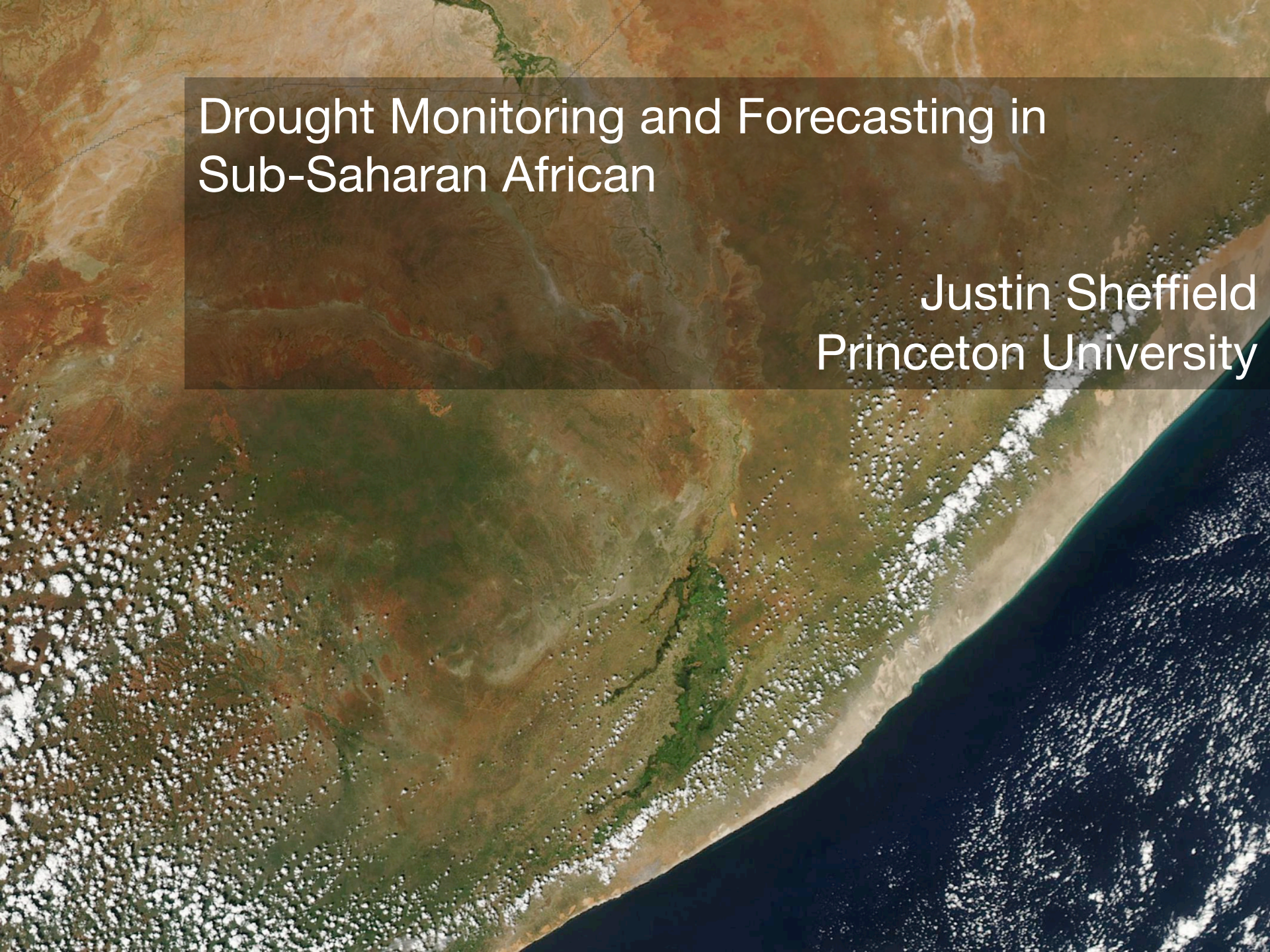


Drought Monitoring and Forecasting in Sub-Saharan African

Justin Sheffield
Princeton University

Outline

- Challenges for sub-Saharan Africa (SSA)
- Current capabilities (national, regional, international)
- Princeton African (Flood and) Drought Monitor
- Approach and Implementation
- Validation (large-scale and local scale)
- Seasonal forecasts
- Ongoing issues, challenges, opportunities, …

Other More Detailed GDIS Talks on Thu/Fri

Thursday

11:20 Brad Lyon: Drought in East Africa

14:00 Roberto Mechoso/Belen Rodriguez: West African Droughts

Friday

10:30 Chris Funk/Gideon Galu: An integrated drought prediction system for Eastern Africa to support food security

11:10 Micha Werner/Gilbert Ouma (UNESCO-IHE, ICPAC): DEWFORA - Drought Early Warning and Forecasting in Africa

National/Regional Capability for Drought Monitoring

One Conceptual Framework	Level 1 (NADM Model)	Level 2	Level 3
Drought Experts	In-house expertise for monitoring, forecasting, impacts, research, planning, education	Limited in-house expertise	Rely on external expertise
National Climate Observing Network	Extensive data networks, near-real time daily observations	Limited networks (spatial density and/or timeliness)	Rely on national CLIMAT/ WWW reports and external observations (e.g., satellite obs & global models)
National Drought Assessments	National Drought Monitor already routinely produced timely (monthly or more frequently)	National assessments produced to support regional/continental monitoring	Rely on external expertise to produce national assessments
International Data Exchange	Station data exchanged for creation of regional or continental standardized indicators	Limited data exchanged internationally	Only CLIMAT or WWW data exchanged internationally
International Collaboration	National experts collaborate to create regional or continental Drought Monitor	Some national input to regional or continental Drought Monitor	Rely on external experts to produce national assessment for regional/ continental Monitor
IT Infrastructure	GIS, web, email	Limited GIS, web, and/or email access	No IT infrastructure, rely on alternatives

Decreasing capability

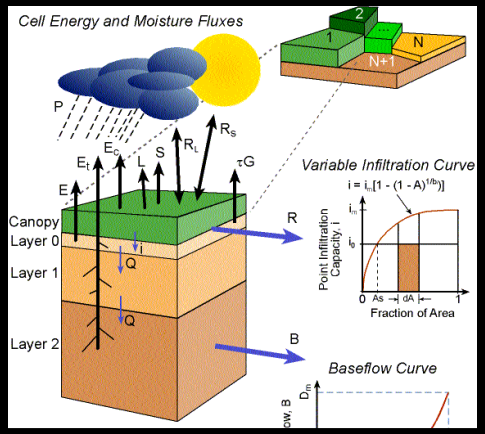
Slide from Richard Heim, NCDC, US

Real-time hydrological monitoring is sparse in Africa

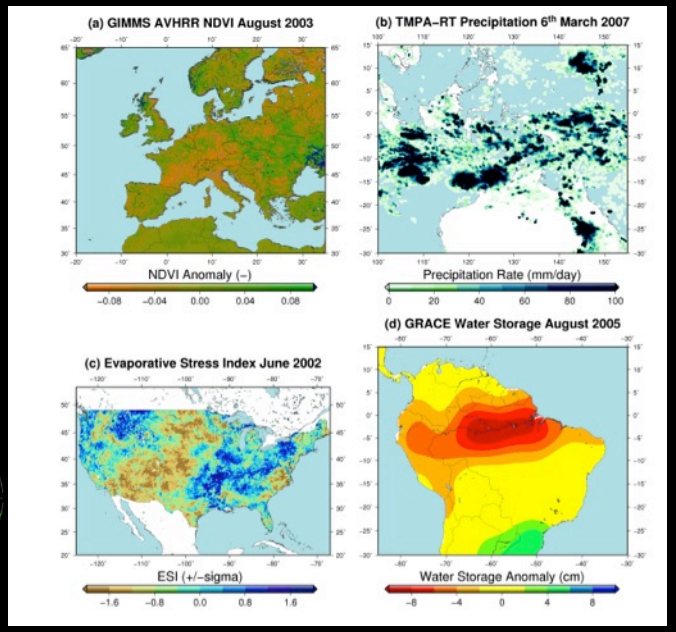
- Lack of national capacity in many places hinders development and use of monitoring and prediction systems.
- Observations are limited in many places. Where station data are available there may be months to years delay in data availability. For streamflow, available records are often years to decades out of date.
- Water resources and hydrometeorological hazards are transboundary, but data (if they exist) are often national interests.

Data and Tools for Drought Monitoring and Prediction

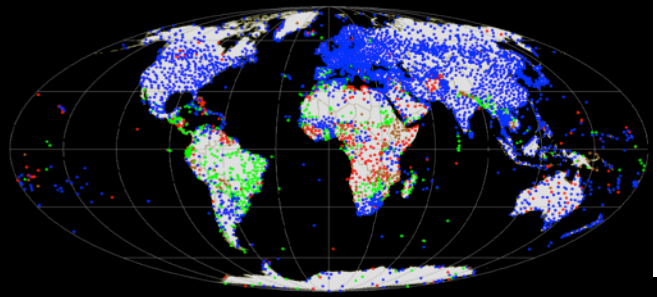
Hydrological Modeling



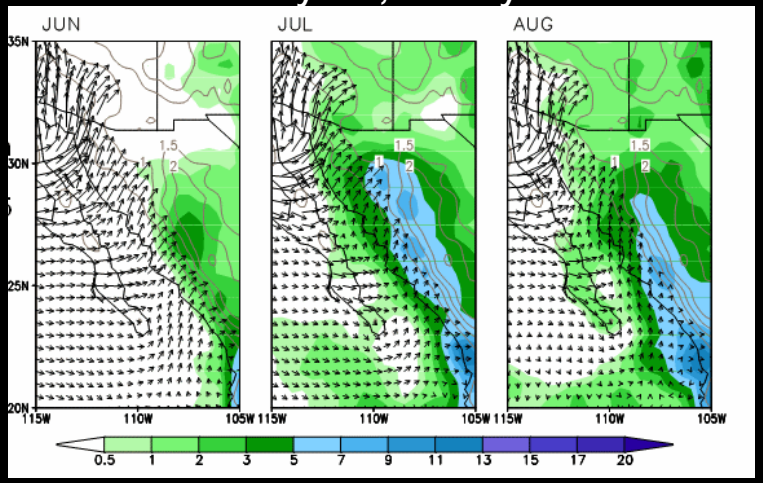
Satellite Remote Sensing



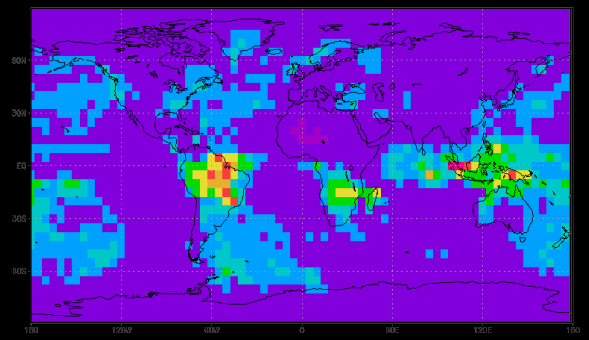
Ground Observations



Reanalysis, Analysis



Regional/Global Climate Models, Statistical Prediction



Current Capabilities in Drought Monitoring and Early Warning in sub-Saharan Africa

- National capabilities
  - Operational / experimental drought early warning systems (e.g. South Africa)
  - National meteorological/hydrological departments (collect and provide data, perhaps with drought monitoring/outlooks)
  - Reliance on regional centers + plus national interpretation/adjustment

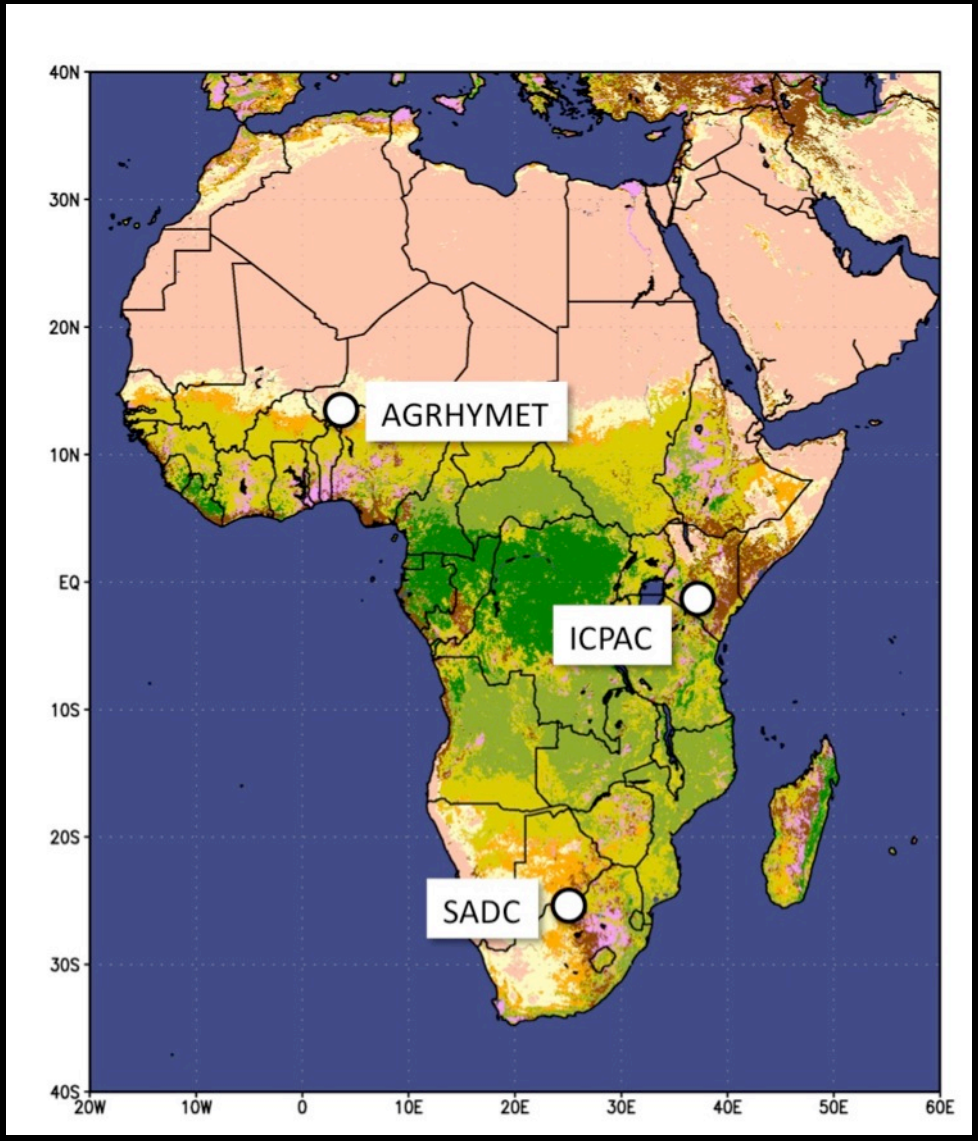
- Regional capabilities
  - Several regional centers provide monitoring and outlooks
  - Climate Outlook Forums (COFs) are main sources of forecasts

- International capabilities
  - Remote monitoring
  - Collaboration with regional centers
  - Embedded with national agencies and NGOs
  - Targeted applications/projects

Current Regional Capabilities

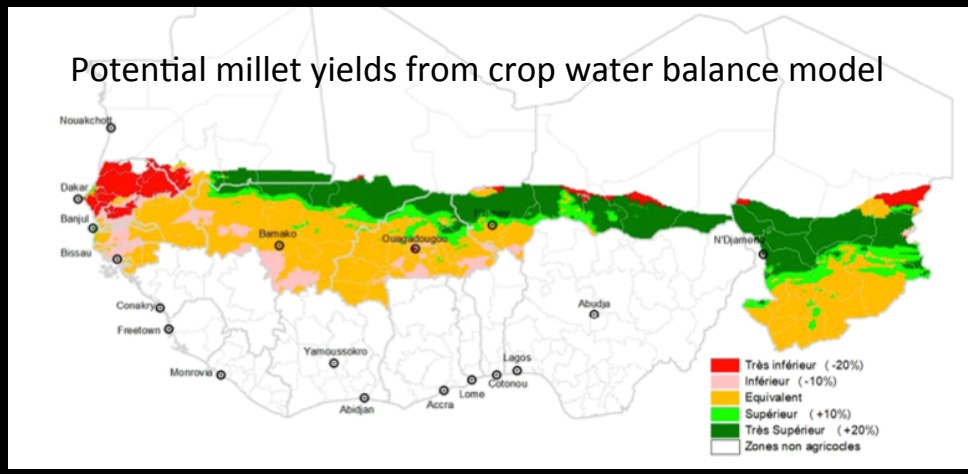
Several regional centers that provide climate-hydro-agricultural monitoring and outlooks

- AGRHYMET – West Africa
- ICPAC – Greater Horn of Africa
- SADC Drought Monitoring Center – southern Africa
- Other climate/water orientated centers and programs

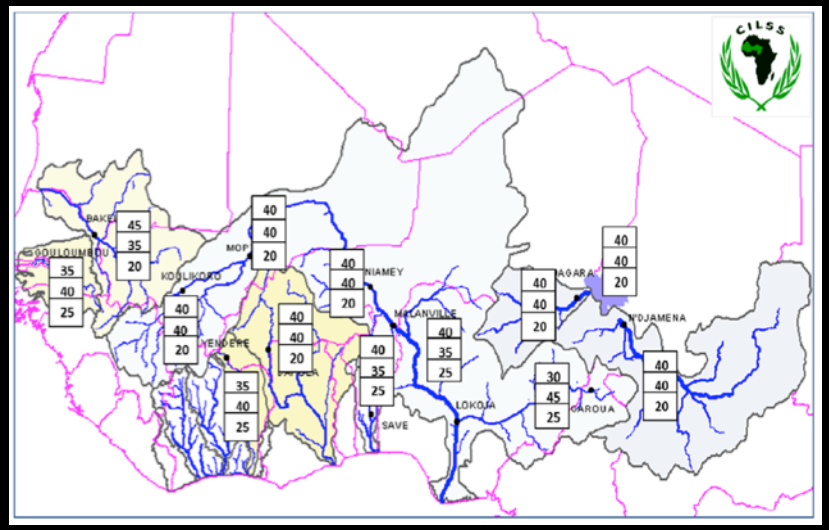


Current Regional Capabilities – AGRHYMET

- *The* West African drought monitoring center (legacy of 1970s drought)
- 13 member CILSS countries and since 2009 the Economic Commission of West African States (ECOWAS)
- Undertakes actions towards food security and to combat the effects of drought and desertification
- Main activities include co-producing west African Climate Outlook Forums (COF) seasonal rainfall and agro-hydrological outlooks



- Rainfall monitoring draws from national met service networks plus Meteosat estimates
- Forecasts from coupled models plus national statistical models
- Surface water monitoring from national hydrological agencies
- NDVI for pastoral conditions
- Crop model for yield outlooks
- Recently moving towards more targeted forecasts (within-season, sub-national)

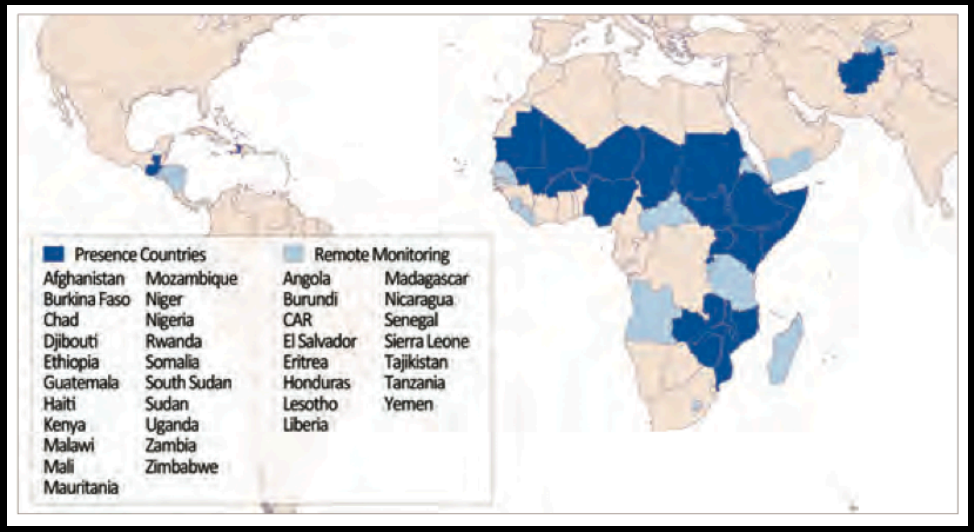


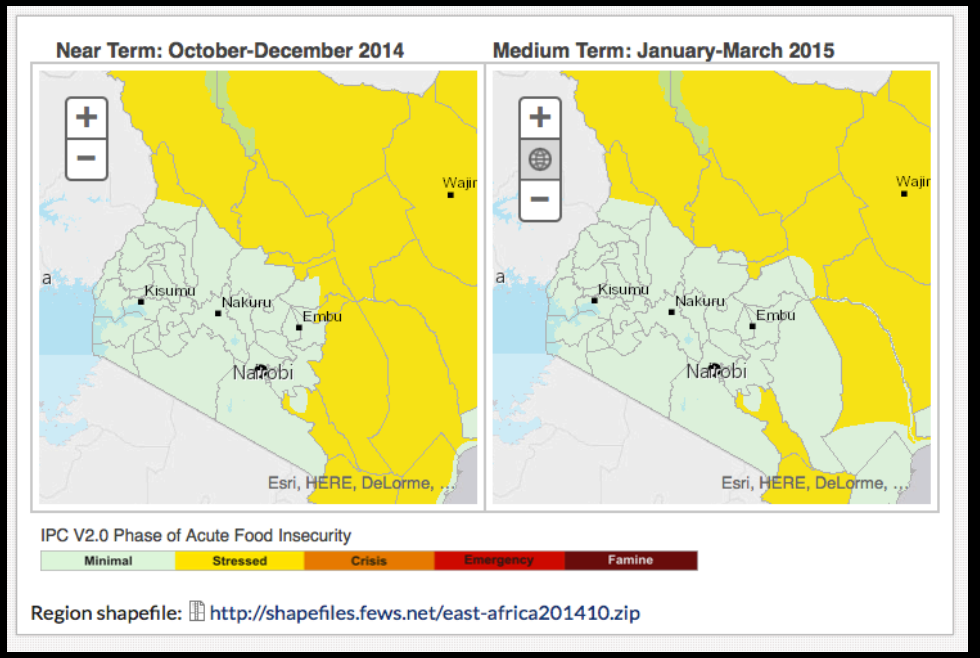
Tercile probabilities for seasonal maximum stream discharge

Traore et al. 2014, Weather Climate Extremes

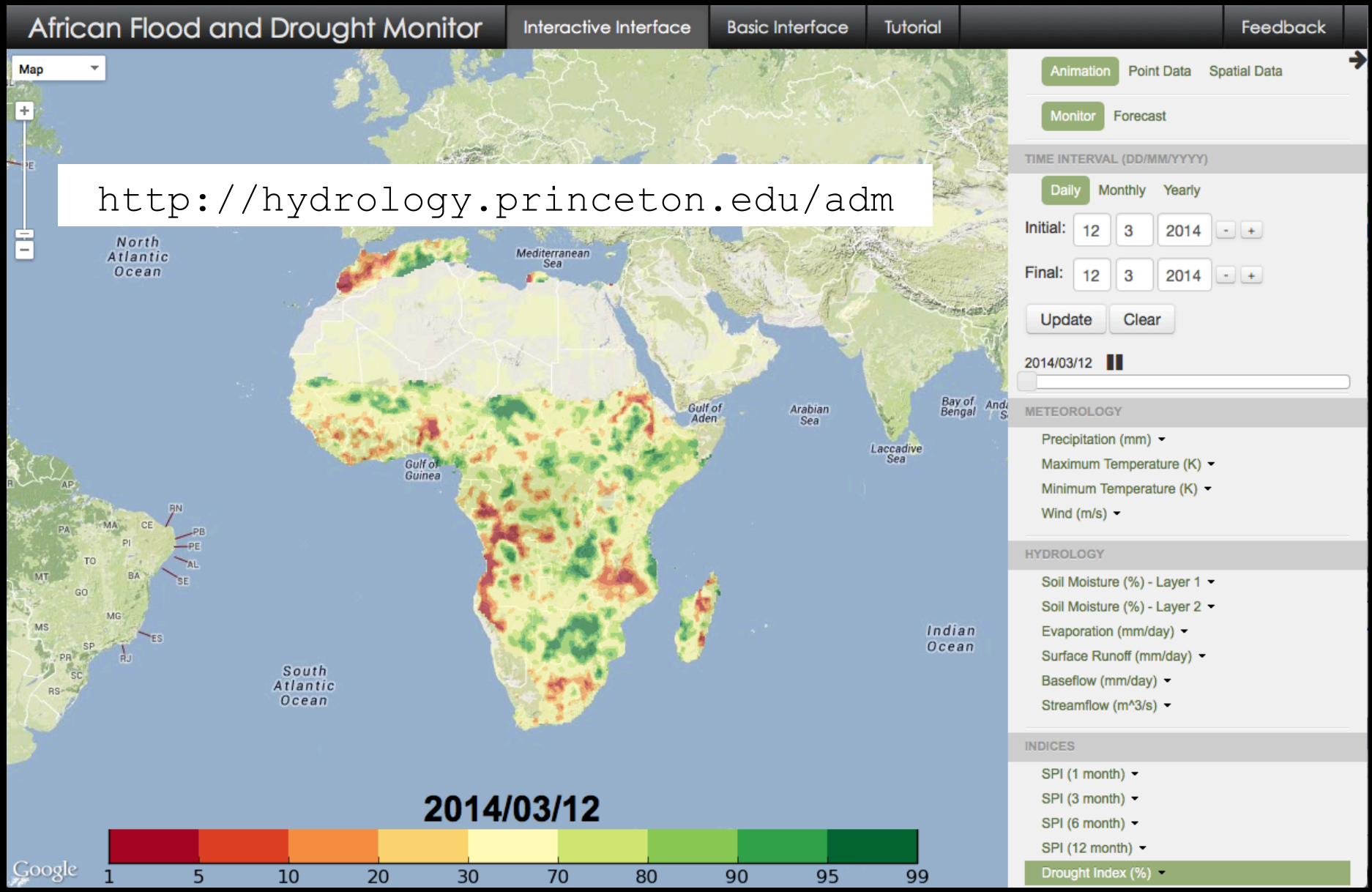
Current International Capabilities - FEWSNET

- Early warning and vulnerability information on emerging and evolving food security issues
- Active in 30+ food-insecure countries including Ethiopia, Kenya, and Somalia
- Compilation of outlooks by food analysts based on available agro-hydro-climatic and market/livelihood data
- Mostly focused on rainfall evaluations and outlooks, with agricultural impact assessments based on crop water requirements
- New directions include incorporating soil moisture drought and more sophisticated forecasting based on downscaled climate model output (e.g. Shukla et al., 2014, HESSD).





Current International Capabilities – Princeton African (Flood and) Drought Monitor

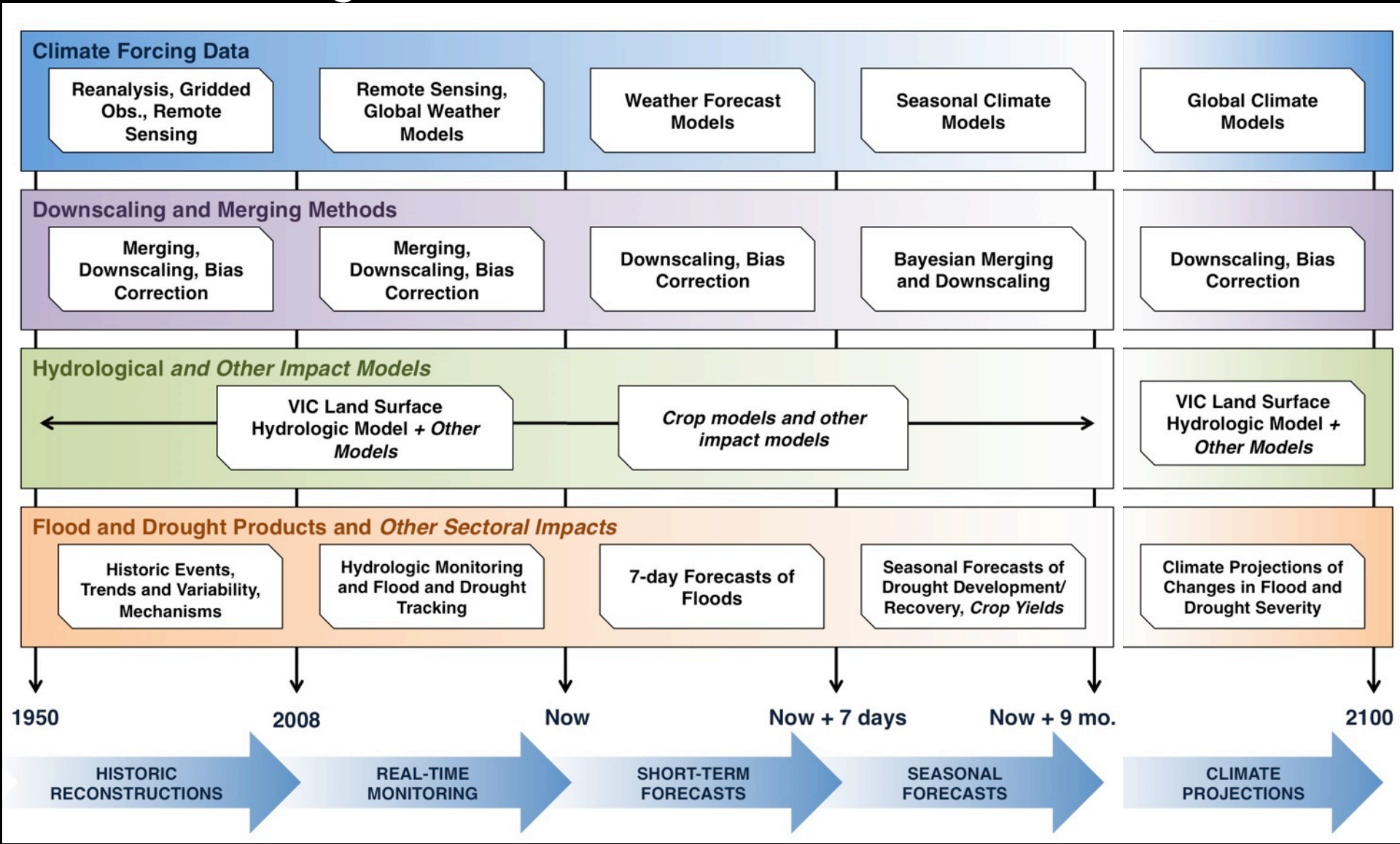


Princeton African (Flood and) Drought Monitor - Installed at regional centers

Goals:

- Adapt the monitoring system to the region.
- Improve data dissemination, knowledge exchange
- Provide training and allow for feedback (participatory exercises)
- Followed by validation plans, operational evaluations, exchange visits, …

Technical Background of the Princeton AFDM Monitoring and Prediction Framework Across Time Scales



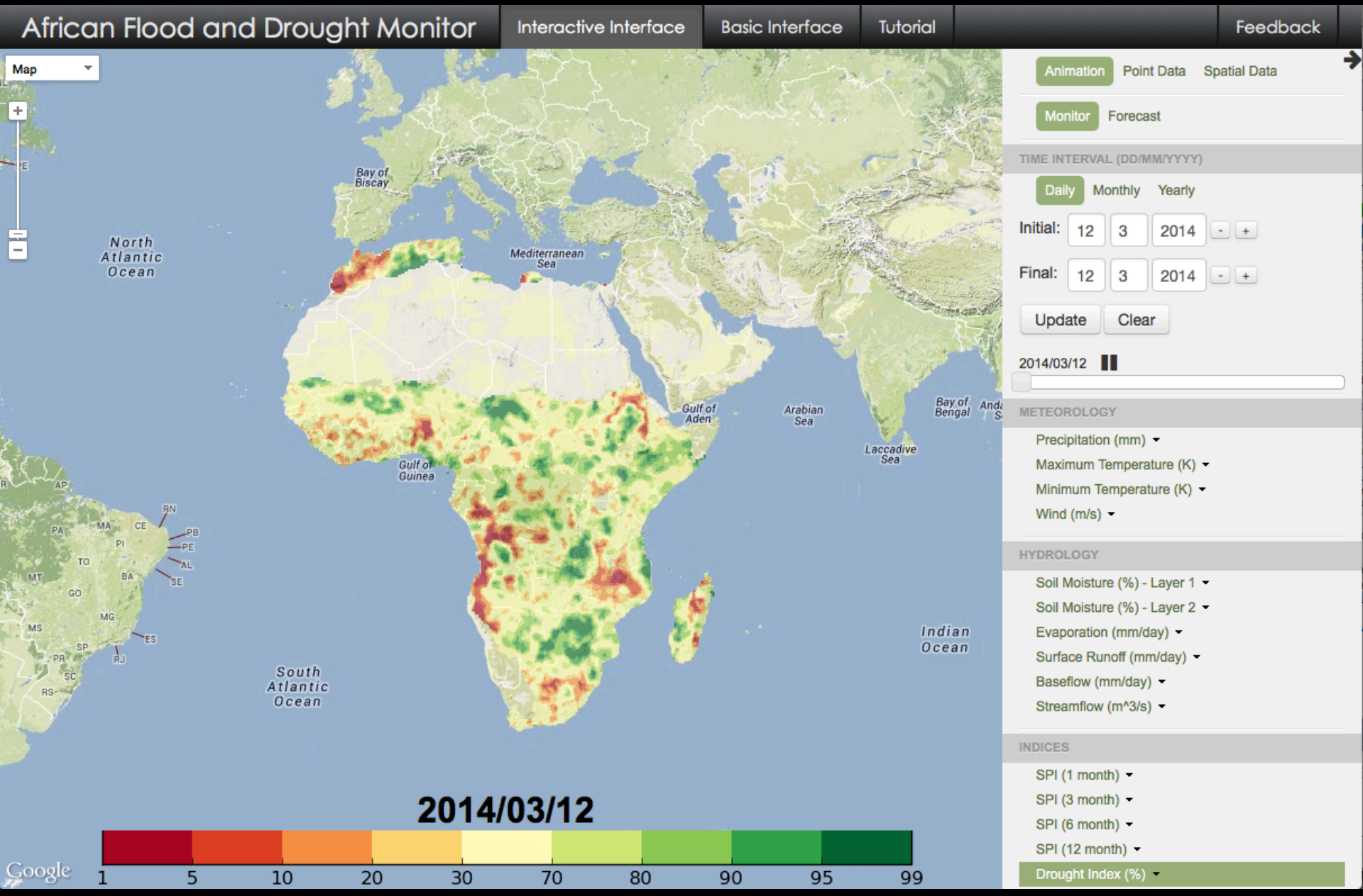
Sheffield, J., et al., 2014; A drought monitoring and forecasting system for sub-Sahara African water resources and food security. *Bull. Am. Met. Soc.*

Drought Indices in the African Flood and Drought Monitor

Index	Data Source	Drought Type	Attributes
Standardized Precipitation Index (SPI)	Bias corrected TMPA (2009-present), hybrid observational/reanalysis (1950-2008)	Meteorological drought	0.25-degree, SPI-1,3,6,12
VIC Soil Moisture Index	VIC land surface model (1950-present);	Agricultural drought	0.25-degree, daily
SMOS Soil Moisture Index	SMOS retrievals (2010-present)	Agricultural drought (top 5cm of soil)	0.25-degree, daily
NDVI/EVI	GIMMS NDVI (1982-2008); MODIS EVI (2000-present);	Ecological drought (optical-based)	8km/0.5-degree, bi-monthly/daily
VOD Index	SSM/I,TRMM,AMSR-E VOD (1987-2008); AMSR-E VOD (2000-present)	Ecological drought (passive microwave)	0.25-degree, daily
dB Index	QuickSCAT (1999-2009), ASCAT (2009-present)	Ecological-hydrological drought (active microwave)	0.25-degree, 2/4 days
Streamflow percentiles	VIC land surface model (1950-present)	Hydrological drought	822 streamflow gauges, daily/monthly
Cumulative streamflow deficit	VIC land surface model (1950-present)	Hydrological drought	822 streamflow gauges, daily/monthly

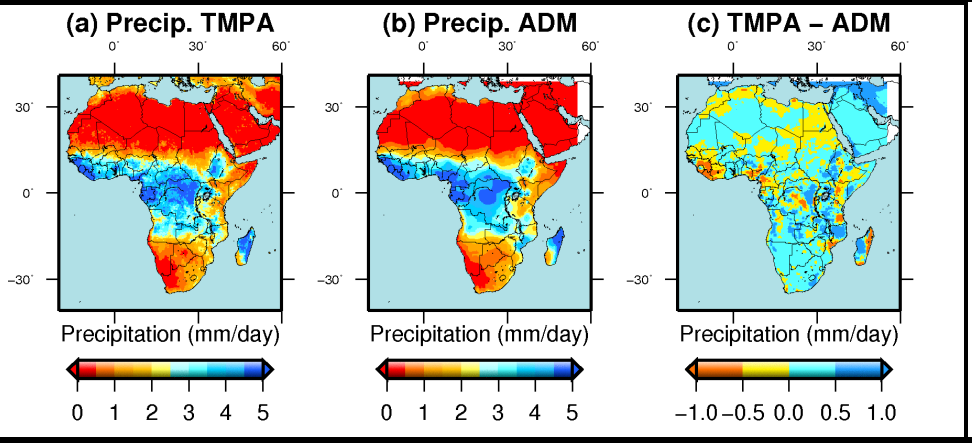
AFDM User Interface

http://hydrology.princeton.edu/adm

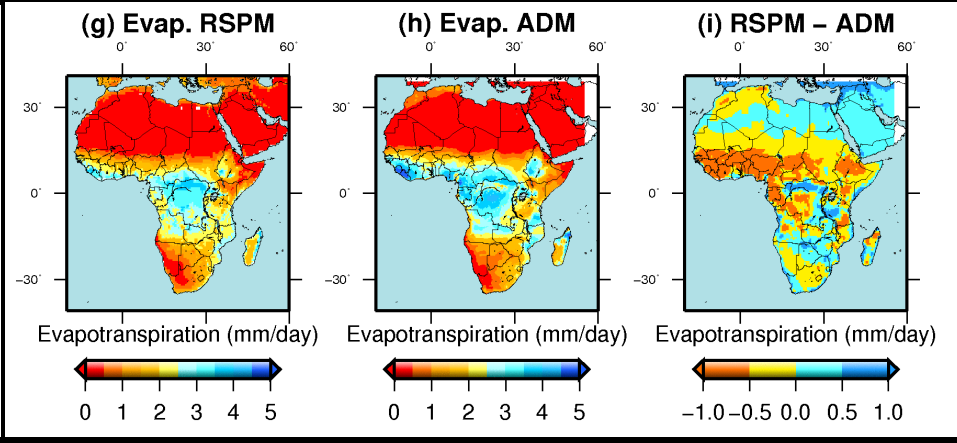


Validation – Continental Scale

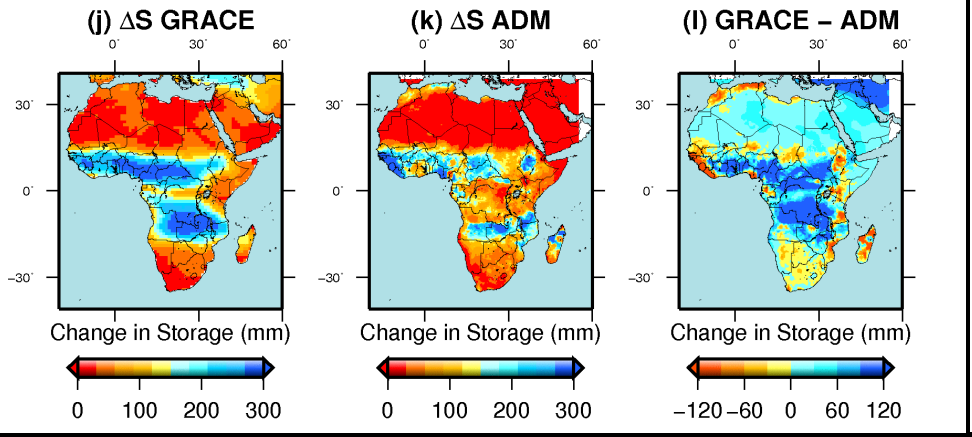
Precipitation



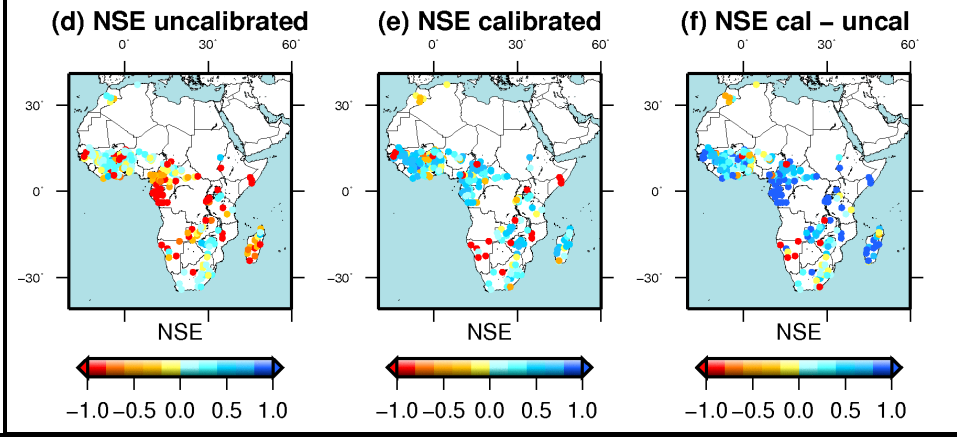
Evapotranspiration



Change in Seasonal Water Storage

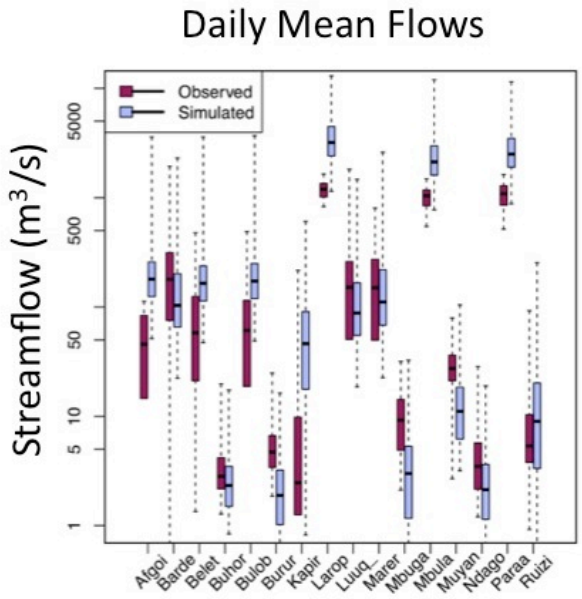


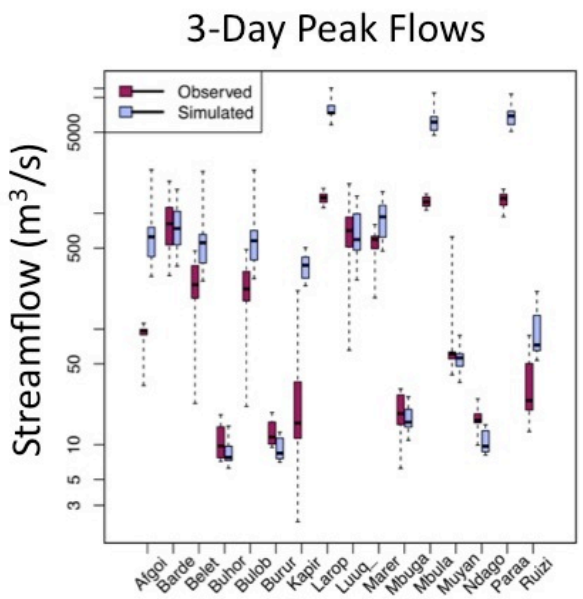
Streamflow

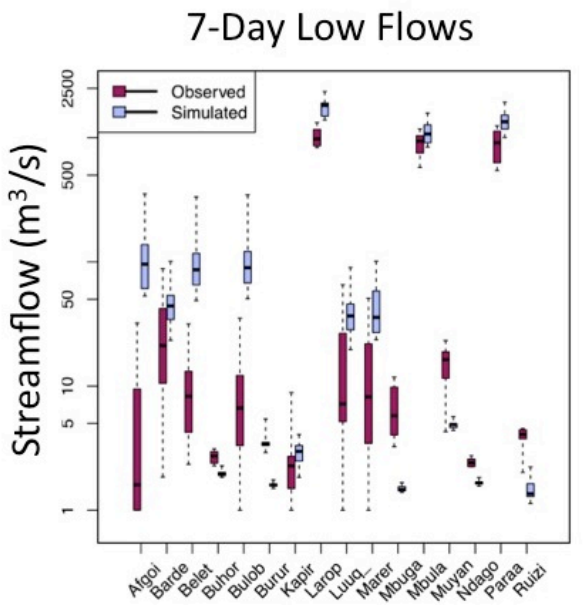


Validation – Local Scale and User Driven

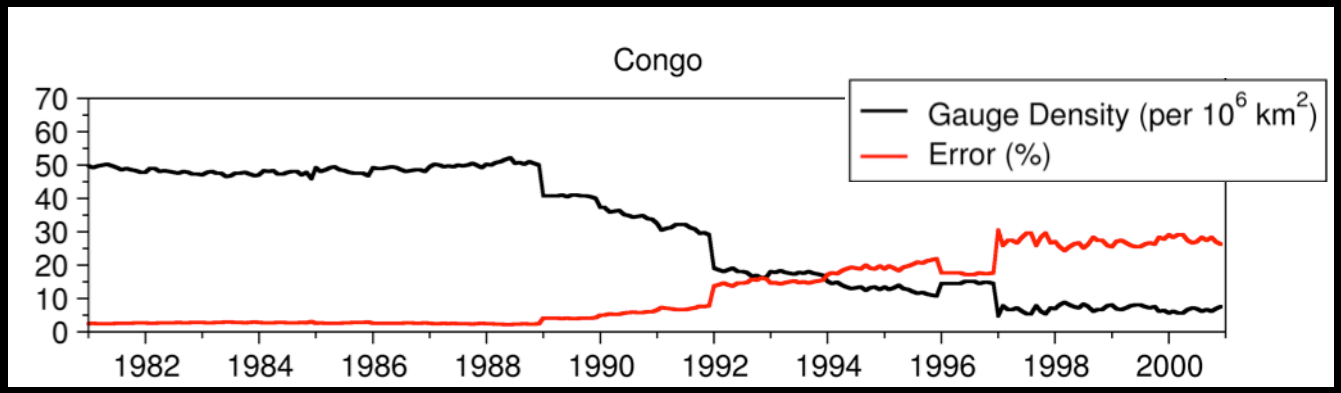
- ~40 sites across Greater Horn of Africa
- 100 to 150,000 km^2







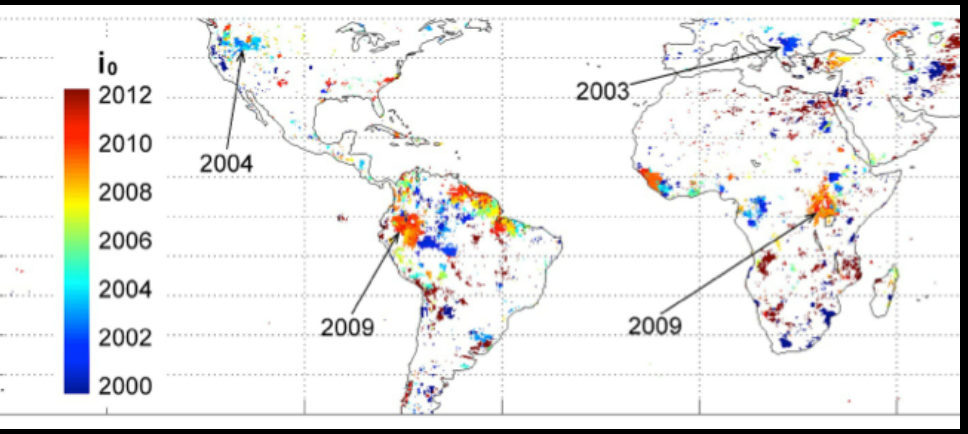
Gridded gauge rainfall products have problems; Satellite precipitation has systematic and random errors



Sheffield et al., 2014

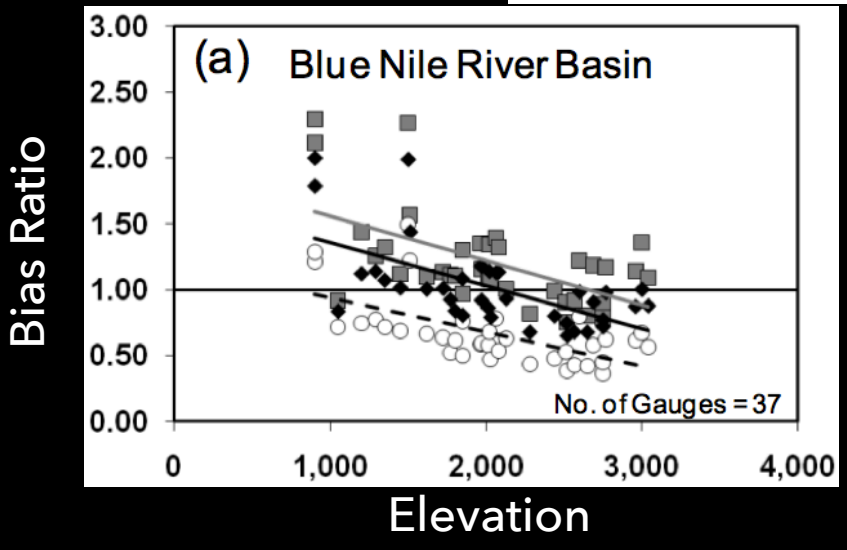
e.g. uncertainties in basin average precipitation can be large and vary over time

Time at which there is a detectable shift between the TMPA satellite research (gauge-corrected) product and the real-time product.



Lettenmaier et al., 2013

Dependency of errors on elevation

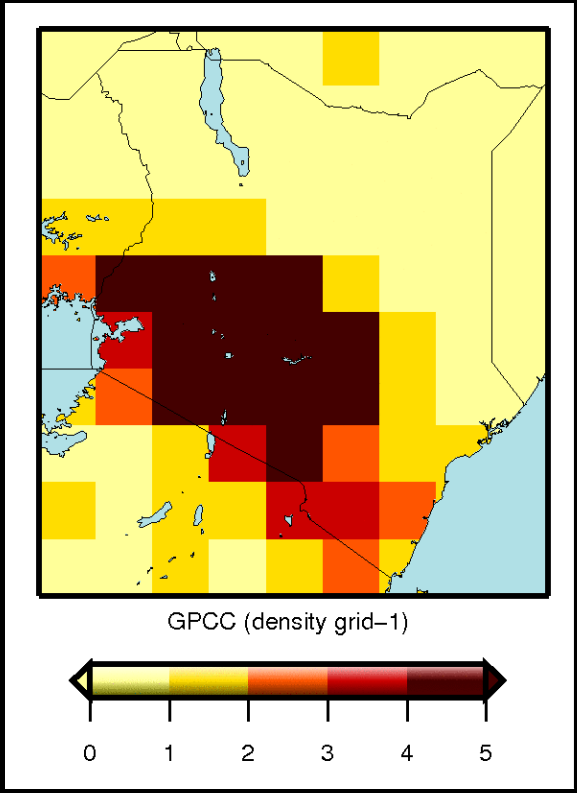


Romilly and Gebremichael, 2011

Validation at Local Scales

Global precipitation datasets rely on a handful of gauges but many more are potentially available

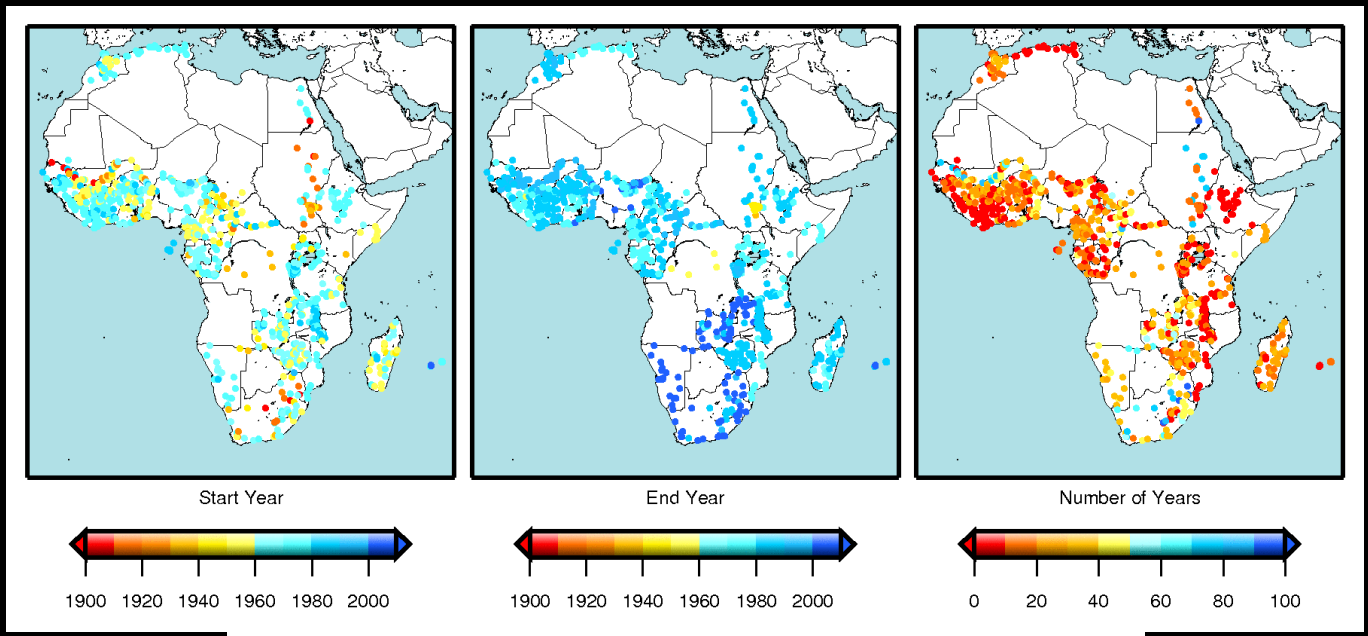
GPCC Global Gridded Product



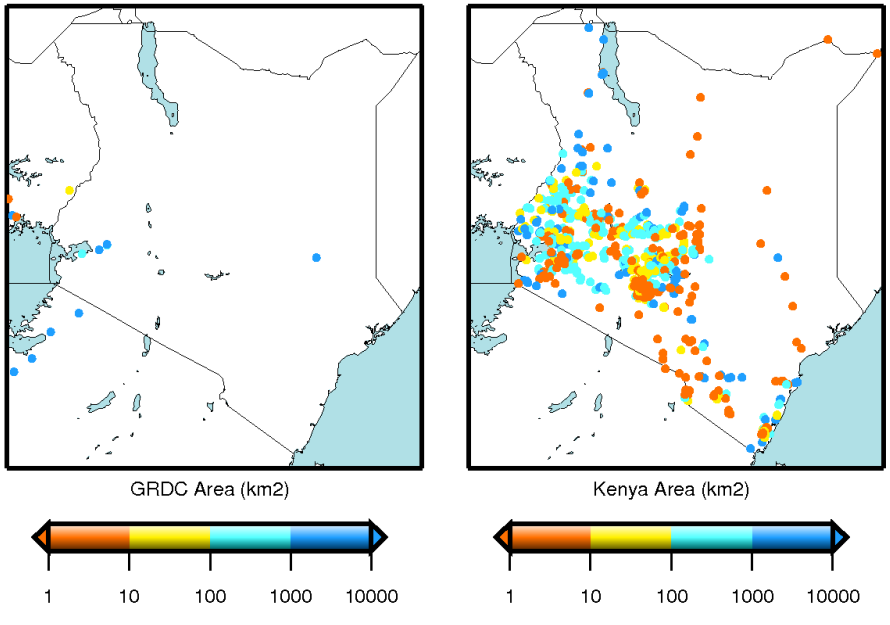
Estimated errors in P due to sampling
5 gauges per 1-degree box → ~5%
2 gauges per 1-degree box → ~20%

Publicly available streamflow data is minimal in some countries, but data do exist

GRDC open database



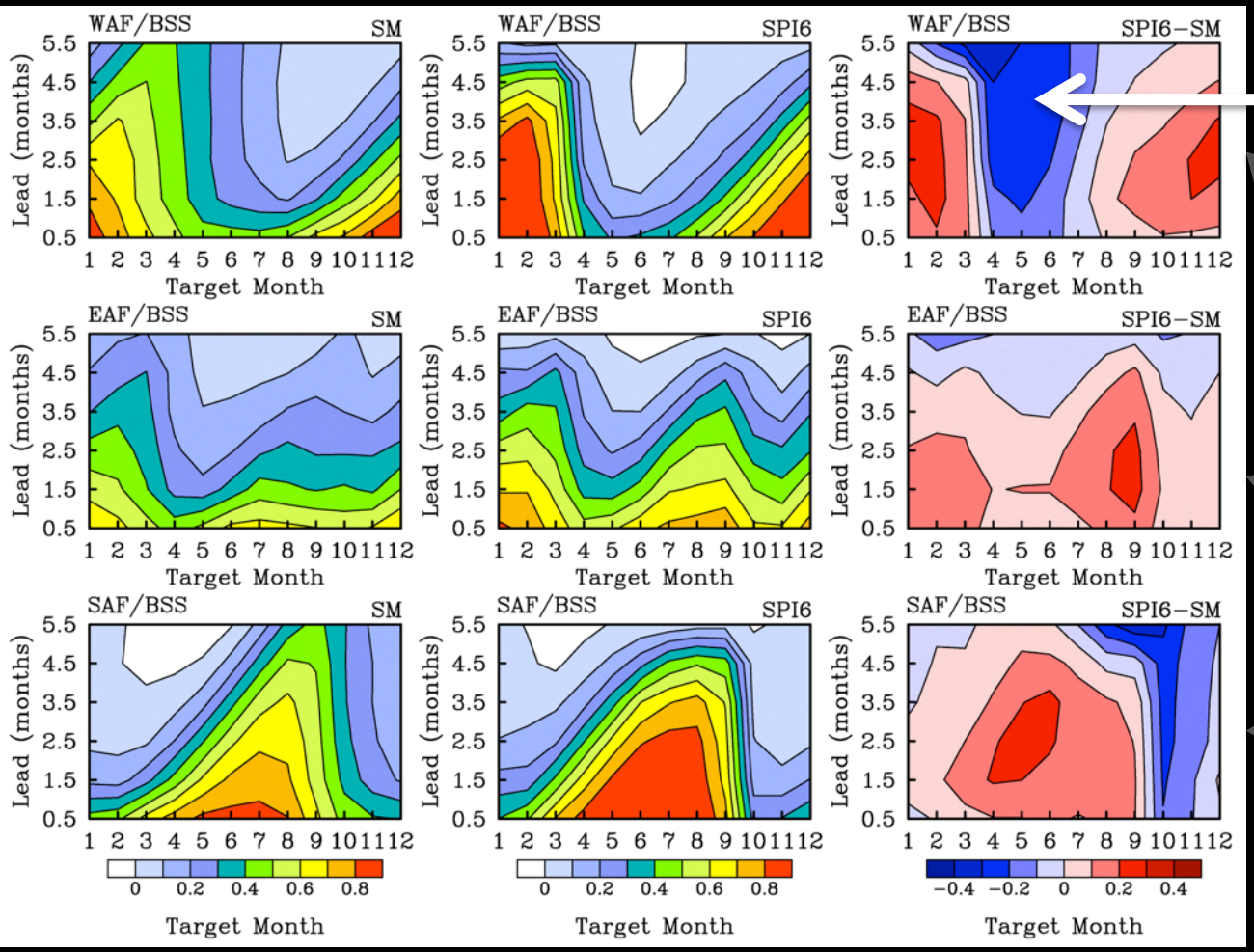
GRDC open database: 4 gauges in Kenya



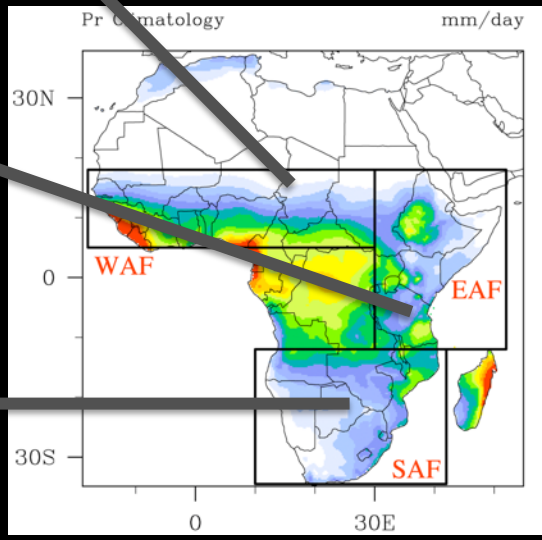
Kenyan Ministry of Water
~ 850 gauges

Seasonal Forecast Skill from Climate Models over African Regions is modest, but …

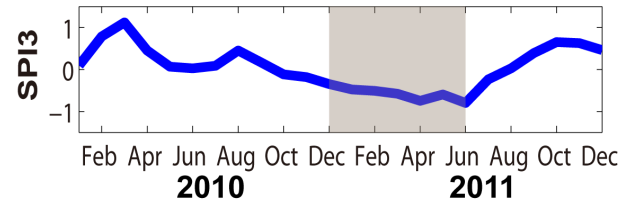
Soil moisture SPI6 SPI6 – Soil Moisture

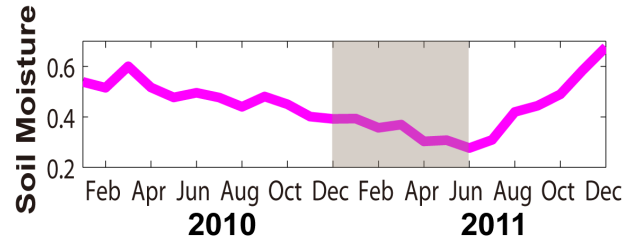


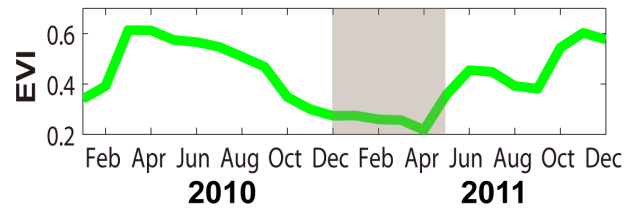
Soil moisture edges out SPI at start to mid growing season

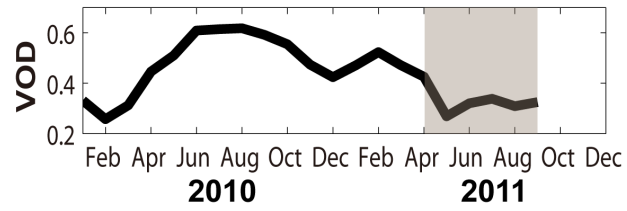


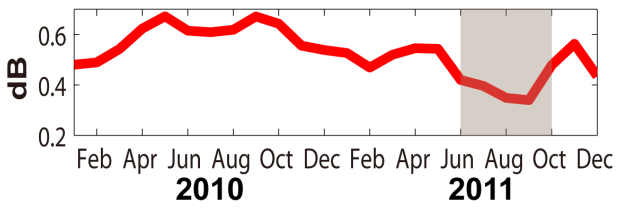
Yuan, Y., E. F. Wood, N. W. Chaney, J. Sheffield, J. Kam, M. Liang, and K. Guan, 2013: Probabilistic Seasonal Forecasting of African Drought by Dynamical Models. *J. Hydrometeor., 14 (6), 1706-1720.*

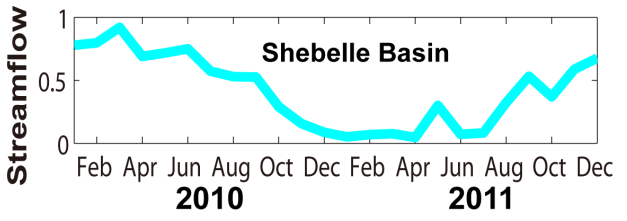


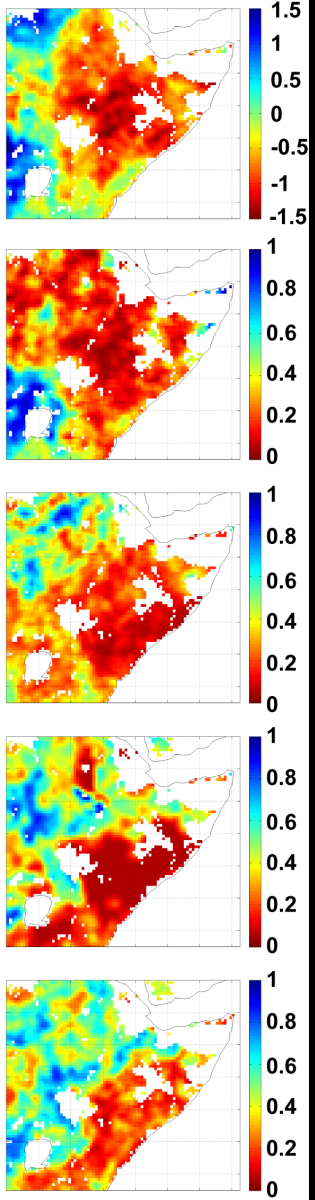








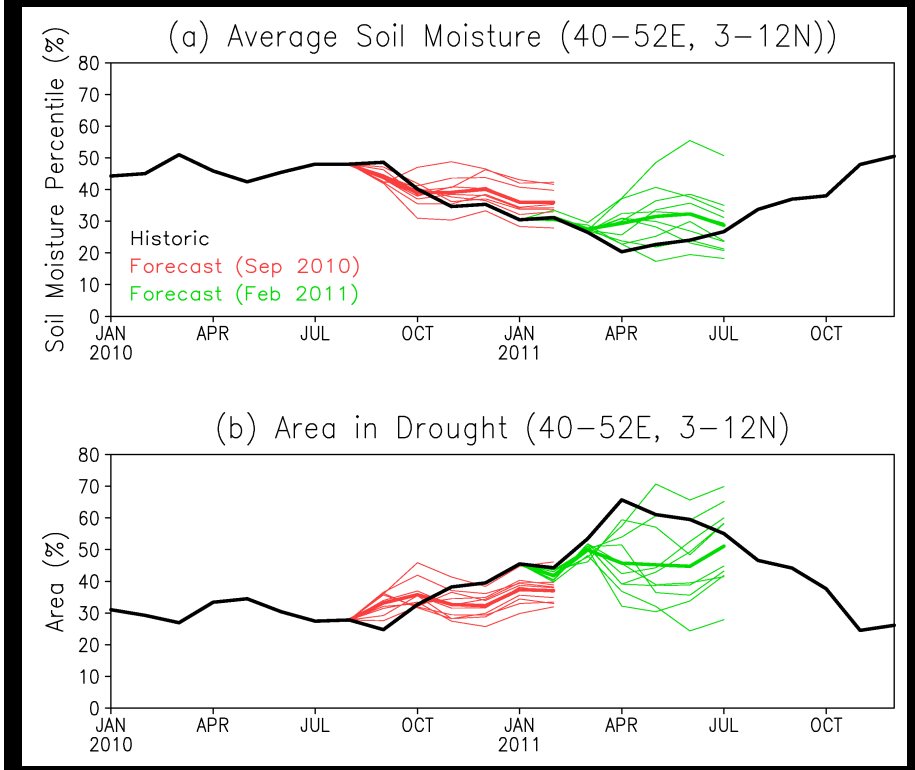




Regional Example: Horn of Africa Drought 2010-2011

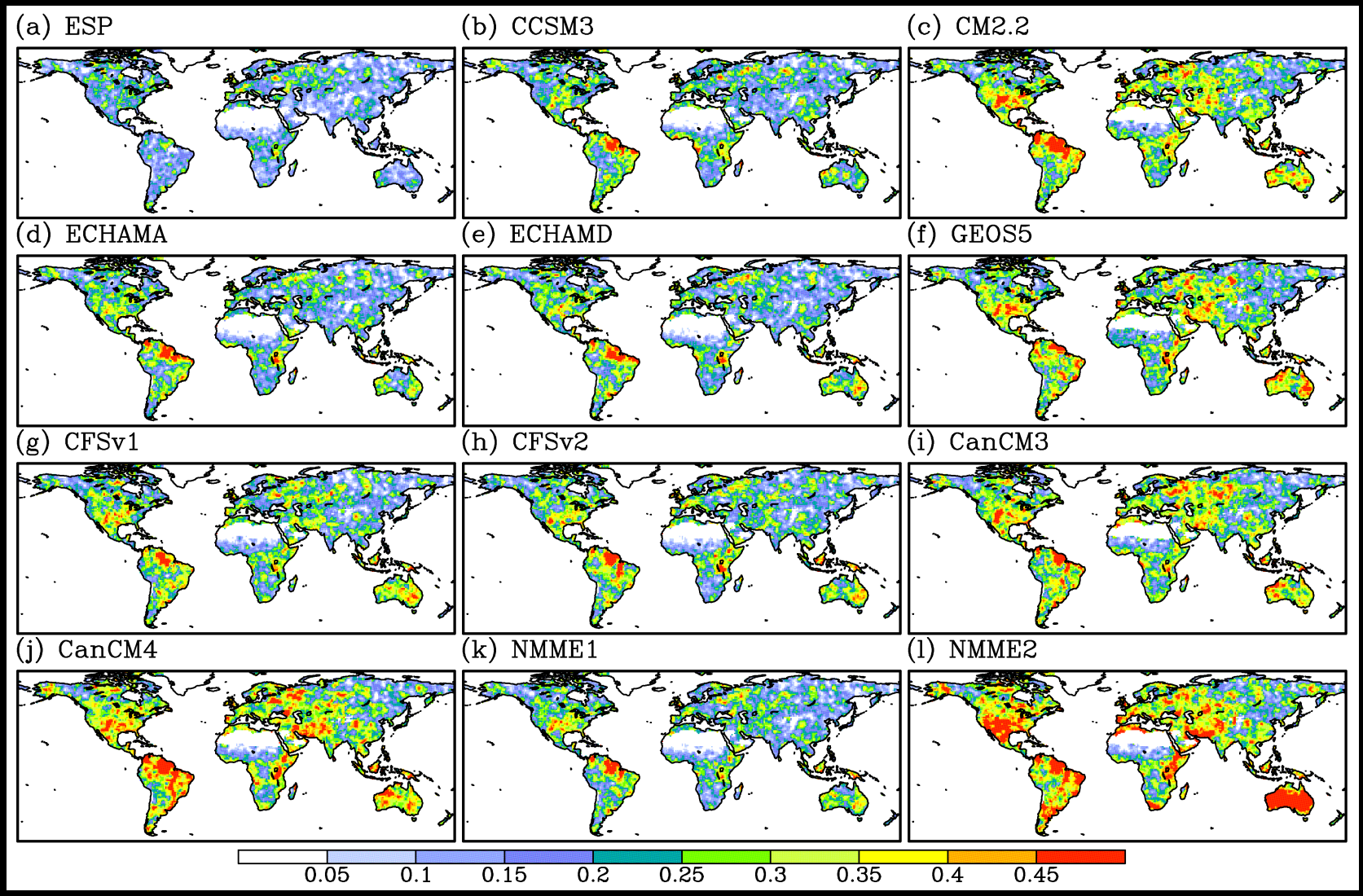
Monitoring the propagation of the drought

Seasonal forecasts (based on CFS model only)



Comparison of skill versus ESP and other regions

Probability of detection $p(y_1|o_1)$ for meteorological drought (SPI6) onset



- Climate models add value over ENSO affected regions.
- Multi-model ensemble improves the forecast where individual models have high skill

Some Big Challenges

1. Identifying and developing new sources of observational data

2. Carrying out local scale evaluations

3. Improving modeled processes (e.g. lakes/wetlands) to enhance real-time monitoring and forecast initialization

4. *Improving forecast skill at time and space scales relevant for decision making*

5. *Understanding the utility of climate/drought information to*
   (i) inform policy making/decision-making at national scales and
   (ii) improve rural agricultural decision making

6. *Transferring knowledge/technology to universities and practitioners for sustainable solutions to achieving water and food security, and improve livelihoods for mitigation and improved resilience*