# Temporal and spatial variations of the mole fraction, carbon and hydrogen isotope ratios of atmospheric methane in the Western Pacific region

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To understand atmospheric $CH_4$ variations in the Western Pacific region, we have conducted systematic observations of the $CH_4$ mole fractions and its carbon and hydrogen isotope ratios ($d^{13}C$ and dD) using air samples collected on board container ships that regularly sail between Japan and Australia/New Zealand. In this study, we analyzed the observation data from 2006 to 2019.
In the temperate zones of both hemispheres, clear seasonal cycles in the $CH_4$ mole fractions, $d^{13}C$ and dD were observed. Using an atmospheric four-box model with prescribed $CH_4$ sink, we estimated the contribution of $CH_4$ sources to the seasonal $CH_4$ change. The results suggest that the seasonal change in the northern hemisphere is caused by the balance between $CH_4$ release from biogenic $CH_4$ sources such as wetlands in summer and $CH_4$ destruction by the reaction with OH radicals that become maximum also in summer. On the other hand, the seasonal $CH_4$ change in the southern hemisphere is almost determined by the seasonal changes in the amount of the $CH_4$ destruction by OH radicals.
In the Western Pacific, the $CH_4$ mole fractions, $d^{13}C$ and dD showed clear latitudinal gradients, with $CH_4$ mole fraction increasing and $d^{13}C$ and dD decreasing from south to north throughout a year. These observational facts suggest that there are isotopically lighter $CH_4$ sources (microbial origin) in the northern hemisphere. The latitudinal distributions of the $CH_4$ mole fractions and $d^{13}C$ obtained in this study were compared with those observed by the National Oceanic and Atmospheric Administration (NOAA/GMD) at background sites far from $CH_4$ source region (hereafter called as NOAA sites). During the boreal summer, the $CH_4$ and $d^{13}C$ in the Western Pacific showed lower and higher values, respectively, compared to those at the NOAA sites, suggesting that the Western Pacific region could be more strongly affected by the destruction by OH radicals. On the other hand, in the boreal winter, the $CH_4$ mole fractions were higher in the Western Pacific than the background NOAA sites. This would be due to the prevailing westerly winds in the winter season, which transported the air-mass strongly influenced by land $CH_4$ sources into the Western Pacific region.
The $CH_4$ mole fractions observed in the Western Pacific, at Syowa Station(69.0˚ S, 39.4˚ E) and Ny-Alesund(78.6˚ N, 11.6˚ E) showed increasing trends after 2006. In contrast, $d^{13}C$ and dD decreased after 2006.We employed the four-box model to investigate the cause of the long-term $CH_4$ variability. When the $CH_4$ destruction rate by reaction with OH radical is fixed after 2006, an increase in $CH_4$ emission after 2006 and decreases in $d^{13}C$ and dD of aggregated $CH_4$ sources in all latitudinal bands after 2007 are required to reproduce the observed $CH_4$, $d^{13}C$ and dD values. This suggests that biogenic $CH_4$ emission has increased since 2006.

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