The Italian science and cooperation at the shadow of K2

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# Water resources and hydrological regimes of the upper Indus basin and CKNP: results from SEED project.

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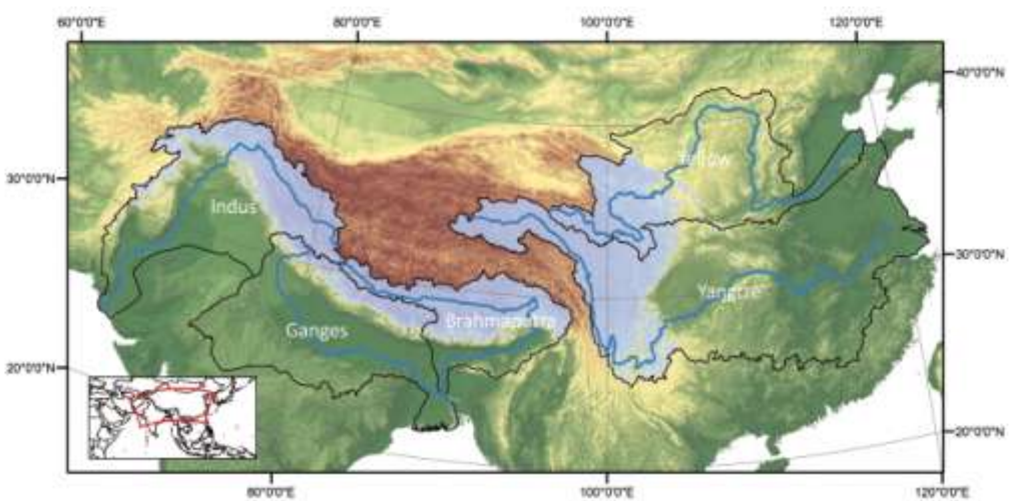
# Karakoram resources: Water

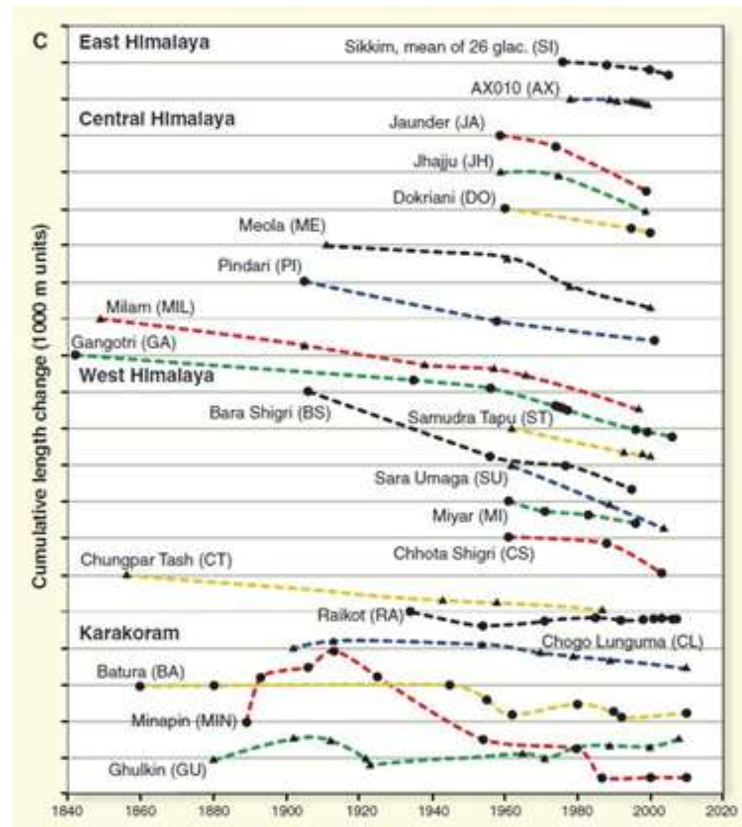
- The mountain range of the Hindu Kush, Karakoram and Himalaya (HKKH) contains a large amount of glacier ice, and it is the *third pole* of our planet.
- The Indo-Gangetic plain (IGP, including regions of Pakistan, India, Nepal, and Bangladesh) is challenged by increasing food production
- While southern Himalaya is strongly influenced by monsoon climate, meteo-climatic conditions of Karakoram suggest a stricter dependence of water resources upon snow and ice ablation.
- Shrinking glaciers may initially provide more melt water, but later their amount may reduced. On the other hand, growing glaciers store precipitation, reduce summer runoff, and can also generate local hazards.
- Most recent observations of glacier fluctuations indicate that in the eastern and central HKKH glaciers are subject to general retreat, while stable or even positive ice mass balances and advancing glaciers have been reported in the Karakoram

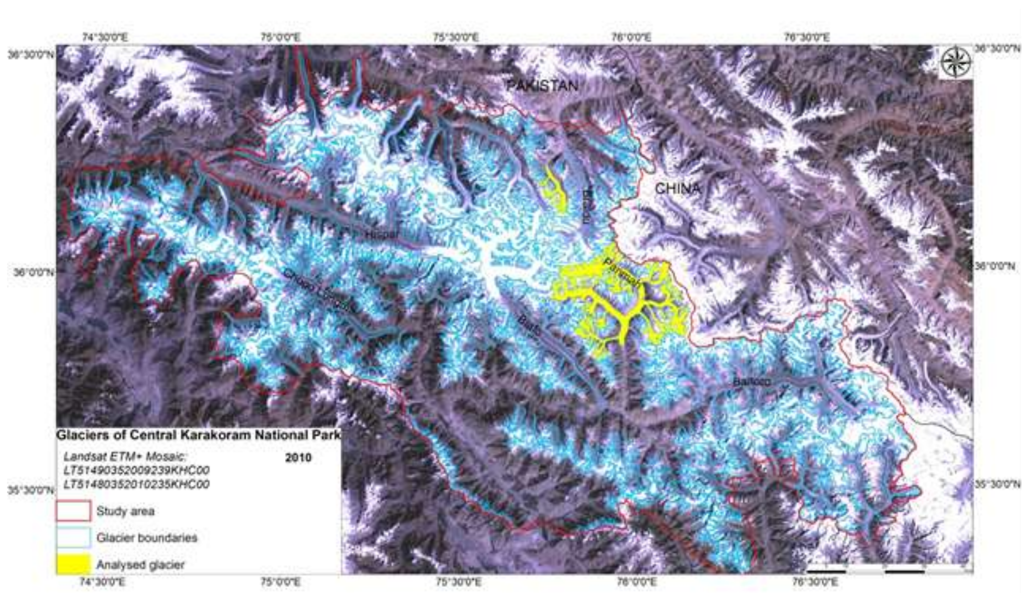



# Karakoram resources: Water

Here, we present the results of research carried in fulfillment of SEED project, aimed at

- Improving our knowledge of physical processes underlying glacier dynamics, and hydrology of the upper Indus Basin UIB
- Modeling hydrological cycle of strongly snow and ice fed catchments in this area
- Providing believable projections of hydrological behavior within UIB until the end of the century
- Set up strategies for monitoring and modelling hydrological components and potential future Hydrology and cryospheric cycle within the particular case study area of Central Karakoram National Park, CKNP



# SEED project

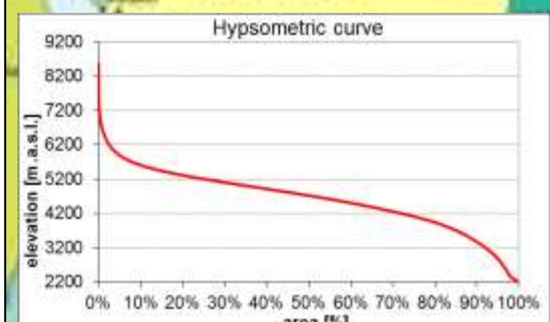
## Water

Within the framework of the **SEED** project, aimed to foster and support social, economic, and environmental development within the CKNP park, we developed studies explicitly devoted to establish procedures and protocols for assessment and management of water resources, specifically aimed to

- Assess hydrological components and timing of water resources within the Upper Indus Basin UIB, and CKNP
- Develop methodologies to model water resources availability, hydrological regimes, and floods under present, and perspective climate conditions.
- Propose a potential hydrological monitoring network for the CKNP area.
- Develop a proposed protocol for stream flow measurements

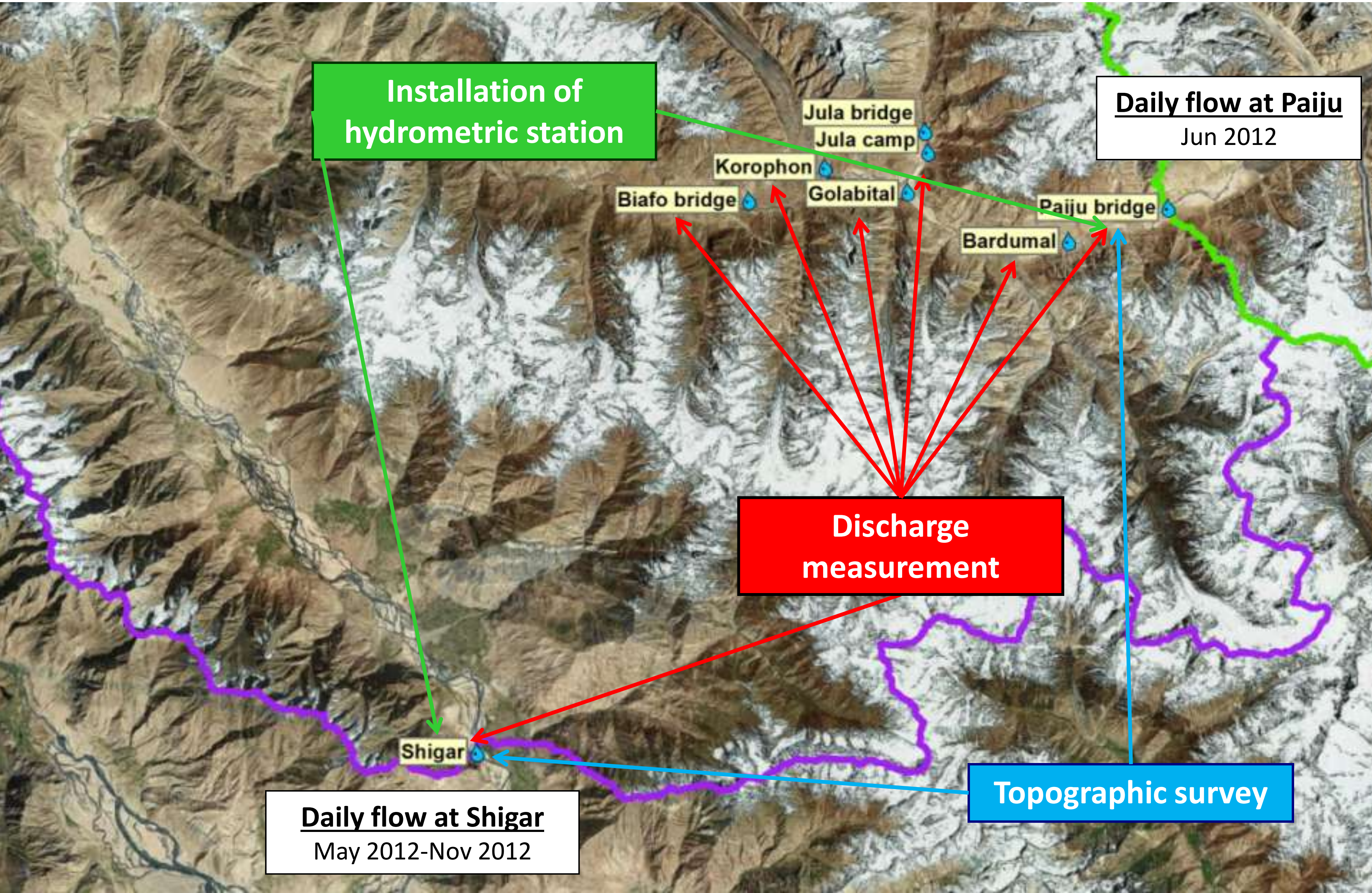
# A case study:  Shigar basin - PAKISTAN

## The Shigar river basin


| | |
|---|---|
| Area [km²] | 6921 |
| Perimeter [km] | 785 |
| Mean elevation [m s.l.m.] | 4612 |
| Min elevation [m s.l.m.] | 2142 |
| Max elevation [m s.l.m.] | 8561 |
| Elevation range [m] | 6419 |
| Main stream lenght [km] | 125 |

# Shigar basin - PAKISTAN
## Field work (2011-2013) summary



# Hydrological modelling

## Available dataset

Field campaigns during 2011-2013

**Daily flow at Shigar**
April 2011-May 2013

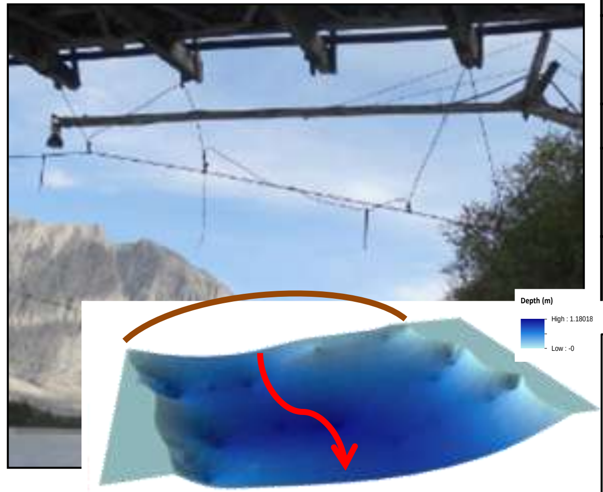
**Daily flow at Paiju**
Jun 2012-June 2013

**Ablation stakes**
Summer 2011-summer 2013

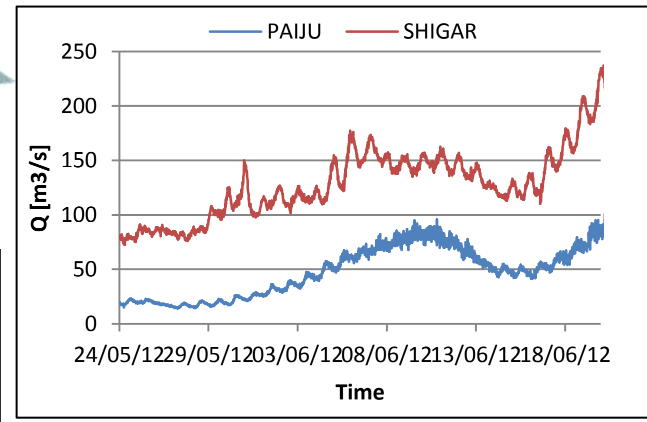
# In-situ works

## Installation of hydrometric stations

Shigar gauge station (ultrasonic sensor) - April 2011



| | |
|---|---|
| Altitude | 2221 m a.s.l. |
| Watershed area | 6923 km$^2$ |
| Datalogger | Campbell Scientific - CR200X |
| Sensor | sonic sensor Vegason 63, 4-20 mA, 24V |
| Power supply | solar panel 20W + battery Pb 12V 40 Ah |

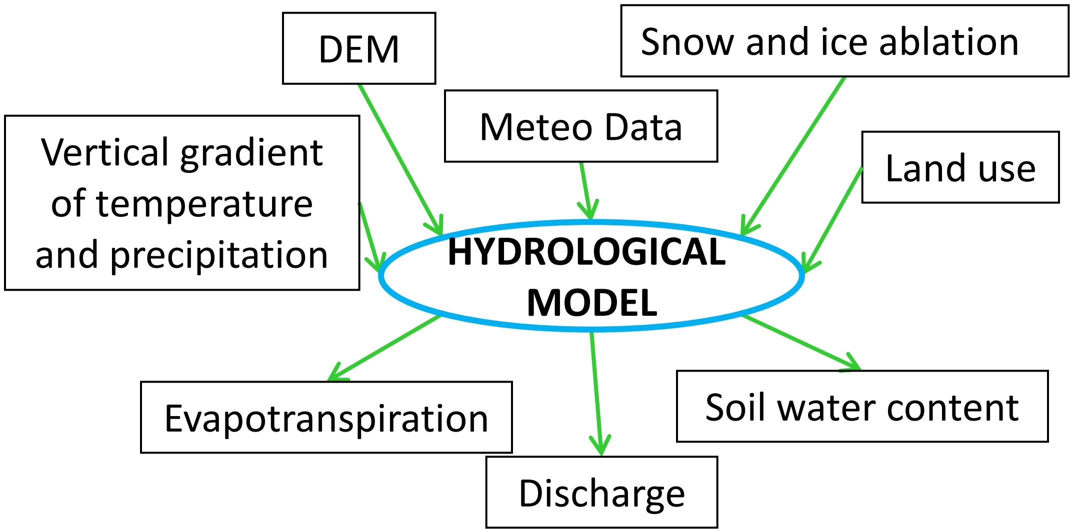



Paiju gauge station - May 2012

| | |
|---|---|
| Altitude | 3356 m a.s.l. |
| Watershed area | 1331 km$^2$ |
| Datalogger | Campbell Scientific - CR200X |
| Sensor | piezometric sensor STS atm.eco/n, 4-20 mA, 12V |
| Power supply | solar panel 20W + battery Pb 12V 16 Ah |

# Hydrological modelling

## The hydrological model




Semplified ice flow modelling:

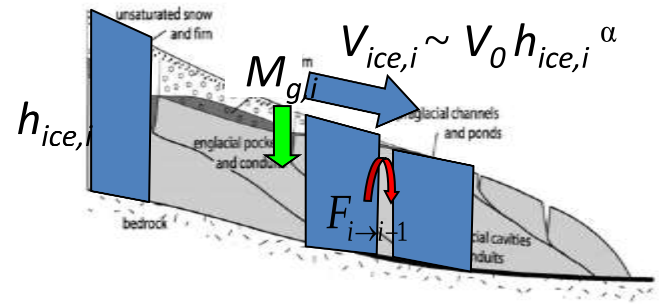



Fig. 2. The hydrological systems and locations of water storage in a temperate glacier (modified from Röthlisberger and Lang, 1987).

Main daily balance equation:

$$S^{t+\Delta t} = S^t + P + M_s + M_g - ET - Q_g$$

S= soil water content
P= total precipitation (rain and snow)
$M_s$= snow melt
$M_g$= ice melt
ET= evapotranspiration
$Q_g$= ground flow

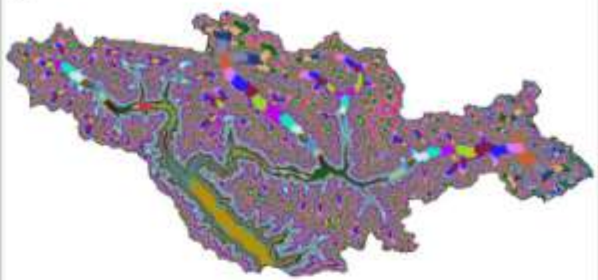
$$Q_s = S^{t+\Delta t} - S_{Max} \qquad se \;\; S^{t+\Delta t} > S_{Max}$$
$$Q_s = 0 \qquad se \;\; S^{t+\Delta t} \le S_{Max}$$

Discharge formation:
$Q_s$= superficial flow
$S_{max}$= max soil water content

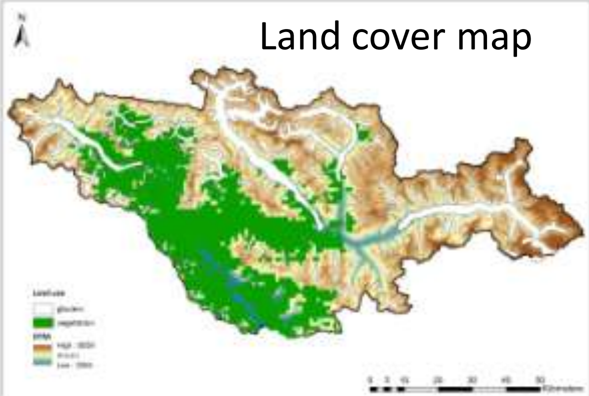
# Hydrological modelling

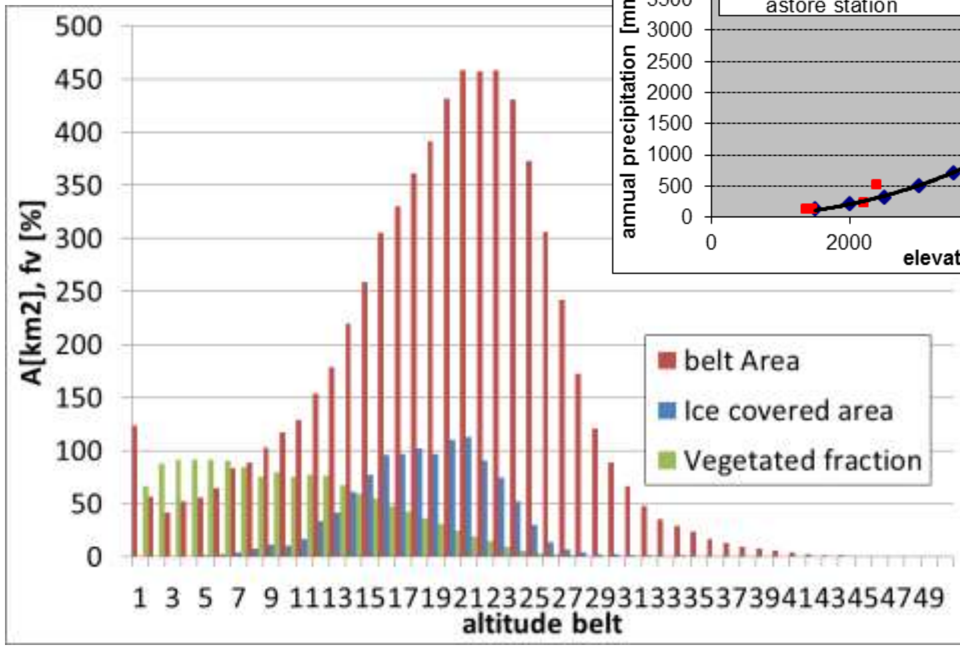
## Model input

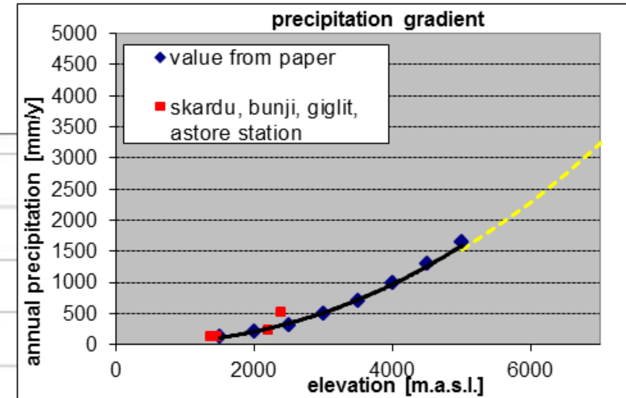
50 equispaced altitude bels



Land cover map





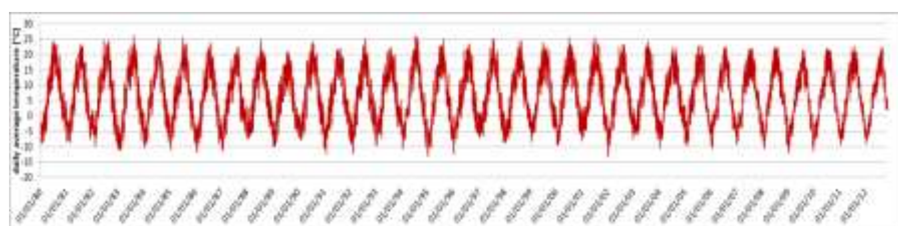

*Winiger M.et al., 2005.*

Available meteorological data

| station | available data | temporal resolution |
|---|---|---|
| Askole | 2005-2012 | daily |
| Astore | 1980-2009 | monthly |

Monthly mean flow data available at Shigar from 1985 to 1997

Statistical downscale on monthly Astore data based on daily Askole data

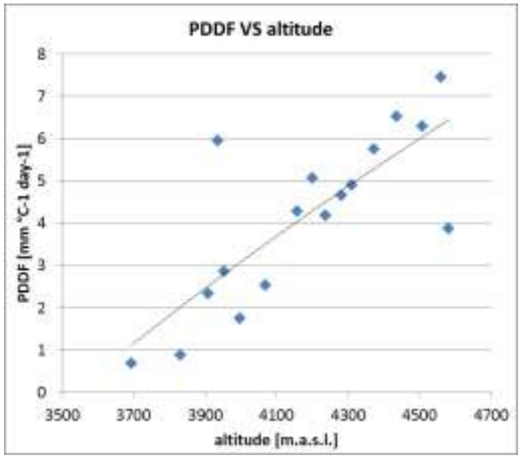


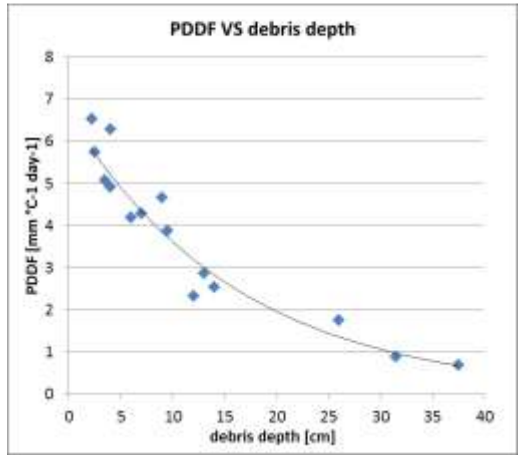
# Hydrological modelling

## Ice Degree day factor estimation

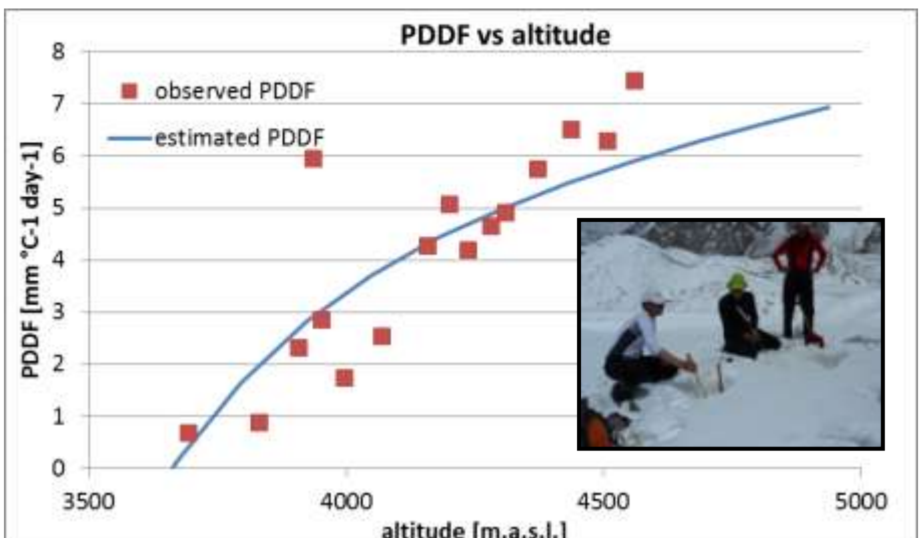
**Ice ablation data collected in summer 2011 by a UNIMI_POLIMI field campaign:**

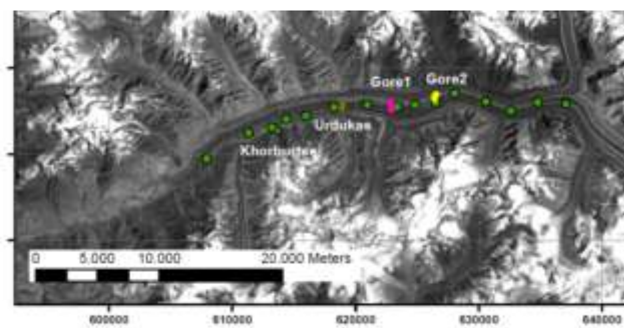
- Debris depth at 17 points
- Ablation data at 17 ablation stakes




| Stake | altitude [m.a.s.l.] | debris depth [cm] | PDDF [mm/°C/d] |
|---|---|---|---|
| b1 | 4580 | 9.5 | 3.8721 |
| b2 | 4560 | 0.0 | 7.4494 |
| b3 | 4507 | 4.0 | 6.2845 |
| b4 | 4436 | 2.2 | 6.5153 |
| b5 | 4371 | 2.5 | 5.7441 |
| b6 | 4310 | 4.0 | 4.9023 |
| b7 | 4281 | 9.0 | 4.6545 |
| b8 | 4236 | 6.0 | 4.1861 |
| b9 | 4200 | 3.5 | 5.0686 |
| b10 | 4158 | 7.0 | 4.2795 |
| b11 | 4069 | 14.0 | 2.5297 |
| b12 | 3997 | 26.0 | 1.7424 |
| b13 | 3952 | 13.0 | 2.8547 |
| b14 | 3935 | 0.0 | 5.9406 |
| b15 | 3830 | 31.5 | 0.8759 |
| b16 | 3907 | 12.0 | 2.3259 |
| b17 | 3693 | 37.5 | 0.6843 |

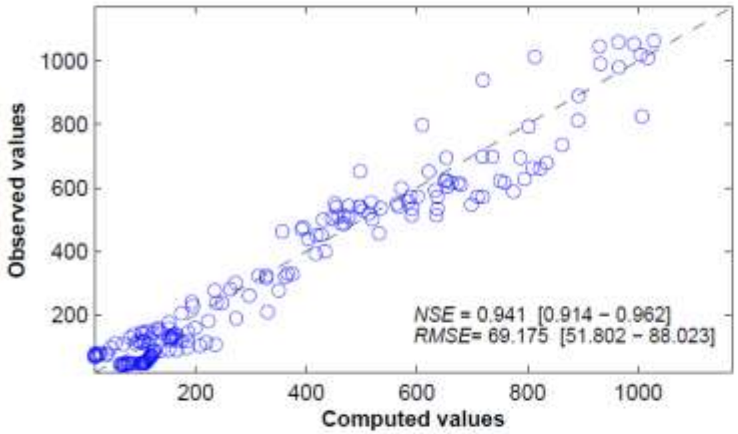


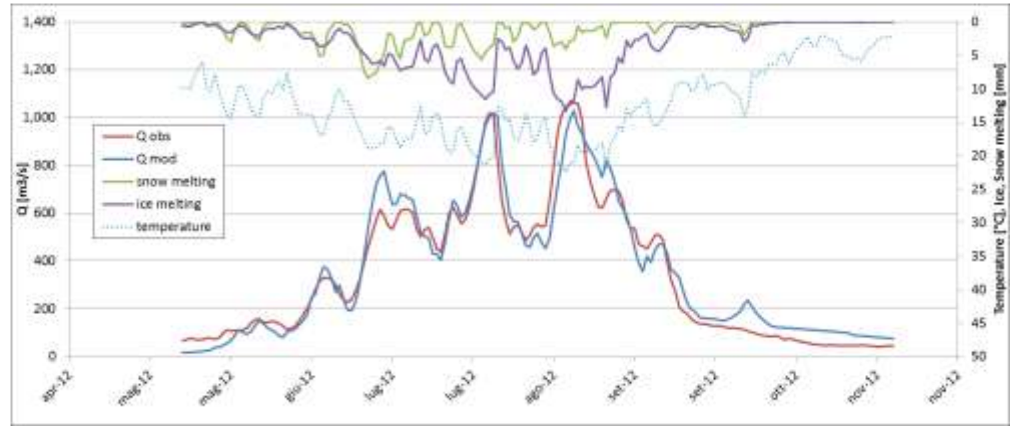



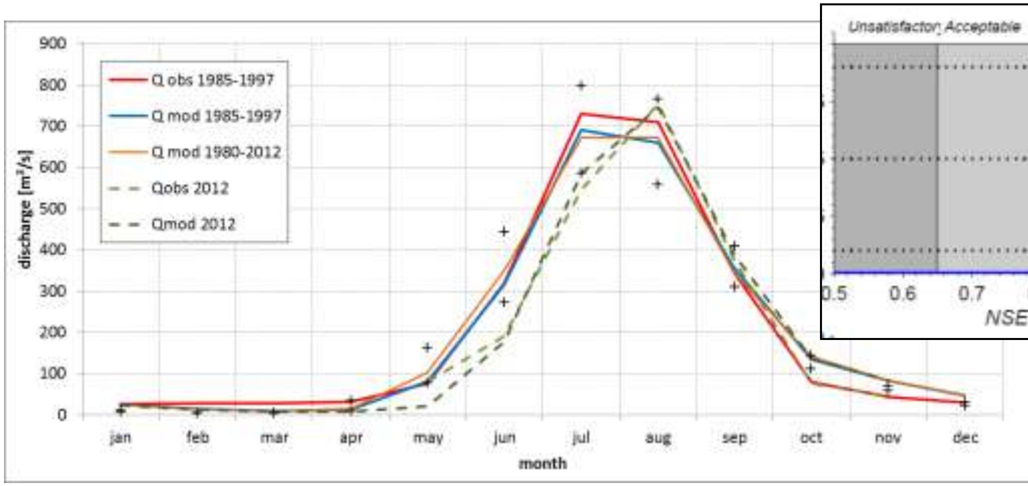

Multiple regression used to stimate PDDF at each altitude belt

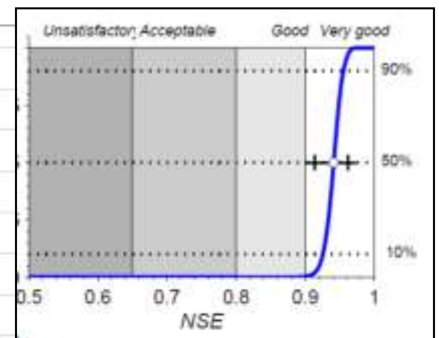
# Hydrological modelling

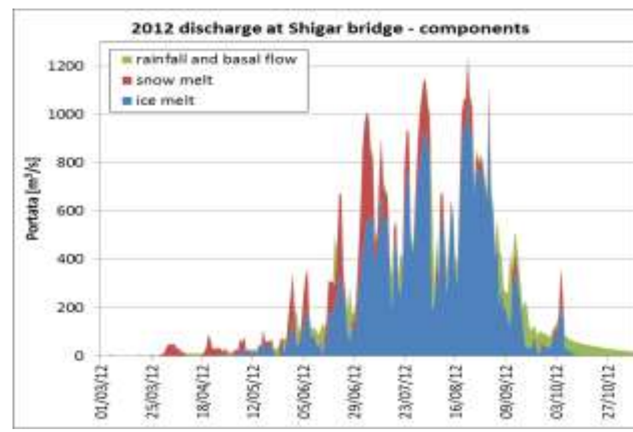
## Calibration 1985-1997 monthly data at Shigar



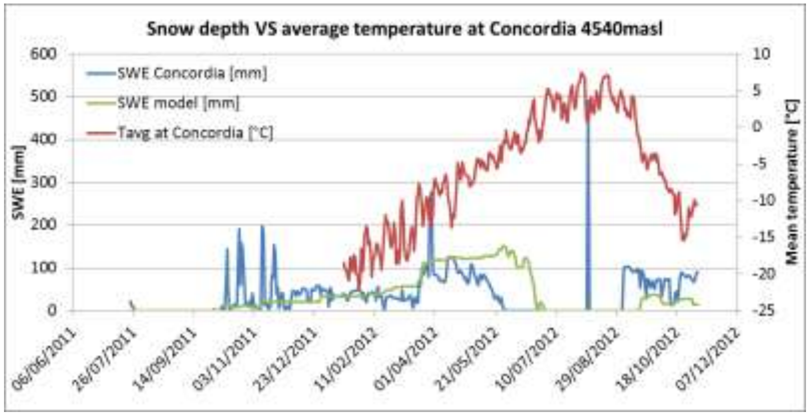



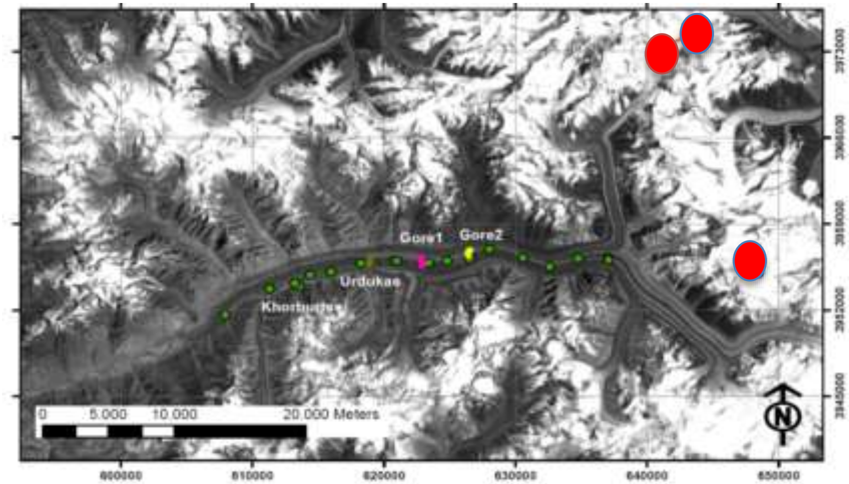

| | jan | feb | mar | apr | may | jun | jul | aug | sep | oct | nov | dec | average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **observed 1985-1997** | 26.07 | 27.76 | 28.55 | 31.81 | 76.47 | 319.42 | 729.21 | 710.09 | 343.53 | 78.71 | 44.13 | 29.05 | **203.73** |
| **model 1985-1997** | 24.05 | 13.43 | 8.72 | 12.78 | 81.27 | 316.22 | 690.03 | 659.95 | 355.54 | 134.27 | 82.60 | 46.61 | **202.12** |
| **model 1980-2012** | 24.07 | 13.23 | 8.49 | 14.60 | 102.16 | 350.68 | 672.78 | 672.71 | 341.39 | 142.38 | 83.61 | 47.24 | **206.11** |
| **observed Shigar 2012** | - | - | - | - | 80.98 | 190.63 | 544.93 | 753.20 | 373.54 | 76.36 | 45.00 | - | **294.95** |
| **model Shigar 2012** | 22.13 | 12.16 | 7.24 | 7.57 | 21.21 | 177.61 | 583.76 | 746.11 | 387.16 | 136.55 | 82.80 | - | **305.03** |

# Hydrological modelling

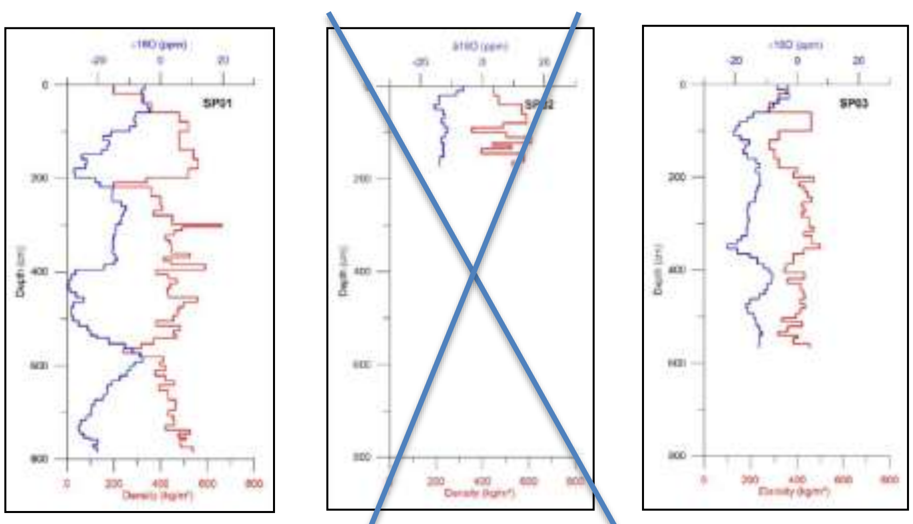
## Calibration 2011 snow pits and 2012 nivometer

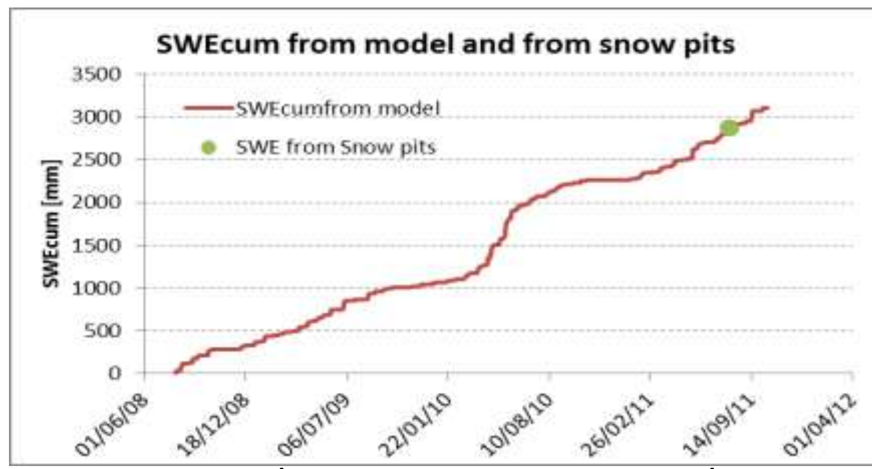
The comparison between Concordia nivometer data (2012) and model SWE at the same altitude need some arrangements




Snow pits data from summer 2011 field campaign



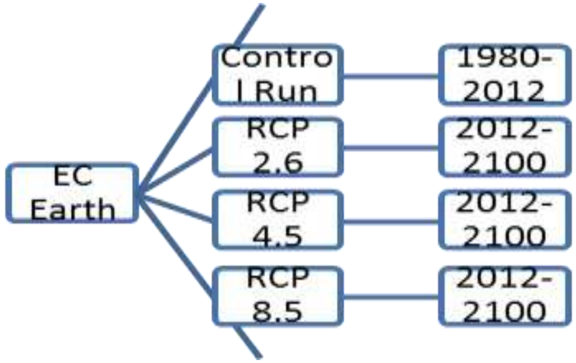

Comparison between 3 years accumulation SWE from model and summer 2011 snow pits

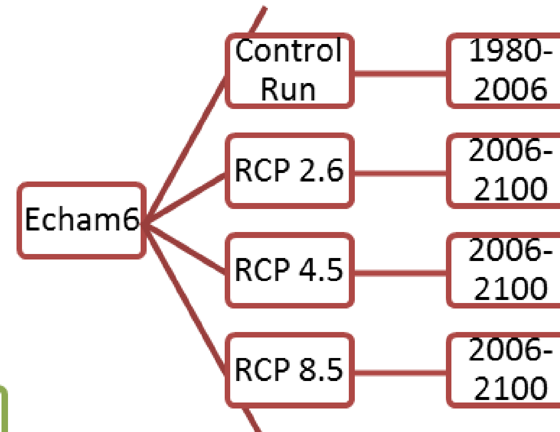
| Site | Three years acc [m] | SWE [mm] |
|---|---|---|
| **SP01 (5600 m.a.s.l.)** | 8.00 | 3280 |
| **SP03 (5900 m.a.s.l.)** | 6.00 | 2460 |
| **Average** | | 2870 |

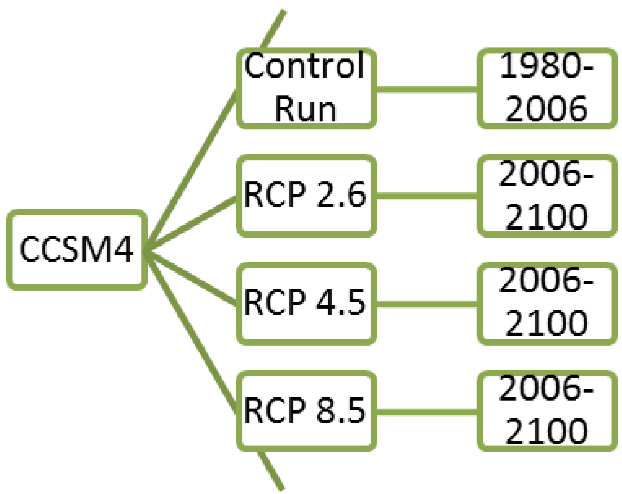
# Hydrological modelling

## GCMs for scenario simulations

We used (properly downscaled) inputs from three different GCMs to project forward hydrology of the Shigar river until 2099.

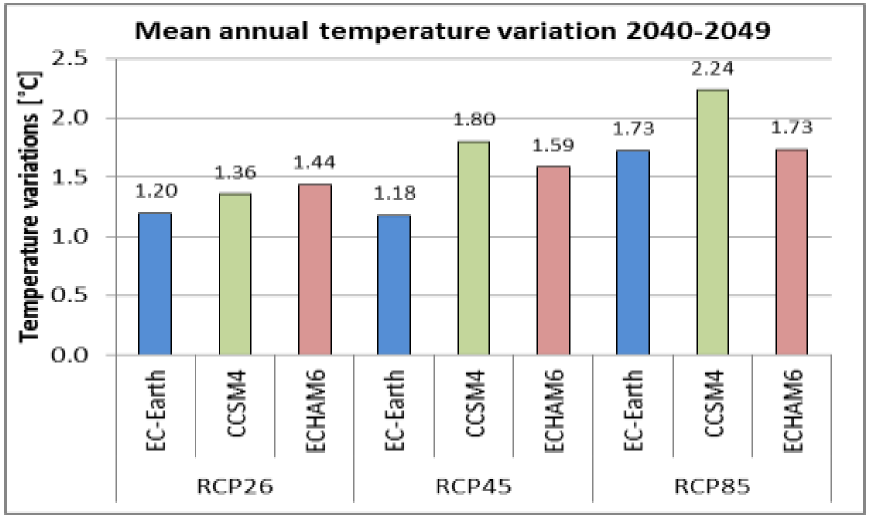


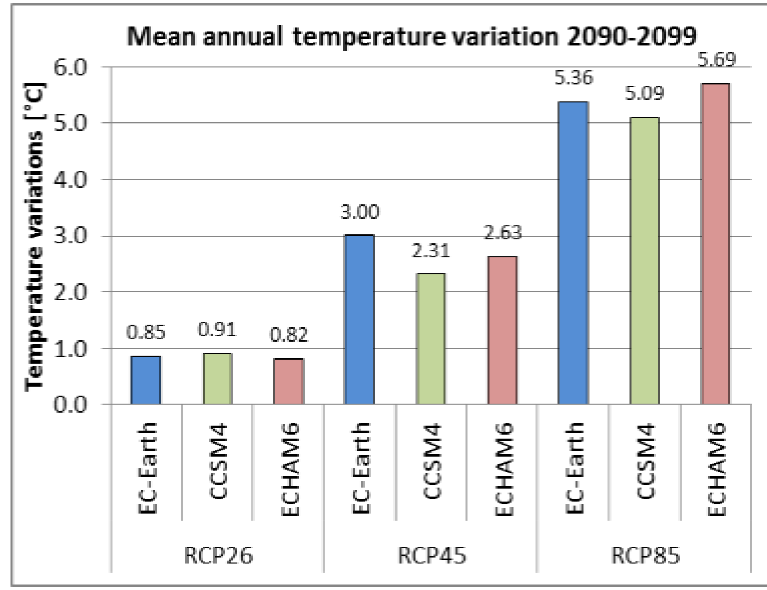



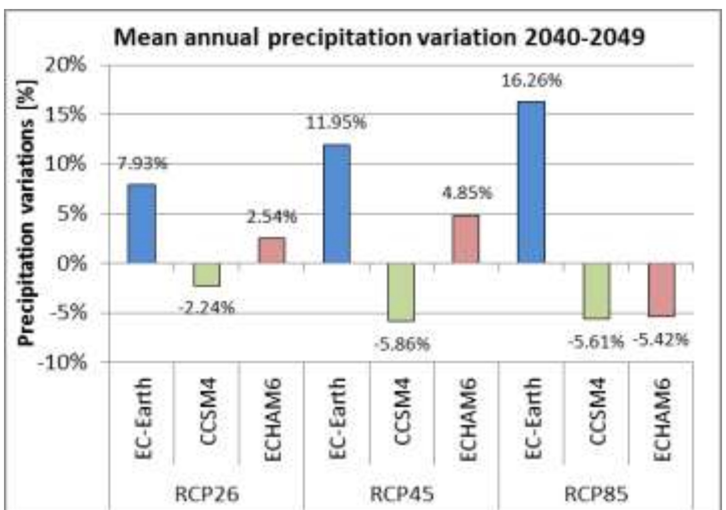

# Hydrological modelling

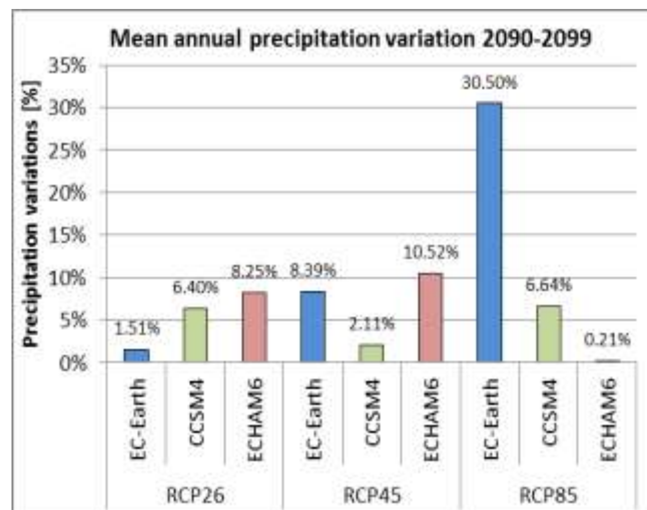
## Temperature changes (yearly, Ref. 1980-2012)




## Precipitation changes (yearly, Ref. 1980-2012)



# Hydrological modelling

## Weather changes (monthly, Ref. 1980-2012)

### Monthly temperature

| TEMPERATURE | | | jan | feb | mar | apr | may | jun | jul | aug | sep | oct | nov | dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2040-2049 | RCP26 | EC-Earth | 1.32 | 1.00 | 0.50 | 1.42 | 1.27 | -0.61 | 1.34 | 1.31 | 0.95 | 1.39 | 2.80 | 2.19 |
| | | CCSM4 | 1.28 | 0.10 | -0.33 | -0.21 | 0.50 | 0.72 | 1.71 | 1.73 | 2.72 | 2.97 | 2.83 | 2.13 |
| | | ECHAM6 | 1.52 | 0.61 | 1.38 | 1.40 | 0.82 | 1.19 | 2.18 | 1.06 | 1.66 | 1.74 | 2.17 | 1.44 |
| | RCP45 | EC-Earth | 0.89 | 1.86 | 1.54 | 0.45 | 0.92 | 1.68 | 2.02 | 1.95 | 2.05 | 1.75 | -0.41 | -0.01 |
| | | CCSM4 | 2.28 | 0.37 | 0.97 | 0.30 | 1.29 | 0.86 | 1.55 | 2.08 | 2.59 | 3.68 | 3.06 | 2.37 |
| | | ECHAM6 | 0.51 | 1.31 | 1.74 | 1.89 | 1.21 | 1.23 | 2.42 | 1.92 | 1.79 | 2.99 | 1.52 | 0.50 |
| | RCP85 | EC-Earth | 1.64 | 1.57 | 1.80 | 2.19 | 1.91 | 1.75 | 0.76 | 1.00 | 2.58 | 2.35 | 2.05 | 1.65 |
| | | CCSM4 | 2.31 | 1.10 | 0.62 | 0.85 | 2.31 | 1.53 | 2.05 | 2.76 | 3.59 | 3.93 | 2.90 | 2.73 |
| | | ECHAM6 | 0.96 | 0.87 | 1.36 | 1.75 | 0.92 | 1.39 | 2.28 | 1.78 | 2.90 | 2.76 | 2.10 | 1.71 |
| 2090-2099 | RCP26 | EC-Earth | 1.57 | 0.67 | 1.06 | -0.34 | 1.88 | 0.40 | 0.94 | 1.15 | 0.82 | 0.88 | -0.47 | 2.04 |
| | | CCSM4 | 0.47 | 0.66 | 0.27 | 0.35 | -0.15 | -0.61 | 0.72 | 1.25 | 2.64 | 2.19 | 2.08 | 0.98 |
| | | ECHAM6 | -0.13 | 0.58 | 1.27 | 1.46 | 0.67 | 0.29 | 1.55 | 0.78 | 0.79 | 1.51 | 0.87 | 0.15 |
| | RCP45 | EC-Earth | 3.61 | 3.28 | 2.36 | 2.87 | 3.01 | 2.76 | 3.13 | 3.37 | 3.93 | 3.19 | 2.89 | 2.14 |
| | | CCSM4 | 2.57 | 2.04 | 1.55 | 0.86 | 1.22 | 1.30 | 2.18 | 2.73 | 3.68 | 4.12 | 2.67 | 2.72 |
| | | ECHAM6 | 3.20 | 1.91 | 3.04 | 2.22 | 1.52 | 2.12 | 3.22 | 2.38 | 3.06 | 2.93 | 2.92 | 3.00 |
| | RCP85 | EC-Earth | 4.02 | 3.79 | 5.91 | 5.69 | 5.29 | 4.65 | 5.08 | 5.97 | 5.68 | 6.57 | 6.78 | 5.29 |
| | | CCSM4 | 4.62 | 4.43 | 2.96 | 3.61 | 4.64 | 3.66 | 5.14 | 5.69 | 6.76 | 8.39 | 5.46 | 5.57 |
| | | ECHAM6 | 5.78 | 4.91 | 5.15 | 5.05 | 4.54 | 6.06 | 6.69 | 5.46 | 5.78 | 6.15 | 6.46 | 6.12 |

### Monthly precipitation

| PRECIPITATION | | | jan | feb | mar | apr | may | jun | jul | aug | sep | oct | nov | dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2040-2049 | RCP26 | EC-Earth | 13.4% | 9.2% | 22.4% | -10.6% | 10.4% | 23.5% | 6.2% | 16.0% | 24.4% | -15.1% | 5.0% | -20.7% |
| | | CCSM4 | -26.8% | 14.8% | -31.9% | 24.7% | -5.4% | -8.3% | 2.8% | 37.1% | -20.7% | -63.0% | 75.7% | -14.0% |
| | | ECHAM6 | 13.0% | -34.5% | 25.8% | -12.8% | 38.8% | 0.4% | -6.2% | -5.0% | 18.0% | -48.4% | -23.2% | 22.0% |
| | RCP45 | EC-Earth | 10.8% | 44.5% | 4.9% | 43.2% | -17.0% | -8.4% | 14.5% | 3.1% | -2.2% | 50.5% | -27.6% | -4.4% |
| | | CCSM4 | 54.9% | 8.6% | -9.7% | 22.3% | -23.9% | 33.9% | -12.2% | -53.8% | -40.2% | -49.5% | -59.6% | -24.2% |
| | | ECHAM6 | 10.3% | 19.0% | -14.3% | 3.1% | 34.5% | -41.6% | -20.7% | 16.0% | 12.2% | -12.4% | -6.2% | 33.8% |
| | RCP85 | EC-Earth | 17.0% | 7.2% | -16.2% | 46.8% | 6.9% | 11.7% | 72.2% | 2.2% | 10.5% | 34.8% | -40.8% | 46.1% |
| | | CCSM4 | 5.7% | 14.2% | -28.5% | 6.5% | -1.8% | 51.2% | -21.4% | -17.0% | -22.3% | -30.1% | -35.9% | 0.1% |
| | | ECHAM6 | -17.6% | -13.4% | -16.9% | -17.0% | 26.0% | -29.3% | -8.5% | 12.6% | -9.7% | 19.2% | -27.4% | 29.0% |
| 2090-2099 | RCP26 | EC-Earth | 8.0% | 21.6% | -8.9% | 23.0% | -45.5% | 48.3% | -2.7% | 10.3% | 0.8% | 21.0% | -31.8% | -14.2% |
| | | CCSM4 | 36.1% | 1.3% | -16.4% | 55.6% | 9.5% | -24.0% | 1.2% | 1.1% | -17.5% | -27.5% | -39.2% | 11.2% |
| | | ECHAM6 | 10.1% | -24.1% | 17.6% | -14.6% | 10.0% | -18.4% | 6.5% | 5.3% | 2.0% | 103.3% | -9.9% | 64.4% |
| | RCP45 | EC-Earth | -25.3% | 28.1% | -18.0% | 11.6% | 15.5% | 37.4% | 22.9% | -10.8% | -17.0% | 33.2% | -34.7% | 76.6% |
| | | CCSM4 | 5.8% | 6.2% | 0.2% | 40.9% | -9.7% | -11.1% | -5.2% | -17.0% | -24.1% | -26.6% | -29.3% | 15.0% |
| | | ECHAM6 | -32.5% | -0.5% | 15.5% | 24.5% | 56.1% | -11.4% | 1.9% | 9.3% | -8.7% | -5.7% | -0.6% | 4.1% |
| | RCP85 | EC-Earth | 36.8% | 13.7% | 70.0% | 42.7% | 9.0% | 30.9% | 39.1% | -27.9% | -11.5% | 28.0% | -1.4% | 93.2% |
| | | CCSM4 | -1.8% | -39.7% | -19.0% | 27.0% | 55.8% | 102.8% | -30.9% | 17.4% | -6.2% | -6.1% | -27.3% | 8.5% |
| | | ECHAM6 | 22.2% | -34.3% | -2.5% | -15.3% | 24.2% | -2.0% | -10.6% | -1.6% | 62.5% | 48.9% | -85.7% | 22.8% |

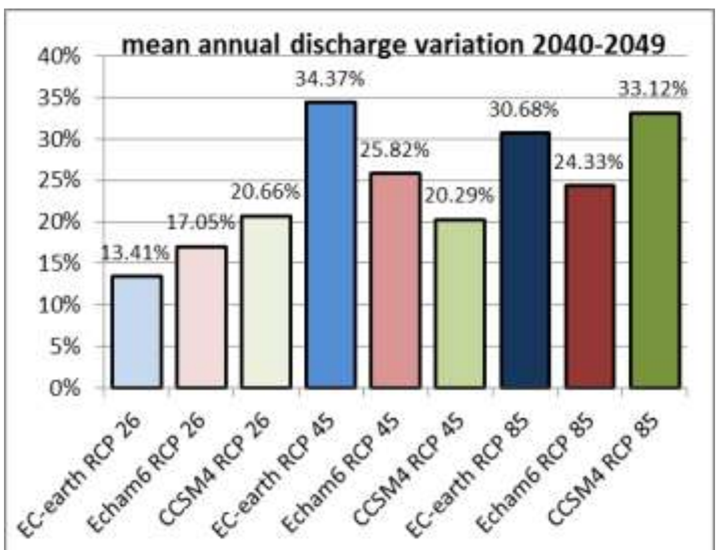
# Hydrological modelling

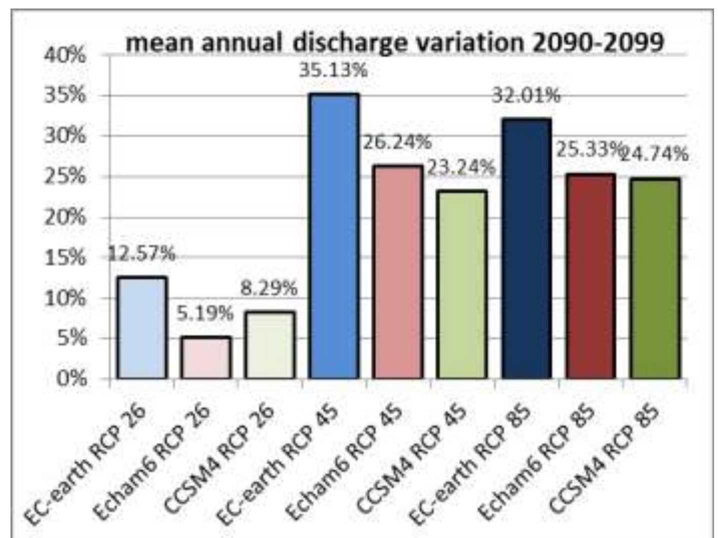
## Hydrological scenarios

### Mean yearly discharges expected

| | Simulation | Mean discharge [$m^3/s$] |
|---|---|---|
| 1980-2012 | Calibration 1980-2012 | 206.110 |
| 2040-2049 | EC-earth RCP 26 | 233.744 |
| | Echam6 RCP 26 | 241.251 |
| | CCSM4 RCP 26 | 248.689 |
| | EC-earth RCP 45 | 276.948 |
| | Echam6 RCP 45 | 259.325 |
| | CCSM4 RCP 45 | 247.926 |
| | EC-earth RCP 85 | 269.352 |
| | Echam6 RCP 85 | 256.256 |
| | CCSM4 RCP 85 | 274.372 |

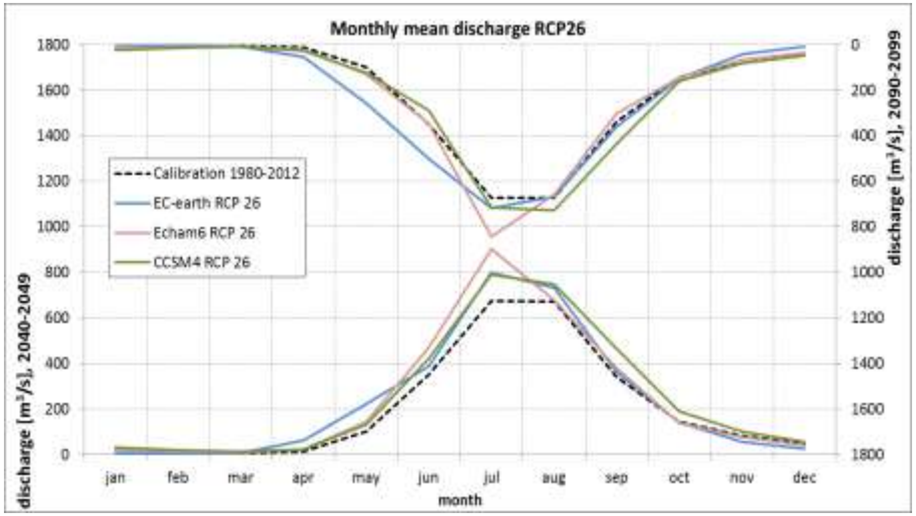
| | Simulation | Mean discharge [$m^3/s$] |
|---|---|---|
| 1980-2012 | Calibration 1980-2012 | 206.110 |
| 2090-2099 | EC-earth RCP 26 | 232.0143 |
| | Echam6 RCP 26 | 216.8158 |
| | CCSM4 RCP 26 | 223.2081 |
| | EC-earth RCP 45 | 278.5178 |
| | Echam6 RCP 45 | 260.1996 |
| | CCSM4 RCP 45 | 254.0167 |
| | EC-earth RCP 85 | 272.096 |
| | Echam6 RCP 85 | 258.3187 |
| | CCSM4 RCP 85 | 257.1026 |

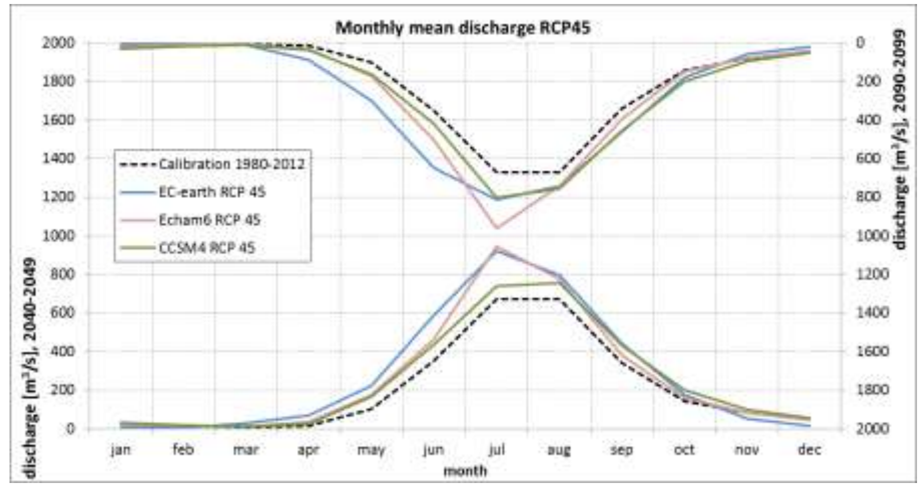


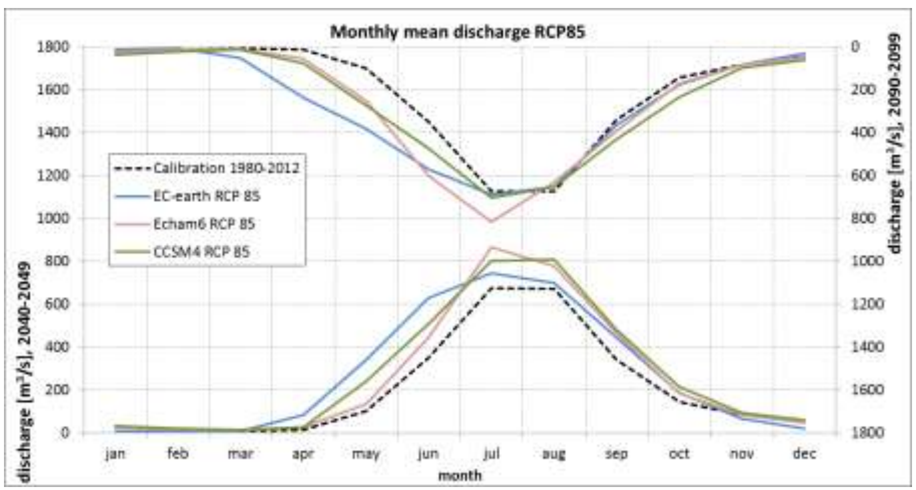



# Hydrological modelling

## Hydrological cycle (monthly)



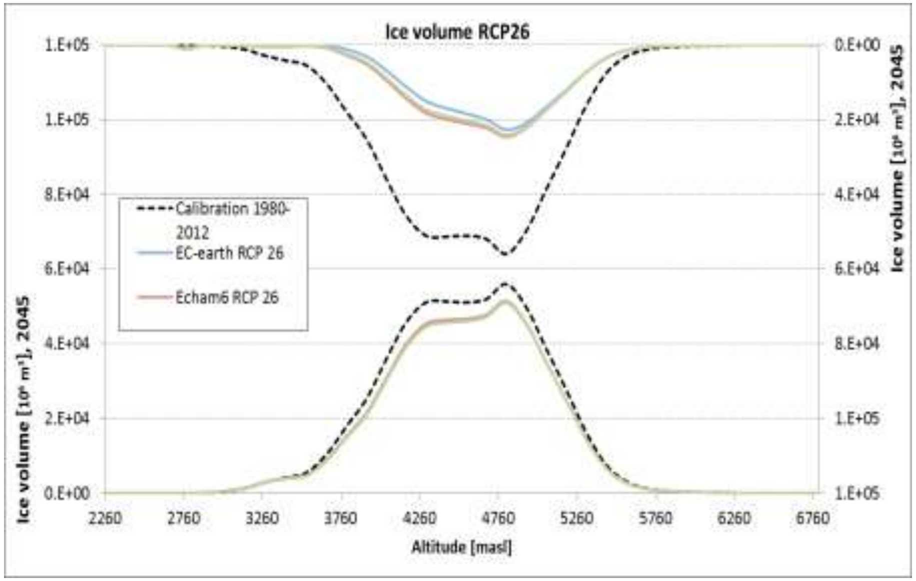



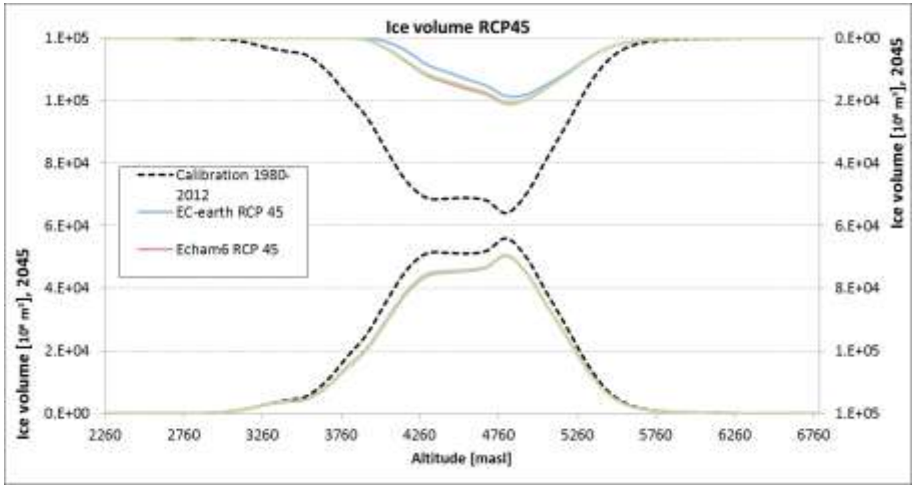



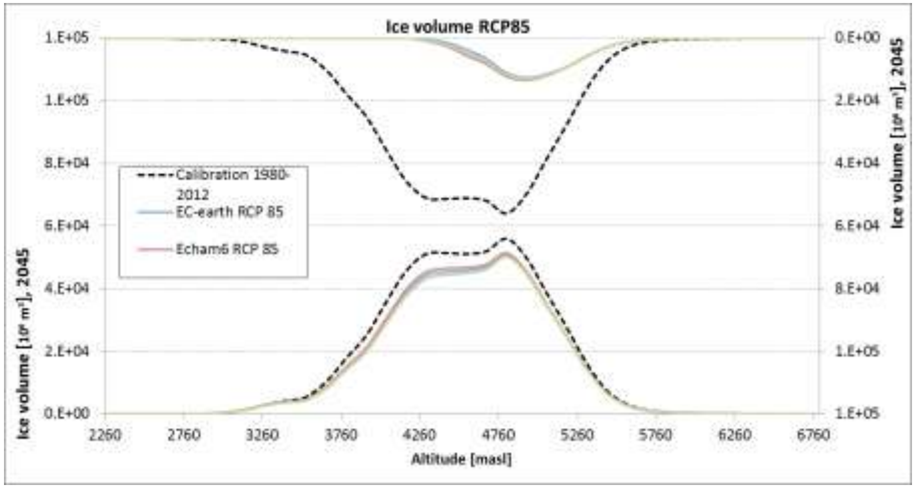

In stream flows will increase during warm season, as sustained by ice melt, especially during July and August, but with potential shift of large flows towards Spring months

# Hydrological modelling

## Expected available ice volume as per altitude bins



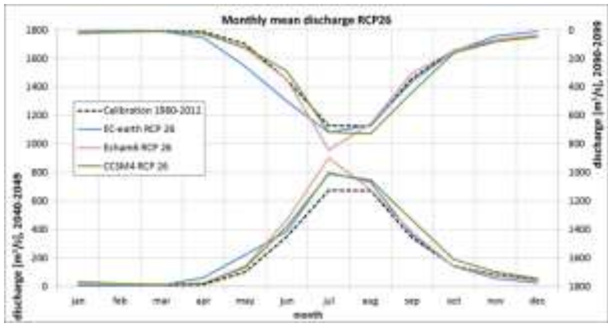

However, acclerated ice melting will lead to rapidly decreasing ice thickness, with potential thinning, especially towards the end of the century.

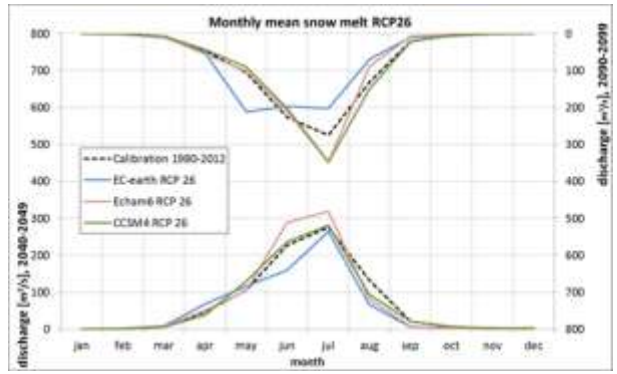
Downwasting of ice cover may have several implication, hydrologically, ecologically, climatically, and touristically.

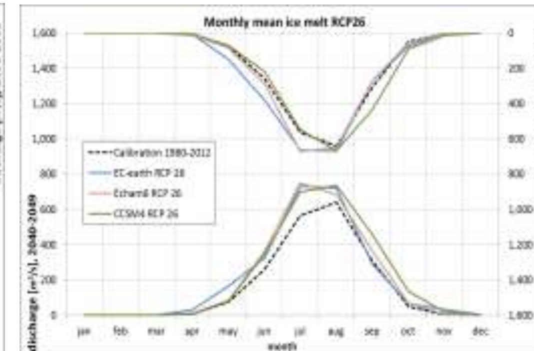
# Hydrological components of water resources in Shigar river

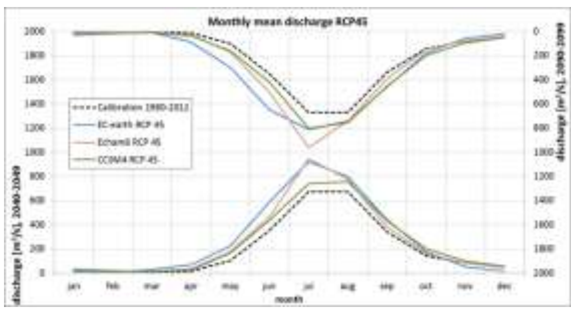
We assessed the relative importance of the different components of the hydrological cycle, namely rainfall, snow melt, and ice melt within the Shigar river, under the present climate, and under prospective climate change, until 2099.

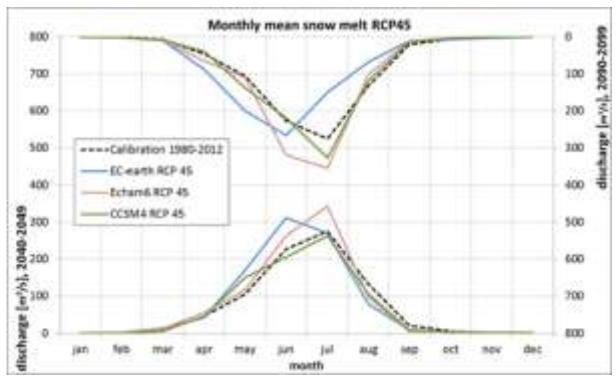
RCP 2.6

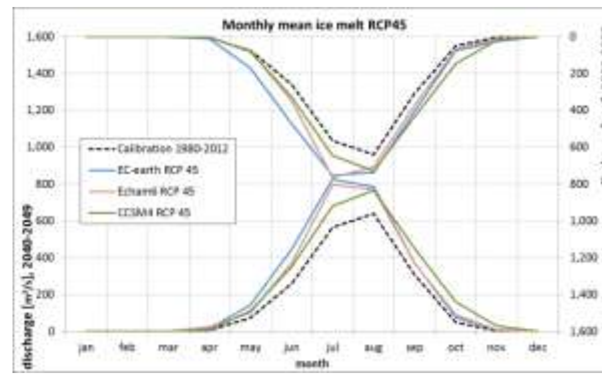


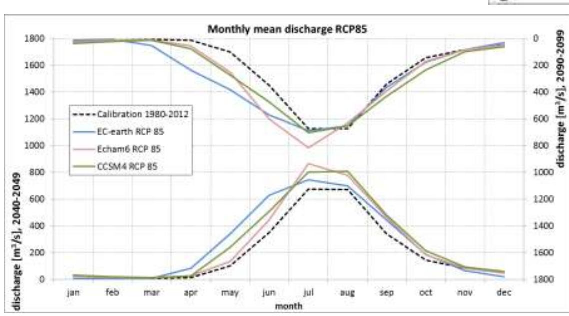



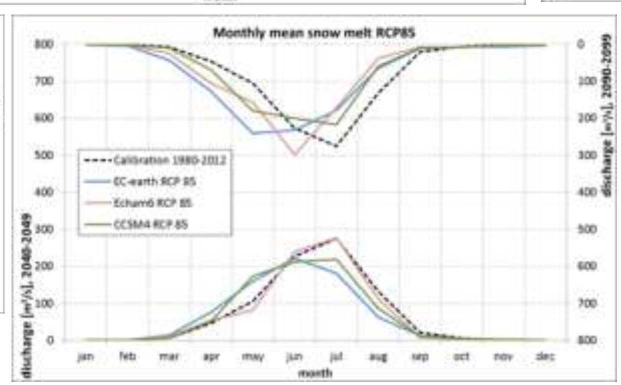



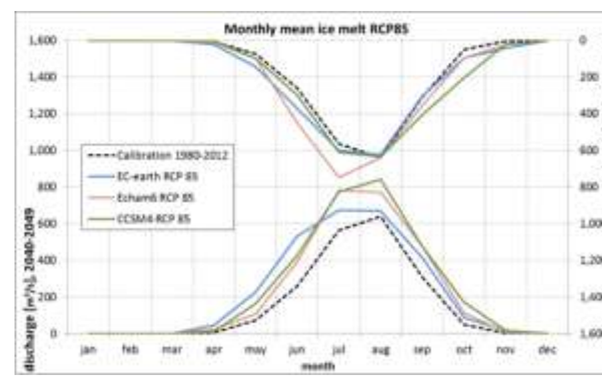




RCP 4.5

RCP 8.5

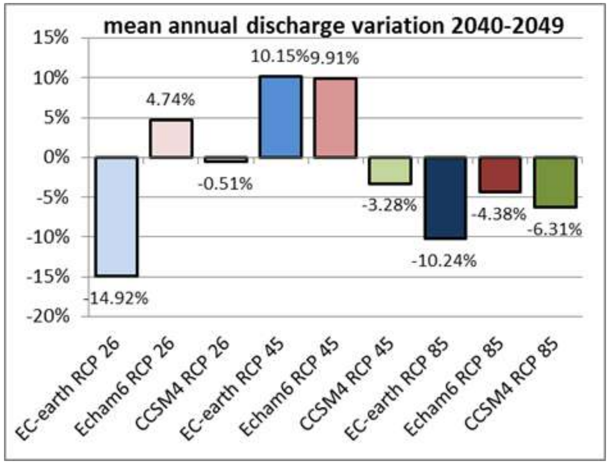


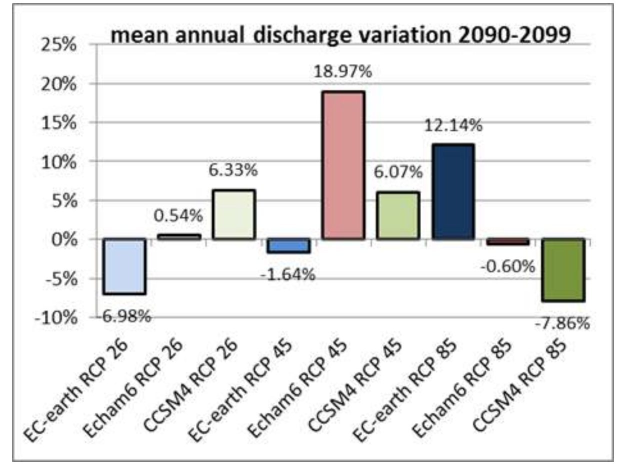



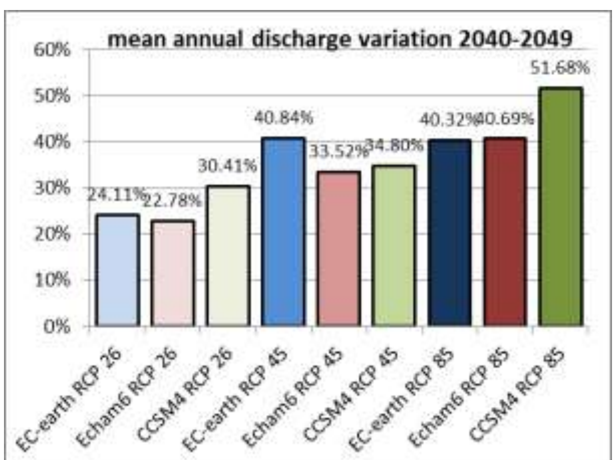
# Hydrological components of water resources in Shigar river

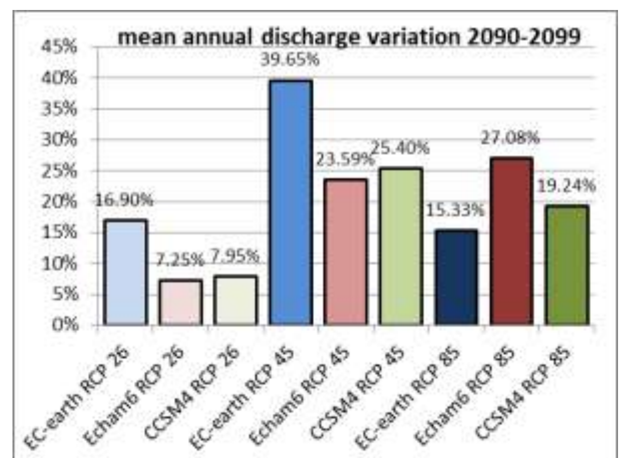
Expected changes (against 1980-2012) in average yearly projected contribution of snow melt to instream flows at Shigar. 2040-2049; 2090-2099.



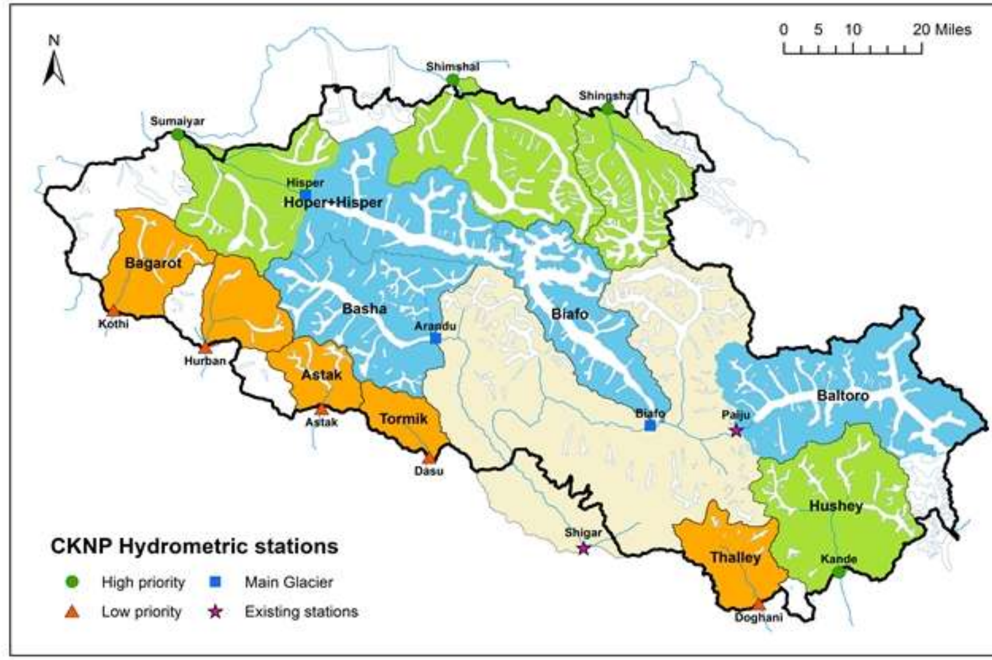

Expected changes (against 1980-2012) in average yearly projected contribution of ice melt to instream flows at Shigar. 2040-2049; 2090-2099.



# A proposed hydrometric network for the CKNP

We developed suggestions for a proposed hydrometric network for CKNP
Priority is given to largest and most glaciated catchments, carrying more water, and more sensitive to climate variations




| Catchment size | Expected deliver | Priority | Village | Valley | Basin Area ($km^2$) |
|---|---|---|---|---|---|
| Large | High | 1 | Sumaiyar | Hisper + Hoper | 1778 |
| Medium | High | 2 | Shimshal | ? | 1101 |
| | High | 3 | Kande | Hushey | 1040 |
| | High | 4 | Shingshal | ? | 690 |
| Small | Low | 5 | Doghani | Thalley | 394 |
| | Low | 6 | Kothi | Bagarot | 431 |
| | Low | 7 | Hurban | ? | 361 |
| | Low | 8 | Astak | Astak | 271 |
| | Low | 9 | Dasu | Tormik | 221 |
| Glacierized | Gauged | | Paiju | Baltoro | 1331 |
| | Glacier study | | Arandu | Basha | 1049 |
| | Glacier study | | Hisper | Hisper | 962 |
| | Glacier study | | Biafo | Biafo | 845 |
| Main | Gauged | | Shigar | Shigar | 6923 |

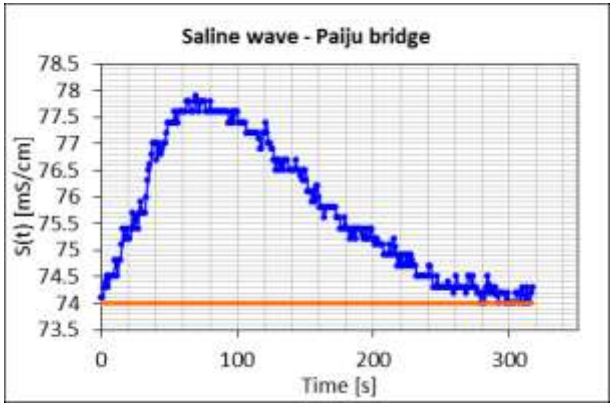
We developed a procedure (bullet points list) to be followed when choosing hydro station sites, items to be verified, and hydrological calculations therein.

# A protocol for stream flow measurements within the CKNP

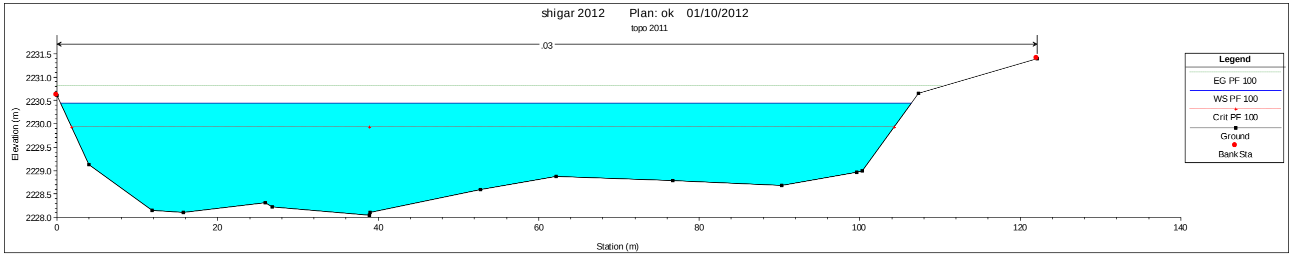
We developed suggestions for a protocol for stream flow measurement.
Stream flow measurements should be based upon continuous monitoring of river stage, and conversion into water flux (discharge, $m^3s^{-1}$) by way of stage-discharge equation, properly tuned using discharge measurements

Time continuous stage measurements through piezometric gauge (Paiju bridge)

Discharge assessment using salt tracer (Paiju bridge)



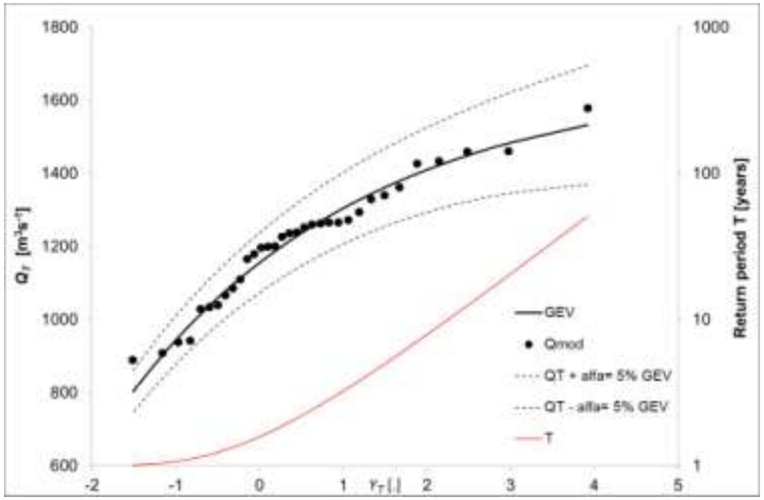

Discharge assessment using area-velocity method (Shigar bridge)




Time continuous stage measurements through Sonic ranger (Shigar bridge)

# Modified floods regime in the Shigar river

Using yearly maximum value of simulated daily discharges (1980-2012), we assessed extreme floods, according to theory of extreme values, within the Shigar river, under the present climate, and under prospective climate change, until 2099.

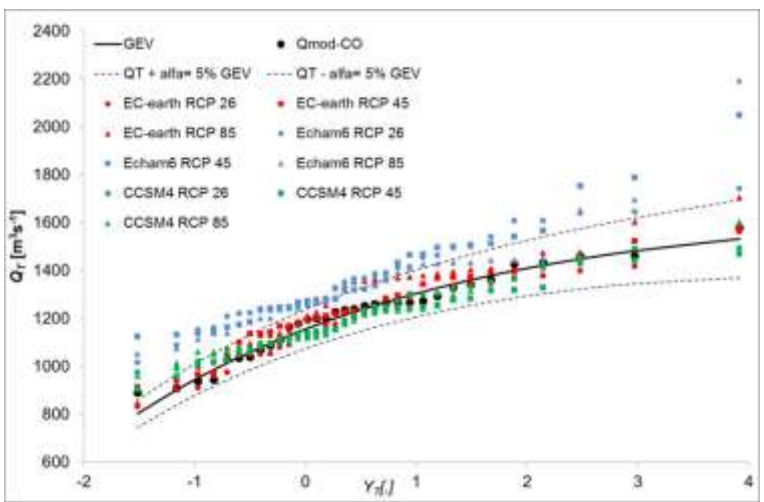



*T*-years return period in stream discharge is expressed as

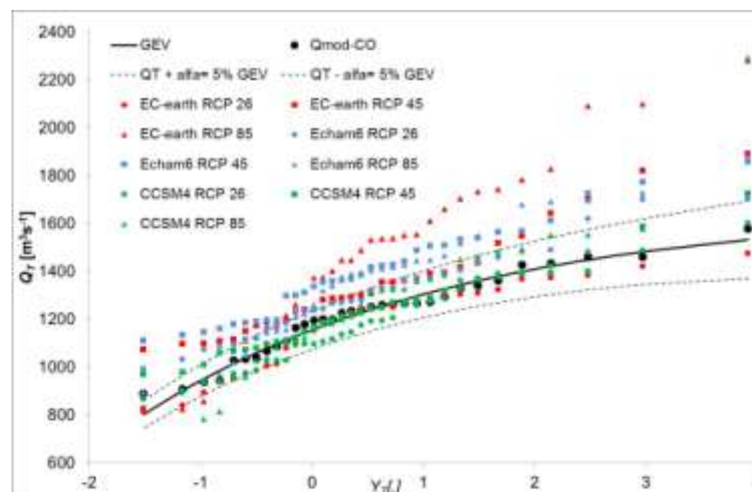
$$Q(T) = Q_{in}\left\{\varepsilon + \frac{\alpha}{k}\left[1-\left(-\ln\left(1-1/T\right)\right)^{k}\right]\right\}$$

$$Q_{in} = E\left[Q_{AFS}\right] = \frac{1}{n}\sum_{j=1}^{n} Q_j$$

*Projected samples during 2024-2056*




*Projected samples during 2068-2100*



# SEED project

## Pasture

Within the framework of the **SEED** project, we developed a preliminary approach to hydrologically based evaluation of production of pasture for livestock farming within or nearby the CKNP park. Livestock farming plays an important role in the economy of CKNP, and in the region's food security due to its contribution to the production of milk, meat, farmyard manure, wool and draft.

We used an ad-hoc developed, hydrologically based pasture growth model allowing the simulation of pasture dynamics. Main drivers of the model are weather variables, soil properties and land management practices, such as irrigation and manure.

$$S^{t+\Delta t} = S^{t} + P + M_{s} + M_{g} - ET - Q_{g}$$

$$B_{PT} = \frac{K_{BT} TP}{VPD}$$

$B_{PT}$ is biomass produced by potential transpiration [Kg/m$^2$/d], VPD vapour pressure deficit [kPa] and $K_{BT}$ *is* biomass-transpiration coefficient [kPa kg/m$^3$]

$$B_{T} = B_{PT}\, T/TP = B_{PT} T_{R} = B_{PT}\ f\left(PAW\right)$$

$$PAW = \frac{\theta - \theta_{w}}{\theta_{l} - \theta_{w}}$$

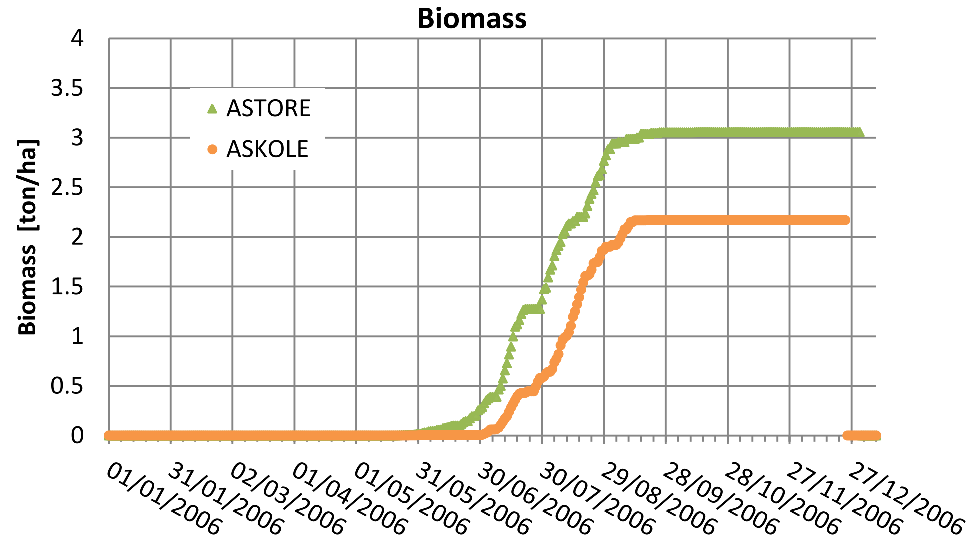
$B_T$ is real biomass produced proportionally to real traspiration ratio $T_R$, a function of potentially available water *PAW, with $\vartheta$ soil water content [0-1], $\vartheta_w$ wilting point, $\vartheta_l$ field capacity*

# Pasture

An example:

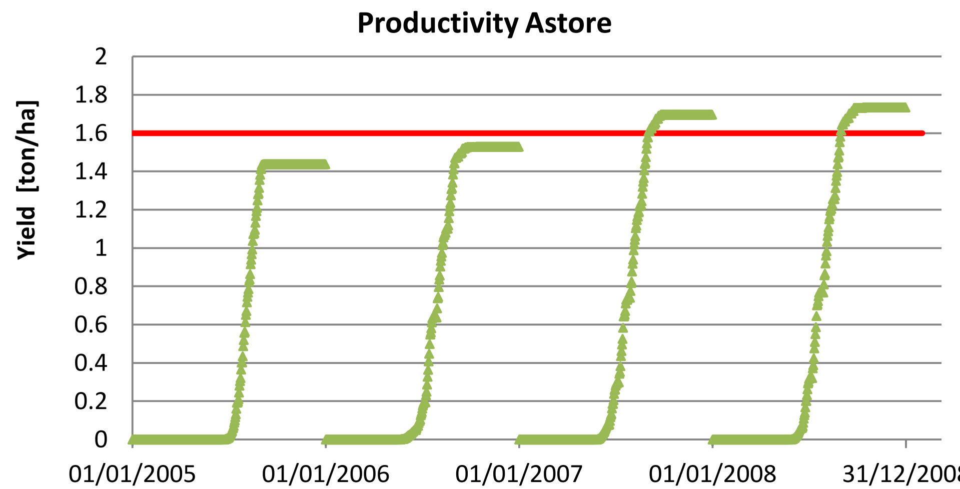
- Astore (2200 m): may-september
- Askole (3015 m): june–september

•We simulated growth of pasture in two locations at different altitudes


| Region/ District | Productivity (kg/ha) | | Remarks | |
|---|---|---|---|---|
| | Estimated Potential Productivity | Productivity at the time of survey | Pasture condition | Pasture trend |
| Gojal | 1400 | 407 | Poor | Down |
| Astore | 1600 | 428 | Poor | Down |
| Skardu | 1200 | 241 | Poor | Down |

*Da: Faizul Bari, MACP/ IUCN 2001*



# Conclusions

- Study of water resources within the cryospheric environment of Karakoram is complex, and requires a blend of i) field studies in sometimes harsh cryospheric environment, ii) continuous monitoring by way of in situ stations including maintenance, and iii) modelling of complex environmental processing
- Notwithstanding so, research and development for water resources management, and flood hazard assessment, is tremendously important in the UIB
- Impending climate change may trigger relevant environmental changes, and adaptation is needed
- International cooperation has demonstrated tremendous potential, and NEEDS be continued hereforth

**Let's saddle up, there's alot to do…..**

The Italian science and cooperation at the shadow of K2

Pakistan

Gilgit - Baltistan

Italy

seed Social Economic Environmental Development

# Thank you very much!

UN Water World Water Day 2013 International Year of Water Cooperation

POLITECNICO MILANO