Enhancing USAID Famine and Malaria Early Warning with NASA Earth Science Results

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Malaria Early Warning
(MEWS)

U.S. Department of the Interior
U.S. Geological Survey

Project Team

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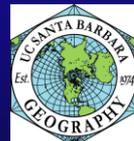
Primary Objectives

- Evaluate FEWS NET user requirements to guide system transformation during the project

- Incorporate new NASA MODIS EO products with existing suite of RS data/models to enable quantitative estimates of environmental anomalies that can be easily compared across products

- Incorporate projections of NDVI into the FEWS NET system for improved decision support

- Integrate observed rainfall into malaria forecasts for identification of malaria outbreaks in areas prone to epidemic outbreak.

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End User Requirements

- Online questionnaire to quantify FEWS NET satellite remote sensing requirements
    - FEWS NET (USGS, NOAA, NASA, USDA, Chemonics) stateside and field personnel
    - General requirements – identification and ranking of environmental variables and spatio-temporal properties
    - Rainfall requirements – particular needs for measured and predicted rainfall
    - Vegetation requirements – focus on vegetation monitoring and proposed predictions of vegetation condition

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End User Requirements

Table 1. FEWS NET general requirements as inferred from review.

Property	User Requirement	Drivers
Spatial resolution	250 m to 1 km	Need to capture variations to support district level analysis
Spatial extent	2000 km to 4000 km across	Need to capture synoptic views at country and regional scales
Temporal frequency	Dekad (primary)	Established operational practice; need to capture variations from typical phenology (dekadal data satisfies those with "Monthly" needs as well)
	Daily (secondary)	Need to capture sudden onset hazards such as flooding
Latency	≤1 day	Need to quickly address sudden onset hazards
Prediction time scale	1 week and 1 month	Need to analyze and prepare for both faster and more slowly evolving hazards

USGS

End User Requirements

Table 2. FEWS NET rainfall requirements as inferred from review.

Property		User Requirement	Drivers
Spatial resolution	Rainfall	2 km to 5 km	Somewhat relaxed because of convolving effects of topography, soils, etc.
Rainfall absolute accuracy *(assuming dekadal time step)*	Current	10 mm per dekad	Response
	1-Month forecast	30 mm per dekad	Short-range planning
	2-Month forecast	50 mm per dekad	Medium-range planning
	4-Month forecast	70 mm per dekad	Medium- to long-range planning
Rainfall anomaly relative accuracy *(assuming dekadal time step)*	Current	15%	Response
	1-Month forecast	20%	Short-range planning
	2-Month forecast	25%	Medium-range planning
	4-Month forecast	30%	Medium- to long-range planning

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Enhancing Famine and Malaria Early Warning

- Early Warning – defined as
  - Provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and to prepare for effective response" (Twigg 2003)

- Key elements of a successful EWS
  - Forecasts of the human consequences of an event must be accurate in predicting its location, time, and severity
  - Warnings must be disseminated in time for populations at risk to take appropriate action(s)

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Enhancing Famine Early Warning

- Provide enhanced information tools supporting better famine early warning (in Africa) by

  - Broadening the scope of satellite information products
    - Adding NDVI (MODIS), TPW (AIRS), LST (MODIS) to RFE products

  - Providing standardized indices
    - RFE, NDVI, TPW, and LST expressed as z-score indices
      - Supports convergence of evidence and historical comparison

  - Integrating statistical forecasts of RFE, NDVI, TPW and LST
    - Supports integrated mid-season assessments

  - Enhancing the existing USGS data portal to better manage and display geospatial data

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Enhancing Famine Early Warning

- Timely, Convergent, Accurate, High-resolution Information
- Predictive, Seamless, Actionable, Physically consistent and comprehensible, Common format and interface

Climate Data

Data Portal

Historical   real-time   forecasts   projections

Precipitation
NDVI
Precipitable Water
Temperature

.

.

.

Web Accessible
Highly Interactive
Time-drillable
Open Source

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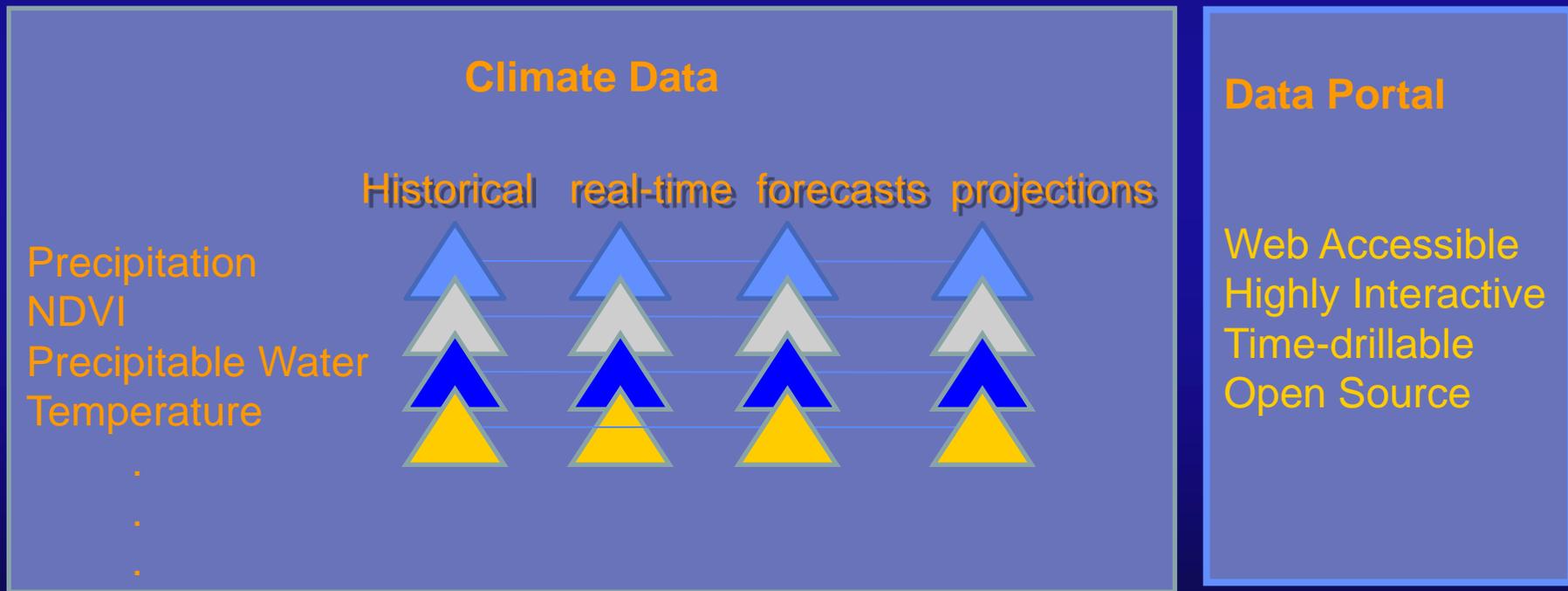
Enhancing Famine Early Warning

- Early Warning eXplorer (EWX)

  - New user interface to dynamically compare standardized anomalies
  - Framework to incorporate NASA data into routine analysis
  - Allows rapid identification of significant anomalies across diverse regimes
  - Used by FEWS NET analysts for comparison to "normal" conditions
  - FEWS NET Convergence of evidence approach

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EWX – Early Warning eXplorer
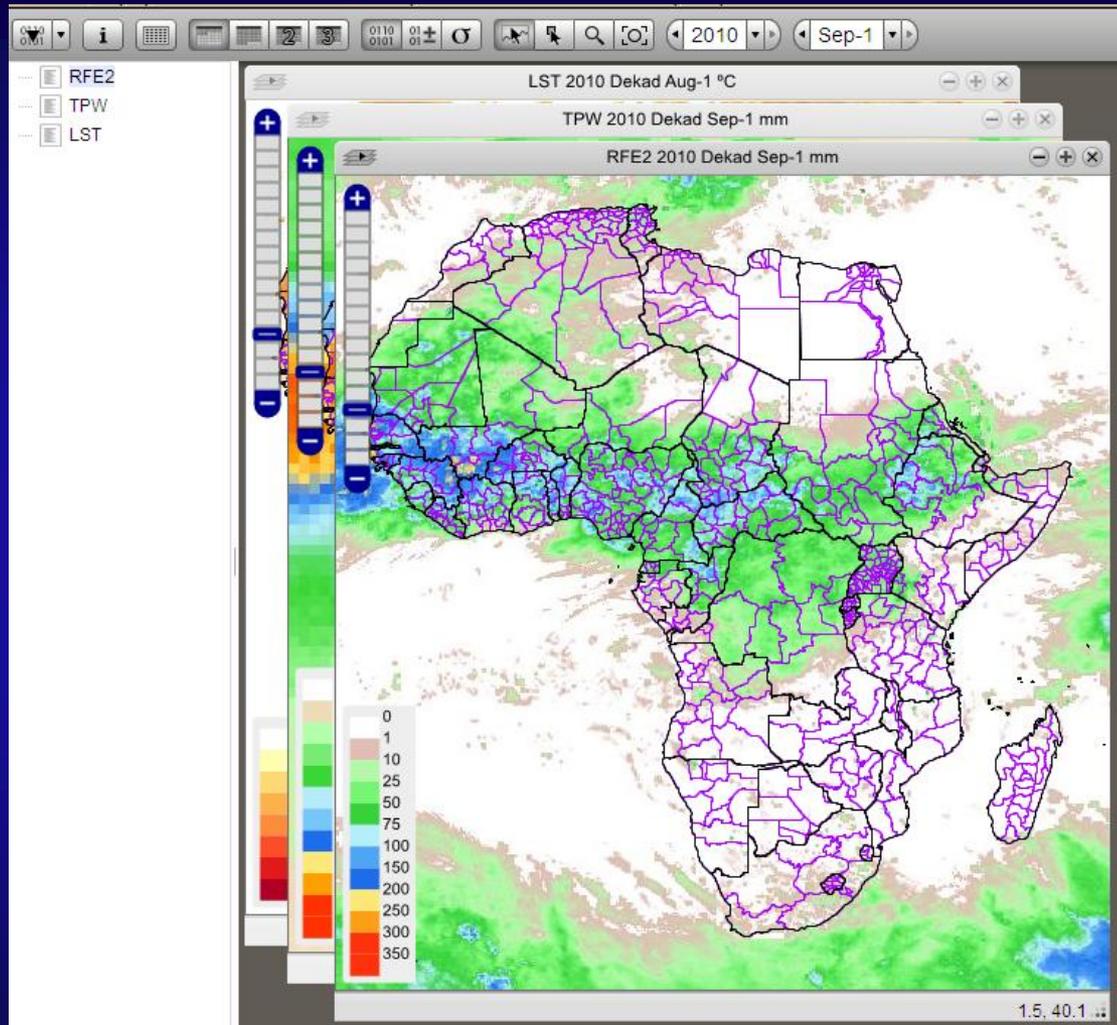
RFE2:
- rainfall estimate
- NOAA CPC
- Mar 2001 – present

TPW
- Total Precipitable Water
- AIRS (Atmospheric Infrared Sounder)
- Sep 2002 – present

LST
- Land Surface Temperature
- MODIS AQUA
- Aug 2002 - present

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EWX – Early Warning eXplorer
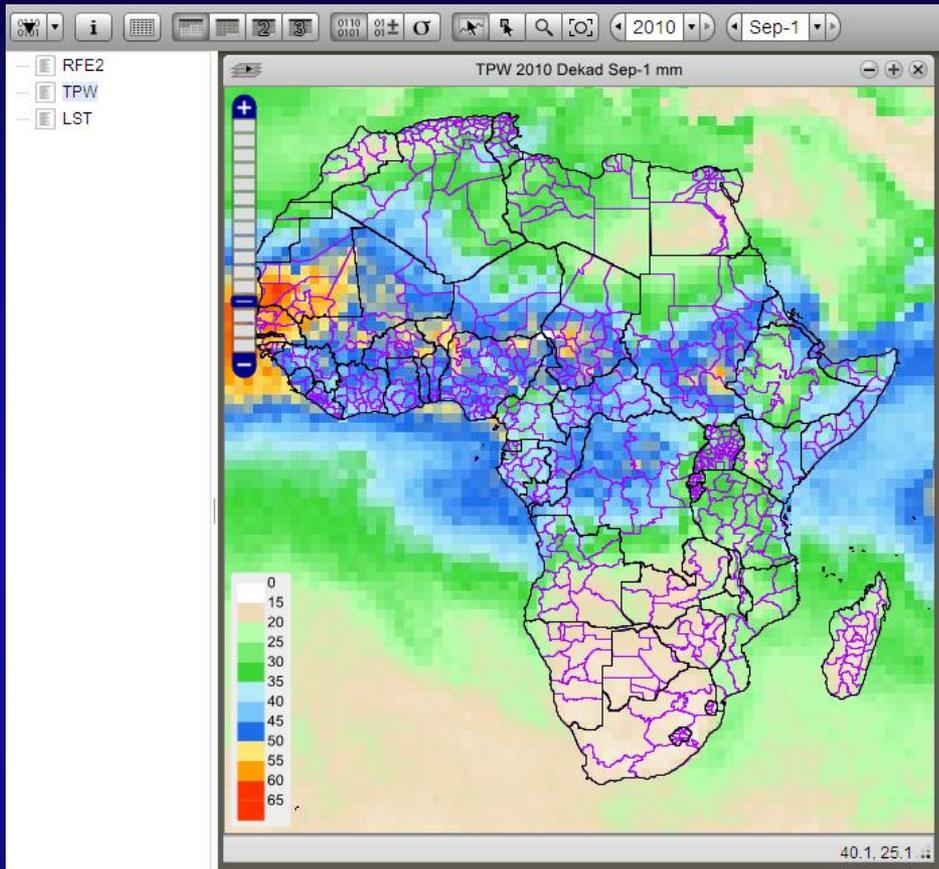
TPW

LST
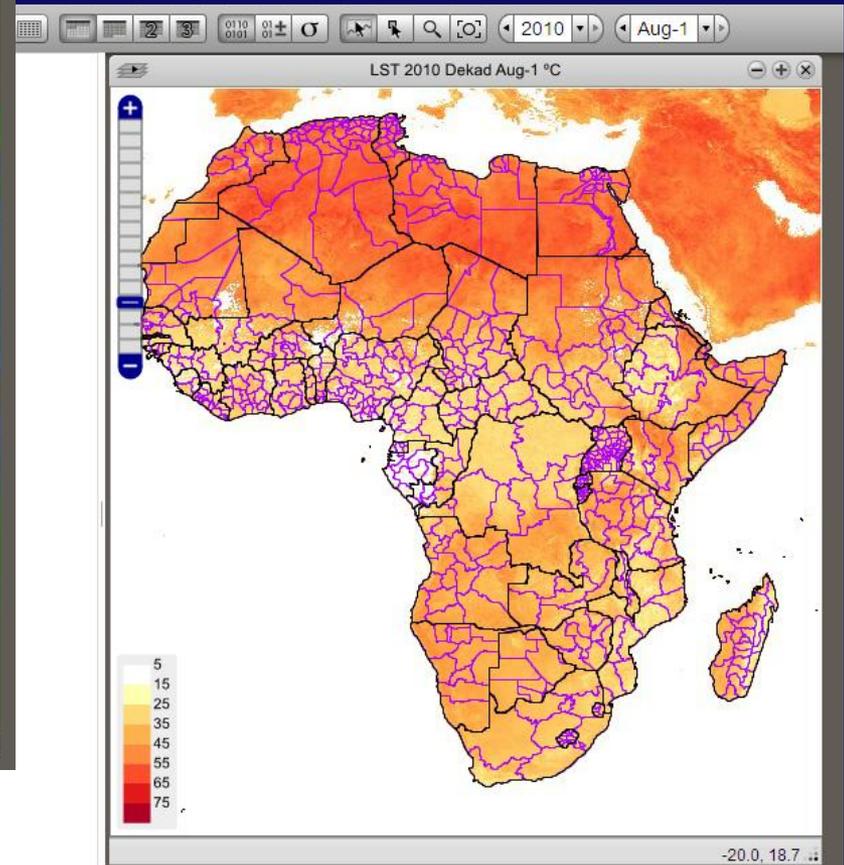
EWX – Early Warning eXplorer
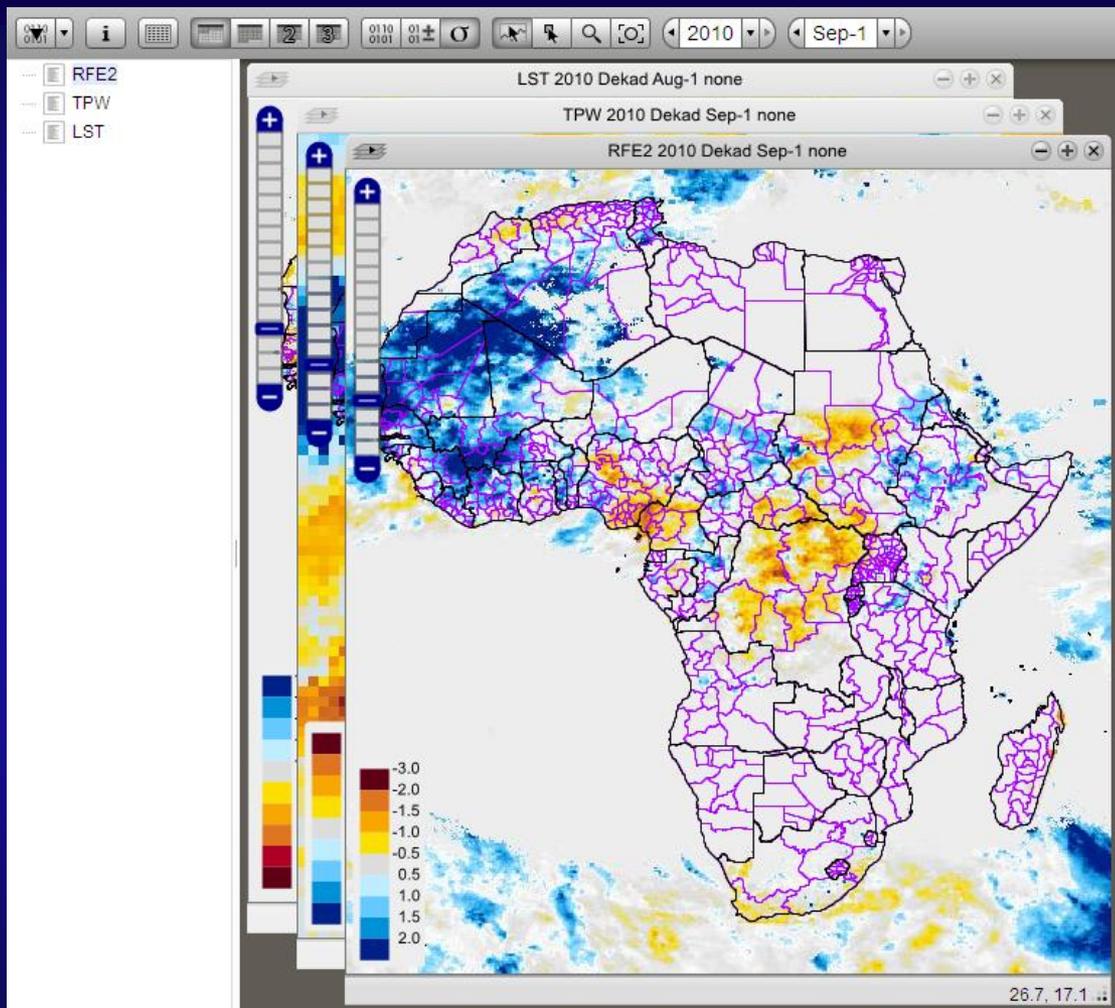
Temporal resolution
- **Dekadal (10-day)**
- **Monthly**
- **2-month**
- **3-month**

Data presentation
- **Raw data**
- **Absolute Anomaly (difference image)**
- **Z-score (standardized index)**

Download graphics/data
- **PNG (graphic)**
- **GeoTIFF (data)**
- **GeoTIFF (with color)**

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EWX – Early Warning eXplorer
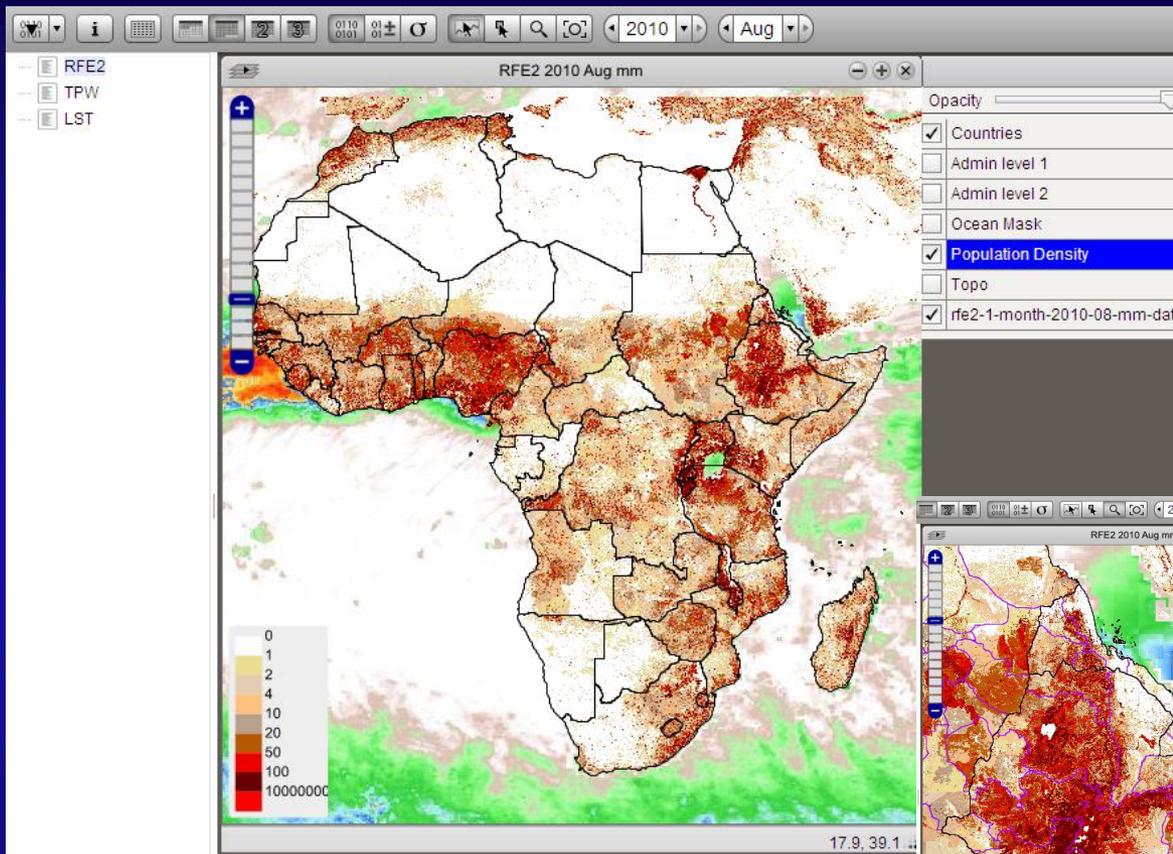
Additional layers (with opacity control
- **Countries**
- **Admin level 1**
- **Admin level 2**
- **Ocean mask**
- **Population density**
- **Topography (DEM)**

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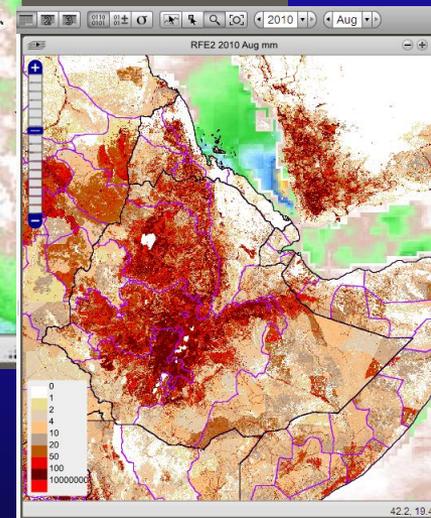
EWX – Early Warning eXplorer
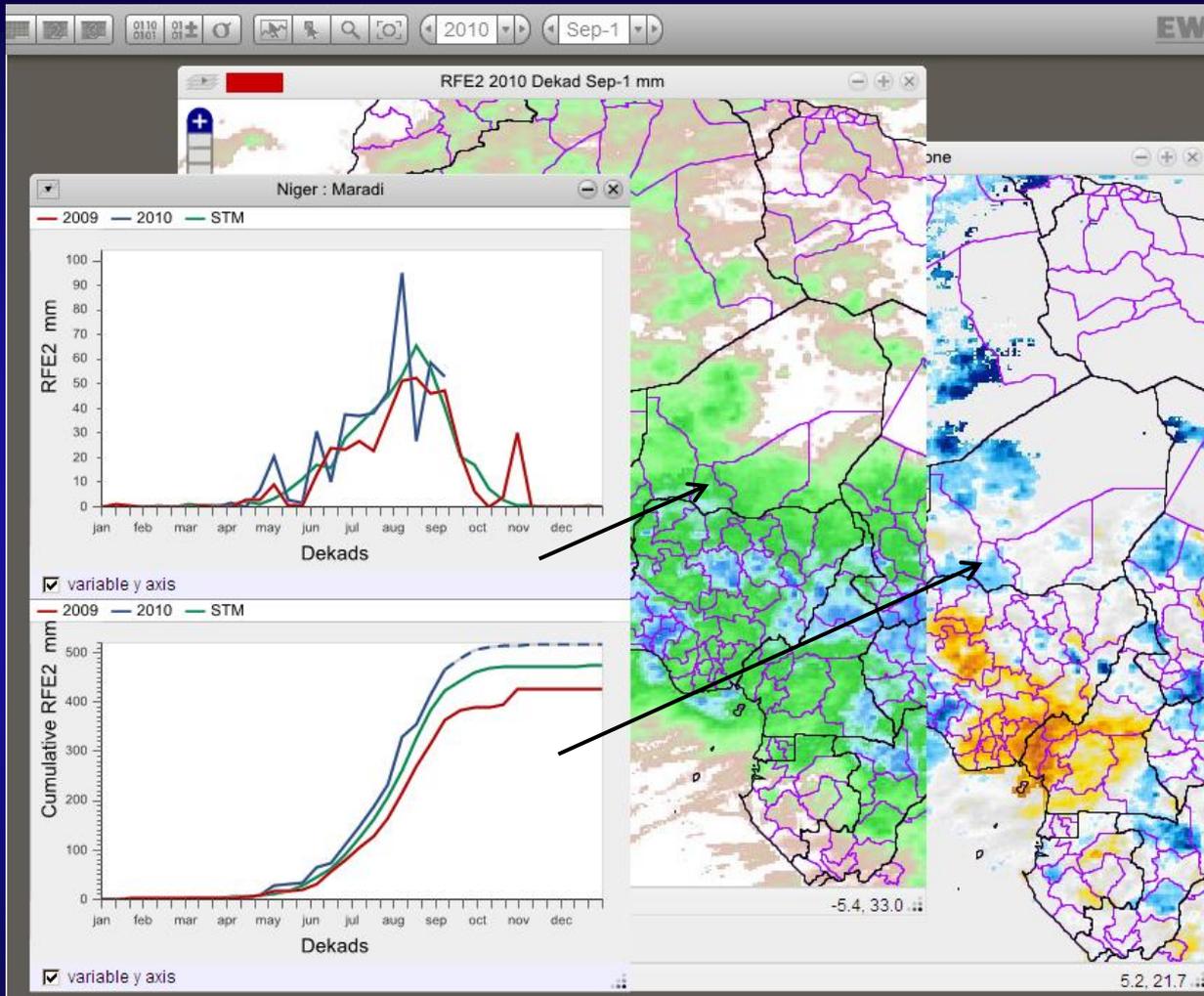
Time series data

- **Default is short-term mean, current and previous years**
- **Choose any combination of years**
- **Available for dekadal, monthly, 2-monthly, etc**
- **Available for raw, anomaly, z-score data**

EWX – Early Warning eXplorer
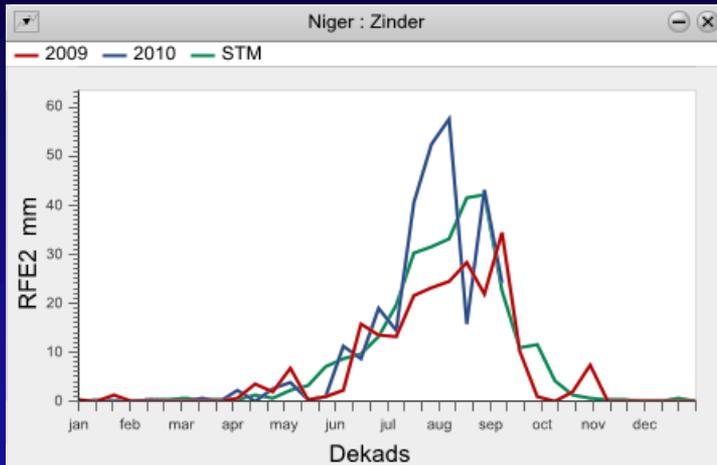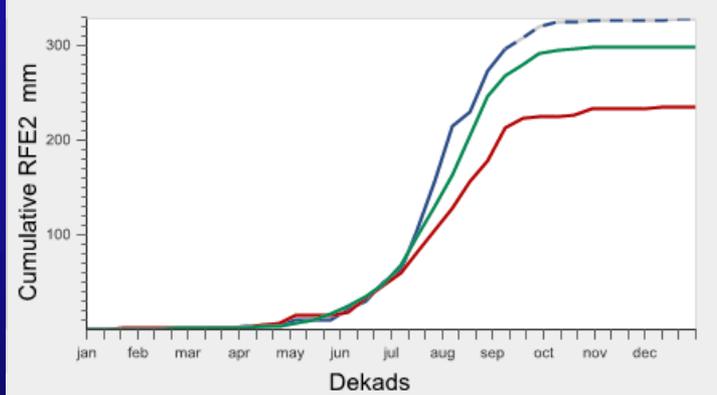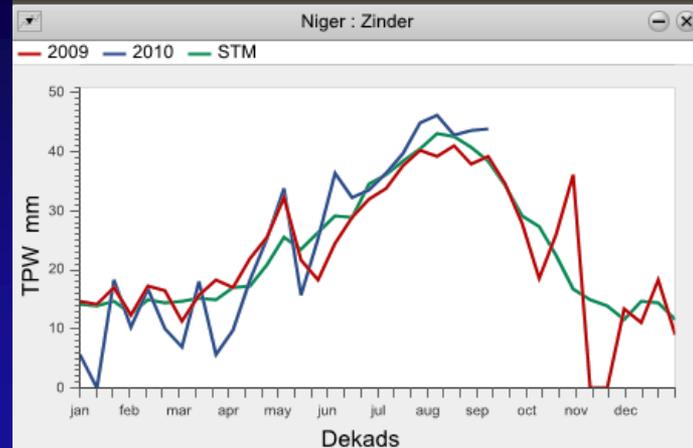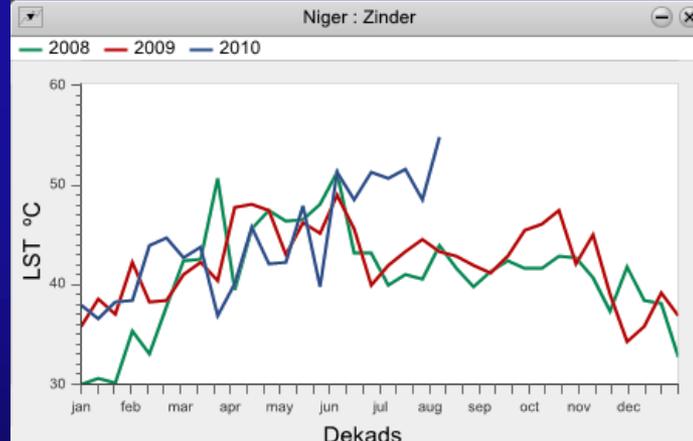
EWX – Early Warning eXplorer

Download data
Dataset information
Dataset navigator
Dekadal / monthly / 2-month / 3-month
Raw data / anomaly / z-score
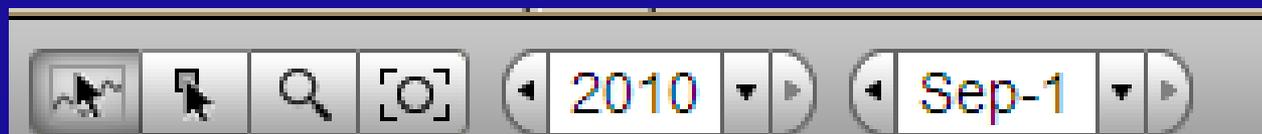
Time series / pixel value / zoom / extent
Year selection
Dekad / month / etc selection

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EWX – Early Warning eXplorer
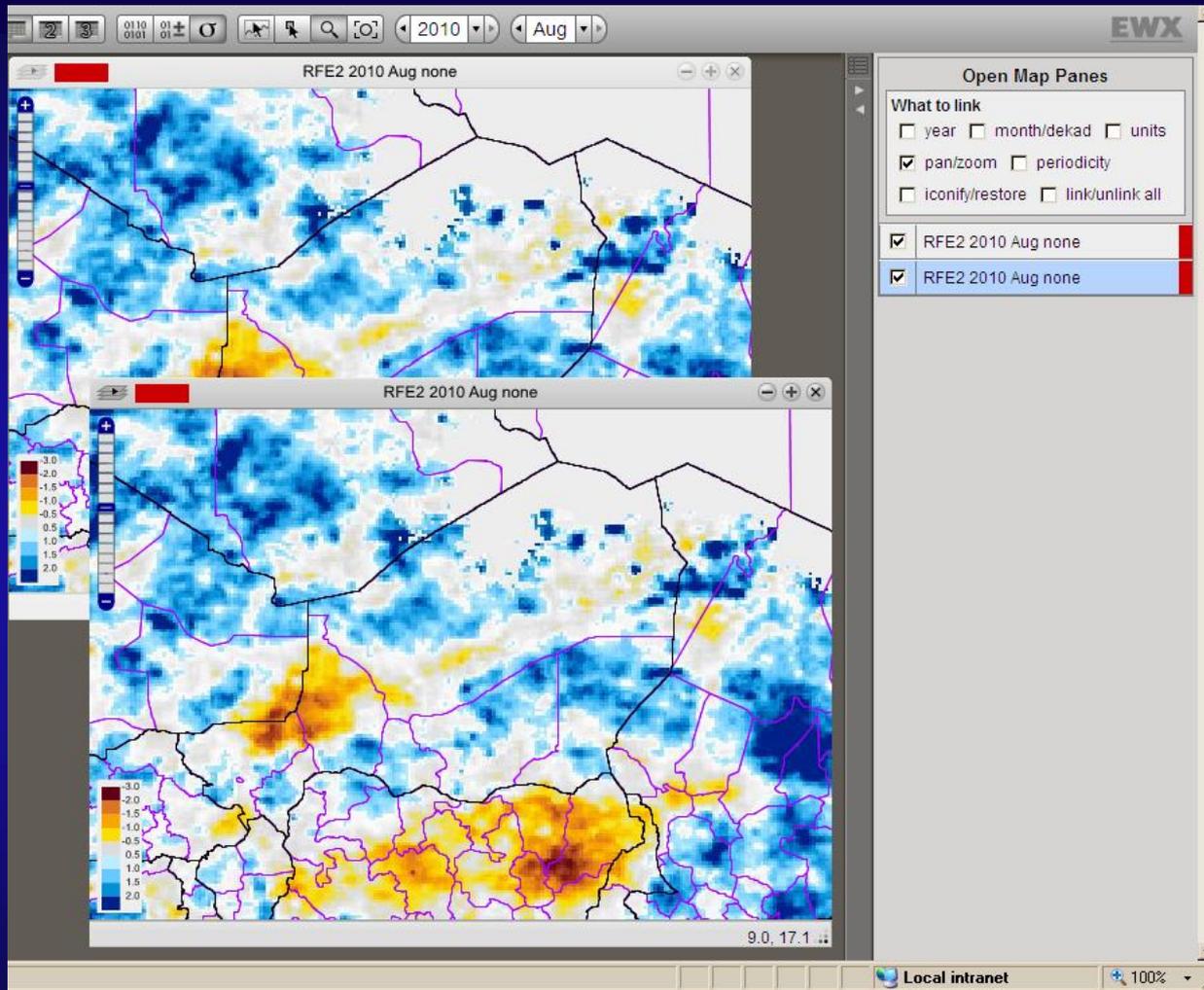
Individual panes (or all panes) can be linked by

- **Year**
- **Month/dekad**
- **Units**
- **Pan/zoom**
- **Periodicity**
- **Iconify/restore**
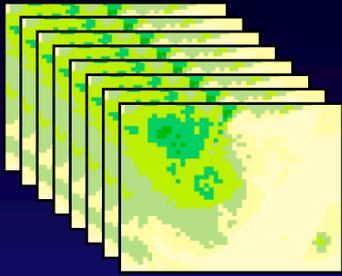
P
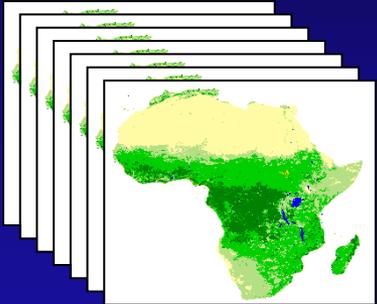
N
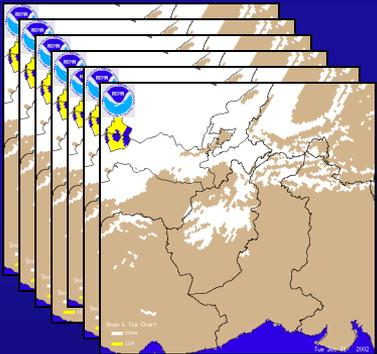
S
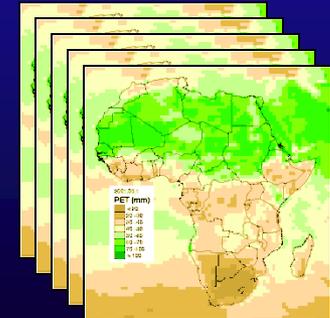
E

Geoserver Database
(GeoTIFF images, MySQL spatial DB)
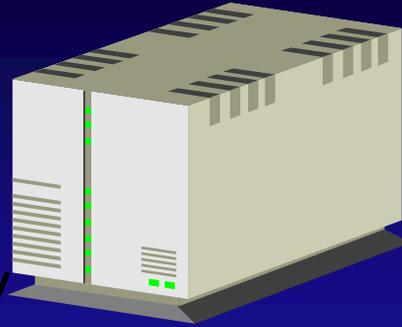
Open Source OGC-compliant
(Open Geospatial Consortium)

Decision
Support
Interface

Interactive
Analysis Tool
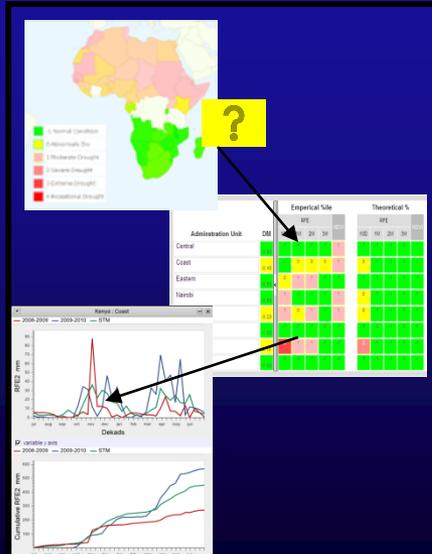
Early Warning
eXplorer (EWX)
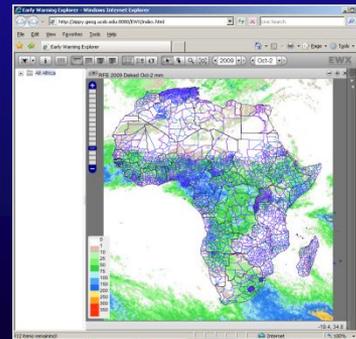
AG GEO DATA

1. **Admin Units**

2. **Rangelands**

3. **Principal crops**

• **Growing areas**

• **Crop calendars**

• **Rain fed?**

• **Irrigated?**

4. **Snow pack**

• **Catchments**

• **Rivers**

• **Growing areas**

EWX – Early Warning eXplorer
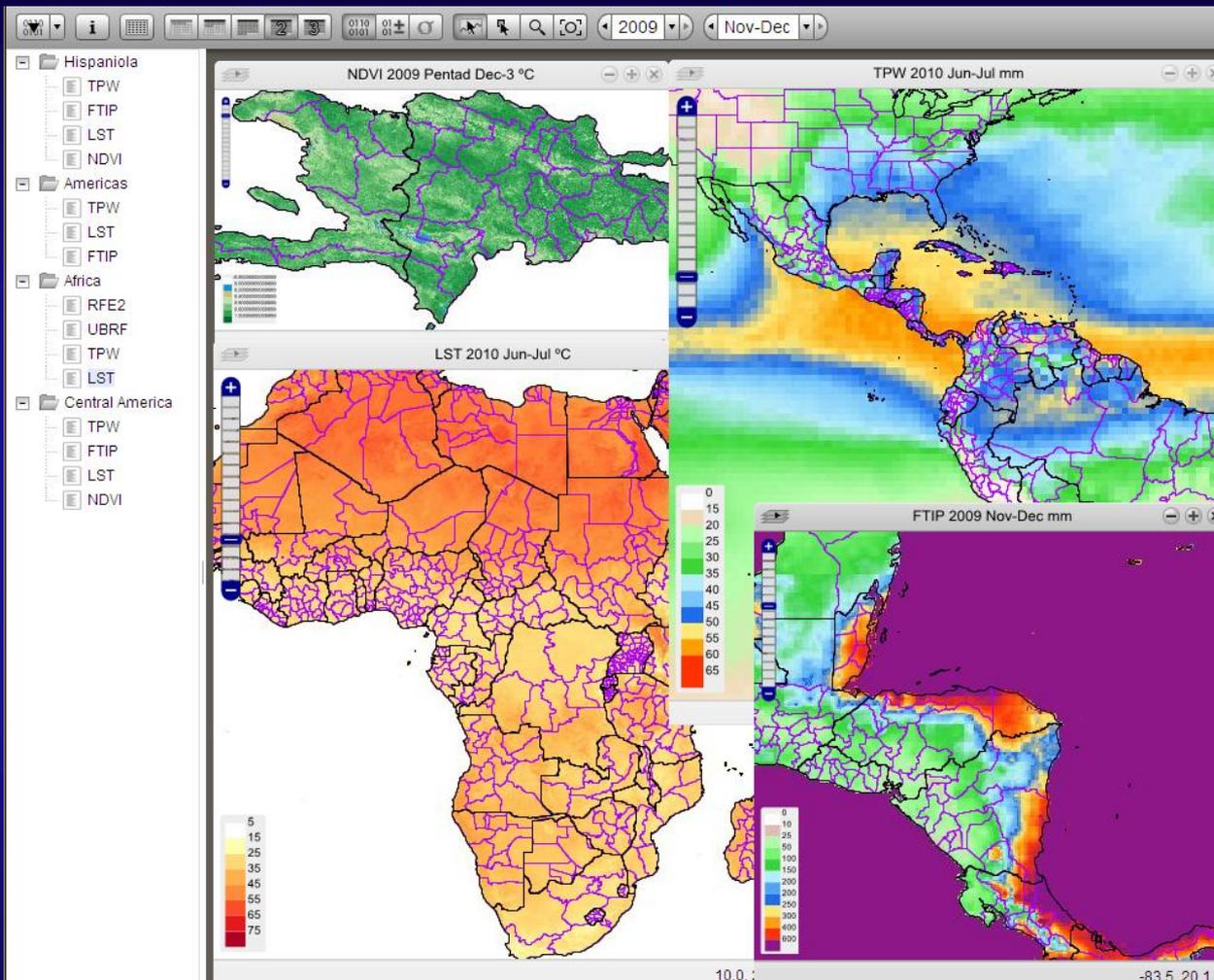
FEWS NET Remote Monitoring (Africa, Central America and the Caribbean, South America, Central Asia, Middle East…

Significant geographic expansion

RS info to monitor regions/ecosystems without in-country presence

Rapid comparison of multiple datasets from multiple sensors

Standardized anomaly maps and time series

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EWX – Early Warning eXplorer
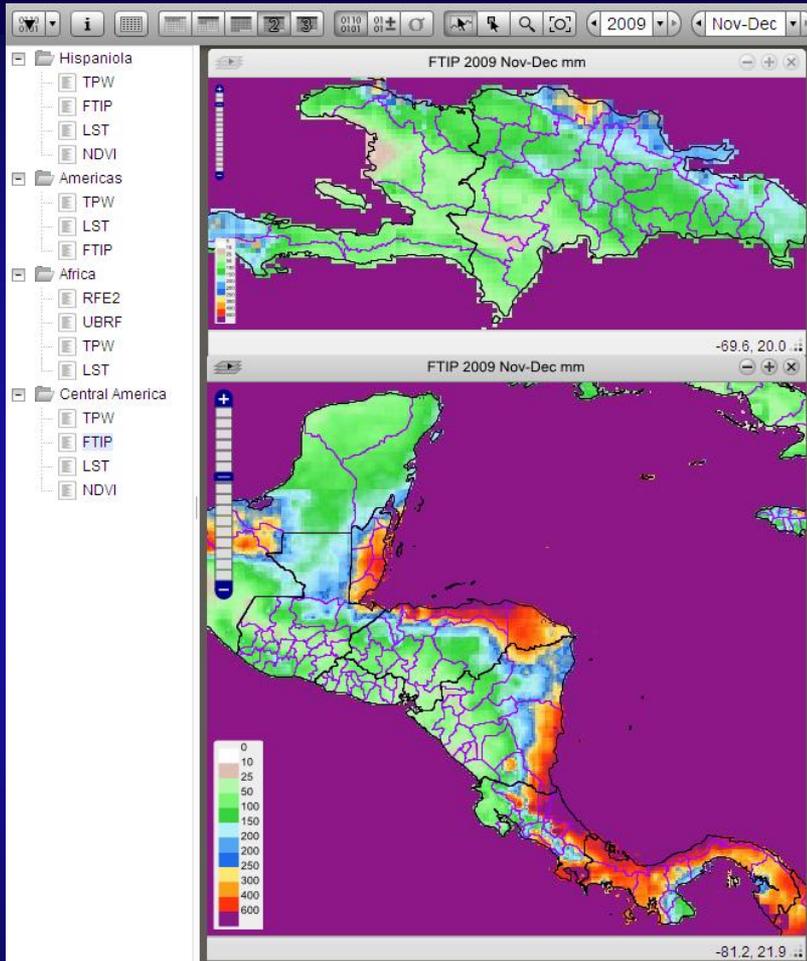
FTIP pentadal rainfall estimate
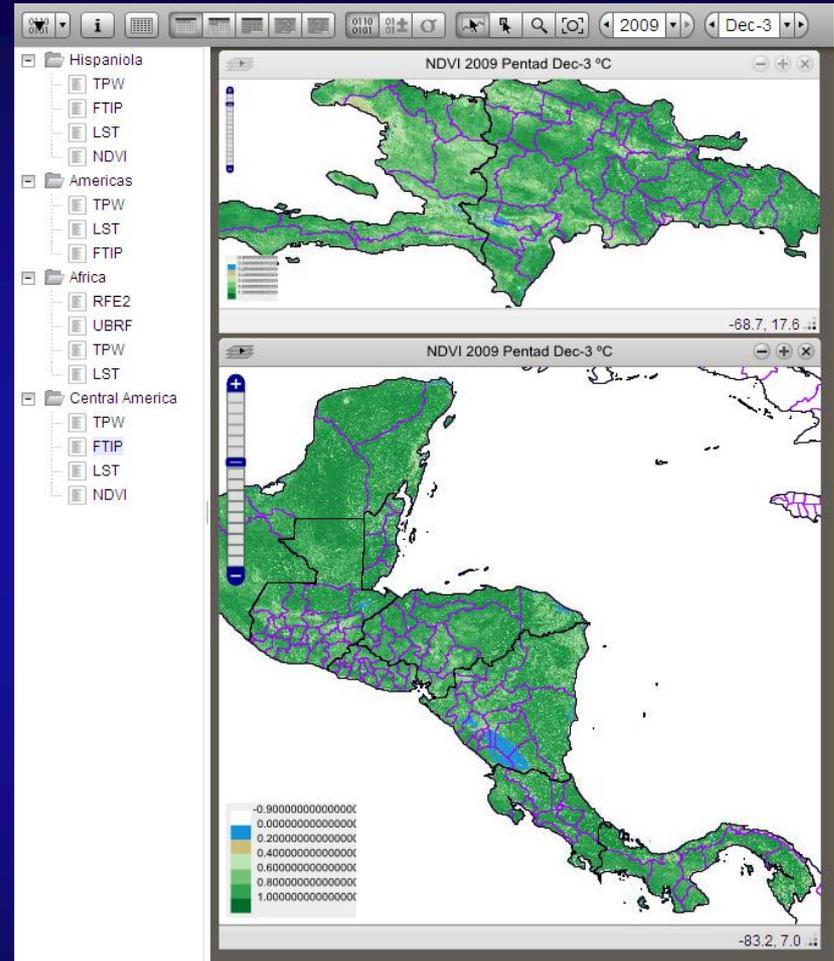
eMODIS: pentadal 10-day composites

≋USGS

eMODIS FEWS NET
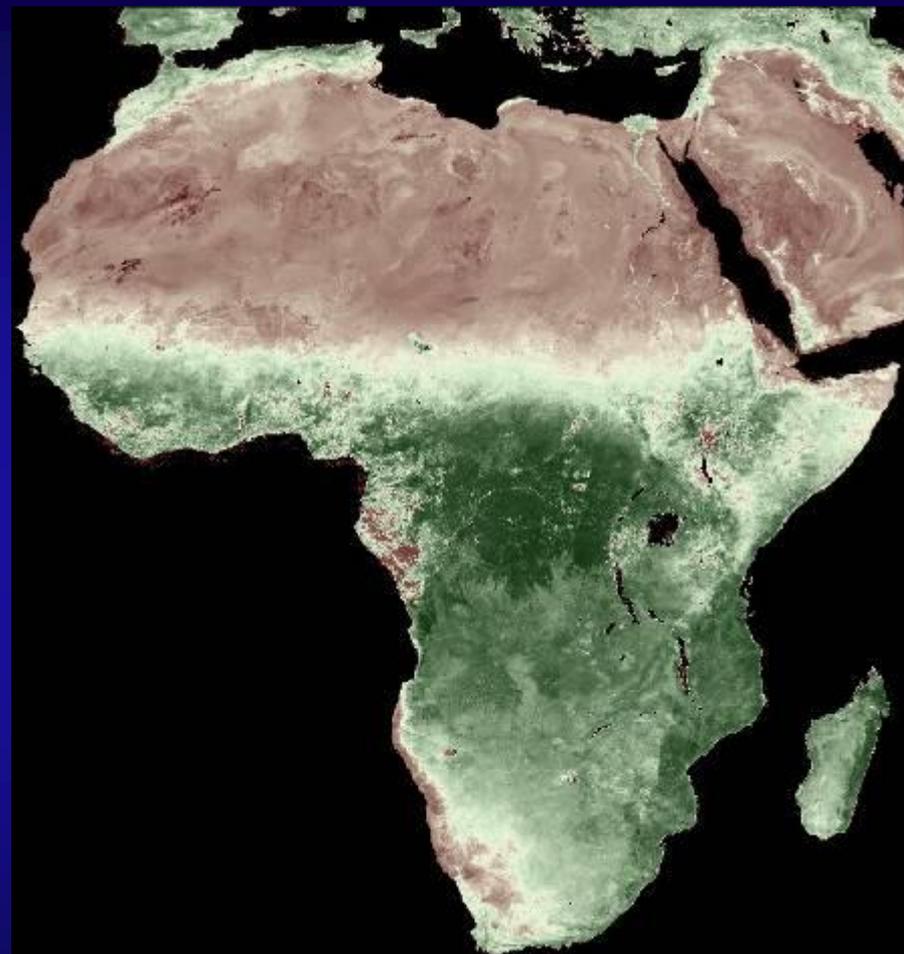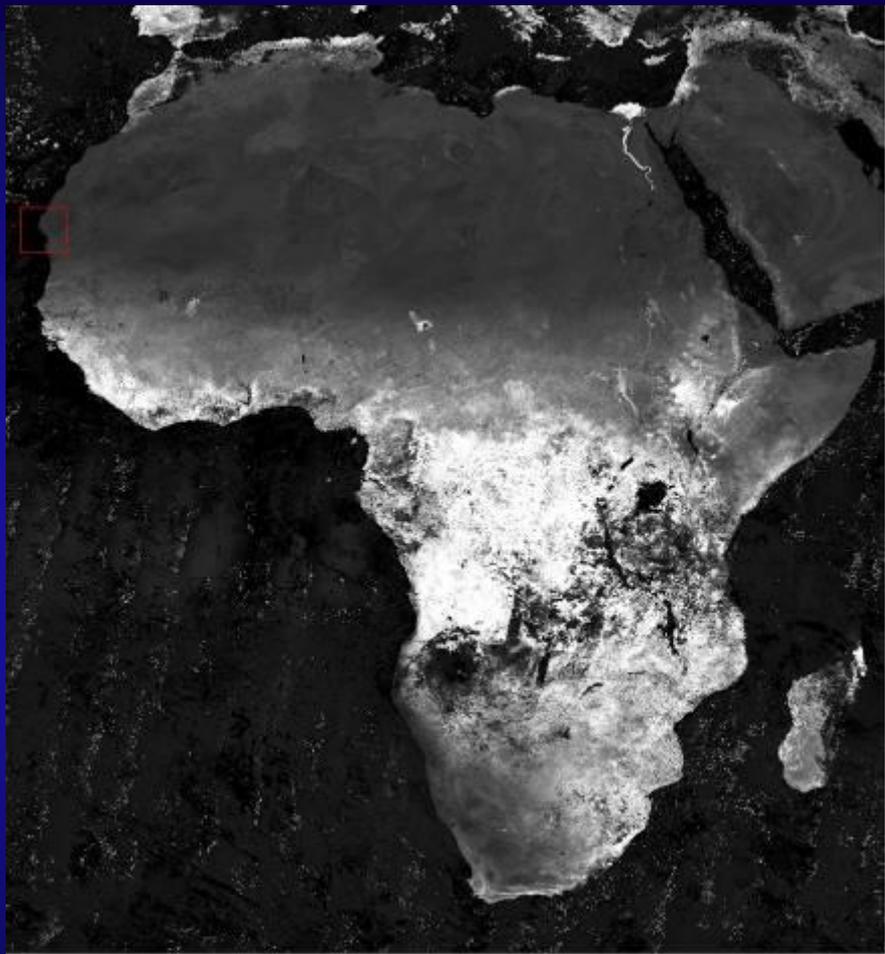
EWX – Early Warning eXplorer
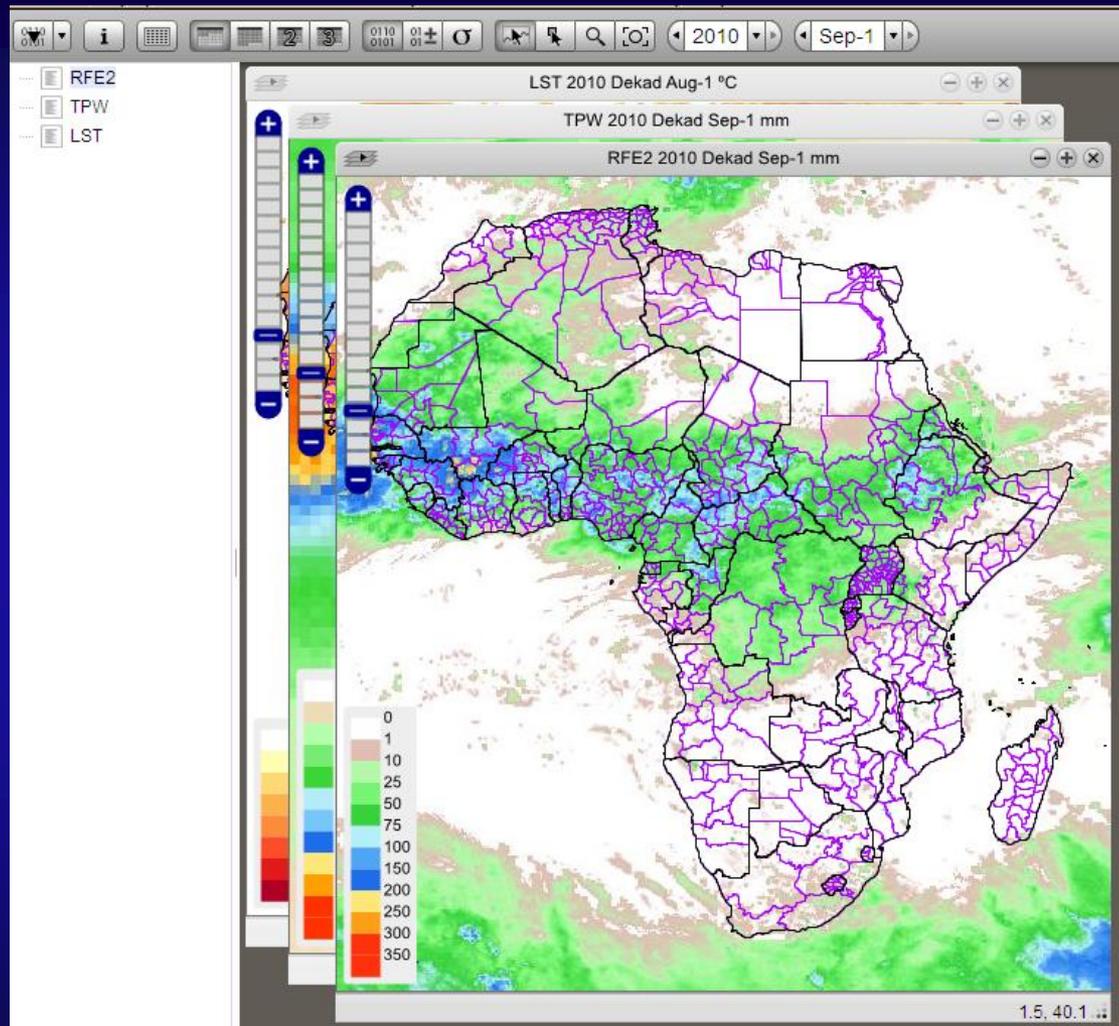
Forecast data

Preparatory analysis and work finished on 1-, 2-, and 3-month forecasts for RFE, TPW, and LST

Waiting for viable MODIS NDVI product to incorporate into EWX

eMODIS development for Africa scheduled at USGS EROS for FY11

Will add forecast data for all variables when NDVI data are available

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EWX Example: MAM Rainfall
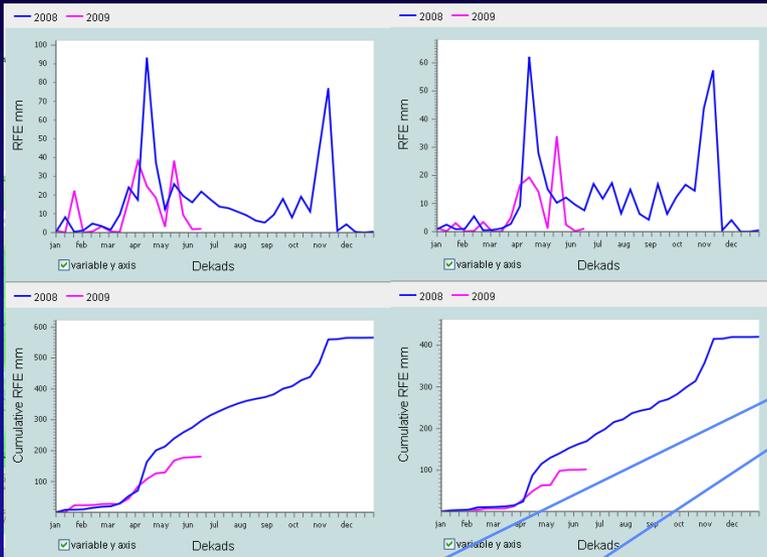
High population and very low Belg rains

March-April-May rainfall performance anomalies [mm]

≋ USGS
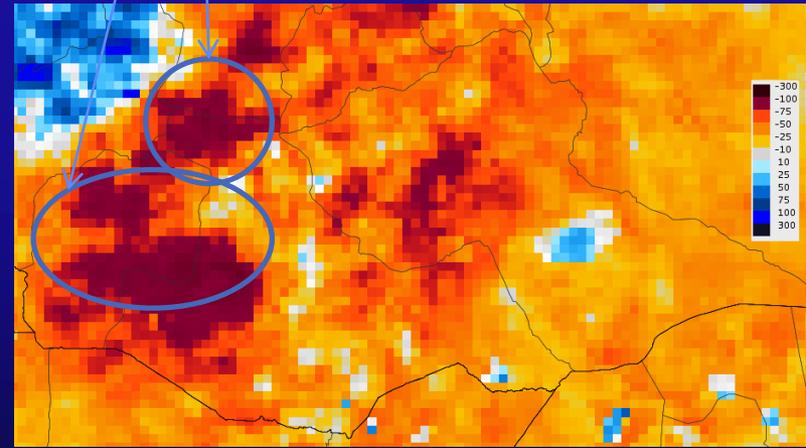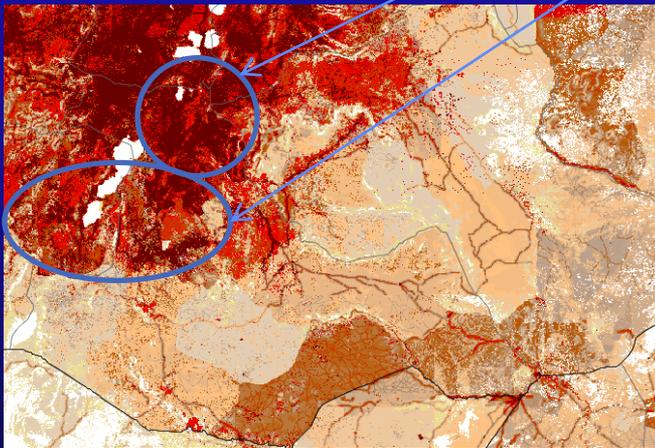
EWX Example: AMJ Rainfall

2008 April-May-Jun RFE   2009 AMJ RFE   2009 AMJ SPI

Precipitation Anomaly (mm)
Based on NOAA/CPC RFE Climatology Method
February 1 2009 – July 28 2009
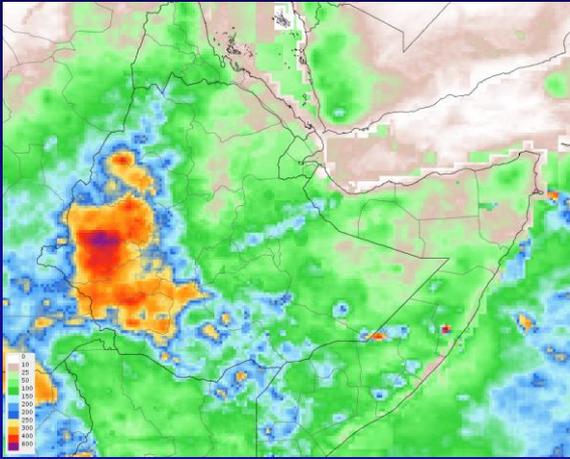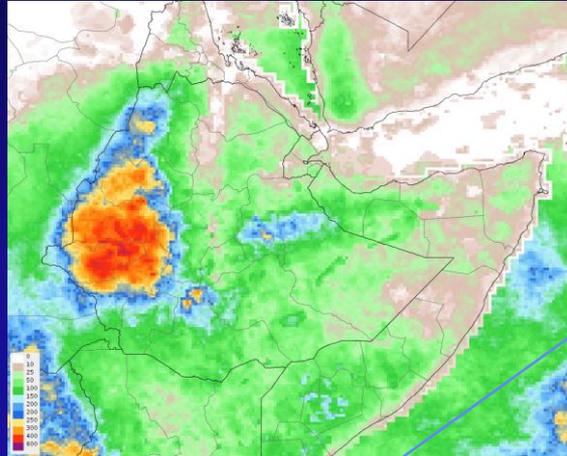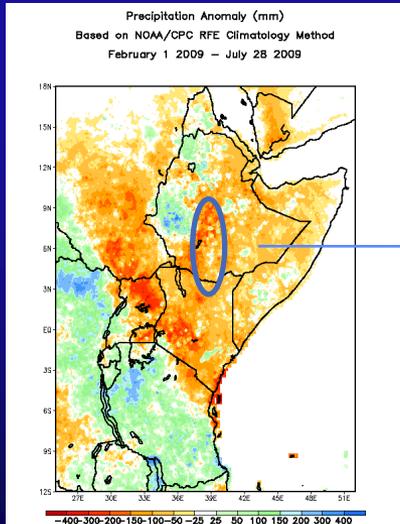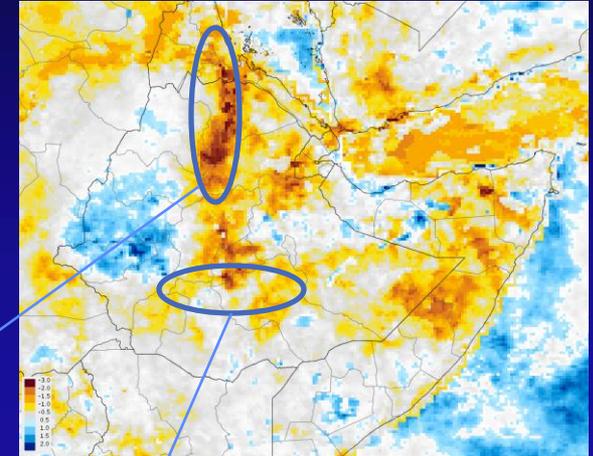
A. Poor rainfall distribution/accumulation over April-May-June period
B. Strong declines in long cycle crops appears likely
C. Biggest concern might be northern portions of Bale and Sidamo, where the rainfall season is almost over

USGS

EWX Example: MJJ Rain/Temp/Pop

Poor rains: May-Jun-Jul 2009
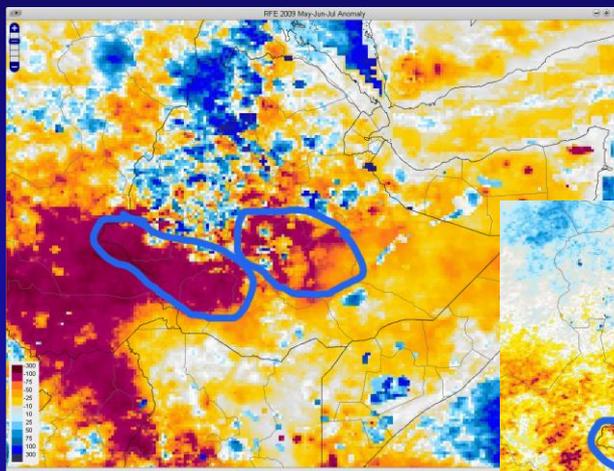
Higher temps, May-Jun-Jul 2009

Population Density (Landscan)

Rainfall Anomaly
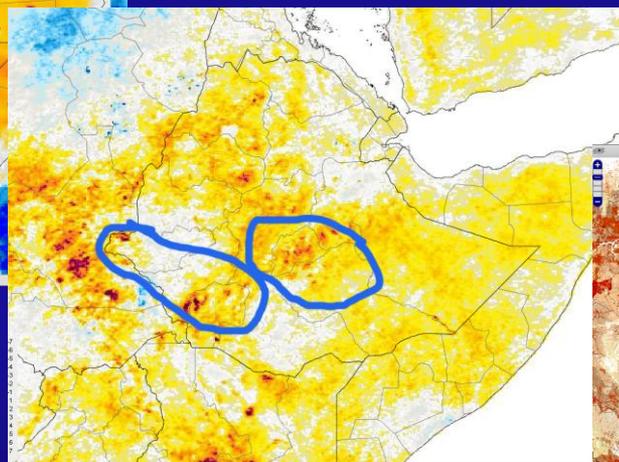
Temperature (LST) Anomaly
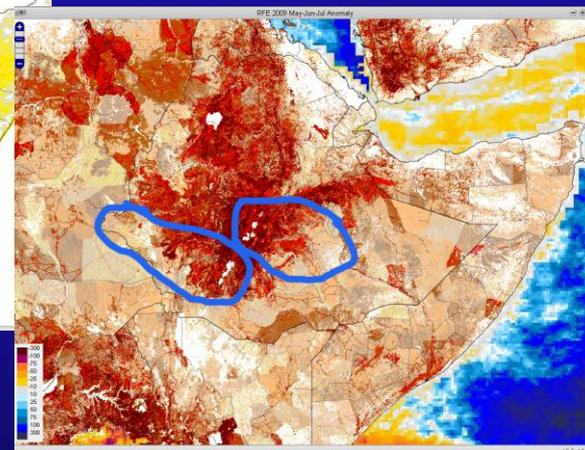
Source: USGS EWX

EWX Example: 2009 Long Rains

- **FEWS NET / Food for Peace (FFP) presentation to the House Foreign Affairs Committee, Oct 2009**
  - **Use of EWX analysis tool – screen downloads**
  - **Outcome – 140 M US$ in aid shipped ~6 months earlier than usual**

Poor rains, March-May 2009   Poor rains, June-July 2009
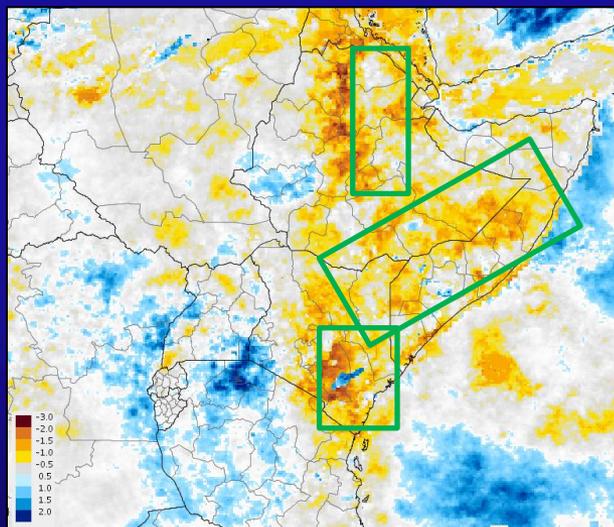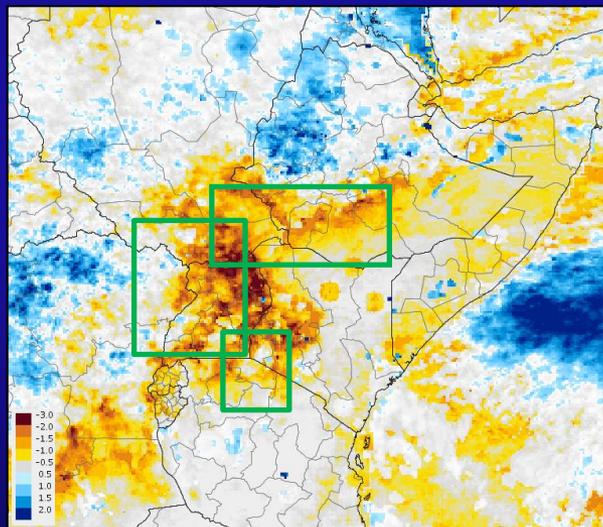
Standardized Precipitation Index

Source: USGS EWX

USGS

Outcome: Earlier & Effective Response
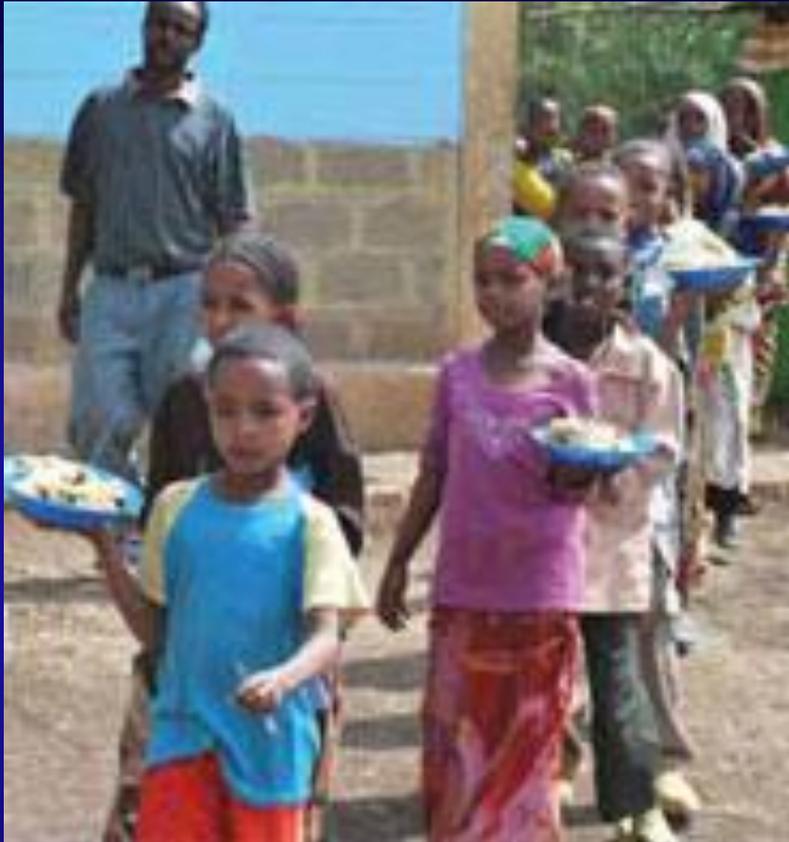
FEWSNET—reports below normal rains…. USAID and U.N. agencies take action to ensure that sufficient stocks are in place, with USAID committing an additional $70 million. [USAID Frontlines, Feb. 2010]

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Famine EW Project Accomplishments

- **Integrated early warning infrastructure developed:**
  - **NOAA RFE2, MODIS LST, AIRS TPW, (MODIS NDVI)**
  - **Data expressed as raw values, anomalies, and SPI values**
  - **Data ingest automated and operational**
- **EWX Software developed**
  - **Interactive display combining raster data, relevant hazard context data, and time series analysis**
  - **Uses Open Source OGC-compliant Geoserver archive**
  - **Automatic updating and time series extraction**

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Enhancing Malaria Early Warning

- Provide enhanced information tools supporting better famine early warning (in Africa) by

  - Integrating rainfall data into the Malaria Early Warning System

  - Integrating temperature data into the Malaria Early Warning System via the Vectorial Capacity (VCAP) model

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Areas at risk of epidemic malaria
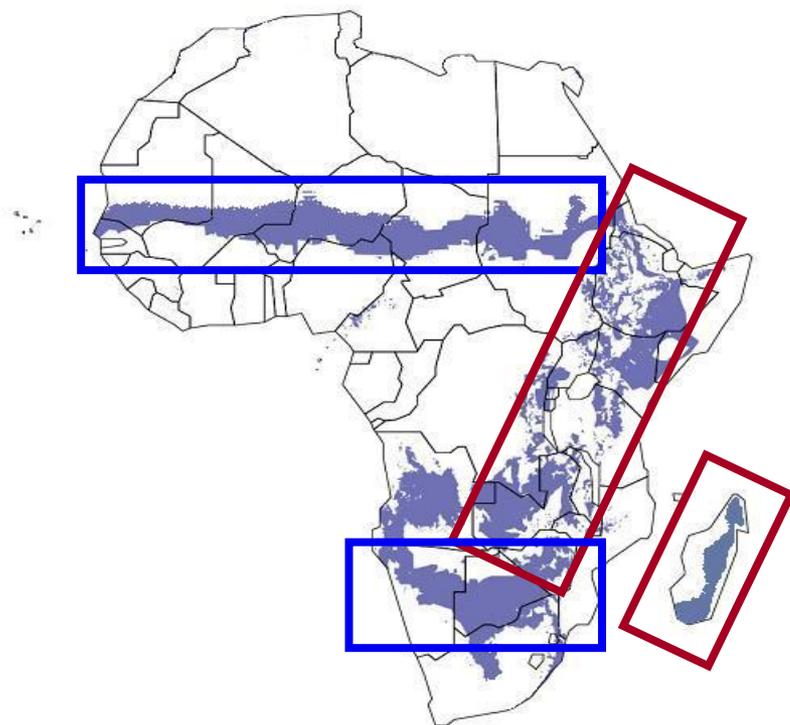
In the warm or seasonally warm lowlands – rainfall is critical

In the highlands both rainfall & temperature are critical factors….

Densely populated and epidemic prone

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Temperature Estimate Study

Daily station data vs.
- Land Surface Temperature (LST), and
- modeled temperature derived from
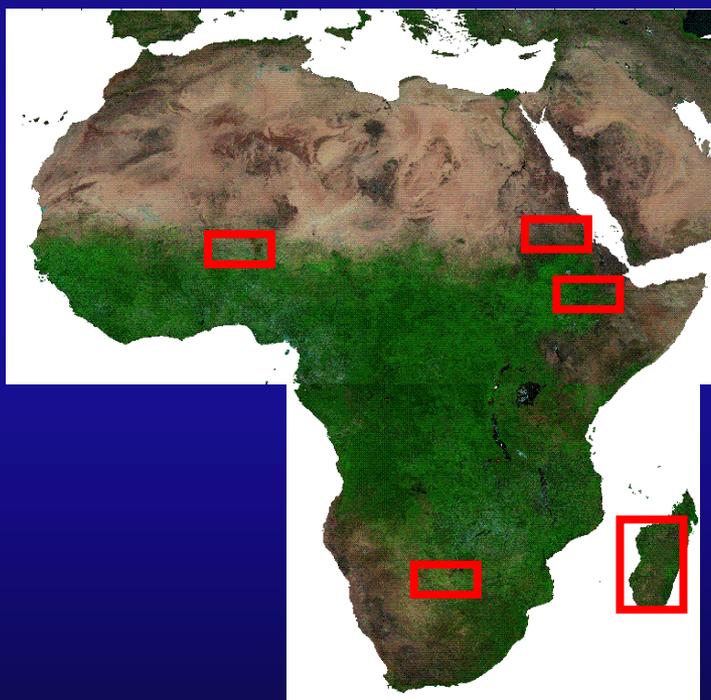
- LST AVHRR: Day – Night (daily) 1995-2000

- LST MODIS TERRA: Day – Night (daily and 8-day composite) 2000-2008

- LST MODIS AQUA: Day – Night (daily and 8-day composite) 2002-2008

- LST METEOSAT: Day – Night (10-day composite) 1995-2005

- MM5: (Daily) 2004-2006

- GFS, GDAS, NCEP reanalysis

Vancutsem, et al RSE (in press)

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Temperature Estimation

Madagascar - Tulear

Legend:
- Ts MODIS Night
- WorldClim Max
- WolrdClim Min
- Ta Station
- Ts+WorldClim drg

Temperature (C)

2002-2008
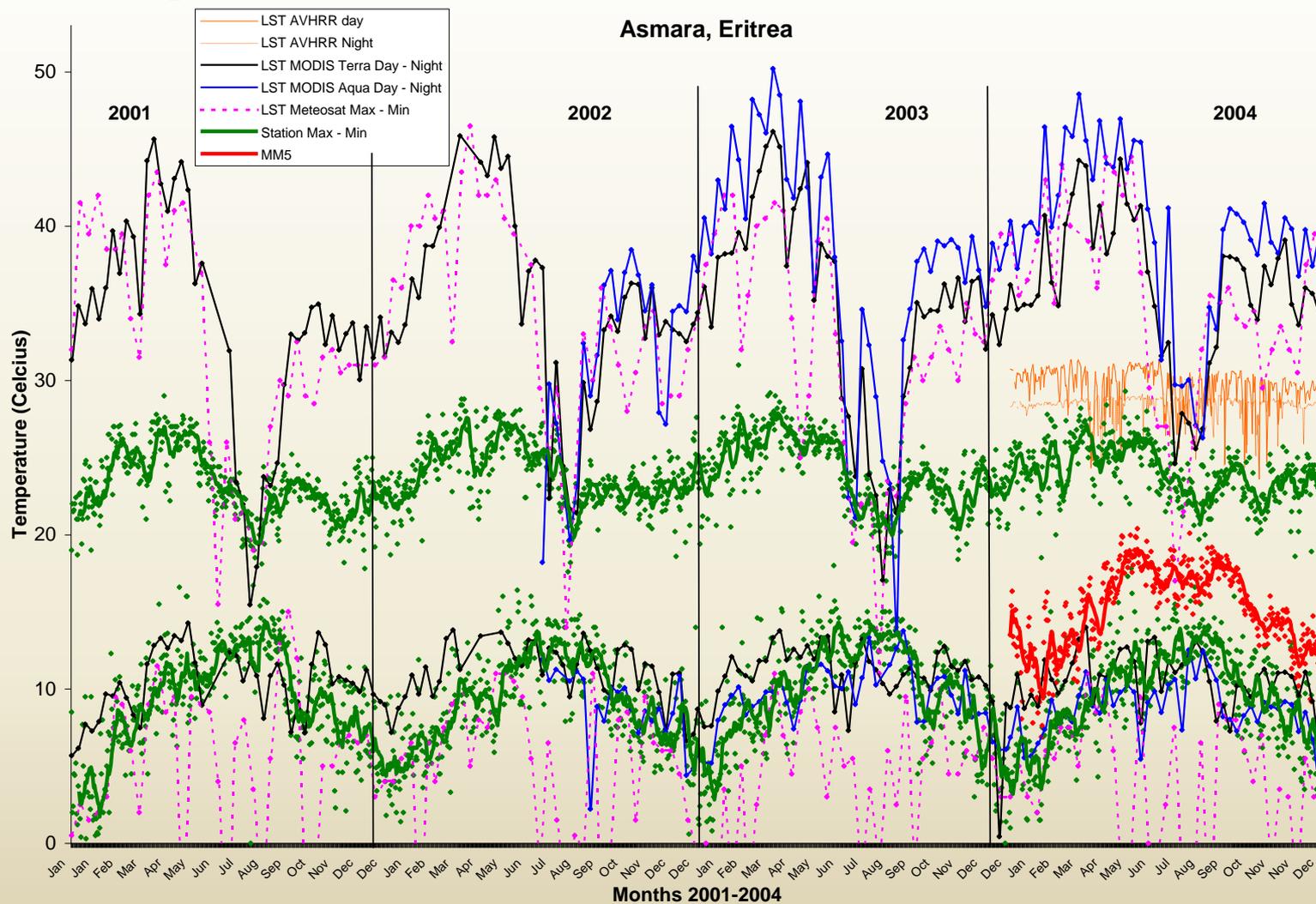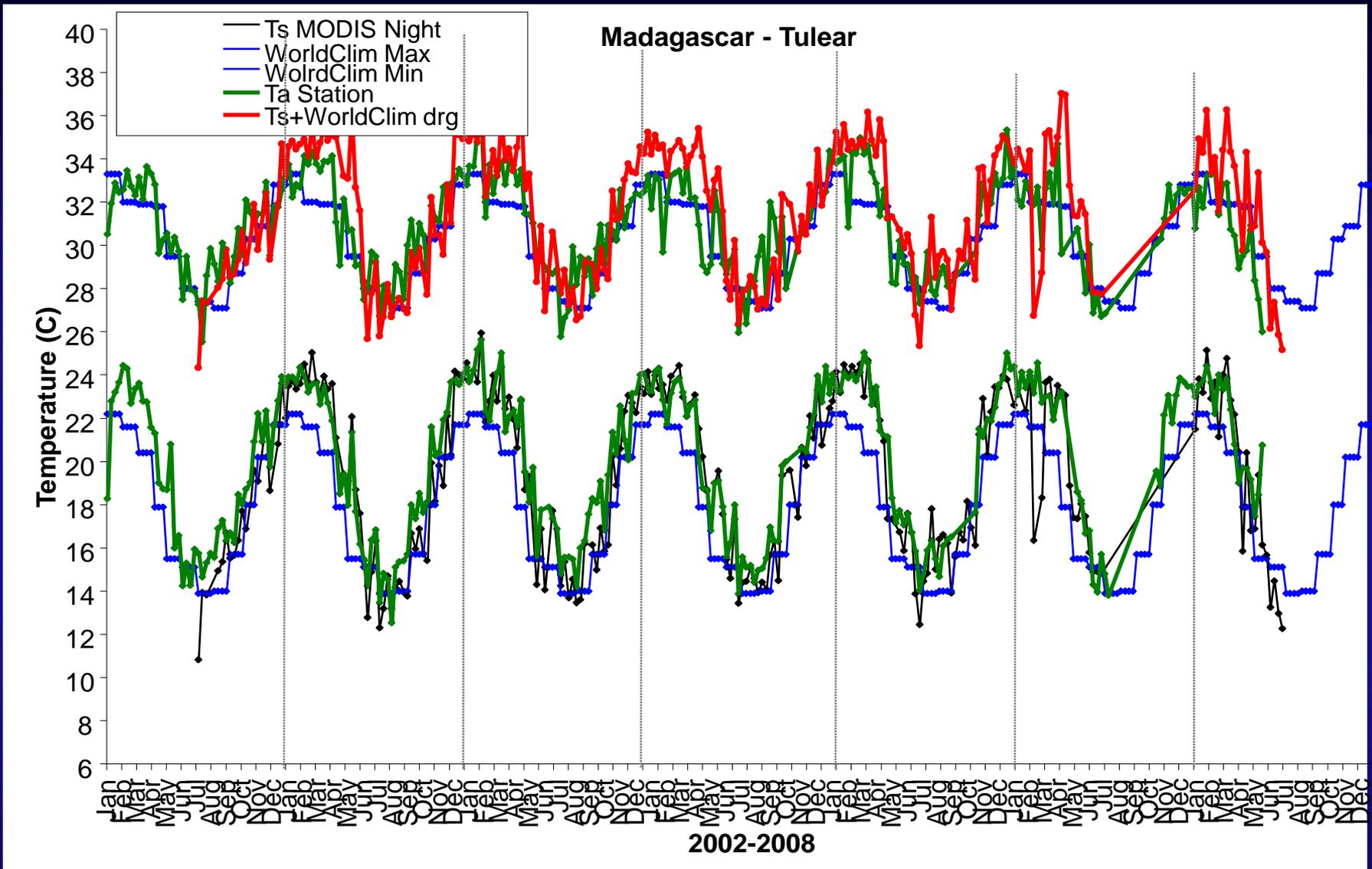
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Malaria: Vectorial Capacity
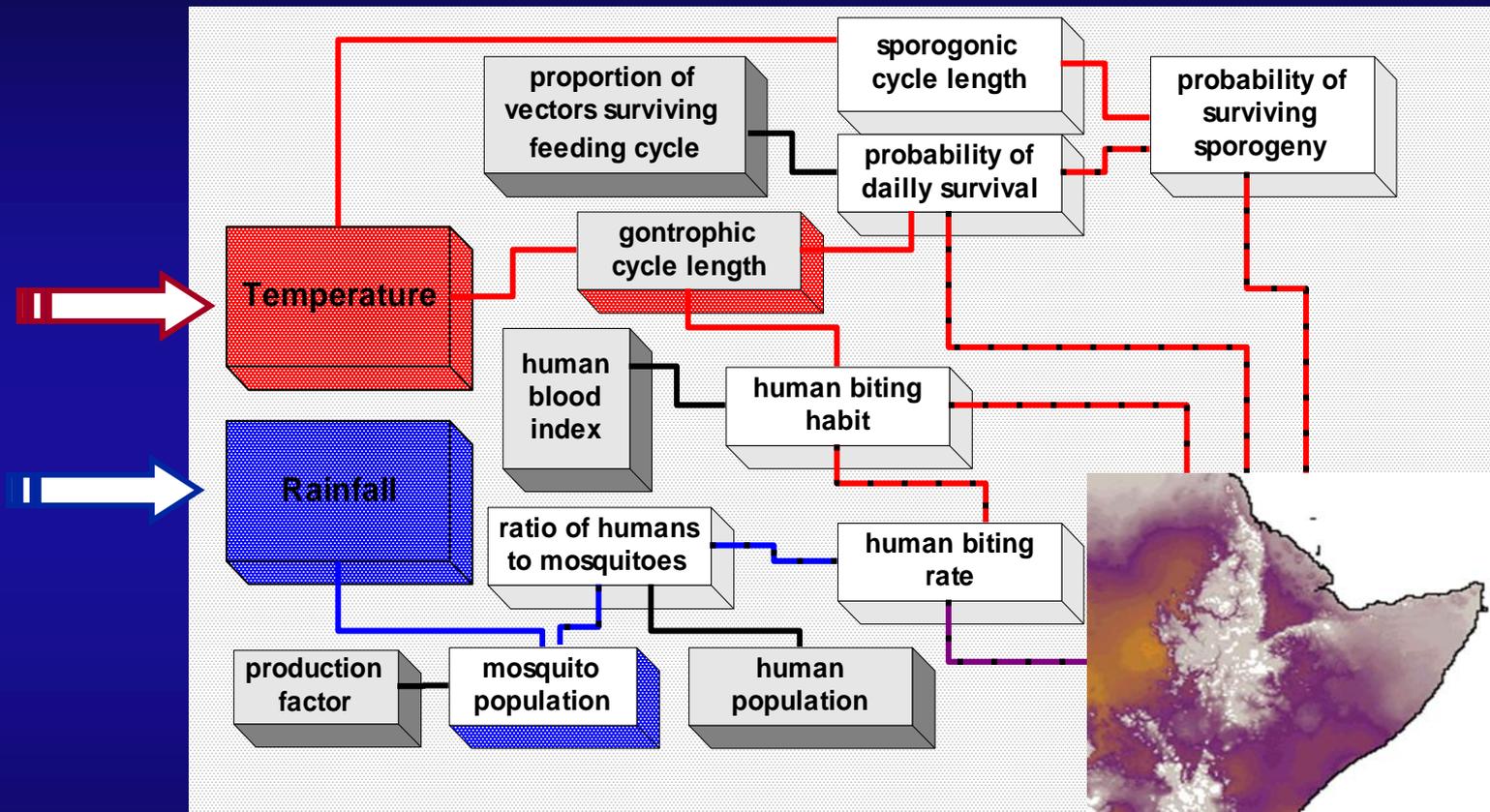
Malaria: Vectorial Capacity model

- 8-day nighttime LST products processed at USGS EROS
  - Standard LP-DAAC product at 1-km resolution
- 8-day TRMM rainfall estimates made from daily estimates
  - Resampled to 1-km resolution (from 0.25 deg)
- LST and TRMM data were processed for 2004 - 2010
- VCAP model run historically for 2004 - 2010
- VCAP model runs in NRT (when LST data are available)
- Climate fields (meteorological forcings) from Sheffield
  - 8-day total precipitation
  - 8-day average minimum temperature
  - 8-day average pressure (to downscale Temperature)
  - VCAP model run for 1990 - 2006

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Enhancing Malaria Early Warning

Malaria Vectorial Capacity model

Dekadal rainfall estimate anomaly

Enhancing Malaria Early Warning

Malaria Vectorial Capacity Model

Dekadal Rainfall Anomaly
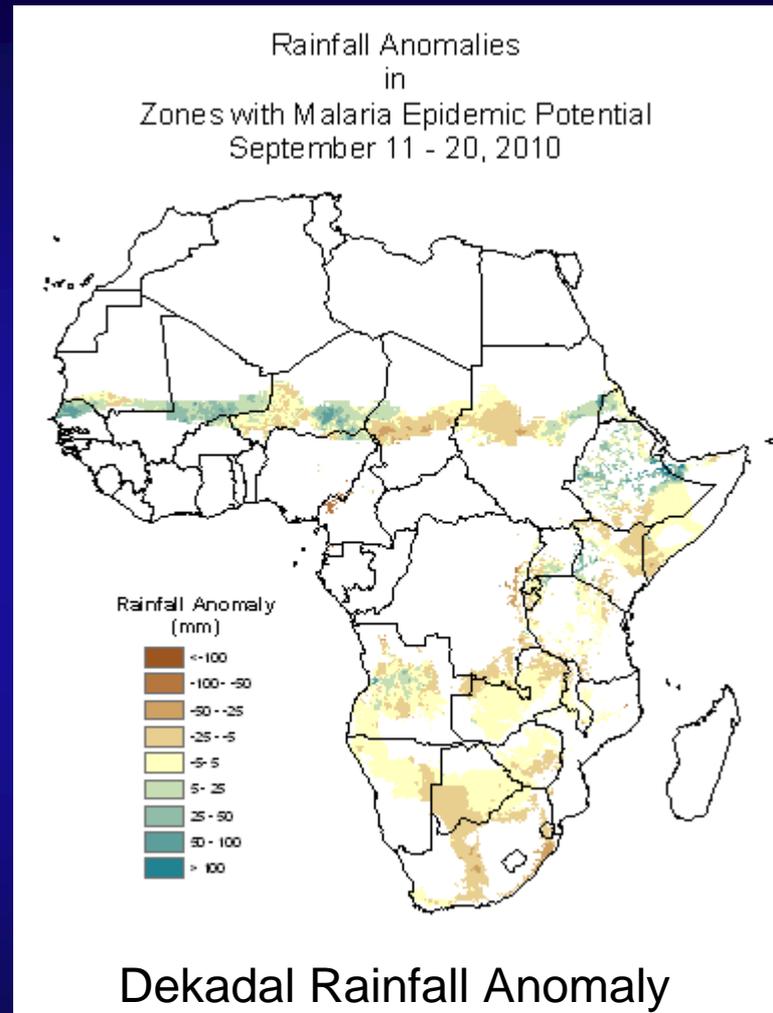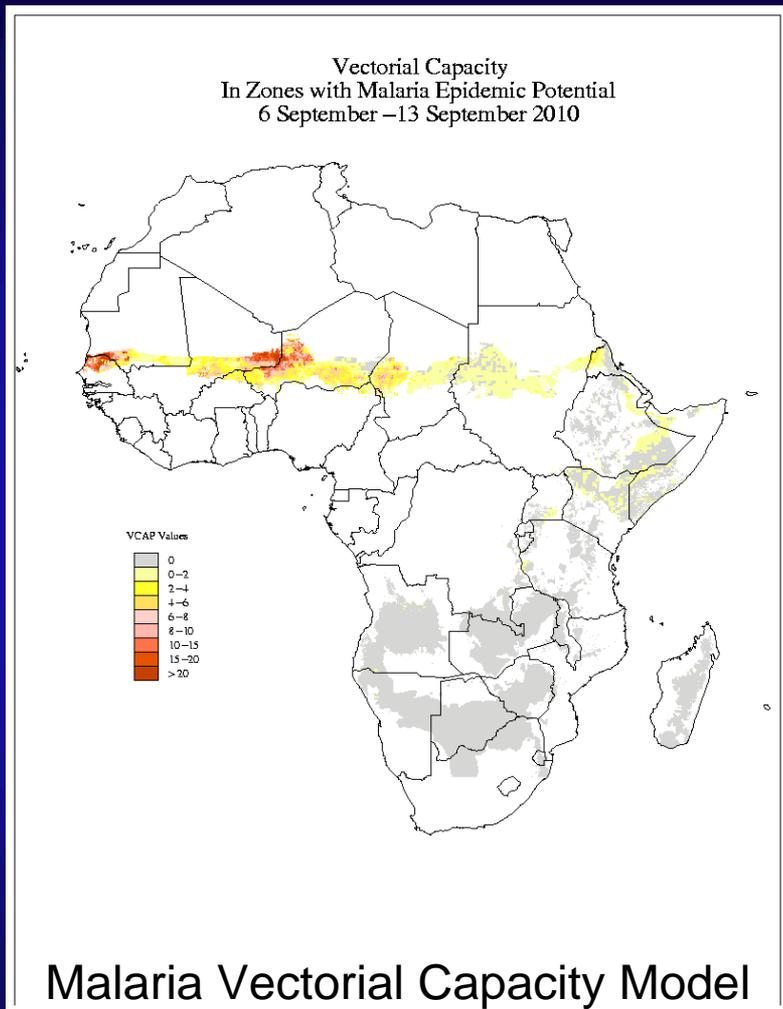
8-Daily VCAP Product

operational 8- daily VCAP via FEWS-NET

…with additional resources on IRI website
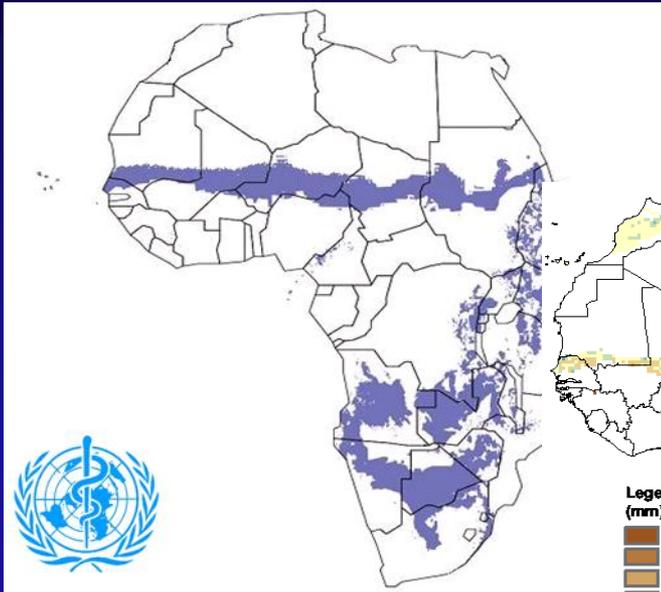
Epidemic Risk Zones (ERZ)

~> RFE anomalies in ERZ

Legend (mm)
< -100
-100 - -50
-50 - -25
-25 - -5
-5 - 5
5 - 25
25 - 50
50 - 100
> 100

~> Vectorial capacity in ERZ

VCAP Values
0
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 15
15 - 20
> 20
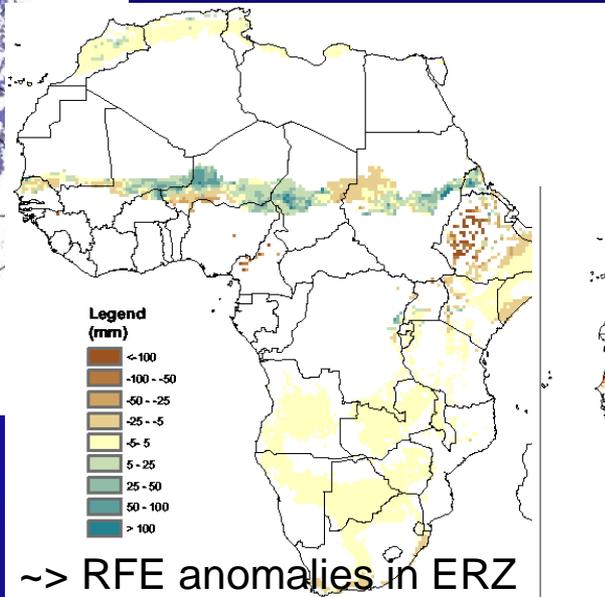
FEWS NET

Africa Data Dissemination Service

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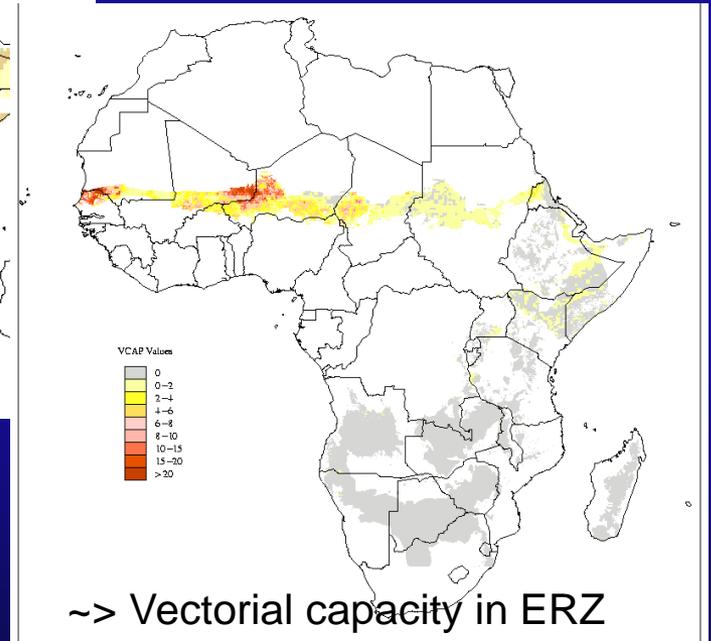
Outputs

☐ **Publications (~10 peer review - research focus)**

☐ **Reports (>25 related publications – including book chapters)**

☐ **Presentations (>30 including U.S., Africa, Asia, Latin America, Europe)**

☐ **Follow on funding (e.g. Google.org project)**

☐ **Trained individuals (cross disciplinary)**

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NASA DSS Publications (FEWS)

- Marshall, M, C. Funk, J. Michaelsen (2010) Agricultural Drought Monitoring with Land Data Assimilation and Remote Sensing, in "Remote Sensing of Drought: Innovative Monitoring Approaches", edited by B. Wardlow, M. Anderson and J. Verdin, Under Review

- Marshall, M., K. Tu, C. Funk, J. Michaelsen (2010) Assimilation of Remote Sensing and Surface Reanalysis for Monitoring Evapotranspiration, Remote Sensing of Environment, Under Review

- Knapp, K.R. , S. Ansari, C., L. Bain , M. A. Bourassa , M. J. Dickinson , C. Funk , C. N. Helms , C. C. Hennon4, C. Holmes , G. J. Huffman , J. P. Kossin, H-Tien Lee , A. Loew , G. Magnusdottir (2010) Globally gridded satellite (GriSat) observations for climate studies, Bulletin of the American Meteorological Society, Under Review

- Funk, C, Verdin, J.P. (2009) Real-Time Decision Support Systems: The Famine Early Warning System Networ. in Gebremichael M, Hossain F, eds., 2010, Satellite Rainfall Applications for Surface Hydrology. Springer, Netherlands, pp. 295-320.

- Husak, G. J., J. Michaelsen, P. Kyriakidis, J. P. Verdin, C. Funk and G. Galu (2009) The Forecast Interpretation Tool - extracting value from probabilistic forecasts, Int. J. of Climatology.

- Funk C. and Verdin, J. (2009) Real-time Decision Support Systems: The Famine Early Warning System Network (2009) Chapter 17 for: Satellite Rainfall Applications for Surface Hydrology, by Springer-Verlag. Edited by Gebremichael MeKonnen and Faisal Hossain. In press. ftp://chg.geog.ucsb.edu/pub/pubs/RealtimeDSS_for_FEWS_NET_wfigs_v5.pdf

- Peters-Lidard CD, JD Bolten, ME Brown, C Funk, M Rodell, DL Toll, JP Verdin (2009) Satellite-Based Assessment of Water Resources and Agricultural Productivity,Conference Proceedings, Water and Agriculture | Implications for Development and Growth, Johns Hopkins School of Advanced International Studies, March 30, 2009, Washington DC, http://www.sais-jhu.edu/water/conference/proceedings/gems/20090330_WA_Tech_4.pdf

- Funk C. (2009) New satellite observations and rainfall forecasts help provide earlier warning of drought in Africa. The Earth Observer. http://earlywarning.usgs.gov/adds/pubs/Funk_EarthObserver_Jan_Feb09.pdf.

- Funk C. and M. Budde (2009) Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe. Remote Sensing of Environment. 113:115-125. ftp://hollywood.geog.ucsb.edu/pub/pubs/NDVIbasedProductionEstimatesForZimbabwe.pdf.

DSS Publications (FEWS) [cont.]

- Brown M. and C. Funk (2009) Early Warning of Food Security Crises in Urban areas: the Case of Harare, Zimbabwe, 2007, Geospatial Techniques in Urban Hazard and Disaster Analysis (Geotechnologies and the Environment). In Press.

- Brown M. and C. Funk (2009) Early Warning of Food Security Crises in Urban areas: the Case of Harare, Zimbabwe, 2007, Geospatial Techniques in Urban Hazard and Disaster Analysis (Geotechnologies and the Environment). In Press.

- Funk, C., M.D. Dettinger, M.E. Brown , J.C. Michaelsen, J.P. Verdin, M. Barlow, and A. Hoell (2008) Warming of the Indian Ocean threatens eastern and southern Africa, but could be mitigated by agricultural development, *Proc. of the Nat. Academy of Sci*. 105, 11081–11086. http://earlywarning.usgs.gov/adds/pubs/WarmingInTheIndianOceanThreatensEasternAndSouthernAfrica.pdf

- Husak, G., M.T. Marshall, J. Michaelsen, D. Pedreros, D., C. Funk, G. Galu, (2008) Crop area estimation using high and medium resolution satellite imagery in areas with complex topography. *J. of Geo. Res.,* 113, D14112, doi:10.1029/2007JD009175. ftp://hollywood.geog.ucsb.edu/pub/pubs/CropAreaEstimationUsingSatellites_GRL_2008.pdf

- Husak, G., Michaelsen, J., Funk, C., (2007) Use of the Gamma Distribution to Represent Monthly Rainfall in Africa for Drought Monitoring Applications, *Int. J. of Clim.* 27(7): 935-944. ftp://hollywood.geog.ucsb.edu/pub/pubs/Husak_IJOC_2007.pdf

- Funk C. & M. Budde, (2007) National MODIS NDVI-based production anomaly estimates for Zimbabwe, Crop and Rangeland Monitoring Workshop, Nairobi, March 2007. Extended Abstract. ftp://hollywood.geog.ucsb.edu/pub/pubs/CRAM_2007_MODIS_NDVI_zimbabwe.pdf

- Funk, C., Verdin, J., and Husak, G., 2006, Integrating observation and statistical forecasts over sub-Saharan Africa to support Famine Early Warning, AMS meeting, Nov. 2006, Extended Abstract. ftp://hollywood.geog.ucsb.edu/pub/pubs/AMSabstract2006_119819.pdf

≋USGS

DSS Publications (FEWS) [cont.]

- **Brown, M. E**., De Beurs, K. M. & Vrieling, A. (2010) The response of African land surface phenology to large scale climate oscillations. Remote Sensing of Environment v.114 (10), pp. 2286-2296.

- **Brown, M.E**. (2010) 'Review of Remote Sensing Needs and Applications in Africa', report published in 2007 by the USGS, prepared by James Rowland, Eric Wood and Larry L. Tieszen. African Geographical Review, vol 29, issue 1, pp 104-108.

- **Brown, M.E**. (2010) Climate Change, Nutrition and Food Security in sub-Saharan Africa. SCN News, vol 38, p 32-36. ISSN 1564 – 3743

- **Brown, M.E**., B. Hintermann, N. Higgins (2009) Markets, Climate Change and Food Security in West Africa, Environmental Science and Technology 43 (21), pp 8016–8020. DOI: 10.1021/es901162d

- K W Ross, **M E Brown, J Verdin** and L W Underwood (2009) Review of FEWS NET biophysical monitoring requirements, Environmental Research Letters. 4 (2009) 024009 (10pp) doi: 10.1088/1748-9326/4/2/024009

- **C. Funk and M.E. Brown** (2009) Declining Global per Capital Agricultural Capacity and Warming Oceans Threaten Food Security, Food Security Journal doi: 10.1007/s12571-009-0026-y

- **Brown, M.E**. (2009) 'Food Security, Decision Making and the use of Remote Sensing in Famine Early Warning Systems', Geography Compass. 3(4): 1381–1407

- **Brown, M.E., C.C. Funk, J.Verdin**, and G. Eilerts (2008) Ensuring Food Security (in Letters). *Science* 320 (5876): 611-612. DOI: 10.1126/science.320.5876.611

- **Brown M.E. and C.C. Funk** (2008) Food Security under Climate Change. Science 319 (5863): 580 - 581. DOI: 10.1126/science.1154102

- **Brown, M.E**. and K. de Beurs (2008) Evaluation of Multi-Sensor Semi-Arid Crop Season Parameters Based on NDVI and Rainfall. Remote Sensing of Environment 112(5): 2261-2271. doi:10.1016/j.rse.2007.10.008

- **Brown, M. E**., J. E. Pinzon and S.D. Prince (2008) Using Satellite Remote Sensing Data in a Spatially Explicit Price Model. Land Economics 84(2): 342–359.

- **Brown, M.E., Funk, C.C**., Galu, G. and Choularton, R. (2007) Earlier Famine Warning Possible Using Remote Sensing and Models. EOS, Transactions of the American Geophysical Union 88(39): 381–382.

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Project Team

Thank you