The Relationship between Desroziers and Three-Cornered Hat Methods

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This note examines the relationship between what at first sight looks like two unrelated methods for estimating second order statistics of relevance to data assimilation. The first method is due to Desroziers et al. (2005) and relies on residual statistics readily available from data assimilation applications. The second method, due to Gray and Allan (1974), only recently making its appearance in atmospheric sciences, is generally formulated to use three data sets and seems in principle capable of deriving estimates of observation, background and analysis just as well. The usefulness of either method lies in them not requiring knowledge of the true value of the quantities at play. Desroziers derives its results by relying explicitly on the constraints associated with the data assimilation minimization problem; the 3CH method is general and its estimates hold as long as random errors in the three data sets of choice are independent. Establishing the relationship between the methods amounts to identifying the data sets of 3CH with be the observation, background, and analysis associated with Desroziers. The choice of observation and background for two of the data sets of 3CH is acceptable under the typical assumption of independence in their errors. Specifying the third data set of 3CH as the analysis seems unreasonable for analysis errors are by construction dependent on errors in both observations and background. This note finds that when the assumption of optimality required of Desroziers is applied to 3CH the latter method recovers the Desroziers error estimates for observation and background. More interestingly, in contrast with Desroziers estimate of errors in the analysis, the remaining corner of 3CH obtains the negative of the analysis error variance. An illustration of this finding is provided by deriving various uncertainties in bending angle.