Spatial Variations of SOC along the Coastline of Northern Alaska

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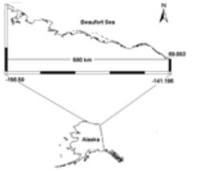


Fig. 1 Map of Sampling Sites

Coastal erosion

Ice Wedge

Suspended Particulate Organic Matter

Cryoturbation

Soil Profile: Active Layer
Permafrost Layer

Introduction

Costal erosion in Arctic regions has become a major pathway of soil organic carbon (SOC) transport across the land/ocean interface under a warming climate and may significantly influence the C budget and biogeochemical cycle in the Arctic Ocean. The eroding of northern Alaska coastline not only causes the loss of thousands of acres of land to the ocean, but also increases the pool of OC with the potential to be mineralized. The goals of this study were to 1) model the spatial variation of SOC in both active and upper permafrost layers and 2) estimate the amount of annual SOC input to the Beaufort Sea.

Methods

Sampling:

❖ A total of 536 soil samples, from 48 sites along the over 1800-km of coastline in northern Alaska, were collected during the summers of 2005 and 2006 (Fig. 1).

Physical and Chemical Analysis of Soil Samples:

❖ All soil samples were frozen until they could be freeze-dried at -50 ^{0}C. Then they were manually ground to pass through a 2-mm sieve and finely ball-milled to pass through a 0.053-mm sieve. All soil samples were treated with 1.0N HCl to remove carbonate before analysis by an elemental analyzer (Carlo Erba EA-1108, Lakewood, NJ, USA) interfaced with a Delta Plus isotope ratio mass spectrometer (Thermo Finnigan, Bremen, Germany) operating in the continuous flow mode flow.

❖ Soil bulk density was determined by dimensional samples upon drying at 105 ^{0}C.

Spatial Modeling of SOC and other Soil Properties:

❖ Our basic geostatistical model is:

$$Z = \begin{pmatrix} Z(s_0) \\ Z(s_1) \\ \cdots \\ Z(s_n) \end{pmatrix} \sim MVN(\underset{\sim}{\mu}, \Sigma)$$

where $\Sigma = \sigma^2 H + \tau^2 I$, τ^2 is nugget effect.

$$\underset{n\times n}{H} = \text{spatial correlation matrix} = \frac{1}{\sigma^2}\begin{bmatrix} \Gamma(s_1,s_1)\ldots\ldots\Gamma(s_1,s_n) \\ \Gamma(s_2,s_1)\ldots\ldots\Gamma(s_2,s_n) \\ \ldots \\ \Gamma(s_n,s_1)\ldots\ldots\Gamma(s_n,s_n) \end{bmatrix}$$

$$\Gamma(s_i,s_j) = Var(Z(s_i)-Z(s_j)) = 2\gamma_{ij} = 2\gamma(d(s_i,s_j))$$

$$2\gamma(h) = Var(Z(s_i)-Z(s_j)) \quad \text{where } h = d(s_i,s_j)$$

❖ Annual SOC erosion rate was integrated using the predicted SOC values from the Gaussian model along the coastline with interval of 500 m.

Table 1. Cross validation values of the 1-D model, 1-D with shortcut distance, and 2-D model with isotropic and anisotropic using different variograms.

	1-D model	1-D model with shortcut distance	2-D model	
	Isotropic	Isotropic	Isotropic	Anisotropic
Spherical	0.76421	0.76345	0.7642	0.7838
Exponential	0.76489	0.76417	0.7702	0.7839
Circular	0.76326	0.76255	0.7634	0.7961
Gaussian	0.76325	0.76126	0.7574	0.7688

Table 2. Estimated parameters for the 1-D, 1-D with shortcut distance, and 2-D models with isotropic using Gaussian by R.

1-D model			1-D model with shortcut distance			2-D model		
Range (km)	Nugget	Sill	Range (km)	Nugget	Sill	Range (km)	Nugget	Sill
	(ln(kg C m^{-2}))			(ln(kg C m^{-2}))			(ln(kg C m^{-2}))	
1812.7604	0.1072	0.0966	1688.11	0.1059	0.0995	576.4785	0.5197	0.8372

Fig. 2 Spatial variation of SOC along the Coastline of Northern Alaska

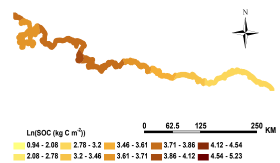


Fig. 5 Spatial Variation of Active Layer along the Coastline of Northern Alaska

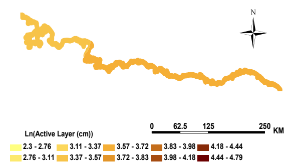


Fig. 3 Spatial Variation of C:N Ratio of Soil Organic Matter along the Coastline of Northern Alaska

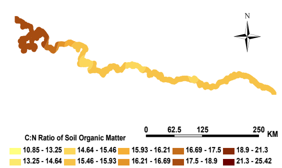


Fig. 6 Spatial Variation of The Proportion of Total Sampling Layer as Active Layer along the Coastline of Northern Alaska

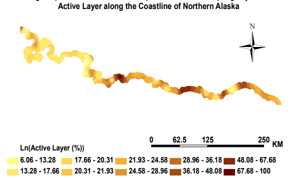


Fig. 4 Spatial variation of Erosion Rate of SOC along the Coastline of Northern Alaska

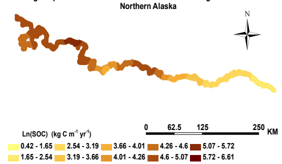
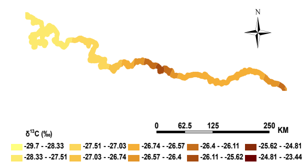


Fig. 7 Spatial Variation of Stable Isotope Carbon along the Coastline of Northern Alaska



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Results

➢ Compared to 1-D model or 1-D model with short-cut distance, 2-D Gaussian model had smaller cross validation value for SOC (Table 1). Similar results were also observed for other soil properties.

➢ There was a large variation in total SOC content along the coastline, ranging from 2.6 to 187.4 kg C m^{-2} with the greatest value observed in the middle and the lowest value observed in the northeastern section (Fig. 2). The mean of total SOC was 41.67 kg C m^{-2}. The estimated SOC along the coastline was 6.86 * 10^7 kg C m^{-1}. The C:N ratio of soil organic matter had a similar pattern as SOC with higher value in the western portion of the coastline (Fig. 3).

➢The empirical variogram showed a large nugget effect for SOC, which accounts for 62 % of the partial sill (Table 2).

➢ In an early study Jorgenson and Brown (2005) found annual SOC input was higher in western portion than in eastern portion during coastal erosion along the Beaufort Sea coast (Fig. 4). This study estimated the potential annual loss of SOC being 1.5 * 10^5 Mg C yr^{-1} for land coastline of northern Alaska.

➢ In contrast to SOC, active layer had different spatial pattern with the depth increasing from the East to West (15 cm to 50 cm) (Fig. 5).

➢ Figure 6 demonstrated the spatial variation of total sampling depth. Compared to the active layer, more variations were observed for total sampling depth, indicating spatial variations in upper permafrost depth or the depth of exposed soil profiles.

➢ Stable C isotope had heavier C values in the western portion of the coastline than in other portions (Fig. 7). The range of δ^{13}C was from -29.7‰ to -23.4‰. Stable N isotope showed a more variable pattern along the coastline with the lighter values in the central-western coastline, ranging from -4.78‰ to 7.96‰.

Conclusions

Our study was among the first to investigate the spatial variations of SOC and other soil properties along the coastline of northern Alaska in such intensity. Gaussian model showed the spatial variation of SOC and other soil properties along the 1800-km coastal line better than other geostatistical models. SOC content had a large variation ranging from 2.6 to 187.4 kg C m^{-2} with an average of 41.67 kg C m^{-2}. The estimated annual SOC erosion was 1.5 * 10^5 Mg C yr^{-1}. Both active and upper permafrost layers showed spatial variation, but greater variation was associated with the latter. Stable C isotope ranged from -29.7 ‰ to -23.4 ‰ with heavier δ^{13}C value in the western portion. Greater variation was observed for stable N isotope composition.