Climate Impact Assessment for the Upper Tarim under the RCM and GCM Climate Scenarios, including agriculture management

Work Block 2

Valentina Krysanova, Doris Duethmann, Michel Wortmann, Shaochun Huang, Christoph Menz, Tobias Bolch, Sergiy Vorogushyn, Jiang Tong, Su Buda, Zbigniew Kundzewicz & Bruno Merz

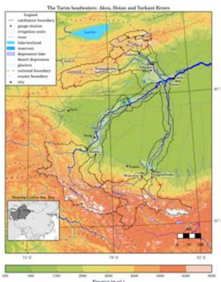
TECHNISCHE UNIVERSITÄT DRESDEN

P I K

GFZ Helmholtz Centre Potsdam

国家气候中心 National Climate Center

Outline



Upper Tarim

- Changes of the Cryosphere
- Climate trends and scenarios
- Modelling tools: WASA and SWIM
- Climate impacts on headwaters
- Climate impacts on discharge of the U. Tarim
- Climate + agriculture management impacts
- Summary

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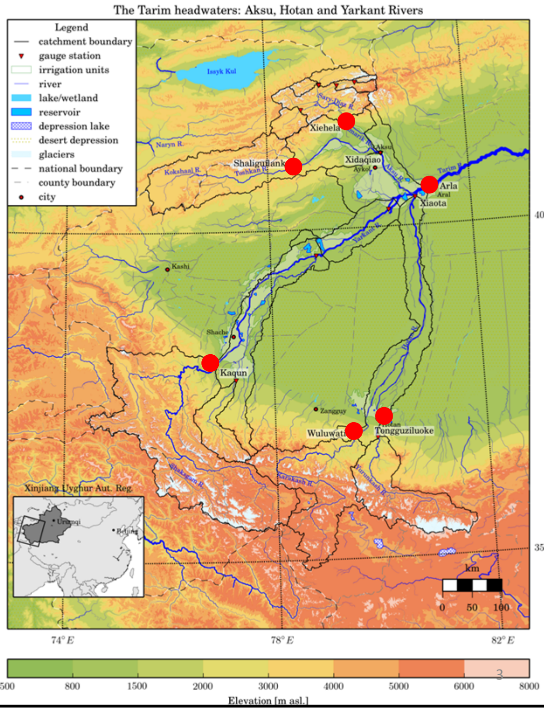
Study area: Upper Tarim until Alar



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Changes of the Cryosphere

(Tobias Bolch et al.)

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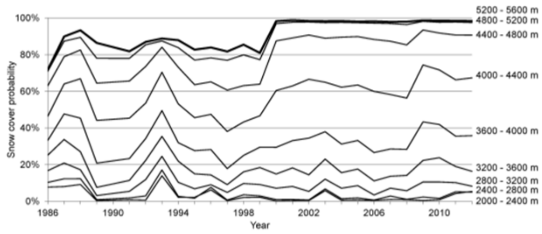
Changes in snow cover

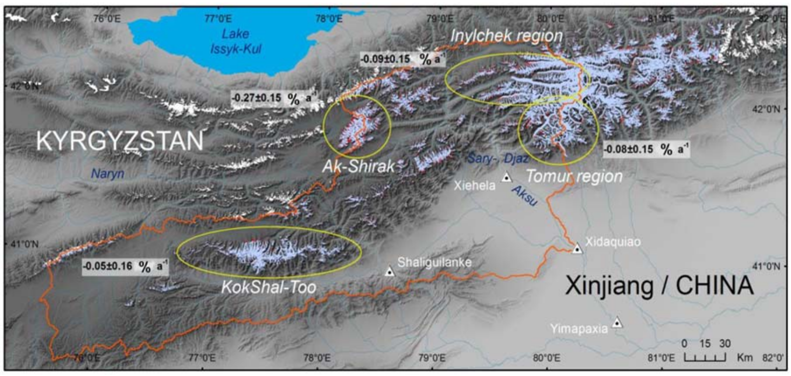


- Significant trend (α = 5%) in upper elevation levels
- But: data shift based on
  AVHRR (1996-2002) and
  MODIS data (2000-2013)

Elevation level (m a. s. l.)	Trend per year	p-value
1000 – 1200	0.0001	0.077
1200 – 1600	0.0001	0.286
1600 – 2000	-0.0006	0.082
2000 – 2400	-0.0003	0.673
2400 – 2800	-0.0004	0.673
2800 – 3200	-0.0017	0.333
3200 – 3600	-0.0013	0.673
3600 – 4000	0.0022	0.602
4000 – 4400	0.0062	0.286
4400 – 4800	0.0066	0.244
4800 – 5200	0.0037	0.070
5200 – 5600	0.0022	**0.050**
5600 – 6000	0.0016	**0.045**
6000 – 6400	0.0025	**0.027**

Peters et al. (2015), TGARS

Changes in glacier area



1975: 6,607 ± 251 km² (Hexagon and MSS images)
2008: 6,362 ± 191 km² (Landsat TM images)

Change:

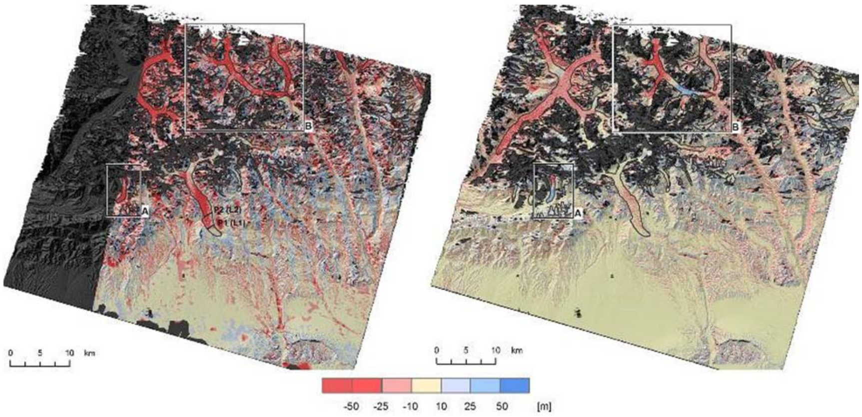
-245 ± 315 km² (-0.11 ± 0.15 %a-1)

(Pieczonka & Bolch, 2015, GPC)

Change for the Kyrgyz part:

-0.19 ± 0.13 %a-1, 1990-2010 **(Osmonov et al., 2013, RSL)** 6

Changes in mass budget: Tomur Region



Mass budget 1976-2009
-0.35 ± 0.15 m w.e./a

Mass budget 1999-2009
-0.23 ± 0.19 m w.e./a

Pieczonka et al. (2013), RSE

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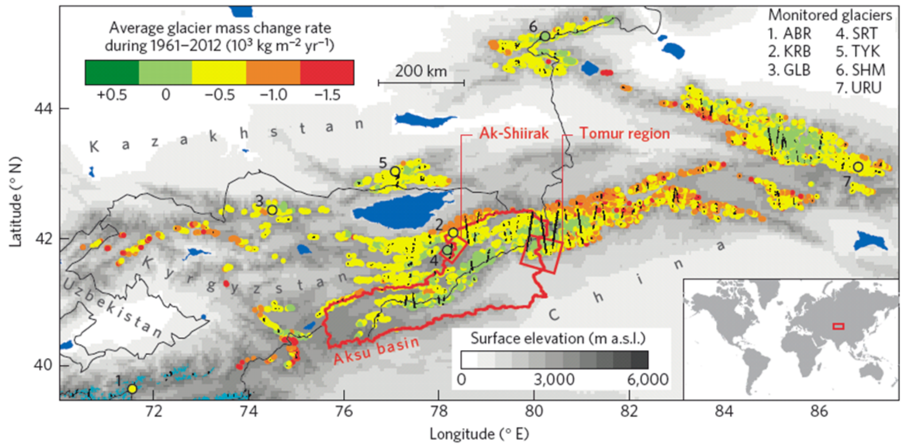
Modelled glacier mass changes in Tien Shan



Glacier Mass Loss (1961 – 2012): **- 5.4 ± 2.8 Gt/a (27 ± 15%)**

Glacier Area Loss (1961 – 2012): **- 2960 ± 1030 km² (18 ± 6%)**

→ Presentation of Tobias Bolch 11.12.15: Changes of the cryosphere

Farinotti et al., 2015, NG

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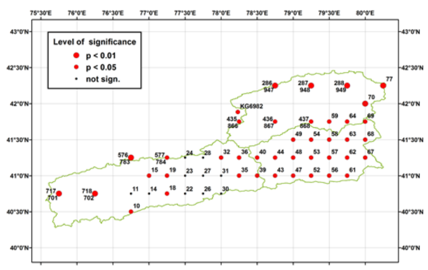
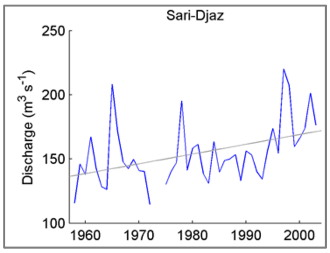
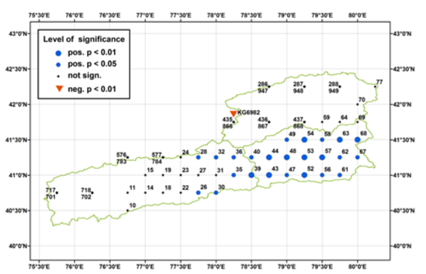
Climate trends and scenarios: T, P

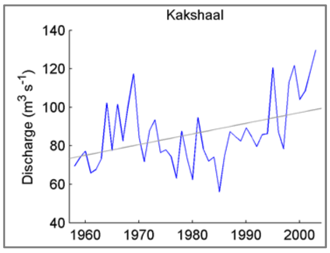
(Christoph Menz, Sergiy Vorogushin)

Past changes: T, P and Q Trends in the Aksu









→ **Presentation of Bruno Merz 11.12.15: Attribution of changes in discharge**

Krysanova et al., 2015, HSJ; Kundzewicz et al., 2015, EES; Duethmann et al., 2015, WRR

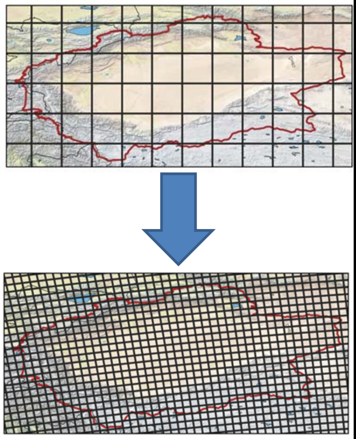
GCMs/ESMs/RCMs

Nine global and two regional climate models were used to build an ensemble of climate change projections

GCM/ESM	Resolution	GCM/ESM	Resolution
CNRM-CM5	T127/1.4°	MIROC5	1.4° x 1.4°
GFDL-ESM2M	2.5° x 2°	MIROC-ESM	2.8° x 2.8°
HadGEM2-ES	1.875° x 1.25°	MIRCO-ESM-CHEM	2.8° x 2.8°
IPSL-CM5A-LR	1.9° x 3.75°	MRI-CGCM3	T159
MPI-ESM-LR	T63/1.9°		
	Scenario:	RCP2.6, RCP4.5, RCP8.5	

RCM	Resolution	Scenario
CCLM-44 – ECHAM5	0.44°	SRES-B1, SRES-A1B, SRES-A2
CCLM-44 – MPI-ESM-LR	0.44°	RCP2.6, RCP4.5, RCP8.5
REMO-50 – ECHAM5	0.5°	SRES-A1B
REMO-16 – ECHAM5	0.16°	SRES-A1B

MPI-ESM-LR



CCLM-44

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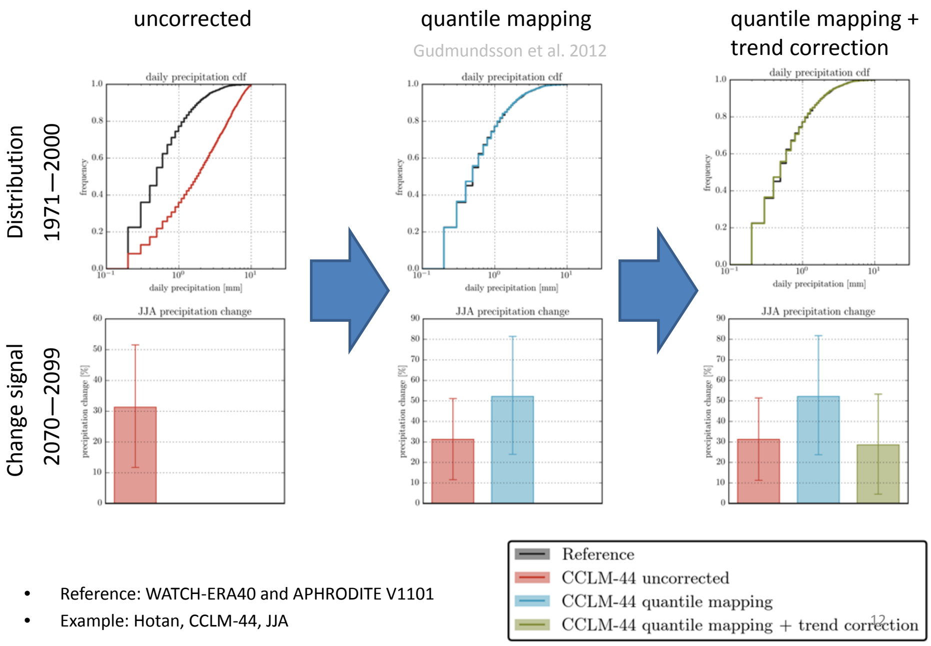
Bias Correction Method



- Reference: WATCH-ERA40 and APHRODITE V1101
- Example: Hotan, CCLM-44, JJA

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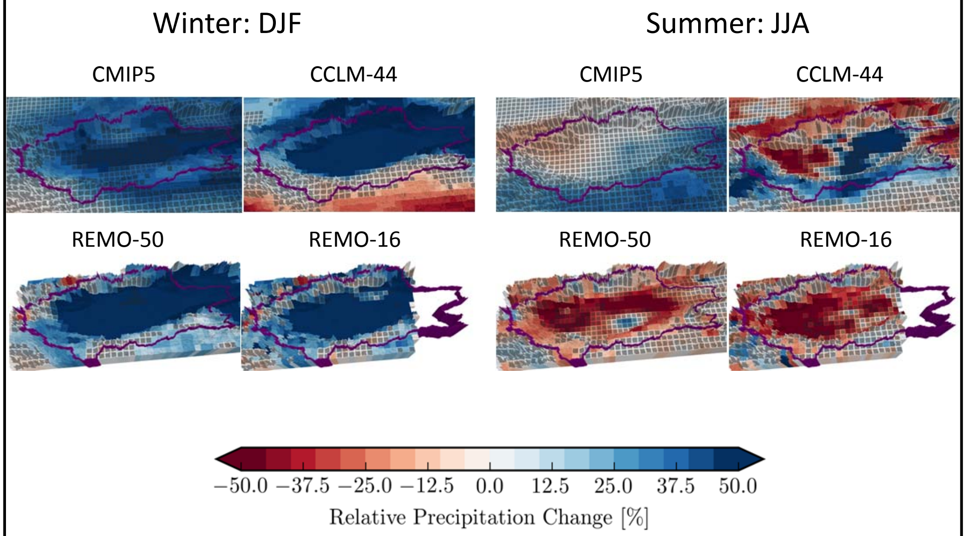
Precipitation change: far future



- CMIP5: 2070—2099 vs 1971—2000
- CCLM & REMO: 2071—2100 vs 1971—2000
- Change signals below 5% significance level are shown as grey shaded boxes

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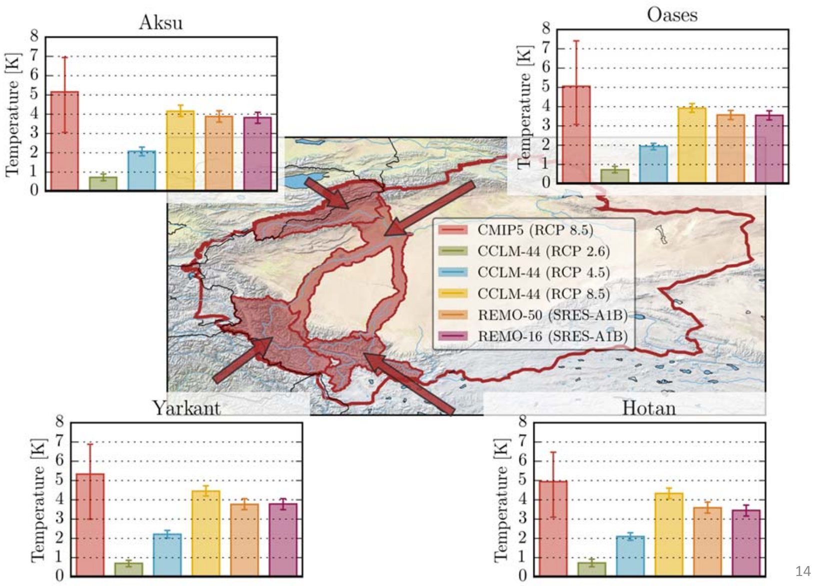
Temperature change



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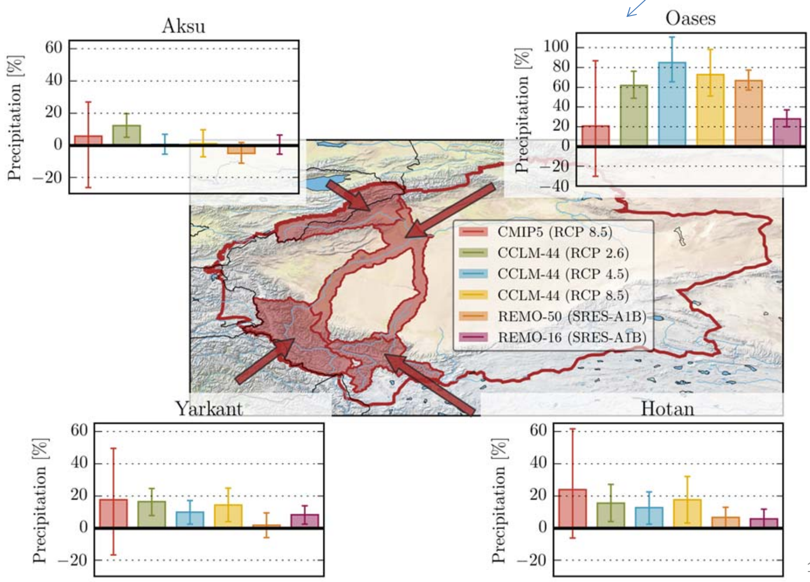
Precipitation change

(here: very low abs. values)



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Modelling tools: WASA and SWIM

Both models were calibrated & validated,
results have been shown previously

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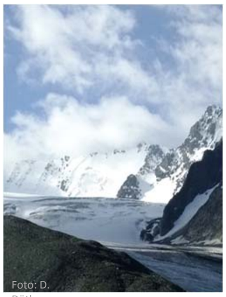
Hydrological model WASA

(**W**ater **A**vailability in **S**emi-**A**rid Environments)



Snow accumulation and melt

– Temperature index approach with seasonally varying melt factor; Simulation of snow cover in addition to snow water equivalents, enables comparison to satellite snow cover;

Glacier geometry changes: Δh-approach

– WASA model uses Δh-approach (Huss et al. , 2010, HESS): Redistribution of ice mass from accumulation to ablation area is represented with a parameterization, which is applied individually to each glacier. Glacier geometry is updated at the annual time step.

Duethmann et al. (2013), HESS
Duethmann et al. (2014), WRR

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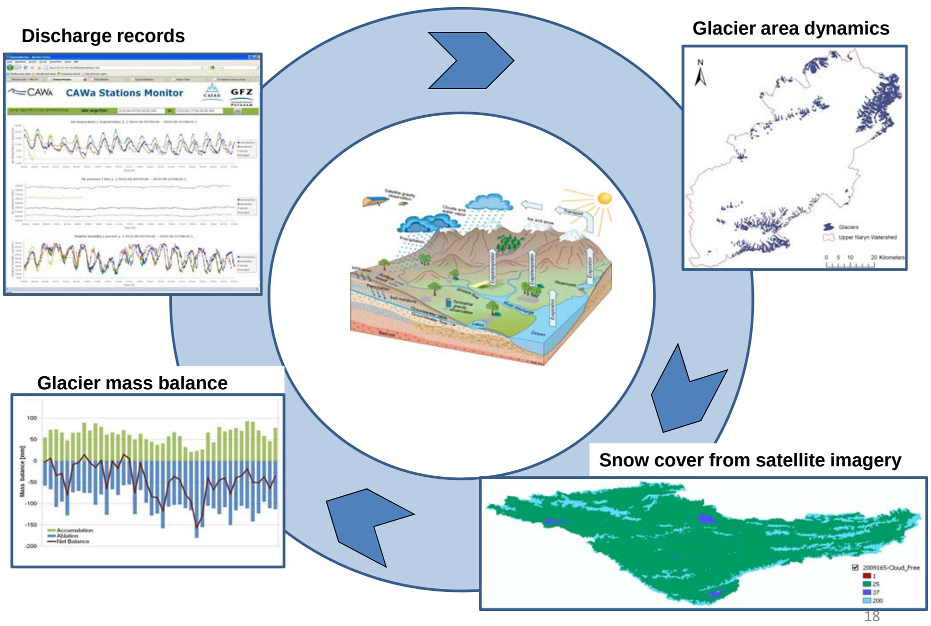
WASA: multi-objective model calibration



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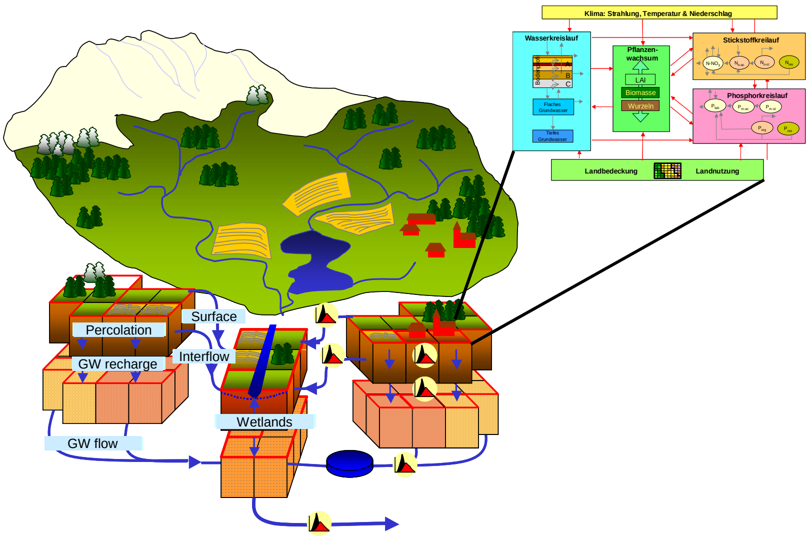
SWIM (Soil and Water Integrated Model)



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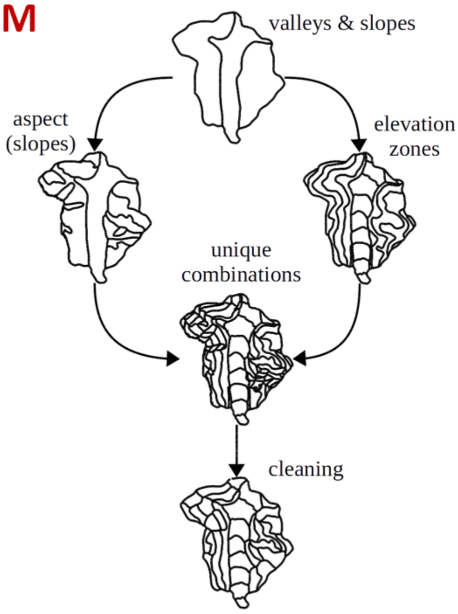
Glacier dynamics in SWIM

- Newly developed glacier dynamics module allows a fully integrated glaciological and hydrological climate change impact assessment
- Based on **elemental slope/glacier units** by combination of subbasin, elevation zone and aspect
- Mapped onto **HRUs**: hydrological response units (tight integration)
- Implementing important glacier processes: **accumulation, melt, sublimation, ice flow, avalanching, debris cover** through simple parameterization for data scarce catchments



Wortmann et al. (to be submitted)

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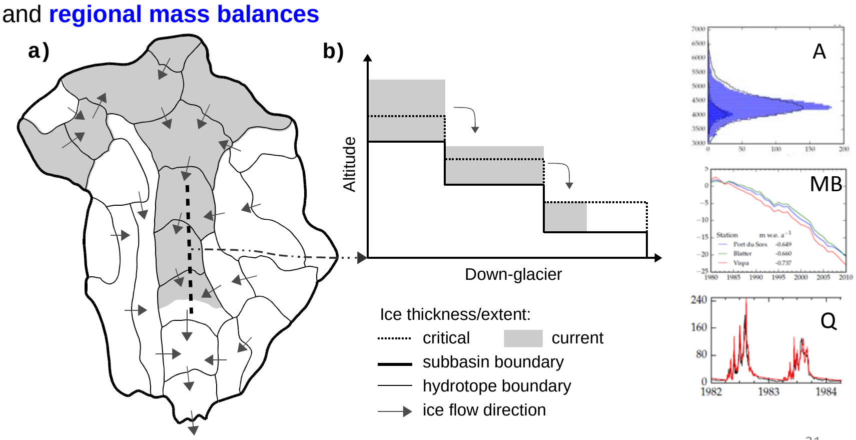
Glacier dynamics in SWIM

- **1D ice flow and avalanching** are simpler than computationally intensive 2/3D modelling approaches, and allow modelling of larger domains
- Initialised and calibrated together with hydrology to **observed discharge** and **regional mass balances**



Wortmann et al. (to be submitted)

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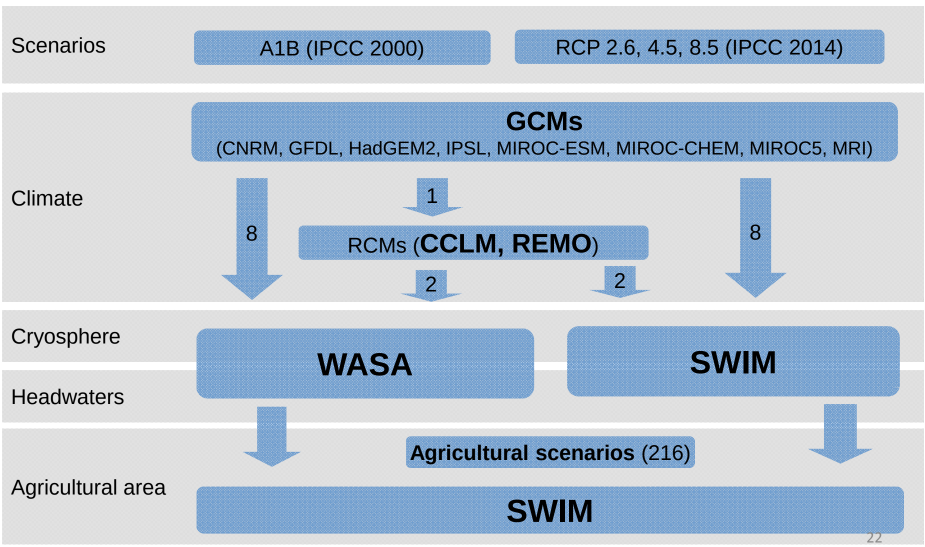
Climate change impact modelling chain



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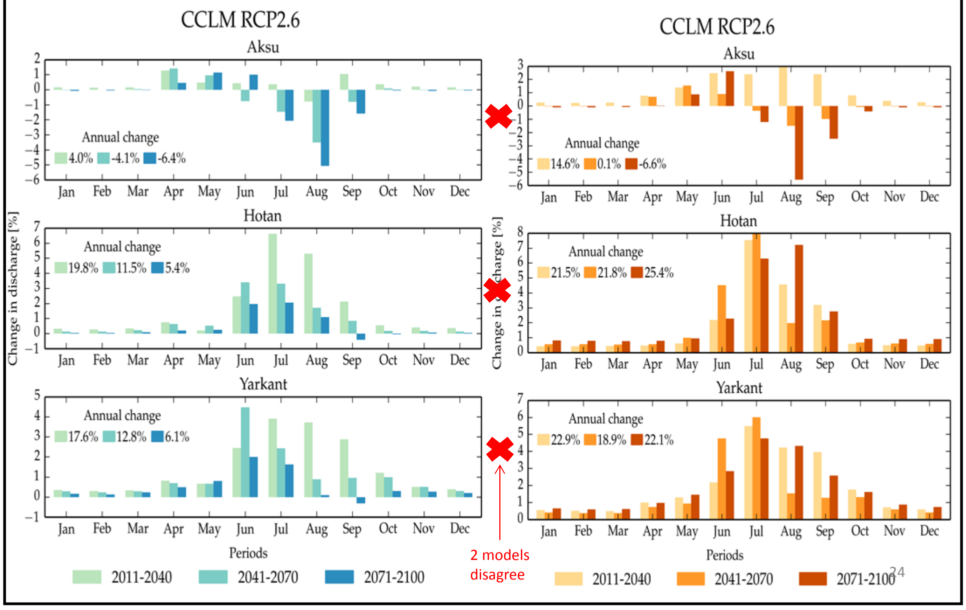
Impact on discharge for headwaters: Aksu, Hotan, Yarkant

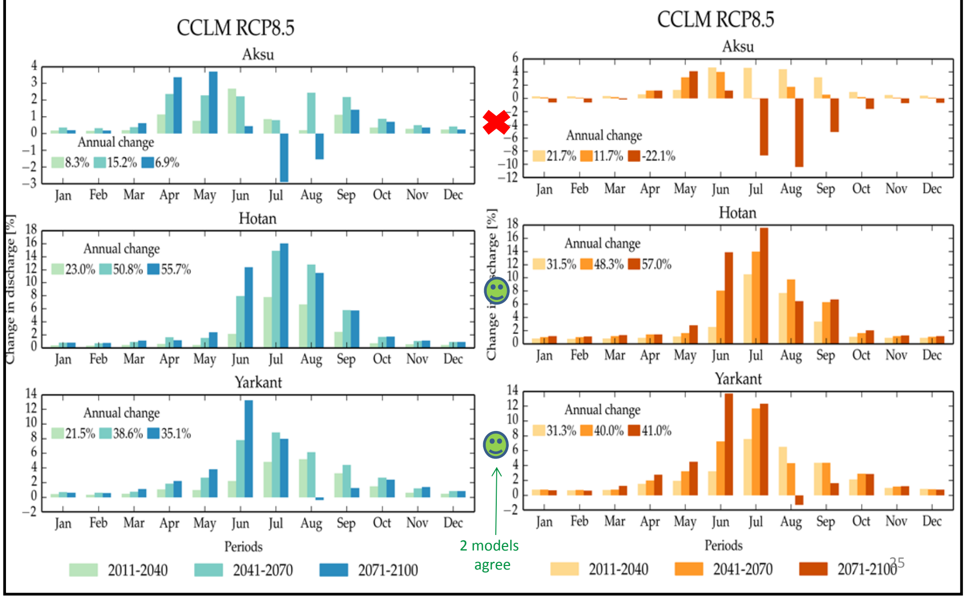
(D. Düthmann, M. Wortmann et al.)

Seasonal changes in discharge, CCLM RCP2.6

SWIM & WASA



Seasonal changes in discharge, CCLM RCP8.5
SWIM & WASA



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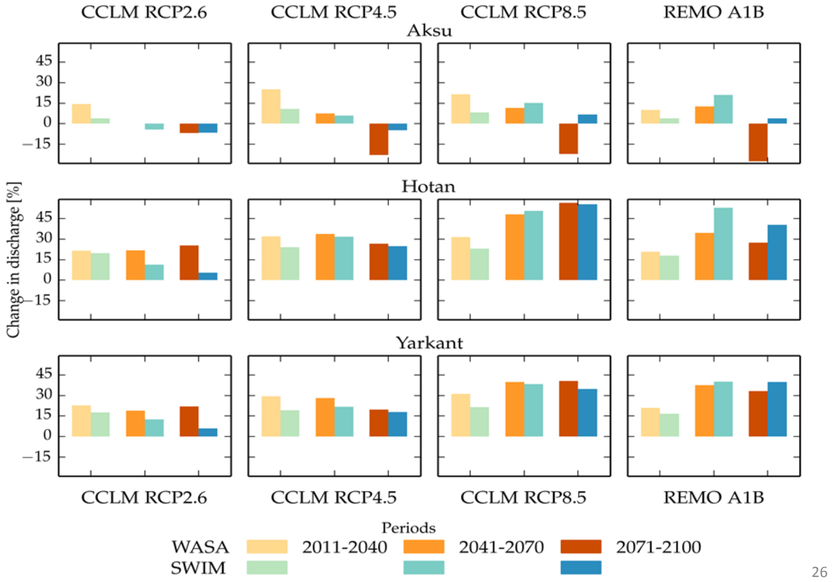
Average annual changes in discharge
SWIM & WASA



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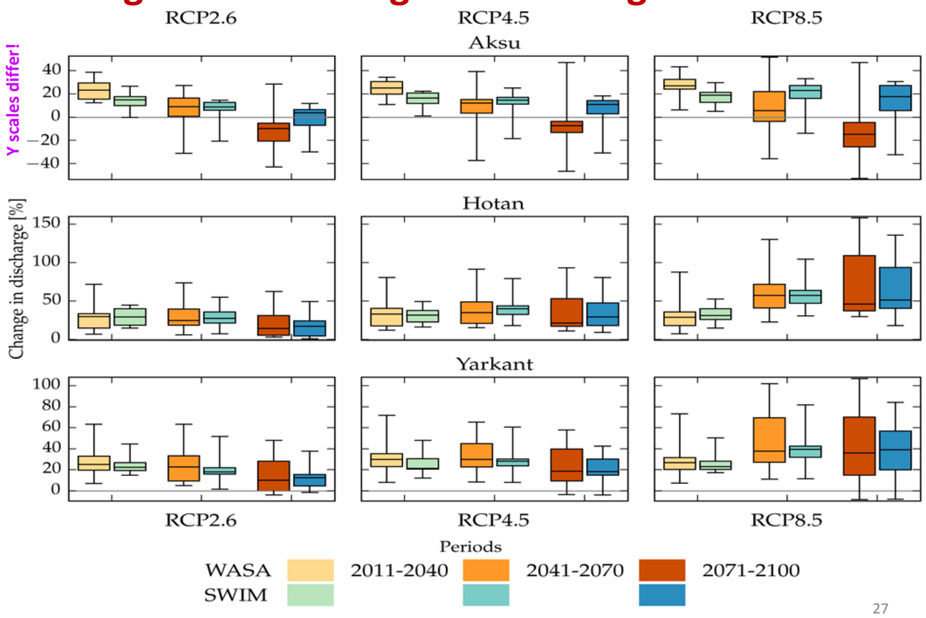
Average annual changes in discharge under GCMs



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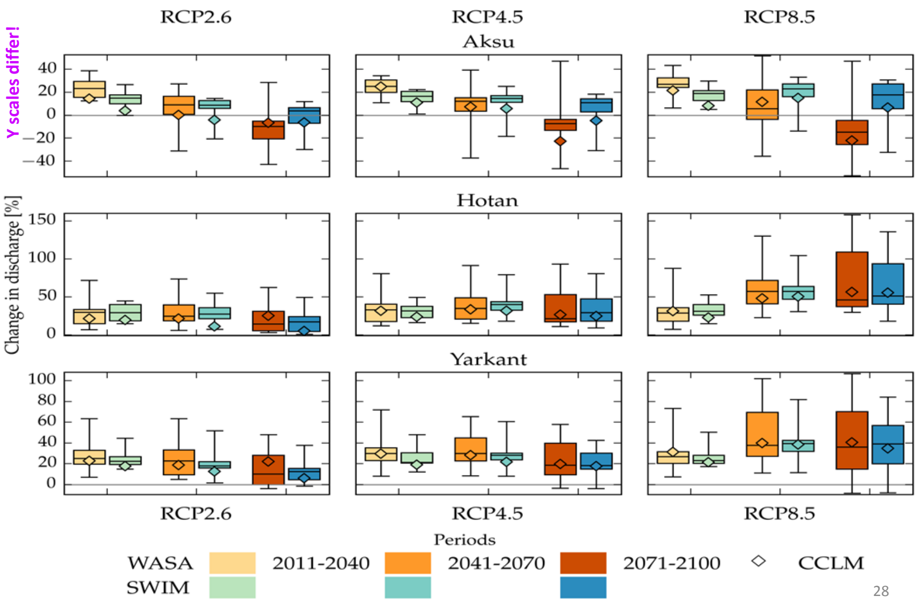
Under GCMs + CCLM



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Impact on discharge for the Upper Tarim

(Shaochun Huang, Doris Düthmann, Michel Wortmann et al.)

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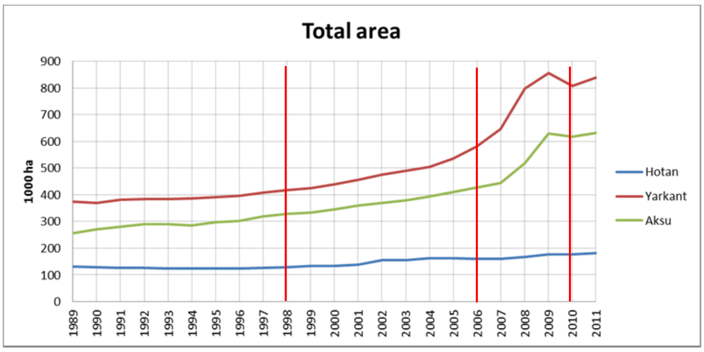
Agriculture area in the Upper Tarim oases



REF 31111

Important: In the reference scenario irrigated agriculture area is assumed as it was in 1998

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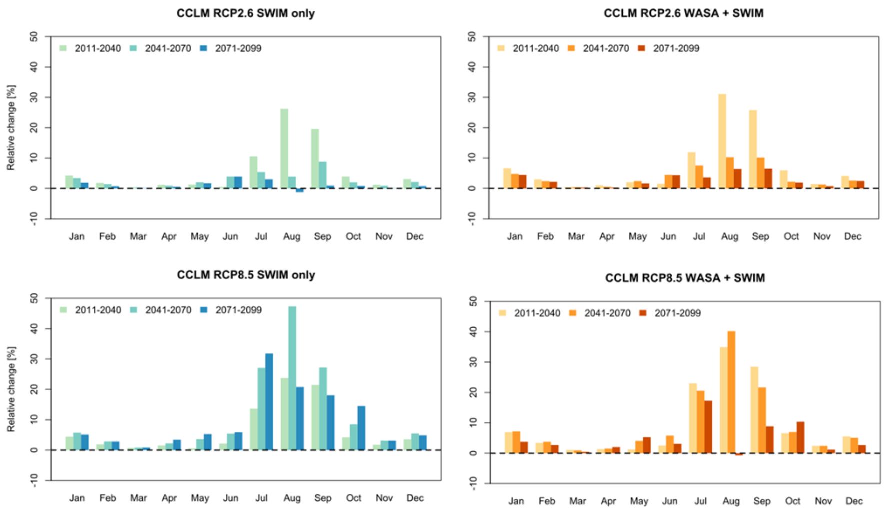
Monthly relative change at Alar under RCMs, climate change only



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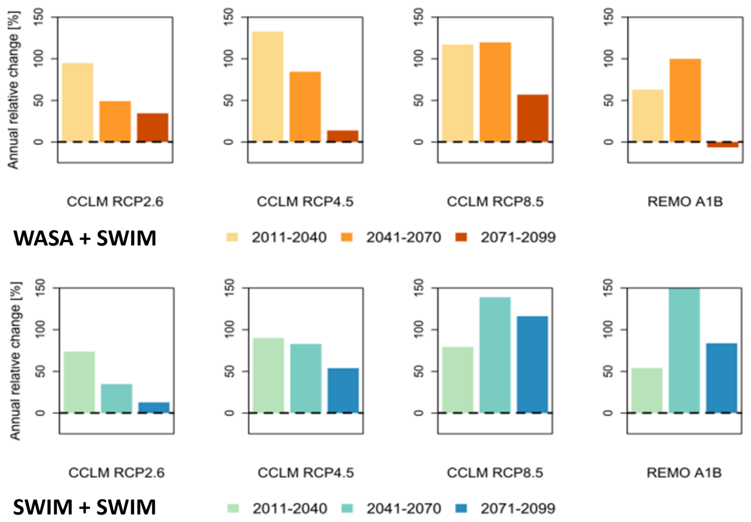
Annual relative change at Alar under RCMs, climate change only



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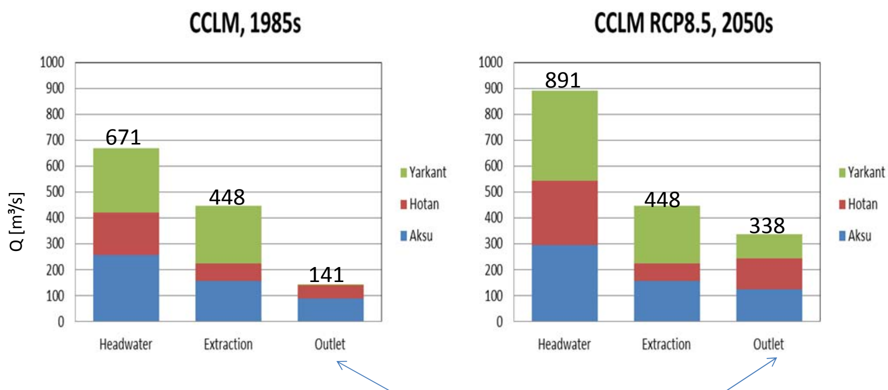
How does an increase of 33-45% Q in headwaters turn into 100-140% at Alar assuming climate change only?



1. Water abstraction is assumed to be the same

2. Compare shares of 3 tributaries

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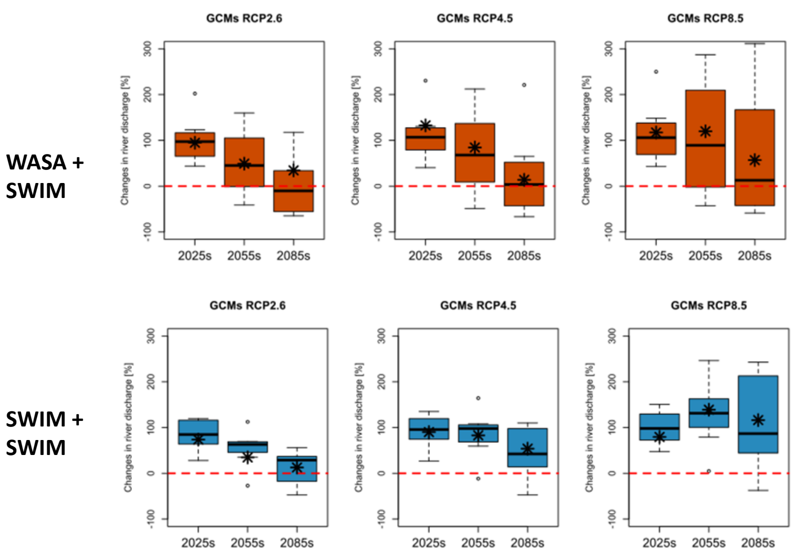
Annual relative change at Alar under GCMs & CCLM, climate change only



* stars show results driven by CCLM scenarios

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Impact on discharge for the Upper Tarim considering land & water management

(Shaochun Huang et al.)

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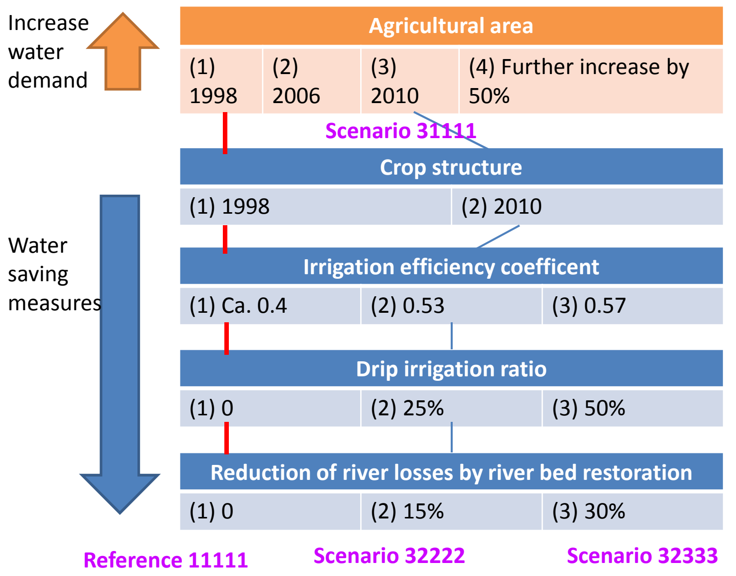
Agricultural scenarios



In total:
4x2x3x3x3 = 216 scenarios,
3 will be shown

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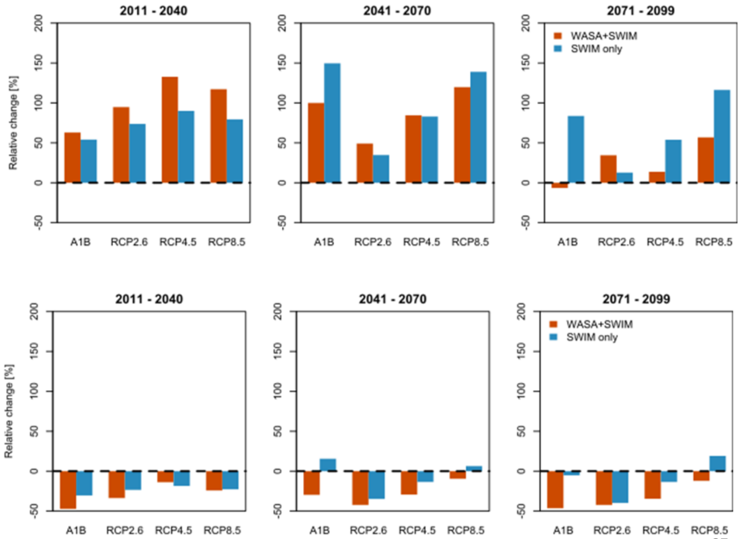
Relative annual changes for agricultural scenario 31111

Reference 11111, agr area as in 1998

Scenario 31111, Agr area ⬆ as in 2010



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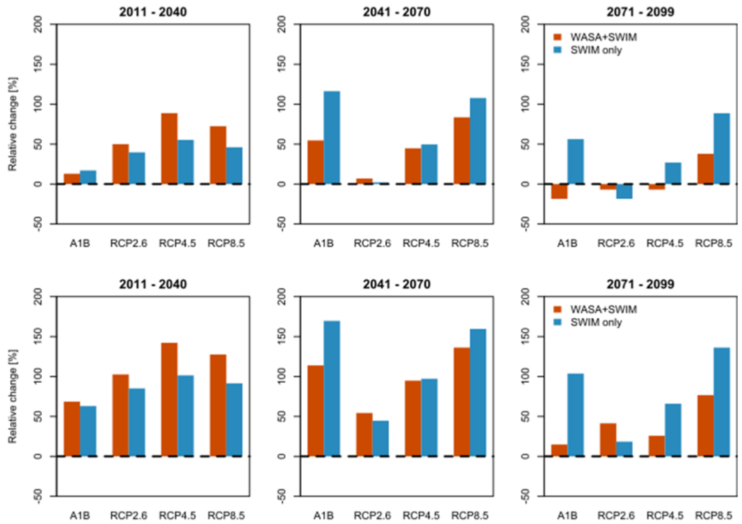
Relative annual change for agricultural scenarios 32222 & 32333

Scenario 32222 (moderate water saving measures)

Scenario 32333 (strong water saving measures)



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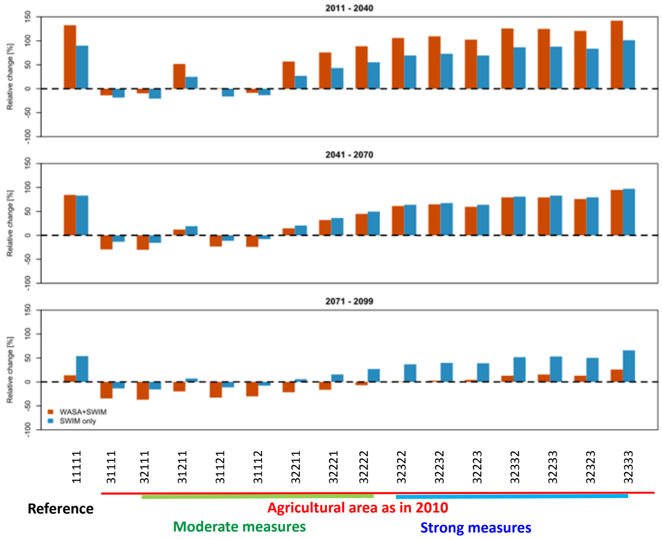
Comparison of the effects of different measures, RCP4.5



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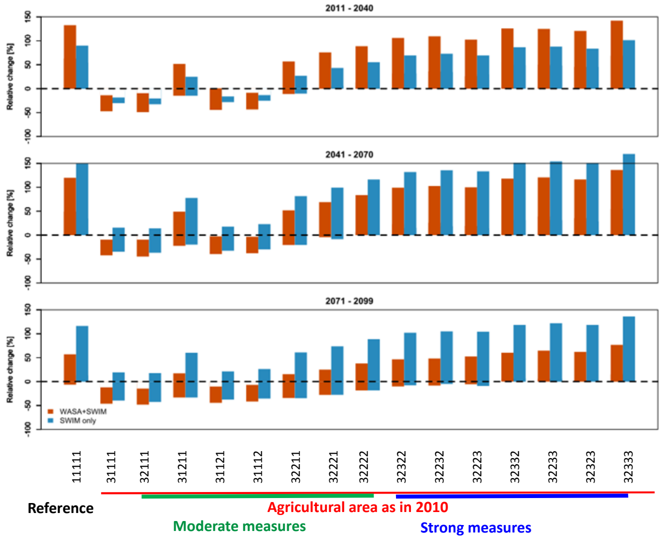
Comparison of the effects of different measures, RCMs combined



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Conclusions

- **Cryosphere:**
  - Snow cover shows slightly positive trends above 4800 m asl, 1986-2013;
  - Glacier area decrease relatively small, but heterogeneous;
  - Heterogeneity also for mass loss of glaciers. The ***rates of mass loss*** are, however, on average ***within the global mean***.
- **Climate**:
  - ***Strong increases in both T and P*** under climate change are projected;
- **Headwaters:**
  - The two glaciohydrological models confirm ***increases in headwater discharge*** under all scenarios, ***except in the Aksu in the far future*** where results of two models differ;
  - Increases are driven by both glacier melt and increase in precipitation, with ***stronger increases in the Hotan and Yarkant*** than in the Aksu.

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Conclusions

- **Discharge at Alar under climate change scenarios:**
  - ***Under RCMs river discharge is expected to increase*** practically in all cases;
  - ***Under GCMs uncertainties are high***, with diverging results by two models at the end of the century;
  - ***Under higher RCPs scenarios there are higher increases*** in river discharges than under RCP2.6.
- **Discharge at Alar under climate change and change in agriculture management**:
  - ***If agriculture area would be reduced to 1998 level (our reference scenario), an increase in water discharge could be expected***;
  - ***The increase of discharge in headwaters cannot secure the ecological water demand in the main Tarim river if the agricultural area remains as in 2010 and without additional water-saving measures***;
  - The moderate measures ***are needed*** to maintain the current water flows if the agricultural area remains as in 2010;
  - The strong water-saving measures ***would be favourable*** for river discharge in the lower Tarim if the agricultural area remains as in 2010 .

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Thanks for your attention!

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Papers published (GFZ + PIK):

Duethmann, D., Bolch, T., Farinotti, D., et al. 2015. Attribution of streamflow trends in snow and glacier melt-dominated catchments. - Water Resources Research, 51, 6, p. 4727-4750.

Farinotti, D., Longuevergne, L., Moholdt, G., Duethmann, D., Mölg, T., Bolch, T., Vorogushyn, S., Güntner, A., 2015. Substantial glacier mass loss in the Tien Shan over the past 50 years. - Nature Geoscience, 8, p. 716-722.

Hartmann, H., Krysanova, V., Jiang, T., Livingston, J., Stein, S., Kundzewicz, Z.W., 2013. Predictors of Precipitation. Journal of Arid Environments.

Huang, S., Krysanova, V., Zhai, J., Su, B., 2014. Impact of Intensive Irrigation Activities on Water Resources Management 29, 945–959. doi:10.1007/s11269-014-0853-2

Krysanova, V., Wortmann, M., Bolch et al. 2015. Analysis of current trends … Hydrological Sciences Journal 60, 566–590. doi:10.1080/02626667.2014.925559

Kundzewicz, Z.W., Merz, B., Vorogushyn, S., et al., V., 2014. Analysis of changes in climate and river discharge.... Environ Earth Sci 73, 501–516. doi:10.1007/s12665-014-3137-5

Rumbaur, C., Thevs, N., Disse et al. Sustainable management of river oases along the Tarim River (SuMaRiO) in Northwest China under conditions of climate change. - Earth System Dynamics, 6, p. 83-107.

Wortmann, M., Krysanova, V., Kundzewicz, Z.W., Su, B., Li, X., 2013. Assessing the influence of the Merzbacher Lake outburst floods…, Hydrological Processes. doi:10.1002/hyp.10118

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Papers to come (GFZ + PIK):

- Düthmann, D. et al. "Projections for headwater catchments of the Tarim River reveal glacier retreat and decreasing surface water availability but uncertainties are large"
- Wortmann, M. et al. Catchment-scale glacier dynamics in a hydrological model.
- Huang, Sh. et al. Analysis of adaptation strategies of agricultural and water managements to climate change in the Upper Tarim river basin, Northwest China
- Wortmann, M., D. Duethmann, Sh. Huang, V. Krysanova et al. Climate change projections of the highly-glacierised Tarim River headwaters, NW China.

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