Developing an autonomous buoy for surface CO_2 measurement

Shuichi Watanabe (Mutsu Institute for Oceanography, JAMSTEC)

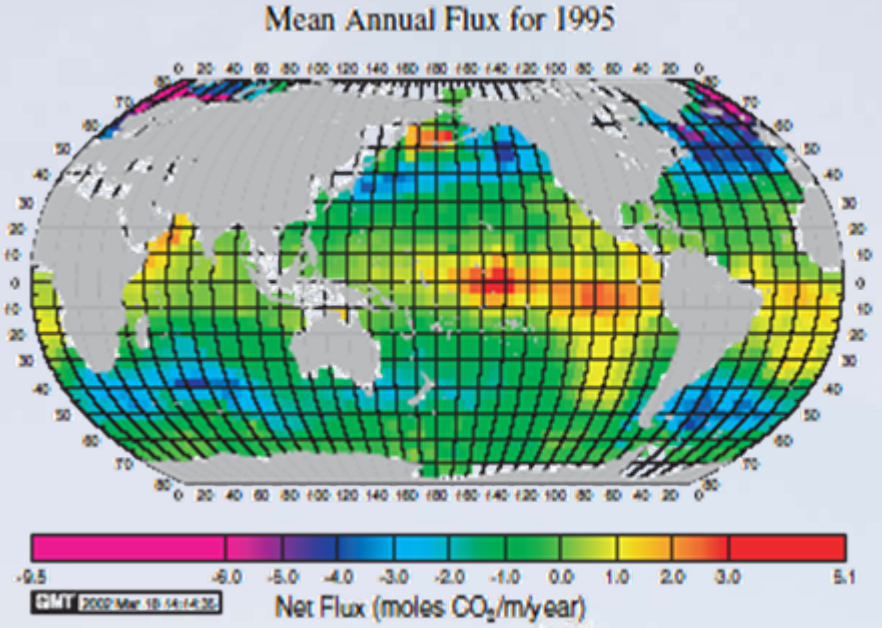
We are developing a compact autonomous buoy for surface CO_2 measurement.

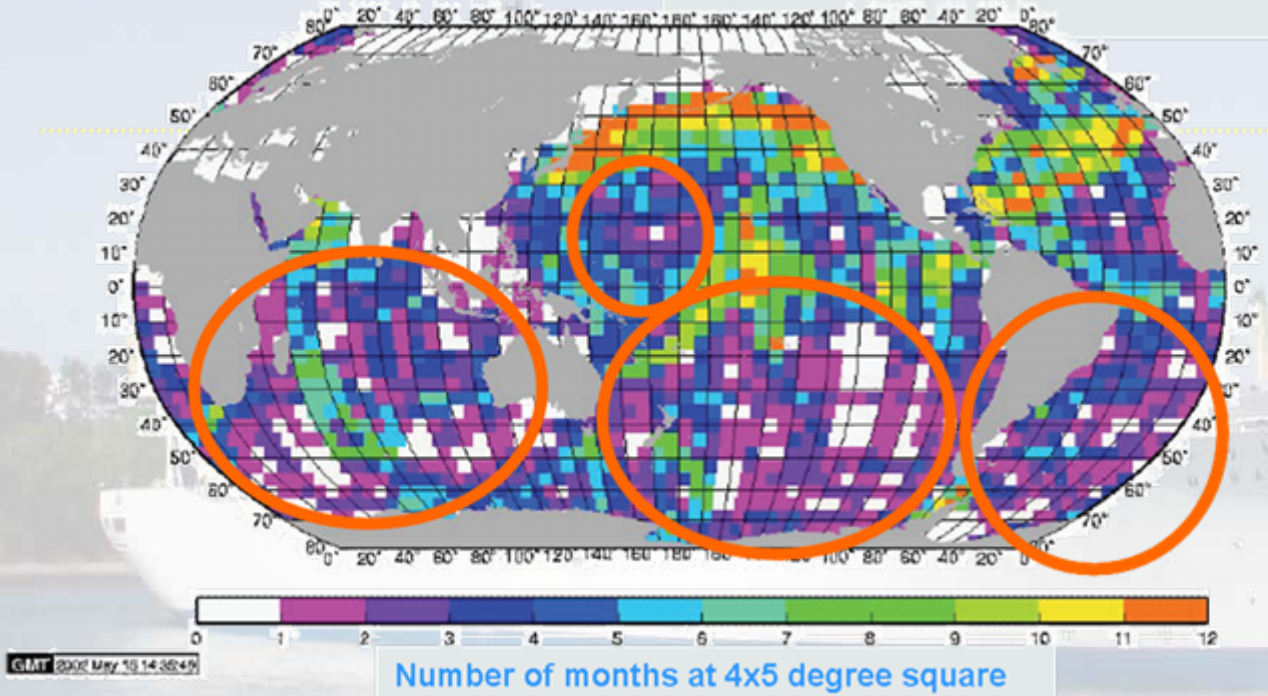
This project is supported by MEXT funding system, JEPP (Japan EOS Promotion Program).

General back ground

~700, 000

Gas exchange rate





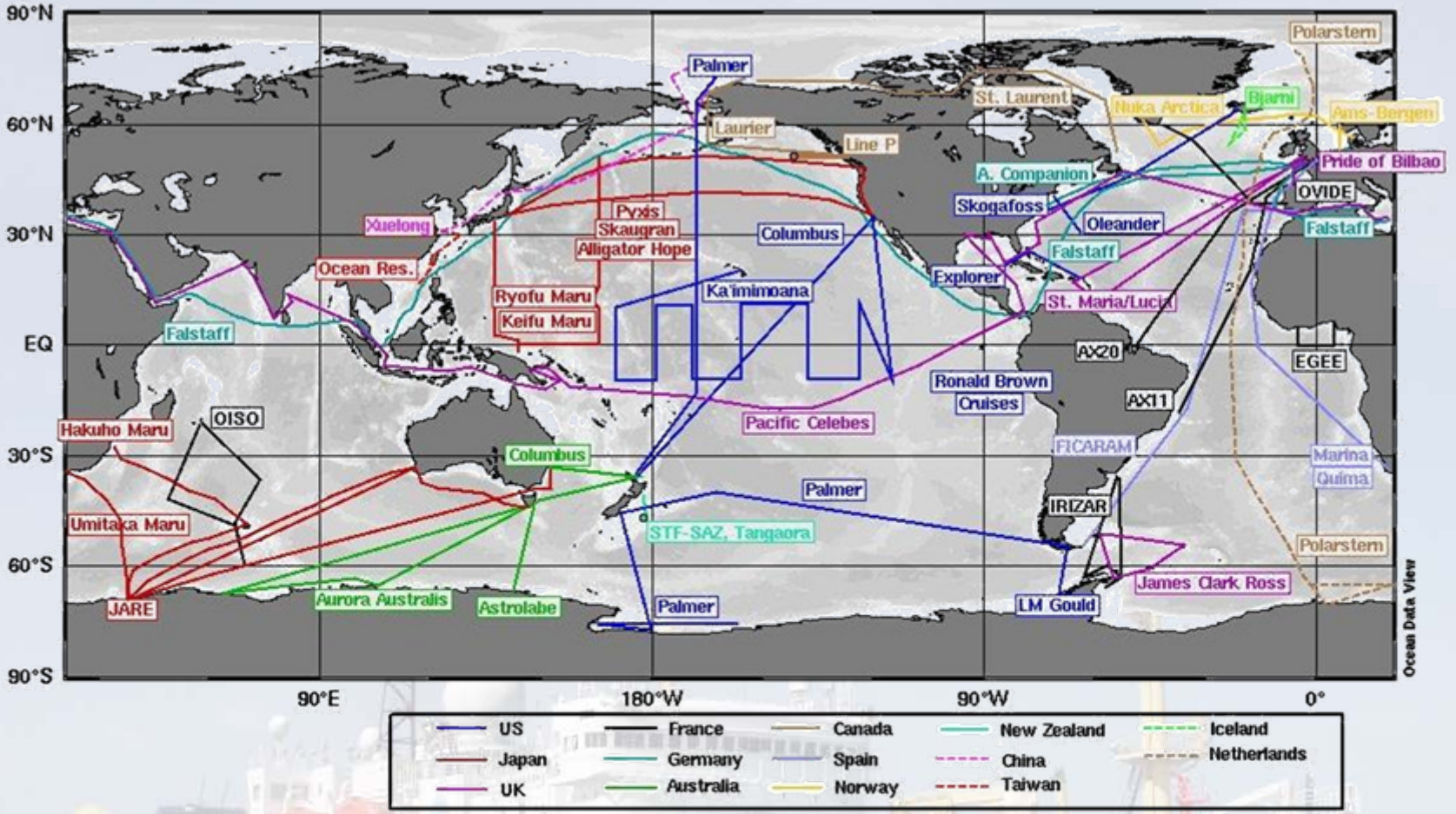
Takashi et al. 2002

2.0±0.6PgC/y

0.1PgC

There is area where are lack of data.

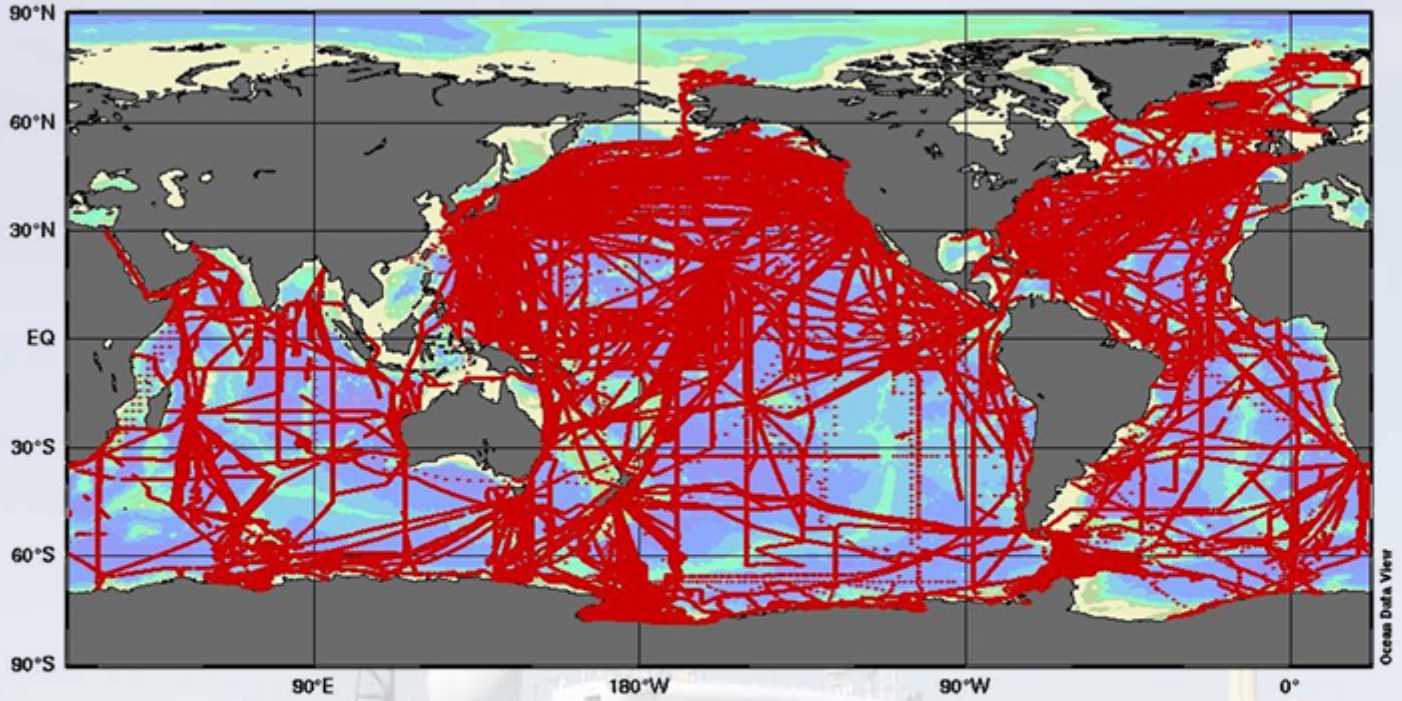
Coverage of sea surface with ship opportunity or research vessel



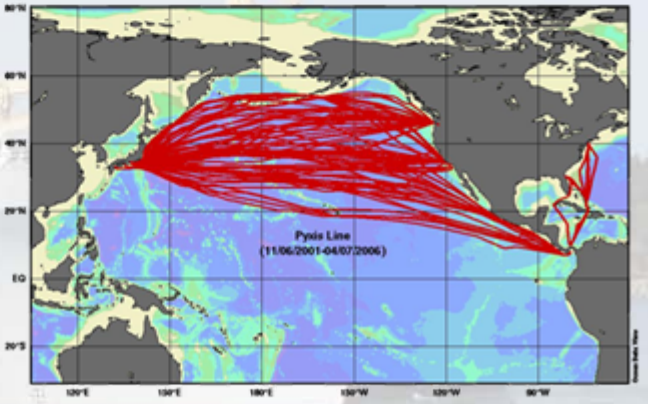
Ref. http://cdiac.ornl.gov/oceans/VOS_Program/VOS_home.htm

A lot of countries are collecting a large number of pCO2 data using research vessels and cargo ships with automated pCO2 systems. However, we need more number of data for getting more precise yearly CO2 flux map which is estimated with less than 0.1 PgC/year.

Cruises using LOED data base, "Global Ocean Surface Water Partial Pressure of CO2 Database: Measurements Performed During 1968–2006 (Version 1.0)"



LOED data base is not covered all sea surface. There is no data area in the Indian Ocean and southern hemisphere.



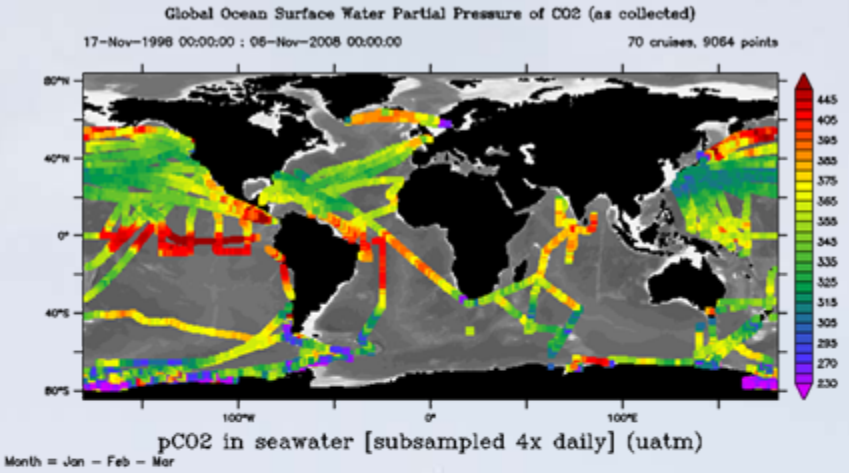
Ref.
http://cdiac.ornl.gov/oceans/LDEO_Underway_Database/LDEO_home.html
http://cdiac.ornl.gov/oceans/VOS_Program/pyxis.jpg

Map of sea-surface pCO2 map

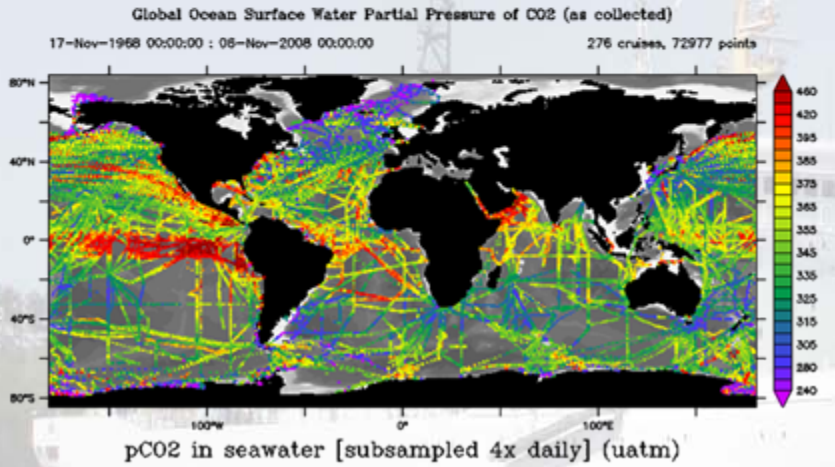
These were drawing using the PMEL Ocean Carbon Data Management system(OSDMC).

These were not sufficient for making yearly flux map.

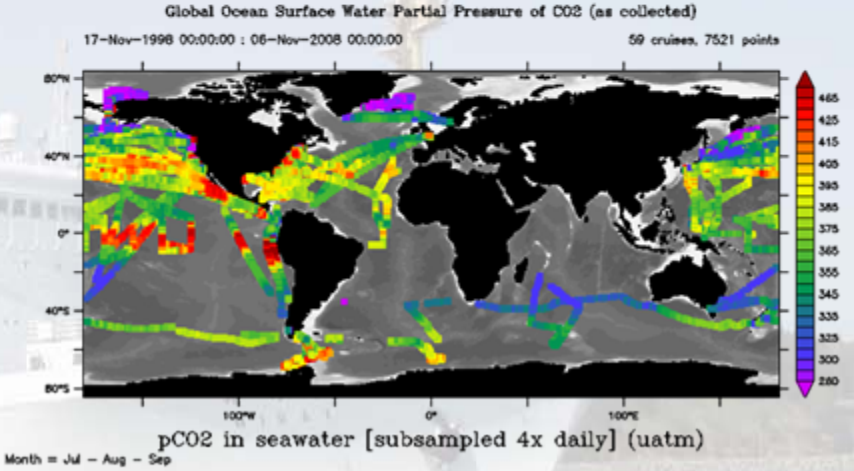
Data in January-March from 1998 to 2008



All data from 1968 to 2008

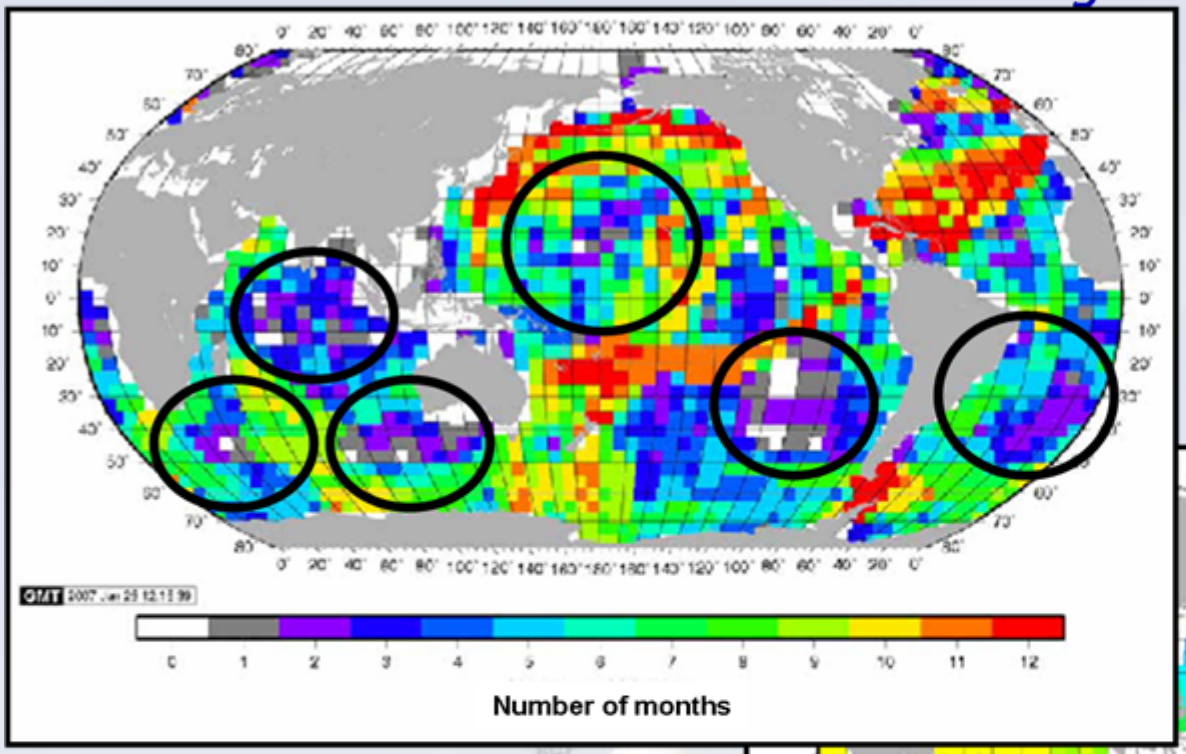


Data in July-Sept. from 1998 to 2008

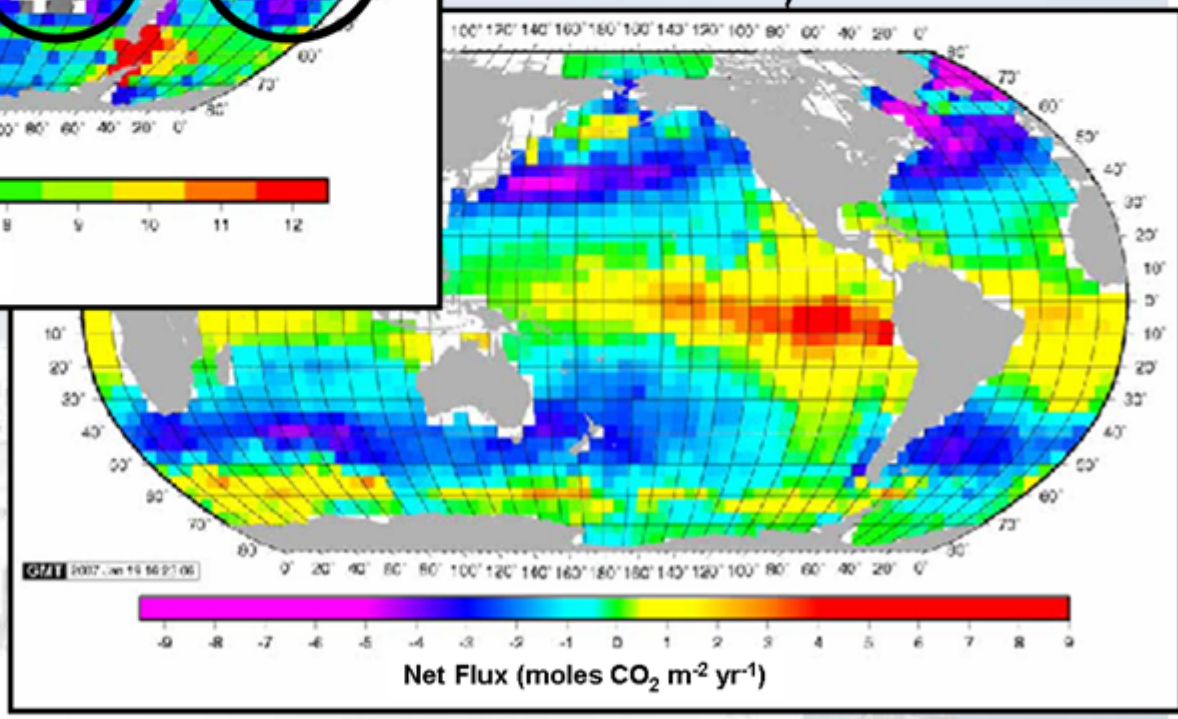


Ref.
http://cdiac.ornl.gov/oceans/LDEO_Underway_Database/LDEO_home.html

Yet we are still struggling to produce a global climatology with sufficient data coverage after 35 years



From Takahashi et al. manuscript in preparation based on a data set of approximately 2.8 million data points collected over 35 years



Two Complicating Factors:

1) Complex Chemistry
2) Variable in Time and Space

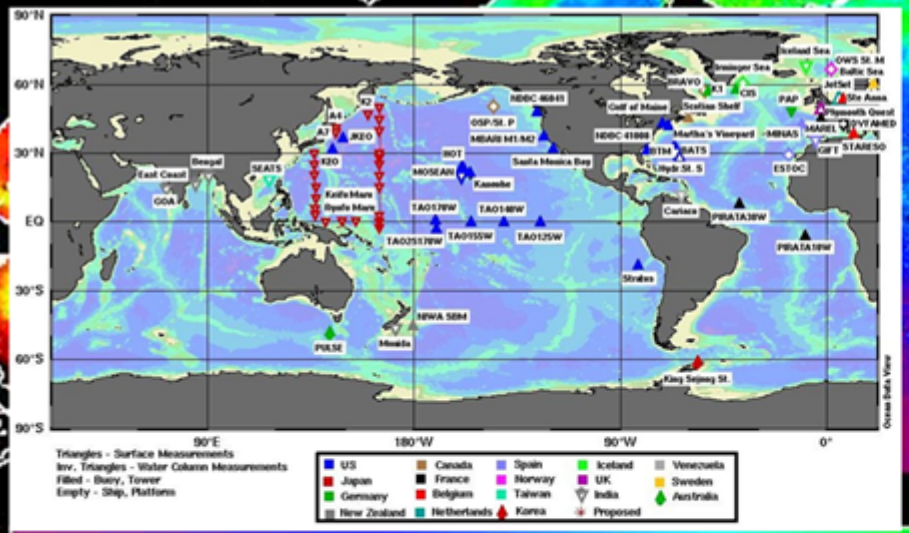
From C. Sabin's presentation at IOCCP meeting
http://ioc.unesco.org/ioccp/pCO2_workshop/SOCOVVhome.html#PPTS

Time-series observation site in the NW North Pacific

KNOT
(44N/155E, ~4500m)
1992 – present

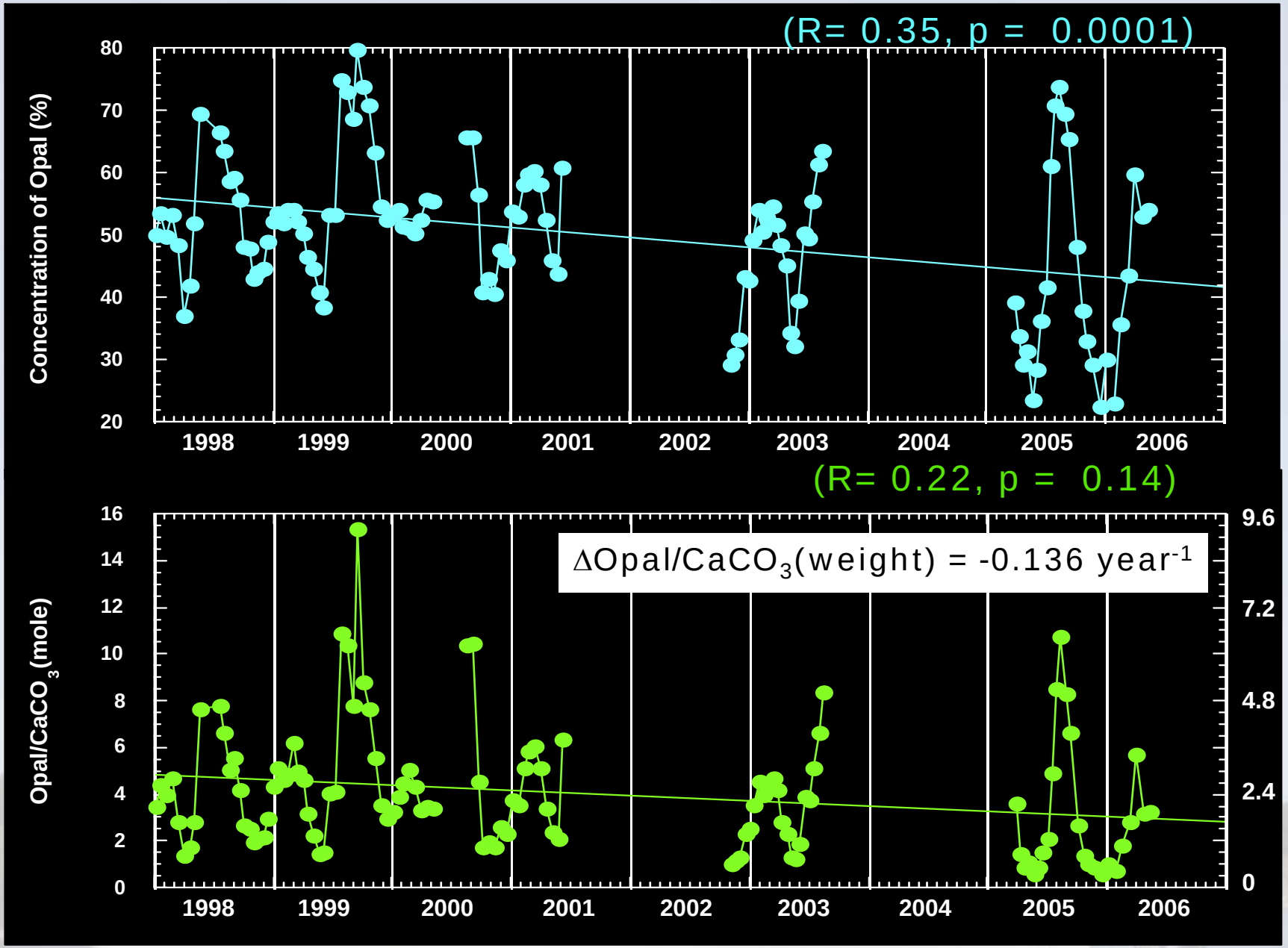
K2
(47N/160E, 4810m)
2001 – present

K1
50N
K2
KNOT



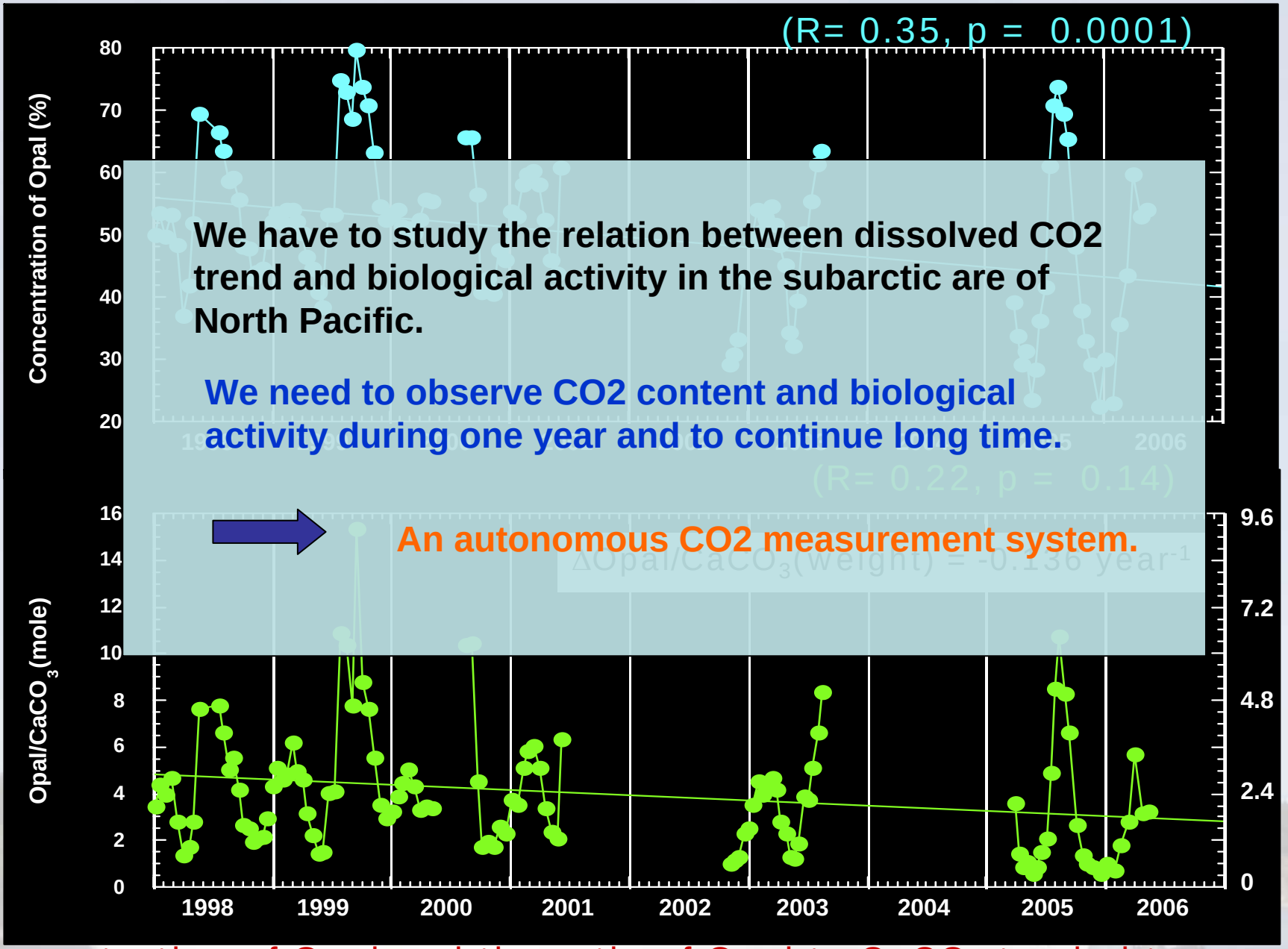
JAMSTEC is conducting time-series observation in the western North Pacific and WOCE repeat observations.

SeaWiFS Chl-a Monthly composite (Oct. 2001)
(courtesy of Dr. K. Sasaoka of JAMSTEC)



Concentration of Opal and the ratio of Opal to $CaCO_3$ tended to decrease with time.

Ref. http://www.pices.int/publications/presentations/PICES_16/Ann16_S2/S2_Honda.pdf



Concentration of Opal and the ratio of Opal to $CaCO_3$ tended to decrease with time.

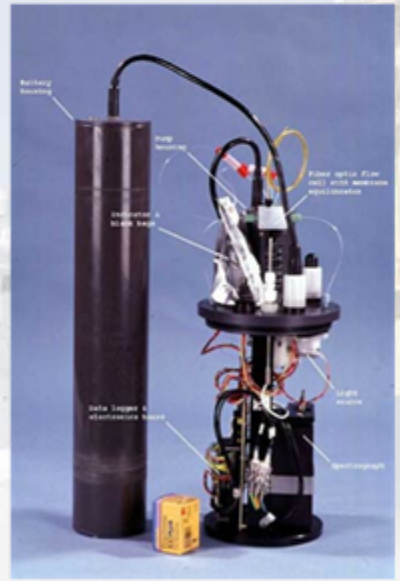
Ref. http://www.pices.int/publications/presentations/PICES_16/Ann16_S2/S2_Honda.pdf

Before the project

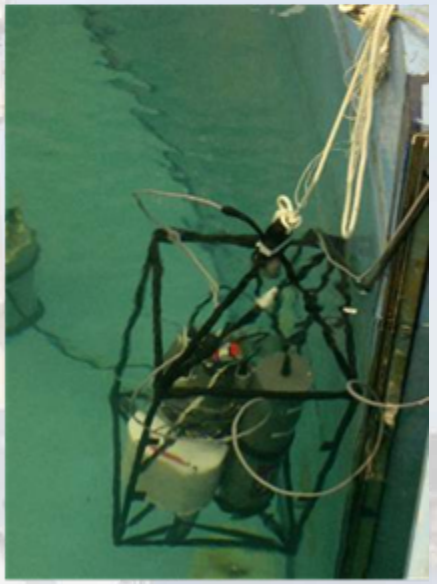
In situ autonomous pCO_2 measuring instruments

- **NDIR/equilibrator**
  - MBARI Mooring and Drifter (Friederich et al.)
  - $MAPCO_2$ System (Sabine et al.)
- **Spectrophotometric = Membrane + Indicator**
  - CARIOCA buoy (Merlivat et al.)
  - SAMI-CO_2 (DeGrandpre et al.)
  - CO_2 profiler (Nakano et al.)

CARIOCA



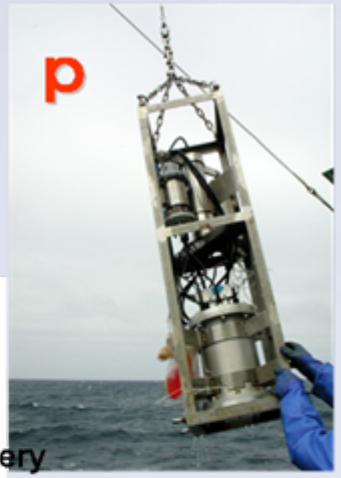
SAMI

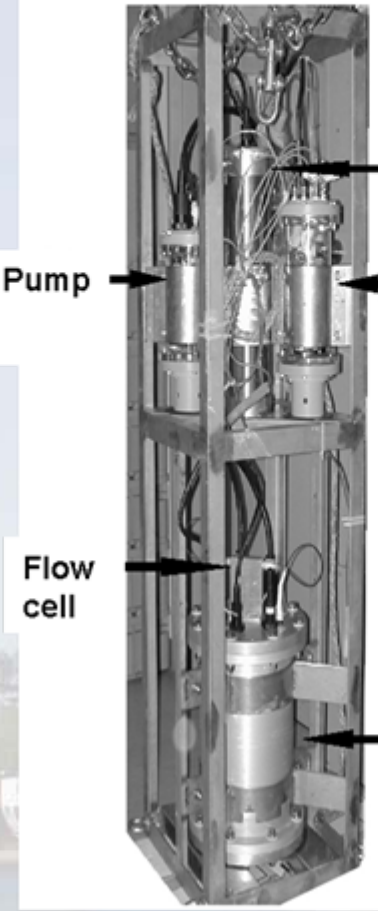


MBARI

fCO2 & pH profilers developed by Japanese scientists before JEPP project

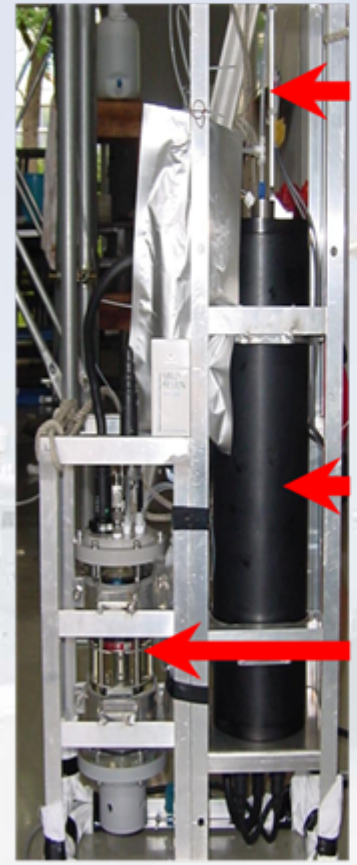
pH profiler





Before 1998

CO_2 profiler



Around 1998-2003
(Nakano et al.)

Development of autonomous buoy for surface CO2 measurement

It is necessary to distribute a lot of measurement systems in all open ocean.

Checking Items

To apply Argo observing system and to have a relation with GOSAT

High precision and long life analytical system

/ 1 μ atom, 1year (Once a week, 1 set is 4 time measurements a day)

Compact, light and cheap measurement system

/ finding small parts

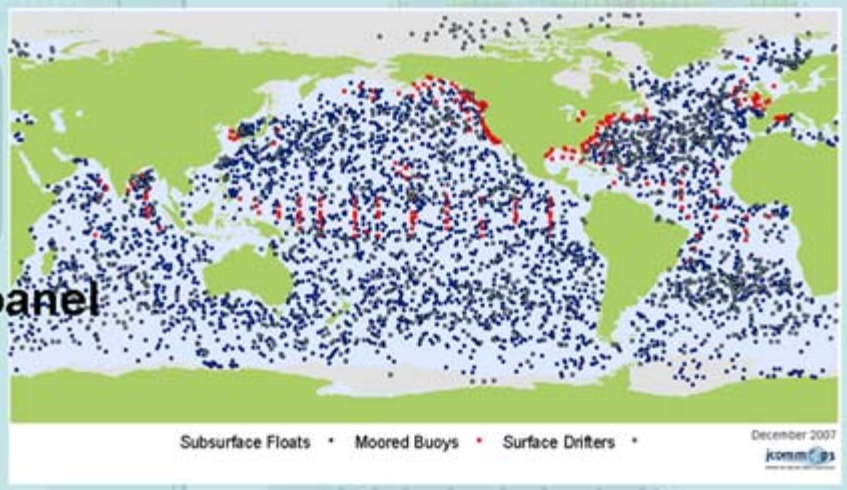
pump, spectrophotometer

Low power, high power buttery

/ using LED, Li buttery or solar panel

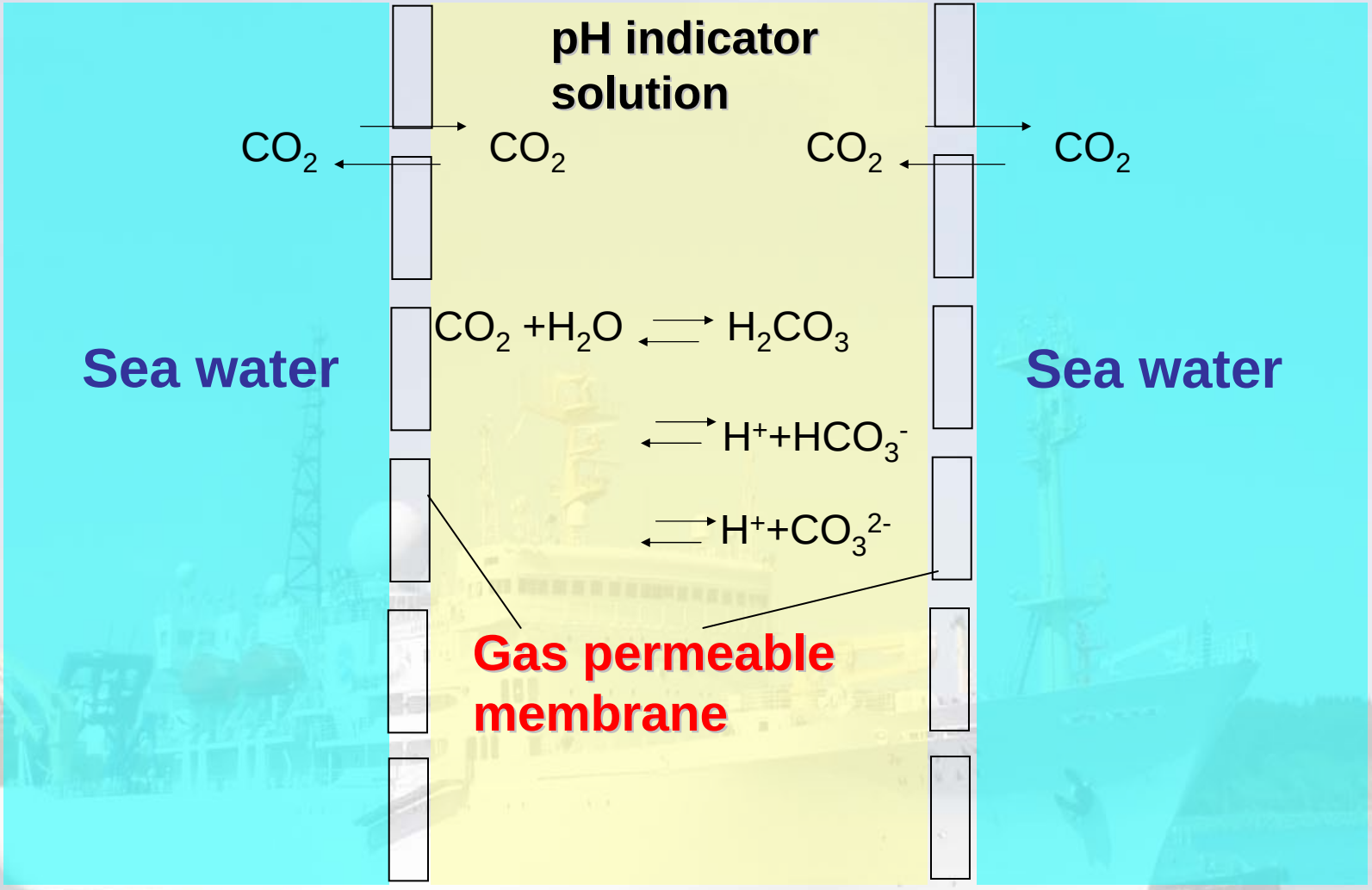
Safety

/ no poison



Argo (Dec 31, 2007)

The measurement principle of pCO_2 in sea water using spectro-photometric technique



Component parts

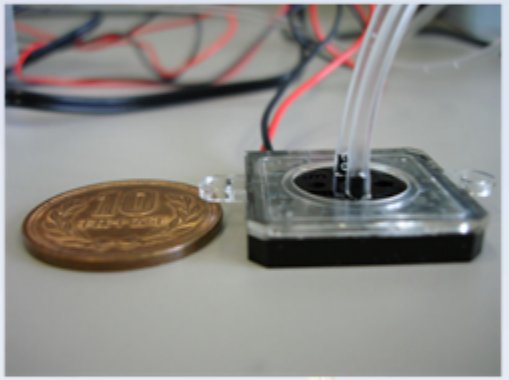
Sensor component parts

Optical instruments

- CCD detector
- LED light source

Micro pump

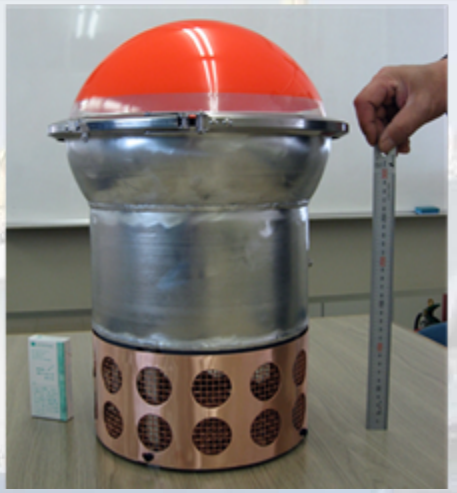
- Power saving（100mW）
- Compact, light weight（25 × 25 × 4.8mm, 4g）
- Long life (1 and half year)



Drifting buoy

- Compact, light weight

（Diameter: 340mm, Height: 470mm
Weight:10kg）



New CO_2 sensor

CO_2 sensor specification

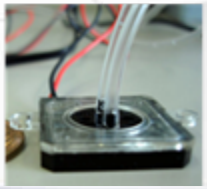
- Precision : 3 μatm
- Operation period : 1 year
- Diameter : 340 mm (max)
  250 mm (mim)
- Height : 470 mm
- Weight : 15 kg
- Battery : Li buttery
- Cost : $15,000 (future plan)

Drifting buoy

- Spectro photometer
- LED light source
- Satellite communication system
- Downsized PC

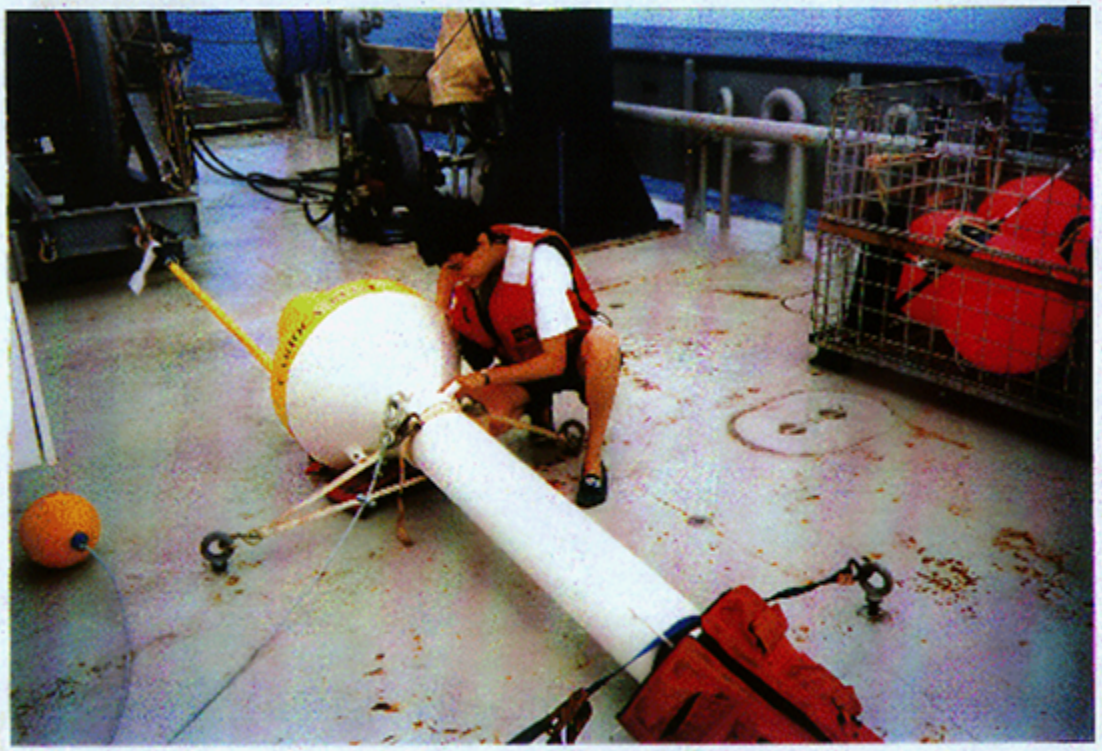
Sensor unit

- Gas permeable membrane
  (Amorphous fluoropolymer tubing)
- TS sensor
- Micro pump



Comparison between CO_2 sensor and CARIOCA buoy

CO_2 sensor



CARIOCA buoy Length:2m Weight:60kg

Ref. http://www.lodyc.jussieu.fr/carioca/photos.html

Developing CO2 bouy

Downsizing Height:47cm, Diameter:34cm(maximum), Weight:15kg

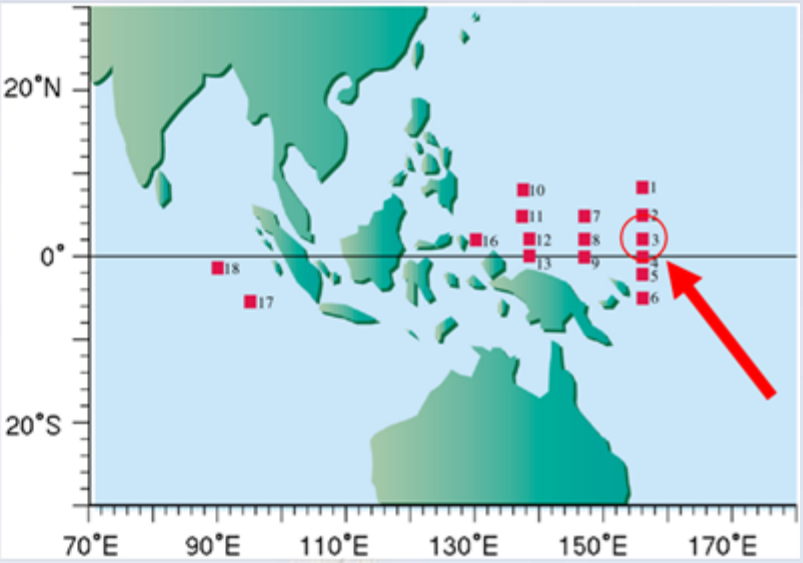
Safety Less toxicity (anti-biofouling paint and reagent)

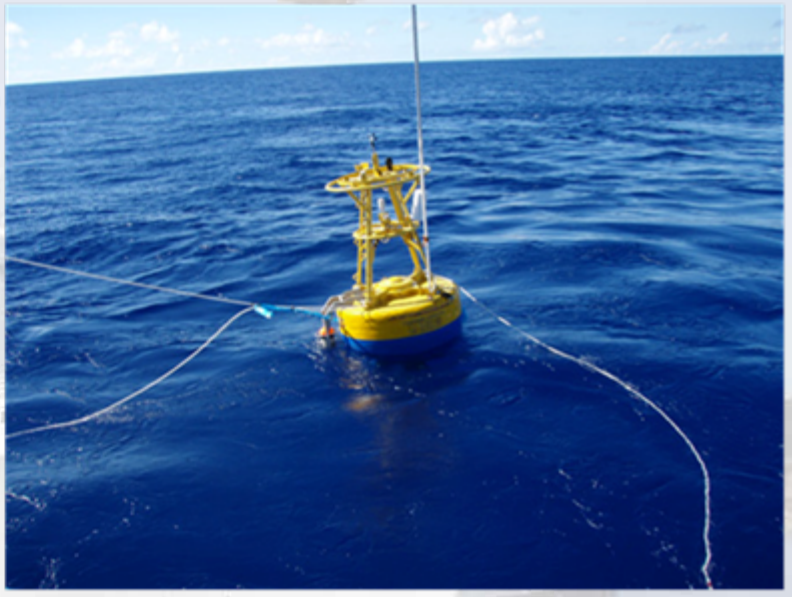
Waterproof battery

First trial in the equatorial Pacific

Mooring in the equatorial Pacific

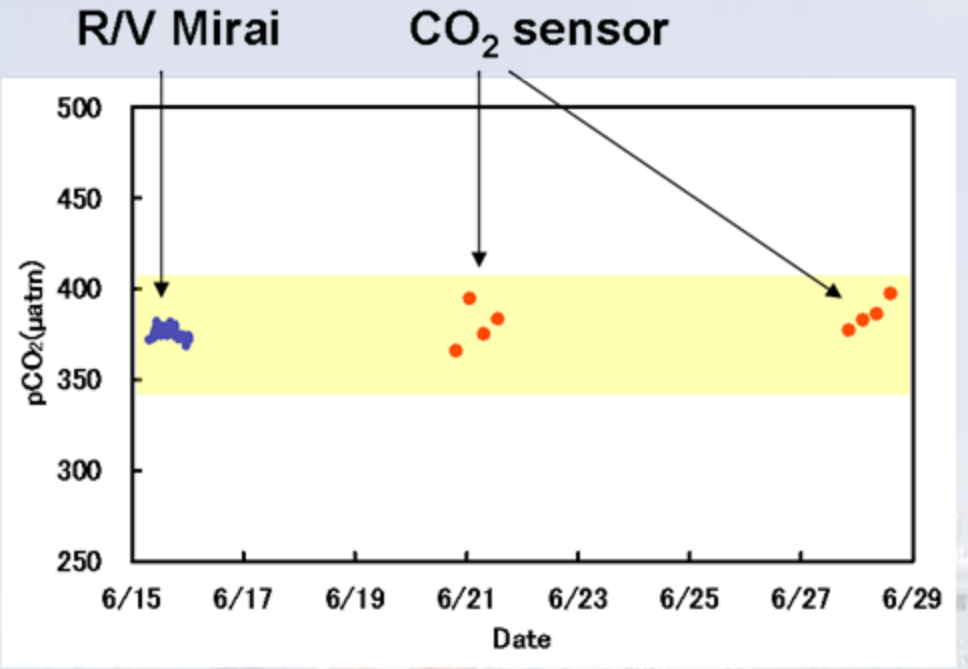
- We attached the CO_2 sensor to TRITON buoy.
- TRITON buoy was moored at 2º N,156º E in June, 2007 (Recovery: July, 2008)
- CO_2 sensor started the observation after 1 week from mooring.





First trial in the equatorial Pacific

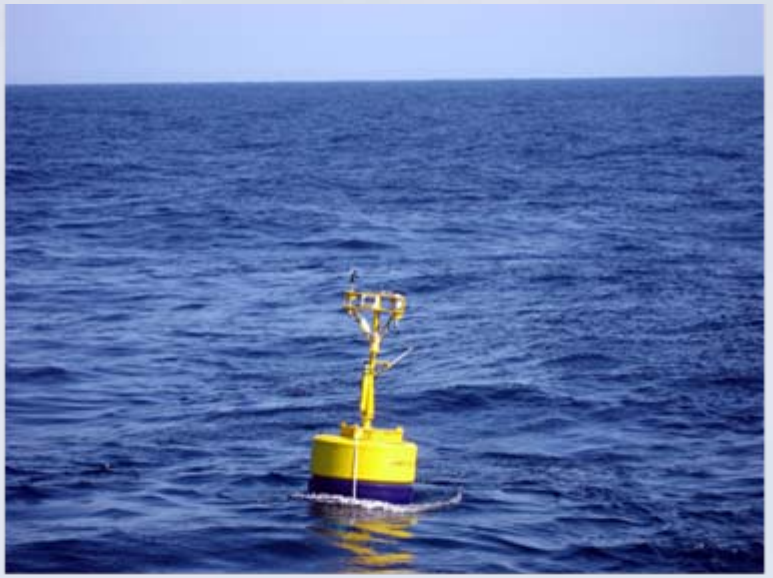
Result



Yellow band represents the distribution range of pCO_2 around mooring point (0-5N, 152-160E) since 1968.

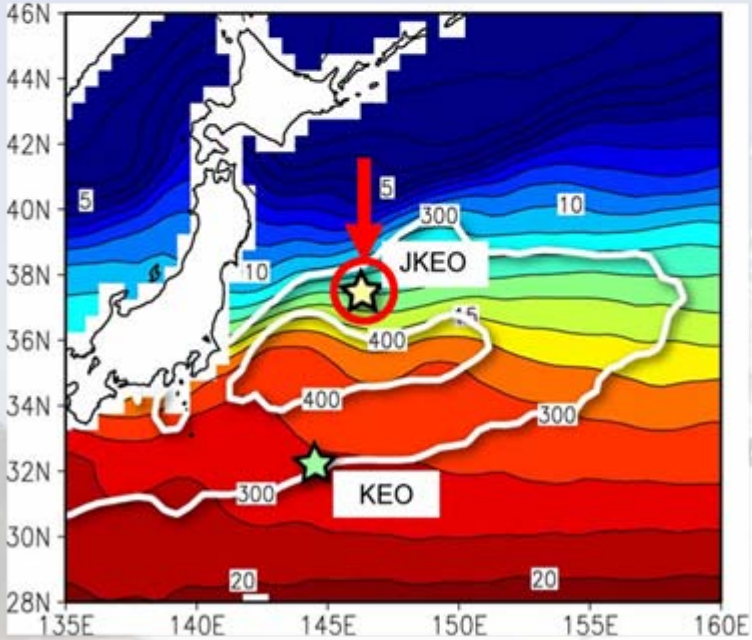
Improved CO_2 sensor

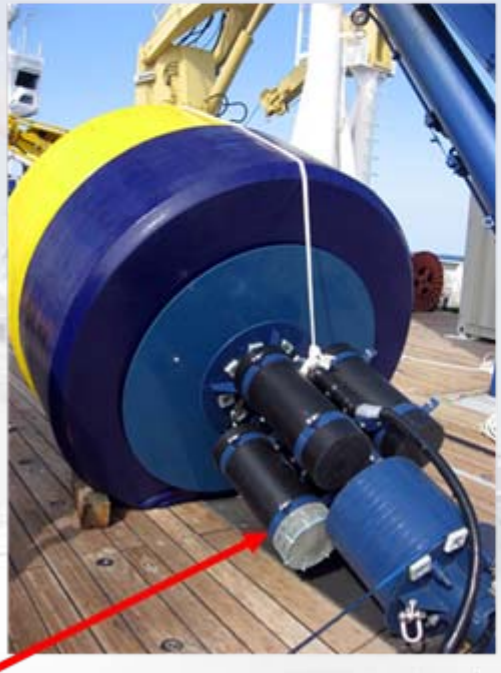
Mooring in the Kuroshio extension



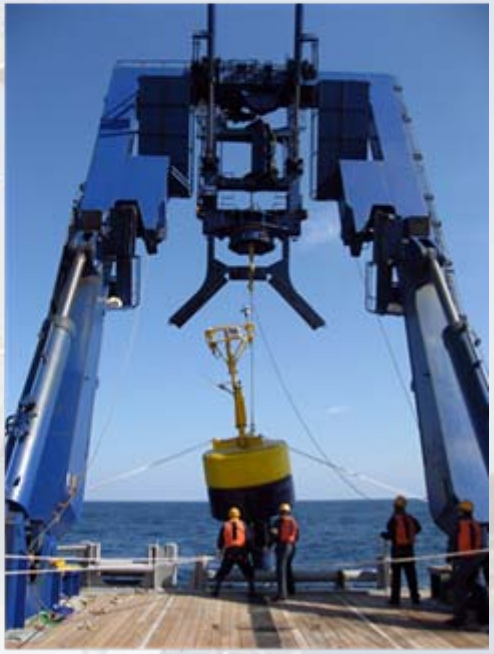
Operation

JKEO site
(38.0N, 146.5E)
Mar, 2008 -





pCO_2 sensor



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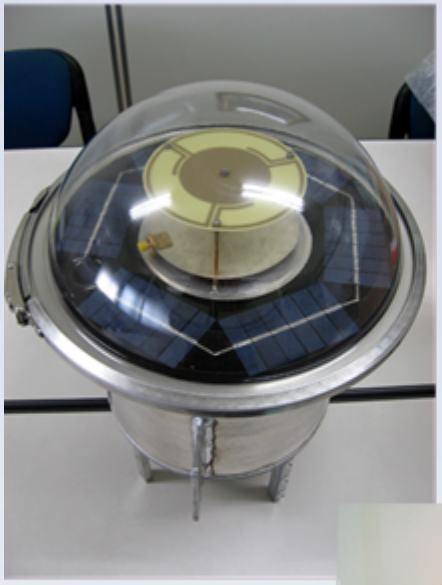
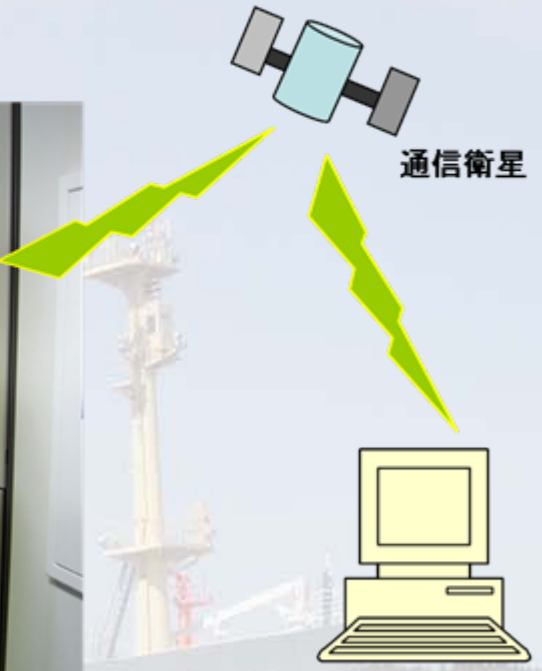




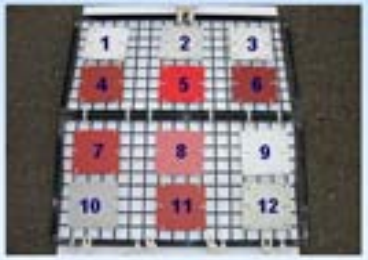
JEPP autonomous buoy for surface CO2 measurement

Micro pump

Inside view

ARGOS Communication system

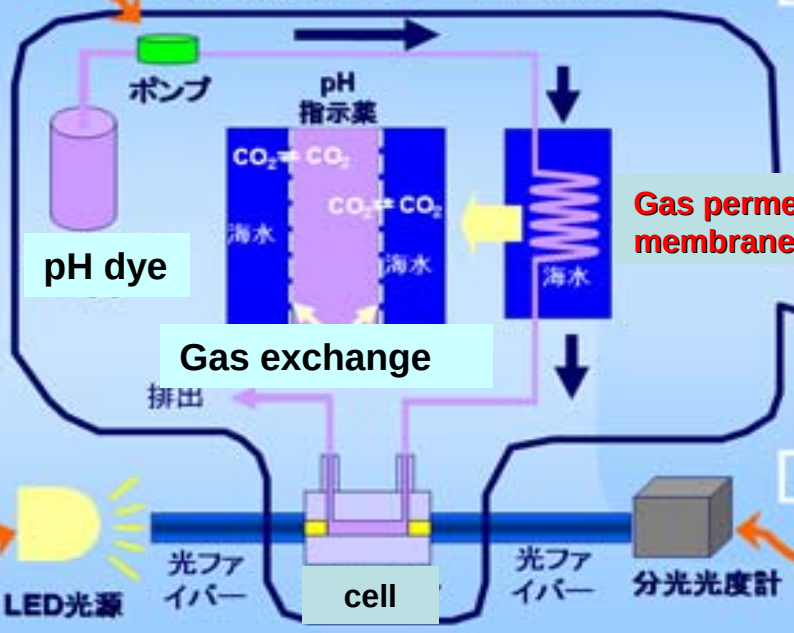
Anti-biofouling



180 days

Anti-biofouling

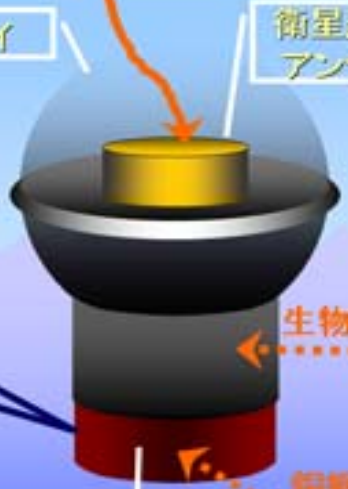
二酸化炭素センサー測定原理図



pH dye

Gas exchange

Gas permeable membrane

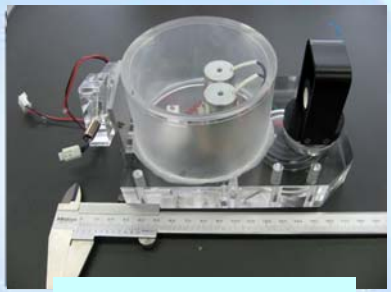


Anti-biofouling

LED light source

Li buttery

Spectrometer



Sensor unit