Seasonal and interannual variations in upwelling and temperatures in the tropical UTLS

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The annual cycle in upwelling is an important aspect of the tropical tropopause layer (TTL) which, for example, has strong links to the annual cycle in temperatures and hence, through modulation of the cold point temperatures, to the annual cycle in concentrations of stratospheric water vapour. The concentrations of chemical tracers, such as ozone and carbon dioxide, with strong vertical gradients in the TTL, are also modulated by the annual cycle in the upwelling. Similar mechanisms are relevant to interannual variations.

Several methods have been used to estimate both the annual mean upwelling and the annual cycle from reanalysis and other datasets and, in many cases have also been applied to inter annual variations. One such method is based on angular momentum balance, using a "downward control" type calculation which, in the steady state, relates the upwelling and the wave torques. To capture the seasonal variation in upwelling this calculation must be modified to include the rate of change of zonal wind, supplied from observations. Another method of estimating the upwelling makes use of diabatic heating rates and thermodynamic balance. In the presentation we will examine, using ERA-Interim reanalysis data, the differences between the momentum balance and thermodynamical balance estimates and the effect of various approximations that are frequently made in carrying out the calculations. We will also analyse the contribution to the seasonal variation in upwelling, and to the resulting seasonal variation in temperatures, from wave torques in different regions of the height-latitude plane. This contribution is not clear from the momentum balance calculations, since the variation in zonal wind included in these calculations is independently specified, where in fact it is itself, in part, a response to the wave torques. Therefore instead we use calculations from the zonally symmetric dynamical equations, linearised about the annual mean state and with a correspondingly linearised radiation scheme, with the wave torque estimated from the reanalysis data as an imposed forcing. Similar methods will be used to analyse interannual variations. Differences between the conclusions from these calculations and those drawn from earlier work on this topic will be discussed.

Key words: TTL temperatures, annual cycle, interannual variability,