Monitoring and Forecasting Water Availability in Food Insecure Regions

Amy McNally, Christa Peters-Lidard, Kristine Verdin, Jossy Jacob, and NASA GSFC Land Information System Team

Water availability, for what?

Soil water storage: agriculture & pasture (i.e. plant water availability), water points for people and animals

Groundwater storage: irrigation, domestic water supply

Surface water storage: reservoirs, lakes, streams used for domestic, agricultural and industrial needs

Snow water storage: irrigated agriculture and domestic water supplies

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The Famine Early Warning Systems Network (FEWS NET) has long history of monitoring plant available water for agriculture and pasture with NDVI and rainfall statistics.

NASA LIS modeling capabilities let us model different storage reservoirs to monitor conditions that impact food security, beyond rainfed agriculture.

FEWS NET LDAS (FLDAS) Africa

Parameters:
IGBP MODIS landcover, FAO soils, GTOPO30 elevation, NCEP albedo (quarterly/seasonal)

Meteorological Inputs:
MERRA-2, GDAS
CHIRPS, CHIRPS-prelim, RFE2

LIS-based LSMs:
Noah3.3
10km x 10km resolution,
VIC 4.1.2
25km x 25 km resoultion

Daily & Monthly outputs:
Full water balance e.g. ET, SM, runoff
Full energy balance e.g sensible heat flux, ground heat flux, net raditaion

Evaluation
remote sensing
(e.g. MODIS NDVI, SSEBop ET, ESA CCI SM), GRDC streamflow, GRACE TWS

Data delivery:
LIS Data Portal, USGS Early Warning Data Portal, NASA GES DISC & GIOVANNI

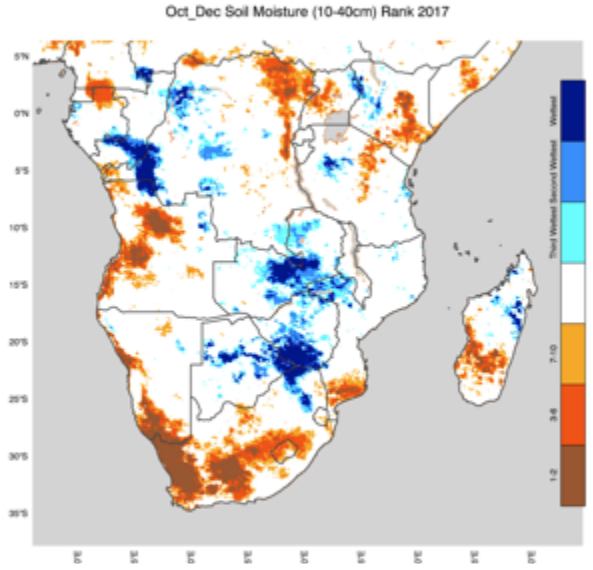
McNally, Amy, Kristi Arsenault, Sujay Kumar, Shraddhanand Shukla, Pete Peterson, Shugong Wang, Chris Funk, Christa D. Peters-Lidard, and James P. Verdin, 2017: "A land data assimilation system for sub-Saharan Africa food and water security applications." Scientific Data 4. doi: [10.1038/sdata.2017.12](https://doi.org/10.1038/sdata.2017.12)

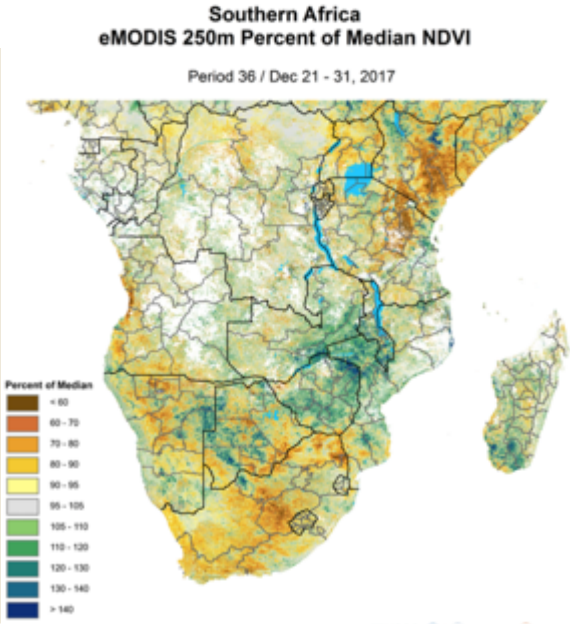
Detailed specifications available at https://ldas.gsfc.nasa.gov/FLDAS/FLDASspecs.php

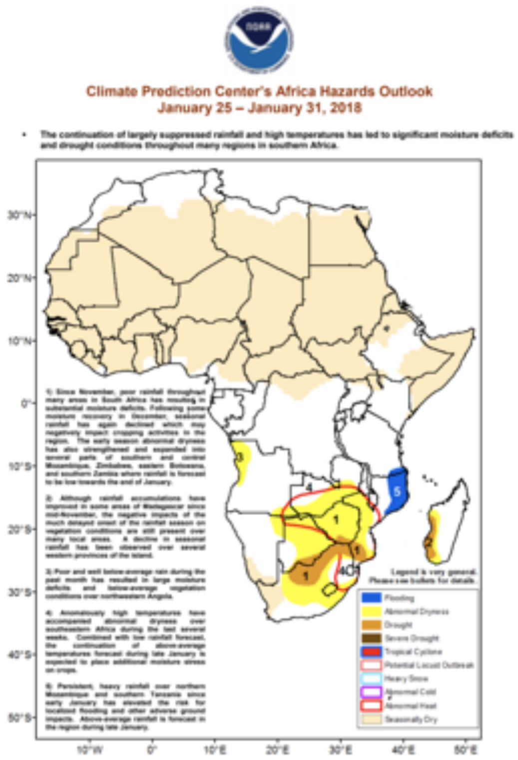
FLDAS Drought Monitoring

Plant water availability 2017/18

Subsurface soil moisture rank

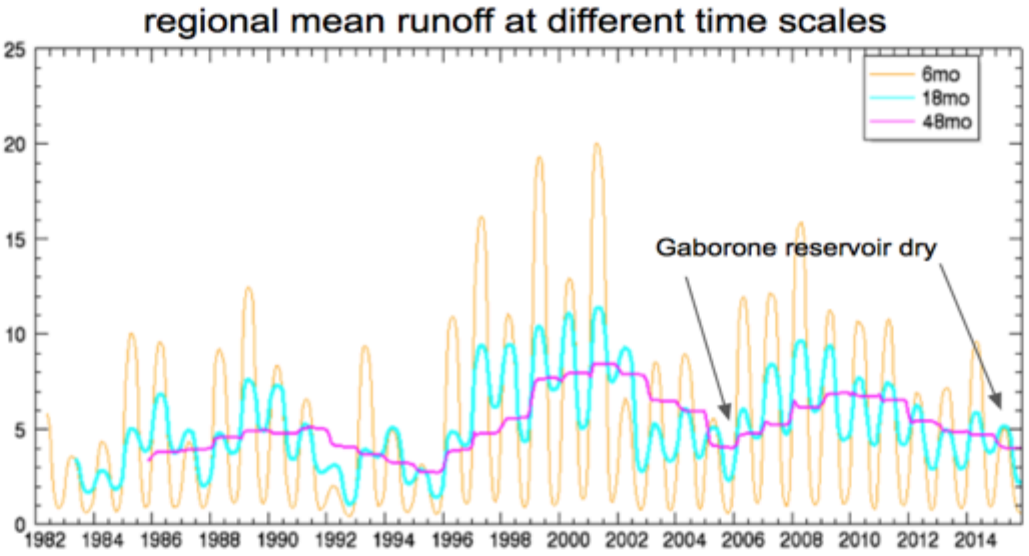




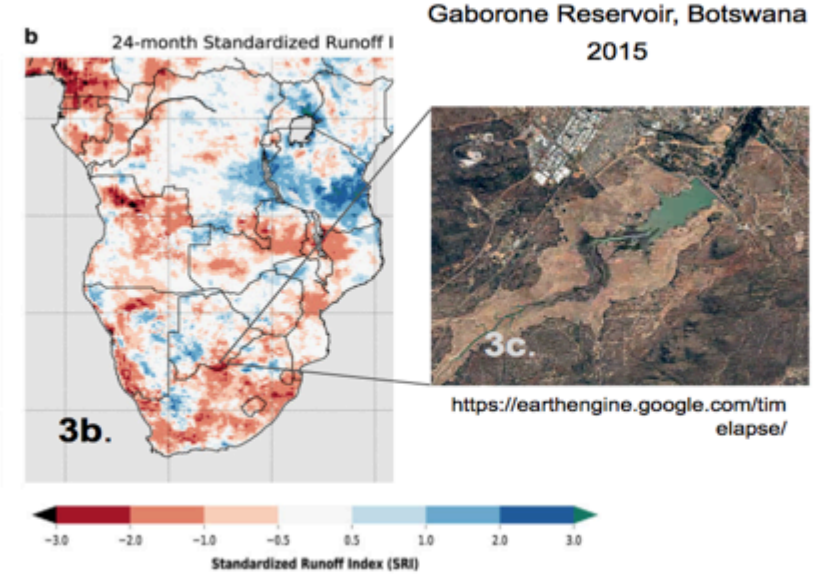


Southern Africa was facing abnormally dry, abnormally hot and drought conditions as classified by NOAA CPC. We find that the Oct-Dec average surface and subsurface soil moisture is some of the driest since 1982.

FLDAS Reservoir Monitoring

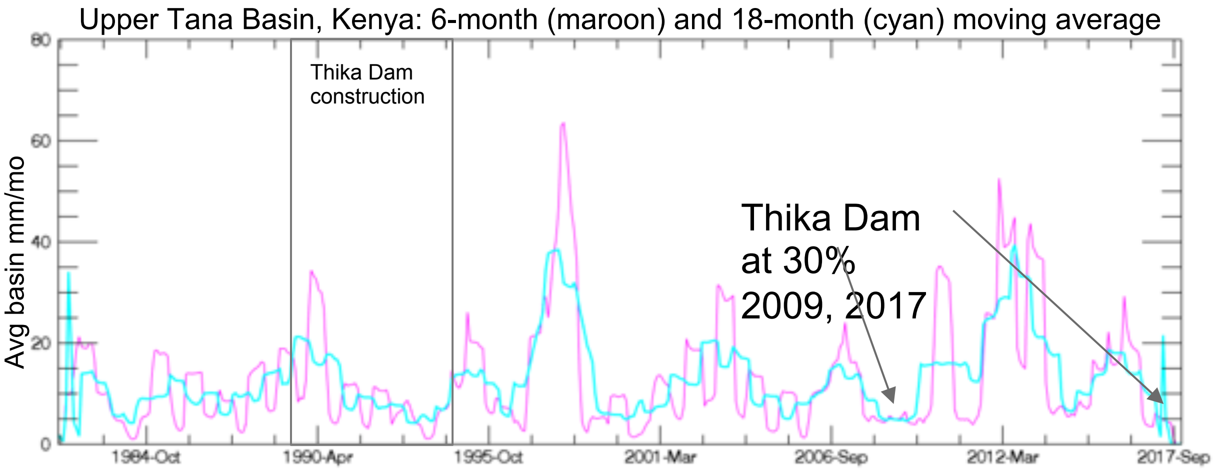


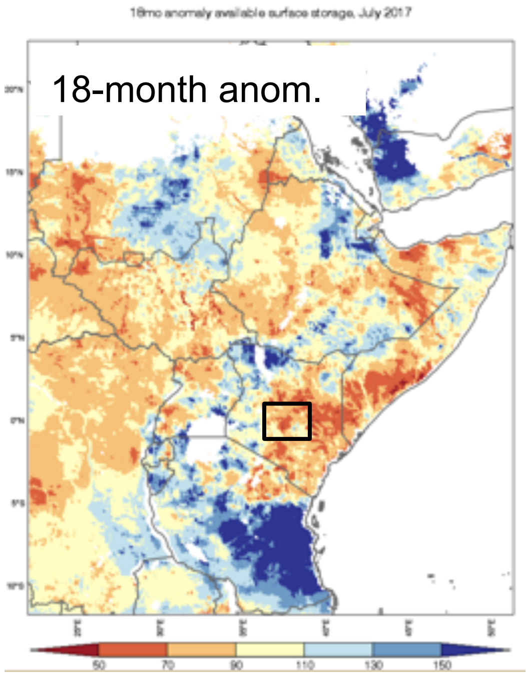
Gaborone Dam, Botswana 2015-16 drought



Time series analysis and Standardized Runoff Index (SRI-1, SRI-24)

FLDAS Reservoir Monitoring



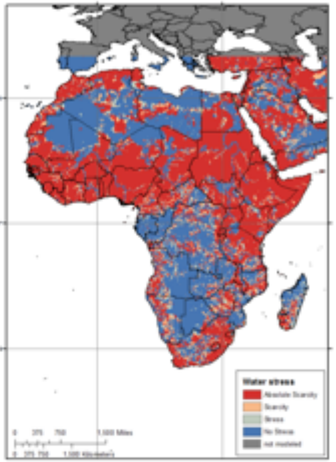


Thika Reservoir, Kenya Sept-2017

Time series analysis and Multi-month anomalies

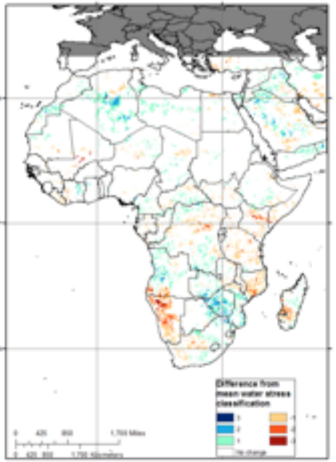
Water Stress per Falkenmark Index (runoff per capita)

Water Stress



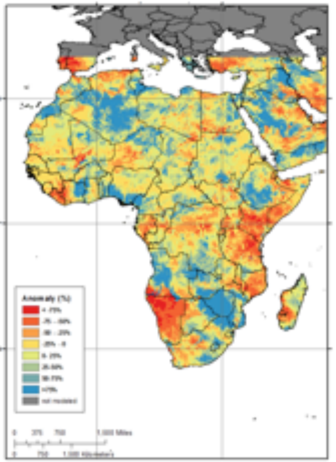
Water Stress maps highlight locations experiencing water stress based on current runoff and 2015 population.

Water Stress Anomaly



Water Stress Anomaly maps highlight departure from average (1982-2017).

Runoff Anomalies



Runoff Anomaly maps highlight water supply departures from average conditions (1982-2017).

Water Stress Thresholds from Falkenmark

Water Stress

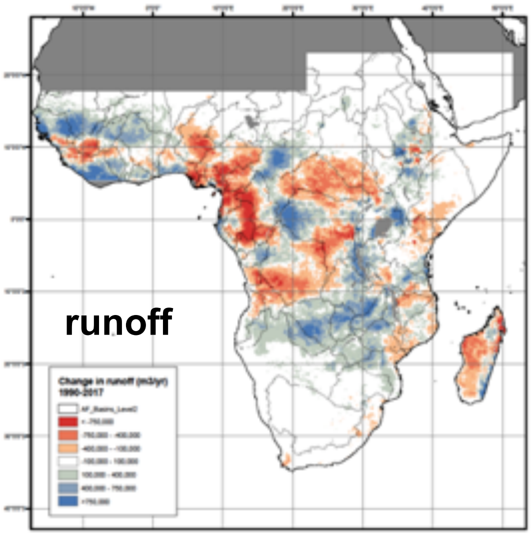
- Absolute Scarcity
- Scarcity
- Stress
- No Stress
- Not Modeled

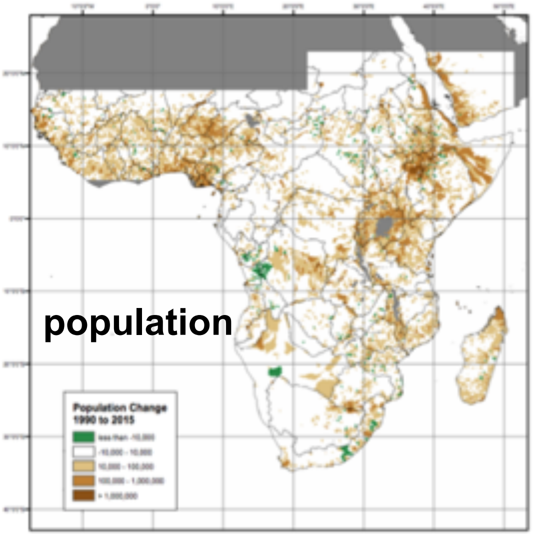
Table 1. Annual and Monthly Falkenmark Categories

category	m3/yr/cap	m3/mo/cap
no stress	>1700	>142
stress	1000–1700	83–142
scarcity	500–1000	41–82
absolute scarcity	<500	<41

Maps updated twice a month at https://lis.gsfc.nasa.gov/projects/fewsnet

Trends in Runoff & Population

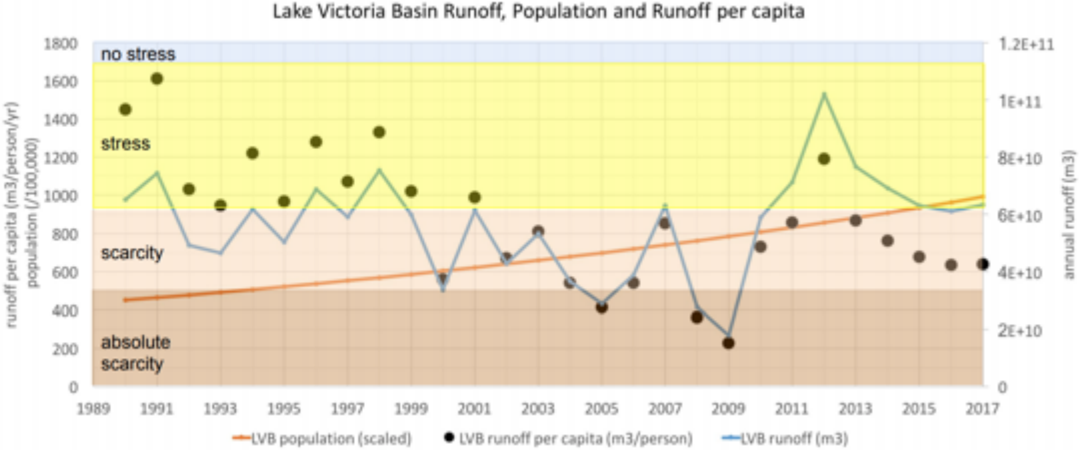




Maps of annual runoff and population change, and time series of the Lake Victoria Basin show the relationship between runoff and water stress.

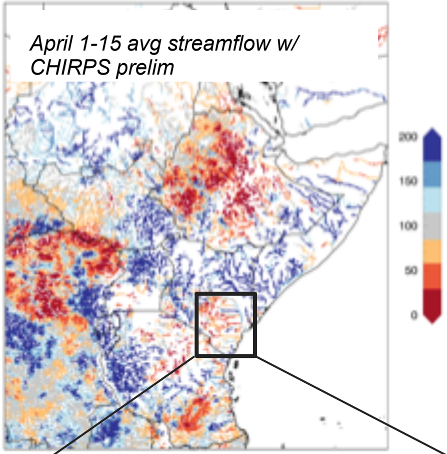
Water Stress Change Over Time: Lake Victoria Basin

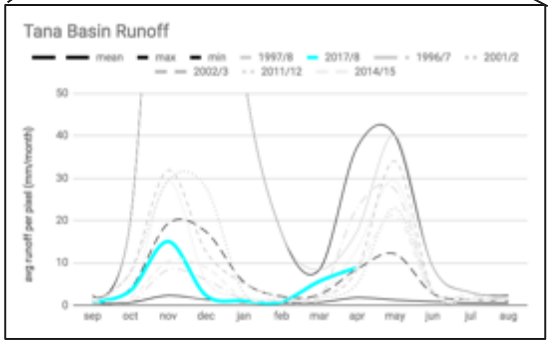
Annual runoff varies from year to year, while water availability trends downward with increasing population.



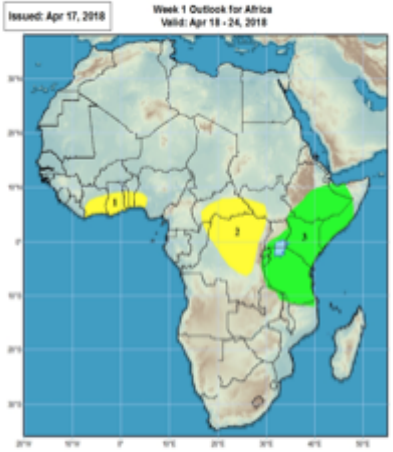
Water Availability Forecasts

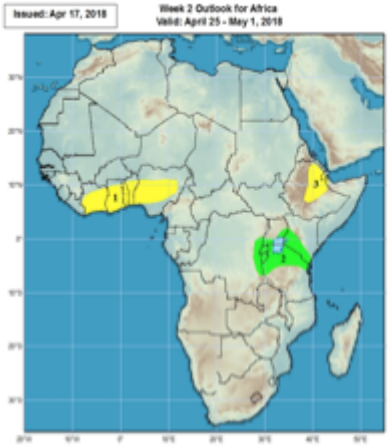
Current Conditions & Historical Context



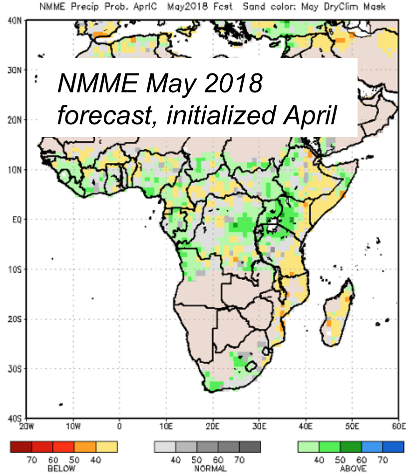


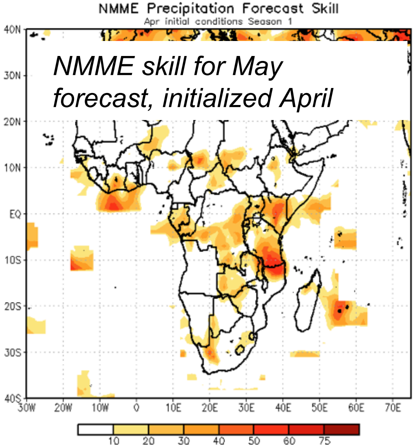
1-week & 2-week weather forecasts





NMME Probability for next 1 - 6 months





FLDAS Model Evaluation-East and Southern Africa

Basin	SSEBop ET vs Noah33 (R)	GRACE TWS vs Noah33 (R)	Streamflow (R) (#stations)
Blue Nile	0.49	0.85	0.46-0.94 (11)
Awash	0.72	-	0.47-0.72 (3)
Juba-Shabelle	0.8	-	0.41-0.53 (4)
Upper Tana	0.64	-	-
Rufiji	0.56	-	0.41-0.61
Pangani	0.74	-	0.41-0.81
Orange	0.72	0.74	0.61-0.66 (3)
Zambezi	0.72	0.76	
Limpopo	0.78	0.66	
Wami-Ruvu	-	-	0.41-0.61

FLDAS Noah33 CHIRPS+MERRA-2 estimates are well correlated with independent observations in Southern and Eastern Africa basins.

Streamflow correlations are a function of human influence (e.g. irrigation, dams).

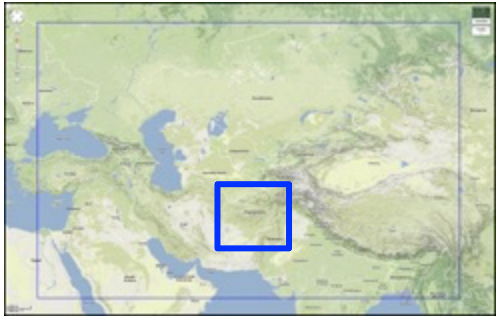
Additional evaluation published in McNally et al. 2016 & 2017 and Jung et al. 2017

FEWS NET LDAS (FLDAS) Central Asia

Parameters:
UMD-AVHRR landcover, FAO soils, GTOPO30 elevation, NCEP albedo (quarterly/ seasonal)

Meteorological Inputs:
6 hourly GDAS - NCEP Global Data Assimilation System Final (FNL) Operational Global Analysis

LIS-based LSMs:
Noah3.6
1km x 1km resolution,
1 hr model timestep,
No snow assimilation



Daily - near real time outputs:
Snow water equivalent
Snow covered area
Snow depth
Air temperature

Evaluation
remote sensing
(e.g. MODIS & Landsat Snow Cover Fraction, SSM/I & AMSR-2 snow depth)

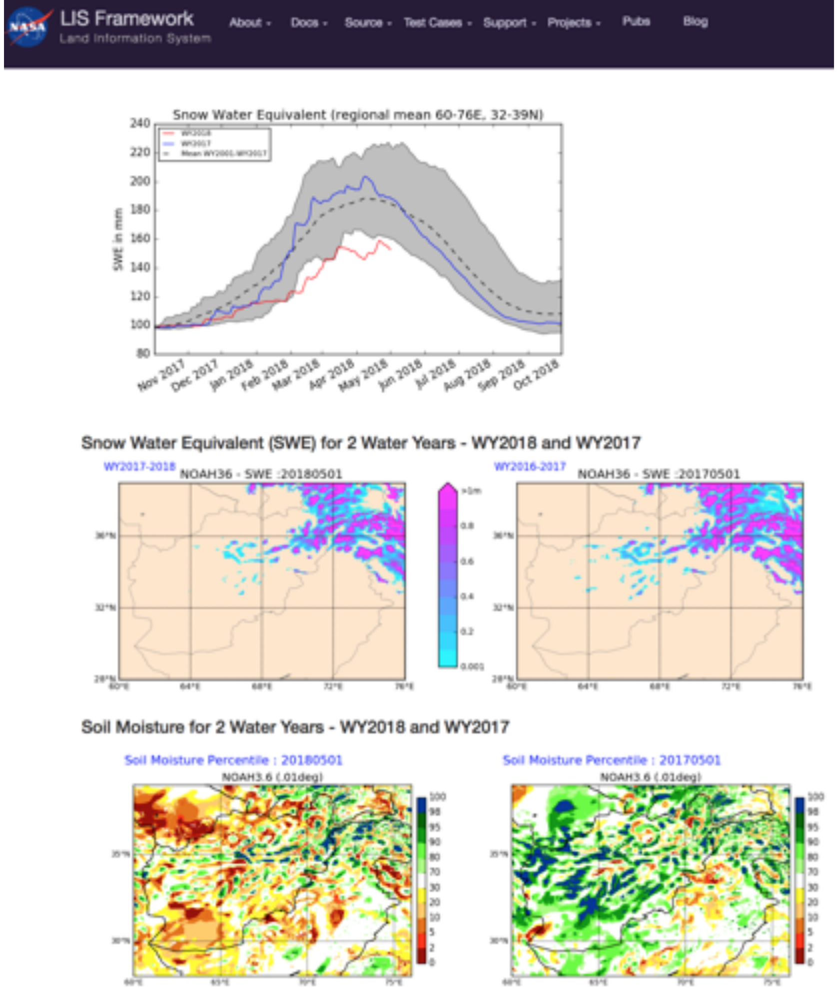
Data delivery:
LIS Data Portal,
USGS Early Warning Data Portal

Detailed specifications available at https://ldas.gsfc.nasa.gov/FLDAS/FLDASspecs.php

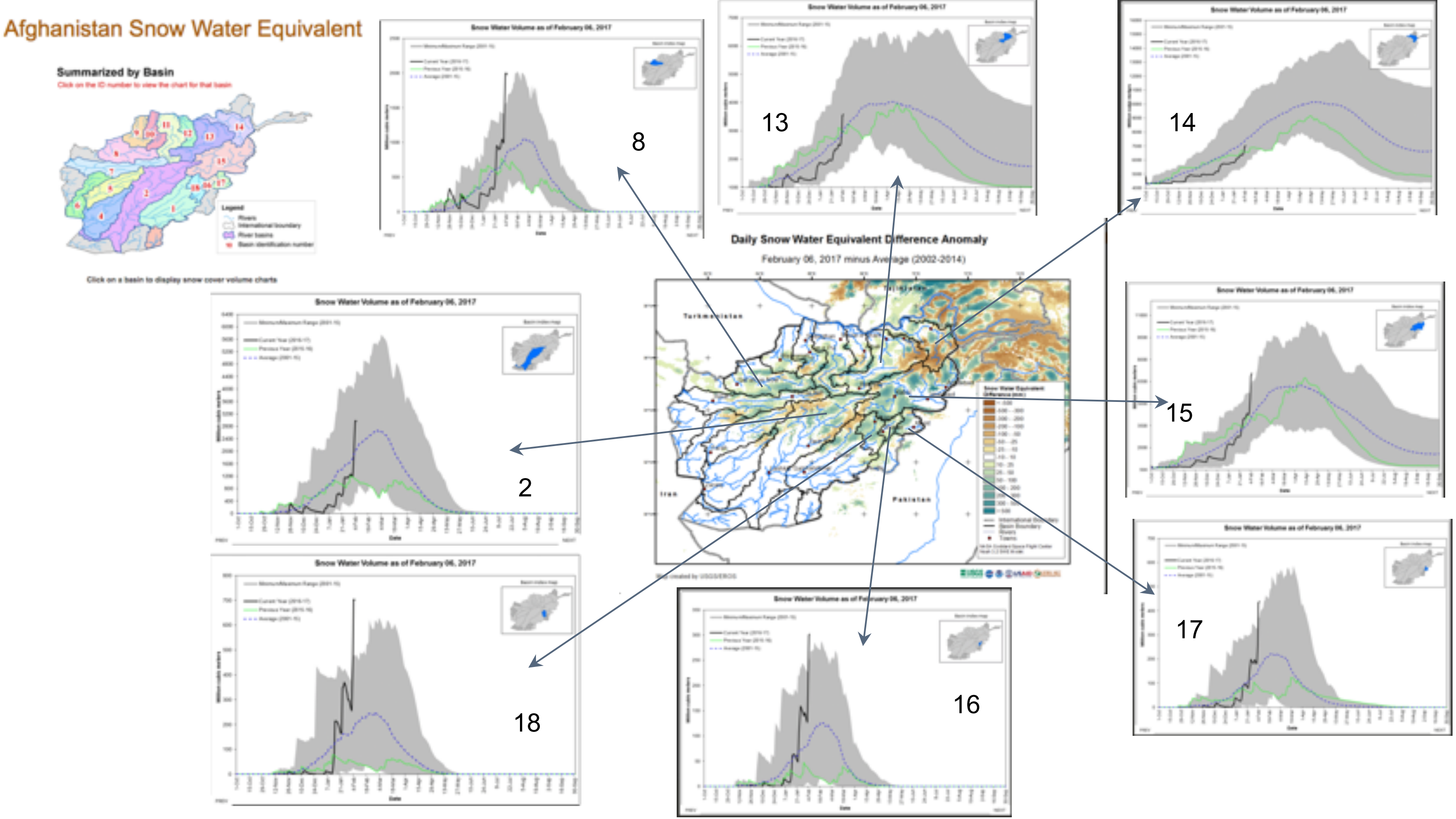
Central Asia Snow Modeling

Estimates of Snow Water Equivalent (SWE) and Snow Depth are provided daily to USGS Early Warning https://earlywarning.usgs.gov

These estimates are then used by CPC NOAA and FEWS NET to track conditions in Afghanistan.



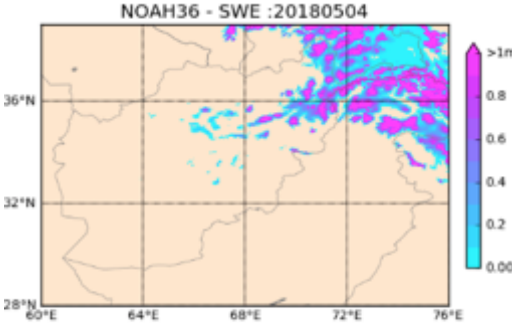
https://lis.gsfc.nasa.gov/projects/fewsnet

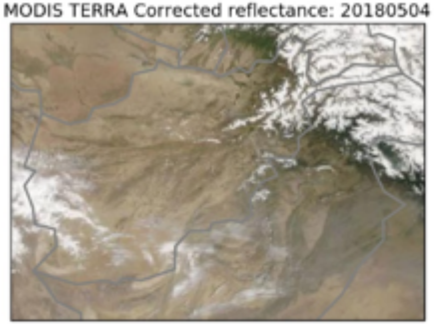


The Daily SWE by basin's tool allows us to compare the current season's evolution to historic season time series.

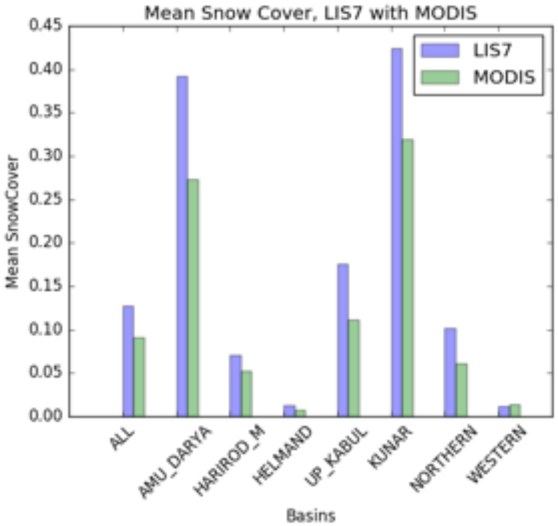
Central Asia Evaluation

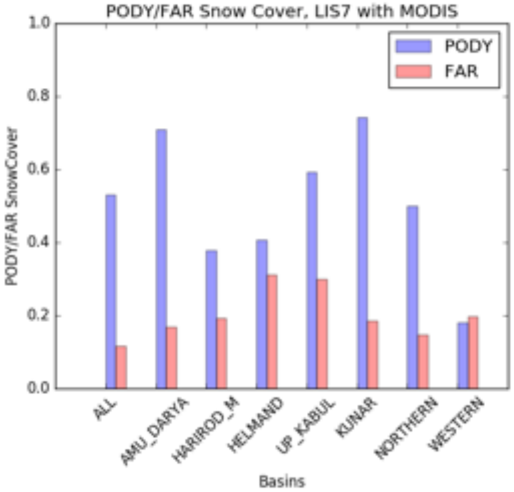
Modeled estimates of SCA are routinely compared to MODIS.





Mean snow cover fraction corresponds well at the basin level during the peak snow season (Water Year 2016).





Probability of Detection (POD) > 0.6 and False Alarm Rate (FAR) < 0.2.

Central Asia Applications

These snow estimates contribute to Food Security Outlooks produced by FEWS NET.

For the current 2017/18 season the low snowpack in Afghanistan is expected to impact crop production.

FEWS NET
FAMINE EARLY WARNING SYSTEMS NETWORK

AFGHANISTAN Food Security Outlook — February to September 2018

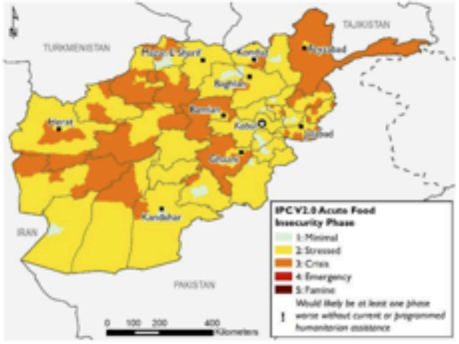
Low snow accumulation and dry soil conditions likely to impact 2018 staple production

KEY MESSAGES

- The weakening of the casual labor market since 2014 has made it more difficult for poor households to earn sufficient income to support dietary needs during the lean season. Furthermore, 2017 rainfed production was poor in some provinces, including in Ghor, Balkh, Jawzjan, Takhar, Badakhshan, Samangan, Herat, Baghlan, and Sar-i-Pul Provinces. Poor households affected by poor own production or who were not able to find sufficient employment to support food purchases are likely experiencing Crisis (IPC Phase 3) outcomes until local spring labor opportunities facilitate access to income and market purchases of food.

- The ongoing conflict between various insurgent groups, primarily the Taliban and IS, and the Government of the Islamic Republic of Afghanistan has increased in geographic extent and severity in recent years, with more than 1.1 million people displaced since the beginning of 2016. Beyond displacement, insecurity has continued to disrupt normal livelihoods by limiting access to farms, rangelands, markets, and labor opportunities, and by reducing local economic activity. Although seasonal improvements in access to food and income will occur during the spring and summer months, displacement and reduced non-agricultural labor opportunities are expected to drive Stressed (IPC Phase 2) outcomes throughout much of the country during the scenario period, with many households in Crisis (IPC Phase 3).

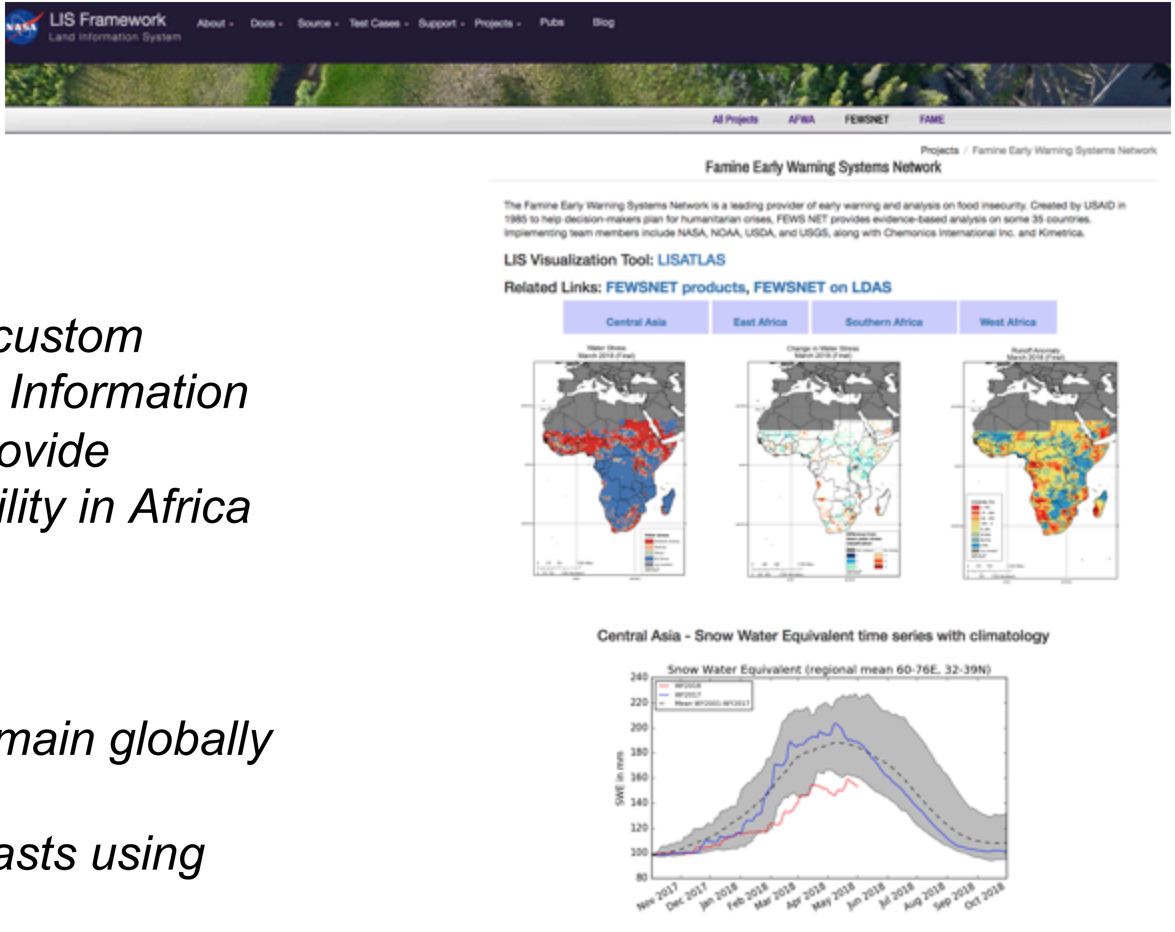
Current food security outcomes, February 2018



Source: FEWS NET

FEWS NET classification is IPC-compatible. IPC-compatible analysis follows key IPC protocols but does not necessarily reflect the consensus of national food security partners.

Summary & Next Steps



- *NASA GSFC routinely runs custom instances of the NASA Land Information System for FEWS NET to provide information on water availability in Africa and Central Asia.*

- *Ongoing efforts include:*
- ❑ *Expanding the modeling domain globally &*
- ❑ *Developing hydrologic forecasts using input from NMME models.*

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

References

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[3] McNally, A., et al. (2017). A land data assimilation system for sub-Saharan Africa food and water security applications. Scientific Data, 4, 170012.

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[5] Bosilovich, M. *et al.* MERRA-2: Initial Evaluation of the Climate. *NASA Technical Report Series on Global Modeling and Data Assimilation, NASA/TM-2015* 39, 136 (2015).

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[9] Linard, Catherine, et al. "Population distribution, settlement patterns and accessibility across Africa in 2010." *PloS one* 7.2 (2012): e31743.

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FLDAS Africa evaluation:

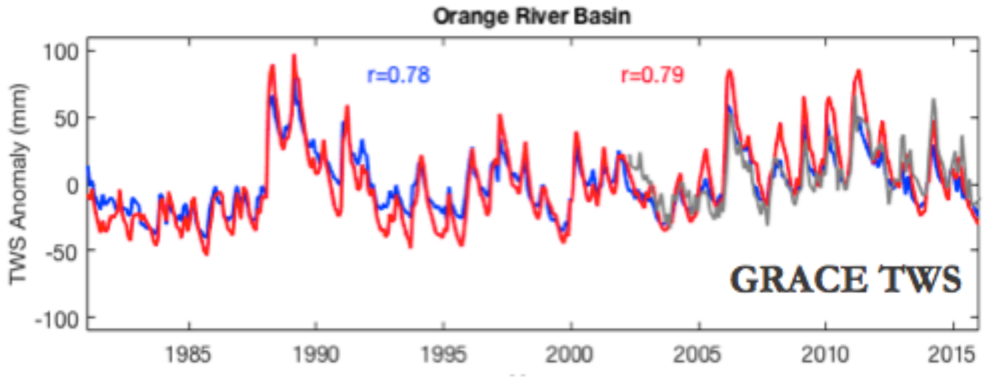
2016. McNally, A., S. Shukla, K. Arsenault, S. Wang, C. Peters-Lidard, J.P. Verdin: Evaluating ESA CCI soil moisture in East Africa. International Journal of Applied Earth Observation. doi:10.1016/j.jag.2016.01.001 - Abstract

2017. McNally, Amy, Kristi Arsenault, Sujay Kumar, Shraddhanand Shukla, Pete Peterson, Shugong Wang, Chris Funk, Christa D. Peters-Lidard, and James P. Verdin. "A land data assimilation system for sub-Saharan Africa food and water security applications." Scientific Data 4. doi: 10.1038/sdata.2017.12

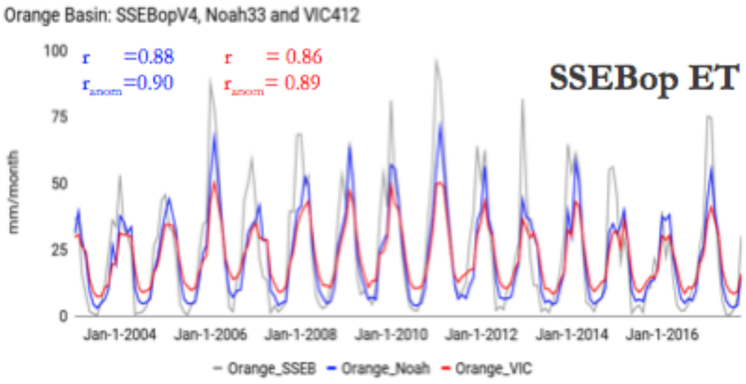
2017. Jung, H. C., Getirana, A., Policelli, F., **McNally, A.,** Arsenault, K. R., Kumar, S., ... & Peters-Lidard, C. D. Upper Blue Nile Basin Water Budget from a Multi-Model Perspective. Journal of Hydrology. https://doi.org/10.1016/j.jhydrol.2017.10.040

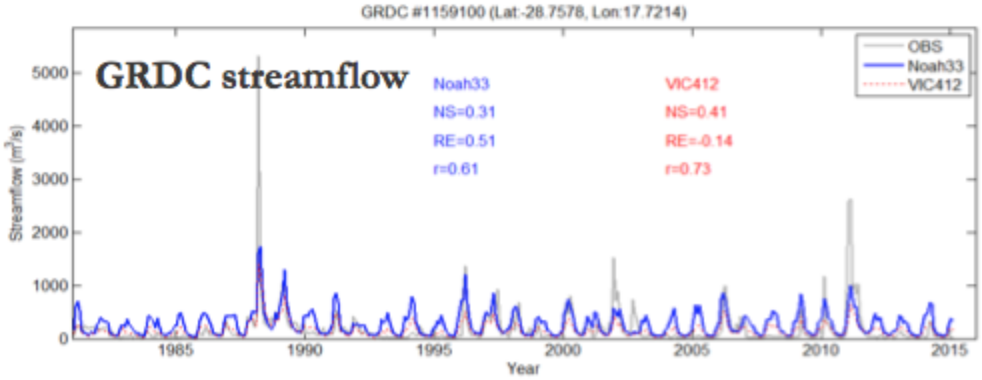
FLDAS Model Evaluation

Southern Africa - Orange Basin



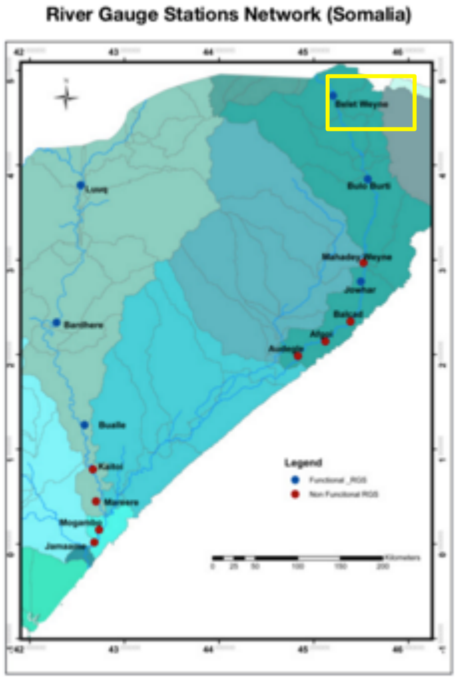
FLDAS Noah33 & VIC412 estimates are well correlated with GRACE terrestrial water storage (TWS), SSEBop evapotranspiration (ET) and in situ streamflow in the Orange Basin, Southern Africa



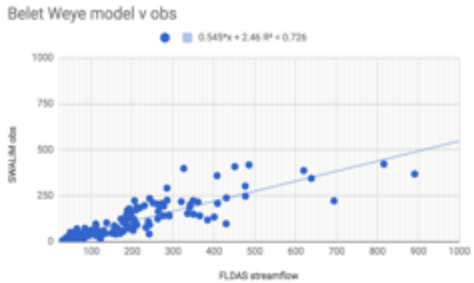


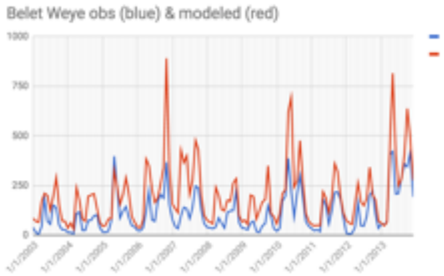
FLDAS Model Evaluation

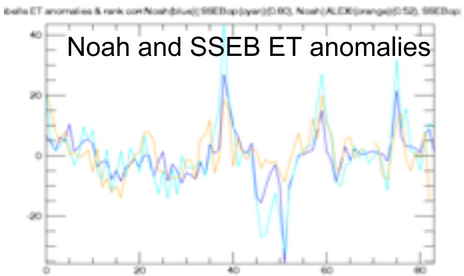
Eastern Africa - Shabelle Basin



Gauges from *FAO's Somalia Water and Land Information Management (SWALIM) http://sddr.faoswalim.org/*







FLDAS Noah33 streamflow estimates are well correlated (R=0.73) with in situ streamflow from SWALIM. Correlations decline downstream, likely due to human abstractions.

Central Asia Evaluation

Mean snow cover fraction corresponds well at the basin level during different water years.

When considering a full water year, probability of Detection (POD) metrics are moderate and False Alarm Rate (FAR) is relatively low. Cloud contamination likely contributes to poor statistics.