NASA's Seasonal Hydrological Forecast System for Improved Food Insecurity Early Warning in Africa

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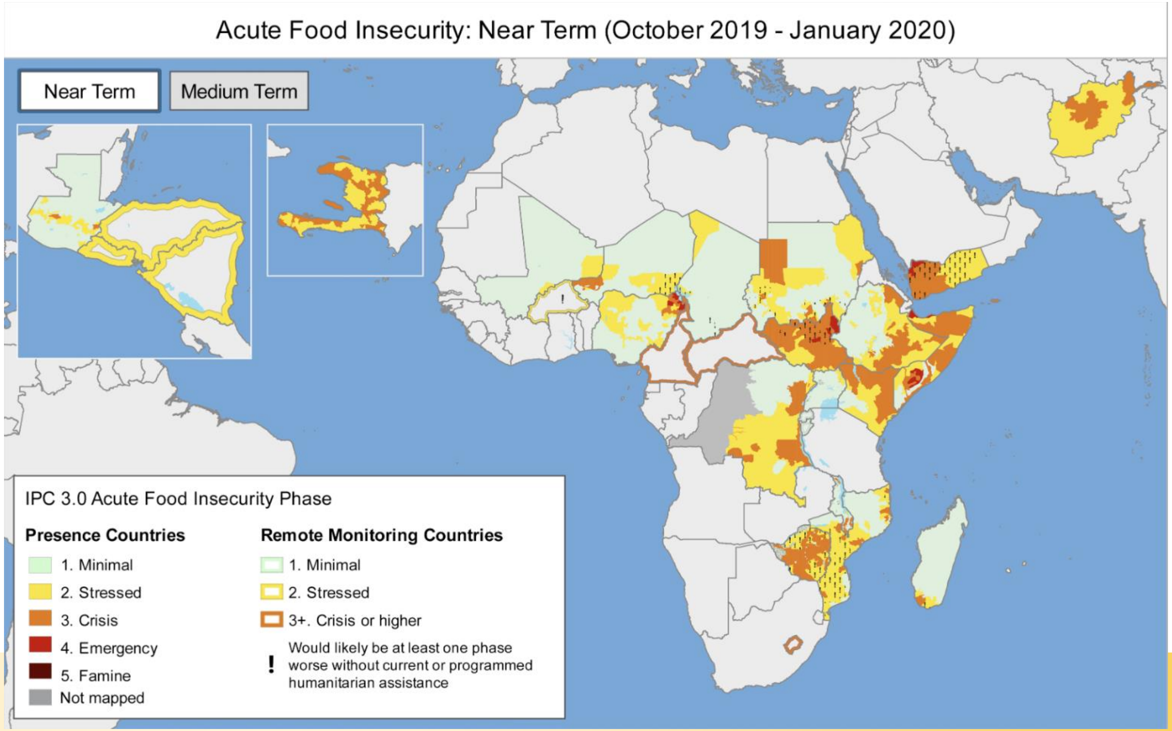
Motivation and Overview

Goal: To develop a seasonal scale drought forecasting system to strengthen FEWS NET's progressive early warning efforts in Africa and the Middle East.

This presentation provides an overview of the implementation, validation, and ongoing operational applications of this system.

An example of Acute Food Insecurity Outlook Map Provided by The Famine Early Warning Systems Network Team (FEWS NET)



Background

(1) Close collaboration between the science team and primary end user (FEWS NET) since the proposal inception, which facilitated the successful operational application during the project life.

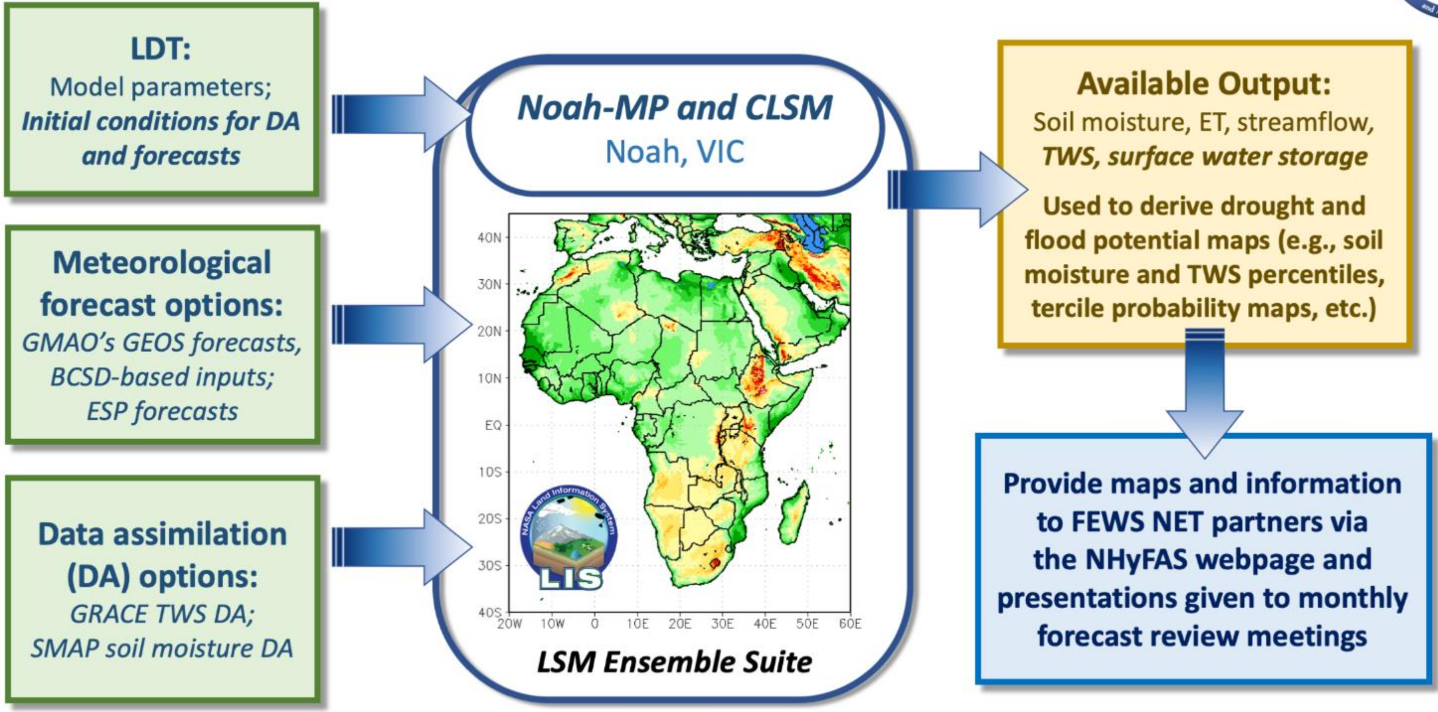
(2) Operational applications guided by the regional expertise of FEWS NET's Africa scientists.

(3) Hydrologic simulations, driven by the Climate Hazards Center Infrared Precipitation with Stations (CHIRPS) data set, which benefits from satellites as well as a relatively large data base of in-situ observations in Africa.

(4) Continuation of research and development in parallel to operational application, leading to future improvements in the system.

NHyFAS Outline

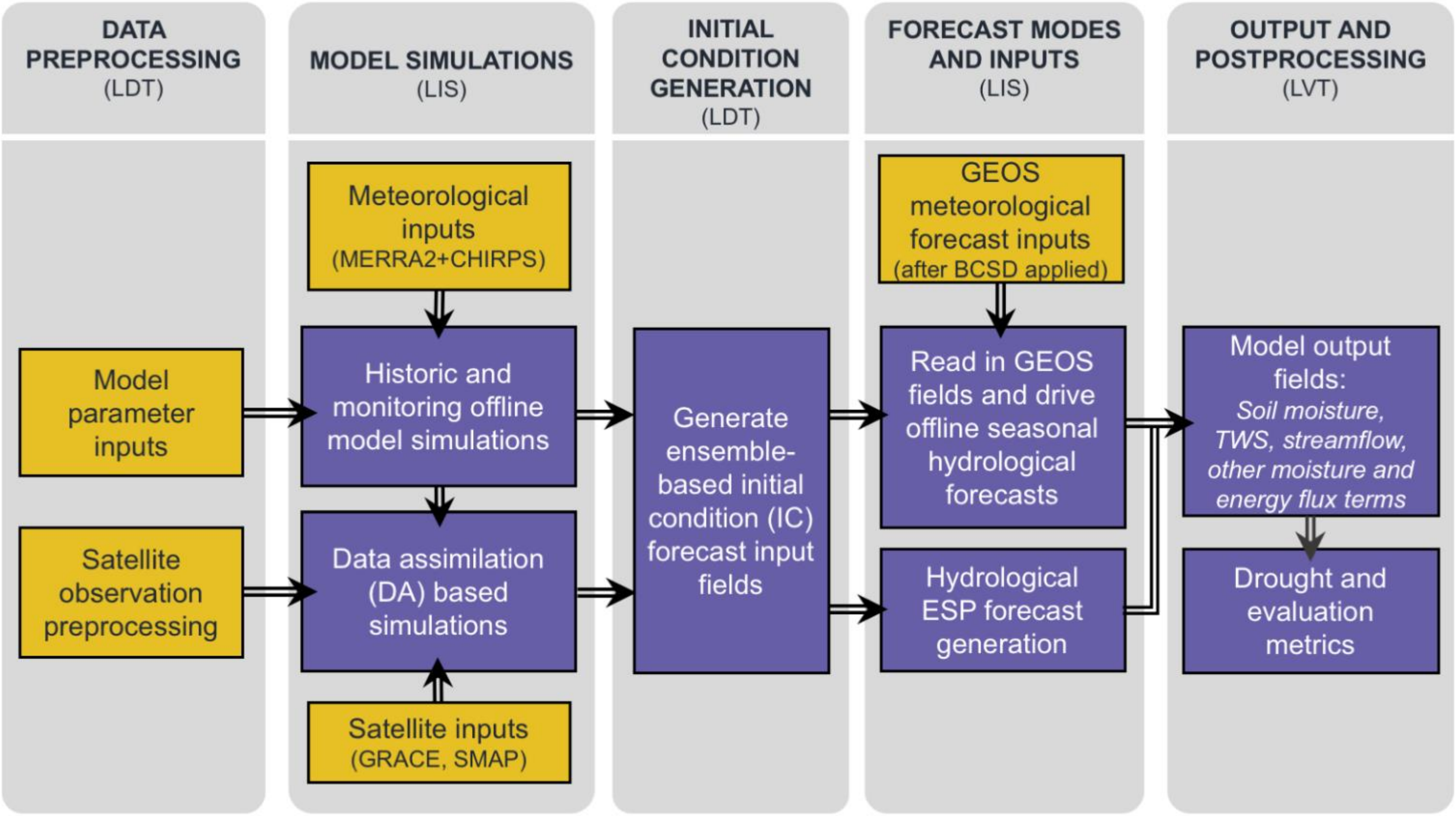
NASA's Hydrological Forecast and Analysis System (NHyFAS)



https://lis.gsfc.nasa.gov/projects/nhyfas

(From Arsenault et al., 2020)

System Flowchart



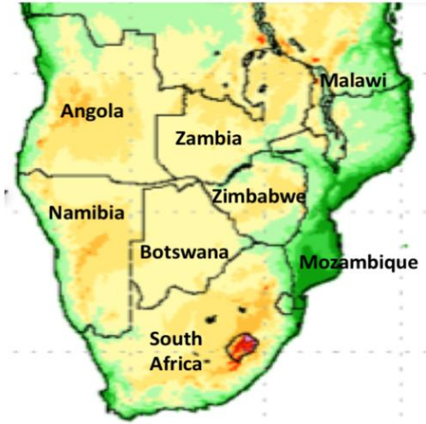
(From Arsenault et al., 2020)

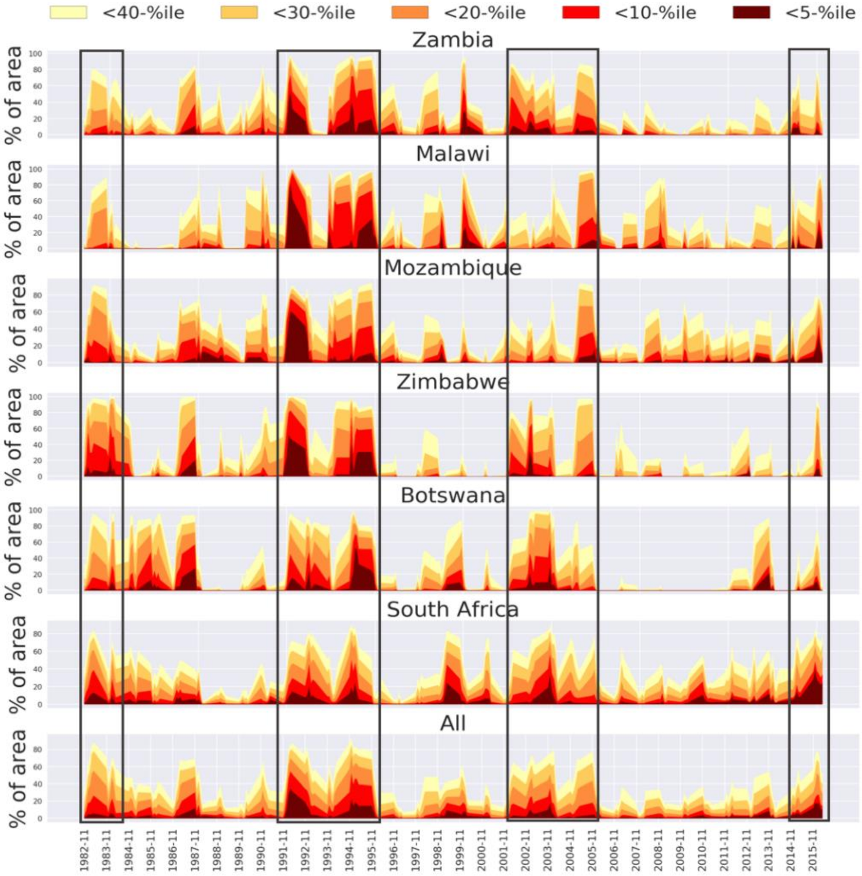
Drought Event Verification - Monitoring

(On Right) Timeseries of TWS drought percentile categories (e.g., 20%-tile), capturing changes in areal percentages for each category, for each of the Southern African countries shown below.

TWS, from combined CLSM+NoahMP open-loop (OL) historic runs, are shown for each growing season period, Nov.-Mar., 1982-2016.

Major drought years are highlighted within the black thin boxes.





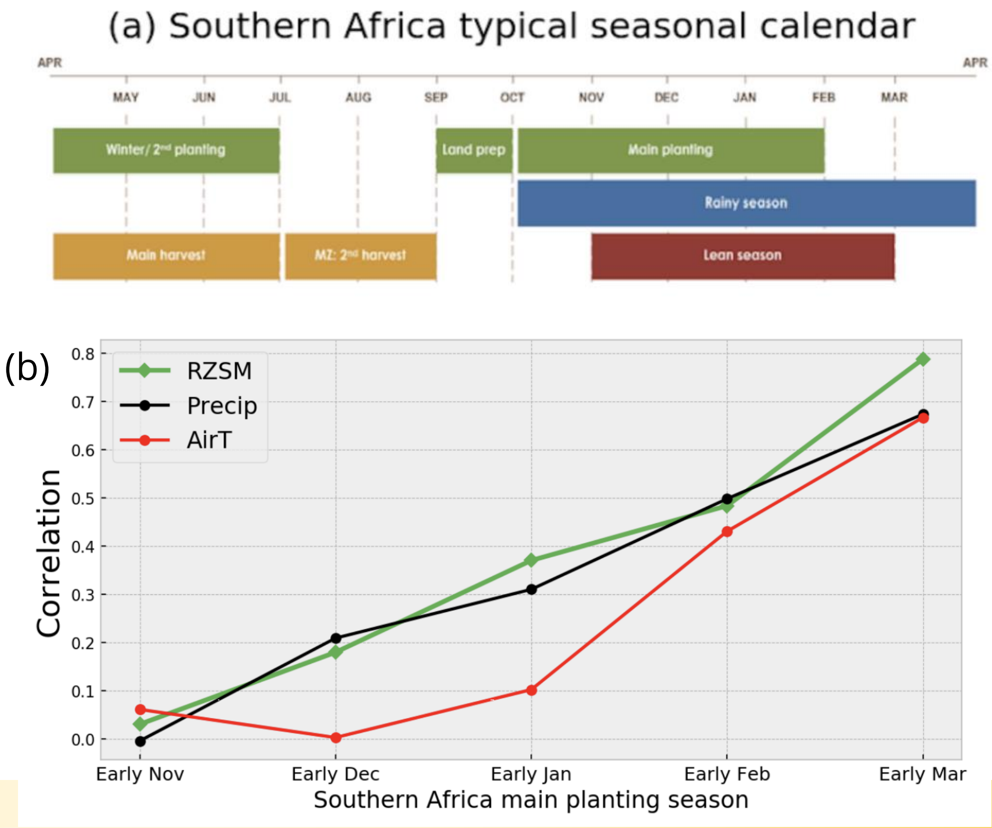
(From Arsenault et al., 2020)

Soil moisture as a predictor of crop yield

(a) Schematic representation of a typical FEWS NET-based seasonal calendar for the Southern Africa region.

(b) Skill shown between 3-month seasonal precipitation, air temperature, and monthly root zone soil moisture (RZ SM).

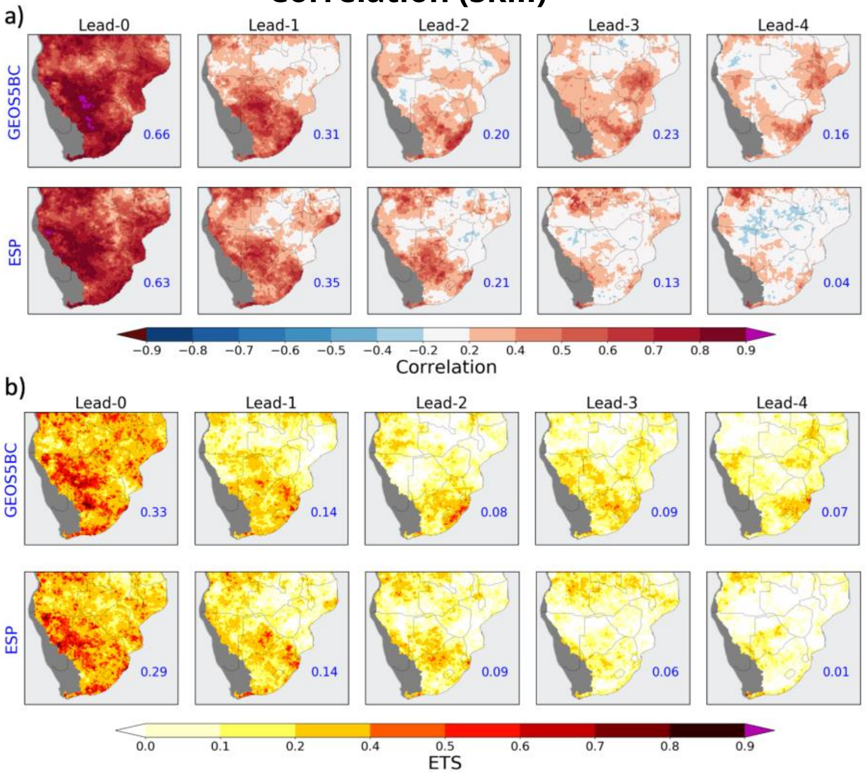
RZSM is shown to be a potentially better predictor of crop yield than the seasonally based precipitation and temperature fields, which have been used in the past to indicate potential yield results.



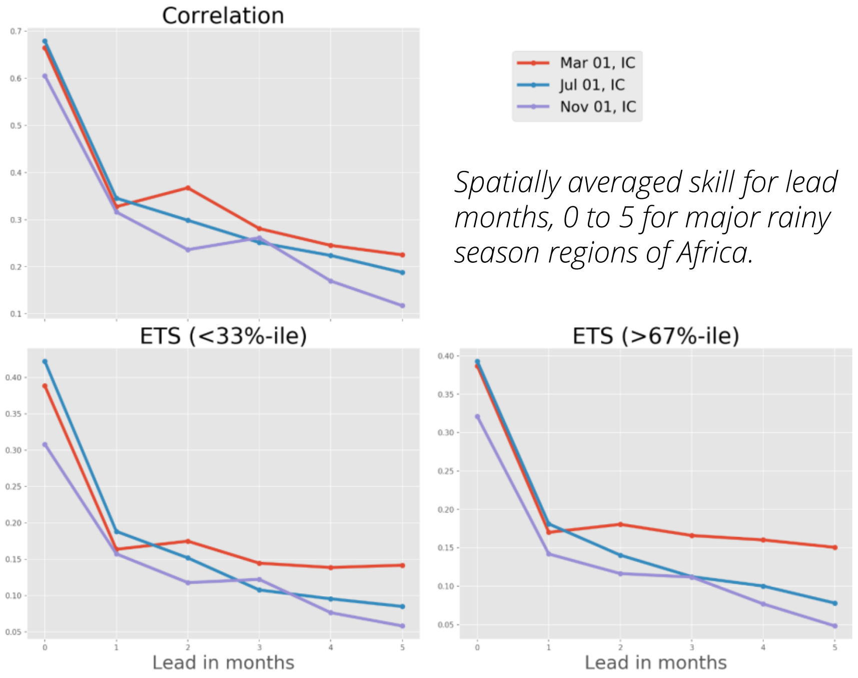
(From Shukla et al., 2020)

Hindcast Evaluation: Skill and Tercile Events

Correlation (Skill)



Using historic OL run as reference to evaluate GEOS-based hindcasts, benchmarked against ensemble streamflow prediction (ESP) forecast runs.



Spatially averaged skill for lead months, 0 to 5 for major rainy season regions of Africa.

Lowest tercile (<33%-tile): Drought events

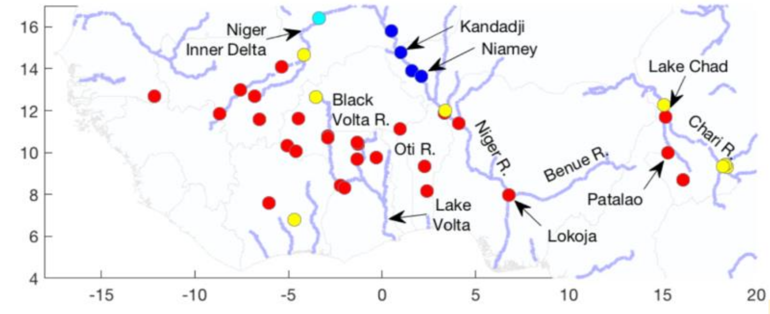
(From Arsenault et al., 2020)

Improving TWS Initial Conditions with GRACE Obs

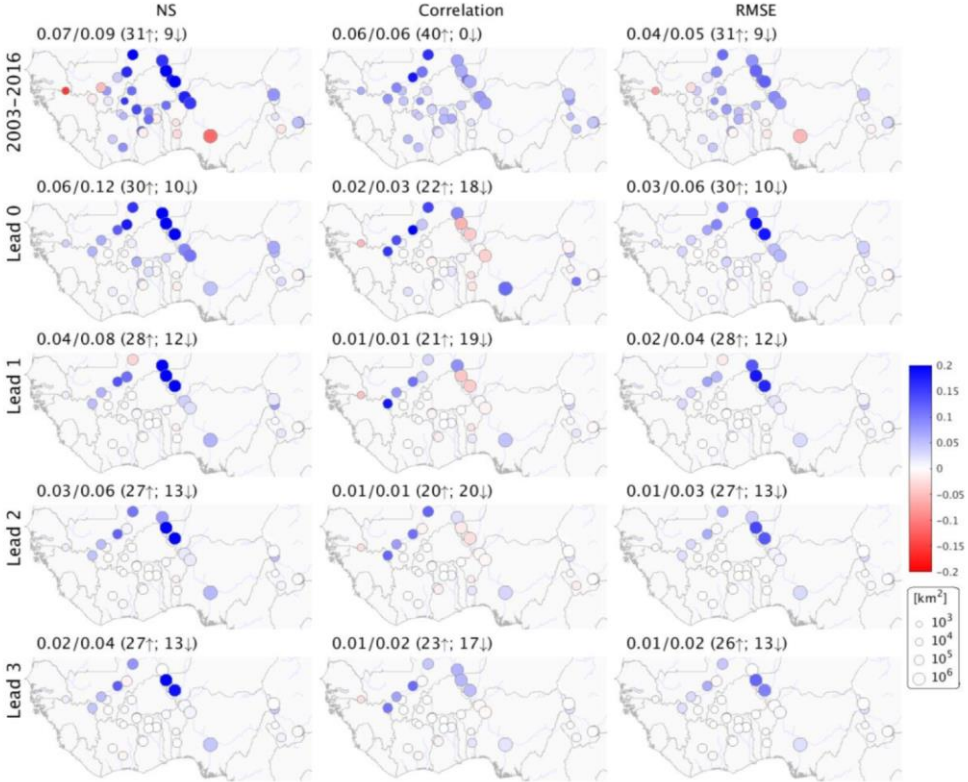
Initializing NHyFAS forecasts with GRACE TWS assimilated conditions can provide blended satellite+model states, which is more optimal than initializing the forecasts with model-only states.

(On right) Streamflow skill evaluation shown at several streamflow gages (*below*). Improvement in initial conditions is shown when GRACE TWS is assimilated compared to hindcasts initialized with only the open-loop (OL) conditions.

Western Africa streamflow stations in evaluation



(From Getirana et al., 2020)



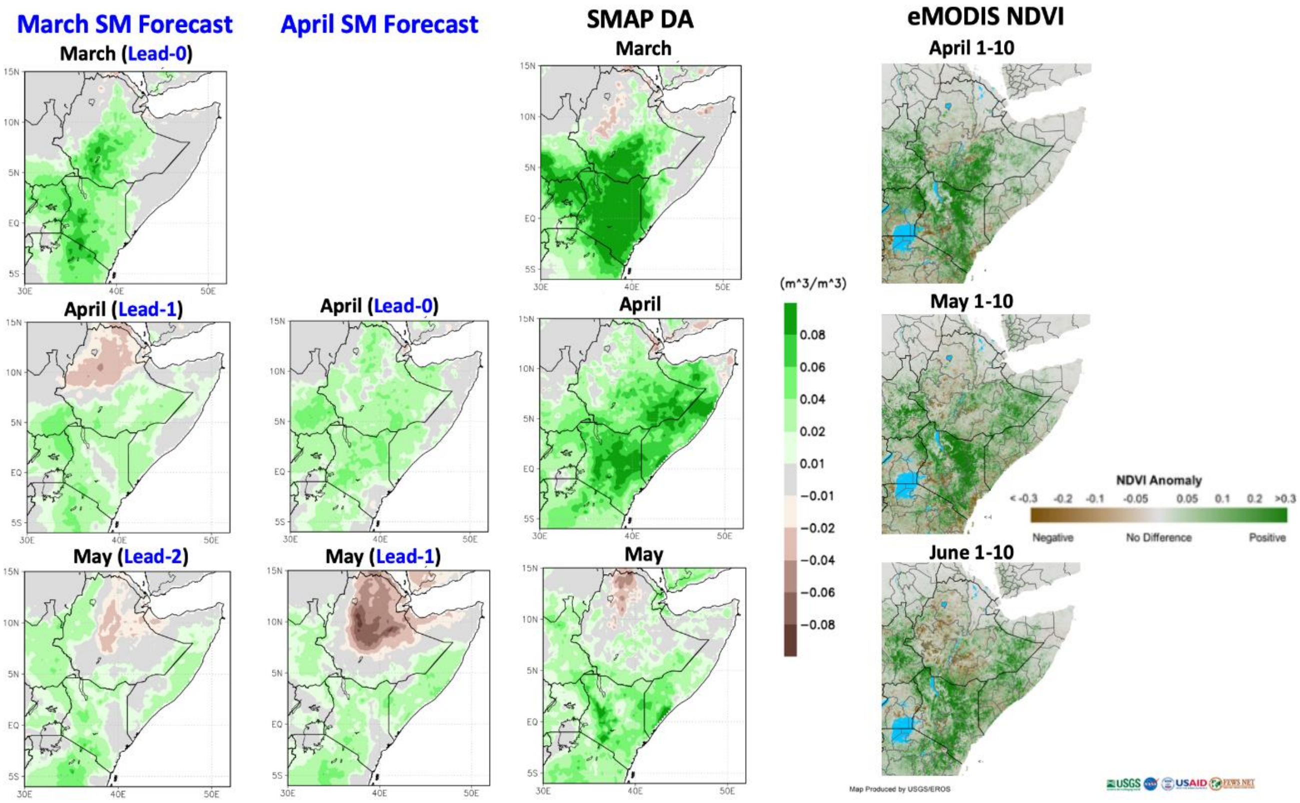
Blue shades indicates improvement in forecasted streamflow when initialized with assimilated GRACE TWS states

Flood Potential Forecast: Wet Extreme Example

East Africa's rainy season, March-May, 2018 experienced severe flooding, and destruction to homes, crops and loss of life.

(*On right*) March and April, 2018 forecasts of monthly surface SM anomalies shown (*first two columns*), relative to a SMAP-SM data assimilated (DA) run (all using Noah-MP LSM) ane MODIS-based NDVI.

The GEOS forecasts, initialized with SMAP assimilated SM, capture much of the region's anomalous conditions, esp. Kenya and Ethiopia. Results verified with NDVI anomalies.



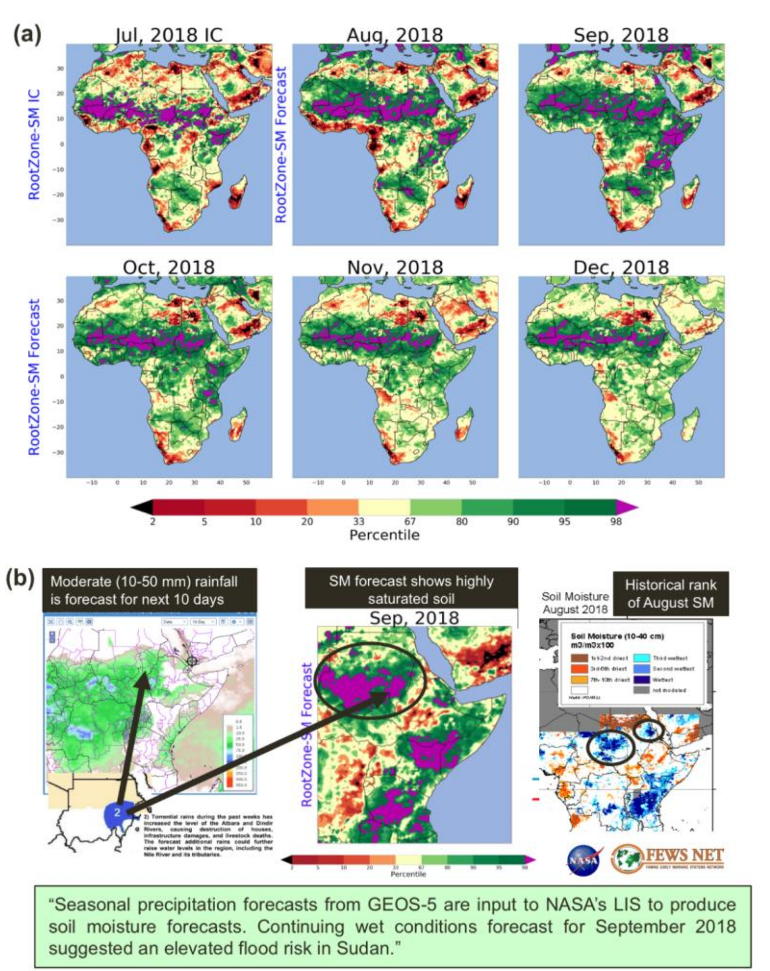
All anomalies calculated relative to 2003-2017 median values.

(From Arsenault et al., 2020)

Use of NHyFAS Forecasts in FEWS NET's Seasonal Forecast Review

(a) Example of routine NHyFAS seasonal hydrologic forecasted RZ SM percentile product, with July initial conditions (*upper-left*) and combined NoahMP+CLSM soil moisture GEOS-V2 seasonal forecasts (20-members total).

(b) Real example case shown where FEWS NET regional scientists used Sept-2018 forecast to confirm other precipitation-based forecast and pre-existing wet soil conditions, contributing to an elevated flood risk in Sudan.



(From Arsenault et al., 2020)

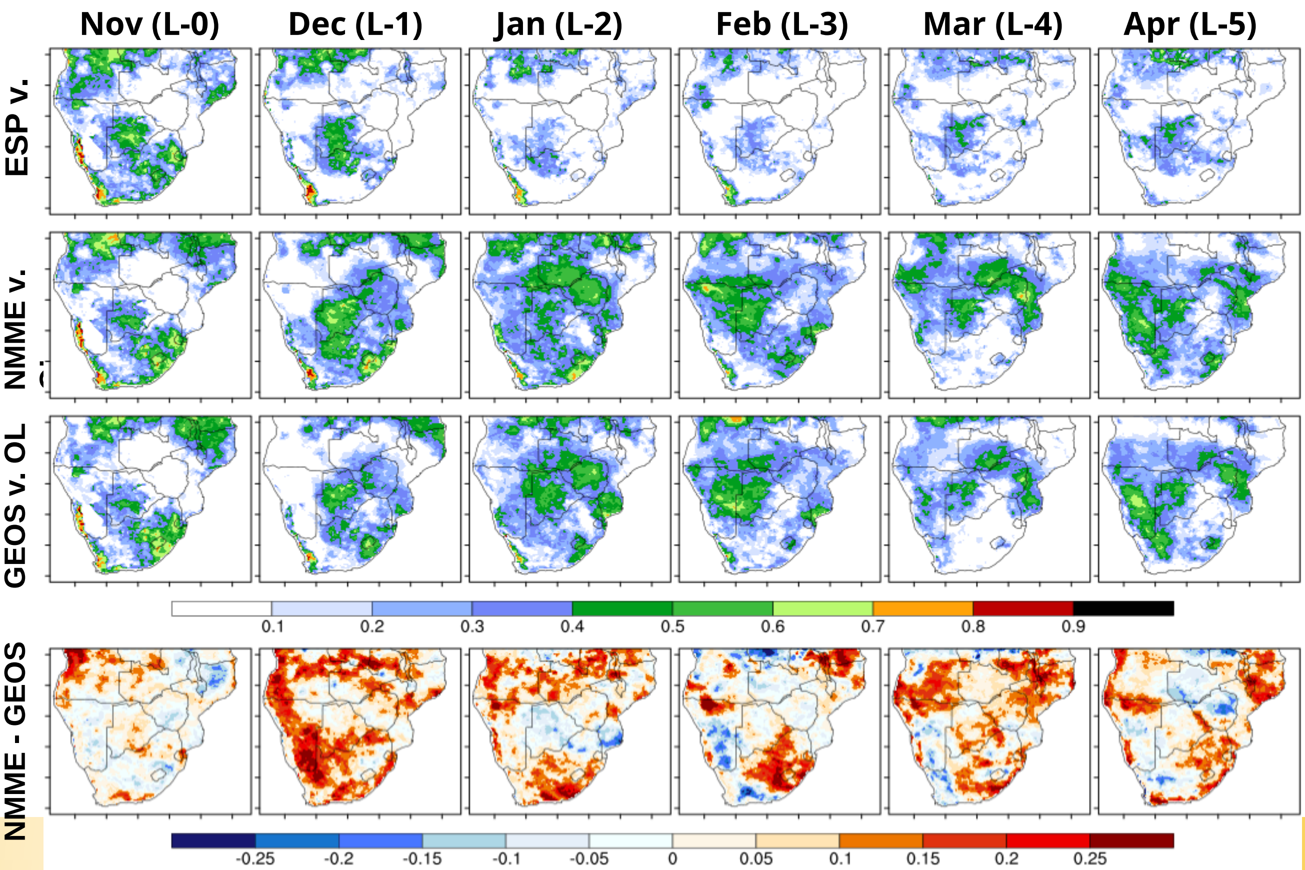
The NHyFAS webpage:
https://lis.gsfc.nasa.gov/projects/nhyfas

Expanding to NMME-based forecasts: Hindcast skill evaluation

RZ SM Percentiles

Using the historic OL runs, as the "truth", NMME shows overall to have better skill (correlation) in RZ SM than GEOS and ESP-climatological hindcasts when compared for the period, 1982-2010.

Lead 0 skill, first column, looks very similar for all the forecasts as they have the same initial condition.



(From A. Hazra et al.)

Summary

(1) The new NASA Hydrological Forecast and Analysis System, NHyFAS, has been developed to help forecast drought and other extreme events that impact food and water insecurity in regions, such as Africa.

(2) Using NASA's GEOS seasonal forecasts and satellite-based datasets, such as GRACE and SMAP, to improve the initial conditions of the forecasts.

(3) Skill shown to be overall better than the benchmark ESP hindcasts for different cases, and examples of extreme events are captured well in areas greatly affected, e.g., by drought or flooding.

(4) Ongoing and routine use of the system and products by FEWS NET team members and end-users. Continuing to build on to the system with additional downscaled and bias-corrected NMME precipitation forecasts.

Thank you!

Questions?

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NHyFAS

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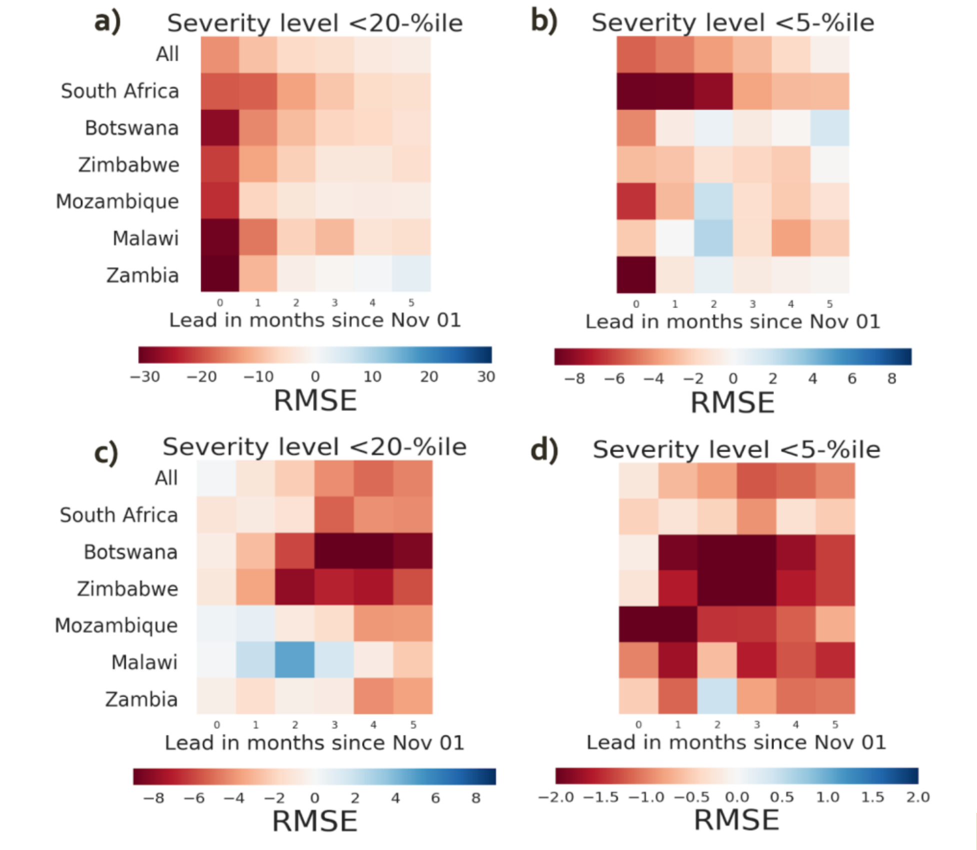
Miscellaneous/Backup slides

Hindcast Evaluation: Soil moisture and Yield

(On right) Differences in RMSE for forecasting percent area in drought between ESP and randomized forecasts (top two rows) and between GEOS and ESP forecasts (bottom row) are shown for the two drought severity thresholds, 20th and 5th percentiles of TWS (from combined NoahMP+CLSM) forecasted percentage areas for different Southern African countries.

Results shown for the Nov. 1 hindcasts and over lead months from 0 to 5 (Nov - April).

Red = Improvement over ESP
Blue = Degradation of skill relative to ESP

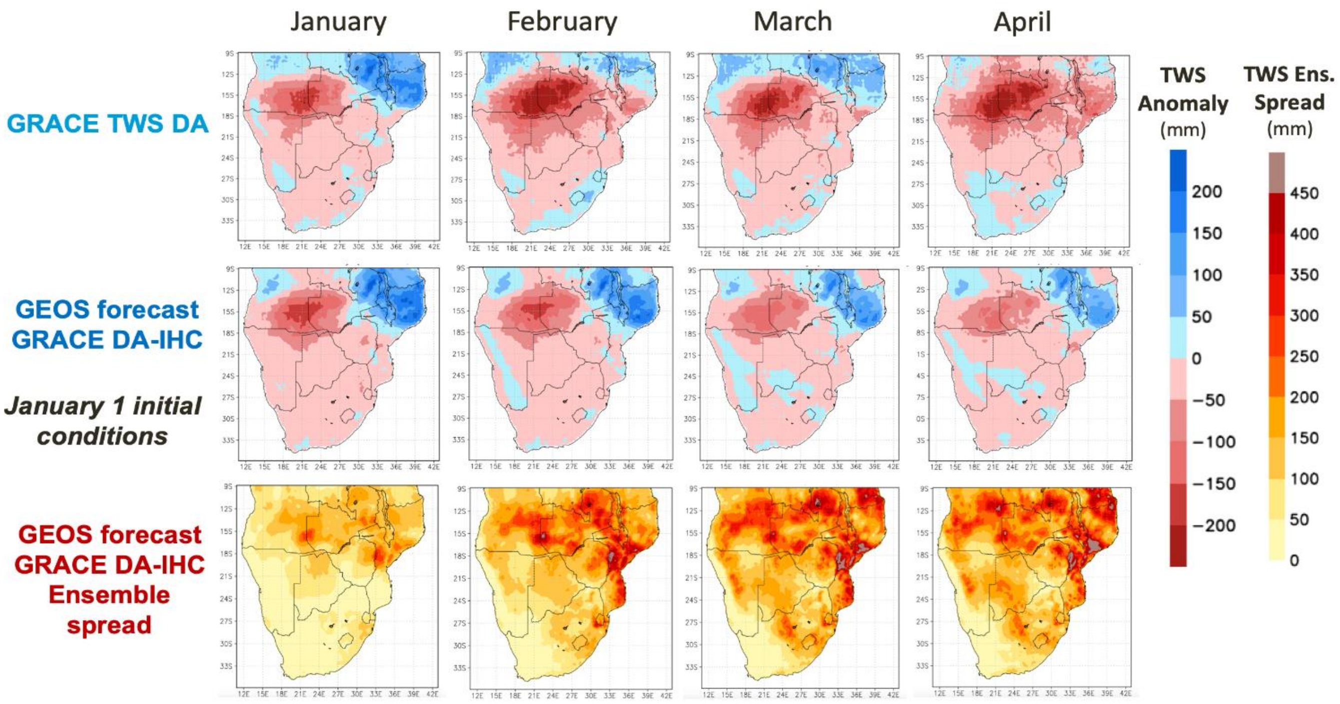


(From Arsenault et al., 2020)

Improving TWS Initial Conditions with GRACE Obs

Initializing NHyFAS forecasts with GRACE TWS assimilated conditions can help provide blended satellite+model states, which can be more optimal than initializing the forecasts with model-only states.

(On the right) The 2005 Southern Africa drought is captured in TWS by the assimilated GRACE TWS run, which is used to initialize the Jan-2005 hindcast. Spread of the forecasted TWS ensemble members (*bottom row*) grows with each lead month.



(From Arsenault et al., 2020)