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Water storage in a Himalayan snowpack

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Snow is an important component of water storage in the Himalayas. Previous snowmelt studies in the Himlayas have predominantly relied on remotely sensed snow cover. However, this provides no information on the actual amount of water stored in a snowpack i.e. the snow water equivalent (SWE). Therefore, we assimilated remotely sensed and in situ snow observations into a snow model to estimate the SWE. We modelled snow depth in a Kalman filter framework. This allows for data-constrained estimation of snow depth rather than snow cover alone and this has great potential for future studies in complex terrain, especially in the Himalayas.

Study area

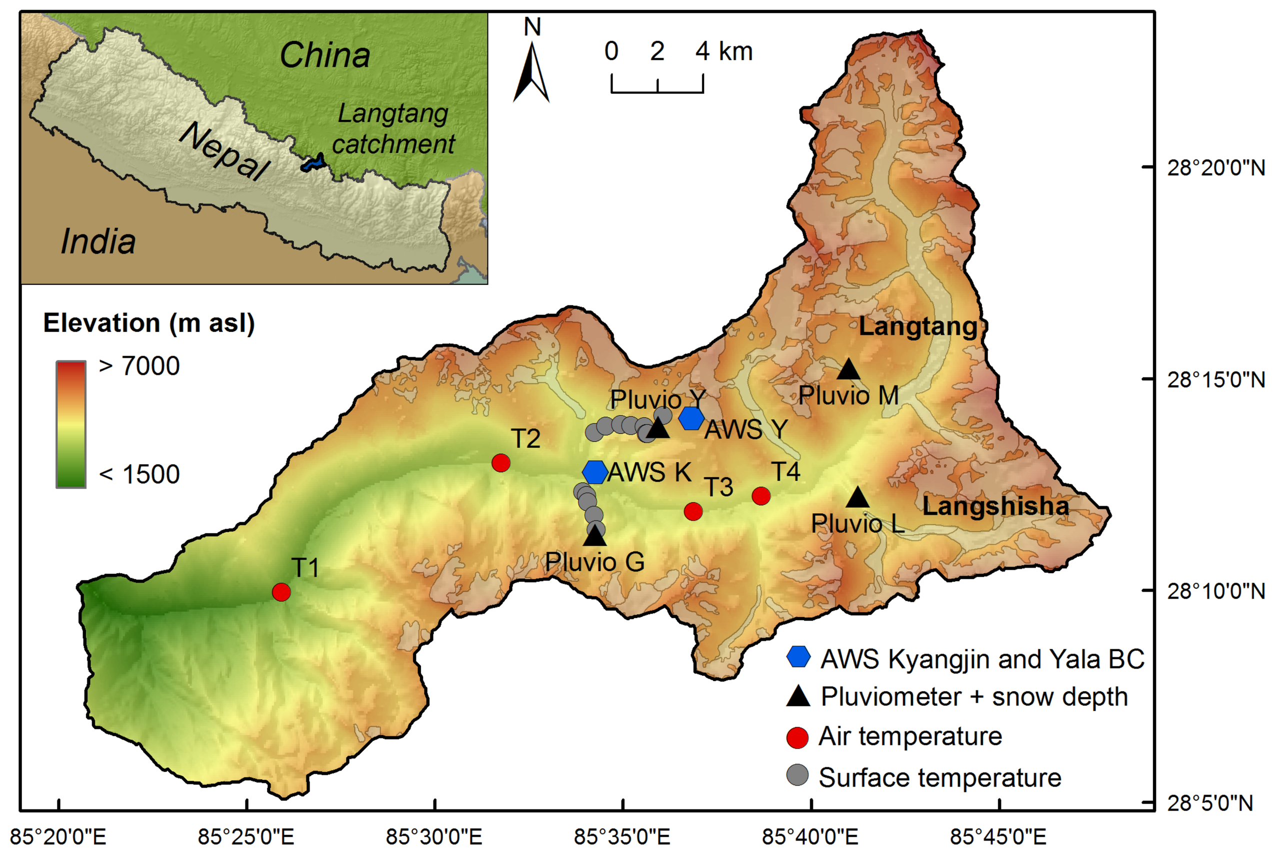

Figure 1 Langtang catchment with an overview of in situ observations and the main glaciers in the valley Langshisha and Langtang.

Methodology

- Validation of remotely sensed snow cover with in situ snow observations (snow depth and surface temperature)
- Obtain optimal model parameter values by assimilating snow depth measurements and remotely sensed snow cover into the modified seNorge snow model (Saloranta, 2016) using an Ensemble Kalman Filter (EnKF)
- Testing climate sensitivity of SWE by perturbing air temperature and precipitation (Table 1)

Sensitivity test	ΔT (°C)	ΔP (%)
Dry, cold	1.5	-3.2
Dry, warm	2.4	-2.3
Wet, cold	1.3	12.4
Wet, warm	2.4	12.1

Table 1 Changes in temperature and precipitation for the climate sensitivity tests (same as in Immerzeel et al. (2013)).

Results

- Validation of remotely sensed snow cover (Landsat 8 and MOD10A2) show high accuracies (85.7 and 83.1% respectively) against in situ snow observations (Fig.1)

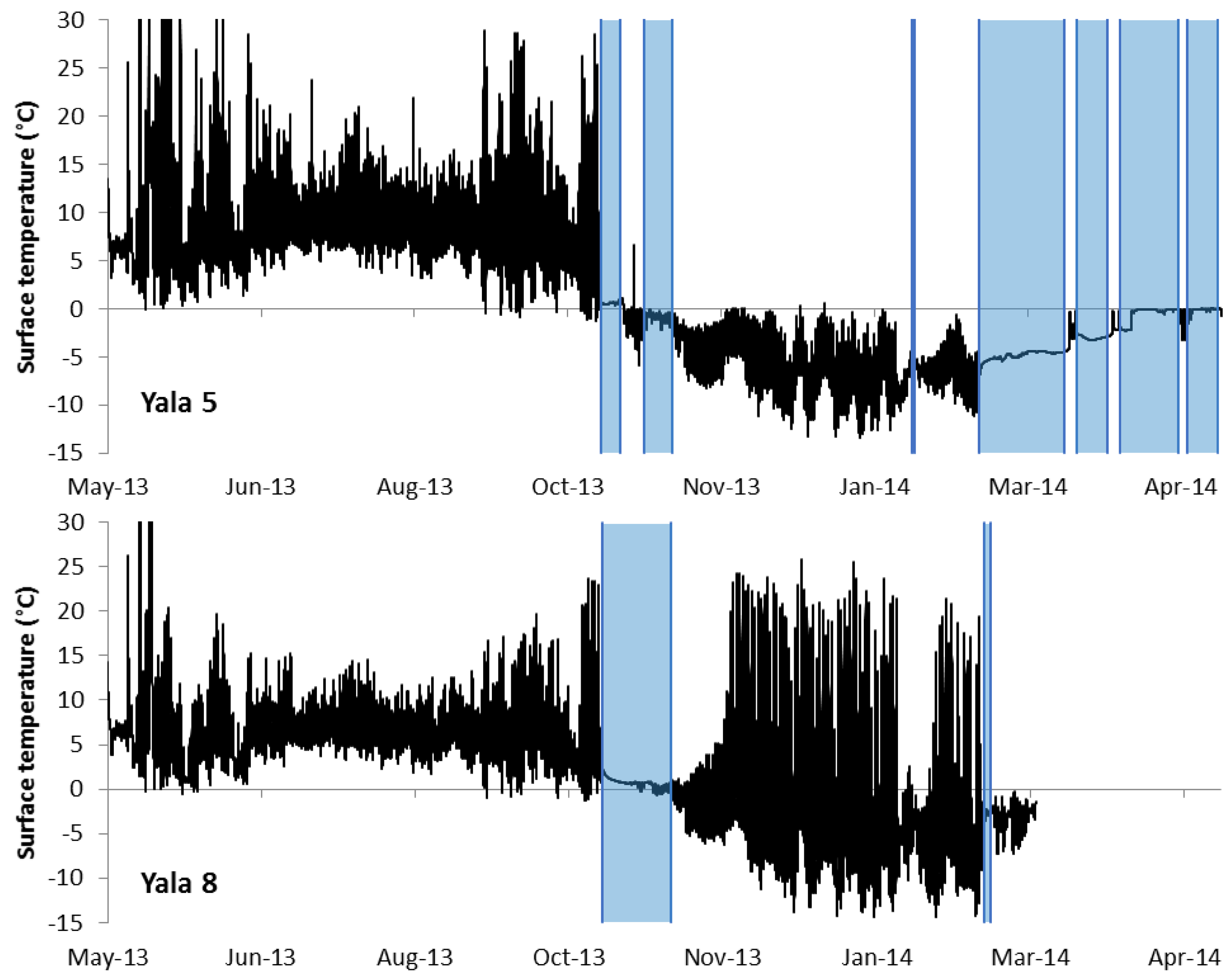

Figure 2 Observed surface temperature at two locations. When snow is present it isolates the temperature logger positioned on the surface and therefore diurnal temperature variability becomes small. The blue vertical lines indicate the start and end of the snow cover.

- SWE increases with increasing elevation due to lower air temperatures and consequently less melt (Fig.3)
- An increase in temperature and therefore an increase in melt can be compensated by an increase in precipitation (Fig.4)

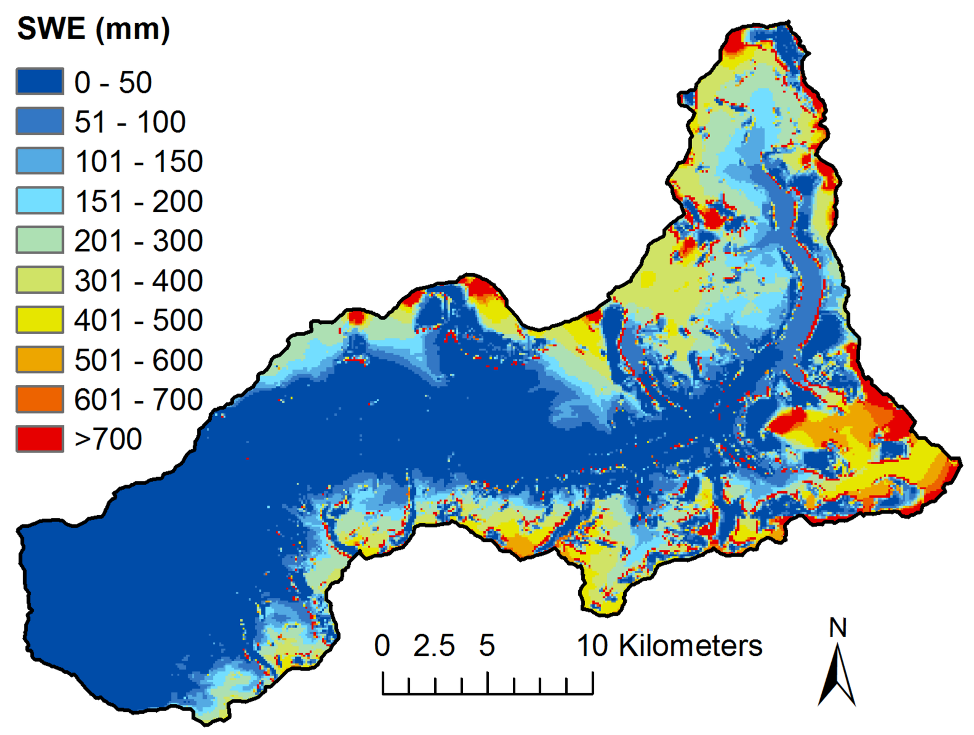

Figure 3 Spatial distribution of SWE averaged over the simulation period (Jan. 2013 and Sep 2014).

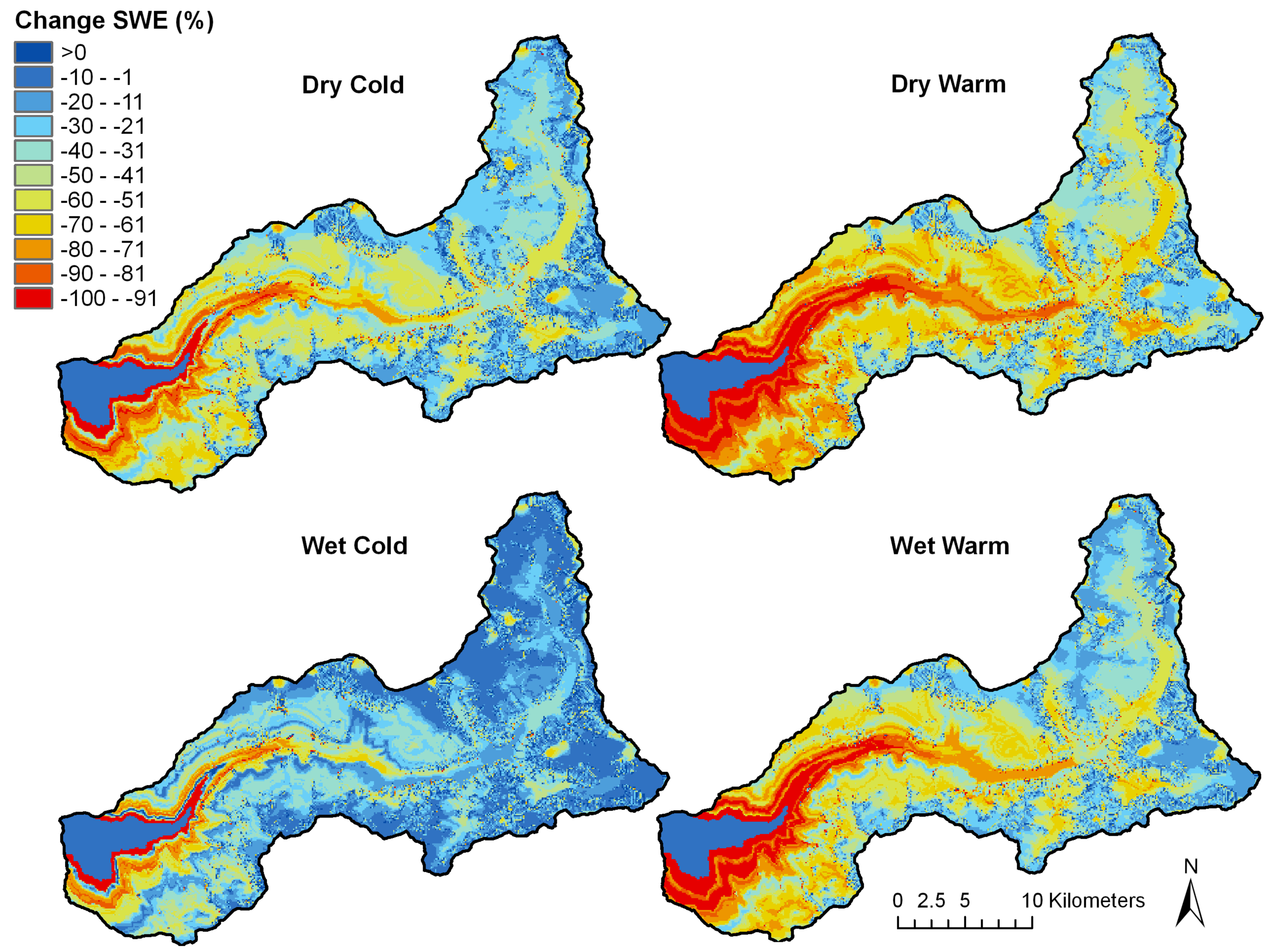

Figure 4 Change in SWE averaged over the simulation period (Jan. 2013 and Sep 2014) for all climate sensitivity tests.

Conclusions

- Data assimilation of snow cover and snow depth data proves to be succesfull for obtaining optimal model parameter values
- The spatial distribution of SWE shows an increase in SWE with increasing elevation and also reflects the spatial and temporal distribution of precipitation.
- Climate sensitivity tests show a strong relative decrease in SWE in the valley. At higher elevations an increase in precipitation partly compensates for increased melt due to higher temperatures.
- The compensating effect of precipitation emphasizes the importance and need for accurate prediction of change in spatial and temporal distribution of precipitation.

References

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