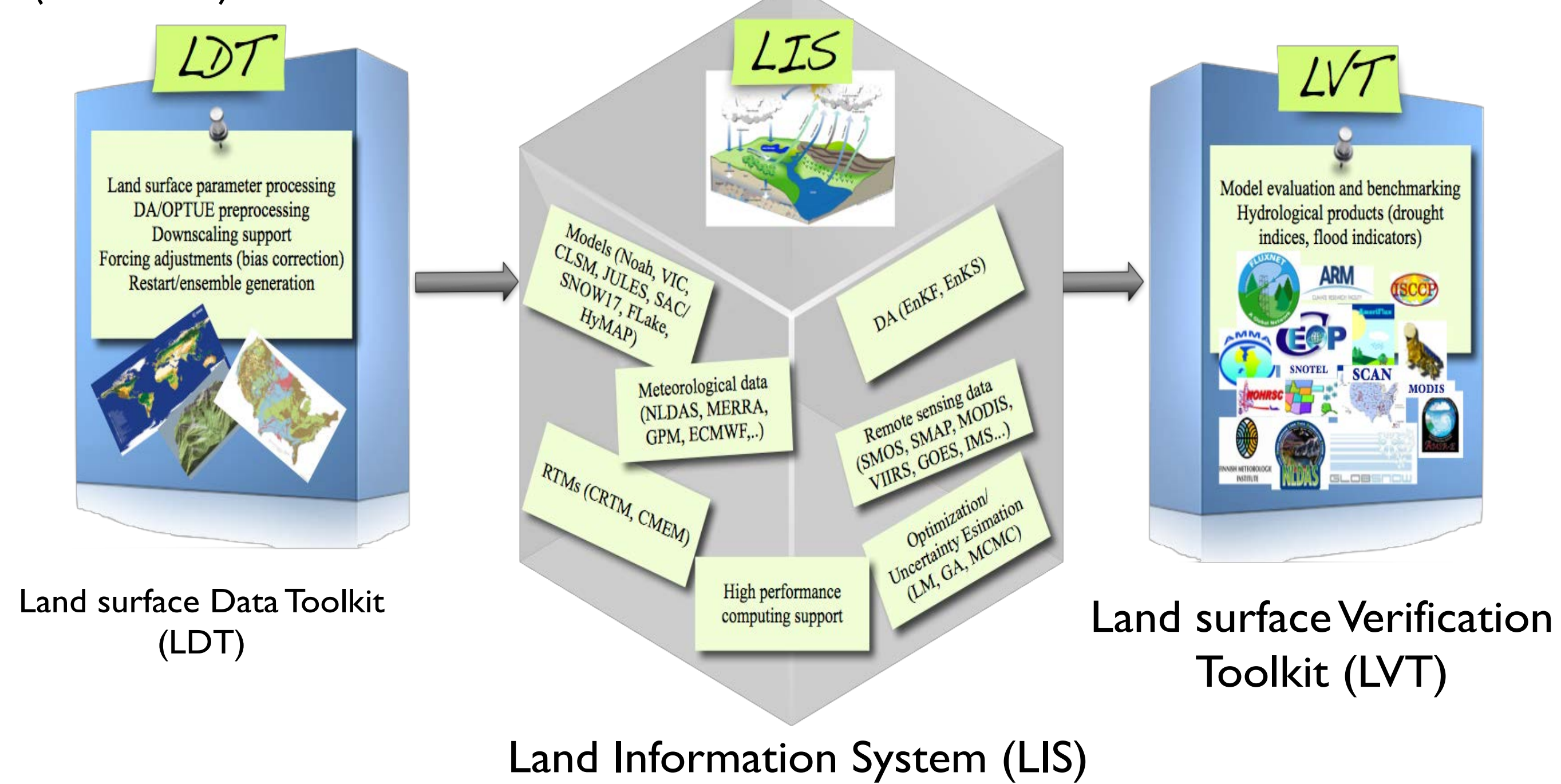


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Introduction

- The United States Air Force (USAF) has a proud and storied tradition of enabling significant advancements in the area of characterizing and modeling land state information.
- 557th Weather Wing (557 WW; DoD's Executive Agent for Land Information) provides routine geospatial intelligence information to war-fighters, planners, and decision makers at all echelons and services of the U.S. military, government and intelligence community.
- 557 WW and its predecessors have been home to the DoD's *only* operational regional and global land data analysis systems *since January 1958*.
- As a trusted partner since 2005, Air Force Weather (AFW) has relied on the Hydrological Sciences Laboratory at NASA/GSFC to lead the interagency scientific collaboration known as the Land Information System (LIS).
- LIS is an advanced software framework^[1,2,3] for high performance land surface modeling and data assimilation of geospatial intelligence (GEOINT) information.



Recent Data Assimilation Enhancements

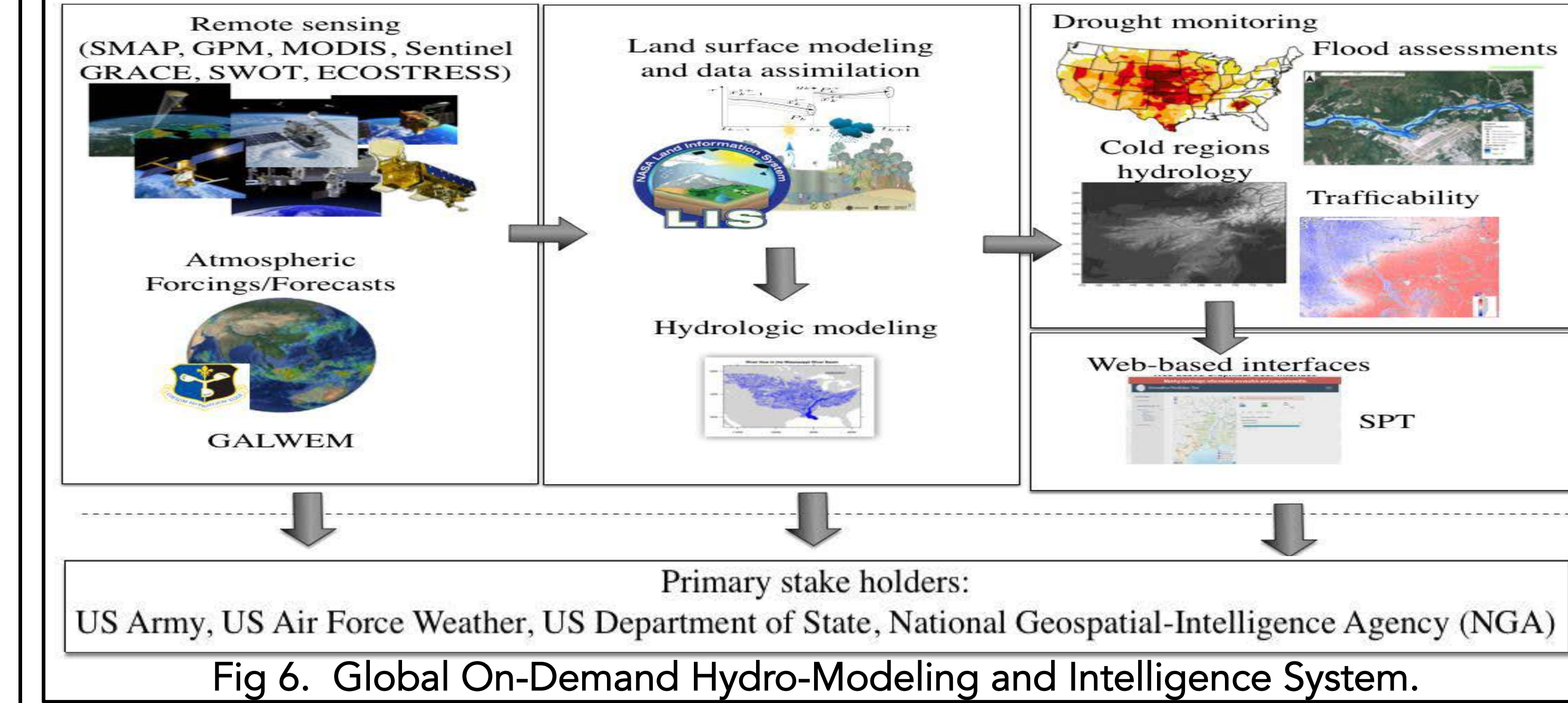
- Updates to the meteorological analysis (e.g., improved precipitation processing using a Bratseth scheme; Ability to ingest IMERG (see: ppm.nasa.gov/data-access/downloads/gpm); dynamic use of GALWEM as first-guess) [Improved overall quality of analyses while enabling decommissioning of legacy GEOPRECIP application].
- Next-generation, global 10-km "USAF Snow and Ice analysis (USAF SI) [Enables decommissioning of legacy SNODEP application; DA-method of Direct Insertion replaced with EnKF].
- Global 10-km configurations of NoahV3.9.1 (Last), Noah-MPV4.0.1 and JULESV5.0+ land surface models [All of which possess optimized/tuned EnKF of 'USAF Snow & Ice Analysis', SMAP L2, and ASCAT Metop- A/B SM in model space^[4] on a common 10-km global grid].—see <https://www.jpl.nasa.gov/news/news.php?feature=7544>

Other Significant Enhancements to Operations

- Southern limit of domain extended from 60° S to 90° S (now truly global).
- Replaced undocumented, outdated, multi-step pre-processing method with streamlined, LDT-contained methodology using the latest/greatest source data available (to include Met Office Ancillaries needed for initialization of GALWEM).
- Replaced SOILPARM.TBL (Cosby, 1984) used with Noah with corrected SOILPARM.TBL coefficients.
- In-house LISpost replaced with LVT. Improved functionalities enabled:
 - Appending USN GOFS [Improves upon both 1/4° navysst used by WRF and provides a 1/20° (poleward of 40 N/S) U.S.-based alternative (or backup) for SSTs and Sea Ice Fraction and thickness to 1/20° (~5-km) OSTIA (produced by Met Office), respectively.] [Enables GALWEM COOP under INFOCON-1 (.mil-to-.mil)];
 - Uncertainty estimation applied on 12-member ensemble and mean to derive standard deviations of several parameters; [Enables satisfaction of (most) vertical profiles of land state variable requirements for PAIS]; and
 - Transition from GriB-1-to-GriB-2 [Enables decommissioning of legacy data flows].
- DISA STIG-compliant with zero vulnerabilities/findings.

Future Work

- Direct radiance assimilation of NRT SMAP L1 Tb (9-km).
- Extend the NRT-assimilation of albedo, vegetation conditions, and Tsfc from MODIS/VIIRS for the Noah LSM to the Noah-MP and JULES LSMs.
- Extend the data assimilation capabilities of LIS to allow for the assimilation of near-real-time (NRT) soil moisture products from ESA's Soil Moisture and Ocean Salinity (SMOS) mission.
- Exploitation of Soil Moisture, Snow Water Equivalent (SWE) and Snow Depth derived from Weather Satellite Follow-on-Microwave (WSF-M).
- Exploitation of snow cover and SWE from GCOM (AMSR2).
- Update the snow analysis by including geostationary satellite inputs (GOES-16 and 17, Himawari- 8 and 9) and by extending the snow gauge coverage (include a broader set of GTS stations).
- Extend the data assimilation capabilities of LIS to allow for the assimilation of Total Water Storage (TWS) from GRACE Follow-On (GRACE-FO).



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- LIS consists of a large suite of land surface models and data assimilation algorithms (EnKF, EnKS, ...) and support for remote sensing data (SMAP, SMOS, AMSR2, ASCAT, AMSR-E, SSM/I, SMMR, ...).
- LDT supports the data preprocessing needs for LIS (parameter data processing, data assimilation support, forcing bias correction, ...)
- LVT includes the support of in-situ (SCAN, USDA, NASMD, ISMN, ...), remote sensing and model/analysis datasets for model benchmarking and evaluation.

Fig 1. Primary Subsystems comprising the LIS Framework.

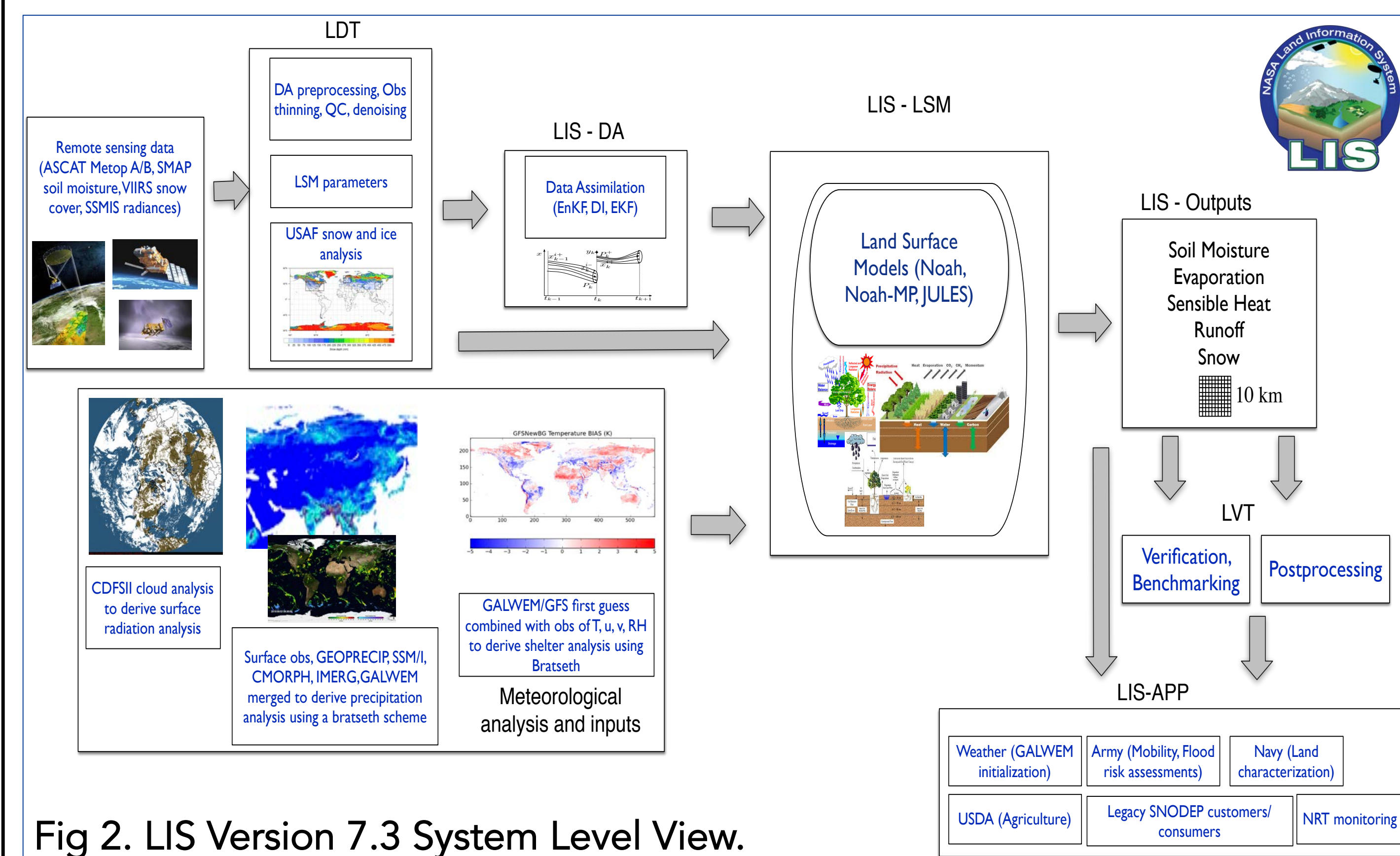


Fig 2. LIS Version 7.3 System Level View.

Summary of Results

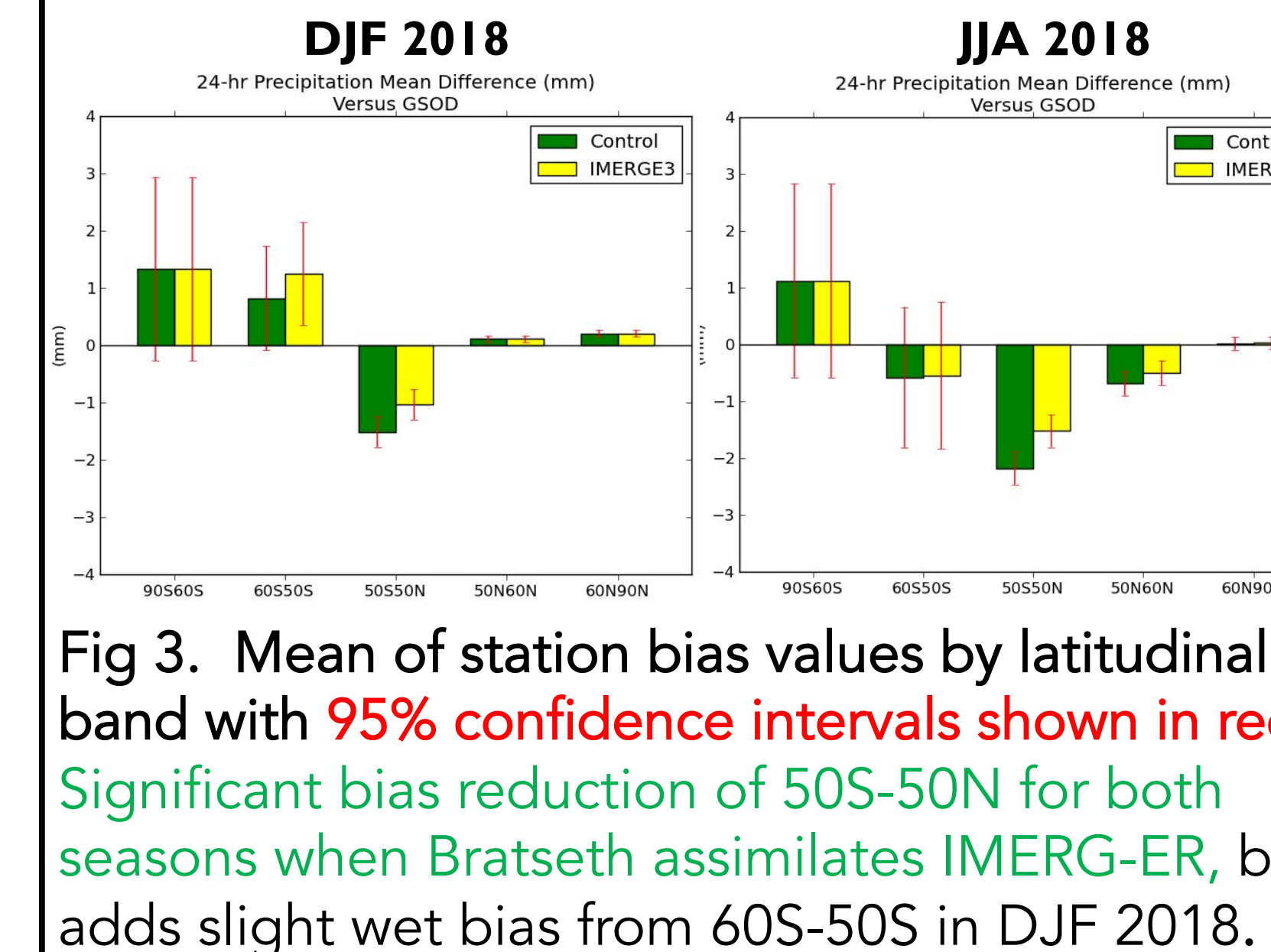


Fig 3. Mean of station bias values by latitudinal band with 95% confidence intervals shown in red. Significant bias reduction of 50S-50N for both seasons when Bratseth assimilates IMERG-ER, but adds slight wet bias from 60S-50S in DJF 2018.

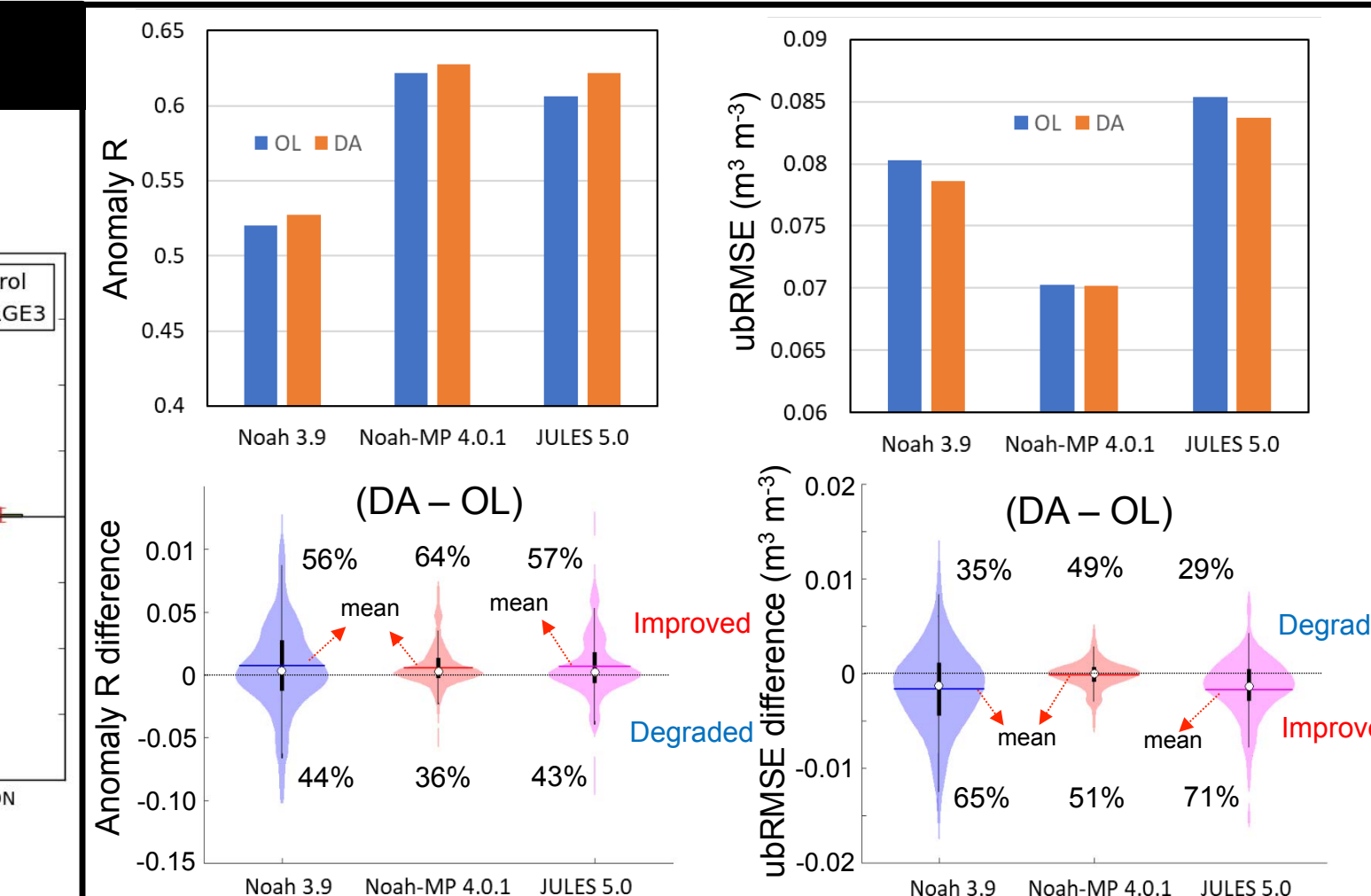


Fig 4. Summary of CONUS results (4/1/15 - 1/1/18; USDA ARS, SCAN, USCRN). DA method optimized: fine-grained CDFs; Obs thinning for JULES; >50% of model grid cells improved; # obs assimilated increased.

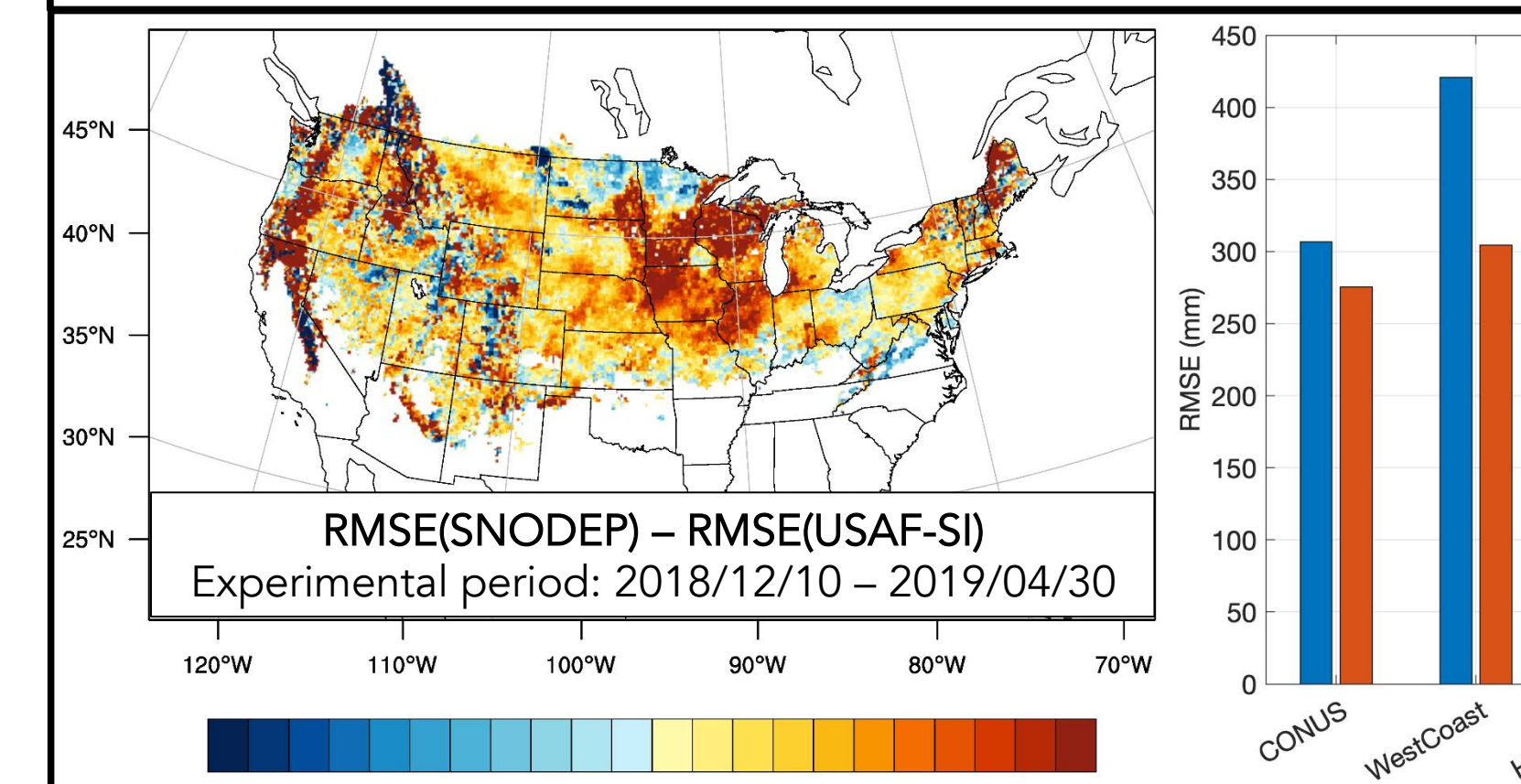


Fig 5. Difference RMSE between SNODEP and USAF-SI vs. SNOFAS. Warm colors indicate improvement and cool degradation. USAF-SI performance improved over 76.6%, degraded 23.4% locations.