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Shipboard measurements and modelling of the distribution of CH_4 and $^{13}CH_4$ in the Western Pacific

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We present first observations and analysis of methane (CH_4) mixing ratio and $^{13}C/^{12}C$ isotopic ratios in CH_4 ($\delta^{13}C$) data from a collaborative shipboard project using bulk carrier ships sailing between Nelson, New Zealand and Osaka, Japan in the Western Pacific Ocean. Measurements of the CH_4 mixing ratio and its $\delta^{13}C$ are obtained from large clean air samples collected in each 2.5° to 5º of latitude between 30ºS and 30ºN on eight voyages from 2004 to 2007. The data show large variations in CH_4 mixing ratio in the tropical Western Pacific. Data analysis and model simulations show that these variations are related to the positions and strengths of the South Pacific and Inter-Tropical Convergence Zones suggesting that the complex tropical meteorology associated with these zones plays a major role in the distribution of CH_4 and its transport south from the northern hemisphere in this part of the Pacific.

Relatively large seasonal differences in the inter-hemispheric CH_4 mixing ratio and $\delta^{13}C$ gradients were also observed. During southern spring/summer voyages we measured $\delta^{13}C$ inter-hemispheric gradients of up to 0.5‰. In this situation the Southern Hemisphere always showed more enriched $\delta^{13}C$ values than the Northern Hemisphere which we ascribe to enrichment in ^{12}C of methane remaining in air caused by the action of a kinetic isotope effect involved during the removal of methane from the atmosphere by the hydroxyl radical. Essentially we measured the "aging" of the air as it was transported from methane source regions in the northern hemisphere southwards through the convergence zones. Remarkably the inter-hemispheric gradient in $\delta^{13}C$ reduced to almost zero during southern winter voyages which we attribute to a minimum phase difference between the seasonal cycles of $\delta^{13}C$ in each hemisphere.

Data from the voyages are compared with results from the UMeth general circulation model along two transects, one similar to the ship transects, and another 18.75º to the east. Model simulated results for the western transect were similar to the observations, particularly for $\delta^{13}C$ of CH_4. Although UMeth was run to a steady state with the same sources and sinks each year, the gradient structures varied considerably from year to year. Similar results were obtained for the modeled eastern transect, but details of the variability were different. We conclude that although the El Nino Southern Oscillation (ENSO) cycle has a significant effect on model variability, there is a large component arising from internal variability independent of ENSO, and that the variability seen in the measured data in space and time is a result of the inherent variability of the climate system.