NH3.7 Space and time forecasting of landslides

ENVISAGING POST-EARTHQUAKE SNOWMELT-INDUCED SHALLOW LANDSLIDES UNDER CLIMATE CHANGE

Srikrishnan Siva Subramanian [1], Xuanmei Fan [1], Ali. P. Yunus [1], Theo van Asch [1], Qiang Xu [1] and Runqui Huang [1]

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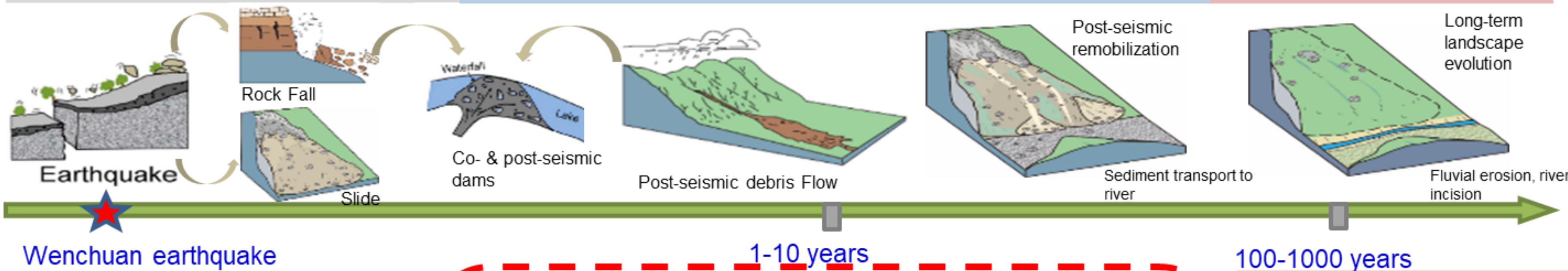
Summary of our main research aspects on geo-hazards and their evolution at different temporal scales

Co-seismic Phase	Post-seismic short-medium term	Long-term



Triggering and development of co-seismic geo-hazards

- Mapping, spatial distribution patterns
- Initiation and failure mechanism analyses
- Evaluation of runout characteristics
- Formation and failure of co-seismic landslide dams

Post-seismic landslides and debris flows

- Case studies and inventory
- Initiation and runout: mechanisms and modelling
- Observations and modelling of changing rainfall threshold
- Risk management and mitigation (including structural and non-structural measures)

Post-seismic landslides and their hazard assessment

- Spatial and temporal evolution
- Controls on the post-earthquake geo-hazards evolution
- Hazard, risk assessment and reconstruction strategies

Long-term impact of strong earthquakes

- Weathering related post-seismic landsliding
- Sediment cascade and yield after a strong earthquake
- Long-term landscape evolution: the mass balance problem

Fan et al., 2019
Review of geophysics, 57

- Quantification of post-earthquake landslide evolution in time, space and in magnitude. The challenge is to analyze the controlling factors for the post-seismic landslide evolution. Developing integrated physically-based landslides and debris flow simulation models. The present generation of numerical models are poorly suited for post-earthquake settings.

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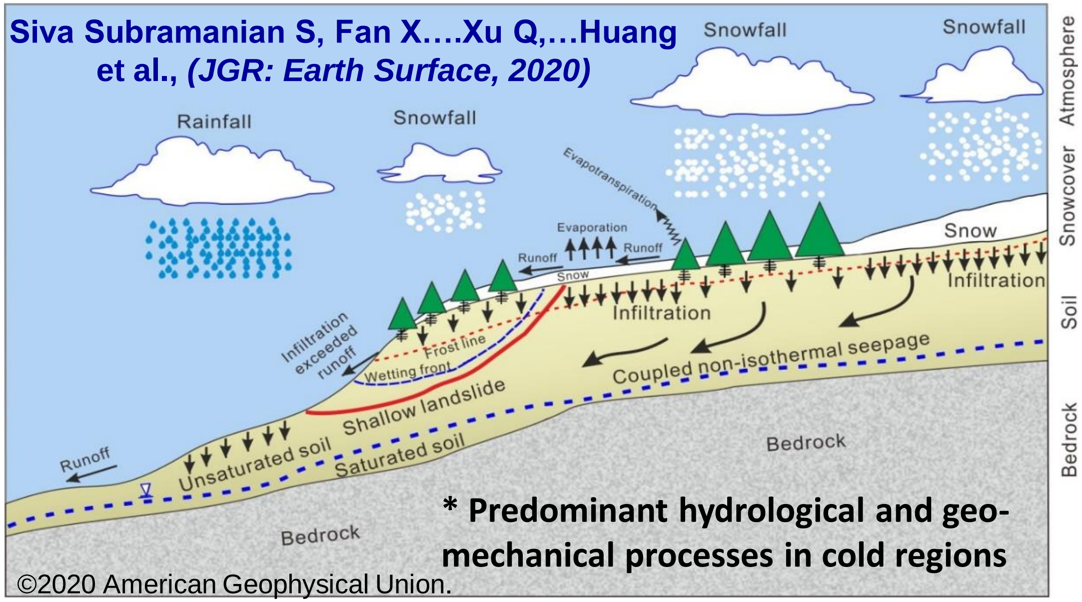
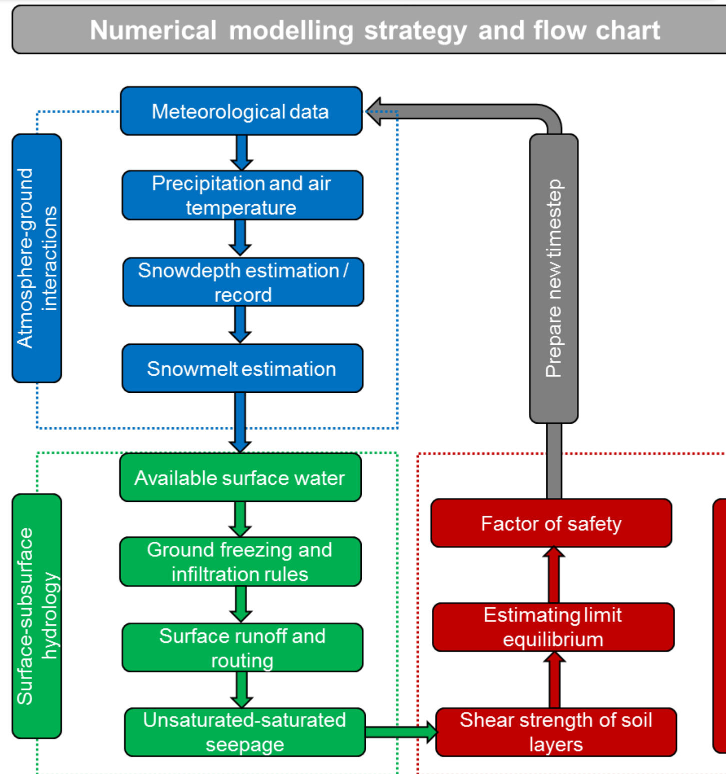
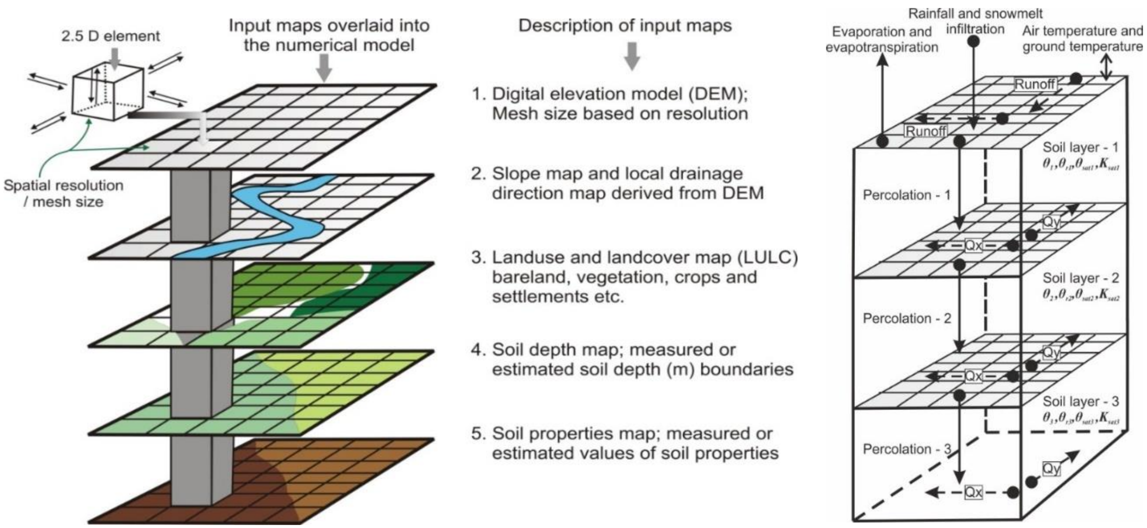
Model development: A sequentially coupled catchment-scale numerical model for snowmelt-induced soil slope instabilities







- Simplified account of below-freezing temperature on hydro-mechanical-behaviour for catchment-scale slope stability assessment.

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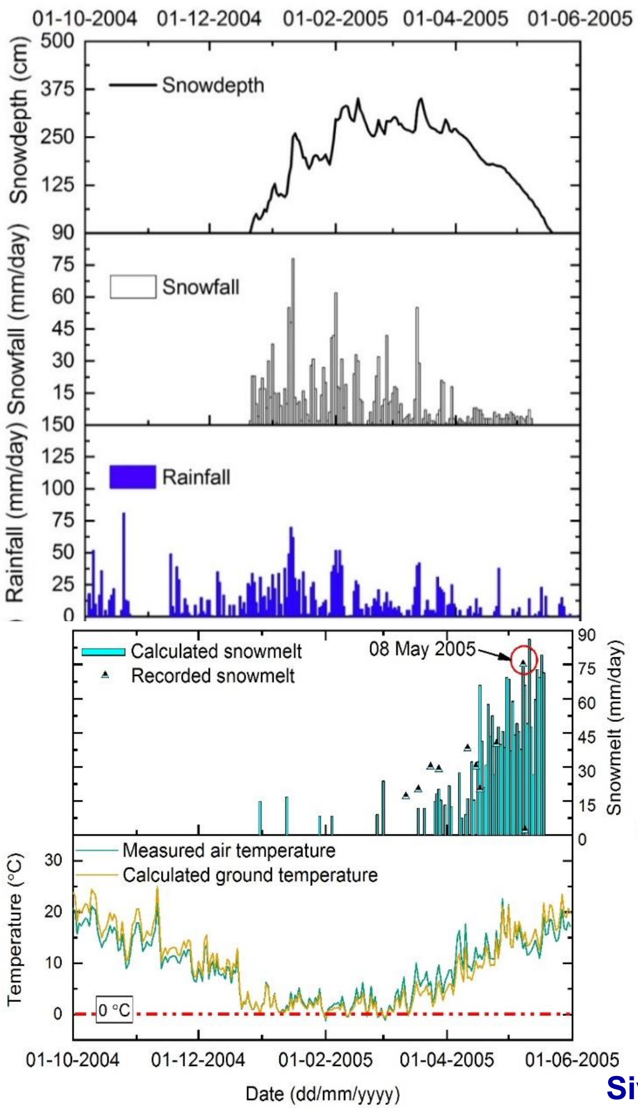
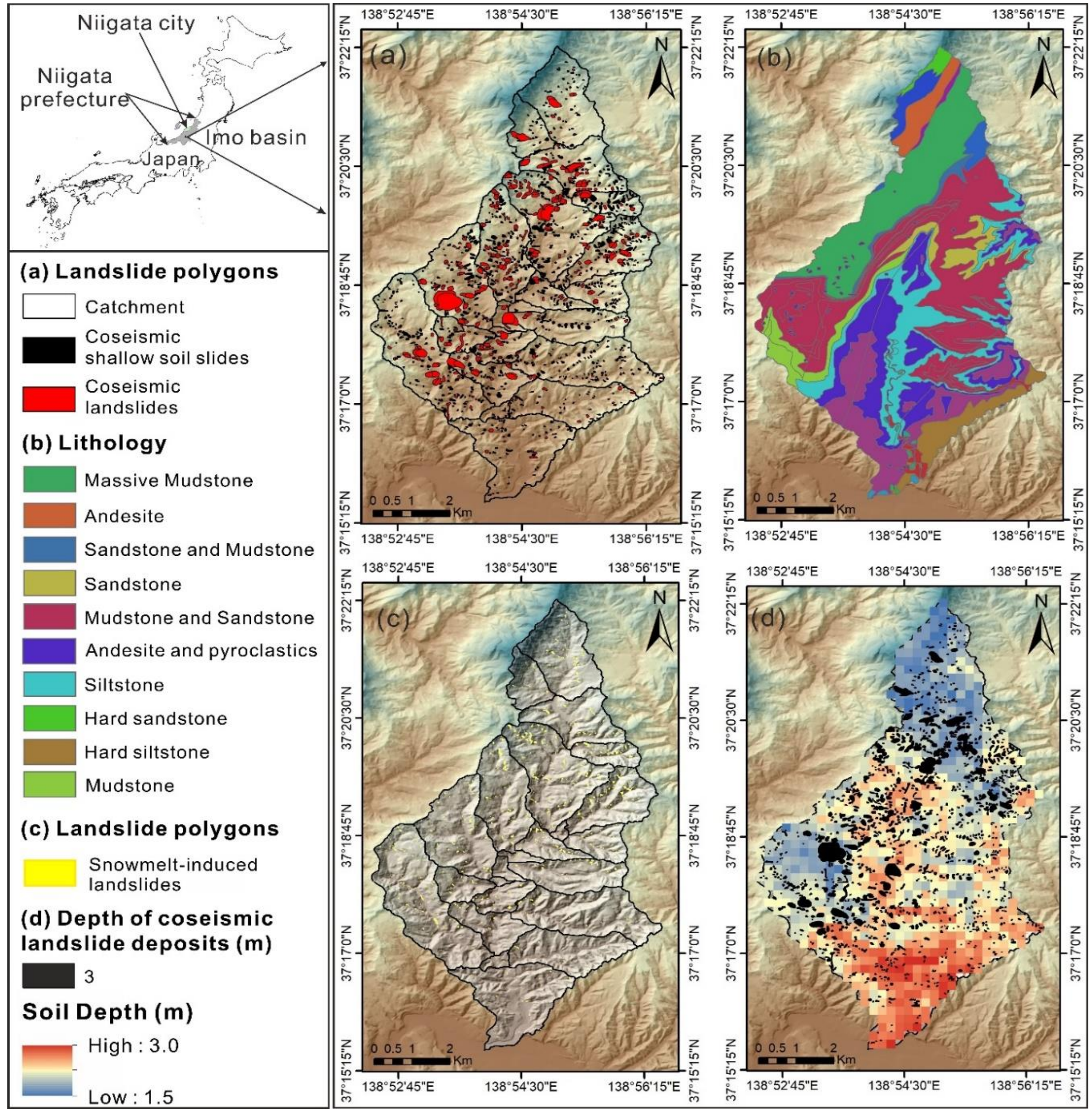
Model testing and validation:





Siva Subramanian S, Fan X….Xu Q,…Huang et al., *(JGR: Earth Surface, 2020)*

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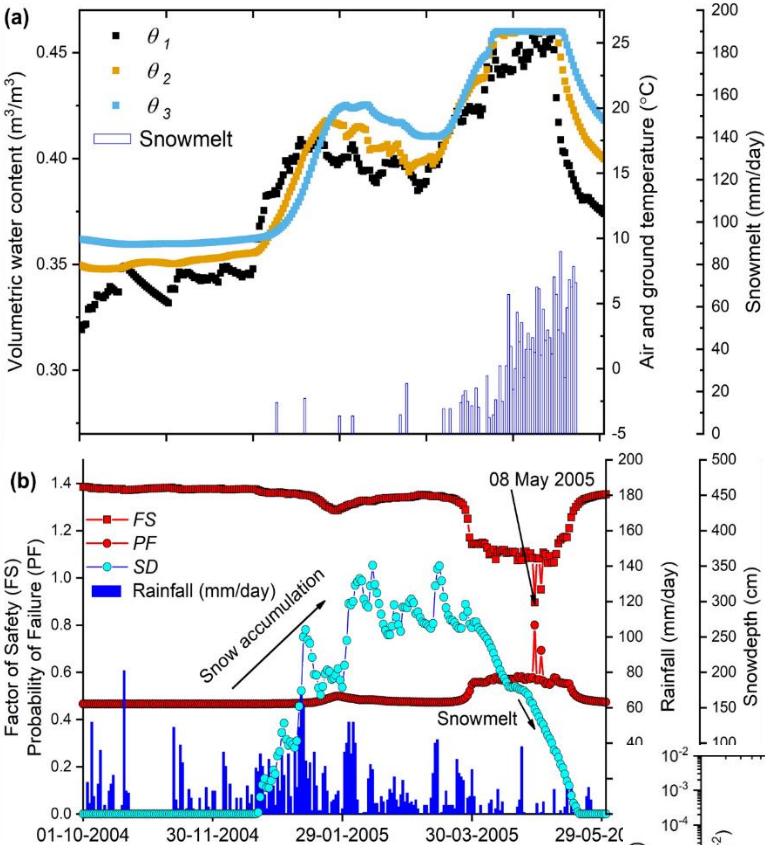
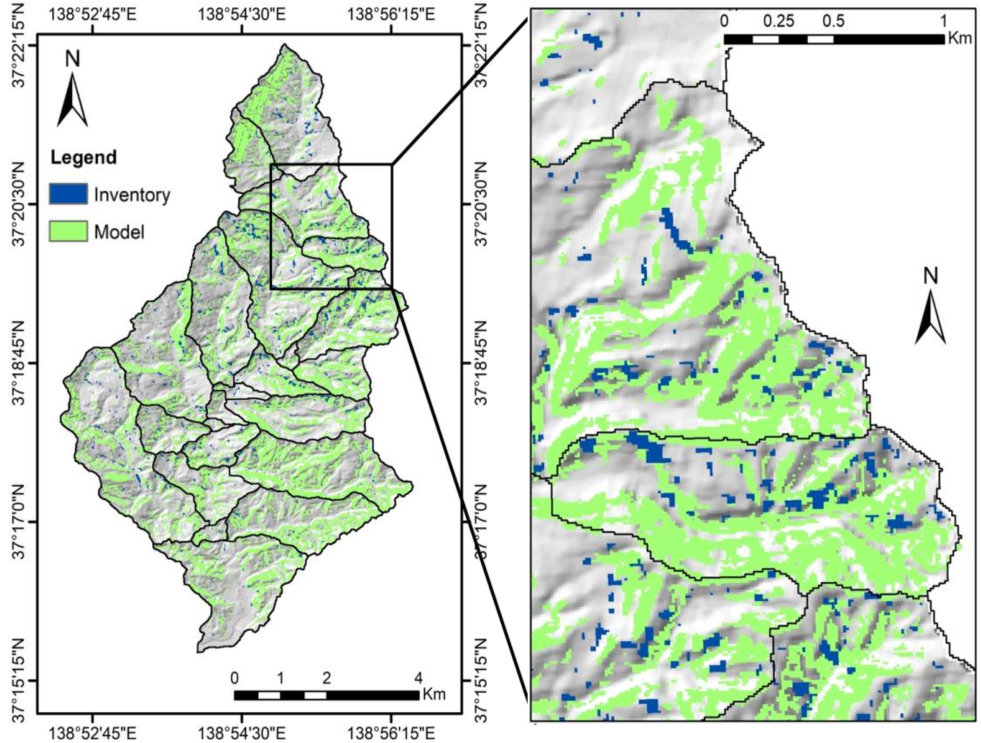
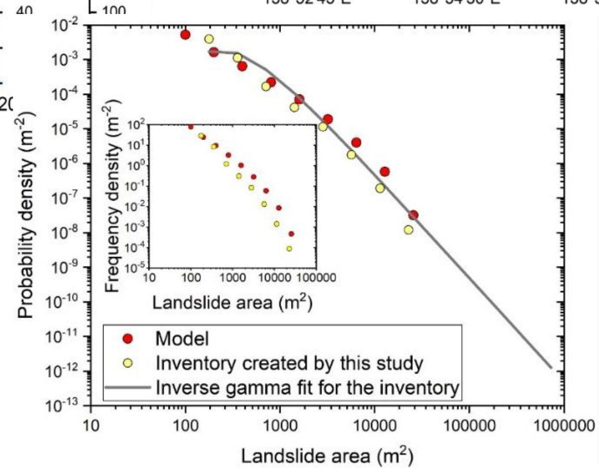
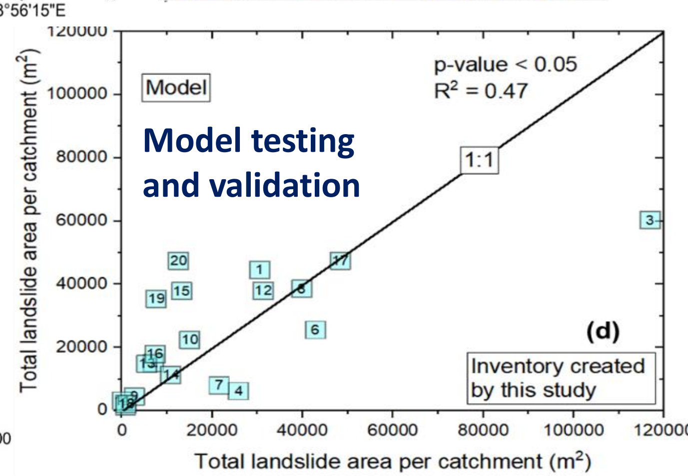






Model testing and validation



Metrics (%)	
True Positives	9
True Negatives	50
False Positives	21
False Negatives	20
Accuracy	59
Cohen's Kappa	0.38

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Improvements in the present snowmelt model for large scale applications

- Snowmelt water is estimated using the meteorological data according to the following relationship,

$$SM = \Delta SWE - S \qquad (1)$$

- SWE is calculated using snow density (ρ_s) and snow depth (h_s) through the following relationships ,

$$SWE = h_s \frac{\rho_s}{\rho_w} \qquad (2)$$

Improved distributed model

$$\lambda \Delta \mathrm{SWE} = S + L_a - L_t + H + E + G + P - \mathrm{SWE}(C \Delta T_s)$$

- *Distributed snowmelt model according to lapse rate change Δ6°C/km!*
- *More sophisticated energy balance of snowmelt at watershed scale*

where λ is the latent heat of fusion (3.35 X 10^5 kJ m^{-3}), ΔSWE is the change in the snowpack's water equivalent (m), S is the net incident solar radiation (kJ m^{-2}), L_a is the atmospheric long wave radiation (kJ m^{-2}), L_t is the terrestrial long wave radiation (kJ m^{-2}), H is the sensible heat exchange (kJ m^{-2}), E is the energy flux associated with the latent heats of vaporization and condensation at the surface (kJ m^{-2}), G is ground heat conduction to the bottom of the snowpack (kJ m^{-2}), P is heat added by rainfall (kJ m^{-2}) and SWE($C\Delta T_s$) is the change of snowpack heat storage (kJ m^{-2}).

Reference: *Tarboton, D. G., Chowdhury, T. G., & Jackson, T. H. (1994).*

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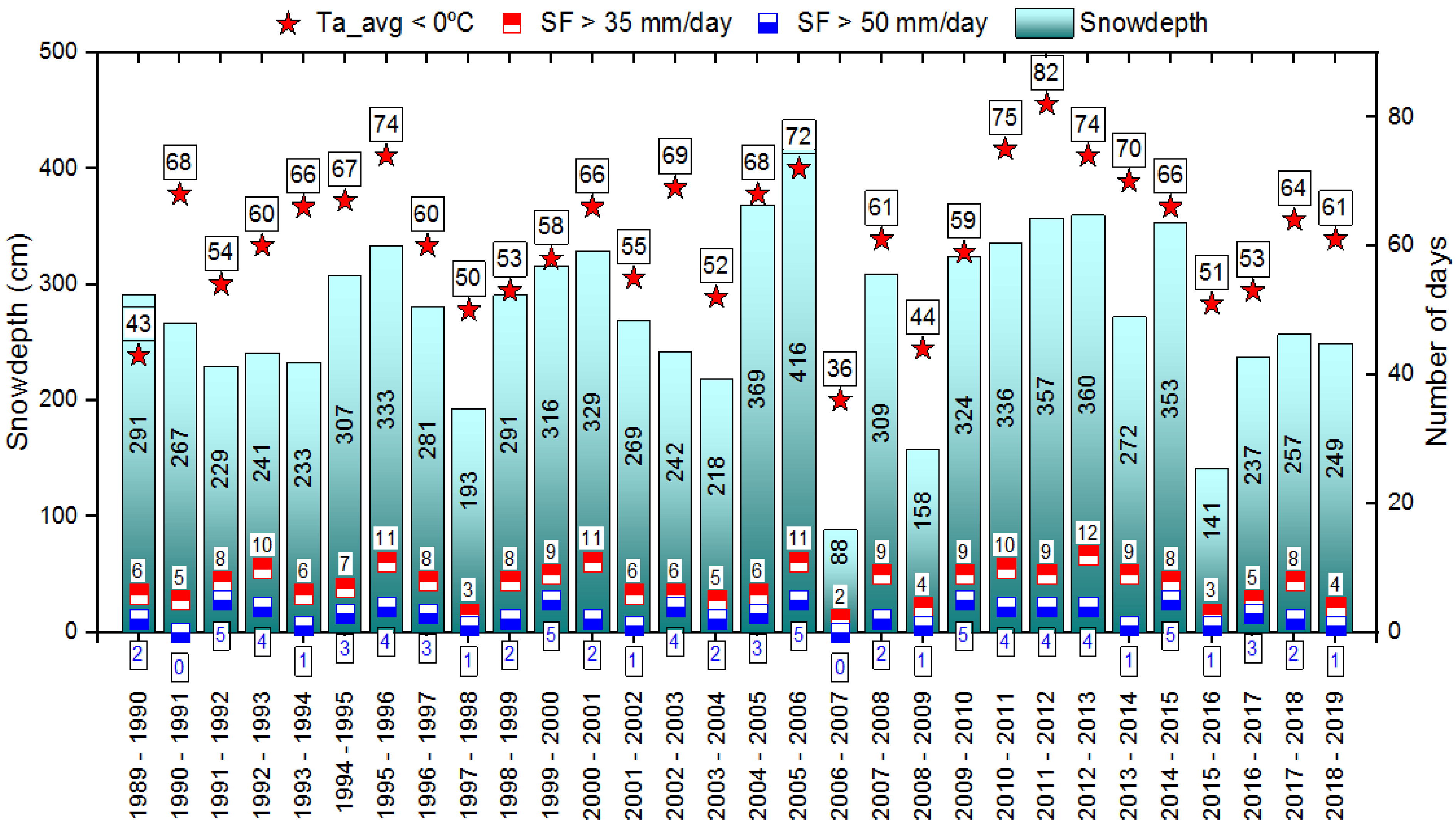

- Statistics from long-term 1989 – 2019 (30 years) daily weather records from selected AMeDAS (Automated Meteorological Data Acquisition System) inside Niigata .

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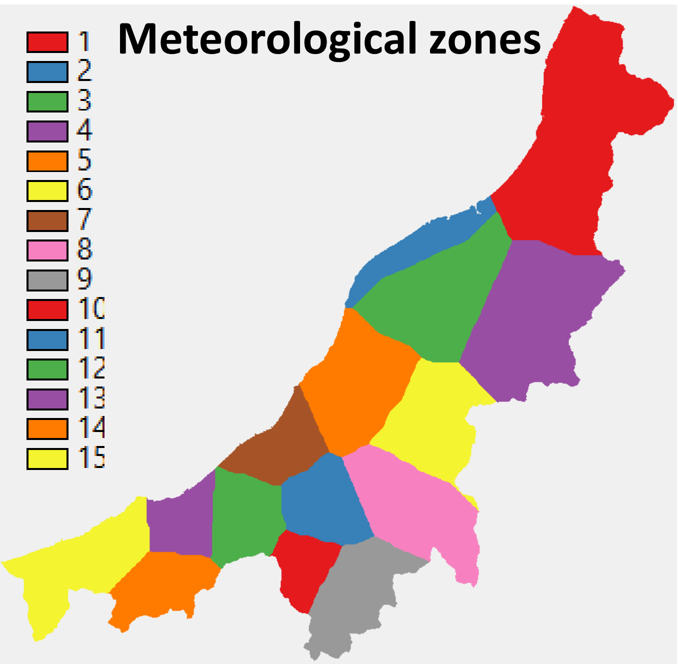
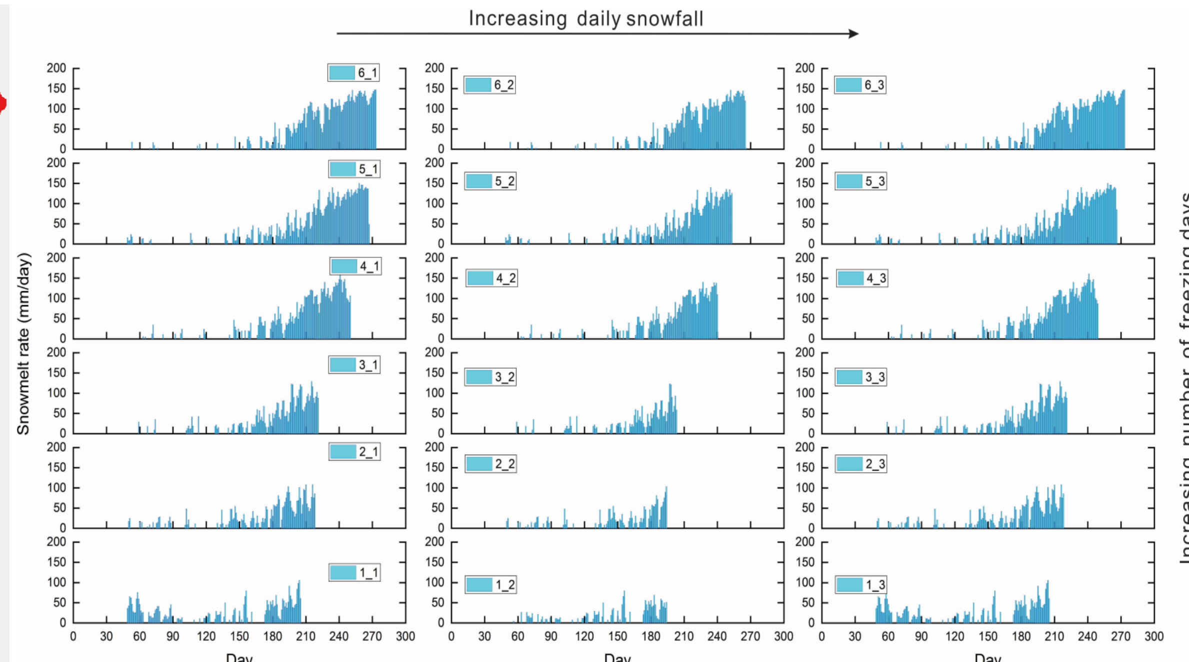
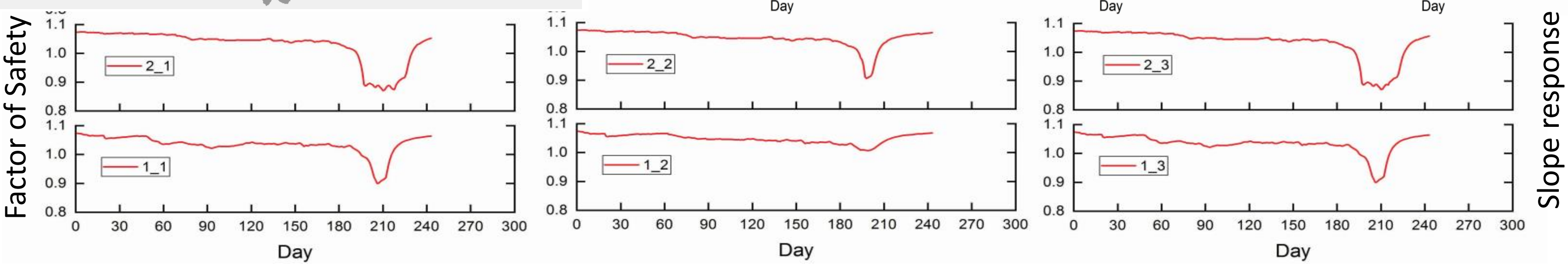
Modeling snowmelt-induced shallow landslides under boundary conditions from the past and presumed future

- Meteorological data was collected for 15 AMeDAS stations inside Niigata prefecture.
- Meteorological domain was set dividing the Niigata area in to 15 zones.







Siva Subramanian S, Fan X….Xu Q,…. Huang et al., (*Manuscript under preparation*)

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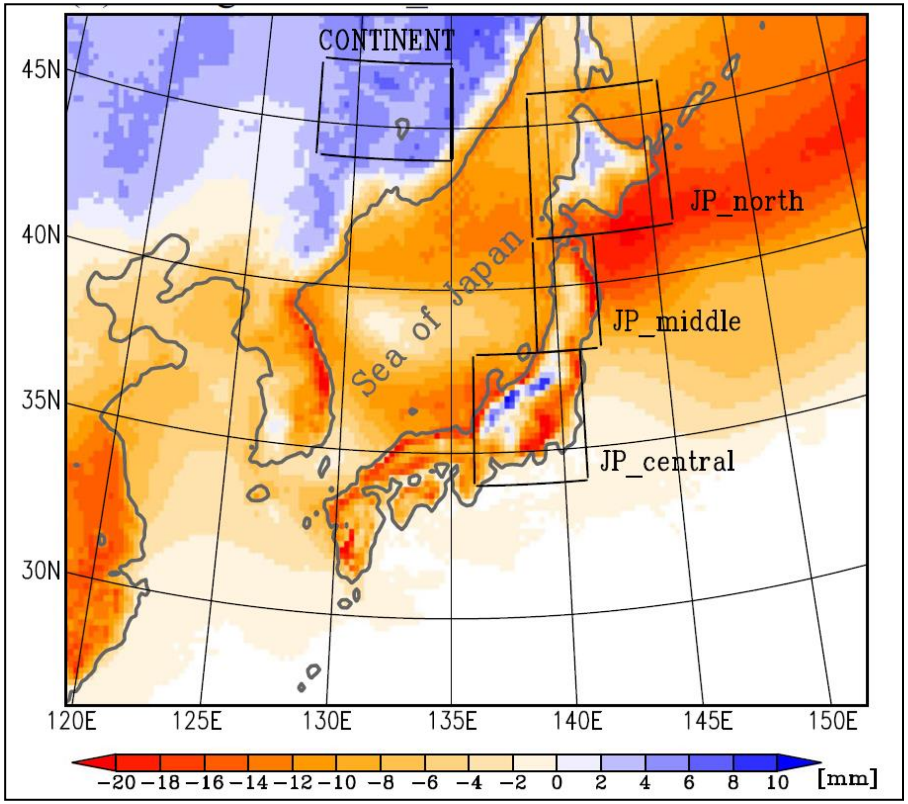

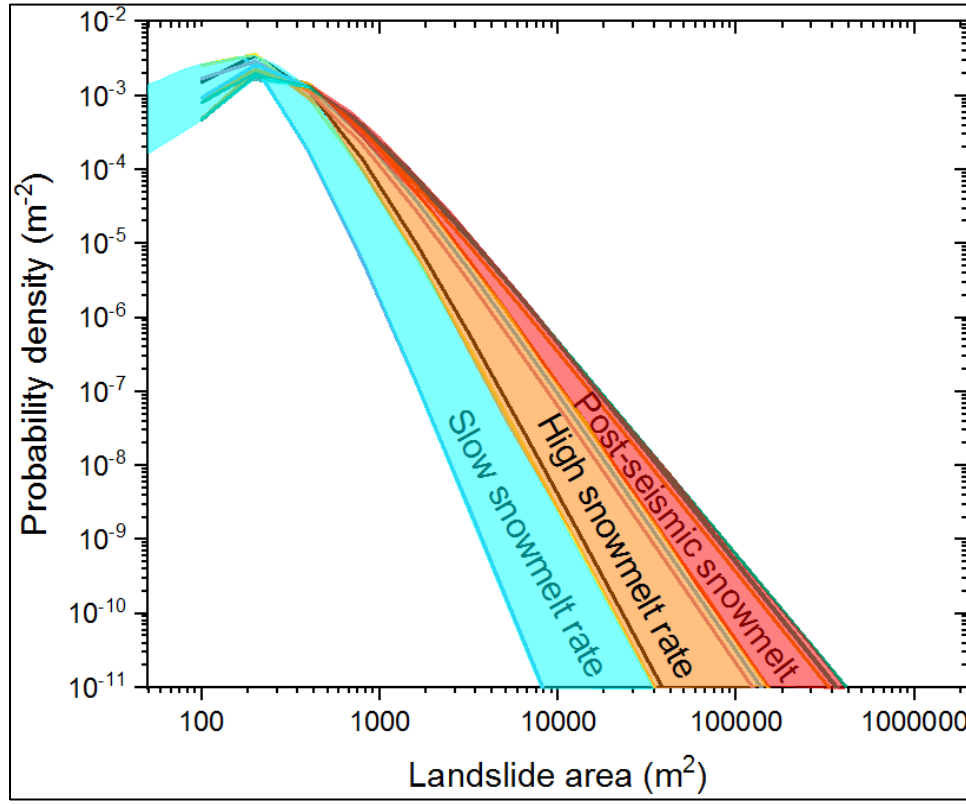

10 mm increase in daily snowfall projected for Niigata region in Japan. Kawase et al., 2016 *(Climatic Change 139:265–278)*

Over the Niigata region, landslide area increases under high snowmelt and exaggerated if follows an earthquake.

- Space and probability forecasting of future snowmelt-induced landslides under increased and decreased melt rates and post-earthquake settings.

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Conclusions

- We developed a novel spatially distributed, a physically-based numerical approach to compute slope stability within a basin, explicitly considering the atmosphere-ground, hydrology, and mechanical interactions on a day to day time step.
- Using this model, we envisaged future snowmelt-induced landslides under increased and decreased melt rates and post-earthquake settings.
- The probability density curves of these future landslides suggest that under slower snowmelt rates, *the occurrence probability of individual landslides remains the same*, whereas, under rapid and increased snowmelt rates, *the size-distribution of the landslides increase one magnitude* and *doubles if rapid snowmelt follows an earthquake*.

--------------------------------Thank you for your kind attention ! --------------------------------