Determining optimal parameters for gravity wave schemes using 4DVar

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The aim of this work is to estimate objectively parameters of a gravity wave scheme using an inverse technique based on variational assimilation. We use twin experiments to show which parameters can be

Motivation

The drag imposed by small-scale gravity waves (GW) to the general circulation is represented by means of schemes in GCMs. However these schemes need to specify the launch momentum flux which at the moment is very poorly constrained. Here we develop an inverse technique that assuming the drag is known it is able to estimate the optimal parameters that fit the drag profile.

Because most gravity wave drag schemes assume instantaneous vertical propagation of GWs in a column, drag observations in a single column can be used to obtain information about input parameters. Therefore we designed a 1+t D variational assimilation technique.

The GW scheme we use is the hydrostatic one from McLandress and Scinocca's (2005). This simplified scheme was preferred because it has a minimum number of switches.

Sensitivity experiments

In order to see the parameters that can be estimated, we performed sensitivity experiments where we prescribe a known set of parameters as the observations and evaluate the geometry of the cost function in the control space, in the neighbour of the prescribed parameters. The cost function is defined as

$$J(EP(z_l),\lambda_*,c_*)=\sum\left(X-X^{True}\right)\left(X-X^{True}\right)^T$$

where

$$X^{True}=X(EP(z_l)^{True},\lambda_*^{True},c_*^{True};U,T)$$

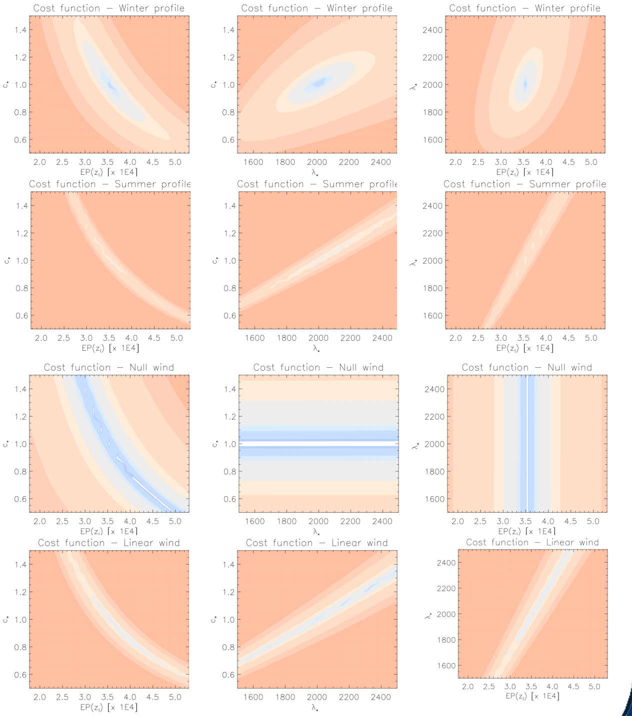

Fig 1. Cost function geometry for realistic summer and winter profiles and simple (null wind and linear wind) profiles.

Adjoint model evaluations

The adjoint model of the GW scheme was developed by hand. The code has several switches, including physical ones (saturation process) however a smooth cost function gradient is expected (see Fig. 1). To test the adjoint model we compare the derivative calculated using the adjoint model with the one calculated using finite differences. There are no visible differences (See Fig. 2)

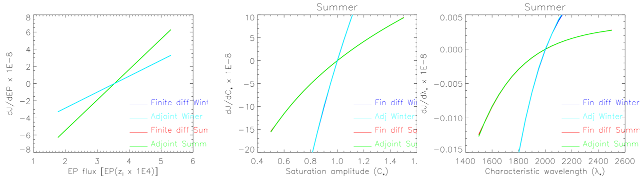

Fig 2. Derivative of the cost function as a function of the parameter.

Estimation of the parameters

Next, we designed twin experiments to estimate one parameter each time. The drag profile is calculated with the scheme using the true parameters. Then we use the assimilation system and specify two true parameters while one is uncertain.

The assimilation system uses a minimization module based on conjugate gradients and the adjoint model to calculate the cost function gradient. The convergence of the technique as a function of minimization iteration is shown in Fig. 3.

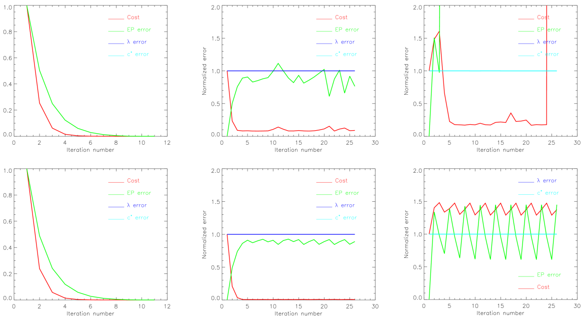

Fig 3. Convergence of the cost function and the parameter errors for winter (upper panels) and summer profiles (lower panels).

Conclusions

- Saturation process is independent of the parameter λ_*. There is a relationship between EP and c_* so that any set of parameters in the curve gives exactly the same drag.
- The adjoint model reproduces well the nonlinear behavior of the parameters λ_* and c_*.
- The parameter EP is well estimated in both winter and summer profiles. The estimation of c_* shows convergence to other EP parameter without sensitivity to λ_*. The estimation of c_* shows convergence to a maximum of J.
- The results show that the only parameter that needs to be estimated is EP for realistic drag profiles (Pulido and Thuburn 2008).

References

McLandres and Sccinoca, 2005: *J. Atmos. Sci.*, 62, 2394-2413.
Pulido and Thuburn, 2008: *J. Climate*, 21, 4665-4679.