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Direct linearization and adjoint approaches to evaluation of atmospheric weighting functions and surface partial derivatives: general principles, synergy, and areas of applications

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In remote sensing, atmospheric weighting functions (WFs) are, by their physical meaning, the sensitivities of the observed radiances to atmospheric parameters, which are the functions of vertical coordinate in the atmosphere. Similarly, surface partial derivatives (PDs) are sensitivities of the observed radiances to surface parameters. Fast and accurate evaluation of these sensitivities is crucial to the performance of retrieval algorithms of remote sensing.

For non-scattering atmospheres, the observed radiances can be modeled by closed-form analytic expressions through relevant atmospheric and surface parameters. Then, explicit expressions for both WFs and PDs can be obtained by direct linearization of these radiances with respect to desired parameters. For scattering atmospheres, we promote using the adjoint approach resulting in explicit expressions for WFs and PDs through solutions of the forward and adjoint radiative transfer (RT) problems for a given model of the atmosphere/surface system.

There is a substantial synergy in using these two approaches. In both cases, the specific RT computations are actually limited to evaluation of intermediate radiative WFs and PDs with respect to those few radiative parameters that directly enter the forward RT problem. With the exception of the RT computations, the retrieval algorithms are essentially independent on the approach used. Also, the use of the concept of source function in the adjoint approach makes the RT formalisms themselves similar for non-scattering and scattering cases. This provides additional synergy of retrieval

algorithms for these two approaches.

The direct linearization approach for non-scattering atmospheres, and the adjoint approach for scattering atmospheres can be used in essentially all applications of remote sensing, including but not limited to solar/thermal spectral regions, nadir/limb/upward viewing geometries, and cases of scalar/vector radiation. Currently, very few research groups around the world are using the adjoint approach in practical applications of remote sensing. But because of its general nature, the adjoint approach, as well as the direct linearization approach will certainly see more applications in coming years.