

## Methods to evaluate prediction skill in the Madden-Julian oscillation phase space

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Indices of prediction skill over the Madden-Julian oscillation (MJO) phase space are examined with reanalysis and forecast data provided by the Japan Meteorological Agency (JMA). In addition to the bivariate root-mean-square error (RMSE) and the bivariate anomaly correlation coefficient (ACC), the mean-error vector is assessed. Conventionally, the ACC and RMSE has been used, although this approach misses information on the model bias for MJO events. Moreover, the ACC is not suitable for models in which the MJO signal tends to damp in some phases, because the ACC strongly depends on the MJO amplitude. The mean-error vector compensates for this drawback by associating a model's erroneous mean tendency with RMSE. For example, the JMA forecast produces a leftward mean error vector field uniformly distributed over the MJO phase space with its amplitude related to RMSE. RMSE should be then used with the mean error vector for evaluating MJO prediction skill.

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