Statistical analysis of temporal and spatial variations of air-water CO2 flux in the Kuroshio region

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The Kuroshio region is one of the strongest sinks for atmospheric CO_2 in the world, and thus has an important role in regulating the future climate. This CO_2 absorption mechanism is controlled by the Kuroshio current and seasonal winds. However, an existing temporal and spatial measurement resolutions is not enough for precise analysis including the coastal area. In this study, we quantified the CO_2 flux variations and the regulating factors in the Kuroshio regions including the coastal area using an improved interpolation technique.
We used ocean surface fugacity of CO_2 (fCO_2) data in the Pacific coast of Japan (20-40 ºN, 130-150 ºE) from 2000 to 2019 observed, which are available from SOCAT (the Surface Ocean CO_2 Atlas). We also used wind data in the same range from the open product of the CCMP (the Cross-Calibrated Multi-Platform). The data was re-gridded to a horizontal resolution of 1º×1º grid and a temporal resolution of 0.1 year. The missing values were interpolated with the observed data by the Fourier series and the ridge regression given the periodic variation of related parameters. The grids were finally clustered using the Ward’ s method (Ward, 1963) into three areas by the similarity of the CO_2 flux time variation for the analysis of the temporal and spatial variations of the air-sea CO_2 flux. The standard error of the interpolated air-sea CO_2 flux in each clustered area was less than 0.35 mol m^{-2} $year^{-1}$.
The three clustered area was categorized as the near-shore area (Area 1), the eastward area (Area 2) and the southward area (Area 3) (Fig. 1). The CO_2 flux in Area 2 became the largest by the strong winter seasonal winds while the fluxes in summer season was the almost same among other areas (Fig. 1). Consequently, Area 2 showed roughly twice atmospheric CO_2 absorption (2.90 mol m^{-2} $year^{-1}$) of those in other two areas (1.29-1.39 mol m^{-2} $year^{-1}$). A different spatial distribution pattern of the clustered area was found during Kuroshio large meander period (2005, 2017~2019). During the meander period, some grids of Area 2 was replaced by the grids of Area 3 and the number of the grids decreased to 76% of those during non-meander period. As a result, the Kuroshio large meander was one of the decreasing factors of atmospheric CO_2 absorption in the Kuroshio region. As for temporal variation, the CO_2 absorptions in three areas have increased mainly by the increase of the fCO_2 difference between air and seawater, which was the result of the overcome of the air fCO_2 increase to the seawater fCO_2 increase. Meanwhile, the weakening of wind speed was considered as the decreasing factor of the CO_2 absorption. The wind weakening effect was the largest in Area 2 and decreased to 88% of the CO_2 absorption increase by the fCO_2 difference. Because our results depended highly on the wind effect, more quantification of the wind effect and the higher spatial distribution especially in the near-shore area were required for more precise CO_2 flux analysis in the Kuroshio region.

Citation
Ward Jr., J.H. (1963) Hierarchical Grouping to Optimize an Objective Function. Journal of the American Statistical Association, 58, 236-244.

Keywords: Air-water CO2 flux, Clustering, Kuroshio

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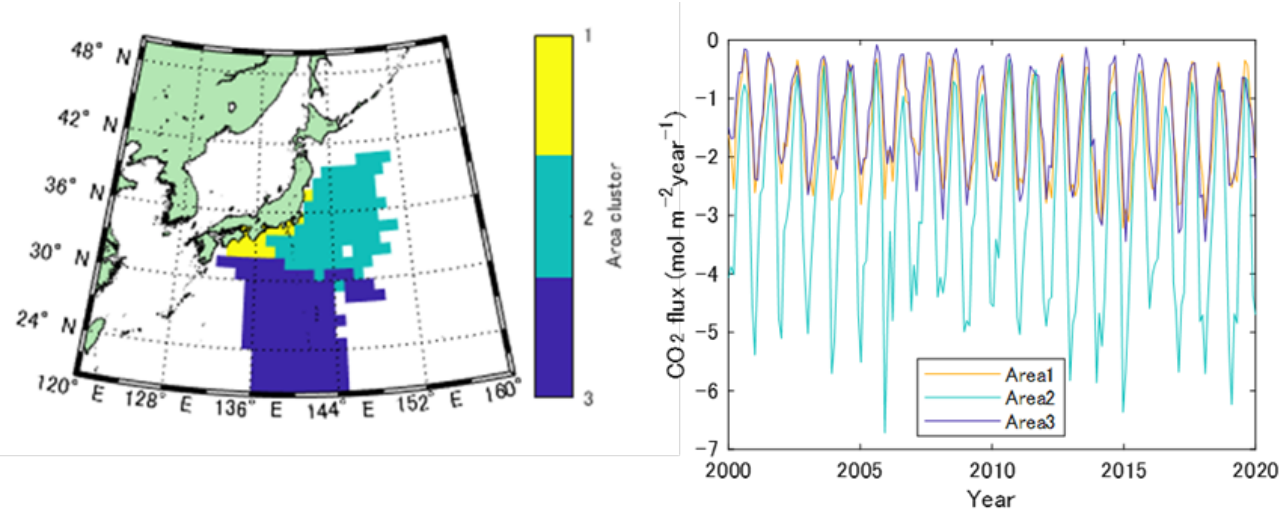

Figure 1
(left): Clustered areas based on temporal and spatial CO_2 flux variation. Yellow, Green and Blue areas show Area 1, 2, 3, respectively. (right): Temporal variation of mean CO_2 flux in each clustered area.

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