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Interhemispheric concentration gradient of CH_4 around the last glacial maximum (20-30 kyr BP) and attenuation of the atmospheric signal due to enclosure process in the ice

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The natural emissions of the greenhouse gas methane (CH_4) occur to a major part in the wetlands of the tropical regions. However, when the northern hemisphere is warming during glacial/interglacial and stadial/interstadial transitions, a northern higher latitude source becomes important too. On contrary, southern emissions are small since the ocean is no important CH_4 source. In the polar ice sheets of Greenland and Antarctica air is enclosed providing a unique climate archive of the past atmospheric composition. The rapid and large variations of the greenhouse gas CH_4 are useful to perform synchronization between different climate records, e.g. polar ice core records from Greenland and Antarctica. This is possible because greenhouse gases are well mixed over the whole globe with an interhemispheric mixing time of 1 – 2 years. However, the mean atmospheric lifetime of CH_4 (about 10 years) is only an order of magnitude higher than the mixing time. Combined with the asymmetric source distribution this leads (in certain time intervals) to a significant interhemispheric concentration gradient of CH_4.

We present 392 new CH_4 measurements from the ice cores of the North Greenland Ice Core Project (NGRIP) and the European Project for Ice Coring in Antarctica Dronning Maud Land (EDML) in the time interval 20,000 – 30,000 years before present (BP) around the Last Glacial Maximum (LGM) including the Dansgaard Oeschger events (DO) 2, 3 and 4. The time resolution is better than 70 years on the EDML1 timescale for both, the NGRIP and EDML records. Since the measurements are performed in one lab and Greenland and Antarctic ice samples have been measured in parallel within the same measurement series, any systematic offsets between the two records can be excluded. The measurements allow for a better synchronization in this time interval, where CH_4 variations are relatively small, as well as a precise determination of the interhemispheric concentration gradient. At NGRIP, CH_4 is stabilized at 410 ppbv just after DO3 followed by a fast drop down to 380 ppbv and a slow increase back to 400 ppbv before DO2. At EDML, a slow decrease occurs after DO3 down to 365 ppbv where it stays stable until the onset of DO2, apart from a small bump of about 5 ppbv. Therefore the gradient is about 25 ppbv before DO4, decreases from 25 ppbv to 15 ppbv after DO3, then slowly increases up to 35 ppbv just before DO2 and finally achieves a value of about 10 ppbv after DO2.

In order to determine the gradient over fast variations like DO2, 3 and 4, it is necessary to calculate the attenuation of the atmospheric signal due to diffusive mixing in the firn column and gradual bubble close-off in both, the NGRIP and EDML sites. We apply a firn diffusion model to our data to take care of this effect. Based on the information of the interhemispheric concentration gradient, a three-box model is applied in order to estimate the source distribution of CH_4.