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Numerical uncertainty at mesoscale in a Lagrangian model in complex terrain

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Recently, it has been shown that mass conservation in Lagrangian models is improved by using time-average winds out of Eulerian models. In this study, we evaluate the mass conservation and trajectory uncertainties in complex terrain at mesoscale using the FLEXPART Lagrangian particle dispersion model coupled with the WRF mesoscale model. The specific form of vertical wind used is found to have a large effect. Time average wind with time average sigma dot, instantaneous wind with geometric cartesian vertical wind (w) and instantaneous wind with sigma dot are used to simulate mixing ratios of a passive tracer in forward and backward runs using different time interval outputs and horizontal resolutions in California. Mass conservation in the FLEXPART model was not an issue when using time-average wind or instantaneous wind with sigma dot. However, mass was poorly conserved using instantaneous wind with w, with a typical variation of 25% within 24 h.

Uncertainties in surface residence time (a backtrajectory product commonly used in source receptor studies or inverse modeling) calculated for each backtrajectory run were also analyzed. The smallest uncertainties were systematically found when using time-average wind. Uncertainties using instantaneous wind with sigma dot were slightly larger, as long as the time interval of output was sufficiently small. The largest uncertainties were found when using instantaneous wind with w. Those uncertainties were found to be linearly correlated with the local average gradient of orography. Differences in uncertainty were much smaller when trajectories were calculated over flat terrain. For a typical run at mesoscale in complex terrain, 4 km horizontal resolution and 1 h time interval output, the average uncertainty and bias in surface residence time is, respectively, 8.4% and -2.5% using time-average wind, and 13% and -3.7% using instantaneous wind with sigma dot in complex terrain. The corresponding values for instantaneous wind with cartesian w were 24% and -11%.

While the use of time-average wind systematically improves uncertainty in FLEXPART, the improvements are small, and therefore a systematic use of time-average wind in Lagrangian models is not necessarily required. Use of cartesian vertical wind in complex terrain, however, should be avoided.