Data and Applications for Study of the Water Cycle in Africa

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Abstract – There are a number data set development, data dissemination, and applications activities at the U.S. Geological Survey (USGS) that contribute to the study of the water cycle in Africa. Some of these stem from global change research initiatives, while others are the result of technical assistance provided to international development and humanitarian assistance projects. Data themes include topography and related hydrological derivatives, land cover, satellite rainfall estimates, and vegetation indices. Some data sets are USGS products, while others originate from cooperating agencies like NASA and NOAA and are distributed secondarily. In Africa, applications include agrometeorological estimates, drought and flood monitoring. Many of the data sets are available to the user community without charge by internet, or at cost of reproduction on CDROM and tape media.

INTRODUCTION

Water cycle studies in Africa at continental or regional scales can benefit from a number data sets available or in development at the EROS Data Center of the U.S. Geological Survey (USGS). Some of these were produced as USGS contributions to the U.S. Global Change Research Program, while others were specifically developed for the African continent. Themes include topography, hydrological varibles derived from topography, and land cover derived from multidate satellite imagery. Several important data sets produced by other organizations can be obtained from USGS as well, including rainfall estimate (RFE) images, digital soil maps, and an eighteen year time series of vegetation index images. Satellite images from NOAA/AVHRR, Landsat, and the declassified Corona program are also available. Worldwide web interfaces have been developed to facilitate access to the data.

GLOBAL DATA SETS

Topographic Data and Hydrologic Derivatives

Digital elevation data can support hydrologic studies in many ways. In 1996, USGS released the GTOPO30 global elevation data set at 30-arcsecond resolution, or about one kilometer (Gesch et al., 1999). In Africa, elevation values were derived primarily from two sources: generalized Digital Terrain Elevation Data, originally 3-arcsecond resolution, and interpolated contours and spot elevations from the 1:1,000,000 Digital Chart of the World. Many of the valuable derivative information themes of interest to hydrologists have already been prepared and are available as the HYDRO1K data set (USGS, 1999). To create HYDRO1K, GTOPO30 data were resampled to a 1-km grid in the Lambert Azimuthal Equal Area projection, the elevation values were edited to be hydrographically correct, and derivative data sets were calculated. The HYDRO1k package provides a suite of six raster and two vector data sets. The raster data sets are the corrected elevations, derived flow directions, flow accumulations, slope, aspect, and a compound topographic (wetness) index. The vector data sets are streamlines and basin boundaries derived from the raster data. Basin polygons carry as attributes the mean and standard deviation of elevation, slope, and aspect. Streamlines carry attributes for upstream area drained, gradient, upstream distance to the basin divide, downstream distance to the ocean, elevation at upstream and downstream end of each reach, and Strahler stream order. Both basin polygons and streamlines carry topological identification numbers according to the Pfafstetter system (Verdin and Verdin, 1999). These codes make linkage tables unnecessary and facilitate queries to determine topological relationships between hydrographic elements such as upstream/downstream and on/off main stem.

Land Cover Characteristics

A global land cover characteristics data base (Loveland and Belward, 1998), derived from 1-km AVHRR data for the period April 1992 through March 1993, is available from USGS. There are two map projections available, Interrupted Goode Homolosine and Lambert Azimuthal Equal Area, and in each case the data are arranged on a 1-km grid. There is flexibility in the selection of the land cover classes to be used, with six different legends possible, including those assumed by land-atmosphere interaction models used by global circulation modelers.

Digital Soil Maps

The United Nations' 1:5,000,000 Digital Soil Map of the World must be ordered from the FAO or UNESCO, but the order can be placed through USGS using the internet. The soil polygons carry soil attributes that are useful for a

number of water resources investigations, including water holding capacity and soil texture.

The Zobler World Soils Data Set is also available. Unlike the Digital Soil Map of the World, the data set is in raster format, at the relatively coarse resolution of one degree of latitude/longitude, or about 100 km.

CONTINENTAL DATA SETS

Rainfall Estimate Images

Rainfall Estimate (RFE) images are prepared by NOAA's Climate Prediction Center (Herman et al., 1997) for the USAID Famine Early Warning System (FEWS). The images are archived and disseminated by USGS. They are compiled on a nominal 10-day time step from thermal infrared images from Meteosat, acquired every 30 minutes, which are used to identify areas of cold cloud top temperatures (less than 235K). The duration of these temperatures over a day is used to make an initial estimate of convective rainfall. Then, daily rainfall totals from 760 stations that report electronically through the World Meteorological Organization (WMO) Global Telecommunication System (GTS) are used to remove bias from the cold cloud estimates. Finally, areas of "warm cloud" rainfall, associated with orography, coastal areas, and frontal activity are estimated from output fields of NOAA's Global Data Assimilation System (GDAS), a system that integrates operational weather forecast modeling with observations of atmospheric state (Kanamitsu, 1989). Fields of wind, relative humidity, and a digital elevation model are used to identify these areas of non-convective lifting and condensation.

Time Series Vegetation Index Images

Normalized Difference Vegetation Index (NDVI) images produced from AVHRR imagery acquired by the NOAA polar orbiters have a long history of use in the FEWS project. They are prepared for FEWS by the Global Inventory Monitoring and Modeling Studies research unit at the NASA Goddard Space Flight Center in Greenbelt, Maryland, according to techniques described by Los et al. (1994). Since the NDVI signal is linearly related to the area average photosynthetic capacity of the plant canopy at a location (Tucker and Sellers, 1986), it is used by FEWS as a measure of the condition of rainfed crops and rangeland. The images are produced every 10 days and the archive for Africa dates back to July 1981.

SATELLITE IMAGERY

Global 1-km imagery from the Advanced Very High Resolution Radiometer of the NOAA polar orbiters has been systematically collected since 1992 with the cooperation of 23 ground stations around the world (Eidenshink and Faundeen, 1994). These data are available from USGS at cost of reproduction. Large inundated areas associated with regional flooding can be discerned. Changes in surface area associated with seasonal water bodies can also be detected (Verdin, 1996).

Landsat Multispectral Scanner and Thematic Mapper imagery can also be obtained from the EROS Data Center. Some coverage dates back to the early 1970s. The recent successful launch of Landsat 7 began an new era of access to low cost, high quality imagery with 30 meter resolution and valuable bands for detecting surface water, vegetation, and soil.

Imagery from the recently declassified Corona program is now available from the EROS Data Center. Coverage of Africa has been used to document important changes in land cover (Wood et al., 1999).

APPLICATIONS AND EXPERIMENTAL PRODUCTS

Agrometeorological Applications

In support of FEWS, USGS has implemented methods for estimating start of the growing season from the RFE time series. On a per pixel basis, simple rainfall accounting is applied. The first ten day period with 25 mm of rainfall is considered the start, provided 20 mm more fall during the next 20 days. Once start of season is determined, grid cell crop water accounting is performed to compute maps of the FAO Water Requirement Satisfaction Index (WRSI). Potential evapotranspiration images are computed for this purpose from GDAS fields. The WRSI is highly correlated with crop yield where water limitation is the controlling factor. It can therefore give an early indication of below normal crop production. These applications are described by Verdin and Klaver (in press). The image products are not yet available for distribution, pending review by cooperators in the early warning community.

Flood Applications

Conditions of regional flooding due to sustained heavy rainfall can be identified by processing the RFE in conjunction with the basin data sets of HYDRO1K. USGS is doing this to produce Basin Excess Rainfall Maps (BERM). Dissemination of these images is planned for later in 2000. Development of BERM maps with daily RFE is also planned.

RFE images are also being used in hydrological models to perform stream flow estimation. The RFE in this case are compiled on a 1 day time step, instead of a 10 day time step. Successful simulation of the daily flows in the Nzoia basin

of western Kenya has been achieved (Dvorsky et al., 1999). Modeling of this kind will be expanded across the continent, with posting of flow status maps on the internet, during the latter half of 2000.

DATA DISSEMINATION

Internet dissemination of data for Africa by USGS occurs at three sites that can be reached from the EROS Data Center home page, http://edc.usgs.gov. The Global Land Information System can be accessed at http://edc.usgs.gov/webglis to obtain soil maps and satellite images. Global land cover characteristics, GTOPO30, and HYDRO1K data can all be accessed through the Land Data Distributed Active Archive Center website, http://edc.usgs.gov/landdaac. Landsat 7 imagery can also be obtained from this site.
RFE and NDVI images for Africa from the FEWS project can be obtained from the Africa Data Dissemination Service (ADDS) webserver at http://edcintl.cr.usgs.gov/adds/adds.html. The ADDS server also has many other country level data sets for FEWS countries, including administrative boundaries, transportation infrastructure, and other themes that have been compiled to support food security analysis.

CONCLUSION

Water cycle studies in Africa at continental and regional scales can potentially benefit from data sets available or under development at the EROS Data Center. Many of the data sets are available over the internet without charge. Symposium participants with an interest in this area are invited to visit the USGS website at http://edc.usgs.gov.

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