

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

Annual Report
October 1, 2007 – September 30, 2008

A mid-project coordination meeting was held May 21-22, 2008, at the NOAA Earth Systems Research Laboratory in Boulder, Colorado. The meeting provided the group with the opportunity to review accomplishments and progress against the Year One Work plan, and to identify new points of synergy and cooperation. A special emphasis was placed on the transition to operations. We finalized plans for the last two quarters of the year and coordinated data requirements among participating organizations. Following is a summary of progress in each area, with identification of the responsible partner organization.

Malaria Early Warning

1. **Vectorial Capacity Model:**

Development and production of 10-daily Vectorial Capacity products has been undertaken and to date we have four years (2004-2006) of these products completed. Back processing of the total requirement of 10 years is underway. To assemble the necessary inputs, we are in the process of generating unbiased rainfall estimates for the remaining years. We are also investigating the availability of temperature and atmospheric data for the same time period. Testing of these products is due to begin soon, which will set the stage for making prospective monitoring products. **(USGS)**

2. **Rainfall/Temperature Estimate and Anomaly Mapping:**

Further research has been carried out (and is ongoing) with respect to inter-comparison of higher spatial and temporal resolution rainfall estimation products – see paper by Dinku, et al. 2008. This work has required similar comparative analysis of various available gridded rainfall products for Africa also – paper by Dinku, et al. 2008. Significant advances have been made in comparison of various temperature estimate products and this study is in process of being written up for publication **(IRI)**

3. **User Workshops:**

Following the establishment of the Climate-Health Working Group (CHWG) in February 2008, the CHWG recently held a 3 day Science and Technical Meeting to elicit research needs and information product needs to enable more effective

epidemic prevention and control. Presentations were given on: Climate-sensitive diseases; and Use of climate information for Malaria Early Warning. A summary of this workshop was reported in the United Nations Environmental Programme Newsletter, "Addis Ababa Highlights", Vol 5, No10. **(IRI)**

4. **Data Collection:**

Updates of daily rainfall and temperature data have been obtained from five African countries where we have malaria data. These are being used to test the VCAP products. **(IRI)**

5. **Other:**

We were involved in collaborative activities regarding the dissemination of MEWS products through NASA's SERVIR-Viz and WorldWind products. This activity included the incorporation of a menu item in SERVIR-Viz which allows direct online access to information products produced in IRI's Data Library and Map Rooms. We have also been in discussion with Google regarding the potential for dissemination of the products using Google Earth.

We are involved in MEWS projects beyond Africa also – Sri Lanka in Asia and Colombia in Latin America. Relevant activities during this reporting period include joint publications and training as outlined below. **(IRI)**

6. **Publications (project and related):**

Ghebreyesus, T.A., Tadesse, Z., Jima, D., Bekele, E., Mihretie, A., Yihdego, Y.Y., Dinku, T., Connor, S.J., Rogers, D.P. (2008): Public Health Services and Public Weather Services: Increasing the Usefulness of Climate Information in the Health Sector, WMO Bulletin, 000-000.

Zubair, L., Galappaththy, G.N., Yang, H., Chandimala, J., Yahiya, Z., Amerasinghe, P., Ward, N. and S.J. Connor (2008): Epochal changes in the association between malaria epidemics and El Nino in Sri Lanka, Malaria Journal 2008, 7:140

Connor, S.J., T. Dinku, T Wolde-Georgis, Endalkachew Bekele, Daddi Jima, (2008): A collaborative Epidemic Early Warning & Response initiative in Ethiopia. In proceedings of International Symposium on PWS: A Key to Service Delivery, Geneva, 3-5 December 2007, World Meteorological Organization, Geneva. pages 166-171.

Dinku, T., S. Chidzambwa P. Ceccato, S.J. Connor and C.F. Ropelewski (2008): Validation of high resolution satellite rainfall products over complex terrain in Africa . *International Journal of Remote Sensing*, 29 (14) 4097-4110.

Dinku, T., S.J. Connor, P. Ceccato, and C.F. Ropelewski (2008) Intercomparison of global gridded rainfall products over complex terrain in Africa, *International Journal of Climatology*, DOI: 10.1002/joc.1669 www.interscience.wiley.com

Connor,S.J., Thomson,M.C. Menne,B. (2008) Seasonal Climate Forecasting for Health. In M. C. Thomson, R. Garcia-Herrera, and M. Beniston, Eds, *Seasonal Forecasts, Climatic Change and Human Health, Advances in Global Change Research (AGLO)*, Springer, Dordrecht, 1-4.

Connor,S.J.,Mantilla,G.C. (2008) Integration of Seasonal Forecasts into Early Warning Systems for Climate-Sensitive Diseases such as Malaria and Dengue. In M. C. Thomson, R. Garcia-Herrera, and M. Beniston, Eds, *Seasonal Forecasts, Climatic Change and Human Health, Advances in Global Change Research (AGLO)*, Springer, Dordrecht, 71-84.

Ruiz, D., S. Connor, and M. Thomson (2008). *Malaria Modelling and Integrated Surveillance and Control Systems*. In: *Dinamica de Sistemas - Casos y aplicaciones en Latinoamerica. Parte III: Aplicaciones en Politica Publica*. Isaac Dyner and Luisa Rodriguez (ed). System Dynamics Society - Capitulo Latinoamericano. ISBN 978-958-44-3260-5. Pages: 314-326.

Ruiz,D., Connor,S.J., Thomson,M.C. (2008) A Multimodel Framework in Support of Malaria Surveillance and Control. Thomson, R. Garcia-Herrera, and M. Beniston, Eds, *Seasonal Forecasts, Climatic Change and Human Health, Advances in Global Change Research (AGLO)*, Springer, Dordrecht, 101-126.

Thomson,M.C., Connor,S.J., Menne,B. (2008) Recent Developments and Next Steps in Seasonal Forecasting and Health. In M. C. Thomson, R. Garcia-Herrera, and M. Beniston, Eds, *Seasonal Forecasts, Climatic Change and Human Health, Advances in Global Change Research (AGLO)*, Springer, Dordrecht, 127-130.

Kinney, P.L., Garcia-Herrera,R., Connor,S.J. (2008) Recent Developments and Next Steps in Climate Change and Health. In M. C. Thomson, R. Garcia-Herrera, and M. Beniston, Eds, *Seasonal Forecasts, Climatic Change and Human Health, Advances in Global Change Research (AGLO)*, Springer, Dordrecht, 203-206.

Ross,K.W., Brown,M.E., Connor,S.J., Verdin,J.P., Ceccato,P.N., Funk,C.C (2008) Decision Support Evaluation Report for USAID Famine and Malaria Early Warning Systems. NASA Technical Memorandum NASA/CR—2007—000000.

Ceccato, P., Bell, M.A., Dinku, T., Connor, S.J. (2007). Application of remote sensing technologies for monitoring human health. In: The Full Picture, Published by Tudor Rose on behalf of the Group on Earth Observations (GEO) ISBN 978-92-990047-0-8, pp: 184-187

Ceccato, P., Ghebremeskel, T., Jaiteh, M., Graves, P.M., Levy, M., Ghebreselassie, S., Ogbamariam, A., Barnston, A.G., Bell, M., Del Corral, J., Connor, S.J., Fesseha, I., Brantly, E.P., Thomson, M.C., (2007). Malaria Stratification, Climate and Epidemic Early Warning in Eritrea. American Journal of Tropical Medicine and Hygiene 77: 61-68

Cuevas, L.E., Jeanne, J., Molesworth, M., Bell, M., Savory, E.C., Connor, S.J., and Thomson M.C. (2007). Risk mapping and early warning systems for the control of meningitis in Africa Vaccine 25S (2007) A12-A17

7. Presentations at international meetings (project and related):

Biloxi, Mississippi, 18-19 Sept, 2008. Participant in NASA's Earth Science Applications Division - Public Health Program Review Meeting.

Nairobi, Kenya, 9-11 Sept, 2008. Presenter and participant in the Climate Health Challenge Dialogue Workshop organized by Google.org and the International Livestock Research Institute (ILRI).

Addis Ababa, Ethiopia, 3-5 Sept, 2008. Presenter and participant in the Science and Technical Meeting of the Climate and Health Working Group (CHWG) of Ethiopia.

Boston, USA, 8-10 May 2008, Harvard School of Public Health, Participation in the Meeting of the Strategic and Technical Advisory Group on Malaria: Evaluating Malaria Burden, Trends and the Impact of Control Programmes. Sponsored by the World Health Organization.

Addis Ababa, Ethiopia, 24 Feb - 7th March 2008, Presentations in joint IRI-AMA (Anti-Malaria Association) Workshop on "Climate Matters in Health" followed by the "Science with Africa" Conference hosted by the UN Economic Commission for Africa.

Geneva, Switzerland, 3-5 December 2007, Invited speaker presenting "A collaborative Epidemic Early Warning & Response initiative in Ethiopia," at the International Symposium on Public Weather Services: A Key to Service Delivery, World Meteorological Organization.

Bergen, Norway, 20-21 November 2007, Invited speaker/facilitator at a Workshop on Climate and Health in the Nile River Basin, Nile Basin Research Programme, Global Challenges Centre at the University of Bergen.

Philadelphia, 6 November 2007, Invited speaker "Malaria Early Warning System(MEWS) - experience in getting research into policy and practice", NASA Public Health Program Symposium held at the Annual Meeting of the American Society for Tropical Medicine and Hygiene.

New York, 1 November 2007, Invited speaker on Health at a Symposium on: "Climate Change and the Millennium Development Goals: Meeting the Challenge", Co-Sponsored by the UN Permanent Mission of Denmark and the Earth Institute at Columbia University, Italian Academy, New York.

8. Training

Various presentations drawing on the project results were used in a Summer Training Institute on Climate and Health held at Columbia University during June 2008. **(IRI)**

Famine Early Warning

1. **Products:** Table 1 summarizes the products we have settled upon, as reported last year. There are four new standardized global indices for use by FEWS NET and its decision makers: precipitation, precipitable water, vegetation, and potential evapotranspiration. They will be integrated with 1- to-3 month forecasts, blending observations and projections of hydrologic indicators. **(GSFC, UCSB)**

Table 1. Current FEWS NET data products and descriptions.

Variable	Data sources	Period of Record	Spatial Resolution	Frequency of Obs
Precipitation	TRMM/GPM	1999-present	0.25°	Daily/Monthly
	GMOS gauge	1973-present	Point data	Daily
Precipitable Water	NVAP	1988-1999	1.0°	Daily/Pentad/Monthly
	NVAP NG	2000-2001	1.0°	2x Daily/Monthly
	AIRS	2003-present	1.0°	3-Hourly/daily
PET	GDAS/EROS	2000-present	1.0°	Daily/Dekad/Monthly
	AIRS	2003-present	1.0°	2x Daily/Monthly
Vegetation	MODIS CMG	2000-present	0.05 °	Monthly

2. **Data Processing:** Systematic data acquisition and storage procedures have been set up, and the following progress has been made in each of the categories in Table 1 **(UCSB, USGS)**:

a. Precipitation

The year 1 user questionnaire identified dekadal, unbiased, 5 km rainfall as a key requirement. We have pursued precipitation enhancement through two primary activities: i) production of global 0.05° climatological surfaces and ii) the acquisition and quality control of daily quasi-real time in situ precipitation observations.

The objective of this work is to create orographically enhanced 0.05° dekadal standardized precipitation indices incorporating near real time gauge observations. Pursuant to the objective the following datasets and methods have been completed:

a.1. The creation of global 0.05° Hydro 1K elevation derivatives

This data set was produced by USGS EROS and delivered to UCSB. These fields are being used to create orographically enhanced high resolution precipitation mean fields. The following fields were derived:

1. The majority of the aspects within each of the 0.05-degree pixels.
2. The majority Pfafstetter level 1 basin with each 0.05-degree pixel.
3. The maximum flow accumulation value within each pixel.

4. The mean flow accumulation value within each pixel.
5. The mean Compound Topographic Index (CTI) per pixel.
6. The mean elevation per pixel in Meters.
7. The mean slope for each pixel.

a.2 The creation of global 0.05° climatological surfaces

Hydro 1K fields are being used in conjunction with 2002-2007 TRMM 3B40 & 3B41 satellite retrievals and rain gauge data to produce climatological surfaces and orographic correction procedures. Initial coding and testing has been completed by Chris Funk.

a.3. In situ station acquisition

An extensive effort has been made to pool existing sources of global station data. At monthly temporal resolutions we have pooled the Global Historical Climate Network (GHCN), Food and Agriculture Organization (FAO), and Famine Early Warning System Network (FEWS NET) archives. The merged dataset has 25,559 independent stations, for a total of 1.4 million observations over the 1950-2007 period. At daily scales 1979-2007 Global Daily Climate Network (GDCN, 22,101 stations), Global Summary of the Day (GSOD, 14,075 stations) and Global Telecommunication System (GTS, 11,726 stations) data have been acquired and pooled to produce 36,636 stations. Current work focuses on blending these gauge data with microwave imagery.

b. Precipitable water

Work for this sub-task is currently focused on switching over the acquisition and monitoring procedures to operate with collect 5 AIRS data. AIRS, NVAP and NVAP NG data are being inter-calibrated and standardized.

c. Potential Evapotranspiration

AIRS data have been acquired and processed. Processing is being switched to collect 5. Automated data acquisition is being set up by programming staff.

3. Historical NDVI Time-series:

Greg Husak has used Komologorov-Smirnov goodness-of-fit tests to evaluate the relative performance of gamma and normal distributions for the CMG NDVI dataset. Most pixels were fit adequately by both distributions, but almost all pixels were fit well using normal distributions. Normal distributions will thus be used to produce standardized imagery via an arithmetic sigma calculation: $SNI = (NDVI - NDVI_{mean}) / NDVI_{stdev}$. CMG acquisition and processing routines are being finalized. **(UCSB)**

4. Seasonal projections

Routines and data archives supporting the seasonal prediction of precipitation and temperature have been created. The twenty year SSMI archive will be used to enhance predictive capabilities of the forecast models. Figure 1 summarizes these data. Quasi-operational [QSCAT](#) and [SSMI](#) climate monitoring products are also being routinely posted and used to inform FEWS NET weekly weather hazard discussions. Cross-validation procedures for the matched filter regression scheme have been implemented. **(UCSB)**

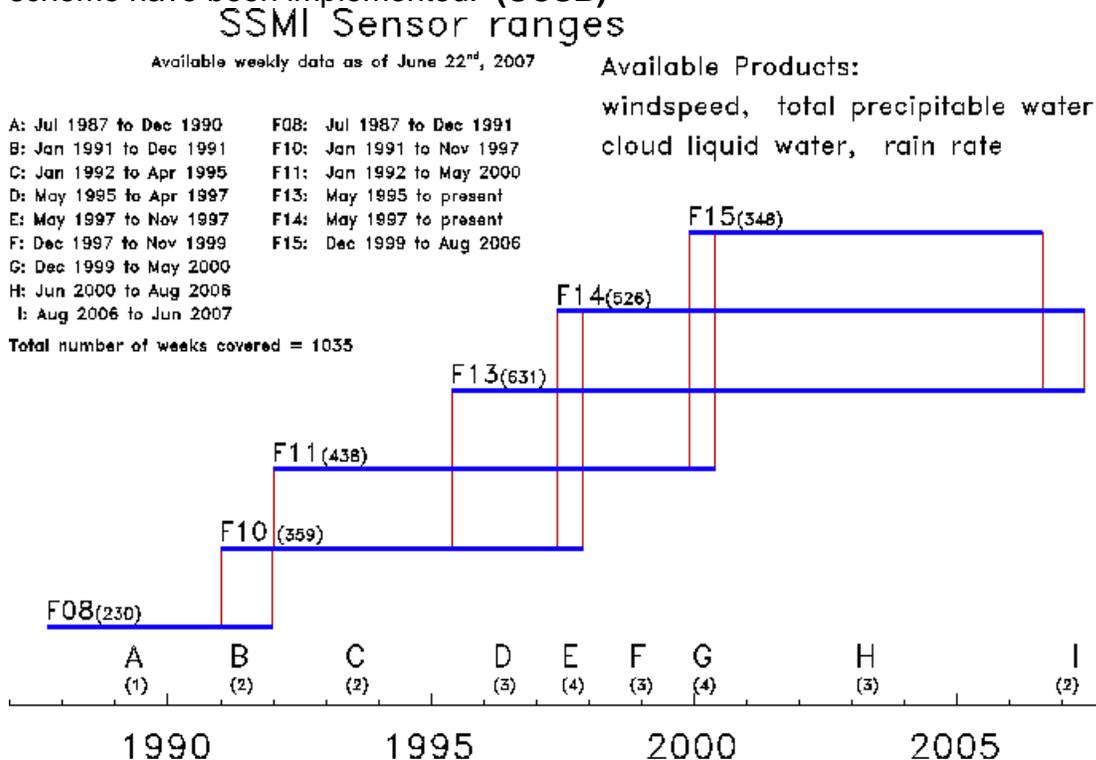


Figure 1. SSMI data history.

Tasks completed for extension on Market Prices and NDVI: (GSFC)

This extension of the work focuses on enhancing the FEWS NET CAN project through the implementation of an economic model that links variations in commodity prices to weather-related local variations in production, making it possible to provide commodity price projections and regional price maps for the most food insecure regions of Africa. The model will enhance food security by providing projected price data to FEWS NET and its partners, thereby increasing the efficiency of food distribution and enabling better decisions regarding future food aid needs. The project will begin by extending the research presented in Brown et al (2008) in *Land Economics* (see paper list), through the use of standard economic panel analysis.

Our current work is focused on amending the constructed panel model to deal

with the three markets per country which are available in real time (Figure 2). The panel model has been constructed for the 445 historical price dataset. When dealing with a restricted set, the importance of the vegetation index will be greatly enhanced. We are currently working on a paper for publication in *Economic Geography* or *Land Economics* on this topic.

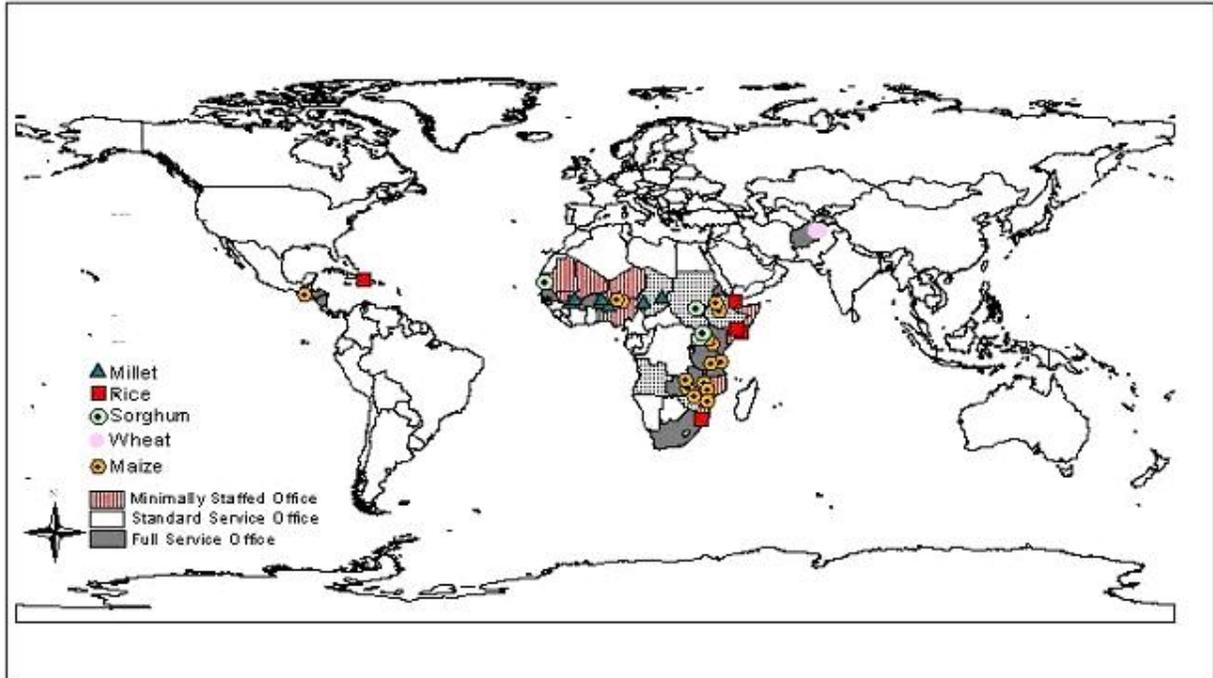


Figure 2. Cities and countries where FEWS NET collects price data each month on millet, rice, sorghum, wheat and maize and delivers the information to Washington DC in real time. These commodities and locations will be the target of the new integrated econometric model.

5. Other

The October 2008 public health review was attended by Jim Rowland for FEWS, Steve Conner for MEWS and Kent Ross for the systems engineering portions. Steve and Jim gave presentations, compiled by team members, of each of their sections. **(IRI, USGS, NASA, UCSB)**

Web programming with Open GIS GeoServer and OpenLayers has been carried out. The DSS tool will support image analysis and display capabilities. A provisional, under-development tool is available at <http://zippy.geog.ucsb.edu:8080/EWX/>. **(UCSB)**

Meeting presentations (project and related):

Funk, C., Huffman, G., Verdin, J., Verdin, K., Climatologically Assisted Satellite Estimation, 3rd International TRMM Meeting, Las Vegas, NV, Feb. 5th 2008.

- Funk, C. Climate Change: Our Health in the Balance-Panel Discussion, Ventura, CA, Invited Panelist, KEYT news coverage.
- Funk, C., Huffman, G., Verdin, J., Verdin, K., Climatologically Assisted Satellite Estimation, 3rd International TRMM Meeting, Las Vegas, NV, Feb. 5th 2008.
- Funk, C. Using TRMM for drought monitoring, NIDIS Knowledge Assessment Workshop: Contributions of Satellite Remote Sensing to Drought Monitoring, Boulder, CO, Feb. 7th, 2008. Invited Panelist/Presenter.
- Funk, C. & Verdin, J., Climate Change, Agricultural Capacity and Trends in African Food Security, AAAS symposium and Science Perspectives piece of Climate Change and African Food Security, Boston, February 17th, 2008
- Funk, C., Dettinger, M., Verdin, J., Examining the potential impact of a warming ocean on food insecure Africa: concerns and mechanisms for abrupt climate change, *EOS Trans. AGU 88(52)*, Fall Meet. Suppli., GC33A-0946, December, 17, 2007.
- Freund, J.T., Funk, C., Budde, M.E, Michaelsen, J., MODIS NDVI-Based Crop Production Estimates for Zimbabwe in 2006/07, *EOS Trans. AGU 88(52)*, Fall Meet. Suppli., B13D-1533, December, 15, 2007.
- Husak, G.J., Marshall, M., Funk, C., Pedreros, D., Michaelsen, J., Harrison, L., Developing Cropped Area Estimates for Niger From Multi-sensor Satellite Imagery, *EOS Trans. AGU 88(52)*, Fall Meet. Suppli., B13D-1532, December, 15, 2007.
- Brown, M.E., C.C. Funk, G. Galu and R. Choularton 'Integrating Earth Observations and Model Forecasts for Earlier Famine Early Warning', presented at a conference entitled 'Climate Information: Responding to User Needs', held at the University of Maryland, College Park, MD October 22-23, 2007.
- Brown, M.E., 'Integrating Long Term Vegetation Data Records with Millet Prices in West Africa' presented at a seminar entitled 'Integrating Socio-economic and Remote Sensing Information for Food Security and Vulnerability Analysis', held by the European Commission's Joint Research Council's Agriculture Unit in Ispra, Italy on October 11-12, 2007.
- Brown, M.E., C. Funk, J. Verdin and R. Choularton, 'Remote Sensing Innovations for FEWS NET', for the Biospheric Sciences Branch (Code 614.4) Brown Bag Seminar Series on November 1, 2007.
- Brown, M.E., G. Husak, T. Love, A. Bennett, E. Wolvovsky, and K. Ross 'Incorporating Simulated GPM data into NOAA CPC's Rainfall Estimate Product for USAID', LIS (Land Information System) Science Seminar Series (Code 613.3) on November 14, 2007 at the NASA Goddard Space Flight Center.
- Brown, ME, Funk, CC, Galu, G, Choularton, R., Integrating earth observations and model results provides earlier Famine Early Warning, *EOS Trans. AGU 88(52)*, Fall Meet. Suppli., H31L-05. December, 17, 2007.
- Brown, M.E. participated as a panelist at the 8th National Conference on Science, Policy and the Environment, Washington D.C., January 16-18, 2008, with Cristina Rumbaitis del Rio, Rockefeller Foundation; Lakhdar Boukerrou, Florida Atlantic University; James W. Hansen, the Earth Institute at Columbia University; Jenny Olson, Michigan State University. The panel was entitled 'Climate Change Adaptation for the Developing World: Expanding Africa's Climate Change Resilience'.

Brown, M.E. presented a paper at the 2008 Annual Meeting of the American Association for the Advancement of Science (AAAS), held in Boston, MA from February 14-18, 2008. The talk was entitled 'Remote Sensing Data for Food Security Early Warning'.

Brown, M.E. presented a paper to the University Honors Program at Long Island University, Brooklyn, NY, on March 28, 2008 entitled 'Climate Change and Food in Africa'.

Brown, M.E. presented a paper to the Department of Geology and Geography at the University of West Virginia, Morgantown, WV, on March 15, 2008 entitled 'Earth Observations and Models for Earlier Famine Early Warning'.

Brown, M.E., C.C. Funk, G.Galu, R.Choularton, 'Innovative Climate and Economic Analysis for Earlier Famine Early Warning' presented at the Association of American Geographers Annual Meeting, Boston, MA, April 2008.

Brown, M.E. participated as a panelist at the Association of American Geographers Annual Meeting, Boston, MA, April 2008, at a panel entitled: 'Development Geography and the Human Dimensions of Environmental Change II: Practice', with Kenneth R. Young - University of Texas at Austin, Dianne E. Rocheleau - Clark University, and Ben Wisner - Independent Scholar, Brent McCusker - West Virginia University.

Brown, M.E., Session Convener at an international conference entitled 'Food Security and Environmental Change' held on April 2-4, 2008 in Oxford, England. The session was entitled 'Improving climate forecasting for food security research'. James Verdin presented a paper at the session.

Brown, M.E. presented a paper to the Institute of Zoology at the Zoological Society of London, England, on April 1, 2008 entitled 'Earth Observations and Models for Earlier Famine Early Warning'.

Brown, M.E. presented at the Climate Change Impacts Interagency Workgroup Meeting at NASA-Headquarters on April 24, 2008. The talk was entitled 'Climate Change and Food Security: Using Remote Sensing to Anticipate Crises' and was coauthored by C. Funk, G Galu,R. Choularton, and J. Verdin.

Brown, M.E. gave a talk to NASA Earth Science Division Director Franco Einaudi and NASA Science Exploration Director Edward Weiler entitled 'Climate Change and Food Security: the Role of NASA Data and Models', Greenbelt, MD, July 2008.

Brown, M.E. presented at the *International Geoscience and Remote Sensing Society* meeting, Boston, MA, July 2008 a paper entitled 'Merging Models with Earth Science Observations for Earlier Famine Early Warning', coauthored by C. Funk, G Galu, R. Choularton, and J. Verdin.

Brown, M.E. presented at the *SPIE Conference: Security and Defense*, in Cardiff, Wales, UK, September 2008, entitled 'The use of remote sensing-derived biophysical data for early warning of food security crises: evidence from FEWS NET' (given by S. Habib)

Brown, M.E. presented at the *Environmental Information Management 2008* conference, University of New Mexico, September 2008 entitled 'Challenges of AVHRR Vegetation data for Real Time Applications', (given by P. Griffith).

Verdin, J., 'Drought Mapping, Assessment and Monitoring', invited speaker, 2nd Asian Ministerial Conference on Disaster Risk Reduction, New Delhi, India, November 7, 2007.

Verdin, J., 'Drought Information for Risk Management and Early Warning', invited speaker, Indian Institute of Public Administration, New Delhi, India, November 6, 2007.

Verdin, J., G. Galu, R. Choularton, and G. Husak, 'Integrating Seasonal Climate Forecasts into Food Security Outlook Analyses', Global Environmental Change and Food Systems (GECAFS) Conference, April 2, 2008, Oxford, UK.

Papers (project and related):

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.

Funk, C., Brown, M., Choularton, R., Verdin, J., Dettinger, M., (2008), FEWS NET Climate Change Impact Report, *Special Report for USAID* (accepted pending revisions)

Funk, C., Dettinger, M. D. and Verdin, J. P. (200-), Increasingly El Niño-like climate threatens drought in parts of Africa, Central-South America and Asia under IPCC climate-change projections, Analysis of Global Climate Change precipitation fields suggests that an increasingly El Niño-like climate may threaten food insecure (*in final preparation*)

Funk, C., Ederer, G., Pedreros, D. (2008) The Tropical Rainfall Monitoring Mission, NIDIS Knowledge Assessment Workshop: Contributions of Satellite Remote Sensing to Drought Monitoring, February 6-7, Boulder, CO, Extended Abstract.

Funk, C., Budde M., (2008) Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe, *Remote Sensing of Environment* (accepted, 2008).

Funk, C., Brown, M., Choularton, R., Verdin, J., Dettinger, M., (200-), FEWS NET Climate Change Impact Report, *Special Report for USAID* (accepted pending revisions)

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. *Journal of Geophysical Research* (accepted)

Brown, M and Funk, C., (2008) Food security under climate change, *Science*, (319): 580-581.

Brown, M.E. (2008) Famine Early Warning Systems and Remote Sensing Data, Springer-Verlag: Heidelberg and New York. pp 313 (May 2008).

Brown, M.E. and C.C. Funk (2008) Early Warning of Food Security Crises in Urban areas: the Case of Harare, Zimbabwe, 2007, Geotechnical Contributions to Urban Hazard and Disaster Analysis, edited by Pamela Showalter and Yongmai Lu, Springer-Verlag (in press).

Brown, M.E. (2008) Challenges of AVHRR Vegetation Data for Real Time Applications. Extended abstract for the Environmental Information Management Conference 2008, Albuquerque, New Mexico, September 10-11, 2008.

- Vrieling, A., K. M. de Beurs and M. E. Brown (2008) Recent trends in agricultural production of Africa based on AVHRR NDVI time series. SPIE Europe Security + Defense, September 15-18, 2008.
- 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.
- Tarnavsky, E., Garrigues, S. and Brown, M. E. (2008) Multiscale Geostatistical Analysis of AVHRR, SPOT-VGT, and MODIS Global NDVI Records. *Remote Sensing of Environment*, 112, 535-549.
- Brown, M.E. and B. McCusker (2008) Climate Change and Agriculture in Africa: Impact Assessment and Adaptation Strategies. Book Review in *EOS Transactions of the American Geophysical Union*. (in press).
- Brown, M. E., D. Lary, A. Vrieling, D. Stathakis, and H. Mussa (2008) Neural Networks as a Tool for Constructing Continuous NDVI Time Series from AVHRR and MODIS. *International Journal of Remote Sensing* (in press).
- Ross, K.W., M.E. Brown, S.J. Connor, J.P. Verdin, P. Ceccato, and C.C. Funk (2007) Decision Support Evaluation Report for USAID Famine and Malaria Early Warning Systems, NASA Goddard Space Flight Center, Greenbelt, MD. 76 pp.

Systems Engineering

During this period, we completed and submitted the evaluation report. We submitted a journal manuscript based on the professional review conducted for the FEWS portion of the evaluation report. This manuscript was submitted to the open access Environmental Research Letters, and has been authored by Kent Ross, Molly Brown, James Verdin and Lauren Underwood.

For MEWS, we translated the baseline questionnaires for West Africa. We completed French version of the questionnaire and worked with the International Research Institute for Climate and Society (IRI) to distribute it to public health professional contacts in West Africa in the next quarter. We received nine responses and have compiled the answers with previous responses.

We have brought on Lauren Underwood, a systems engineer at SSAI to take over some of Kenton Ross's responsibilities because of a change of his time availability. Lauren has been integrated into the work before the final year of the project when the evaluation report should be written. **(SSC, GSFC)**

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