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A cooling event during the last geomagnetic reversal: climate change affected by variations of geomagnetic field

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One of the main goals of climatology is to reveal the factors which invoke the Earth's climate. In recent years, the effect of low-level clouds which is induced by cosmic ray (CR) is highly discussed in addition to the primary factors such as insolation and air-ocean circulation. CR flux into the Earth is modulated by the shielding effect of geomagnetic field. During the geomagnetic reversal, the decline of the shielding effect causes an increase in CR flux, which would raise cloud cover (Svensmark effect) and at last Earth's planetary albedo. Therefore, cooling can be caused by variation in geomagnetic field intensity. In this study, we reconstruct and quantify the climate change to examine a link between geomagnetic field intensity and climate based on pollen analysis. In early MIS 19, the proportion of the warm-temperate evergreen broad-leaved taxon Quercus (Cyclobalanopsis) gradually increased as sea level rose, indicating a progressive warming. However, after ca. 2 kyr of warming, a cooling began with an abrupt reduction in Quercus (Cyclobalanopsis) and an increase in Fagus (cool-temperate deciduous broad-leaved taxon). The cooling persisted for about 4 kyr coincident with the sea-level highstand 19.3, was followed by a rapid warming and reached thermal maximum of MIS 19. This cooling event, during the highest sea-level highstand contrasts with the climates of MISs 21, 17, 11 and 1 when the thermal maxima coincided with the highest sea-levels. In addition, the cooling event within MIS 19 is not consistent with an insolation peak. Compared the climate to the relative paleointensity record, the period of cooling is confined during an interval when the geomagnetic field intensity was lower than 30% of its normal value. During this time, the global relative paleointensity data of Sint-800 also shows its lowest values of 10-30%. In addition, the cooling also coincides with the early stage of the broad low in the high-resolution paleointensity record from the North Atlantic. When we convert the paleomagnetic intensity proxy into cosmogenic radionuclide production rate or CR flux proxy controlled by geomagnetic field, an increase of about 80% in CR flux is estimated for a geomagnetic field intensity decrease to 30%, and the flux increases up to 120% when the geomagnetic intensity has the lowest value (ca. 20%). After that, Fagus/Quercus (Cyclobalanopsis) decreased/increased, showing the climate turned to warm, with decrease in CR flux accompanied by the field intensity recovery. An increase of 80-120% in cosmic ray flux corresponds to about 2-3 deg C cooling effect based on the cloud radiative forcing over the past century. During this period of cooling, a drop of 3.5 deg C in mean annual temperature was estimated by applying the modern analogue technique to our palynological data. At the same time, the biome changes from broad-leaved evergreen warm-mixed forest into temperate deciduous forest, the quantitative vegetation also supports the occurrence of the cooling. Consequently, this cooling was probably caused by an increase in albedo due to an increase of cloud cover that results from an increase in the CR flux due to variation of geomagnetic intensity. This result would be an evidence of that the correlation between CR and cloud affects the climate through the Earth's magnetic field. At the same time of the cooling, the relatively cool climate is also observed in the palynological records from Italy, central Japan and Colombia. Hence, the cooling event would occur in at least low-middle latitude. The cooling event occurred with the large decrease in

geomagnetic field intensity during the MB reversal suggests that the geomagnetic field can affect the Earth's climate through the modulation in CR flux. If the link between geomagnetism and climate is universal, it is apparent that the geomagnetic field would play an important role in the long-term climate changes, and also be a critical factor in future climate prediction.

Keywords: Svensmark effect, Cosmic ray, Paleoclimate, Geomagnetic polarity reversal, Cooling