Supplement of Earth Surf. Dynam., 10, 997–1015, 2022
https://doi.org/10.5194/esurf-10-997-2022-supplement

Earth Surface Dynamics
Open Access
EGU

Supplement of

The effects of late Cenozoic climate change on the global distribution of frost cracking

Hemanti Sharma et al.

Correspondence to: Todd A. Ehlers (todd.ehlers@uni-tuebingen.de)

Supplementary material

1. Model 1: FCI as a function of frost cracking window (FCW)

In Model 1, the FCI is calculated as a function of the number of days bedrock spent in frost cracking window (between -8℃ to -3℃), and ranges between 0 to 155 days a year for all the time slices considered (Fig. 6). The highest values are observed in mid to high-latitudes ($30°N - 60°N$ *and* $30°S - 60°S$) and coincide with ground surface MATs ranging between −10 °C and 5 °C. This is the case in all time-slices as frost cracking intensity is highly dependent on MAT. In the Pliocene, the warmest of investigated climates, the maximum in FCI values are found Polar Regions.

A prominent band of frost cracking is observed for the PI and MH simulations (yellow regions, Fig. 6) on the North American and Eurasian continents in the latitudinal range of 35 °N – 80 °N and 30 °N – 80 °N respectively. Here, the FCI values are ~120 - 130 days between 50 °N and 70 °N for the North America and 45 °N and 70 °N for Eurasia. Regions to the north or south of this band of high FCI values have lower values because the temperatures are cooler or warmer, respectively, than the frost cracking window. The highest FCI values occur in eastern margin of the Tibetan Plateau (~150 days). For South America, low values of FCI are observed in the Andes Mountains and range from 0 to 25 days between 15°S and 50°S. Also, small values (15 – 30 days) are observed on the periphery of Antarctica.

In the LGM, there were ice sheets for most of North America and Europe. The highest FCI values (~105 days) can be observed in the mid- to high latitudes of North Eurasia (40 °N – 60 °N). For South America, frost cracking is observed between 15 °S and 50 °S with lower values of FCI in the north (~25 - 65 days).

In the Pliocene, North America (55 °N – 80 °N) and Eurasia (45 °N – 80 °N) contain high FCI values of up to ~120 days, with the highest values located again on the eastern margin of the Tibetan Plateau (~155 days). In contrast to other time-slices, high FCI values are observed in southern Greenland (~130 days), and lower values in the north (~ 30 – 50 days) due to the cooler temperatures there (more often below the frost cracking window). In South America, lower values (~10 – 30 days) are predicted in the LGM, and higher values along the western periphery of Antarctica.

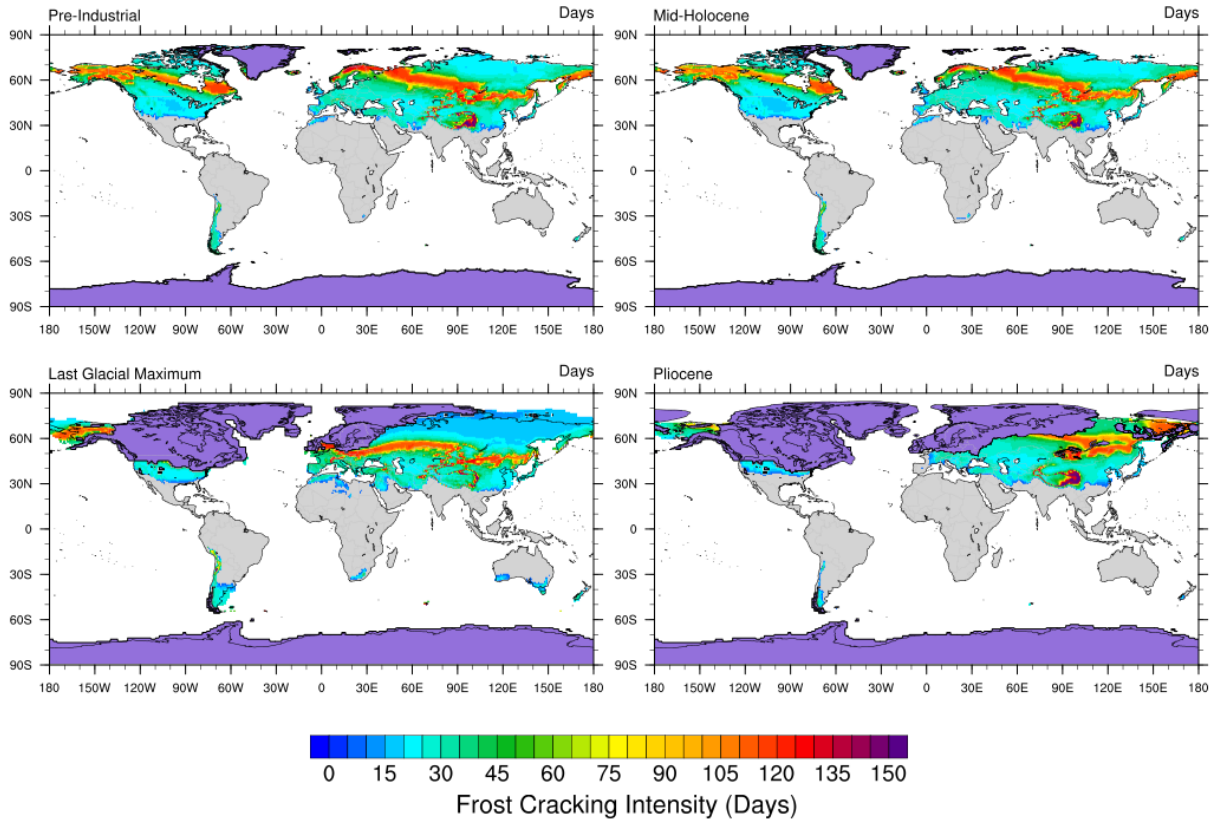

Figure S.1. Predicted days in the FCI (Model 1) determined by the number of days spent in frost cracking window (-8 °C - -3 °C) for Pre-Industrial (top-left), Mid-Holocene (top-right), Last Glacial Maximum (bottom-left), and Pliocene (bottom-right) times (unit: °C m). The grey areas in plots indicates the absence of frost cracking. For all time slices, the regions covered by ice were removed from the calculation and are highlighted in violet color (Bracannot et al., 2012). For the PLIO results, the maximum Quaternary ice extent (Batchelor et al., 2019) is used, since the assumption of modern soil depth is heavily violated in these regions.

2. Model 2: FCI as a function of thermal gradient

The FCI observed in Model 2 is in the range of 0 – 1400 ℃ from 30 °N – 80 °N and 20 °S – 80 °S for all time-slices (Fig. 7). Similar to Model 1, in Model 2 the maximum values are observed as band of high values across the mid to high latitudes (30 °N – 60 °N and 30 °S – 60 °S), coinciding with MAT values in the range of (−10℃ – 5℃). These areas cover much of northern Asia. The highest values are observed in western Russia and Northern China (850℃ – 1050℃).

In the PI and MH simulations, the regions marked by high potential for frost cracking (with FCI up to ~ 900°C) include North America (40 °N – 60 °N) and Eurasia (30 °N – 60 °N). FCI values in the Andes Mountains in South America (15 °S – 50 °S) and western periphery of Antarctica (180 °W – 0 °W) range between ~150 °C and 400 °C. Also, the periphery of Greenland exhibits FCI values of ~200 °C.

In the LGM simulation, the highest FCI values are observed in North America (35 °N – 45 °N) and Eurasia (35 °N – 55 °N) with the values ranging between ~ 400 °C – 900 °C. Also, high FCI values are observed for South America (15 °C – 55 °C) and New Zealand and range between ~100 °C and 800 °C. Low values of FCI (~ 0 – 200 °C) are observed in the northern and southern Africa and Australia.

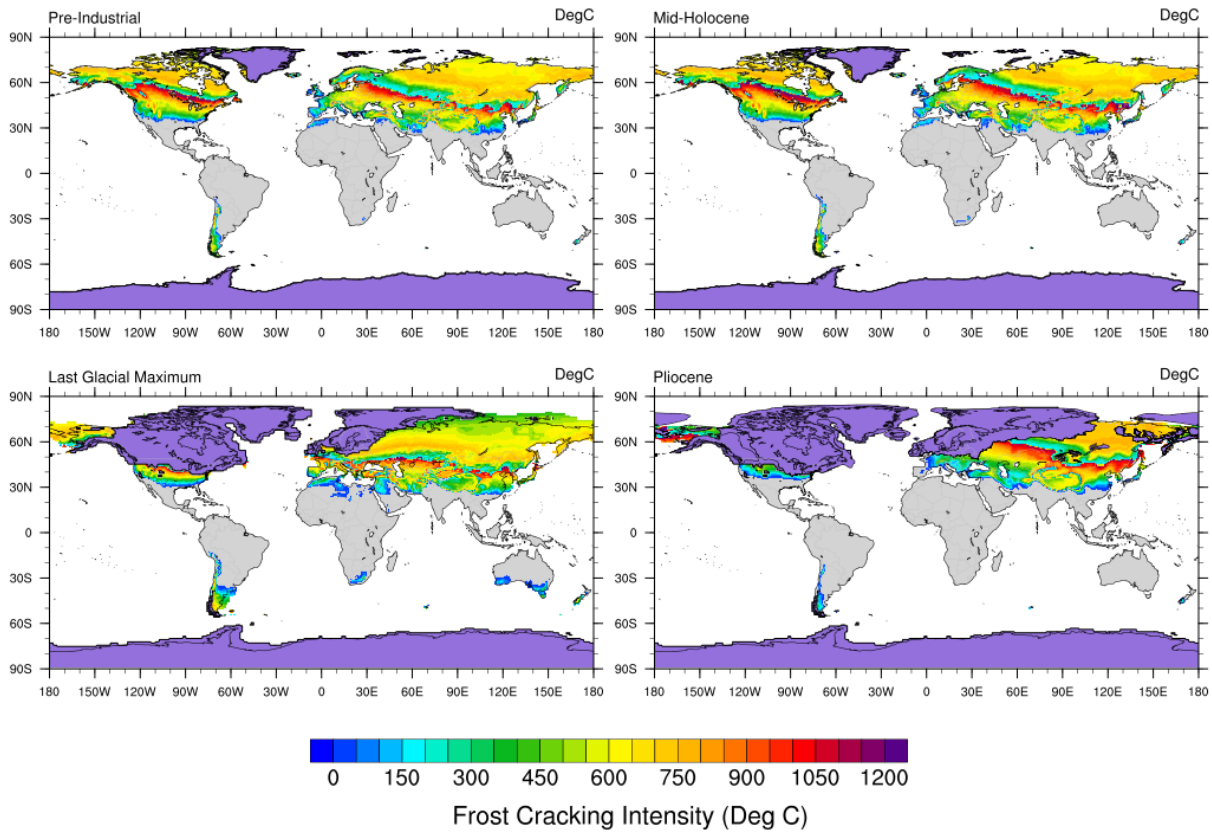

Figure S.2. Model 2 output with Integrated FCI as a function of thermal gradient of the bedrock for Pre-Industrial (top-left), Mid-Holocene (top-right), Last Glacial Maximum (bottom-left), and Pliocene (bottom-right) times (unit: °C). The grey areas in plots indicates the absence of frost cracking. For all time slices, the regions covered by ice were removed from the calculation and are highlighted in violet color (Bracannot et al., 2012). For the PLIO results, the maximum Quaternary ice extent (Batchelor et al., 2019) is used, since the assumption of modern soil depth is heavily violated in these regions.

For the Pliocene, similar to Model 1, the highest FCI values are observed in higher latitudes in North America and Eurasia (~950 °C), and Greenland shows high values of ~ 200 °C – 650 °C. Low FCI values are observed in South America and the periphery of Antarctica (~ 0 °C – 200 °C).