North Pacific Marine Science Organization 2016 Annual Meeting

-25 years of PICES: Celebrating the past, Imagining the Future-

Potential environmental changes in the western Arctic and the western North Pacific: their impacts on lower trophic level organisms

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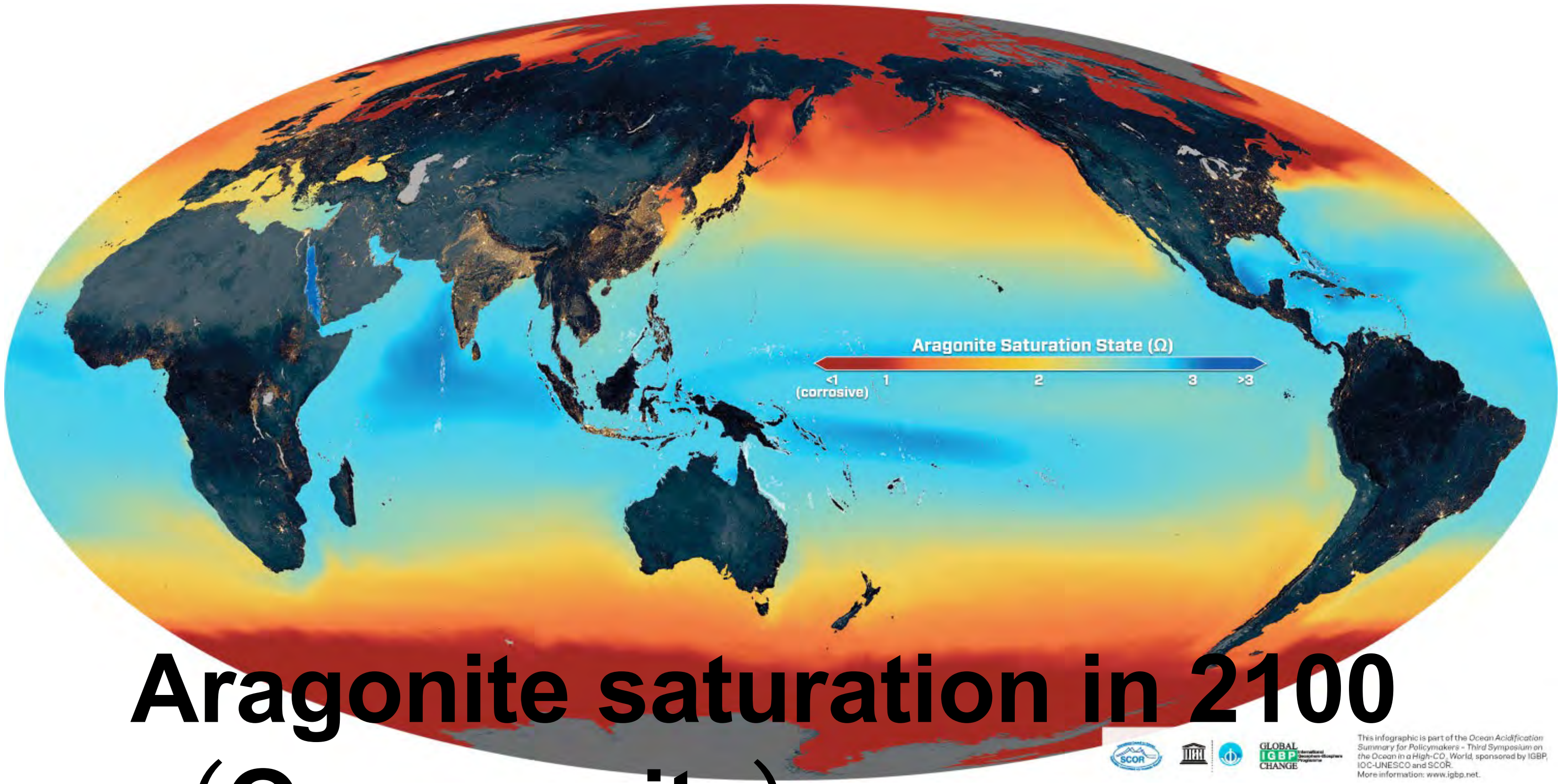
Today‘s topics

- Monitoring sites, sub-arctic North Pacific and western Arctic Ocean
- New technique to quantify the response of marine calcifier to ocean acidification
- Time series data of shell density, pteropods from Arctic Ocean and planktic foraminifera from North Pacific
- Comparison of genetic diversity of pteropods between Atlantic and Pacific
- Outlook for future



Aragonite saturation in 2100 （Ω aragonite）

Sub-Arctic and Polar Seas: Low CO_3^{2-} brings low Ω

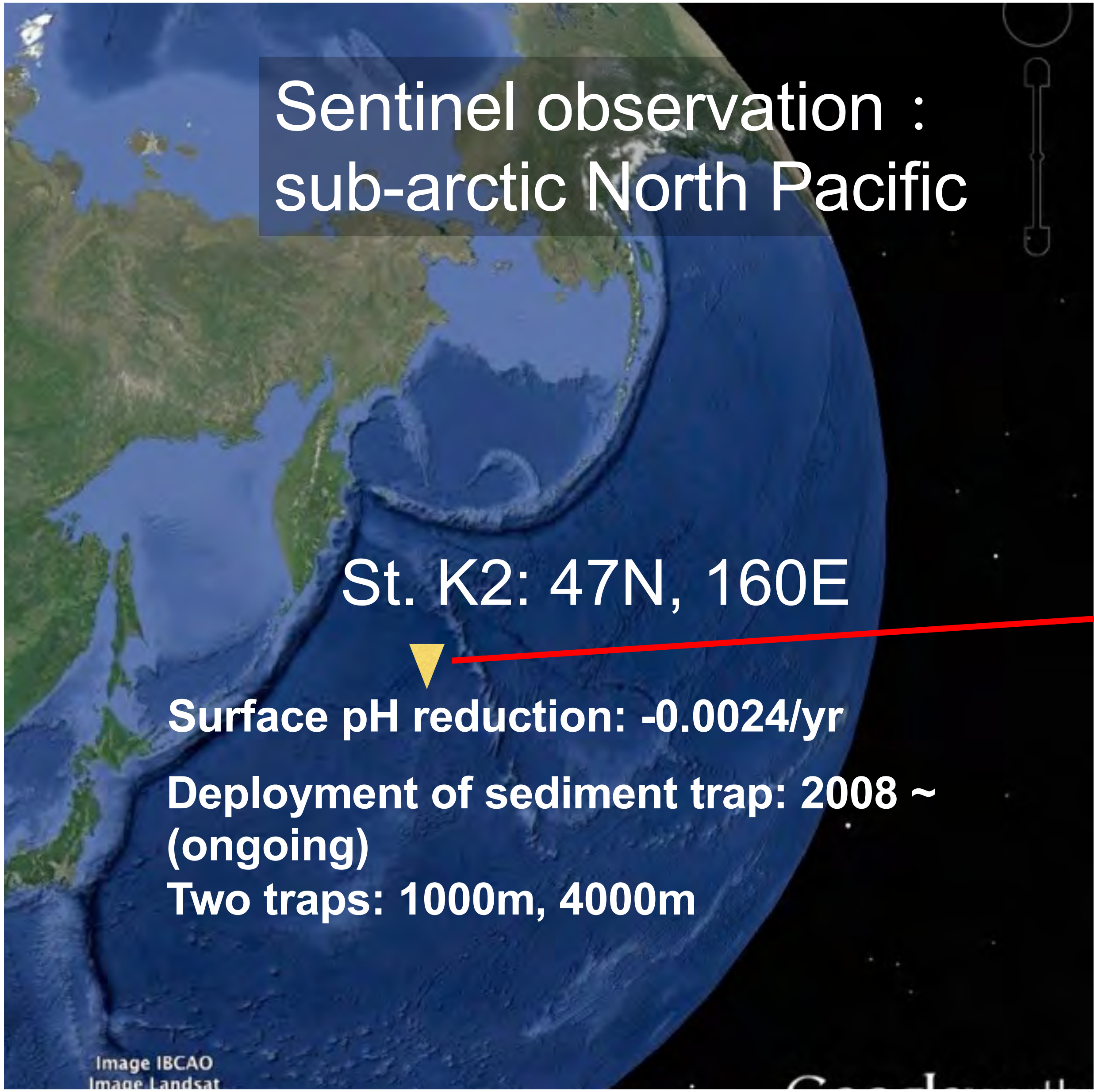
$\Omega = [Ca^{2+}][CO_3^{2-}] / K'_{sp}$

Saturation index　(Ω)

K'_{sp} : solubility product of calcite/aragonite

Ω>1: precipitation(shell preserved)

Ω<1: undersaturation (shell dissolved)



World Meteorological Organization
Weather • Climate • Water

GLOBAL ATMOSPHERE WATCH

WMO GREENHOUSE GAS BULLETIN

The State of Greenhouse Gases in the Atmosphere
Based on Global Observations through 2013

ISSN 2078-0796

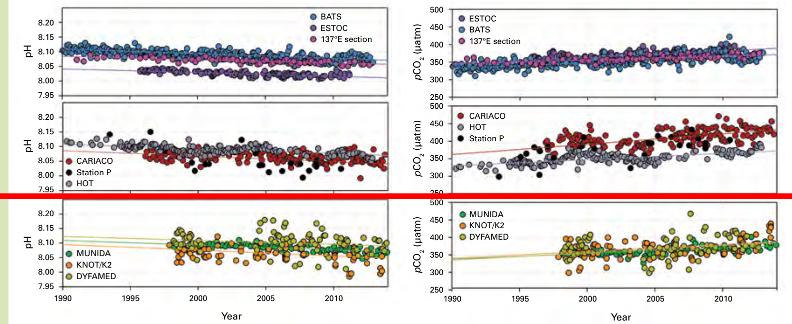


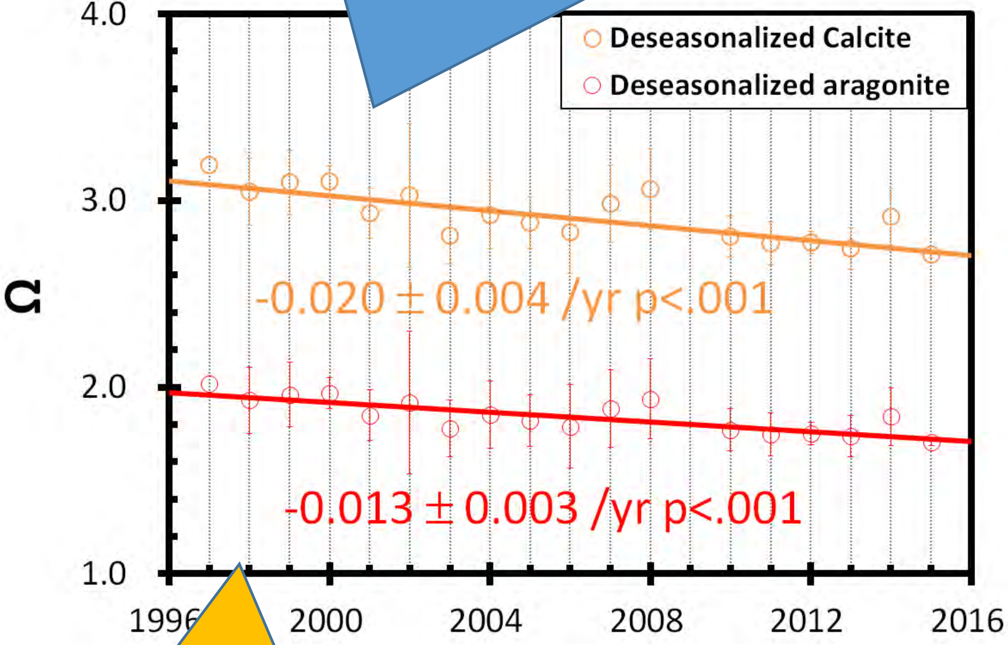
Figure 6. Time series of de-seasonalized surface seawater pH and respective trendlines (left) and of de-seasonalized surface pCO_2 (μatm) and respective trendlines (right). Featured time series include the Bermuda Atlantic Time-series Study (BATS; blue) the European Station for Time Series in the Ocean near the Canary Islands (ESTOC; purple), the Hawaii Ocean Time-series (HOT; grey); CARIACO (red); Station P (black); MUNIDA (green); the Kyodo North Pacific Time series (KNOT; orange); the station known as the Dynamics of Atmospheric Fluxes in the MEDiterranean Sea (DYFAMED; yellow); the Japan Meteorological Agency 137°E section repeat hydrographic line at 10°N, 137°E (137°E section; pink). The locations of the featured time series are shown in Figure 2. Temporal sampling resolution varies from monthly to annually.

Table 2. Linear trends and standard errors for surface pH[a] and pCO_2 at the nine featured ocean time series

Time series	pH (yr^{-1})	pCO_2 (μatm yr^{-1})	*Reference*
BATS[b]	−0.0017±0.0001	1.75±0.08	Bates et al., 2014
ESTOC[b]	−0.0014±0.0001	1.78±0.15	Bates et al., 2014 González-Dávila et al., 2010
HOT[b]	−0.0017±0.0001	1.89±0.15	Bates et al., 2014 Dore et al., 2009
CARIACO[b]	−0.0024±0.0003	2.79±0.37	Bates et al., 2014 Astor et al., 2013
DYFAMED[b]	−0.0019±0.0009	2.56±0.85	Touratier and Goyet, 2011
MUNIDA[b]	−0.0016±0.0003	1.55±0.24	Bates et al., 2014

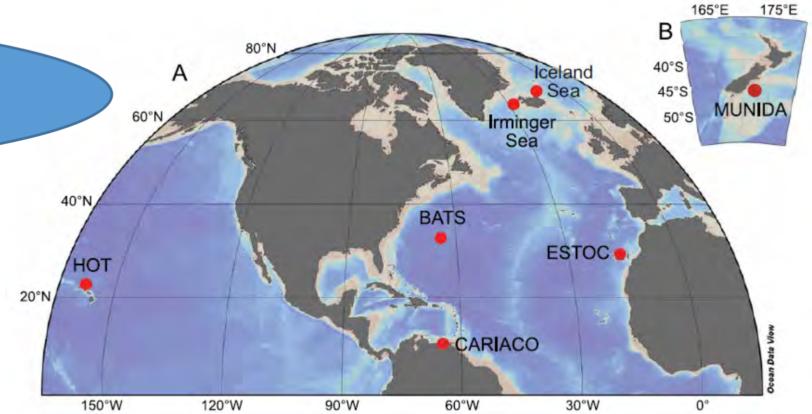
Ω in the mixed layer at K2

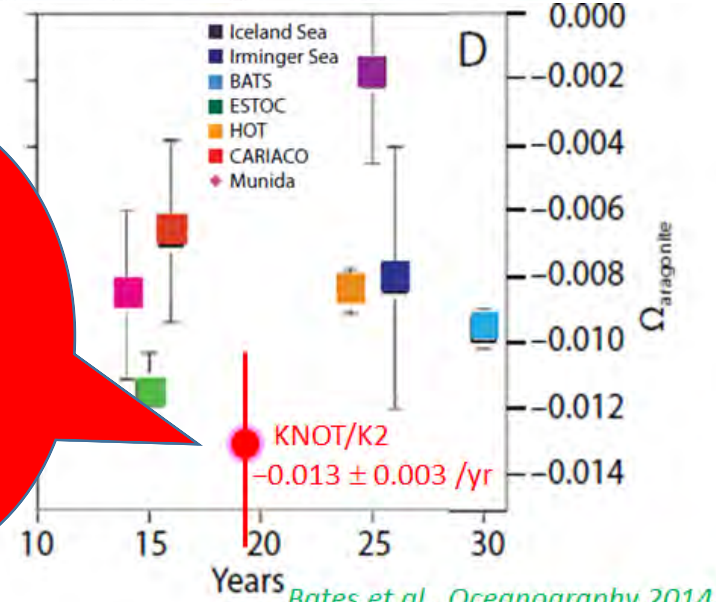
Aragonite saturation horizon: 120m
Calcite saturation horizon: 150m



Less than 1 after ~2100?

Wakita et al., in prep

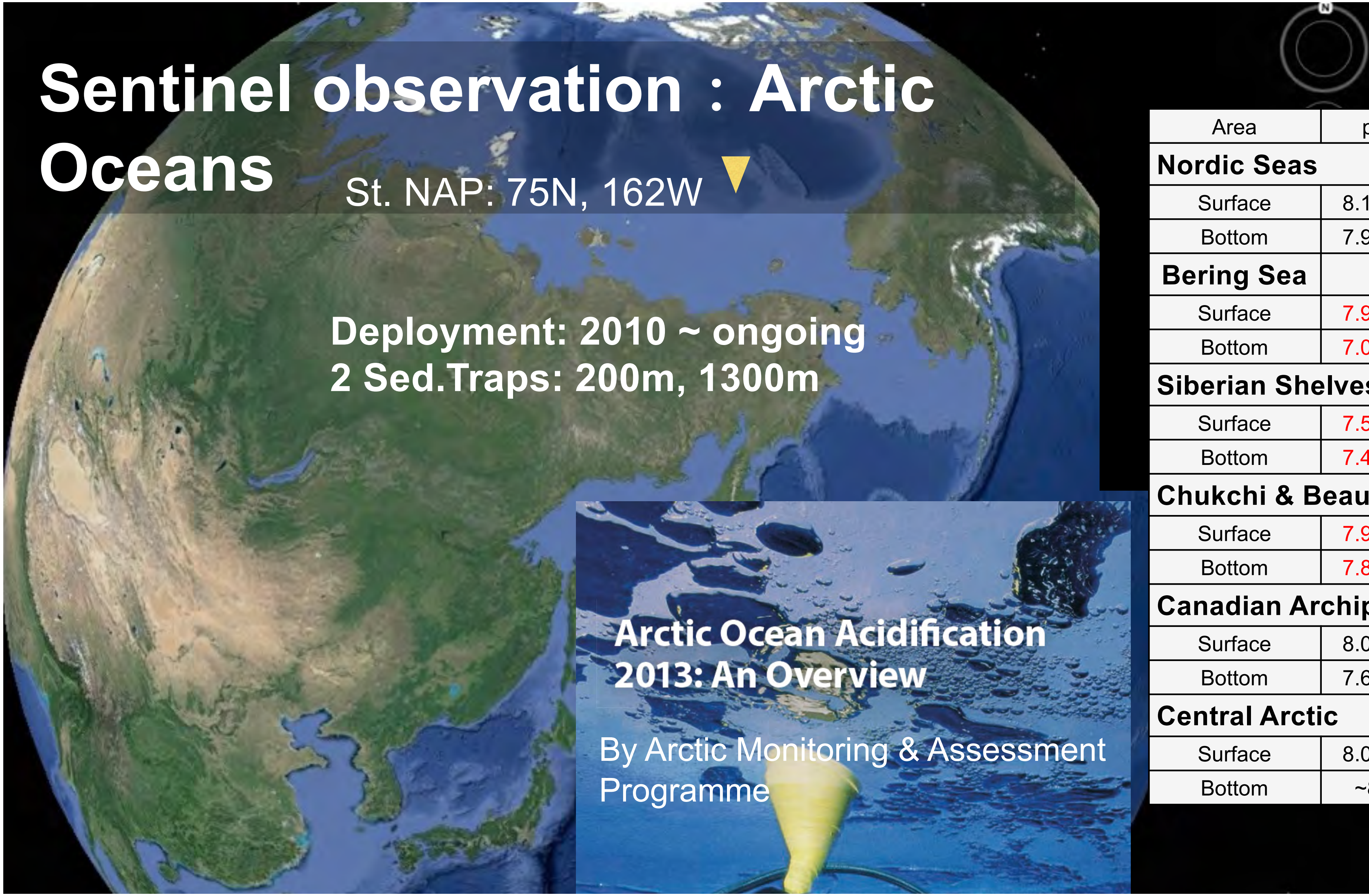




Largest annual reduction rate at K2

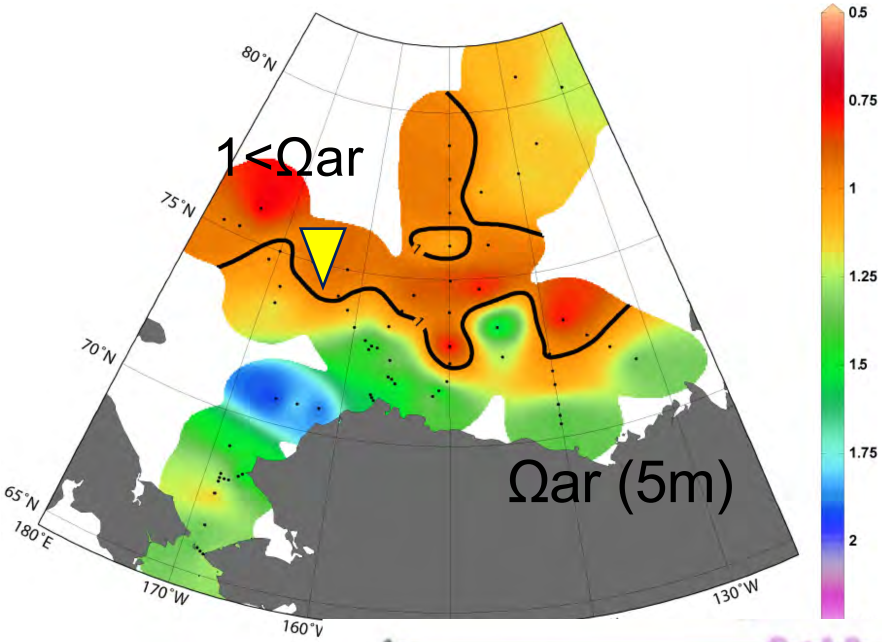
Bates et al., Oceanography 2014

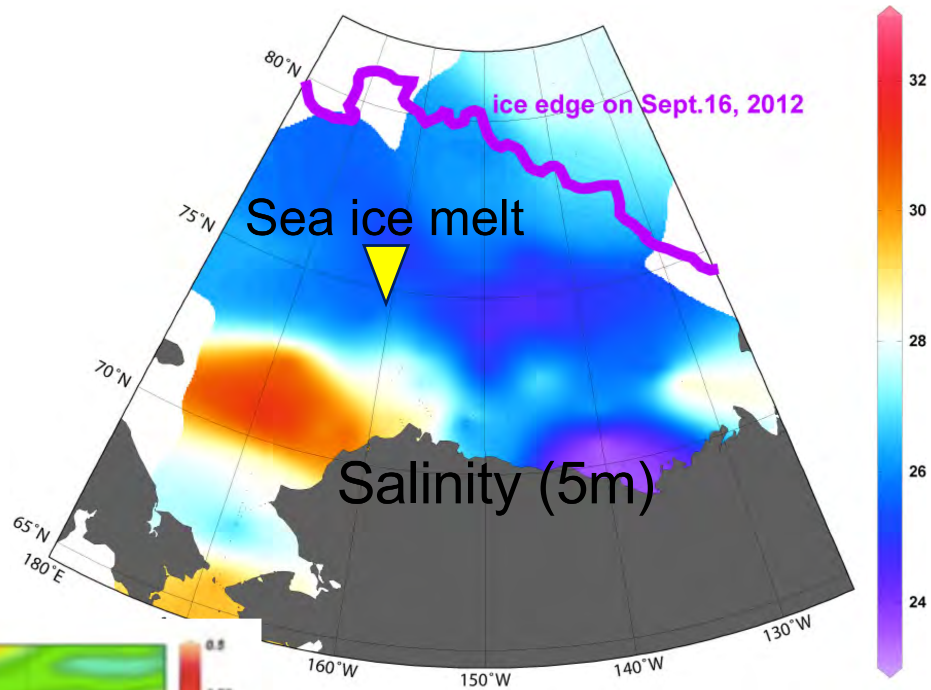
Sentinel observation : Arctic Oceans

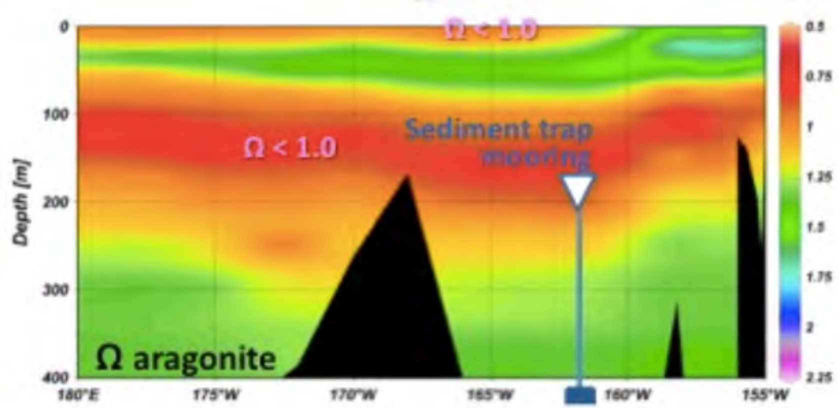


Area	pH	Ω
Nordic Seas		
Surface	8.1-8.4	1.5-3.5
Bottom	7.9-8.3	0.7-2.2
Bering Sea		
Surface	7.9-8.3	0.7-2.9
Bottom	7.0-7.7	0.1-2.0
Siberian Shelves		
Surface	7.5-8.1	0.2-2.5
Bottom	7.4-7.9	0.2-1.4
Chukchi & Beaufort shelves		
Surface	7.9-8.4	0.8-2.0
Bottom	7.8-8.1	0.8-2.0
Canadian Archipelago		
Surface	8.0-8.3	0.8-2.2
Bottom	7.6-8.1	0.8-2.0
Central Arctic		
Surface	8.0-8.2	1.3-1.8
Bottom	~8.1	0.6-1.0

Decreasing Ωar by sea ice melt (Sep. 2012)



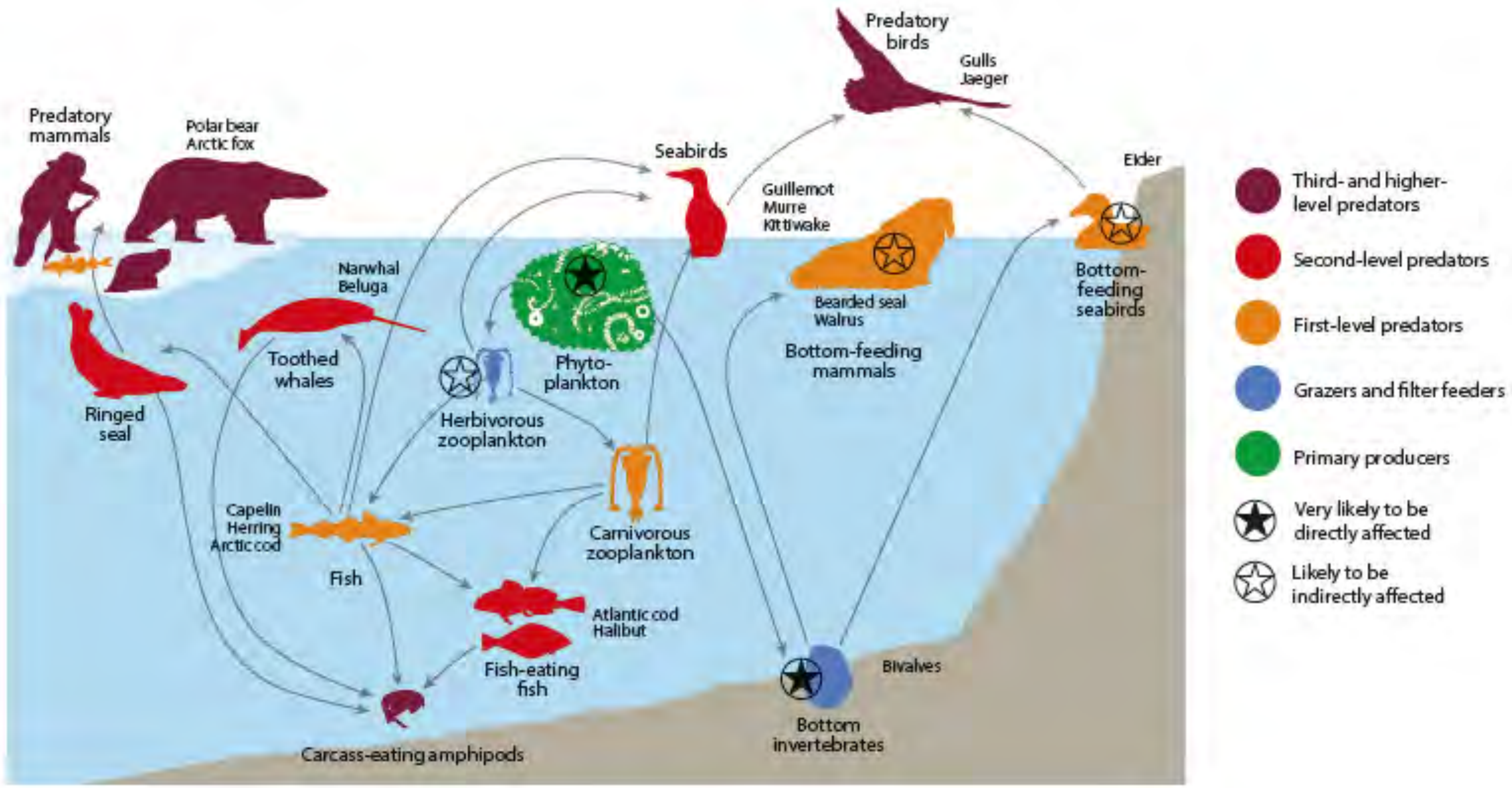




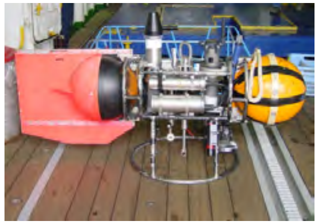
▽ Trap site

Undersaturated subsurface water for aragonite dissolved living pteropod shells?

Influence of acidification to marine ecosystem

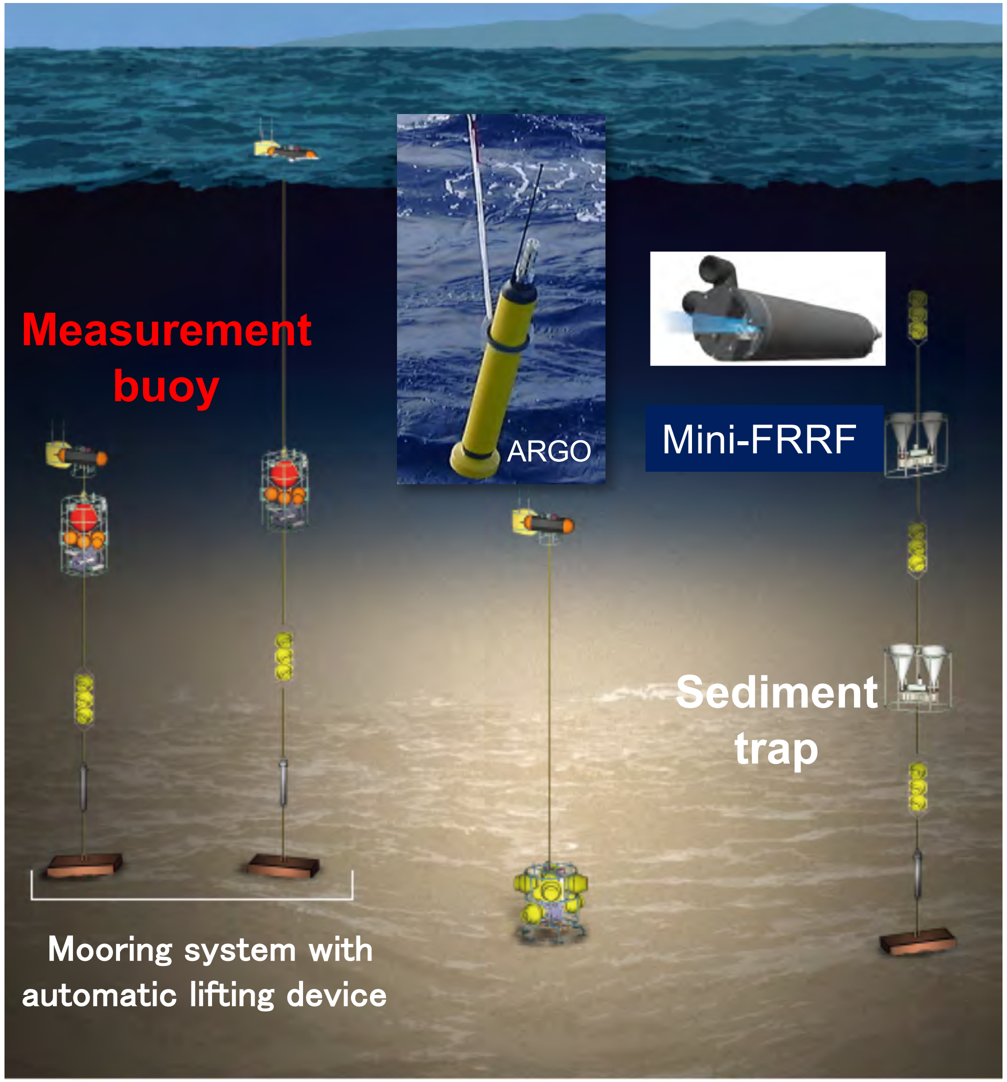


Time-series mooring system with multi sensors



Measurement buoy

Automatic lifting winch



Sensors

・CTD
・DO sensor
・Illuminance sensor
・Fast repetition rate fluorometry (FRRF)
・Acoustic doppler current profiler (ADCP)
・Remote access sampler (RAS)
・ pH/pCO_2 sensor

Sediment trap

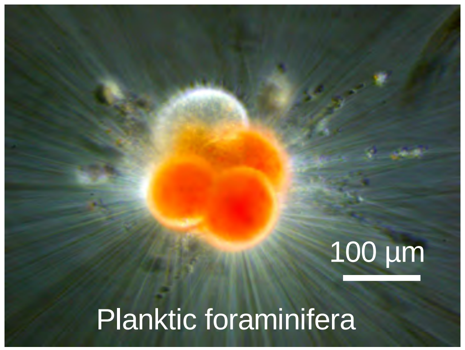
Motivation of development of new technique

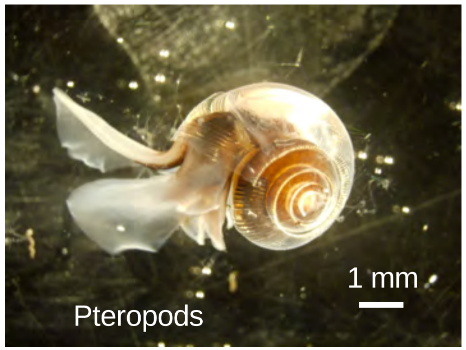
- Reducing of carbonate ions by ocean acidification will accelerate shell dissolution or to prevent the production of carbonate shelled organisms.

- Marine plankton is the largest carbonate producer in the world. Especially, the global planktic foraminiferal flux to the ocean floor of 0.36–0.88 GTC y^{-1} accounts for 32–80% of the total deep marine calcite budget (Schiebel, 2002) .

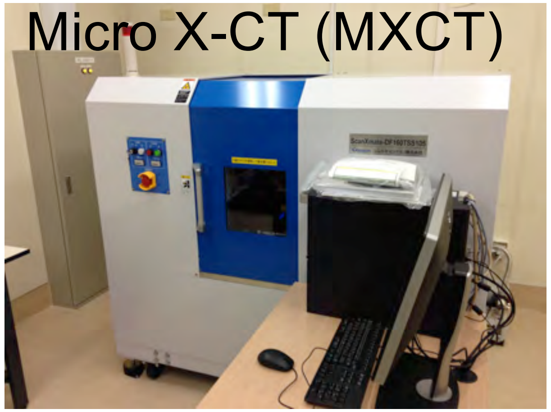
- Serious damage of marine plankton due to OA potentially give a negative impact on food web.

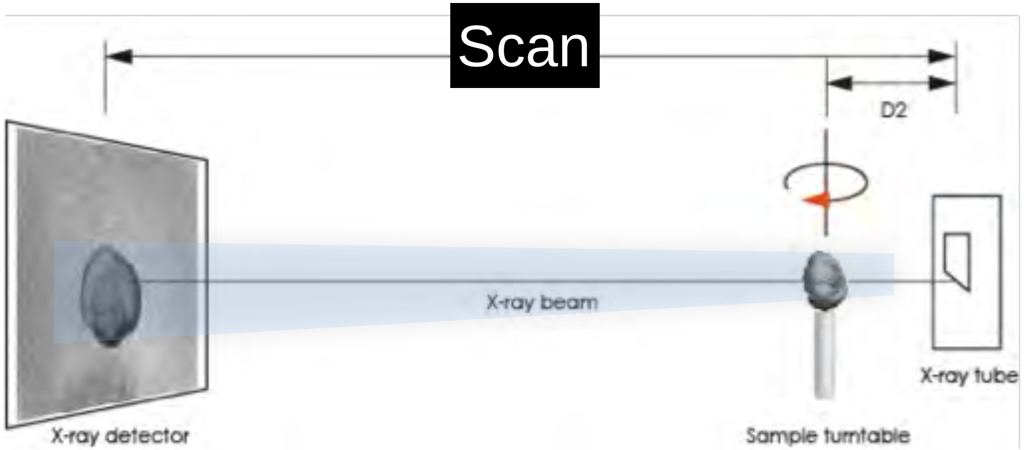
- There is no well quantitative and comparable estimation method to evaluate impacts (damages) of the ocean acidification on marine plankton. So, we have developed new technique to quantify carbonate density.



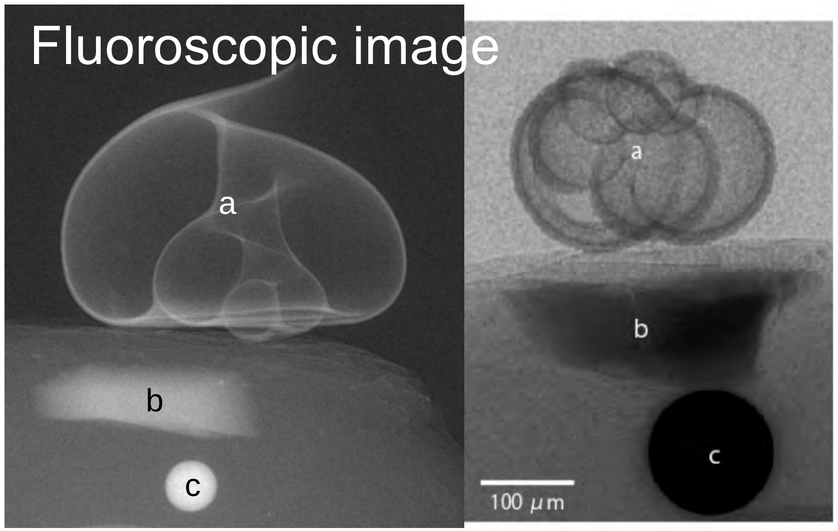


Micro focus X-ray Computing Tomography method





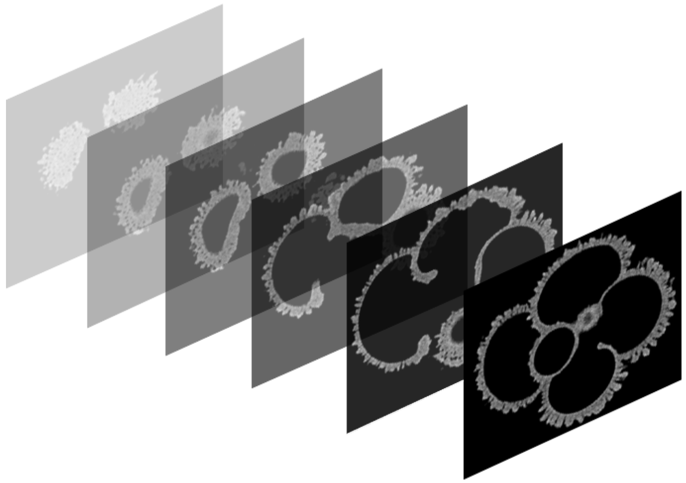
Reconstruct



a. Specimen

b. Standard material (Calcite)

c. Position maker



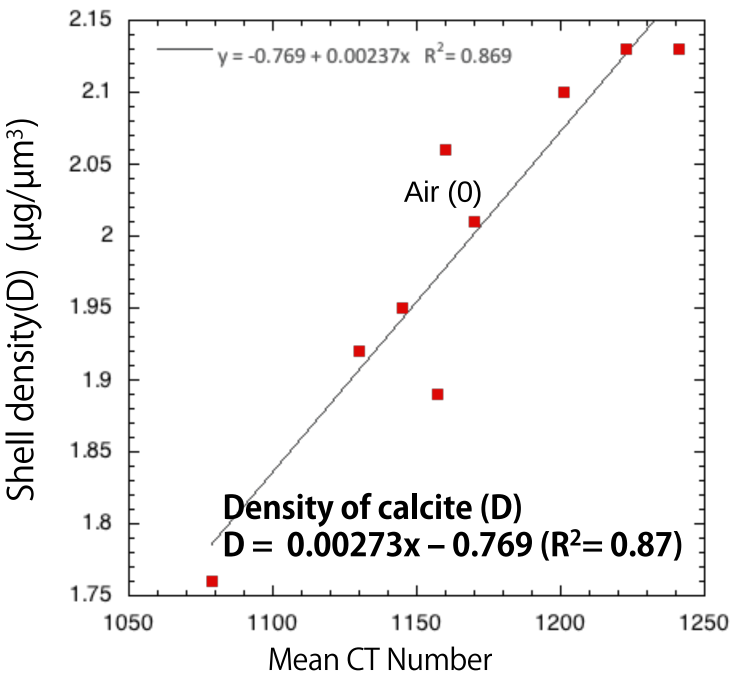
Calcite CT Number as a shell density index

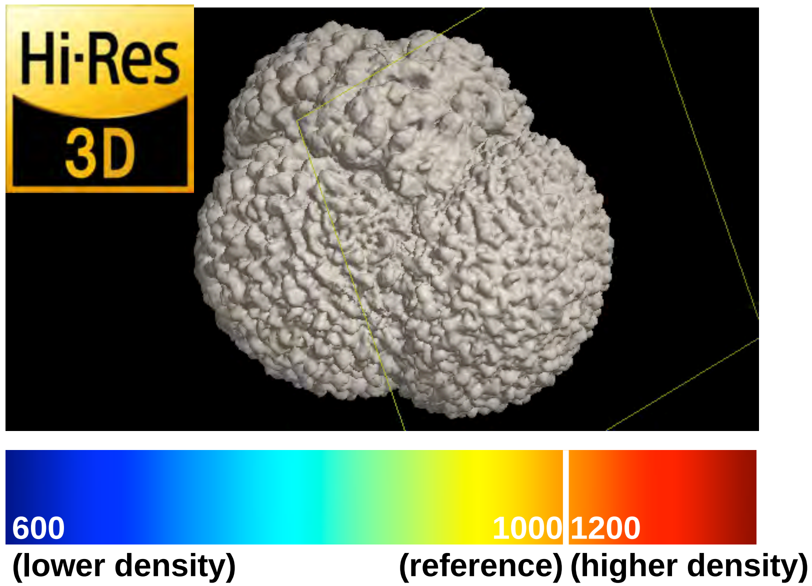
relative value of X-ray attenuation coefficient in each voxels

$$\text{Calcite CT Number} = \frac{\mu\text{sample} - \mu\text{air}}{\mu\text{calcite} - \mu\text{air}} \times 1000$$

µsample: X-ray attenuation coefficient of samples
µair: X-ray attenuation coefficient of the surrounding air = -1000
µcalcite: X-ray attenuation coefficient of calcite (standard material:Calcite or Aragonite) = 1000

Mean CT number vs Shell density

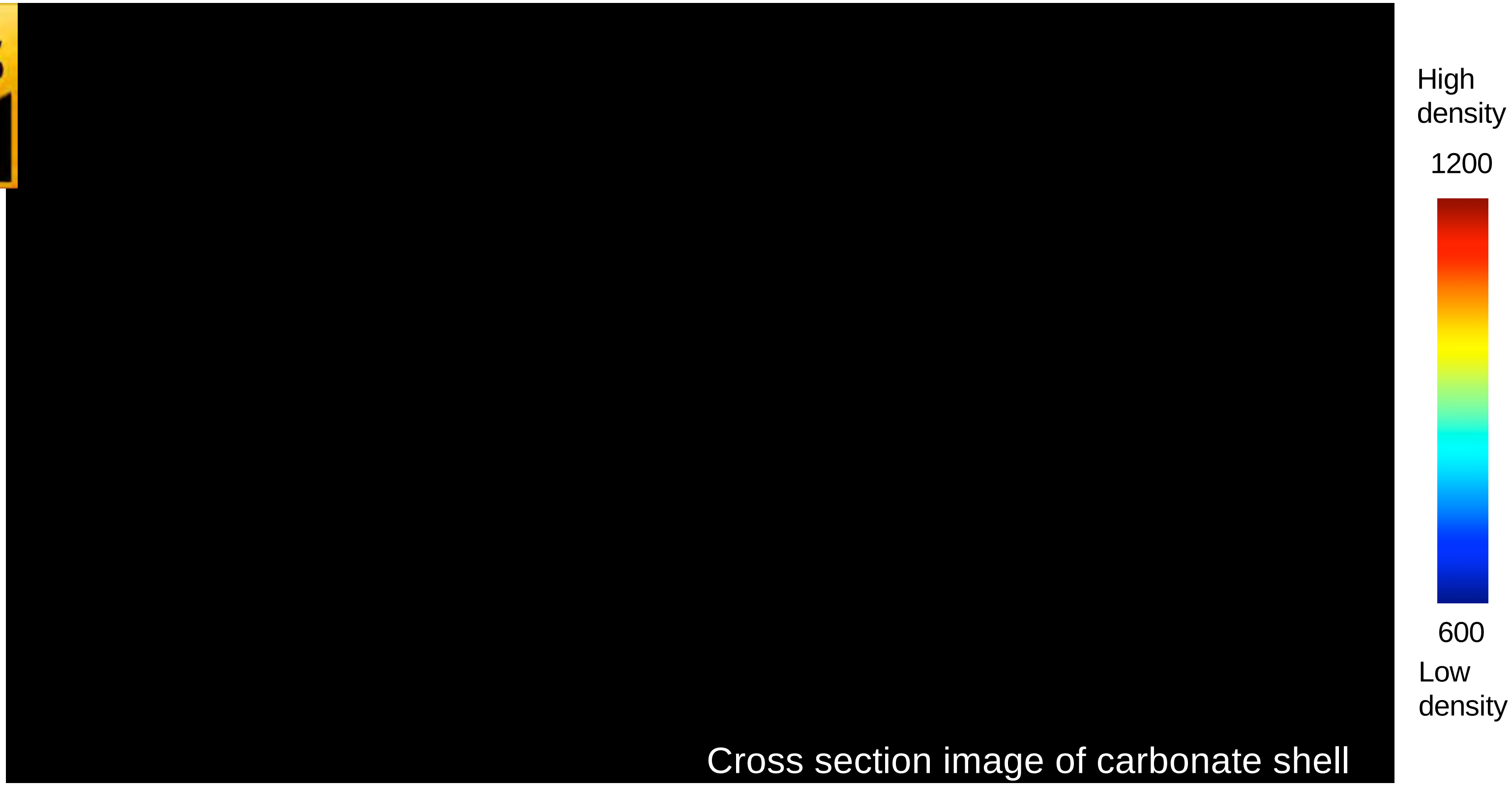




MXCT: 3 Dimension precise morphometry

Thecosomata (Pteropod): *Limacina helicina*

(spatial resolution：0.8 μm)



The biggest advantages of MXCT are: **Quantitative** **Nondestructive**

Summary

- Micro-Focus X-ray Computing Tomography (MXCT) technique can be applied successfully to evaluate the impact of OA for marine calcifiers quantitatively.
- Carbonate density of marine calcifier changes seasonally and 35-40% reduction were observed in specific seasons in sub-arctic NP (winter) and Arctic Ocean (summer & beginning of sea-ice season).
- Further sentinel time series observation (e.g. mooring and float) is important to understand responses of marine organisms on rapid acidifying in sub-Arctic and Arctic Ocean.
- MXCT has a potential to be common standard method to evaluate the shelled plankton responses on OA.-----more higher trophic level plankton (e.g., Copepoda---chitinous substance)

Outlook for future

- Application of carbonate density as an Essential Ocean Valuables of marine calcifier for ocean acidification
- To make carbonate density popular as EOV for OA, JAMSTEC can provide the technique how to analyze carbonate density by MXCT and is also preparing to receive measurement request from the world.
- Further connecting/networking time-series sites with basin (e.g., GACS) and global scales (e.g., Argo) observing programs to understand complicated responses of marine organisms to OA with other environmental stressors.

Please contact us if you are interested in MXCT

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