Poster #1-34

Harmonized High-Resolution Estimates of Soil Organic Carbon Stocks and Its Uncertainties in the Permafrost Region

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BER Program: TES
Project: Argonne National Laboratory SFA
Project Website: http://tessfa.evs.anl.gov

Permafrost-region soils store more than half of global soil organic carbon (SOC) stocks and are a sensitive component of the global carbon cycle under changing climate. However, our knowledge about the distribution of permafrost-region SOC stocks and their environmental controllers is limited due to the relatively sparse and uneven distribution of soil observations. As a result, substantial uncertainty exists in the current estimates of permafrost-region SOC stocks, and their fate under changing environmental conditions. Using a larger number of soil profile observations (n=2703) than previously available and spatially referenced information on environmental factors including topographic positions, land cover types, and climatic variables, we derived new high-resolution (250-m) estimates of the distribution of SOC stocks and their uncertainties (95% CI) across the northern circumpolar and Tibetan permafrost regions. In the northern circumpolar region, we estimated 510 (432–589), 441 (382–504), and 355 (311–402) Pg C are stored at depths of 0–1, 1–2, and 2–3 m, respectively. In the Tibetan region, our estimates were 9.2 (7–11), 2.5 (0.4–6), and 2.7 (1.4–3) Pg C at 0–1, 1–2, and 2–3 m depth intervals, respectively. Among topographic positions, the largest uncertainty in SOC stocks was found in the hill toe-slope positions (37%) in the circumpolar region, whereas in the Tibetan region the greatest uncertainty occurred in flat areas (63%). Among different land cover types, uncertainties in SOC stocks were greatest under needle leaved forest (69%) and lowest under wetlands (19%) in the northern circumpolar region. In the Tibetan permafrost region, we observed the largest uncertainty under grasslands (75%) and the lowest under mixed forests (10%). In the northern circumpolar region, SOC stocks decreased linearly with increasing precipitation but showed a nonlinear relationship with temperature. The uncertainty in SOC stocks increased as temperature and precipitation increased. In the Tibetan permafrost region, all relationships between SOC stocks and climatic factors were nonlinear, and in contrast to the northern circumpolar region, uncertainties decreased with increasing temperature and precipitation. We report the first harmonized assessment of SOC stocks and associated uncertainties across the permafrost domain of the northern hemisphere. Our results also provide a high-resolution assessment of permafrost region SOC stocks and their relationships with environmental factors, which can be used to optimize the collection of new field observations and benchmark the representation of permafrost-region SOC stocks in CMIP6 models.