An evaluation of current and future ocean acidification based on pCO_2 database around Okinawa Island

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1. Introduction

Ocean acidification is caused by the dissolution of anthropogenic CO_2 into seawater. When CO_2 is dissolved in seawater, pH and the carbonate ion concentration decrease. A variety of marine organisms may be adversely affected since they use calcium carbonate as the main component of hard tissues such as shells and skeletons.

Coral reefs in the tropical zone are thought to be vulnerable to ocean acidification as they have a skeleton of aragonite which is a form of calcium carbonate. Ocean acidification will have adverse impacts on not only coral reefs but also whole tropical ecosystem since coral reefs are important for spawning, hatching, and habitat for many organisms.

Many coral reefs exist around Okinawa and bring a lot of benefits there by fishery and tourism. Geographically, coral reefs around Okinawa are located at the higher latitudinal area where the water temperature drops largely in winter.

In this study, we use the Surface Ocean CO_2 Atlas (SOCAT) database to evaluate the progress of ocean acidification around Okinawa from the 1980s to the present. Based on the results, we project the progress of acidification under future CO_2 concentration scenarios. This projection will reproduce seasonal variation in pCO_2 and aragonite saturation (Ω_A) there more realistically than existing predictions on a global scale.

2. Methods

The data of surface water temperature (SST), salinity (SSS) and pCO_2 around Okinawa (24-30°N, 123-130°E) were extracted from SOCAT database. We used the results of hydrographic observations conducted by the Japan Meteorological Agency in the same area between 2010 and 2017 in order to derive an empirical equation between salinity and total alkalinity (TA). Ω_A were calculated from pCO_2 and estimated TA using the CO2SYS program.

3. Results

In 1982-2016, pCO_2 showed a long-term trend of increase (Fig. a). At the same time, pCO_2 was high in summer and low in winter. Long-term and seasonal variation in pCO_2 was separated by using the method by Ishii et al., [2011]. As a result, the component of the long-term trend was +1.49±0.26 μatm/year (95% CI). This was as high as the rate of increase in atmospheric pCO_2 at Mauna Loa in Hawaii in the same period (+1.73±0.04 μatm/year).

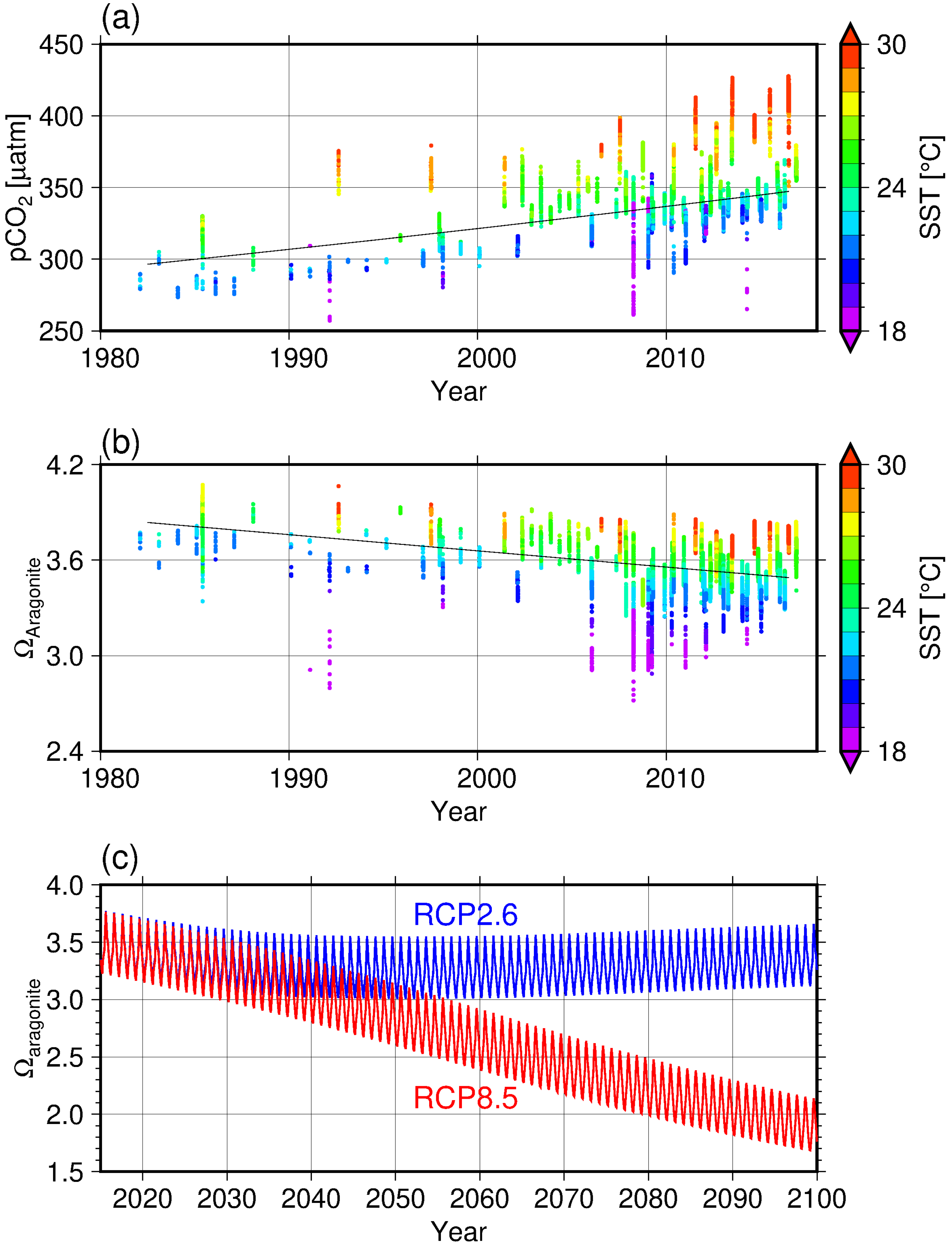
TA was basically proportional to salinity (TA = 2297.1 / SSS * 35). In some areas near the shelf in the East China Sea, however, there was a positive anomaly from this relation. This may be due to the influence of river water originated from the Changjiang River. Another equation was applied (TA = 1347 + 897.6 / 34.2 * SSS) to the data to the north of 26°N with SSS < 34.2 from July to September.

As for Ω_A, a long-term trend -0.0102±0.0018/year was calculated in the same manner as pCO_2. Previous studies showed that the coral reef habitat coincided with the area where Ω_A does not fall seasonally below 3.0 [Kleypas et al., 1999]. In the present situation, Ω_A around Okinawa island (SST > 21°C in winter) was kept at 3.0 or more throughout the year.

4. Future projections
We can project the fluctuation in the ocean pCO_2 and Ω_A under future CO_2 concentration scenarios assuming that the current difference between in pCO_2 in the atmosphere and the ocean (ΔpCO_2) will not change in the future. Monthly ΔpCO_2 was averaged from the SOCAT database. CO_2 concentrations for the Representative Concentration Pathways (RCPs) were used to calculate atmospheric pCO_2 up to 2100 [Meinshausen et al., 2011]. Climatology of SST and SSS from 1982 to 2014 was calculated from Northwest Pacific Ocean Long-term Reanalysis Data Set (FORA-WNP30) and applied to the prediction.
In the RCP 2.6 scenario, Ω_A will be at 3.0 or larger during this century. However, in the RCP 8.5 scenario, Ω_A will drop seasonally below 3.0 in the north of Okinawa island around 2030. In that scenario, Ω_A will be lower than 3.0 throughout the year in the 2060s (Fig. C). If the current increase in atmospheric CO_2 continues, coral reefs around Okinawa will be seriously affected by ocean acidification in the near future. On the other hand, there is a possibility that a suitable environment for coral reefs around Okinawa can be maintained under a strict emission reduction.

5. Figure captions
(a) pCO_2 around Okinawa during 1982-2016 from SOCAT database. SST is shown in color. Black line indicates the deseasonalized trend of pCO_2.
(b) Ω_A around Okinawa during 1982-2016 calculated from pCO_2 and estimated TA. SST is shown in color. Black line indicates the deseasonalized trend of Ω_A.
(c) Projected Ω_A in the coast of northern Okinawa Island (26.8°N, 128.1°E) during 2015-2100.

Keywords: ocean acidification, coral reef, SOCAT database, Future prediction


(a)
450
400
350
300
250
1980
1990
2000
2010
Year
pCO2 [µatm]
30
24
18
SST [°C]
(b)
4.2
3.6
3.0
2.4
1980
1990
2000
2010
Year
ΩAragonite
30
24
18
SST [°C]
(c)
4.0
3.5
3.0
2.5
2.0
1.5
2020
2030
2040
2050
2060
2070
2080
2090
2100
Year
Ωaragonite
RCP2.6
RCP8.5