International Symposium on Ocean Acidification
- Dialogues between scientists and stakeholders –
Ocean Policy Research Institute, Sasakawa Peace Foundation
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Trend of acidification in the open ocean around Japanese Islands

日本周辺の外洋域における海洋酸性化

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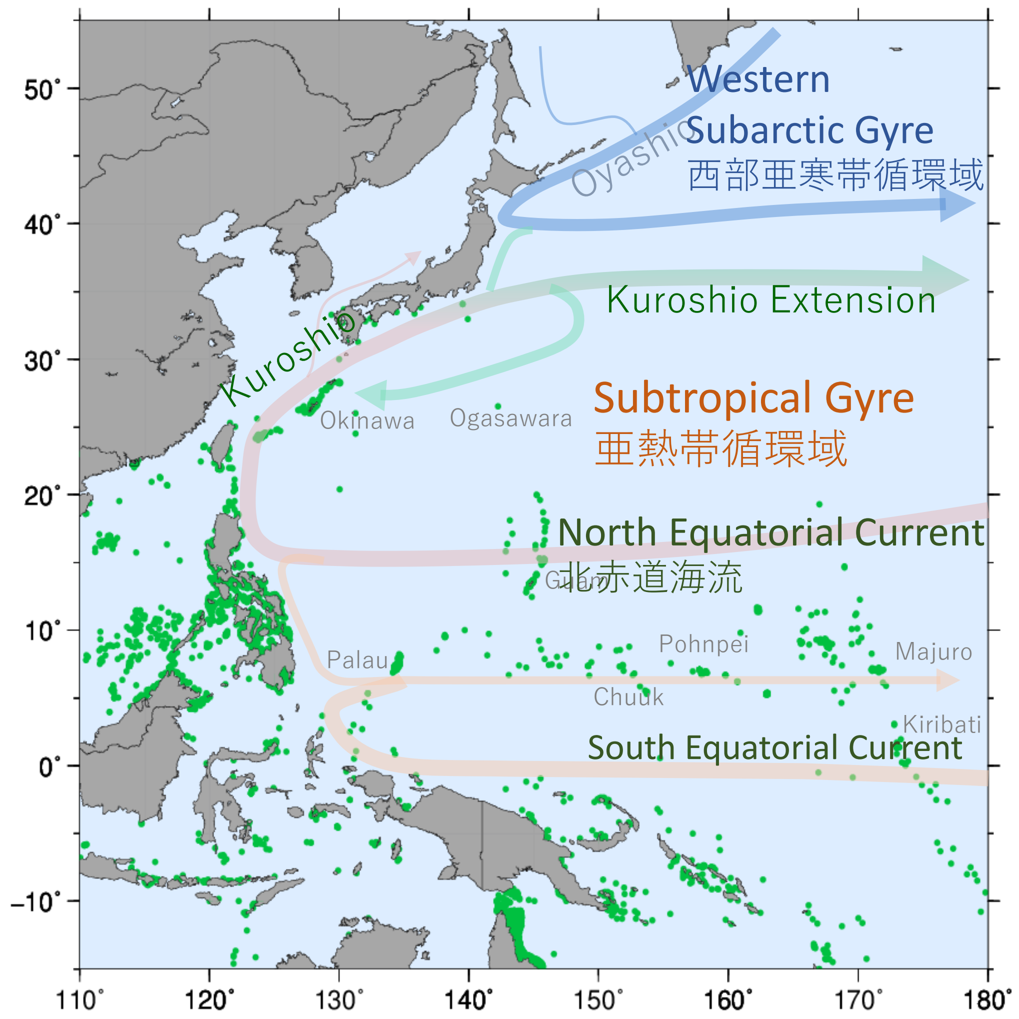
気象庁 Japan Meteorological Agency GOOS IOCCP GOA-ON 14 LIFE BELOW WATER

Western North Pacific
西部北太平洋



• Coral reef habitats サンゴ礁

Subarctic

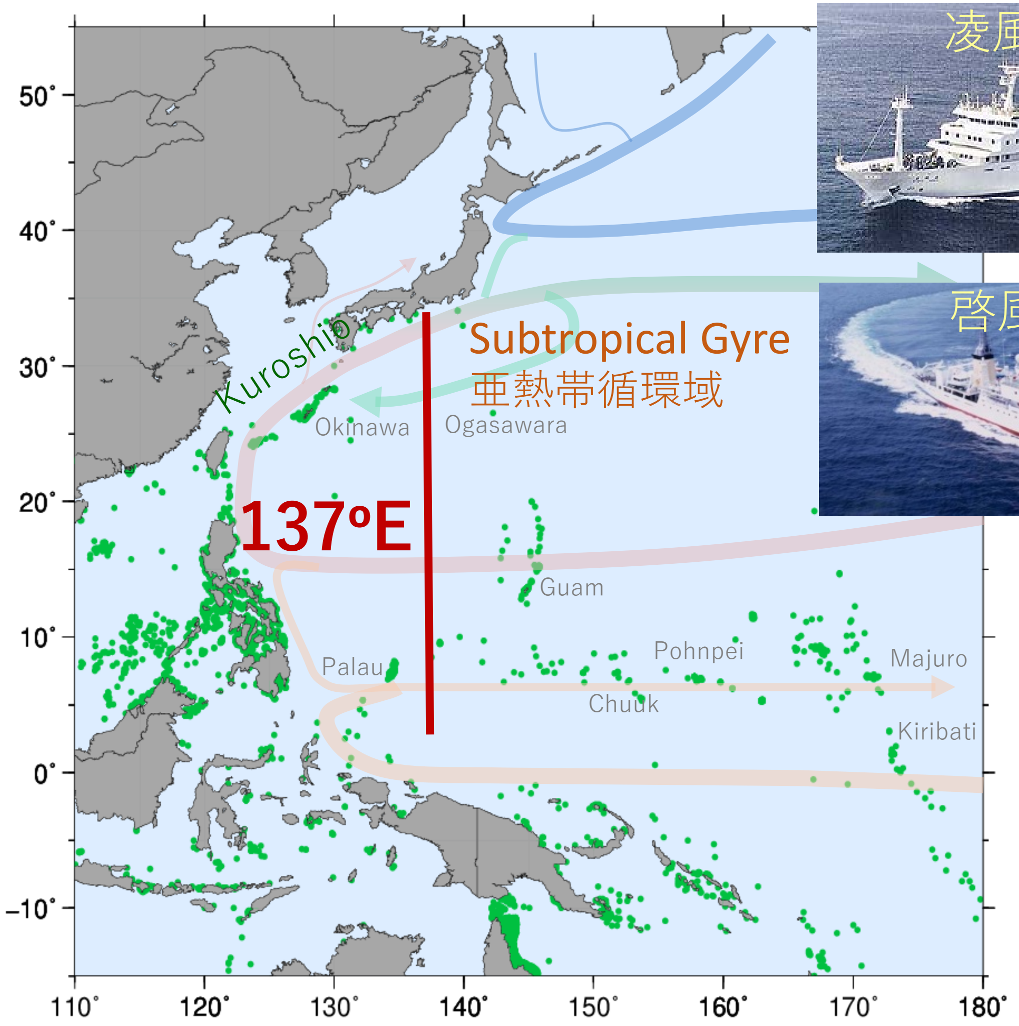
– High productivity in summer
– Large catch of fish

Subtropics and Tropics

– 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

Subtropics and Tropics



• Coral reef habitats サンゴ礁

Repeat measurements at 137ºE

1967 – Temperature., Salinity, O_2 and nutrients.

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

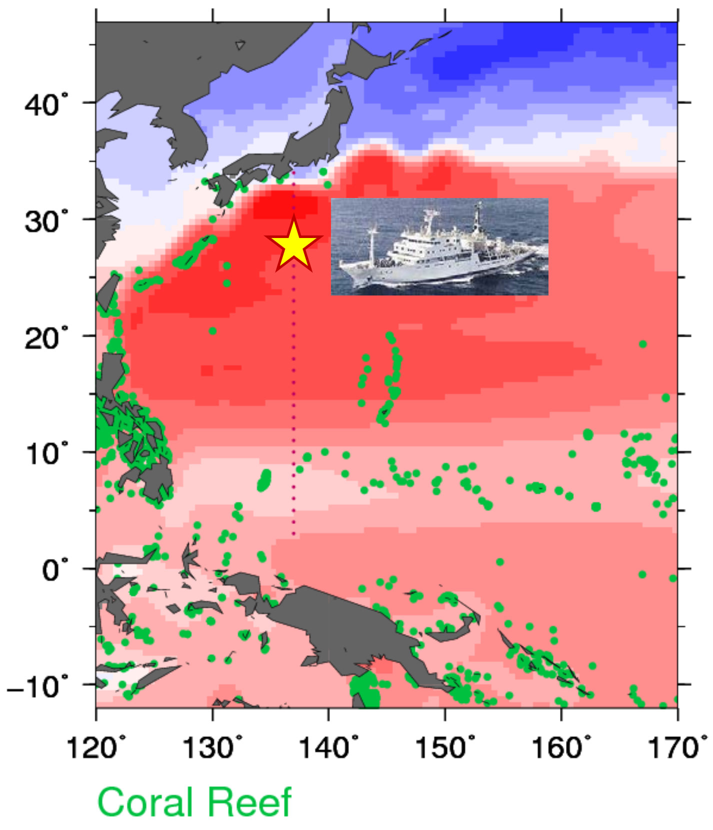
1994 – total dissolved inorganic carbon (DIC) at depths. 全炭酸

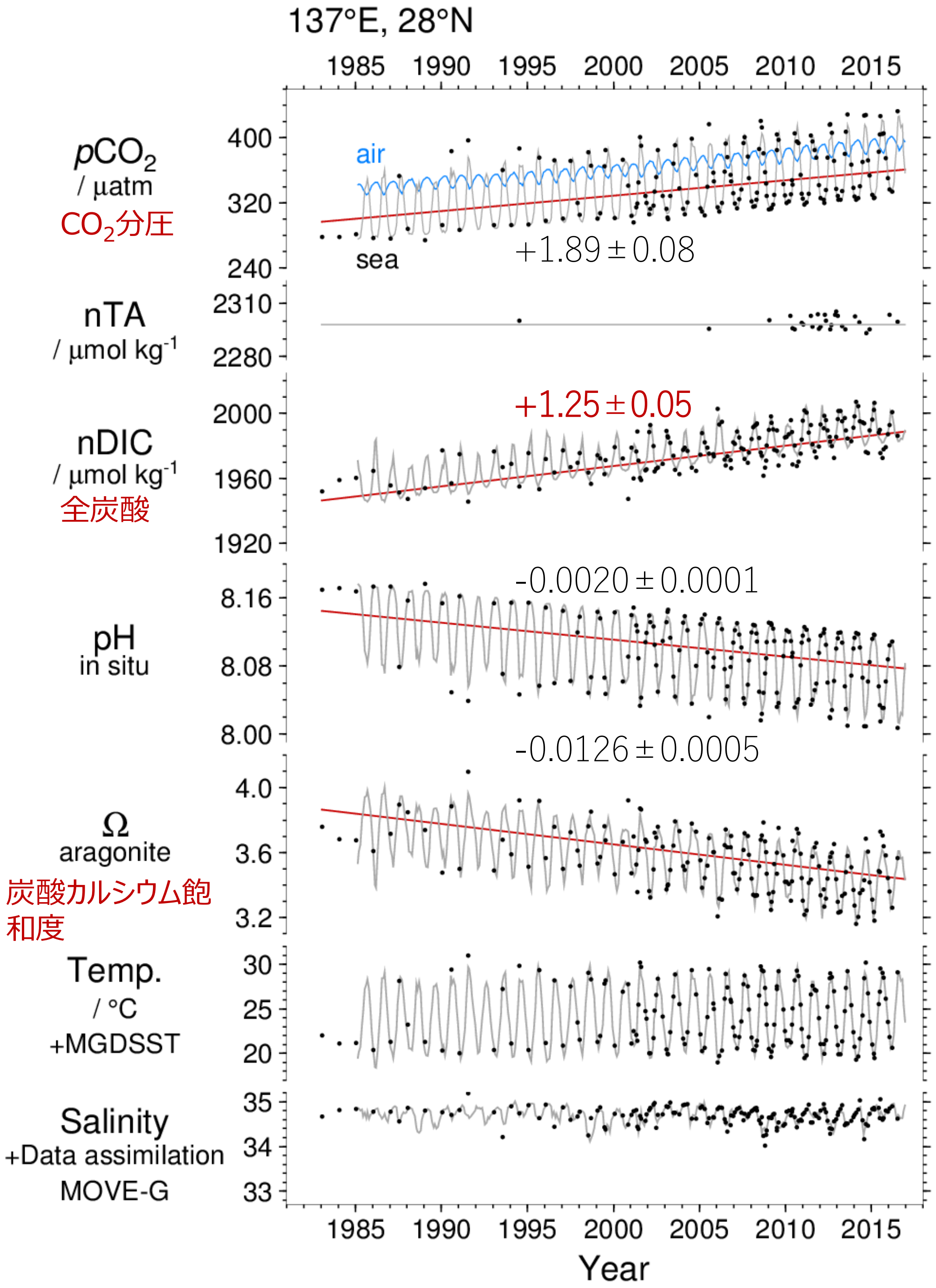
2010 – Total alkalinity (TA) and pH at depths

Shower-head type equilibrator for pCO_2

Automated measuring system for DIC & TA

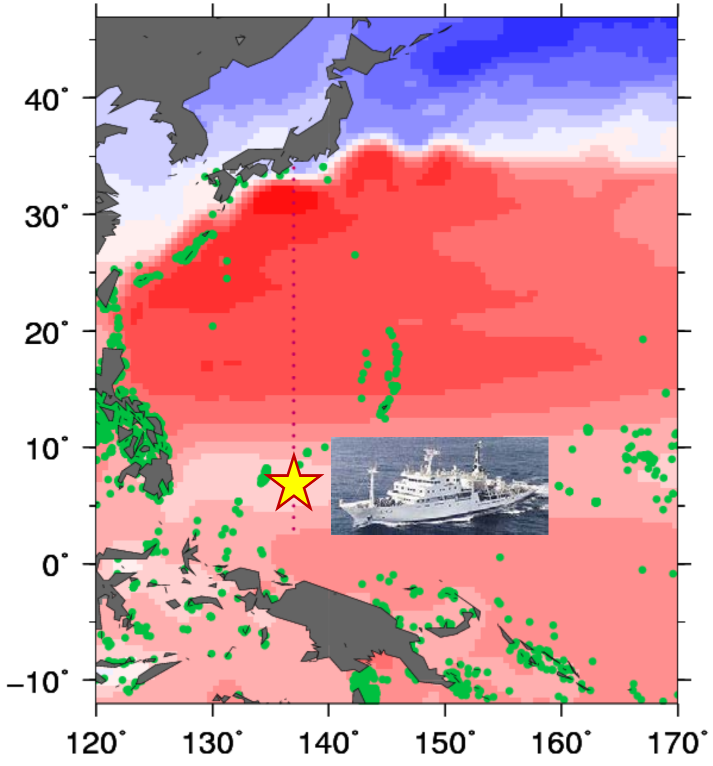
Trends @137^{o}E, 28^{o}N
in surface layer in 1983-2017

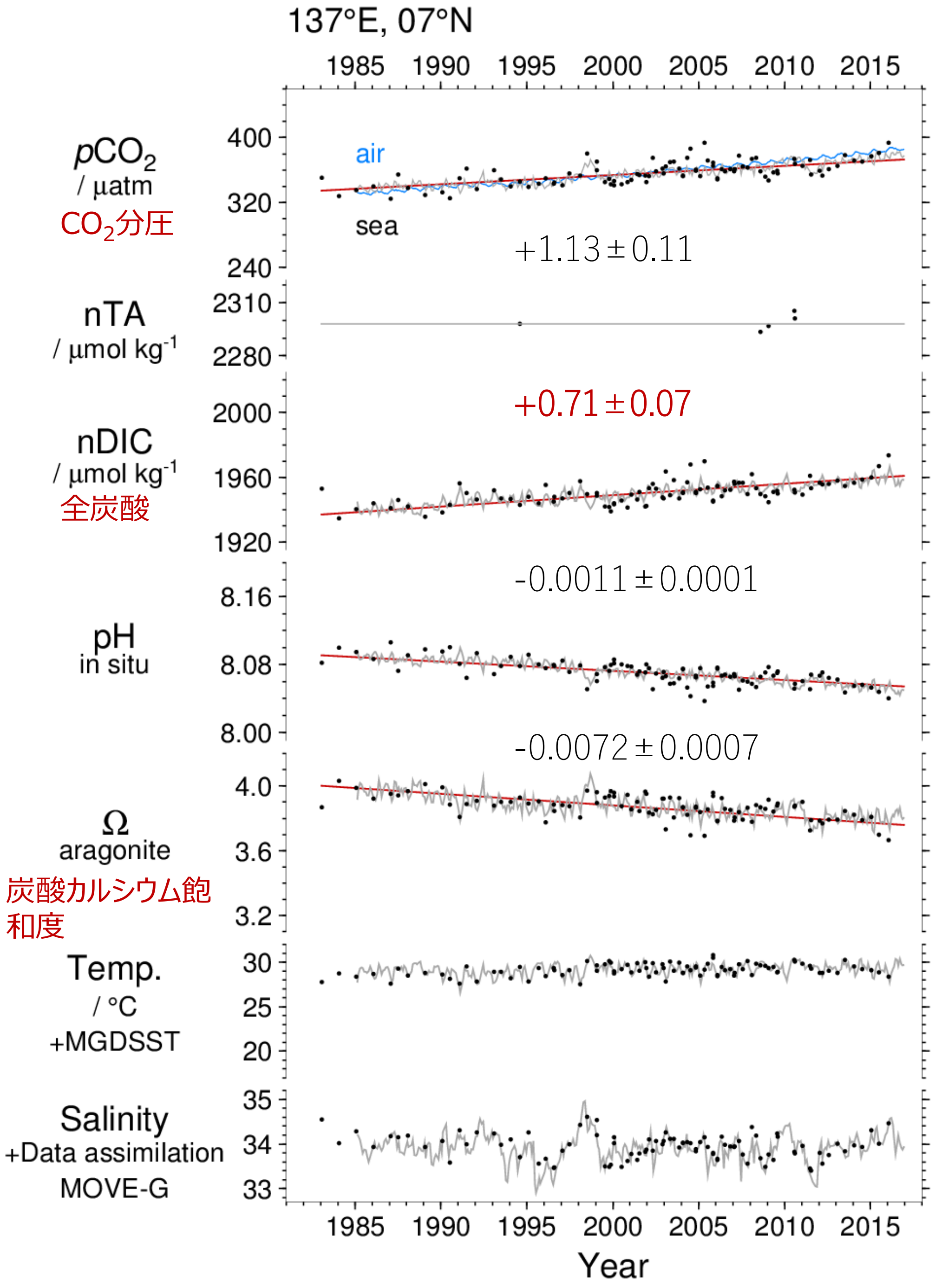




- Seasonal variability is large but long-term trend of CO_2 increase and acidification are evident.

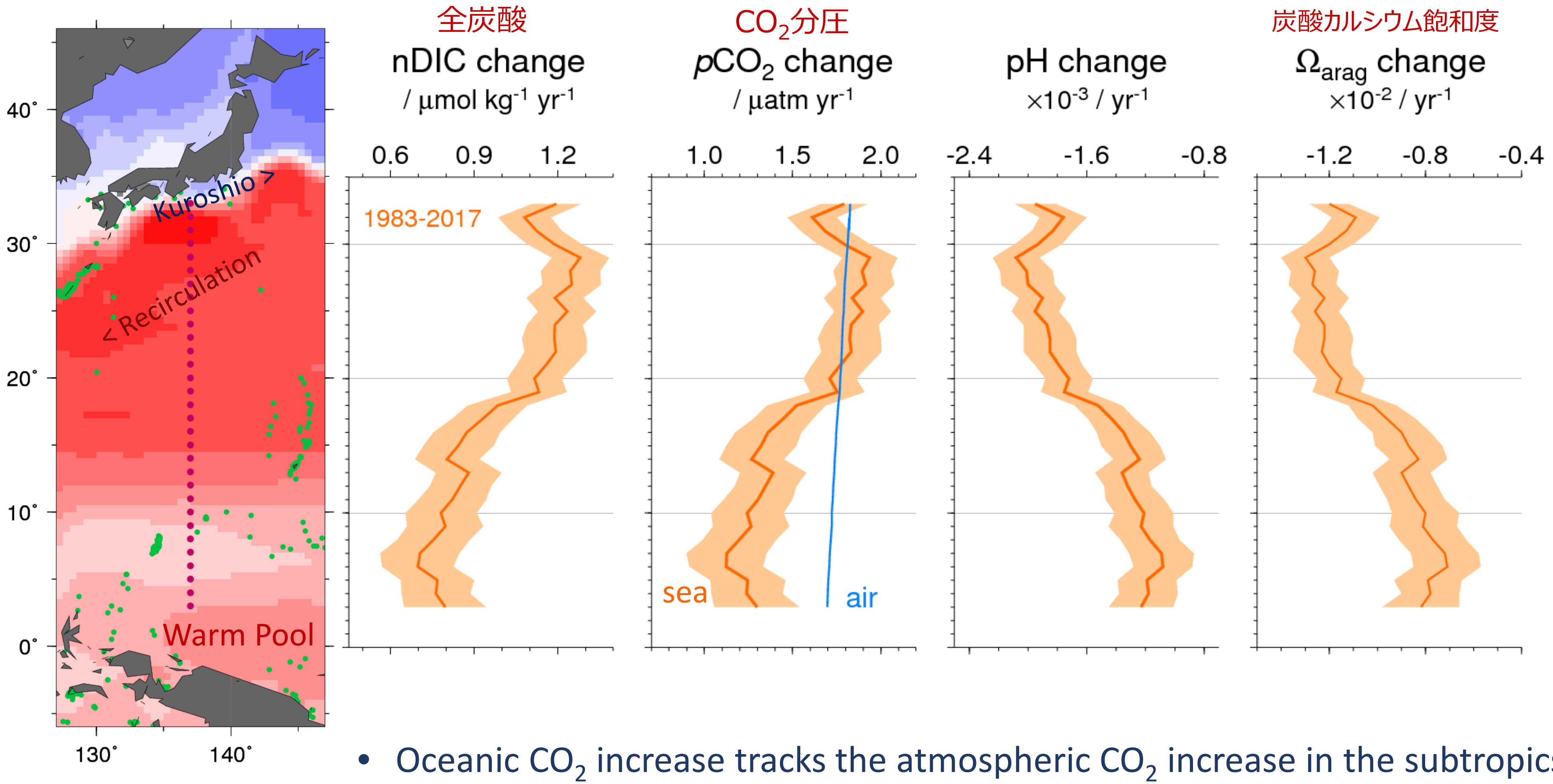
Trends @137ºE, 07ºN
in surface layer in 1983-2017





- Seasonal variability is small. Long-term CO_2 increase and acidification are evident but slower than in the subtropics.

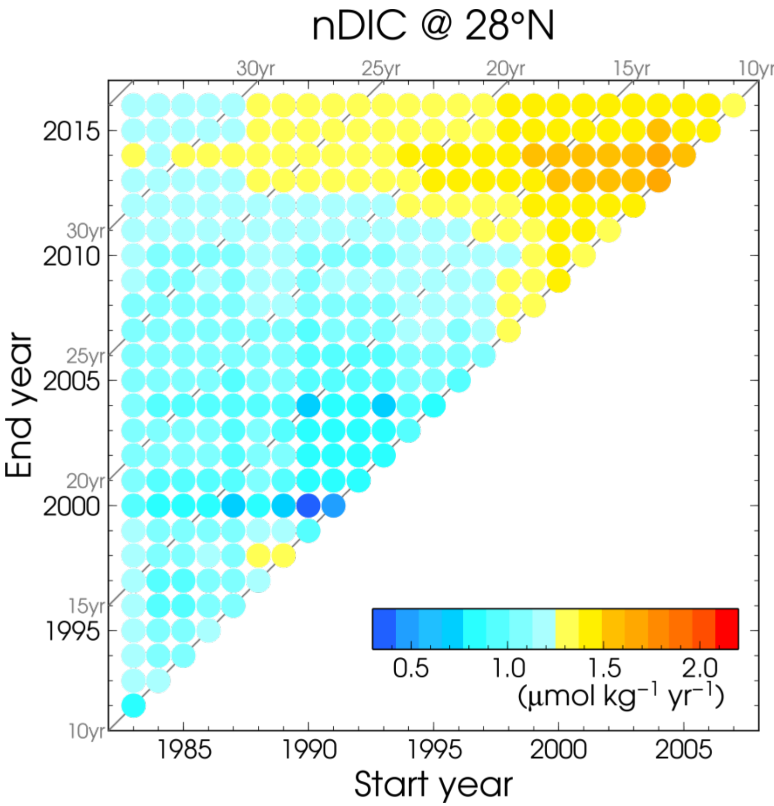
Meridional distributions of the mean rate of oceanic CO_2 increase and acidification (1983 - 2017)

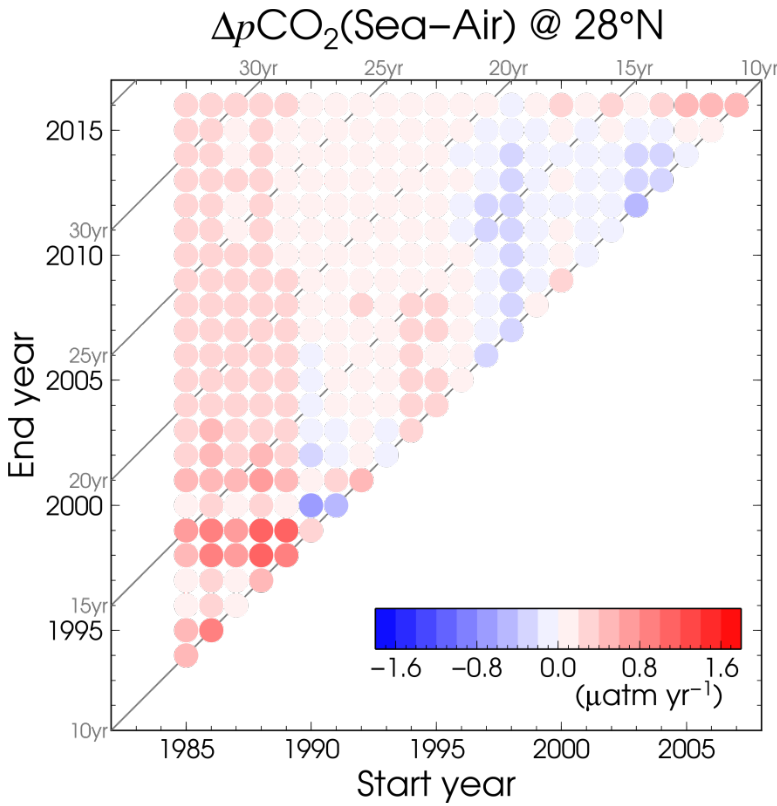


- Oceanic CO_2 increase tracks the atmospheric CO_2 increase in the subtropics (Kuroshio recirculation), but is slower in the tropics.

Rates of anthropogenic nDIC increase and Δ$p$$CO_2$ change

as a function of start year and end year of analysis





Trend of anthropogenic nDIC increase and minor effects of warming and its effect on nDIC have been considered.

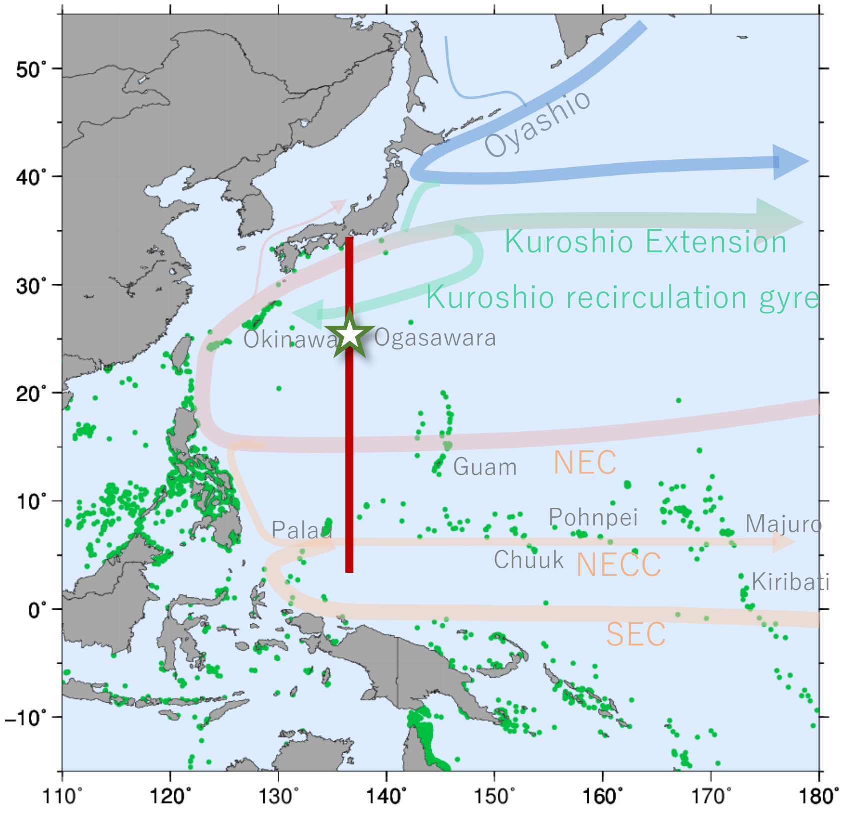
- Rate of nDIC increase is accelerating in recent decades.
- Rate of Δ$p$$CO_2$ change is usually very low, *i.e.*, $p$$CO_2$sw is well tracking the atmospheric $p$$CO_2$ acceleration.

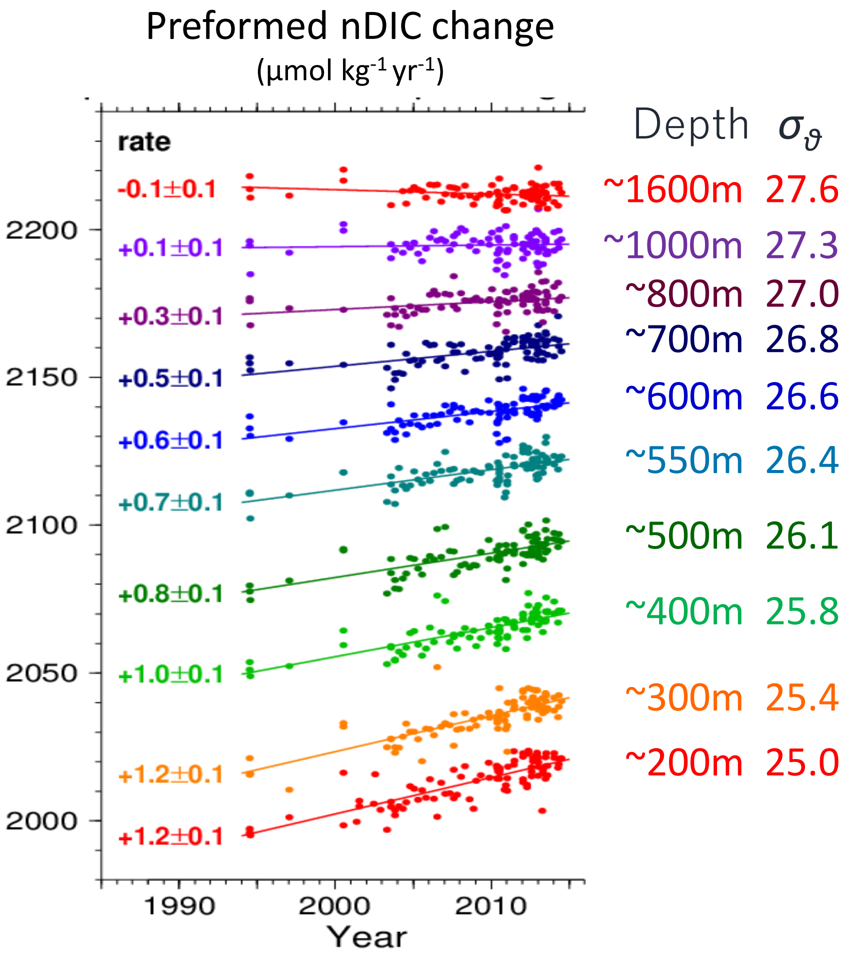
Trends of CO_2 increase and acidification in the **ocean interior** of the subtropical gyre at 137ºE

"How deep have the anthropogenic CO_2 penetrated into the ocean interior?"

RV Ryofu Maru and CTD/multi-sampler.

Trends in the interior of the subtropical gyre at 137°E, 25°N



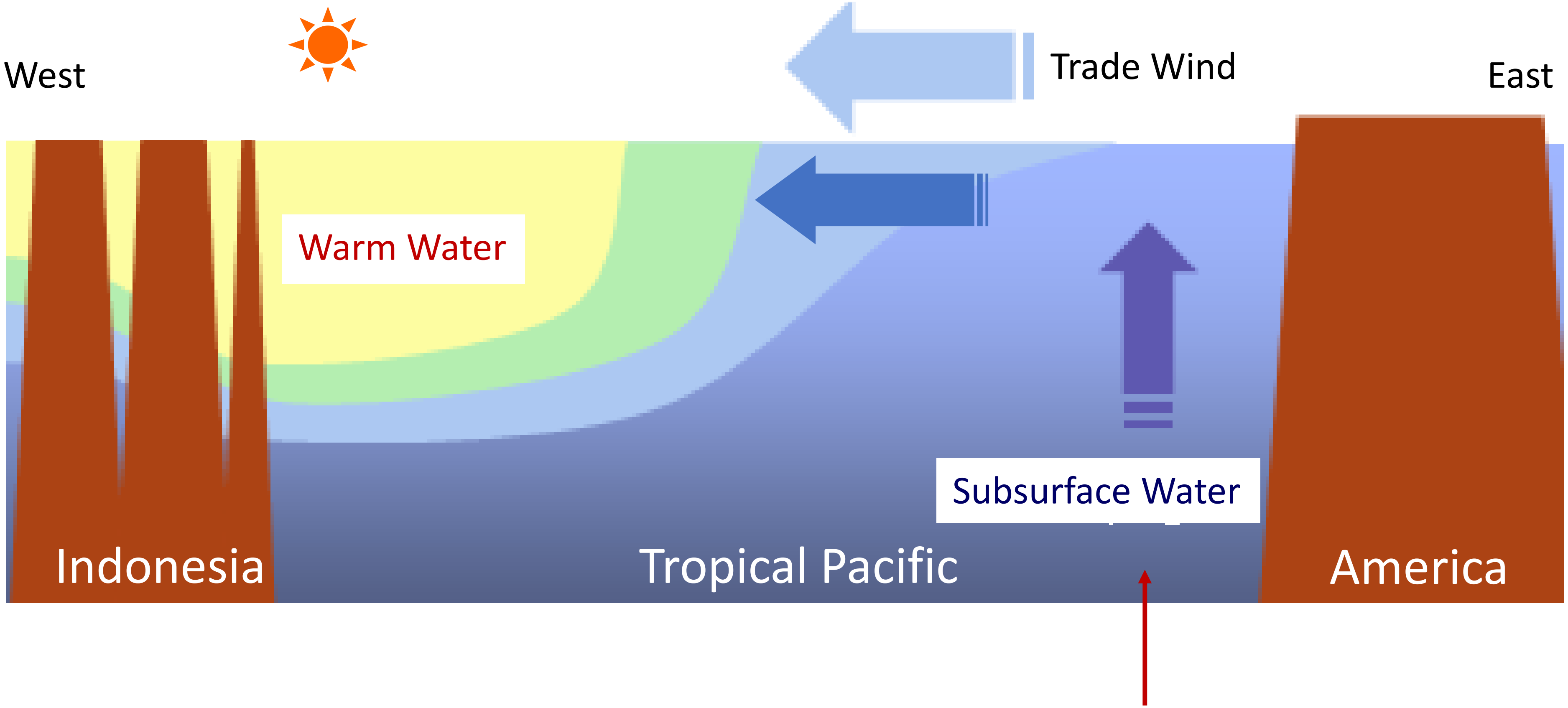


- Upward trend of nDIC has been detected down to the layer of $27.0\sigma_\vartheta$ (~800m).
- These DIC increases at depths are primarily attributable to the invasion of anthropogenic CO_2.

Preformed nDIC : nDIC when the water was last contact with the atmosphere

= {DIC – 117/170 (O_2sat- O_2)}·*S*/35 : changes due to $CaCO_3$ dissolution not taken into account

Why is the rate of preformed nDIC increase slow in the western tropical Pacific?

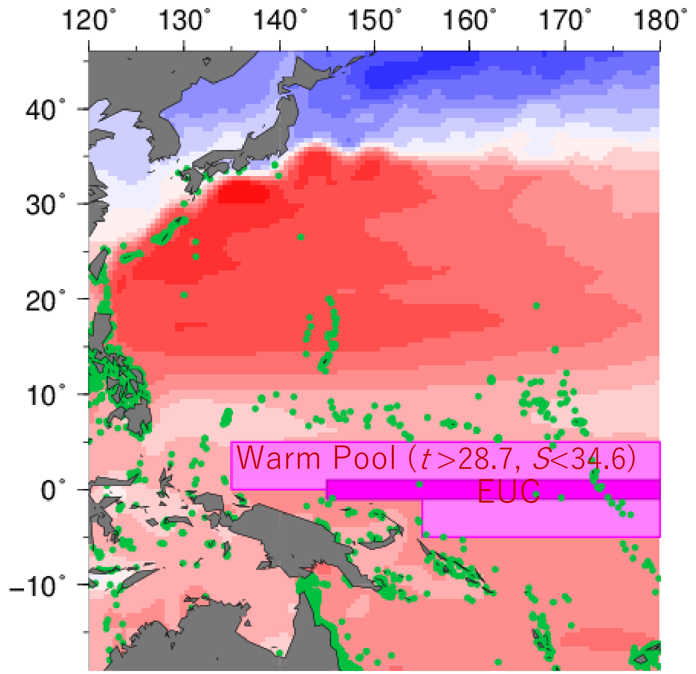


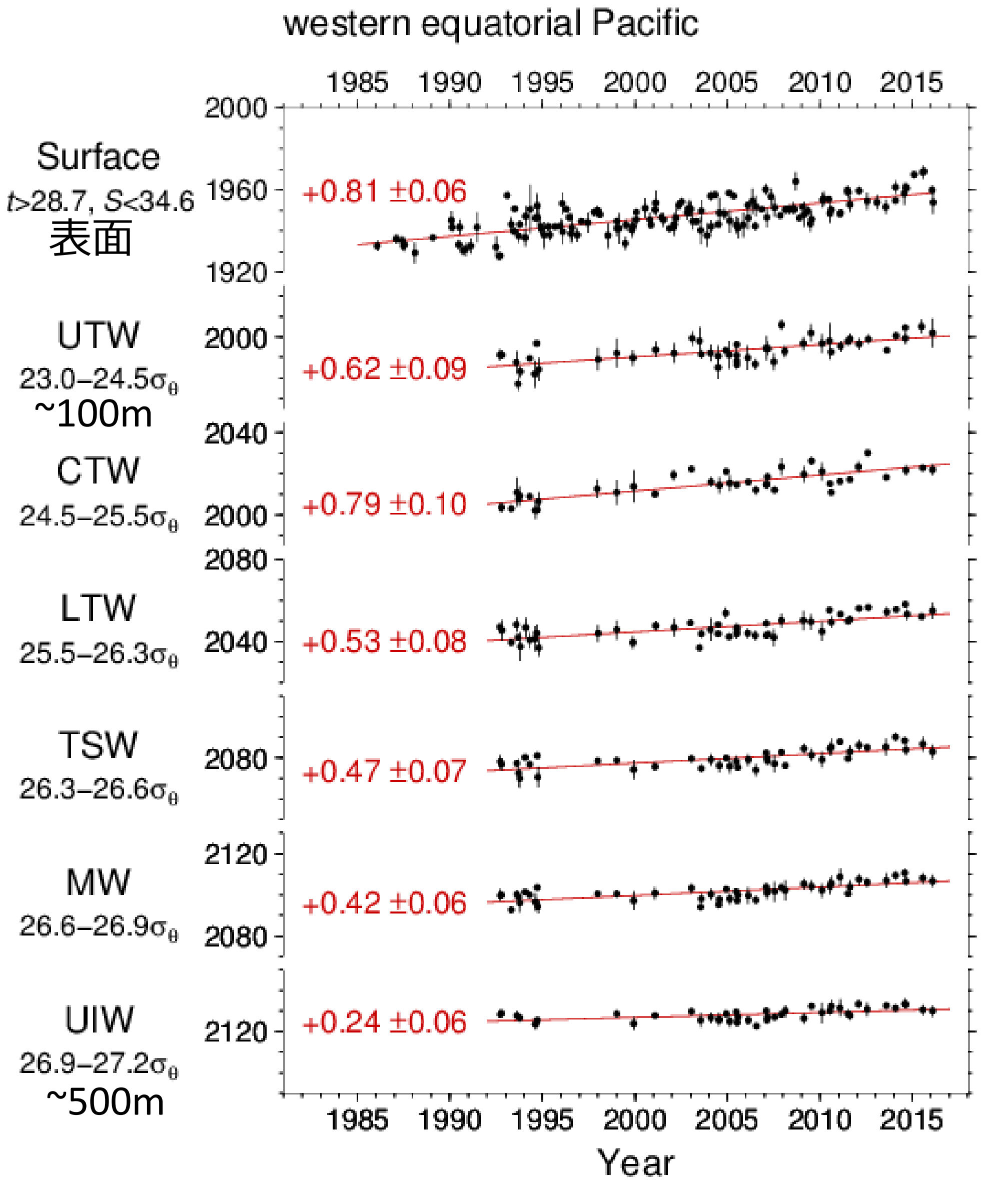
Subsurface water of the topical Pacific comes mainly from subtropical regions in both hemispheres, taking about **10 years** to get to the tropics.

Therefore, the slower nDIC increase in the western tropical Pacific is ascribed to the transport of anthropogenic CO_2 through shallow meridional overturning circulations in the Pacific and the acceleration of the atmospheric CO_2 increase.

Increase of preformed nDIC in the Equatorial Undercurrent

- In fact, preformed nDIC is increasing but slowly in the EUC.



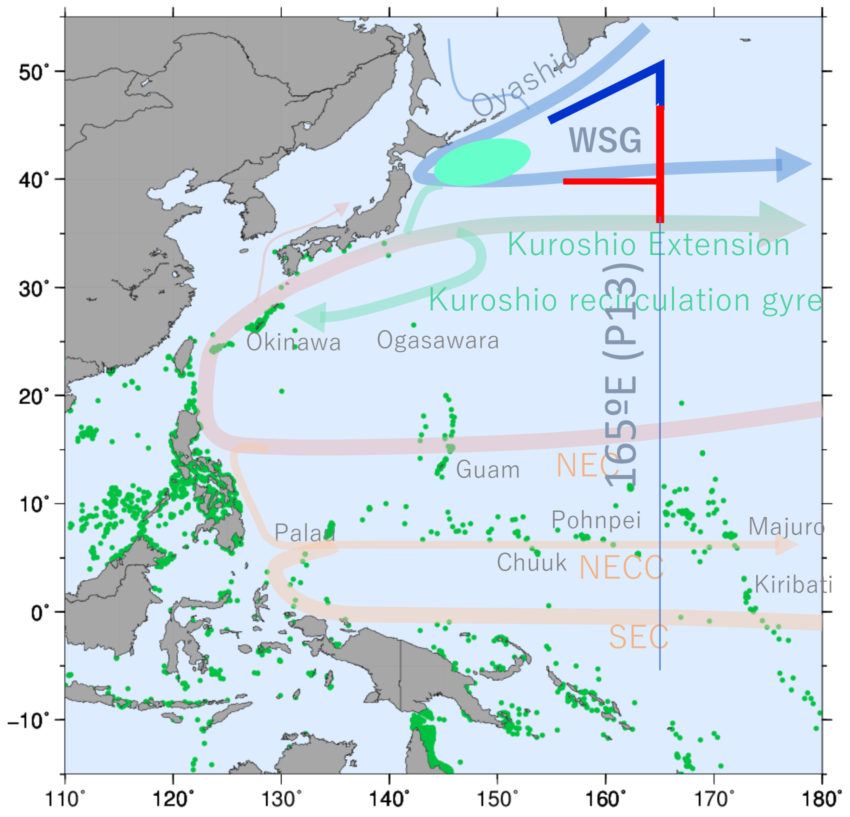


Multi-parameters regression analysis:

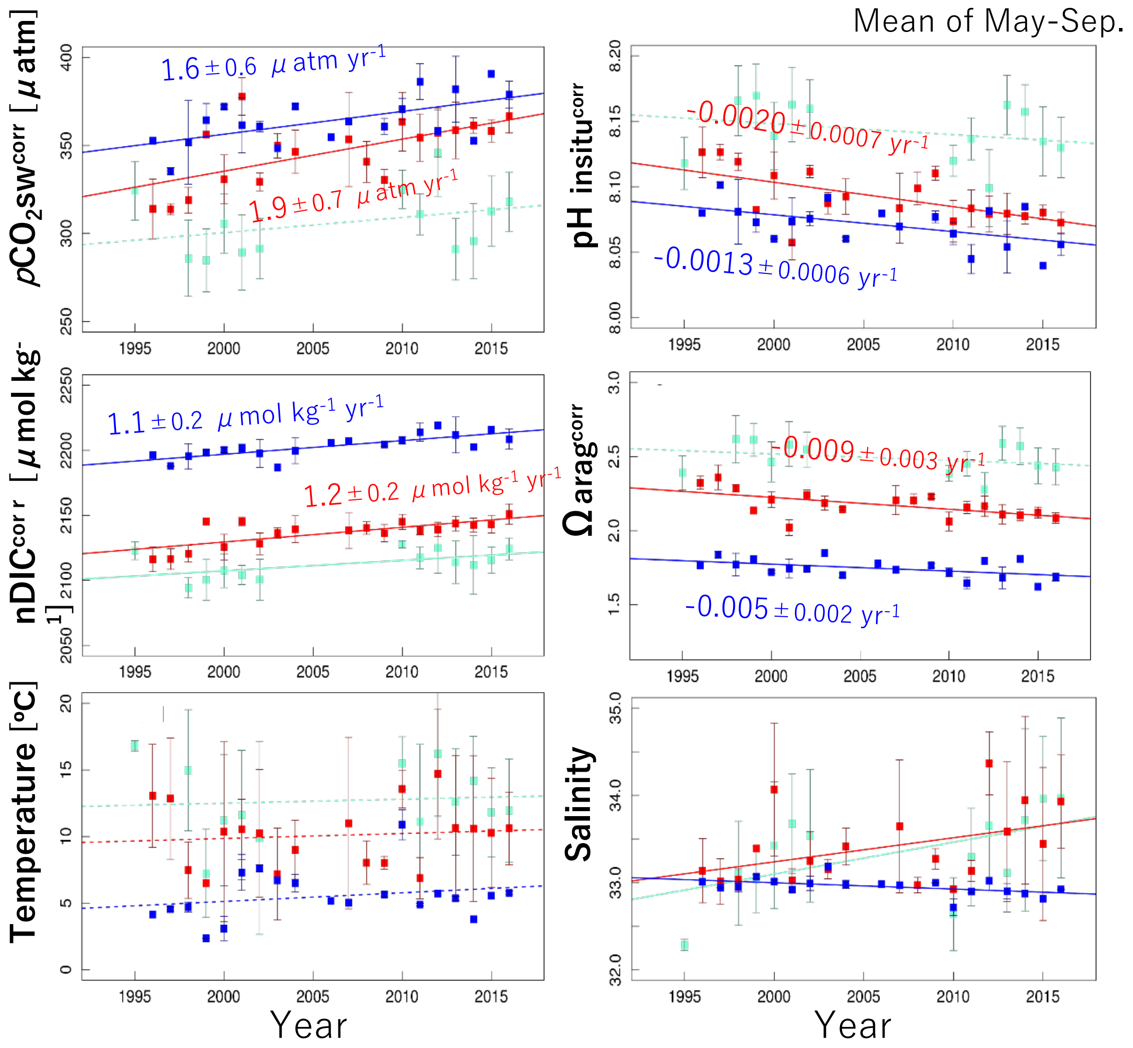
pref-nDIC = pref-nDIC$^{@2000,\sigma ave}$

$+ r_{anth} \cdot (\text{Year} - 2000) + c_1 \cdot (\sigma_\vartheta - \sigma_{\vartheta ref})$

Trends in the surface of the western subarctic and subtropical-to-subarctic zones and of the Oyashio region



- Occurrence of ocean acidification is evident, but it appears that it is largely affected by the changes in the ocean circulation.



$nDIC^{corr} = nDIC - a \cdot SST^{anomaly} - b \cdot \log(Chl.a)$

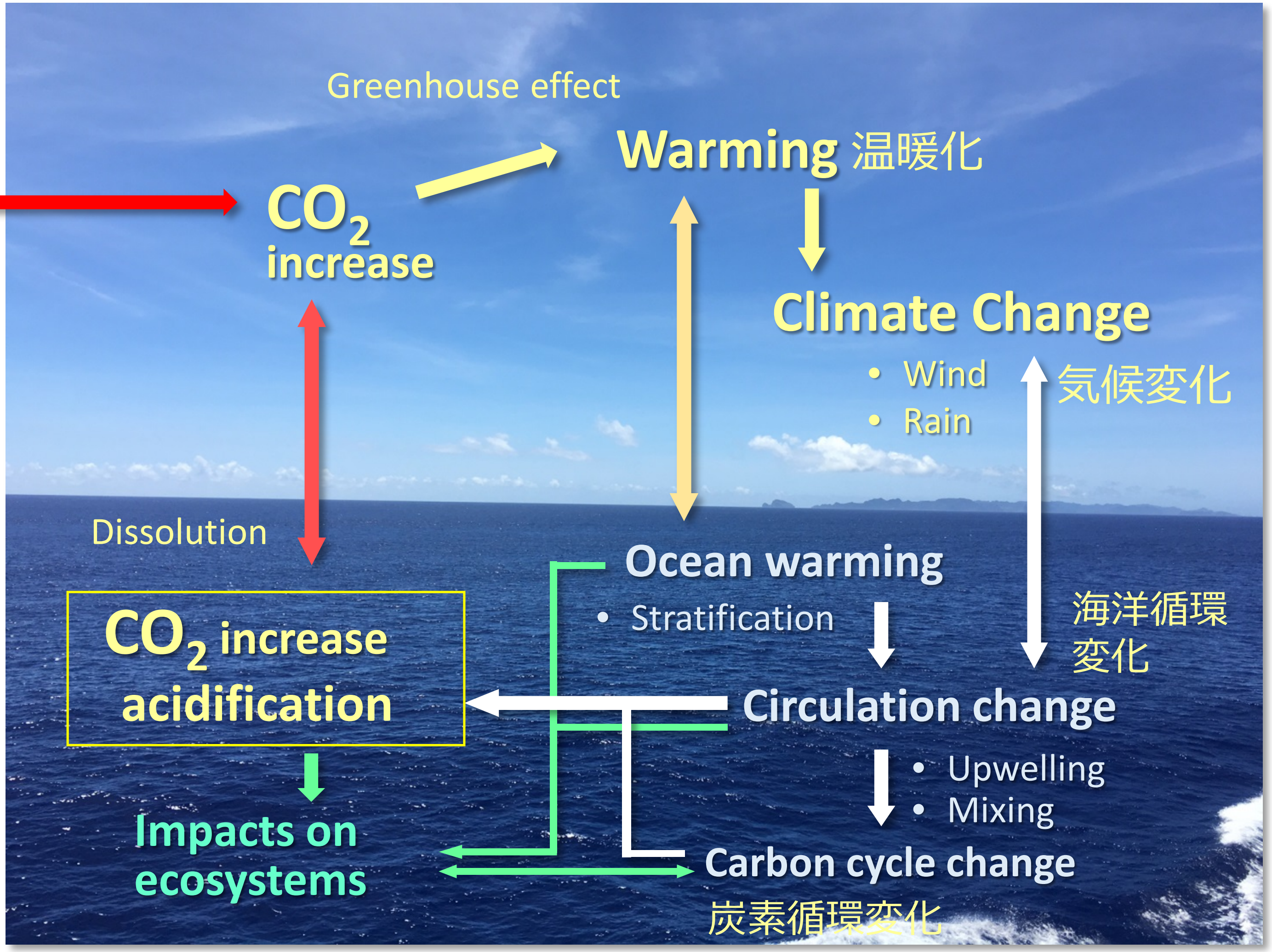
(The rates indicated are preliminary)

Courtesy of Y. Iida

Anthropogenic CO_2 invasion into the ocean and carbon-climate feedback

Fossil fuel combustion

Land-use changes



Ocean acidification will be assessed in Chapter 5 of IPCC WGI AR6 in the context of carbon-climate feedback

ar6 Working Group I Report

https://wg1.ipcc.ch/index.html

ipcc INTERGOVERNMENTAL PANEL ON climate change

Conclusion

- **Ocean acidification is occurring undoubtfully in the western North Pacific around Japan.**

  海洋酸性化は、日本の周辺の西部北太平洋でも確実に進行しています。

  - In the subtropics, the rate of ocean acidification is accelerating along with the acceleration of the atmospheric CO_2.

    特に亜熱帯域の海洋表層では、大気中のCO_2濃度増加の加速にともなって、海洋酸性化（全炭酸の増加）も加速しています。

  - In the tropics and subarctic, rate of ocean acidification has been also affected by the ocean circulation and its changes.

    熱帯域や亜寒帯域では、海洋酸性化の速度が海洋循環やその変化の影響を顕著に受けています。

- **Trend of ocean acidification and its impact on marine ecosystem need to be investigated sustainably and globally, together with the changes in physical ocean circulation.**

  今後も海洋酸性化の動向を海洋循環の変化とともに長期かつ広域で観測し、CO_2の排出抑制の効果や気候変動の影響を評価する必要があります。

- A variety of oceanographic and marine meteorological information related to maritime safety and climate issues including those of ocean acidification is publicly available from the website of Japan Meteorological Agency at:

海洋酸性化など、海洋と海上気象に関するさまざまな防災と気候の情報は、気象庁の下記ウェブサイトからご覧頂けます。

http://www.data.jma.go.jp/gmd/kaiyou/shindan/index.html