A DYNAMIC DROUGHT TOOL FOR THE CAROLINAS

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Abstract: This paper chronicles the development of a drought monitoring tool. A web-based mapping tool emerged in response to user needs during the 1998-2002 drought in the Carolinas. It was shaped by interactions with stakeholders during Federal Energy Regulatory Commission (FERC) relicensing of dams on major river basins in the Carolinas, and will be part of plans to more closely manage drought in the Catawba-Wateree Basin. The presentation will discuss to tool’s functionality, and application, and future direction.

Introduction: Water resource managers require methods to detect and predict drought and to assess its potential impacts. Their choice of index to measure drought intensity, duration, and spatial extent may depend on the sensitivity of particular physical and/or human systems or simply on institutional culture. The might consider precipitation deficit only, or broader components of the water budget. Some demand information on short-term conditions, others manage resources sensitive to longer-term deficiencies. Some use a particular index because of its traditional use at their institution or by associated state and local agencies.

Drought information requirements also vary spatially and temporally. Some decisions require information at daily or weekly periods, particularly during droughts, but many drought indices are computed at longer time scales, limiting their use. Decision makers also represent a variety of political (e.g., municipal, county, state) or physical (e.g., river basins) regions for which drought indices are not regularly calculated. Moreover, the spatial units for which they are calculated (e.g., climatic divisions) sometimes do not coincide with management regions. Drought monitoring – an essential component of an integrated drought management system – requires consideration of these diverse needs (Svoboda et al. 2001). Drought management and planning at regional, state, and local levels provide an opportunity for prototype development to address many of them (e.g., Jacobs et al. 2005).

The Carolinas Dynamic Drought Index tool described below was born out of a combination of crisis management during an extreme event, and long-term planning of water resources. These two factors provided an opportunity to hear what stakeholders needed at a time when it was most relevant and mattered most to them. The 1998-2002 drought in North and South Carolina, followed by multiyear dam relicensing negotiations, spurred development of a regional, web-based drought monitoring tool that addresses the scale, flexibility, and relevance demands described above.

1998-2002 Carolinas Drought: The 1998-2002 drought was the worst in the Carolinas during the modern record. It changed the physical hydrology and affected agriculture, navigation, forestry, and public drinking-water supplies.

Reflecting on their experiences during the drought, members of the North Carolina Drought Monitoring Council, the South Carolina Drought Response Committee, and other groups (e.g., the South Carolina Governor's Water Law Review Task Force) identified several monitoring deficiencies that prompted development of a regional drought monitoring tool. First, local estimates of drought severity were restricted to available precipitation gages, a handful of groundwater monitoring wells, and limited USGS streamflow gages. Second, water systems managers had to get drought information from several different agencies. Third, standard measures of drought such as the Palmer Drought Severity Index (PDSI, Palmer 1965), Palmer Hydrological Index (PHDI), and Standardized Precipitation Index (SPI, McKee et al. 1993) were calculated and historically available only for climate divisions (CPC, 2005). The South Carolina Drought Response Committee repeatedly struggled to make county-specific drought declarations using drought data from climate divisions since county-scale assessment is important for federal disaster relief. Water systems and power generating facilities could not evaluate water needs for specific basins. Fourth, many users were confused by the indices' different ranges (e.g., -4 to +4 for the PDSI, -2 to +2 for the SPI) with the scales having little intuitive meaning. Fifth, drought severity varied greatly within and between river basins and climatic divisions, and such local variation was not adequately depicted with available tools. In summary, the 1998-2002 drought provided a nexus for understanding what kind of information stakeholders needed to manage drought events.

Data and Methods: The design of a drought monitoring system for the Carolinas considered several specific requirements: inclusion of a wide range of drought measures; an ability to combine different measures appropriately; spatial and temporal scalability; open-architecture software that allows display of maps, tables and graphs; and an intuitive user interface. Daily temperature and precipitation data from 238 stations in, and along the borders of, North Carolina and South Carolina were acquired for the period 1950 to present in order to develop a prototype using historical data.

We aggregated raw precipitation data at 1-, 3-, 6-, 12-, 24-, and 60-month periods. To incorporate drought measures used by government agencies, the private sector, and other decision makers, we calculated monthly PDSI, PHDI, Z-index, and modified PDSI (PMDI) values, and the standardized precipitation index (SPI) for 1-, 3-, 6-, 9-, 12-, and 24-months. Daily Keetch-Byram Drought Index (KBDI) and weekly Crop Moisture Index (CMI) were also calculated. Raw streamflow values were aggregated at 7 and 14 days, and at 1, 3, 6, 12, and 24 months. Since the interface allows users to choose percentiles as well as raw data values, we calculated the empirical cumulative distribution function for each variable, during each appropriate time interval (Hayes et al. 2005; Svoboda et al. 2002; Steinemann 2003). This latter option allows combinations of drought measures similar to the approach taken by NOAA's experimental long- and short-term blends.

We first calculated indices and percentiles at individual stations, then interpolated these values to a 4-km grid. Spatial averaging from the grid allows the drought measures to be displayed for a variety of spatial units including the USGS 2-, 4-, 6-, and 8-digit hydrologic unit codes (HUCs), climate divisions, drought management areas, counties, or other relevant region.

We included options for monthly, weekly, and daily time scales. Historical data display satisfied a need to understand the likelihood for specific drought triggers important to the FERC relicensing process. However, operational drought monitoring requires more timely information since drought response committees often meet weekly during intense drought periods (Dupigny-Giroux 2001). The system ingests near real-time daily data to meet this need. Code for the Palmer indices and SPI values was modified to use daily temperature and precipitation data and output values at a weekly time step. Palmer indices were calculated on a weekly basis using three different methods, compared in Rhee and Carbone (2007).

Functionality: The Carolinas Dynamic Drought Index allows selection of numerous variables and drought indices. Users can choose either raw values in appropriate units, or percentile of occurrence; the latter option allows blending of multiple indices. As appropriate, the variables or indices can be displayed at daily, weekly, or monthly time steps.

By default, indices are displayed in choropleth map form with options to manipulate classification method (e.g., equal interval, quantile, natural breaks) and number of classes (5-11). The application provides an original classification scheme for each drought index and allows classification using the same intervals and color scheme as the U.S. Drought Monitor. Another classification method conforms to intervals defined in state drought legislation. As with most geographical information systems, users may overlay points (weather stations, stream gages), lines (e.g., streams), and polygons (e.g., states, counties, drought management areas, climatic divisions, USGS HUCs). Some of these map layers are available simply for display, such as basin hydrology, stream gages, and shaded relief. For most other layers, users either can view the polygon borders as background, or as an analysis layer to which gridded data are aggregated to create choropleth maps. For example, it is possible to view drought conditions for the same month at several different spatial aggregation levels. The application allows users to select multiple polygons of the same spatial unit to create a new choropleth map, showing a drought index for a group of counties or for a particular watershed not defined by one specific 2-, 4-, 6-, or 8-digit HUC. Map navigation tools allow users to zoom in and out, to pan to a particular region, and to create a new map extent or map center.

Users also can produce graphs or tables for points or areas of particular interest. They initiate this feature by selecting a point or polygon on a map or directly from a list. The default setting produces a graph or table for the most recent selection. Users may adjust the beginning and end dates for tables and graphs, toggle between the two, and adjust aggregation regions or the individual components within them (e.g., weather stations, counties, river basins).

The application provides a variety of metadata features. When mapping drought indices, a roll-over feature displays the label and value for each point and polygon. Users can view color-coded polygons and points simultaneously showing percentiles of their custom drought blend. They may also see the weather stations used to produce the interpolated grid from which polygon values were derived. This feature also identifies any points with missing data. A list of relevant stations or areas accompanies each table and graph. Help features provide users with additional information. This includes comments on the functionality of each user option, methods used in application development, error messages, specific calculations for each drought index, references to relevant literature, and caveats associated with the methods used in the production of maps, tables, and graphs.

Summary: The drought monitoring tool was developed for the Carolinas in response to specific challenges, including an intense four-year drought and negotiation of new dam operation licenses. It evolved from discussions between researchers, state-level resource agencies, and stakeholders about drought information needs and strategies for managing water in times of scarcity. The tool's resulting array of drought indices, and its flexibility with respect to spatial and temporal aggregation, reflect the diverse requirements of regional decision makers.

Consideration of decision makers' needs also should influence NOAA and other federal agencies planning a National Integrated Drought Information System (NIDIS; Western Governors' Association 2004). This comprehensive early warning system and proactive model for anticipating and reducing drought impacts will require coordinate activities at both national and regional levels. Nationally, agencies must work together to improve observations required for drought monitoring, modeling of the climate system, prediction, research, and data delivery. In addition to integrating NIDIS with other national- or international-scale observation efforts, it will be important to develop new monitoring tools at regional scales where social and economic impacts are sharply expressed, and mitigation and adaptation policies intersect. Stakeholders should guide the scope and design of such tools so that they address decision makers' most salient challenges (Jacobs 2002; Avery et al. 2003). State-level drought response plans (Wilhite et al. 2000) provide a foundation and stimulus for the monitoring tools that will be required at a sub-national level.

Of course, the needs of stakeholders will evolve, and so too must their decision-support tools. Even in the case of long-term agreements, such as those involved with FERC relicensing, mechanisms must exist to allow management practices to adapt. In the case of the Catawba-Wateree Basin, a Drought Management Advisory Group has been formed to review, update, and improve the low-inflow protocol during the new license term. The Carolinas drought monitoring tool will be an integral part of that process and, therefore, must mature in ways that address decision-makers' future needs.

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