10.1 A GLOBAL DROUGHT MONITORING WEB PORTAL

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1. Introduction

Drought has had a significant impact on civilization throughout history. Every continent has semi-arid areas which are especially vulnerable to drought. In North America and Europe today, drought impacts are largely economic. But in most of the rest of the world, drought-induced crop failure and famine can create severe hardship. In a globally-warmed world, drought-affected areas will likely increase in extent and the vulnerability of semi-arid regions to drought will also likely increase. The IPCC (2007) specifically noted that annual average river runoff and water availability are projected to decrease by 10-30% over some dry regions at mid-latitudes and in semi-arid low latitudes, and increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes, as well as reduce water availability for hydropower potential and summer tourism.

As noted by the IPCC (2007), some countries have made efforts to adapt to the recent and projected changing climate conditions, particularly through conservation of key ecosystems, early warning systems, risk management in agriculture, strategies for flood drought and coastal management, and disease surveillance systems. Local, national, and regional collaborative drought monitoring efforts have been summarized at several venues, including World Meteorological Organization (WMO)-sponsored gatherings of experts in Lisbon, Portugal in 2000 (Wilhite *et al.*, 2000) and Lincoln, Nebraska, USA in 2009. However, the effectiveness of these efforts is outweighed by: lack of basic information, observation and monitoring systems; lack of capacity building and appropriate political, institutional and technological frameworks; low income; and settlements in vulnerable areas, among others (IPCC, 2007). These shortcomings have inhibited the development of an integrated global drought early warning system (GDEWS) (Wilhite, 2005).

In 1992, an International Conference on Climate, Sustainability and Development in Semi-arid Regions (ICID-I) focused the world's attention on the plight of drylands peoples and was influential in the negotiation of the United Nations (UN) Convention to Combat Desertification (UNCCD). With 193 country Parties to the Convention, the UNCCD is a global mechanism to combat desertification and mitigate the effects of drought through national action programs that incorporate long-term strategies supported by international cooperation and partnership arrangements. The Second International Conference on Climate, Sustainability and Development in Semi-arid Regions (ICID 2010) seeks to build upon this work to help turn agreements into local development outcomes.

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For many decades, attempts to manage drought and its impacts through a *reactive*, crisis management approach have proven to be ineffective, poorly coordinated, and untimely (WILHITE *et al.*, 2005). In the United States, the National Integrated Drought Information System (NIDIS) was established by the NIDIS Act in 2006 as a *proactive* mechanism to:

- develop the leadership and networks to implement an integrated drought monitoring and forecasting system at federal, state, and local levels;
- foster and support a research environment focusing on risk assessment, forecasting, and management;
- create an "early warning system" for drought to provide accurate, timely, and integrated information;
- develop interactive systems, such as the Web Portal, as part of the early warning system; and
- provide a framework for public awareness and education about droughts (NPIT, 2007).

The U.S. Drought Monitor is the primary drought monitoring tool utilized within the NIDIS web portal drought management framework. The geographical scope of the NIDIS drought portal is being expanded with data and web services capabilities to support drought monitoring across North America, with the North American Drought Monitor (NADM) as the centerpiece.

At the Fourth Plenary Session and Ministerial Summit of the Group on Earth Observations (GEO) held in Cape Town, South Africa, in November 2007, representatives from more than 70 nations reaffirmed their commitment to working together, at both the political and technical levels, to improve the interoperability of observation, prediction and information systems as part of the Global Earth Observation System of Systems (GEOSS). Recognizing the growing problem of drought and its impact on long-term sustainability of Earth's water resources, the event concluded with a U.S. proposal that technical representatives from participating countries build upon existing programs to work toward establishing a GDEWS within the coming decade to provide: a system of systems for data & information sharing, communication, & capacity building to take on the growing worldwide threat of drought; and regular drought warning assessments issued as frequently as possible with increased frequency during a crisis.

In April 2010, a Global Drought Assessment Workshop was held in Asheville, North Carolina, USA to move the coordinated global drought monitoring efforts of the WMO and GEO forward. Noting that the robust services of the NIDIS drought portal could serve as the foundation for an even broader international drought Clearinghouse, the portal managers agreed to develop a prototype Global Drought Monitoring web portal (GDMP) to serve as a Clearinghouse for international drought information. Once the digital infrastructure was created, the GDMP could be populated with drought information from all corners of the world and serve as the foundation for the development of a GDEWS.

The GDMP would be available to all parties who have an interest and stake in drought monitoring, forecasting, impacts, mitigation, research, and education. It could provide crucial support for drought monitoring and mitigation, especially in semi-arid regions, thus enhancing climate monitoring, sustainability, and development in semi-arid regions.

2. Drought monitoring in North America

The wide variety of sectors affected by drought, its diverse geographical and temporal distribution, and the demand placed on water supply by human-use systems make it difficult to develop a single definition of drought. As a result, numerous indices have been developed during the last hundred years to measure the intensity, impact, and geographic extent of drought (Heim 2002). At the end of the 20th century, a new drought monitoring tool – the Drought Monitor (USDM) – was developed for the United States. Similar national Drought Monitors were developed in Canada and Mexico during the early years of the 21st century. Collaboration between these three countries has resulted in the North American Drought Monitor (NADM), a monthly product which assesses current drought conditions on a continent-wide basis.

a. U.S. Drought Monitor

The USDM (http://drought.unl.edu/dm/monitor.html) was developed in 1999 in a federal/state collaborative effort to consolidate and centralize drought monitoring activities. Agencies within the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture (USDA) team with the National Drought Mitigation Center (NDMC) and NOAA Western Regional Climate Center (WRCC) to produce a weekly map (see Fig. 1) and narrative product that incorporates climatic data and professional input from all levels (Svoboda *et al.,* 2002). Since no single definition of drought works in all circumstances, the USDM authors rely on the analyses of several key indices and ancillary indicators, including impacts information, from different agencies to create the final map. Some of these ancillary indicators are available in a delayed mode or only on a local/regional basis. The key parameters are objectively scaled to five percentile-based USDM drought categories – D1 (moderate drought) to D4 (exceptional drought event, likened to a drought of record), plus a "pre-drought" or "recovering drought" category D0 (abnormally dry area) – and labels are used to indicate which sectors are being impacted by drought (A for agricultural impacts, H for hydrological impacts). The USDM maps are based on many objective inputs, but the final maps are adjusted manually to reflect real-world conditions as reported by numerous experts throughout the country. Consequently, the USDM is a consensus product reflecting the collective best judgment of many experts based on several indicators.

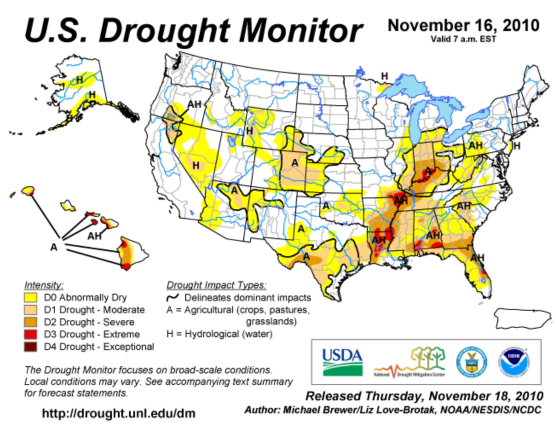

Figure 1. US Drought Monitor depiction from November 16, 2010.

b. North American Drought Monitor

In a late 2001 meeting, U.S., Canadian, and Mexican representatives agreed in principle to establish a climate extremes monitoring partnership and that the first step would be to develop monthly continental drought monitoring capabilities. The result was the creation of the NADM (http://www.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/), which is an extension of the USDM concept to the continental scale. While the USDM is a weekly product, the NADM is a monthly map and narrative product which is constructed by integrating the national drought depictions from the three countries into a continental depiction (see Fig. 2). The national depictions are each prepared by experts within the three countries independently from each other (Agriculture and Agri-Food Canada [AAFC] prepares the Canadian depiction, the

National Meteorological Service [SMN] prepares the Mexican depiction, and the USDM for the week closest to the end of the month is used for the U.S.). This can result in discontinuities in drought depiction along the international borders. Drought indices covering the entire continent are needed to provide guidance for adjusting the border depictions. These continental indicators (Standardized Precipitation Index, Palmer indices, and percent of normal precipitation) are computed using the same methodologies and same analysis period for consistency. Other continental and global indicators (such as modeled soil moisture and the satellite-based Vegetation Health Index) are also used.

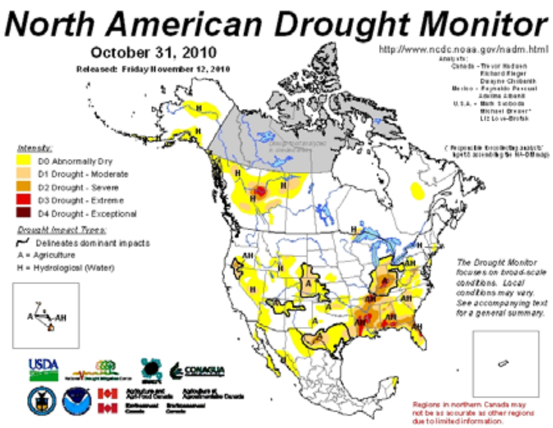

Figure 2. North American Drought Monitor depiction from October 2010.

c. National Integrated Drought Information System and NIDIS Drought Portal

The passage of the NIDIS Act Public Law in December 2006 resulted in the establishment of NIDIS (http://www.drought.gov/), which was created to enable the U.S. to move from a reactive to a more proactive approach to managing drought risks and impacts, resulting in better informed and more timely drought-related decisions leading to reduced impacts and costs. The five components of NIDIS include: 1) NIDIS Program Office, 2) U.S. drought portal, 3) climate/drought test beds which prototype the integration of data and forecasts, 4) integrated applications research into coping with drought, and 5) development of early warning information systems at the local level to demonstrate workable design and prototyping approaches and methods which could be utilized in the implementation of regional then national drought early warning systems. A critical component of NIDIS is the drought portal (see Fig. 3), which serves as a web services-based internet hub for drought information related to current conditions, forecasts, impacts, planning, education, research, and recovery. The geographic scope of the NIDIS portal is being expanded with data and web services capabilities to support the NADM.

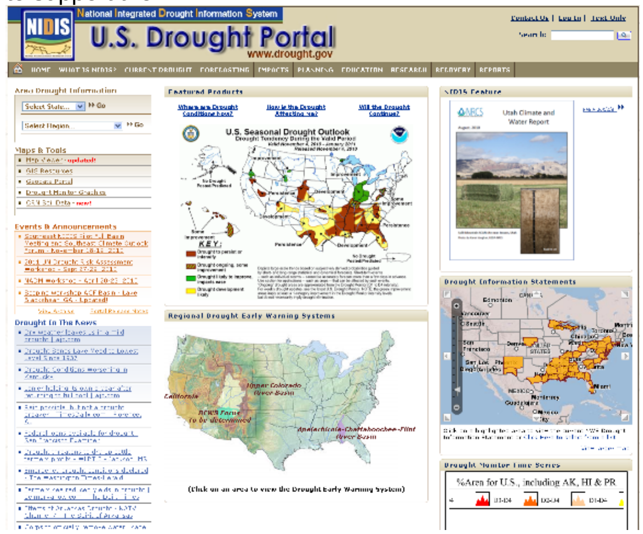

Figure 3. The NIDIS US Drought Portal

d. U.S.-Canadian GEO-Related Drought Activities

Scientists in the U.S. and Canada engage in collaborative research through a bi-lateral agreement under the auspices of U.S. GEO (USGEO) and Canadian GEO (CGEO). This collaboration enables an expanded view of North America – as a single geographic space. The following opportunities for transboundary cooperation are being pursued:

- Developing three international, interdisciplinary water-related monitoring testbeds, building on existing initiatives, along the U.S.-Canada border:
  - The Great Lakes. The goal of this testbed activity would be to bring together the many initiatives to facilitate coordination both on water availability and water quality monitoring.
  - The Prairie Region. The goal of this testbed activity would be to close gaps in critical Earth observation requirements for agriculture, specifically soil moisture, as they relate to drought and flooding extremes.
  - The Rocky Mountains. This region was identified because of its role as a laboratory for cold-water processes, as well its importance as the source of many trans-boundary river systems.
- Initiating two studies of drought in the context of hazards and extreme events:
  - Surface Water Supply Index (SWSI) Study. The study will examine how SWSI, a popular and valuable index for drought management in the Western U.S., can be further refined and tested, including in Western regions of Canada.
  - Drought Definitions and Indices. Consensus emerged around the need to improve the

definition of drought for different climatic regions, and the need to develop new and improved indices for drought, including vegetation. Continent-wide study is needed for comparative analysis across regions, and close links to the testbed activities should be pursued to refine definitions and indices for specific regions.

These areas of research and collaboration are of interest to ICID 2010 participants because all but the Great Lakes testbed deal directly with drought in arid or semi-arid regions.

3. Creating a Global Drought Monitoring Portal

It has long been recognized that a global-scale drought monitoring, mitigation, and response system would provide important benefits to all Nations affected by drought, especially to those peoples in semi-arid regions. As noted at the 2000 and 2009 drought workshops in Lisbon and Lincoln, respectively, national DEWSs have been created in many areas, including the U.S. (USDM and NIDIS), Australia, Brazil, Canada, China, Hungary, India, Mexico, Nigeria, the Philippines, Romania, and South Africa, and regional drought monitoring centers or activities have been established in North America (NADM), Europe (European Drought Observatory), southeastern Europe, eastern, western, and southern Africa, North Africa, West and Central Asia, and the Caribbean. Many of these efforts have come to fruition through work associated with the UNCCD. However, the creation and maintenance of national and regional DEWSs in other areas, as well as the creation and maintenance of a global DEWS, face many hurdles, including: inadequate data networks (station density and data quality), inadequate data sharing (both between government agencies and due to the high cost of data), data and information products that are too complex for use by decision-makers, unreliable seasonal forecasts, inadequate indices for detecting the early onset and end of drought, the lack of integrated physical and socioeconomic indicators for drought, the lack of impact assessment methodology, data and information frequently unavailable on an operational real-time basis, and inadequate comprehensive global historical data base and assessment products (Wilhite *et al.*, 2000; Wilhite & Buchanan-Smith, 2005). An additional hurdle is the lack of resources to address these issues. With these limitations in mind, NOAA and its partners organized the Global Drought Assessment Workshop in Asheville, North Carolina, USA in April 2010 to pick up on the previous work toward GDEWS and determine next steps that are possible without new resources.

a. The April 2010 Global Drought Assessment Workshop

The Global Drought Assessment Workshop was part of a series of drought workshops held in Asheville during the week of 20-23 April 2010. The other workshops included the biennial NADM Forum and the U.S.-Canadian GEO Bi-lateral Technical Workshop. The NADM Forum addressed scientific, technical, administrative, and user issues associated with the NADM, while the U.S.-Canadian GEO Bi-lateral Technical Workshop's goals included reporting on the status and progress of each of the three testbeds and two drought studies and developing guidelines for the testbeds and studies. Many of the NADM Forum attendees were also involved in the GEO bi-lateral studies and had an interest in global drought monitoring, so the biennial NADM Forum provided an excellent opportunity for coordinated gatherings of these groups. Organizational assistance for the workshops was provided by NOAA, NIDIS, USDA, WMO, NDMC, USGEO, CGEO, the GEO Secretariat, AAFC, and SMN.

It was quickly recognized at the global workshop that no single Nation or organization can afford to tackle all of the hurdles involved in creating a GDEWS in their entirety. However, it was believed that small pieces of the problem could be solved in an incremental way. If an international drought Clearinghouse and web services infrastructure could be established – a global web portal "foundation" could be laid – then it might be easier to construct the GDEWS "building" atop it. A series of breakout groups addressed two components of this problem: *what pieces are necessary for a global Clearinghouse of drought information*, and *how should such a Clearinghouse be housed, portrayed, and distributed*.

The breakout groups concluded that the pieces of a Clearinghouse should include drought indices that can be computed on a continental to global scale and that drought impacts information should be included globally, if available. It was suggested that categories of indices be identified instead of specific indices (i.e., some evapotranspiration-based index, some soil moisture index, and modeled indices as well as satellite-based vegetation indices). Remotely-sensed data should be used in conjunction with *in situ* data, especially in parts of the world where *in situ* data are difficult to obtain. An effort at continental-scale analyses and coordination (the NADM model) should be made where feasible, but the approach should be tailored to the needs and resources of each continent (i.e., the NADM model may not be applicable to other continents). The WMO was suggested as a mechanism or a liaison with the countries/continents to determine what their alternatives are, or for integrating their alternatives into the Clearinghouse. While the initial focus of the Clearinghouse may be limited to just drought monitoring, it should expand to also include impacts, mitigation, forecasts, research, education, and planning (like NIDIS).

It was recognized that neither the WMO nor GEO has the resources to house, portray, and distribute such a Clearinghouse. The NIDIS drought portal managers noted that the NIDIS portal was developed to support drought monitoring, forecasting, research, and impacts assessment in the U.S., but new web mapping services have been developed to distribute the information that Canada, Mexico, and the U.S. integrate to aid in the production of the NADM (see Fig. 4). These new web services will be housed in the U.S. Drought Portal in a North American-specific site. These new tools will allow additional accuracy in the development of the NADM by allowing overlaying of information as well as increase the utility of the data by providing it in more accessible and useful formats. With minimal additional effort, a prototype Global Drought Monitoring Portal (GDMP) could be developed as an outgrowth of the NIDIS portal modifications (see Fig. 4). The GDMP will provide a number of different depictions of drought on the global-scale, developed using data from WMO World Data Centers. Products will include several drought indices, such as the Standardized Precipitation Index (SPI) at various time-scales and possibly precipitation, Palmer drought indices, and satellite-based Vegetation Health depictions. The GDMP will also serve as a launching point for continental-scale drought depictions where not only an international assessment such as the NADM could reside, but also drought indicators used to develop the assessment.

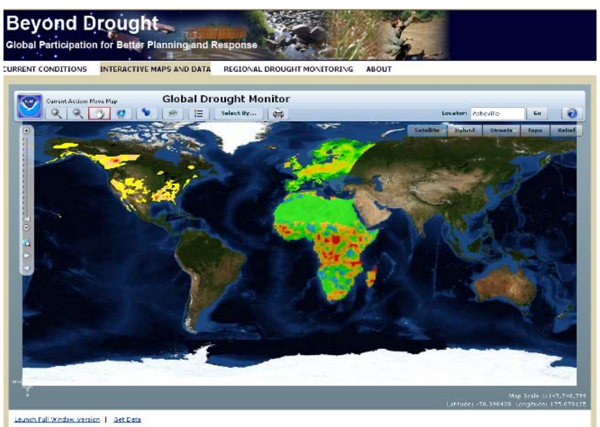

Figure 4. Interoperability of drought web services from the NADM, the European Drought Observatory and Princeton prototyped within the US Drought Portal environment.

b. A Vision for a Global Drought Early Warning System / Global Drought Monitor

With the creation of a GDMP "foundation" upon which to build a GDEWS or Global Drought Monitor (GDM), how would such a GDEWS/GDM look? How would it function? One possibility is that the GDM be prepared, distributed, and managed by one organization or Nation and be made available to the other Nations of the world, while an alternative is that it be a collaborative process whereby national or regional Drought Monitor products are prepared by the participating Nations, integrated on a regional basis into a global product, and distributed via the GDMP. In the collaborative scenario (see Fig. 5), the national Drought Monitors (DMs) would be prepared by each Nation according to processes established within the Nation and using national datasets. Regional or continental DMs could be prepared following the NADM model or using a model uniquely adapted to the requirements and resources of each region or continent. The regional/continental DMs (or national DMs for regions/continents that don't have their own DM) are integrated into the GDMP for global display. The GDMP resources would be available to the Nations and regions/continents for preparation of their DMs. This process would require the establishment of certain standards for the depiction of drought on each DM (using a D0-D4 scale similar to the NADM), creation of DM shape files in a GIS environment, and smoothing of GDMP drought depictions along international borders.

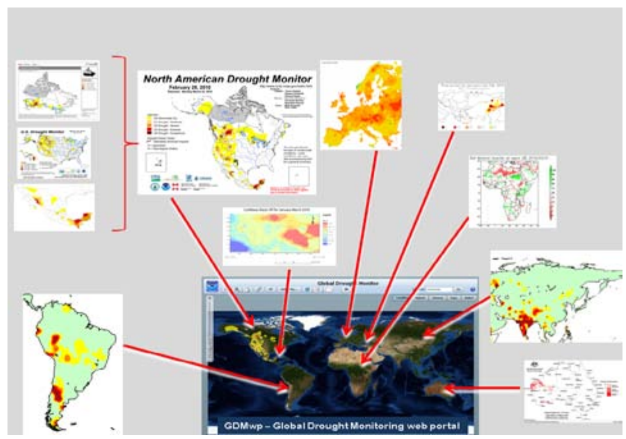

Figure 5. A conceptual framework for service integration into a Global Drought Monitoring Portal.

4. Opportunities for drought monitoring in under-served areas

Limited scientific and technical resources frequently inhibit climate monitoring, sustainability, and development in semi-arid regions. Mechanisms such as the UNCCD help peoples in these areas to combat desertification and mitigate the effects of drought. The creation of a GDMP will be a new tool which could provide crucial support for drought monitoring and mitigation in semi-arid regions and other parts of the world. The GDMP will be available to provide important drought information to participating Nations, as well as serve as an infrastructure which could be populated with drought information originating from Nations in semi-arid regions. It will be available to all parties who have an interest and stake in drought monitoring, forecasting, impacts, mitigation, research, and education. The GDMP could provide crucial support for drought monitoring and mitigation, especially in semi-arid regions, thus enhancing climate monitoring, sustainability, and development in semi-arid regions.

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