Scaling Issues in Hydrological Modeling
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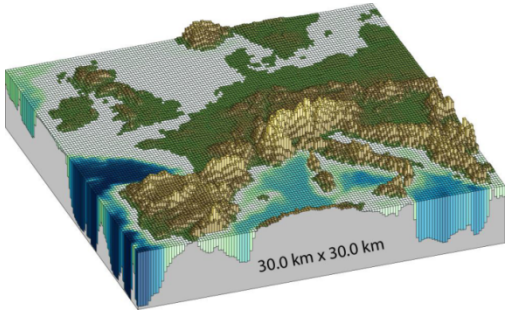
Climate Induced Changes on the Hydrology of Mediterranean Basins - CLIMB

Ralf Ludwig

Ludwig-Maximilians-Universitaet Muenchen
Department of Geography

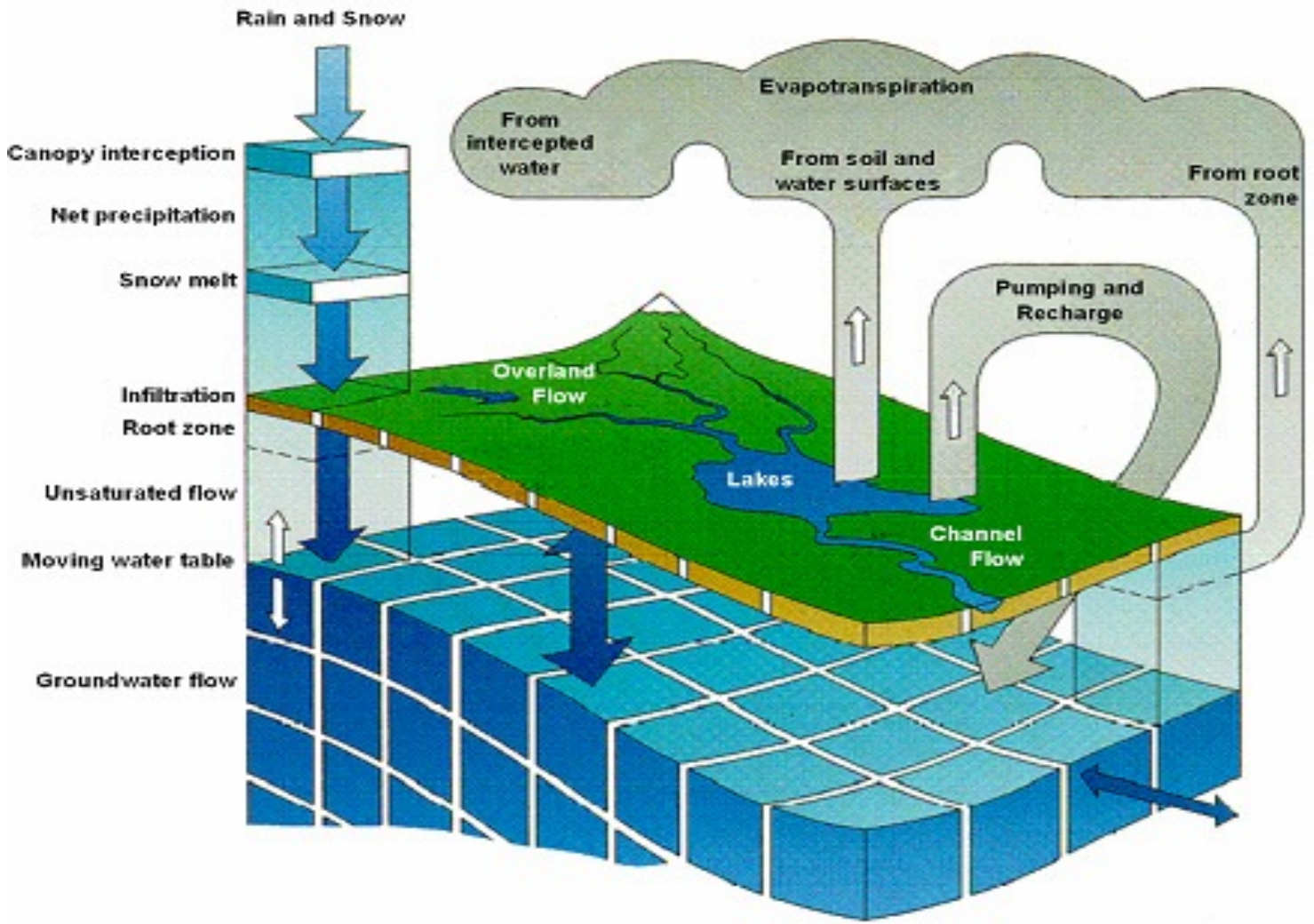


Scale Issues in Hydrological Modeling

CLIMB
Climate Induced Changes on the Hydrology of Mediterranean Basins

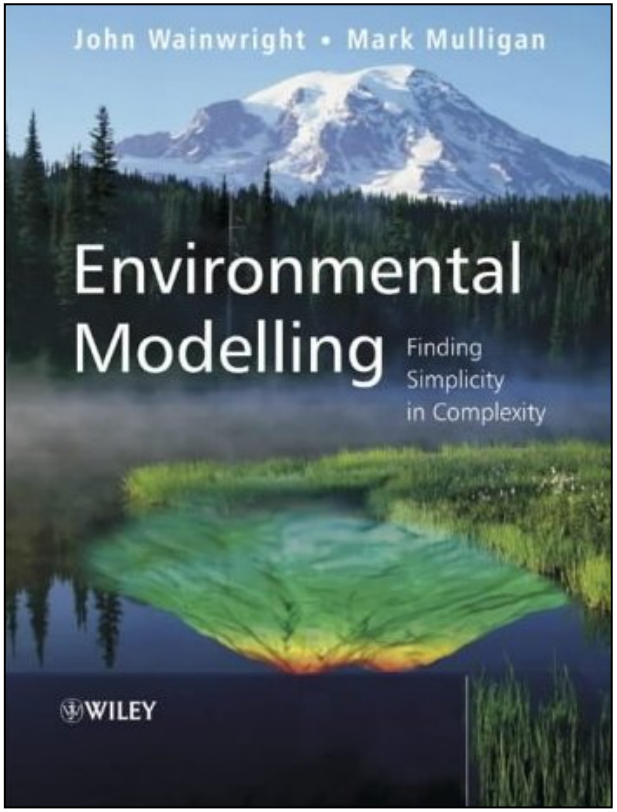
Climate induced changes on the Hydrology of Mediterranean basins

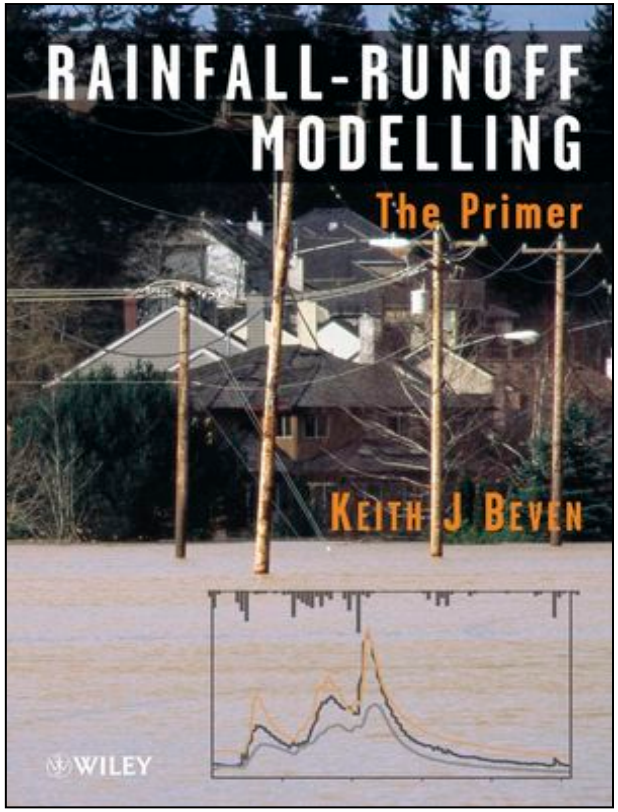
Introduction

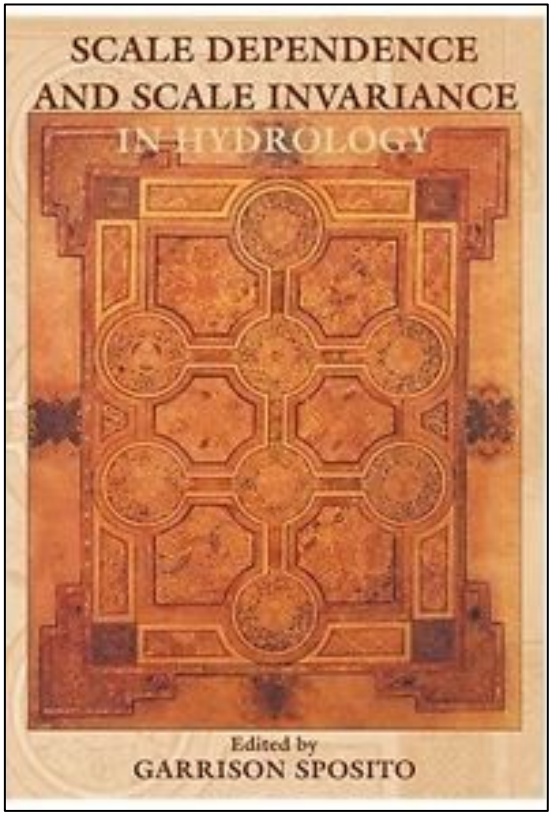


http://www.crwr.utexas.edu/gis/gishyd98/dhi/mikeshe/Mshebody.htm

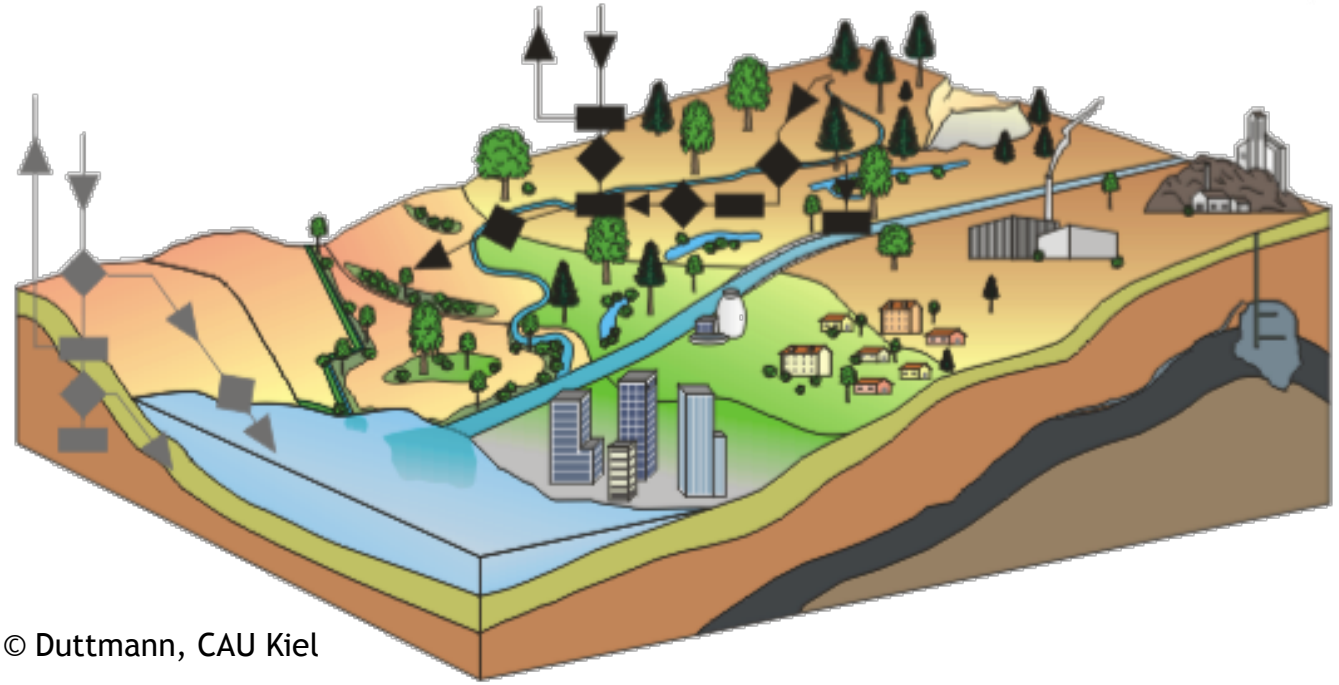
Introduction







Scales in (Distributed) hydrological modeling



© Duttmann, CAU Kiel

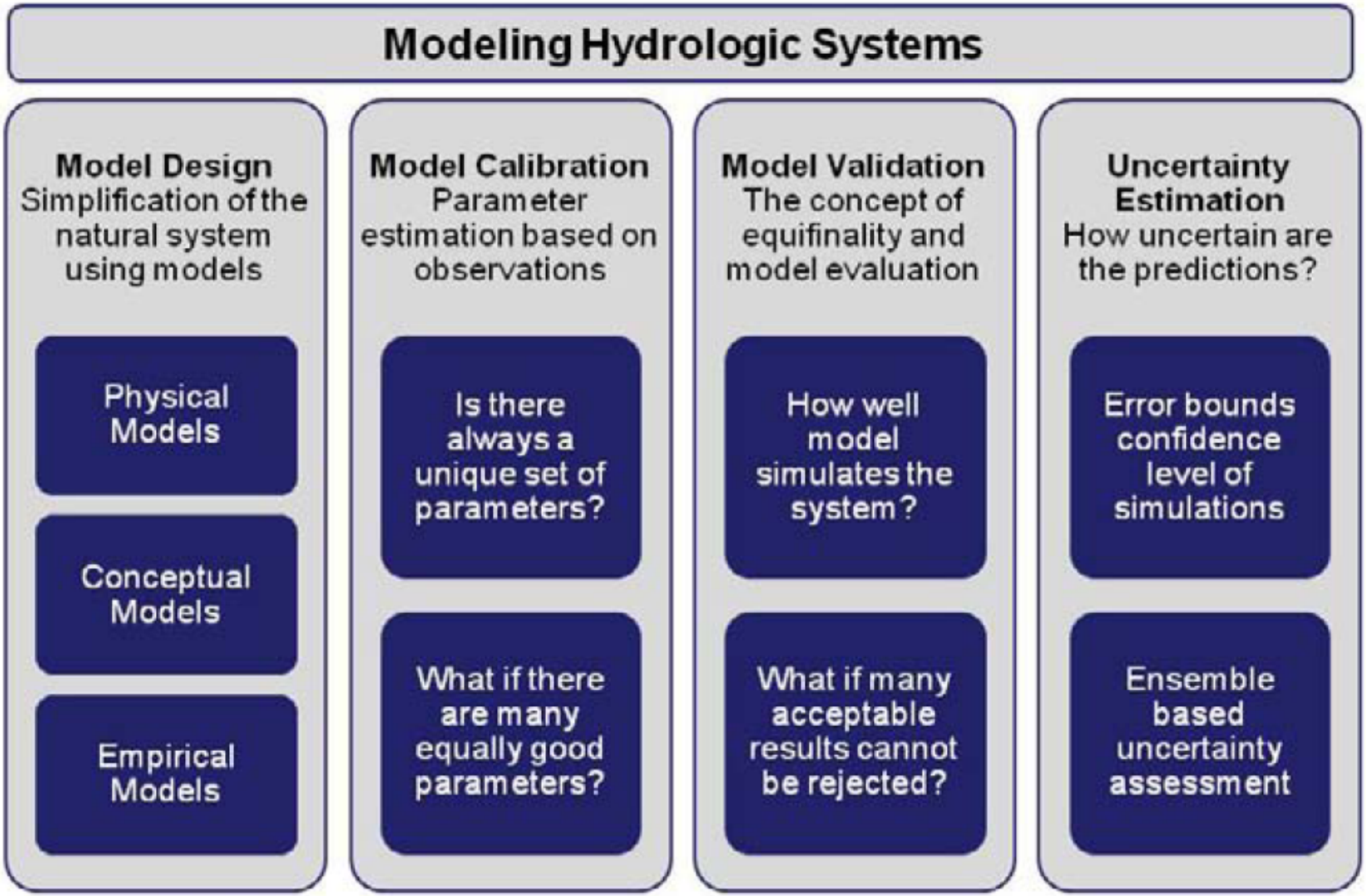
Distributed parameter models try to quantify the hydrological variability at a range of scales by subdividing the catchment into a number of units:

- **Grid cells**
- Hydrological response units
- Representative elementary areas
- Hydrologically similar units

→ processes with a characteristic length scale smaller than the grid/element size are assumed to be represented implicitly (=parameterized)

→ processes with length scales larger than the grid size are represented explicitly by element to element variations.

Introduction



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Complexity & Scaling

- Grand (2000):

  „Something is complex if it contains a great deal of information that has a high utility, while something that contains a lot of useless or meaningless information is simply complicated“

- Bar-Yam (1997):

  „Loosely speaking, the complexity of a system is the amount of information needed in order to describe it“

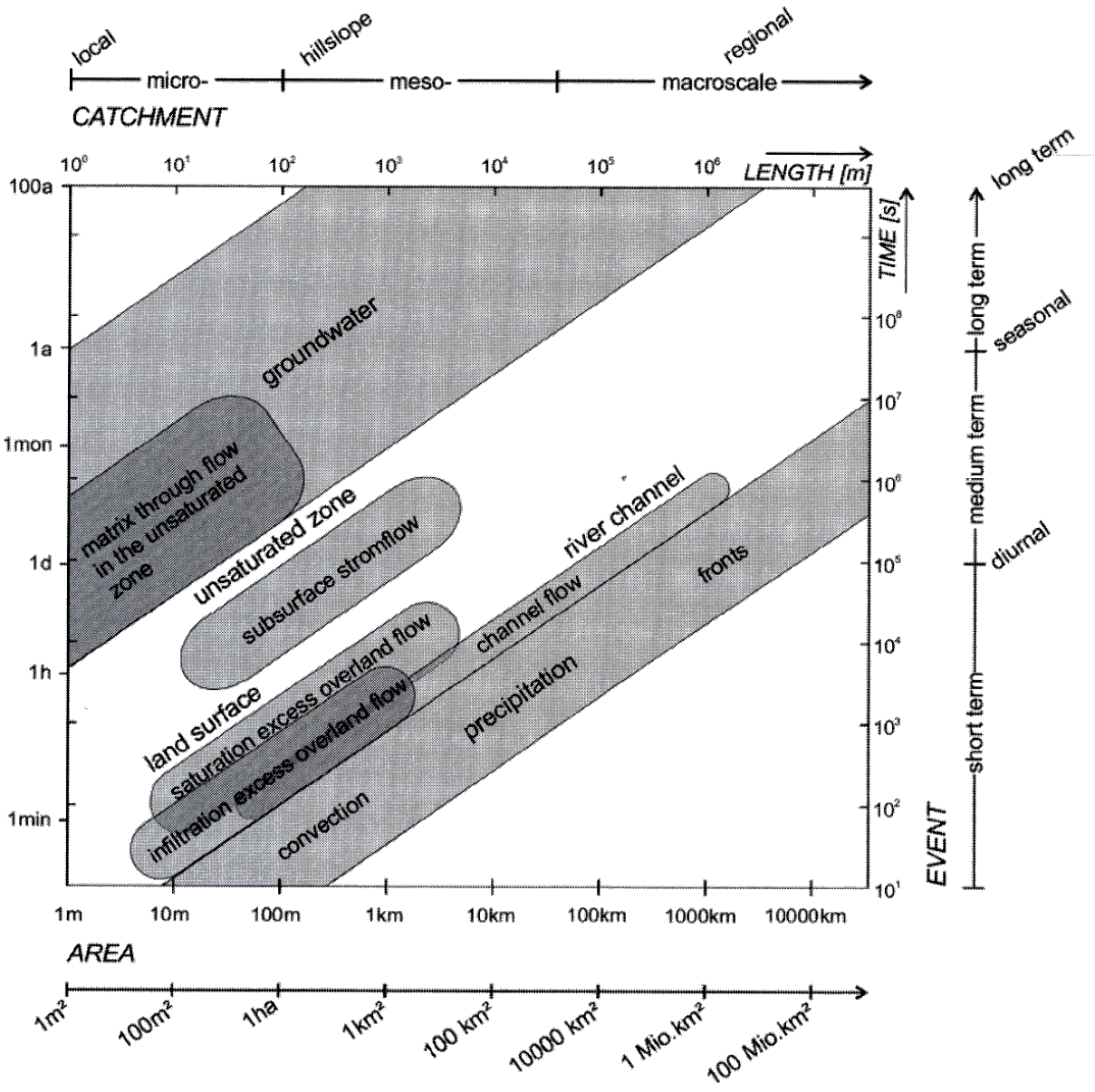
- Wainwright and Mulligan (2003):

  „a parsimonious model is usually one with the greatest predictive power and the least parameters and model complexity“

Scales in hydrology and hydrological modeling

Differentiation:

- Point/local scale
- Micro/hillslope scale
- Meso/catchment scale
- Macro/regional scale



from BLÖSCHL & SIVAPALAN, 1995)

Scales in hydrology and hydrological modeling

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Process versus observation scale

Ideally, processes should be observed/simulated at the scale they occur. Often the interest lies in large-sale processes while only (small-scale) point samples are available (or vice-versa…).

Modeling (working) scale

In space, typical modelling scales are:

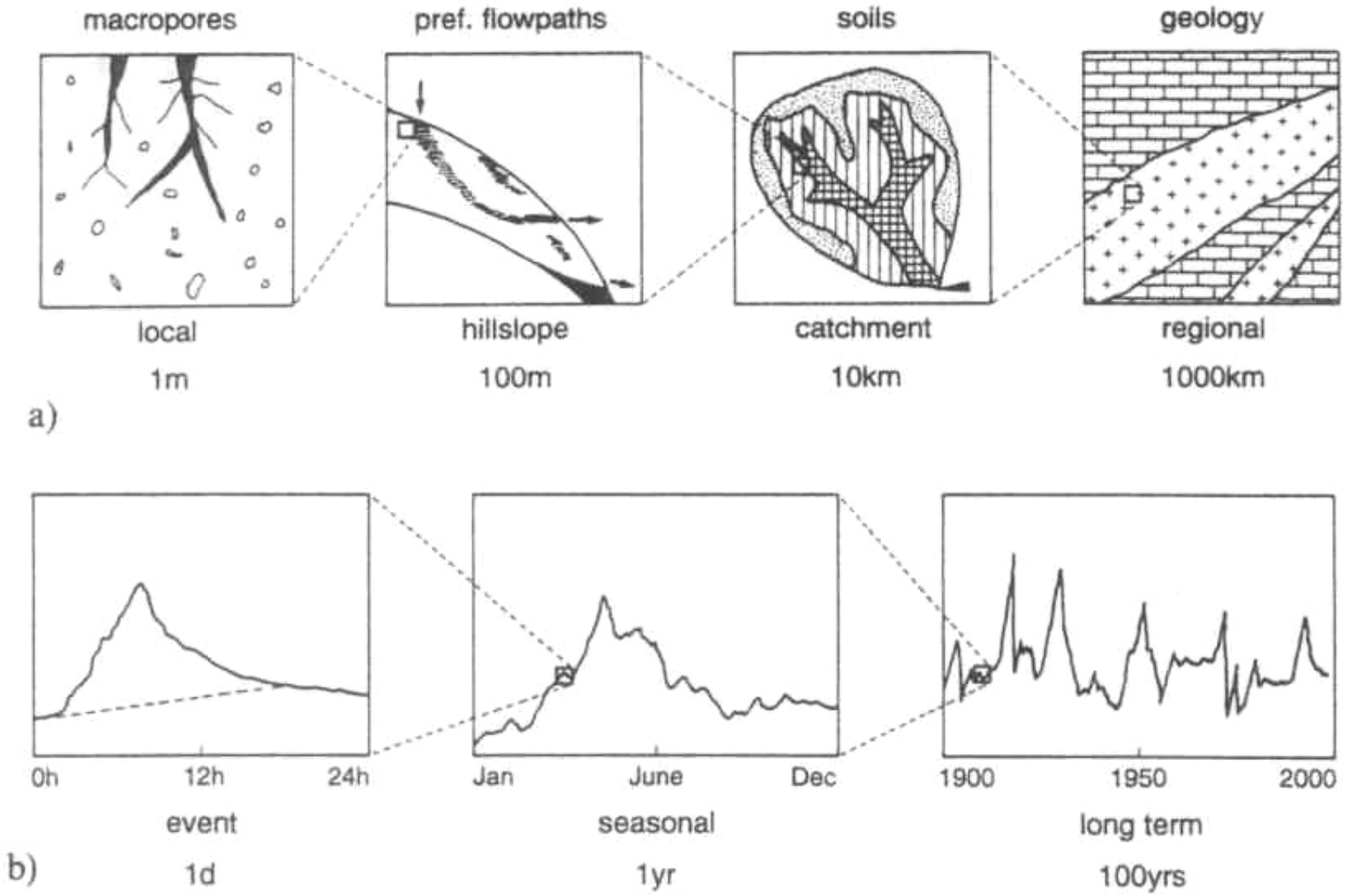
The local scale (1m)
The hillslope (reach) scale (100 m)
The catchment scale (10 km)
And the regional scale (1000 km)

In time, typical modeling scales are:

The event scale (1 hour/day)
The seasonal scale (1 year)
And the long-term scale (100 yrs)

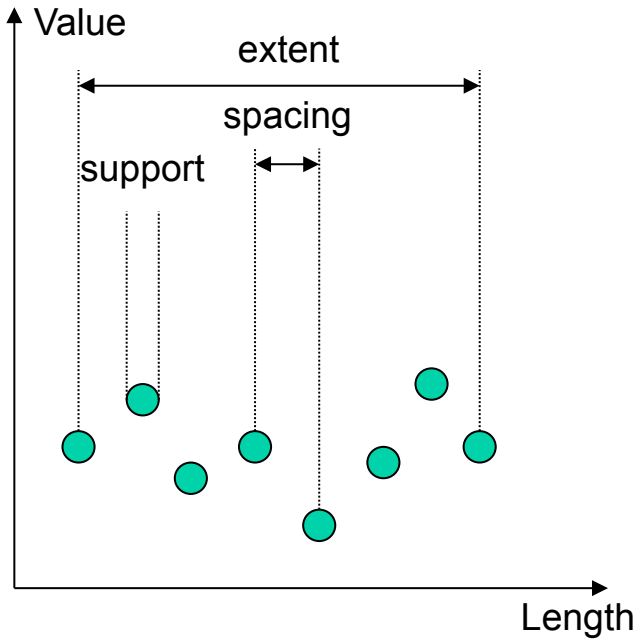
Unfortunately, more often than not, the modelling scale is much larger or much smaller than the observation scale. To bridge that gap, ‘scaling’ is needed.

Scales in hydrology and hydrological modeling

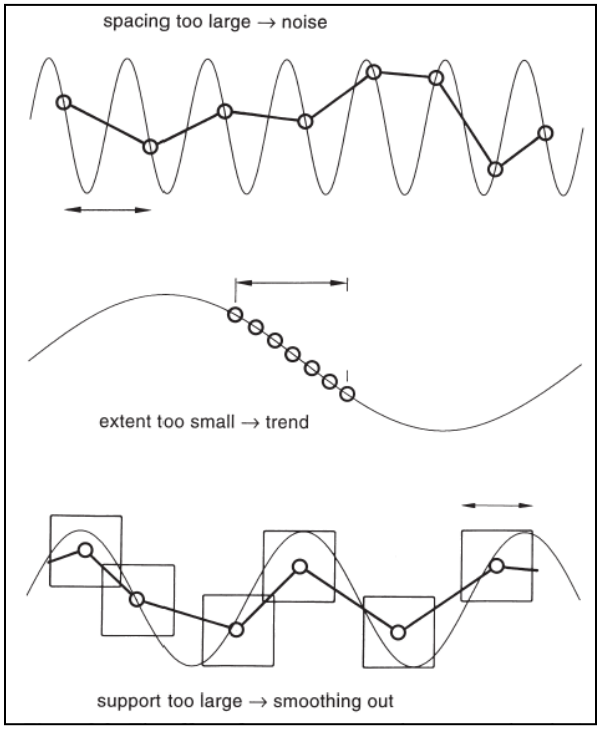


from BLÖSCHL & SIVAPALAN, 1995)

Scaling problems in hydrological modeling



Definition of the Scale-Triplett *support*, *spacing* and *extent* (Blöschl and Sivapalan (1995))



Possible deviations between model and process scale
(from Grayson & Blöschl, 2000)

Scaling problems in hydrological modeling

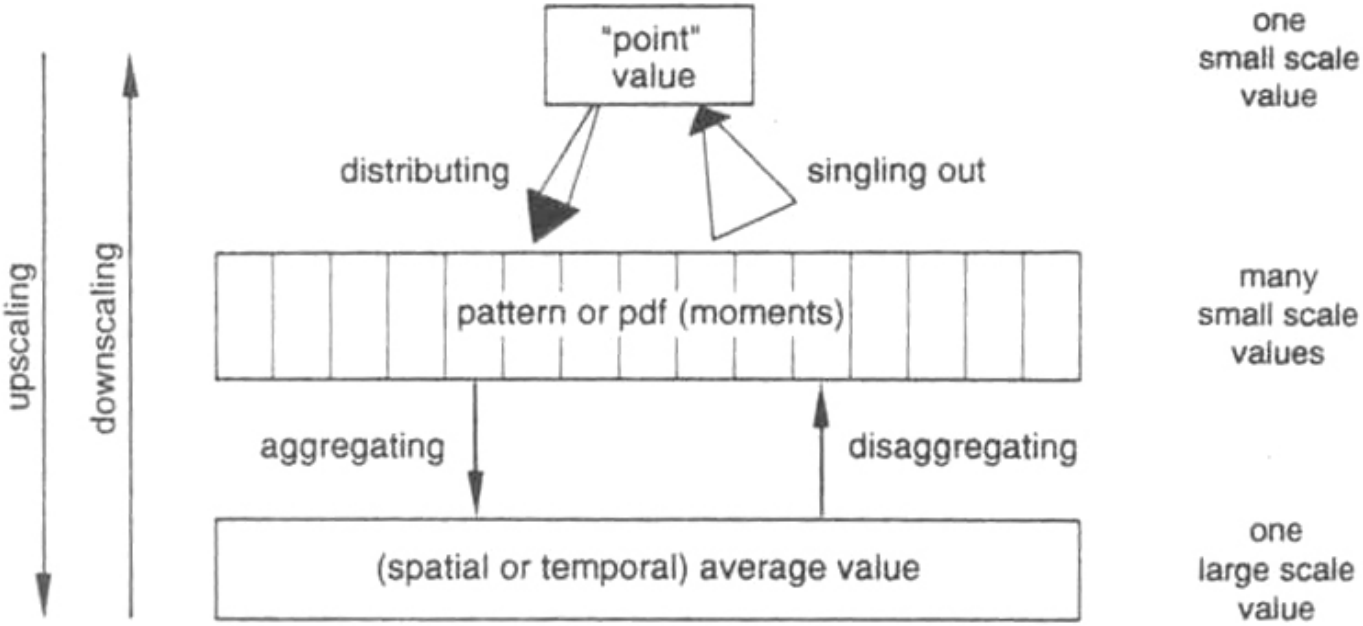
Now, why would that be difficult at all?

→ Well…: - the **heterogeneity** of catchments
- the **variability** of hydrological processes

(a)discontinuity

(b)periodicity

(c)randomness (PDF)



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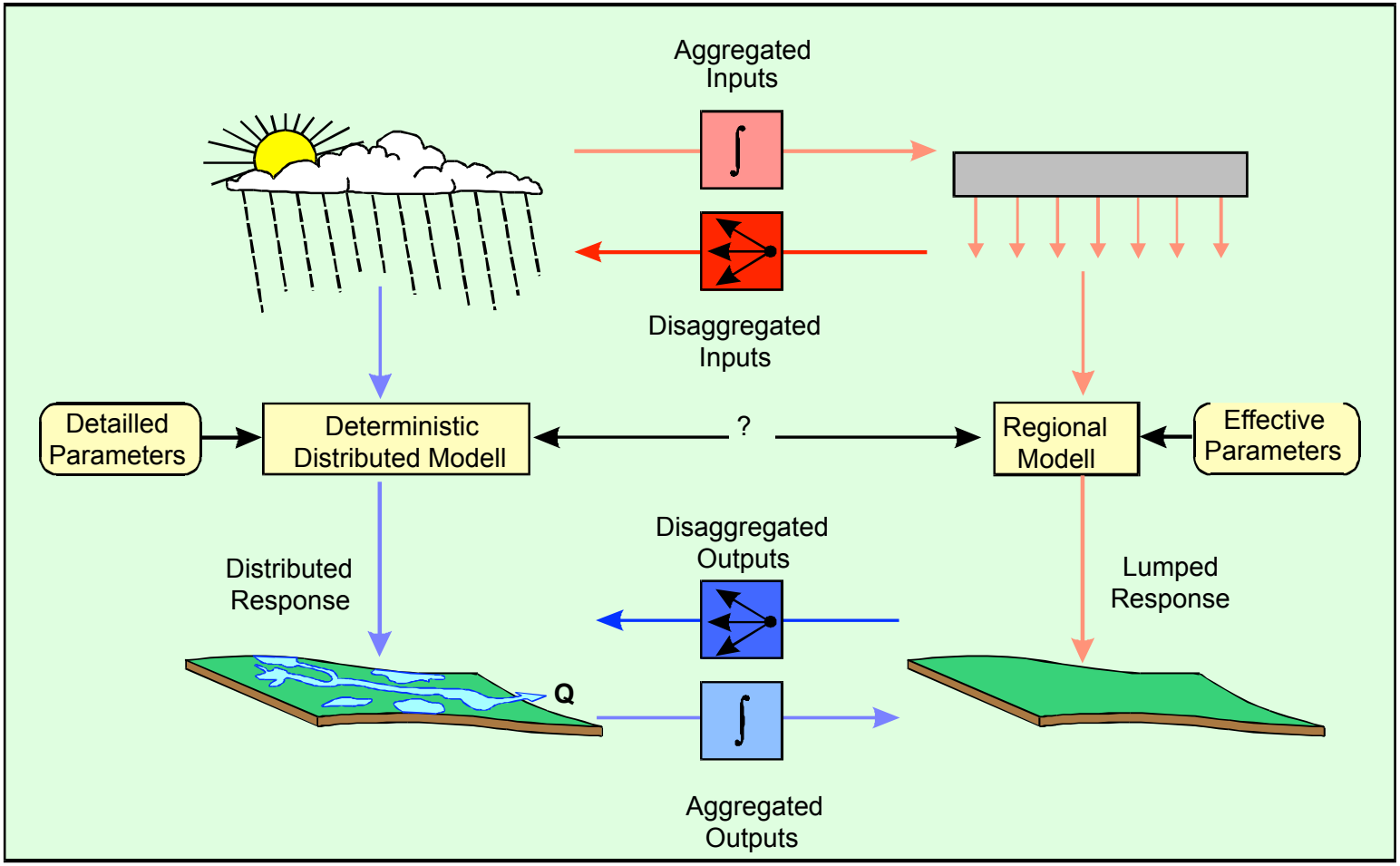
Scaling problems in hydrological modeling



Two cases:

a) Aggregation of in-and outputs – Upscaling

b) Disaggregation of in- and outputs - Downscaling

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Upscaling Example - Geocomplexes

A scaling problem in hydrological modeling:

- for long-term simulations, microscale distributed modeling (≤ 100 m) is rather demanding wrt to computing time
- mesoscale modeling (1 km^2) may, however, be too coarse to properly represent small-scale landscape variability
- Scaling – aims at providing equivalent modeling results with strongly reduced computing time

→ scaling procedure ‚Geocomplexes'

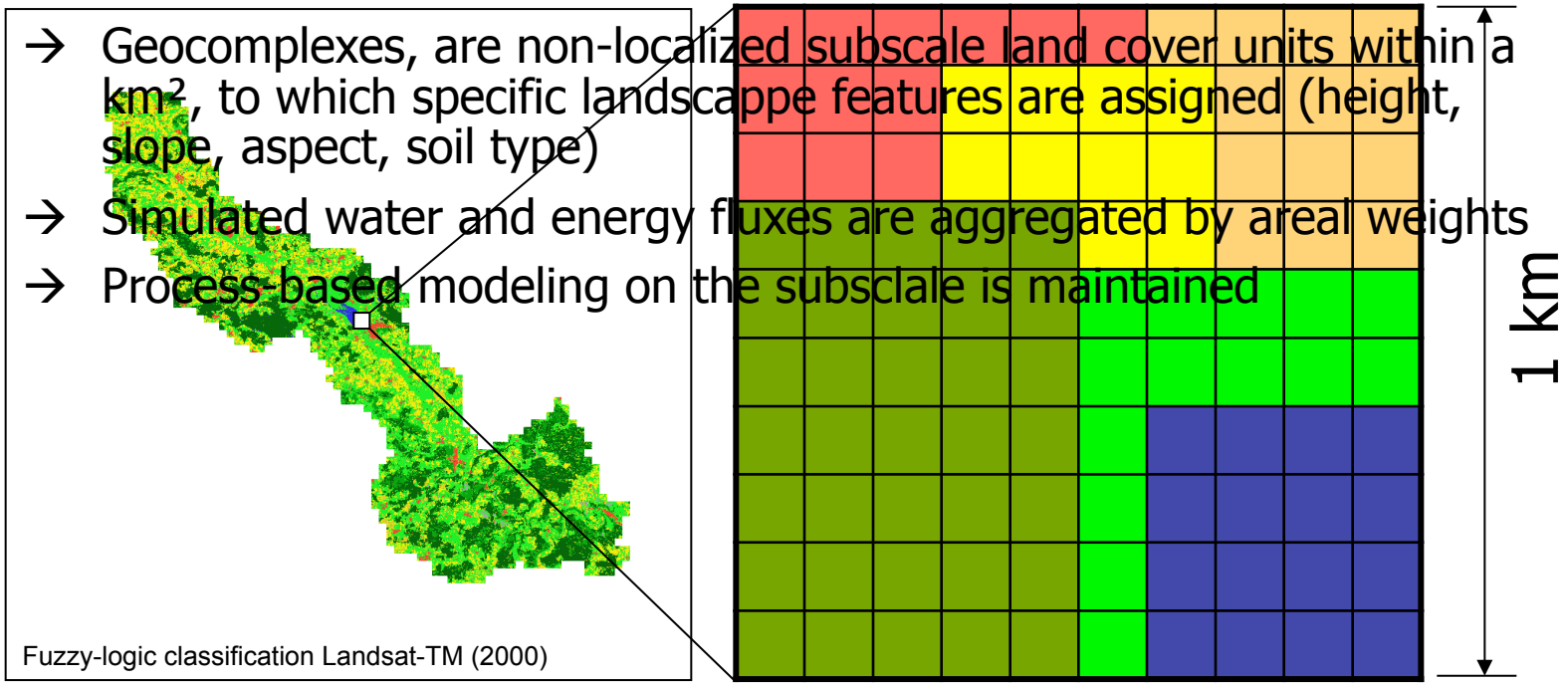
Hypotheses:

- Land cover is not arbitrarily distributed in a km^2, but organised according to topographic and pedologic/geologic boundary conditions
- Heterogeneity can be represented by means of aggregating microscale land surface features in hydrologically relevant parametersets

Scales in hydrology and hydrological modeling

Upscaling Example - Geocomplexes

- → Geocomplexes, are non-localized subscale land cover units within a km², to which specific landscappe features are assigned (height, slope, aspect, soil type)
- → Simulated water and energy fluxes are aggregated by areal weights
- → Process-based modeling on the subsclale is maintained



Fuzzy-logic classification Landsat-TM (2000)

Geocomplex	Land cover	Height	Slope	Aspect	Soil type	Area (%)
1	**Urban**	452	1.5	N	sL	12
2	**Maize**	450	1	NE	lU	10
3	**Cereal**	448	0.5	E	lU	13
4	**Pasture**	447	2	SE	SL	14
5	**Deciduous**	482	7	E	lS	35
6	**Water**	445	0	-	-	16

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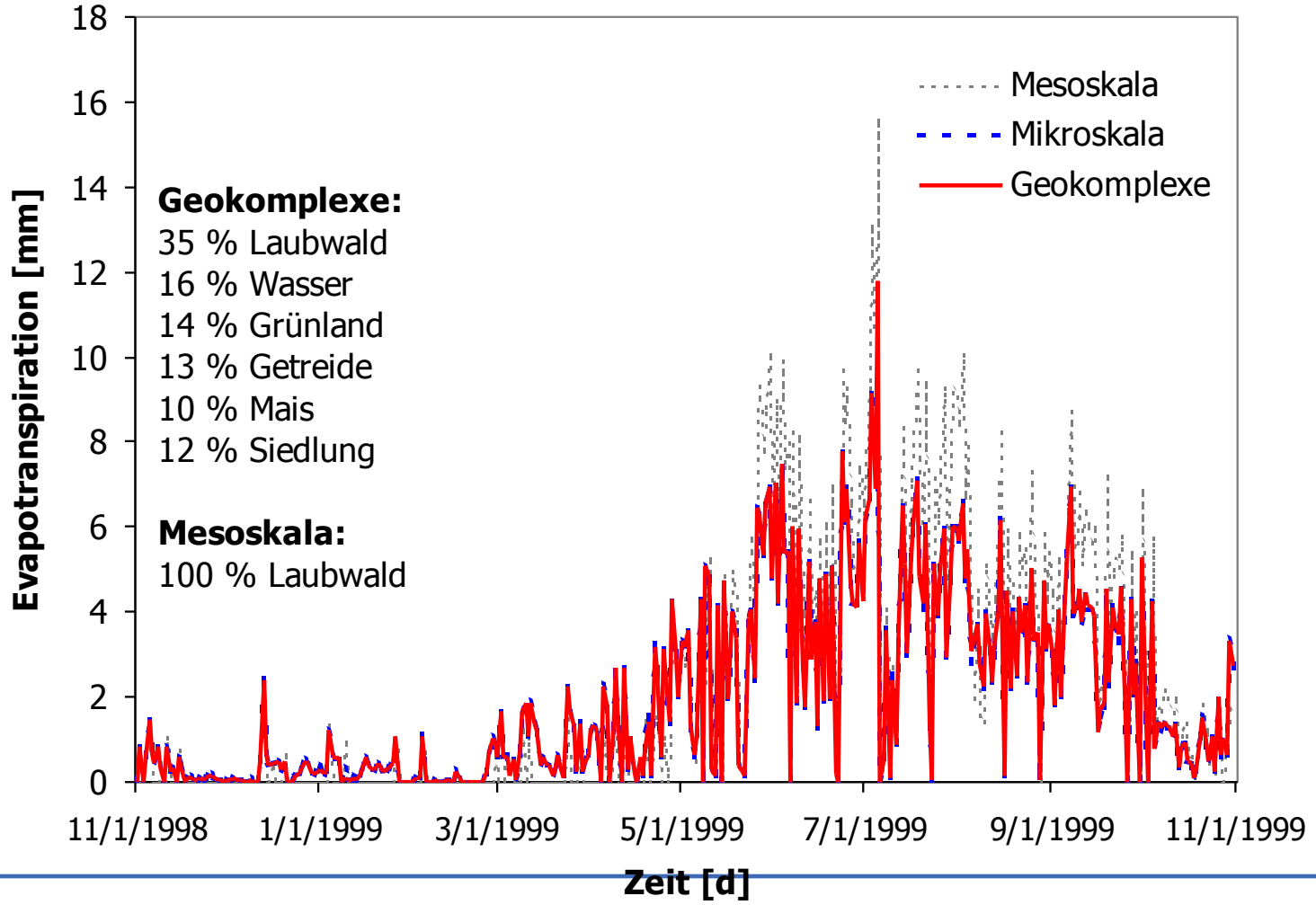
Upscaling Example - Geocomplexes

Annual course of evapotranspiration



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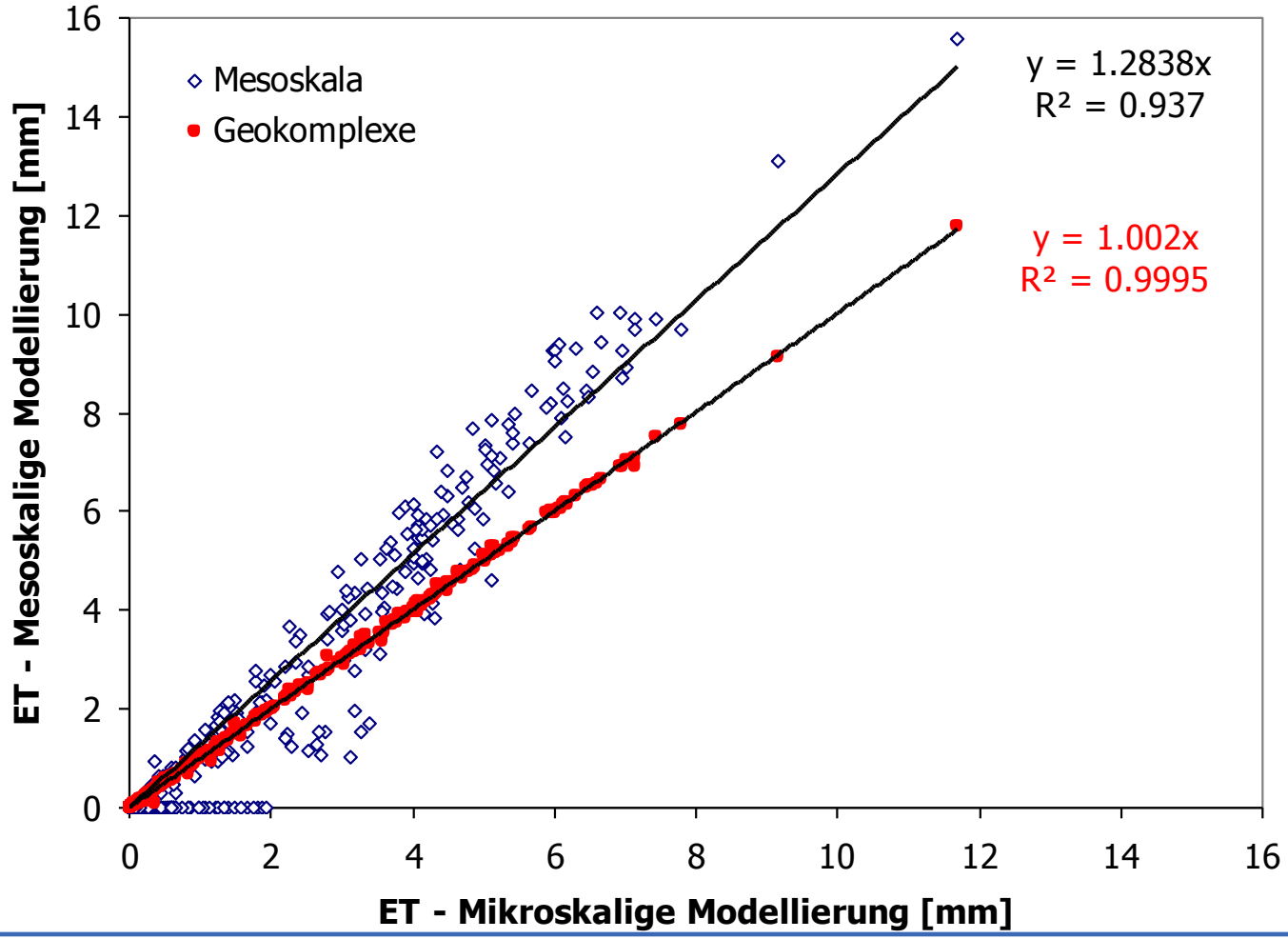
Upscaling Example - Geocomplexes

Annual course of evapotranspiration



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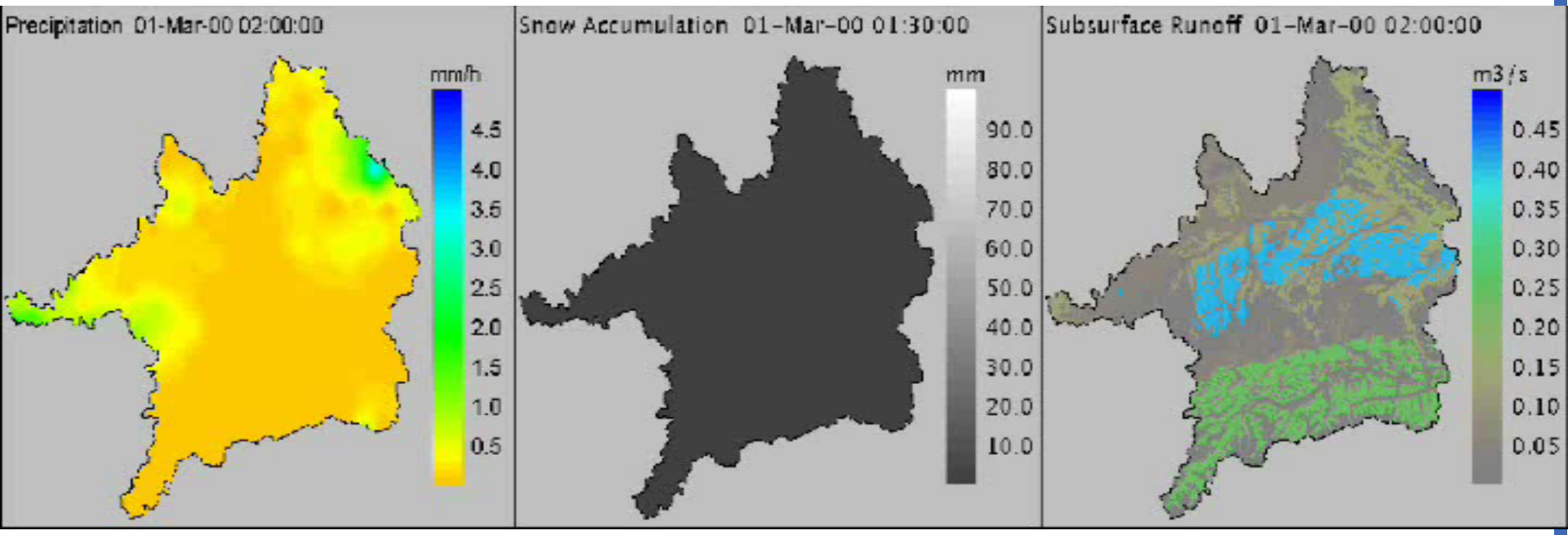
Application Examples

Upper Danube – 1 km resolution

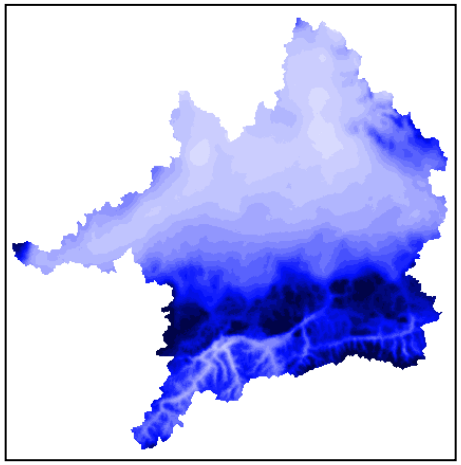


1. March 2000 to 15. May 2000
2. 5 months of coupled hourly modeling of:
   - Precipitation
   - Snow water equivalent
   - Subsurface runoff

Application Examples

Water balance of the Upper Danube, 1971-2000

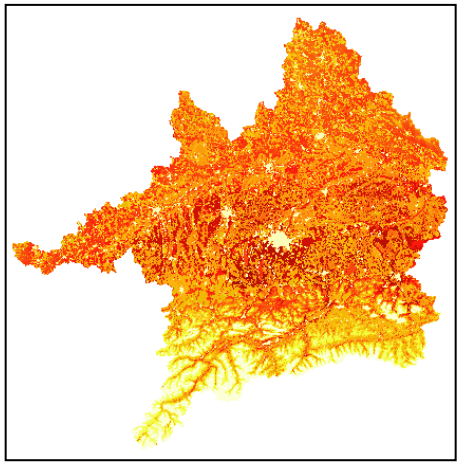
Precipitation



1078 mm/a

-

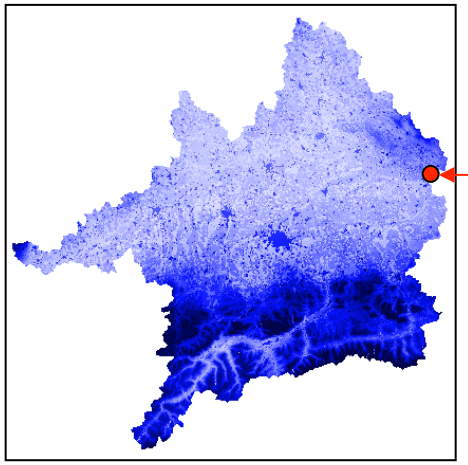
Evapotranspiration



481 mm/a

=

Runoff



597 mm/a

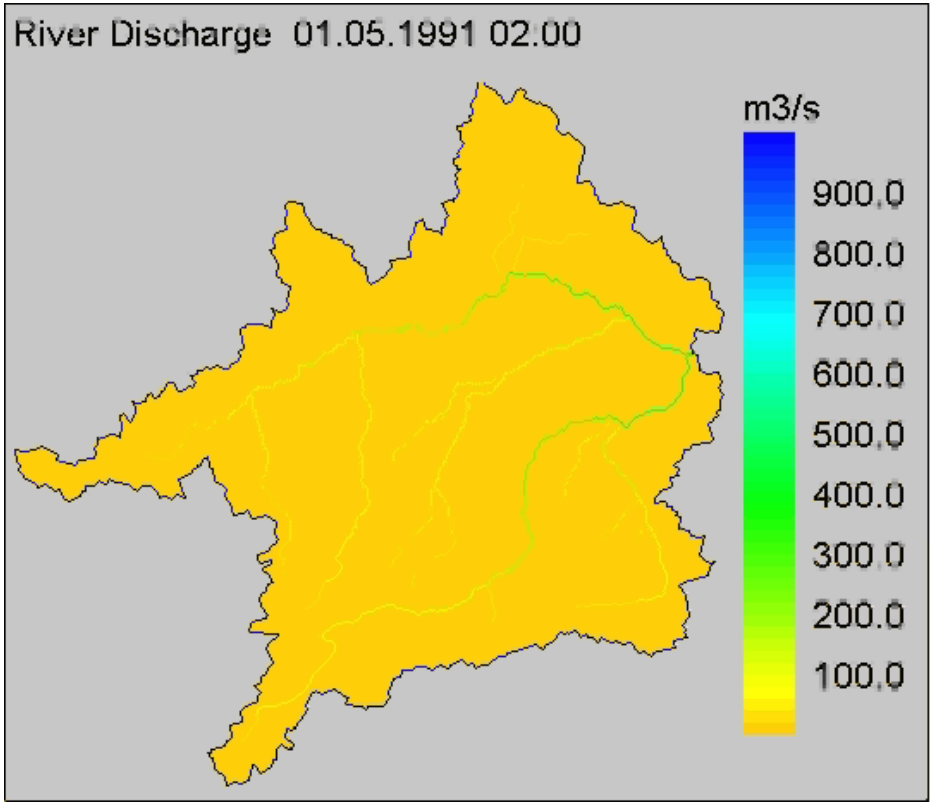
Mean runoff at gauge Achleiten (76653 km², 1971-2000):

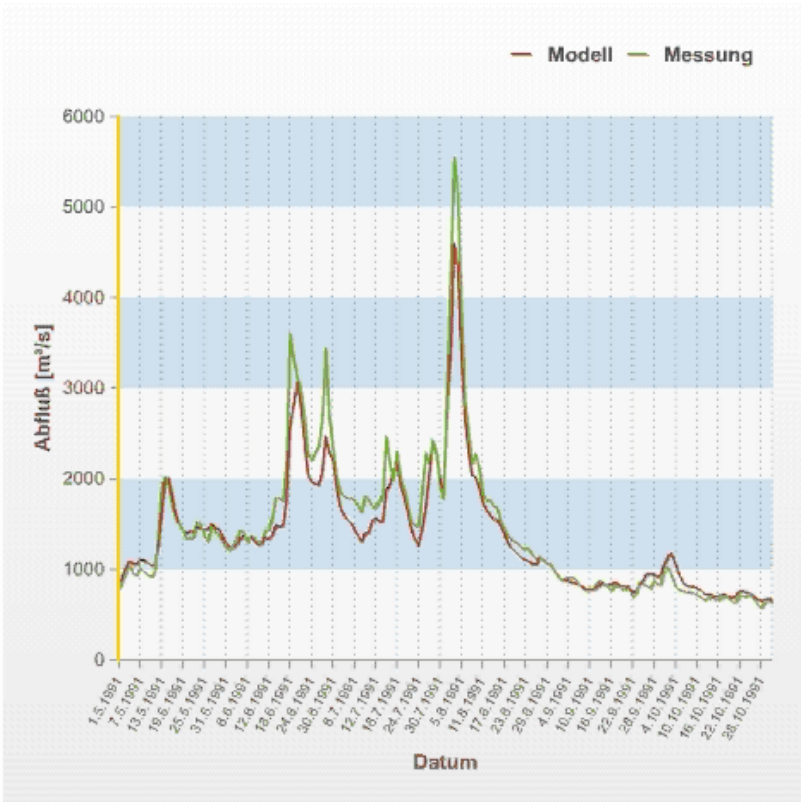
587 mm/a

+ 1.7 %

Application Examples

Stream discharge - total NSC = 0.68 at gauge Achleiten (uncalibrated)





Scales in hydrology and hydrological modeling

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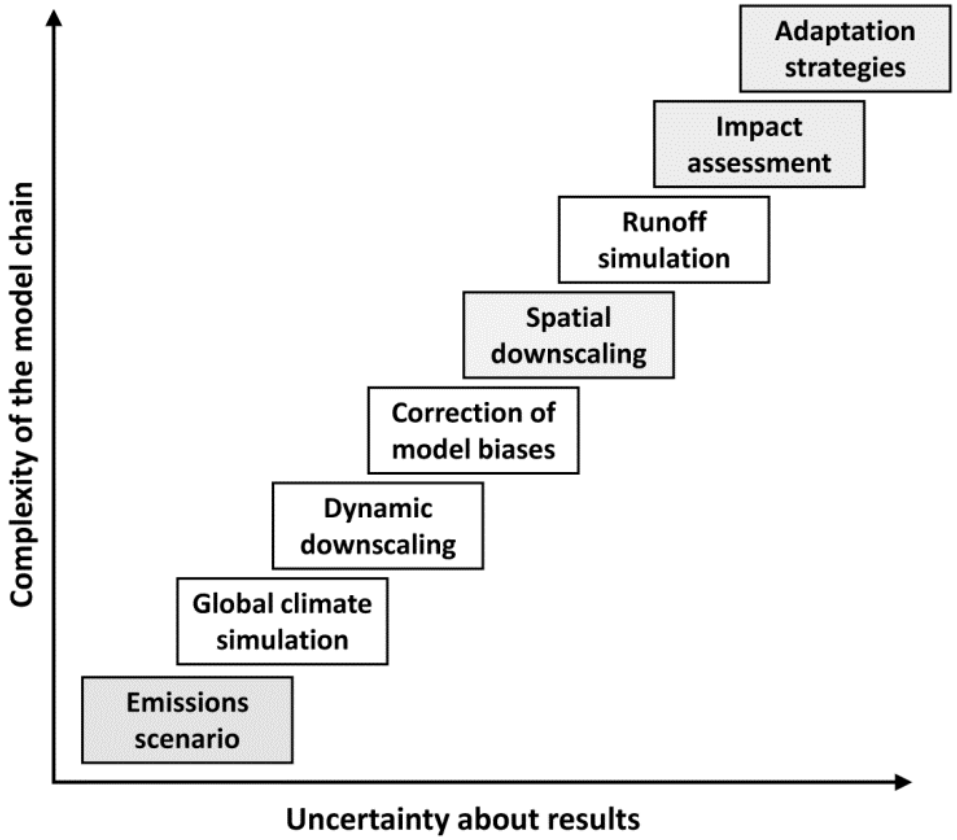
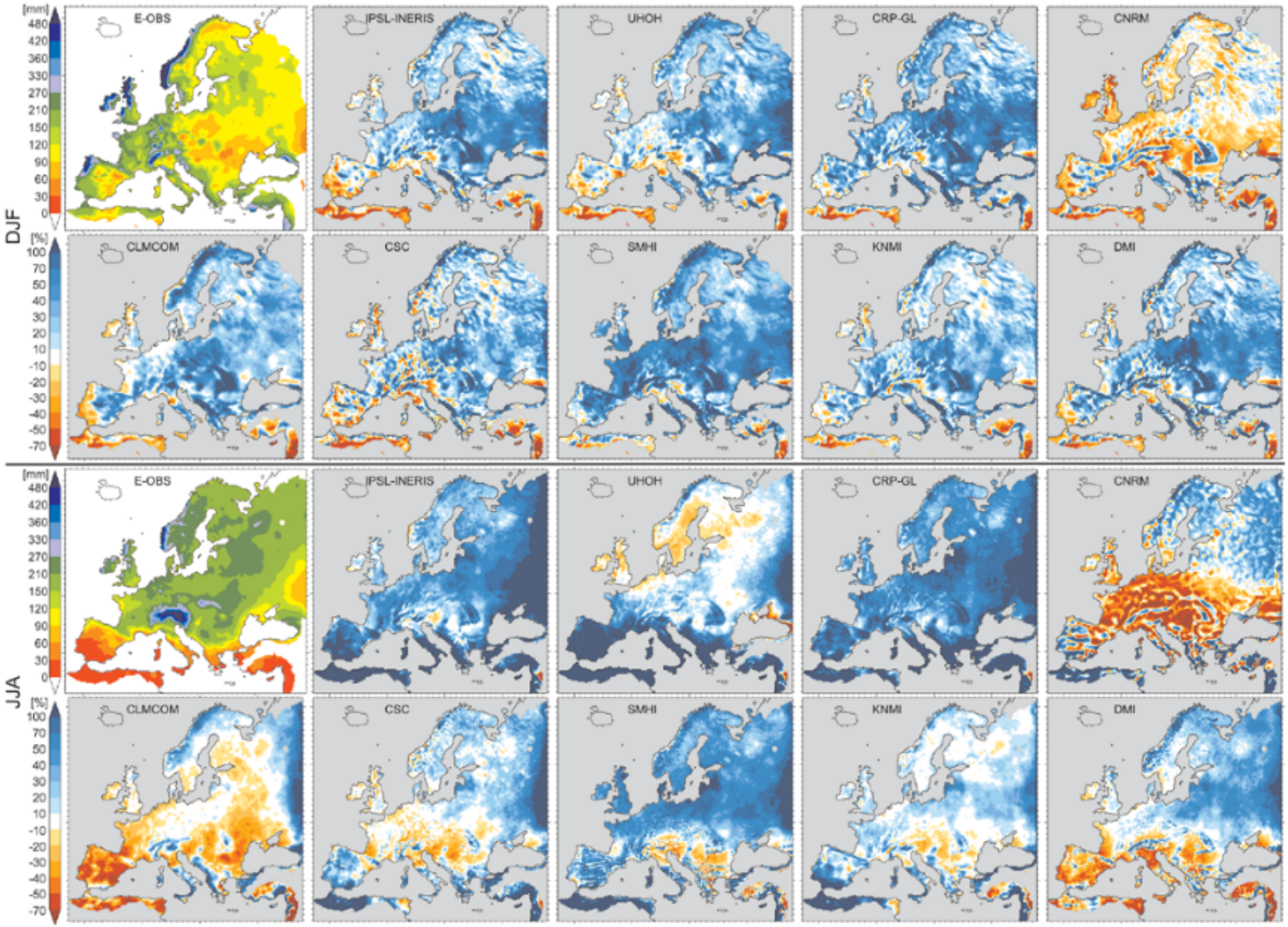
Now what if we look from the other direction) - Downscaling

From Climate Models to Hydrological Models…





from KOTLARSKI et al. 2013

Bias-correcting climate model data

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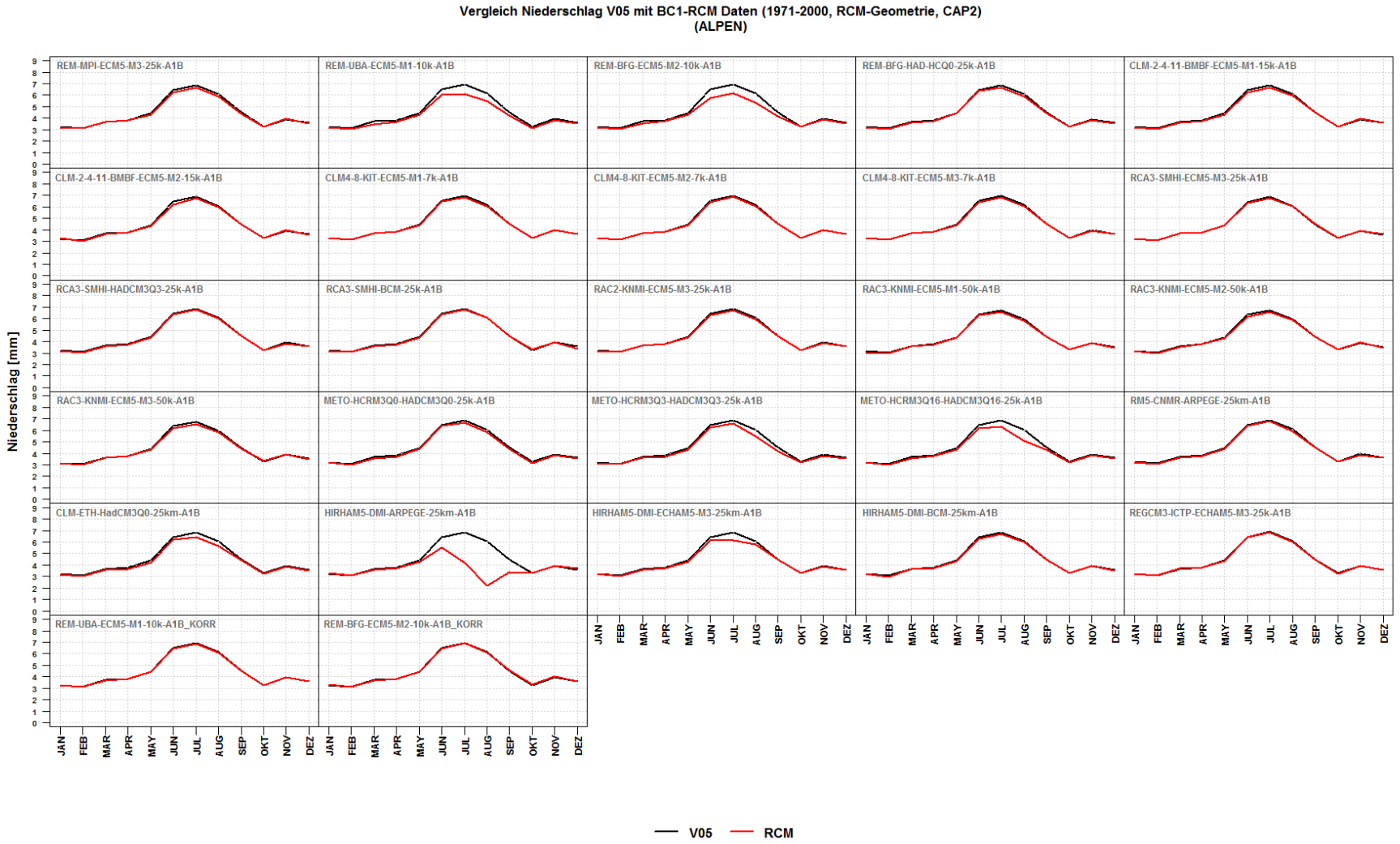
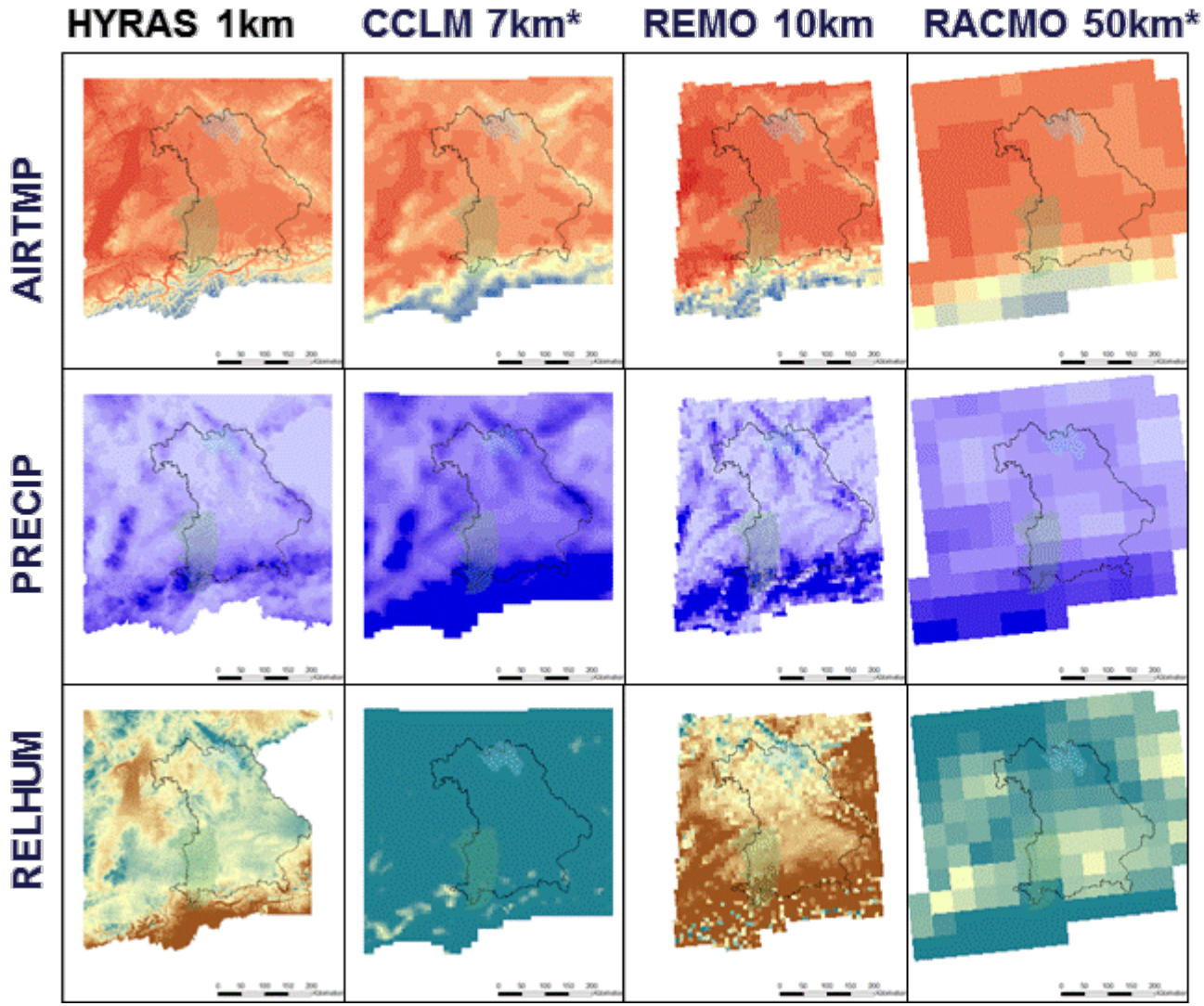
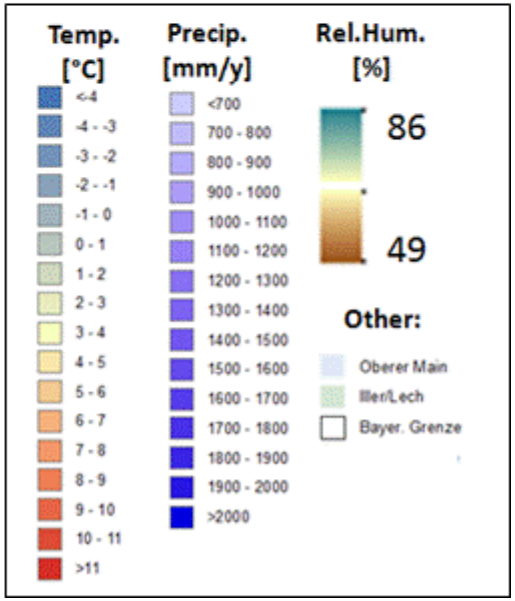
Quantile-mapping (monthly) …just an example…



Downscaling climate model data



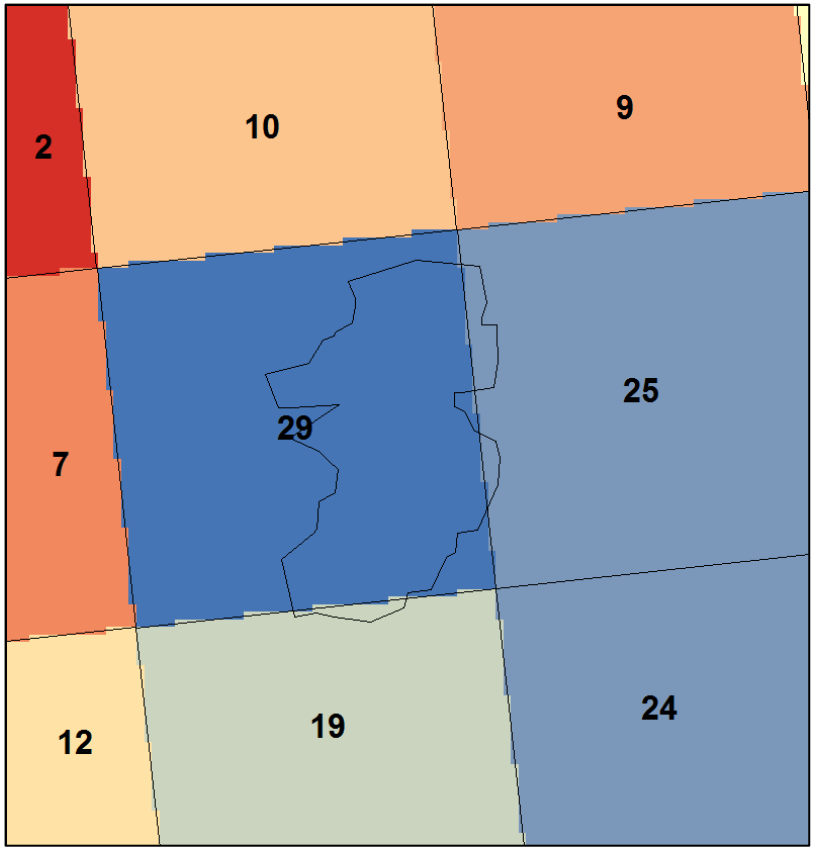
Why is Downscaling (to the hydrological model scale) necessary?



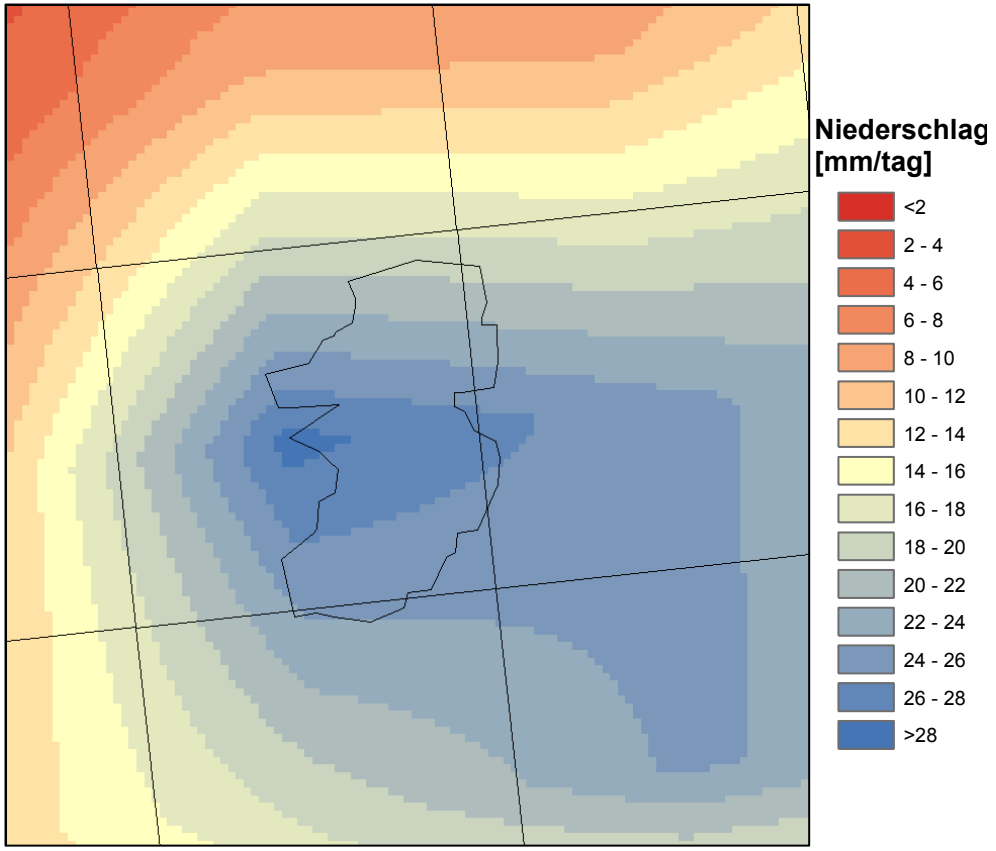
Downscaling climate model data

Why is Downscaling (to the hydrological model scale) necessary?

Regional Climate Model Scale …



Hydrological Model Scale…



Downscaling climate model data

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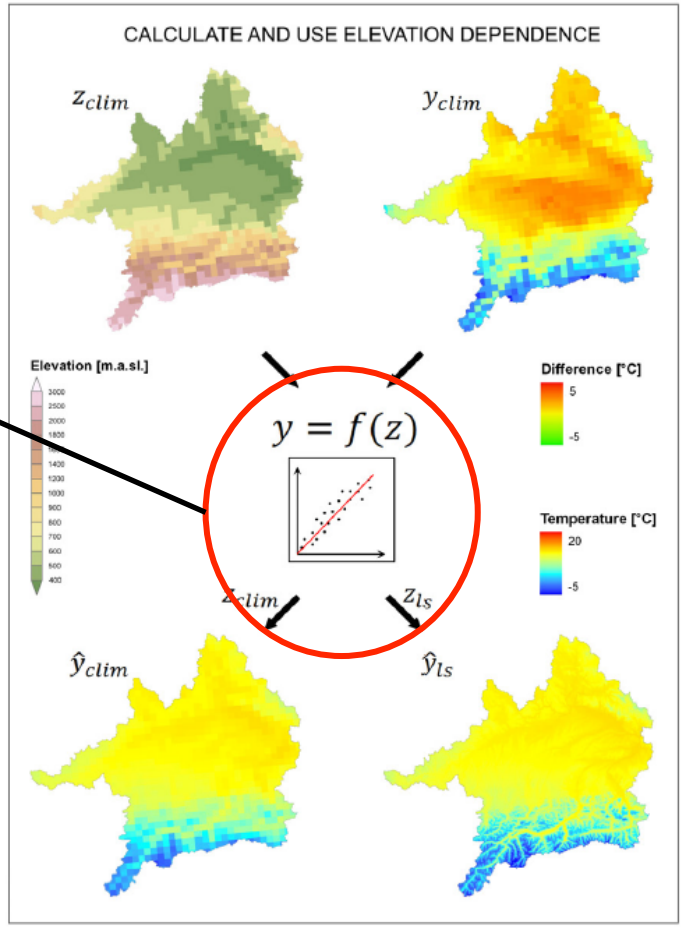
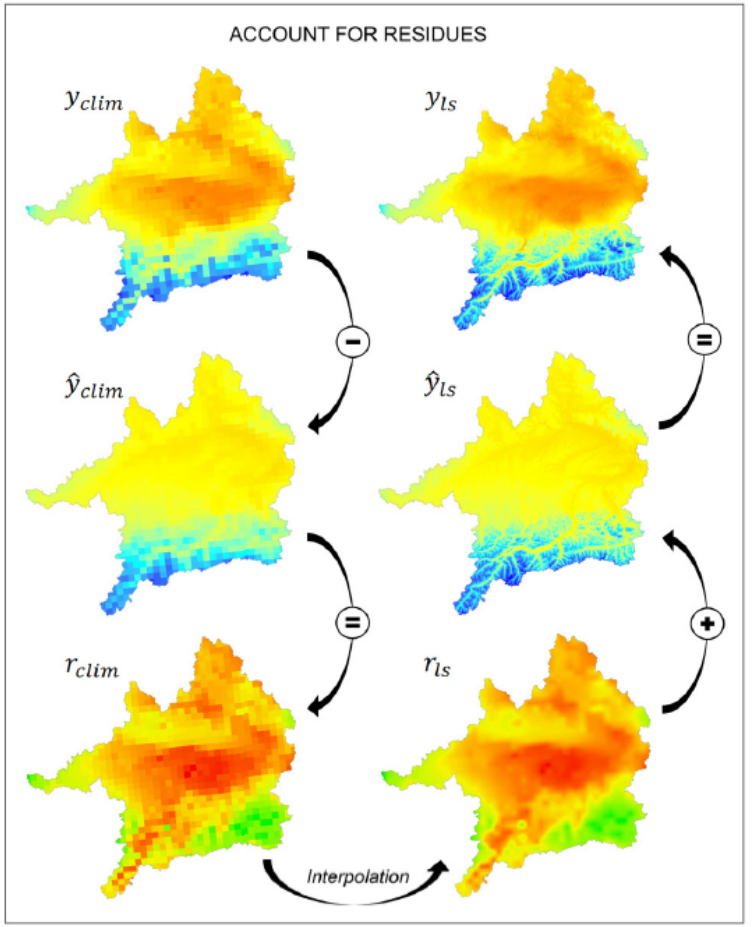
SCALMET (Marke et al. 2008)

Regression of RCM parameter value and elevation:



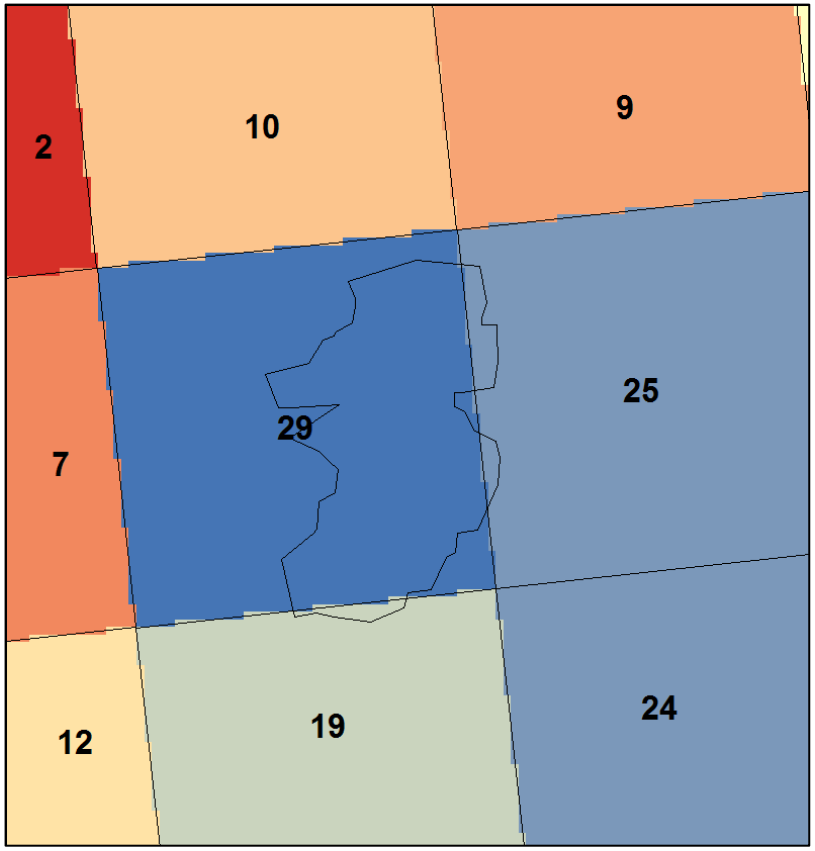


→ **Elevation dependence of parameters (z: elevation, y: value, clim: RCM, ls: destination elevation)**

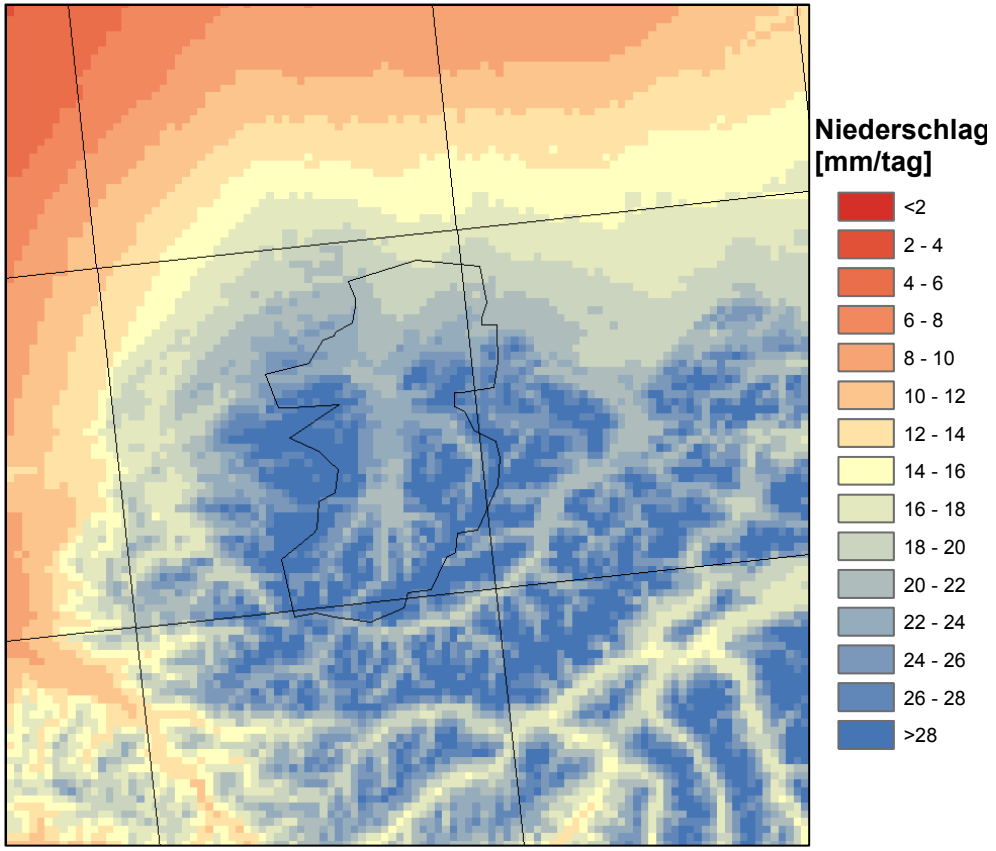
Downscaling climate model data

Why is Downscaling (to the hydrological model scale) necessary?

Regional Climate Model Scale …

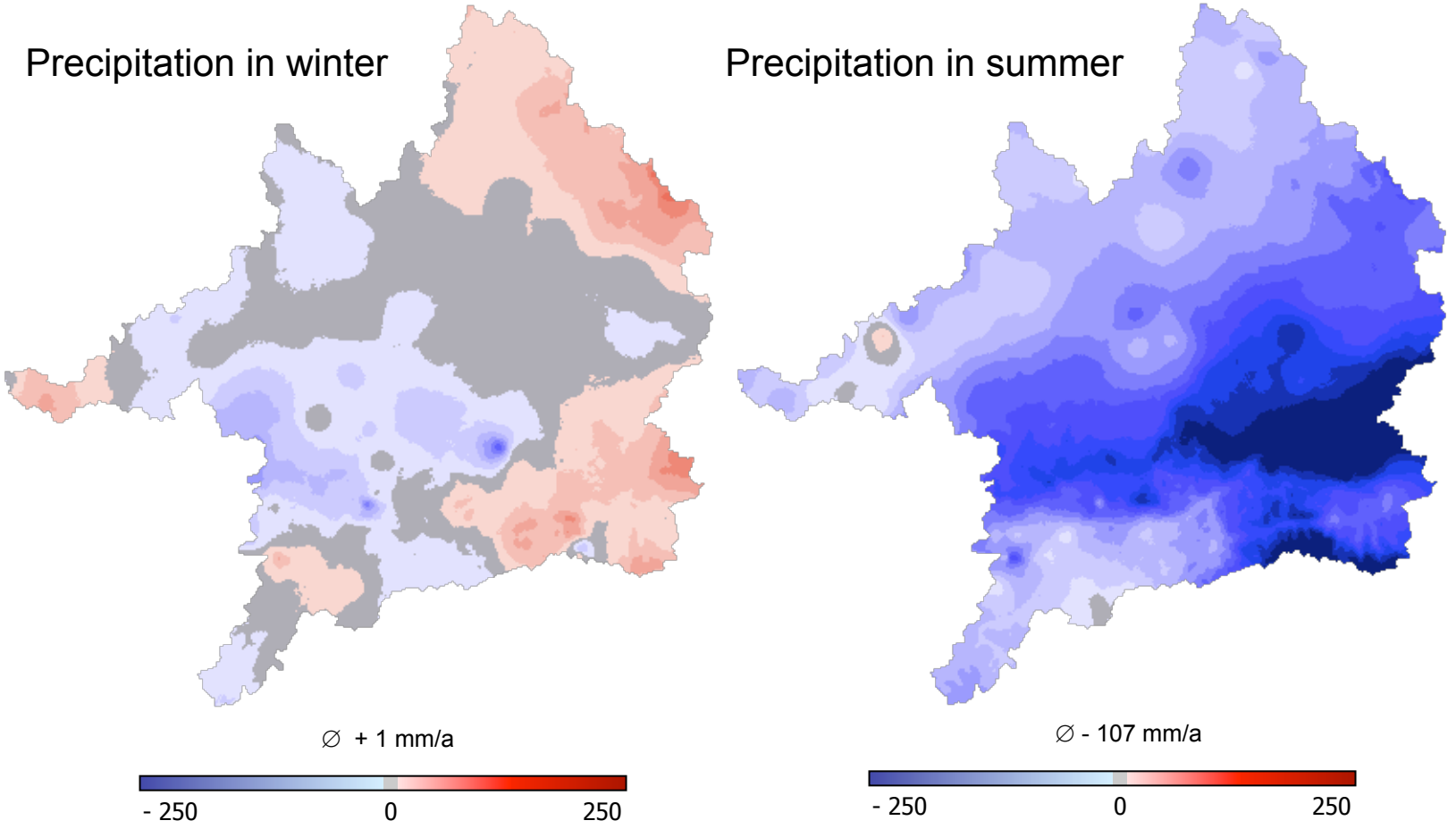


Hydrological Model Scale…



Examples – applications in climate change impact studies

Trend of seasonal precipitation patterns 2010 -> 2100



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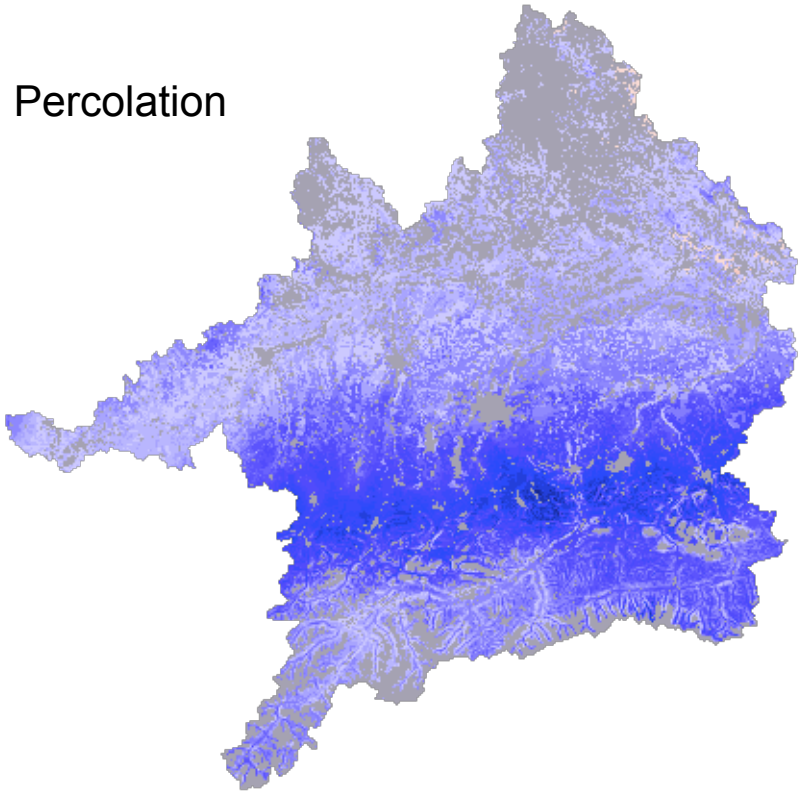
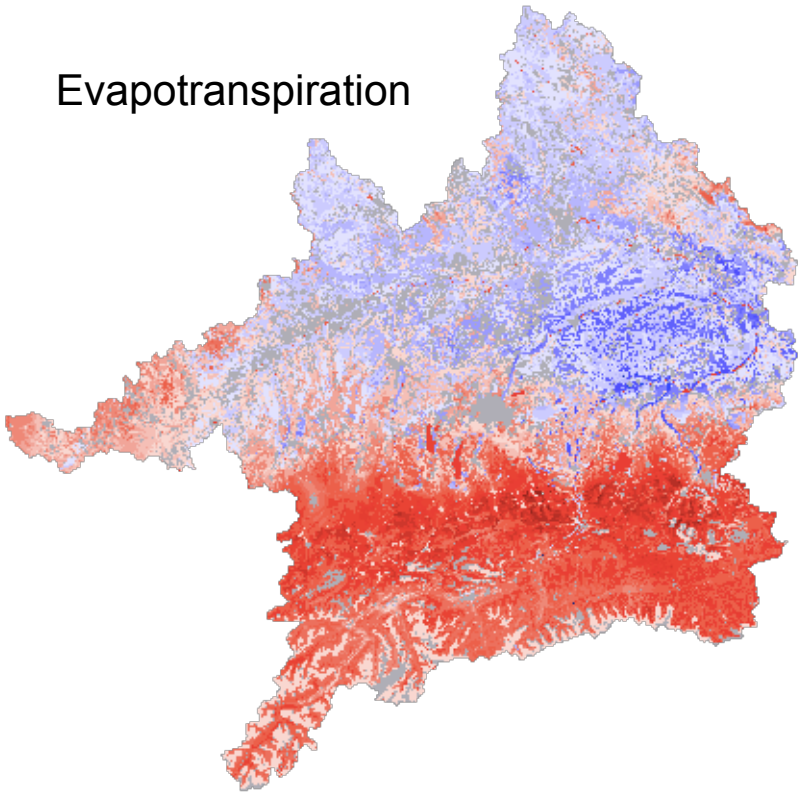
Examples

Trend of annual water balance terms 2010 -> 2100





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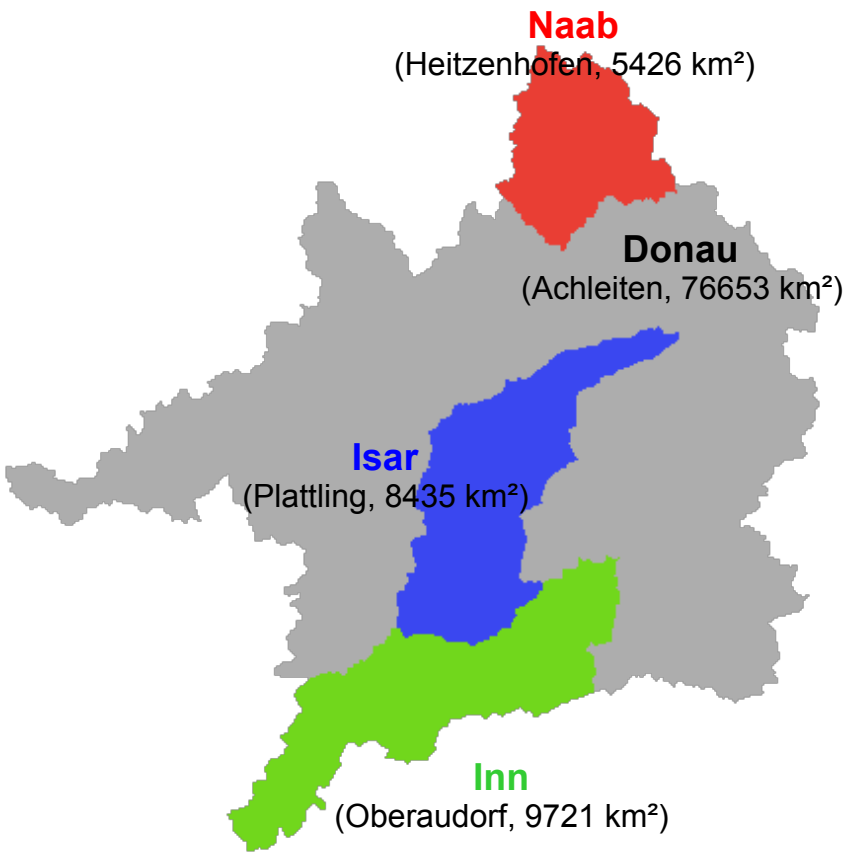
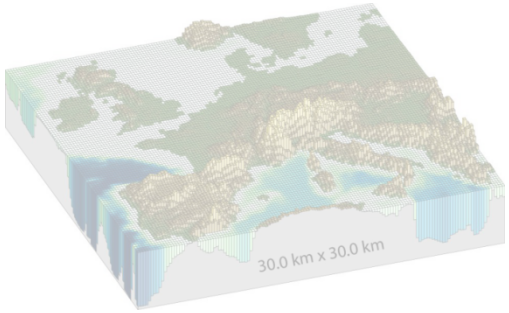
Examples
Climate Change (Impact)



SUBC	Periode	N	ET	A
Donau Zahlen in % der Validierung periode	1971-2000	100	100	100
	2011-2040	95	103	89
	2041-2070	93	106	83
	2071-2100	86	107	70
Naab	1971-2000	100	100	100
	2011-2040	99	112	80
	2041-2070	99	109	84
	2071-2100	95	107	77
Isar	1971-2000	100	100	100
	2011-2040	101	122	88
	2041-2070	98	127	79
	2071-2100	89	130	63
Inn	1971-2000	100	100	100
	2011-2040	107	125	102
	2041-2070	107	137	98
	2071-2100	99	147	86



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