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Modelling non-Gaussianity of background and observational errors by the Maximum Entropy method

Carlos Pires (1), Olivier Talagrand (2), and Marc Bocquet (3)

(1) Universidade de Lisboa, Instituto Dom Luiz - Faculdade de Ciencias - DEGGE, Lisboa, Portugal (capires@fc.ul.pt, tel.+351 217500807), (2) LMD, École Normale Supérieure, Paris, France, (talagran@lmd.ens.fr, tel. +33 1 44 32 22 21 ; fax +33 1 43 36 83 92, (3) Université Paris-Est, CEREA, Joint Laboratory, École des Ponts ParisTech and EDF R&D, Champs-sur-Marne, France+33 1 64 15 21 57, Fax : +33 1 64 15 21 70

The Best Linear Unbiased Estimator (BLUE) has widely been used in atmospheric-oceanic data assimilation. However, when data errors have non-Gaussian pdfs, the BLUE differs from the absolute Minimum Variance Unbiased Estimator (MVUE), minimizing the mean square analysis error. The non-Gaussianity of errors can be due to the statistical skewness and positiveness of some physical observables (e.g. moisture, chemical species) or due to the nonlinearity of the data assimilation models and observation operators acting on Gaussian errors. Non-Gaussianity of assimilated data errors can be justified from a priori hypotheses or inferred from statistical diagnostics of innovations (observation minus background). Following this rationale, we compute measures of innovation non-Gaussianity, namely its skewness and kurtosis, relating it to: a) the non-Gaussianity of the individual error themselves, b) the correlation between nonlinear functions of errors, and c) the heteroscedasticity of errors within diagnostic samples. Those relationships impose bounds for skewness and kurtosis of errors which are critically dependent on the error variances, thus leading to a necessary tuning of error variances in order to accomplish consistency with innovations. We evaluate the sub-optimality of the BLUE as compared to the MVUE, in terms of excess of error variance, under the presence of non-Gaussian errors. The error pdfs are obtained by the maximum entropy method constrained by error moments up to fourth order, from which the Bayesian probability density function and the MVUE are computed. The impact is higher for skewed extreme innovations and grows in average with the skewness of data errors, especially if those skewnesses have the same sign. Application has been performed to the quality-accepted ECMWF innovations of brightness temperatures of a set of High Resolution Infrared Sounder channels. In this context, the MVUE has led in some extreme cases to a potential reduction of 20-60% error variance as compared to the BLUE.