Phase reduction analysis of the synchronization of the quasi-biennial oscillation to the annual cycle

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The quasi-biennial oscillation (QBO) is characterized by alternating eastward and westward zonal-mean zonal winds in the equatorial stratosphere [1]. While the QBO has an average period of about 28 months, it has been pointed out that the period of the oscillation varies and is to some extent synchronized to the annual cycle [1]. While numerical studies, e.g. [2], have reproduced this synchronization phenomenon and offered predictions, simple theoretical frameworks that explain these results remain limited.

Meanwhile, the phase reduction theory [3, 4] has been successfully utilized to understand various synchronization phenomena. By using this theory, an oscillatory dynamical system is reduced to a phase equation, in which the response of the rhythm to perturbations is quantified by the phase sensitivity function. However, the application of the phase-reduction theory to the synchronization of the QBO has been limited.

Here, we formulate a phase reduction method for a simple model of the QBO [5] and obtain the phase sensitivity function. The theory provides conditions under which the QBO is synchronized to a given annual forcing. It also suggests the waveform of the annual cycle that entrains the QBO most efficiently to the annual cycle. Thus, our theory provides insights into dynamical properties of the QBO and its synchronization to the annual cycle.

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