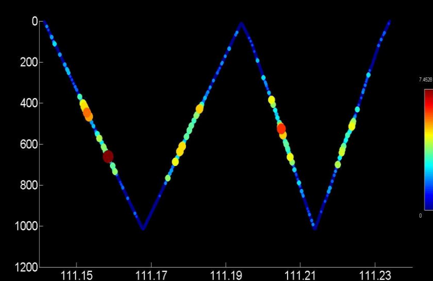
Undersampled and underrated?

Observing the role of marine snow in aquatic ecosystems

Möller KO, St.John M, Giering SLC, Möllmann C



ICES/PICES 6ZPS Bergen

Session S1: Application of optical and acoustical methods in zooplankton studies

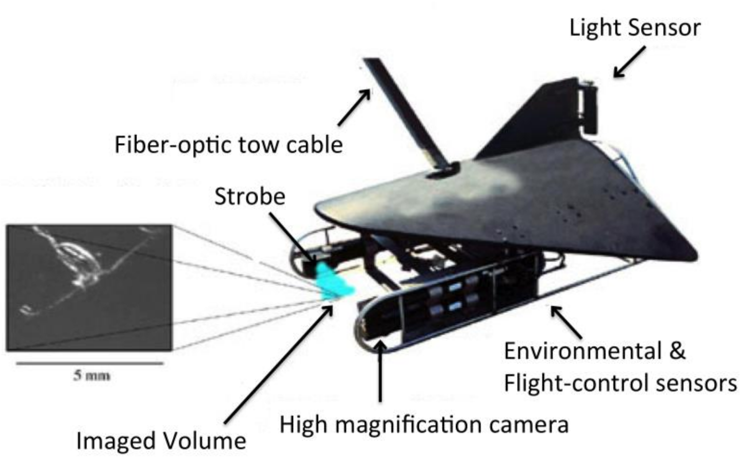
10 May 2016

Motivation

- Estimates of carbon flux to the deep oceans are essential for our understanding of **global carbon budgets**
- **Passive**: Sinking marine aggregates of biogenic origin, known as marine snow, are considered to play a major role in the oceans **particle flux** (‚biological pump‘)
- **Active**: Zooplankton mediated processes include feeding on primary production through **fecal pellets**, **disruption** of aggregates and **vertical migration** (daily, ontogenetic and annual overwintering)
- Aggregates may represent a concentrated **food source** for zooplankton
- ***In-situ* observations** are still rare due to traditional sampling methods

Elucidate processes affecting the carbon flux in different marine ecosystems by using a non-invasive optical approach

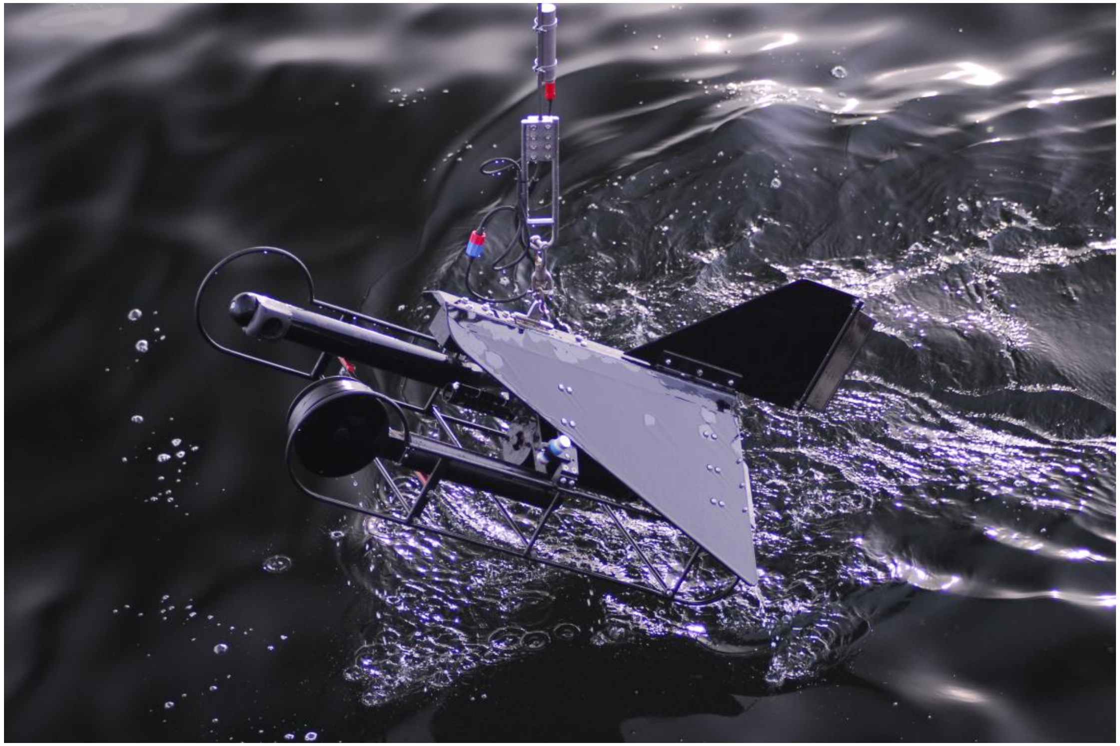
Sampling: Video Plankton Recorder (VPRII)



© Carin Ashjan

- Towed „underwater microscope“
- Equipped with high resolution camera and CTD, turbidity-, fluorescence-, and light sensors
- Images (25 fps) combined with sensor data sent in real-time on board
- Calibrated image volume = 41.2 ml
  Field of view = 24 x 24 mm
- Undulating between surface & bottom

Sampling: Digital autonomous VPR (DAVPR)



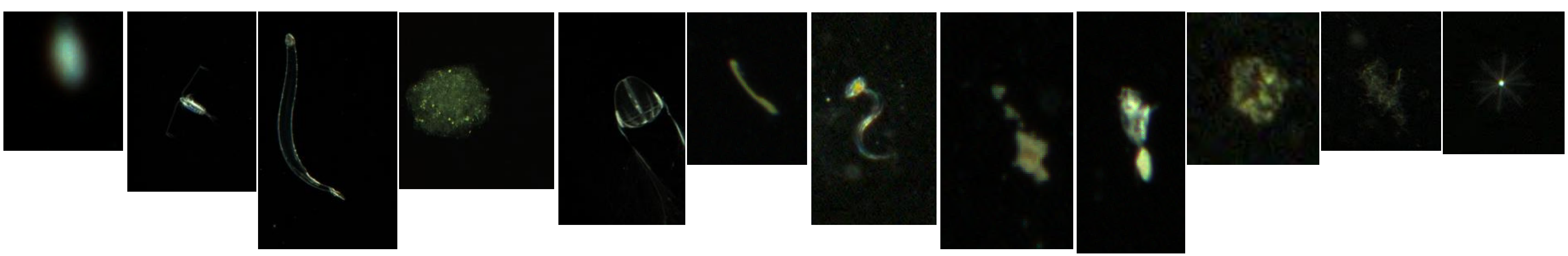
- Color camera, 15 fps, 1028x1024 pix
- Magnification setting: 24x24 mm field of view
- Calibrated image volume: 44.72 ml
- 1200 m depth rating
- Battery pack: 2 hours of continuous operation
- Hydrographic sensor: CTD

Data processing and classification

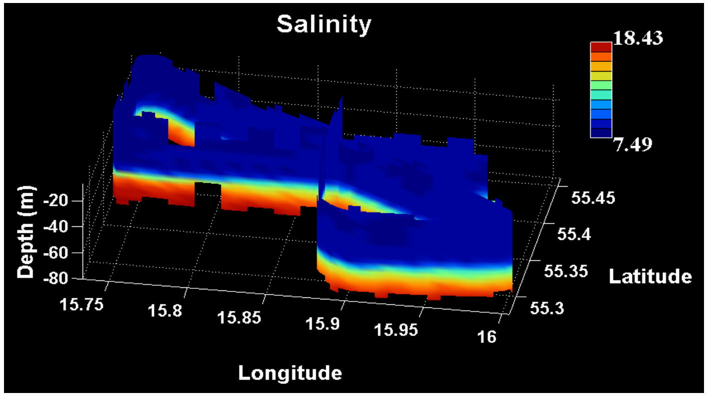
- „Rois“ were extracted from all captured image frames / building Training set
- Dual classification method (SVM & Neural network) with automatic correction (Hu & Davis 2006)
- Manually corrected afterwards

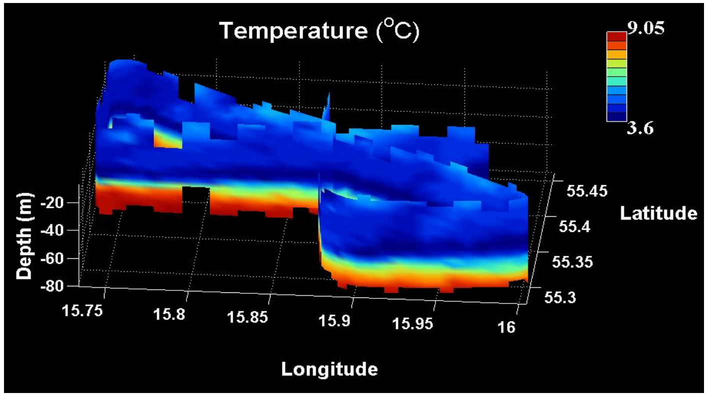
Confusion matrix (machine vs. human counts)

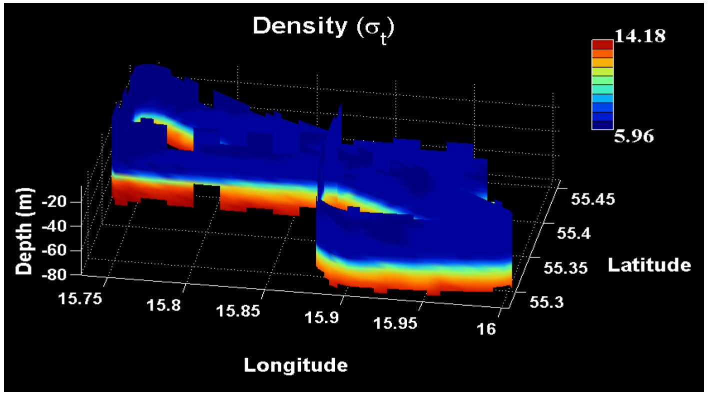
	blurry	calanus	chaetognath	diatom snow	jelly	krill fecal string	appendicularian	marine snow	other copepods	phaeocystis	phaeocystis snow	radiolaria	others
blurry	380	0	0	0	3	0	0	6	1	0	0	3	0
calanus	36	289	15	0	6	0	0	0	2	0	0	0	0
chaetognath	0	31	233	0	5	1	6	0	0	0	0	0	2
diatom snow	0	0	1	399	2	0	0	0	0	0	3	0	0
jelly	1	0	2	0	172	0	8	6	1	0	0	0	48
krill fecal string	0	0	4	0	0	281	2	21	5	0	0	0	0
appendicularian	0	1	3	0	9	7	244	4	1	0	3	0	0
marine snow	0	0	0	0	2	8	2	189	14	0	0	0	2
other copepods	1	10	0	0	2	1	6	5	291	0	0	0	6
phaeocystis	0	0	0	0	2	0	1	0	0	309	17	0	0
phaeocystis snow	0	0	1	0	0	0	6	0	0	3	244	0	1
radiolaria	0	0	0	0	4	1	1	0	1	0	0	363	2
others	24	111	183	43	235	143	166	211	126	130	175	76	386

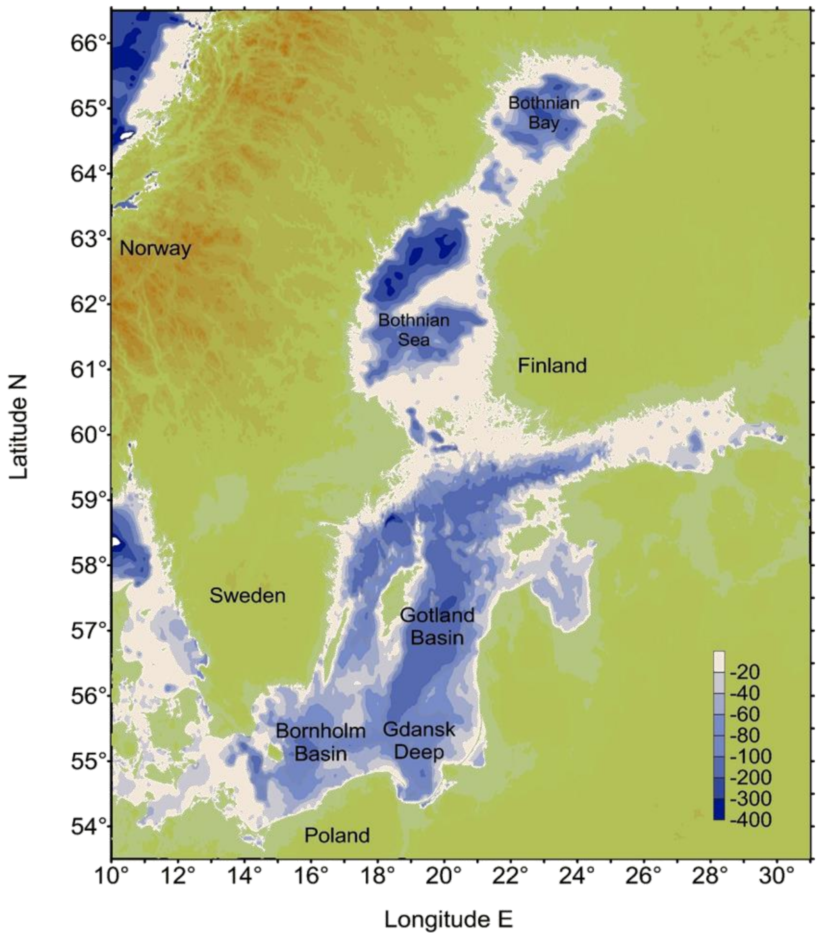


Baltic Sea: Hydrography



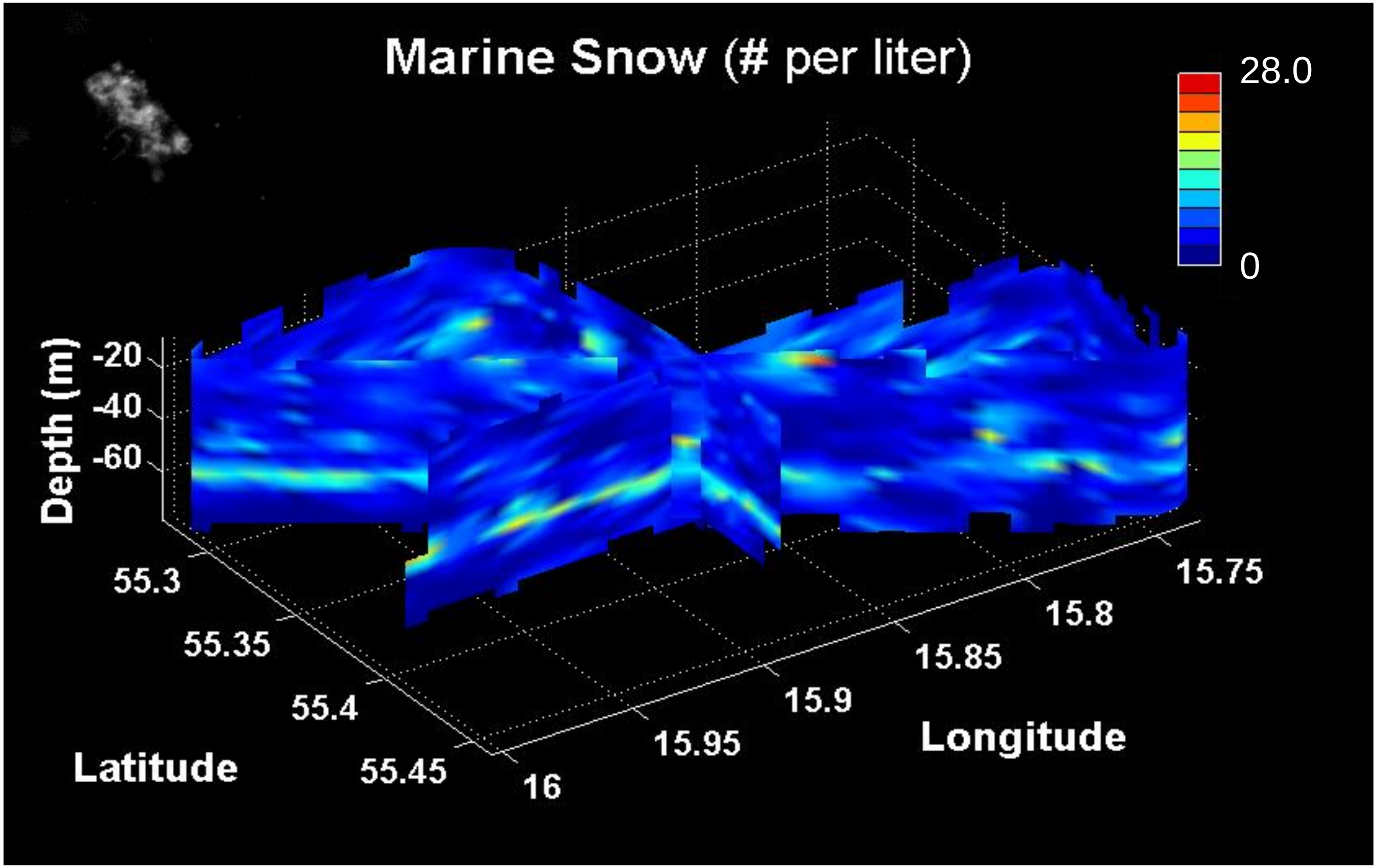






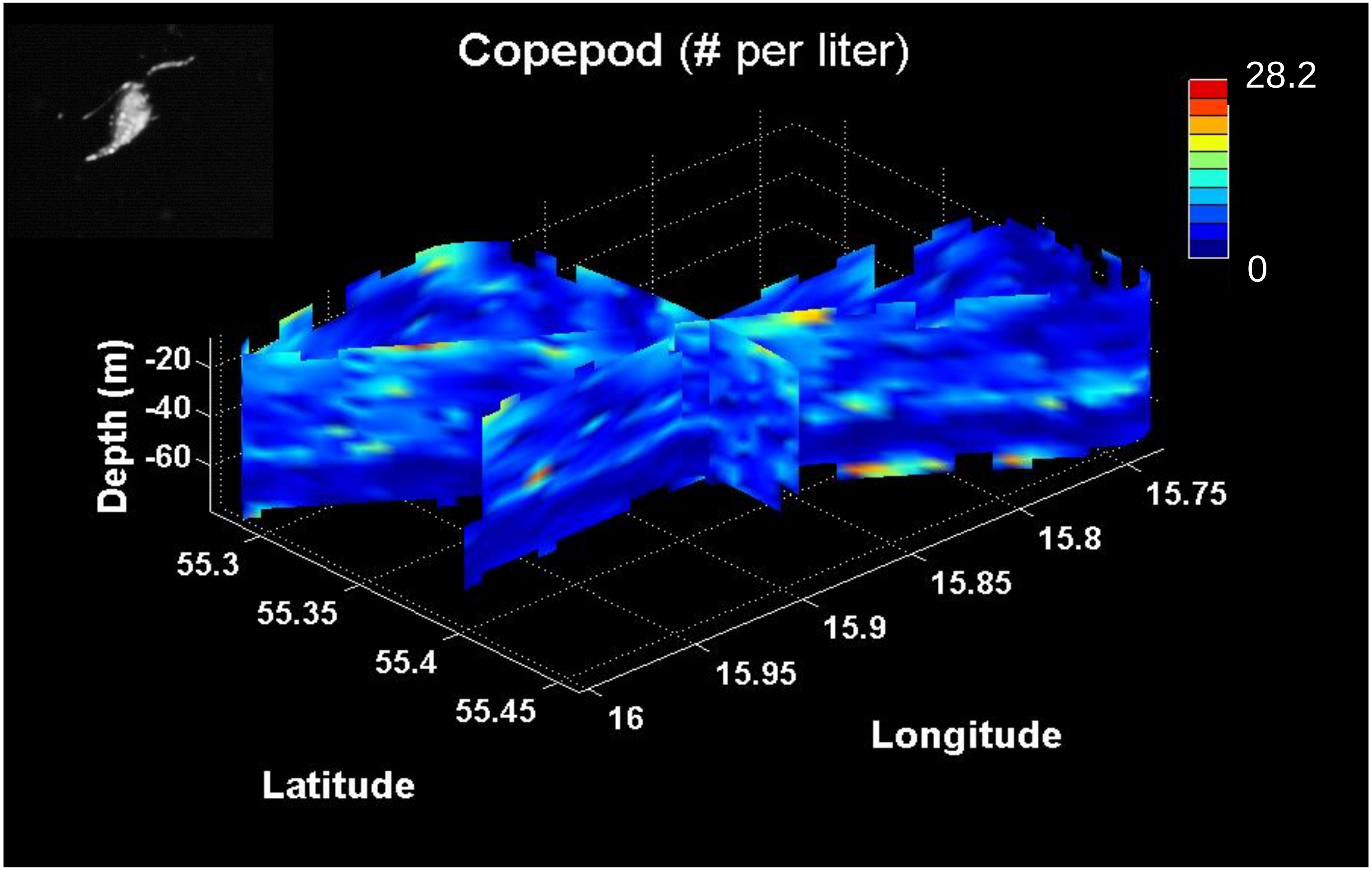
- Characteristic spring conditions
- Pronounced density gradient in 50 m

Along-track distribution: Marine snow

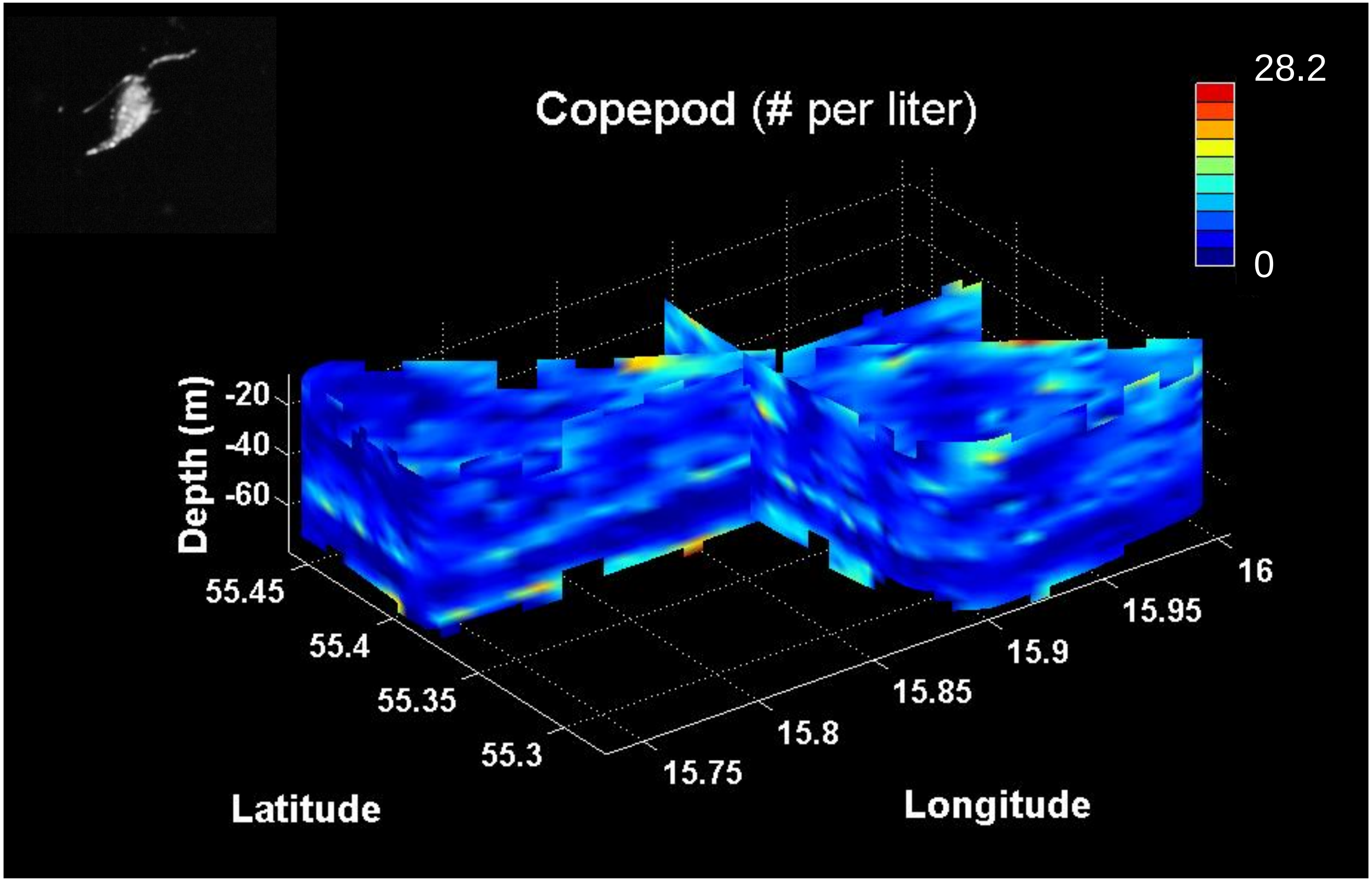


- Pronounced thin layer of aggregates at halocline

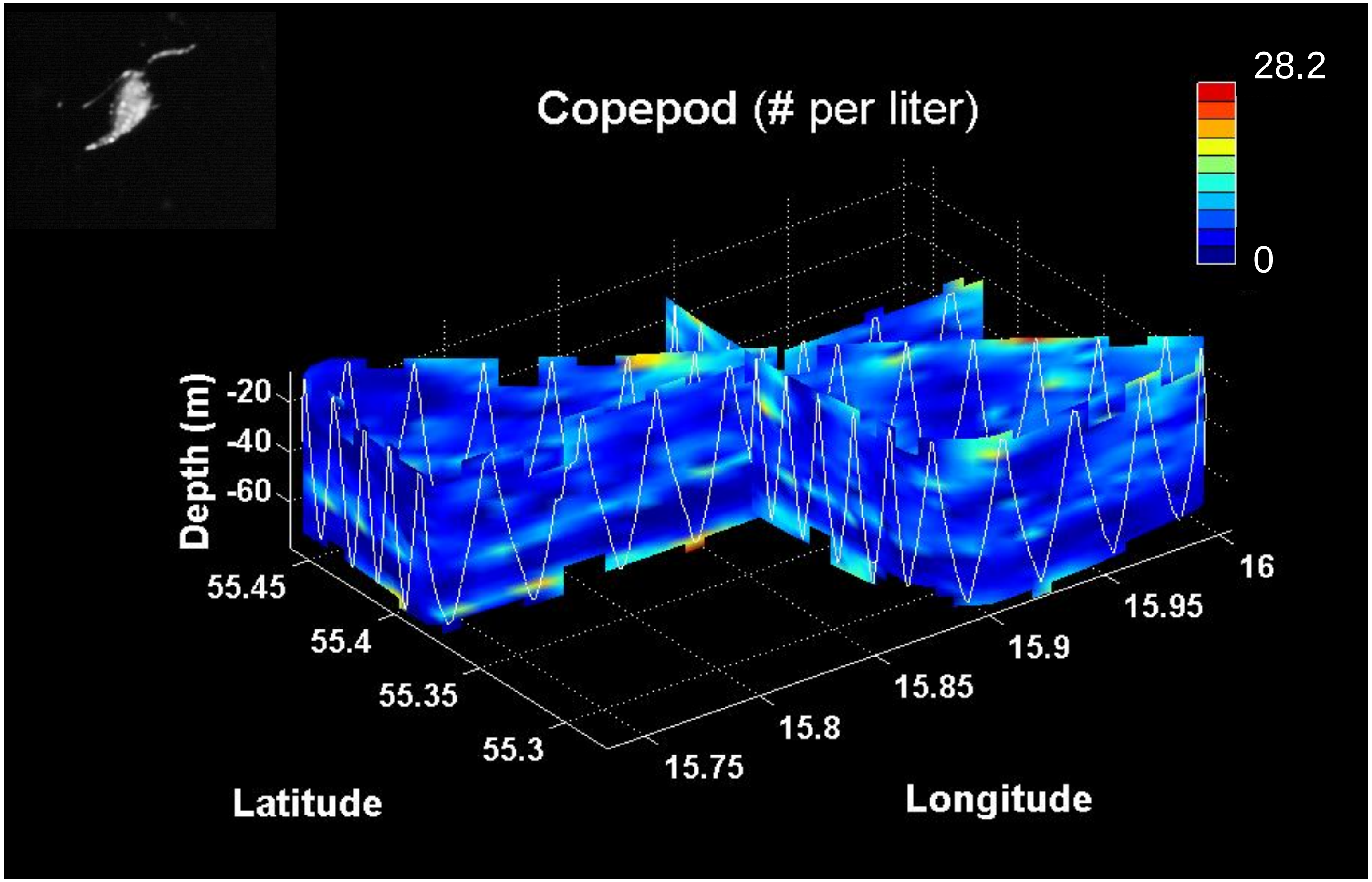
Along-track distribution: Copepods



Along-track distribution: Copepods



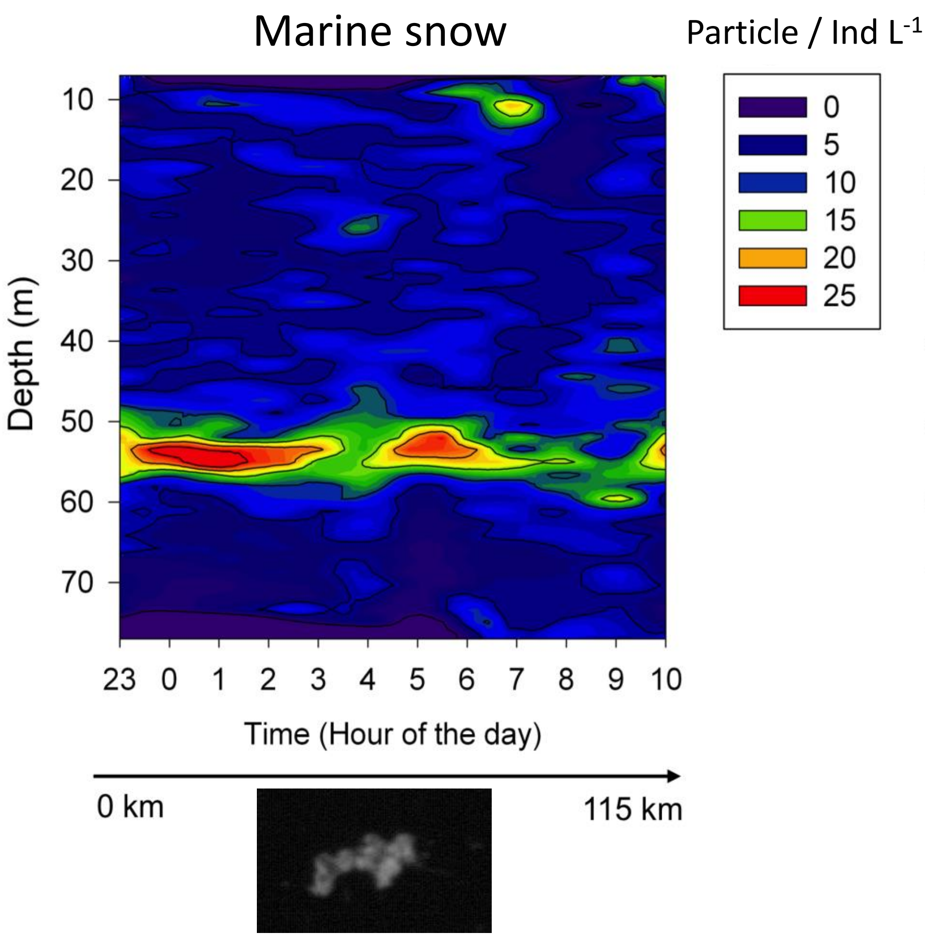
Along-track distribution: Copepods



- Real datapoints and not interpolation artifacts

Vertical distribution pattern

Möller et al. (MEPS 2012)



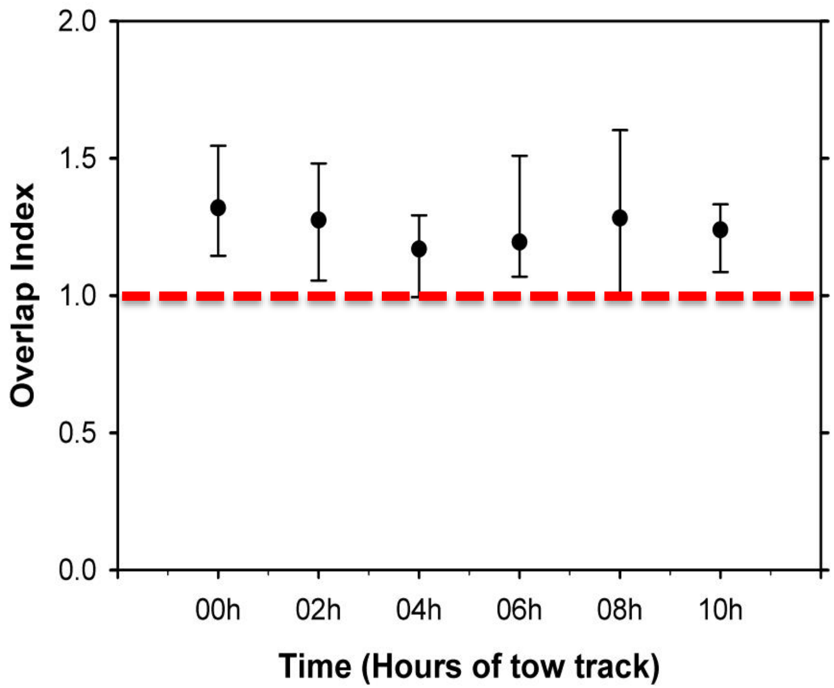
- Pronounced thin layer of marine snow
- High copepod concentrations within this layer

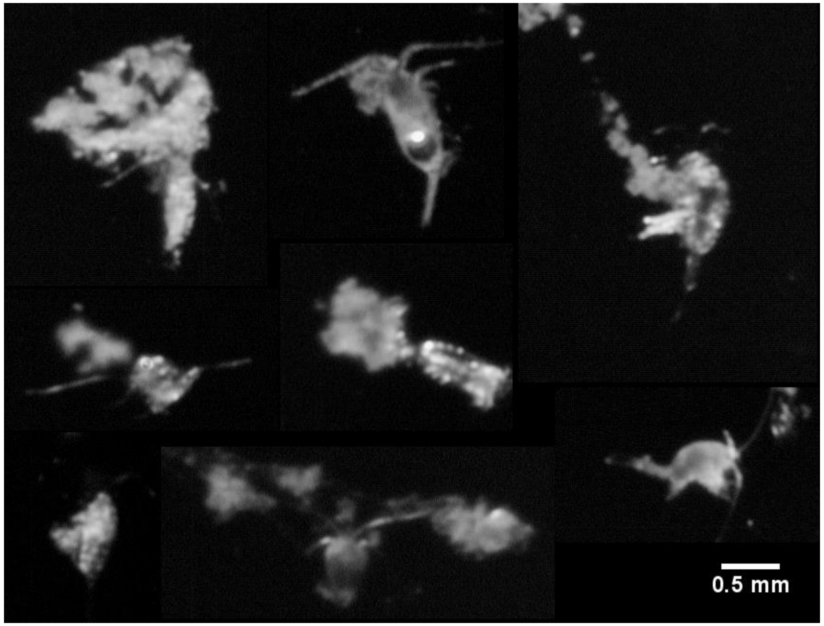
Spatial overlap & trophic interaction

Williamson & Stoeckl (1990)

$$O = \frac{\sum_{z=1}^{m} (N_z * n_z)m}{\sum_{z=1}^{m} (N_z) * \sum_{z=1}^{m} (n_z)}$$

Z = depth strata, m = number of depth points sampled, N_z = density of copepods, and n_z = density of marine snow aggregates at a given depth.





- Strong spatial overlap
- Images of copepods attached to aggregates
- Antenna in feeding position
- Marine snow as a food source in the Baltic: undersampled & underrated?

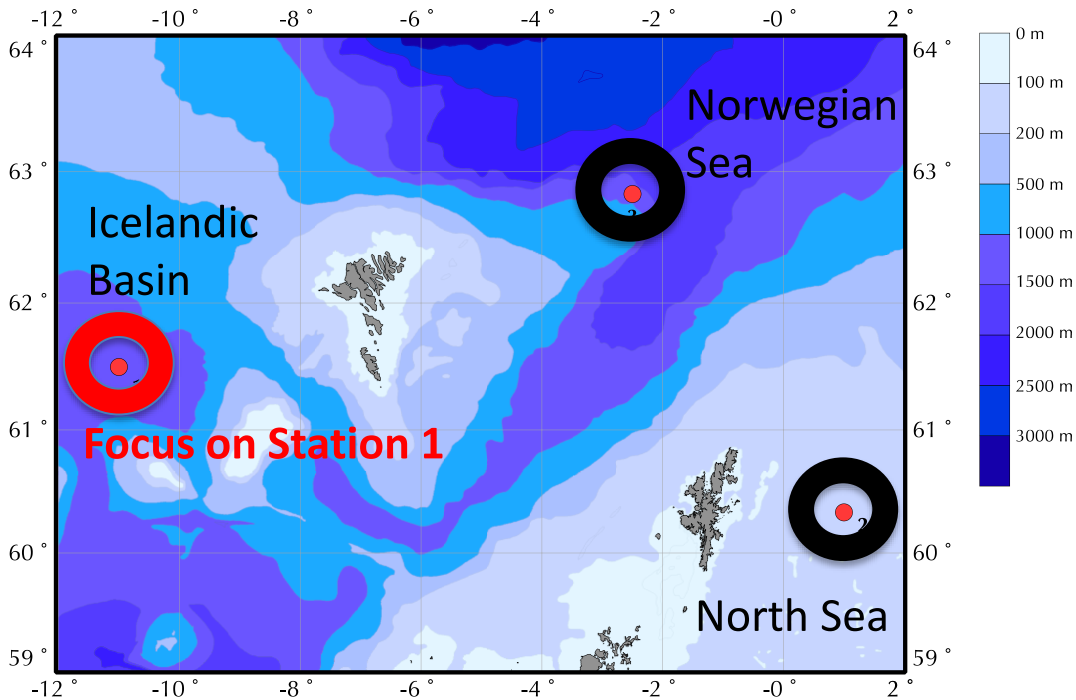
Deep convection cruise with RV ‚Meteor' in 2012 (19.03 – 02.05.)

Key objectives :

- Identify the vertical distribution of plankton & particles during the transition from winter convection to spring bloom conditions

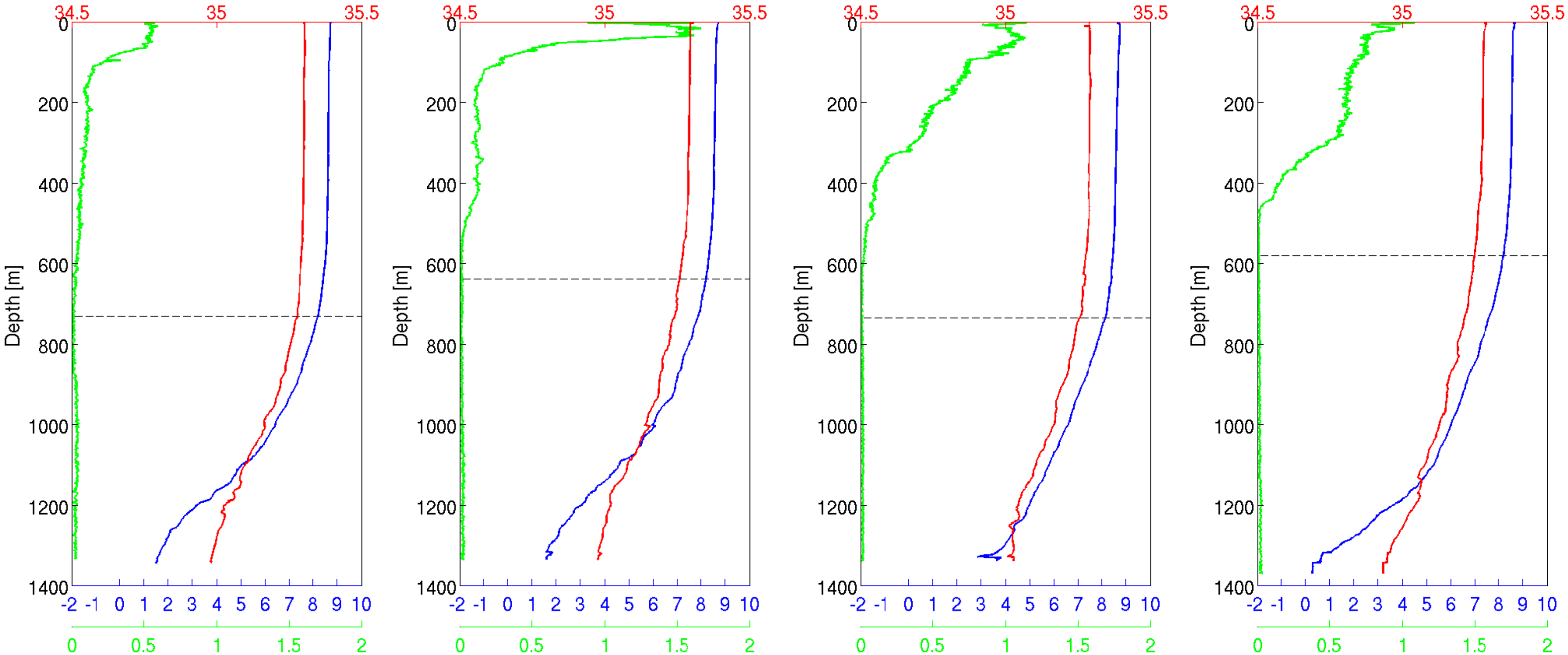
- Observe the diapause depth of *Calanus finmarchicus* in relation to deep convection

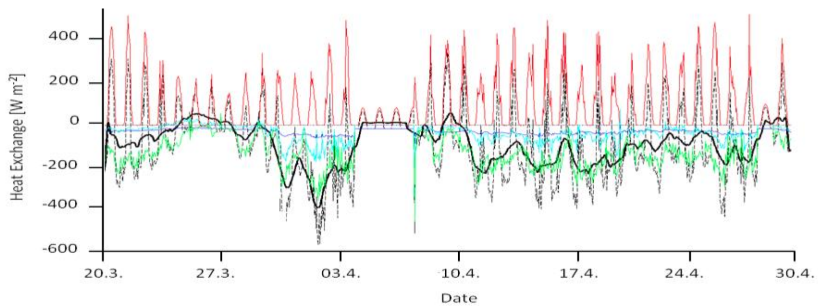
- Resolve potential individual interactions between zooplankton consumers and sinking particles



Icelandic Basin: Hydrography

1st visit	**2nd visit**	**3rd visit**	**4th visit**
March 28th	April 10th	April 21st	April 28th

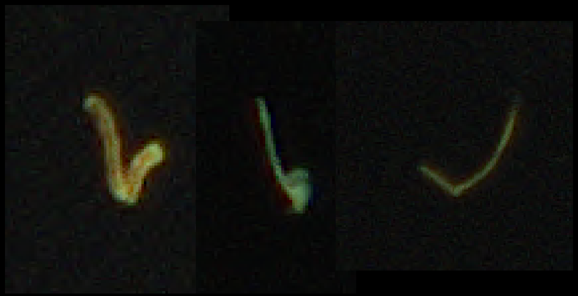


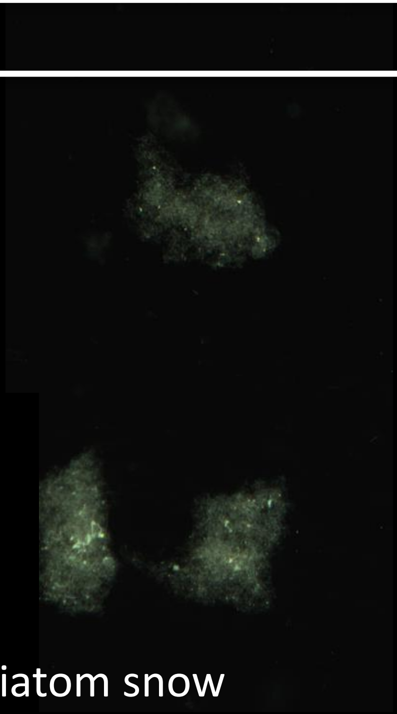


$$T_{convection} = T_0 - 0.5$$

Classification and marine snow categories

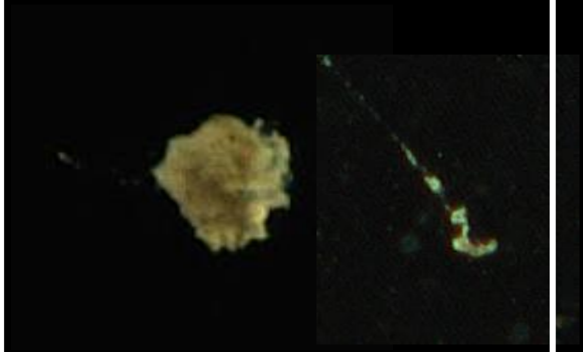

Calanus


Krill fecal string


Diatom snow


Phaeocystis


Phaeocystis snow


„regular“ Marine snow

Icelandic Basin: Marine snow combined

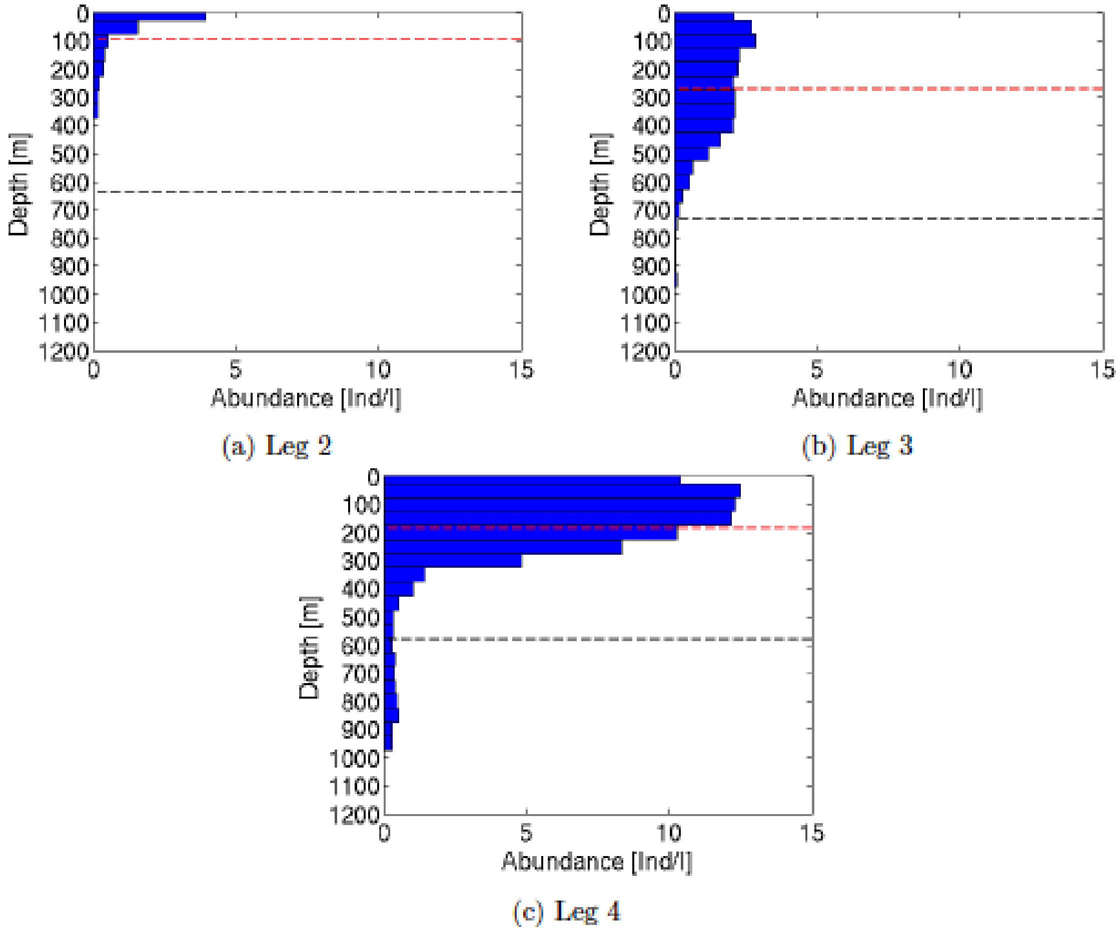
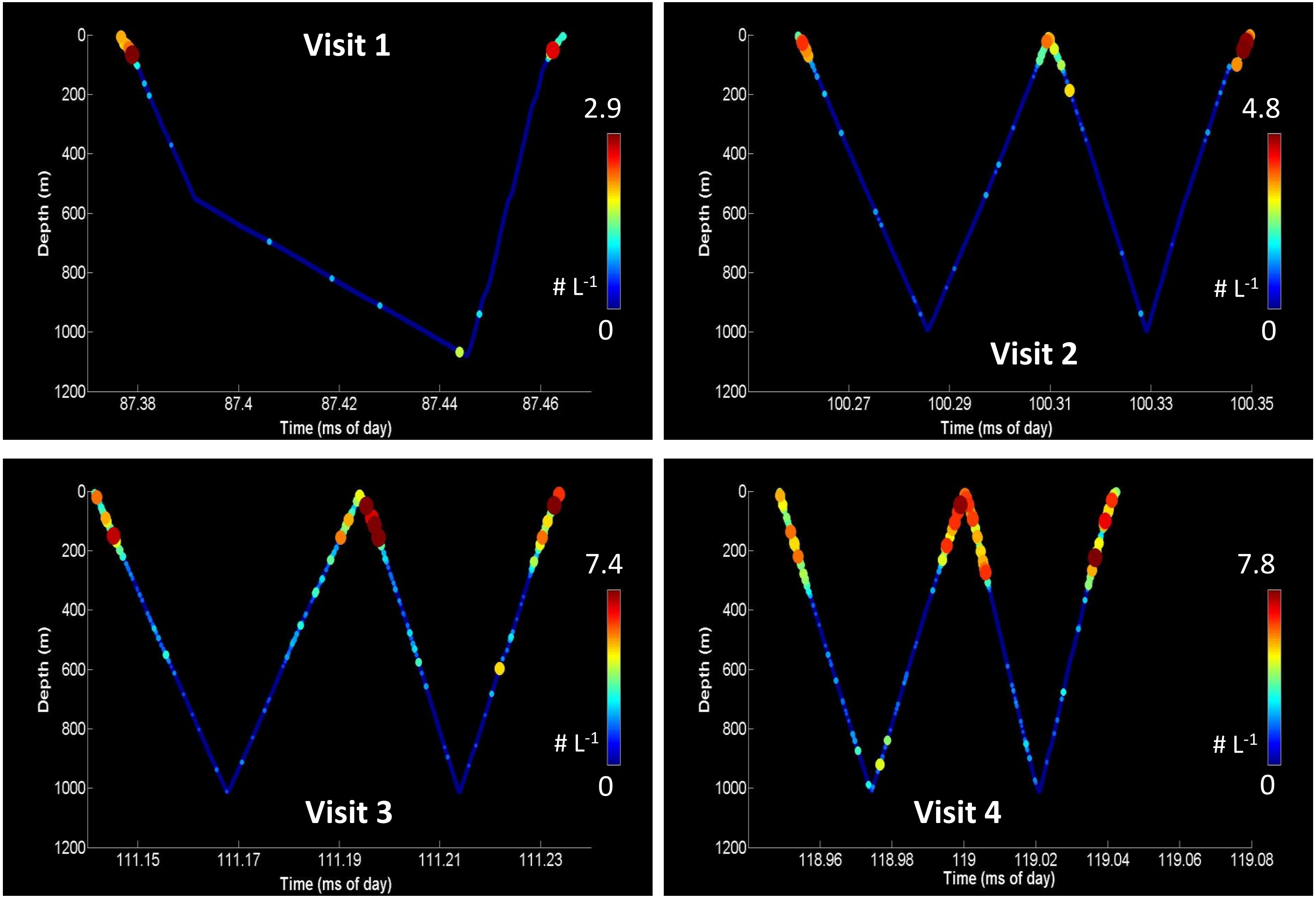


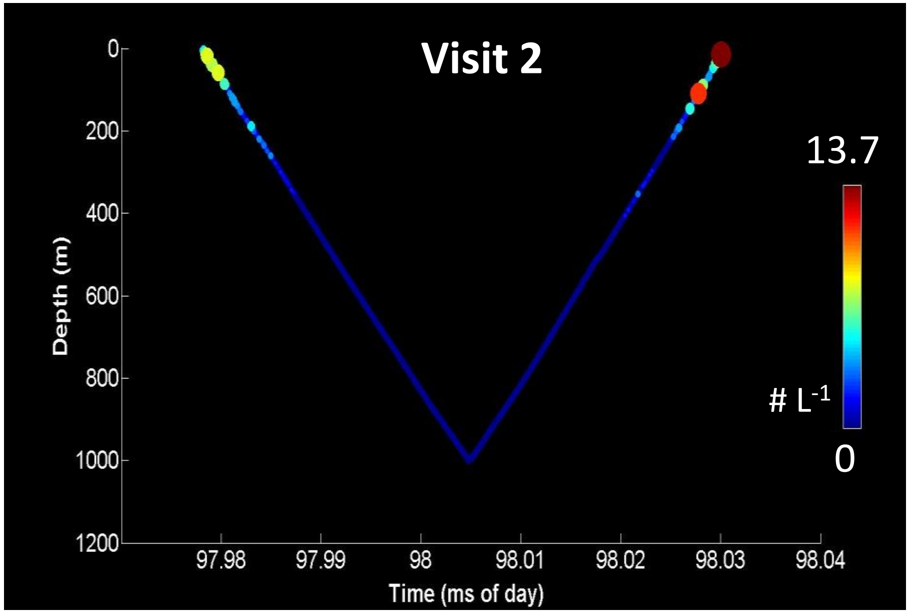
Figure 11: Abundance of marine snow for 4 legs at Station 1 of the M87 cruise. The bars show the abundance in 50 m bins, the black dashed line the numerically calculated convection depth and the red dashed line the weighted mean depth.

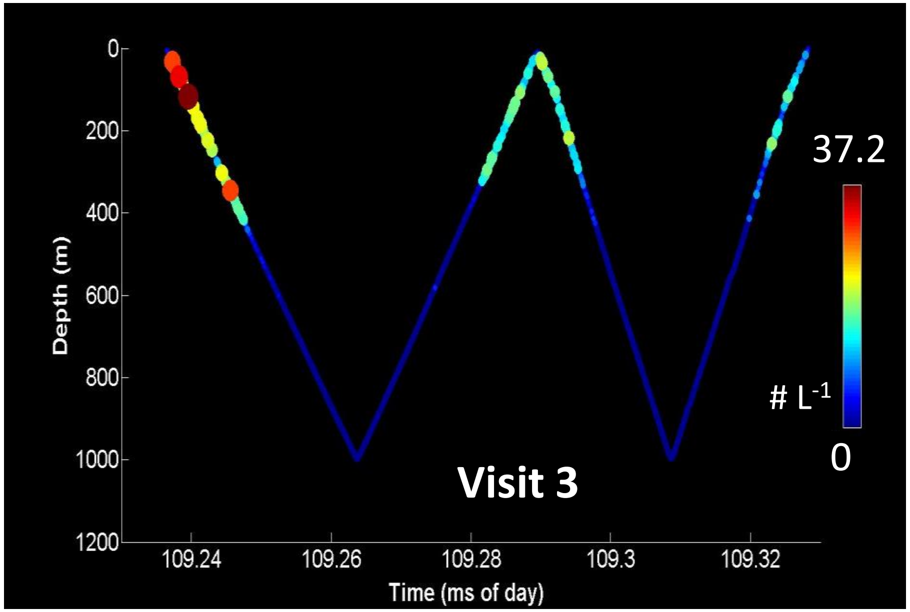
Krill fecal string - vertical distribution

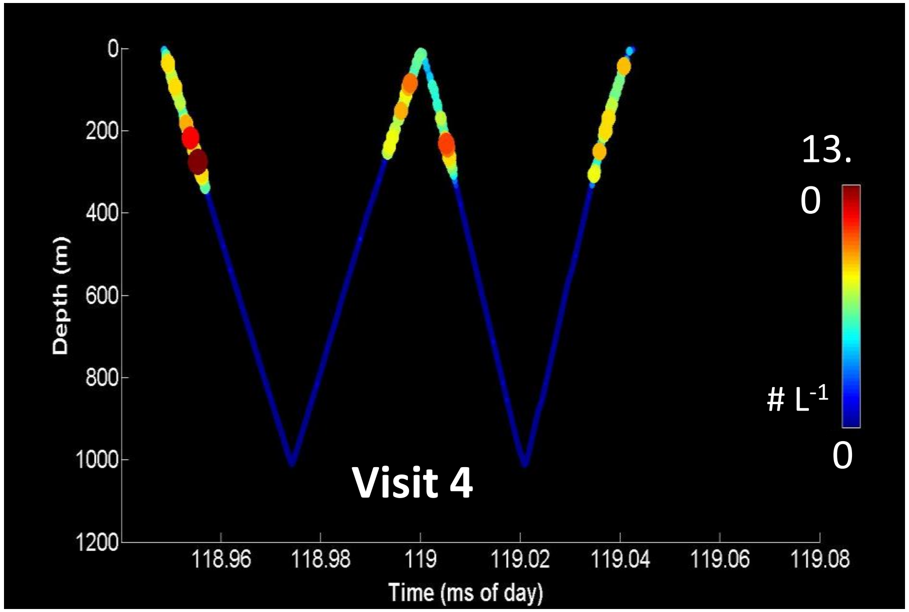


Phaeocystis snow - vertical distribution

- No Phaeo-snow during first visit
- Increase – bloom during second visit
- Accumulation at surface
- No sinking out - Grazing?

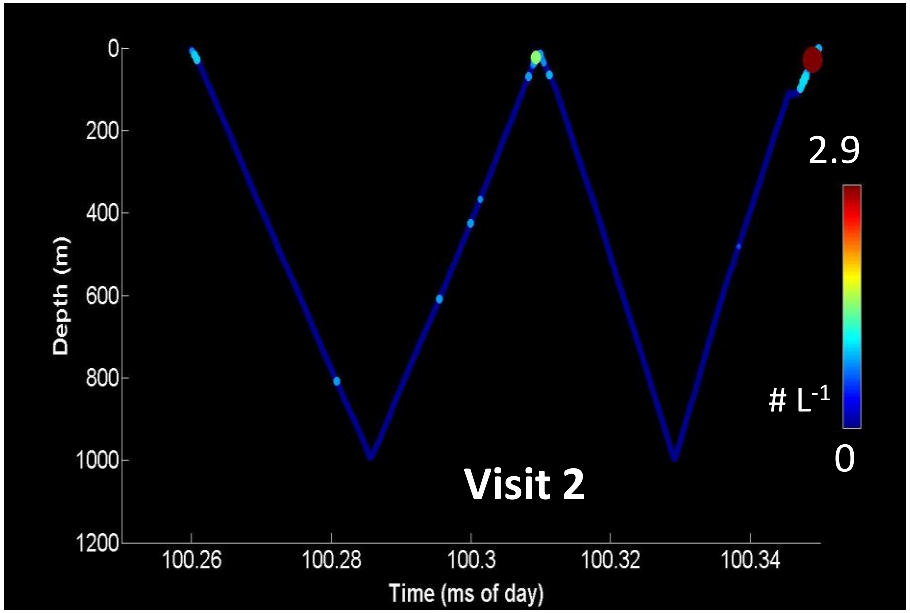


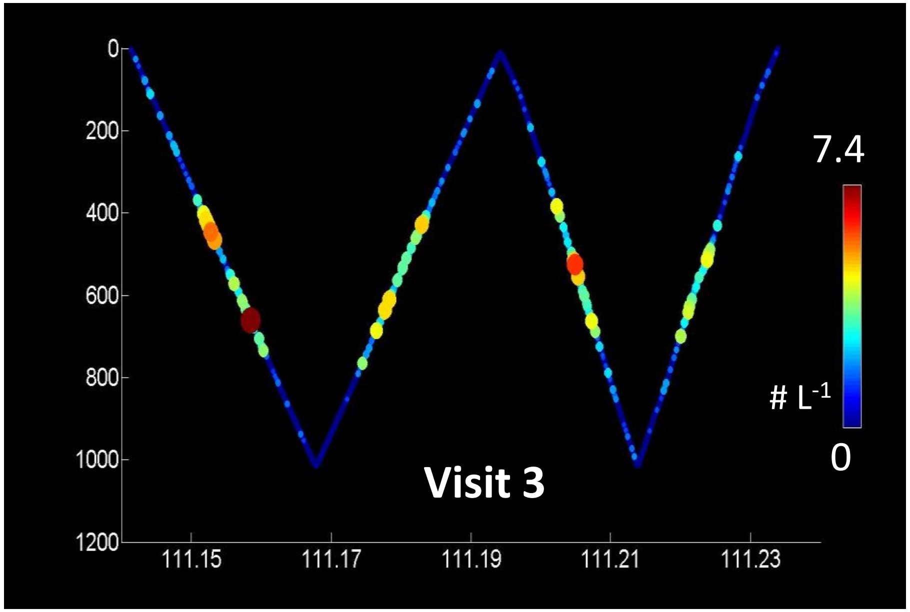


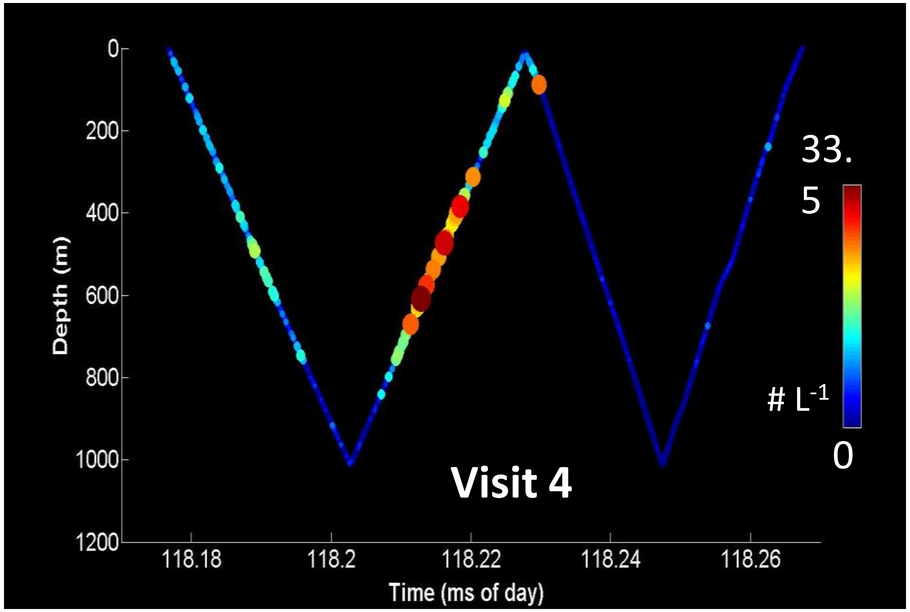


Diatom snow - vertical distribution

- No diatom snow during first visit
- Low abundant during visit 2
- Increase with time / visits
- Diatom bloom during last visit
- Sunken out or grazed away?

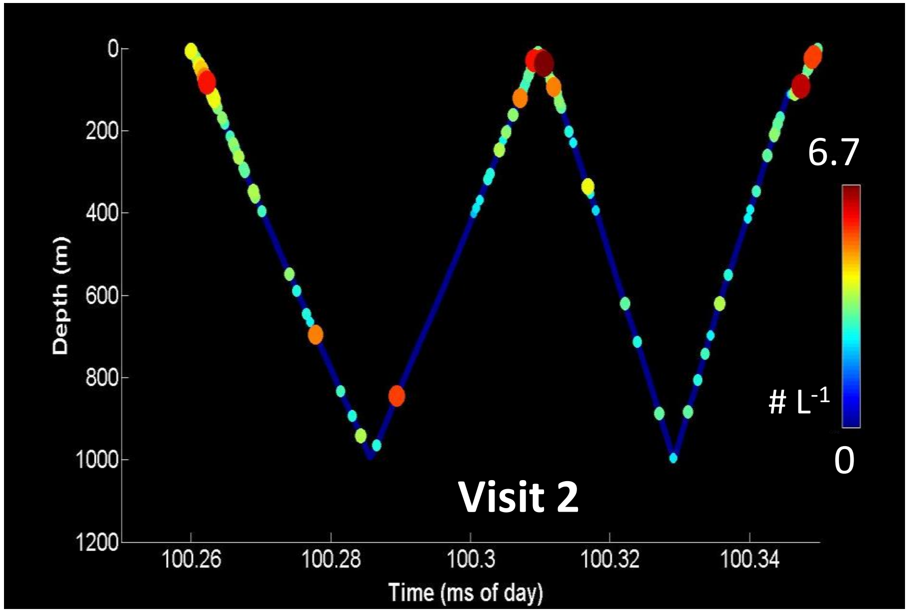


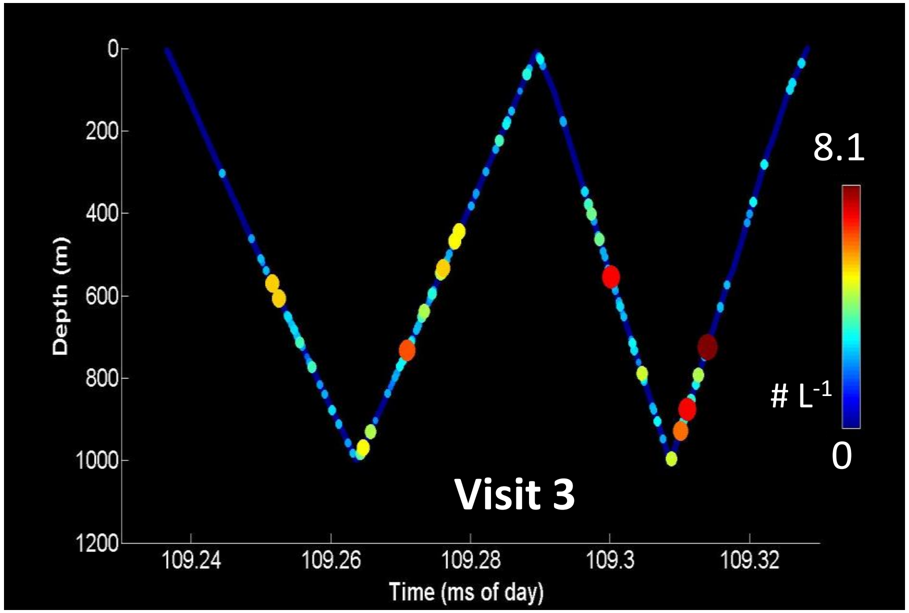


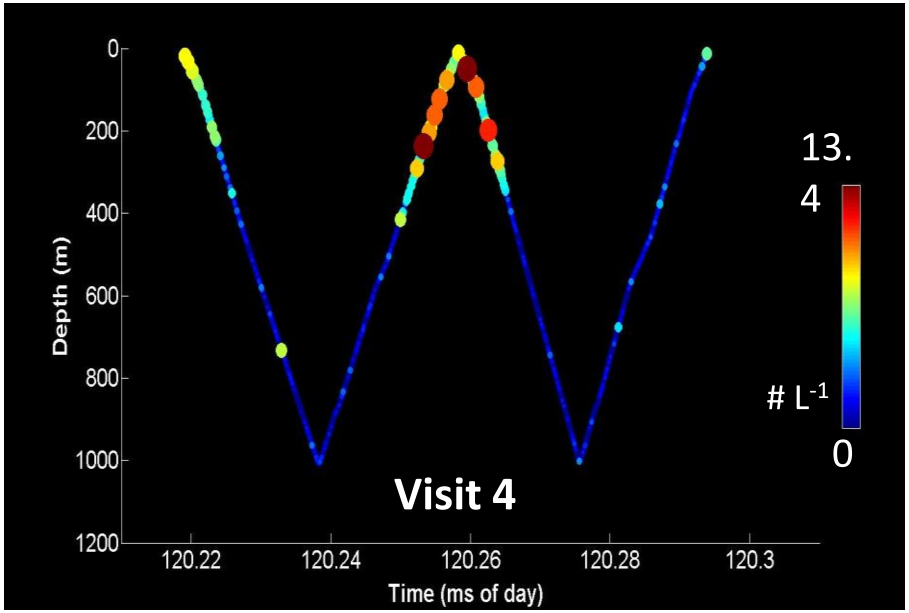


Regular snow - vertical distribution

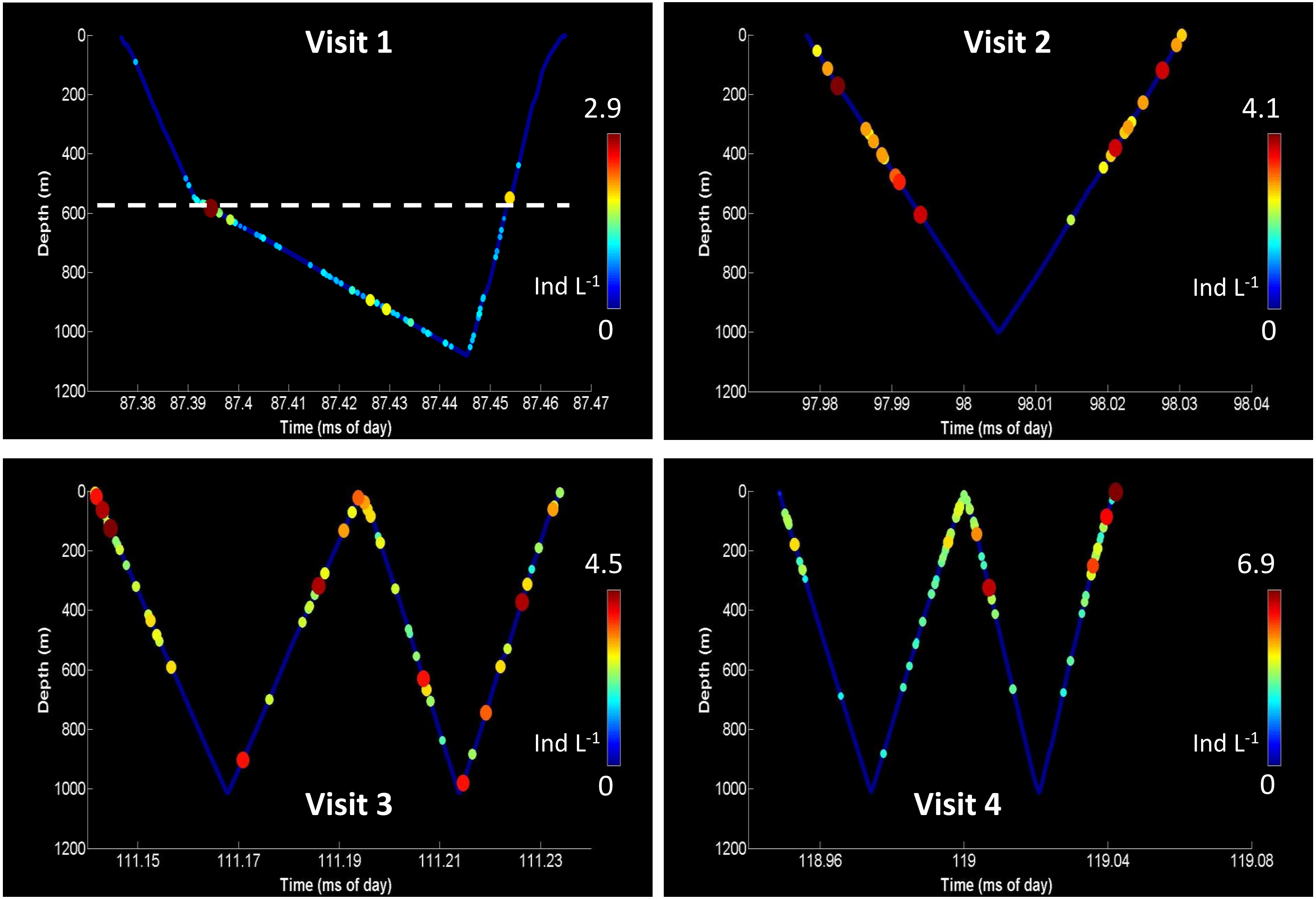
- No marine snow during first visit
- Increase with time / visits



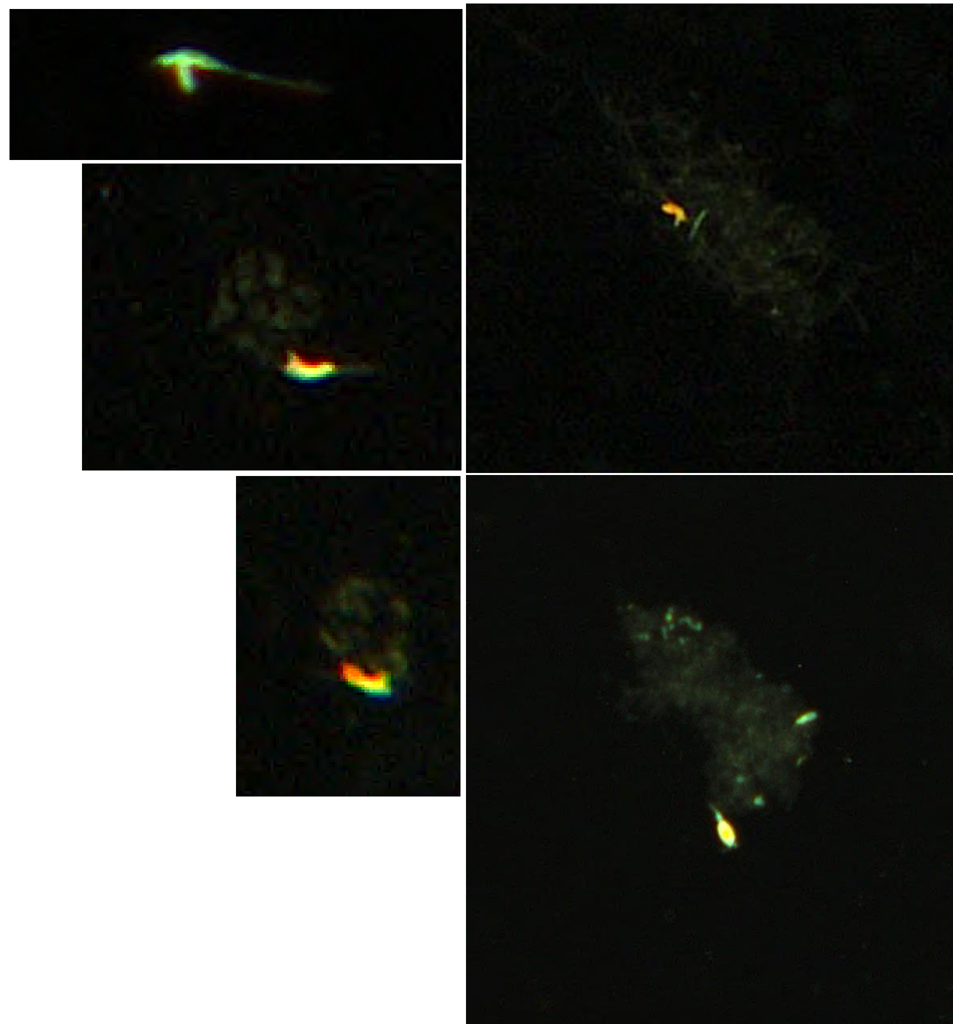




Calanus finmarchicus vertical distribution

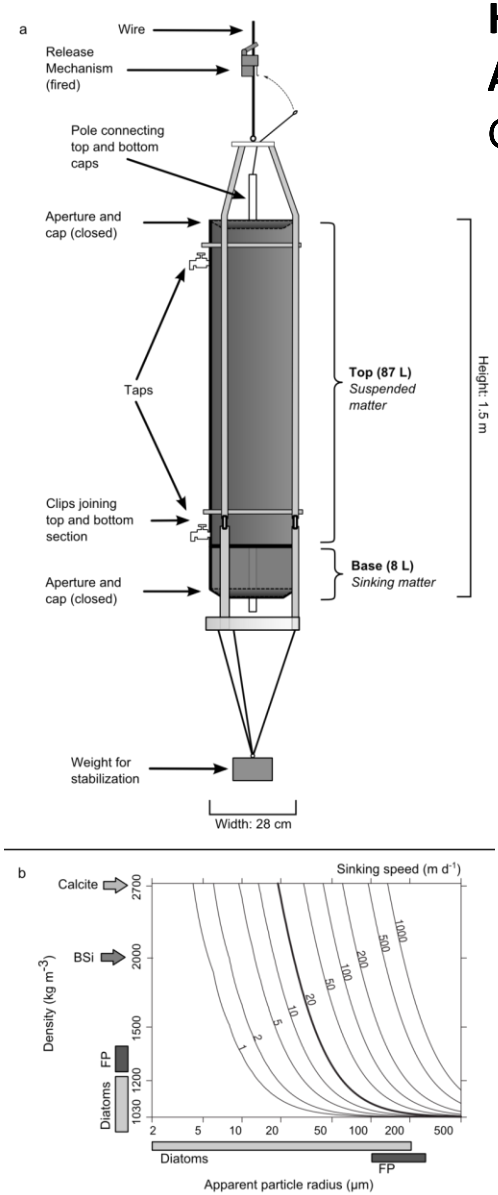


Interaction between zooplankton and sinking particles



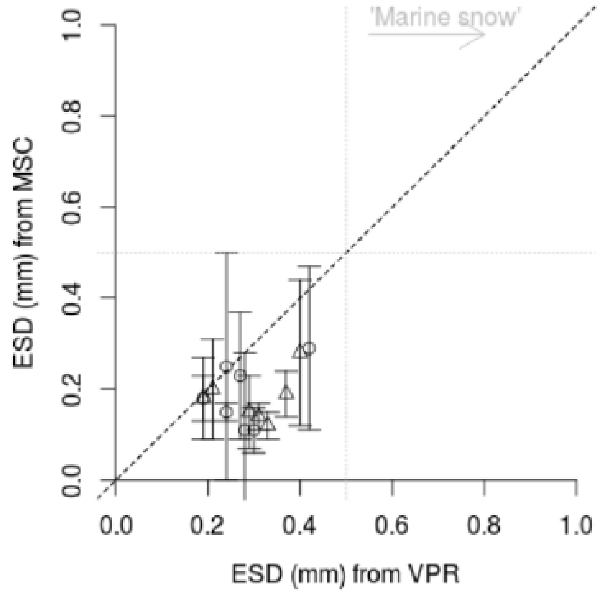
- App. 85% of *Microsetella* spp. was found to be attached to aggregates.
- Exclusively on *Phaeocystis* snow & colonies
- *Oncea* spp. was found exclusively on marine snow of diatom origin

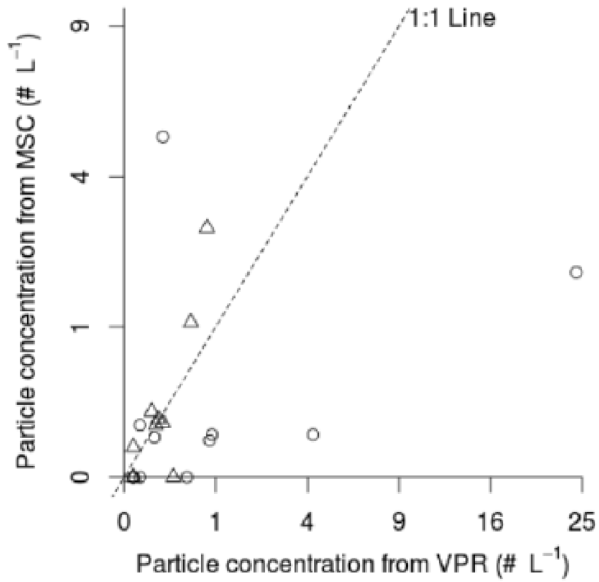
Quantify particle flux & utilization:



High export via small particles before the onset of the North Atlantic spring bloom

Giering et al. (submitted)

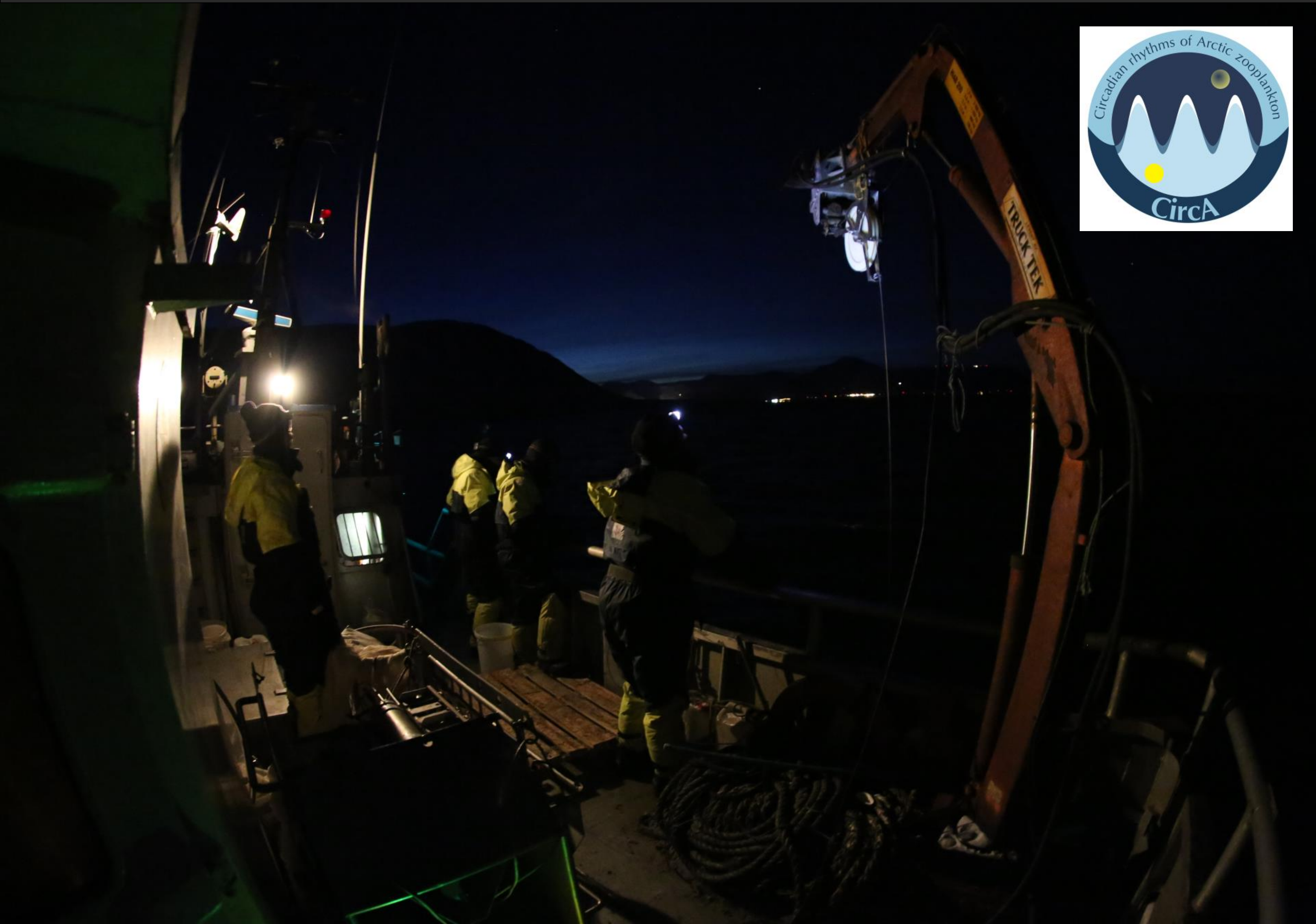




- Calculate sinking speeds for different aggregate types & sizes
- Determine aggregate utilization rates of zooplankton

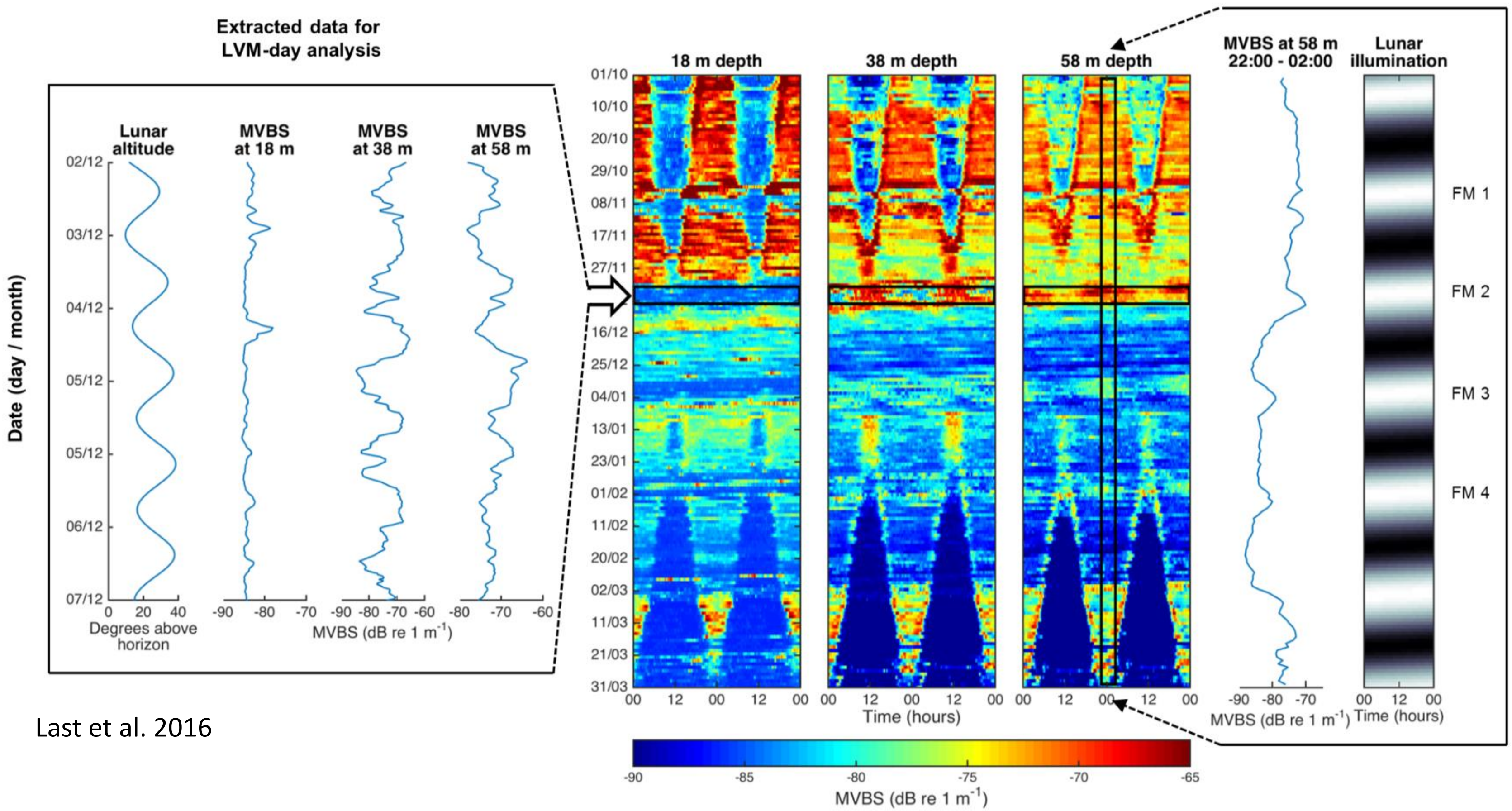
→ Nutrient recycling vs. sinking out of particles

Polar night cruise



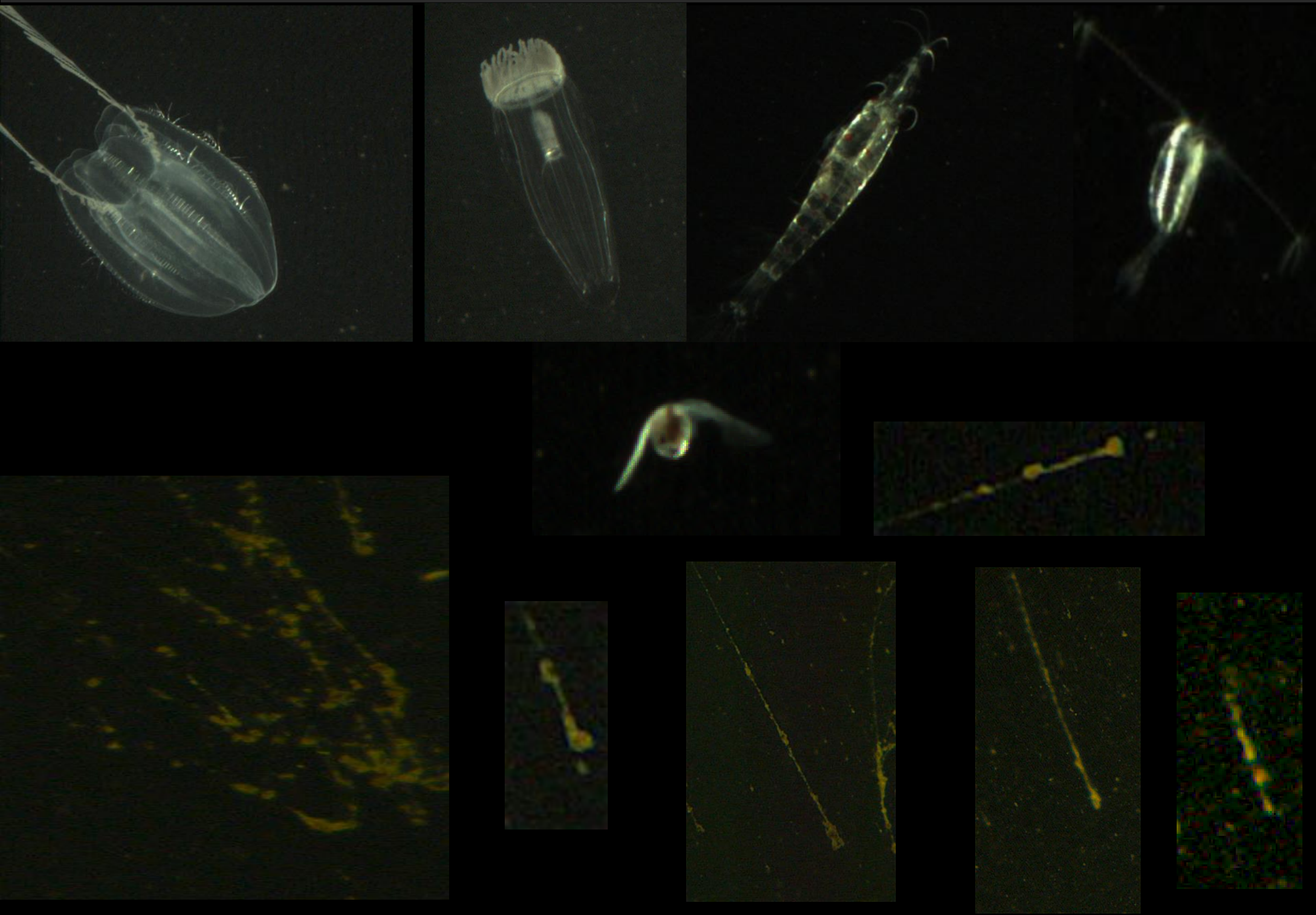
Circadian rhythms of Arctic zooplankton
CircA

Lunar Vertical Migration patterns



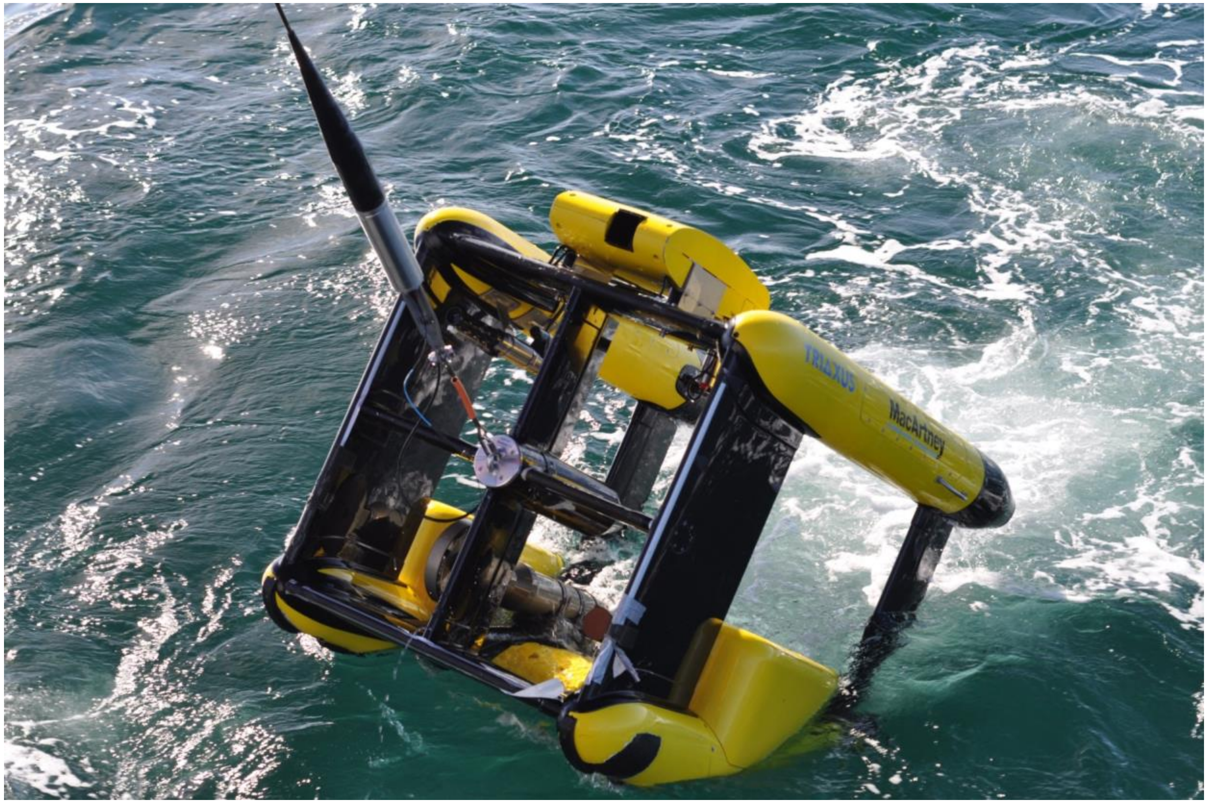
Last et al. 2016

Who is there?



North Sea Windpark: Integrative monitoring

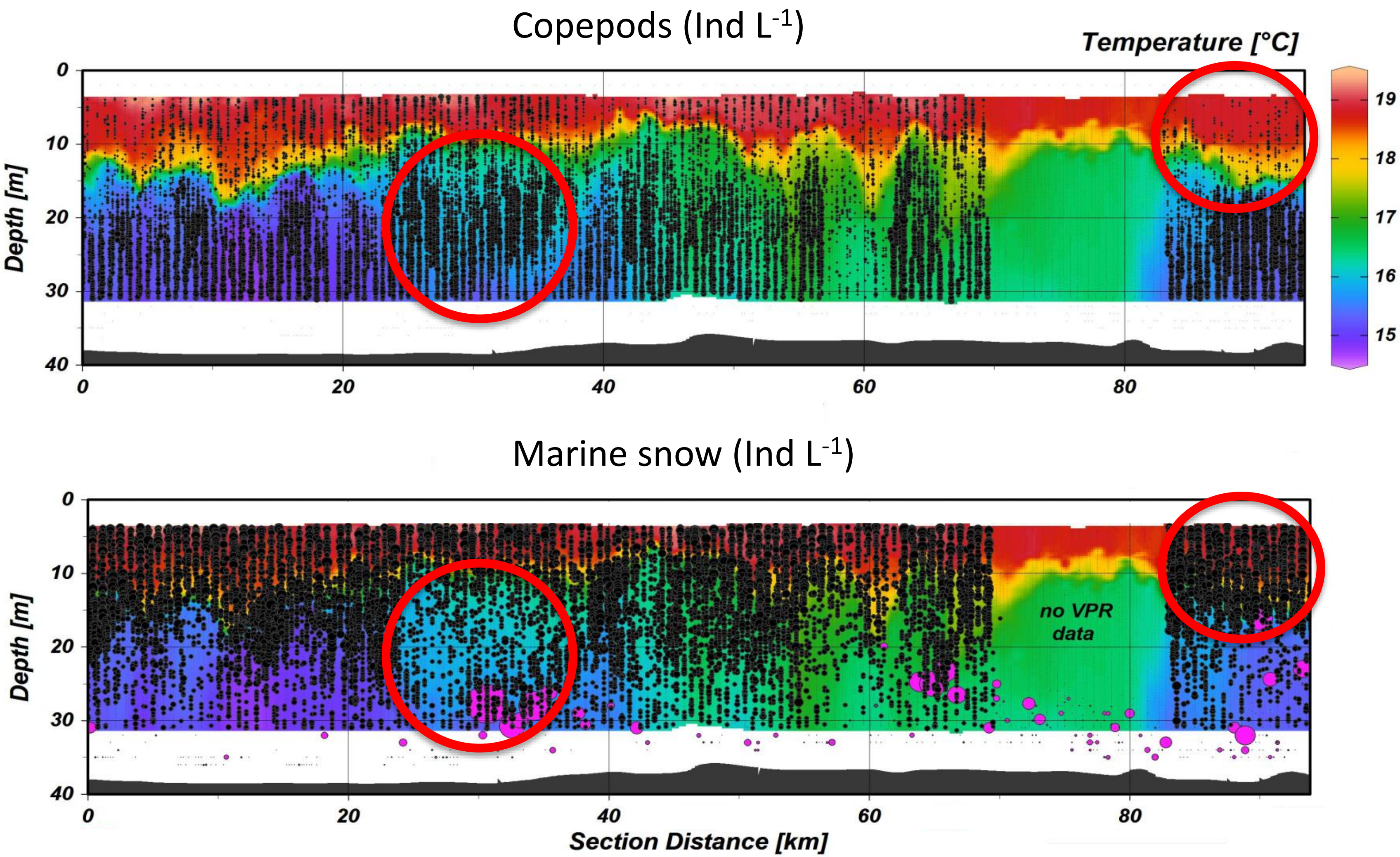
VPR II on TRIAXUS high speed tow-body



Scientific equipment connected via fibre optic cable (2000m)

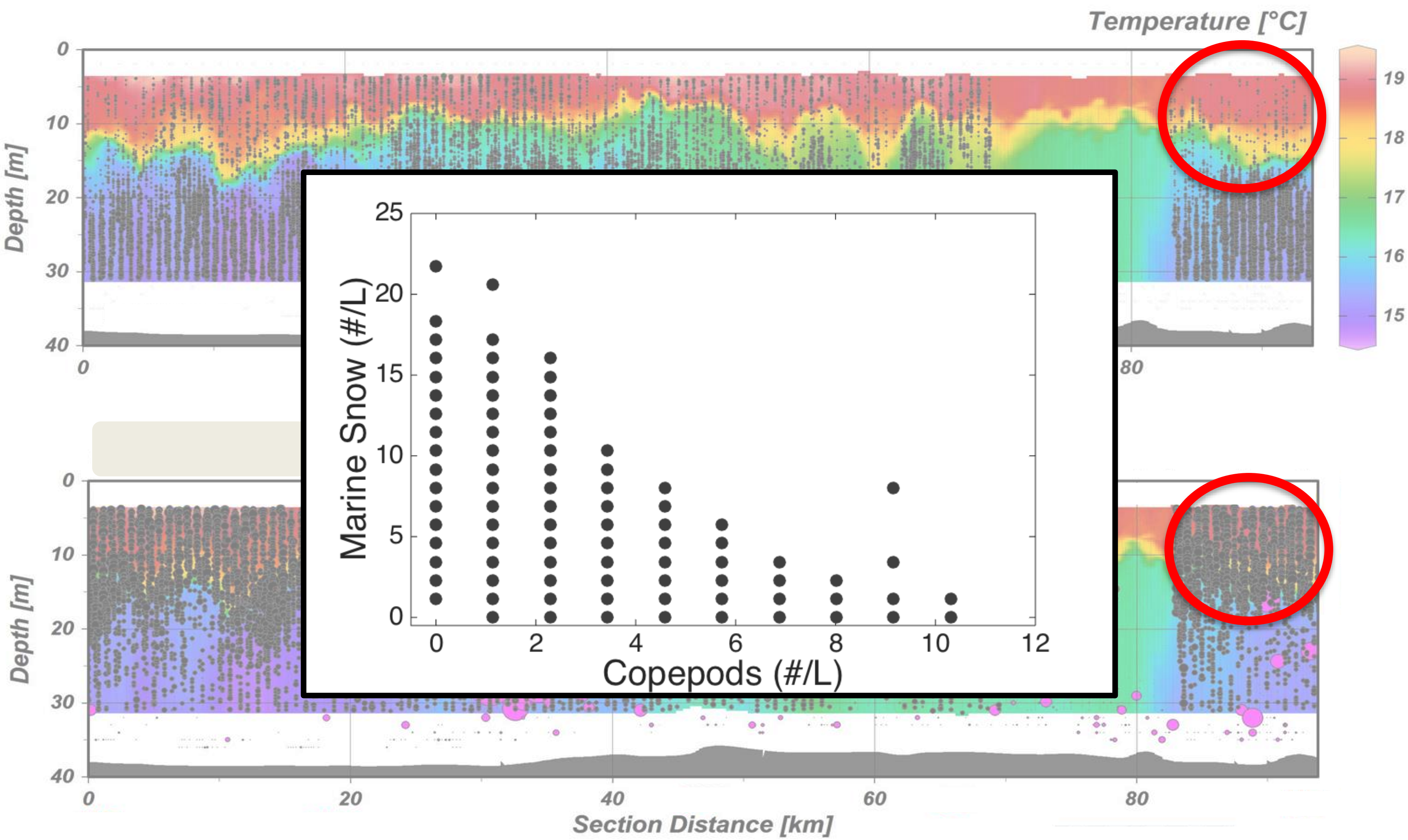
- Seabird Fast Cat SBE 49, 16 Hz, pumped)
- TRIOS PAR sensor
- Aanderaa Oxygen Optode 4330 F (Response Time (63%) < 8 s)
- Simrad EK60 Hydroacoustic System (200 & 333 kHz, split beam)
- ODIM LOPC Laser Optical Plankton Counter (100 µm to 3.5 cm)
- Turner C6 Cyclops, pumped, sensors: Chl-*a* , Phycocyanin, Phycoerythrin, Turbidity

Horizontal distribution



- Mirror-inverted distribution pattern of copepods and marine snow

Horizontal distribution

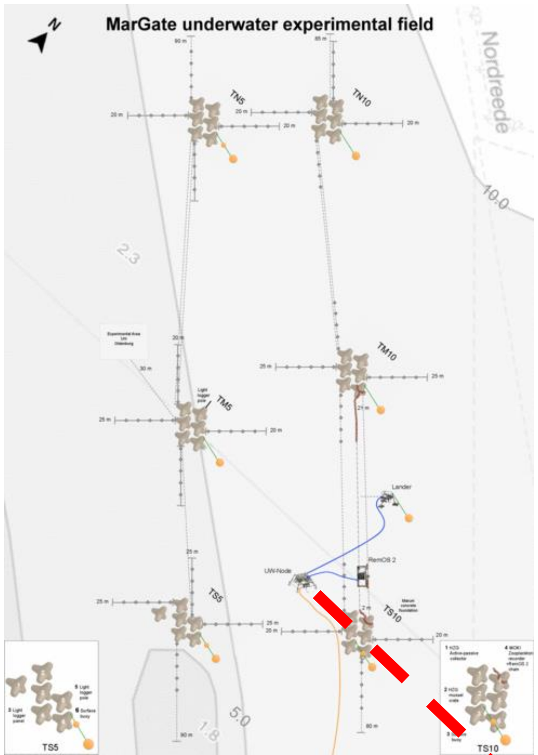


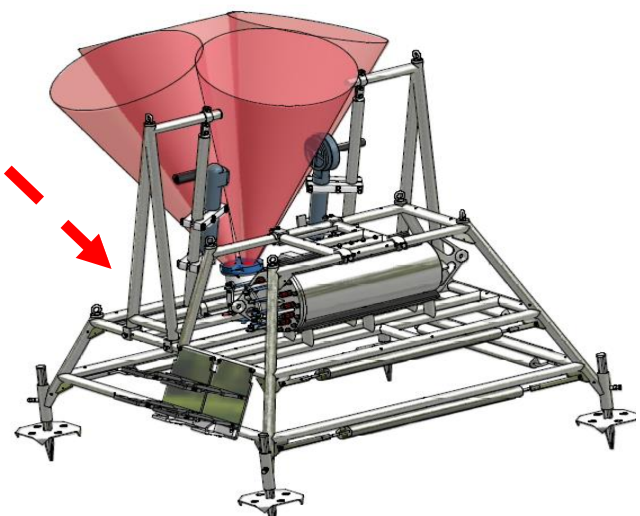
- Negative relationship between copepods and marine snow

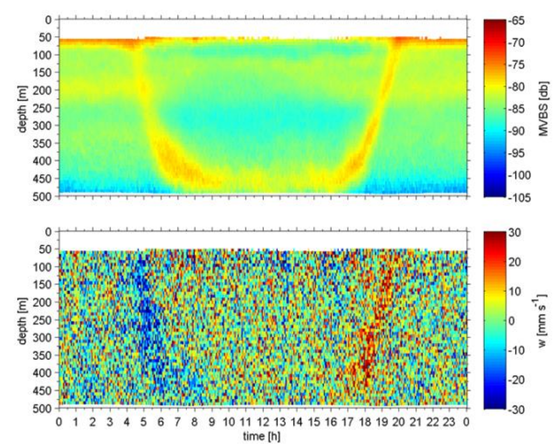
Conclusions:

- **Marine snow is potentially an important food source for zooplankton in many different marine ecosystems**
- **Different copepod species have specific preferences depending on the biogenic origin of aggregates**
- **Different marine snow categories show different particle characteristic vertical distribution patterns depending on their specific properties**
- **Vertical heterogeneity and peak concentrations averaged out in traditional sampling scales**
- **Marine snow is a potential „wake-up" trigger for diapausing *Calanus***

Optical particle trap: Quantification!







Translation of **O**ptical **M**easurements into particle **C**ontent, **A**ggregation & **T**ransfer

Sinking particles transport organic carbon to the deep sea, where they form the base of life. The magnitude of particle export and the rate at which particles are consumed determine carbon seque ... ons and global ... ver, the limite ... ocus on

https://tomcatscor.wordpress.com/

optical measurements to allow the collection of large data sets describing both frequencies and types of sinking particles. These can be used from ships or installed on remote platforms, promising greater spatial and temporal coverage. Yet, whilst technologies to image particles have advanced greatly during the last two decades, techniques to analyze the often immense data sets have not. One short-coming is the translation of optical particle properties (e.g. the image) into particle characteristics such as carbon content and sinking speed. Moreover, different devices often measure different optical properties, leading to difficulties in comparing results. **This working group aims to bring together experts in observation, experimentation, theoretical modelling, and data analyses to systematically improve the process of converting *in-situ* particle measurements to global export estimates.** Final outcomes will include publications detailing intermediate steps and a framework outlining the most efficient way of converting large volumes of particle measurements into export estimates. The output of this working group should have high impact on future ocean research by enabling efficient use of the rapidly developing field of optical sensors.

TOMCAT
FROM OPTICS TO EXPORT

BODC

International Council for Science
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Scientific Committee on Oceanic Research

Thank you!