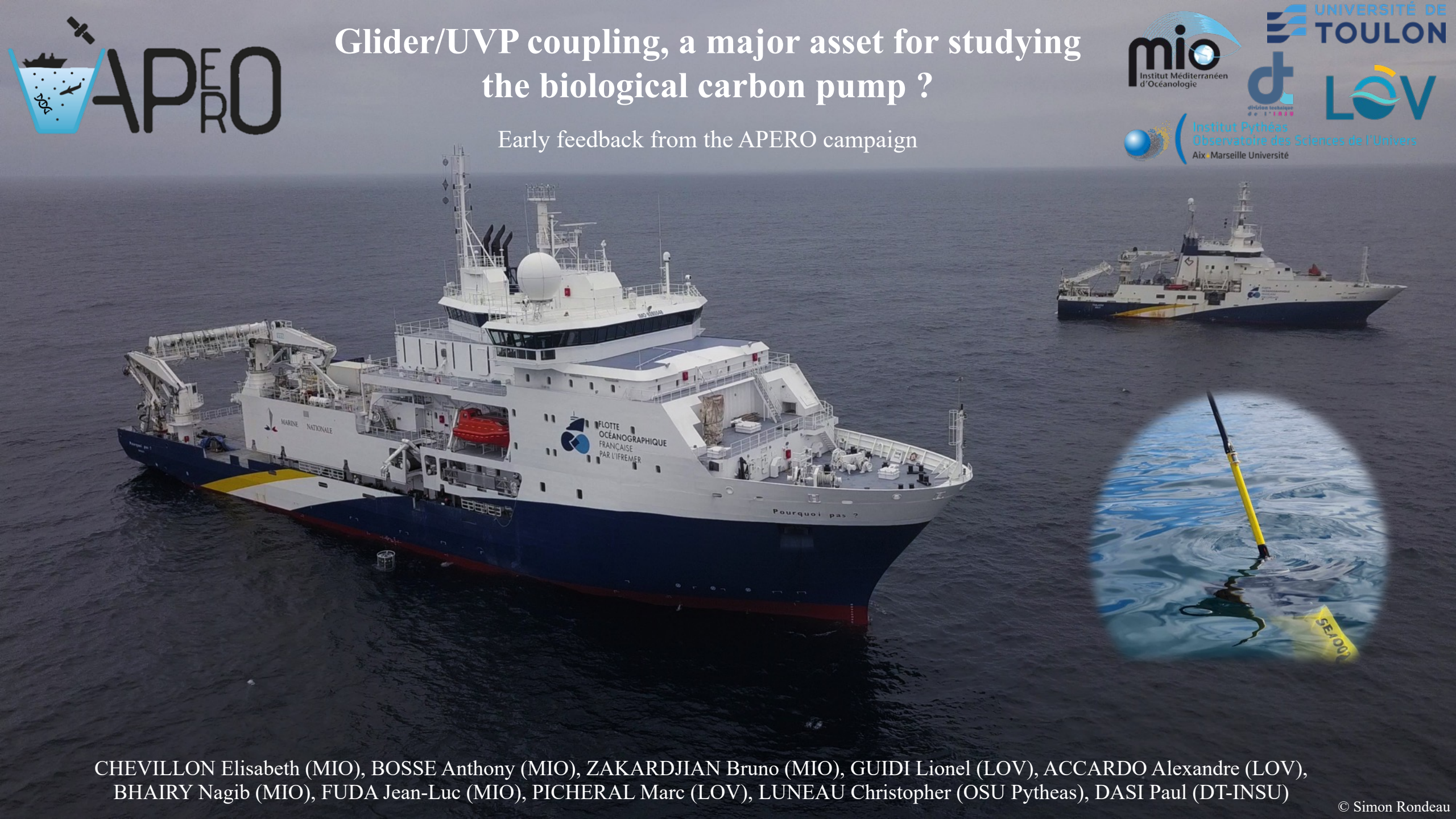
Glider/UVP coupling, a major asset for studying the biological carbon pump ?

Early feedback from the APERO campaign

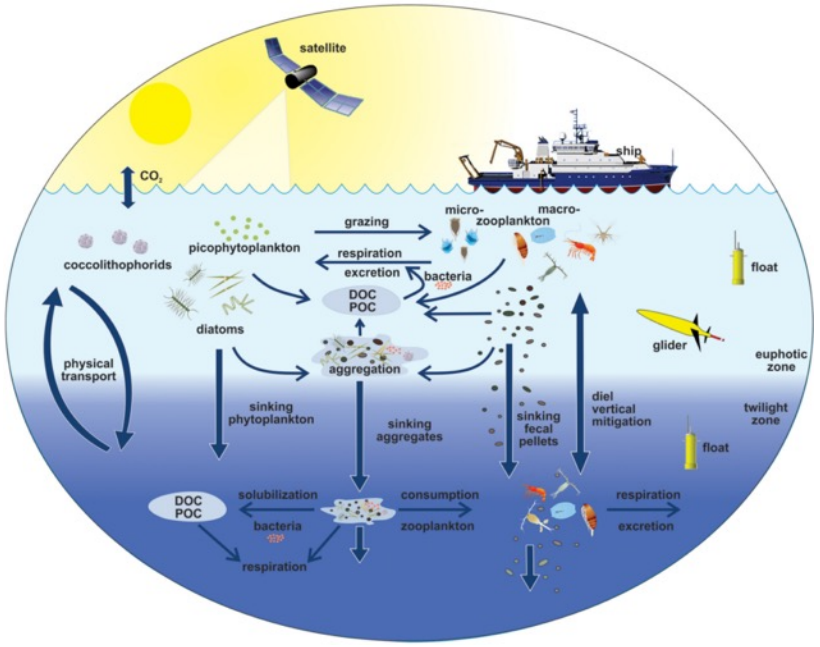


CHEVILLON Elisabeth (MIO), BOSSE Anthony (MIO), ZAKARDJIAN Bruno (MIO), GUIDI Lionel (LOV), ACCARDO Alexandre (LOV), BHAIRY Nagib (MIO), FUDA Jean-Luc (MIO), PICHERAL Marc (LOV), LUNEAU Christopher (OSU Pytheas), DASI Paul (DT-INSU)

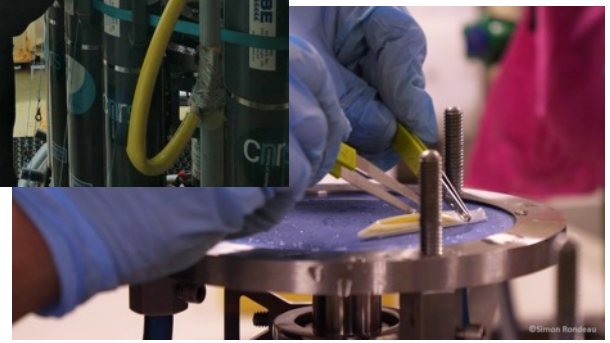
Assessing marine biogenic matter **P**roduction, **E**xport and **R**emineralisation: from the surface to the dark **O**cean

- Project involving an international community of over **120 scientists** focusing on the **biological pumping of carbon** into the ocean

- <u>3 co-PIs :</u>
  - L. **MEMERY** (CNRS, LEMAR, Brest)
  - C. **TAMBURINI** (CNRS, MIO, Marseille)
  - L. **GUIDI** (CNRS, LOV, Villefranche-sur-Mer)



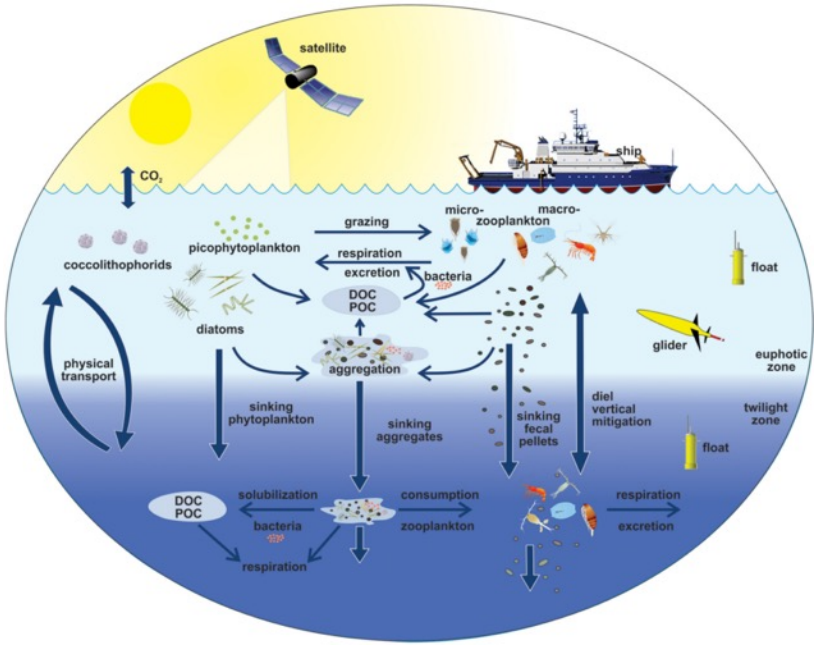
From Siegel et al. 2016



Assessing marine biogenic matter **P**roduction, **E**xport and **R**emineralisation: from the surface to the dark **O**cean

- Project involving an international community of over **120 scientists** focusing on the **biological pumping of carbon** into the ocean

- <u>3 co-PIs :</u>
  - L. **MEMERY** (CNRS, LEMAR, Brest)
  - C. **TAMBURINI** (CNRS, MIO, Marseille)
  - L. **GUIDI** (CNRS, LOV, Villefranche-sur-Mer)

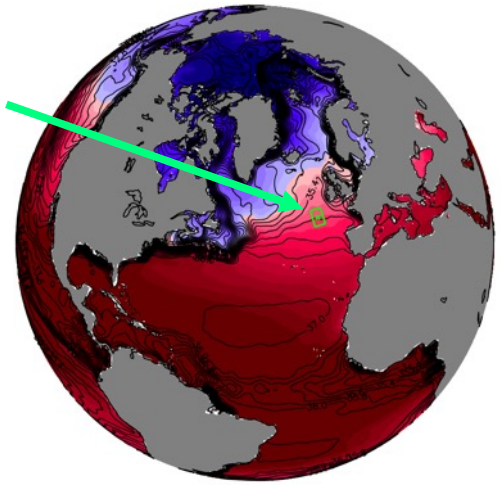


From Siegel et al. 2016

Quantify the **physical**, **ecological** and **biogeochemical** connections between the surface layer and the mesopelagic domain, for a better understanding of **the biological carbon pump** and its role in the **sequestration of anthropogenic carbon** in the ocean

Campaign strategy :

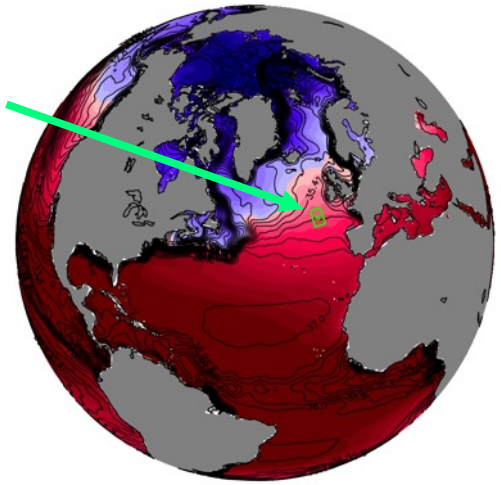
→ **Where ?**



- In the **North-East Atlantic**, in the area of the British permanent PAP station (*Porcupine Abyssal Plain*)

Campaign strategy :

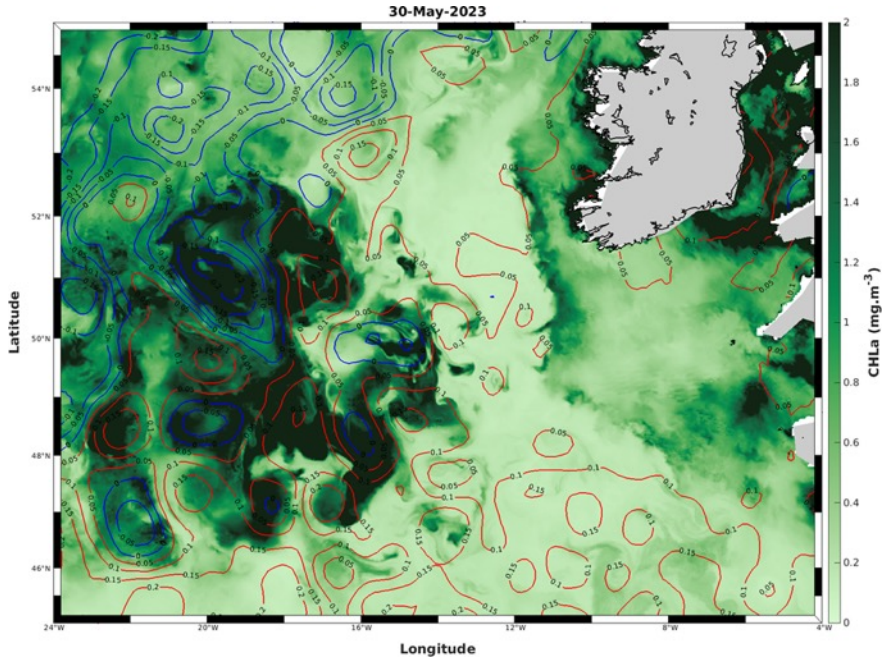
→ **Where ?**



→ **When ?**

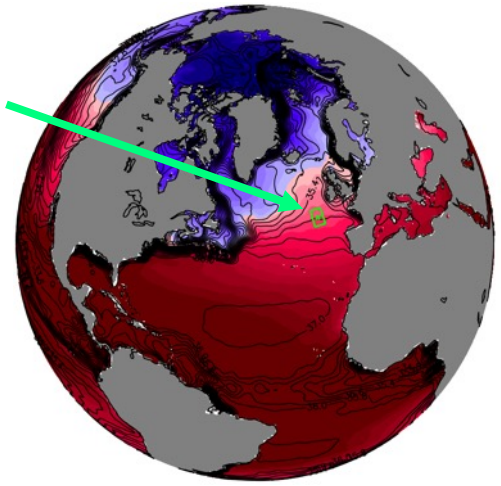
- From **3 June to 15 July 2023** at the time of maximum particulate export (end of spring phytoplankton bloom)

- In the **North-East Atlantic**, in the area of the British permanent PAP station (*Porcupine Abyssal Plain*)



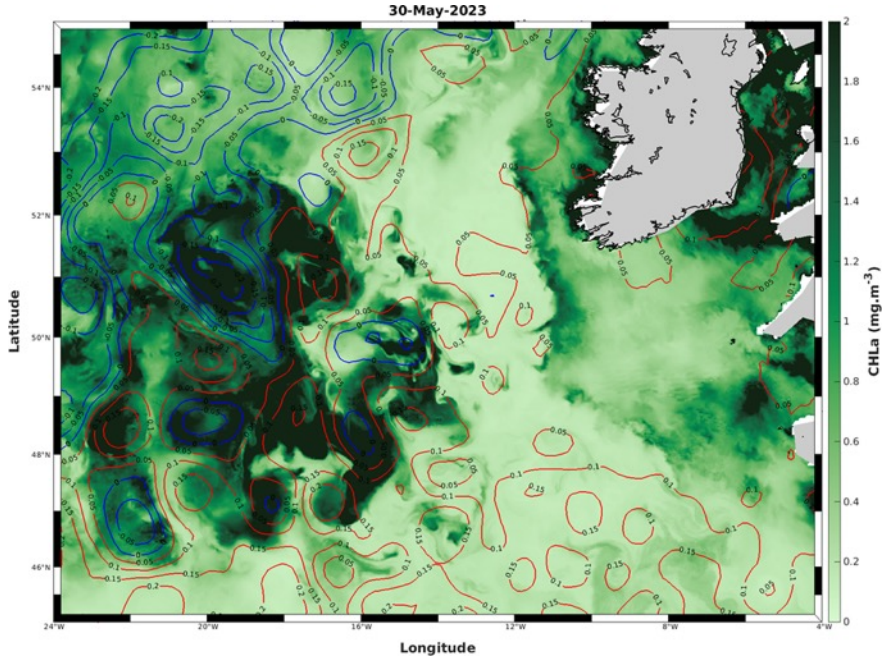
Campaign strategy :

→ Where ?



→ When ?

- From **3 June to 15 July 2023** at the time of maximum particulate export (end of spring phytoplankton bloom)



- In the **North-East Atlantic**, in the area of the British permanent PAP station (*Porcupine Abyssal Plain*)

→ How did we do it ?

R/V *Le Thalassa*
(25 scientists)

Regional coverage :
Acoustics/Nets/Trawls/OMICS

R/V *Le Pourquoi Pas ?*
(40 scientists)

Process studies :
Drifting mooring of particle traps / High-resolution biogeochemical sections

+ Real-time analysis on land :
satellites, operational models, in situ data, daily ZOOM
→Adaptive strategy

+ Autonomous platforms :

- 4 BGC-Argo with UVP6
- **3 SeaExplorer gliders, 2 with UVP6**

SEA002 (0-600 m)

SEA092 (0-1000 m)

9 June to 3 July

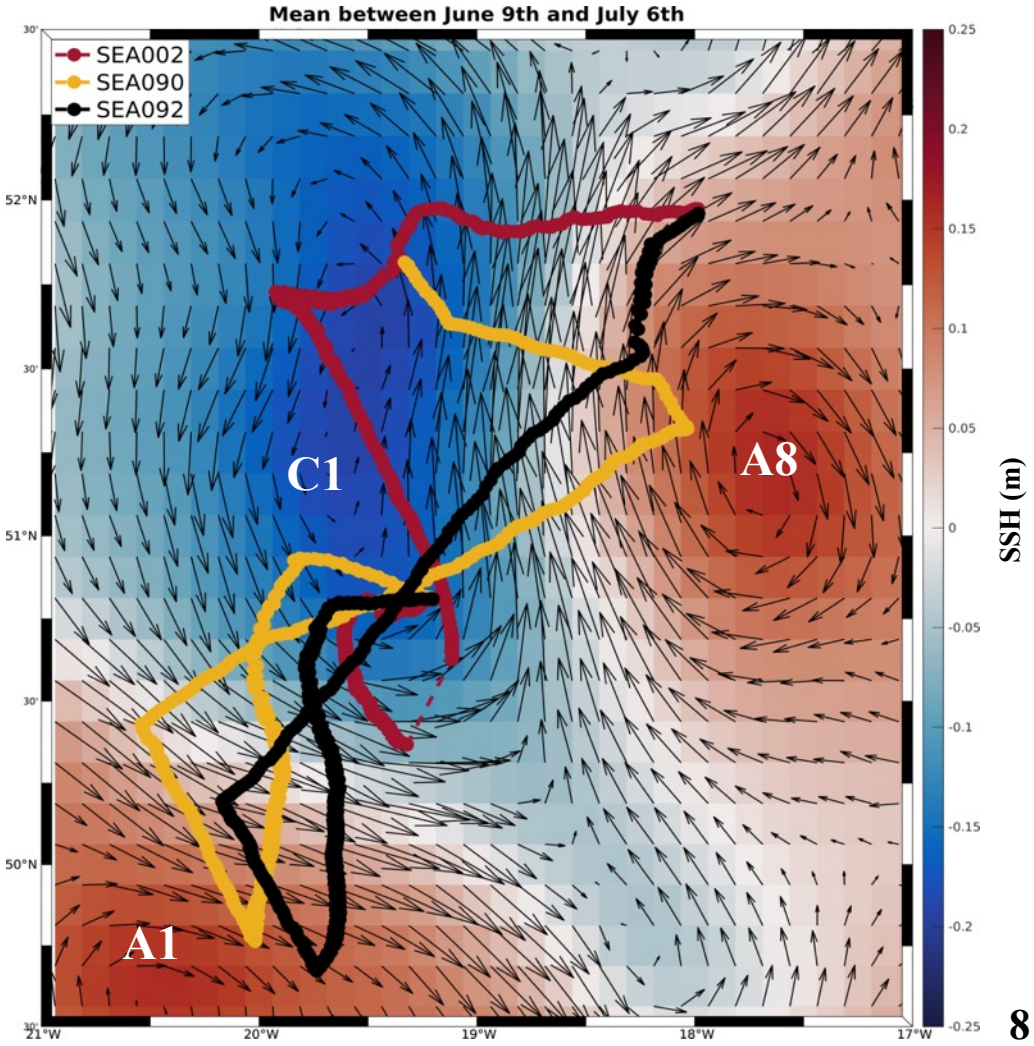
CTD RBRlegato
AROD_FT (Oxygen)
ECO-FLBBCD (Chlorophylle + BackScattering + CDOM)
UVP6

SEA090
(0-1000 m)

9 June to 6 July

CTD RBRlegato
AROD_FT (Oxygen)
ECO-FLNTU (Chlorophyll + Turbidity)

A total of 8 high-resolution frontal sections, half with UVP6



SEA002 (0-600 m) **SEA092** (0-1000 m)

9 June to 3 July

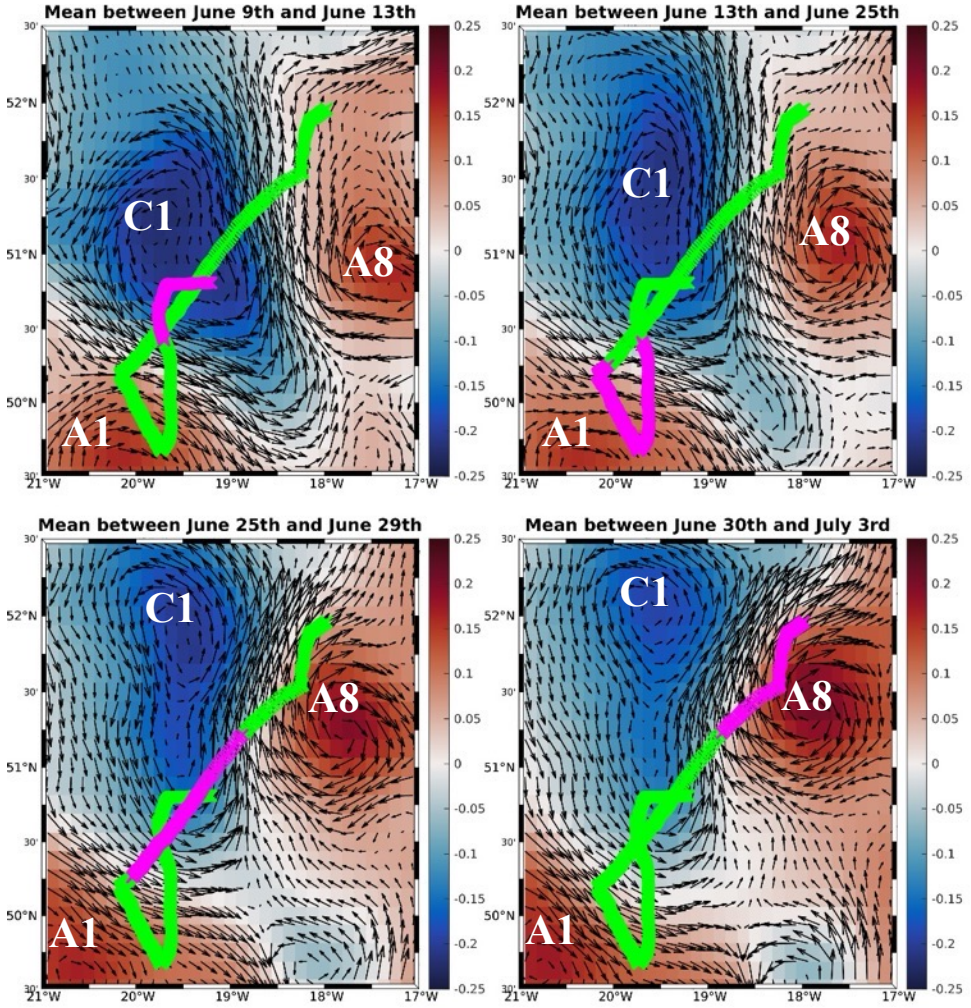
CTD RBRlegato
AROD_FT (Oxygen)
ECO-FLBBCD (Chlorophylle + BackScattering + CDOM)
UVP6

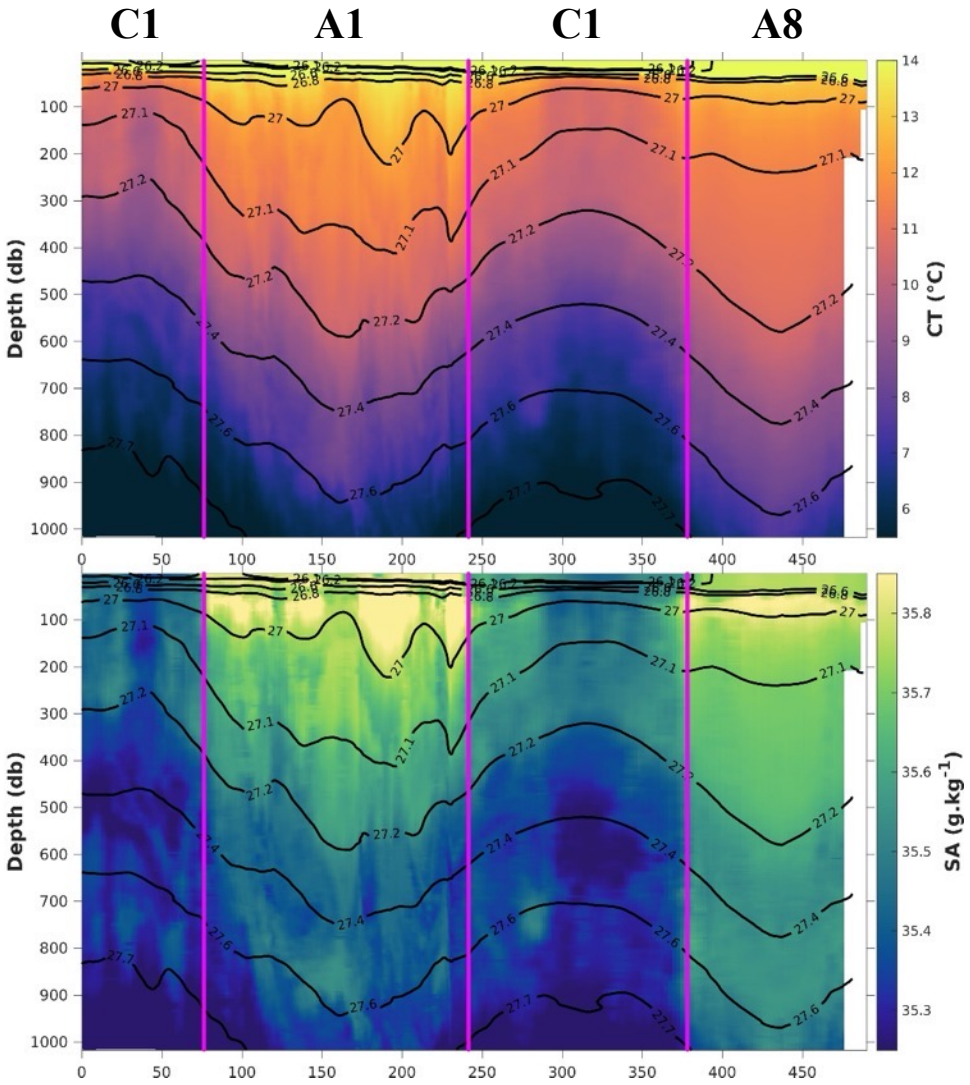
SEA090
(0-1000 m)

9 June to 6 July

CTD RBRlegato
AROD_FT (Oxygen)
ECO-FLNTU (Chlorophyll + Turbidity)

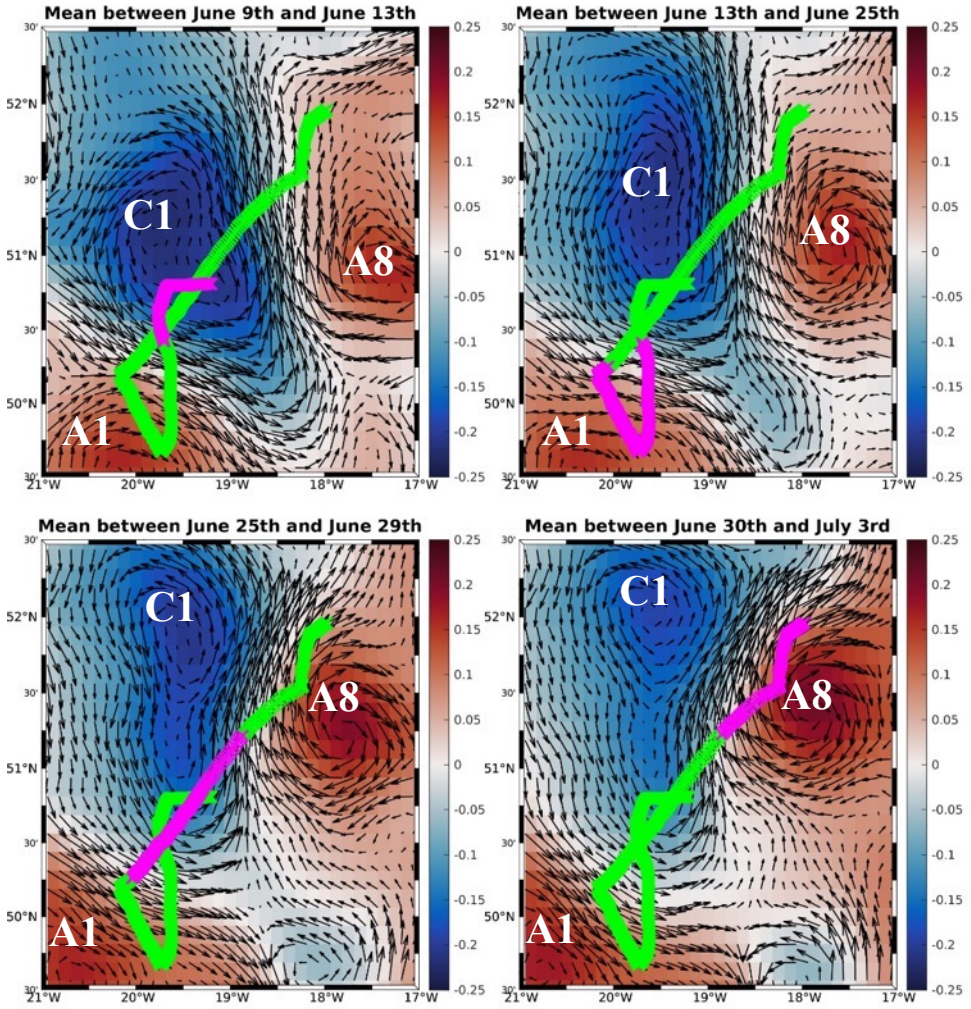
Altimetric context of the path of SEA092 and vertical sections of the conservative temperature (CT TEOS-10) and the absolute salinity (SA TEOS-10)



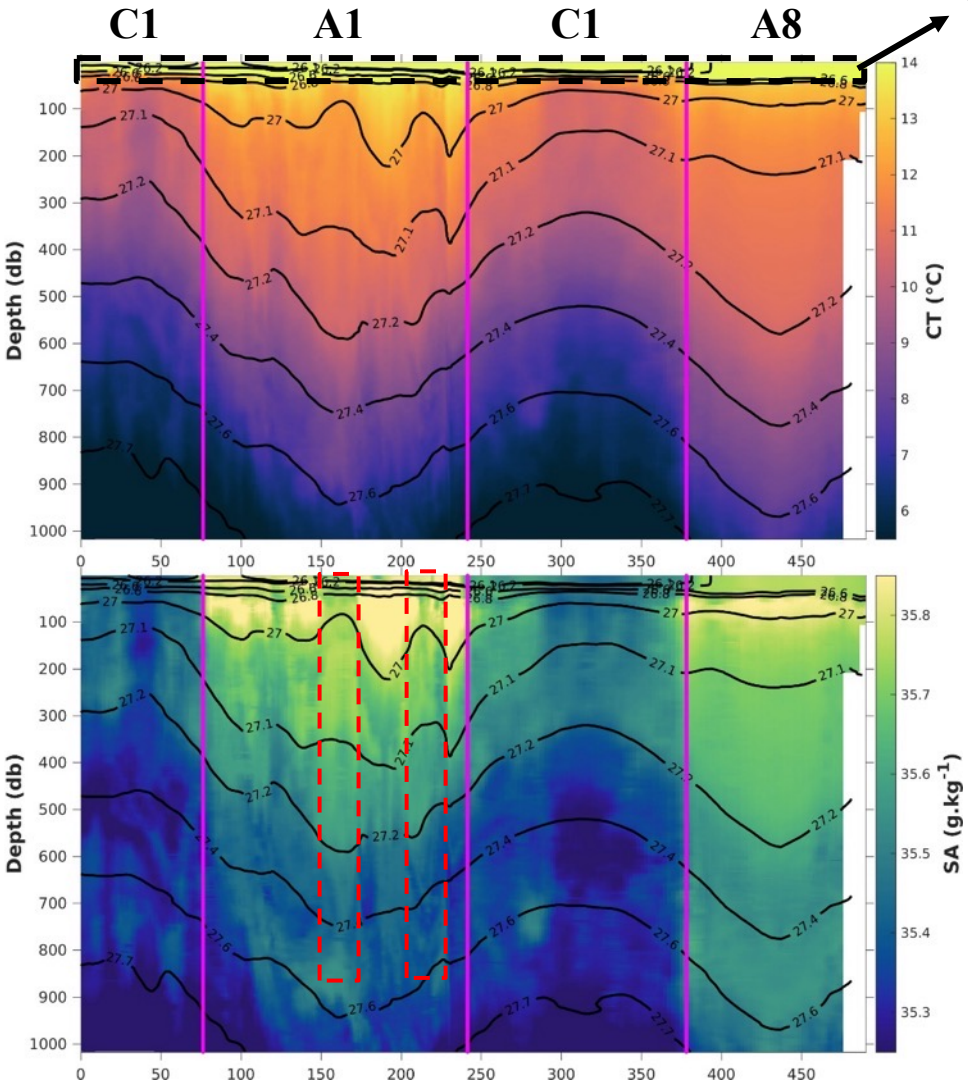


ADT (AVISO/CMEMS) : In green, the path of SEA092 and in pink the average residence time of the glider in a cyclone or an anticyclone

Altimetric context of the path of SEA092 and vertical sections of the conservative temperature (CT TEOS-10) and the absolute salinity (SA TEOS-10)



ADT (AVISO/CMEMS) : In green, the path of SEA092 and in pink the average residence time of the glider in a cyclone or an anticyclone



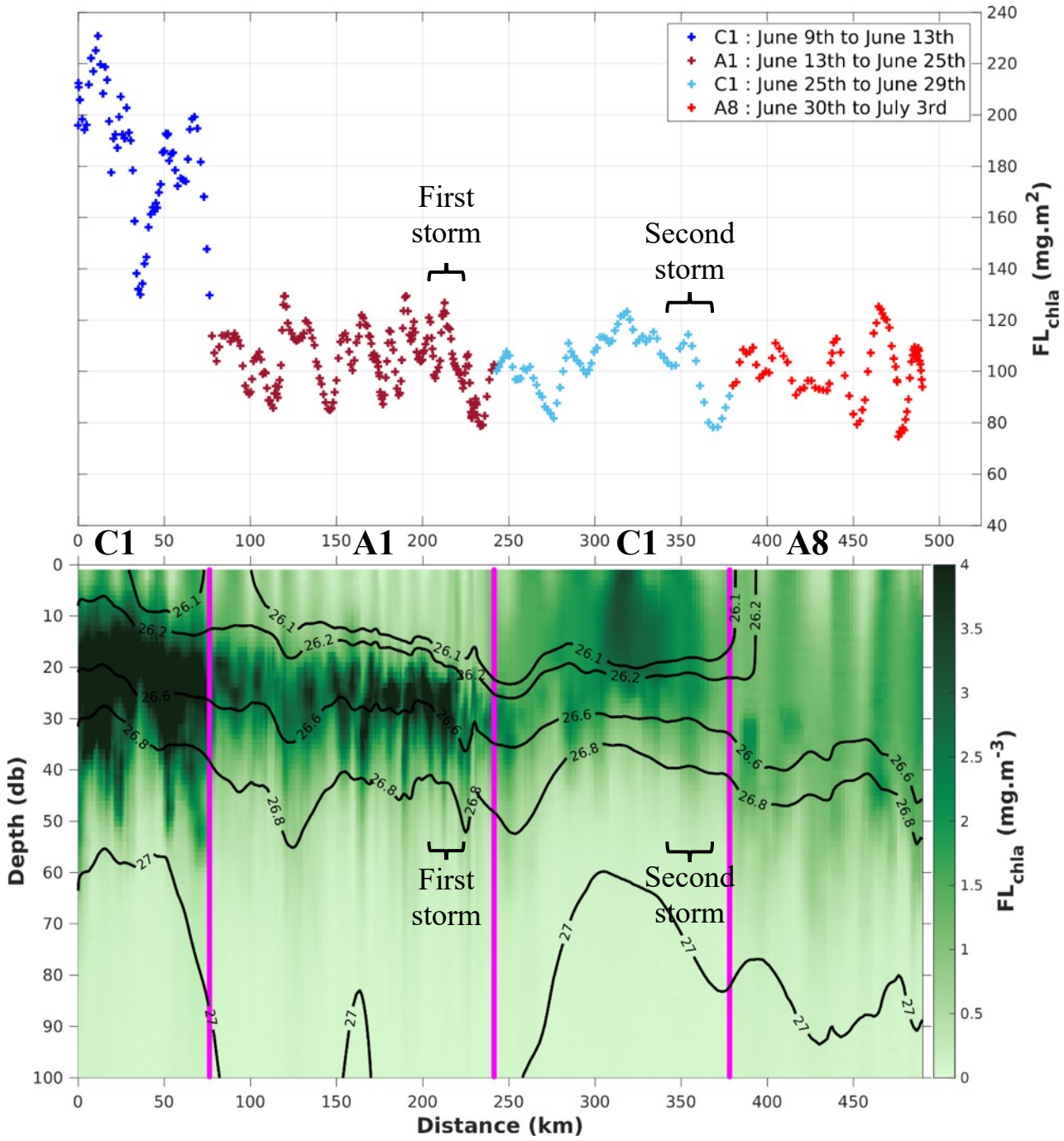
MLD + seasonal thermocline ~ 20-30 m

- **Cyclone** → Eastern North Atlantic Central Water of subpolar (ENACWp)
- **Anticyclone** → ENACWt (subtropical)

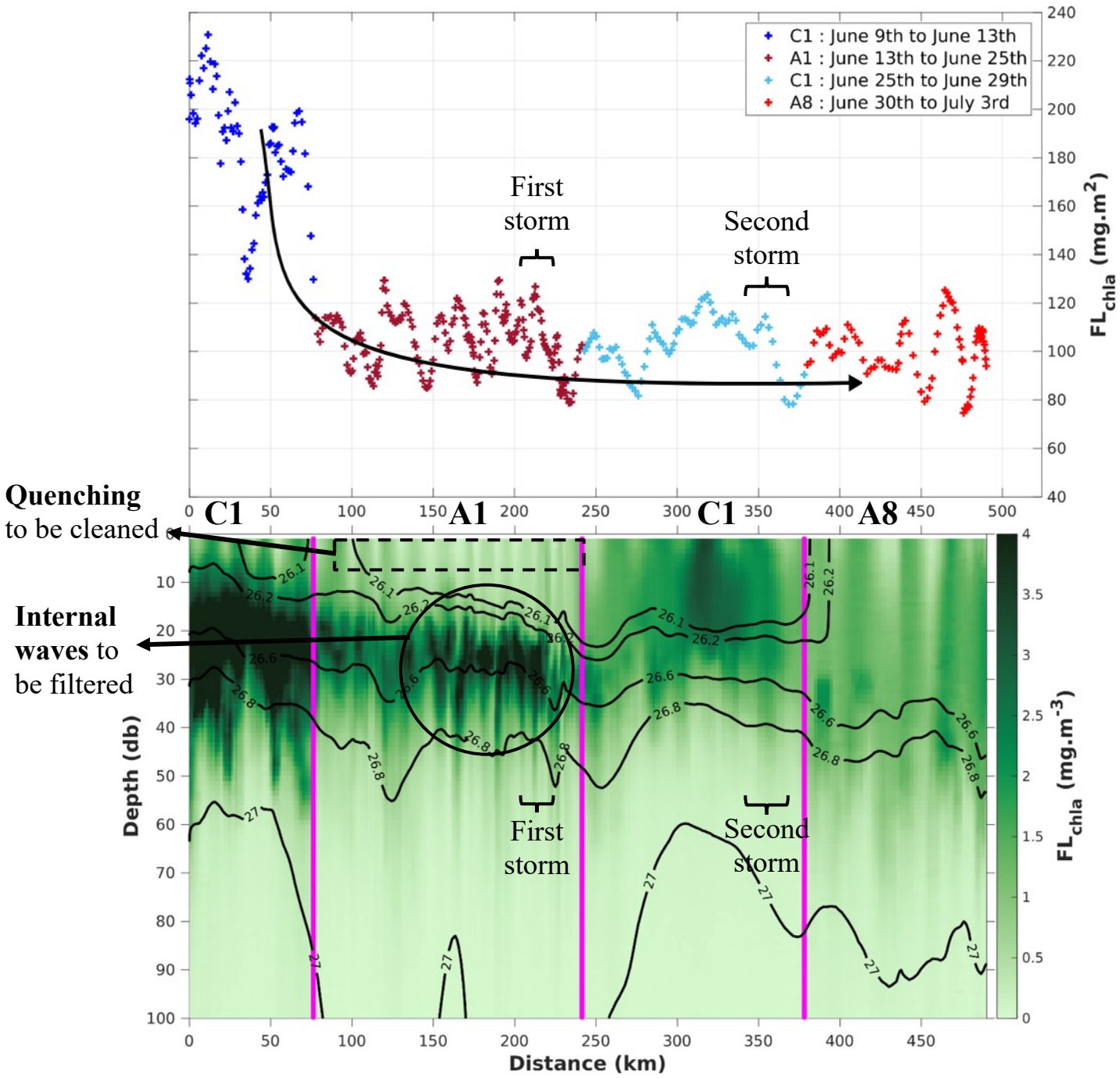
↳ **Marked** salinity fronts

- Isopycnal signal at depth (27.2 - 27.6 kg m^{-3}) and ADT are **inversely related**
- **Greater variability** at A1 than at A8 : frontal dynamics? **filaments**?

Fluorescence of chlorophyll a integrated over the water column (mg m^{-2}) and its vertical section (mg.m $)^{-3}$



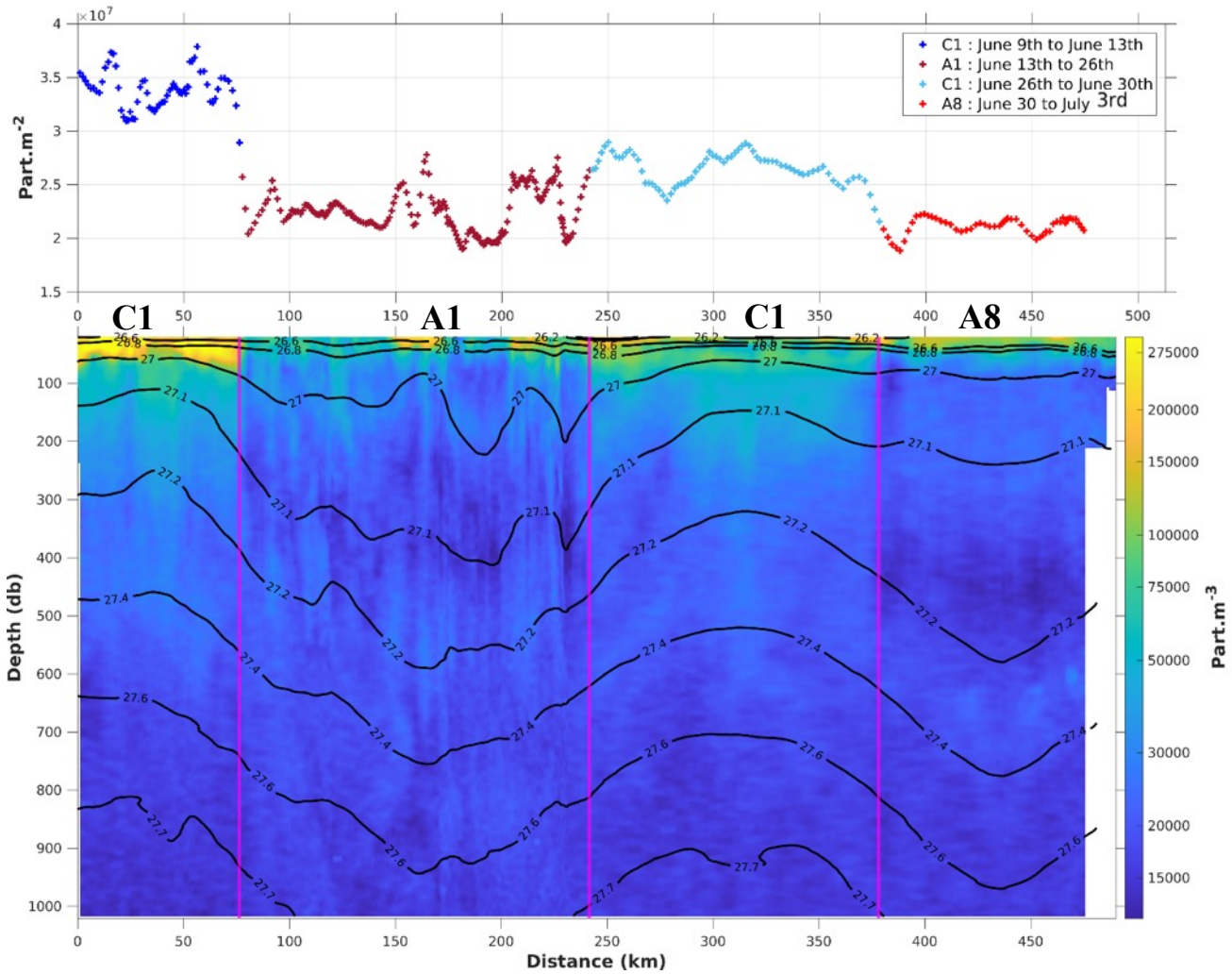
Fluorescence of chlorophyll a integrated over the water column (mg m^{-2}) and its vertical section (mg.m $)^{-3}$

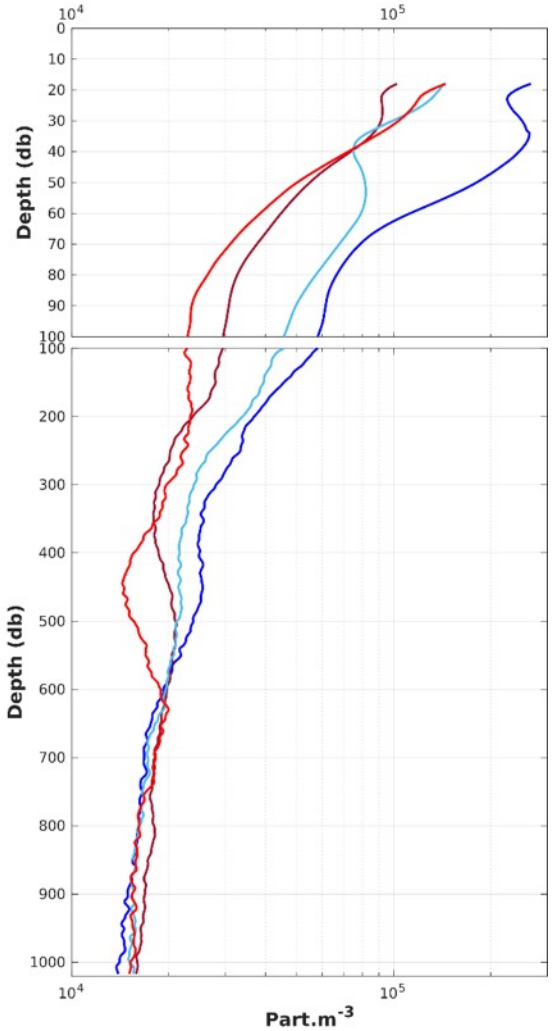


- **Bloom values** at C1, at the start of deployment
- Loss of half of the chla after **crossing the front** between C1 and A1
- **Relatively stable** integrated chla afterward :
  - → In 2 weeks, C1 lost **half of chla**
  - → No significant effects of the two storms: **redistribution without significant loss**

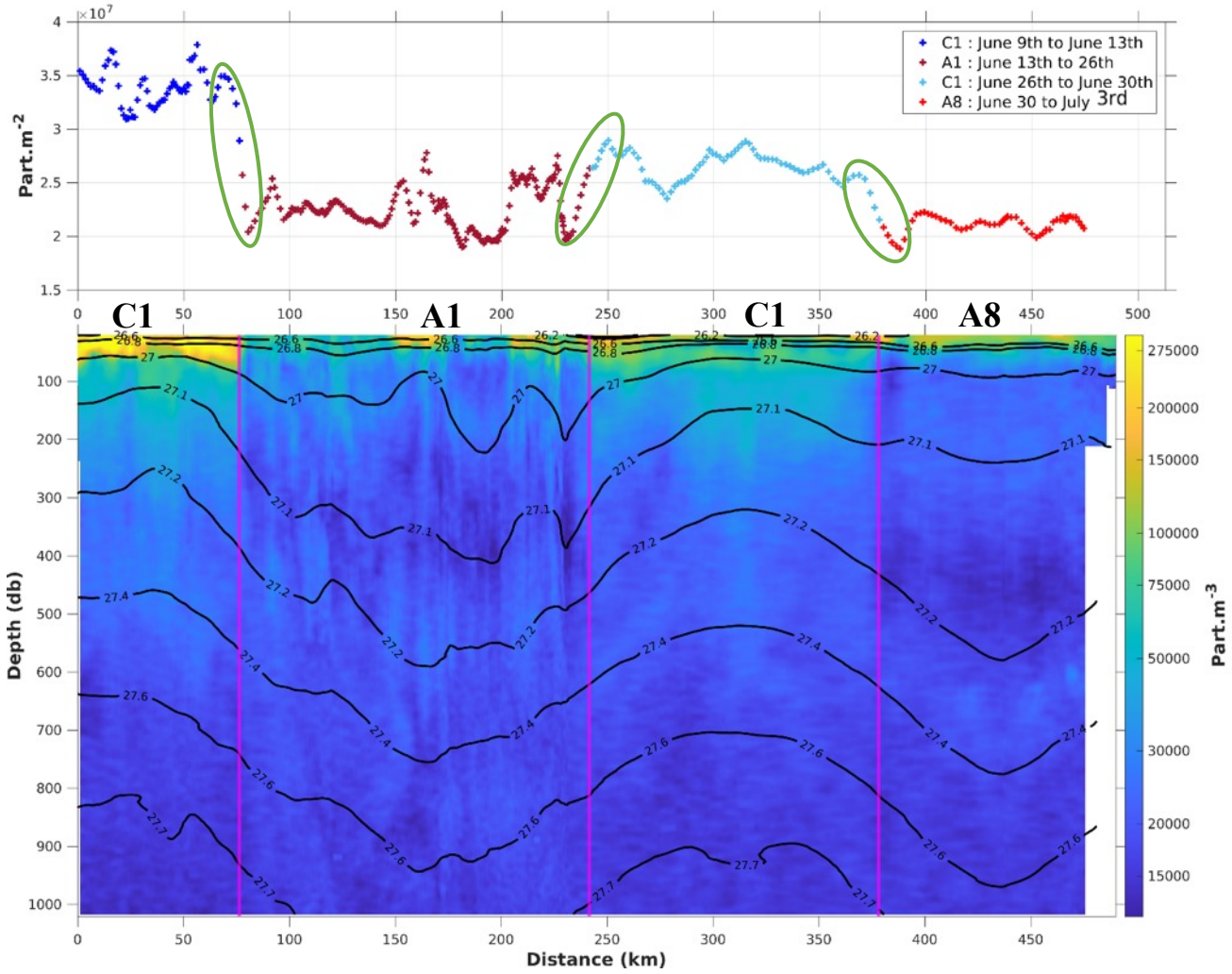
- First storm : **vanished DCM** + chla **homogeneous** in the MLD
- Second storm : **Deepening of** the MLD + **dilution of** the chla

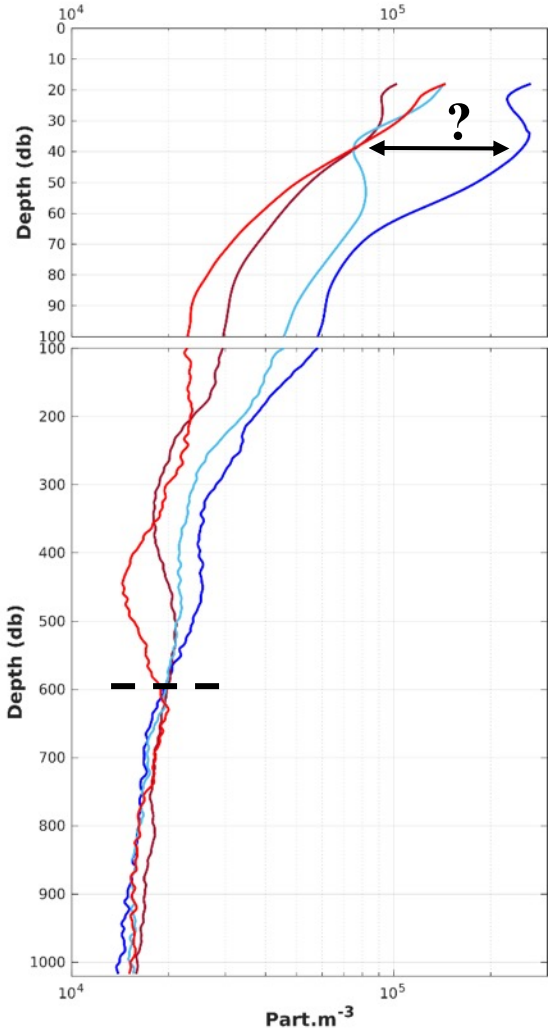
Integrated abundances, vertical section and vertical particle number profiles
UVP6 (80.6 to 102 µm) - SEA092





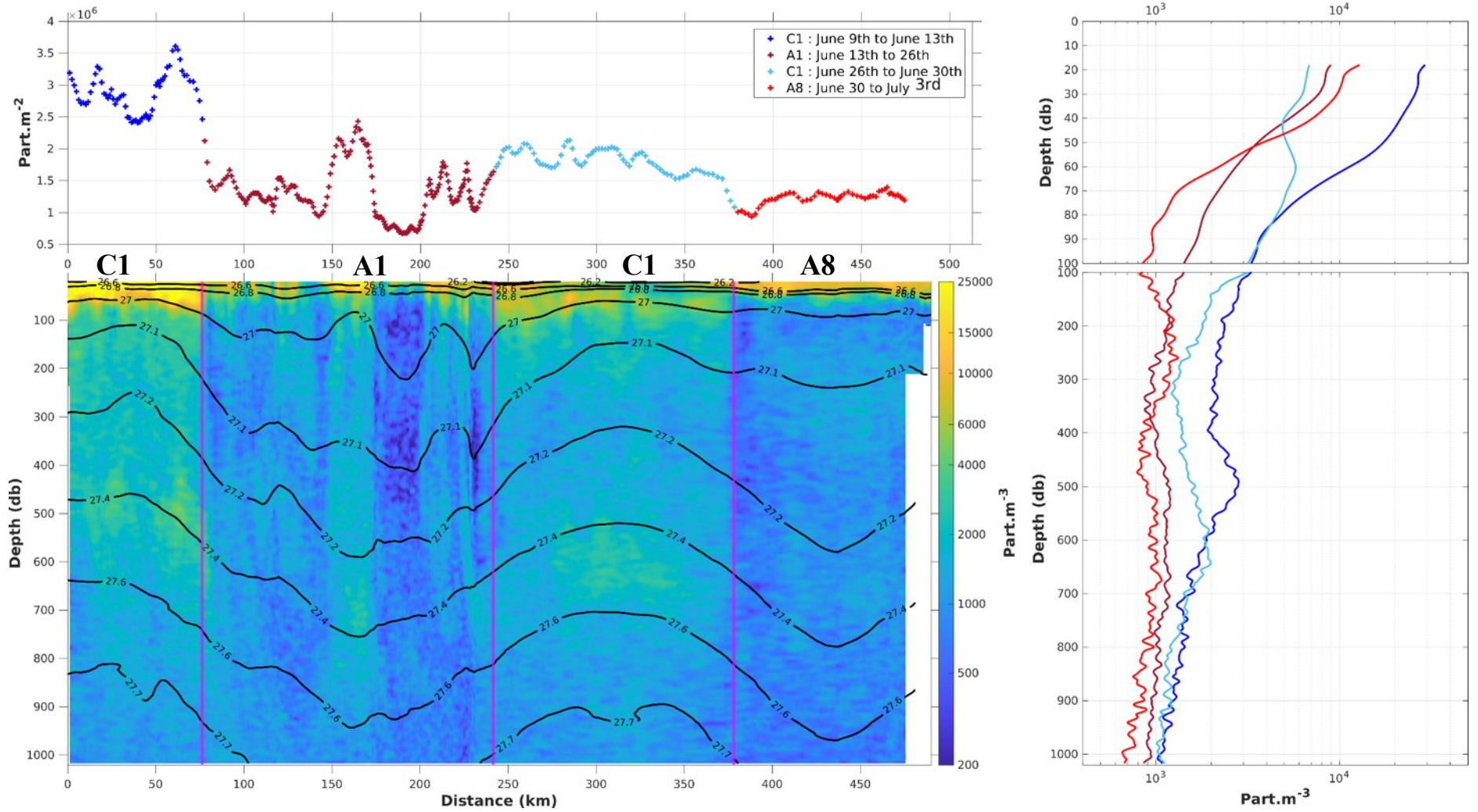
Integrated abundances, vertical section and vertical particle number profiles
UVP6 (80.6 to 102 µm) - SEA092



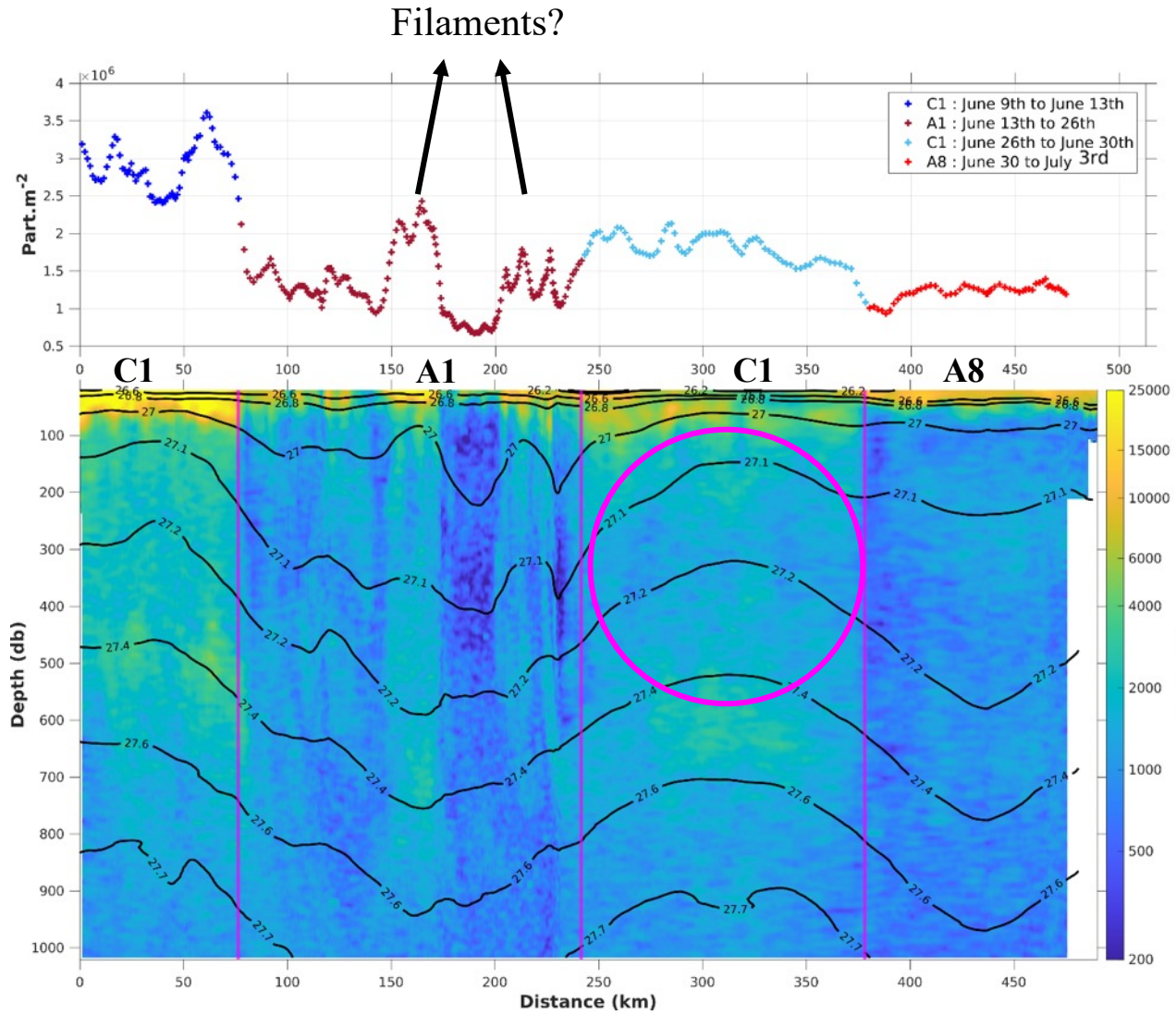


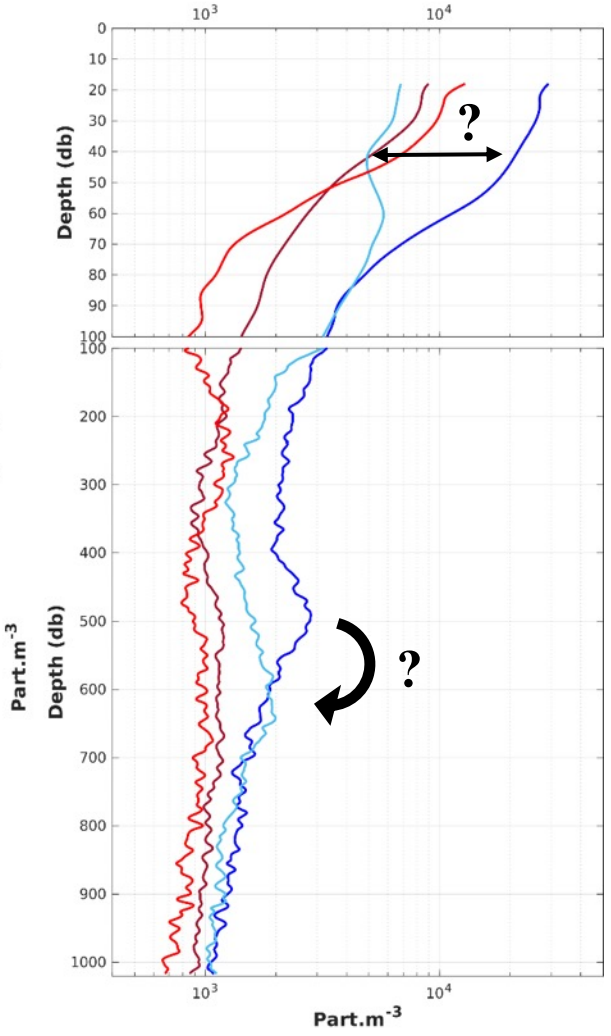
- **Differentiation** cyclone/anticyclone → [particles] **more important** in C1 until 600m
- **Below** 600m, **equivalent** [particules] on average between the different systems
- **Marked fronts**, particularly between C1 and A1 → **[particles]/4** in A1 at the surface
- **Large variability** inside A1
- C1 (26-30 June) → Surface [particles] **divided by 3 on average: where are they?**

Integrated abundances, vertical section and vertical particle number profiles
UVP6 (256 to 323 µm) - SEA092



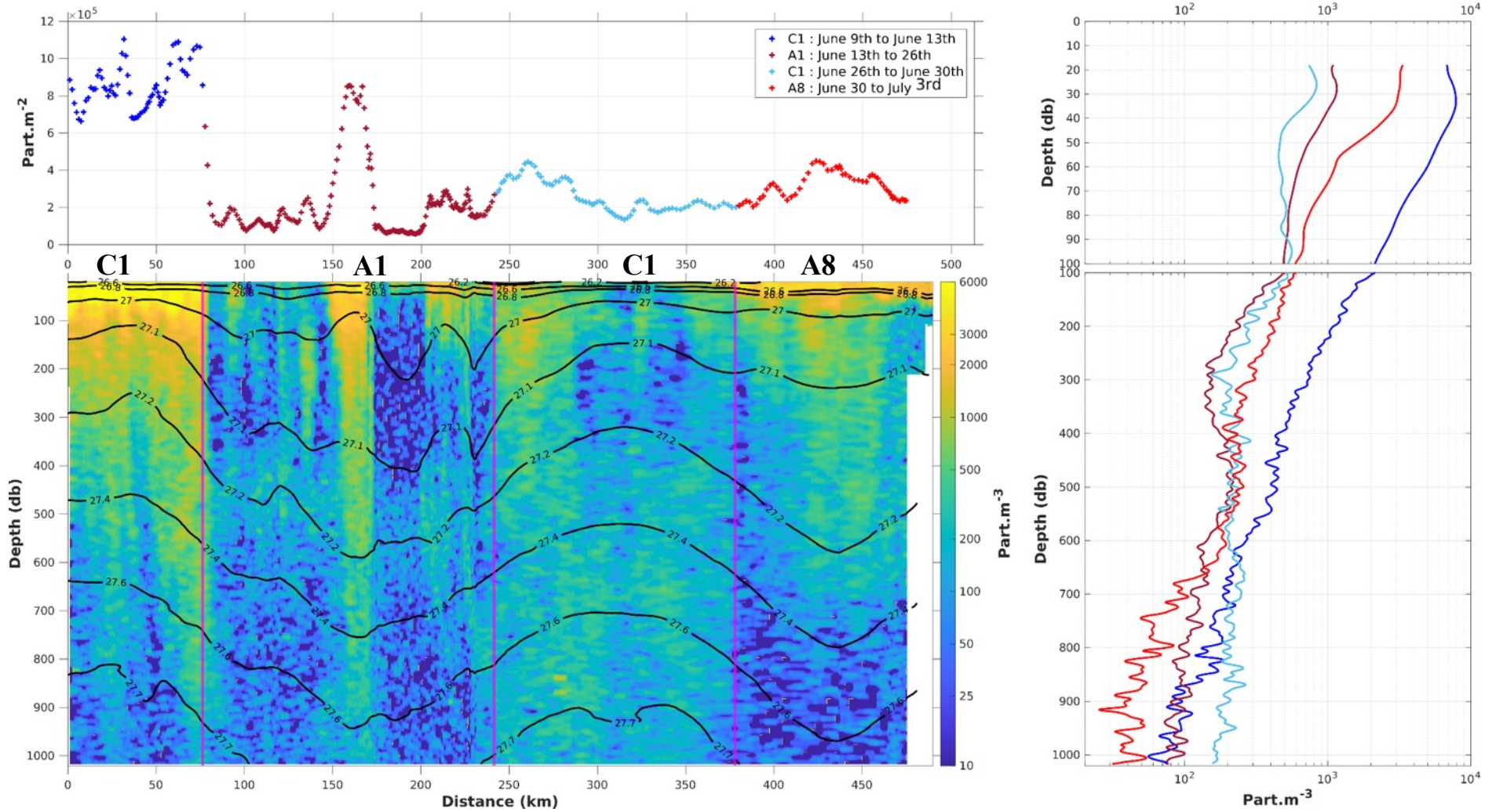
Integrated abundances, vertical section and vertical particle number profiles
UVP6 (256 to 323 µm) - SEA092



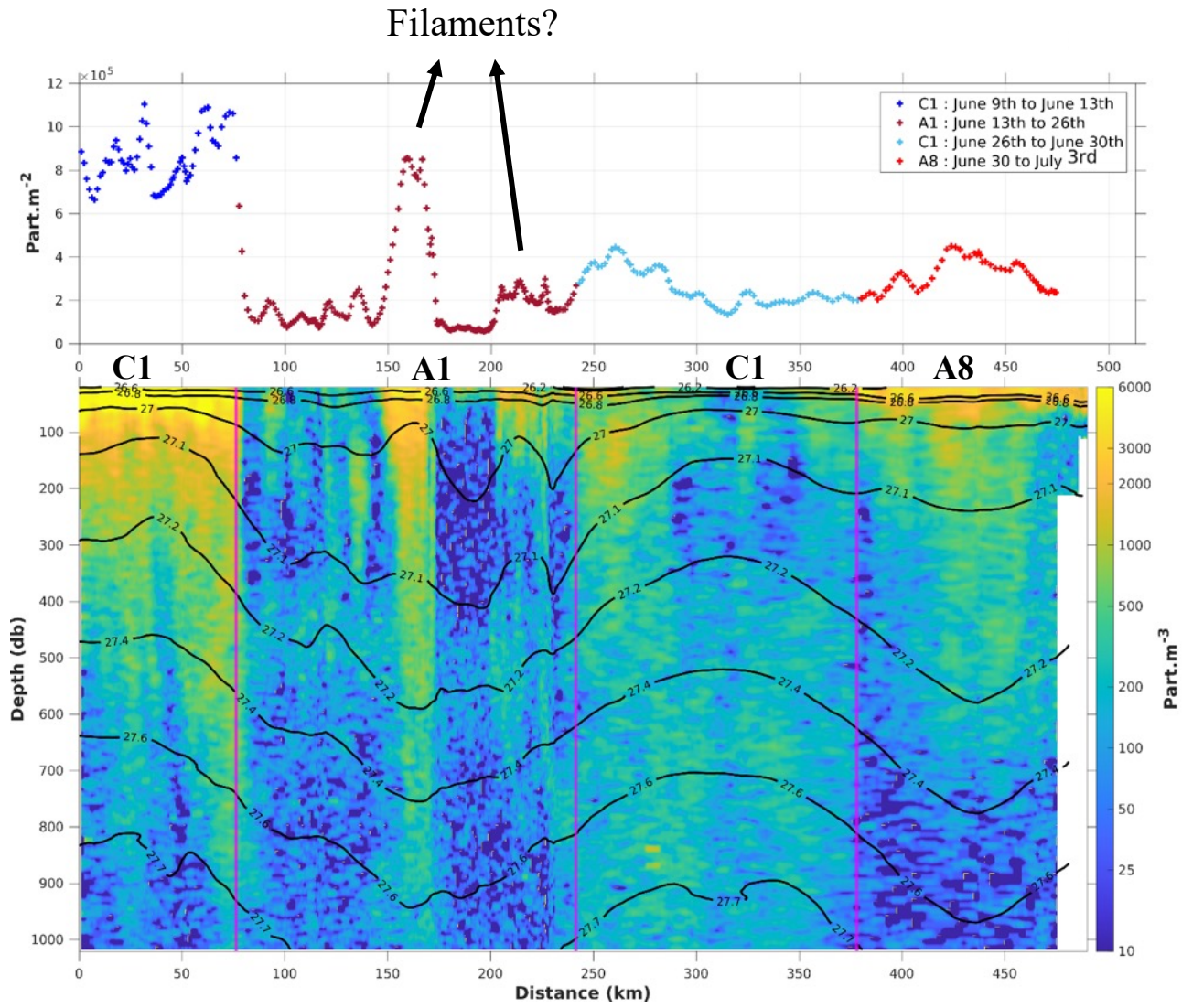


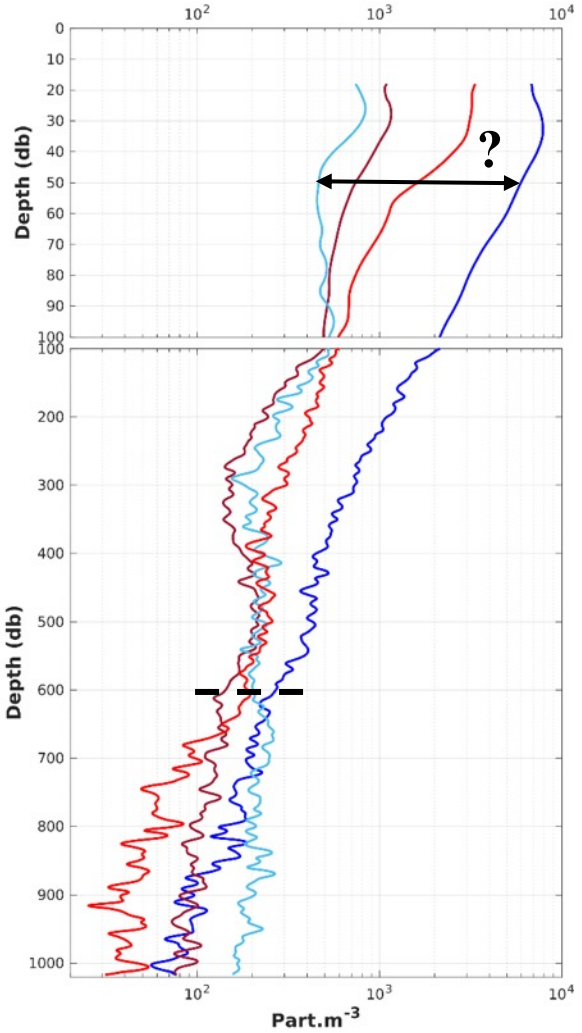
- C1 (26-30 June) → Surface [particles] **divided by 4 on average: where are they?**
- **Increased** [particles] at **depth** in C1:
  - First pass → around 500 db
  - Second pass → around 650 db
- **Small-scale** (~20 km) increased [particles] in A1 → **filaments** ?
- **Decreased** [particles] during the second pass through C1 between 100 and 600 db

Integrated abundances, vertical section and vertical particle number profiles
UVP6 (645 to 1290 µm) - SEA092



Integrated abundances, vertical section and vertical particle number profiles
UVP6 (645 to 1290 µm) - SEA092

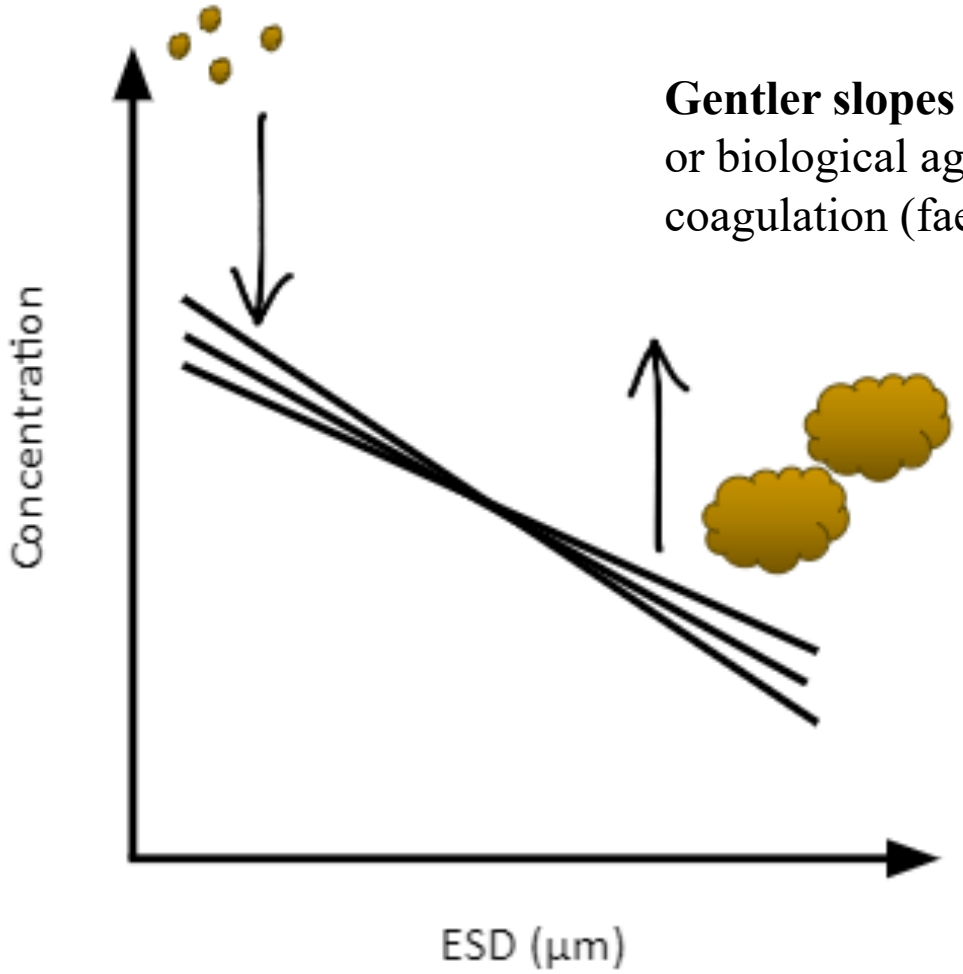




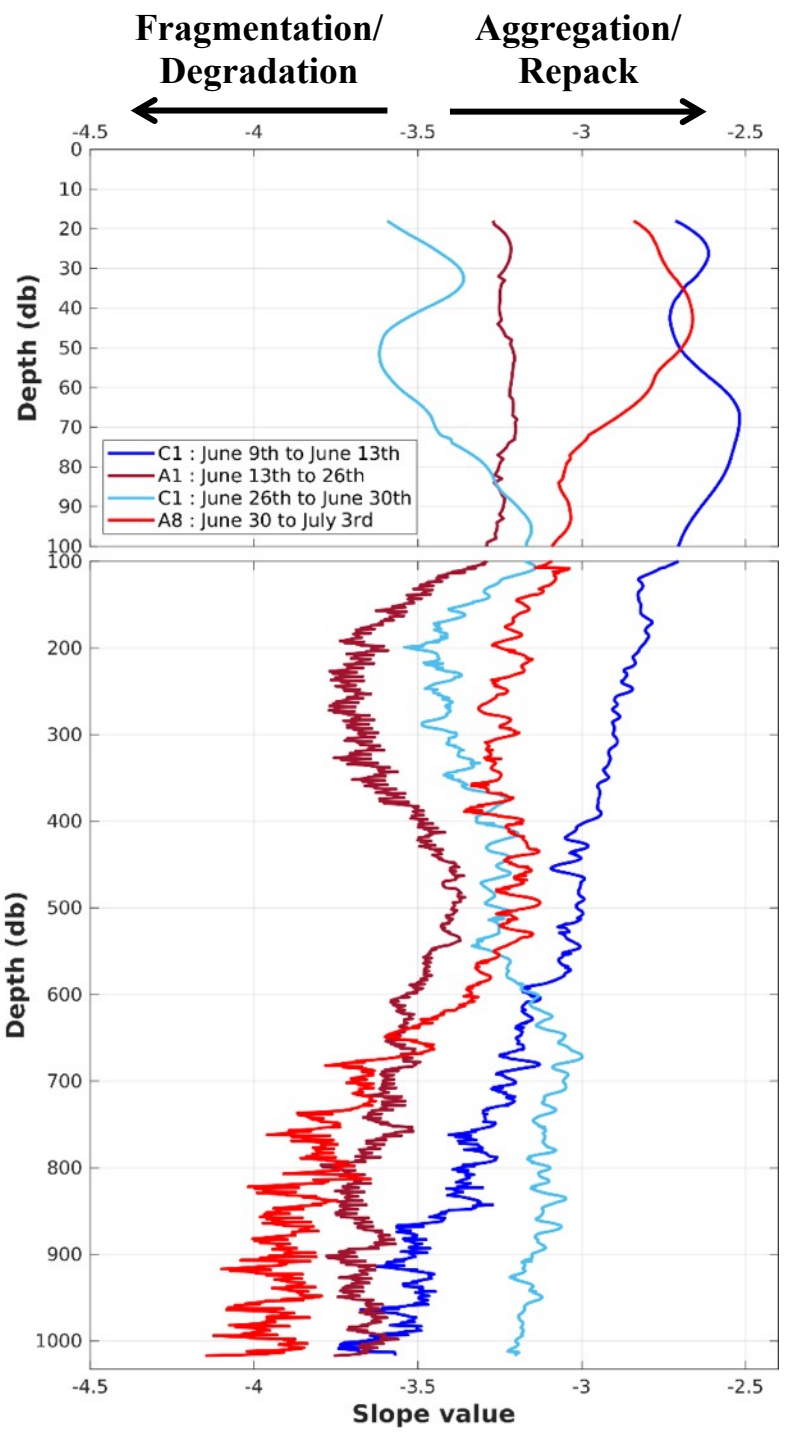
- C1 (26-30 June) → Surface [particles] **divided by 10 on average: drastic drop until 600 db, where are they?**
- **Greater** [particles] **below 600 db** during the second pass through C1
- **No more** mid-depth (500-600 db) [particles] **maxima** in C1
- More pronounced first « filament » in A1
- **Greater** integrated [particles] in A8 than in A1 or C1 (26-30 June)

Spectral slopes of particles distribution

Steeper slopes = biological (grazing), physical (turbulence) or chemical (remineralisation of OM) disintegration



Gentler slopes = chemical or biological aggregation/ coagulation (faecal pellets)



Spectral slopes → aggregation/disaggregation dynamics

Marked differences between the three systems :

→ C1 (9-13 June) vs C1 (26-30 June) :

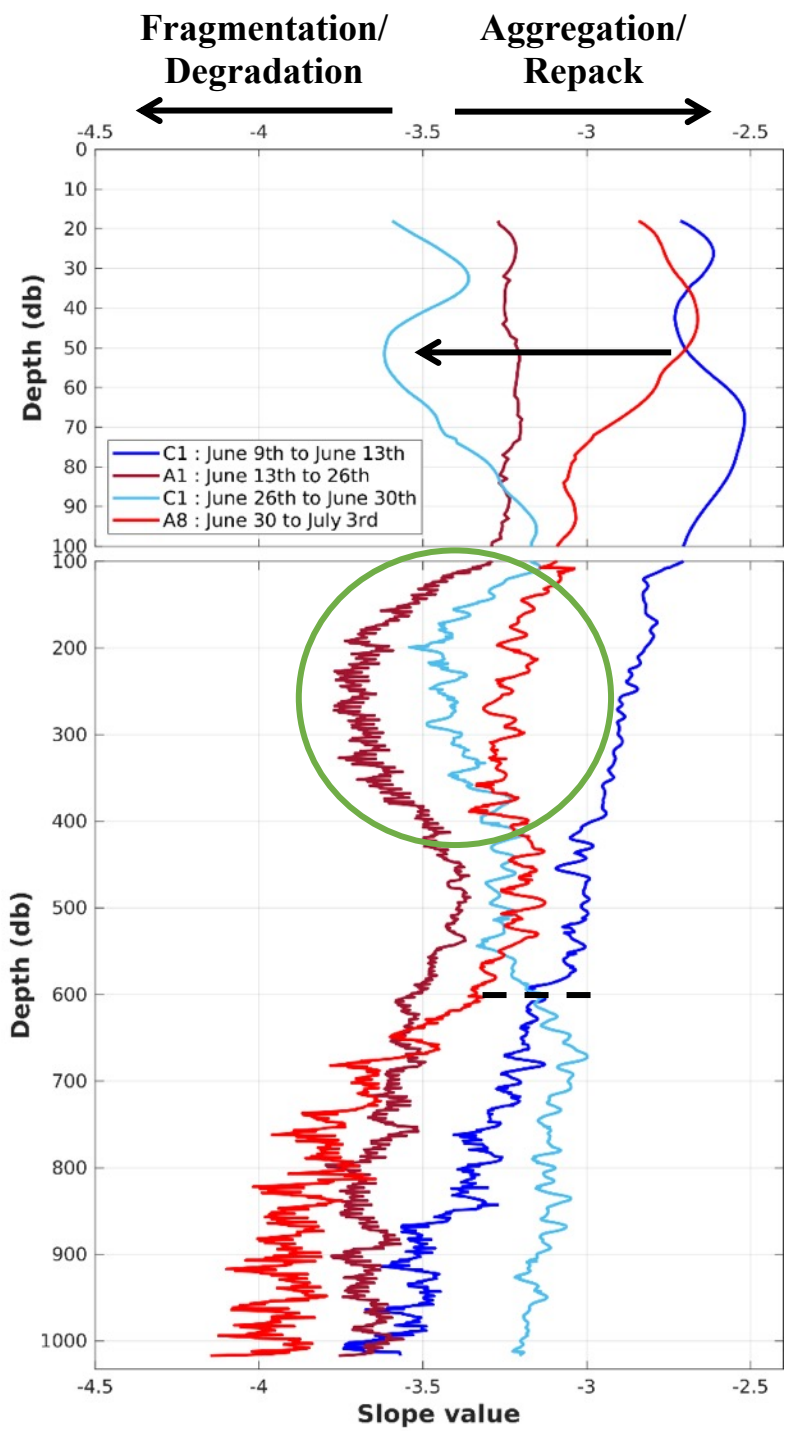
- **Steeper** slopes during the second pass through C1, especially above 100 db

- **Gentler** slopes below 600 db

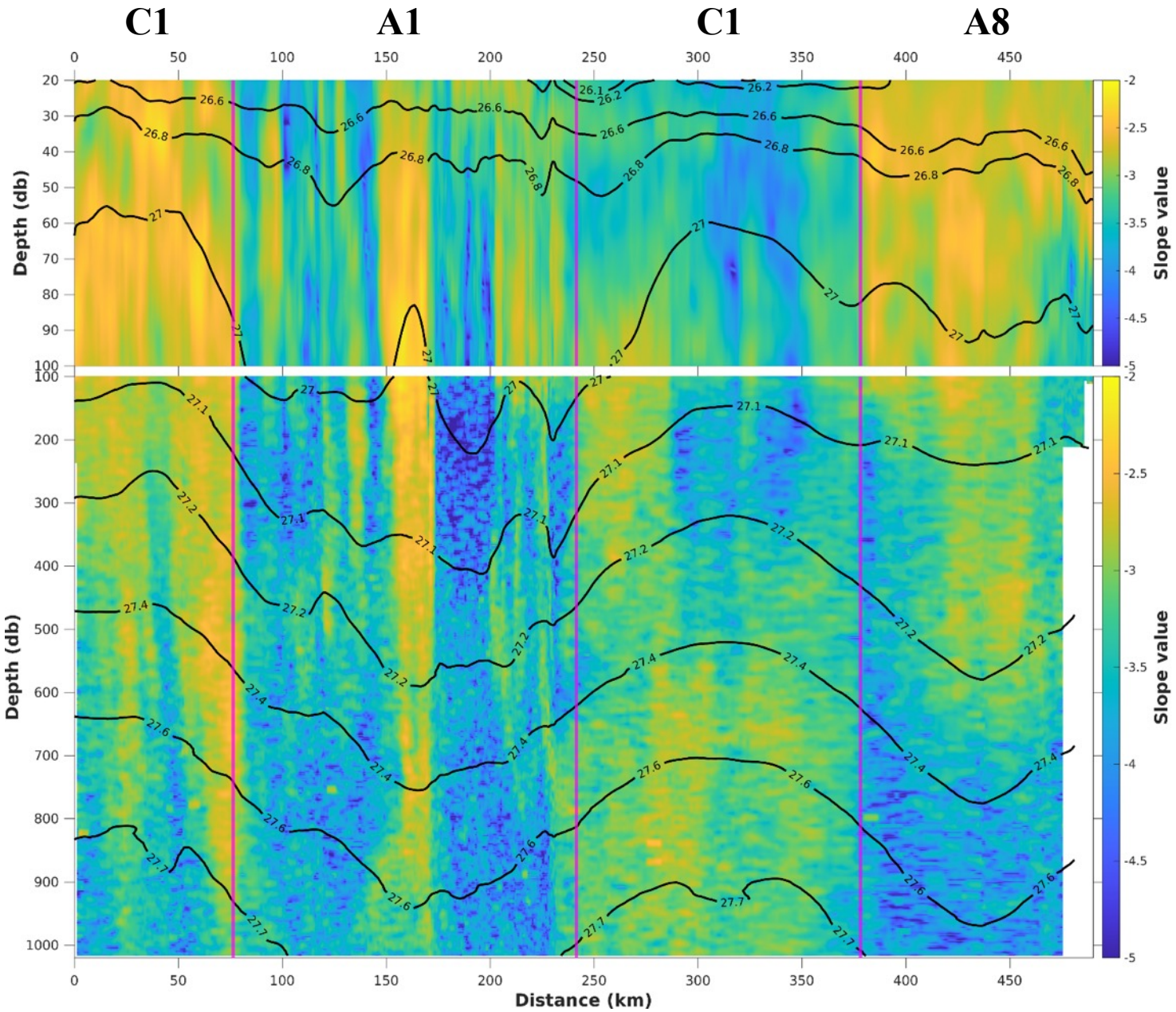
↳ **Aggregation/repack at depth of the particles that have been fragmented above ?**

→ **steeper** slopes in A1/A8/C1 second pass 100-400 db

↳ **Possible signs increased biological activity (zooplankton grazing on particles)**



Spectral slopes → aggregation/disaggregation dynamics

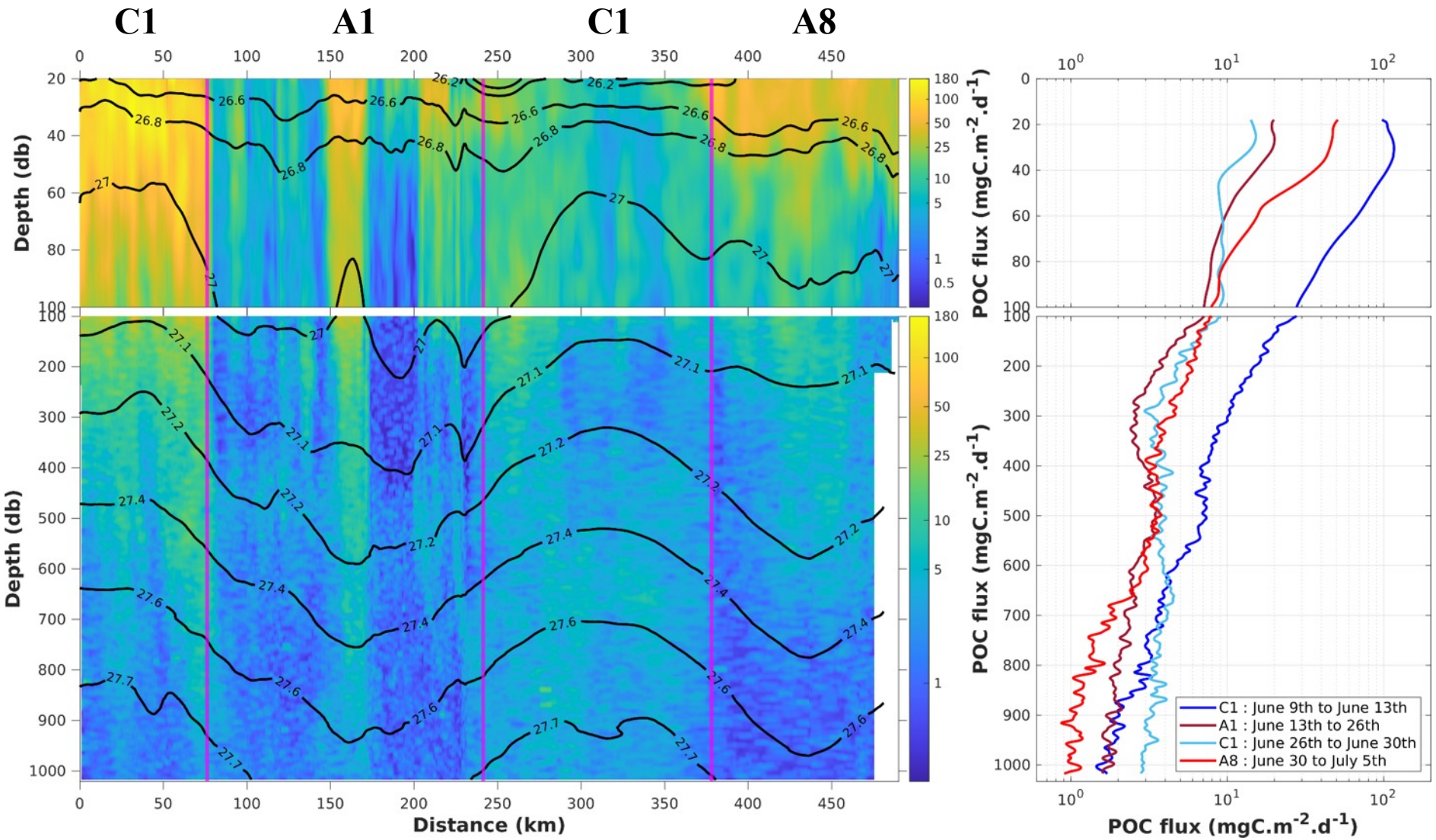


Marked differences between the three systems, but also within them at small scales

$$\textbf{POC flux} = \sum_{\textit{Particule size class } i} \boldsymbol{C(i) \times A \times d(i)^b}$$

(Guidi et al. 2008)

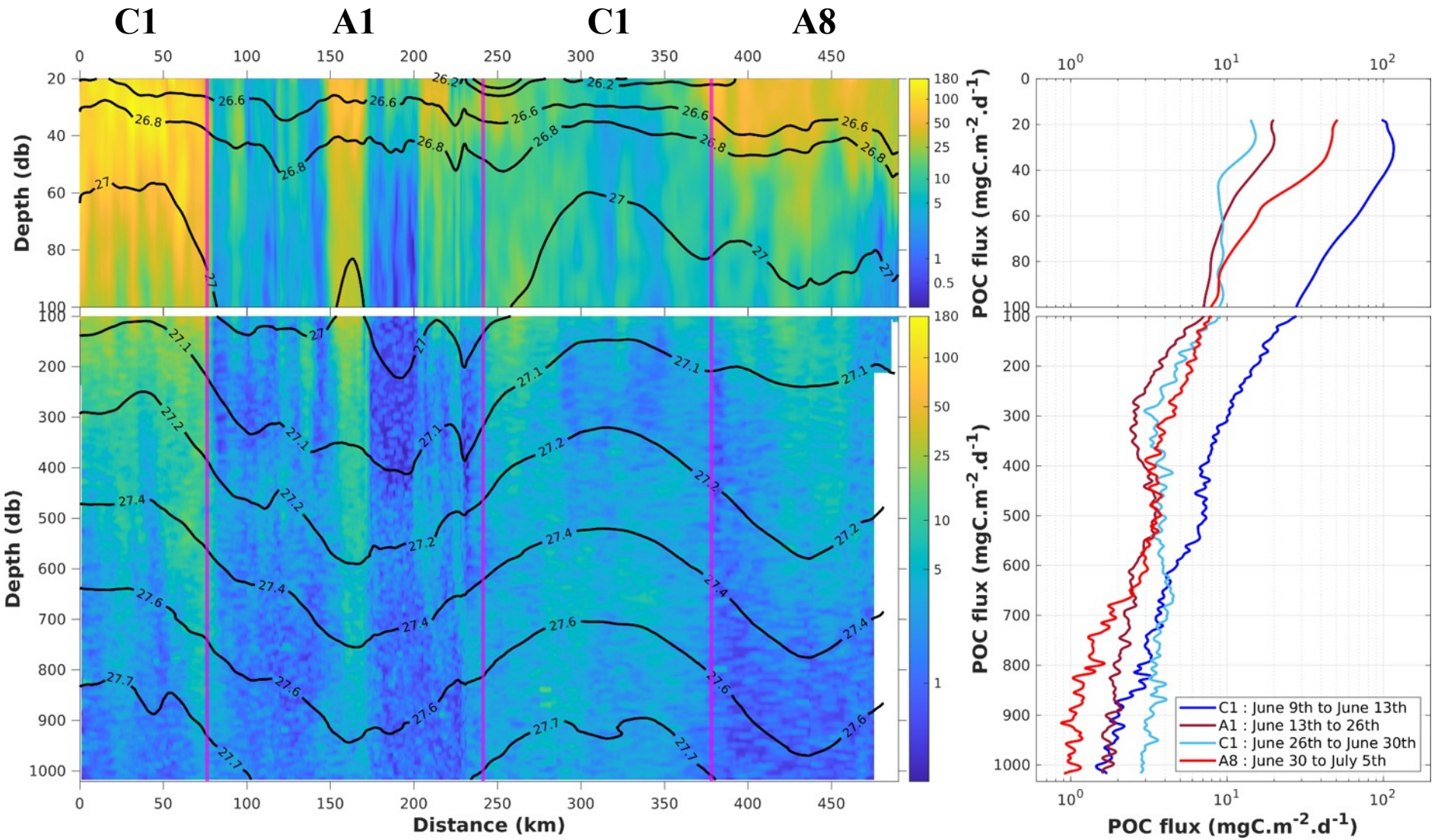
C(i) = Concentration of particles ($\#.l^{-1}$)
d(i) = diameter (mm)
A = 12.5
b = 3.81



$$\text{POC flux} = \sum_{\textit{Particule size class } i} C(i) \times A \times d(i)^b$$

(Guidi et al. 2008)

C(i) = Concentration of particles ($\#.l^{-1}$)
d(i) = diameter (mm)
A = 12.5
b = 3.81



<u>Same patterns than before :</u>

- **Variability at sub-mesoscale** in each systems
- filaments in A1
- Ten fold decrease of POC flux in C1 (26-30 June) above 100 db
- **more important** POC flux below 600 db in C1 ten days latter

(work in progress...)

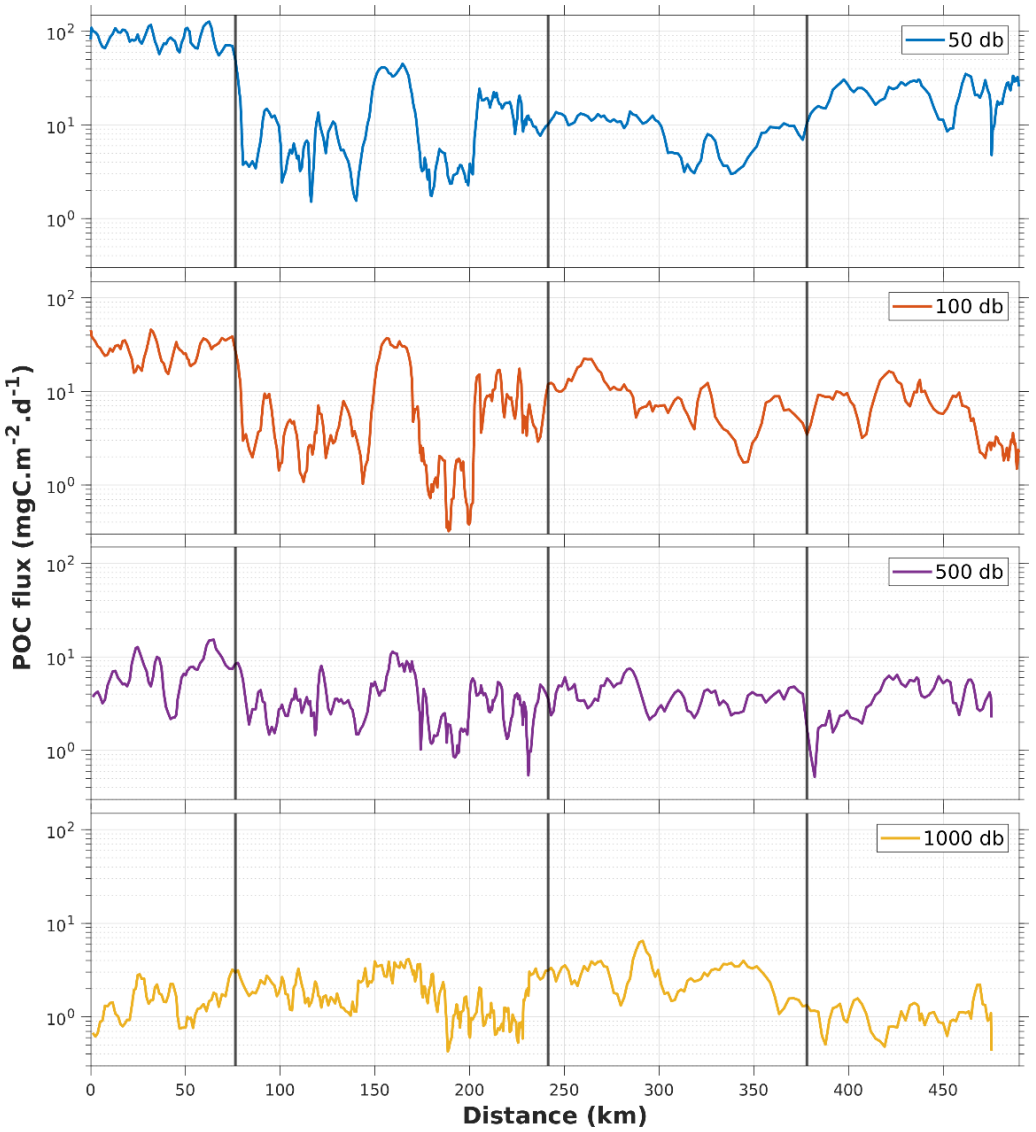
Conclusions and outlook

- UVP/glider coupling → high-resolution information on the **variability** of particles **distribution**, aggregation/fragmentation **dynamics** and **fluxes**

- POC flux variability → **factor of 10-20** on a few km, even at depth

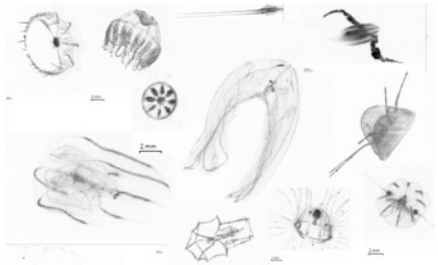
  ↳ **sub-mesoscale patterns** in A1 : fronts/filaments?

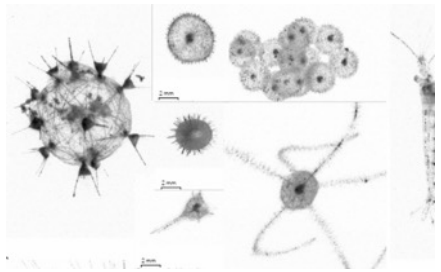
  ↳ **drastic drop** of [particles] on second pass through C1

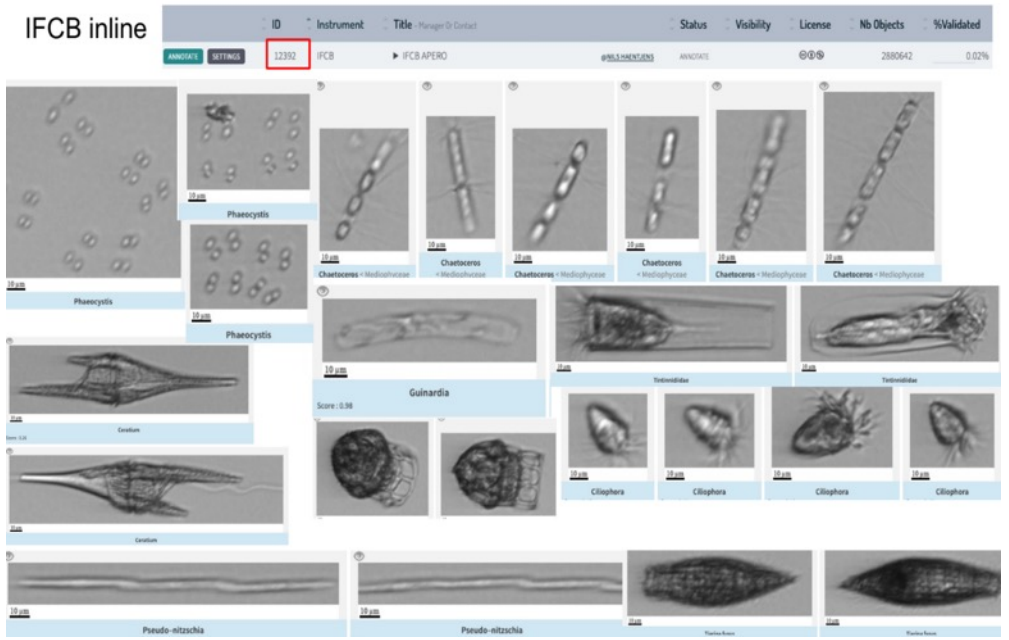


Conclusions and outlook

- UVP images : find out the proportion of living and non-living particles



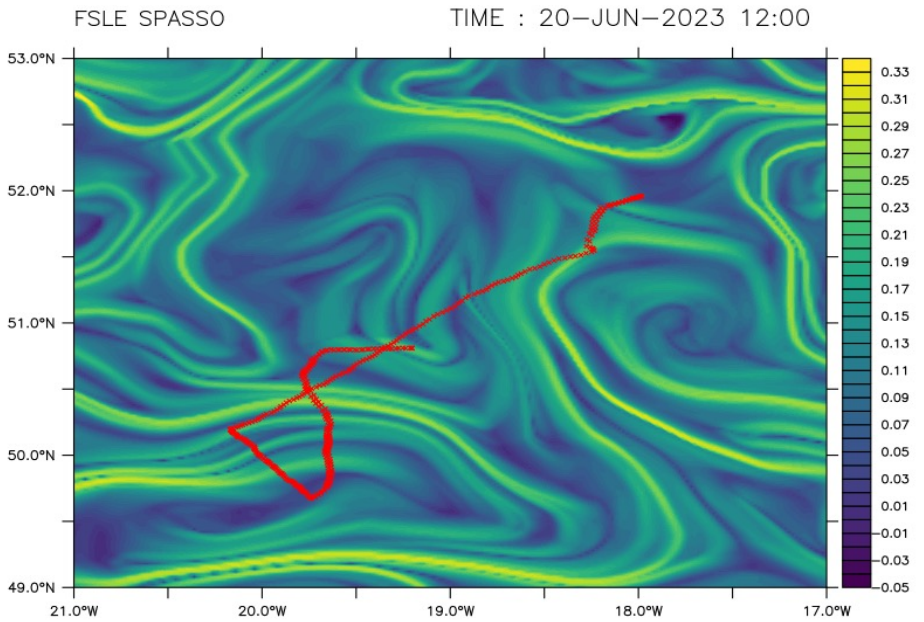


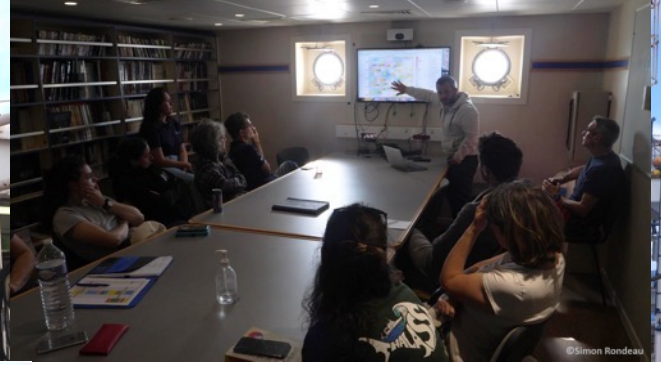


- Find the contribution of each size class to the total flux of POC

- Compare with results obtained from particle traps

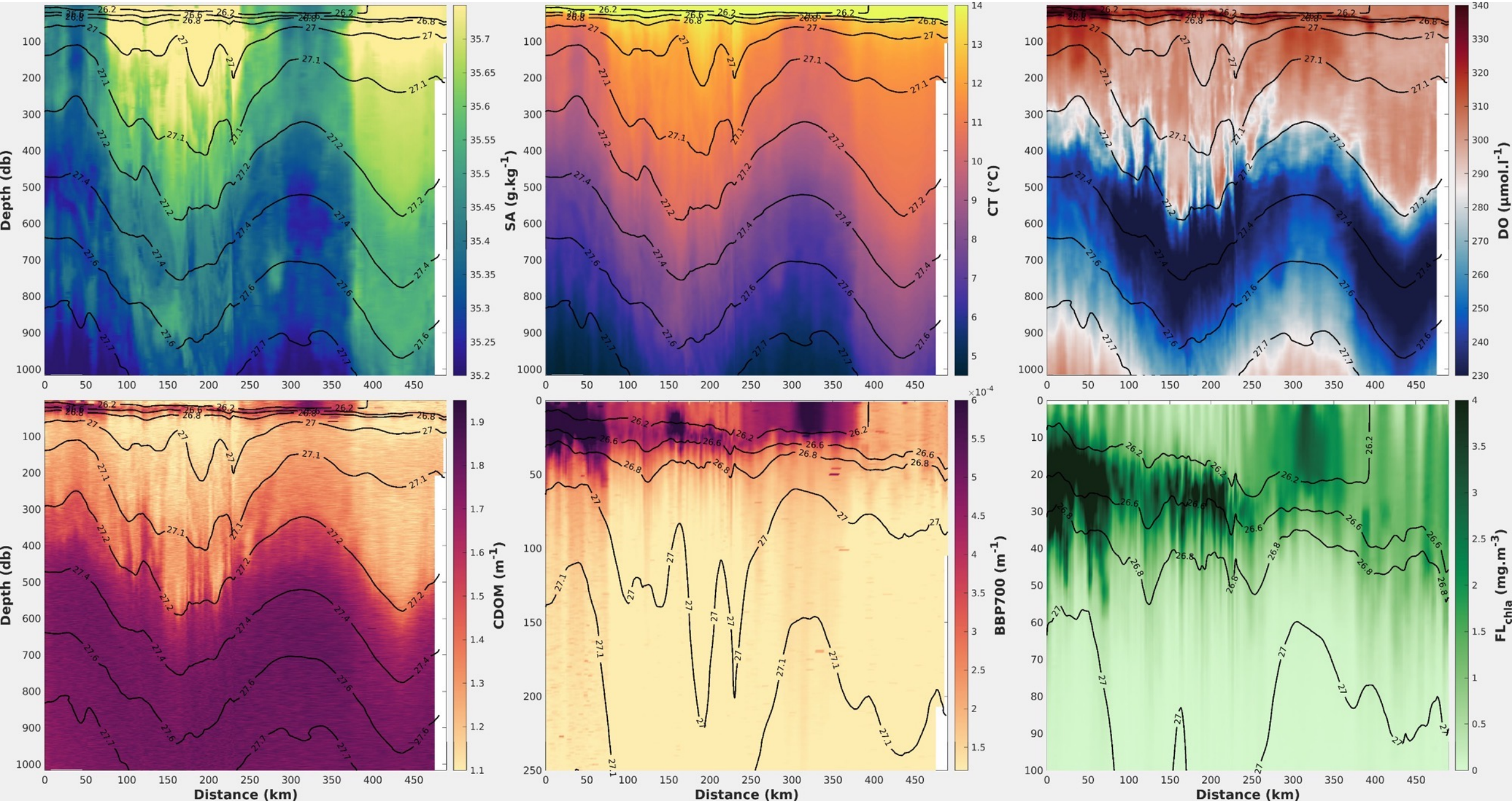
- Lagrangian diagnostic on the origin of the detected filaments

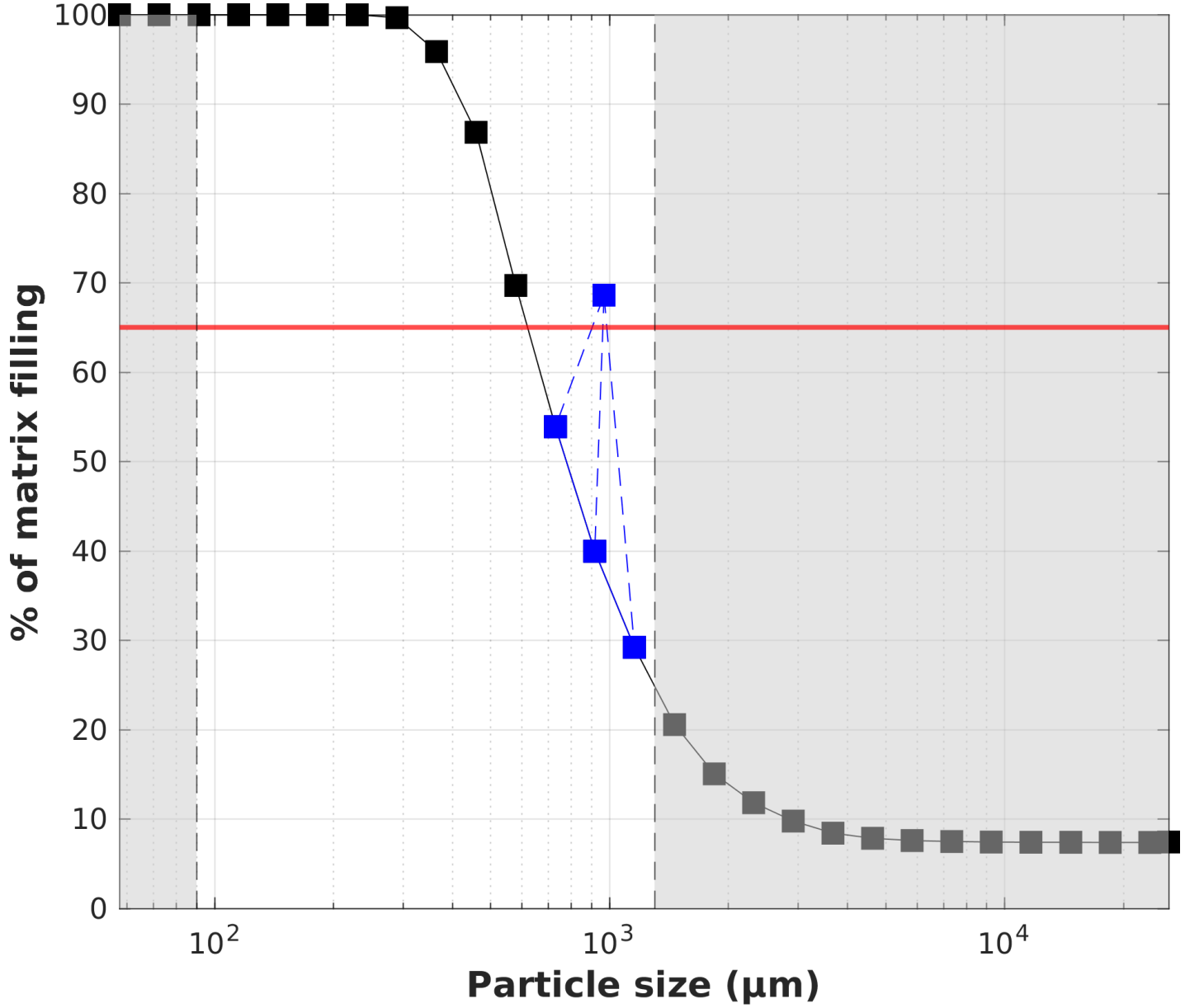


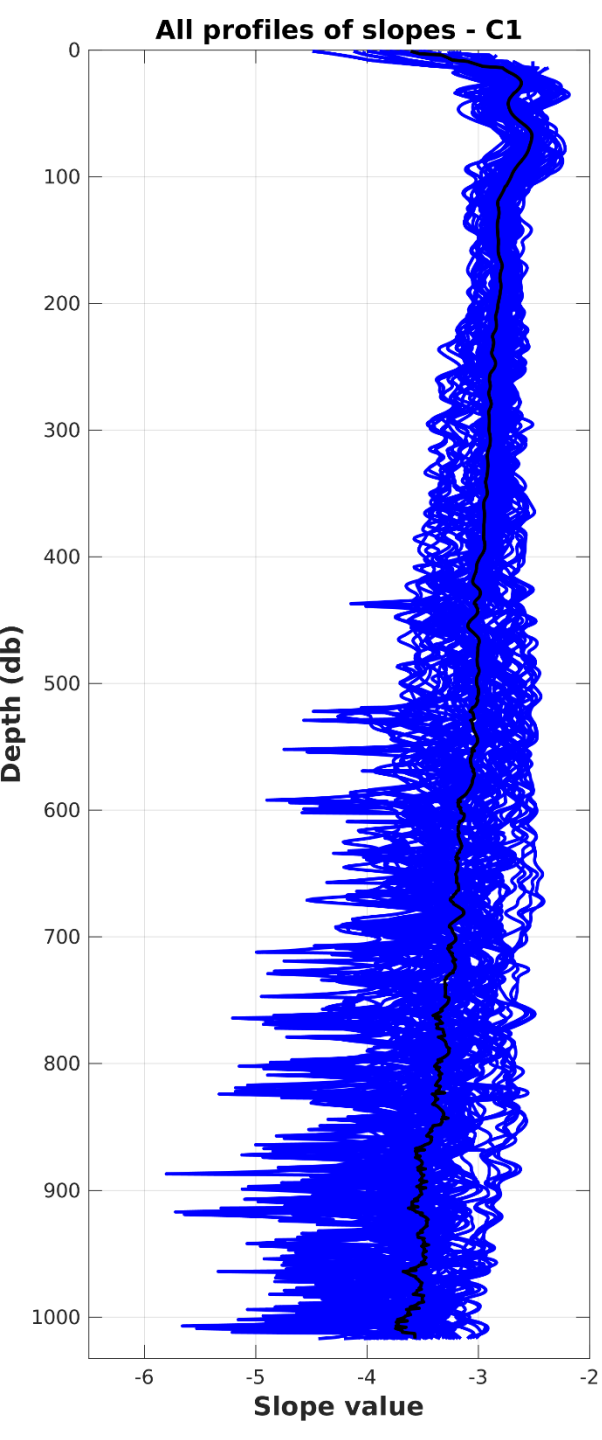


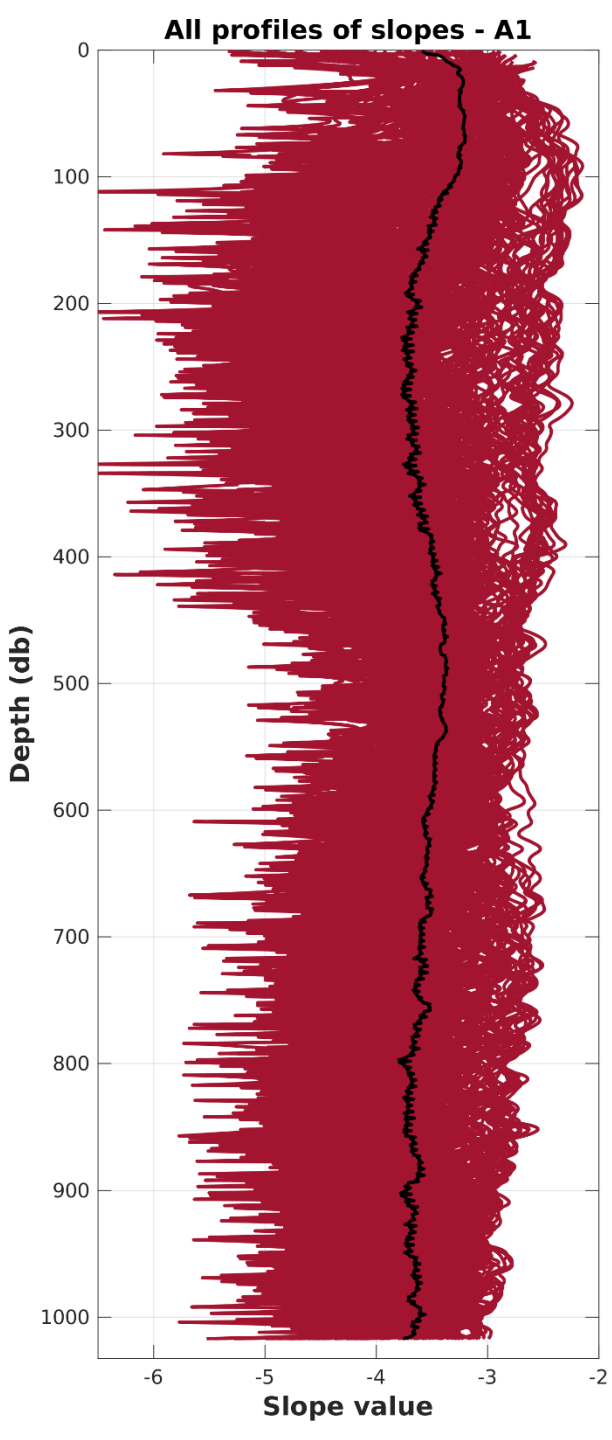
Thank you for your attention

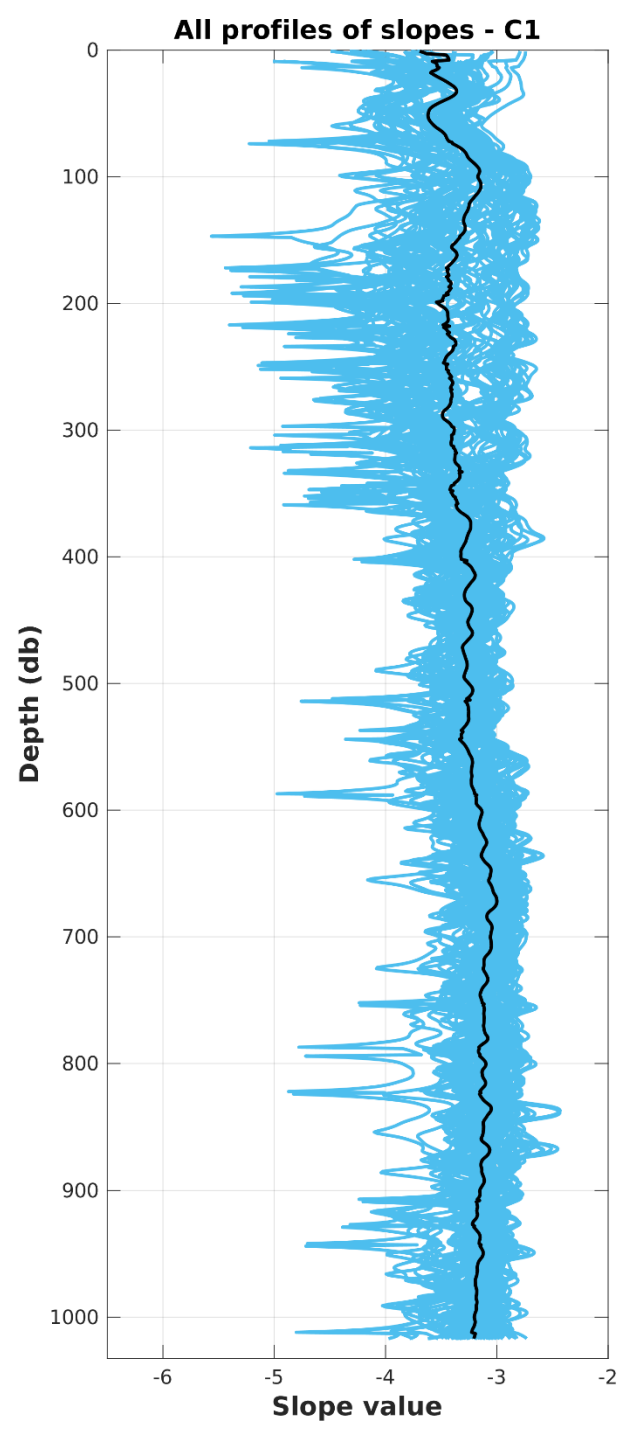
APPENDIX

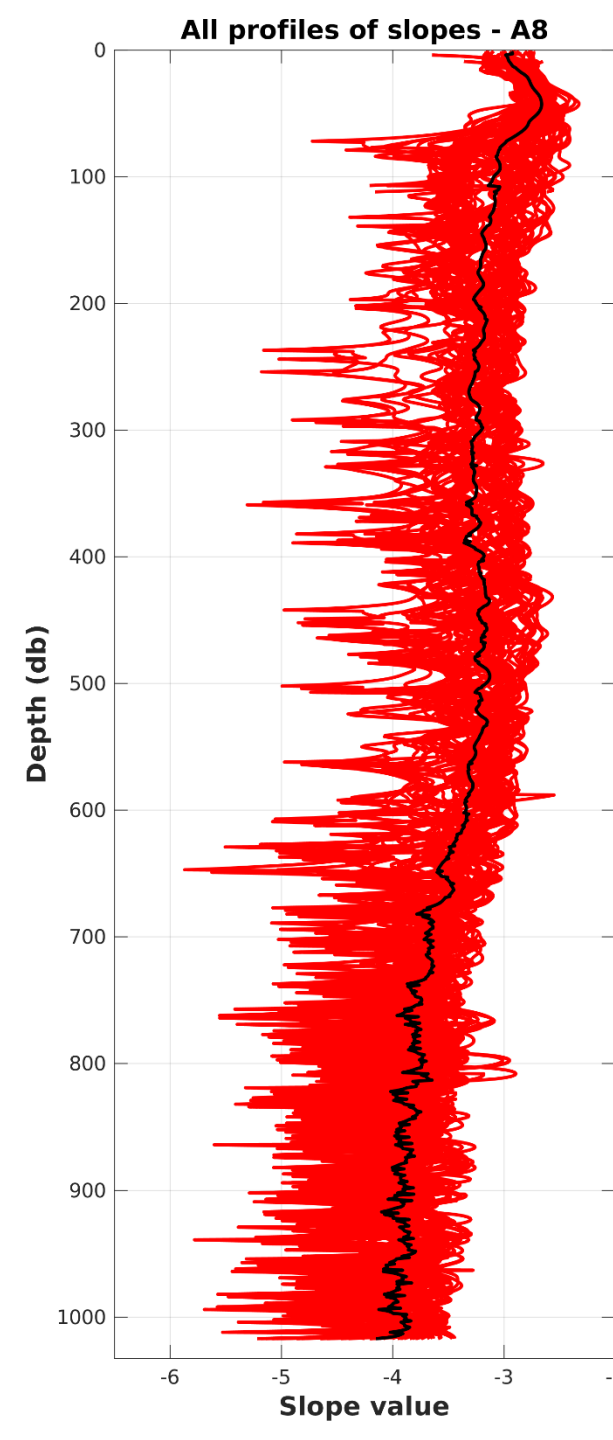

Depth (db)
SA (g.kg^{-1})
CT (°C)
DO (µmol.l^{-1})
CDOM (m^{-1})
BBP700 (m^{-1})
FL$_{chla}$ (mg.m^{-3})
Distance (km)
Distance (km)
Distance (km)

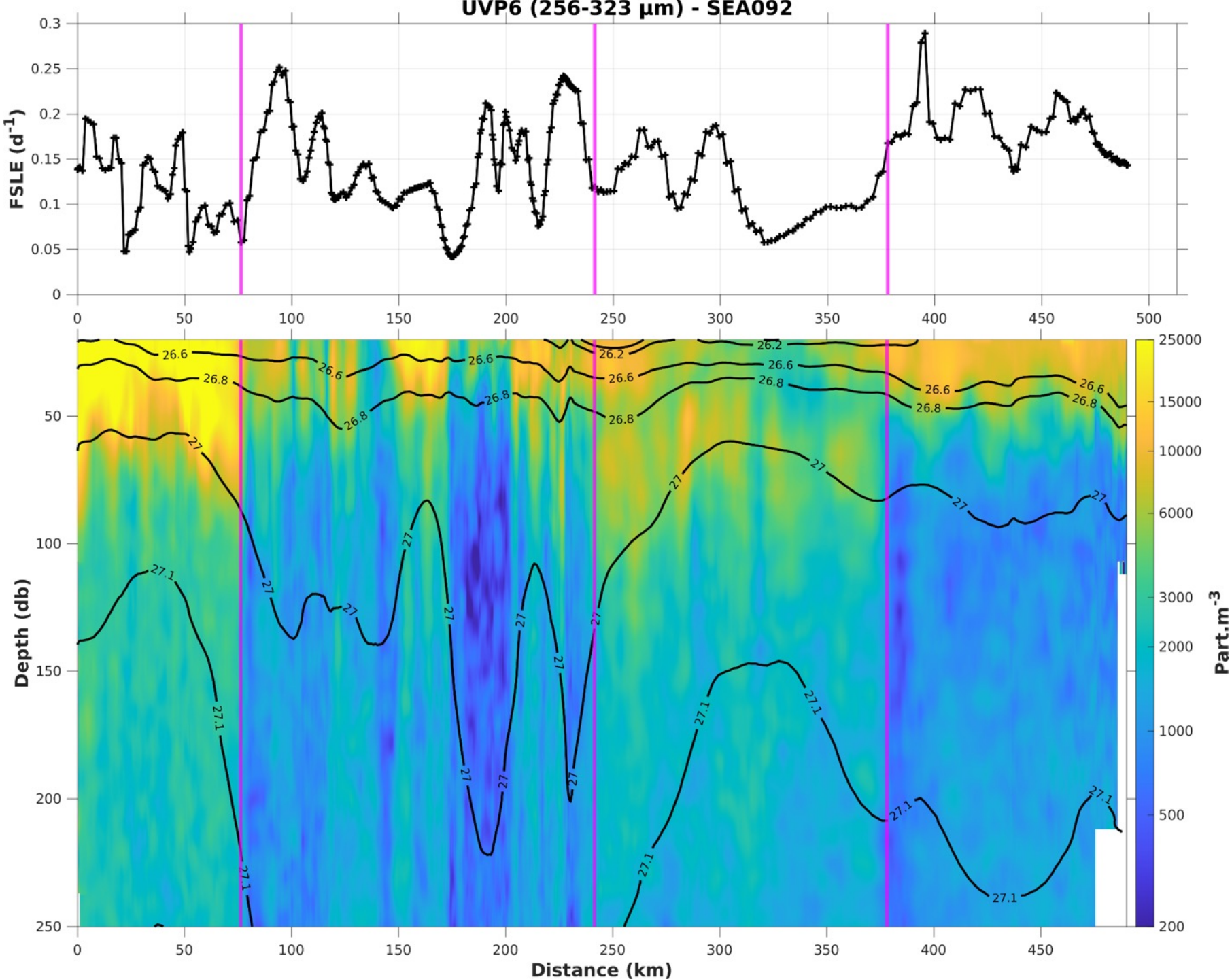

100
90
80
70
60
50
40
30
20
10
0
% of matrix filling
10^2
10^3
10^4
Particle size (µm)

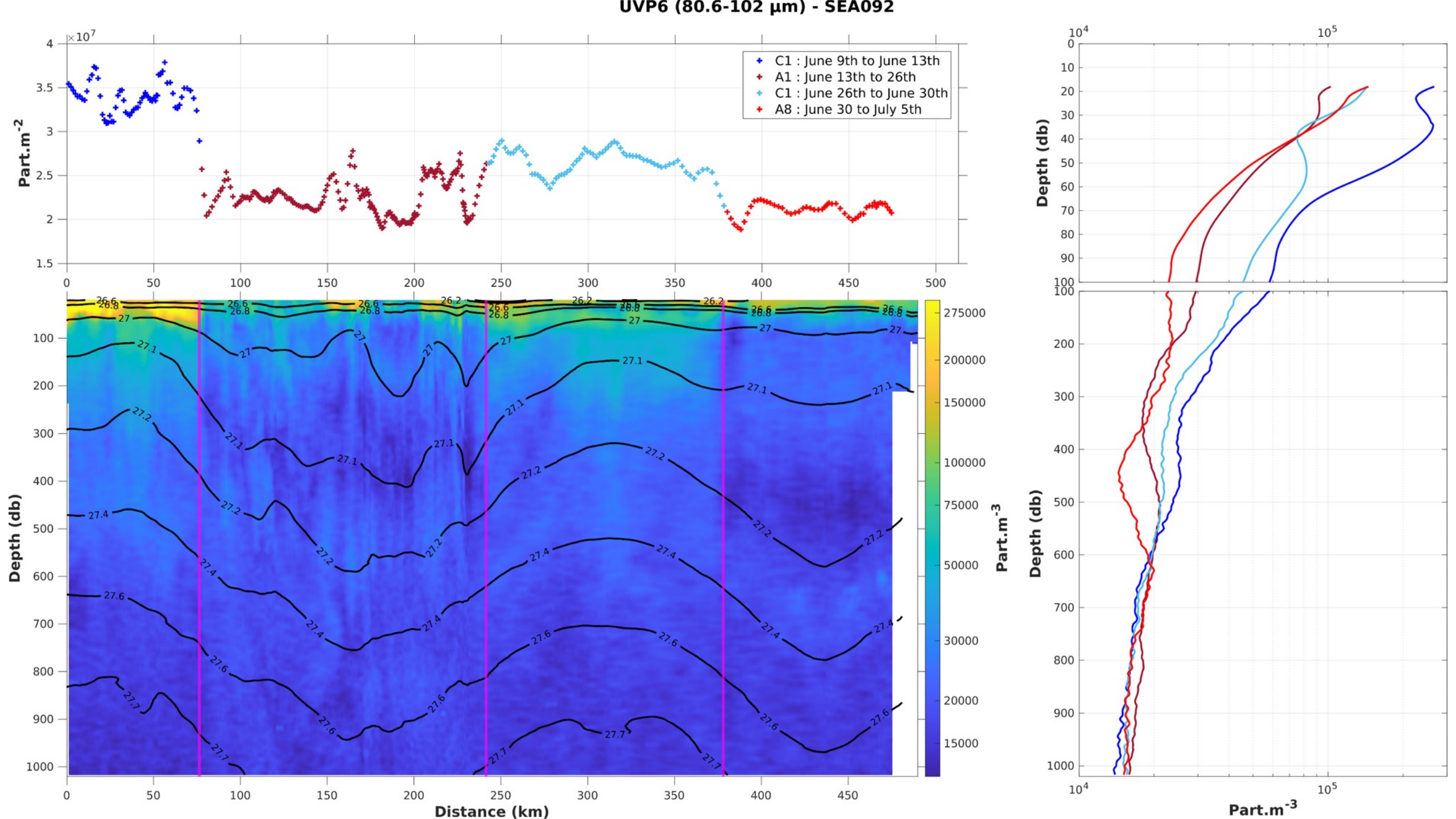

All profiles of slopes - C1
Depth (db)
Slope value
0
100
200
300
400
500
600
700
800
900
1000
-6
-5
-4
-3
-2

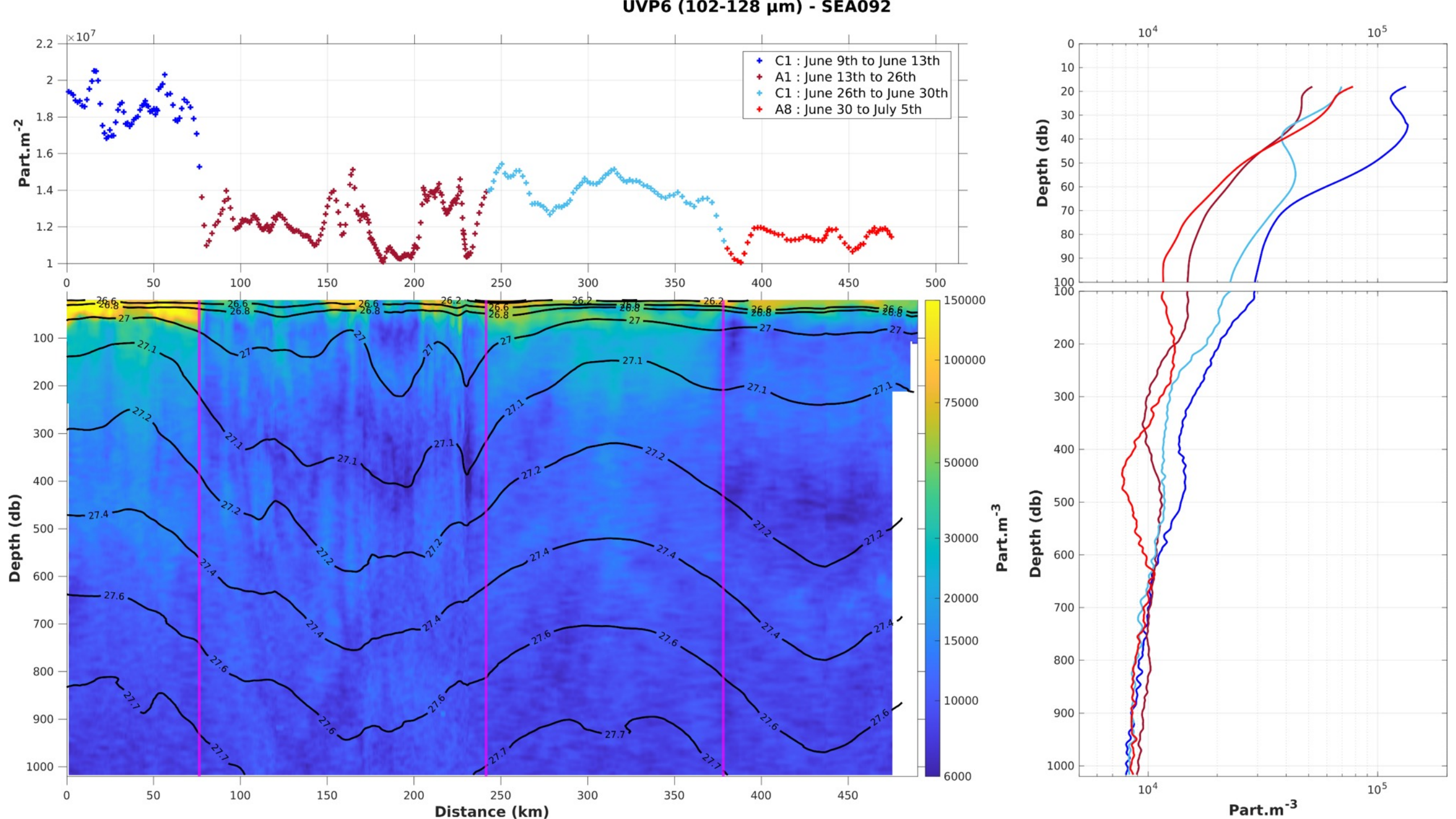

All profiles of slopes - A1
Depth (db)
Slope value
0
100
200
300
400
500
600
700
800
900
1000
-6
-5
-4
-3
-2

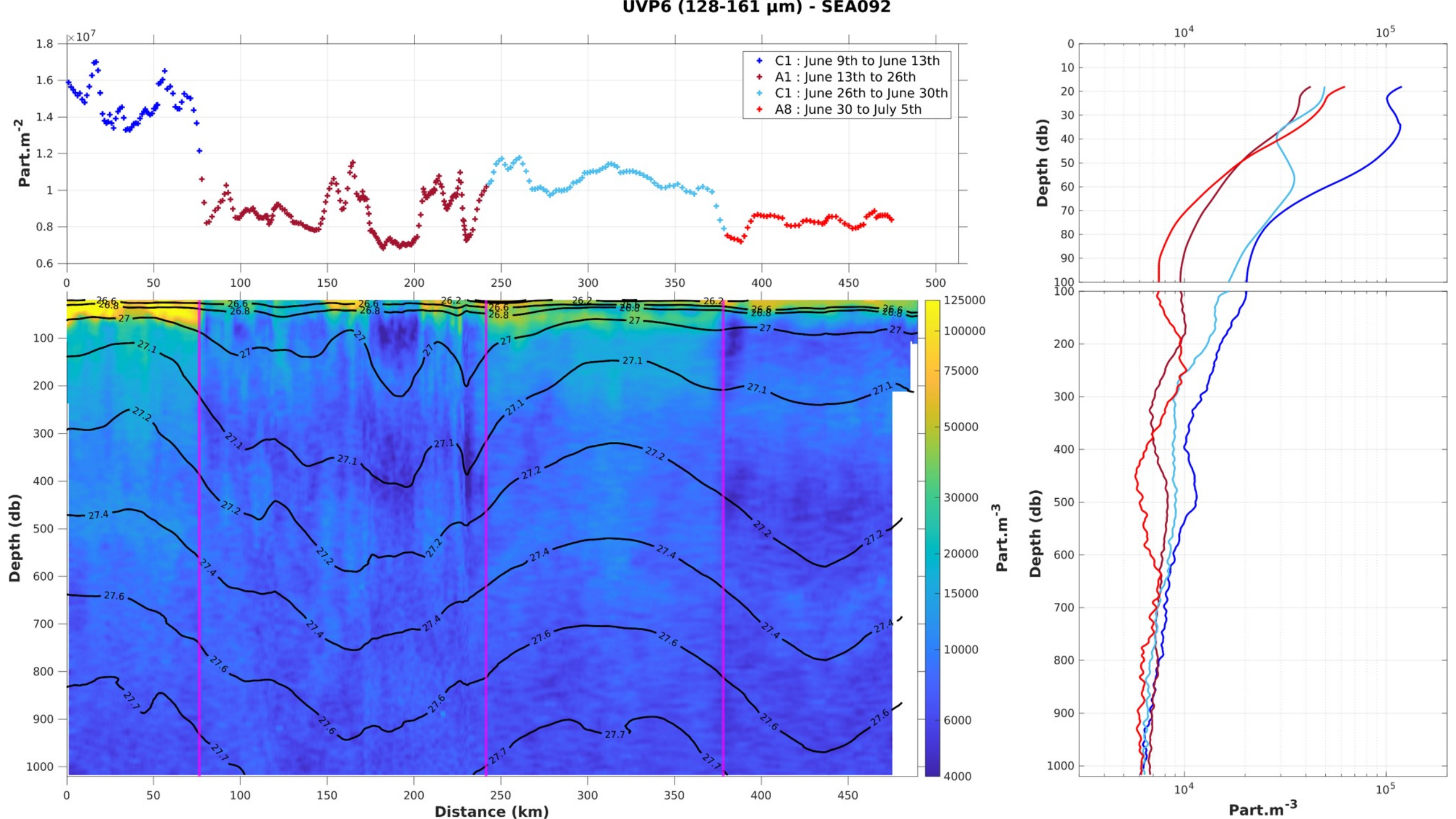

All profiles of slopes - C1
Depth (db)
Slope value
0
100
200
300
400
500
600
700
800
900
1000
-6
-5
-4
-3
-2

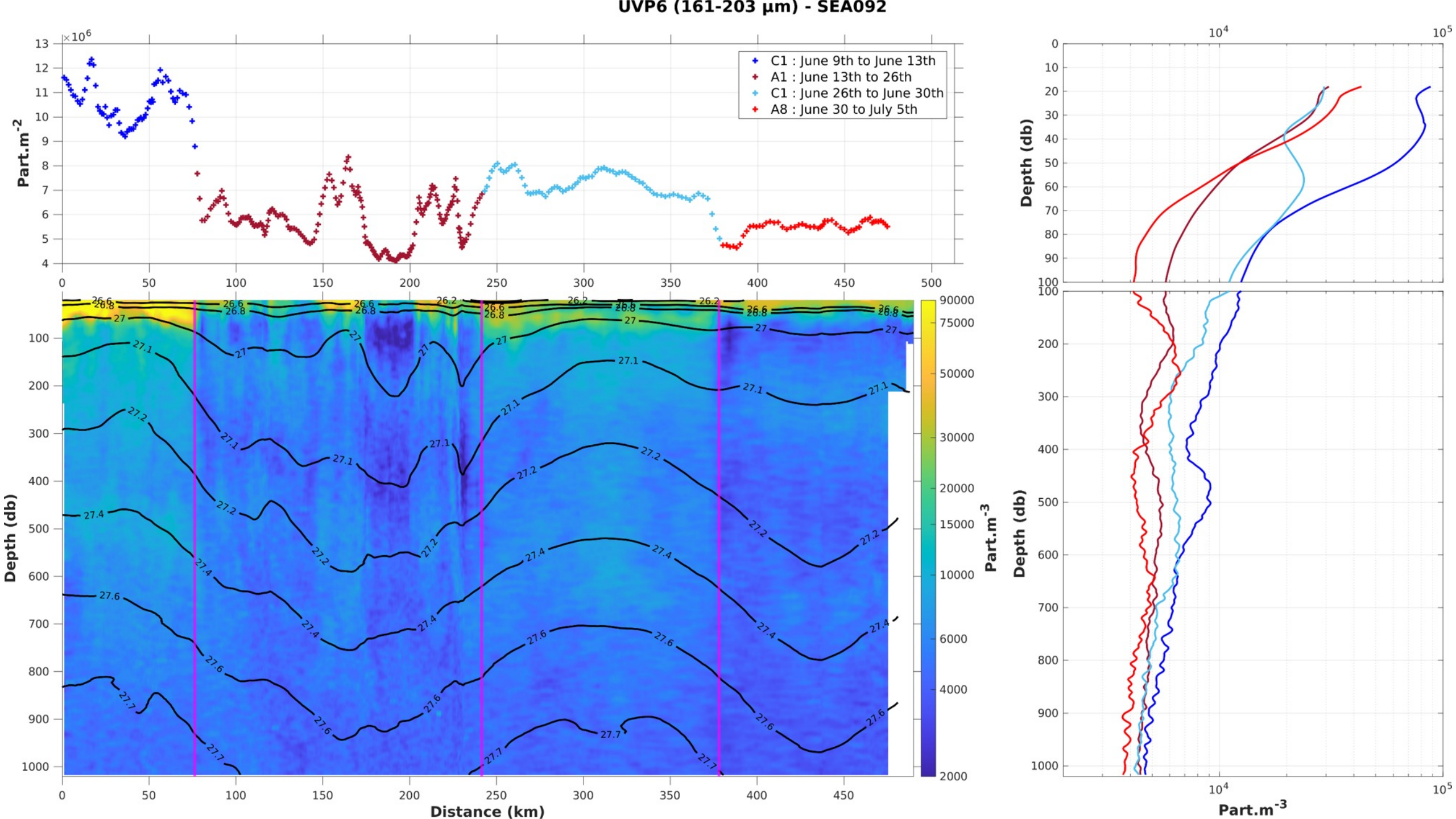

All profiles of slopes - A8
Depth (db)
Slope value
0
100
200
300
400
500
600
700
800
900
1000
-6
-5
-4
-3
-2

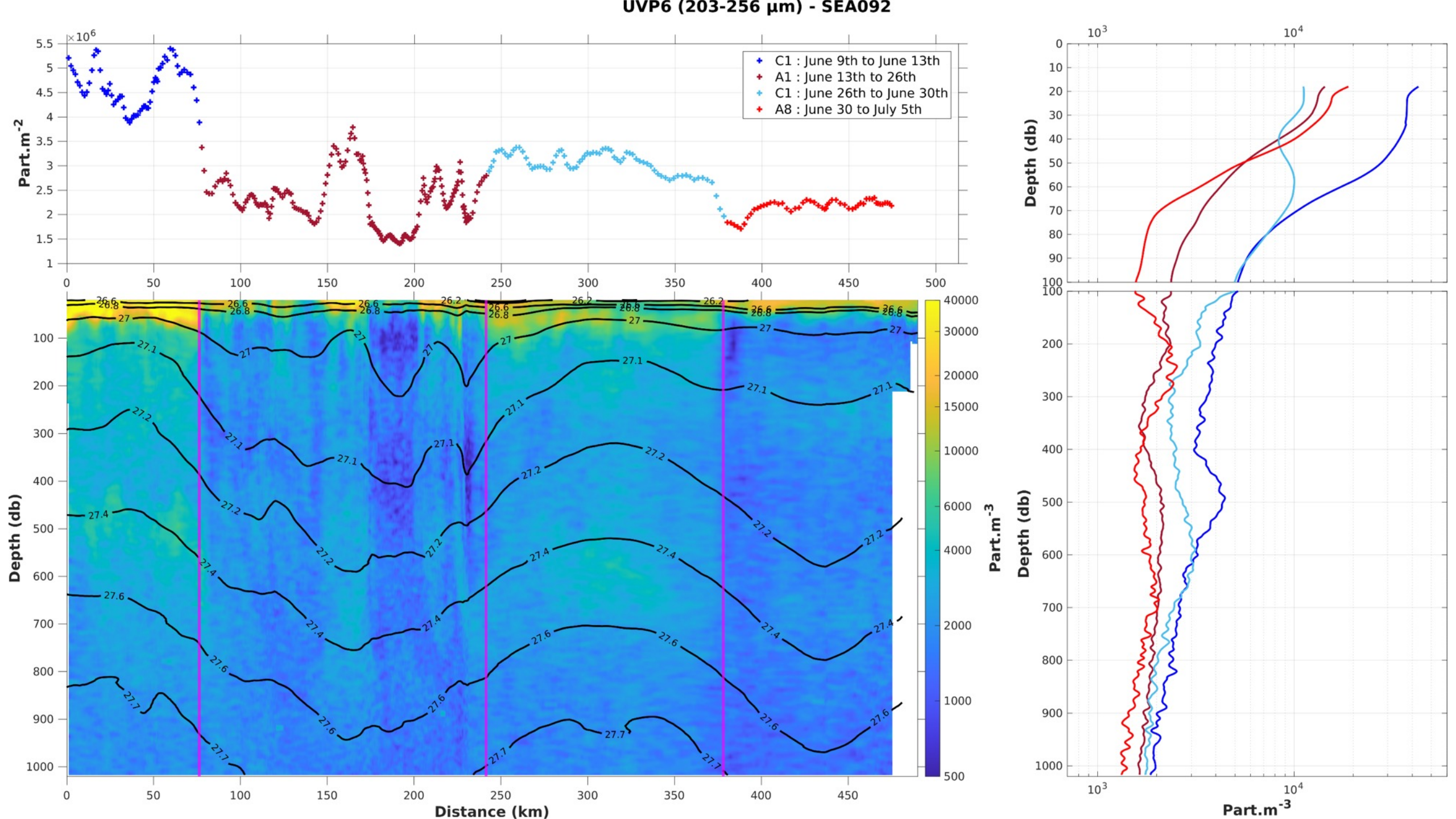

UVP6 (256-323 µm) - SEA092
FSLE (d-1)
0
0.05
0.1
0.15
0.2
0.25
0.3
0
50
100
150
200
250
300
350
400
450
500
Depth (db)
Distance (km)
Part.m-3
25000
15000
10000
6000
3000
2000
1000
500
200
26.2
26.6
26.8
27
27.1

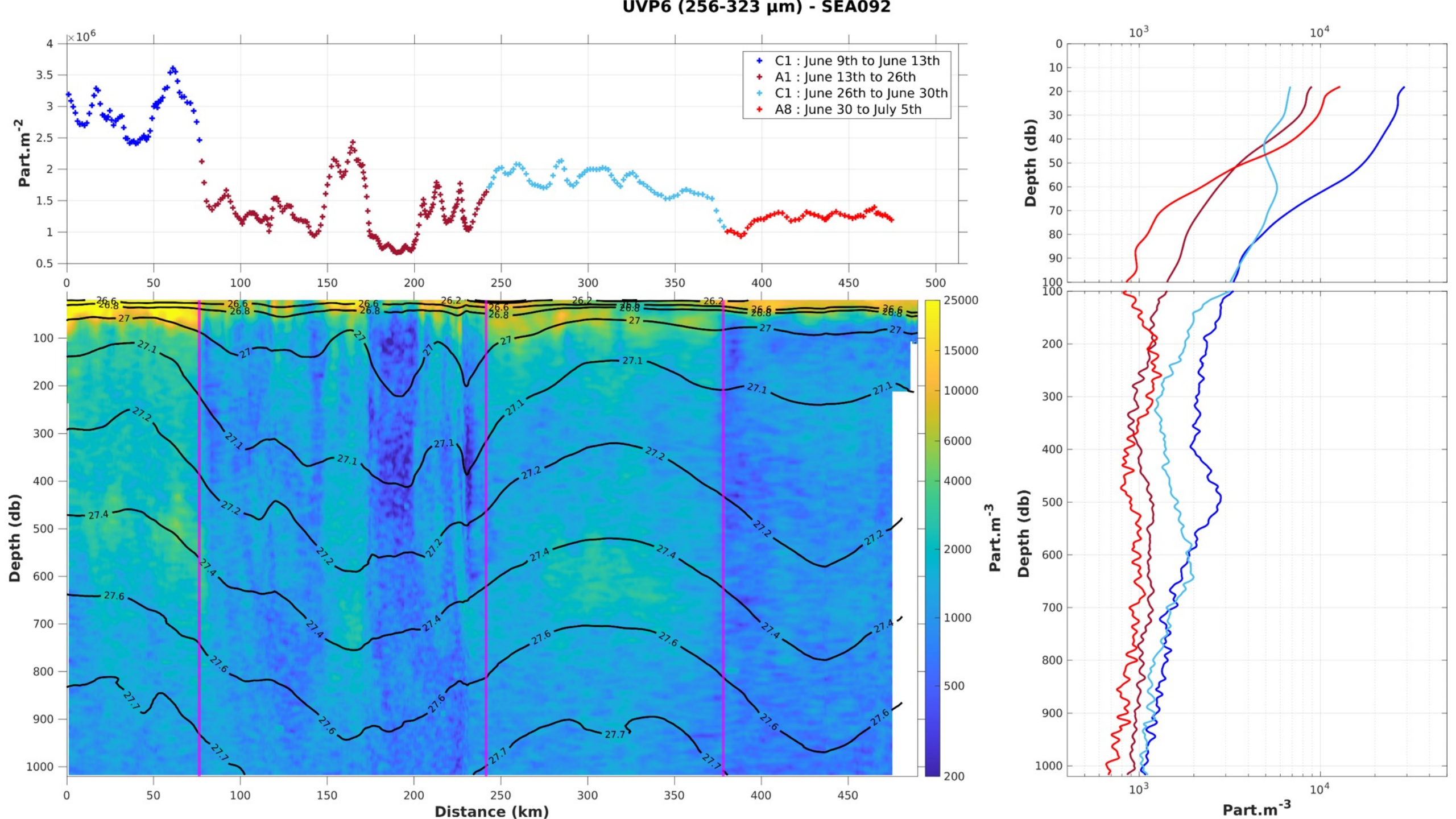

UVP6 (80.6-102 µm) - SEA092
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Part.m-2
Depth (db)
Distance (km)
Part.m-3

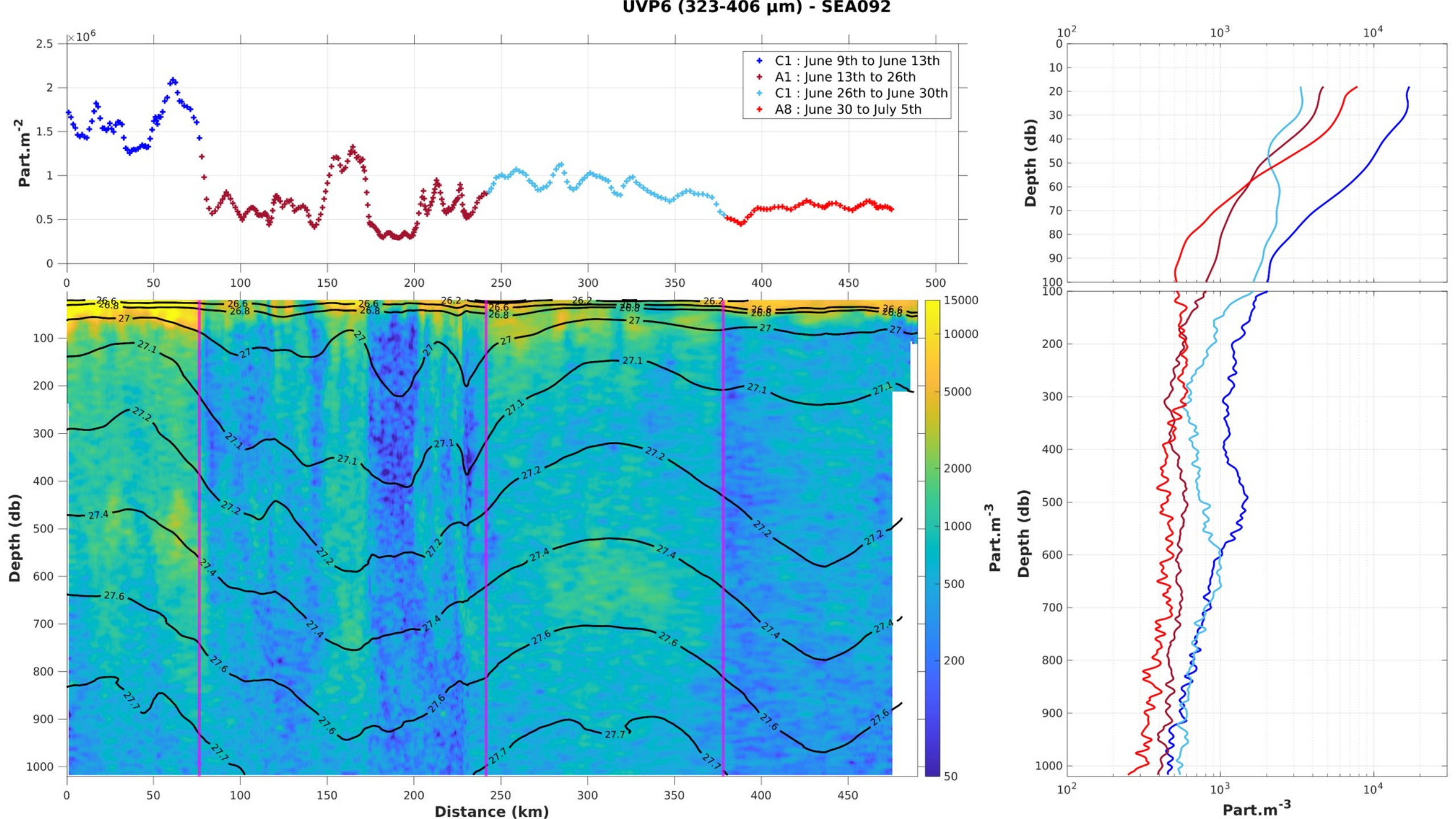

UVP6 (102-128 µm) - SEA092
Part.m-2
×10^7
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3

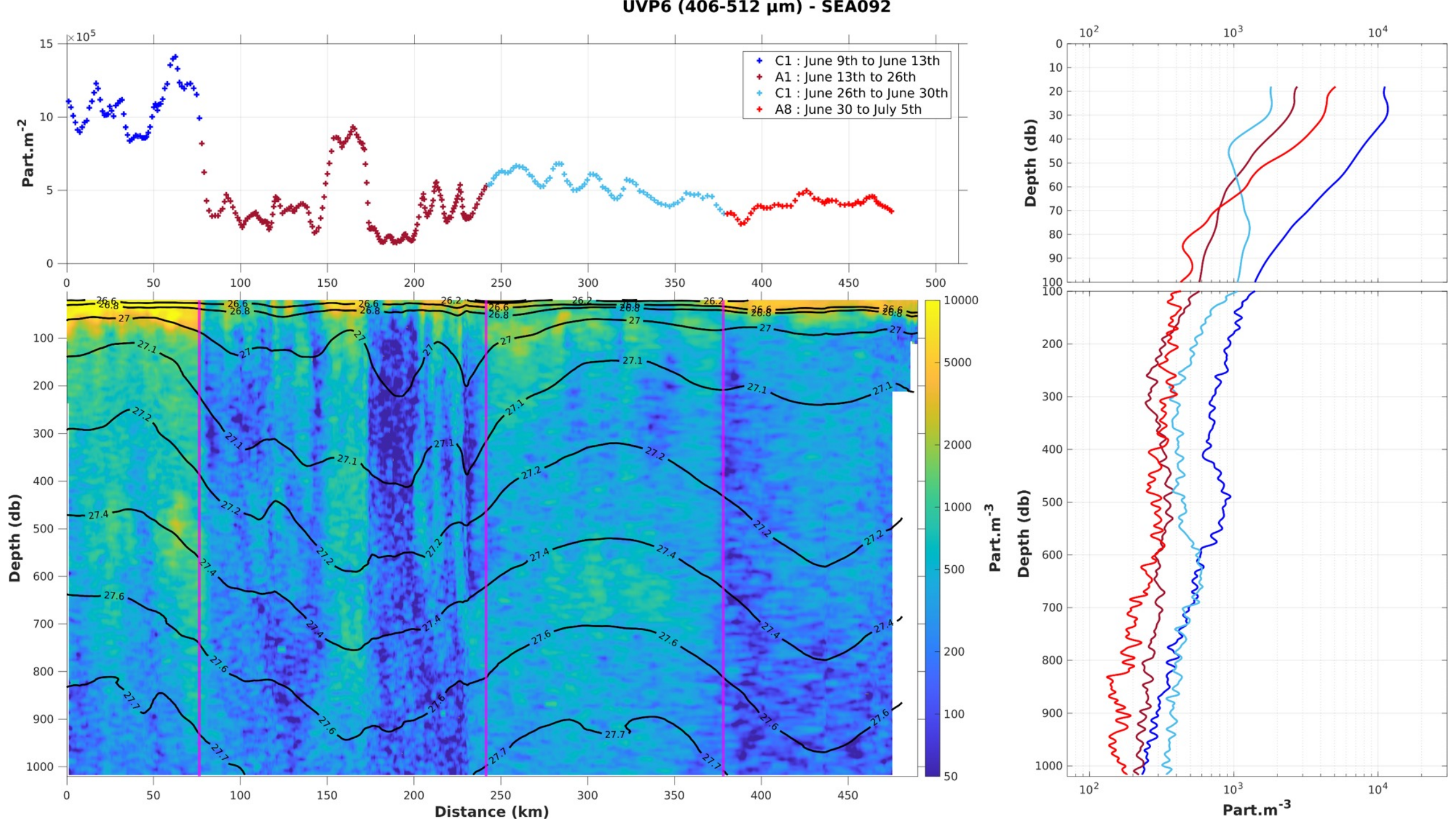

UVP6 (128-161 µm) - SEA092
Part.m-2
×10^7
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3

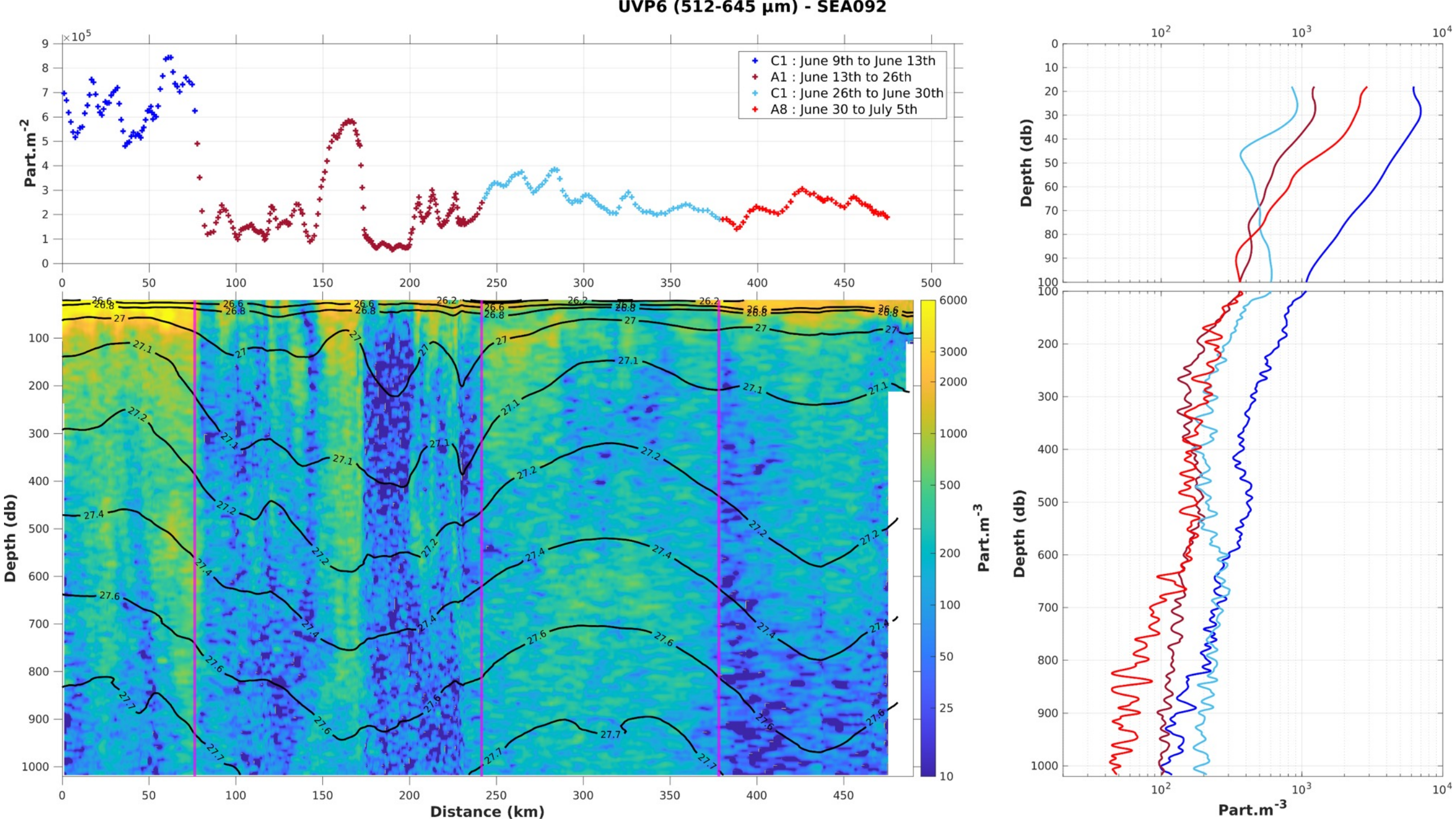

UVP6 (161-203 µm) - SEA092
Part.m-2
×10^6
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3

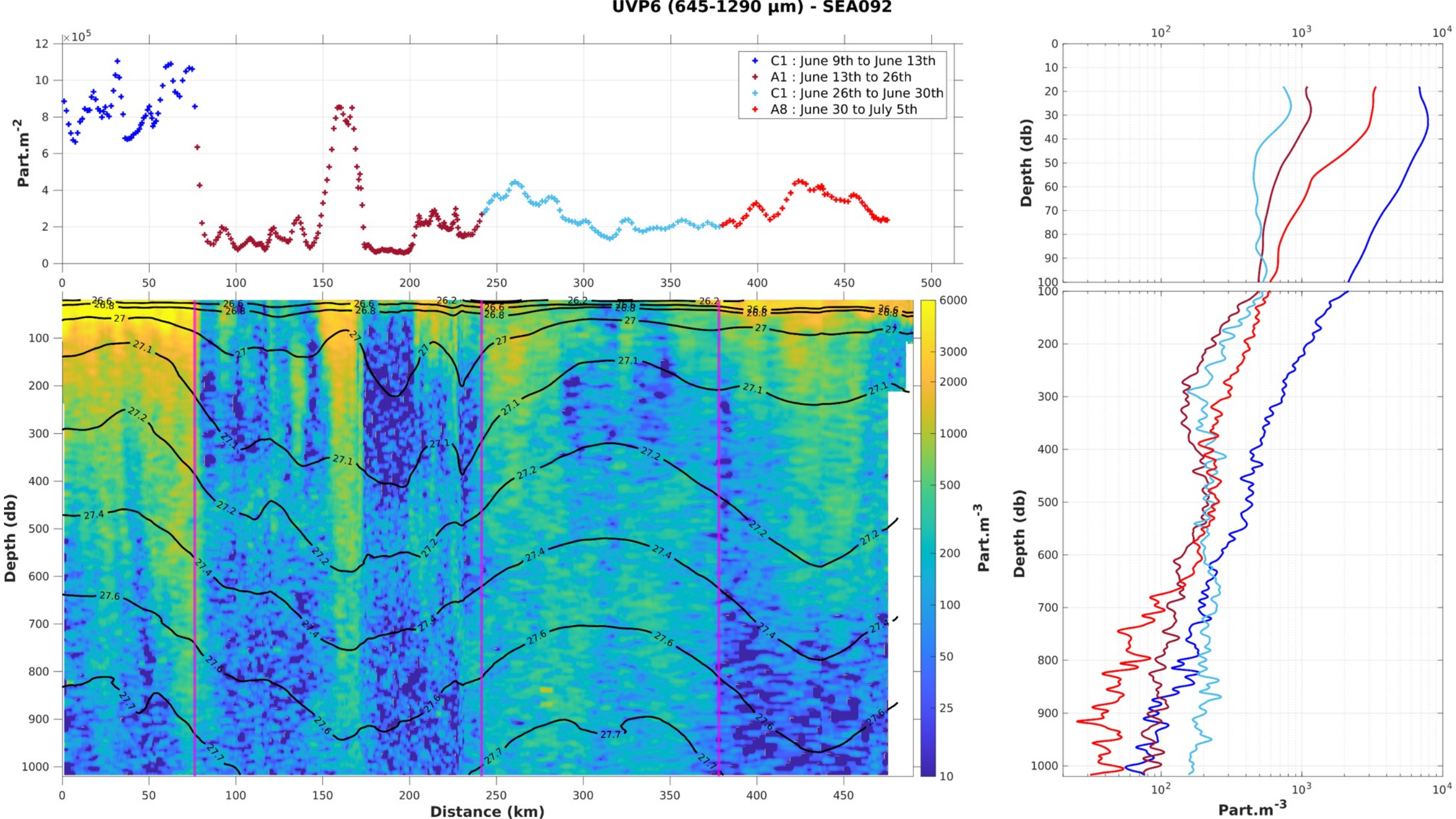

UVP6 (203-256 µm) - SEA092
Part.m-2
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3


UVP6 (256-323 µm) - SEA092
Part.m-2
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3


UVP6 (323-406 µm) - SEA092
Part.m-2
×10^6
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Depth (db)
Distance (km)
Part.m-3
Depth (db)
Part.m-3


UVP6 (406-512 µm) - SEA092
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Part.m-2
Depth (db)
Distance (km)
Part.m-3


UVP6 (512-645 µm) - SEA092
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Part.m-2
Depth (db)
Distance (km)
Part.m-3


UVP6 (645-1290 µm) - SEA092
C1 : June 9th to June 13th
A1 : June 13th to 26th
C1 : June 26th to June 30th
A8 : June 30 to July 5th
Part.m-2
Depth (db)
Distance (km)
Part.m-3