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Effect of localized high basal melting on transient subglacial water flow evolution beneath Campbell Glacier

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Abstracts

Observing the flow of subglacial water evolution beneath the polar ice sheet has long been a challenging issue. The spatiotemporal subglacial water evolution can be indirectly estimated by ice-radar, GPS, and satellite altimetry technique. At present, one of the leading causes of the accelerated migration of the Antarctic ice sheet is ice-bed boundary conditions in terms of subglacial hydrology. However, its reliability is low due to the limited observation and verification data. Based on the GPS time series along the Campbell Glacier, we observed that the ice sheet surface height (h) and ice sheet velocity (v) represent a specific periodicity. In terms of the subglacial hydrologic flow, these changes are caused by the sequential steps as follows: accumulation of melted water around subglacial lake → increasing the water pressure → increasing the ice sheet velocity due to the lower friction → channel(efficient) flow activation →rapid depletion of water storage →the decrease of altitude and the reduction of ice sheet velocity. In this study, the GlaDS (Glacier Drainage System) model, which can realize interactions between sheet flow type and channel flow type, was used to realize the temporal and spatial hydrological variability beneath the Campbell glacier. The basal topography was constructed by recent ice radar (KOPRI/UTIG flight line) data with mass conservation(MC). Based on the assumption of high basal melting around active volcano Mt. Melbourne, with the various channel and sheet hydraulic conductivity conditions, spatiotemporal subglacial flow evolution was analyzed. The localized high basal melting around Mt. Melbourne activates the high concentration of channelized flow, which modulates the effective pressure and subglacial discharge. The results showed that boundary conditions(e.g.. basal topography, basal melting distribution) beneath the ice sheet should be better constrained to represent the flow close to reality.

Objectives

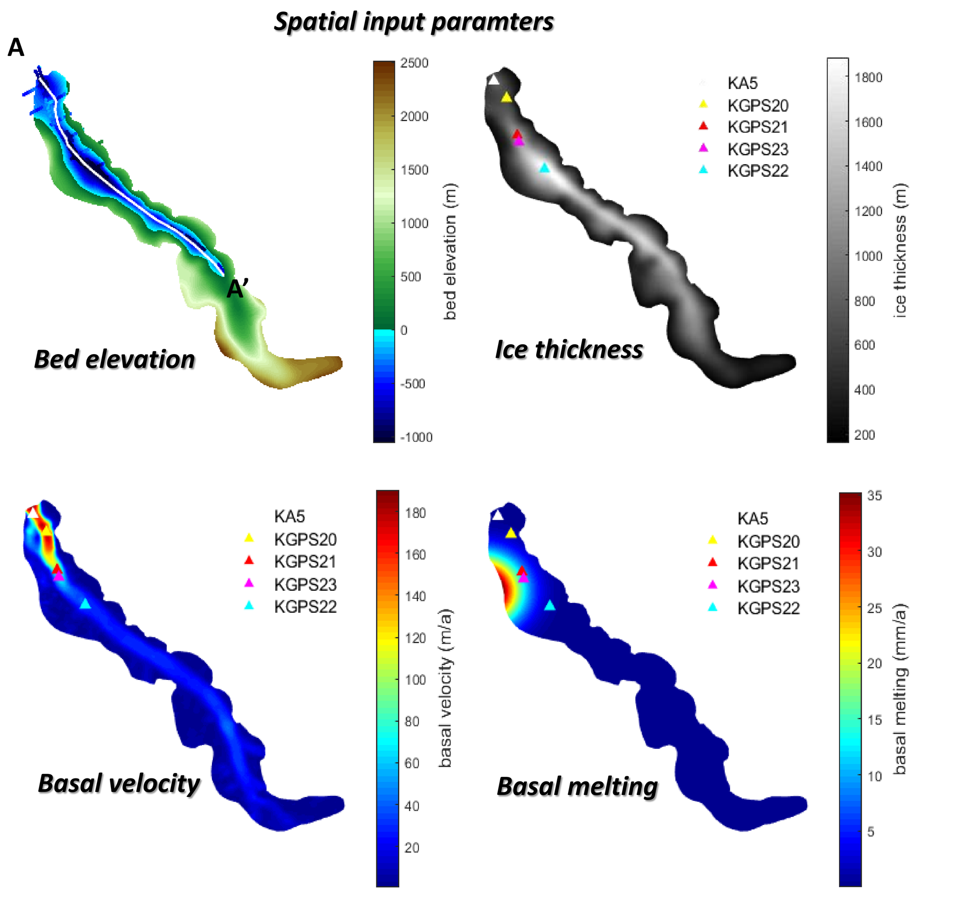
To identify how the high subglacial basal melting around Mt.Melbourne(MTM) controls subglacial hydrology at downstream region, Campbell Glacier

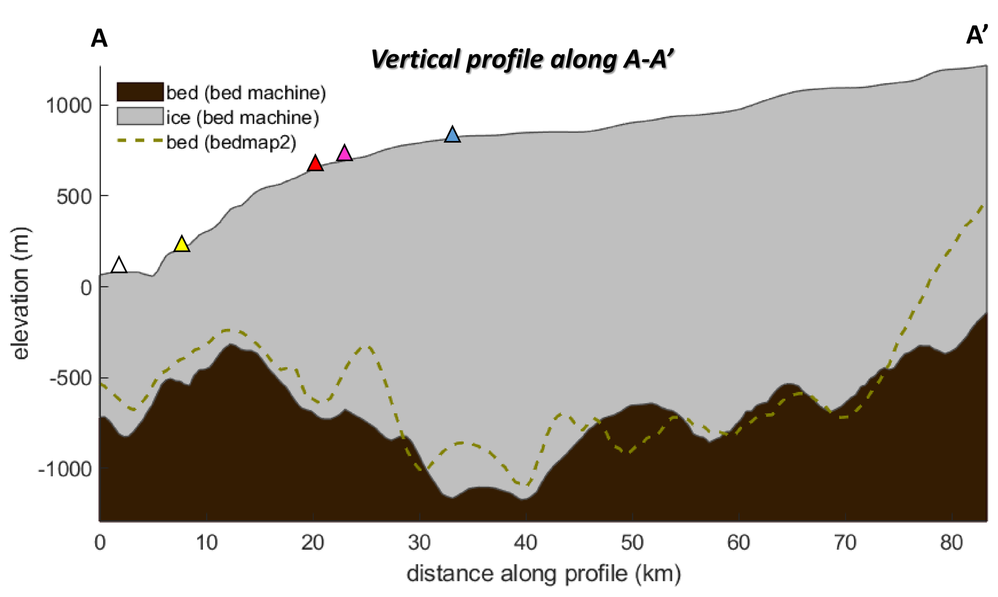
Model setup

Model input parameters

- *60 years transient model run from the initial condition*
- *Improve basal topo boundary condition based on recent ice radar data*
- *0.5 mm/a initial basal melting increased to heterogeneous basal melting based on the assumption of high basal melting around MTM over a 3-year lamp*

Spatial input paramters



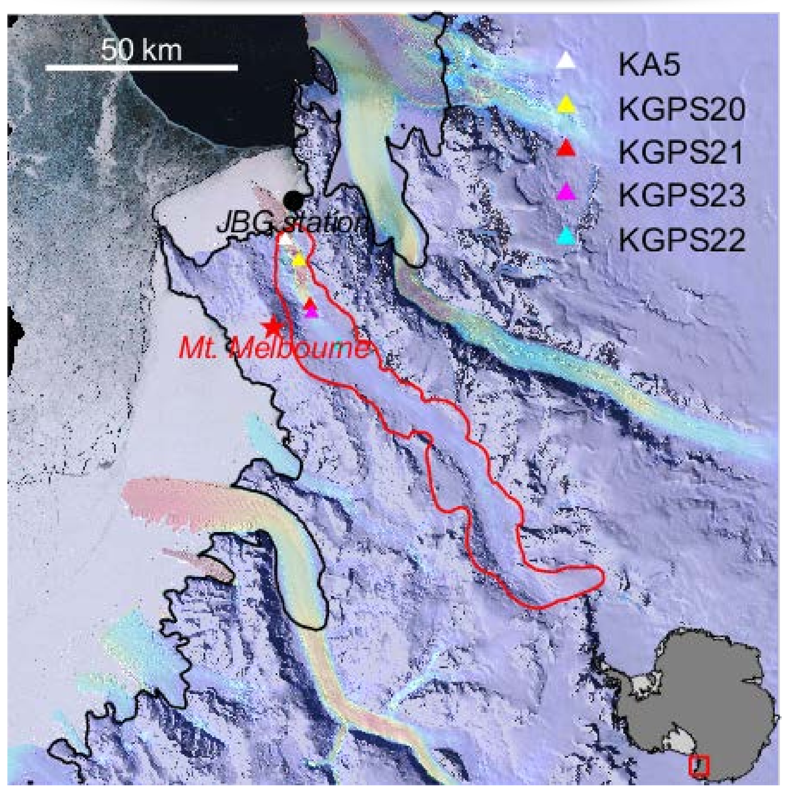


Global model parameters

Parameters	Value	Unit
Channel conductivity	4e-3	$m^{3/2}kg^{-1/2}$
Sheet conductivity	1e-5	$m^{7/4}kg^{-1/2}$
Bed rock bump height	0.7	m
Cavity spacing	2	m
Sheet width below channel	2	m
Ice flow constant	2.5e-25	Pa^{-3}/s
Basal melting	Spatially distributed	Mm/a
Basal velocity	0.9 * MEaSUREs velocity	m/a
Englacial void ratio	10e-5	

Introduction

Study site



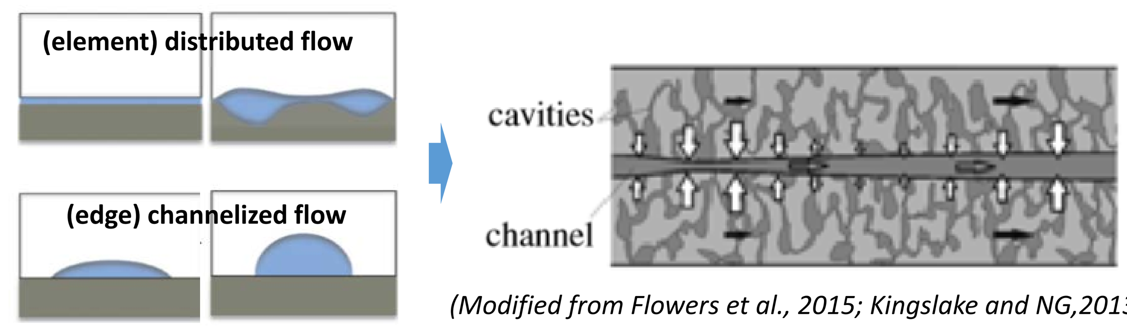
Modeling domain(Campbell Glacier) with locations of 5 GPS sites. Inset shows the study location in Antarctica

Methods

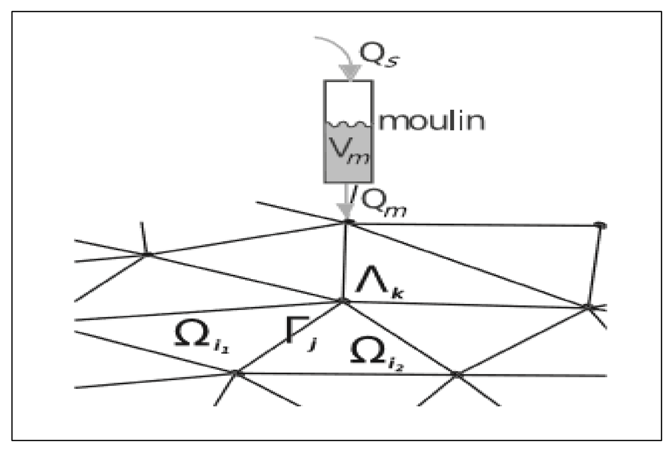
1. *GPS installation*

- *deployment of 5 GPS station along the Campbell glacier during 2016-2019*
- *velocity : 10-day averaged*
- *Surface elevation: slope and snow accumulation rate correction*

2. *Subglacial hydrology model(GlaDS: werder et al., 2013)*



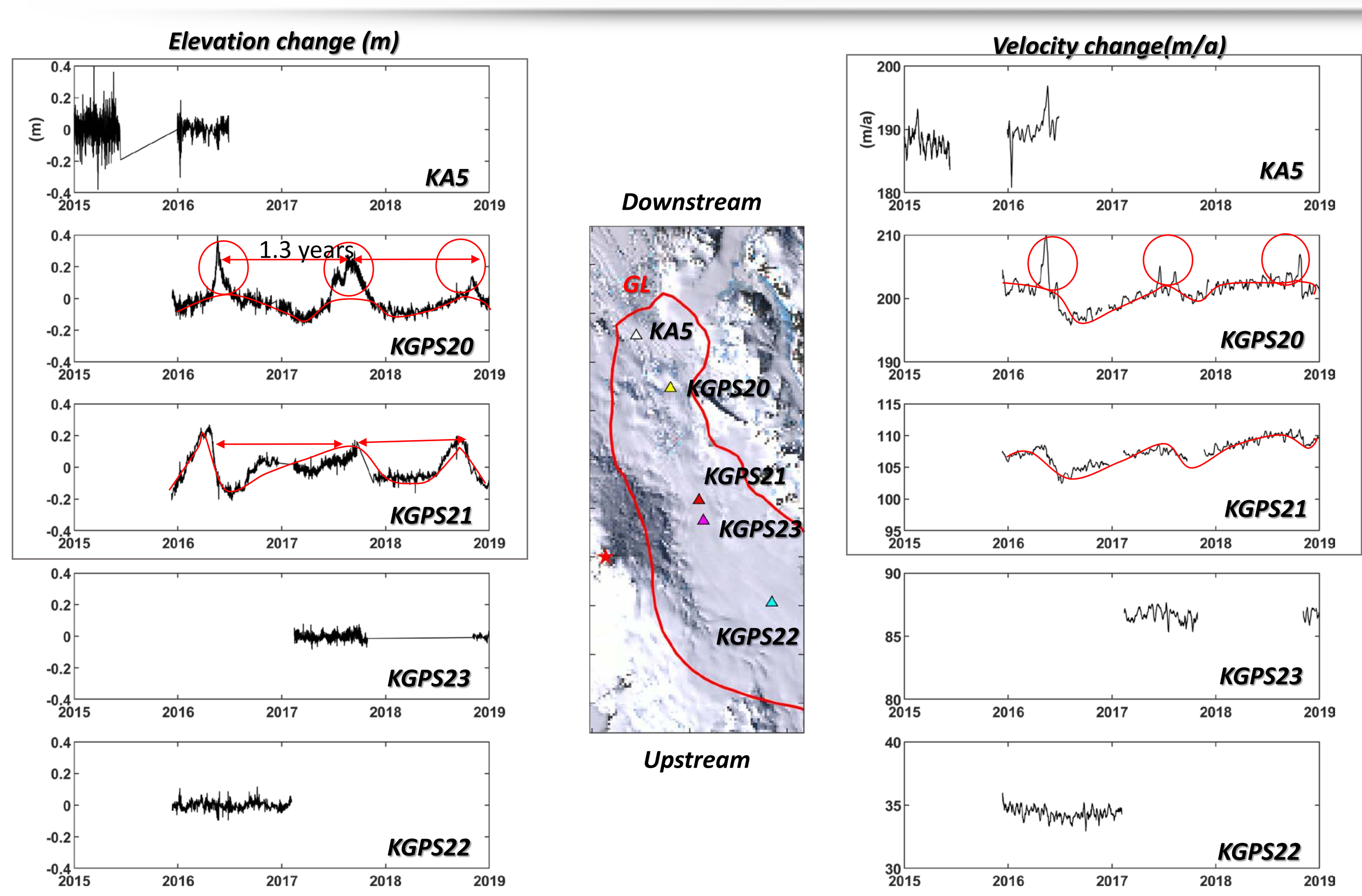
(Modified from Flowers et al., 2015; Kingslake and NG,2013)



- *GlaDS model couples distributed and channelized subglacial flow, which realize dynamic subglacial evolution*
- *Distributed flow is represented as a continuous water sheet of variable thickness on model elements, and channelized flow occurs on model edges, which interact depending on effective pressure conditions*

Results and discussions

Surface elevation changes and velocity time series from GPS data



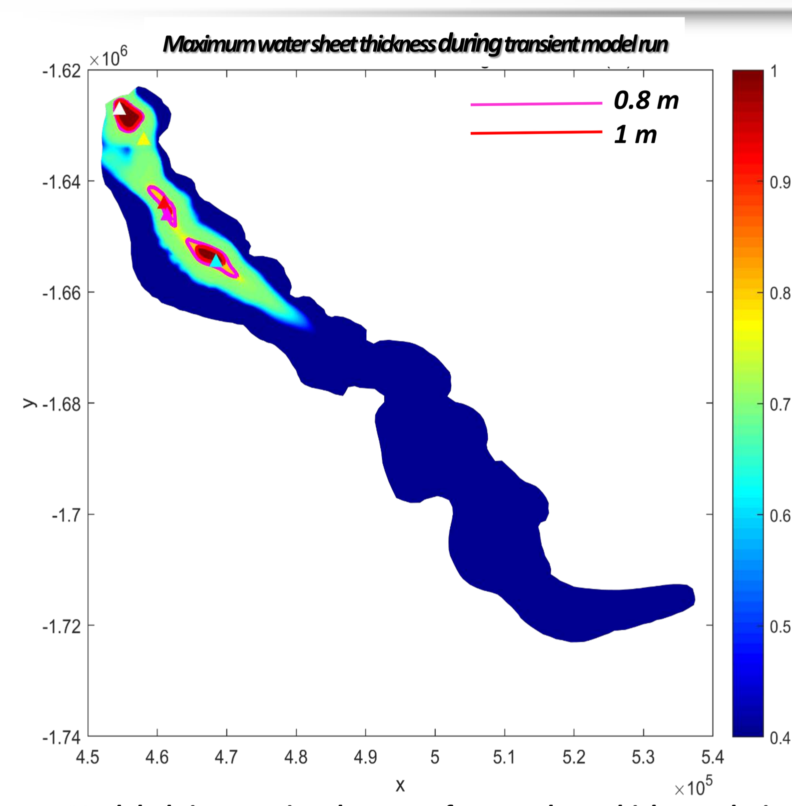
Downstream region

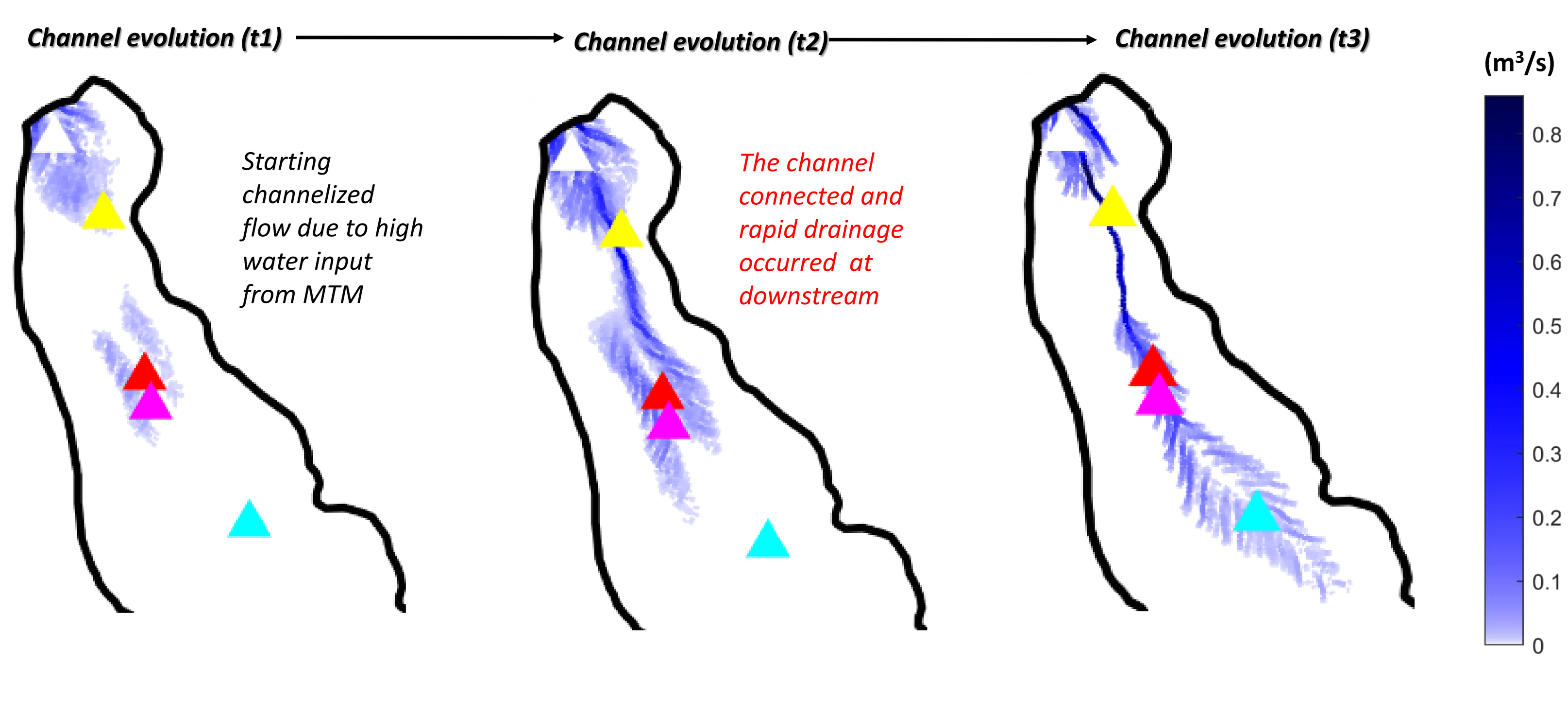
- ***sequential cyclic elevation change from KGPS21 to KGPS20***
- ***about 1.3-year elevation & velocity change cycle***
- ***spike peak at KGPS20, which is likely to occur horizontal compression and stretch due to the upstream ice flow***

Upstream region

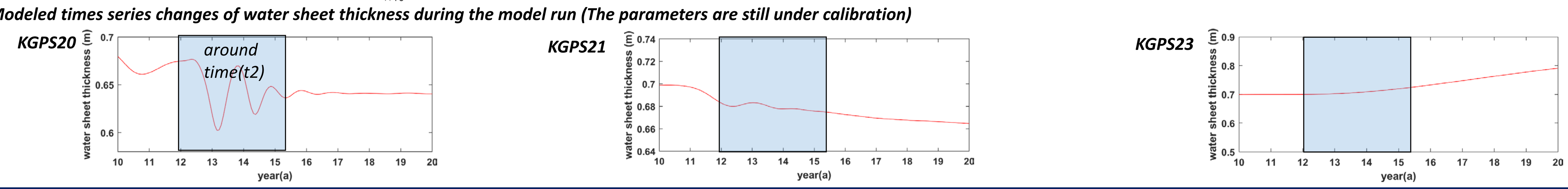
- ***relatively stable compared to GPS time-series at downstream***
- ***no significant trend of both elevation and velocity at KGPS 23 and KGPS22***

Spatio-temporal subglacial flow evolutions from GlaDS model



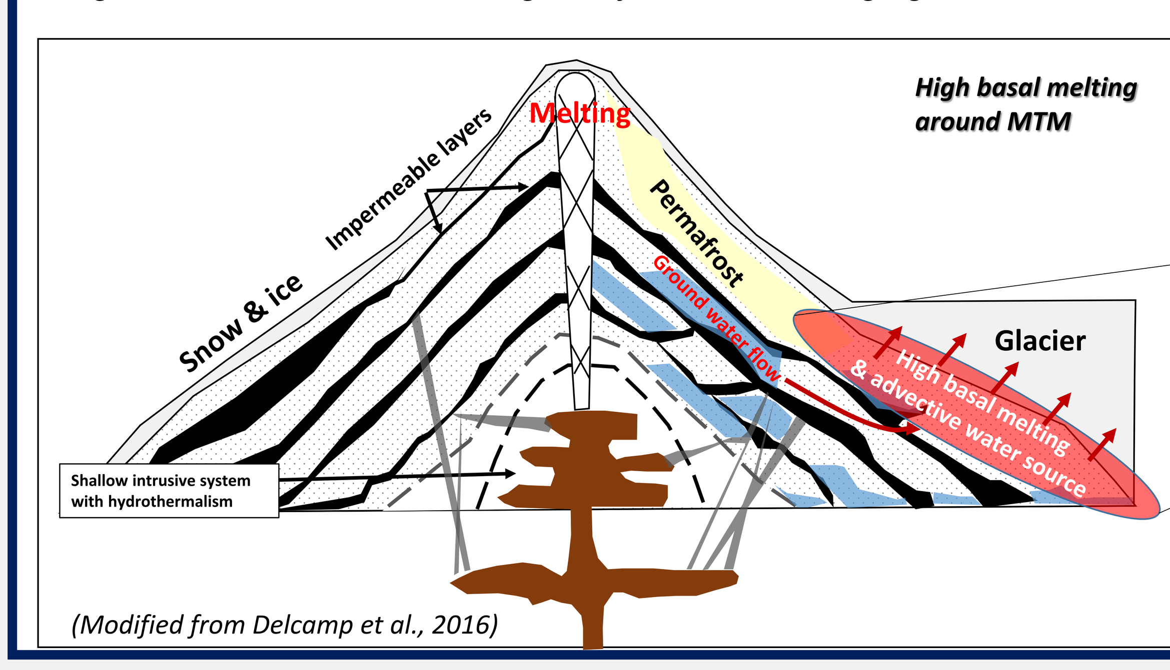


Modeled times series changes of water sheet thickness during the model run (The parameters are still under calibration)

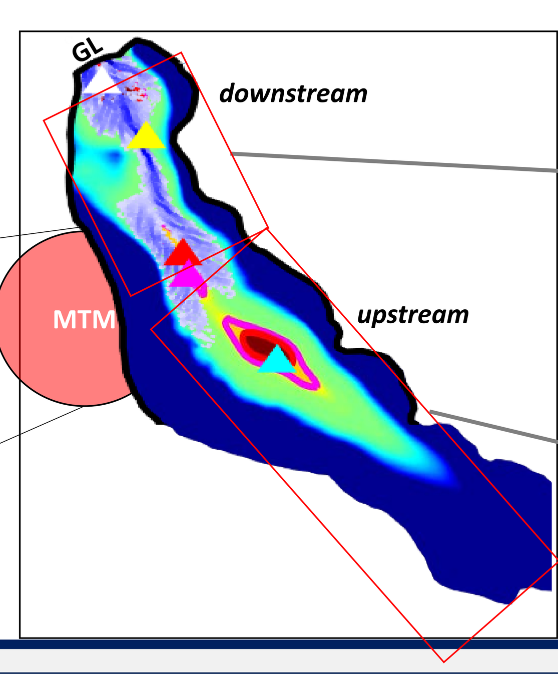


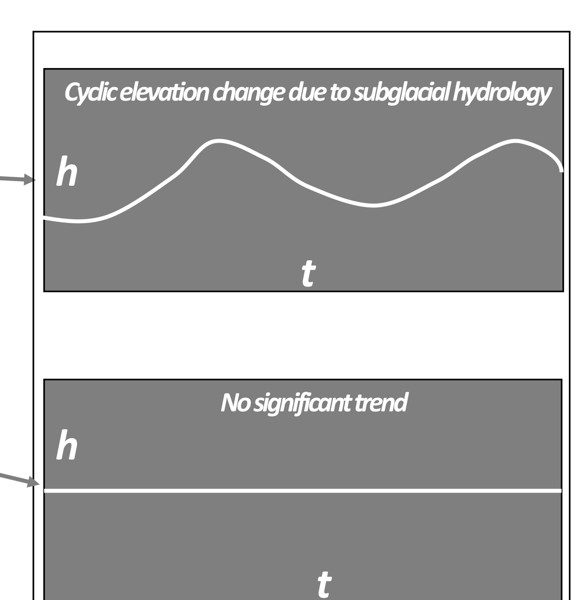
Conclusions

- ***The GPS times series shows different behavior of velocity and elevation changes between upstream and downstream***
- ***The elevation changes from GPS at downstream shows cyclic elevation change which is likely to subglacial water source input around MTM***
- ***High basal water sources due to the high heat flux around MTM might generate concentrated channelized flow around downstream, which modulate the subglacial flow system, Campbell Glacier***



(Modified from Delcamp et al., 2016)





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