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Substantial zonal temperature gradients in the tropical free troposphere

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We show with ERA5 reanalysis data that substantial zonal virtual temperature gradients, on monthly time scales, exist in the tropical free troposphere. The strength of the temperature gradients changes seasonally: the Equatorial Western Pacific Ocean (EWP) is usually much warmer than the Equatorial Central Pacific Ocean (ECP) during December-January-February (DJF), while ECP becomes slightly warmer than EWP during June-July-August (JJA). During DJF, the virtual temperature gradients in the Pacific prevail throughout the entire free troposphere, and are most pronounced in the upper troposphere near 300hPa. We find that the free-tropospheric temperature gradients are related to the pressure gradients, while the pressure gradient force is mainly balanced by the nonlinear terms in the momentum equation---zonal wind advection. Strong zonal winds occur near the equator in January, transporting momentum zonally and balancing the pressure gradient force. The reason that strong zonal winds occur is that vigorous large-scale equatorial waves are excited due to the heating pattern being more symmetric to the equator. In July, the large-scale equatorial waves are less active in the Pacific Ocean. No strong zonal wind exists to sustain the pressure gradient as well as temperature gradient to develop. As a result, the virtual temperature distributions are much more uniform. The results point out the important role of the nonlinear terms in the tropical balanced dynamics on monthly time scales, stressing the need of an improved theoretical understanding and modeling framework of the tropical atmosphere by including the nonlinear terms in the dynamical balance.