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Poleward atmospheric energy transports and their variability as evaluated from reanalysis data

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Global reanalyses are powerful new datasets that allow for advanced diagnostics of atmospheric energy fluxes. Using the vertically integrated equation for the tendency of the total atmospheric energy, $\frac{1}{g}\frac{\partial}{\partial t}\int_0^{p_s}(c_pT+\Phi_s+Lq+k)dp+\frac{1}{g}\int_0^{p_s}\nabla\cdot((c_pT+\Phi+Lq+k)v_2)dp+F_s-Rad_{TOA}=0$ (with temperature T, kinetic energy k, specific humidity q, geopotential F, moist static energy h, kinetic energy k, surface flux F_s and radiation at the top of the atmosphere Rad_{TOA}) the vertically integrated horizontal energy flux divergence $\frac{1}{g}\int_0^{p_s}\nabla\cdot((c_pT+\Phi+Lq+k)v_2)dp=\langle\nabla\cdot F_A\rangle$ can be computed in two ways.

The direct method computes it directly from the 6-hourly temperature, moisture and velocity fields. This is straightforward but the results are noisy because of the coarse time resolution and due to mass inconsistencies of the prediction model which also lead to erroneous divergent energy transports.

The indirect method computes the energy flux divergence as residual from short term forecasts of all other terms in the above equation, which leads to much smoother fields as vertical fluxes are accumulated during all model integration steps. However, this method also suffers from spurious pressure tendencies in the model.

The effect of inconsistencies in the mass budget on the energy budgets can be substantially reduced with the help of the analysed pressure field. By this adjustment, unrealistic features such as hemispheric imbalances of $\langle\nabla\cdot F_A\rangle$ (leading to unrealistically strong net energy transports across the equator) are removed from the field. In the next step, we calculate divergent energy transports from $\langle\nabla\cdot F_A\rangle$ using the spectral method.

Main data source is ERA-Interim, the most recent reanalysis product from ECMWF. The ERA-Interim (1989-2009) climatology of zonally integrated poleward energy transports shows very good agreement with recent estimates using satellite derived data for radiation at TOA such as CERES (Fasullo and Trenberth [2008]).

It is rather difficult to investigate the interannual variability of the energy budgets using satellite derived radiation as the records are either too short (e.g. CERES) or inhomogeneous in time (e.g. ISCCP-FD). In contrast, ERA-Interim reanalysis data are found to be quite homogeneous and thus more suitable for such studies.

We find quite strong correlation of tropical energy exports, defined by $\langle F_A\rangle(30N)-\langle F_A\rangle(30S)$, with the Niño 3.4 index indicating that ENSO is a main modulating factor. However, the maximum variation of this quantity is ±0.2PW which is only 2.5% percent of its average value. Regional anomalies of tropical energy exports are much more pronounced but strong compensation occurs (e.g. Eastern and Western Pacific). Additionally, it is possible to track energy flux anomalies which propagate slowly eastward around the globe and which appear to be triggered by El Niño.

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