

Testing of techniques for error analysis in assimilation of cloudy radiances

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A one-dimensional variational assimilation (1DVAR) method is used to simulate retrievals of liquid cloud mixing ratio and concentration profiles from simulated radiances at three wavelengths. Channels 1, 2, and 4 of the Geostationary Operational Environmental Satellite (GOES) are used in the simulation (0.63 μm , 3.92 μm , and 10.7 μm respectively). This 1DVAR method employs the forward and adjoint models of SHDOMPPDA (a plane-parallel radiative transfer model derived from the spherical harmonic discrete ordinate method (SHDOM)).

For these simulations, a cloud field generated with a Regional Atmospheric Modeling System (RAMS) is used as the input to the radiative transfer model. An X-Z slice is taken from this three-dimensional cloud field and one column of this slice is chosen for a particular run. This column represents the true cloud profile in the simulation, and also provides the profiles for the radiance simulation in the model.

A series of error analysis techniques are applied to the retrieved columns. In each experiment, the retrieval error is defined as the difference of the “true” atmosphere and the retrieved atmosphere. For each column chosen, an average over sixty retrievals is used to compute error statistics such as mean, median, standard deviation, and root mean square error. A variety of columns are chosen, representing both cloudy and clear atmospheres.

In the first experiment, random Gaussian noise is added to the simulated radiances before performing the retrieval. In the second experiment, simulated radiances from a neighboring column were used instead of the radiances for the column being retrieved. The neighboring columns were chosen randomly and lie within ten columns on either side of the chosen column. For the third experiment, the model is assumed to be linear and the theoretical error is calculated using linear theory, using the observation error covariance and the background error covariance matrices. The diagonal elements of the resulting retrieval error covariance matrix represent the theoretical variance of the chosen column.

In the fourth experiment, the ensemble approach is used to add error to the state vector. The eigenvalues are multiplied by their corresponding eigenvectors in addition to a random Gaussian number. A sum is taken over all the eigenvalues and the resulting vector is added to the mean background state. The resulting vector is used as the initial guess for the cloud mixing ratio and number concentration rather than having the mean background as the initial guess, as was done in the previous experiments.

In comparing each experiment to the first, it is seen that experiments one and two are very similar to each other, as was expected. The theoretical error calculated as in experiment three is significantly less than the actual error obtained in the first experiment. This is in part due to the assumption of linearity made in the third experiment. The background error covariance matrix is also poorly known, contributing to this discrepancy. The fourth experiment is much more similar to experiment one than is experiment three. However, the mean final error of the cloudy retrieval is not negligible. The perturbations added to the background mean vector have the shape of the background error covariance matrix, which reflects model errors in RAMS as the background data were taken from the output of that model. This could bias the retrievals towards the background and by so doing, contribute to the error observed in this experiment.