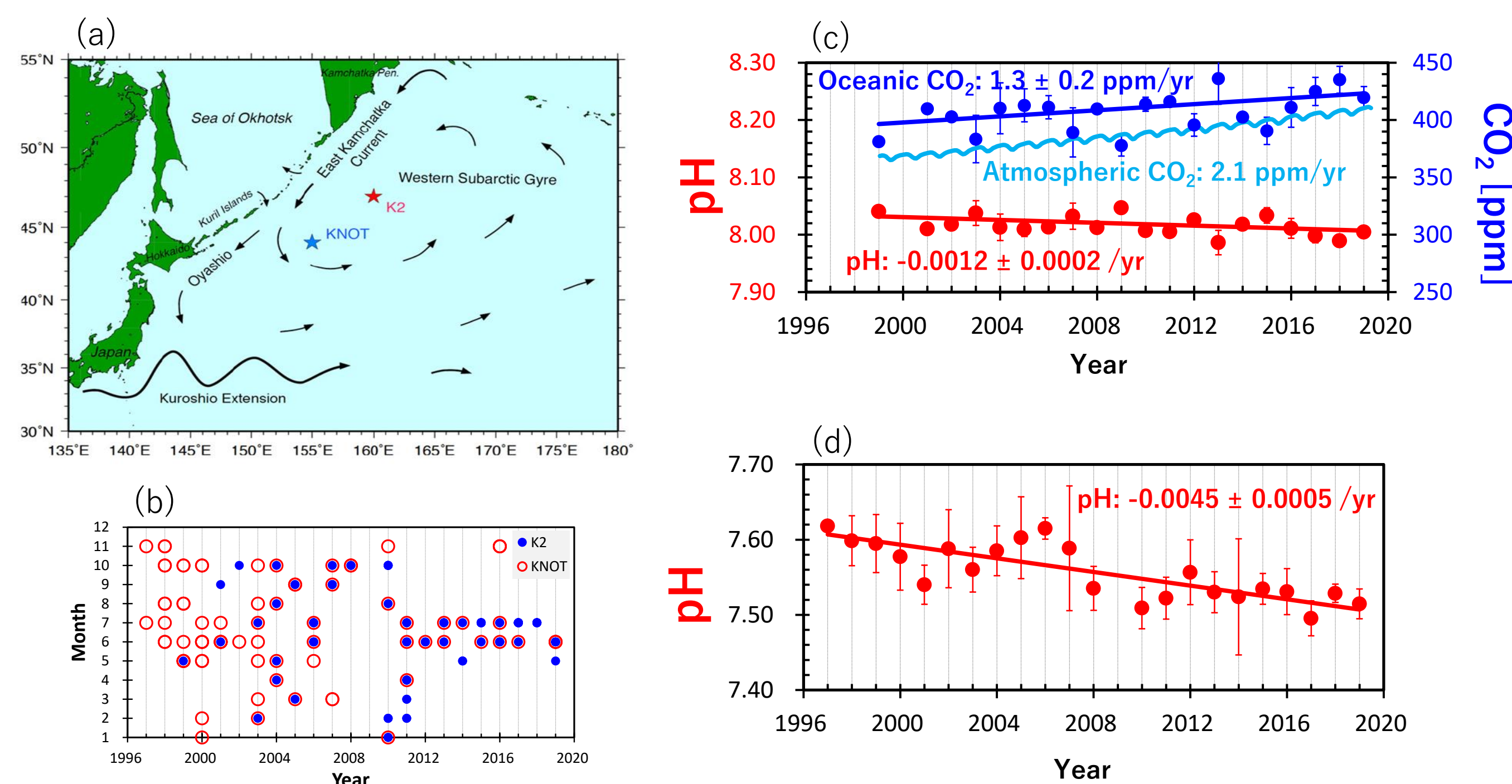


Ocean acidification (OA), which has caused a progressive decrease of the pH of seawater over the past several decades, has been caused mainly by uptake of anthropogenic CO₂. OA can potentially affect marine organisms, especially calcified ones, by decreasing calcification rates. Maintaining the health of the ocean thus requires monitoring and assessment of OA. In the *2030 Agenda for Sustainable Development* adopted by the United Nations, OA is denoted as target 3 of goal 14 (SDG 14.3), and pH is designated as an indicator of OA. This report is an assessment of the progression of OA based on observed changes of oceanic pH and the saturation state of calcium carbonate (CaCO₃), Ω . We have also used images of micro-focus, X-ray computed tomography to show how OA directly impacts calcified organisms, and we describe OA monitoring activities in the near future.

Panel 1

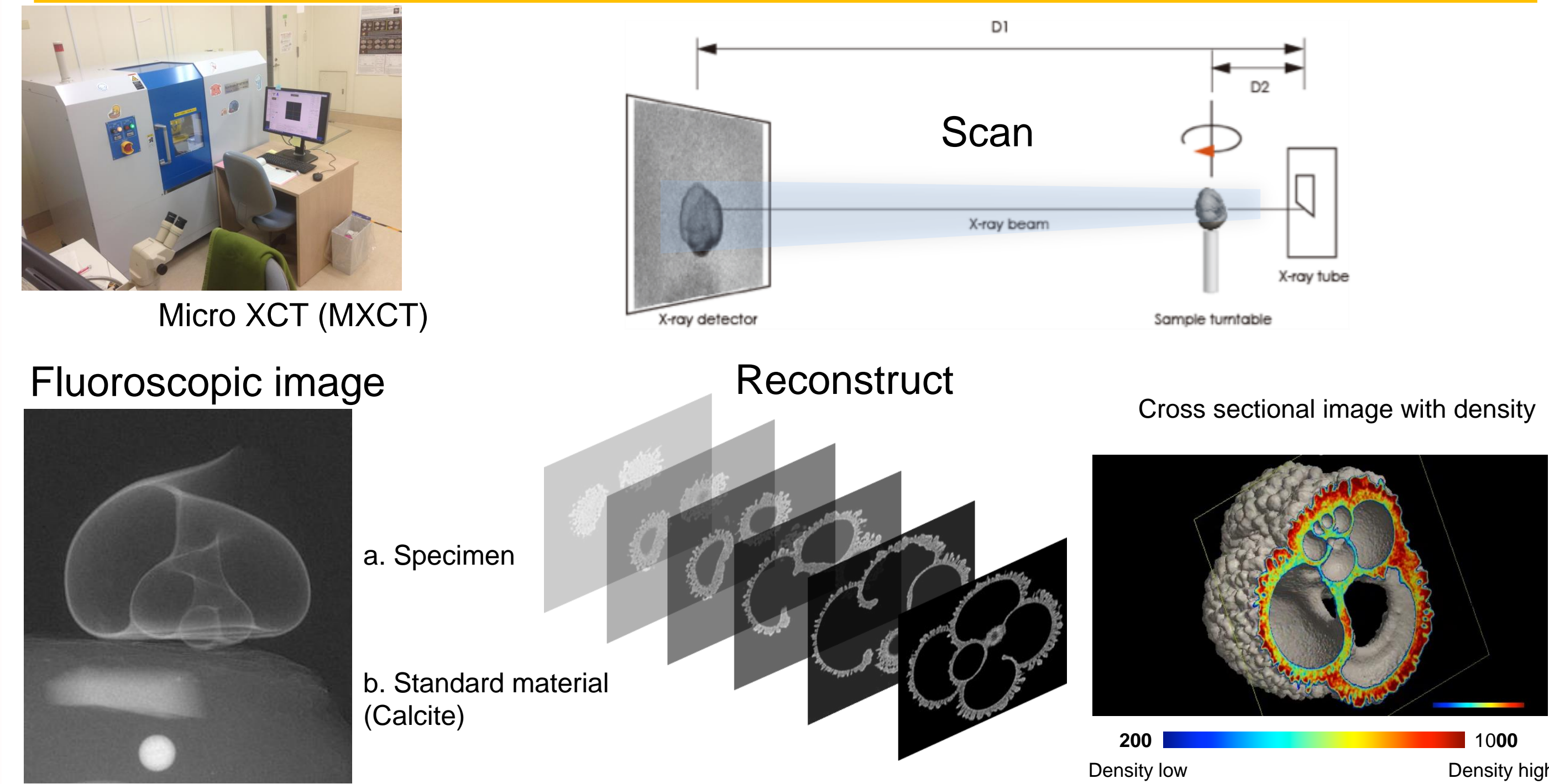
Time-series observations at stations K2 and KNOT



(a) Location of Stations KNOT and K2; (b) Time periods of observations at K2 and KNOT; (c) Temporal changes of CO₂ and pH in the winter mixed layer (> 120 m); (d) Temporal changes of pH in the intermediate layer (~200m).

Panel 3

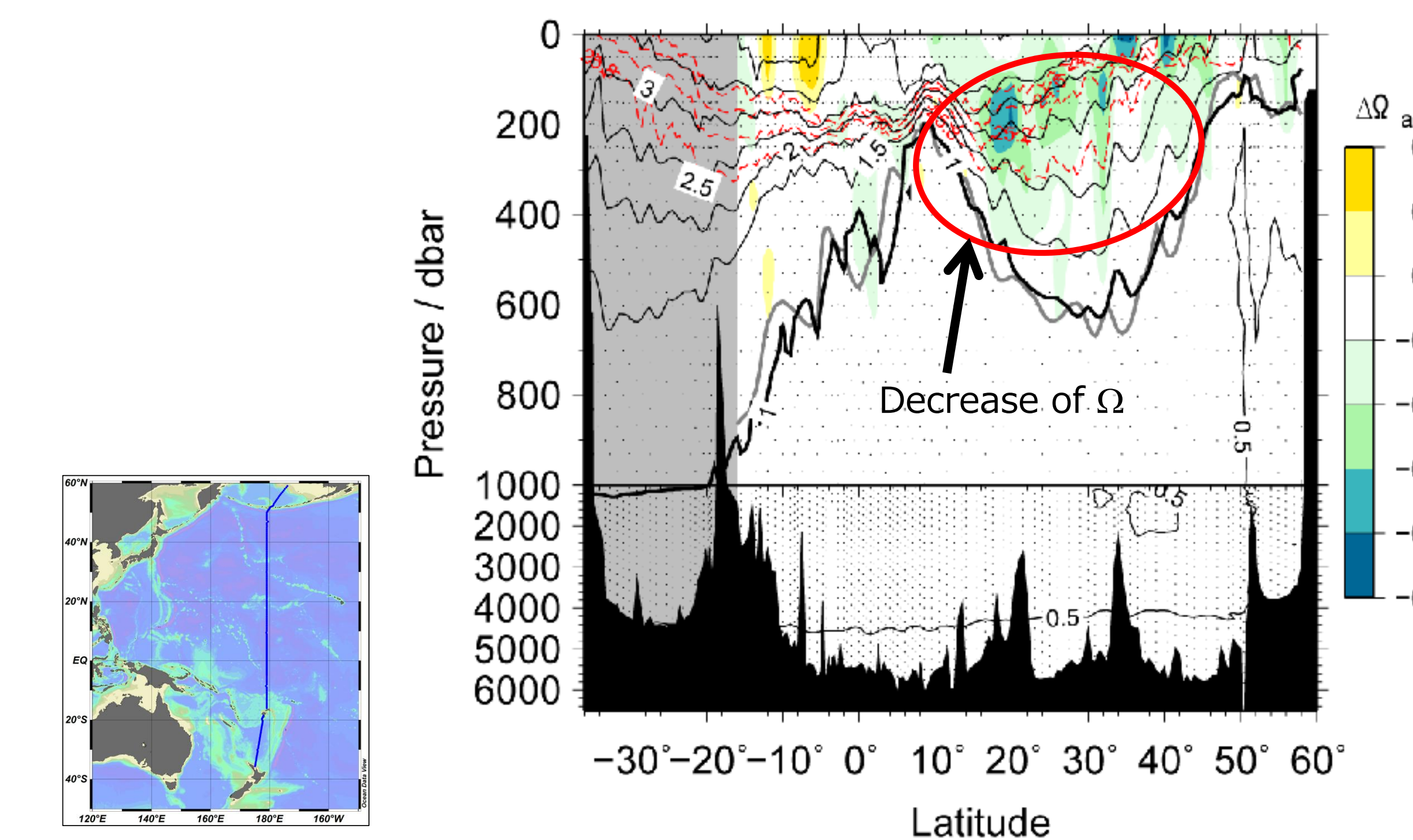
Micro focus X-ray Computed Tomography technique (Patent pending, 2018)



Micro-focus X-ray computed tomography (MXCT) is a new technology that enables quantification of the decline of calcification in a non-destructive manner.

Panel 5

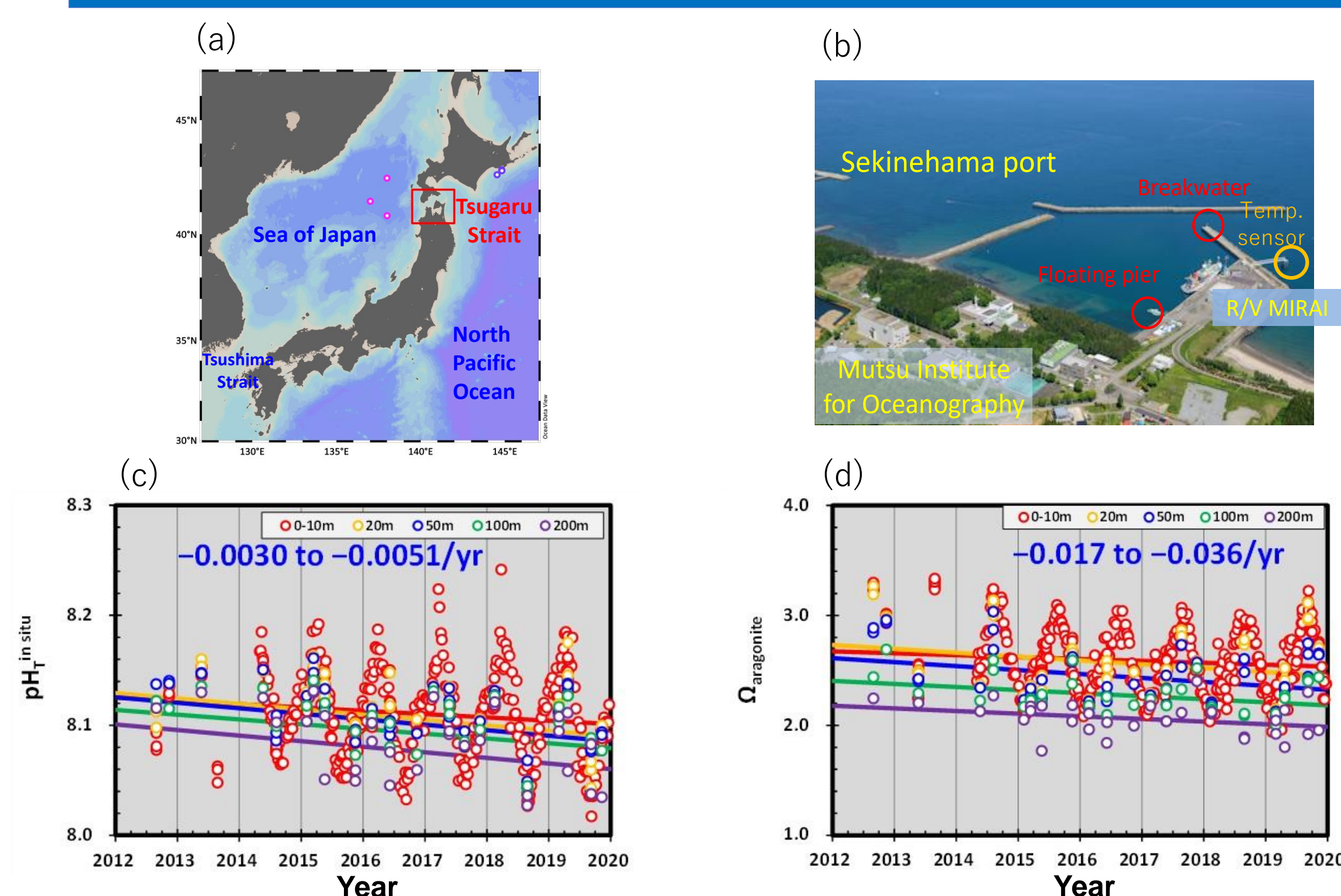
Decadal-scale changes of Ω of aragonite ($\Delta\Omega$)



Our discovery that Ω had decreased by 0.48 (0.034 yr⁻¹) at 200–300 dbar implies that OA is a basin-scale phenomenon in the open ocean.

Panel 2

Coastal time-series observations in the eastern Tsugaru Strait

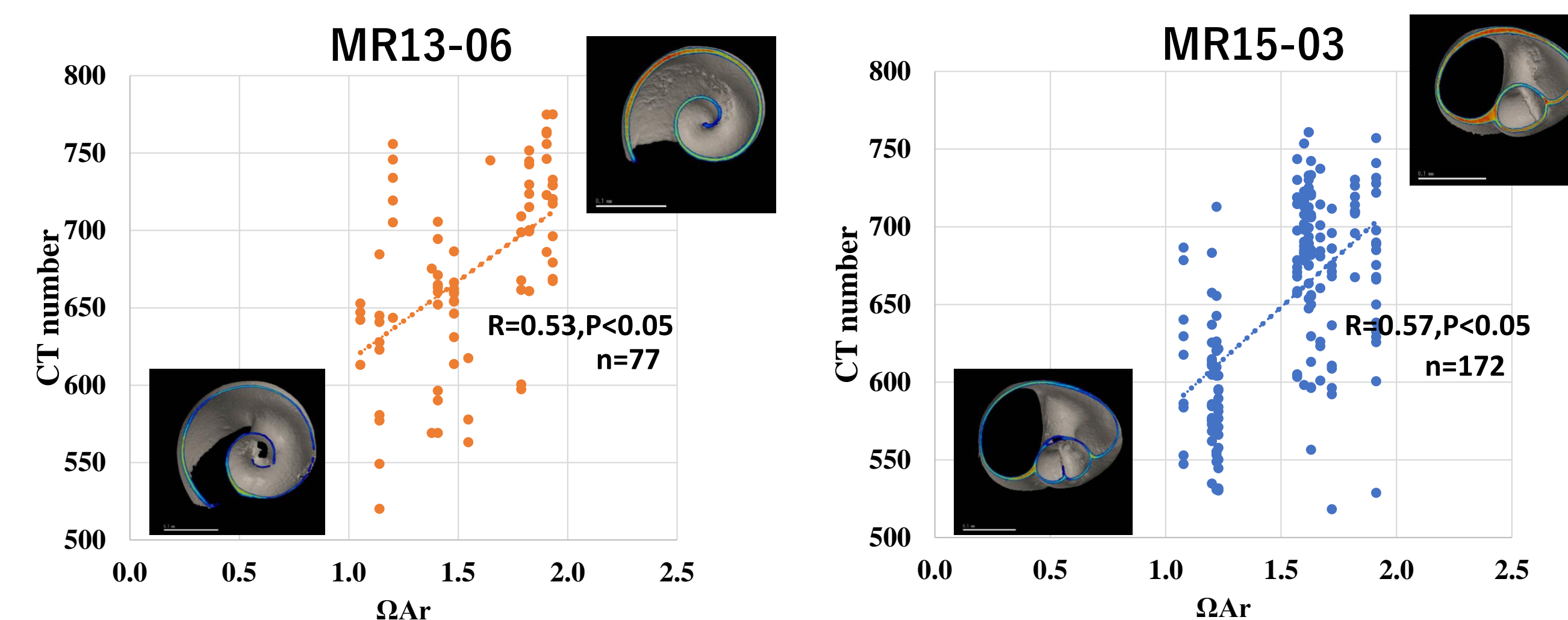


Location of coastal time-series station; (b) Photo of observation site; (c) Temporal changes of pH in the surface water; (d) Temporal changes of Ω in the surface water.

Panel 4

MXCT reveals quantitative shell degradation of pteropod at the surface water (20 m depth) in the Chukchi Sea, western Arctic (2013, 2015)

(Kimoto, Shima et al. in prep)

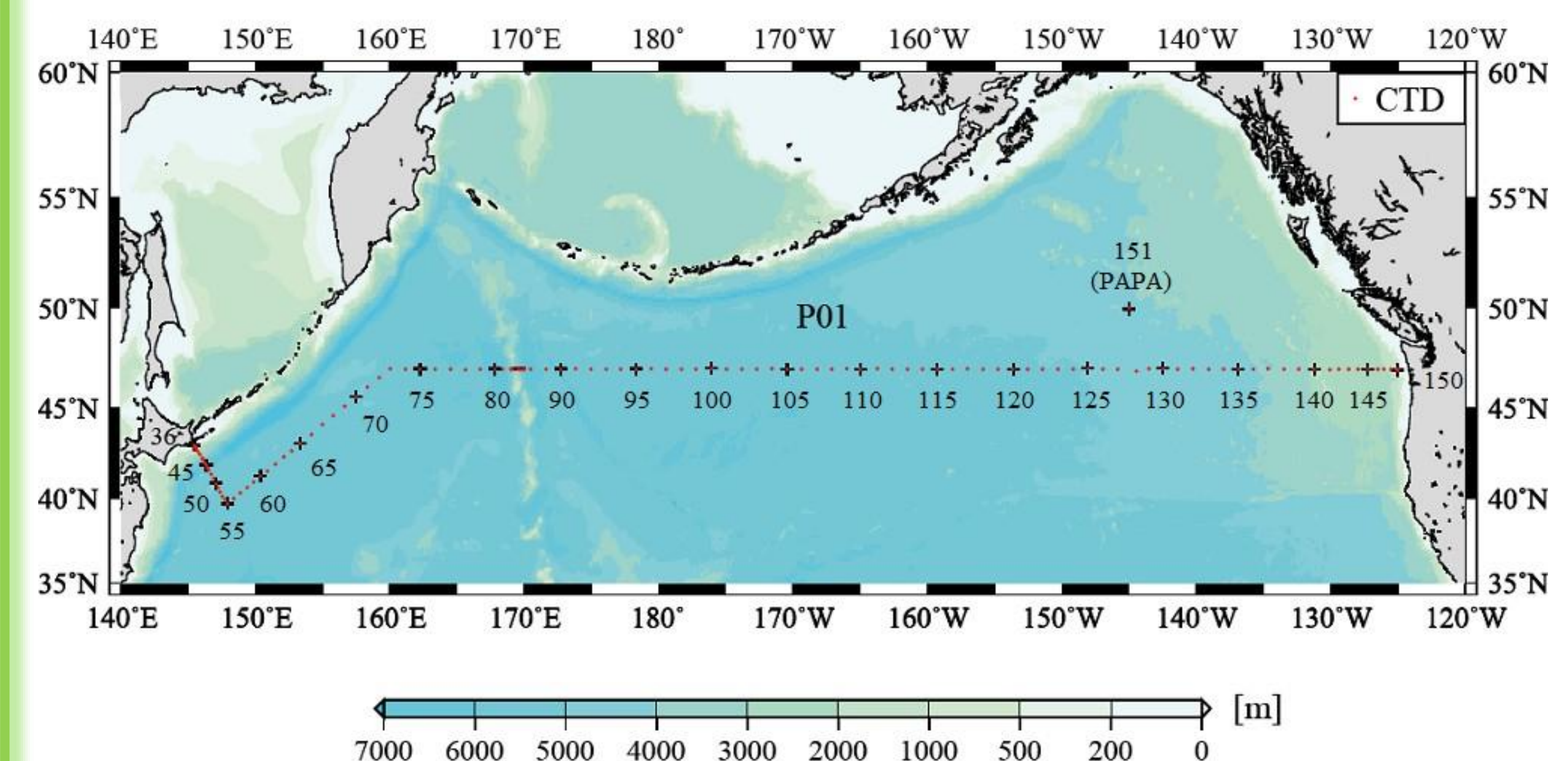


Shell density decreased toward lower Ω_{Ar} . → Hard to build complete shells in lower Ω_{Ar} . ($\Omega_{Ar} < 1.0$ means undersaturated water to aragonite shells.)

The computed tomography numbers from the MXCT analyses were positively correlated with the Ω of aragonite (Ω_{Ar}), which is one of the polymorphs of calcium carbonate. The relationship demonstrated that the MXCT technique is useful for detecting impacts of OA on calcified organisms in the ocean.

Panel 6

Station location for WHP P01



In 2021, we plan to use the JAMSTEC R/V *Mirai* to reoccupy for the first time in 7 years the WHP P01 line, which is an observation line set nominally at 47°N across the subarctic gyre in the North Pacific