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Dynamical controls of mesoscale water vapor variability in the tropical western Pacific

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Idealized simulations of radiative-convective equilibrium (RCE) with cloud resolving models have been used as a numerical laboratory to understand how diabatic processes can drive convective clustering, which in turn leads to significant drying of the free troposphere and increase in spatial humidity variability. These processes, such as feedbacks between radiation, clouds and water vapor have been found to have relevance for numerous large-scale modes of convective organization, such as the width of the upward branch of the Hadley cell, ENSO and the Madden Julian Oscillation. However, the controls of water vapor associated with convective variability on the sub-1000km mesoscale are less well known. We adopt a simple multivariate analysis technique previously used to assess convective organization in RCE, and apply it to analyze convective organization and its impact on column integrated humidity (precipitable water, PW) variability for order 10^6 km^2 mesoscale-size boxes in the tropical western Pacific warm pool region lying on or to the north of the equator. We find that during the boreal summer/autumn periods, when sea surface temperature (SST) gradients are very limited in the target regions, convection remains mostly random and the horizontal PW gradients are small on these scales, this despite the action of diabatic feedbacks such as LW-cloud feedbacks and surface latent heat fluxes that are acting to force clustering of convection. In stark contrast, during the other months of the year, when the zones are subject to a weak meridional SST gradient of SST (> 10^{-3} K km^{-1}), convection is mostly aggregated over the warmer SSTs, with much larger PW gradients associated with an increase of clear sky OLR exceeding 10 W m^{-2}. However, this situation is regularly disturbed by intermittent, multi-day episodes of more homogeneous convection distribution and limited spatial PW gradients. During these periods the SST-PW relationship flips, and the convecting regions are found over the coldest SSTs. By using an index based on the SST-PW covariance, we construct a composite of 44 such events over a 4 year period which shows that they are associated with a westward-propagating, convectively-coupled Rossby wave like mode that is symmetric about the equator. An independent multivariate (SST-PW) rotated EOF analysis confirms this, indicating the robustness of the result. We hypothesize that the longer-term variations in an convective organization index which was directly related to the tropics-wide energy budget (Bony et al. 2020) may be driven by the frequency of occurrence of these westward propagating modes, that seem to act as a primary control on mesoscale water vapor variability in the warm pool region in the boreal winter and spring months.