Evidence of fresh phytoplankton growth and heating feedbacks during fall in the Pacific Arctic

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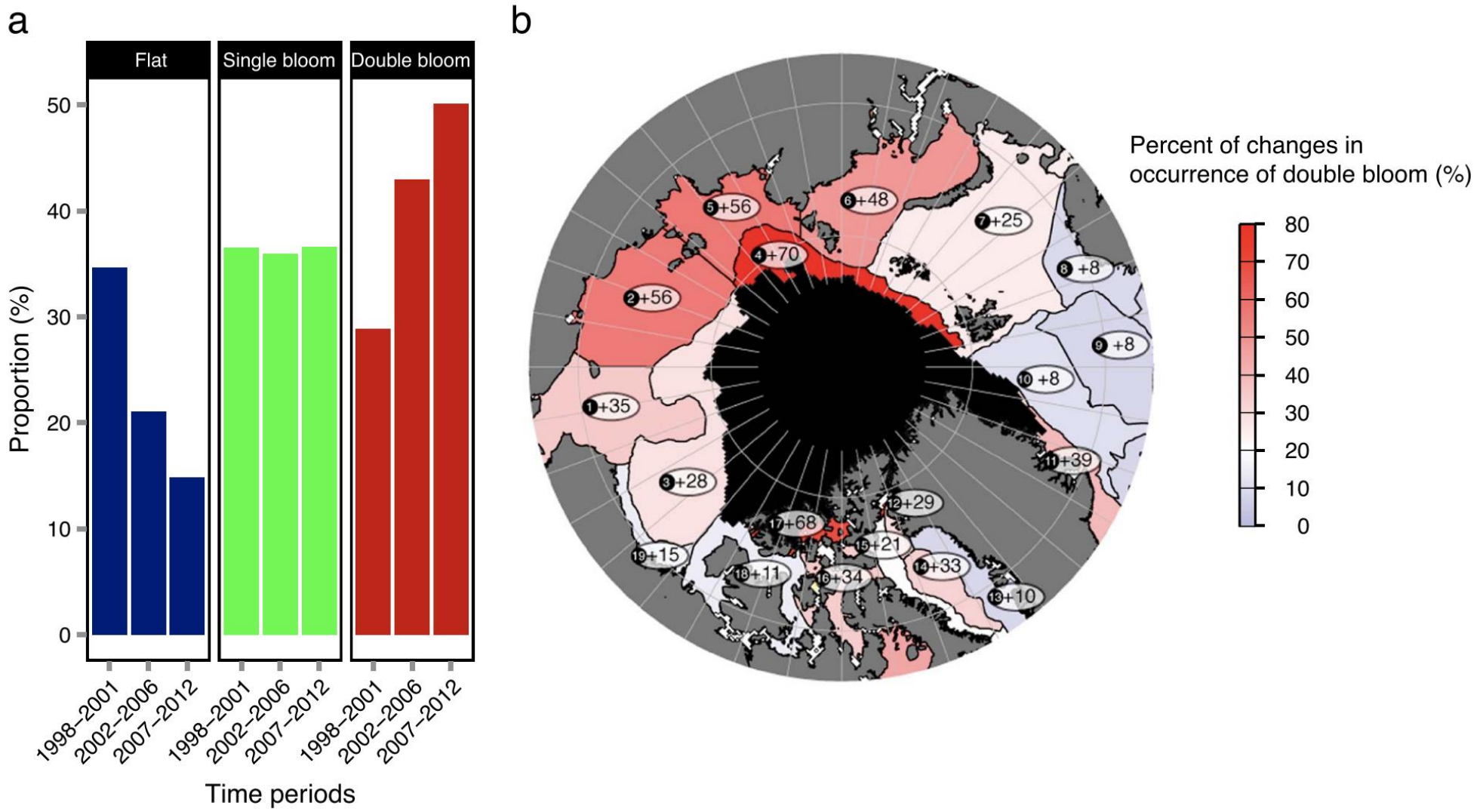
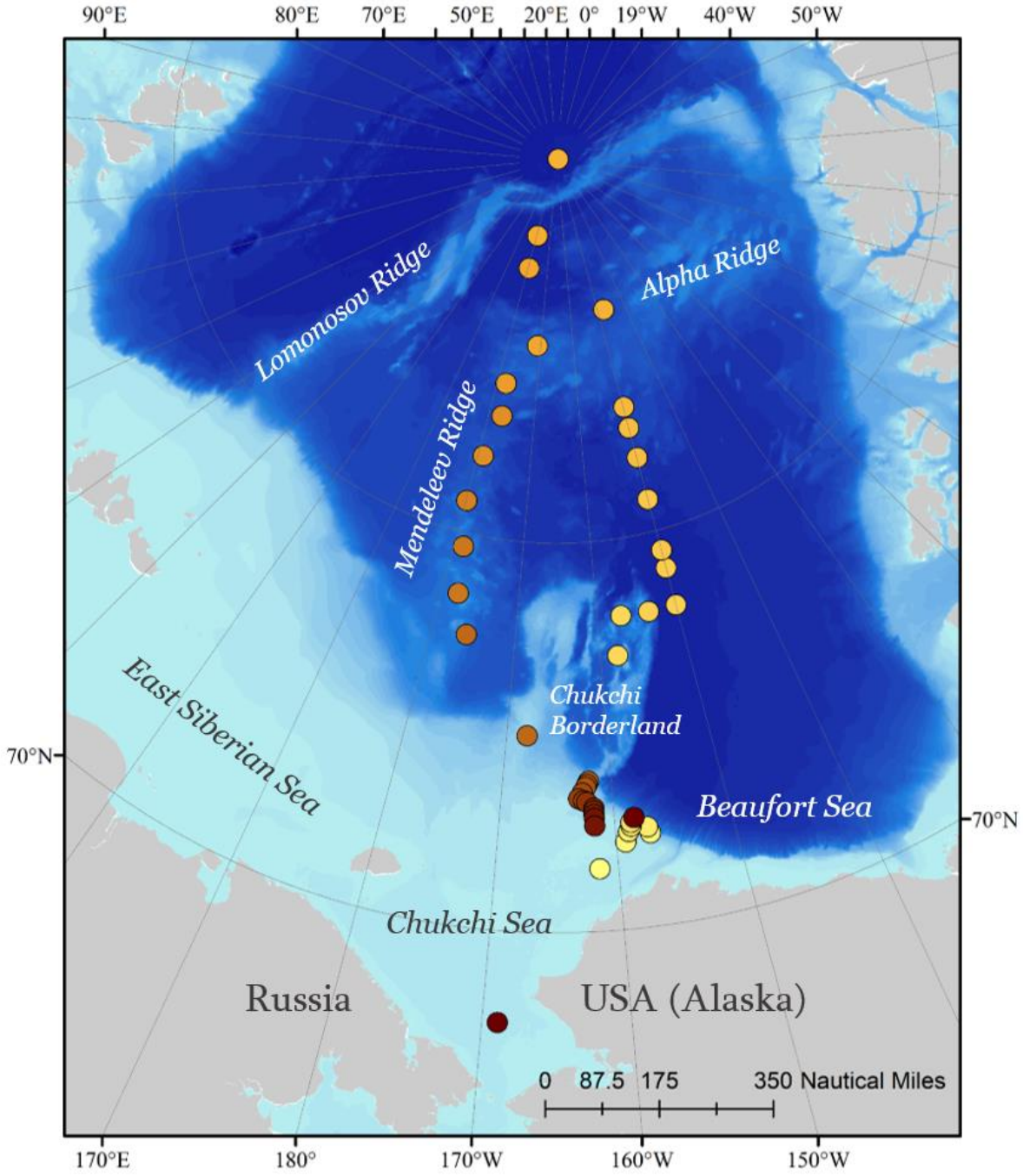


Current shifts in Arctic phytoplankton phenology above the Arctic Circle (>66.58°N). (a) Histogram of different types of annual cycles for three periods. (b) Map showing percent change in double bloom occurrence between two periods (1998–2001 versus 2007–2012) for each Arctic region.
The minimum September sea ice extent in 2012 is indicated in dark color.

Ardyna et al., 2014.



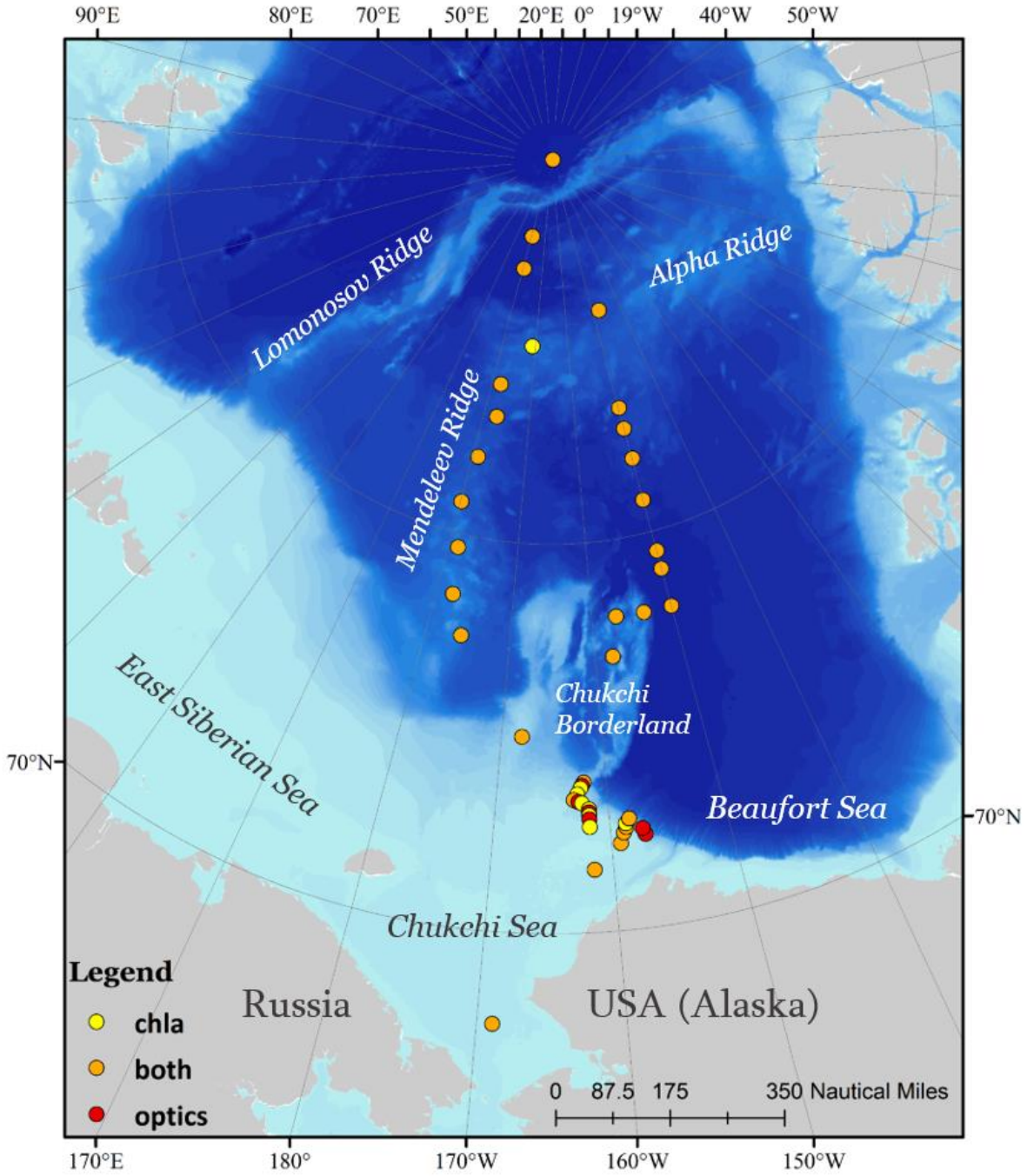
Synoptic Arctic Survey (SAS)

USCGC *Healy*

August-October 2022

Station #	Date	Latitude	Longitude	Apparent Sunrise	Apparent Sunset
0	9/9	71.59	-161.52	04:29	18:54
21	9/30	89.96	-43.02	----	----
49	10/20	72.82	-158.31	07:32	15:02

: Deborah Cordone



Synoptic Arctic Survey (SAS)

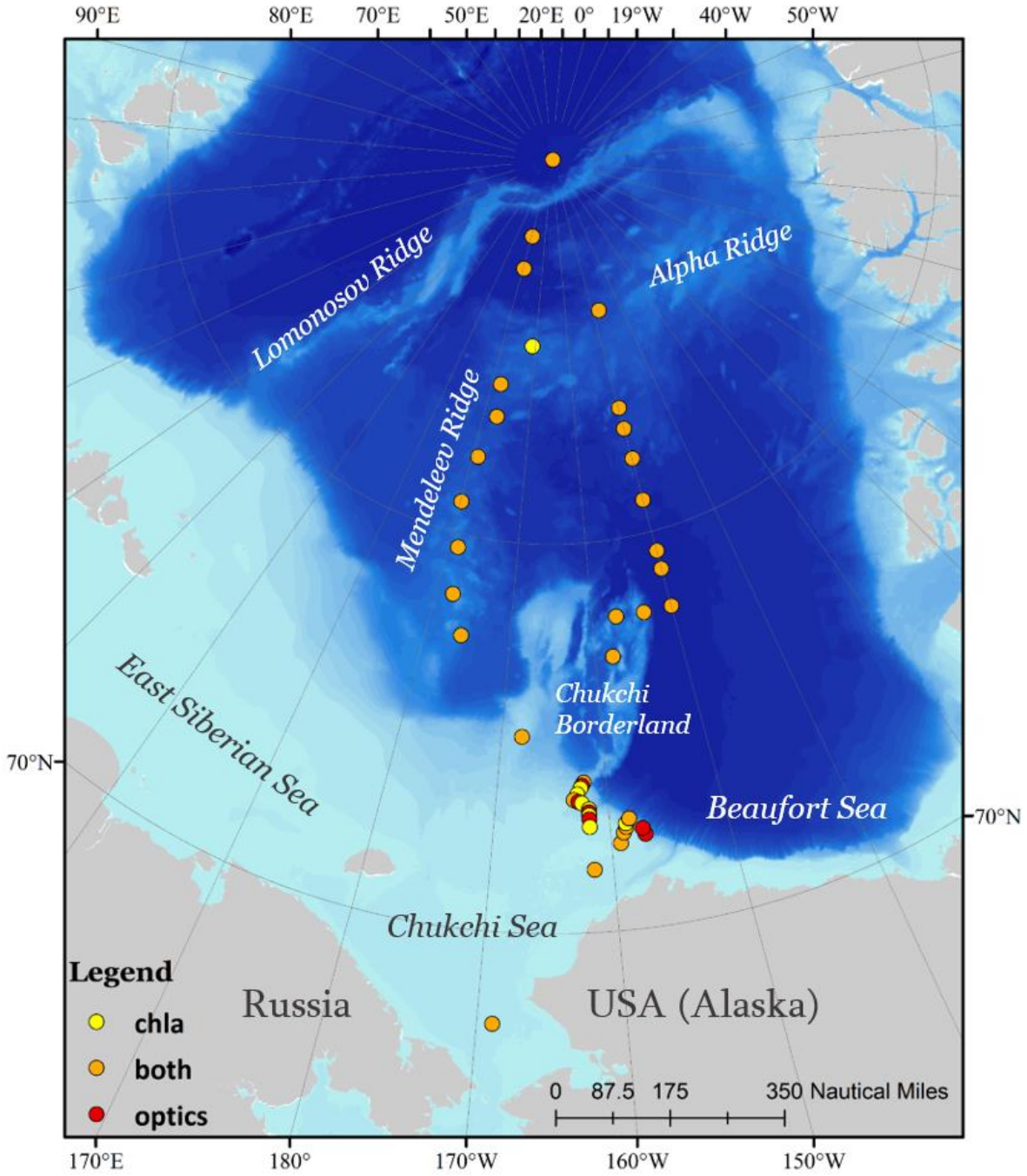
USCGC *Healy*

August-October 2022

Cruise measurements:

Chlorophyll *a* and pheophytin

Optical profiles

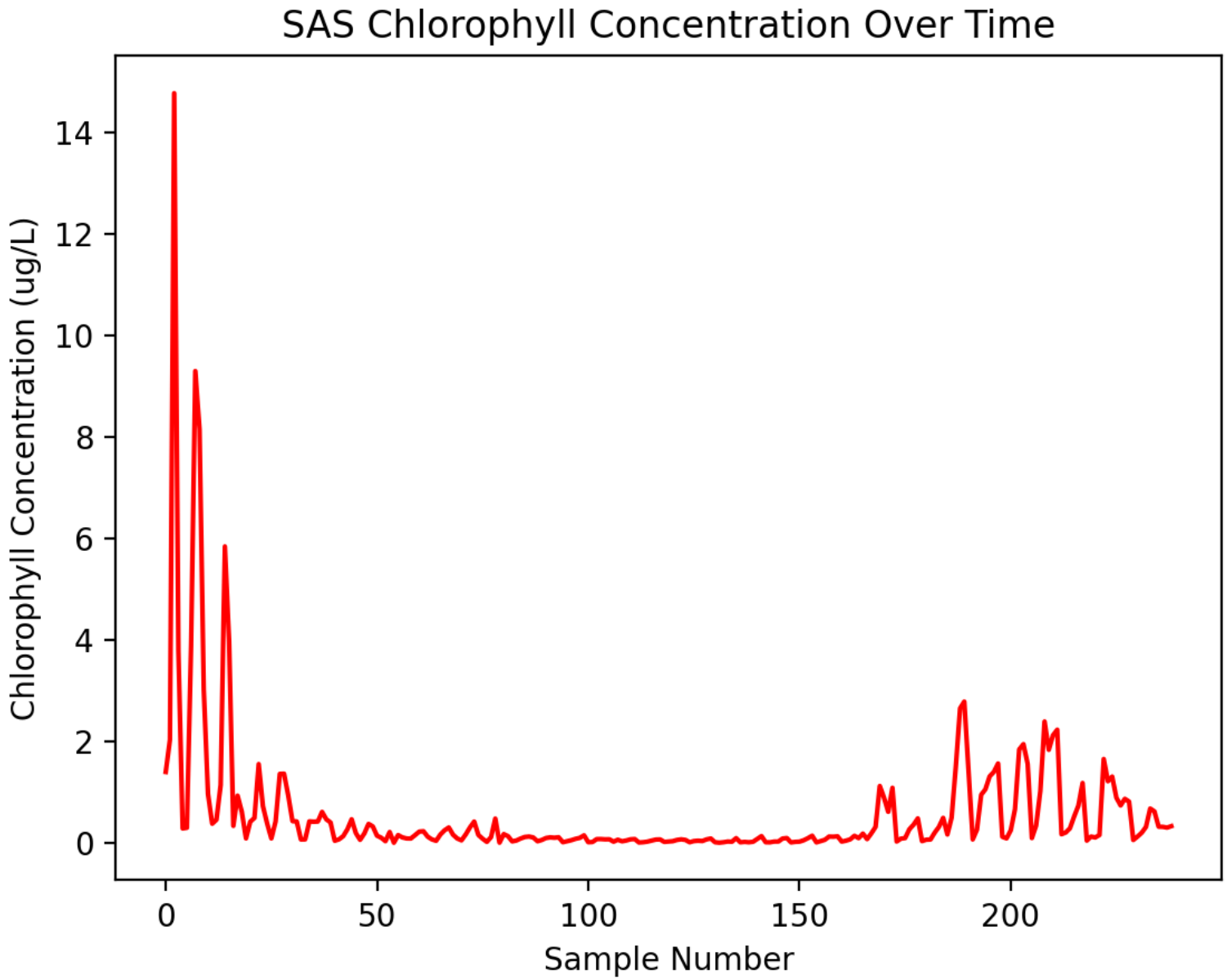


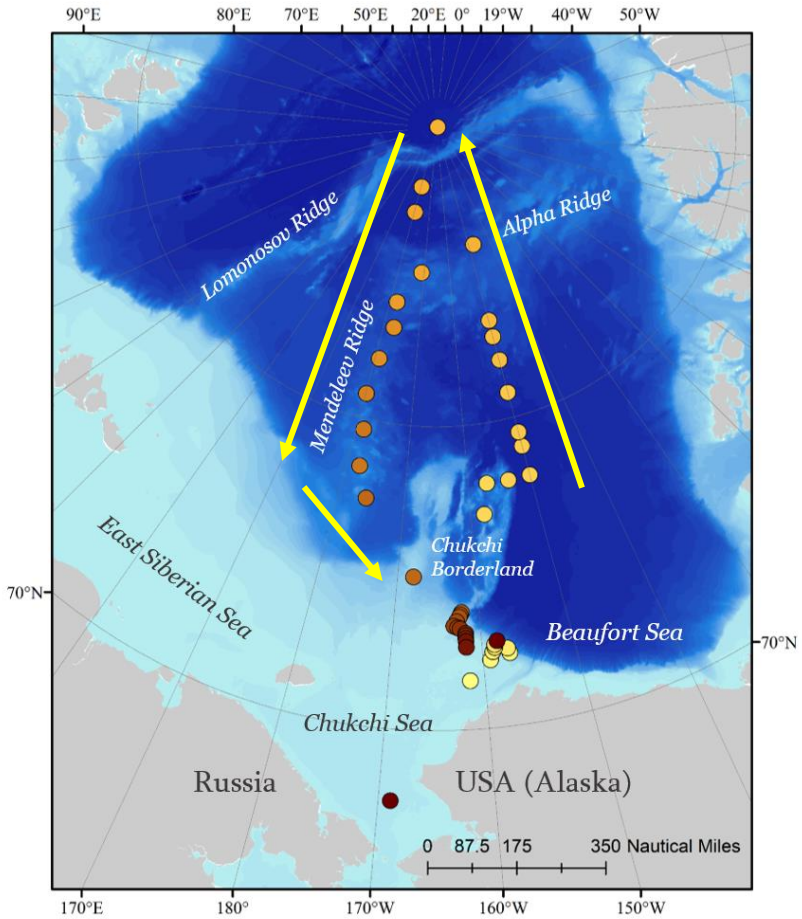
Synoptic Arctic Survey (SAS)
USCGC *Healy*
August-October 2022

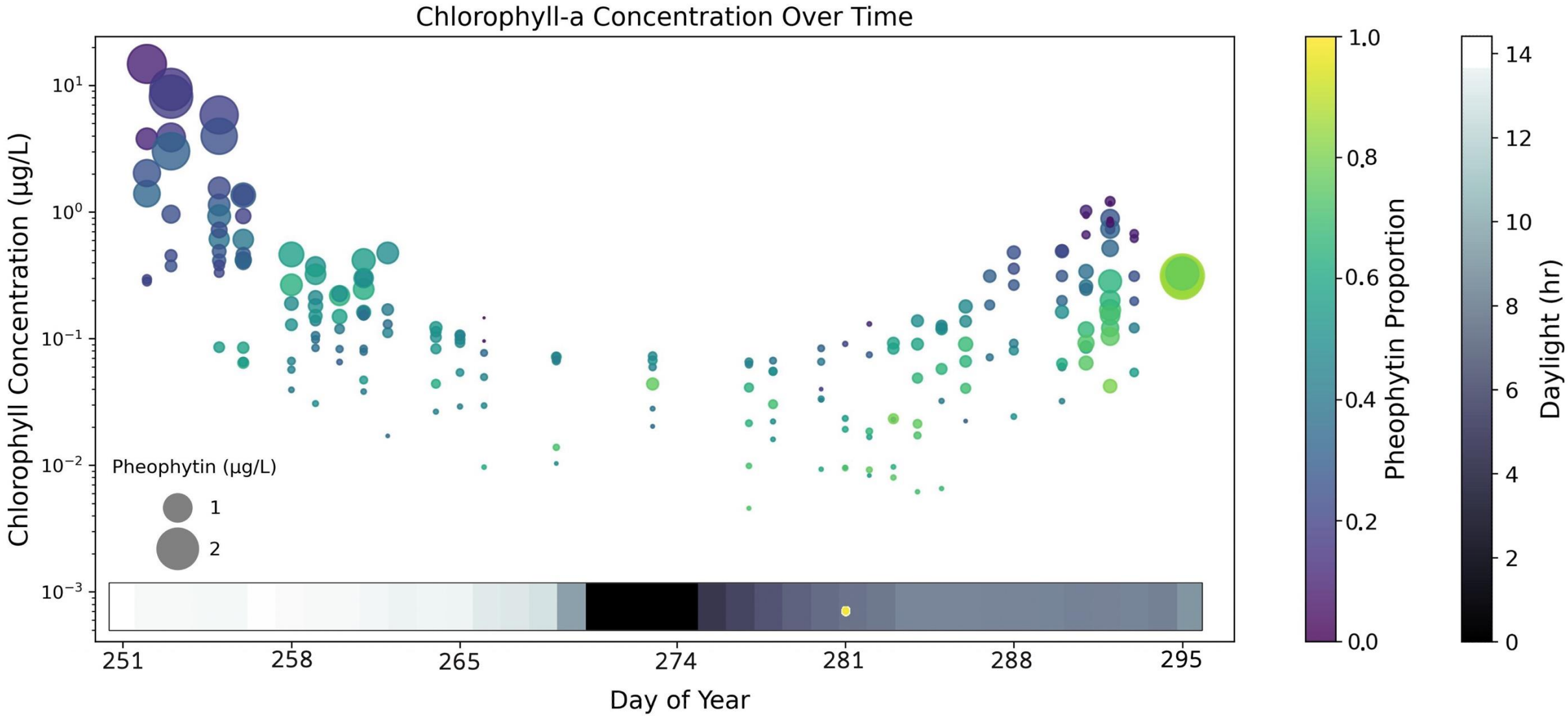
Cruise measurements:
Chlorophyll *a* and pheophytin

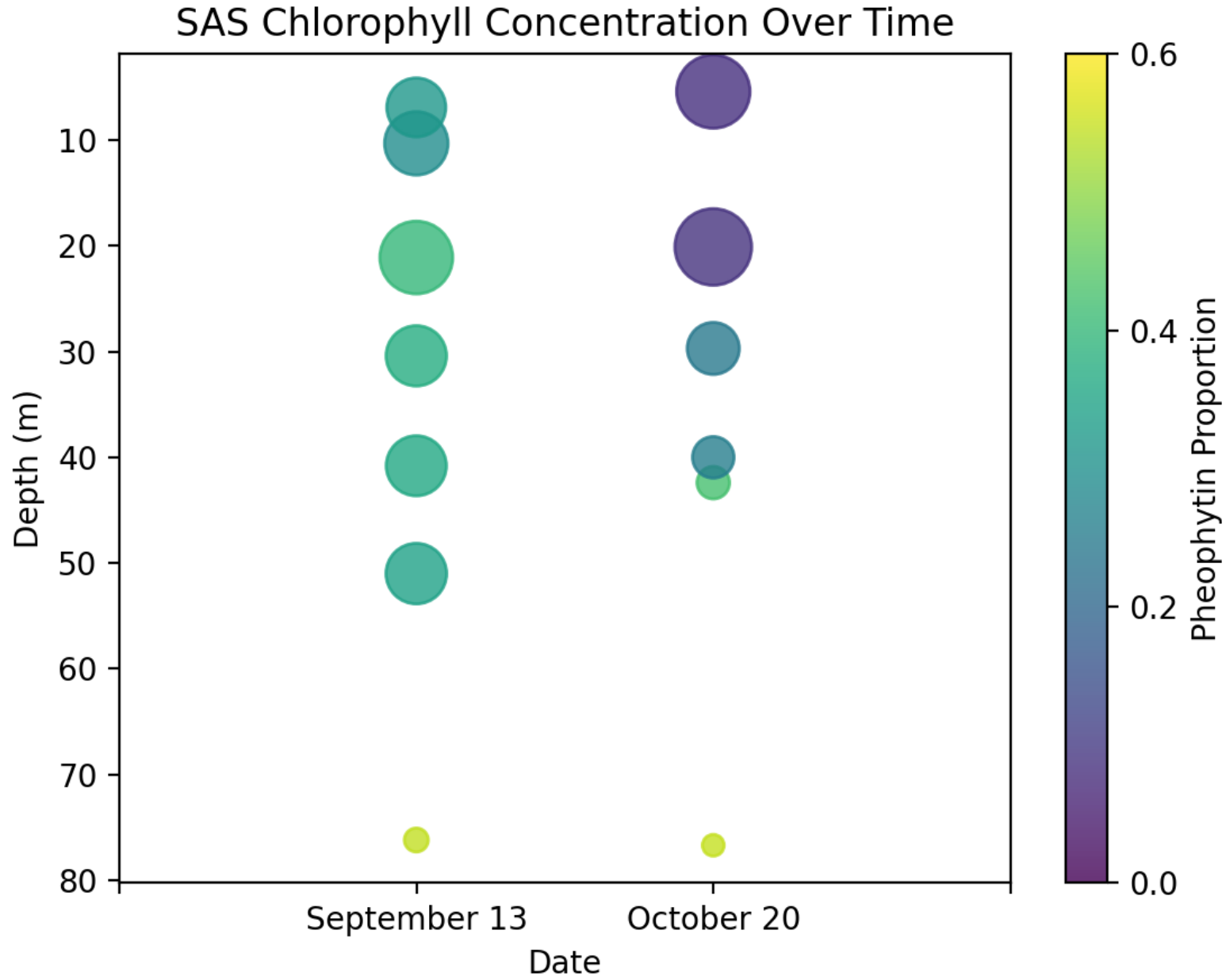
Pheophytin Proportion =
Pheophytin/(Chlorophyll a + Pheophytin)

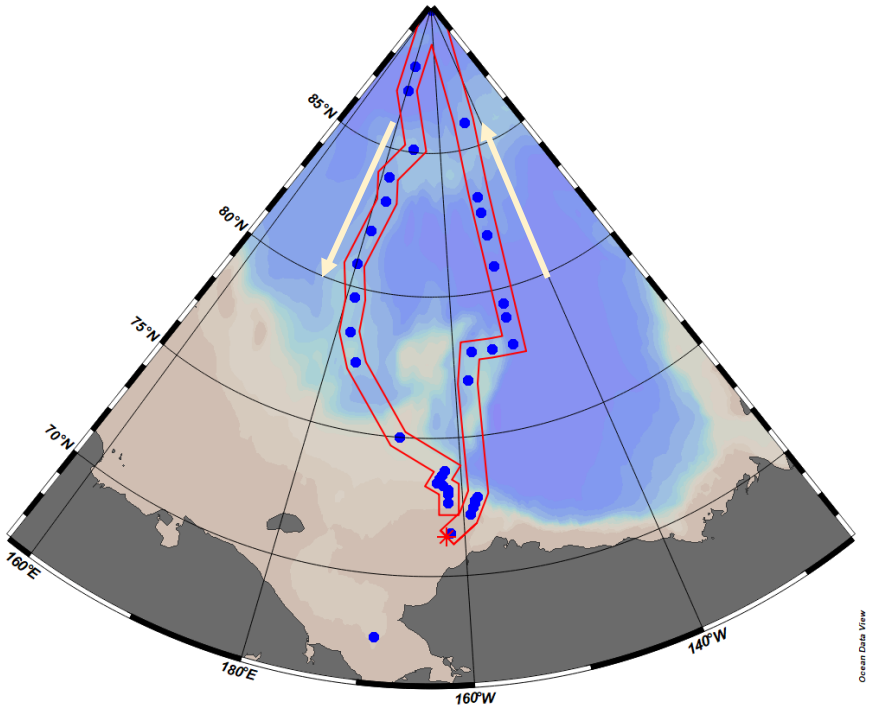
Late season bloom progression


SAS Chlorophyll Concentration Over Time
Chlorophyll Concentration (ug/L)
Sample Number
0
2
4
6
8
10
12
14
0
50
100
150
200


90°E
80°E
70°E
50°E
20°E
0°
19°W
40°W
50°W
Lomonosov Ridge
Alpha Ridge
Mendeleev Ridge
East Siberian Sea
Chukchi Borderland
Beaufort Sea
Chukchi Sea
Russia
USA (Alaska)
70°N
0 87.5 175 350 Nautical Miles
170°E
180°
170°W
160°W
150°W

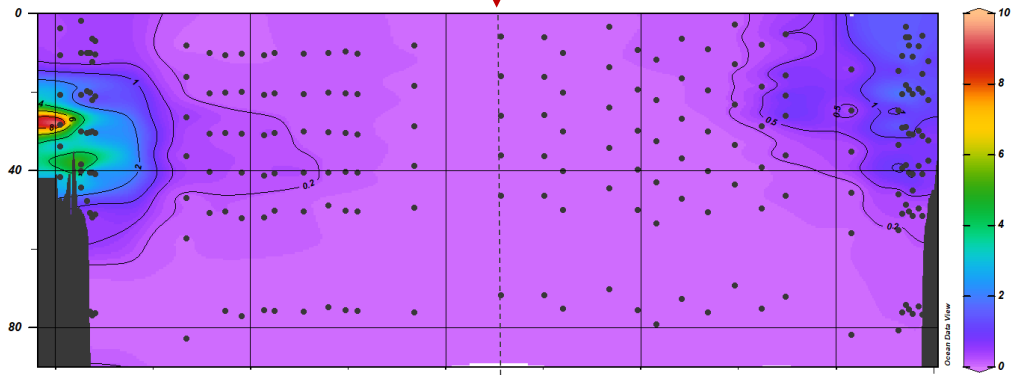

Chlorophyll-a Concentration Over Time
Chlorophyll Concentration (µg/L)
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
Pheophytin (µg/L)
1
2
251
258
265
274
281
288
295
Day of Year
1.0
0.8
0.6
0.4
0.2
0.0
Pheophytin Proportion
14
12
10
8
6
4
2
0
Daylight (hr)


SAS Chlorophyll Concentration Over Time
Depth (m)
10
20
30
40
50
60
70
80
September 13
October 20
Date
Pheophytin Proportion
0.6
0.4
0.2
0.0

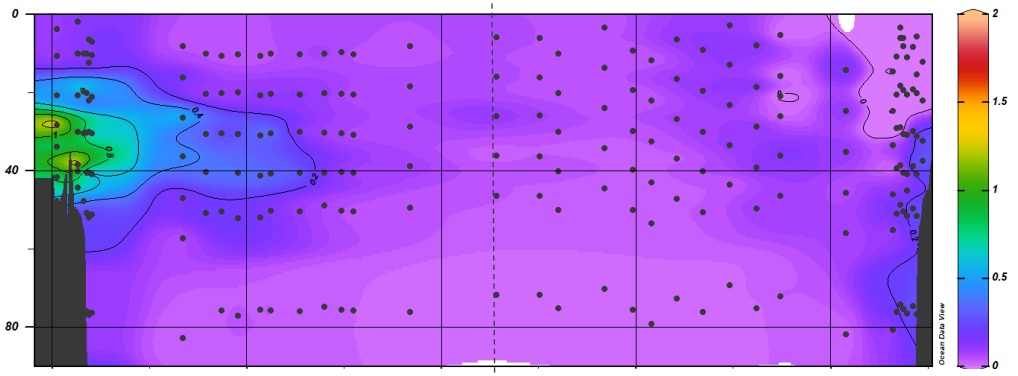


North Pole

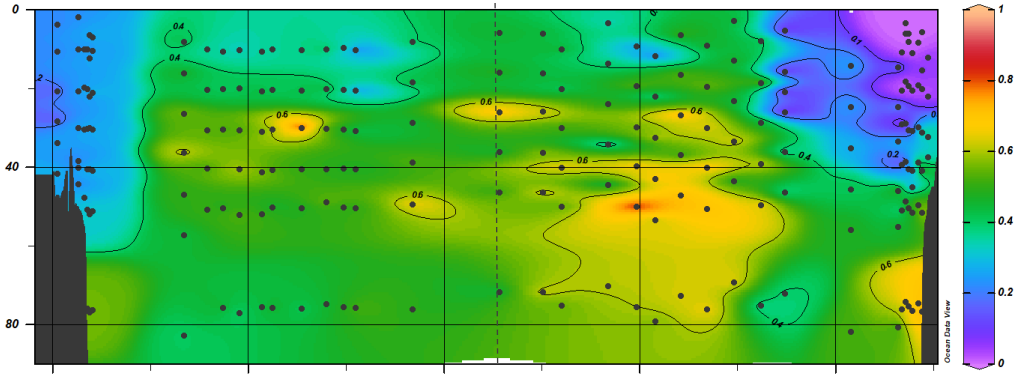
Chlorophyll-*a* (µg/L)

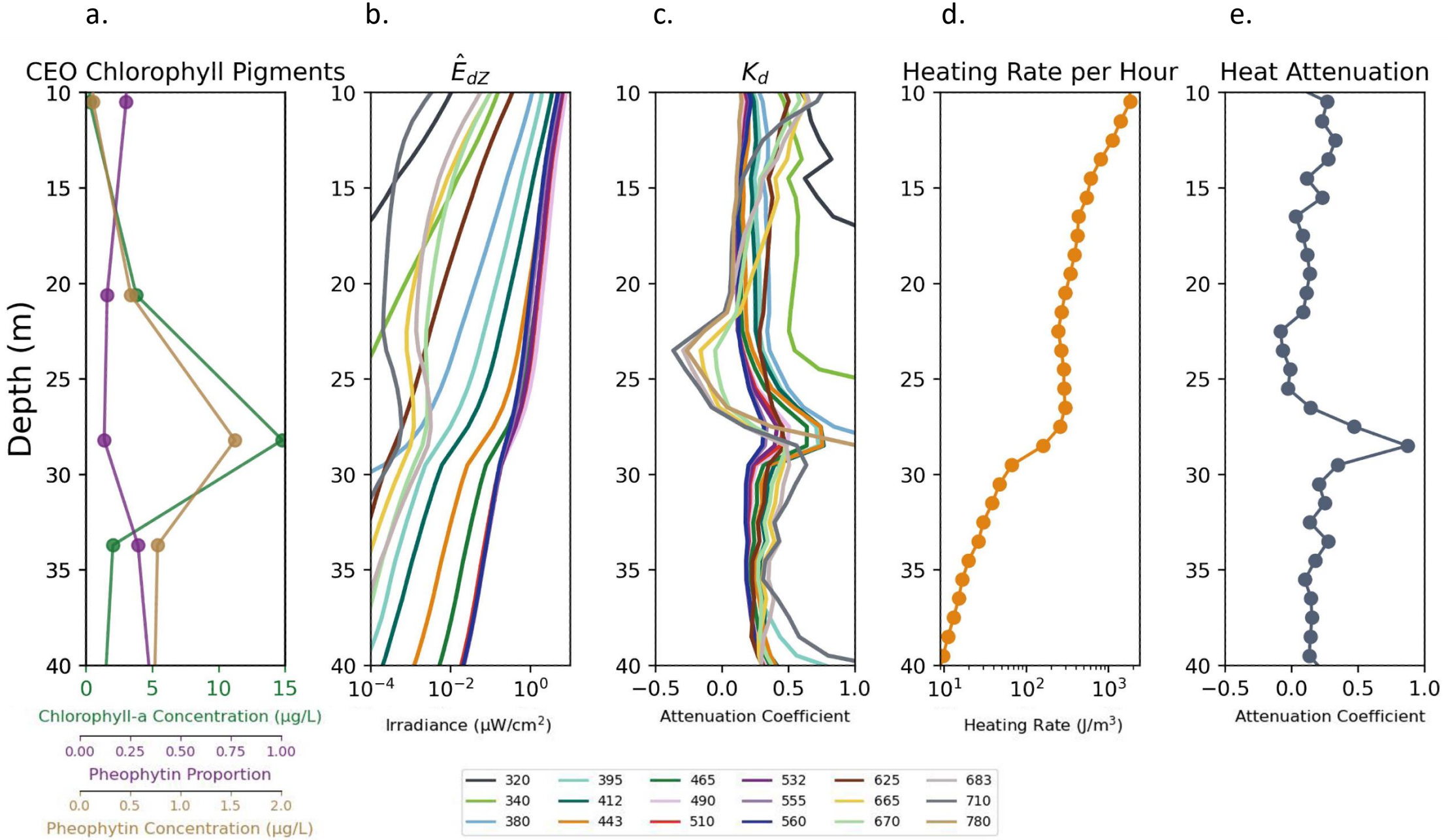


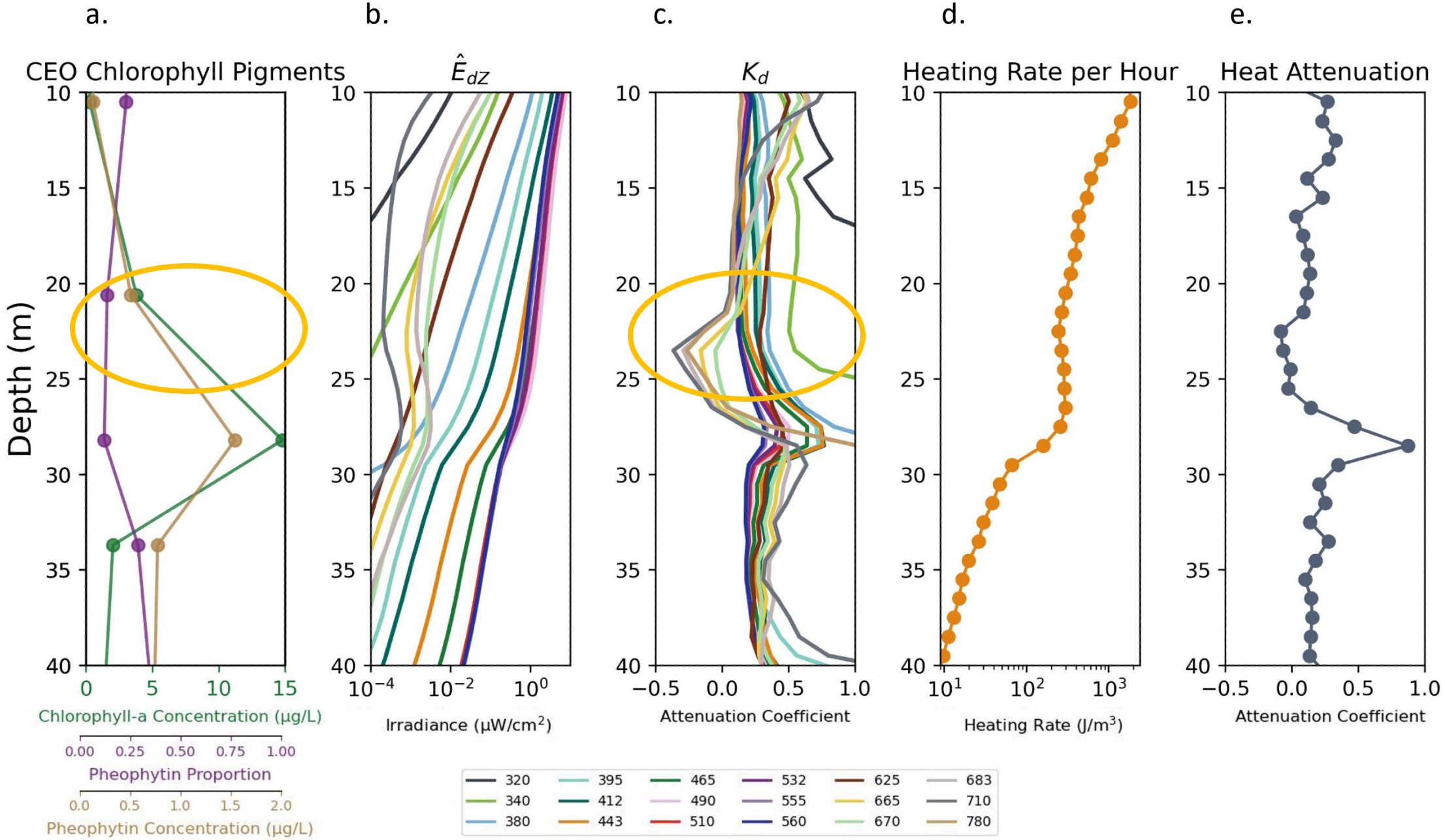
Pheophytin (µg/L)

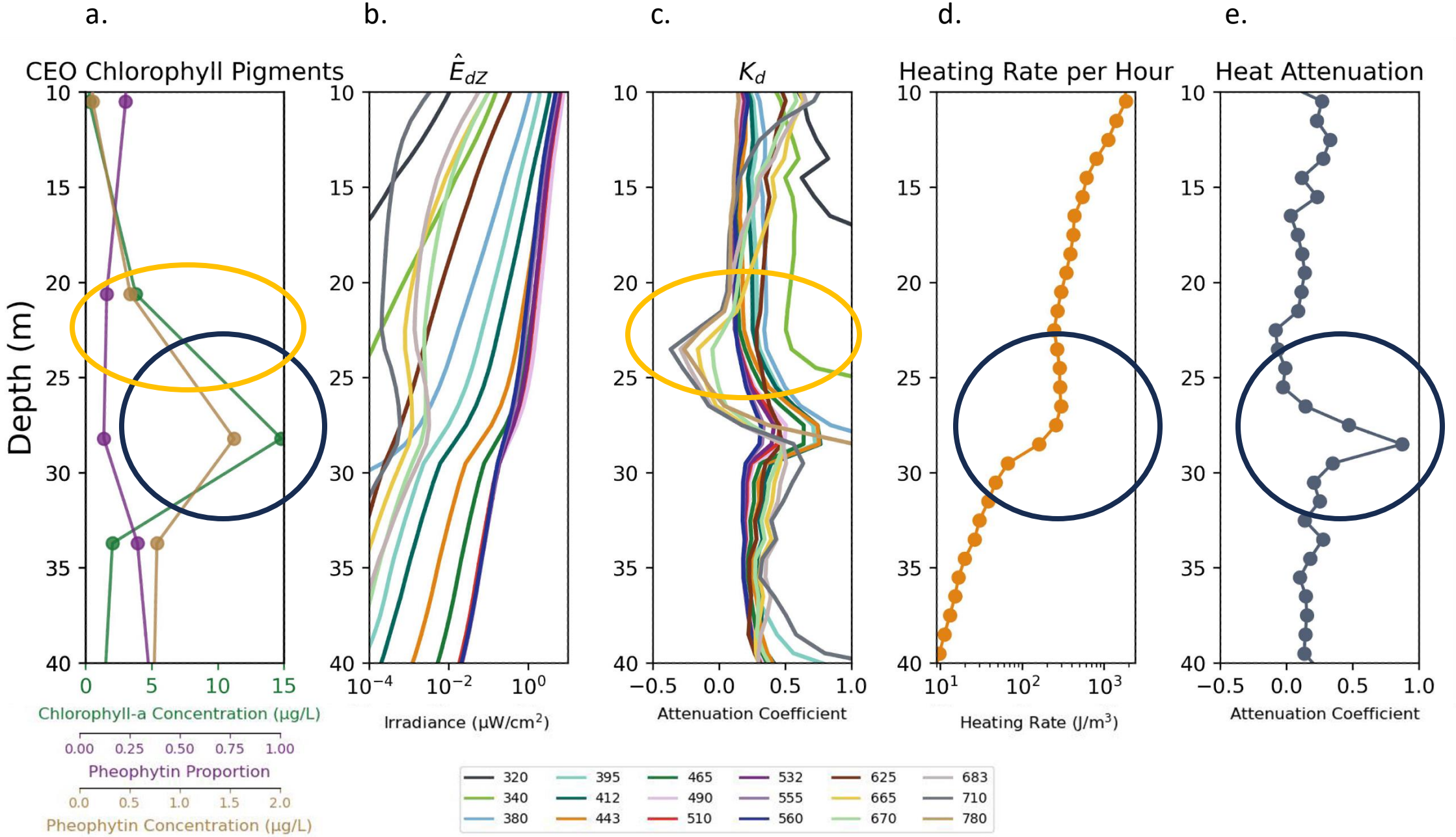


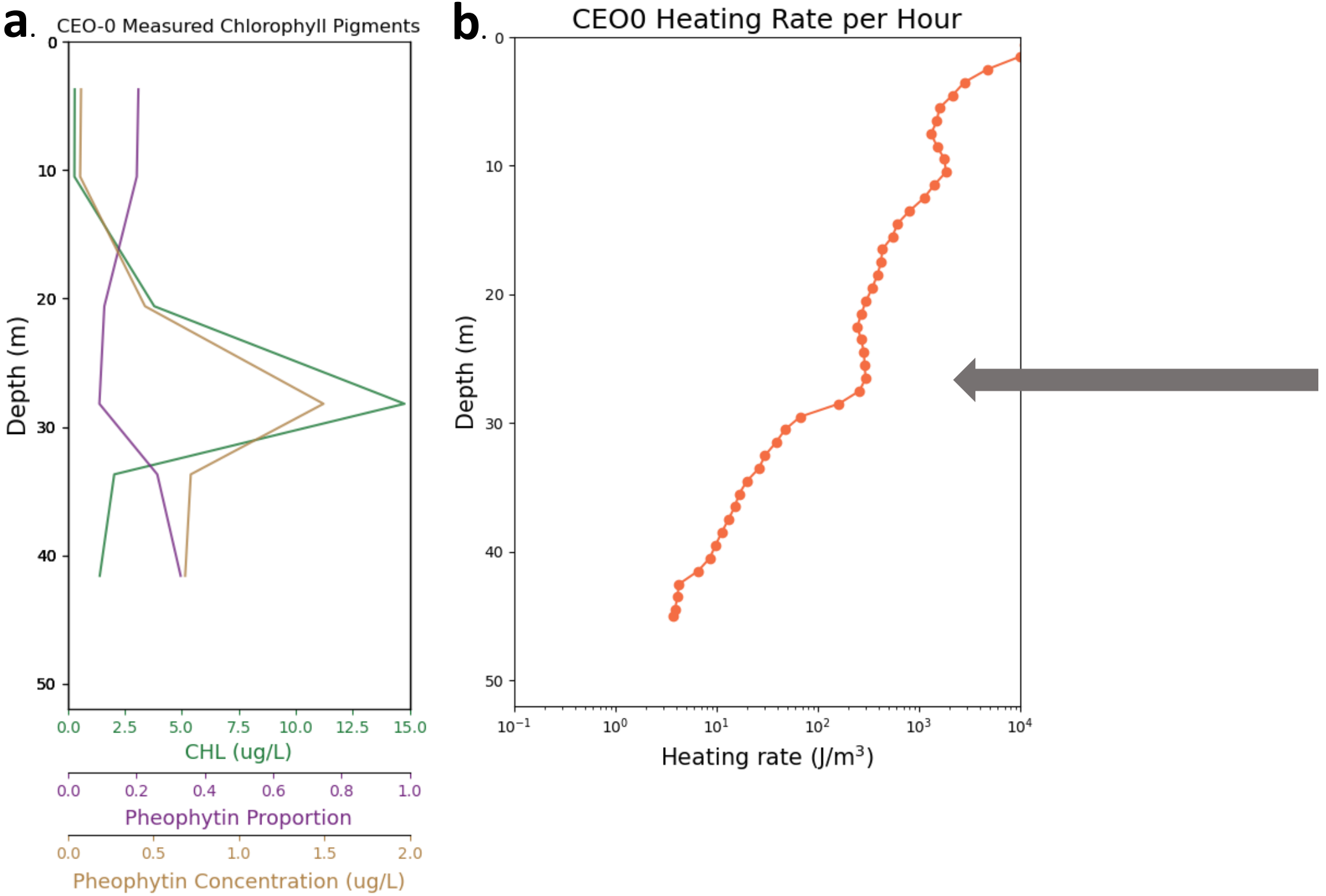
Pheophytin Proportion

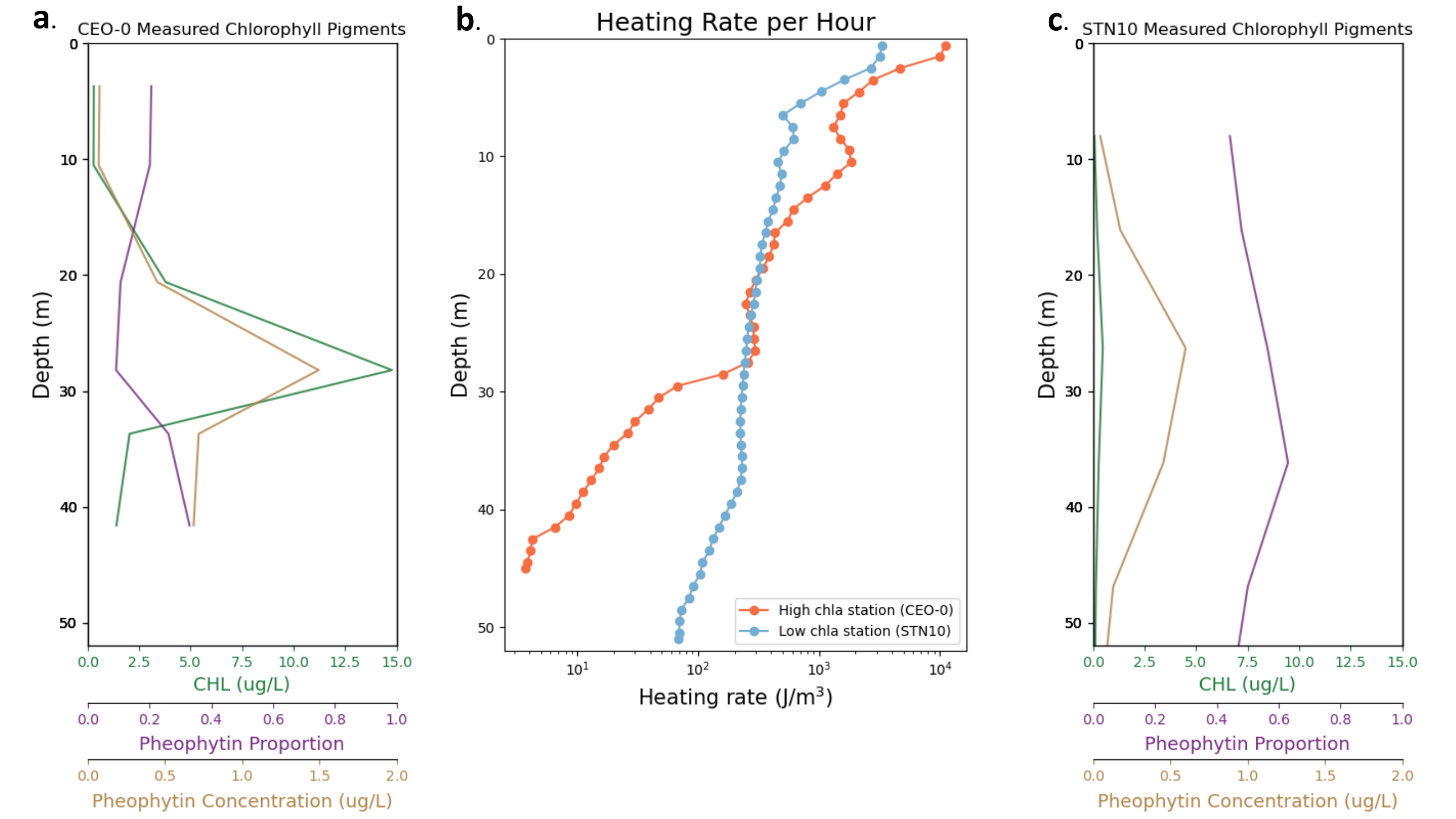


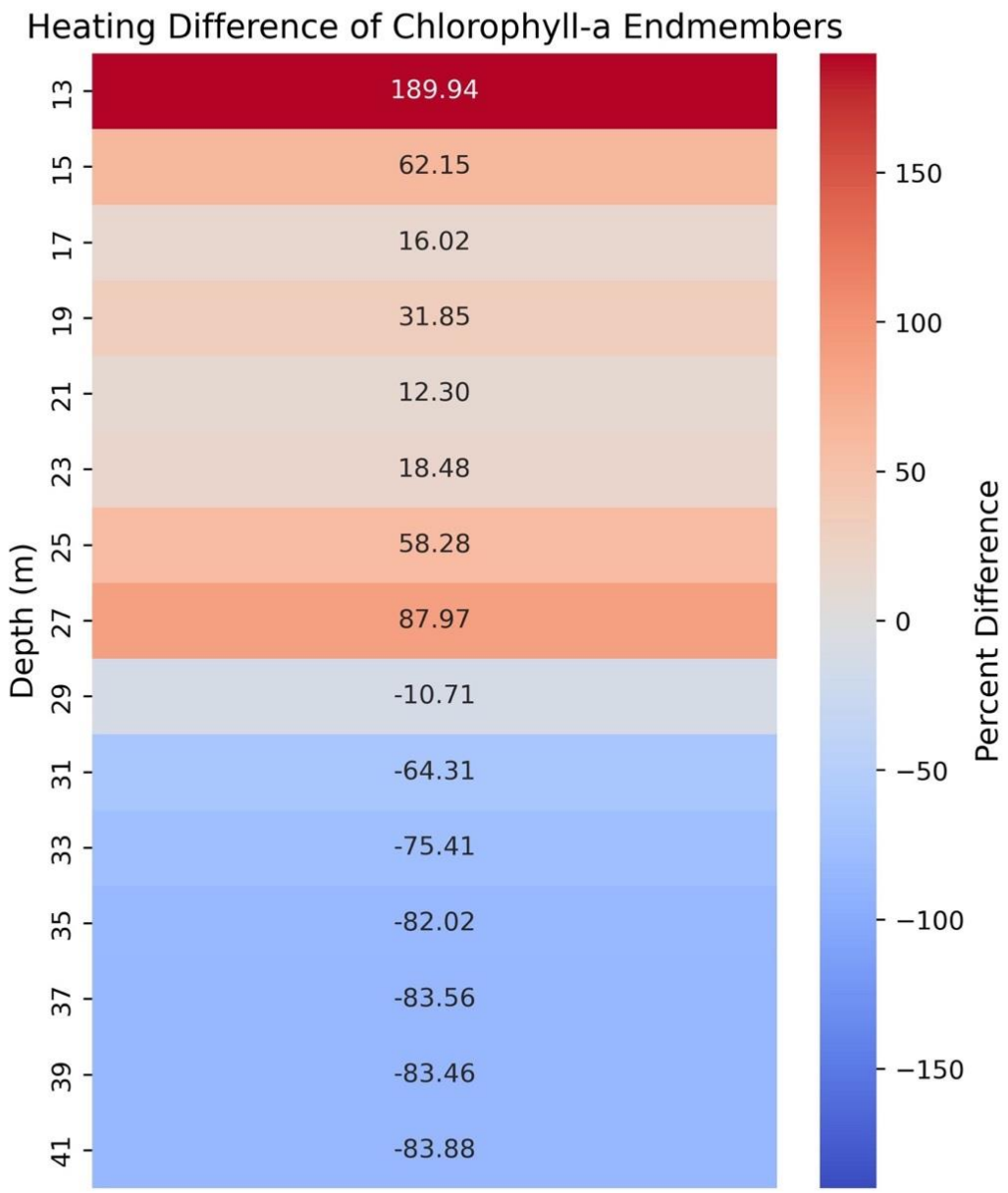

a.
b.
c.
d.
e.
CEO Chlorophyll Pigments
$\hat{E}_{dZ}$
K_d
Heating Rate per Hour
Heat Attenuation
Depth (m)
Chlorophyll-a Concentration (µg/L)
Pheophytin Proportion
Pheophytin Concentration (µg/L)
Irradiance (µW/cm^2)
Attenuation Coefficient
Heating Rate (J/m^3)
Attenuation Coefficient
320
340
380
395
412
443
465
490
510
532
555
560
625
665
670
683
710
780


a.
b.
c.
d.
e.
CEO Chlorophyll Pigments
$\hat{E}_{dZ}$
K_d
Heating Rate per Hour
Heat Attenuation
Depth (m)
Chlorophyll-a Concentration (µg/L)
Pheophytin Proportion
Pheophytin Concentration (µg/L)
Irradiance (µW/cm^2)
Attenuation Coefficient
Heating Rate (J/m^3)
Attenuation Coefficient
320
340
380
395
412
443
465
490
510
532
555
560
625
665
670
683
710
780


a.
b.
c.
d.
e.
CEO Chlorophyll Pigments
$\hat{E}_{dZ}$
K_d
Heating Rate per Hour
Heat Attenuation
Depth (m)
Chlorophyll-a Concentration (µg/L)
Pheophytin Proportion
Pheophytin Concentration (µg/L)
Irradiance (µW/cm^2)
Attenuation Coefficient
Heating Rate (J/m^3)
Attenuation Coefficient
320
340
380
395
412
443
465
490
510
532
555
560
625
665
670
683
710
780


a.
CEO-0 Measured Chlorophyll Pigments
Depth (m)
0
10
20
30
40
50
0.0
2.5
5.0
7.5
10.0
12.5
15.0
CHL (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
Pheophytin Proportion
0.0
0.5
1.0
1.5
2.0
Pheophytin Concentration (ug/L)
b.
CEO0 Heating Rate per Hour
Depth (m)
Heating rate (J/m^3)

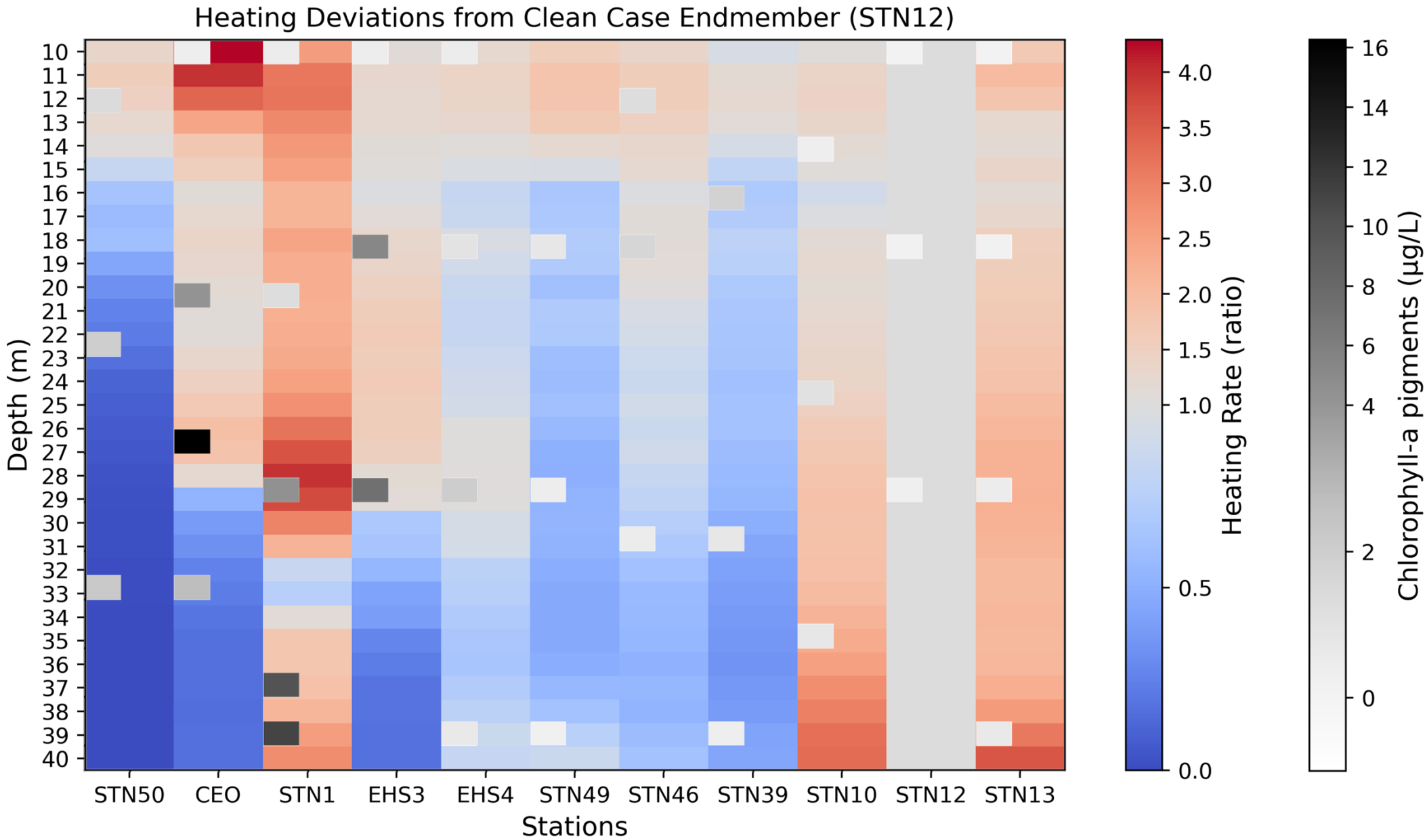

a.
CEO-0 Measured Chlorophyll Pigments
Depth (m)
0
10
20
30
40
50
0.0
2.5
5.0
7.5
10.0
12.5
15.0
CHL (ug/L)
0.0
0.2
0.4
0.6
0.8
1.0
Pheophytin Proportion
0.0
0.5
1.0
1.5
2.0
Pheophytin Concentration (ug/L)
b.
Heating Rate per Hour
Depth (m)
10^1
10^2
10^3
10^4
Heating rate (J/m^3)
High chla station (CEO-0)
Low chla station (STN10)
c.
STN10 Measured Chlorophyll Pigments
Depth (m)
CHL (ug/L)
Pheophytin Proportion
Pheophytin Concentration (ug/L)



Sea surface

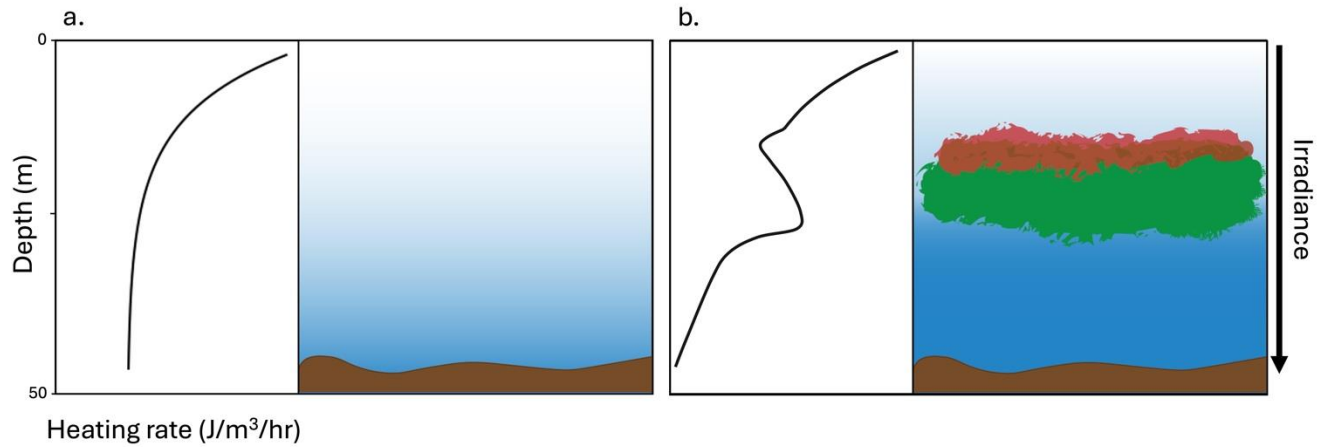
Subsurface chla bloom

Below subsurface chla bloom


Heating Deviations from Clean Case Endmember (STN12)
Depth (m)
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
STN50
CEO
STN1
EHS3
EHS4
STN49
STN46
STN39
STN10
STN12
STN13
Stations
Heating Rate (ratio)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Chlorophyll-a pigments (µg/L)
0
2
4
6
8
10
12
14
16

Conclusions:

- Overall phytoplankton bloom progression observed using pheophytin proportion.
- Observed renewed phytoplankton growth in late October.
- Subsurface blooms attenuate light and heat.



Gaffey, C. B., Frey, K. E., Cooper, L. W., & Grebmeier, J. M. (2022). Phytoplankton bloom stages estimated from chlorophyll pigment proportions suggest delayed summer production in low sea ice years in the northern Bering Sea. *PLoS ONE 17*(7), e0267586.

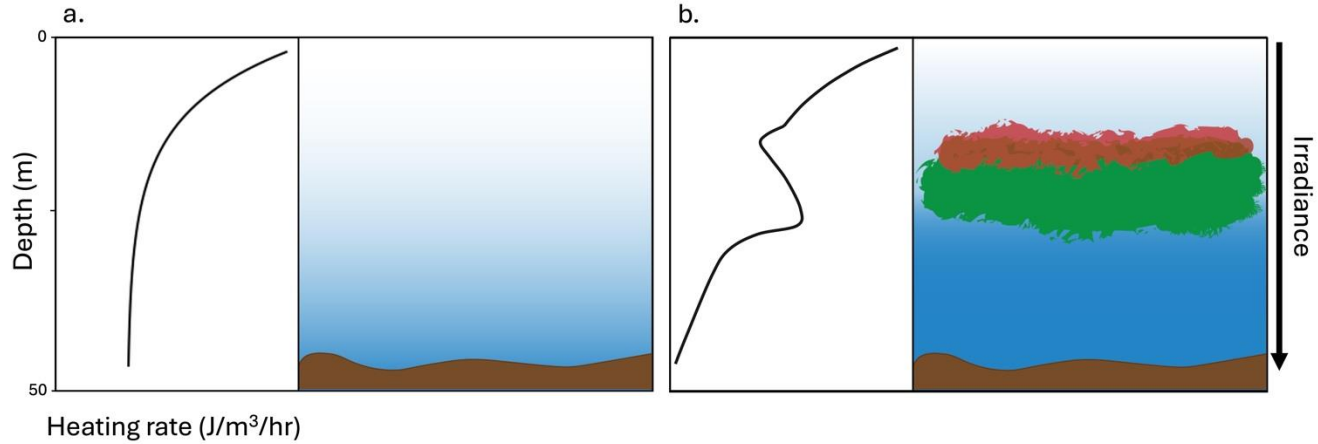
Conclusions:

- Overall phytoplankton bloom progression observed using pheophytin proportion.
- Observed renewed phytoplankton growth in late October.
- Subsurface blooms attenuate light and heat.

Heat concentrated at subsurface blooms.

Shades deeper waters from heat.

Potential implications for stratification and sea ice freeze up.



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Thank you

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