Exploring the pathways of precipitation, snowmelt and glacier melt through the subsurface in Langshisha, Himalaya

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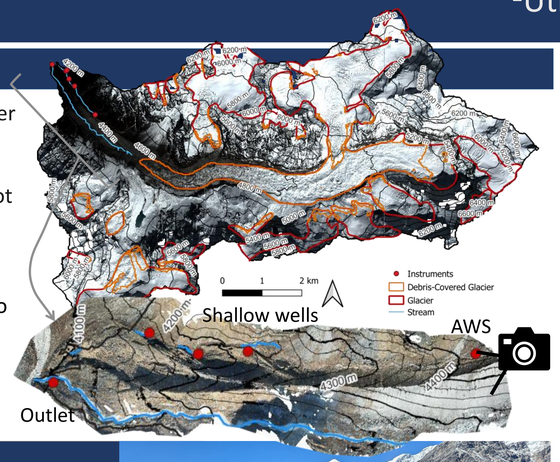
Background

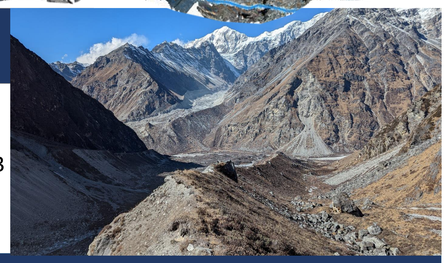
Groundwater can be an important water source for mountain streams, but the linkages between cryosphere, groundwater and surface waters are not understood.

We couple a surface water hydrology model with groundwater simulations to ask:
- Where does recharge occur?
- Where is the groundwater coming back to the surface?



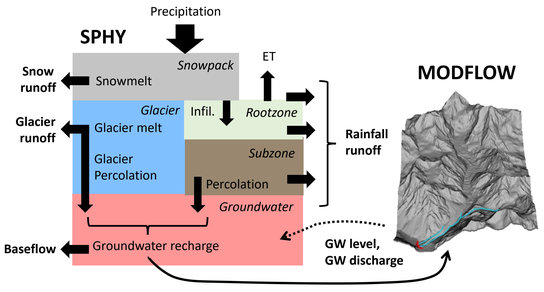
Study Area: Langshisha, Langtang, Nepal

- Area: 56 km^2, Elevation: 4084-6940 m a.s.l.
- 50% glacier cover
- AWS with T, RH, U, radiation budget since 2013
- Streamflow: 2014-2016, 2017
- Shallow groundwater well since 2017



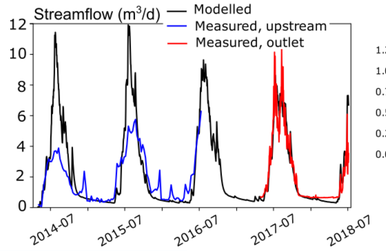
Modelling Approach:

- SPHY (surface water, cryosphere) and MODFLOW-NWT (saturated zone)
- Spatial resolution: 20x 20m (501x740)
- Temporal resolution: daily, for 2014-2020
- Forcings: AWS data distributed with temperature and elevation gradient factors
- Parameters based on manual calibrations + literature
- Glacier melt: 75% to glacier runoff, 25% to glacier percolation



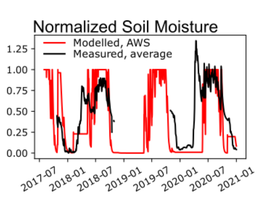
MODFLOW setup:
- 2 layers of surface unconsolidated sediment and 1 layer of shallow fractured bedrock (z ~ 50 to 300m, based on slope)
- Kx =Ky= 0.1, 0.01, 0.001
- Kz = Kx/10.
- Ss = 1e-7, Sy = 0.2
- Packages: RIV, DRAIN, CH

SPHY Model Evaluation: Streamflow, Soil Moisture, Snow Depth

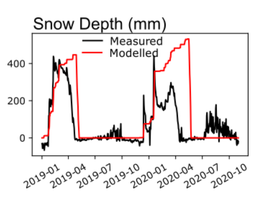


NSE = -0.25, KGE = 0.17, RMSE = 1.69, PBIAS = -17 %

NSE = 0.89. KGE = 0.94, RMSE = 0.81, PBIAS = 2 %



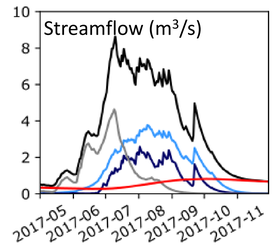
Soil moisture pattern captures the drying, but misses the initial rises in soil moisture in early spring.

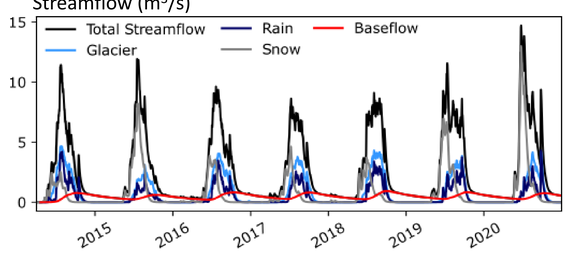


Temperature index, no snow redistribution in SPHY, which might explain the mismatch in melt timing

Langshisha Streamflow Composition

For the 2014-2020 period, simulated streamflow at Langshisha is :
- Glacier: 31%
- Rainfall: 19%
- Snowmelt: 20%
- Baseflow : 19%

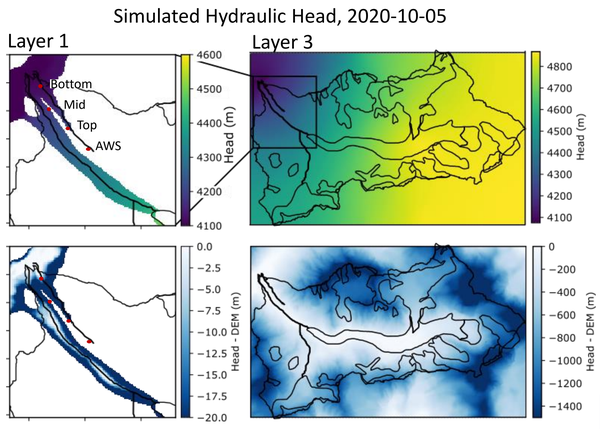




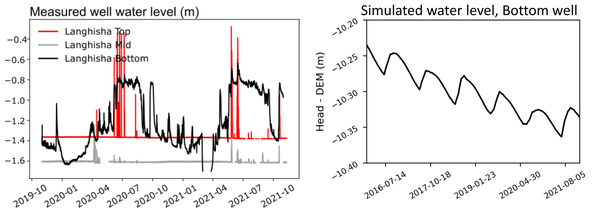
Simulate Water Level

Simulated head > 1500m below surface at higher elevations, but near-surface below glacier tongue and valley bottom.

Water level gradually generally increases with elevation, but not following topography closely.



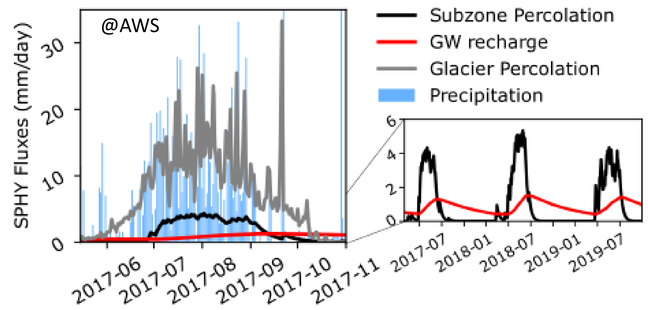
Simulated head does not match amplitude of shallow well near basin outlet

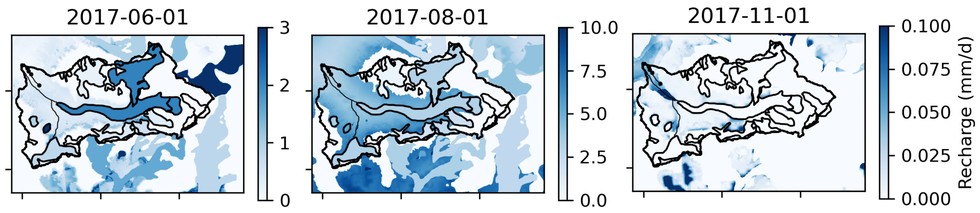


Groundwater Recharge

Simulated groundwater recharge used in MODFLOW is the glacier percolation + subzone percolation to maintain a seasonal patterns.

Simulated groundwater recharge heavily coming from glacier percolation, which is dependant on SPHY parametrization.





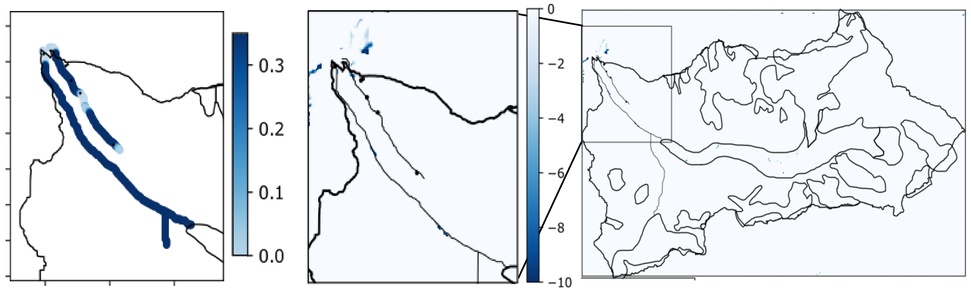
Groundwater – Surface water Exchanges

The proglacial and moraine streams are mainly losing water to the groundwater, except for short sections along the moraine stream.

The groundwater table is intersecting the surface and causing springs along segments of the proglacial stream, near the outlet of the moraine stream, and along the glacier bed.

Riverbed exchange, mm/day (2017-08-05)

Springs, mm/day (2017-08-05)



Ongoing work

Ongoing work is being done to improve the soil properties parametrization in the SPHY model and to test key parameters in MODFLOW, along with more MODFLOW exploration (flowpath, residence time).

Model evaluation with geochemistry data collected in 2021 and further in-situ data are also underway.

Next steps are to move towards an online coupling once further testing is done, and then apply model at a wider scale.

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