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Baroclinic Instability and Atmospheric Heat Fluxes

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In middle and high latitudes most of the poleward transport of heat is accomplished by synoptic and planetary-scale eddies. An accurate representation of this process is therefore an important requirement of climate models. Professor Stone (MIT) presented a scheme by which a parameterisation of the eddy heat flux might be achieved.

Mixing length ideas were used to express the eddy flux $F = \overline{v'\theta'}$ in the form $F = -K\gamma$ where γ is the meridional temperature gradient. Evaluation of the transfer coefficient K requires knowledge of the amplitude and of the meridional and vertical extent of the eddies. The eddy amplitude can be estimated from an energy argument on the assumption that the maximum eddy kinetic energy is equal to the zonal available potential energy.

Professor Stone appealed to linear baroclinic instability theory to estimate the eddy dimensions. The zonal scale thus derived is the Rossby radius of deformation, but in models with a uniform background zonal flow the meridional scale is found to be as large as the system permits. However, the speaker cited a recent study by Kim on the stability of planetary waves to argue that in the presence of large-scale atmospheric waves the appropriate meridional scale is also the radius of deformation. The vertical scale depends on β, the gradient of the Coriolis parameter. When $\beta = 0$, the height scale for baroclinic waves is the depth of the troposphere. This leads to the result $F \propto \gamma^2$. For non-zero values of β, however, the vertical extent of linear, growing baroclinic waves is reduced and Professor Stone described work by Held, who derived $F \propto \gamma^5$ in such circumstances.

Some limitations of the scheme were mentioned: the effects of latent heat release are ignored and only the zonal mean transfer is predicted.

The relationship between F and γ in the atmosphere was illustrated by correlation of the monthly means of these quantities over the annual cycle. The correlation is high, especially when F represents the total eddy flux ('transient' and 'stationary' eddies) rather than just the 'transient' component. The speaker argued that the large-scale 'stationary' eddies were themselves largely generated by baroclinic instability.

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