The 2nd GEOSS AP Symposium
15 Apr 2008, Tokyo

Decadal and Longer-term changes of the CO_2 in the ocean

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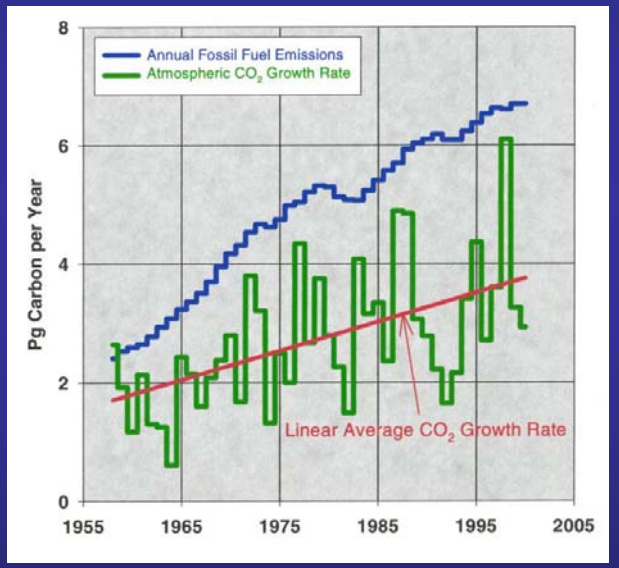
Background

- Strong air-sea interaction
- Distribution of bomb-C14 in the ocean
- Ocean is considered as a major sink for the anthropogenic CO_2.



- Little is "quantitatively" known about the variability in the oceanic CO_2 and its controlling processes.
- Understanding the ocean's role in regulating the atmospheric CO_2 concentration and its long-term changes is one of the key issues in predicting the future atmospheric CO_2 concentration.

- Ocean has been acidified due to anthropogenic CO_2 (carbonic acid) increase in the ocean
- Its status and impact (damage) on the marine ecosystem should be urgently investigated .

Contents

A brief review of international efforts on the observations of …

1. Partial pressure of CO_2 in surface seawater (pCO_2^{sw})

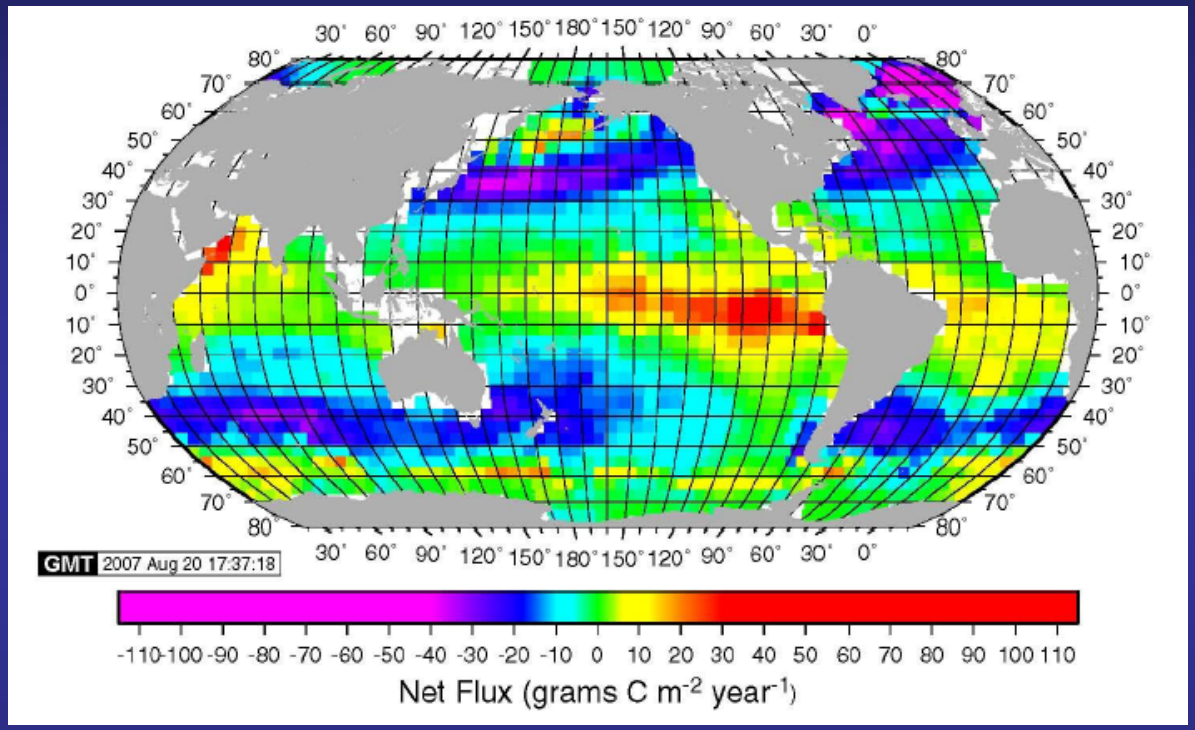
- ➢ Data synthesis
  - Climatological view
  - Interannual variability
  - Long-term trend
- ➢ On-going repeat observations

2. Dissolved inorganic carbon (DIC or TCO_2) in the water columns

- ➢ Data synthesis
  - Anthropogenic CO_2
  - Decadal trend
- ➢ On-going repeat observations
  - Implementation plan for the PICES CO_2 data synthesis

Climatological air-sea CO_2 flux

From 3 million pCO_2 data from 1970 to 2006



Air-sea CO_2 Flux

$= k K_0 (pCO_2sw - pCO_2air)$

K : CO_2 transfer piston velocity

K_0 : CO_2 solubility in seawater

Mean annual air-sea CO_2

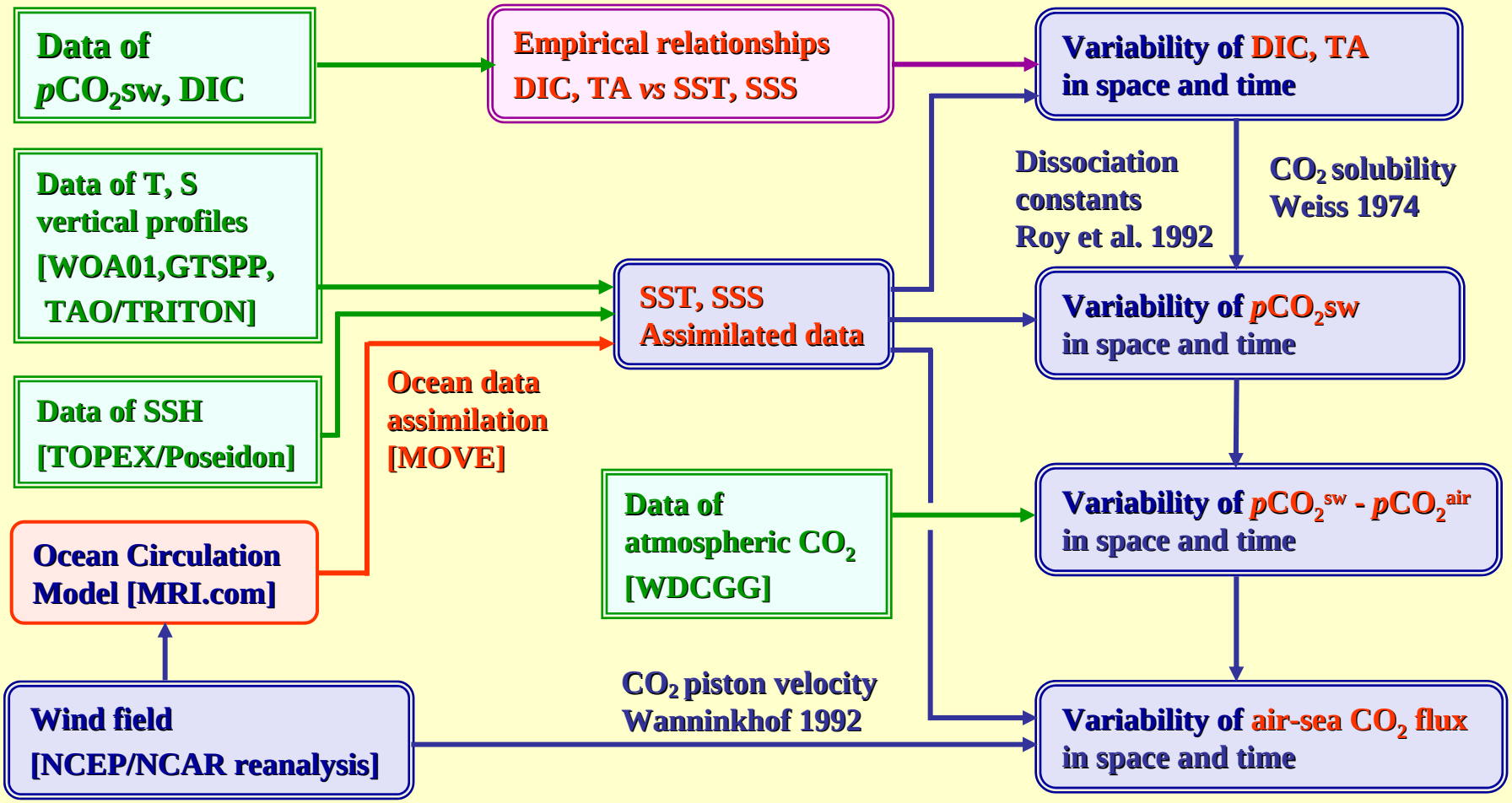
$= -1.4 \pm 0.7$ PgC yr^{-1}

Takahashi et al. submitted

Usefulness :
- ✓ Understanding ocean carbon cycle processes
- ✓ Validating prognostic ocean carbon cycle models
- ✓ Constraining atmospheric CO_2 inversions

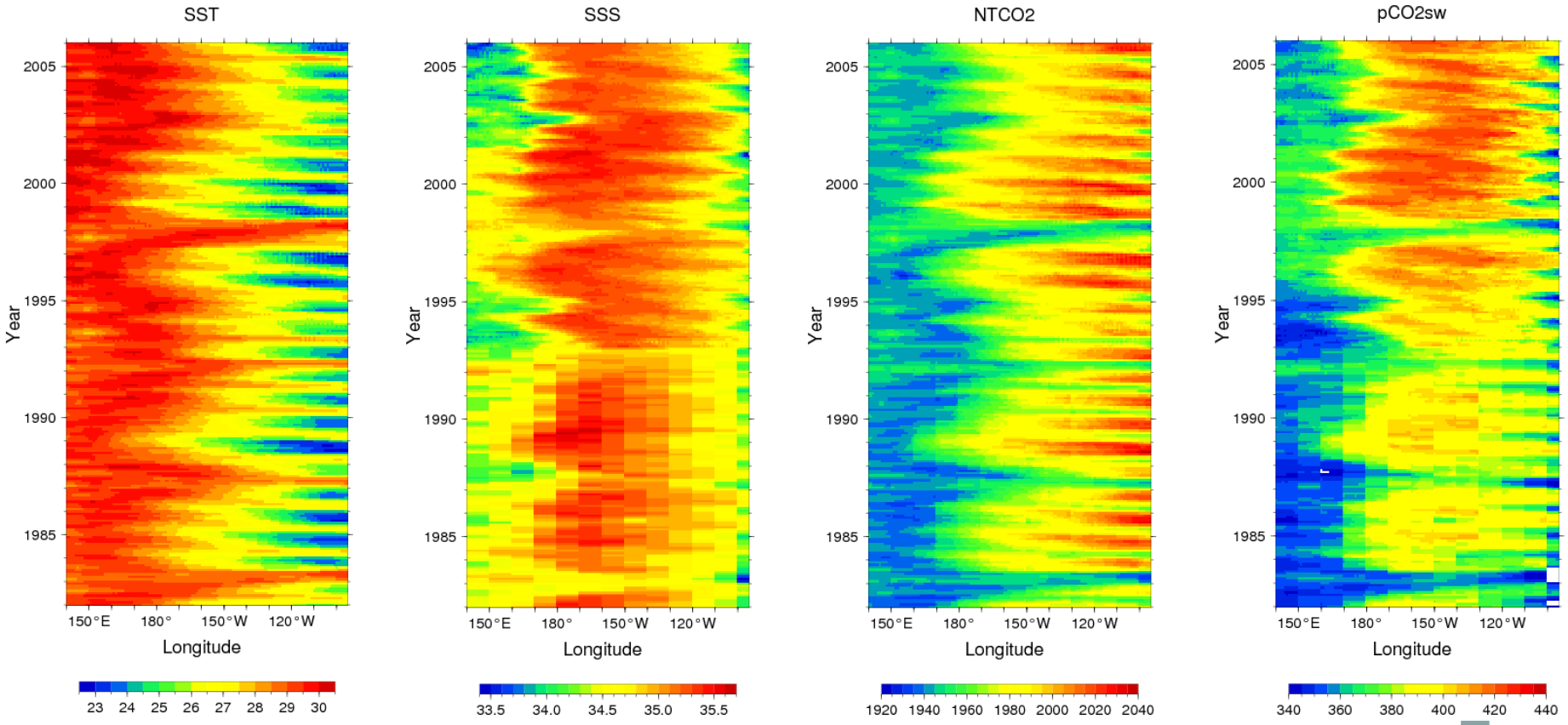
Problems :
- ✓ Uncertainty in the piston velocity
- ✓ Undersampling in space and time

An empirical method to estimate the variability in space and time



Time (1983-2006) - longitude (140°E - 95°W) distributions in the equatorial Pacific (mean of 5°N - 5°S)

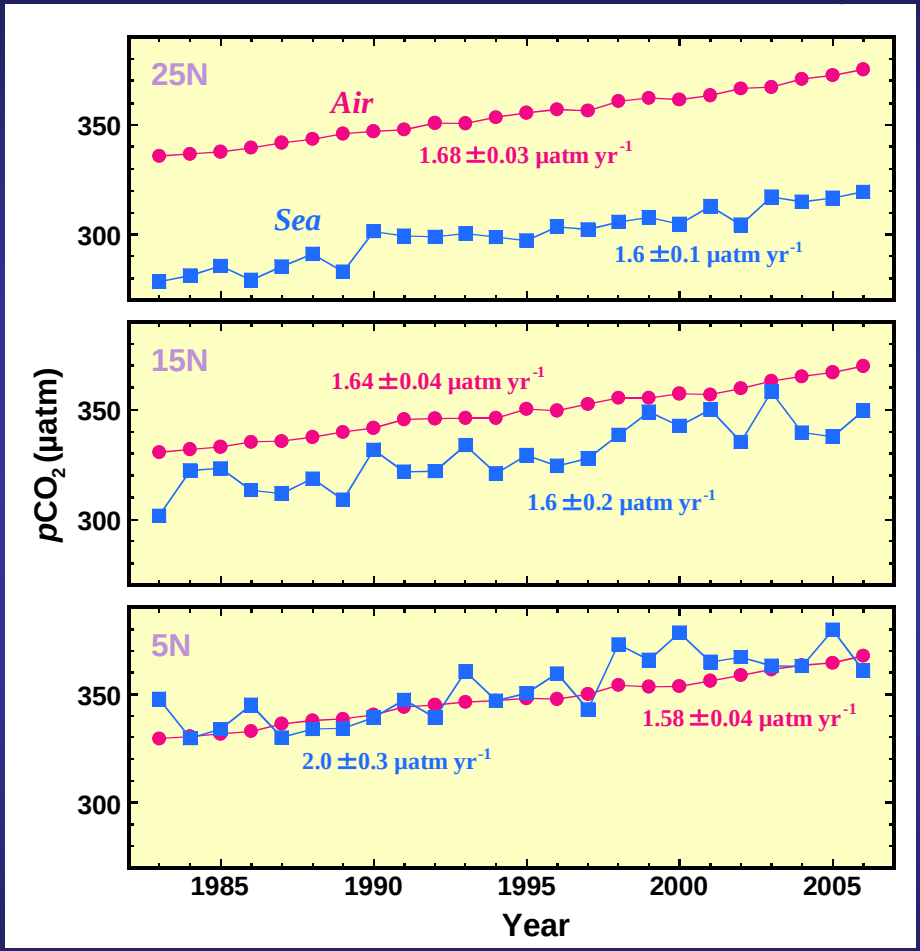
SST → SSS → $NTCO_2$ → pCO_2sw



+0.4—+0.6 PgC / yr

Long-term trend of pCO_2sw in the subtropical zone

137° E line

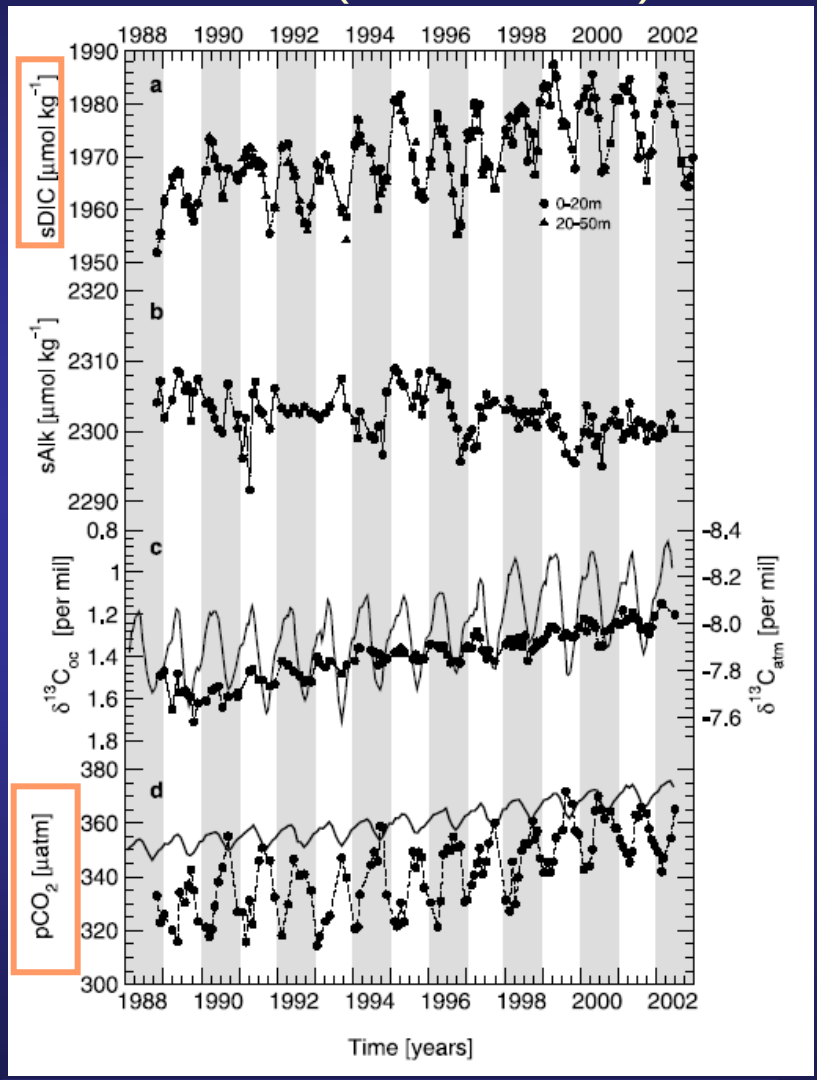


Observation have been made every late January since early 1980s.

Inoue et al., *Tellus,* 1995..

Midorikawa et al., *Geophys. Res. Lett.,* 2005.

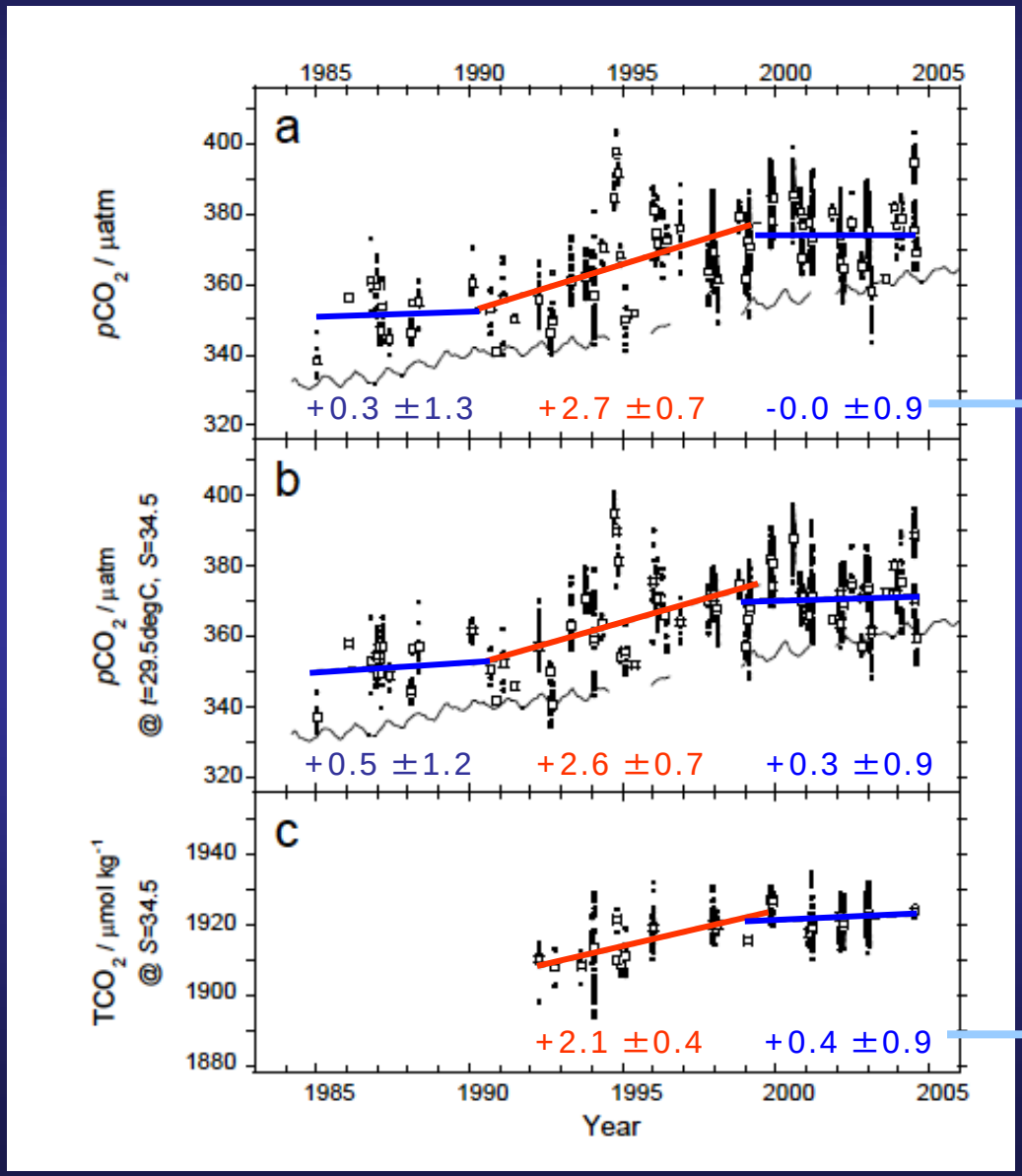
ALOHA (near Hawaii)



Dore et al., *Nature,* 2003.

Keeling et al., *Global Biogeochem. Cycles,* 2004.

Long-term trend of pCO_2sw in the western equatorial Pacific warm pool



Salinity ≤ 34.8,
SST ≥ 29.0 ºC
$\sigma_t \geq 21.4$

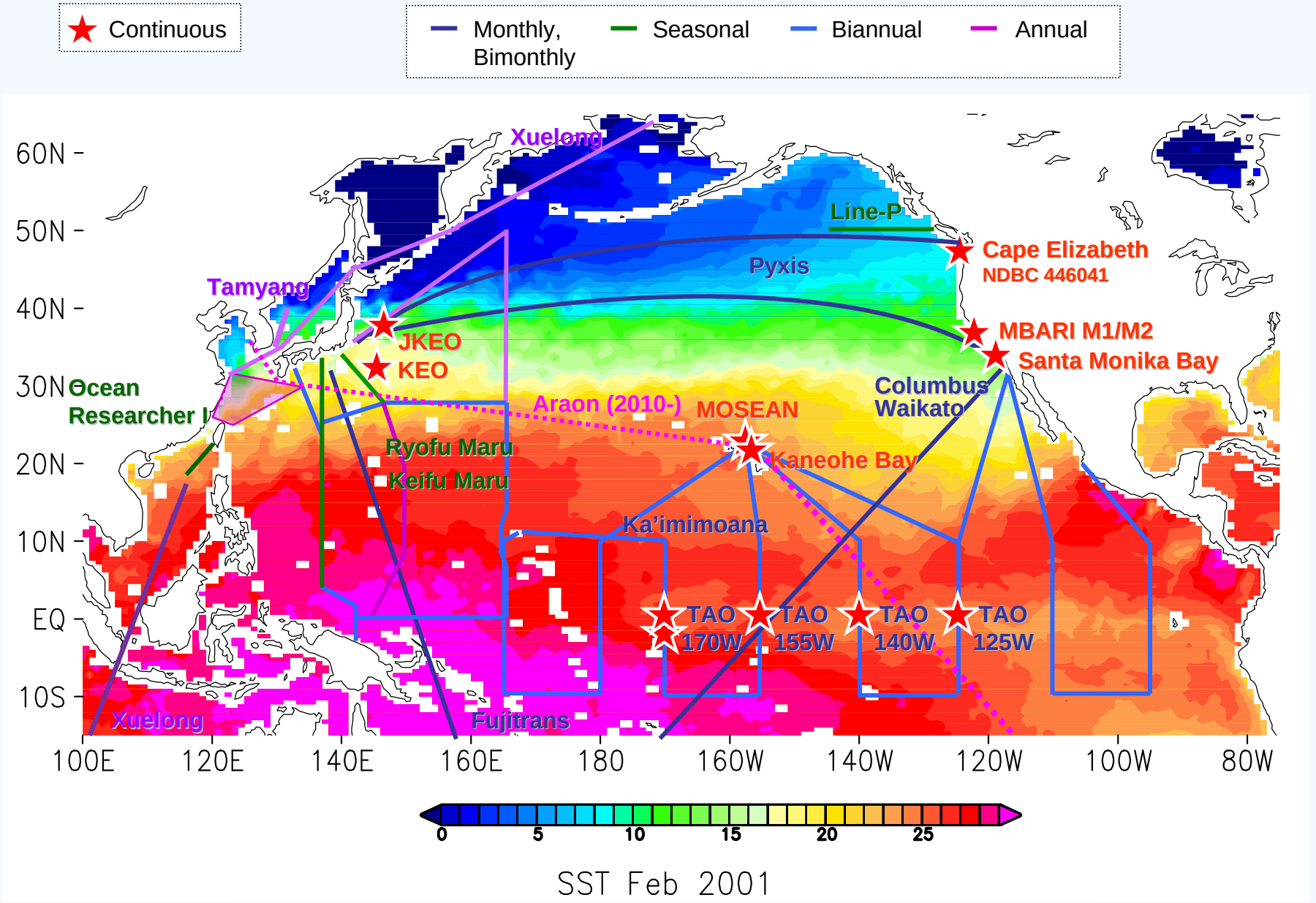
→ Increasing rate / µatm yr^{-1}

pCO_2sw is increasing, but it is likely that the increase rate is changing in decadal time-scale.

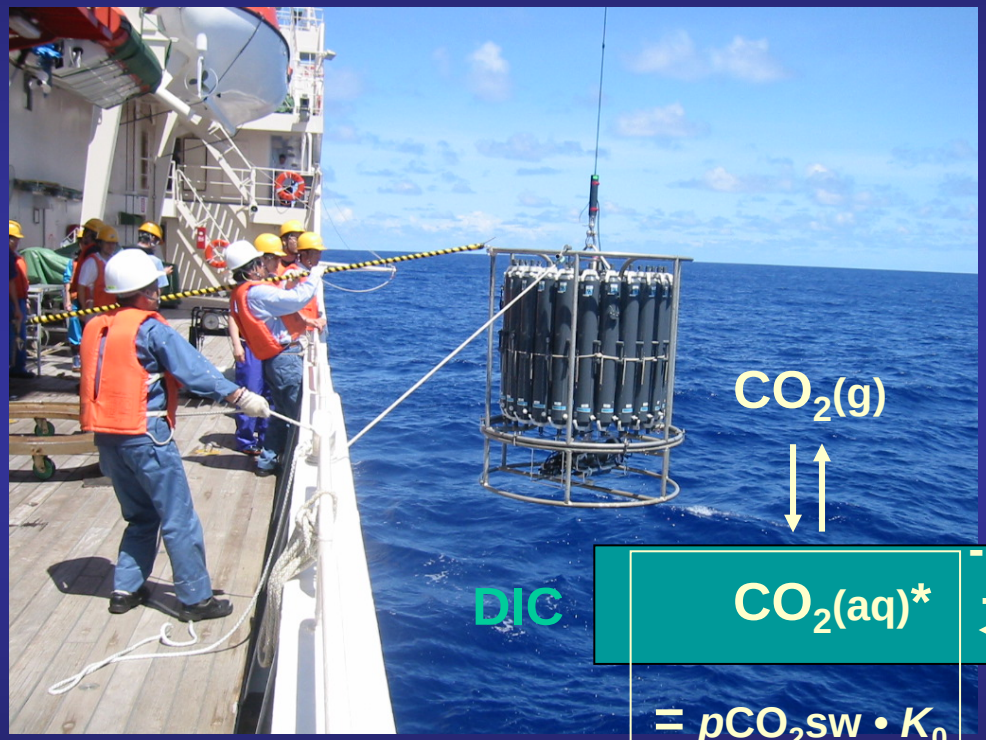
→ Increasing rate / µmol kg^{-1} yr^{-1}

Ishii et al. submitted

Moorings and underway observations for near-surface water CO_2



Dissolved Inorganic Carbon (DIC) at depths



$CO_2(g)$

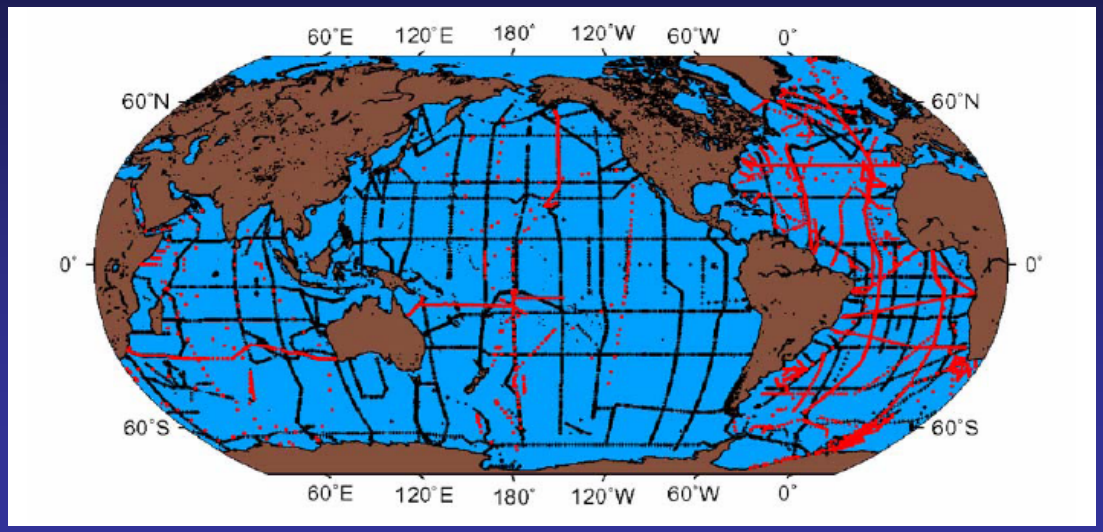
DIC

$CO_2(aq)^*$ $\rightleftharpoons$ $HCO_3^-(aq)$ $\rightleftharpoons$ $CO_3^{2-}(aq)$

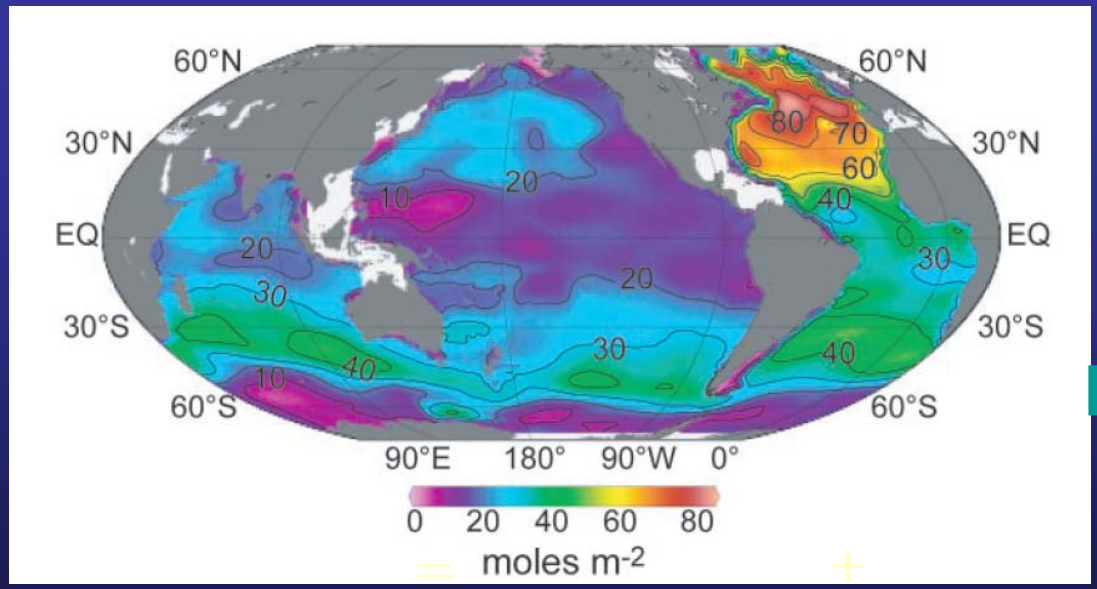
$- H^+(aq)$ $- H^+(aq)$

$= pCO_2sw \bullet K_0$

Global CO_2 Survey in the 1990s : a benchmark



~72,000 sample locations collected in the 1990s with precisions of
± 2 µmol kg^{-1} for DIC (± 2/2000)
± 4 µmol kg^{-1} for TA (± 4/2200)



Emissions from fossil fuel and cement production
244 ± 20 PgC (1800 - 1994)

Storage in the atmosphere
165 ± 4 PgC

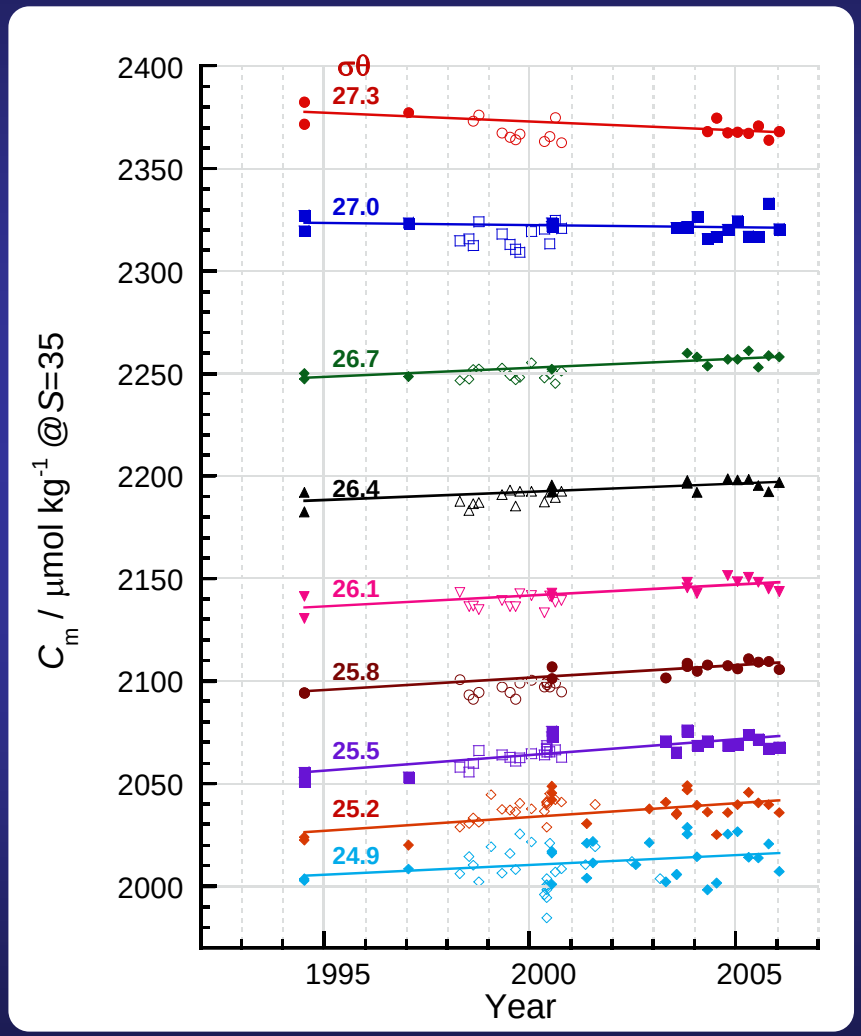
Uptake and storage in the ocean
118 ± 19 PgC

Net terrestrial balance
-39 ± 28 PgC

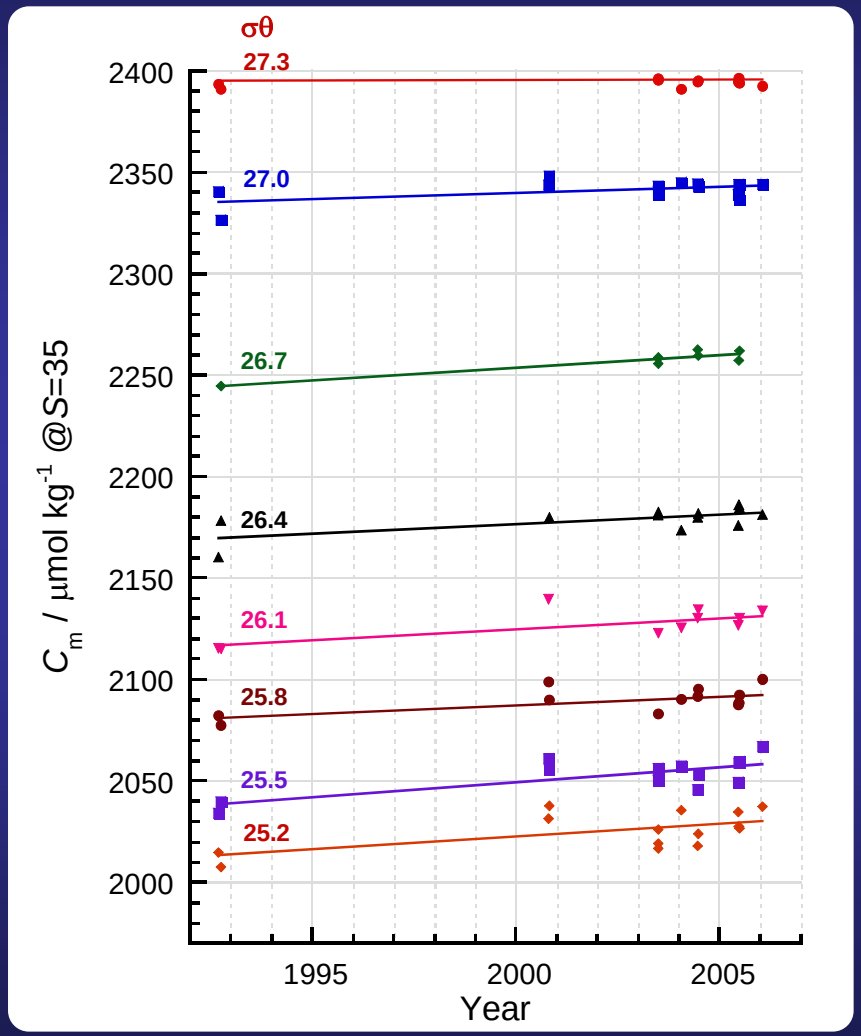
Sabine et al. 2004

Trend of DIC on Isopycnal Surfaces

137°E, 27.5°- 31.5°N & **135.25°E,** 29.5°N

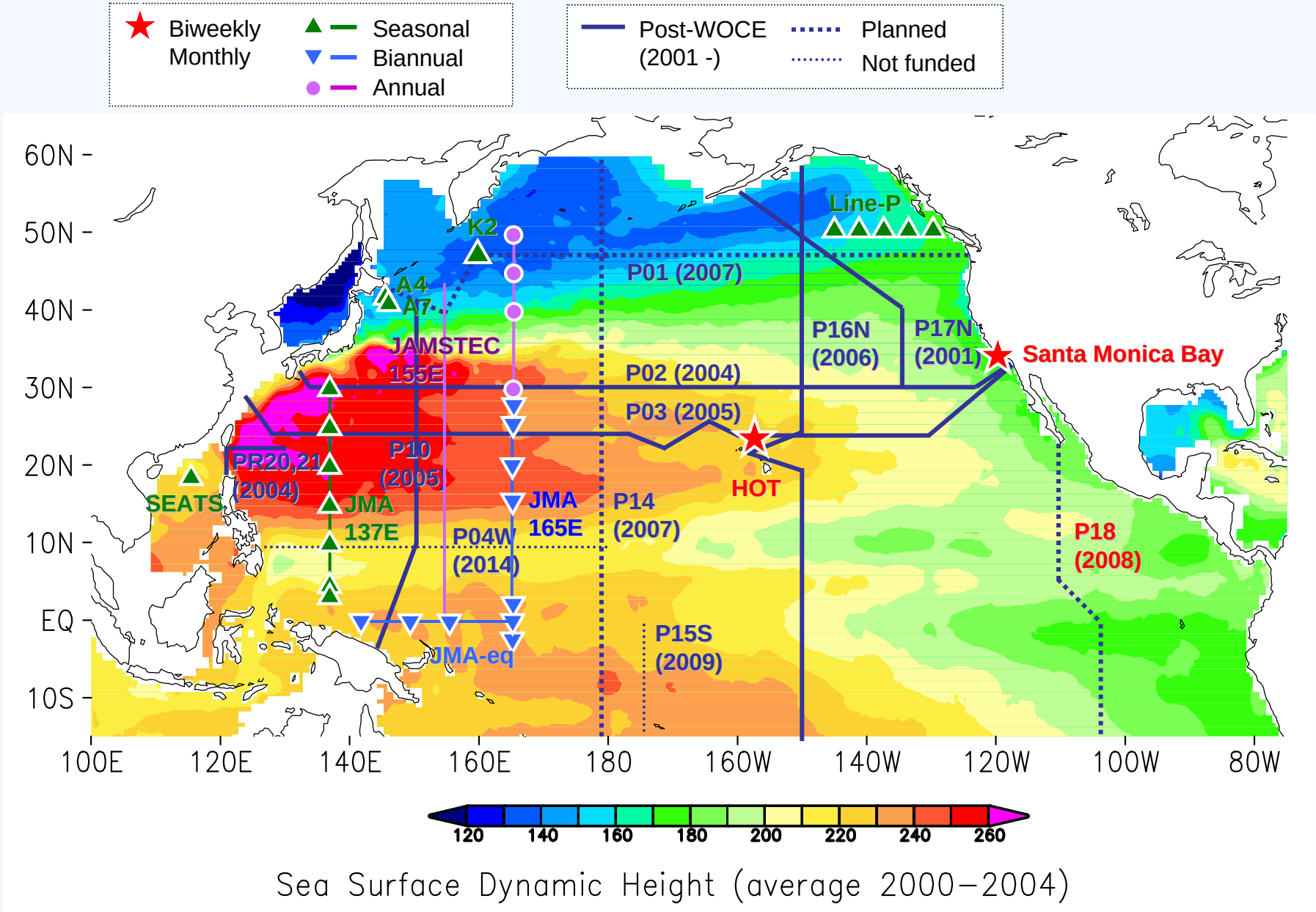


165°E, 28°- 30°N,

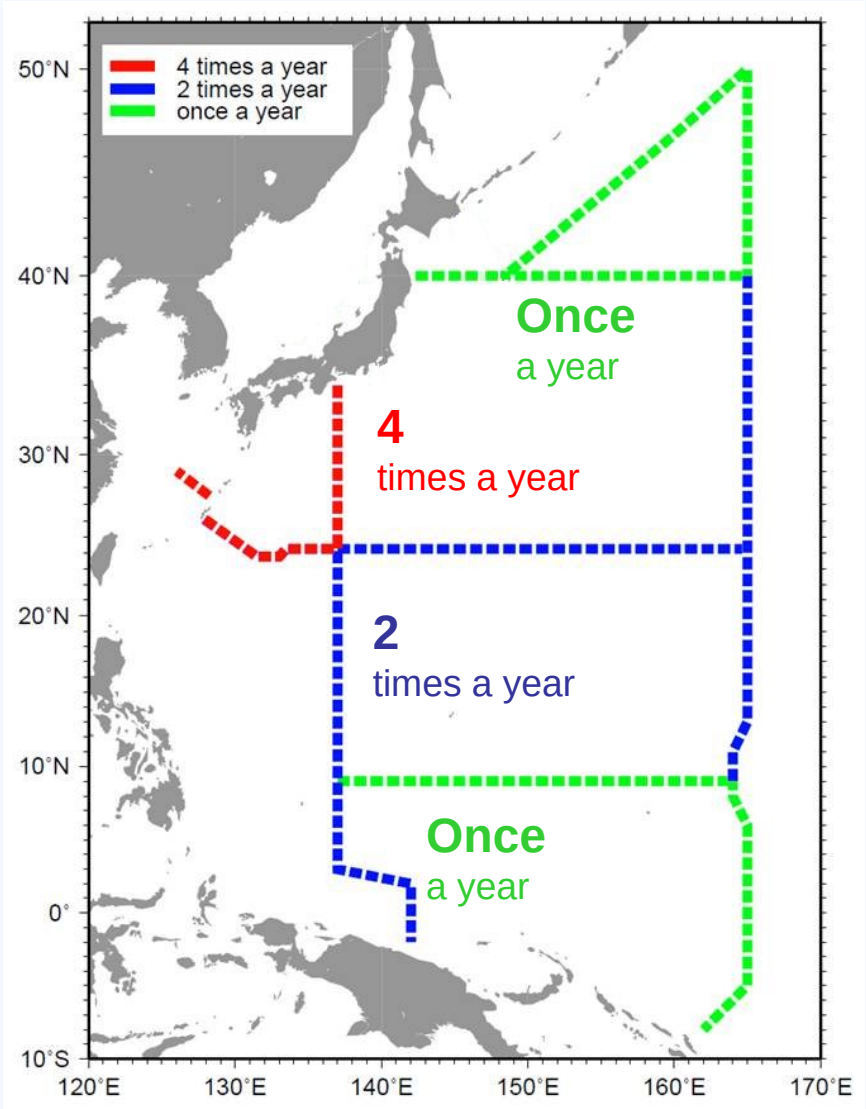


At both sites, significant increasing trends of DIC have been observed at $24.9 \leqq \sigma_\theta \leqq 26.8$

Time-series stations and repeat lines for water column CO_2



Japan Meteorological Agency's plan after FY2010 (not funded)



Parameters	Target
Temp. Salinity Oxygen Nutrients pCO_2 DIC TA pH CFCs Chlorophyl	Ocean warming Calibration of Argo pCO_2 variability CO_2 accumulation Ocean acidification

Every time, to the depth of 2000m, 60 mile intervals.

But once every 5 years, to the bottom, 30(15) mile intervals.

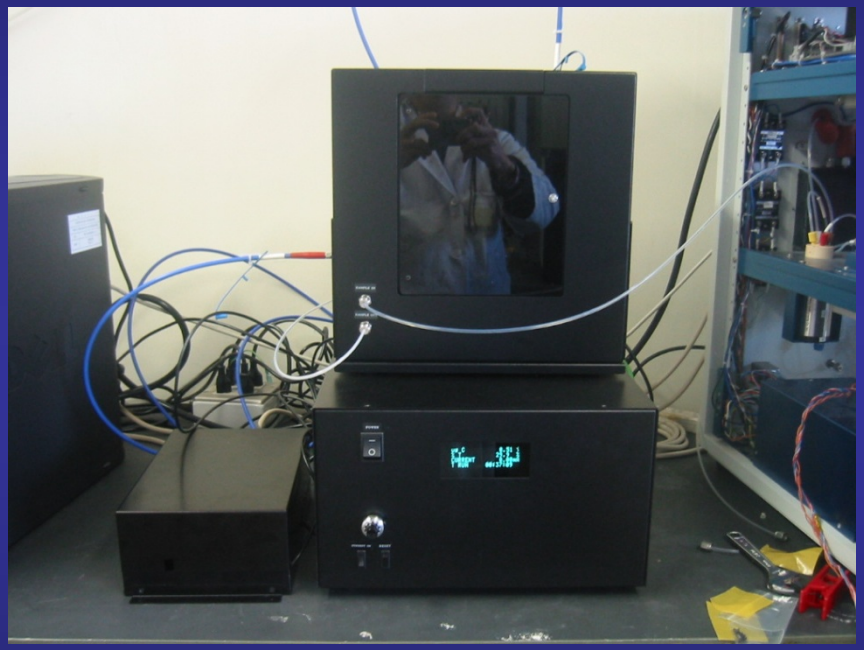
Development of a new high-precision DIC/TA analyzer in seawater

M. Ishii, S. Saito, T. Midorikawa
Meteorological Research Institute **(MRI)**

A. Murata
Japan Agency for Marine-Earth Science and Technology **(JAMSTEC)**

T. Uji
Advanced Earth Science & Technology Organization **(AESTO)**

funded by
Ministry of Education, Culture, Sports, Science and Technology
(FY 2005 -2007)



New high-performance coulometer with dual-beam optical fiber connection (repeatability ± 0.03%)

to contribute to a 10-year implementation plan for **GEOSS**

Water column CO_2 data synthesis in the Pacific Ocean is now underway

- **Planned** as an activity of

  "The North Pacific Marine Science Organization, Carbon and Climate Section (PICES CC-S)"

  Co-chair : T. Saino (JAMSTEC) and J. Christian (Victoria U.)
  Working group: R. Feely (PMEL), M. Ishii (MRI), A. Kozyr (CDIAC), A. Murata (JAMSTEC), C. Sabine (PMEL), T. Suzuki (MIRC), N. Tsurushima (AIST)

- **Overall goals:**
  - Create a quality controlled data base of water column CO_2 related data for the Pacific.
  - Estimate anthropogenic CO_2 and natural variability in the Pacific from regional to basin scales.

- **Data submission deadline :** January 2009.

- **Implementation plan**
  http://www.pices.int/members/sections/CC.aspx

Thank you