Role of Arctic and Antarctic regions in late Neogene climate evolutions

Osamu Seki[1], Jonaotaro Onodera[2], Akira Oka[3], Minoru Ikehara[4]
[1]*Institute of Lowtemperature Science, Hokkaido Unviersity*
[2]*Japan Agency for Marine-Earth Science and Technology*
[3]*Atmosphere and Ocean Research Institute, University of Tokyo*
[4]*Center for Advanced Marine Core Research, Kochi University*

The climate evolution from the late Miocene (12-5 Ma) to the Plio-Pleistocene (5-0 Ma), which is characterized by a transition from conditions significantly warmer than today (Pound et al., 2011) and nearly ice free in the Northern Hemisphere (Zachos et al., 2001) to the current coldhouse, is one of the most dramatic climatic changes of the late Cenozoic. Scientists have struggled to understand the climatic evolutions from the late Miocene to Plio-Pleistocene (Zachos et al., 2001). However, cause and mechanism of the late Cenozoic cooling are still highly uncertain.

Recent studies revealed dramatic climate reorganization occurred in both high and low latitudes around 2 Ma (Melles et al., 2012; Etourneau et al., 2010), long after the "traditional" Northern Hemisphere Glaciation event (~3 Ma). Present day strong La-Niña condition in tropics and moderate summer climate in Arctic region have been established around 2Ma, which probably linked to increase in meridional temperature gradient due to high latitude cooling (Martinez-Garcia et al., 2010; Etourneau et al., 2010). However, why the dramatic climate event occurs in ca. 2 Ma during the time of relatively stable polar climate has been a long-standing question (Martinez-Garcia et al., 2010) and thus cause and mechanism of the early Pliocene climate reorganization remains enigma.

We refine the alkenone paleo-pCO_2 barometer, revise previously published Miocene to present pCO_2 datasets (Pagani et al., 2010; Seki et al., 2010), and provide additional records that are continuous at a given site over the past 10 Myr. Our refined CO_2 record reveals that, although the change was subtle, strong coupling of pCO_2 and high latitude climate has persisted over the last 10Myr, with a decrease in pCO_2 from 300-360 ppm in the warm late Miocene (prior to 7 Ma) to 260-300 ppm at the Northern Hemisphere Glaciation. We hypothesize that the drawdown of pCO_2 was a consequence of Antarctic Ocean cooling, which was probably caused by progressive shoaling of the Panama Gateway since the late Miocene (Lunt et al., 2008). Thus, Antarctic Ocean played substantial role in the late Neogene cooling. The role of pCO_2 in late Cenozoic cooling is as a positive feedback rather than a driver of the climate change.

From analyses of Bering Sea sediment core (IODP 1341), we found the clear evidence for the intense cooling in the Bering Sea around 2 Ma when sea level was >20 m lower than the present level. We propose that this dramatic cooling is a result of reduced meridional ocean circulation (MOC) in the North Pacific caused by a restriction of ocean flow through Bering Strait. Thus, we hypothesize that limiting Bering Strait flow and subsequent reorganization of Pacific MOC is a fundamental cause for the dramatic cooling in Arctic and the intensification of Walker Circulation at 2 Ma.

References

Etourneau, J., R., Schneider, T., Blanz, and P. Martinez, Intensification of Walker and Hadley atmospheric circulations during the Pliocene-Pleistocene climate transition, Earth Planet. Sci. Lett. 297, 103-110, 2010.
Lunt, D.J., Valdes, P.J., Haywood, A. and Rutt, I.C., Closure of the Panama Seaway during the Pliocene: implications for climate and Northern Hemisphere glaciation, Clim. Dyn., 30, 1-18, 2008.
Martinez-Garcia, A., A., Rosell-Melé, E.L., McClymont, R., Gersonde, and G.H., Haug, Subpolar link to the emergence of the modern Equatorial Pacific cold tongue, Science 328, 1550-1553, 2010.
Melles, M. et al., 2.8 million years of Arctic climate change from Lake El'gygytgyn, NE Russia, Science, 337, 315-320 (2012).
Pagani, M., Z. Liu, J. LaRiviere, and A.C. Ravelo, High Earth-system climate sensitivity determined from Pliocene carbon dioxide concentrations, Nature Geosci., 3, 27-30, 2010.
Pound, M. J. et al. A Tortonian (Late Miocene, 11.61–7.25 Ma) global vegetation reconstruction, Palaeogeogr. Palaeoclimatol. Palaeoecol., 300, 29–45, 2011.
Seki, O., G.L., Foster, D.N. Schmidt, A. Mackensen, K. Kawamura, R.D. Pancost, Alkenone and boron-based Pliocene pCO_2 records, Earth Planet. Sci. Lett., 292, 201–211, 2010.
Zachos, J., M., Pagani, L., Sloan, E. Thomas, and K. Billups, Trends, Rhythms, and Aberrations in Global Climate 65 Ma to Present, Science 292, 686-693, 2001.