1-2004

Recent Advances in Drought Monitoring

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Presented at 14th Conference on Applied Climatology. Seattle, WA. January 12-16, 2004.

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1. INTRODUCTION

Recent widespread, severe, and long-lasting droughts across North America have heightened awareness of and interest in how to better monitor drought and its impacts. Since its inception in 1999, the National Drought Mitigation Center (NDMC), United States Department of Agriculture (USDA) and NOAA's Climate Prediction Center (CPC) and National Climatic Data Center (NCDC) have partnered to produce the weekly U.S. Drought Monitor (http://droug ht.unl.edu/m onitor/), a com prehensive drought assessment product based on a simple 5-category severity classification. On the heels of its widespread acceptance and usage, the NCDC, CPC, USDA, NDMC and scientists from Canada and Mexico have worked together to produce a monthly experimental North American Drought Monitor (http://www.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/index.html.

Other projects are underway. An informal interagency push toward better water resource assessment has a goal of developing a watershed-based hydrological drought map that would complement the weekly U.S. Drought Monitor map. The Western Governor's Association and NOAA are developing a framework for a National Integrated Drought Information System. The NDMC is also involved in projects looking to improve our spatial and temporal capabilities in monitoring drought. By tapping into the Applied Climate Information System (ACIS), the NDMC has worked with UNL's Computer Science and Engineering department and the High Plains Regional Climate Center (HPRCC) to develop a web-interface based tool, which allows the user to analyze drought indicators like the SPI, PDSI, and Newhall Soil Moisture Model.

A collaborative team of scientists from the USGS EROS Data Center, the NDMC, and the HPRCC is developing a prototype monitoring system that integrates information from climate and satellite databases using data mining techniques. The goal of this project is modeling the relationships between climate-based drought indicators and satellite-derived seasonal metrics from the NDVI (Normalized Difference Vegetation Index). This includes delivering near-real time information about drought-affected areas in the U.S. using the Internet as the primary delivery mechanism.

Clearly, the products and the cooperative efforts described above have advanced our drought monitoring capabilities and have led us to a better understanding of drought as a complex hazard while also improving our capacity to assess, predict and/or provide an early warning of drought.

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2. BACKGROUND

Indices used to track and define drought have been around for nearly a century now. No one definition covers all possible forms of drought and no one index can possibly capture all the various definitions. Indeed, we have come a long way from using one index or indicator to evaluate drought. When Palmer devised the PDSI (Palmer 1965) back in the 1960s, he didn't intend for it to be applied universally, but it was unique in that it utilized a water balance model approach. In fact, his index proved to be a turning point in the evolution of drought indices in the United States (Heim Jr. 2002). It has become the gospel of drought indices, becoming ingrained in our mind sets, decision making and policy.

We have many more new tools available to us now. The marvels of modern technology (now taken for granted) --satellites, GIS, the Internet (information sharing), access to near real-time data and super computing capabilities-- have changed the way we track and define drought. On both the spatial and temporal level the game has changed and the demands of the users have changed as managing our water resources becomes even more critical into the next century.

The goal of these new tools is to better monitor and predict a drought's onset, intensity, duration and spatial extent along with its impacts. Our tool box has never been better equipped, but there is still much to do and improve upon. Many data and products are now available weekly or daily, rather than on a monthly basis. Many products are now being developed using a grid-based format. In addition, more and more site-specific information (compared to a climate division or coarser scale product) is coming on line every month, leading to the generation of a suite of near real time products updated daily.

3. AN INTEGRATED APPROACH

Given the unique challenges of detecting the onset of drought coupled with the complex nature of its impacts, improved tools are needed to predict and assess drought at a finer spatial and temporal resolution.

An integrated drought monitoring system can be divided into five essential components: 1) determination of applicable climate indicators and resultant trigger levels; 2) identification of data requirements and data network sources; 3) acquisition and analysis of reliable data; 4) synthesis of the data and generation of practical, useful products (application); and 5) information dissemination (Svoboda 2002A).

This comprehensive approach serves as a basis for addressing the aspects and impacts of drought. Indicators are needed to look at not only the climate, but also soil, water (above and below ground) and impact information.

One of the obvious gaps in our current drought tracking lies in the area of impact estimation and documentation. The forefather to the Drought Monitor can be found in the form of the Drought Impacts product produced monthly at the NDMC since 1988. (http://drought.unl.edu/risk/us/usimpacts.htm). These maps are put together with information obtained from climatic and hydrological indicators, various media reports, state and federal reports, the Drought Monitor, and direct contact with state officials responsible for drought. However, there isn't a systematic vehicle in place to consistently track and document the economic costs of drought in a comprehensive fashion. In 1995, the Federal Emergency Management Agency (FEMA) estimated that drought accounts for $6-8 billion in annual impact costs in the United States alone, more than any other natural hazard (FEMA 1995). Ironically, this came on the heels of a relatively wet decade (or more) in some places. Since 1995, however, the United States has been in an active drought cycle, with intense multi-year drought affecting large portions of the country each year. That impact number is now arguably higher.

4. THE DROUGHT MONITORS

Perhaps the best contemporary example of an integrated approach can be found in the development of the Drought Monitor and its classification scheme. The Drought Monitor (DM) was unveiled in 1999 and the experimental North American Drought Monitor (NADM) came on line in 2002 as a first step in a cooperative, multinational effort to improve the monitoring and assessment of climate extremes in Canada, Mexico and the United States (Lawrimore et al. 2002).

The Drought Monitors are not forecasts. Instead, they are set up to portray current drought conditions in the way of intensity, spatial extent and resultant impacts on a weekly (DM) and monthly (NADM) basis.

The fundamental strength of these products is that they are based on multiple indicators and incorporate expert input (over 150 people at this time for the U.S. DM) in an attempt to classify a drought's severity and subsequent impacts (both agricultural and hydrological).

The classification scheme for the Drought Monitor breaks drought down into four categories (D1-D4), with a fifth category (D0) indicating an abnormally dry area (possible emerging drought conditions or an area that is recovering from drought but may still be seeing lingering impacts). The D1-D4 categories reflect increasing drought intensity levels, with D1 representing areas experiencing moderate drought and D4 depicting a region experiencing an exceptional drought event (likened to a "drought of record"). The DM uses a percentile approach with a D0 equal to the 30th percentile, D1 the 20th, D2 the 10th, D3 the 5th and D4 the 2nd percentile. (Svoboda et al. 2002B).

The key variables used in making the DM include streamflow, drought indices, percent of normal rainfall, remotely sensed products, and modeled soil moisture. Many other ancillary indicators are used depending on the region and the season. For example, in the West we also look at things like snow pack, snow water equivalent, reservoir information and water supply indices to guide us. In addition, the Climate Prediction Center produces a weekly short and long-term blend, which is objectively computed using different parameters with different weights as a way of differentiating between agricultural and hydrological drought. These are known as the Objective Blends of Drought Indicators (OBDI) (http://www.cpc.ncep.noaa.gov/products/predictions/experimental/edb/droughtblend-access-page.html).

Both blends are now being generated within a GIS system (ArcInfo), allowing for more geo-statistical analysis and product spin-offs. With it, the future potential exists for a user to click on the Drought Monitor and get down to the level of detail that is needed for them to assess and make decisions in response to the drought.

Another strength of the DM is that it isn't a static product. Continually adapting as more and more tools and indicators come into play, the Drought Monitor has the ability to remain flexible and evolve as our climate monitoring technology and capabilities expand in the coming years.

5. NEW EFFORTS

Work between the National Oceanic and Atmospheric Administration (NOAA) and the Western Governor's Association (WGA) has begun with the intent of determining what would be needed to develop a National Integrated Drought Information System (NIDIS) for the United States. Partners between many state, academic and federal entities have formed a core team to deliver a report for the Western Governor's annual meetings in 2004. An interdisciplinary team has been formed to look at data, monitoring and forecast tools, spatial and temporal requirements, new products, and research needed to better assess and predict drought and its impacts. The goal is to provide information and decision support tools for proactive planning, impact mitigation, informed decision making and education.

The goal of the USGS-backed EROS project with the NDMC is to develop a prototype system that integrates data and information from traditional climate and satellite sources. The combined information provided by satellite-derived metrics on vegetation performance and climate-based drought indicators (utilizing data mining techniques) will be used to deliver a timely and spatially detailed drought monitoring product for decision makers at all levels. (http://gisdata.usgs.gov/website/Drought_Monitoring/viewer.asp).

After years of development, considerable progress has been made in making the Applied Climate

Information System (ACIS) (formerly known as the Unified Climate Access Network)(Pasteris et al. 1997), a fully operational system. The goal is to integrate data from several unique networks into one transparent database maintained by the six regional climate centers. A web-based interface is being tested and products (data and maps) are now being produced that fully utilize all of the preliminary data that comes into the system in SHEF coded format on a daily basis. This will include SNOTEL SCAN, RAWS, USGS and other regional/state Mesonet data from around the country.

What began as a state prototype project involving USDA's Risk Management Agency has led to the development of a National Agricultural Decision Support System (http://nadss.unl.edu). This site contains a collection of decision support tools that are designed to help agricultural producers assess a variety of risks. Bringing together data from a variety of sources, the end result of the collection is the production of maps and tables that help illustrate the hazards of drought on the agricultural infrastructure. A national interface has recently been developed enabling the user to generate tabular or map products for the CONUS United States as a whole. Calculations for both the SPI, PDSI, a newly derived self-calibrated PDI and a soil moisture model can be generated in tabular or map form for individual states on a site-location basis as well. This operational tool is based on acquired quality controlled preliminary real-time data utilizing the ACIS interface.

The fact that NOAA has plans for modernizing the Cooperative (COOP) Observer Network through automation of the existing network and development of a National Cooperative Mesonet (with many sites slated to be equipped with soil moisture probes) is quite encouraging. This network is the backbone of our long-term climate network, which is so vital to monitoring drought. Having access to this vital data resource in near real-time will sustain our ability to create products that can better meet users' spatial and temporal needs.

All of the above are critical for bettering our drought monitoring efforts by using this data to ground truth our climate and soil models, satellite-derived products, and radar-derived precipitation estimates. In addition, the data will serve to help improve our forecast and seasonal outlook products. In addition, this should help speed along and improve NOAA's gridded forecast/product analyses.

Continued expansion and/or equipping of existing Mesonet networks with soil moisture probes continues at the regional and state levels as well. This is a very important step in improving our drought prediction and monitoring capability of the future, as observed soil moisture data is one of the most obvious needs for the Drought Monitor and many other products.

6. WATER RESOURCES

Accurate assessment of current and forecasted water resources is an obvious need for any integrated drought monitoring system. To date, no such comprehensive water resources monitoring tool exists. Authority for tracking our nation's water supplies extends across state and international borders and their management is even more complex with private, state and several federal entities involved at various levels.

Currently, a few states in the West calculate Surface Water Supply Index (SWSI) (Shafer and Dezman 1982) values, which are customized to their specific needs and are not always readily available (or comparable from basin to basin or state to state) or standardized for use in the Drought Monitor. A regional Surface Water Supply Index Application (SWSIA) using the "Garen method" (Garen 1993) is being looked at by USDA-NRCS as a potential tool to better address the complicated nature of drought in the western United States. This tool will incorporate precipitation, snowpack (snow water equivalent), streamflow, reservoir storage, and seasonal streamflow forecasts on a more general level in order to be utilized in the making of the Drought Monitor or as part of a new Water Resources Monitor product (Svoboda 2002C).

7. PREDICTION

CPC's Seasonal Drought Outlook (http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html) was first introduced in Spring 2000. This product is issued monthly on the same day as their regular seasonal outlooks. It uses the current Drought Monitor areas of D1 or worse as the initial depiction and then shows areas of improvement, persistence or development based on the stronger seasonal outlooks (when ENSO and other oscillations are pronounced) while relying on other products like the projected Palmer Drought Index values, medium-range forecasts, analogues, and composites when the seasonal outlooks aren't so strong and show equal chances (especially warm season precipitation). The bottom line is that the Seasonal Drought Outlook is like the DM in that it is a blend of art and science when combining and blending short- and long-term seasonal forecasts. Continued research on the teleconnections between the earth, oceans and atmosphere are needed to improve our understanding and forecasting ability.

8. SUMMARY

As recently as five years ago, the thought of a comprehensive drought monitoring product or an integrated drought information system would have been considered a pipe dream. With the development of the Drought Monitor, the Seasonal Drought Outlook, huge leaps in computing power, the Internet and access to a virtual plethora of data in near real-time, we have the existing building blocks in place and an opportunity to go even further in the coming years in the drought monitoring realm.

Our work is far from done though. New, continued and enhanced cooperation, partnering, coordination and resources will be needed if we want to get where we need to go. Many needs and gaps exist in our infrastructure, research and forecast capabilities.

By no means a comprehensive list, these are some of the gaps or concerns that need to be addressed in order for us to improve our nation's drought monitoring and prediction capability:

1) resources need to be committed to an integrated drought monitoring/information system (tool development, networks, research, mitigation planning)
2) development of better impact assessment tools
3) enhance our observed soil moisture networks
4) development of a user-driven (GIS/IMS) product down at a county level that can aid decision makers
5) better monitoring and access to our water resources, (especially groundwater)
6) better drought prediction capability at more than just the seasonal level (shorter and longer time frames)
7) better utilize remote sensing potential (precipitation, soil moisture, snow cover)
8) better means of accounting for the effects of elevation

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