Oceanic Carbon Cycle Observations in JAMSTEC

Akihiko Murata (RCGC/JAMSTEC)

At 11th GEOSS Asia-Pacific Symposium, Kyoto, Japan, 24 Oct. 2018

1. Atmospheric and surface seawater pCO_2 measurements

2. Anthropogenic CO_2 storage in the ocean interior

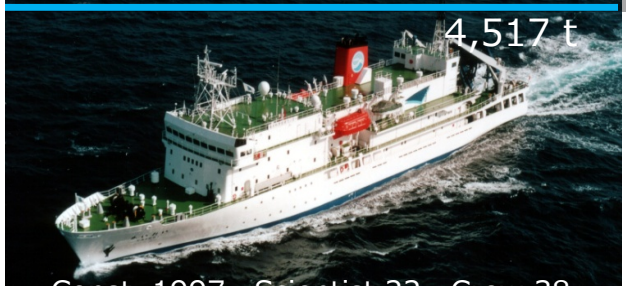
3. Further investigation

0. Research vessels and a scientific program

GROUP ON EARTH OBSERVATIONS

➢ JAMSTEC Fleet

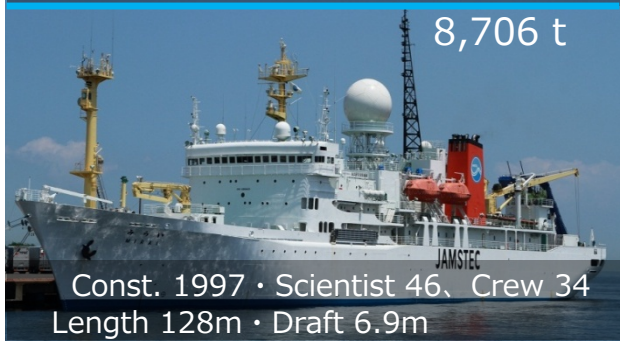
Kairei



4,517 t

Const. 1997・Scientist 22、Crew 38
Length 106m・Draft 4.7m

Mirai



8,706 t

Const. 1997・Scientist 46、Crew 34
Length 128m・Draft 6.9m

Yokosuka

4,439 t

Const. 1990・Scientist 15、Crew 45
Length 106m・Draft 4.7m

Kaimei

5,747 t

Const. 2015・Scientist 38、Crew 27
Length 100m・Draft 6.0m

Hakuho maru

3,991 t

Const. 1989・Scientist 35、Crew 54
Length 100m・Draft 6.0m

Shinsei maru

1,635 t

Const. 2013・Scientist 15、Crew 26
Length 66m・Draft 5.0m

Chikyu

56,752 t

Const. 2005・Scientist 50、Crew 150
Length 210m・Draft 9.2m

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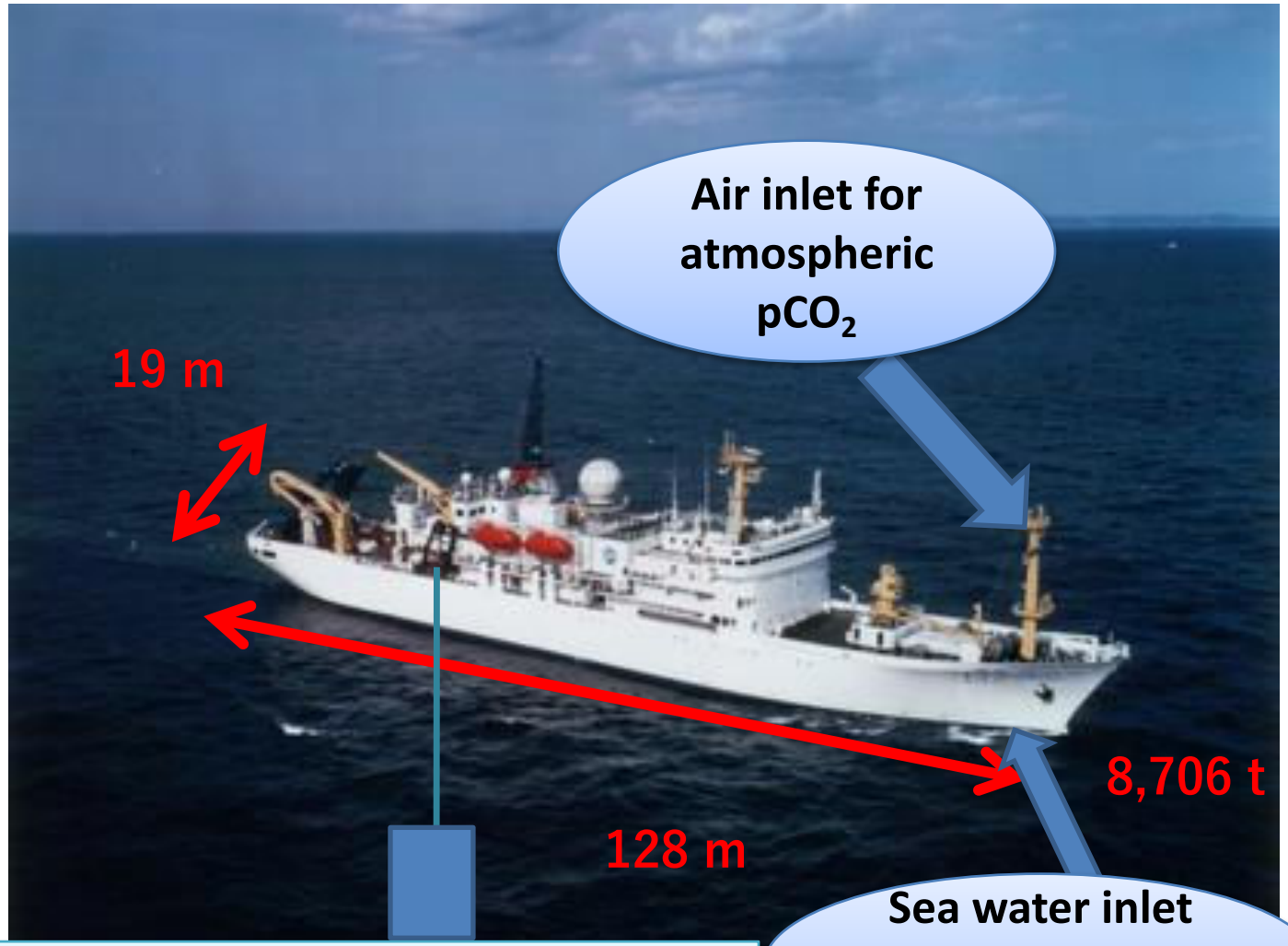
➢ R/V *Mirai*



Scientist 46
Crew 34

Sampling for anthropogenic CO_2 storage in the ocean interior

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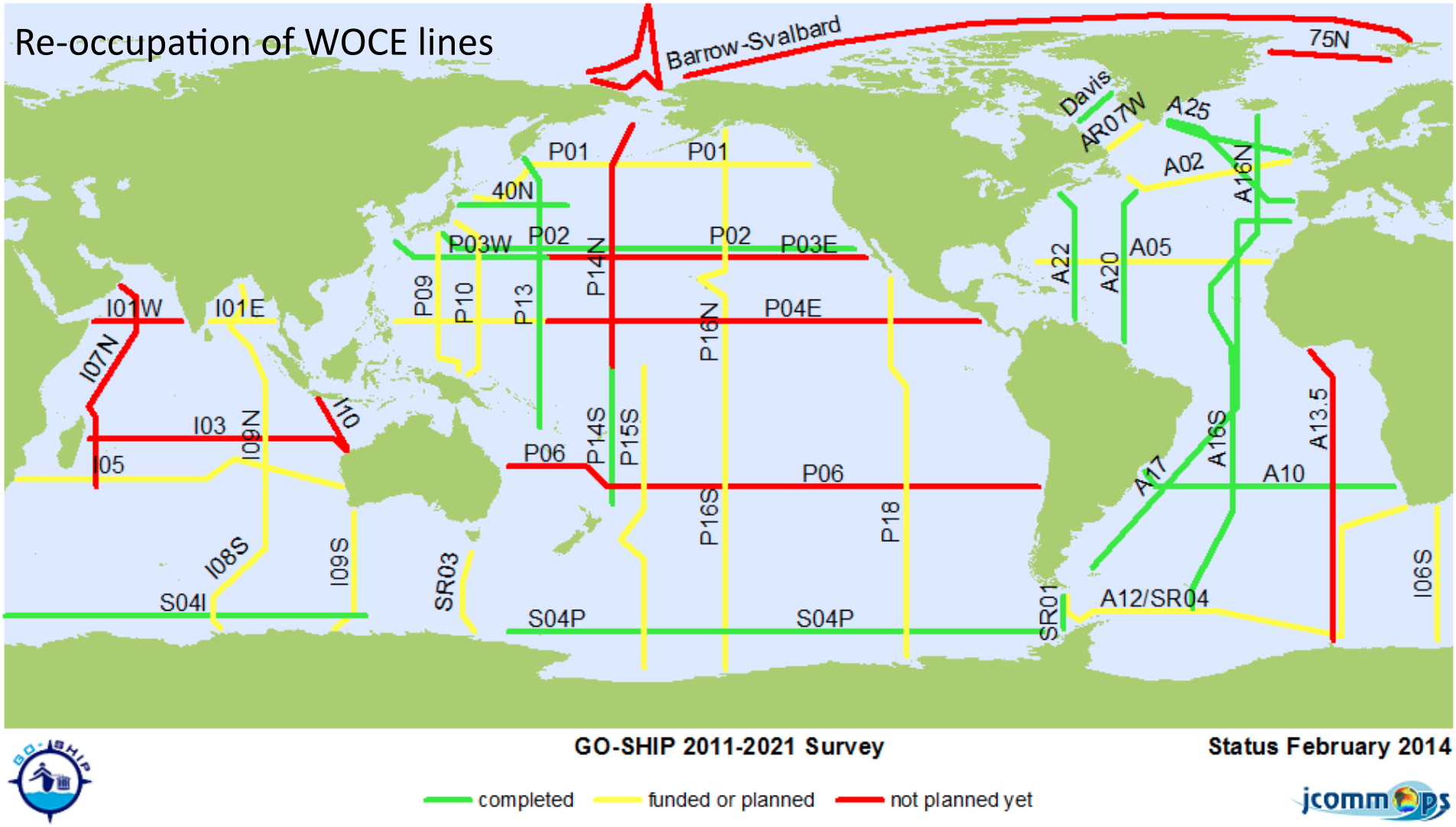
➢ Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP)



➢ GO-SHIP cruise by the R/V *Mirai*

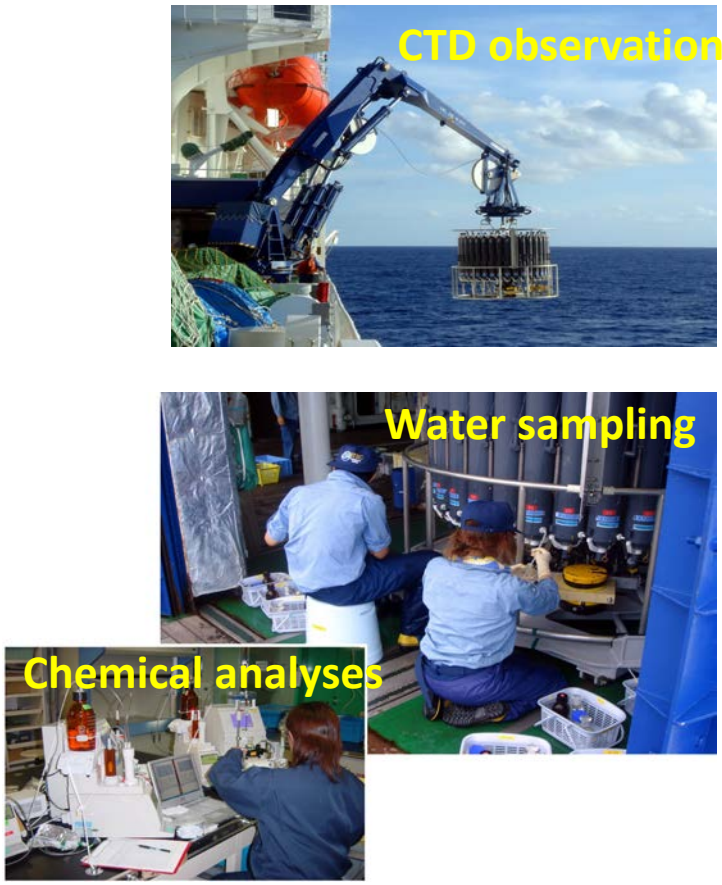


Fig. 1. CTD observations, water sampling, and chemical analyses on board the R/V Mirai.

CTD/Water sampling

Temperature (T), Salinity (S), Dissolved oxygen (DO), Nutrients, Dissolved inorganic carbon, Total alkalinity, pH, Density, Chl-a, Colored dissolved organic matters, CFC s （CFC-11, CFC-12, CFC-113), SF_6, ^{13}C, ^{14}C, ^{134}Cs, ^{137}Cs, ^{18}O, LADCP

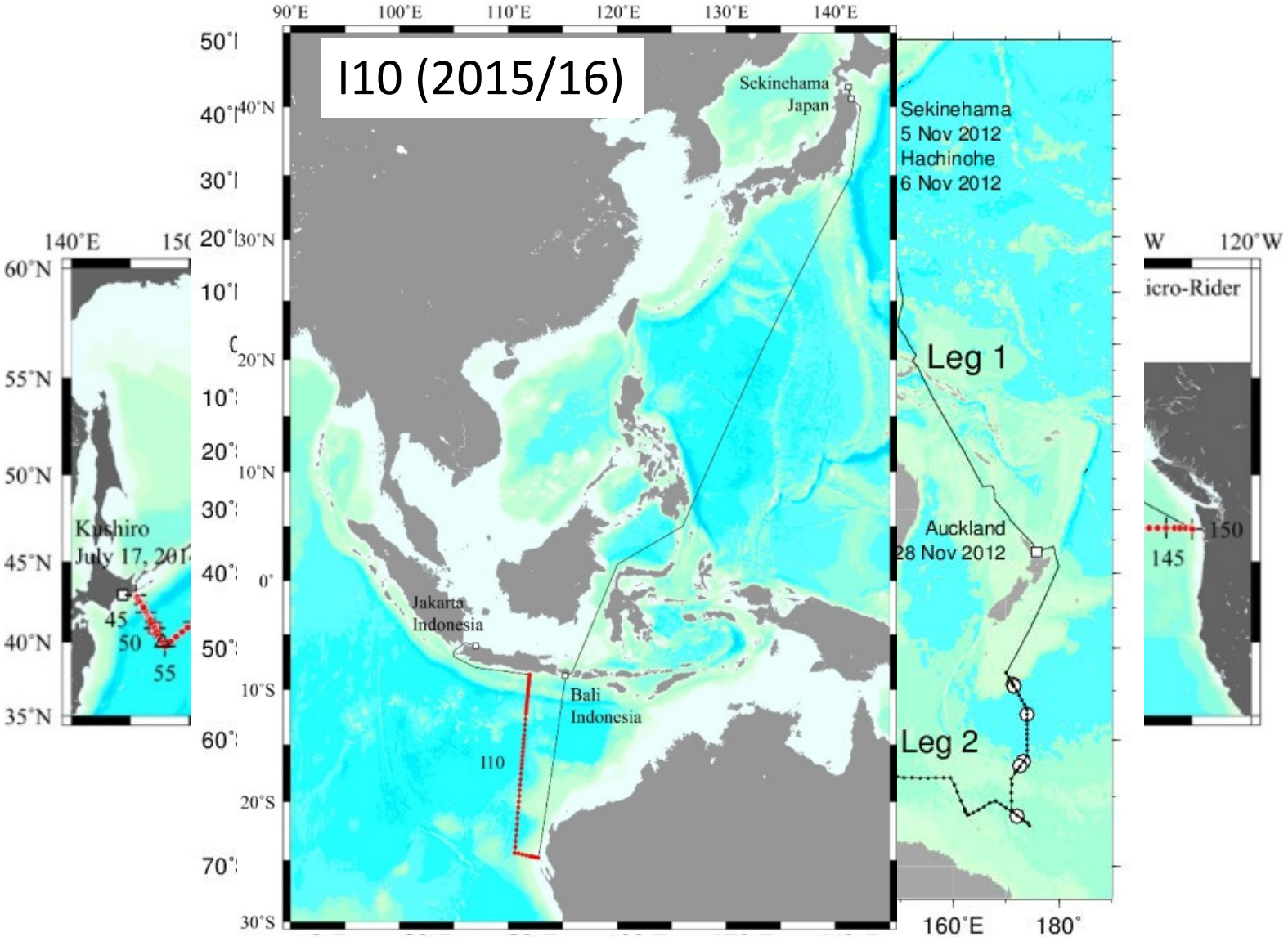
Continuous surface observations

T, S, DO, pCO_2

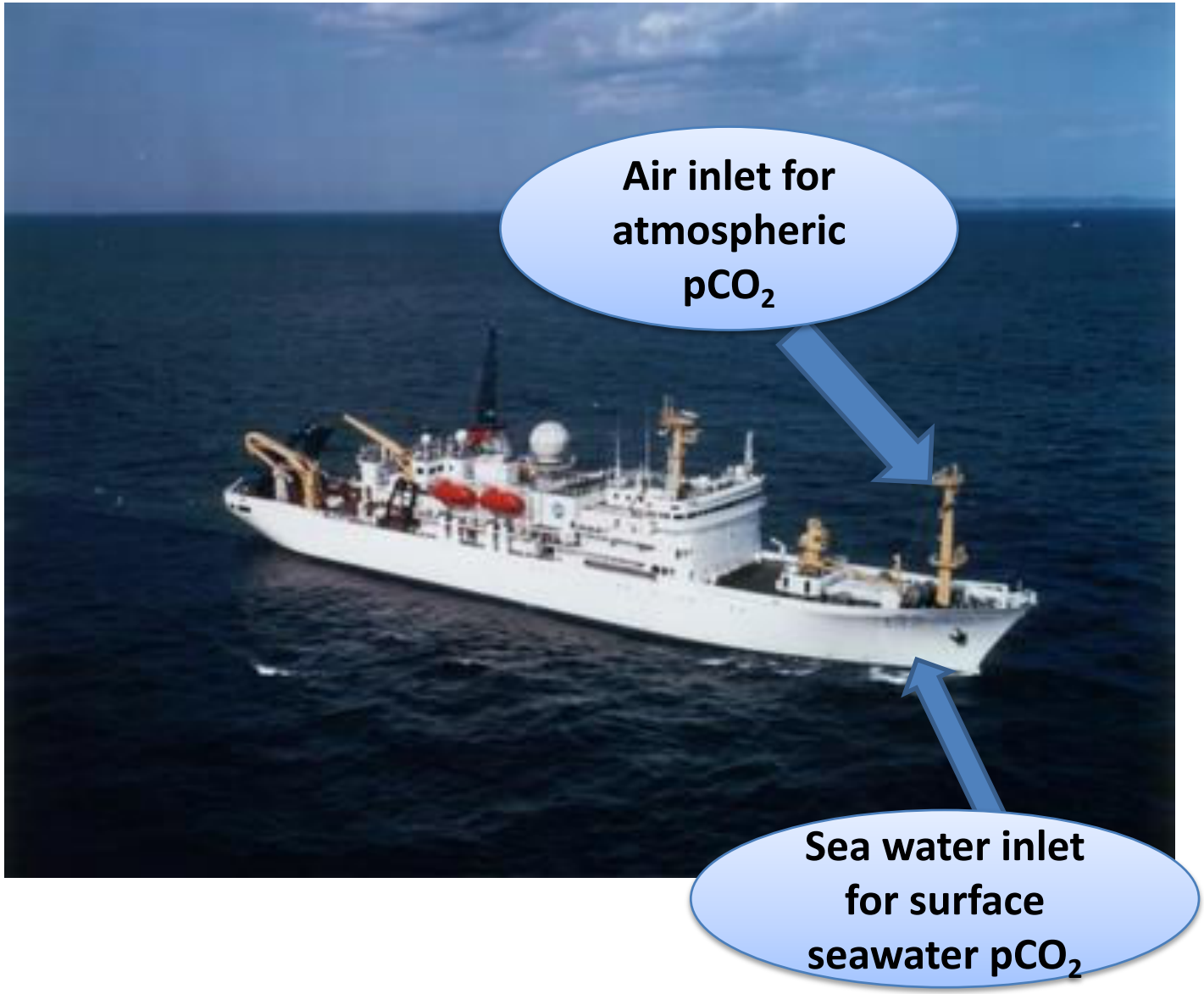
Deployment of Argo floats

Fig. 2. Lists of main observation items

➢ GO-SHIP cruise by the R/V *Mirai*

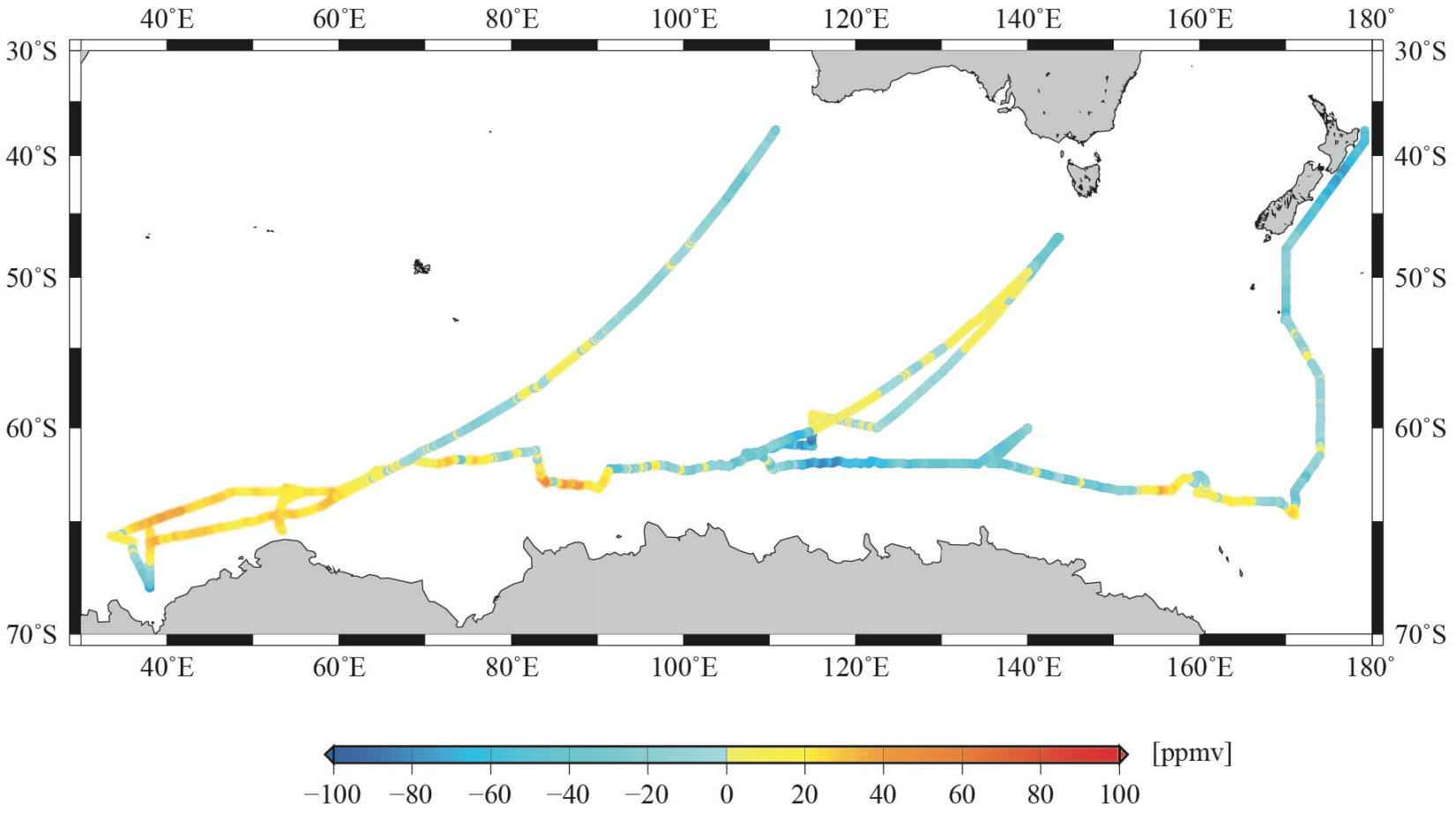


1. Atmospheric and surface seawater pCO_2 measurements


Air inlet for atmospheric pCO_2
Sea water inlet for surface seawater pCO_2

➢ Shipboard CO_2 observations by the R/V *Mirai*

ΔpCO_2 in the Indian and western Pacific sectors of Southern Ocean



ΔpCO_2 = surface seawater pCO_2 – atmospheric pCO_2

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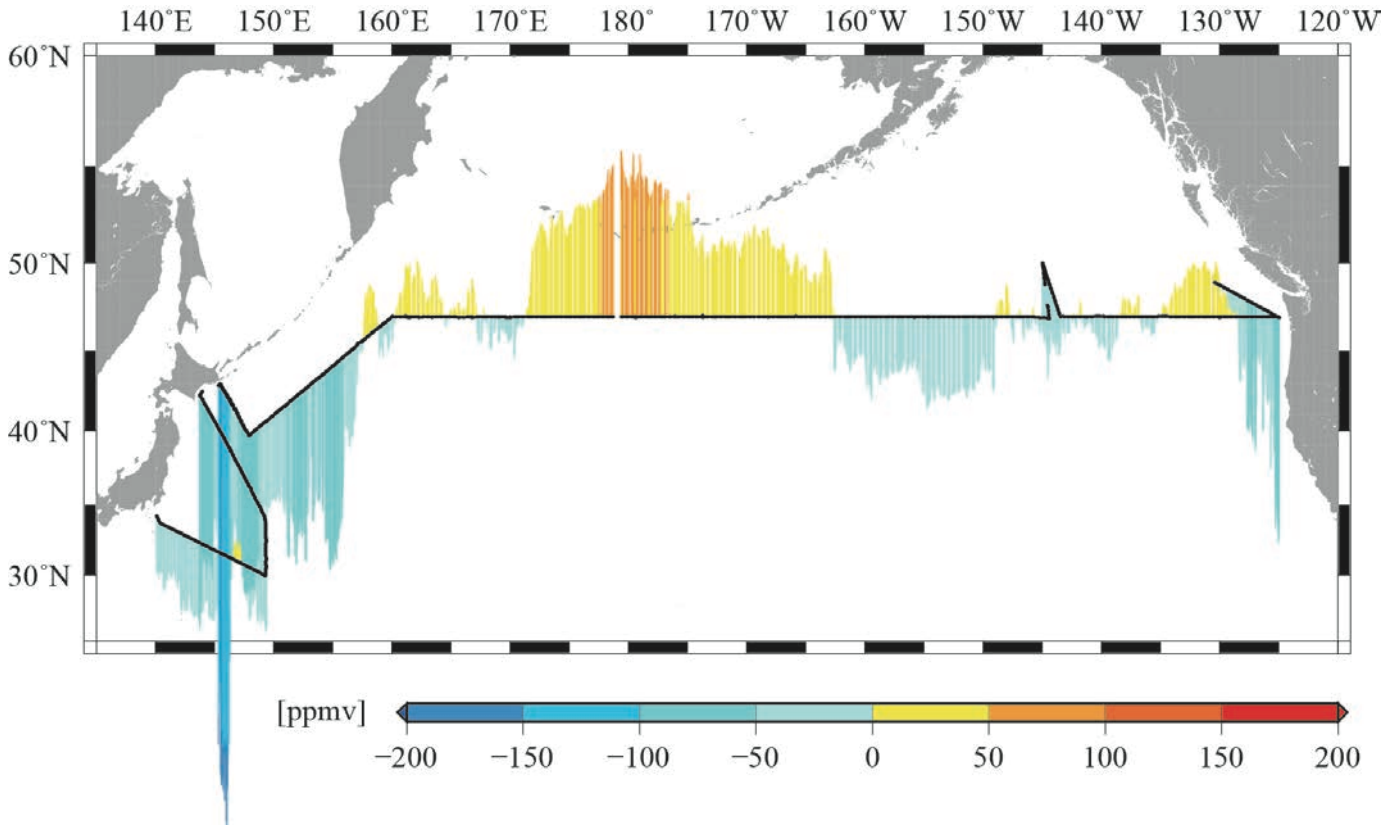
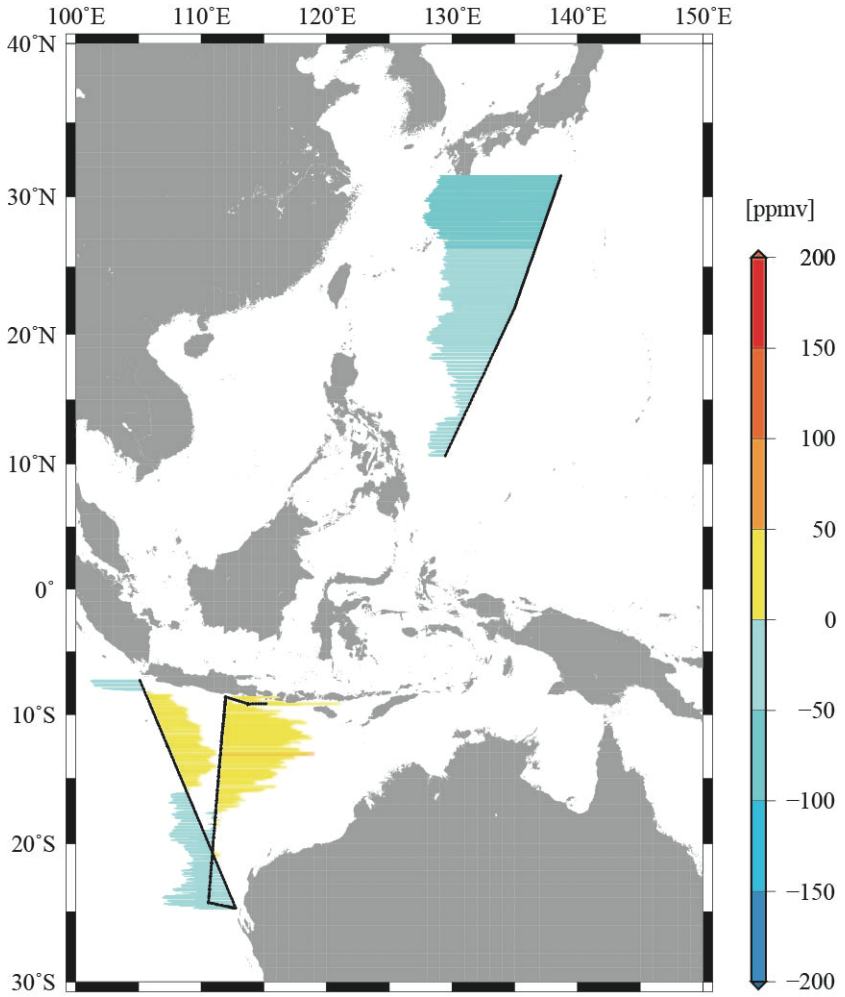
➢ Shipboard CO_2 observations by the R/V *Mirai*

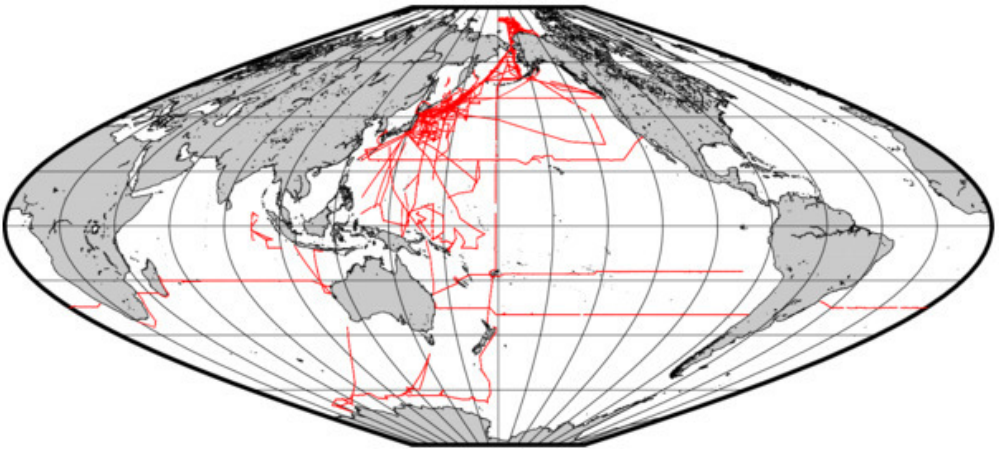
ΔpCO_2 in the North Pacific



➢ Shipboard CO_2 observations by the R/V *Mirai*

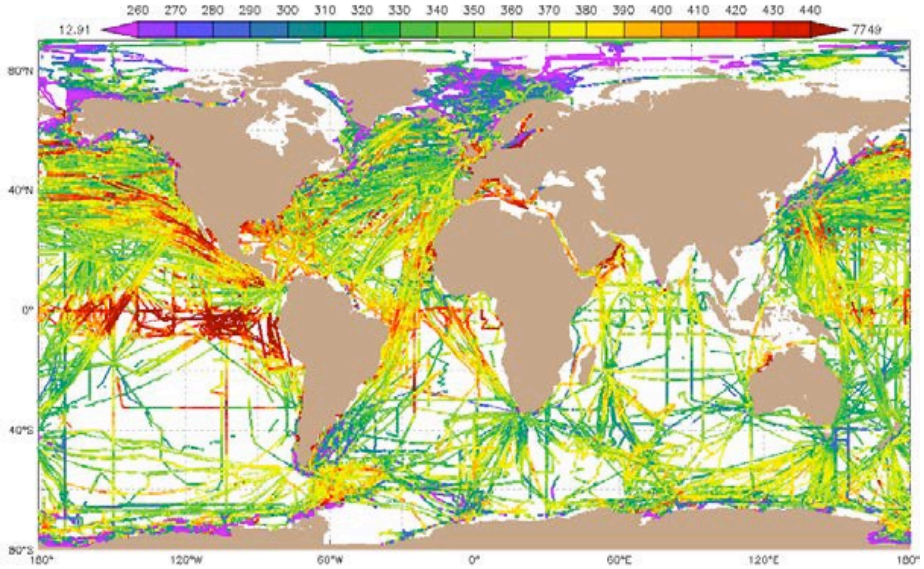
ΔpCO_2 in the eastern Indian and western Pacific Oceans



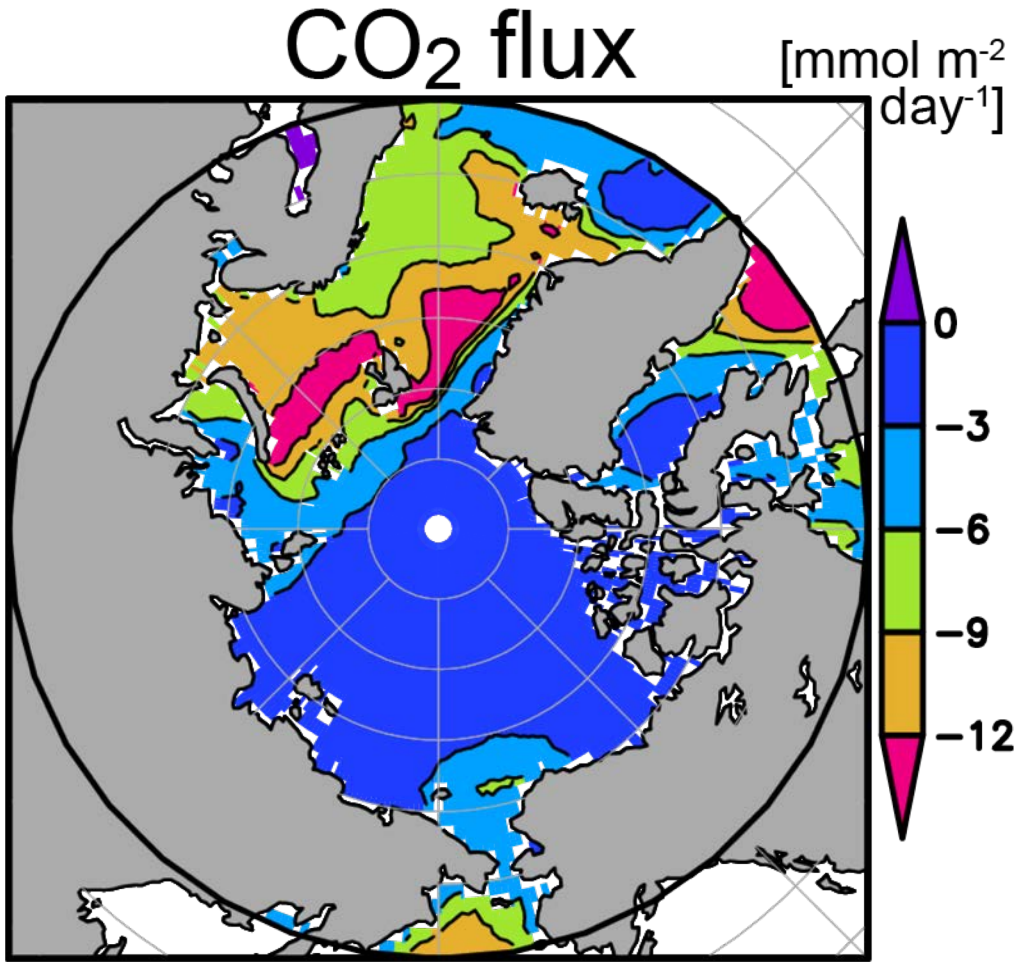


CO_2 data obtained by the R/V *Mirai* (1998-2015)

SOCAT database (https://www.socat.info/)



pCO_2 data obtained by the R/V *Mirai* are submitted to Surface Ocean CO_2 Atlas (SOCAT) database.



Net annual Arctic Ocean CO_2 uptake = 180 ± 130 TgC yr^{-1} (Yasunaka et al., 2018; Biogeosciences, doi:10.5194/bg-15-1643-2018)

2. Anthropogenic CO_2 storage in the ocean interior

Anthropogenic CO_2

= dissolved inorganic carbon (DIC) – natural CO_2

Measurable

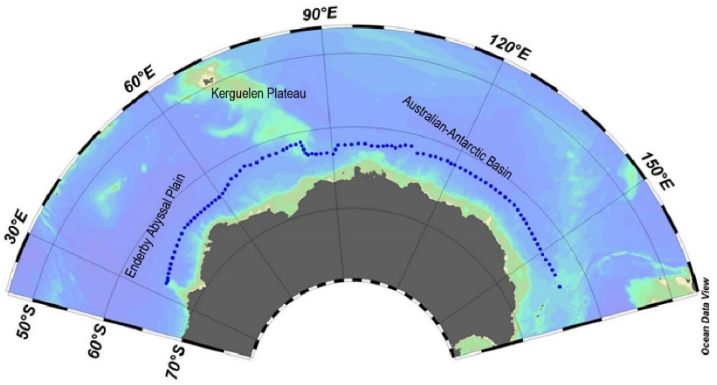
Estimation from other properties

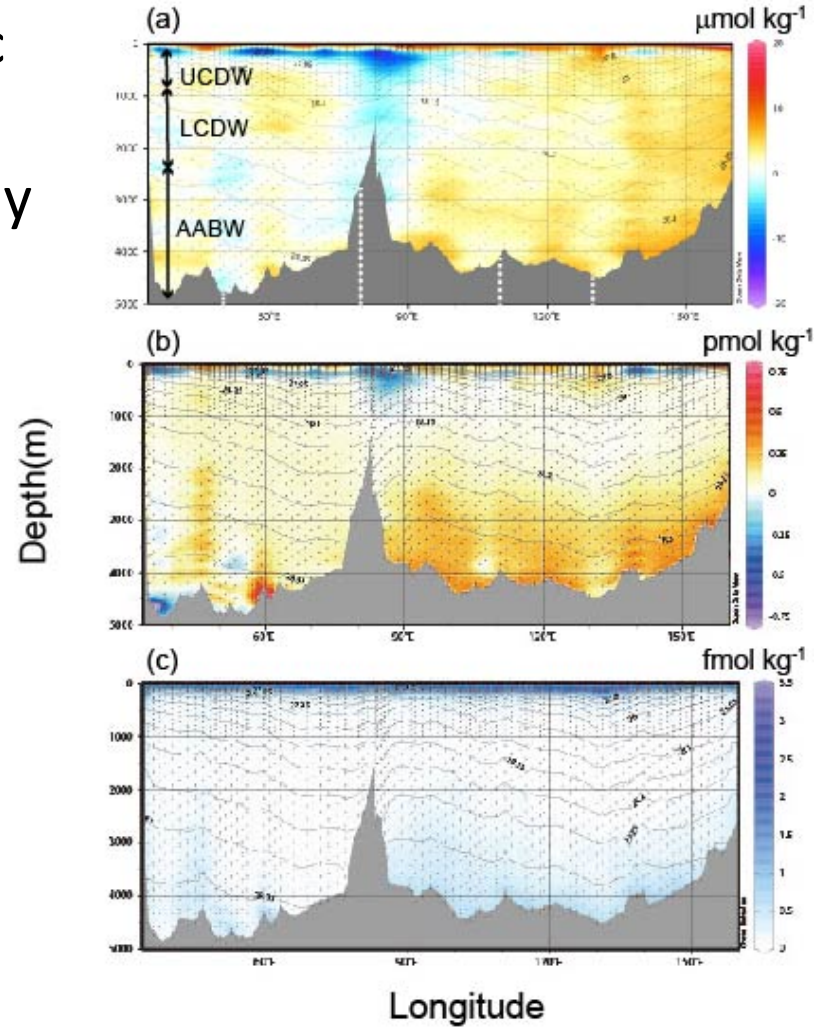
$\cong f(Salinity, DO, Nutrients, Alkalinity \ \ldots)$

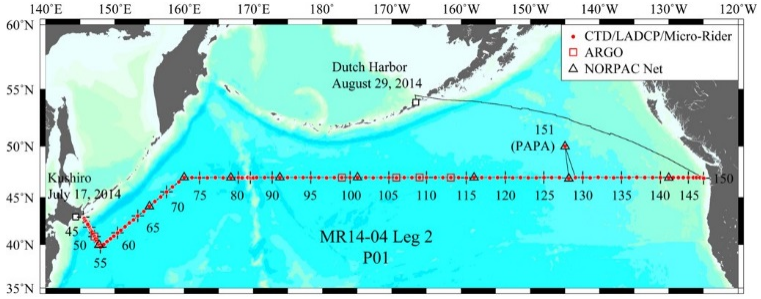
DIC measuring system on board the R/V *Mirai*

➢ Anthropogenic CO_2 storage in the Southern Ocean

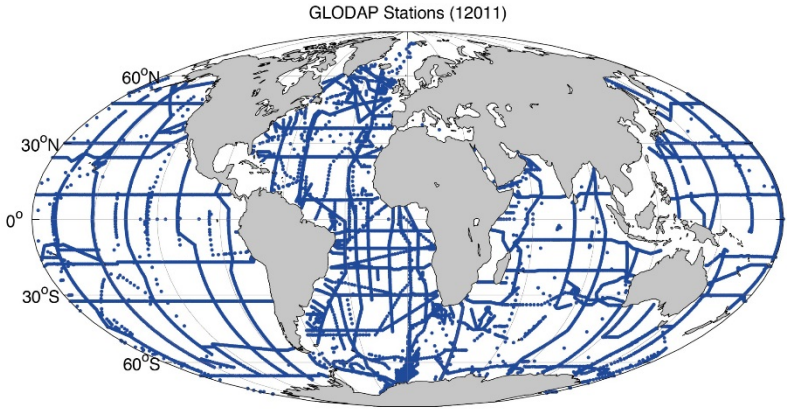
Large increases of anthropogenic CO_2 were found in Antarctic Bottom Water (AABW), previously considered a small sink of anthropogenic CO_2.



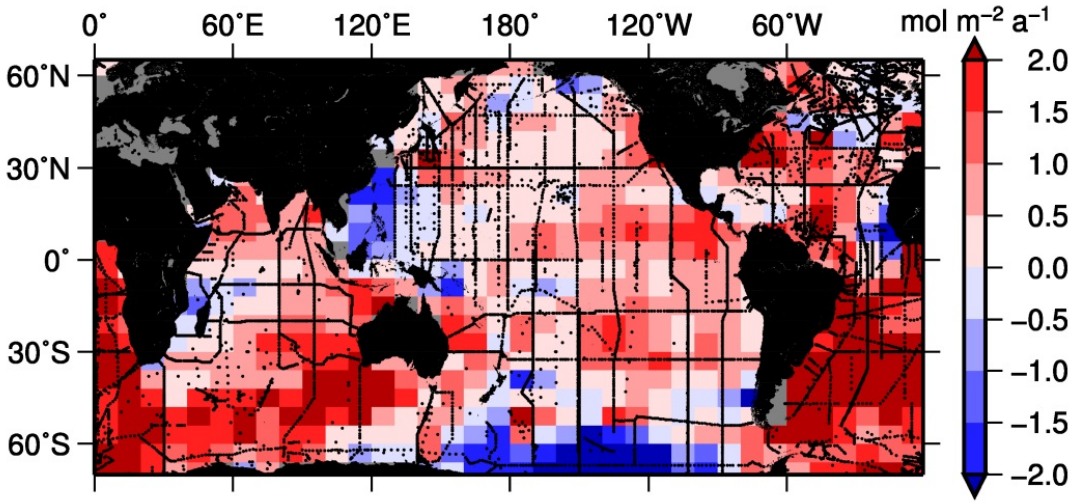




The *Mirai*'s data are submitted to Global Ocean Data Analysis Project (GLODAP) for 2nd QC.



28.7 Pg C



Decadal-scale increases of anthropogenic CO_2 in the ocean (Kouketsu et al., 2014, GRL, doi:10.1002/2014GL060516)

➢ GO-SHIP cruise in the Indian Ocean (2019/2020)

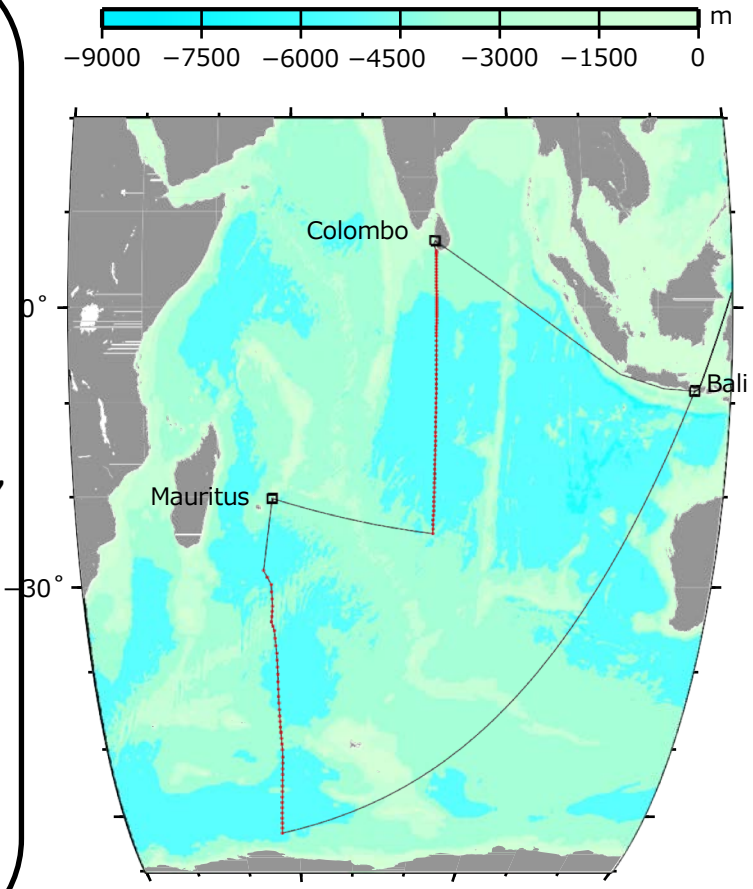
CTD/Water sampling

Temperature (T), Salinity (S), Dissolved oxygen (DO), Nutrients, Dissolved inorganic carbon, Total alkalinity, pH, Density, Chl-a, Colored dissolved organic matters, CFC s （CFC-11, CFC-12, CFC-113), SF_6, ^{13}C, ^{14}C, ^{134}Cs, ^{137}Cs, ^{18}O, LADCP

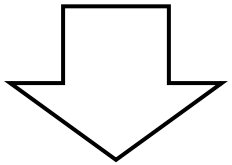
Continuous surface observations

T, S, DO, pCO_2

Deployment of Argo floats



We are conducting pCO_2 and anthropogenic CO_2 observations under international frameworks.



Enough for sink and source estimation?

There are still large areas with few or no data!

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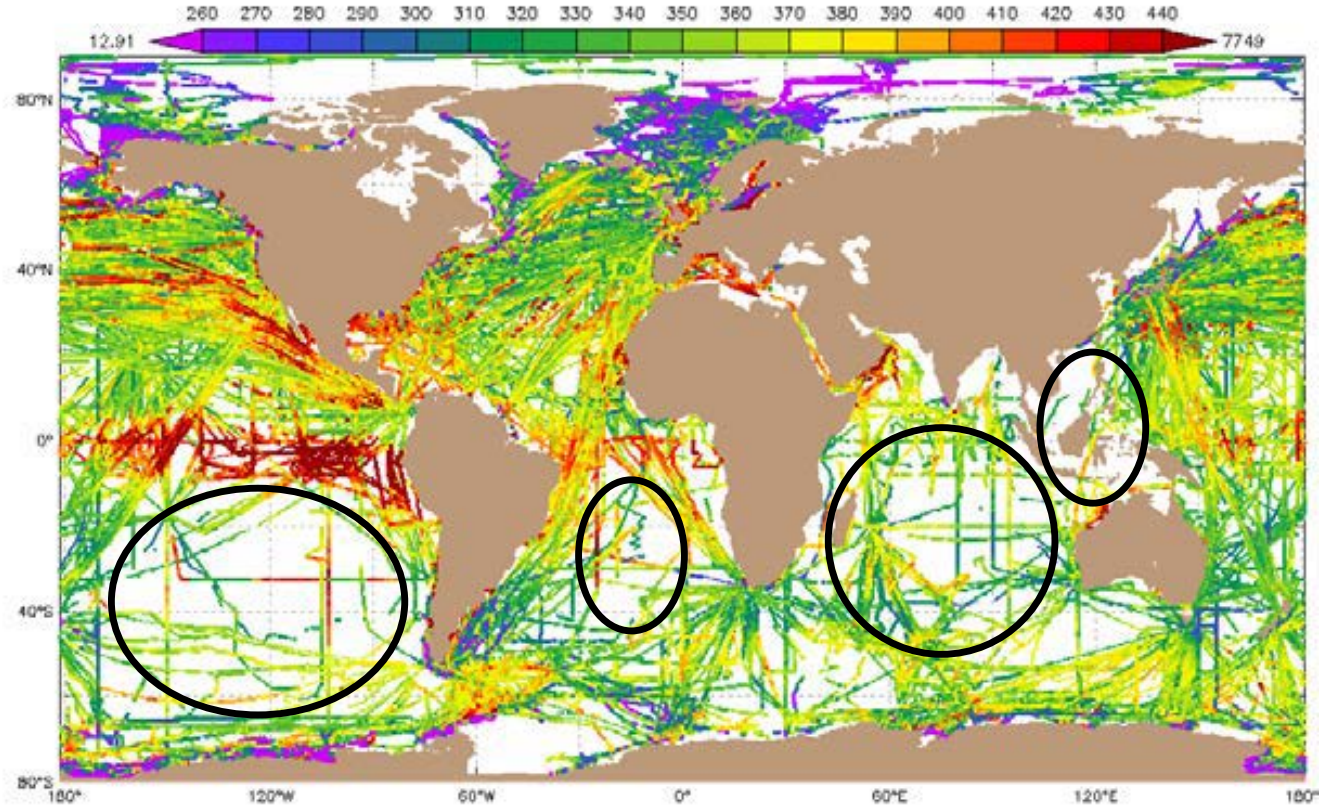
- Sink and source estimation in the ocean still includes large uncertainties.

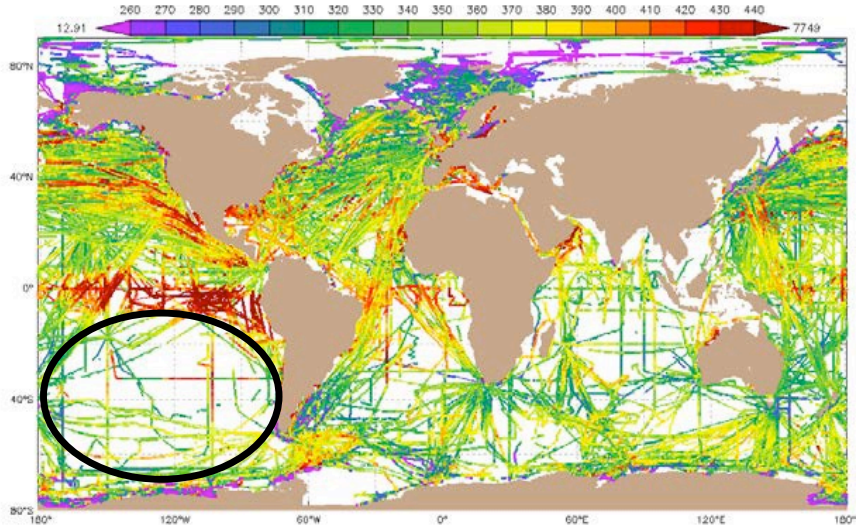


From https://www.socat.info/

3. Further investigation

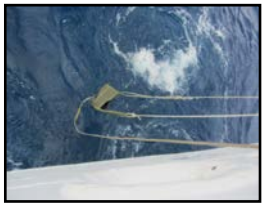
3.1 Deployment of autonomous platforms

➢ Deployment of drifting CO_2 buoy



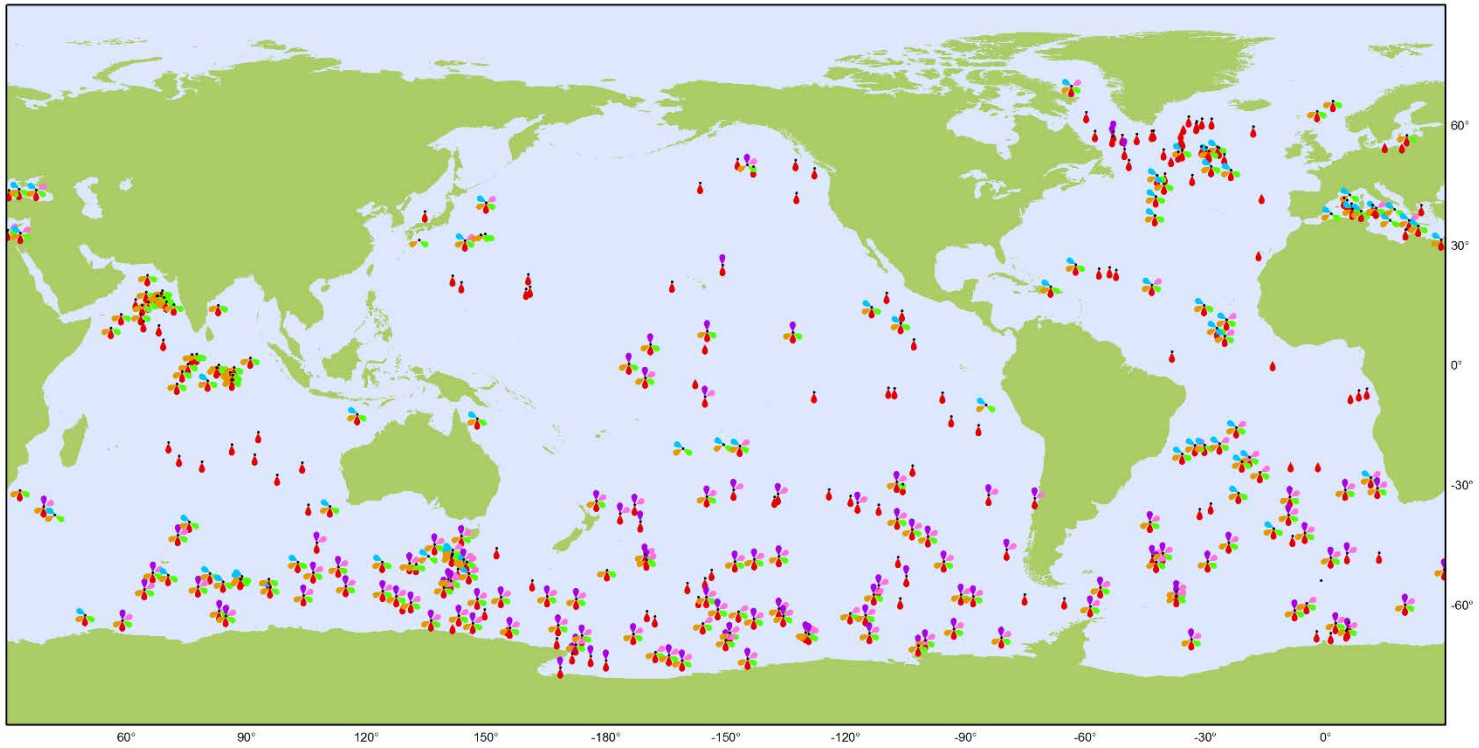
There is a large area with few or no pCO_2 data in the South Pacific

A drifting buoy in its cloth cradle.



Deployment of a drifting buoy from the R/V *Mirai*. Left: the drifting buoy is lowered from the stern in its cradle. Middle: the cradle is tilted, releasing the drifting buoy so that it drops onto the sea surface. Right: a drifting buoy just after deployment.

➢ Deployment of Biogeochemical (BGC) floats



Biogeochemical Argo

Sensor Types

Latest location of operational floats (data distributed within the last 30 days)

September 2018

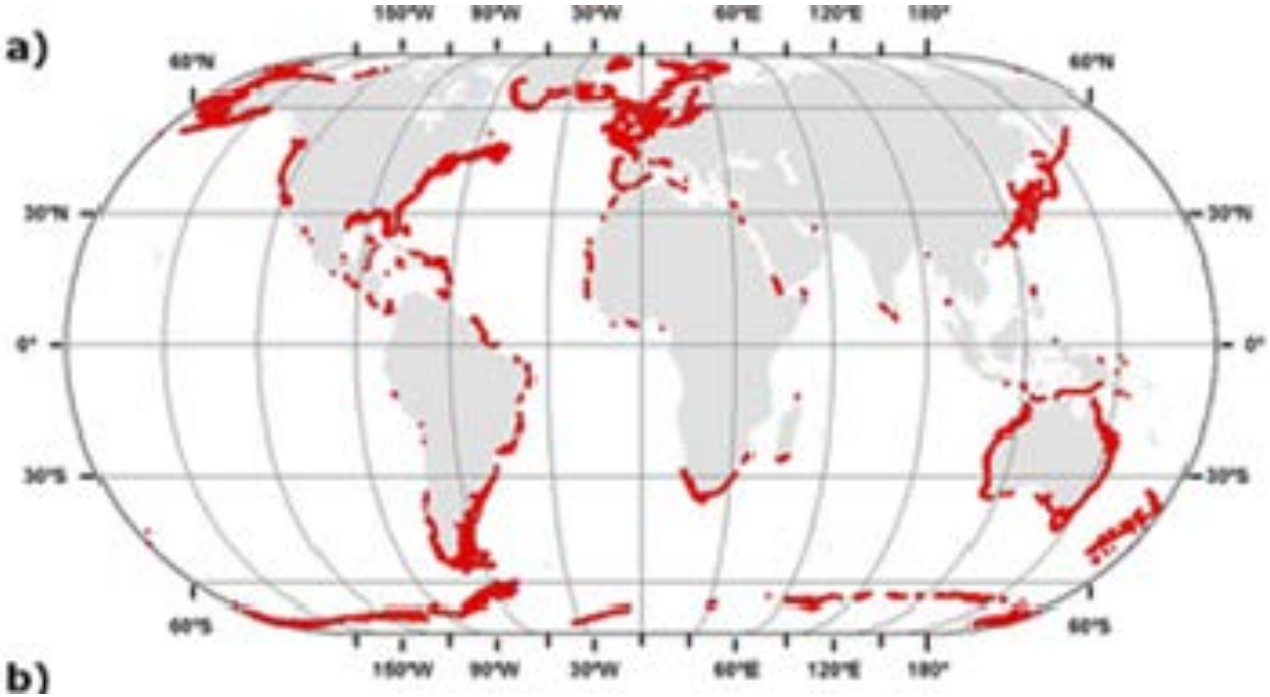
- Operational Floats (329)
- Suspended particles (208)
- Downwelling irradiance (70)
- pH (117)
- Nitrate (131)
- Chlorophyll a (208)
- Oxygen (333)

Generated by www.jcommops.org, 03/10/2018

3. Further investigation

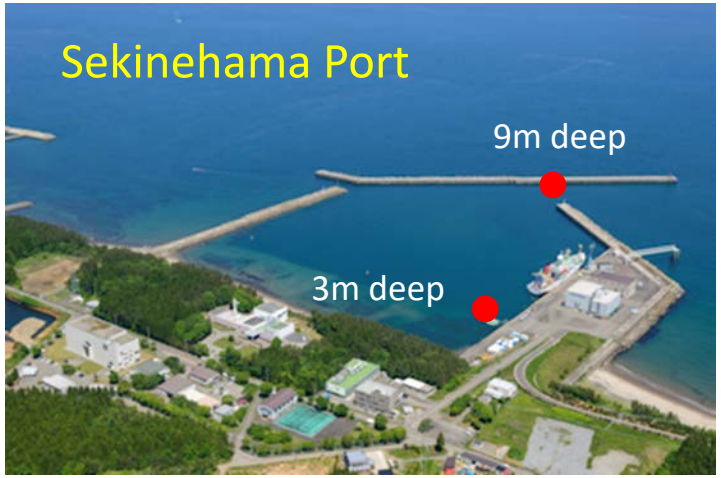
3.2 Observation in coastal areas

- Continental shelf seas are not well evaluated yet for CO_2 sink and source activities.



Distributions of continental shelf seas from SOCAT ver.2. (Laruelle et al., 2014, doi:10.1002/2014GB004832)

Coastal ocean monitoring
-An example in Tsugaru Strait-



Measurement items:
Water temperature, Salinity, Dissolved oxygen Total alkalinity, Nutrients, Water isotope, Total organic carbon, Total dissolved nitrogen, Chlorophyll a, Phytoplankton identification


Bucket sampling


CTD sensors


NORPAC net

Summary

- In JAMSTEC, observations of oceanic carbon cycle are conducted mainly by the R/V *Mirai;*
- The observations are made under international frameworks, e.g., GO-SHIP;
- Atmospheric and surface seawater pCO_2 are measured for the estimation of air-sea flux of CO_2;
- DIC and related properties are measured for the estimation of anthropogenic CO_2 storage;

- Autonomous platforms, e.g., drifting buoys, BGC ARGO, etc. are used for improving uncertainty of CO_2 sink and source estimation in open ocean;

- Costal ocean observations are also conducted for a better estimation of CO_2 source and sink.