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Lagrangian transport and inverse emission modeling of non-CO_2 greenhouse gases in Europe

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Lagrangian models, which track the movement of fluid parcels in their moving frame of reference, have gained in popularity and sophistication over the past few decades. More recently, Lagrangian models, in particular the class of Lagrangian Particle Dispersion Models (LPDMs), have demonstrated their great potential in the context of inverse emission estimation as the Lagrangian framework provides a simple means to establish the relationship between receptor (measurement) locations and upstream sources. We will first briefly summarize the basic concepts of LPDMs, their application in forward and backward mode, and their use in inverse modeling. We will then present several examples of inverse emission estimation of non-CO_2 greenhouse gases and ozone depleting substances. The main transport modeling tool is the Lagrangian Particle Dispersion Model FLEXPART which was driven either with meteorological fields of the global IFS model of ECWMF or, in an adapted and augmented version, with high-resolution fields of the mesoscale weather forecast model COSMO. Using ECMWF meteorology, FLEXPART was applied to quantify European halocarbon emissions based on measurements at Jungfraujoch, Mace Head and a few other sites in Europe. While for some compounds our estimates were in good agreement with officially reported numbers, we also identified important examples of large discrepancies. FLEXPART was also applied at smaller scales to study anthropogenic and semi-natural methane emissions in Switzerland. For this purpose, it was driven by high-resolution fields of the COSMO model and combined with observations from a small aircraft and from a new measurement network recently established in Switzerland. We will compare our independently estimated methane emissions with the numbers presented in the Swiss National Inventory Report.