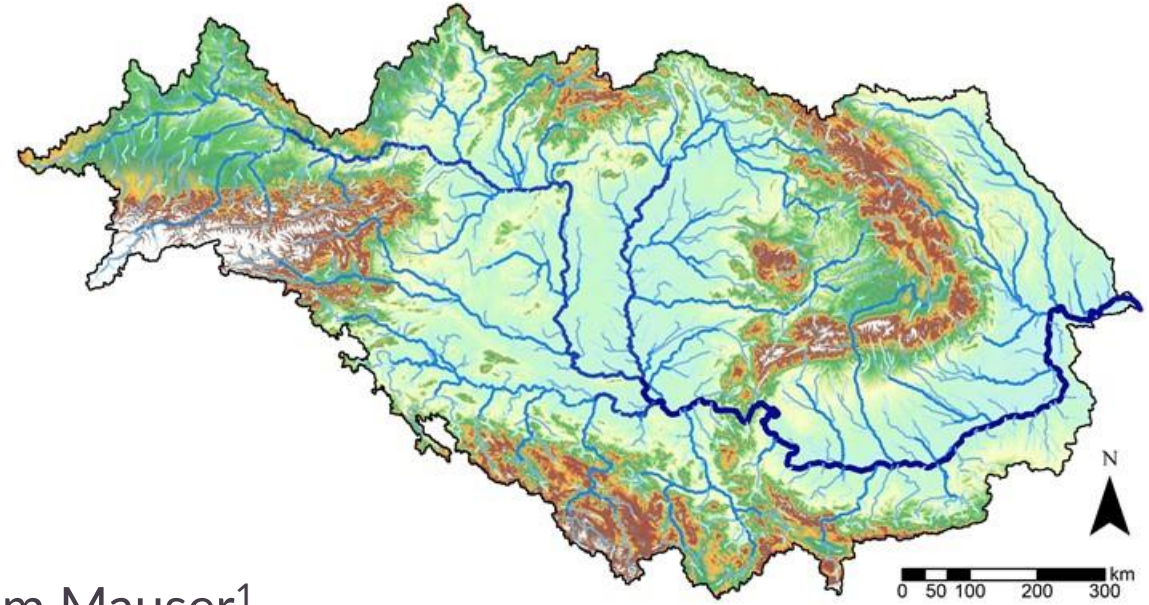
Virtual Water Values (ViWA)

ViWA

Multiscale Monitoring of Global Water Resources and Options for their Efficient and Sustainable Use

The Danube River Basin – Model Set-Up, Discharge and Water Balance



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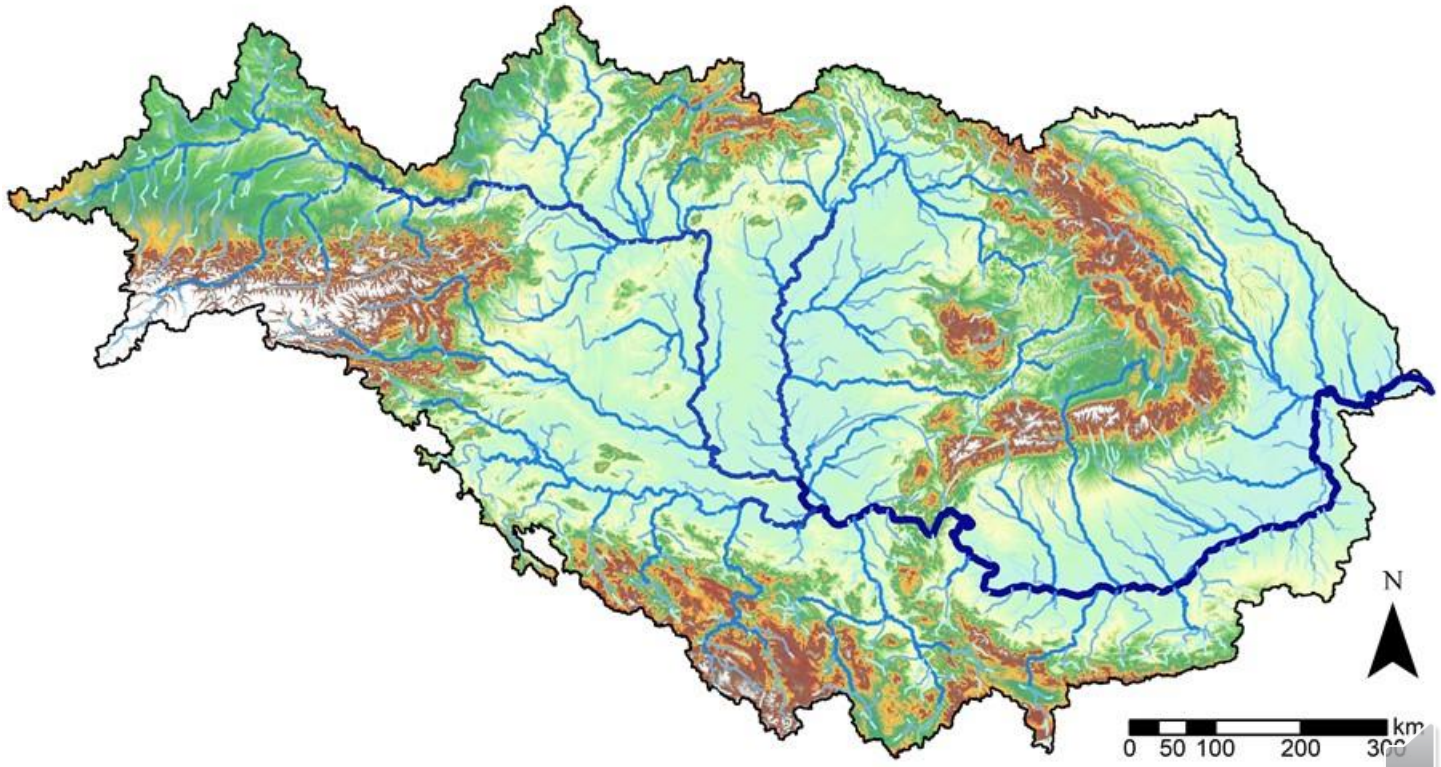
The Danube river basin

- Most international river basin in the world (shared by 20 countries, most of them EU members)
- Regionally uneven rainfall distribution: “water tower” Alps & Dinarids vs. dry regions in the Pannonian Basin & Romanian Plain
- Extensive agricultural use in lower reaches (esp. Pannonian Basin, Romanian Plain, Moldavian Plain)



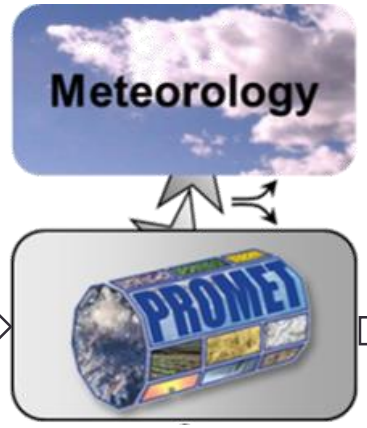
Basin area: **817,000 km²**

Long-term annual precipitation: **~800 mm**

Mean outlet discharge (MQ): **~6,500 m³/s**

The PROMET set-up in the Danube basin

Global reanalysis ERA5 (0.25°, 1h)

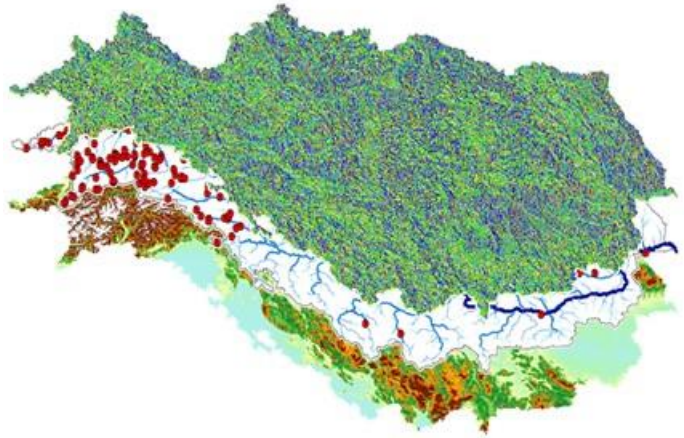


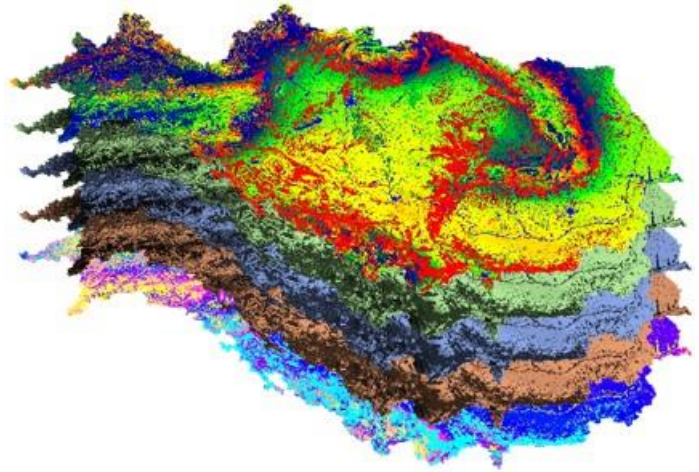
- Dynamic downscaling to 1 km²
- Bias-correction by precipitation climatologies

Gridded input data (1 km²):
- Topography: SRTM
- Soil: Harmonized World Soil Database
- Land use: CORINE (EU countries), ESA CCI land cover (non-EU countries)
- Hydrology: HydroSHEDS

Gridded output data (1 km²):
- LAI, phenology, yield
- Evapotranspiration, water use efficiency
- Discharge
- …

Hydro-agroecological model:
(Mauser & Bach 2009; Hank et al. 2015)
- Interlinkage of **hydrological modeling** and **biophysically based crop growth modeling**
- Spatially explicit (1 km²)
- Hourly time steps

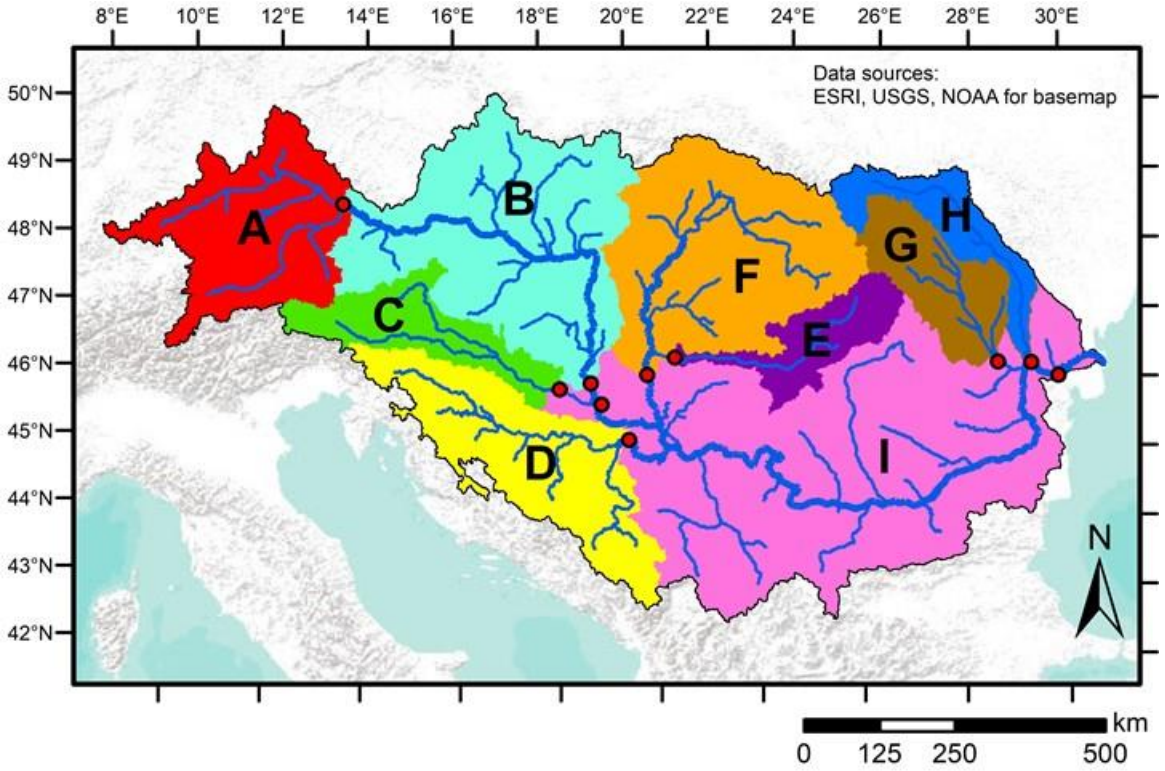




Vegetation | Soil | Hydrology | Management

Parametrizations

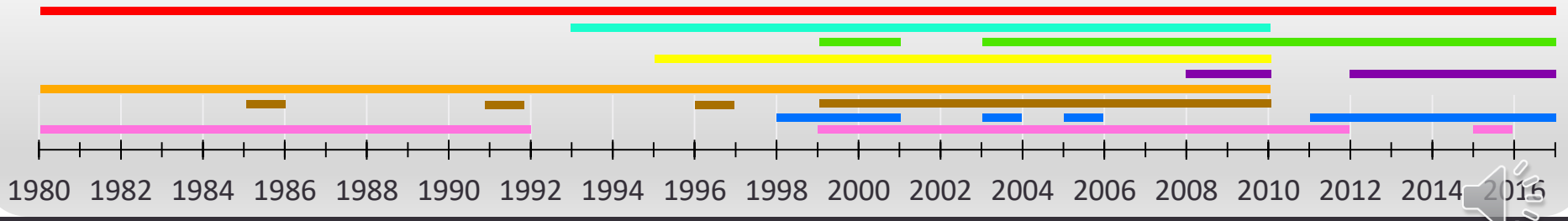
Danube sub-basins & discharge observations



Discharge observations in major Danube sub-basins (1980-2016)

	Sub-basin	Gauge	Observation Source
A	Upper Danube	Achleiten (DE/AT)	GRDC
B	Middle Danube	Bezdan (RS)	GRDC
C	Drava	Dravaszabolcs (HU)	ICPDR
D	Sava	Sremska Mitrovica (RS)	GRDC
E	Mures	Nagylak (HU)	ICPDR
F	Tisza	Senta (RS)	GRDC
G	Siret	Lungoci (RO)	GRDC
H	Prut	Giurgiulesti (RO)	ICPDR
I	Lower Danube	Reni (UA)	ICPDR
I	Lower Danube	Ceatal Izmail (UA/RO)	GRDC

Discharge observations availability over time



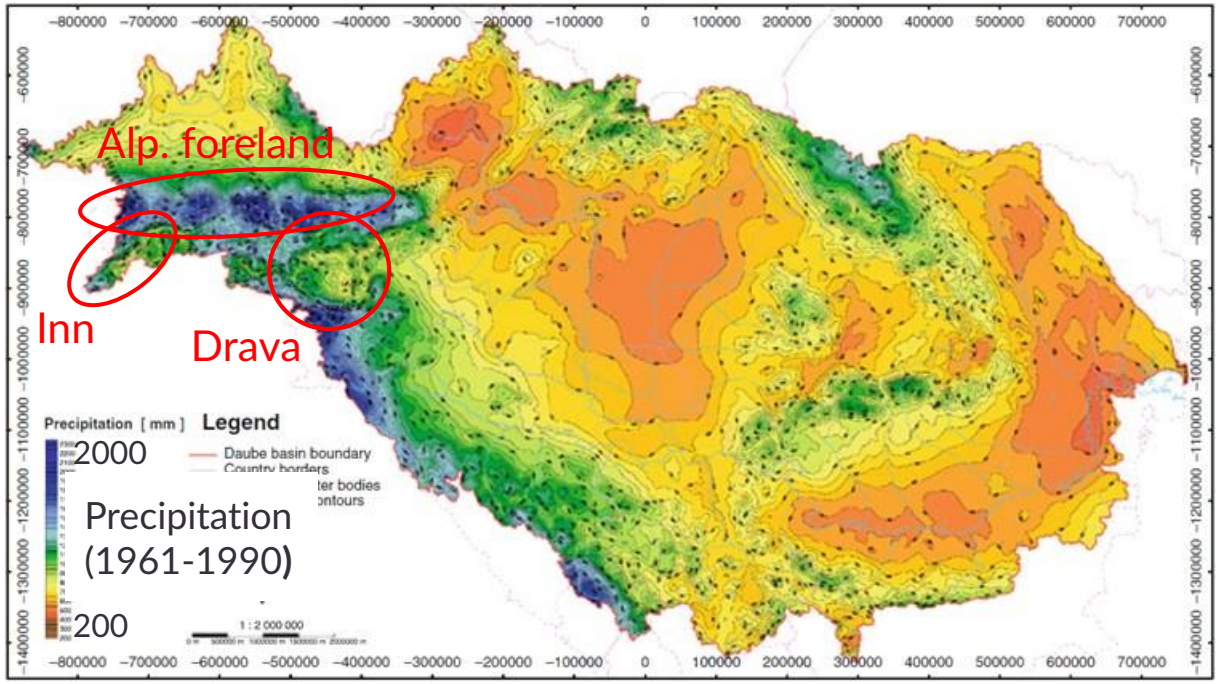
Bias-correction of precipitation

Climatologies for bias-correction of ERA5 precipitation:

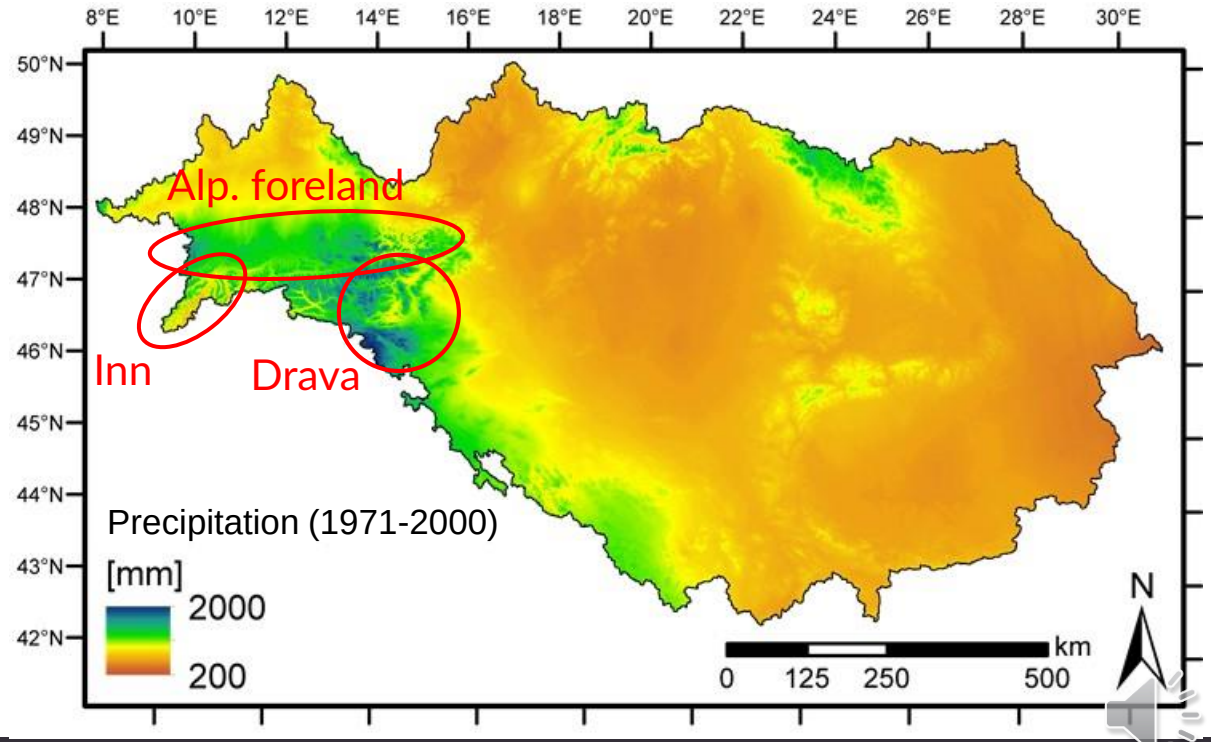
- GLOWA (Früh et al. 2006): Upper Danube
- PRISM (Frei & Schär 1998): Alps & Dinarides outside the Upper Danube
- WorldClim-2 (Fick & Hijmans 2017): Lower Danube

→ Alpine precipitation patterns not fully covered by WorldClim-2!

Mean annual precipitation 1961–1990 (Slovak Academy of Sciences)



Mean annual precipitation 1971–2000 (WorldClim)



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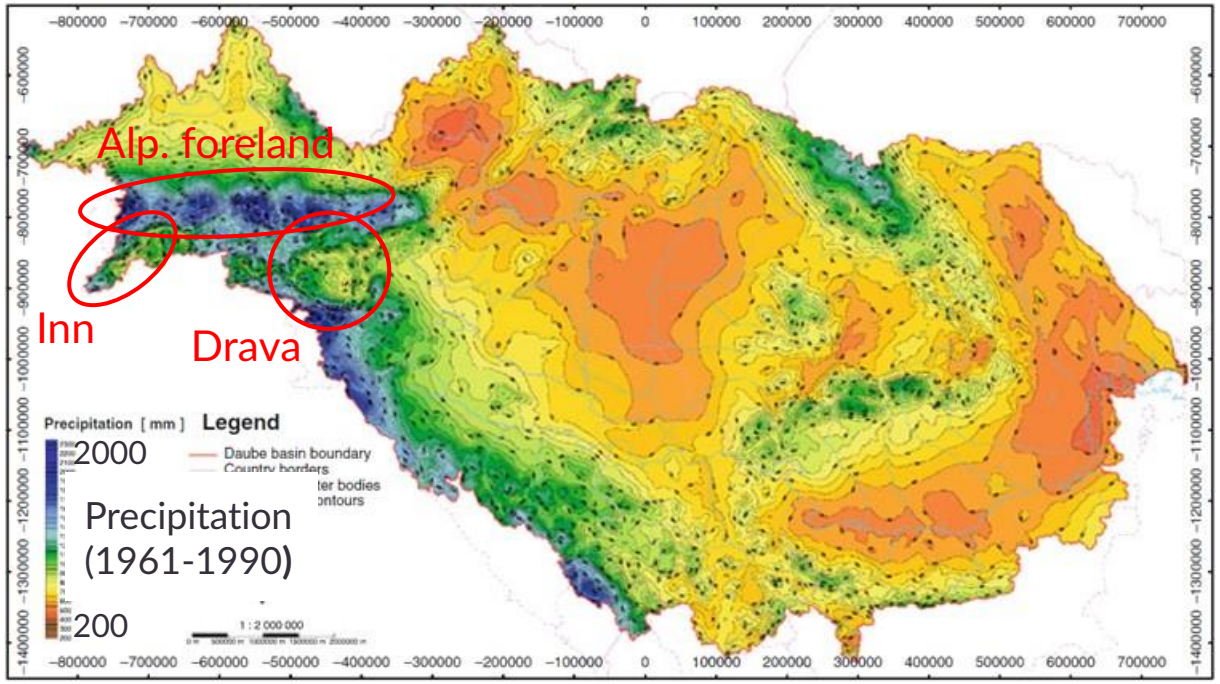
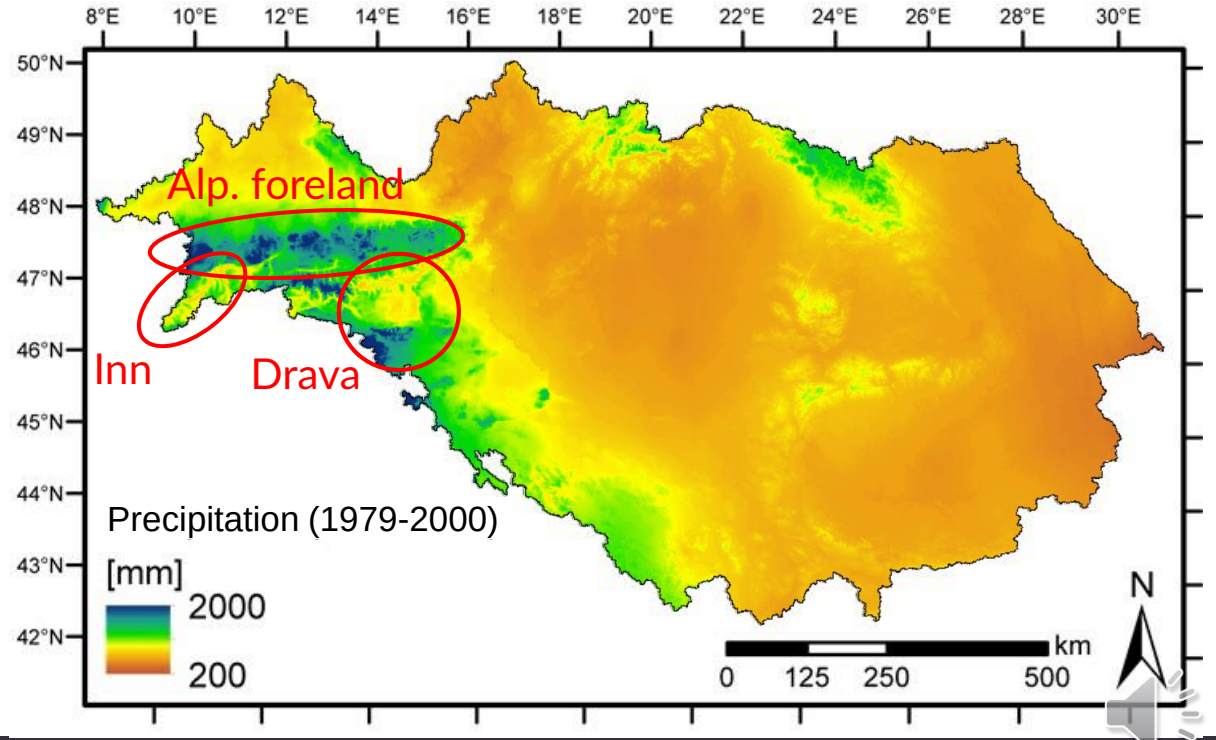


Mean annual precipitation 1979–2000 (GLOWA, PRISM, WorldClim-2)



Performance of bias-correction datasets

Simulated monthly discharge (1980-2016)

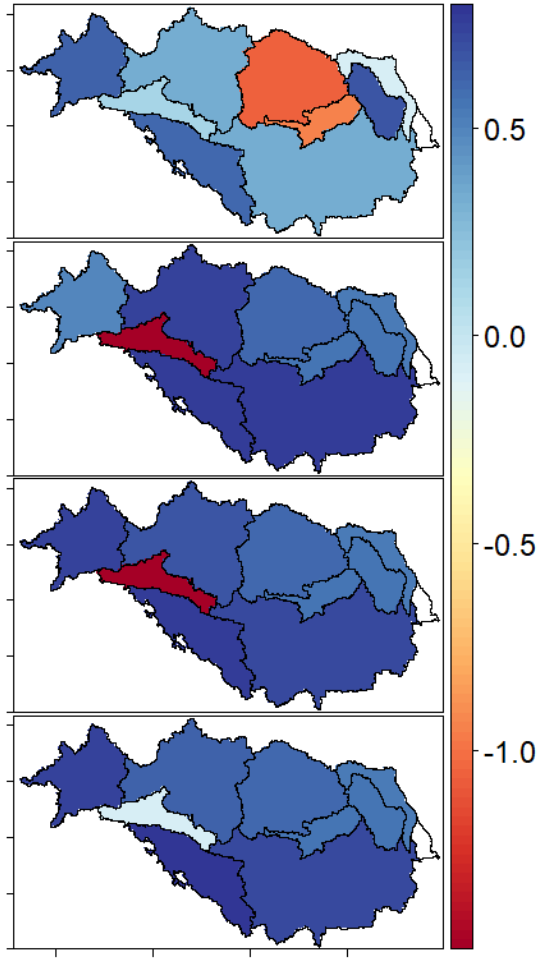
ERA5

ERA5 (WorldClim)

ERA5 (WorldClim, GLOWA)

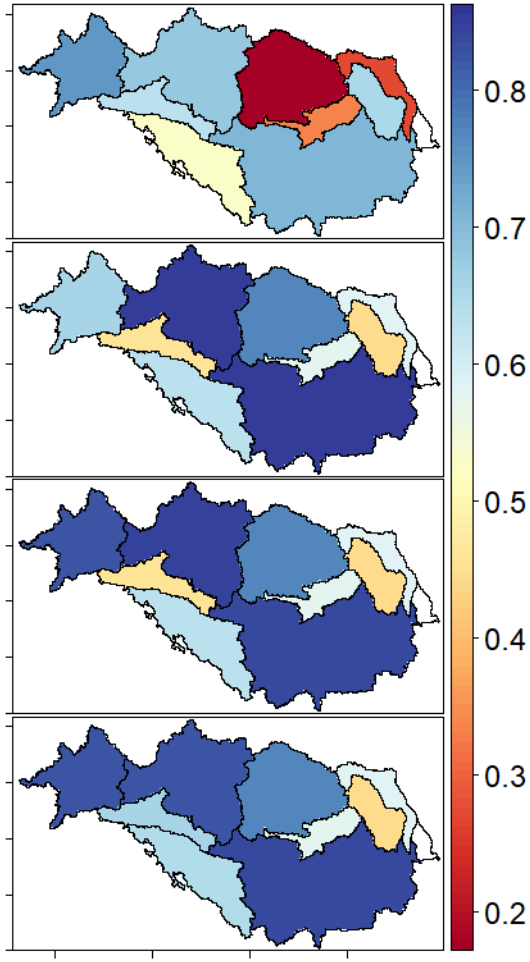
ERA5 (WorldClim, GLOWA, PRISM)

NSE



NSE: Nash-Sutcliffe-Efficiency

KGE



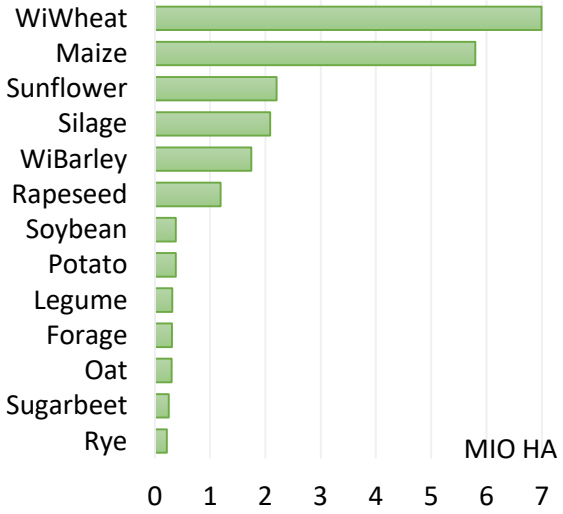
KGE: Kling-Gupta-Efficiency

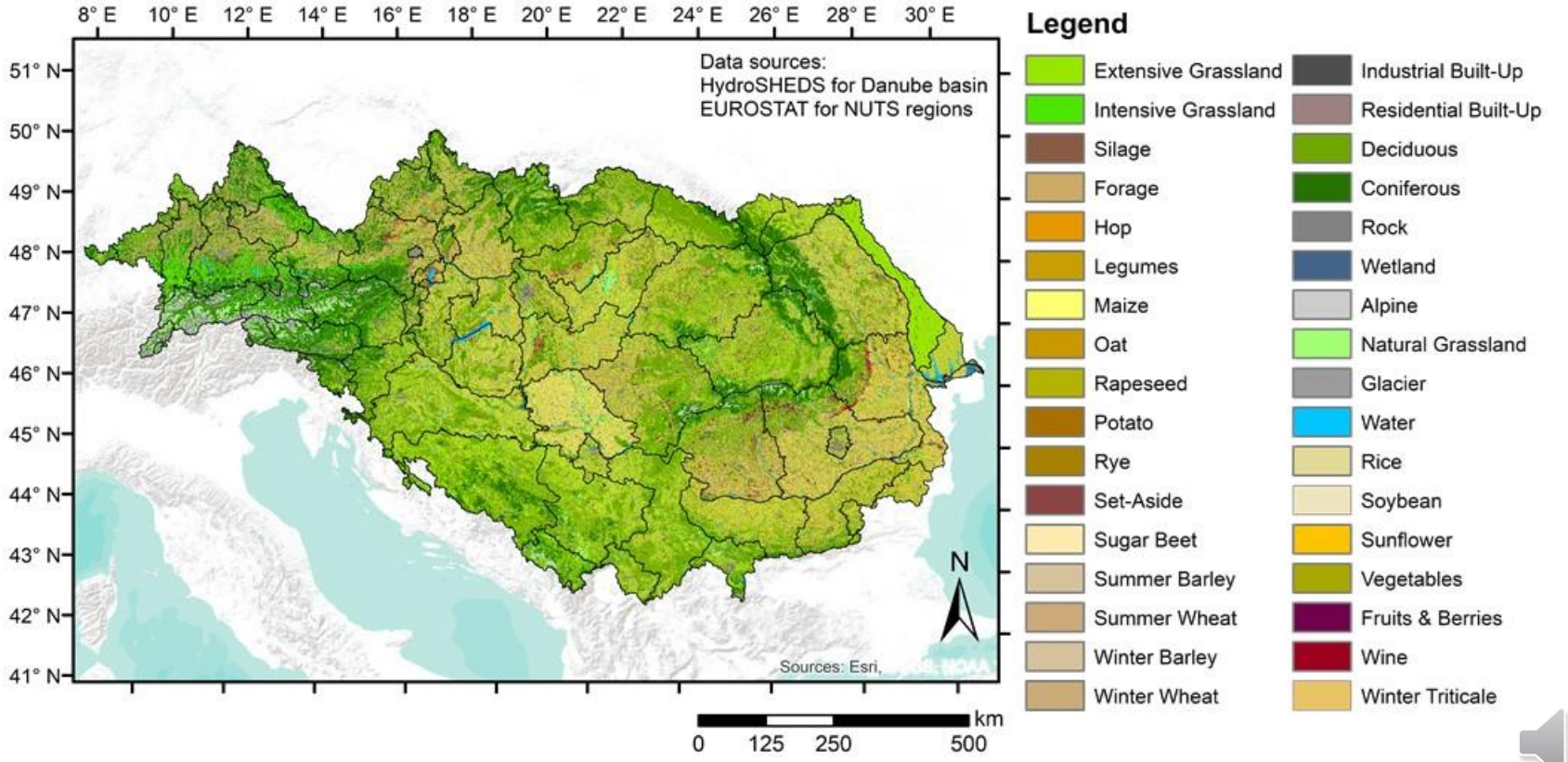
Generation of land use map

Generally, land use maps hold no information on crop distribution → crucial for yield & discharge modeling

Generation of land use map:

- Mosaic of CORINE Land Cover (EU states) and ESA CCI land cover (non-EU states)
- Statistical distribution of crops over agricultural area based on EUROSTAT cultivation statistics in NUTS-2 regions

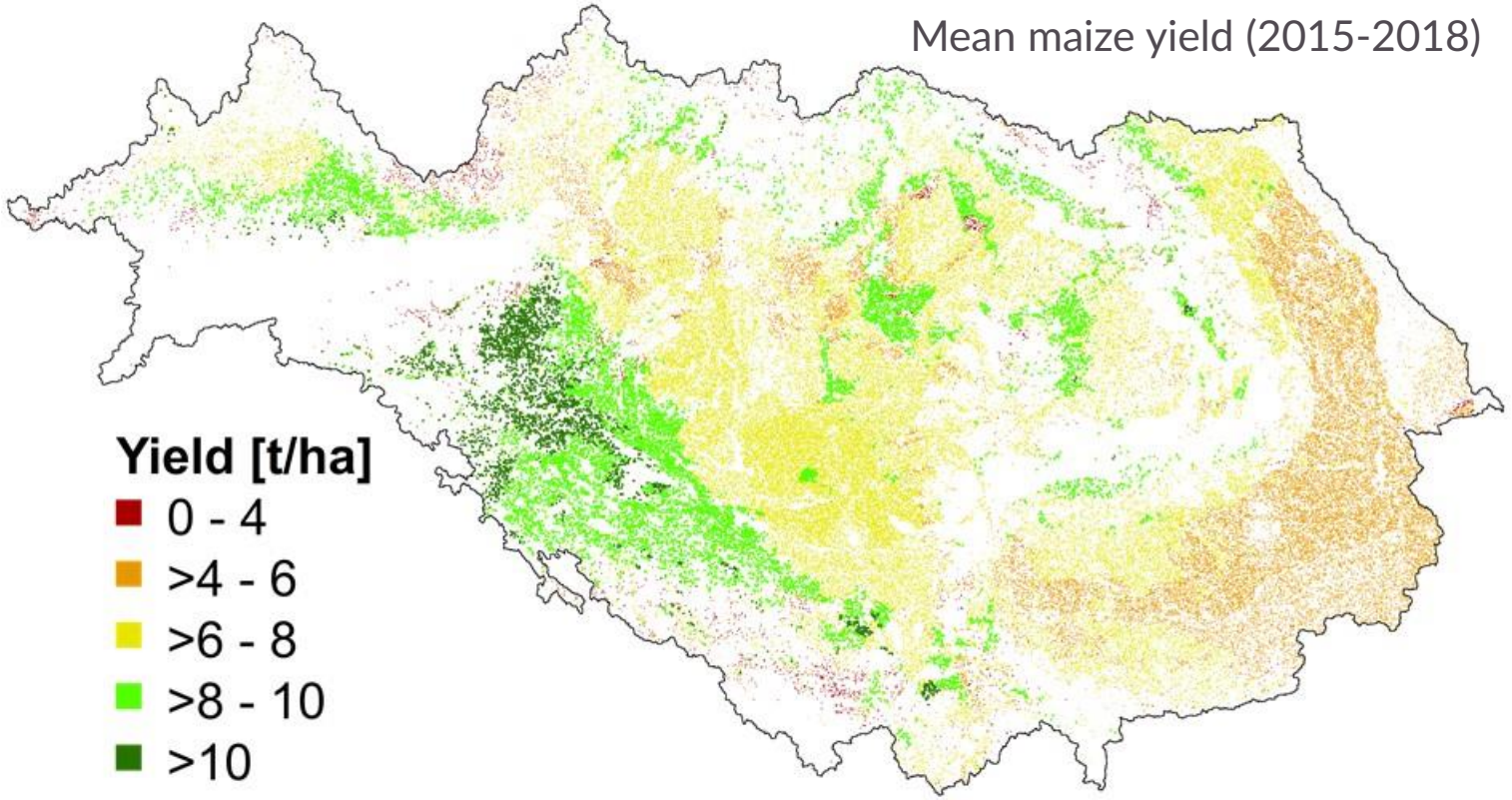




Management and basin-wide crop yields

Management information on crops:

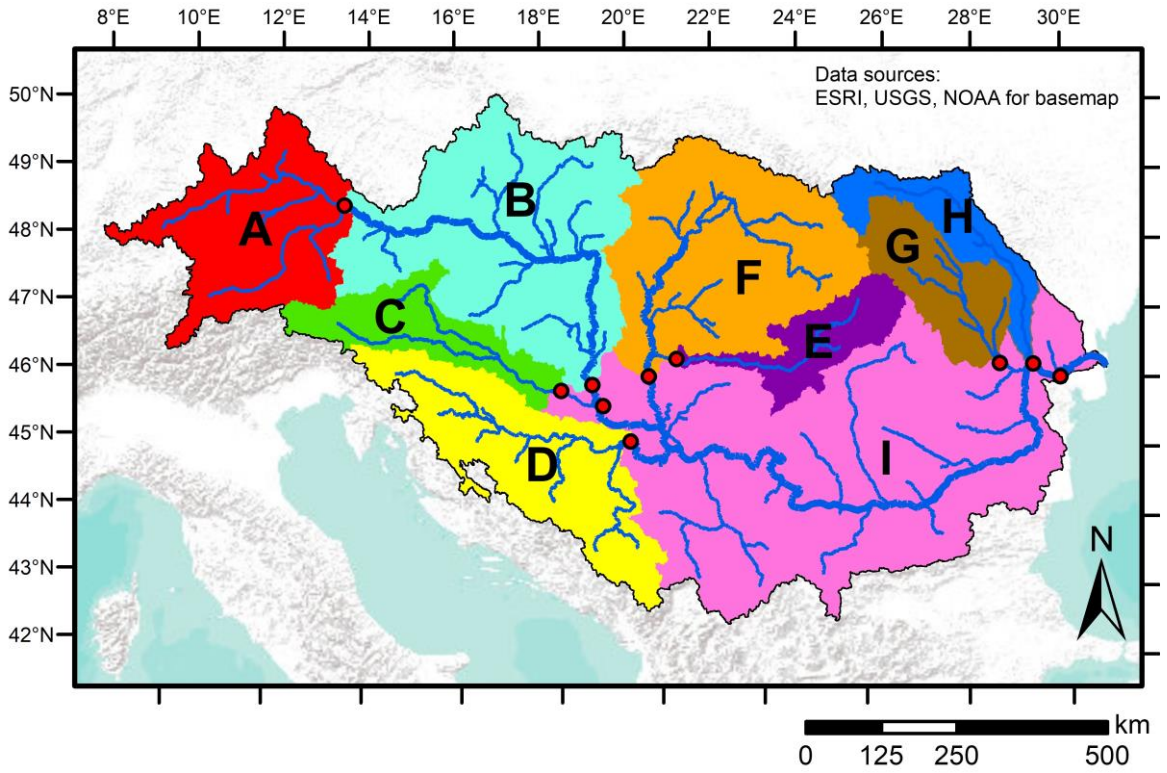
- Crop-specific seeding dates and growing seasons were taken from Sacks et. al (2010) augmented by JRC-MARS European Crop Calendar
- Fertilization was adjusted to national crop yield statistics 2000-2018



Modelled maize yield (2015-2018, on average): 6.9 t/ha

EUROSTAT maize yield in Danube countries (2015-2018, on average): 6.8 t/ha

Long-term water balance

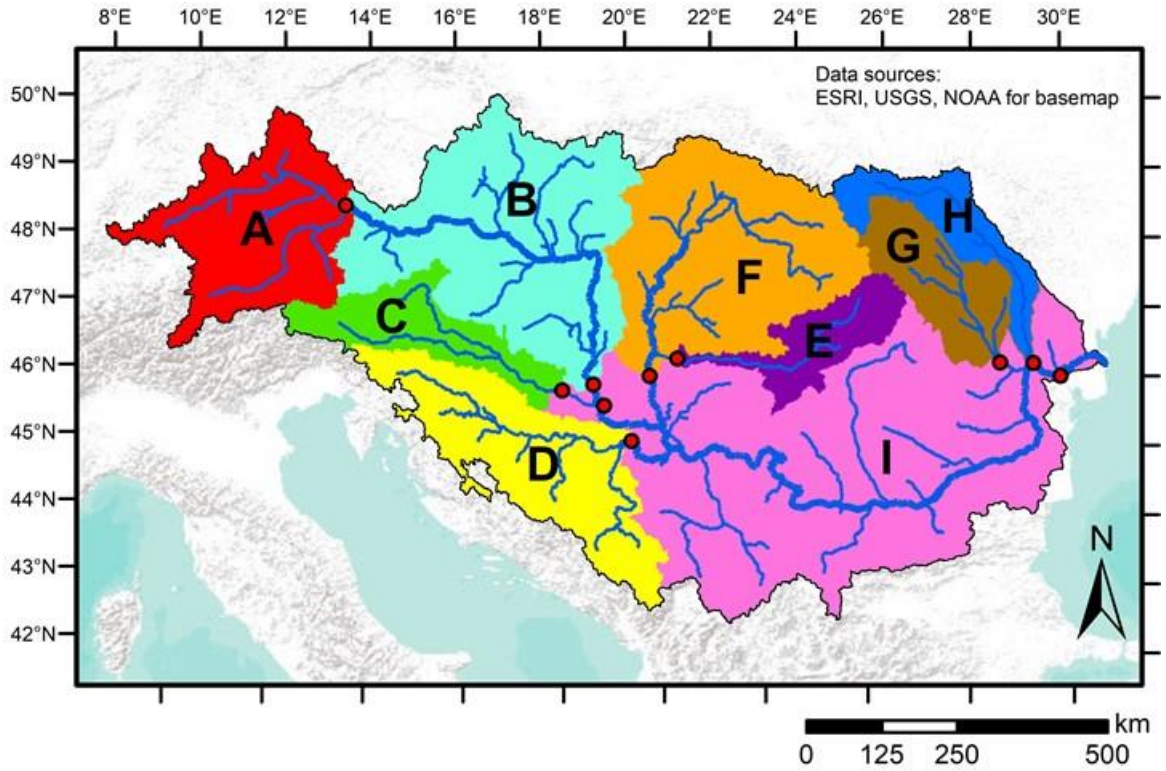


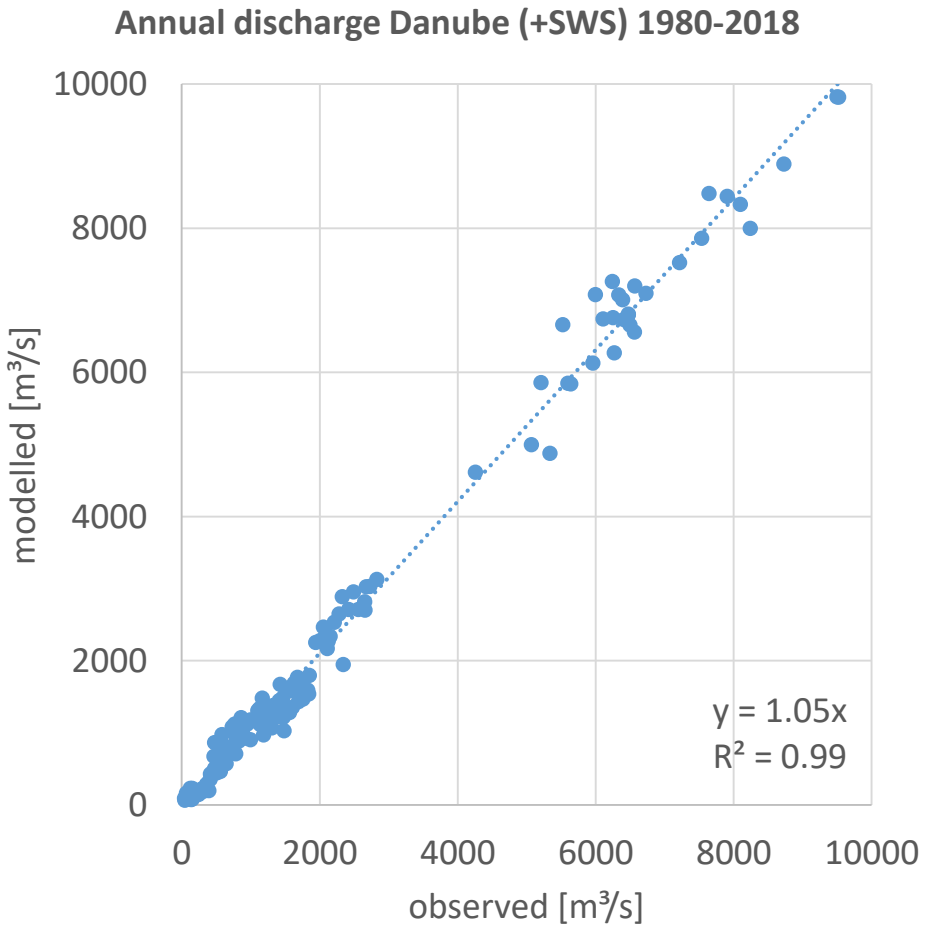
Water balance Danube (1980-2016)

	SB/Gauge	Precipitation [mm]	Evapotranspiration [mm]	Discharge [mm]	Water balance [mm]
A	Achleiten	1096	526	592	-23
B	Bezdan	897	522	349	26
C	Drava	968	572	441	-42
D	Sava	1127	586	613	-76
E	Mures	612	516	152	-58
F	Tisza	691	501	183	7
G	Siret	594	475	192	-76
H	Prut	579	460	97	31
I	Reni	776	530	279	-21
I	C. Izmail	773	508	267	0

Water balance = Precipitation – Evapotranspiration – Discharge (– Δ Storage)

Closing the water balance

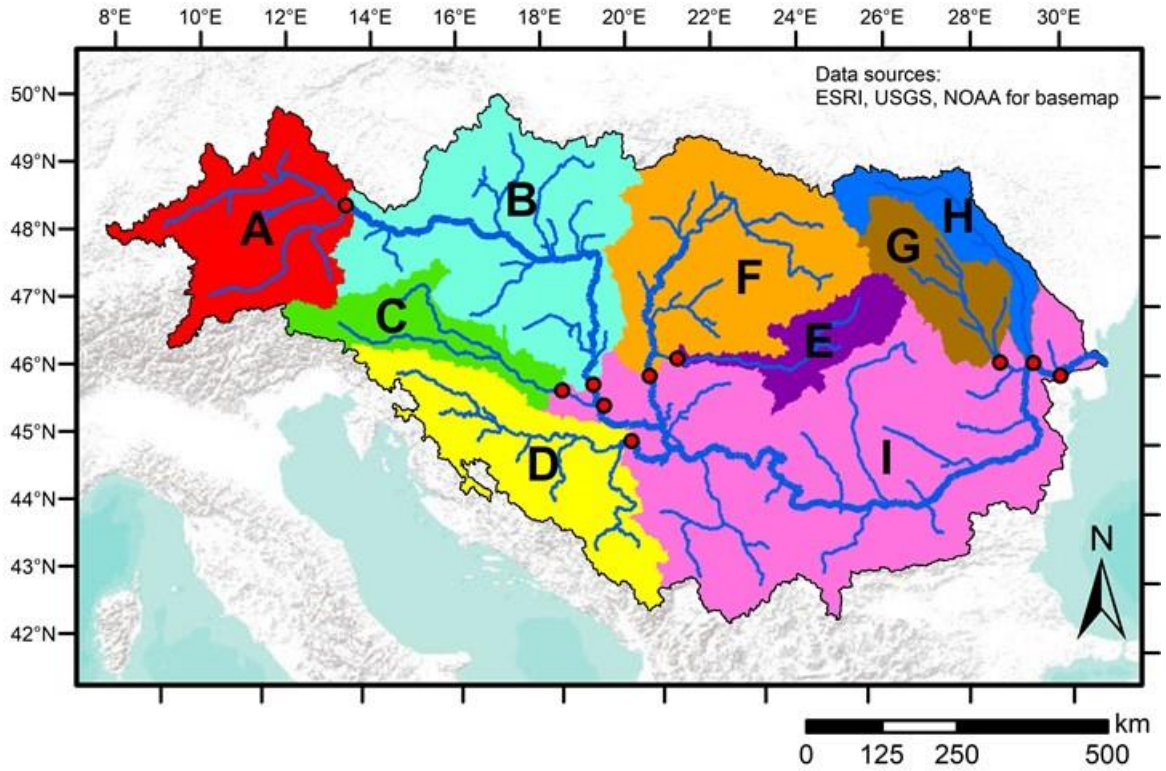


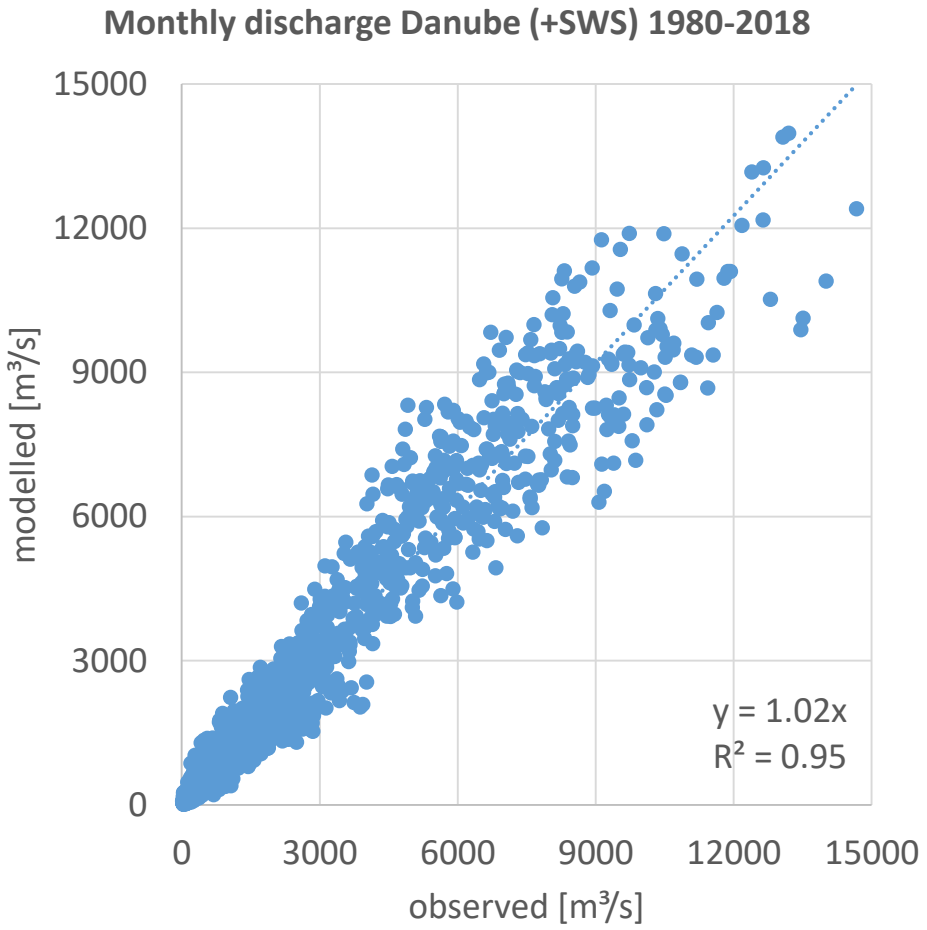


Approach:

- No calibration with measured data, closed water-, energy- and carbon-balance

Closing the water balance





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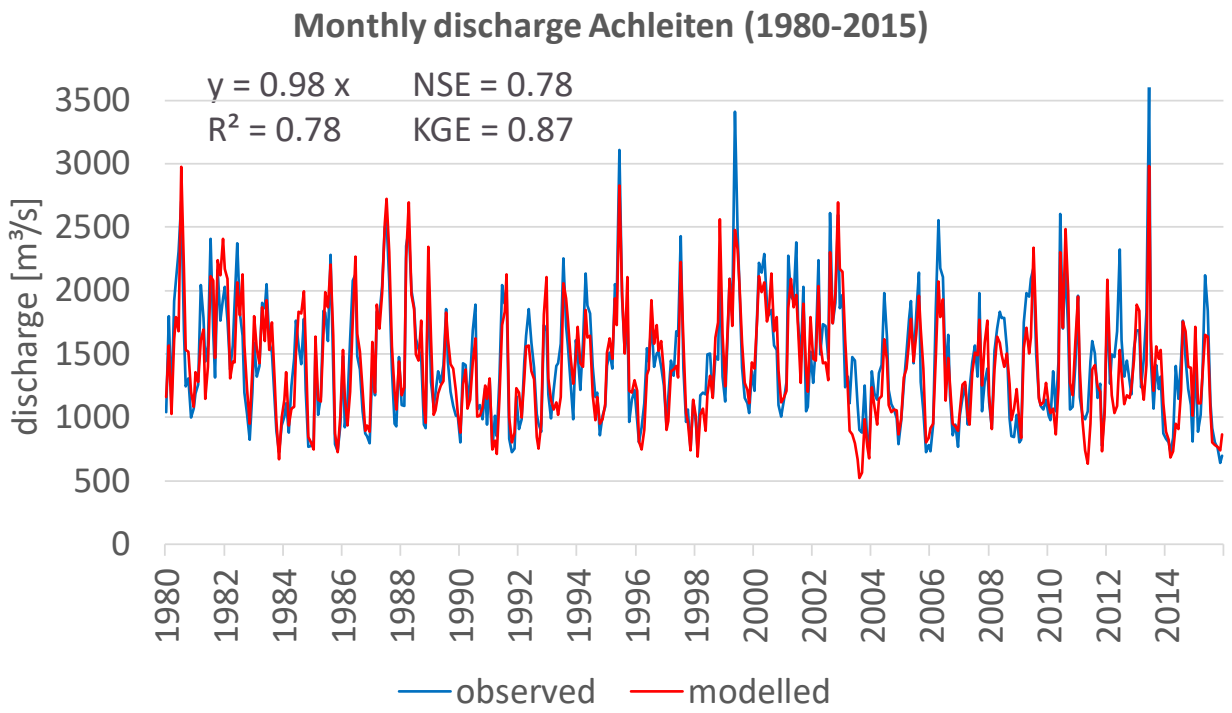
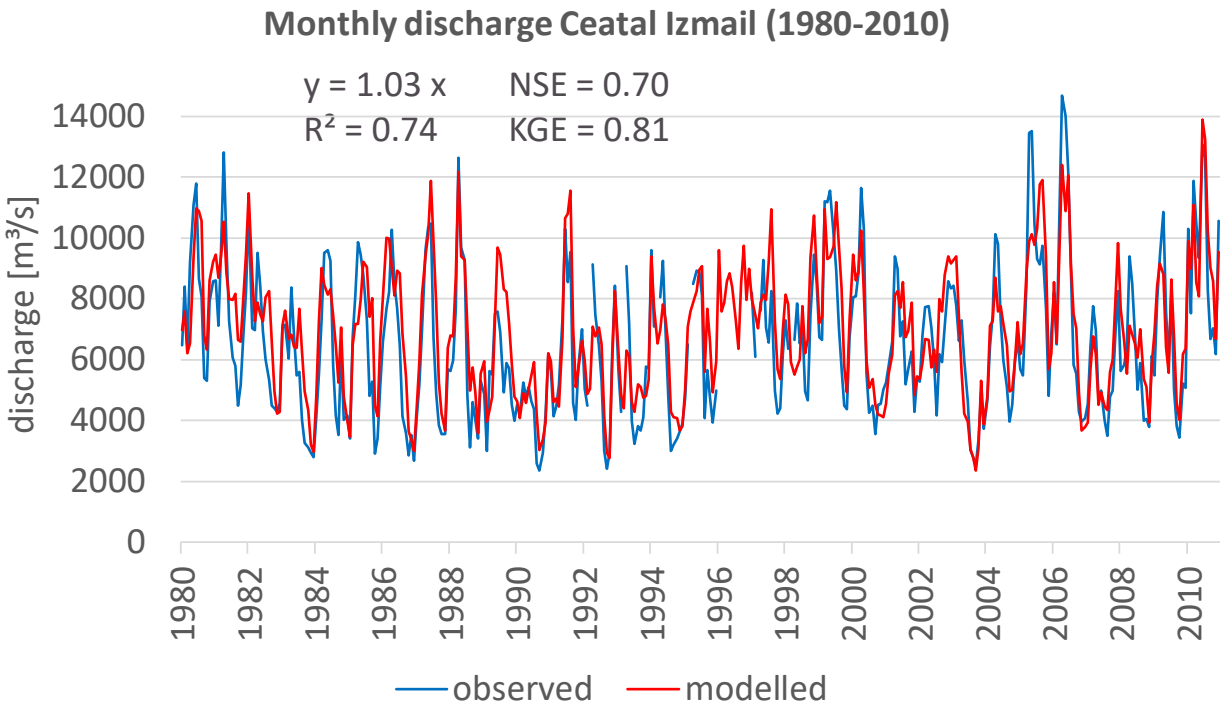
Discharge validation



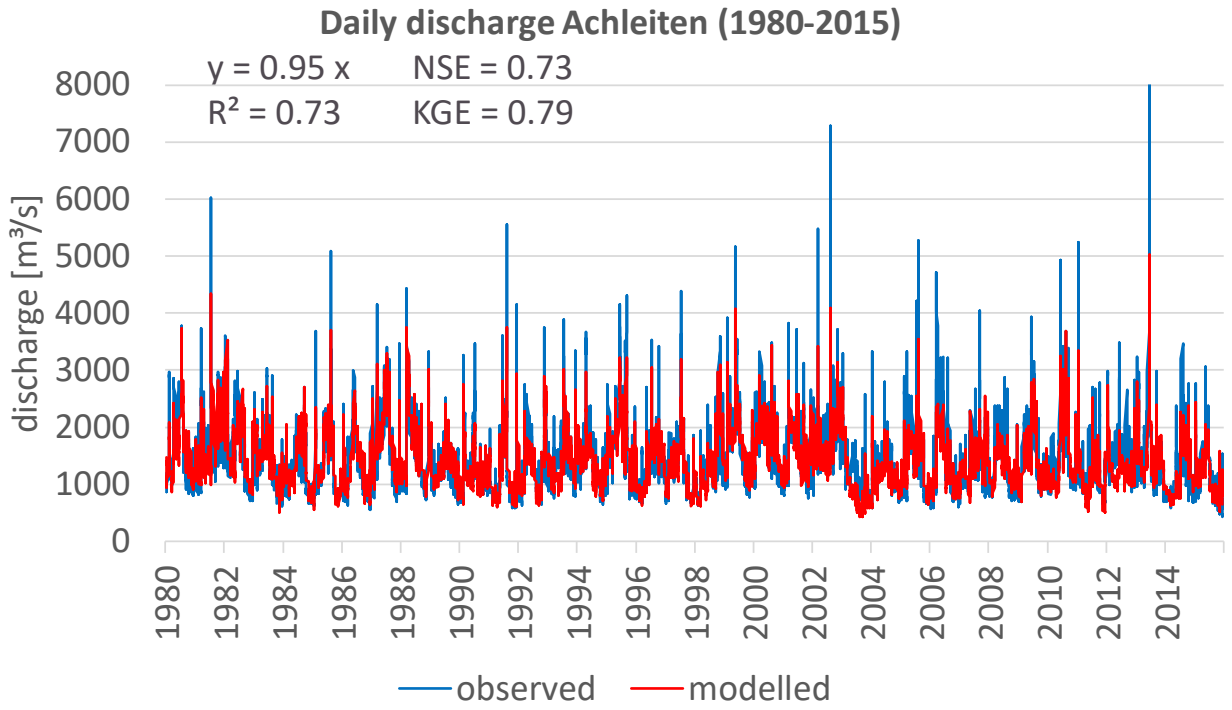


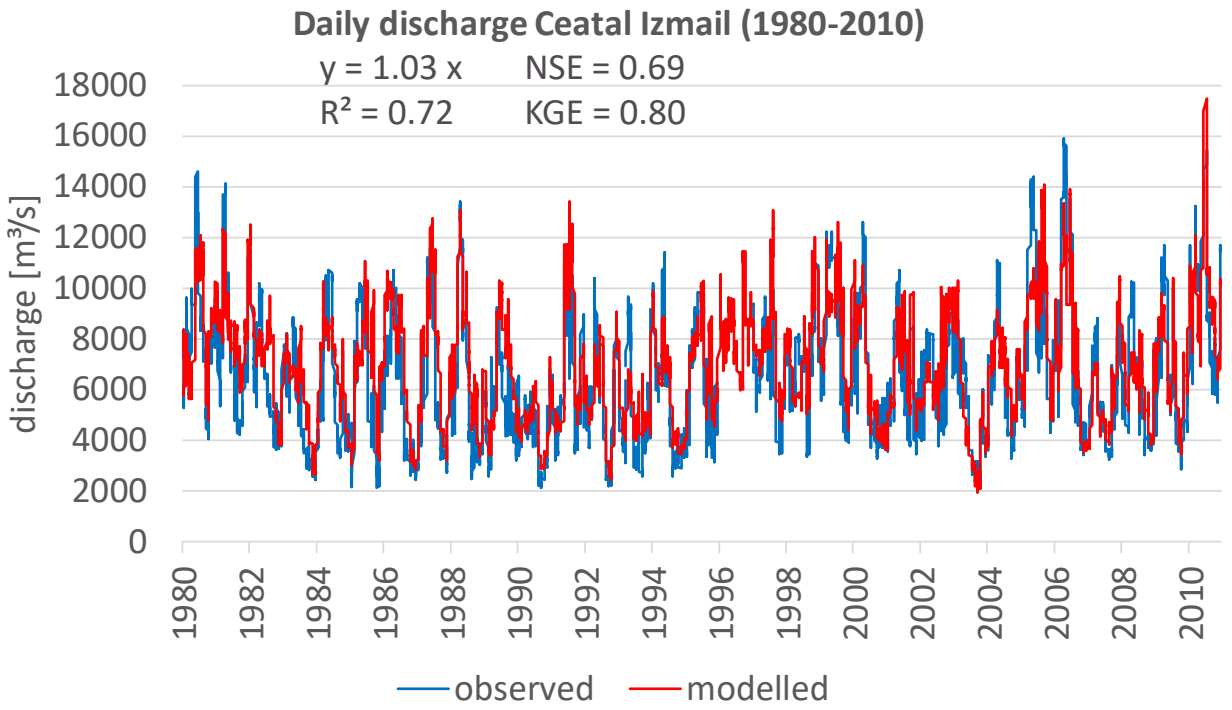
Monthly efficiency coefficients Danube (1980-2016)

SB/Gauge	Achleiten	Bezdan	Drava	Sava	Mures	Tisza	Siret	Reni	Ceatal Izmail
NSE	0.78	0.65	0.65	0.64	0.61	0.44	0.57	0.80	0.70
KGE	0.87	0.83	0.82	0.55	0.66	0.65	0.53	0.88	0.81

NSE: Nash-Sutcliffe-Efficiency, KGE: Kling-Gupta-Efficiency

Discharge validation





Daily efficiency coefficients Danube (1980-2016)

SB/Gauge	Achleiten	Bezdan	Drava	Sava	Mures	Tisza	Siret	Reni	Ceatal Izmail
NSE	0.73	0.65	0.49	0.62	0.40	0.33	0.44	0.77	0.69
KGE	0.79	0.80	0.75	0.53	0.59	0.60	0.40	0.85	0.80

NSE: Nash-Sutcliffe-Efficiency, KGE: Kling-Gupta-Efficiency

Conclusions

Integrated modeling of the Danube water balance by the hydro-agroecological model PROMET

- Biophysically based crop growth modeling → actual ET, actual yield
- Physically based hydrological modeling → discharge

→ closed water, energy and carbon balance! Water balance and yields very close to measurements!

→ overall good to very good regional efficiency coefficients for runoff-dynamics

→ no calibration, easy transfer to other watersheds.

Use of ERA5 reanalysis data as meteo-driver for hydrologic simulations:

- solid basis on the regional scale of watersheds with A > 200 km² up to >1 000 000 km²
- WorldClim-2 data very supportive for downscaling and bias-correcting ERA5 data
- WorldClim-2 inaccurate in Alpine regions, more local data necessary

Partners

Dept. of Geography, University of Munich

Prof. Dr. Wolfram Mauser
(coordinator)

Institute for the World Economy, Kiel

Prof. Dr Gernot Klepper
Dr. Ruth Delzeit

Helmholtz Center for Environmental Research (UFZ), Leipzig

Prof. Dr. Sabine Attinger

Institute for Environmental Planning, University of Hanover

Prof. Dr. Christina von Haaren

Helmholtz-Zentrum Geesthacht, Climate Service Center Germany, Hamburg

Prof. Dr. Daniela Jacob
Dr. Susanne Pfeifer

Leibniz Supercomputing Centre (LRZ) of the Bavarian Academy of Sciences, Munich

Prof. Dr. Dieter Kranzlmüller
Dr. Anton Frank

VISTA Geoscience Remote Sensing GmbH, Munich

Dr. Heike Bach

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Virtual Water Values

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