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An alternative to the TEM (Transformed Eulerian Mean) equations

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The TEM equations constitute a powerful means to get access to the residual circulation. However, due to their foundation on the wave perspective, they deliver only a zonally averaged picture without access to the three-dimensional structure or the local origins of the residual circulation. Therefore it is worth to investigate whether there are alternatives.

The pathway followed here is to perform a transformation of the momentum and the potential temperature equation before taking the zonal mean. This is done by removing the steady state ideal wind solution $\mathbf{v}_{id} = \nabla\theta \times \nabla B/(\varrho P)$ from the equations (θ – potential temperature, B – Bernoulli function, P – Ertel's potential vorticity EPV, ϱ – density). The advantage of that approach is that the total EPV-flux does no longer contain an explicitly visible 'do-nothing-flux'. This flux, $\nabla\theta \times \nabla B$, does only vanish when averaging on isentropic surfaces, but not on other isosurfaces. Here we find the reason why the conventional zonal mean on isentropes delivers a direct overturning cell on each hemisphere, whereas on other isosurfaces we obtain the typical three-cell structure with Headley, Ferrel, and polar cells. It will be demonstrated and made visible through idealized climate experiments with the ICON-IAP model that the zonal averages of the nonideal wind components $v_{nid} = v - v_{id}$ and $w_{nid} = w - w_{id}$ constitute similar direct overturning cells on non-isentropic surfaces as obtained with the TEM-generated v^* and w^*. It is also interesting to inspect fields of local nonideal wind components, the very origin of the residual circulation.