

# NASA Science Mission Directorate Earth Science Division Applied Sciences Program



***Predicting Middle Eastern and African Seasonal  
Water Deficits using NASA Data and Models***

***Water Resources***

***Team Meeting– April 26-27, 2016***



- Project Title: ***Predicting Middle Eastern and African Seasonal Water Deficits using NASA Data and Models***
- Project PI: Peters-Lidard, Christa D(GSFC)
- Solicitation: A.45 Earth Science Applications (Water Resources)
- Project Summary: To develop a seasonal water deficit forecasting system that is relevant for USAID and USACE activities in the Middle East and Africa based on existing/mature NASA and NOAA Earth science capabilities.
- Geographic scope: Africa and Middle East
- Earth observations / models / technologies applied:
  - NASA's MERRA/GEOS-5, NOAA's CFS, Noah and Catchment land surface models, RFE2 and CHIRPS satellite-insitu precipitation data, GRACE, GPM/TRMM precipitation, MODIS and VIIRS based vegetation, land temperature and ET datasets, AMSR-e/SSMI/SMAP/ASCAT soil moisture products, DSSAT crop model

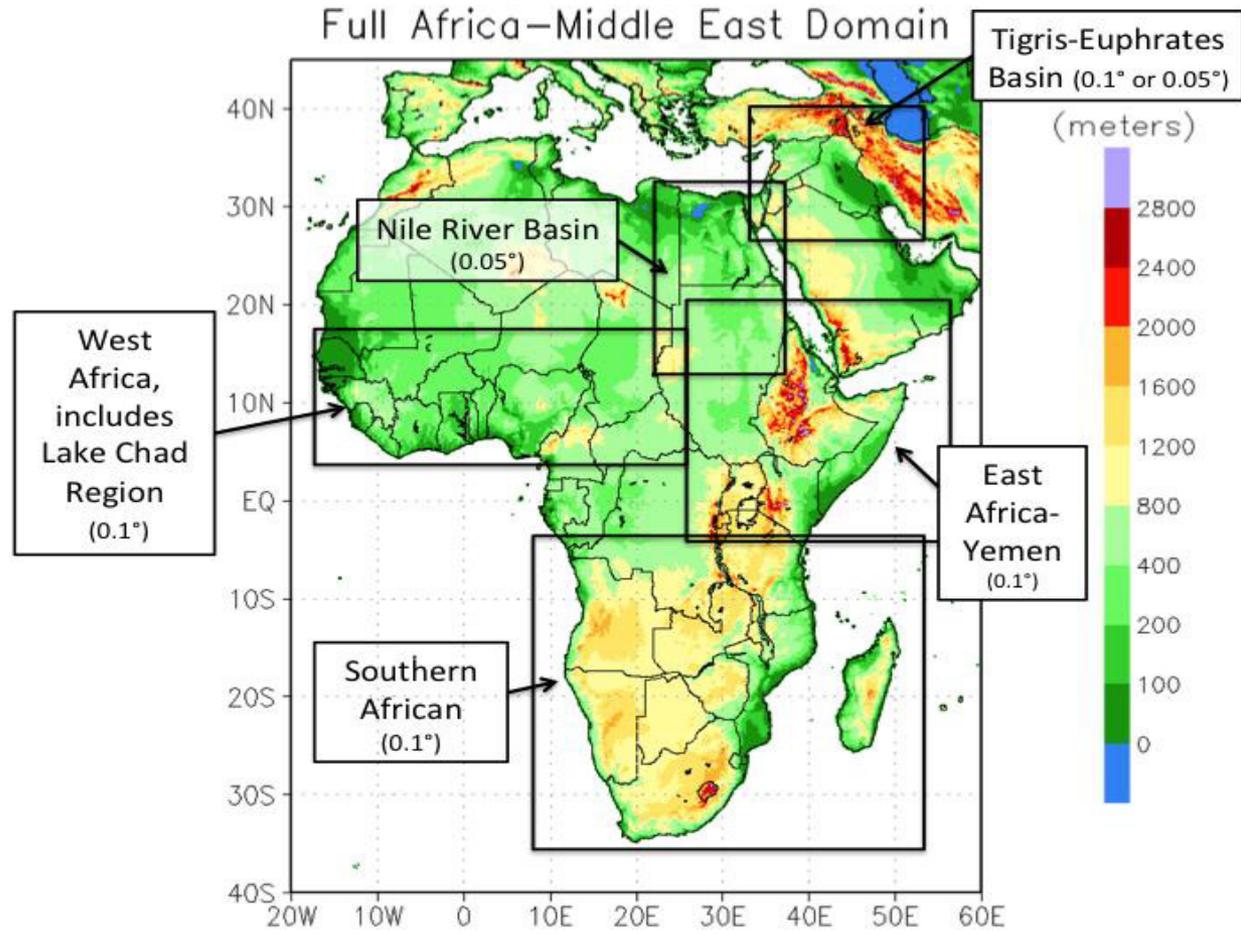
## Project Partners

Role	Name(s)	Affiliation
PI	Christa Peters-Lidard	NASA GSFC
Co-Is	Shahid Habib Randy Koster Kristi Arsenault Sujay Kumar Bala Narapusetty Augusto Getirana James Verdin Shrad Shukla Chris Funk John Eylander Jeanne Roningen Ben Zaitchik	NASA GSFC NASA GSFC NASA GSFC / SAIC NASA GSFC / SAIC NASA GSFC / ESSIC NASA GSFC / ESSIC USGS UCSB USGS / UCSB DoD / USACE / ERDC/ CRREL DoD / USACE / ERDC / CRREL Johns Hopkins University
Collaborators	Amy McNally Grey Nearing Greg Husak Fritz Policelli Hahn Jung	NASA GSFC / ESSIC NASA GSFC / SSAI UCSB NASA GSFC NASA GSFC / SSAI

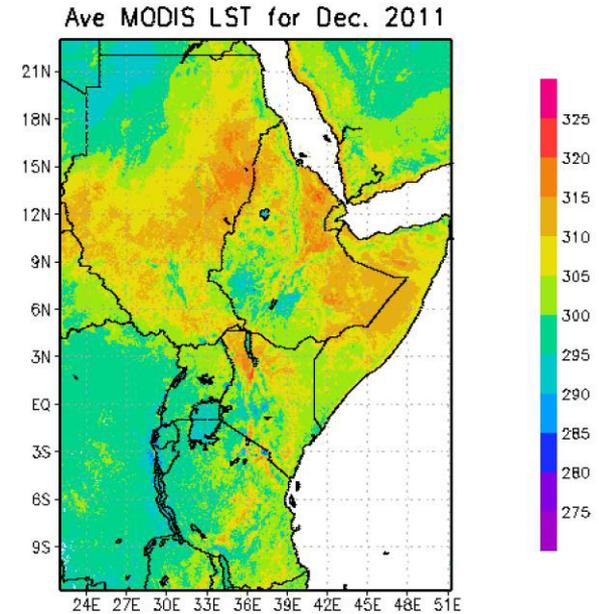
## End-Users / Stakeholders

Role	Organization Name	Organization Type
End-user	USAID (Gary Eilerts) ICBA (Rachael McDonnell)	Federal agency International organization

- **Challenges:** Working in regions most affected by droughts, with little in the way of ground observations to verify models and forecasts;
- **Need:** Improved seasonal forecasts, utilizing best available models (land surface, climate forecast), satellite-data, etc., for drought-related crop impacts
- **Opportunity:** Working with end-users within these regions to help verify and work towards improved forecasts



## East Africa Region



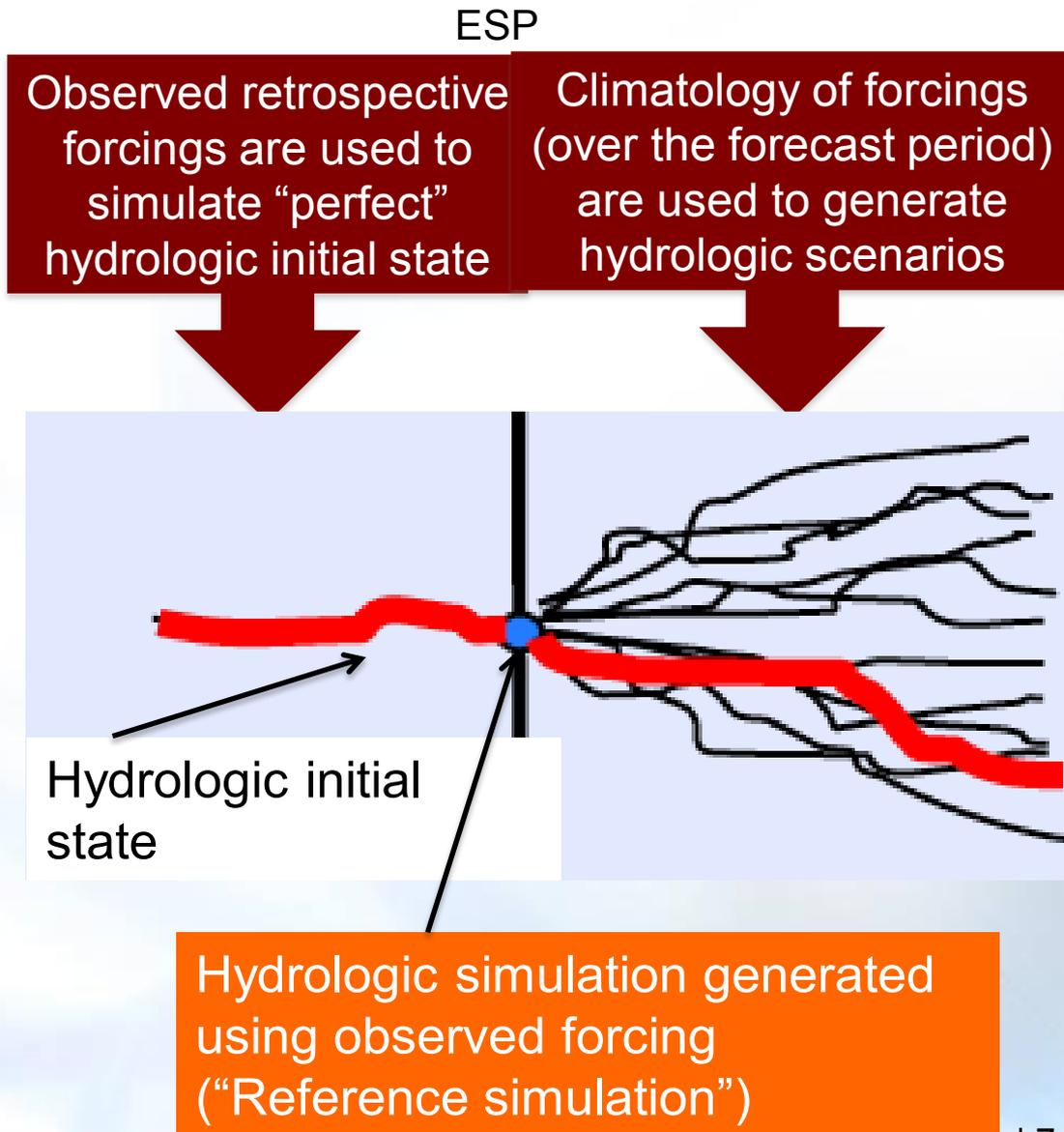
- for East Africa:**
- Longitude: 22.05 to 51.350 deg E
  - Latitude: -11.750 to 22.950 deg E
  - Model resolution: 0.10 deg (in both lat/long directions)

## Schedule

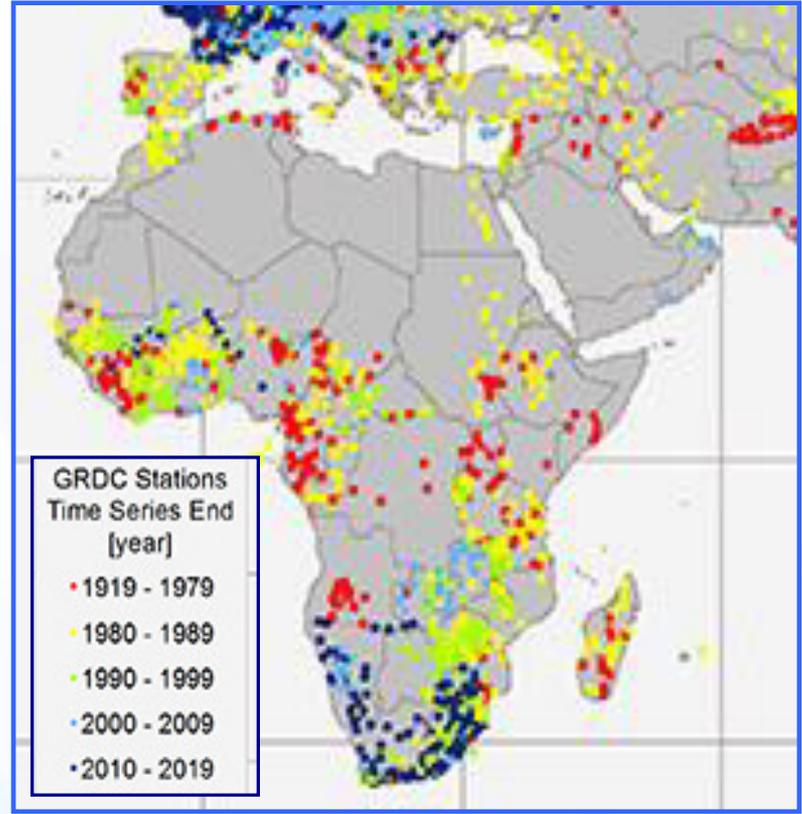
Milestone	2014	2015				2016				2017				2018			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Phase 1: Test SM and TWS DA and seasonal forecasts from GEOS-5 and CFS in FLDAS																	
Phase 2: Evaluate the information content and contributions from GEOS-5 forecasts and NASA products for water deficit warning in African and Middle Eastern domains.																	
Phase 3: Evaluate and demonstrate the forecasting system for crop production estimates.																	
Phase 4: Transition FLDAS water deficit forecasting system to operational partners at USAID and USACE																	

- Use monthly to seasonal forecasts to better predict drought and water supply in FAME regions
- Downscale and bias-correct monthly to seasonal forecasts
- Implement and Benchmark forecasts capability in the LIS framework
- So far, an ensemble streamflow prediction (ESP) method is implemented in LIS and has been tested with Noah 3.3 LSM (CLSM and offline HyMAP experiments are also planned).

Source: Figure modified from Wood and Lettenmaier, 2008 (GRL)



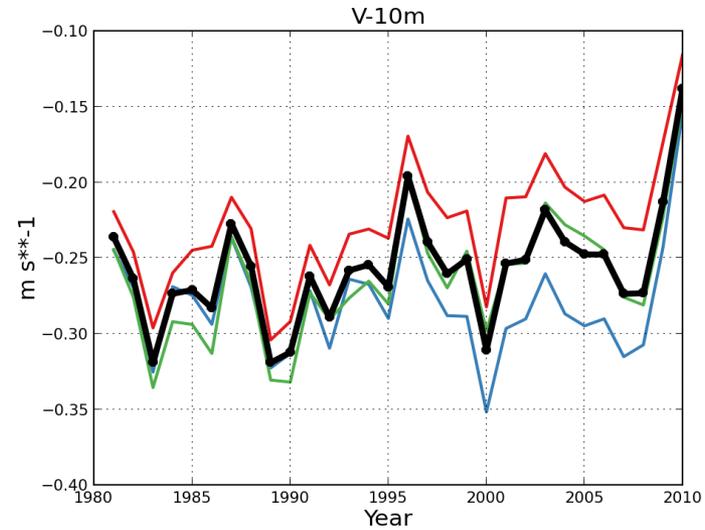
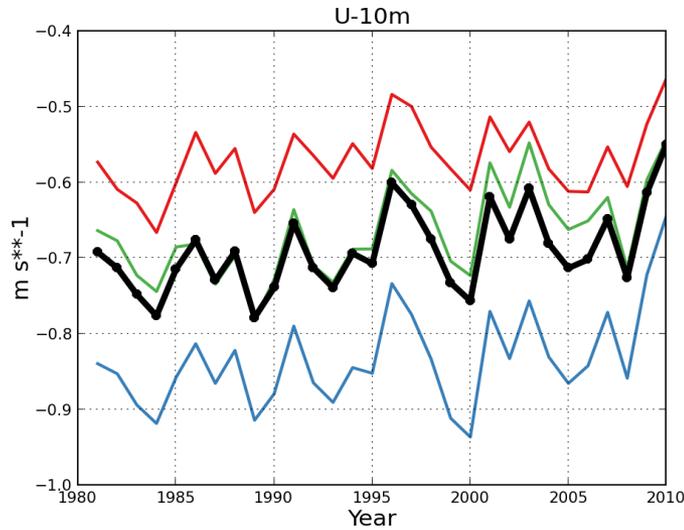
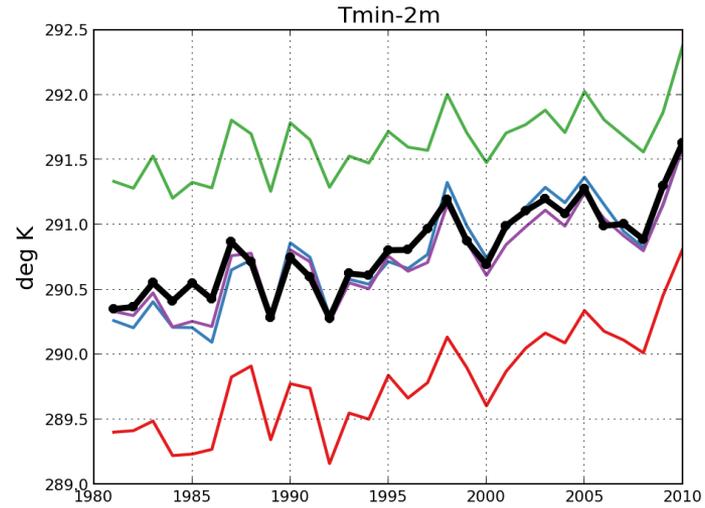
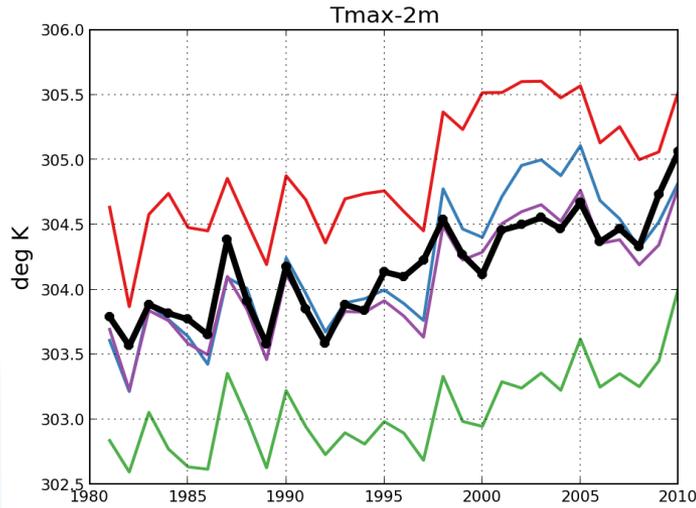
- **Seasonal forecasts:** GEOS-5, CFSv2, NMME-based ensembles
- **Retrospective/NRT:** MERRA-2, CFS-R, CHIRPS precipitation
- **Satellite observations for assimilation and forecast initialization:** ASCAT soil moisture, GRACE Terrestrial Water Storage (TWS), SMAP soil moisture.
- **Evaluation:**
  - Temperature/Precipitation: GHCN-D in-situ data sets (near real-time); CRU temperature, CHIRPS precipitation
  - Streamflow: GRDC Stations (see picture at right); Some sites up to present
  - Water Levels for rivers and lakes: *Radar Altimetry from numerous satellites (Topex-Poseidon, Envisat, Jason series, Altika)*
  - Water Extent: *GIEMS and MODIS-based NASA Global Flood Mapping*
  - Soil moisture: CCI ECV (blended satellite product); Data available till end of 2014
  - Evapotranspiration: ALEXI, SSEB, FLUXNET, (Also MODIS ET and LST)
  - Vegetation Indices: GIMMS NDVI, MODIS NDVI, LAI



9252 GRDC stations with monthly data, incl. data derived from daily data (Status: 26 Nov 2015)  
 Koblenz: Global Runoff Data Centre, 2015. 

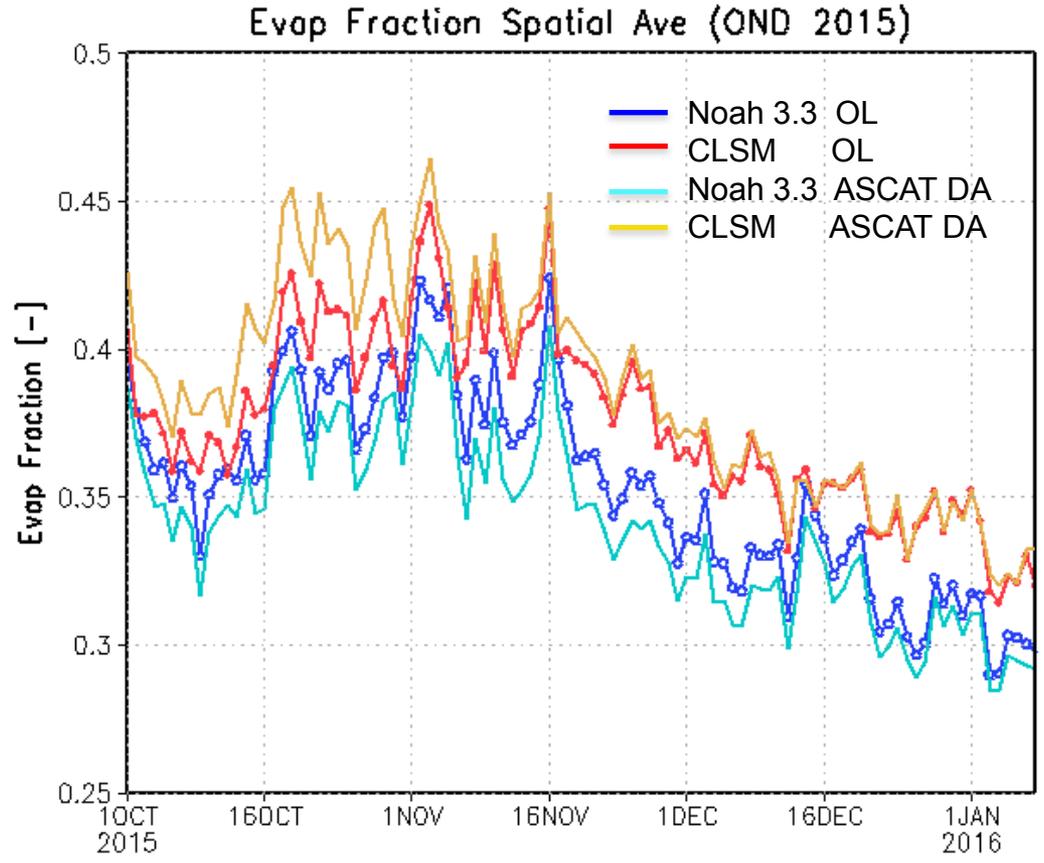
## Annual mean over Africa & Middle East

— CFSR    — MERRA-2    — ERA-interim    — Ensemble Mean    — Observation



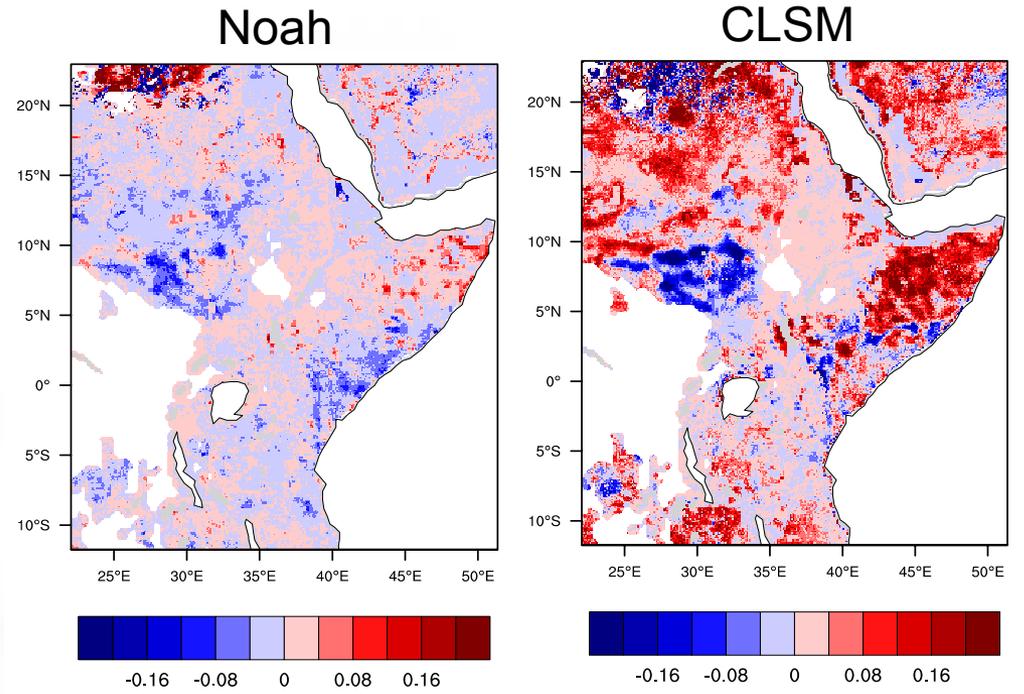
## Noah 3.3 vs CLSM

- Evaporative Fraction - Spatial Averages for EA region
- In terms of Qh and Qle, CLSM has greater (less) Qle amounts than Noah
- When ASCAT SM obs are assimilated, Noah 3.3 experiences a decrease in the Qle, opposite of CLSM



## ASCAT SM-DA Evaluation

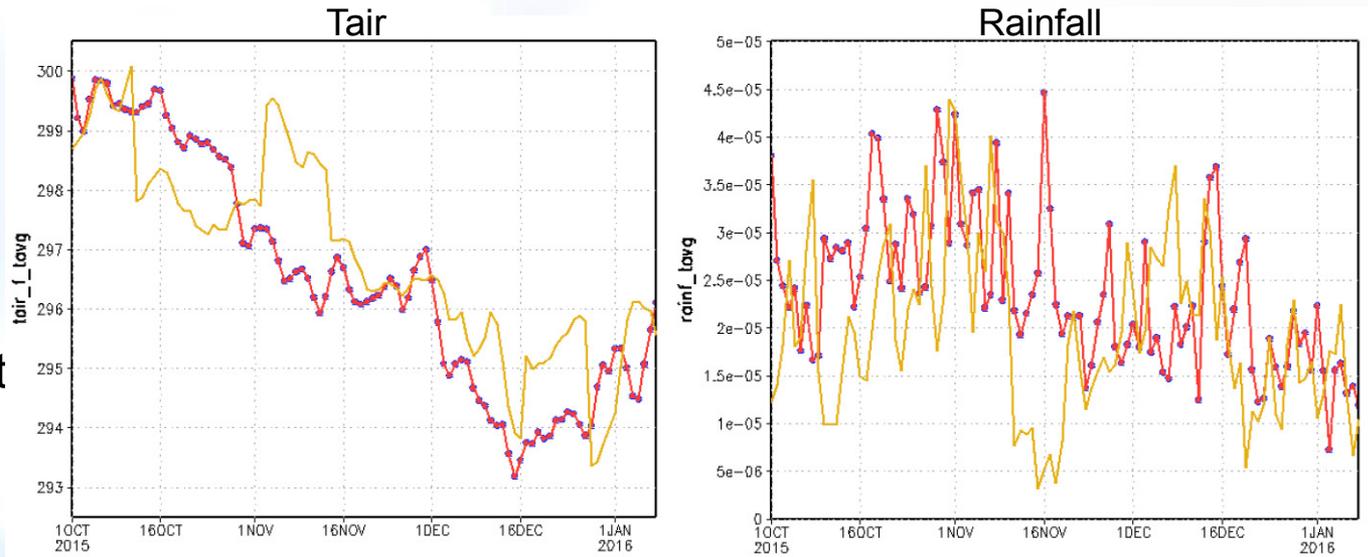
- Anomaly correlations are calculated using daily anomalies derived from monthly soil moisture climatologies, for the entire DA time period (2007-2015).
- Improvements in surface soil moisture from ASCAT DA compared to the ESA CCI data (blue-improvements, red – degradations).



## Noah 3.3 ESP Forecast Runs

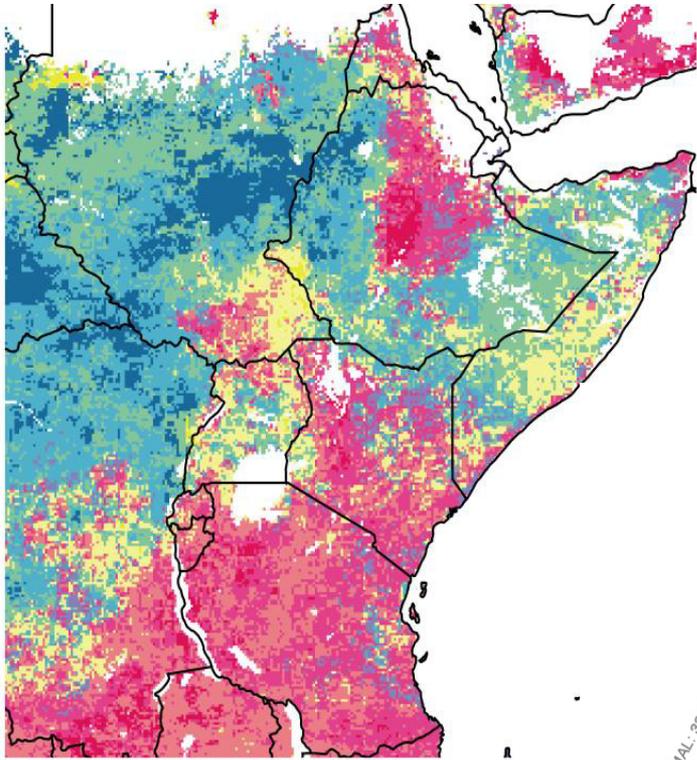
- Ran MERRA-2+CHIRPS over 100 ensemble members for the period Oct 2015 to Feb. 2016.
- Sample member-1 from ESP run compared with original OND-2015 period for MERRA2 (+CHIRPS precipitation) forcings. Additional ensemble evaluation to follow.

- OL
- ASCAT DA
- No DA Init
- ASCAT DA Init



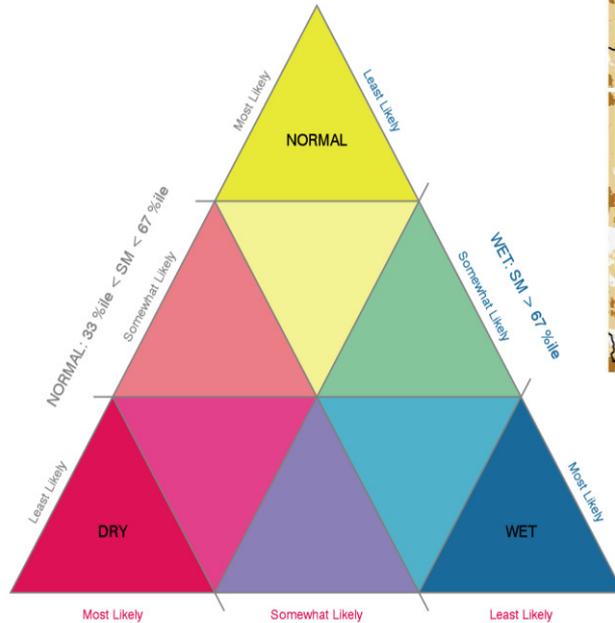
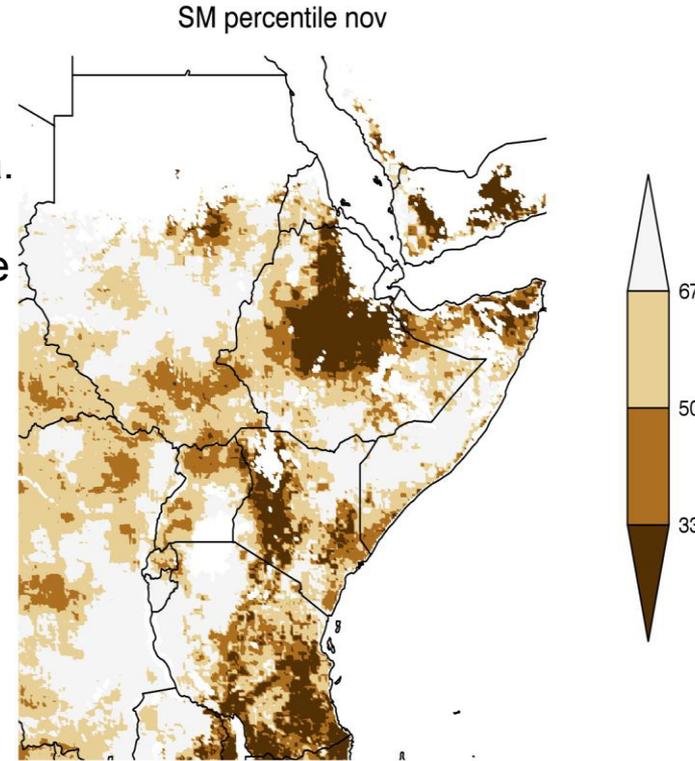
MERRA2+CHIRPS

ESP Forecast November 2015  
 Initialized September 30



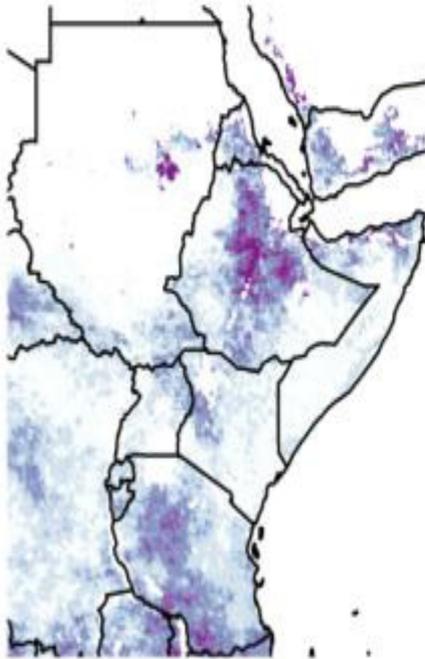
The ESP method captures the anomalous initial conditions in Ethiopia, but climatology alone didn't predict the wet conditions in Tanzania. The GEOS-5 model, however did anticipate the ENSO impacts.

FLDAS "Observed"  
 Noah SM 0-10cm w/ obs.

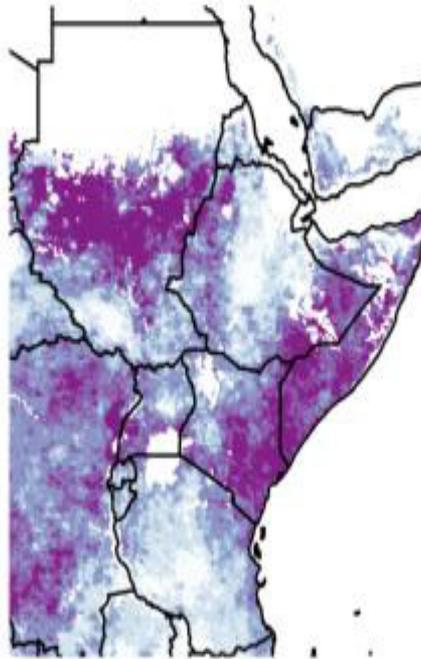


## January ESP-bootstrap forecast initialized on Sept 30

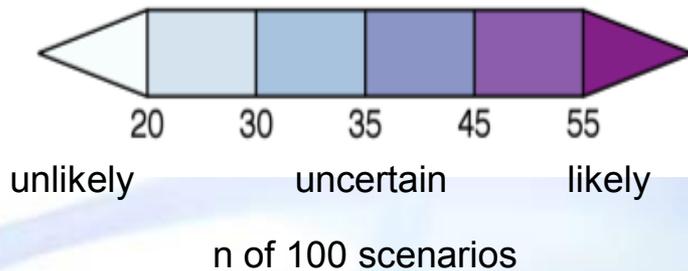
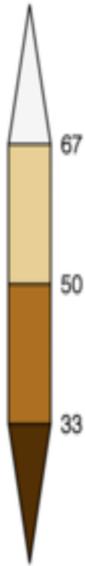
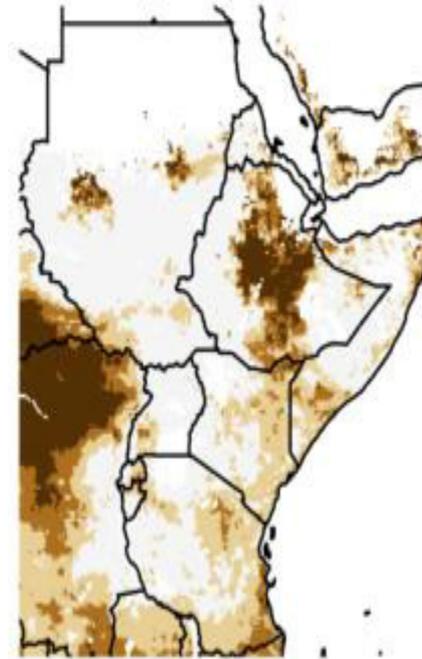
P(DRY)



P(WET)

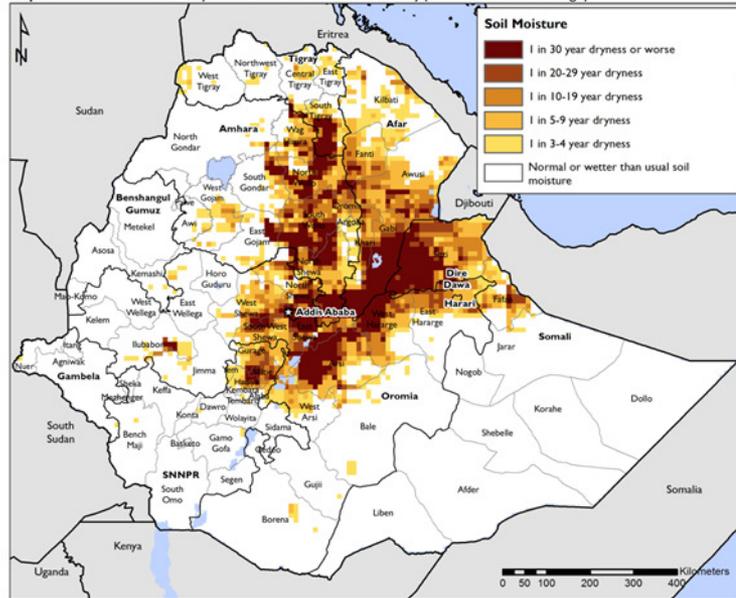


Noah SM 0-10cm w/  
obs. rainfall inputs



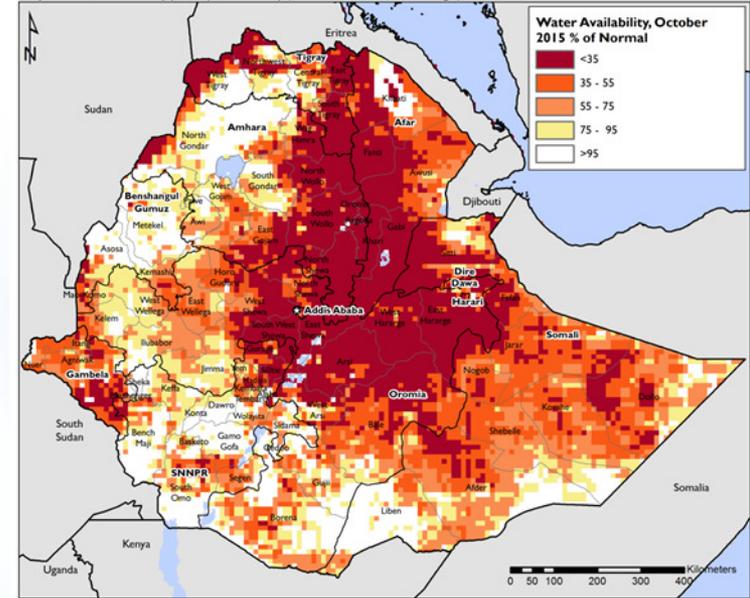
## FLDAS used to assess summer 2015 Ethiopian drought

Map 3. Standardized March – September 2015 soil moisture anomaly (vs. the 1981-2014 average)



**Figure 1.** Standardized March-September 2015 soil moisture anomaly (vs. the 1981-2014 Period)

Map 4. Water availability per capita anomaly (% of the 1981-2014 average)



**Figure 2.** Water availability per capita anomaly (% of the 1981-2014 average)

**FEWS NET Food Security Analysis at USAID** map FLDAS outputs for decision support. During the 2015 main cropping/rangeland regeneration period soil across much of central Ethiopia was driest in at least 30 years. Per capita water availability shows severe water deficits (less than 35% of average) in the northern pastoral and eastern cropping areas.

## Monthly FLDAS-Noah33 and VIC412 outputs can be downloaded from the NASA GES DISC for hydro-meteorological analysis over East, West, and Southern Africa domains.

EARTHDATA Data Discovery DAACs Community Science Disciplines

# GES DISC

Atmospheric Composition, Water and Energy Cycle, and Climate Variability Data

FLDAS

Feedback Help

### 01/10 Datasets

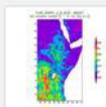
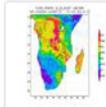
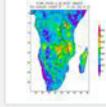
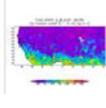
Showing (12) datasets associated with FLDAS...

#### Refine By

- Subjects Sort
- Atmospheric Pressure (12)
  - Atmospheric Radiation (12)
  - Atmospheric Temperature (12)
  - Atmospheric Water Vapor (12)
  - Atmospheric Winds (12)
  - More...

- Measurements Sort
- Evapotranspiration (12)
  - Heat Flux (12)
  - Humidity (12)
  - Humidity Index (3)
  - Humidity Indices (3)
  - More...

- Source
- Models/Analyses Noah-LSM (6)
  - Models/Analyses VIC-LSM (3)

Image	Dataset	Source	Temporal Resolution	Spatial Resolution	Process Level	Begin Date	End Date
	FLDAS Noah Land Surface Model L4 monthly 0.1 x 0.1 degree for Eastern Africa (GDAS and RFE2) (FLDAS_NOAH01_A_EA_M.001) - Atmospheric Pressure, Atmospheric Radiation, Atmospheric Temperature	Models/Analyses Noah-LSM	1 month	0.1 °	4	2001-01-01	present
	FLDAS Noah Land Surface Model L4 monthly 0.1 x 0.1 degree for Southern Africa (MERRA and CHIRPS) (FLDAS_NOAH01_B_SA_M.001) - Atmospheric Pressure, Atmospheric Radiation, Atmospheric Temperature	Models/Analyses Noah-LSM	1 month	0.1 °	4	1982-01-01	present
	FLDAS VIC Land Surface Model L4 monthly 0.25 x 0.25 degree for Southern Africa (GDAS and RFE2) (FLDAS_VIC025_A_SA_M.001) - Atmospheric Pressure, Atmospheric Radiation, Atmospheric Temperature	Models/Analyses VIC-LSM	1 month	0.25 °	4	2001-01-01	present
	FLDAS Noah Land Surface Model L4 monthly 0.1 x 0.1 degree for Western Africa (MERRA and CHIRPS) (FLDAS_NOAH01_B_WA_M.001) - Atmospheric Pressure, Atmospheric Radiation, Atmospheric Temperature	Models/Analyses Noah-LSM	1 month	0.1 °	4	1982-01-01	present

## Schedule

Milestone	2014	2015				2016				2017				2018			
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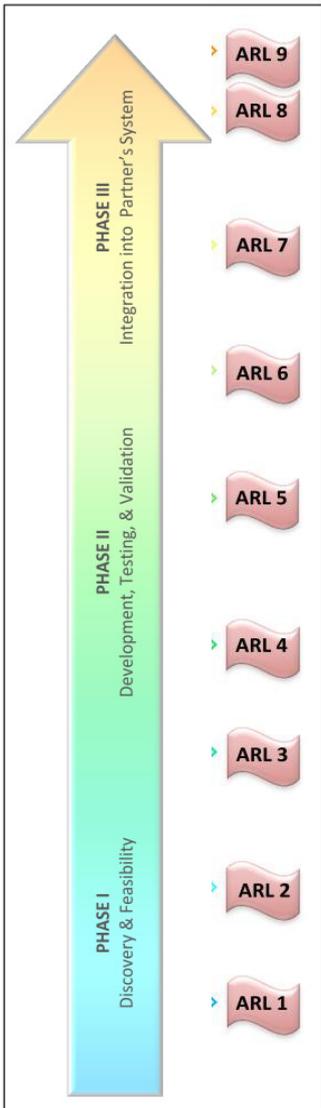


# Backup



MODEL	Experiment	POC	Run Completed	HyMAP Run completed	Time Period of Interest
Noah3.3	Spinup (1,2,3)	Amy	Yes	N/A	JAN1981-DEC2015
	OL	Amy	Yes	Yes	JAN1981-FEB2016
	MODEL_RUNS/EA_Noah33	DA_ASCAT	Sujay	No	JAN2007-FEB2016
		ESP_NoDA	Amy	Yes	OCT-FEB;2009,2011,2015
		ESP_ASCAT	Kristi	Yes	OCT-FEB;2009,2011,2015
		BCSD_NoDA	Amy	No	OCT-FEB;2009,2011,2015
	BCSD_ASCAT	Kristi	No	OCT-FEB;2009,2011,2015	
CLSM2.5	Spinup (1,2,3)	Augusto	Yes	N/A	JAN1981-DEC2015
	OL	Augusto	Yes	No	JAN1981-FEB2016
	MODEL_RUNS/EA_CLSM	DA_ASCAT	Sujay	No	JAN2006-FEB2016
		DA_TWS	Augusto	No	JAN2002-FEB2016
		ESP_NoDA	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015
		ESP_ASCAT	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015
		ESP_TWS	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015
		BCSD_NoDA	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015
	BCSD_ASCAT	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015	
	BCSD_TWS	Kristi/Jeanne	No	OCT-FEB;2009,2011,2015	

# Performance/ARL

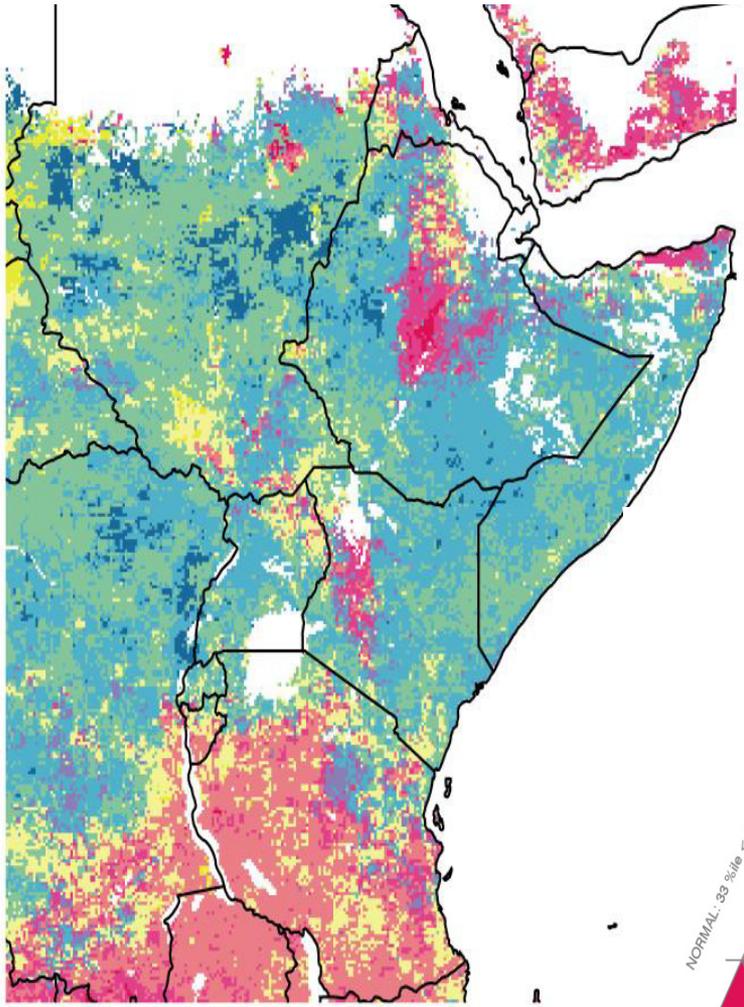


- Start of project ARL = 3 (Jan. 1., 2015)
- Current ARL = 3
  - Prototype drought forecasting systems for Africa have been developed for FEWS NET (e.g., Shukla et al., 2014);
  - Project using mature (ARL-3) Earth Science products, modeling and data assimilation capabilities, including NASA’s GEOS-5 and NOAA’s CFS climate forecasts;
  - Expanding and applying existing FEWS NET Land Data Assimilation System (FLDAS) land models, forcing observations and data assimilation techniques within NASA’s Land Information System (LIS);
- Expected Ending ARL = 7 (Dec. 31, 2018)

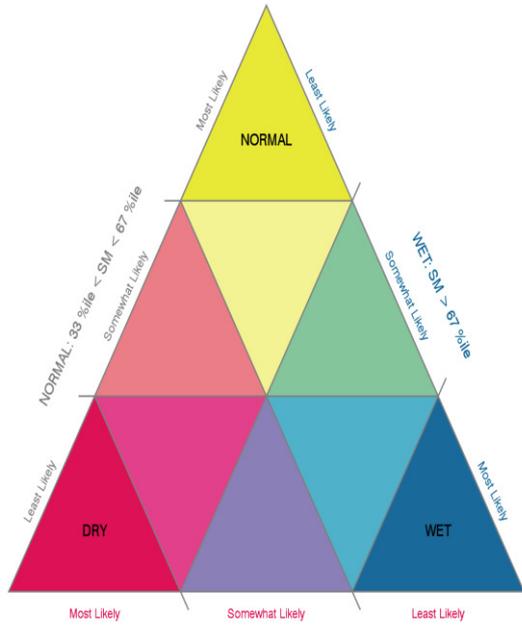
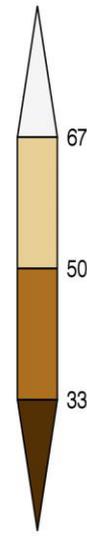
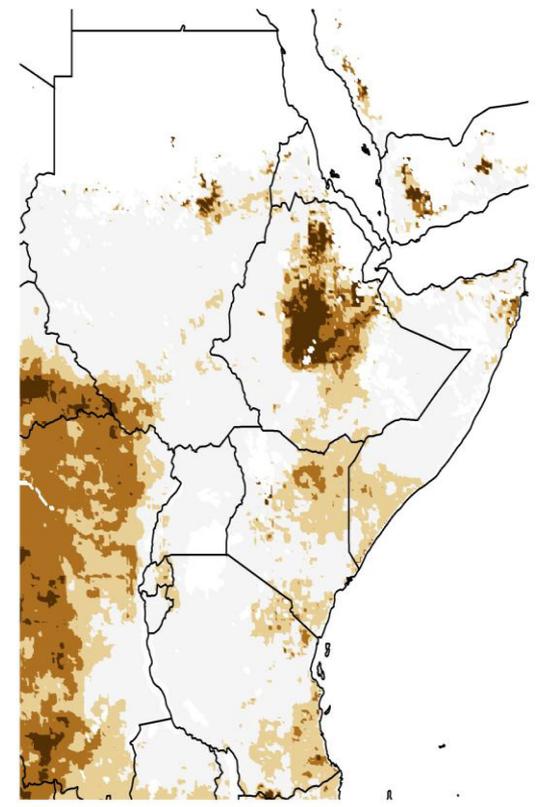


FLDAS "Observed"  
Noah SM 0-10cm w/ obs.  
rainfall inputs

The  
an  
Ethiopia, but climatology alone  
didn't predict the wet conditions  
in Tanzania. The GEOS-5  
model, however did anticipate  
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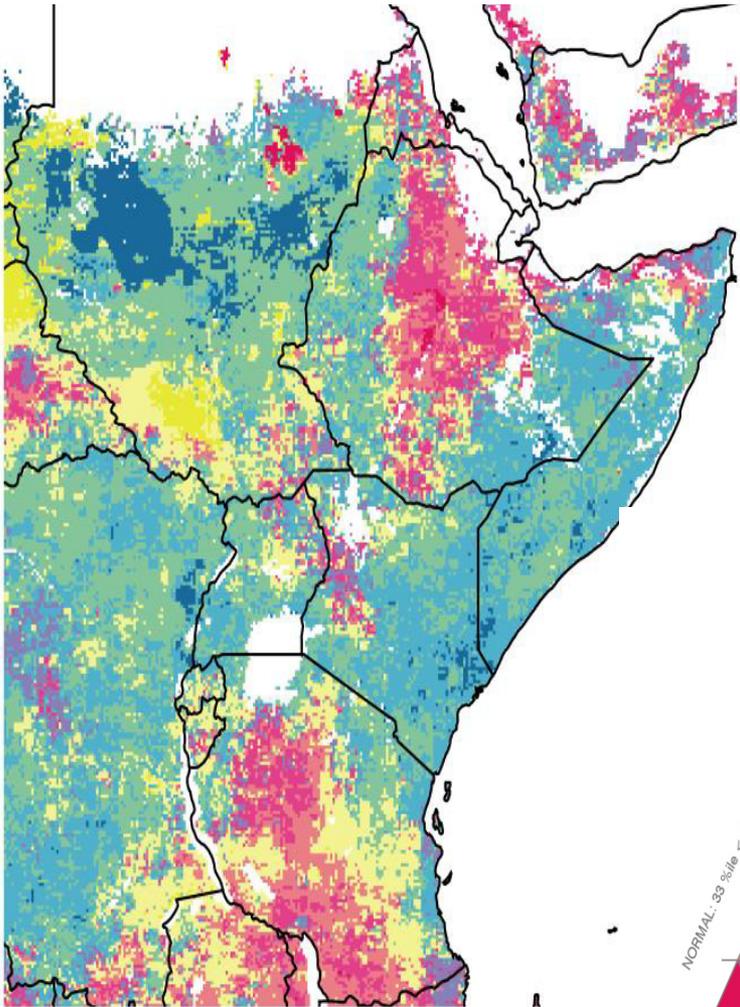
SM percentile dec



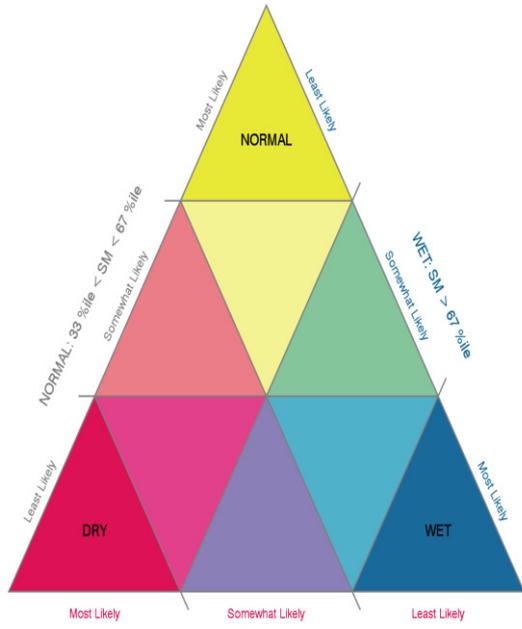
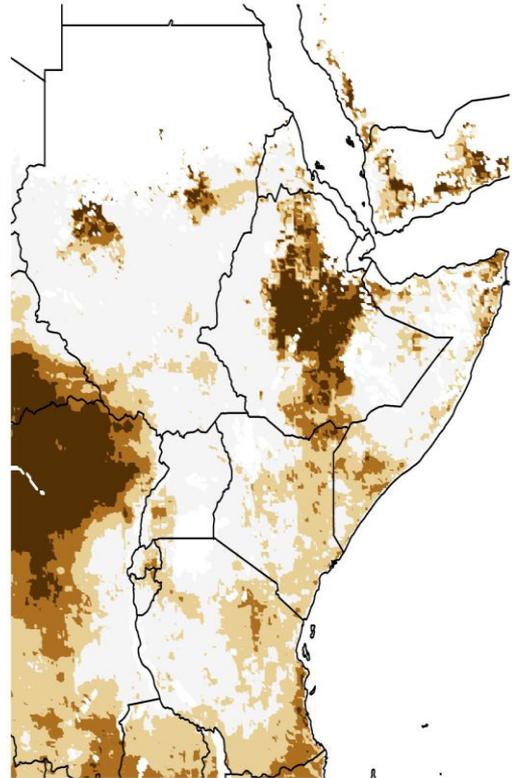


FLDAS "Observed"  
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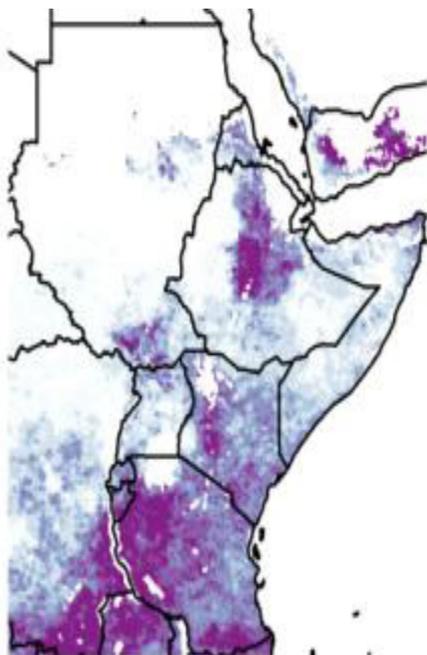
SM percentile jan



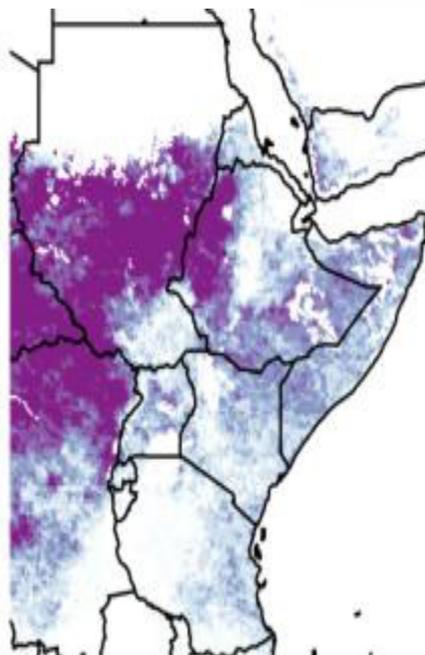
DRY: SM < 33 %ile

# November ESP-bootstrap forecast initialized on Sept 30

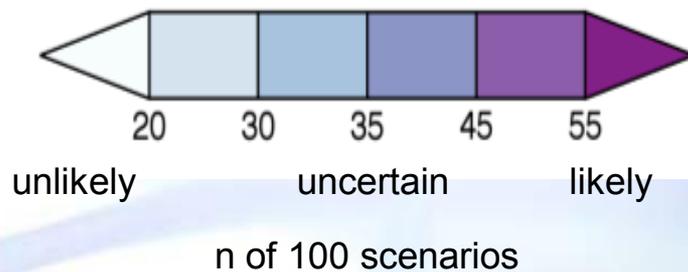
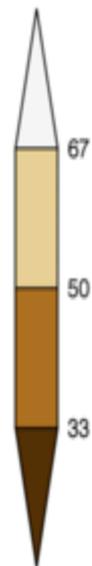
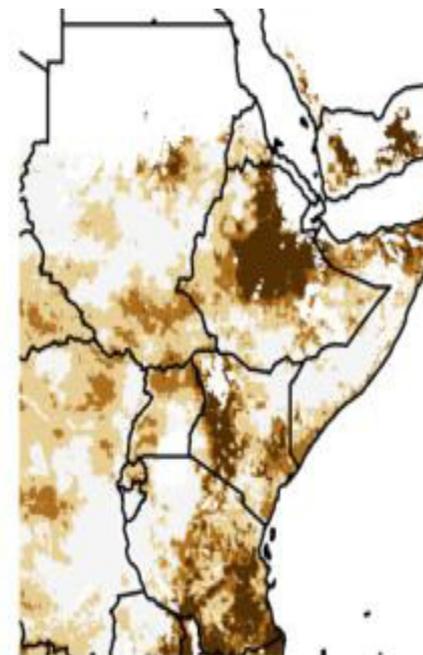
P(DRY)



P(WET)

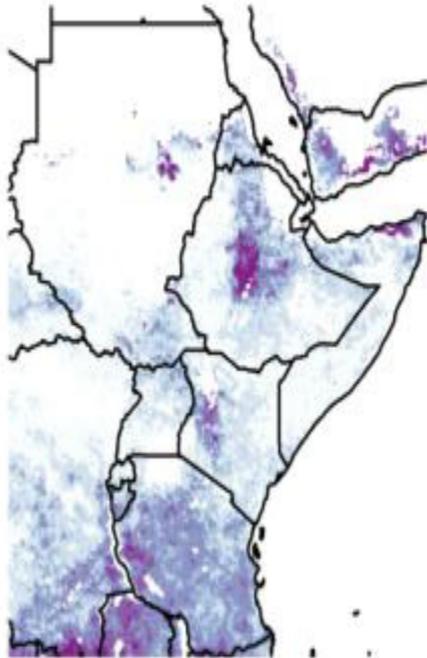


Noah SM 0-10cm w/  
obs. rainfall inputs

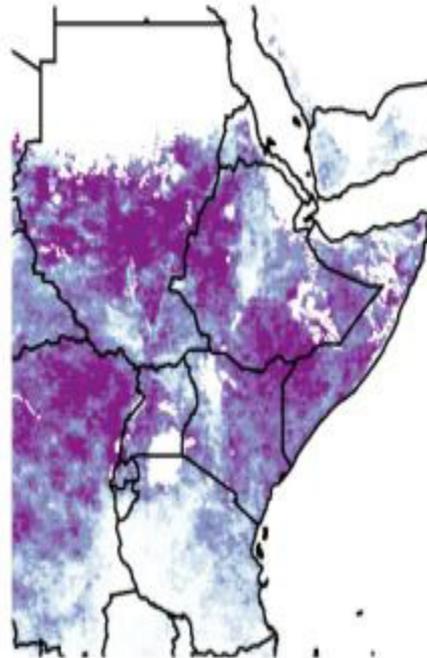


# December ESP-bootstrap forecast initialized on Sept 30

P(DRY)



P(WET)



Noah SM 0-10cm w/  
obs. rainfall inputs

