Peatland Organic Matter Chemistry Trends Over a Global Latitudinal Gradient

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Why is this important?

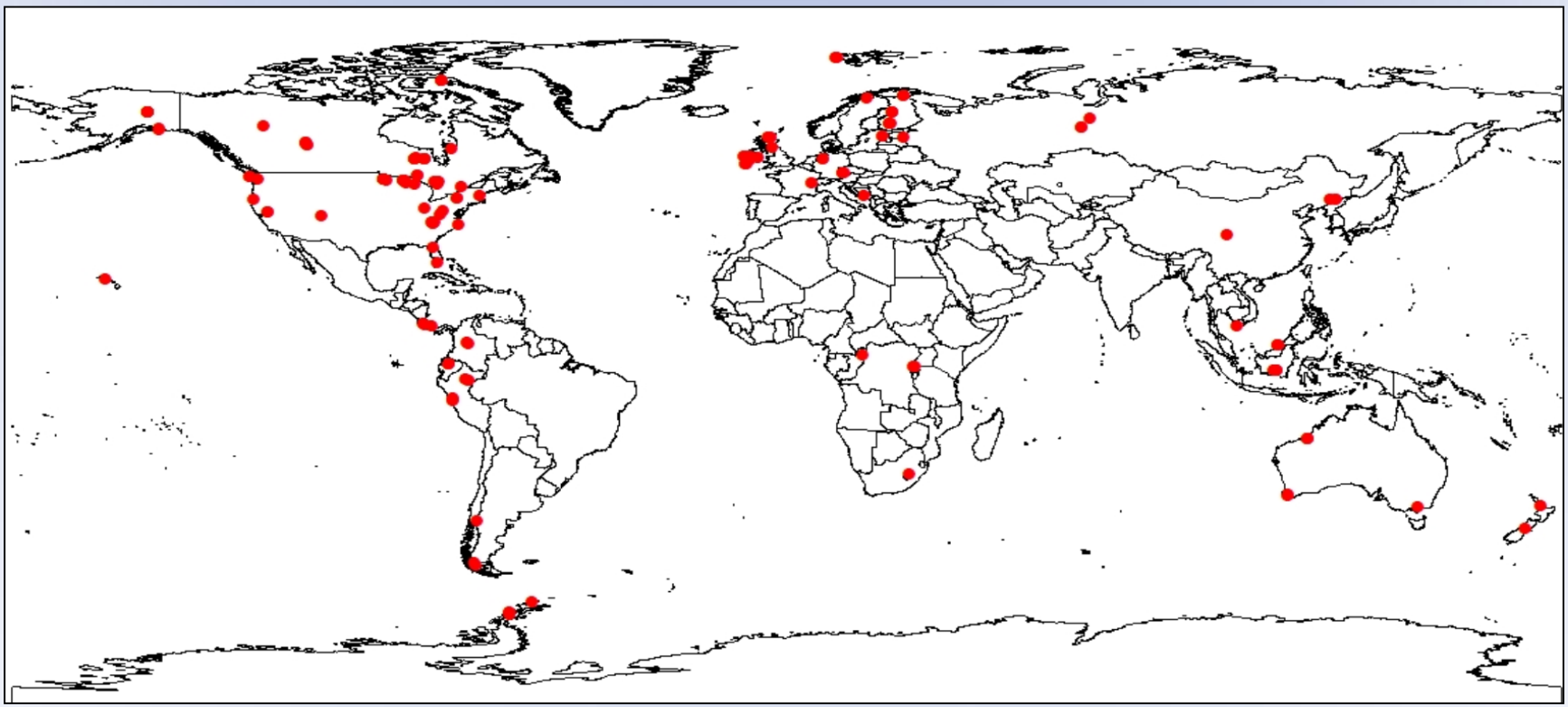
-Northern peatlands are estimated to contain about one-third of the total global soil carbon (455-621 Pg) while only occupying about 3% of the terrestrial global surface

- Tropical peatlands have only recently been included and add 65-92 Pg, or 15-19% of the global peat carbon pool (Yu et al., 2010; Page et al., 2011)

-Stability of these peatlands with a warming climate is uncertain, peat reactivity and state of decomposition needs to be evaluated to determine potential emissions

-Why is there peat at low latitudes?

Global Peatland Microbiome Project



- ~ 2000 samples from peat cores
  (10 cm depth intervals down to 70 cm)
- 175 sites, 7 continents, 70 collaborators

GPMP Peat Biogeochemistry Analyses

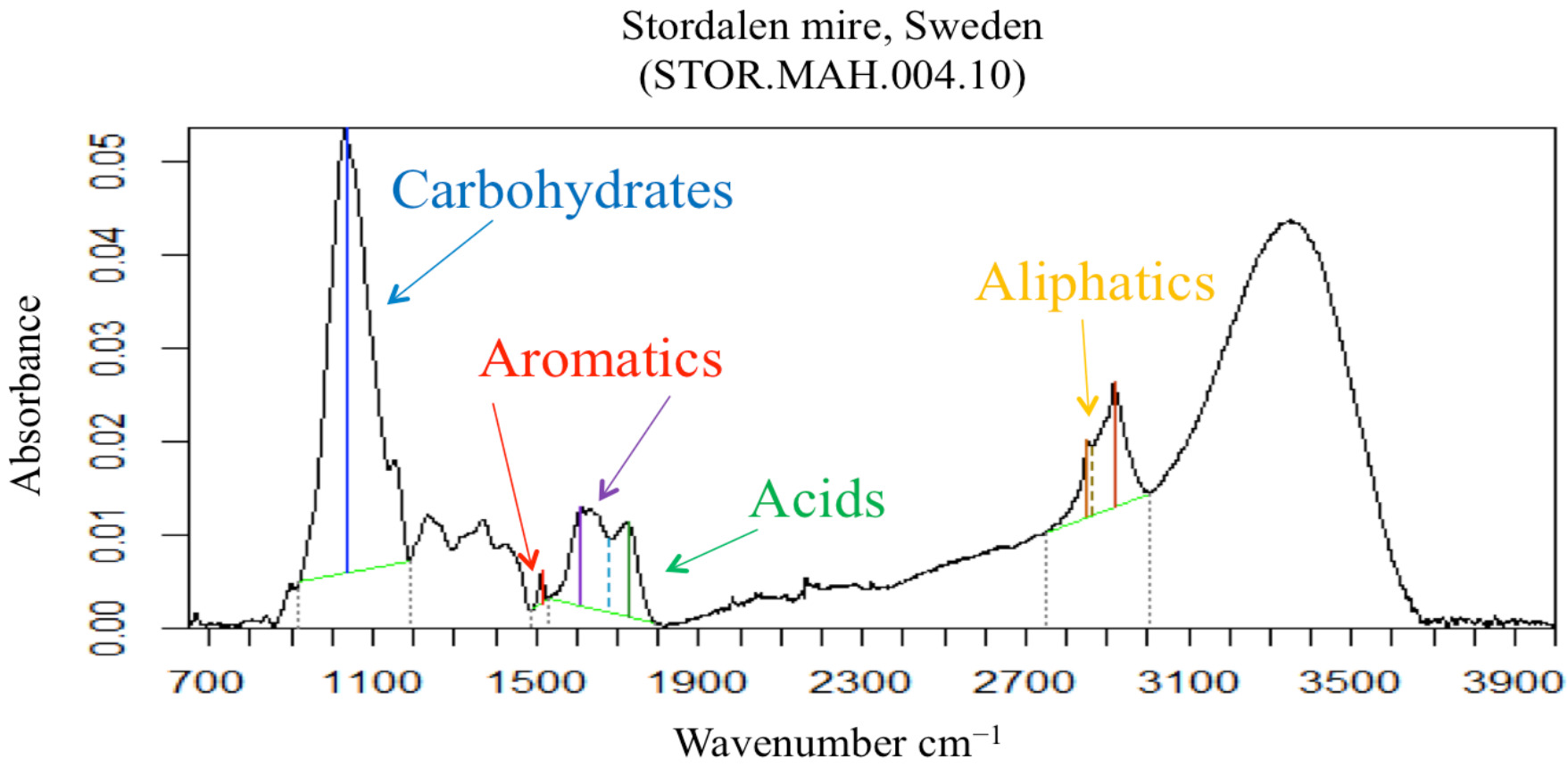
-DNA extracted and sequenced

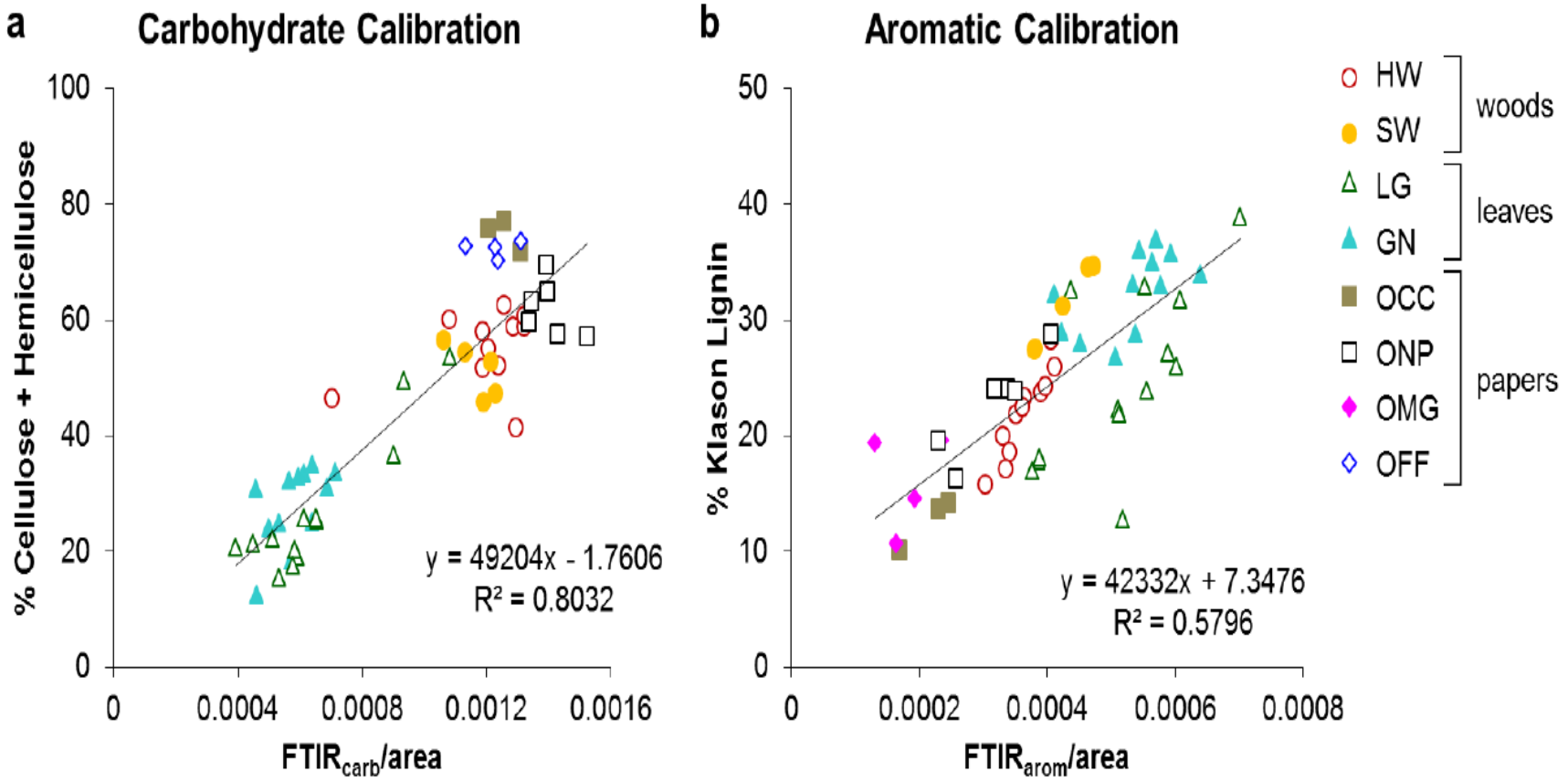
-Elemental composition including total C, N, S

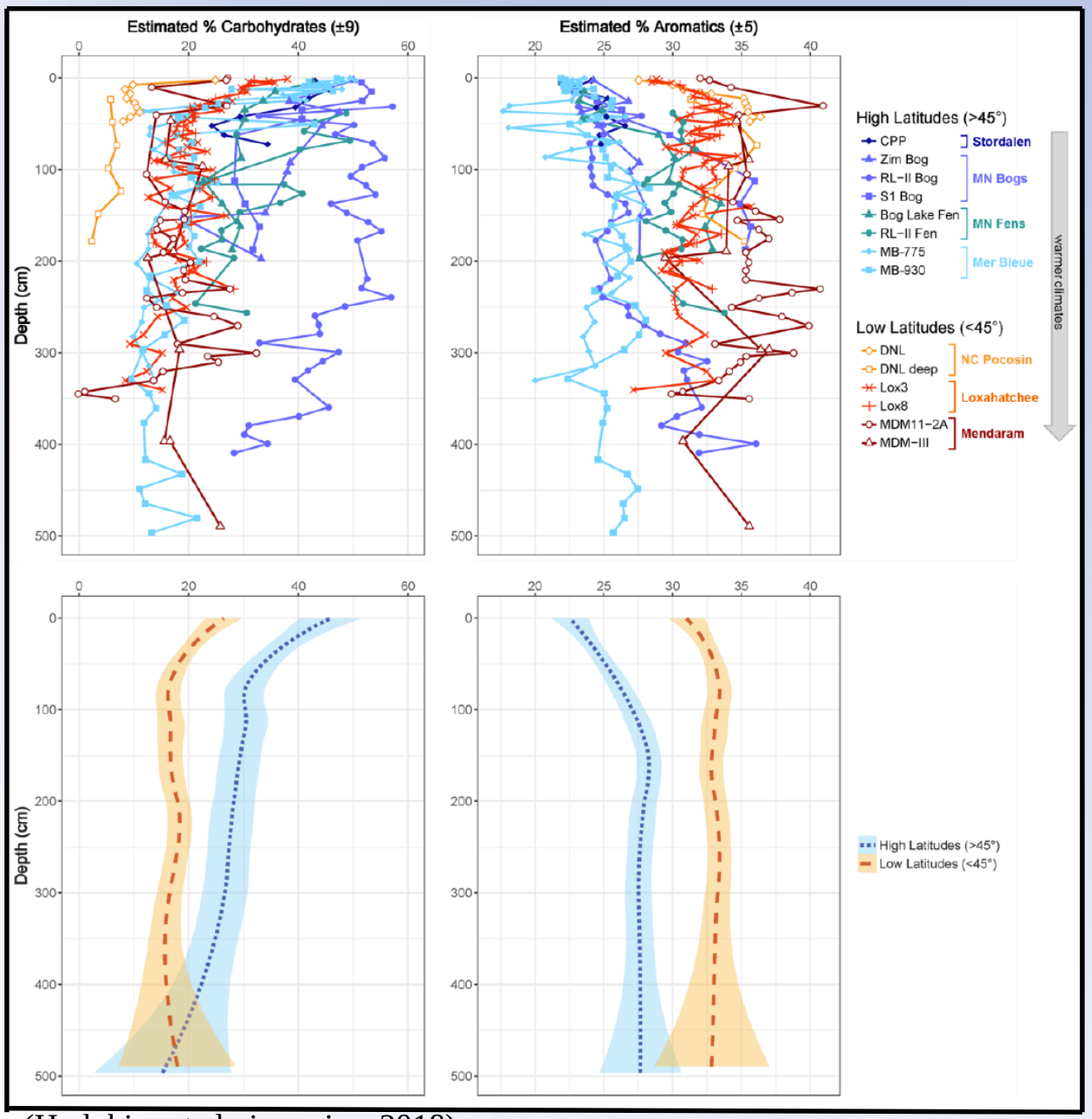
-DOC through extraction

-Porewater methane isotopes, ^{14}C dating, and ^{13}C NMR

Chemical composition of peat as defined by Fourier transform infrared spectroscopy (FTIR) organic matter functional groups


Stordalen mire, Sweden
(STOR.MAH.004.10)
Carbohydrates
Aromatics
Acids
Aliphatics
Absorbance
0.00
0.01
0.02
0.03
0.04
0.05
700
1100
1500
1900
2300
2700
3100
3500
3900
Wavenumber cm⁻¹


a
Carbohydrate Calibration
% Cellulose + Hemicellulose
100
80
60
40
20
0
0
0.0004
0.0008
0.0012
0.0016
FTIR$_{carb}$/area
y = 49204x - 1.7606
R² = 0.8032
b
Aromatic Calibration
% Klason Lignin
50
40
30
20
10
0
0
0.0002
0.0004
0.0006
0.0008
FTIR$_{arom}$/area
y = 42332x + 7.3476
R² = 0.5796
HW
SW
LG
GN
OCC
ONP
OMG
OFF
woods
leaves
papers



(Hodgkins et al., in review 2018)

Previous Work

- 6 locations

- Latitudes 4N-68N

- Hypothesized that peat would show higher recalcitrance (greater relative abundance of aromatics to carbohydrates) at lower latitudes

GPMP Peat Samples

- Sampling locations ranged from latitudes 79N to 65S

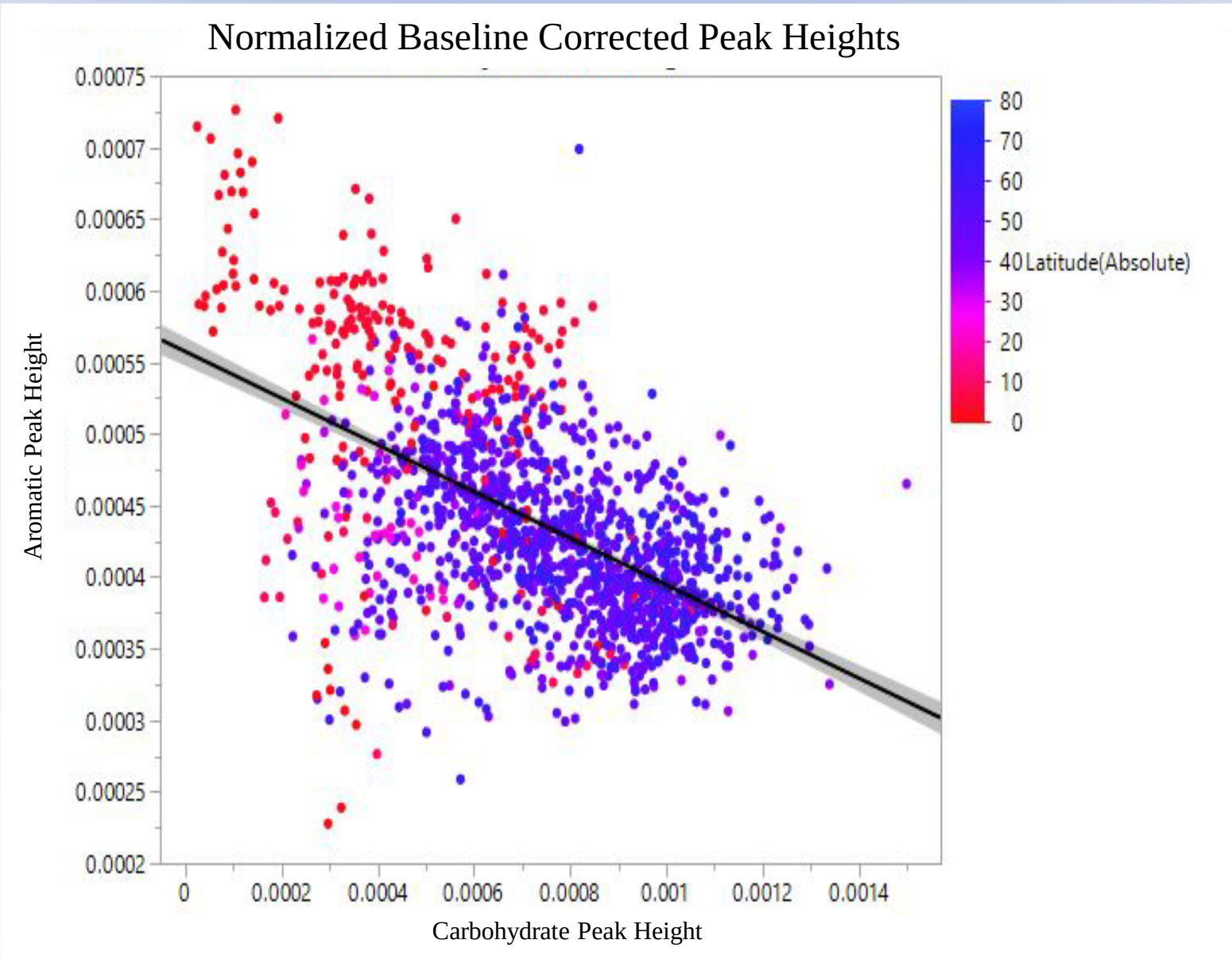
- Cores were taken to a depth of 70 cm

- Divided into subsamples of 10 cm intervals

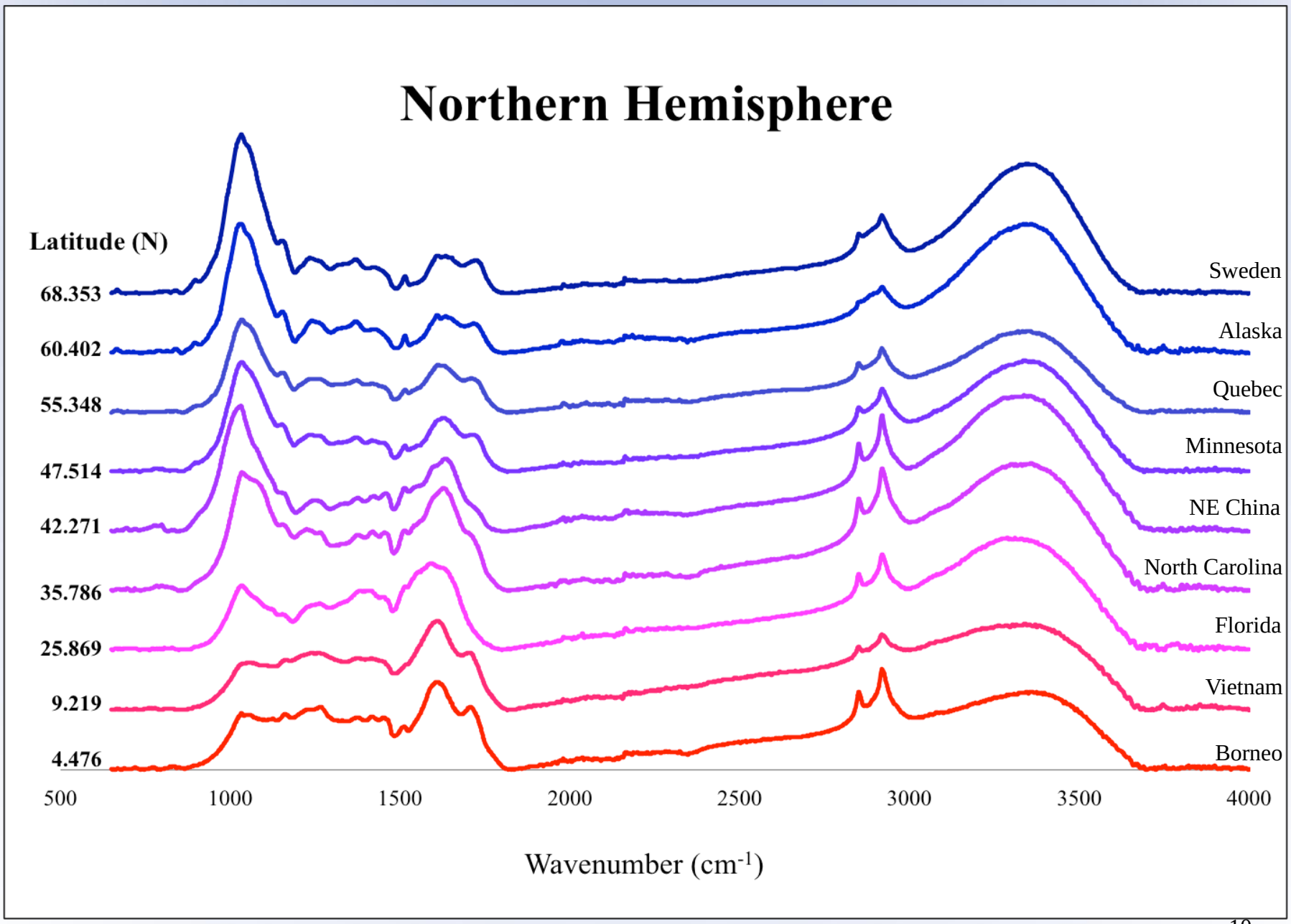
-Freeze dried or dried in an oven, ground

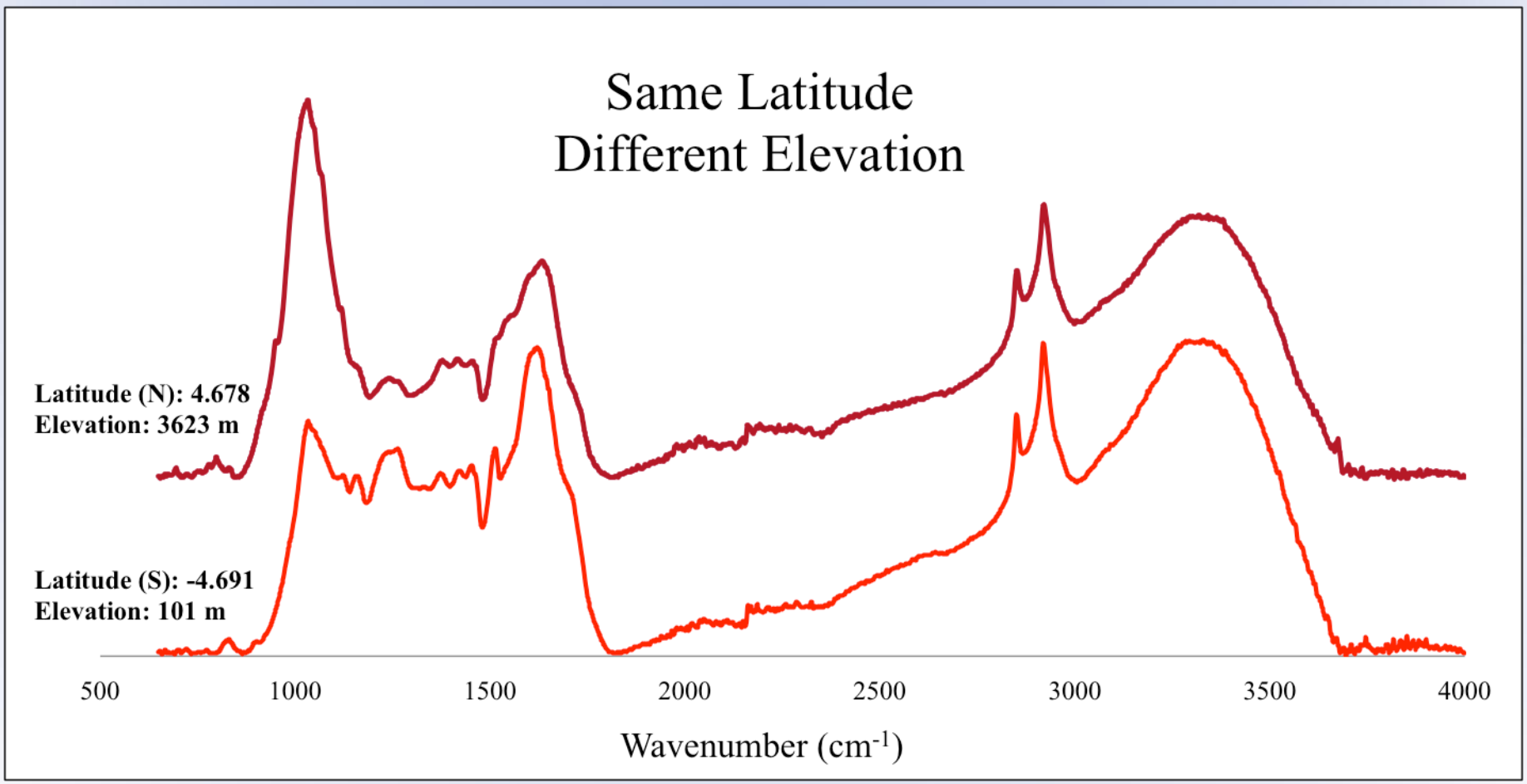
1394 samples were included in this analysis

Von Post data provided for 1284 of the 1394 samples

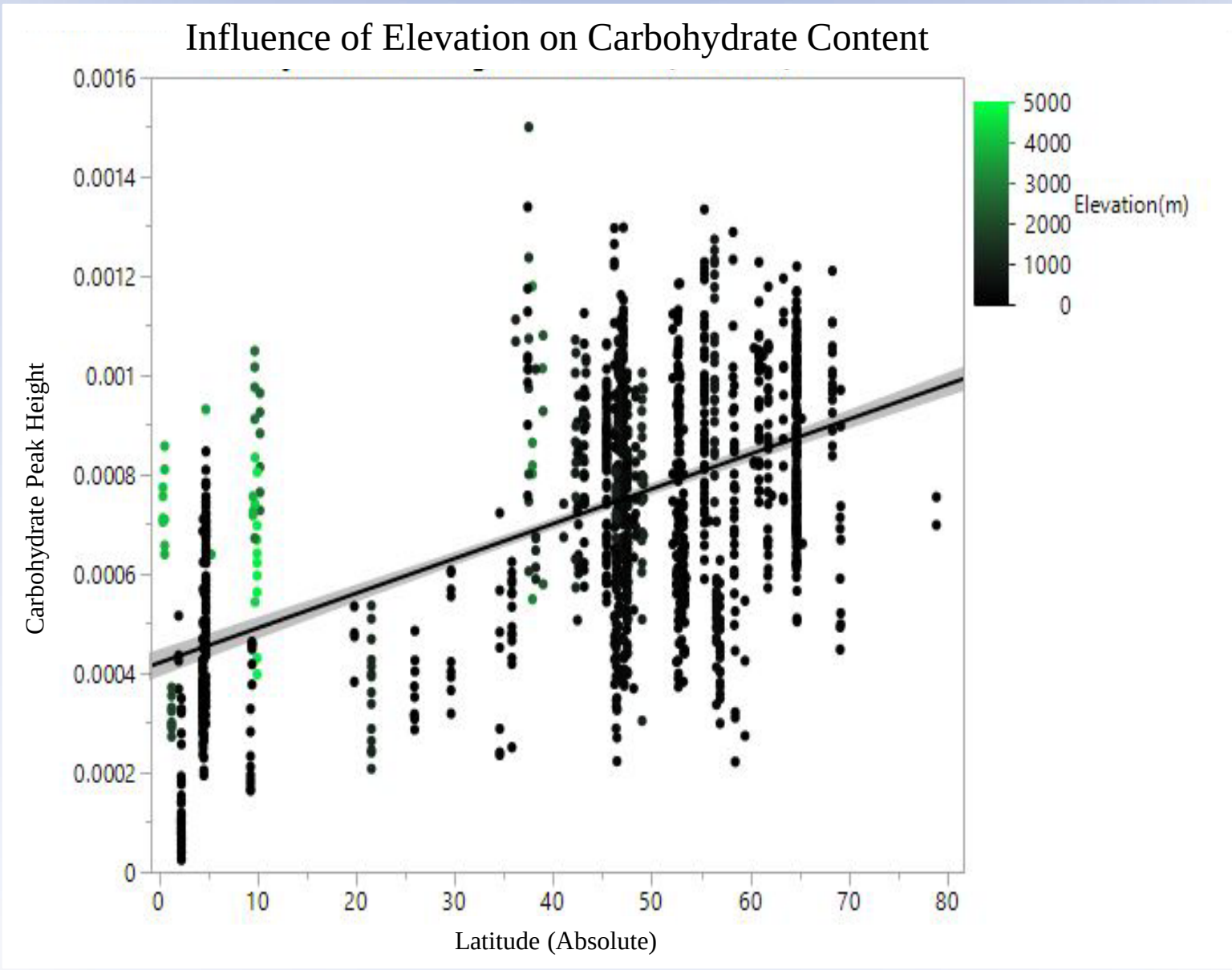


(n = 1394, r = 0.55, p < .0001)


Northern Hemisphere
Latitude (N)
68.353
60.402
55.348
47.514
42.271
35.786
25.869
9.219
4.476
Sweden
Alaska
Quebec
Minnesota
NE China
North Carolina
Florida
Vietnam
Borneo
500
1000
1500
2000
2500
3000
3500
4000
Wavenumber (cm-1)

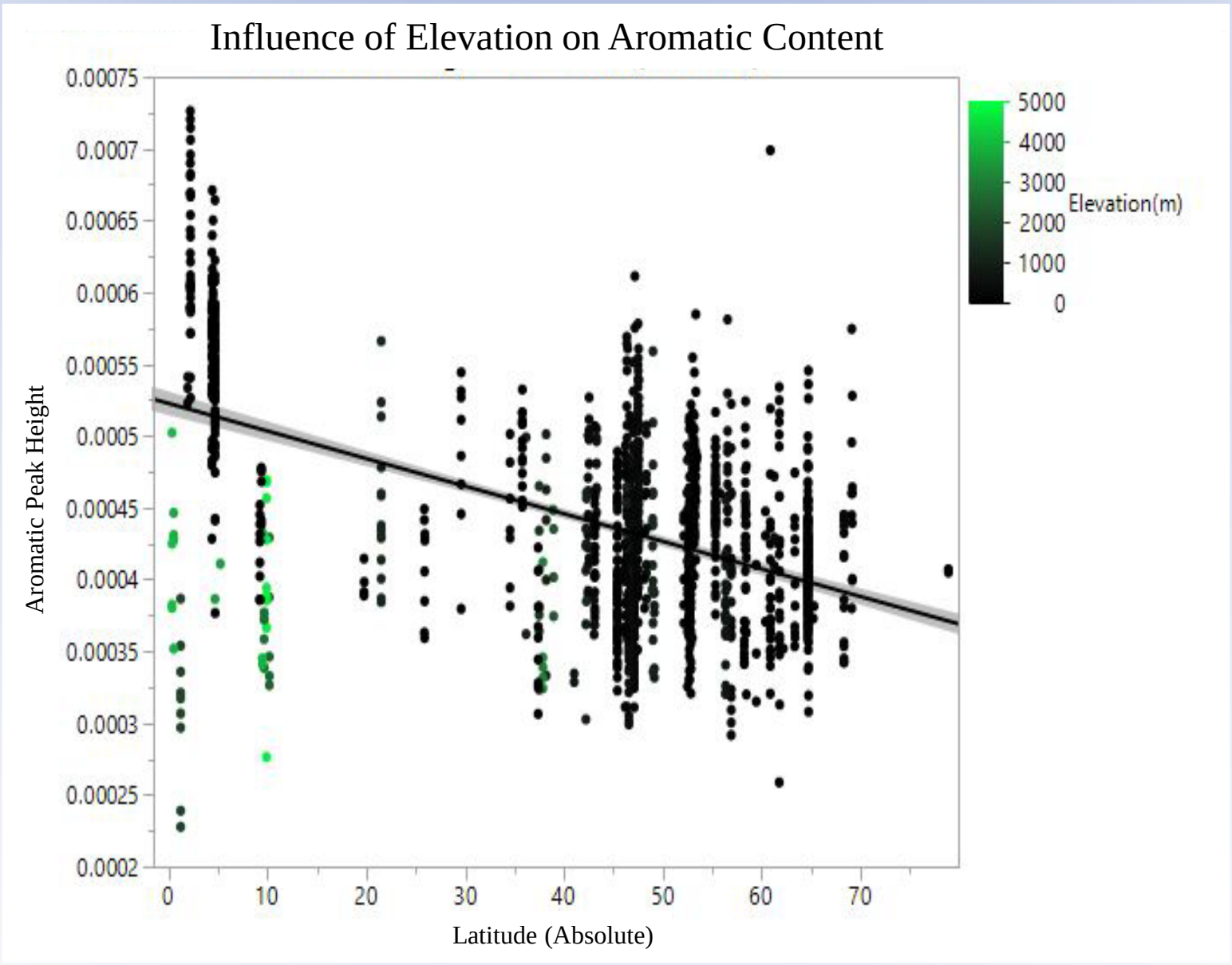


Latitude 4.691S and elevation 101 m is from the Peruvian Amazon, Peru, and latitude 4.678N and elevation 3623 m is from the Andes Mountains, Colombia



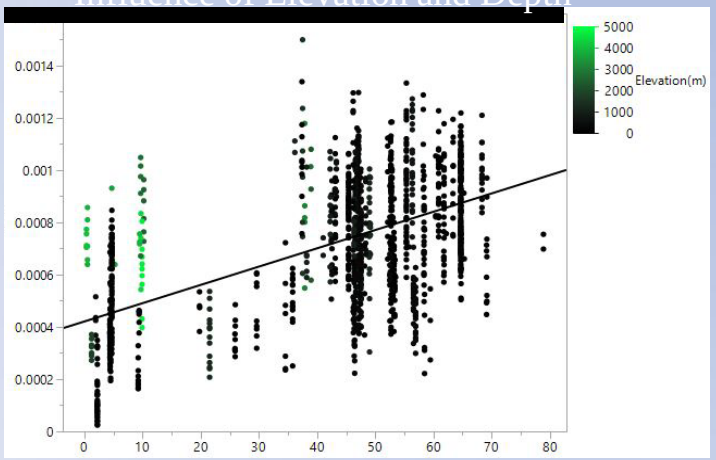
(n = 1394, r = 0.54, p < .0001)

Influence of Elevation on Aromatic Content

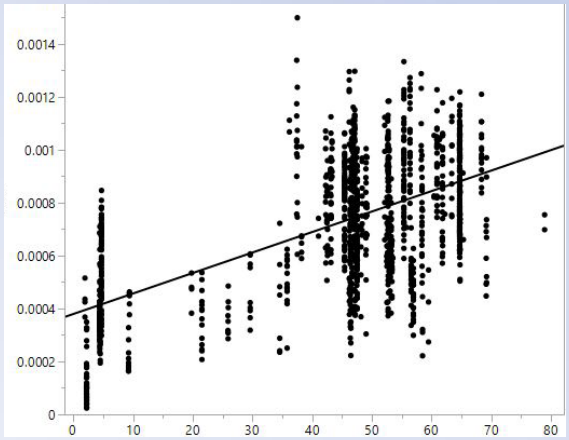


(n = 1394, r = 0.54, p < .0001)

Influence of Elevation and Depth

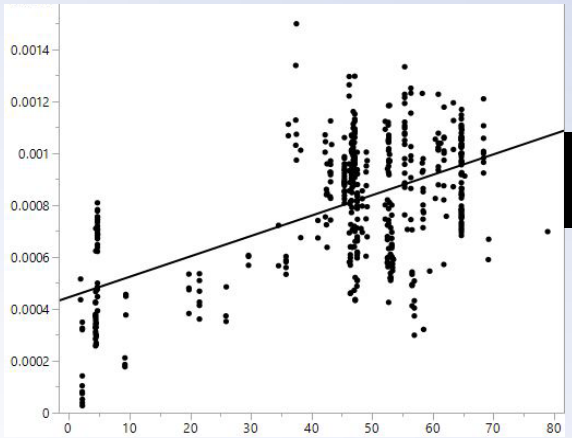


A) n=1394 r = 0.54



< 1900 m

B) n =1339 r = 0.57



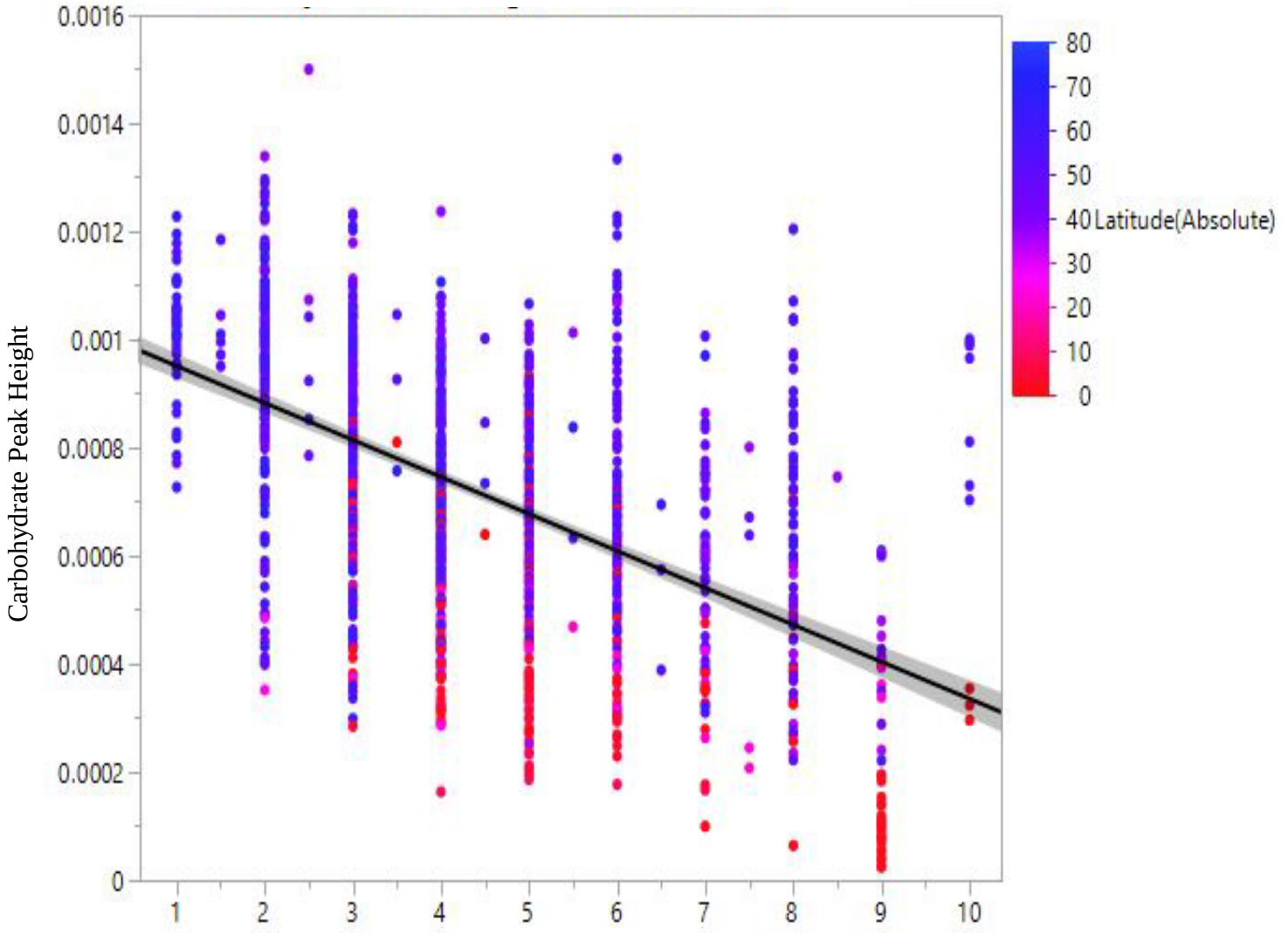
< 1900 m
< 10 cm

C) N = 512 r =0.58

Carbohydrate Peak Height

Latitude (Absolute)

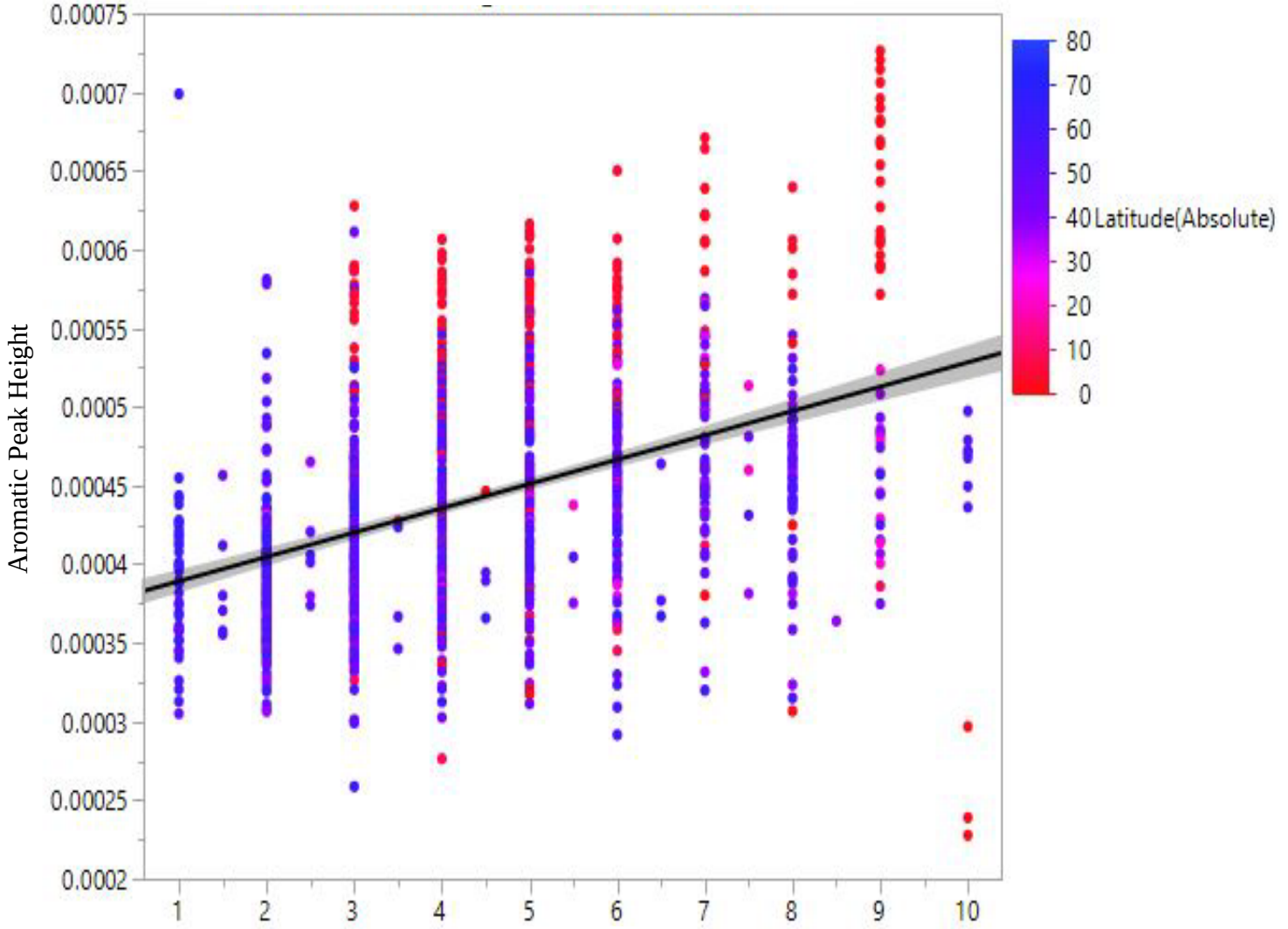
Carbohydrate Content and Humification



(n = 1284, r = 0.54, p < .0001)

Increasingly Decomposed

Aromatic Content and Humification



(n = 1284, r = 0.42, p < .0001)

Increasingly Decomposed

Data Consistent With Hypotheses

1) Carbohydrate relative abundances decreased on a latitudinal gradient from the poles towards the equator

1) Aromatic relative abundances increased

1) Higher elevation peat from lower latitudes had greater relative abundances of carbohydrates and lower relative abundances of aromatics than lower elevation peat from similar latitudes

Carbon Quality

Peat with relatively higher carbohydrate content and lower aromatic content

Undecomposed and Labile = Reactive

Peat with relatively lower carbohydrate content and higher aromatic content

Decomposed and Recalcitrant = Stable

LOW CARB DIET for LOW LATITUDE MICROBES KEEPS THEM SLENDER

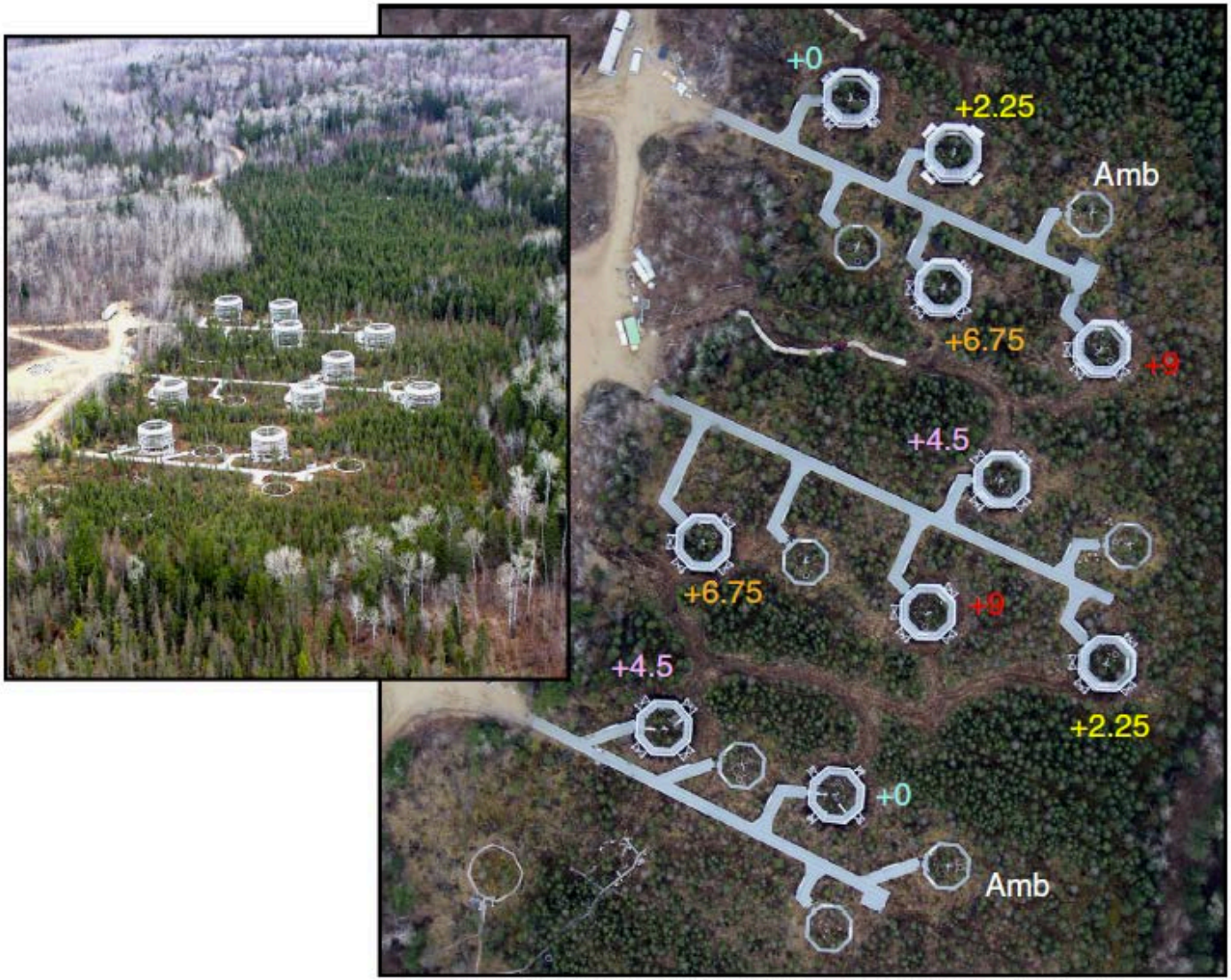
They are not fat happy microbes.

Global Warming

- Carbohydrates are first constituent of peat to be lost through decomposition processes while the aromatics would be left behind

- The positive feedback of greenhouse gas emissions from peat decomposition on the climate might not occur to the extent that would be predicted without factoring in heightened recalcitrance

Significance to a Warming Climate

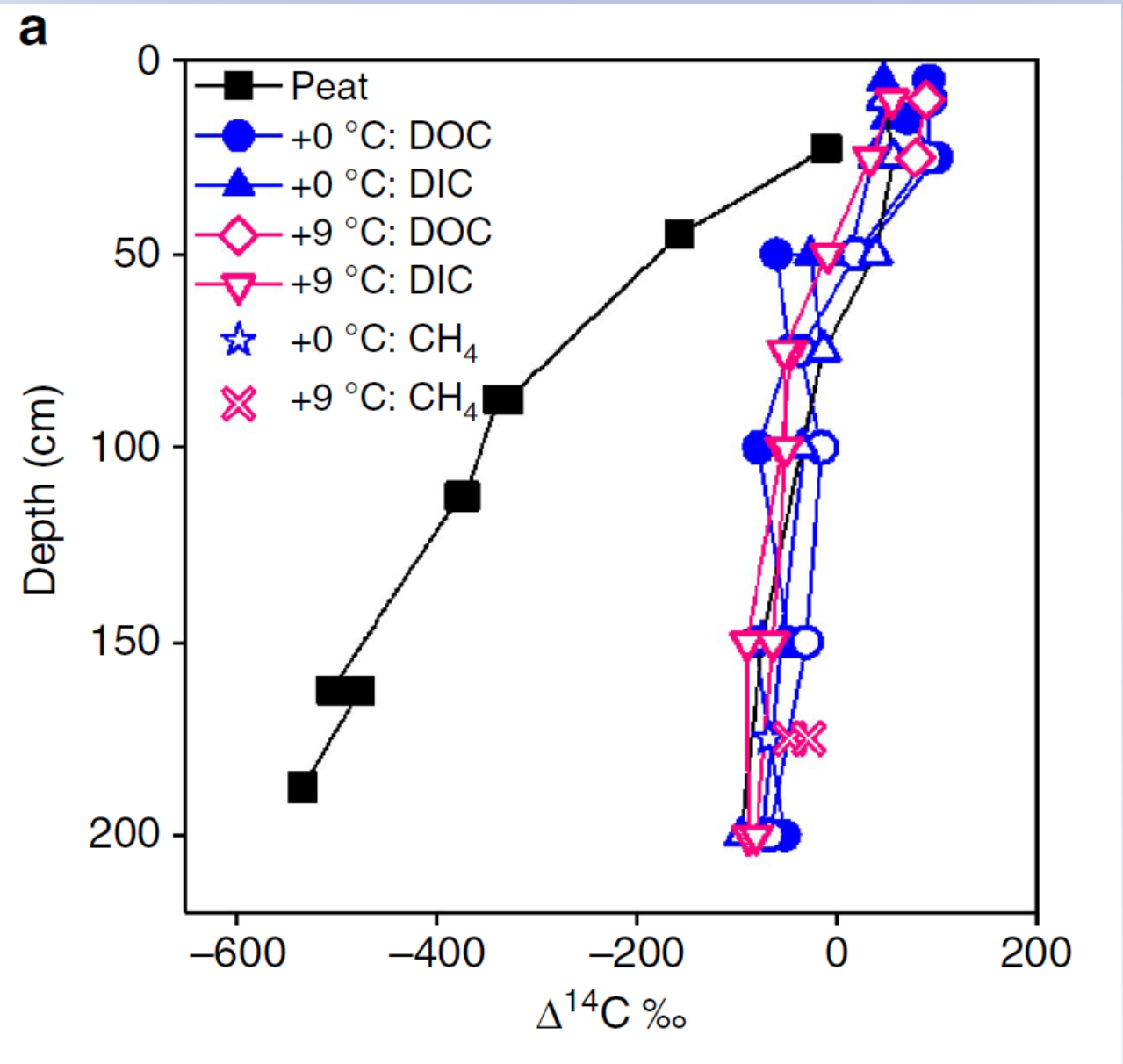


- Higher concentration of labile organic matter in surface peat

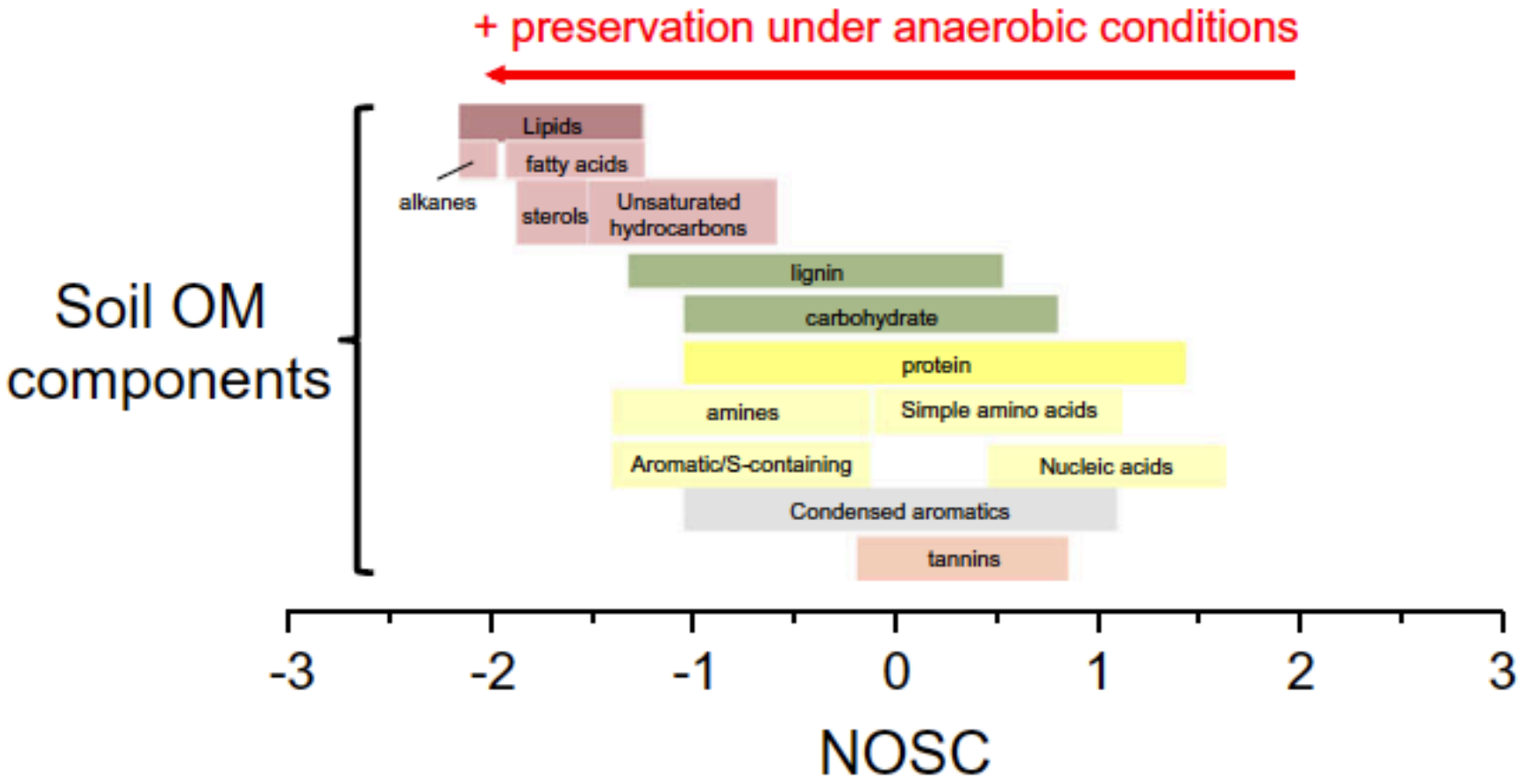
- SPRUCE plots show no increased reactivity at depth with warmer temperatures

- Likely that only surface peat will be affected

SPRUCE, Minnesota (Wilson et al., 2016)


a
Peat
+0 °C: DOC
+0 °C: DIC
+9 °C: DOC
+9 °C: DIC
+0 °C: CH4
+9 °C: CH4
Depth (cm)
0
50
100
150
200
–600
–400
–200
0
200
Δ14C ‰

Different biological and chemical availabilities distinguish mechanisms of decomposition and transformation (Tfaily et al., 2014)

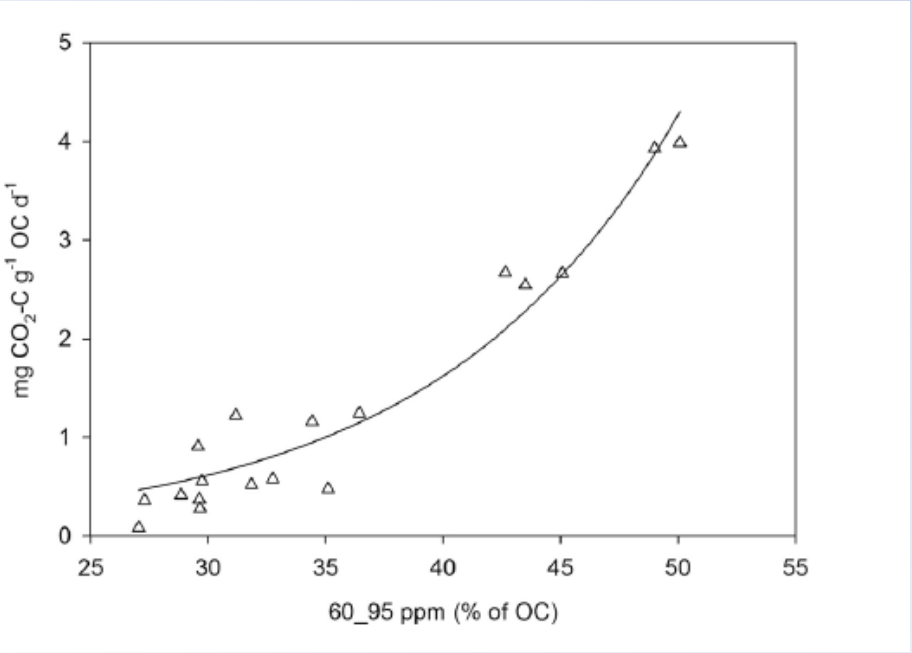


(Keiluweit et al., 2015)

Decomposition Proxy – solid-state ^{13}C NMR

Baldock et al. (1997) showed that the accumulation of aromatic carbon structures with decomposition was closely associated with a decrease in O-alkyl-C structures

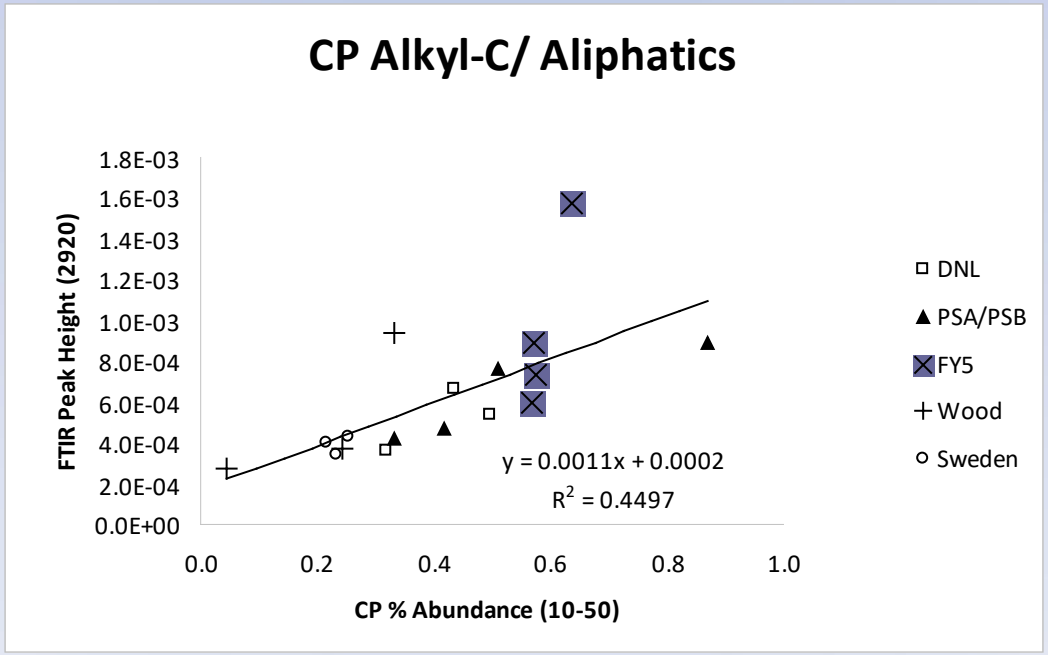
(Leifeld et al., 2012): O-alkyl-C abundances have been shown to be the best proxy for decomposition potential against other factors such as soil pH, depth, and C/N, O/C, H/C ratios



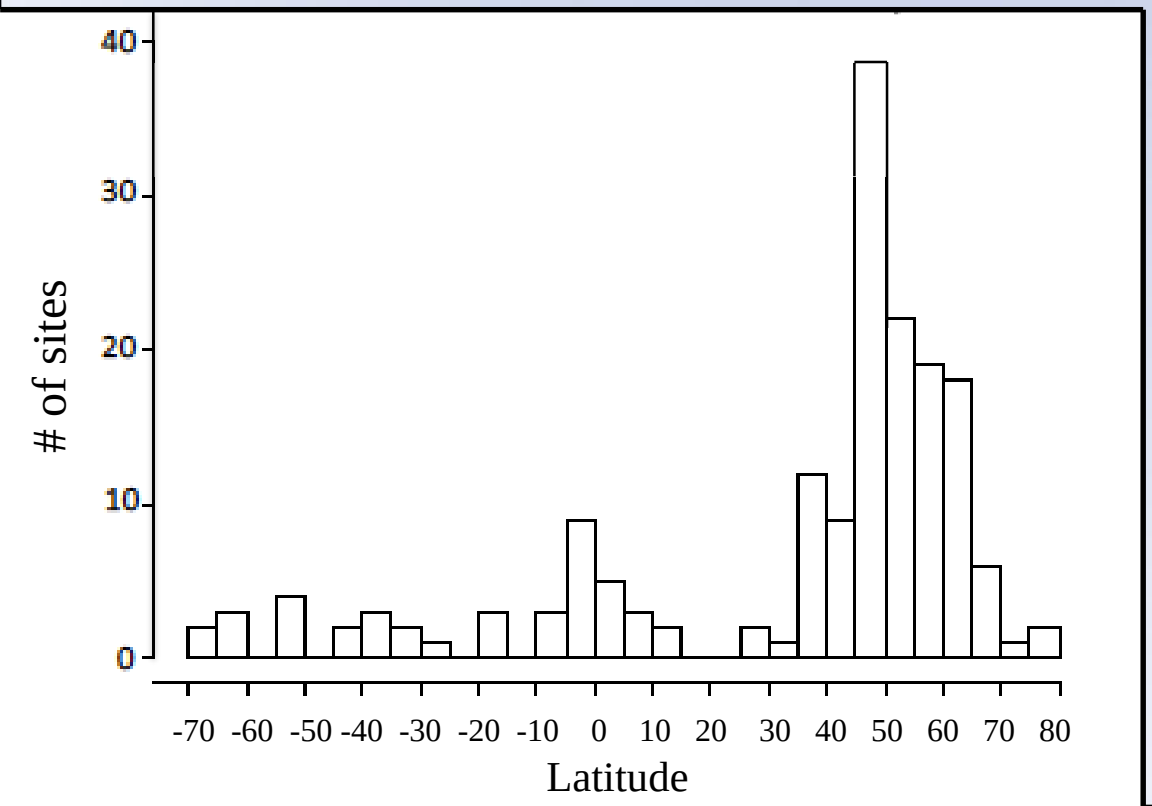
(Leifeld et al., 2012)

Carbohydrates = Labile

Aromatics = Recalcitrant


CP Alkyl-C/ Aliphatics
FTIR Peak Height (2920)
1.8E-03
1.6E-03
1.4E-03
1.2E-03
1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
0.0
0.2
0.4
0.6
0.8
1.0
CP % Abundance (10-50)
y = 0.0011x + 0.0002
R2 = 0.4497
DNL
PSA/PSB
FY5
Wood
Sweden

Goal of GPMP: Find and assess the geographic patterns in peatland biogeochemistry



- Majority of sites are boreal or subarctic because the greatest amount of peatlands fall within higher latitudes

Von Post Scale of Humification (Ekono, 1981)

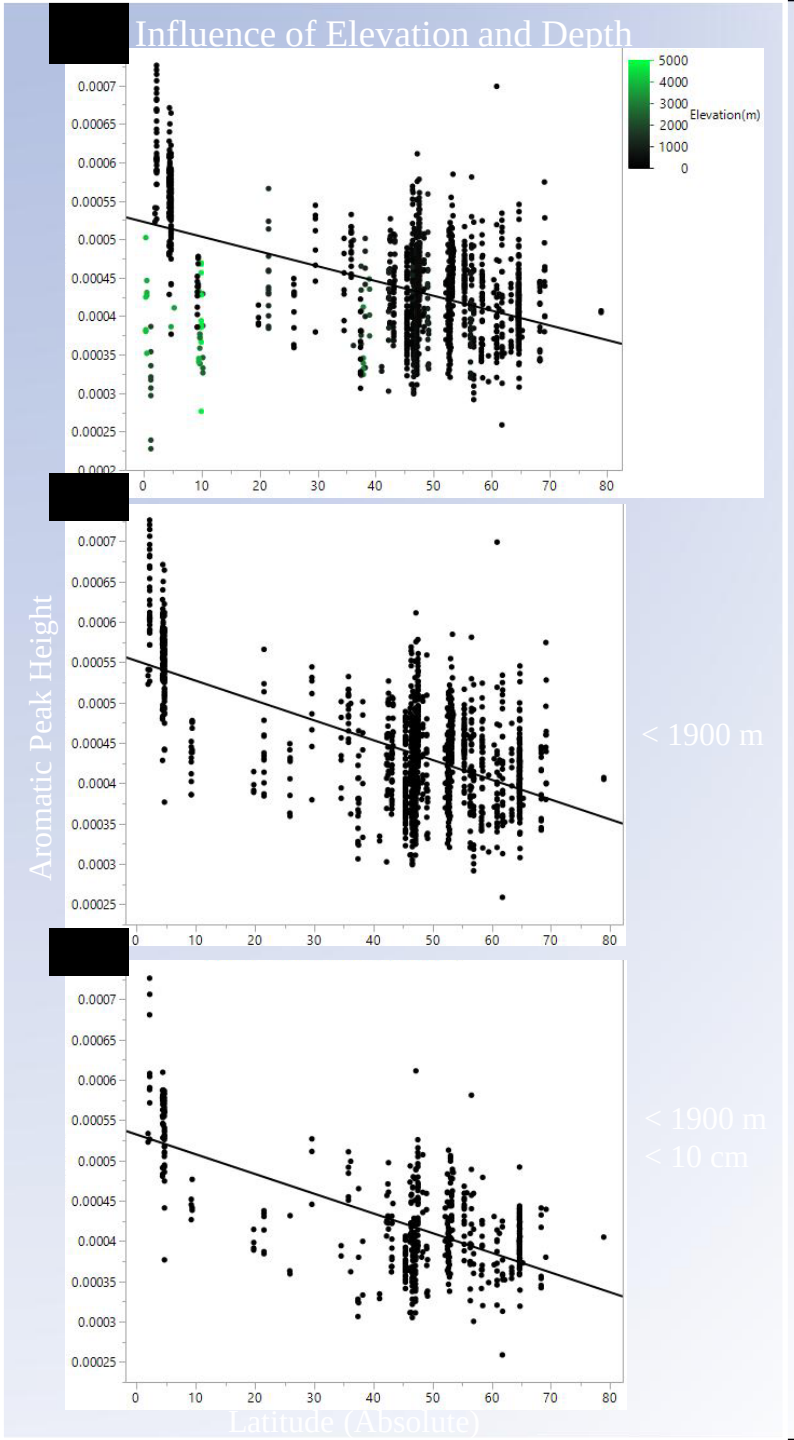
Increasingly Decomposed

Symbol	Description
1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remians easily identifiable. No amorphous material present.
2	Almost entirely undecomposed peat which, when squeezed releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.
3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but from which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present
4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features
5	Moderately decomposed peat which, when squeezed, releases very “muddy” water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty.
6	Moderately highly decomposed peat with a very indistict plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is very pasty but shows the plant structure more distinctly than before squeezing.
7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
8	Very highly decomposed peat with a large quantity of amorphous material and very indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed it is a fairly uniform paste.
10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

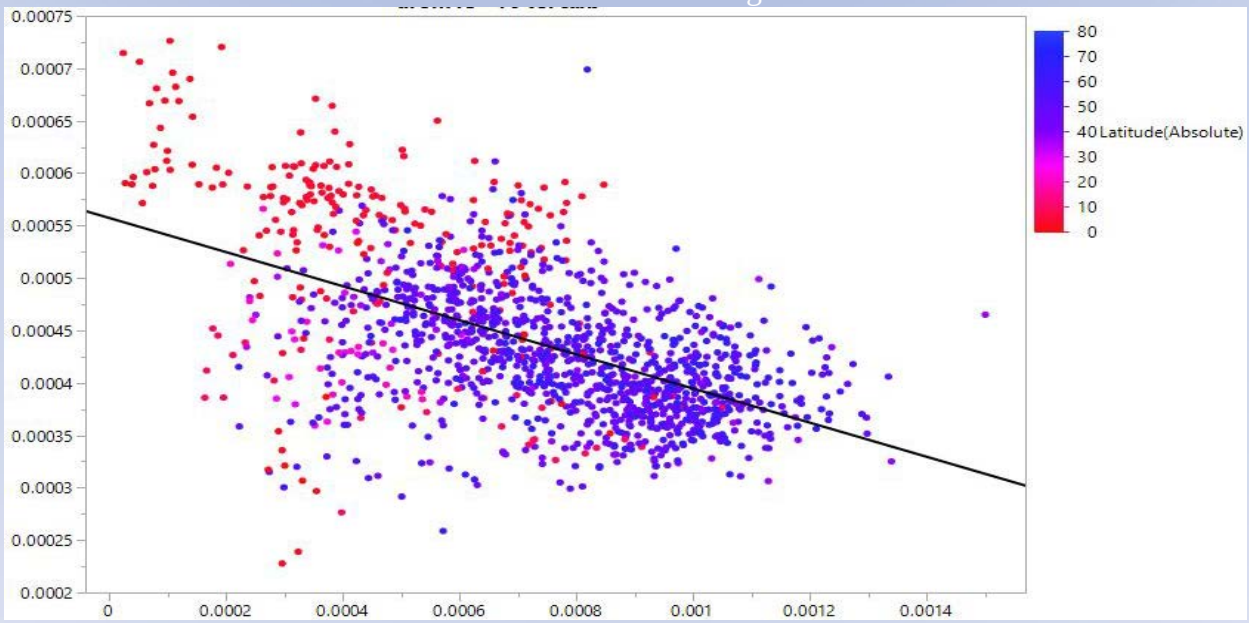
Arom A) n=1394 r2=0.253

B) n=1339 r2=0.381

C) n=512 r2=0.426

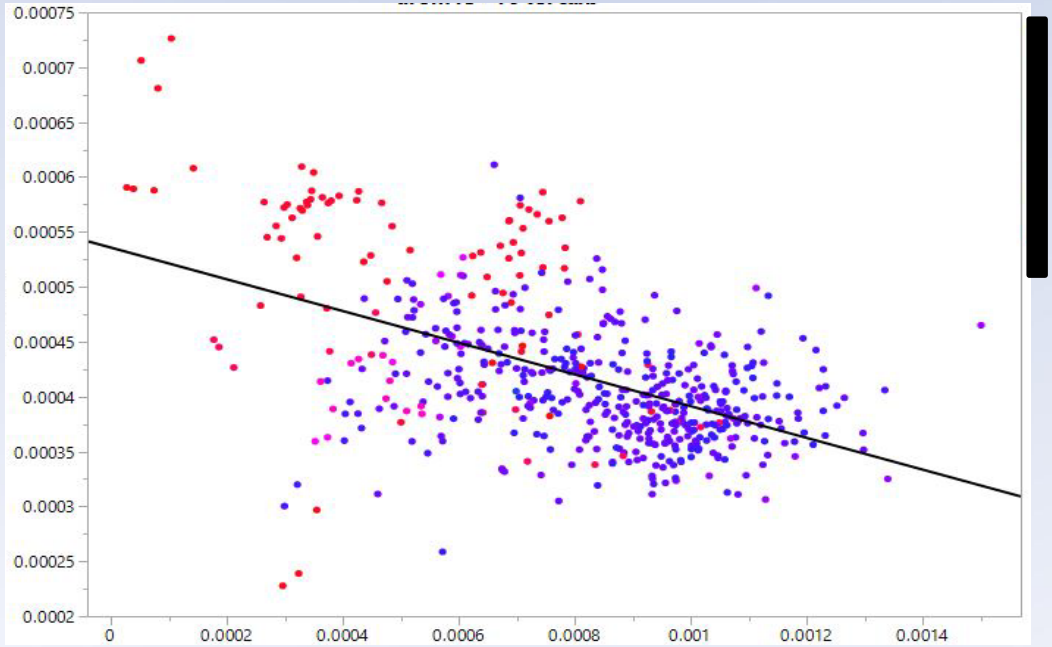


Normalized Baseline Corrected Peak Heights



n=1394
r^2=0.306

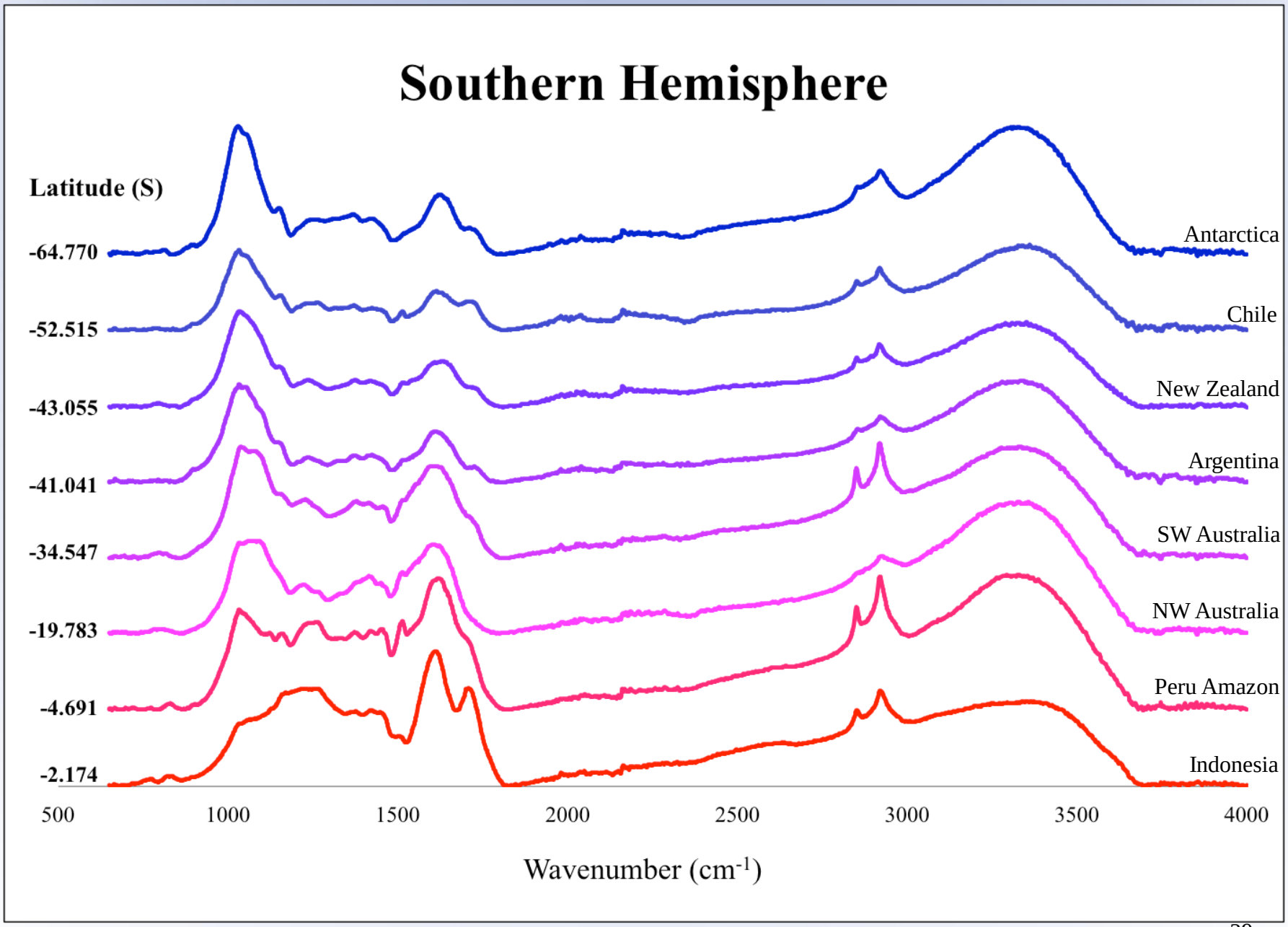
Aromatic Peak Height



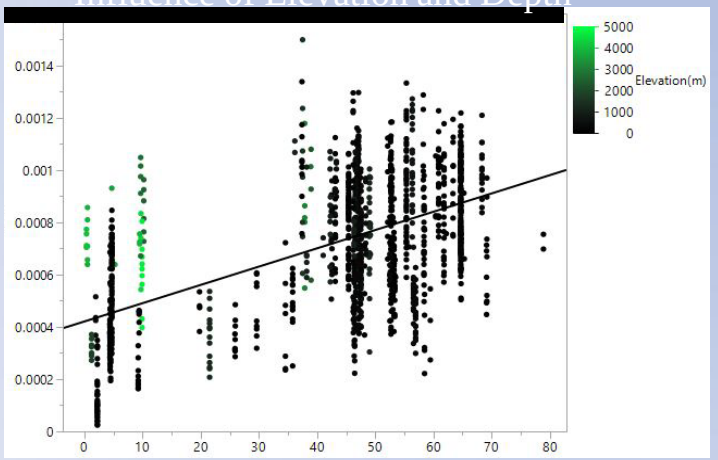
B) n=537 r^2=0.272

10 cm

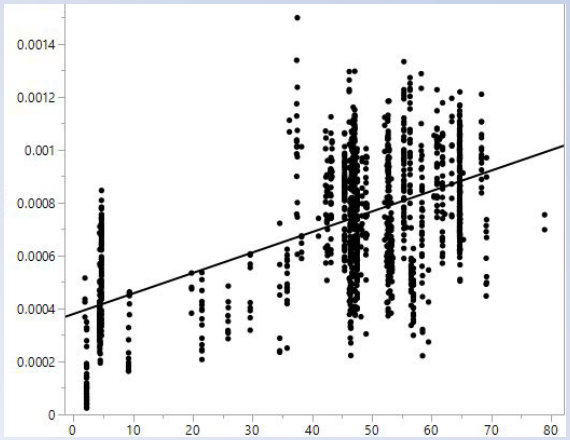
Carbohydrate Peak Height


Southern Hemisphere
Latitude (S)
-64.770
-52.515
-43.055
-41.041
-34.547
-19.783
-4.691
-2.174
Antarctica
Chile
New Zealand
Argentina
SW Australia
NW Australia
Peru Amazon
Indonesia
500
1000
1500
2000
2500
3000
3500
4000
Wavenumber (cm-1)

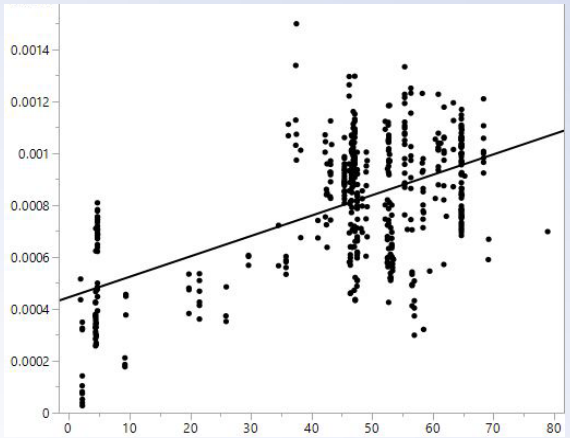
Influence of Elevation and Depth



Carbohydrate Peak Height



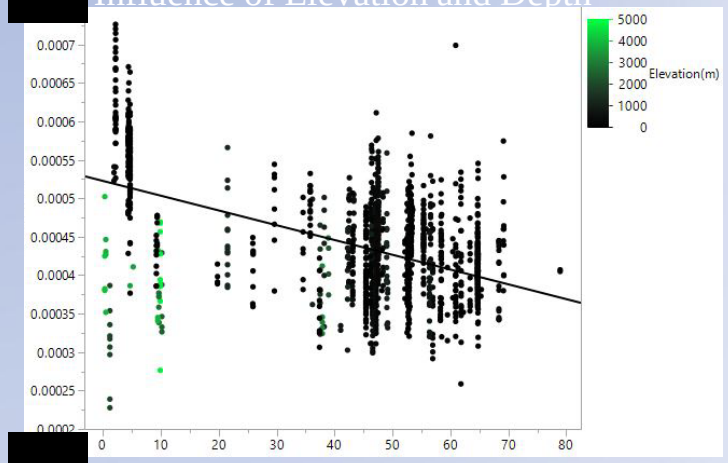
< 1900 m



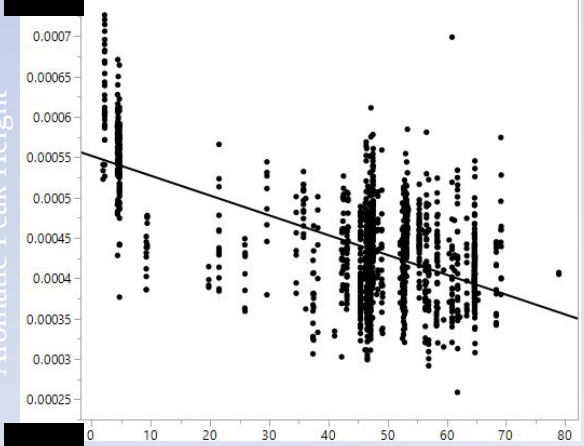
< 1900 m
< 10 cm

Latitude (Absolute)

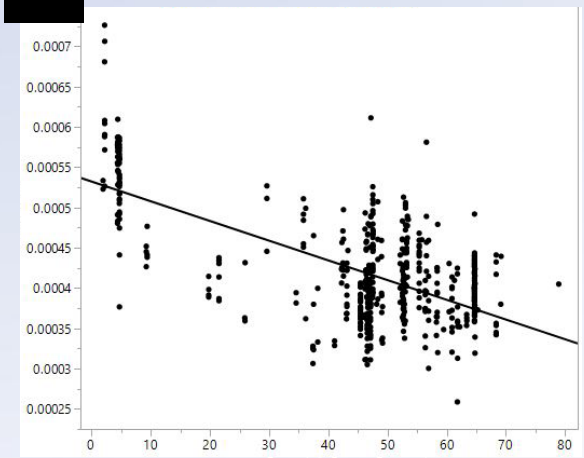
Influence of Elevation and Depth



Aromatic Peak Height

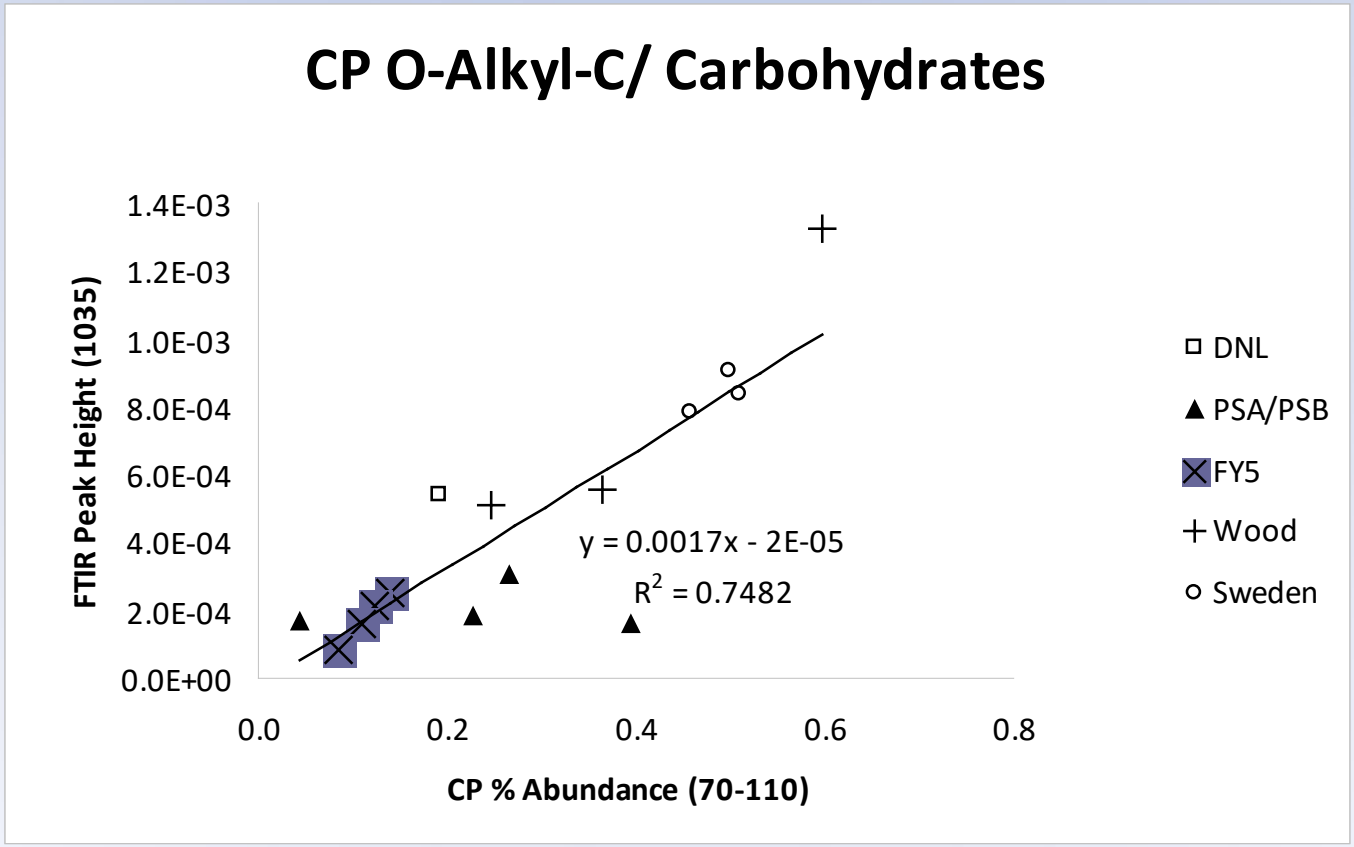


< 1900 m



< 1900 m
< 10 cm

Latitude (Absolute)


CP O-Alkyl-C/ Carbohydrates
FTIR Peak Height (1035)
1.4E-03
1.2E-03
1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
0.0
0.2
0.4
0.6
0.8
CP % Abundance (70-110)
y = 0.0017x - 2E-05
R2 = 0.7482
DNL
PSA/PSB
FY5
Wood
Sweden