

LUCCi Climate Cluster Progress:

1. LUCCi climate data: Availability, reliability, usage
2. Coupled hydrological-economical modeling system

Patrick Laux & Thinh Dang

Karlsruhe Institute of Technology (KIT)

Institute of Meteorology and Climate Research

Department of Atmospheric Environmental Research (IMK-IFU)



Long-term regional climate projections

Population Growth, Economic Development & Technological Progress



Emission Scenarios
Greenhouse Gas Concentrations



Global Climate Models



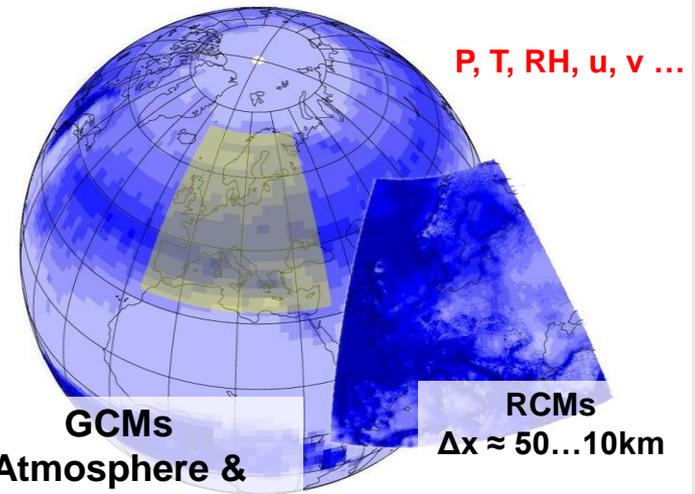
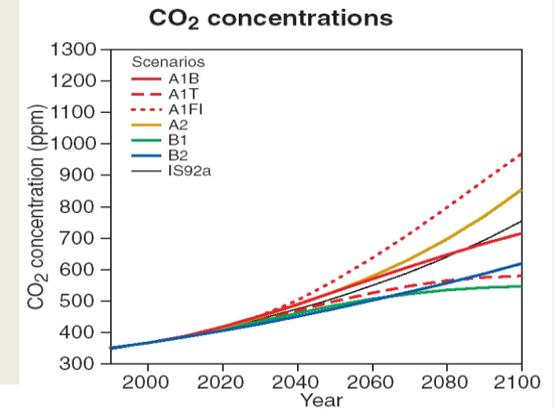
Global Climate Scenarios



Downscaling Methods



Regional Climate Scenarios



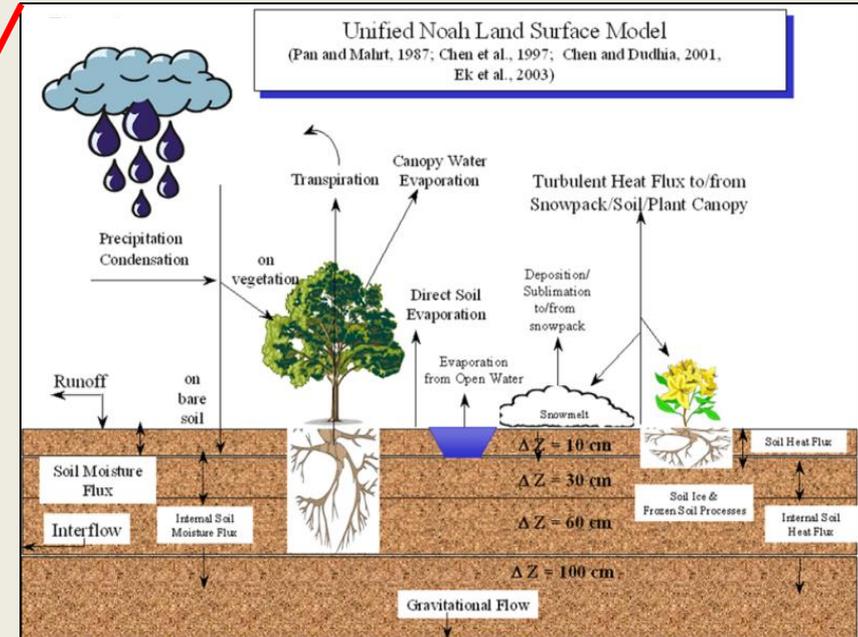
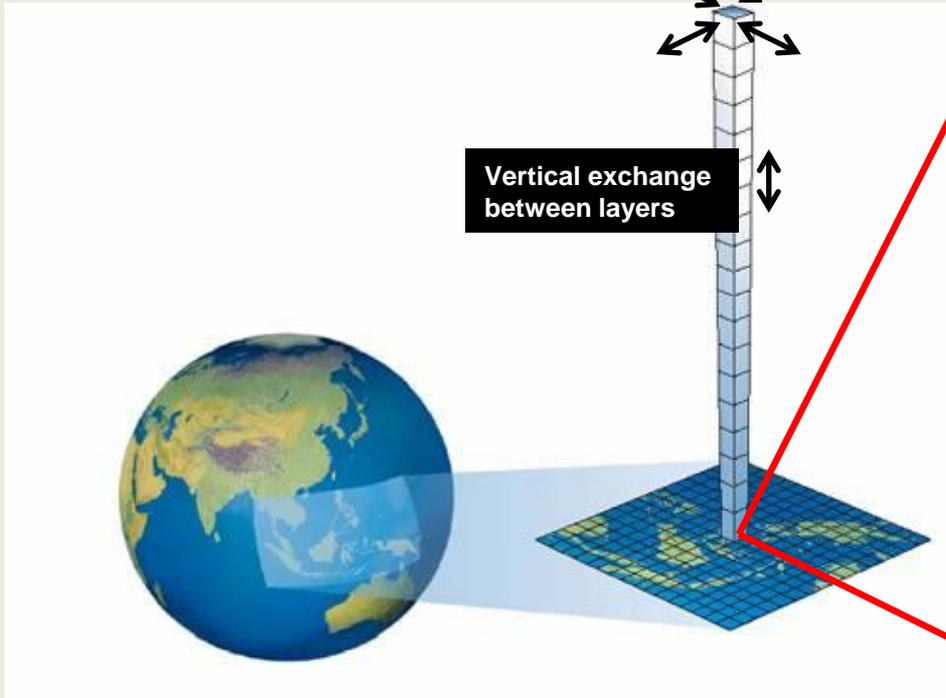
Weather Research and Forecast model



Atmosphere: GCM provides lateral boundary conditions

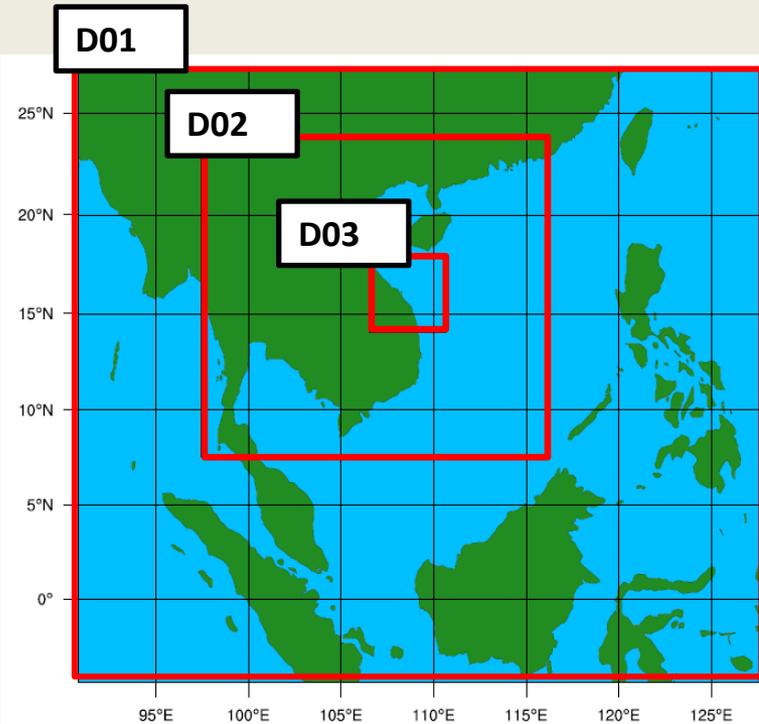
Horizontal exchange between columns of momentum, heat and moisture

Surface & subsurface: SVAT model as lower boundary conditions



→ WRF model: Joint atmospheric-terrestrial water budget calculations

LUCCi: Downscaling setup



- **Domain 1**
 - horizontal: 99 x 99 grid points with a resolution of **45 km**
 - vertical: 50 layers up to 50 hPa
 - time step: 180 s
- **Domain 2**
 - horizontal: 142 x 145 grid points with a resolution of **15 km**
 - vertical: 50 layers up to 50 hPa
 - time step: 120 s
- **Domain 3**
 - horizontal: 66 x 75 grid points with a resolution of **5 km**
 - vertical: 50 layers up to 50 hPa
 - time step: 30 s

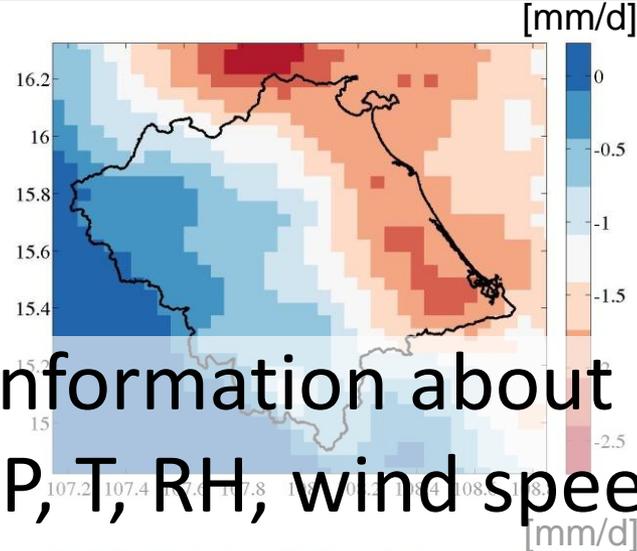
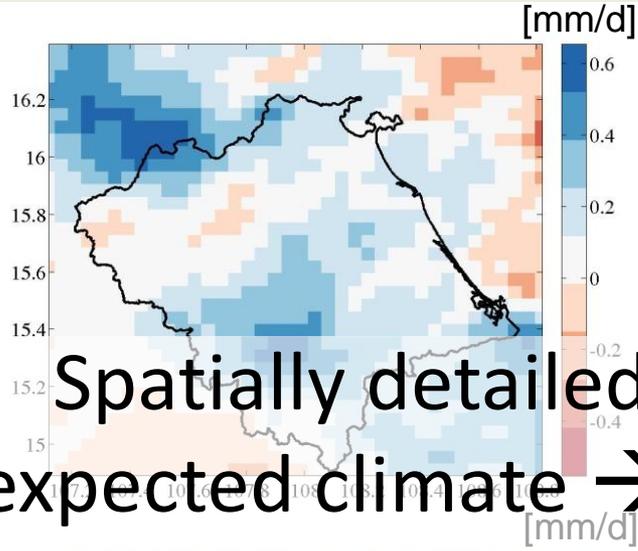
→ ~ 2 Mio CPU h on HPC cluster to finalize simulations (2 years real time)

VGTB: Expected rainfall change

2001-2030

2021-2050

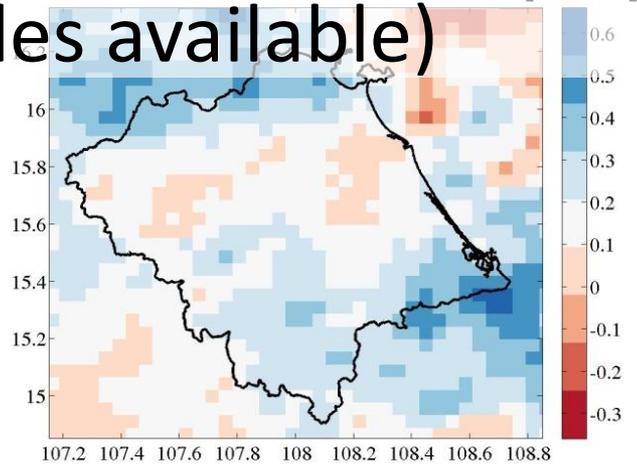
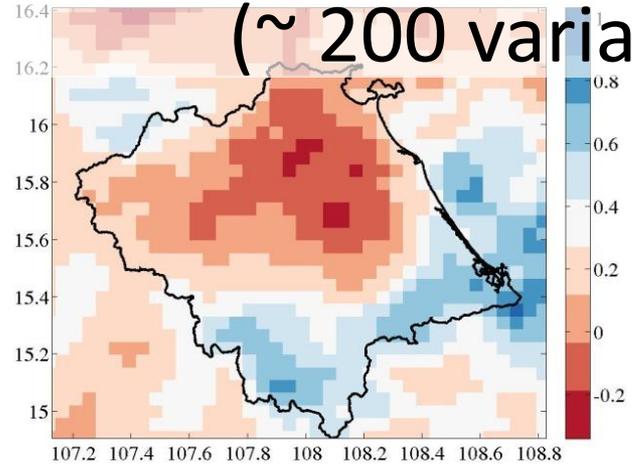
A1b



Spatially detailed information about expected climate → P, T, RH, wind speed

(~ 200 variables available)

B1

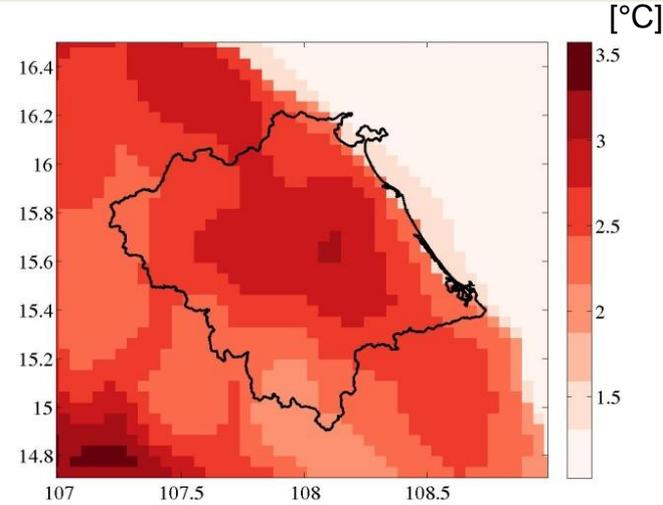
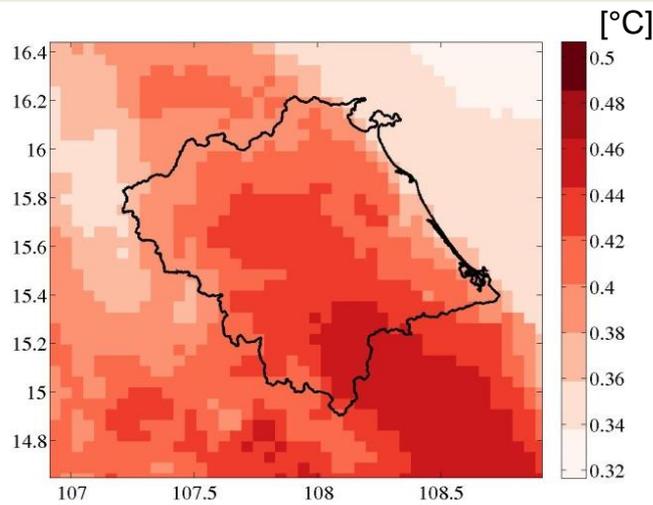


VGTB: Expected temperature change

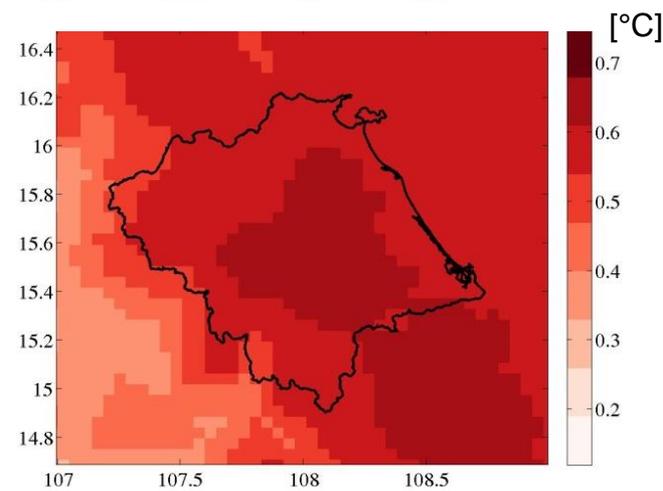
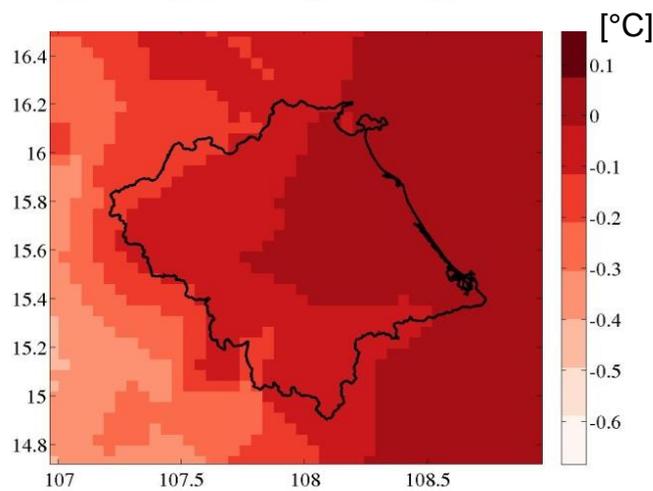
2001-2030

2021-2050

A1b



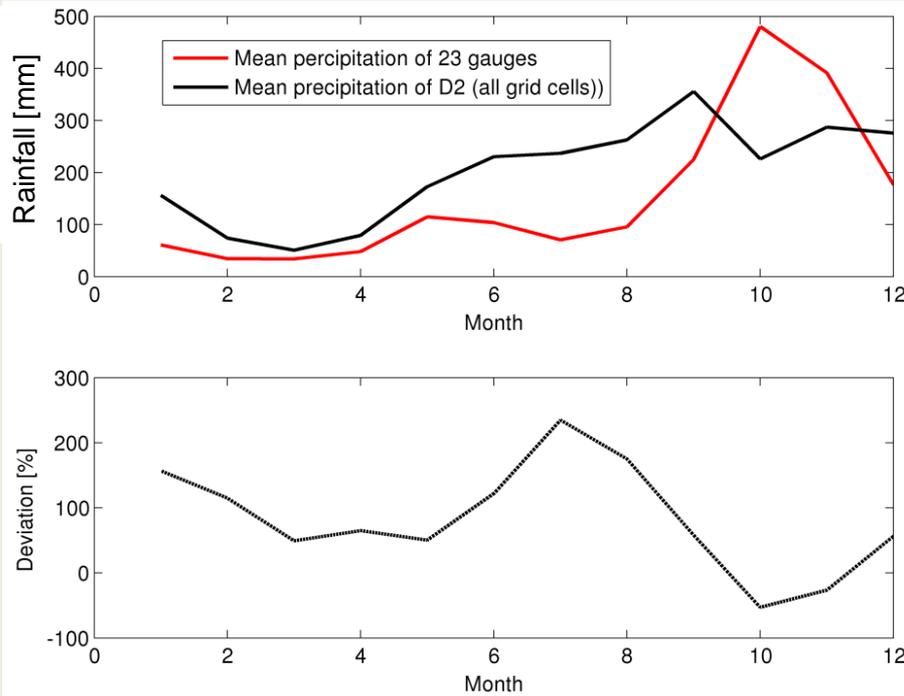
B1



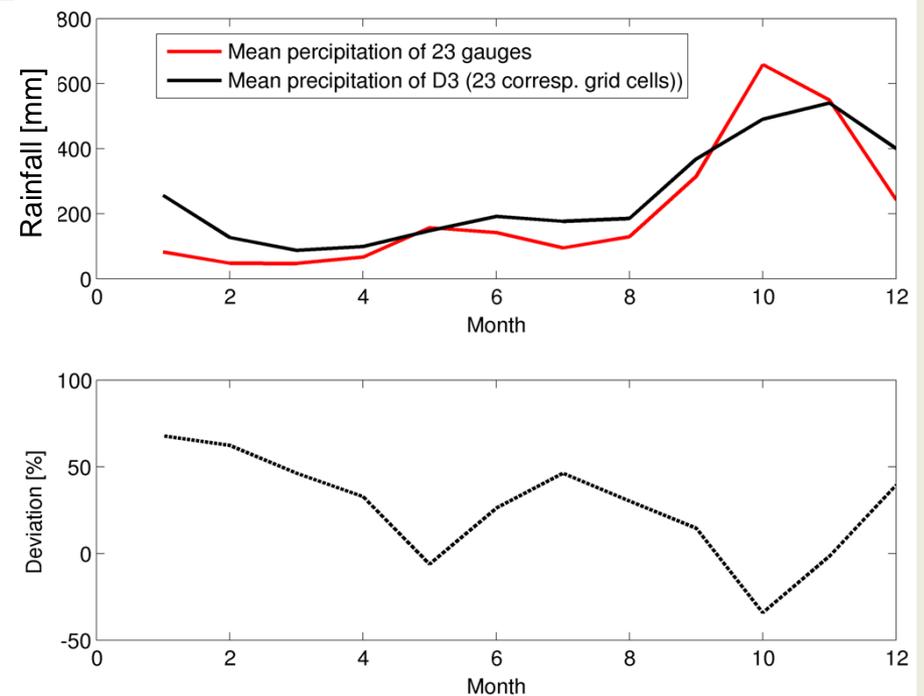
Performance gain of downscaling



D2 @ 15 km

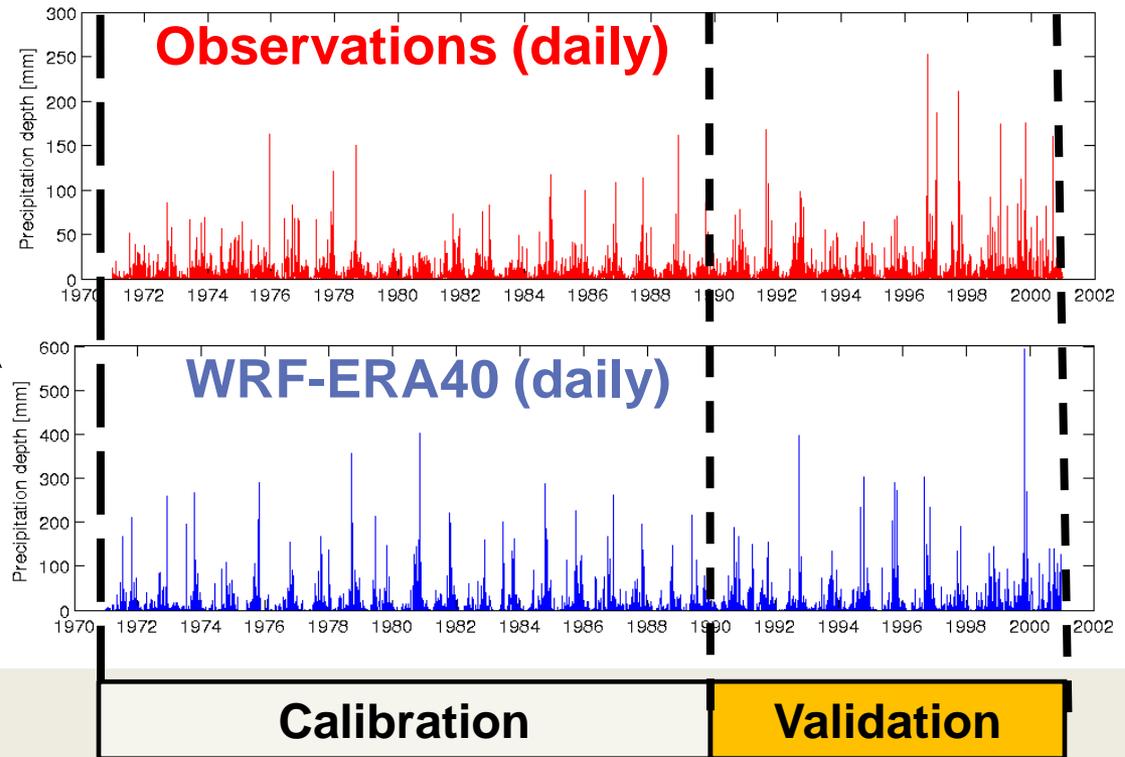
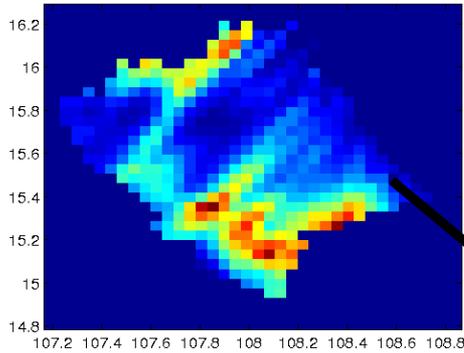


D3 @ 5 km



- **D2**: Seasonality not well captured, high deviations from observations
- **D3**: Improved seasonality, acceptable deviations

Further refinement: Bias correction



Observations: Precipitation data obtained by IMHEN

WRF-ERA40: WRF simulation driven by ERA40 reanalysis (ECMWF)

→ Various bias correction methods (mean correction, q-q mapping, Copula approach) applied and validated

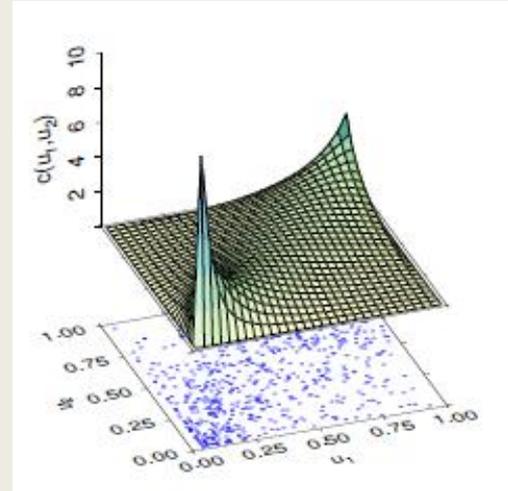
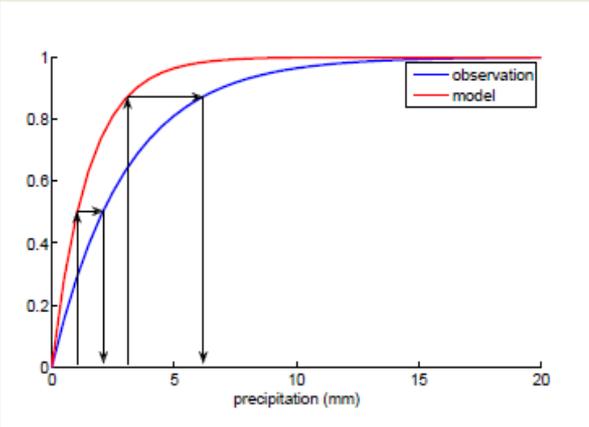
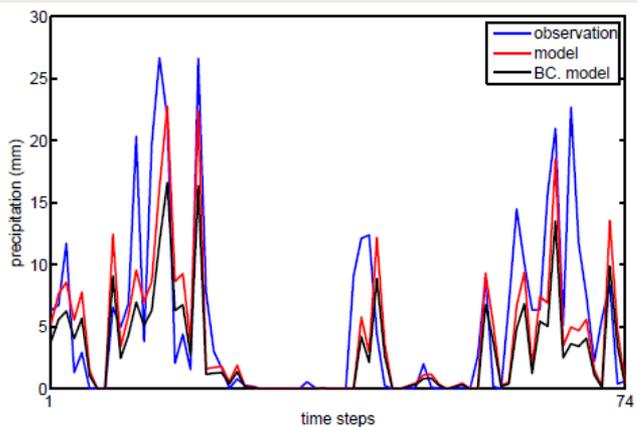
Overview: Bias correction methods



Mean value correction

Quantile mapping (q-q mapping)

Copula correction



$$q = \frac{\overline{obs}}{\overline{model}} \Rightarrow mod_{bc}(t) = q * mod(t)$$

$$mod_{bc}(t) = F_{obs}^{-1}(F_{mod}(mod(t)))$$

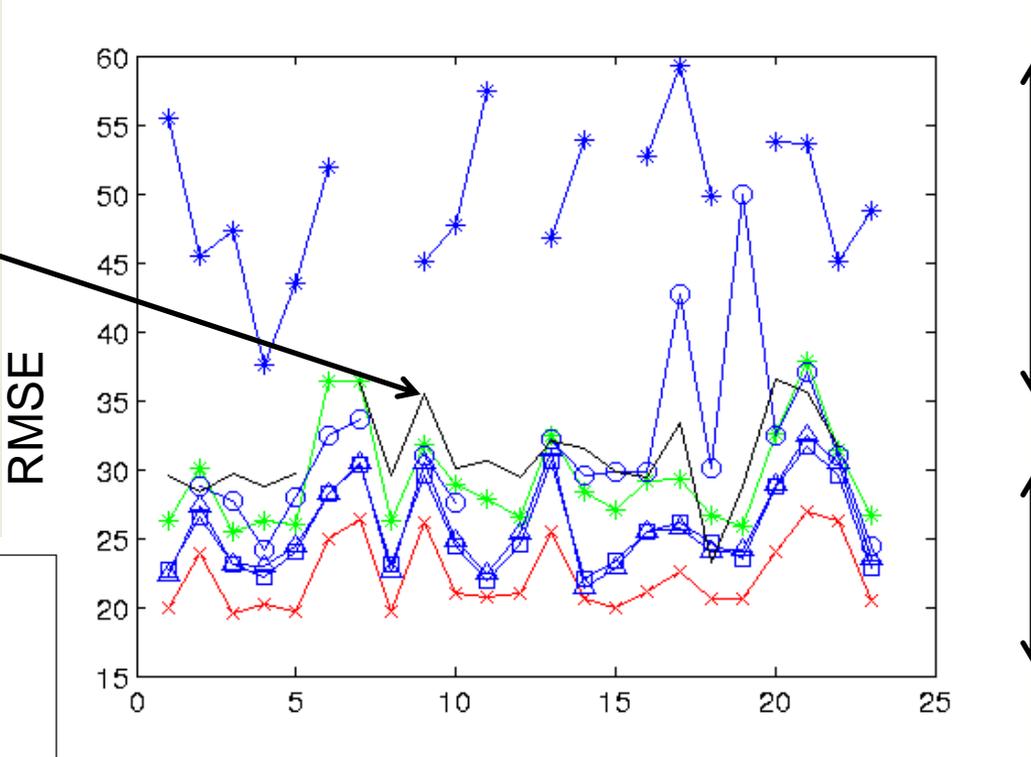
Level of complexity

„Static“

„Dynamic“

Focus on rainfall peaks: Performance?

Without bias correction



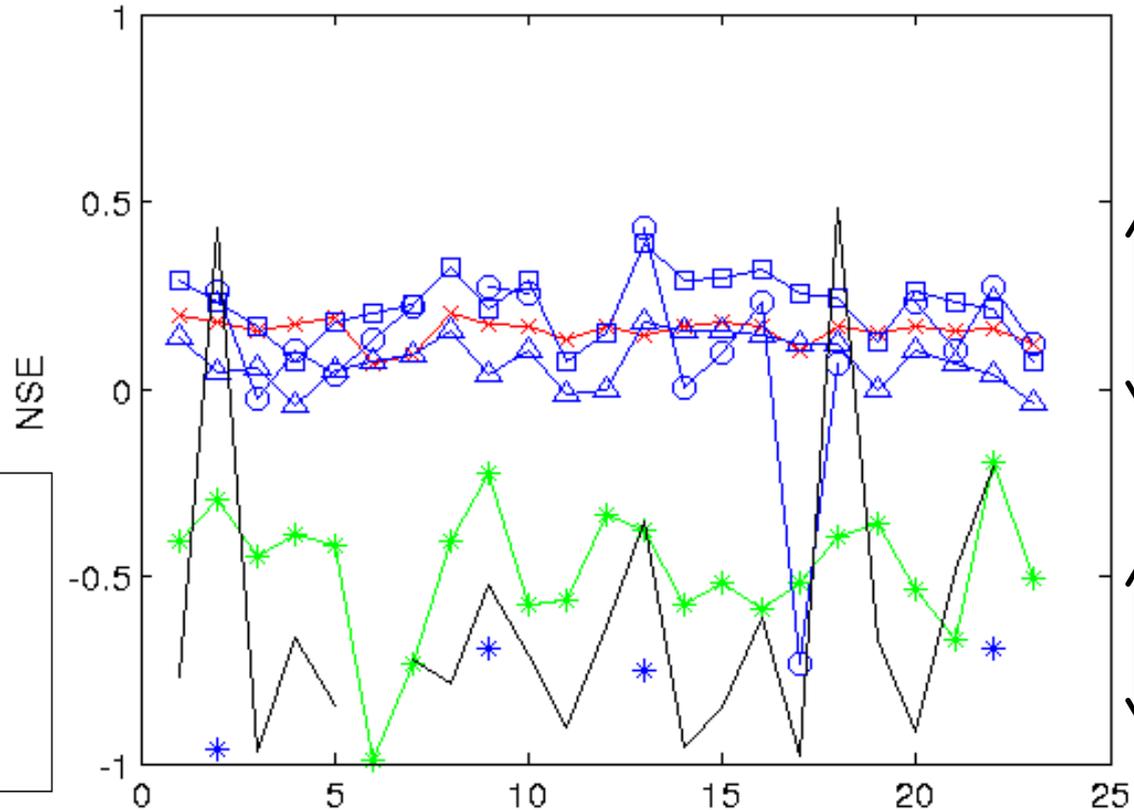
Worse than w/o bias correction

Better than w/o bias correction

Observation station (e.g. DaNang = 5)

→ Suitable methods to bring the model results closer to observations

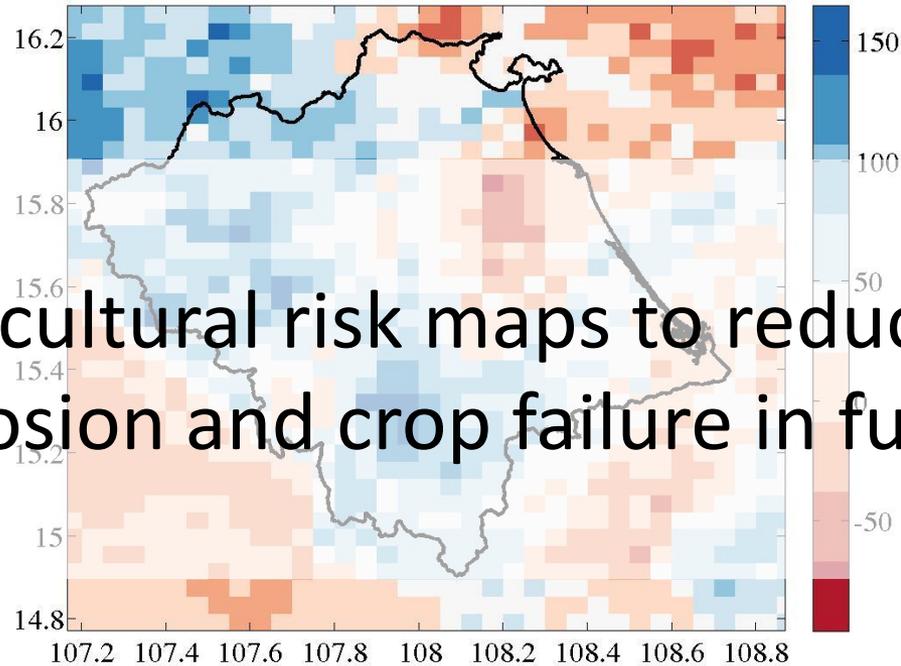
Improvement: yes or no?



→ „Dynamic“ Copula BC slightly outperforms „Static“ methods

Agricultural application: Erosive Rains

Agricultural risk maps to reduce soil erosion and crop failure in future



Expected changes in number of harmful rain events (precipitation > 20 mm) during 2001-2030 (A1b)

Take Home



1. **WRF long-term climate simulations** (T, P, Rad, RH, etc.) finished, available, and **ready to be used** for impact studies
→ Daily resolution, but also 6h or even 1h is available for selected variables
2. D3 suitable for CC impact studies, further refinement by bias correction methods (will be uploaded to RBIS soon)
3. Specific **tailor-made information** (e.g. agricultural risk maps) can be delivered on request (Email me: patrick.laux@kit.edu)

Ongoing work: LUCCi



- **Statistical Downscaling for uncertainty estimation** of selected variables (T, P, etc.) coming from other GCMs and additional emission scenarios (next 6-12 months)
- **Impacts of land use change** on meteorological surface variables using updated LU maps in the climate simulations (PhD thesis of Nguyen Phuong, LUCCi)

... beyond LUCCi

- Improved **seasonal climate predictions** to assist farmers with cropping strategies (planting date, choice of crops/varieties, locations) in cooperation with Prof. Van Tan, HUS
- Identification of **optimized cultivation strategies** (rice, cash crop) and **sustainable water management strategies** in the VGTB river basin using coupled WaSim - Gams simulations (PhD thesis Dang Thinh, DAAD scholar)

Optimized agricultural management strategies for the VGTB basin

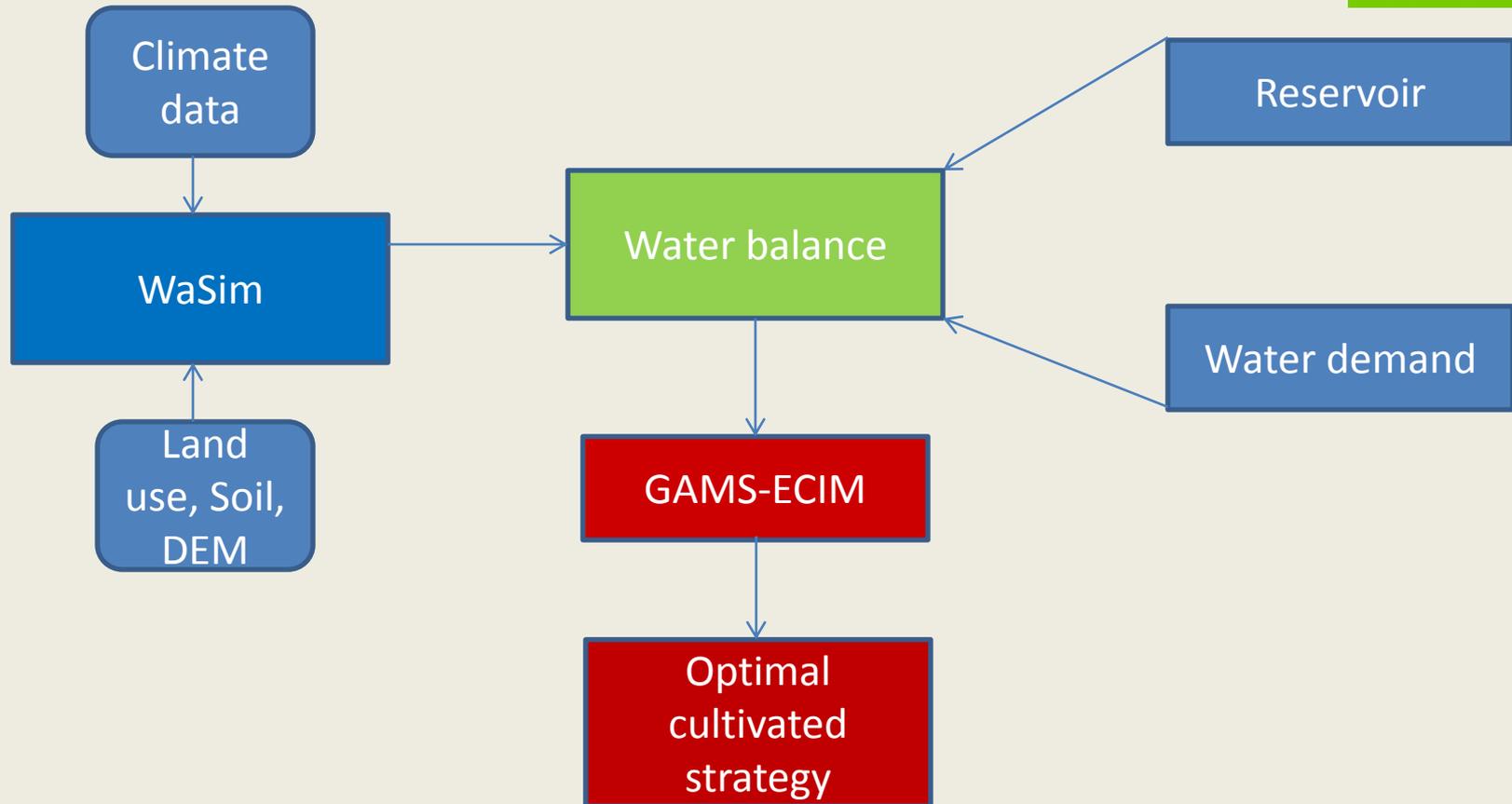


Objectives

→ To investigate regional **interdependencies between economy and hydrology** in VGTB

→ To derive **optimized cultivation strategies and sustainable water management strategies** in the basin

Coupled hydrological – economic modeling system



WaSim model: Physically distributed hydrological catchment model to simulate the water cycle above and below the land surface

GAMS-ECIM model: Non-linear mathematical optimization model

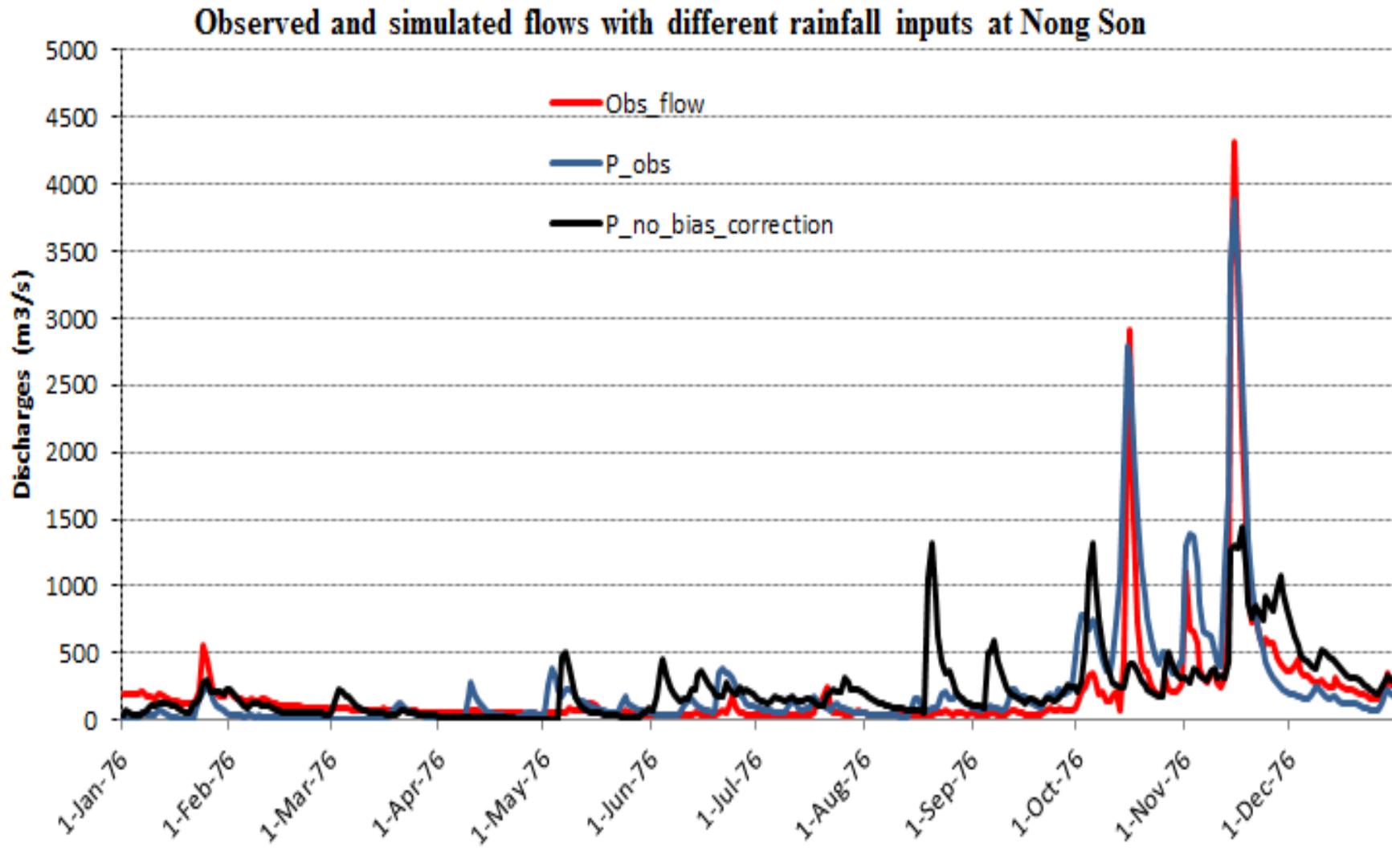
Data requirements

Hydro-met data	Topographic data	Economic data
<ul style="list-style-type: none">Climate data (daily) Reanalysis data (WRF-ERA40)	<ul style="list-style-type: none">DEM	<ul style="list-style-type: none">Cultivated area
<ul style="list-style-type: none">Flow data (daily)	<ul style="list-style-type: none">Land use data	<ul style="list-style-type: none">Crop patterns
<ul style="list-style-type: none">Reservoir and dam	<ul style="list-style-type: none">Soil map	<ul style="list-style-type: none">Water demand for various crops
<ul style="list-style-type: none">Dam operation regulation		<ul style="list-style-type: none">Water supply data
		<ul style="list-style-type: none">Productivity, production, crop price, cost...

First model calibration results

Precipitation	Nash-Sutcliffe	RRMSE
Measured	0.75	1.03
No-bias correction (WRF-ERA40)	0.33	1.74
Bias correction (WRF-ERA40)	On going	

Validation: Nong Son



Next steps



- Finalize calibration of WaSim (manually, PEST) based on observations as well as bias corrected WRF-ERA40 data
- Set up GAMS-ECIM with most important economic drivers
- Coupling GAMS-ECIM to WaSim to derive spatially distributed optimized agriculture management strategies

Related publications



- Phan VT, Hiep VM, Long TT, Trung NQ, Thanh ND, Laux P, & Thanh NX (2014) Seasonal Prediction for Vietnam using the Regional Climate Model version 4.2 (RegCM4.2), *Advances in Meteorology* (under revision)
- Laux P, Phan VT, Thuc T, Kunstmann H (2013) High Resolution Climate Change Information for the Lower Mekong River Basin of Southeast Asia. *High Performance Computing in Science and Engineering 13*. Nagel W, Kröner D, Resch, M (eds.). Springer Berlin Heidelberg (in press).
- Souvignet M, Laux P, Freer J, Cloke H, Thinh DQ, Thuc T, Cullmann J, Nauditt A, Flügel WA, Kunstmann H, Ribbe L (2013) Recent climatic trends and linkages to river discharge in Central Vietnam. *Hydrol. Process.*. doi: 10.1002/hyp.9693.
- Laux P, Phan VT, Lorenz C, Thuc T, Ribbe L, Kunstmann H (2012) Setting Up Regional Climate Simulations for Southeast Asia. *High Performance Computing in Science and Engineering 12*. Nagel W, Kröner D, Resch, M (eds.). Springer Berlin Heidelberg, 391–406.
- Laux P, Vogl S, Qiu W, Knoche HR, Kunstmann H 2011, Copula-based statistical refinement of precipitation in RCM simulations over complex terrain, *Hydrology and Earth System Sciences*, 15, 2401–2419.