Ph.D. Defense Announcement
Michael Natoli
March 28, 2022, at 2:00 p.m.

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Ph.D. Defense

Monday, March 28, 2022
2:00 p.m.

Defense
ATS Large Classroom (101 ATS) or Virtual

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Eric Maloney (Adviser)
Michael Bell
David Randall
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Intraseasonal Variability in the Tropical Island Diurnal Cycle

The relationship between large-scale intraseasonal variability in tropical convection and the local diurnal cycle on tropical islands is explored with observations and an idealized model. In part one, the impact of quasi-biweekly variability in the monsoon southwesterly winds on the precipitation diurnal cycle in the Philippines is examined using CMORPH precipitation, ERA5 reanalysis, and outgoing longwave radiation (OLR) fields. Both a case study during the 2018 Propagation of Intraseasonal Tropical Oscillations (PISTON) field campaign and a 23-year composite analysis are used to understand the effect of the QBWO on the diurnal cycle. QBWO events in the west Pacific, identified with an extended EOF index, bring increases in moisture, cloudiness, and westerly winds to the Philippines. Such events are associated with significant variability in daily mean precipitation and the diurnal cycle. It is shown that the modulation of the diurnal cycle by the QBWO is remarkably similar to that by the boreal summer intraseasonal oscillation (BSISO). The diurnal cycle reaches a maximum amplitude on the western side of the Philippines on days with average to above average moisture, sufficient insolation, and weakly offshore prevailing wind. This occurs during the transition period from suppressed to active large-scale convection for both the QBWO and BSISO. Westerly monsoon surges associated with QBWO variability generally exhibit active precipitation over the South China Sea (SCS), but a depressed diurnal cycle. These results highlight that modes of large-scale convective variability in the tropics can have a similar impact on the diurnal cycle if they influence the local scale environmental background state similarly.

In part two, a specific large-scale mode is neglected, and the impact of variability in the background wind at any timescale on the local diurnal cycle is isolated. Luzon Island in the northern Philippines is used as an observational test case. Composite diurnal cycles of CMORPH precipitation are constructed based on an index derived from the first empirical orthogonal function (EOF) of ERA5 zonal wind profiles. A strong precipitation diurnal cycle and pronounced offshore propagation in the leeward direction tends to occur on days with a weak, offshore prevailing wind. Strong background winds, particularly in the onshore direction, are associated with a suppressed diurnal cycle. Idealized high resolution 2-D Cloud Model 1 (CM1) simulations test the dependence of the diurnal cycle on environmental wind speed and direction by nudging the model base-state toward to composite profiles derived from the reanalysis zonal wind index. These simulations can qualitatively replicate the observed development, strength, and offshore propagation of diurnally generated convection under varying wind regimes. Under strong background winds, the land-sea contrast is reduced, which leads to a substantial reduction in the strength of the sea-breeze circulation and precipitation diurnal cycle. Weak offshore prevailing winds favor a strong diurnal cycle and offshore leeward propagation, with the direction of propagation highly sensitive to the background wind in the lower free troposphere. Offshore propagation speed appears consistent with density current theory rather than a direct coupling to a single gravity wave mode, though several gravity wave modes apparent in the model likely contribute to a destabilization of the offshore environment.

In part three, the hypotheses developed in parts one and two regarding the mechanisms regulating the diurnal cycle response are rigorously tested. A novel probabilistic framework is applied to the Luzon test case to improve the understanding of diurnal cycle variability. High amplitude diurnal cycle days tend to occur with weak to moderate offshore low-level wind and near to above average column moisture in the local environment. The transition from the BSISO suppressed phase to the active phase is most likely to produce the wind and moisture conditions supportive of a substantial diurnal cycle over western Luzon and the South China Sea (SCS). Thus, the impact of the BSISO on the local diurnal cycle can be understood in terms of the change in the probability of favorable environmental conditions. Idealized high-resolution 3-D Cloud Model 1 (CM1) simulations driven only by a base-state derived from BSISO composite profiles can reproduce several important features of the observed diurnal cycle variability with BSISO phase, including the strong, land-based diurnal cycle and offshore propagation in the transition phases. Background wind appears to be the primary variable controlling the diurnal cycle response, but ambient moisture distinctly reduces precipitation strength in the suppressed BSISO phase and enhances it in the active phase. A land-breeze, lingering deep convection over land after sunset, and strong mechanical convergence appear to all be required to produce offshore propagation in CM1. Simulations in which the diurnal cycle of insolation is removed suggest the potential for a natural timescale for convective regeneration related to the island size.

Topic: Ph.D. Defense: Mike Natoli
Time: Mar 28, 2022 02:00 PM Mountain Time (US and Canada)

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