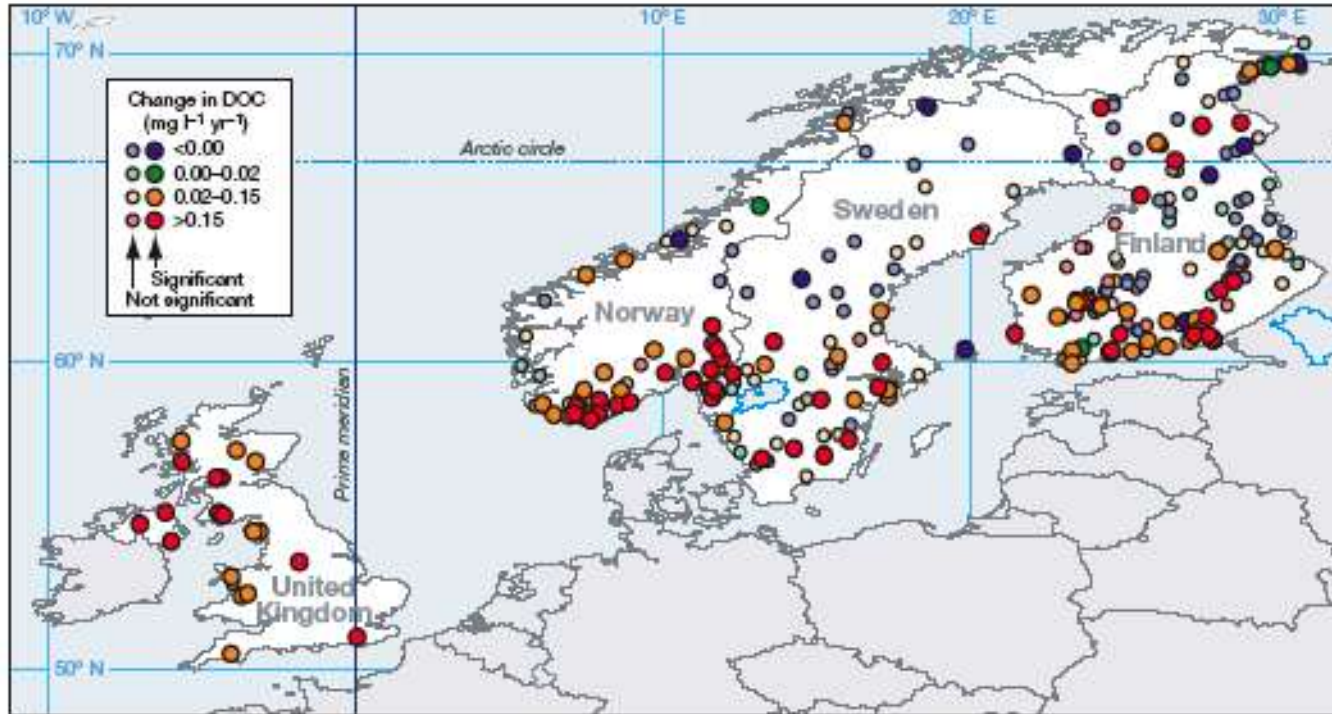


Dynamics of dissolved organic carbon (DOC) at the catchment scale:

Karsten Rinke, Steffen Zacharias, Peter Dietrich

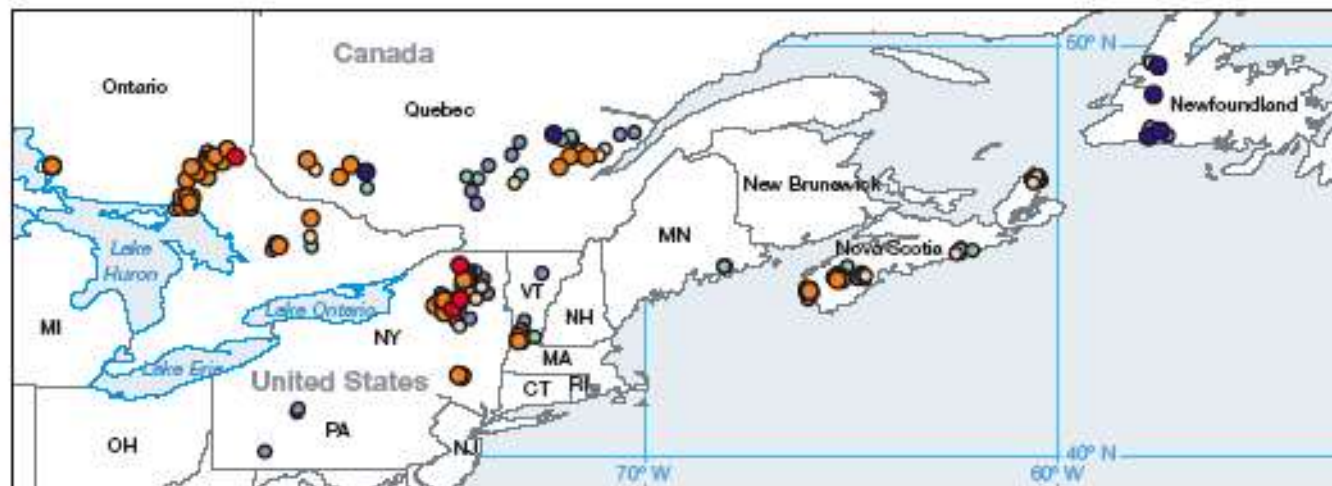
Department of Lake Research
Department of Monitoring and Exploration

Cross-continental consistency in DOC increase

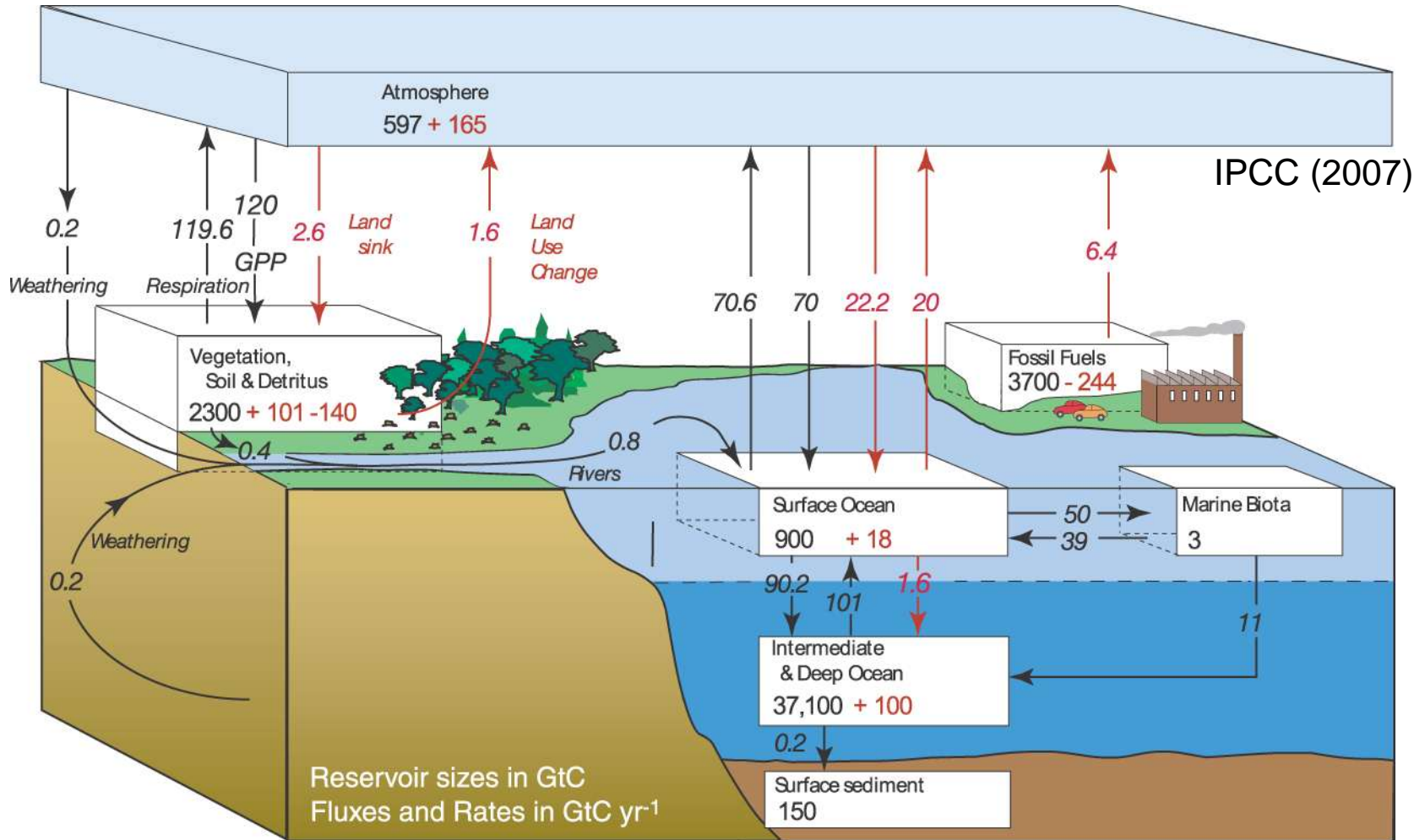


Increase in DOC in >70% of studied lake systems

Monteith et al. Nature 450: 537-541 (2007).



Global carbon cycle



Pools

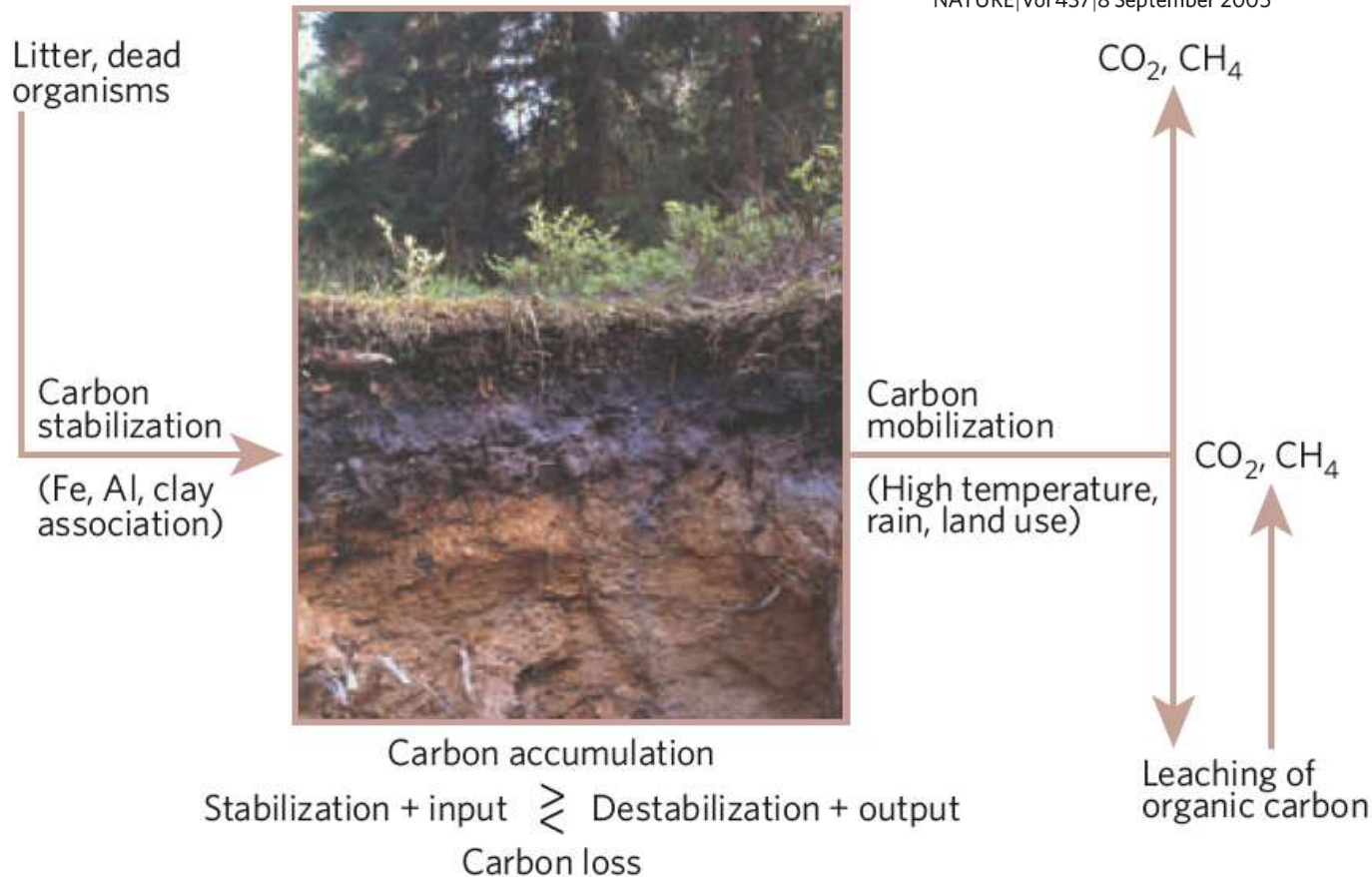
DOC Ocean 700 Gt
 CO₂ Atmosphere 750 Gt
 Terrestrial plants 600 Gt

Fluxes

Lake sediments 0.04 Gt a⁻¹
 Peatlands 0.1 Gt (?) Gt a⁻¹
 Reservoirs 0.6 Gt a⁻¹

Flux of dissolved organic carbon on the catchment scale

Loss of soil organic carbon



ENVIRONMENTAL SCIENCE

Carbon unlocked from soils

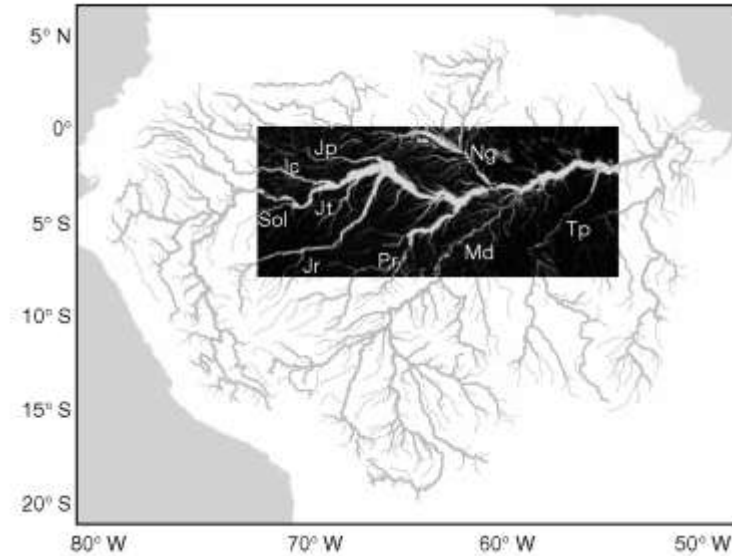
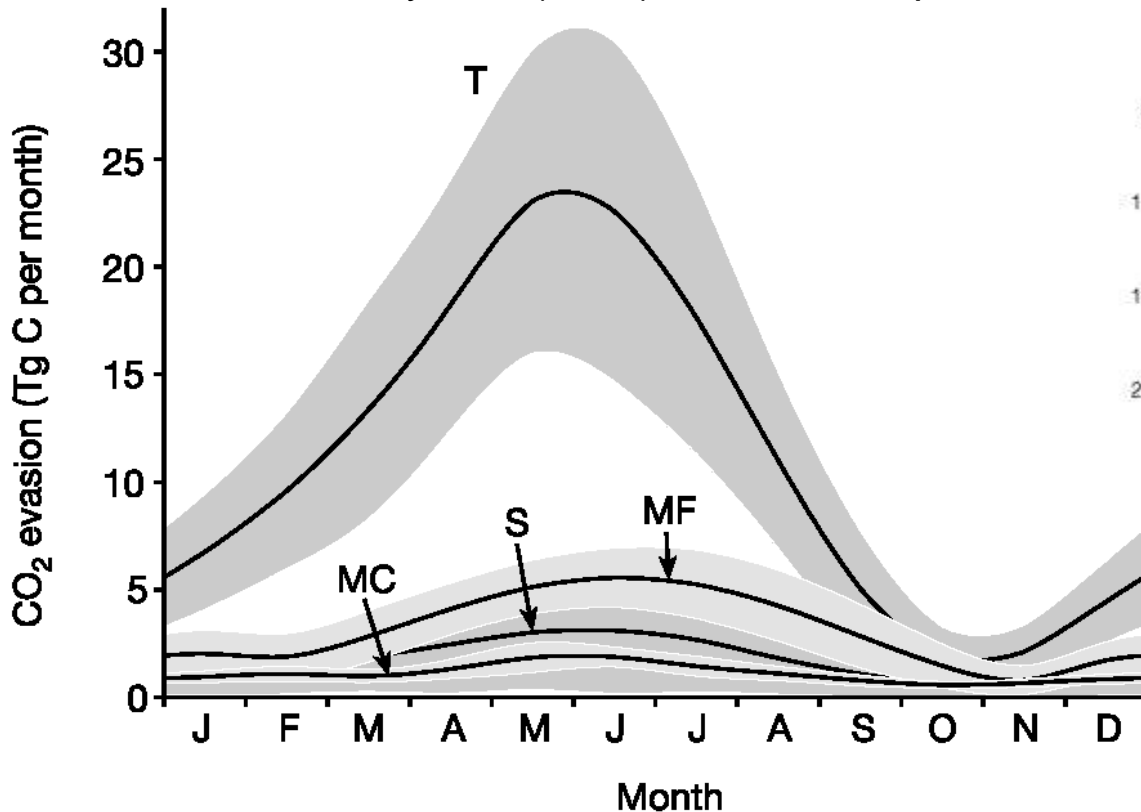
E. Detlef Schulze and Annette Freibauer

NATURE|Vol 437|8 September 2005

Loss of SOC: $66 - 550 \text{ g C m}^{-2} \text{ a}^{-1}$
(equals 8% of UK emission of $\text{CO}_2 = \text{CO}_2$ reduction 1990-2002)

Transport (hydrology) and transformation (ecology) in aquatic systems are relevant for the carbon dynamics at the catchment scale

Richey et al (2002), Nature 416, p617-620



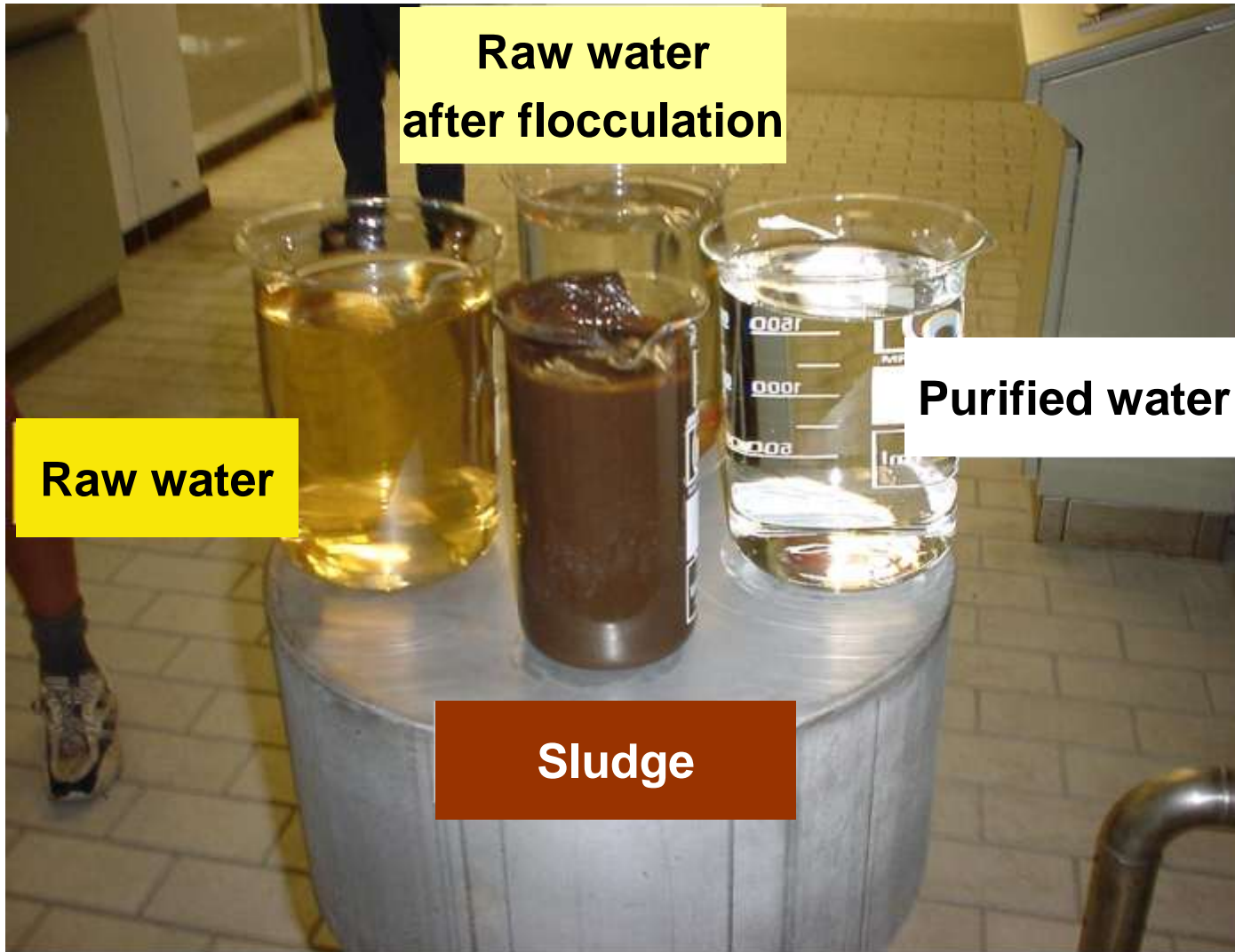
Outgassing from Amazonian rivers and wetlands as a large tropical source of atmospheric CO₂

Jeffrey E. Richey⁺, John M. Melack[†], Anthony K. Aufdenkampe⁺,
Victoria M. Ballester[‡] & Laura L. Hess[†]

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Problems in the waterworks:

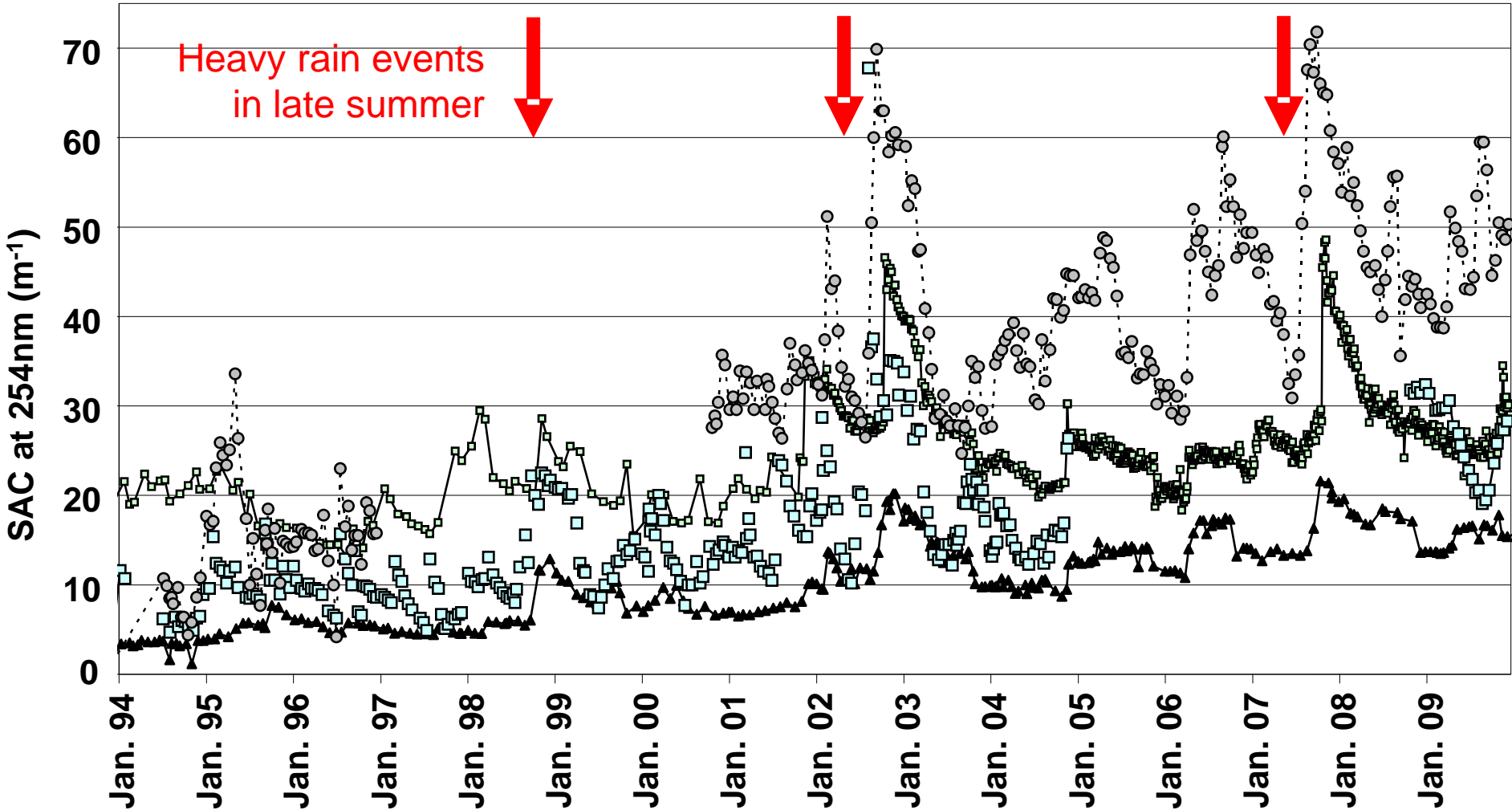
stability of flocculation, sludge production & disinfection byproducts, ...



Source:
LTV Sachsen

HELMHOLTZ
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Long-term trends of DOC in german drinking water reservoirs

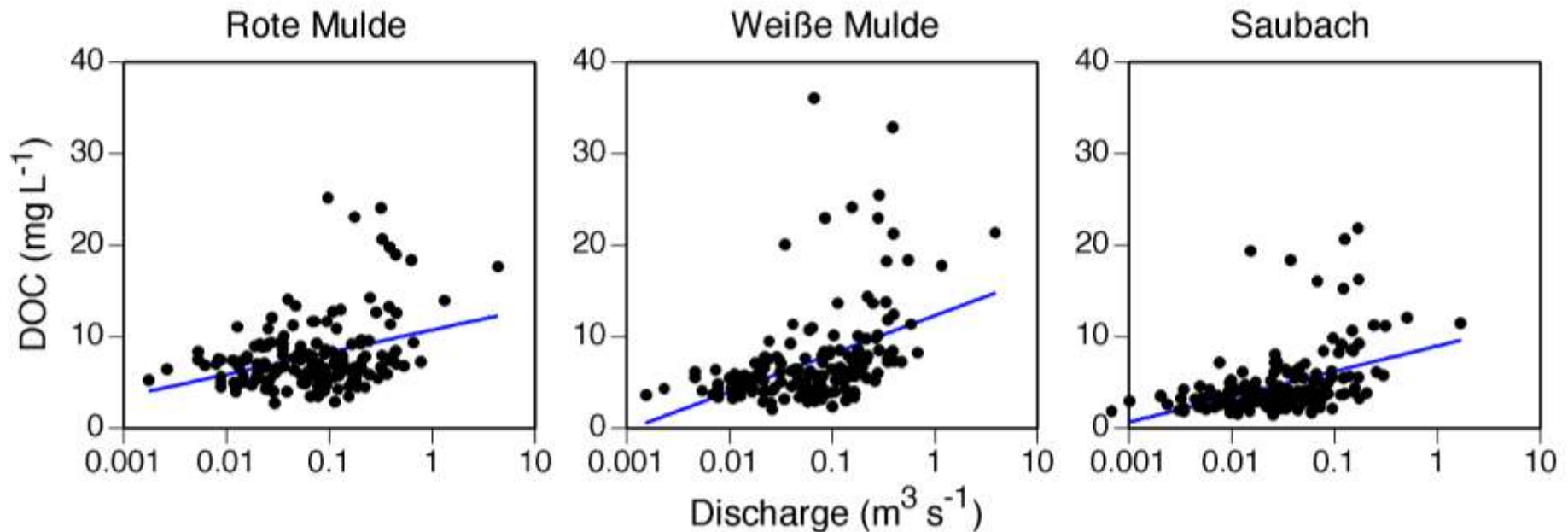


▲ Eibenstock reservoir
□ Muldenberg reservoir

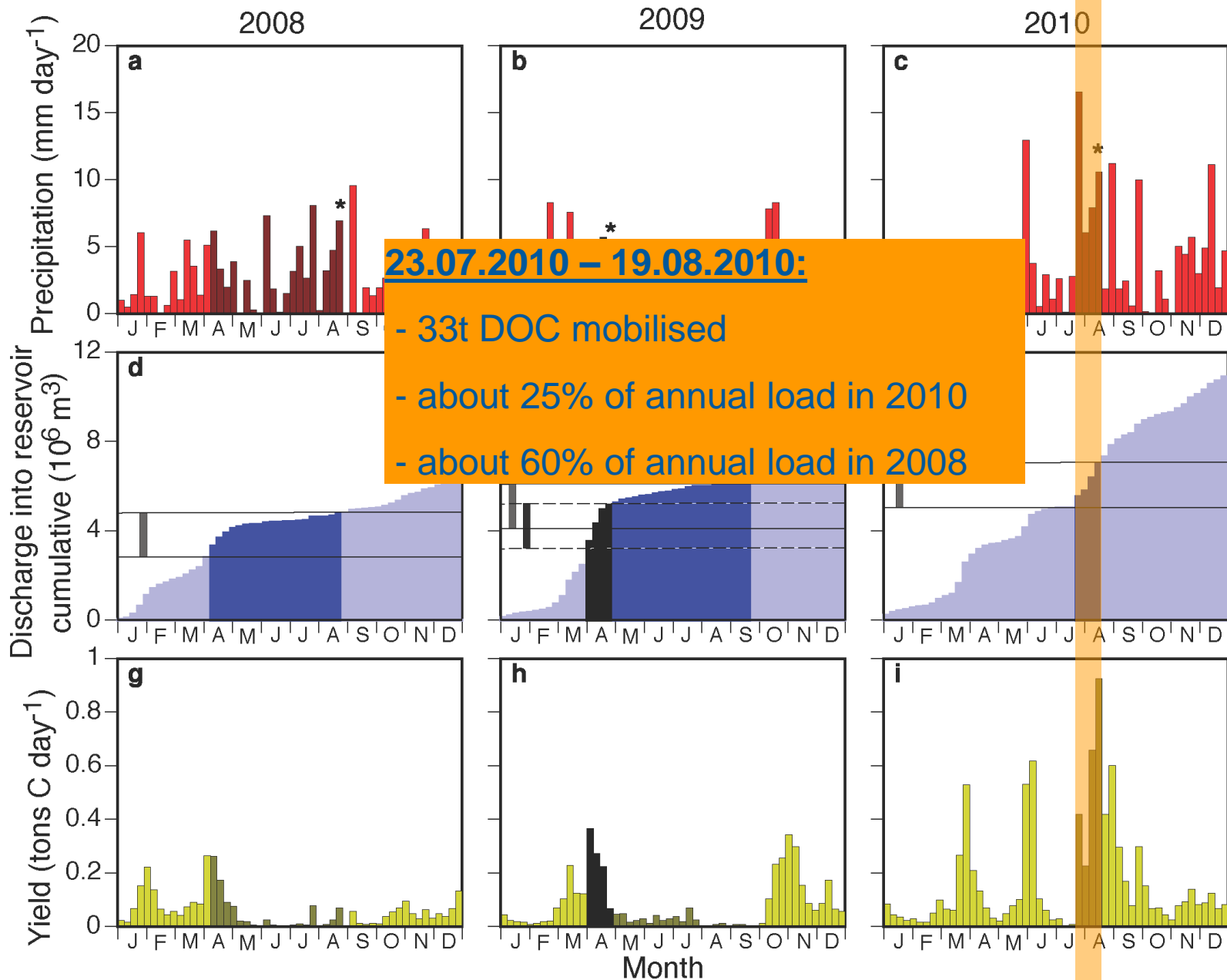
■ Ecker reservoir
○ Carlsfeld reservoir



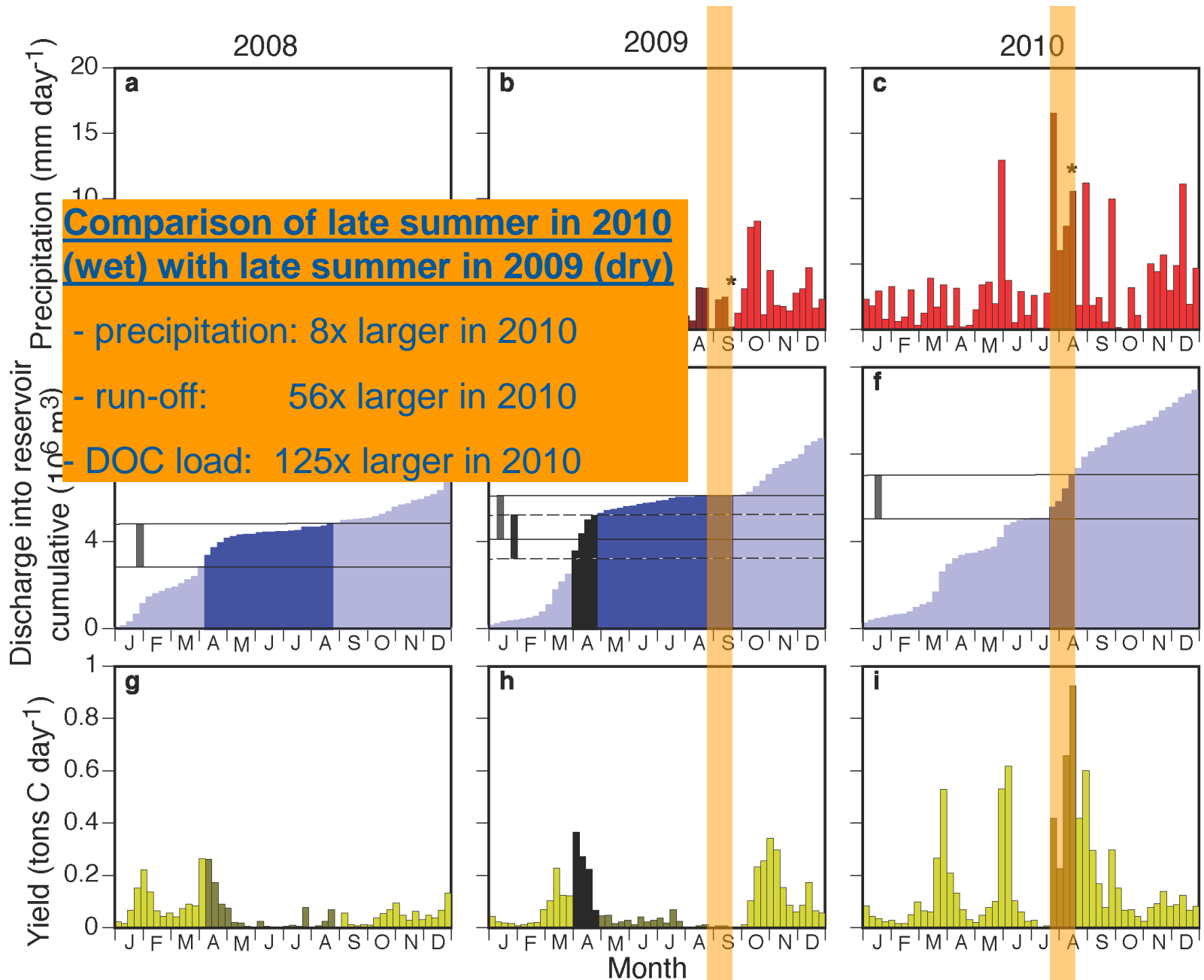
DOC transport over a range of hydrological conditions



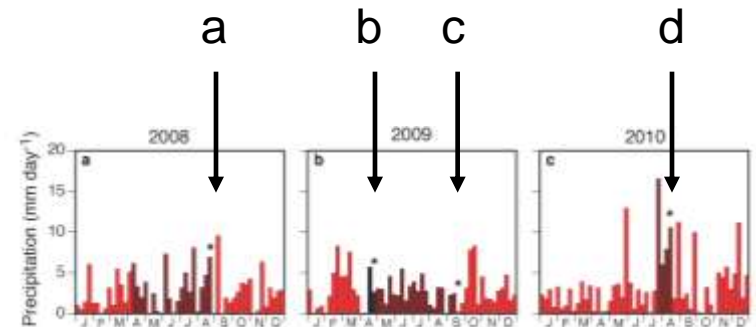
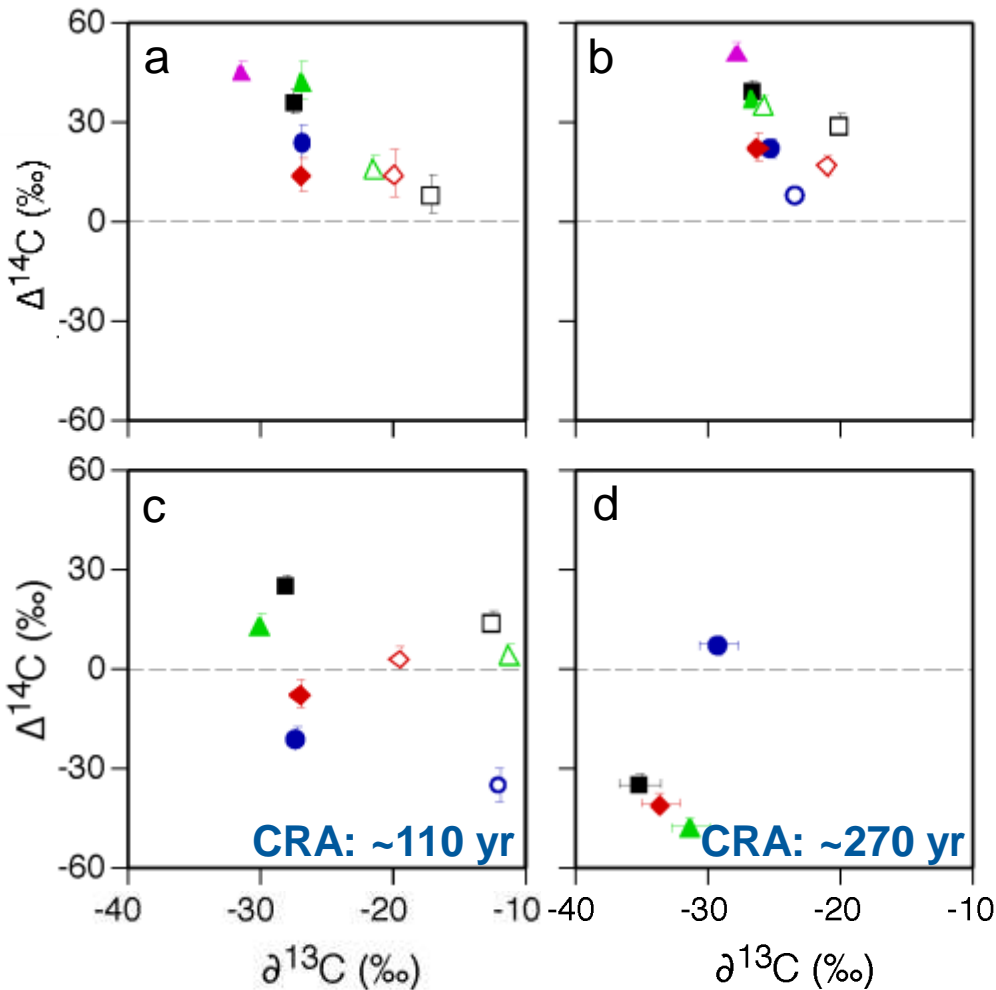
DOC transport from the catchment



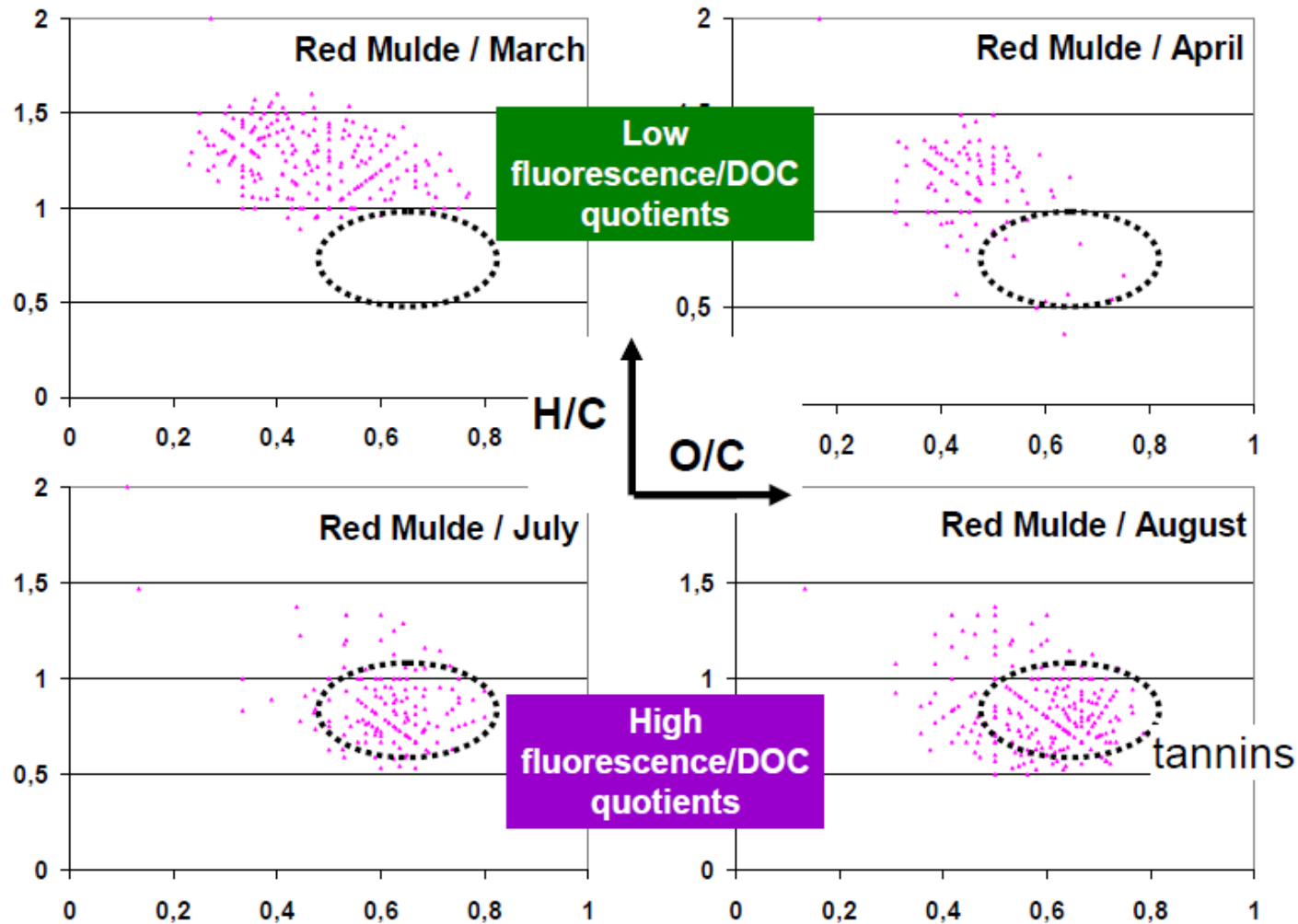
DOC transport from the catchment



^{14}C signatures



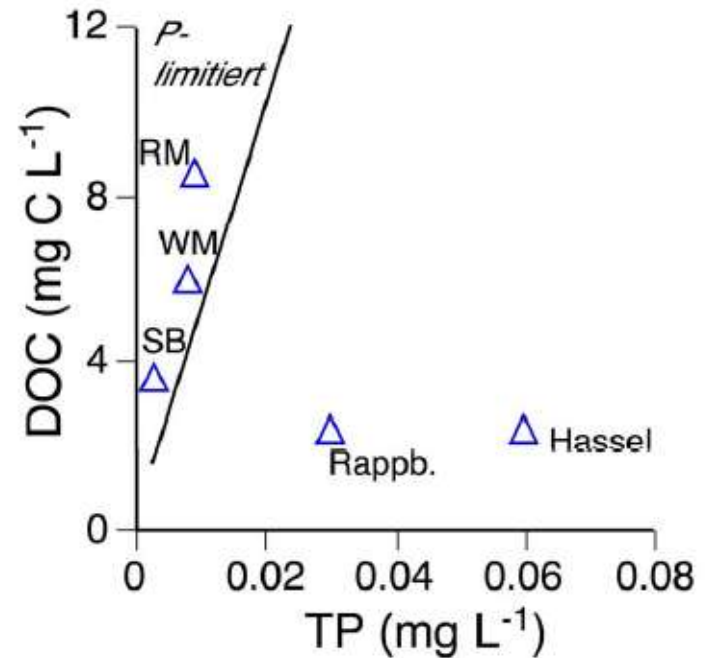
Quality and elemental composition of DOC varies seasonally (FTICR-MS)



DOC is processed within the reservoirs

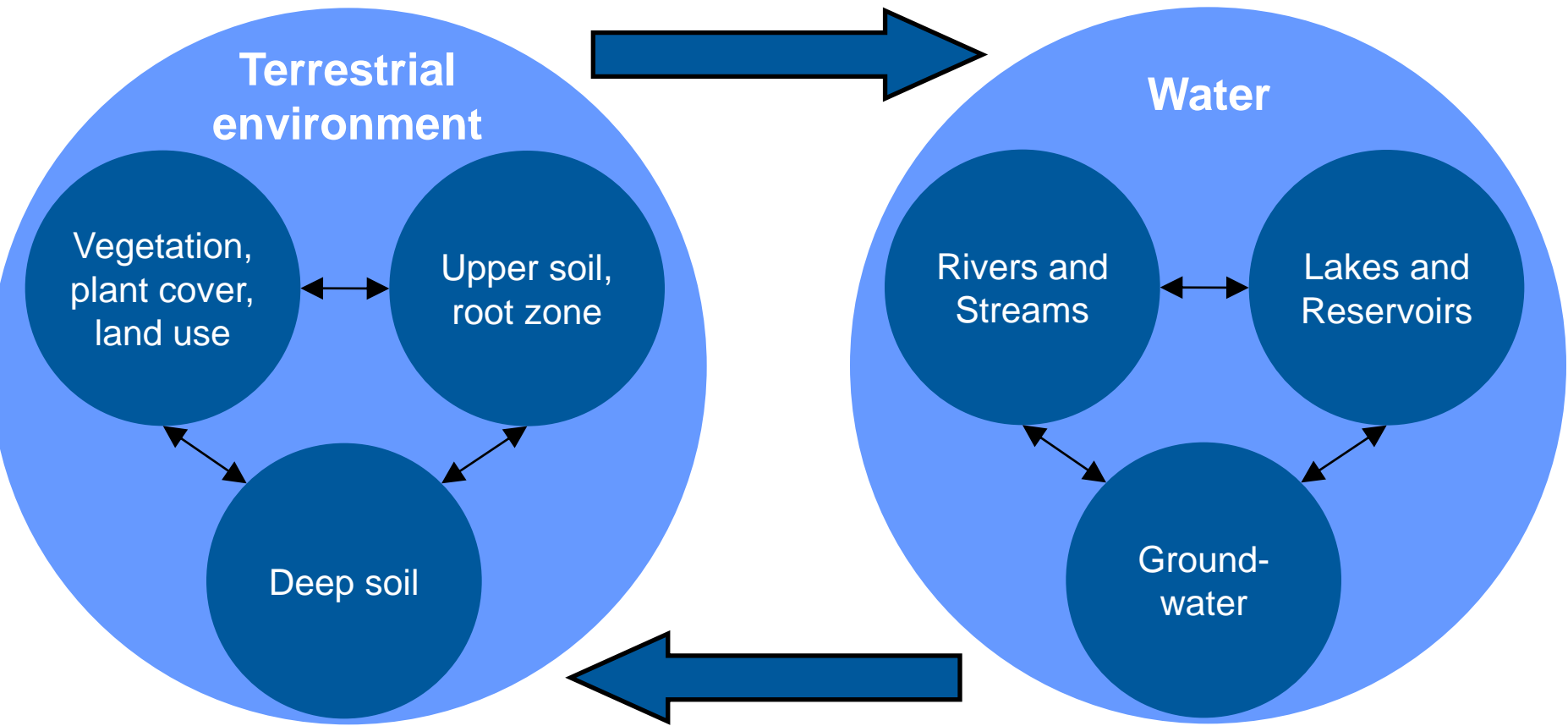
Muldenberg Reservoir (Saxony)

Year	Inflow t DOC	Outflow t DOC	Breakdown rel.
2008	35	23	0.35
2009	85	59	0.31



chemostat picture

Flux of dissolved organic carbon at the catchment scale



Flux of dissolved organic carbon at the catchment scale

Potential Work packages and activities

a) Sources, transport and processing of DOC within the catchment

- DOC in surface waters
- DOC mobilisation in the soil
- Measurement of DOC dynamics
- Age of DOC
- Exploration of systems
- Modelling of DOC-fluxes in catchments
- Microbial processing of DOC

b) Influence of global change on DOC dynamics

- Increase of temperature
- Change of pH in precipitation
- Hydrological Extremes
- Landuse change
- Ecosystem functioning
- C-Budget at the catchment scale

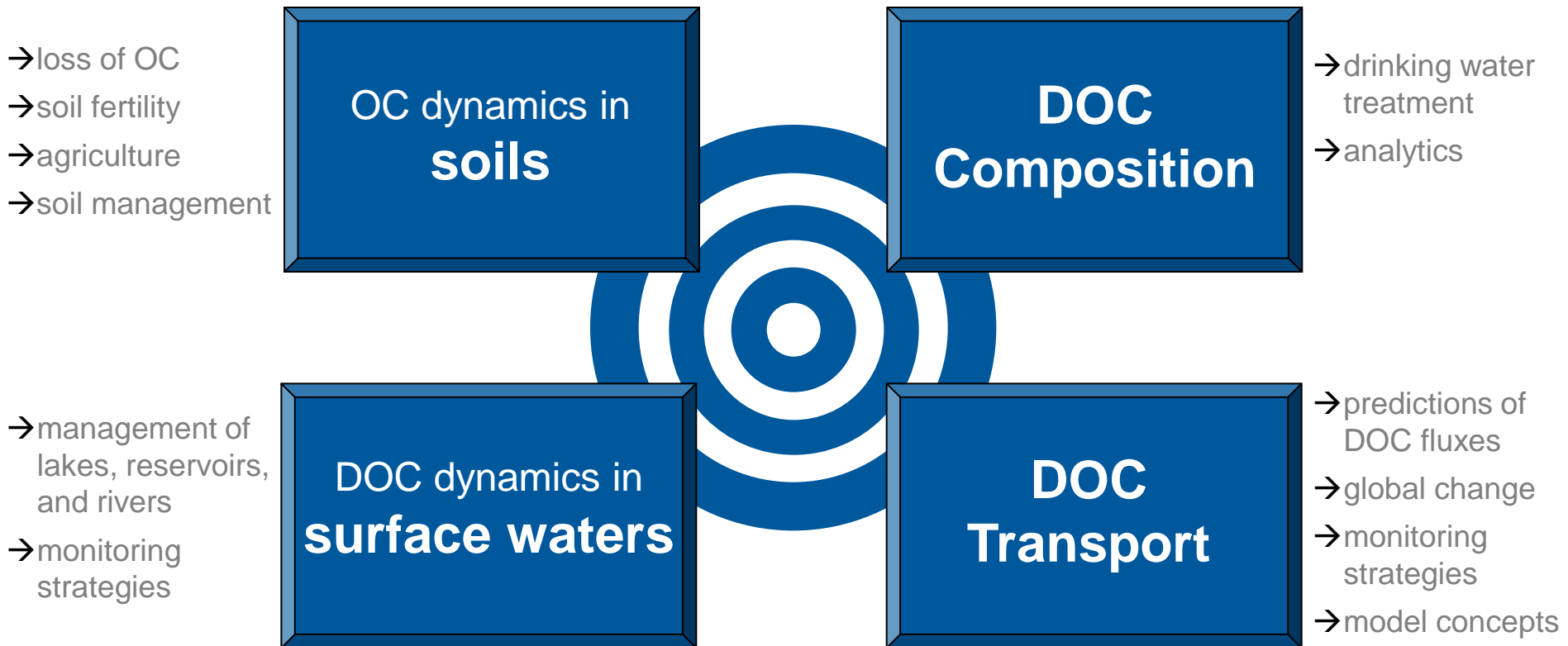
c) Management

- Landuse structure at the catchment scale
- Optimization of internal processes in the water bodies
- Technical developments in drinking water treatment
- Cost-Use-Calculations
- By-products and health hazards, acceptance of colored water
- Use conflicts (bog renaturation, flood control, ...)

Organisational setting of the work package

“Sources, transport, and processing of DOC within the catchment”

Interfaces to scientific challenges or economic relevance



„Flux of dissolved organic carbon on the catchment scale“

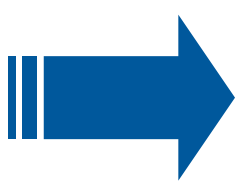
2 – Research Hypothesis

Research Hypotheses

- o Soluble C transport from terrestrial environments represents a substantial component of the ecosystem carbon balance in northern latitudes
- o An increase in temperature (2 K) leads to higher DOC (N,P,...) loads in surface water system
- o Reduced acidic atmospheric deposition entirely explains the increase in DOC concentrations
- o DOC quality differs between different hydrological situations
- o Areal DOC export from soils depend strongly on land use
- o Ecological processing of DOC depends on nutrient stoichiometry

Summary

- Steigende DOC-Konzentrationen sind ein globales Phänomen
- Relevanz: Trinkwasserbereitstellung aus Talsperren, Kohlenstoffzyklus
- Starker Einfluss der Hydrologie
- Hohe Dynamik erfordert räumlich-zeitliche hochauflösendes Monitoring
- Prozessierung im aquatischen Ökosystem ist wichtig
- Zusammensetzung des DOC (chemisch, isotopen-Signatur) variabel

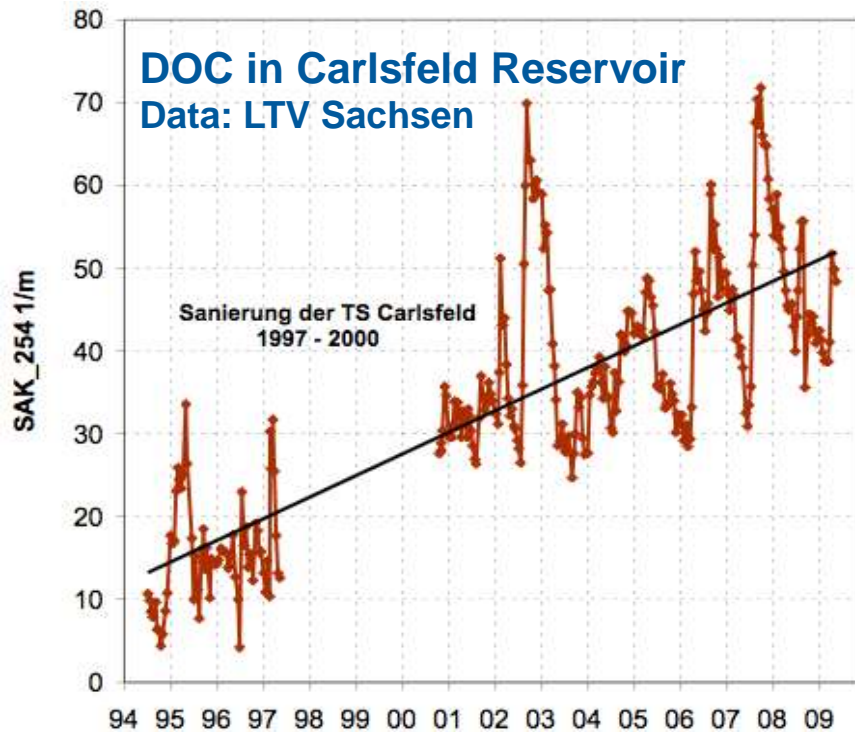


**Thema verlangt disziplin-
übergreifenden Ansatz und ein
umfassendes Monitoring**

Photo: André Künzelmann (UFZ)



Reservoirs & DOC

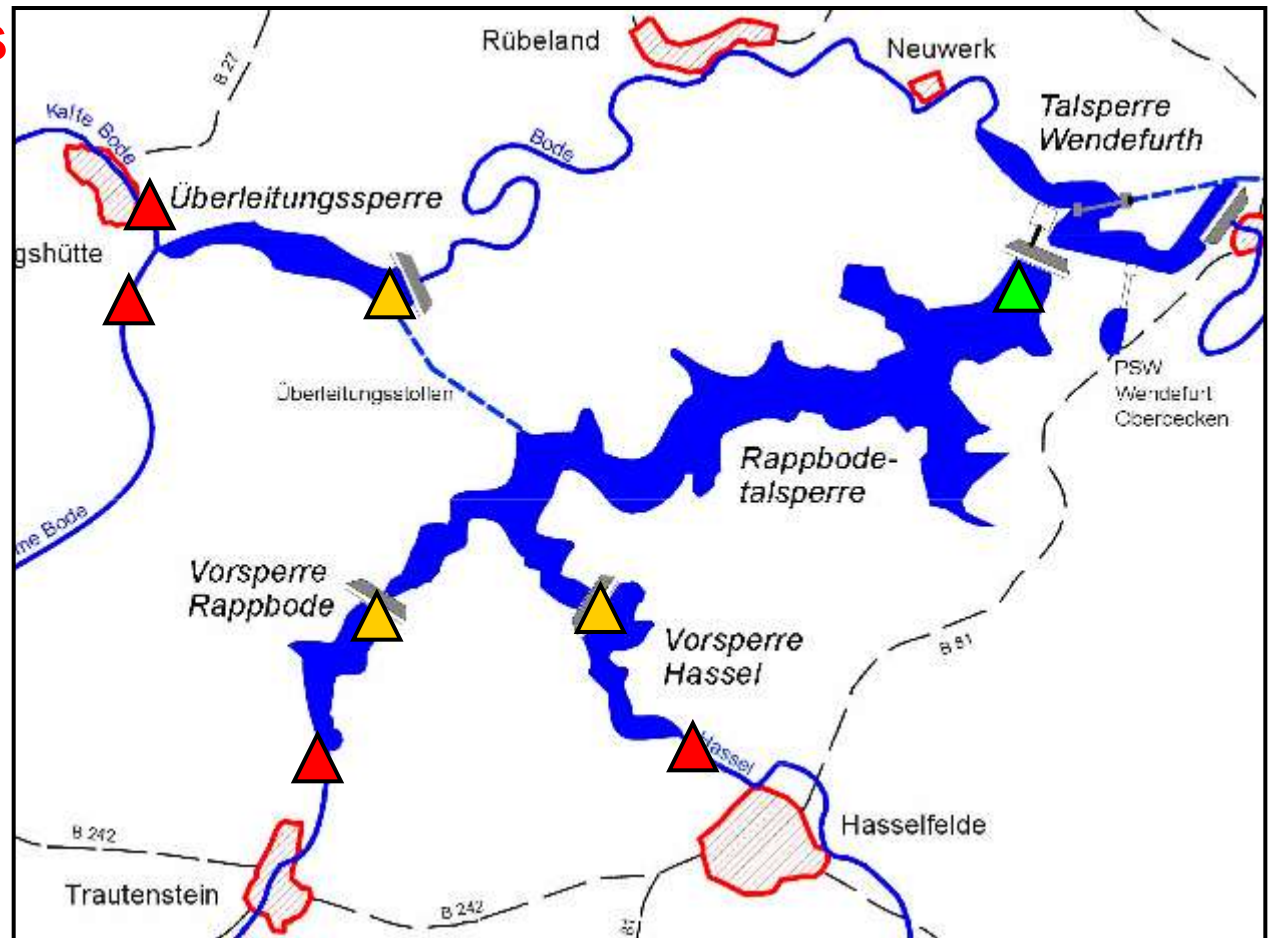


The Rappbode Reservoir Observatory

▲ 4 inflow stations

▲ 3 connecting stations

▲ 1 offshore station



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The Rappbode Reservoir Observatory

- located at Rappbode reservoir (Harz Mountains, Germany)
- monitoring of ecosystem dynamics
- continuous monitoring of nutrient and carbon fluxes

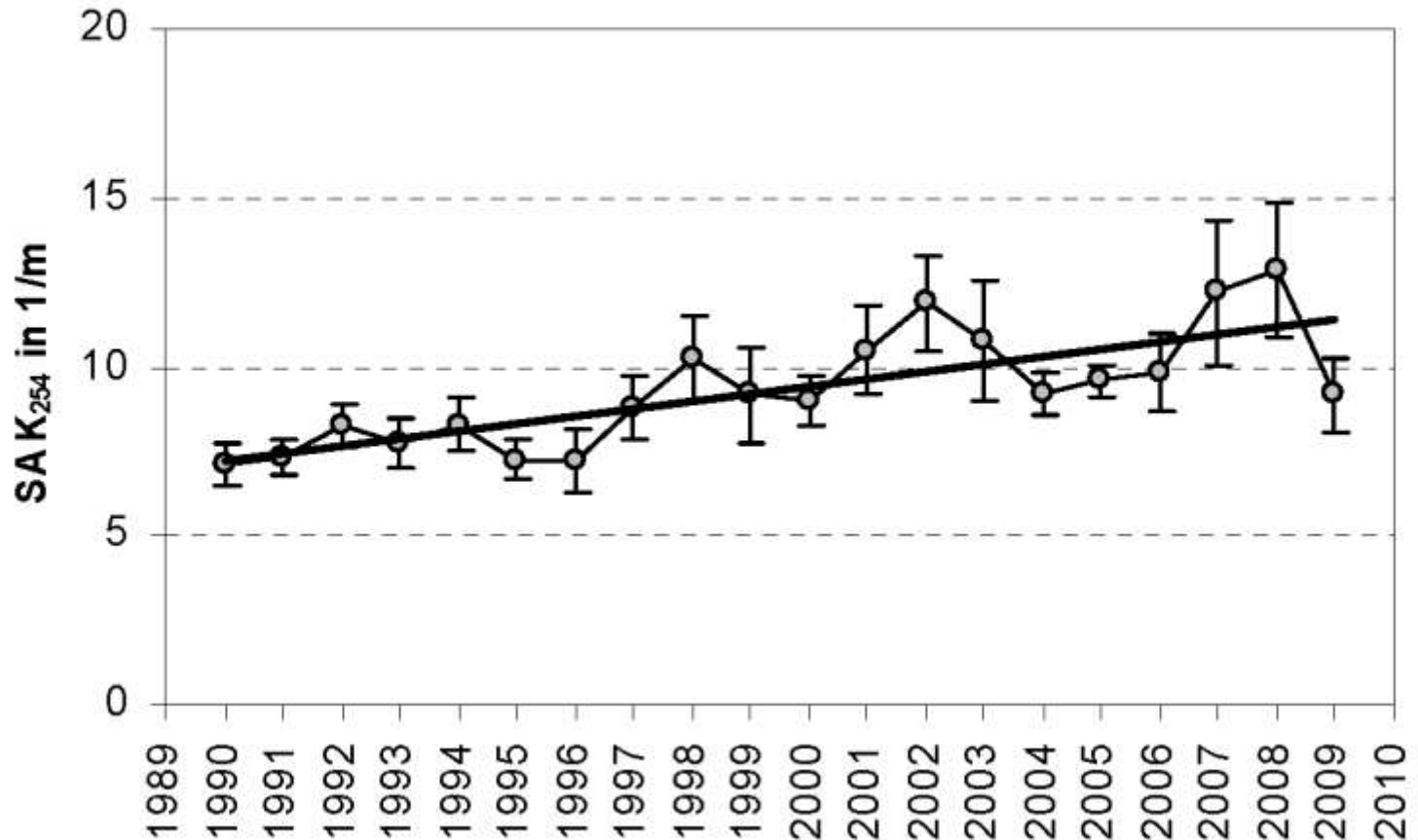


Rappbode Reservoir

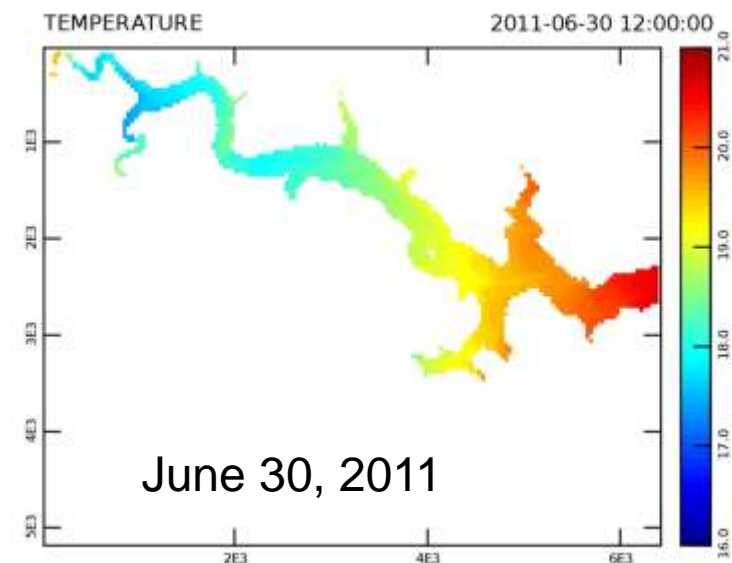
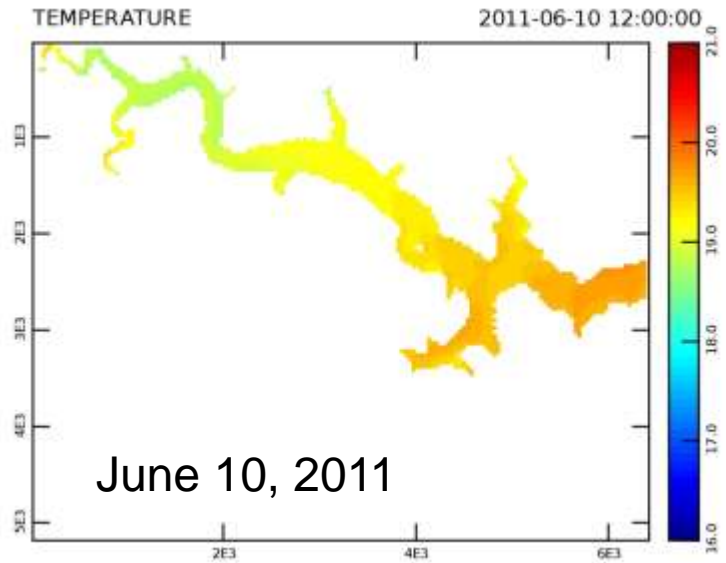
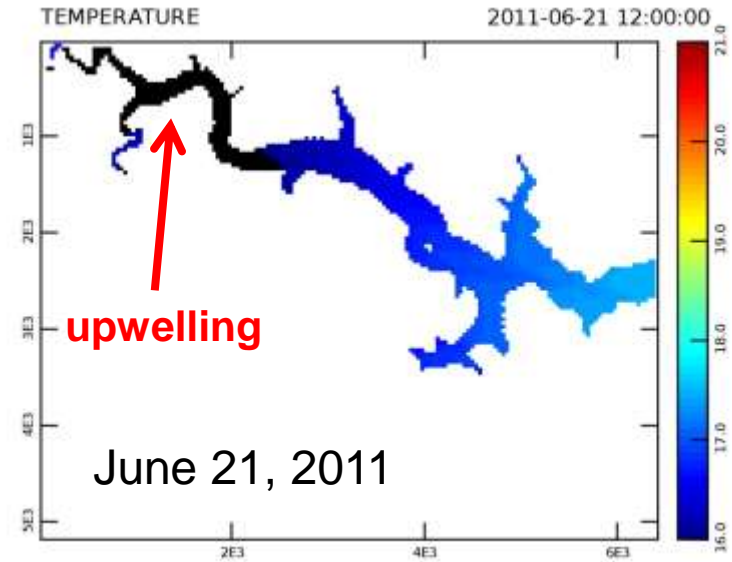
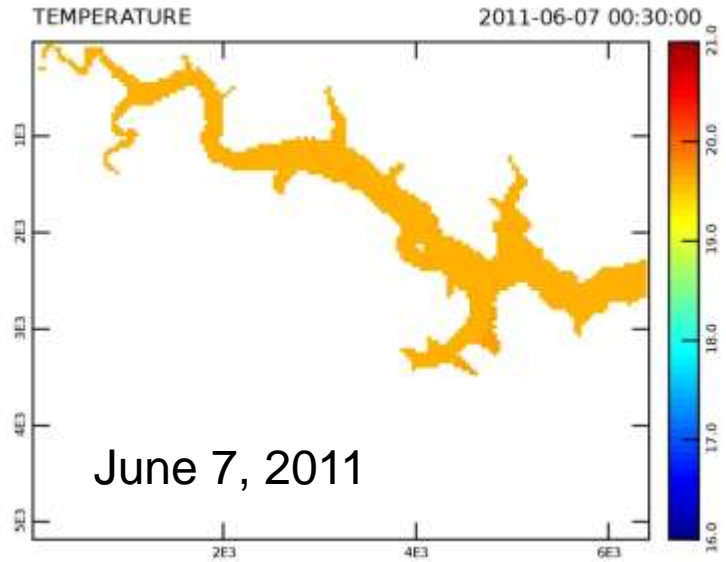
- One main reservoir and 3 pre-dams
- Drinking water supply for over 1 Mio people
- Surface area: 395 ha
- Volume: 113 Mio m³
- Max. depth: 89 m
- mesotrophic

DOC trends in the Rappbode Reservoir

SAK₂₅₄ - Jahresmittelwerte 1990-2009



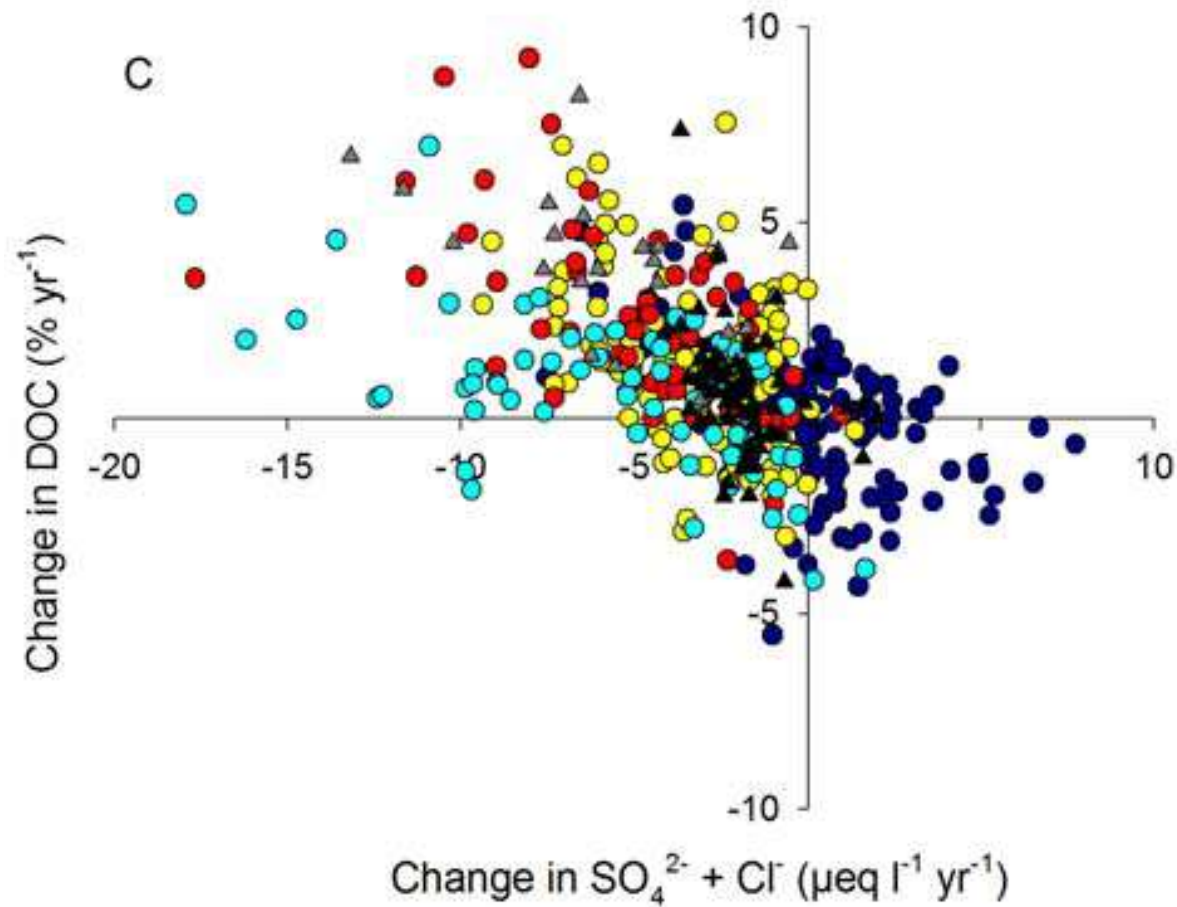
Aims of the reservoir observatory



Next steps in our DOC Research

- Breakdown of DOC: experimental testing of hypotheses about controlling factors (phosphorus supply, light exposure, the role of sediments,...)
- Modelling of DOC mobilisation and transport within the catchment → *interaction with Jan Fleckenstein*
- Projecting DOC import into surface waters based on predictions about future hydrological regimes → *interaction with Luis Samaniego*
- Determining the quality of DOC from various sources and the effect of hydrological regimes and microbial processing on DOC quality → *interaction with Thorsten Reemtsma*

Reduced acidic atmospheric depositions initiated DOC release?



Monteith et al 2007

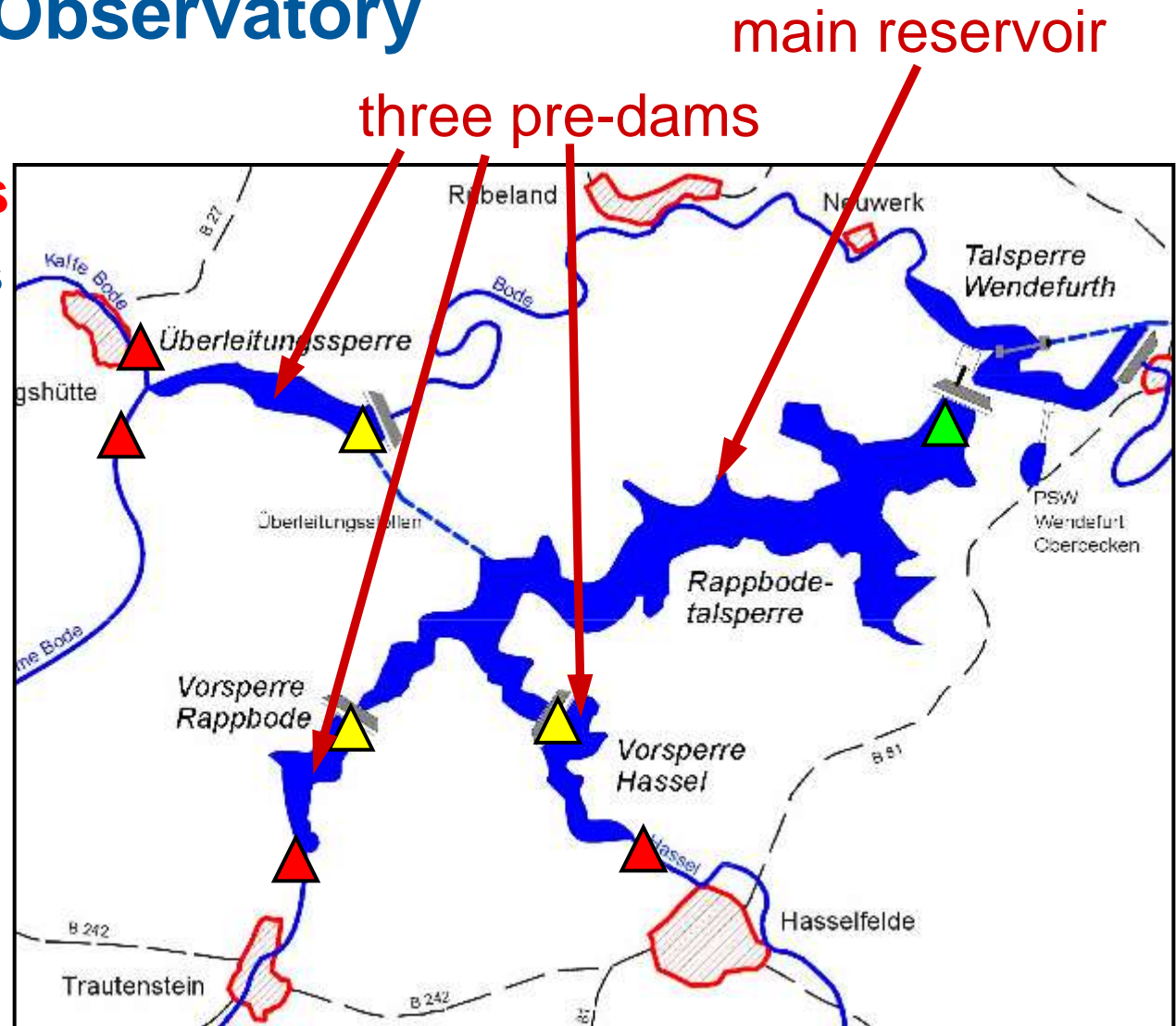
The Rappbode Reservoir Observatory

▲ 4 inflow stations

Real-time & continuous measurement of

- temperature
- conductivity
- turbidity
- nitrate
- DOC

and event-dependent water sampling by automated water samplers



Talsperrenbetrieb Sachsen-Anhalt

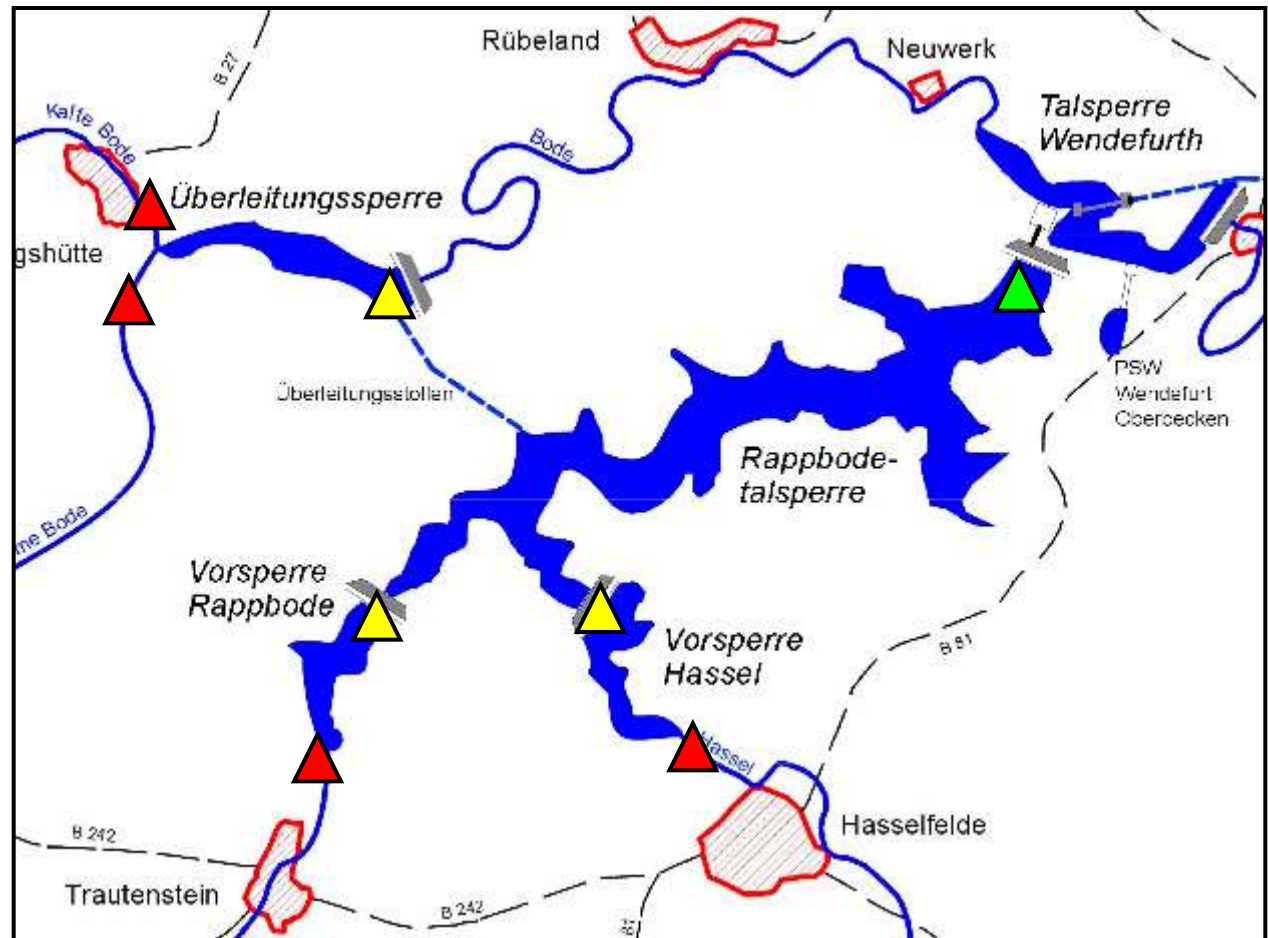
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The Rappbode Reservoir Observatory

▲ 3 connecting stations

Real-time & continuous measurement of

- temperature
- conductivity
- turbidity
- nitrate
- DOC
- oxygen
- chlorophyll



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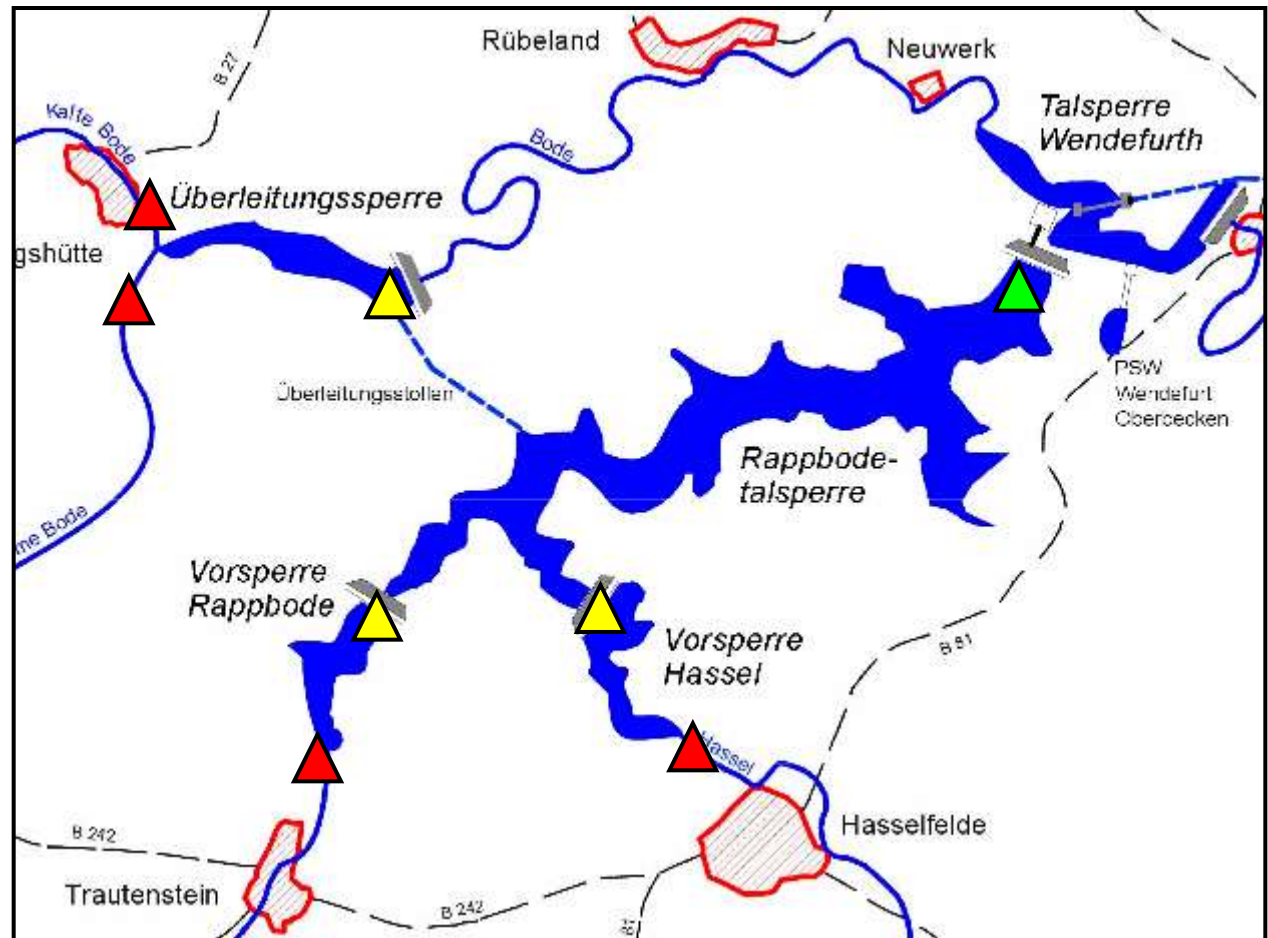
The Rappbode Reservoir Observatory

▲ 1 offshore station

Meteorological buoy
(wind, temperature,
humidity, radiation)

Real-time & continuous
measurement of

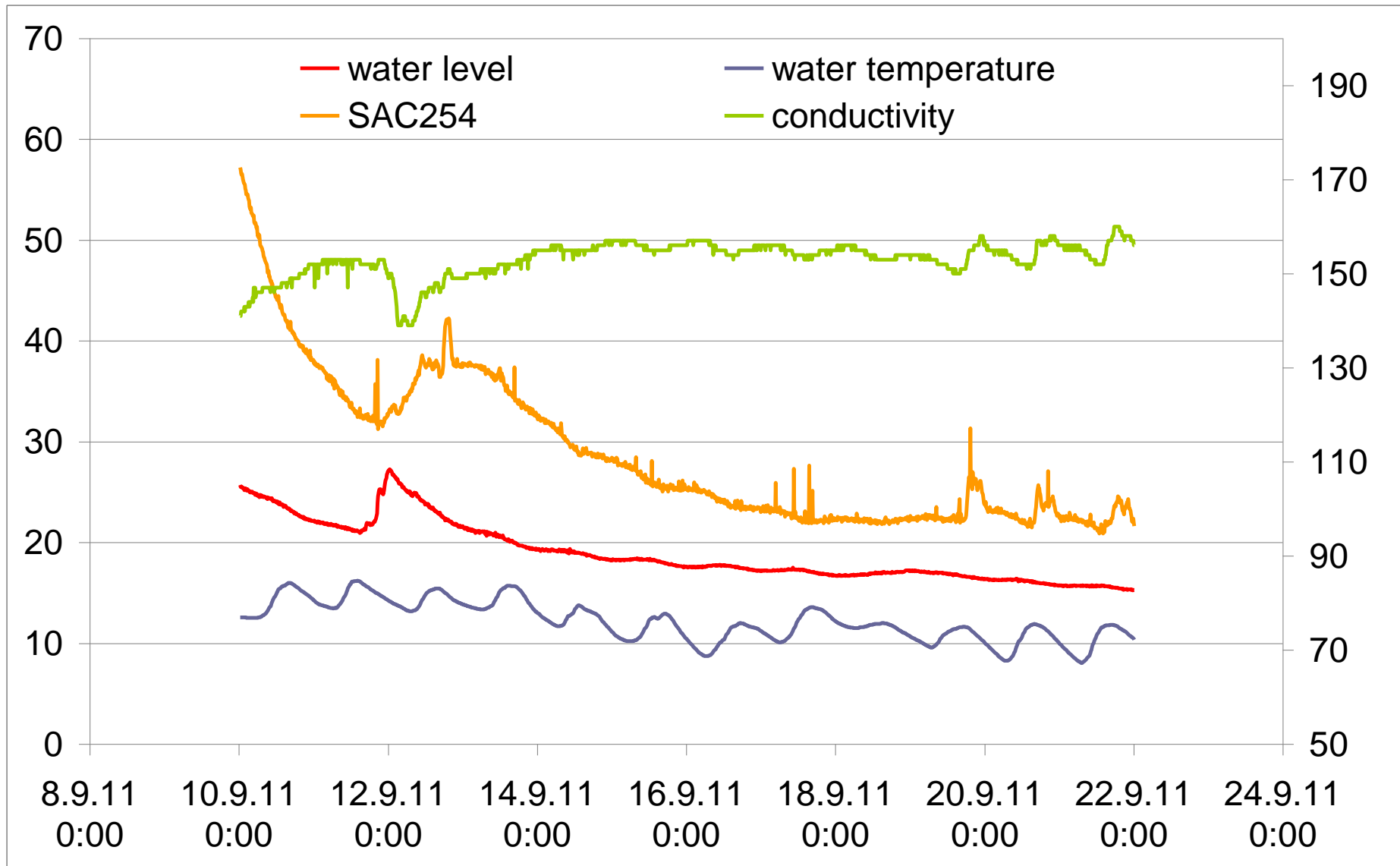
- temperature
- conductivity
- turbidity
- nitrate
- DOC
- oxygen
- chlorophyll



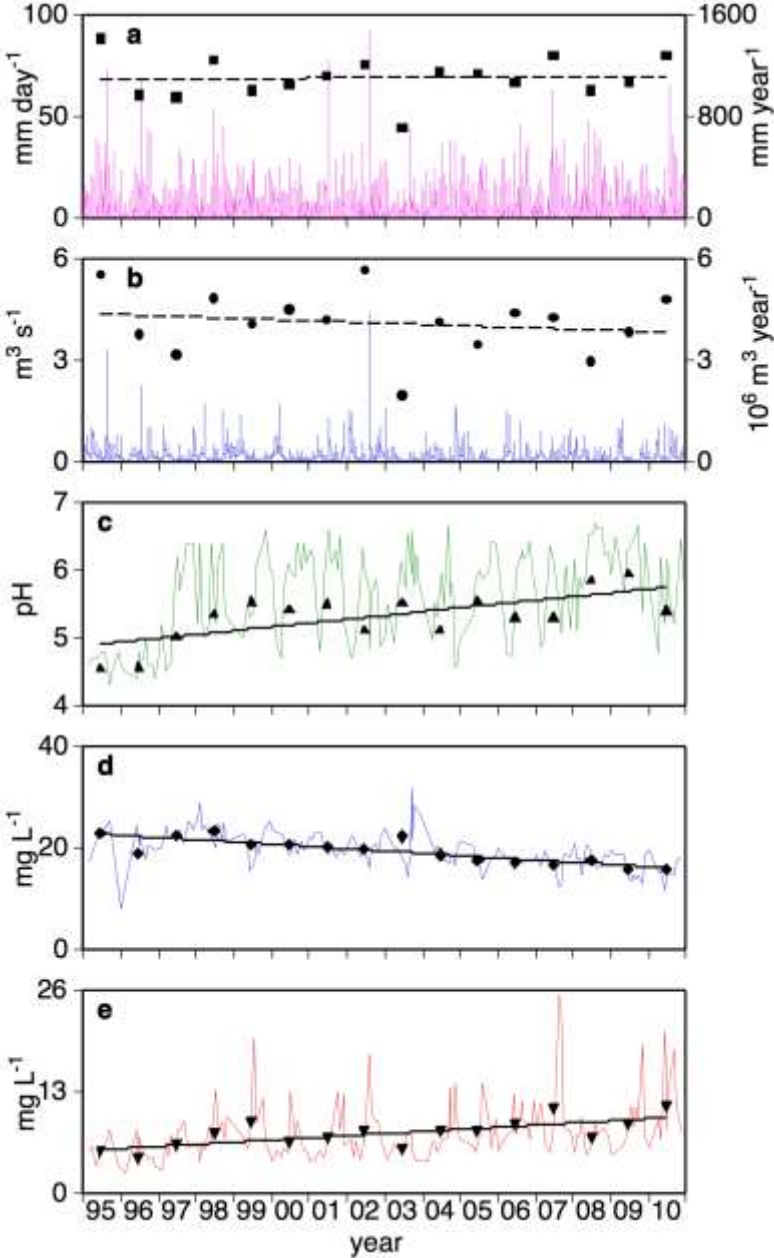
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Example: Warne Bode 10-22. Sept. 2011



Rote Mulde 1995 - 2010



Precipitation
n.s.

Discharge
n.s.

Proton
concentration
 $P = 0.017$

Sulfate
 $P < 0.001$

DOC
 $P = 0.003$

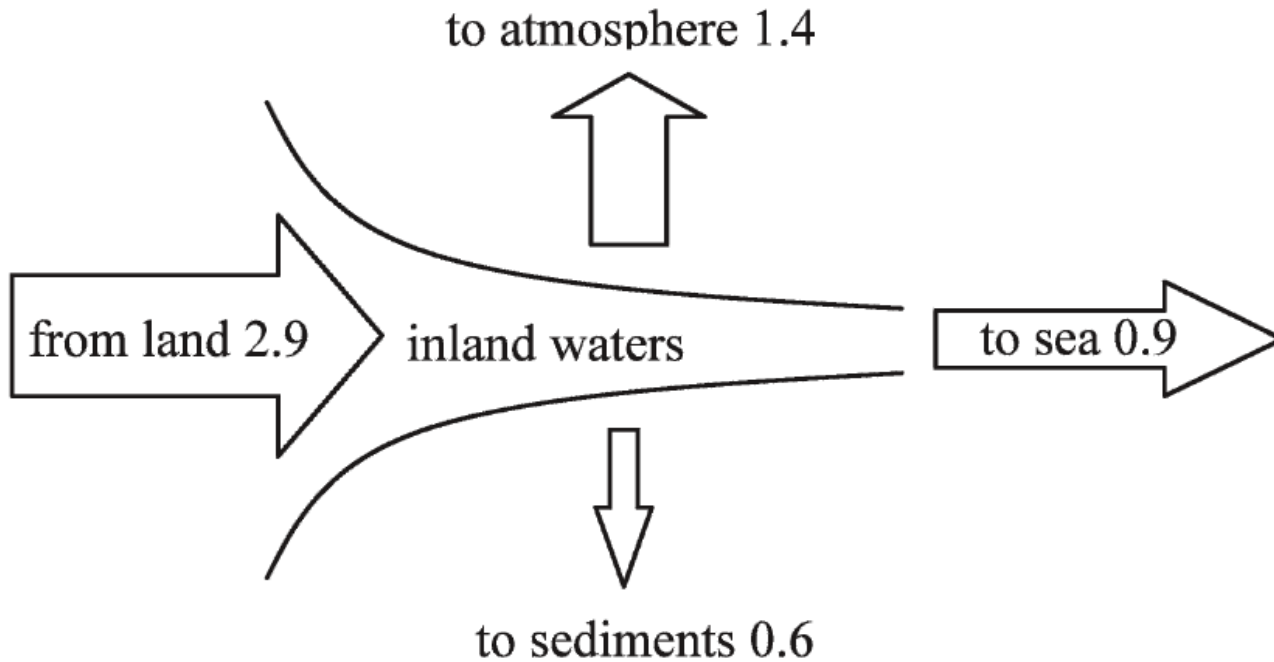
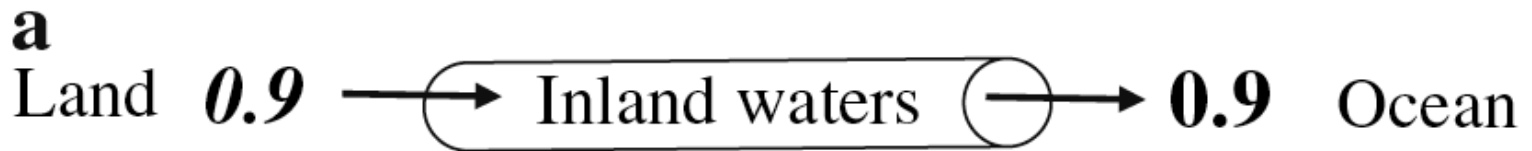
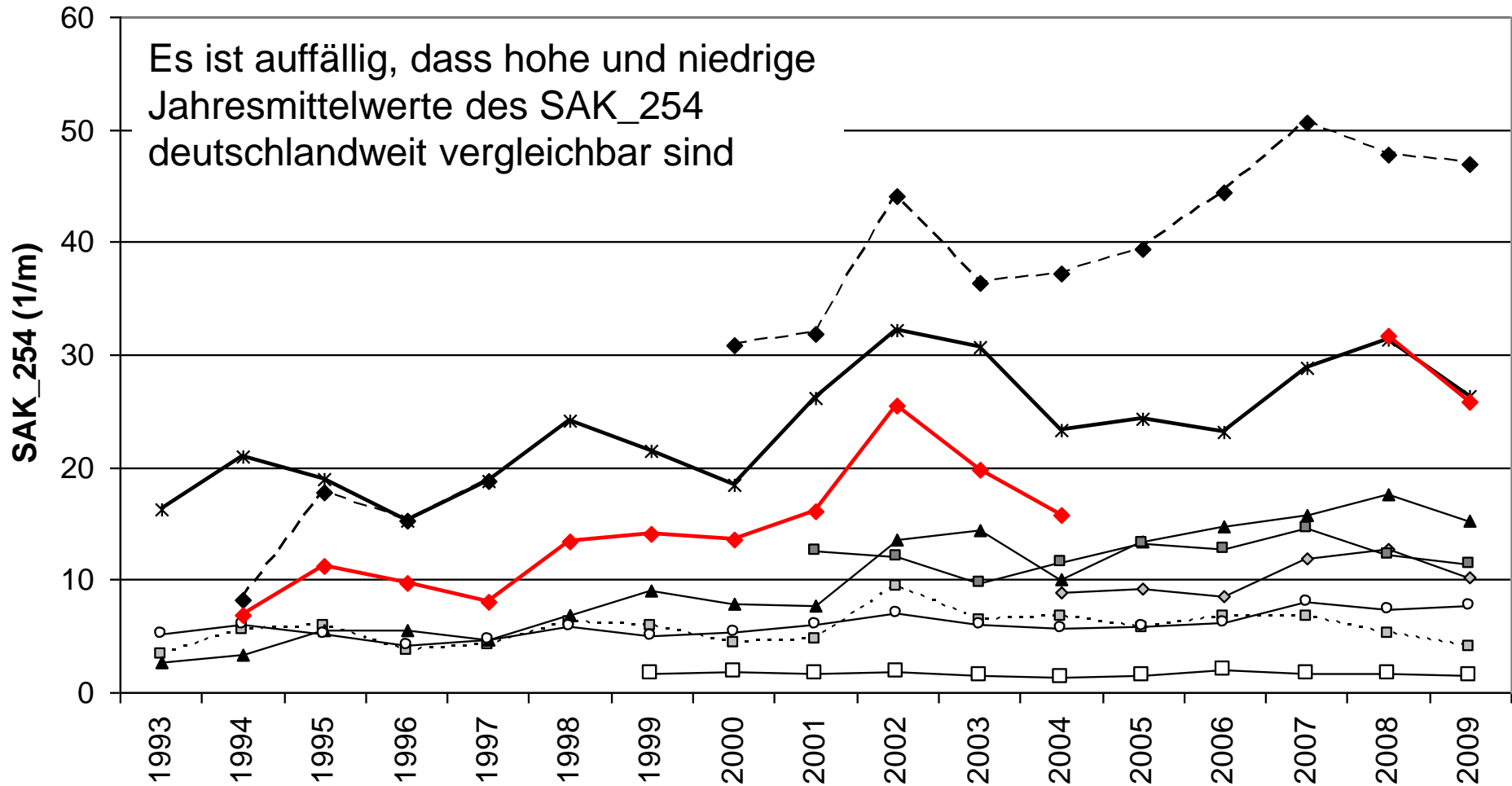


Fig. 5. Revision of the ‘active pipe’ hypothesis advanced by Cole et al. (2007). Revised values are explained in the text and represent annual transport of carbon (Pg, 10^{15} g).

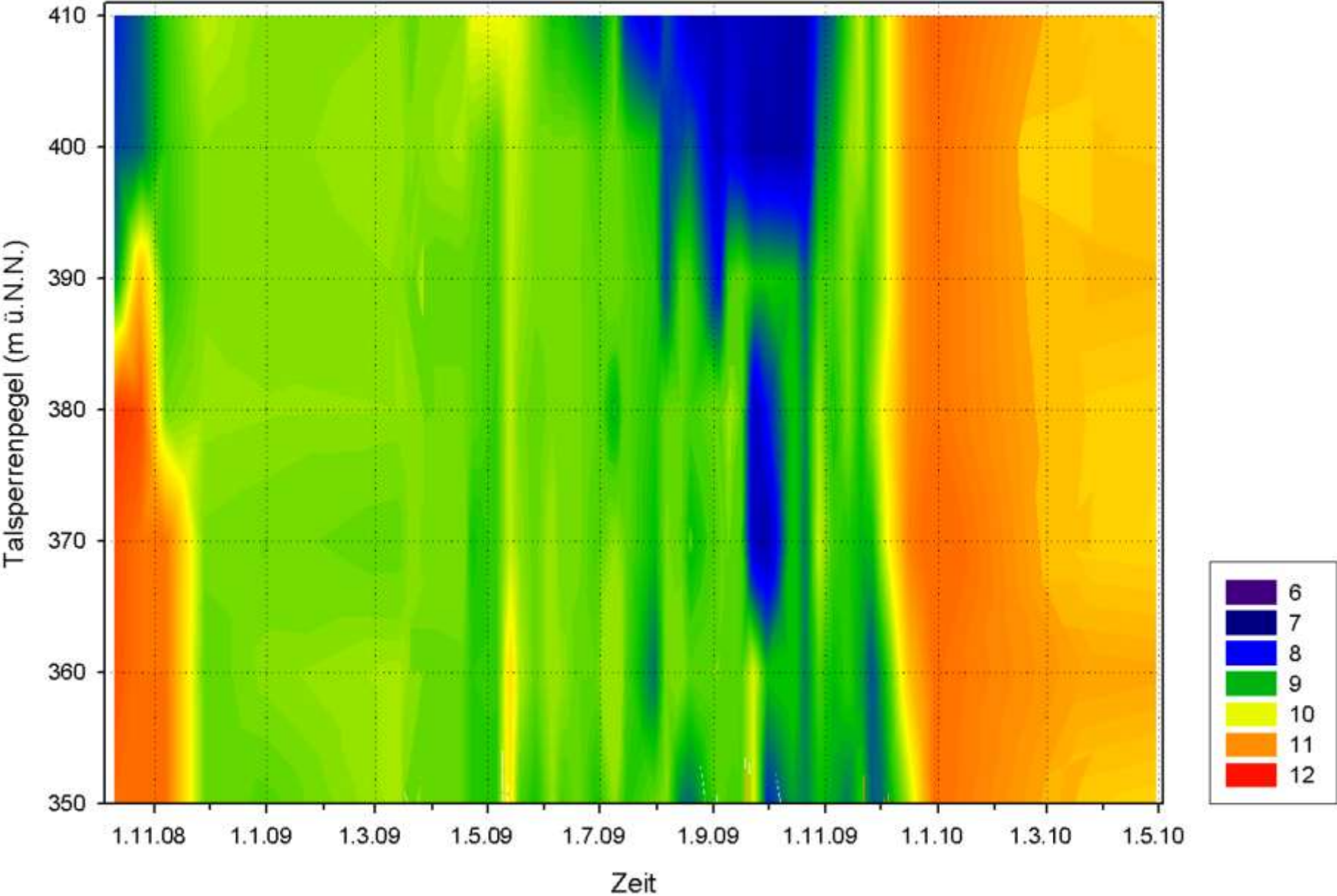
Jahresmittelwert SAK_254 (1/m)

Es ist auffällig, dass hohe und niedrige Jahresmittelwerte des SAK_254 deutschlandweit vergleichbar sind

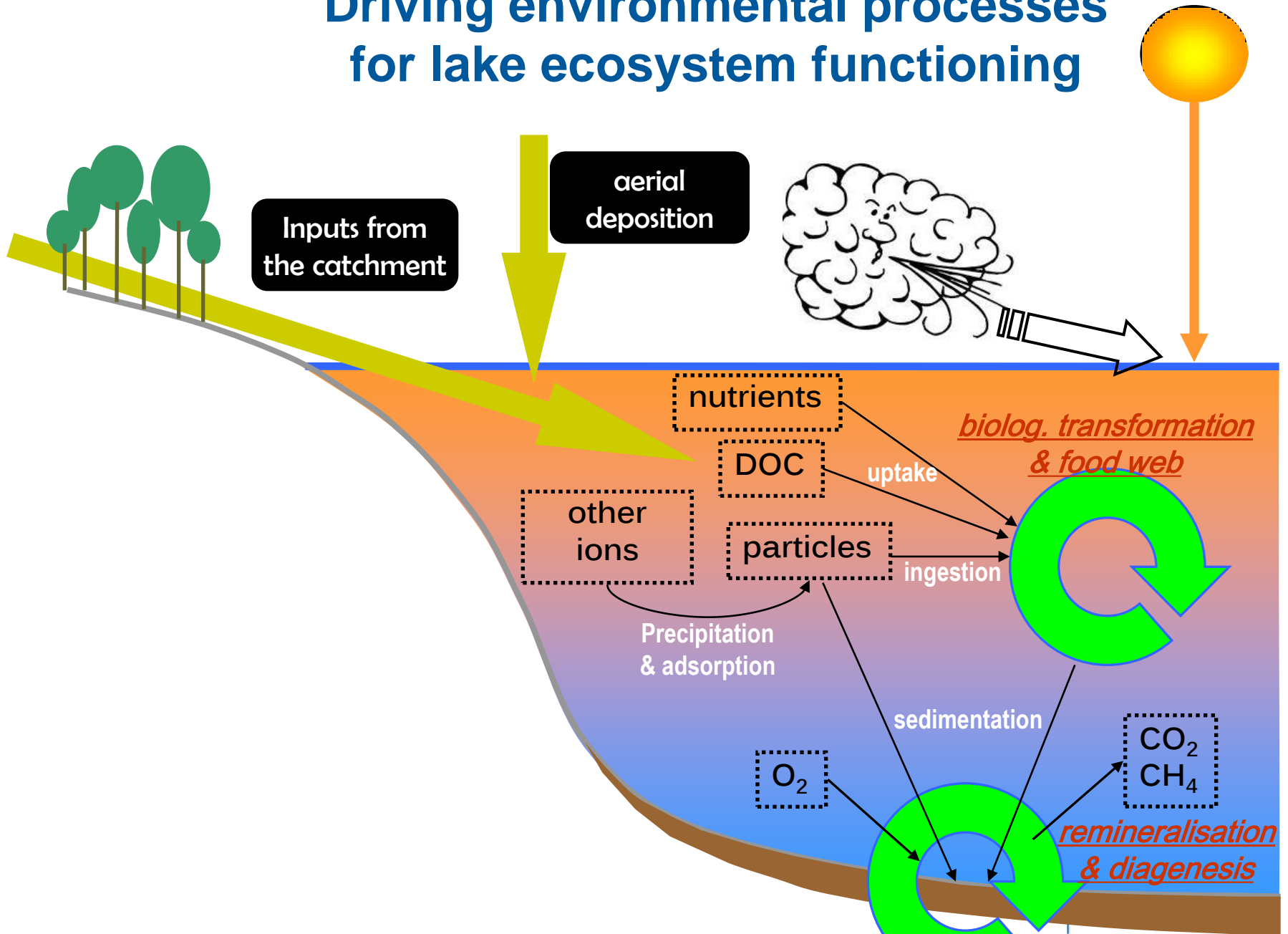


- ◇— Aabachtalsperre (NW)
- *— Eckertalsperre (NI)
- ◆— TS Muldenberg (SN)
- Kleine Kinzig (BW)
- Sösetalsperre (NI)
- TS Ohra (TH)
- ▲— TS Eibenstock (SN)
- ◆— TS Carlsfeld (SN)
- DreilägerbTS (NW)

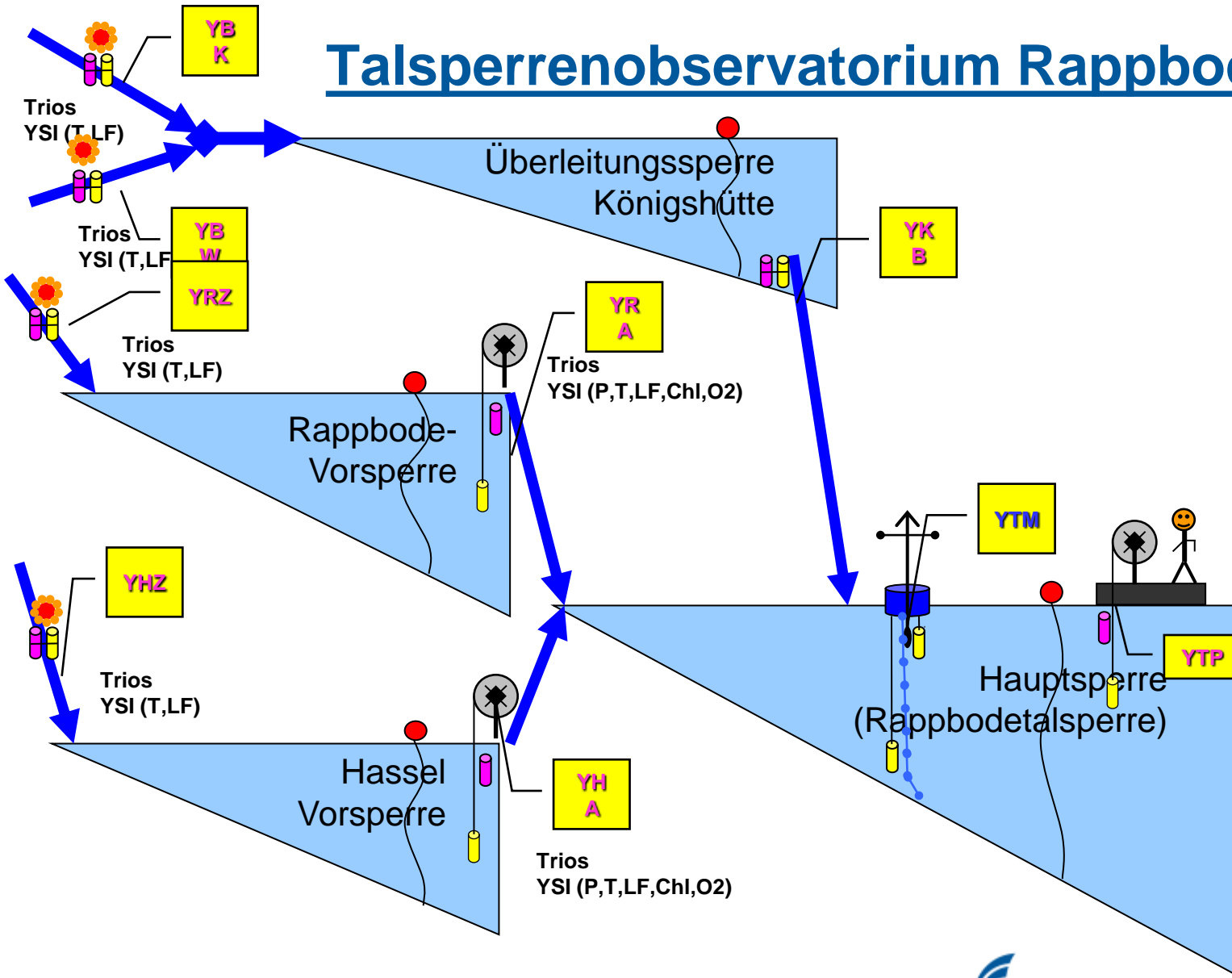
DOC in the Rappbode Reservoir











Driving environmental processes for lake ecosystem functioning



Talsperrenobservatorium Rappbode



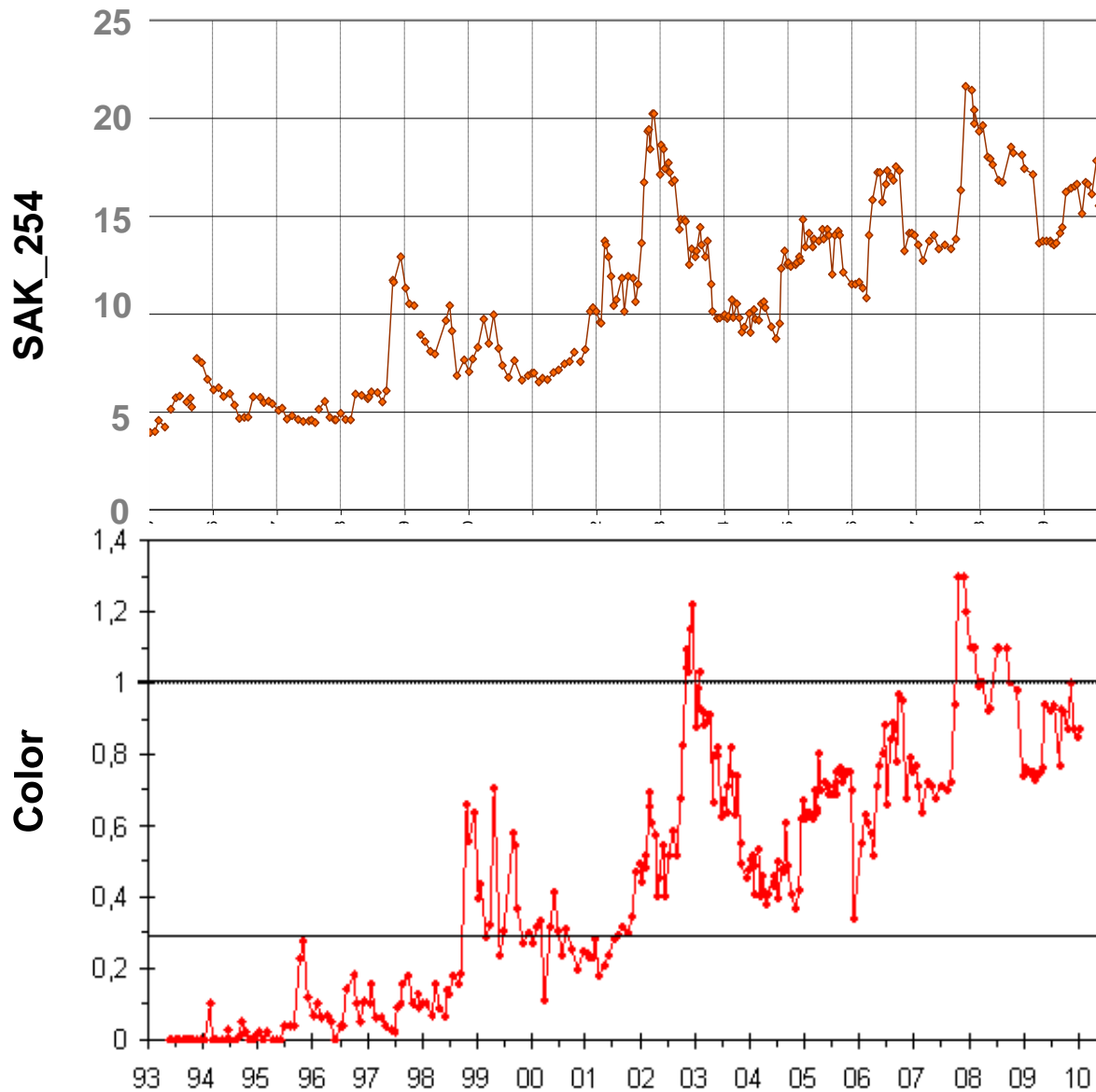
	TRIOS-Sonde		Profilier		Boje für Probenahme		Datenfernübertragung
	YSI-Sonde		Autosampler		Meteo-Boje		Probenahmepunkt



Austrag nach Sommer- Starkregen

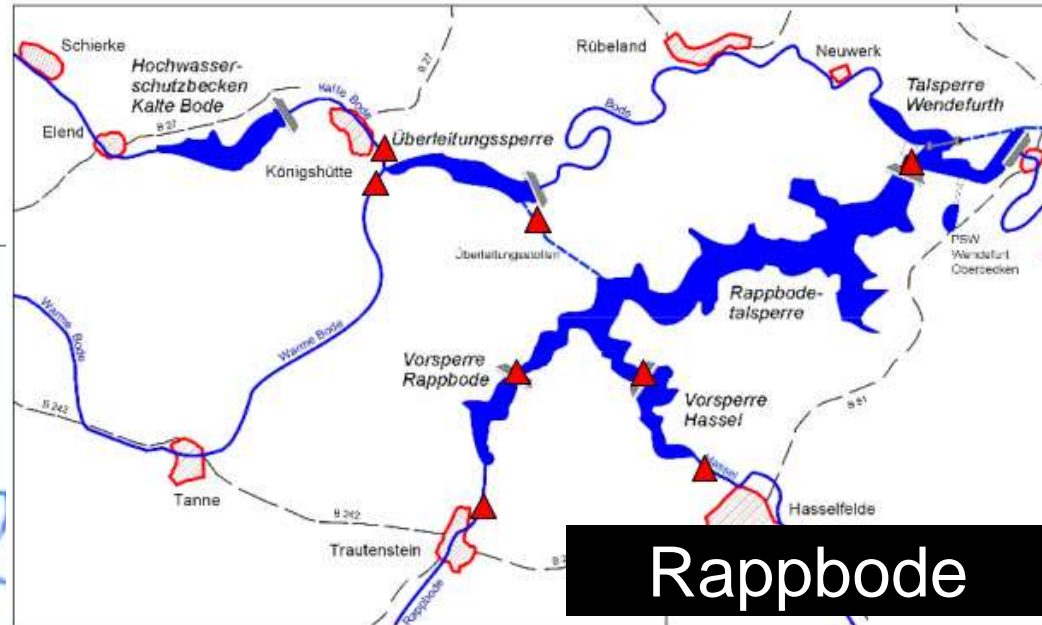
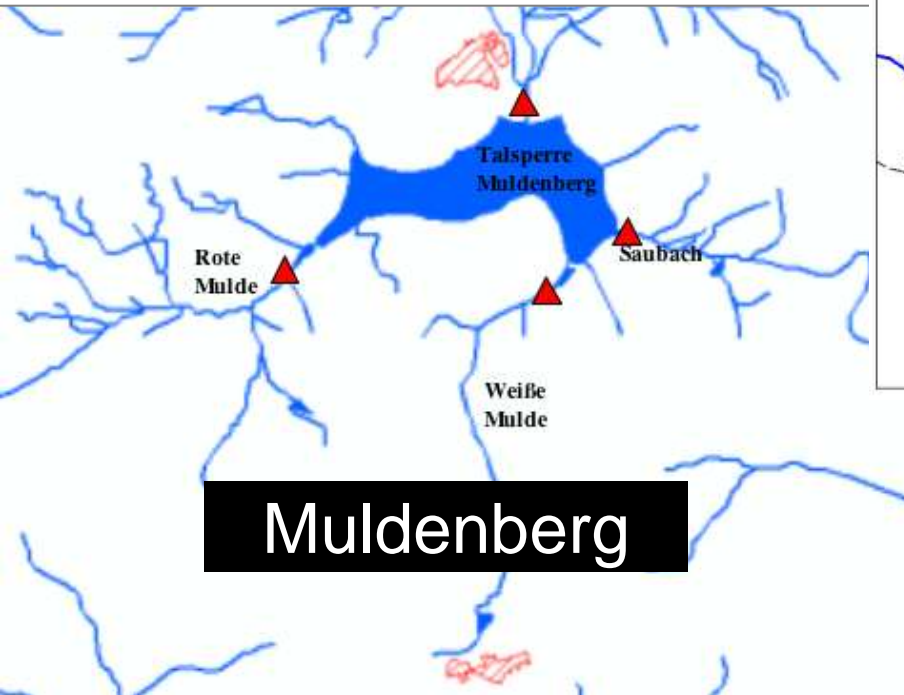


Eibenstock Reservoir 1993-2010

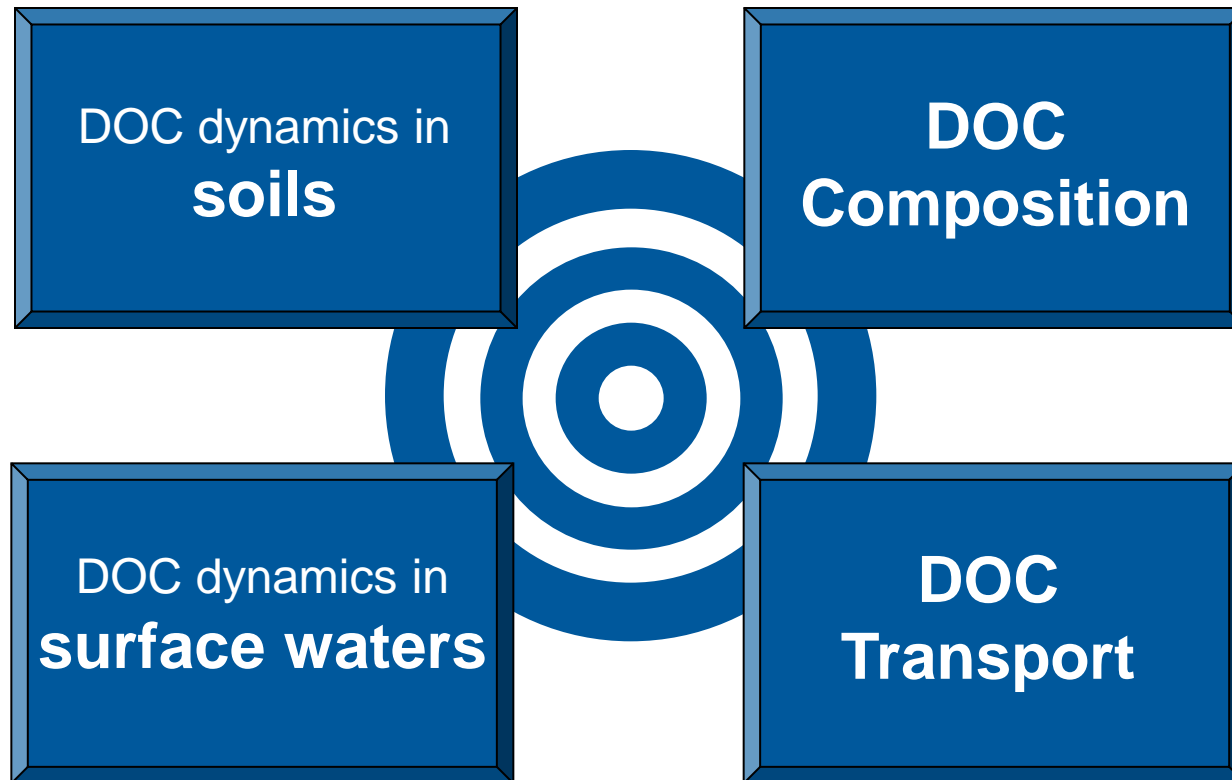


Data:
Landestalsperrenverwaltung
des Freistaates Sachsen

Study sites



Expert Pools



Activity: DOC in drinking water reservoirs

Assessing the carbon dynamics in reservoirs

chemical characterization of DOC

Interference of DOC with technical systems

Microbial processing of DOC in lakes & reservoirs

Activity: DOC in drinking water reservoirs

Assessing the carbon dynamics in reservoirs

- monitoring DOC fluxes and concentrations
- carbon budget
- modelling of DOC dynamics
- age of DOC

chemical characterization of DOC

- development of methods for assessing DOC quality
- elemental composition
- fluorescence behaviour

Interference of DOC with technical systems

- formation of carcinogenic by-products during chlorination
- interference with flocculation

Microbial processing of DOC in lakes & reservoirs

- controlling environmental factors of breakdown of DOC
- bacterial communities and diversity & DOC processing
- Effect of microbial processing on DOC composition

Activity: DOC in drinking water reservoirs

Assessing the carbon dynamics in reservoirs

J. Tittel	50%	SEFO
M. Schultze	50%	SEFO
O. Büttner	10%	ASAM

chemical characterization of DOC

N.N.	40%	ANA
P. Herzprung	40%	SEFO
W. v. Tümpling	10%	FLOEK

Interference of DOC with technical systems

P. Herzprung	40%	SEFO
W. v. Tümpling	10%	FLOEK

Microbial processing of DOC in lakes & reservoirs

A. Chatzinotas	25%	UMB
J. Tittel	25%	SEFO
K. Wendt-Potthoff	25%	SEFO
N. Kamjunke	10%	FLOEK