Bias correction of satellite radiance observations at ECMWF

ECMWF, 2020

In 2006 ECMWF developed and operationally implemented an adaptive bias correction system for all satellite radiance observations. The *Variational Bias Correction* scheme (or VarBC) is fully described in Auligne et al., 2007, and only a brief overview is presented here.

Systematic differences between the observed radiances and values simulated from the short-range forecast background are evaluated every analysis cycle (typically a 12-hour assimilation window) and corrected using a parametric model. The predictors of this parametric model vary in complexity (depending on the sensor and channel being considered). In the simplest case predictors are limited in number to only allow a fixed global correction and removal (flattening) of any scan dependent bias. For other channels, multiple air-mass dependent predictors may be used to characterize and remove more complex bias patterns. The coefficients of the parametric correction model are estimated and updated automatically and autonomously every analysis cycle as an augmentation of the 4D-Var control vector.

By removing systematic differences in this way, satellite radiance observations are essentially corrected to be unbiased with respect to the ECMWF background atmospheric state. Clearly such an approach is vulnerable to any systematic errors in this model state and measures are in place to guard against erroneous corrections being applied to the data:

- The predictor coefficients are estimated inside the 4D-Var, simultaneously with all other analysis variables. Any erroneous satellite bias corrections (resulting from model bias) that would degrade the fit of the analysis to other assimilated observations in the system (such as radiosondes or GPS-RO) are automatically penalised in the cost function, satellite bias corrections that improve the fit to these data are automatically preferred. In this sense the process of satellite bias correction is anchored to trusted independent observations embedded in the assimilation system (such as radiosondes and GPS-RO).
- Aspects of the background atmospheric state not sufficiently constrained by independent reference observations may still be anchored by assimilating some satellite radiance observations without any correction. An example is the uppermost sounding channel of the AMSUA instrument (channel 14 peaking around 2hPa). At this altitude the ECMWF model is prone to significant and seasonally varying temperature biases, unconstrained by radiosondes or GPS-RO. In this case it is assumed that, while the observation is not free from bias, its biases are smaller than those of the model. The assimilation of AMSUA channel 14 observations without bias correction, constrains the assimilation system at this altitude, but also anchors the bias corrections computed for other stratospheric channels.

The fact that the bias correction of satellite observations is adaptive and autonomous offers many operational advantages, but also places a critical dependence on a comprehensive monitoring system. At ECMWF we have developed an automatic alert facility which interrogates the bias corrections applied each day to every observation and checks these for anomalies against fixed limits, but also against machine learnt variable thresholds. Any violation of these thresholds triggers and alarm for manual investigation and (if necessary) intervention.

Further reading:

Auligné T., McNally A.P., Dee DP. 2007. Adaptive bias correction for satellite data in a numerical weather prediction system. Q. J. R. Meteorol. Soc. 133: 631–642.

Auligné T. and McNally A.P., Dee DP. 2007. Interaction between bias correction and quality control Q. J. R. Meteorol. Soc. 133: 643–653