

Model-Based Scenarios of Drought in Europe

Sara Vassolo



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Siebert, Sara Vassolo

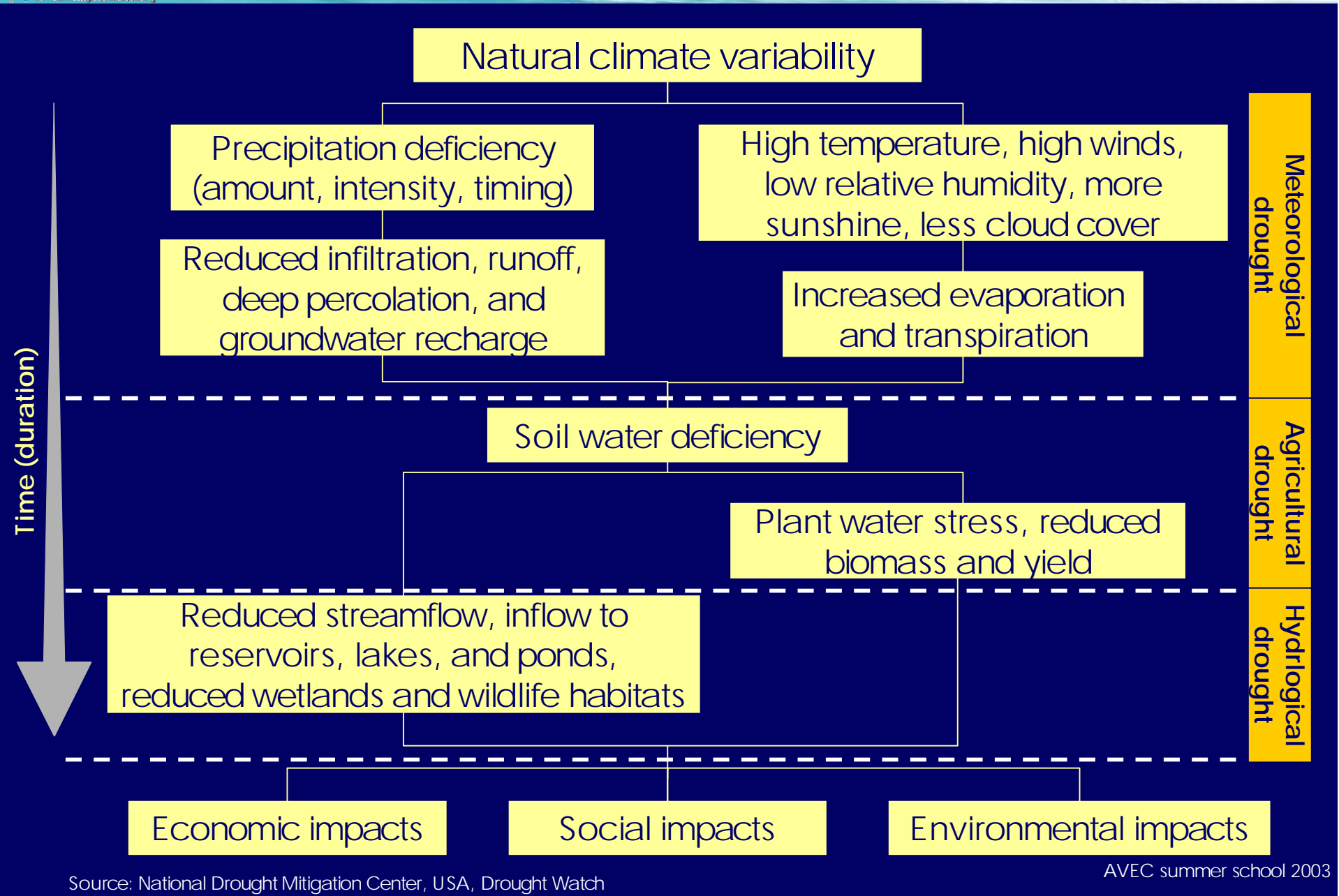
The WaterGAP Team at the Center for
Environmental Systems Research –
University of Kassel, Germany:

Overview

- Definitions of drought
- What is WaterGAP?
- Ability of WaterGAP to model low-flow
- Drought frequency analysis
- Impact of global change on water availability and water use
- Impact of global change on droughts
- Summary

Definitions of drought

- Climatological drought (rainfall deficit)
- Agro-meteorological drought (soil water deficit)
- River flow drought (deficit of river discharge)
- Groundwater drought (recharge deficit)
- Operational drought (water demand > supply)



What is WaterGAP?

Water Global Assessment and Prognosis

WaterGAP – Model overview

- Land Cover
- Climate
- Flow Direction
- Soil Texture
- Slope
- Hydrogeology

*Global
Hydrology Model*

- Water Availability
- Runoff (by grid-cell)
 - Recharge (by grid-cell)

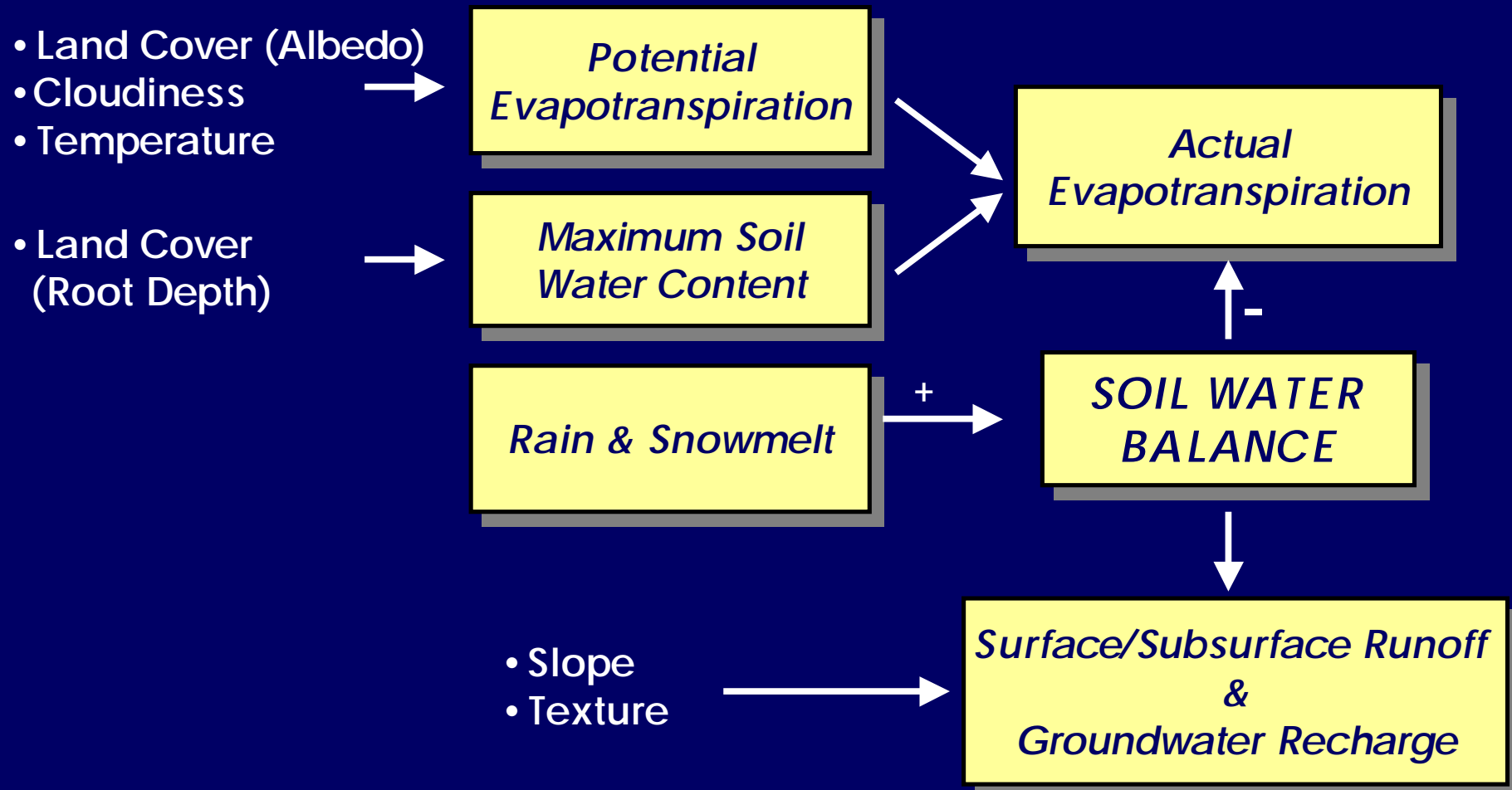
***WATER STRESS &
Reduction of discharge***

- Population
- Income
- Technology
- Climate
- Irrigated Area

*Global Water
Use Model*

- Water Withdrawals
- Domestic (by country)
 - Industrial (by country)
 - Irrigation (by grid-cell)
 - Livestock (by grid-cell)

Global Hydrology Model



Global Water Use Model

- Population
- Income
- Electricity Production
- Water Intensity

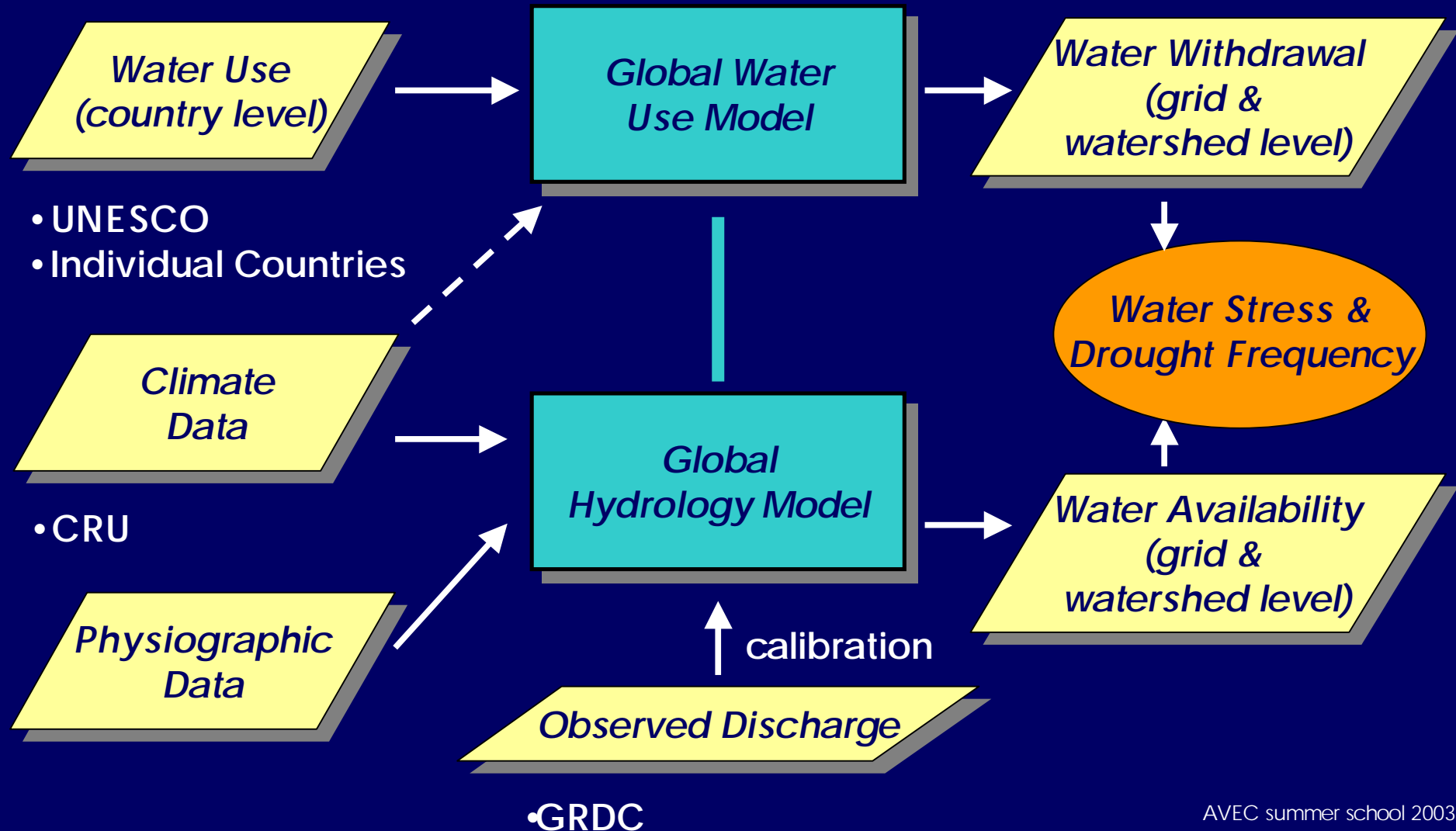
*Domestic
Water Use*

*Industrial
Water Use*

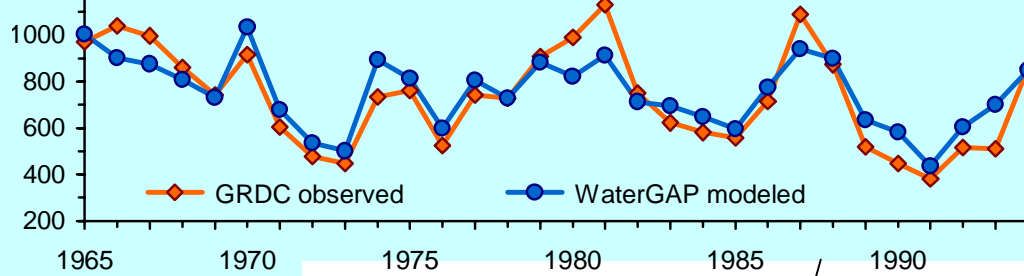
- Irrigated Area
- Cropping Intensity
- Livestock Intensity
- Water Use Efficiency
- Climate

*Irrigation
(+Livestock)
Water Use*

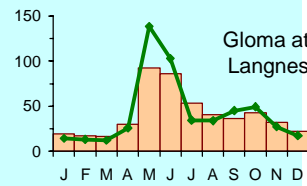
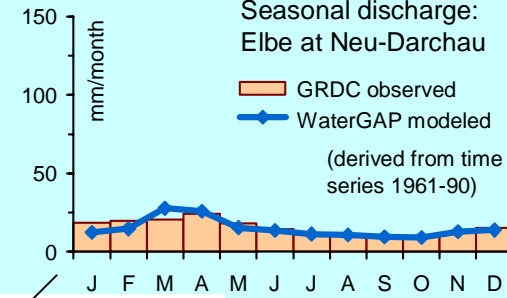
"Current" Situation



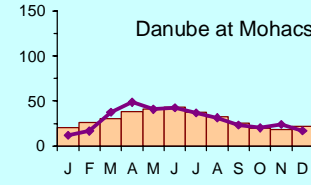
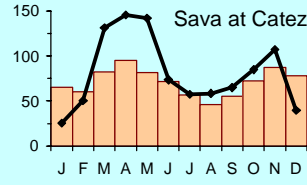
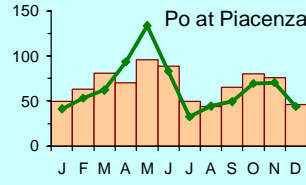
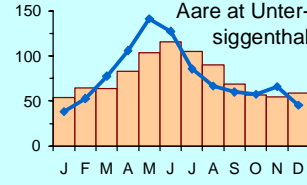
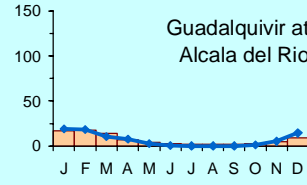
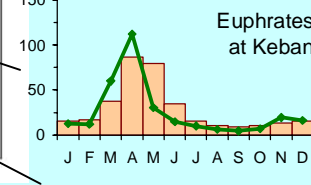
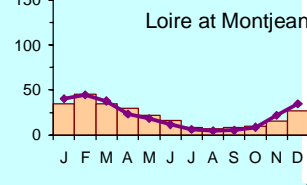
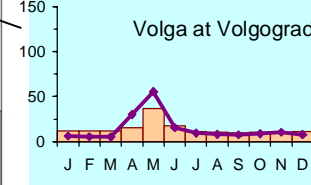
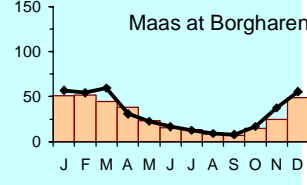
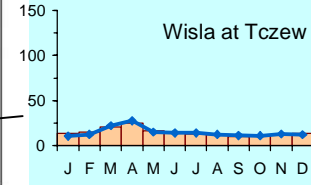
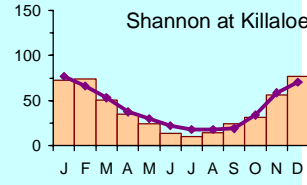
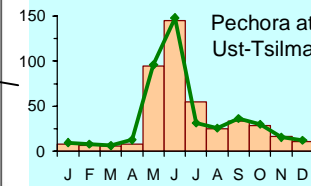
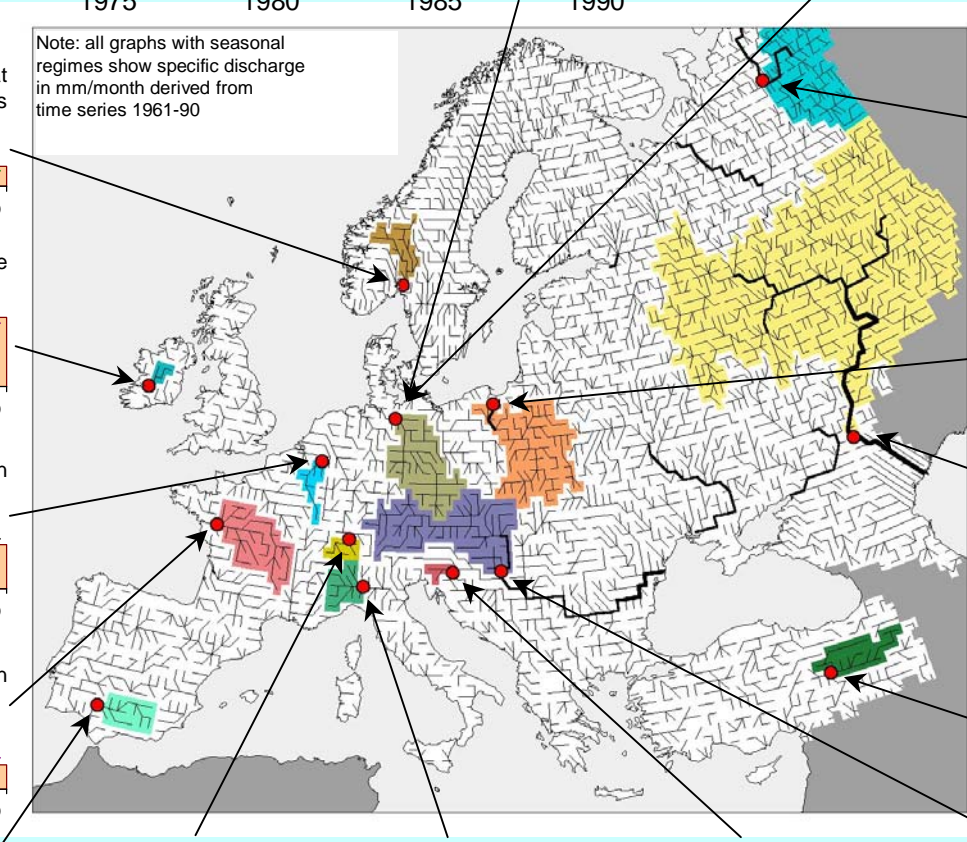
Annual discharge: Elbe at Neu-Darchau



Seasonal discharge: Elbe at Neu-Darchau

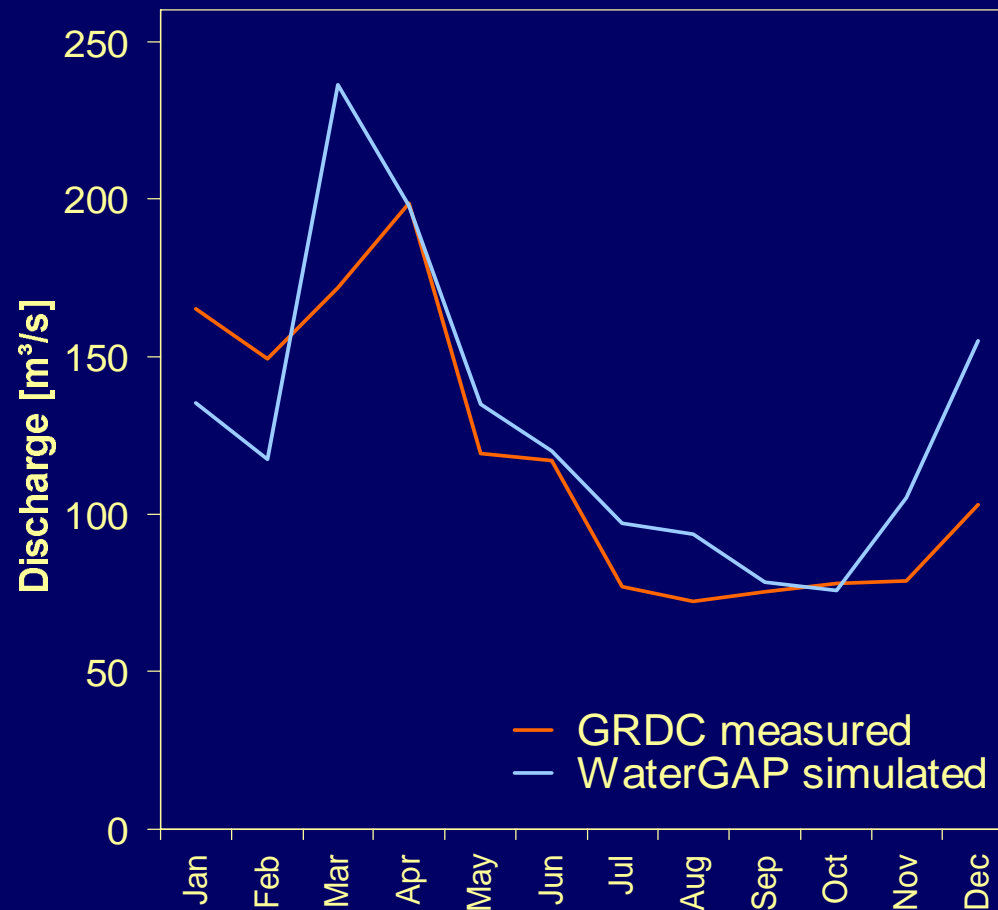


Note: all graphs with seasonal regimes show specific discharge in mm/month derived from time series 1961-90

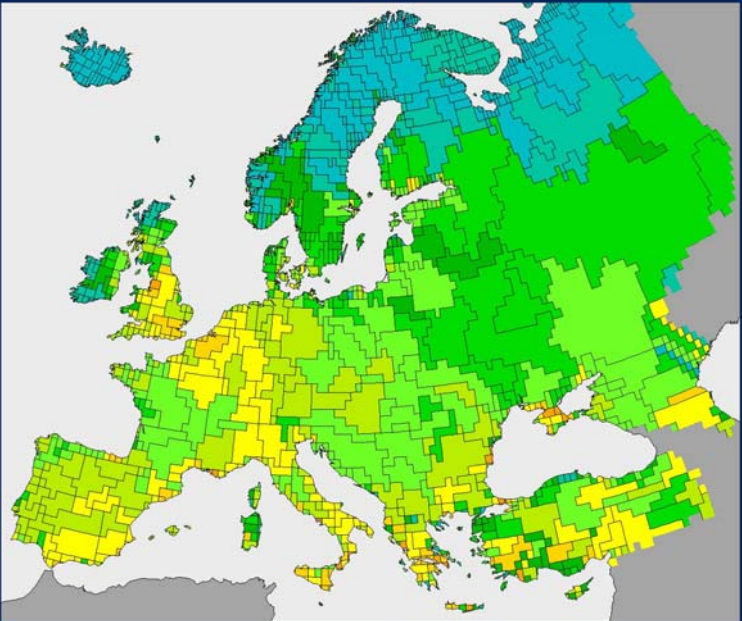


- Mean Annual Discharge -

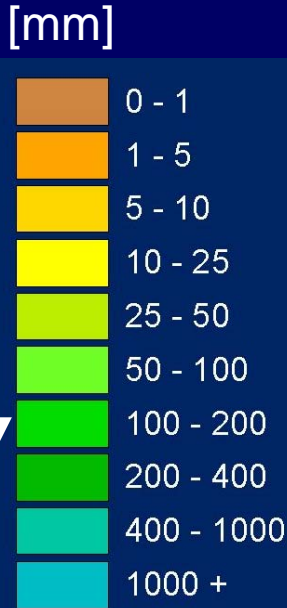
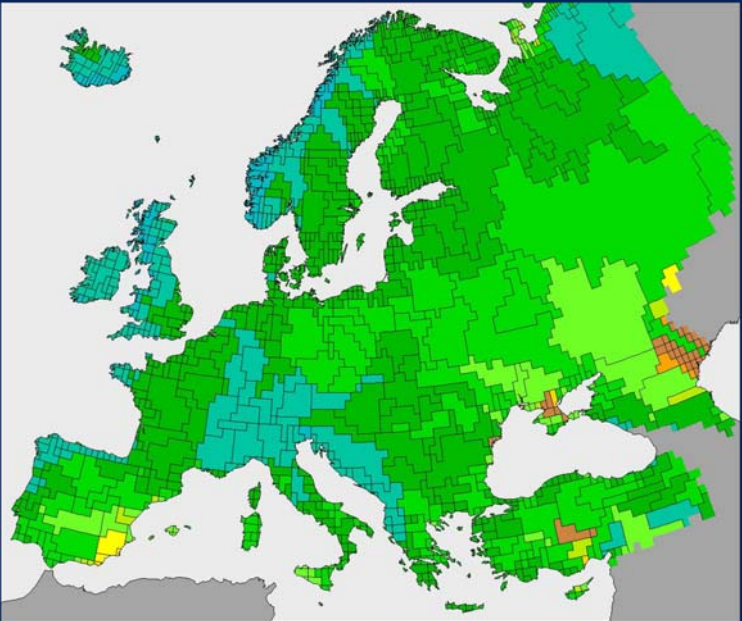
Saale River, long-term monthly mean for 1982-1995 (23.000 km²)



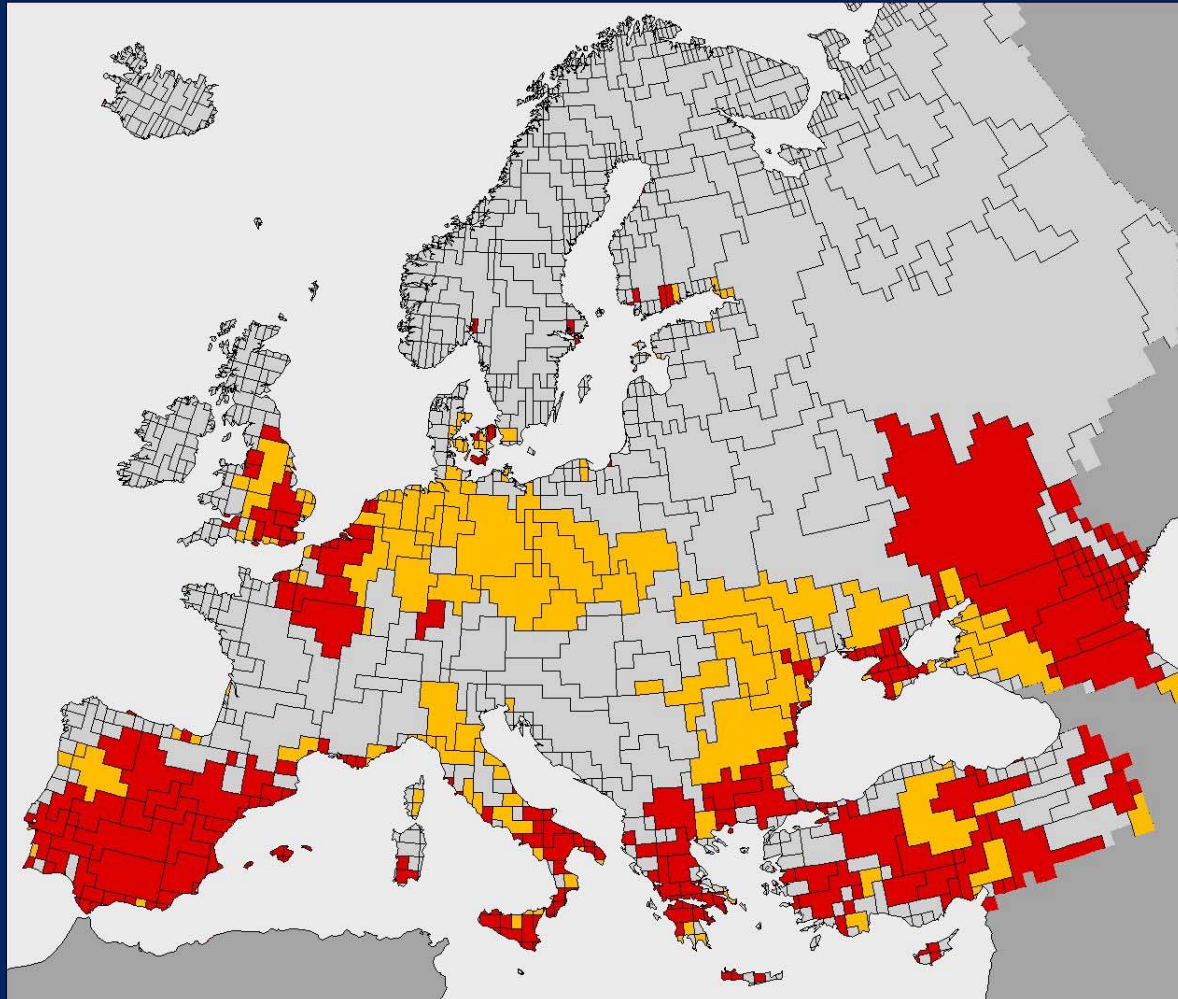
Water Withdrawals Current (1995)



Water Availability Current (1961-90)



Current Water Stress



Water Stress
(Withdrawal to
Availability Ratio)

Low

----- 0.2

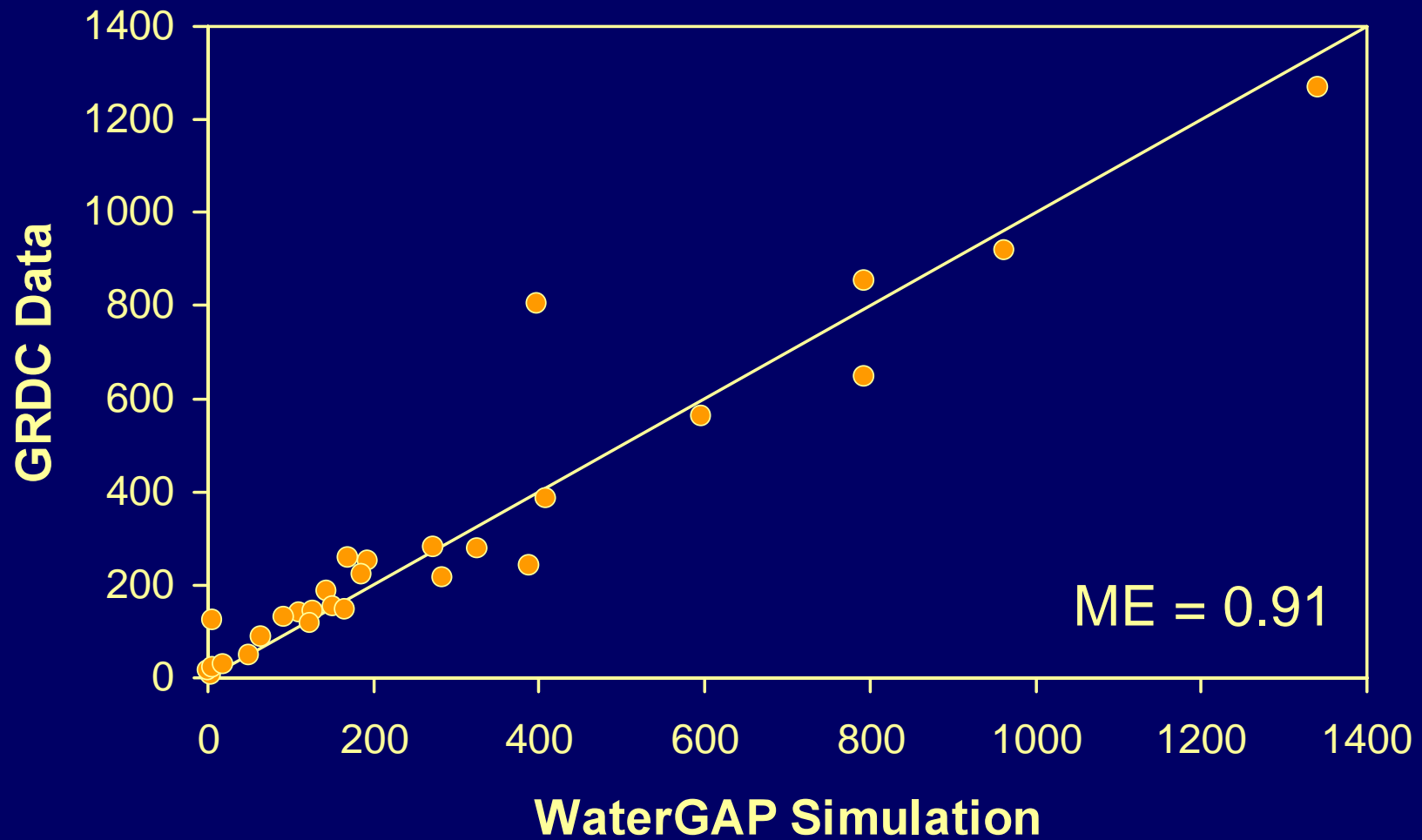
Medium

----- 0.4

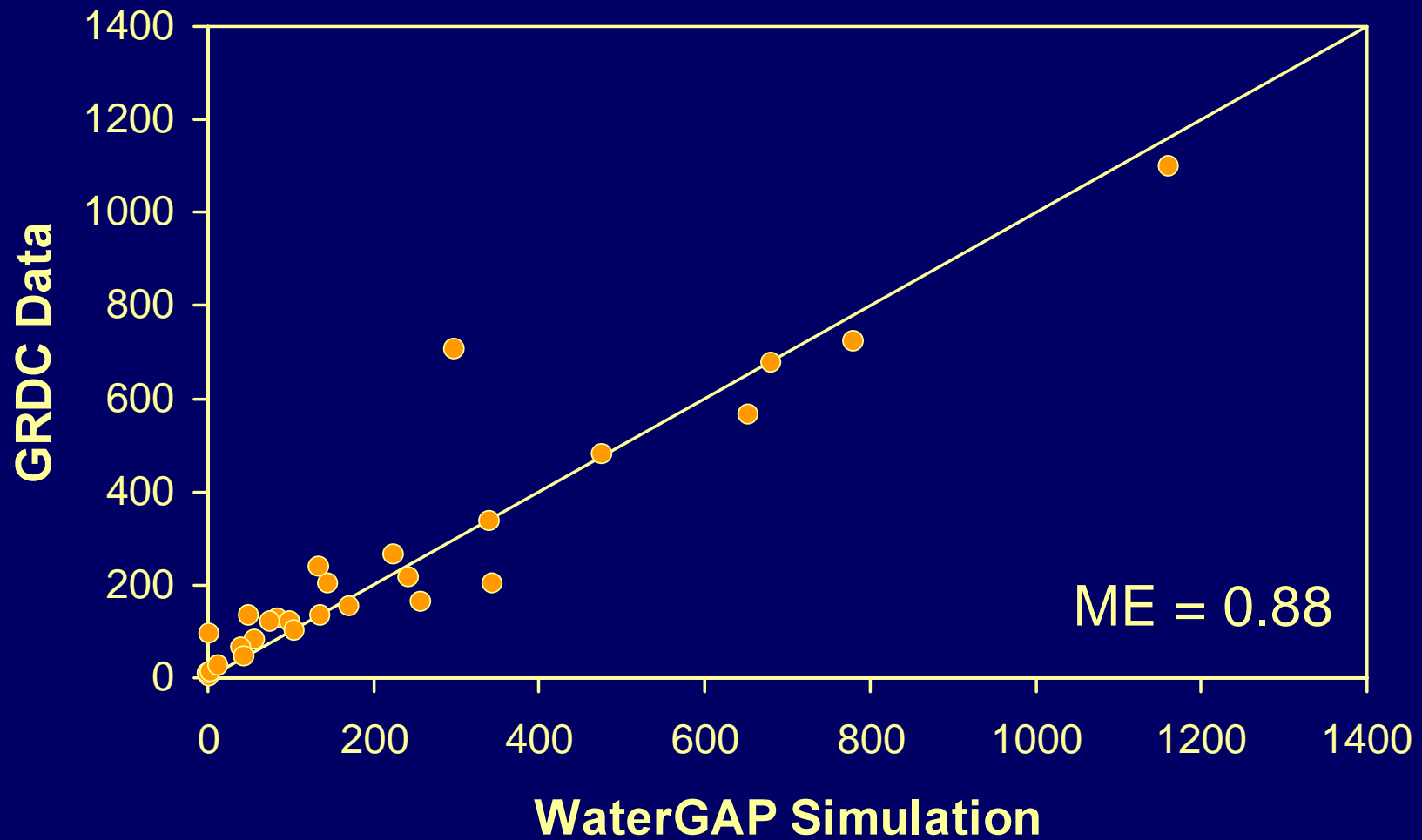
Severe

Is WaterGAP able to reproduce low-flow?

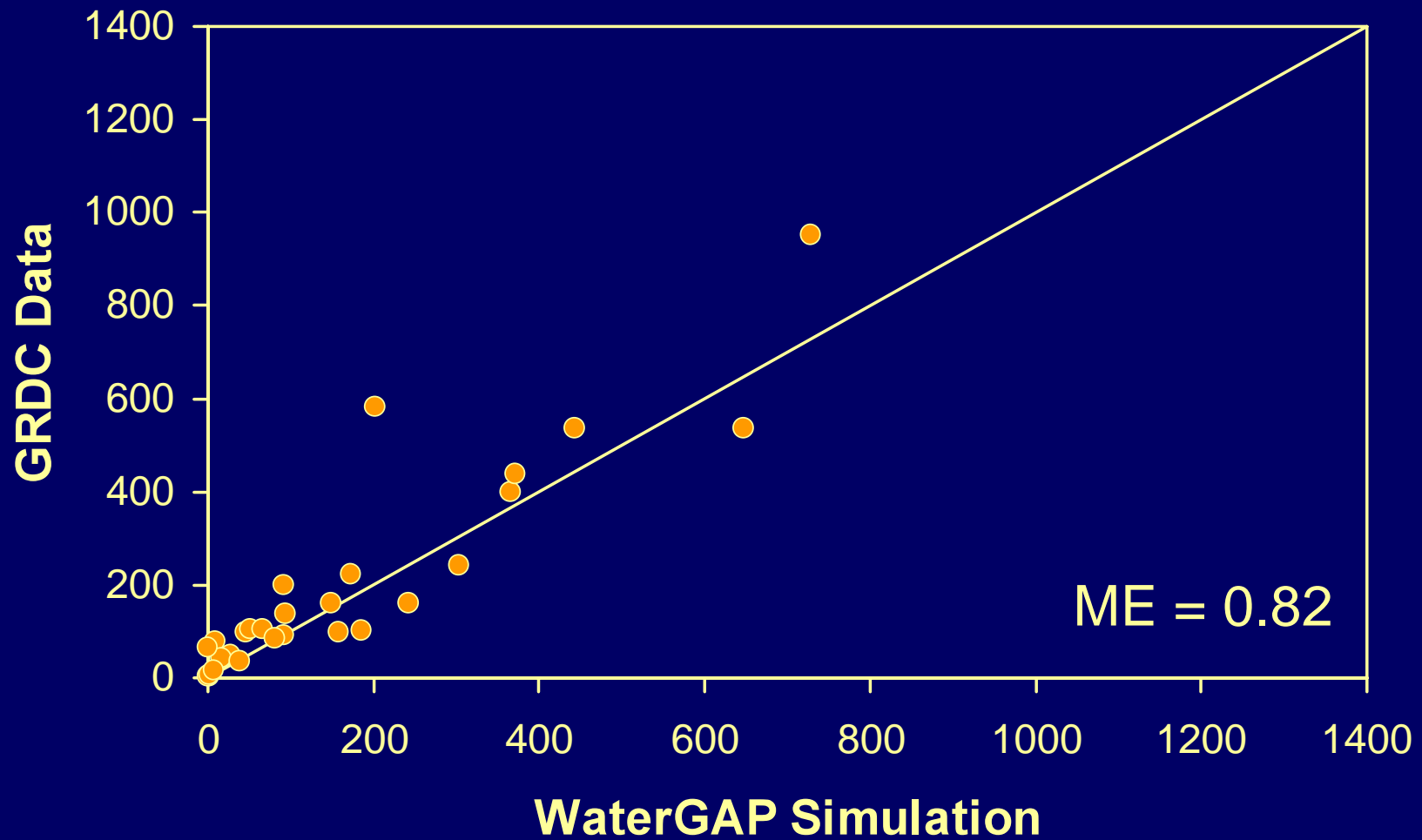
Q90 [m³/s] from monthly figures 1961 - 1990



Q95 [m³/s] from monthly figures 1961 - 1990

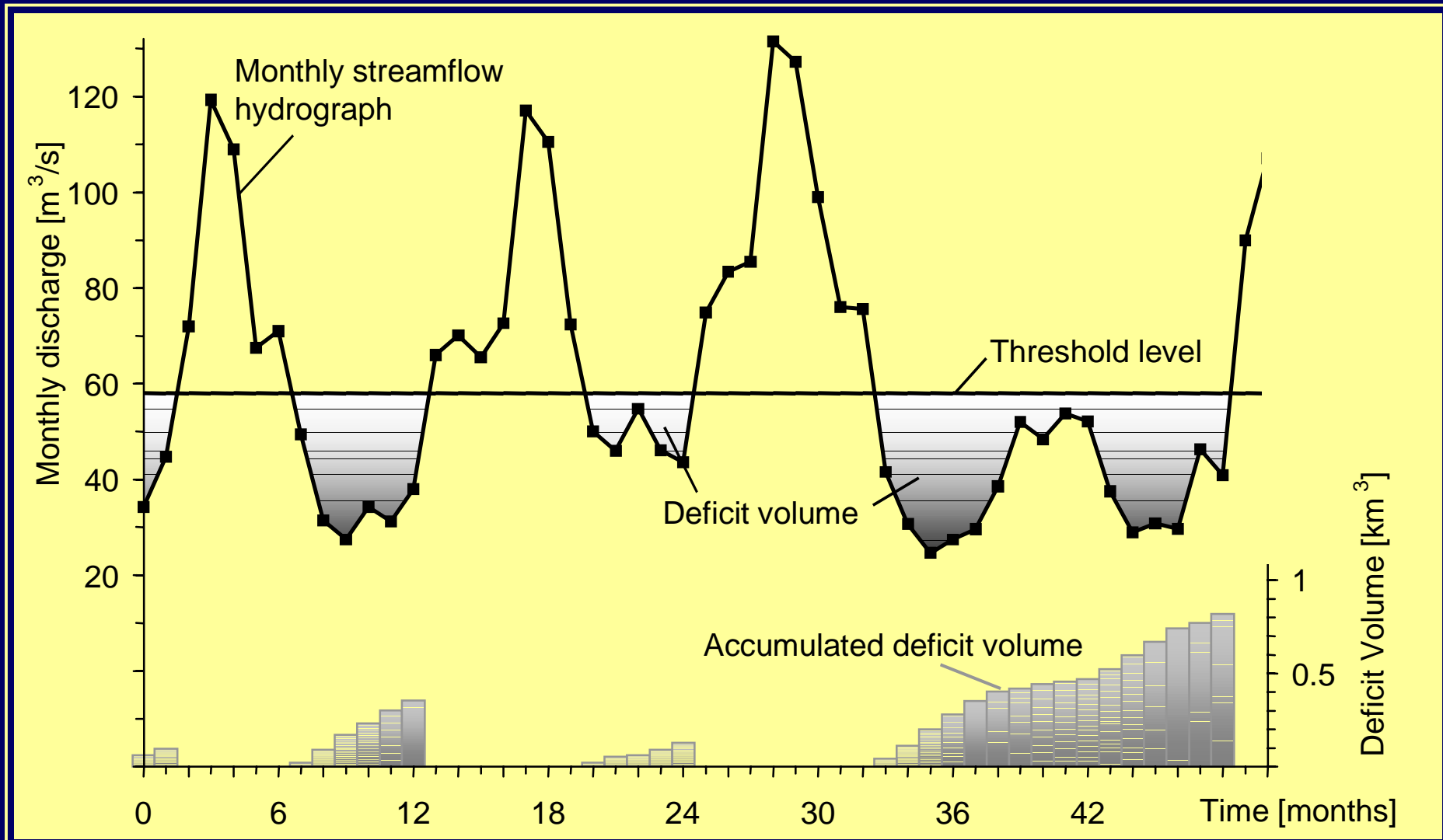


Q99 [m³/s] from monthly figures 1961 - 1990

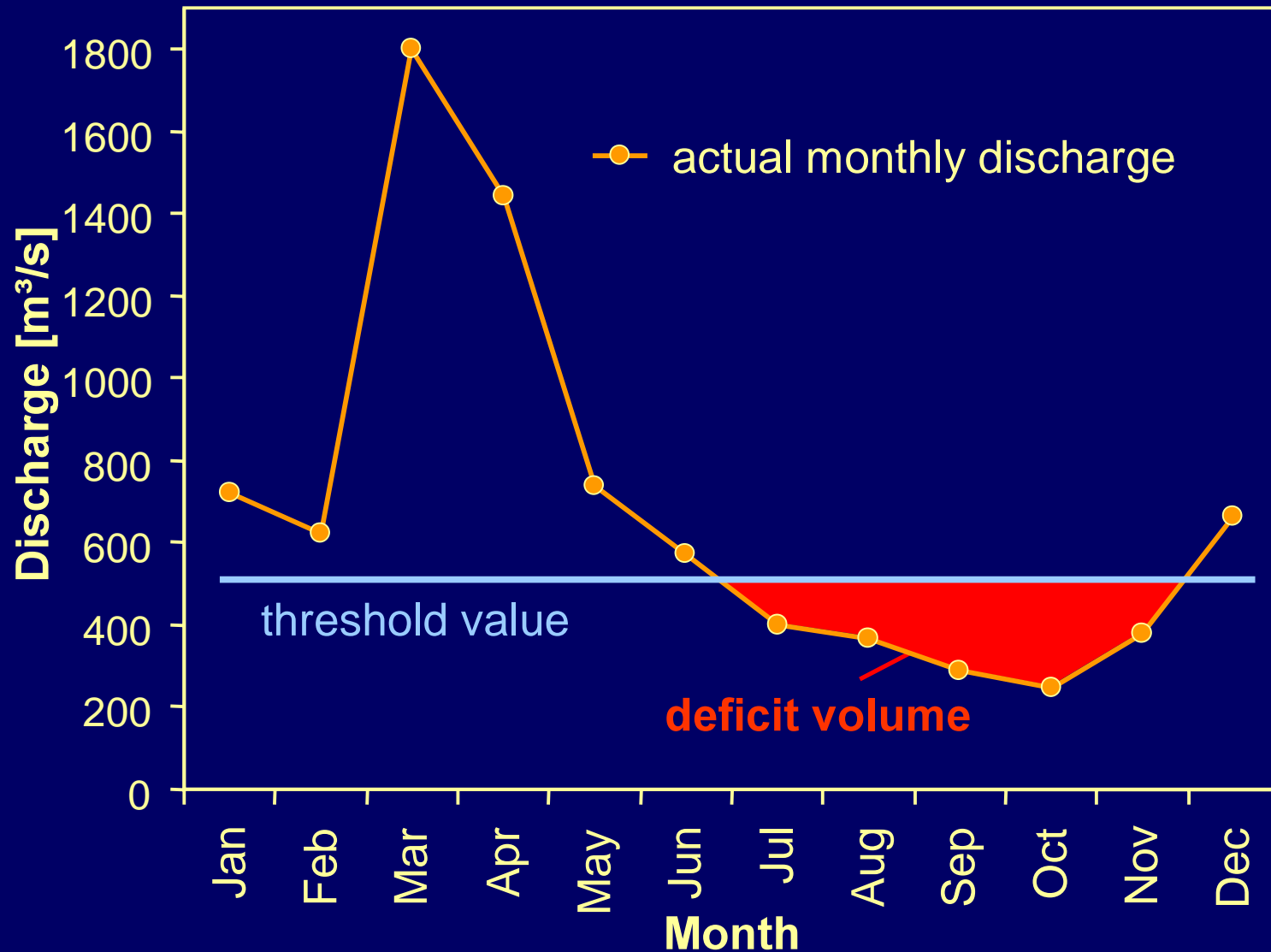


Drought frequency analysis

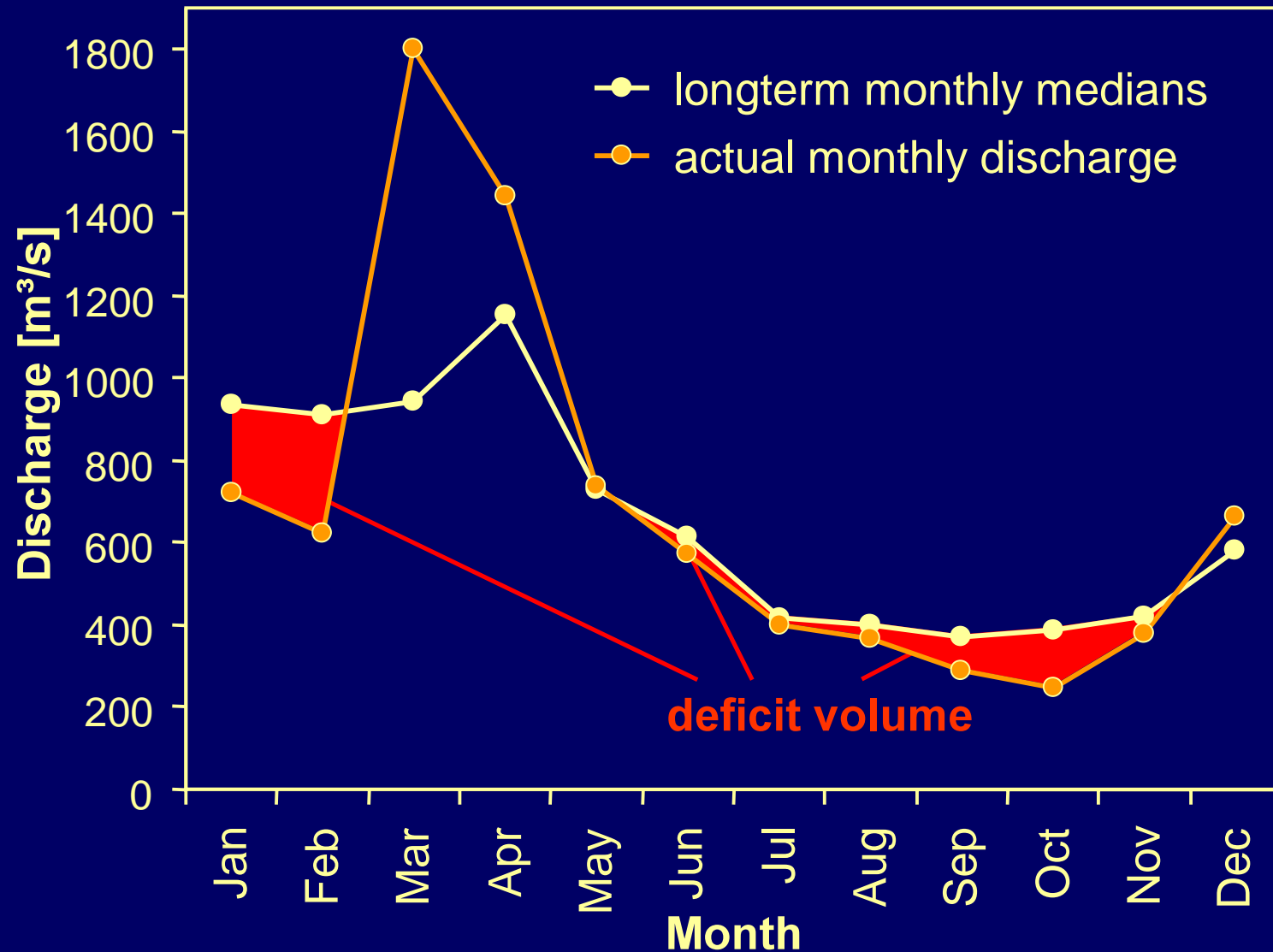
Drought events and deficit volumes



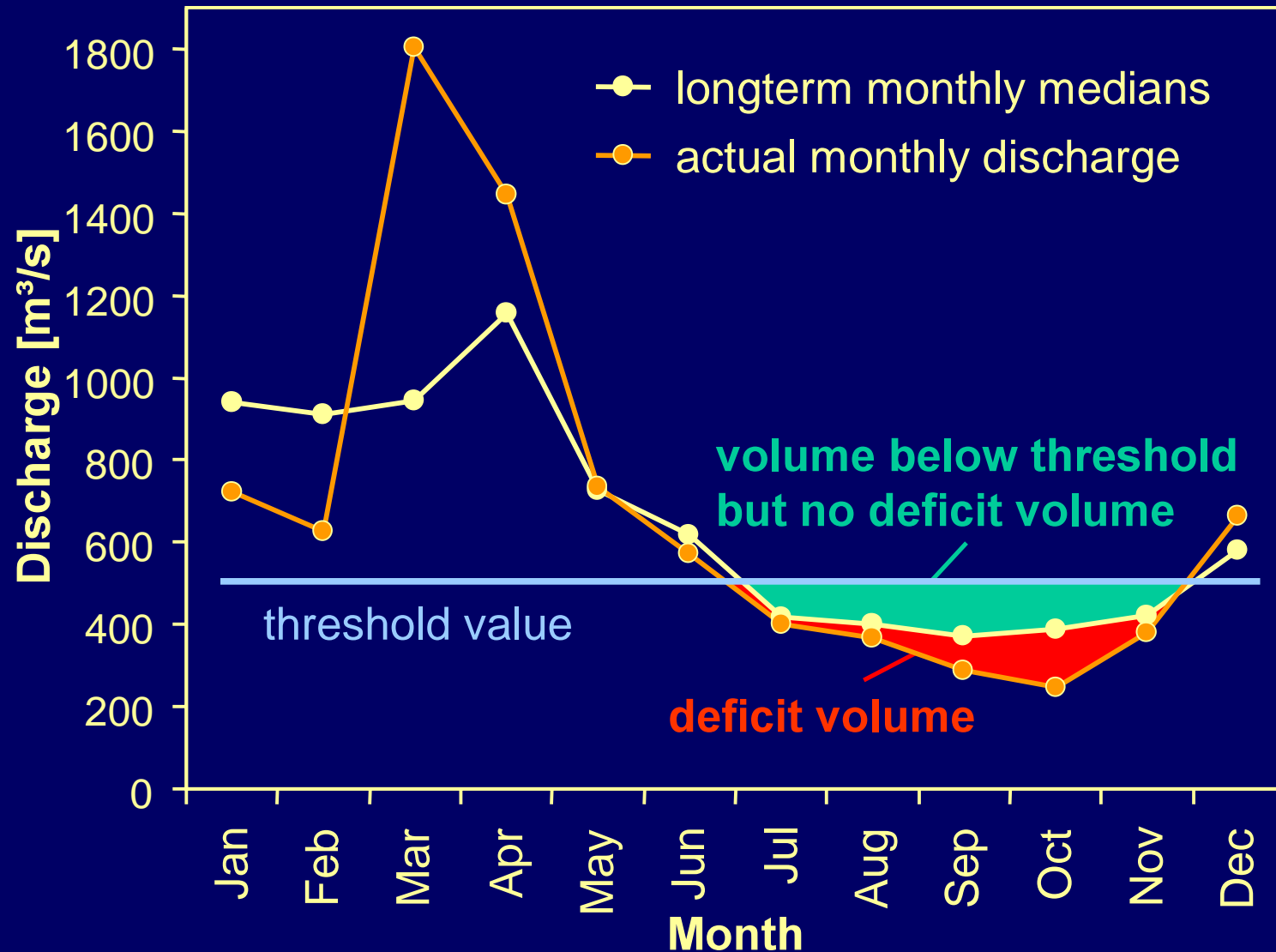
Deficit volume with constant threshold



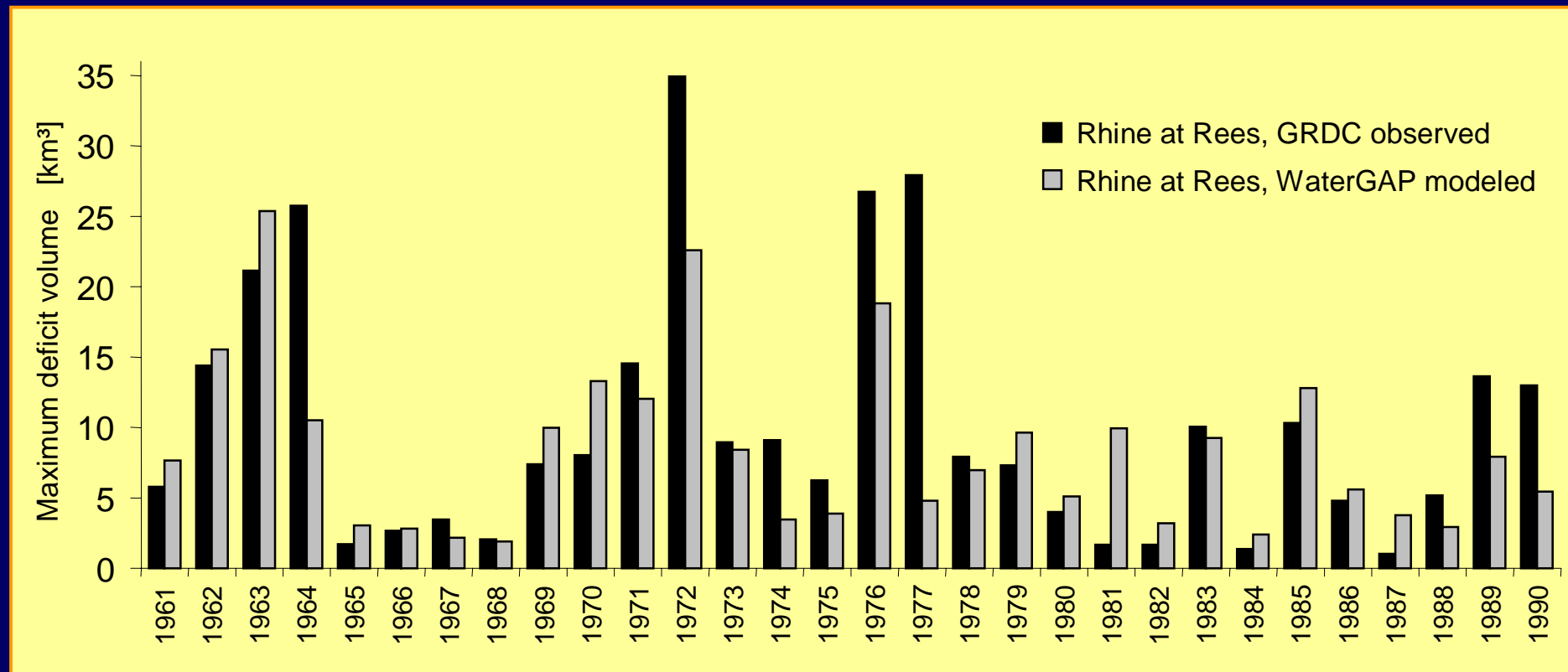
Deficit volume with seasonal threshold



Deficit volume with combination of thresholds

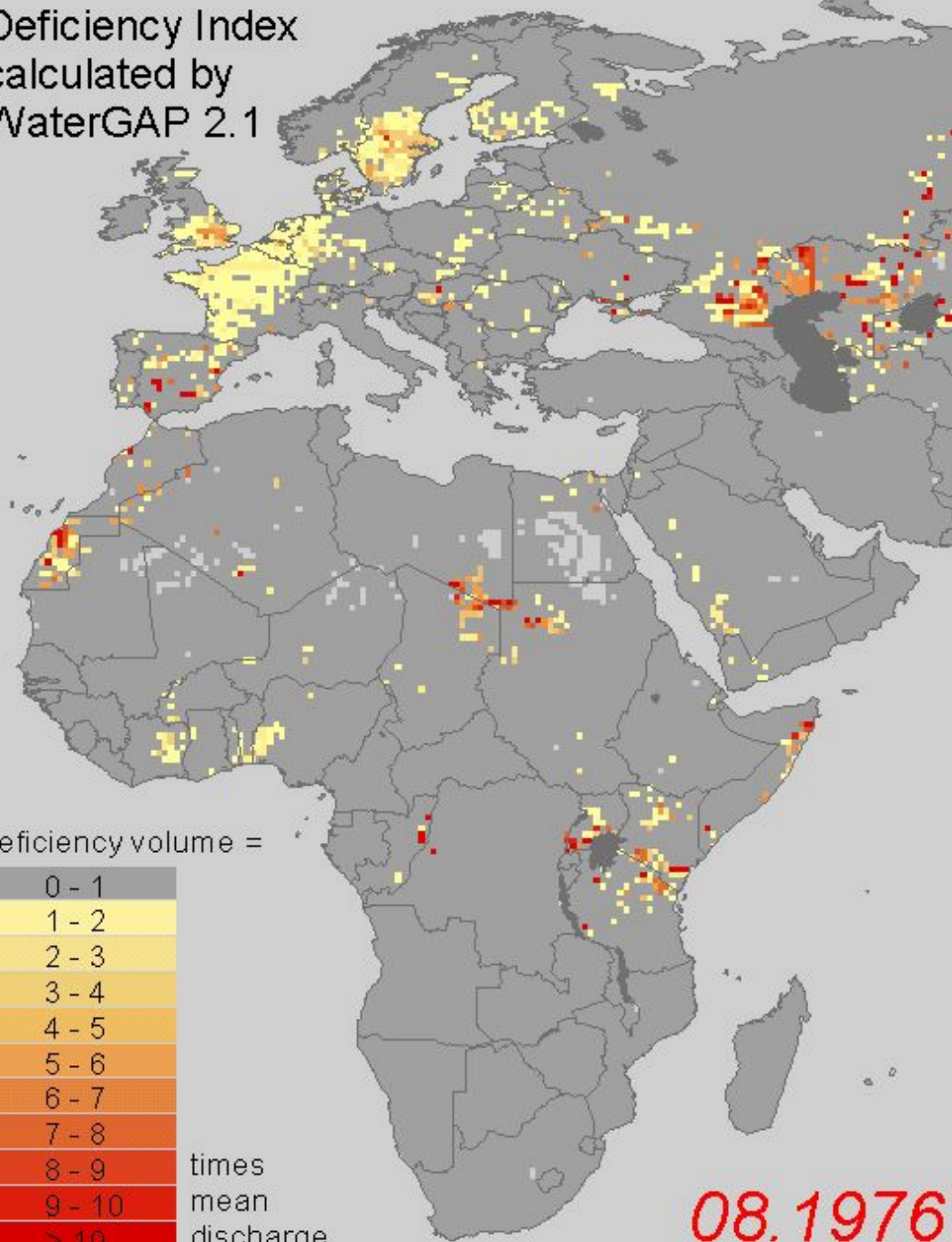
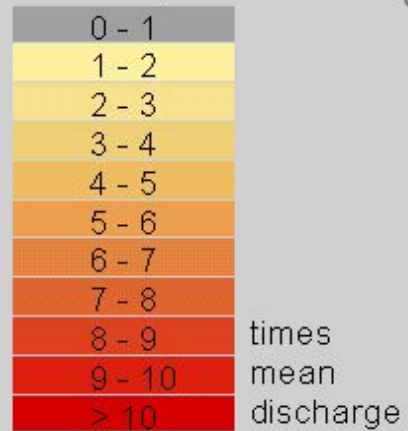


Deficit volumes using WaterGAP



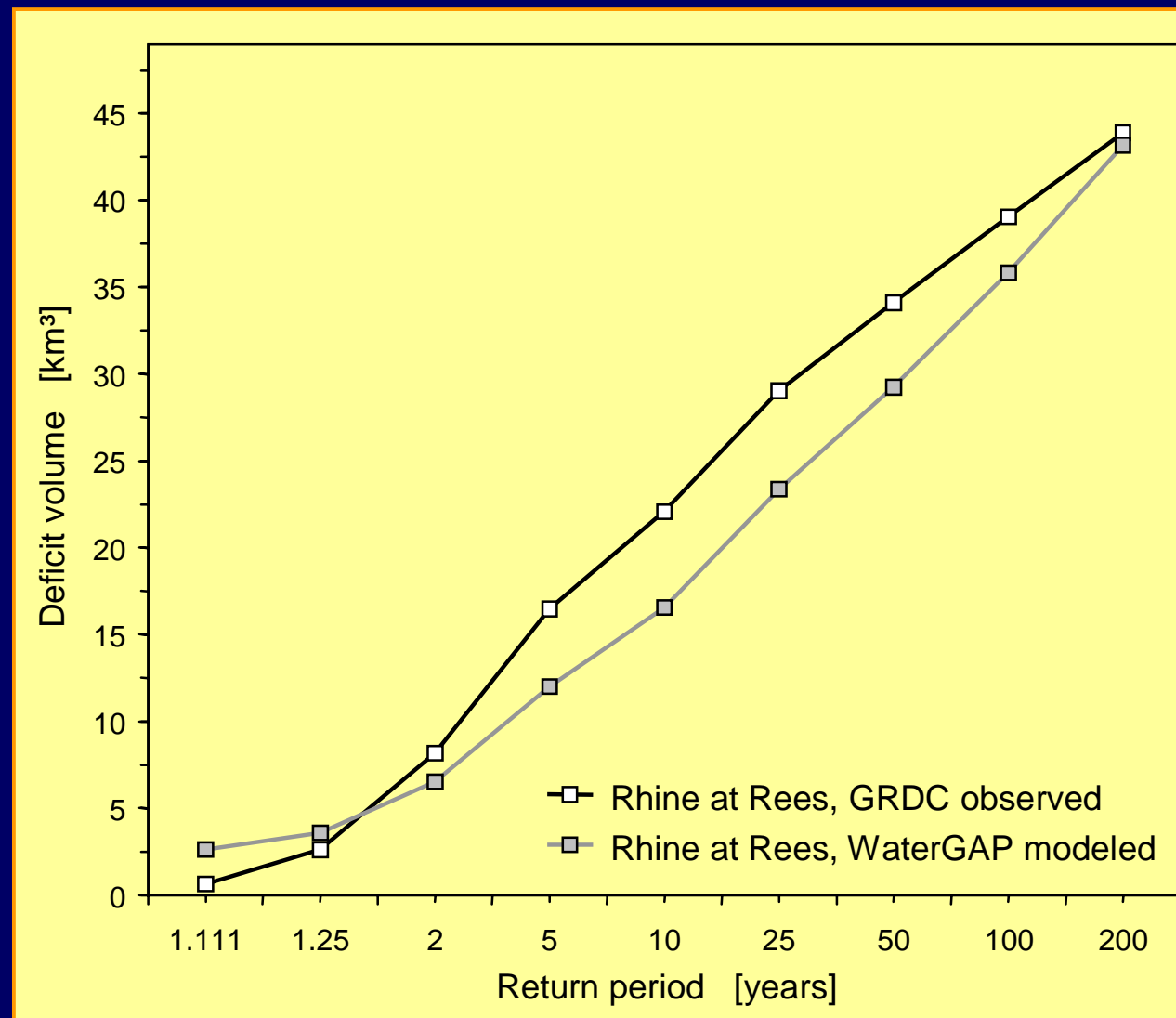
Deficiency Index
calculated by
WaterGAP 2.1

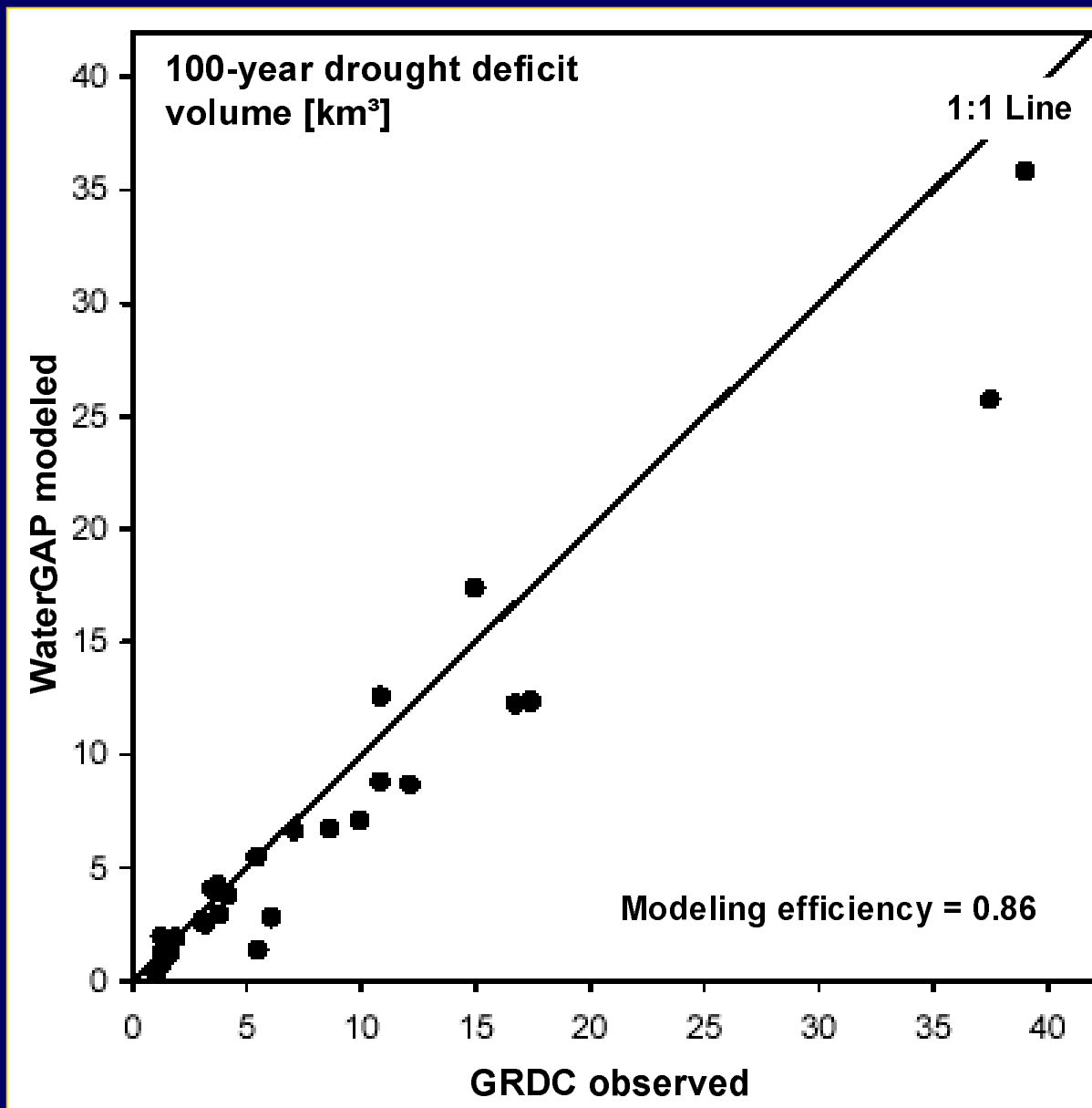
Deficiency volume =



08.1976

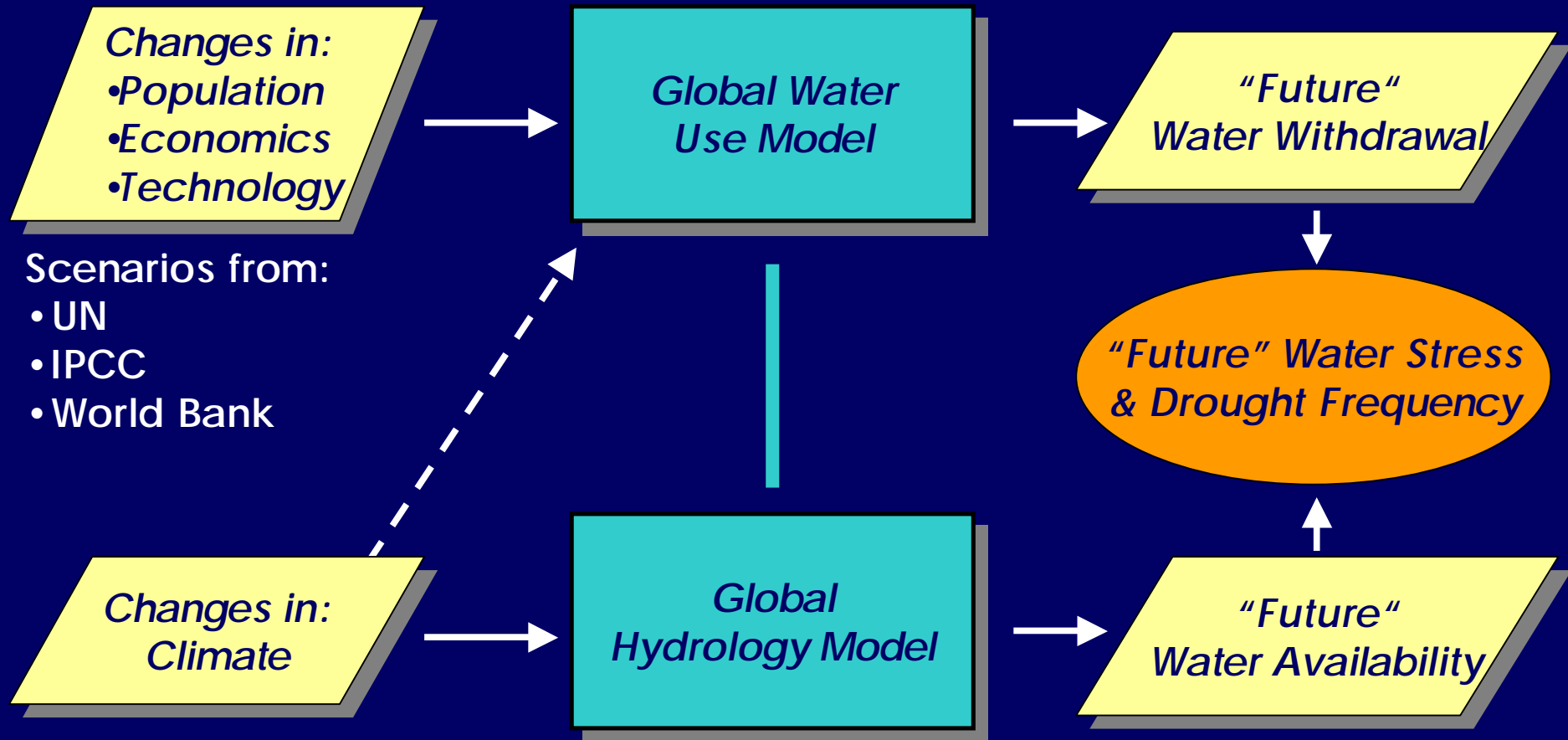
Drought frequency distribution





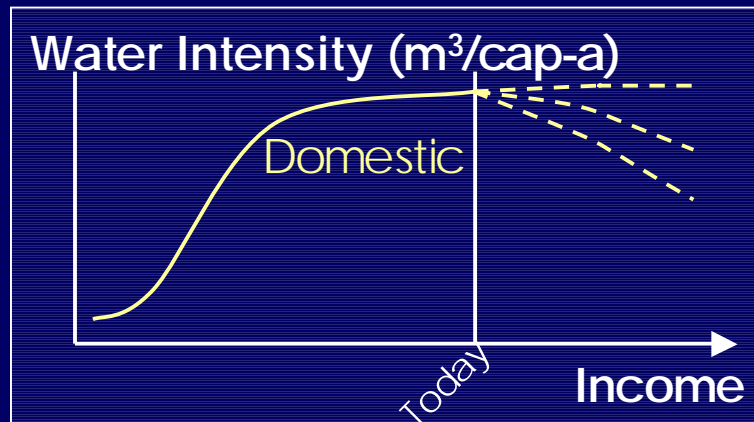
Impact of global change on water availability and water use

To consider Global Change

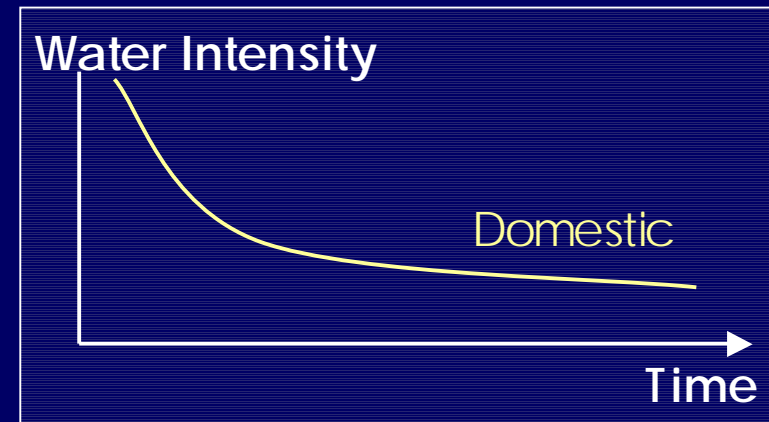


- GCM: HadCM3, Hadley Centre
- GCM: ECHAM4-OPYC3, Max Planck Inst.

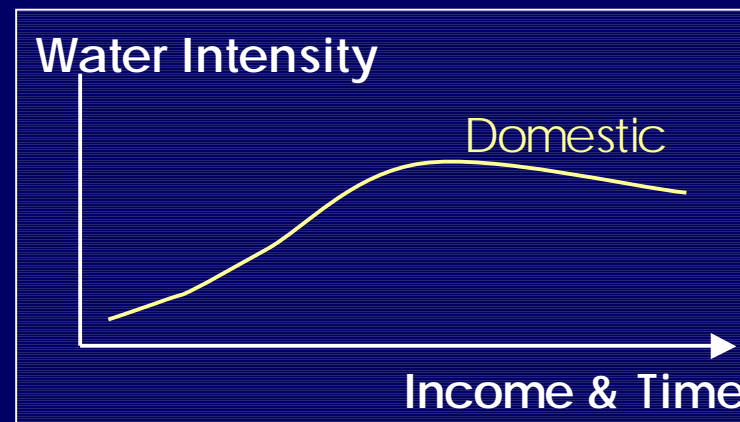
- Water Use Model : Domestic Sector -



Structural Change
(*changing behaviour
and infrastructure*)

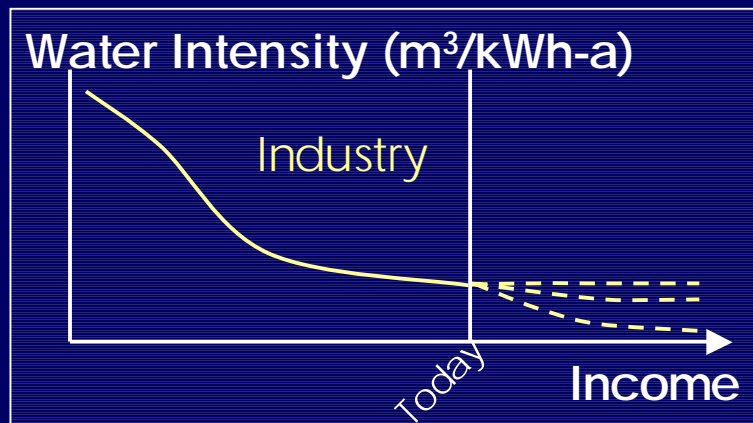


Technological Change
(*improving water use
efficiency*)

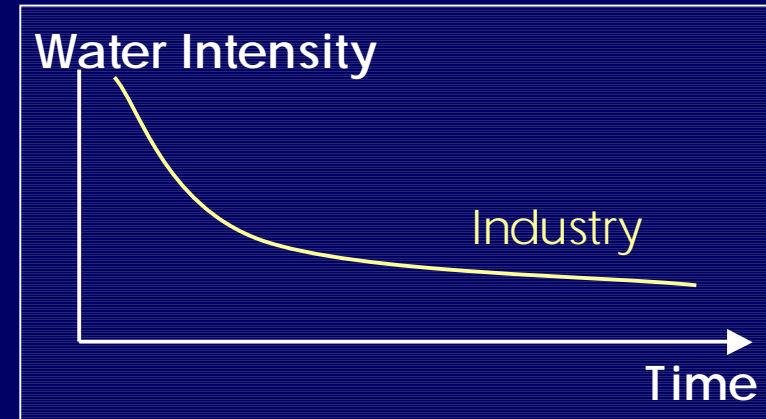


Structural & Technological Change (per country)

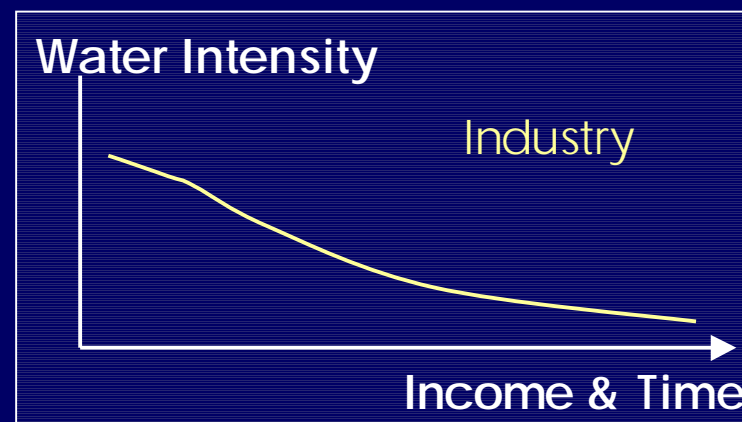
- Water Use Model : Industry Sector -



Structural Change
(*changing behaviour
and infrastructure*)

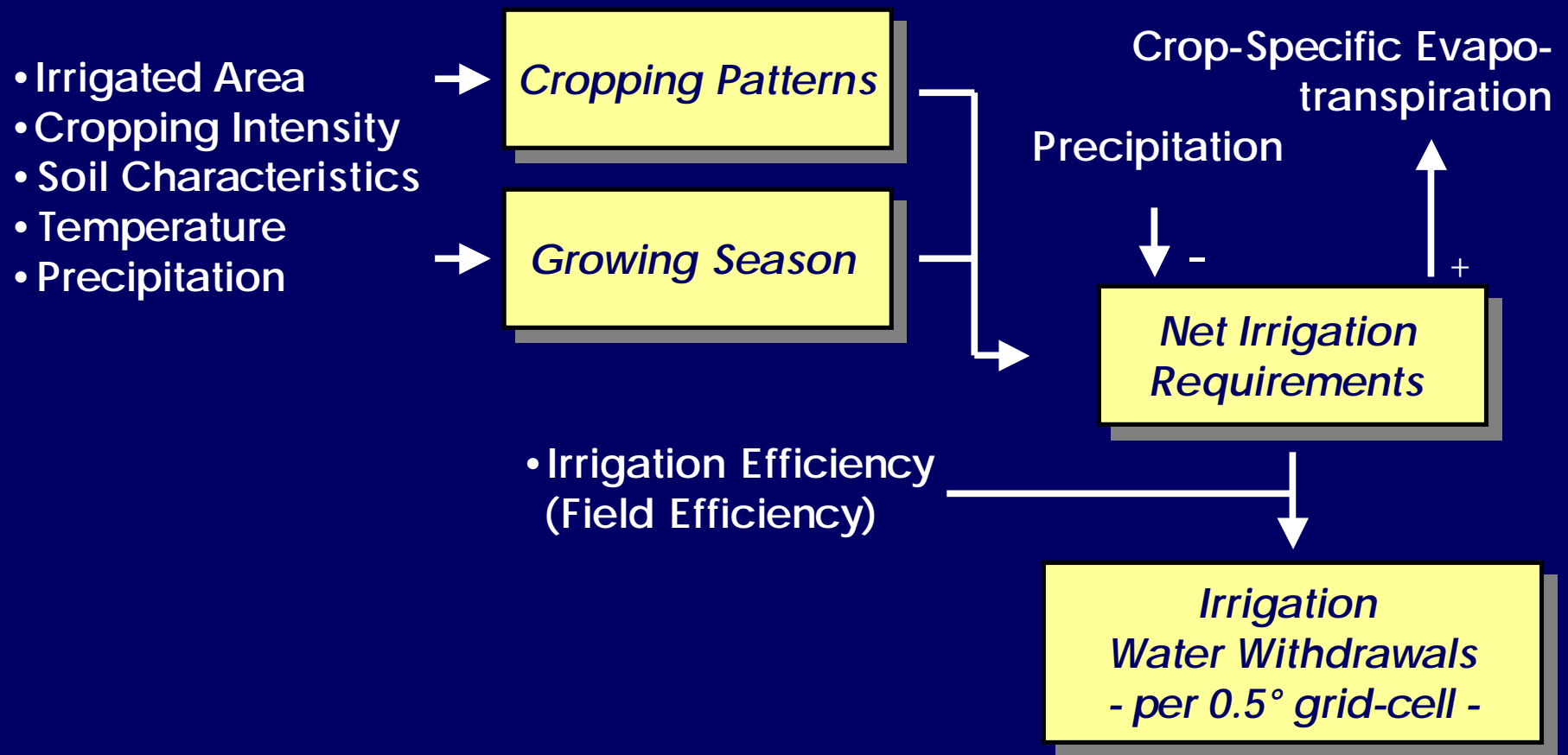


Technological Change
(*improving water use
efficiency*)

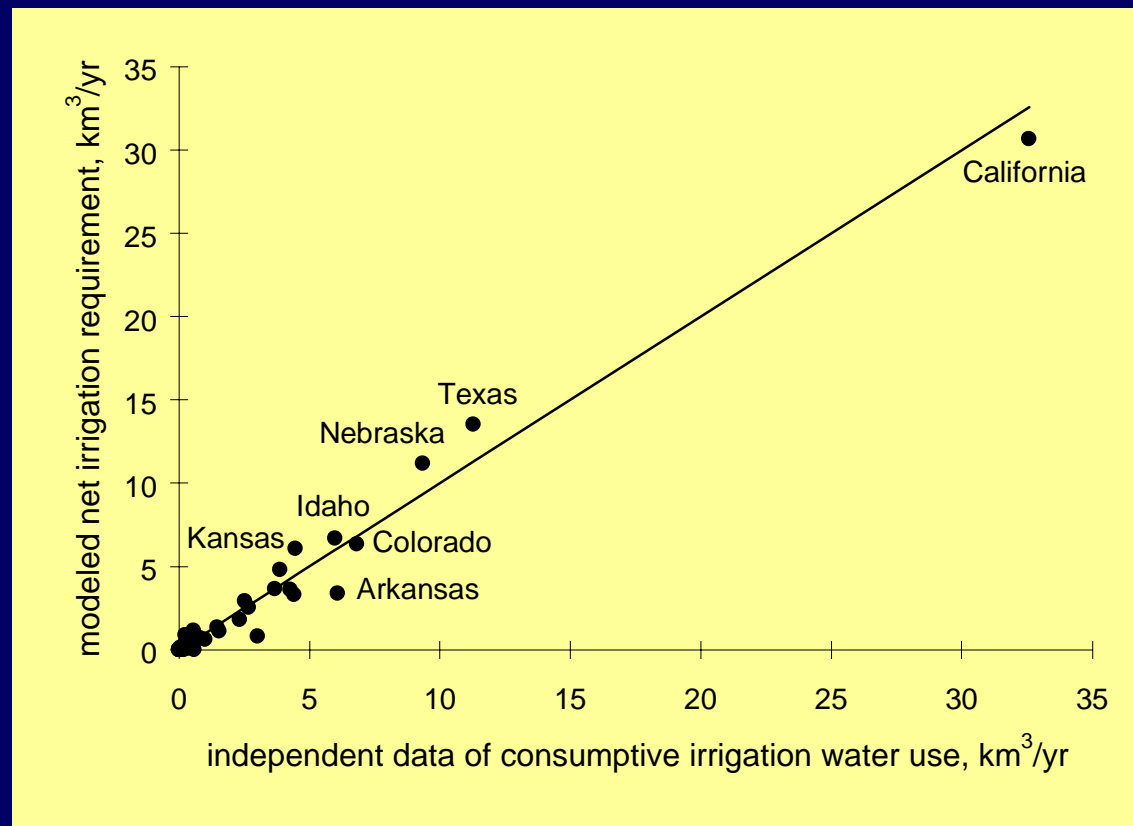


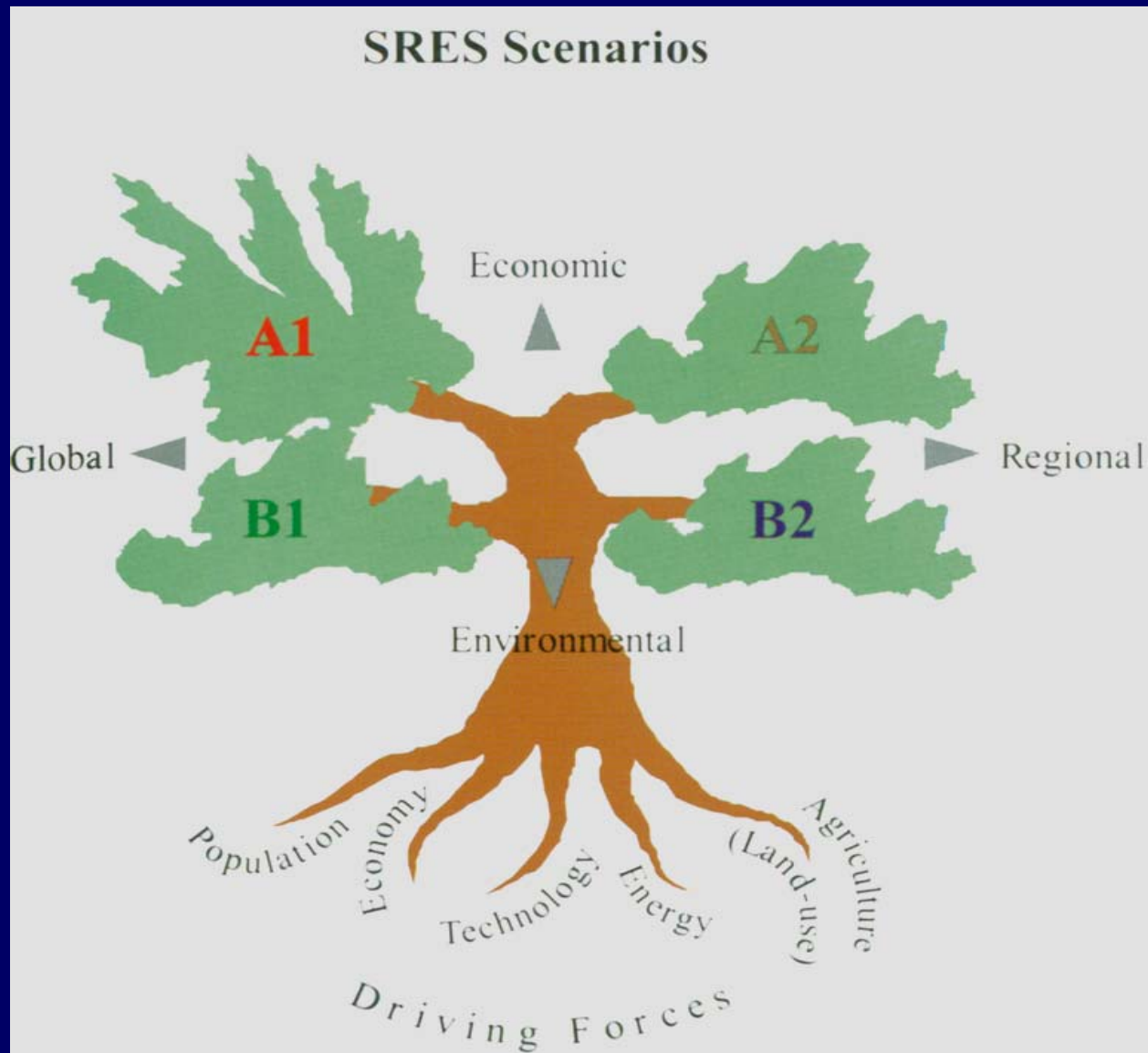
Structural & Technological Change (per country)

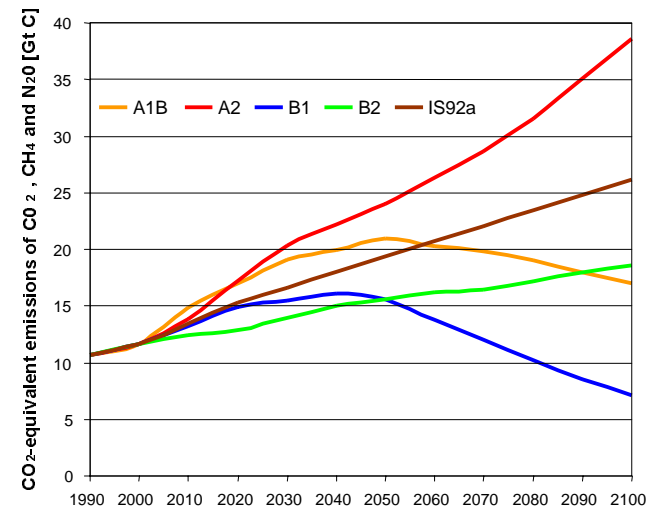
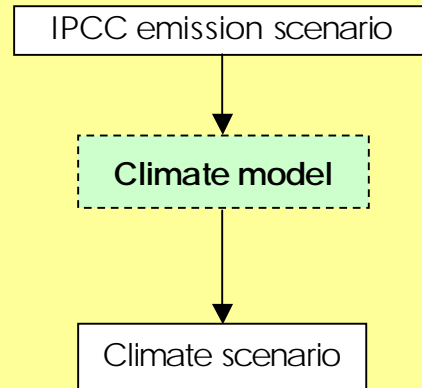
- Water Use Model : Irrigation -

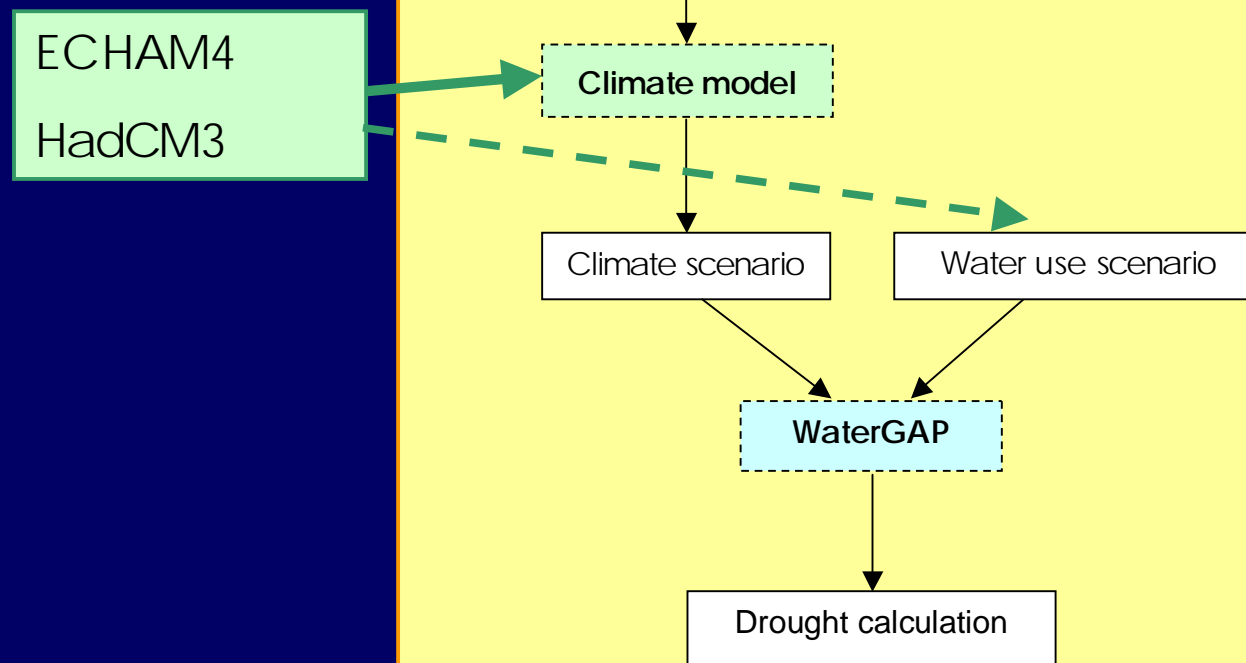


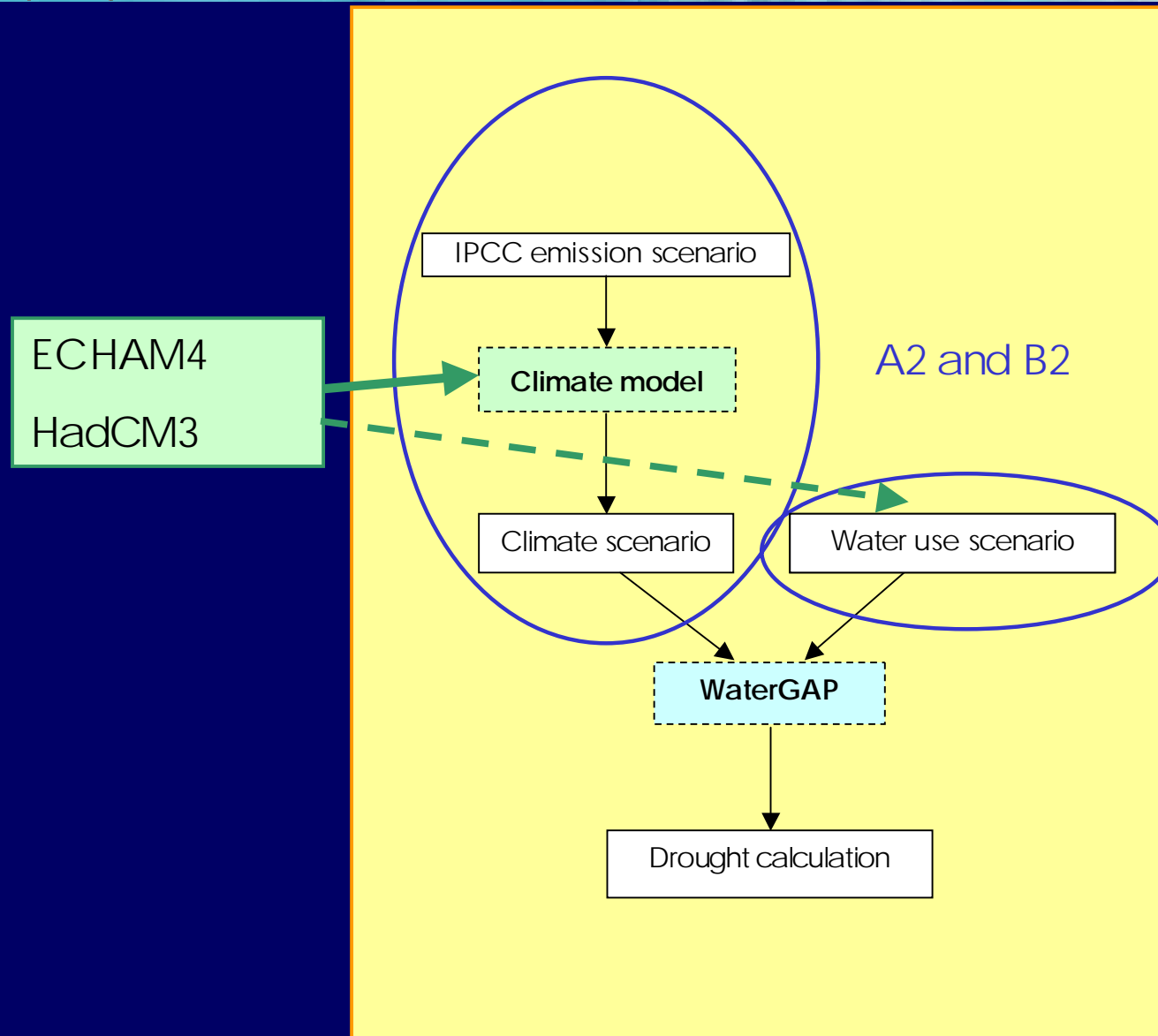
- Water Use Model : Irrigation -





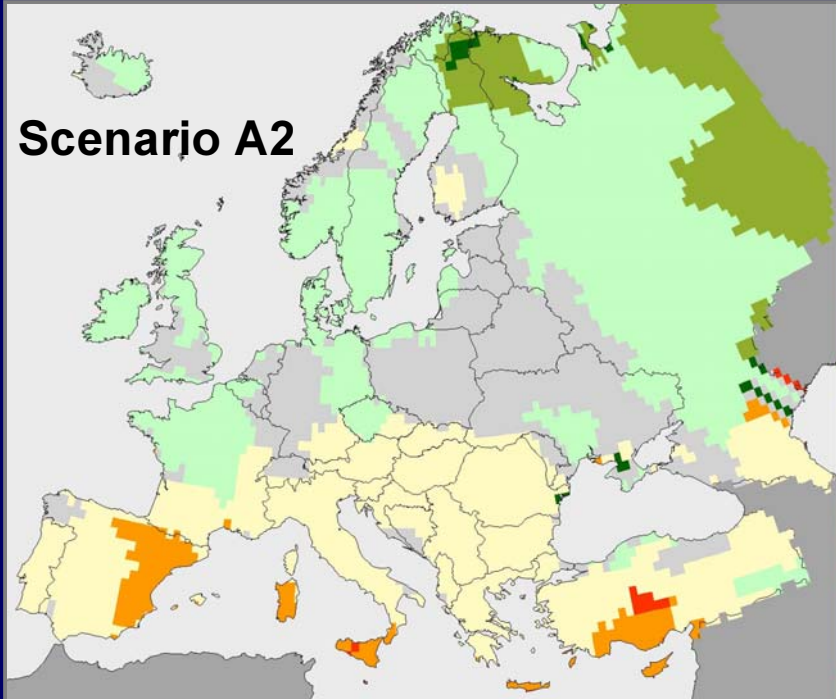




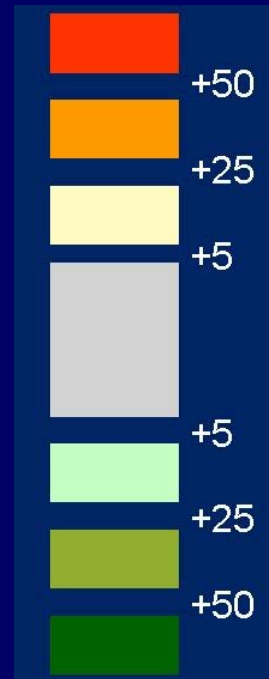
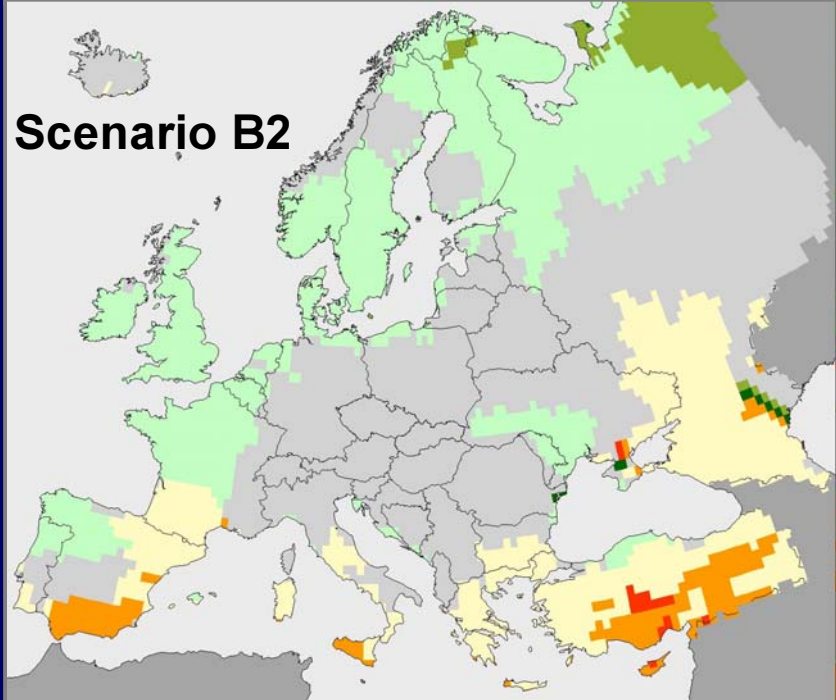


Change in Water Availability (HadCM3 - 2070s)

Scenario A2



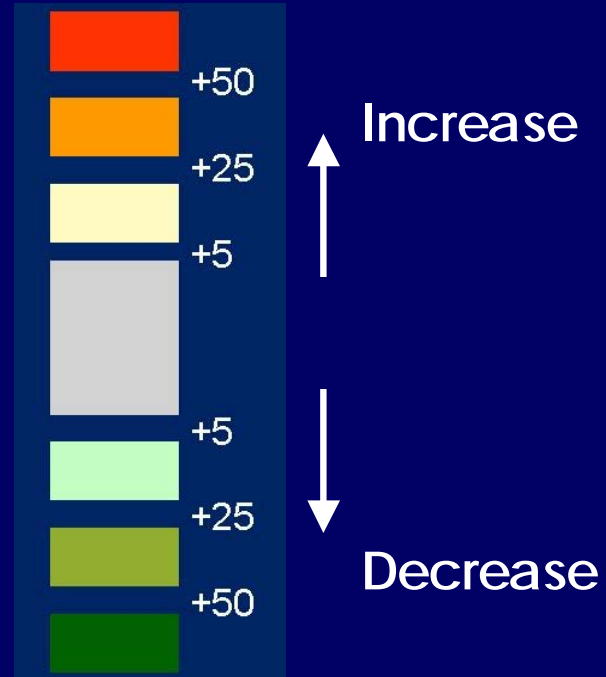
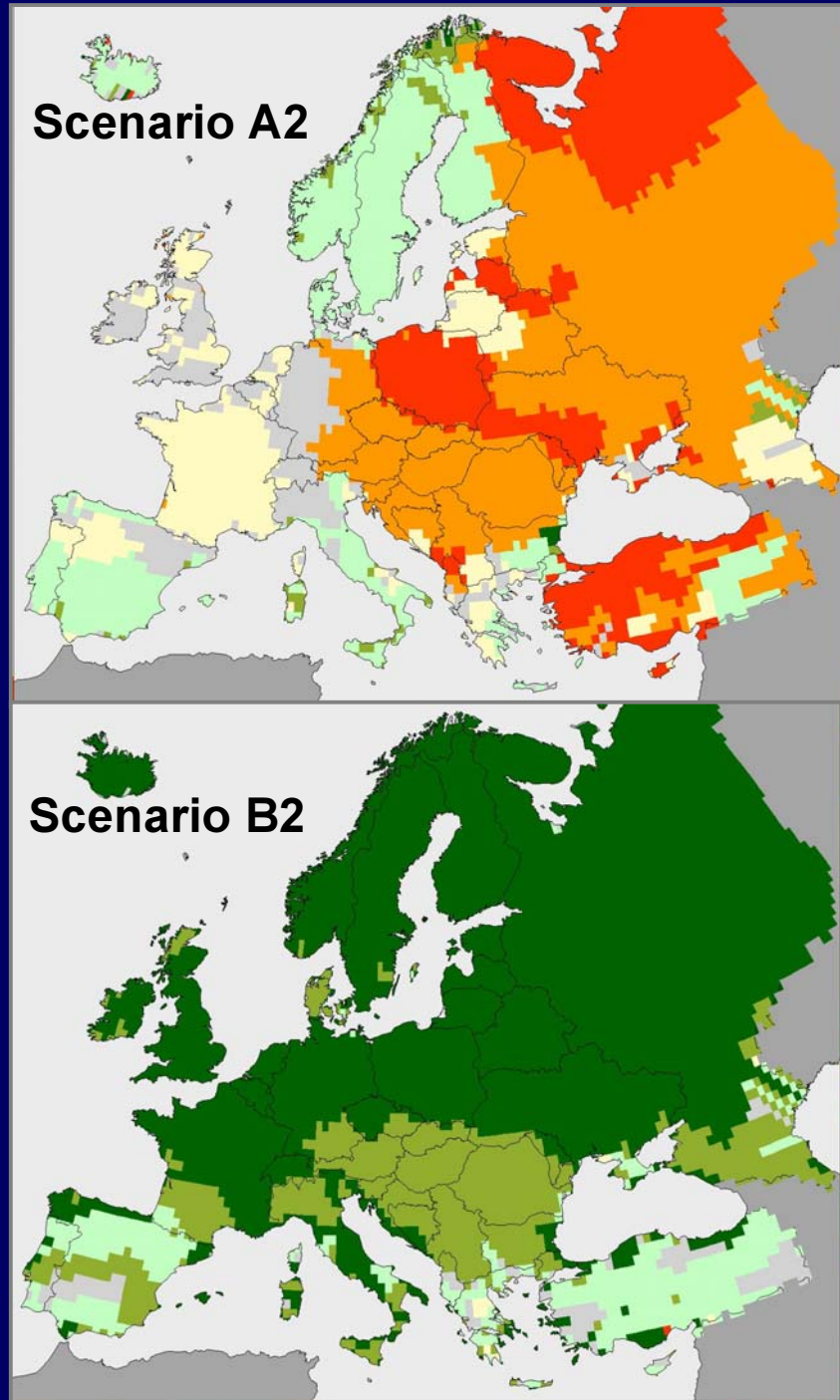
Scenario B2



Decrease

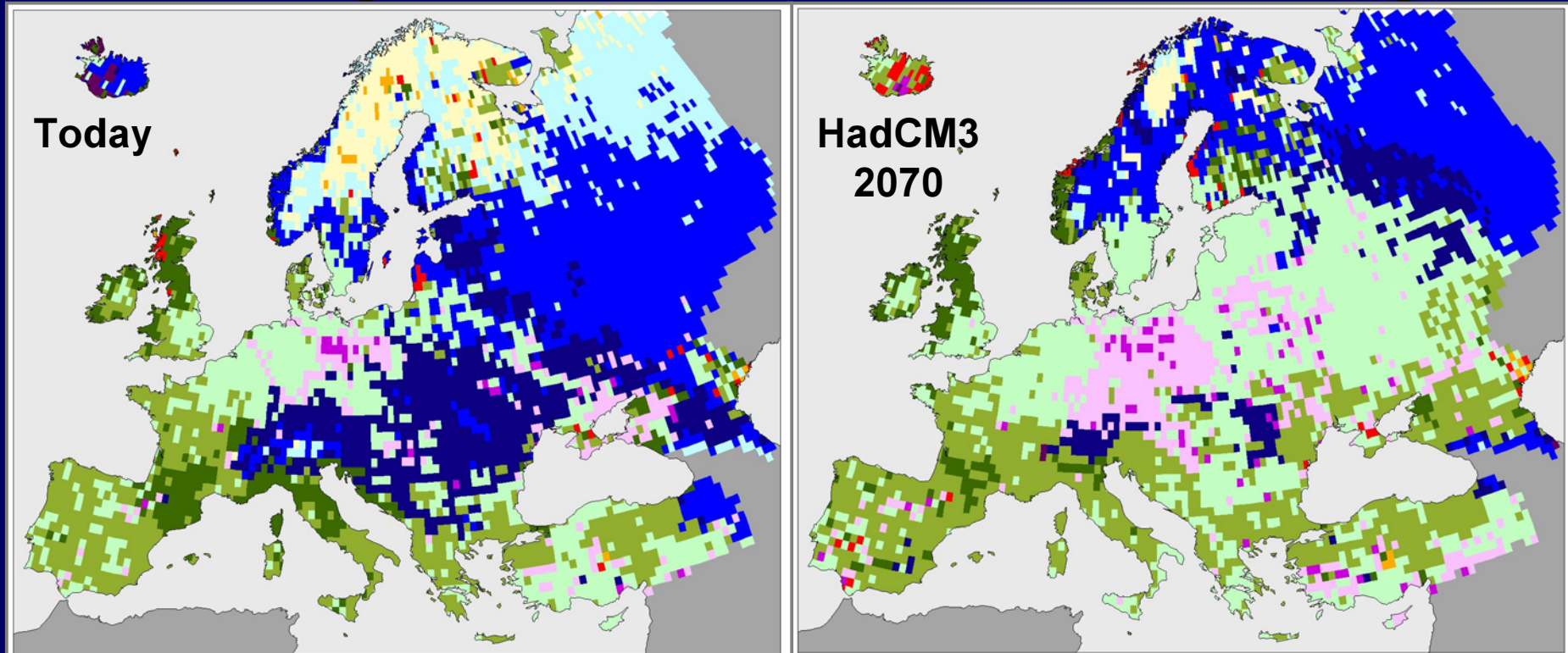
Increase

Change in Water Withdrawals (2070s)



Impact of global change on droughts

Changes in low flow discharge



Month with minimum average discharge

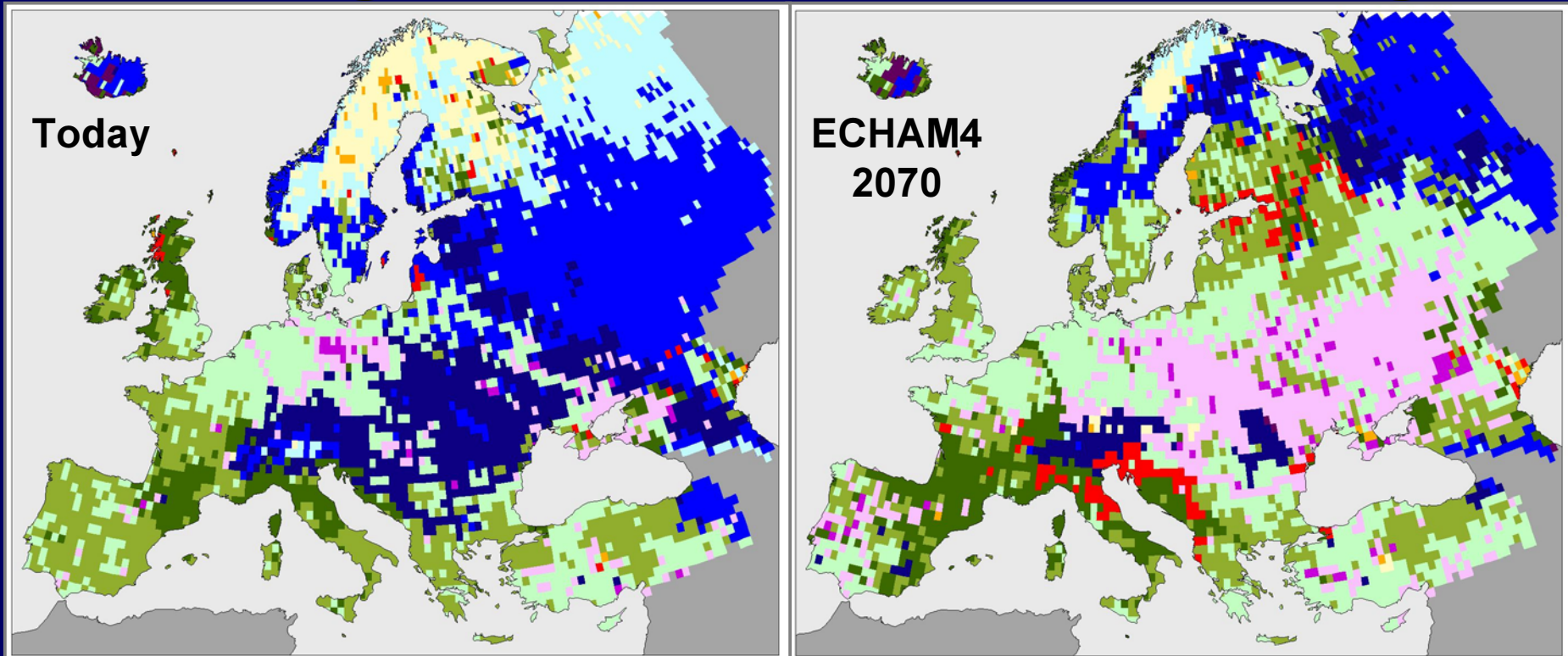


Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Scenario A2

(c) Center for Environmental
Systems Research,
University of Kassel,
March 2003 - WaterGAP 2.1D

Changes in low flow discharge



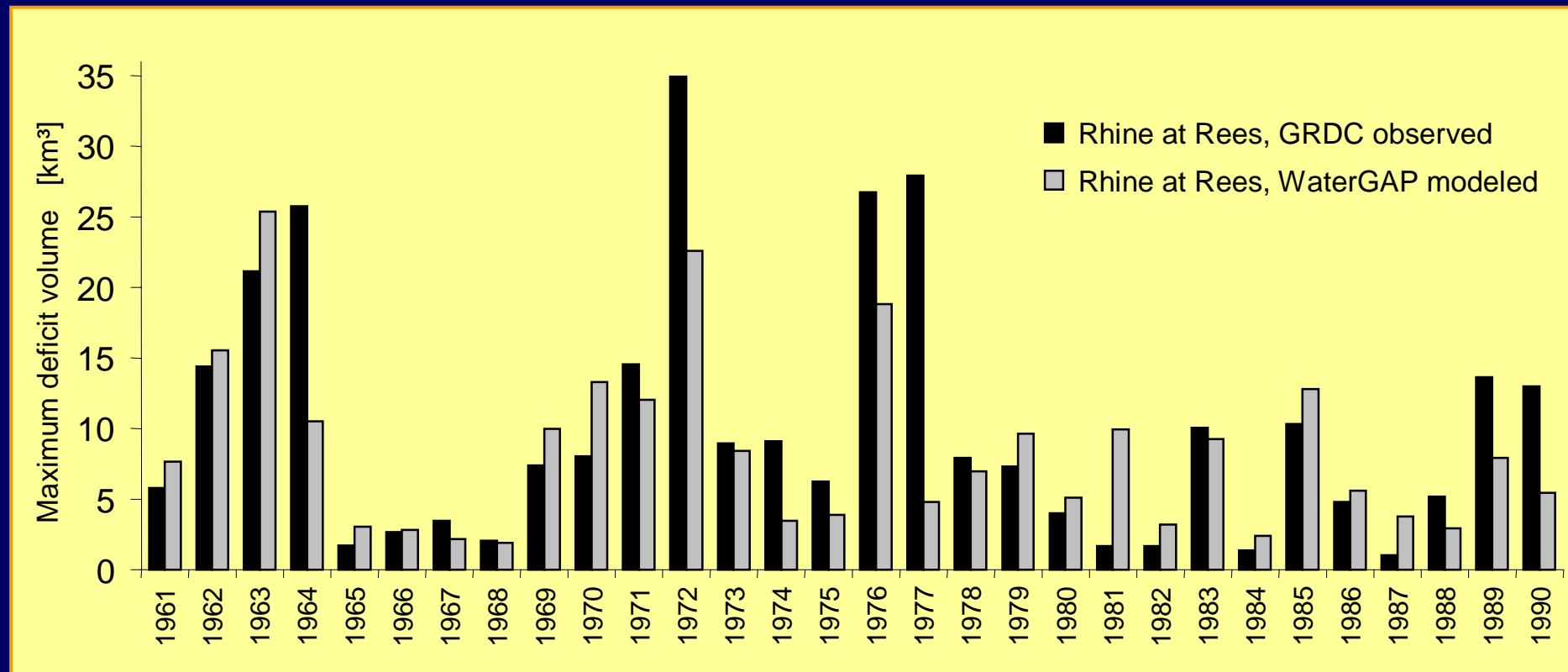
Month with minimum average discharge



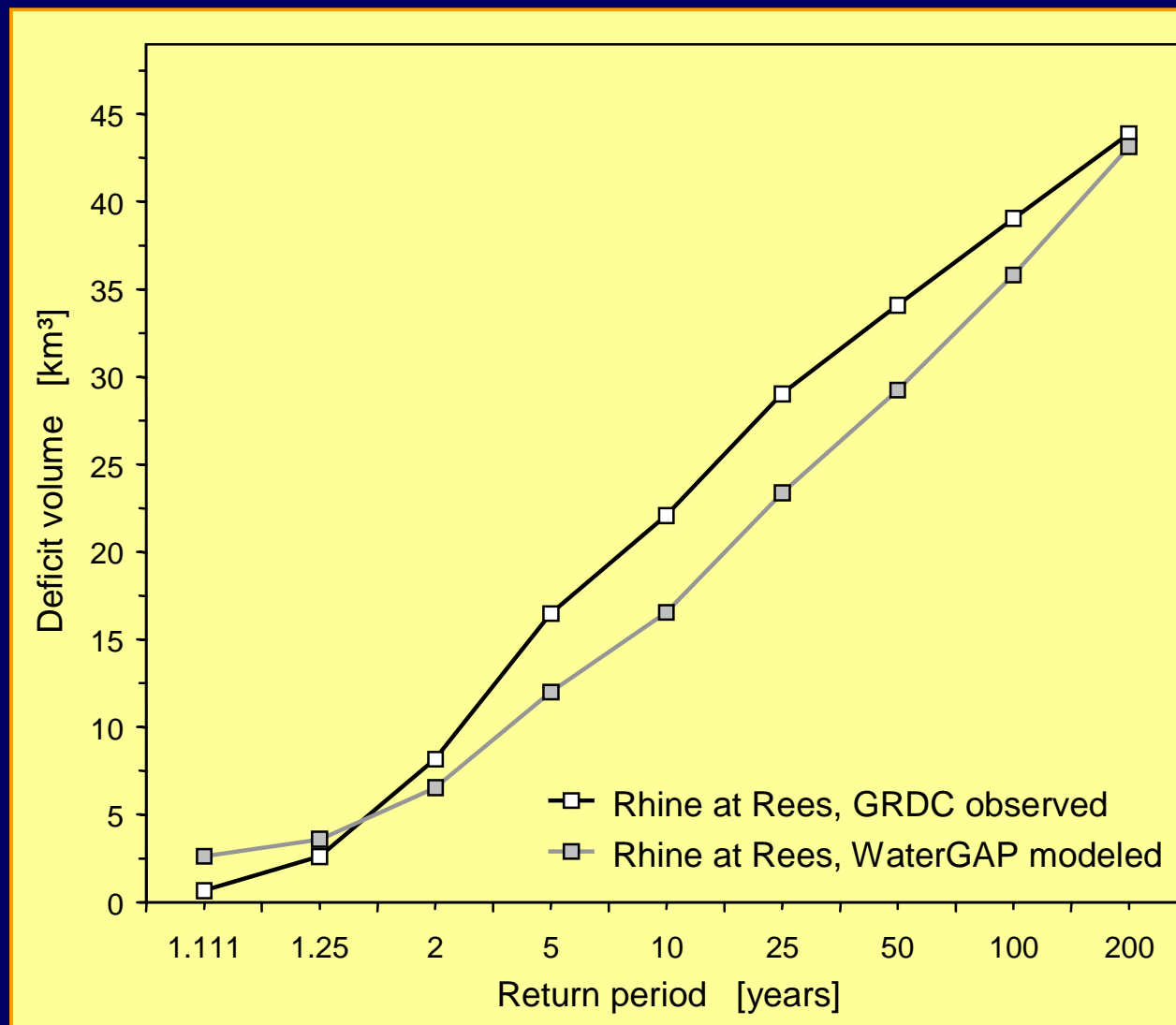
Scenario A2

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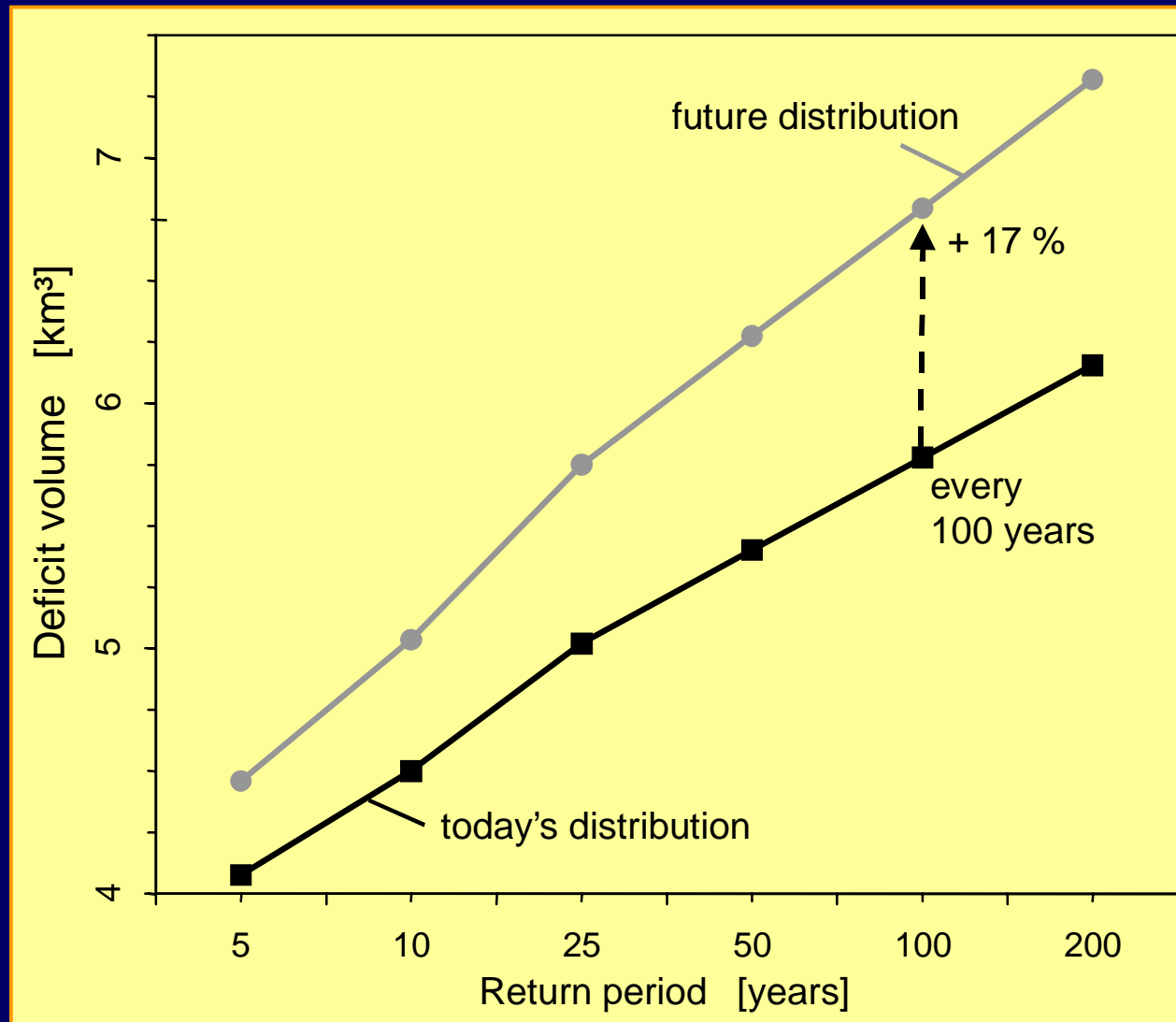
Deficit volumes using WaterGAP



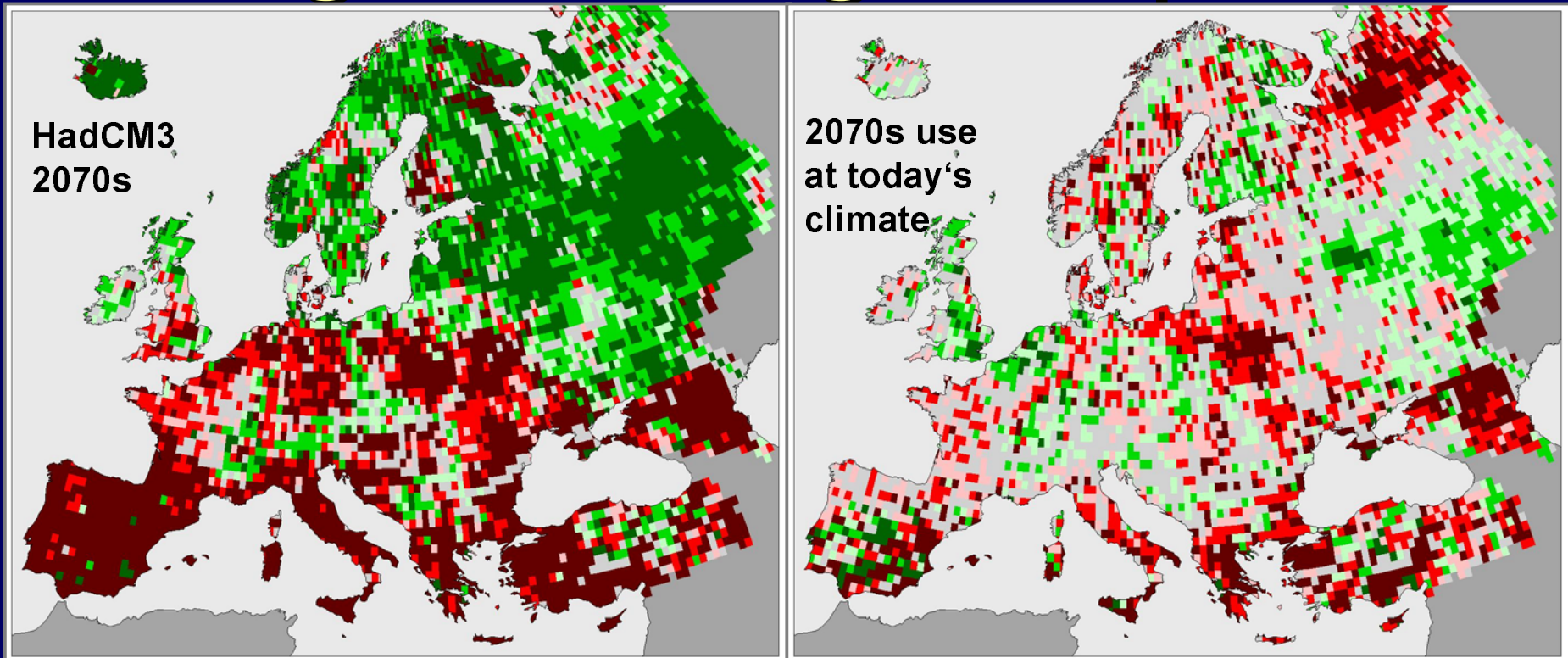
Drought frequency distribution



Changes of drought frequencies



Changes of drought frequencies



Change in 100-year drought deficit volume (%)

decreases

small changes

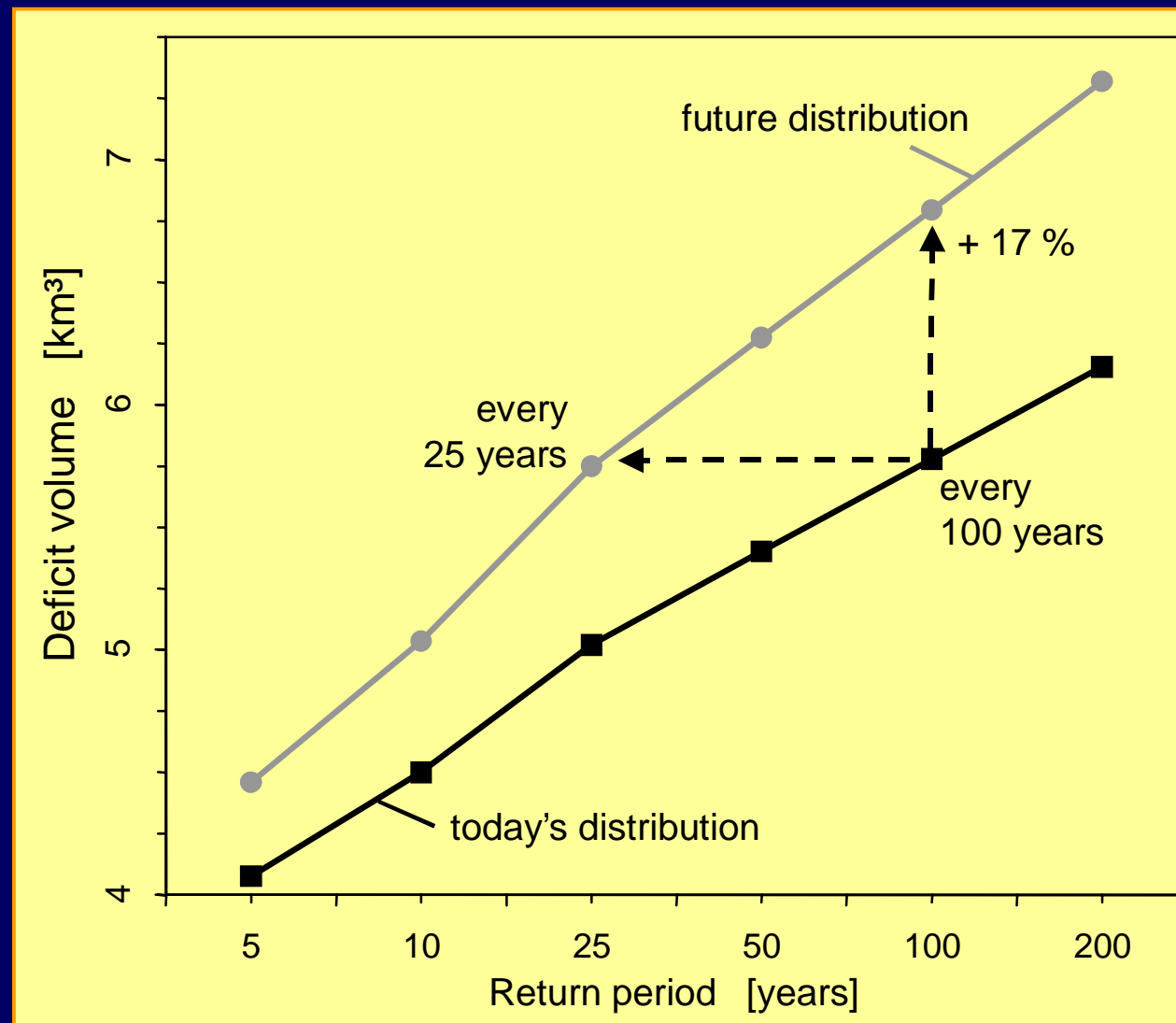
increases

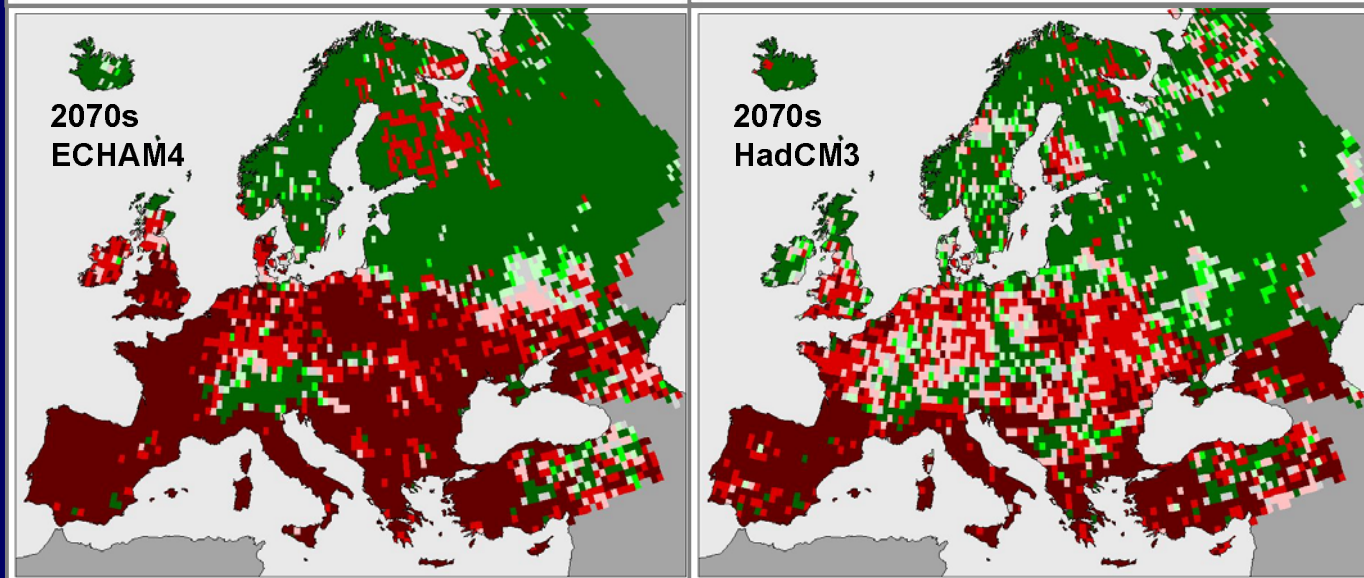
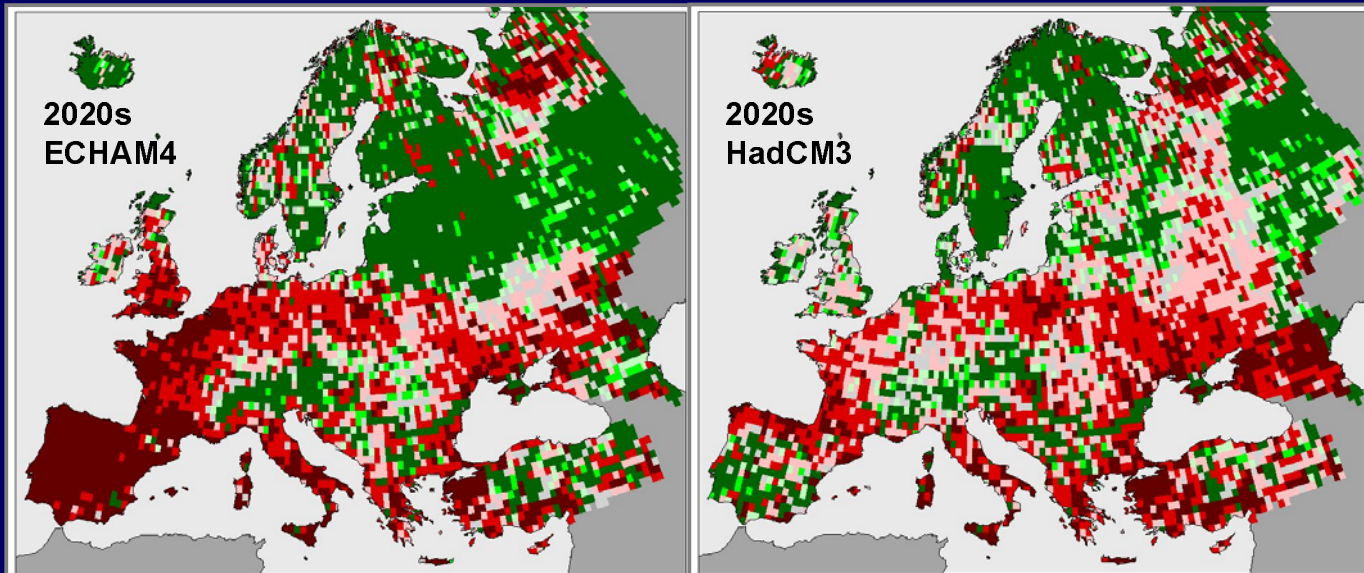


Scenario A2

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Changes of drought frequencies



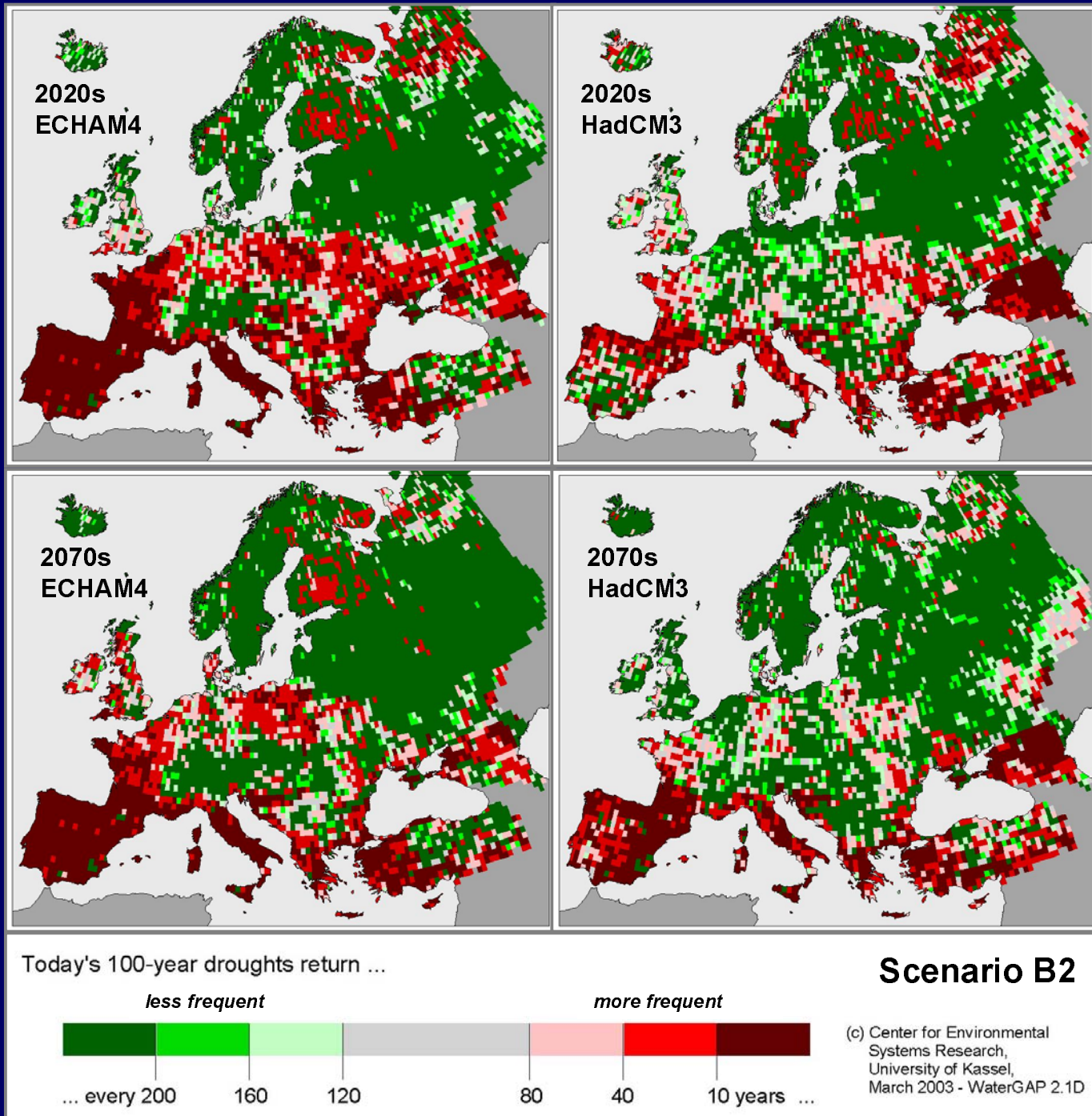


Today's 100-year droughts return ...



Scenario A2

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March 2003 - WaterGAP 2.1D



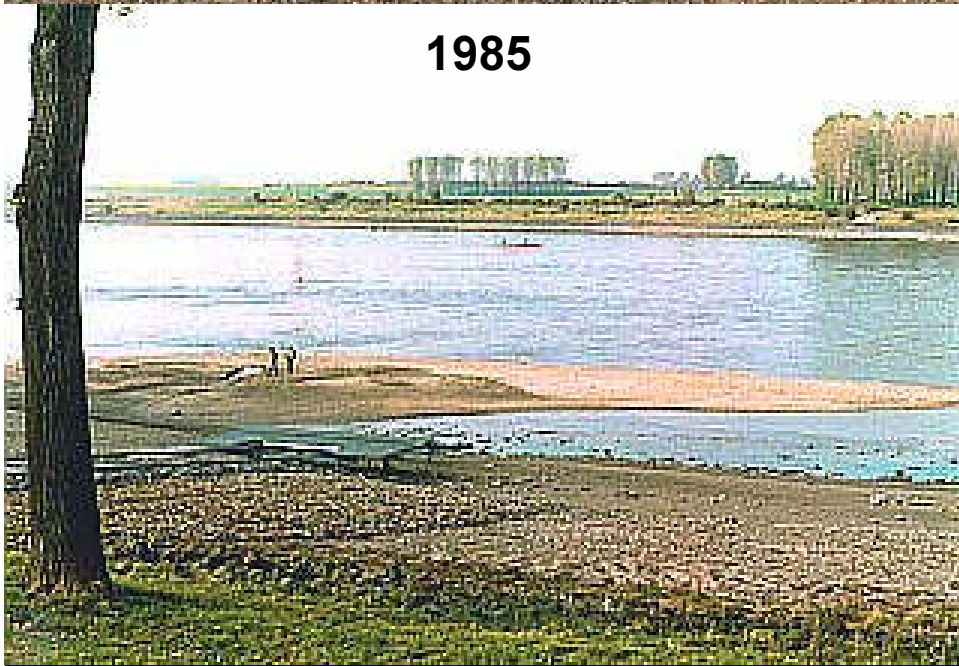
Summary

- WaterGAP delivers “acceptable” results for low-flow discharge analysis (and includes water use!)
- The macro-scale is suitable for the analysis of drought (droughts spread widely in space and time)
- Drought frequencies react to climate changes and use changes
- Today’s 100-drought return period in Europe shows opposite results in a north-south direction with regional differences



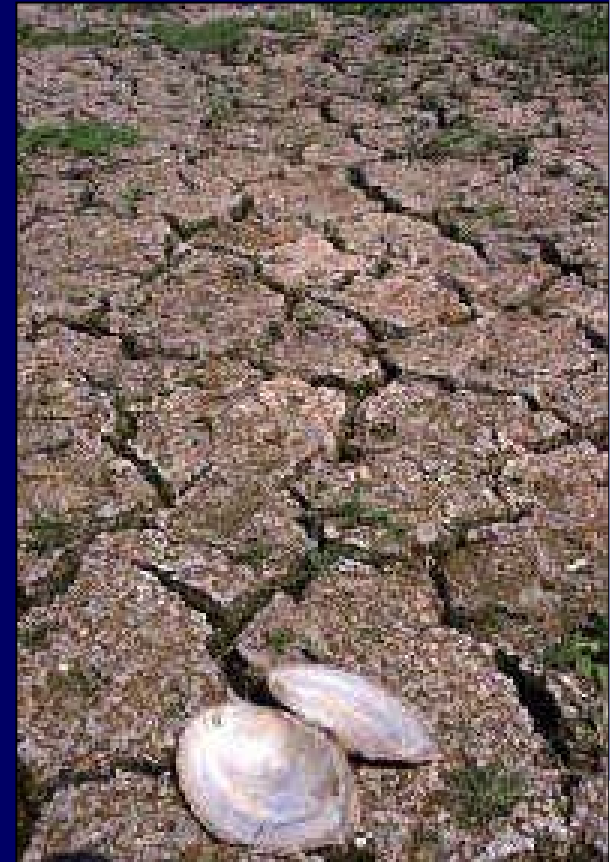


1985



1991



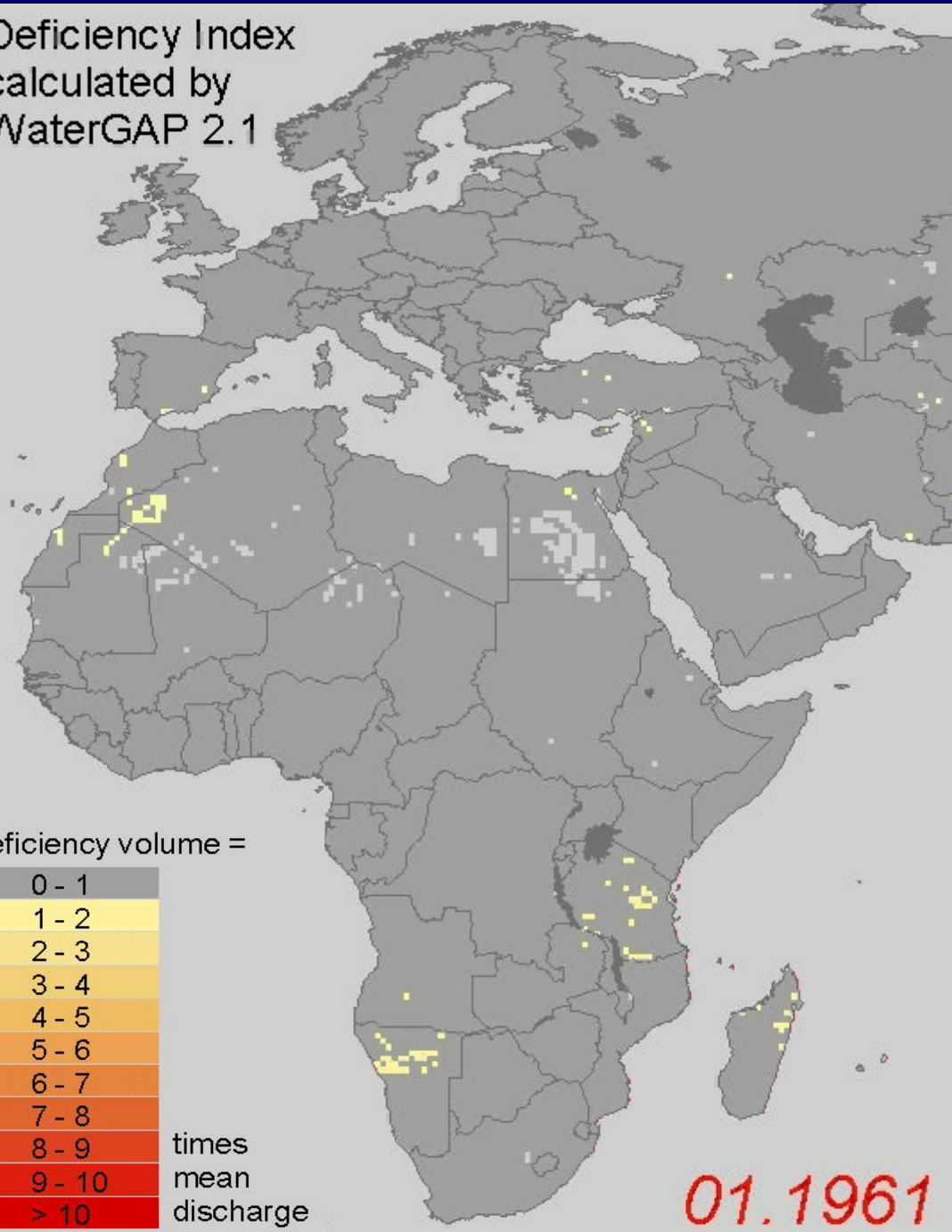
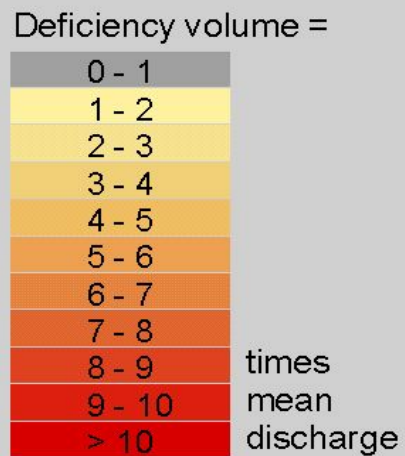


The impact of climate change:

- The upper picture is a real photograph of the river Rhine taken at Düsseldorf.
- The picture on left hand-side has a very low probability of occurrence.
- The picture on the right hand-side remains as a fantasy!



Deficiency Index
calculated by
WaterGAP 2.1



01.1961



Center for Environmental Systems Research, University of Kassel, Germany

Thanks!