Atmos. Chem. Phys., 3, 1023-1035, 2003
www.atmos-chem-phys.net/3/1023/2003/

Constraining tropospheric mixing timescales using airborne observations and numerical models

P. Good[1], C. Giannakopoulos[1], F. M. O'Connor[2], S. R. Arnold[3], M. de Reus[4], and H. Schlager[5]
[1]National Observatory of Athens, Greece
[2]Centre for Atmospheric Science, Cambridge, UK
[3]School of the Environment, University of Leeds, UK
[4]Max-Planck-Institute for Chemistry, Atmospheric Chemistry Department, Mainz, Germany
[5]German Aerospace Center, Institute of Atmospheric Physics, Oberpfaffenhofen, Germany

Abstract. A technique is demonstrated for estimating atmospheric mixing time-scales from in-situ data, using a Lagrangian model initialised from an Eulerian chemical transport model (CTM). This method is applied to airborne tropospheric CO observations taken during seven flights of the Mediterranean Intensive Oxidant Study (MINOS) campaign, of August 2001. The time-scales derived, correspond to mixing applied at the spatial scale of the CTM grid. They are relevant to the family of hybrid Lagrangian-Eulerian models, which impose Eulerian grid mixing to an underlying Lagrangian model. The method uses the fact that in Lagrangian tracer transport modelling, the mixing spatial and temporal scales are decoupled: the spatial scale is determined by the resolution of the initial tracer field, and the time scale by the trajectory length. The chaotic nature of lower-atmospheric advection results in the continuous generation of smaller spatial scales, a process terminated in the real atmosphere by mixing. Thus, a mix-down lifetime can be estimated by varying trajectory length so that the model reproduces the observed amount of small-scale tracer structure. Selecting a trajectory length is equivalent to choosing a mixing timescale. For the cases studied, the results are very insensitive to CO photochemical change calculated along the trajectories. That is, it was found that if CO was treated as a passive tracer, this did not affect the mix-down timescales derived, since the slow CO photochemistry does not have much influence at small spatial scales. The results presented correspond to full photochemical calculations. The method is most appropriate for relatively homogeneous regions, i.e. it is not too important to account for changes in aircraft altitude or the positioning of stratospheric intrusions, so that small scale structure is easily distinguished. The chosen flights showed a range of mix-down time upper limits: a very short timescale of 1 day for 8 August, due possibly to recent convection or model error, 3 days for 3 August, probably due to recent convective and boundary layer mixing, and 6-9 days for 16, 17, 22a, 22c and 24 August. These numbers refer to a mixing spatial scale of 2.8°, defined here by the resolution of the Eulerian grid from which tracer fields were interpolated to initialise the Lagrangian model. For the flight of 3 August, the observed concentrations result from a complex set of transport histories, and the models are used to interpret the observed structure, while illustrating where more caution is required with this method of estimating mix-down lifetimes.

Final Revised Paper (PDF, 862 KB)   Discussion Paper (ACPD)

Citation: Good, P., Giannakopoulos, C., O'Connor, F. M., Arnold, S. R., de Reus, M., and Schlager, H.: Constraining tropospheric mixing timescales using airborne observations and numerical models, Atmos. Chem. Phys., 3, 1023-1035, 2003.   Bibtex   EndNote   Reference Manager