

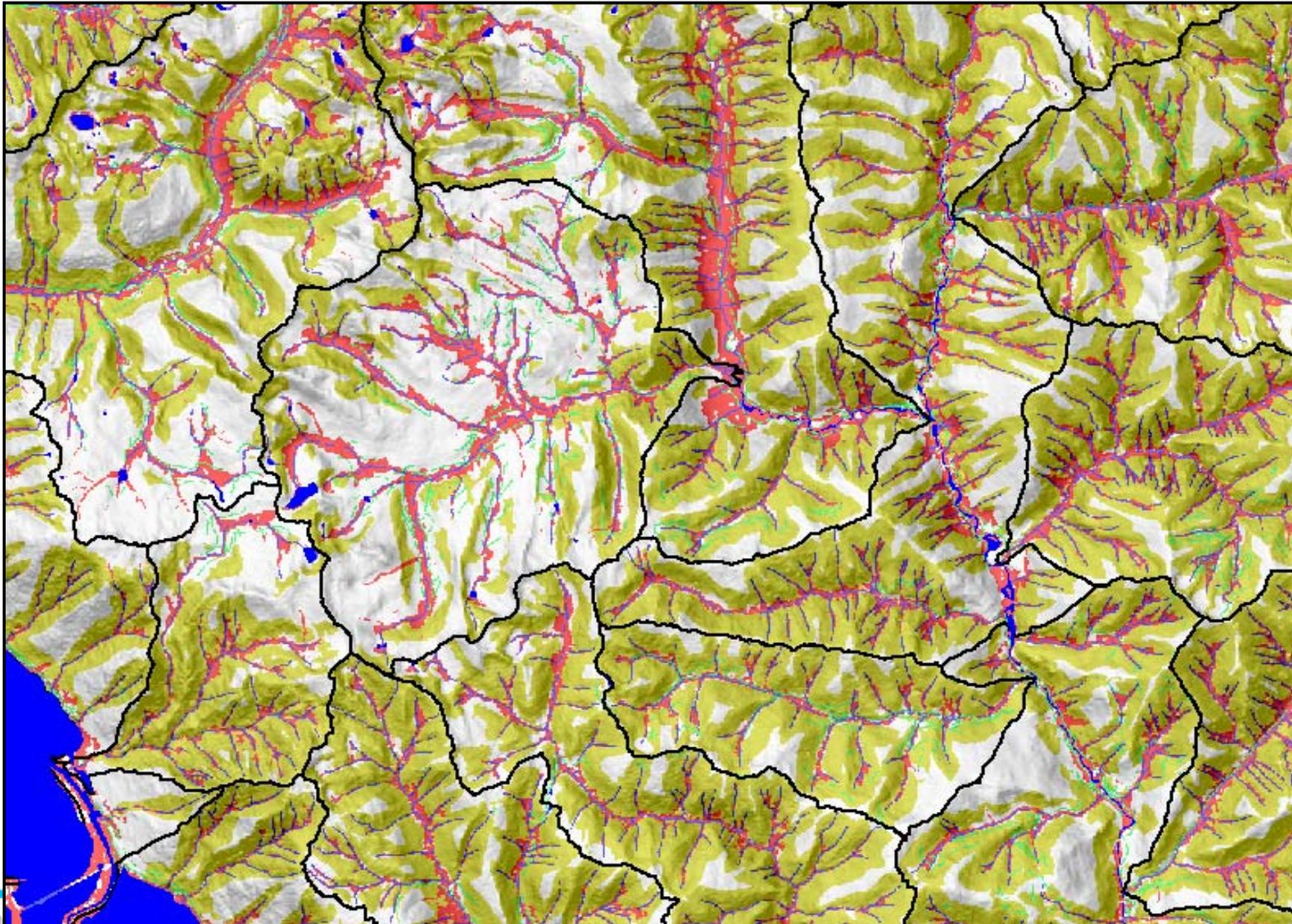
Umsetzung von Abflussprozessen (dominanten) in hydrologische Modelle

Markus Weiler

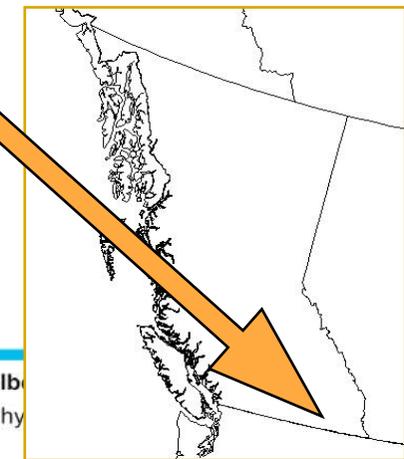
University of Freiburg

Germany

Ausgangspunkt?



-  Water
 -  HOF
 -  SOF
 -  SSF
- (25m grid)



Modellierungsansätze

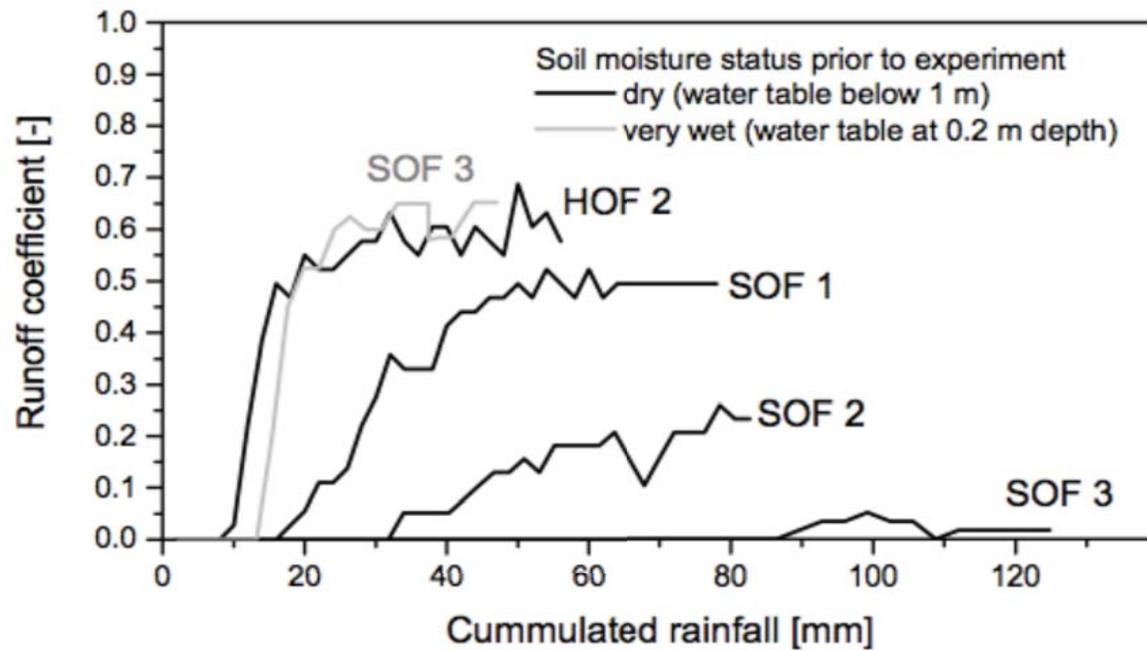
- Entwicklung eines N-A-Modells aus DRP Karten
- Entwicklung eines prozessbasierten Hydrologischen Modells
- Parametrisierung mittels DRP Karten von einem räumlich expliziten hydrologischen Modells

- Modelverifikation (Kalibrierung)
- Modellunsicherheit

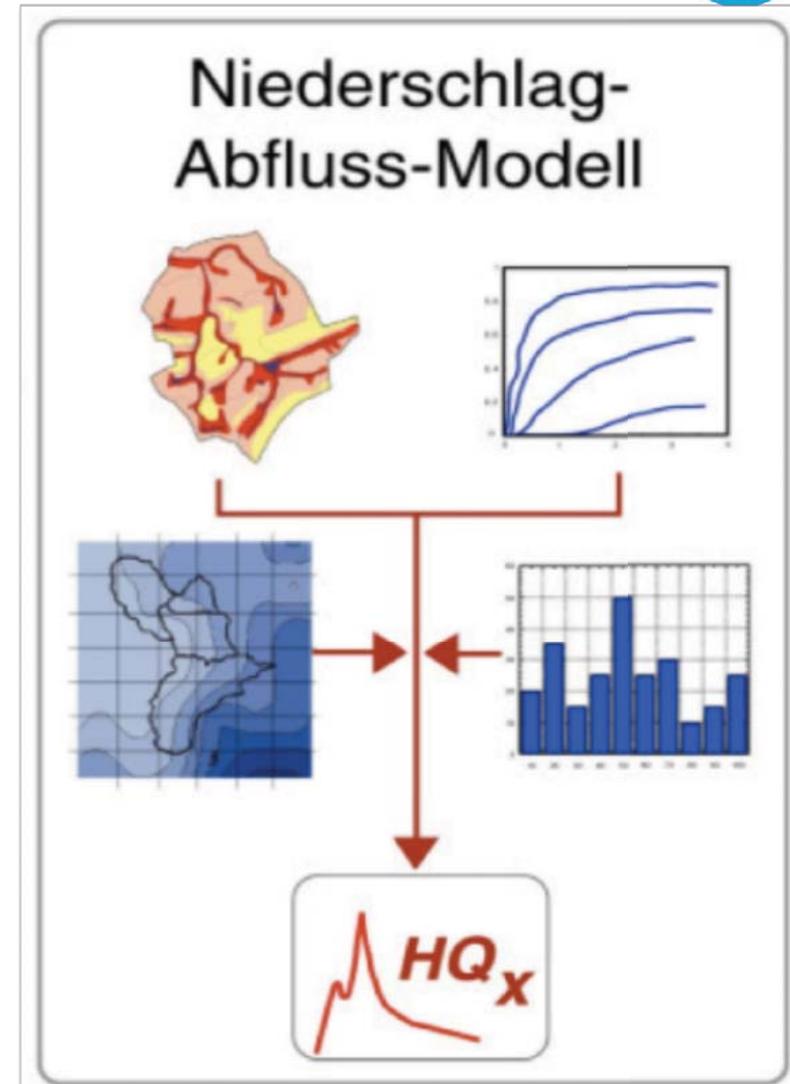
Entwicklung eines N-A-Modells aus DRP Karten

- Abflussbeiwert (konstant oder zeitinvariant)
- Einfache Konzeptmodelle für jeden DRP
- Komplexere Modelle für jeden DRP

Abflussbeiwert - Abflussreaktionskurven

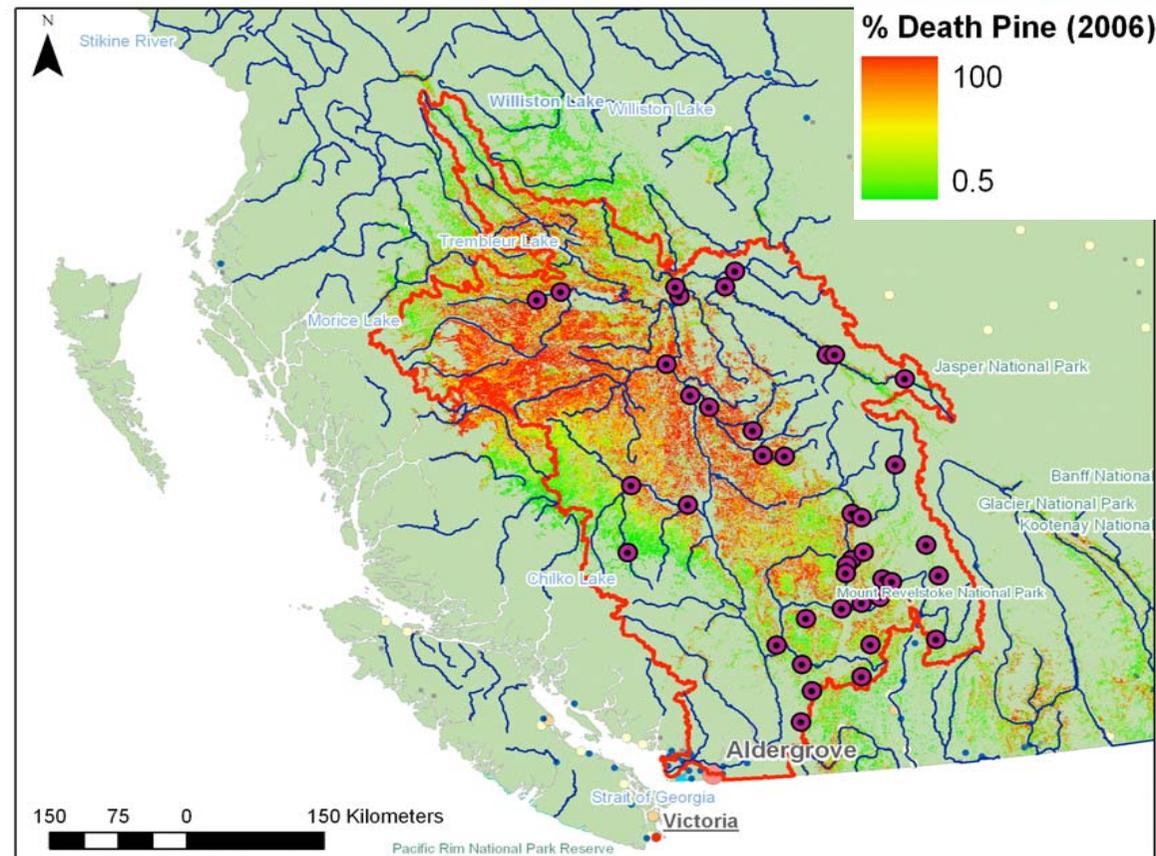


Schmocker-Fackel et al, 2007



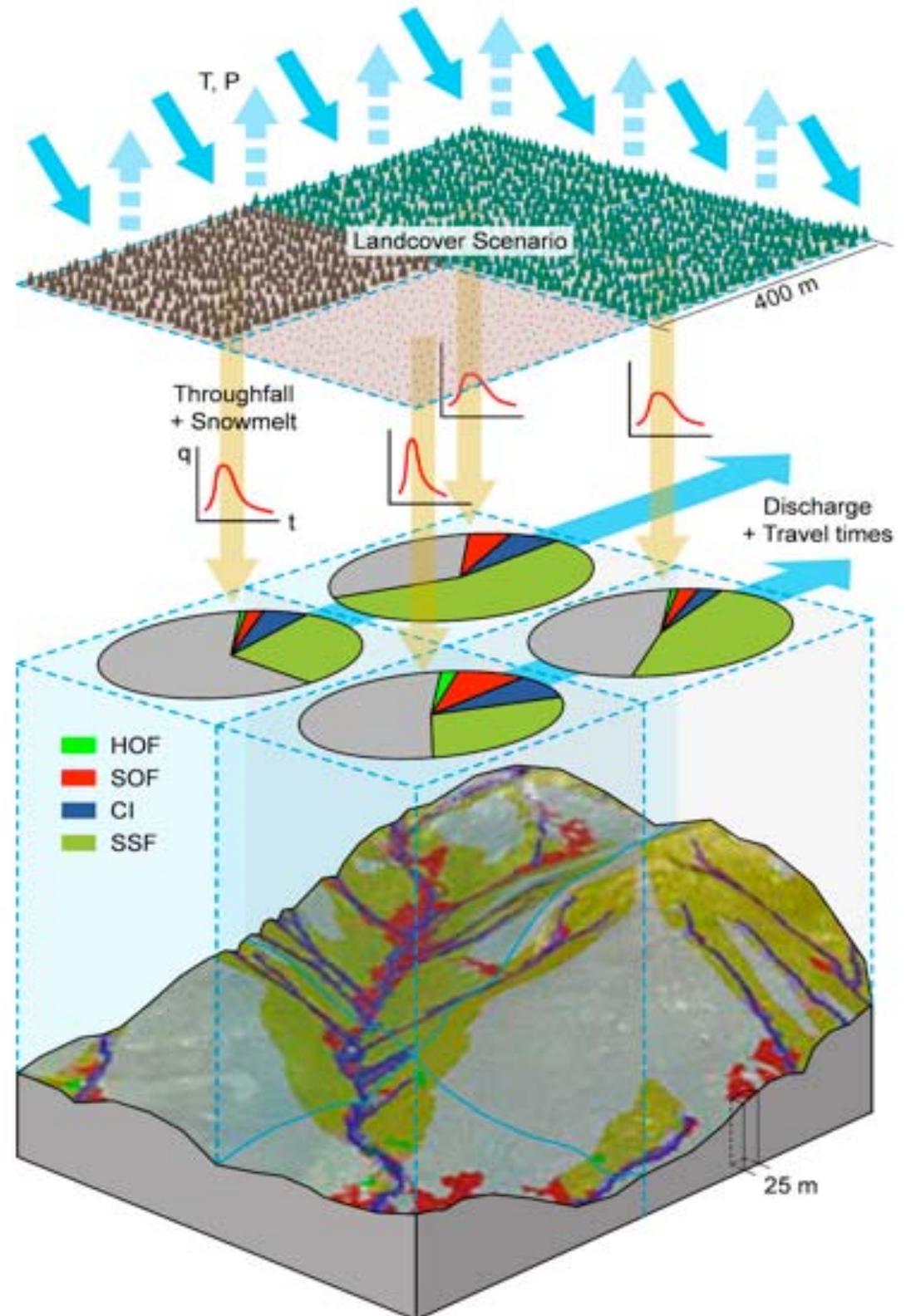
Einfaches Abflussbeiwertmodell im Fraser EZG

- Mountain pine beetle epidemic in BC
- Unprecedented land-use change (> 12 Mio ha, 2007)
 - Red and grey attack
 - Forest management (salvage logging, roads)



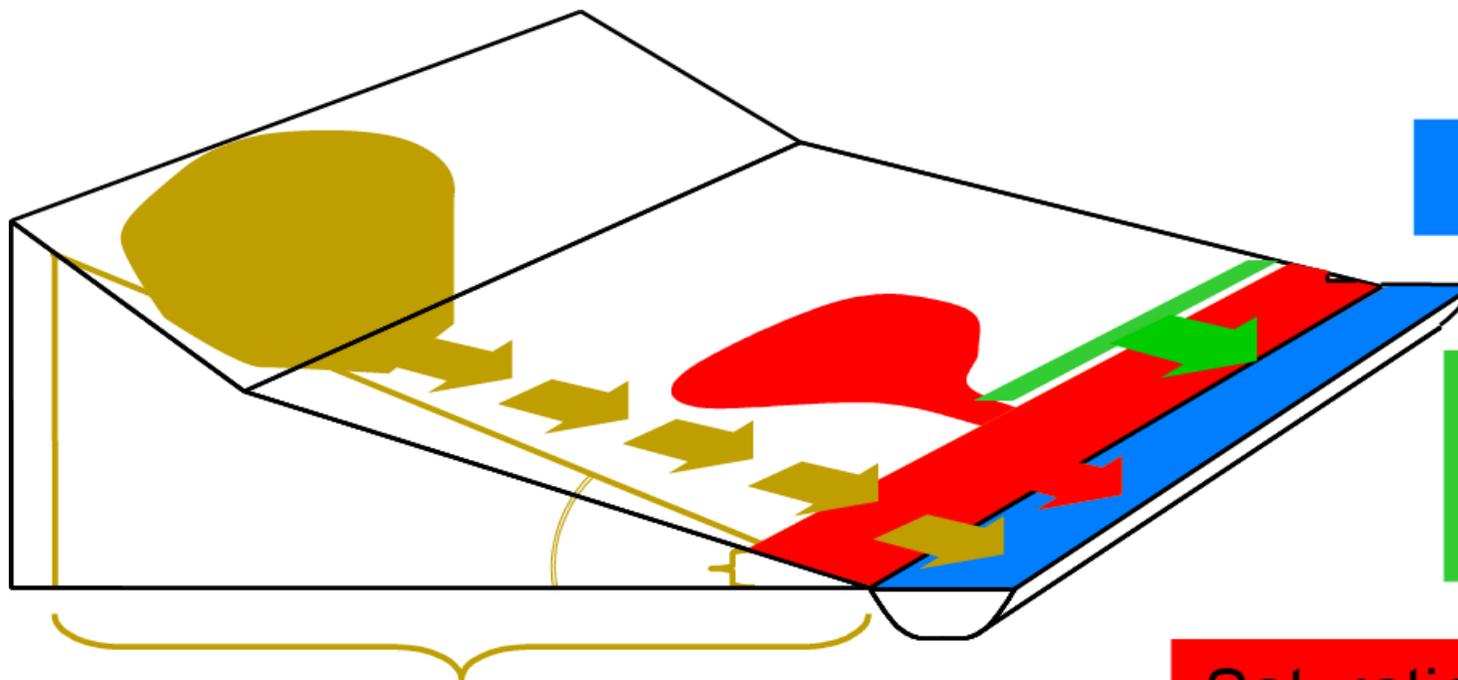
SAMM

- Climate Input Module
- Land cover modification module
- Stream routing module
- Runoff generation module:
 - Runoff contribution
 - Mapping of Dominant runoff producing (DRP) areas



Dominant runoff producing (DRP) areas

Mapping of dominant runoff generation processes using morphometric, geological and land-use data



Channel Interception

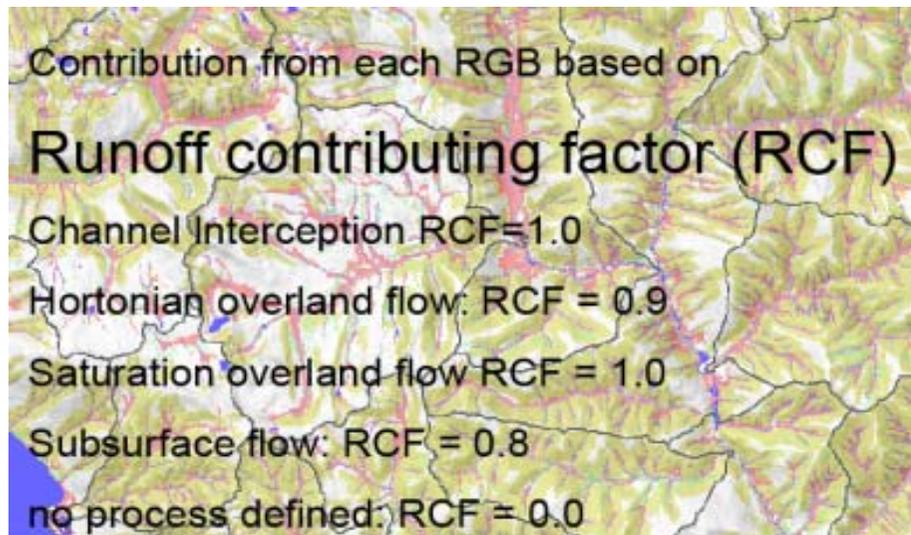
Horton Overland Flow
f (Roads, Fire history,
Distance to stream)

Saturation Overland Flow
f (wetness index,
vertical distance to groundwater)

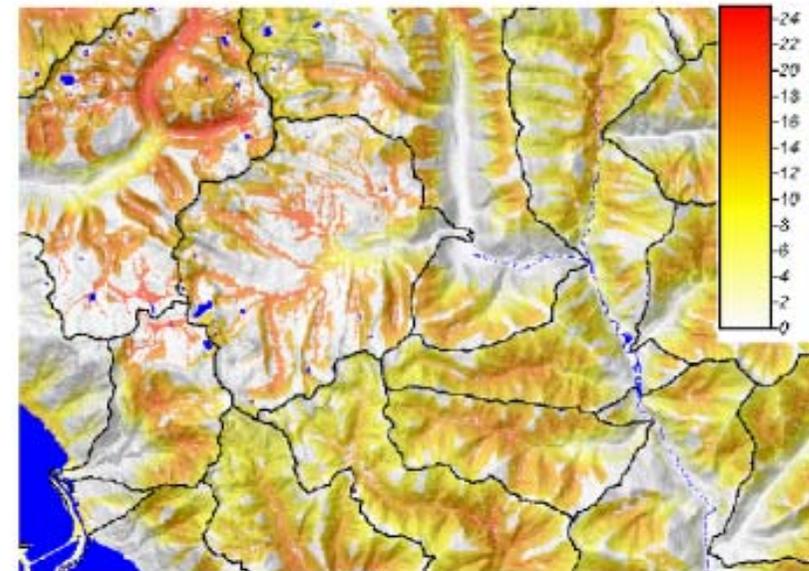
Subsurface Flow
f (Gradient to stream, Horizontal
distance to stream, Bedrock permeability)

Peak flow contribution component

Predicting runoff contribution to peak flow based on the spatial explicit runoff generation process and input



Average peak flow contribution without vegetation modification

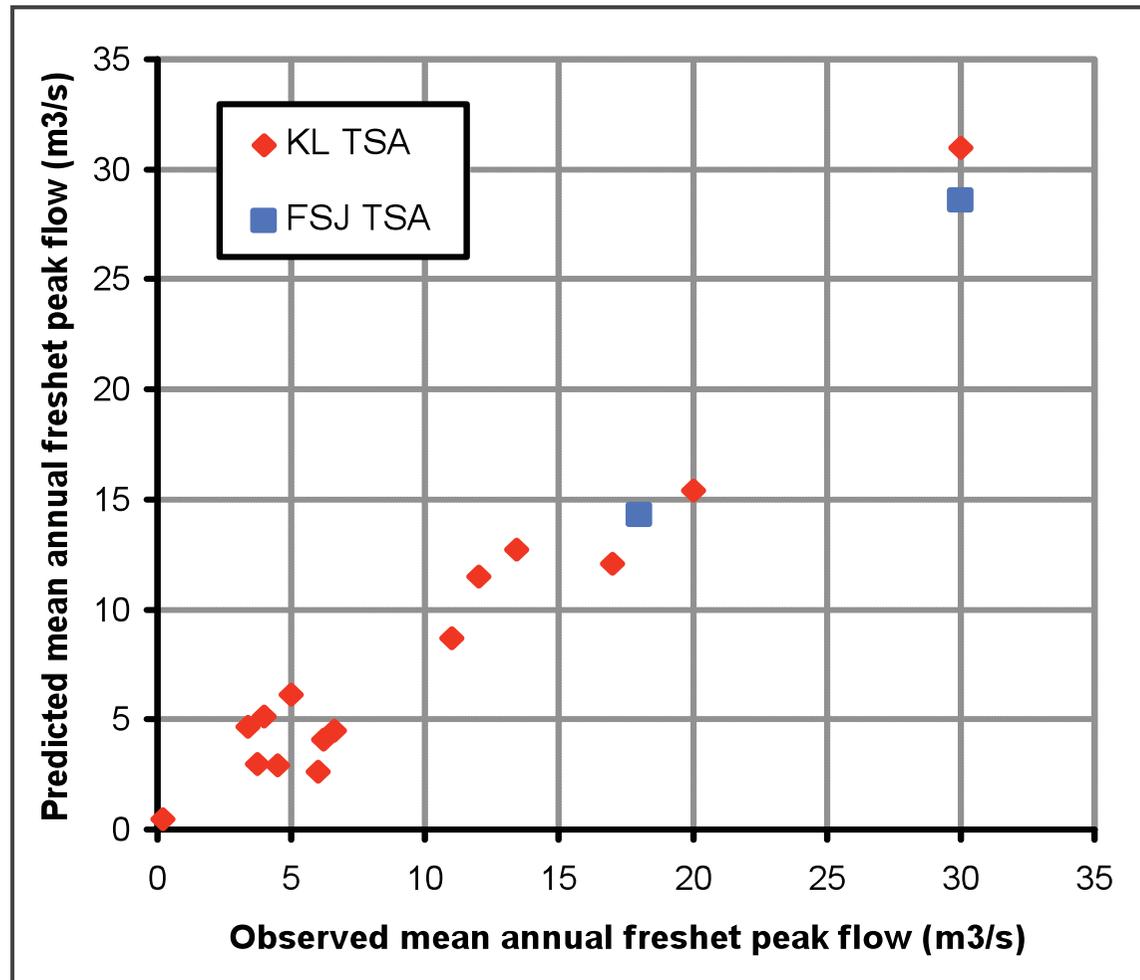


X =

Input map (snowmelt or rainfall)

Validation of input and runoff generation module

- Comparison to mean annual snowmelt peak flow for 17 3rd and 4th order watersheds



($R^2 = 0.96$)

Saturation overland flow

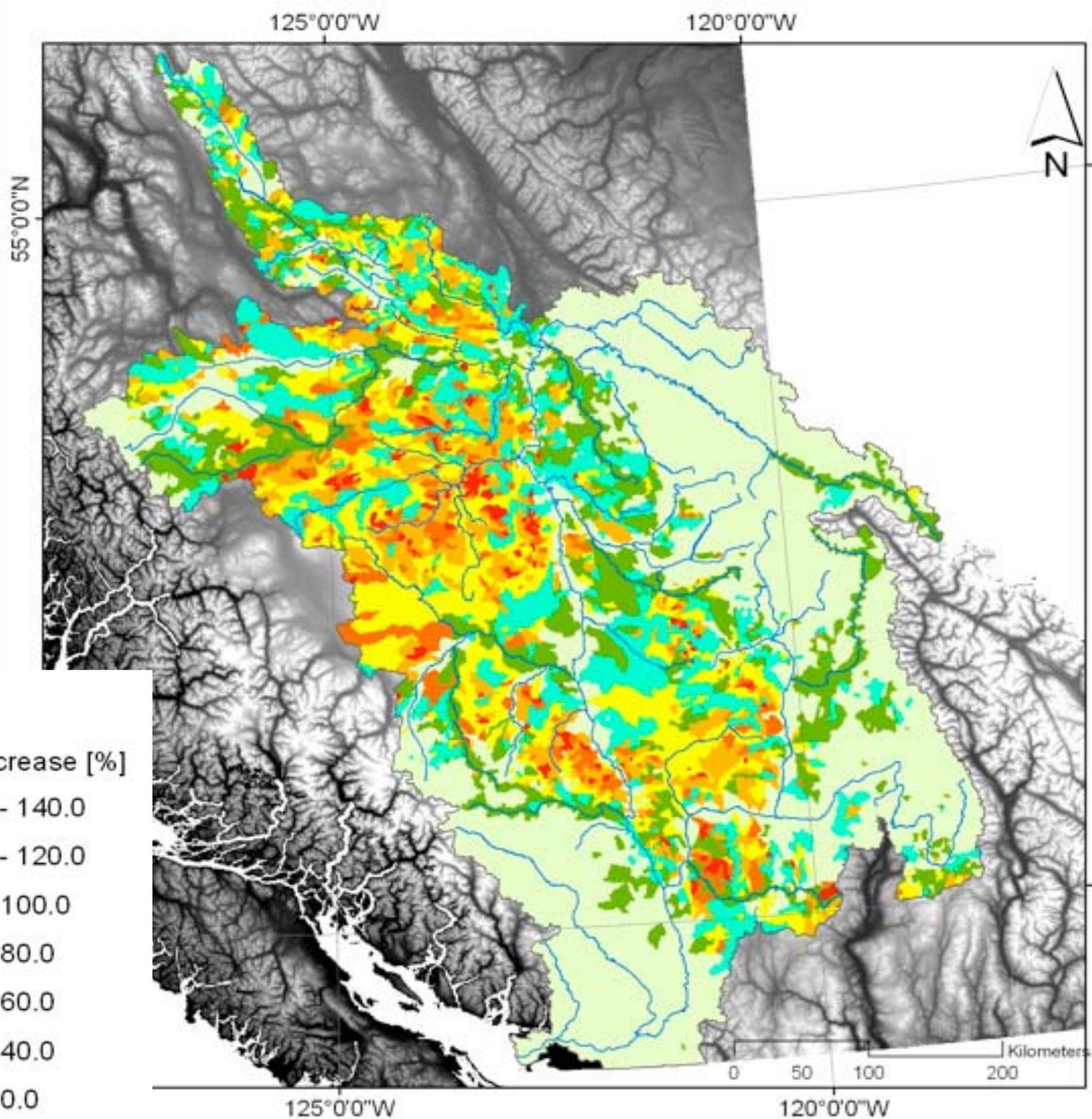
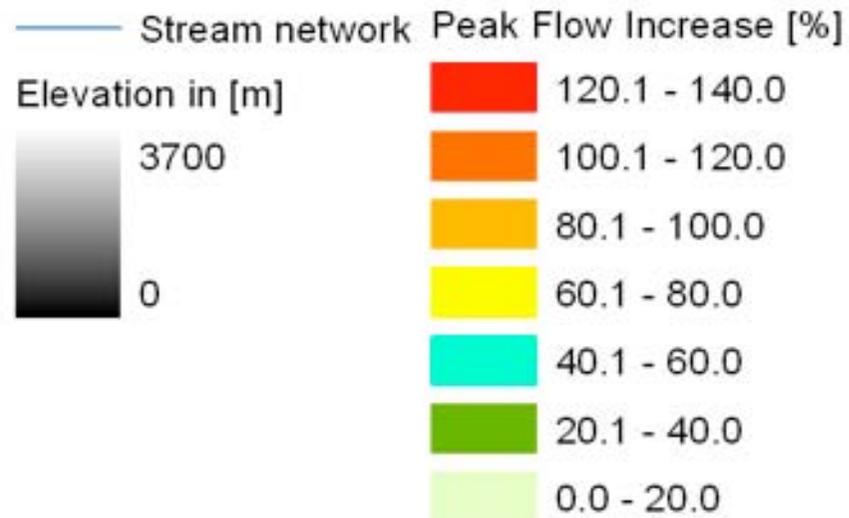


Subsurface flow

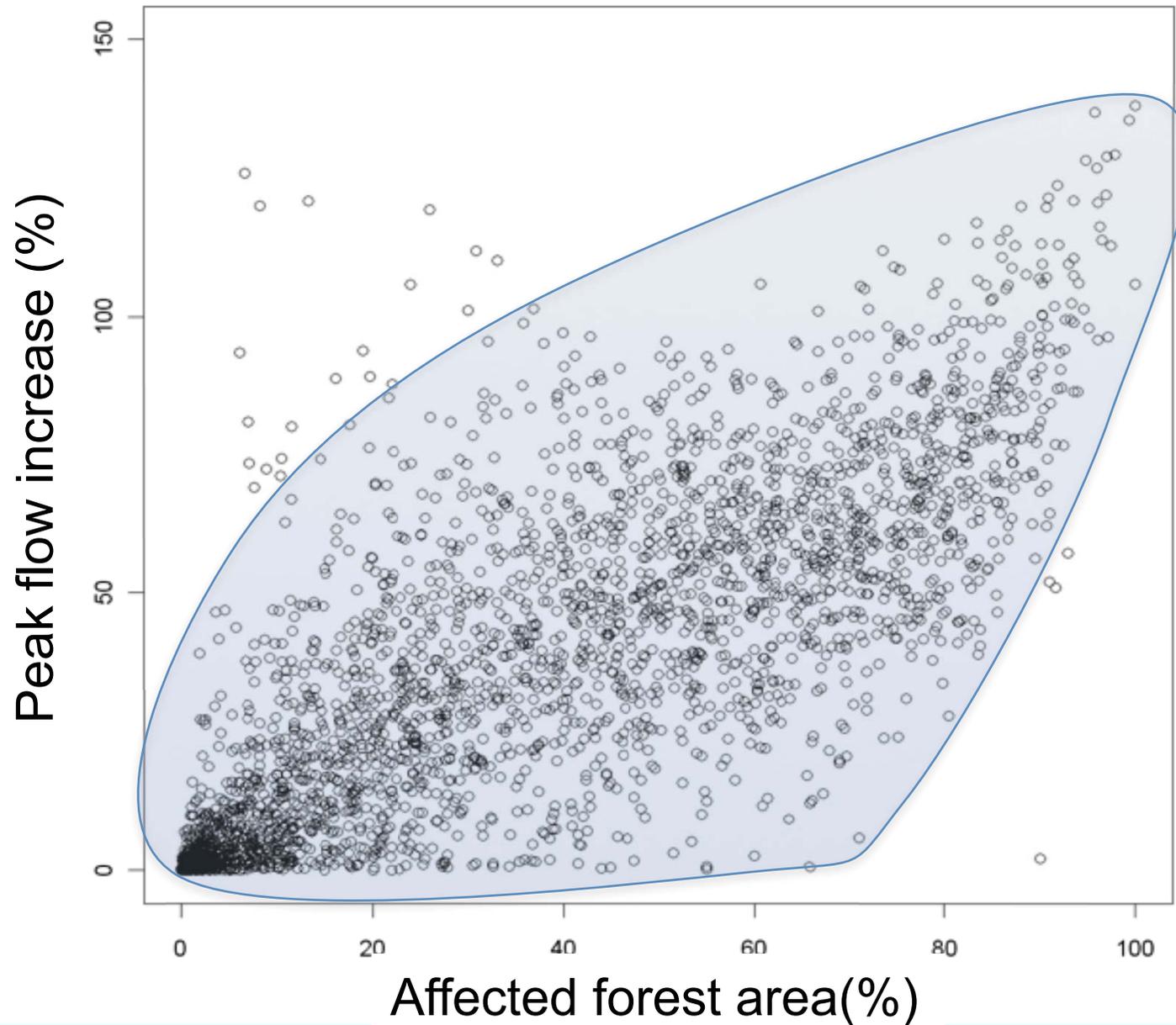


Scenario 2

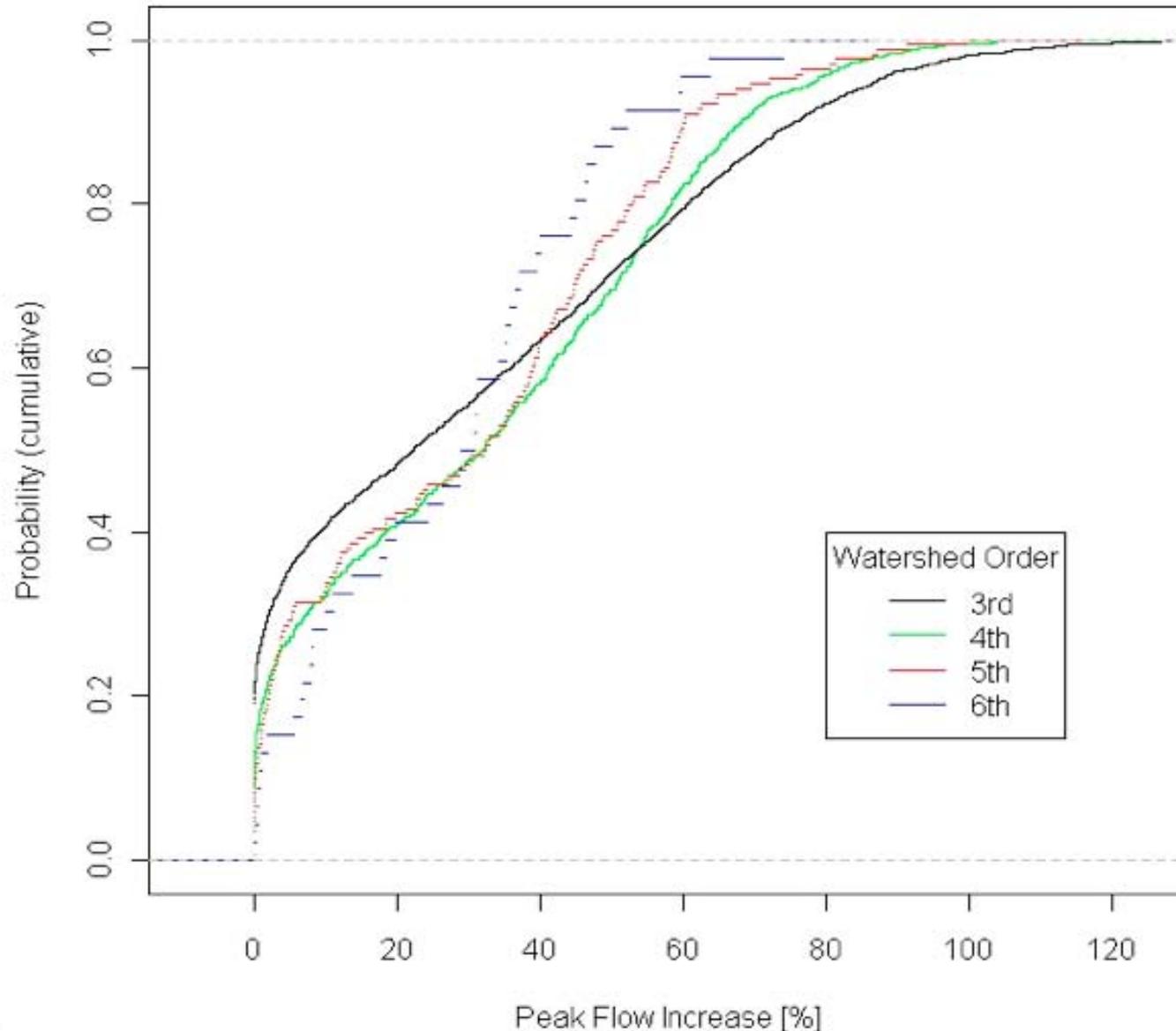
Legend



MPB and peak flow increase (SC1)



Scaling of peak flow increase



Many small watersheds will not show a measurable change (50% of watersheds will increase less than 20%)

Larger watersheds will be slightly less impacted, but more widespread

Entwicklung eines N-A-Modells aus DRP Karten

- Abflussbeiwert (konstant oder zeitinvariant)
- Einfache Konzeptmodelle für jeden DRP
- Komplexere Modelle für jeden DRP

Einfache Konzeptmodelle für jeden DRP

- Was unterscheidet DRPs bezüglich der Abhängigkeit von:
 - Niederschlagsintensität
 - Niederschlagsmenge
 - Vorfeuchte
 - Variabilität innerhalb von DRPs

Generelle Idee

Process

Process hydrograph

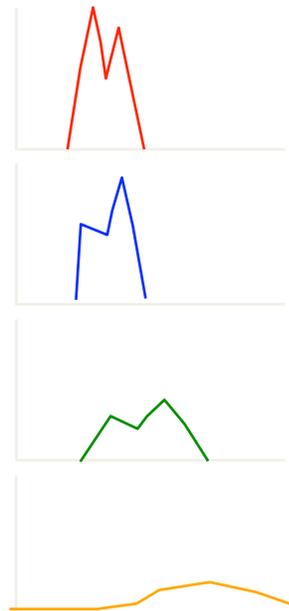
Total discharge

HOF

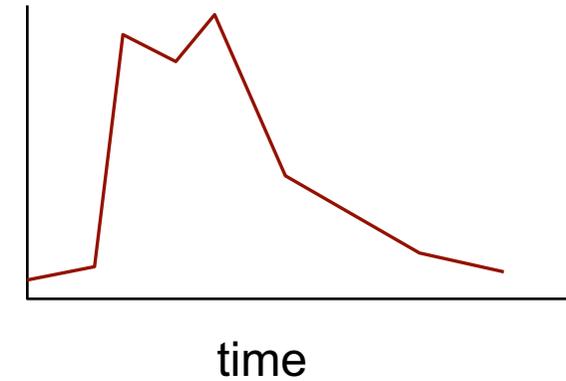
SOF

SSF

DP

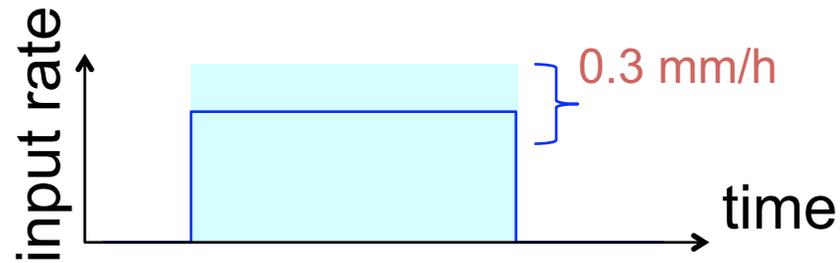


q

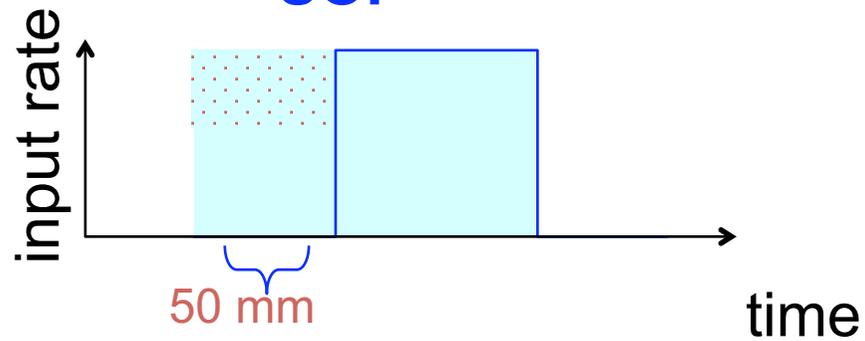


Einfache Abstraktionen

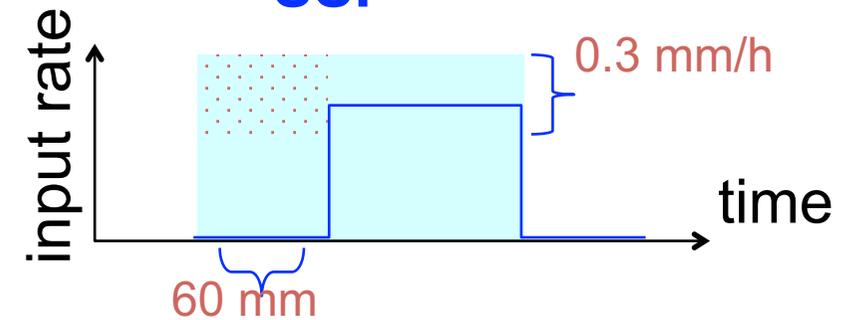
HOF



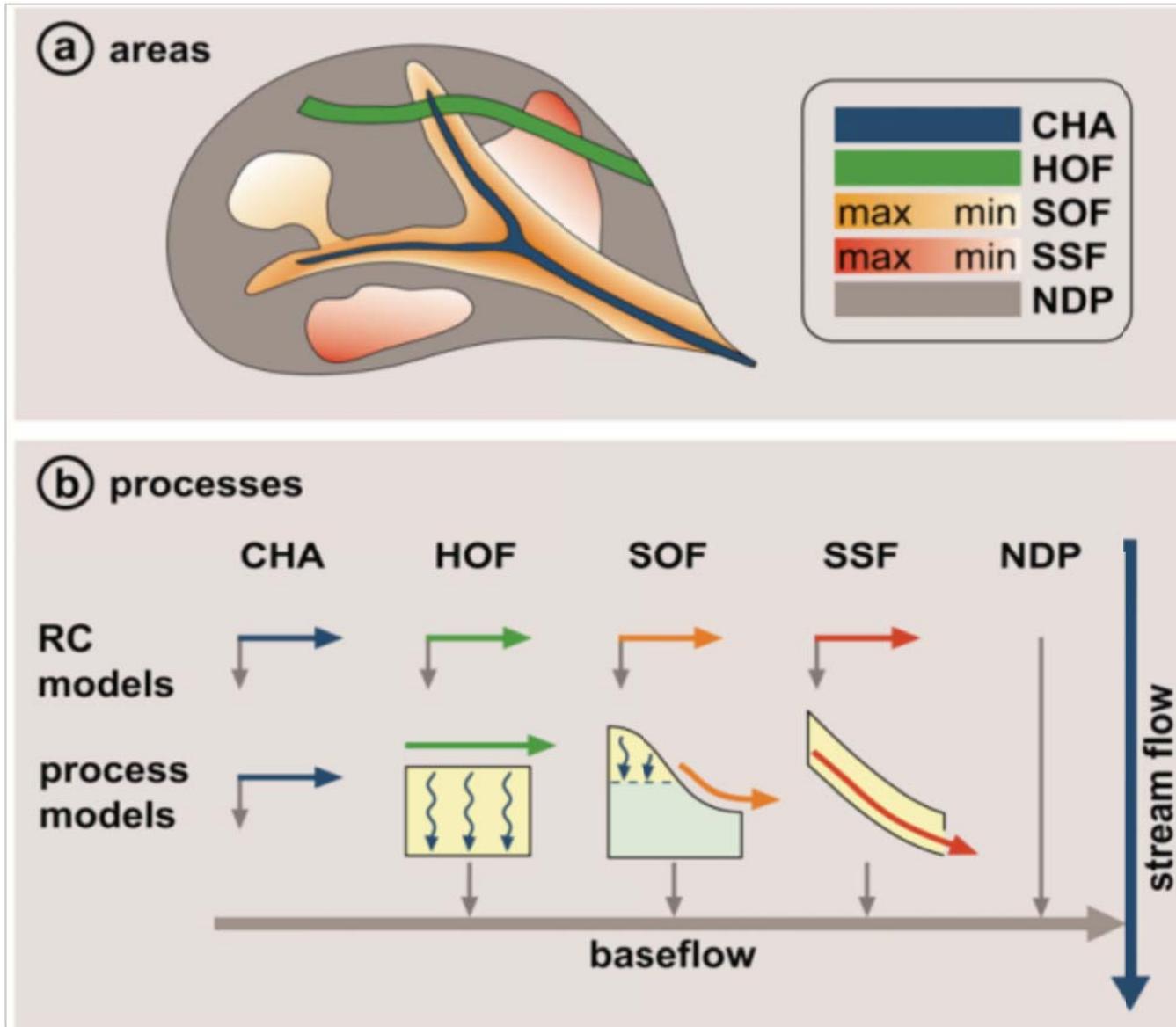
SOF



SSF



Komplexer Modellstruktur



Rosin und Weiler, 2010

Entwicklung eines N-A-Modells aus DRP Karten

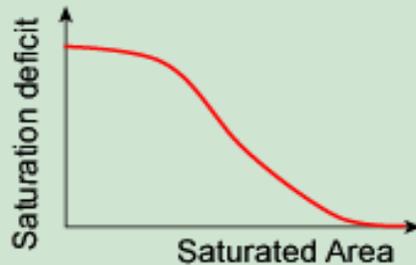
- Abflussbeiwert (konstant oder zeitinvariant)
- Einfache Konzeptmodelle für jeden DRP
- **Komplexere Modelle für jeden DRP**
 - Mehr Prozesswissen wird implementiert
 - Mehr Parameter
 - Realistischer?

Simulation - DRP

R

Percentage of areas with same dominant runoff generation

Saturated Overlandflow



Shape of the deficit curve from the distribution of saturated areas in the catchment

Max. Saturation deficit (mm)

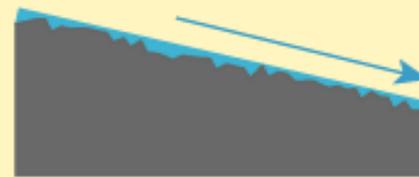
Initial Saturation deficit (mm)

Muldenrückhalt (mm)

Constant decline of saturation deficit, when no rainfall (mm/h)

Routing Coefficient (Linear Storage)

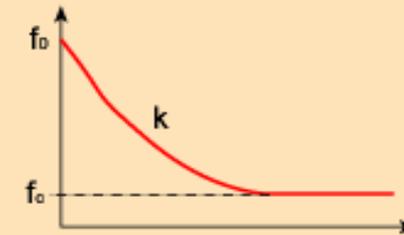
Runoff on paved areas



Wetting losses (mm)

Minimum Rainfall Intensity for Runoff (mm/h)

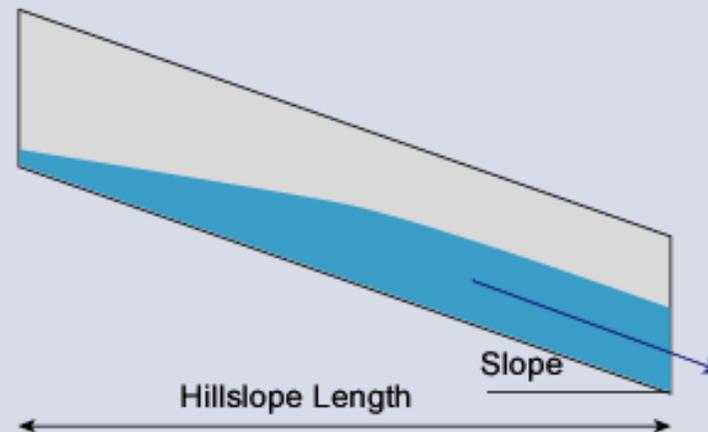
Hortonian Overlandflow



f_0 Initial infiltration rate (mm/h)

f_0 Final infiltration rate (mm/h)

Subsurface Flow from hillslopes



Saturated hydraulic conductivity (mm/h) at the soil surface

Power law exponent (for the power law transmissivity function)

Hillslope length (m)

Average slope (°)

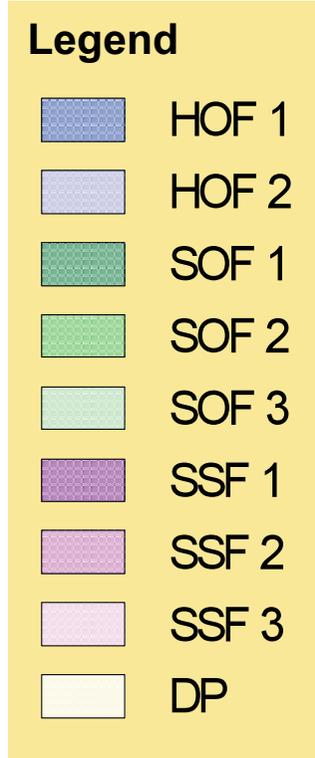
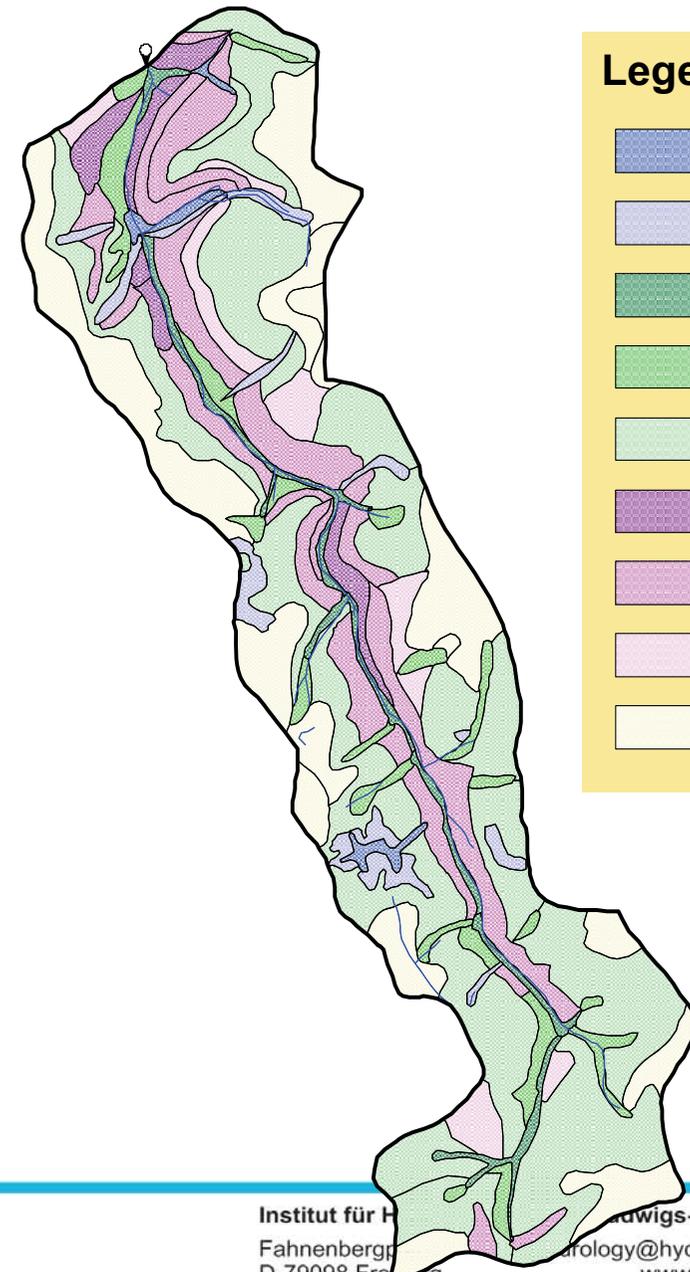
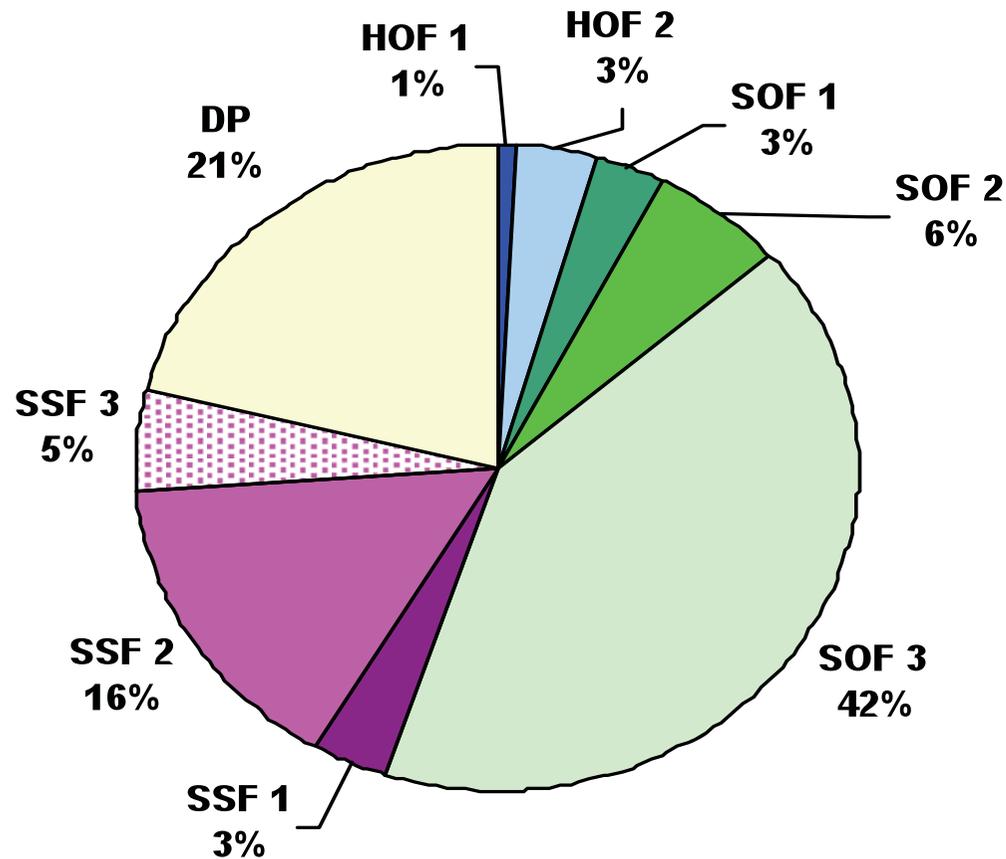
Max. soil depth

Initial water depth lower boundary condition

Initial slope of water table in hillslope

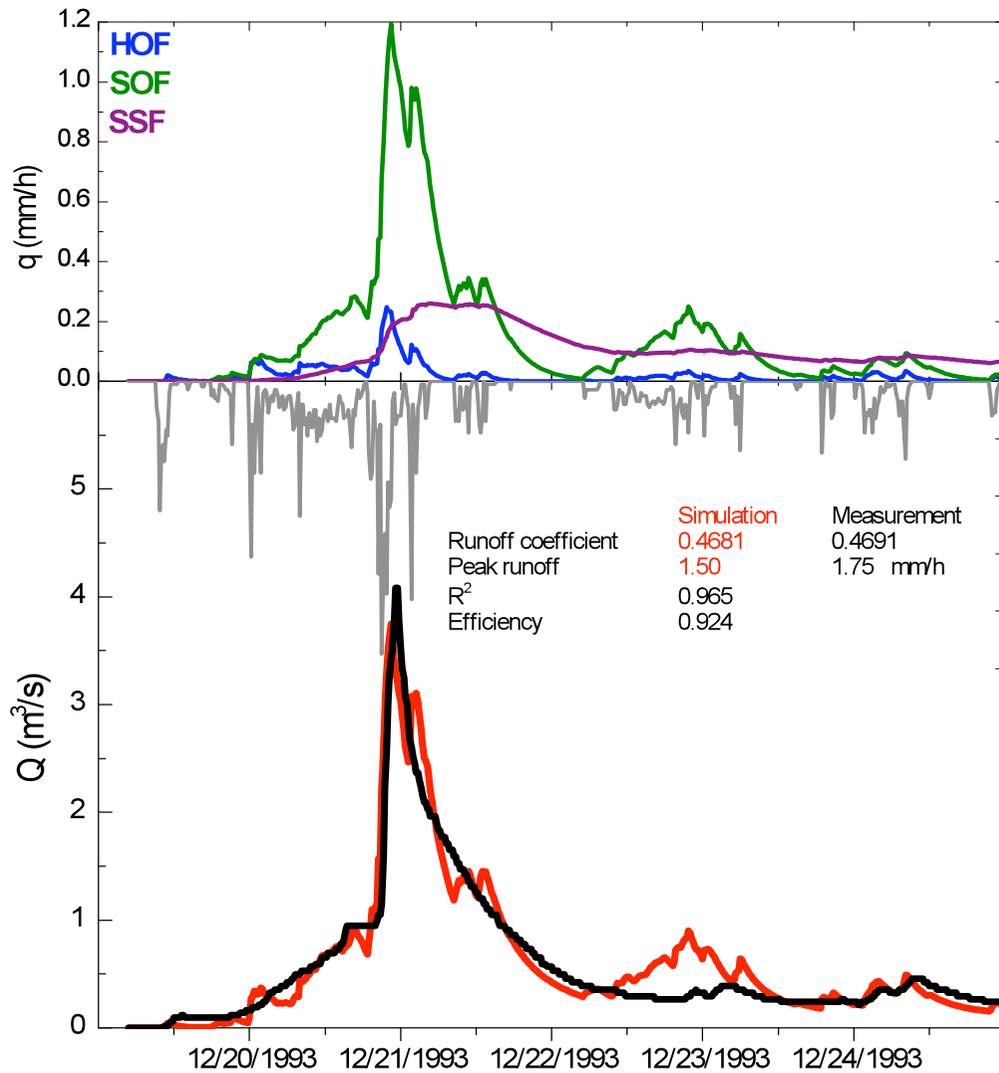
Spatial variation of DRP

Sulzbach catchment
8.4 km²

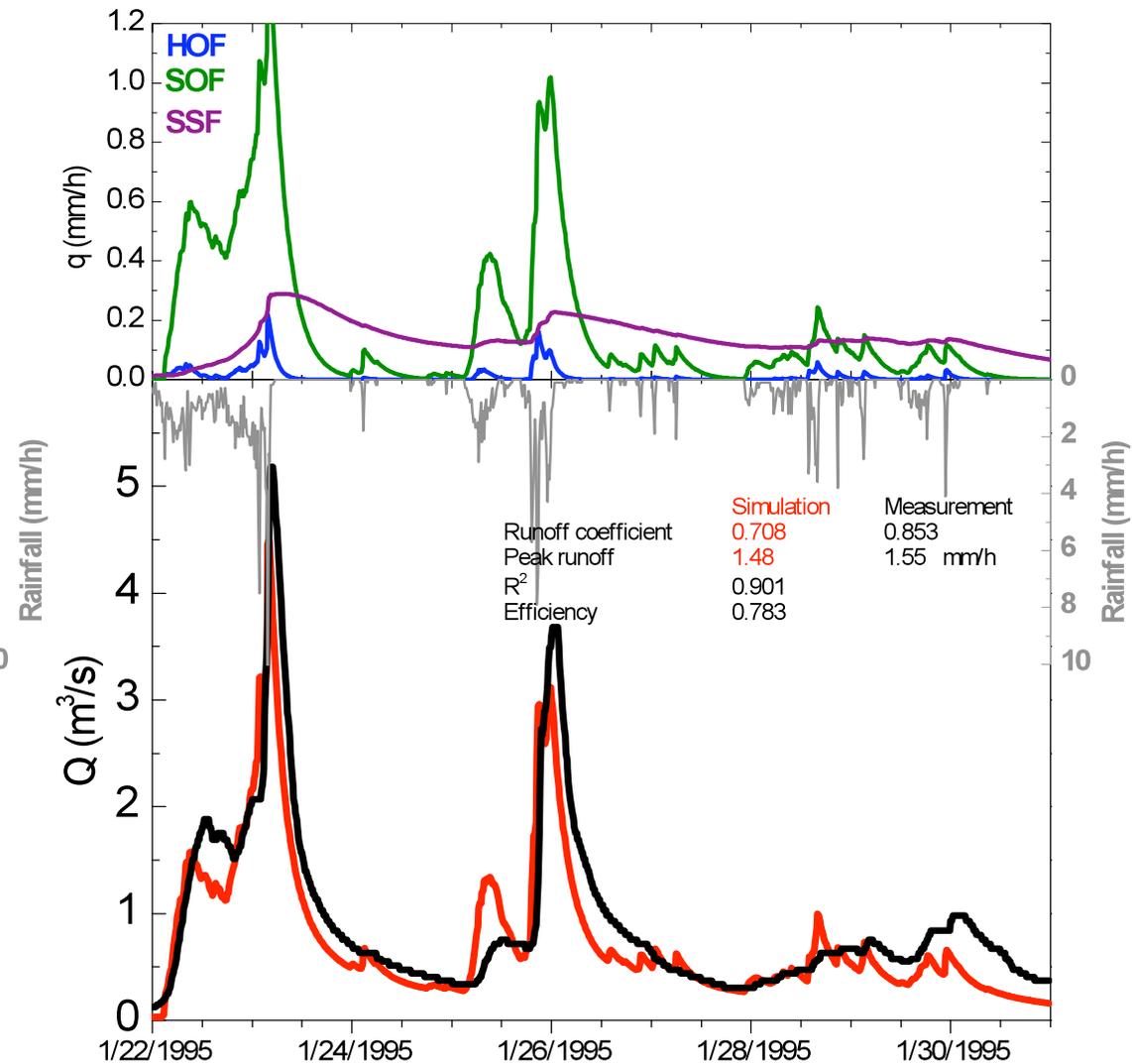


Sulzbach – 2 Events

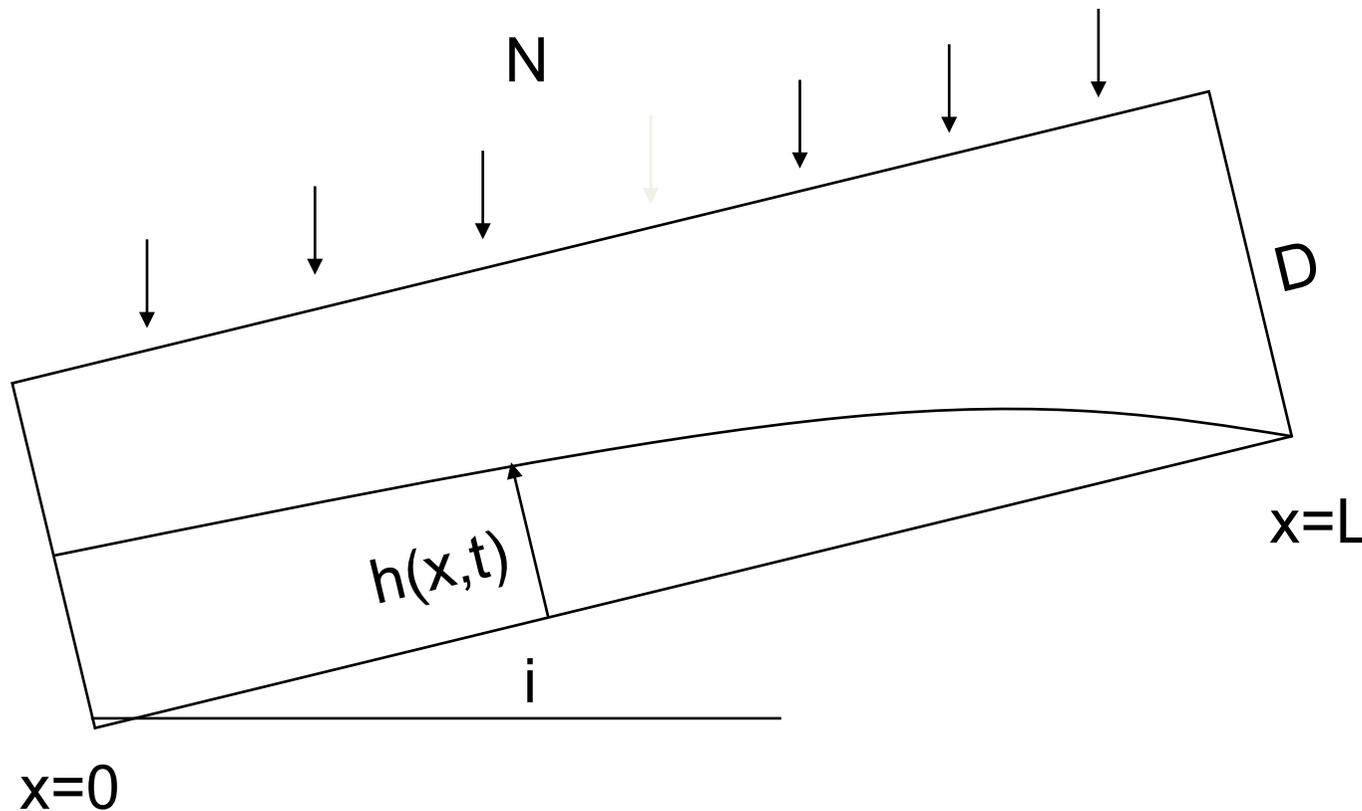
Dec 1993



Jan 1995

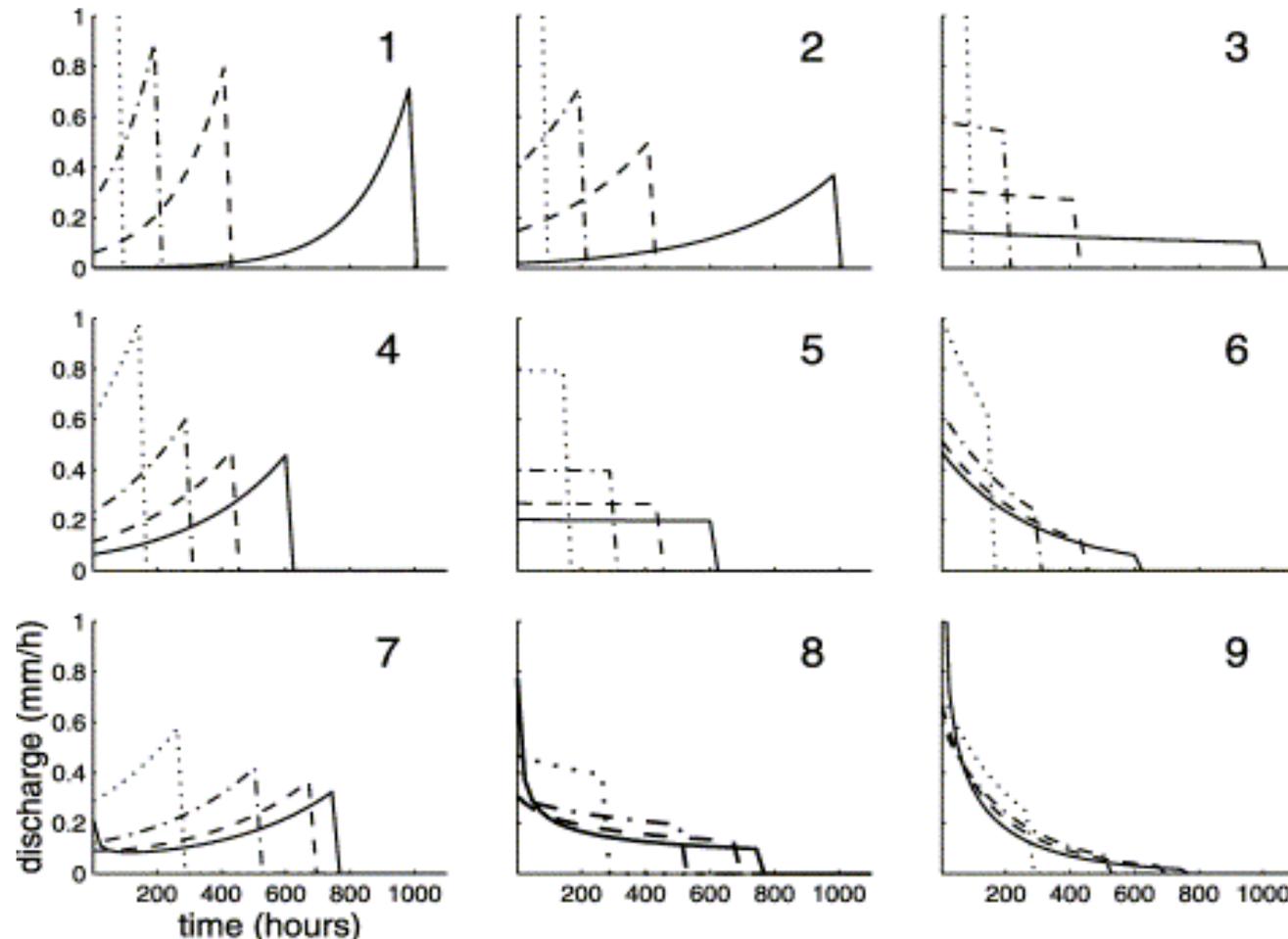
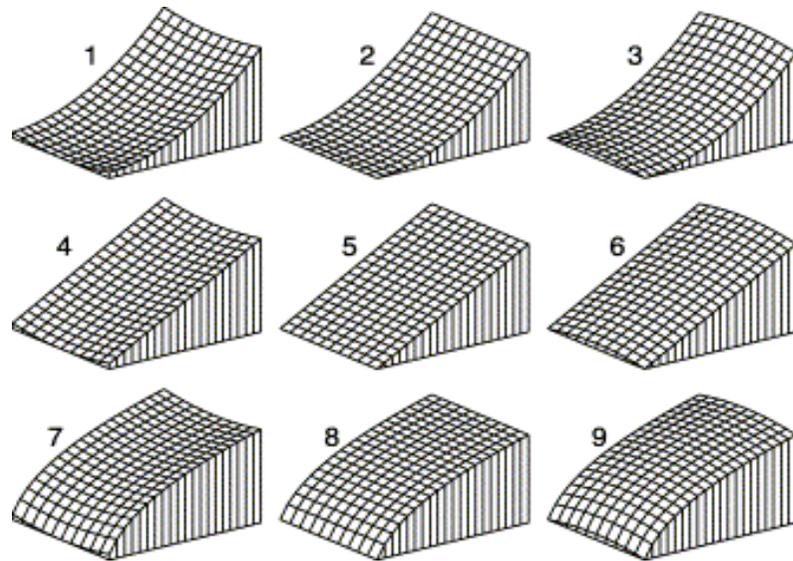


SSF - Fluss in einem geneigten Aquifer



$$\frac{\partial h}{\partial t} = \frac{K}{\phi_d} \left[\cos i \frac{\partial x}{\partial t} \left(h \frac{\partial h}{\partial x} \right) + \sin i \frac{\partial h}{\partial x} \right]$$

Reaktionen



Normalized subsurface flow rates at different locations along the nine hillslopes during **free drainage** (dotted line: $x=25$ m; dash-dotted line: $x=50$ m; dashed line: $x=75$ m; solid line: at outlet, $x=100$ m).

Troch, 2002, AWR,
Analytical solutions to a hillslope-storage kinematic wave equation for subsurface flow

HOST

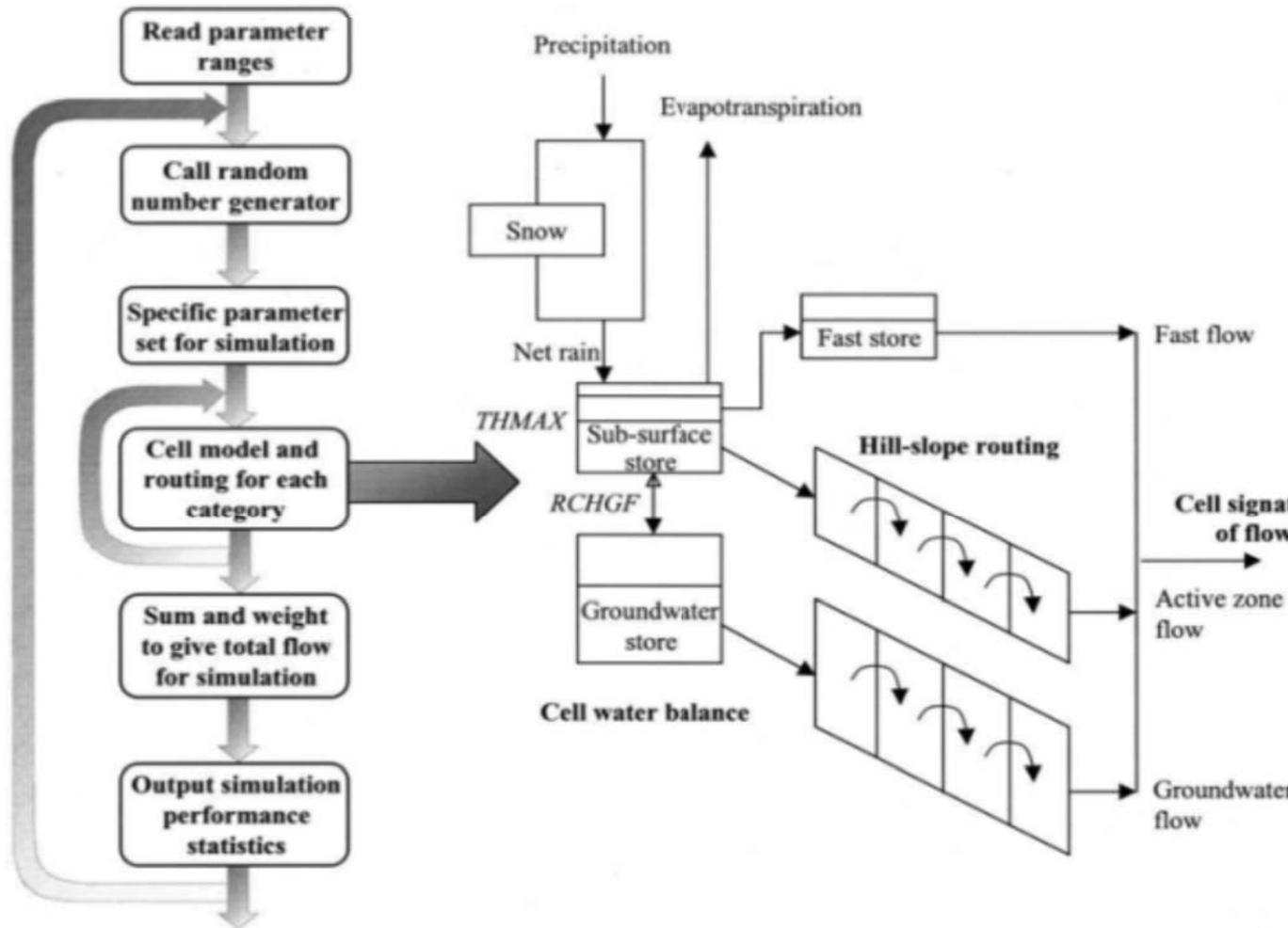


Table 1
Relative parameter values (RPV) assigned to each HOST class that occurs in Scotland

HOST class	KACT	THMAX	RCHGF	PORE	FASTD
4	L	H	M	0.29	H
5	L	H	M	0.54	H
6	L	H	M	0.51	H
7	M	H	H	0.55	H
8	M	H	H	0.51	H
9	M	L	H	0.52	M
10	L	M	H	0.54	L
12	L	L	H	0.49	L
13	M	M	M	0.45	M
14	M	L	M	0.52	L
15	H	L	M	0.49	L
16	L	H	L	0.46	H
17	L	M	L	0.48	H
18	M	M	L	0.47	M
19	M	M	L	0.5	M
22	H	M	L	0.15	M
24	H	L	L	0.47	L
28	H	L	L	0.77	L
29	H	L	L	0.77	L

Fig. 1. Schematic of the DIY model within a multi-simulation framework.

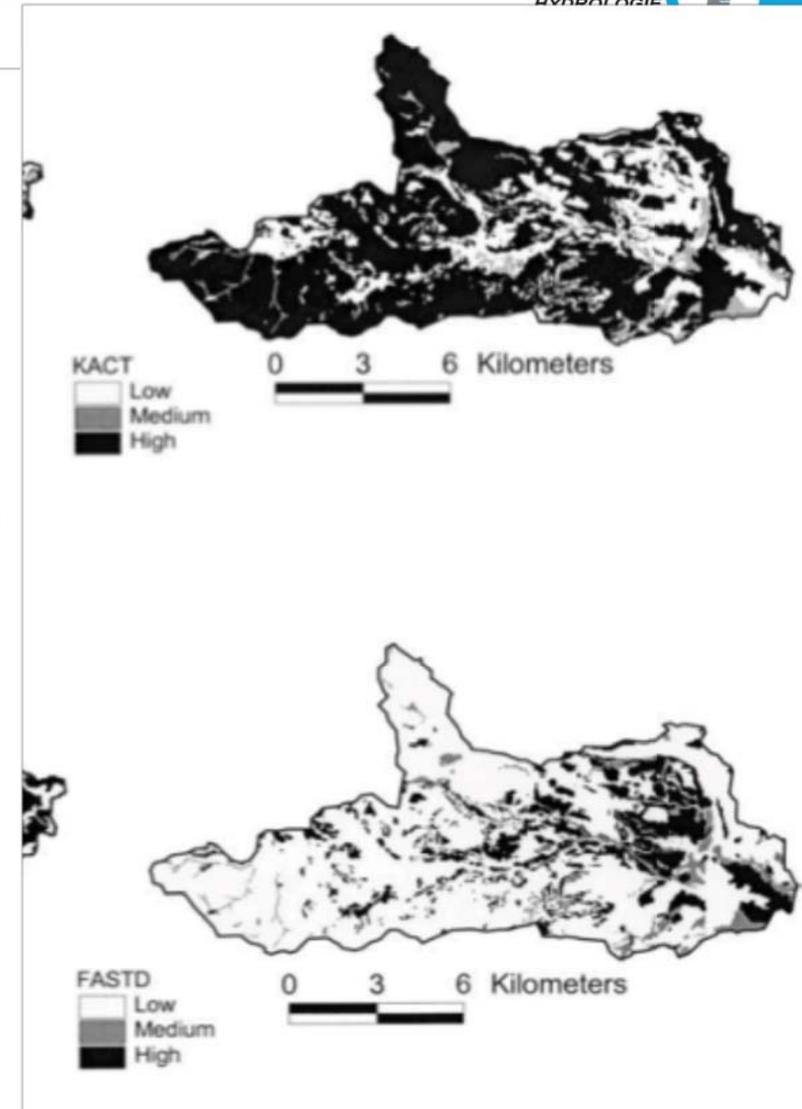
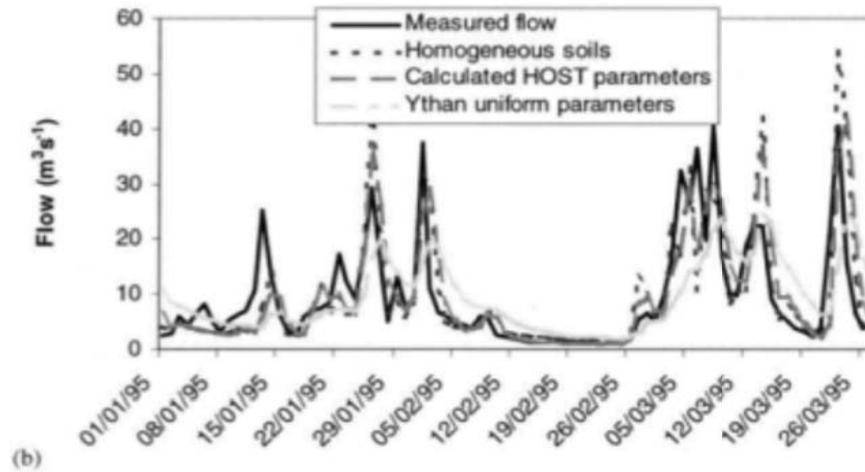
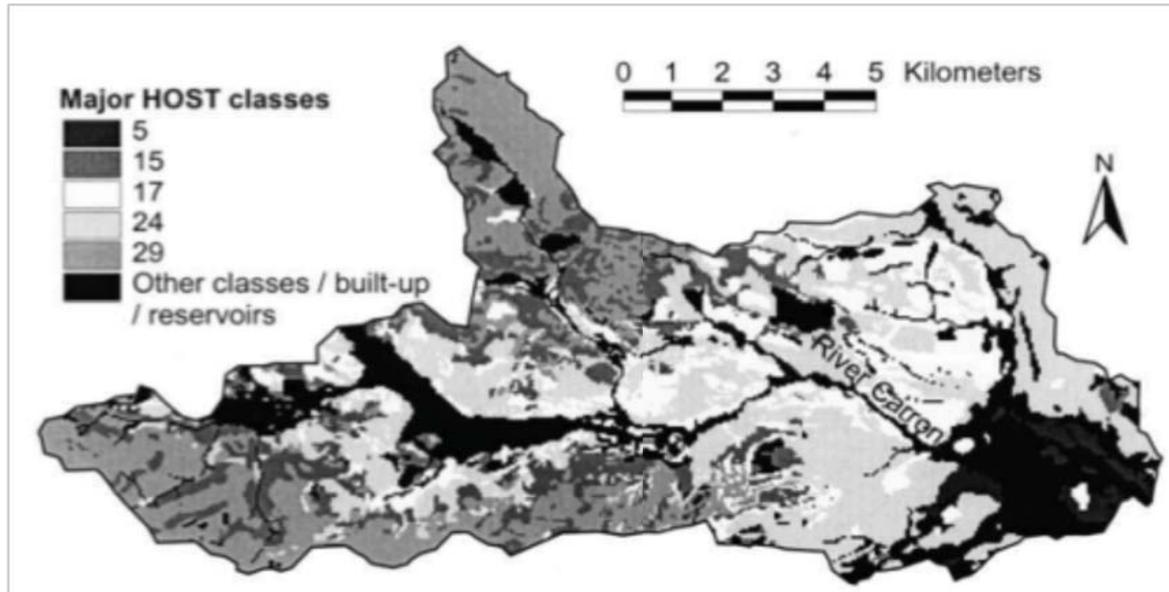
Dunn and Lilly, 2001

- Entwicklung eines N-A-Modells aus DRP Karten
- Entwicklung eines prozessbasierten Hydrologischen Modells
 - Vortrag gestern bei Andreas Steinbrich
- Parametrisierung mittels DRP Karten von einem räumlich expliziten hydrologischen Modells
- Modelverifikation (Kalibrierung)
- Modellunsicherheit

Modellierungsansätze

- Entwicklung eines N-A-Modells aus DRP Karten
- Entwicklung eines prozessbasierten Hydrologischen Modells
- Parametrisierung mittels DRP Karten von einem räumlich expliziten hydrologischen Modells
- Modelverifikation (Kalibrierung)
- Modellunsicherheit

HOST



Direktabflussbildungswahrscheinlichkeit

Well drained HRU



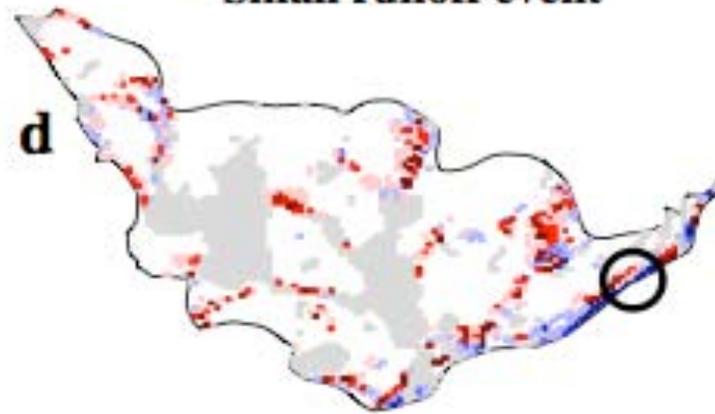
0 $0 < p < 1$

Poorly drained HRU

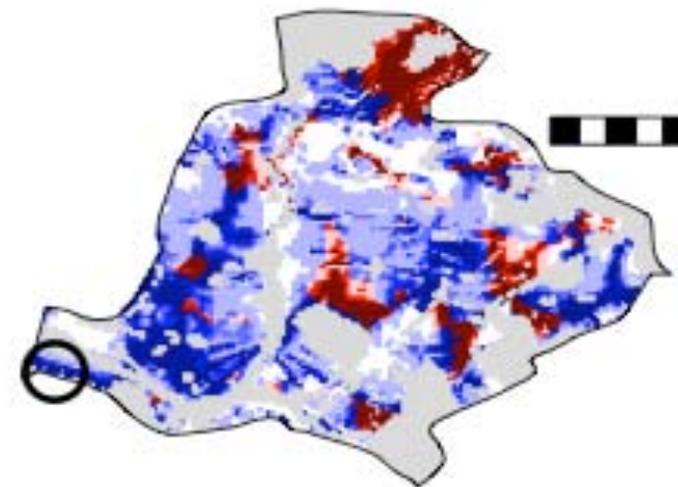
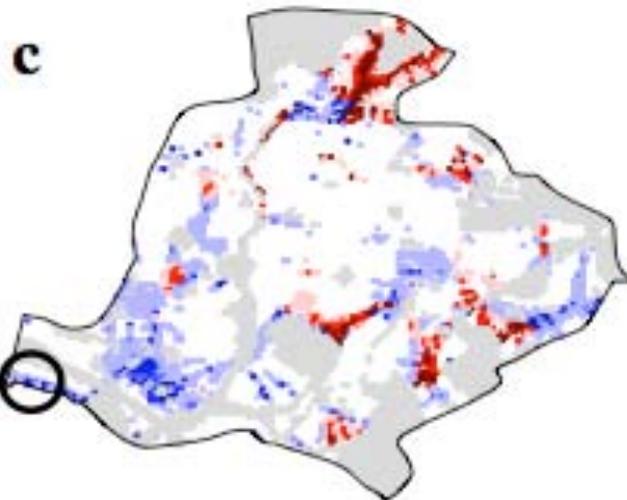
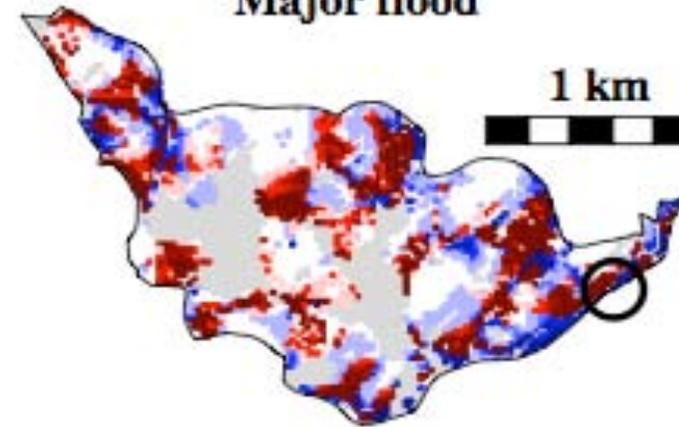


0 $0 < p < 1$

Small runoff event



Major flood



P. Lazarotto

Modellierungsansätze

- Entwicklung eines N-A-Modells aus DRP Karten
- Entwicklung eines prozessbasierten Hydrologischen Modells
- Parametrisierung mittels DRP Karten von einem räumlich expliziten hydrologischen Modells
- **Modelverifikation (Kalibrierung)**
- Modellunsicherheit

Gesättigte Flächen

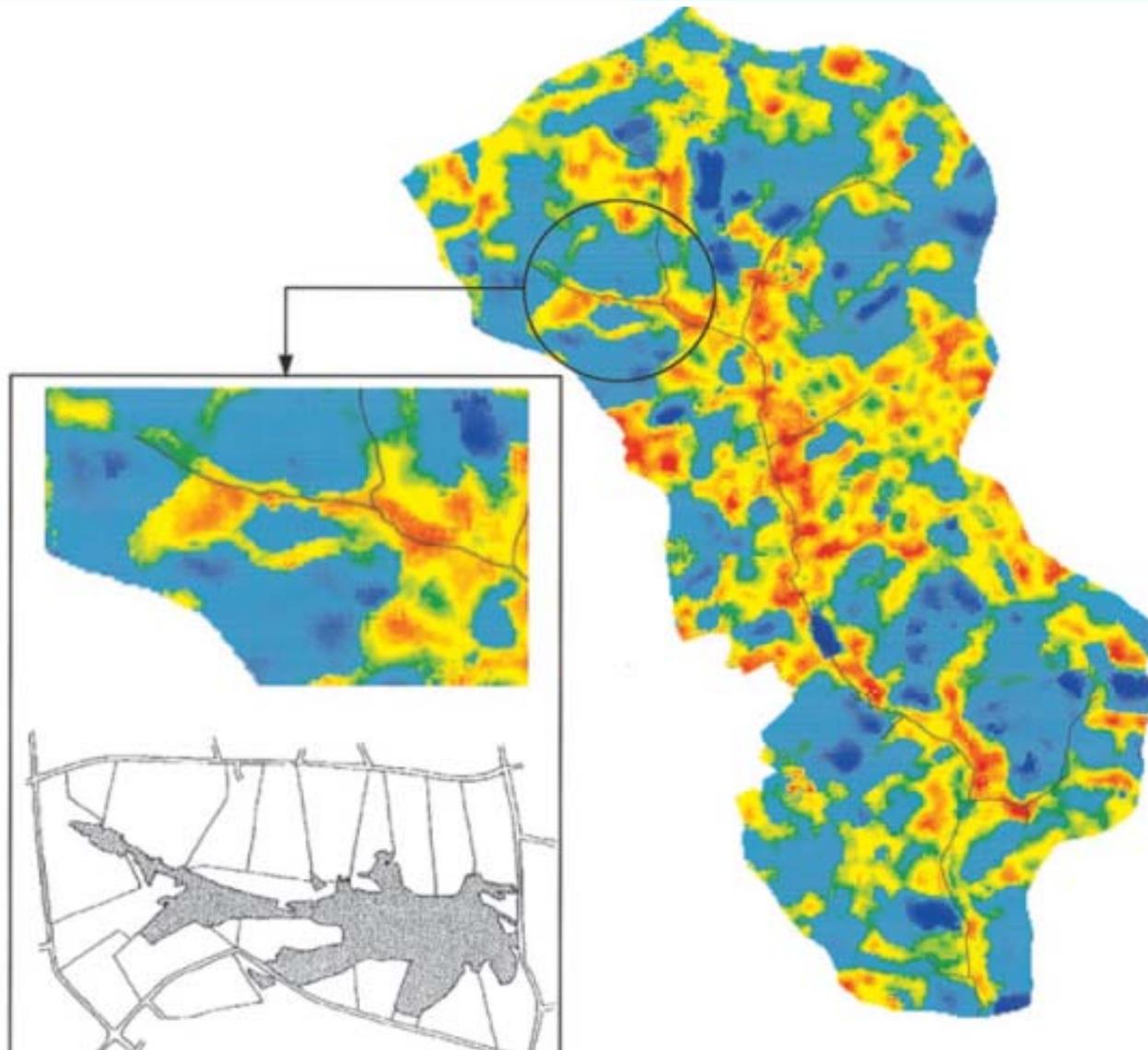
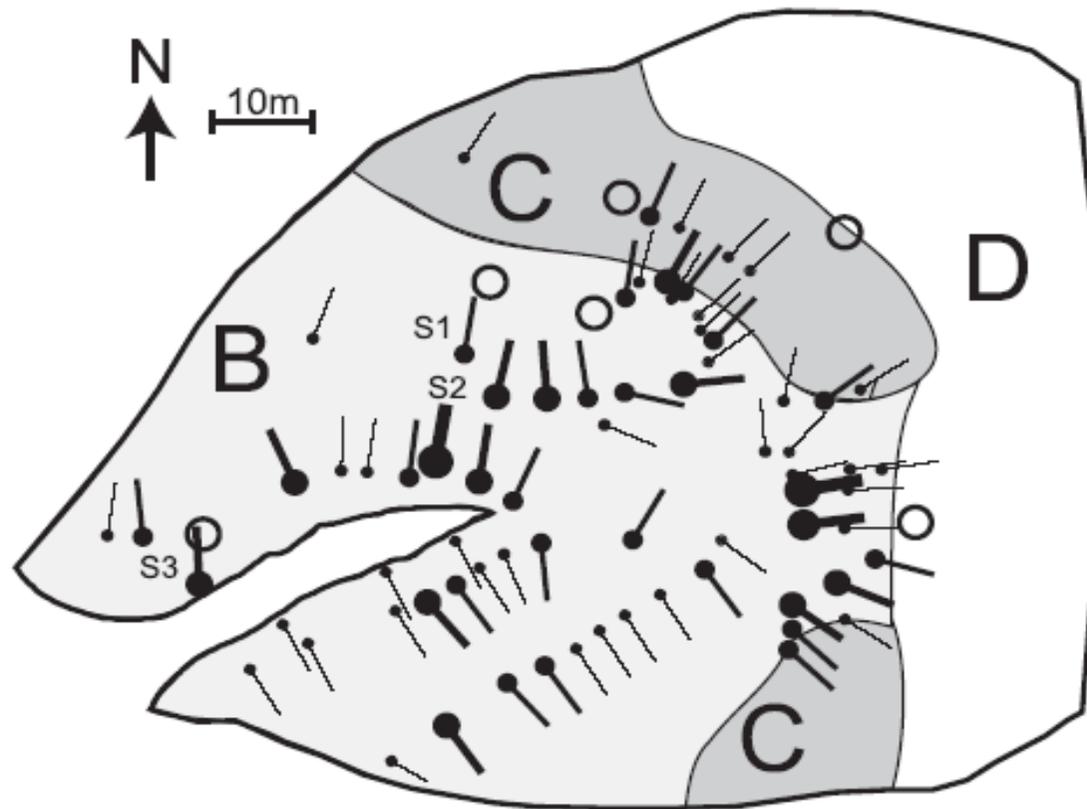


Figure 8.5. Saturated areas observed from field campaigns on February 15, 18, and 21 for the Coët-Dan catchment. The right image shows the saturation potential index (SPI) for the Coët-Dan basin, calculated on the sequence of ERS-1 images taken during the winter period of 1992. The SPI varies from low (red) to high (blue). Low (red) values indicate saturation prone areas.

Oberflächenabfluss



S1-3: continuous monitoring sites of overland flow
○ pipe outlets

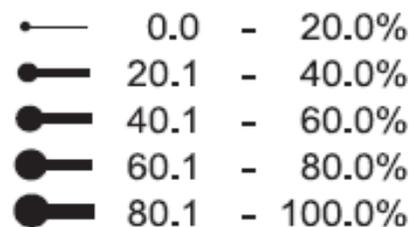
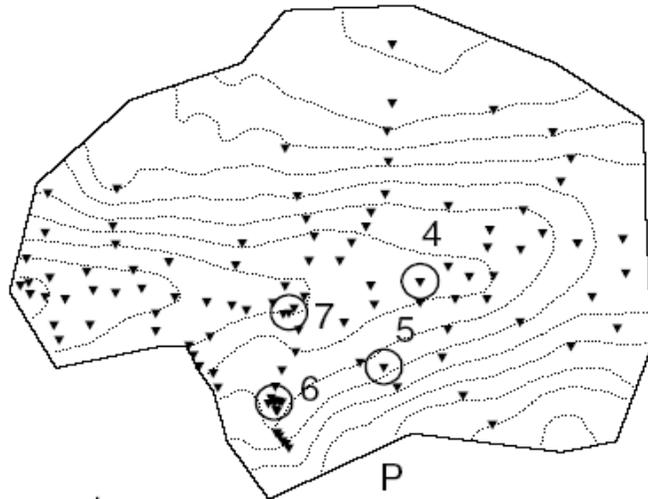


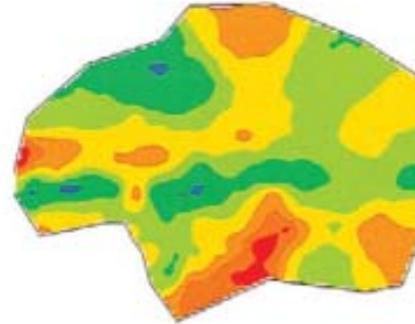
Figure 10.3. Position of land units B, C and D in the La Cuenca catchment, showing the location of major sub-surface pipes and the frequency of overland flow occurrence at 72 detector sites for 187 separate events, after Vertessy and Elsenbeer (1999).

Grundwasser

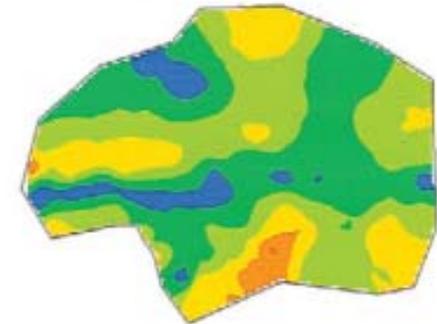
Minifelt catchment Sweden



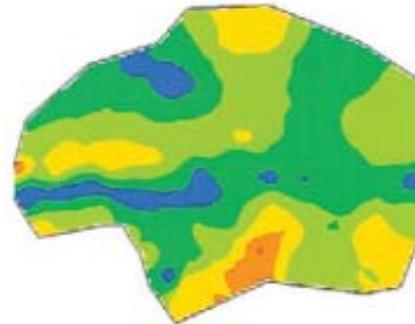
$\bar{Q} = 0.1 \text{ mmh}^{-1}$



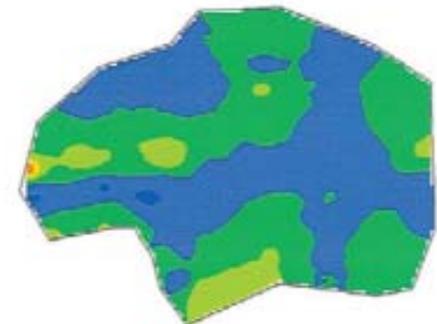
$\bar{Q} = 0.54 \text{ mmh}^{-1}$



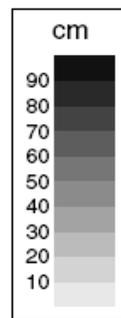
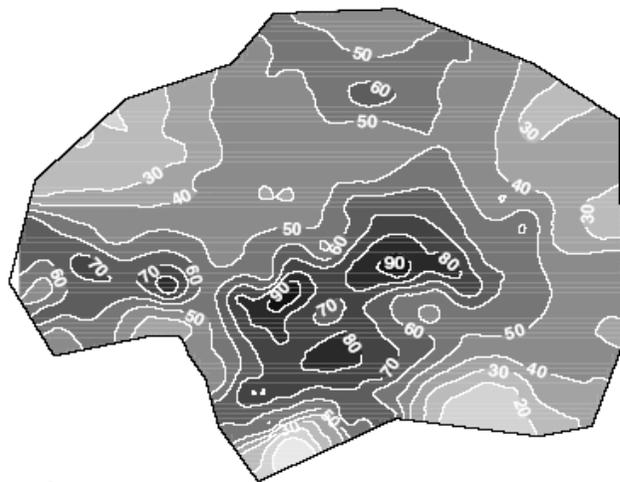
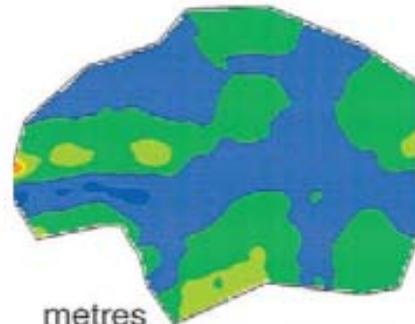
$\bar{Q} = 0.61 \text{ mmh}^{-1}$



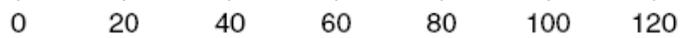
$\bar{Q} = 4.9 \text{ mmh}^{-1}$



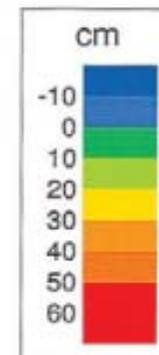
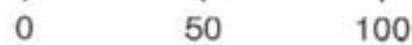
$\bar{Q} = 6.8 \text{ mmh}^{-1}$



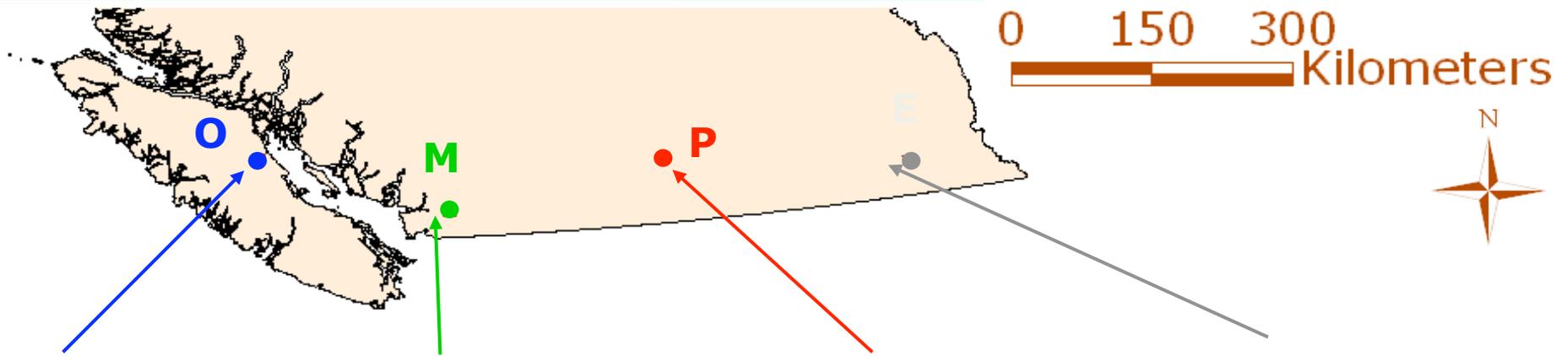
metres



metres



Bestimmung der Bodensättigung



Oyster Creek

Malcolm Knapp

Penticton Creek

Elk Creek

P = 1390mm

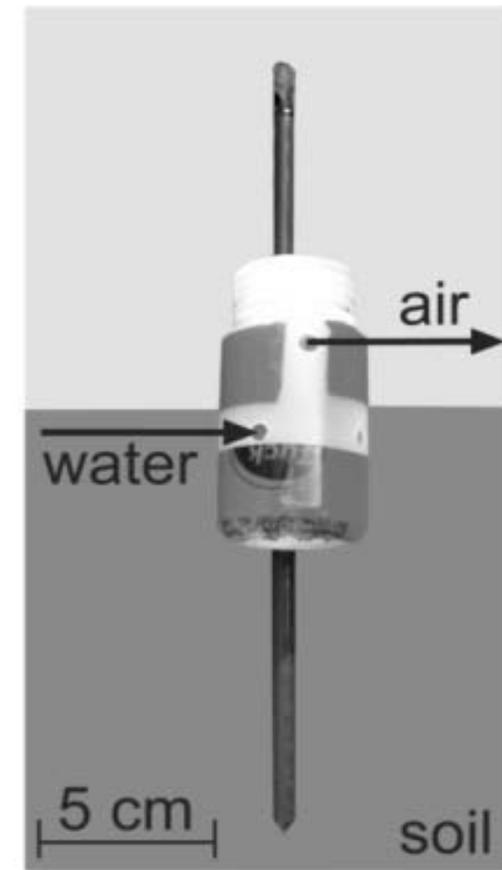
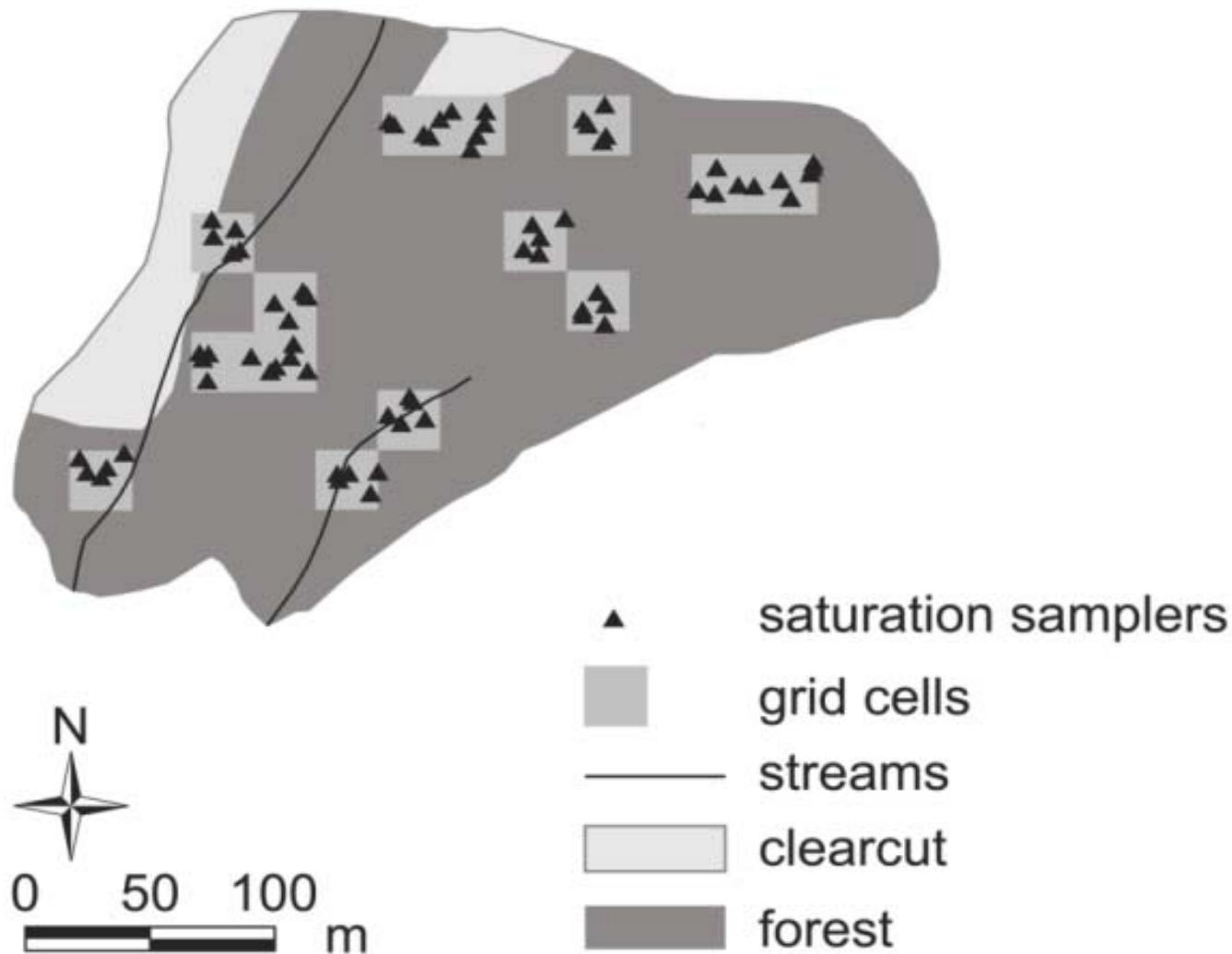
P = 2190mm

P = 750mm

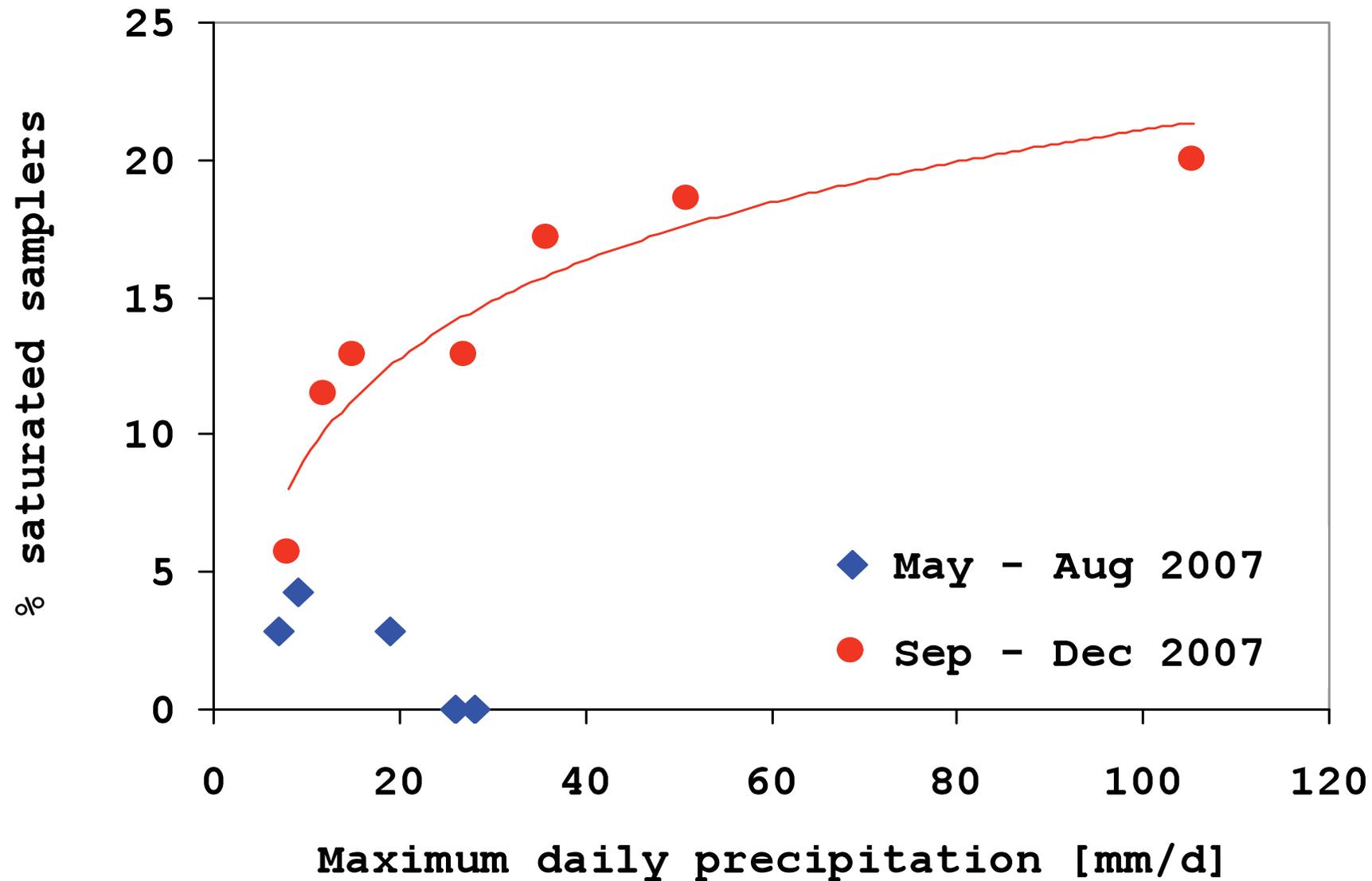
P = 580mm



Sättigungsflächen



Sättigung und Niederschlag



Spatial modelling of soil saturation

1) TO

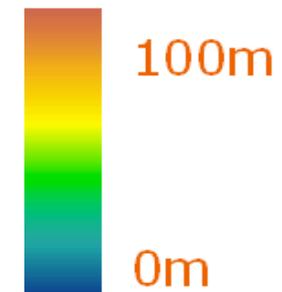
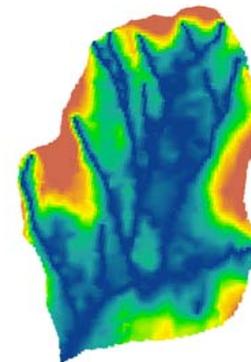
$$TOPO = \ln\left(\frac{A}{\tan(\alpha)}\right)$$

A =upslope area, α =local slope



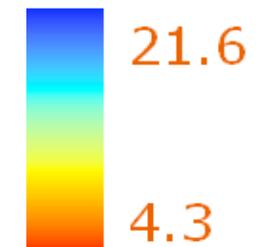
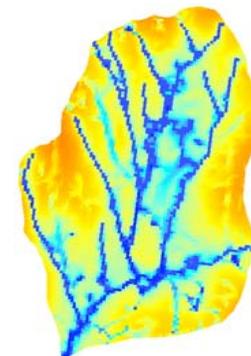
2) VE

Vertical distance to the groundwater

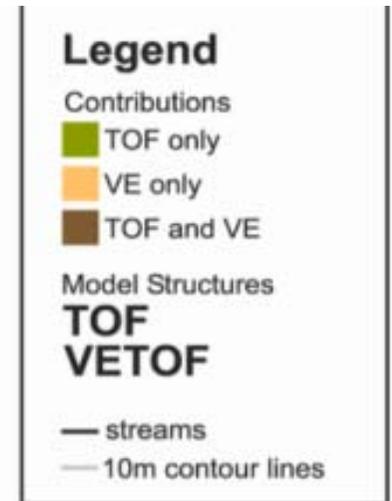
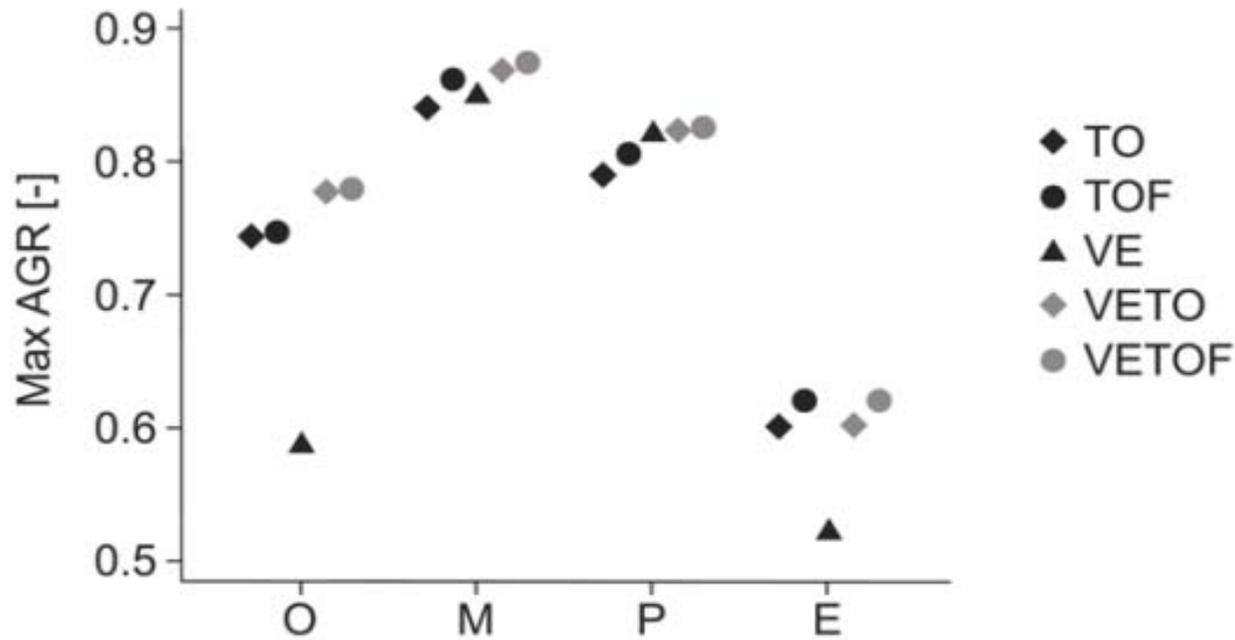


3) VETO

$$\max(TOPO, 10 - \ln(VERT + 0.1))$$



Valuation of mapping procedure

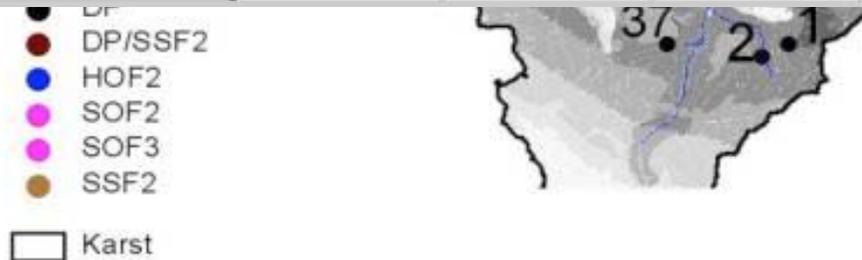


Verifikation: Abflussbildungsprozesse

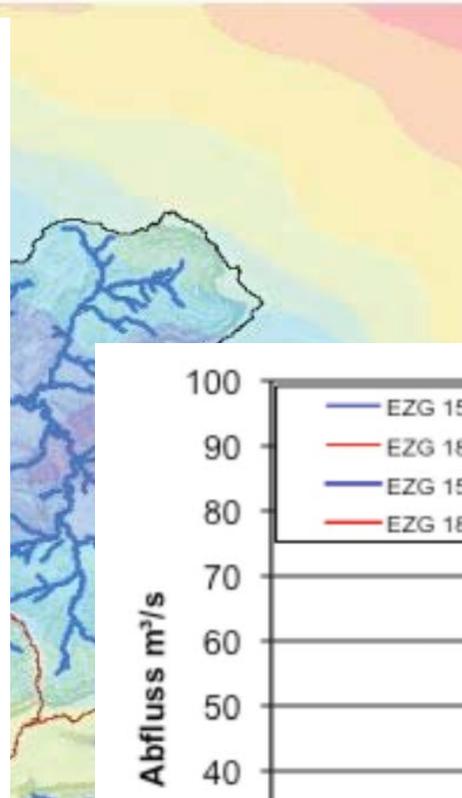
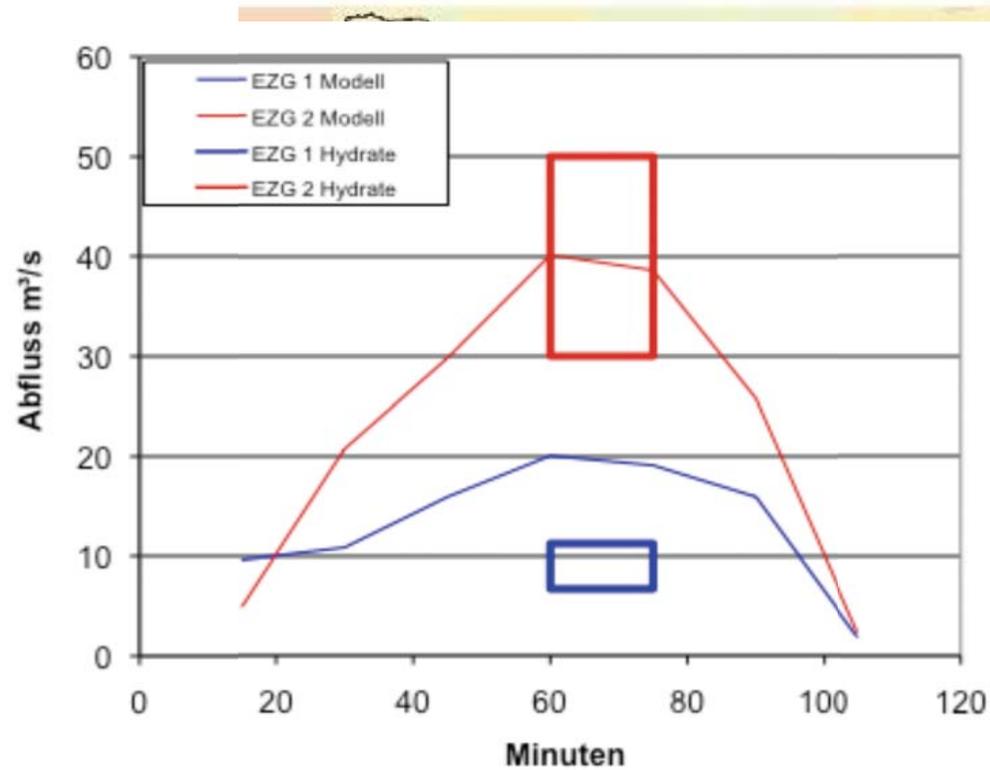
„Statische“ DRPs wurden nach Scherrer (1997, 2003) und mit Kleinberegnungsversuchen bestimmt



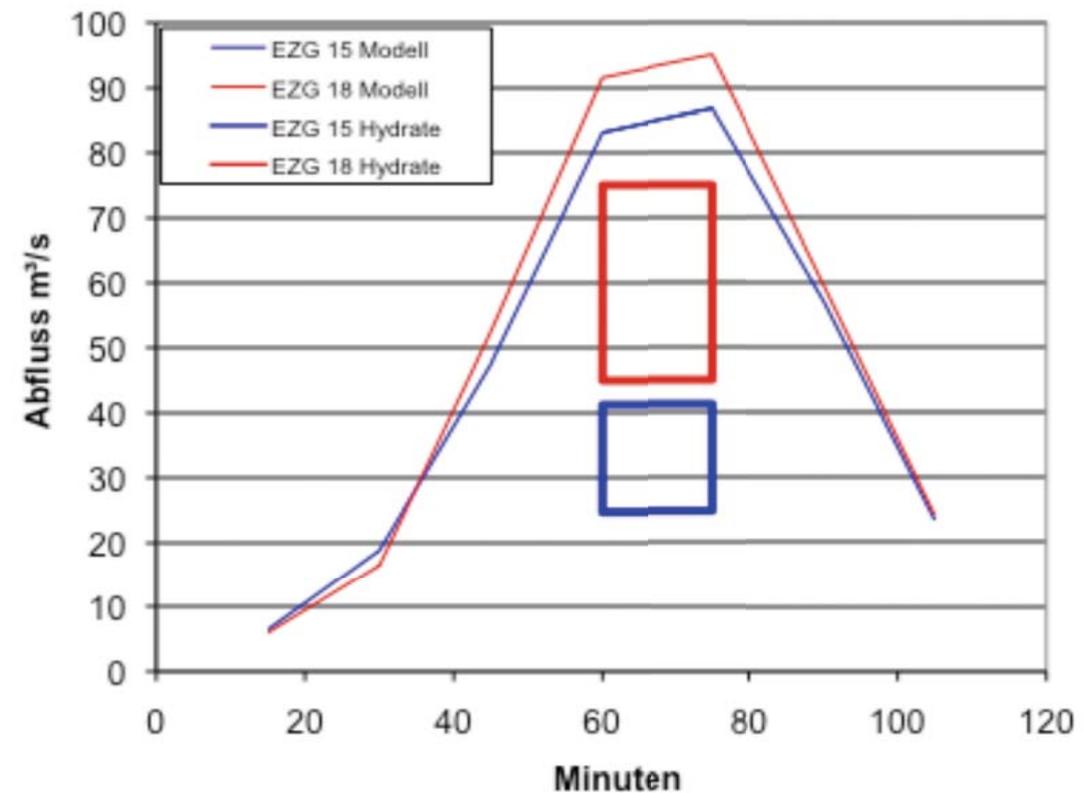
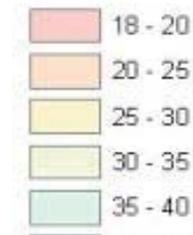
Count	DRP Model				Total
	DP	HOF	SOF	SSF	
DRP obs					
DP	15	1	0	1	17
HOF	3	4	0	2	9
SOF	1	3	0	1	5
SSF	0	0	0	4	4
Total	19	8	0	8	35



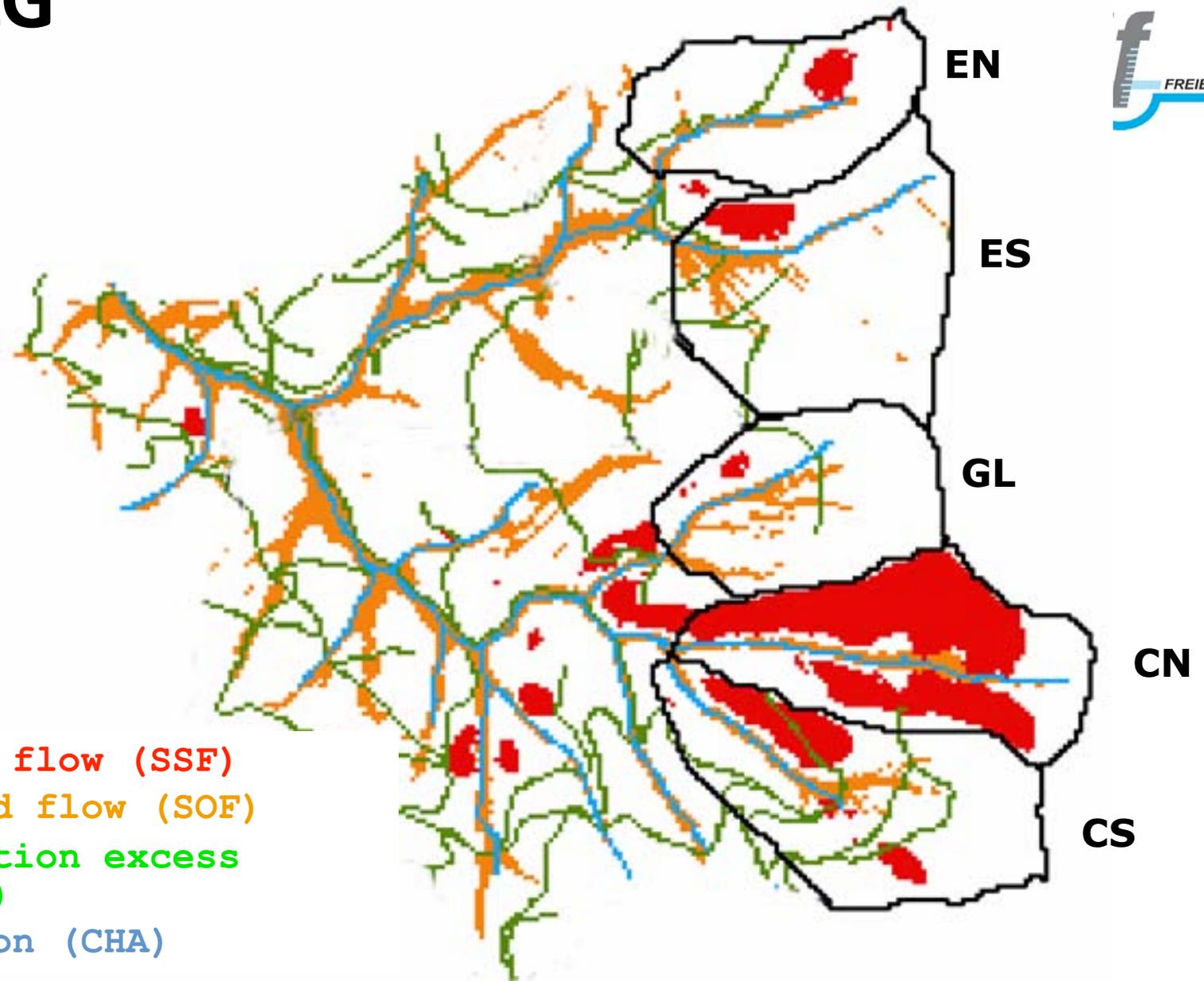
Verifikation: Teil-EZG



2-Stunden
Niederschlag
[mm]



Mehrere EZG



- Shallow subsurface flow (SSF)
- Saturation overland flow (SOF)
- Hortonian infiltration excess overland flow (HOF)
- Channel interception (CHA)

Beregnungsexperimente

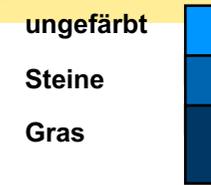
Niederschlag 70 mm

Horton
Oberflächen-
abfluss

Saturation
Overland Flow

Subsurface
Flow

Legend



Gefärbte Flächen mit

Niedriger Konzentration
Mittlerer Konzentration
Hoher Konzentration

Tiefenperkolation
(Speicher)

30

15

0

0

0

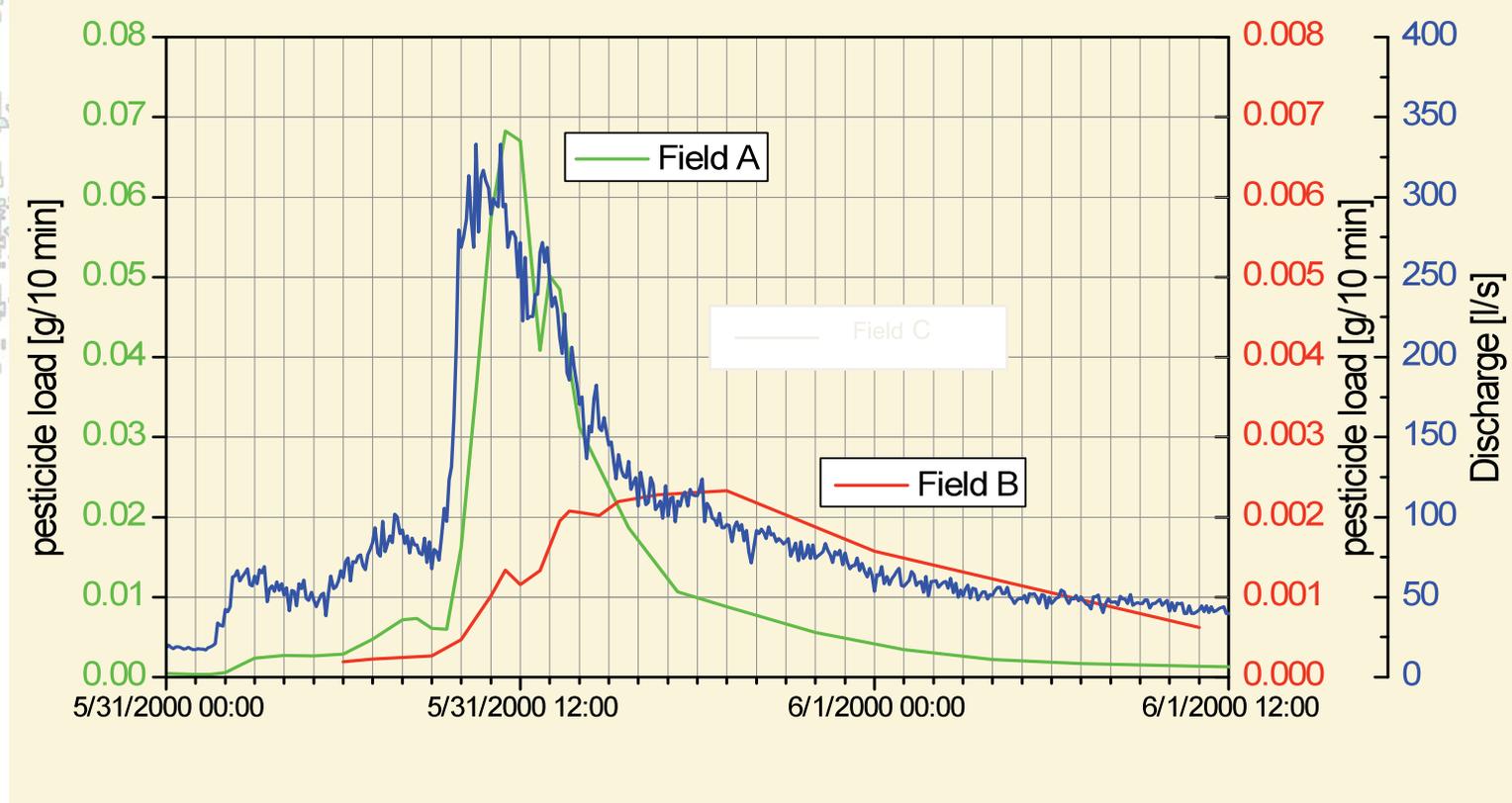
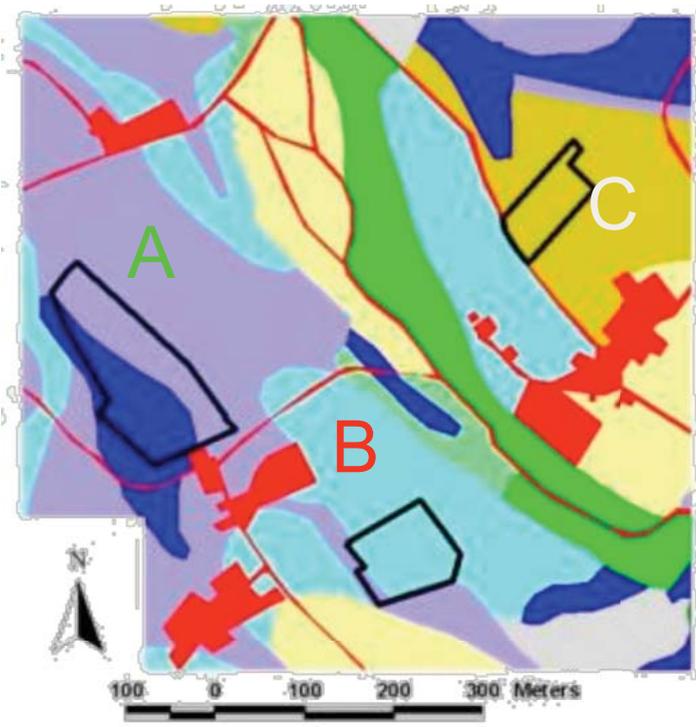
1m

25

40

Perkolation

Transport von Pestiziden



Modellunsicherheit

- Unsicherheit im Input (Niederschlag)
- Unsicherheit in Kalibrierungsdaten (Abfluss)
- Parameterunsicherheit
 - GLUE
 - SOBOLE
- Modelstrukturunsicherheit (siehe mein Talk)