Implication of atmosphere and cloud state uncertainties on the global retrieval of ice cloud microphysical properties

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Cirrus clouds play an important yet poorly determined role in the Earth's climate system and its various feedback mechanisms. As such, a significant amount of work has been accomplished not only in understanding the fundamental physics of the ice cloud problem but also in using this knowledge to infer cirrus cloud microphysical properties from satellite- based observations. A virtual plethora of retrieval schemes based upon known spectral sensitivities of top of the atmosphere radiance to ice cloud microphysical properties are found throughout the literature. Each of these different retrieval schemes, however, is susceptible to its own unique set of potential errors resulting from the inversion assumptions used in mapping between radiance and retrieval space. Since the deviations of these assumptions from truth behave in a spectrally un- predictable manner, it is likely that retrieval schemes using different wavelengths will give highly dissimilar retrieval results. This work re- examines the ice cloud retrieval problem in context of these often- neglected inversion uncertainties and examines their implications for the global retrieval of ice cloud microphysical properties.

The optimal combination of MODIS measurements for an ice cloud microphysical property retrieval scheme constrained by CloudSat cloud boundary information was determined through application of a formal information content analysis. Channel selection for the retrieval depends not only on the sensitivity of the measurements to changes in retrieved cloud properties but also to the combined uncertainty in the measurements from the instrument itself and from such inversion assumptions as ice crystal habit, particle size distribution, and atmospheric profile. Quantification of these uncertainties was made possible only by the recent development of optical properties at the MODIS wavelengths for a variety of realistic, non- spherical ice crystals. The results show that that channels that maximize retrieval information are strongly dependent upon the state of the atmosphere, meaning that there is no ideal combination of two or three channels that will always ensure an accurate retrieval. We therefore suggest a five- channel retrieval scheme consisting of a combination of error- weighted visible, near-infrared, and infrared channels chosen to use the inherent sensitivities in each of these spectral regions to ensure high retrieval information content across expected cloud and atmospheric conditions. The performance of the five- channel retrieval scheme was assessed in terms of both synthetic studies and real- world CRYSTAL-FACE data. Uncertainties in retrieved ice water path and effective radius are large and state dependent, with typical random errors near 40 to 50 percent. The large uncertainties found using this relatively complex retrieval scheme need consideration when examining the utility of absolute numbers or small trends found in existing cloud products that are often based on much simpler retrieval techniques.