Drought Monitoring and Early Warning Systems

Robert Stefanski
Chief, Agricultural Meteorology Division
Climate and Water Department

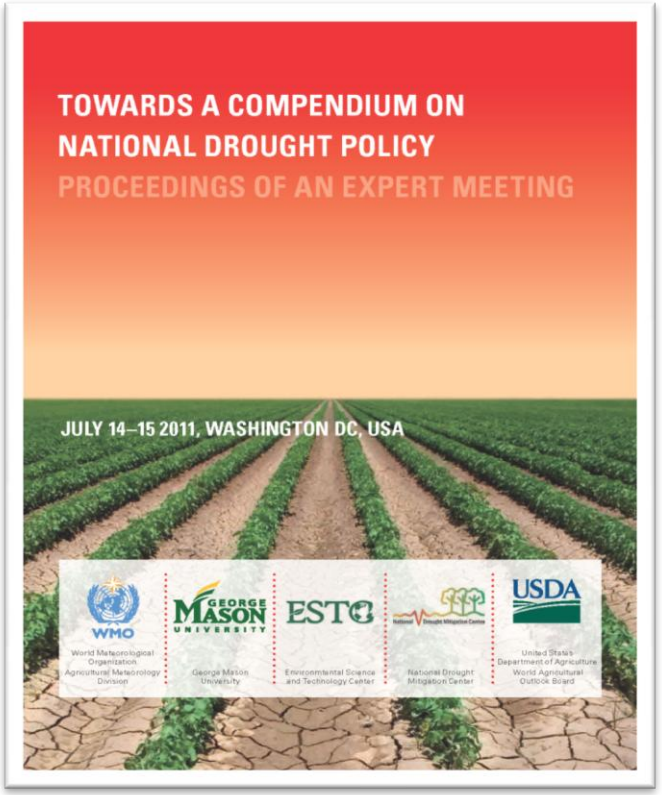
Summary

- Review of High-Level Meeting on National Drought Policies
- Introduction to Drought Monitoring and Early Warning Systems
- Different Drought Indices and Data Issues
- Successful examples/ongoing initiatives

Preparation Meetings on National Drought Policy – July 2011 – Wash DC

"Proposed Elements in the Compendium on National Drought Policy"

These elements were revised and updated as HMNDP Science and Policy Documents.



Sivakumar, Mannava V.K., Raymond P. Motha, Donald A. Wilhite, and John J. Qu (eds.), 2011.

HMNDP Main Organizers and Partners

- **World Meteorological Organization (WMO)**
- **United Nations Convention to Combat Desertification (UNCCD)**
- **United Nations Food and Agriculture Organization (FAO)**
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- United Nations Development Programme (UNDP)
- **UN-Water Decade Programme on Capacity Development (UNW-DPC)**
- United Nations International Strategy for Disaster Reduction (UNISDR)
- World Food Programme (WFP)
- Global Water Partnership (GWP)
- International Fund for Agricultural Development (IFAD)
- A total of 17 Organizations

Attendance

414 registered participants from 87 countries

Scientific Segment

- 9 substantive sessions in the Scientific Segment plus 2 synthesis/reporting sessions (regional breakout groups and summary)
- 28 posters in three poster sessions. 16 Side events

- All sessions produced summaries and recommendations
- Proceedings will be published

- Compendium from July 2011 Workshop revised as HMNDP Science Document

Recommendations

Develop national drought policies and preparedness plans that place emphasis on risk management rather than crisis management;

Establish scientifically sound, comprehensive and integrated drought Early Warning Systems;

Formulate networks/collaborations to enhance knowledge and information sharing to improve public understanding and preparedness to drought;

Develop research and monitoring to improve drought forecasting on the seasonal scale.

www.hmndp.org

Recommendations (II)

Encourage countries to systematically collect data that will allow the assessment of drought impacts;

Promote integrated water management for irrigated, rainfed and mixed agricultural systems;

Bridge the gaps with early warning and preparedness by utilizing traditional and newly developed tools to evaluate cross-sectoral impacts and the effects of relief measures;

Promote Institutional coordination at local, state (sub-national) and federal (national) level is very important to ensure efficiency and effectiveness of measures to address drought.

Launch of initiatives

- **2013 World Day to Combat Desertification, UN Decade for Deserts and the Fight against Desertification, and UN Decade on Biodiversity**

- **Integrated Drought Management Programme (IDMP) with WMO & GWP**

- **National Drought Management Policies Initiatives (NDMP) with UNW-DCP, FAO, UNCCD, & WMO**

Early Warning Systems Essential elements of NDMP

National Drought Management Policy (NDMP) has several key elements:

- **Promoting standard approaches to vulnerability and impact assessment**
- **Implementing effective drought monitoring and early warning systems**
- **Enhancing preparedness and mitigation actions**
- **Implementing emergency response and recovery measures that reinforce national drought management policy goals**
- **Understanding the cost of inaction**

Introduction

Why Monitor Drought?

- Drought is a ***Normal*** Part of the Climatic Cycle
- Drought ***Impacts*** are Significant & Widespread
- ***Many*** Economic Sectors Affected
- Drought is ***Expensive***
  - Droughts cause more deaths and displace more people than any other kind of natural disaster.
  - Since 1980, major droughts and heat waves within the U.S. alone have resulted in costs exceeding 100 billion dollars

Source: Svoboda, 2009

Importance of a Drought Monitoring System

- allows for ***early*** drought detection
- improves response (***proactive***)
- ***"triggers"*** actions within a drought plan
- a critical ***mitigation*** action
- ***foundation*** of a drought plan

Source: Svoboda, 2009

Components of a Drought Monitoring System

- timely data and timely acquisition
- synthesis/analysis of data used to “trigger” set actions within a plan
- efficient dissemination network (web, media, extension, etc.)

Source: Svoboda, 2009

Potential Monitoring System Products and Reports

- ***Historical analysis*** (climatology, impacts, magnitude, frequency)
- ***Operational assessment*** (cooperative data, SPI and other indices, automated networks, satellite and soil moisture data, media and official requests)
- ***Predictions/Projections*** (SPI and other indices, soil moisture, streamflow, seasonal forecasts, SST's)

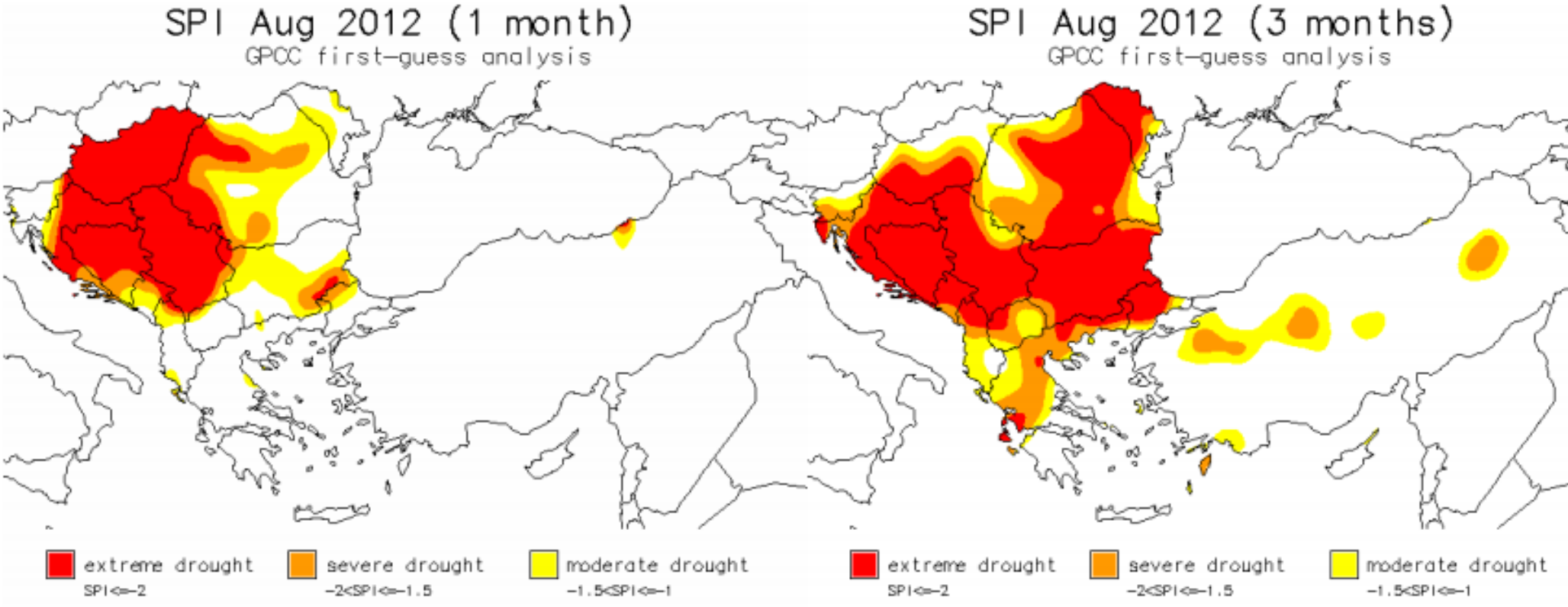
Source: Svoboda, 2009

Components of a Drought Early Warning and Information System

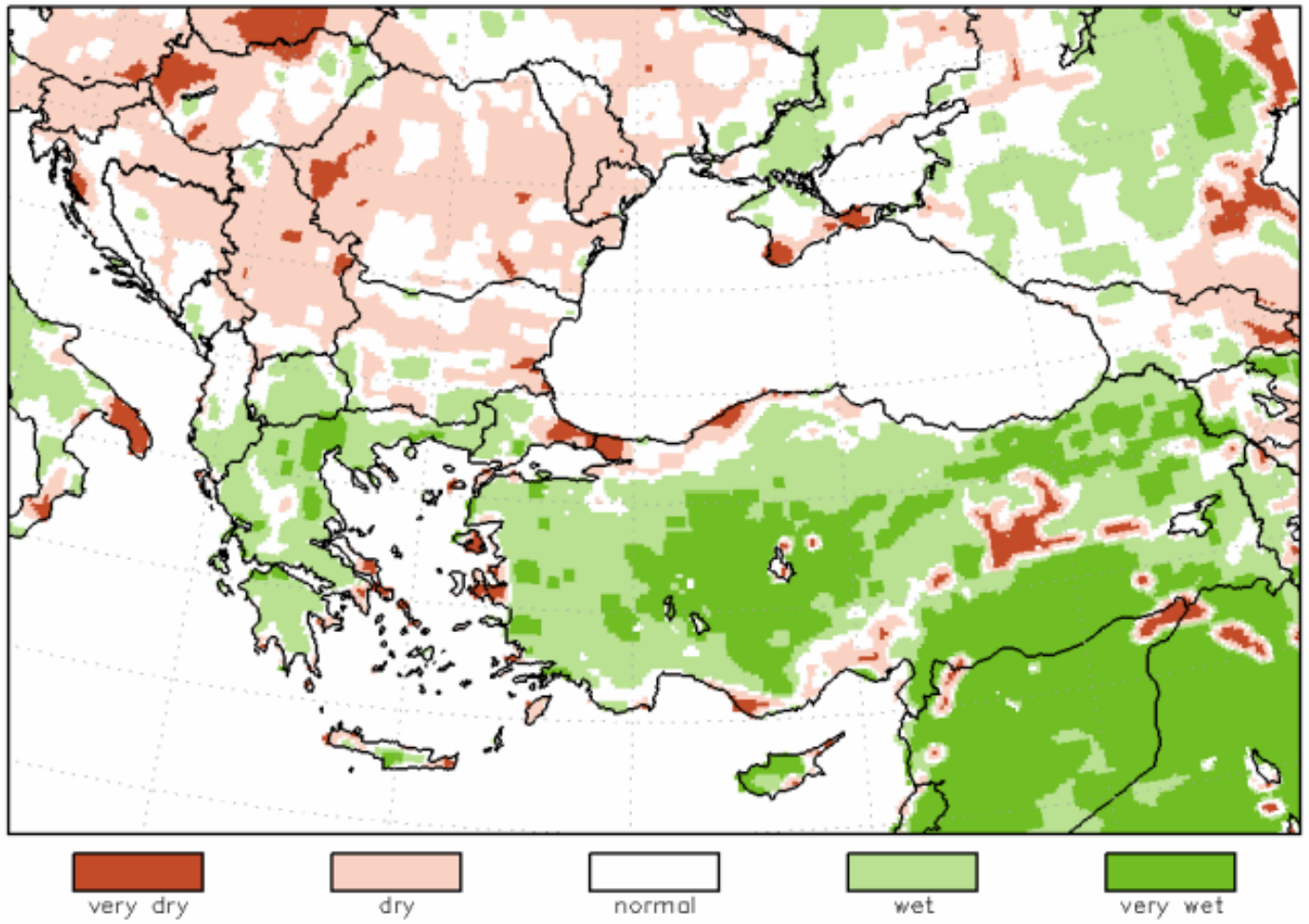
- Monitoring **AND** Forecasting
- **Tools** for decision makers
- Drought risk assessment and planning
- **Education** and awareness

Source: Wilhite, 2013

SPI Index


SPI Aug 2012 (1 month)
GPCC first-guess analysis
SPI Aug 2012 (3 months)
GPCC first-guess analysis
extreme drought
SPI<=-2
severe drought
-2<SPI<=-1.5
moderate drought
-1.5<SPI<=-1
extreme drought
SPI<=-2
severe drought
-2<SPI<=-1.5
moderate drought
-1.5<SPI<=-1

Outlook



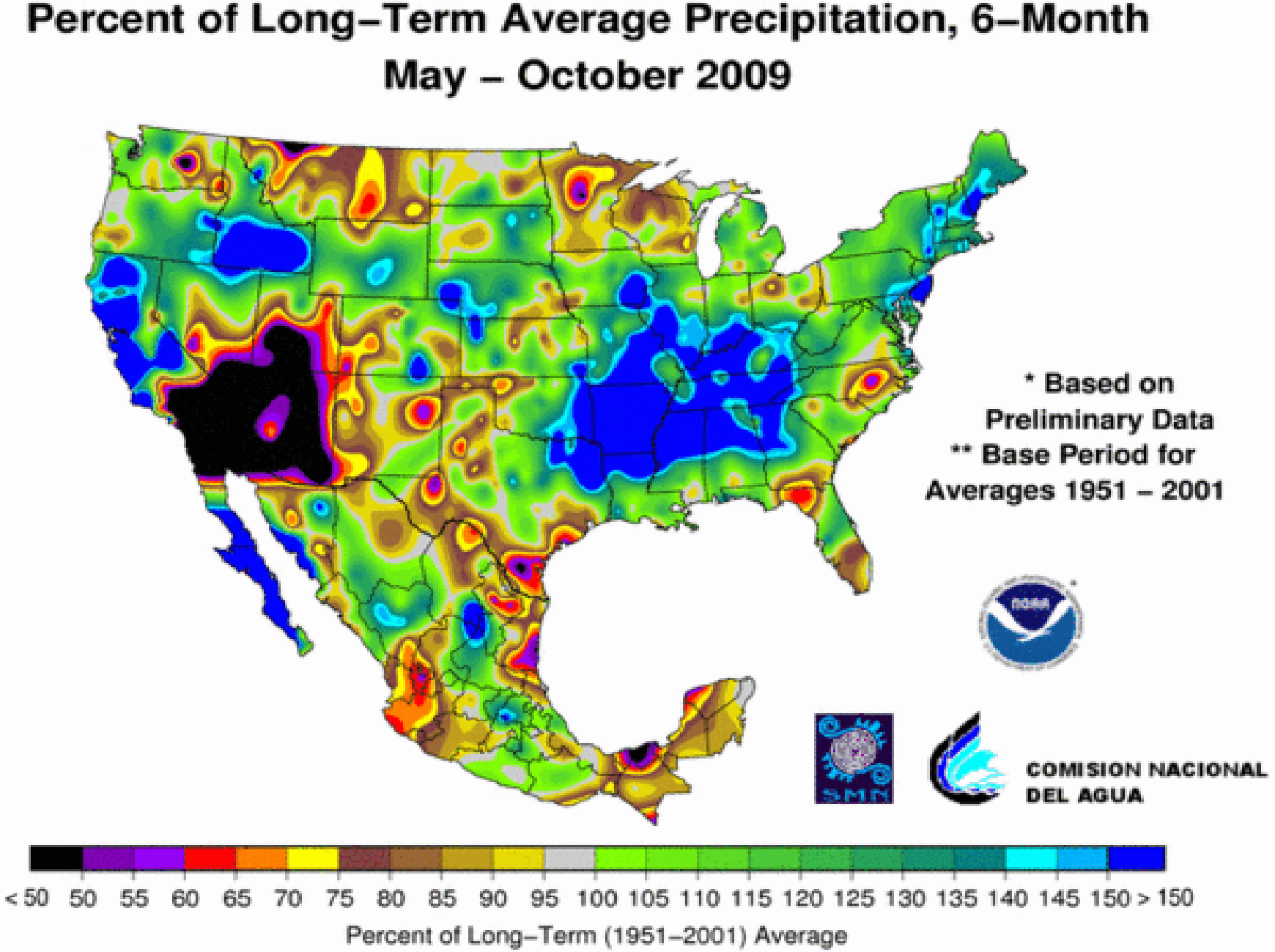
Model simulations of the water balance for the time period from 30 July to 27 September show that drought conditions will persist in the northern part of the region while in the southern Balkans and Turkey, wet conditions will prevail.

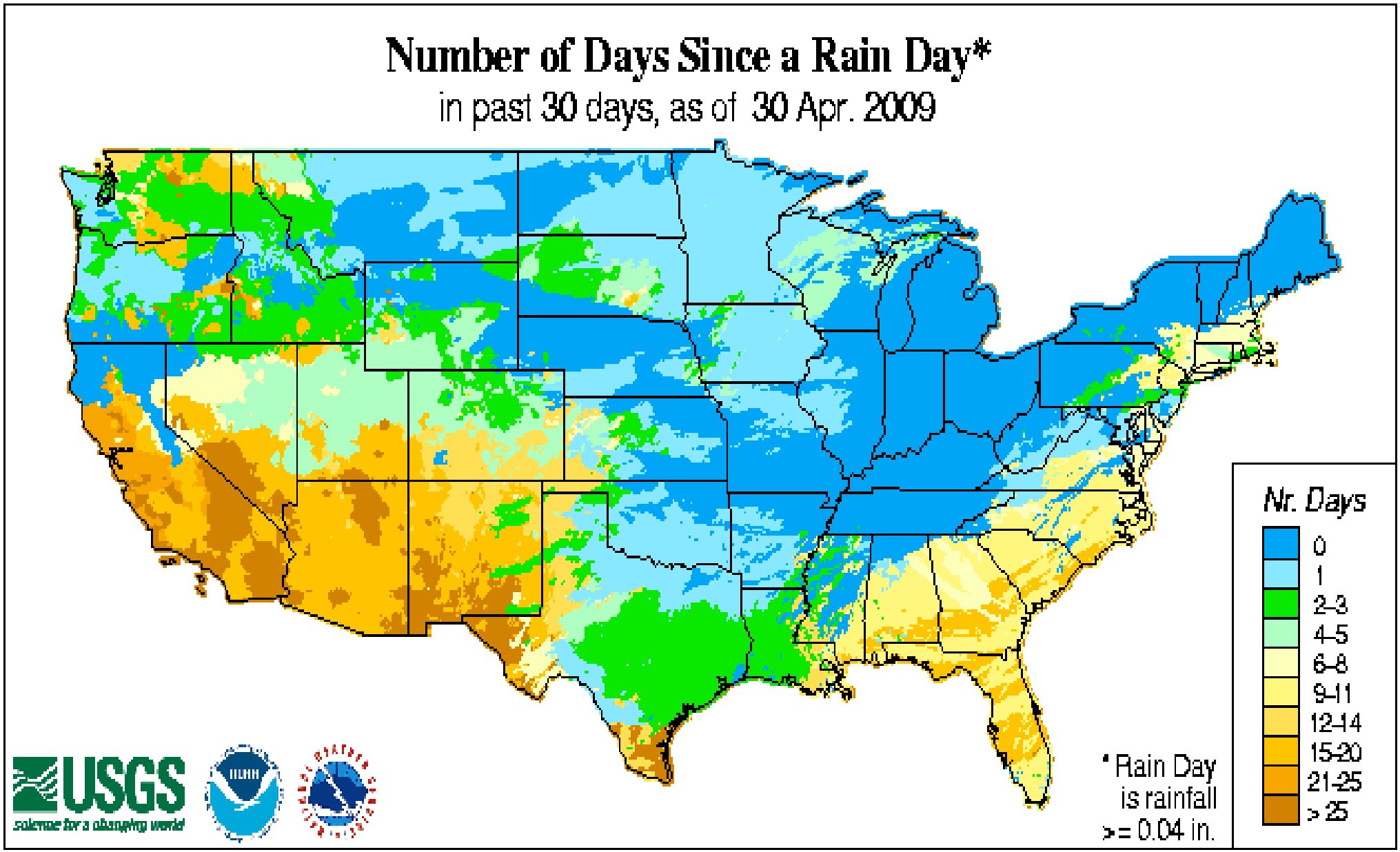
Indices and Data Issues

Approaches to Drought Monitoring

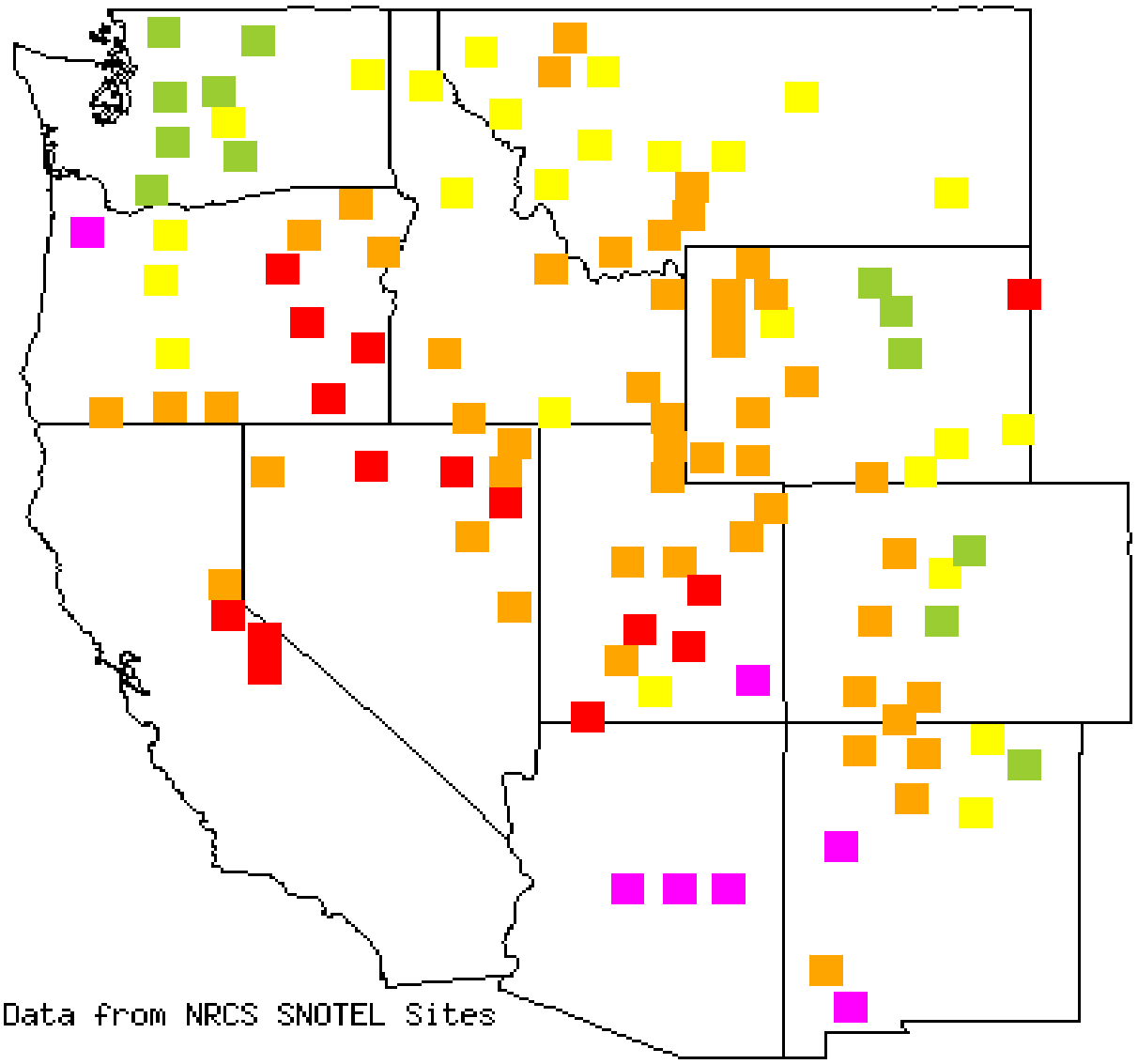
- **Single index or parameter**
- **Multiple indices or parameters**
- ***Composite* index**

Source: Svoboda, 2009


Percent of Long–Term Average Precipitation, 6–Month
May – October 2009
* Based on
Preliminary Data
** Base Period for
Averages 1951 – 2001
COMISION NACIONAL
DEL AGUA
< 50 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 > 150
Percent of Long–Term (1951–2001) Average


Number of Days Since a Rain Day*
in past 30 days, as of 30 Apr. 2009
Nr. Days
0
1
2-3
4-5
6-8
9-11
12-14
15-20
21-25
> 25
* Rain Day is rainfall >= 0.04 in.
USGS
science for a changing world

Basin Average Snow Water Content. (% of Average.)



Percent of Average

- > 200
- 175 to 200
- 150 to 175
- 125 to 150
- 110 to 125
- 90 to 110
- 75 to 90
- 50 to 75
- 25 to 50
- < 25

Report Date:

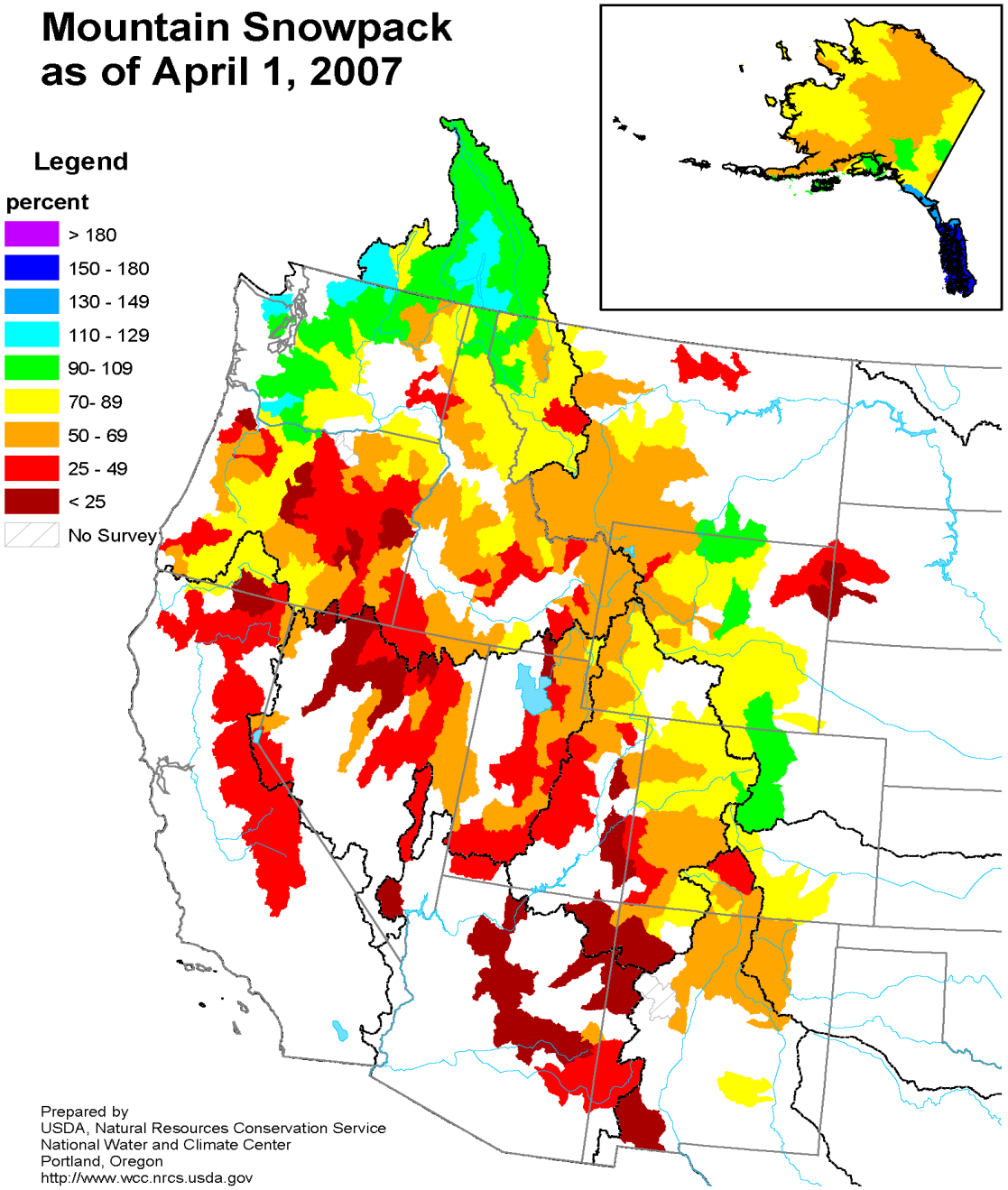
MARCH 31 , 2007

Provisional Data
Based on Mountain Data from NRCS SNOTEL Sites

Data provided by
Water and Climate Center
Natural Resources Conservation Service
Portland, Oregon

Western Regional Climate Center
Desert Research Institute
Reno, Nevada

Mountain Snowpack as of April 1, 2007



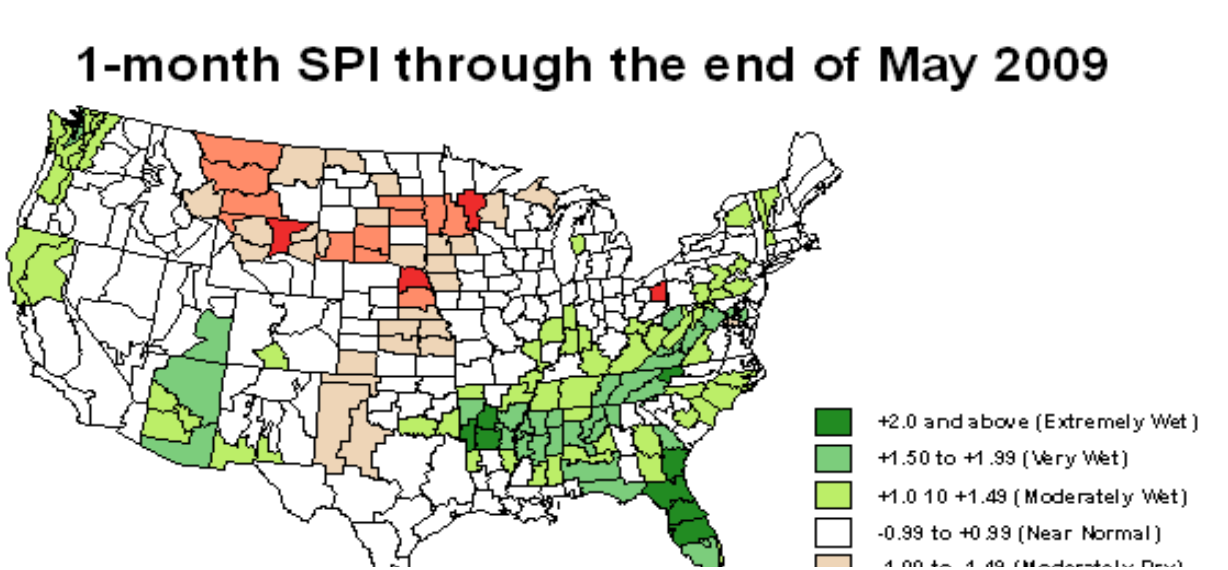
Prepared by
USDA, Natural Resources Conservation Service
National Water and Climate Center
Portland, Oregon
http://www.wcc.nrcs.usda.gov

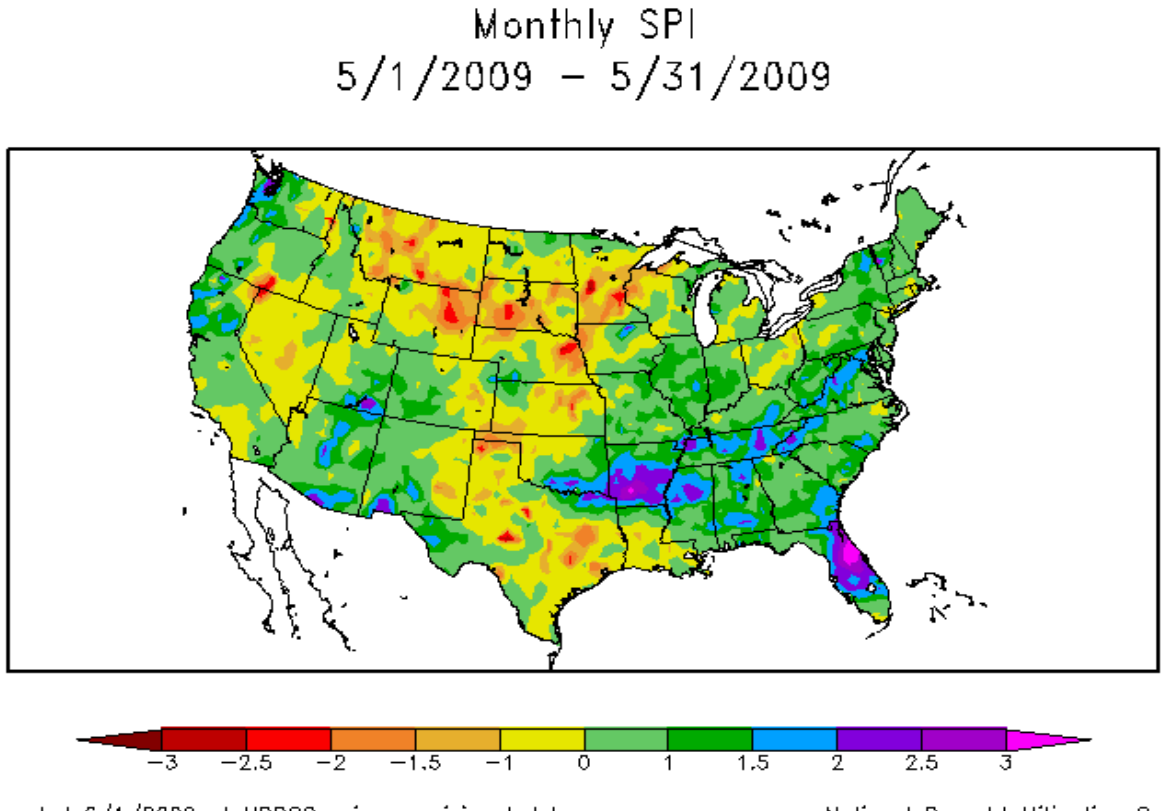
RESOLUTION:

Standardized Precipitation Index (SPI)

by Climate Division (above), and by 0.4º grid (below)

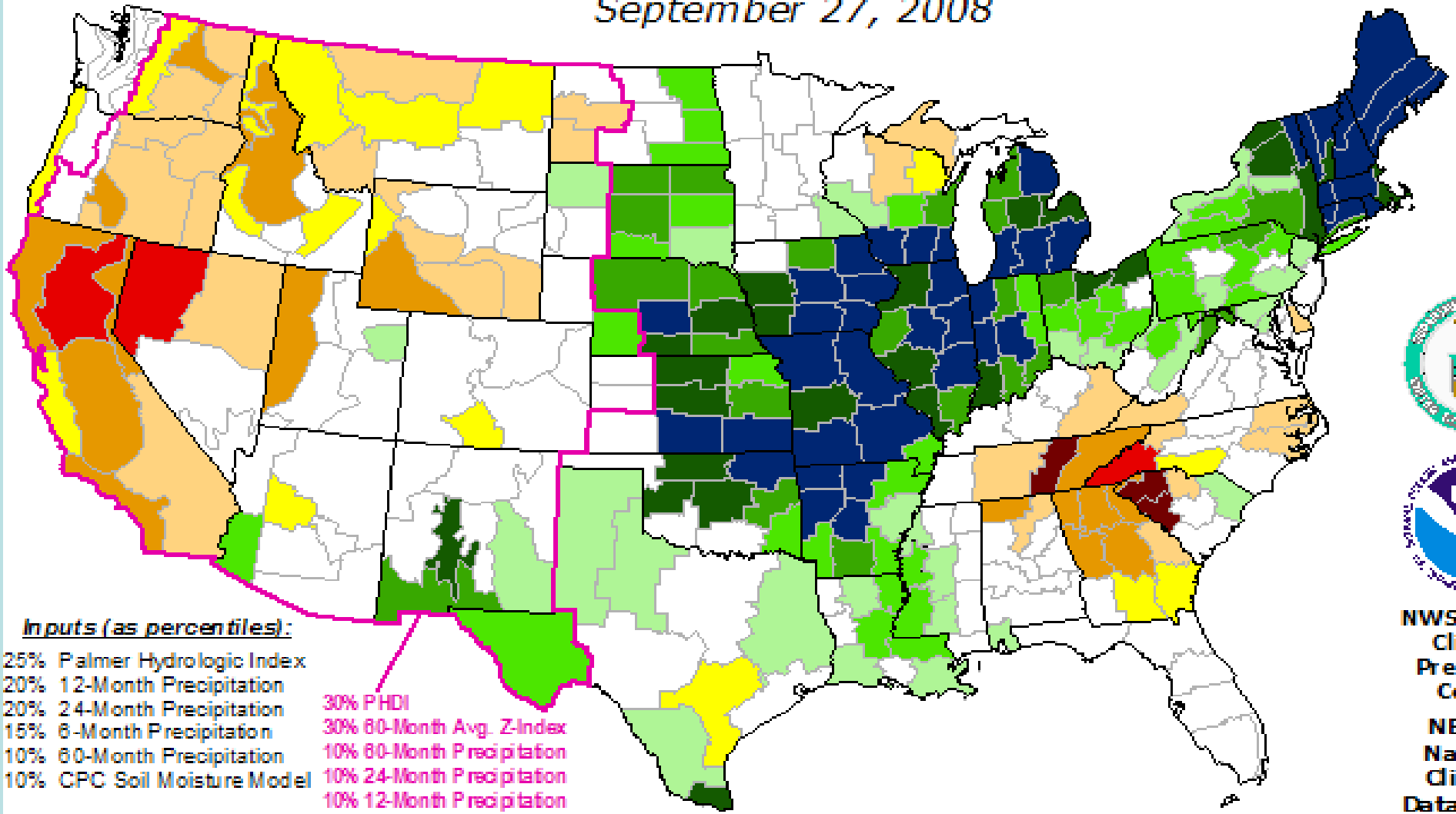
Source: ACIS/HPRCC/NDMC





Objective Long-Term Drought Indicator Blend Percentiles

September 27, 2008



Inputs (as percentiles):

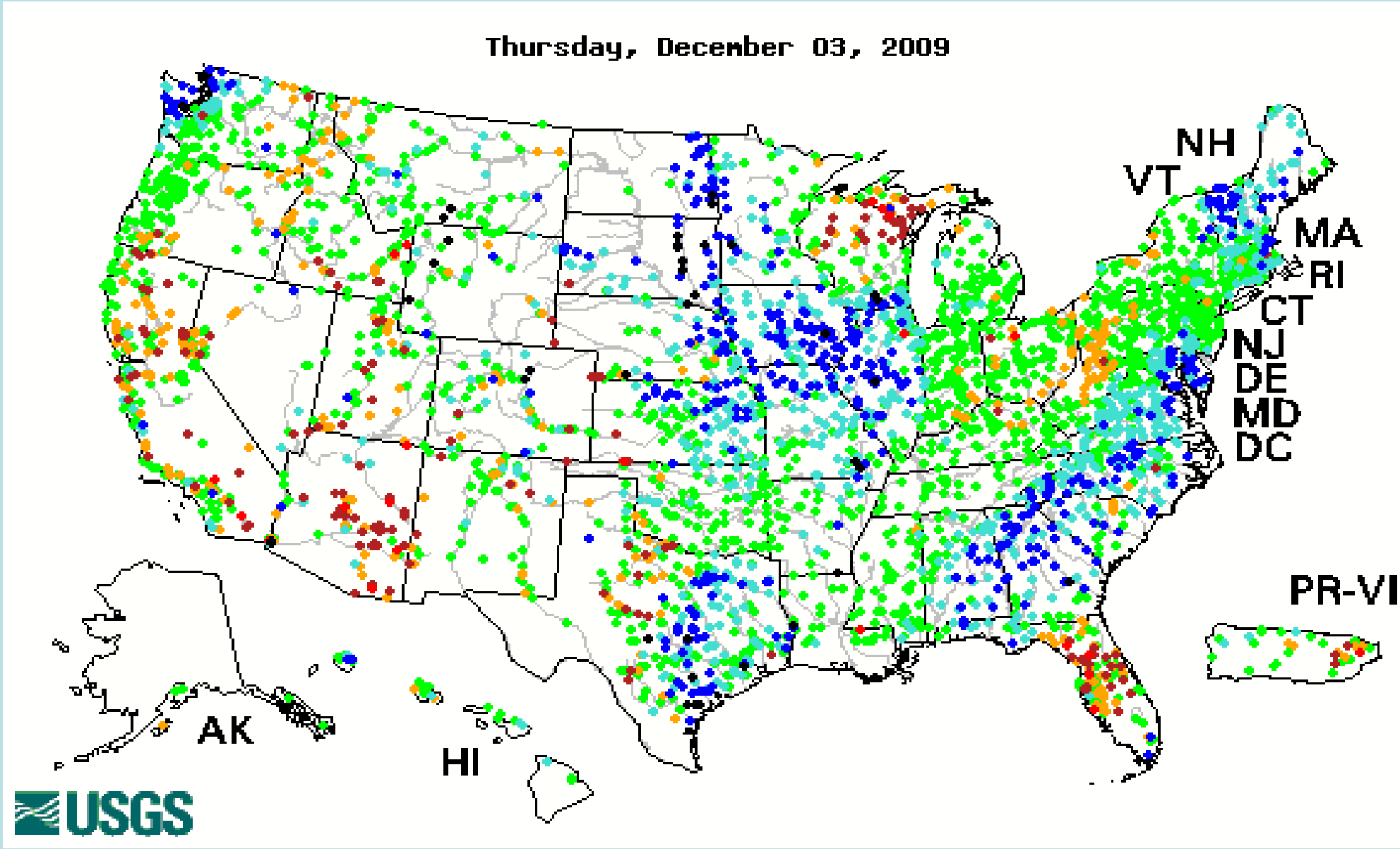
25% Palmer Hydrologic Index
20% 12-Month Precipitation
20% 24-Month Precipitation
15% 6-Month Precipitation
10% 60-Month Precipitation
10% CPC Soil Moisture Model

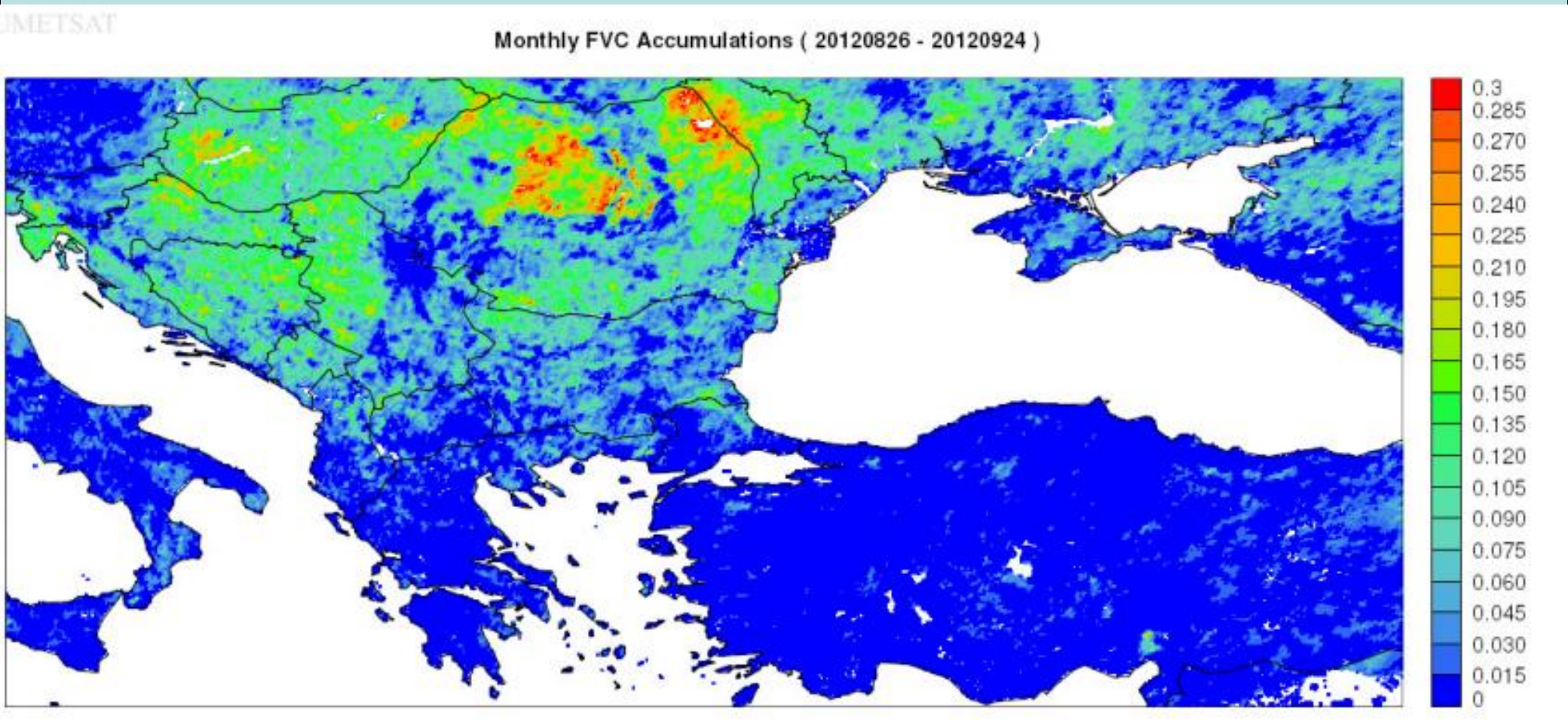
30% PHDI
30% 60-Month Avg. Z-Index
10% 60-Month Precipitation
10% 24-Month Precipitation
10% 12-Month Precipitation
10% CPC Soil Moisture Model

NWS / NCEP
Climate Prediction Center

NESDIS National Climatic Data Center

The short-term map (top) approximates impacts that respond to precipitation over the course of several days to a few months, such as agriculture, topsoil moisture, unregulated streamflows, and most aspects of wildfire danger. The long-term map (bottom) approximates impacts that respond to precipitation over the course of several months to a few years, such as reservoir content, groundwater depth and lake levels. HOWEVER, the relationship between indicators and impacts can vary significantly with location and season. THIS IS PARTICULARLY TRUE OF WATER SUPPLIES, which are additionally affected by source, and management practices.


Thursday, December 03, 2009
NH
VT
MA
RI
CT
NJ
DE
MD
DC
PR-VI
AK
HI
USGS



Fraction of vegetation cover

Indicators & Triggers Definitions

- **Indicators: Variables to describe drought conditions.**

  Examples: precipitation, streamflows, groundwater, reservoir levels, soil moisture, Palmer indices, …

- **Triggers: Specific values of the indicator that initiate and terminate each level of a drought plan, and associated management responses.**

  Example: precipitation below the 5th percentile for two consecutive months is a Level 4 Drought.

Source: Svoboda, 2009

Importance of Drought Indices

- ***Simplify*** complex relationships and provide a good communication tool for diverse audiences
- ***Quantitative*** assessment of anomalous climatic conditions
  - Intensity
  - Duration
  - Spatial extent
- ***Historical*** reference (probability of recurrence)
  - Planning and design applications

Source: Svoboda, 2009

Considerations in Choosing Indicators / Triggers

- Proper and Timely Detection of Drought
- Spatial and Temporal Sensitivity
- Supplies and Demands
- Drought In / Drought Out
- Composite and Multiple Indicators
- Data Availability, Validity, and Clarity
- Ease of Implementation

Source: Svoboda, 2009

Key Variables for Monitoring Drought

- climate data
- soil moisture
- stream flow / ground water
- reservoir and lake levels
- snow pack
- short, medium, and long range forecasts
- vegetation health/stress and fire danger
- remote sensing products
- **impacts**

Source: Svoboda, 2009

Lincoln Workshop

- **Inter-Regional Workshop on Indices and Early Warning Systems for Drought held in Lincoln, Nebraska, USA from 8 to 11 December 2009**

- **Co-Sponsors:**
  - **National Drought Mitigation Center (NDMC)**
  - **United States Department of Agriculture (USDA)**
  - **United States National Oceanic and Atmospheric Administration (NOAA)**
  - **United Nations Convention to Combat Desertification (UNCCD)**
  - **University of Nebraska-Lincoln, School of Natural Resources**
  - **World Meteorological Organization**

http://www.wmo.int/pages/prog/wcp/agm/meetings/wies09/index_en.html

Workshop Objectives

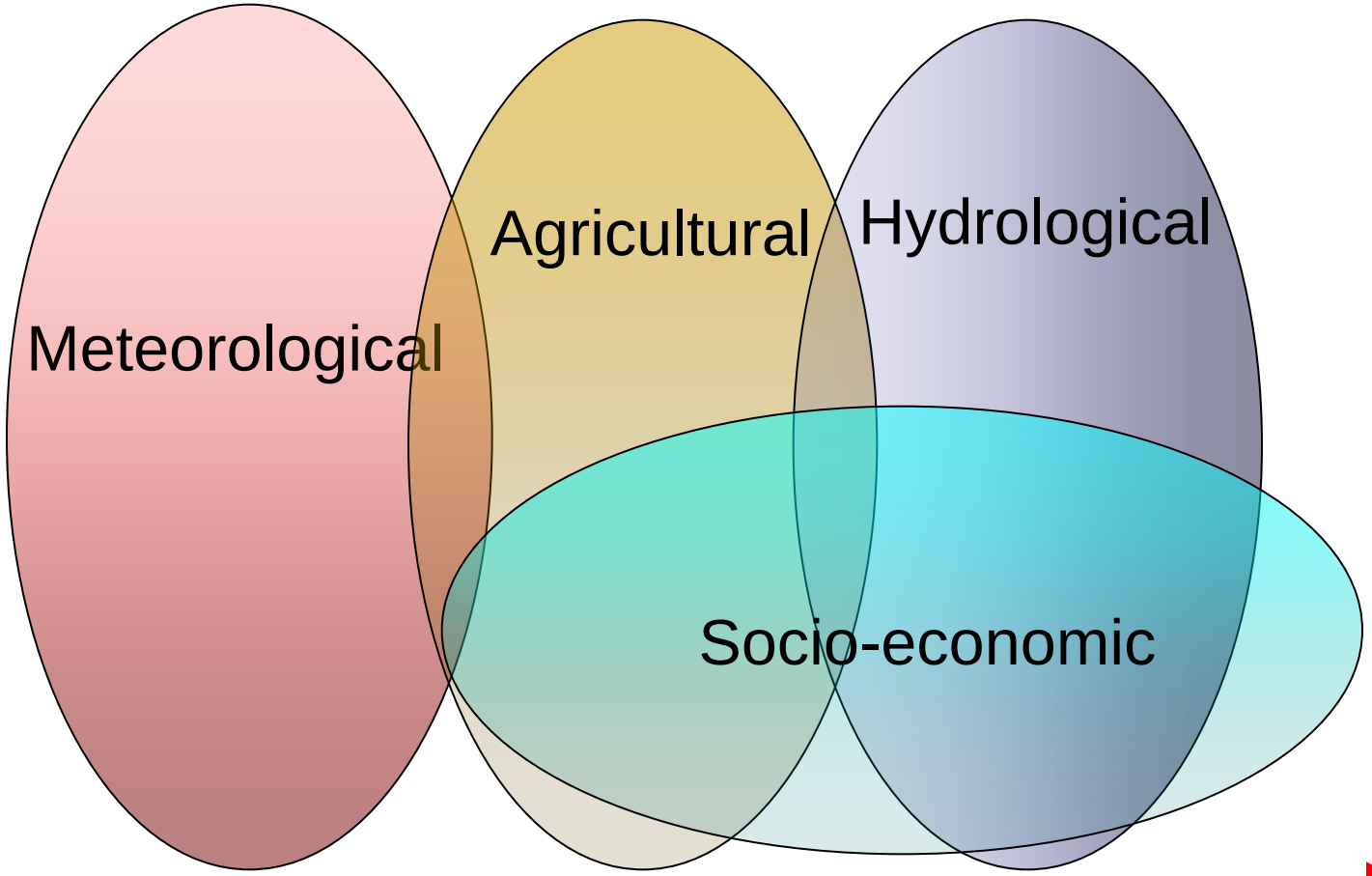
- To review and assess drought indices currently used around the world for the three types of drought (meteorological, agricultural, and hydrological);
- To review and assess the strengths, weaknesses and limitations of existing drought indices and early warning systems;
- To develop a consensus standard index for each of the three types of drought;
- To develop guidelines for WMO Members in implementing and improving drought early warning systems.

Natural and Social Dimensions of Drought

Decreasing emphasis on the natural event (precipitation deficiencies)

Increasing emphasis on water/natural resource management

Increasing complexity of impacts and conflicts



Time/Duration of the event

Source: Wilhite 2006

Breakout Groups

- Mostly followed methodology from Keyantash and Dracup (2002) "The Quanification of Drought: An Evalution of Drought Indices" – Bulletin of AMS - August 2002

Used following criteria:

- Robustness
- Tractability
- Transparency
- Sophistication
- Extendability
- Dimensionality

Meteorological Drought Group

- **Precipitation Percentiles (includes deciles and quartiles)**
- **Percent of Normal Precipitation**
- **Palmer Drought Severity Index (PDSI)**
- **Standardized Precipitation Index (SPI)**

Meteorological Drought Outcome

- **SPI and Percentiles were very close, but the SPI had a slightly higher score**

- **Percent of Normal Precipitation was ranked third**

- **PDSI was a distant fourth**

Recommendation: Use drought indices that are based on a sound statistical and historical perspective (SPI and Percentiles). The SPI is the recommended Meteorological drought index.

Agricultural Drought Outcome

- **No consensus (17 indices)**

Conclusions

- **Water Balance models are quite good since they take into account soil and crop growth**

- **NDVI is very useful and is comparable with hydrological balance**

- **For all indices, a temperature component is important**

Hydrological Drought Outcome

- **No consensus (6 indices)**

Recommendations

- **Examine composite indices that take into account streamflow, precipitation, reservoir levels, snowpack, groundwater levels such as:**
  - **Surface Water Supply Index (SWSI)**
  - **Aggregate Dryness Index (ADI)**
  - **Normalised ADI (NADI) (Barua and Perera 2009)**

Also suggested;

- **Streamflow drought Index (SDI) Nalbantis and Tsakiris (2009)**
- **Artificial Neural Networks (Perera et al. 2009)**

Lincoln Declaration - Recommendations

- **The National Meteorological and Hydrological Services (NMHSs) are encouraged to use SPI to characterize meteorological droughts and provide this information in addition to indices currently in use.**

- **A comprehensive user manual for the SPI should be developed that describes the index, computation methods, specific examples of current use, the strengths and limitations, mapping capabilities, and how it can be used.**

Lincoln Declaration - Recommendations

- A simple, systematic analysis of drought impacts in different sectors should be initiated in all affected countries in order to provide useful decision-making information for policy-makers.

- Drought indices and early warning systems must be implemented from the beginning with the end-users in mind. To accomplish this goal, a multi-disciplinary approach incorporating user involvement is absolutely necessary.

Probability of Recurrence

SPI	Category	# of times in 100 yrs.	Severity of event
0 to -0.99	Mild dryness	33	1 in 3 yrs.
-1.00 to -1.49	Moderate dryness	10	1 in 10 yrs.
-1.5 to -1.99	Severe dryness	5	1 in 20 yrs.
< -2.0	Extreme dryness	2.5	1 in 50 yrs.

Latest Actions

- The recommendation to use the SPI was approved by the WMO Congress in June 2011.
- The UN International Strategy for Disaster Risk Reduction (ISDR) provided funding for the meetings of the working groups on agricultural (June 2010 - Spain) and hydrological (Sept 2011 - Geneva) drought indices.
- With these recommendations, WMO contributed to ISDR on chapter on drought risks for the 2011 UN Global Assessment Report on Disaster Risk Reduction.

Standardized Precipitation and Evapotranspiration Index (SPEI)

- New variation of the SPI index by Vicente-Serrano et al. (2010) includes a temperature component.
- The inputs required are precipitation, mean temperature, and latitude of the site(s) to run the program on.
- More information can be explored through obtaining the SPEI at http://sac.csic.es/spei/index.html.

- Vicente-Serrano, S.M., Beguería, S., and López-Moreno, J.I. (2010). A multi-scalar drought index sensitive to global warming: The Standardized Precipitation Evapotranspiration Index – SPEI. *Journal of Climate* 23(7), 1696-1718, DOI: 10.1175/2009JCLI2909.1

Recommendations from Murcia

- Countries move beyond the use of rainfall data in computation of indices for description of agricultural droughts and their impacts.
- It is important to use more comprehensive data on rainfall, temperature, and soils in computing drought indices. Hence, greater cooperation is required between different ministries/ agencies responsible for addressing drought issues at the sub-national, national, and regional levels.

- Recommends that all countries examine the use of a composite approach (such as the U.S. Drought Monitor).

Data Issues I

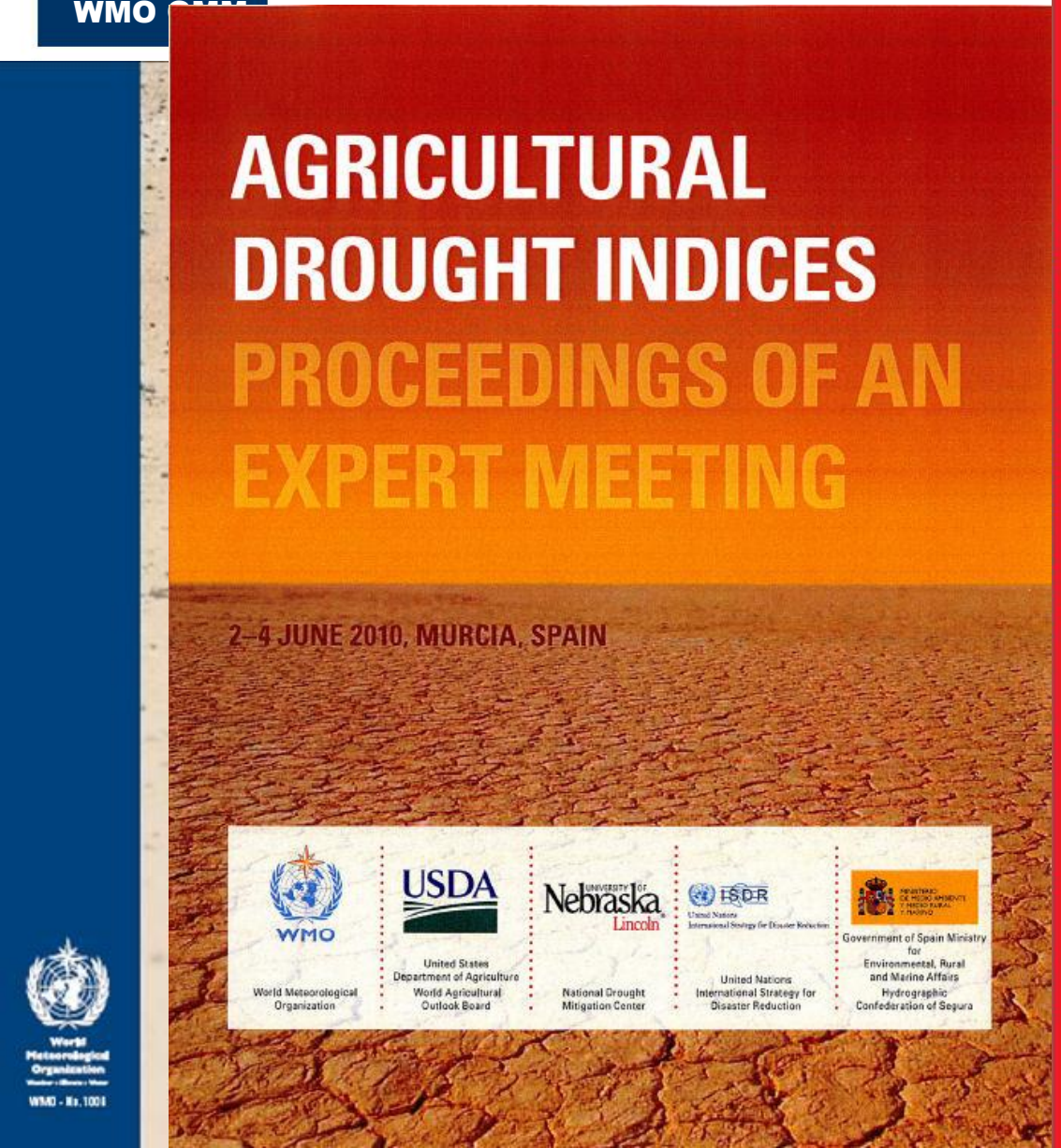
- Accurate and long-term weather data is needed
- Need at least years 30 years of rainfall data for SPI
- Can use fewer years but SPI will become unreliable
- For Agricultural and Hydrological drought need other data
  - Potential evapotranspiration (ETP)
  - Departure of ETP from normal?
  - Affected crops – conditions, growth stages
  - Soil moisture (measurement/simulation/departure from normals)

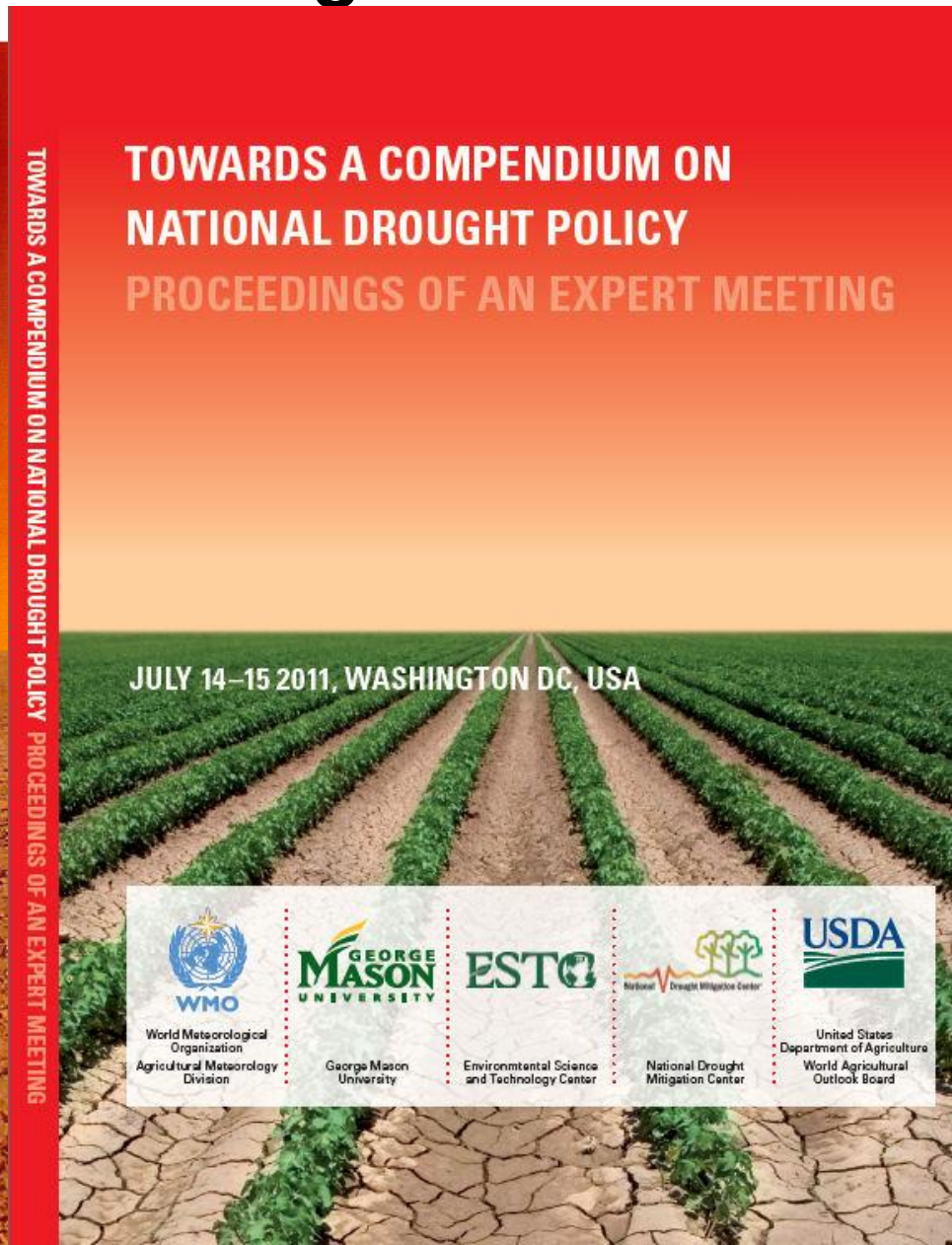
Data Issues II

- **Gridded datasets can be used (i.e. GPCC-**Global Precipitation Climatology Centre)
- **Remotely sensed data**
- **Reanalysis of weather model data**

- **Vulnerability and impact data are limited in area and length of record**

WMO Publications on Drought





HMNDP Science Document

Implementing Effective Drought Monitoring and Early Warning Systems

18) Evaluate the availability of comprehensive, integrated drought monitoring systems which couple multiple climate, water and soil parameters and socio-economic indicators to fully characterize the magnitude, spatial extent and potential impacts of droughts.

19) Assess the adequacy of networks, in particular, meteorological, hydrological and ecological networks for drought monitoring and data quality.

20) Examine current arrangements and procedures for coordinating the collection and analysis of meteorological, hydrological, and ecological data and eliminate fragmentation between many agencies and ministries at the different administrative levels.

Implementing Effective Drought Monitoring and Early Warning Systems

21) Evaluate existing procedures for data sharing and their applications of drought monitoring, preparedness, mitigation and response.

22) Assess the availability of early warning and decision-support tools and methodologies in support of drought preparedness planning and policy development.

23) Assess the current capabilities of regional outlooks and forecasts for the duration and severity of drought, improve the skill of these forecasts and enhance communication to users.

Implementing Effective Drought Monitoring and Early Warning Systems

24) Evaluate the four phases in drought risk management: vulnerability and risk assessment; monitoring and early warning systems; preparedness and mitigation; and emergency response and recovery.

25) Examine the need for the development of useful end products, information or decision-support tools for delivery to the end users.

26) Assess the capacity of delivery systems to disseminate data, information, products and services to users in a timely manner to enhance their usefulness for decision support.

Ongoing Initiatives

DMCSEE

Drought Management Centre for Southeastern Europe

Drought Management Centre for Southeastern Europe - DMCSEE

Drought is a normal part of climate in virtually all regions of the world. South Eastern Europe is no exception; in past decades the drought-related damages have had large impact on the economy and welfare. Therefore the need to establish a Drought Center for SE Europe to alleviate the problems caused by drought in the area became evident at the end of the past century. The idea was further elaborated by International Commission on Irrigation and Drainage (ICID) and UN Convention to Combat Desertification (UNCCD). The UNCCD national focal points and national permanent representatives with the World Meteorological Organization have agreed upon the core tasks of the Drought Management Center for South Eastern Europe (DMCSEE) and the proposed project document.

The mission of the proposed DMCSEE is **to coordinate and facilitate the development, assessment, and application of drought risk management tools and policies in South-Eastern Europe with the goal of improving drought preparedness and reducing drought impacts**. Therefore DMCSEE will focus its work on monitoring and assessing drought and assessing risks and vulnerability connected to drought.

www.dmcsee.org

Founding countries:

- → Albania
- → Bosnia and Herzegovina
- → Bulgaria
- → Croatia
- → FYROM
- → Greece
- → Hungary
- → Moldova
- → Romania
- → Slovenia
- → Turkey
- → Montenegro
- → Serbia

Founding agencies:

- → WMO
- → UNCCD

WMO working on establishing Drought Management Center for Central Asia (DMCCA)

- WMO, United Nations Convention to Combat Desertification (UNCCD) and the Organization for Security and Cooperation in Europe (OSCE) working together to establish the DMCCA.
- Technical Seminar on preparation towards Terms of Reference for a Regional Drought Centre in Central Asia (20-21 November, 2007, Tashkent, Uzbekistan)
- Second Workshop on establishing a Drought Management Centre in Central Asia (May 2008, Kyrgyzstan)
- WMO Consultant visited the five Central Asian countries ie., Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan in November 2009 to consult with relevant organizations and institutions and prepare project proposal.

Global Framework for Climate Services

- Goal:
  - Enable better management of the risks of climate variability and change and adaptation to climate change at all levels, through development and incorporation of science-based climate information and prediction into planning, policy and practice.

World Meteorological Organization
Weather • Climate • Water

WORLD CLIMATE CONFERENCE - 3

Geneva, Switzerland

31 August–4 September 2009

GFCS Priorities

- Agriculture
- Disaster risk reduction
- Water
- Health

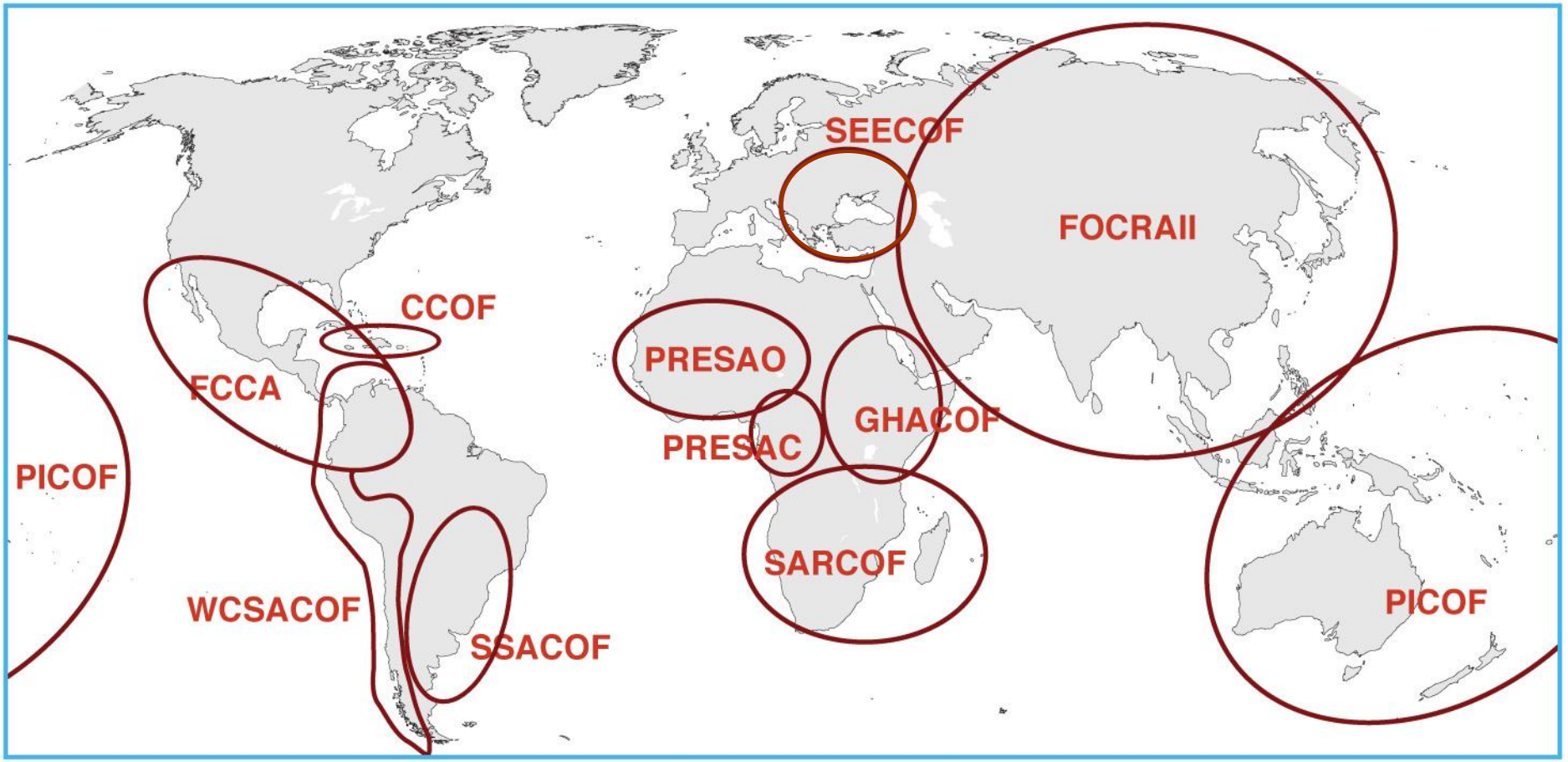





GFCS & Drought

All WMO drought activities contribute to Global Framework for Climate Services

Regional Climate Outlook Forums (RCOFs)



http://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html

Integrated Drought Management Programme (IDMP)

Integrated Drought Management Programme (cont)

- **The expected services to be provided are:**
  - **Regional coordination** of drought monitoring, prediction and early warning activities
  - **Inception of pilot projects** and coordination of regional projects to showcase best practices
  - **Collection and dissemination** of information and knowledge on good practices;
  - **Guidelines, methodologies, tools** and supporting documentation on policy development and management practices and procedures; and
  - **Capacity building** and advice on Integrated Drought Management.

Current Actions - IDMP

- IDMP will integrate and incorporate WMO efforts on drought indices and High-Level Meeting on National Drought Polices (HMNDP)
- IDMP will liaise with National Drought Management Policy Initiative (UN-Water)
- IDMP regional project in Central and Eastern Europe
- GWP has hired an expert to be Seconded to WMO & IDMP
- IDMP webpage: www.wmo.int/idmp

GWP CEE region - IDMP

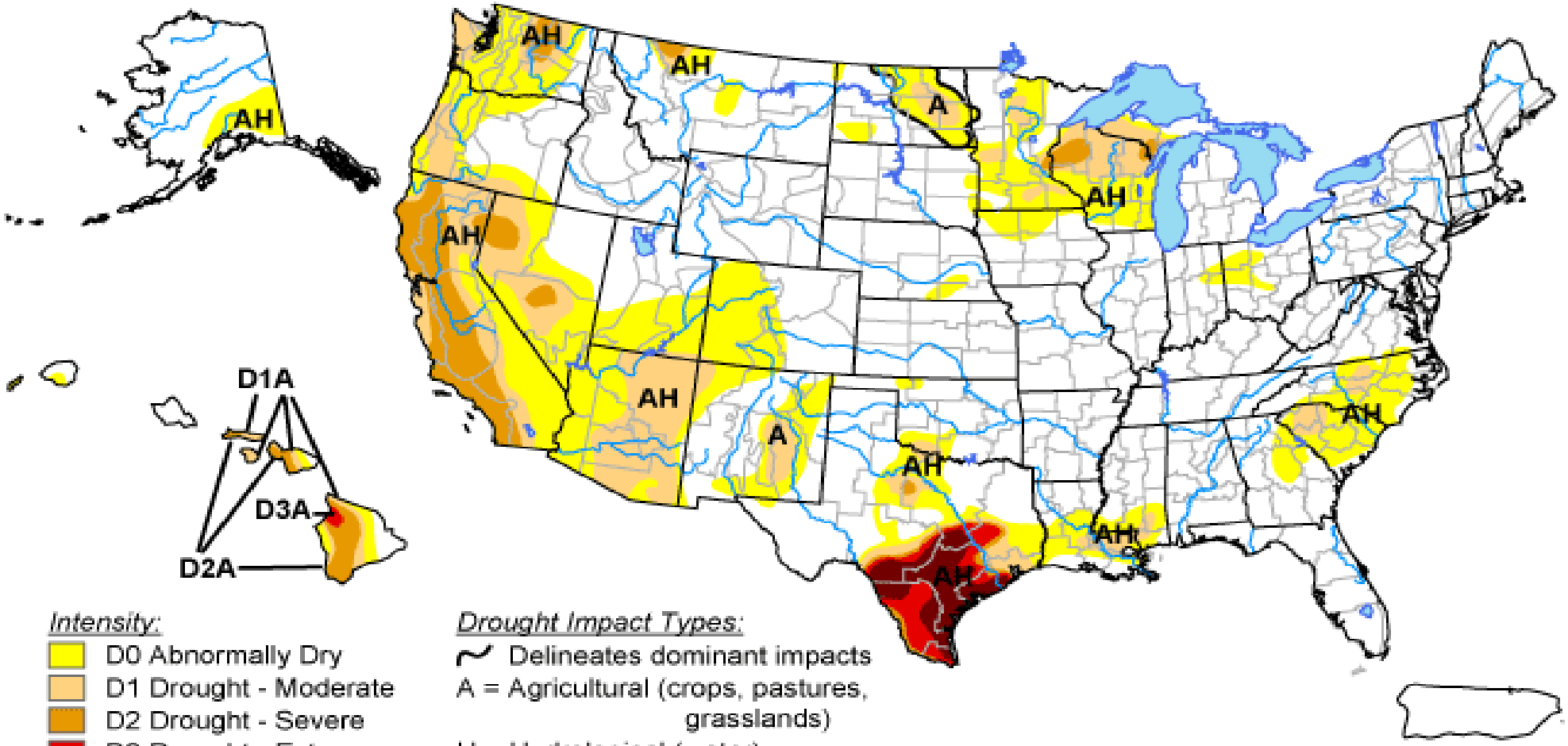
- Review of:
- Drought situation,
- existing drought risks
- Policies and strategies
- National and regional initiatives
- … in GWP CEE region

The GWP CEE region

Examples

U.S. Drought Monitor

September 8, 2009
Valid 8 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm

Released Thursday, September 10, 2009

Author: Rich Tinker, CPC/NCEP/NWS/NOAA

The Drought Monitor is widely used:

- ***Policy: Farm Bill/IRS/USDA/NOAA DGT/State drought plan triggers***
- ***~3.75M page views and ~2M visitors/year***
- ***Media: The Weather Channel and all major newspapers/Internet Media/ Network News/ CNN/NPR/etc.***
- ***Presidential/Congressional briefings***
- ***A model of interagency/level collaboration***

Source: Svoboda, 2009

Some Examples of Decision Making Using the Drought Monitor

- USDA Dried Milk Program 2002-03
- USDA CRP Release hot spot trigger
- Numerous states use as a drought trigger (Governor's declarations)
- 2006-07 USDA Livestock Assistance
- 2006-07 IRS (tax deferral on livestock losses)
- 2008 Farm Bill
- NWS Drought Information Statements

Source: Svoboda, 2009

Breakout Sessions

Group Questions

- **Group A:** What are the current procedures/challenges on early warning systems?

- **Group B:** What are the meteorological and hydrological networks, data quality, sustainability needed?

- **Group C:** What mechanisms are in place for communicating and liaising drought monitoring and early warning information between national institutions?

Breakout Group Guidelines

- Each Group will have a facilitator.
- Group identifies leader and rapporteur.
- Either group leader or rapporteur makes presentation in Session 3c.
- Each group will spend 45 minutes on main group question and 15 minutes each on other questions