

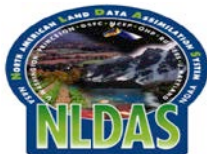


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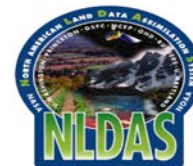
NLDAS CCB Briefing Meeting 18 April 2018

North American Land Data Assimilation System (NLDAS) Version 2.5.0 -- an Upgraded Implementation

Youlong Xia and Jack Kain



NCWCP, 5830 University Research Court, College Park, Maryland

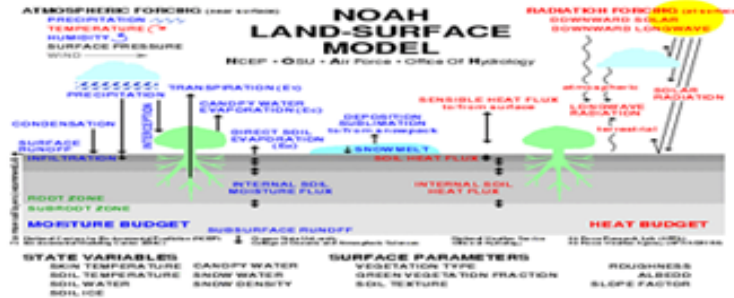


NLDAS: Partners

- **NLDAS, Data Sets, Land Model Development:**
 - J. Kain, Y. Xia, H. Wei, J. Meng, J. Dong (NCEP/EMC)
 - J. Sheffield, E. Wood et al (Princeton U.)
 - D. Mocko, C. Peters-Lidard, S. Kumar (NASA/GSFC)
 - B. Cosgrove, David Kitzmiller (NWS/NWC)
 - D. Lettenmaier et al (UCLA)
 - L. Luo (Michigan State University)
 - Z-L Yang(UT-Austin), M. Ek(UCAR), and F. Chen(NCAR)
- **NLDAS Maintenance and Operational Transition:**
 - Y. Xia (NCEP/EMC), Simon Hsiao (NCO)
- **NLDAS Products Application:**
 - K. Mo, L. Chen, M. Chelliah, M. Rosencrans(NCEP/CPC)
 - Eric Luebehusen (USDA), H. Rui (NASA), USDM Author Group, Regional Climate Centers

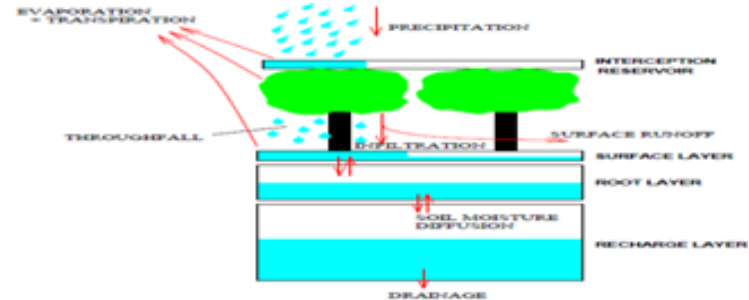
NLDAS: Land Models

Atmospheric Community



Noah

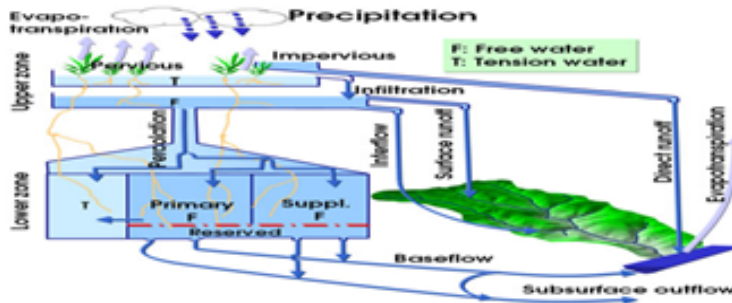
**NCEP operational
land model**



Mosaic

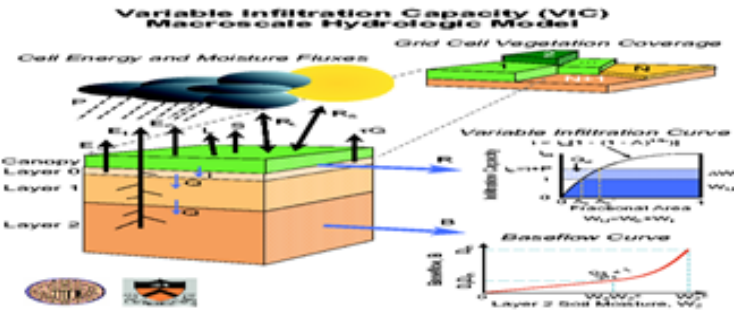
NASA GSFC

Hydrology Community



SAC

**NWS operational
hydrological model**



VIC

**Princeton &
U. Washington**

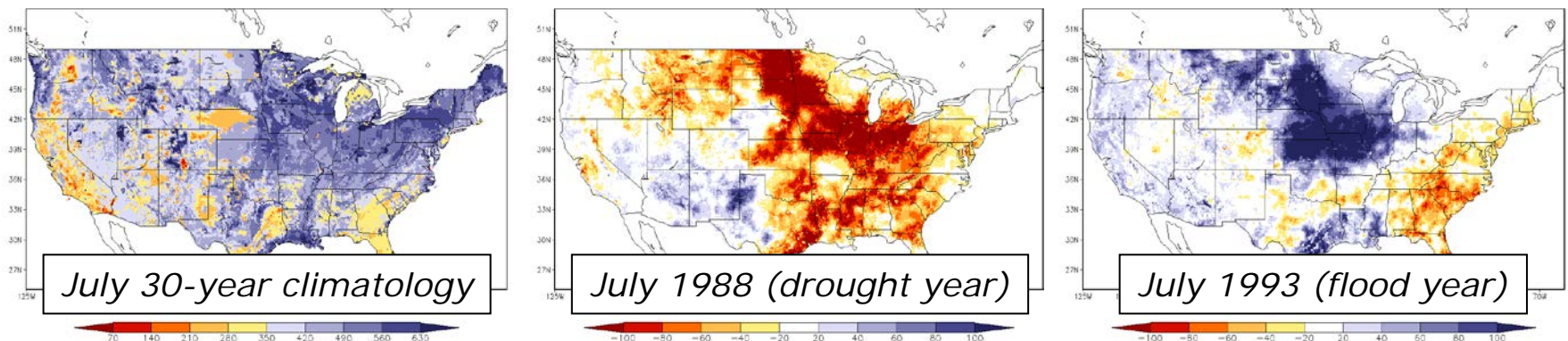
Operational Model

Research Model

NLDAS: Simulations

- 30-year retrospective land model runs, Oct 1979 – Sep 2008 (after 15-year spin-up) to provide land model climatologies.
- Quasi-operational near real-time, Sep 2008–July 2014
- NCEP operational, August 2014 - present, hourly, 0.125-deg, CONUS domain.
- Land model output: surface fluxes (latent, sensible & soil heat fluxes, & net radiation), soil states (soil moisture, temperature & ice), runoff/streamflow.
- Depict conditions as anomalies and percentiles.

Ek et al., GEWEX Newsletter, 2011, Xia et al., JGR-Atmos, 2012a; 201b



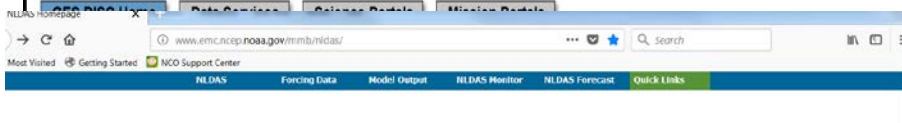
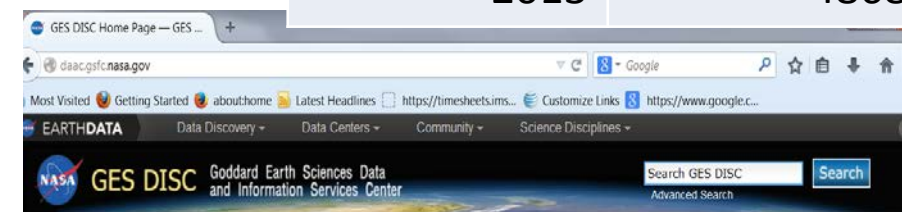
NLDAS four-model ensemble monthly **soil moisture** anomaly

NLDAS Users Information Report

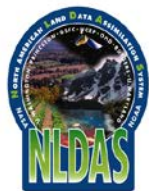
Users Statistics Information from NASA/GES/DISC website – an example

NASA Statistics

Year	No. of Users	No. of Files Downloaded	Total Volume Downloaded
2017	5279	~ 56 million	149 TB
2016	5038	~64 million	149 TB
2015	5392	~71 million	144 TB
2014	5437	~44 million	93 TB
2013	4868	~ 36 million	66 TB



EMC LDAS ftp://ldas.ncep.noaa.gov/nldas2/



forcing and outputs of four models and real-time updates (2009-present) are at the [NCEP Idas ftp site](#). River routed hourly data from four NLDAS models can be downloaded from the link [Streamflow](#), and post-processed SAC soil moisture data can be downloaded from the link [Post-Processed SAC Soil Moisture](#). NLDAS became NCEP Operational on 5 August 2014 and the [Operational Products](#) can be downloaded from the link [Products](#). also, see [LDAS White Paper](#) "EMC NLDAS-2 real-time and retrospective products are back online through a newly rebuild sever. Contents of data and products included at NCEP Idas ftp site can see [this README file](#)."

North American Land Data Assimilation System (NLDAS)

North American Land Data Assimilation (NLDAS) is being developed that will lead to more accurate reanalysis and forecast simulations by numerical weather prediction (NWP) models. Specifically, this system will reduce the errors in the stores of soil moisture and energy which are often present in NWP models and which degrade the accuracy of forecasts. NLDAS is currently running retrospective and in near real-time on a 1/8th-degree grid resolution. The system is currently forced by terrestrial NLDAS precipitation data, space-based radiation data and numerical model output. In order to create an optimal scheme, the project involves several LSMs, many sources of data, and several institutions. Data from the project can be accessed on the [NLDAS forcing pages](#), the [NLDAS model output pages](#), as well as on the [NLDAS Realtime Image Generator page](#). This is an official NLDAS website which includes NLDAS overview, land surface characteristics parameters, forcing data, land models, model outputs, publications, useful links, and NLDAS thought leaders.

This webpage originally developed and constructed by Brian Considine, Matthew Rodell, and Charles Deser for NASA & GES. It was transferred to NOAA/NCEP/EMC in June 2008. Now this web is maintained and updated by Michael Ek and Ingrid Sta for NLDAS Project.

Our NCEP/EMC NLDAS team acknowledges all NLDAS partners. Without their contributions, the NLDAS is impossible to become a NCEP operational product. As NLDAS v2.0 has a 3.5-4 day lag behind real-time, based on users' request (e.g., USDAM) and our survey conducted in 2016 and 2017, we update NLDAS v2.0 into version 2.5 by using various feasible data sources (NAMv4, Stage IV) to catch up real-time system.

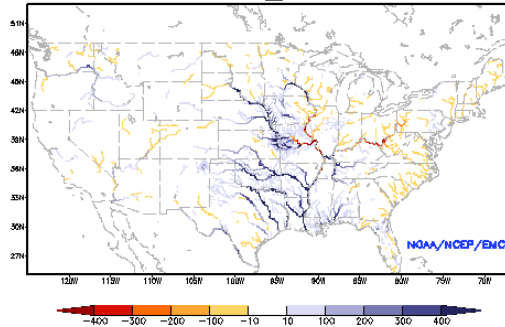
Highlight: Add timely needed products to NLDAS users in support for their operational drought (e.g., CPC, ESRL, USDAM), NWP forecast (e.g., NASA/MSFC), and researches on water resource (e.g., NASA/GSFC)

NLDAS2.0 vs NLDAS2.5 (Harvey Case)

Daily Streamflow Anomaly

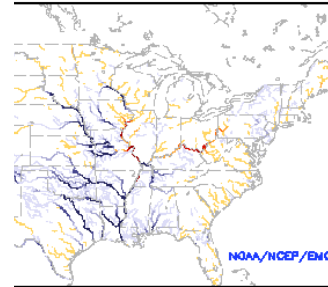
23 AUG

Ensemble-Mean, Current Streamflow Anomaly (m³/s)
NCEP NLDAS Products Valid: AUG 23, 2017



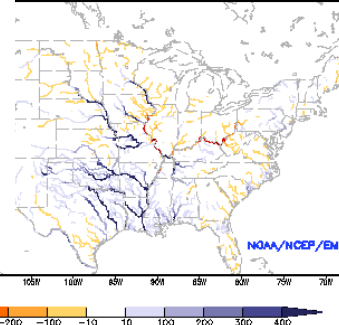
24 AUG

Current Streamflow Anomaly (m³/s)
Products Valid: AUG 24, 2017



25 AUG

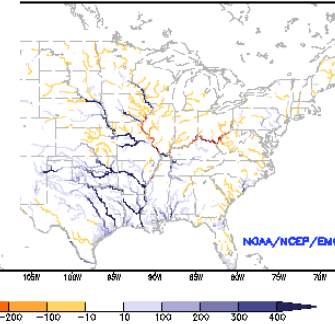
In: Current Streamflow Anomaly (m³/s)
DAS Products Valid: AUG 25, 2017



NLDAS v2.0

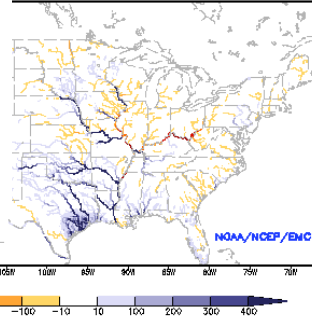
26 AUG

n: Current Streamflow Anomaly (m³/s)
AS Products Valid: AUG 26, 2017



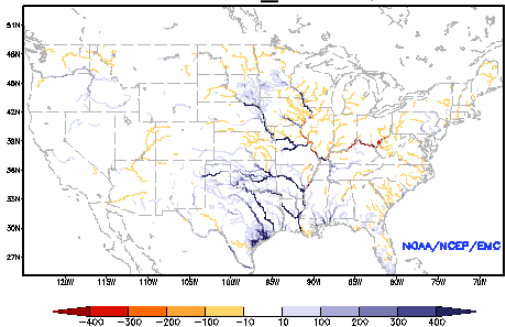
27 AUG

Current Streamflow Anomaly (m³/s)
Products Valid: AUG 27, 2017



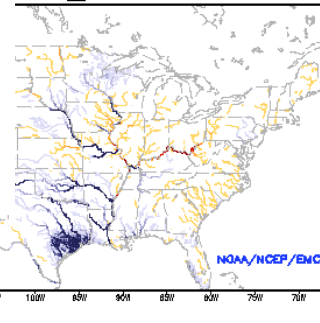
27 AUG

Ensemble-Mean, Current Streamflow Anomaly (m³/s)
NCEP NLDAS Products Valid: AUG 27, 2017



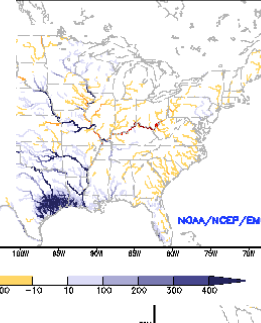
28 AUG

Current Streamflow Anomaly (m³/s)
Products Valid: AUG 28, 2017



29 AUG

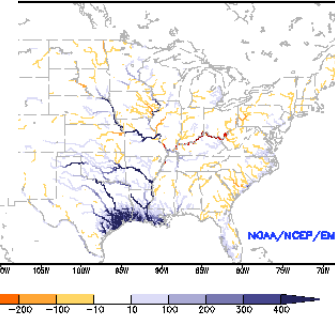
ent Streamflow Anomaly (m³/s)
ducte Valid: AUG 29, 2017



NLDAS v2.5

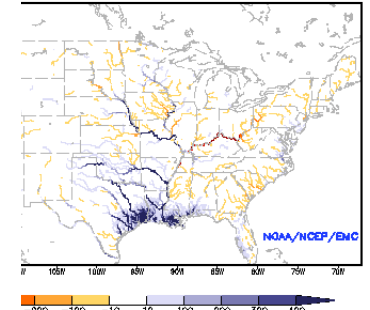
30 AUG

san: Current Streamflow Anomaly (m³/s)
LDAS Products Valid: AUG 30, 2017



31 AUG

Mean: Current Streamflow Anomaly (m³/s)
NLDAS Products Valid: AUG 31, 2017



Timing has large impact
for monitoring flood situation

NLDAS v2.5 Flowchart

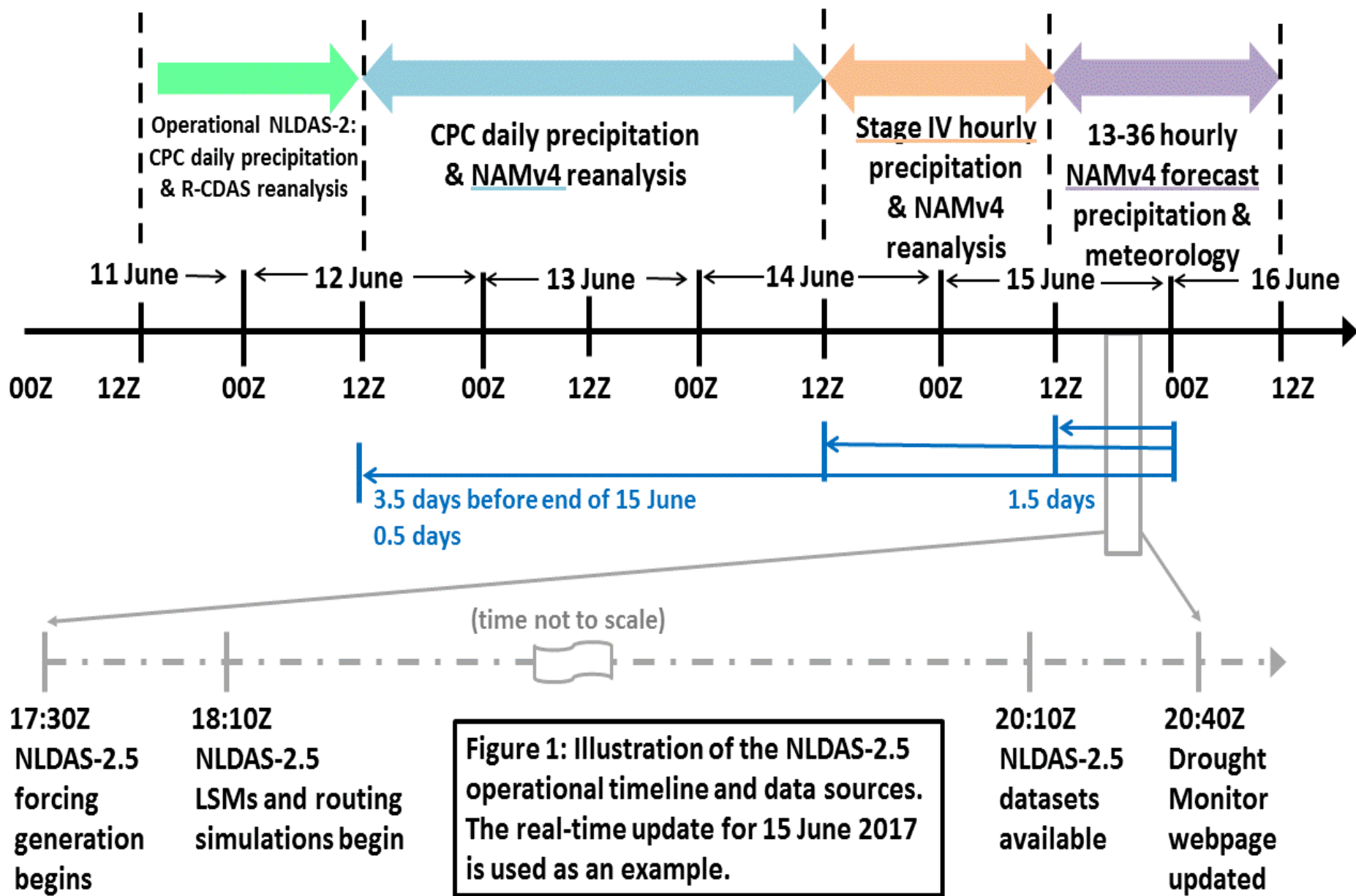
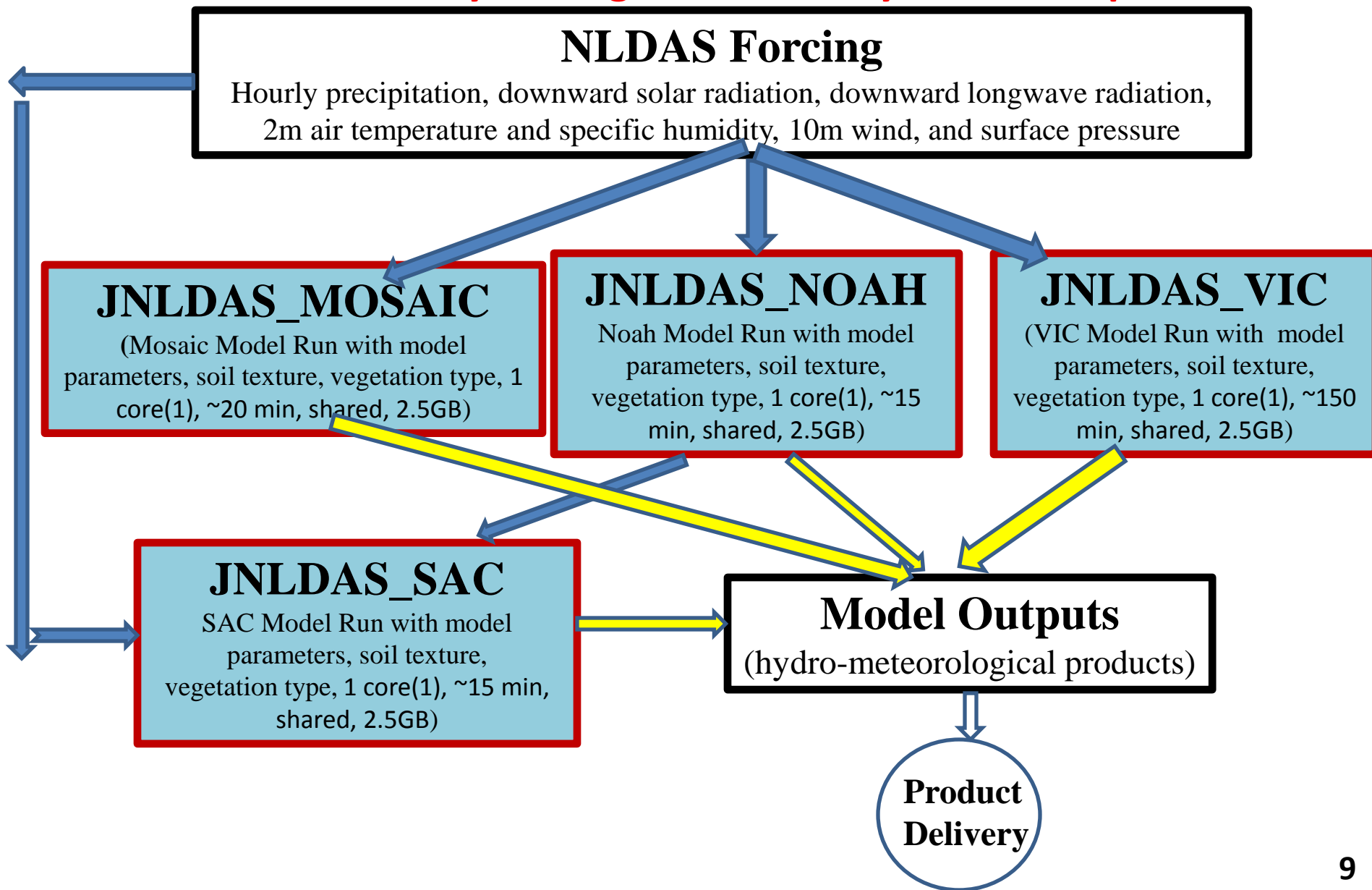


Figure 1: Illustration of the NLDAS-2.5 operational timeline and data sources. The real-time update for 15 June 2017 is used as an example.

Operational Four NLDAS Models Run

Add 3.5 day forcing and 3.5-4 day model output



EMC NLDAS v2.5 Quads



NLDAS Version 2.5.0
Status as of 04/03/2018



Project Information & Highlights

Leads: /Youlong Xia/Jack Kain (EMC), Steven Earle (NCO)

Scope: Extend current operational NLDAS ver. 2.0 to reach actual realtime system by using Stage IV and NAMv4 forcing data. This will be two-cycle run with a similar method as used in CFSR/GLDAS.

Expected benefits: To reach realtime NLDAS system to efficiently support US operational drought monitoring and prediction, and land ICs for regional NWP models, and user community from private sectors and academia.

Dependencies: RCDAS, Stage II & IV, NAMv4, CPC gauge P



Issues/Risks

Risk: USDA, NASA-GSFC, ESRL/PSD, NASA-MSFC (Short-term Prediction O Research and Transition - SPORT) have all recommended implementation. Still waiting for CPC evaluation and concurrence;

Mitigation: coordinate the evaluation with CPC



Schedule

Milestones & Deliverables	Date	Status
Freeze system code and deliver to NCO	10/15/17	Completed
Complete full real time runs and evaluation	04/02/18	Completed
Conduct CCB and deliver final system code to NCO	04/15/18	On track
Deliver Technical Information Notice to NCO	04/15/18	On track
Complete 30-day evaluation and IT testing	TBD	TBD
Operational Implementation	9/23/18	TBD

EMC NCO Red text indicates change from previous quarter



Resources

Staff: 0.05 Fed FTEs + 1 contractor FTEs; including Dev (QC, test, eval. etc.)

Funding Source: MAPP, EMC Base

Compute: EMC Dev: two nodes (devhigh); Ops: Change onre node to two nodes

Archive: ~1GB for current NLDAS2.0.4; ~5GB for new implementation



Management Attention Required



Potential Management Attention Needed



On Target

After a meeting between EMC and CPC, our NLDAS v2.5 evaluation from NLDAS team to deliver a comprehensive explanation for CPC evaluation, and they agree our proposed implementation as the other 4 evaluation institutes did.

NLDAS V2.5.0 Products: Evaluation and Validation

Most NLDAS 2.0 products have been well comprehensively evaluated against *in situ* observations and/or remotely sensed data by EMC NLDAS team and its partners. The results were documented in various journal papers and presentations (<https://ldas.gsfc.nasa.gov/nldas/NLDAS2valid.php>, <https://ldas.gsfc.nasa.gov/nldas/NLDASpublications.php>).

Major purpose for this upgrade is to catch up 4-day delay to achieve a real-time system. The data quality will become lower when the data is approaching real-time. **Bottom line:**
NLDAS v2.5 is an add-on, not a replacement of NLDAS v2

Besides we made our own evaluation and monitoring work for NLDAS v2.5 (about 9 months), NASA/GSFC, CPC, NASA-MSFC, ESRL/PSD, and USDA partners also made their own subjective evaluation for NLDAS v2.5. A briefing of these results are presented below.

Near Real-time NLDAS v2.0 and Real-time v2.5 drought monitor

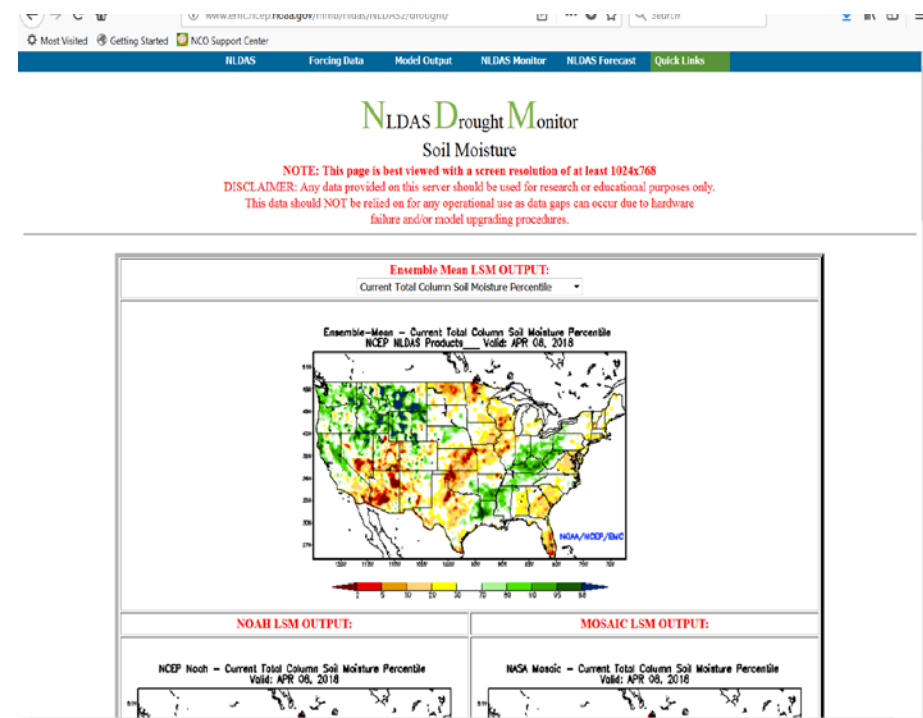
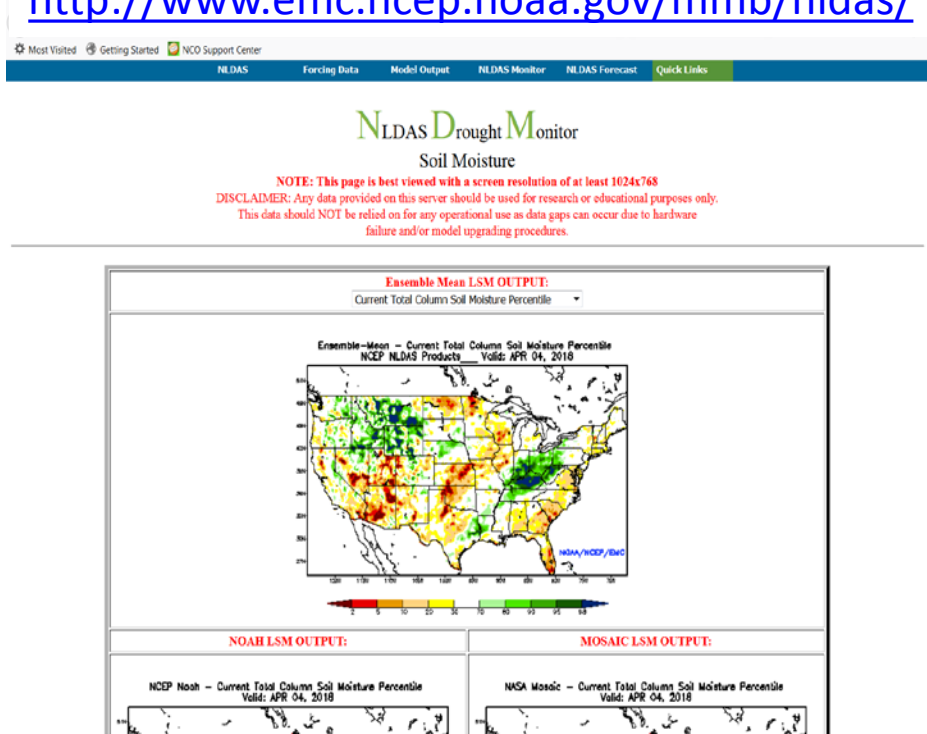
Parallel run daily drought monitor

NLDAS v2.0 with 4-day delay

Real-time NLDAS v2.5

<http://www.emc.ncep.noaa.gov/mmb/nldas/>

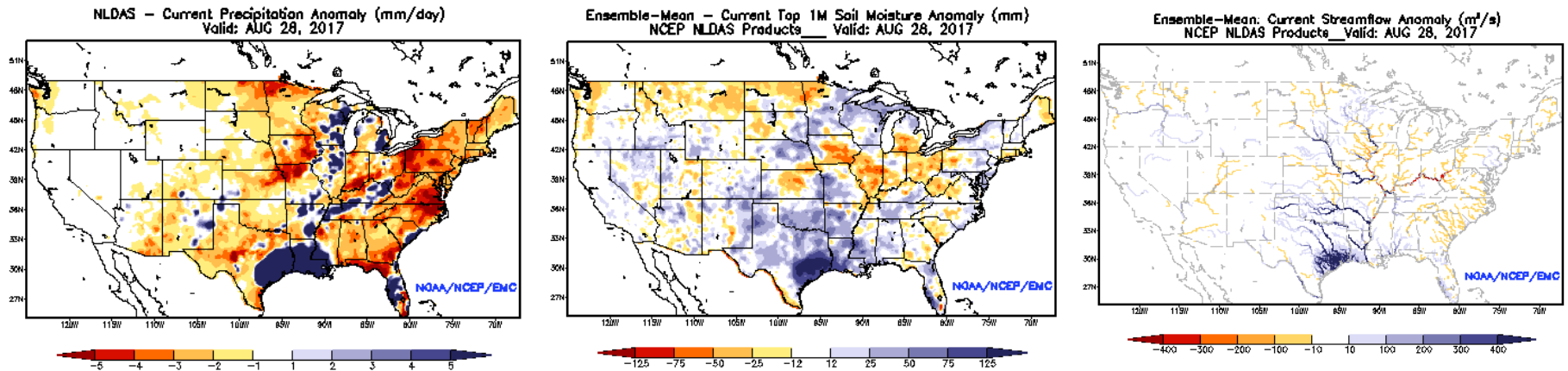
<http://www.emc.ncep.noaa.gov/mmb/nldas/NLDAS2/>



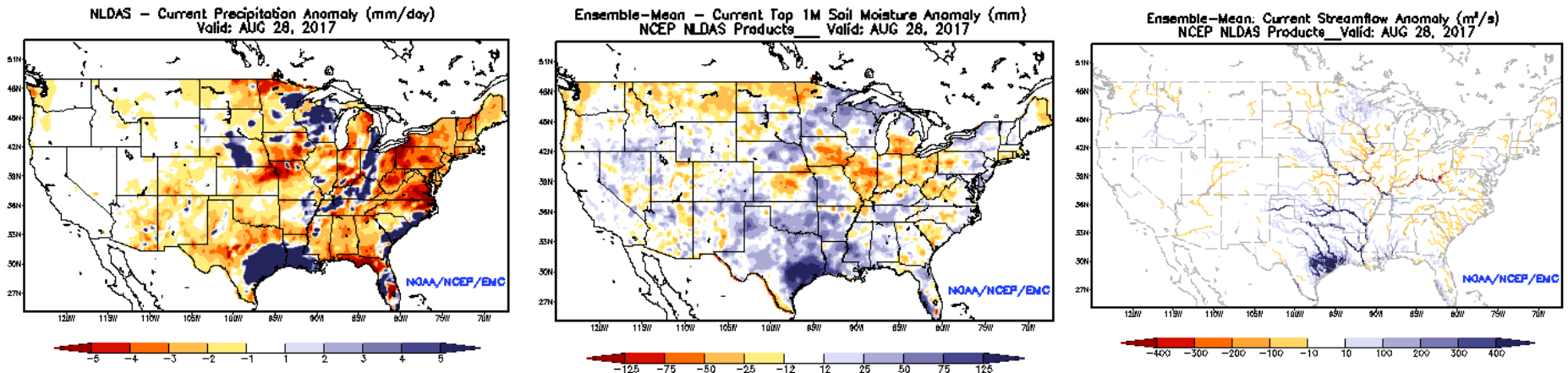
Anomaly and percentile (daily, past week and month) for SM1m, SMtotal, total runoff, routed streamflow, SWE, and ET (4 models: Noah, Mosaic, SAC, VIC, and their ensemble mean)

Harvey Case Comparison: NLDAS v2.0 vs NLDAS v2.5

NLDAS v2.0 (generated on 1 September 2017)



NLDAS v2.5 (generated on 28 August 2017)

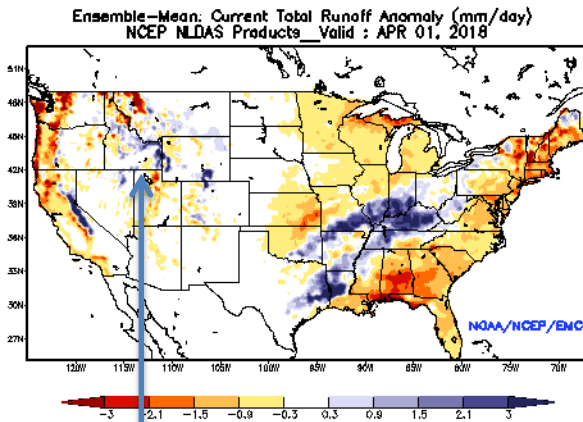


v2.5 reasonably captures impact of Harvey precipitation immediately and the difference between the two systems is small

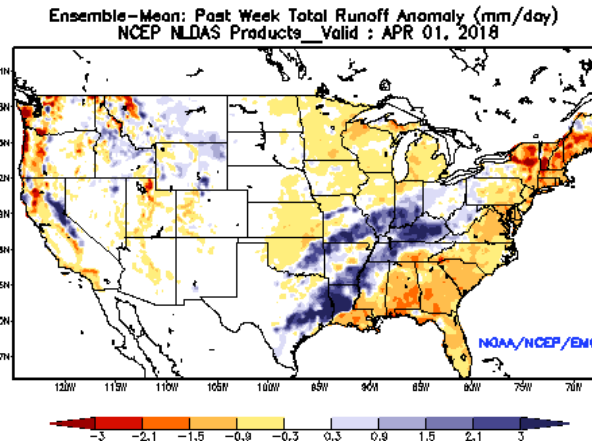
Comparison of total runoff for 3-timescale on 1 April 2018

Near Real-time NLDAS v2.0

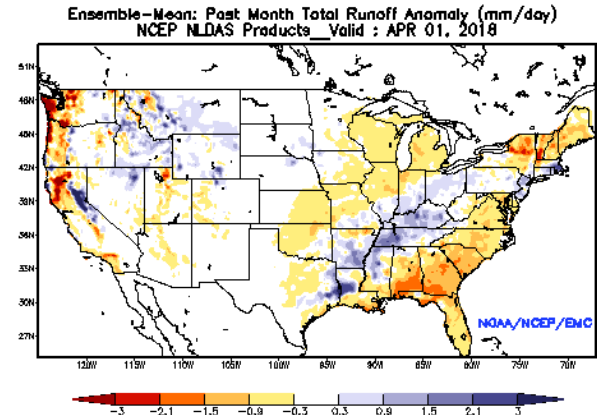
Daily



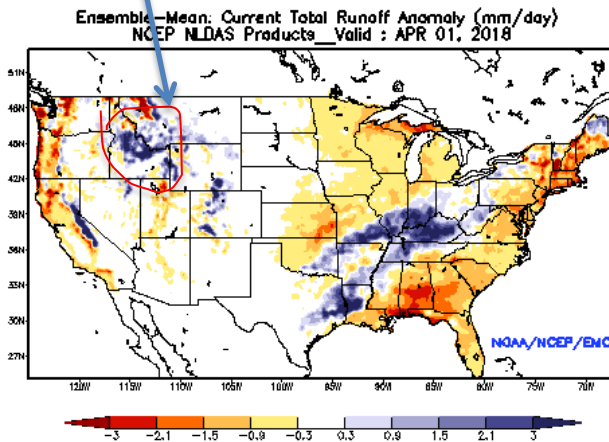
Past week



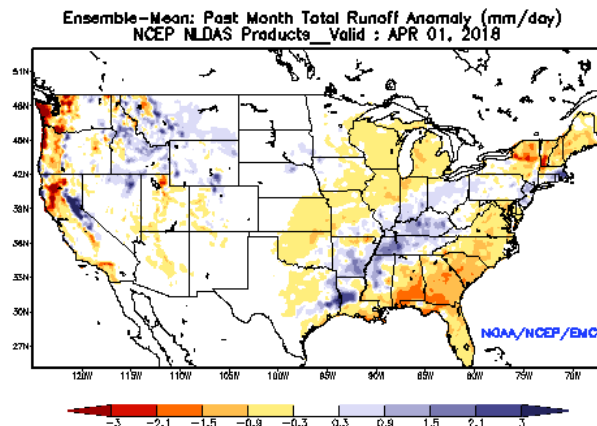
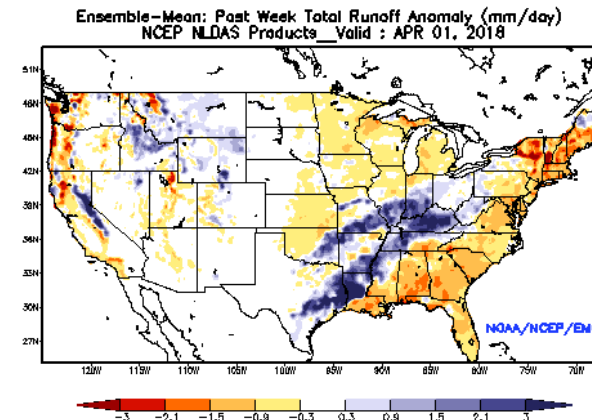
Past month



Some difference



Real-time NLDAS v2.5



In spite of some difference in daily total runoff anomaly, weekly and monthly results are quite similar 14

Daily Comparison of Various Variables on 6 April 2018

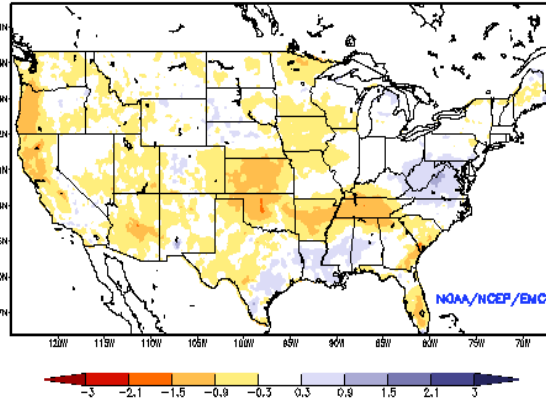
Near Real-time NLDAS v2.0

ET

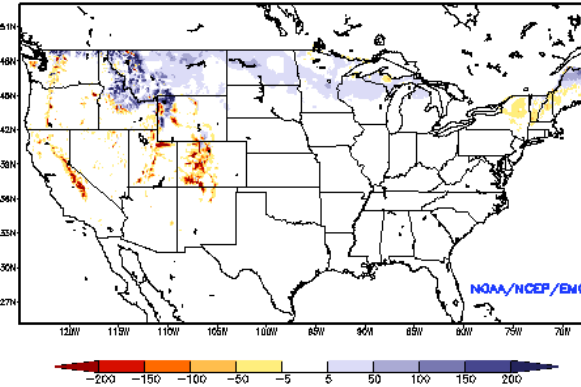
SWE

SM total column

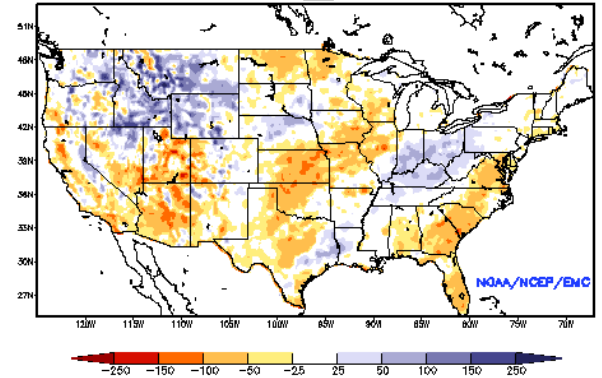
Ensemble-Mean: Current Evaporation Anomaly (mm/day)
NCEP NLDAS Products Valid: APR 06, 2018



Ensemble-Mean: Current Snow Water Equivalent Anomaly (mm)
NCEP NLDAS PRODUCTS Valid: APR 06, 2018

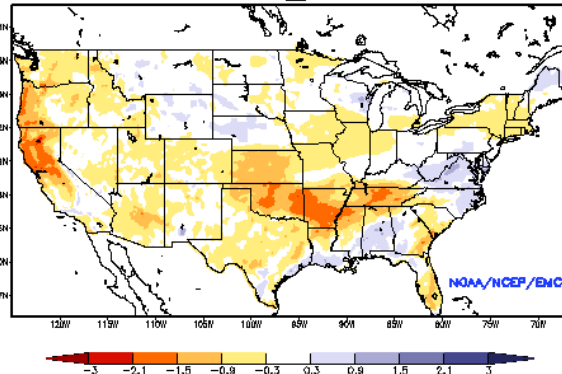


Ensemble-Mean - Current Total Column Soil Moisture Anomaly (mm)
NCEP NLDAS Products Valid: APR 06, 2018

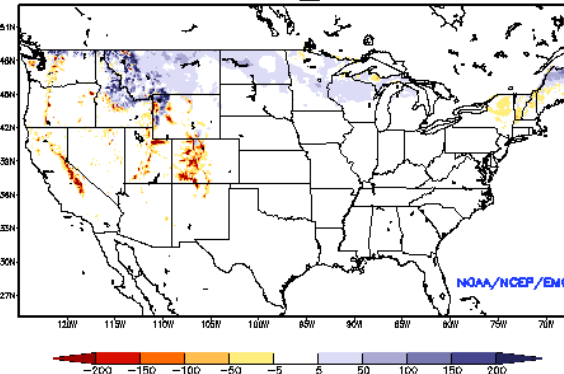


Real-time NLDAS v2.5

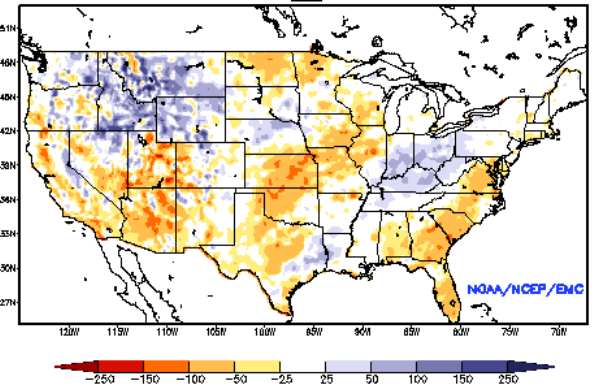
Ensemble-Mean: Current Evaporation Anomaly (mm/day)
NCEP NLDAS Products Valid: APR 06, 2018



Ensemble-Mean: Current Snow Water Equivalent Anomaly (mm)
NCEP NLDAS PRODUCTS Valid: APR 06, 2018



Ensemble-Mean - Current Total Column Soil Moisture Anomaly (mm)
NCEP NLDAS Products Valid: APR 06, 2018



There is small-moderate effect on daily ET and runoff, and there is small effect on daily SWE and soil moisture (state) 15

NLDAS v2.5: Users Evaluation

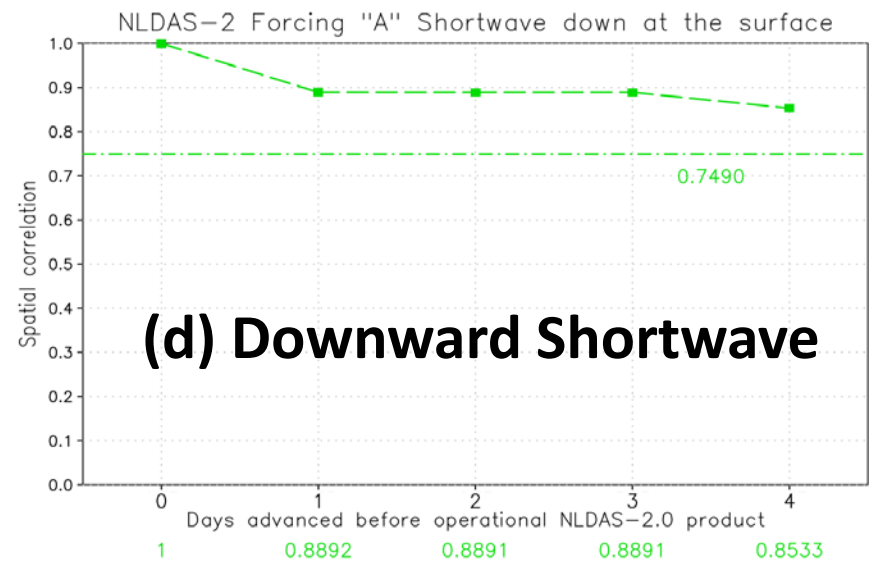
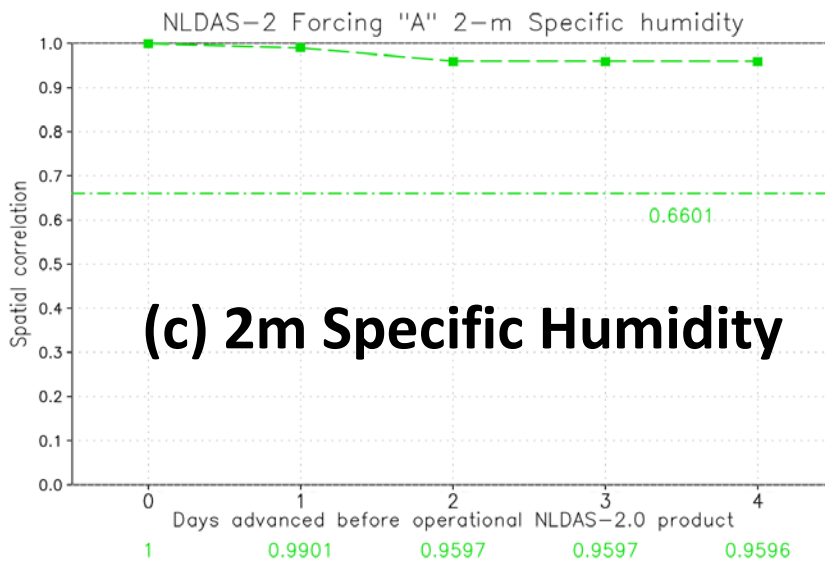
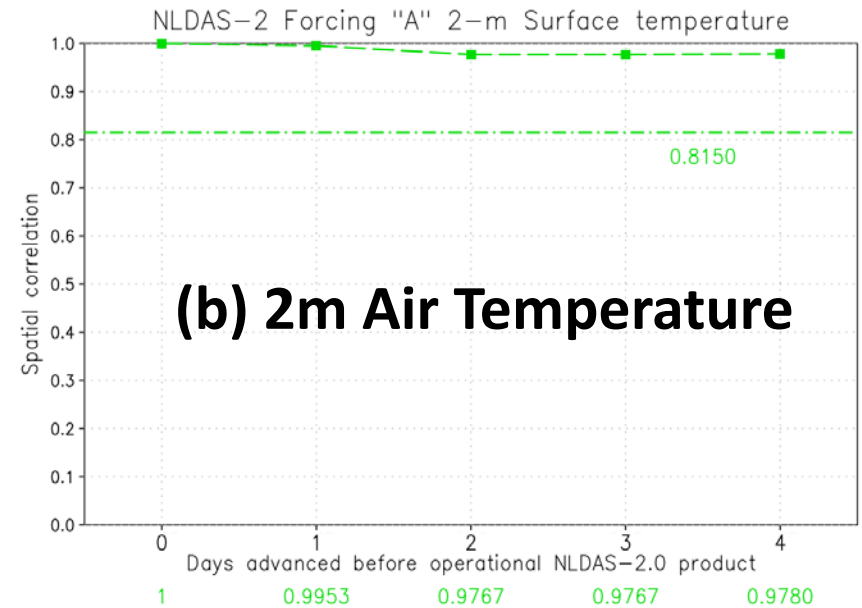
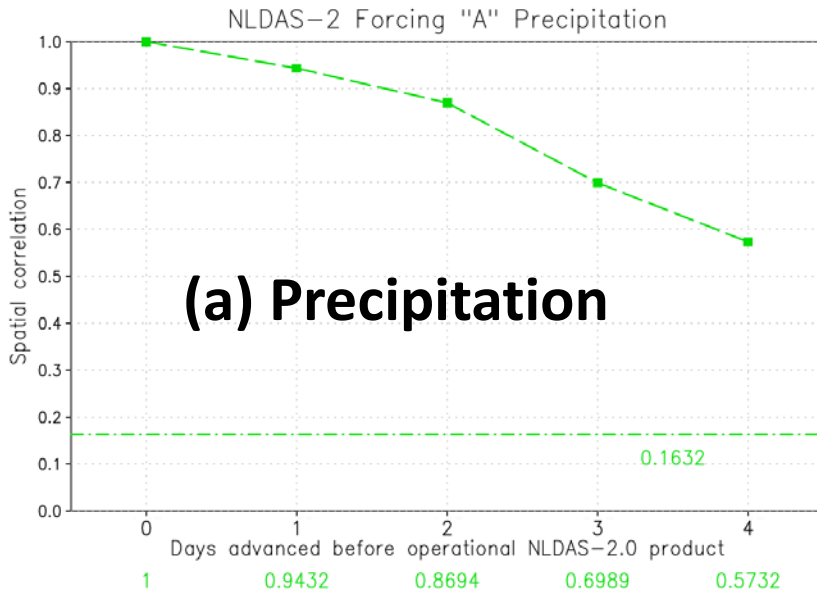
Benchmark – persistence, use January 2018 data to make evaluation

NLDAS-2.5 evaluation by NASA/GSFC

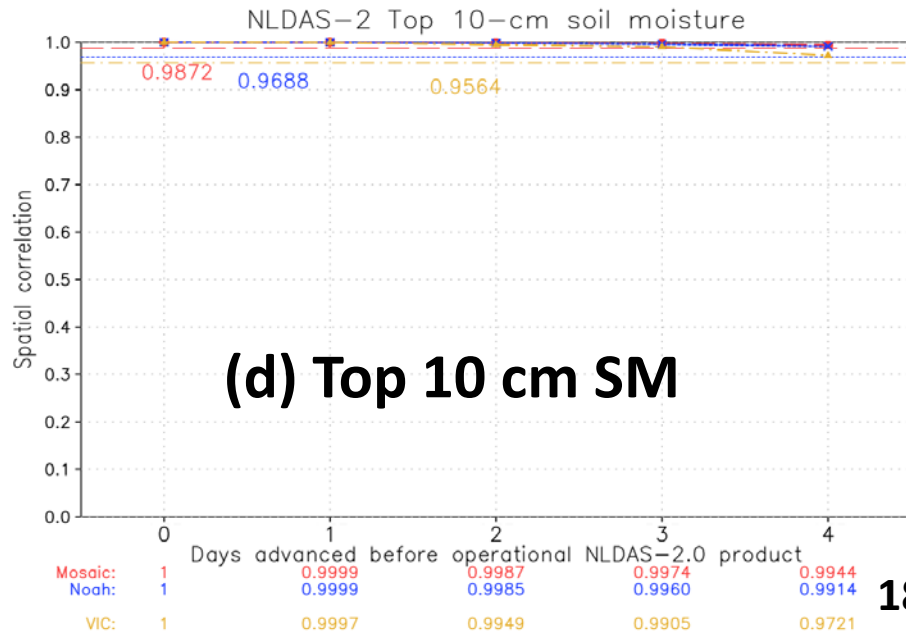
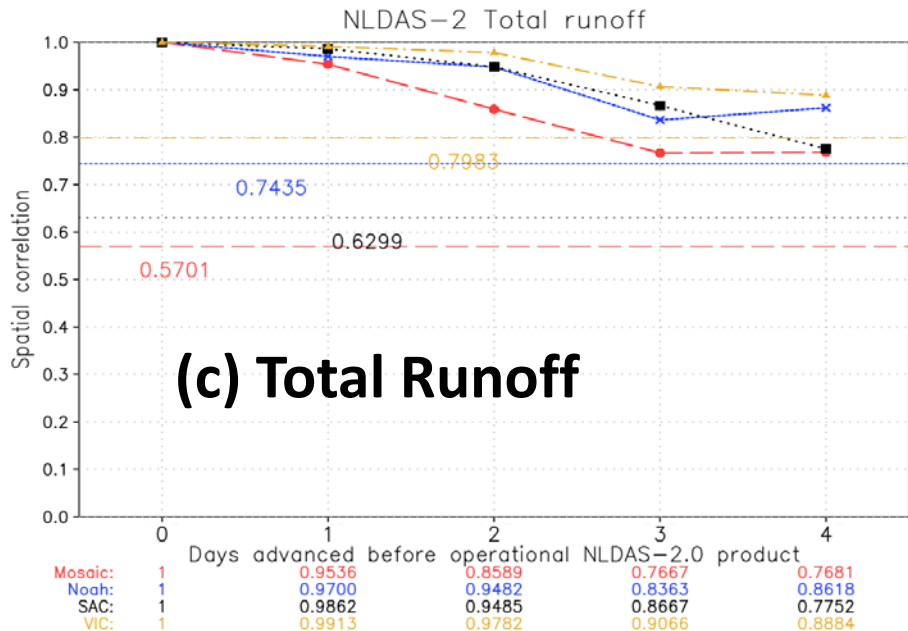
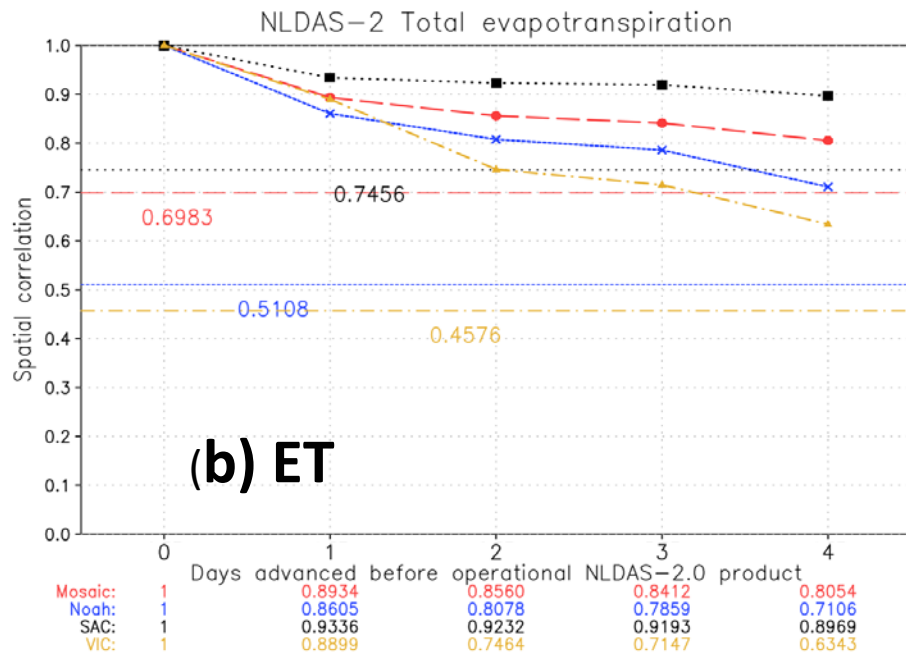
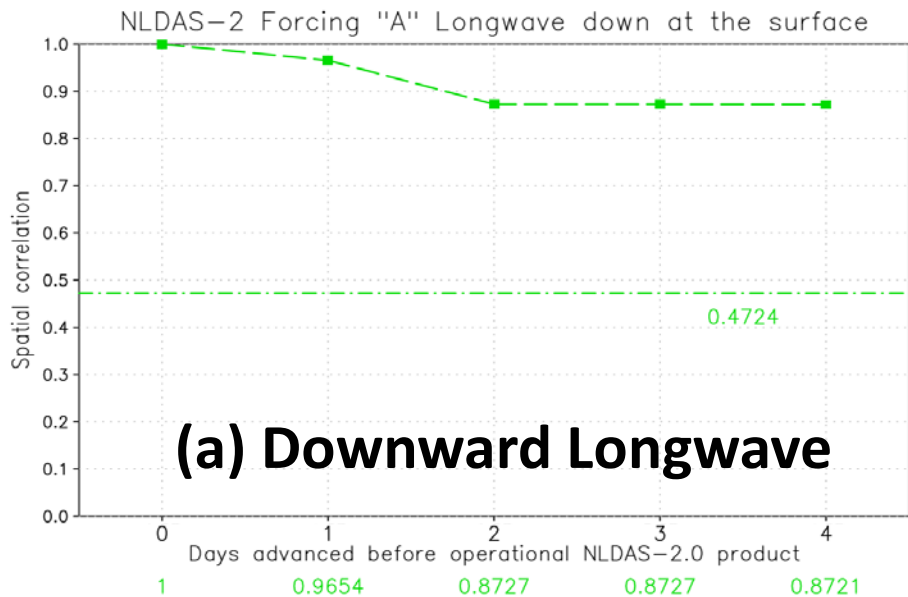
NASA/GSFC performed an evaluation of the real-time NLDAS-2.5 products for data over the month of January 2018.

- Spatial correlations and RMSEs of important hydrological and drought monitor variables were calculated between the NLDAS-2.5 products and the current operational NLDAS-2.0 products.
- NLDAS forcing and the four (4) NLDAS LSMs (Mosaic, Noah, SAC, and VIC) were evaluated.
- The metrics were calculated for each of the 5 days of the NLDAS-2.5 product as well as between the 4-day lagged NLDAS-2.0 product and the current date NLDAS-2.0 product.
- Daily averages (00Z-23Z) of the fields were first calculated, and then the daily correlations/RMSEs were calculated. Monthly-averages are plotted.

NLDAS v2.5 Forcing and Output Evaluation

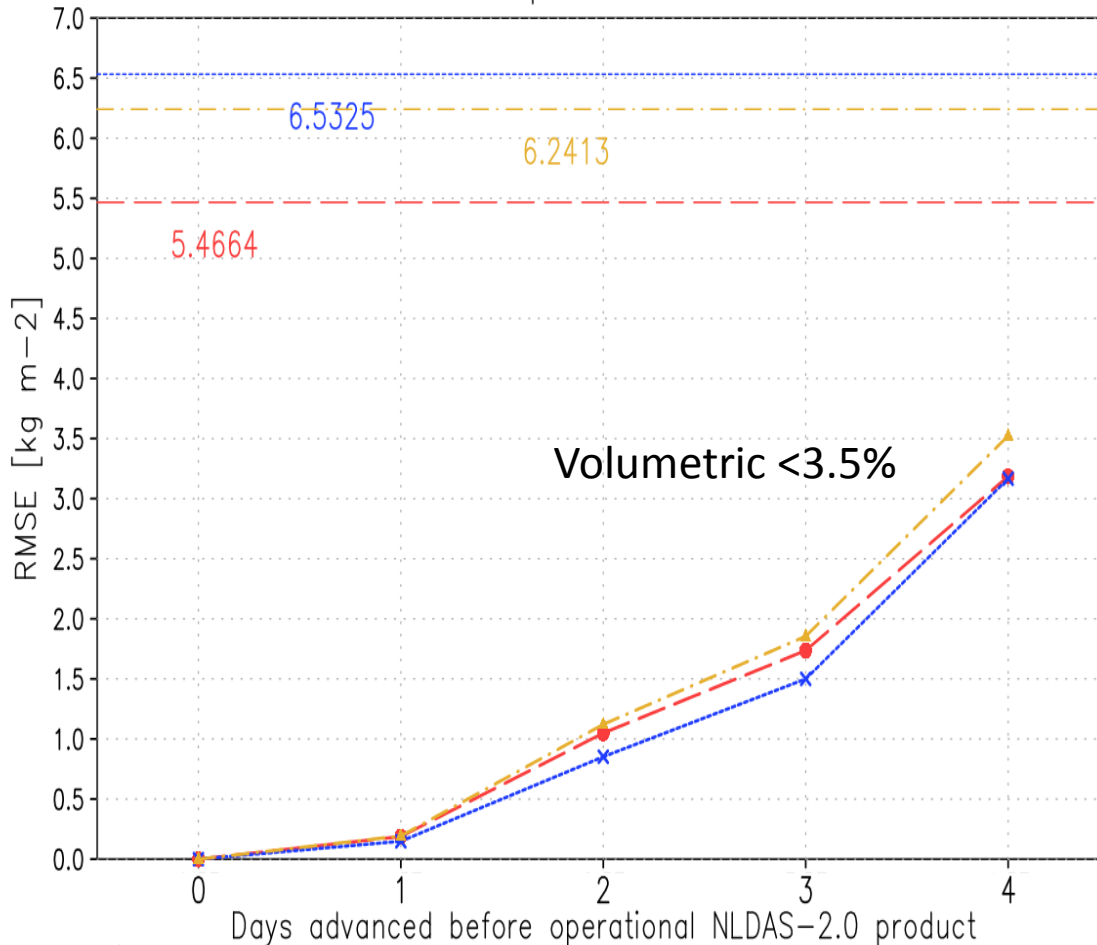


NLDAS v2.5 Forcing and Output Evaluation (Cont.)



NLDAS-2.5 LSM evaluation - RMSE

NLDAS-2 Top 1-m soil moisture



Mosaic:	0.0000	0.1882	1.0489	1.7363	3.1857
Noah:	0.0000	0.1490	0.8524	1.5000	3.1666
VIC:	0.0000	0.1931	1.1216	1.8554	3.5228

Day 4 (current date):

NLDAS-2.5 has the highest RMSE values compared to the NLDAS-2.0 on the same date (half the precip. is from the NAMv4 forecast; the other half is from Stage II)

Day 3 (1-day lag):

Precip. ½ from Stage II and half from CPC analysis

Day 2 (2-day lag):

Precip. from CPC analysis

Day 1 (3-day lag):

Precip. from CPC analysis

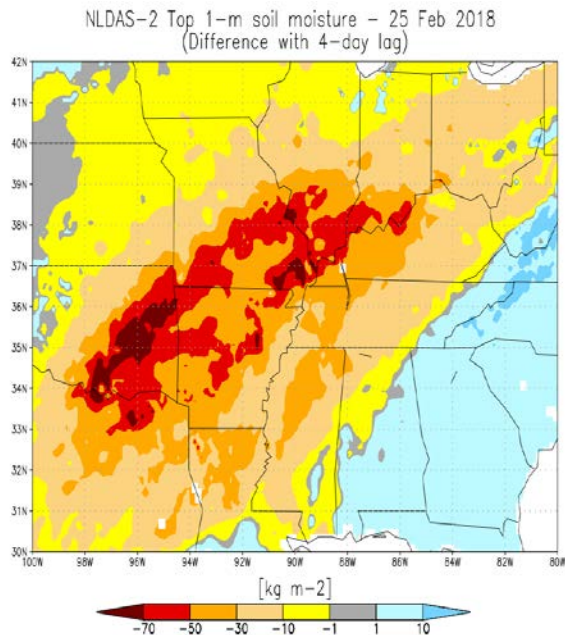
Day 0 (4-day lag):

Precip from CPC analysis. RMSE = 0 because it is the same day and precip source as NLDAS-2.0.

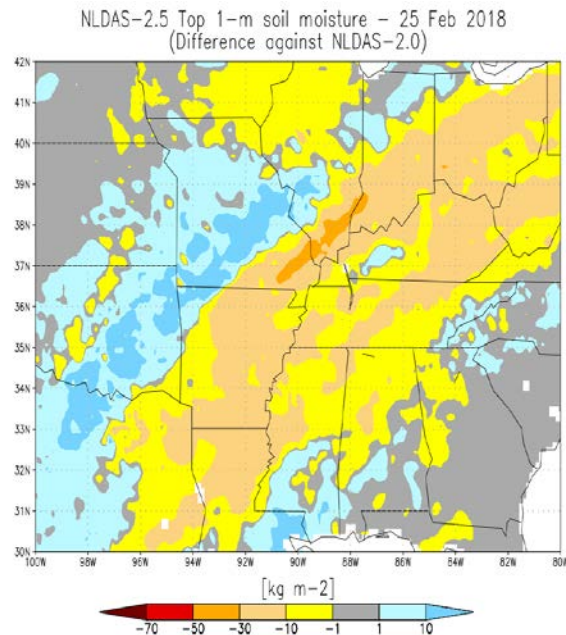
The flat line on the top represents the RMSE between the NLDAS-2.0 precip. on a day against the NLDAS-2.0 precip. 4-days earlier. In other words, if you only had the 4-day lagged NLDAS-2.0 precip. on the date you need the latest NLDAS dataset (aka, the current operational system), how useful would it be?

The lower RMSE value of the NLDAS-2.5 product below this flat line show that NLDAS-2.5 is improved.

NLDAS-2.5 LSM drought recovery



LEFT) NLDAS-2 for 21 Feb 2018
minus NLDAS-2 from 25 Feb 2018
(test available on 25 Feb 2018)



RIGHT) NLDAS-2.5 for 25 Feb 2018
minus NLDAS-2 from 25 Feb 2018
(available on 25 Feb 2018)

- This period was immediately after the end of a heavy rain period in the central U.S.
- **Same fields, only taking the difference between the two products as available on 25 Feb 2018**
- The more timely actual real-time NLDAS-2.5 data has a greatly reduced bias on this day

NLDAS-2.5 evaluation by NASA/GSFC

Conclusions:

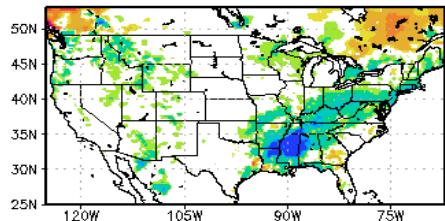
- NLDAS-2.5 real-time products are an improvement over using NLDAS-2.0 4-day lagged products for operational drought monitoring.
- The current NLDAS-2.0 system should continue to run operationally to provide a long-term consistent climatology.
- NASA/GSFC recommends that the NLDAS-2.5 system be run operationally in its present form.

EMC NLDAS Team Re-evaluation for Day 3

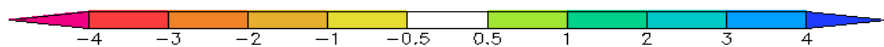
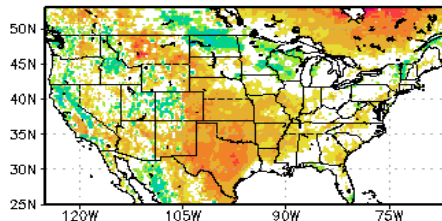
based CPC evaluation findings (NLDAS-2.5: stage II radar precip, NAMv4 2m air temperature)

February

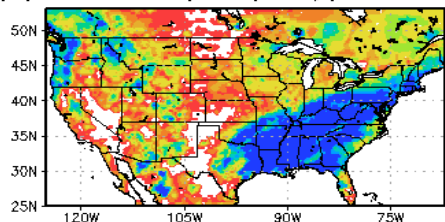
(a) P bias(mm/day) FEB2018



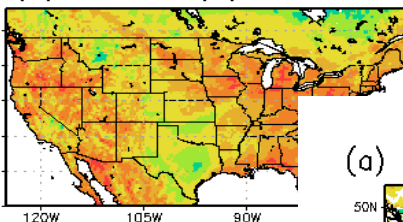
(b) T bias(K) FEB2018



(c) P RMSE(mm/day) FEB2018

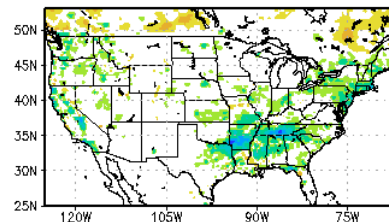


(d) T RMSE(K) FEB2018

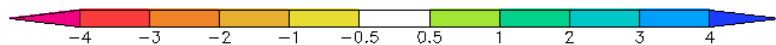
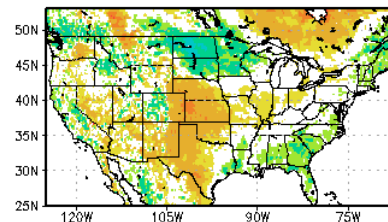


- ✓ Confirm correct codes and scripts
 - ✓ Confirm that Stage II radar precipitation leads to errors
 - ✓ Confirm not due to orographic adjustment for T but two systems (NARR vs NAMv4)
 - ✓ March has smaller error when compared with February
- ## March

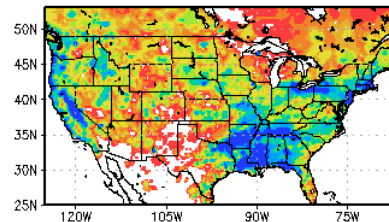
(a) P bias(mm/day) MAR2018



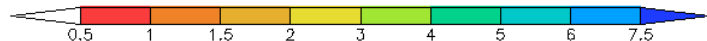
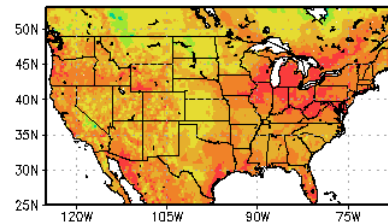
(b) T bias(K) MAR2018



(c) P RMSE(mm/day) MAR2018



(d) T RMSE(K) MAR2018

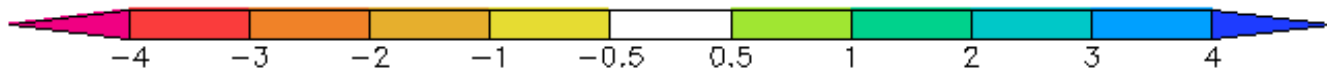
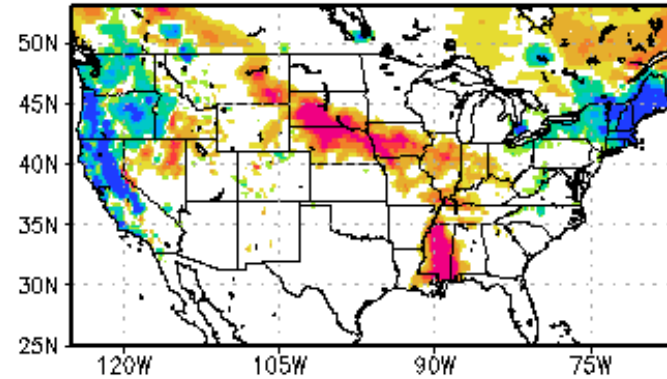
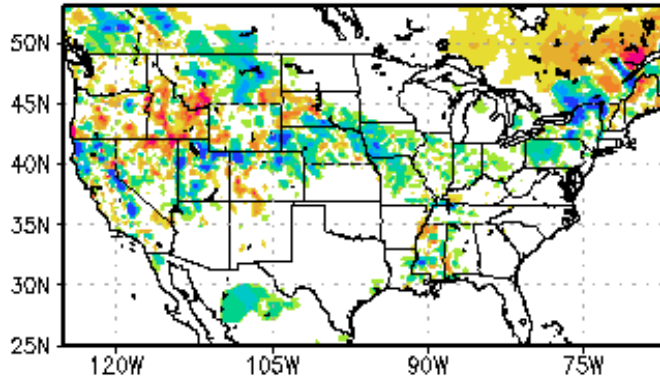


For 2m air temperature error, **no maturated algorithm and/or reasonable observed based product** can be used in present status. We are ready if any progress will be made in future, we will upgrade our system as soon as possible.

EMC NLDAS Team Evaluation for Stage II and IV

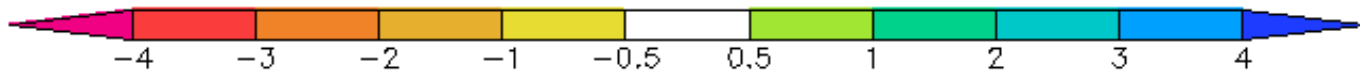
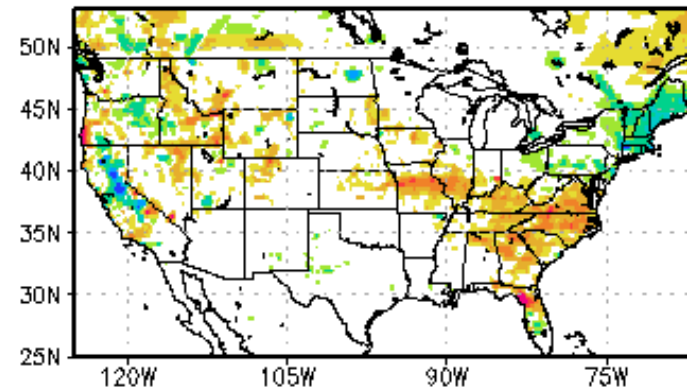
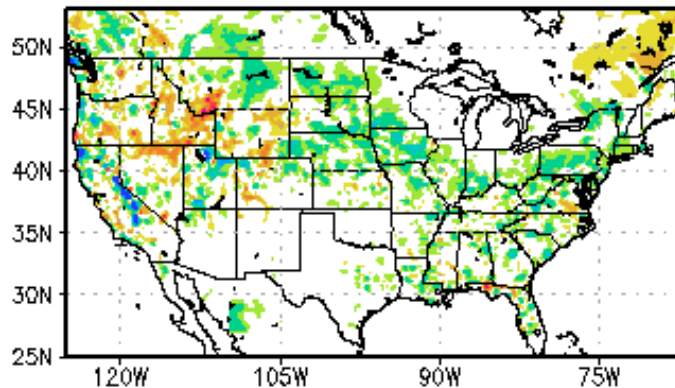
14-17 March 2018

(a) StageIV P bias(mm/day) (b) Stage II P bias (mm/day)



14-27 March 2018

(a) StageIV P bias(mm/day) (b) Stage II P bias (mm/day)



Stage II vs IV

Based on [review for references of comparison of Stage II and Stage IV](#), [some experts inquiry \[Ying Lin \(Stage II and IV\), Yan Luo \(CCPA\), Jack Kain\]](#) and **our own preliminary evaluation**,

we decide to **use hourly Stage IV to replace Stage II for NLDAS v2.5 real-time catchup run**. We still use **Stage II hourly for NLDAS v2.0 run (mainly for temporally downscaling for daily CPC gauge precipitation) to keep the consistency** with 30-year (1979-2008) retrospective run and previous near-real-time run (2009-present).

The advantage is that the users can base on their application purposes to select NLDAS v2.5 output.

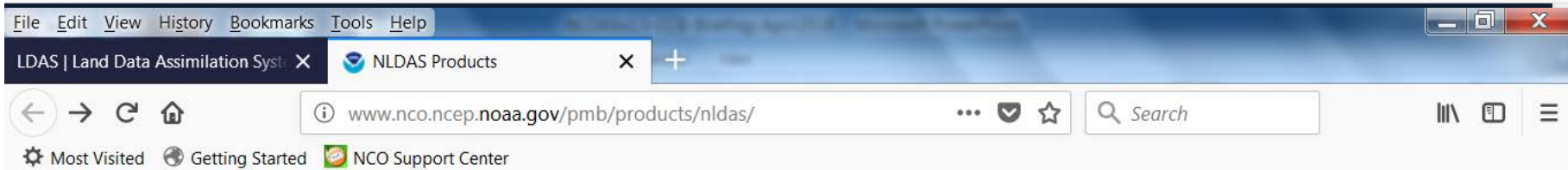
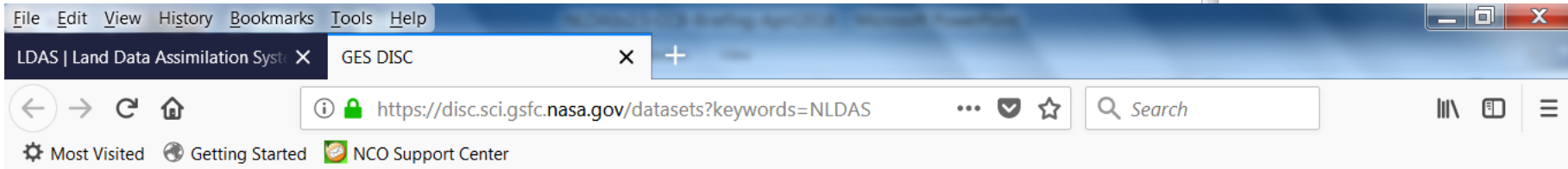
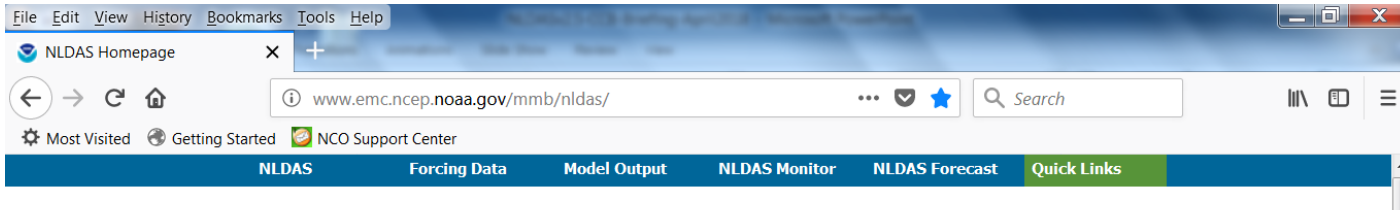
Information of 5 Evaluation Institutes

All evaluation Institutes agree with present implementation plan

1. NASA/GSFC Hydrological Sciences Laboratory (NASA/GSFC/HSL, **Christa Peters-Lidard, David Mocko**)
2. NCEP Climate Prediction Center (NCEP/CPC, **Muthu Chelliah , Gwen Chen**)
3. USDA Office of the Chief Economist and USDM author (USDA/OCE, **Eric Luebehusen**)
4. NOAA Earth Science Research Laboratory (NOAA/ESRL, **Mike Hobbins**)
5. NASA MSFC Short-term Prediction Research and Transition Center (NASA/MSFC/SPORT, **Jonathan Case**)

NLDAS v2.5: Data Distribution

<http://www.emc.ncep.noaa.gov/mmb/nldas/>



[Additional NLDAS documentation](#)

fh is the forecast hour (i.e. 00, 01, 02, ..., 23)
Click on the links under **Inventory** to see the file's contents.

NLDAS is only run for the 12Z cycle
Note: The "NLDAS" domain contains the CONUS region, the northern part of Canada, and southern part of Mexico.

DESCRIPTION	NCEP FTP SERVER File Name	NWS FTP SERVER File Name
NLDAS-2 model forcing - Surface level 1/8 degree NLDAS domain	Available in GRIB2 via FTP Available in GRIB2 via HTTP	Not Available
Filename	Inventory	

Other Distribution Sites: UCAR, USGS, CDC WONDER (Centers for Diseases Control and Prevention), etc.

Future Development of NCEP LDAS

NLDAS

- Run NLDAS under NASA Land Information System (LIS) parallel environment, latest land model versions, land data assimilation and validation tools.
- Improve atmospheric and observational precipitation and air temperature forcing; data sets (e.g. land use, soils, greenness).
- Improve land model physics (e.g., irrigation, ground water, vegetation dynamics, carbon and nitrogen cycle).
- Land data assimilation: snow, soil moisture, GRACE.
- Higher res/downscaling, enhance land model spin-up.
- Extend NLDAS domain (entire North America, eventually global); initial land cond. for FV3GFS.

Collaboration Research of NLDAS Development between EMC and NASA sponsored by CPO/MAPP

(NASA scientists, **EMC scientists**)

- **CPO/MAPP/NLDAS FY11-13:** Assimilating Soil Moisture and Snow Products for Improved Drought Monitoring with the North American Land Data Assimilation System (NLDAS) DA (**Peters-Lidard, Mocko, Kumar, Ek, Xia, Dong**)
- **CPO/MAPP/NLDAS FY14-16:** Advancing Probabilistic Drought Monitoring through Multisensor Ensemble DA (**Peters-Lidard, Mocko, Kumar, Wang, Ek, Xia, Dong**)
- **CPO/CTB/NLDAS FY17-18:** Operational Transition of Soil Moisture and Snow Data Assimilation in the North American Land Data Assimilation System (NLDAS) (**Peters-Lidard, Mocko, Kumar, Ek, Xia, Dong**)
- **CPO/MAPP/NLDAS FY18-20:** Representing human-managed influences through thermal and vegetation product data assimilation in NLDAS: Impacts on the terrestrial water budget and drought estimation (**Peters-Lidard, Mocko, Kumar, Hain, Xia**)

These efforts are being integrated to use for NLDAS-3

NULDAS development and future plan – white paper

Next Phase of the NCEP Unified Land Data Assimilation System (NULDAS): Vision, Requirements, and Implementation

Michael B. Ek¹, Christa D. Peters-Lidard², Youlong Xia¹, David M. Mocko², Jesse Meng¹, Sujay V. Kumar², Helin Wei¹, Jiarui Dong¹, Augusto Getirana², and Shugong Wang²

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10 September 2017

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NULDAS development and update will help enhance its capability for both drought and flooding monitoring task, as well as optimal ICs for coupled system.

Interaction with other EMC projects and outside community

- **Speed up NULDAS development via unifying NLDAS and GLDAS (e.g., forcing generation, model choice, and system test)**
- **Efficiently use radar, reanalysis and model product in NULDAS testbed via collaboration with EMC scientists**
- **Enhance couple model system tests (e.g., FV3GFS) for land model (Noah, Noah-MP) to identify key parameters and processes to improve skills from sub-seasonal to seasonal forecast**
- **Achieve standalone->SCM->fully coupled system test strategy**
- **Enhance internal collaboration within EMC, in particular related to atmospheric and boundary layer physics processes – working two systems together**
- **Speed up development and transition of land-related processes (lake, groundwater, irrigation, vegetation dynamics, wild fire, biochemistry, and ecosystem, global river router) to Noah or Noah-MP model to meet EMC coupled system requirements.**
- **Use land model as a component to support for coupled system upgrade and development at EMC**

References (EMC scientists are indicated in bold)

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Thanks for your attention!

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