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CDOM-HEAT - Source and transformations of Chromophoric Dissolved Organic Matter and its role in surface ocean heating and carbon cycling in Nordic Seas and European Arctic.

Polish-Norwegian Research Programme

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Survey of Inherent and Apparent Optical Properties in Atlantic Waters West of Svalbard

r/v Oceania, AREX 2013/2

13 July – 24 July 2013

Longyear – Longyear, Norway

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Sopot, 2013

Instrumentation and methodology

Measurements of inherent optical properties were measured in situ, along the ship track, using Integrated Optical-Hydrological Probe. The TRIOS MicroFlu-CDOM and TRIOS MicroFlu-Chla fluorometers and Sea-Bird Electronics SBE 49 FastCAT CTD were coupled with the WET Labs Inc. ac-9 plus spectrophotometer, which functioned as the data integrator. The instrument setup, referred to as the Integrated Optical-Hydrological Probe, was fitted into one rig and connected by telemetry cable with the power supply and data transmission and control deck unit. The ac-9 plus and CTD water intakes were installed on the same horizontal plane as the optical window of the fluorometer. The data from instruments were merged and synchronized along with their time stamps with WAP 4.25 software supplied by the WET Labs. Data were processed further using software written in the Matlab® environment. This had calibration procedures for all the sensors, and it merged all the measured geophysical parameters and calibrated values in physical units into a depth binned matrix.

The inherent optical properties of the sea water were measured using an ac-9 plus (WET Labs Inc., USA) spectral attenuation and absorption meter. In situ measurements of the light attenuation *c* were performed at wavelengths of 412, 440, 488, 510, 532, 555, 650, 676 and 715 nm. The instrument was calibrated against Milli-Q water. and routinely checked for stability with air-readings. Air and water offsets, temperature and salinity corrections were applied according to the manual. The instrument was water calibrated and necessary corrections for temperature and salinity were applied. Casts were performed with vertical resolution of approximately 30 cm, signal stream were smoothed with 3 point median filter.
Due to unrecoverable ac9's optics malfunction at the beginning of the research polygon ('S'), the absorption as well as light scattering is missing.

The Integrated Optical-Hydrological probe was also deployed as the quasi-flow through instrument for continuous underway measurements of inherent optical properties of sea water. It was placed in the tank filled with flowing water pumped from the ships non-toxic water supply system. The retention time of water present in the tank was estimated for ca. 3 minutes. Assuming and average ship cruising speed for 10 knots and average retention time of water in the tank, this gives ca. 900 m spatial displacement between place where water volume was taken by the non-toxic water supply and actual ships position during measurement time in the tank.

CDOM fluorescence was measured wi1th a MicroFlu-CDOM fluorometer (TRIOS GmbH, Germany), which is suitable for in situ measurements without the prior filtration of the water. The MicroFlu-CDOM fluorometer uses UV-LED in pulse mode as the excitation light source. The maximum of the excitation light spectrum is 370 nm. A small percentage of light is reflected by the dicroitic beam splitter and is used as the reference signal for calculating the excitation energy. The fluorometer excites samples of a small volume of water at the front of the optical window at a focal length of 15 mm. It uses a photo-diode with an interference filter as the light detector. The maximum emission of the light detector is set at 460 nm. Specially developed circuitry eliminates the influence of ambient light. The MicroFlu-CDOM fluorometer was calibrated by the manufacturer annually during the deployment period (2008–2013). The measured signal was transmitted to the via telemetry cable to a deck power supply and telemetry control unit in the form of the analog DC voltages. The voltages were converted to QSE calibrated units, as described in details by Kowalczuk et al., (2010). The TRIOS MicroFlu-Chla fluorometer has the same functional features the one for CDOM measurements except different excitation, (470 nm), and emission (685 nm), wavelengths. The TRIOS MicroFlu-Chla fluorometer was factory calibrated in chlorophyll a concentration units – $\mu g\, l^{-1}$.

The laser in situ scattering and attenuation meter LISST 100X (Sequoia Instruments, Inc., USA) was deployed along with the Integrated Optical-Hydrological probe for continuous underway measurements of particle size distribution. This instrument was equipped with flow through measurements chamber fed with the marine water from the ship's non-toxic water supply system. This self-contained instrument consists of the a solid-state laser operating at 670 nm wavelength and fiber-optically connected to a laser beam collimating system, a beam manipulation and orienting system, a scattered-light receiving lens, the specially designed 32-ring detector, preamplifier electronics, a ring-selecting multiplexer circuitry, and a data logger. The principal measurement - angular scattering distribution - is obtained over 32 ring detectors whose radii increase logarithmically from 102 to 20,000 microns. The detector is placed in the focal plane of the receiving lens. The rings cover an angular range from 0.0017 to 0.34 radians. This angular range corresponds, respectively, to size ranges from 1.2 to 250 microns. The laser diffraction method for sizing particles is used for determining size distribution for the simple reason that for laser diffraction, the composition or refractive index of the particles is not important. This method determines size distribution of an ensemble of particles, as opposed to counting type devices that size one particle at a time (Agrawal, et al., 2008). The cleaning, maintenance and field calibration schedule was the same as for the Integrated Optical-Hydrological probe.

Measurements of apparent optical properties were measured at the most of the stations as well. The vertical profiles of downwelling irradiance and upwelling radiance were performed with Compact Optical Profiling System C-OPS (Biospherical Instruments Inc.). The instrument was equipped with 19 spectral channels (340, 380, 395, 412, 443, 465, 490, 510, 520, 532, 555, 565, 589, 625, 665, 683, 710, 765 nm and PAR channel). The C-OPS radiometer was deployed in free-fall mode, away from the ship shadow. The underwater measurements were accompanied by the above-water measurements of spectral downwelling irradiance, $E_s(\lambda)$, with a sensor mounted on the ship deck. Measurements of diffuse and direct solar irradiance have been recorded. These profiles have been used to calculate level of PAR and spectral characteristic od of the light field in the depth profiles. Also R_{rs} at stations has been calculated from these measurements. Additionally the Trios hyperspectral Ramses radiometer placed just below the water surface from specially designed float, accompanied by hyperspectral irradiance Ramses radiometer, mounted on the ship deck have been used for calculation of R_{rs} at the stations as well.

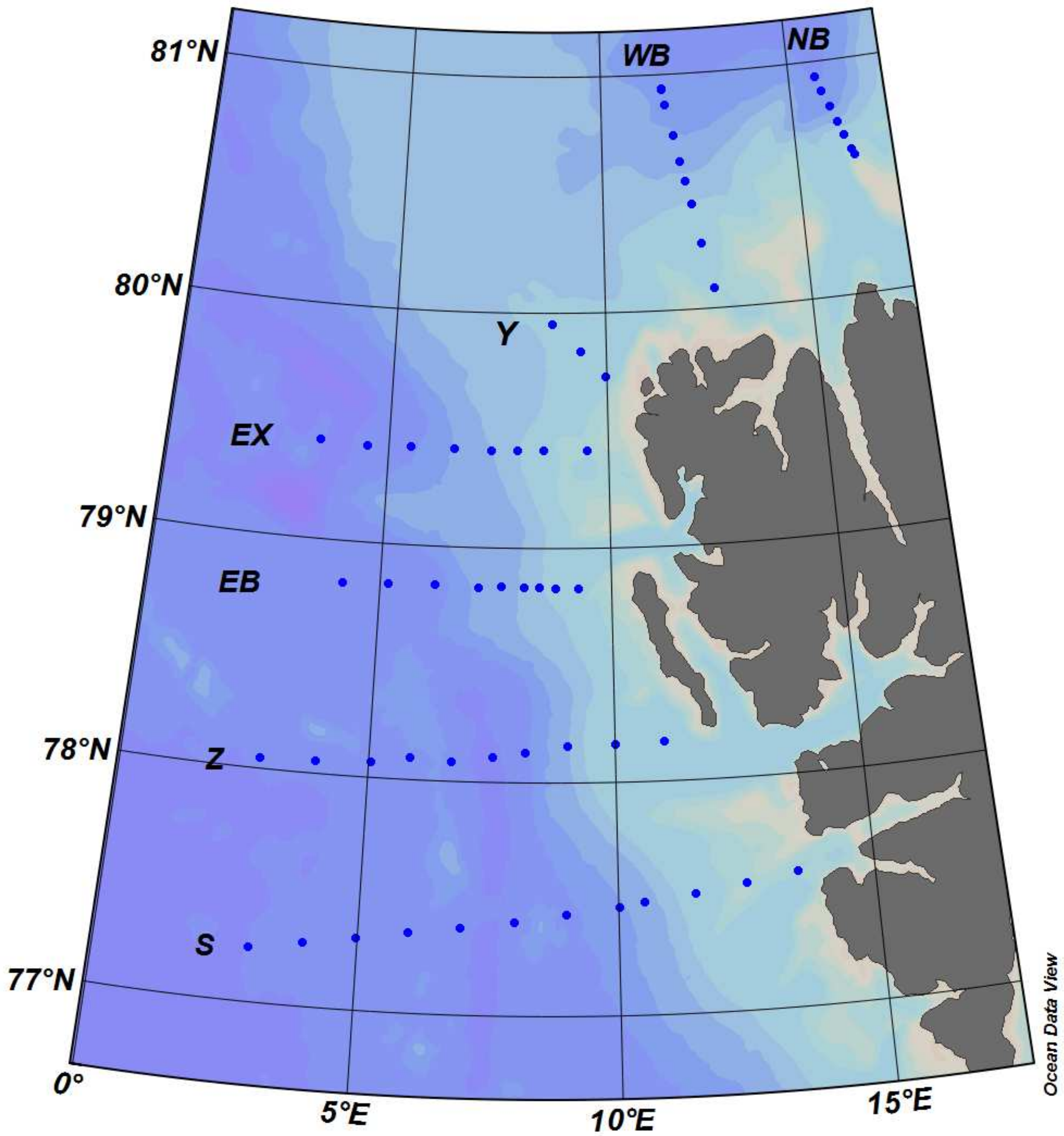


Fig. 1. Map of stations with vertical sounding carried out during the AREX 2013/2 cruise

Tab.1 Station list

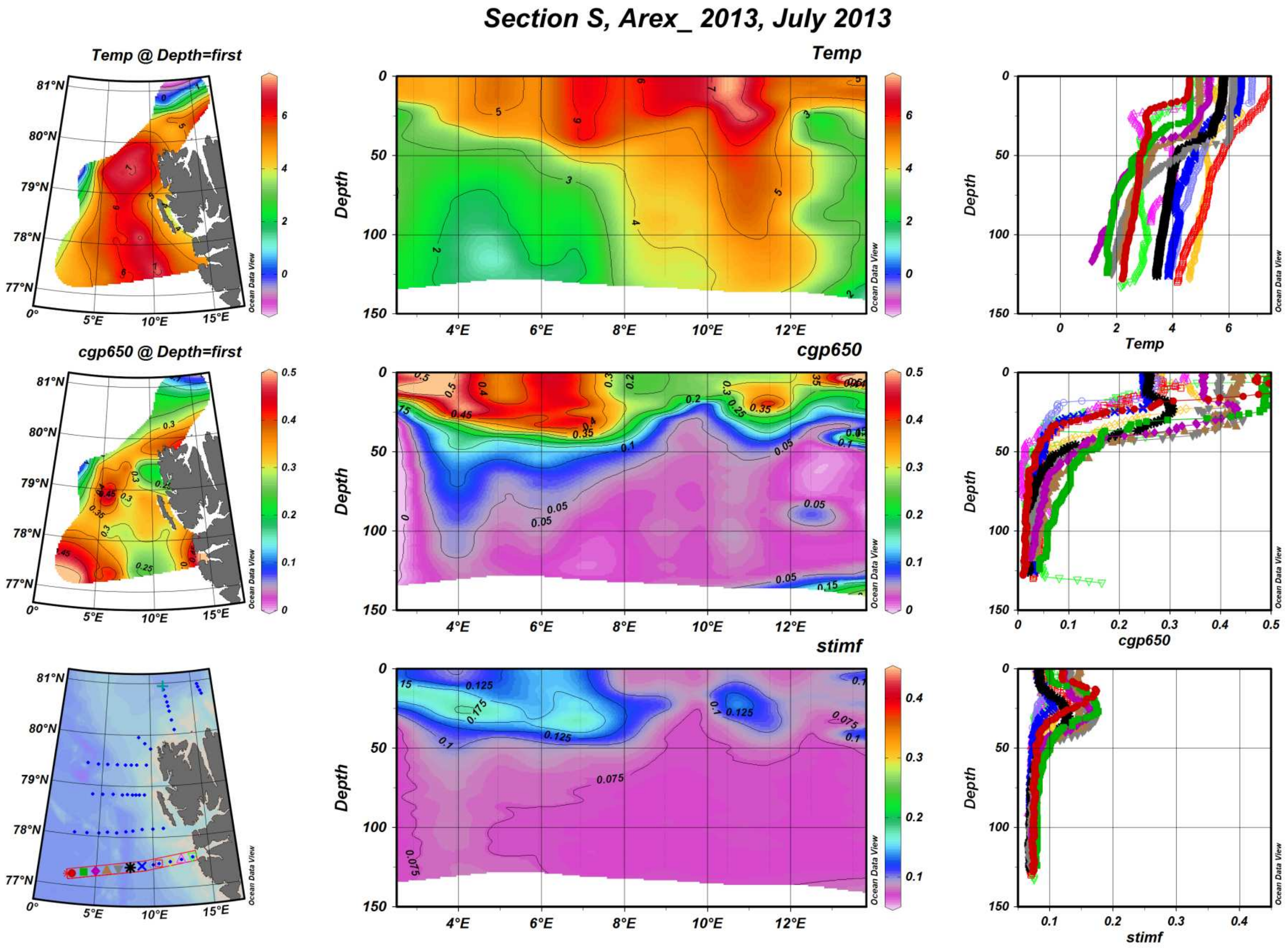
Station	YYYY-MM-DD	Time [UTC]	Longitude	Latitude
S00	2013-07-13	0:07	13.5016	77.584
S02	2013-07-13	2:55	12.4959	77.549
S04	2013-07-13	5:07	11.4967	77.515
S06	2013-07-13	7:46	10.4877	77.486
S07	2013-07-13	9:31	9.9983	77.466
S08	2013-07-13	12:34	8.9828	77.439
S09	2013-07-13	15:52	7.9883	77.406
S10	2013-07-13	18:55	6.9458	77.374
S12	2013-07-14	0:05	5.9441	77.349
S13	2013-07-14	3:27	4.9562	77.311
S15	2013-07-14	8:58	3.9472	77.277
S16	2013-07-14	13:07	2.9293	77.236
Z13	2013-07-14	20:35	2.7885	78.047
Z11	2013-07-15	14:50	5.0362	78.068
Z10	2013-07-15	18:17	5.8177	78.095
Z09	2013-07-15	21:47	6.6589	78.084
Z08	2013-07-16	18:43	7.4965	78.111
Z07	2013-07-16	21:38	8.1514	78.13
Z05	2013-07-17	1:23	9.0169	78.158
Z02	2013-07-17	4:41	10.0035	78.165
Z01	2013-07-17	6:35	11.0018	78.173
EB21	2013-07-17	11:47	9.2724	78.832
EB22	2013-07-17	13:34	8.7691	78.833
EB23	2013-07-17	15:21	8.432	78.834
EB24	2013-07-17	19:03	8.0906	78.834
EB25	2013-07-17	21:34	7.6011	78.839
EB26	2013-07-18	0:01	7.1036	78.831
EB28	2013-07-18	6:59	6.1634	78.836
EB210	2013-07-18	13:14	5.1679	78.831
EB211	2013-07-18	17:28	4.1716	78.823
EX11	2013-07-19	0:43	3.4239	79.423
EX09	2013-07-19	5:52	4.5088	79.414
EX08	2013-07-19	10:12	5.4918	79.419
EX07	2013-07-19	14:12	6.49	79.418
EX04	2013-07-19	19:39	7.9176	79.417
EX03	2013-07-19	21:12	8.5013	79.417
EX01	2013-07-19	23:08	9.5	79.416
Y04	2013-07-20	4:24	9.9667	79.73
Y07	2013-07-20	7:06	9.3675	79.837

Y09	2013-07-20	9:04	8.7024	79.956
WB01	2013-07-21	0:16	12.6397	80.089
WB04	2013-07-21	3:33	12.4108	80.28
WB09	2013-07-21	6:52	12.2057	80.449
WB13	2013-07-21	10:10	12.0838	80.548
WB15	2013-07-21	12:34	11.9885	80.63
WB17	2013-07-21	15:30	11.8456	80.744
WB19	2013-07-21	18:54	11.6725	80.874
WB20	2013-07-21	20:35	11.5932	80.939
WB20	2013-07-21	21:15	11.596	80.941
NB13	2013-07-22	4:24	15.6938	80.935
NB12	2013-07-22	6:29	15.8167	80.873
NB11	2013-07-22	7:56	15.9784	80.805
NB08	2013-07-22	11:44	16.1323	80.739
NB04	2013-07-22	14:34	16.2586	80.68
NB02	2013-07-22	16:20	16.4007	80.615
NB02-NB01	2013-07-22	17:02	16.47821	80.59289

On the following pages the surface distribution, cross-section (DIVA interpolated) and vertical distribution of selected parameters are presented.

The parameters are:

- temperature (Temp),
- light attenuation coefficient for wavelength 650 nm (cpg650), directly related to suspended particle concentration
- stimulated chlorophyll fluorescence (stimf), [V] of range 0 – 5.
- particle size distribution for the stations of Section S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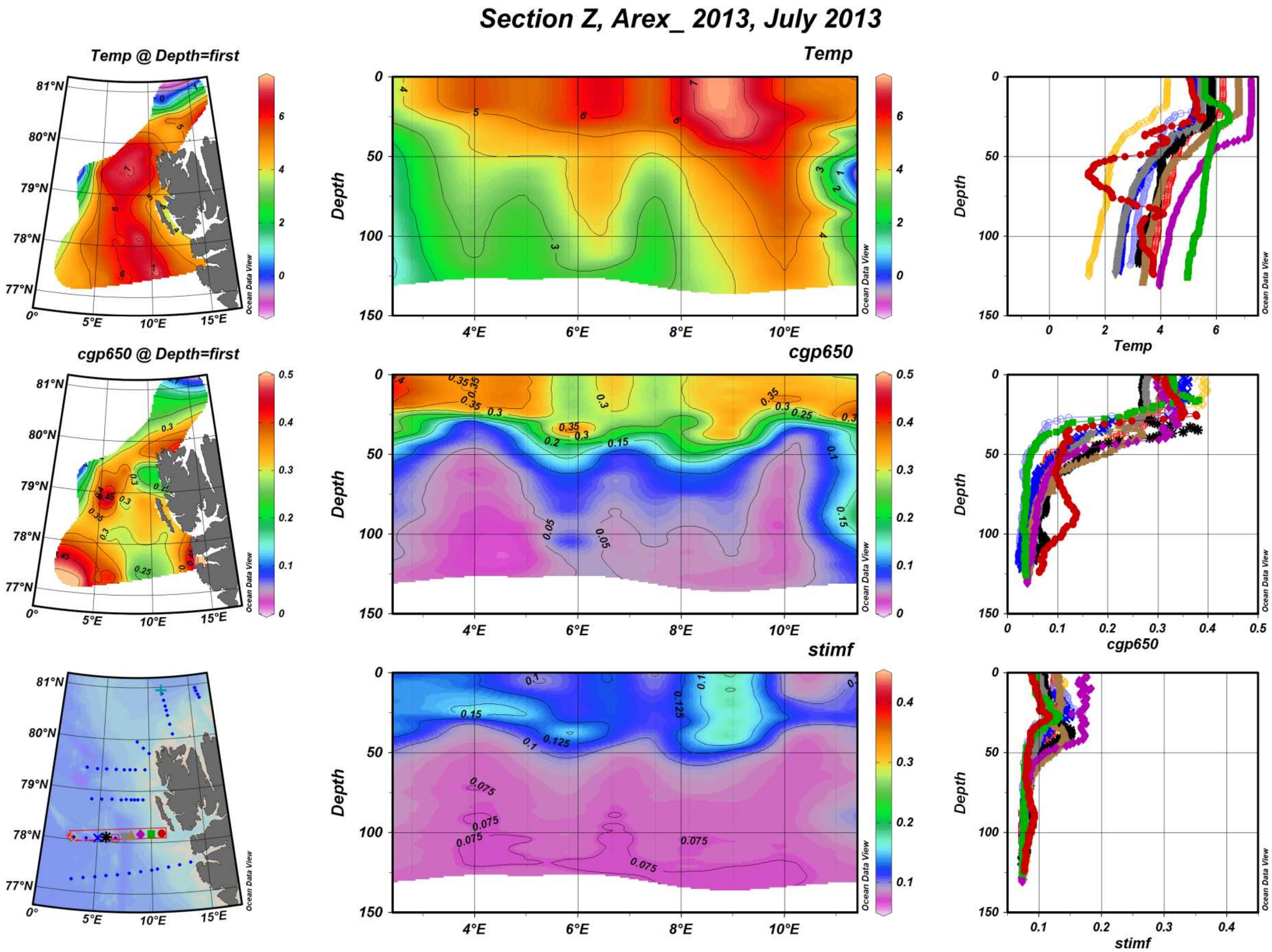
Temp
cgp650 @ Depth=first
cgp650
stimf
Depth
Temp
cgp650
stimf
Ocean Data View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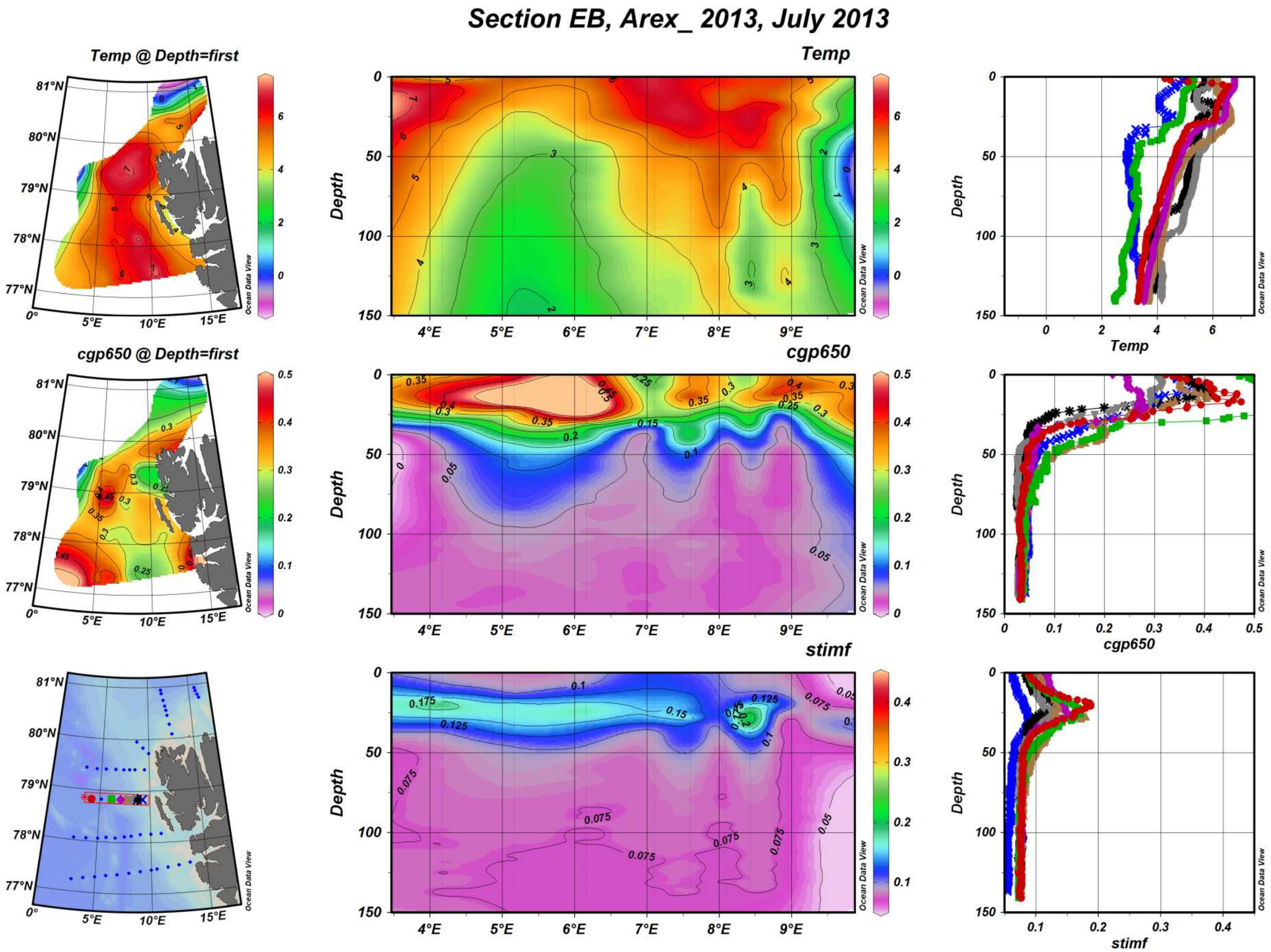
cgp650 @ Depth=first
Temp
cgp650
stimf
Depth
4°E
6°E
8°E
10°E
81°N
80°N
79°N
78°N
77°N
0°
5°E
10°E
15°E
Ocean Data View



Section EB, Arex_ 2013, July 2013
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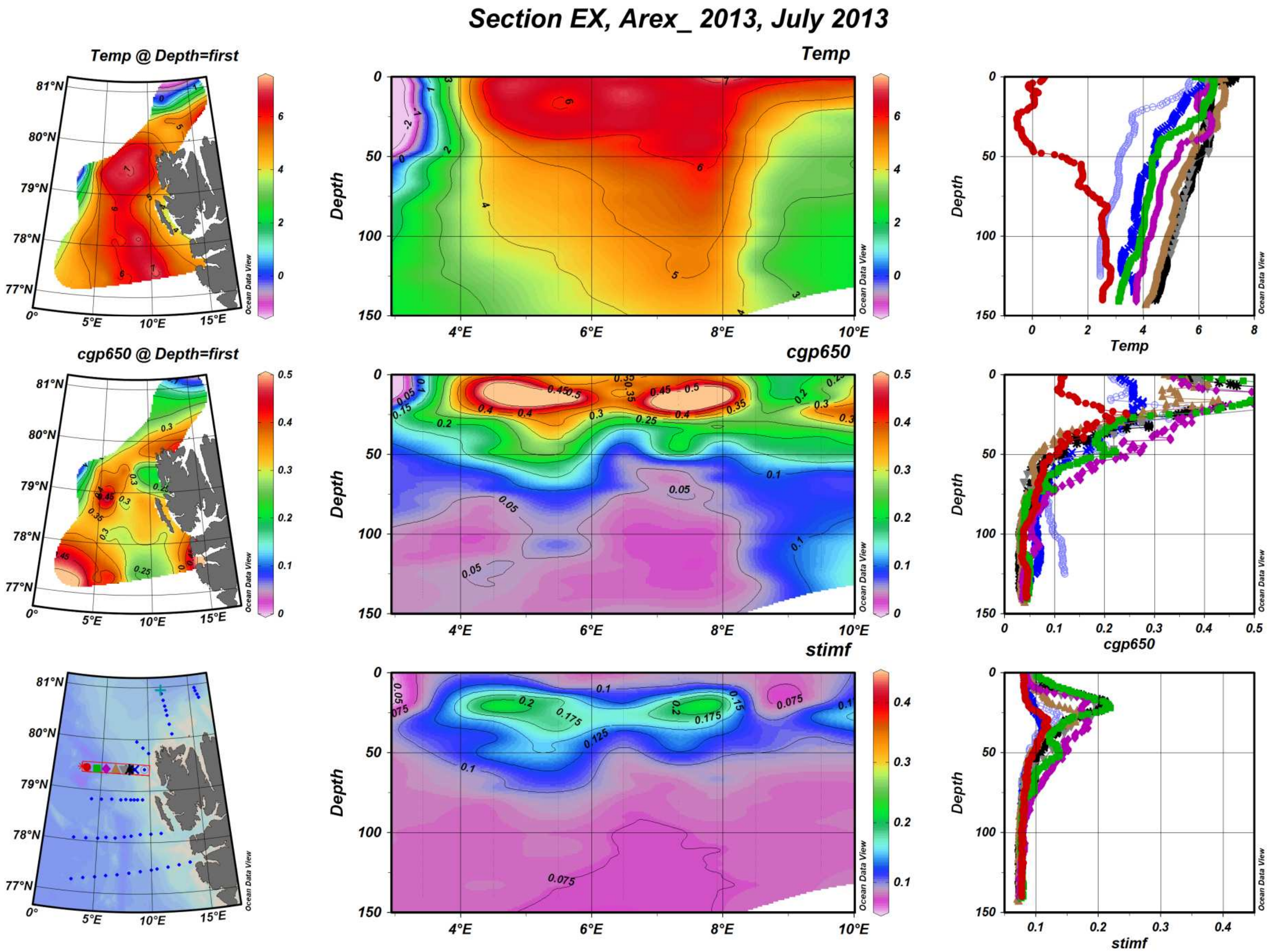
Temp
cgp650 @ Depth=first
cgp650
stimf
Depth
Ocean Data View


Section EX, Arex_ 2013, July 2013
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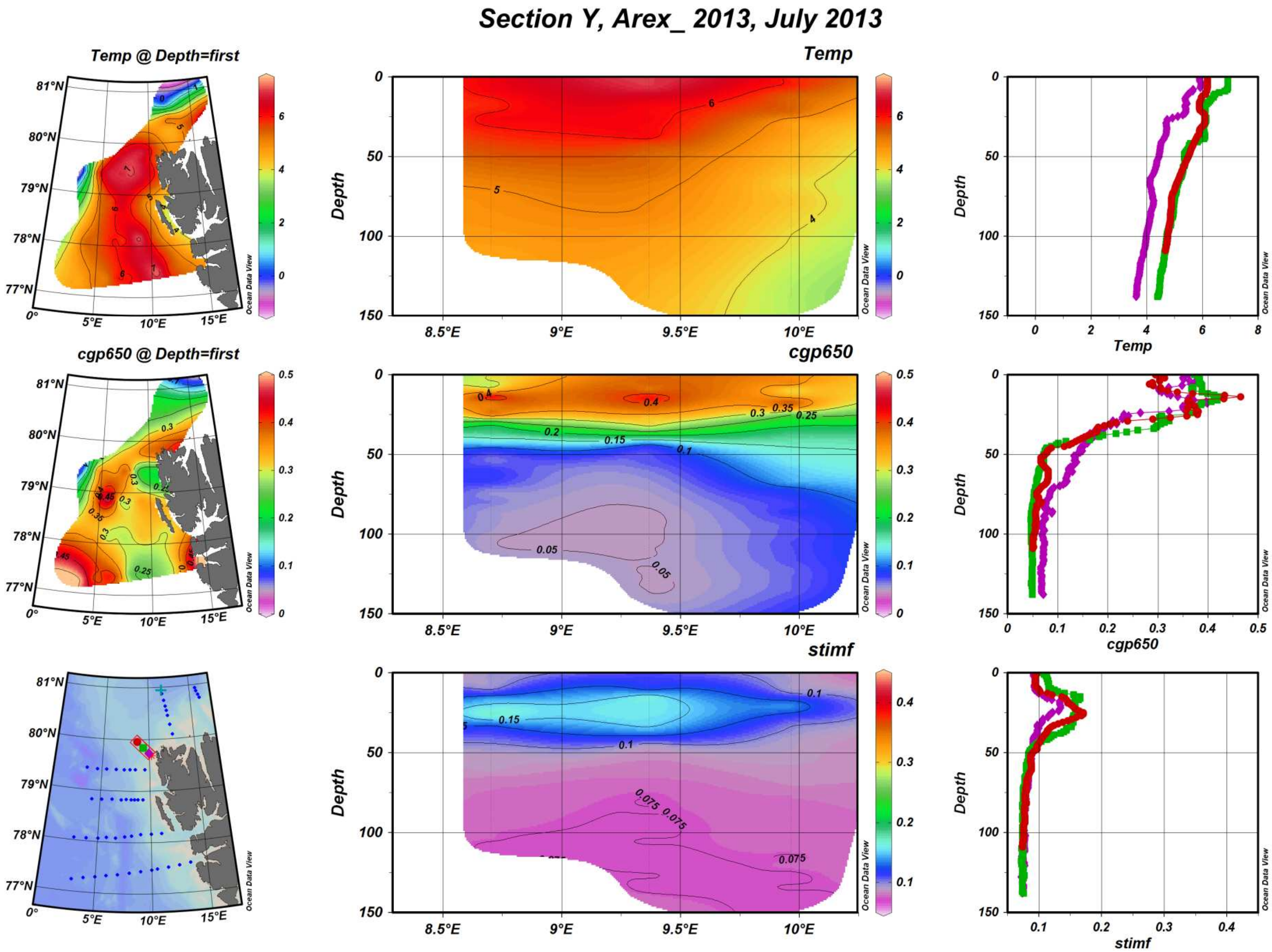
Temp
cgp650 @ Depth=first
cgp650
stimf
Depth
Ocean Data View


Section Y, Arex_ 2013, July 2013
Temp @ Depth=first
cgp650 @ Depth=first
Temp
cgp650
stimf
Depth
Ocean Data View
81°N
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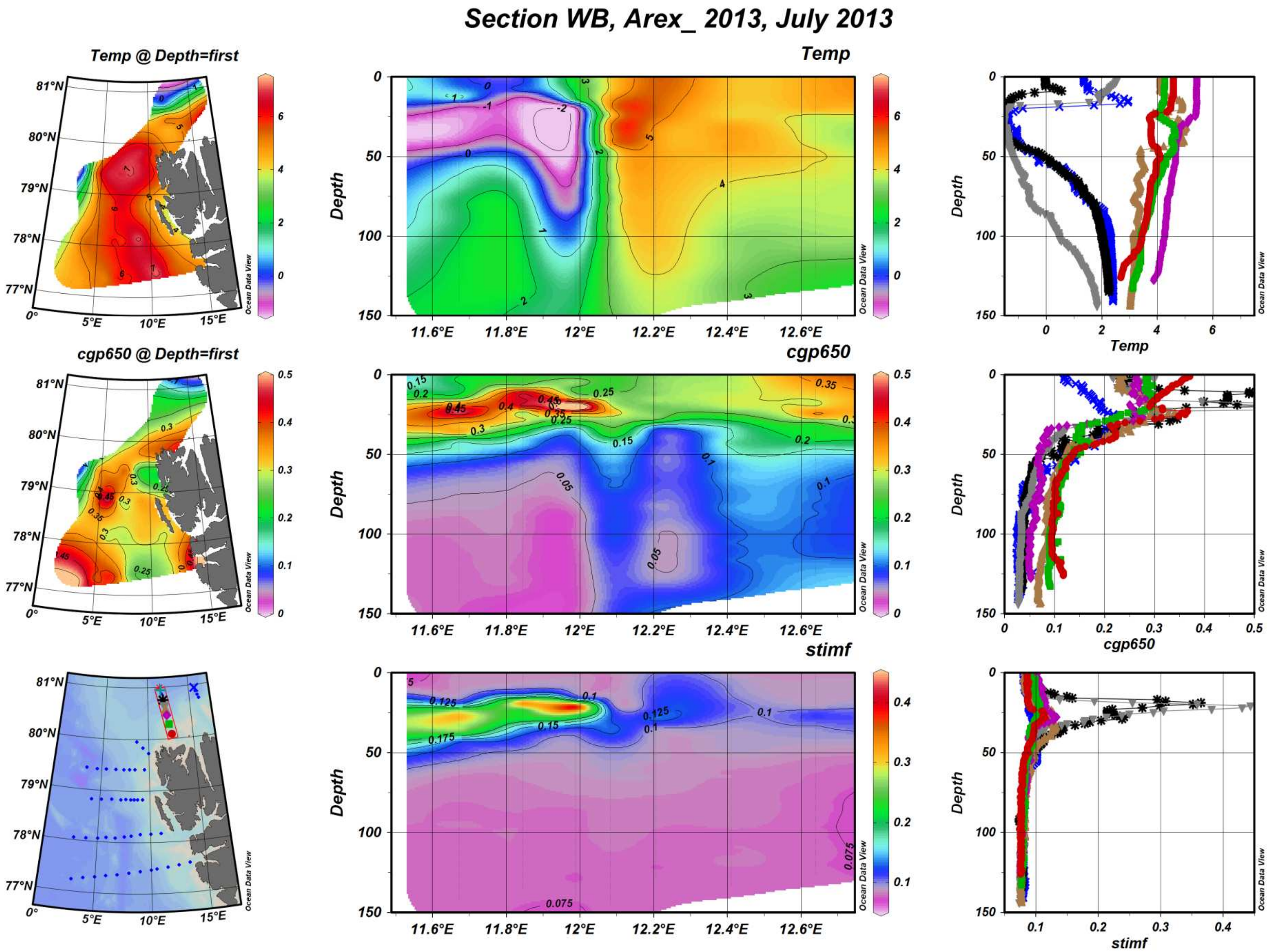
9°E
9.5°E
10°E


Section WB, Arex_ 2013, July 2013
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Temp
cgp650 @ Depth=first
cgp650
stimf
Depth
Ocean Data View
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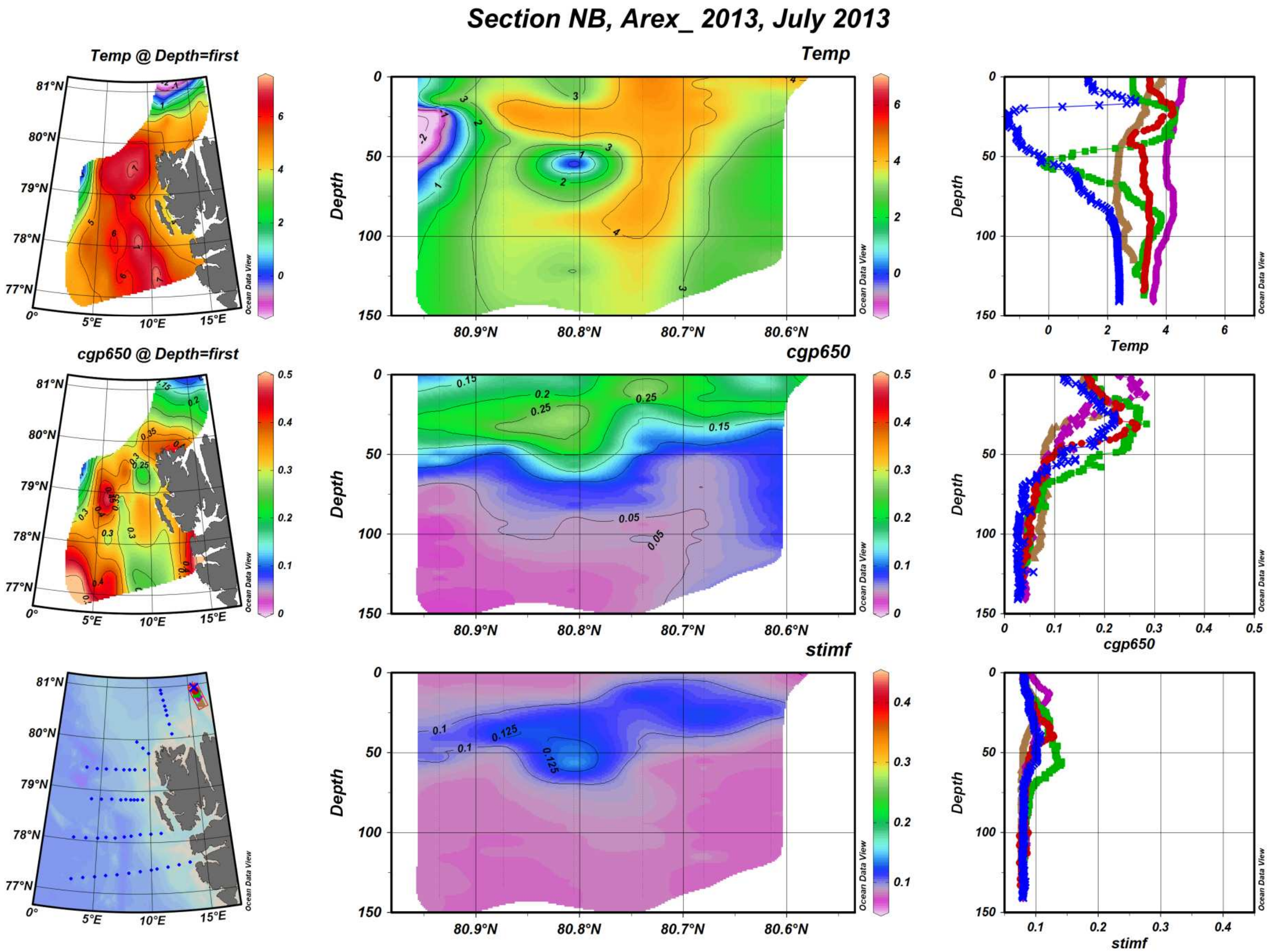
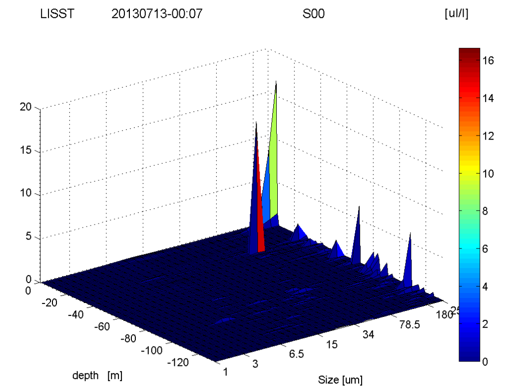
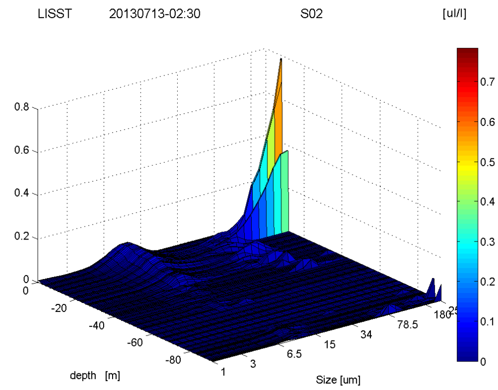
11.8°E
12°E
12.2°E
12.4°E
12.6°E
81°N
80°N
79°N
78°N
77°N
0°
5°E
10°E
15°E


Section NB, Arex_ 2013, July 2013
Temp @ Depth=first
Temp
cgp650 @ Depth=first
cgp650
stimf
Depth
80.9°N
80.8°N
80.7°N
80.6°N
Ocean Data View

Particle size distribution for the stations of Section S (LISST





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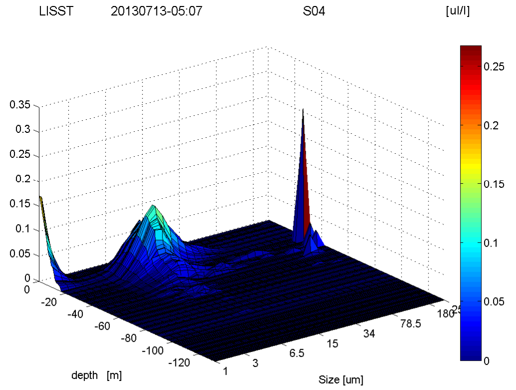

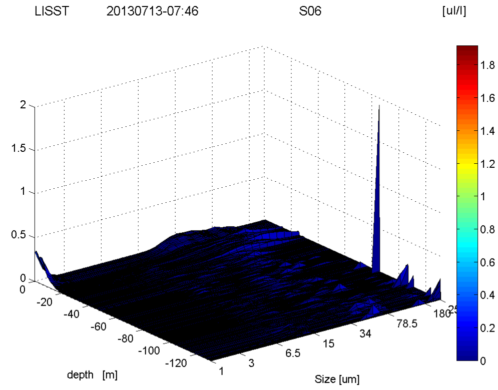

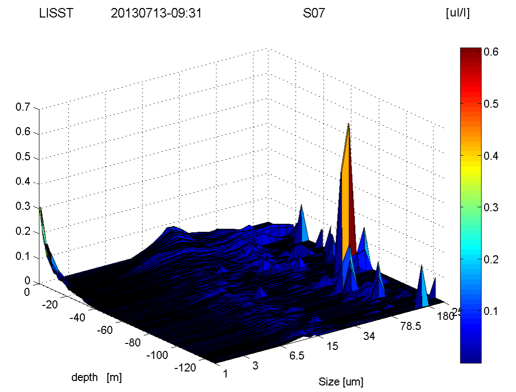

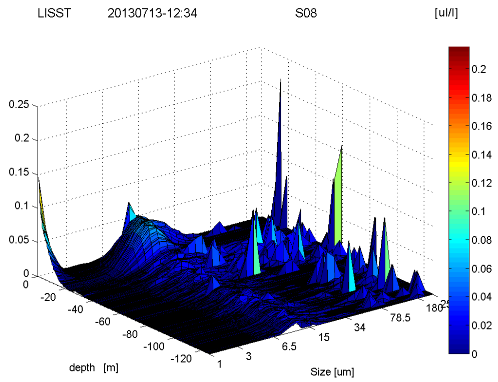

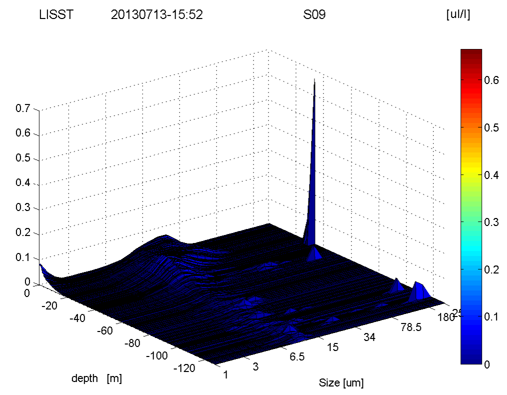
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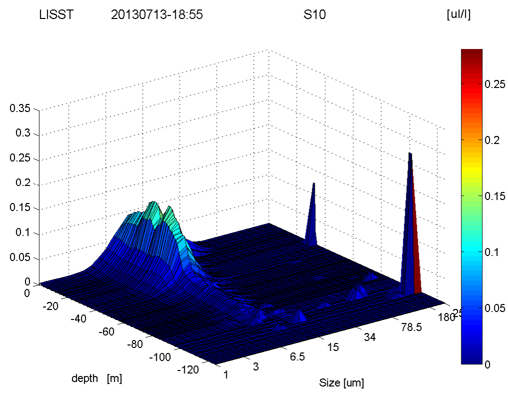
Size [um]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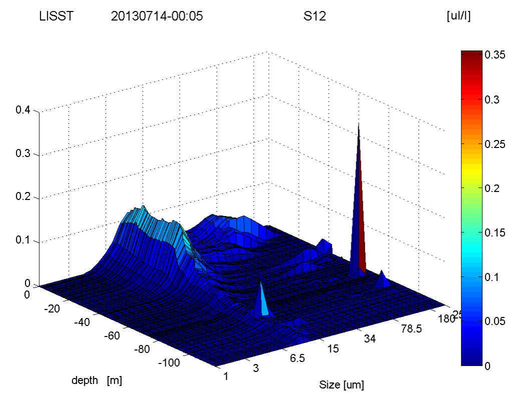
Size [um]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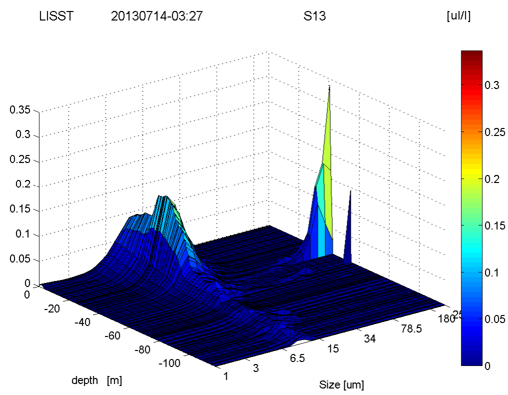
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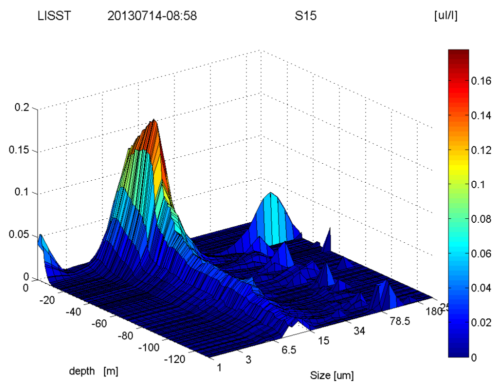
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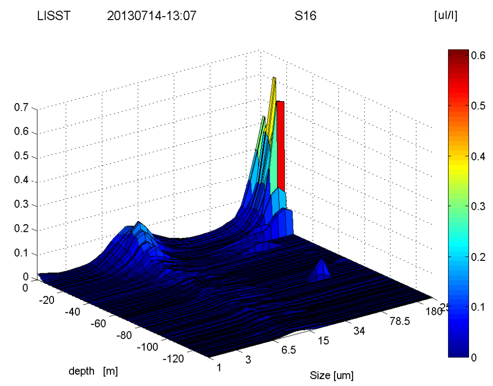
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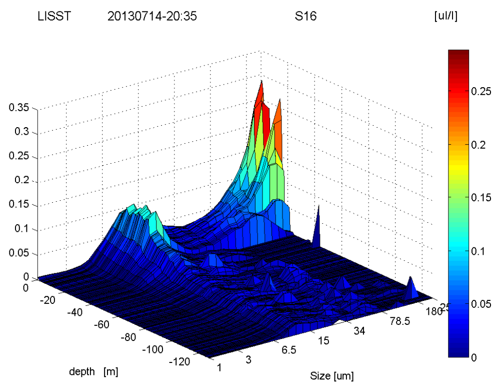
Size [um]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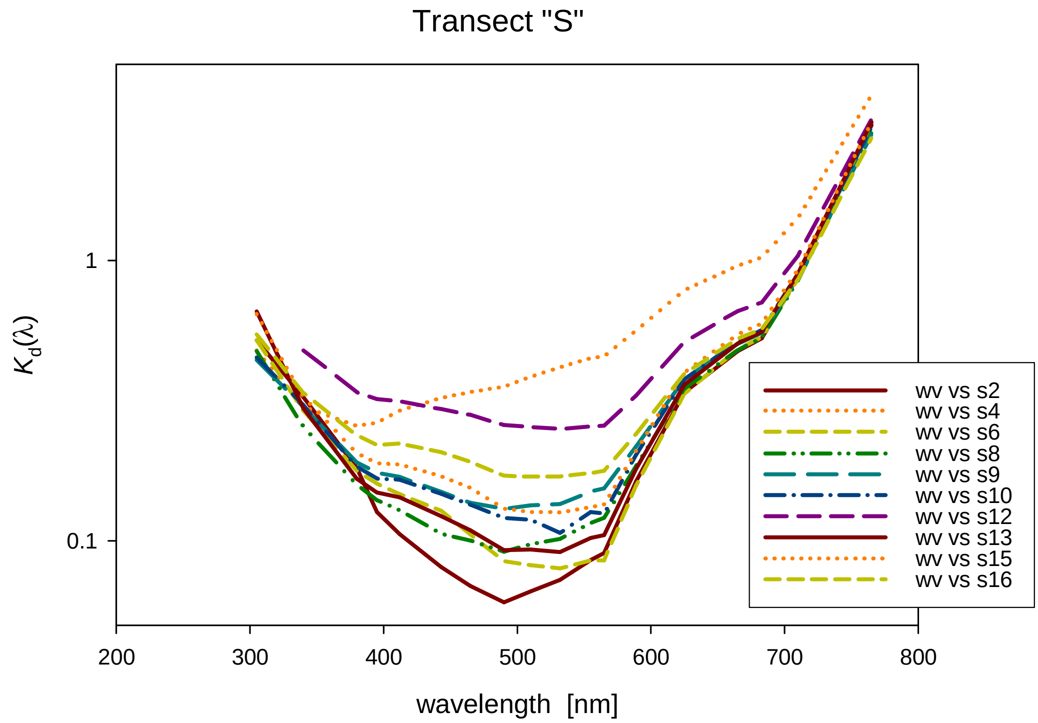
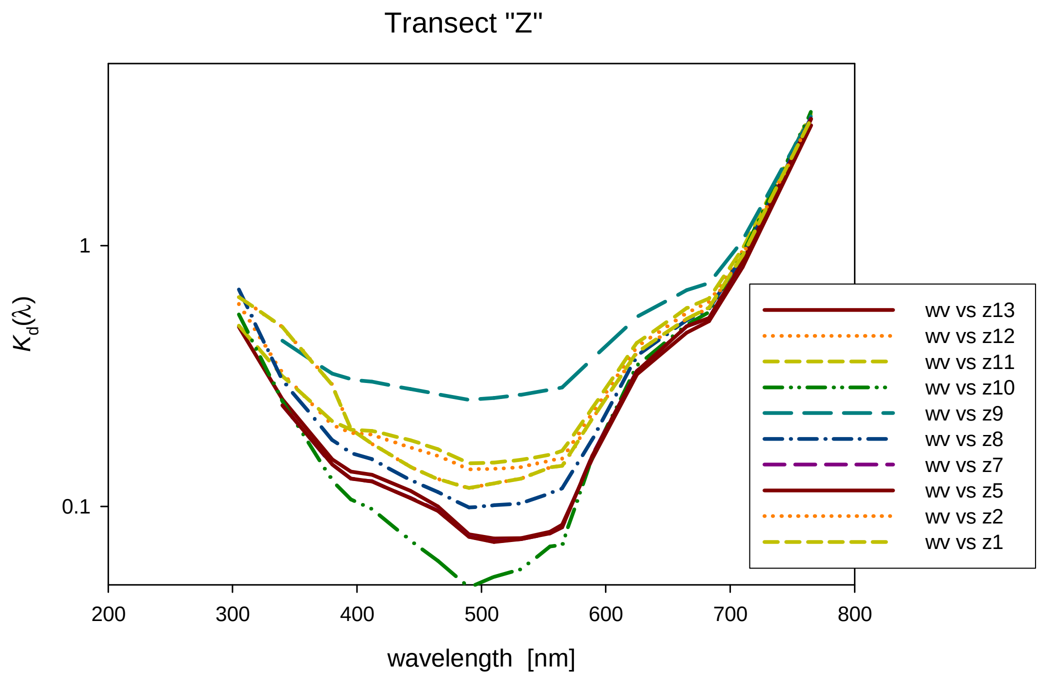
Size [um]

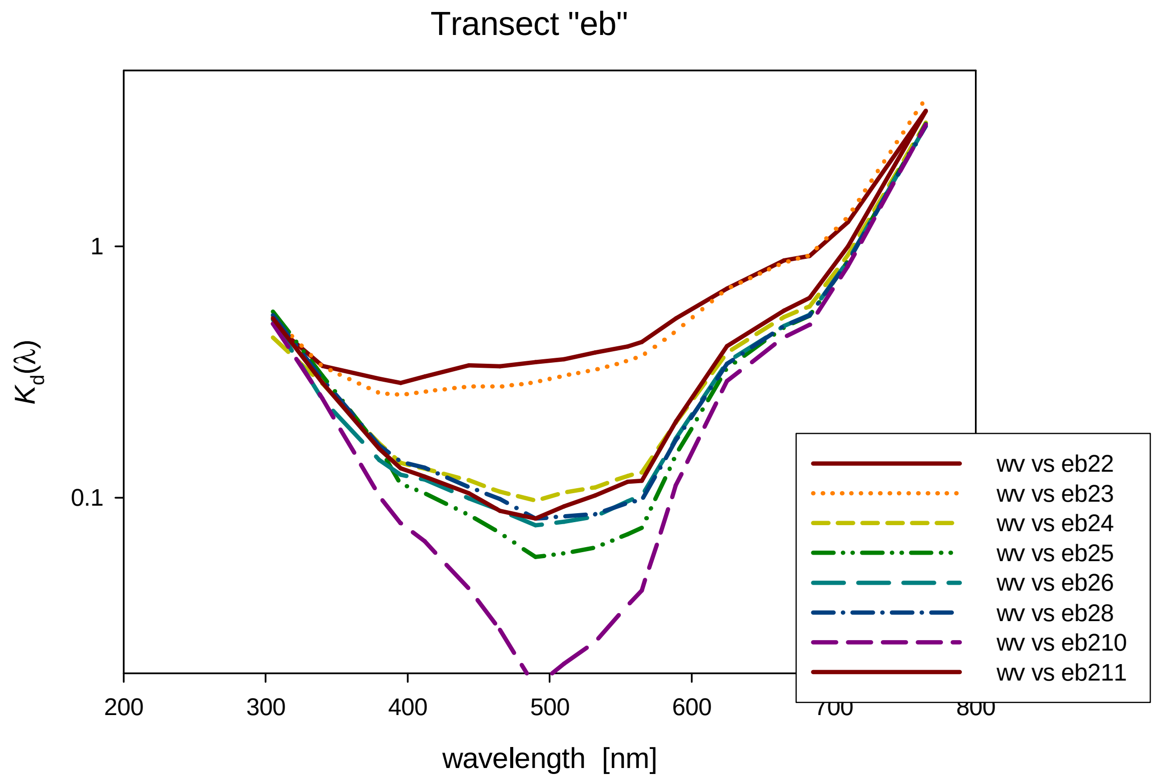
Examples of diffuse attenuation coefficient of downwelling irradiance at the stations along the section S.



Examples of diffuse attenuation coefficient of downwelling irradiance at the stations along the section Z.



Examples of diffuse attenuation coefficient of downwelling irradiance at the stations along the section EB



Examples of diffuse attenuation coefficient of downwelling irradiance at the stations along the section EX