A Sensitivity Study of the FLDAS-Forecast System for Food Insecurity Early Warning

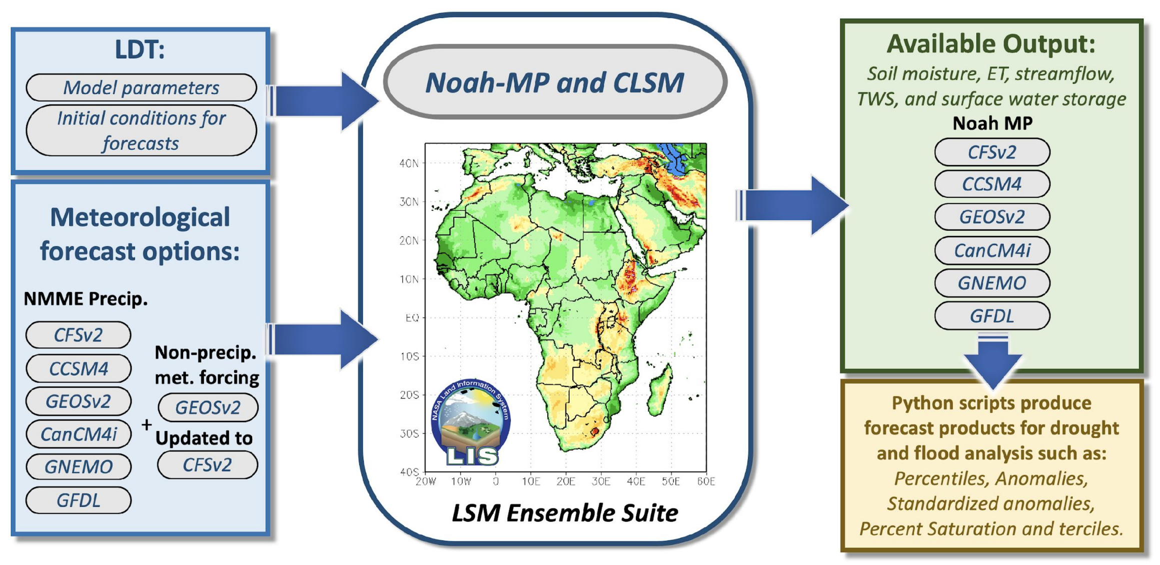
Abheera Hazra[1,2], Kimberly Slinski[1,2], Amy McNally[1], Weston B Anderson[1,2], Kristi R Arsenault[1,3], Shraddhanand Shukla[4], Augusto Gentiana[1,3], Sujay V Kumar[1]
[1]NASA GSFC, Greenbelt, MD, [2]ESSIC, UMD, College Park, MD, [3]SAIC, Reston, VA, [4]Climate Hazards Center, University of Santa Barbara, Santa Barbara, CA

1. Introduction

FEWS NET Land Data Assimilation System (FLDAS) Forecast uses NMME precipitation and GEOSv2 non-precipitation forecasts as inputs to produce hydrologic forecasts -> FLDAS-Forecast 1 (FF1)

Hazra, A., and Coauthors, 2023: https://doi.org/10.1016/j.jhydrol.2022.129005

Updated to use NMME precipitation and CFSv2 non-precipitation forecasts as inputs to produce hydrologic forecasts -> FLDAS-Forecast 2 (FF2)



FLDAS-Forecast uses the Land Information System Framework (LISF) to generate ensemble forecasts of hydrologic conditions that are used to estimate drought and flood risk over Continental Africa and the Middle East.

Monthly FLDAS-Forecast derived products are routinely updated on https://ldas.gsfc.nasa.gov/fldas/models/forecast.

2. Motivation & Study

Why do we need forecasts of hydrologic conditions?

- Soil moisture provides a more accurate representation of water availability for plants than precipitation does
- Supports agriculture by optimizing planting, irrigation, and fertilization strategies based on water availability
- Helps flood management with forecasts of river levels
- Helps food security analysts provide early warnings using forecasts of hydrologic extremes such as droughts and floods

What is being updated in the FLDAS-Forecast?

- Soil texture has been updated from ISRIC to STATSGO-FAO to better align the forecast with FLDAS monitoring products
- The sub-daily temporal disaggregation of CHIRPSv2 has been updated to utilize MERRA2 (CHIRPS2), previously, it used CFS (CHIRPS1)
- Noah-MP land surface model (LSM) updated from version 3.6 to version 4.0.1 which has improved initialization of the hydrological variables and uses a different radiation transfer option that eliminates instability issues due to low vegetation fraction
- CFSv2 non-precipitation meteorological forecasts replace GEOSv2 because GEOSv3 will not provide daily forecasts beyond 3-month forecast lead
- Forecast sub-daily temporal disaggregation method changed to use CFSv2 sub-daily data instead of MERRA2 sub-daily climatology
- Use of Catchment Land Surface Model (CLSM) is discontinued as the skills between both LSMs are comparable

How are the updates tested?

Sensitivity of the land surface model (LSM; Noah-MP) for reanalysis is examined by applying the individual changes and analyzing them when:

- Soil texture is changed
- NoahMP, version is changed
- CHIRPS sub-daily temporal disaggregation scheme is changed

3. Sensitivity Experiment Results of Land Surface Model

3a. Percent Difference of Water-Balance Variables between Experiments with Individual Changes
Analysis Period: January 1991– December 2020

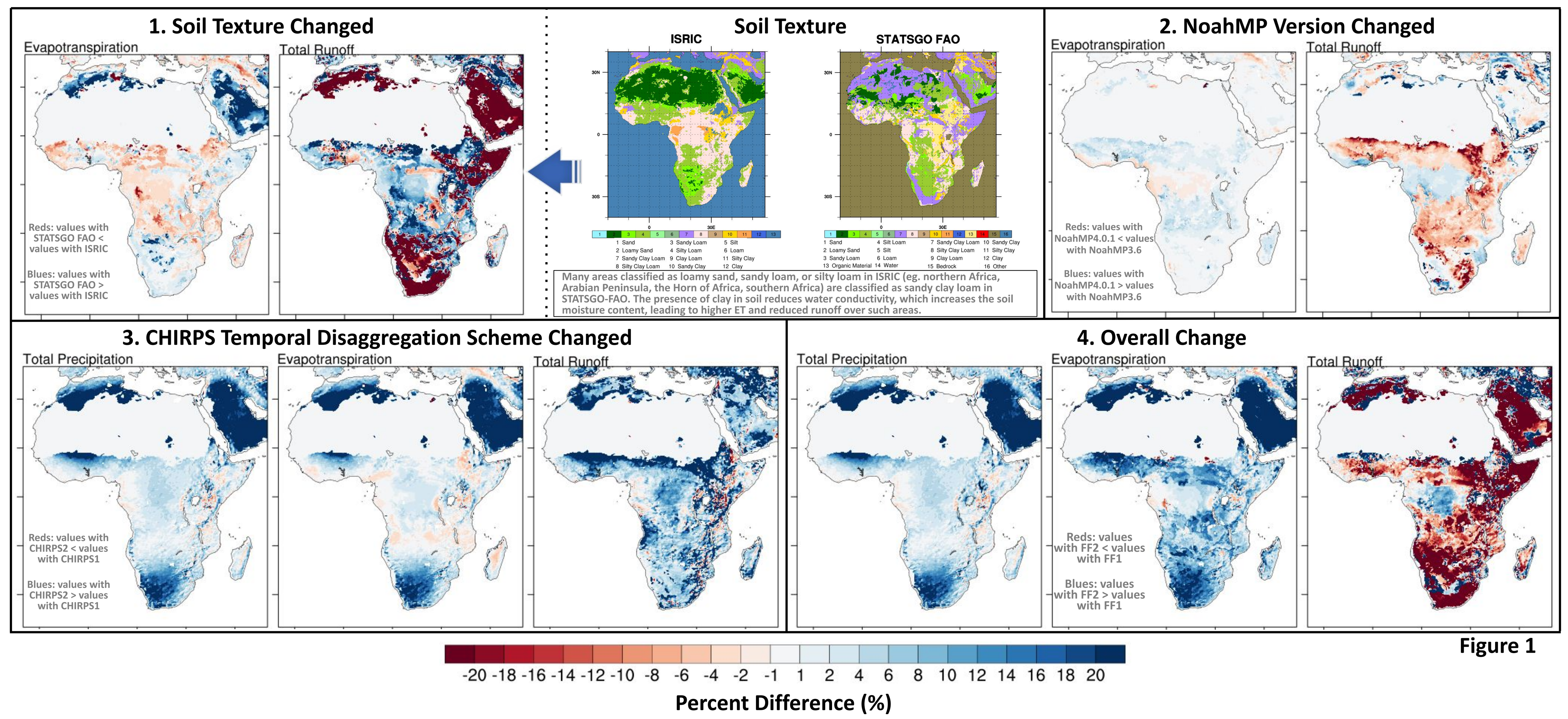


Figure 1

Figure 1: Panels 1 to 3 illustrate the percent difference between simulations using individually updated parameters (new; FF2) and those using previously used (old; FF1) parameters. These differences are calculated for key water-balance variables: total-precipitation (primary meteorological input), evapotranspiration (ET) and total-runoff (primary hydrological outputs). Note that total-precipitation remains unchanged in panels 1 and 2. The panels demonstrate that the changes in parameters and input precipitation result in significant differences in hydrological output. Of the changes applied, updating soil-texture has the most substantial impact on hydrologic output (panel 1), followed by changing the sub-daily temporal disaggregation scheme of the input precipitation (panel 3), and lastly, updating the NoahMP version (panel 2), as summarized in panel 4.

3b. Interannual Correlation Relative Observations

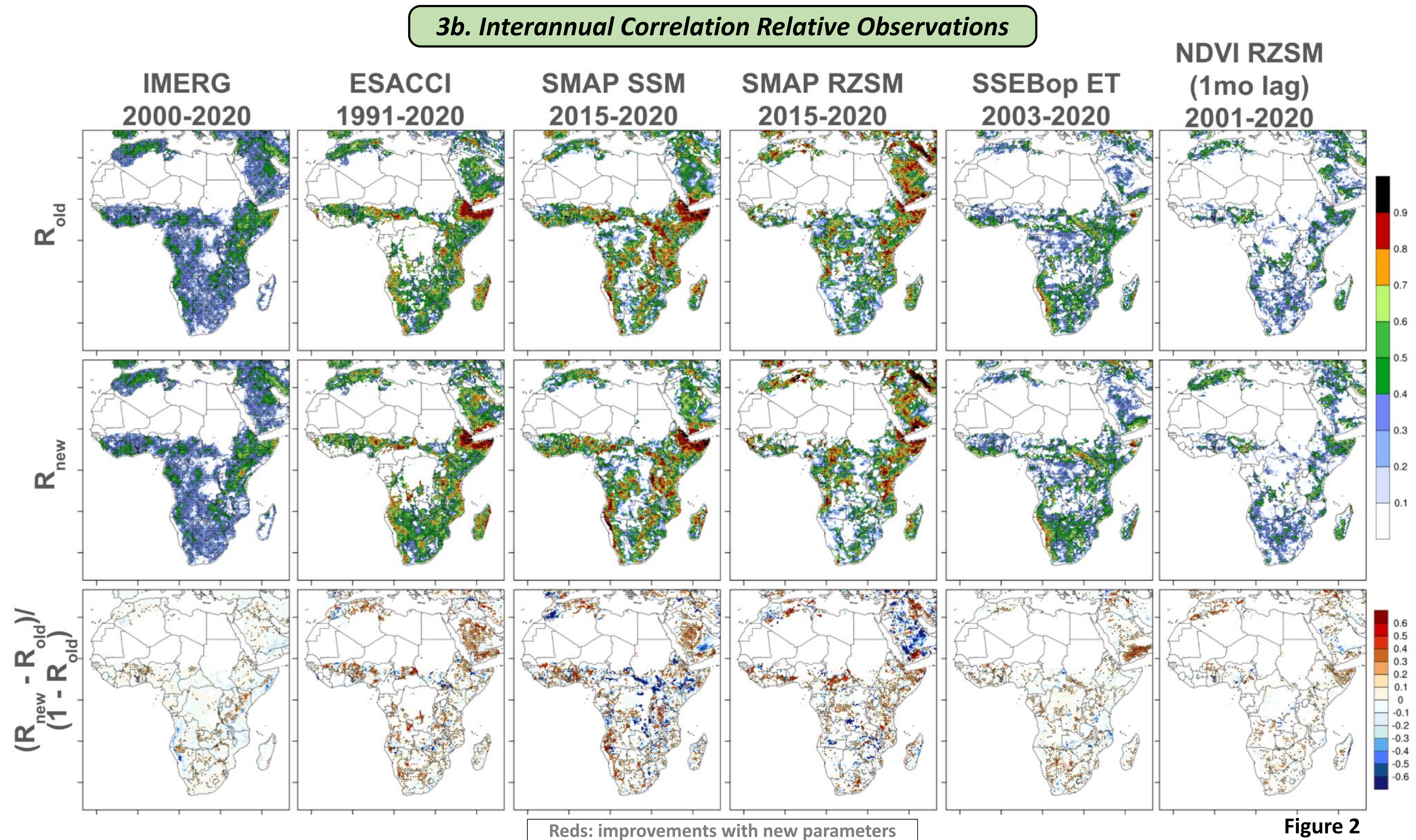


Figure 2

Figure 2: The panels above display the **interannual** correlation coefficients of the old (FF1) and new (FF2) FLDAS-Forecast, which are comparable as seen in the first two rows (R_{old}, R_{new}). These coefficients are computed after standardizing the datasets for each month over the individual observational periods. FF2 includes all the updates, and the correlation coefficients are calculated relative to various observations, as indicated in the observation box below. The last row presents the normalized information contribution (NIC), defined as $(R_{new} - R_{old})/(1 - R_{old})$, which measures the extent of maximum potential skill improvement $(1 - R_{old})$ realized through the applied changes $(R_{new} - R_{old})$. Improvements in FF2 are highlighted in reds, and deteriorations in blues. The results indicate that FF2 generally shows improved interannual variability.

Observations: IMERG precipitation, ESACCI surface soil moisture (SSM), SMAP SSM, SMAP-based rootzone soil moisture (RZSM), SSEBop evapotranspiration (ET) and NDVI at one-month lag relative simulated RZSM

3c. Seasonal Correlation Relative Observations

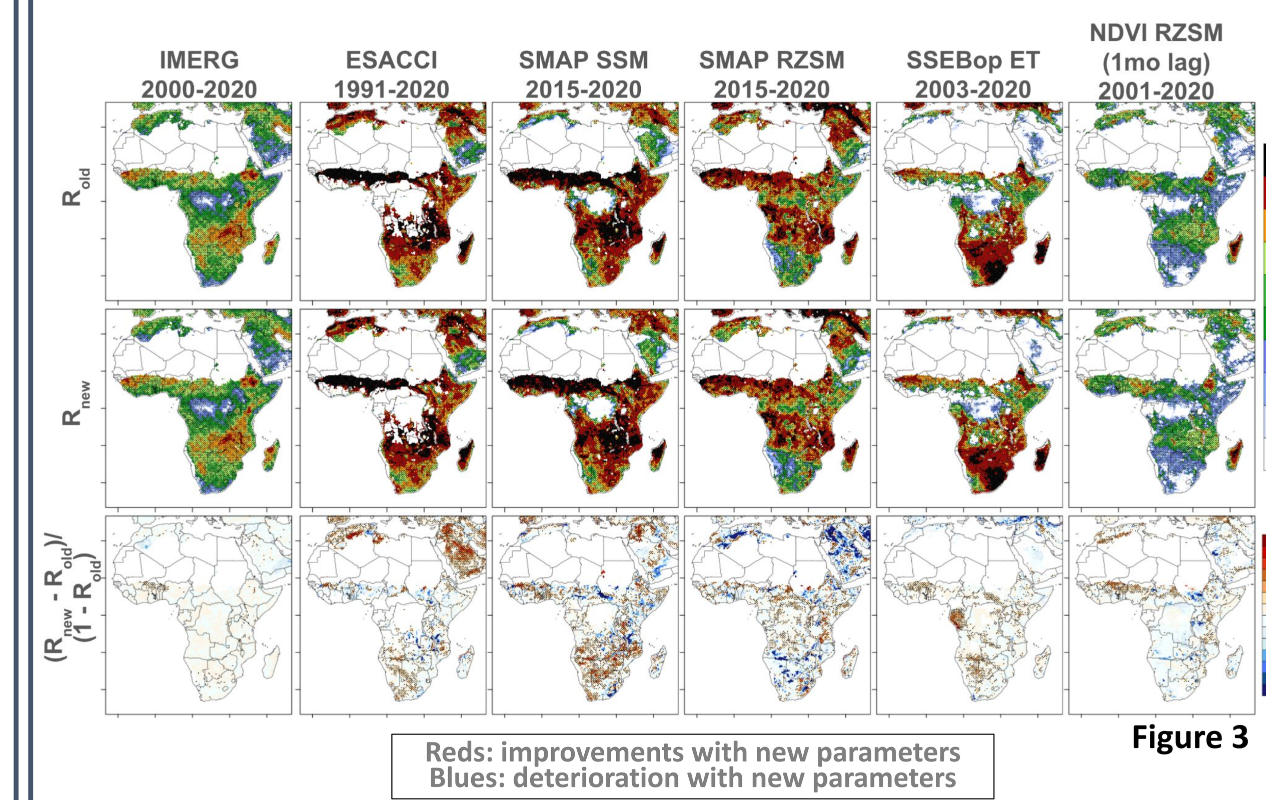


Figure 3

Figure 3: The panels above show the **seasonal** correlation coefficients of FF1 and FF2 are comparable in the first two rows, relative to different observations, as noted in the observation box, similar to the panels in figure 2. These coefficients are calculated using the complete time series for each observational period without any standardization. The last row highlights the NIC of the seasonal correlation coefficient, showing mostly improvements in the seasonal variability of FF2. However, it is worth noting that FF2's root zone soil moisture (RZSM) shows significant deterioration compared to the SMAP-based RZSM.

4. Conclusion & Further Study

- **Soil Texture Sensitivity:** The sensitivity experiments show that changing the soil texture has the most significant impact on hydrologic output.
- **Interannual and Seasonal Correlation:** The application of all changes results in comparable interannual and seasonal correlation coefficients in FF1 and FF2, relative to observations.
- **NIC Analysis:** The NIC analysis shows that FF2 generally exhibits improvements over FF1. However, some detereorations are noted in FF2's RZSM relative to SMAP-based RZSM.
- **FF2 Reanalysis Output:** The sensitivity experiments indicate that the FF2 reanalysis output is mostly improved compared to FF1. This enhanced FF2 reanalysis will provide valuable simulated validation data and serve as initial conditions for forecasts.
- **Future Research:** Further studies will focus on analyzing the individual changes made to the meteorological forecast forcings used in the hydrologic forecasts.
- **Forecast Performance Evaluation:** The performance and validation of the FF2 forecast output will be assessed relative to the FF2 reanalysis.

Abbreviations: ***FEWS NET***:Famine Early Warning Systems Network, ***FLDAS***:FEWS NET Land Data Assimilation System, ***NMME***:North American Multi-Model Ensemble, ***CHIRPS***:Climate Hazards Center InfraRed Precipitation, ***MERRA2***:Modern-Era Retrospective analysis for Research and Applications, Version2, ***ISRIC***:International Soil Reference and Information Centre, ***STATSGO-FAO***:Soil Information for Environmental Modeling and Ecosystem Management-Food and Agricultural Organization, ***SSEBop***:operational Simplified Surface Energy Balance, ***ET***:Evapotranspiration, ***IMERG***:Integrated Multi-satellitE Retrievals for Global Precipitation Measurement Mission, ***ESACCI***:European Space Agency Climate Change Initiative, ***SMAP***:Soil Moisture Active Passive, ***NDVI***:Normalized Difference Vegetation Index, ***FF1 & 2***:FLDAS Forecast version 1 & 2, ***LISF***: Land Information System Framework, ***GEOS***:Goddard Earth Observing System, ***CFS***:Coupled Forecast System, ***v***:Version, ***LSM***:Land Surface Model, ***SSM***:Surface Soil Moisture, ***RZSM***:Rootzone Soil Moisture, ***NIC***:Normalized Information Contribution, ***CLSM***:Catchment Land Surface Model, ***Noah-MP***:Noah-Multiparameterization Land Surface Model

Funding: U.S. Agency for International Development, PAPA AID-FFP-T-17-00001 "FAMINE EARLY WARNING SYSTEMS NETWORK (FEWS NET)." and NASA Harvest Consortium (NASA Applied Sciences grant # 80NSSC17K0625).

Contact: abheera.hazra@nasa.gov, abheera@umd.edu