１０万年周期氷期間氷期サイクルと数千年スケール気候変動
～氷床変動ヒステリシスの役割～

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Insolation-driven 100 kyr glacial cycles and millennial climate change

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The waxing and waning of Northern Hemisphere ice sheets over the past one million years is dominated by an approximately 100-kyr periodicity and a sawtooth pattern (gradual growth and fast termination). Milankovitch theory proposes that summer insolation at high northern latitudes drives the glacial cycles, and statistical tests demonstrated that the glacial cycles are indeed linked to eccentricity, obliquity and precession cycles. However, insolation alone cannot explain the strong 100 kyr cycle which presumably arises through internal climatic feedbacks. Prior work with conceptual models, for example, showed that glacial terminations are associated with the build-up of Northern Hemisphere "excess ice", but the physical mechanisms of 100-kyr cycle at work remain unclear. Here, using comprehensive climate and ice sheet models, we show that the ~100-kyr periodicity is explained by insolation and internal feedback amongst the climate, ice sheet and lithosphere/asthenosphere system (reference). We found that equilibrium states of ice sheets exhibit hysteresis responses to summer insolation, and that the shape and position of the hysteresis loop play a key role in determining the periodicities of glacial cycles. The hysteresis loop of the North American ice sheet is such that, after its inception, the ice sheet mass balance remains mostly positive or neutral through several precession cycles whose amplitude decreases towards an eccentricity minimum. The larger the ice sheet grows and extends towards lower latitudes, the smaller is the insolation required to turn the mass balance to negative. Therefore, once the large ice sheet is established, only a moderate increase in insolation can trigger a negative mass balance, leading to a complete retreat within several thousand years, due to the delayed isostatic rebound. The effect of ocean circulation and millennial scale climate change are not playing the dominant role for determing the 100kyr cycle, but are effective for modifying the speed and geographical pattern of the waxing and waning of the Northern Hemisphere ice sheets and their melt water.

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