Introduction to the NASA-GHA project:

Seasonal Prediction of Hydro-Climatic Extremes in the Greater Horn of Africa under Evolving Climate Conditions to Support Adaptation Strategies

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University of Nebraska-Lincoln (UNL), USA

Investigators

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S. Habib (NASA Goddard Space Flight Center)
C. Funk (Climate Hazard Group, UCSB)
G. Senay (USGS Earth Resources and Observation Science Center)
T. Dinku (IRI, Columbia University)
F. Policelli (NASA Goddard Space Flight Center)
P. Block (University of Wisconsin-Madison)
G. Baigorria (SNR/Agronomy & Horticulture, UNL)
S. Beyene (Institute for Ethnic Studies, UNL)
B. Wardlow (UNL)
M. Hayes (National Drought Mitigation Center, UNL).

Motivation

- Improved performance and application of seasonal forecast is a critical no-regrets climate adaptation strategy

- But in in many parts of the world including GHA:

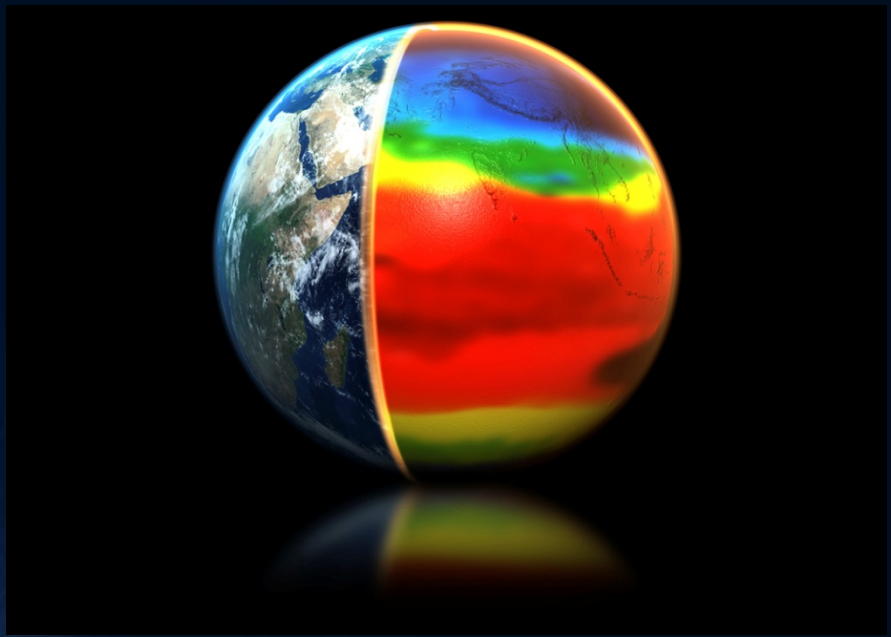
  (1) many forecast systems perform poorly,

  (2) forecasts are not always tied to user needs, and

  (3) there is a lack of systematic forecast evaluation and comparison

- There is also a need to understand how forecasts influence the outcomes they are designed to predict

Impacts of Global Climate Change



Storms

Floods

Droughts

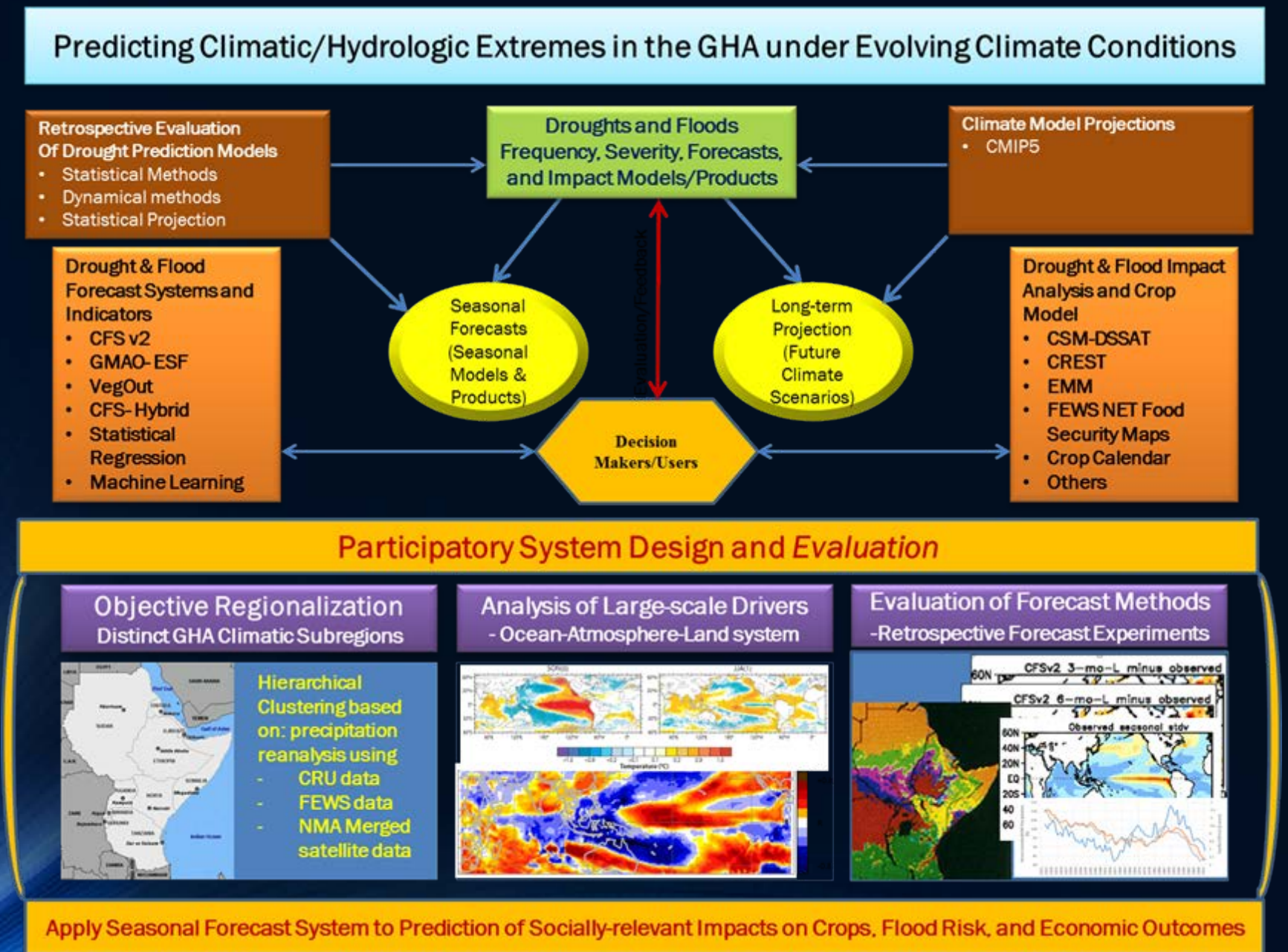
Increased frequency of extreme weather events

Project Goal

To understand and, where possible, extend the predictive time horizons for extreme drought and flood in the GHA given the challenges of an evolving climate baseline and diverse information needs to support adaptation strategies.

NASA Theme: Understanding Earth system Vulnerabilities to Climate Extremes

Schematic diagram of the project



Primary Objectives of the project

NASA_IDS_GHA

Seasonal Prediction of Hydro-Climatic Extremes in the GHA under Evolving Climate Conditions to Support Adaptation Strategies

Lead PI: Tsegaye

Objective 1

Characterize and explain large-scale drivers in the ocean-atmosphere-land system associated with years of extreme flood or drought in the GHA

Lead: Ben

(Chris/Tufa/Tsegaye)

Objective 2

Evaluate the performance of state-of-the-art seasonal forecast methods for prediction of decision-relevant metrics of hydrologic extremes

Lead: Ben/Shim

(Chris/Gabriel/Shahid/Fritz/Tufa/Paul/Brian/Mike/Gui/Tsegaye)

Objective 3

Apply seasonal forecast systems to prediction of socially relevant impacts on crops, flood risk, and economic outcomes, and assess the value of these predictions to decision makers

Lead: Tsegaye/Shim

(Gui/Paul/Fritz/Gabriel)

Objective 4

Evaluate the robustness of seasonal prediction systems to evolving climate conditions

Lead: Ben/Chris

(Tufa/Shim/Tsegaye)

Elements of Objective 1 (Investigators)

NASA_IDS_GHA

Seasonal Prediction of Hydro-Climatic Extremes in the GHA under Evolving Climate Conditions to Support Adaptation Strategies

Objective 1

Characterize and explain large-scale drivers in the ocean-atmosphere-land system associated with years of extreme flood or drought in the GHA

Lead: Ben

Objective Regionalization

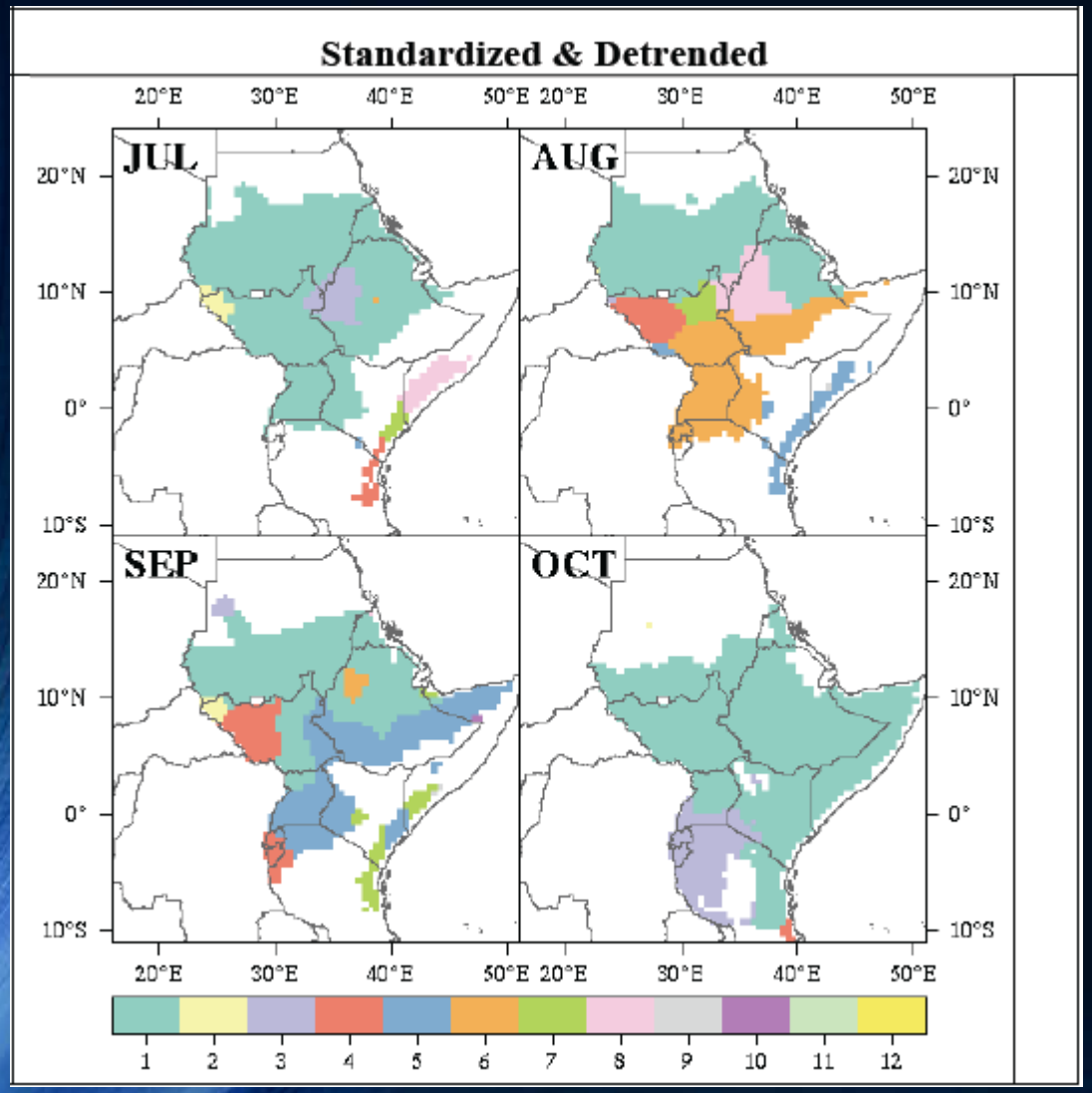
(Paul/Tufa/Tsegaye)

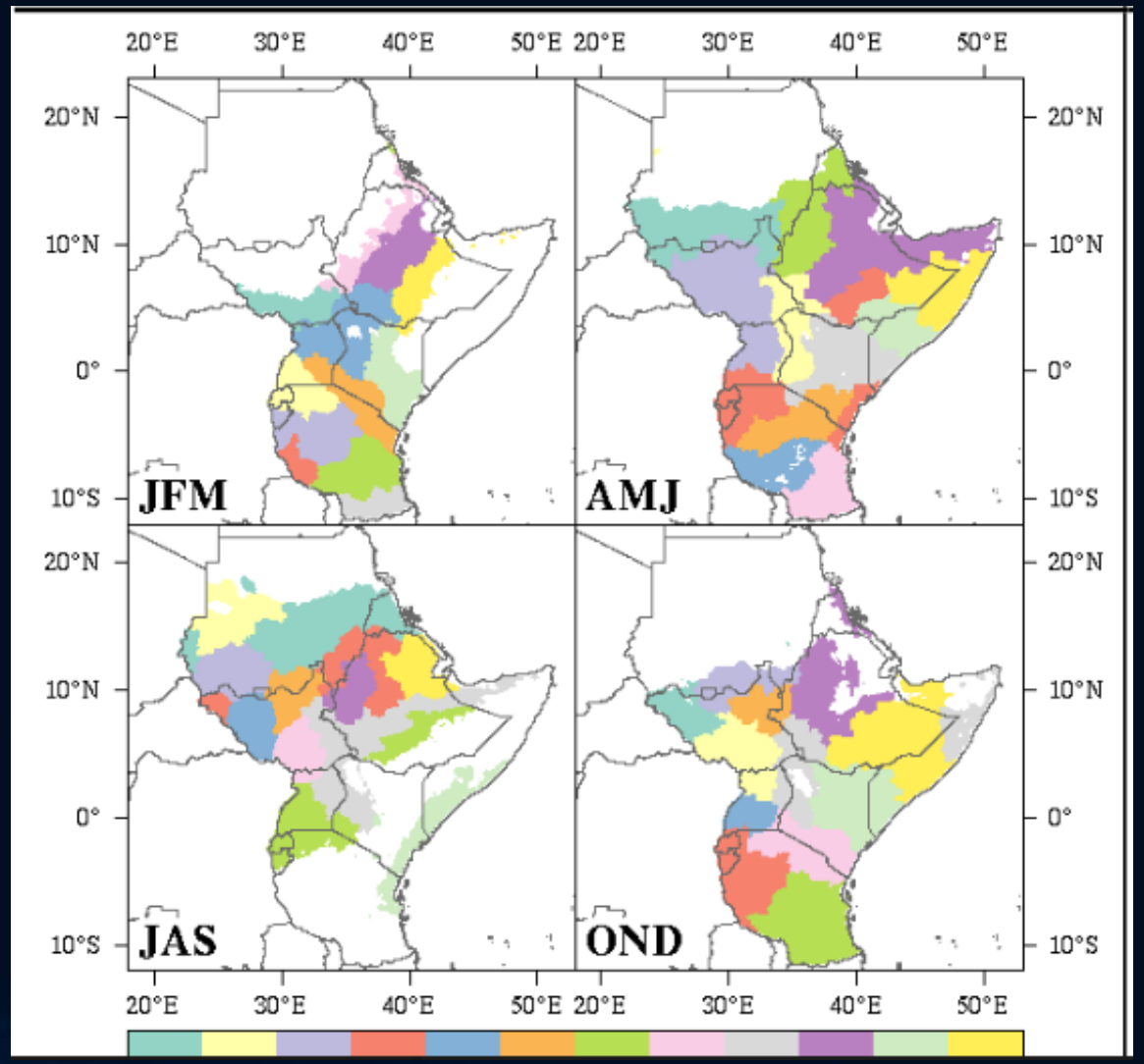
Analysis of Large-scale Drivers

(Chris/Paul/Tufa/Tsegaye)

Objective Regionalization

identifying climatically coherent subregions of the GHA





Badr et al. (2014)

Large-scale Drivers

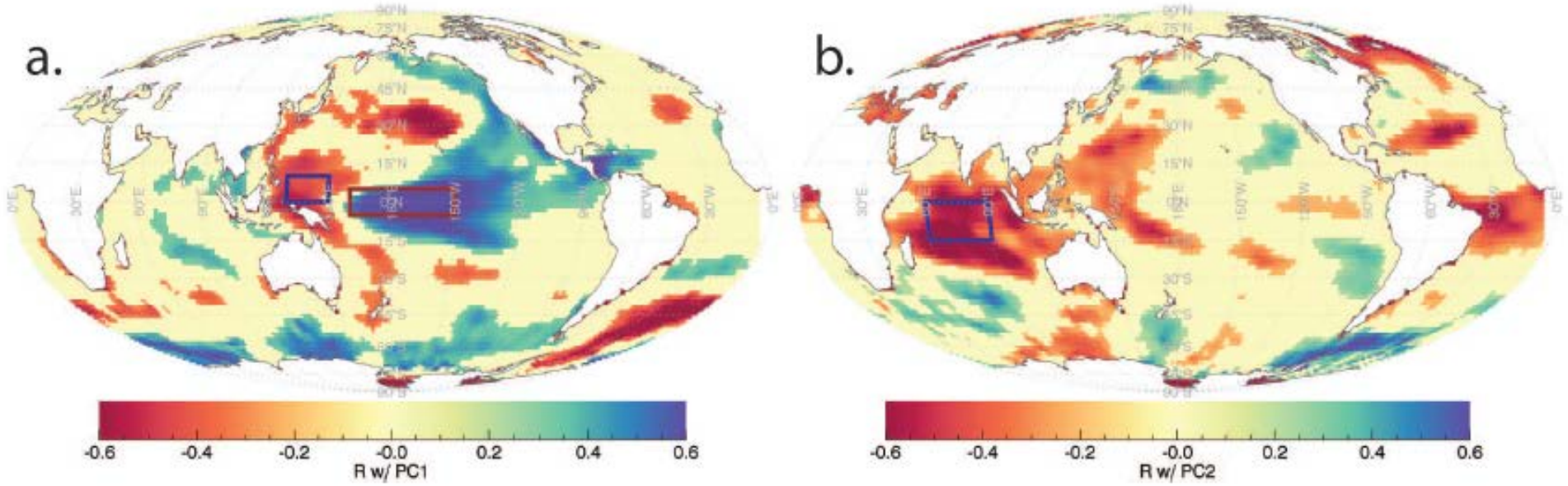


Fig. 2. (a) Correlations between March–May CHIRPS PC1 and January SSTs. **(b)** same for CHIRPS PC2. Values have been screened at a 10 % significance level. Boxes in panel a and b show the regions used to the define the WPG and CIO SST indices.

Funk et al. (2014) HESSD

Elements of Objective 2 (Investigators)

NASA_IDS_GHA

Seasonal Prediction of Hydro-Climatic Extremes in the GHA under Evolving Climate Conditions to Support Adaptation Strategies

Objective 2

Evaluate the performance of state-of-the-art seasonal forecast methods for prediction of decision-relevant metrics of hydrologic extremes

Lead: Ben/Shim

Retrospective Forecast Experiment

Lead: Ben

- **NOAA Coupled Forecast System (CFS, v2) -** *(Chris/Paul)*
- **NASA GMAO Experimental Seasonal Forecasts (ESF) -** *(Shahid/Paul)*
- **NDMC VegOut Experimental Forecast Tool –** *(Tsegaye/Brian)*
- **CFS-Statistical Hybrid –** *(Chris/Paul)*
- **Statistical Regression –** *(Ben)*
- **Machine Learning Algorithms –** *(Ben)*

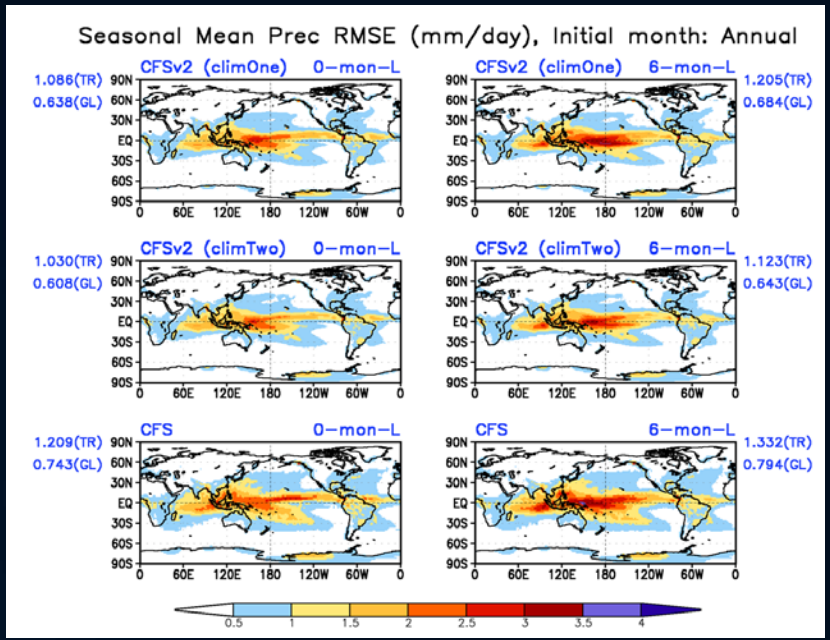
Participatory System Design and Evaluation

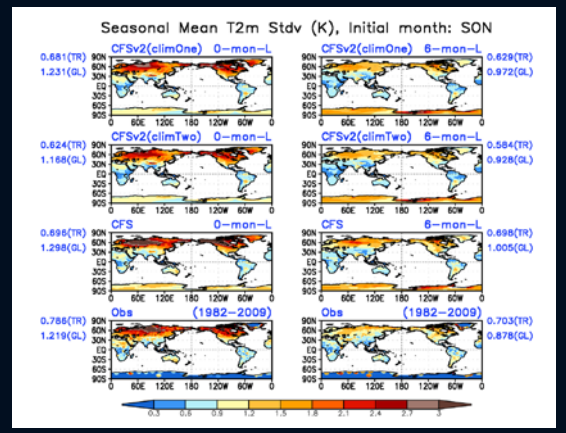
Lead: Shim

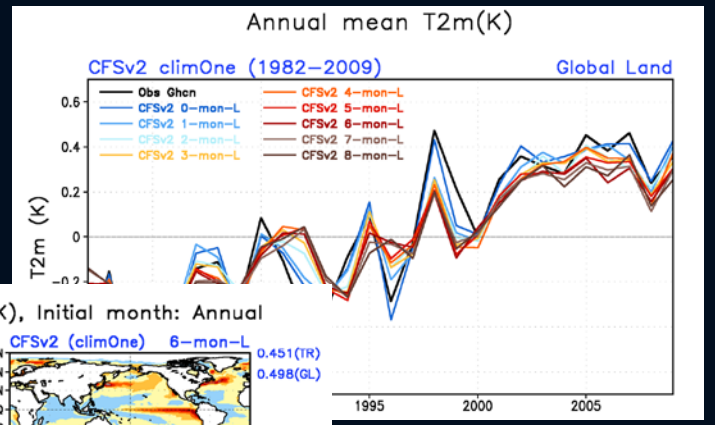
Shim
Ben
Chris
Gabriel
Shahid
Fritz
Tufa
Paul
Gui
Brian
Mike
Tsegaye

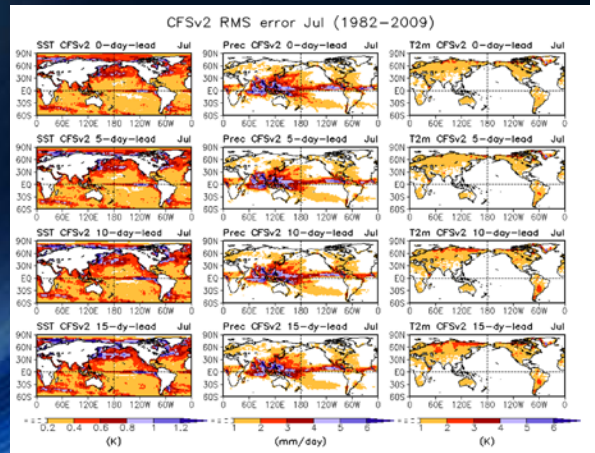
NOAA Coupled Forecast System (CFS, v2)

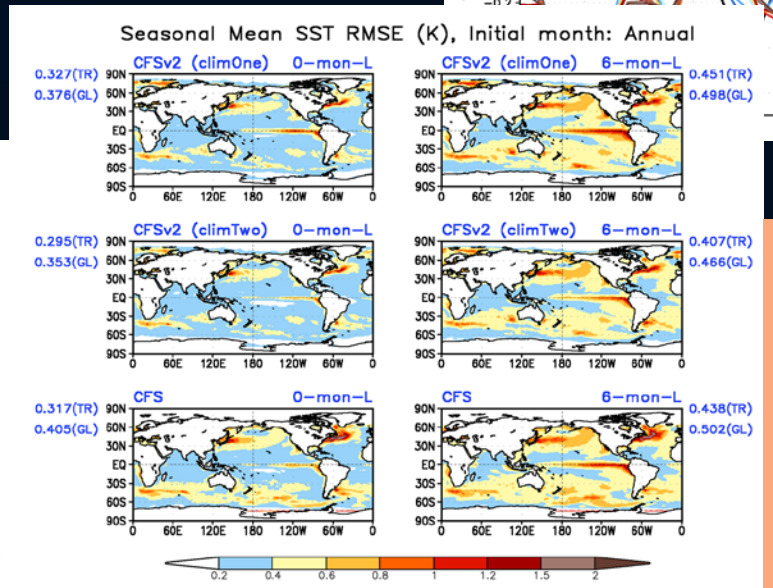
- CFSv2 shows less RMSE than CFS globally and over tropics











- Two climatology CFSv2 shows less RMSE globally and over tropics

NASA GMAO Experimental Seasonal Forecasts (ESF)

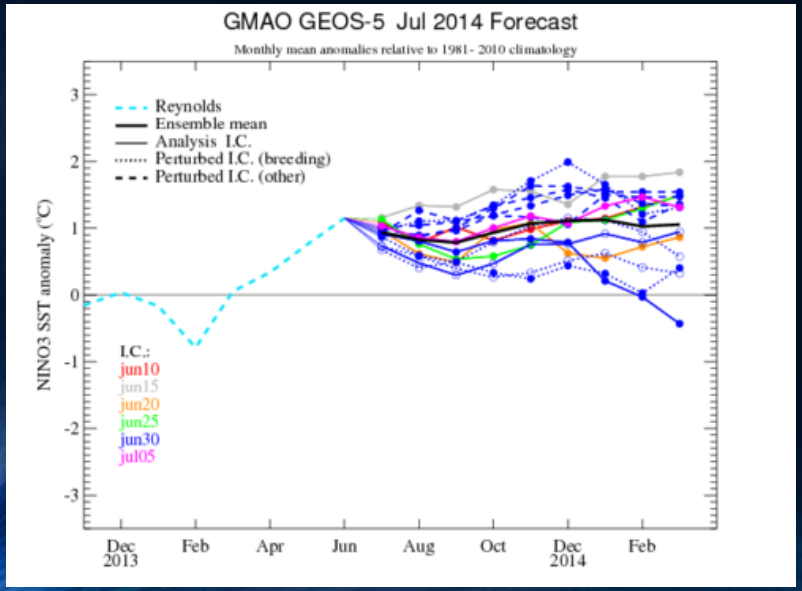
EXPERIMENTAL SEASONAL FORECASTS

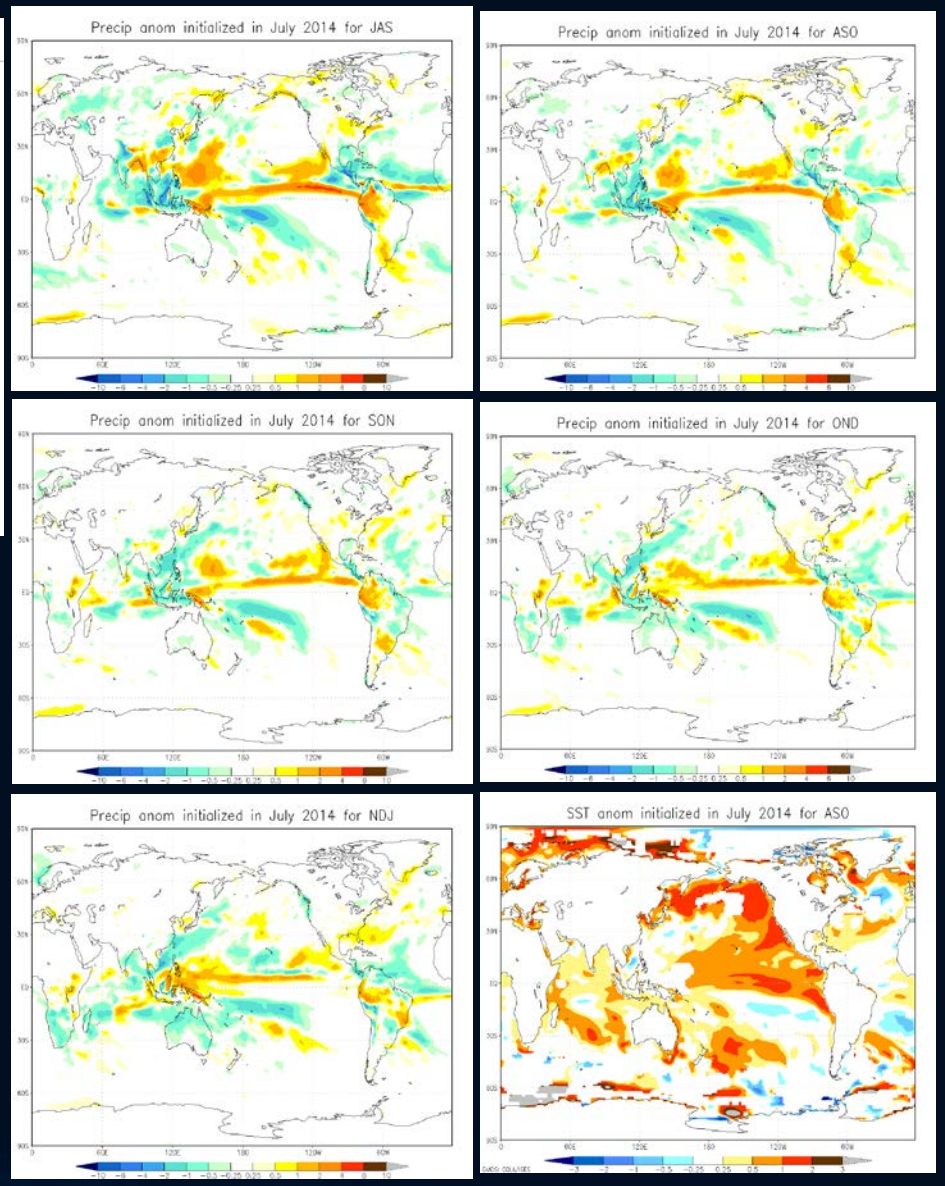
Atmospheric Forecast Anomalies: July 2014

Variable	Monthly			Seasonal		
	Global	N. America	S.E. Asia	Global	N. America	S.E. Asia
T2M	anom mask anom	anom mask anom	anom mask anom	anom mask anom	anom mask anom	anom mask anom
Precip	anom mask anom	anom mask anom	anom mask anom	anom mask anom	anom mask anom	anom mask anom
SST	anom mask anom	NA	NA	anom mask anom	NA	NA
H250	anom	NA	NA	anom	NA	NA
H500	anom	NA	NA	anom	NA	NA

Please note that these predictions are experimental and are produced for research purposes only. Use of these forecasts for purposes other than research is not recommended.

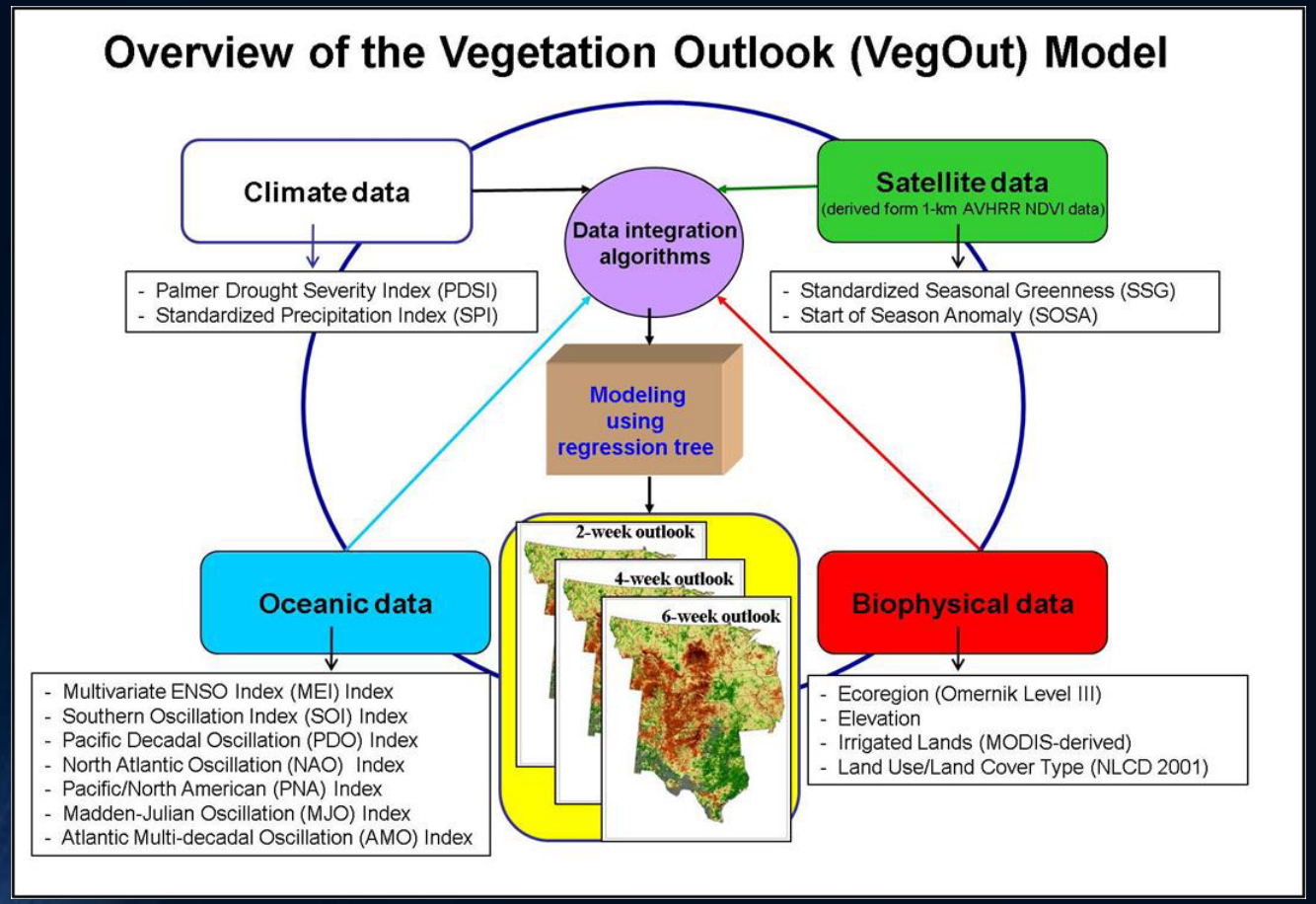
Source: http://gmao.gsfc.nasa.gov/cgi-bin/products/climateforecasts/GEOS5/index.cgi



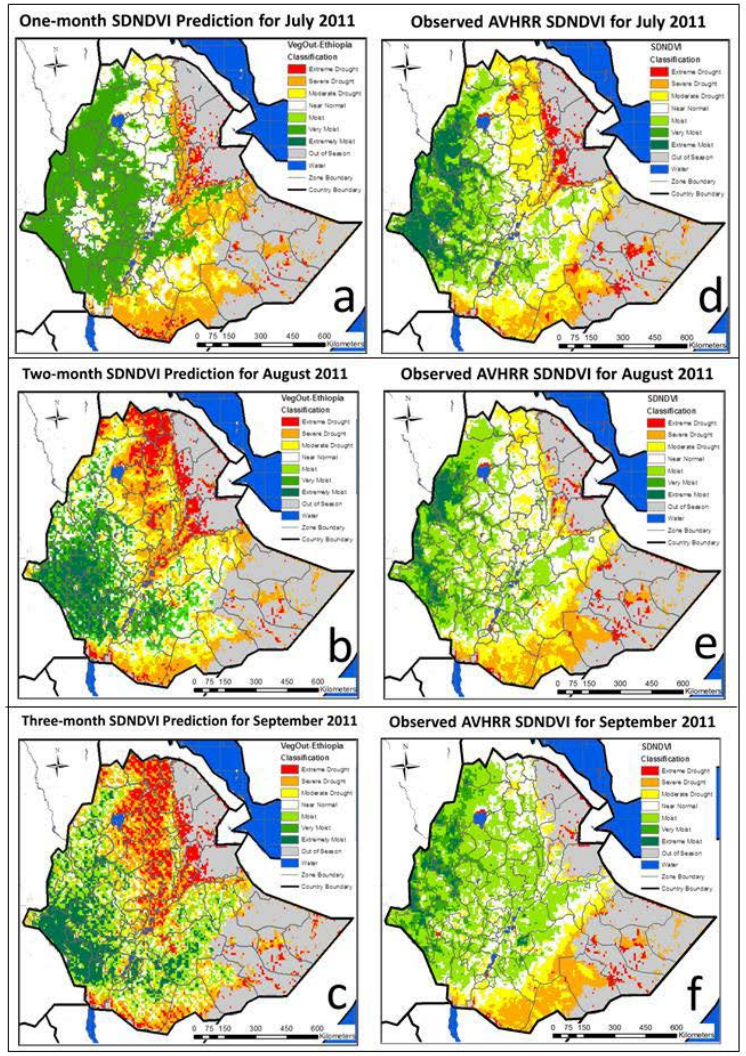


Atmospheric Forecast Anomalies: July 2014
Global Seasonal Anomaly

NDMC VegOut Experimental Forecast Tool

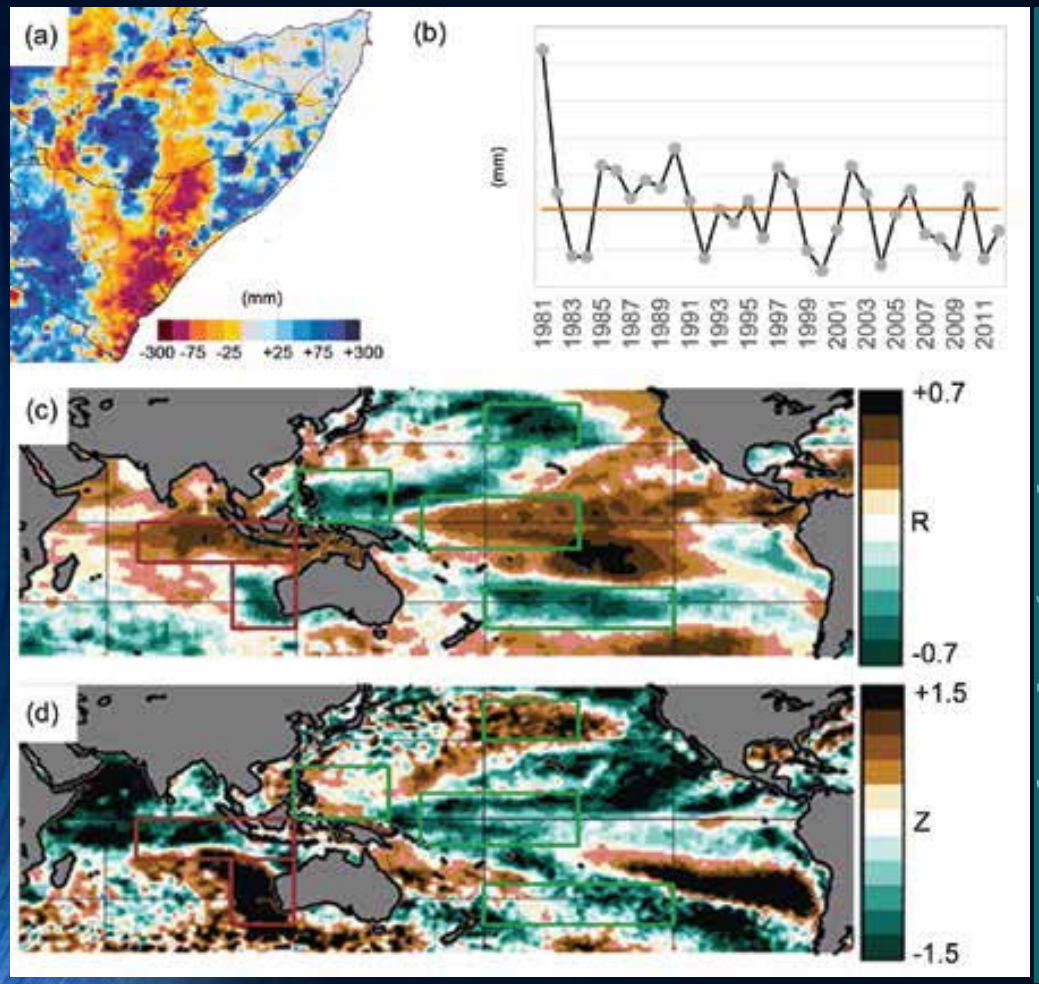


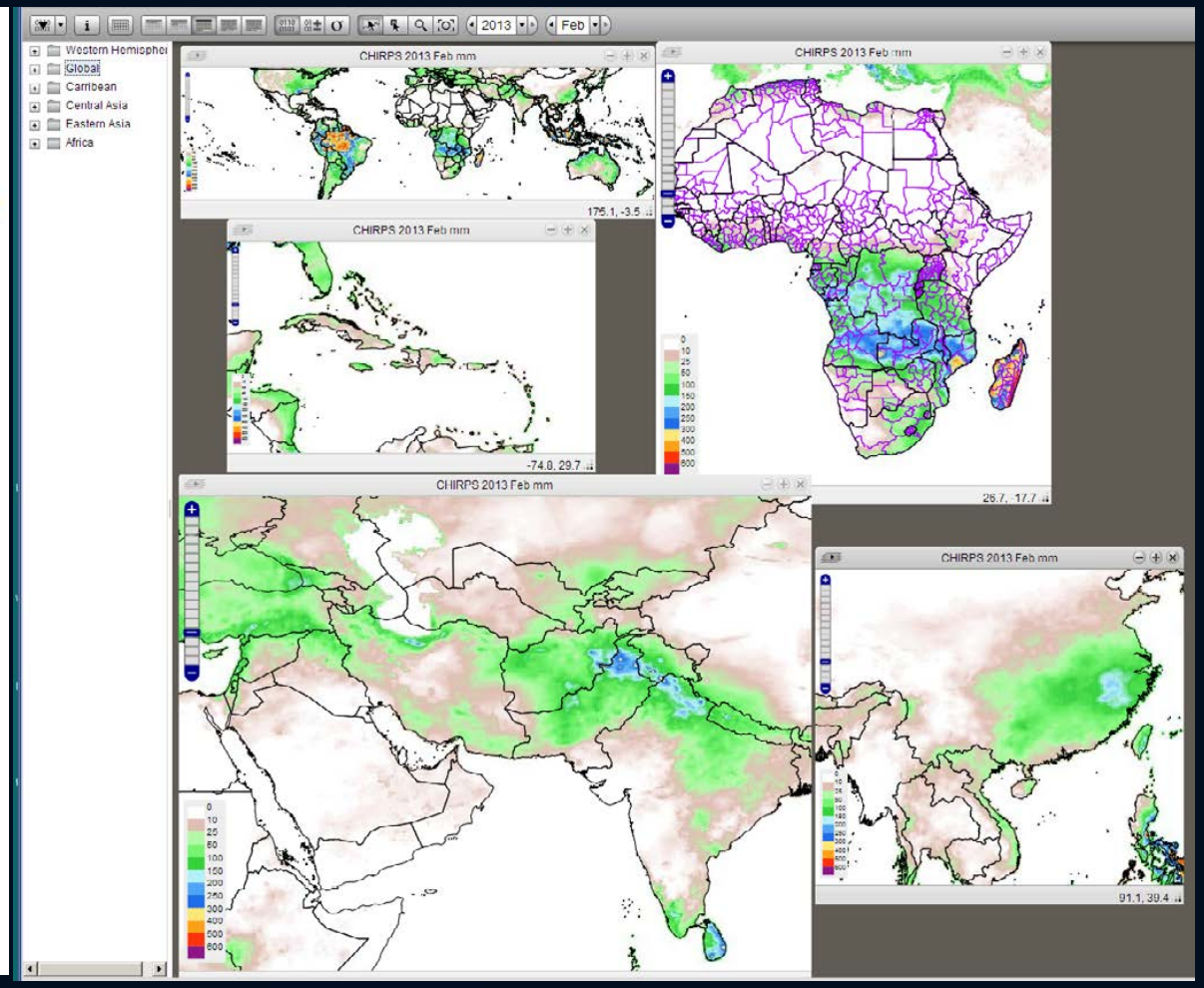
No.	Input parameters	Resolutions		Data years	Updated year	Source
		Temporal	Spatial			
1	Landcover		300 m		2008	European Space Agency (esa)
2	Normalized Difference Vegetation Index (NDVI)	Dekadal	250m	2001 - 2013		USGS famine early warning systems network (FEWS NET)
3	Digital Elevation Model (DEM)		1 km		2010	USGS
4	Standard Precipitation Index (SPI)	Dekadal	5Km	1981 - 2013		Climate Hazards Group Infrared Precipitation with Stations (CHIRPS)
5	Ecoregion				2008	The Nature Conservancy
6	Evaporation Stress Index (ESI)			2000-2013		USDA/NOAA
	Soil map and Available water					European Soil Portal - Soil Data and Information



Source: Tadesse et al., 2014. Water Resource Research Journal

CFS-Statistical Hybrid

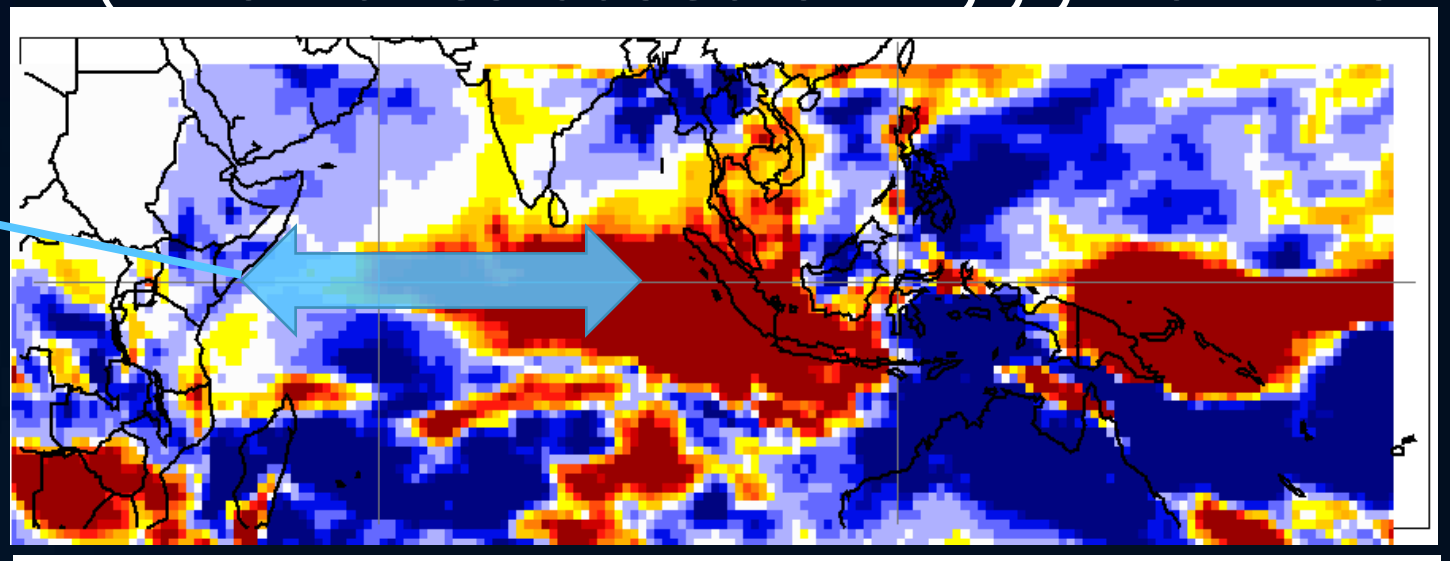




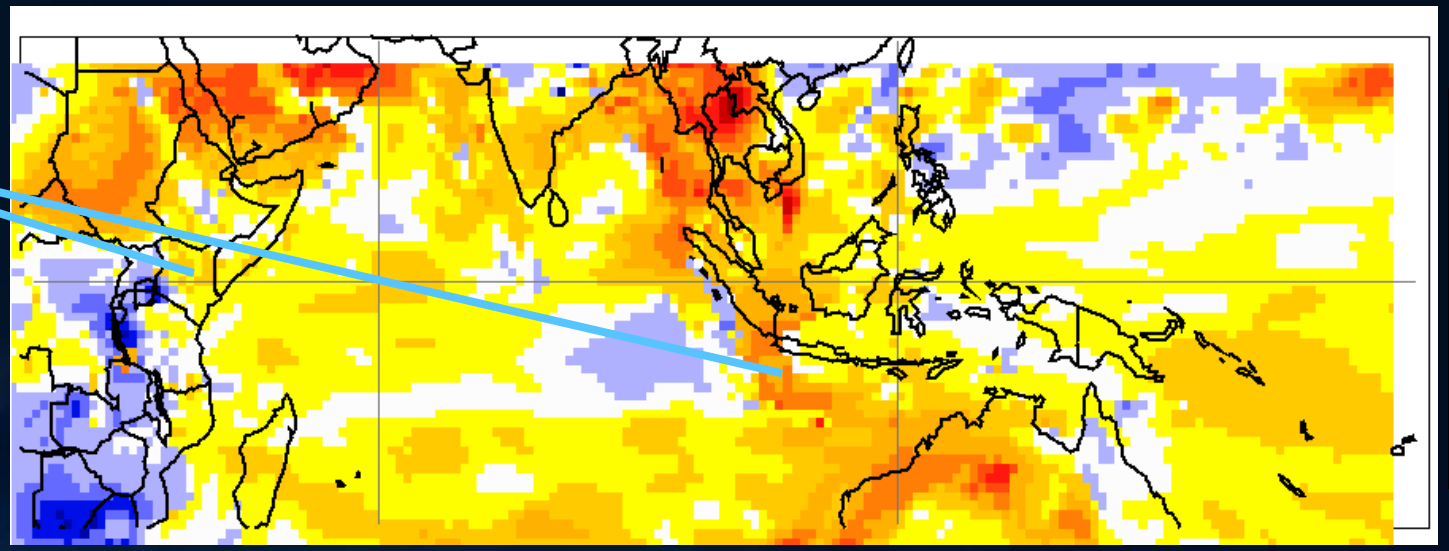
Funk et al.

Coupled Forecast System MAM 2013 Forecasts (Anomalies based on 1999-2012 normal)

Rainfall dipole likely to persist



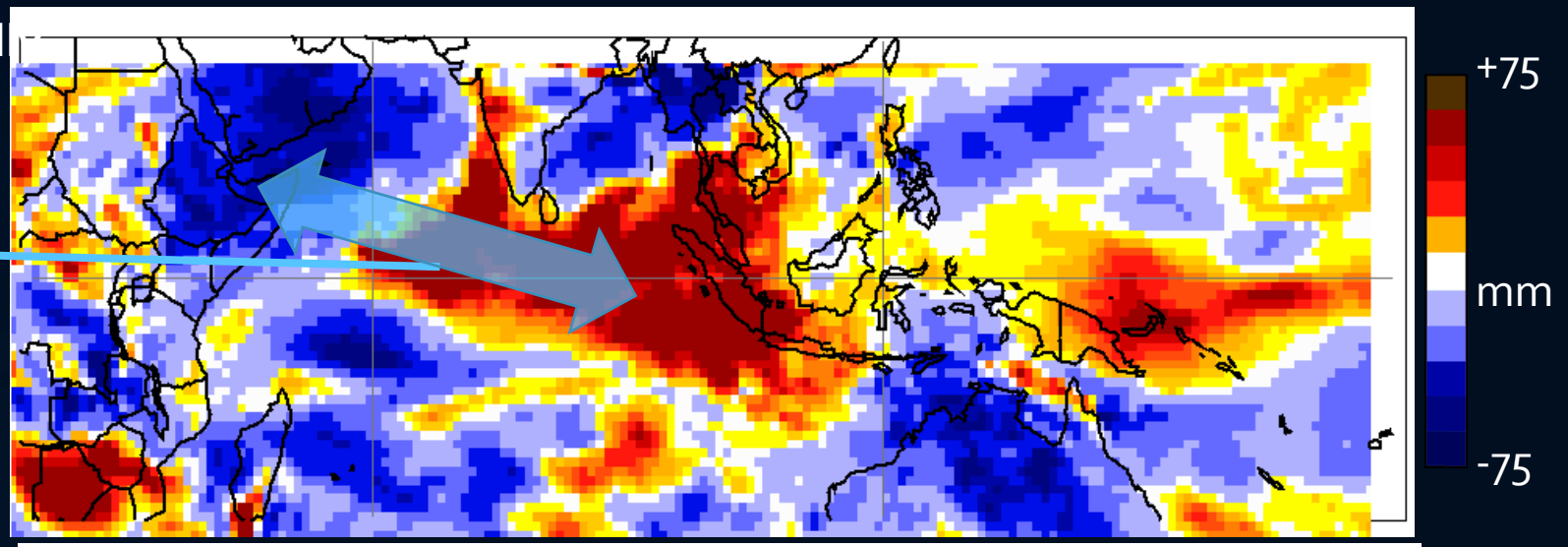
Accompanied by Warm temperatures



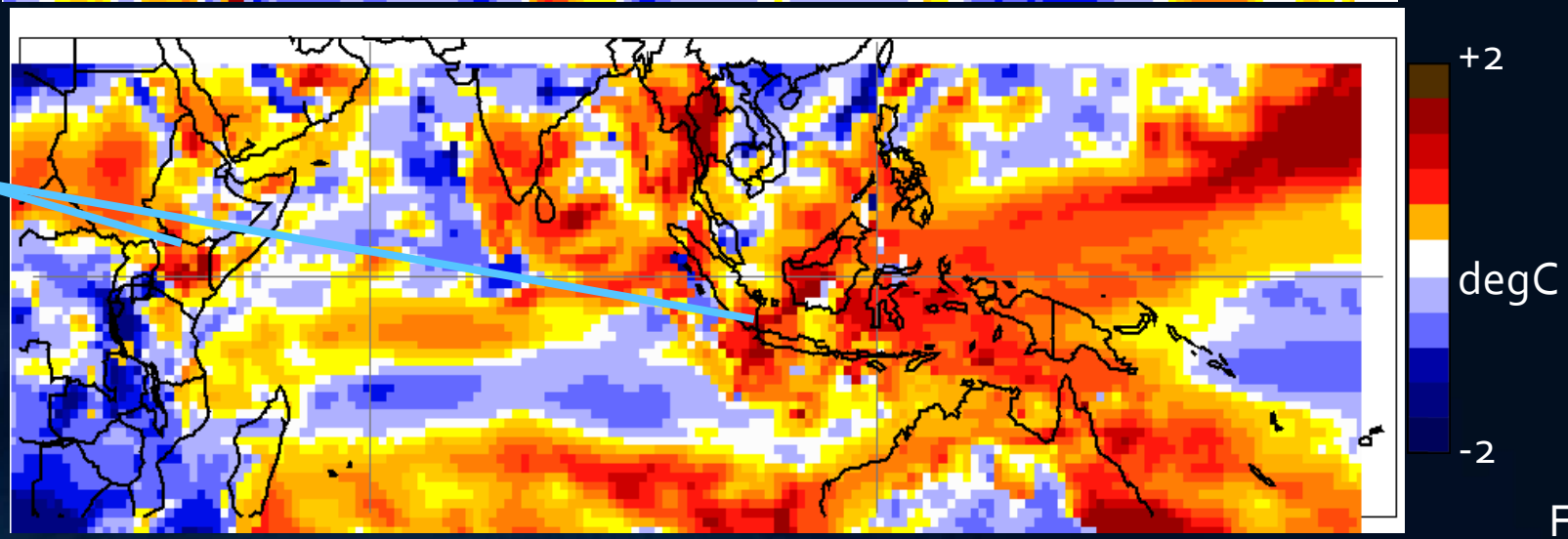
Funk et al.

Coupled Forecast System MAM 2013 Forecasts (Z-scores based on 1982-2012 normal)

Rainfall dipole statistical extreme
~-2 σ over horn
+2 σ over Indian Ocean



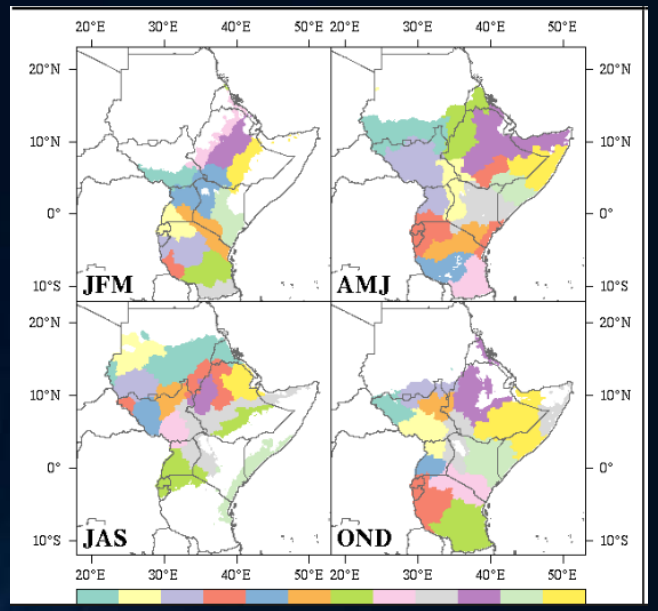
Very warm temperatures statistically extreme
~+2 σ over horn
+2 σ over eastern Indian Ocean

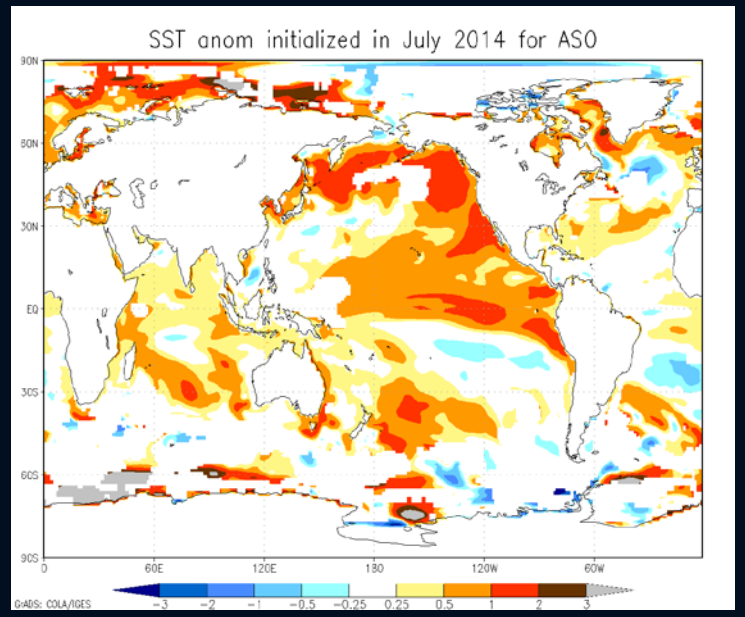


Funk et al.

Statistical Regression

Objective Regionalization





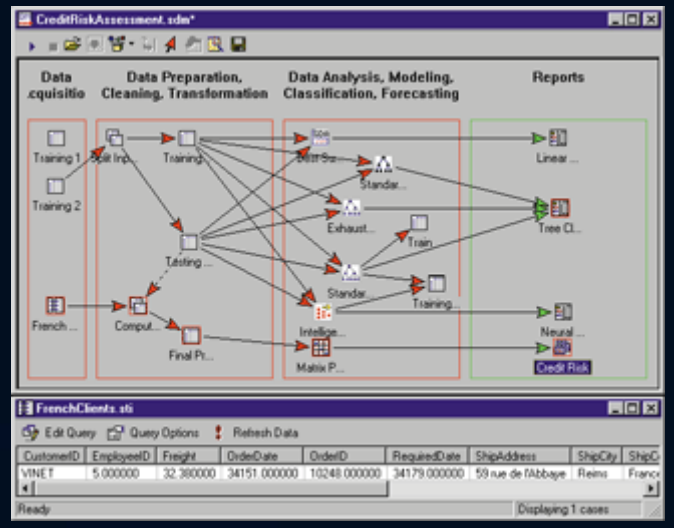
- **Apply a set of parametric and non-parametric statistical models to predict precipitation in climatically coherent subregions of the GHA, as defined under *Objective Regionalization*.**
- Models of the form of the existing (e.g., ENSO-based forecast system of the NMA) will serve as a starting point
- develop statistical methods using standard climate indices and PCAs of relevant SST, air temperature, and atmospheric pressure fields as predictors, and using generalized linear models (GLM) as well as generalized additive models (GAM) and tree-based models to optimize for predictive skill

Machine Learning Algorithms

Data Mining Techniques to improve seasonal prediction

- artificial neural network (ANN)
  - properly constrained ANN can provide enhanced seasonal prediction of Sahelian precipitation relative to standard regression models (Badr et al., in review)
- Decision Tree Regression Techniques (Brown et al., 2008)
- Association Rules to predict climate and oceanic parameters: a case study for Nebraska (central U.S.) (Tadesse et al., 2005)

Source: http://ondalys.fr/en/services/data-mining/

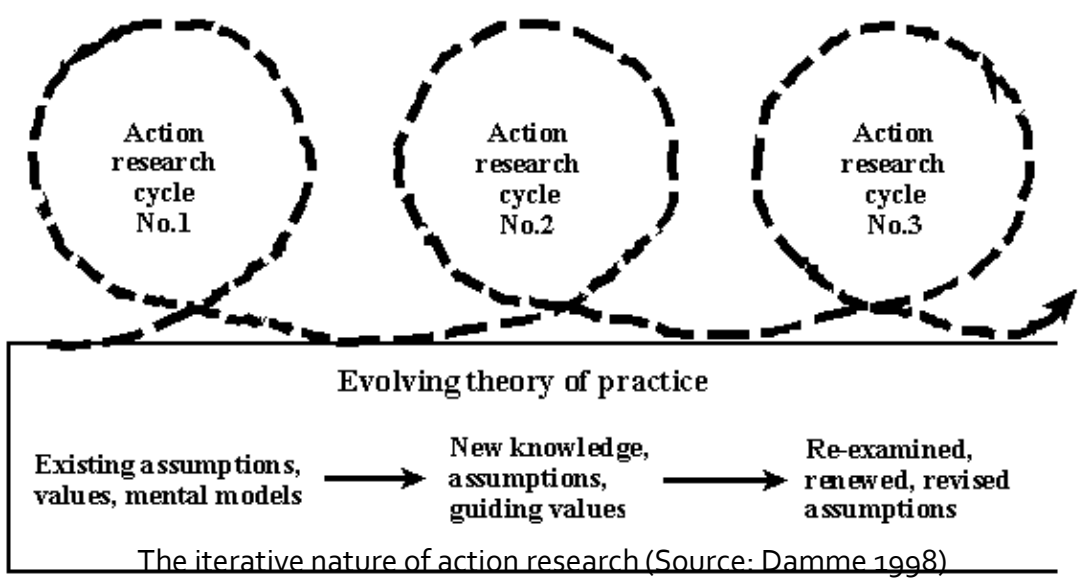


Source: http://www.statsoft.com/Textbook/Data-Mining-Techniques

Participatory Research Design

- The First Participatory Research Workshop: August 11-12, 2014 Addis Ababa, Ethiopia
- Participants from: international organizations, development NGOs, national agencies and universities in Ethiopia, Kenya, South Sudan, Tanzania, and South Africa
- Objective: Characterize the value of existing systems and identify key time horizons, prediction targets, and uncertainties relevant to decision makers

Source: http://www.agrotechconsult.com/what-we-do/field-surveys-Source: and-participatory-research



Source: http://learningforsustainability.net/research/thesis/thesis_ch3.html

Elements of Objective 3 (Investigators)

NASA_IDS_GHA

Seasonal Prediction of Hydro-Climatic Extremes in the GHA under Evolving Climate Conditions to Support Adaptation Strategies

Objective 3

Apply seasonal forecast systems to prediction of socially relevant impacts on crops, flood risk, and economic outcomes, and assess the value of these predictions to decision makers

Lead: Tsegaye/Shim

Impacts Models

Lead: Tsegaye

- **Crop System Modeling-Decision Support System for Agro-technology Transfer (CSM-DSSAT) –** *(Gui)*
- **Coupled Routing and Excess Storage (CREST) Model –** *(Fritz)*
- **Ethiopia Multi-market Model (EMM) –** *(Paul)*
- **FEWS NET Food Security Projections –** *(Gabriel/Chris)*

Participatory System Design and Evaluation

Lead: Shim

Shim
Ben
Chris
Gabriel
Shahid
Fritz
Tufa
Paul
Gui
Brian
Mike
Tsegaye

Impact Models

(1) Crop System Modeling-Decision Support System for Agro-technology Transfer (CSM-DSSAT)

- geospatial crop/climate model that integrates GIS capabilities and dynamic crop models to generate maps of crop yields

(2) Coupled Routing and Excess Storage (CREST) Model

- CREST will be used for seasonal scale predictions of probability of high and low flows. Using probabilistic daily precipitation time series generated from the seasonal forecast products, we will perform ensemble simulations to derive probability of statistically-defined flood and low-flow events.

(3) Ethiopia Multi-market Model (EMM)

- As the EMM is only under development for Ethiopia, we will focus on Ethiopian case studies as a proof of concept (to estimate the economic and social benefits of forecast use)
- Model outputs may be observed at local to national scales all supply and demand functions and production and consumption decisions are defined at administrative zone level.
- Performance metrics to compare the forecast vs. no-forecast approaches will include agricultural GDP and poverty rates at select zones, across the basin, and at the national level.
- Varying levels of forecast adoption rates (i.e. how many farmers use the forecast) will also be considered.

(4) FEWS NET Food Security Projections

- climate forecasts and climate indicators help guide scenario building and food security outlooks.
- This typically occurs before or during the early phase of the crop growing season. In the middle of the season, satellite rainfall fields are used to monitor crop growing conditions. At the close of the growing season, satellite observations of vegetation are used to assess crop production and/or yield

Elements of Objective 4 (Investigators)

NASA_IDS_GHA

Seasonal Prediction of Hydro-Climatic Extremes in the GHA under Evolving Climate Conditions to Support Adaptation Strategies

Objective 4

Evaluate the robustness of seasonal prediction systems to evolving climate conditions.

Lead: Ben/Chris

Evolving Climate Conditions

(Chris/Tufa/Paul)

CMIP5 projections

(Chris/Paul/Tufa)

Stakeholder engagement

Lead: Shim

Shim
Ben
Chris
Gabriel
Shahid
Fritz
Tufa
Paul
Gui
Brian
Mike
Tsegaye

Robustness of seasonal prediction systems to evolving climate conditions

(1) Evolving Climate Conditions

- to test the robustness of the physical relationships between large-scale variability and GHA precipitation over a multi-decadal record: the stationarity of the relationship between large-scale drivers and flood/drought frequency in the GHA will be tested over the historical record [by fitting the statistical models generated under Objective 1 to various baseline periods, making use of the entire period of NCEP-NCAR Reanalysis Project (NNRPv1) coverage (1948-present) and CRU precipitation data.]

(2) Coupled Model Intercomparison Project (CMIP5) projections

- The statistical models will be applied using CMIP5 projected large-scale conditions for the period 2020-2050 to evaluate GCM consensus in projecting trends in extreme floods and droughts in each sub-region of the GHA and mechanisms associated with these trends.

(3) Stakeholder Engagement

- perceptions of changing climate and planning time horizon for climate change adaptation are of critical interest, as is the perceived value of improved seasonal prediction systems as an adaptation tool
- discussion of the projected frequency and intensity of hydroclimate extremes generated under objective 2 above (CMIP5 Projections) in stakeholder workshops and surveys

Summary and Timeline

Year 1

1. Perform objective regionalization of the GHA
2. Build climate, satellite, oceanic, and environmental data that will be used for model development & evaluation
3. Perform robust analysis of large-scale drivers and mechanisms of association for extreme wet/dry anomalies
4. Assess forecast models for GHA
5. First "User Interaction-oriented Seminar/Workshop"

Year 2 and Year 3

1. Examine case studies on forecast & response of major drought & flood
2. Evaluate performance of about 6 seasonal forecast methods in predicting decision-relevant metrics of hydrologic extremes
3. Assess information requirements to implement a scientifically robust and responsive EWS to stakeholder information needs
4. Develop & implement about 3 impacts models relevant to decision makers coping with hydrologic/climatic extremes in the GHA
5. Second and third "User Interaction-oriented Seminar/Workshop" in Year 2 and 3, respectively.

THANK YOU !!