AN INTEROPERABLE, AGRICULTURAL INFORMATION SYSTEM BASED ON SATELLITE REMOTE SENSING DATA

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ABSTRACT

Monitoring global agricultural crop conditions during the growing season and estimating potential seasonal production are critically important for market development of U.S. agricultural products and for global food security. The Goddard Space Flight Center Earth Sciences Data and Information Services Center Distributed Active Archive Center (GES DISC DAAC) is developing an Agricultural Information System (AIS), evolved from an existing TRMM Online Visualization and Analysis System (TOVAS), which will operationally provide satellite remote sensing data products (e.g., rainfall) and services. The data products will include crop condition and yield prediction maps, generated from a crop growth model with satellite data inputs, in collaboration with the USDA Agricultural Research Service. The AIS will enable the remote, interoperable access to distributed data, by using the GrADS-DODS Server (GDS) and by being compliant with Open GIS Consortium standards. Users will be able to download individual files, perform interactive online analysis, as well as receive operational data flows. AIS outputs will be integrated into existing operational decision support systems for global crop monitoring, such as those of the USDA Foreign Agricultural Service and the U.N. World Food Program.

INTRODUCTION

The goal of the NASA Earth Science Enterprise (ESE) Applications Program is to maximize the economic and societal benefits of its investments in Earth science, information, and technology. To fully realize this goal, data from ESE missions need to be accessible and usable, beyond the mission science teams and even the science communities, by the much larger general user community and, specifically, the various applications user communities. The Goddard Earth Sciences Data and Information Services Center Distributed Active Archive Center (GES DISC DAAC) has long been a leader in facilitating the use of ESE data by the applications communities, including that of the agriculture-related users. This latter community contains some of the largest users of satellite data and, potentially, of ESE data, for global crop monitoring, a high priority activity of national importance. Accurate and timely assessments of global agricultural crop conditions during the growing season and significant estimated production decline due to natural disasters, such as drought, are crucial for disaster mitigation, strategic planning, enhancement of U.S. agricultural competitiveness, and global food security.

Conducting these assessments using Earth science data sets from multiple sources can be a daunting task. It involves locating and then obtaining voluminous amounts of data, subsetting to extract the parameters and spatial areas desired, and co-locating the data with other data. This effort may include building and maintaining a data management system, a processing system, and visualization and graph generation tools. Thus, there is often a significant upfront investment before the core investigation can begin.

In order to ease the burden of such investigations, the GES DISC is developing an Agricultural Information System (AIS), based on an existing (since March 2001) TRMM Online Visualization and Analysis System (TOVAS). The latter has been effectively used to provide ESE data and information to various agricultural users of satellite remote sensing data. The goal of AIS is to relieve the agricultural users of some of the upfront data preparation work and provide a tool for obtaining useful information via plots, graphs, and tables without having to download and prepare large amounts of data. To accomplish this goal, AIS provides a Web interface to data,

analysis, and data visualization tools, all without having to download the data. The graphs and plots generated by AIS are suitable for publication. If additional analyses are required, the original data can be easily retrieved.

The wealth of multi-mission data at the GES DISC makes AIS an ideal environment for regional and global agricultural assessments. AIS will operationally provide ESE and other data products and services, to be dynamically integrated into and thus enhance the existing GIS-based, agricultural decision support systems. Agriculture-oriented, ESE data products are being developed in collaboration with the USDA Agricultural Research Service (ARS). The AIS will have the capability for easy remote access of distributed data, by being compliant with community-based interoperability standards.

AGRICULTURE-ORIENTED DATA PRODUCTS

The AIS currently has the following data sets: (1) three-hourly TRMM and Other Satellite Rainfall (3B42RT) for Jan 2002-present; (2) TRMM Level-3 Daily Rainfall (3B42) for Jan 1998-present; (3) TRMM Level-3 Monthly Rainfall (3B43) for Jan 1998-present; (4) TRMM Monthly Rain and Latent Heat (3A12) for Jan 1998-present; (5) Willmott and Matsuura Global Precipitation for Jan 1950-Dec 1999; and (6) Global Precipitation Climatology Center (GPCC) Monthly Global Precipitation for Jan 1986-present. One important consideration of agricultural users of satellite-derived precipitation data is the consistency between different data sets. Regional biases between data sets are being examined in this project to help agricultural users in their decision-making (Chiu et al., 2004). Figure 1 shows some preliminary results from an analysis of bias between TRMM rainfall products and rain gauge data for Oklahoma. A major limitation in rain-fed agriculture is the accurate estimate of spatial rainfall distribution. TRMM-derived products, providing spatial data at grid levels, will be imported into a simple mechanistic crop growth model (Fig. 2) developed and validated by USDA Agricultural Research Service (ARS) (Doraiswamy et al., 2001, 2002).

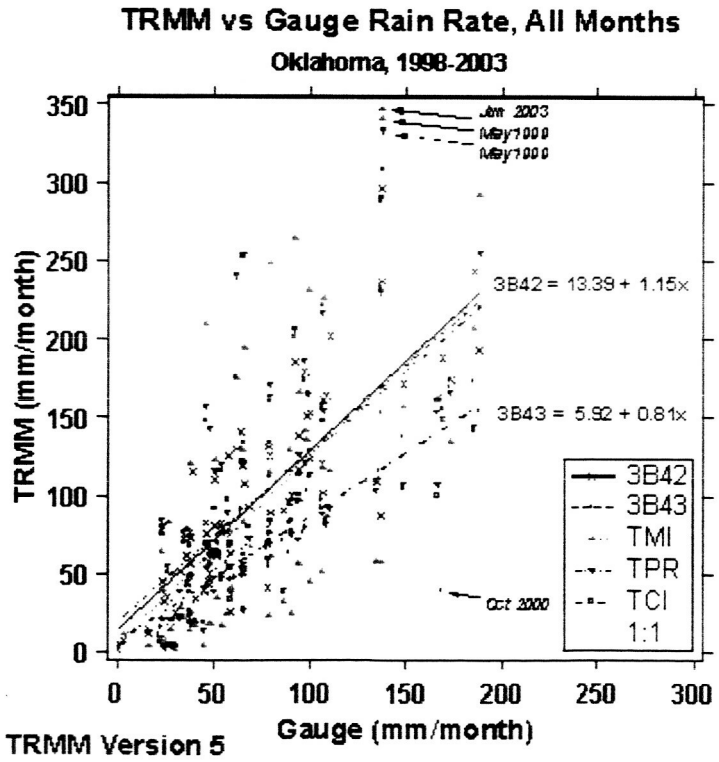

Figure 1. Bias analysis of rainfall rates for Oklahoma.

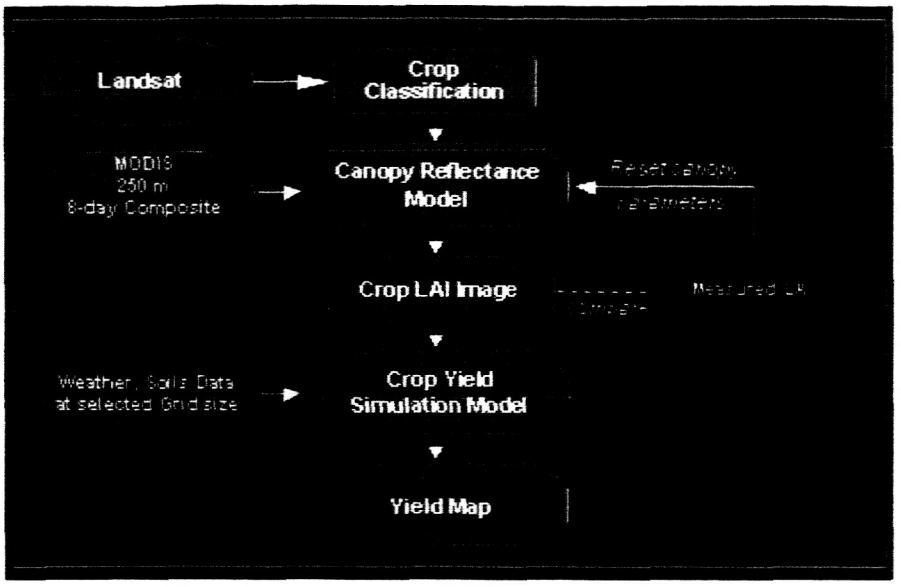

Figure 2. Crop growth model developed by USDA ARS.

DEVELOPING AN AGRICULTURAL INFORMATION SYSTEM (AIS)

AIS Design Goals

The principal design goal for AIS is to provide a quick and simple interactive means for agricultural data users to study crop-related phenomena by trying various combinations of parameters measured by different instruments, arrive at a conclusion, and then generate graphs suitable for publications. Alternatively, AIS would provide a means to ask relevant what-if questions and get back answers that would stimulate further investigations. This would all be done without having to download and preprocess large amounts of data. Secondary design goals are to (1) make AIS easily configurable, extensible, and portable; (2) be able to run AIS on multiple platforms (a prototype AIS is currently running on an SGI platform, whereas the operational version will be run on a Linux platform); (3) off-load as much as possible the data processing workload onto the machines hosting the data and to reduce data transfers to a minimum. Given the enormous amount of HDF data at the GES DISC, it was also a requirement that AIS support HDF, HDF-EOS, as well as binary.

AIS Data Flow

AIS consists of HTML templates, CGI scripts written in Perl and GrADS (Grid Analysis and Display System) language. In addition, there is an image map Java applet through which a user can select a bounding box area to process. Access to data is via one or more GrADS-DODS (Distributed Oceanographic Data System) Servers (GDS) running on remote machines that have GrADS readable data. (NB: DODS has been renamed OPeNDAP or OPeN Data Access Protocol.) The data flow is illustrated in Figure 3, which shows the existing components of TOVAS (in blue-gray) and the planned enhancements (in yellow) for the AIS. The AIS will be able to serve three tiers of users: (1) general users who do not have the capability to do data processing and need "ready-to-use" precipitation data (AIS standard web interface with customized features); (2) operational users who want to obtain their customized data products routinely (customized options); and (3) advanced users who want to do more complex data analyses (customized analyses and applications).

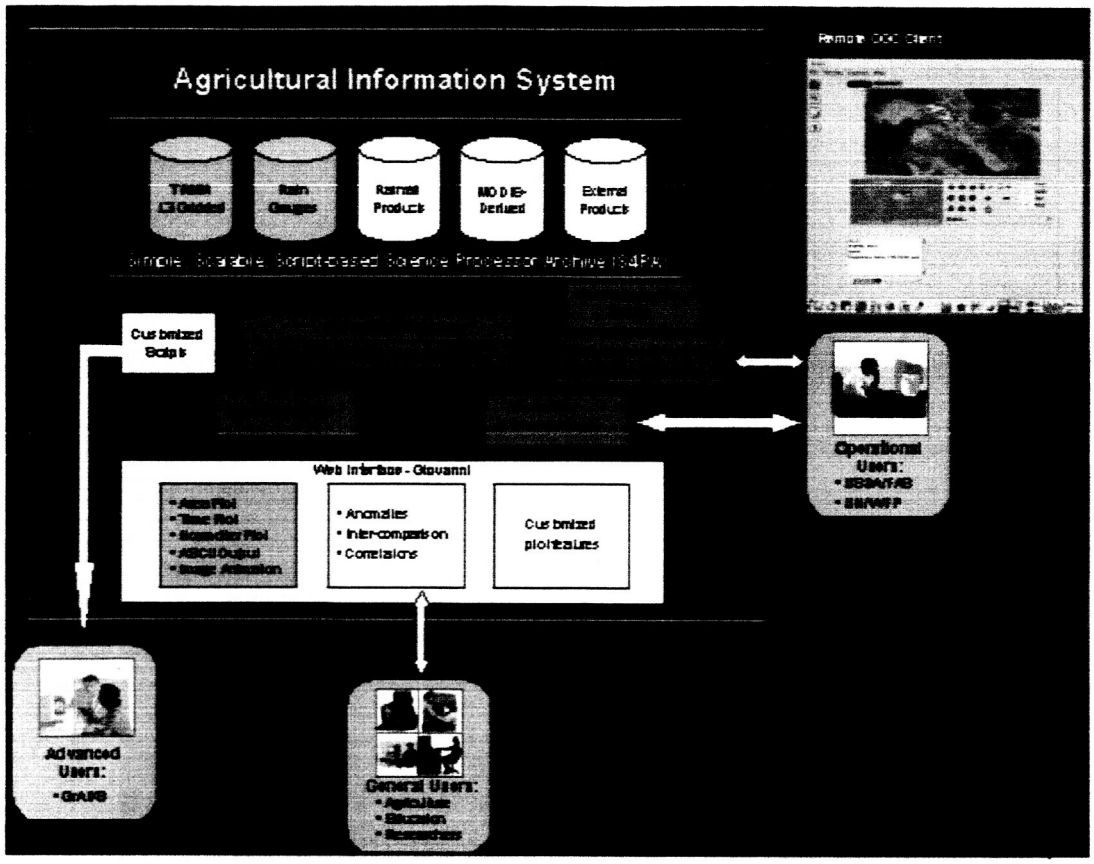

Figure 3. Data flow of Agricultural Information System.

GrADS was chosen for its widespread use for providing easy access, manipulation, and visualization of Earth science data. It supports a variety of data formats such as binary, GRIB, NetCDF, HDF, and HDF-EOS. When combined with DODS (OPeNDAP), as in GDS, the result is a secure data server that provides subsetting and analysis across the network or even the Internet. The ability of GDS to subset data on the server drastically reduces the amount of data that need to be transferred across the network and improves overall performance. GDS provides spatial or temporal subsetting of data while applying any of a number of analysis operations including basic math function, averages, smoothing, correlation, and regression. An equally important feature is the ability to run GrADS data transformations on the server.

Agricultural Users Select Parameters. Via the AIS Web interface, the user selects one or more data sets, the spatial area, the temporal extent, and the type of output. Supported output types are listed in Table 1. The selection criteria are passed to the CGI scripts for processing.

GrADS Makes Request for Subsetted Data. CGI scripts process the parameters submitted by the user. GrADS scripts are then used to formulate GDS data requests. These requests include parameters by which the data can be subsetted and processed. The requests are directed to the appropriate GDS machine.

GDS Processes the Data Requests. GDS on a remote machine receives the request for data along with subsetting and processing parameters. The requested subsetting and processing is performed on the server and the resulting subsetted data are sent back to the client (AIS).

CGI Passes the Output Back To the User. The subsetted data are processed by the CGI scripts on the AIS machine into an image (for plots or graphs) or into ASCII data that the user can download. For plots or graphs, the results will be displayed in the Web browser.

Table 1. Output Types Supported By AIS.

Output Type	Description
Area Plot	Area plot averaged or accumulated over any available data period within any rectangular area
Time Plot	Time series averaged over any rectangular area
Hovmoller Plot	Longitude-time or latitude-time plot
Animation	Animation available for area plots
ASCII Output	ASCII output, available for all plot types, suitable for input to GIS or other applications

AIS User Interface

From the user's perspective, AIS is a simple Web application. A user can select either the Java or non-Java version. The resulting Web page allows the user to select a spatial area via the Java image map applet or, if the non-Java version was selected, manually by entering in coordinates defining a bounding box. The user also selects the temporal range of the data, one or more parameters from the data set, and the output type (ASCII or one of several plot types). For plots, several color options are also available. Figure 4 shows the TOVAS Web interface, illustrating the user interface and the available options. Once the options are selected, the user has the option of generating a plot or outputting the results to an ASCII file that can be downloaded. ASCII output is useful for GIS or other user applications. If plotting is selected, another Web browser window is opened within which the plot is displayed. A sample area plot is shown in Figure 5 for the case of TRMM data. Links to the data are provided so the user can download the entire data set. Depending on the parameters selected, most users will see the results in a matter of seconds. For users who choose large amounts of data either spatially or temporally, the results may take several minutes.

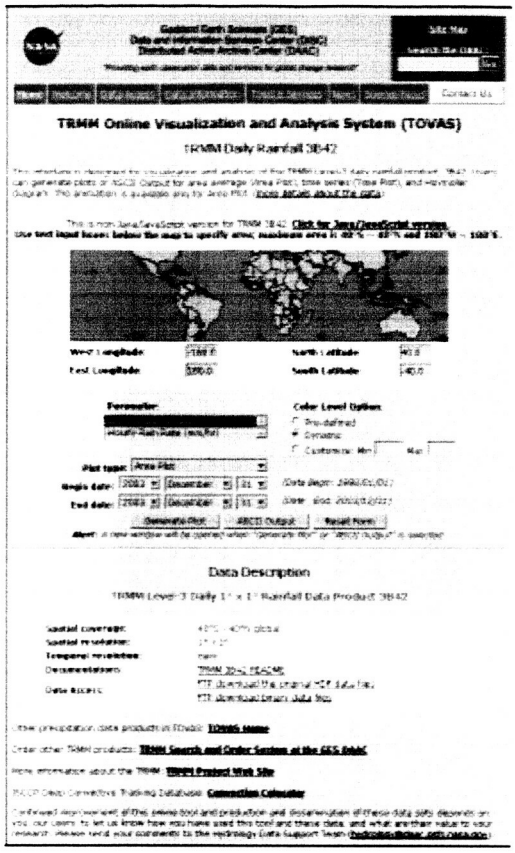

Figure 4. TRMM Online Visualization and Analysis System (TOVAS), a simple and easy-to-use Web interface for access to global precipitation data.

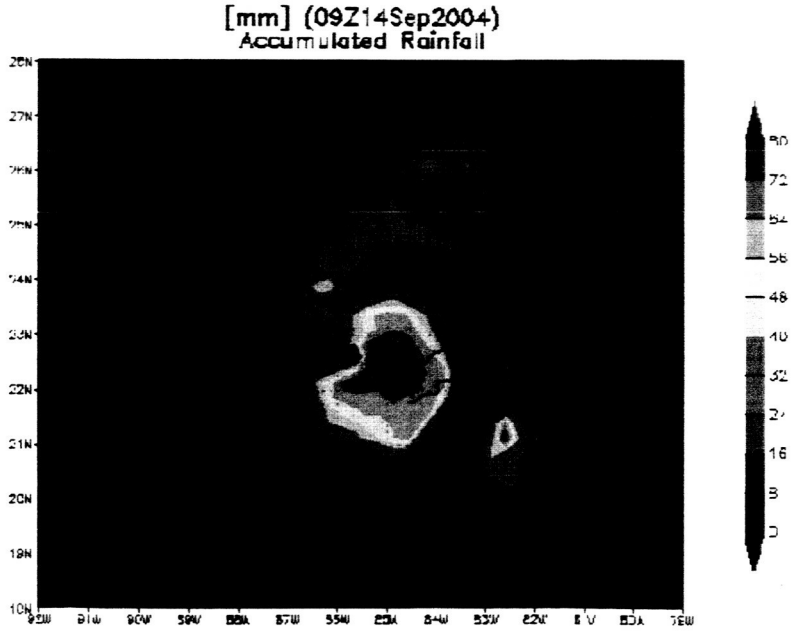

Figure 5. Sample AIS area plot from TOVAS: Rainfall accumulation from Hurricane Ivan between September 10 and September 14, 2004, as the Category 5 hurricane brought widespread destruction across the Caribbean.

Integrating AIS Outputs into Decision Support Systems

AIS outputs will be integrated into existing operational decision support systems for global crop monitoring, such as those of the USDA Foreign Agricultural Service (FAS) and the U.N. World Food Program (WFP). A key FAS tool is an existing, Web-based decision support system called Crop Explorer, in which global crop condition information (e.g., precipitation, soil moisture) are automatically generated and dynamically updated every 10 days (http://www.pecad.fas.usda.gov/cropexplorer/). AIS products will be integrated into the Crop Explorer and thus enable FAS to better understand weather's effect on agricultural production. WFP uses satellite imagery of rainfall and crop conditions and monitoring of food prices in local markets to identify and map populations and geographical areas most vulnerable to hunger (food insecurity) and then target their needs. This information is contained in a series of routinely published WFP reports, which are invaluable for contingency planning and rapid response to disasters. Outputs from TOVAS are currently being routinely used in these WFP reports. The AIS will be able to provide many more products to the WFP.

Future Plans for AIS

In the near-term, AIS will add support for product inter-comparisons and precipitation anomalies generation. An important future step for AIS to take is support for output formats suitable for Geographic Information Systems (GIS), e.g., GeoTIFF, and for integration with existing Open Geospatial Consortium (OGC)-compliant clients. AIS will also provide better support for multi-sensor analyses with smart handling of multiple grids. Other directions include the ability to represent errors due to missing data and data quality in meaningful ways.

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