Orbital Eccentricity and the Seasonal Cycle of the Tropics

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The seasonality of Earth's climate is driven by two factors: the tilt of the Earth's rotation axis relative to its orbital plane (**tilt effect**) and the variation in Earth-Sun distance due to orbital eccentricity (**distance effect**). While the distance effect is dismissed due to today's low eccentricity, we demonstrate—using climate model simulations—that it can a significant driver of tropical seasonal climate. Specifically, it exhibits distinct seasonal behaviors in surface temperature, precipitation, and atmospheric circulation. At higher eccentricity (as was the case with past climates), the distance effect can dominate regional seasonality in the Tropics.

The distance-driven seasonality of tropical sea surface temperature is characterized by two mechanisms: a tropics-wide warming peaking approximately two months after perihelion (a direct thermodynamic response) and a dynamic cooling of the Pacific cold tongue peaking five to six months after perihelion. **Tropical rainfall patterns** also respond strongly, with equatorial convection increasing over land and decreasing over adjacent oceans during perihelion. This shift drives a seasonal cycle in the zonal overturning circulation, transporting atmospheric energy from land to ocean.

Decomposing seasonality into tilt and distance components provides a straightforward framework for predicting tropical seasonal changes under precessional forcing, through a straightforward addition of the two components. Because the tilt and distance cycles have slightly different periods (tropical vs. anomalistic years), their superposition can lead to pronounced shifts in the net seasonality of the Tropics over a precession cycle.

The larger message we convey is that the Earth possesses not one but two seasonal cycles, and that the distance effect should be given due consideration as a seasonal cycle in its own right. This is especially relevant to understanding Milankovitch cycles, where associated changes to eccentricity, obliquity, and precession are all tied to the varying seasonal cycle of the Earth.

Keywords: Seasons, Orbital eccentricity, Sea surface temperature, Rainfall, Zonal overturning circulation, Milankovitch cycles

