Towards assessment of river discharge and glacier dynamics in the Aksu River basin in the context of climate change

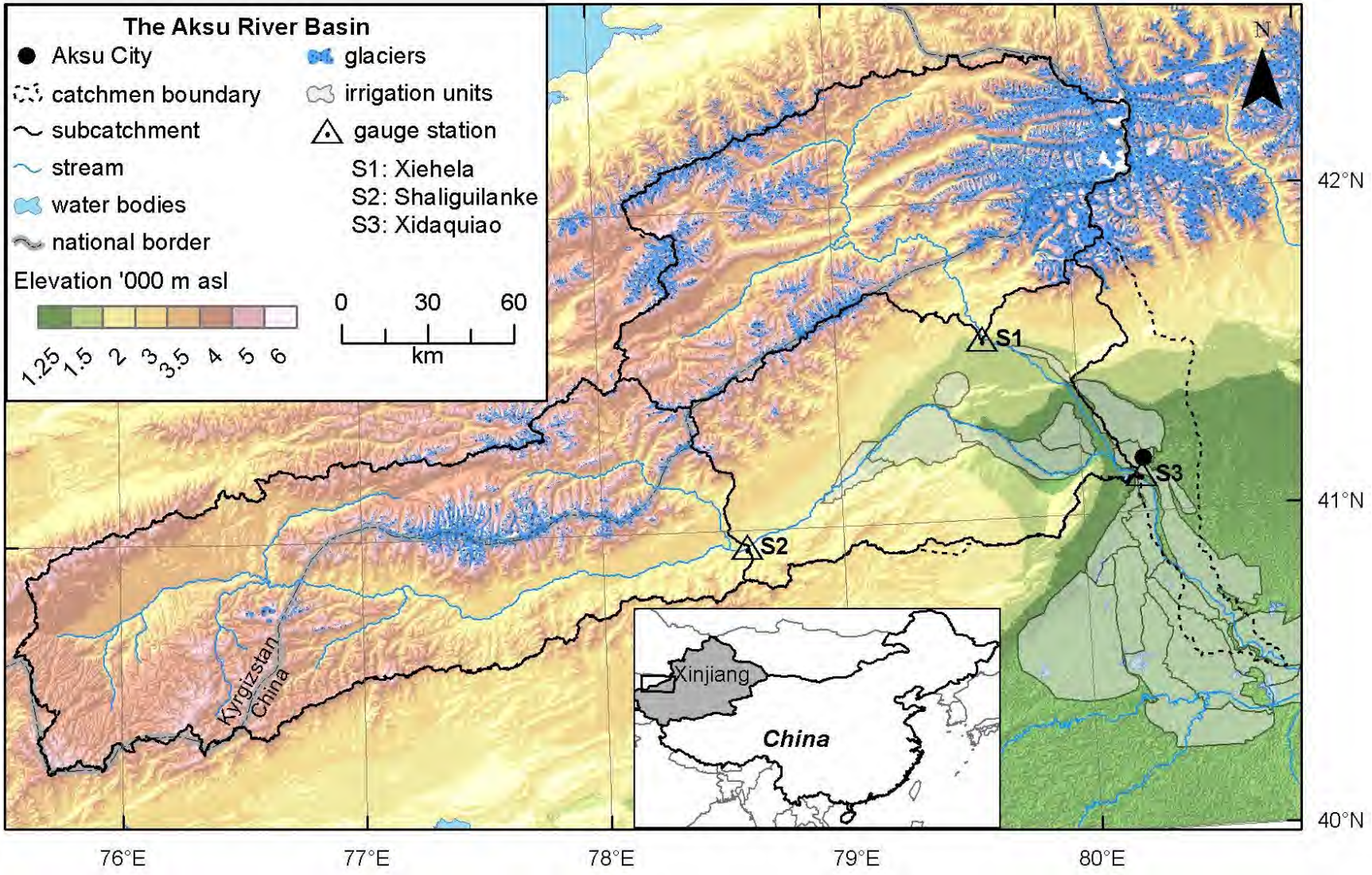
Valentina Krysanova, Tobias Bolch, Manfred Buchroithner, Doris Düthmann, Shaochun Huang, Zbigniew Kundzewicz, Christoph Menz, Bruno Merz, Juliane Peters, Tino Pieczonka Sergiy Vorogushyn and Michel Wortmann

(PIK, GFZ, TUD)

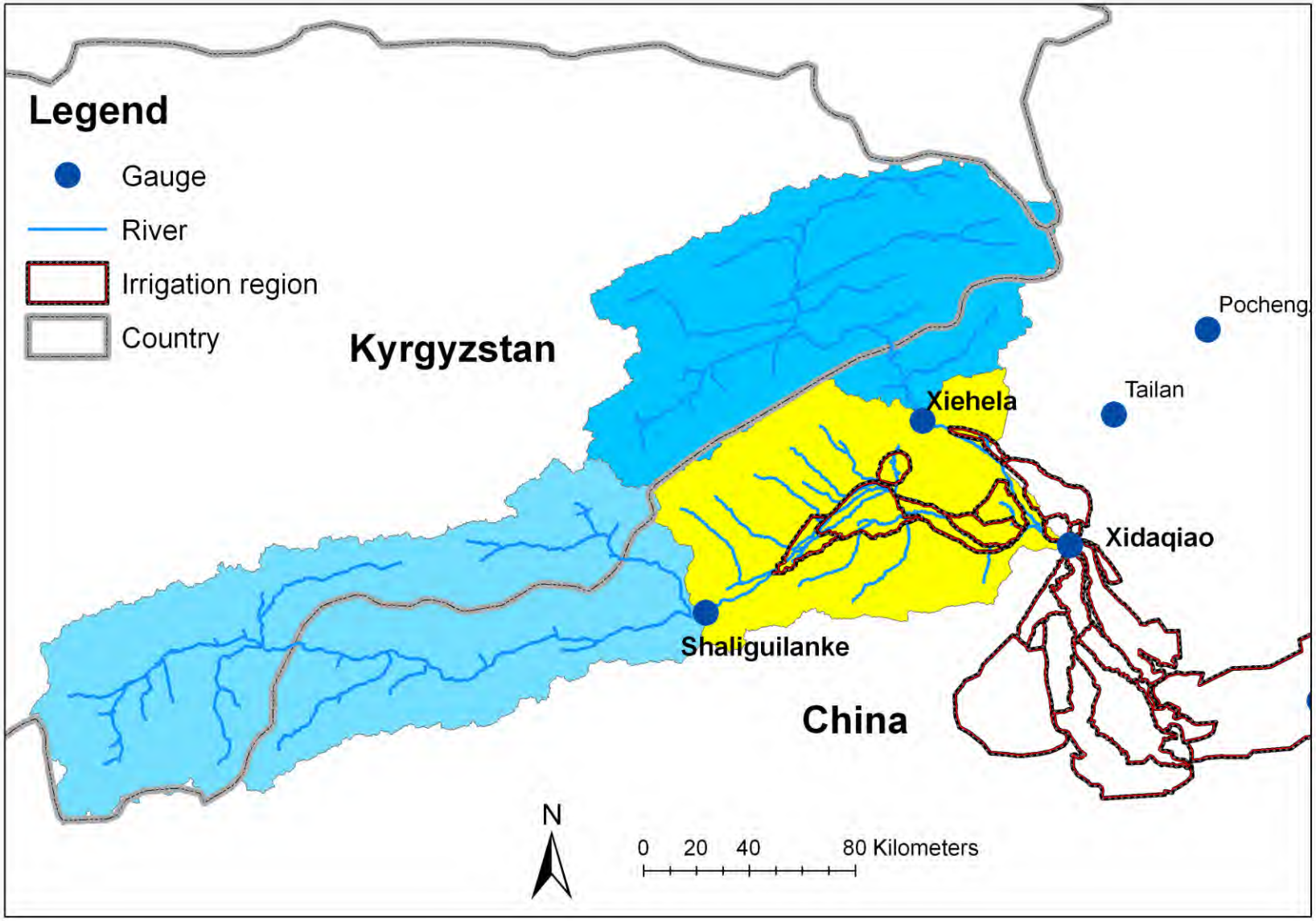
OUTLINE

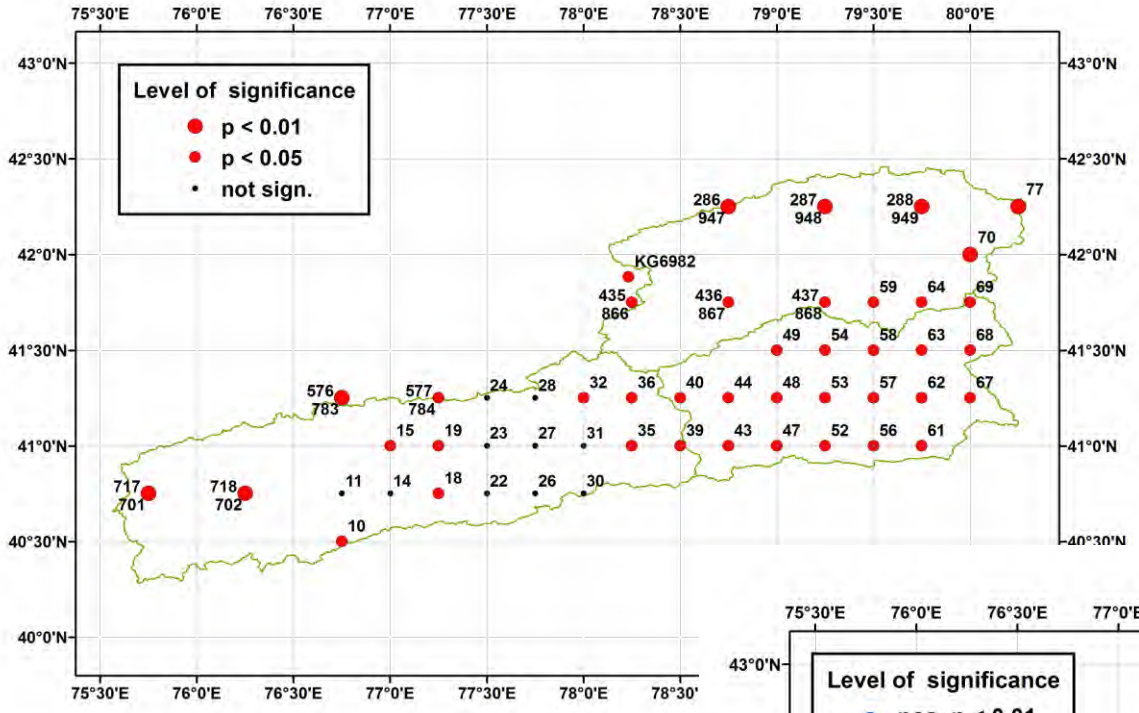
- **Case study area**
- **Data analysis**
  - Trends T, P, Q
  - Correlation T, P, Q
  - Glaciers dynamics
- **Climate scenarios**
- **Hydrological modelling**
  - Modelling of the headwater subcarchments
  - Influence of GLOFs on river discharge: a model-based analysis
  - Modelling of the lower part of the basin
- **Publications**

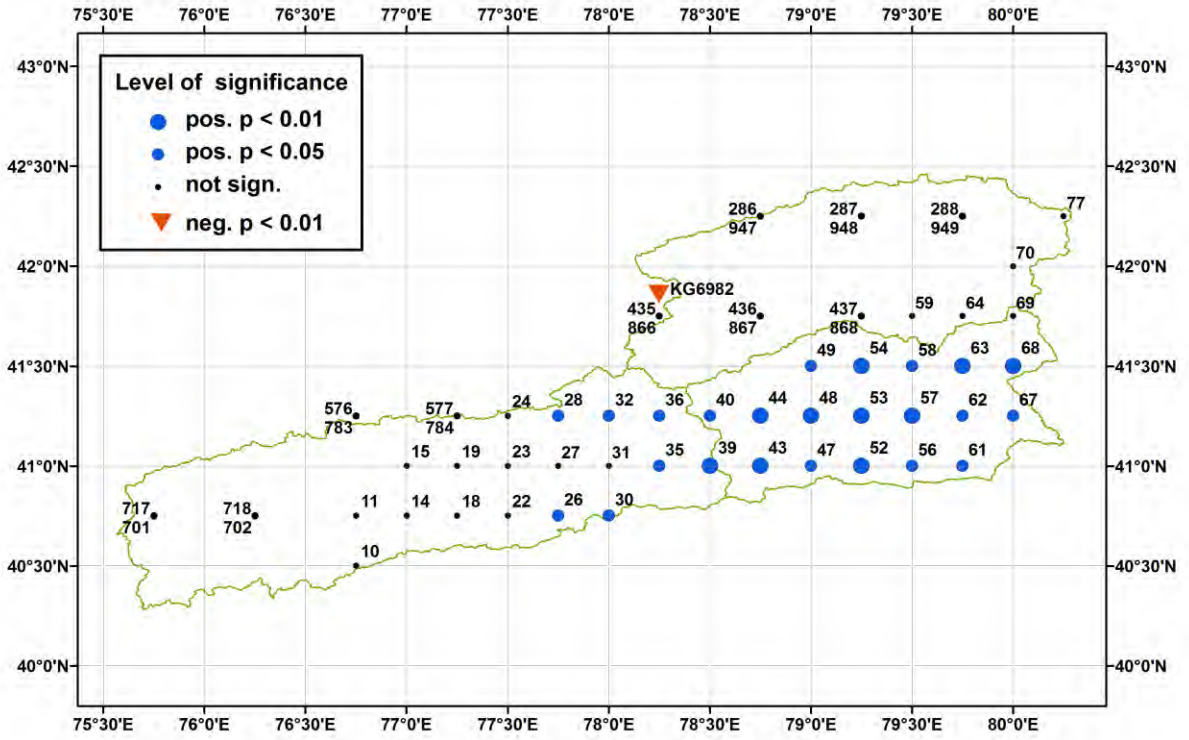
CASE STUDY AREA: the Aksu River basin



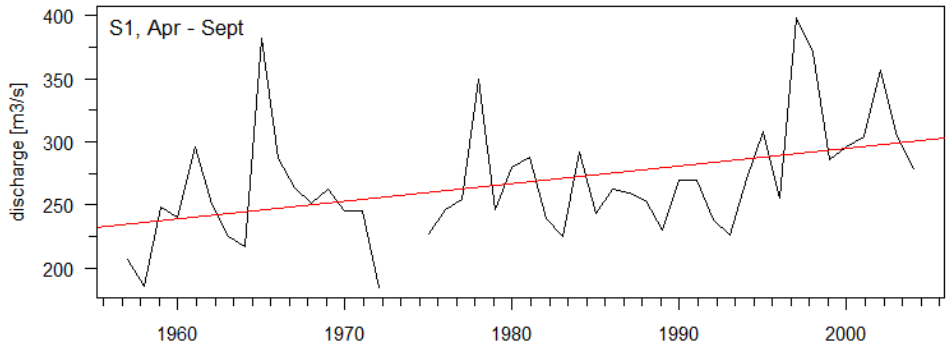
STUDY AREA: the Aksu basin & 3 subbasins

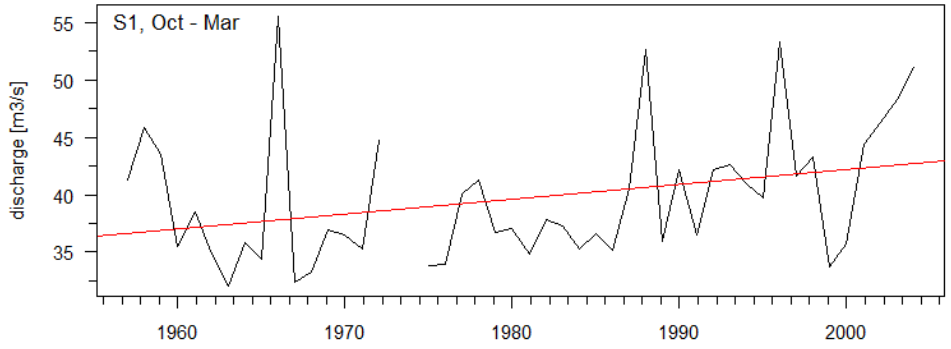


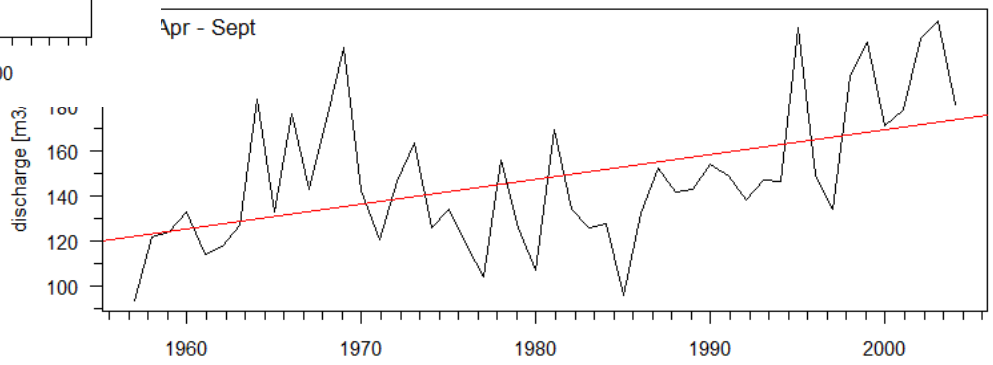




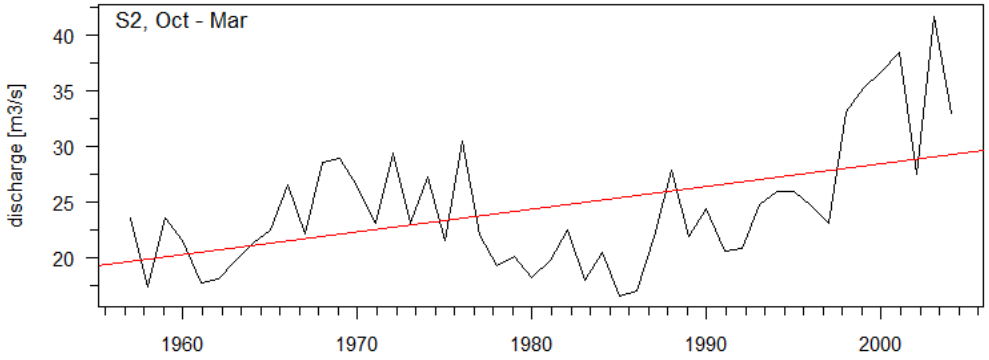
DATA ANALYSIS:
Trends in T, P





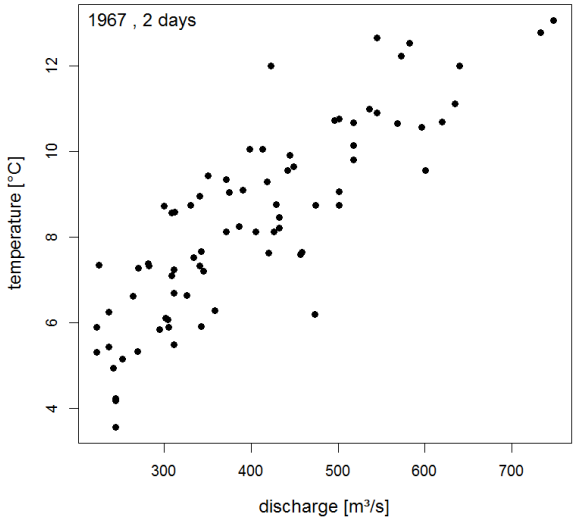


DATA ANALYSIS:
Trends in river discharge

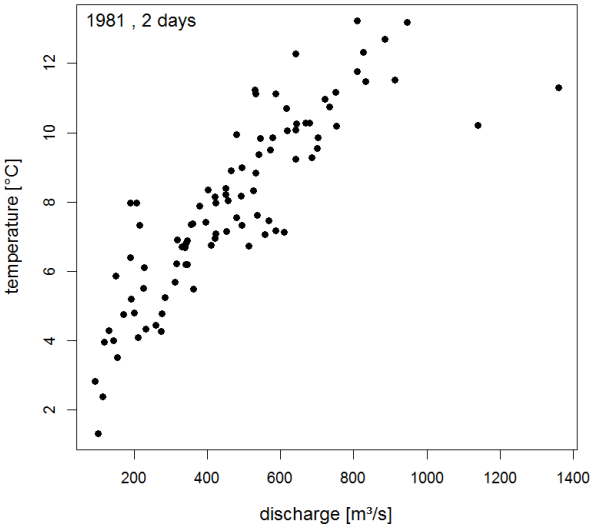


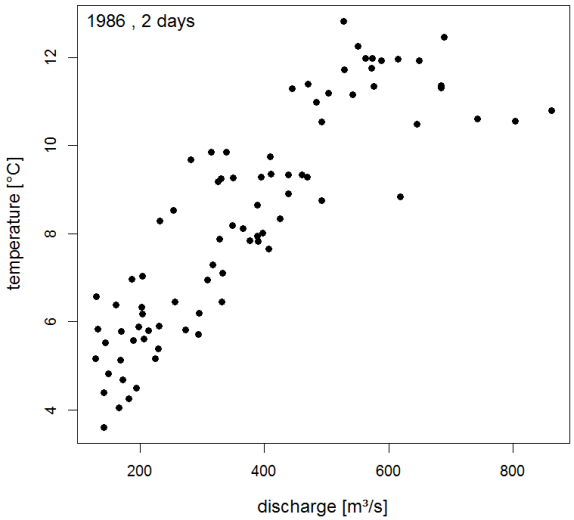
DATA ANALYSIS: Correlation T & Q, P & Q

at headwater sub-catchments



Xiehela, T & Q, 2 days delay





	S1, 29% gl.		*S2, 4% gl.*	
	T&Q	**P&Q**	**T&Q**	**P&Q**
daily	+	--	+	--
seasonal	+	--	--	+

DATA ANALYSIS: Glacier area change

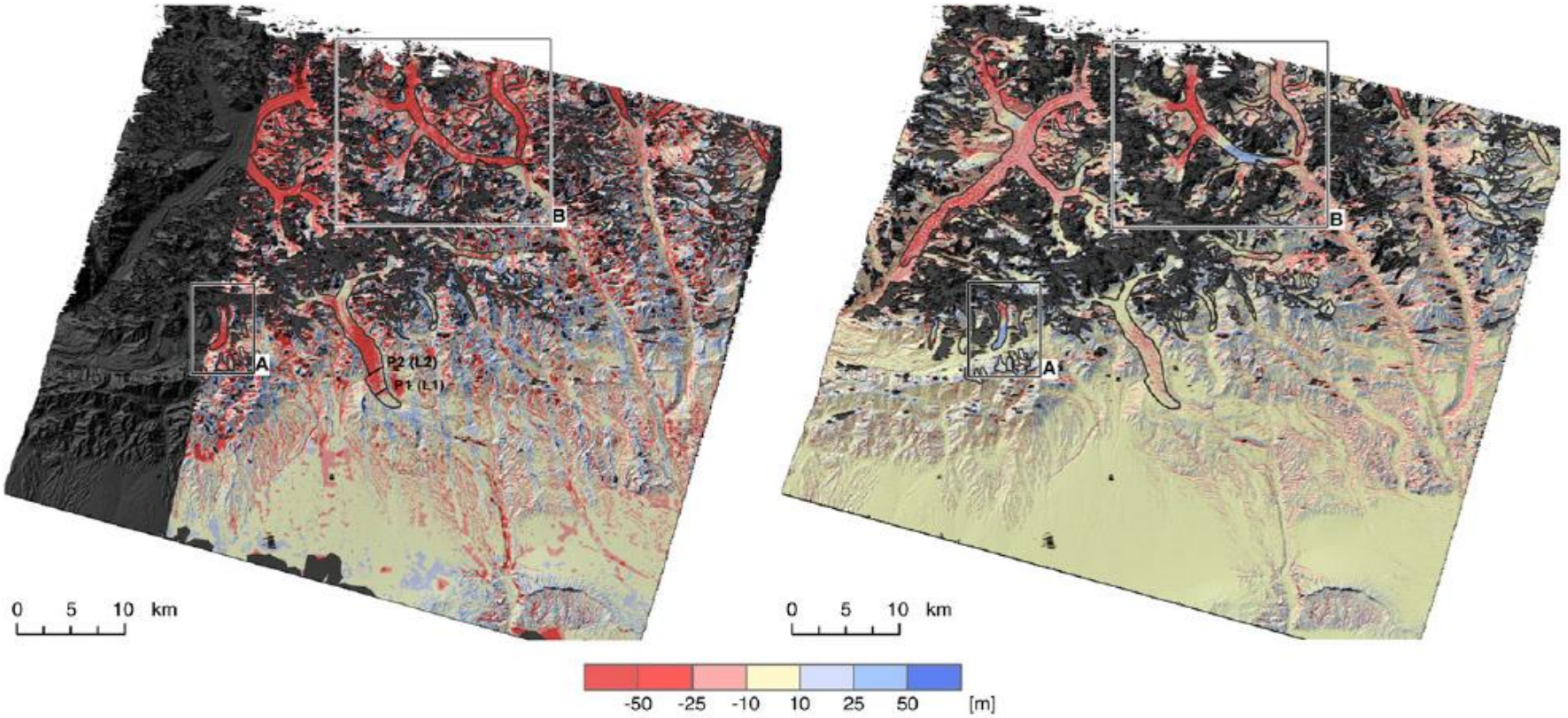
Glacier area changes in Sary-Djaz river basin

Region	Glaciated area (km^2)		Change in glaciated area (1990–2010)	
	1990	2010	Absolute value (km^2)	Relative value (%)
North	487.4 ± 9.7	455.8 ± 9.1	−31.6 ± 13.4	6.5 ± 2.7
East	926.8 ± 18.5	912.8 ± 18.3	−14.0 ± 26.0	1.5 ± 2.7
South	130.1 ± 2.6	124.1 ± 2.5	−6.0 ± 3.6	3.4 ± 2.7
West	510.7 ± 10.2	485.2 ± 9.7	−25.5 ± 14.1	5.0 ± 2.7
Total	2055 ± 41.1	1977.9 ± 39.6	−77.1 ± 57.0	3.7 ± 2.7

Ozmonov et al. (2013)

Glacier mass changes in Central Tien Shan:

Pik Pobedy/Tomur Feng Area (evaluation by the TUD team)



Mass budget 1976-2009

-0.35 ± 0.15 m w.e./a

Mass budget 1999-2009

-0.23 ± 0.19 m w.e./a

CLIMATE SCENARIOS under preparation at PIK

- Climate scenarios for the Tarim basin are currently being produced at PIK using CCLM (Cosmo Climate Model, a regional climate model) and STARS (statistical downscaling). CCLM downscales the global climate model results, and STARS is driven by T trend.
- CCLM is driven by 2 different GCM's for 3 emission scenarios with 1 simulation each:

  ECHAM5/MPI-OM – **SRES B1, A1B, A2**,

  MPI-ESM-LR – **RCP2.6, RCP4.5, RCP8.5**

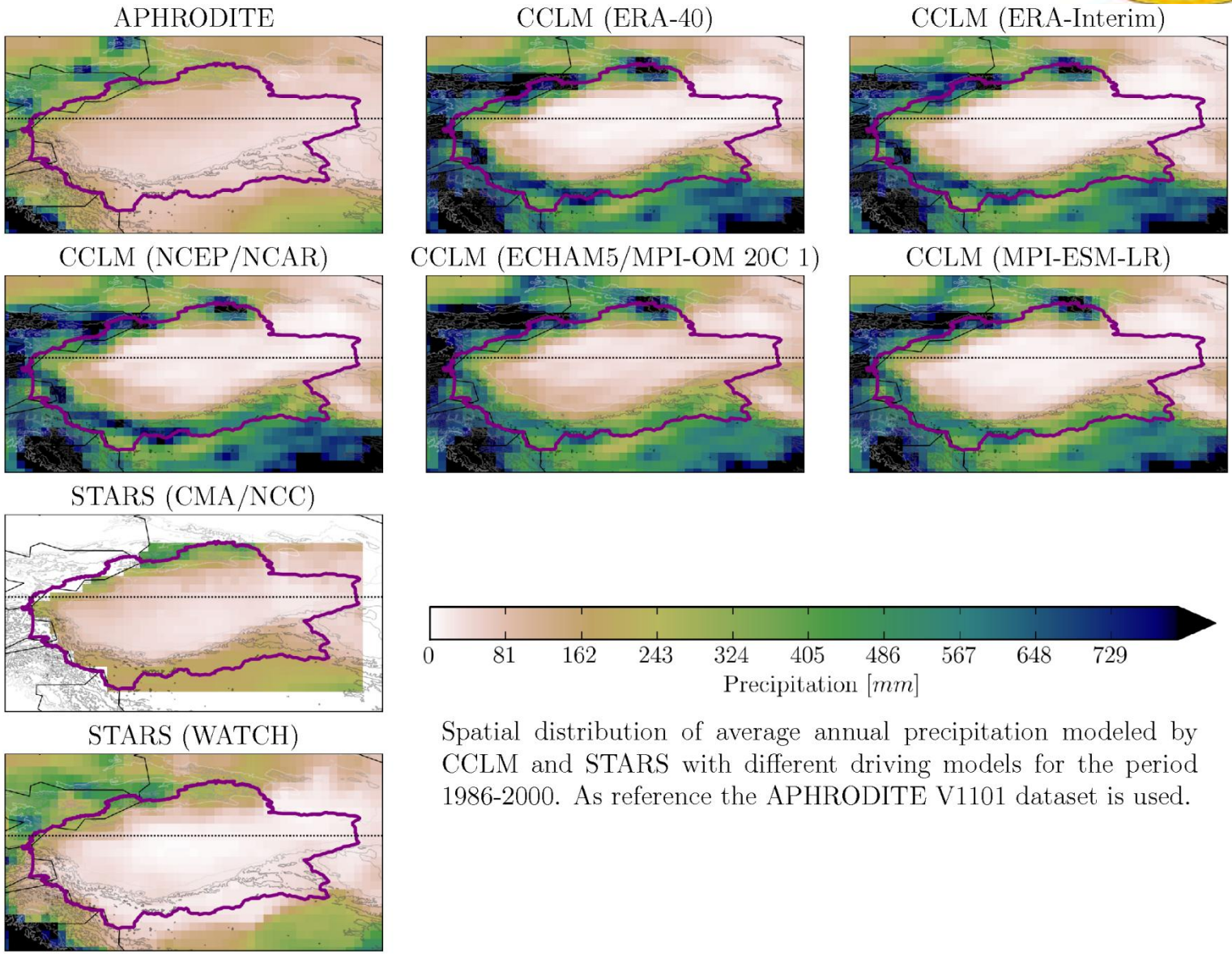
  = 6 climate scenarios representing the whole bandwidth of the emission scenarios used in IPCC AR4 and AR5
- STARS scenarios driven by WATCH-FD with temperature trends:

  -1.5, -1.0, -0.5, 0, +0.5, +1.0, +1.5, +2.0, +2.5, +3.0,

  whereas each scenario includes 100 simulations

  = 1000 simulations in total.

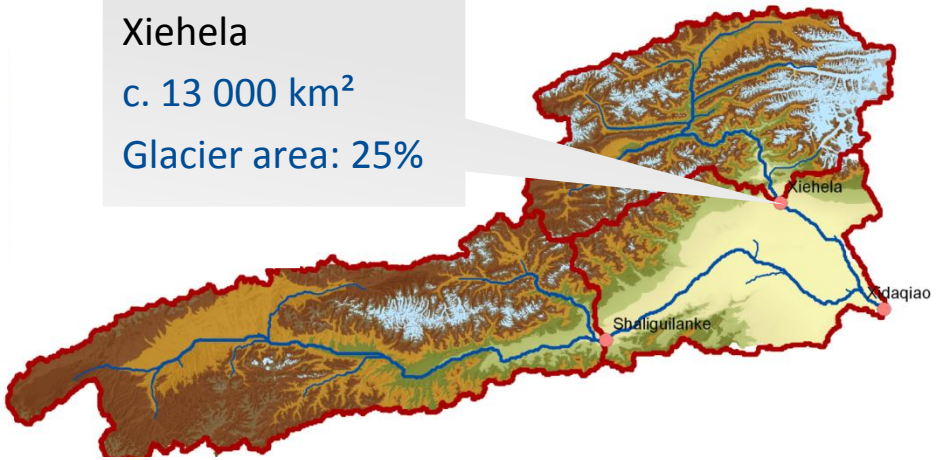
Example: CCLM and STARS simulation of P, 1986-2000 (PIK, Ch. Menz, PIK)

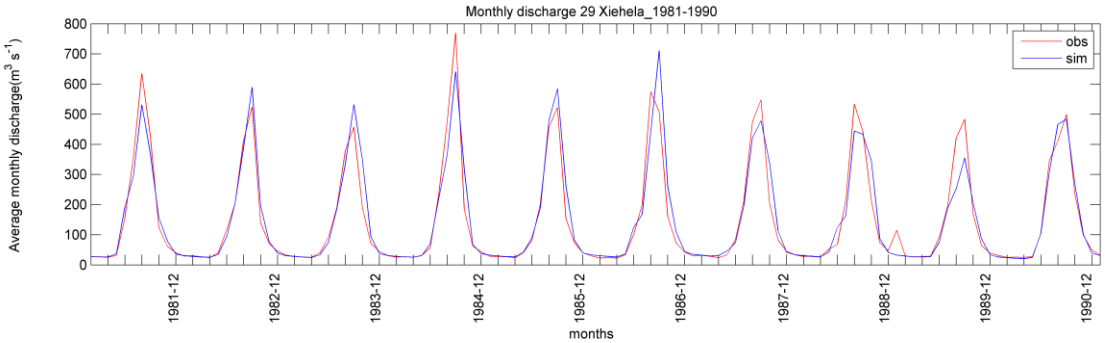


Spatial distribution of average annual precipitation modeled by CCLM and STARS with different driving models for the period 1986-2000. As reference the APHRODITE V1101 dataset is used.

HYDROLOGICAL MODELLING of headwater sub-catchments (GFZ, Doris Düthmann)

- Headwater catchments strongly influenced by snow and glacier melt
- Hydrological model: WASA
- Challenge: get right answers for the right reasons - precipitation bias can be compensated by bias in glacier melt
- Approach: multi-objective calibration considering glacier mass balance and snow cover data



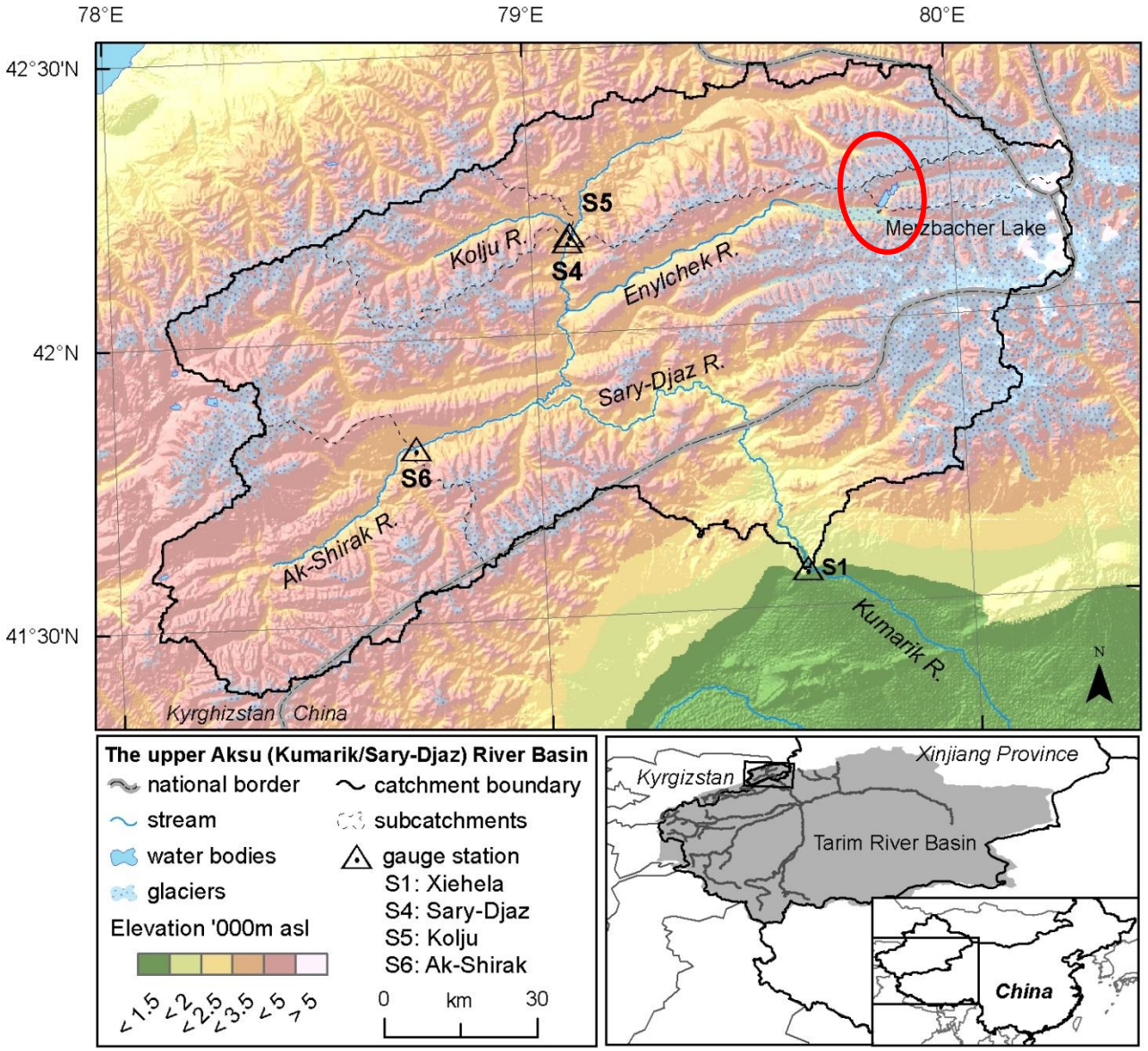


Simulated with WASA and observed discharge in Xiehela, 1981-90

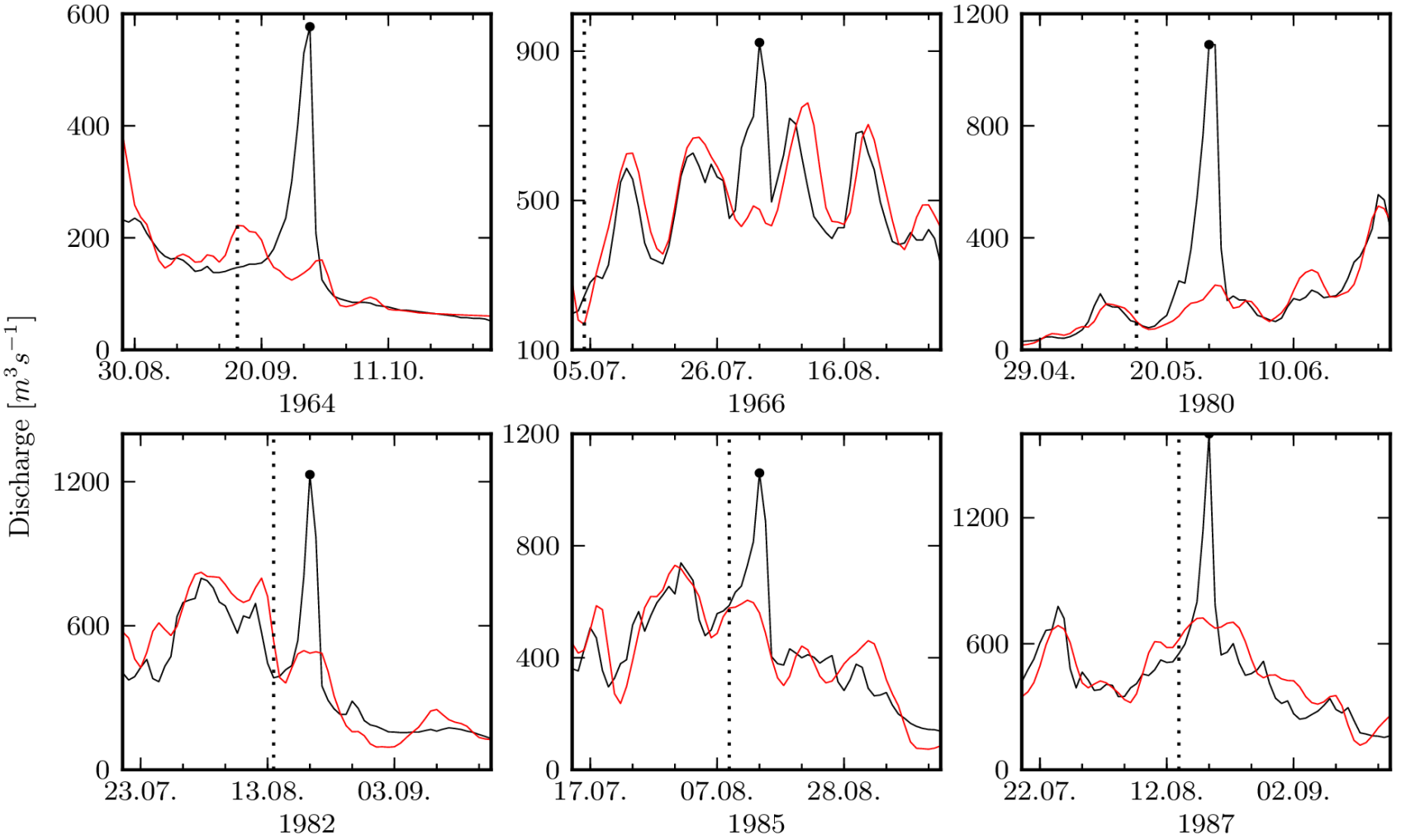
GFZ Helmholtz Centre Potsdam

HELMHOLTZ ASSOCIATION

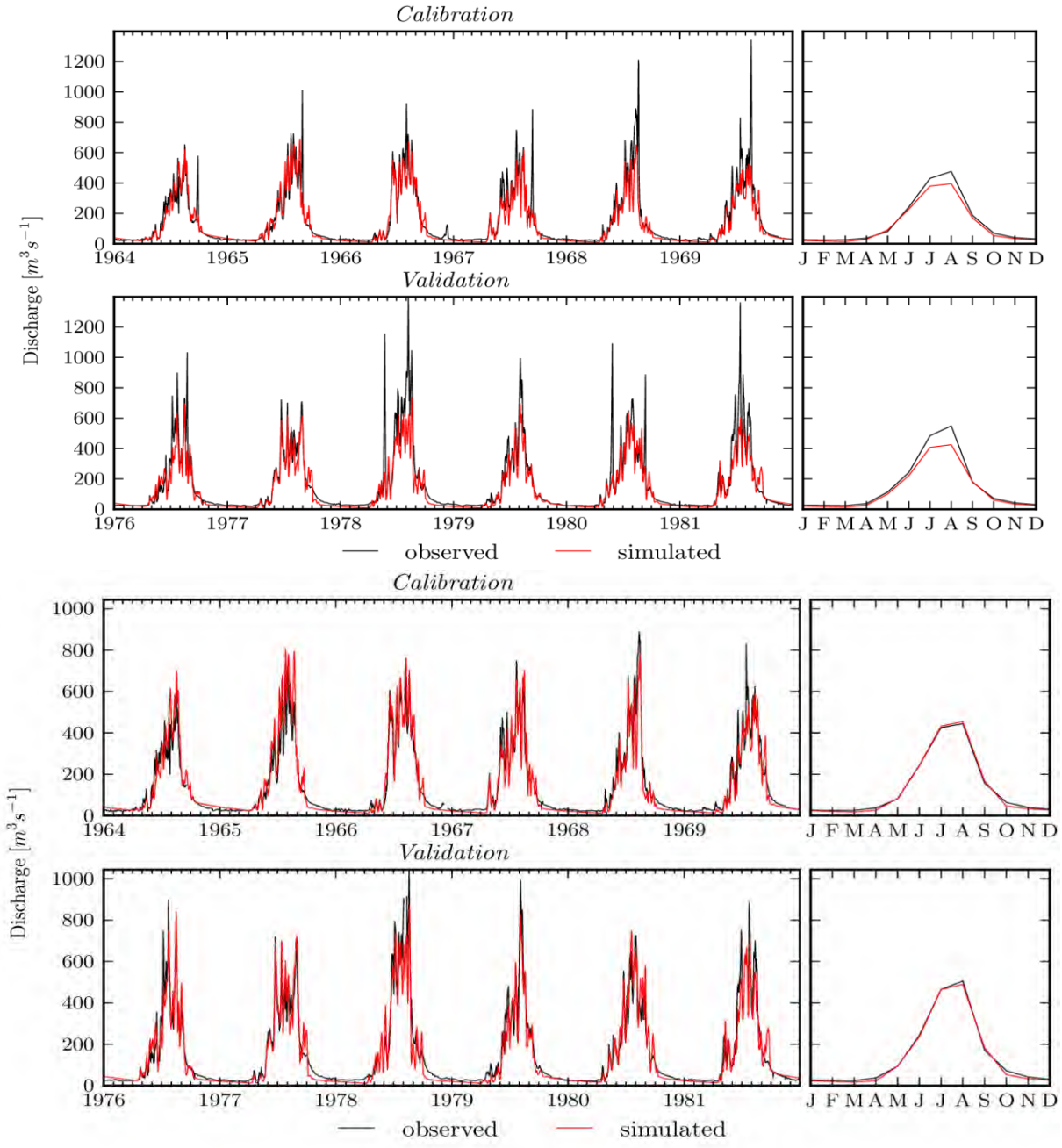
Influence of glacier lake outburst floods from Merzbacher Lake on river discharge



Glacial lake outburst floods observed at Xiehela



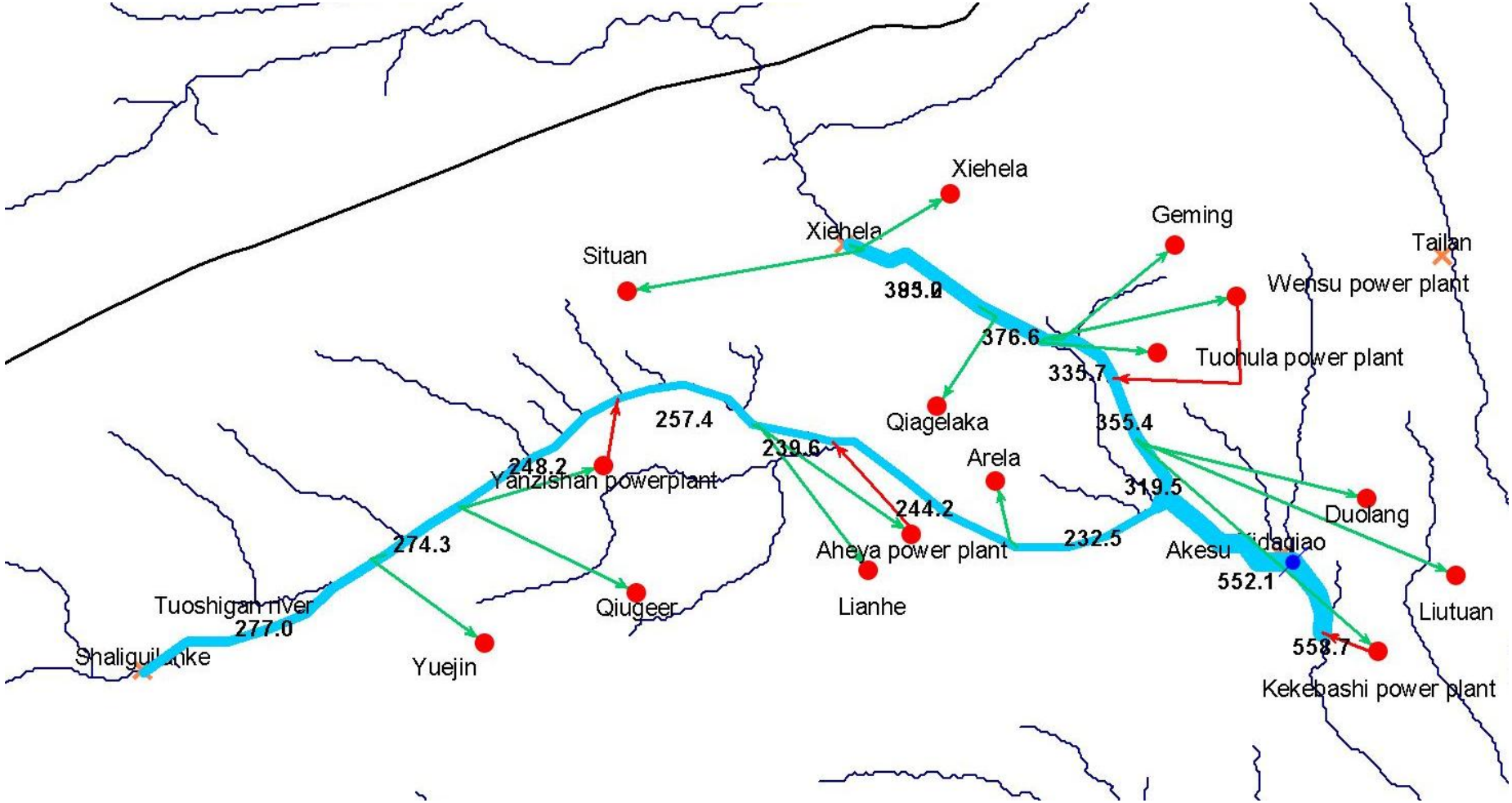
Observed vs simulated discharge at Xiehela (PIK: M. Wortmann)



with GLOFs in observations:
NSE: 0.82, bias: -10%

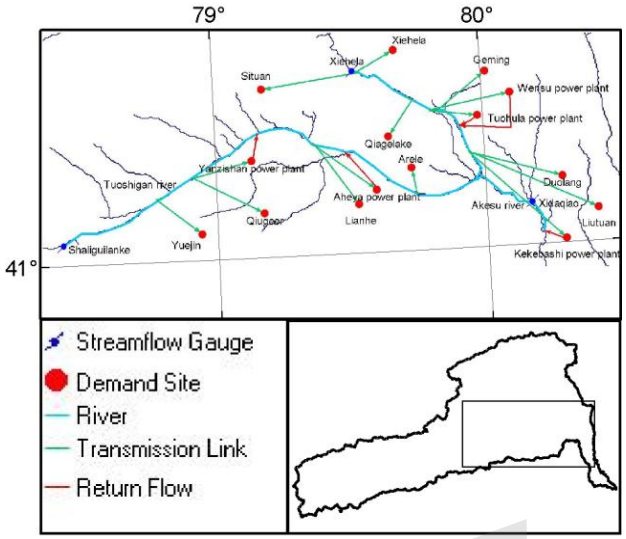
without GLOFs in observations:
NSE: 0.90, bias: -4%

SCHEME of water use in the lower part

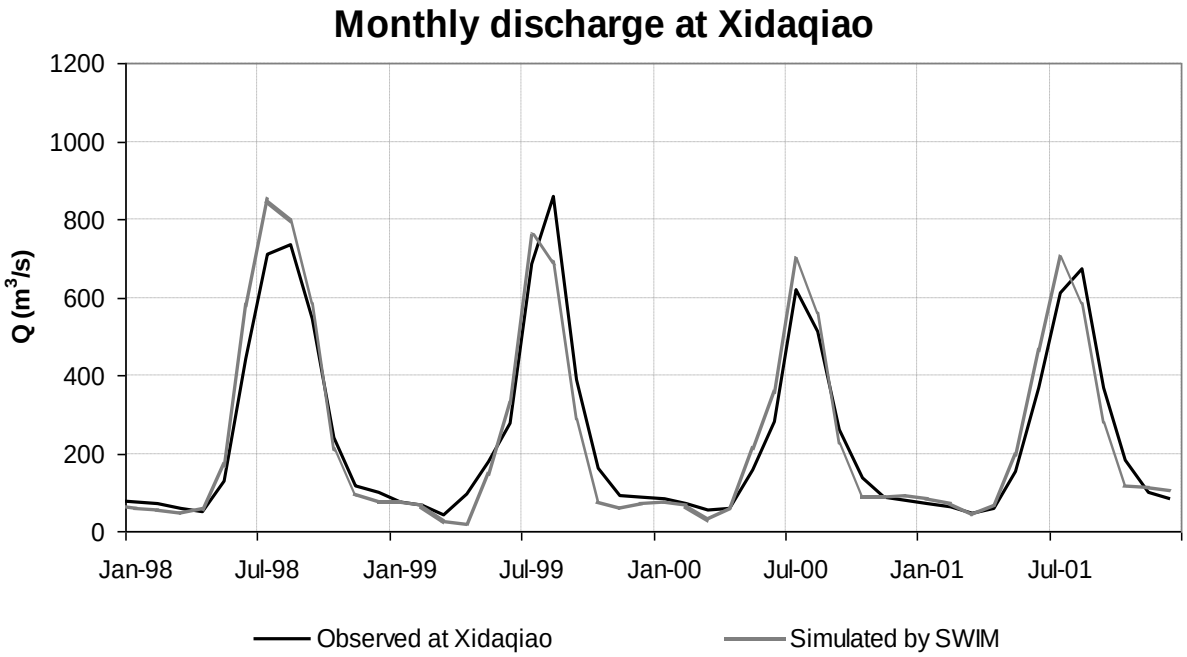


HYDROLOGICAL MODELLING of the lower part with oasis agriculture (PIK, Sh. Huang et al.)

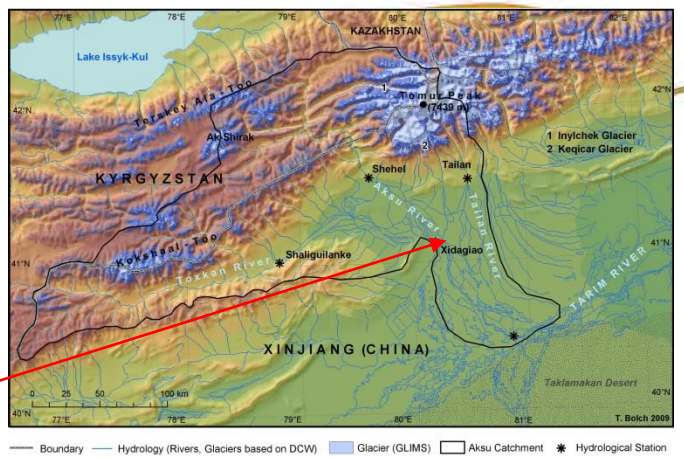
- River discharge in the lower part of the ASksu basin (Xidaqiao) is heavily influenced by water abstraction for irrigation.
- Hydrological model: SWIM + an irrigation module
- Data on irrigation: from the Aksu book



Lower part until Xidaquiao



Climate impact on water discharge



- The current status of the hydrological modelling: WASA and SWIM models are calibrated and validated for the Aksu River basin until the last gauge of the Aksu (Xidaqiao) at GFZ and PIK.
- The next step is to test how the models reproduce the observed water discharge for other two tributaries: the Hotan and Yarkant (Q data for the Horan and Yarkant are still missing).
- A perspective: after getting the data for the Hotan and Yarkant SWIM will be calibrated for these subregions and extended to the total headwater part of the Tarim basin until Alar. After that the climate impact assessment will be done with WASA and SWIM for the total headwater of the Tarim until Alar.

Papers published, submitted and in preparation

- Pieczonka, T., Bolch, T., Liu, S., Wei, J. (2013): Heterogeneous mass loss of glaciers in the Aksu-Tarim Catchment (Central Tien Shan) revealed by 1976 KH-9 Hexagon and 2009 SPOT-5 stereo imagery. ***Remote Sensing of Environment*, 130, 233-244.**
- Sorg, A., Bolch, T., Stoffel, M., Solomina, O., Beniston, M. (2012): Climate change impacts on glaciers and runoff in Tien Shan (Central Asia). ***Nature Climate Change*, 2, 725-731.**
- Ozmonov, A., Bolch, T., Xi, C., Wei, J., Kurban, A. (2013): Glaciers characteristics and changes in the Sary-Jaz River Basin (Central Tien Shan) 1990-2010. ***Remote Sens. Lett.*, accepted.**
- Krysanova V., M. Wortmann, T. Bolch, B. Merz, D. Düthmann, J. Walter, Sh. Huang, T. Jiang, B. Su, Z. Kundzewicz. Analysis of current trends in climate parameters, river discharge and glaciers in the Aksu River basin (Central Asia), **submitted to Hydr. Sciences Journal.**

- Duethmann, D. et al.: The value of satellite snow cover images for hydrological model calibration, (in prep.)
- Hartmann, H.; Mao, W., Jiang, T. Statistical relationships between multiple oceano-climatic variables and precipitation in the Tarim River basin, China (in preparation).
- Huang S., V. Krysanova, M. Wortmann B. Su and T. Jiang. Impact of intensive irrigation activities on river discharge under agricultural scenarios in the arid Aksu river basin, northwest China (in preparation).
- Hui, T, Ch. Menz, J. Huang, M. Gemmer. Simulated and projected temperature extremes in the Tarim River basin (in prep.)
- Kundzewicz et al. Observed changes in climate and river discharge in the Aksu River Basin. In preparation for the Environmental Earth Sciences, Special Issue „Sustainable Water Management in Central Asia" (in preparation)
- Wortmann M., V. Krysanova, T. Jiang, B. Su and Z. Kundzewicz. Influence of glacier lake outburst floods on water discharge in the Aksu catchment: modelling study with SWIM (in preparation).