Hydrochemie und Tracermethoden

Markus Weiler

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Inhalt

- Einführung
- Künstliche Tracer
  - Grundlagen
  - Salze
  - Fluoreszenzfarbstoffe
  - Versuchsdurchführung
  - **Anwendungen**

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Anwendungen

- Hanghydrologie
- Seen
- Gletscher (Thomas Schuler)
- Hyporeisches Interstezial - Bäche
- Fliessmuster im Boden (Sophie Bachmair)
- Künstliches Feuchtgebiet (Tobias Schütz)
- Temperatur (Bach und Feuchtgebiet)

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Set up for sprinkling experiments in Alptal, CH

Area: 60-70m²

Rainfall Intensity: 50 mm/h – 100 mm/h

Measurement of water content, matric potential and water table

Trench, 5 m wide

Measurement of overland flow and subsurface flow

Site description

- Two steep hillslopes of 17° and 25°
- Grassland and Forest
- Located in the pre-alpine Swiss research basin Vogelbach, Alptal
- Two extreme rainfall events of 60 and 100 mm/h were artificially simulated at each of the two sites

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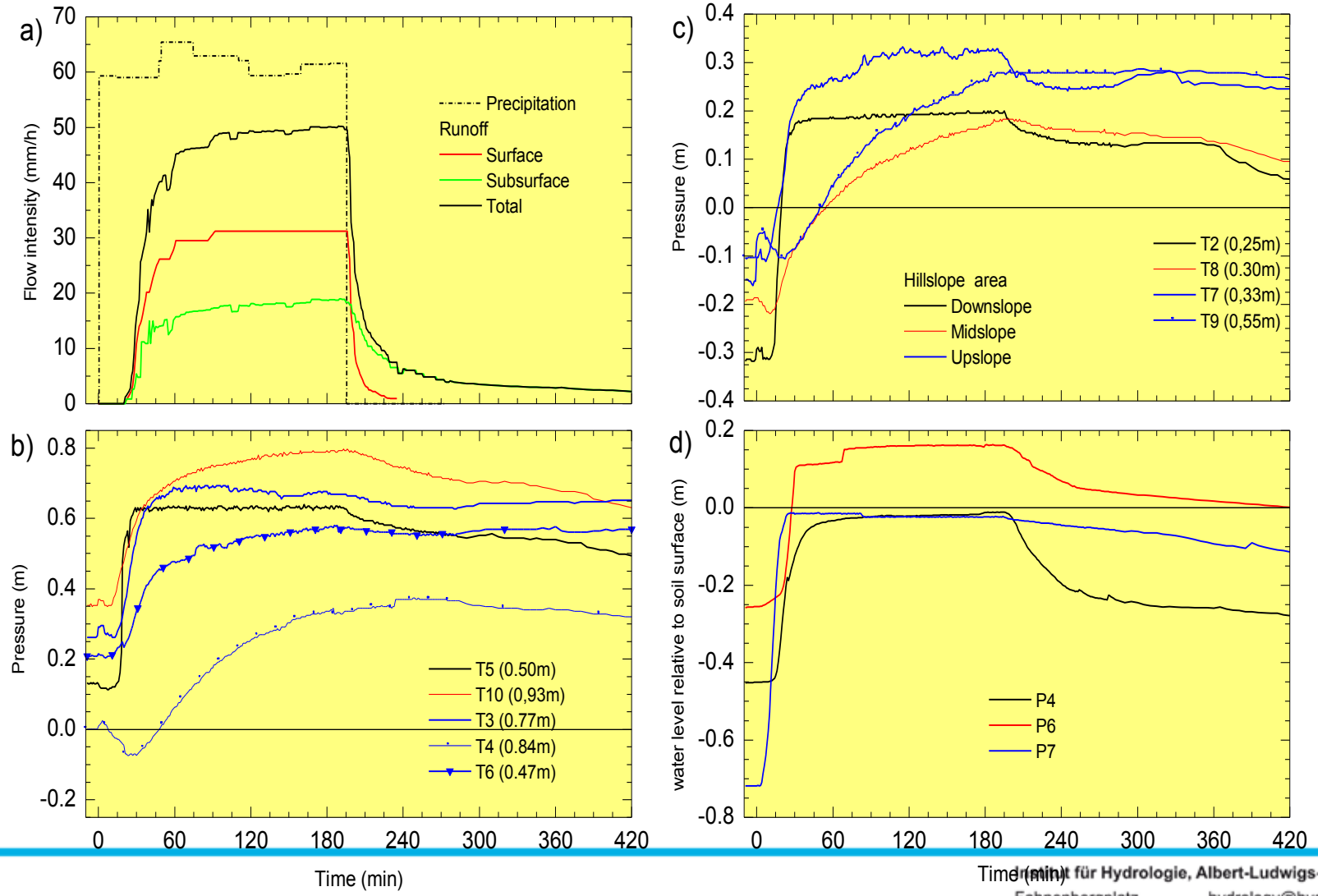
Hillslope experiment – Measurements



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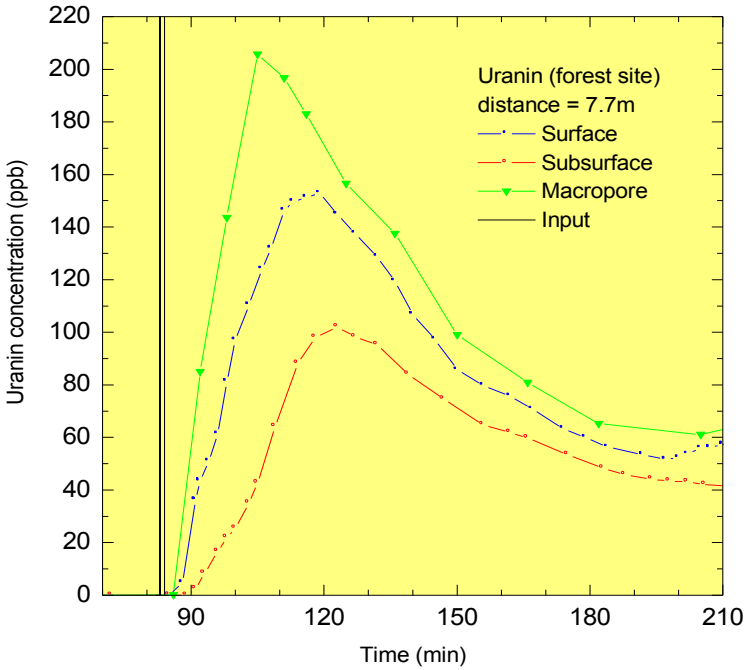
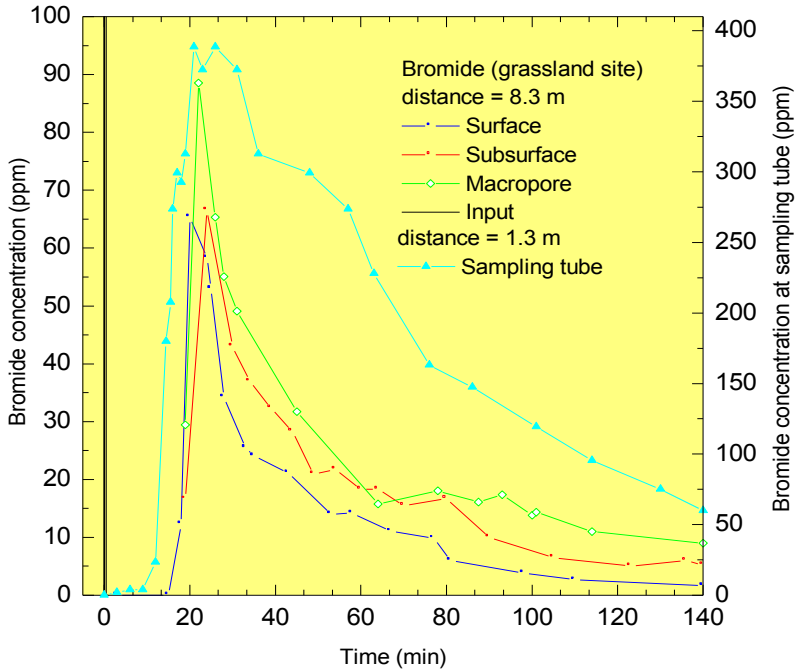
Tracer Experiments

- Tracer experiments with fluorescein (Uranin) at the forest site (steady state, near surface point source)
- Tracer Tracer experiments with bromide (NaBr) at the grassland site (near surface line source





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Analysis of the tracer experiments

- Fit to the tracer breakthrough curves obtained from surface and subsurface runoff components, sampling tubes and single macropores in the pit.
- Transport models:
  - Convection-Dispersion-Model (CDM)
  - Transfer-Function-Model (TFM)
  - Single-Fissure-Dispersion-Model (SFDM)
  - Mobile-Immobile-Water-Model (MIM)

Selection of one transport model for each breakthrough curve based on goodness-of-fit and the physical plausibility of the transport parameter.

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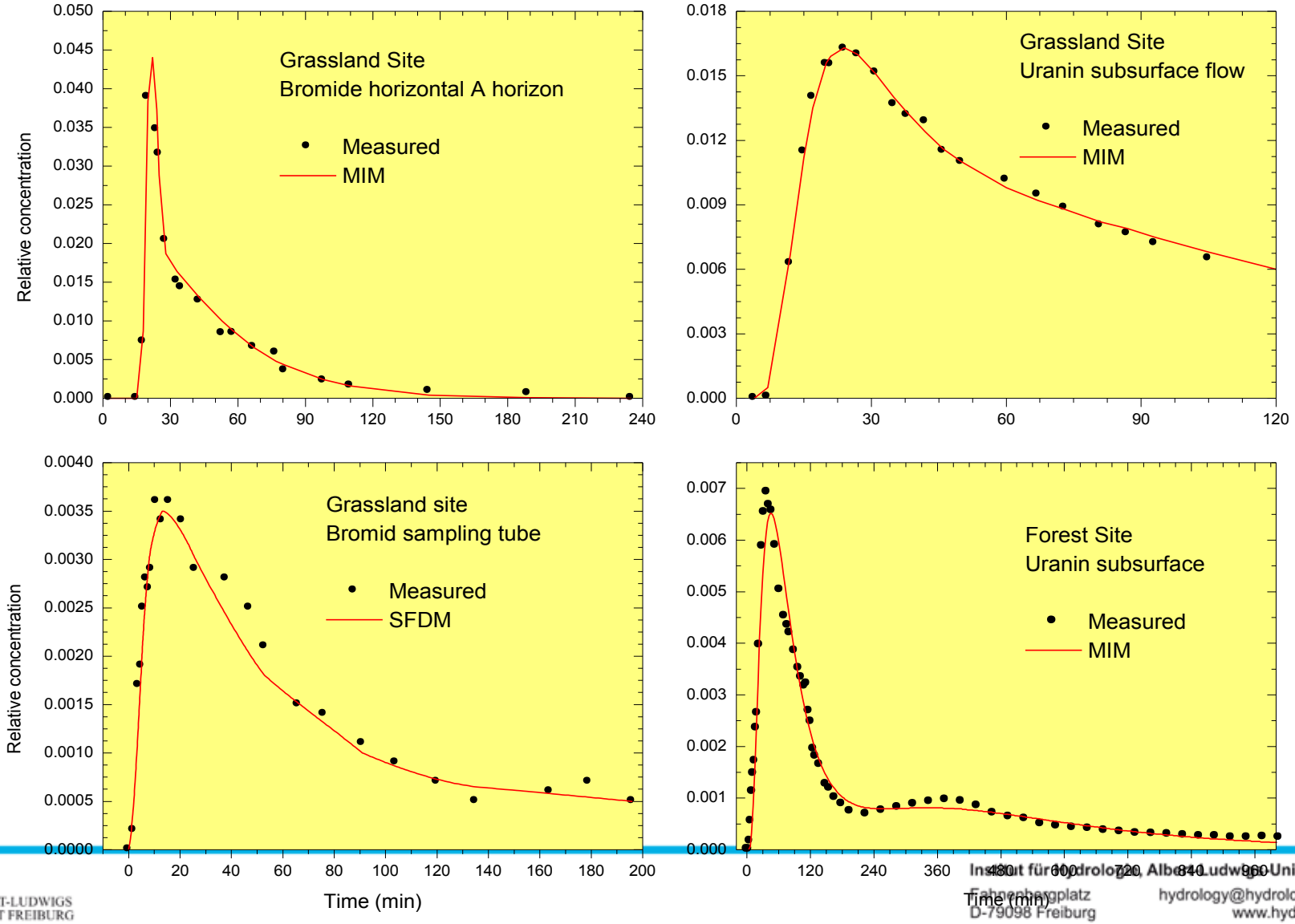
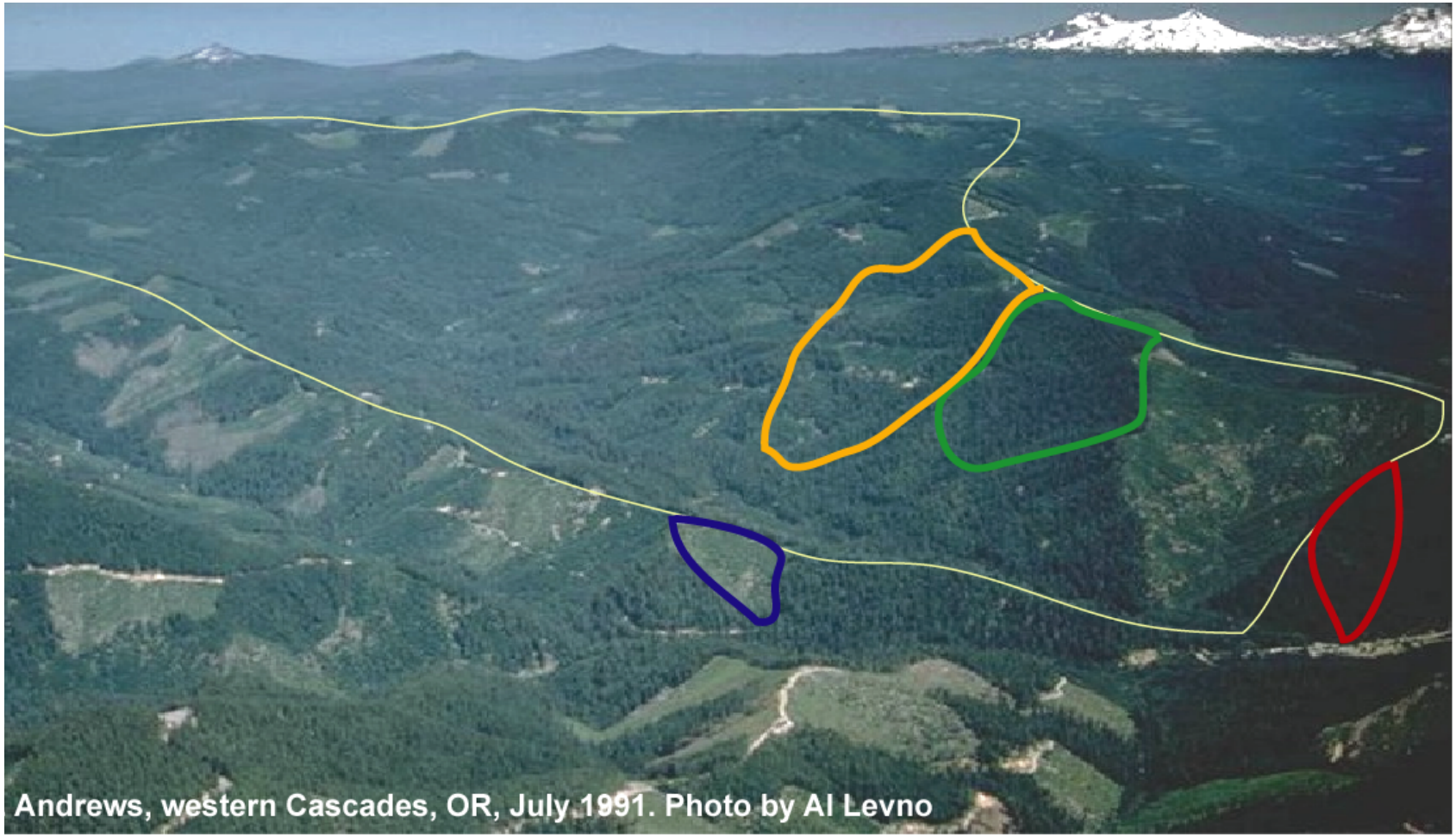
Examples of measured and fitted breakthrough curves



Tracer experiment H.J.Andrews



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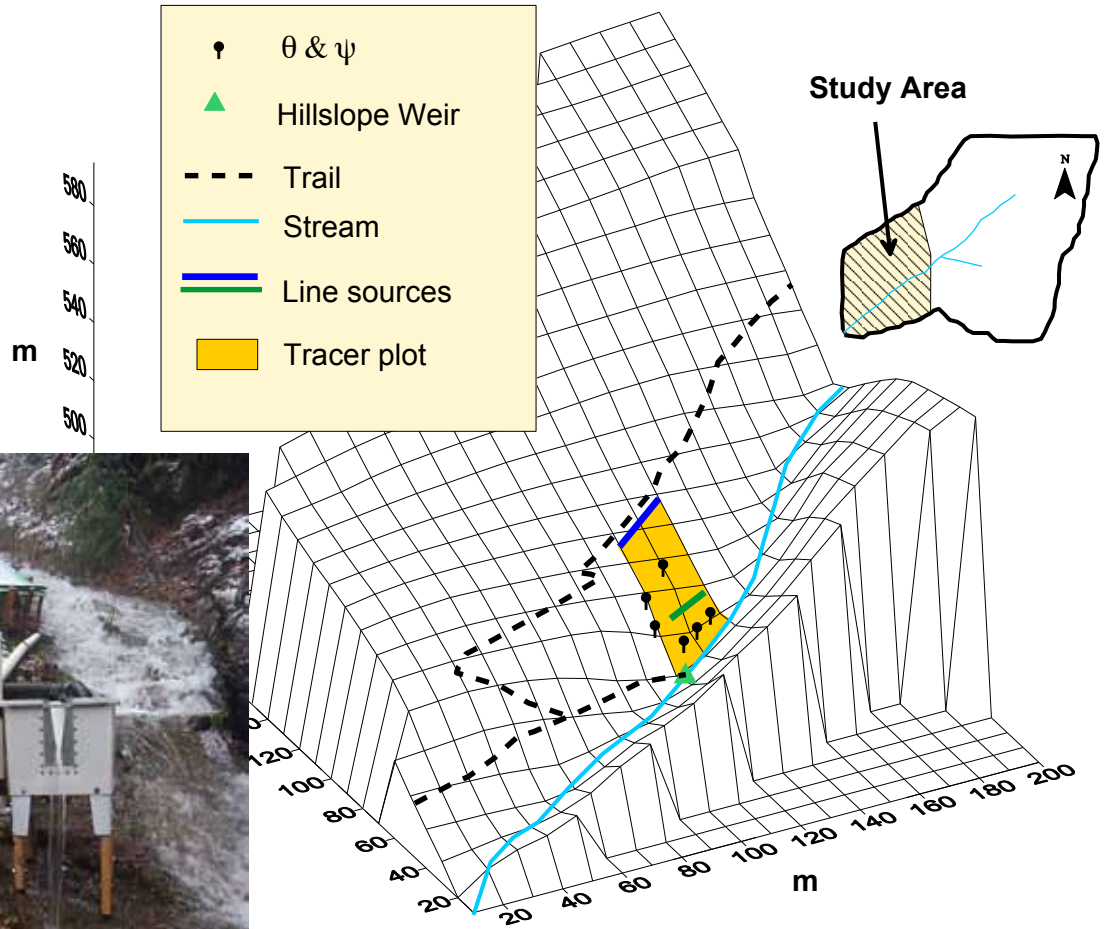
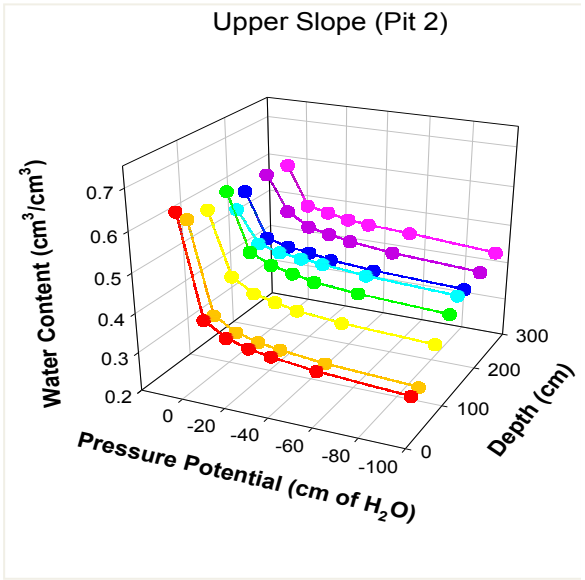
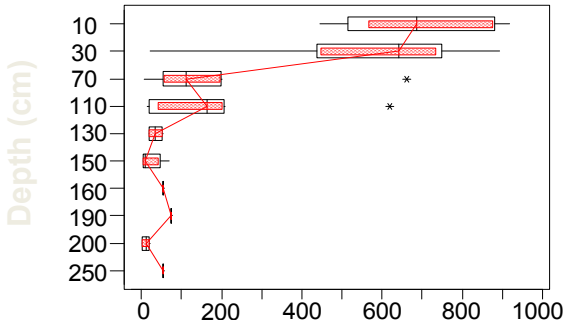
Experimental set-up

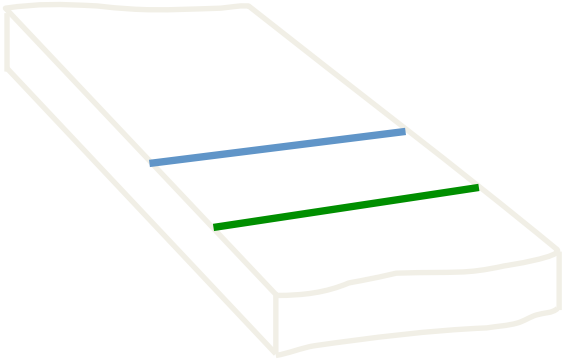


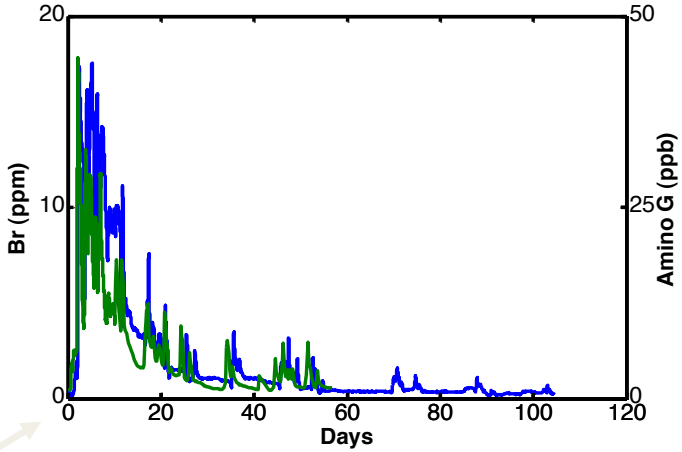




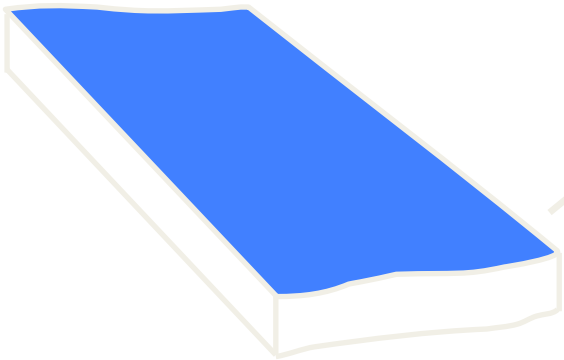
Interpretation Through Modeling:
A Forward Approach

Field Experiment

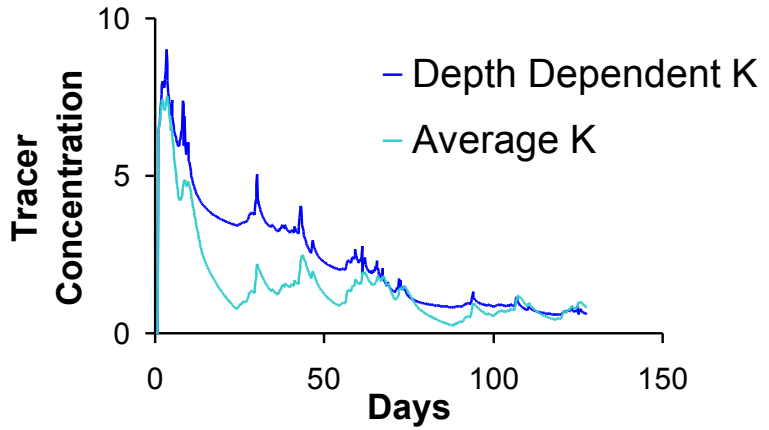




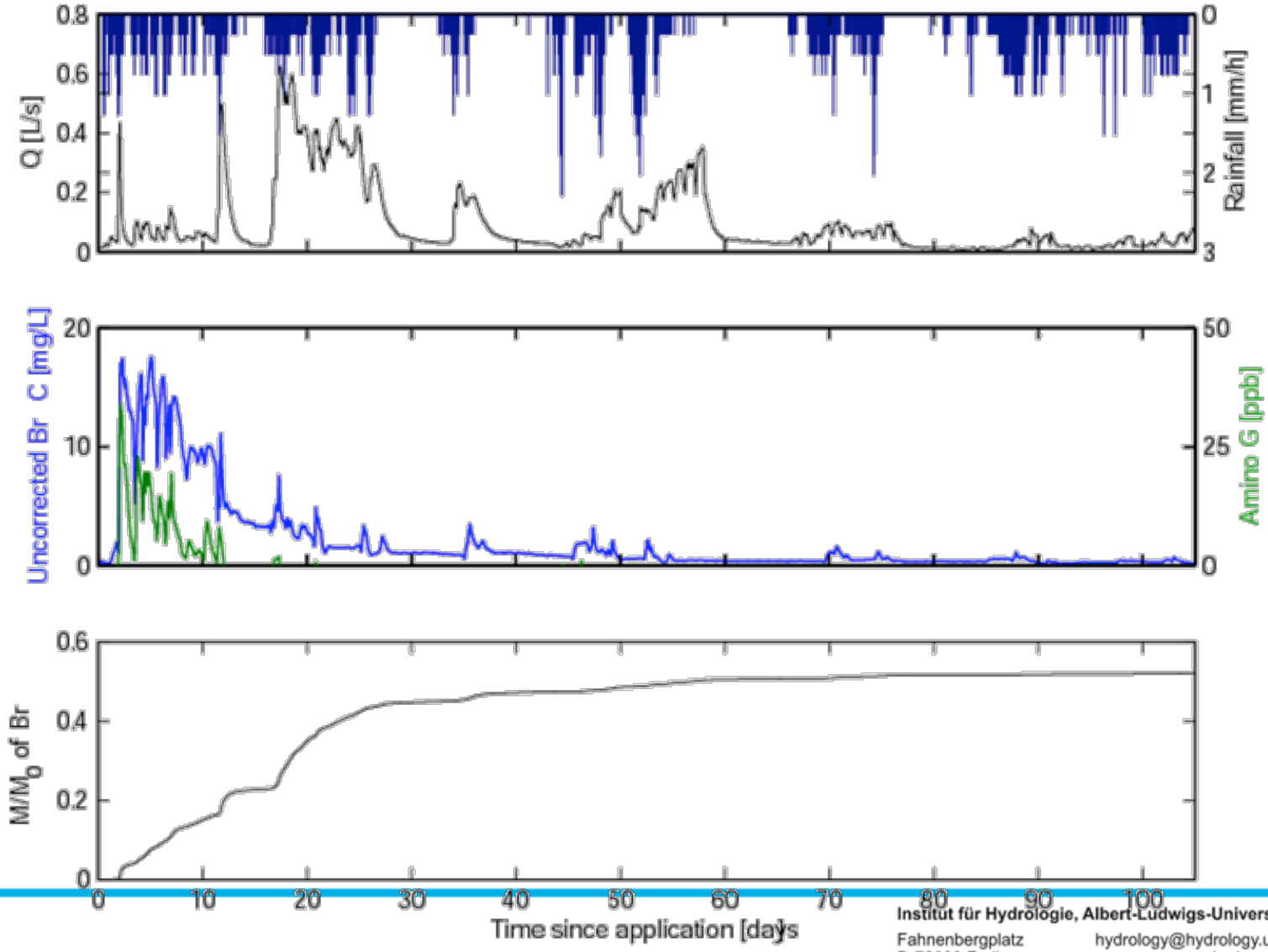
Model Experiment



Model



Measurements



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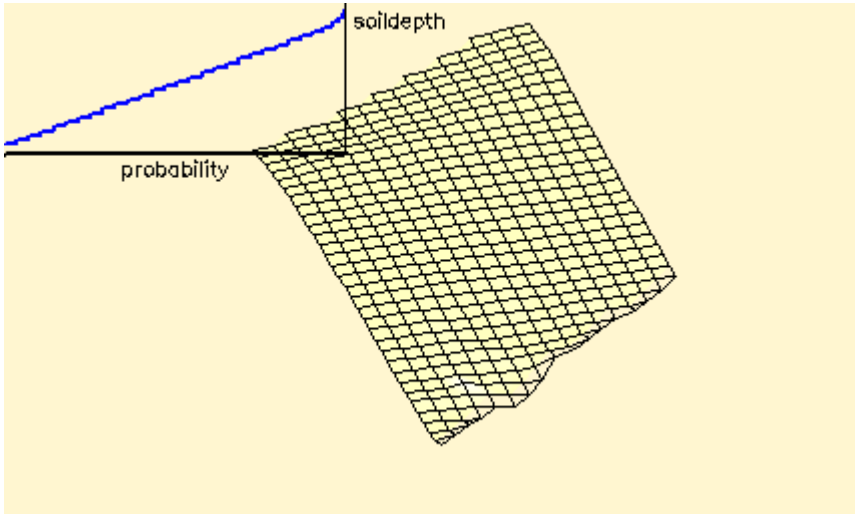
Animations

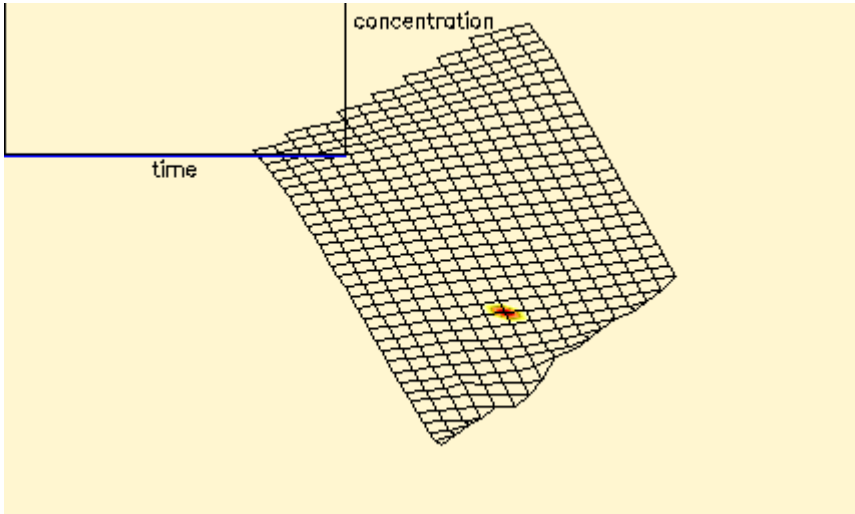
Saturation depth



Depth of saturation

0 > Average soil depth

Concentration



Relative concentration in soil column

0 max

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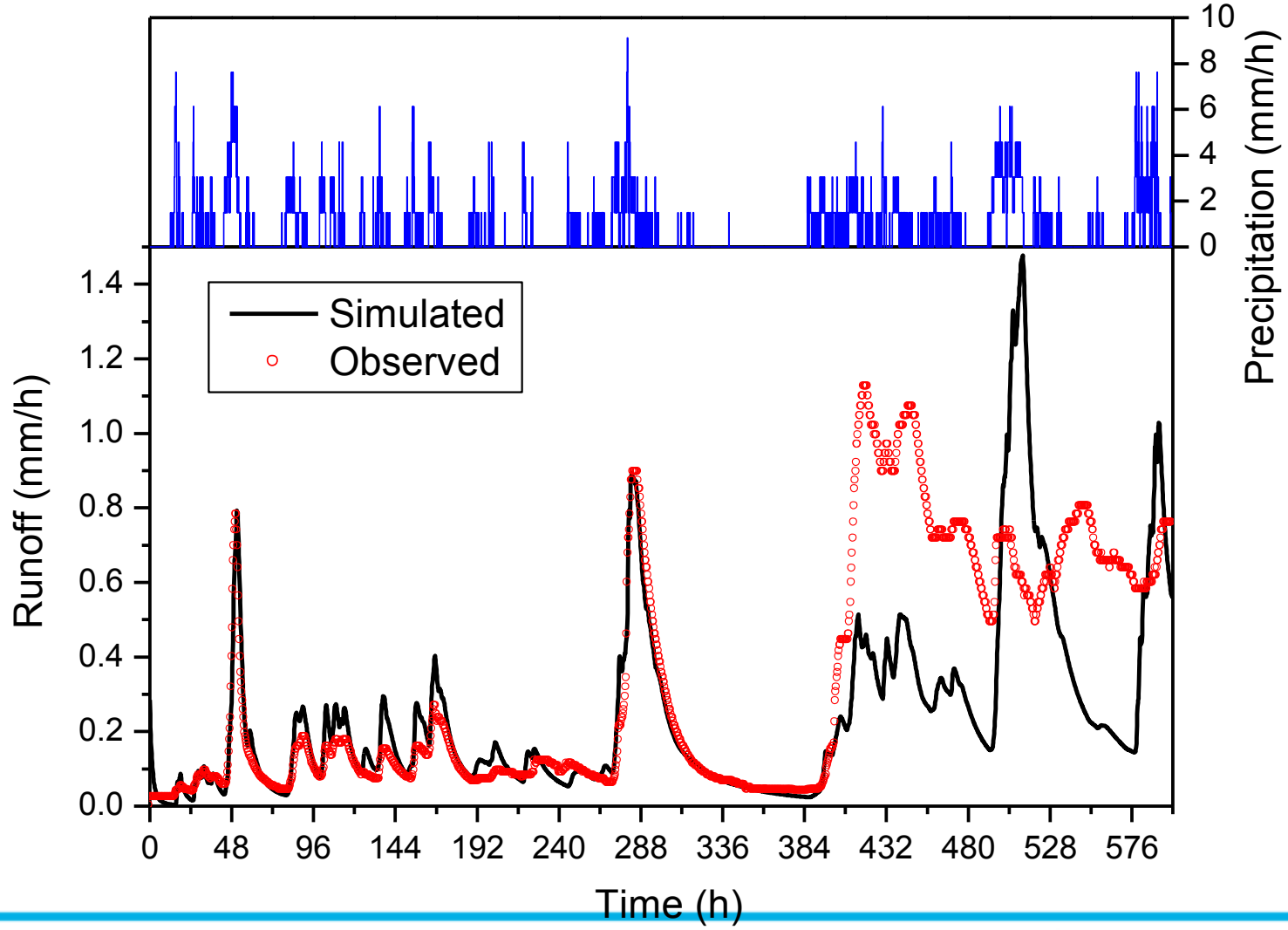
Subsurface runoff simulation



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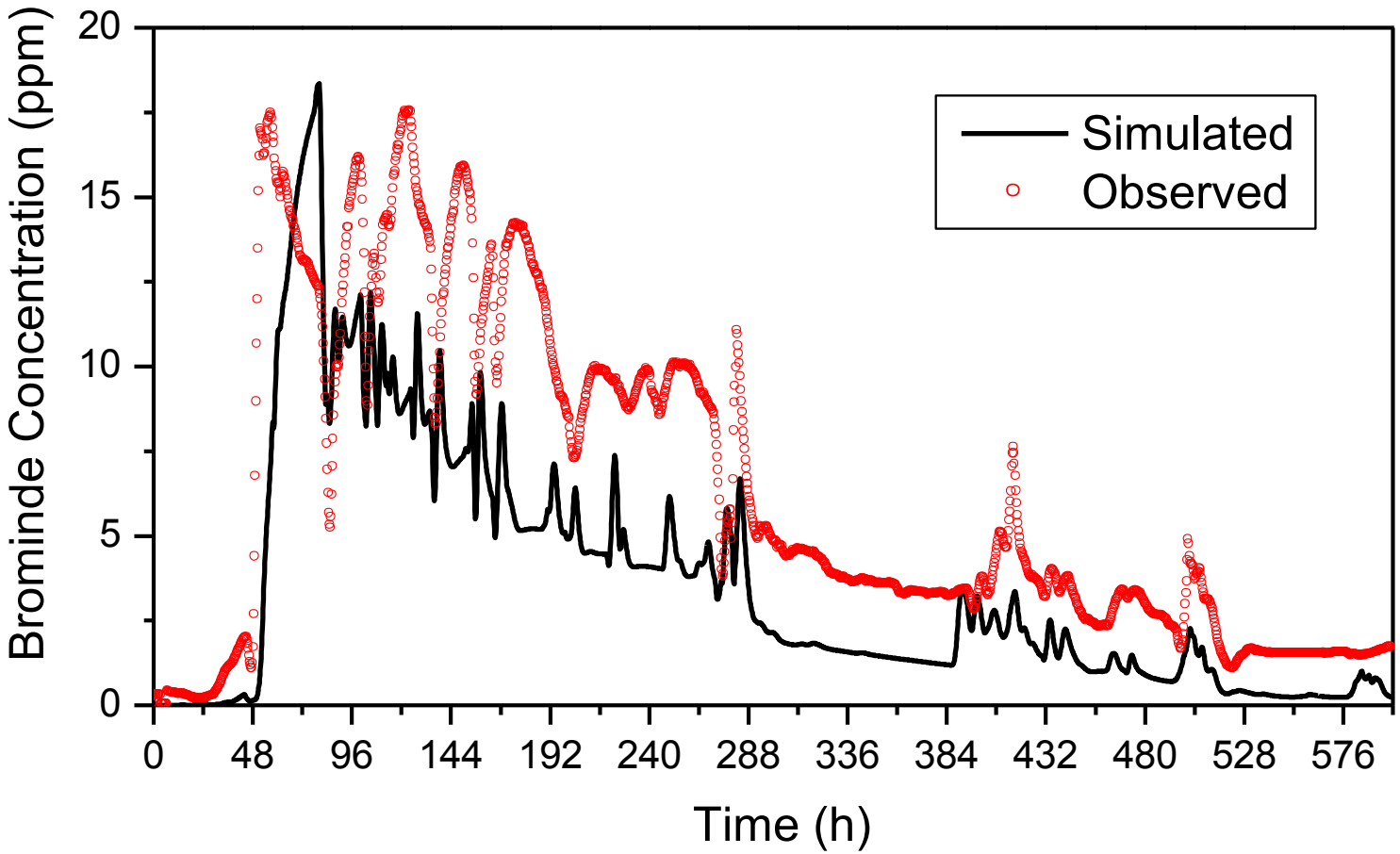
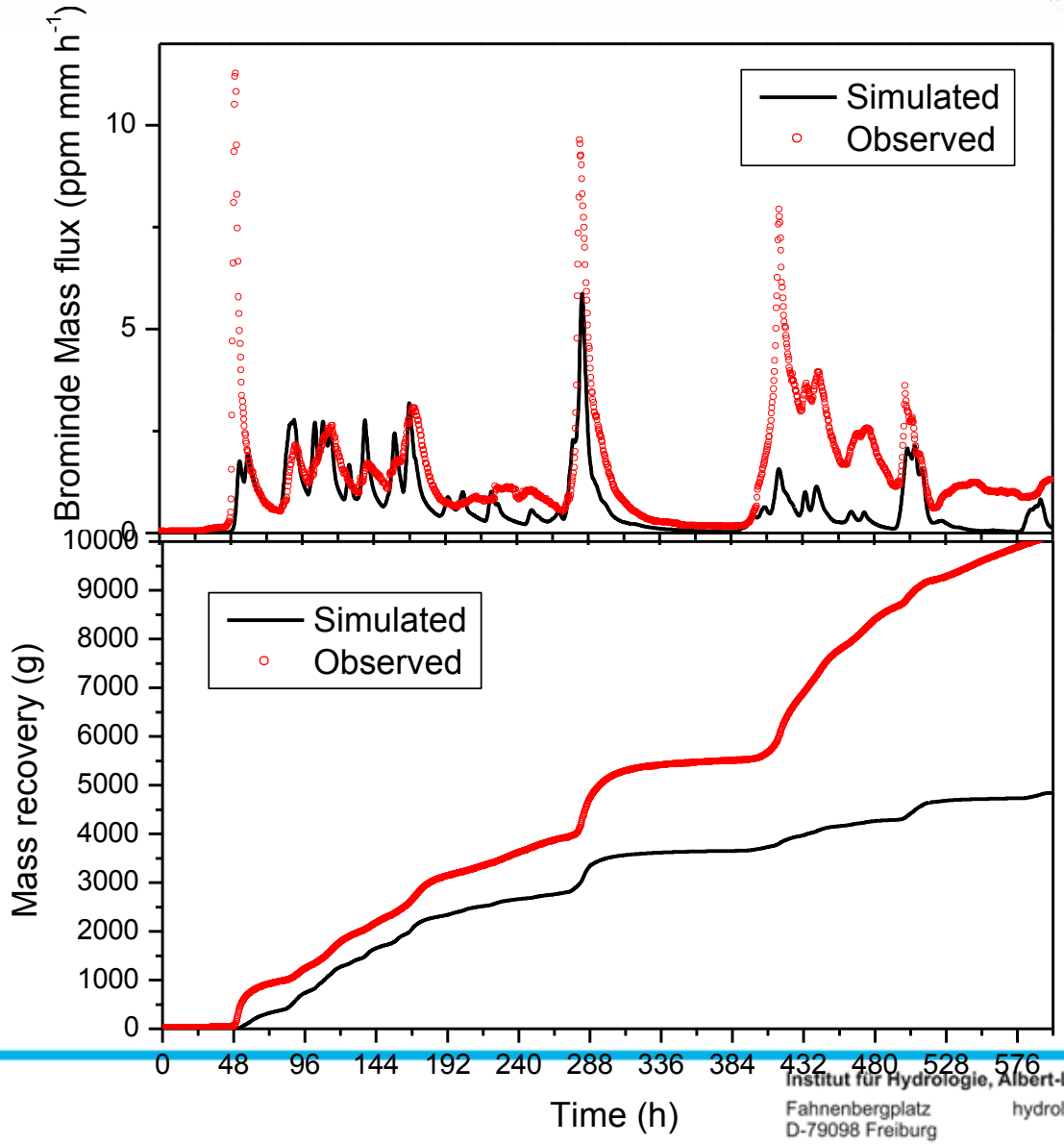
Concentration



Mass flux and recovery



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Seen (Murtensee, Leibundgut)

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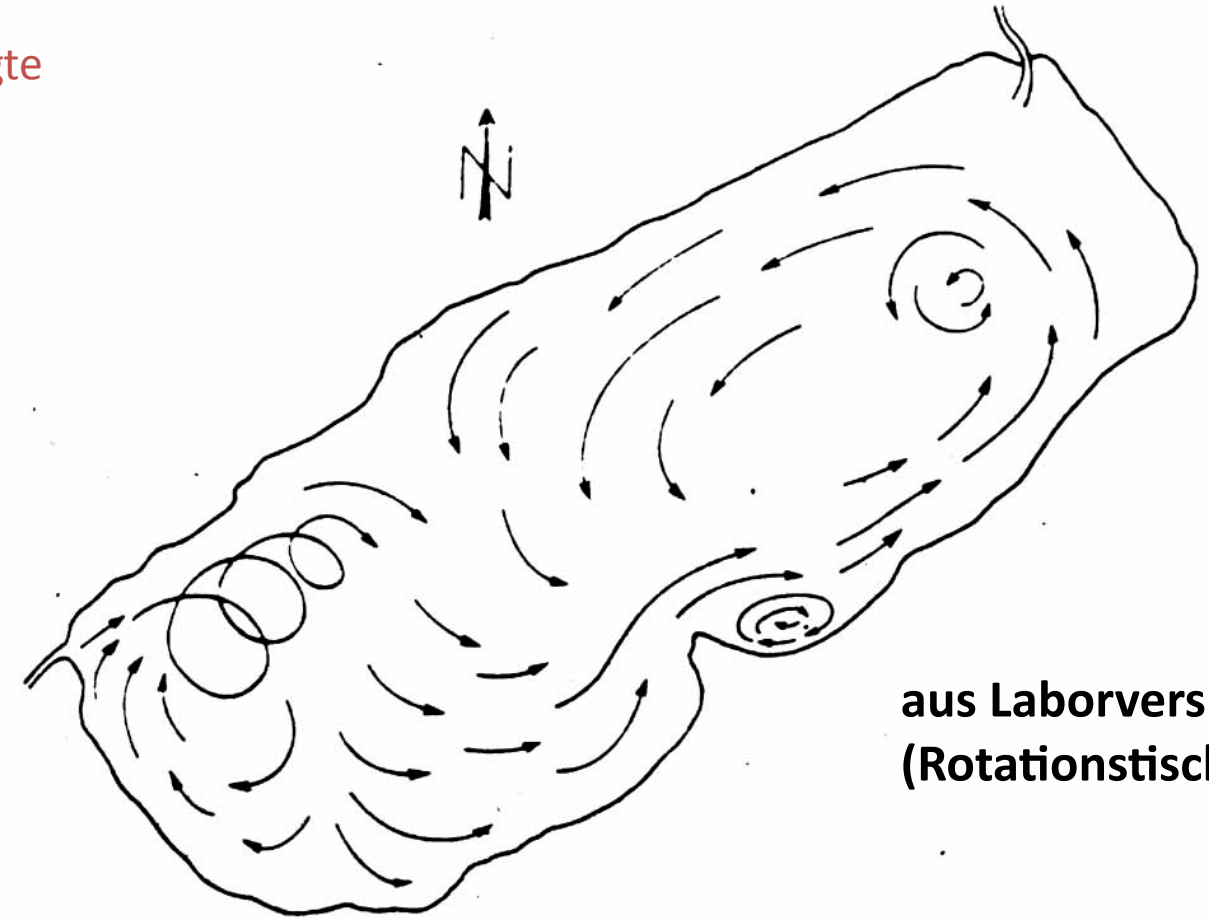
Stömungsbild_Murtensee

Zuflussbedingte Strömung



Zufluss

aus Laborversuchen (Rotationstisch)

Strömungsbild des Murtensees in Einschichtungstiefe der Broye. Aus: NYDEGGER 1967.

Versuchsbeispiel „Abwassereinleitung Murtensee“

Ziele:

- Rekonstruktion der Schichtungsprozesse im Gebiet der Abwassereinleitung
- Verfolgung der subaquatischen Wege des markierten Abwassers (verursacht durch Wassertemperatur, Strömung wind und Zuflüsse)
- Erweiterung der methodischen Erfahrungen

Methoden:

- Uranin, Einspeisemenge 6kg
- 6 Messfahrten an 2 Tagen mit Unterwasserfluorimeter

Resultate:

- Abwassereinleitungstiefe: 9 m
- Verdünnungsfaktor: 1 : 200 bis 4000
- Abwasser erreicht ausreichend verdünnt Seeoberfläche, bedingt durch windinduzierte Strömung

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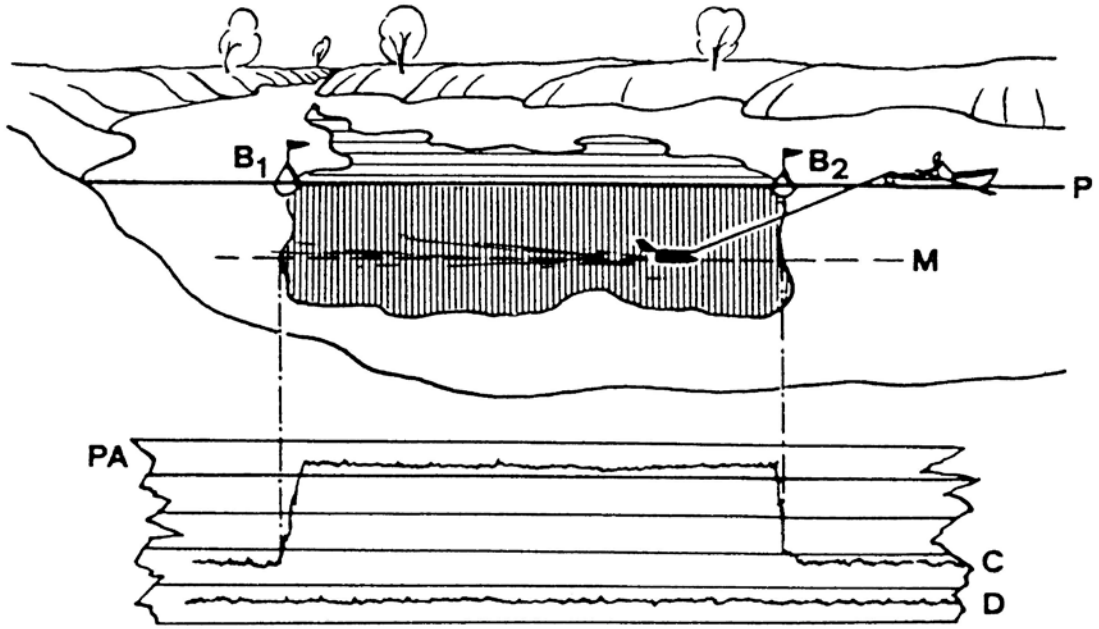
Tracermessung in einem See



The principle of measurements of a "tracer cloud" within the body of lake water.
Prinzip der Ausmessung einer "Tracerwolke" in einem Seewasserkörper.

TC	tracer cloud / Tracerwolke
P	profile line (boat) / Profillinie
M	measurement profile (Variosens) / Messprofil
B_1, B_2	marker buoys / Markierbojen
C	concentration of the tracer / Tracerkonzentration
D	depth of measurement / Messtiefe
PA	registration paper / Schreiberstreifen

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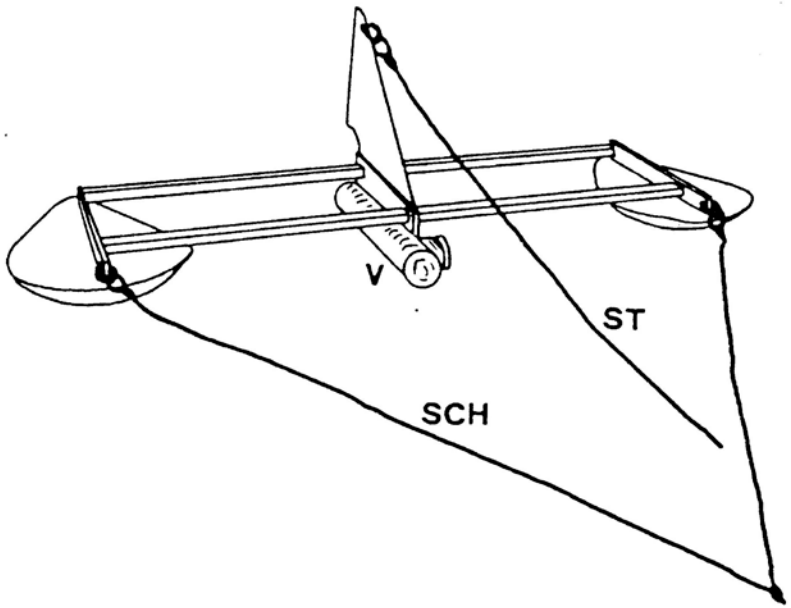
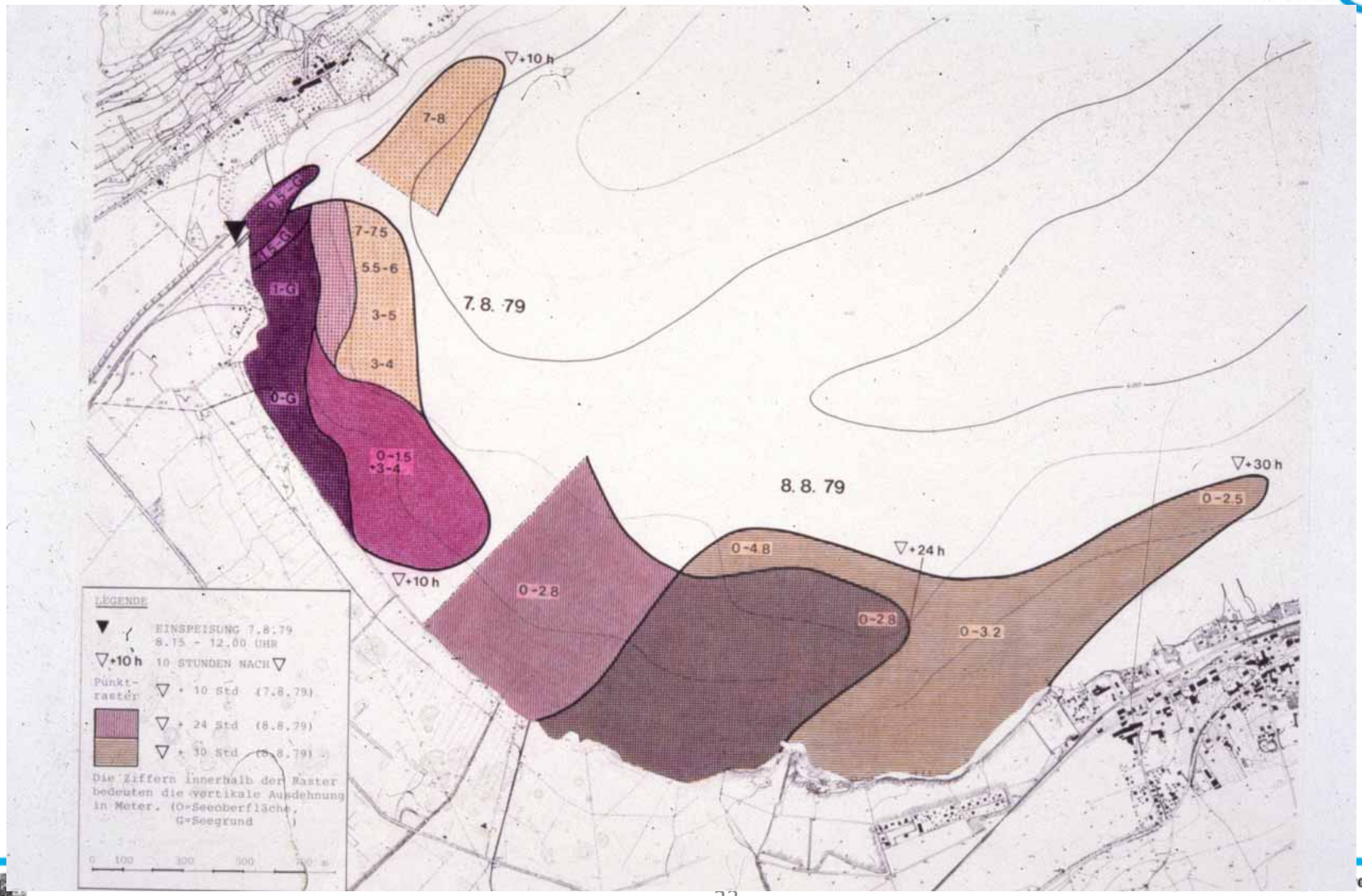
Steuerbarer Schleppträger



Manoeuvrable towing device for stabilisation of the underwater fluorometer (V) in the desired depth.
Steuerbarer Schleppträger zur Stabilisation des Unterwasserfluorometers (V) in der gewünschten Tiefe.
ST guide rope / Steuerseil
SCH towing lines / Schleppseile

Markierversuch See



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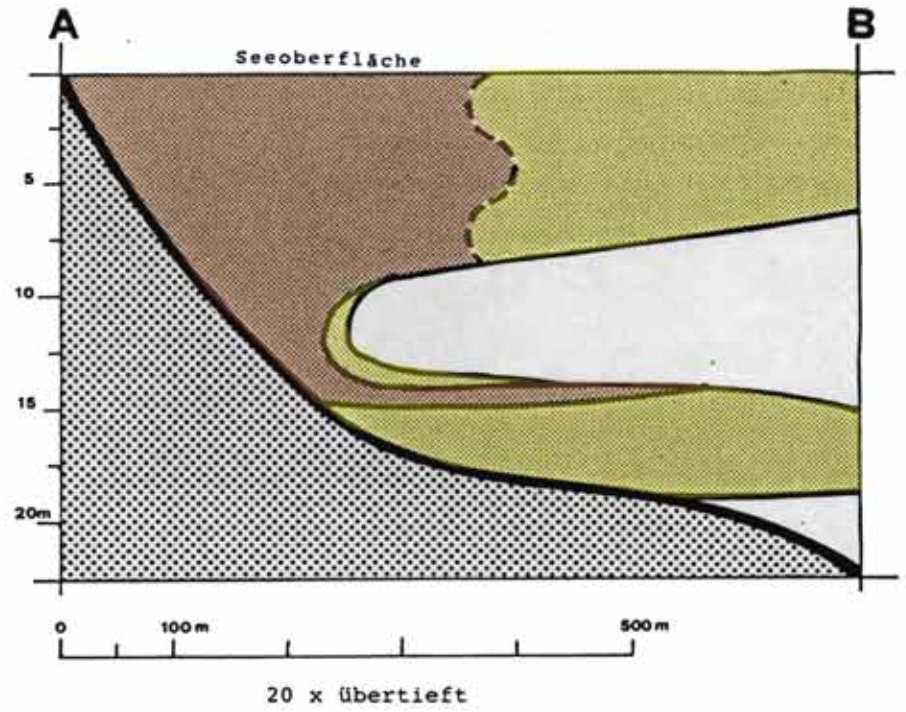
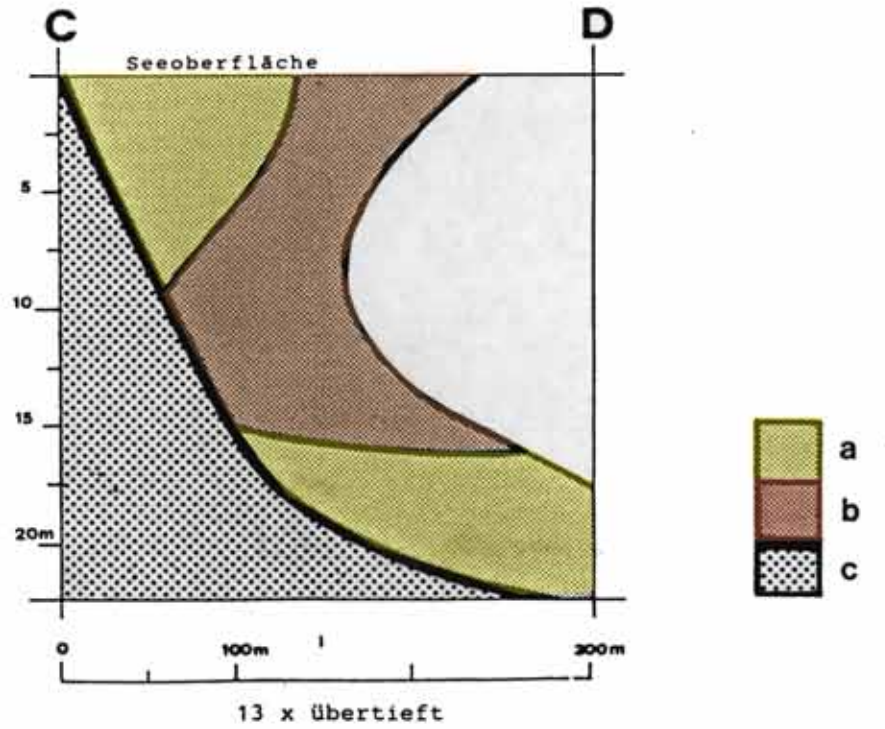
Vertikalprofile

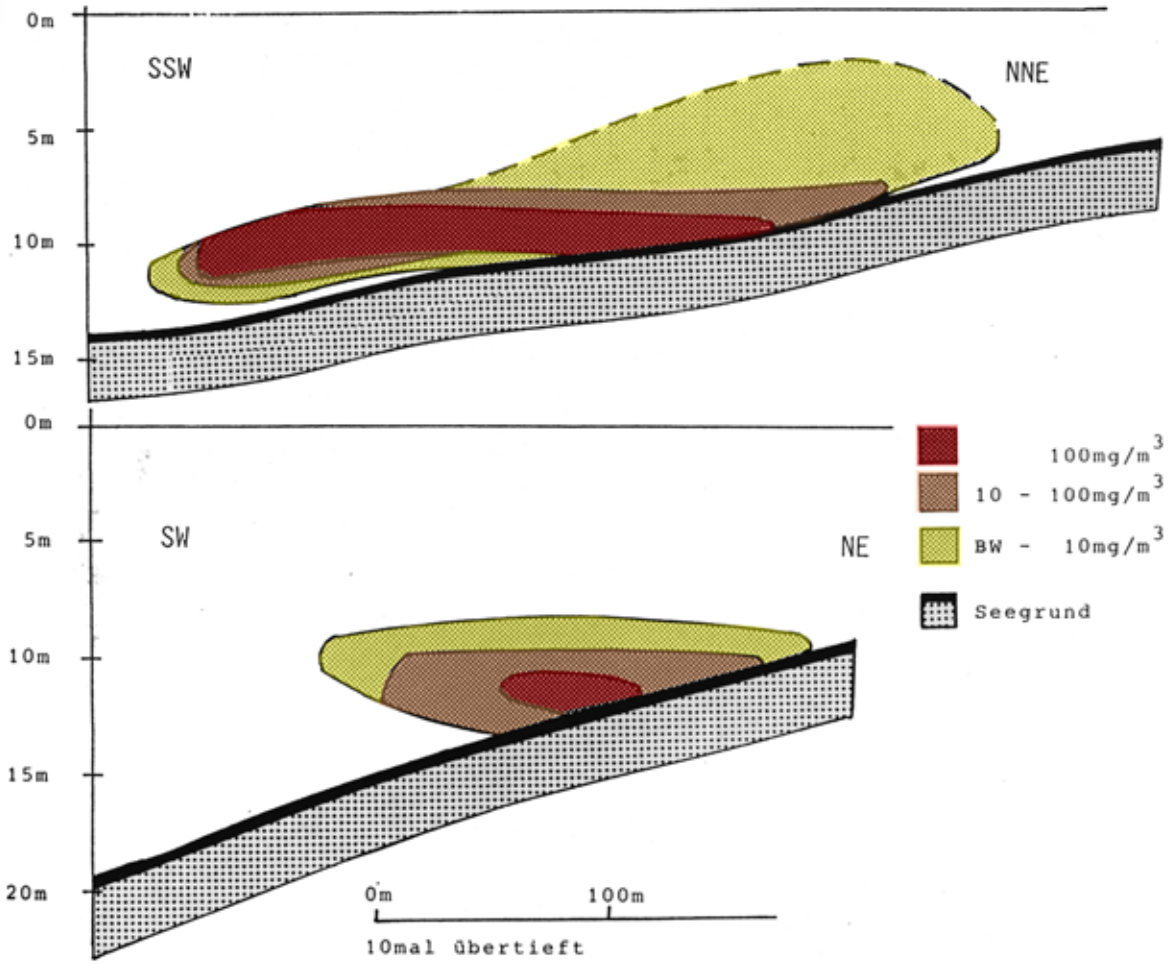




Vertikalprofile durch die Tracerwolke
10.7. 1980 (nachmittags).

a fresh water concentration bis 1 mg/m^3
b tracer concentration: 1-10 mg/m^3
c lake bottom / Seegrund

Vertikalprofile



Vertikalprofile durch die Tracerwolke vom 9.7. 1980 (nachmittags)

oben: Profil E-F
unten: Profil G-H

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Gletscher

Properties of a glacial drainage system revealed by repeated tracer tests

- Thomas Schuler, ETH Zürich
- Unteraargletscher CH

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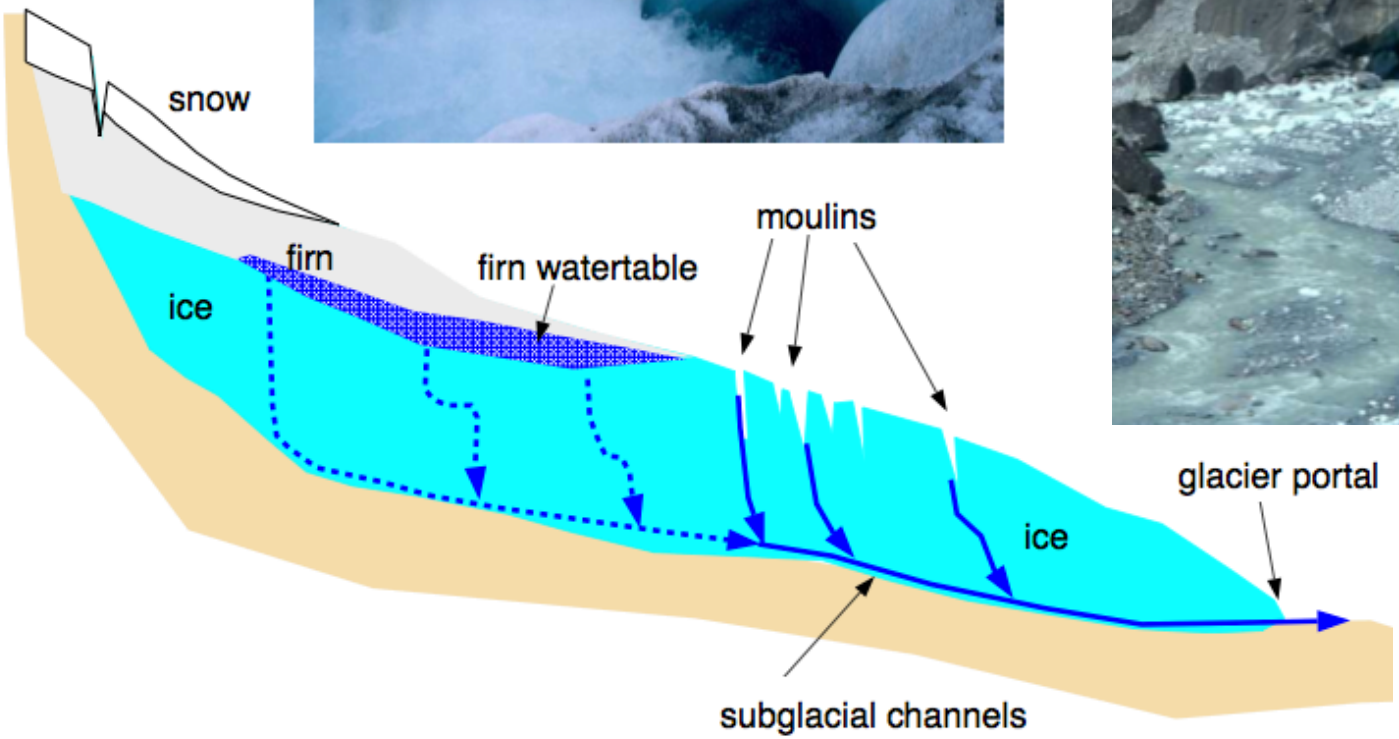
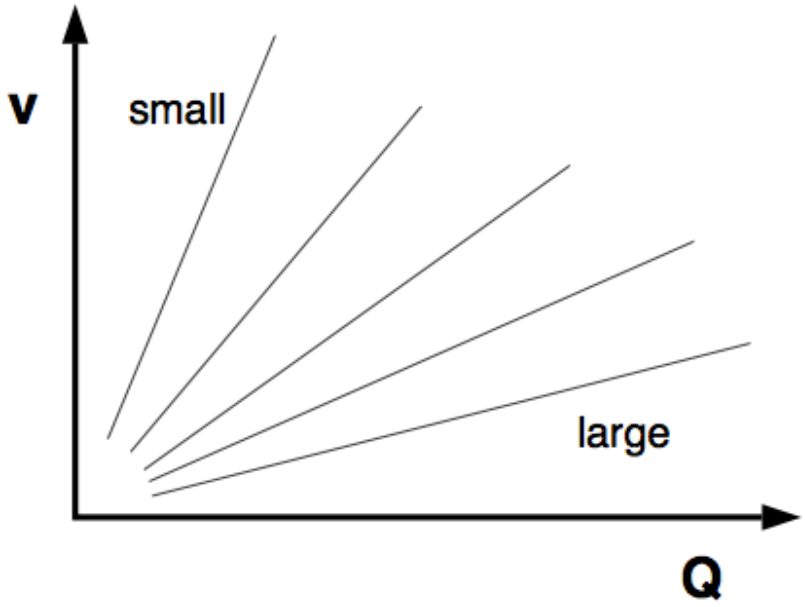
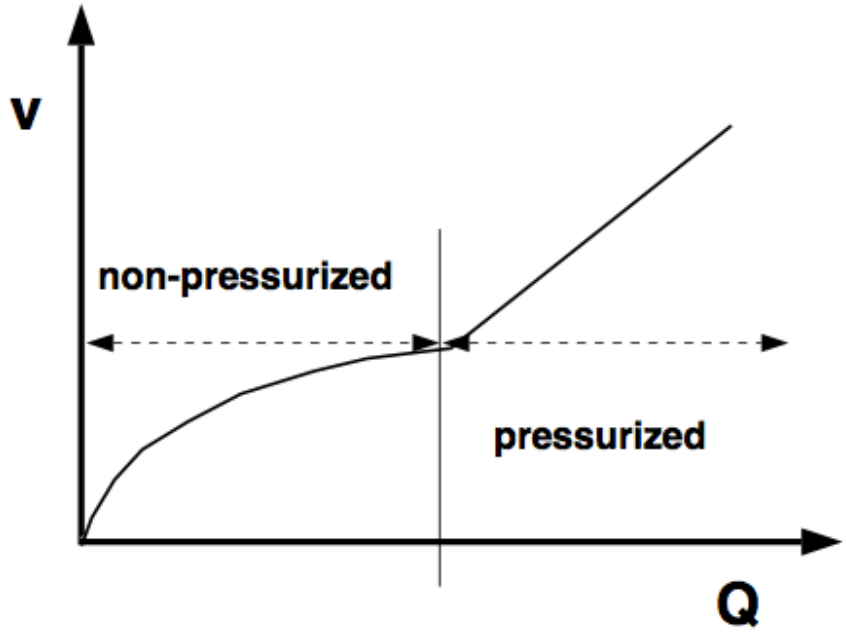
Alpine Gletscher



Fragestellung





requires: repeated tracer tests at different discharge stages

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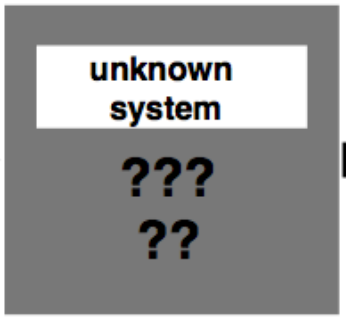
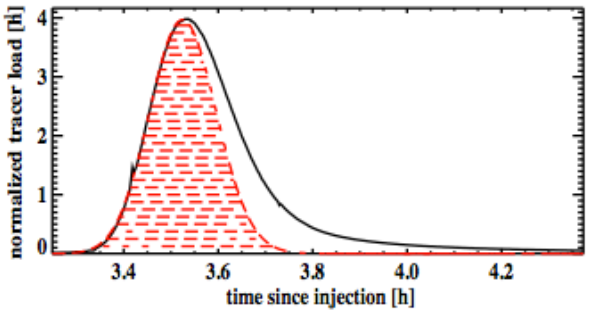
Methode





- hydraulic connection
- transit time
- shape of breakthrough-curve

- discrimination of drainage systems
- hydraulic characterization

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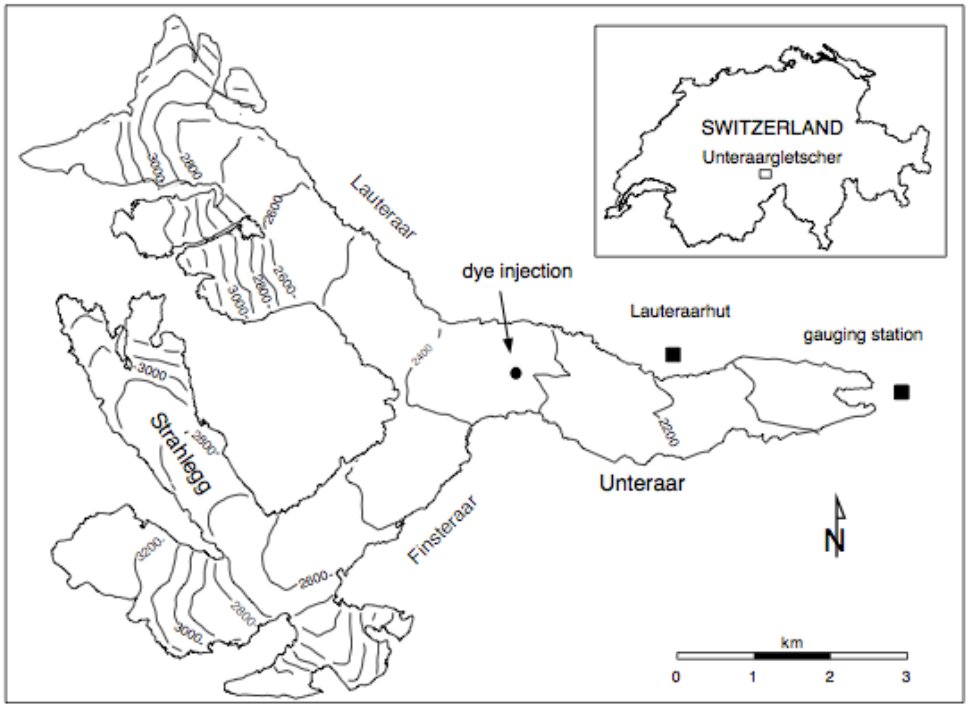
Tracer experiments at Unteraargletscher

repeated tracer tests over one diurnal discharge cycle



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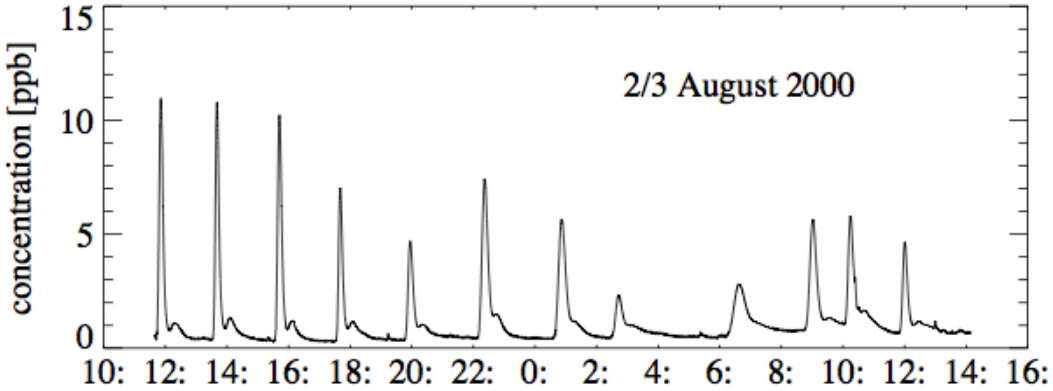
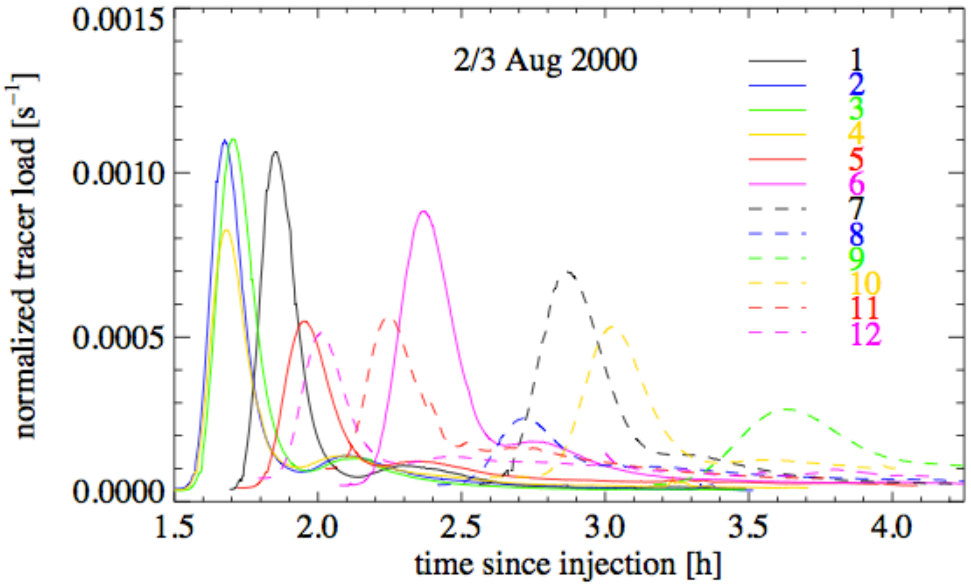
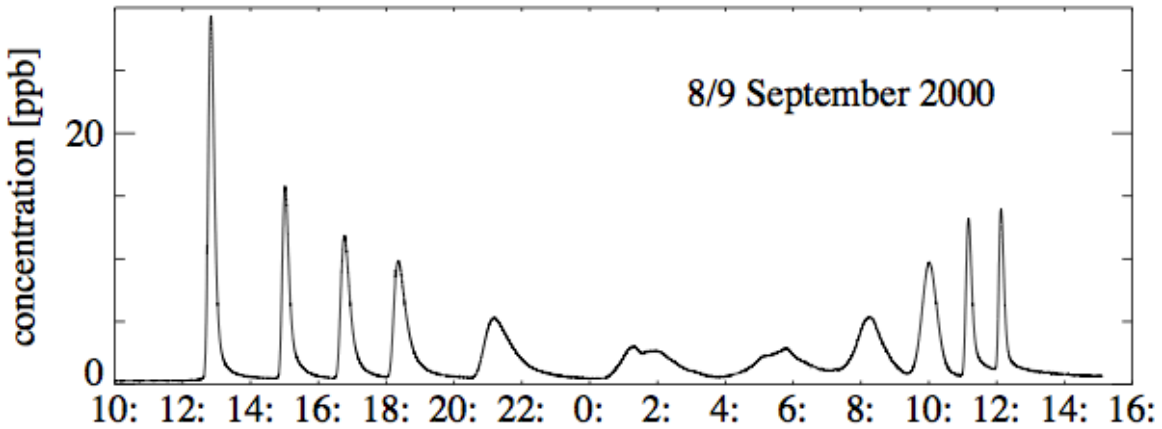
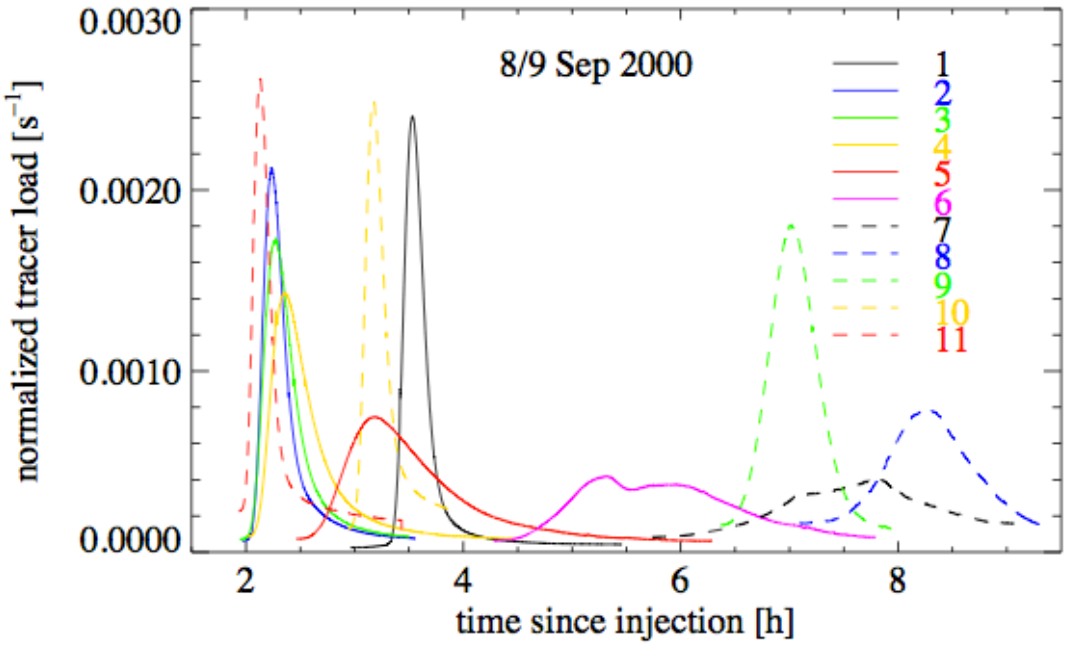
August Experiment





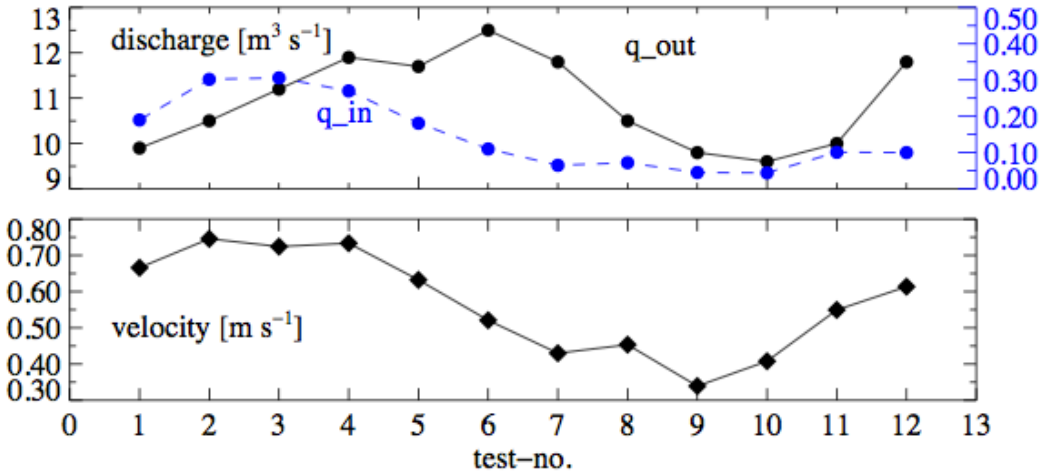
September Experiment



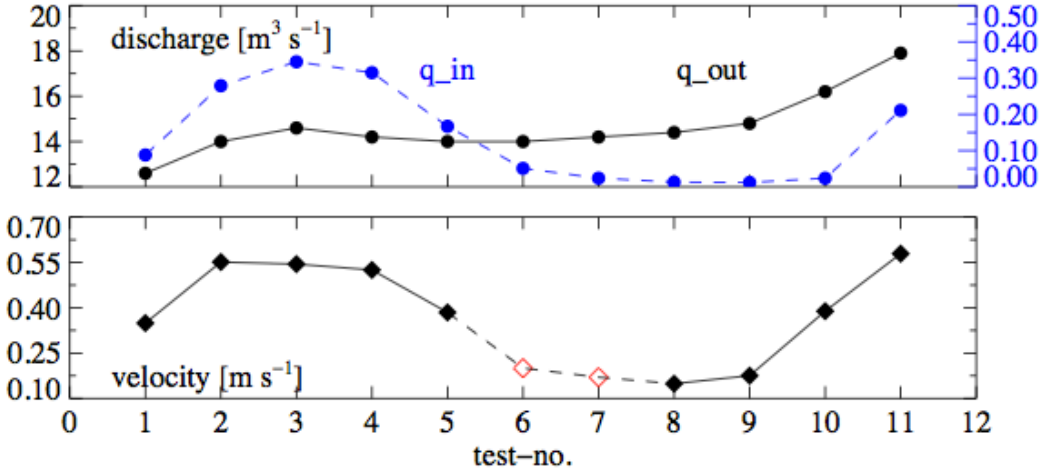


Ergebnisse

August



September



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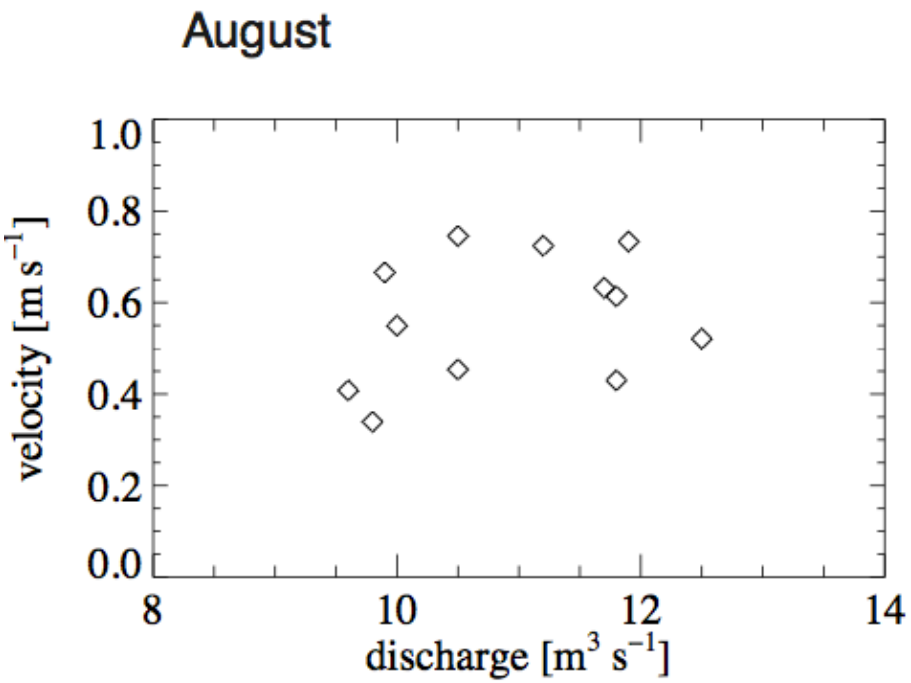
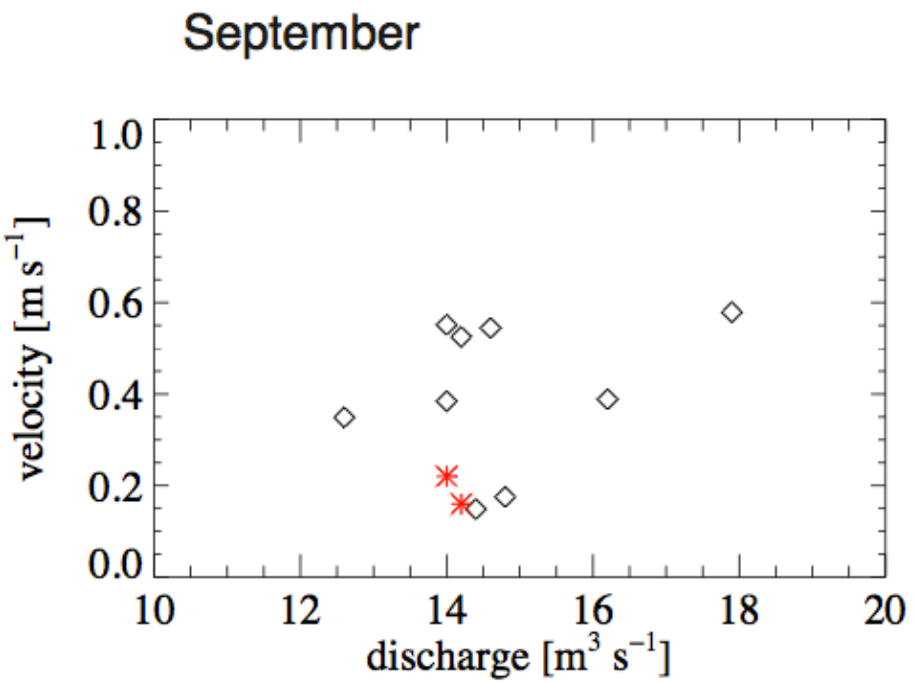
Geschwindigkeit und Abfluss





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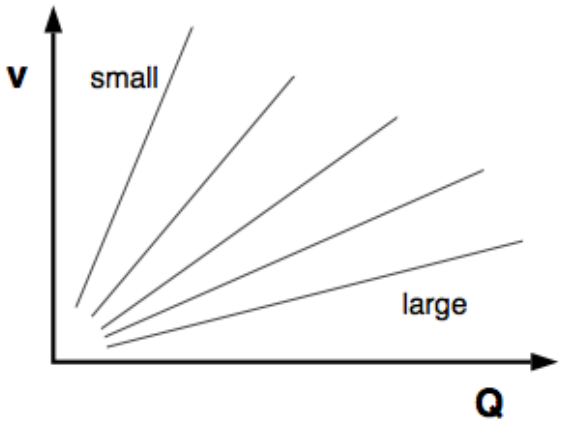
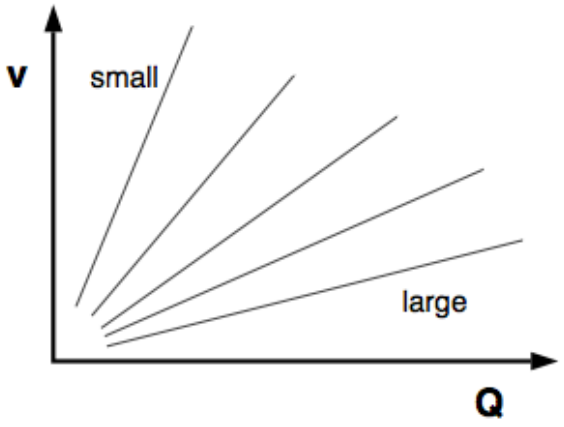
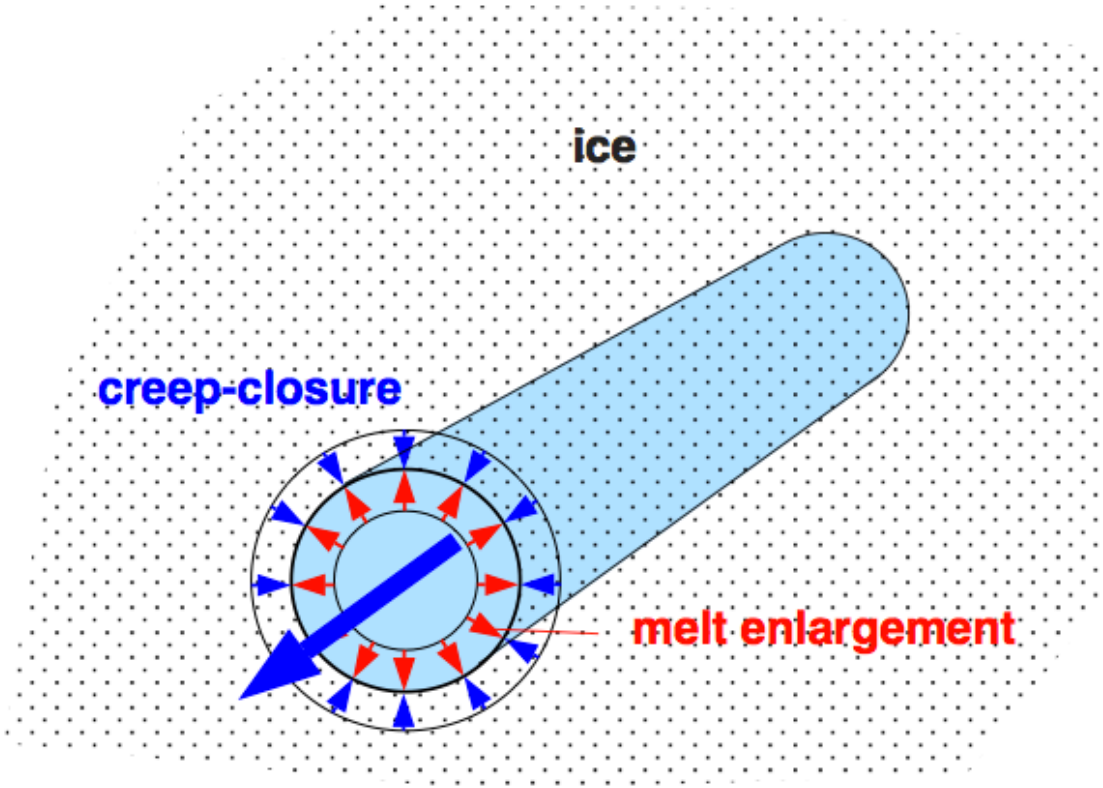
Erklärungsmodell







dynamic conduit geometry
(Röthlisberger-channel)

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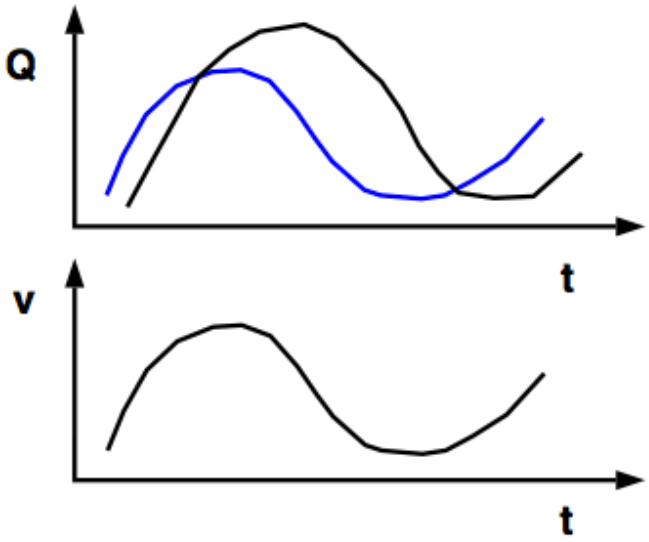
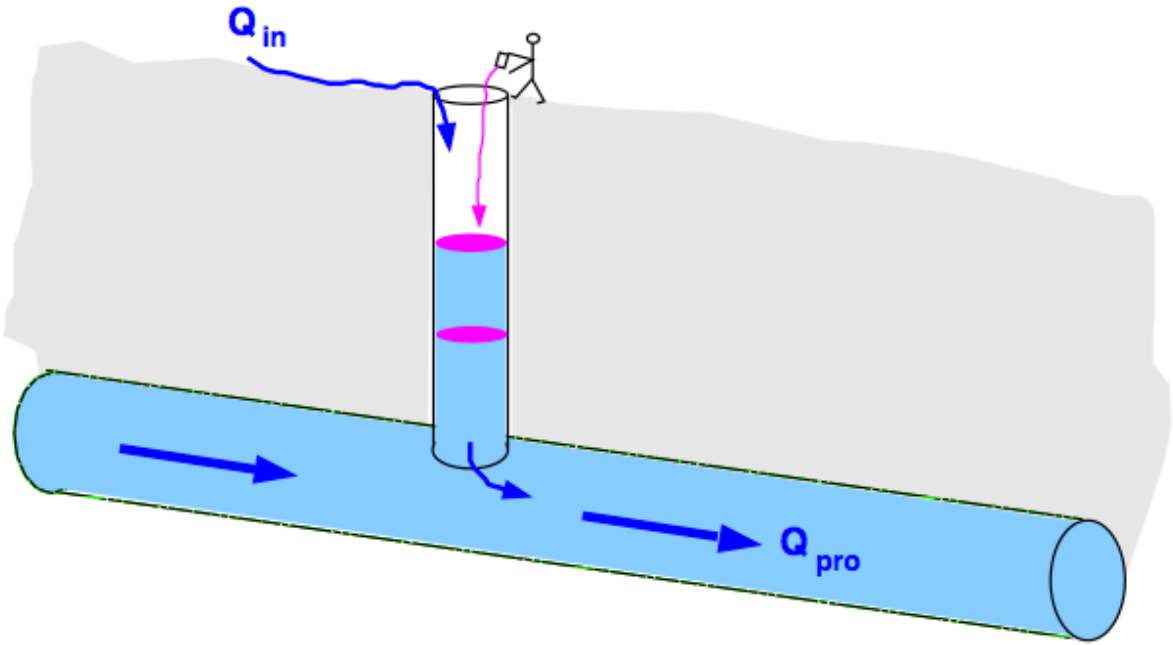
Erklärungsmodell





Inflow modulation

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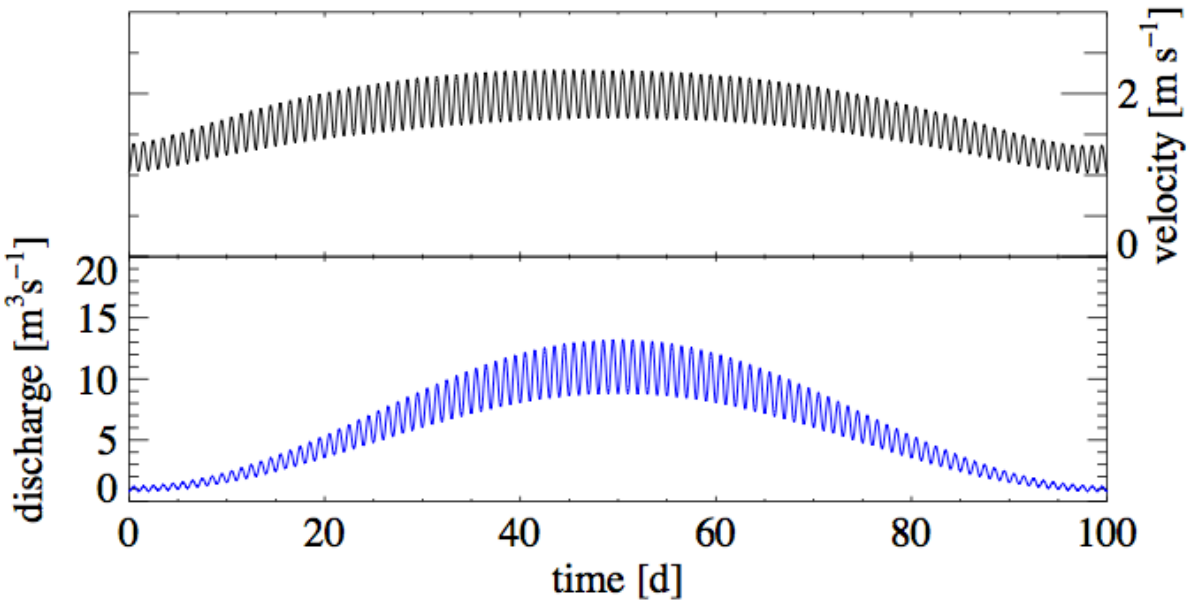
Zusammenfassung

Tracer tests repeated at short intervals over one diurnal discharge cycle reveal a pronounced diurnal variability of transit velocity.
(➽ single tests have only limited significance for investigating the seasonal evolution of a subglacial flowpath).



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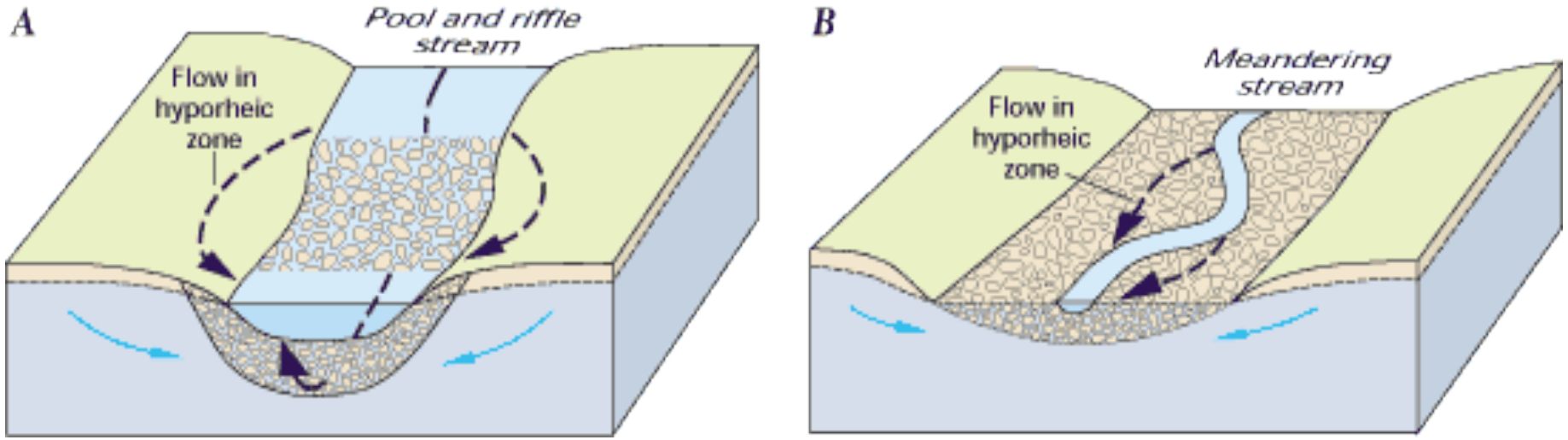
Hyporheic Zone

- Zone of subsurface flow adjacent to a stream through which stream water exchanges



USGS Circular 1139, 1998

- HZ is important because it increases stream water residence time *and* represents a biogeochemically active region underpinning stream ecosystems.

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Hydrologic Characterization

- Three methods
  - Piezometer deployment

Rio Calaveras, NM

  - Solute release experiment and transport modeling
  - Groundwater flow modeling

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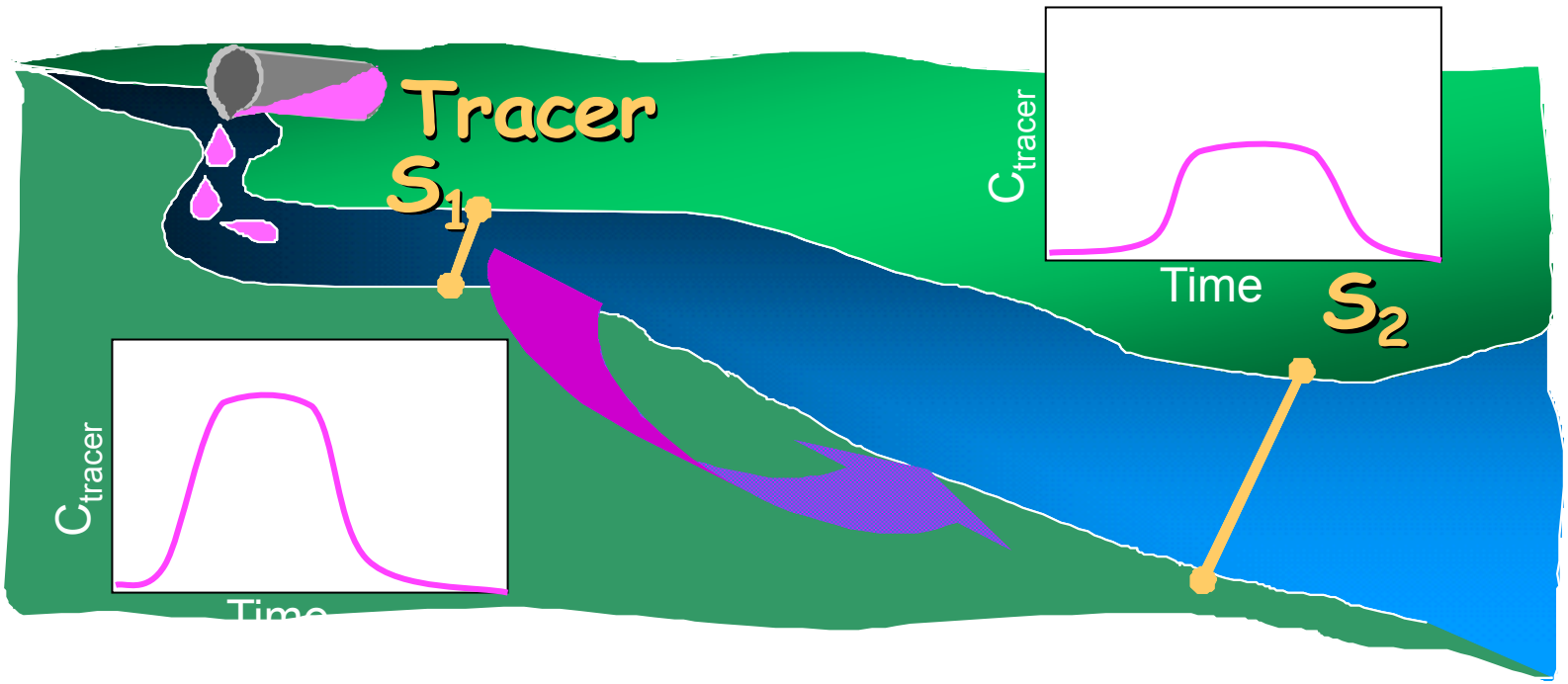
Solute Release Experiment and Transport Modeling

- Stream tracer technique at reach scale
  - Release tracer upstream, collect downstream
  - Analyze change in tracer concentrations



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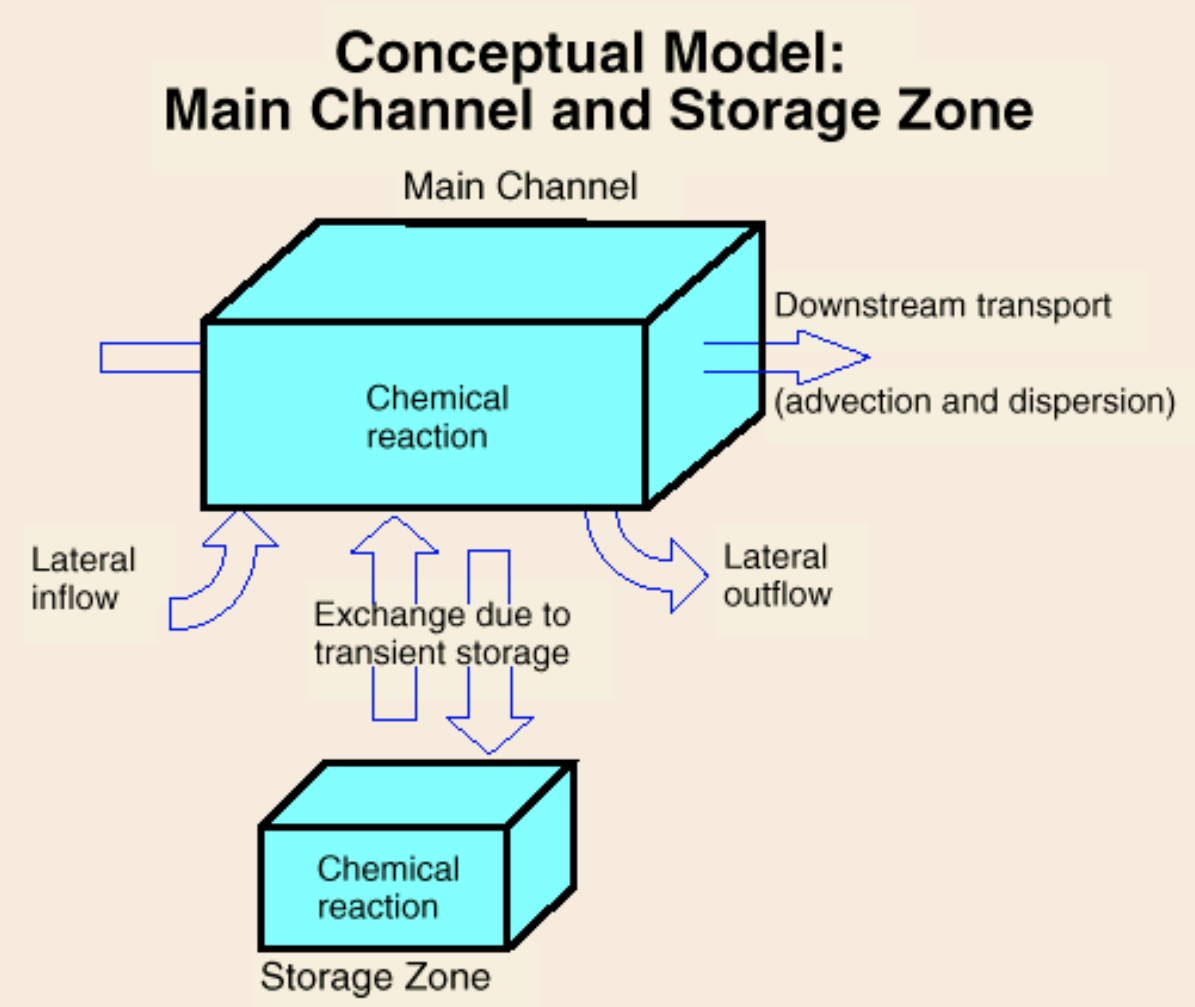
Solute transport modelling



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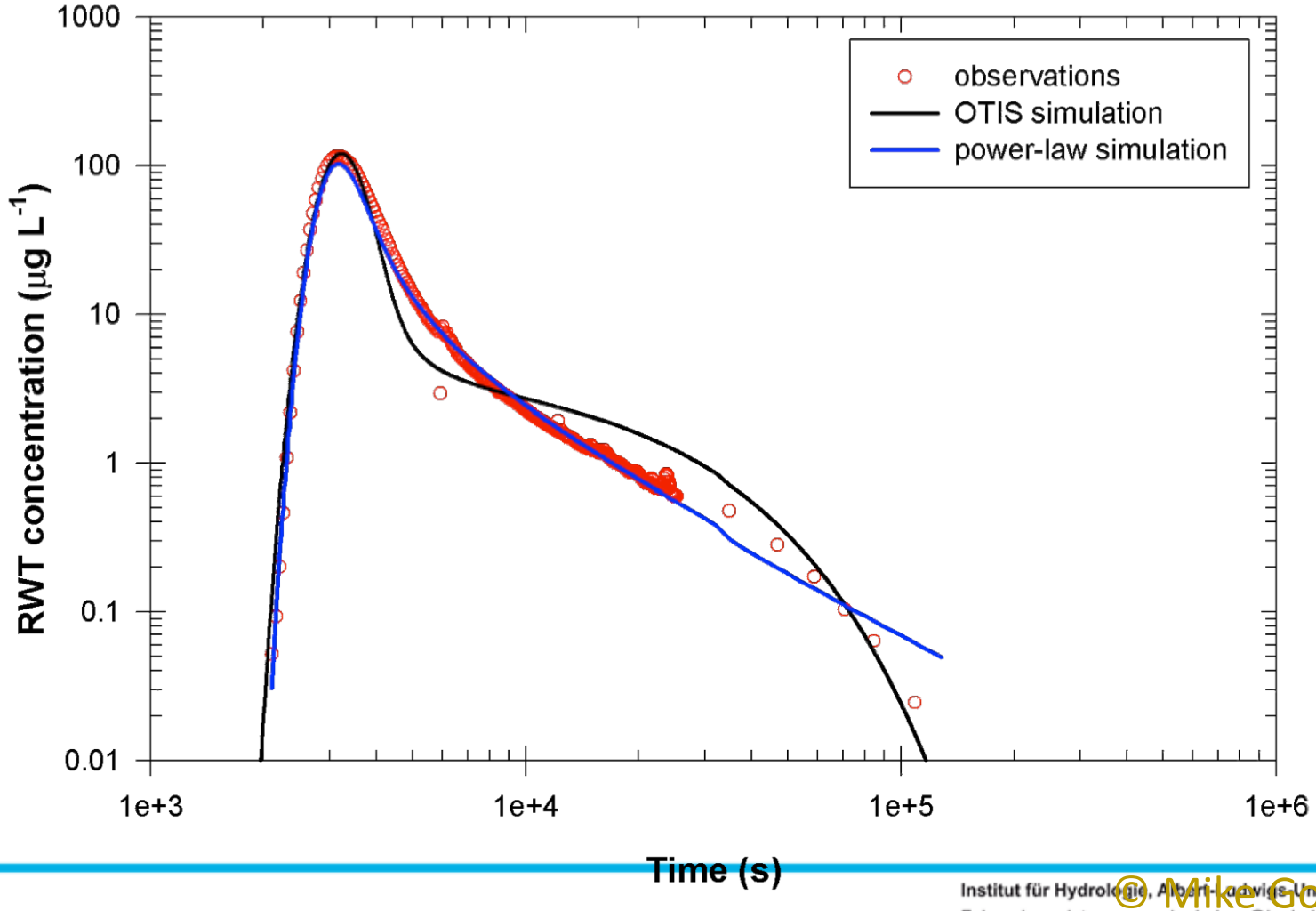
Some breakthrough examples

Lookout Reach 411



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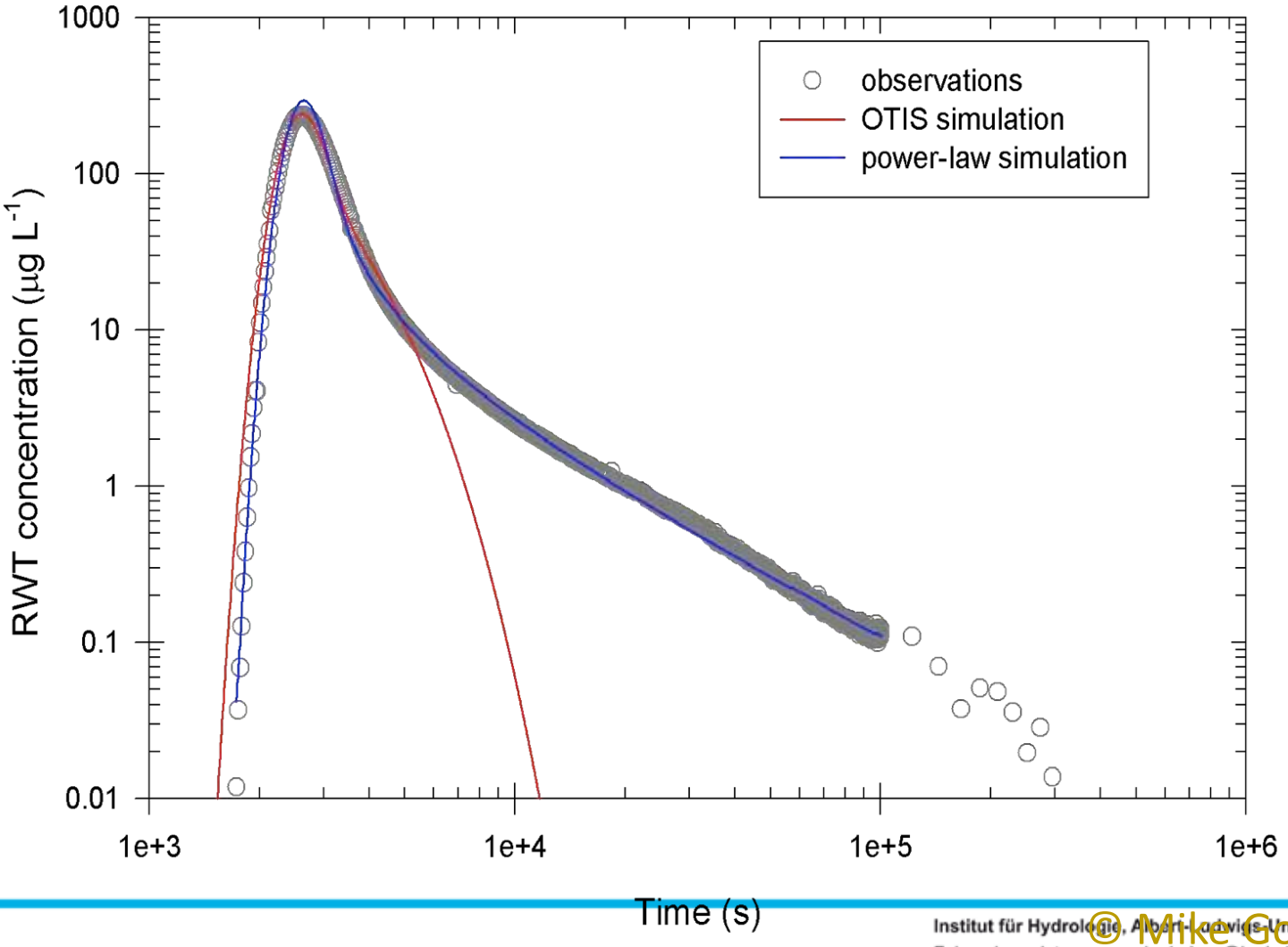
Some breakthrough examples



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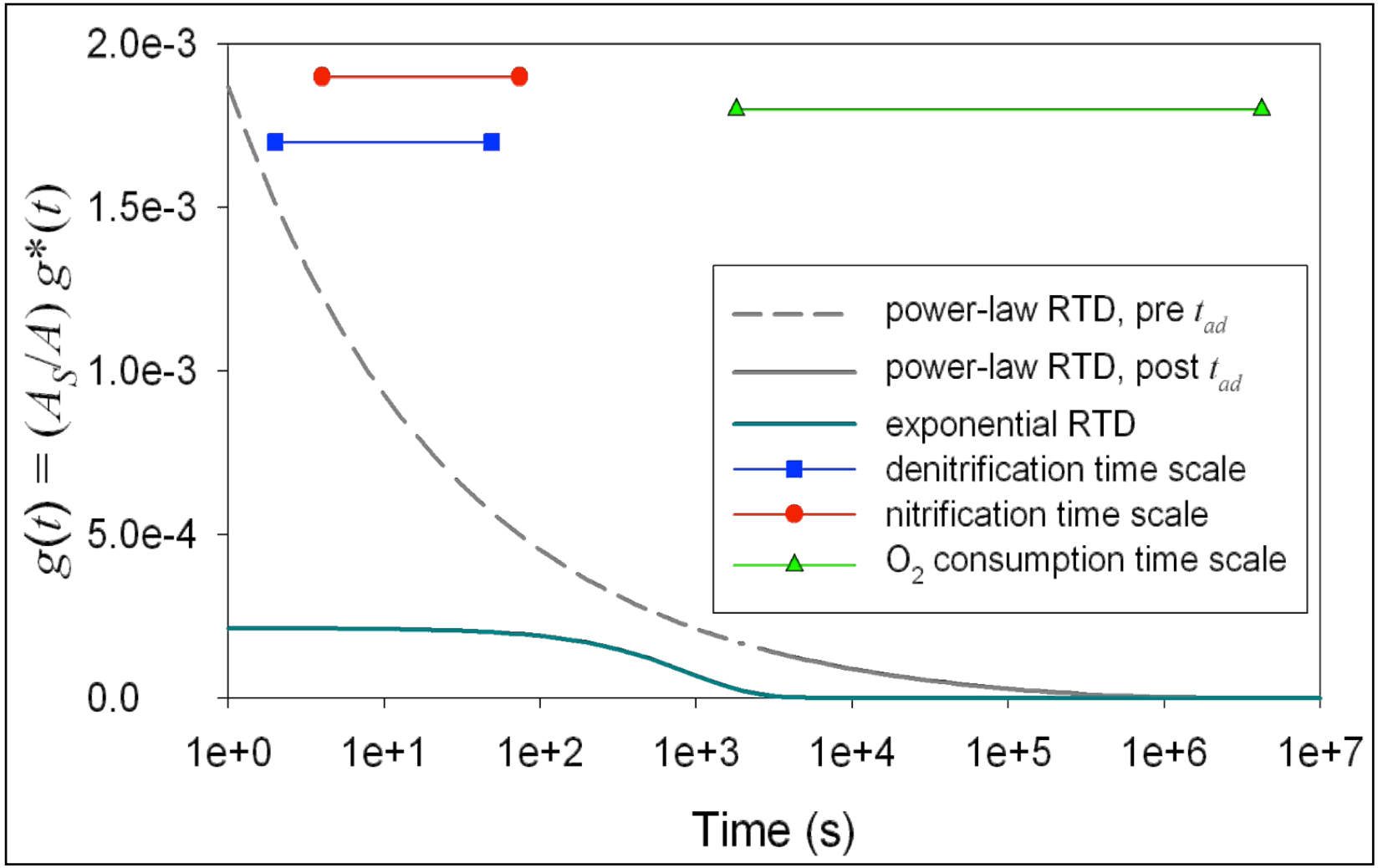
Which model is better?
Why does it matter?



Literature

- Gooseff, MN, DM McKnight, RL Runkel and BH Vaughn. 2003. Determining long time-scale hydrologic flow paths in Antarctic streams. Hydrological Processes, 17 (9):1691-1710.
- Gooseff, MN, SM Wondzell, R Haggerty, and J Anderson. 2003. Comparing transient storage modeling and residence time distribution (RTD) analysis in geomorphically varied reaches in the Lookout Creek basin, Oregon, USA. Advances in Water Resources, 26(9): 925-937.

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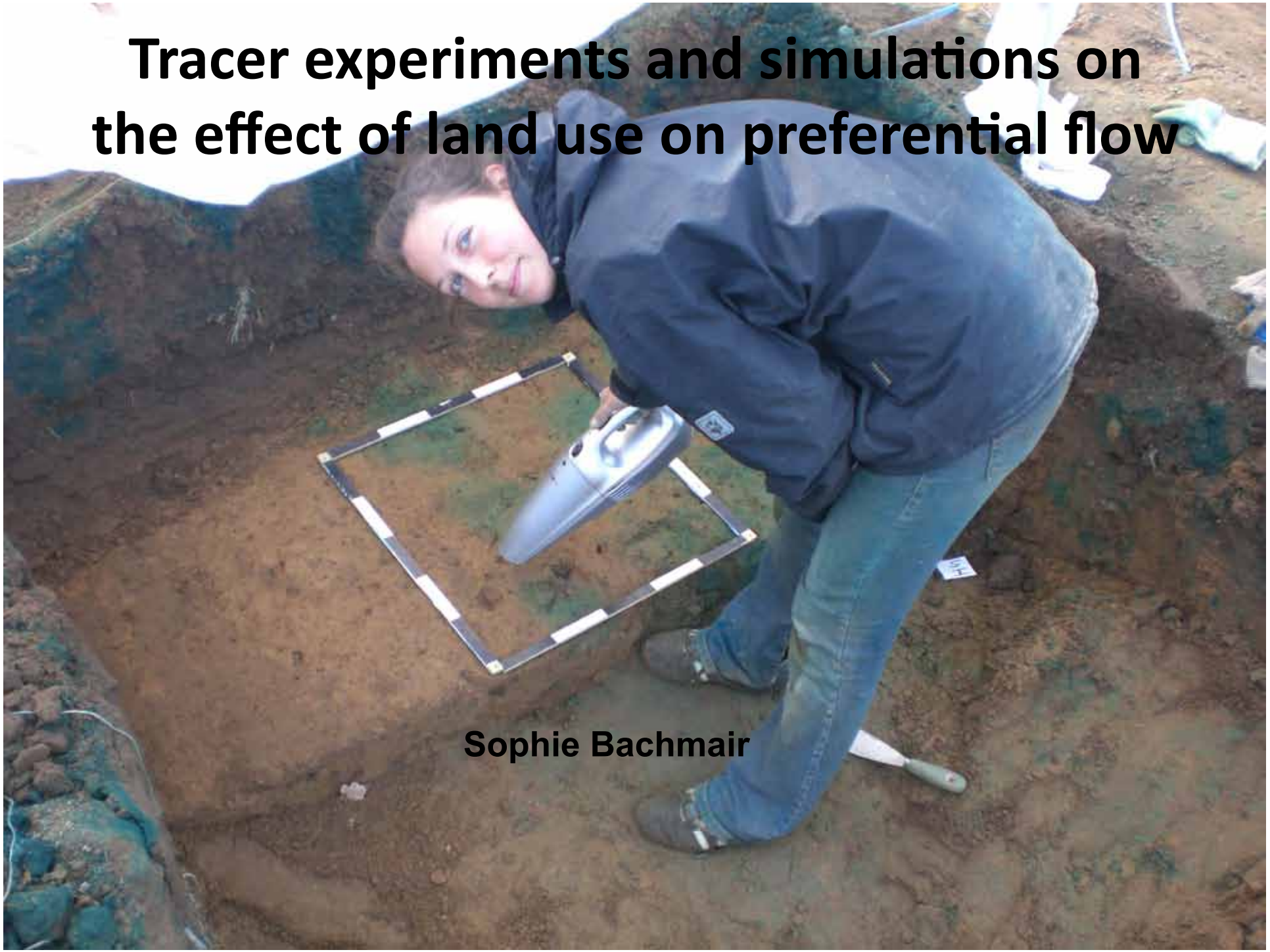
Tracer experiments and simulations on the effect of land use on preferential flow



Sophie Bachmair

Objectives

The objectives of the study are to investigate

- the **effects of different land use, land cover and management practices** on the formation of **soil structure** and the significance of **preferential flow**
- the **effects of different rainfall application amounts**
- and to test whether the **INfiltration–INitiation–INteraction Model (IN³M)** is capable to predict water flow in macroporous soil under different land use and land cover.

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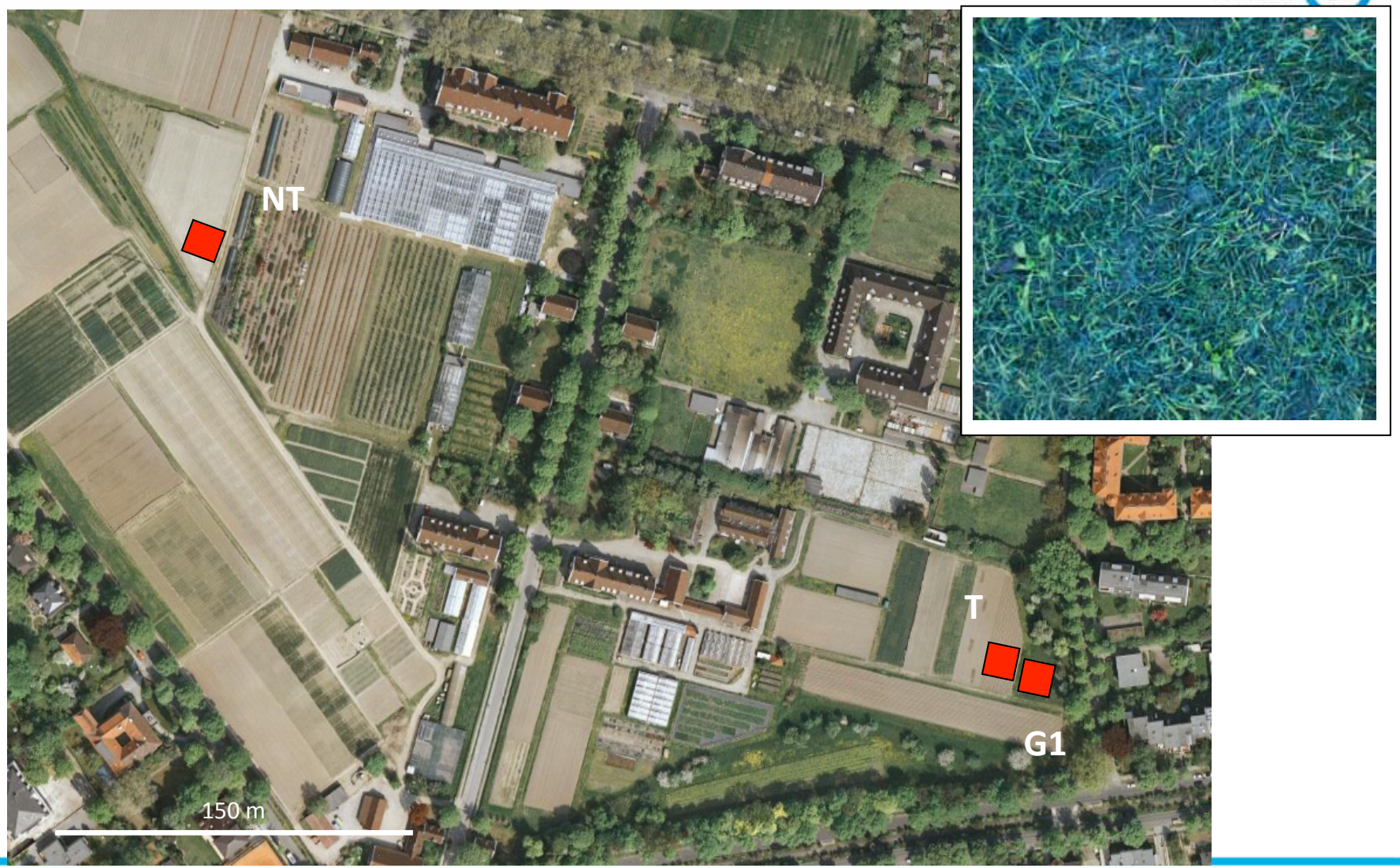
Site description



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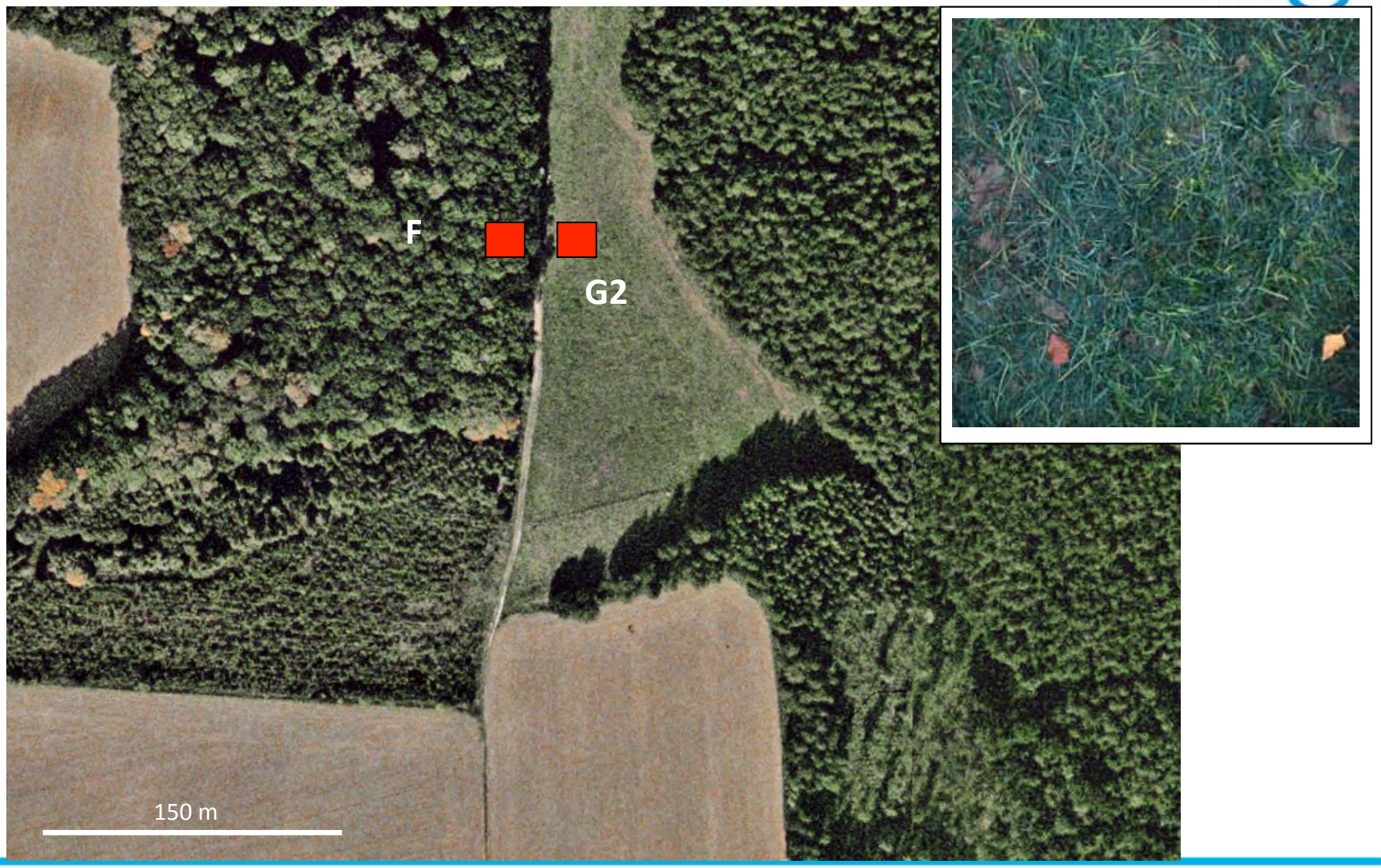
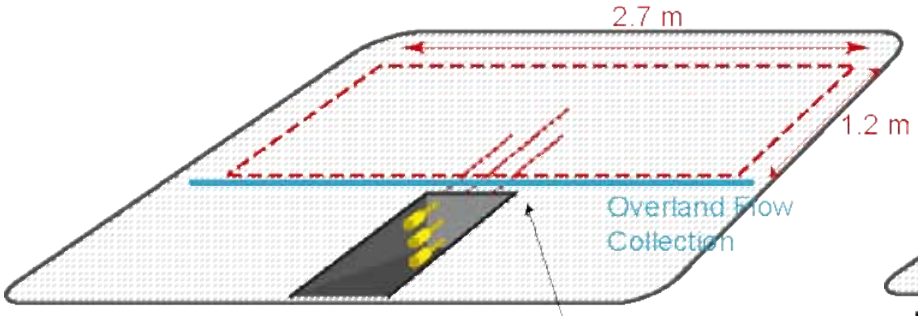


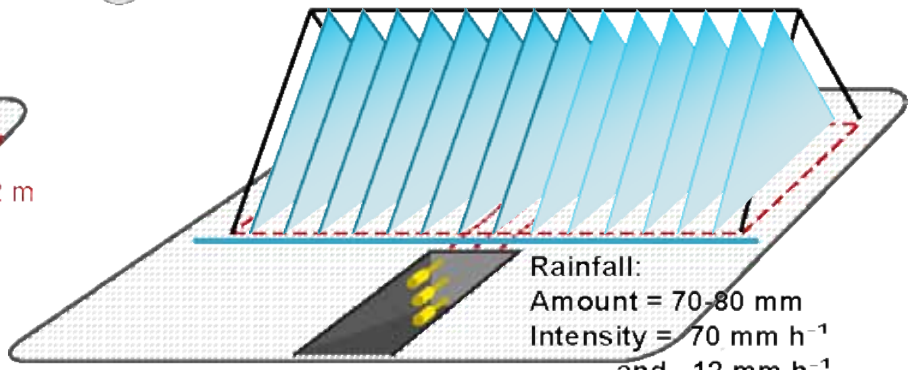
Sprinkling and dye tracing experiments

1 Set-up of experimental plot

(land-use: meadow)



2 Rainfall Simulation



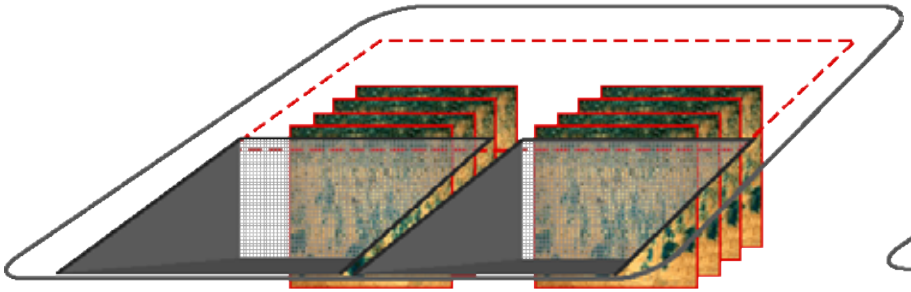
Rainfall:
Amount = 70-80 mm
Intensity = 70 mm h^{-1}
and 12 mm h^{-1}

Different initial soil moisture conditions

"dry" and "wet"

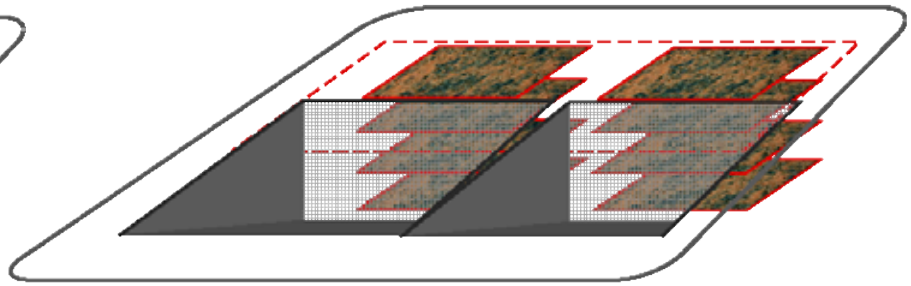
Dye tracer (Brilliant Blue FCF) continuously added to the sprinkling water

3 Preparing 4-5 vertical sections



Area (100 cm * 100 cm), Horizontal distance 10 cm

4 Preparing 4-5 horizontal sections



Area (100 cm * 50 cm), Vertical distance 10-20 cm

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Traceraufbringung

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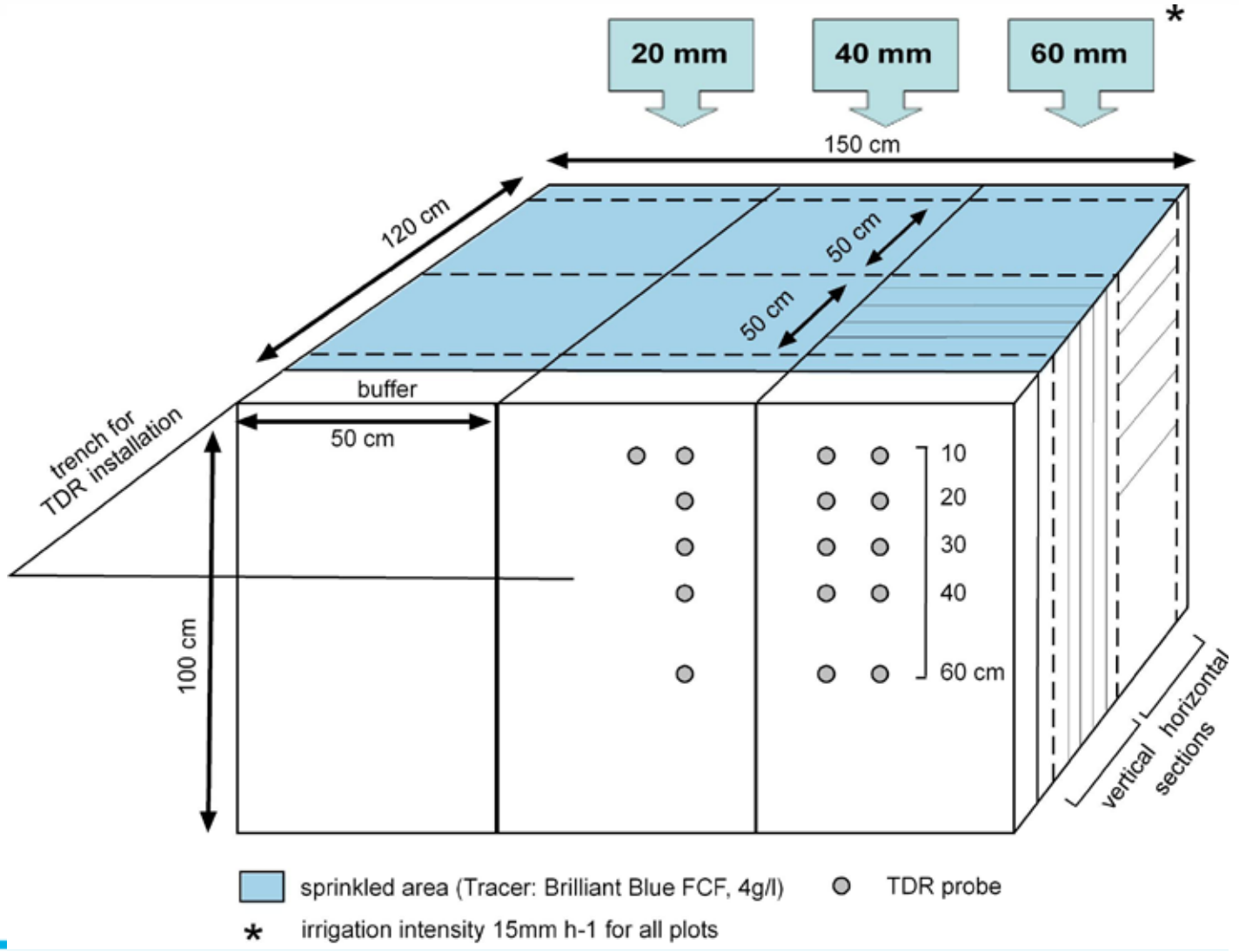
Experimental set-up



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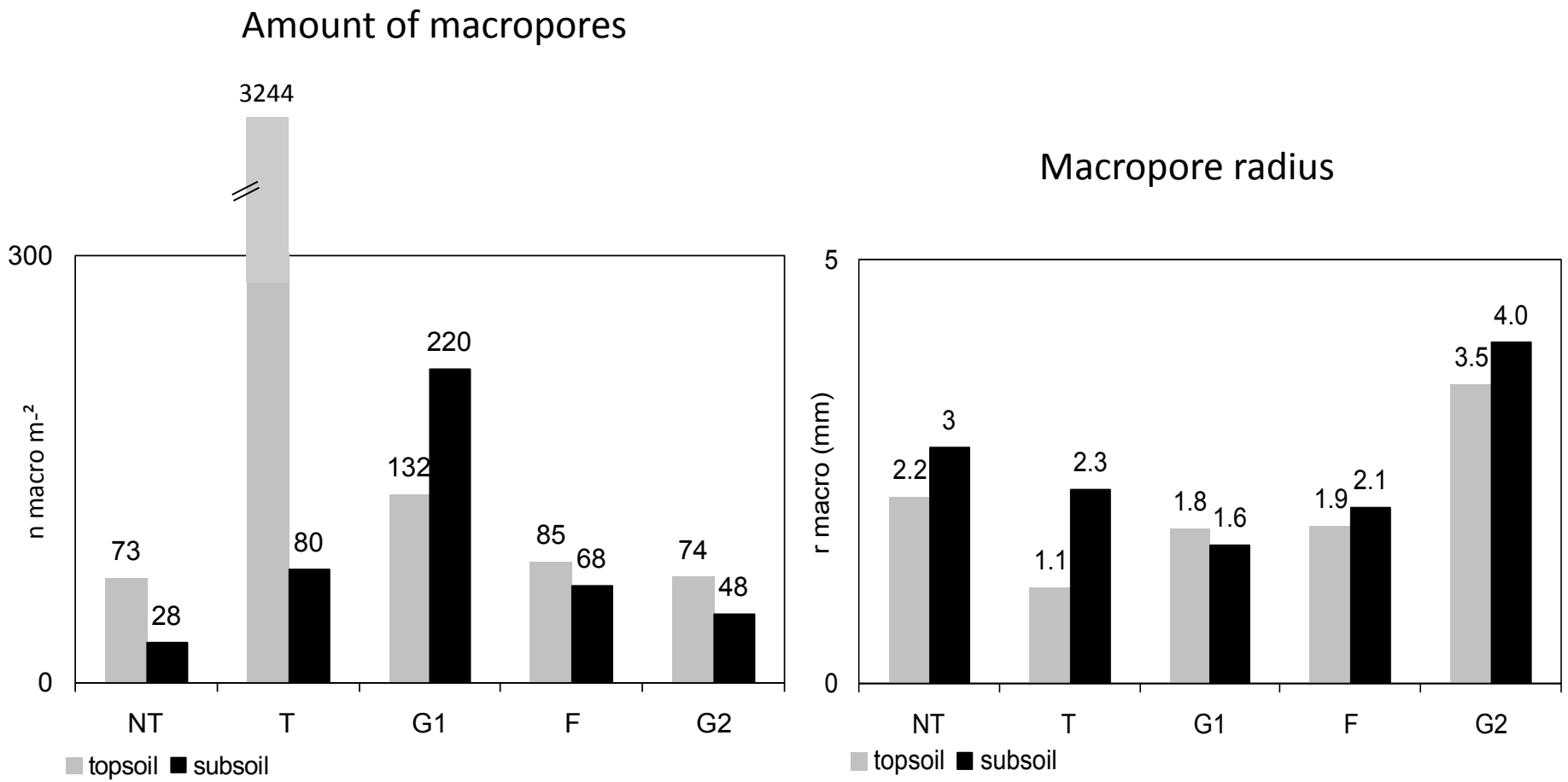
Results – Macropore structure



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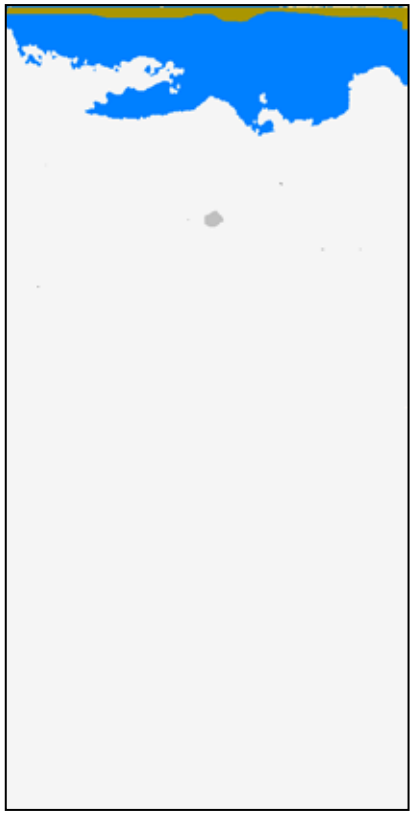
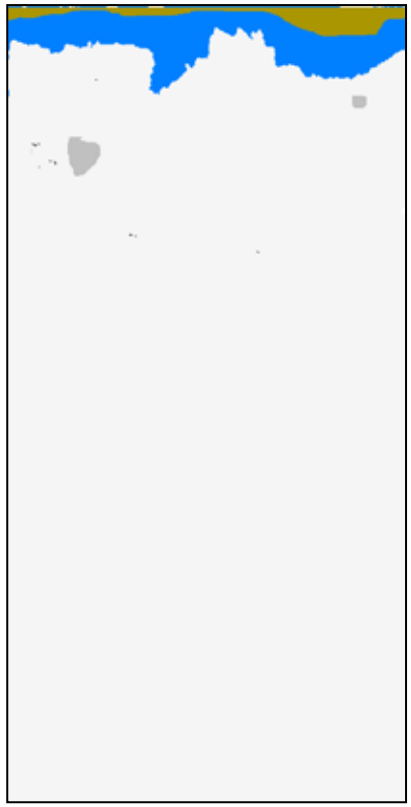
Results – Untilled farmland

20mm



40mm



60mm

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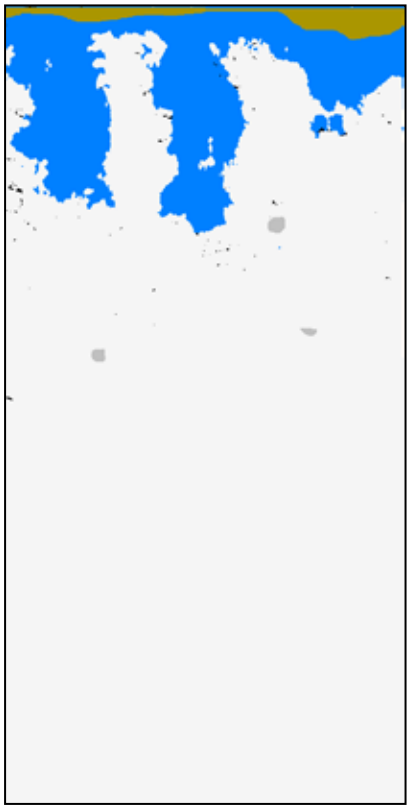
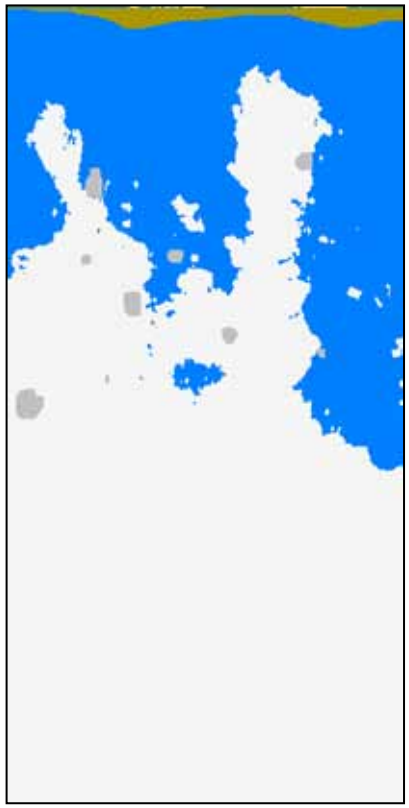
Results – Tilled Farmland

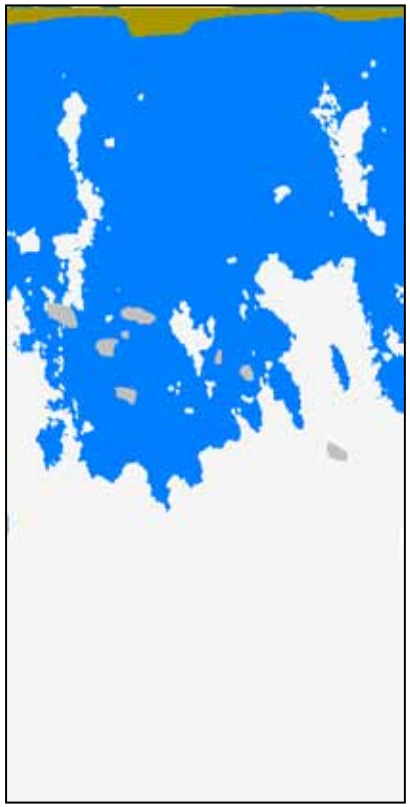
20mm



40mm

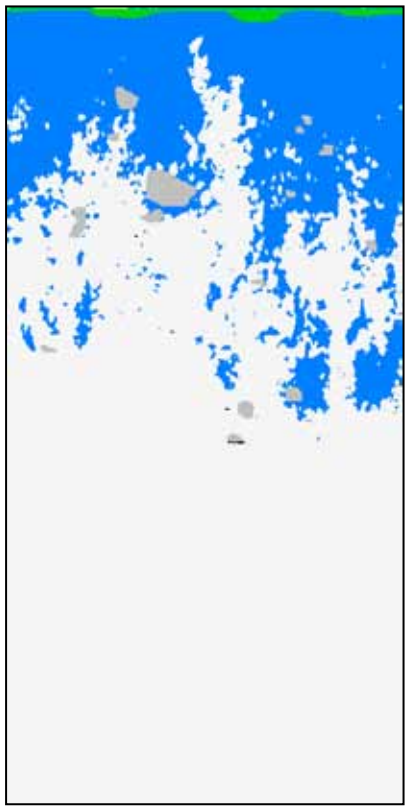


60mm

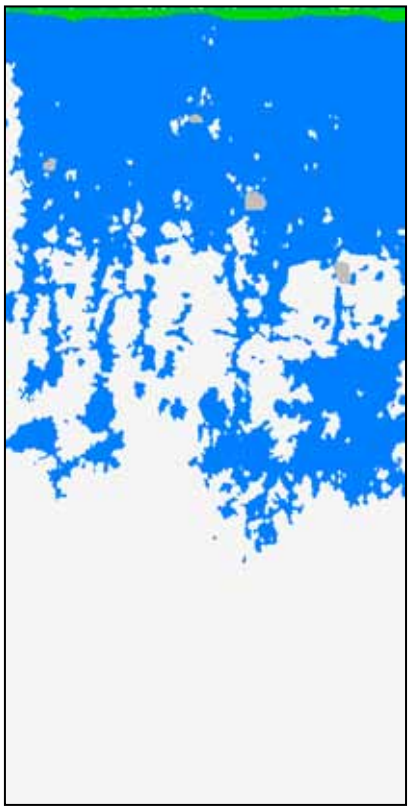


Results – Grassland 1

20mm



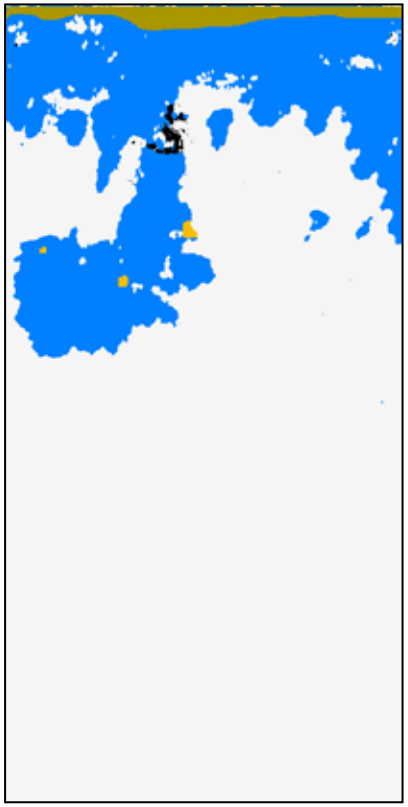
40mm



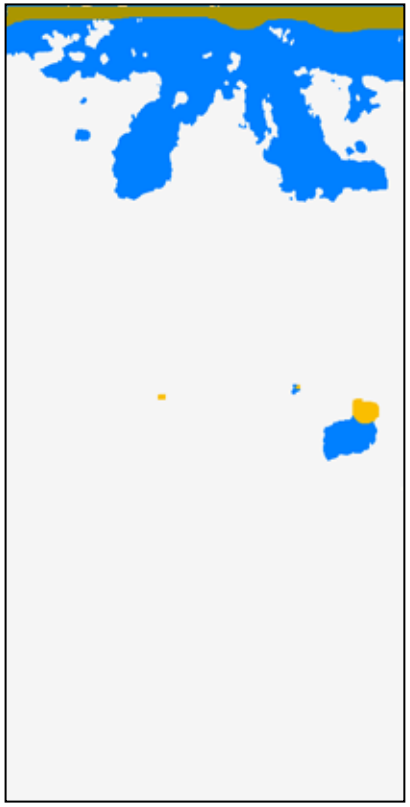
60mm

Results – Deciduous forest

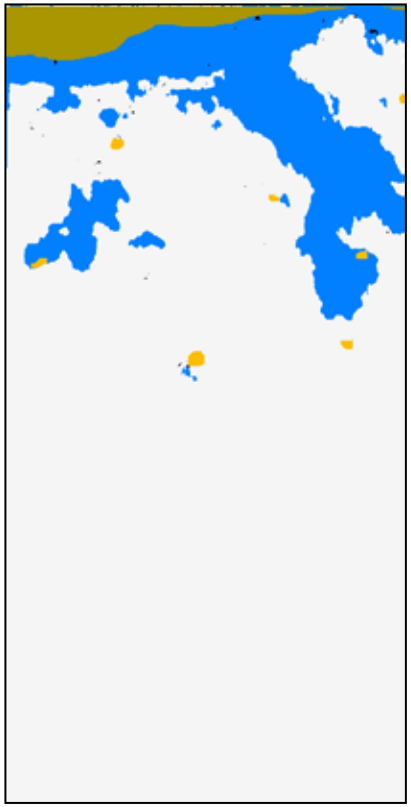
20mm



40mm



60mm



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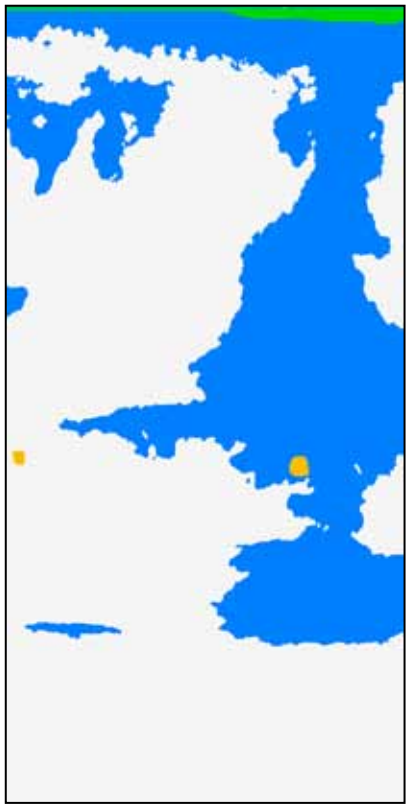
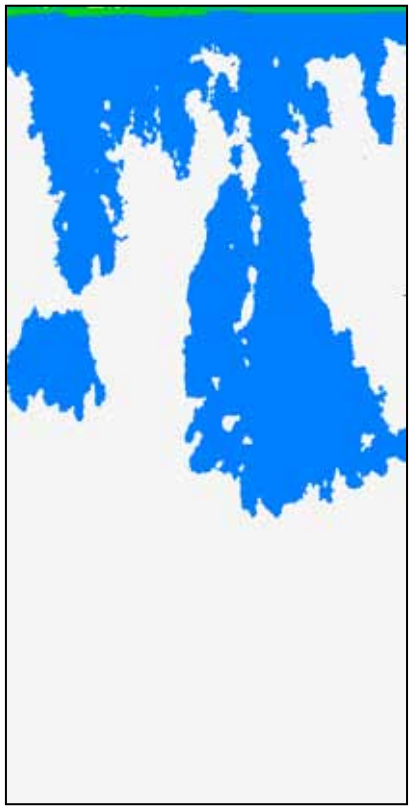
Results – Grassland 2

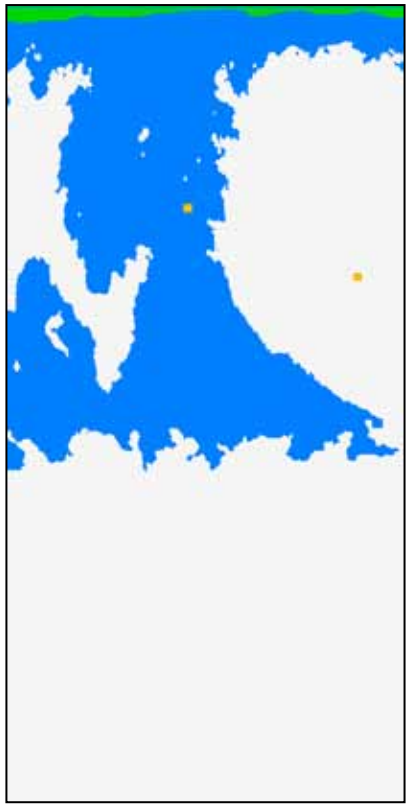
20mm



40mm



60mm



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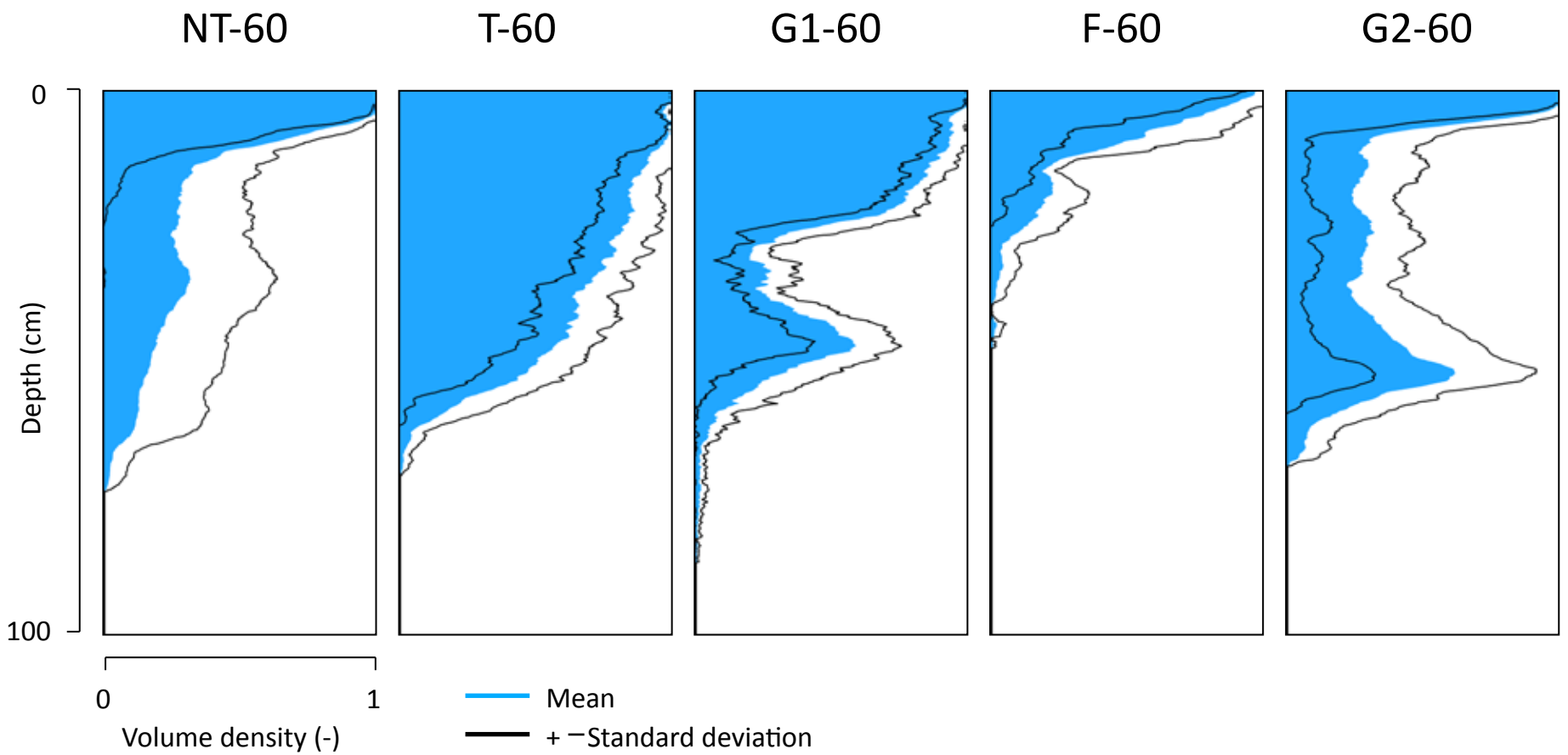
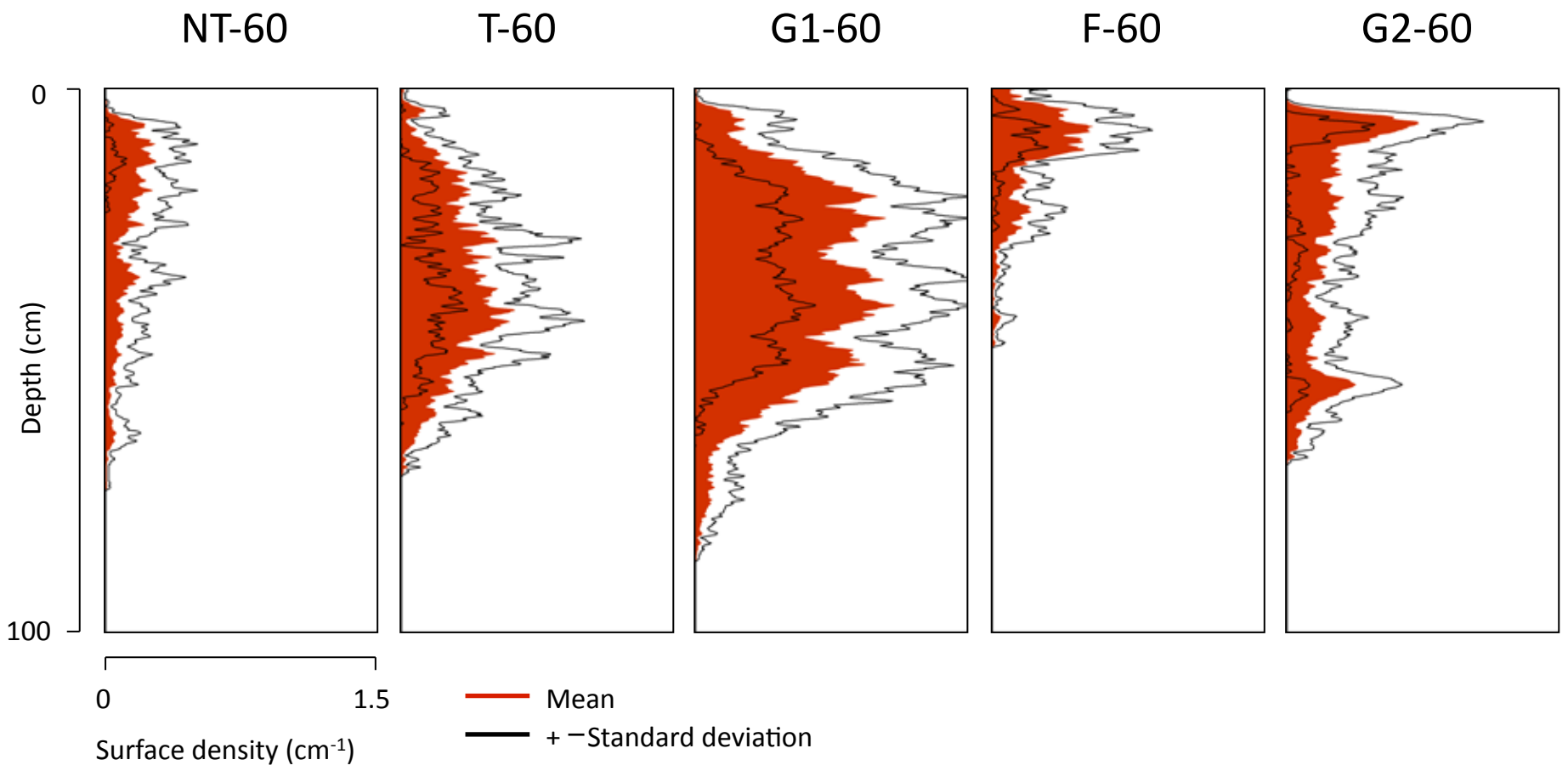
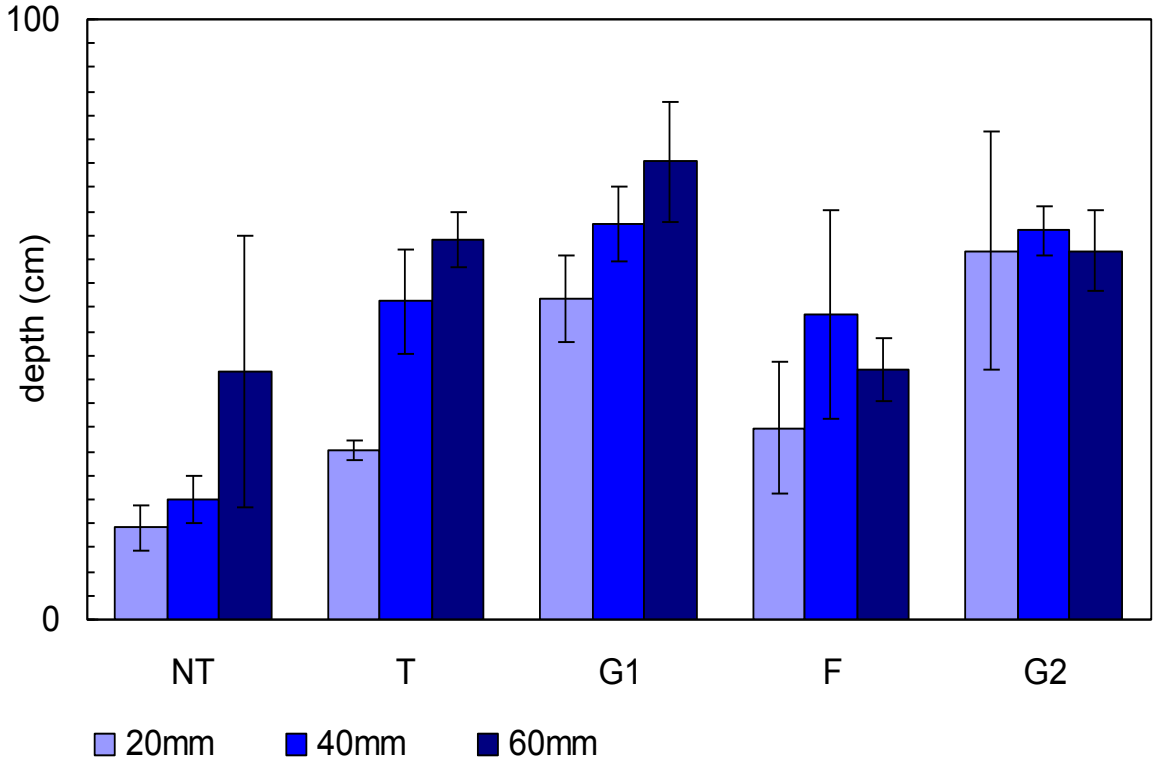
Results – Volume density 60mm plots



Results – Surface density 60mm plots



Results – Maximum infiltration depth



Analysis of Variance

Between application amounts

	Test-value	P-value
NT	10.831	0.004
T	15.904	3.52E-04
G1	12.824	0.002
F	5.234	0.073
G2	1.264	0.532

Between sites

	Test-value	P-value
60mm	22.225	1.81E-04
40mm	27.295	1.81E-04
20mm	29.717	1.81E-04

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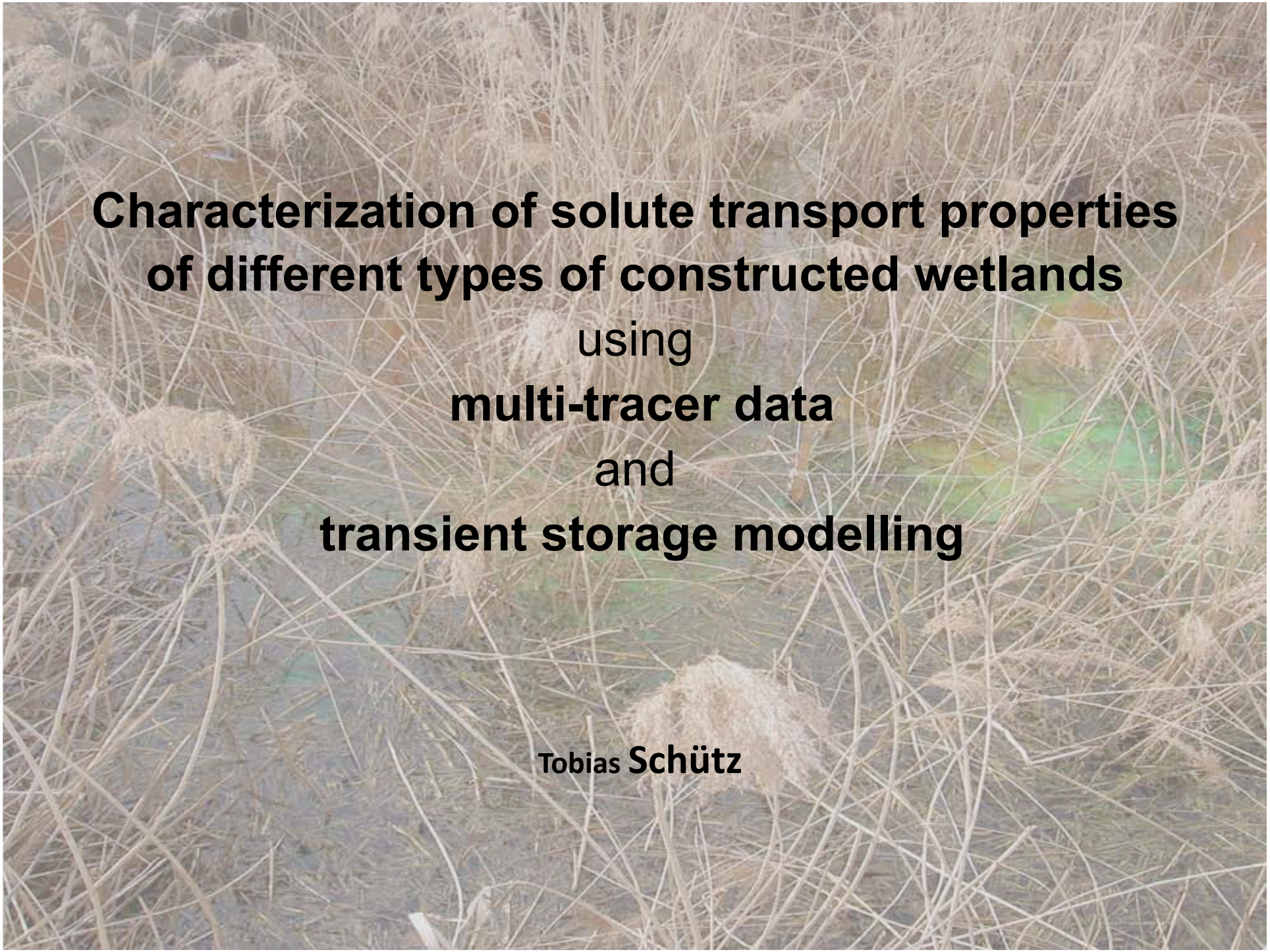

Characterization of solute transport properties of different types of constructed wetlands using multi-tracer data and transient storage modelling

Tobias Schütz

Introduction

- **Pesticides as non-point-source pollution in agricultural headwater catchments are documented**
- **→ Still measureable concentrations in large rivers e.g. River Rhine**
- **Measures to retent and to mitigate pesticides in surface waters:**
- **→ Constructed wetlands (CW)**

0884 (E)7-(Z)9-Dodecadienylacetat
0673 (Z)-9-Dodecenylacetat
1039 1-Methylcyclopropen
0641 Clofentezin
0864 Clomazone
0446 Clopyralid
0849 Fluazinam
0887 Fludioxonil
0922 Flufenacet
1019 Mesosulfuron
0975 Mesotrione
1079 Metaflumizone
0900 Pyrimethanil
1093 Pyroxsulam
0867 Quinmerac
0852 Quinoclamin
1046 Acequinocyl
9610 Coniothyrium minitans
1012 Cyazofamid
0811 Cycloxydim
1034 Fluoxastrobin
0925 Flupyrsulfuron
0845 Fluquinconazol
0456 Metamitron
0617 Metazachlor
0945 Metconazol
0840 Quizalofop-P
0757 Rapsöl
0846 Rimsulfuron
0184 Schwefel
0986 Silthiofam
0963 S-Metolachlor
1008 Spinosad
1031 Spirodiclofen
0914 Spiroxamine
0897 Sulcotrion
0955 Sulfosulfuron
1043 Sulfurylfluorid
0894 tau-Fluvalinat
0784 Tebuconazol
0905 Tebufenozid
0886 Tebufenpyrad
0778 Tefluthrin
1089 Tembotrione
0967 Tepraloxydim
0316 Terbuthylazin
0941 Tetraconazole
0256 Thiabendazol
0982 Thiacloprid
0987 Thiamethoxam
1104 Thiencarbazone
0761 Thifensulfuron
0370 Thiophanat-methyl
0119 Thiram
0621 Tolclofos-methyl
0371 Tolylfluanid
1047 Topramezone
0605 Triadimenol
0802 Triasulfuron
0676 Triazoxid
0800 Tribenuron
0525 Triclopyr
0972 Trifloxystrobin
0882 Triflusulfuron
0893 Trinexapac
0936 Triticonazol
1024 Tritosulfuron
0114 Warfarin
0228 Wildschadenverhütungsmittel
0898 zeta-Cypermethrin
0003 Zinkphosphid
1006 Zoxamide
0876 Amidosulfuron
1055 Aminopyralid
1094 Amisulbrom
9650 Ampelomyces quisqualis Stamm
0902 Azoxystrobin
9350 Bacillus subtilis Stamm QST 713
9310 Bacillus thuringiensis
9302 Bacillus thuringiensis
1038 Benalaxyl-M
0335 Bentazon
1032 Benthiavalicarb
0937 Benzoesäure
0813 beta-Cyfluthrin
0537 Bifenox
0753 Bifenthrin
1080 Blutmehl
1023 Boscalid
0683 Brodifacoum
0618 Bromadiolon
0264 Bromoxynil
0603 Calciumcarbid
0348 Calciumphosphid
0012 Captan
0378 Carbendazim
0927 Carfentrazone
1095 Chlorantraniliprole
0089 Chloridazon
0388 Chlormequat
0238 Chlorphacinon
0021 Chlorpropham
0363 Chlorpyrifos
0276 Chlorthalonil
0279 Chlortoluron
0921 Clethodim
0895 Clodinafop
0498 Cypermethrin
0825 Cyproconazol
0907 Cyprodinil
0037 Deiquat
0415 Desmedipham
0218 Dicamba
0771 Dichlorprop-P
0521 Difenacoum
0698 Diflufenican
0413 Dimethachlor
0988 Dimethenamid-P
0042 Dimethoat
0841 Dimethomorph
1028 Dimoxystrobin
0045 Dithianon
0048 Dodin
0947 Eisen-III-phosphat
0229 Eisen-II-sulfat
0875 Epoxiconazol
0767 Esfenvalerat
0928 Essigsäure
0481 Ethephon
0383 Ethofumesat
0829 Etofenprox
0944 Famoxadone
1009 Fenamidone
0885 Fenazaquin
0956 Fenhexamid
0796 Fenoxaprop-P
0765 Fenoxycarb
0881 Fenpropidin
0608 Fenpropimorph
0880 Fenpyroximat
0952 Flazasulfuron
0973 Florasulam
0833 Fluazifop-P
1057 Flutolanil
0091 Folpet
1015 Foramsulfuron
0522 Fosetyl
0214 Fuberidazol
1051 gamma-Cyhalothrin
0651 Glufosinat
0405 Glyphosat
0779 Hexythiazox
0607 Hymexazol
0448 Imazalil
0931 Imazosulfuron
0866 Imidacloprid
0966 Indoxacarb
0983 Iodosulfuron
0212 Ioxynil
0419 Iprodion
0968 Iprovalicarb
0411 Isoproturon
0674 Isoxaben
0924 Isoxaflutole
0653 Kali-Seife
0923 Kieselgur
0785 Kohlendioxid
0904 Kresoxim-methyl
0347 Kupferhydroxid
0940 Kupferoktanoat
0147 Kupferoxychlorid
0751 lambda-Cyhalothrin
0612 Lecithin
0354 Magnesiumphosphid
0297 Maleinsäurehydrazid
0010 Mancozeb
1085 Mandipropamid
0073 Maneb
0074 MCPA
0980 Mepanipyrim
0510 Mepiquat
0143 Mineralöle
0776 Myclobutanil
0367 Napropamid
0934 Nicosulfuron
0969 Pelargonsäure
0655 Penconazol
0649 Pencycuron
0404 Pendimethalin
1044 Penoxsulam
1021 Pethoxamid
0233 Phenmedipham
0013 Phosphan (Phosphorwasserstoff)
0308 Picloram
0989 Picolinafen
0971 Picoxystrobin
1059 Pinoxaden
0309 Pirimicarb
0476 Pirimiphos-methyl
0631 Prochloraz
0909 Prohexadion
0516 Propamocarb
0869 Propaquizafop
0624 Propiconazol
1011 Propoxycarbazone
0350 Propyzamid
1053 Proquinazid
0763 Prosulfocarb
0917 Prosulfuron
1035 Prothioconazol
9380 Pseudomonas chlororaphis StammMA 342
0929 Pymetrozin
1013 Pyraclostrobin
0098 Pyrethrine
0610 Pyridat

Active substances in authorized plant protection products, Germany, April 2010.

Introduction

Problem & Approach

- **Numerous active substances with different physico-chmical characteristics**
- **Expensive laboratory analysis**
- **Mitigation measures (CW´s) which need to be characterized, regarding functioning and efficiency**

→ **Hydrological tracers to investigate hydraulics and transport behaviour of CW**

(e.g.: SR WT: Stern et Al.,2001;R WT and Li: Dierberg and De Busk, 2005; Li: Kadlec,1994; Br: Maloszewski et Al., 2006;…….)

→ **Simulation and prediction of CW sytems using hydrological transport models**

(e.g.: Werner and Kadlec, 2000a/b,1996; Crohn et Al., 2005; Vanclooster et Al., 2000; Somes et Al.,1999;Koskiaho,2003; Walker,1998,2001;…)

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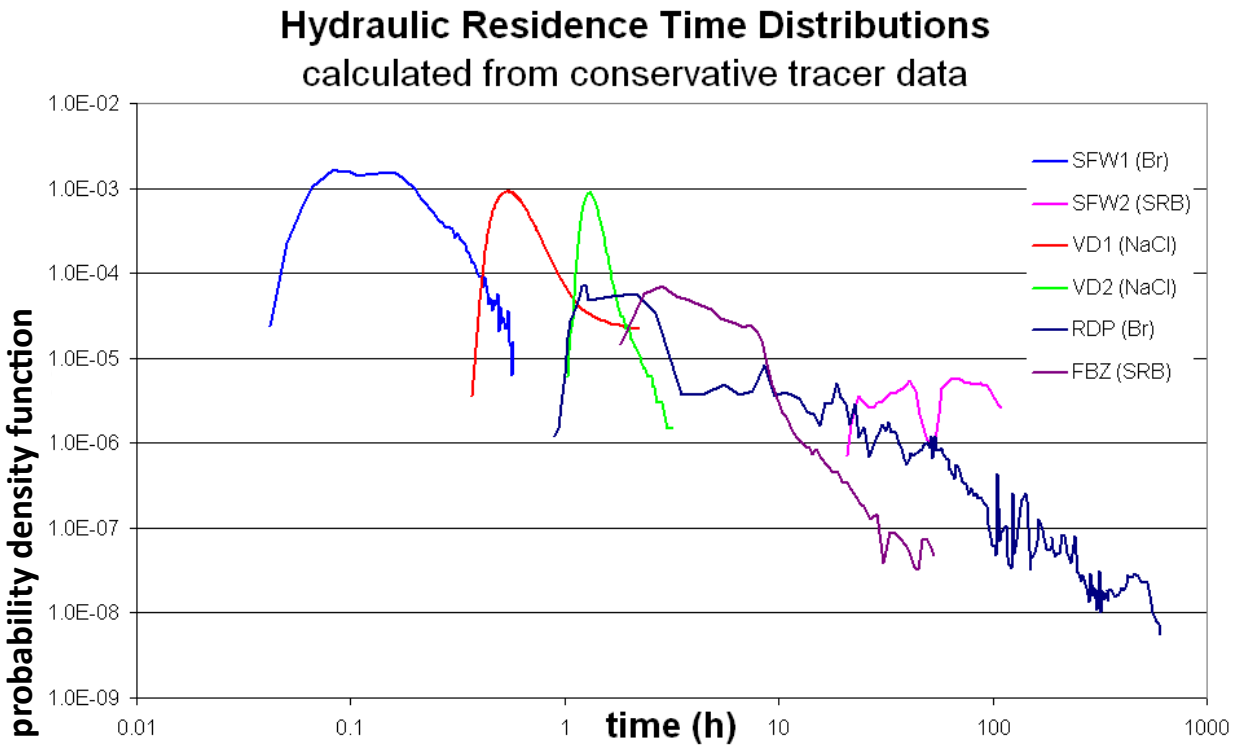
Methods & Materials

Multi tracer data set

- Conservative tracers: NaCl ($VD_{1/2}$), Bromide (SFW_1, RDP)
- Reactive tracers: Uranin (UR) photosensitive, all CW´s; Sulphorhodamine B (SRB) sorptive, all CW´s
- Pulse injection at CW inlets, measurements at CW outlets



Lange et al., submitted: *Multi-tracer experiments to characterize contaminant mitigation capacities for different types of artificial Wetlands*. Int. J. of Env. An. Ch..
Passeport et. al., 2010: *Artificial Wetland and Forest Buffer Zone: Hydraulic and Tracer Characterization. V. Z.J.*.

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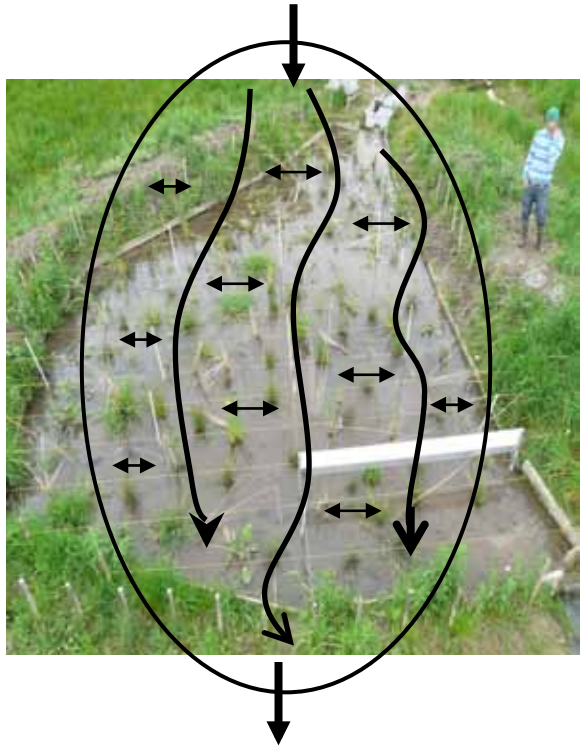
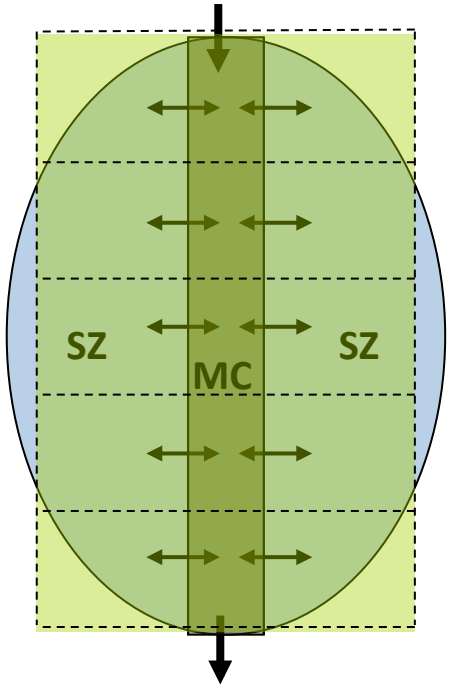
Methods & Materials

Concept of water and solute transport in typical constructed wetland system

Presumed flow system of a surface flow wetland



Wetland concept model



Model requirements:

- Hydraulic description of preferential flow and exchange with shallow storage zones in a CW
- Solute transport with different physico-chemical properties

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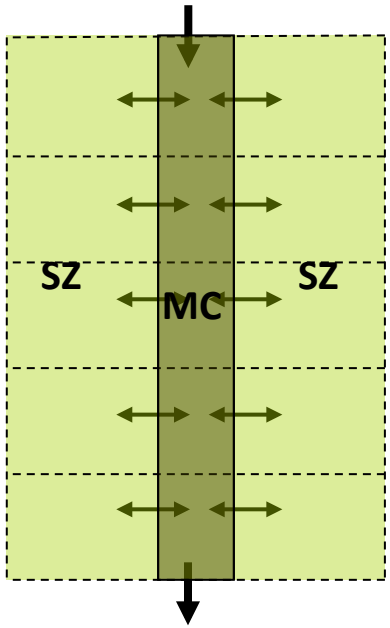
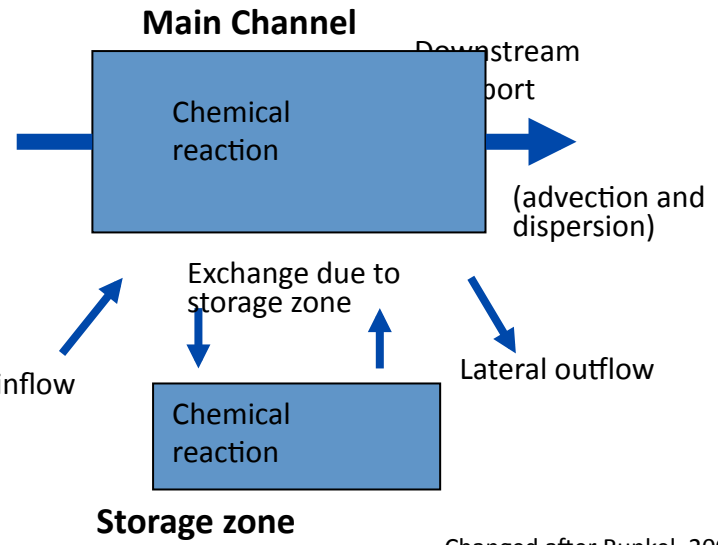
Methods & Materials

OTIS ONE-DIMENSIONAL TRANSPORT WITH INFLOW AND STORAGE
(Runkel, 1998.)

Wetland concept model



OTIS concept model



Changed after Runkel, 2000.

- Plug-flow with dispersion in the main channel (MC)
- First-order-exchange with transient CSTR-zones (SZ)
- Sorption and first-order-degradation can be included (MC& SZ)
- OTIS-P includes automated parameter estimation

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Methods & Materials

Solute transport in CW´s - modelling approach

OTIS calibration parameters:

Calibration with:

Conservative transport

- D dispersion coefficient
- A_{MC} cross-sectional area of MC
- A_{SZ} cross-sectional area of SZ
- α exchange coefficient

Conservative tracer data

✓ ✓ ✓ } comparison with measured cross sections

✓

Sorption

- $\Lambda_{sorp.}$ sorption rate coefficient → MC, SZ
- KD distribution coefficient
- Rho available sediment concentration → MC

Reactive tracer data (SRB)

✓ → SZ

— → determined in batch experiments

—

First-order-decay

- Λ_{decay} 1^{st} order rate coefficient → MC, SZ

Reactive tracer data (UR)

✓ → MC

Parameter estimation → Nonlinear-Least-Squares

Convergence criteria → Residual sum of squares and relative change of parameters

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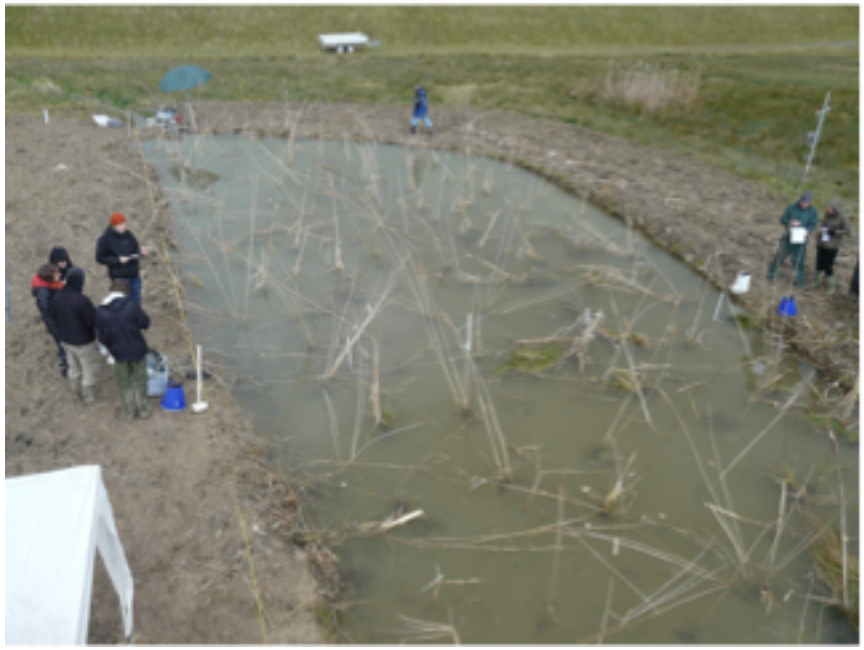
Study site

Emerging vegetation

March 2010



August 2010

→ *Wasserkresse*

Phragmitis austr.

Typha spec.

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Methods

4 multi-tracer experiments using 4 tracers (Bromide (Br), Sulphorhodamine B (SRB), Uranine (UR) and Eosine (EOS))with different physico-chemical properties and 2 different injection methods

Season	Inj. Method	Q	Inj. Time	Injected Mass				Injected Concentration			
				Br	SRB	UR	EOS	Br	SRB	UR	EOS
		l/s	h	mg	µg	µg	µg	mg/l	µg/l	µg/l	µg/l
3	IA	10	0.01	271	1	0.2	0.8	754.9	2777.8	555.6	2222.2
3	CRA	8.4	0.5	278	2.23	0.43	1.76	18.4	147.4	27.4	119.2
8	IA	3.2	0.01	388	1.6	0.2	0.8	11.2	13888.9	1736.1	6944.4
8	CRA	6.9	2.78	776	2.5	2	2	3370.2	36.2	28.9	28.9

Instantaneous tracer addition (IA)

Constant rate tracer addition (CRA)

Methods

Turbidity → SSC *(Gassmann et al., submitted.)*

Tracer tailing auto sampling

Water level

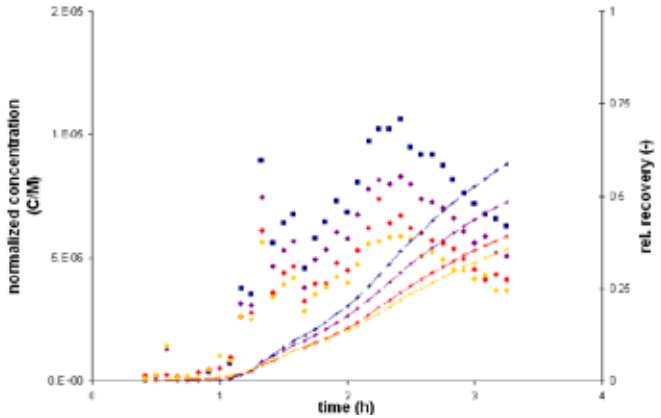
Light decay

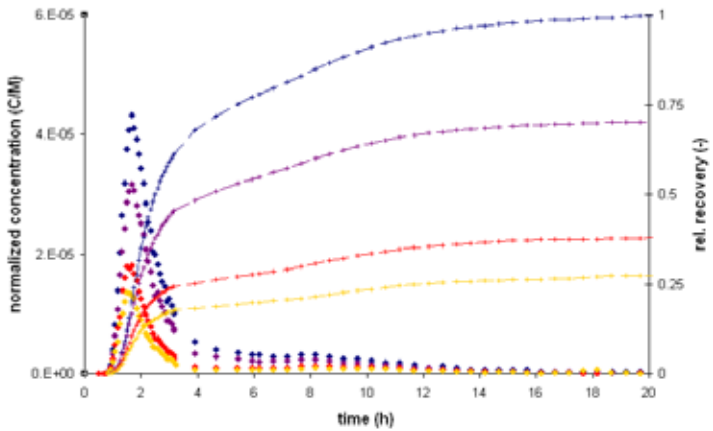
Global radiation

Results

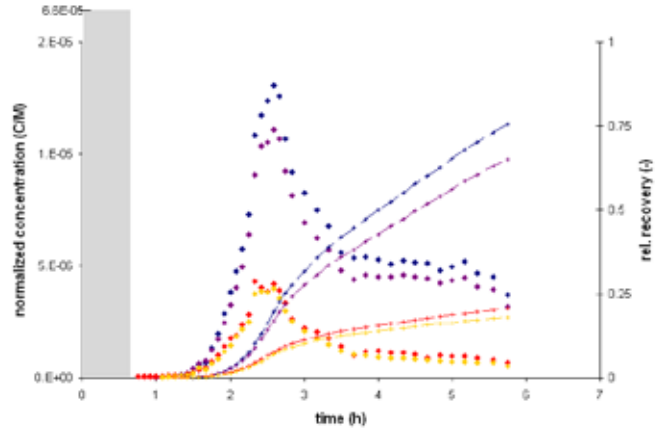
Non-vegetated **Vegetated**

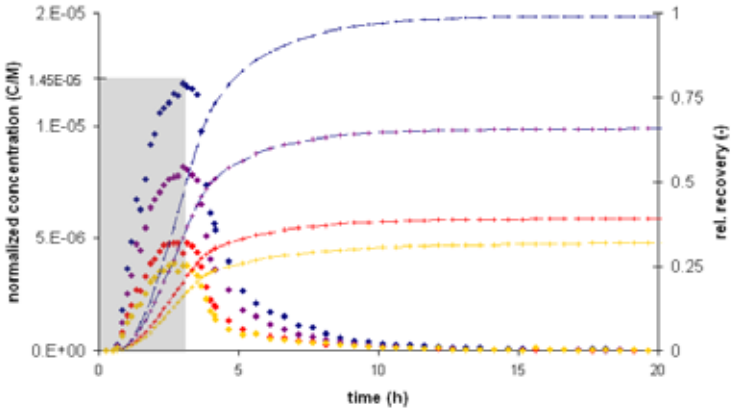
IA





CRA





Br (obs) SRB (obs) UR (obs) EOS (obs)

Br (obs) Recovery SRB (obs) Recovery UR (obs) Recovery EOS (obs) Recovery

Results

Experiment	Br (NaBr)		SRB		UR		EOS	
	M (g)	R (-)	M (g)	R (-)	M (g)	R (-)	M (g)	R (-)
Non-vegetated – IA	271	0.58	1	0.34	0.2	0.39	0.8	0.44
Non-vegetated – CRA	278	0.75	2.23	0.65	0.43	0.21	1.76	0.19
Vegetated – IA	388	0.99	1.6	0.71	0.2	0.38	0.8	0.28
Vegetated – CRA	776	0.98	2.5	0.66	2	0.39	2	0.32

0.59

Next step: Simulation of tracer data

→ to evaluate wetland hydraulics

→ to estimate retention parameters

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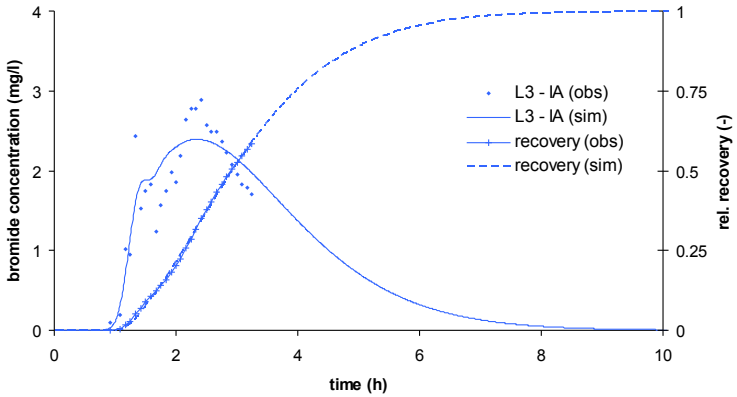
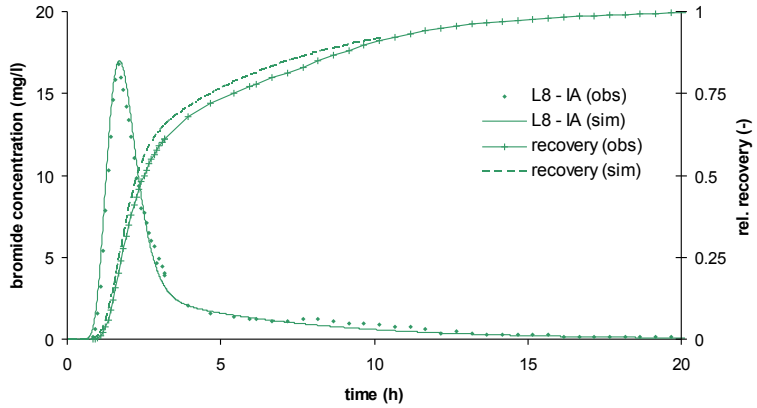
Modelling Br

Non-vegetated

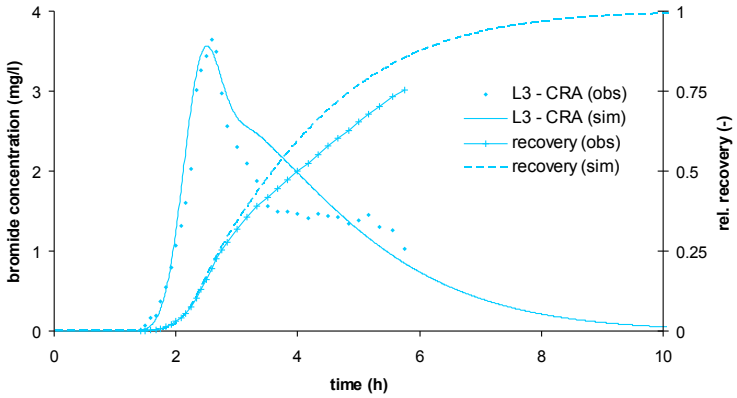
Vegetated

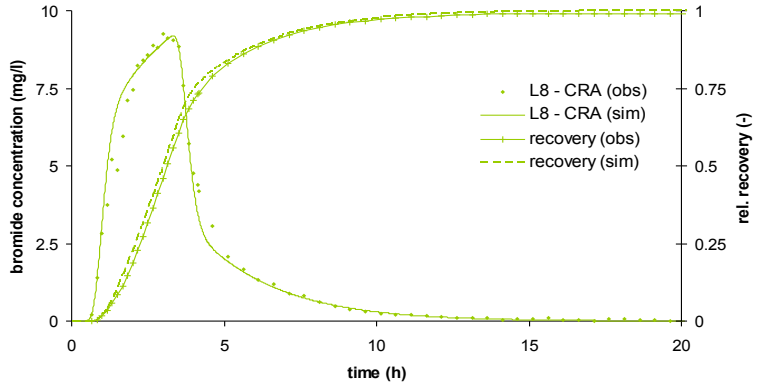
IA



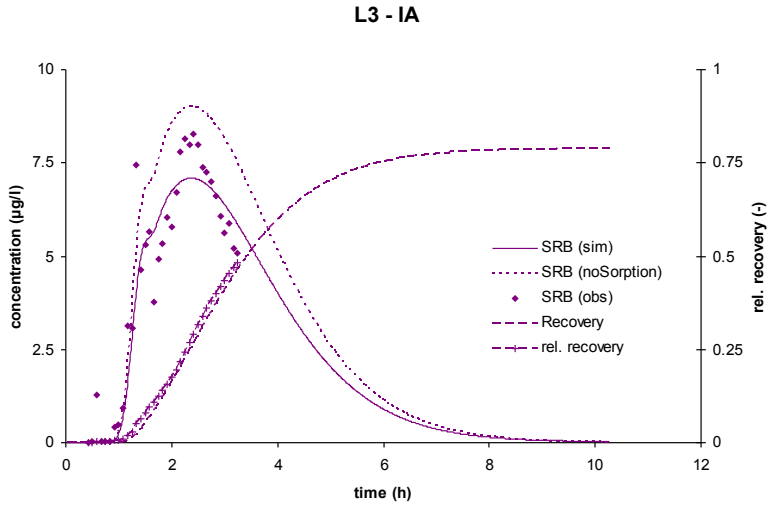


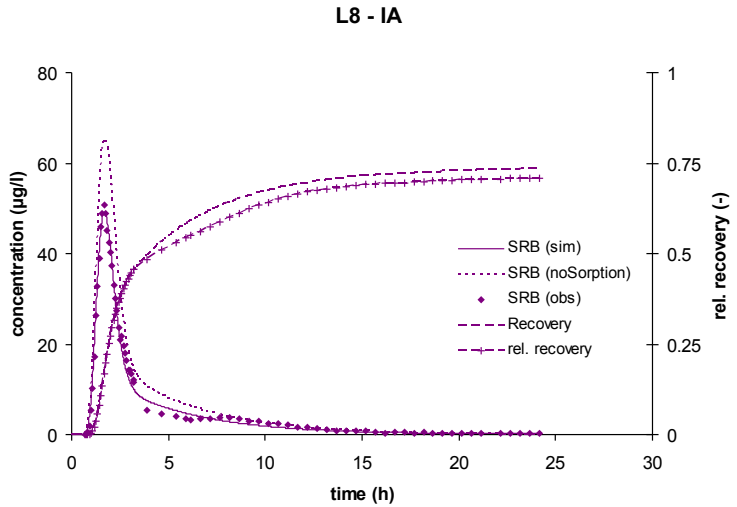
CRA

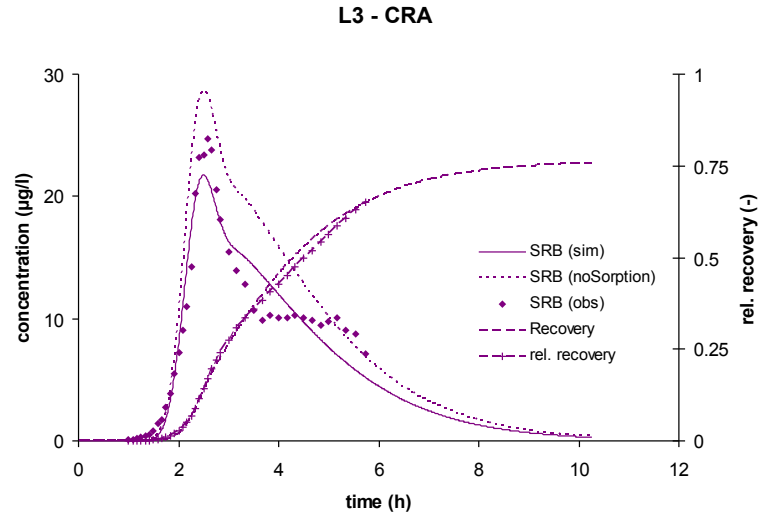


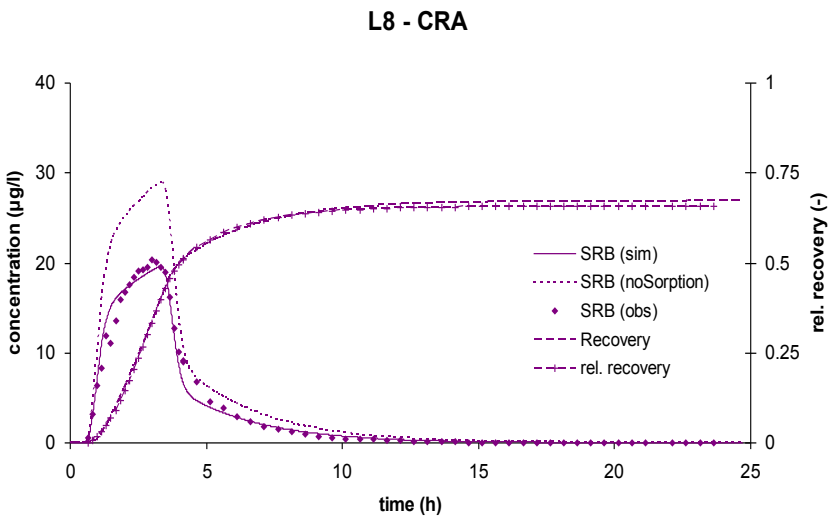


Modelling SRB









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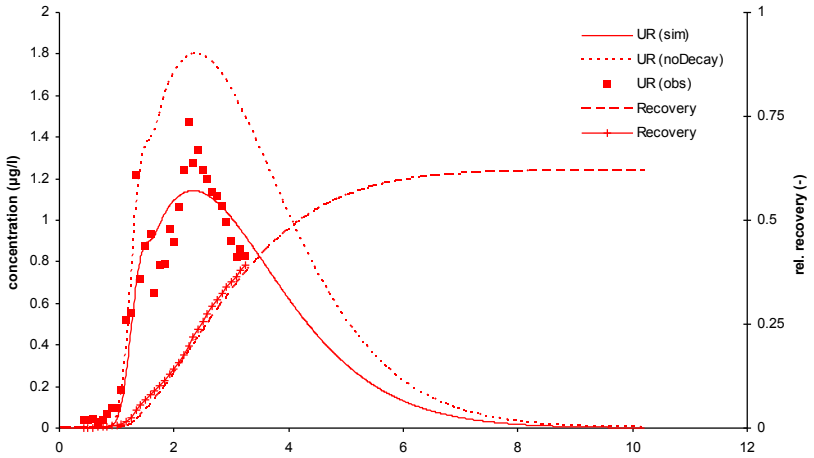
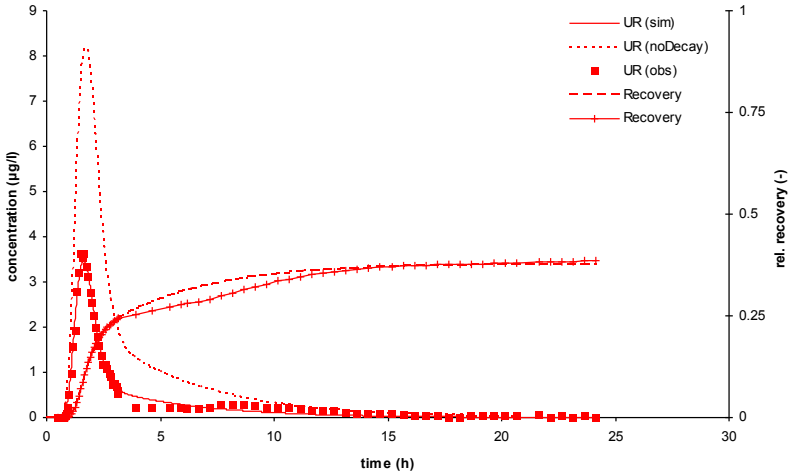
Modelling Uranin

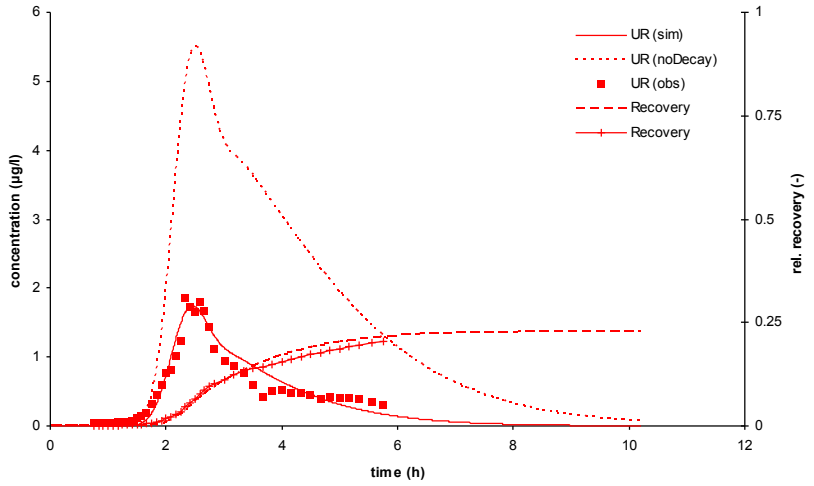
L3 - IA



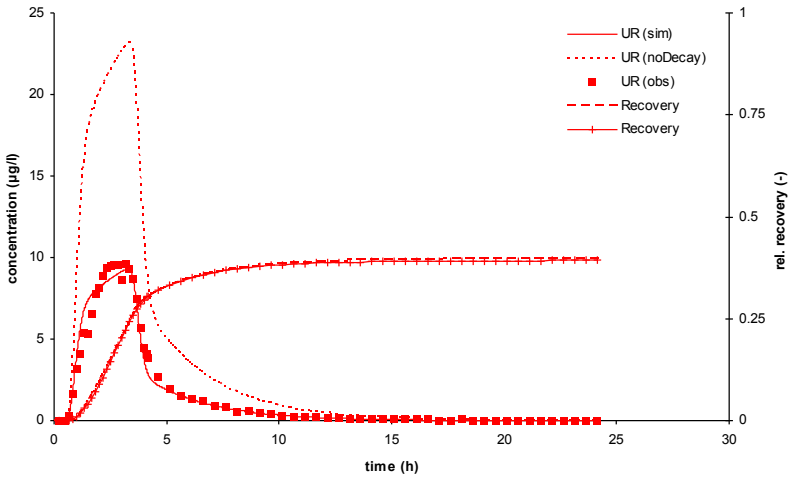
L8 - IA



L3 - CRA



L8 - IA



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Zusammenfassung

- Verbindung von konservativen und nicht konservativen Tracern
- Tracer werden verwendet um Umweltverhalten von Spurenstoffen zu verstehen

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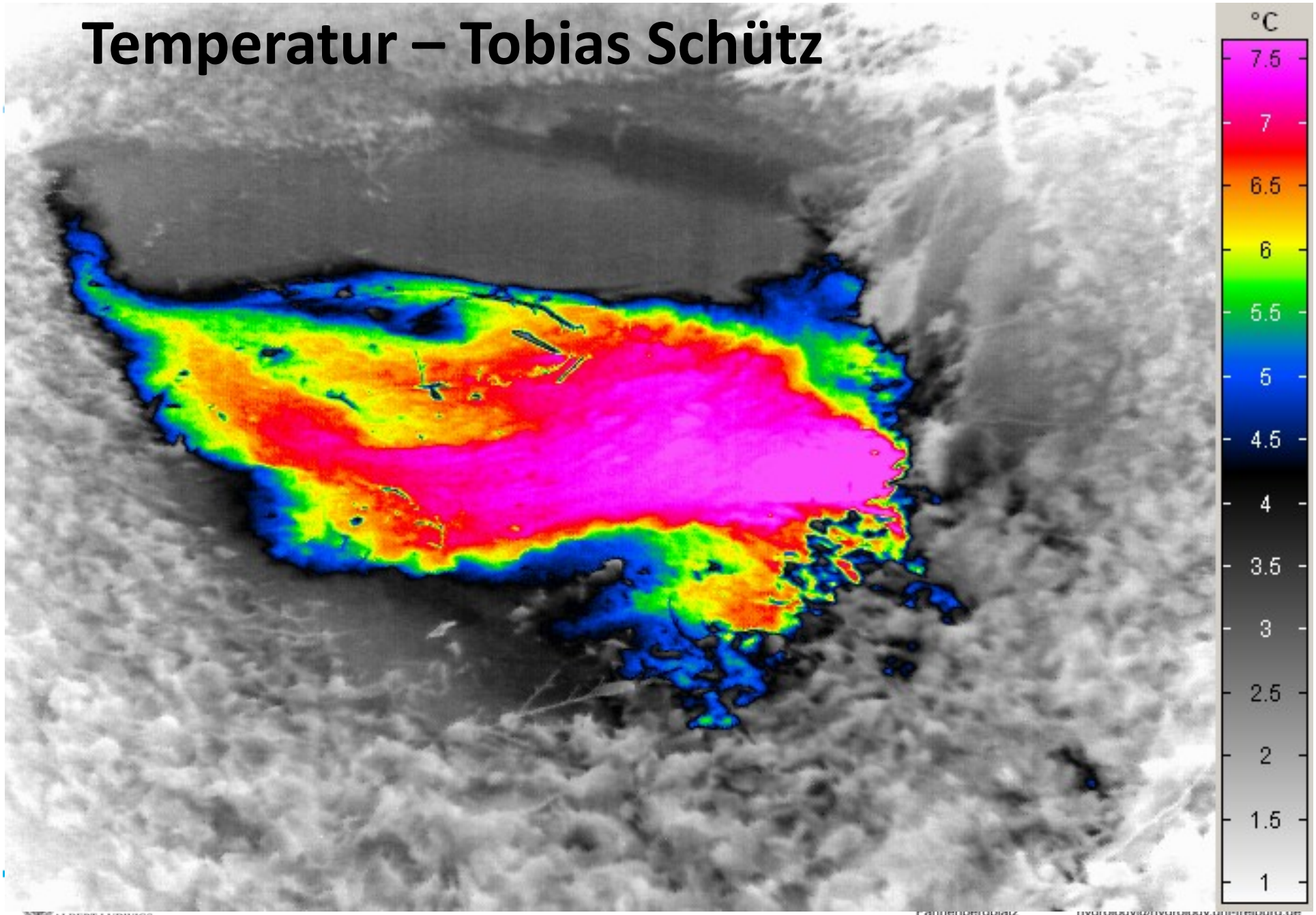
Temperatur – Tobias Schütz



Infrarot Thermographie

<u>technical aspects:</u>

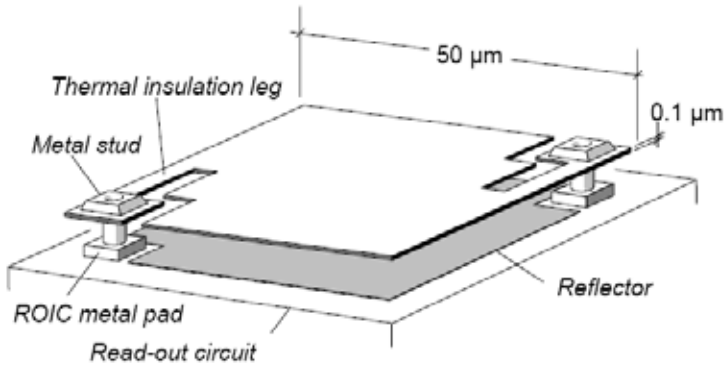
measuring system: uncooled microbolometer focal plane array (FPA)

material: vanadium oxide / amorphic silicium / germanium

observed spectra: 7-14µm wavelength

uncooled microbolometer, focal plane array (FPA):

- adsorption of near infrared radiation
- change of electrical resistance is measured
- dimension of a microbolometer: 50*50*0.1µm
- thermal conductance: $<5*10^{-8}$ W/K
- reaction time: 20ms



Schematic of microbolometer pixel

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Infrarot Thermographie

Stefan–Boltzmann law:
The total energy P, radiated per unit surface area A of a black body in unit time, is directly proportional to the fourth power of the black body's thermodynamic temperature *T*

$$P = \sigma * A * T^4$$

A grey body, is characterized by its emissivity ε

$$P = \boldsymbol{\varepsilon} * \sigma * A * T^4$$

material	emissivity ε
wood	0.94
paper	0.92
sand	0.76
glas	0.91
water	0.96

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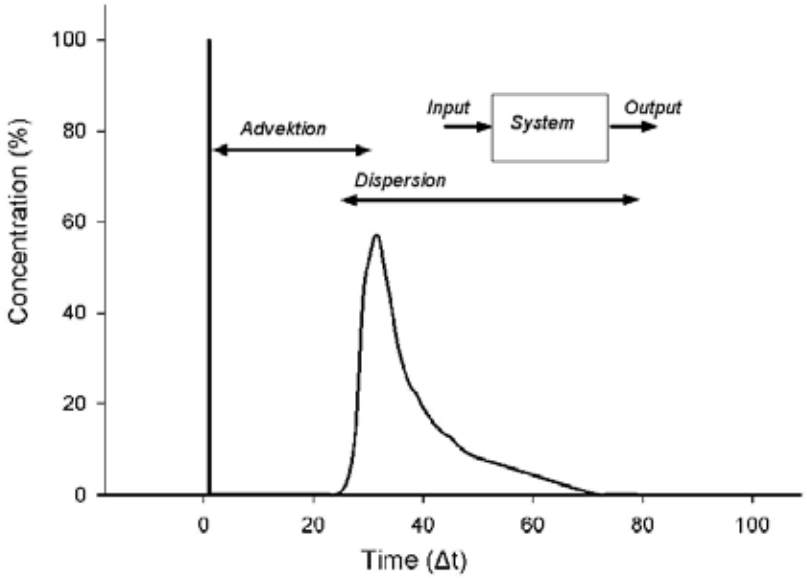
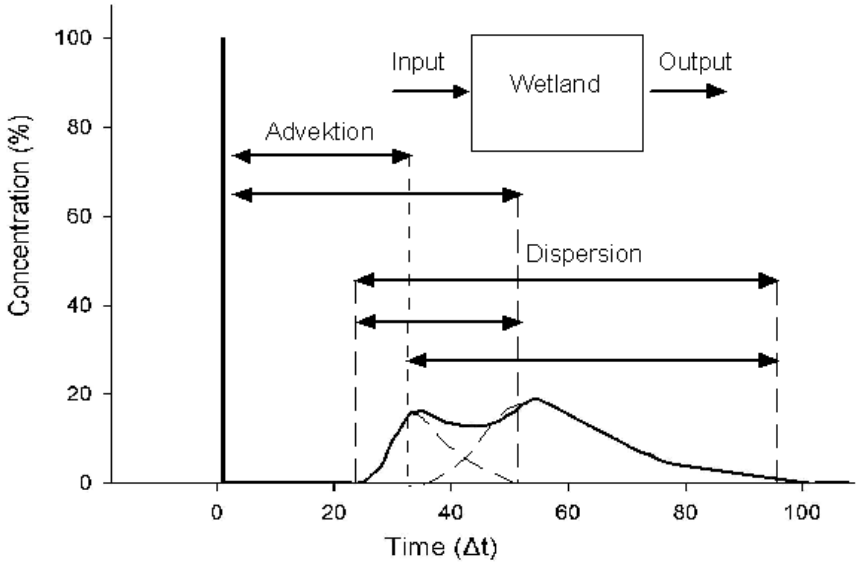
ground-based infrared thermography

artifical tracing

approach:

Is it possible to detect flow path distribution in a constructed wetland?





advektive and dispersive transport of warm water can be observed with infrared thermography!

ground-based infrared thermography

Camera systems applicated in tracer experiments:

- Trotec IC80 thermography camera
  (160*120 Pixel,38° wide angel objective)

- FLIR Thermacam E320
  (320*240 Pixel,45° wide angel objective)

- Infratec VarioCam_hr inspect
  (640*480 Pixel,65° wide angel objective)

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paper-project in progress

Tracer experiment with FLIR Thermacam E320 (320*240 Pixel,45° wide angel objective)

50l water 57°C

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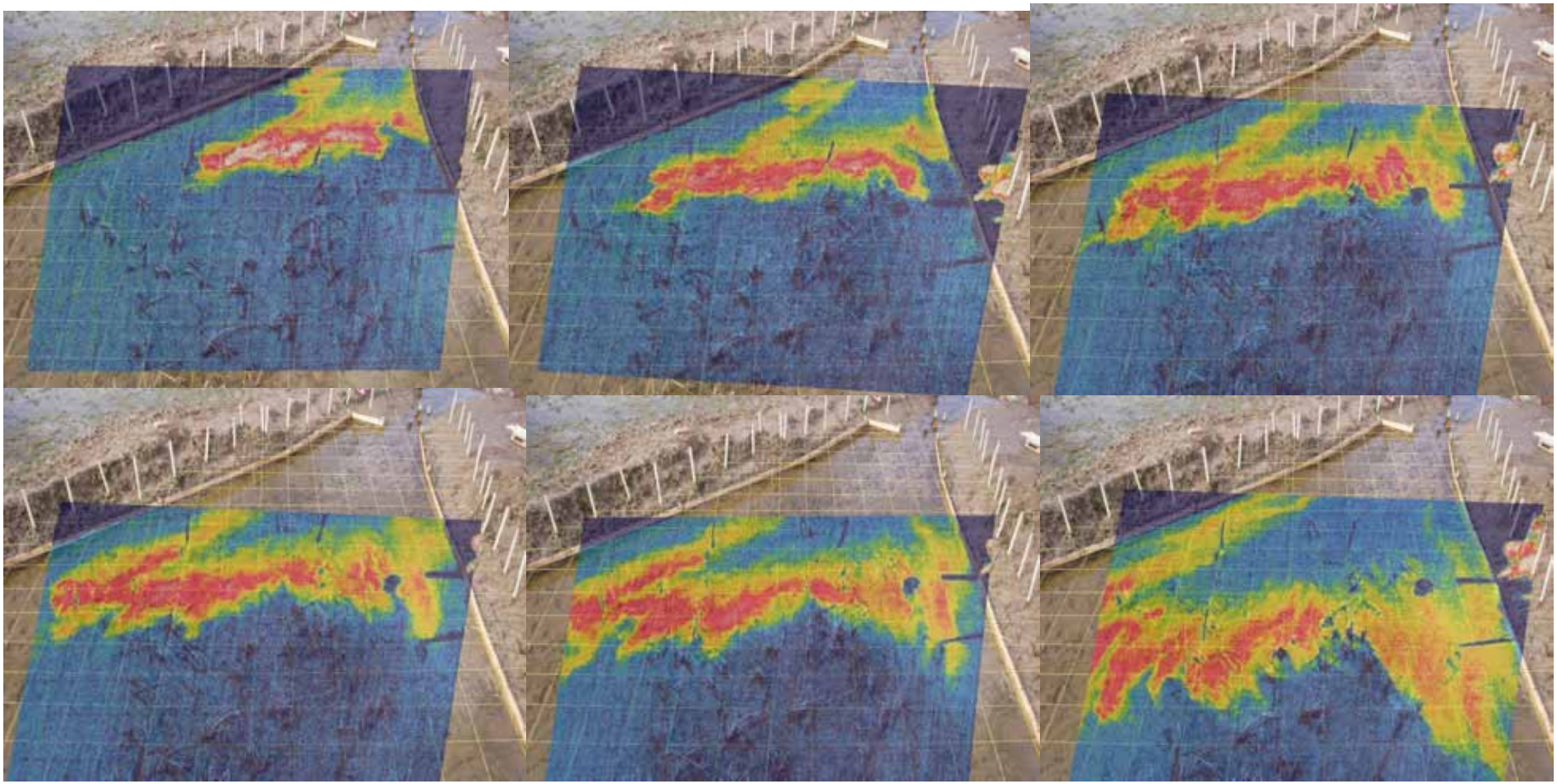
Ergebnisse



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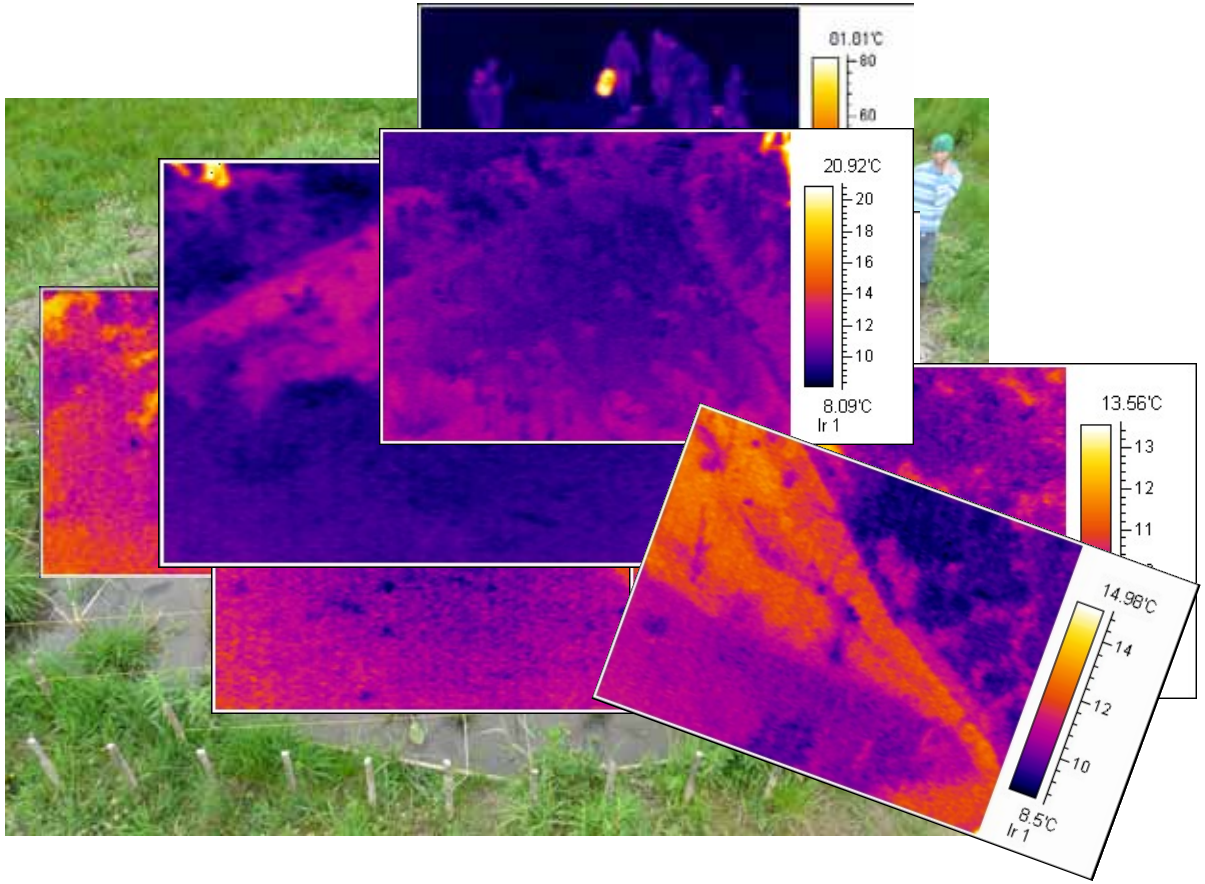
Ergebnisse

Tracer experiment with Trotec IC080 (160*120 Pixel,38° wide angel objective)

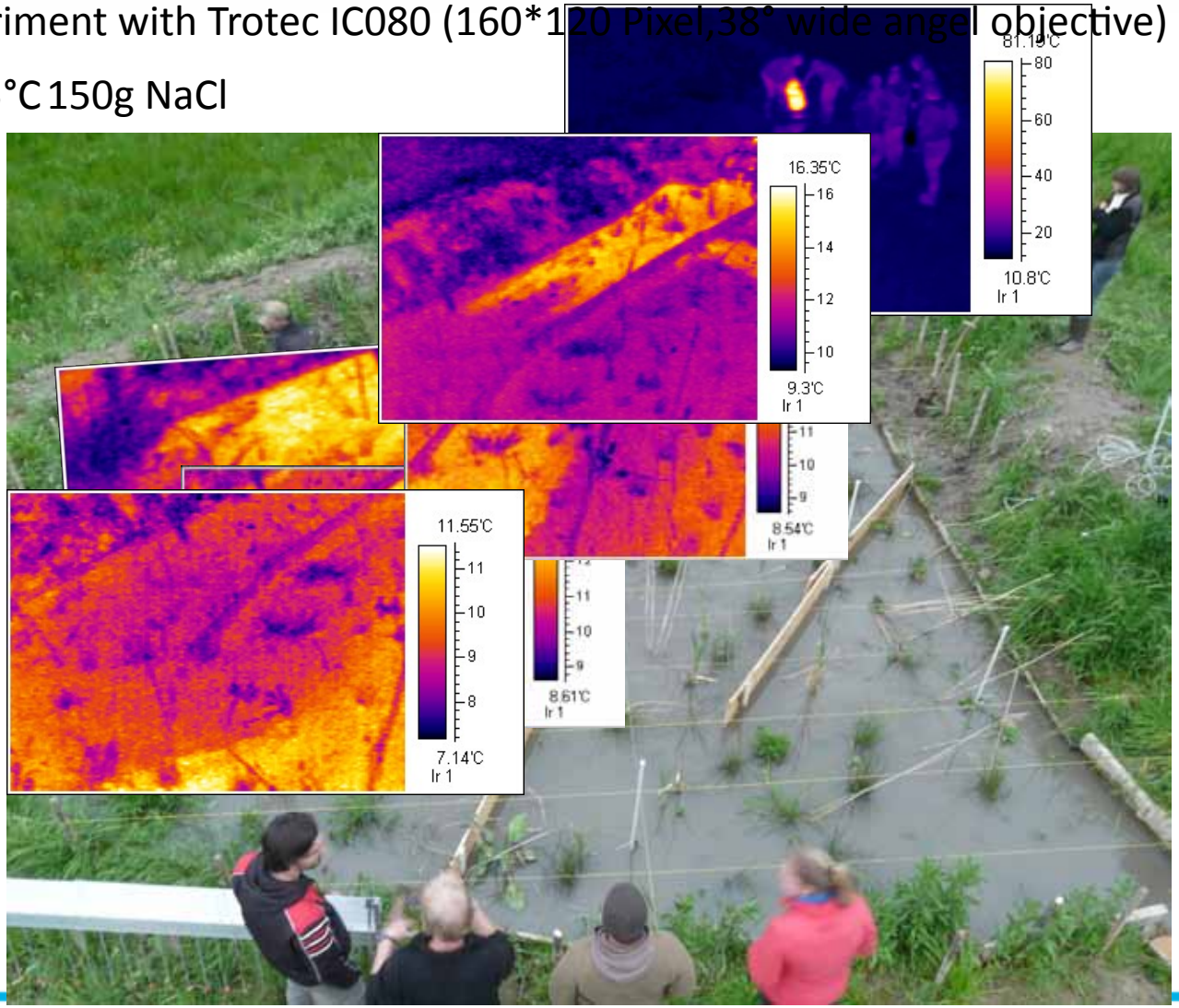
40l water 85°C 100g NaCl



Ergebnisse

Tracer experiment with Trotec IC080 (160*120 Pixel,38° wide angel objective)

40l water 85°C 150g NaCl



Bemerkungen

artifical tracing

conclusions:

in general obsrvation of flow path distribution is possible

difficulties:

- determination of water volume for injection in relation to observed water body
- air temperature and solar radiation
- work intensive analysis (->spatial distortion of thermogram)
- temperature distribution of the water coloumn has to be considered and investigated -> temporal resolution of temperature measurement devices

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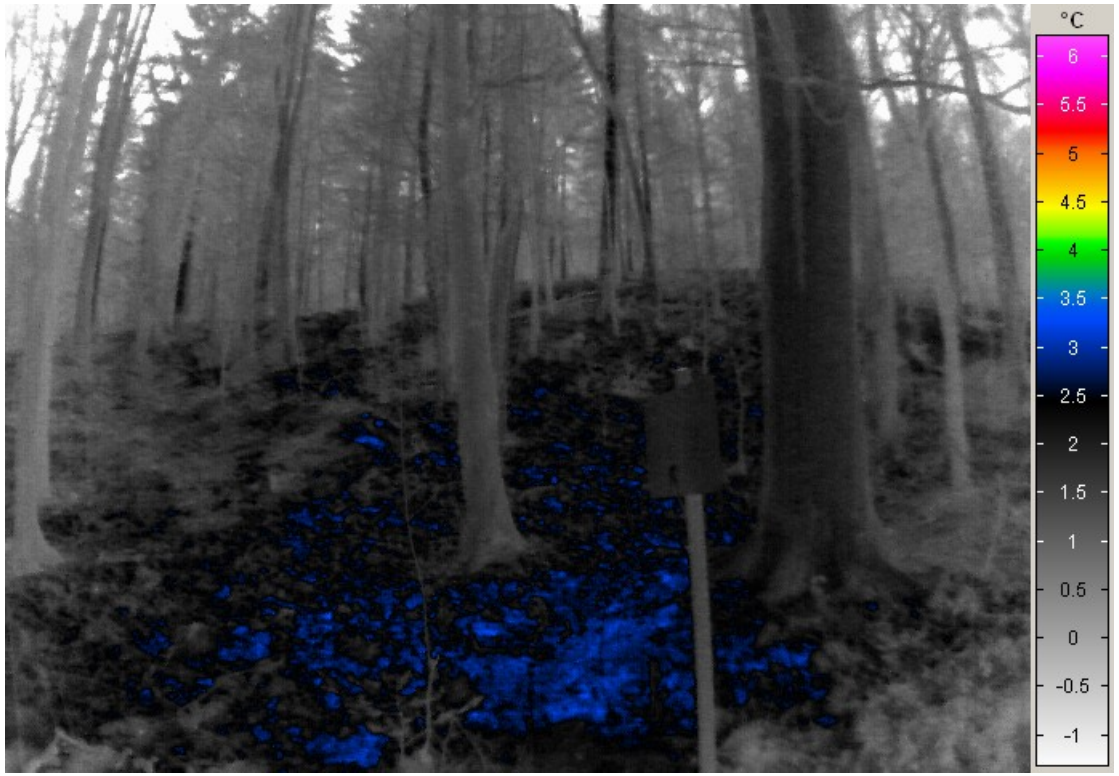
IRT unter natürlichen Bedingungen



thermal signature of a forested slope

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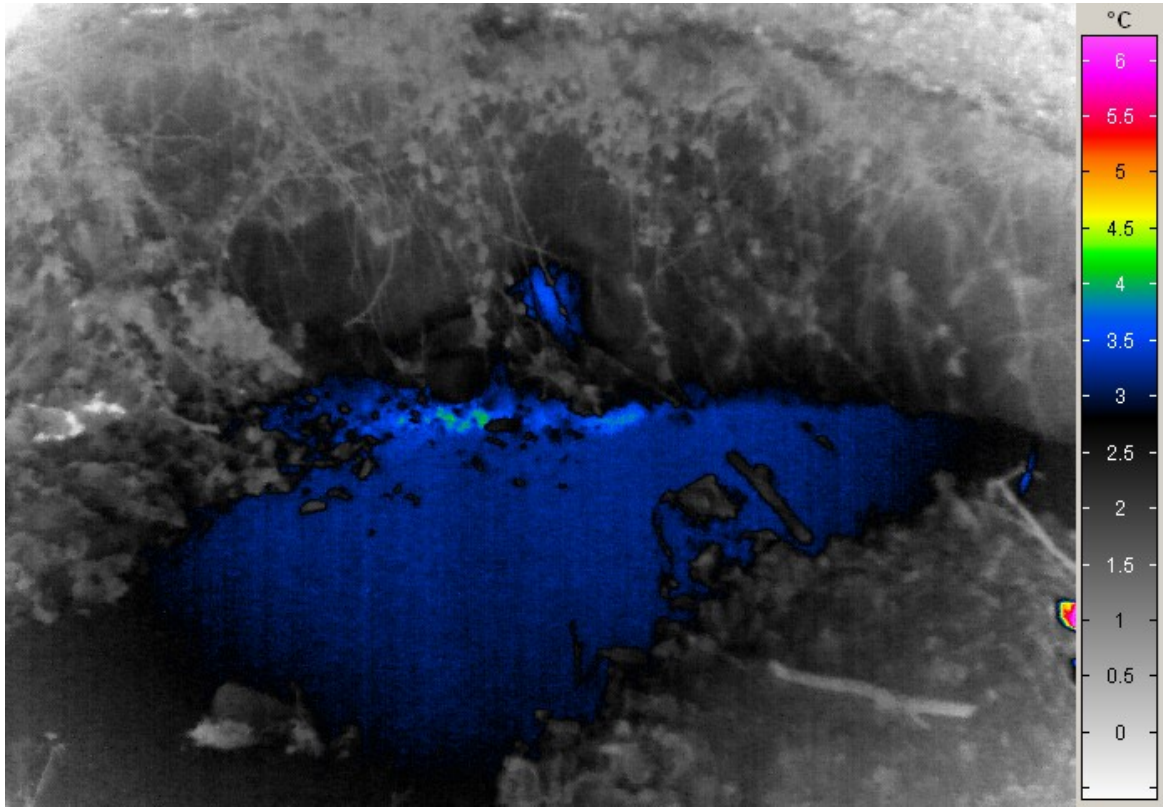
IRT unter natürlichen Bedingungen



thermal signature of soil water entry into a small creek

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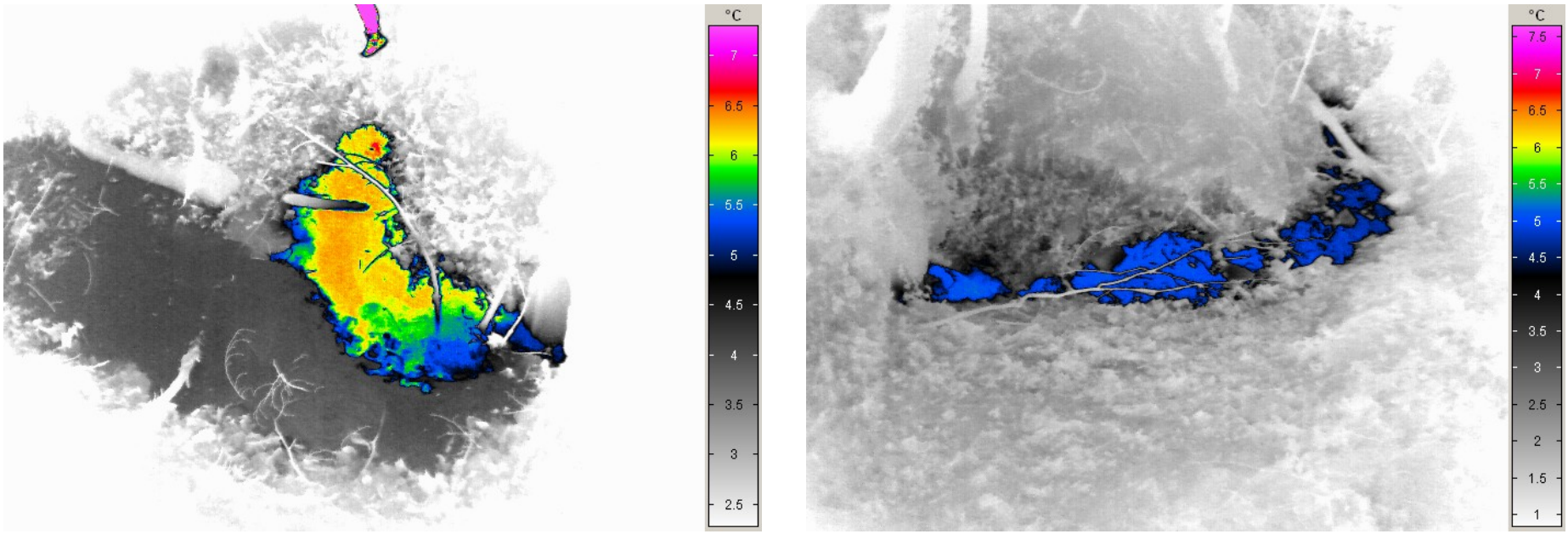

thermal signature of ground water entry into a small creek

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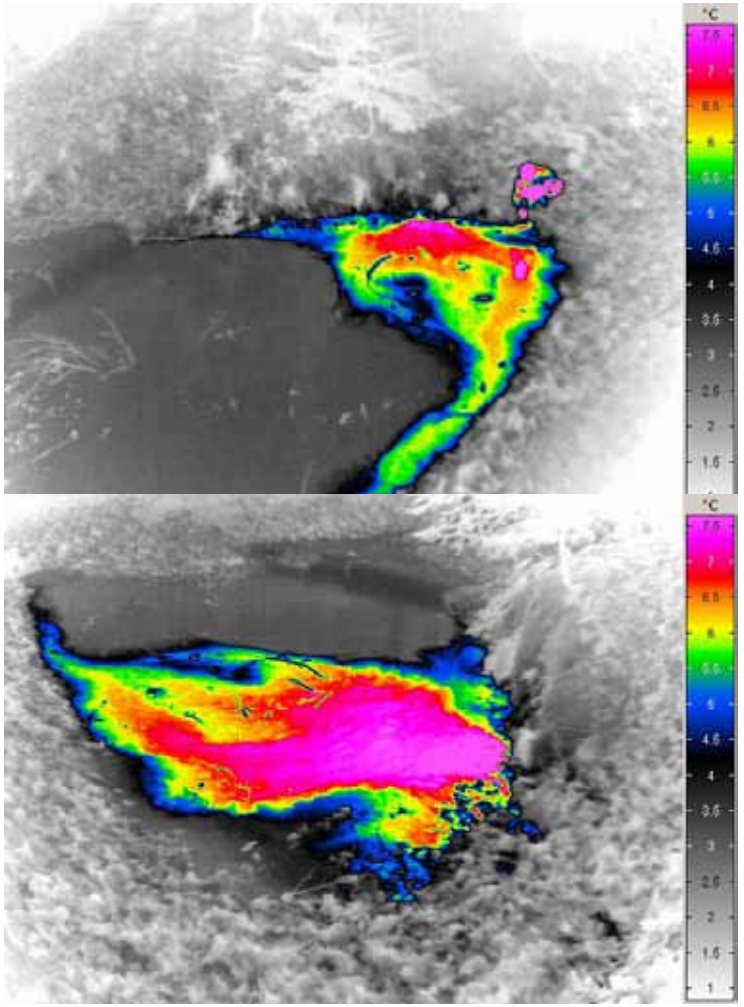

thermal signature of ground water entry

into a small detention pond

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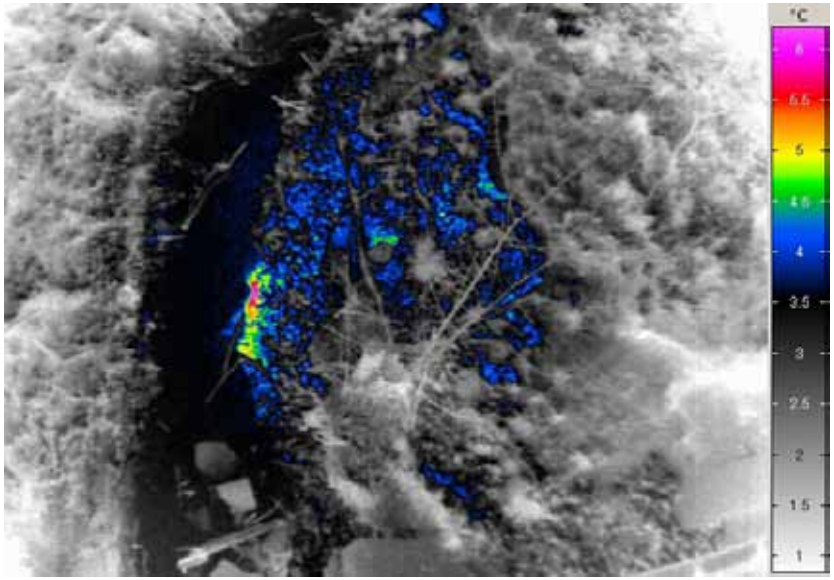

thermal signature of ground water entry into a small creek

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