

New Drought Indices

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Why drought indices?

- **to identify main characteristics of droughts:**
 - onset
 - end
 - severity
 - spatial extent
- **to describe and map drought events**
- **to compare drought events in space and time**
- **to quantify droughts**
- **to simplify a complex phenomenon**
- **to provide a basis for drought management**
 - helping to define thresholds, triggers, alarm levels

Characteristics of drought indices:

- **relation of normal (long-term average, expected) values to current values of a physical parameter**
- **usually no physical quantity (no units!)**
- **often a combination and/or integration of various parameters / datasets**
- **... apparent common sense to use 3-4 letter acronyms with an “I” in the end!**

NMDC – Normalized Multi-Band Drought Index
VCADI – Vegetation Condition Albedo Drought Index
PDI – Perpendicular Drought Index
MPDI – Modified Perpendicular Drought Index
RDRI – Remote Sensing Drought Risk Index
VegDRI – Vegetation Drought Response Index
ADI – Aggregate Drought Index
SMDI – Soil Moisture Deficit Index
ETDI – Evapotranspiration Deficit Index
RDI – Reconnaissance Drought Index
RSDI – Regional Streamflow Deficiency Index
SDI – Sperling Drought Index
NDVI – Normalized Difference Vegetation Index
VCI – Vegetation Condition Index
NDVIA – Anomaly of Normalized Difference Vegetation Index
SVI – Standardized Vegetation Index
NDWI – Normalized Difference Water Index
NDII – Normalized Difference Infrared Index
LWCI – Leaf Water Content Index
DTx – agricultural drought index
DFI – Drought Frequency Index
TCI – Temperature Condition Index
VHI – Vegetation Health Index
SRWI – Simple Ratio Water Index
GVWI – Global Vegetation Water moisture Index

WI – Water Index
%N – percentage of normal
DECILES – deciles
RAI – Rainfall Anomaly Index
BMDI – Bhalme and Mooly Drought Index
SAI – Standardized Anomaly Index
DSI – Drought Severity Index
PAI – Palfai Aridity Index
EDI – Effective Drought Index
Q90 – low flow index
BFI – Base Flow Index
SWSI – Surface Water Supply Index
PHDI – Palmer Hydrological Drought Index
RDI – Reclamation Drought Index
CMI – Crop Moisture Index
SMDI – Soil Moisture Drought Index
CSDI – Crop Specific Drought Index
CDI – Corn Drought Index
SCI – Soybean Drought Index
KBDI – Keetch-Byram Drought Index
NBR – Normalized Burn Ratio
PDSI – Palmer Drought Severity Index
PMDI – Palmer Modified Drought Index
Z-Index – Palmer Z-Index

... so why NEW drought indices?

motivation:

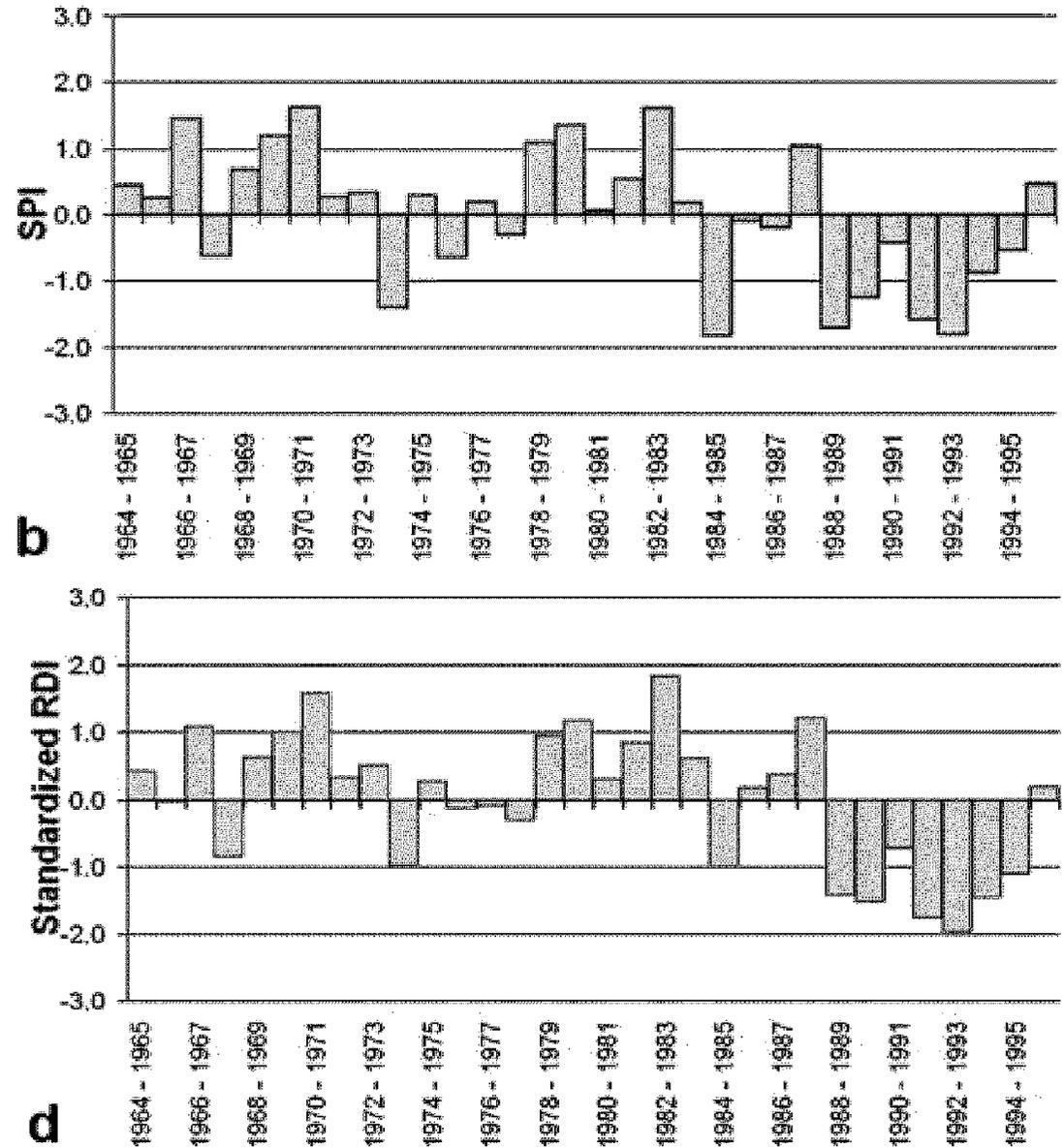
- **not satisfied with currently existing DIs**
 - fail to detect droughts, describe their severity, or insufficient description of spatio-temporal development
 - new applications require better tailored drought indices
 - ... to create one's own drought index
- **new opportunities emerge**
 - new sources of data available
 - new methodologies developed / transferred from other disciplines

new drought indices by categories

- **meteorological**
 - routine synoptic network data
 - no new data
 - innovations essentially application-driven
 - typical: SPI – Standardized Precipitation Index (McKee et al. 1992)

- **new:**
 - RDI – Reconnaissance Drought Index
 - Tsakiris, Pangalou, and Vangelis (2007)
 - monthly P, ET_{pot}
 - characterization of drought severity, analogous to SPI
 - meteorological index, towards agricultural applications
 - selected river basins in the Mediterranean region

Figure 8 Annual drought identification for Nestos Basin.
a Deciles. **b** SPI. **c** Normalized RDI.
d Standardized RDI.



new drought indices by categories

- **hydrological**
 - predominantly discharge data, time series analysis
 - no new data
 - new methodologies, threshold derivation
 - typical: BFI – Base Flow Index (Institute of Hydrology 1980)

- **new:**
 - RDI – Regional Streamflow Deficiency Index
 - Stahl (2001)
 - FDC, Q90
 - regionalization, neighbourhood analysis
 - river catchments in Europe

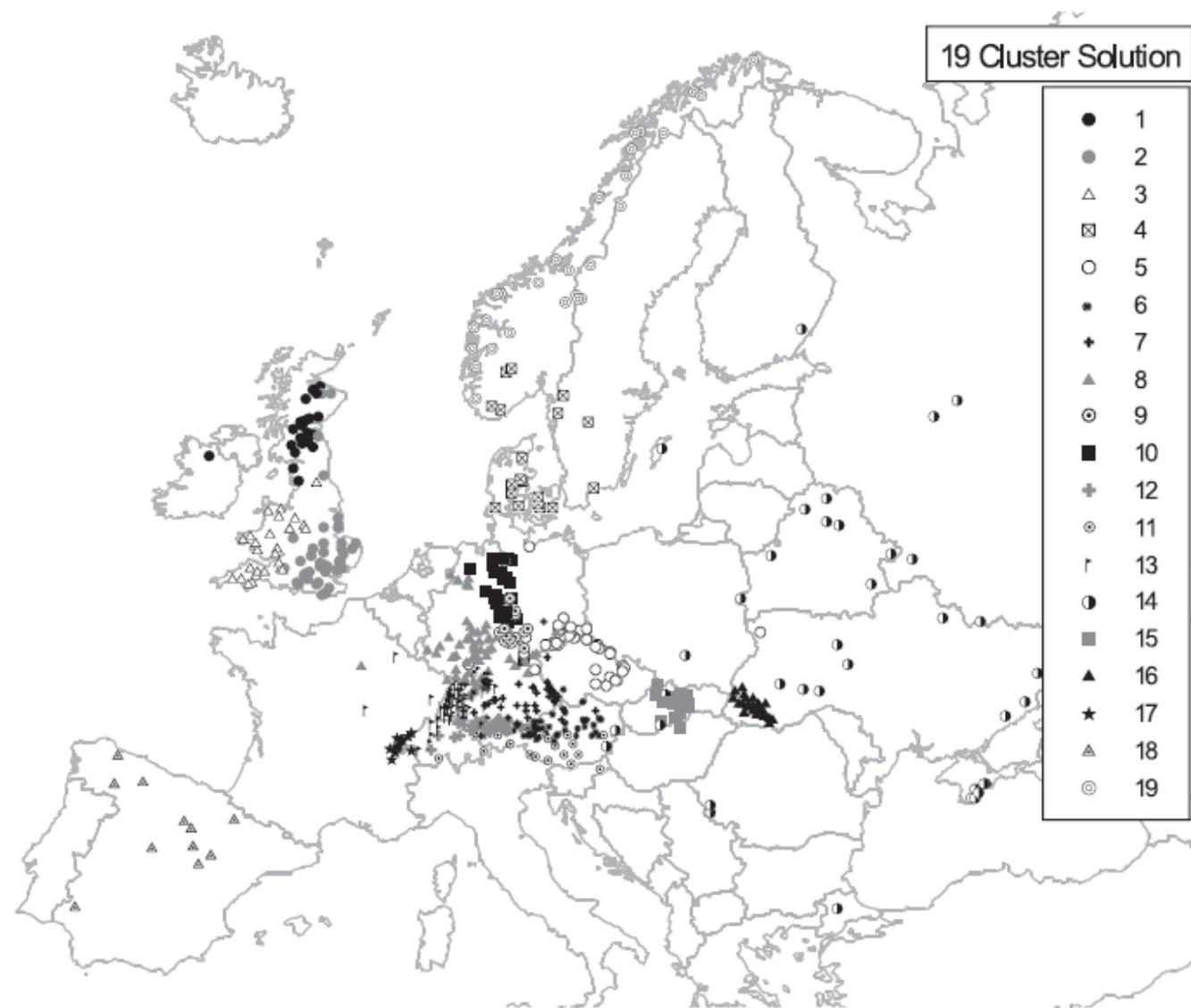


Fig. 6.3 Spatial distribution of the 19 Cluster solution

Table 6.1 Cluster description and characteristics

No.	geographic location*	no. of stations	RDI _{area} x 100
C1	northern Great Britain	24	7.53
C2	southeastern UK	41	8.77
C3	southwestern UK	27	7.26
C4	southern Scandinavia	19	9.76
C5	Czech Rep. and eastern Germany	40	10.18
C6	northern Austria	44	10.37
C7	southeastern Germany	48	9.87
C8	western Germany	57	7.82
C9	central Germany	22	8.05
C10	northern Germany	27	8.72
C11	southern Austria and Switzerland	21	12.04
C12	high Alps, Switzerland, Germany, Austria	37	8.93
C13	southwestern Germany	66	8.63
C14	eastern Europe	38	14.28
C15	Slovakia	19	9.61
C16	Carpathian Mountains, Ukraine	23	8.97
C17	south Jura, France	11	6.74
C18	Spain	11	12.14
C19	western and northern Norway	27	12.18

* For sake of convenience, the location relates to the region with the majority of stations.

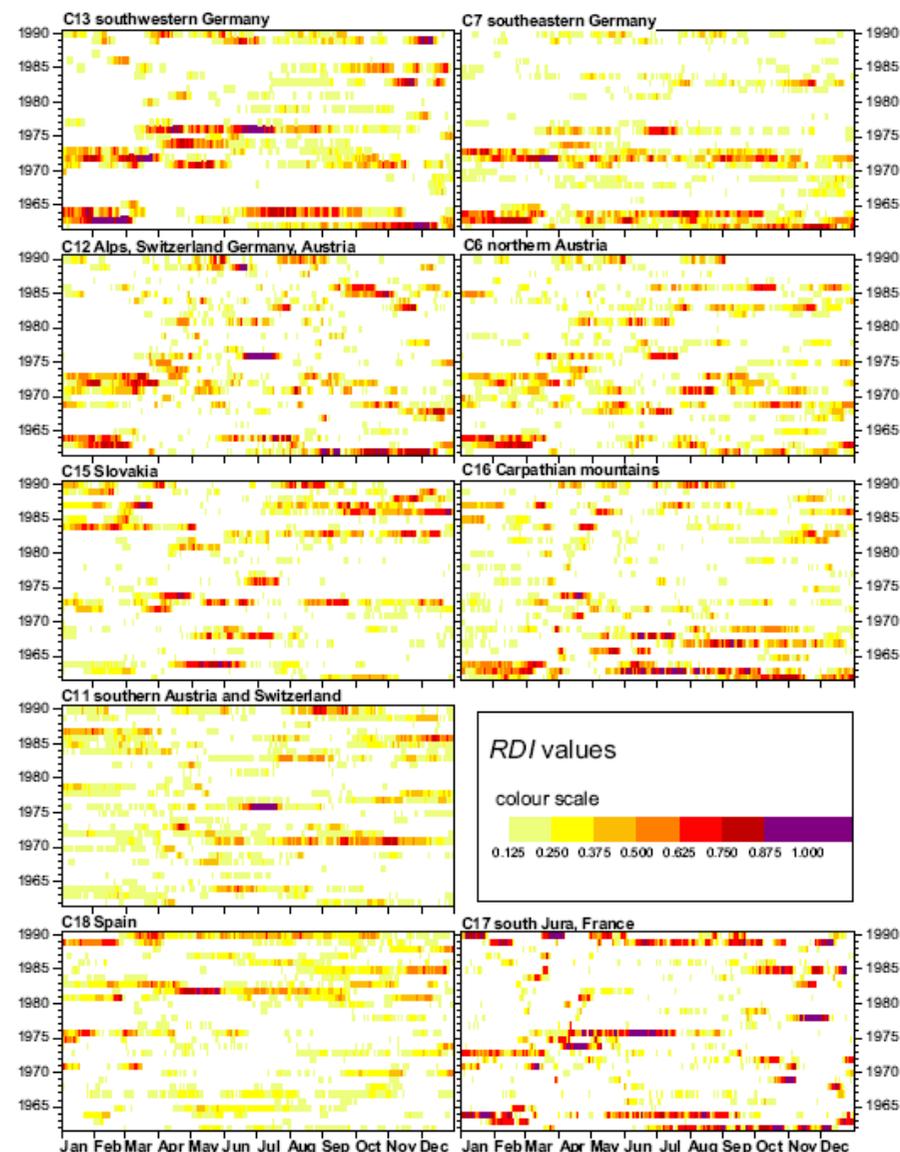


Fig. 6.5 The RDI time series for the 19 clusters across Europe, arranged according to their geographic location. (continued)

new drought indices by categories

- **comprehensive**

- water balance, combining meteorology, soil, hydrology, ...
 - few / some new data
- new combination of available datasets
- new methodologies
- typical: PDSI – Palmer Drought Severity Index (Palmer 1965)

- **new:**

- ADI – Aggregated Drought Index
 - Keyantash and Dracup (2004)
 - precipitation, discharge, evapotranspiration, soil moisture, snow water content
 - PCI, first PC normalized by st.dev
 - based on monthly (measured) input data
 - California / Western U.S.

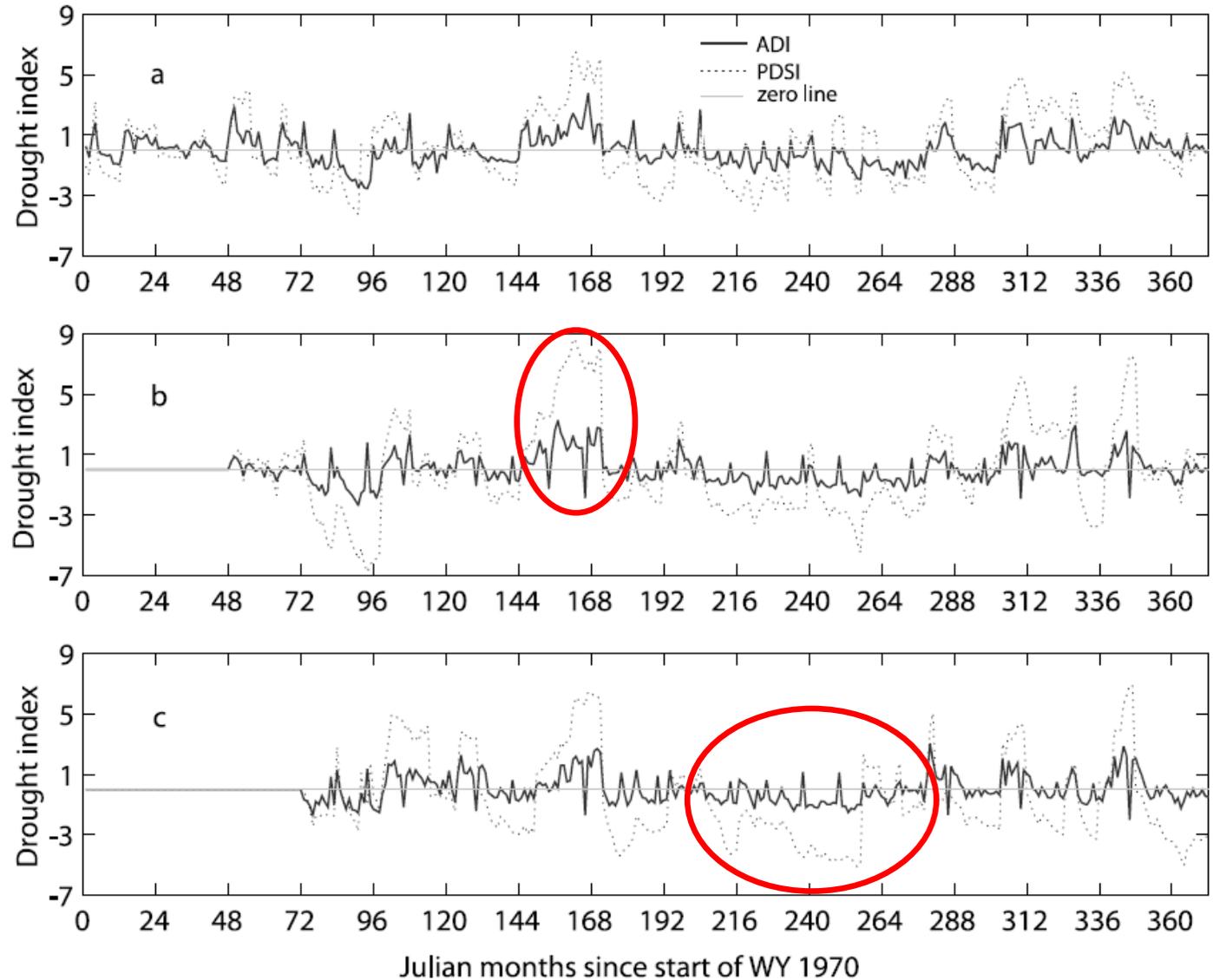
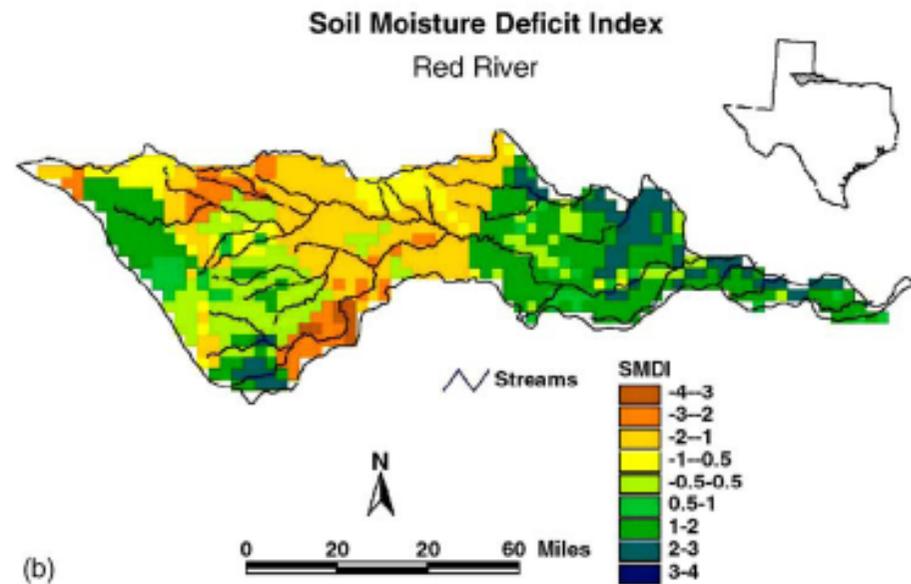
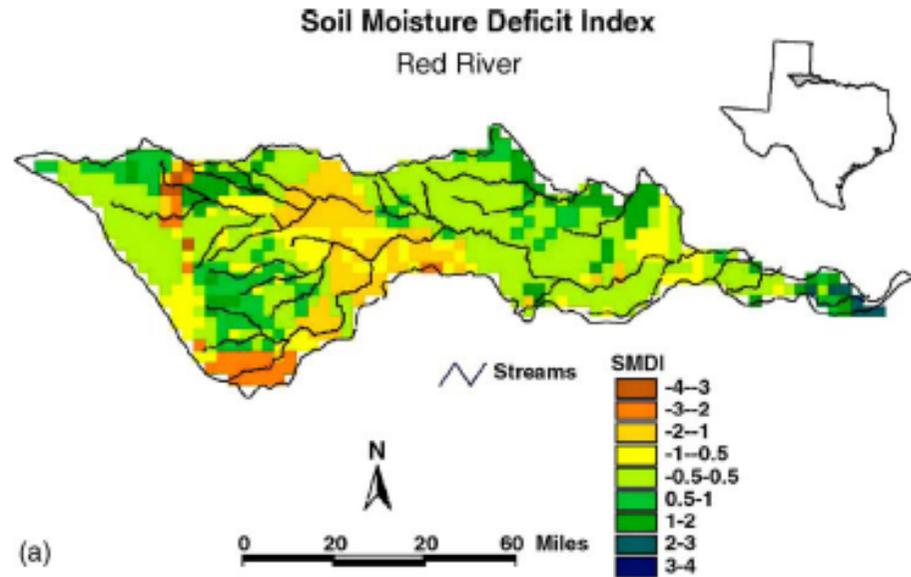


Figure 5. ADI and Palmer Drought Severity Index (PDSI) time series for the (a) North Coast (NC), (b) Central Valley (CV), and (c) South Coast (SC) climate divisions.

new drought indices by categories

- **agricultural**
 - emphasis on soil moisture, actual evapotranspiration
 - no new data
 - new methodologies, new applications
 - specialization, crop-specific indices (CSDI, Meyer et al. 1993)
 - typical: CMI – Crop Moisture Index (Palmer 1968)

- **new:**
 - SMDI – Soil Moisture Deficit Index
 - Narasimhan and Srinivasan (2005)
 - high resolution input data, local application
 - application of water balance modelling (SWAT/HRU)
 - SMDI for different soil layers / depths
 - reflect short-term dry conditions in crucial phases of plant development
 - weekly SMDI, allow for fast reaction
 - catchment areas in Texas / U.S.



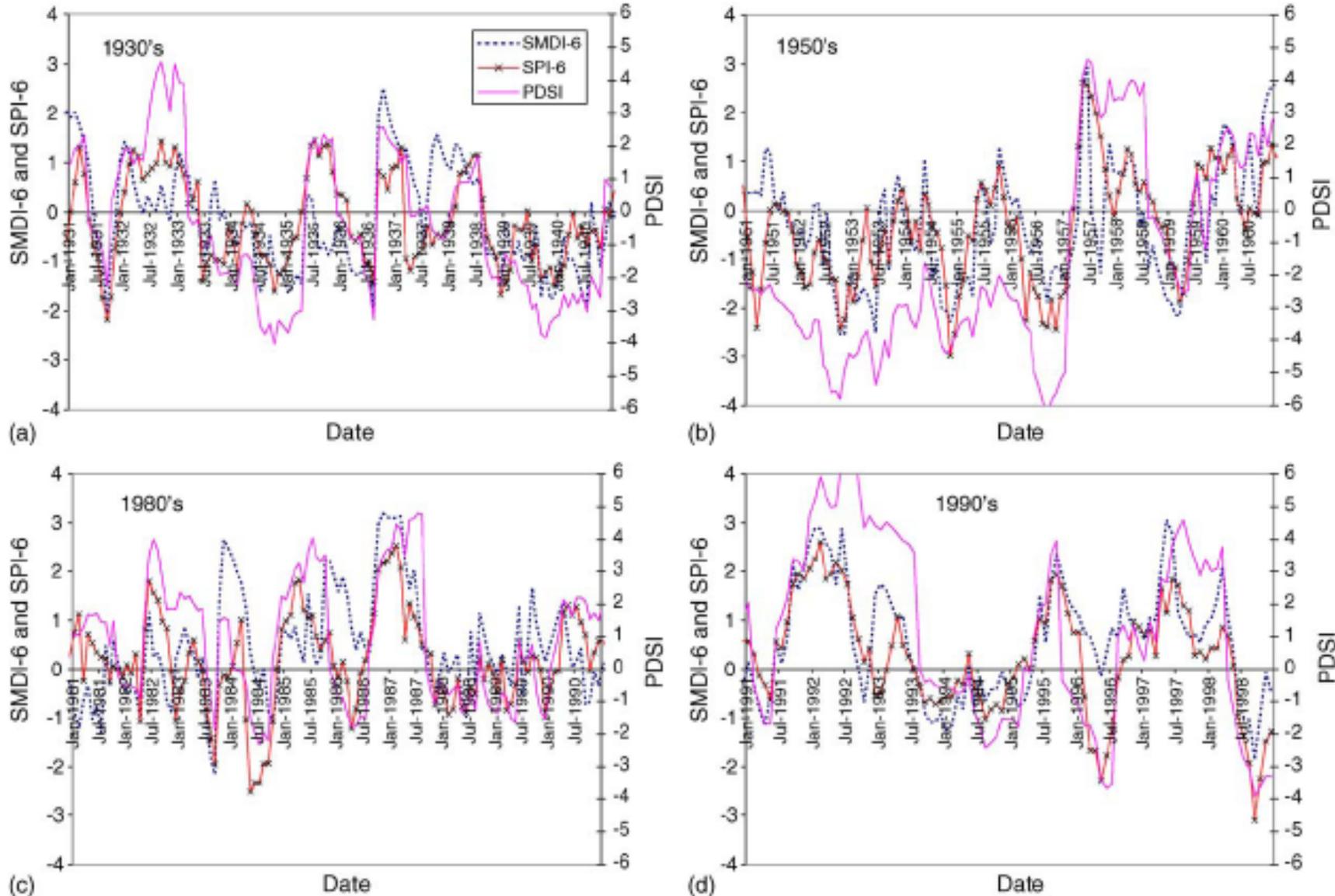


Fig. 8. Comparison of long-term drought indices SMDI-6, SPI-6 and PDSI for the Red River watershed.

new drought indices by categories

- remote sensing

- data availability driven by technological development
 - continuously new data sources on the market
 - often experimental character
- characterization of land surface and vegetation
 - detection of anomalies, but not necessarily drought specific
- optical and thermal bands
- typical: VCI – Vegetation Condition Index (Kogan 1990)

- new:

- NMDI – Normalized Multi-Band Drought Index
 - Wang and Qu (2007)
 - combining information from three bands
 - 1 nIR + 2 SW-IR reflectances (MODIS bands 2, 6, 7)
 - simultaneously accounting for soil moisture and vegetation water content
 - test area in Kansas, Oklahoma / U.S.

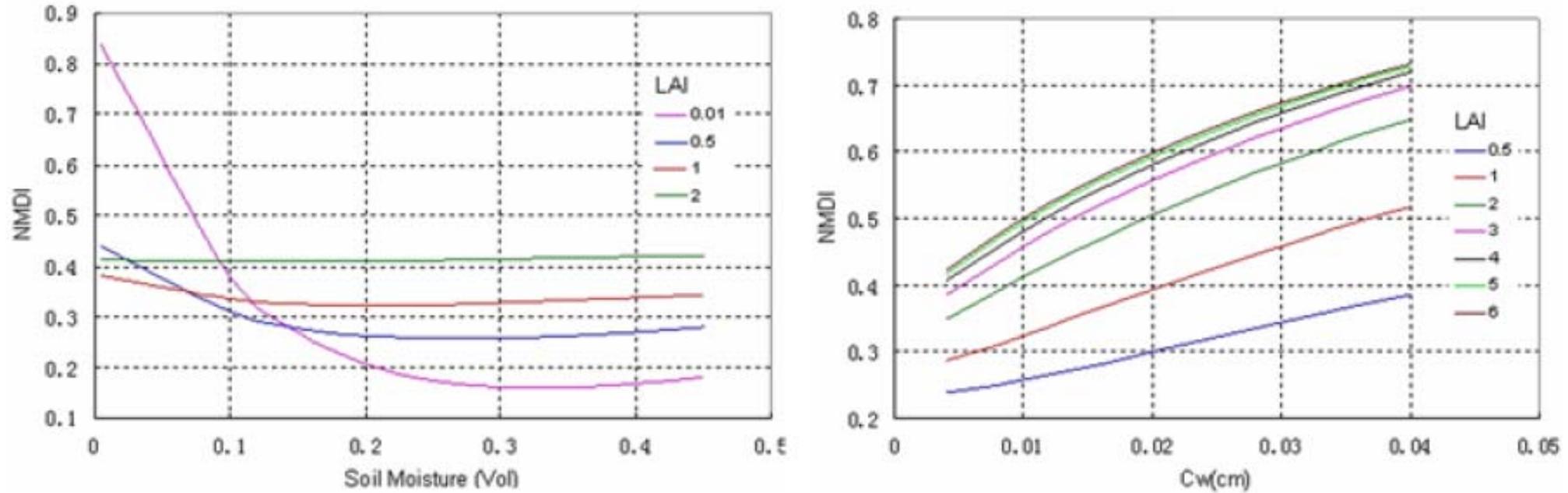


Figure 2. Sensitivity of NMDI to (left) soil moisture and (right) leaf water content.

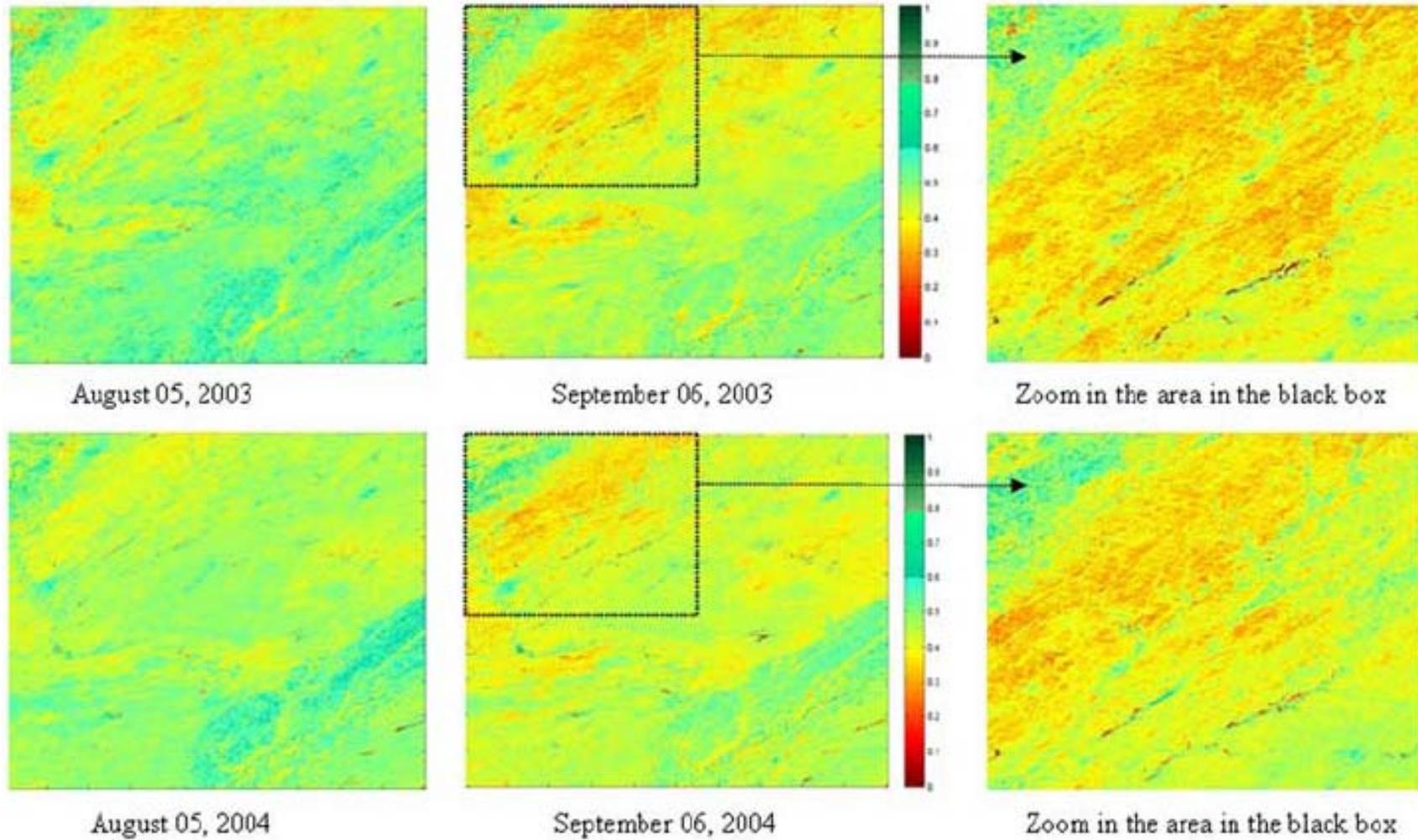


Figure 6. Spatial distribution of NMDI over the Flint Hills.

new drought indices by categories

- **combined**
 - combination of drought indices from different domains
 - novel approach, new methodology
 - manual combination so far, mapping
 - typical: U.S. Drought Monitor

- **new:**
 - VegDRI – Vegetation Drought Response Index
 - Brown, Wardlow, Tadesse, Hayes, and Reed (2008)
 - combining NDVI, SPI, PDSI in order to be drought-specific
 - currently tested in mid/western U.S.
 - designed for operational, continental application

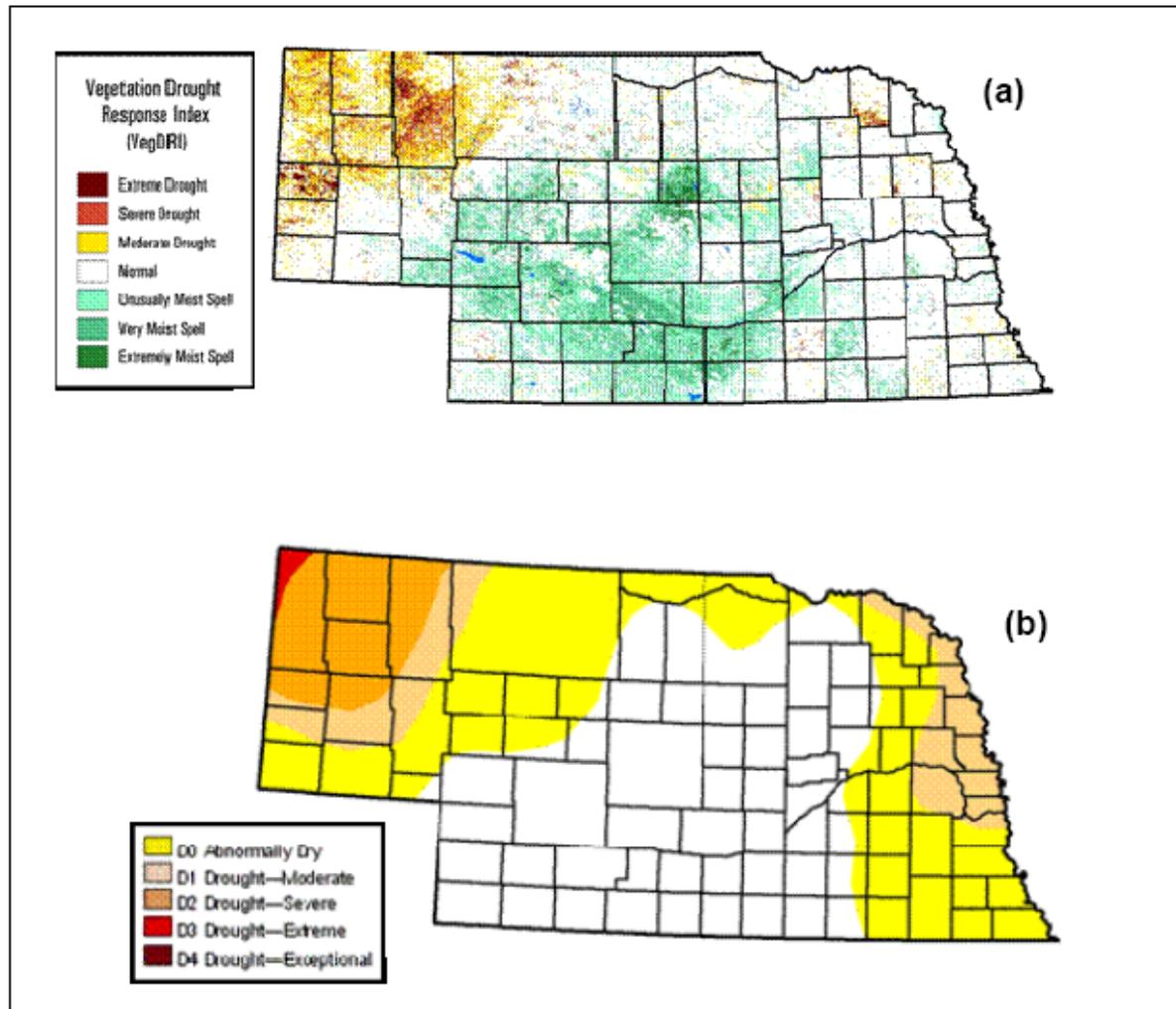
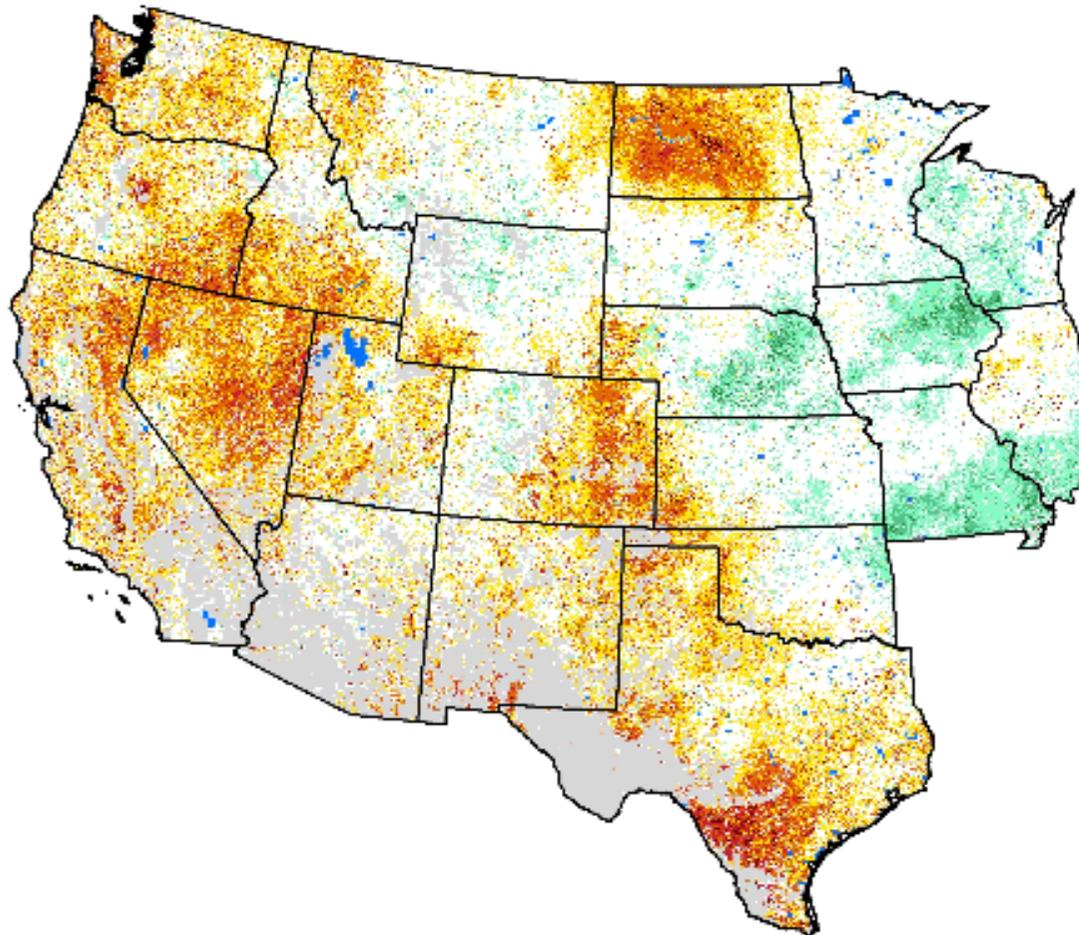


Figure 2. (a) VegDRI for July 30, 2007 and (b) the U.S. Drought Monitor for July 31, 2007. (Note: White areas indicate no drought in Figure 2b.)

Vegetation Drought Response Index Complete

June 2, 2008



Vegetation Condition



many drought indices, many more new ...

... but which one to choose?

- **strongly depending on YOUR requirements**
 - field of application
 - specific boundary conditions
 - data availability
 - reliability / robustness
 - spatial / temporal resolution necessary
 - resources available

many drought indices, many more new ...

... but which one to choose?

- **continental overview application:**

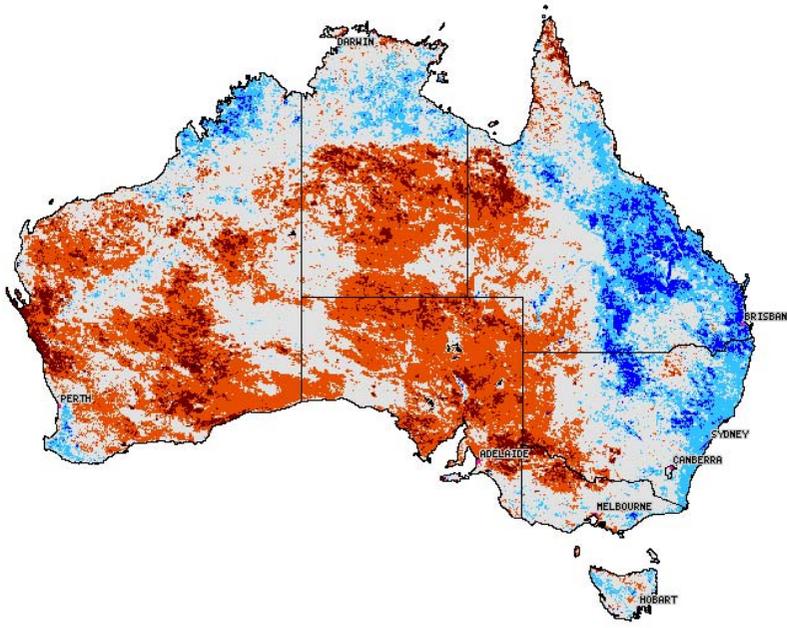
- consistent methodologies over large regions
 - e.g. remote sensing
- consistent datasets available
 - e.g. produced by large national / international agencies
- produce comparable information
 - which regions are more affected
 - delineate spatial extent of a drought event
- cover droughts in all disciplines
 - meteorological, hydrological, agricultural, economic, ...
- targeted to a large public audience
 - intuitive to understand, limited number of classes / levels, simple colour coding, ...

Home
Choose a Region
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Explore

1. Choose your layers

- Contextual
 - Elevation
 - Water Holding Capacity
 - Soil Type
 - Locations
 - Rail
 - Roads
 - Climate Zones
 - Detailed Climate Zones
 - Dryland land use
 - Irrigated land use
 - Topographic Map
- Boundaries
 - State Masks
- Climate Variables
 - Rainfall
 - Totals (mm)
 - Percentiles
 - Calendar Month
 - Calendar Season
 - Growing Season
 - Calendar Year
 - Averages
 - Reliability
 - Forecast
 - Temperature
 - Actuals
 - Forecast
 - Anomalies
- Production Information
 - Vegetation Greenness
 - Calendar month
 - Calendar Season
 - Modelled Plant Growth
 - AussieGRASS 3 months
 - AussieGRASS 6 Months
 - AussieGRASS Annual
 - Percentile Pasture Growth
 - Dryland Production
 - Predicted Wheat Yield
 - Predicted Sorghum Yield



Map Tools



Legend

Greenness Anomalies
Mar/2008

- Extremely High
- Above Average
- Average
- Below Average
- Extremely Low
- Cloud
- No Data
- Capital Cities
- Coastline
- State

2. Select a period

Mar 2008 < >

3. Redraw map

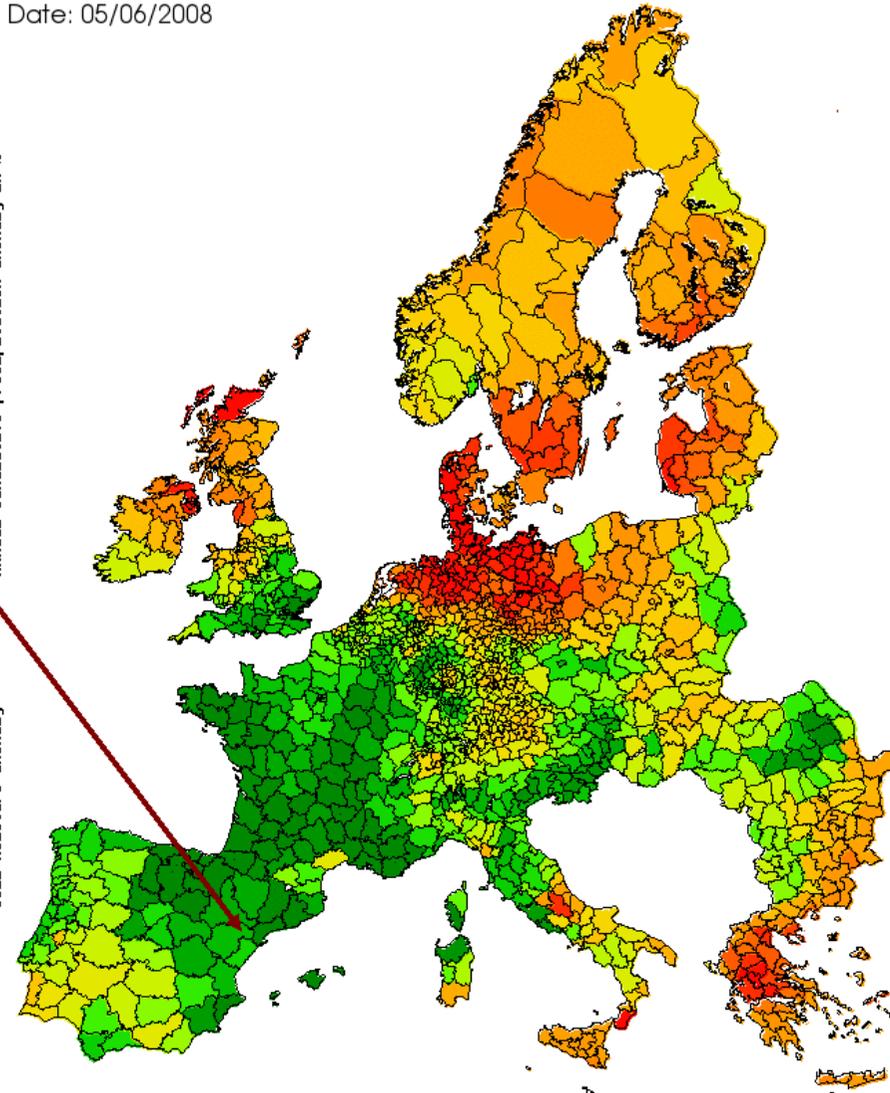
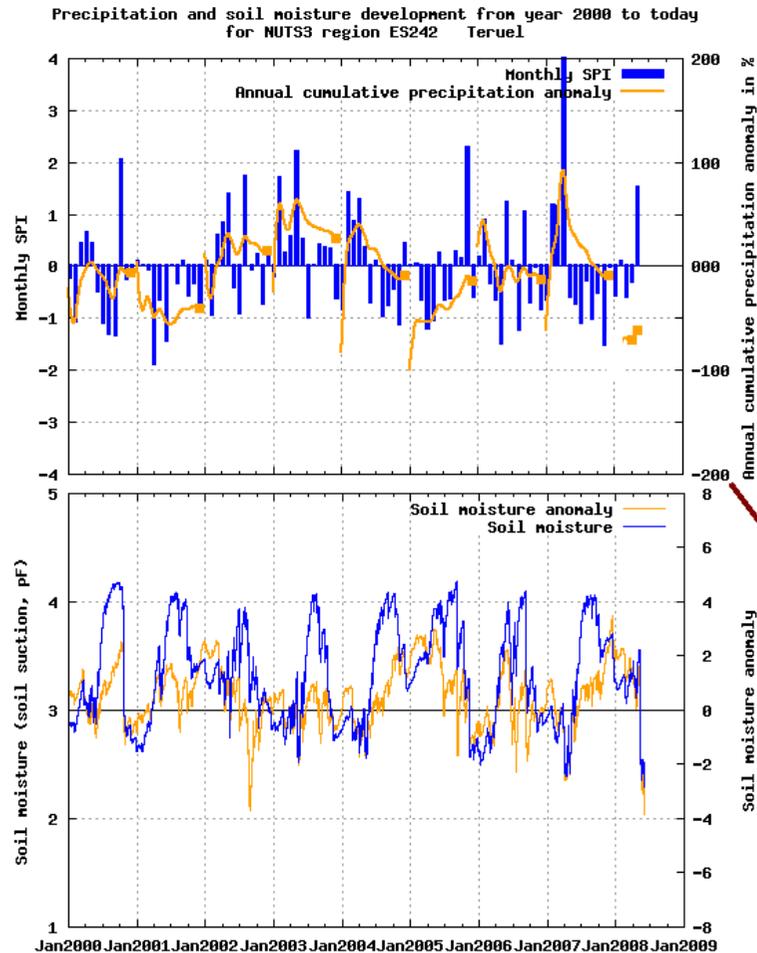
Greenness Anomalies data from Jan/1992 to Apr/2008

Scale: 1:21059606
Lat: -34.419 , Long: 110.876

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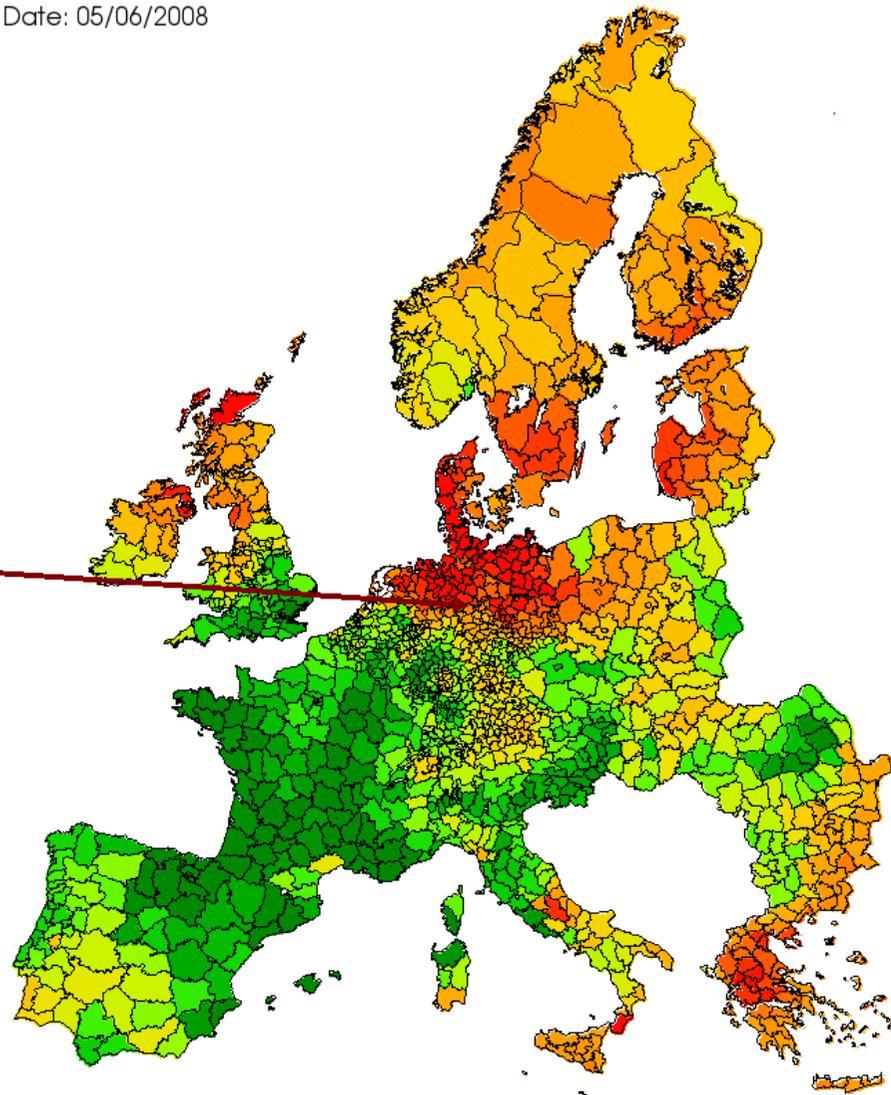
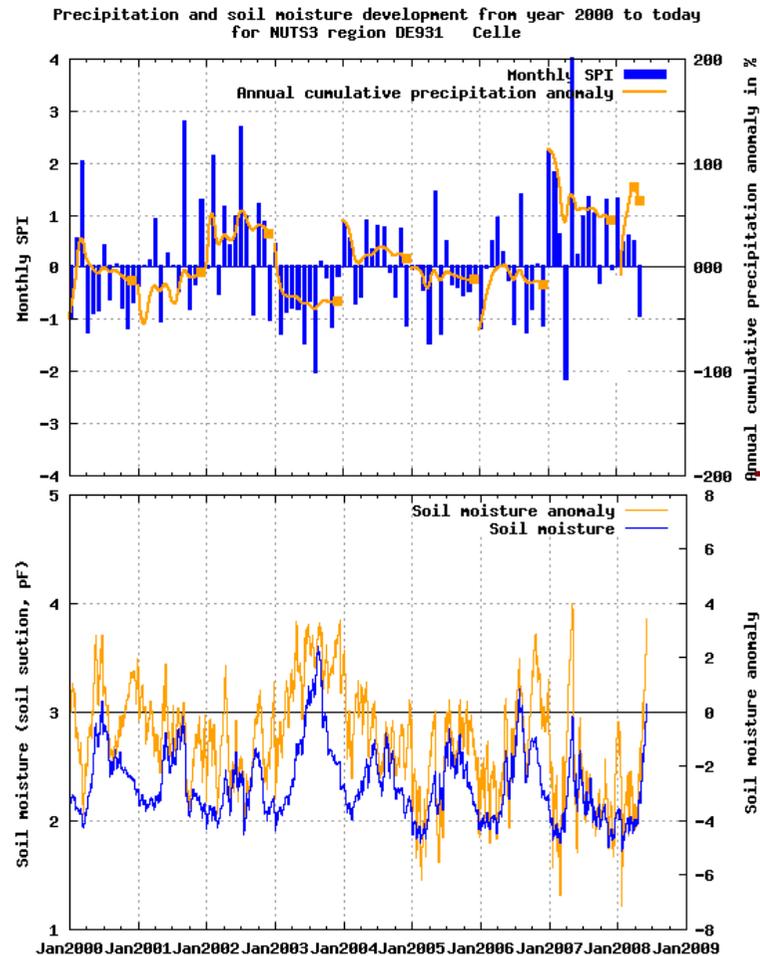
combined precipitation & soil moisture anomaly

Date: 05/06/2008



combined precipitation & soil moisture anomaly

Date: 05/06/2008



many drought indices, many more new ...

... but which one to choose?

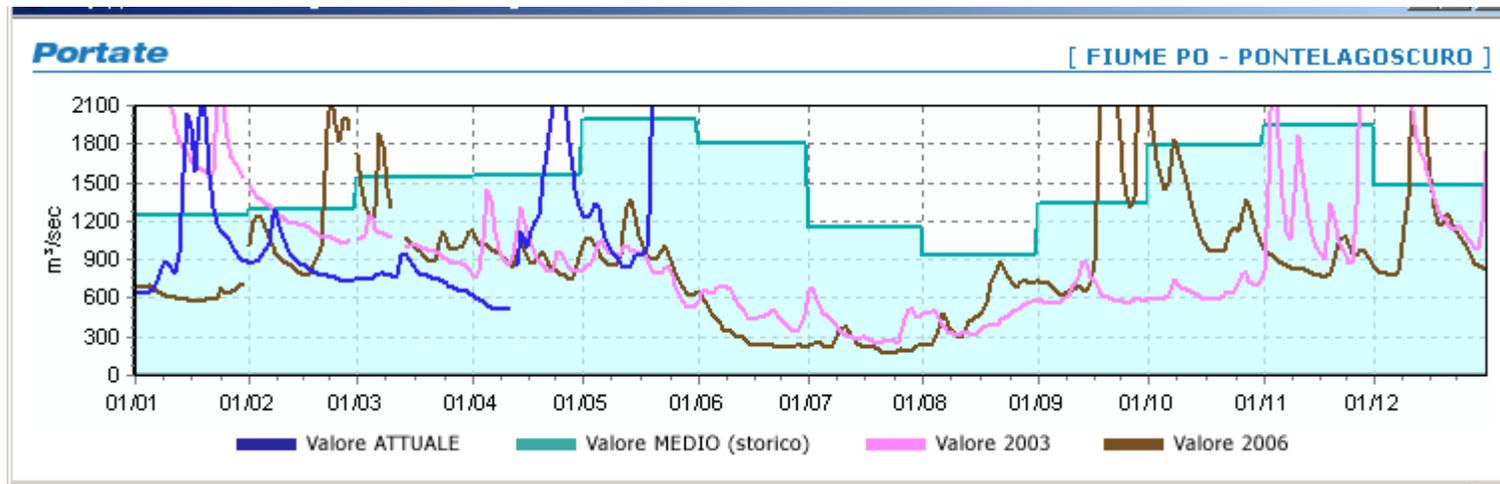
- local river authority application:

- specific to hydrology of the catchment area
 - e.g. snow melt decisive for spring water availability
 - existing reservoirs and their management rules
- taking into account existing measurements / network
 - e.g. local groundwater observation network
- consider local, national legislation
 - RBMP, DMP, ...
- cover the field of application of interest
 - e.g. agricultural drought, yield deficits
- targeted to specific audience
 - e.g. farmers applying irrigation schemes
 - e.g. water managers / agencies to apply restrictions on water use

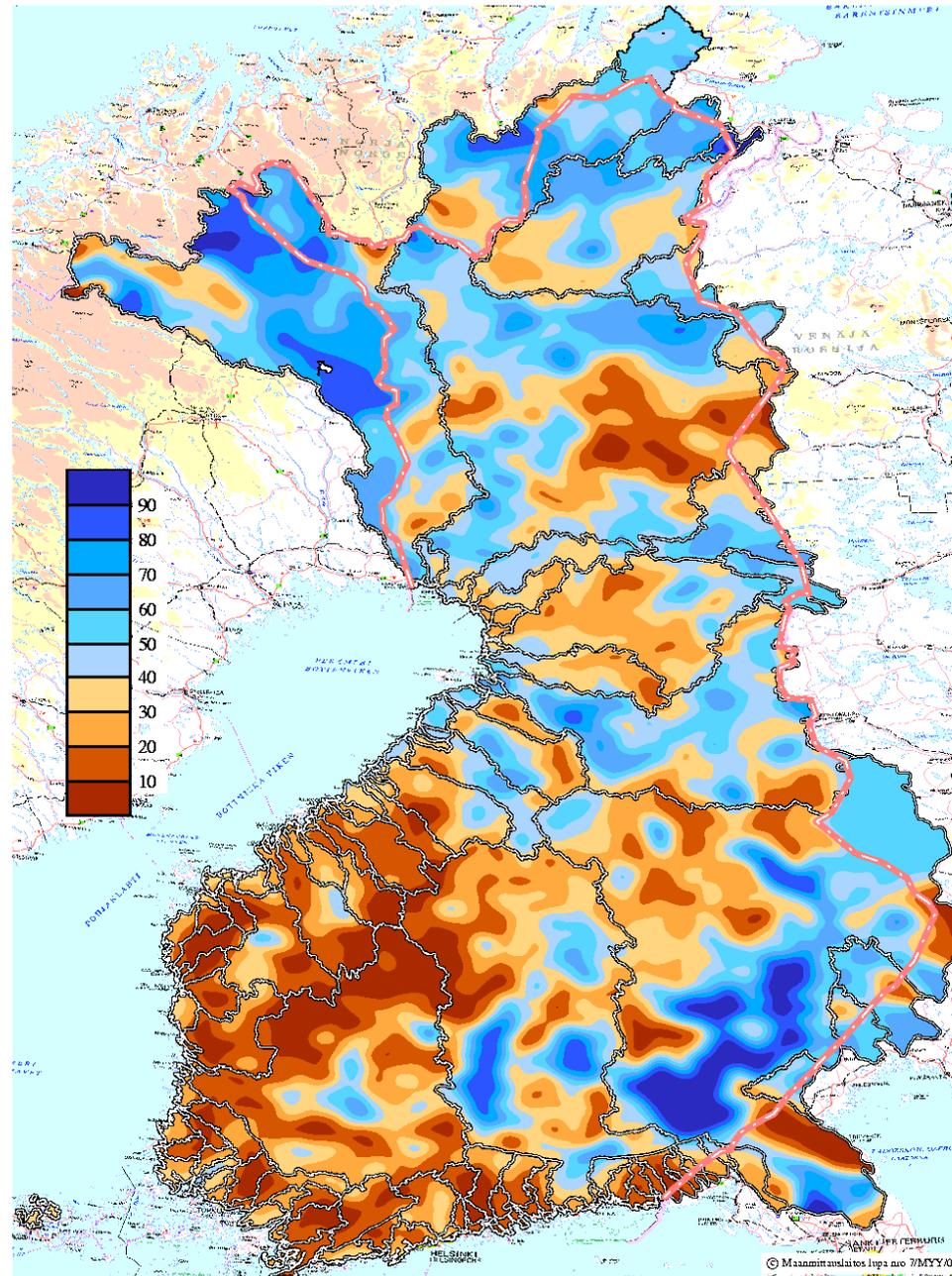


Autorità di bacino del fiume Po

Bacino di rilievo nazionale



Environmental Administration, Finland



Vedenkorkeus verrattuna 8. 6.1961- (50=keskim.) 8. 6.2008

Forecast day 8. 6.

Water level 8. 6.1961- (0=dry,50=mean,100=wet) 8. 6.2008

many drought indices, many more new ...

... but which one to choose?

- **check existing DIs against your requirements**
 - original motivation of authors?
 - data availability at creation?
 - regional context, spatial validity, valid temporal resolution?
 - demonstrated added value as compared to existing DIs?
 - extensive testing and comparison of performance / validation?
 - **explicit mentioning of boundary conditions, limitations?**
 - operational application already proven?

... and another new drought index:

Sperling Drought Index

- “easy to understand”
- <http://www.bestplaces.net/docs/studies/Drought.aspx>

Methodology

With the Sperling Drought Index, we sought to provide an easy-to-understand measure of the current drought status by looking at the long-term effects of weather patterns. A score of 100 is the normal - scores over 100 indicate dry conditions, under 100 indicate wetness.

We used statistics from the National Climatic Data Center to create the Sperling Drought Index. We specifically considered long-term precipitation trends and patterns, and the Palmer drought indices. These metrics are particularly valuable in that they attempt to measure the duration and intensity of long-term drought-inducing circulation patterns. We used a rolling average, weighted more heavily towards recent precipitation trends.

Since the hydrological effects of drought such as groundwater and reservoir levels take longer to develop and recover, we based the Sperling Drought Index on those metrics which respond more slowly to immediate weather conditions.

Accordingly, a short-term wet spell may have little direct effect on the Sperling Drought Index.

Drought score	Description
over 120	Extreme Drought
120-115	Severe Drought
115-110	Moderate Drought
110-105	Mild Drought
105-102.5	Temp Dry Spell
102.5-97.5	Near Normal
97.5-95	Temp Wet Spell
95-90	Mildly Wet
90-85	Moderately Wet
85-80	Very Wet
under 80	Extremely Wet

We created our index so that a score of 100 represents the climatic normal. Values greater than 100 represent drier conditions, and values less than 100 indicate wetter conditions.

It would not be accurate to use the Sperling Drought Index to quantify differences in drought. For example, if one place has a Drought Score of 110 compared to another with a Drought Score of 95, it would be misleading to say the place has "15% more drought," or faces a "15% greater drought risk." The effects of drought vary greatly between different places, and cannot be reduced to a single measure.

For more information about the measurement of drought, consult the NCDC resources for the Standardized Precipitation Index (SPI), the Crop Moisture Index (CMI), the Palmer Z Index, the Palmer Drought Severity Index (PDSI) and the Palmer Hydrological Drought Index (PHDI).

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America's Drought-Riskiest Cities

How Dry is Your City?

Scientists are warning that raging brush fires could become routine. Florida is running out of water to meet the needs of its growing population. New England water reserves are reaching record lows. Atlanta's main water supply may run dry in a few months. Boat ramps are becoming surrounded by dry land and streams are disappearing. Even the mighty Great Lakes are seeing historically low levels.

America's Drought-Riskiest Cities measures the drought severity for the 100 largest metro areas in the United States.

SoCal the driest, Texas the wettest

Los Angeles tops the list of drought-plagued cities, with its recent annual rainfall only 25% of normal. Other top-ten driest cities include Salt Lake City, Nashville, and Birmingham.

At the other end of the list are cities suffering from too much water. Cities in the central Texas region such as San Antonio, Dallas, Houston, and Oklahoma City have been afflicted by flood conditions this summer. Ironically, these floods which have caused deaths and property damage in Texas are the product of abnormal climate patterns that prevented the moisture-laden clouds to be carried northward to the already-parched Deep South.

Top ten drought-riskiest metro areas

1. Los Angeles-Long Beach-Santa Ana, CA
2. San Diego-Carlsbad-San Marcos, CA
3. Oxnard-Thousand Oaks-Ventura, CA
4. Riverside-San Bernardino-Ontario, CA
5. Salt Lake City, UT
6. Nashville-Davidson--Murfreesboro, TN
7. Chattanooga, TN-GA
8. Birmingham-Hoover, AL

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Drought-Riskiest Cities - Full Ranking

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Rank	Metro Area	Sperling Drought Index	Recent trend
Extreme Drought			
1	Los Angeles-Long Beach-Santa Ana, CA	127.3	Little change
2	San Diego-Carlsbad-San Marcos, CA	127.3	Little change
3	Oxnard-Thousand Oaks-Ventura, CA	126.9	Little change
4	Riverside-San Bernardino-Ontario, CA	126.5	Little change
5	Salt Lake City, UT	123.7	Slight increase
6	Nashville-Davidson--Murfreesboro, TN	122.3	Moderate increase
7	Chattanooga, TN-GA	121	Slight increase
8	Birmingham-Hoover, AL	120.9	Slight increase
9	Greenville, SC	120.8	Moderate increase
Severe Drought			
10	Knoxville, TN	119.8	Moderate increase
11	Jacksonville, FL	119.7	Little change
12	Atlanta-Sandy Springs-Marietta, GA	119	Moderate increase
13	Charlotte-Gastonia-Concord, NC-SC	118.6	Major increase
14	Deltona-Daytona Beach-Ormond Beach, FL	118.2	Little change
15	Orlando-Kissimmee, FL	118.2	Little change
16	Tampa-St. Petersburg-Clearwater, FL	118.2	Little change
17	Raleigh-Cary, NC	117.8	Major increase
18	Washington-Arlington-Alexandria, DC-VA-MD-WV	117.7	Major increase
19	Greensboro-High Point, NC	117.3	Major increase
20	Cape Coral-Fort Myers, FL	116.5	Slight increase
21	Palm Bay-Melbourne-Titusville, FL	116.4	Little change

Moderately Wet			
78	Detroit-Warren-Livonia, MI	89.3	Slight increase
79	Akron, OH	88.2	Moderate increase
80	Cleveland-Elyria-Mentor, OH	88.2	Moderate increase
81	Colorado Springs, CO	87.7	Slight increase
82	Milwaukee-Waukesha-West Allis, WI	87.5	Slight decrease
83	Poughkeepsie-Newburgh-Middletown, NY	87.3	Moderate increase
84	McAllen-Edinburg-Mission, TX	86.9	Major decrease
85	Denver-Aurora, CO1	86.6	Slight increase
86	Tulsa, OK	86.2	Major decrease
87	Madison, WI	85.1	Slight decrease
Very Wet			
88	Toledo, OH	84.5	Little change
89	Portland-South Portland-Biddeford, ME	84.2	Moderate increase
90	Omaha-Council Bluffs, NE-IA	84	Little change
91	Albany-Schenectady-Troy, NY	83.5	Moderate increase
92	Albuquerque, NM	82.5	Moderate increase
93	Des Moines, IA	82.5	Slight increase
94	Wichita, KS	82.4	Slight decrease
95	El Paso, TX	82	Slight decrease
Extremely Wet			
96	Houston-Sugar Land-Baytown, TX	77.1	Major decrease
97	Dallas-Fort Worth-Arlington, TX	71.5	Major decrease
98	Austin-Round Rock, TX	70.3	Major decrease
99	San Antonio, TX	69.5	Major decrease
100	Oklahoma City, OK	68.4	Major decrease

Conclusions

- **there are already many drought indices existing**
- **more drought indices are developed every year**
 - with RS probably leading the innovation due to technology progress
- **important for developers**
 - combined and comprehensive drought indices lead innovation on the methodological side
 - clear purpose and necessity for a new drought index
 - boundary conditions for its validity
 - extensive testing and validation
- **important for potential users**
 - clear definition of scope
 - specific user requirements and boundary conditions

... thank you!

