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# Short communication: a new dataset for estimating organic carbon storage to 3 m depth in soils of the northern circumpolar permafrost region

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## Abstract

High latitude terrestrial ecosystems are key components in the global carbon (C) cycle. The Northern Circumpolar Soil Carbon Database (NCSCD) was developed to quantify stocks of soil organic carbon (SOC) in the northern circumpolar permafrost region ($18.7 \times 10^6$ km$^2$). The NCSCD is a digital Geographical Information systems (GIS) database compiled from harmonized regional soil classification maps, in which data on soil coverage has been linked to pedon data from the northern permafrost regions. Previously, the NCSCD has been used to calculate SOC content (SOCC) and mass (SOCM) to the reference depths 0–30 cm and 0–100 cm (based on 1778 pedons). It has been shown that soils of the northern circumpolar permafrost region also contain significant quantities of SOC in the 100–300 cm depth range, but there has been no circumpolar compilation of pedon data to quantify this SOC pool and there are no spatially distributed estimates of SOC storage below 100 cm depth in this region. Here we describe the synthesis of an updated pedon dataset for SOCC in deep soils of the northern circumpolar permafrost regions, with separate datasets for the 100–200 cm (524 pedons) and 200–300 cm (356 pedons) depth ranges. These pedons have been grouped into the American and Eurasian sectors and the mean SOCC for different soil taxa (subdivided into Histels, Turbels, Orthels, Histosols, and permafrost-free mineral soil taxa) has been added to the updated NCSCDv2. The updated version of the database is freely available online in several different file formats and spatial resolutions that enable spatially explicit usage in e.g. GIS and/or terrestrial ecosystem models. The potential applications and limitations of the NCSCDv2 in spatial analyses are briefly discussed. An open access data-portal for all the described GIS-datasets is available online at: http://dev1.geo.su.se/bbcc/dev/v3/ncscd/download.php. The NCSCDv2 database has the doi:10.5879/ECDS/00000002.





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## 1 Introduction

High latitude terrestrial ecosystems are considered key components in the global carbon (C) cycle (McGuire et al., 2009). In these regions, low temperatures and high soil water contents reduce decomposition rates (Davidson and Janssens, 2006) and combustion losses (Harden et al., 2000), resulting in large stocks of soil organic C (SOC) in permafrost mineral soils, organic soils, deltaic deposits and ice-rich late Pleistocene silty deposits (Yedoma) (Schuur et al., 2008). If widespread permafrost thaw occurs, large pools of SOC that were previously frozen and thus protected from mineralization may be subjected to e.g. biological decomposition or combustion leading to increased greenhouse gas fluxes to the atmosphere (Schuur et al., 2011; Grosse et al., 2011). Using the Northern Circumpolar Soil Carbon Database (NCSCD; see Hugelius et al., 2013 for a full technical description of the database), Tarnocai et al. (2009) estimated SOC mass (SOCM) in the northern circumpolar permafrost region (with a total area of $18.7 \times 10^6$ km$^2$ as estimated by Brown et al., 1997) to be 191 Pg (1 Pg = $10^{12}$ kg) for topsoil (0–30 cm depth) and 496 Pg for the upper 100 cm of soil. Based on limited field data (46 pedons), and not included in the first version of the spatially distributed NCSCD, SOCM to 300 cm soil depth was estimated to be 1024 Pg (Tarnocai et al., 2009). Estimated SOCM in deeper (> 300 cm) Yedoma deposits (407 Pg) and deltaic deposits (241 Pg) brings the total estimate to 1672 Pg, of which 1466 Pg is stored in perennially frozen ground (Tarnocai et al., 2009). This is about twice as much C as what is currently stored in the atmosphere (Houghton, 2007).

While it is recognized that the pool of SOC stored in permafrost regions is very large and potentially vulnerable to remobilization through permafrost thaw, estimates are poorly constrained and quantitative error estimates are lacking (Hugelius, 2012). Tarnocai et al. (2009) assigned qualitative levels of confidence for different components of the circumpolar SOC estimate and the deep soil (100–300 cm) estimate was assigned the lowest degree of confidence (low to very low) because of a lack of field data and limited spatial representativeness. Here we describe the compilation of an





ESSDD
6, 73–93, 2013

updated pedon dataset for describing SOC content (SOCC; kg C $m^{-2}$) in deep soils of the northern circumpolar permafrost regions. The new dataset provides separate estimates for the 100–200 cm and 200–300 cm depth ranges, and represents a significant increase in the amount of available pedons compared to the previous estimate (increase by factors 11 and 8 for the two depth ranges, respectively). This database has been integrated with the NCSCD (Hugelius et al., 2013) to enable upscaling and calculation of regional/circumpolar SOCM. The updated NCSCDv2 is freely available online in several different file formats and spatial resolutions that enable use in e.g. Geographical Information systems (GIS) and/or terrestrial ecosystem models.

## 2 Database structure

Georeferenced pedons from the northern circumpolar permafrost region were compiled and included in the updated database if they fulfilled the following criteria: (1) pedon described following a classification system suitable for permafrost affected soils, e.g. US Soil Taxonomy, The Canadian System of Soil Classification or the World Reference Base for soil resources (Soil Survey Staff, 2010; Soil Classification Working Group, 1998; IUSS Working Group WRB, 2007) and (2) data available on percentage organic C (OC), percentage coarse fragments (> 2 mm diameter) and/or segregated ice content (% weight) and dry bulk density (BD) of described soil horizons down to sufficient soil depths (at least > 150 cm, see Sect. 2.1 below). Data sources include pedons from previously published scientific studies, existing databases and previously unpublished material (all original data sources are provided in the Supplement spreadsheet). The compiled database follows the US Soil Taxonomy classification. The database is subdivided into the following classes: the three suborders of the Gelisol soil order (Histels, Turbels and Orthels) as separate classes, the Histosol soil order as a separate class and, lastly, all remaining soil orders (non-permafrost soil orders) grouped as one class. Because of very limited representation of organic soils from Siberia, 102 peat cores from the West Siberian Lowland (Smith et al., 2012, supplementary online material)





ESSDD
6, 73–93, 2013





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that are located within the northern circumpolar permafrost region were also used in the study. While these sites lack a pedon description, in this study they are classified as Histosols if there is a > 40 cm surface O-horizon and they are described as non-permafrost or alternatively they are classified as Histels if there is a > 40 cm surface O-horizon and presence of permafrost is confirmed from measured thaw depths included within this dataset. For a subset of cores where no information on the absence or presence of permafrost is available ($n = 11$, applies to pre-existing Russian peat cores collected from literature by Smith et al., 2012), only those sites that are located within the continuous permafrost zone are included (classified as Histels).

### 2.1 Soil sampling, analyses and calculations

In general, deep soil cores (below 100 cm depth) were collected using motorized coring equipment or through manual soil coring. In some cases pedons were sampled from natural exposures (e.g. along river valleys, coastal erosion banks or thermal erosion fronts) that were cleaned to exposed fresh soil material prior to sampling. For detailed descriptions of soil sampling methodology, laboratory analyses and calculation of soil horizon SOCC we refer to Hugelius et al. (2013). In many places the pedon dataset was incomplete and data-gapfilling (pedo-transfer functions), extrapolation or estimation was needed to complete calculations. The details of these procedures are described below. All pedons where such procedures have been used are flagged in the pedon database so that data users may easily identify them.

#### 2.1.1 Gap-filling with pedo-transfer functions

In some pedons ($n = 25$, all from silty sediments) a subset of the sampled soil horizons lacked data for BD which was gap-filled using a power-based regression model that approximates BD from OC % from Muhs et al. (2003). The regression model ($\mathrm{BD} = 1.4593^{(-0.133\times\mathrm{OC}\,\%)}$) is based on 282 loess samples and has an $R^2 = 0.73$. A correction for volumetric ice content was used in permafrost soil horizons, based on





ESSDD
6, 73–93, 2013





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measured ice content data. For the West Siberian Lowland peat cores, only loss on ignition (LOI) was available to estimate OC %. To translate LOI % into OC % a 2nd order polynomial regression model (OC % = $(-0.0013 \times \mathrm{LOI}\,\%^2) + (0.637 \times \mathrm{LOI}\,\%)$) with an $R^2 = 0.79$ was created based on 101 peat samples from similar environments and peat deposits in the Pechora River Basin where both LOI and OC % was measured on the same homogenized samples (Hugelius et al., 2011). For mineral soil samples from the same database, the regression for LOI % to OC % conversion described by Hugelius et al. (2011) was used.

### 2.1.2 Extrapolation and estimates based on default values

In pedons where field data were not available to full depths of 200 cm or 300 cm, the lower-most available values for BD and OC % in that pedon were extrapolated to the full depth if field data were available for depths within 50 cm of the full depth. Such extrapolations were limited to C soil genetic horizons or deep, homogenous, Quaternary deposits (loess or deltaic deposits).

To avoid overestimation of deep SOC storage to depths of 200 or 300 cm, areas with unconsolidated deposits shallower than 200 or 300 cm should also be accounted for. The compiled database includes all available pedons where bedrock or massive ice-wedges were represented as having deep, carbon-free horizons that extended to the 200 or 300 cm baselines.

To avoid a similar bias for deep organic soils in the database, the database also includes organic soil pedons (Histosols and Histels) with relatively shallow (from 40 cm) O-horizons but that lacked full deep characterization. In this case, to estimate SOC storage in the underlying mineral subsoil, data from mineral soil genetic C-horizons were extrapolated to the full 300 cm baseline depth. In some cases where the underlying mineral soil was not sampled, the default values BD = $1.04 \pm 0.53$ and OC % = $3.29 \pm 2.98$ % were used for extrapolation for the upper 30 cm of mineral soil beneath peat deposits (mean ± one standard deviation values calculated from Histel





ESSDD
6, 73–93, 2013



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C-horizons, $n = 98$) and below that a C-horizon default SOC density of 9.6 kg C cm$^{-3}$ was used (following Hugelius and Kuhry, 2009).

### 2.2 Calculating SOCC for soil taxa in different regions

The compiled pedon dataset was used to calculate regionalized mean SOCC for those soil taxa where data were available to the reference depths: 0–30 cm (topsoil), 0–100 cm, 100–200 cm and 200–300 cm. As there was insufficient representation of soil taxa for most individual regions of the NCSCD (see Hugelius, 2012, for discussion of sample sizes in thematic upscaling) we grouped the data into the North American (incl. Greenland) and Eurasian sector. See Table 1 for a summary of the number of available pedons in upscaling soil classes from different geographic regions.

For a methodological description of the procedure for calculating pedon SOCC, see Hugelius et al. (2013). The full database including geographic coordinates, soil classification following US Soil Taxonomy, SOCC to the four reference depths, original source/citation for the data and additional site information (site vegetation and/or geomorphological description and thaw depth at the time of sampling) is available as Supplement. The mean SOCC values to the four reference depths were calculated for different soil orders and soil sub orders. The different soil taxa where tested for class independence by comparing 0–200 or 0–300 cm SOCC in between upscaling classes using Student's $t$ test in the Statistical software PAST (Hammer et al., 2001). See Hugelius (2012) for a comprehensive discussion of class subdivision in upscaling. The SOC storage calculated from peat cores from the West Siberian Lowlands were also compared against other organic soils from the Russian sector included in the current database.

### 2.3 Incorporating data into the updated NCSCDv2

All GIS-analyses have been performed using the software package ArcGIS Desktop, release 10.0 (Environmental Systems Research Institute, Redlands CA, USA).





ESSDD
6, 73–93, 2013



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The polygon database of the NCSCD accounts for percentage coverage and polygon SOCC/SOCM in the 0–30 cm and 0–100 depth ranges of all soil orders as well as the three suborders of the Gelisol soil order (Histels, Turbels and Orthels) in Soil Taxonomy. The new pedon spreadsheet database corresponds to this thematic resolution but for spatial upscaling and calculation of polygon SOCC/SOCM a reduced geographic and thematic resolution is used (see Results/Discussion). The version of the NCSCD that includes these new 100–200 cm and 200–300 cm SOCC/SOCM data is called NCSCDv2.

The SOCC data were included into the NCSCDv2 by adding new columns containing 100–200 cm and 200–300 cm SOCC to the regional shape-files and calculating 100–200 cm and 200–300 cm SOCM for the separate regions. The regional datasets were merged to form a combined circumpolar polygon shape-file. The new regional 100–200 cm and 200–300 cm SOCM data was converted to gridded formats (see Hugelius et al., 2013 for a technical description of merging and rasterisation of geospatial data). Tables 2 and 3 describe the additional variables that were added to the updated NCSCDv2 (information complementary to tables 2 and 3 in Hugelius et al., 2013).

The NCSCDv2 is also updated by recalculation of 0–30 cm and 0–100 cm SOCM for the Entisol, Spodosol, Histosol, Mollisol and Orthel soil classes for polygons in Alaska, where data for some polygons was found to be missing in the earlier NCSCD.

## 3 Results and discussion

This updated database provides a framework for spatially distributed quantification of SOCM at 100–300 cm depths in soils across the circumpolar permafrost region. A previous first-order estimate of SOCM in this deeper soil component was based on a significantly smaller pedon database and was not included into the NCSCD as a spatially distributed variable (Tarnocai et al., 2009). Harden et al. (2012) combined a larger pedon database (131 pedons extending to > 150 cm depth and 49 pedons extending to > 250 cm depth) with numbers of total areal coverage of the three Gelisol sub-orders





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reported in the NCSCD to estimate SOCM in permafrost-affected soils only, but did not provide spatially distributed estimates. In the supplementary information of this study by Harden et al. (2012) more detailed data on depth distribution of C and nitrogen is available, reported on a Gelisol suborder basis as averages for 5 cm depth increments. The current data-base presented here (524 pedons in the 100–200 cm depth range and 356 pedons in the 200–300 cm depth range) and its integration with the geospatial NCSCDv2 constitutes a significant addition to the knowledge of SOCM at 100–300 cm depths in soils across the circumpolar permafrost region and provides opportunities for researchers to use the data in spatially distributed applications. However, users of this data must keep in mind that the geographical spread of currently included pedons remains highly uneven, with little or no representation in the permafrost affected regions of Central Asia, Scandinavia, Greenland, Svalbard and Eastern Canada, among other regions (Fig. 1). Moreover, there are more pedon data available for the American sector in the 100–200 cm depth range (57 % of pedons) while there is more data from the Eurasian sector 200–300 cm depth range (58 % of pedons). This discrepancy is due to higher numbers of available pedons from organic soils in Eurasia (Table 1), in which all pedons extend to 300 cm depth because of the methodological differences between mineral and organic soils applied in this study.

The West Siberian Lowland is the world's largest peatland complex, with evidence of substantial early Holocene peatland establishment (Smith et al., 2004) and therefore there was a concern that organic soils in this region might differ substantially compared to other organic soils in the Russian permafrost zone. In the currently assembled database, there is no significant difference in 0–300 cm SOCC between Histels from the West Siberian Lowland and Russian Histels outside of the West Siberian Lowland ($t$ test, $p > 0.05$), however West Siberian Lowland Histosols in the permafrost region have significantly less 0–300 cm SOCC than Russian Histosols in the permafrost region outside of the West Siberian Lowland ($t$ test, $p < 0.05$). There are no significant differences in reported peat depths or peat OC % between regions ($t$ test, $p > 0.05$); this difference in 0–300 cm SOCC is mainly due to lower bulk densities reported for





ESSDD
6, 73–93, 2013



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Histosols in the West Siberian Lowlands compared to Histosols from other parts of Russia ($t$ test, $p < 0.05$). No separation of the West Siberian Lowland compared to other Russian regions was made in the upscaling.

The data-base is subdivided into classes which reflect our process understanding of how SOC is incorporated into deep soils. Gelisols and Histosols are affected by specific pedogenic processes which may cause C to be incorporated into the deeper layers of soils, these include: cryoturbation (Turbels only), long-term accumulation of peat (Histels and Histosols only) and repeated deposition and stabilization of organic-rich material (alluvium, proluvium, colluvium or wind-blown deposits) in mineral syngenetic permafrost deposits (Bockheim, 2007; Tarnocai and Stolbovoy, 2006; Schirrmeister et al., 2011; Strauss et al., 2012). To account for these important processes, the three suborders of Gelisols are retained as separate classes in the database and the Histosols are separated from mineral soils without permafrost. Tests of class independence also confirm that the SOCC of these four soil taxa are suitably separated for upscaling ($t$ test, $p < 0.05$). Harden et al. (2012) showed that SOC density is significantly impacted by gleying in mineral soil horizons of Gelisols, but this process is not accounted for in this current database.

For permafrost-free mineral soils the main mechanisms for moving C into deeper soil layers are deep rooting, leaching and burial by repeated deposition. The permafrost-free soils in periglacial regions are often poorly developed (Tarnocai et al., 2009) and since the vegetation in these regions is relatively shallow-rooted (Kleidon, 2004), it contributes little C to the deeper soil layers. Of the permafrost-free mineral soil orders, the Alfisols, Entisols, Inceptisols, and Spodosols are represented in the present 100–300 cm SOC stock database. The representation of pedons largely corresponds to the geographical range of soil orders; in the NCSCD, the Inceptisols, Spodosols, Entisols, and Alfisols cover 15.8 %, 8.6 %, 4.3 % and 3.6 %, respectively, of the soil area in the northern circumpolar permafrost region. The Mollisols are also significant with 3.5 % coverage, but are not represented in the current database. Hugelius (2012) found that in a regional study of SOC storage in periglacial terrain, most permafrost-free mineral





ESSDD
6, 73–93, 2013

A new dataset for estimating organic carbon storage

G. Hugelius et al.



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soil classes could be amalgamated into one class with very little effect on the overall upscaling results. Analogous tests of the presently described database show that there is no statistically significant difference in the 0–300 cm SOCC for most of the permafrost-free mineral soil orders (*t* test, $p > 0.05$). The only exception is that Alfisols store significantly less SOC than all other soil orders. However, the Alfisols are represented by few sites with a very narrow geographical range (5 sites all within a 45 km radius). Therefore, because the permafrost-free mineral soil orders have an uneven geographical distribution of pedons (Table 1) and because they are similar with regards to 0–300 cm SOC stocks and because several permafrost-free mineral soil orders are not represented in the present 100–300 cm SOCC database, they are all aggregated into one class with circumpolar coverage for upscaling in the NCSCDv2.

In many parts of the northern circumpolar permafrost region, soils may be absent or unconsolidated deposits do not extend to depths of 300 cm. The NCSCD partly accounts for this by mapping areas of non-soil, including rocklands. However, in many parts of the northern circumpolar permafrost region, shallow soils (< 300 cm deep) may overlie bedrock and in some regions there are significant occurrences of massive ground ice (Schirrmeister et al., 2011). In this present database all available pedons that terminate in bedrock ($n = 8$) or massive ice ($n = 7$) are also included into the deep C database. While we thus assume that these available pedons represent an unbiased and representative sample of circumpolar soils we recognize that the occurrence of shallow soils or massive ground ice may not be adequately accounted for in the database. Field studies have shown that massive ground ice accounts for up to 30 % of upper permafrost in Alaskan soils (Kanevskiy et al., 2013) or up to 50–80 % in Yedoma deposits (Kanevskiy et al., 2013; Schirrmeister et al., 2011).

In soils of the permafrost region, the density of C is significantly higher in organic horizons than in mineral soil horizons (Harden et al., 2012) and to accurately predict SOC stocks of Histosols and Histels, the depth of surface O-horizons is a key variable (Hugelius, 2012). When sampling soils in the field, researchers often strive to reach the bottom of deep organic soils in order to accurately describe the depth distribution





ESSDD
6, 73–93, 2013

and deep SOC storage of these deposits. Many peat cores were also collected for purpouses of palaeo-environmental reconstruction, when there is often a specific interest in coring the deepest parts of a peat deposit. Together, these circumstances may cause a bias where deep organic soils are overrepresented in the available data of deeper soils; in organic soils with shallower O-horizons researchers are more likely to stop coring well before 200 or 300 cm depth. To avoid a bias towards deep organic soils in the database, all sites with organic soils were included in this study, even if data from the mineral subsoil was missing. The available data from mineral C-horizons below organic deposits were subsequently extrapolated to full depth (or default values were applied). These extrapolations undoubtedly introduce uncertainties into the estimate, especially in those cases when default C-horizon SOC densities from the literature are used for sites with organic soils lacking field data from mineral soil horizons. However, we consider the magnitude of these uncertainties to be minor compared to the errors introduced by upscaling with a database that is biased towards deep organic soils with very high SOCC. Further, as all defaults are calculated exclusively from pedons without any buried palaeo-soil horizons underlying peat deposits and as no extrapolation of cryoturbated, SOC rich, soil horizons has been done, the use of extrapolated data will err towards more conservative estimates.

The new 100–300 cm SOC stock database is the product of a wide collaborative effort to gather data from many different projects and research groups. Thanks to this approach the database contains many pedons from regions that were previously not represented in circumpolar estimates of SOC stocks. While there are some geographic limitations in the representation of soils, the three suborders of Gelisols and the Histosol soil order are well characterized, thus, increasing our understanding of and possibilities to model the unique processes that sequester large amounts of SOC in these high-latitude soils. Further, the database links these valuable field data to the updated NCSCDv2, opening up opportunities for the research community to apply the data in geospatial analyses and modeling which may further our understanding of C cycling in these environments.





ESSDD
6, 73–93, 2013



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## 4 Data access

The compiled database describing site characteristics and SOC stocks to the different reference depths for all 524 sites can be accessed through the Supplement.

The updated NCSCDv2 is hosted by the Bert Bolin Centre for Climate Research at Stockholm University, Sweden. An open access data-portal for all the described GIS-datasets is available online at: http://dev1.geo.su.se/bbcc/dev/v3/ncscd/download.php. The NCSCDv2 database has the doi:10.5879/ECDS/00000002.

**Supplementary material related to this article is available online at: http://www.earth-syst-sci-data-discuss.net/6/73/2013/ essdd-6-73-2013-supplement.zip.**

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ESSDD
6, 73–93, 2013



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6, 73–93, 2013

A new dataset for estimating organic carbon storage

G. Hugelius et al.



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6, 73–93, 2013

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G. Hugelius et al.



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**Table 1.** Summary of number of available pedons with data in the 100–200 cm (the first number) and 200–300 cm (the second number) depth ranges for soil taxa from different regions (regional subdivision following NCSCD). The regions are grouped into the American and Eurasian sections of the northern circumpolar permafrost region.

| | Soil taxa ($n$: 100–200 cm/200–300 cm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Histel | Turbel | Orthel | Histosol | Alfisol | Entisol | Inceptisol | Spodosol |
| | | | | America[1] | | | | |
| Alaska | 31/31 | 53/8 | 29/8 | 6/6 | – | 14/1 | 45/8 | 8/– |
| Canada | 57/56 | 8/5 | 9/5 | 10/10 | 5/5 | 3/1 | 10/5 | – |
| Greenland | 1/1 | 1/– | 6/1 | – | – | – | – | – |
| | | | | Eurasia[2] | | | | |
| Europe | 1/1 | – | 2/2 | – | – | – | – | – |
| Russia | 95/94 | 24/14 | 27/21 | 66/66 | – | 2/2 | 9/7 | 4/1 |
| Total sum | 186/184 | 90/29 | 73/37 | 82/82 | 5/5 | 19/4 | 64/20 | 12/1 |

[1] There are no pedons in the NCSCD region Contiguous USA.

[2] There are no available pedons in the NCSCD regions Mongolia, Iceland or Kazakhstan. Europe includes Scandinavia and Svalbard.





ESSDD
6, 73–93, 2013

A new dataset for estimating organic carbon storage

G. Hugelius et al.

**Table 2.** Description of the data added to the polygon attribute tables of NCSCD v2. The table gives a description of the data, the column field name, the precision of numeric fields (Prec) the data format the variable is stored in (Form: F = float numeric field, I = integer numeric field, S = string) and the number of decimal values of float numeric fields (Dec). This table is complementary to Table 2 in Hugelius et al. (2013).

| Description | Fieldname | Prec | Form | Dec |
|---|---|---|---|---|
| SOCM 100–200 cm depth Histel (kg) | GEHSOCM200 | 16 | F | 1 |
| SOCM 100–200 cm depth Turbel (kg) | GETSOCM200 | 16 | F | 1 |
| SOCM 100–200 cm depth Orthel (kg) | GEOSOCM200 | 16 | F | 1 |
| SOCM 100–200 cm depth non-permafr., mineral soils (kg) | NPMSOCM200 | 16 | F | 1 |
| SOCM 100–200 cm depth Histosol (kg) | HISOCM200 | 16 | F | 1 |
| SOCM 200–300 cm depth Histel (kg) | GEHSOCM300 | 16 | F | 1 |
| SOCM 200–300 cm depth Turbel (kg) | GETSOCM300 | 16 | F | 1 |
| SOCM 200–300 cm depth Orthel (kg) | GEOSOCM300 | 16 | F | 1 |
| SOCM 200–300 cm depth non-permafr., mineral soils (kg) | NPMSOCM300 | 16 | F | 1 |
| SOCM 200–300 cm depth Histosol (kg) | HISOCM300 | 16 | F | 1 |
| SOCM 100–200 cm depth of polygon (kg) | SOCM_200 | 16 | F | 1 |
| SOCM 200–300 cm depth of polygon (kg) | SOCM_300 | 16 | F | 1 |
| SOCC 100–200 cm depth of polygon (kg m$^{-2}$) | SOCC_200 | 8 | F | 1 |
| SOCC 200–300 cm depth of polygon (kg m$^{-2}$) | SOCC_300 | 8 | F | 1 |



ESSDD
6, 73–93, 2013

**Table 3.** Description of the NCSCD v2 variables that have been converted to gridded file formats (TIFF-files and NetCDF-files). Each variable is stored in a separate gridded file. This table is complementary to Table 3 in Hugelius et al. (2013).

| Variable | Description |
|---|---|
| SOCC 100–200 cm depth | SOCC ($hgC\,m^{-2}$) in the 100–200 cm depth interval |
| SOCC 200–300 cm depth | SOCC ($hgC\,m^{-2}$) in the 200–300 cm depth interval |





ESSDD
6, 73–93, 2013

A new dataset for estimating organic carbon storage

G. Hugelius et al.

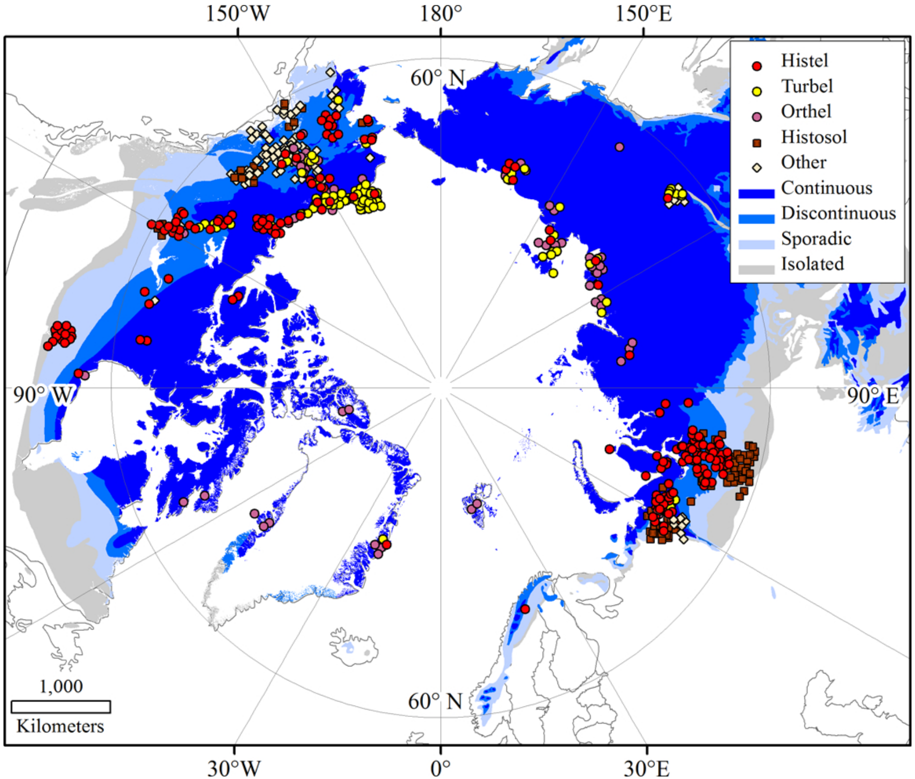


**Fig. 1.** Geographical distribution of pedons with data in the 100–300 cm depth range in the northern circumpolar permafrost region. Pedons are shown according to NCSCD upscaling classes. Permafrost zonation from Brown et al. (2002). Exact pedon locations have been manipulated for cartographic representation; projection: Azimuthal Equidistant, datum: WGS84.





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