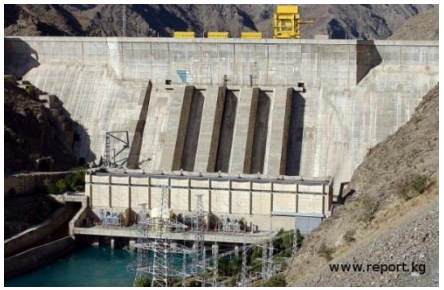
Permafrost and Glaciers in the Kyrgyz Tian Shan

- relevance for the water balance and
as hazard factors for a sustainable development
[catchment of Naryn river, Kyrgyzstan]





Lorenz King & Murataly Duishonakunov

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UNIVERSITÄT
GIESSEN

Project background (LUCA)

Study objectives and research areas

Methods and work done

Results and conclusions:

- **Permafrost**
- **Glaciology and Hydrology**
- **Hazards and environmental concerns**

Project background:

VolkswagenStiftung
Junior scientists programme

LUCA
Land Use, Ecosystem Services and Human Welfare in Central Asia

ZEU, JLU Giessen (Center for International Development and Environmental Research),

GFZ (GeoForschungszentrum) Potsdam,

CAIAG, Bishkek (Central Asian Institute for Applied Geosciences),

Phillips University Marburg

The LUCA sub-projects (with local PhD students)

SP 1: Water Resources of Central Asian Mountain Areas – relevance for the agriculture in semiarid regions under climate change conditions
SP 2: Monitoring dust and extreme precipitation events in Central Asia during the last century and the impact of desertification on land use
SP 3: Remote sensing and GIS based analysis of landslide occurrence and related land use changes in areas of high landslide activity in Southern Kyrgyzstan
SP 4: Sustainable Transition in Agriculture – Impact of macroeconomic conditions, water availability, and land degradation on agricultural sector of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan
SP 5: Land use, food, nutrition security – case studies in rural and urban Uzbekistan
SP 6: Land use strategies in Central Asia: Cash crops or food crops?
SP 7: Grassland phytodiversity in mountainous regions at patch and landscape scale: Indicator for environmental and socio-economic change
SP 8: Ecohydrology in a changing environment
SP 9: Property Rights and Land Tenure in Central Asia
SP 10: Sustainable Pasture Management in Tajikistan: Solving the Transition Problem of Fodder Scarcity by a Better Management of Eco-System Services
SP 11: Trans-boundary water governance in the Amu Darya Basin : Current water and land use conflicts along the Amu Darya

Study Objectives and research areas in the Kyrgyz Tian Shan

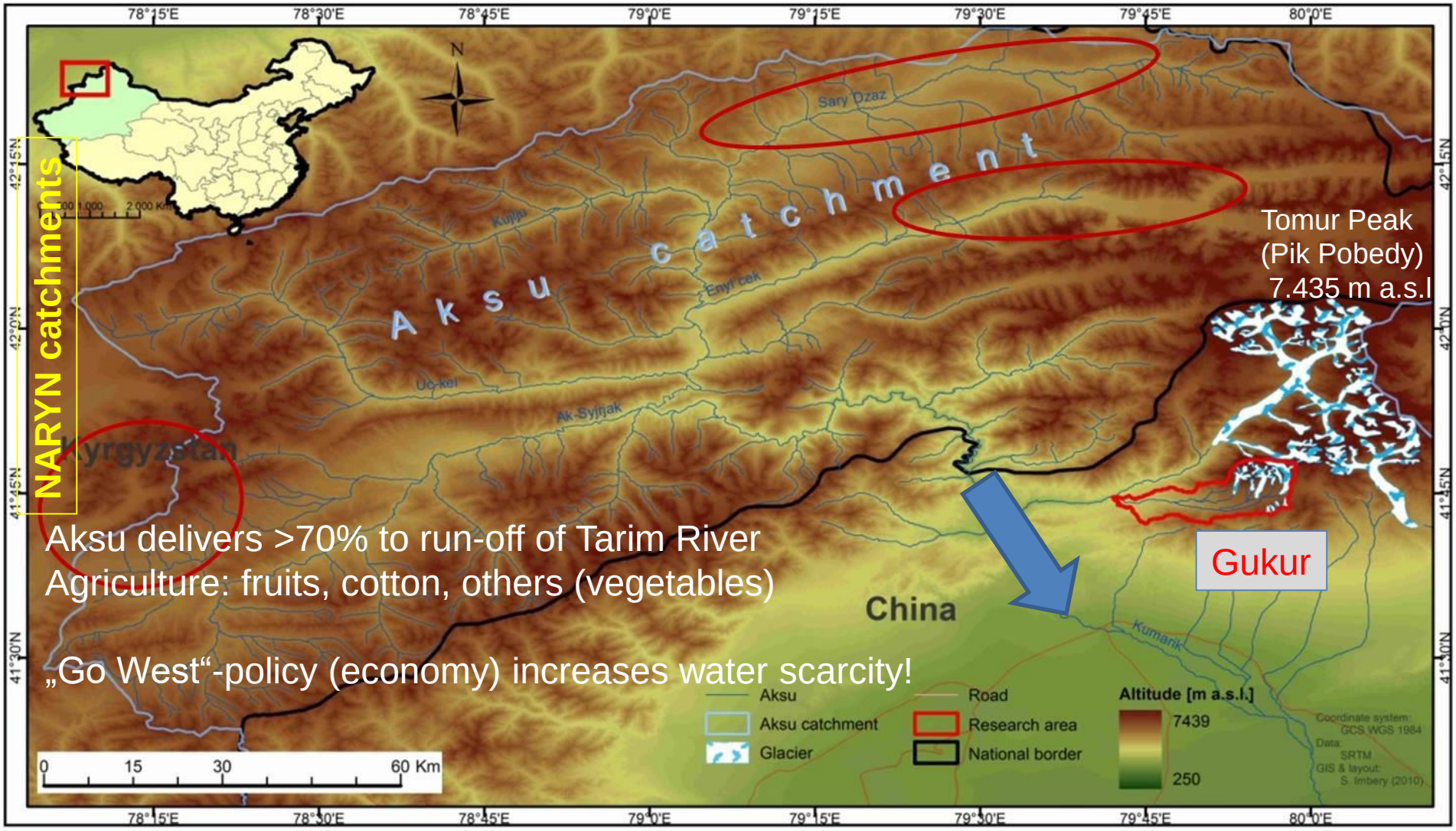
- New primary data for climate and ground temperature (loggers)
- Glacier retreat in the upper Naryn catchments (RS and on site)
- Distribution and thickness of mountain permafrost
  (model based on MASGT, topography, vegetation and snow cover)
- Regime of river flow and glacier run-off
- Glacier, Permafrost and Climate Change as Geohazards

LUCA subproject 1:

Water Resources of Central Asian Mountain Areas –
relevance for the agriculture in semiarid regions under CC conditions.

Coordinators: King Lorenz (Giessen), Usubaliev Ryskul (Bishkek)
Supported: CAIAG, BIshkek: Bolot Moldobekov

Aksu and Gukur catchment areas (KYR + CN Tian Shan)



Research areas: Chon Naryn catchment (~5.710 km²)
Kichi Naryn catchment (~3.870 km²)

Study Areas Upper Naryn and Gukur (Kyrgyzstan, China)

Central Asia and Study area

Source: ESRI map with additions

Methods and work done (permafrost studies)

- Temperature measurement chains connected to loggers, recording of hourly values over 3 years

- Single and multi chain loggers with 5 loggers, 120 cm depth (GeoPrecision and physics department at JLU)

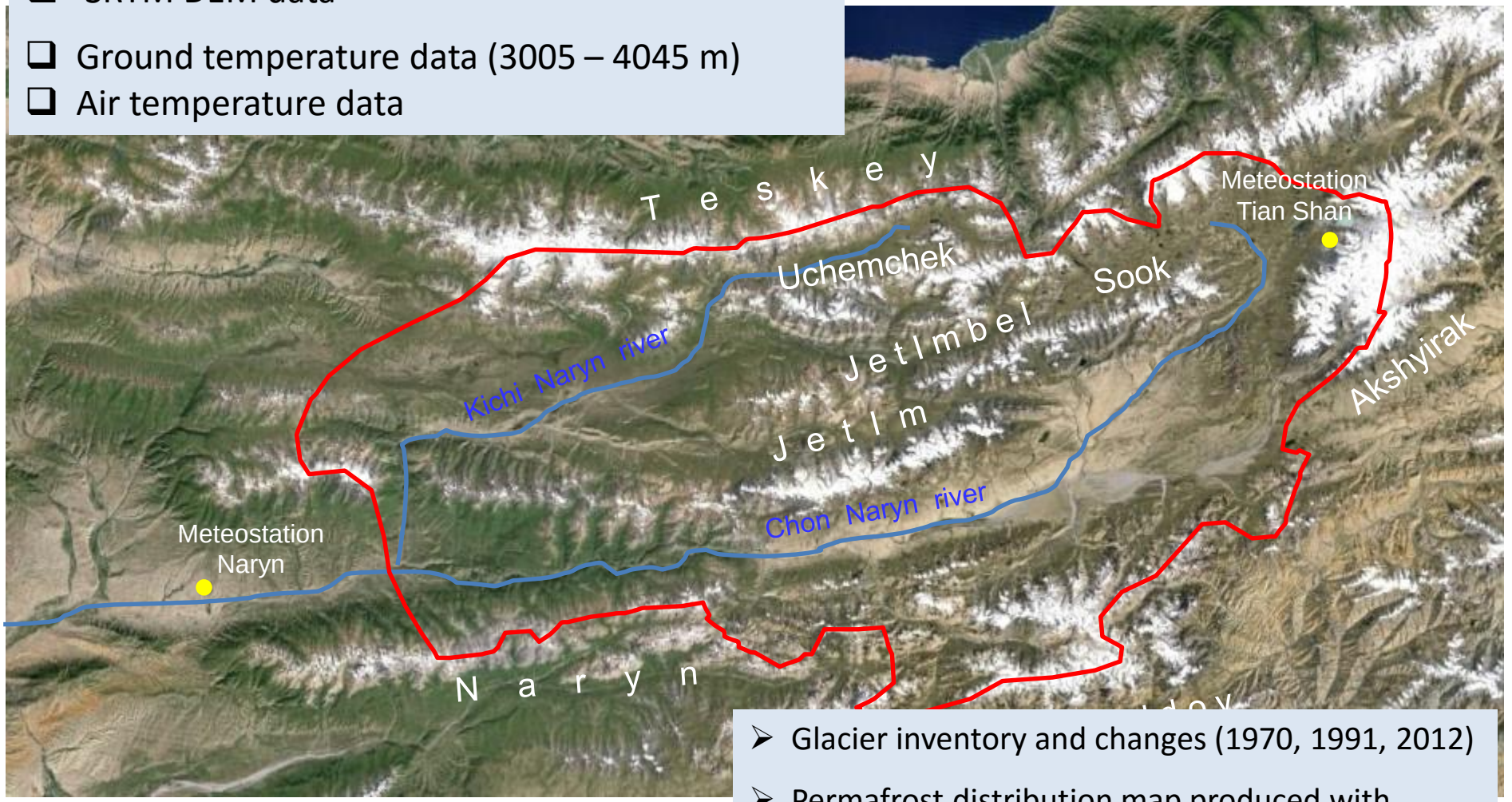
- Accurate data can be recorded and stored up to 5 years (remote data read-out)

- Installation at 65 locations (40 chains and 25 single loggers)

Glacier and permafrost studies, Upper Naryn catchment

(M. Duishonakunov)

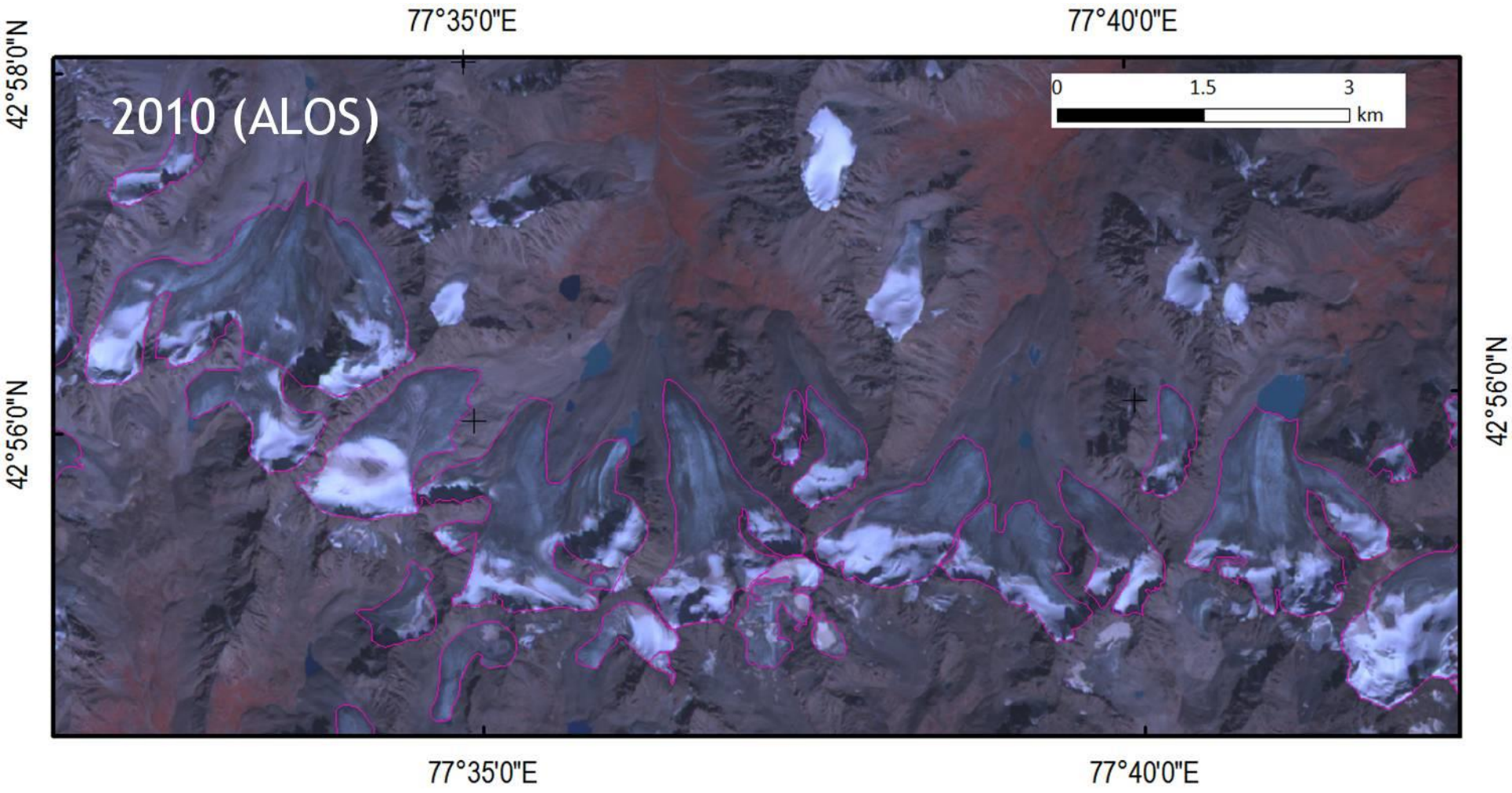
- ❑ 1:25,000 topographic maps (1960's)
- ❑ Landsat and ALOS Satellite images (1999+2010)
- ❑ SRTM DEM data
- ❑ Ground temperature data (3005 – 4045 m)
- ❑ Air temperature data



Source: Google Imagery with additions

- ➢ Glacier inventory and changes (1970, 1991, 2012)
- ➢ Permafrost distribution map produced with GIS tools using ground temperature data

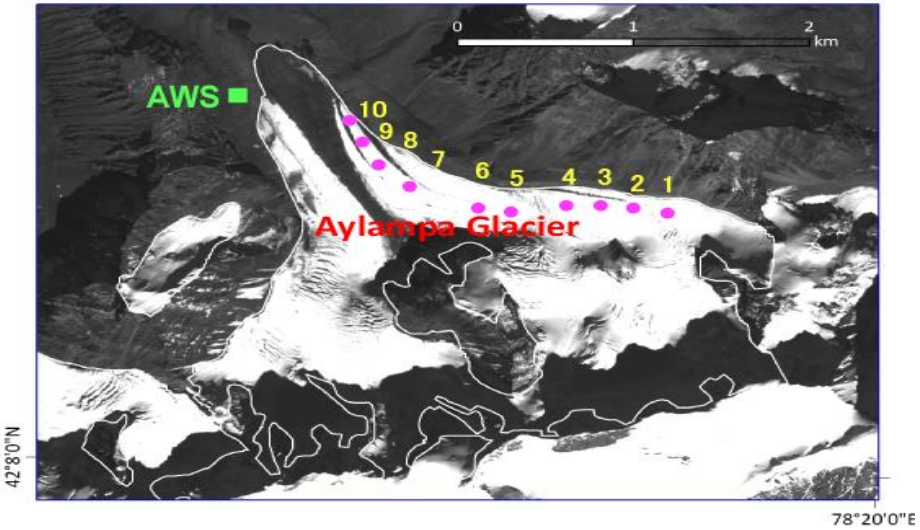
Glacier area analysis



Glacier changes using remote sensing data

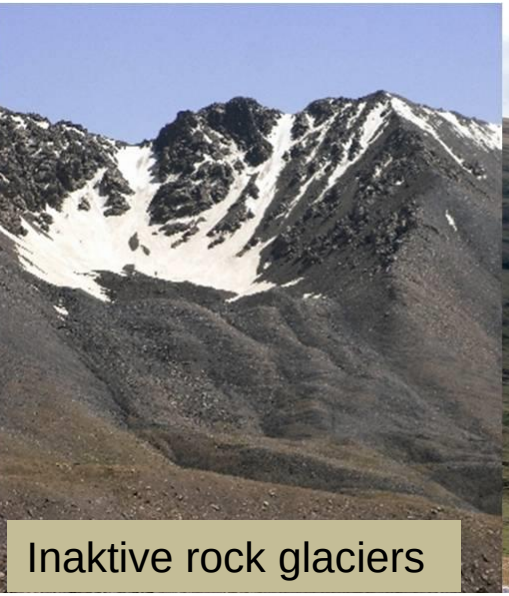
Glacier analysis

Stake measurements: Aylama Glacier, Teskey Mountain



Field work, July – September 2010

Logistic success and difficulties



Inaktive rock glaciers

Solifluction lobes

Success:

Area reached by ATV,

often also by horses

Installation easily possible,

Read-out of data excellent

Stone stripes

Studies continued 2011, 2012, 2013

Results and conclusions - Permafrost

Ice in permafrost areas, characteristics

NW slope of Akshyirak mountain massif (~ 3800 m a.s.l.).

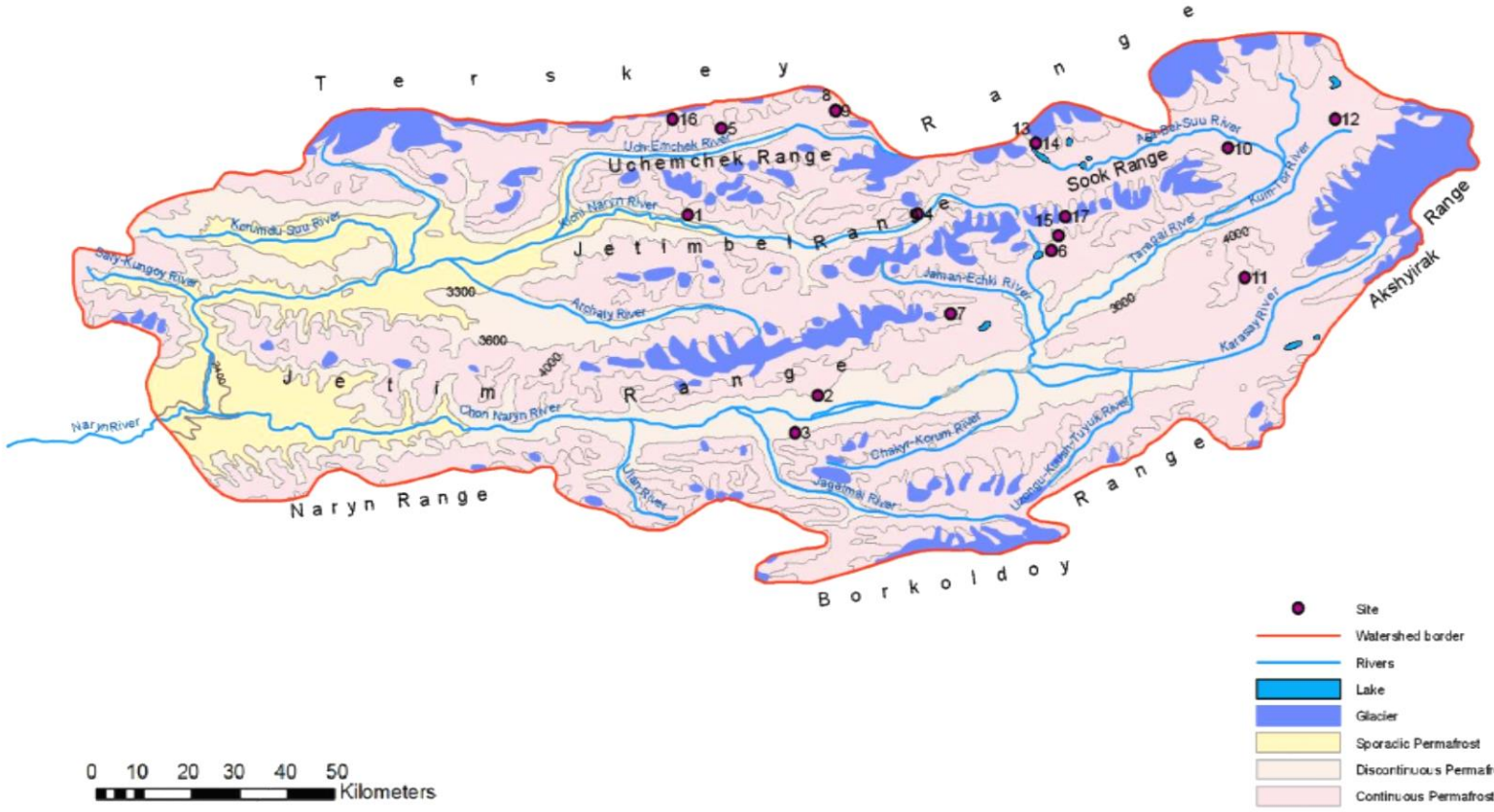
How to proove permafrost without geophysical soundings (seismic, geoelectric)?

Zero curtain effect: Freezing and melting releases / needs energy
-> Zero curtain is an indicator for massive subsurface ice

Results:

Discontinuous permafrost exists above 3300 m a.s.l.,

above 3600 m a.s.l. the continuous permafrost zone starts



Permafrost / Glacier distribution map of the river basins Chon and Kichi Naryn. Dots show the location of ground temperature sensors.

Glaciological methods used

- Advanced Land Observing Satellite (ALOS) datasets acquired during 2010 and 2011
- 1:25 000 scale topographic maps based on aerial photography collected in the 1960s
- Glacier Inventory of Kyrgyzstan 1973 - 1977
- GPS Data

Satellite data processing and Glacier outline extraction

- Orthorectification:
  - AlOS with SRTM DEM
  - Topographic maps scanned at 700 dpi and were projected by georeference on ArcGIS 9.2.
- Manual digitizing of glacier outlines.
- We added the polygon data to attribute data such as mean, maximum and minimum altitudes, area and aspect in each glacier area class.
- GPS measurements: The change in the terminus position of some glaciers was observed during field work from 2010 to 2013 using GPS measurements.
- Stake measurements

Results and conclusions - Glaciology

The basic information of investigated glaciers

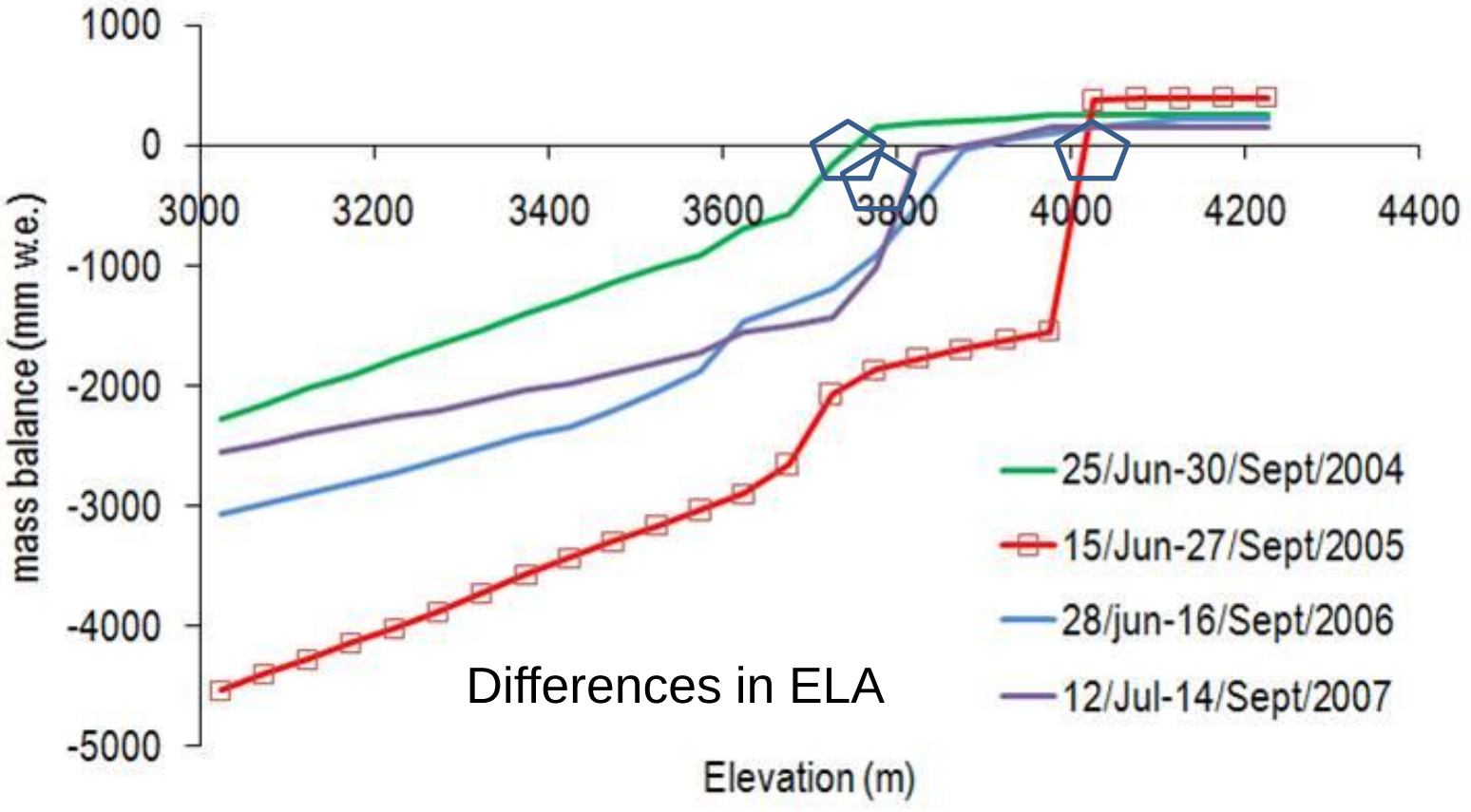
Class (km^2)	Number of glacier	Total area		Minimum elevation (m)	Maximum elevation (m)	Mean elevation (m)
		(km^2)	(%)			
0.1 – 0.5	395	98.1	16.8	3580	4960	4187
0.5 – 1	177	186.6	31.9	3510	4960	4214
1 - 2	40	70.9	12.1	3580	5020	4232
2 - 5	30	120.6	20.6	3720	4880	4222
5 >	12	109.2	18.6	3600	5170	4258
Total	654	585.4	100	3510	5170	4223

Small glaciers in lower elevations suffer stronger loss

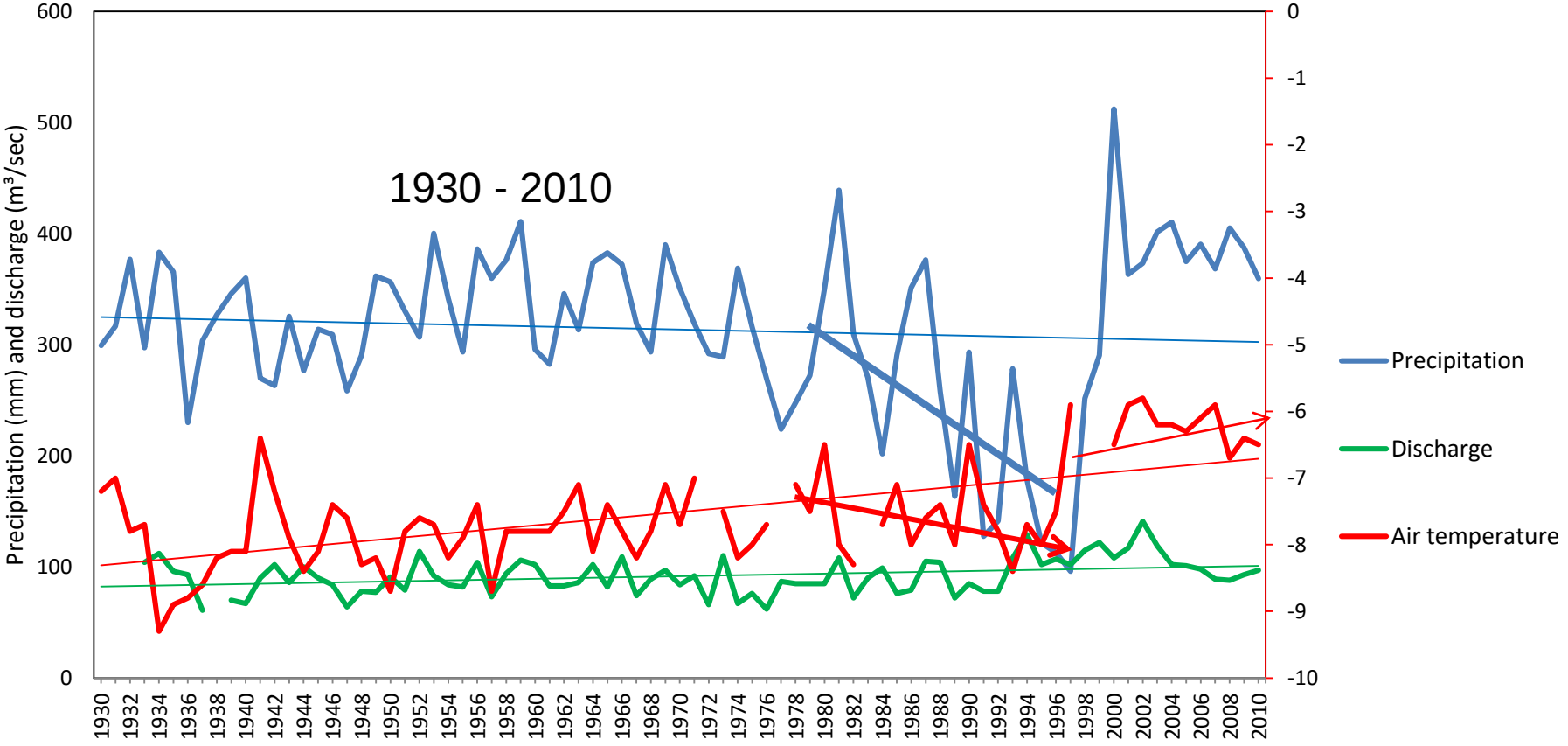
Area of glaciers less than 1 km^2 is 48%

Aylama Glacier, summer mass balance along profile, 3020 to 4250 m

(Chon Kyzylsuu catchment, Terskey mountain range)



Climate and Run-off

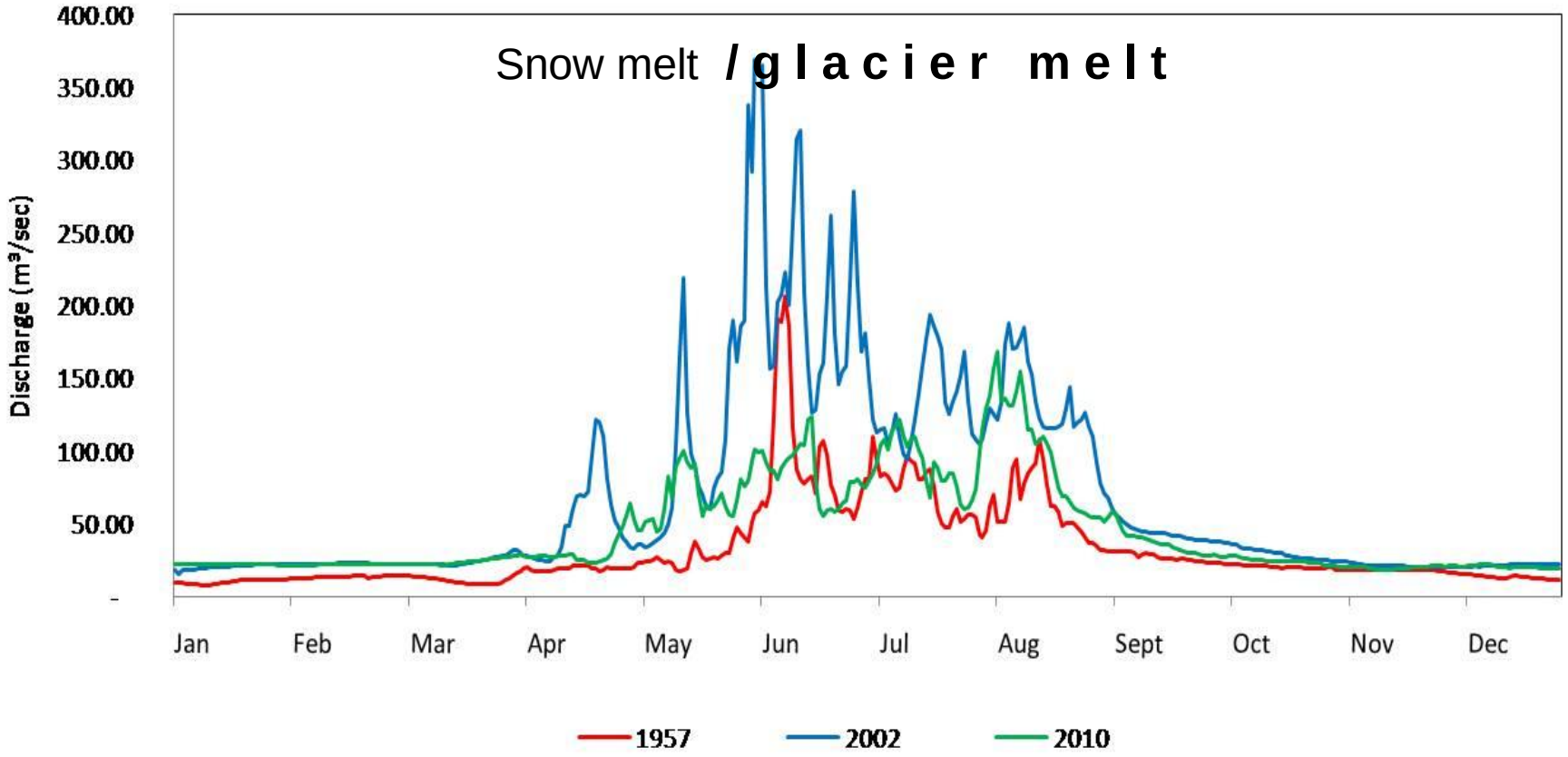


Annual precipitation, mean annual air temperature, discharge of Naryn

(Tian Shan meteorological station, 3614 m a.s.l.)

Results — Hydrology

(surface water run-off and glacier runoff)



Hydrographs of Chon Naryn river for maximum run-off (2002), minimum (1957) and recent (2010):

high variability, glacial melt water contributes main part to river run-off

Geocryological Conclusions and Perspectives (Duishonakunov)

- Discontinuous frozen grounds are wide-spread above 3300 meters,
  continuous permafrost is developed above 3600 meters,
  permafrost islands can exist down to an altitude of 2700 m.

- The active layer varies from about 30 cm up to about three meters

- Future studies are urgently needed in a new project with detailed studies concerning
  the effect of topography on the distribution of permafrost and ground ice

- This future project should also include the hazards involved with
  different warming climate scenarios

- The results have to be communicated globally,
  e.g. within the International Permafrost Society (IPA)

Glaciological Conclusions and Perspectives (Duishonakunov)

- The total area of glaciers in the Chon Naryn and Kichi Naryn catchments decreased significantly between ~1965 and ~2010 with a glacier retreat of >21%, due to increasing summer temperatures.
- Largest **glacier area loss in Naryn range (28.9%) because of the dominance of small-scale glaciers**
- Glacier retreat results in decreased summer runoff leading to **water shortages for lowland areas**
- In addition, glacier shrinkage enhances the probability for development and increase of glacier lakes, **producing glacier hazards such as GLOF**s.
  It is recommended to establish an inventory of dangerous glaciers and permafrost sites
- **Future studies are necessary** in order to give a more detailed quantitative outlook concerning the effects of glacier area changes on the water balance in Kyrgyz Republic
- The results of the thesis Duishonakunov may bring detailed knowledge concerning water availability for agriculture and hydropower, but also for transboundary water management
- The data has to be included in “World Glacier Inventory” as Kyrgyz contribution to the global perspective

Further implications:
Hazards and environmental concerns

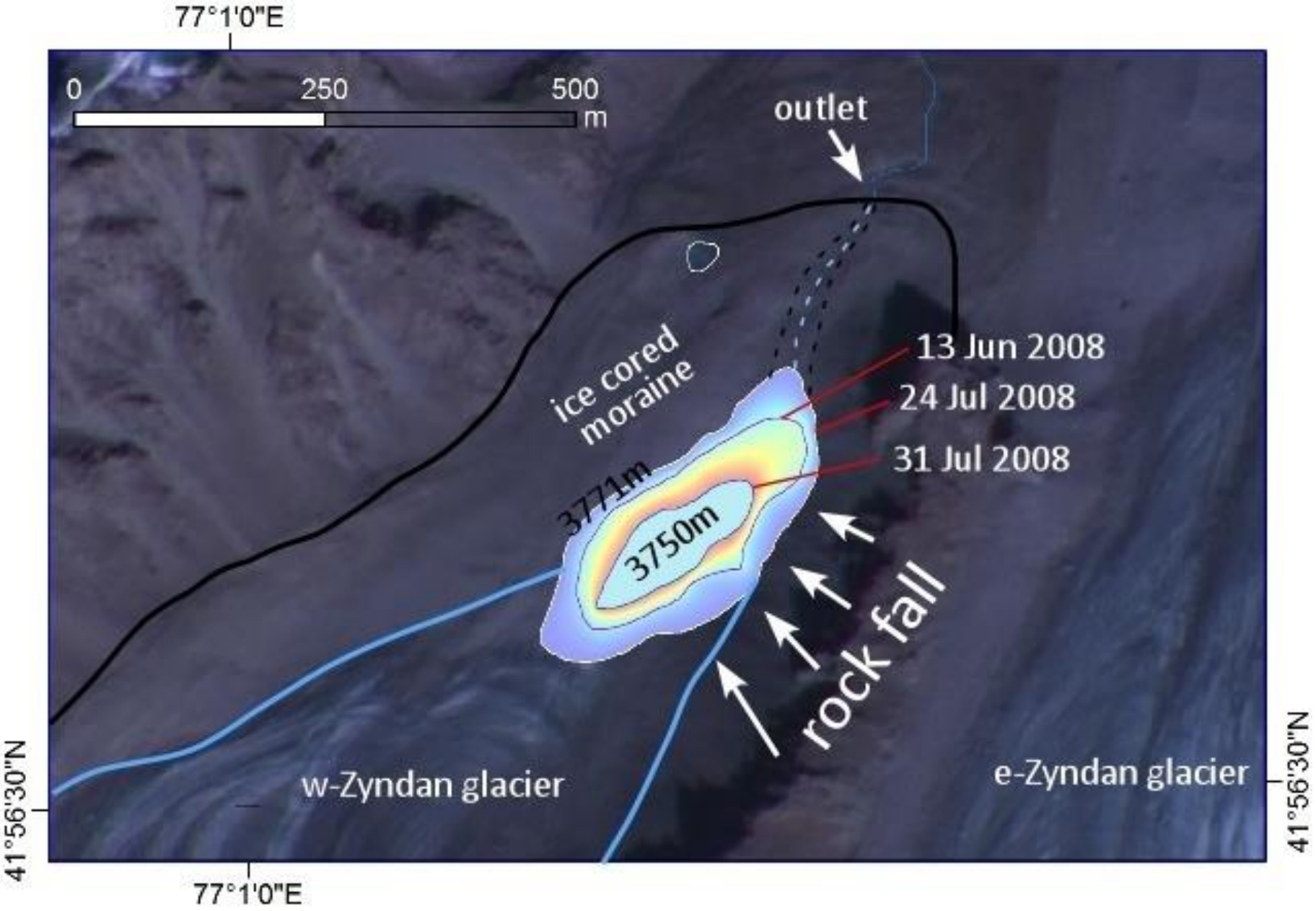
Human impact to the glacier, upstream part of the Chon Naryn river

A - Kumtor gold mine open pit

B – Cutting the glacier

C - Depositing as new artificial glacier

Glaciers as Geohazard (Zyndan Glacier, 2008)



Results — Geohazards

КЫРСЫКТЫН ТИЛИН КИМ БИЛЕТ?

ТОҢДО МӨҢГҮ КӨЛҮ КАНТИП «МӨҢКҮДҮ»?

2008-жылдын 24-июлунда Ысык-Көл облусунун Тоң районундагы Бөкөнбаев, Төрткүл жана Туурасуу айылдарын аралай аккан Зындан суусунун башындагы мөңгү көлү жарылып, төмөнкү агымы чоң селге айланды. Анын кесепетинен бир үйбүлөдөн үч адам кайтыш болду. Айылдыктардын көптөгөн мал, үй канаттуулары да агып кеткен. Сел суу нугундагы көпүрөлөр, жолдун айрым бөлүктөрү, үй, сарайларды жана арпа, картошка аянттарынын кээ бир бөлүктөрүн түшүм алына электе талкалап кеткен. Бул макала 2008-жылдын 26-31-июлундагы Зындан суусун жээктей жүргүзүлгөн изилдөөлөрдүн негизинде жазылды.

Glacier Lake outburst floods

“GLOF”

Results — Glacier, Permafrost and Climate as a Geohazards (GLOFs)

Duishonakunov, Murataly T. (2014):
Glaciers and permafrost as water resource in Kyrgyzstan: distribution, recent dynamics and hazards, and the relevance for sustainable development of Central Asian semiarid regions. PhD thesis, JLU Giessen, 127 pp.
http://geb.uni-giessen.de/geb/volltexte/2014/10962/

Glaciers in Kyrgyzstan → Aksu catchment

Location of Upper Naryn catchments, Kyrgyz Tian Shan

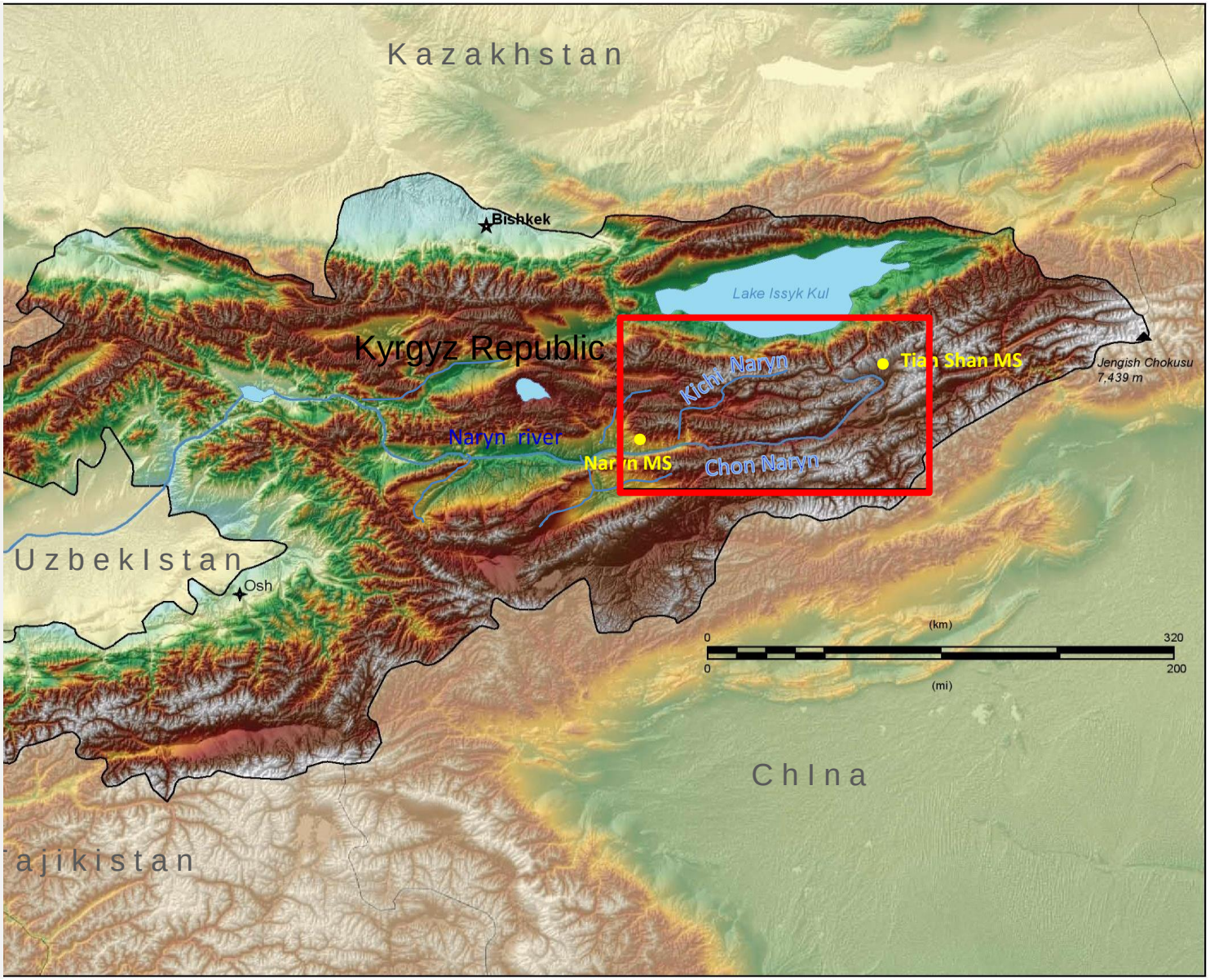
Naryn basin
(~ 60.000 km²)

Chon Naryn catchment
(~5.710 km²)

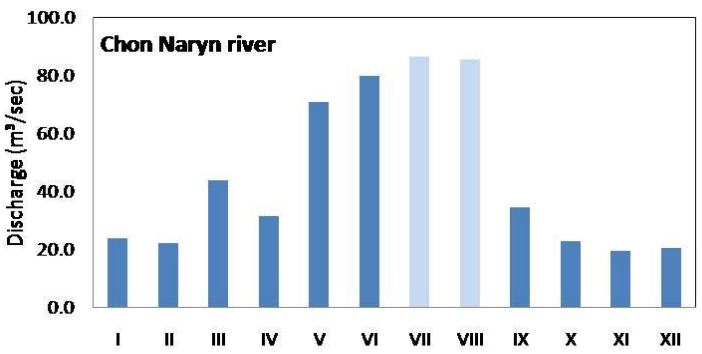
Kichi Naryn catchment
(~3.870 km²)

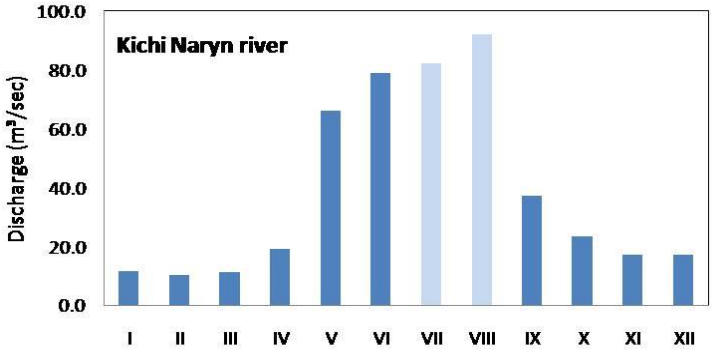
Main tributary to Syrdarya River

Head water catchments are glaciated

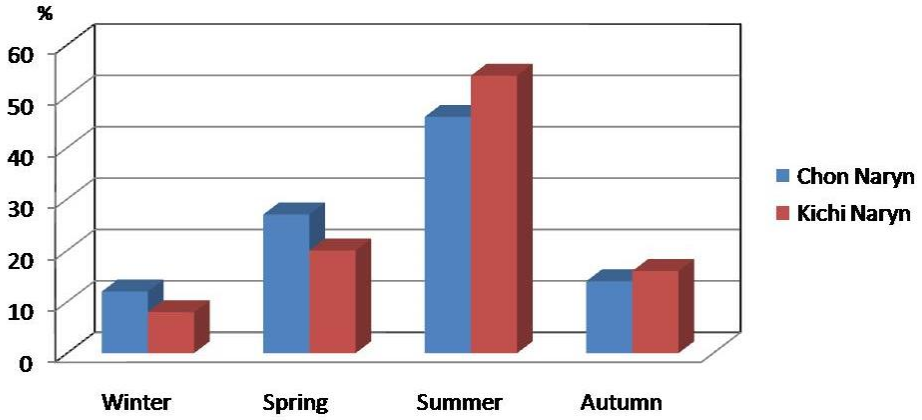


Hydrological regime of surface water flow and Glacier runoff





Annual run-off, Chon Naryn and Kichi Naryn rivers, 2001-2011



Seasonal flow in Chon Naryn and Kichi Naryn rivers (%)

Results — Hydrological regime of surface water flow and Glacier runoff

Total and glacier runoff in the Naryn catchment

River – observation station	Average annual discharge (m^3/sec)	Volume (10^6 m^3)	Glacier runoff (10^6 m^3)			Share of glacier water in total runoff (%)	Share of glacier water in summer runoff (%)
			From snow melt	From glacier melt	Total		
Chon Naryn - estuary	**46.5**	**1479**	**196.5**	**258.5**	**455.0**	**30.7**	**51.3**
Kichi Naryn - estuary	**41.1**	**1340**	**201.6**	**119.7**	**321.3**	**23.9**	**36.5**
Kokomeren – Sarykamysh vill.	102.0	3217	44.5	64.9	109.4	3.4	6.0
Atbashy – Jangyztal village	33.1	1044	33.2	68.0	101.2	9.7	22.4
Alabuga – Koshtobo vill.	31.0	978	54.4	75.5	129.9	13.2	25.5
Naryn – Uchkurgan vill.	432.0	13624	378.6	665.9	1244.5	9.1	16.7

Aylama glacier runoff with HMS model, 2005-2009

(Chon Kyzylsuu catchment, Terskey mountain range)