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A novel framework to harmonise satellite data series for climate applications

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Long term climate data records derived from satellite observations provide vital information for climate monitoring and research. However, most satellites only operate over a limited time after which they are replaced. Thus, providing a long term climate data record requires the combination of measured values from several different satellite sensors.

A simple combination of calibrated measurements from several sensors will produce an inconsistent record. For historical sensors, the behavior in space can be different from its behavior during pre-launch calibration in the laboratory and more scientific value can be derived from considering the series as a whole.

Here we consider harmonisation as a process that obtains new calibration coefficients and/or a new calibration model for the sensor by comparing the output of one satellite to a more radiometrically accurate sensor using appropriate match-ups, such as simultaneous overpasses. When we perform a comparison of two sensors using match-ups we must take into account the fact that those sensors are not observing exactly the same radiance. This is in part due to uncertainties of the radiation due to the match-up process itself and due to differences in the spectral response functions of the two instruments, even when nominally observing the same 'band'. We do not aim to correct for spectral response function differences, but to reconcile the calibration of different sensors given their estimated spectral response function differences.

We present a harmonisation framework that establishes calibration coefficients for several sensors simultaneously and rigorously with respect to their uncertainties and covariances. We discuss this problem, and its mathematical formulation as a large structured non-linear least squares problem called Marginalised Error In Variables. The mathematical problem is challenging to solve because it involves large numbers of match-ups and has significant error correlation in the measured data. The posterior uncertainties of the optimized parameters are evaluated as the inverse of the Hessian matrix at the minimum. The algorithm is matrix free since it uses matrix vector products which are computed efficiently by code generated by Automatic Differentiation. Results of the harmonisation of AVHRR sensors will be presented and discussed. The misfit is reduced substantially and its statistic is consistent with assumptions and uncertainties.

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