Diagnosing the Bayesian Balance in Atmospheric Inversions

A.R. Jacobson[1], D.F. Baker[2], M.P. Butler[3] and P.K. Patra[4]

[1]Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; 303-497-4916, E-mail: andy.jacobson@noaa.gov
[2]Cooperative Institute for Research in Atmospheres, Colorado State University, Fort Collins, CO 80521
[3]Department of Meteorology, Penn State University, University Park, PA 16802
[4]Frontier Research Center for Global Change, Yokohama, Japan

Atmospheric inversions are challenged by a strongly underdetermined mathematical problem characterized by highly variable surface fluxes and an undersampled atmospheric CO_2 field. In the face of this problem, modelers must somehow set a balance between extracting as much signal as possible from observations and maintaining a stable inversion, one free of obvious artifacts. In the face of these competing requirements, Bayesian, geostatistical, and variational inverse schemes must choose a strength of extrinsic information, supplied in the form of prior flux estimates, flux covariance length scales, and other configuration choices. Setting this “Bayesian balance” requires careful consideration by the researcher, but the optimal level of prior constraint is made evident when plotting flux variance against observational residuals for varying levels of prior error covariance. Underdetermined problems tend to reveal an “L-curve” structure (Fig. 1), for which the optimal balance is represented by a sharp corner towards the origin. In this presentation, we discuss the Bayesian balance for recent inversions, including CarbonTracker and the Transcom3 interannual inversions. This analysis yields insights into the performance of transport models and flux inversion schemes.

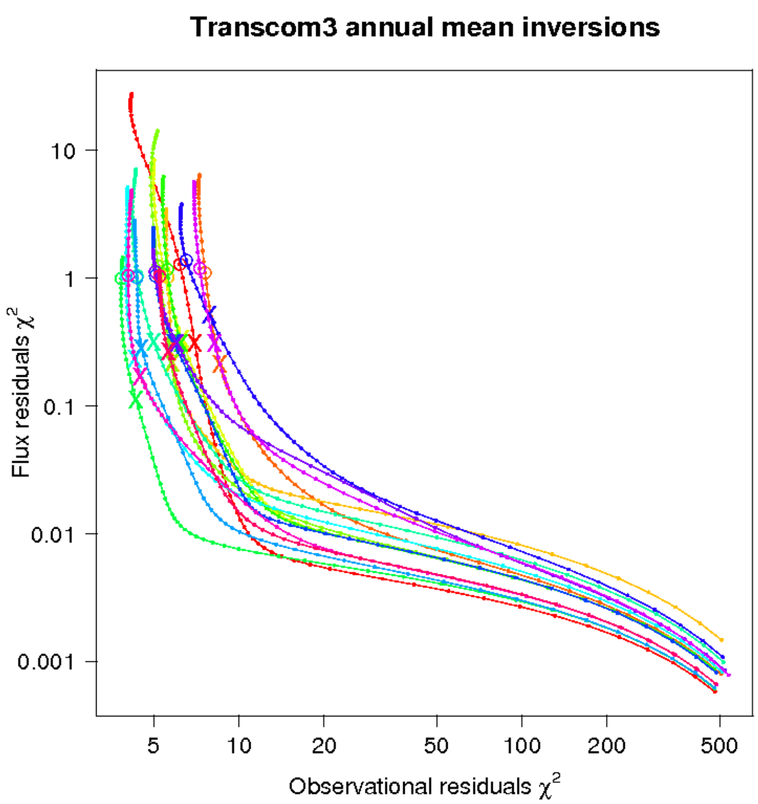

Figure 1. The Bayesian balance chosen by the Transcom3 annual mean inversions of Gurney et al. (2002), as revealed by each model's characteristic L-curve. Models are shown in different colors, with the balance between prior and observations as published shown with X symbols. The curves show that all models are challenged to agree with measurements (observations χ^2 values are relatively large), and that some models are significantly more successful than others. While this particular Bayesian balance resides away from the optimum (at the elbow of each curve), the Transcom3 researchers chose their prior constraints wisely. This balance favors aggressive fitting of measurements at the risk of allowing some flux artifacts, which would presumably be attenuated by considering the across-model average.