The role of climate-vegetation feedback in climate changes driven by orbital parameter changes: the Arctic land surfaces and seasonality

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Periodic summer insolation change accompanying Earth's orbital parameter changes is widely known as a main driver of the glacial cycles. Realistic orbital parameters are prescribed with climate models and ice-sheet models to reproduce and explain the characteristic of the glacial cycles in past several hundred thousand years(e.g. Abe-Ouchi et al., 2007; 2013). On the other way, radiative feedback analyses at the top of the atmosphere enable to understand the Earth's climate response to the orbital forcing (Mantsis et al., 2011; Erb et al., 2013). In this study, we investigate the surface climate responses to the orbital forcing, by using MIROC-GCM and a surface climate feedback analyses method. We focus on the relationship between summer insolation and summer temperature on the land in the northern high latitude, since the former is a major index and the later is important for the ice-sheets melt.

We use a coupled atmosphere-vegetation GCM with slab ocean of MIROC-GCM (O'ishi and Abe-Ouchi, 2011) and performed numerous experiments by systematically changing the combinations of orbital parameters (maximum, minimum and present values of each parameter). A seasonal surface feedback analysis method (Lu and Cai, 2009) is also applied.

Results show that summer temperature change over the Arctic land due to obliquity change can be larger than that due to precession-eccentricity change, when the summer insolation maxima are the same. The results also show that the different efficiency is mainly caused by vegetation feedback with a meridional shift of a tundra-boreal forest boundary. In the northern high latitude, insolation change due to the summer solstice at the perihelion has a typical pattern of seasonality (increased in the mid-summer decreased in the spring and autumn) with no annual-mean component. This seasonality is unfavorable for snow melt in the spring (hence delay the melt) and surface albedo feedback, which accompany cooling in the spring and prevent boreal forests from growing. On the other hand, insolation change due to large obliquity has the other pattern of seasonality (increased the insolation in half a year) with increased annual mean insolation. This seasonality is favorable for the snow melt (hence promote the melt) and surface albedo feedback, which accompany warming throughout the year and assist the growing. These differences cause that obliquity changes promote vegetation-snow-albedo feedback stronger than precession-eccentricity changes.

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