Drought Research Priorities in the United States

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Global Modeling and Assimilation Office
NASA/GSFC

Third Drought Research Initiative Workshop

Calgary AB
17-19 January 2008
Overview

• Research community priorities
  – 2005 Drought workshop

• Progress in addressing priorities
  – USCLIVAR working group
Results and Recommendations of a Workshop on

Observational and Modeling Requirements for Predicting Drought on Seasonal to Decadal Time Scales

17-19 May 2005
University of Maryland Inn and Conference Center
• **Organizers:** S. Schubert, R. Koster, M. Hoerling, R. Seager, D. Lettenmaier, A. Kumar, and D. Gutzler

• **Sponsors/support:** NASA programs on Modeling, Analysis and Prediction, and Terrestrial Hydrology, and NOAA’s Climate Prediction Program for the Americas
  – *Don Anderson and Jared Entin (NASA)*
  – *Mike Patterson and Jin Huang (NOAA)*

• **The more than 100 participants** included experts in both drought research and applications, and spanned the drought communities of the United States, Canada, Mexico, Central and South America and Australia.

Workshop report is available at
Summary is published in Oct 2007 BAMS
Short-term drought problem

- **Develop coordinated effort in drought monitoring, prediction and early warning, in support of NIDIS:**
  - Creation of a “National Drought Attribution and Prediction Consortium” that uses multiple models and analysis techniques to address drought problems in coordination with stakeholders

- **Establish long (multi-decade) climate records adequate for retrospective studies, and as required for initialization, calibration and validation:**
  - global and regional atmosphere/land reanalyses, with a focus on the improved representation of the hydrological cycle

- **Improve (real-time) observation/assimilation of key surface variables needed for monitoring, model initialization and/or validation (with uncertainty estimates):**
  - soil moisture profiles (monitoring system focused on “sensitive” regions, such as a pilot effort focused on the Great Plains)
  - forcing data (precipitation, radiation, etc.) for land data assimilation
  - vegetation properties (e.g., from NDVI, EDVI MODIS data)
  - Snowpack, surface temperature, streamflow

- **Improve coupled (atmosphere-ocean-land) model prediction system. Development should focus on:**
  - teleconnections between SST variations and continental precipitation
  - weather statistics (particularly extreme events)
  - land/atmosphere interaction
  - surface/subsurface water reservoirs (including estimates of recovery time)

- **Improve understanding of roles of local and remote processes on drought variability and predictability, as a function of timescale:**
  - role/predictability of drought-related SST variations (including ENSO)
  - role/predictability of subsurface land water
  - role/predictability of short-term atmospheric variability (e.g., weather, MJO)
Long-term drought problem

• **Foster research into the mechanisms that control the land surface branch of the hydrological cycle at multi-year (decadal) timescales:**
  - decadal ocean variability in the context of regional drought
  - connection of ENSO and other shorter-term SST variability to the initiation and demise of long-term drought
  - deep soil moisture variability (drought unforced by SSTs)
  - aerosol feedbacks (i.e., the Dust Bowl)
  - decadal vegetation feedback
  - global change
  - drought migration

• **A research effort focusing on the causes of historical droughts (attribution studies):**
  - multiyear-to-decadal hindcasts of past droughts
  - characterization of drought duration, seasonality and spatial extent
  - development and improved use of paleodata for estimating decadal and longer term drought variations, including mega-droughts

• **Improve simulations of hydrological variability on decadal time scales. Development should focus on:**
  - realistic decadal SST variability and teleconnections to regional drought
  - realistic simulation of subsurface water on decadal time scales

• **Foster research focusing on the predictability of multiyear-to-decadal drought:**
  - assess the predictability of SST variability related to long term droughts
  - assess the predictability of the onset and demise of long term drought
  - experimental forecasting of droughts on the multiyear timescale
The US CLIVAR Drought Working Group

U.S. Membership

• Tom Delworth  NOAA GFDL
• Rong Fu  Georgia Institute of Technology
• **Dave Gutzler** (co-chair)  University of New Mexico
• Wayne Higgins  NOAA/CPC
• Marty Hoerling  NOAA/CDC
• Randy Koster  NASA/GSFC
• Arun Kumar  NOAA/CPC
• Dennis Lettenmaier  University of Washington
• Kingtse Mo  NOAA CPC
• Sumant Nigam  University of Maryland
• Roger Pulwarty  NOAA- NIDIS Director
• David Rind  NASA - GISS
• **Siegfried Schubert** (co-chair)  NASA GSFC
• Richard Seager  Columbia University/LDEO
• Mingfang Ting  Columbia University/LDEO
• Ning Zeng  University of Maryland

International Membership: Ex Officio

• Bradfield Lyon  International Research Institute for Climate
• Victor O. Magana  Mexico
• Tim Palmer  ECMWF
• **Ronald Stewart**  Canada
• Jozef Syktus  Australia

http://www.usclivar.org/Organization/drought-wg.html
Activities

• Evaluating model-based drought indices

• Coordinating AGCM experiments to assess the roles of the ocean and land in long term drought

• Organizing a community workshop in 2008 to present and discuss results
In GSWP-2, a number of land surface models were driven for 10 years with the same observations-based meteorological forcing. What we will try to demonstrate here is that the models produce a similar WI product – i.e., that WI is largely a model-independent quantity.

The “robustness” of the model-based soil moisture drought index – a study using GSWP-2 data.

Contact: Randy Koster randal.d.koster@nasa.gov
Let \( w(j,n) \) = model’s total soil moisture for day \( j \) of year \( n \).

Define:

\[
WI(j,n) = \frac{w(j,n) - \mu_w(j)}{\sigma_w(j)}
\]

where

\( \mu_w(j) \) = Mean (over many years) of \( w \) on day \( j \).
\( \sigma_w(j) \) = Standard deviation of \( w \) on day \( j \).

Note: \( \mu_w(j) \) and \( \sigma_w(j) \) are specific to the model considered. (Their values may differ greatly between models, and not just because of differing profile thicknesses or soil types.)
WI values for 7 different GSWP-2 models over a point in the U.S. Great Plains.

The unprocessed soil water diagnostics (shown here as degree of saturation) are not nearly as model-independent.
Average $r^2$ between models
31-day smoother, detrended

Note: Under the definition of WI, the seasonal cycle of soil moisture is subtracted out before statistics are computed, making it that much more difficult to get a high $r^2$. 
Idealized Model Simulations

• The idea is for several modelling groups to do identical (somewhat idealized) experiments to address issues of model dependence on the response to SSTs (and the role of soil moisture), and to look in more detail at the physical mechanisms linking the SST changes to drought.

• Currently have results from NSIPP1 (NASA), NCAR’s CCM3 (Lamont), and GFS (NCEP). Expect to get results from CAM3 (NCAR), the GFDL model, and NCEP/CFS coupled model (Ben Kirtman, Univ of Miami).
Idealized Forcing Patterns

Second and Third Leading Rotated EOFs of Annual SST (warm phase)
Annual 200mb Height Anomalies (m)

Pacific (warm-cold)

- CCM3
- NSIPP1
- GFS

Atlantic (warm-cold)

- CCM3
- NSIPP1
- GFS
Annual Mean $T_{\text{skin}}$ (°C)

**Pacific (warm-cold)**

- **CCM3**
- **NSIPP1**
- **GFS**

**Atlantic (warm-cold)**

- **CCM3**
- **NSIPP1**
- **GFS**

Legend:

-3 -2.5 -2 -1.5 -1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1 1.5 2 2.5 3
Annual Precipitation (mm/day)

Pacific (warm-cold)

Atlantic (warm-cold)
Seasonality in the Response to Pacific SST

Shift in storm tracks

SST forcing

Change in LLJ
Summary Remarks

- **US CLIVAR Drought Working Group is making progress on achieving its research goals**
  - New model-based definitions of drought for monitoring and validation
  - coordinate evaluations of existing relevant model simulations
  - developed new model experiments designed to address some of the outstanding uncertainties concerning the roles of the ocean and land in long term drought

- **We look forward to more community participation**
  - We will be making model datasets available (TBD)
  - Joint CDP and USCLIVAR Workshop in Oct 2008 in Nebraska
  - Link to Canadian DRI and follow-on
Extra Slides
Leading EOFs and Time series (annual mean SST - 1901-2004)

Linear Trend Pattern (LT)

Pacific Pattern (Pac)

Atlantic Pattern (Atl)
**Idealized Experiments**

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SST Forcing patterns
(warm phase)
Annual Mean Precipitation Responses

Responses to combined EOFs

Pluvial conditions

Major drought conditions

Responses to combined EOFs
Annual Mean Temperature Responses

Responses to combined EOFs
Impact of Soil Moisture Feedbacks on JJA Precipitation

Interactive soil moisture

No soil moisture feedbacks