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Investigating the sensitivity of soil freeze/thaw dynamics to environmental conditions at different scales in the central Tibetan Plateau

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Widespread soil thaw has been observed in the Tibetan Plateau (TP) with regional warming, and a better understanding of the environmental sensitivity of these changes is critical for projecting hydro-ecological responses to future climate conditions. In this study, we used a multi-scale soil temperature and moisture networks from the Asia-Australia Monsoon Project sites within the Tibetan Plateau domain (CAMP-Tibet) and Central Tibetan Plateau Soil Moisture and Temperature Monitoring Network (CTP-SMTMN), as well as a process model, to investigate the sensitivity of soil freeze/thaw (F/T) dynamics to environmental conditions in the central TP region. The results showed that model simulated soil temperatures generally agreed well with the observations, with RMSE lower than 1.3 [U+2103] and 2.0 [U+2103] for CAMP-Tibet and CTP-SMTMN sites, respectively. Relatively large errors in the CTP-SMTMN sites were likely due to the uncertainties in the deep soil parameterization, where no soil moisture observations were available below 40 cm depth. The analysis on the relationships between the soil F/T dynamics and environmental conditions showed that maximum frozen depths (MFDs) were significantly influenced by elevation ($R=0.48$, $p<0.005$), soil moisture content ($R=0.57$, $p<0.005$), and SOC content ($R=0.46$, $p<0.005$). However, the main factors affecting MFDs vary at different scales. Even though the elevation which indicates temperature differences is the first-order factor controlling the MFD at the regional scale, soil moisture also plays an important role regulating MFD at local scale. Soil thaw onset is more closely associated with environmental factors examined than soil freeze onset at the seasonally frozen ground (SFG) study sites. Since F/T dynamics may be different between SFG and permafrost regions, more analysis is still needed to evaluate the potential differences of soil F/T sensitivity to environmental factors in these two regions. Our study highlights the importance of soil moisture in affecting soil F/T dynamics in central TP region, which should be properly addressed in future studies in soil F/T and permafrost modelling for the TP region.