Stratosphere-Troposphere Dynamical Coupling: The Role of Analytical Studies in the Development of Our Understanding

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Role of Analytical Studies

- Identification of idealized mechanisms
- Hypothesis forming

The basic dynamical study on which most subsequent work is built is Charney and Drazin (1961), which was an analytical study of upward wave propagation.

Mechanisms of Stratosphere-Troposphere Downward Dynamical Coupling

Mechanism 1.

Reflection of planetary waves 1 and 2 from the stratosphere, modifying the poleward eddy fluxes of heat and momentum in the troposphere.

Analytical studies: Bates (1977, 1981)

GCM study: Boville (1984) .

Mechanism 2.

Eddy-induced mean zonal force in the stratosphere due to Rossby and gravity-wave breaking induces a mean meridional circulation in the region below.

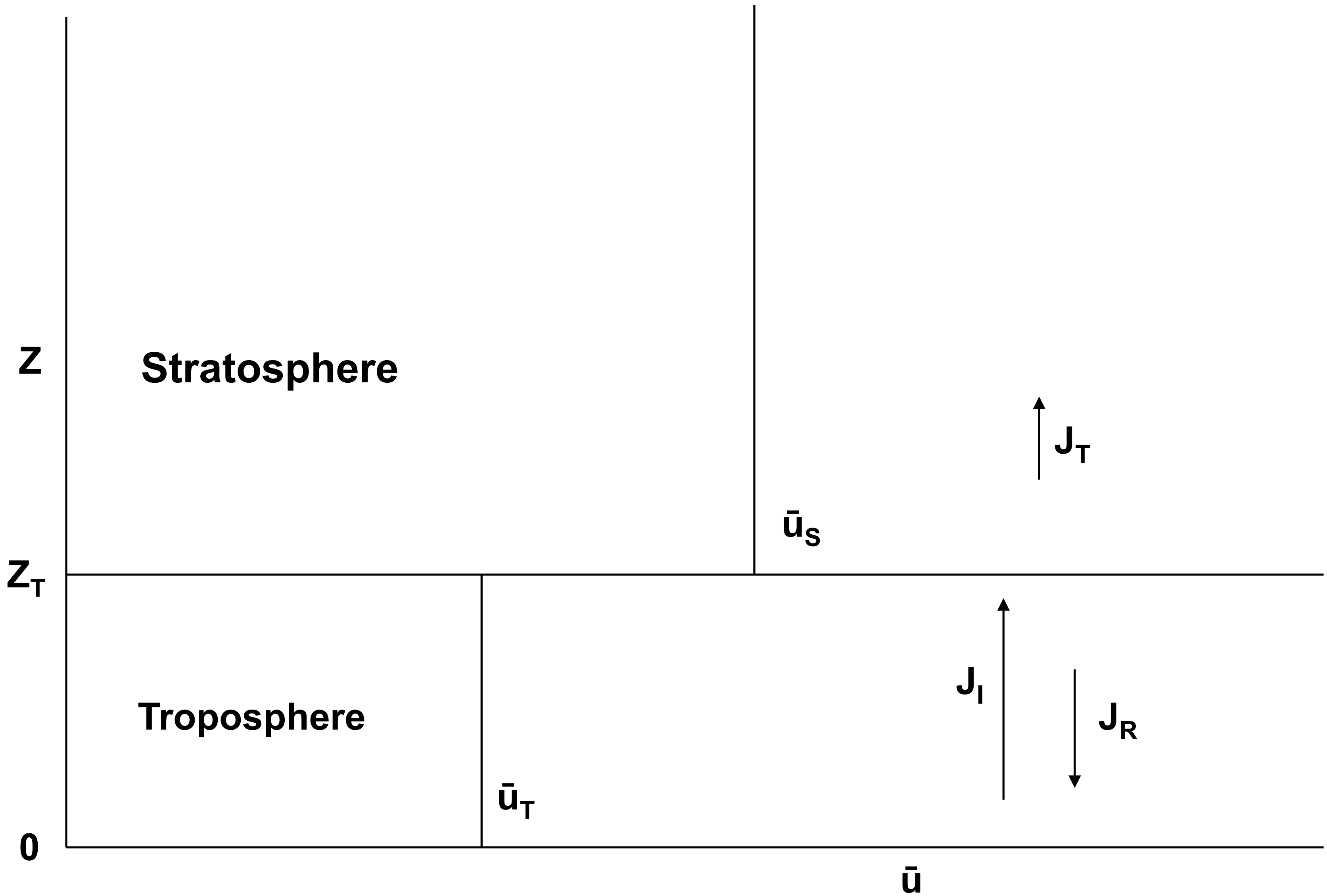
(Haynes et al. 1991).

Mechanism 3.

Annular modes (Baldwin and Dunkerton, 1999; Wallace, 2000).

Anomalies in the strength of the stratospheric polar vortex propagate downward and are seen at the surface as zonally asymmetric anomalies (NAO in the NH). Stationary eddy fluxes play an important role.

What is the relationship to Mechanisms 1 and 2?



An idealized atmospheric model with a step function wind field
(Bates, Solar Physics, 1981)

Possible areas of application of Mechanism 1

- Climatic effects of the variation of solar UV radiation over the solar cycle
- Climatic effects of stratospheric ozone changes (due to solar or anthropogenic causes)
- Climatic effects of enhanced stratospheric cooling due to CO_2 increase
- Communication of stratospheric variability to the troposphere with predictive applications.
- Effects of deficient dynamical representation of the stratosphere, or of an upper lid, in GCMs.

Evidence of Stratospheric Dynamical Influence on the Troposphere

- GCM experiments (Scaife et al., 2005, 2008) show a pronounced influence of the stratospheric wind field on the North Atlantic Oscillation in winter. The influence appears to be exerted through planetary wave reflection and modified eddy fluxes (Mechanism 1).

- Observational studies (e.g., Perlwitz and Harnik, 2003) show an influence of the stratospheric wind field on the amplitude and phase of planetary wave 1 in the troposphere by planetary wave reflection.

Other studies in which changes in the stratospheric wind or static stability have been shown to influence tropospheric heat and momentum fluxes

- Shindell et al. 1999: Solar cycle variability, ozone and climate.

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- Haigh and Blackburn, 2006: Solar influences on dynamical coupling between the stratosphere and troposphere. *Space Science Revs*., **125**, 331-344.
- Matthes et al., 2006: Transfer of the solar signal from the stratosphere to the troposphere: Northern winter. *JGR*, **111**, D06108.

Influence of Critical Surfaces

Upward-propagating planetary waves are partially refracted in the meridional direction. On the equatorward side they encounter a critical surface (zero-wind surface in the case of stationary waves).

The question of whether the waves are reflected or absorbed at the critical surface is of central importance.

Tung (1979) has argued that for conditions prevailing in the atmosphere, planetary waves are primarily reflected at a critical surface. This issue is still being debated.

If Tung’s argument is valid, the likelihood of Mechanism 1 being relevant is greatly increased.

Difference of focus between middle atmospheric and tropospheric studies

In the context of middle atmosphere dynamics, the primary focus is often on wave-mean flow interaction and the dynamics of the wave-driven Brewer-Dobson circulation. Here, the eddy fluxes of heat and momentum are most meaningfully considered in combination as forming components of the E-P flux vector, whose divergence enters as a forcing term in the mean zonal momentum equation and in the equation determining the streamfunction of the mean meridional circulation.

In the context of the tropospheric general circulation, however, the heat and momentum transports are most meaningfully considered separately. Here, the primary focus is on the role of the eddy heat fluxes in balancing the tropical radiative heat excess and the extratropical radiative heat deficit, and on the role of the eddy momentum fluxes in maintaining the mean tropical surface easterlies and midlatitude surface westerlies.

References

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Bates, J.R., 1977: Dynamics of stationary ultra-long waves in middle latitudes. *Quart. J. Roy. Met. Soc.,* 103, 397-430.

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Scaife et al., 2008: European climate extremes and North Atlantic Oscillation. *J. Climate*, 21, 72-83.

Tung, K.K., 1979: Quasi-normal modes in a singular wave guide. *Mon. Wea. Rev*., 107, 751.

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