abstract

Eugene A. Ustinov

Sensitivity analysis of radiative heating and cooling rates in planetary atmospheres: general linearization and adjoint approaches

Radiative heating and cooling provide primary source and ultimate sink of energy driving lower planetary atmospheres. Corresponding heating and cooling rates represent important inputs of the models of atmospheric dynamics. In their turn, these rates are outputs of corresponding radiative transfer models where the inputs are fields of primary atmospheric parameters, such as temperature, mixing ratios of greenhouse gases, etc. Evaluation of sensitivities of outputs of models of atmospheric dynamics on these primary atmospheric parameters requires knowledge of sensitivities of heating and cooling rates on these same parameters. We discuss two approaches which make it possible to directly compute the sensitivities of heating and cooling rates in parallel with evaluation of heating and cooling rates themselves.

For non-scattering atmospheres, the heating and cooling rates can be evaluated analytically. In this case, sensitivities to atmospheric parameters are obtained by straightforward linearization of corresponding analytic expressions. For scattering atmospheres (e.g., with scattering aerosol and/or clouds) the heating and cooling rates can, in general case, be obtained only from the numerical solution of the corresponding forward problem of radiative transfer. It turns out that the solution of corresponding adjoint problem, obtained in parallel with its forward counterpart, can be used to evaluate sensitivities of heating and cooling rates with respect to atmospheric parameters.

An analogy with evaluation of weighting functions in remote sensing is pointed out and applications to the sensitivity analysis of models of atmospheric dynamics are discussed.