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Trend of Ocean Acidification for the past three decades in the western North Pacific Subtropical zone and in the western equatorial Pacific warm pool

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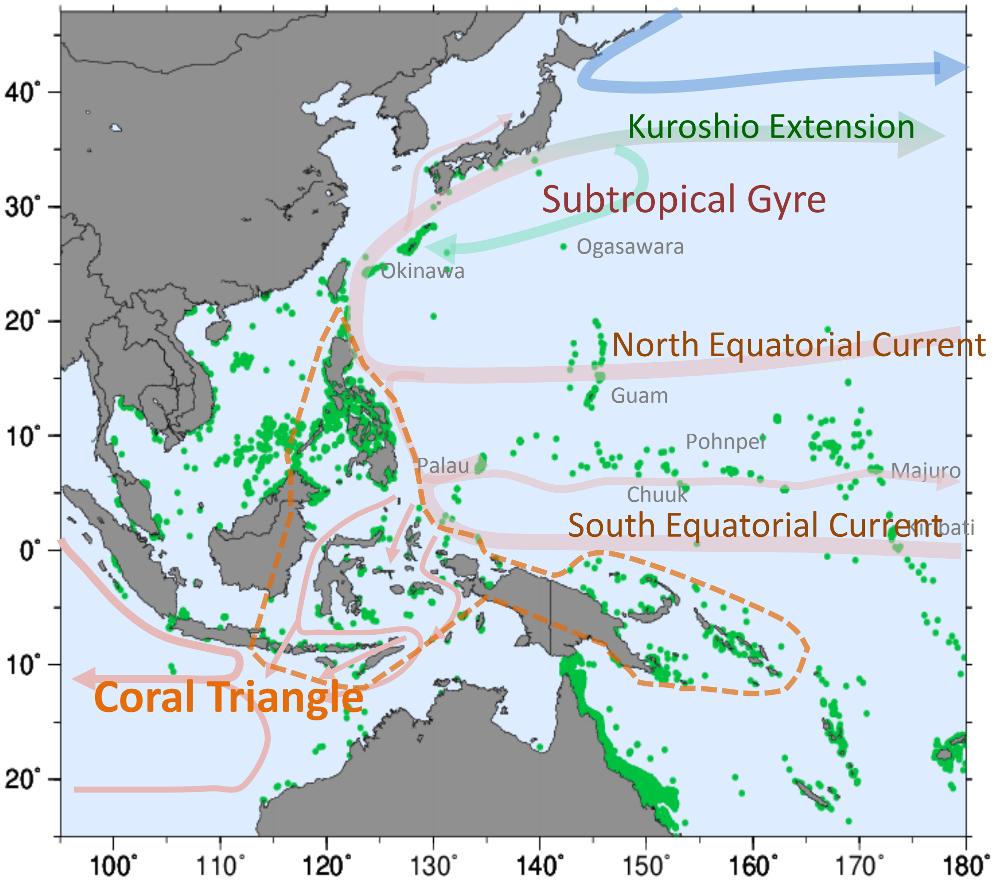
Subtropics and tropics of the western North Pacific



▪ **Coral reef habitats**

– Accommodating many coral reef habitats and marine biodiversity hotspots,

e.g., 75% of the world's coral species and more than 3000 species of fish.

Photo by WWF

“Is ocean acidification in fact occurring in the western North Pacific?”

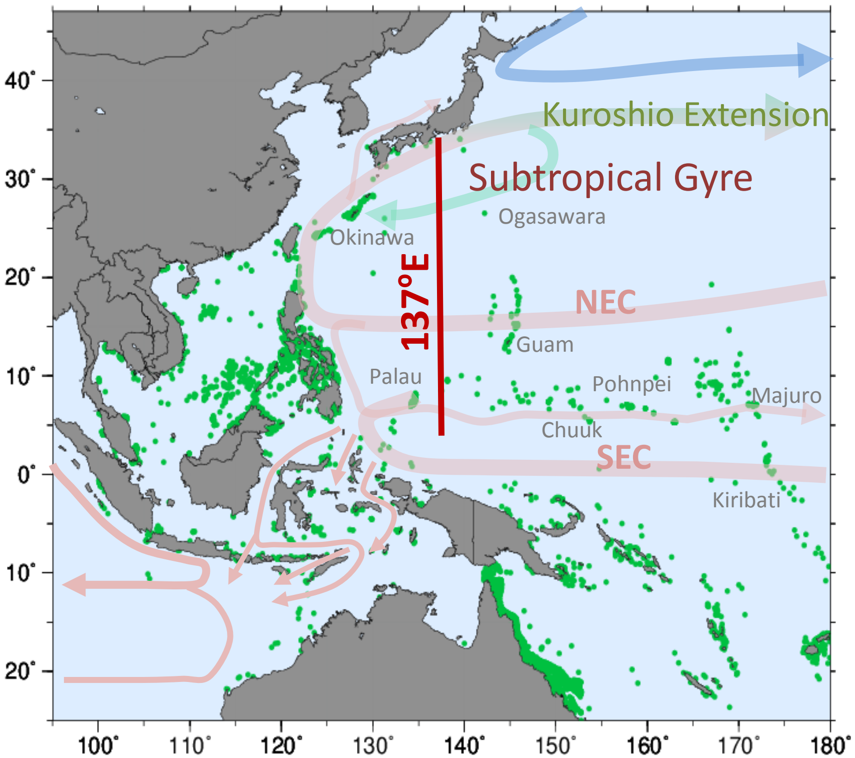
Contents

Trends of ocean acidification in surface layers for the past decades in :

(1) 137^{o}E repeat line between Japan and Indonesia (3^{o}N – 34^{o}N) across subtropical and tropical zones.

(2) Western equatorial Pacific warm pool (130^{o}E – 180^o, 5^{o}S – 5^{o}N).

137°E Repeat Line by Japan Meteorological Agency (JMA)



Repeat measurements at 137°E

1967 – *T*emp., *S*alinity, oxygen and nutrients.

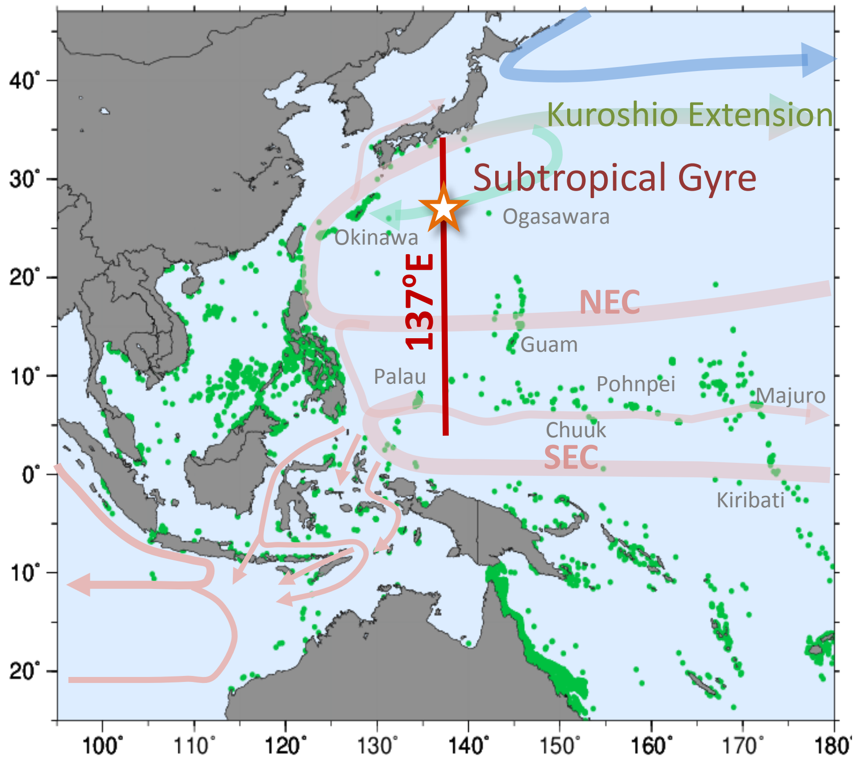
1983 – Partial pressure of CO_2 in surface water (pCO_2^{sw}) and in the atmosphere (pCO_2^{air}) .

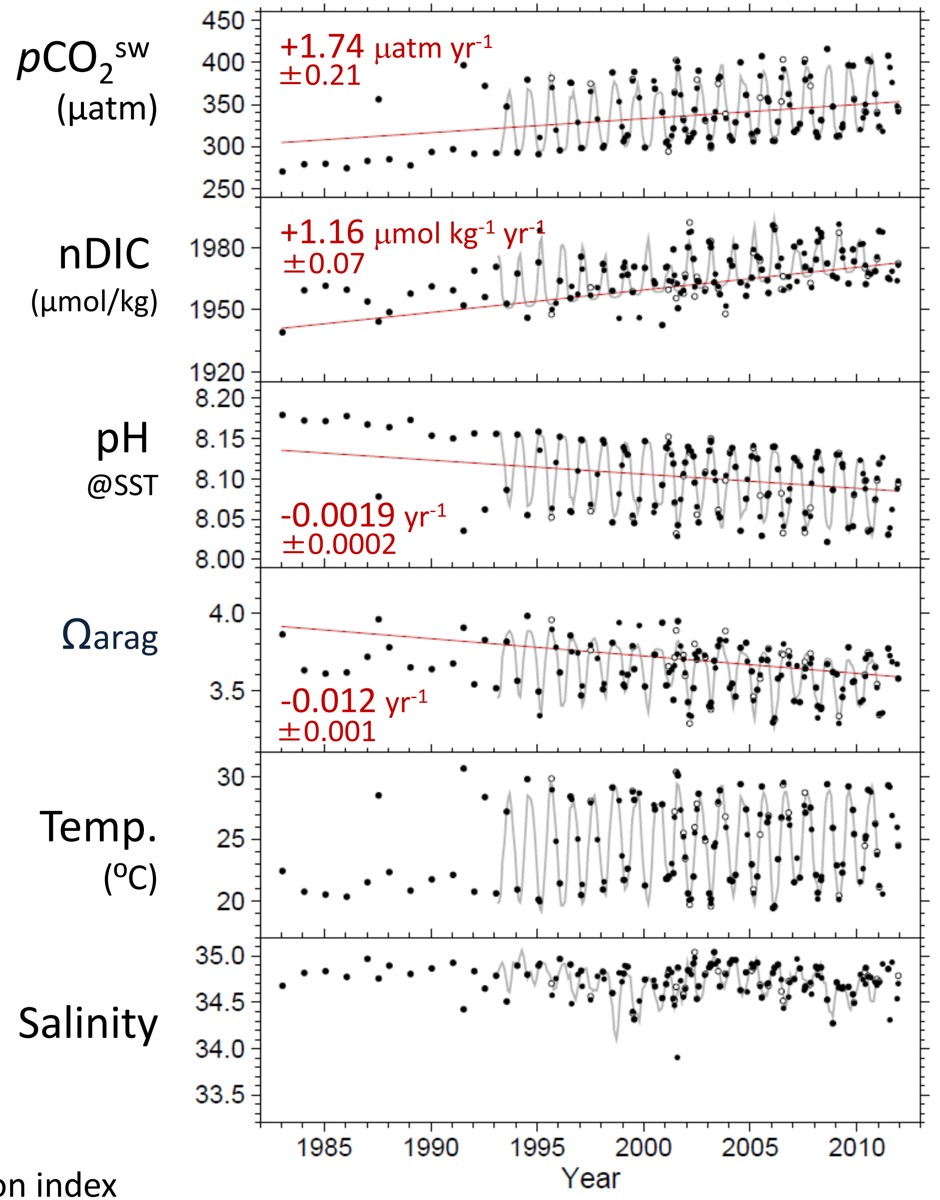
1994 – total dissolved inorganic carbon (DIC) at depths.

2010 – total alkalinity (TA) and pH at depths

- Saturation level of CO_2 in surface water
  > sea-air CO_2 flux
- DIC increase in surface water and in the ocean interior
  > Anthropogenic CO_2 accumulation and carbon cycle / ocean circulation changes
  > Ocean acidification

Trends in the surface of the subtropics at 137ºE, 27ºN

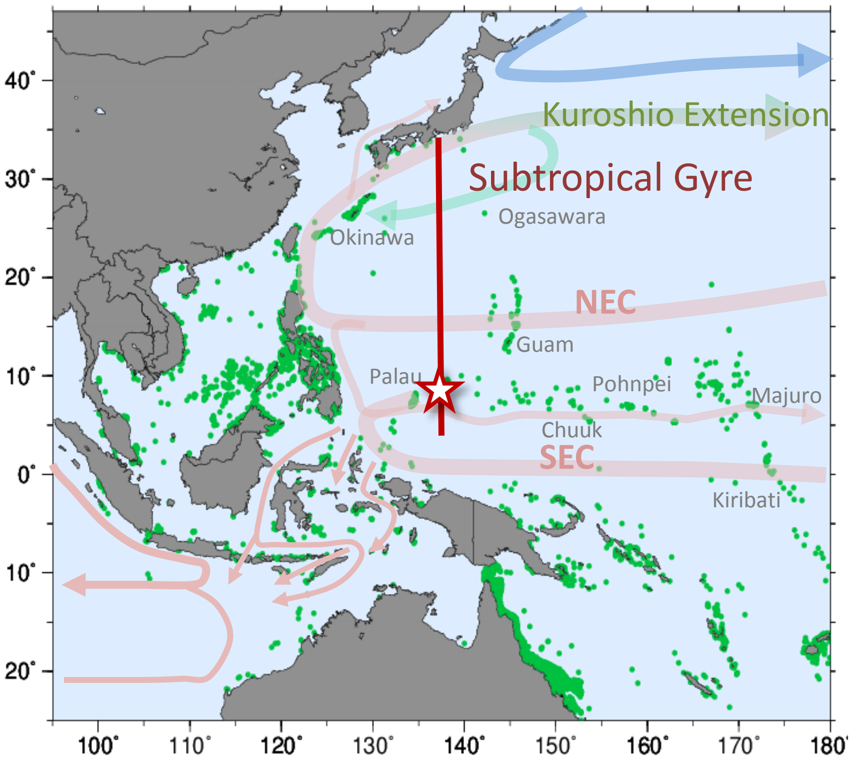


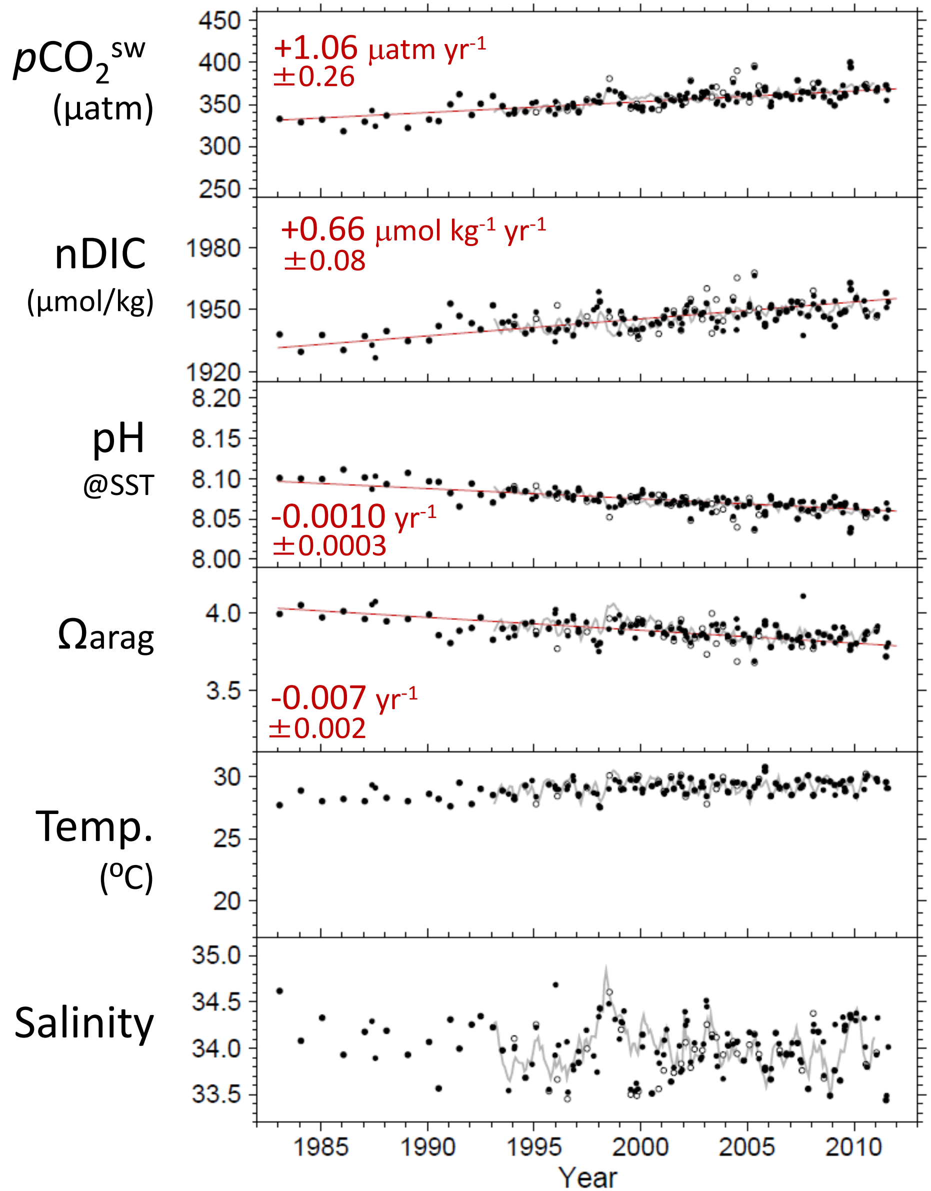


- Despite large seasonal and year-to-year variations, trends of CO_2 increase and acidification are significant.

Ωarag : Calcium carbonate mineral "aragonite" saturation index

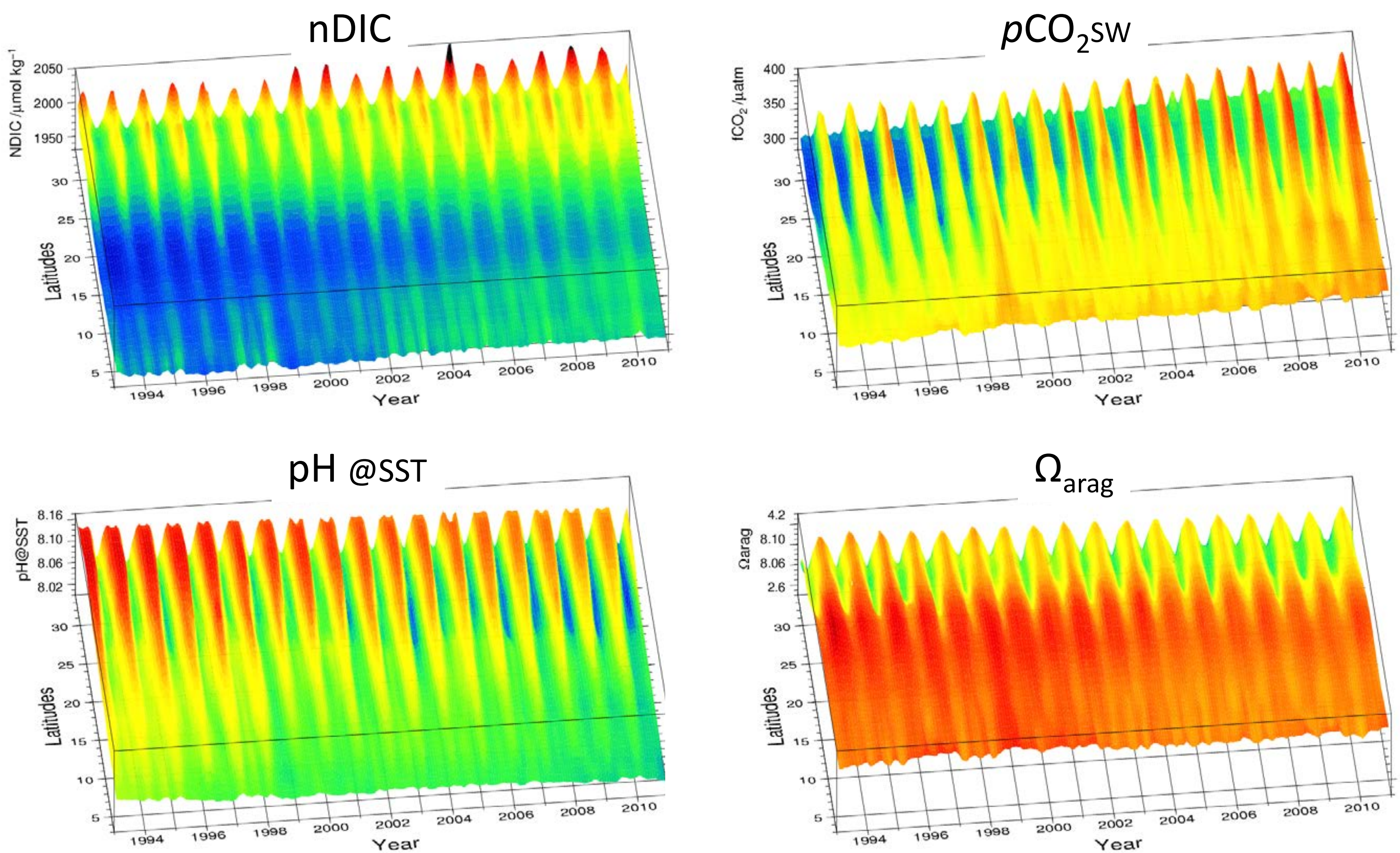
Trends in the surface of the tropics at 137ºE, 7ºN





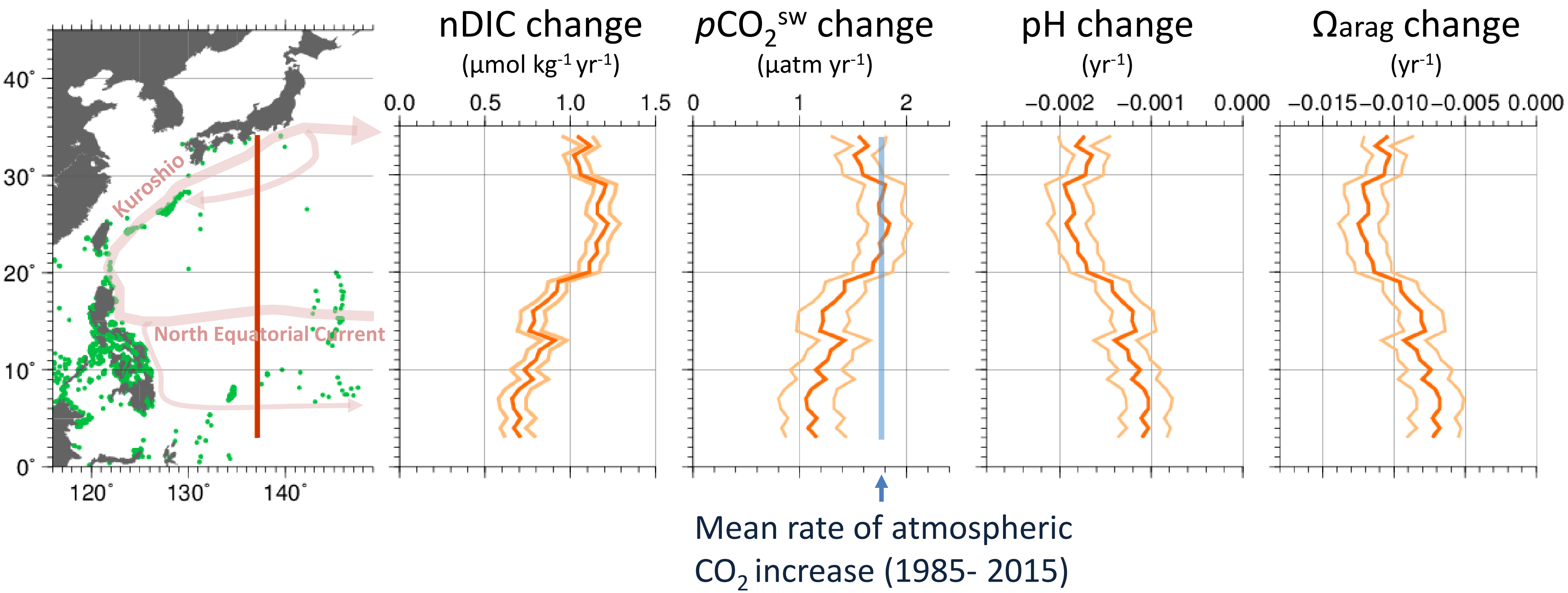
- Trends of CO_2 increase and acidification are clear, but their rates of change are lower than in the subtropics and than the rates under the condition of air-sea CO_2 equilibrium.

3-D view of nDIC, pCO$_2$sw, pH@SST, and Ωarag at 137ºE, 3ºN - 34ºN



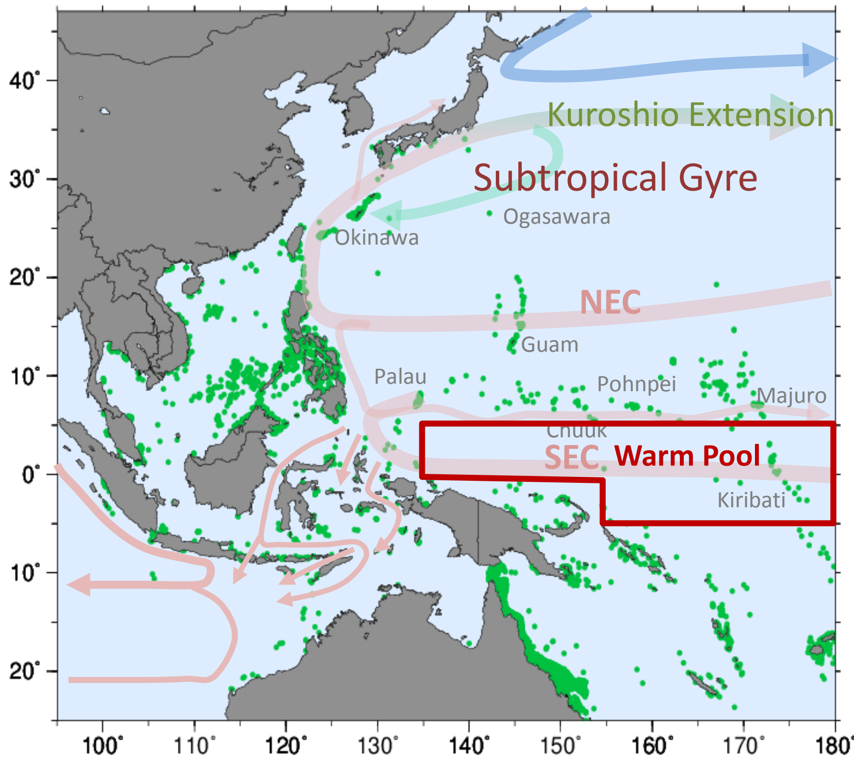
- Large seasonal variation in the northern subtropics under nitrate depletion.
- Large meridional gradient at around 20ºN.
- Long-term changes with significantly different rates between subtropics and tropics.

Meridional distributions of the linear rate of ocean CO_2 increase and acidification at 137°E



- Rates of DIC increase and acidification are consistent with those expected from the rate of atmospheric CO_2 increase in the subtropics (20°N-34°N), but are lower in the tropics (3°N-19°N).
- From the biogeochemical point of view, marine ecosystems in the subtropics are more threatened by the ocean acidification.

Oceanic CO_2 measurements in the western equatorial Pacific



- Here, we define the "warm pool" as the region where t>28.7°C, S<34.6 in the western equatorial Pacific.

1987 –2003; MRI-JAMSTEC collaborative studies on ocean CO_2 in the western equatorial Pacific.

R/V Natsushima *R/V Kaiyo* *R/V Mirai*

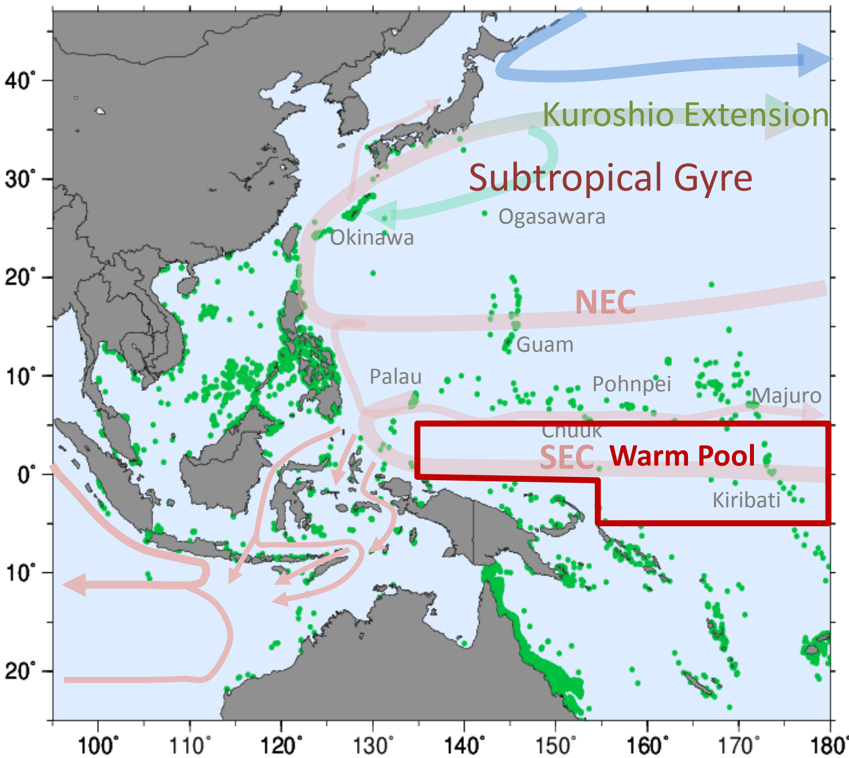
1996 – JMA's repeat line at 165E.

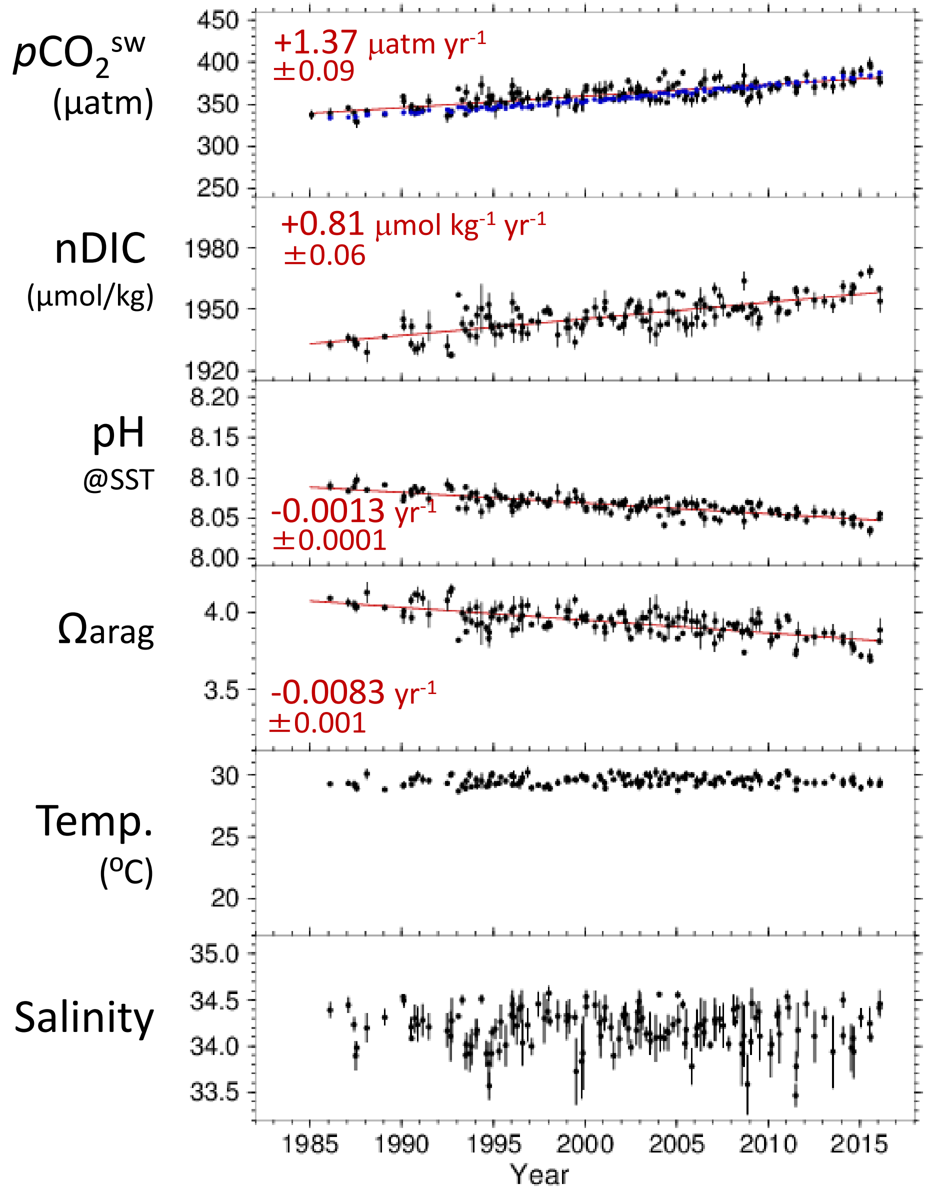
and many others cruises by Japan, USA and France. Data of $p$$CO_2$sw taken in these cruises have been stored in

"Surface Ocean CO_2 Atlas"

The $p$$CO_2$sw measurements in the equatorial Pacific have originally been made in order to understand the variability in sea-air CO_2 flux associated with El Nino Southern Oscillation.

Trends in the warm pool





- Rate of CO_2 increase and acidification in the warm pool are also slower than the rates expected under the conditions of air-sea CO_2 equilibrium.
- Why slower?

Why ocean acidification is slower in the warm pool?

1) Excess CO_2 uptake in the surface of the vast extratropics

2) Subduction into the ocean interior

10 ~ 15 years

3) Equatorial Undercurrent (EUC)

< 2 years

4) Upwelling to the surface in the central equatorial Pacific

+ excess CO_2 uptake in the equatorial zone

5) Westward transport to the warm pool

a) Smaller CO_2 buffering capacity

b) Time-lag of CO_2 increase in the warm pool after the atmospheric CO_2 growth

c) Increasing transport from the South Pacific with naturally lower preformed nDIC?

= Negative feedback from the climate variability/change?

Summary

- Progress of OA for the past decades have been distinctly observed at a variety of site in the subtropical and tropical zones of the western North Pacific.
- Rate of OA in surface layer has been primarily controlled by the growth rate of the atmospheric CO_2 concentration.
- In the tropics, rate of OA appears to have a time-lag of 10-15 years behind the rate corresponding to the growth of the atmospheric CO_2 because of the transport of anthropogenic CO_2 from the extratropics through the ocean interior.
- Climate variability/change is likely to have a significant impact on the rate of OA in the tropics.