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Application of trajectory clustering and source attribution methods for investigating regional CO_2 and CH4 concentrations at Germany's highest mountain site

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Carbon dioxide (CO_2) and methane (CH4) represent the most important contributors to increased radiative forcing enhancing it together by contemporary 2.65 W/m2 on the global average (IPCC 2013). The unbroken increase of atmospheric greenhouse gases (GHG) has been unequivocally attributed to human emissions mainly coming from fossil fuel burning and land-use changes, while the oceans and terrestrial ecosystems slightly attenuate this rise with seasonally varying strength. Short-term fluctuations in the GHG concentrations that superimpose the seasonal cycle and the climate change driven trend reflect the presence of regional sources and sinks. A perfect place for investigating the comprehensive influence of these regional emissions is provided by the Environmental Research Station Schneefernerhaus (47.42°N, 10.98°E, 2.650m a.s.l.) situated in the eastern Alps at the southern side of Zugspitze mountain. Located just 300m below the highest peak of the German Alps, the exposed site is one of the currently 30 global core sites of the World Meteorological Organisation (WMO) Global Atmosphere Watch (GAW) programme and thus provides ideal conditions to study source-receptor relationships for greenhouse gases.

We propose a stepwise statistical methodology for examining the relationship between synoptic-scale atmospheric transport patterns and climate gas mole fractions to finally receive a characterization of the sampling site with regard to the key processes driving CO_2 and CH4 concentration levels. The first step entails a reliable radon-based filtering approach to subdivide the detected air masses according to their regional or 'background' origin. Simultaneously, a large number of ten-day back-trajectories from Schneefernerhaus every two hours over the entire study period 2011 – 2015 is calculated with the Lagrangian transport and dispersion model FLEXPART (Stohl et al. 2005) and subjected to cluster analysis. The weather- and emission strength-related (short-term) components of the regional CO_2 and CH4 concentration time-series are assigned to the back-trajectory clusters. The significant differences in the greenhouse gases' distributions associated with each cluster are confirmed by the non-parametric Kruskal-Wallis test thereby delivering the prerequisites for further investigations, in particular by Potential Source Contribution Functions for the detection of probable locations of within-cluster emission sources. The advantages of this comprehensive approach are site-specificity (by considering trajectories arriving at Schneefernerhaus as well as a site-appropriate filter method) and concentration-specificity (each greenhouse gas has its own source regions) combined with granting the space and time scales related to the synoptic flow patterns in source attribution studies.

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