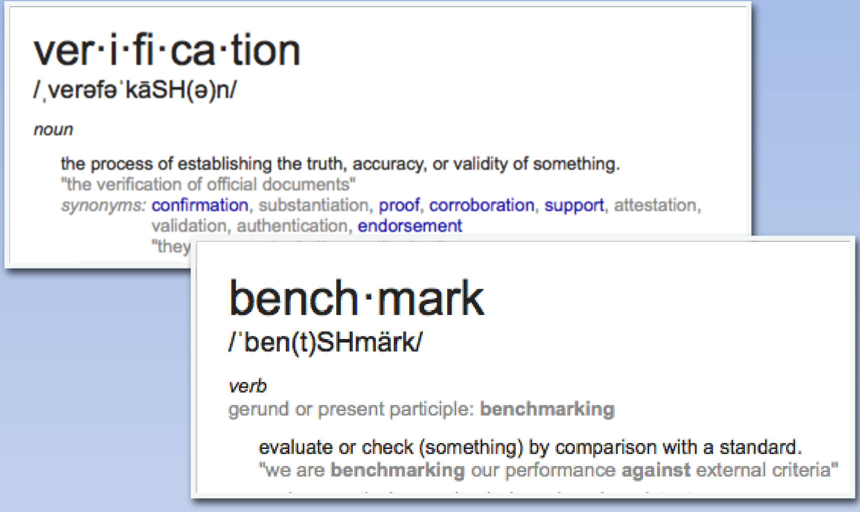
M. J. Best,[a] G. Abramowitz,[b] H. R. Johnson,[a] A. J. Pitman,[b] G. Balsamo,[c] A. Boone,[d] M. Cuntz,[e] B. Decharme,[d] P. A. Dirmeyer,[f] J. Dong,[g] M. Ek,[g] Z. Guo,[f] V. Haverd,[h] B. J. J. van den Hurk,[i] G. S. Nearing,[j] B. Pak,[k] C. Peters-Lidard,[j] J. A. Santanello Jr.,[j] L. Stevens,[k] and N. Vuichard[l]

[a] *Met Office, Exeter, United Kingdom*
[b] *ARC Centre of Excellence for Climate System Science, University of New South Wales, Sydney, New South Wales, Australia*
[c] *ECMWF, Reading, United Kingdom*
[d] *CNRM-GAME, Météo-France, Toulouse, France*
[e] *Helmholtz Centre for Environmental Research–UFZ, Leipzig, Germany*
[f] *Center for Ocean–Land–Atmosphere Studies, George Mason University, Fairfax, Virginia*
[g] *NOAA/NCEP/EMC, College Park, Maryland*
[h] *Oceans and Atmosphere Flagship, CSIRO, Canberra, Australian Capital Territory, Australia*
[i] *KNMI, De Bilt, Netherlands*
[j] *Hydrological Sciences Laboratory, NASA GSFC, Greenbelt, Maryland*
[k] *Oceans and Atmosphere Flagship, CSIRO, Aspendale, Victoria, Australia*
[l] *Laboratoire des Sciences du Climat et de l'Environnement, UMR 8212, IPSL-LSCE, CEA-CNRS-UVSQ, Gif-sur-Yvette, France*

(Manuscript received 27 August 2014, in final form 19 December 2014)

ABSTRACT

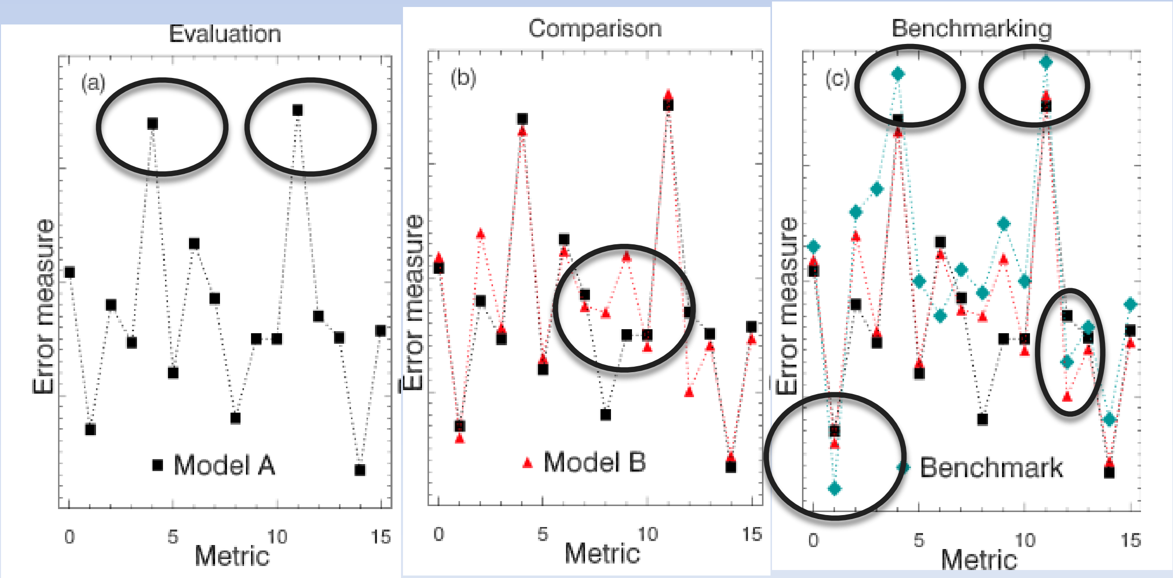
The Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project (PLUMBER) was designed to be a land surface model (LSM) benchmarking intercomparison. Unlike the traditional methods of LSM evaluation or comparison, benchmarking uses a fundamentally different approach in that it sets expectations of performance in a range of metrics a priori—before model simulations are performed. This can lead to very different conclusions about LSM performance. For this study, both simple



ver·i·fi·ca·tion
/ˌverəfəˈkāSH(ə)n/
noun
the process of establishing the truth, accuracy, or validity of something.
"the verification of official documents"
synonyms: confirmation, substantiation, proof, corroboration, support, attestation, validation, authentication, endorsement
"they

bench·mark
/ˈben(t)SHmärk/
verb
gerund or present participle: **benchmarking**
evaluate or check (something) by comparison with a standard.
"we are **benchmarking** our performance **against** external criteria"

- **Evaluation** - model outputs are compared to observations to derive an error measure
- **Comparison** - model is not just compared to observations, but also to other models
- **Benchmarking** - performance expectation defined a priori



source: Best et al. (2015)

NLDAS Science Testbed Plans

The LIS group has developed an NLDAS Science Testbed, designed to test various LSMs, parameters, and data assimilation within the Land Information System using the NLDAS configuration. These simulations are also being evaluated against the four operational LSMs running in NLDAS Phase 2.

- Spin-Up: 70 years (1979 to 2014 twice) – and then running 1979 to 2015
- Evaluation period: (2002-2012; 11 years with the most evaluation data)
- Output:
    - Monthly water states during the two spin-up periods to track number of years required for equilibrium
    - Daily output during the third simulation of all relevant energy/water terms
- Evaluation: Using the Land Verification Toolkit (LVT) to evaluate soil moisture, snow, ET/fluxes, surface radiation, runoff, streamflow, groundwater

NLDAS Science Testbed Metrics

Metrics of the simulations are also being recorded and compared. All of the runs are being done on the NASA NCCS Discover platform, using 252 processors and O1 optimization. Some sample wall-clock times for the 36-year final simulation:

LSM / EXP ID	Wall-clock time (hours)	Description / Changes
Noah-3.2 / 100	16.25	Used 6-m for U/V and T/q forcing height
Noah-3.3 / 100	16.81	Same as [Noah-3.2 / 100], but with 10-m for U/V and 2-m for T/q
Noah-3.6 / 100	16.81	Same as [Noah-3.3 / 100], but with Univ. of Arizona snow-physics
CLSM-F2.5 / 100	15.56	CLSM-F2.5 with updated parameters
CLSM-F2.5 / 101	15.79	Same as [CLSM-F2.5 / 100], but with original lower-resolution parameters
CLSM-F2.5 / 102	15.79	Same as [CLSM-F2.5 / 100], but with 2-meters added to bedrock depth
Noah-MP-3.6 / 100	18.67	WRF default configuration
Noah-MP-3.6 / 101	20.65	Same as [Noah-MP-3.6 / 100], but with dynamic vegetation
Noah-MP-3.6 / 102	20.22	Configuration as close as possible to [Noah-3.6 / 100]

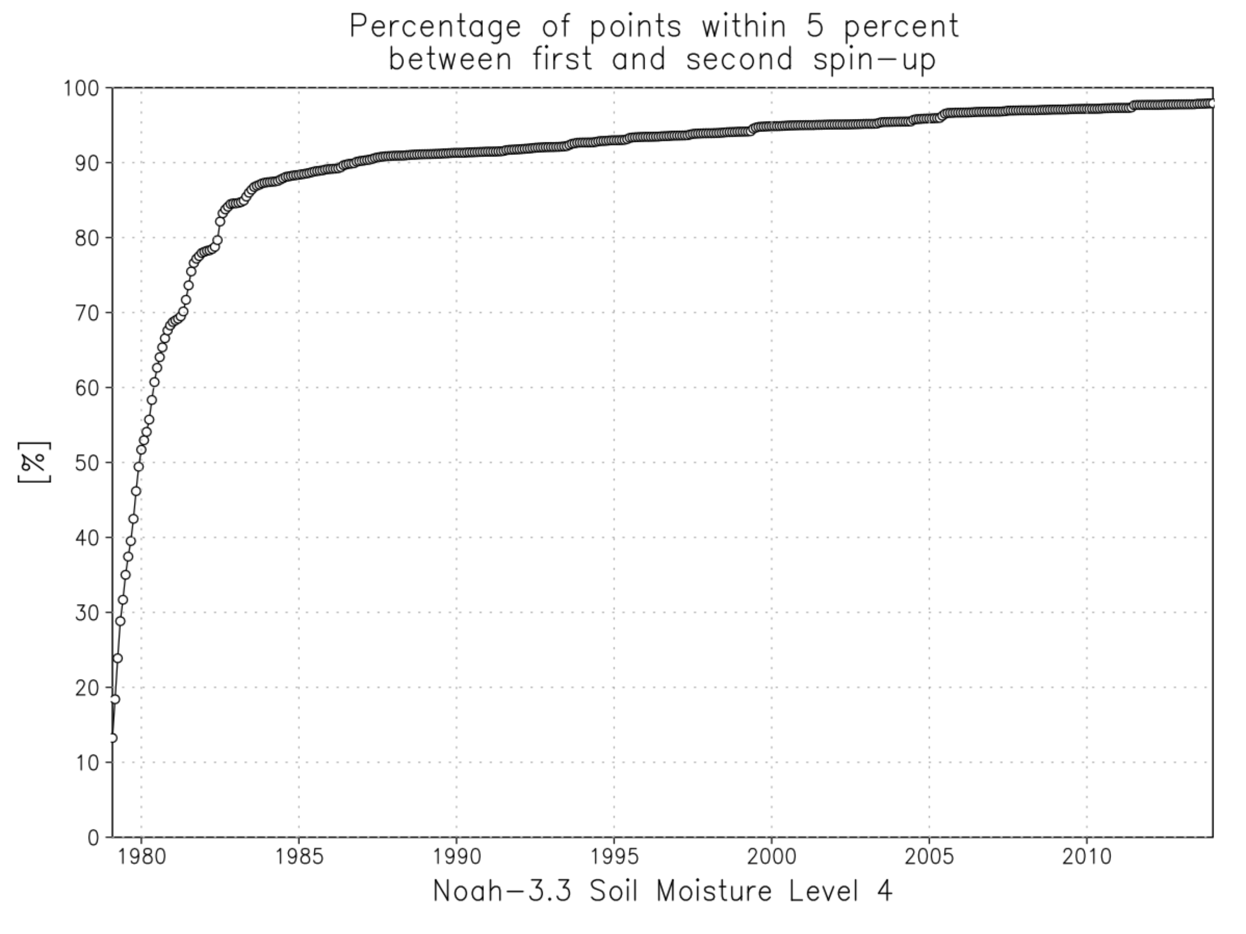
NLDAS Science Testbed Spin-Ups

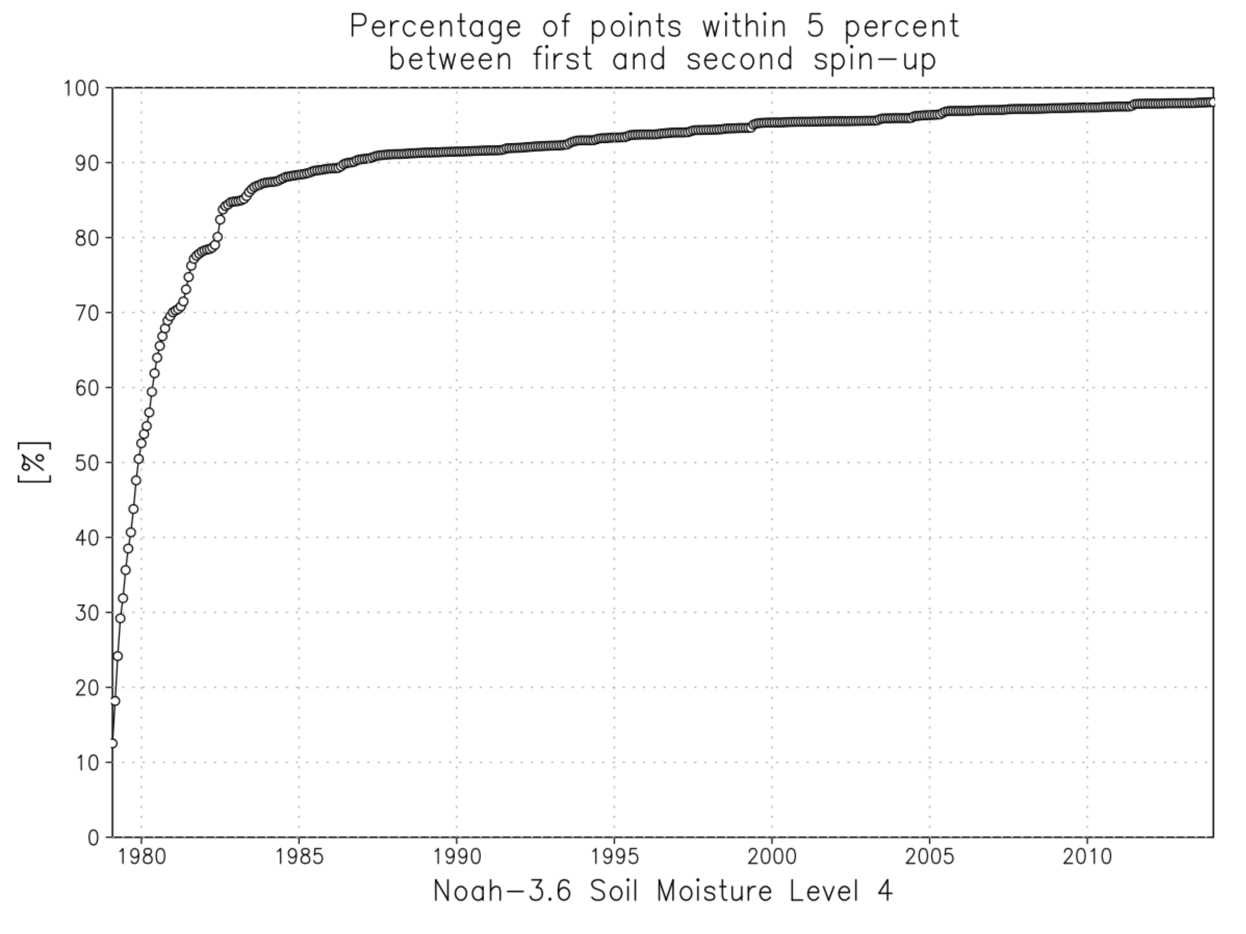
The Global Soil Wetness Project (GSWP) instructed for the LSMs to be cycled through a single year for 2-10 times until the soil moisture/ temperature variables were with 5% of the value at the end of the previous year.

For the NLDAS Science Testbed, we calculated the fraction of all 76088 NLDAS grid points that are within 5% and are within 1% of the same end-of-month instantaneous value between the first “coldstart” simulation and the second “spin-up simulation”.

Variables: soil moisture/temps, SWE, streamflow, TWS, vegetation

100-200cm soil moisture within 5%

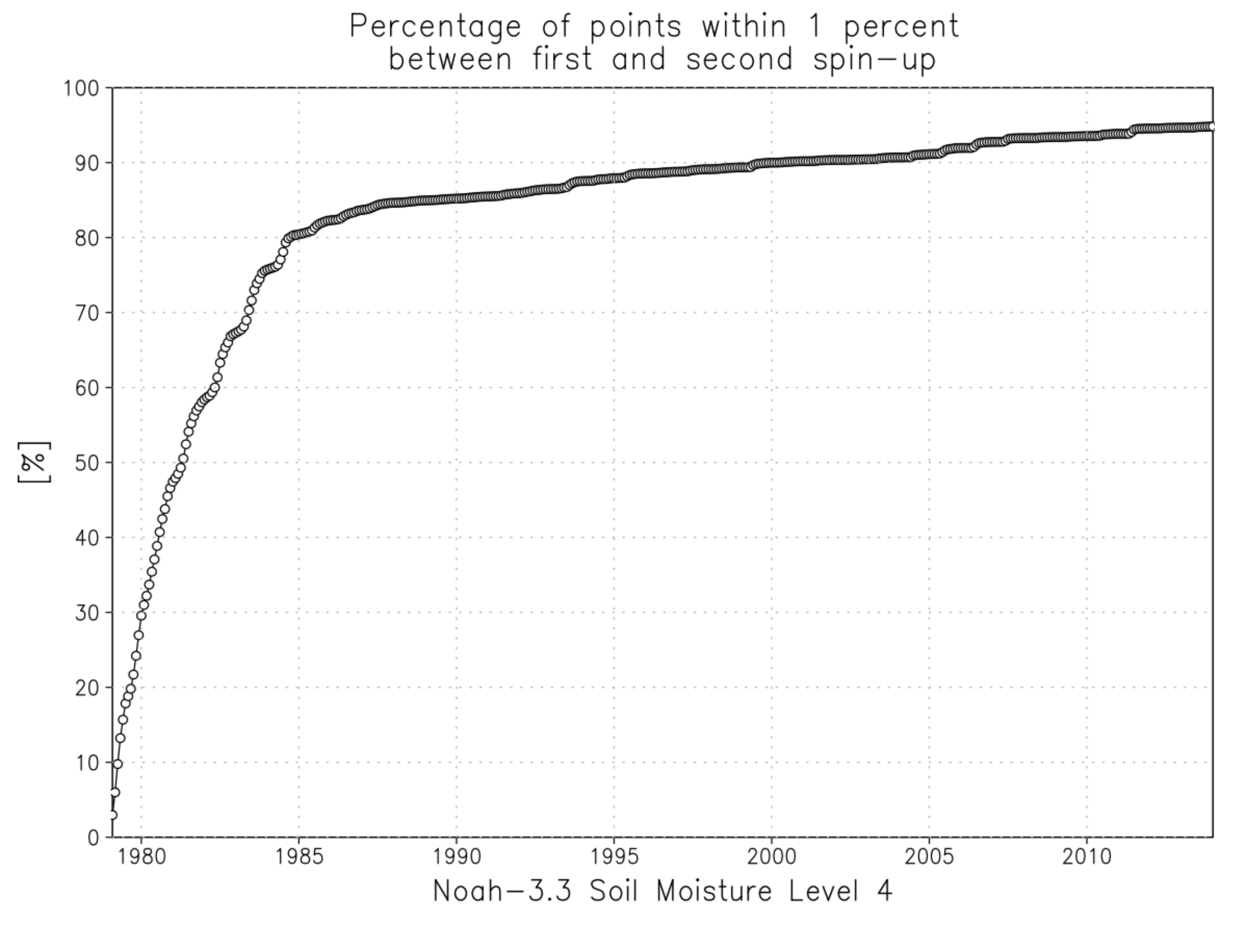


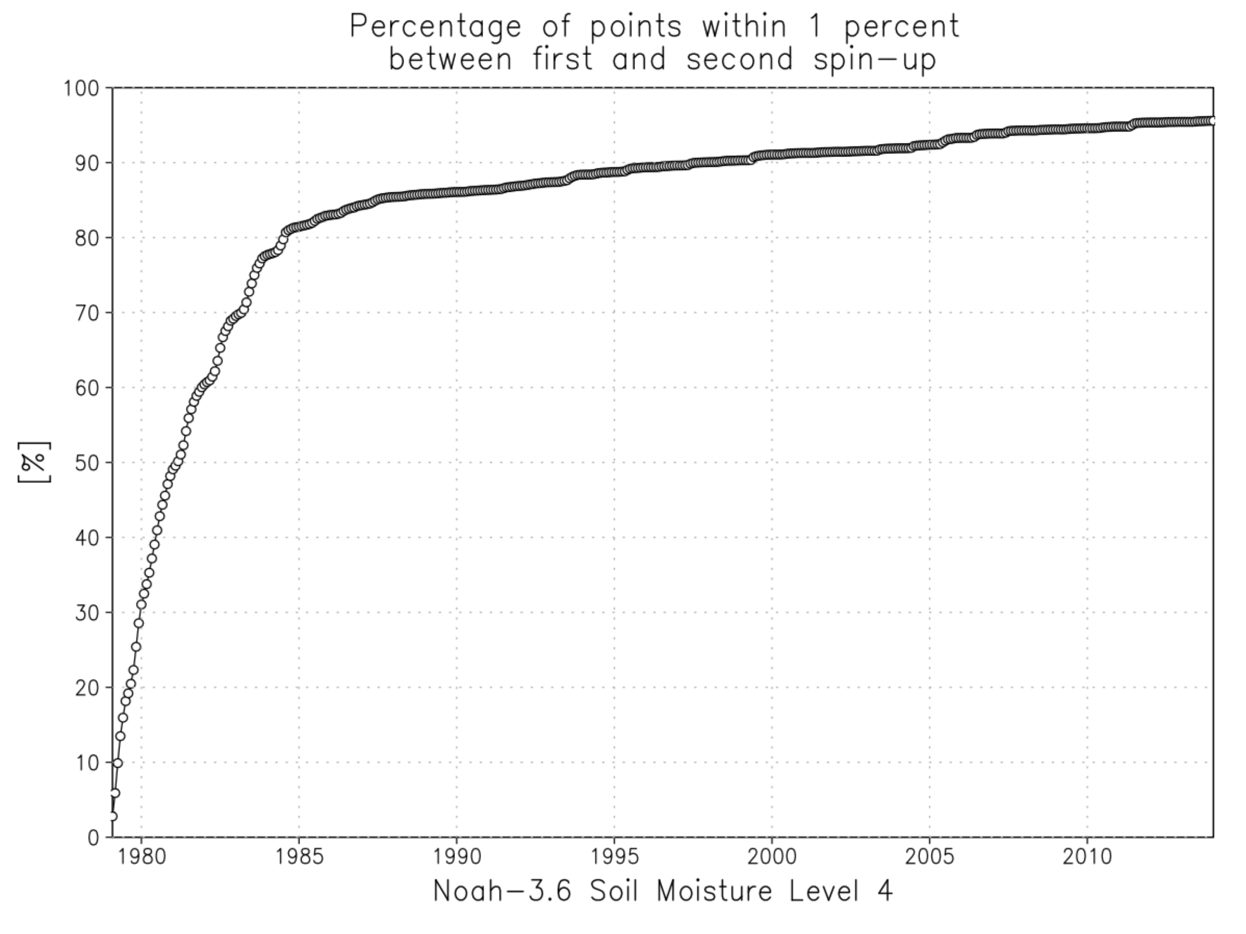


Noah-3.3 / 100

Noah-3.6 / 100

100-200cm soil moisture within 1%

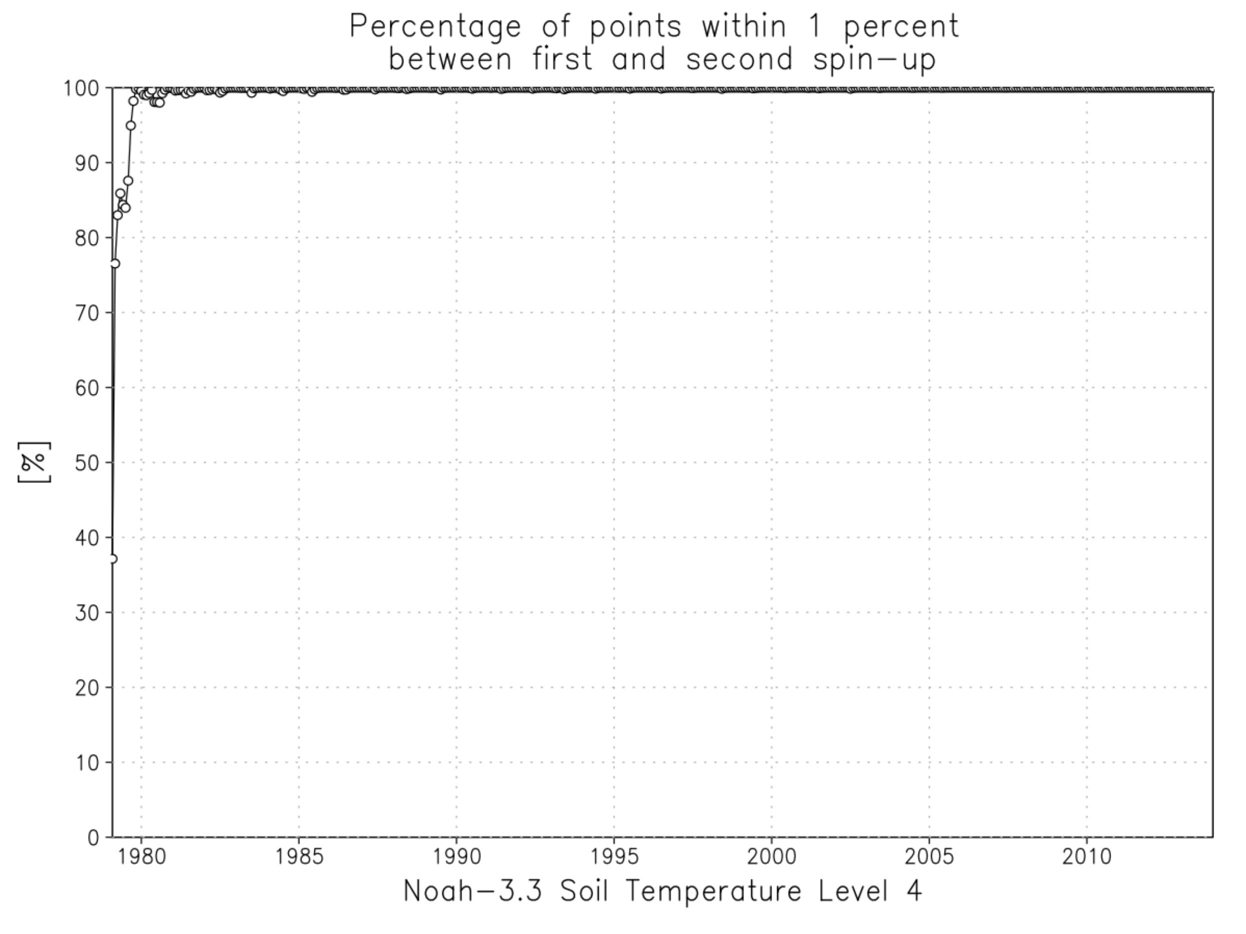


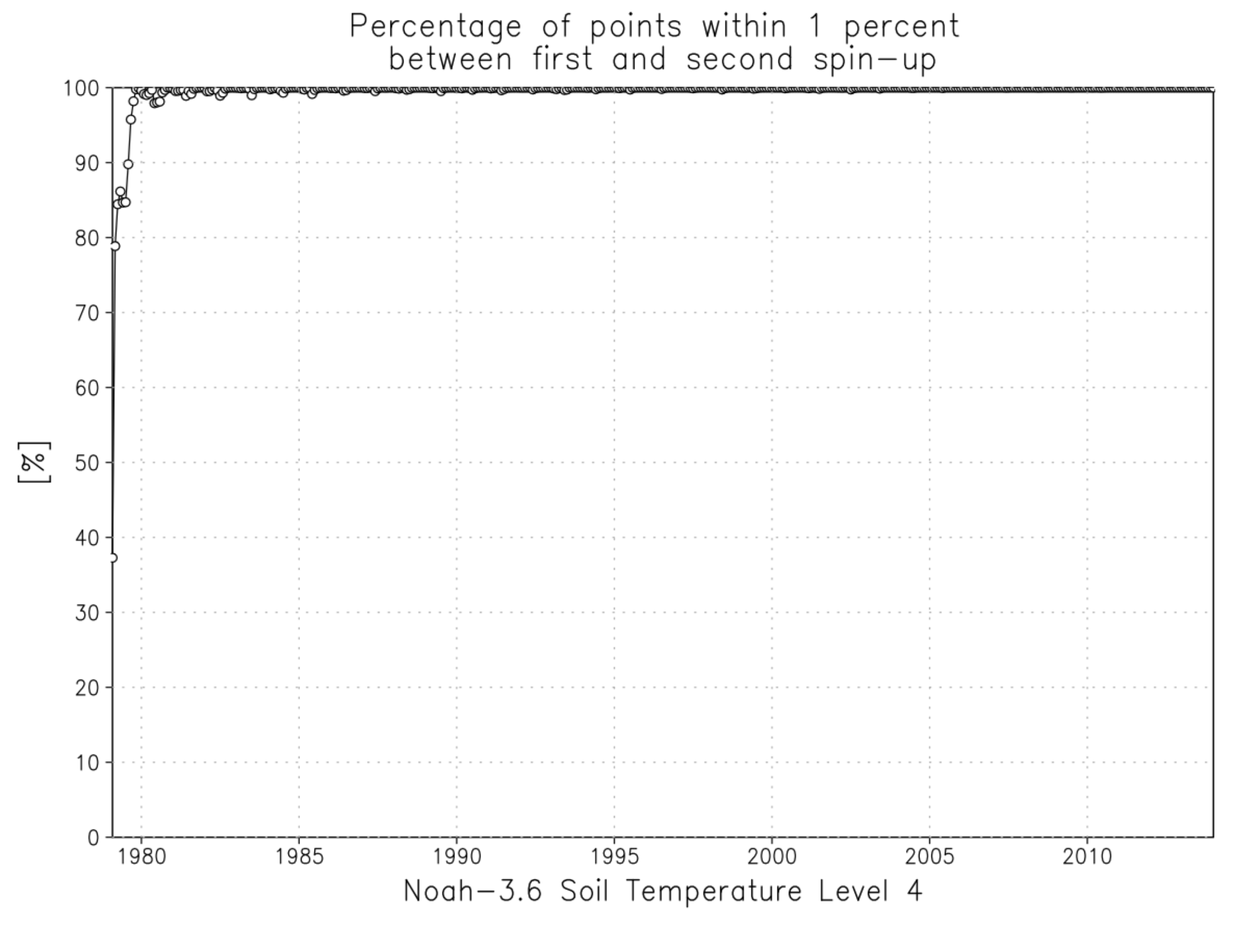


Noah-3.3 / 100

Noah-3.6 / 100

100-200cm soil temperature within 1%

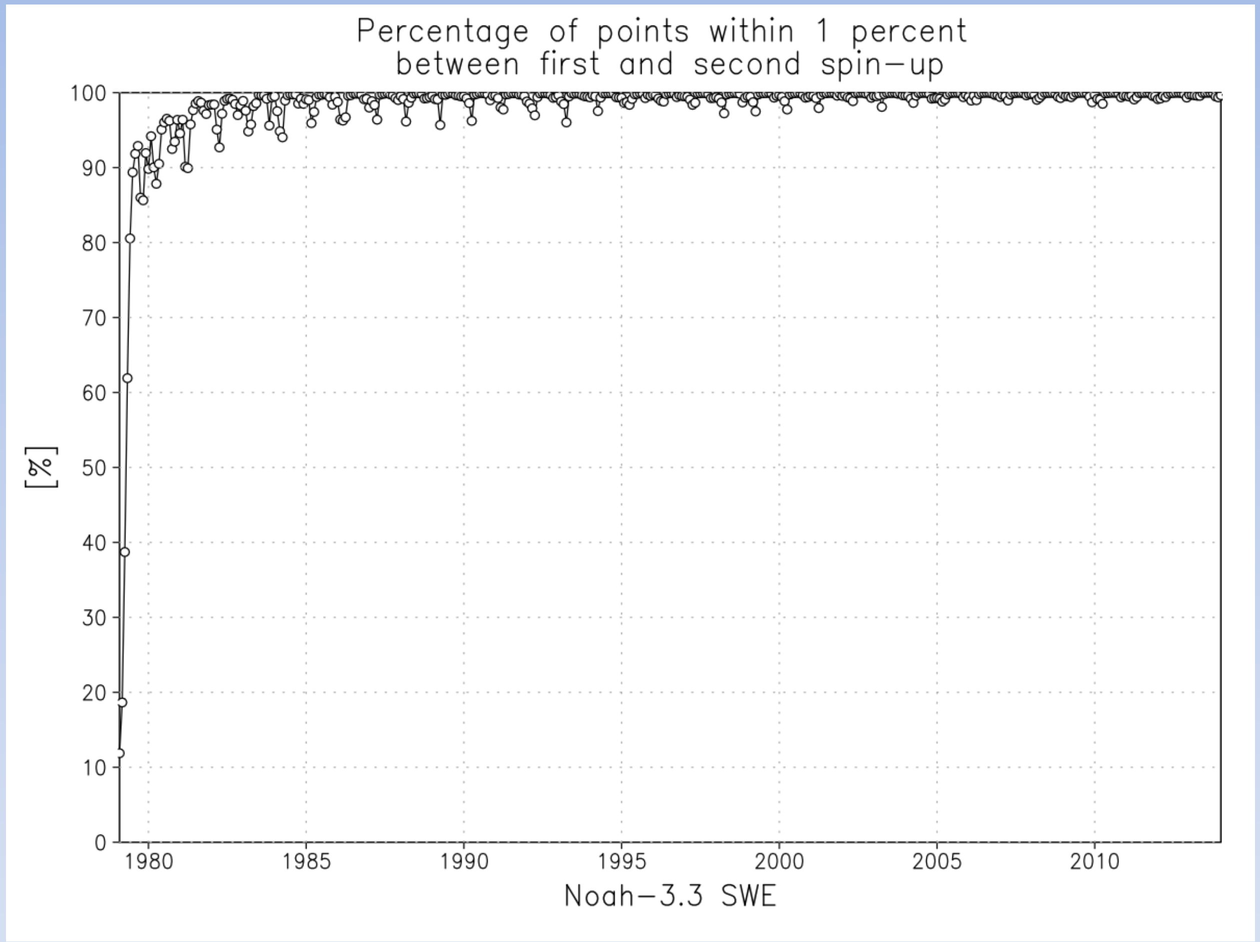


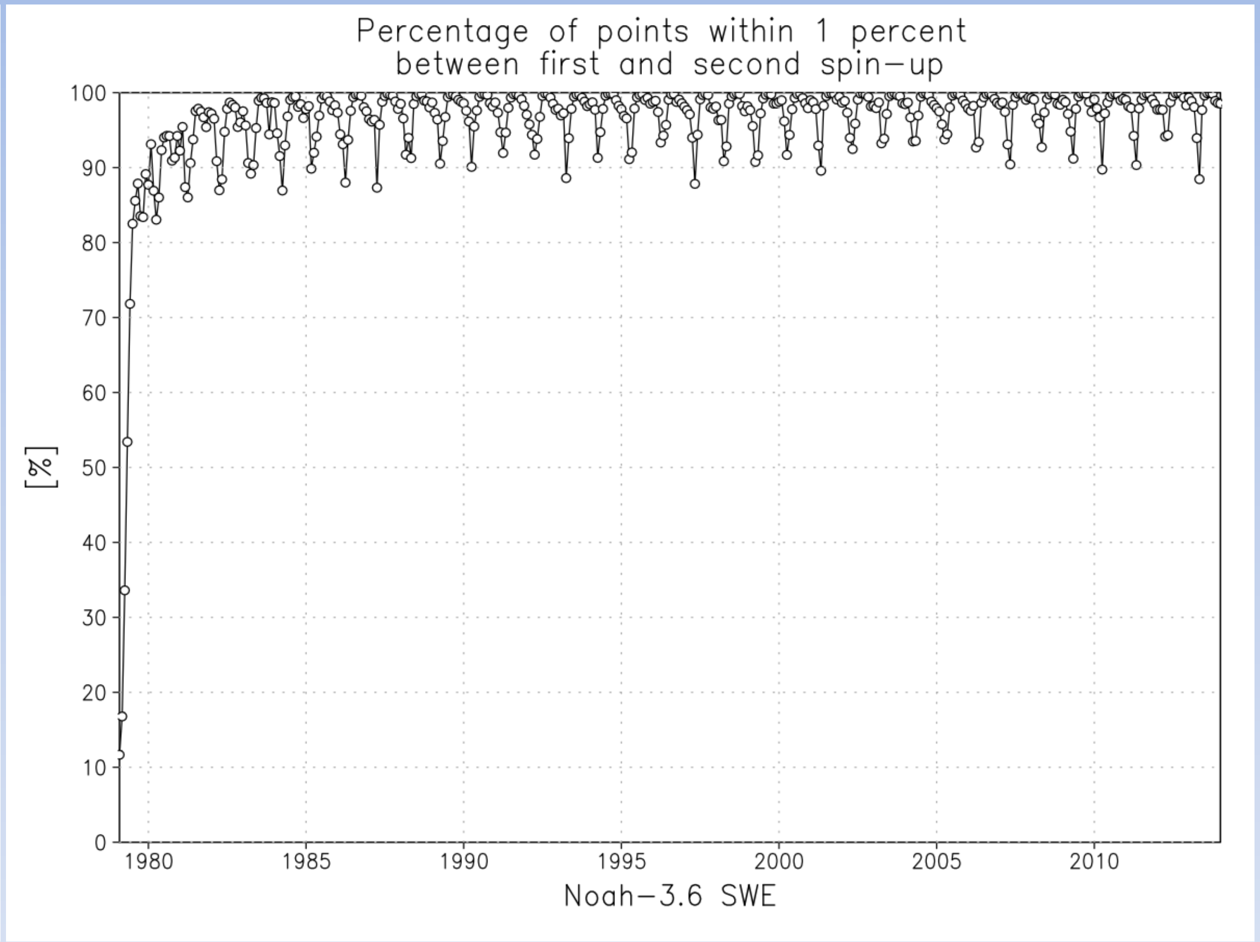


Noah-3.3 / 100

Noah-3.6 / 100

Snow Water Equivalent (SWE) within 1%

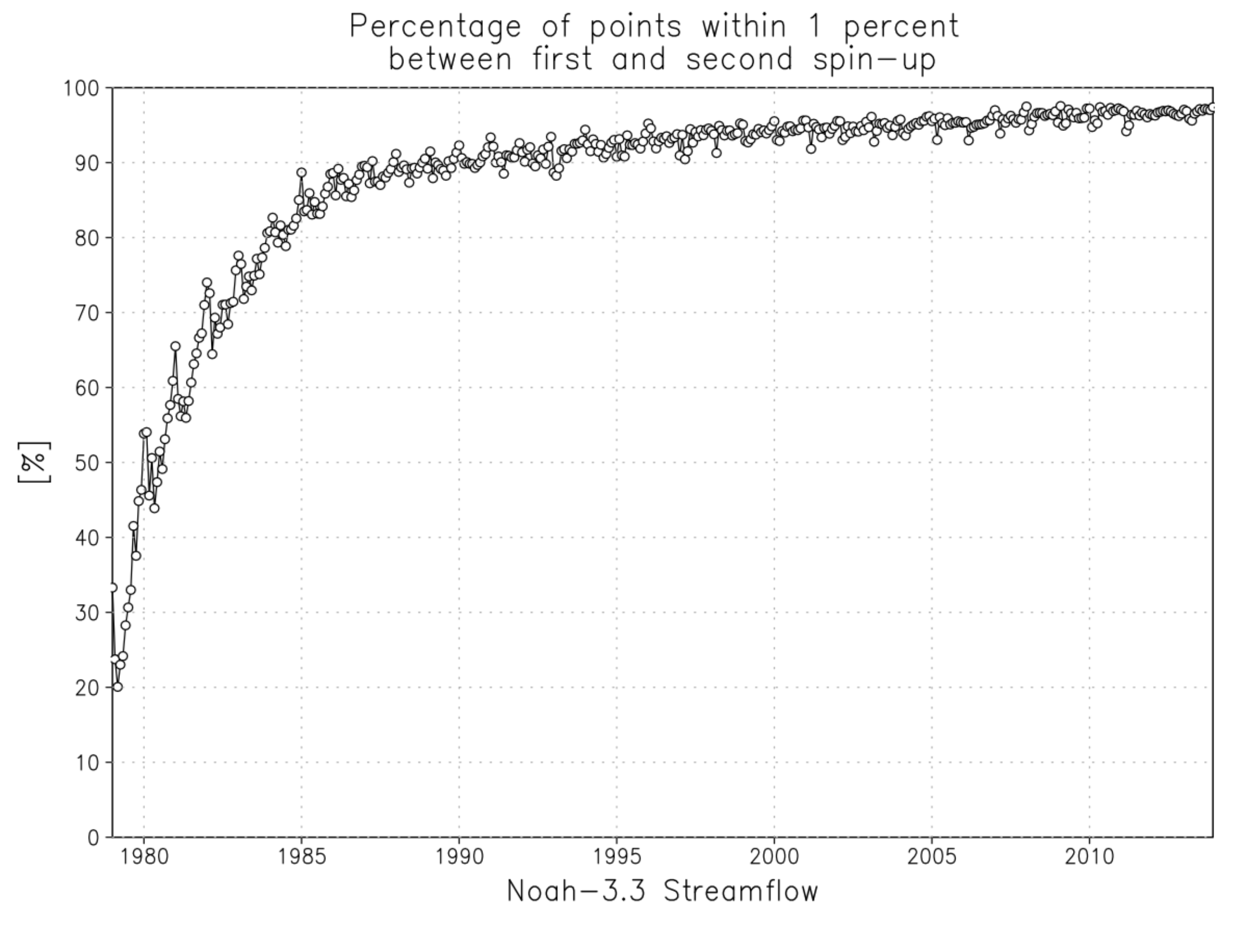


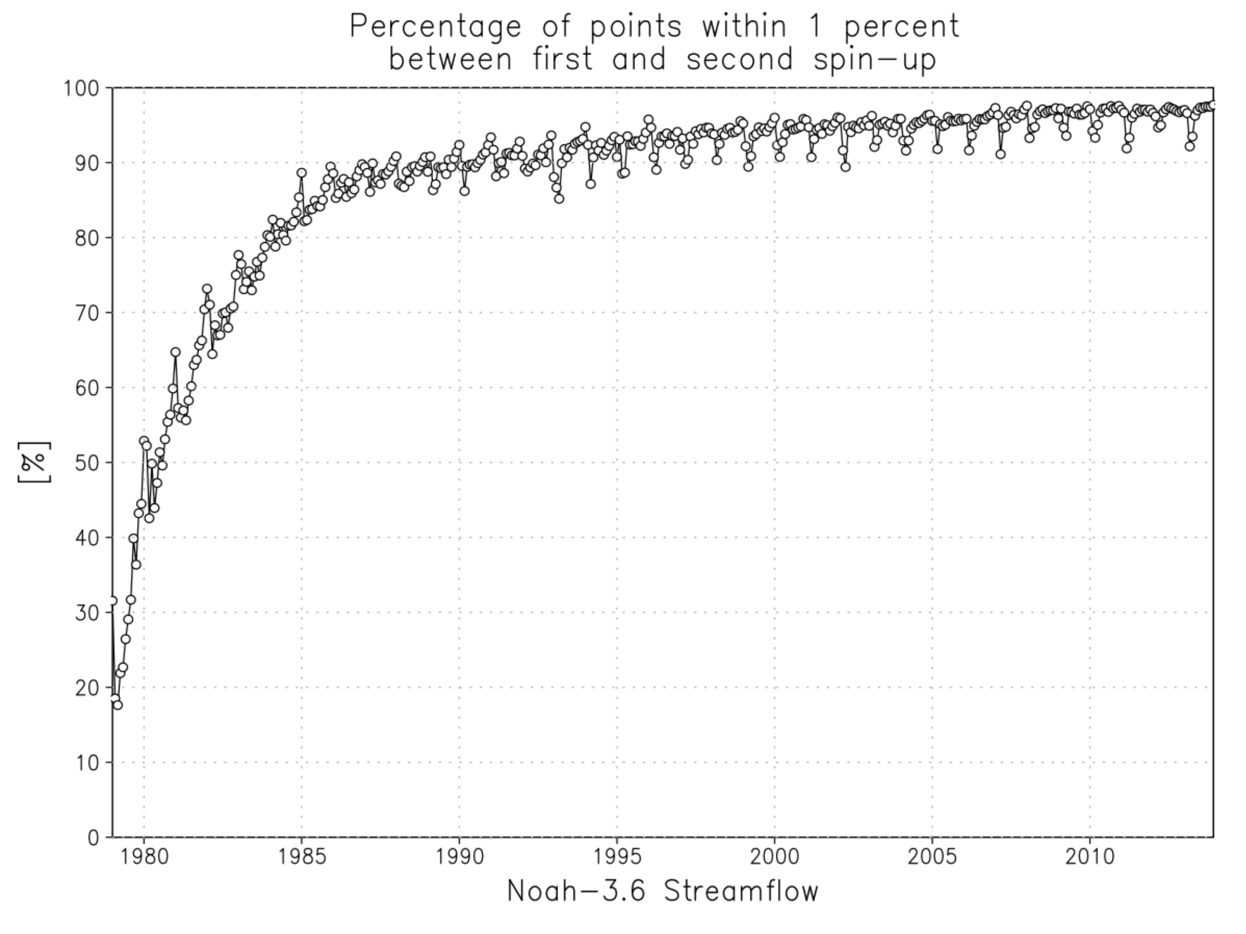


Noah-3.3 / 100

Noah-3.6 / 100

Streamflow within 1%

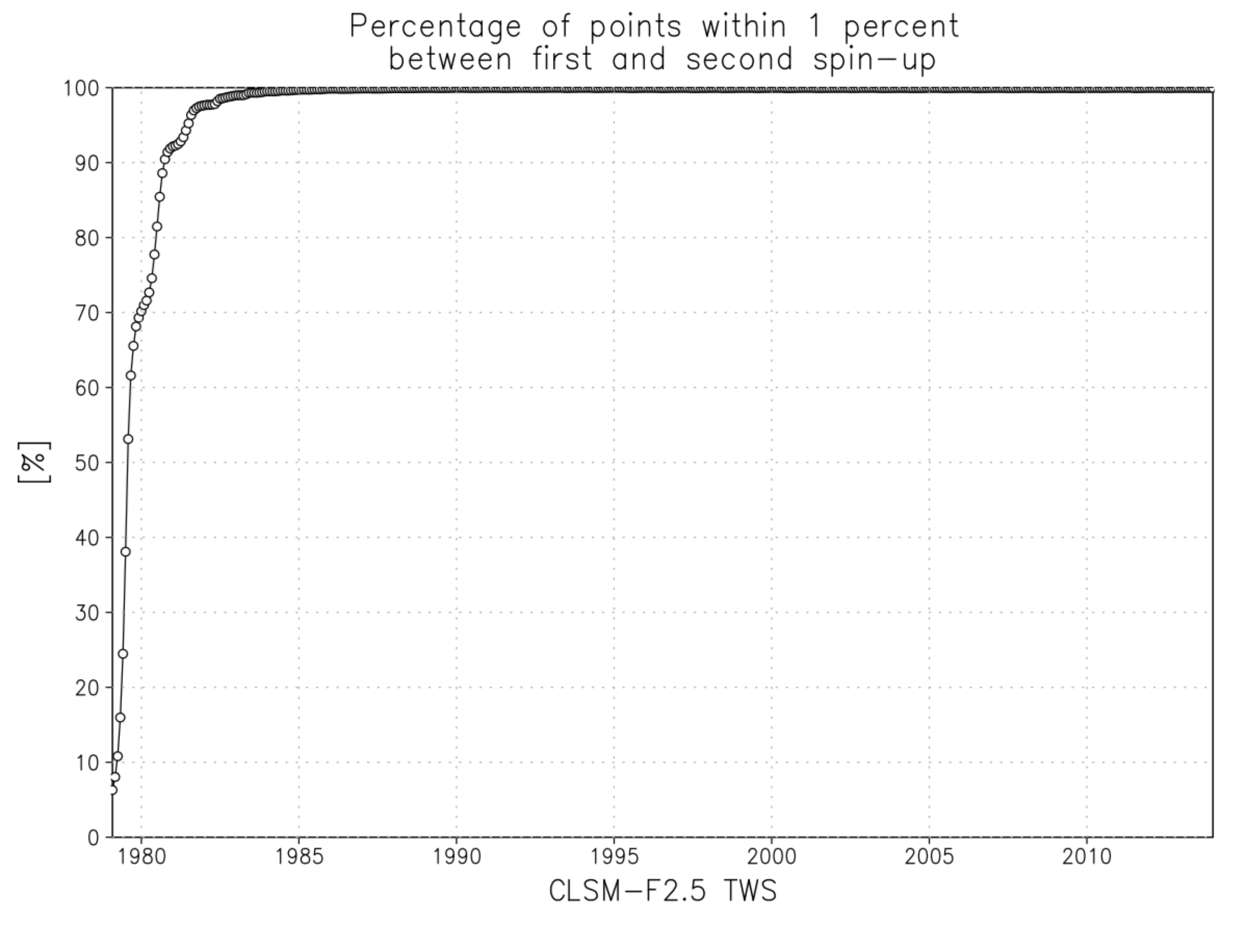


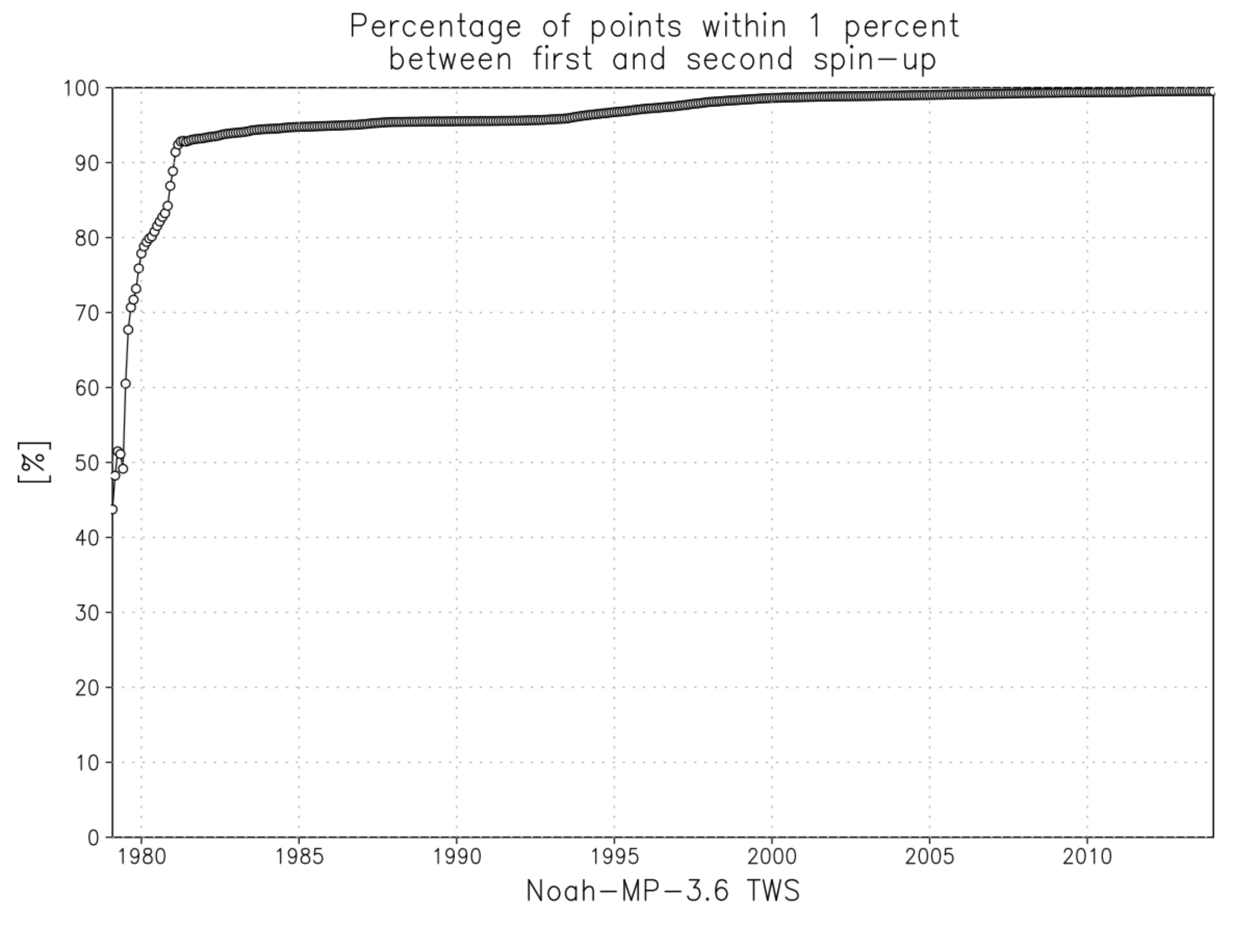


Noah-3.3 / 100

Noah-3.6 / 100

Terrestrial Water Storage (TWS) within 1%

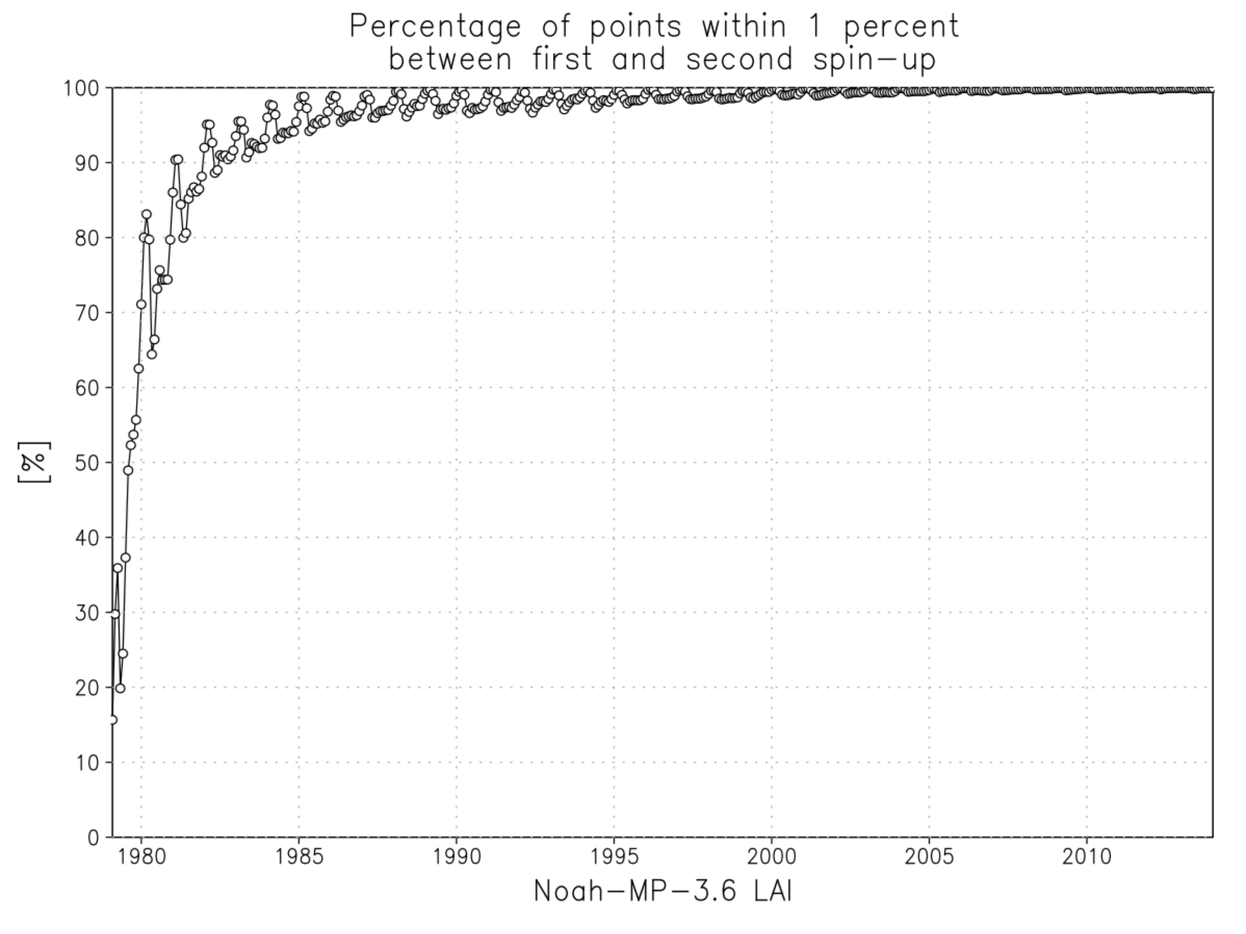


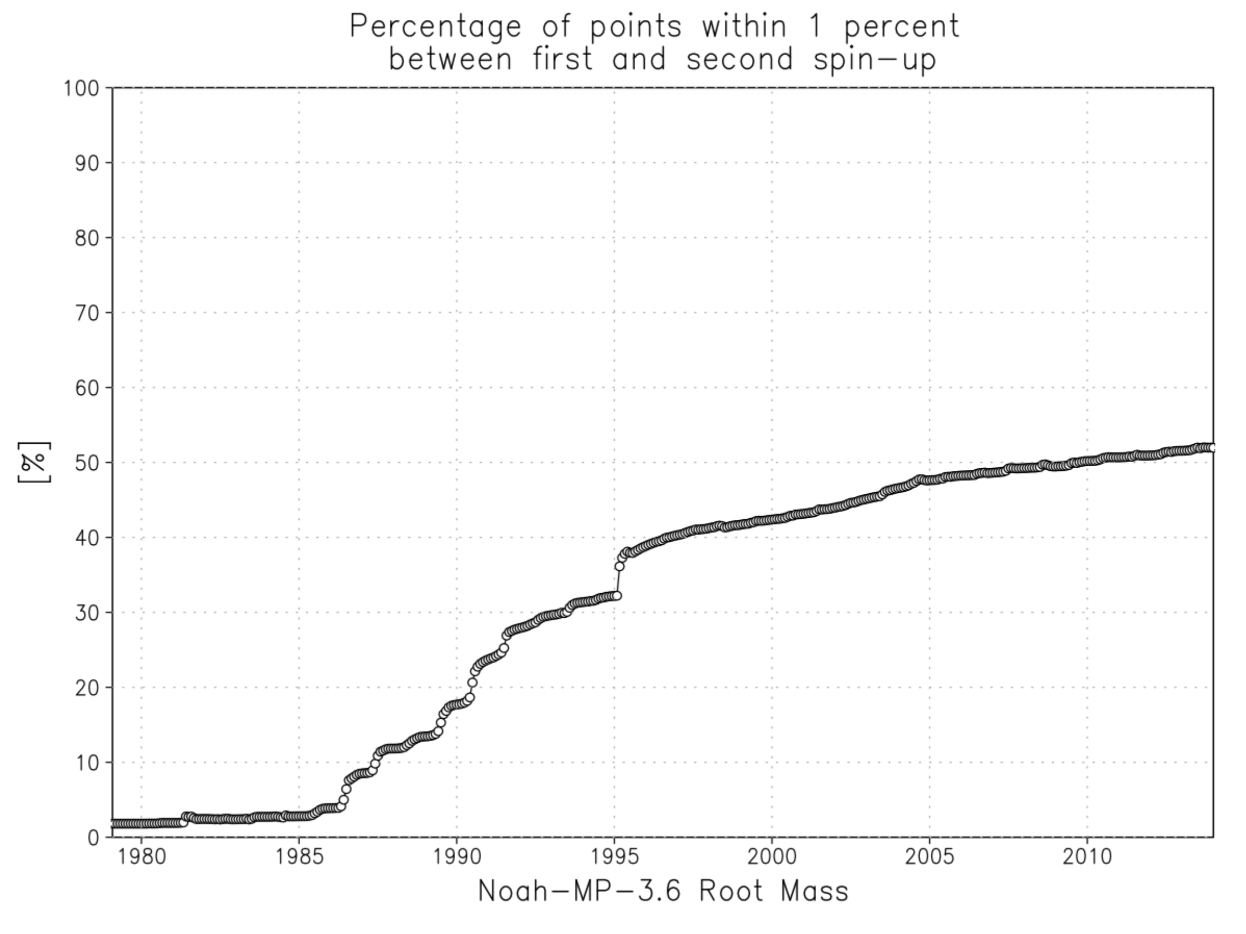


CLSM-F2.5 / 100

Noah-MP-3.6 / 100

Dynamic vegetation variables within 1%



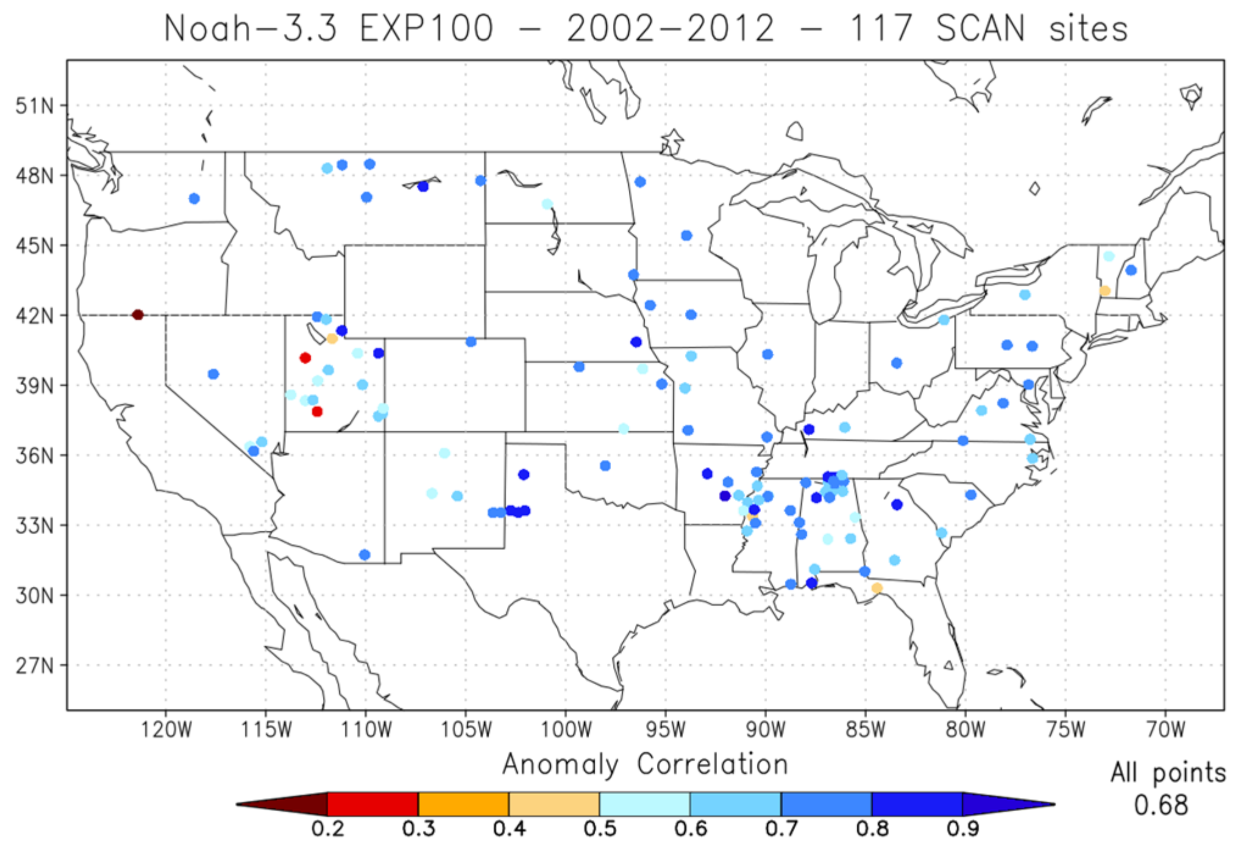


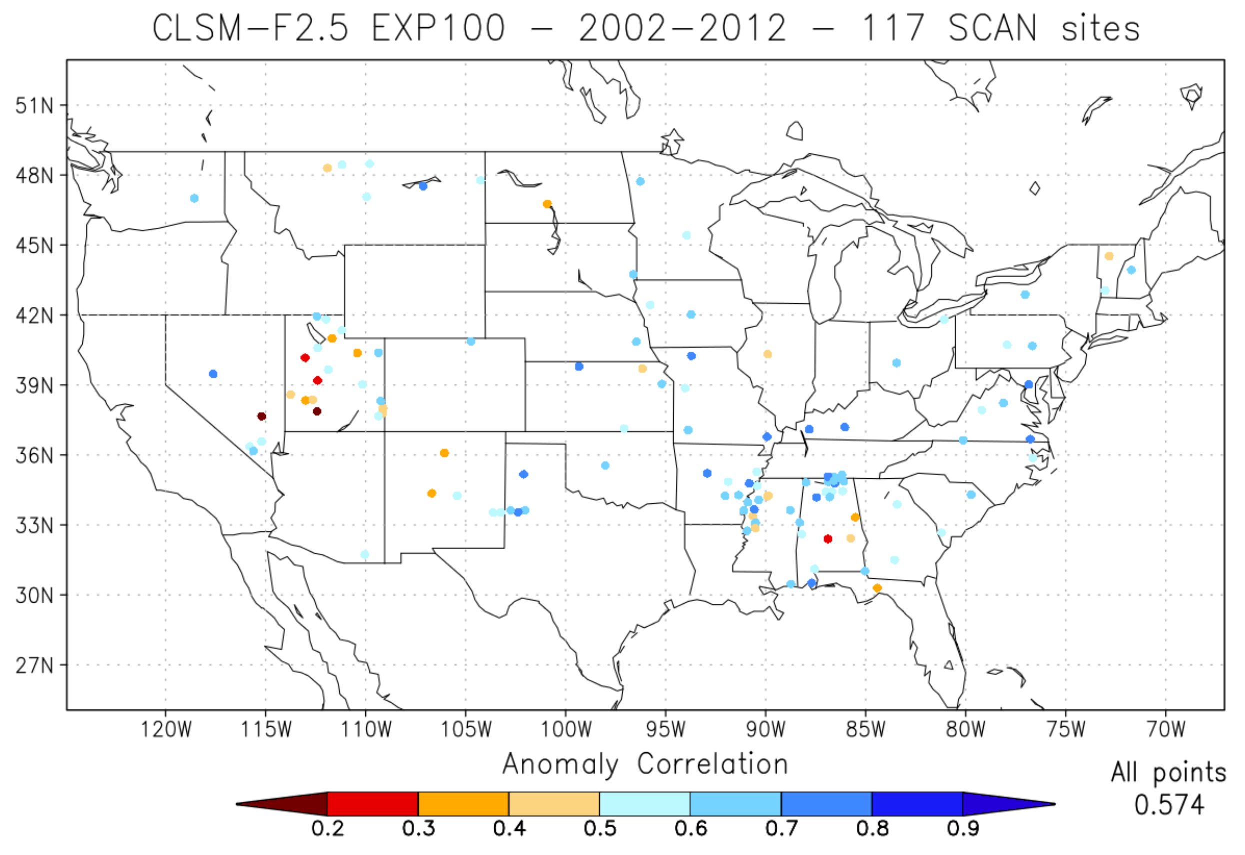
Noah-MP-3.6 / 101
LAI

Noah-MP-3.6 / 101
Root Mass

NLDAS Science Testbed Preliminary Evaluation

SCAN surface soil moisture – anomaly correlation



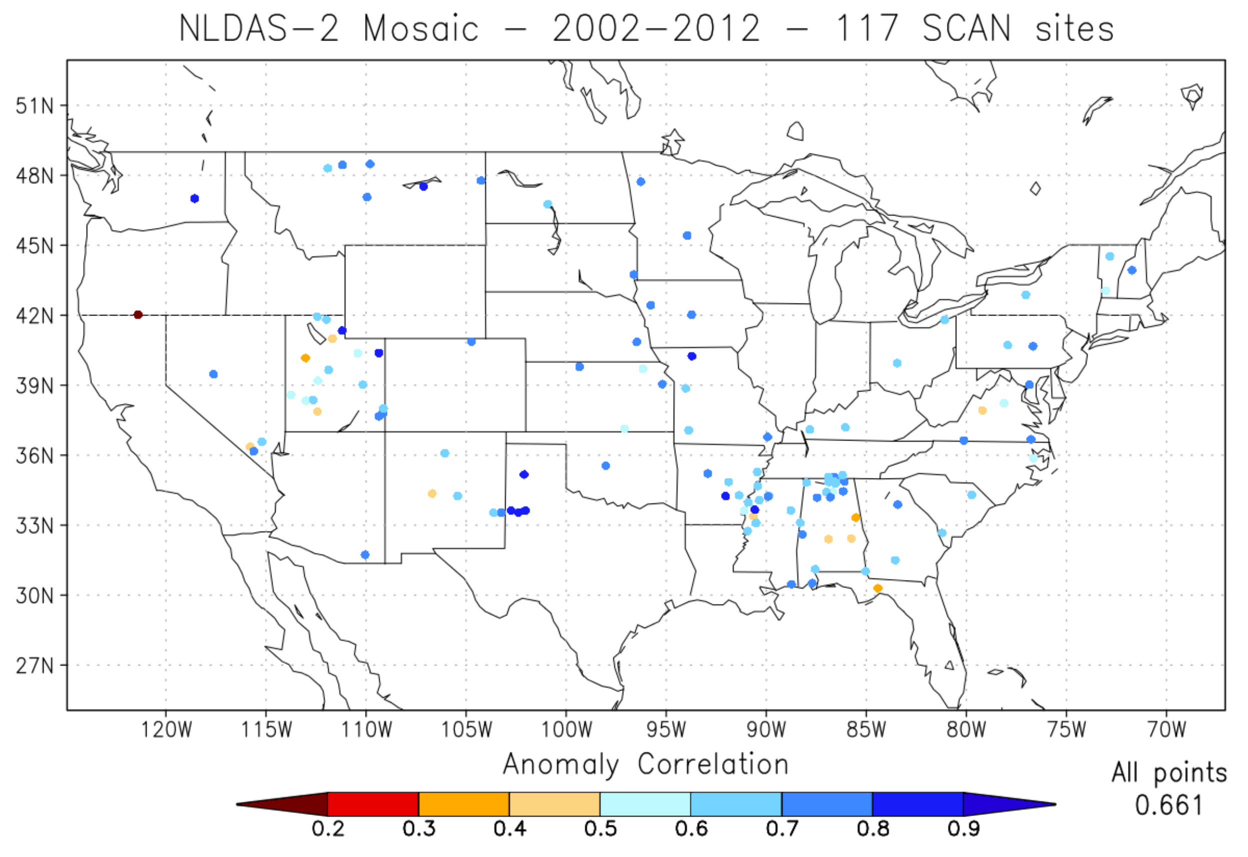


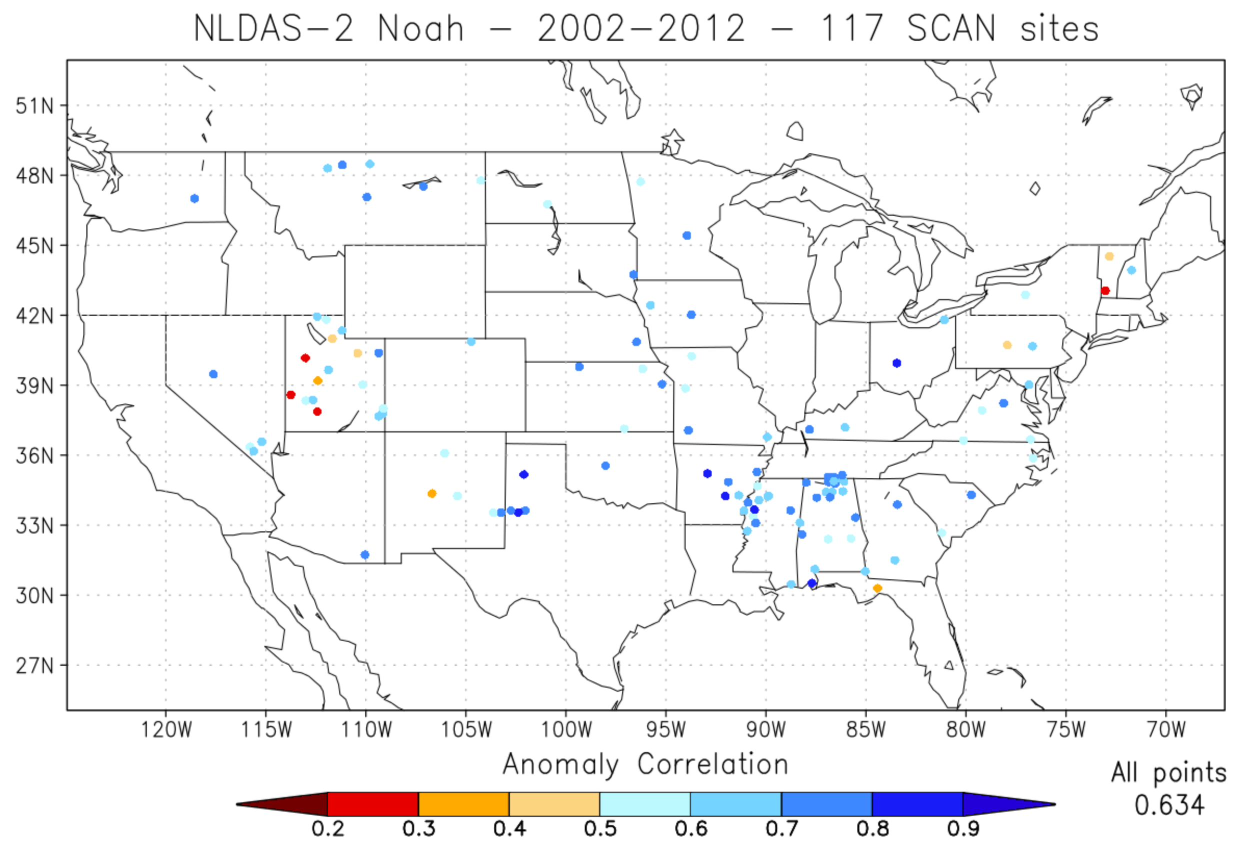
Noah-3.3 / 100

CLSM-F2.5 / 100

NLDAS Science Testbed Preliminary Evaluation

SCAN surface soil moisture – anomaly correlation



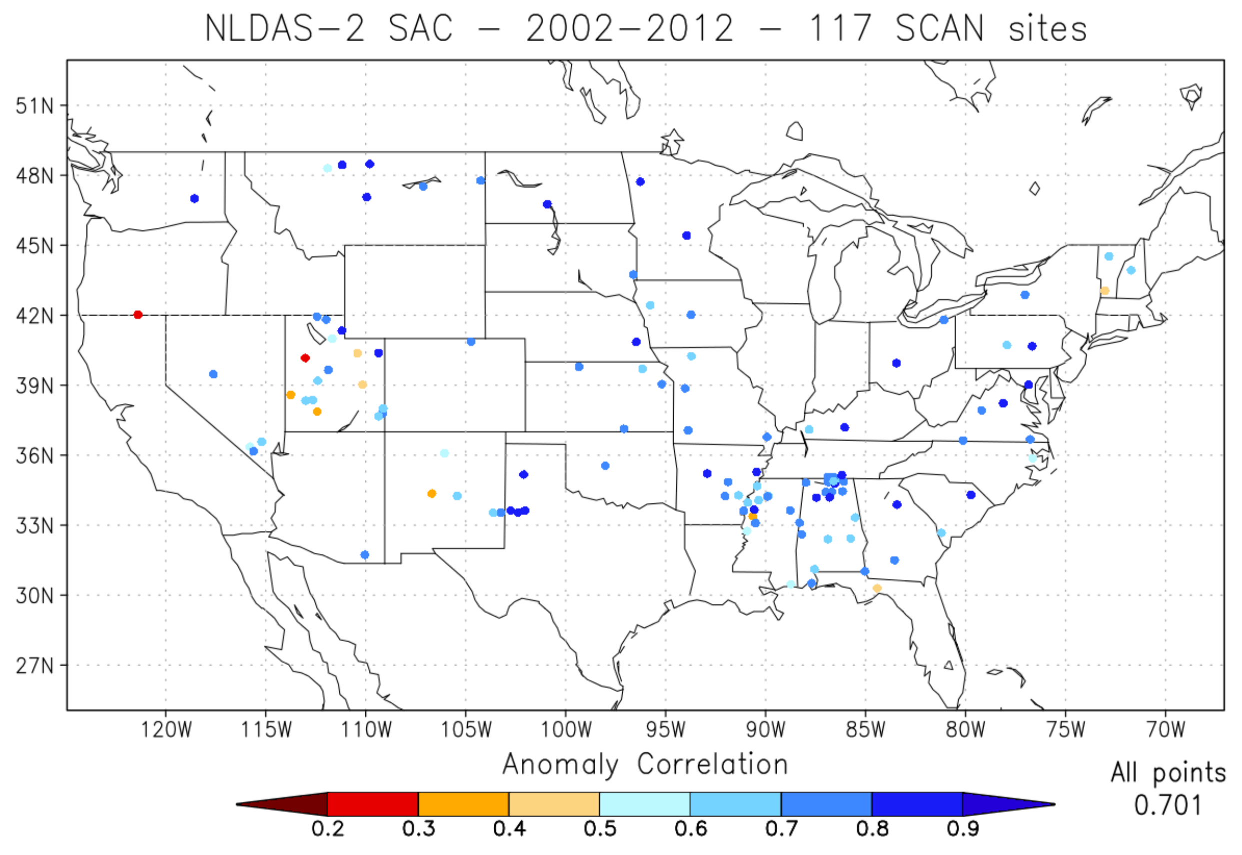


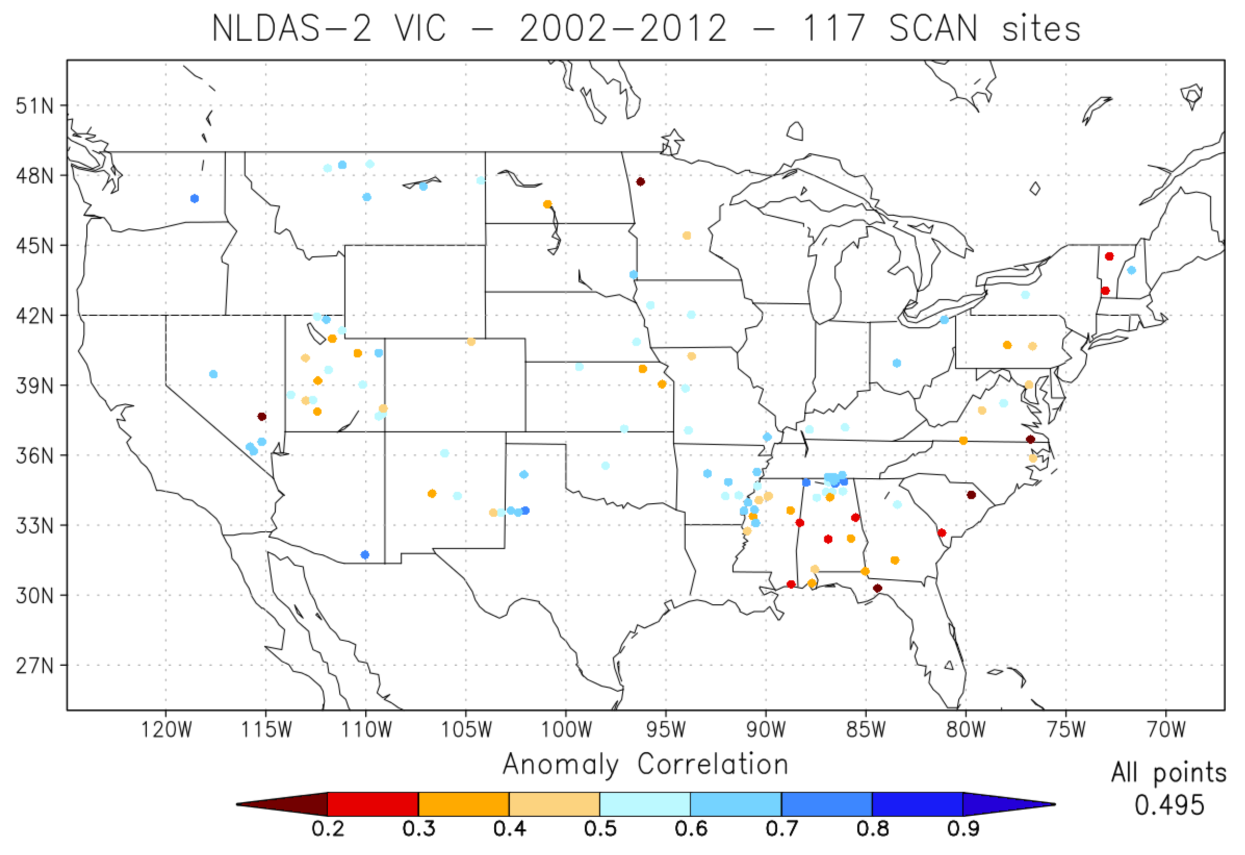
NLDAS-2 Mosaic

NLDAS-2 Noah

NLDAS Science Testbed Preliminary Evaluation

SCAN surface soil moisture – anomaly correlation





NLDAS-2 SAC

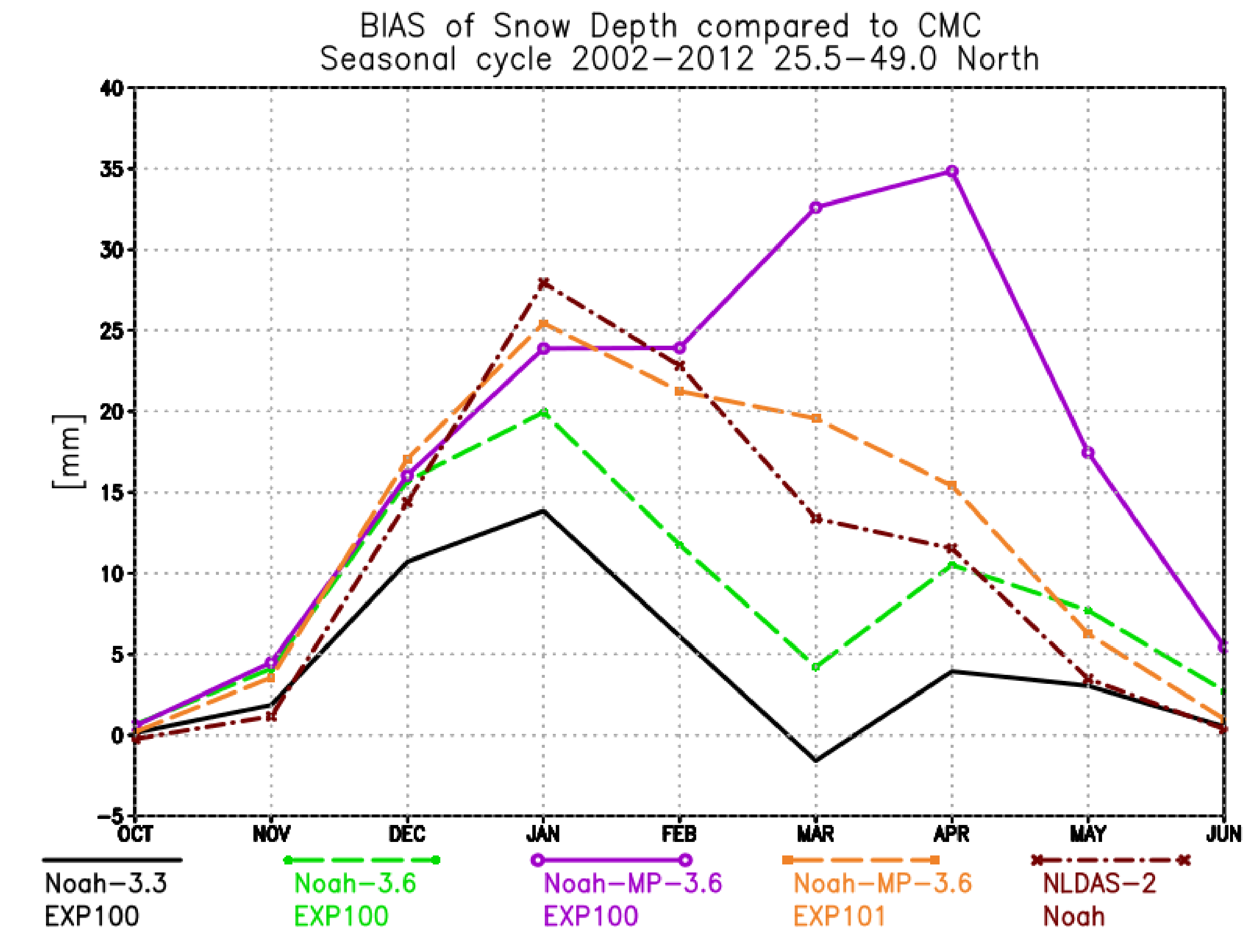
NLDAS-2 VIC

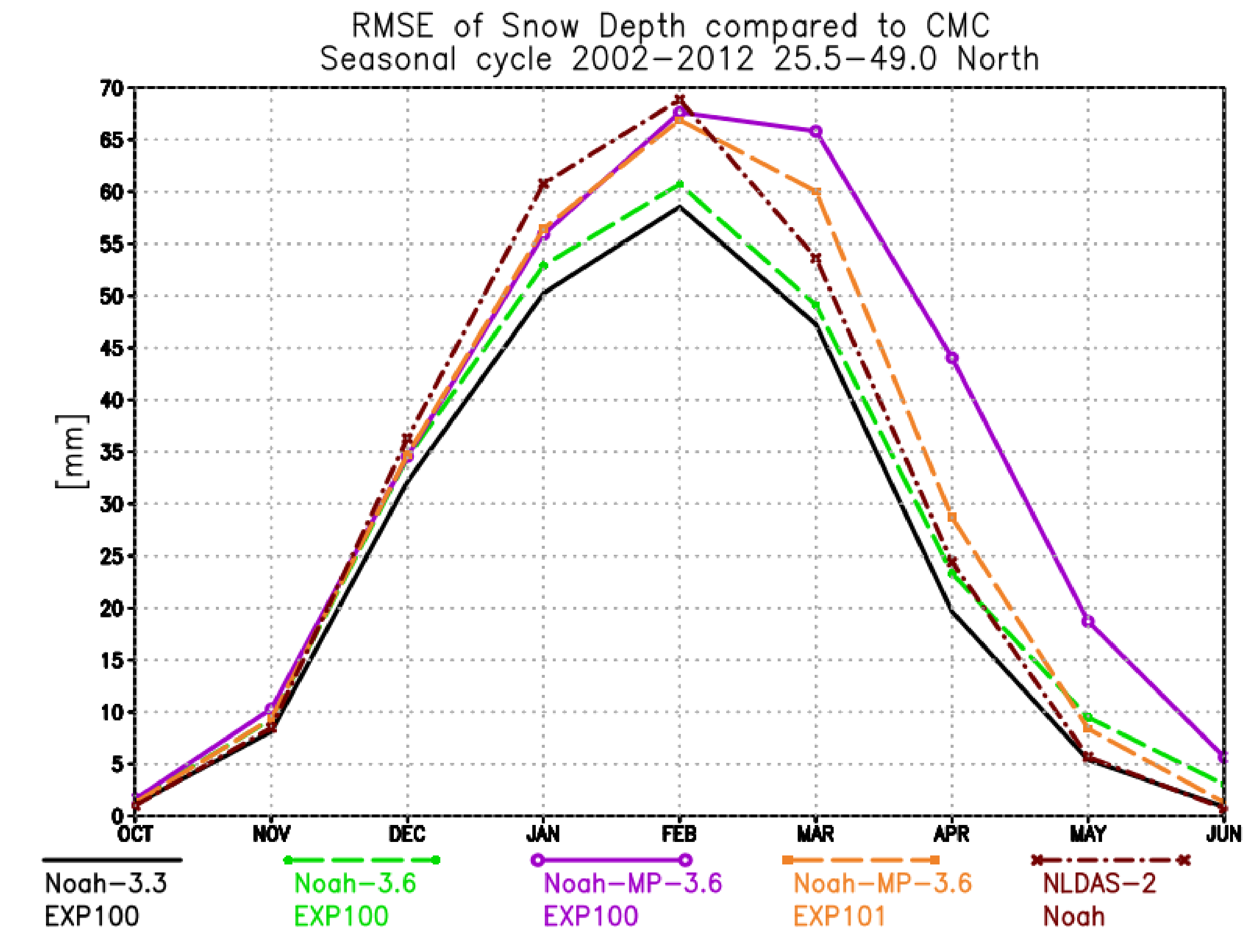
NLDAS Science Testbed Preliminary Evaluation

Anomaly correlation of surface soil moisture calculated using LVT for 117 SCAN locations:

LSM / EXP ID	SCAN Anomaly Corr.	Description / Changes
NLDAS-2 Mosaic	0.661	Using an older version of LIS
NLDAS-2 Noah	0.634	Noah-2.8
NLDAS-2 SAC	0.701	SAC soil moisture conceptual zones converted to Noah soil moisture levels
NLDAS-2 VIC	0.495	VIC-4.0.3
Noah-3.2 / 100	0.683	Used 6-m for U/V and T/q forcing height
Noah-3.3 / 100	0.680	Same as [Noah-3.2 / 100], but with 10-m for U/V and 2-m for T/q
Noah-3.6 / 100	0.678	Same as [Noah-3.3 / 100], but with Univ. of Arizona snow-physics
CLSM-F2.5 / 100	0.574	CLSM-F2.5 with updated parameters
CLSM-F2.5 / 101	0.570	Same as [CLSM-F2.5 / 100], but with original lower-resolution parameters
CLSM-F2.5 / 102	0.567	Same as [CLSM-F2.5 / 100], but with 2-meters added to bedrock depth

NLDAS Science Testbed Preliminary Evaluation





CMC snow depth analysis – Bias and RMSE

NLDAS-3 Forcing generation using LIS/LDT

Used LIS/LDT to generate sample NLDAS-3 forcing data at the target grid spacing of 0.03125° (1/32nd of a degree, ~3.125 km). The sample data has the same domain as NLDAS-2 (25-53 North).

Attributes:

NLDAS-2: *464 x 224* (103,936 points; 76,088 land points)

NLDAS-3: *1856 x 896* (1,662,976 points; 1,209,311 land points)

Precipitation downscaled using budget-bilinear method

Other variables downscaled using bilinear method

File sizes for NLDAS-2 (GRIB-1 format): ~*1.6 MB*

File sizes for NLDAS-3 (compressed netCDF-4 format): ~*18.5 MB*

NLDAS-3 Forcing generation using LIS/LDT

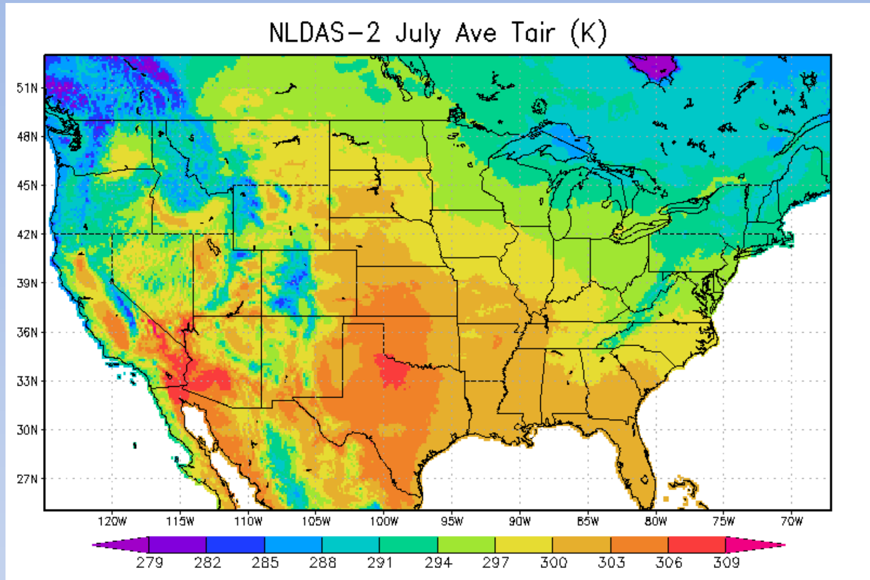
Results – Two NLDAS-3 downscaling experiments:

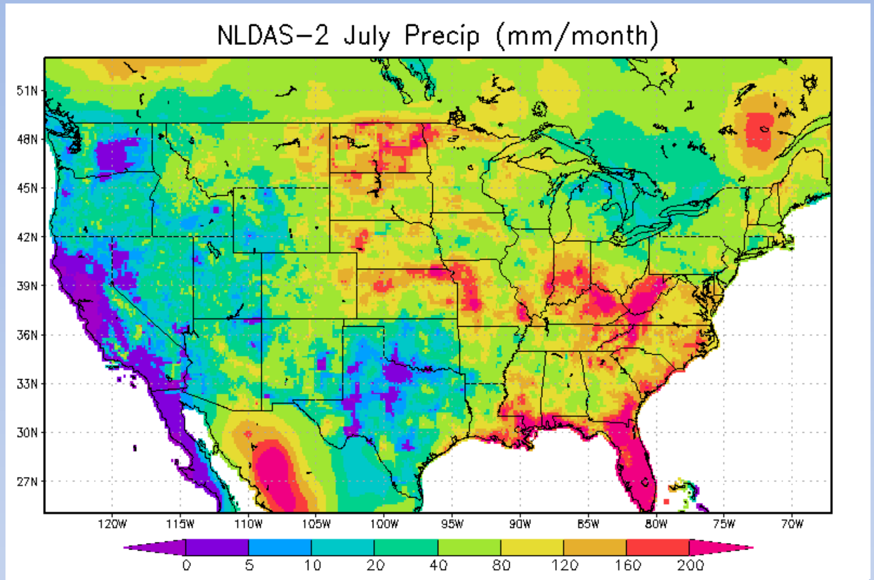
1) Interpolation of NLDAS-2 forcing to the NLDAS-3 grid ("CTL")

2) Same as 1) but removed the original NLDAS-2 lapse-rate correction (with the 0.125° GTOPO30 elevation map) and performed a similar constant lapse-rate correction using a ~3.125 km gridded SRTM30 elevation dataset ("Elev")

NLDAS-3 Forcing generation using LIS/LDT

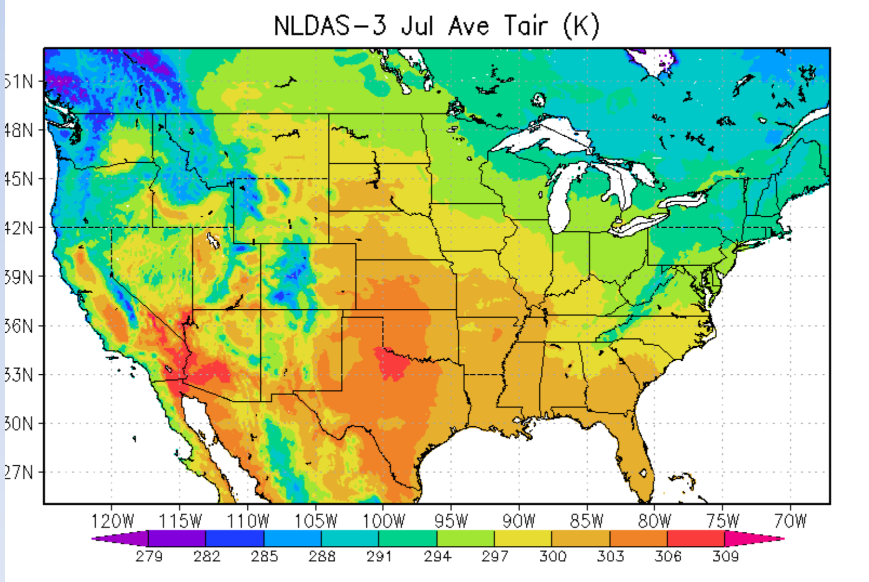
NLDAS-2
(0.125°)

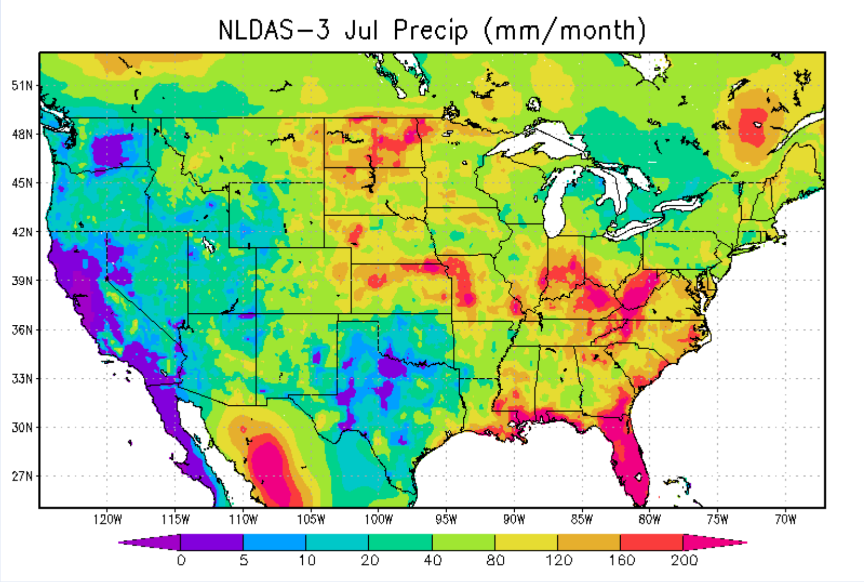




July 2001

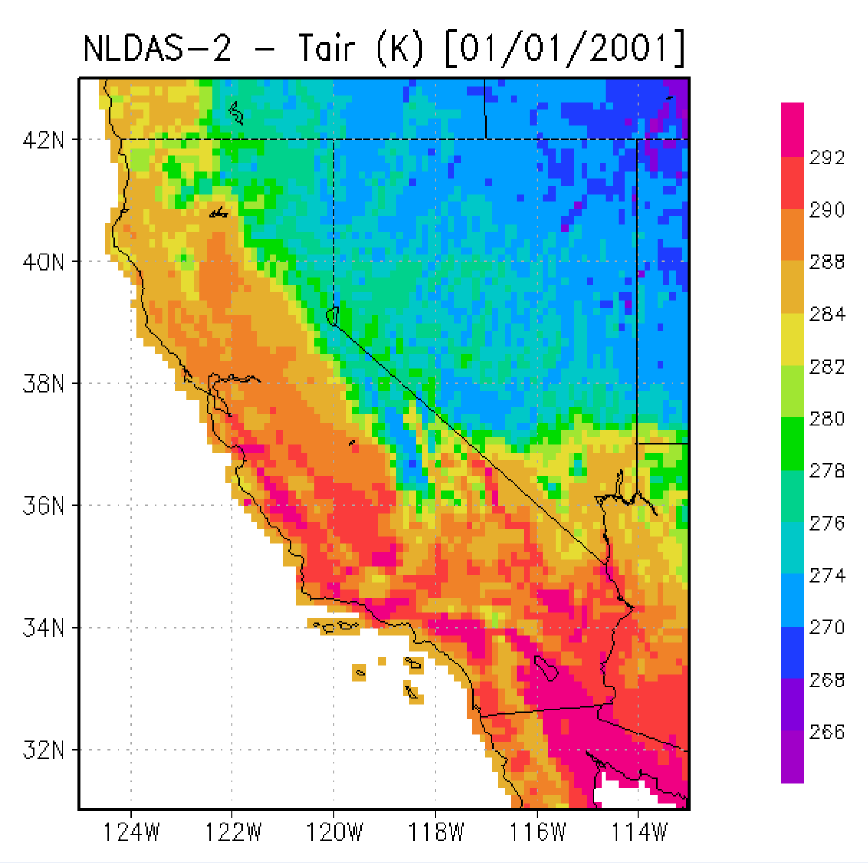
NLDAS-3
(0.03125°)



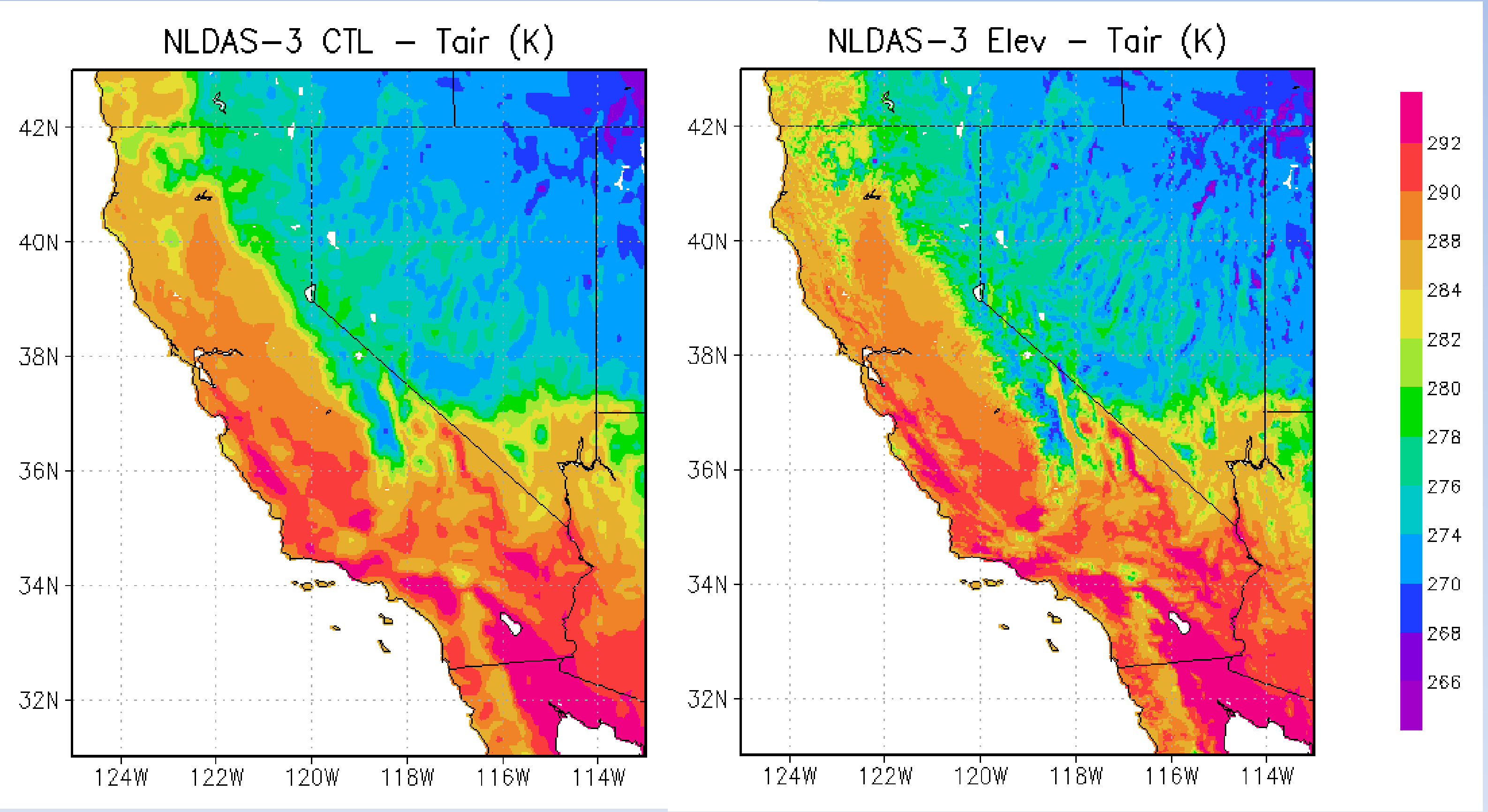


NLDAS-3 Forcing generation using LIS/LDT

NLDAS-2 (0.125°)

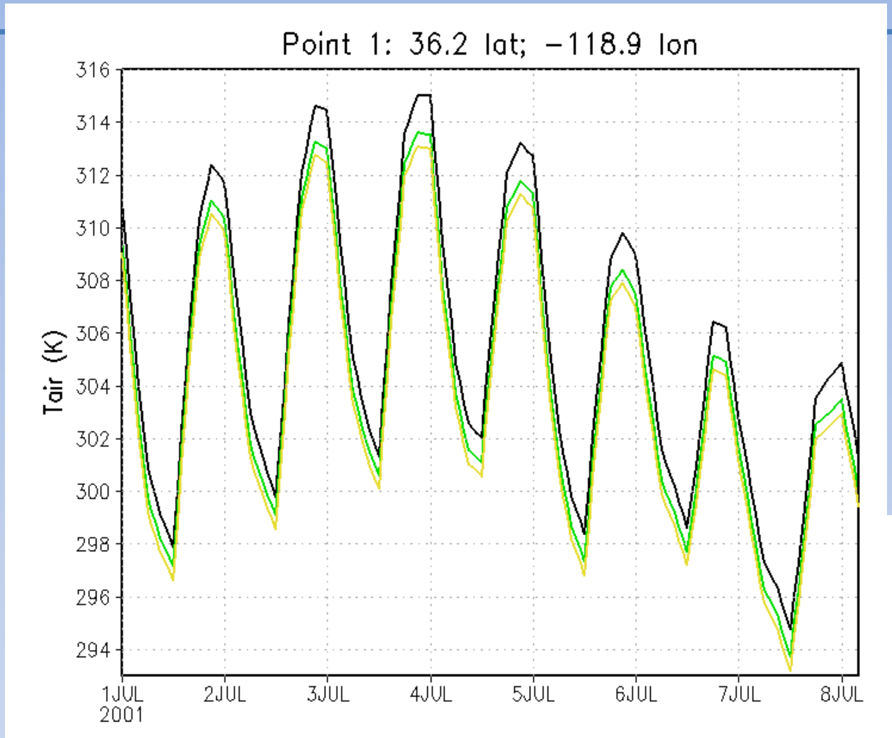


NLDAS-3 (0.03125°)



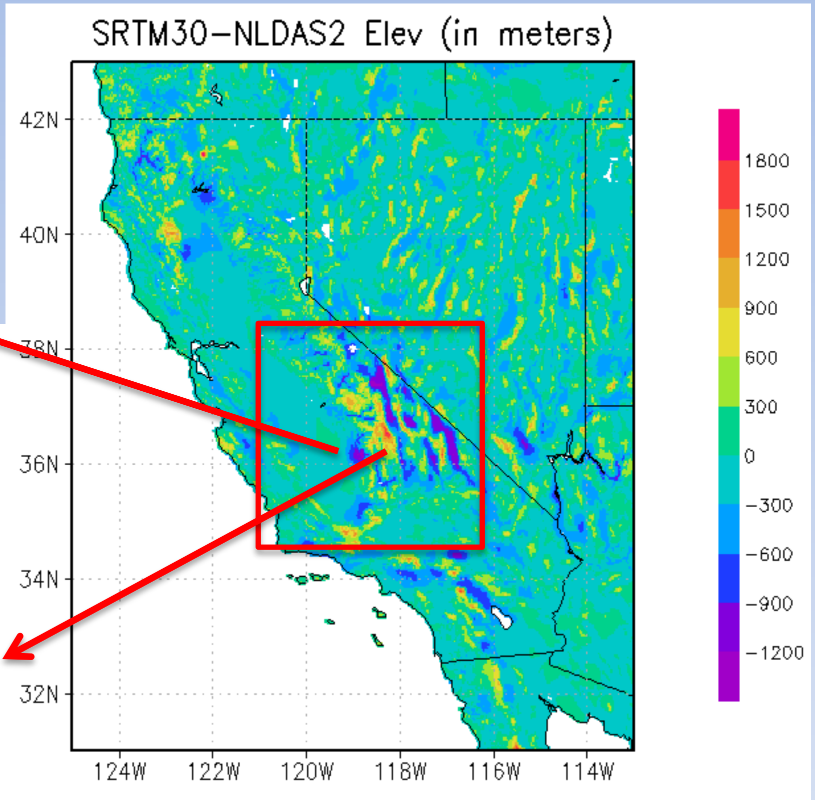
Jan 1, 2001

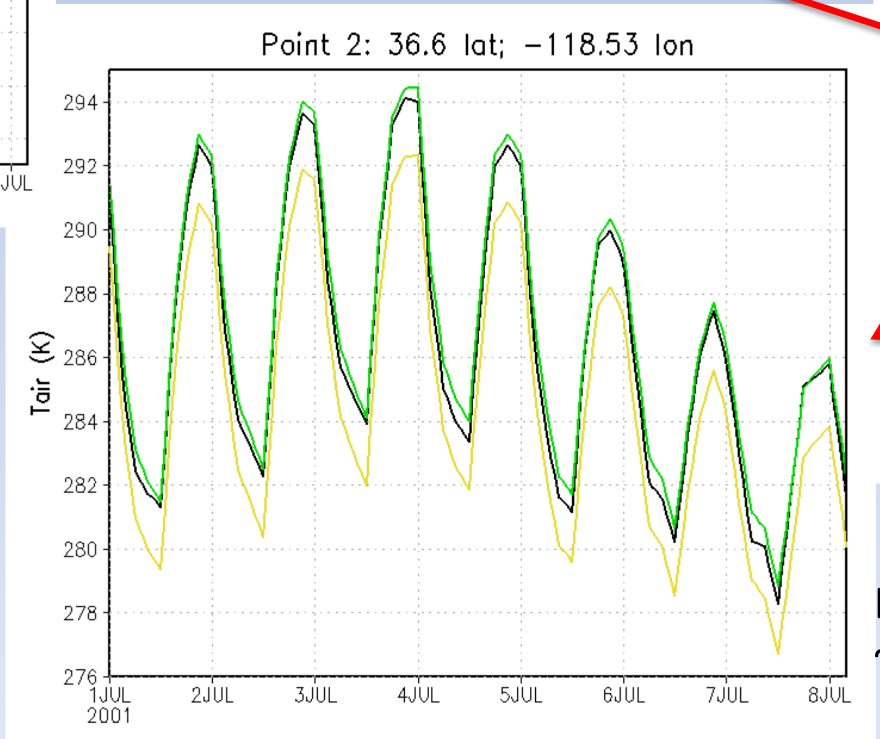
NLDAS-3 Forcing generation using LIS/LDT



Elevation difference:
~ -1000 m (SRTM < GTOPO30)

Elevation Difference Map





NLDAS-2

NLDAS-3 CTL

NLDAS-3 Elev

Elevation difference:
~ 1000 m (SRTM > GTOPO30)

Take-away Messages

- Running new/updated LSMs in the NLDAS configuration within LIS: CLSM-F2.5, Noah-3.3, Noah-3.6, Noah-MP-3.6, VIC-4.1.2.l, etc.
- LVT Tutorial was recently held and was a big success
- NLDAS Science Testbed using LVT for evaluation of new simulations as compared to NLDAS-2
- Full evaluation results to be shown at the AMS Benchmarking session in January
- NLDAS-3 forcing generation using LIS/LDT at 0.03125-deg

http://ldas.gsfc.nasa.gov/nldas/ David.Mocko@nasa.gov