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Retrieval of Temperature and Water Vapour from Multiple Channel Lidar Systems Using an Optimal Estimation Method

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While the application of optimal estimation methods (OEMs) is well-known for the retrieval of atmospheric parameters from passive instruments, active instruments have typically not employed the OEM. For instance, the measurement of temperature in the middle atmosphere with Rayleigh-scatter lidars is an important technique for assessing atmospheric change. Current retrieval schemes for these temperatures have several shortcomings which can be overcome using an OEM. Forward models have been constructed that fully characterize the measurement and allow the simultaneous retrieval of temperature, dead time and background. The OEM allows a full uncertainty budget to be obtained on a per profile basis that includes, in addition to the statistical uncertainties, the smoothing error and uncertainties due to Rayleigh extinction, ozone absorption, the lidar constant, nonlinearity in the counting system, variation of the Rayleigh-scatter cross section with altitude, pressure, acceleration due to gravity and the variation of mean molecular mass with altitude. The vertical resolution of the temperature profile is found at each height, and a quantitative determination is made of the maximum height to which the retrieval is valid. A single temperature profile can be retrieved from measurements with multiple channels that cover different height ranges, vertical resolutions and even different detection methods. The OEM employed is shown to give robust estimates of temperature consistent with previous methods, while requiring minimal computational time.

Retrieval of water vapour mixing ratio from vibrational Raman scattering lidar measurements is another example where an OEM offers a considerable advantage over the standard analysis technique, with the same advantages as discussed above for Rayleigh-scatter temperatures but with an additional benefit. The conversion of the lidar measurement into mixing ratio requires a calibration constant to be employed. Using OEM the calibration constant can be retrieved if additional water vapour measurements, such as those provided by a radiosonde or microwave radiometer, are included.

The success of lidar temperature and composition retrievals using an OEM opens new possibilities in atmospheric science for measurement integration between active and passive remote sensing instruments. This presentation will highlight some of these possibilities, as well as show temperature and water vapour retrievals from the MétéoSuisse Raman Lidar for Meteorological Observations (RALMO) and The University of Western Ontario's Purple Crow Lidar.