The Western Land Data Assimilation System and Drought Monitoring in Colorado

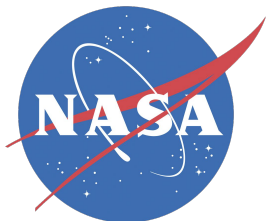**Jessica Erlingis (UMD/GSFC)**

Matt Rodell (GSFC)

Sujay Kumar (GSFC)

Project Partners: Russ Schumacher and Peter Bennett Goble (CCC)

Bailing Li (UMD/GSFC)

Scott Rheingrover (SAIC)

April 30, 2024

Motivation

**Goal:** Support decision makers with data on water availability

- Partnering with Colorado Climate Center (CCC) and other state and local agencies to assist with drought assessment, groundwater and agricultural management needs

Approach: Apply NASA's Land Information System (LIS) software to integrate data from multiple sources (GRACE, MODIS, NLDAS-2, PRISM, STATSGO, FAO, SRTM) in a configuration optimized for the western United States
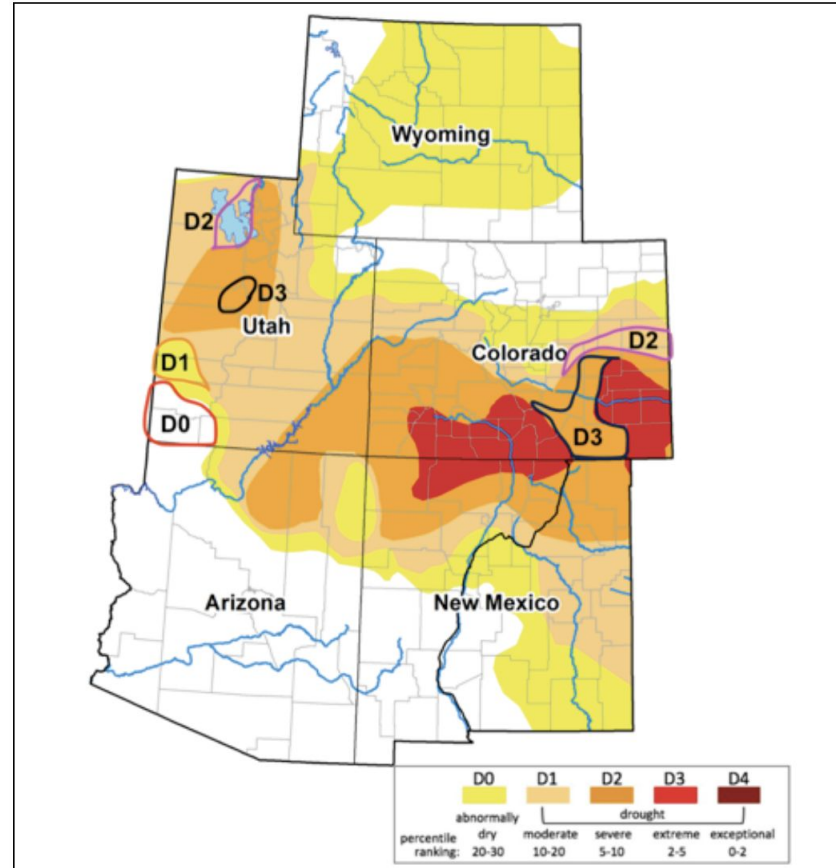
Team: Scientists from GSFC and CCC
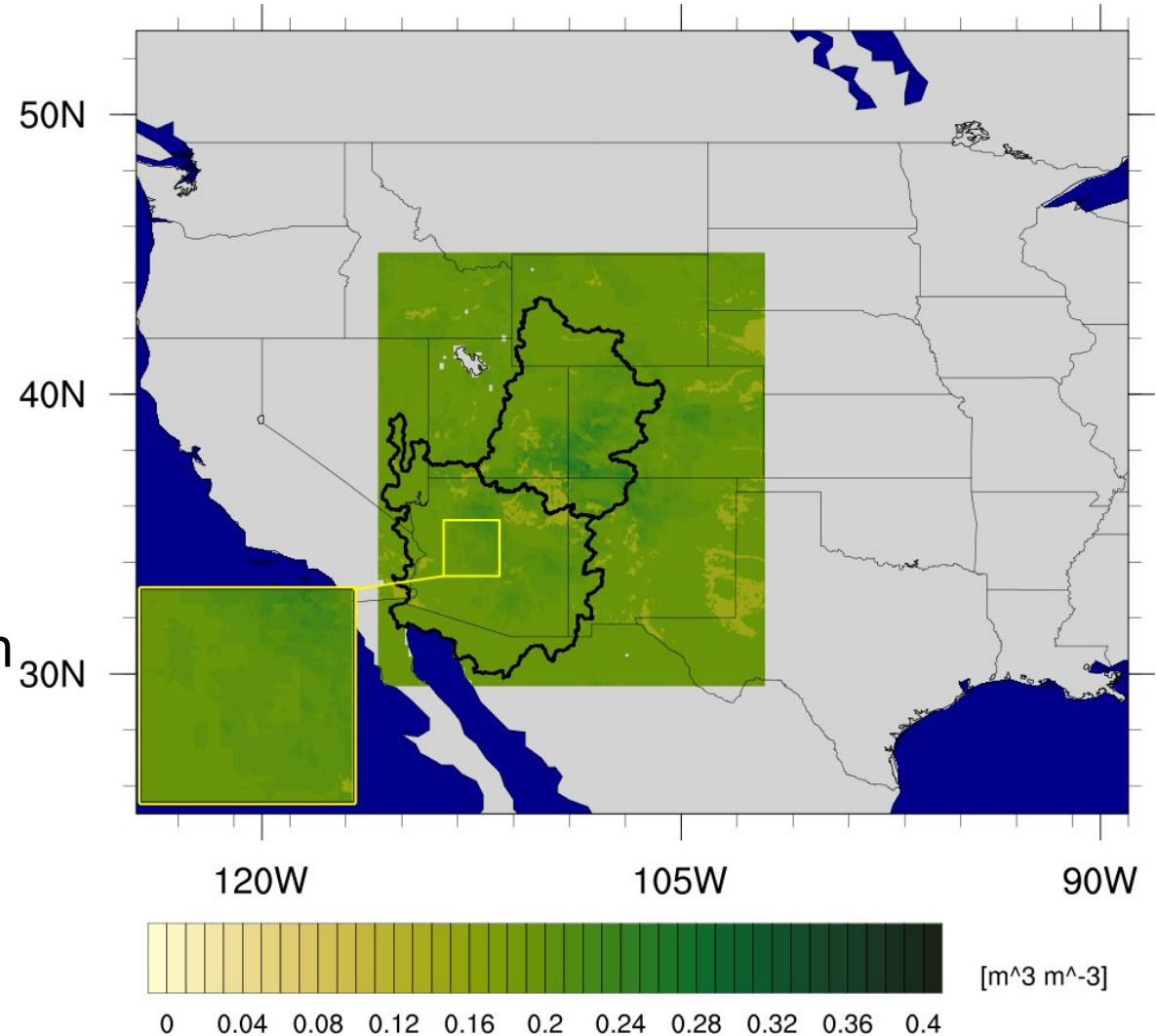
Motivation
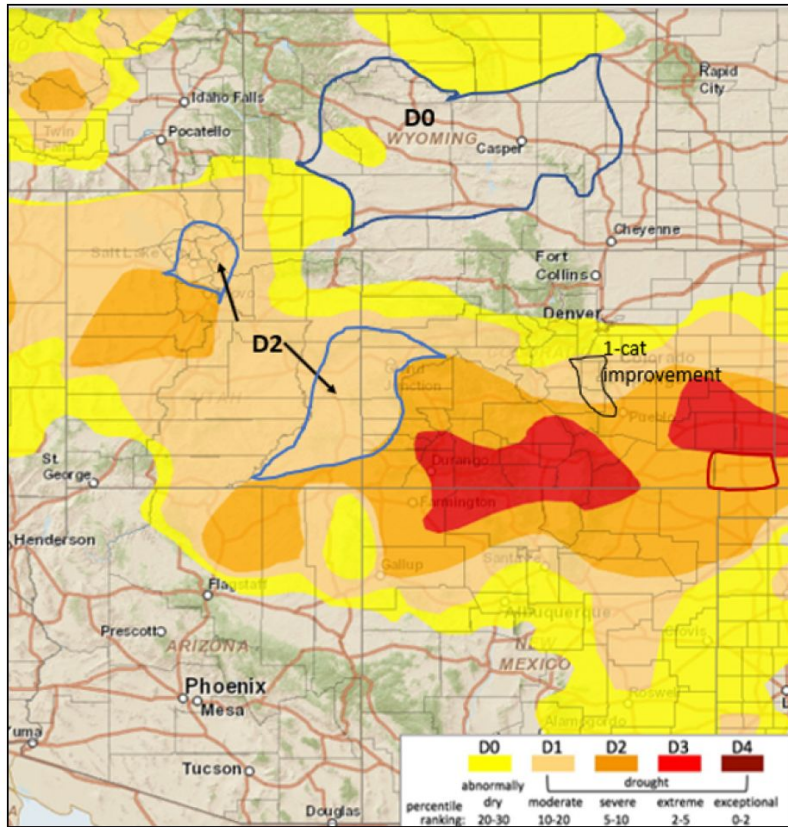
June 2

June 9

Recommendations:

UCRB: Widespread D2 expansion is recommended in western Colorado and eastern Utah along with D2 expansion around the Salt Lake City area. This expansion is driven mostly by poor SPEI numbers on multiple timescales out to 5 months. Low SPI and precipitation percentiles over the past 5 months back this up as well.

Colorado: Improvement is recommended in central Colorado through Teller, southeastern Park, eastern Fremont, northwestern Pueblo, and far western El Paso counties. This area received 1-2 inches of new precipitation over the last week. A 1-category improvement is being proposed, which will improve the D1 to D0 in Teller, Park, Fremont, and El Paso and improve D2 to D1 in Fremont and Pueblo.

Baca County: With D3 being recommended in the adjacent states, we are recommending D3 be included in this expansion and connect to the existing D3 in southeastern Colorado.

Wyoming: Widespread D0 is being recommended in Wyoming. The D0 expansion will connect the north central D0 with the southwest D0 and extending east to Albany County. Conditions in Wyoming have continued to dry out and it looks like it's time for degradations.
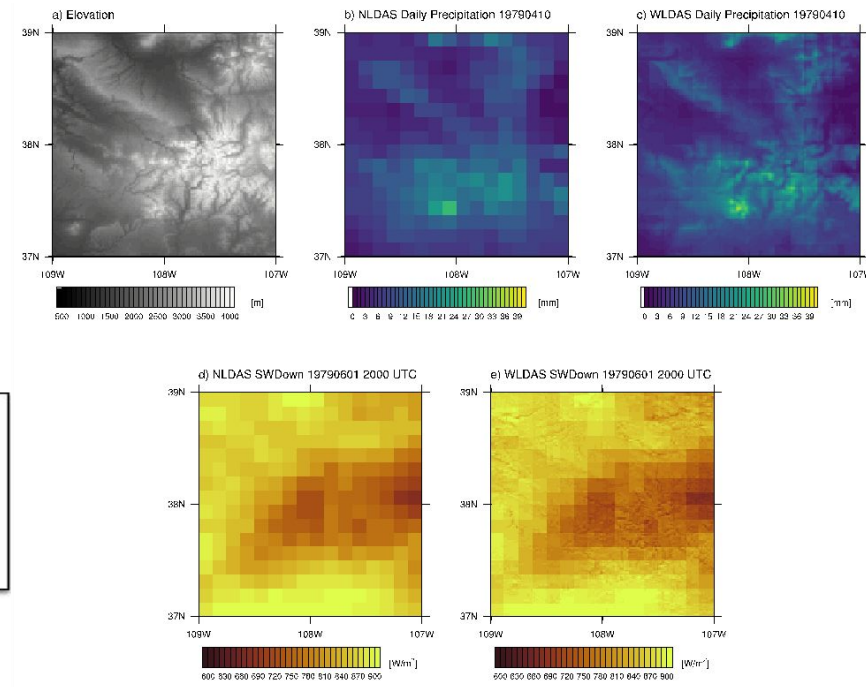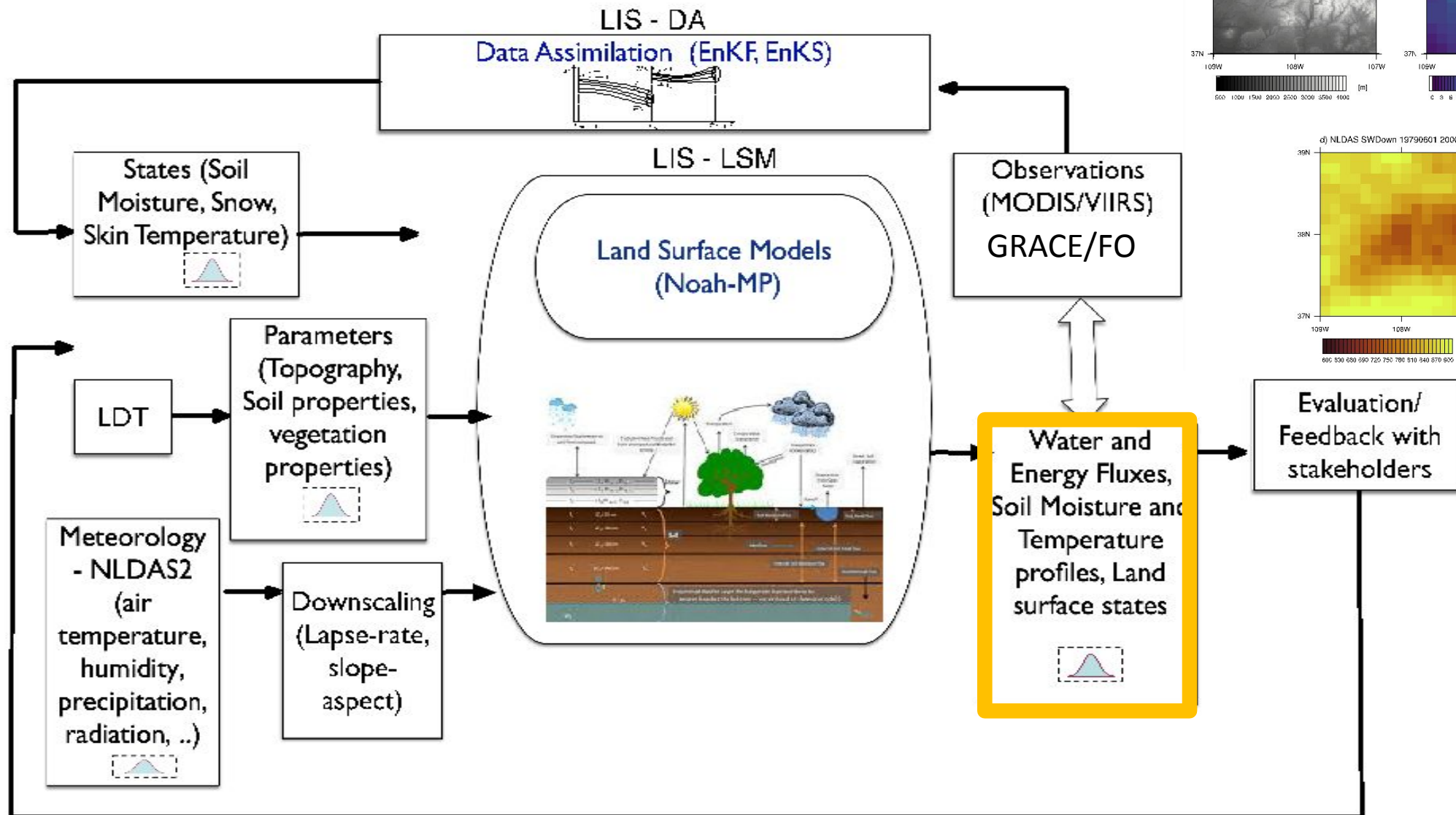
Operational WLDAS products will appear here

Colorado Climate Center drought assessments and recommended changes to the United States Drought Monitor.

https://climate.colostate.edu/assessmain.html
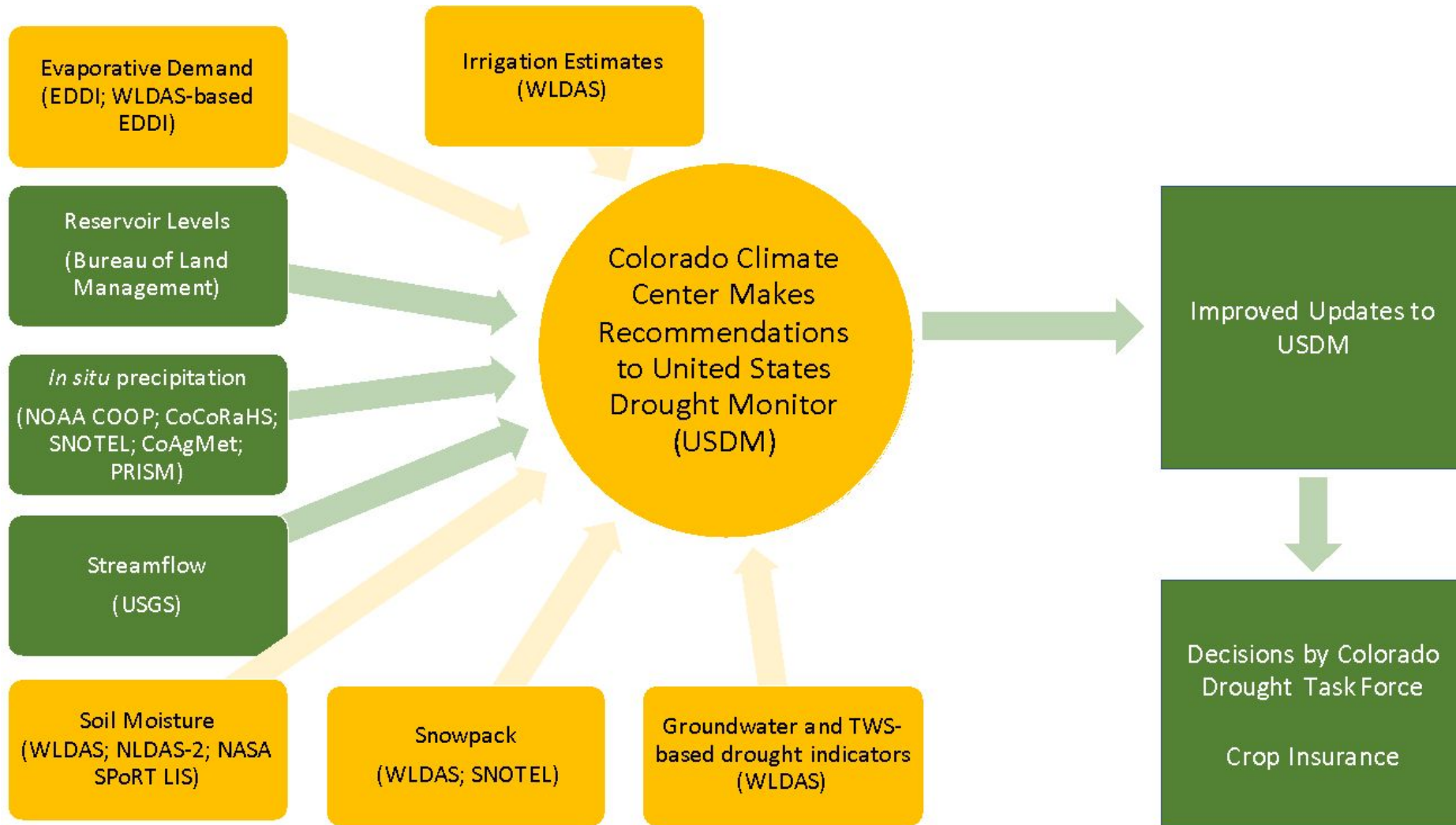
Product Generation Process

a) Elevation, b) NLDAS accumulated daily precipitation on 10 April 1979, c) Downscaled WLDAS accumulated daily precipitation on 10 April 1979, d) NLDAS downward shortwave radiation at 2000 UTC on 1 June 1979, and e) Downscaled WLDAS downward shortwave radiation for 1 June 1979
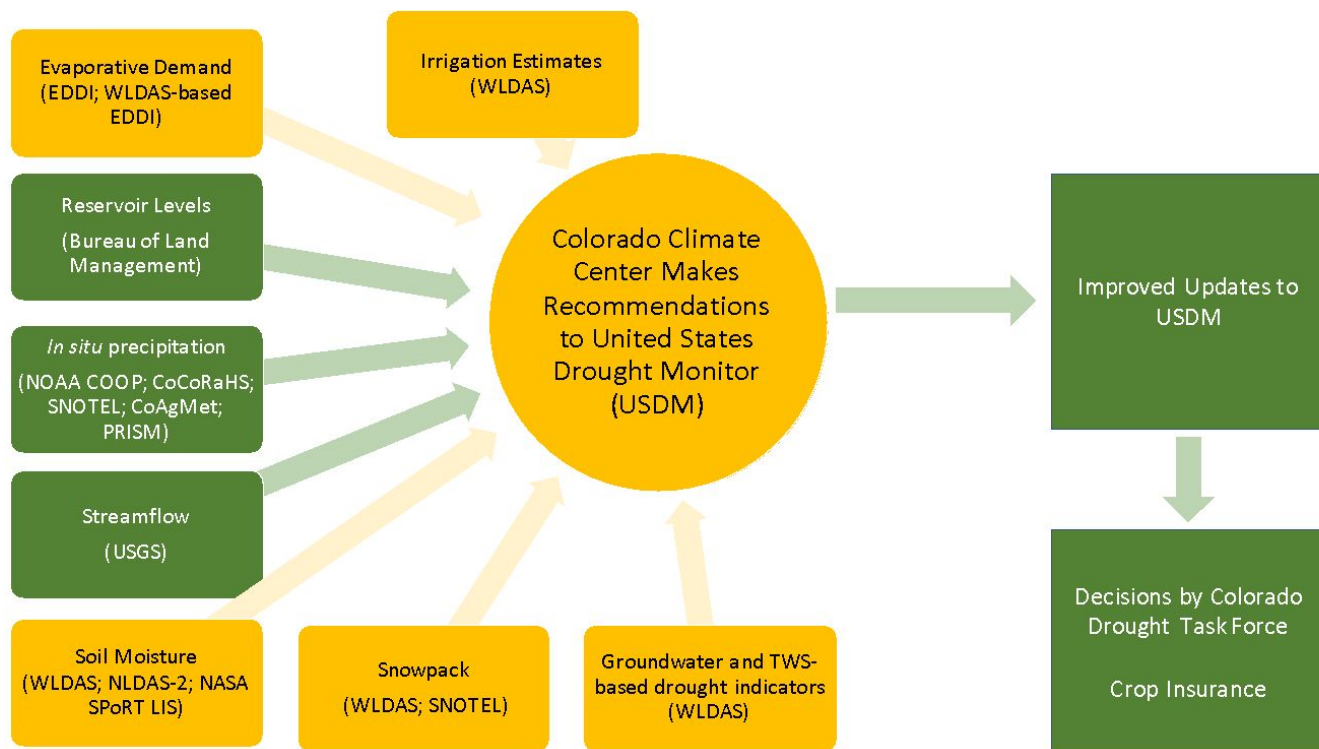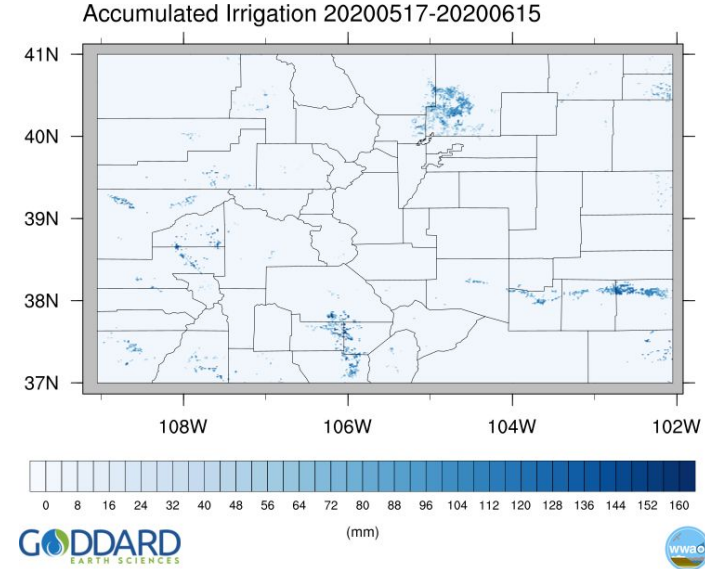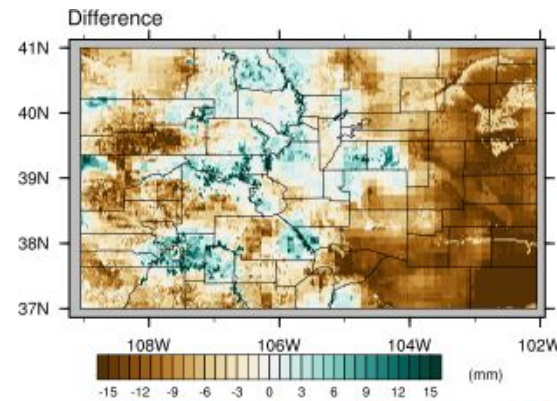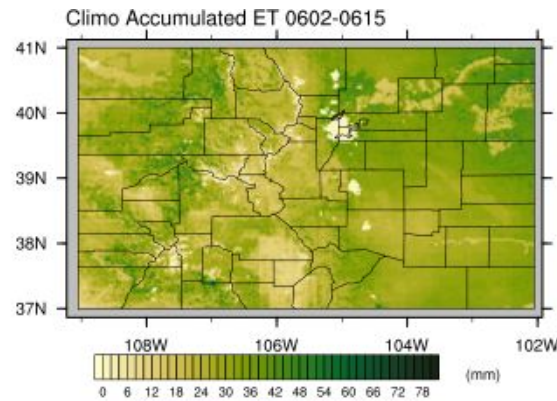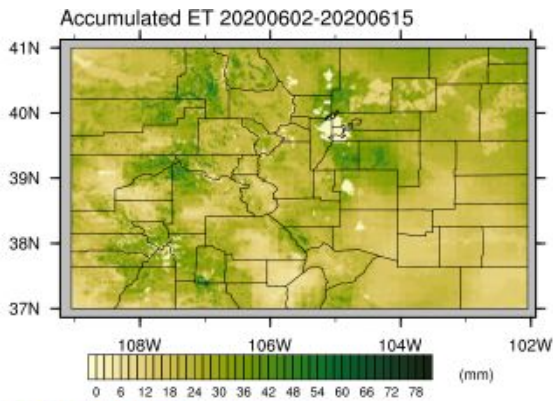
Products

- Soil moisture, groundwater, and TWS drought indicators
- Soil moisture (0-10 cm, 10-40 cm, 40-100 cm, 100-200 cm below surface)
- Groundwater storage anomalies and recharge
- TWS anomalies
- Downscaled meteorological forcing (radiation, precipitation, 2-meter temperature and humidity)
- ET
- Running (weekly, 14-day, 30-day) ET and ET anomalies
- Surface and subsurface runoff
- Snow water equivalent (SWE)
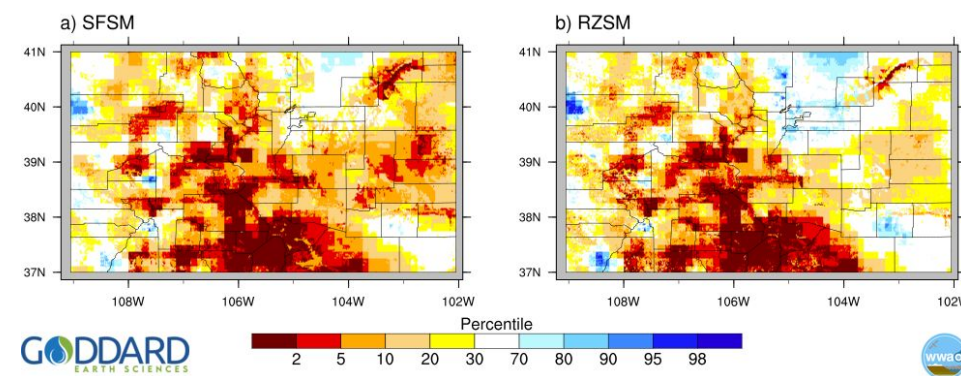- Simulated irrigation water use

New Workflow at CCC

Accumulated ET 20200602-20200615

Climo Accumulated ET 0602-0615

Difference

Accumulated Irrigation 20200517-20200615

20230824
a) SFSM   b) RZSM

30-Day SWE Change

Workflow diagram:

Inputs:
- Evaporative Demand (EDDI; WLDAS-based EDDI)
- Irrigation Estimates (WLDAS)
- Reservoir Levels (Bureau of Land Management)
- In situ precipitation (NOAA COOP; CoCoRaHS; SNOTEL; CoAgMet; PRISM)
- Streamflow (USGS)
- Soil Moisture (WLDAS; NLDAS-2; NASA SPoRT LIS)
- Snowpack (WLDAS; SNOTEL)
- Groundwater and TWS-based drought indicators (WLDAS)

→ Colorado Climate Center Makes Recommendations to United States Drought Monitor (USDM)

→ Improved Updates to USDM

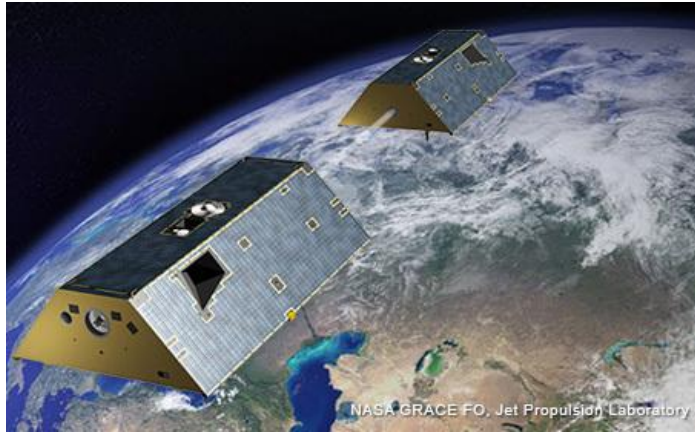→ Decisions by Colorado Drought Task Force / Crop Insurance

WLDAS Suite

- Open Loop (OL)
  - Noah-MP 4.0.1 with NLDAS-2 downscaled forcing

- OL + Irrigation
  - Only differs from (OL) over irrigated pixels
  - Useful for estimating demand for irrigation based on soil moisture conditions (Ozdogan et al. 2010)

- LAI DA
  - Constrains dynamic vegetation parameterization using MODIS LAI
  - Indirectly captures effects of irrigation
  - MCD15A2H v6 LAI data discontinued February 10, 2023

- GRACE DA

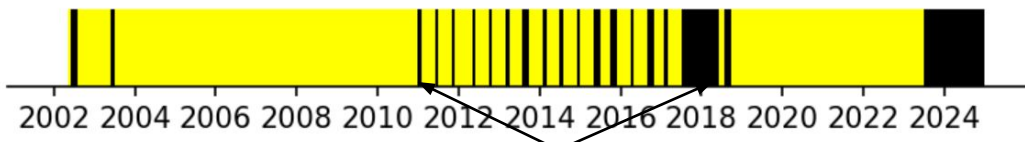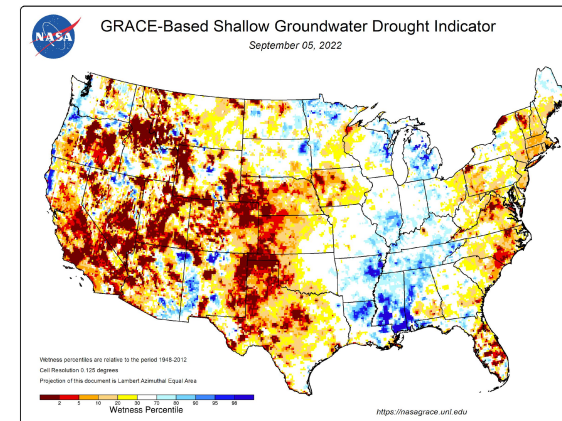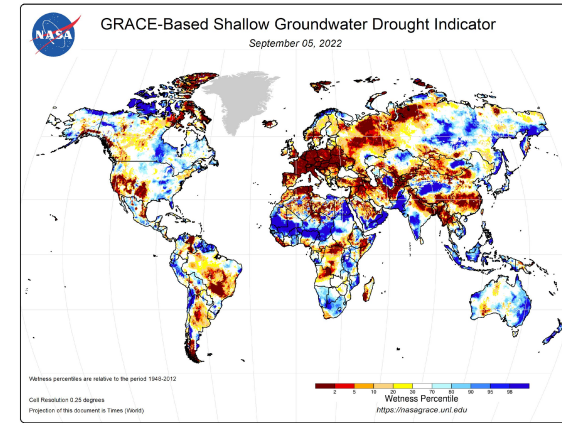# GRACE/GRACE FO data for drought monitoring capability developed at the GSFC/Hydrological Sciences Laboratory

NASA GRACE FO, Jet Propulsion Laboratory

GRACE /GRACE-FO TWS:
- Gravity mapping
- Vertically integrated observations
- Monthly with ~3-month data latency
- ~150,000 km^2 spatial resolution

missing data

GRACE data assimilation (DA)

GRACE-Based Shallow Groundwater Drought Indicator
September 05, 2022

GRACE-Based Shallow Groundwater Drought Indicator
September 05, 2022

Maps available at https://nasagrace.unl.edu/

Li et al. 2019. "Global GRACE data assimilation for groundwater and drought monitoring: Advances and challenges." Water Resour. Res., 55: 7564-7586 [10.1029/2018wr024618]

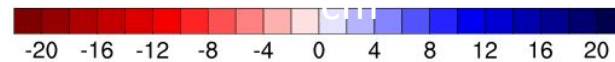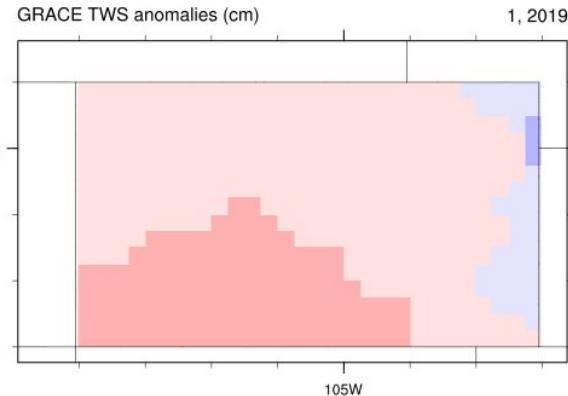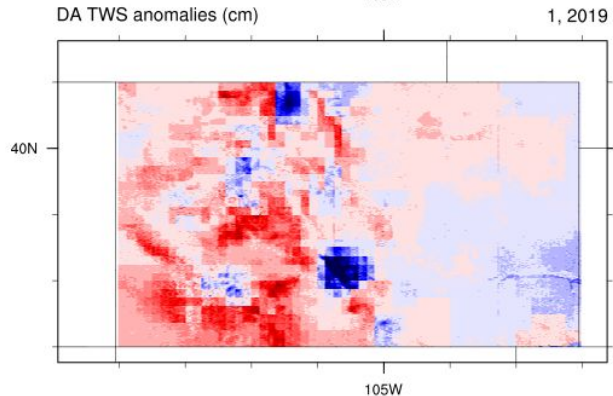# GRACE data assimilation for high resolution data in Colorado

Monthly anomalies (relative to monthly mean)
(2019-2021)

Open loop (1 km)
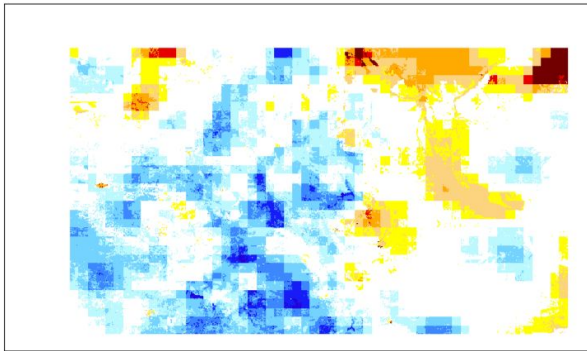
Downscaled GRACE (1 km)
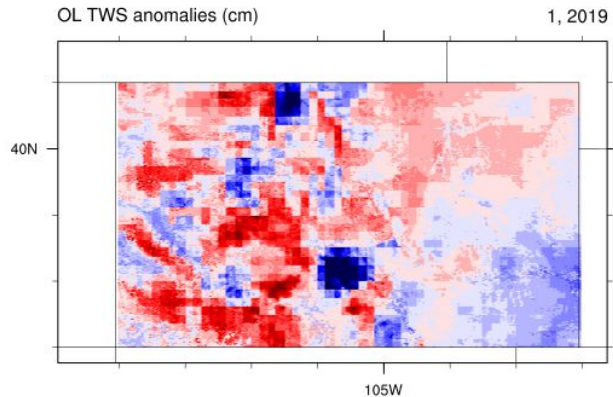
GRACE observations

WLDAS/GRACE DA SPECS:

- Noah-MP (more advanced physics for snow)

- 1 km (to accommodate the complex terrain of Colorado)

Contact: bailing.li@nasa.gov

GRACE-based drought percentile maps at 1 km
(August 2022 - September 2023)

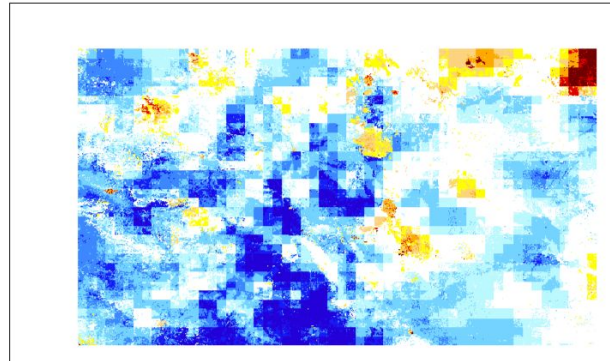### Surface soil moisture

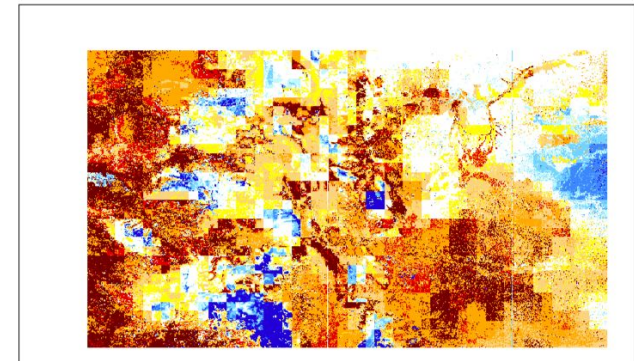### Root zone soil moisture

Groundwater storage

Limitation: Drought percentiles were derived based on short climatology (GRACE DA simulation)

Transitioned GRACE-based drought monitoring capability to CCC:
- Installation of LIS using a containerizing technique (Jim Geiger)
- Set up the LIS run environment in CCC's computer system
- Trained users to run GRACE data assimilation

Contact: bailing.li@nasa.gov

Partner Impact Statements

- Using the additional [drought monitoring] data provided by NASA to improve regional recommendations to the United States Drought Monitor, which is tied to the Livestock

  Forage Program disaster relief fund

- Additional data was also used in updates to the state's Water Availability Task Force. A subcommittee of this team is tasked with choosing whether or not to issue a drought disaster declaration for part, or all, of Colorado.

- Soil moisture maps derived from the WLDAS data were also used to support a disaster request made by the state of Colorado to FEMA for flooding caused by extreme rainfall in May-June 2023. The soil moisture information was used to illustrate that soils remained abnormally wet in between the two primary periods of extreme rainfall, likely

  exacerbating the flooding that occurred

Data Delivery

- GES DISC

  Erlingis, J., Li, B. and Rodell, M., NASA/GSFC/HSL (2024), WLDAS Noah-MP 3.6 Land Surface Model L4 Daily 0.01 degree x 0.01 degree Version D1.0, Greenbelt, Maryland, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/ABBHPUIGJH5M

- CCC dashboard: https://climate.colostate.edu/drought/#soil

- On NCCS Discover supercomputer Centralized Storage System: https://www.nccs.nasa.gov/services/data-collections/css-collections

- NASA Center for Climate Simulation (NCCS) data portal: https://portal.nccs.nasa.gov/datashare/WLDAS/

- Source code is publicly available to the scientific community on Github: https://github.com/NASA-LIS/LISF

https://climate.colostate.edu/drought/#soil

Project Publications

- Li, B., M. Rodell, C. Peters-Lidard, J. Erlingis, S. Kumar, and D. Mocko, Groundwater Recharge Estimated by Land Surface Models: An Evaluation in the Conterminous United States. *J. Hydrometeorol.*, **22**, 499–522, doi:10.1175/JHM-D-20-0130.1.

- Erlingis, J., M. Rodell, C.D. Peters-Lidard, B. Li, S.V. Kumar, D. Mocko, 2021: A High-Resolution Land Data Assimilation System Optimized for the Western United States, *Journal of the American Water Resources Association,* 1-19, doi: 10.1111/1752-1688.12910.

- Erlingis, J., Li, B. and Rodell, M., NASA/GSFC/HSL (2023), WLDAS Noah-MP 3.6 Land Surface Model L4 Daily 0.01 degree x 0.01 degree Version D1.0, Greenbelt, Maryland, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), 10.5067/ABBHPUIGJH5M

Additional Slides

LSM Input and Output Fields

Input Parameters:

vegetation class

vegetation greenness/LAI

soil type

elevation

Required Forcing Fields:

total precipitation

convective precipitation

downward shortwave radiation

downward longwave radiation

near surface air temperature

near surface specific humidity

near surface wind speed *(U & V)*

surface pressure

Simulated 0-10 cm soil moisture on 8 September 2013.

Assimilated Data Fields:

snow cover

snow depth or water equivalent

soil moisture

terrestrial water storage anomaly

leaf area index

irrigation intensity

surface temperature

Summary of Output Fields:
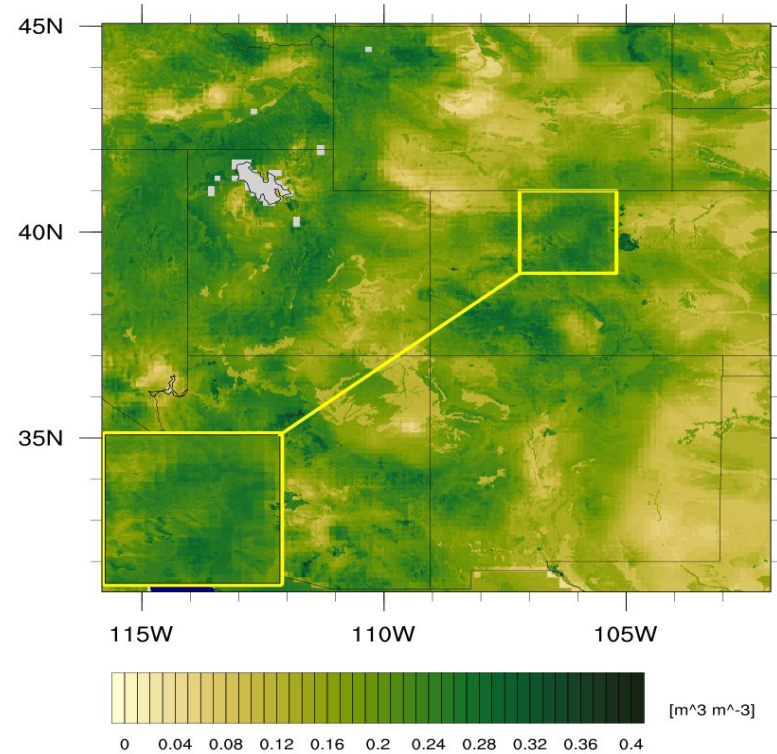
soil moisture in each layer

snow water equivalent

groundwater storage

soil temperature in each layer

surface and subsurface runoff

evaporation

transpiration

latent, sensible, and ground heat fluxes

snowmelt

snowfall and rainfall

net shortwave and longwave radiation

LAI Data Assimilation Improves ET Estimation

- Assimilating 500m MODIS Leaf Area Index (LAI; MCD15A2H v6) 8-day composites to constrain dynamic vegetation from mid 2002-present

- Improves ET estimation (warm colors) over open loop run when compared with UW, ALEXI, GLEAM, and FLUXNET products