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Application of the flux noise reducing filter for CO_2 inverse modelling

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Recent atmospheric remote sensing products from AIRS and GOSAT provide large volume of the observations but with larger errors and variance as compared to in-situ measurements, so efficient noise reduction techniques are required for inverse modeling of the surface fluxes. Inverse models of the atmospheric transport optimize regional or grid resolving surface CO_2 fluxes to fit transport model simulation optimally to the observations. The optimization problem appears to be ill-posed so it is usually solved by applying regularization techniques. Most widely used regularization methods apply constraints on flux deviation from prior and/or from adjacent regions of same surface type (land-ocean, vegetation type), and from adjacent time periods. Convenient method for solving the problem of limited dimension is based on singular value decomposition (SVD) of the transport matrix, because it can decompose the solution space into a combination of the independent singular vectors. Introducing a simple constraint on fluxes limits amplitude of the corresponding singular vectors with larger reduction for smaller singular values. However this amplitude reduction is not sufficient in practice for inverse modeling of the regional CO_2 fluxes, when we have large underconstrained regions in tropics. Alternatively other means of the amplitude reduction are also used, such as truncation, when all amplitudes below threshold singular value are set to zero. We apply a filter which is less abrupt is less abrupt compared to truncation but still suppressing strongly small singular value related vectors. Setting strength of a constraint is often done empirically. To decide a proper value of the cut-off singular value we suggest analyzing a dependence of the singular vector amplitude vs the singular value and set the cut-off value aiming at retaining most of useful information from observation. A graphical tool based on a plot of amplitude spectra is proposed. Advantage of the technique is demonstrated by applying it to optimization of the model-simulated CO_2 seasonality at the Globalview observation network using Transcom-3 simulated transport matrixes. As compared to using a Transcom-3 constraint our filter produces smoother seasonal variations for fluxes with a minor impact on model fit with the observations. At the same time, retrieved flux variability at the regions with weak signal at observation sites is strongly suppressed. Applying a filter combined with iterative optimization procedure leads to faster convergence to the optimal flux solution compared to use of the SVD for larger size problems such as batch inversion of the interannually varying regional fluxes. The approach is extended to iterative optimization of the large dimension problems involving use of the adjoint operator of the atmospheric transport instead of precalculated transport matrix.