Comparison of Gravity Wave Drag Parameterizations using Inverse Techniques

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This work attempts to make an objective comparison between different gravity wave drag (GWD) parameterizations. Optimal parameters are estimatedfor each scheme. To perform a throughout comparison, two inverse techniques are used: the genetic algorithm and the ensemble Kalman filter.

GWD Parameterizations

Parameterizations calculate GWD for a given profile, simulating propagation filtering and saturation of gaves. This work focuses on three nonorographic spectral GWD parameterizations. Each one has a different set of free parameters that can be tuned in order to improve the global performance of the parameterization.

1) Scinocca 2003 (S03)[1]. Hydrostatic non-rotating GWD parameterization. Free parameters are the total momentum flux launch, characteristic wavenumber and a saturation scaling constant.

2) Warner & McIntyre 1996 (WM96)[2]. It assumes that nonlinear dissipation can be modeled by limiting the wave energy density to a m^{-3} form. Free parameters are the characteristic wavenumber, initial momentum scaling coefficient and minimum wavenumber at launch.

3) Alexander & Dunkerton 1999 (AD99)[3]. It assumes that non-linear dissipation can be modeled by depositing the launch spectrum of a spectral element at the altitude of the initial onset of instability. Free parameters are the total momentum flux, spectral amplitude, mean spectral width and horizontal wavenumber.

Methodology

Parameter estimation is carried out through offline experiments using from Met Office analysis. Zonally and monthly averages are taken.

“Observed” drag is taken from ASDE estimations (Pulido and Thuburn 2008[4]). Drag with optimal parameters for each parameterization are compared against ASDE GWD estimation in order to assess each scheme.

Parameter estimation is carried out employing two different techniques:

1) Genetic Algorithm. Charbonneau (2002)[5] implementation. Evolves (optimize) a population of K sets of parameters during N generations. A population of 50 individuals is evolved during 50 generations. Estimations for each column are calculated independently.

2) Ensemble Kalman filter. A Monte Carlo alternative to deterministic Extended Kalman Filter. The technique is modified in order to work offline. It uses an ensemble of 100 members and covariance inflation.

Results

The application of a genetic algorithm results in a notable enhancement in the performance of parameterizations (Fig. 1)

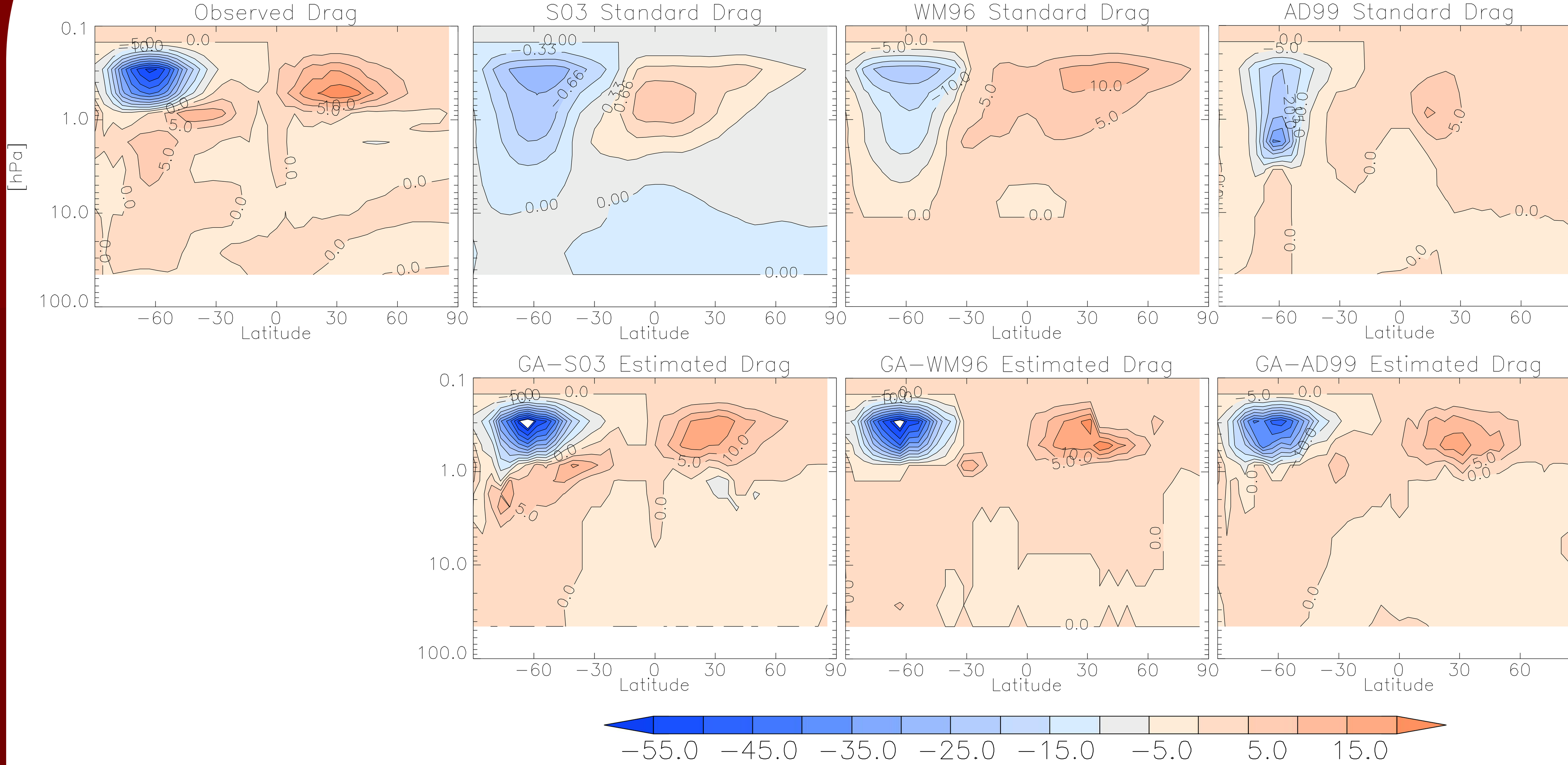

Figure 1. Observed and estimated Drag for July profile. Up: Parameterizations with standard set of parameters. Down: Parameterizations with optimal parameters. Note: Second top level has a different scale.

S03 parameterization gives a close representation of vertical drag distribution at lower heights, probably because of its momentum deposition mechanism. AD99 and WM96 appear to focus only on the representation of the maximum drag.

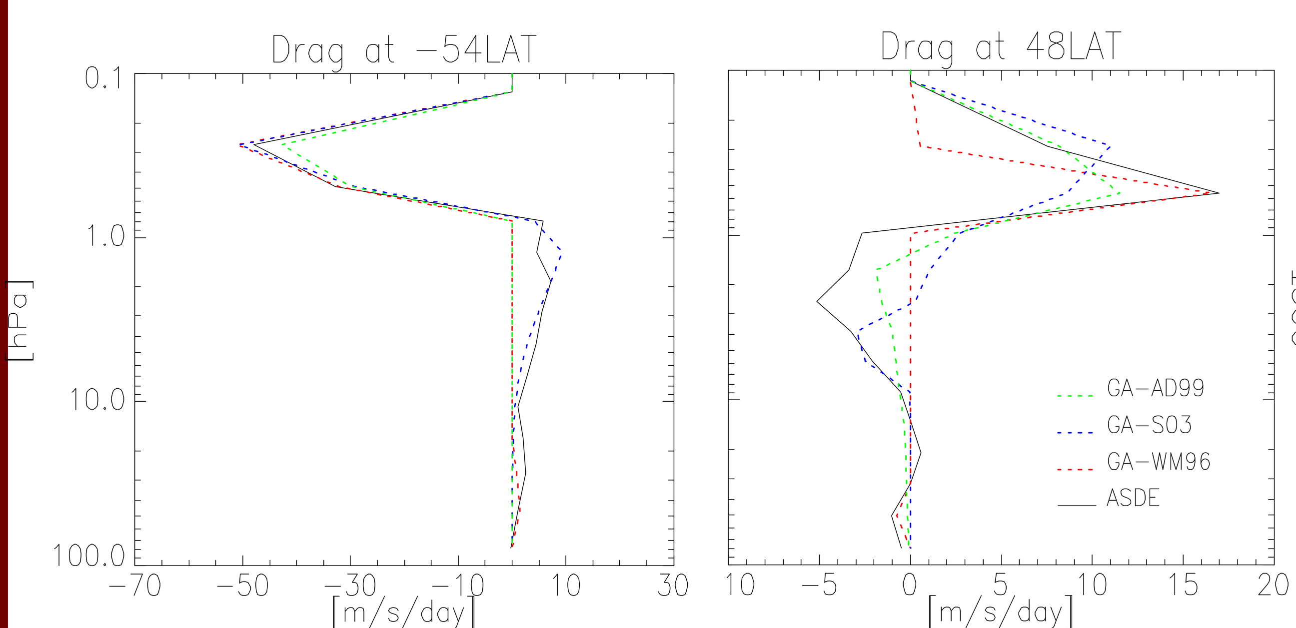

Figure 2. Estimated drag at -54LAT and 48 LAT

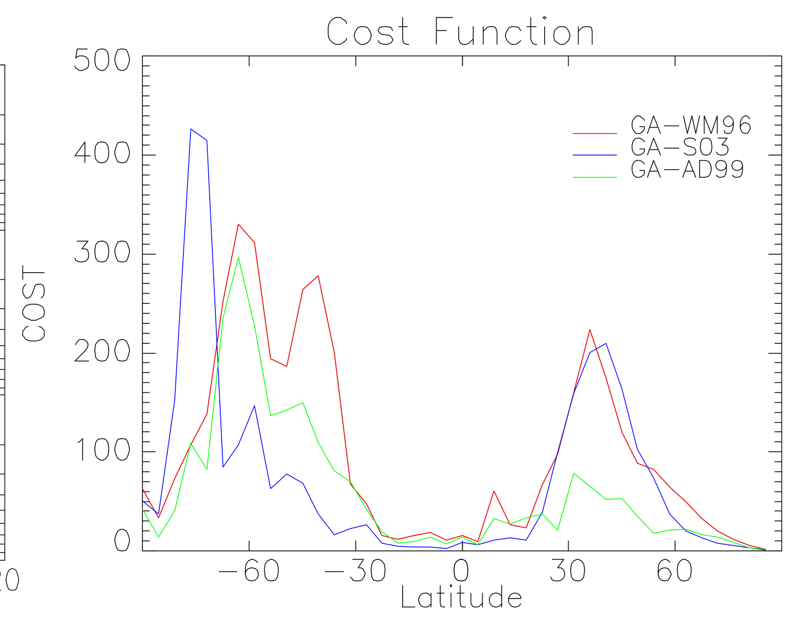

Figure 3. Cost Function at July.

WM96 is able to reproduce the peak of drag. AD99 gives a balance point between precision at the peak and vertical distribution (Fig. 2). EnKF implementation is still under development and needs to be improved to produce results of the same quality as the genetic algorithm (Figs. 4, 5)

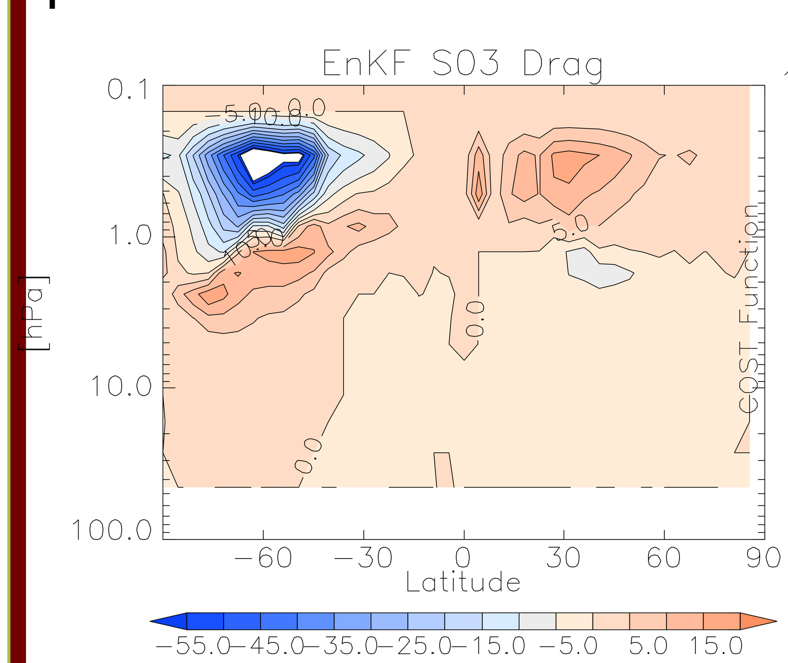

Figure 4 . Drag estimation with EnKF-Scinocca scheme.

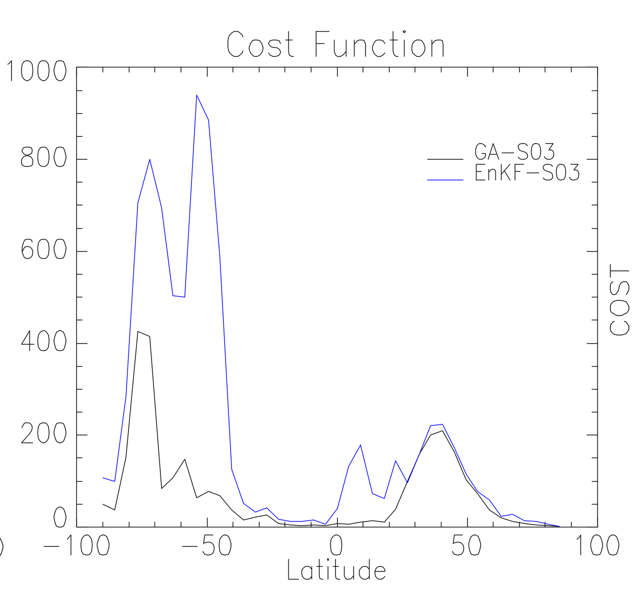

Figure 5 . EnKF and GA cost functions. (July)

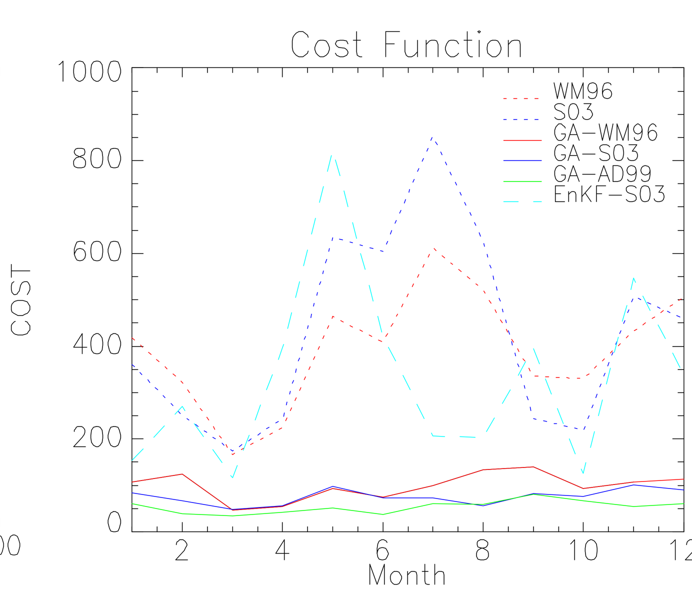

Figure 6 . Mean global cost function.

The use of optimal parameters improves the general performance of parameterizations for every month.

Discussions

- We show that the use of optimal parameters with genetic algorithms can improve gravity wave drag representation
- WM96 and AD99 seem to represent more accurately deposition peaks.
- S03 is able to give a more precise representation of drag distribution at lower altitudes.
- According to 1-year experiments, AD99 parameterization would the best option (i.e. smallest cost function).
- EnKF implementation needs more research in order to overcome the issues brought by discontinuities produced by switches in the parameterization and the possible dependencies between free parameters.

References

[1] Scinocca J., 2003. *J. Atmos. Sci. Vol. 60, 667-682*

[2] Warner C., McIntyre M., 1996 J. Atmos. Sci. Vol. 53, 3213-3235

[3] Alexander M., Dunkerton T., 1999. J. Atmos. Sci. Vol. 56, 4167-4182

[4] Pulido MScinocca J., 2003. *J. Climate. Vol. 21, N. 18, 4664-4679*

[5] Charbonneau P., 2002. NCAR Technical Note TN-450+IA.