



Invers Modelling of energy transports and -budgets of the atmosphere

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The horizontal divergence of the vertically integrated horizontal atmospheric energy transports should, in theory, balance the vertically integrated energy budget in the atmosphere under stationary conditions. This balance is not achieved e.g. when combining horizontal transports derived from ERA-40 and ERA-Interim with radiative fluxes at the top and the bottom of the atmosphere from ISCCP and vertical turbulent transports at the surface again from ERA-40 /ERA-Interim data sets. Partly the imbalance it can be explained from the calculation of the vertically averaged energy transport divergence contaminated by spurious pressure tendencies in the reanalysis. The usually applied corrections to reduce these pressure tendencies do not solve this problem. We therefore chose a different approach by solving a discrete constraint optimization problem by modifying jointly the horizontal energy transports and the vertically averaged atmospheric energy budget energy subjected to the constraint to fulfil the balance between the transport divergence and the budget at each grid point exactly. The solution can be readily computed using a spherical harmonics discretization. Several similar approaches for flux corrections can be found in the literature, but they all focus on correcting the mass flux and calculating the energy flux from these corrected mass fluxes. We are applying the variational approach directly to the energy fluxes without concerning for the mass flux. Additionally, by applying the variational approach we are able to derive the posterior covariance matrices for the energy transport and the energy budget, thereby providing a measure of the uncertainty of the previous calculation. Furthermore, we can use these posterior covariance matrices to give an estimate of the uncertainty of the meridional heat flux and the zonally averaged energy budget in the atmosphere.

We present the mathematical basis including the modelling of the prior errors, but will focus on the results of the above mentioned calculations. We compare results using ERA-40 and ERA-Interim fields in combination with the radiative energy fluxes from ISCCP with our corrected results and present balanced transports and their uncertainty estimates of the zonally averaged energy budget and the meridional energy transport.