Hydrological modeling in alpine catchments – sensing the critical parameters towards an efficient model calibration

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4th International Symposium on Flood Defence:
Managing Flood Risk, Reliability and Vulnerability
Toronto, Ontario, Canada, May 6-8, 2008

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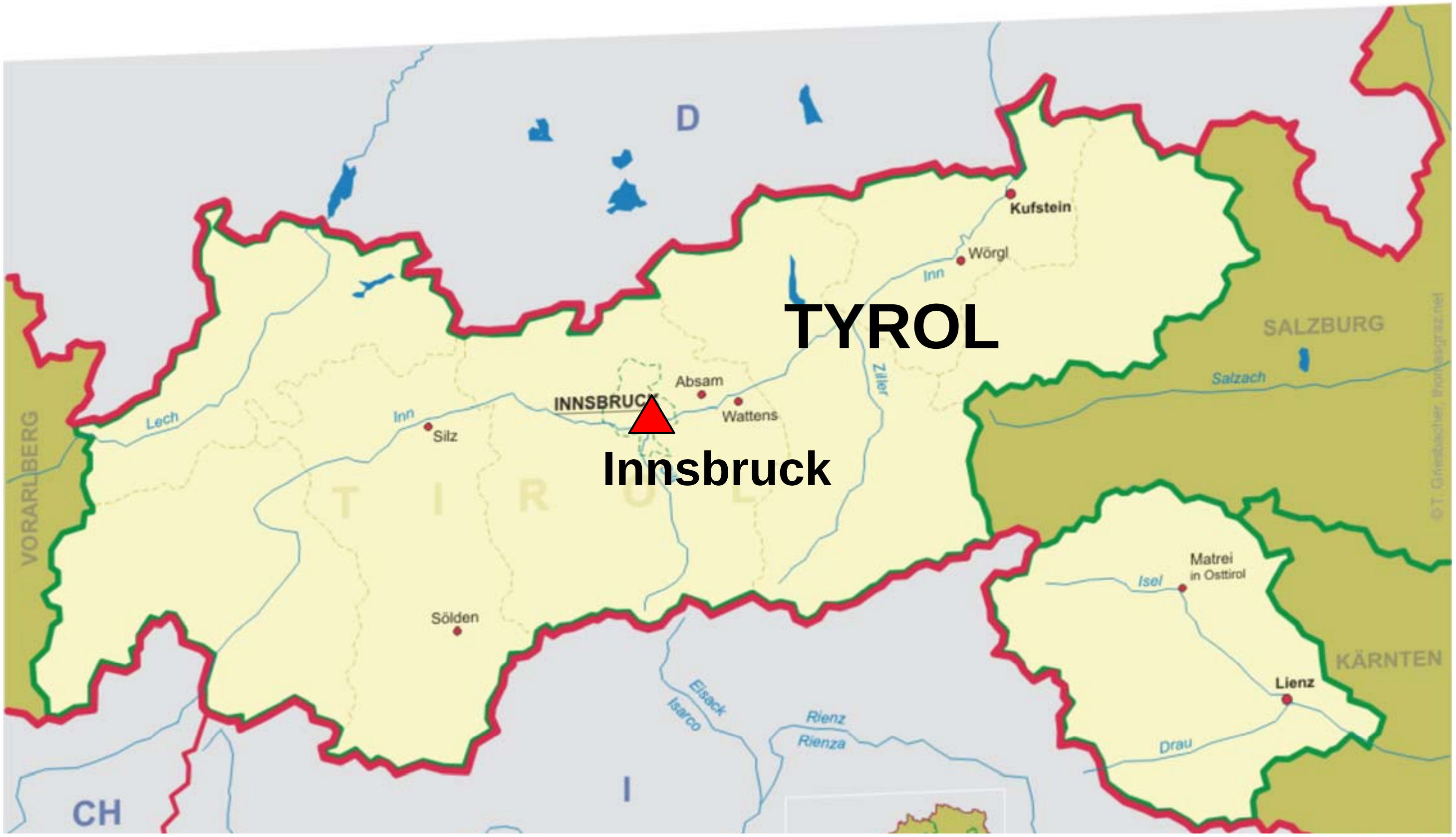
Overview - components of prognosis model

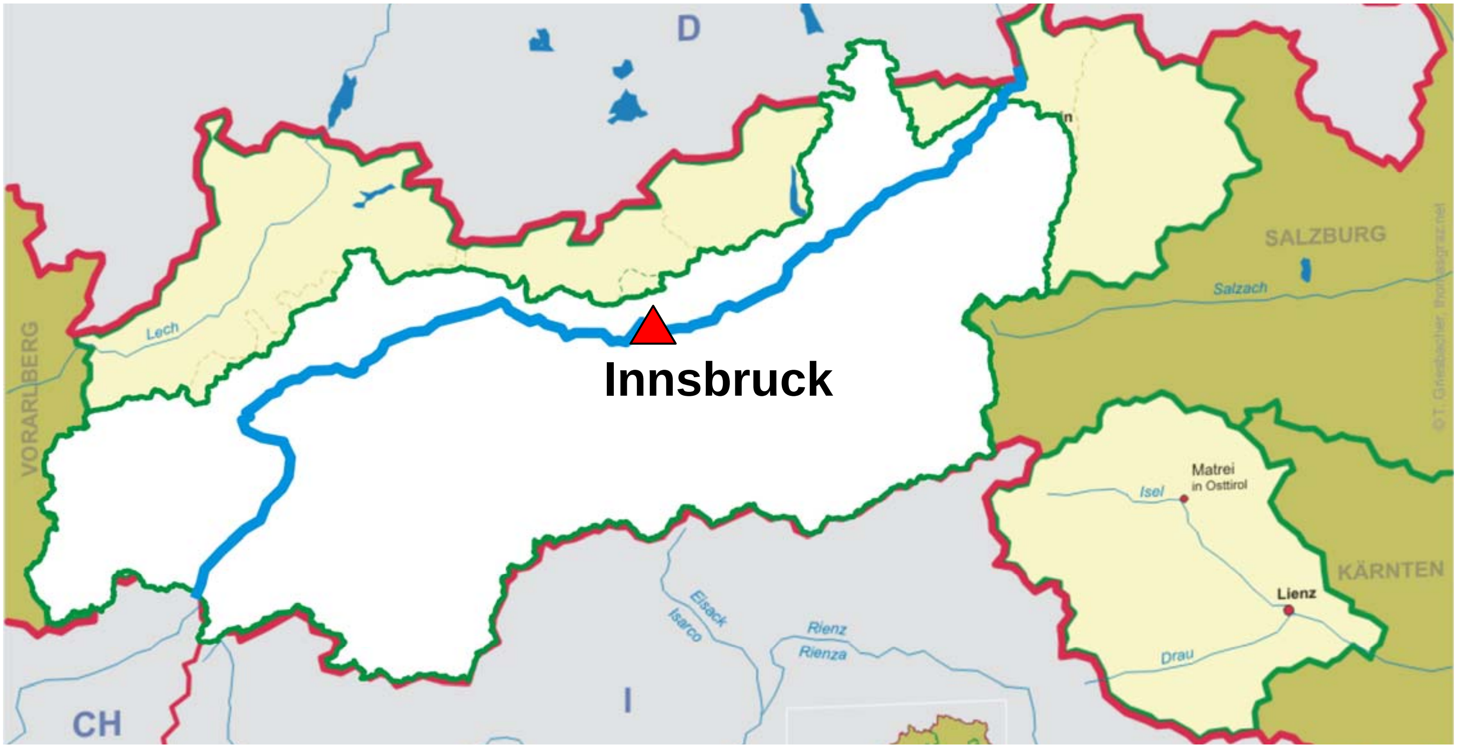


Prognosis model – HoPI

→ “**Ho**chwasser**p**rognose für den Tiroler **I**nn

Overview - components of prognosis model

- River Inn : 200km from Switzerland to Germany/Bavaria
- ~ 60 % of the state area (6700 km2) drain into the River Inn



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Overview - components of prognosis model

- River Inn : 200km from Switzerland to Germany/Bavaria
- ~ 60 % of the state area (6700 km2) drain into the River Inn

- Largest flood event August 2005
- Innsbruck: 1510 m3/s (HQ_{100}= 1370 m3/s)

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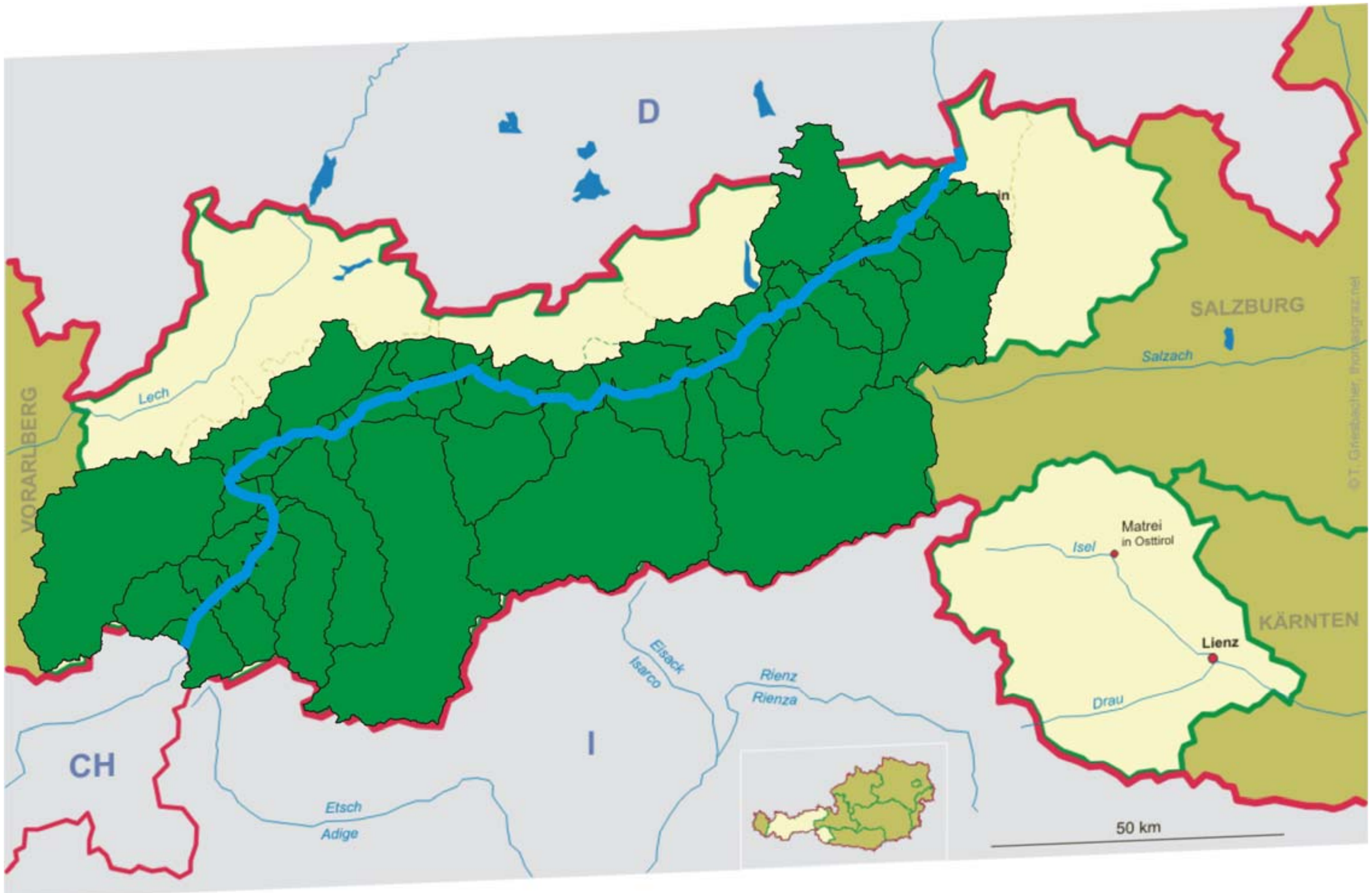

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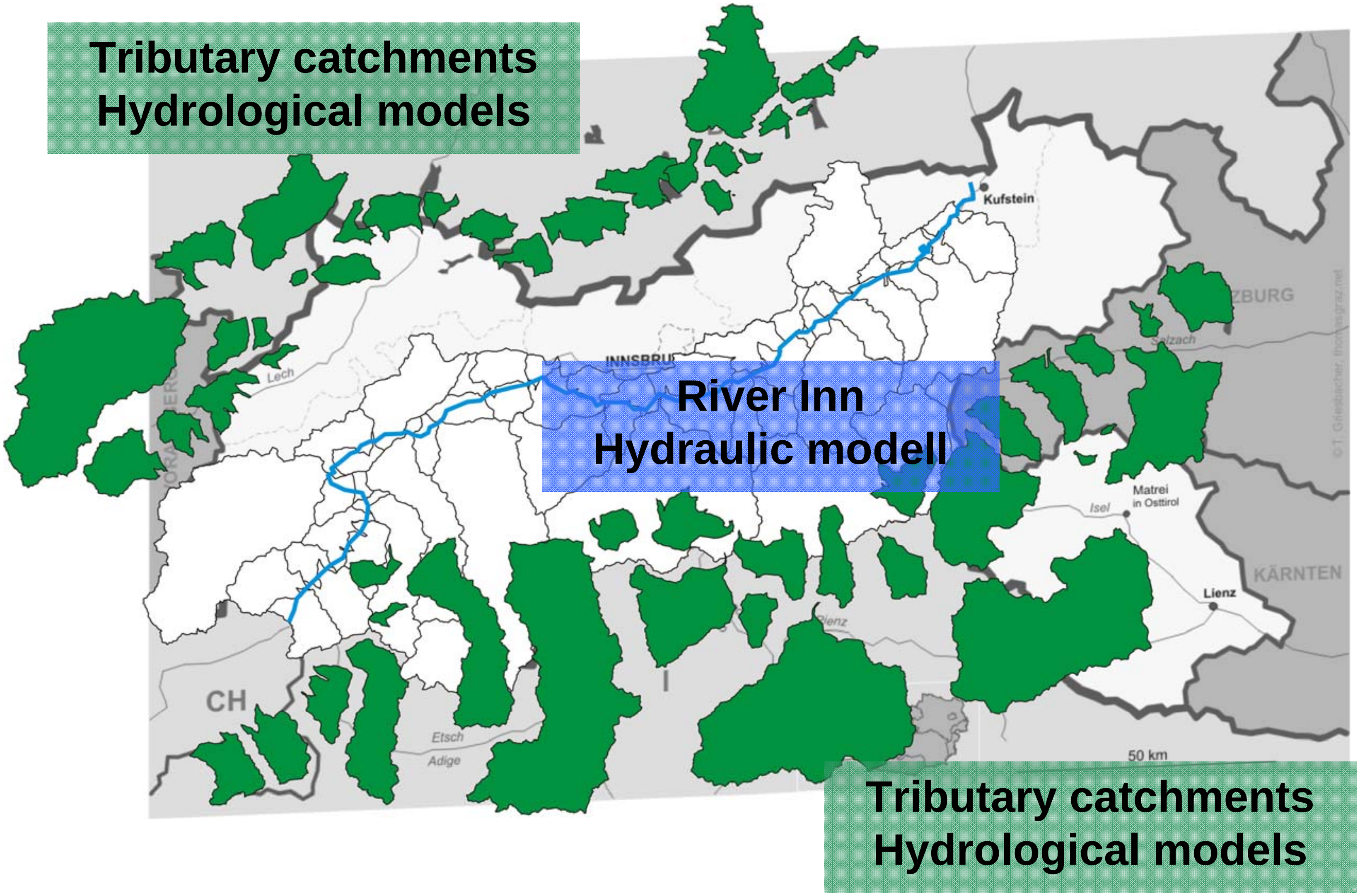
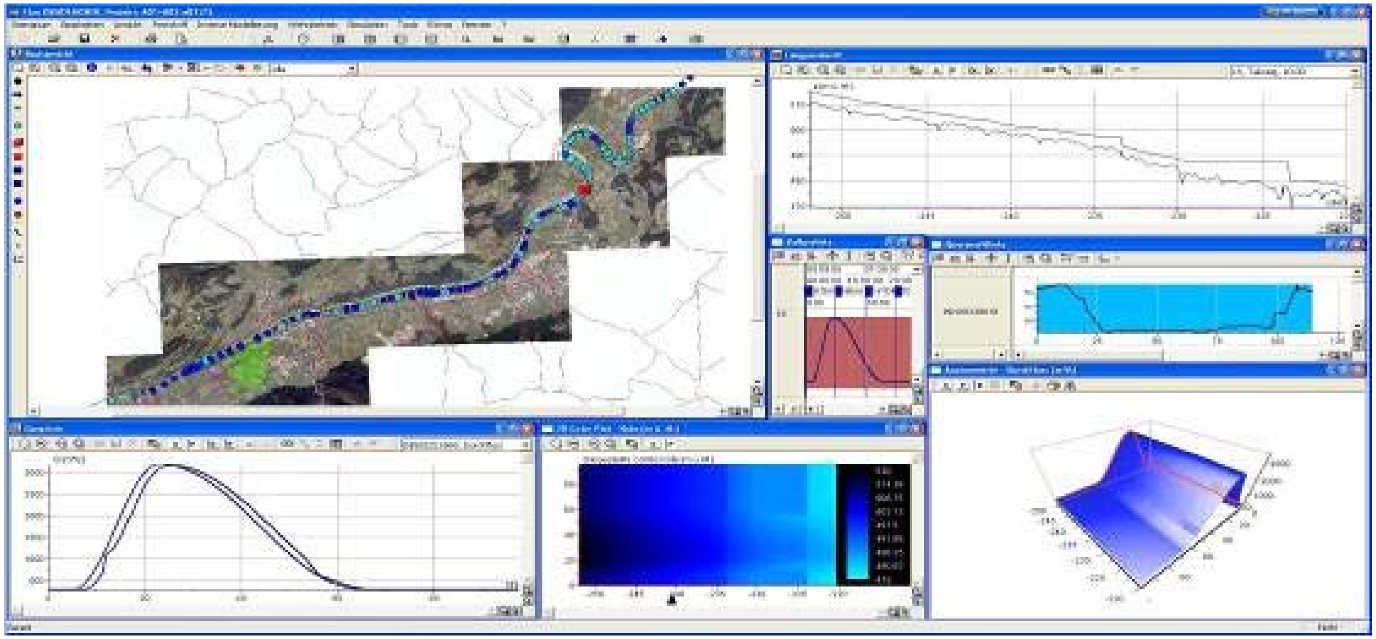


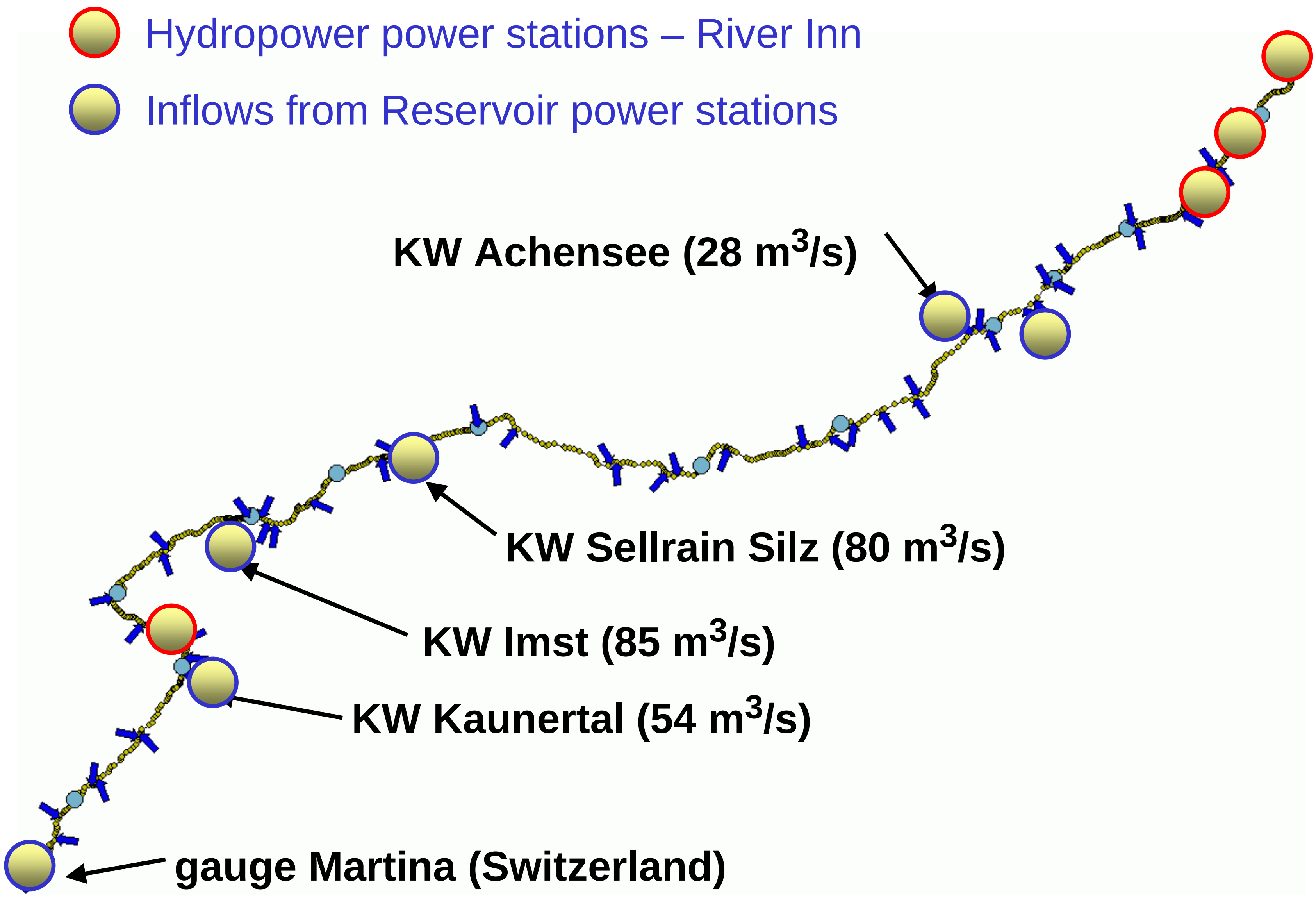
Overview - components of prognosis model

River INN - Flux/Floris Designer

- Hydraulic 1D Model for the River INN
- Optimized features for usage in a prognosis system
- Implementation of rule based hydropower operation
- Driven by external flows → from tributary catchments



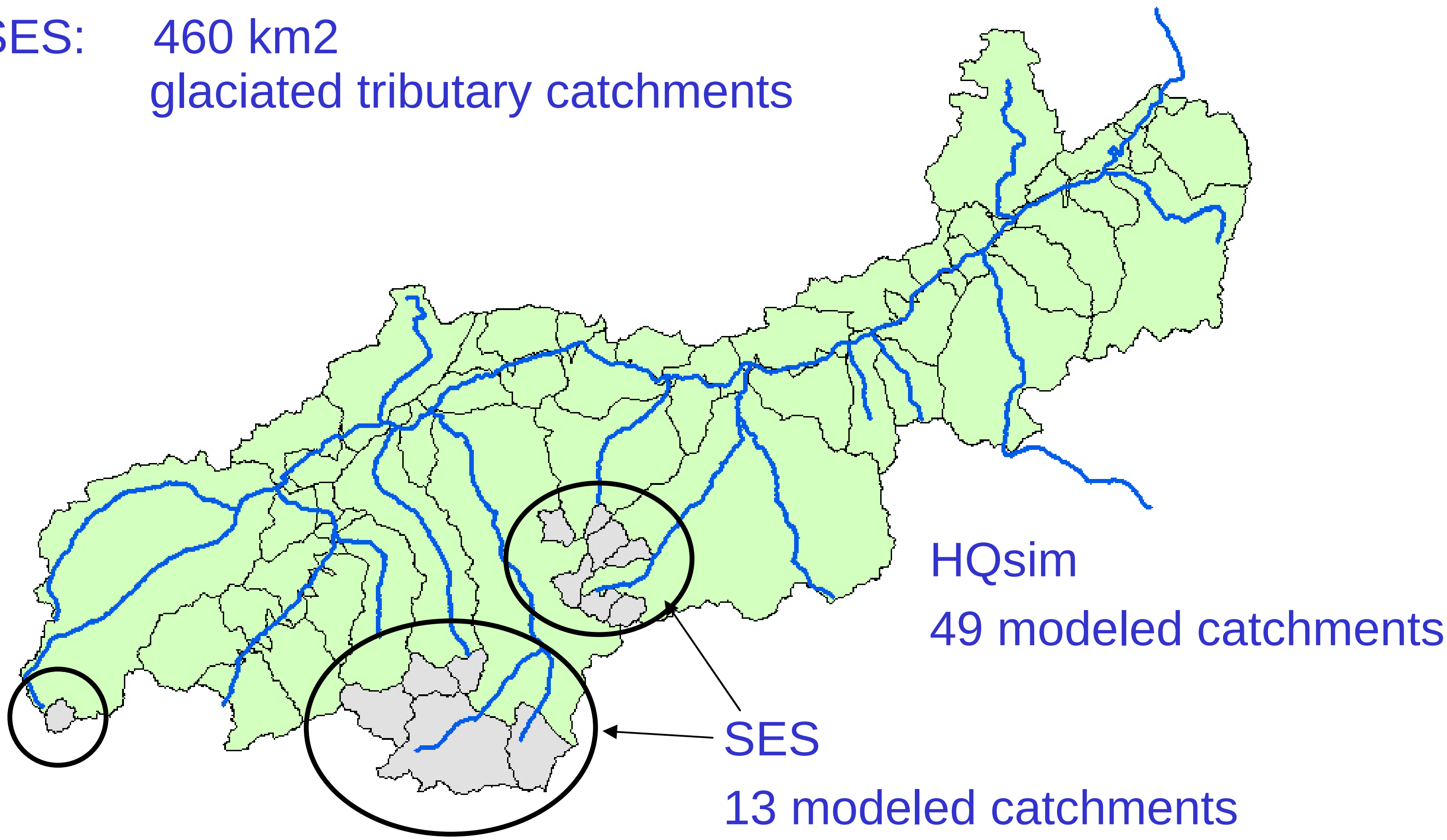
HoPI



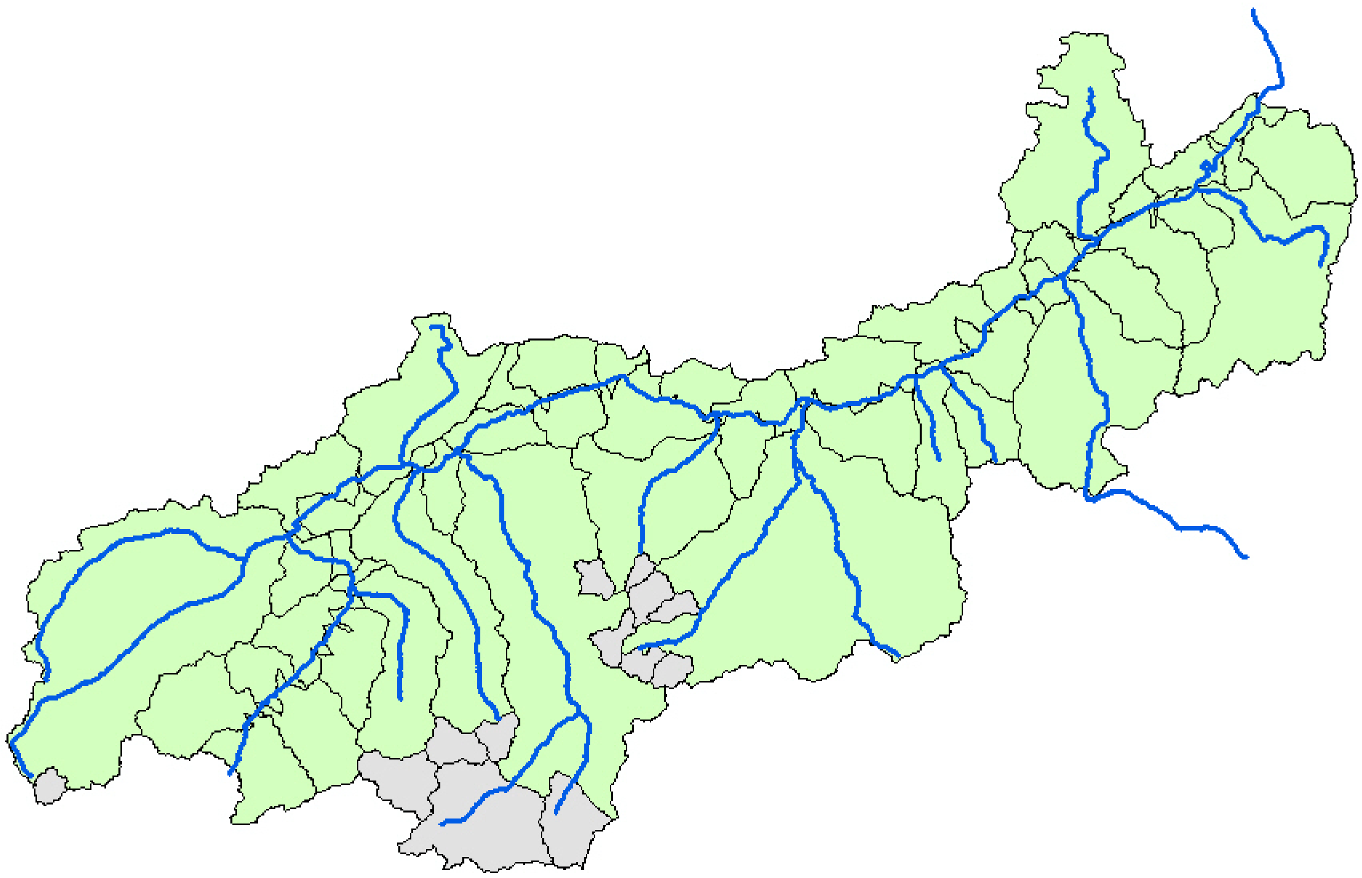
Hydropower power stations – River Inn
Inflows from Reservoir power stations
KW Achensee (28 m³/s)
KW Sellrain Silz (80 m³/s)
KW Imst (85 m³/s)
KW Kaunertal (54 m³/s)
gauge Martina (Switzerland)

Overview – hydrological models

- HQsim: 6290 km2
  non-glaciated tributary catchments
- SES: 460 km2
  glaciated tributary catchments



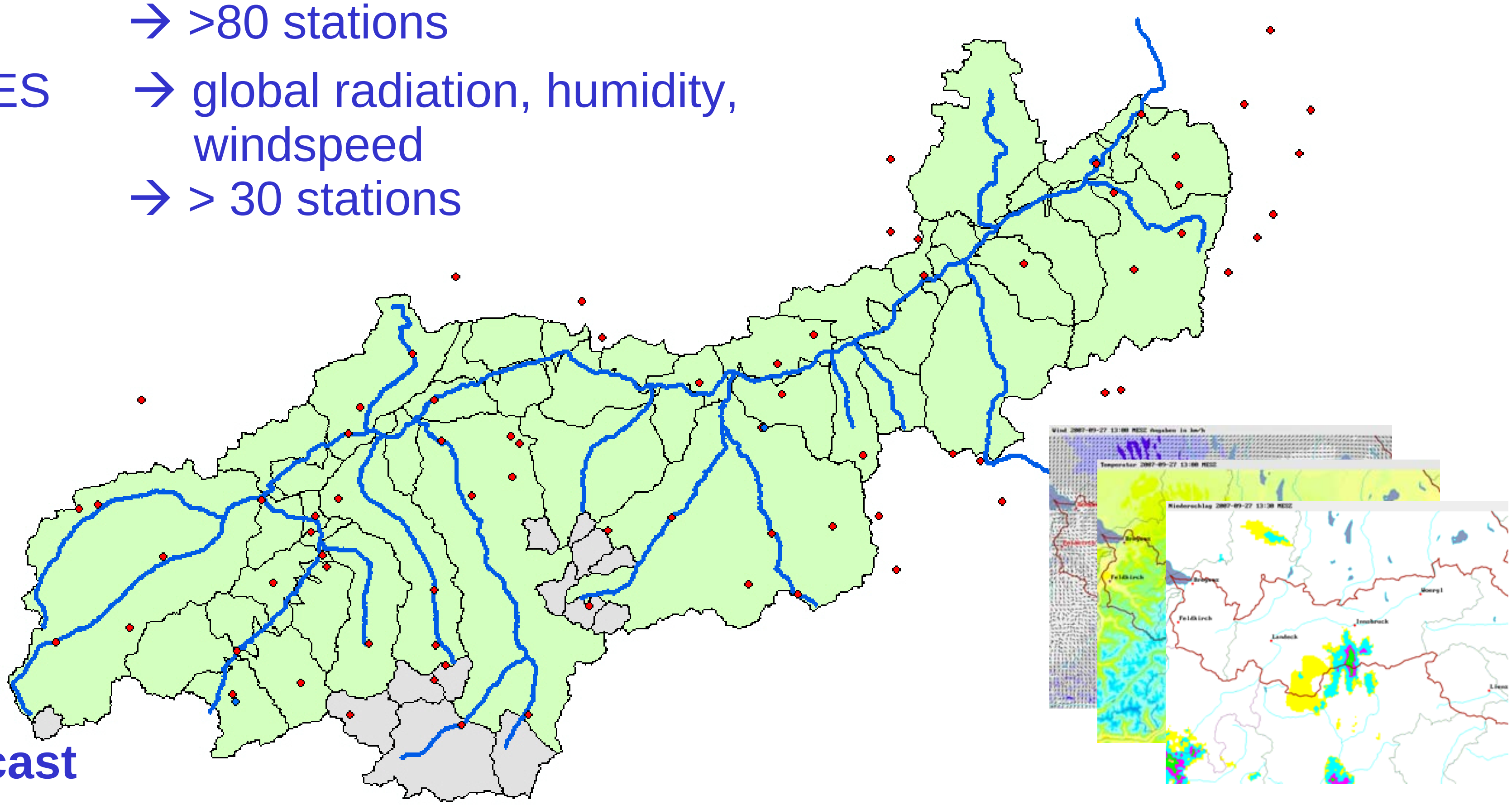
Overview – Meteorological input to the models



Overview – Meteorological input to the models

Measurements (online)

- HQsim → precipitation, temperature
  → >80 stations
- SES → global radiation, humidity, windspeed
  → > 30 stations



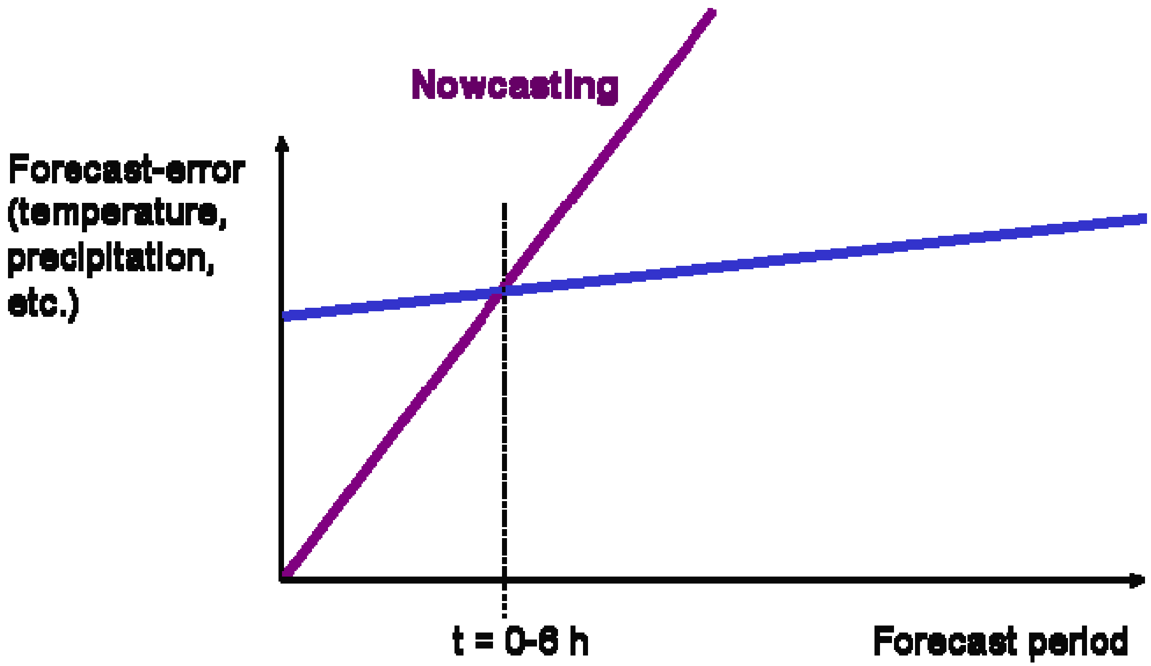
Forecast

- INCA - Integrated nowcasting by comprehensive analysis by ZAMG - Central Institute for Meteorology and Geodynamics

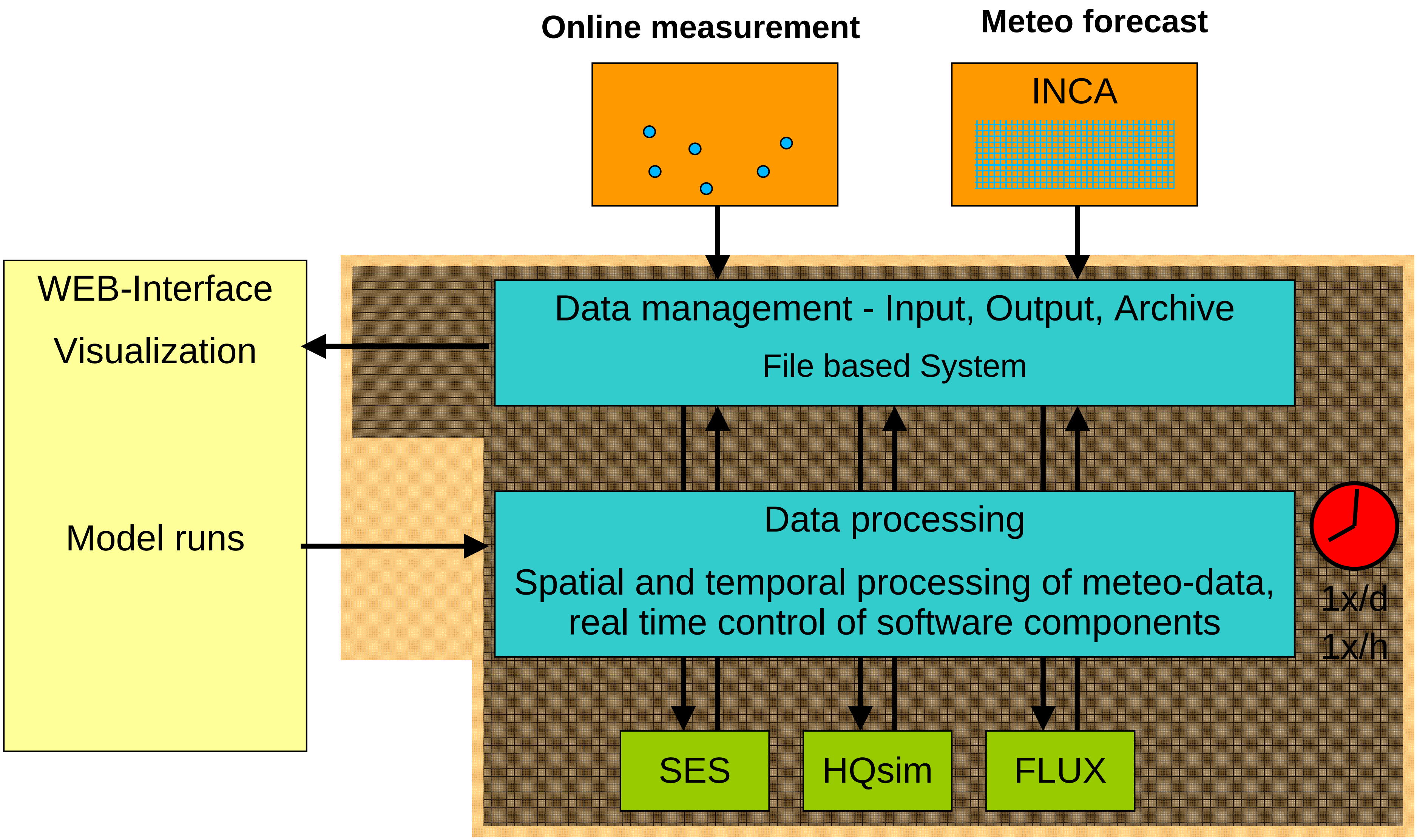
Meteoprozessierung

Meteo Forecast: INCA

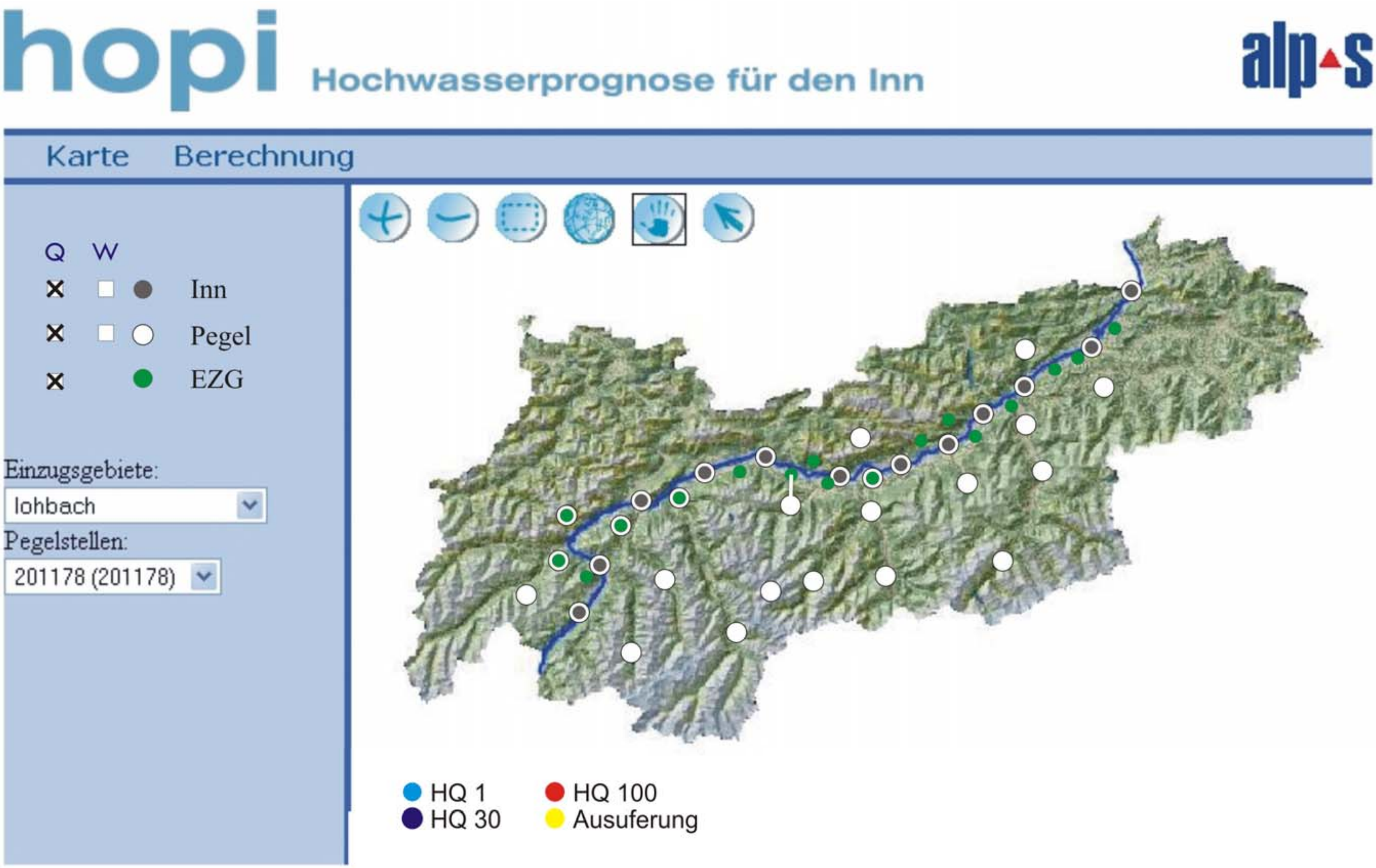
- Mix of numerical weather model (ALADIN) and Nowcasting approach
- Spatial resolution (1x1km), Temporal resolution 15min/1h
- Nowcasting based on online data in the first 4-6 Stunden
- New forecast every hour (Nowcast 1h, Aladin every 6 hours)



HoPI - Data and Information flow



Weboberfläche



HoPI

- System currently in test phase
- Implemented at the Hydrographical Service Tyrol

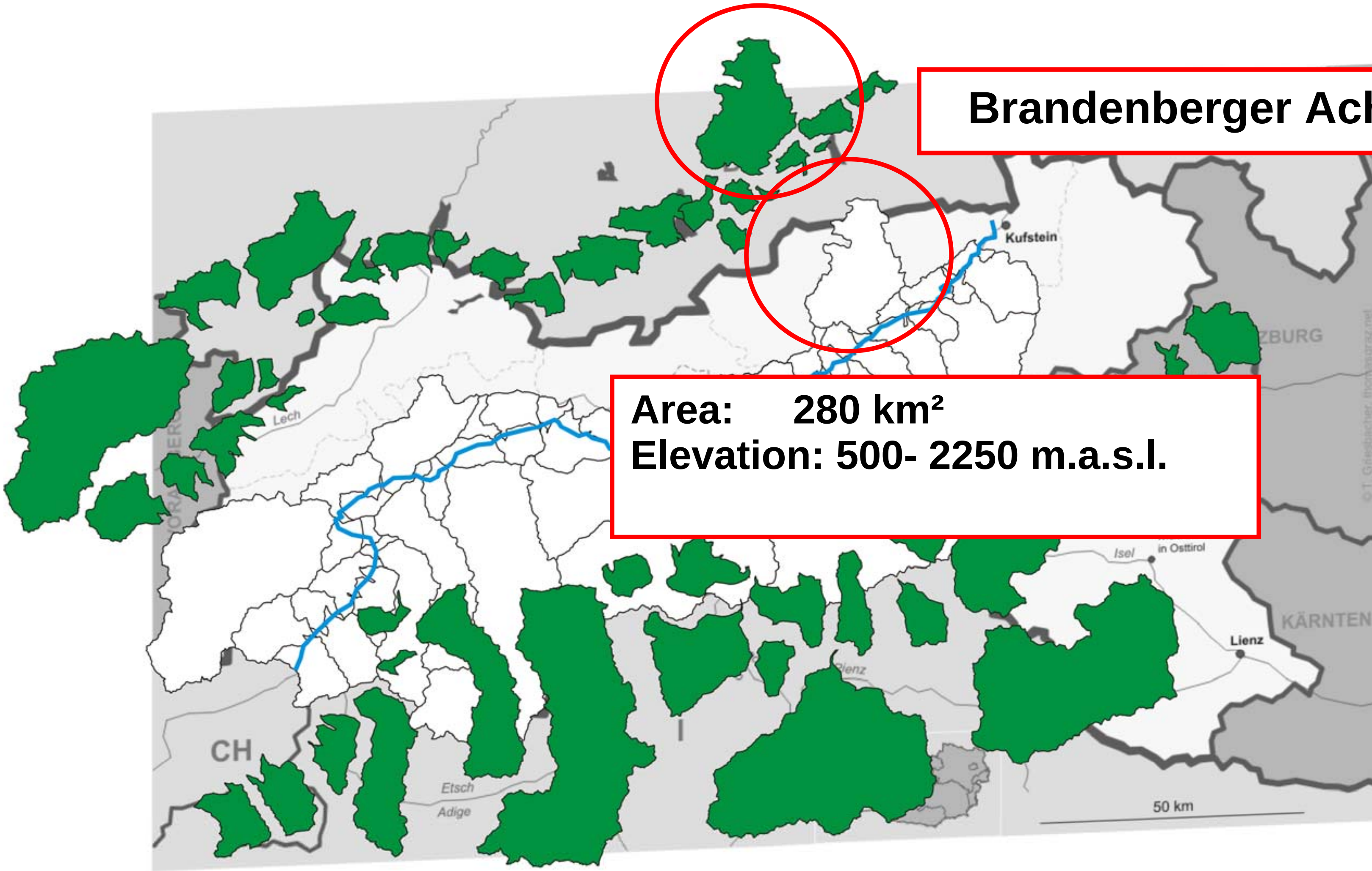
HYDRAULICS – River INN

- Update of Topology → new/adapted cross sections
- Improve the stability in calculations → overcome large gradients in the inflow
  (low flow conditions/hydropower operation)

HYDROLOGY

- Implementation of SES – Snow and Ice melt model
- INCA implemented in SES
- Verification and correction of meteorological data series
- Recalibration of hydrological models

Overview - components of prognosis model



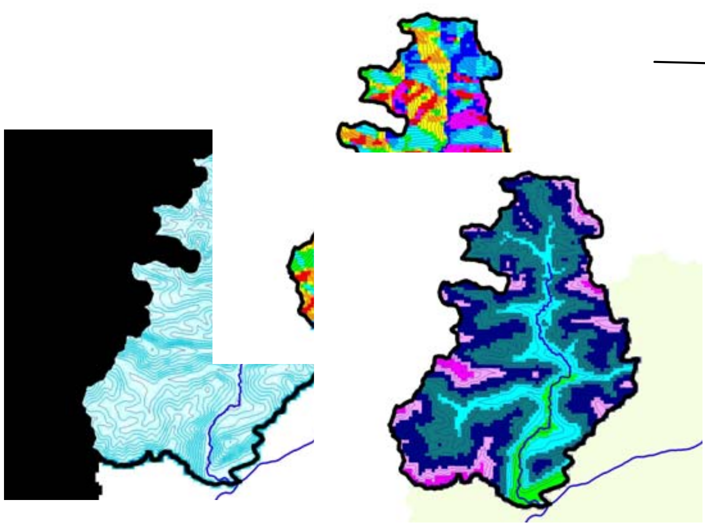
Brandenberger Ache

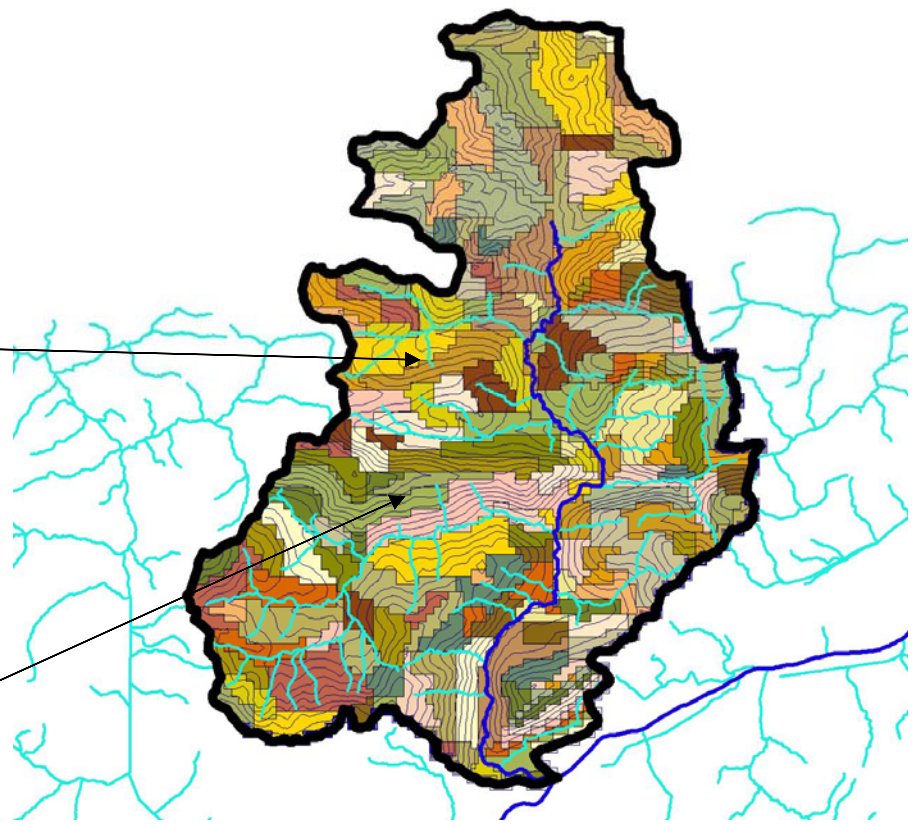
Area: 280 km²
Elevation: 500- 2250 m.a.s.l.

alp▲s

HQsim – non glaciated catchments

- Continuous water balance model
- HRU (Hydrologic responce units) concept derived on basis of
  - Elevation, Slope, Exposition,
  - Soil type distribution
  - Land use





HQsim - parameters

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HQsim - parameters

Why reducing the parameters?

- Too many parameter describing the rainfall-runoff relation
- Confusing when calibrating

- Auto calibration: less parameters to be considered in a first approach

HQsim – model specifics

- Precipitation types - Snowline modeling
  lower and upper temperature thresholds
  (tsrmin/tsrmax)
- Snow melt – modified day degree factor approach
  min and max value of snow melting function
  (snmfmin,snmfmax) [mm/°C/d]
- Snow cover → described by “cold content”
  melting initiated when
  Σ Energy loss < Σ Energy input

  Physical limits of “cold content” accumulation
  sntmem → max. days used for Energy balance
  sntmin → min. threshold temp. to be stored

HQsim – model specifics

- Contributing area for surface runoff described as *arctan* function f (saturation)

$$CA = (1-i)\cdot\frac{\arctan\left(-cap1+\left((0.5\cdot cap1)^{cap2}+cap1\right)\cdot s\right)-\arctan(-cap1)}{\arctan\left((0.5\cdot cap1)^{cap2}\right)-\arctan(-cap1)}+i$$

- *(s)* saturation
- *(i)* fraction of seald surface
- *(cap1, cap2)* describe the shape of the *arctan* function

HQsim – model specifics

- Water movement in soil
  (sd) …soil depth
  (mvgks) …saturated hydraulic conductivity

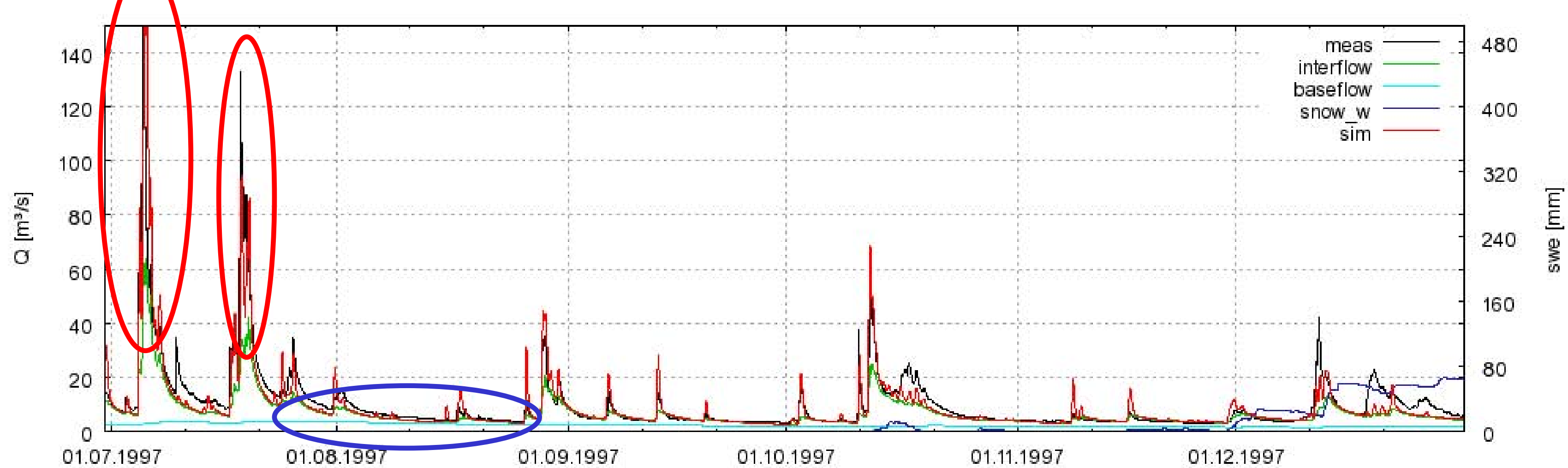
- Unsaturated hydraulic conductivity *(k)*
  Mualem van-Genuchten

$$k = mvgks \cdot s^{mvga} \cdot \left(1 - \left(1 - s^{1/mvgm}\right)^{mvgm}\right)^{2}$$

- *(mvkm, mvga) Mualem van-Genuchten parameters*

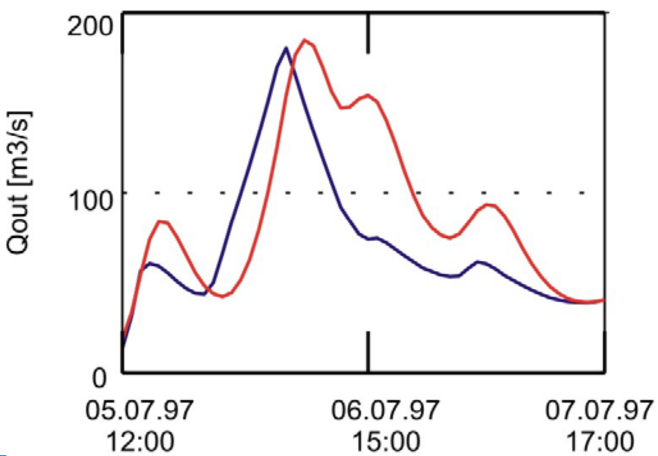
Calibration of hydrological models

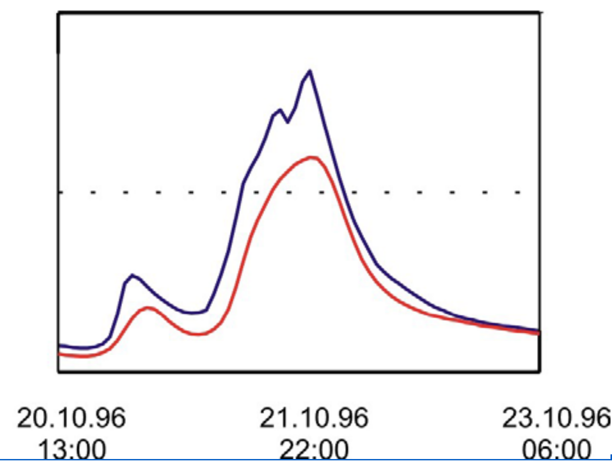
AIM: Best reproduction of large flow events



Δ Qmax= +2.3 % E= +0.07 [-]
Δ T= +2.0 [h] B= +1.23 [-]

Δ Qmax= -28.8 % E= +0.80 [-]
Δ T= +0.0 [h] B= +0.76 [-]



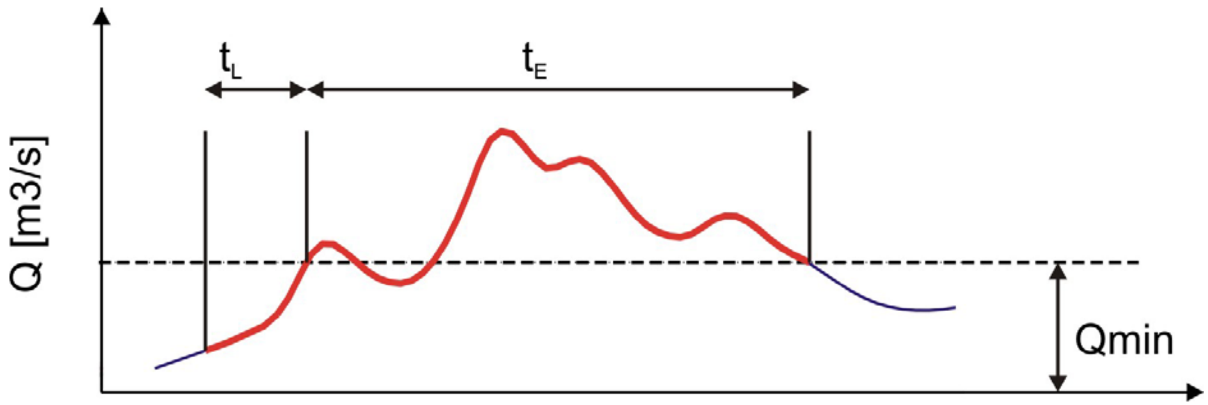


Calibration of hydrological models

AIM: Best reproduction of large flow events

Considering single relevant (large) events

Separation with threshold flow Qmin=~HQ1



Comparability of parameter variations

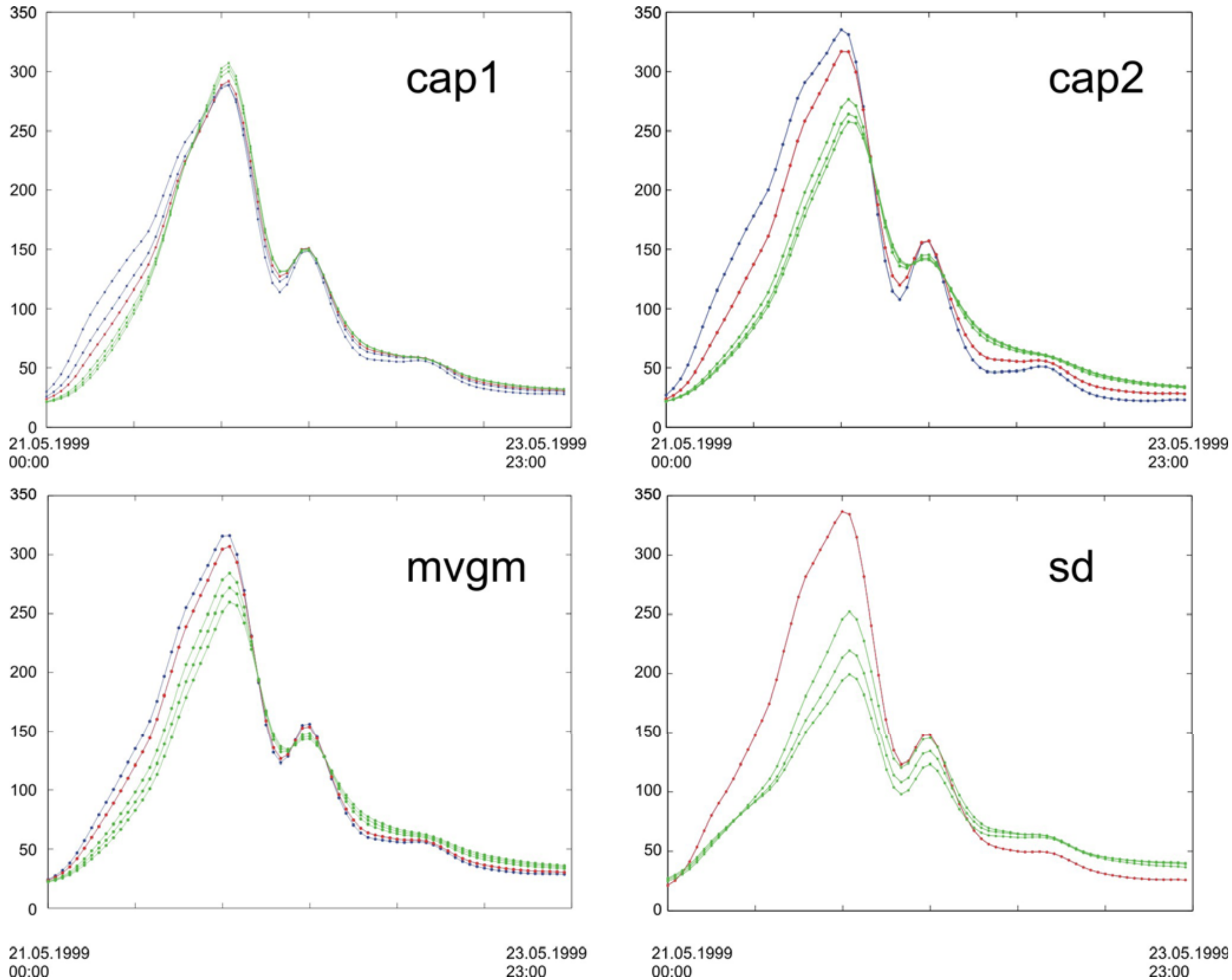
- % variation based on physical feasible range

$$C_V = C_0 + \left(C_{\max} - \mathrm{C}_{\min}\right) \cdot \frac{p_v}{100}$$

- [Cmin, Cmax] …physical range of parameter
- Pv [%] … percentage of variation applied
- C_0 … (current) best fit of parameter

- C_V=f(pv) …Variation of parameter

Indicators for sensitivity



- 30,20,10 %   0 %   + 10,20,30 %

Indicators for sensitivity

Indicators for Calibration quality =
= indicators for sensitivity

- $B_{Q,MAX}$ [-] …Bias of the peak flow
- E [-] …Nash Sutcliffe Efficiency (event period)
- $D_{Q,MAX}$ [h] …Delay of peak flow
- B_{RL} [-] …Bias of the rising limb
- E_{RL} [-] …Nash Sutcliffe Efficiency (rising limb)

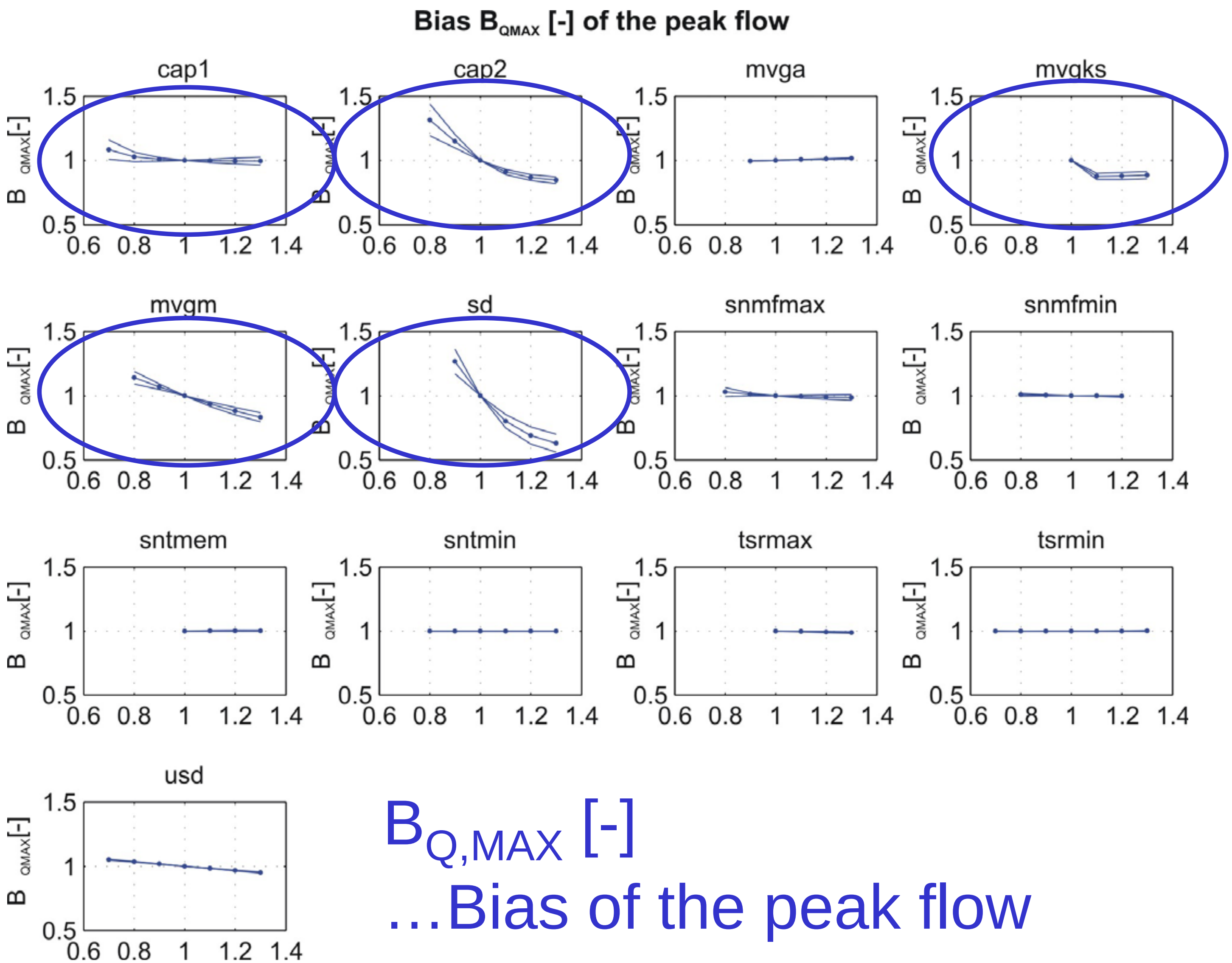
Indicator for time series

→ mean of event indicators + standard deviation

→ Uses the baseline simulation as reference

Results

1994 - 2001

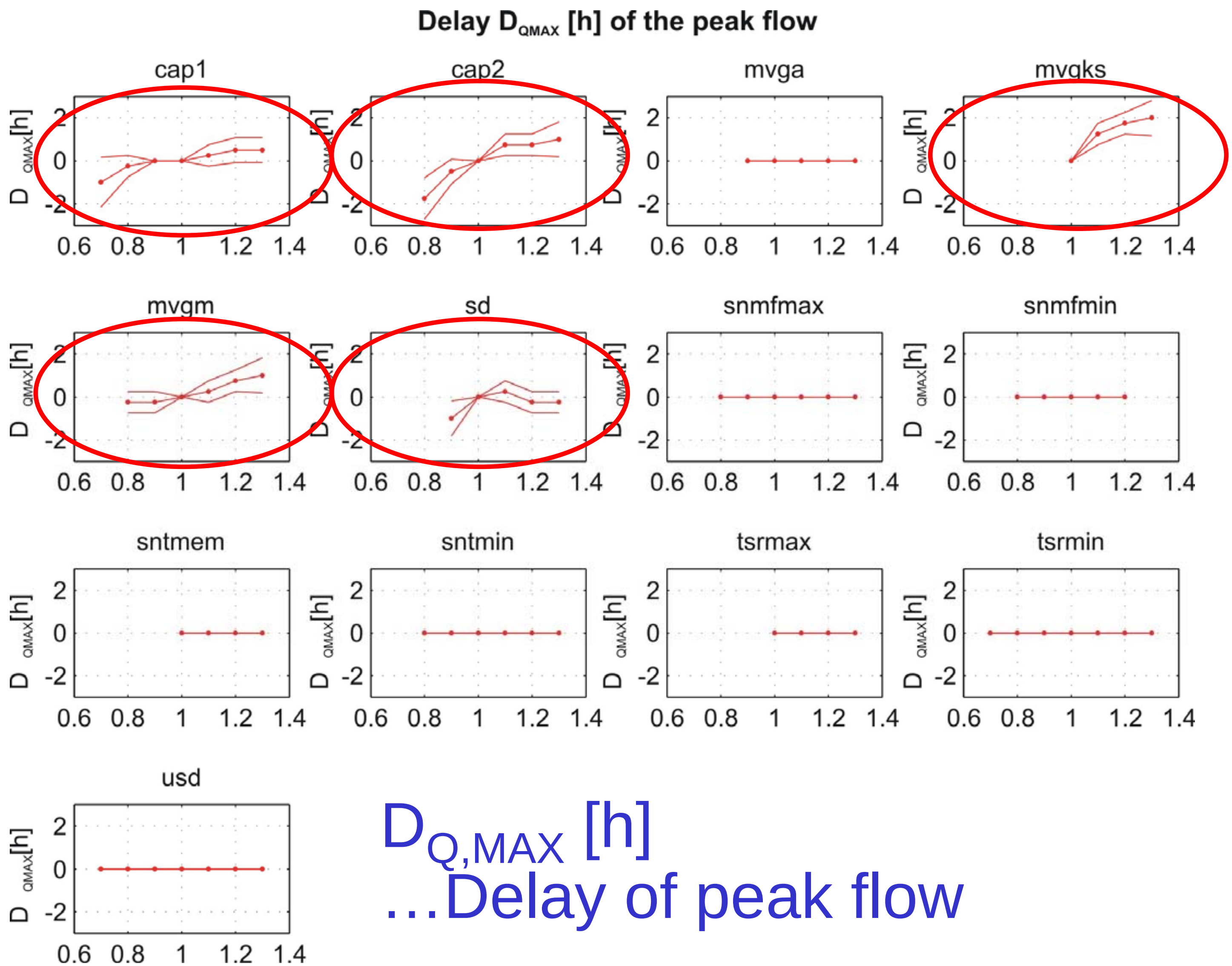


$B_{Q,MAX}$ [-]

…Bias of the peak flow

Results

1994 - 2001



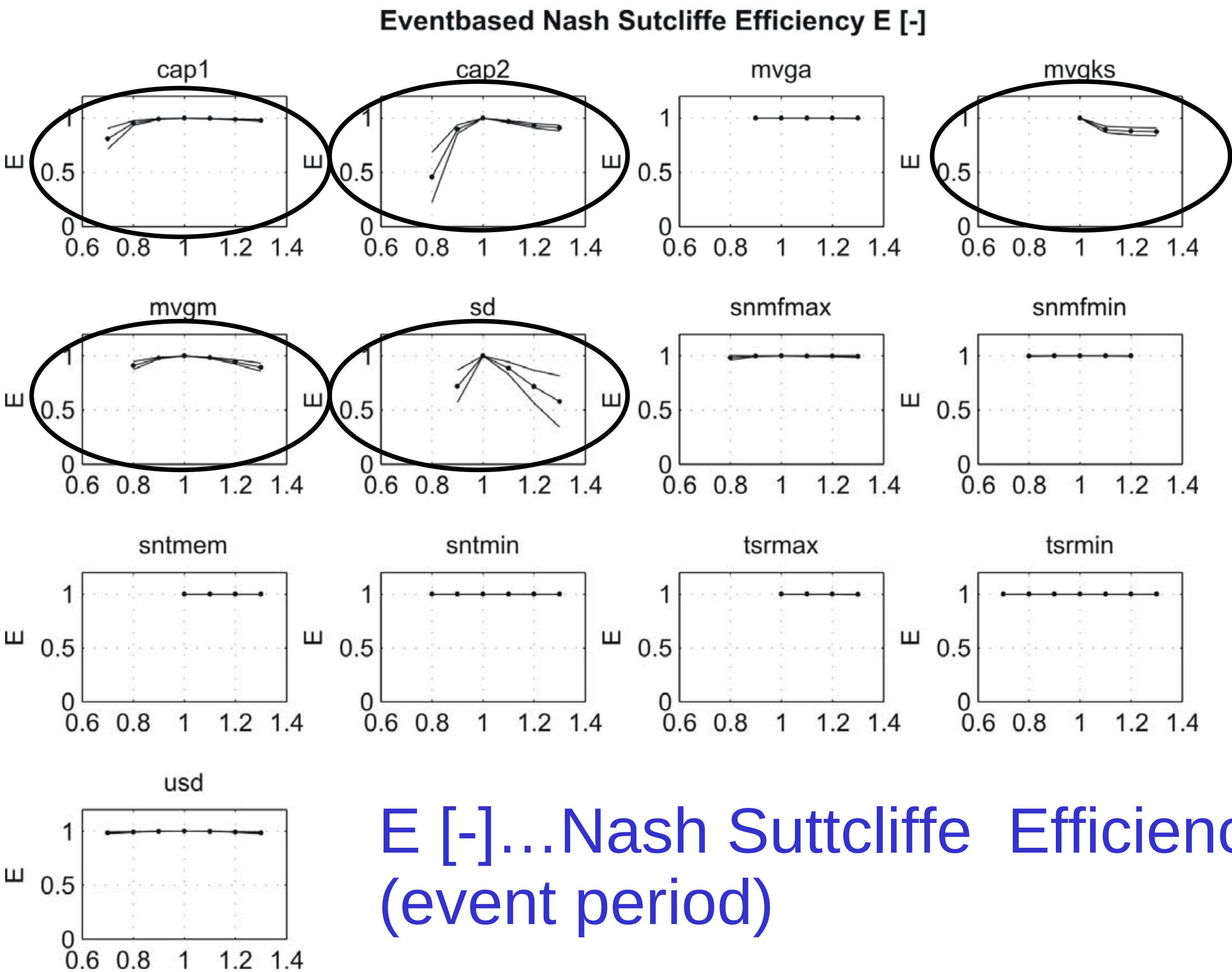
$D_{Q,MAX}$ [h]

…Delay of peak flow

FFG

Results

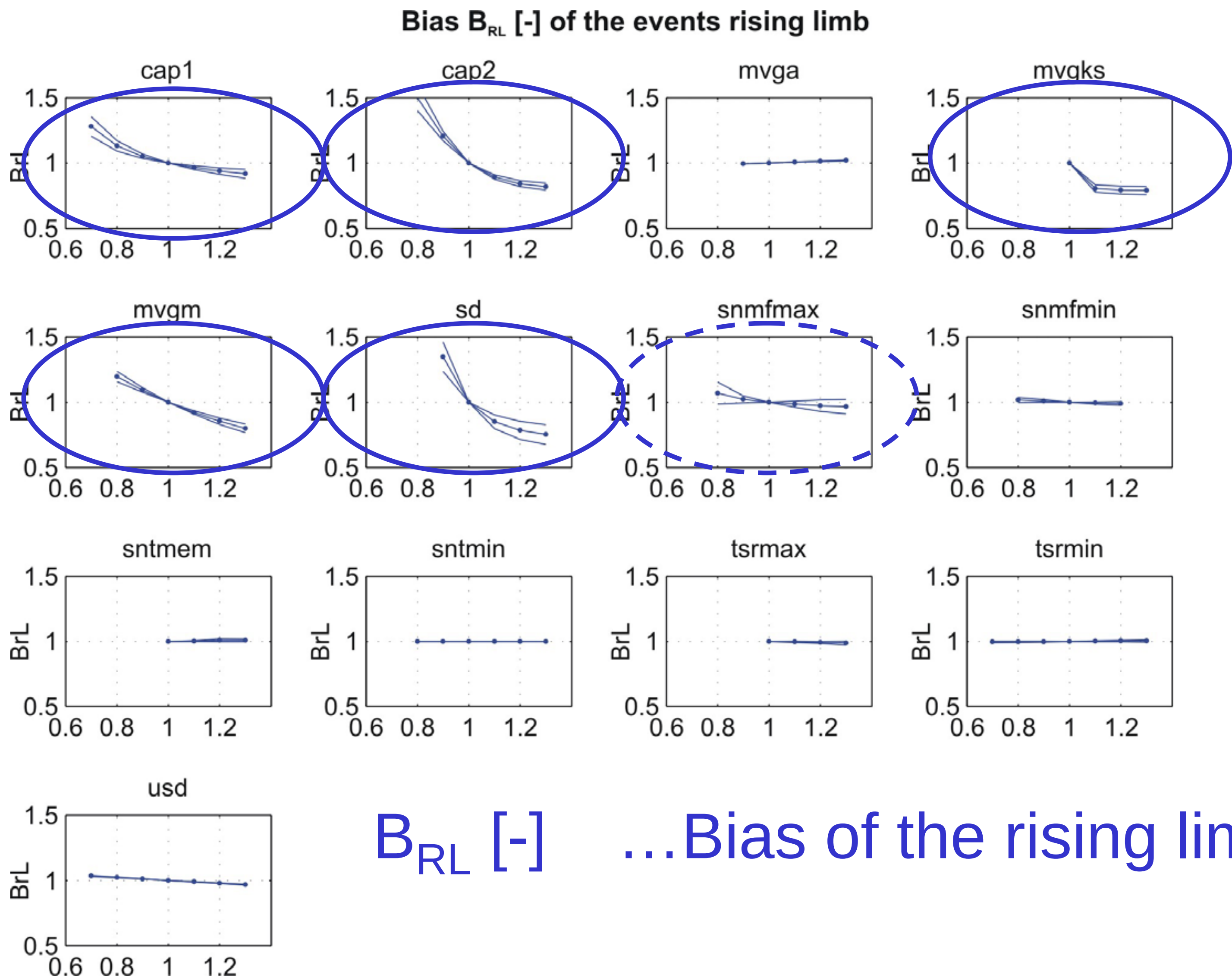
1994 - 2001



E [-]…Nash Suttcliffe Efficiency (event period)

Results

1994 - 2001



B_{RL} [-] …Bias of the rising limb

Conclusions

Sensitive parameters

- *(cap1, cap2)*
  describe flow contributing area
- *(mvgks, mvgm)*
  flow in unsaturated soil zone (Mualem vanGenuchten)
- *(sd)*
  soild depth of the unsaturated soil zone

- Most important (sensitive) parameters were identified
- Indicators account on large flow events
- Temp/Snow type parameters are relevant only in specific events

thank you for your attention

Contact:
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HQsim model background

HQsim – non glaciated catchments

- Derivation of flow paths/river representations
  - Modeled with linear flow routing
- Combination of
  - River paths
  - HRU
  - Flowtimes from HRU 2 flowpaths