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# On the parallelization of atmospheric inversions of $CO_2$ surface fluxes within a variational framework

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Abstract. The variational formulation of Bayes' theorem allows inferring $CO_2$ sources and sinks from atmospheric concentrations at much higher time–space resolution than the ensemble or analytical approaches. However, it usually exhibits limited scalable parallelism. This limitation hinders global atmospheric inversions operated on decadal time scales and regional ones with kilometric spatial scales because of the computational cost of the underlying transport model that has to be run at each iteration of the variational minimization. Here, we introduce a physical parallelization (PP) of variational atmospheric inversions. In the PP, the inversion still manages a single physically and statistically consistent window, but the transport model is run in parallel overlapping sub-segments in order to massively reduce the computation wall-clock time of the inversion. For global inversions, a simplification of transport modelling is described to connect the output of all segments. We demonstrate the performance of the approach on a global inversion for $CO_2$ with a 32 yr inversion window (1979–2010) with atmospheric measurements from 81 sites of the NOAA global cooperative air sampling network. In this case, we show that the duration of the inversion is reduced by a seven-fold factor (from months to days), while still processing the three decades consistently and with improved numerical stability.

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