Zonal Structure of Anomalies in Tropical Atmospheric Energy Budgets

Michael Mayer
University of Vienna, Vienna, Austria

Leopold Haimberger
University of Vienna, Vienna, Austria

Global reanalyses are powerful new datasets that allow for advanced diagnostics of atmospheric energy transports. Using the vertically integrated budget equation for the total atmospheric energy, the divergence of the horizontal atmospheric energy transport, $div(F_A)$, can be computed with a direct (using analysed fields of wind, temperature and moisture) and an indirect method (using short term forecast of radiative and turbulent fluxes and the energy storage rate). Both methods suffer from mass inconsistencies of the forecast model. Hence the mass budget has to be adjusted in order to get meaningful energy results. In the next step, we calculate divergent energy transports F_A from $div(F_A)$ using the spectral method.

Main data source is ERA-Interim (European Re-Analysis Interim), the most recent reanalysis product from ECMWF (European Centre for Medium-Range Weather Forecasts). Additionally, reanalysis products from other centers, such as JRA-25 (Japanese 25-year Reanalysis Project), CFSR (Climate Forecast System Reanalysis) or MERRA (Modern Era Retrospective-analysis for Research and Applications), are used for intercomparison. The ERA-Interim climatology (1979-2011) of zonally integrated poleward energy transports shows very good agreement with recent estimates from the literature which employ a variety of different datasets. This indicates that the discrepancies between the different estimates of this basic property of the climate system are becoming smaller.

The most valuable asset of reanalyses is their suitability for investigation of the interannual variability of the energy budgets, as they provide relatively long time series and best possible homogeneity in time. ENSO (El Niño – Southern Oscillation) is the main modulating factor of the energy budgets. We find a 'quadrupole' (Indic Ocean, Indo-Pacific Warm Pool, Eastern Pacifc, Atlantic) response of the energy budgets to the different phases of ENSO. Especially the anomalies of the divergence of dry static energy transport, indicating diabatic heating processes, show this structure. This means that strong positive (negative) anomalies of diabatic heating over the eastern equatorial Pacific during El Niño (La Niña) are compensated by negative (positive) anomalies of diabatic heating over the Indo-Pacific Warm Pool and the Atlantic. Anomalies over the Indic Ocean generally show the same sign as those over the Eastern Pacific. We interpret this as the signature of anomalous zonal circulation cells in the tropics. In addition, this 'quadrupole' does not only exist during the extreme phases of ENSO but there is a remarkably smooth transition. This leads to strikingly coherent longitude-time structures of anomalous divergences of energy transport across all seasons. Larger discrepancies could be found from CMIP5 (Coupled Model Intercomparison Project Phase 5) output which shows the 'quadrupole' in the energy budgets during the extreme phases of ENSO but lacks the aforementioned smooth transitions in between.

As the zonal compensation of energy divergence anomalies is strong during all phases of ENSO, the zonal mean response to ENSO is relatively weak, but still sizeable. The maximum variation of tropical total energy export, defined by $F_A(30N) - F_A(30S)$, is ±0.2PW which is 2.5% percent of its average value (~8PW). The energy transports across all latitudes show qualitatively similar sensitivities to ENSO in different reanalyses and coupled model runs but they significantly differ in magnitude.

Corresponding Author:

Name: Michael Mayer
Address: Department of Meteorology and Geophysics
University of Vienna
UZA II

Althanstr. 14
1090 Vienna
Austria