Key aspects of low flow and drought

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Low flows in River Gardon, at Pont du Gard, France, August 2003

Key aspects of low flow and drought

Drought has serious **impacts** on the environment, economy and society

Some key figures for Europe:

- In 2003 more than 100 million people and a third of the EU territory was affected;
- The cost to the European economy was at least € 8.7 billion;
- Over the past thirty years, droughts have dramatically increased in number and intensity in the EU and the cost in this period amounts to € 100 billion;
- Climate change is expected to make matters worse

Key aspects of low flow and drought

Outline

I. Characteristics of drought
II. Recent events in Europe
III. Drought processes and propagation
IV. Space-time aspects
V. Drought monitoring and forecasting
VI. Climate change
VII. Concluding remarks

I. Characteristics of Drought

Deviation from normal conditions:

- occurrence of below average natural water availability
- occurs in all hydroclimatological regions
- sustained
- regionally extensive
- different types of drought (meteorological, soil water, groundwater, streamflow)

Do not confuse with:

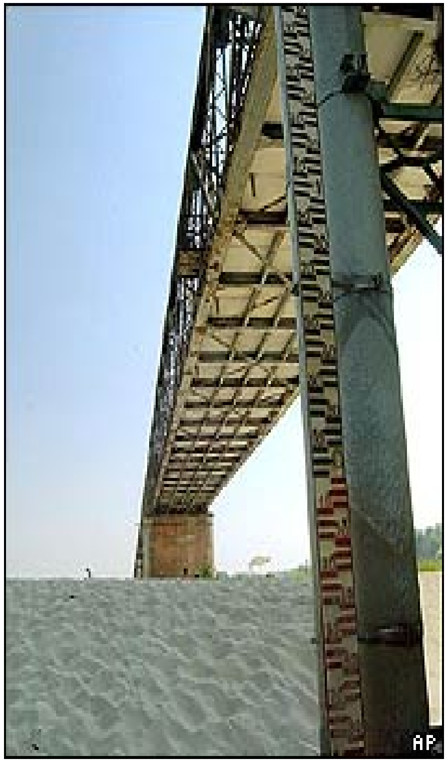
- aridity
- water scarcity
- desertification

I. Characteristics of Drought

Example from Norway

Reservoir for drinking water supply for the city of Bergen, Norway, March 2006 (Bergens Tidende, 24.3.06, Photo: Arne Nilsen)

I. Characteristics of Drought
Impacts



Low flows and dried up rivers

Soil moisture deficit

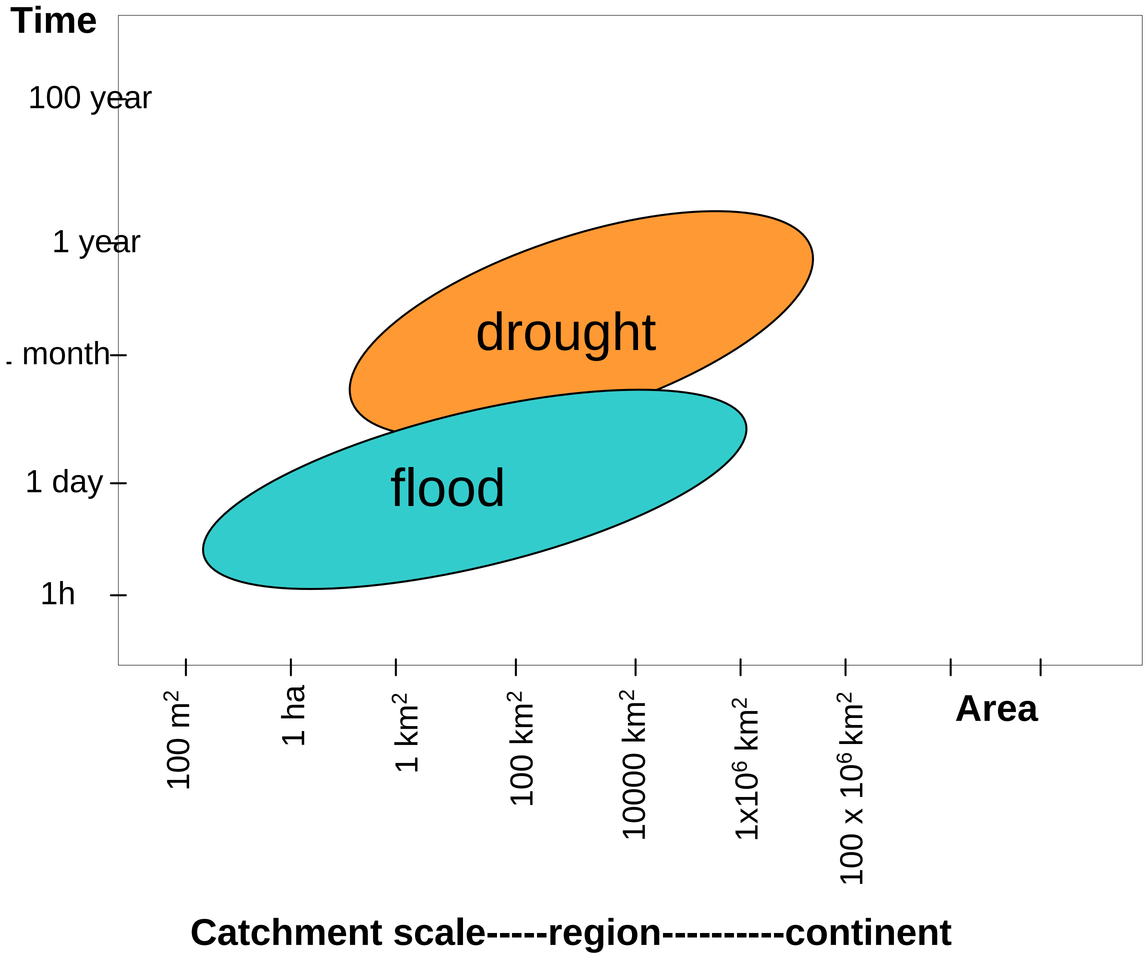
Forest fires

Low reservoir levels

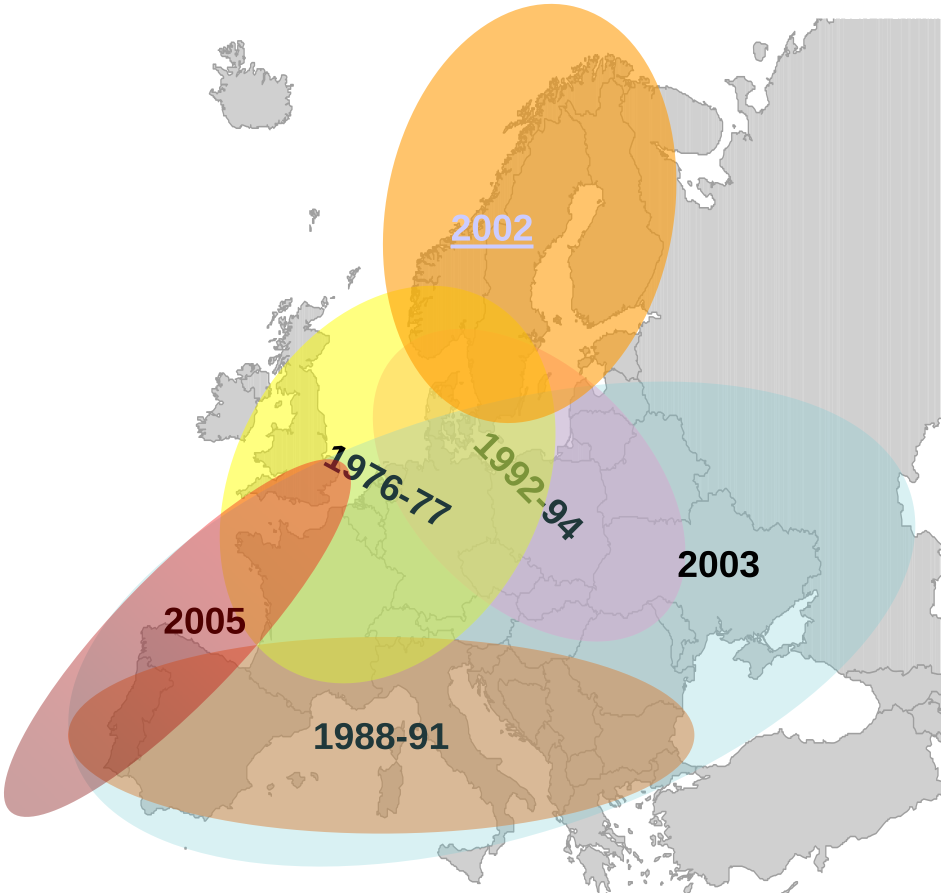
Agricultural production

I. Characteristics of Drought
as compared to Flood

- Drought is a non-event;
- Drought can not be forecasted based on a preceding precipitation event;
- Drought develops slowly in time and space;
- Drought covers large spatial and temporal scales and thus requires transnational data for its analysis.



II. Recent events in Europe



Recent major events:

- 2003
- 2005
- 2006
- 2007

II. Recent events in Europe
2003

A high pressure system developed over Western Europe. This led to blocking of moist airmasses from west and allowed warm, dry airmasses from Northern Afrika to move northwards.

The result: Heat wave and large precipitation deficits

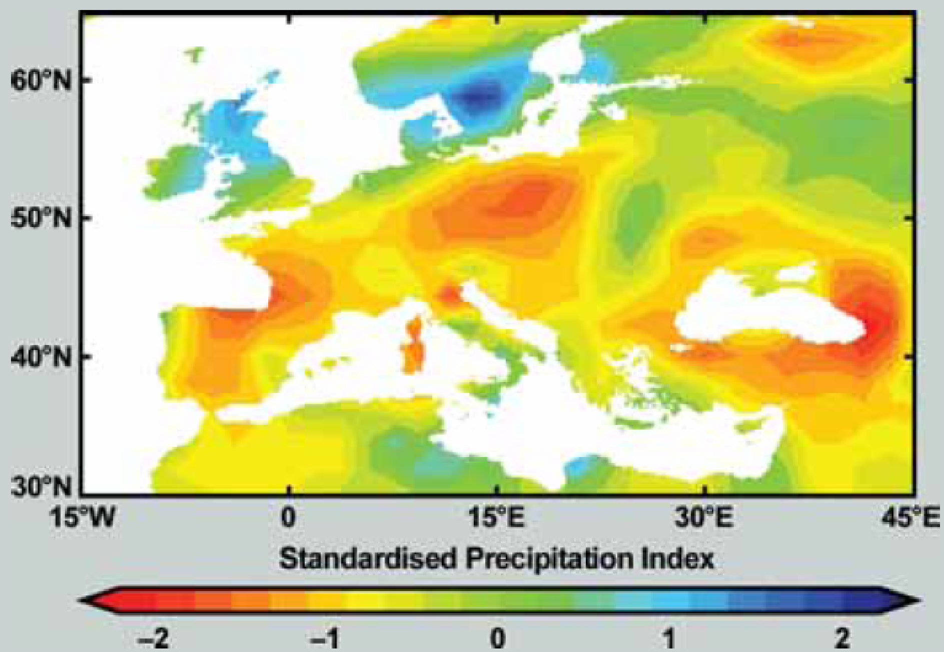


Figure 1: Extent and severity of 2003 drought

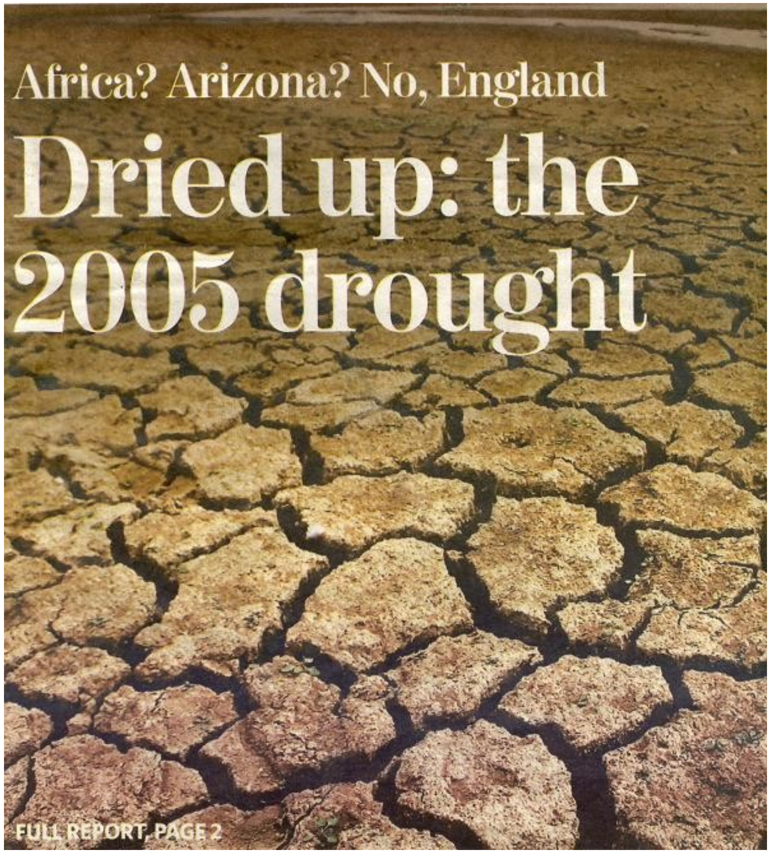
During the summer of 2003, the rainfall deficit extended across most of Europe with drought conditions lasting from March to September. In Central and Eastern Europe 2003 followed a cluster of notably dry years.

II. Recent events in Europe
2003 - Impacts

- Heat wave in Southern Europe (~30.000)
- Forest fires, crop loss (10.6 Billions US$)
- Navigation problems on large rivers
- Lowest water level in Danube in 160 years
- Laveste observed water level in the Rhine v/ Lobith (825 m^3s^{-1})
- Death of fish (almost 30^0C)
- Closure of power plants
- Damage of wooden piles of monumental buildings (NL)

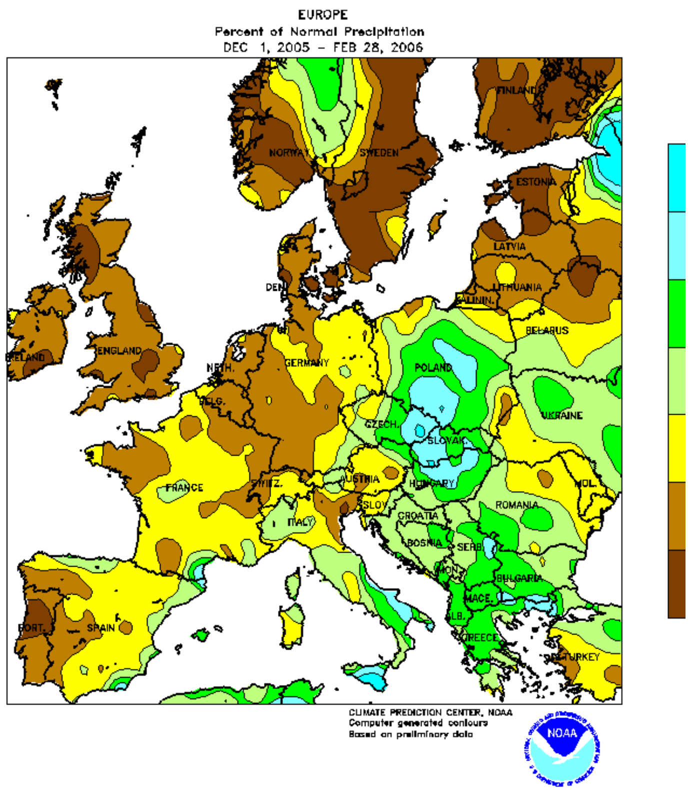
➔Drought on the European agenda!

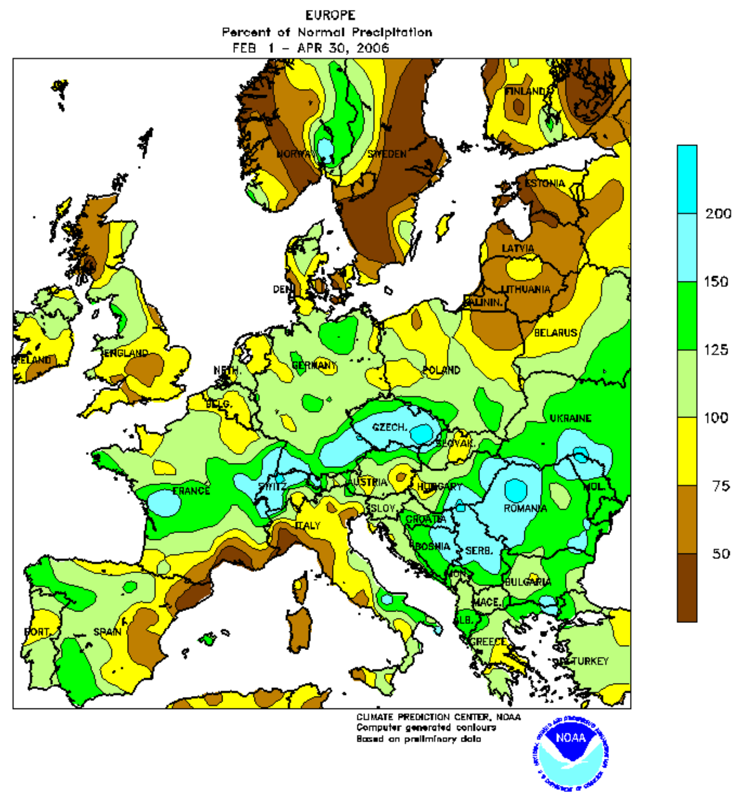
II. Recent events in Europe 2005



- The affected area is less than in 2003
- But some regions, including the Iberian peninsula experience a more severe situation, in particular due to the long duration of the drought
- In France the situation is as bad as in 2003
- And England has experienced the worst drought since 1976

II. Recent events in Europe
2006 - Precipitation





3-month precipitation, February 28 (left) and April 30 (right)

II. Recent events in Europe
2006 - Climate

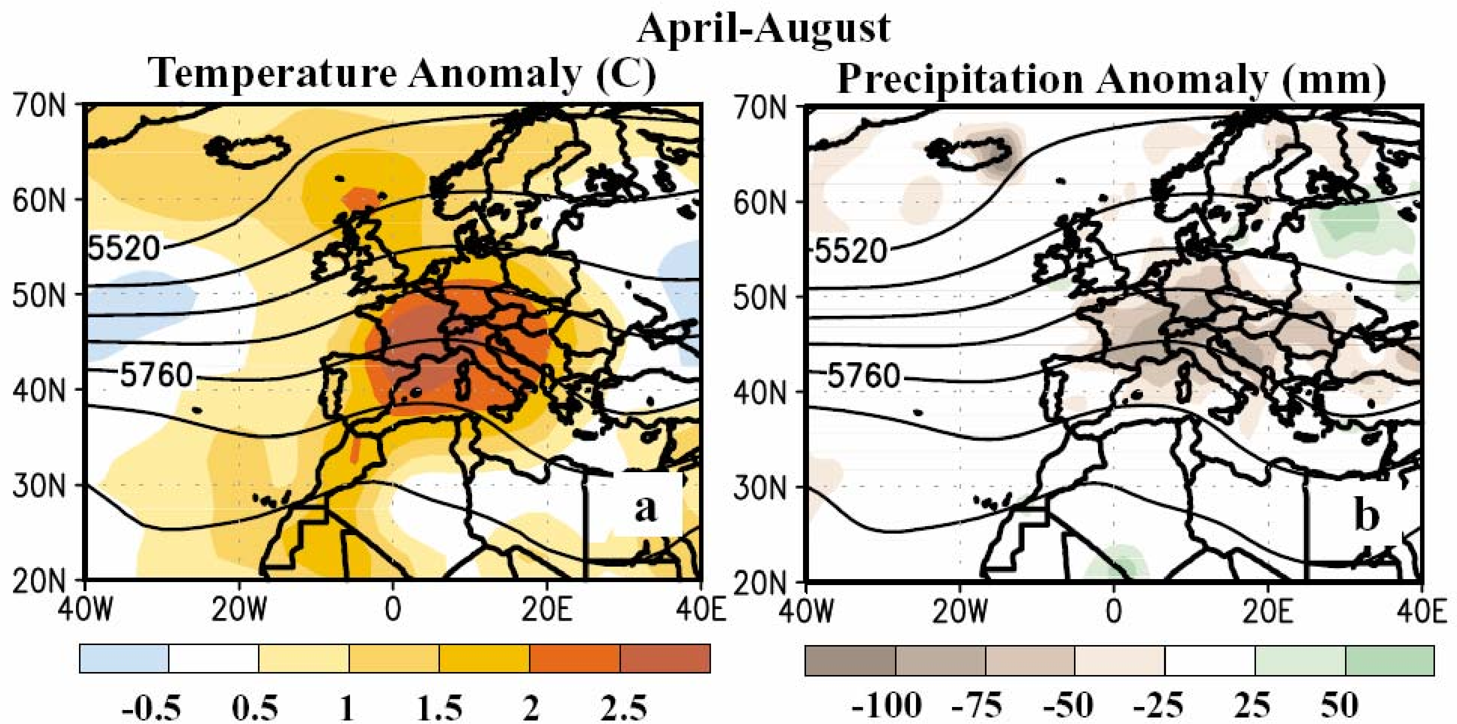
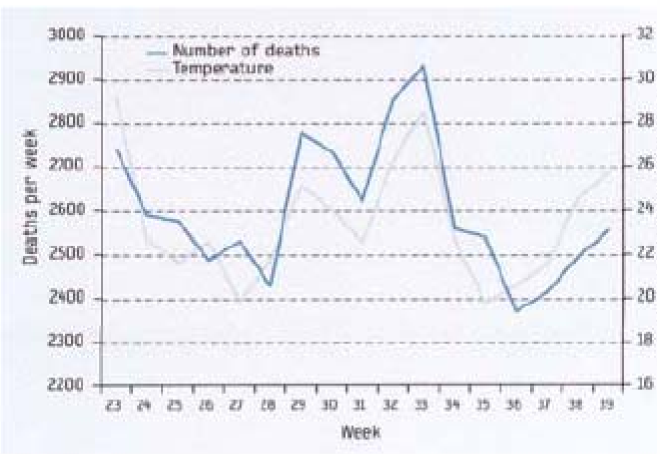


Fig. 4. April-August 2003 mean 500-hPa heights (contours, interval is 60 m) overlaid with (a) surface temperatures anomalies (°C) and (b) precipitation anomalies (mm). Anomalies are departures from the 1971-2000 base period monthly means.

US National weather service; Climate Prediction Centre, 2006

II. Recent events in Europe
2006 - Impacts

- Forest fires (loss of lives)
- Heatwaves (loss of lives)
- Agricultural production
- Water supply
- High river temperature (→ ecology and energy production)
- Tourism



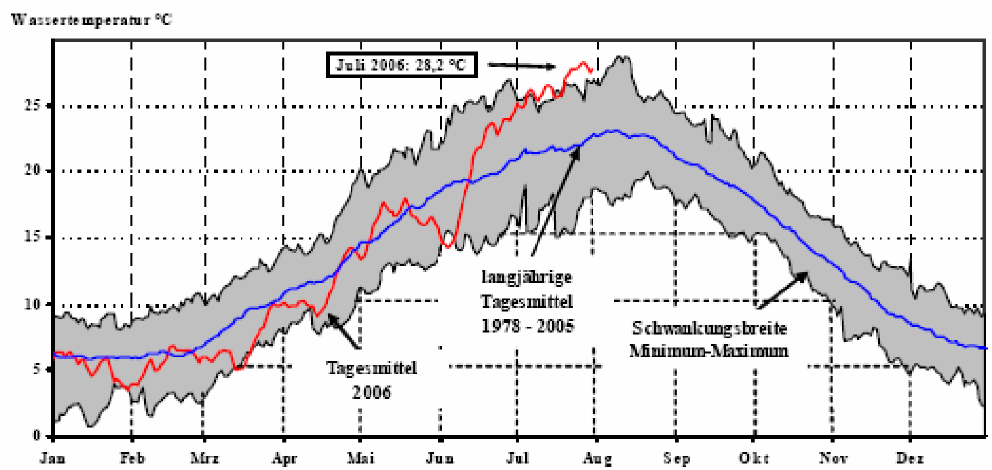


Fig. 4: Water temperatures of river Rhine at Koblenz, time period from 1978 to 2006

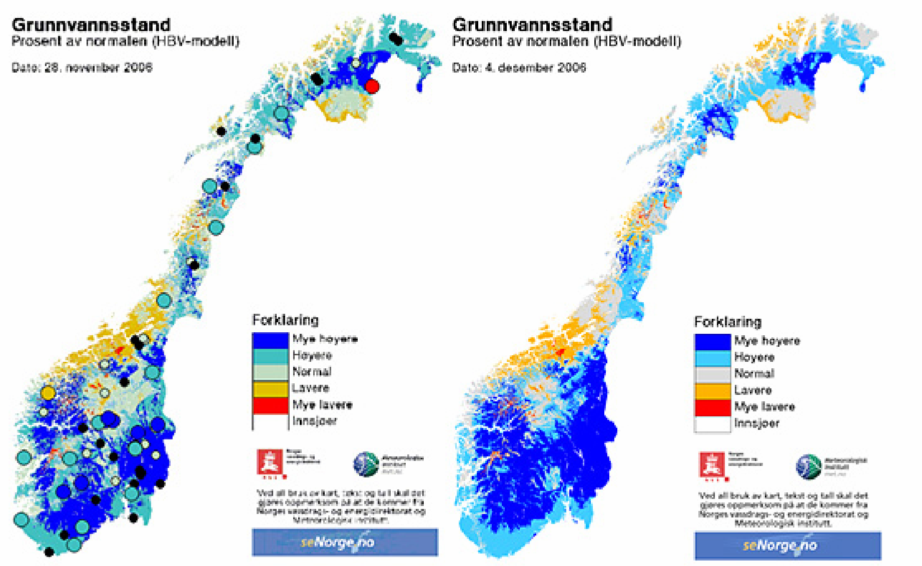
Norway, Groundwater Autumn 2006

24. August
Warning issued due to the low groundwater levels, some places the **lowest** on records since 30 years. Concern for the water supply situation in the coming winter.

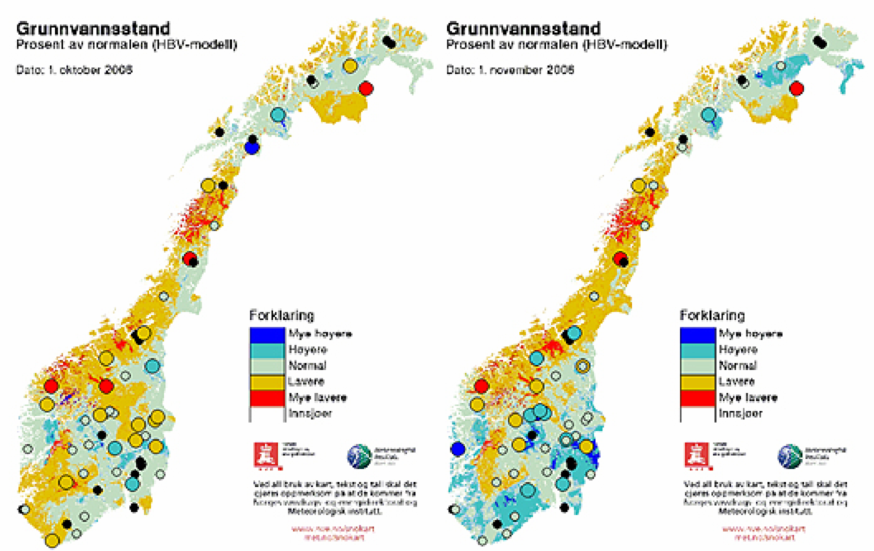
28. November
The drought is definitely over. High groundwater levels are now recorded, somewhere the **highest** for this time of the year.

Warm and wet November!

Kart som viser dagens situasjonen 28. november og prognose for 4. desember

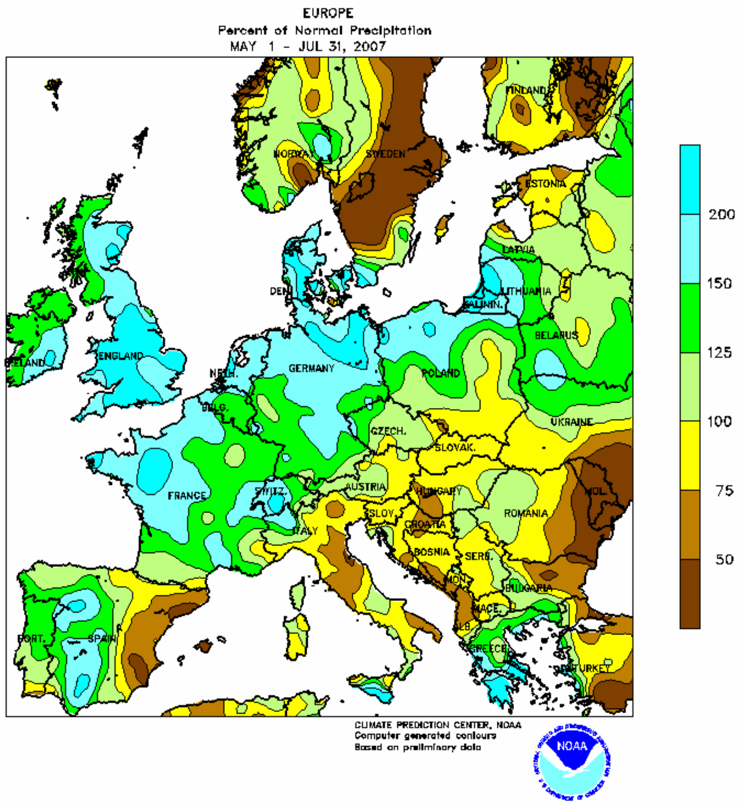


Kart som viser situasjonen for grunnvannsstand 1. oktober og 1. november

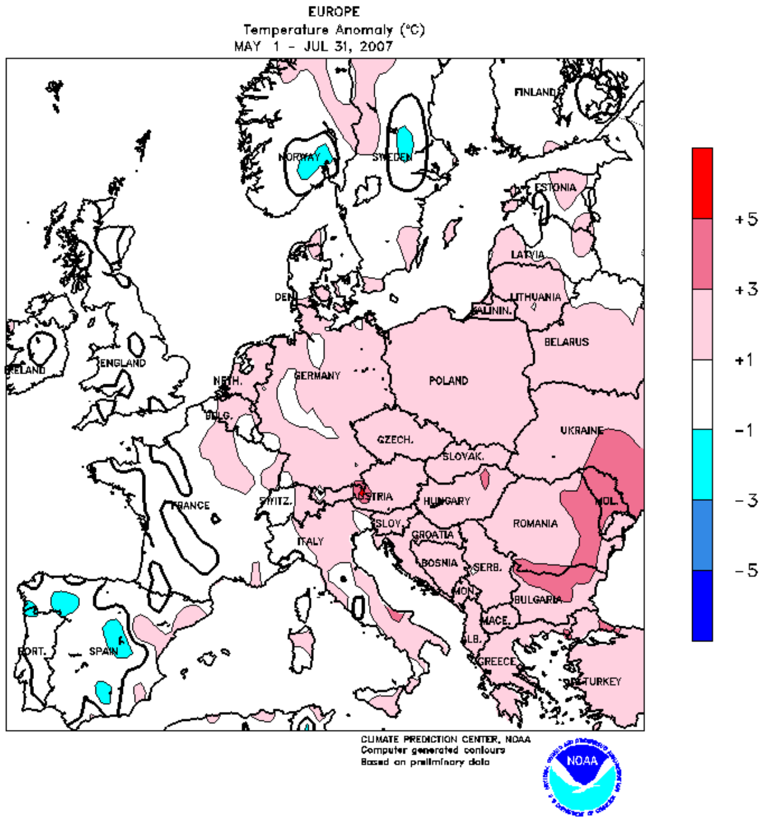


II. Recent events in Europe
2007 – Climate anomaly

May-July Precipitation



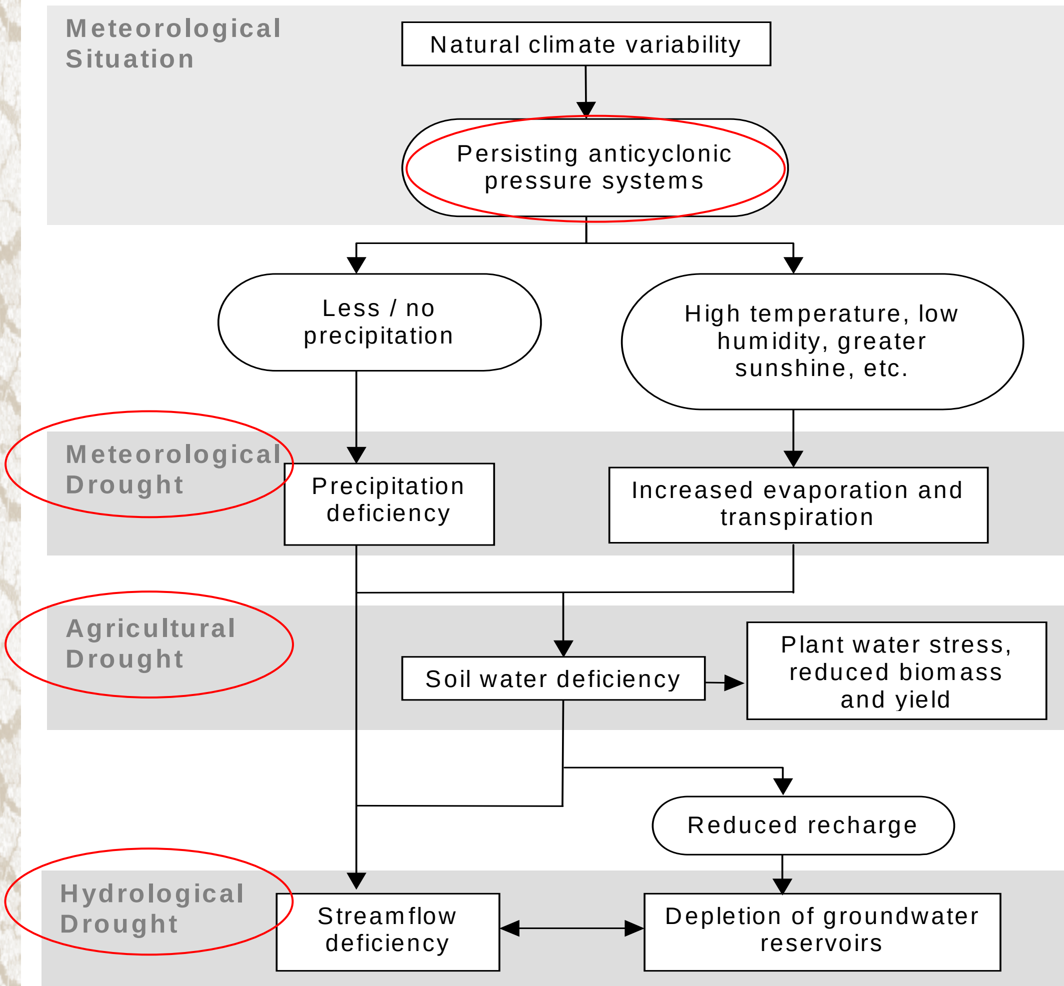
May-July Temperature

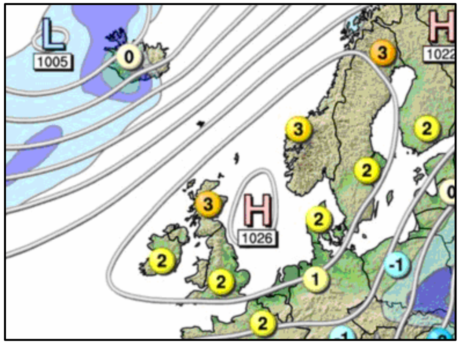


II. Recent events in Europe
2007 - Impacts

- Forest fires
- Heatwave
- Water supply
- Agriculture

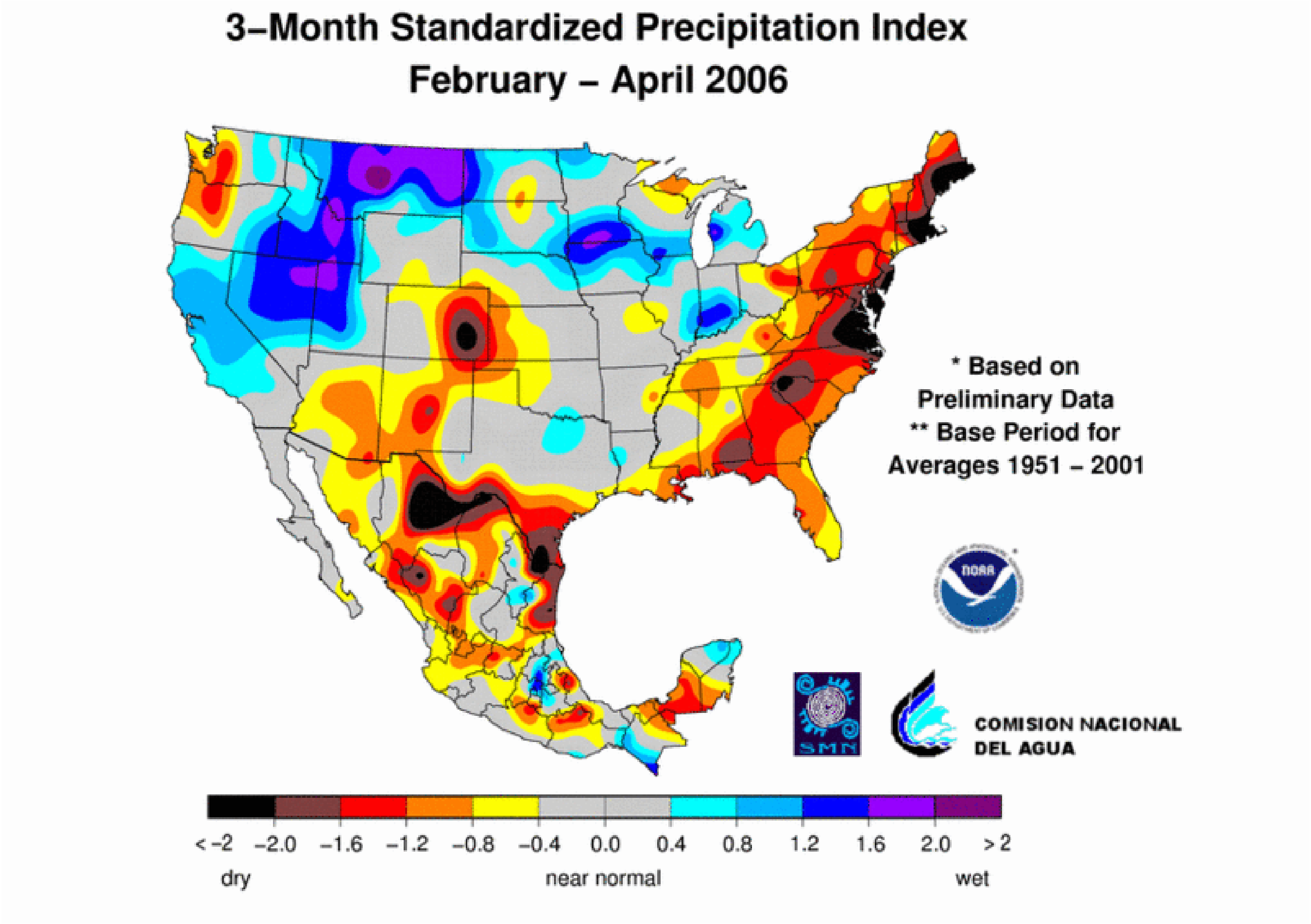
III. Drought processes and propagation
- in the hydrological cycle





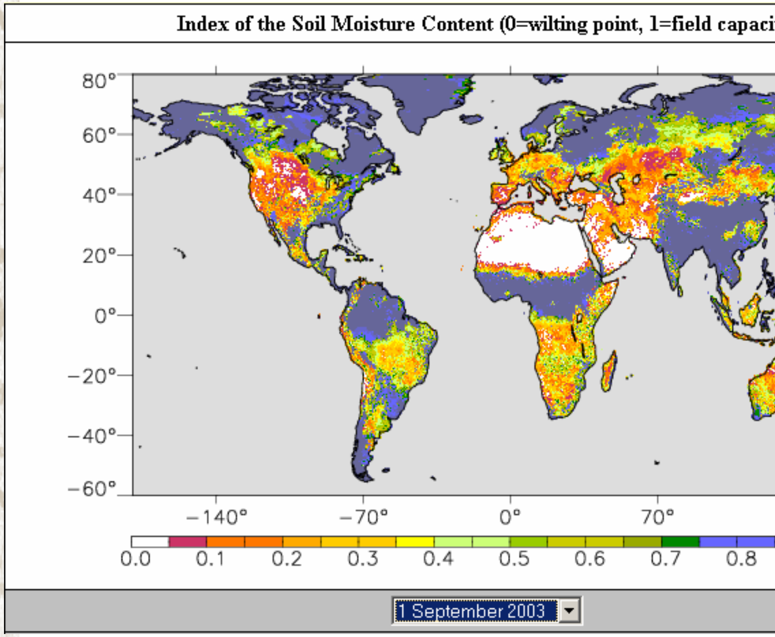
III. Drought processes and propagation

Meteorological drought – Precipitation (SPI)



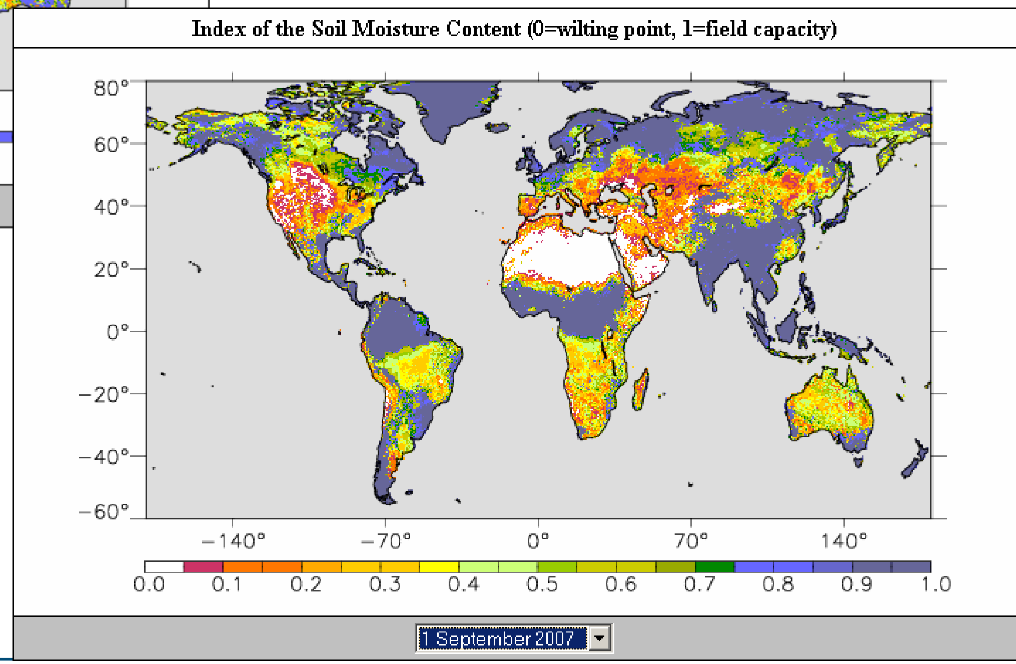
III. Drought processes and propagation

Soil moisture drought – SM content (0-1)



1.September 2003

1.September 2007

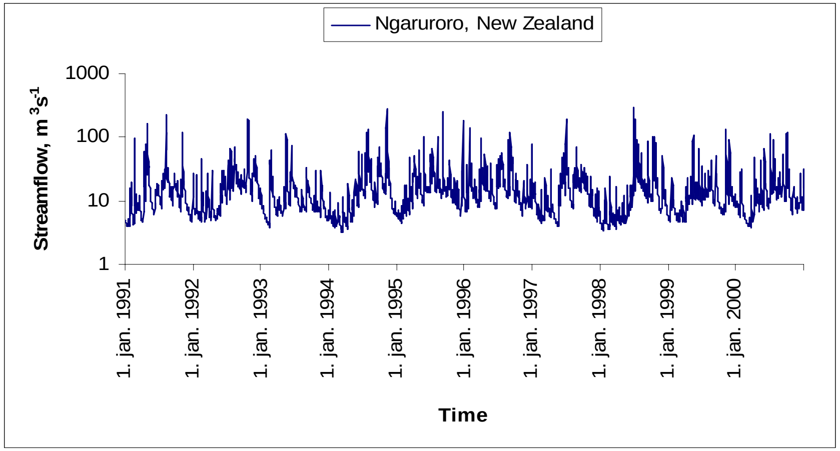


French Global Land Surface Model, *Orchidee*

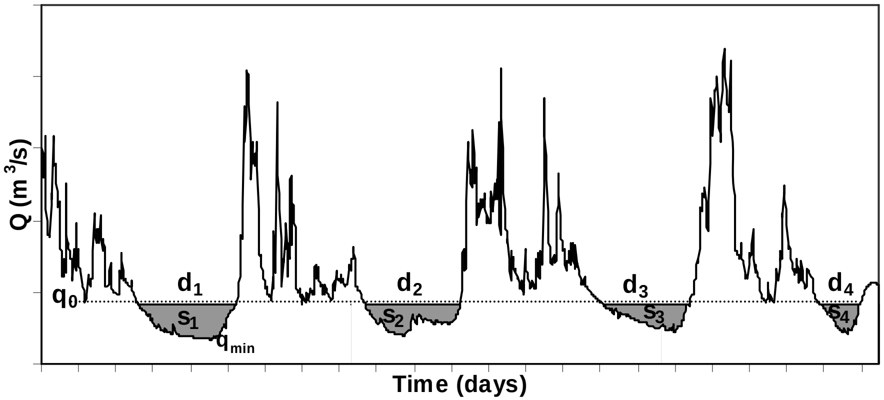
III. Drought processes and propagation

Hydrological drought – Streamflow

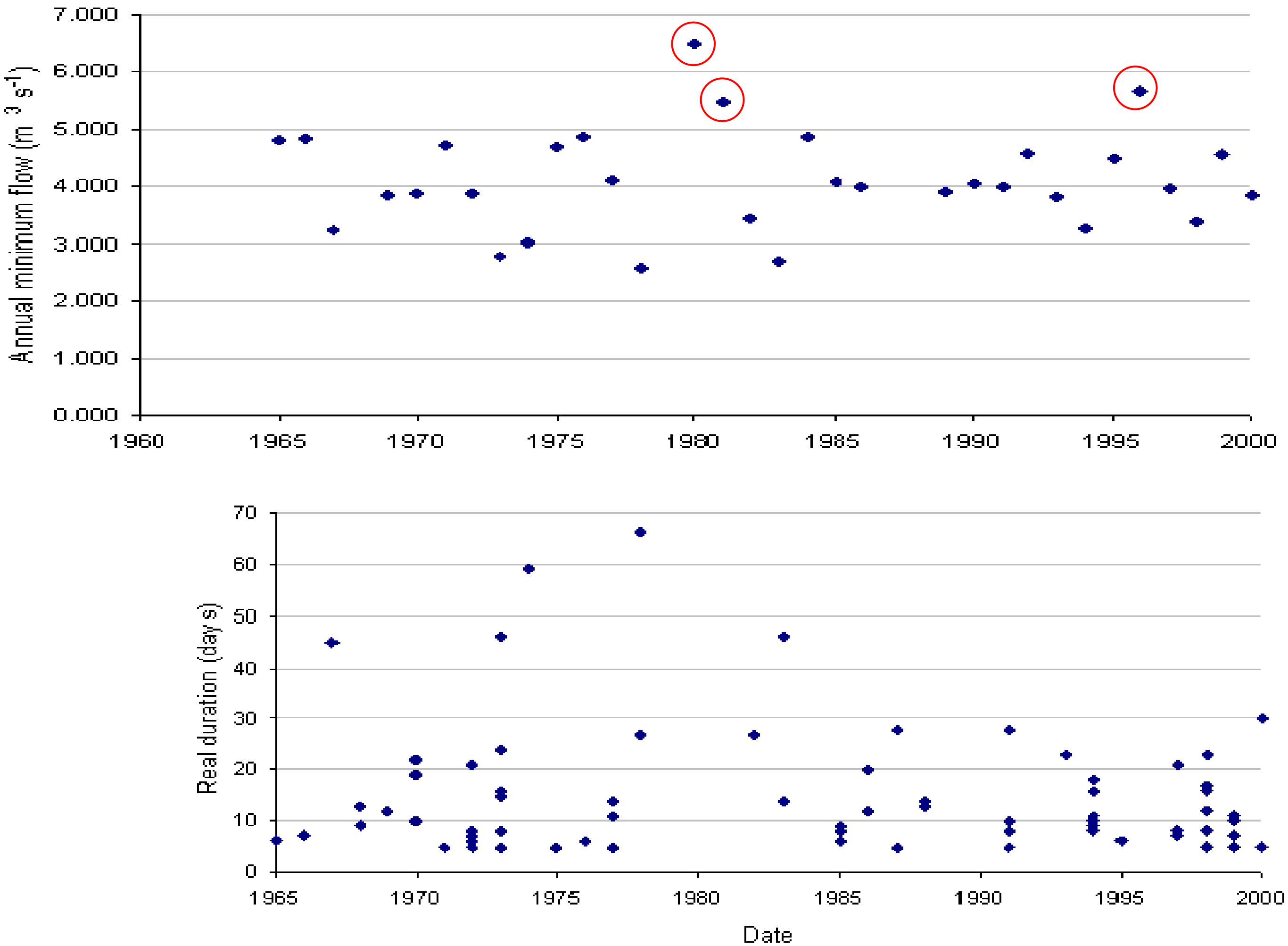
- Low flow characteristics (minimum values)
  - annual minimum series



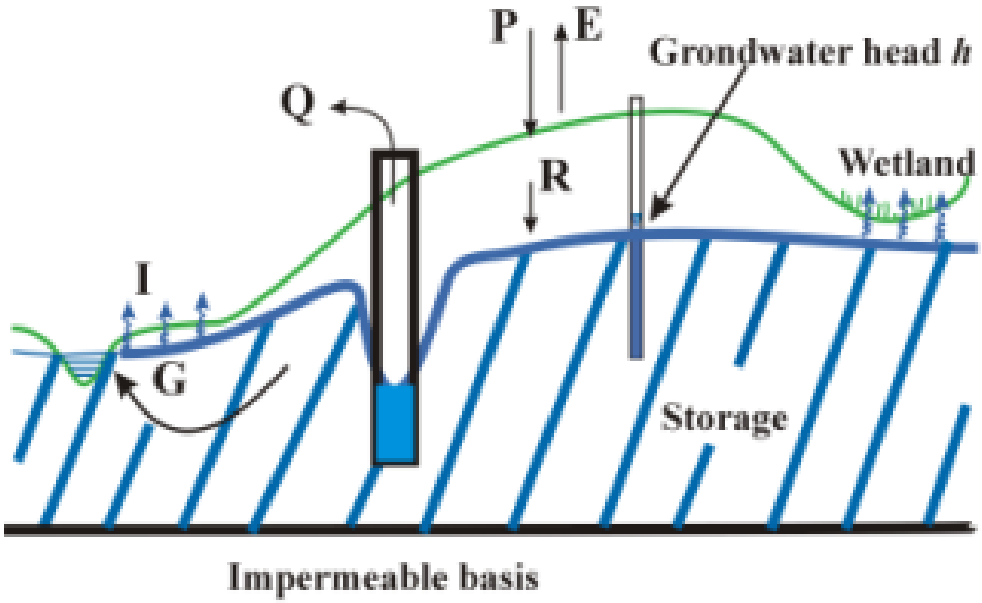
- Deficit characteristics (maximum values)
  - duration
  - deficit volume (severity)



AMS of 1-day minimum flow and PDS of drought duration



Groundwater Droughts



Key variables:

Fluxes

recharge

groundwater discharge (base flow)

State variables

groundwater heads or levels

storage

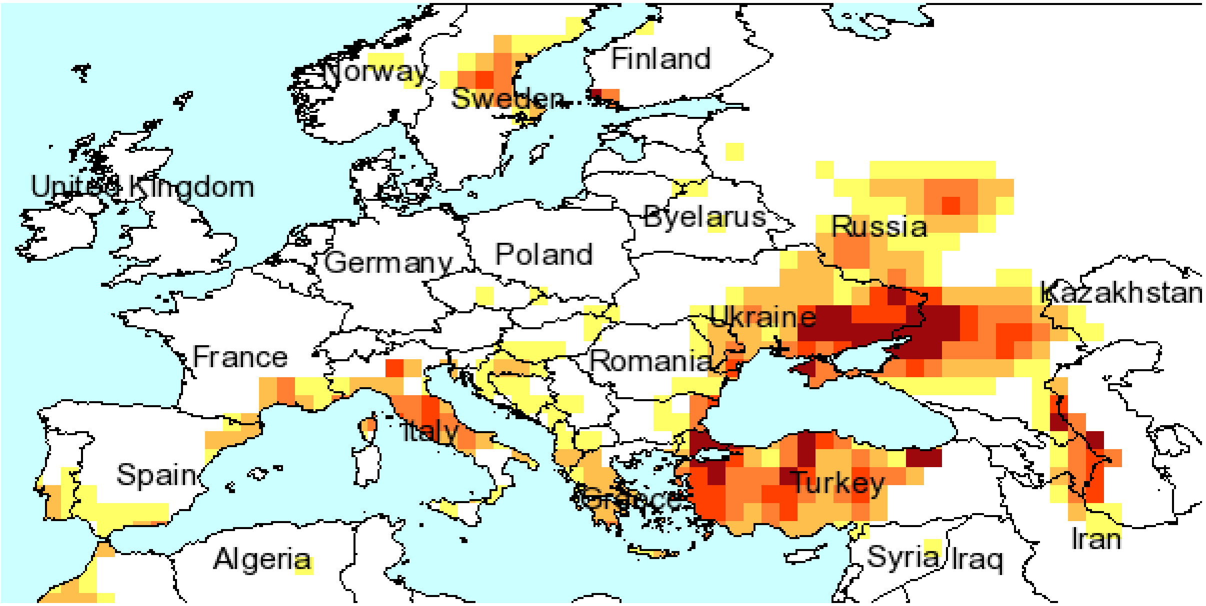
III. Drought processes and propagation

Multivariable indices

•Based on several variables and often include water balance calculations

•PDSI: Meteorological drought index, snow not included

•SWSI: Includes snow, precipitation, reservoir storage, streamflow



PDSI – 9 month

Global Drought Monitor, 15 September 2007

III. Drought processes and propagation

Composite indices – Drought classes

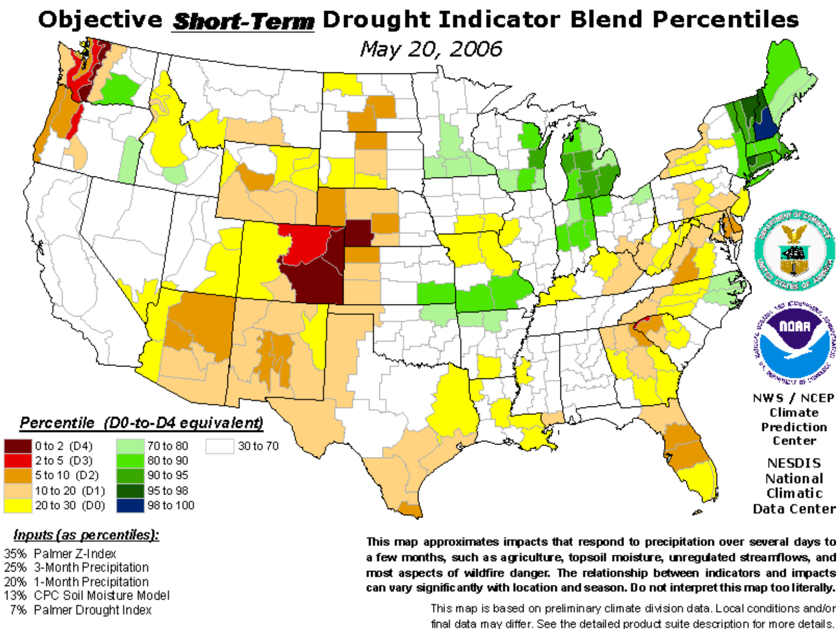
Drought Severity	Return Period (years)	Description of Possible Impacts	Drought Monitoring Indices		
			Standardized Precipitation Index (SPI)	NDMC* Drought Category	Palmer Drought Index
Minor Drought	3 to 4	Going into drought; short-term dryness slowing growth of crops or pastures; fire risk above average. Coming out of drought; some lingering water deficits; pastures or crops not fully recovered.	-0.5 to -0.7	D0	-1.0 to -1.9
Moderate Drought	5 to 9	Some damage to crops or pastures; fire risk high; streams, reservoirs, or wells low, some water shortages developing or imminent, voluntary water use restrictions requested.	-0.8 to -1.2	D1	-2.0 to -2.9
Severe Drought	10 to 17	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed.	-1.3 to -1.5	D2	-3.0 to -3.9
Extreme Drought	18 to 43	Major crop and pasture losses; extreme fire danger; widespread water shortages or restrictions.	-1.6 to -1.9	D3	-4.0 to -4.9
Exceptional Drought	44+	Exceptional and widespread crop and pasture losses; exceptional fire risk; shortages of water in reservoirs, streams, and wells creating water emergencies.	less than -2	D4	-5.0 or less

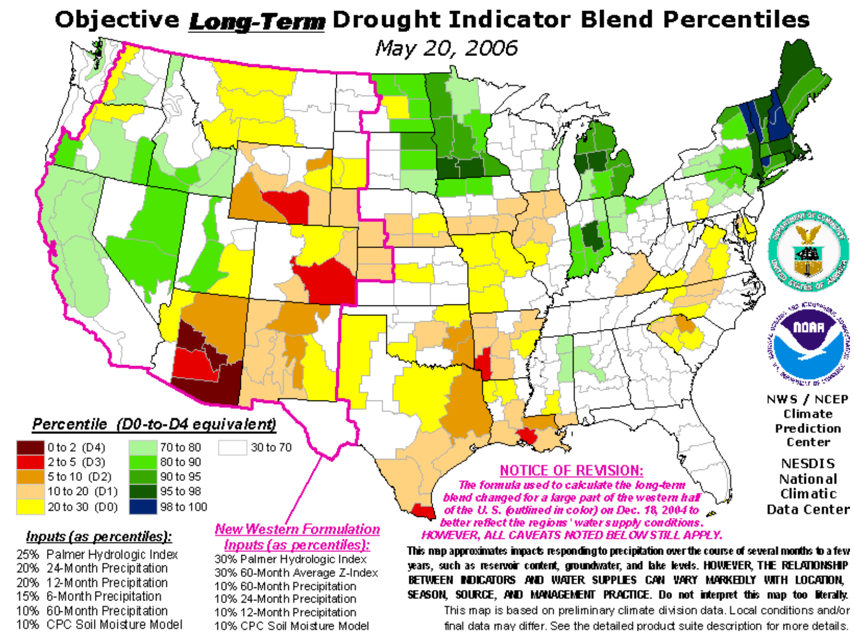
*NDMC - National Drought Mitigation Center

III. Drought processes and propagation

Choice of indices and relief measures

- The purpose of the study
- The hydrological regime under study
- The data availability

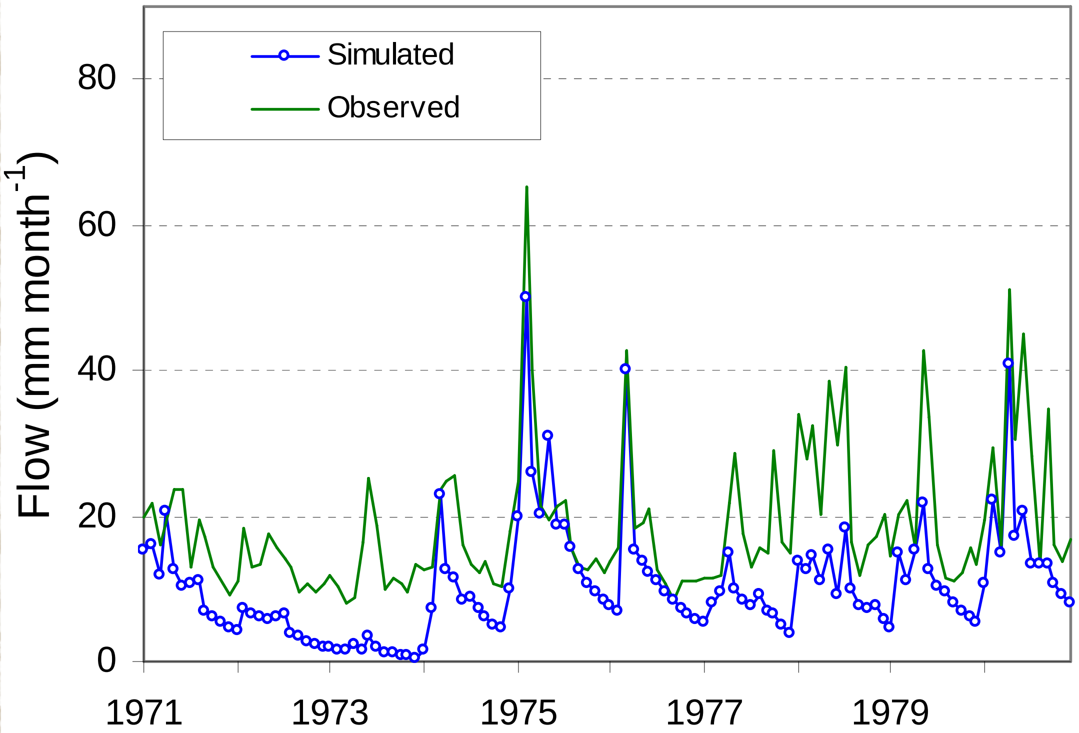




III. Drought processes and propagation

Catchment scale studies

Physically-based modelling



- River Bilina (Czech Rep.)
- Impact of surface water transfer to River Bilina
- Observed: with augmentation
- Simulated: without (naturalized series)

- Droughts:

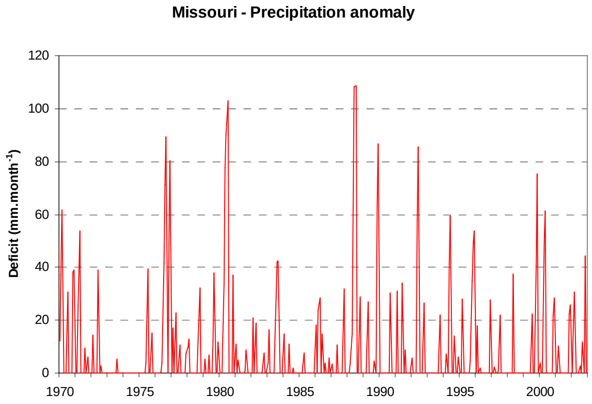
  - with augmentation: 3

  - natural conditions: 22

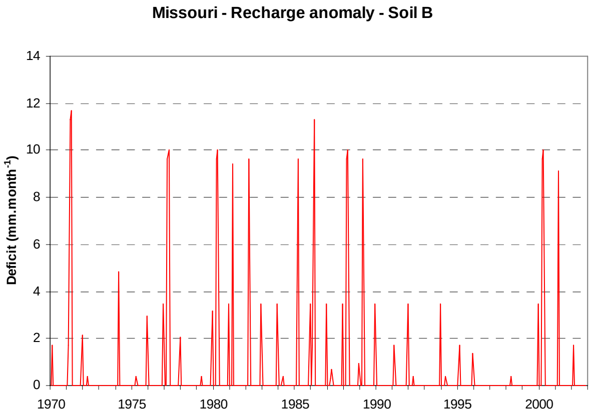
III. Drought processes and propagation
Catchment scale studies

Evolution of Deficit Volume for Missouri

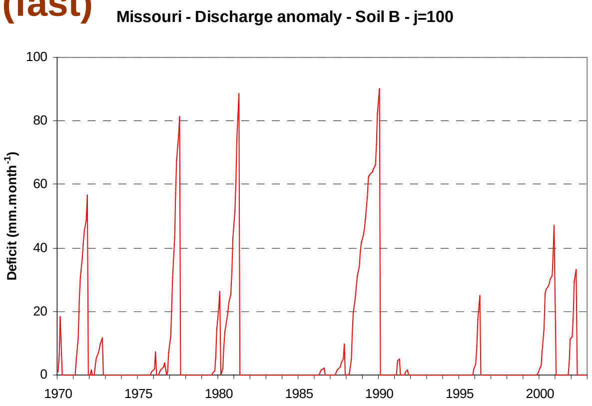
Precipitation



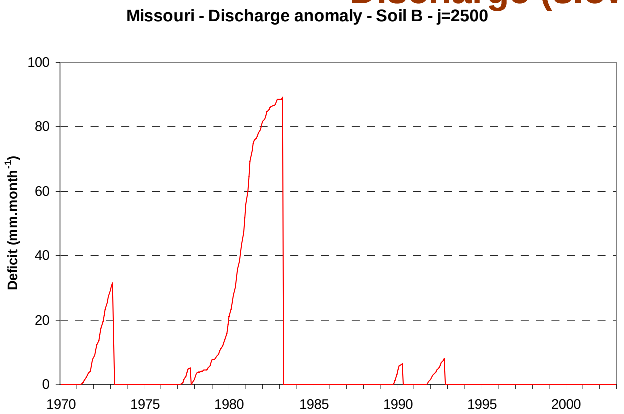
Recharge



Discharge (fast)

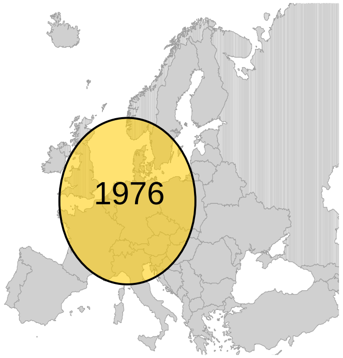


Discharge (slow)



III. Drought processes and propagation
Spatial characteristics

Objective: to characterize the **spatial aspect of drought,** including the area covered by drought and the total deficit over the area:



Data: spatially interpolated information, most commonly gridded values are applied.

Regional scale: Denmark

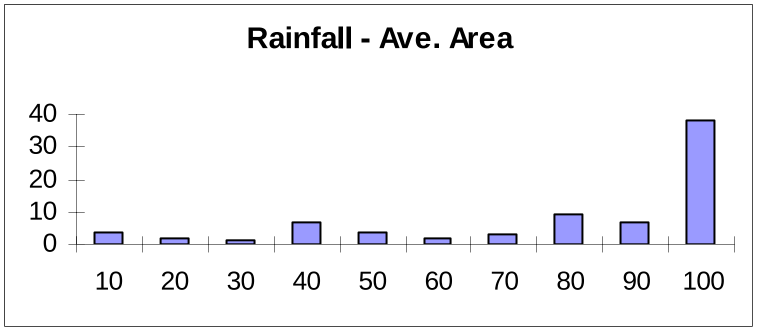
Catchment scale: Pang study

Interpolated and simulated long time series (gridded, monthly) are obtained using interpolated rainfall and simulated groundwater recharge, head and discharge for the Pang catchment, UK.

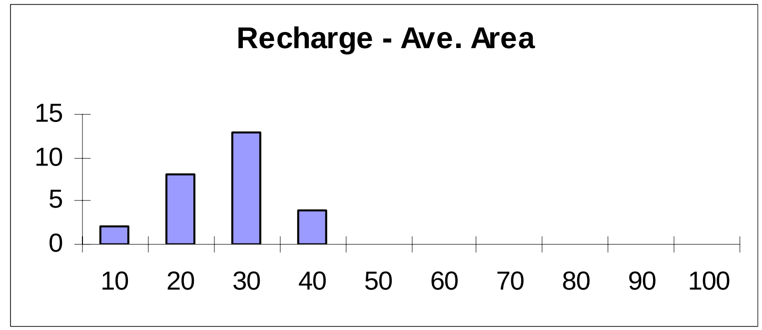
III. Drought processes and propagation

Catchment scale studies – the Pang (UK)

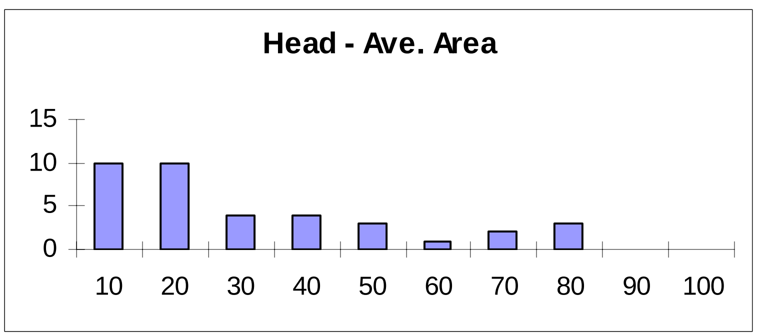
N = 77

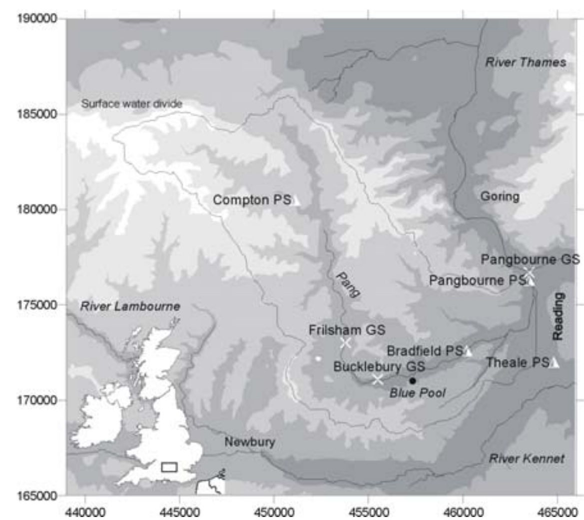


N = 27



N = 37

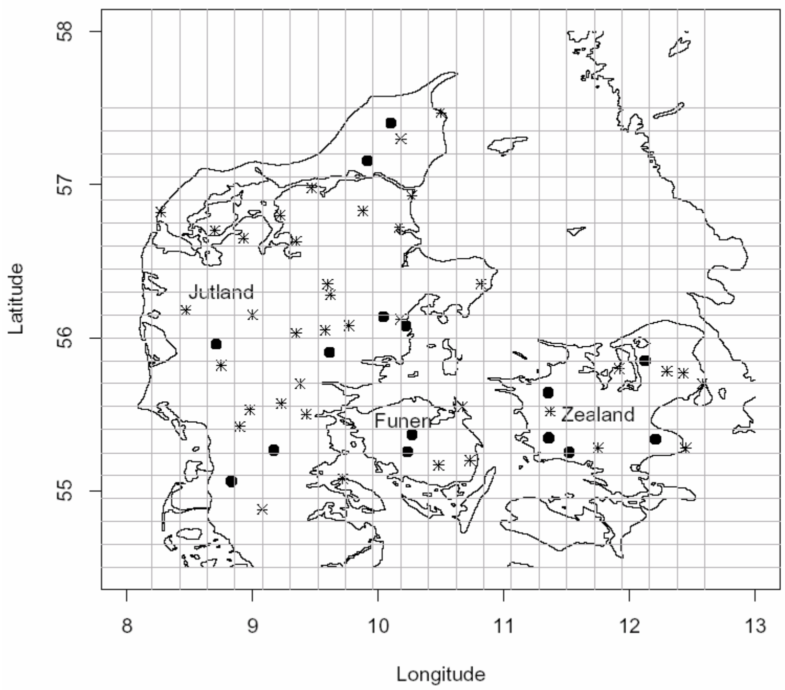




IV. Space-time aspects

Regional drought study - Denmark

1. Divide Denmark into 21 x 21 grid-cells of
   0.220 x 0.150 (~14 x 17 km)
2. Simulate long time series of monthly precipitation and streamflow in each grid cell
3. Select the drought events in each simulated time series – PDS model
4. Derive the empirical probability distribution functions of the area covered by a drought, the drought deficit volume and duration
5. Construct SAF-curves

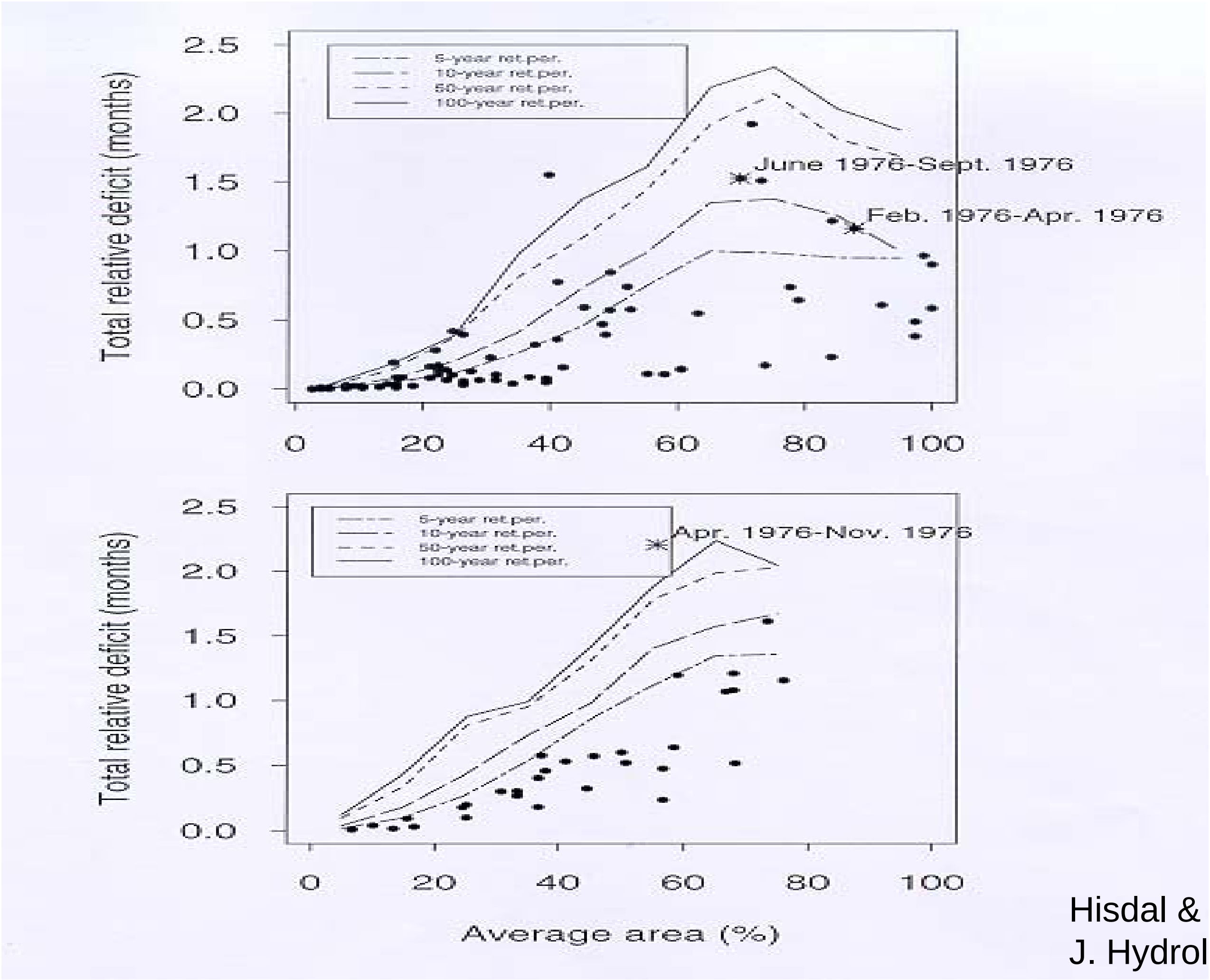


IV. Space-time aspects

Regional drought study - Denmark

P

Q



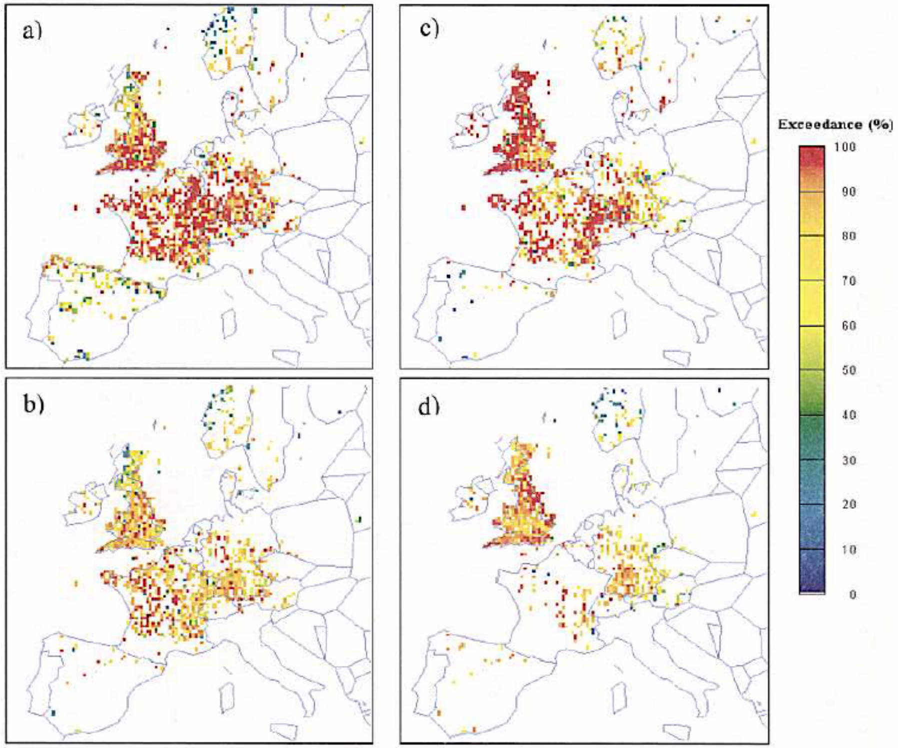
Hisdal & Tallaksen (2003)
J. Hydrol. 281(3), 230-247

IV. Space-time aspects

Synoptic patterns and local variability

Droughts are regional events, it is thus important to assess:

- the spatial extent of the events
- the variability within the affected area
- the dynamics of an event
- possible recurrent patterns in space

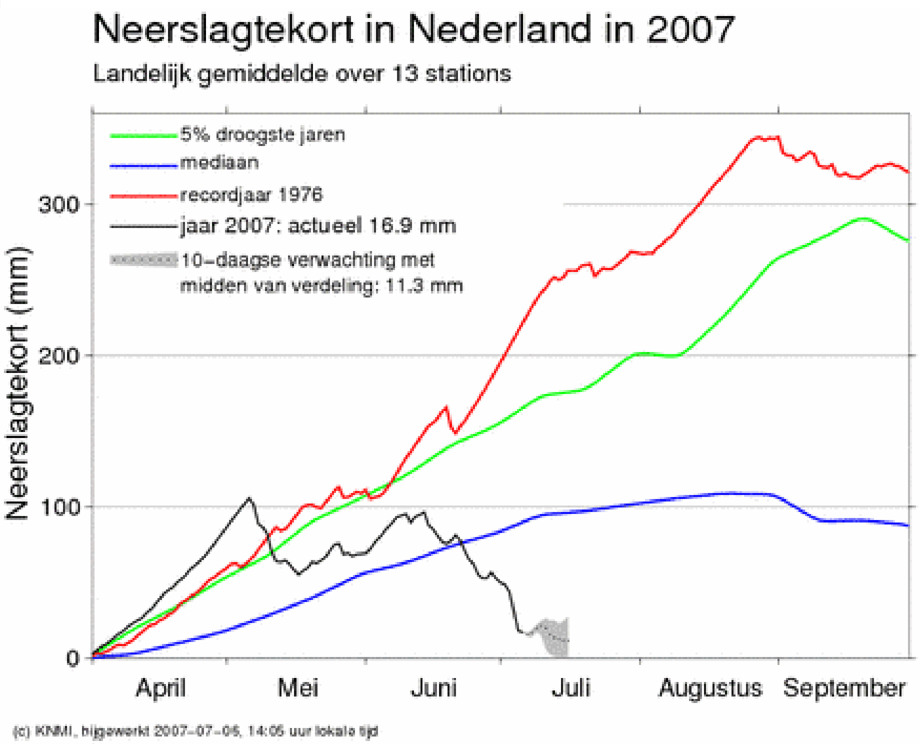


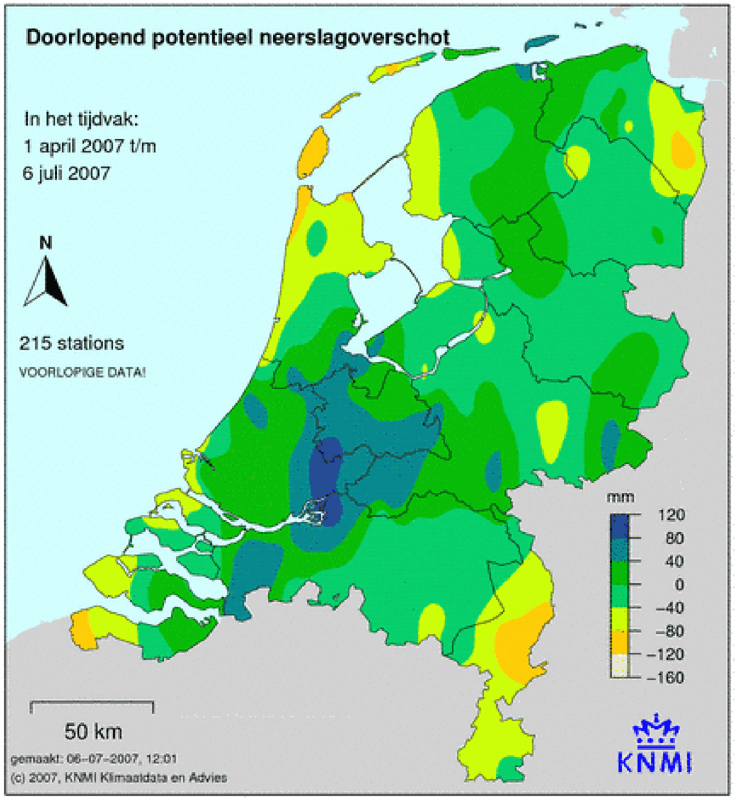
Flow exceedance across Europe (CEH, 2001);

a) 12 Jul. 1976; b) 14 Aug. 1990; c) 1 Dec. 1989; d) 23 Jan. 1992

IV. Space-time aspects

Synoptic patterns and local variability

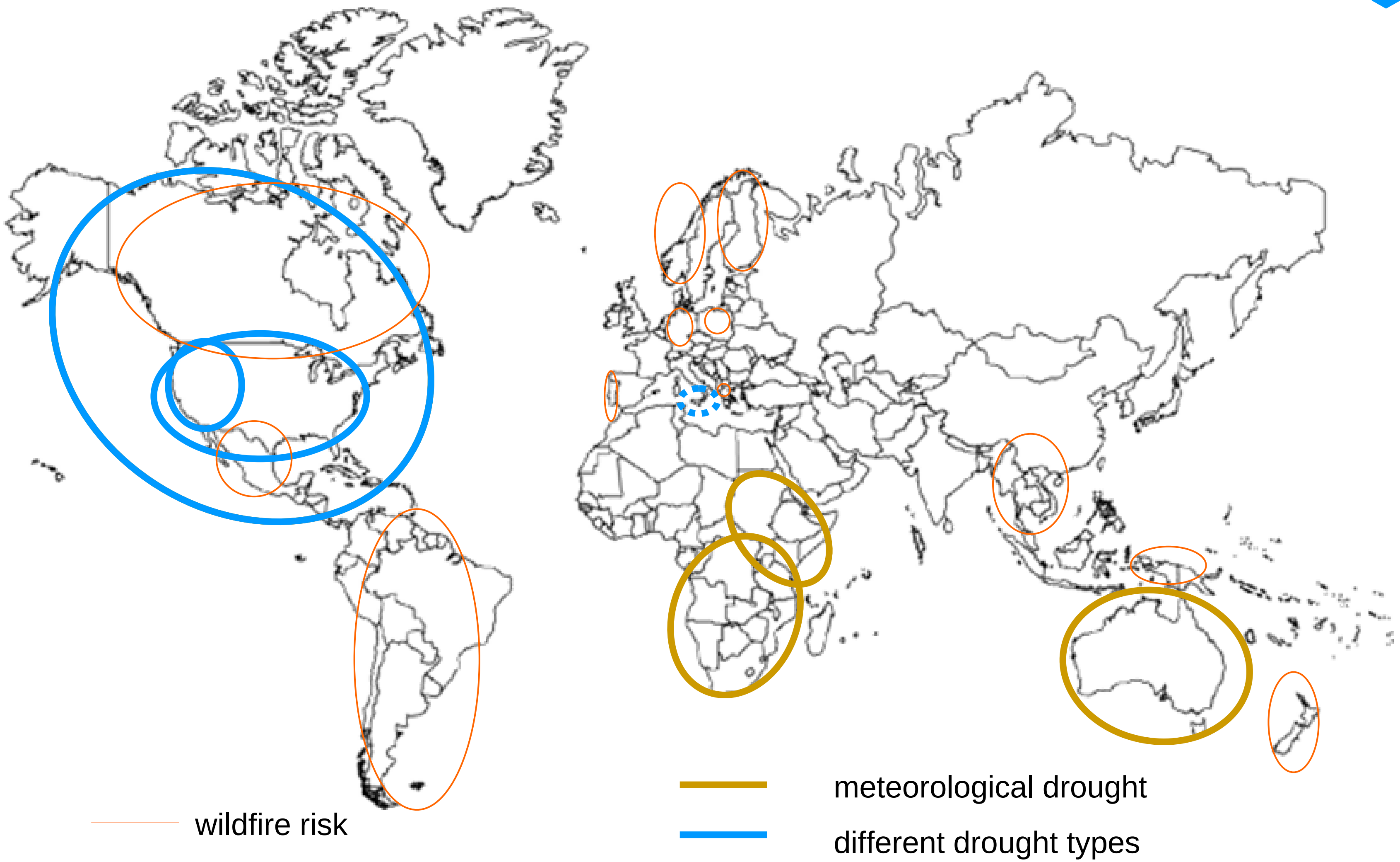




Cumulative precipitation deficit in the Netherlands, 6 July 2007

V. Drought Monitoring and forecasting

Global overview - Monitoring



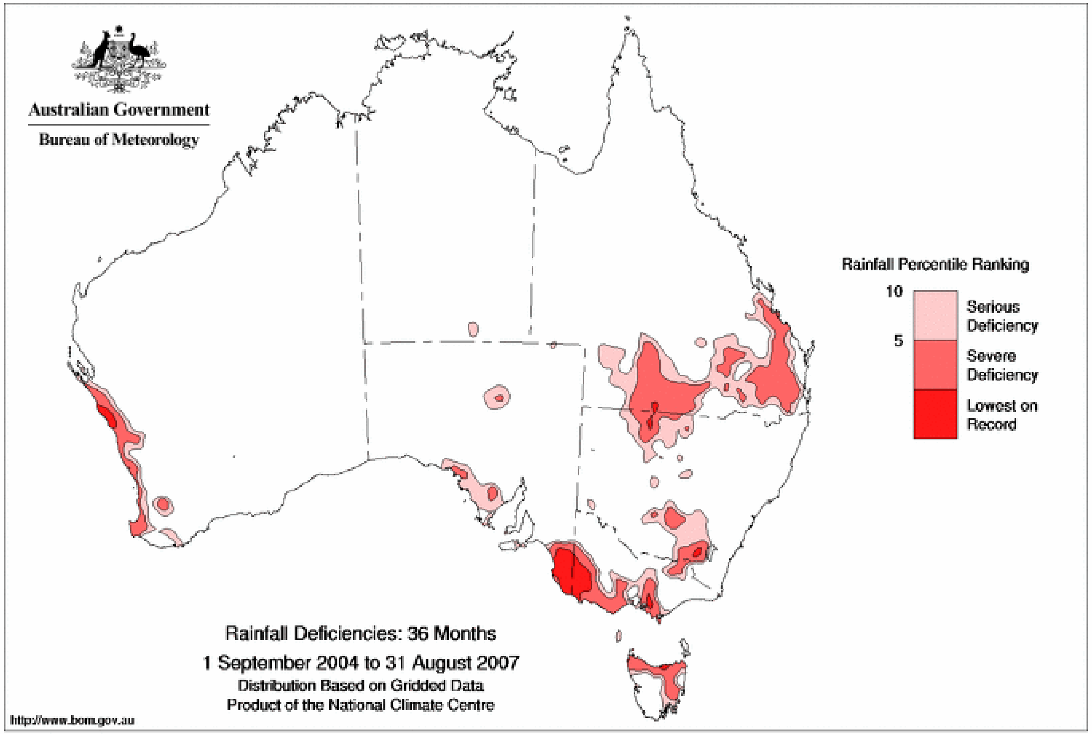
V. Drought Monitoring and forecasting

Precipitation Drought - Monitoring

36-monthly rainfall deficiencies for Australia

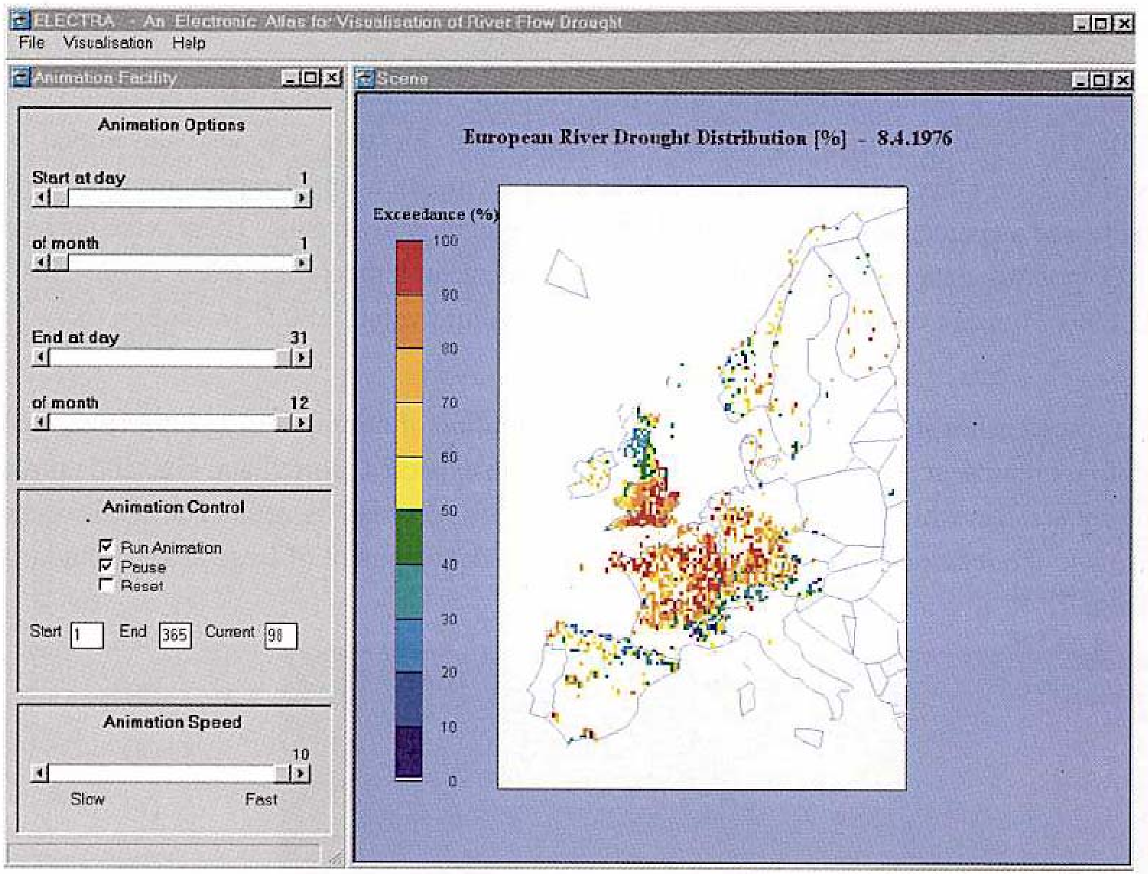
Product Code: IDCKAR8AD0

Click on an area of the Australian map to zoom into it



 Issued: 03/09/2007

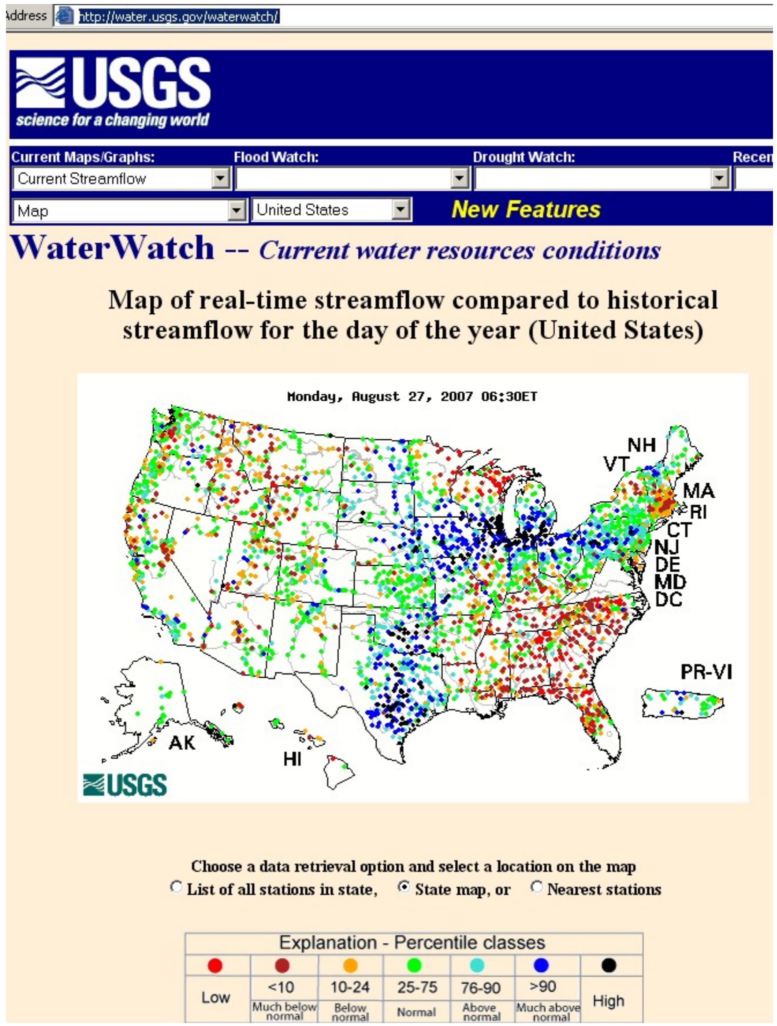
V. Drought Monitoring and forecasting
Streamflow - Monitoring



Exceedance frequency; Elektra software (CEH, 2001)

V. Drought Monitoring and forecasting

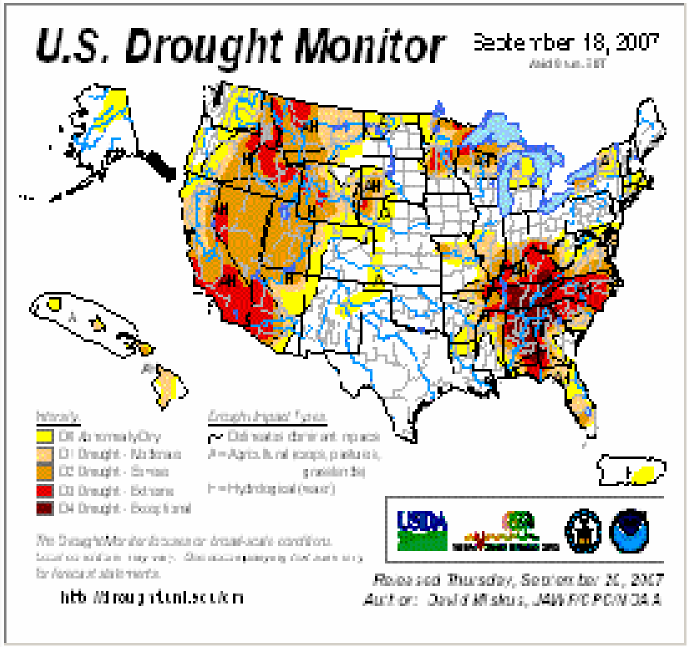
Streamflow - Monitoring

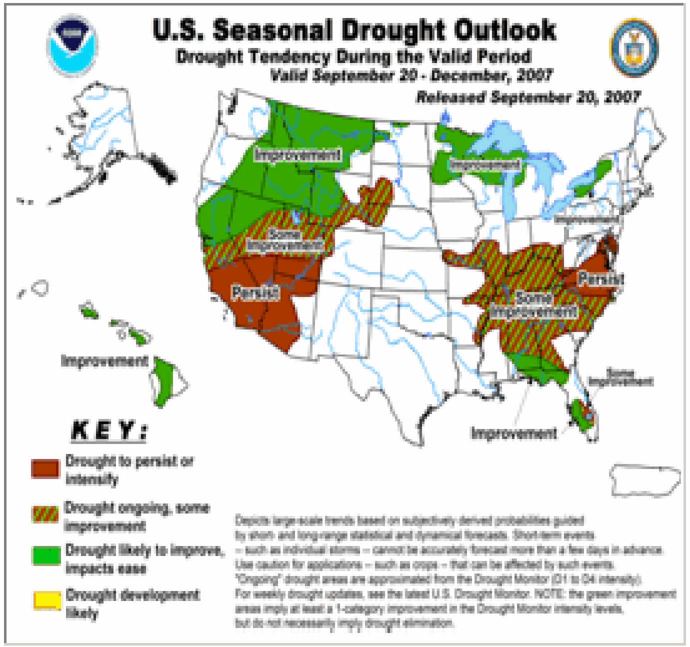


V. Drought Monitoring and forecasting

US Drought Monitor

U.S. Drought Assessment



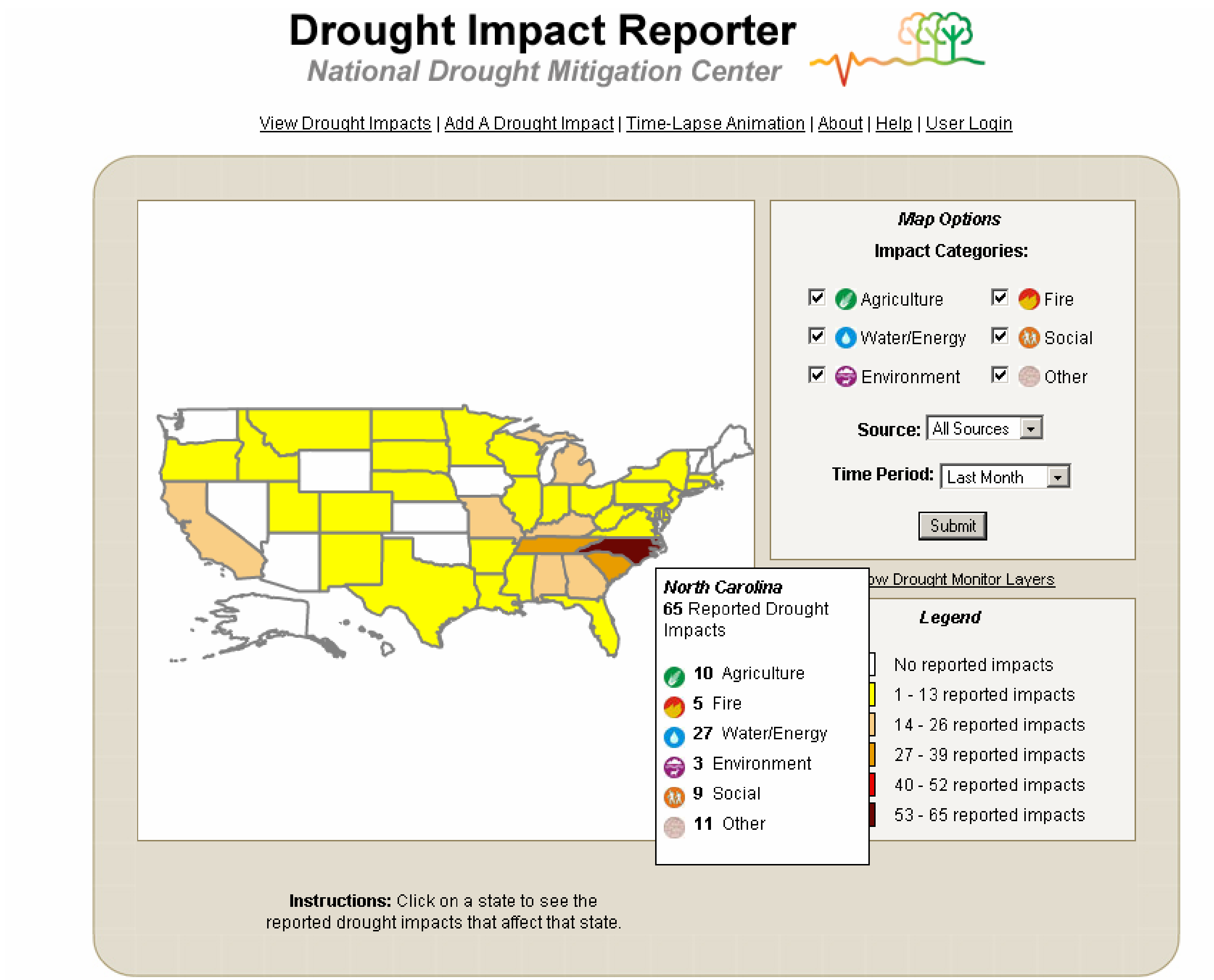


[The Latest Weekly Assessment From the United States Drought Monitor]

[The Latest Seasonal Outlook]

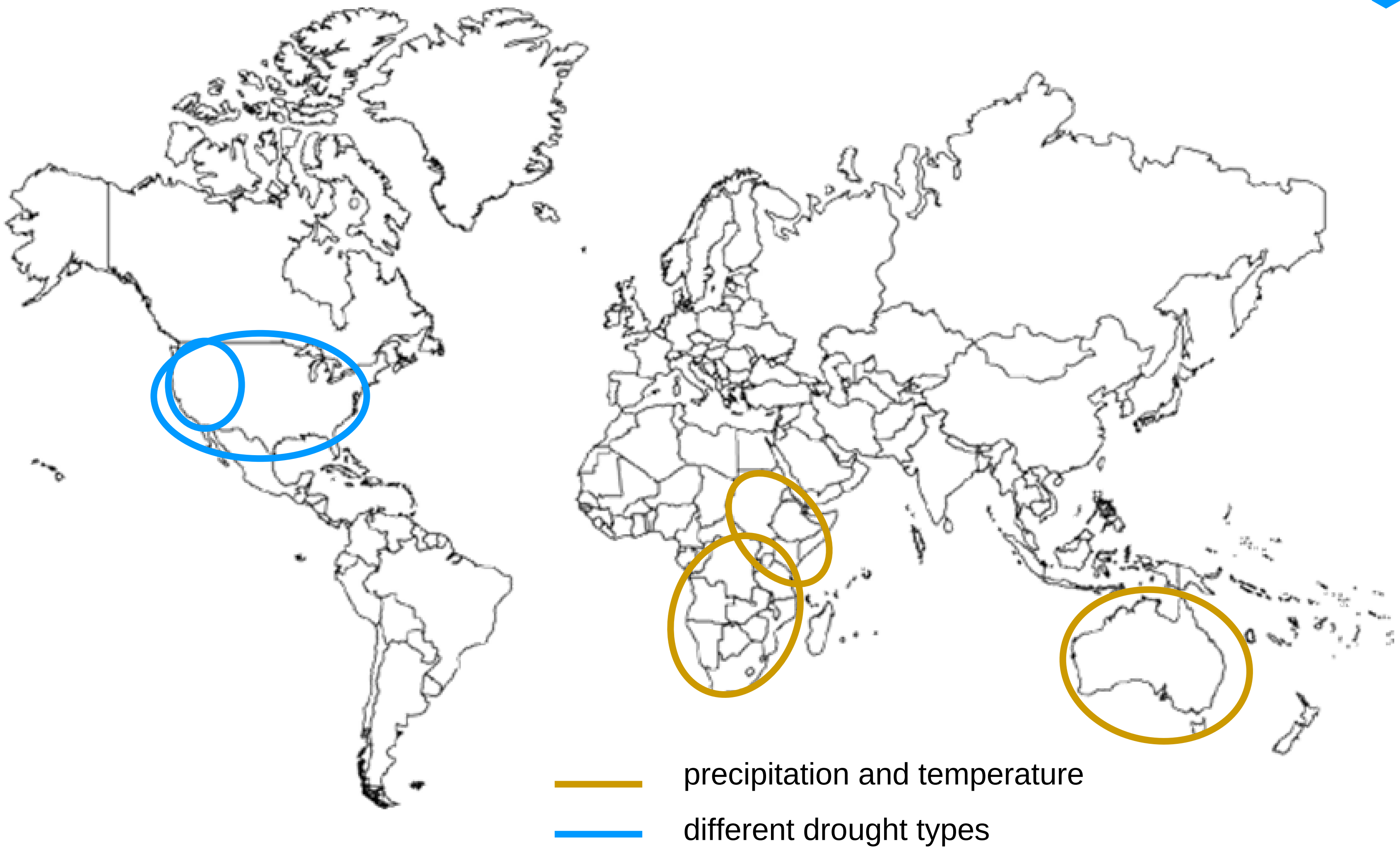
V. Drought Monitoring and forecasting

US Drought Monitor



V. Drought Monitoring and forecasting

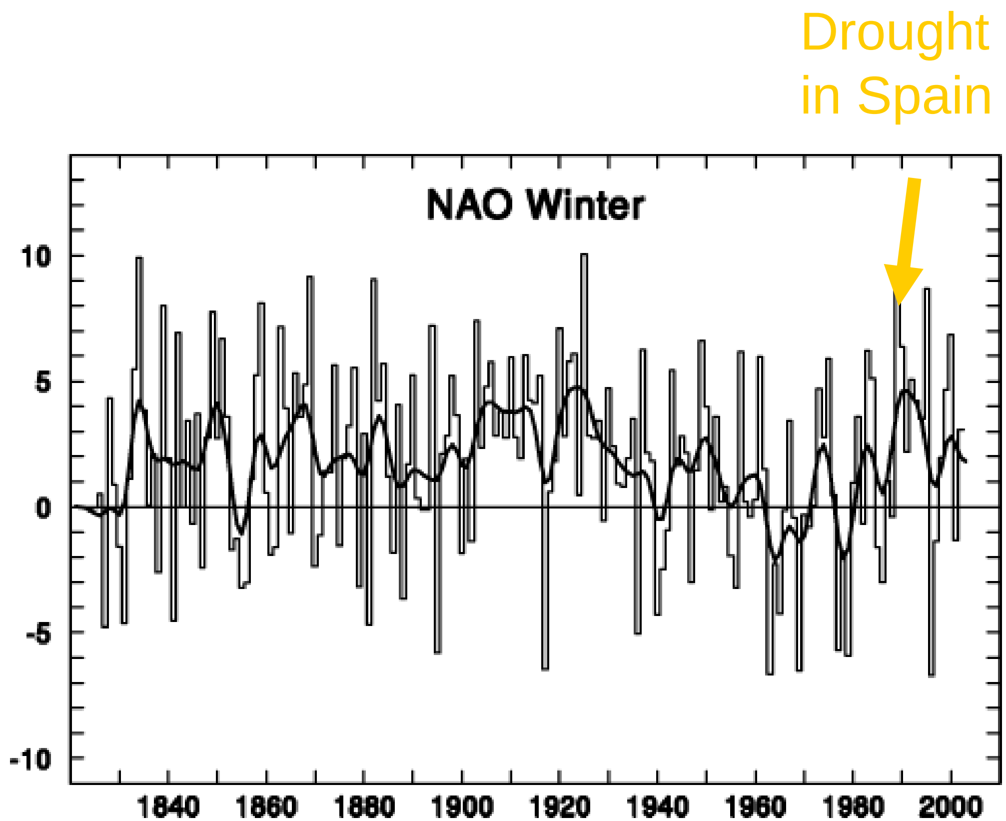
Global overview - Forecasting



Links with the climate system

High winter NAO Index implies that storm tracks shifted northwards, sparing southern Europe, where anticyclone persists, leading to:

- Reduced winter rain
- Drought



(from CRU)

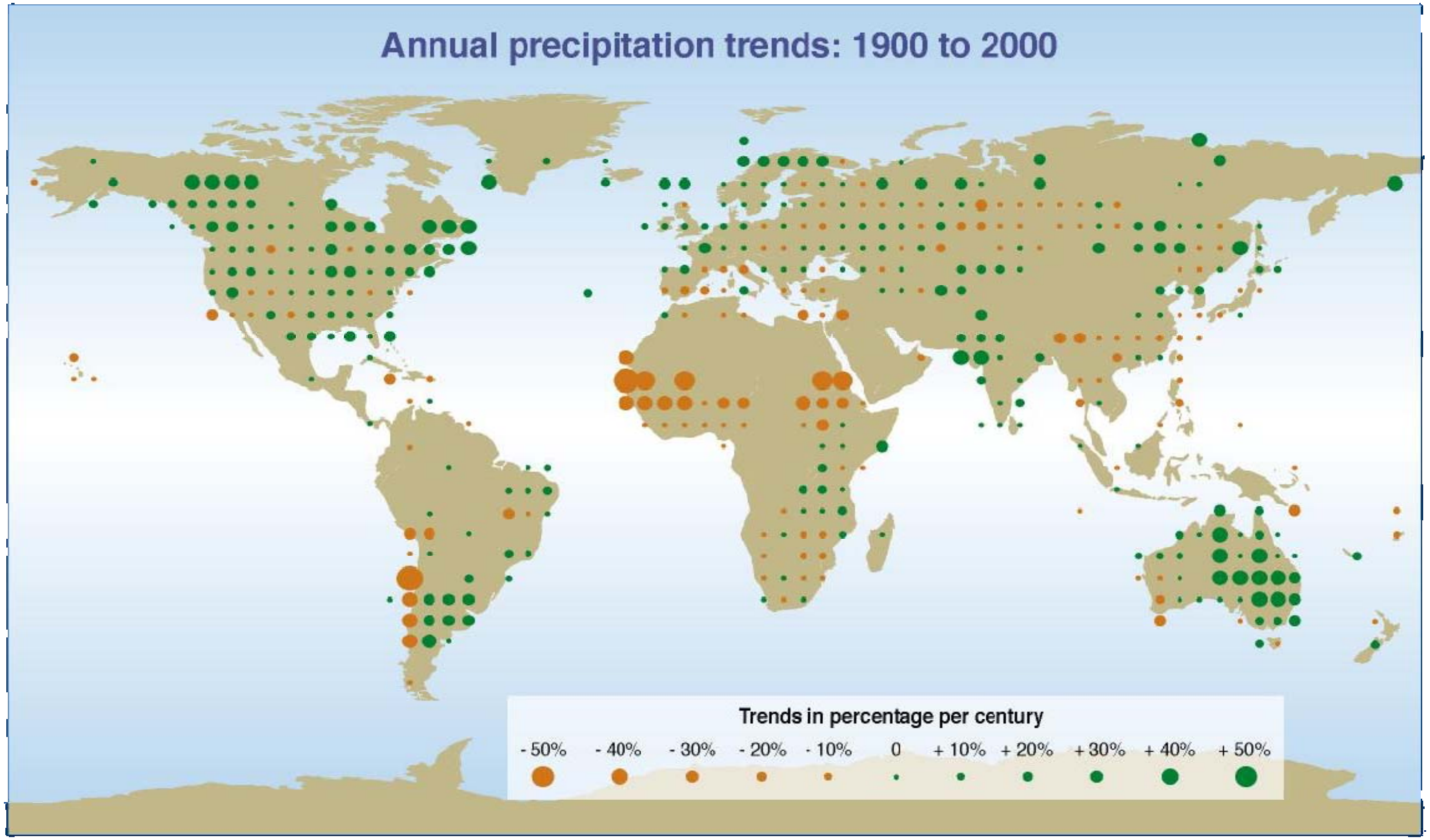
VI. Climate change

Two main approaches to assess the impact of climate change on hydrology:

i) Analysis of **observed data** for changes and trends

ii) Scenario calculations using physically based models

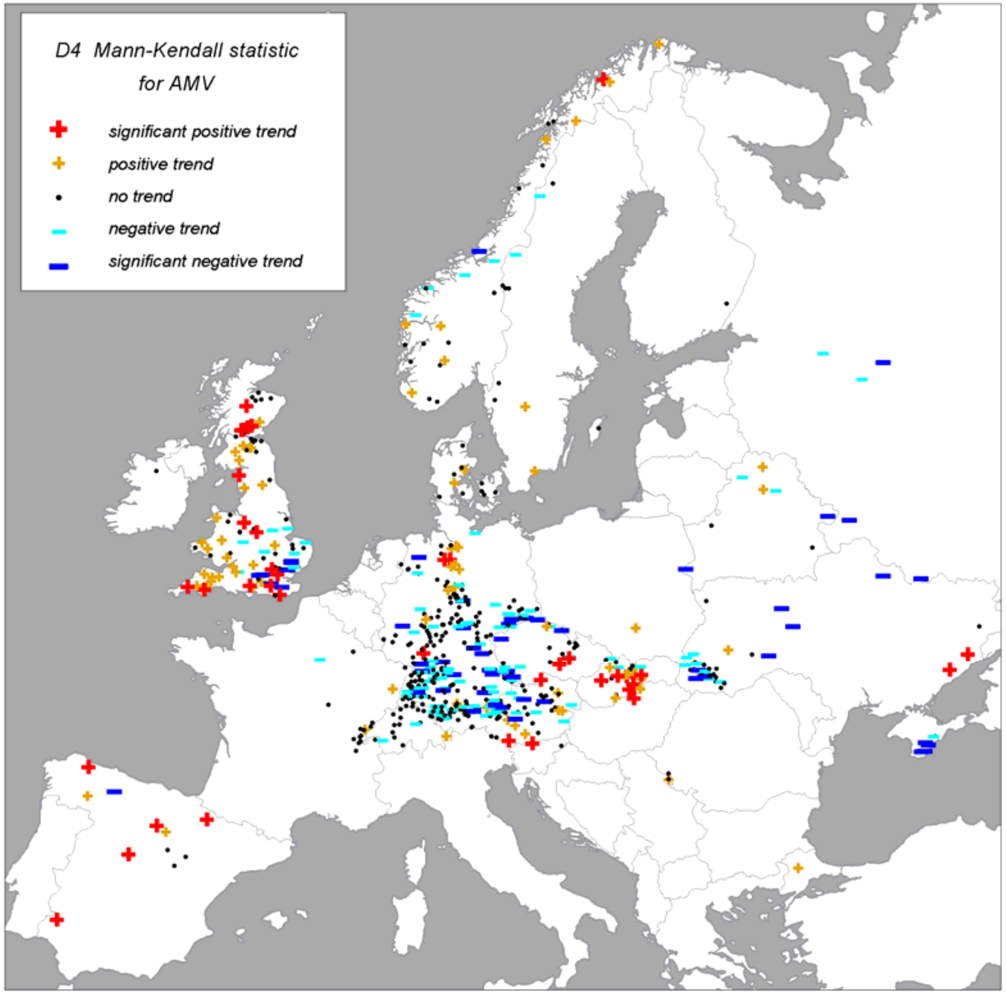
VI. Climate change
Observed trends - Precipitation



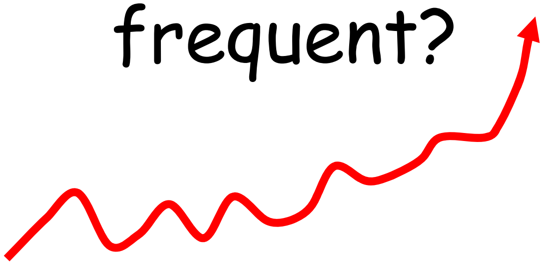
SYR - FIGURE 2-6a

VI. Climate change

Observed trends - Streamflow

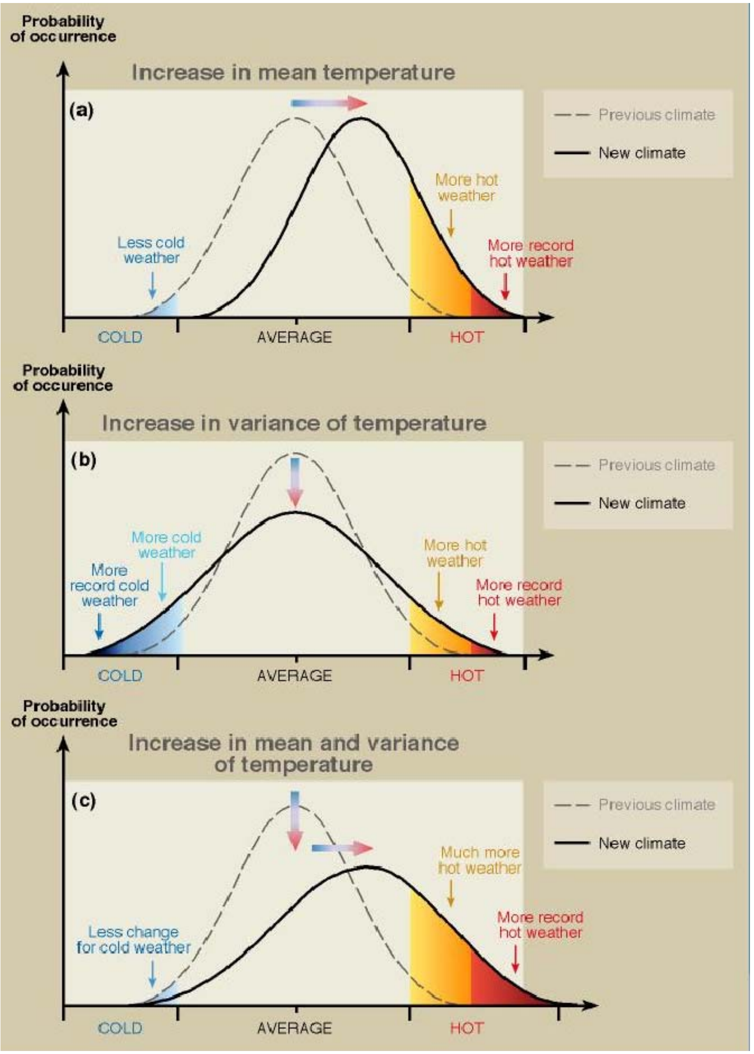


Have streamflow droughts in Europe become more severe or frequent?



Hisdal et al., 2001

VI. Climate change
Predictions - Temperature



From IPCC

VI. Climate change
Predictions

IPCC (2007) expects more severe hydrological extremes as a result of an intensifying of the hydrological cycle;

It is however, difficult:

- **to distinguish between effects of climate change on hydrological drought and multi-decadal climate variability**
- **to discriminate climate change from other human influences (e.g. land use change, water abstractions)**

Understanding of the development of past droughts and how they might change in future is very fragmented and highly uncertain

Current generation GCMs and RCMs is still expected to unsatisfactory reproduce historical extremes

VI. Climate change

Predictions – the WATCH project

EC-IP WATCH: WATer and global Change aims to:

- advance the knowledge and skills to predict the effect of climate change on drought by enhancing our understanding of the present situation (20th C)
- assess uncertainties in the chain of climate/hydrological modeling system
- evaluate how the global water cycle and in particular droughts respond to future drivers of global change (21st C)
- investigate the attribution of changes in the hydrological cycle (incl. the droughts)

VII. Concluding remarks

Research needs

NE & AMHY- FRIEND joint meeting, Bratislava, 2004

- Drought monitoring and forecasting
- Development of drought indicators
- Drought patterns in time and space
- Impact of land use and climate change
- Propagation of drought through the hydrological cycle
- Links between drought and stream ecology
- Methods for assessing the severity of drought
- Estimation at the ungauged site
- Need for good quality, long-term data (easy assess)

VII. Concluding remarks

International cooperation - EDC

http://www.geo.uio.no/edc

VII. Concluding remarks

- Drought is a natural hazard that cannot be prevented
- However, drought are likely to become a larger threat to mankind as:
  - Climate change scenarios predict more frequent and extreme floods and droughts
  - There is an increasing pressure on water resources
- Still, its impacts can be reduced through mitigation, i.e. knowledge, preparedness and good management practice