Mechanisitic land-surface modelling in an Amu Darya (and Brahmaputra) headwater catchment

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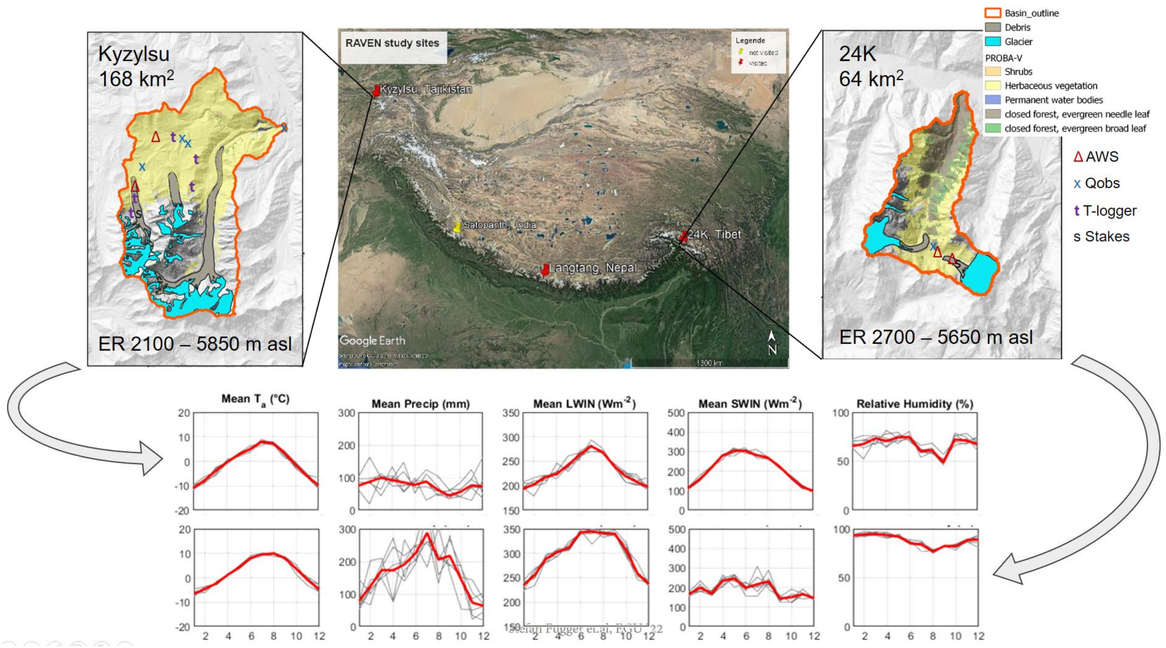
Motivation

We apply a mechanistic land surface model to the newly established COPE research catchment 'Kyzylsu' in the headwaters of the Amu Darya river basin in Tajikistan.

To study the concomitant responses of the cryosphere and biosphere to the region's relatively dry, westerly controlled climate, we apply our model at 100m spatial and hourly temporal resolution. We force the model with statistically-downscaled and bias-corrected ERA5-Land reanalysis data for the period 2010 to 2022. For model setup and independent validation, we leverage extensive in-situ observations, and complement those with spatial datasets on glacier mass balance, snow cover, and vegetation indices.

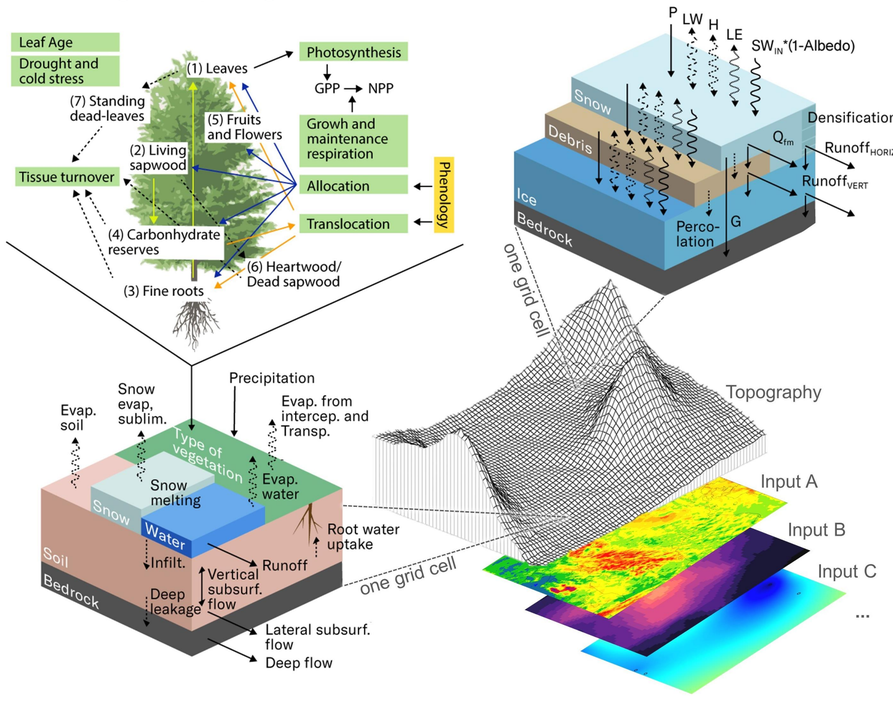
We study:

- The capabilities of an un-calibrated model forced with reanalysis data
- The water and energy balance components, ice-melt under debris
- The spatial and seasonal distribution of transpiration, evaporation and sublimation
- Differences to a monsoon-dominated catchment on the southeastern Tibetan Plateau



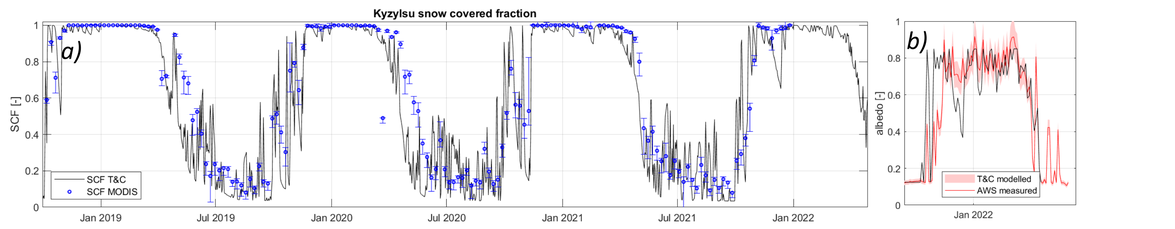
Methods

T&C model: coupled dynamics of water, energy and vegetation physiology, including avalanching, snow metamorphism, sublimation and energy conduction through supra-glacial debris

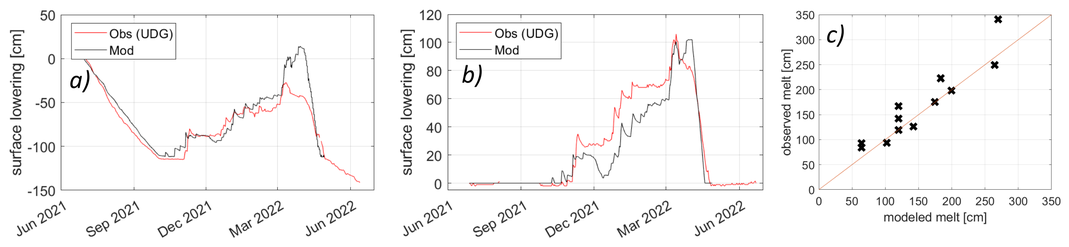


Spat. resolution:	100x100m, square grid
Temp. resolution:	1 hour
Modelling Period:	2010-2022 (2yr spin-up)
Calibration:	no calibration
Computing:	8.5 days @62 cores, MATLAB 2022a
Forcing:	ERA5-Land downscaled (TPS interpolation)
	EQM bias-correction against 5 on and off-glacier stations
Spatial inputs:	Soil: SoilGrids; Vegetation: PROBA-V + field observations; Debris: combination of methods for deriving thickness maps; Ice: RGI-6 & consensus thicknesses + GPR observations

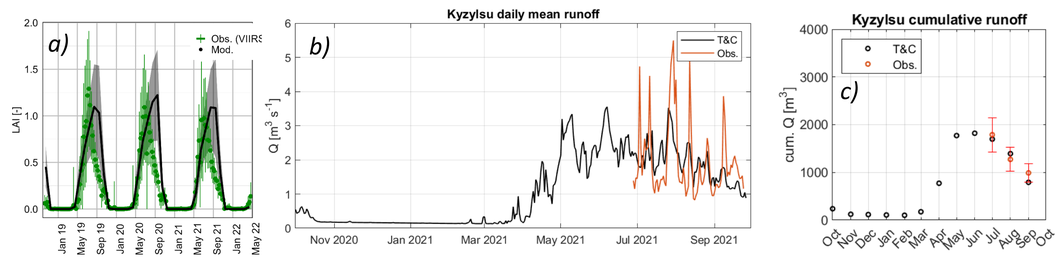
Evaluation (Kyzylsu only)



Figure, a) *snow covered fraction (SCF),* ***b)*** *AWS albedo*

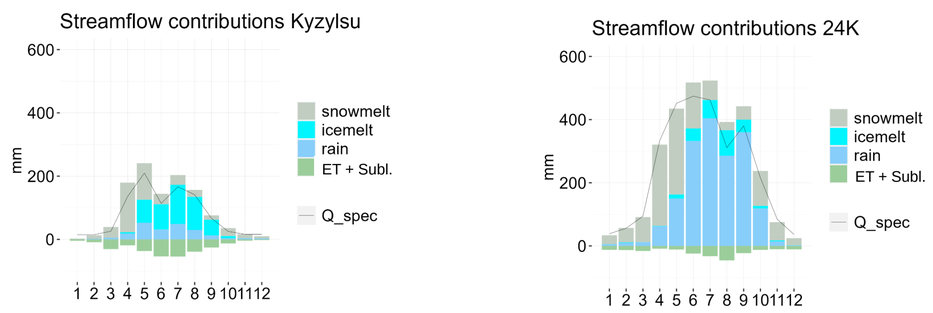


Figure, a) *snow/ice surface height AWS* ***b)*** *snow surface height Pluvio* ***c)*** *ablation stakes*



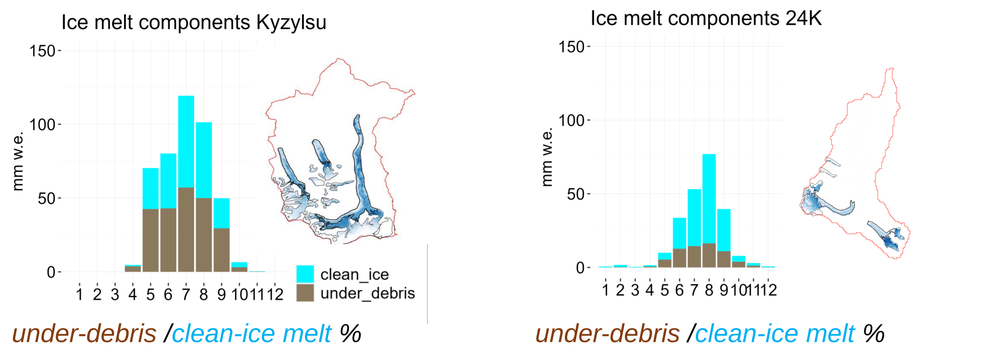
Figure, a) *leaf area index (LAI)* ***b)*** *runoff* ***c)*** *runoff totals*

Comparison to monsoonal catchment



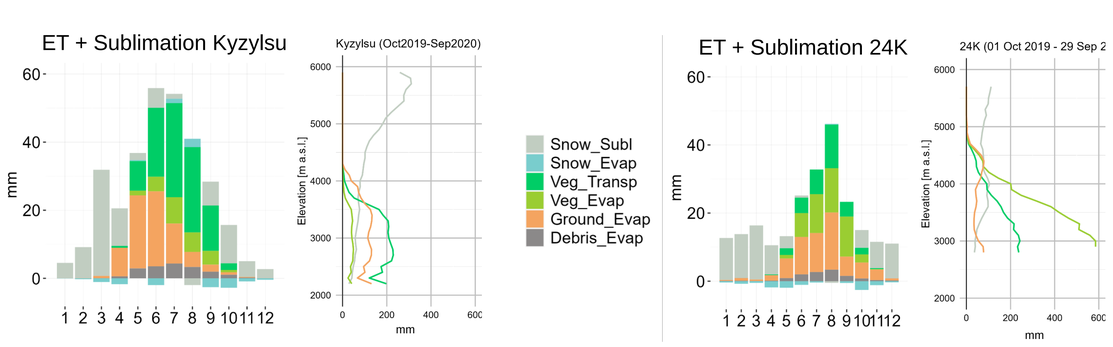
total mm w.e.	*snow/ice/rain/ET+Subl. %*
1408	19/40/41/-26

total mm w.e.	*snow/ice/rain/ET+Subl. %*
3370	36/8/65/-8



under-debris /clean-ice melt %
53/47

under-debris /clean-ice melt %
28/72



Conclusions

- Evaluation overall good, some adjustments needed for snow accumulation, flow routing and grass phenology
- Ice melt is a greater relative streamflow component in drier climate
- ET + Subl. greater relative component in the drier climate
- Snow sublimation is a large mass loss component in high-elevation catchments
- Glacier melt strongly controlled by debris thickness and distribution
- Snow sublimation is temperature-controlled in westerly climate, but moisture-controlled in monsoon climate