NASA GISS Level 2 Turbulence Closure

The GISS model was developed at the NASA Goddard Institute for Space Studies, and, and is briefly summarized here. Further details of this model are presented in Canuto et al. (2001; 2002). A. Howard and V. Canuto of GISS provided the one-dimensional code.

In this local Reynolds stress model, temperature, scalar, and momentum diffusivities are parameterized as follows:

$$\begin{aligned} K_M &= f_M\left(R\ , N, Ri^T,\ \right) \\ K_T &= f_T\left(R\ , N, Ri^T,\ \right), \\ K_S &= f_S\left(R\ , N, Ri^T,\ \right) \end{aligned} \tag{1}$$

where R is the density ration given by

$$R\ =\ \frac{\partial S}{\partial z}\left(\ \frac{\partial T}{\partial z}\right)^{-1}, \tag{2}$$

N is the Brunt-Vaisala frequency given by

$$N^2 = -\frac{g}{}\frac{\partial}{\partial z} = g\ \ \frac{\partial T}{\partial z}\left(1 - R\ \right), \tag{3}$$

Ri^T is a gradient Richardson number where both large-scale (resolved) and small-scale (unresolved) flow contributes to the vertical shear $\sum_T^2 = \sum^2 + \sum'^2$:

$$Ri^T = \frac{N^2}{\sum_T^2}, \tag{4}$$

and   is the turbulent kinetic energy dissipation rate. The resolved wind-driven shear makes the dominant contribution to Ri^T in the mixed layer while the unresolved shear, resulting primarily from internal waves, makes the dominant contribution in the interior ocean. Given the dominance of unresolved shear in the interior ocean, the GISS model specifies Ri^T as a function of the density ratio:

$$Ri^T = cf\left(R\ \right), \tag{5}$$

so that the interior ocean parameterization of the diffusivity coefficients become:

$$\begin{aligned} K_M &= f_M\left(R\ , N,\ \right) \\ K_T &= f_T\left(R\ , N,\ \right). \\ K_S &= f_S\left(R\ , N,\ \right) \end{aligned} \tag{6}$$

This mixing model is valid for the following four cases (Canuto *et al.*, 2002): doubly stable ($\partial T/\partial z > 0$, $\partial S/\partial z < 0$, $R\ < 0$, $Ri^T > 0$), doubly unstable ($\partial T/\partial z < 0$, $\partial S/\partial z > 0$, $R\ > 0$, $Ri^T < 0$), salt fingering ($\partial T/\partial z > 0$, $\partial S/\partial z > 0$, $R\ > 0$, $Ri^T > 0$), and diffusive convection ($\partial T/\partial z < 0$, $\partial S/\partial z < 0$, $R\ > 0$, $Ri^T > 0$).

To implement the model, the diffusivities are represented by the following functional forms:

$$K_M = \Gamma_M \ N^{-2}, \qquad \Gamma_M = \frac{1}{2}(\ N)^2 S_M$$
$$K_T = \Gamma_T \ N^{-2}, \qquad \Gamma_T = \frac{1}{2}(\ N)^2 S_T \ , \tag{7}$$
$$K_S = \Gamma_S \ N^{-2}, \qquad \Gamma_S = \frac{1}{2}(\ N)^2 S_S$$

where $\Gamma_M, \Gamma_T, \Gamma_S$ represent mixing efficiencies, $= 2E/$, with E representing turbulent kinetic energy, is the dynamical timescale, and S_M, S_T, S_S are structure functions. It is then necessary to evaluate the functions E , , Γ, and S to derive the diffusivity profiles. This is achieved in the GISS model by deriving and solving the equations for second order moments. Details of this procedure are presented in Canuto *et al.*, 2002). It must be emphasized that the model is solved differently in two domains depending on whether resolved or unresolved shear has the dominant influence on stability [Equations (1) and (6)]. The former domain represents the surface boundary layer while the latter represents the comparatively quiescent ocean interior. The boundary layer is distinguished as the region where the value of Ri^T based on resolved shear only is less than a critical value. Different parameterizations of are used in the two domains.

Implementation of the GISS model in HYCOM was straightforward. Although substantial reorganization of the code was necessary, it was only necessary to provide vertical profiles of model layer variables and to calculate the appropriate Richardson numbers on model interfaces.

REFERENCES

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