"Using AMIE data to study cloud processes within the Madden-Julian Oscillation"
DOE Grant DE-SC0008452 / ER-65460 in Atmospheric System Research
Final Report (covering 9/1/2013 – 8/31/2015)

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<u>Executive Summary</u>

The MJO is the cloudy disturbance that develops over the Indian Ocean and affects weather throughout the tropics and certain areas in midlatitudes, such as the west coast of the U.S. Predicting this phenomenon has vexed numerical forecasting of the general circulation, largely because the nature of the clouds over the MJO and their response to and influence on the larger-scale atmosphere have not been well observed. AMIE provided many of the observations that have been missing. This project has used the data for the deployment of instruments by numerous agencies including DOE/ARM to provide much of the understanding of the cloud population over the Indian Ocean that has been lacking. We have analyzed data for the radars and soundings to show how the cloud population develops from non-precipitating small clouds into populations containing convective clouds that are both deep and wide. This study show how the small clouds first organize into lines and other patterns, how they develop the first rainshowers, how those showers deposit cool air over the ocean surface, how this cool air spreads and triggers deeper convection, how the deep convection develops into mesoscale systems, how the mesoscale systems modify the heating profile through the depth of the troposphere, and how the development of the clouds responds to and interacts with large-scale waves circumnavigating the globe at upper levels, and how equatorial trapped waves at lower levels modulates the development of the cloud population.

1) *how the research adds to the understanding of the area investigated;*

   This study uses AMIE data to show how the small clouds first organize into lines and other patterns, how they develop the first rainshowers, how those showers deposit cool air over the ocean surface, how this cool air spreads and triggers deeper convection, how the deep convection develops into mesoscale systems, how the mesoscale systems modify the heating profile through the depth of the troposphere, and how the development of the clouds responds to and interacts with large-scale waves circumnavigating the globe at upper levels, and how equatorial trapped waves at lower levels modulates the development of the cloud population.

2) *the technical effectiveness and economic feasibility of the methods or techniques investigated or demonstrated; or*

This study has used innovative techniques to analyze the radar and sounding data collected in AMIE to achieve the above results. To extrapolate from the data analysis to obtain more general results we have used regional modeling with a variety of cloud microphysical schemes.

3) how the project is otherwise of benefit to the public.

Improved understanding and prediction of the MJO will improve the quality of life in both tropics and midlatitudes.

Actual Accomplishments vs. Goals

The proposal aimed to "i) advance understanding of both how the anvil clouds of deep tropical oceanic convection interact with the environment in the case of oceanic tropical convection, and ii) contribute to better understanding of how clouds couple with the large-scale environment to affect the dynamics of the MJO." We have not deviated from these goals except to provide more detail and deeper understanding than could have been obtained at the time of the writing of the proposal. The year by year results show how our publications contributed to these goals. In reading the results elaborated below, the language will have changed slightly in that we tend in our recent work to refer to mesoscale convective systems. We eventually found the terminology of "anvil cloud" to be somewhat limiting and less than comprehensive since the anvil clouds are dominated by the dynamics that produce mesoscale convective systems. Our recent work refers more to mesoscale convective systems and less specifically to anvil. However this change in language does not deviate from our original goals. In addition, we have begun to pay more attention to nonprecipitating clouds because they are the precursors of the heat-releasing deep and mesoscale convection. The following is our year by year summary of accomplishments.

Year 1

In Barnes and Houze (2013) we show that the variability of the precipitating cloud population of the Madden-Julian Oscillation (MJO) over the central Indian and west Pacific Oceans can be represented by radar echo statistics. Echo features identified in radar data include isolated shallow echoes, deep convective cores, wide convective cores, and broad stratiform regions. Isolated shallow echoes are ever present but most numerous during suppressed MJO phases. Broad stratiform regions dominate variability in areal coverage and maximize during active phases. Deep convective and wide convective cores are more common and variable in number than broad stratiform regions. The magnitude of variability is similar in both regions. In the central Indian Ocean, active MJO phases have synchronous maximization of deep convective entities. In the west Pacific, broad stratiform regions maximize prior to wide convective cores. Reanalysis indicates that isolated shallow echoes are most numerous in dry mid-tropospheric conditions and strong low-level (1000–750 hPa) shear. Mid-tropospheric moisture increases before deeper convective features increase in number, maximizes as deep convective features maximize, and decreases as wide convective cores and broad stratiform regions decline in population. Active-stage deep and wide convective cores occur preferentially with moist mid-tropospheric conditions and strong low-level shear. Acute shear may favor downdraft momentum transport and consequently more robust gust-front convective triggering. Broad stratiform regions maximize with a moist mid-troposphere, strong low-level shear, and moderate upper-level (750–500 hPa) shear that is not so strong that the stratiform region disconnects from its convective moisture source.

In Powell and Houze (2013), we show that variability of the cloud population in the central-equatorial Indian Ocean in the context of the Madden-Julian Oscillation (MJO) as seen during the DYNAMO/AMIE field campaign. S-band radar observations obtained on Addu Atoll in the Maldives characterize the types of convective and stratiform radar echoes and the heights reached by their 20 dBZ contours. To gain insight into the relationship between clouds and humidification of the troposphere leading up to and during an active MJO event, this work related variability of the observed precipitation structure to that of tropospheric humidity and upper-level zonal wind. We found that the variability in stratiform precipitation areas dominates variability in the nature of precipitating convection associated with the MJO. Areal coverage of precipitating radar echo, convective echo-top height, and tropospheric humidity above 850 hPa rapidly increase over ~3-7 days near MJO onset. This rate of increase is substantially faster than the 10-20 days needed for build-up of moisture prior to MJO onset as hypothesized by the "discharge-recharge" hypothesis. Convective echoes become more common during the days prior to MJO onset, and the increased convection occurs before low-tropospheric moistening. The upper troposphere rapidly moistens as the first widespread stratiform region passes over an area. Thus, clouds likely play a role in tropospheric humidification. Whether increased low tropospheric humidity causes vertical growth of convection has not yet been determined.

In Yuan and Houze (2013), we found that over the Indo-Pacific region, mesoscale convective systems (MCSs) occur in a pattern consistent with the eastward propagation of the large-scale convective envelope of the Madden Julian Oscillation (MJO). MCSs are major contributors to the total precipitation, and over the open Indian and West Pacific Oceans the MCSs tend to be merged or connected systems, while over the maritime continent area they tend to be separated or discrete. Over all regions affected by the MJO, connected systems increase in frequency during the active phase of the MJO, while separated MCSs do not show much variation in frequency between active and suppressed phases of the MJO. Characteristics of each type of MCS (separated or connected) do not vary much over MJO-affected regions. However, separated and connected MCSs differ in structure from each other. Connected MCSs have a larger size and produce less but colder-topped anvil cloud. For both connected and separated MCSs, larger systems tend to have colder cloud tops and not as much warmer-topped anvil cloud. The maximum height of MCS precipitating cores varies only slightly, and the variation is related to sea surface temperature. Enhanced large-scale convection, greater frequency of occurrence of connected MCSs, and increased mid-troposphere moisture coincide, regardless of the region, season or large-scale conditions (such as the concurrent phase of the MJO), suggesting that the coexistence of these phenomena is likely the nature of deep convection in this region. The increase of mid-troposphere moisture observed in all convective regimes during large-scale convectively active phases suggests that the source of mid-troposphere moisture is not local or instantaneous and that the accumulation of mid-troposphere moisture over MJO-affected regions needs to be better understood.

In addition to the above-described refereed publications, we have presented preliminary versions of the results in a wide variety of venues (see list of presentations below). These presentations have shown details of the observed characteristics of the MJO convective cloud population, both how the population of clouds varies within the MJO and how the MJO convection relates to convection in the tropics as a whole.

Year 2

In Zuluaga and Houze (2013), DYNAMO/AMIE data were analyzed to to evaluate the composition of the population of convective cloud elements during active phases of the MJO over the Indian Ocean. Rainfall in active periods was intermittent, occurring in 11 episodes of about 2–4 days, separated by several non-rainy days. Data for these show four types of echo structures occurring prominently during rainfall episodes: shallow convective echoes (SCE), deep convective cores (DCC), wide convective echo cores (WCC), and broad stratiform (BSR) echo regions. SCE and DCC events were most frequent before the maximum rainfall, with the peak frequency of SCE leading that of DCCs. WCCs were most frequent during the rainfall maximum, and BSR regions were most frequent in the later part of the rainfall episode. Composited ECMWF Interim Re-Analysis (ERA-Interim) data and 3-hourly ARM soundings taken near the radar indicate that the 2–4-day episodes were related to the passage of equatorial waves. In the early part of a rainfall episode, the wave-passage conditions were unstable, favoring deep penetrating convective elements, while in the later period the wave divergence profile was commensurate with convective systems in late anvil-producing stages. These results support the stretched building-block notion of the life cycle of tropical convection and confirm satellite based interpretations of SCE, DCC, WCC, and BSR statistics in the composition of the convective population.

In Rowe and Houze (2014) we found the microphysical characteristics of precipitating convection occurring in various stages of the Madden-Julian Oscillation (MJO) over the Indian Ocean. These characteristics were determined from data obtained from radars deployed in the DYNAMO/AMIE field experiment. Active MJO events with increased rainfall occurred in October, November, and December 2011. During each of these active MJO phases, in addition to enhanced rainfall, convection became deeper and ice-phase microphysics played a greater role. S-PolKa consistently showed non-oriented small ice particles dominating the radar echoes at altitudes of 9–10 km, dry aggregates concentrated between 7 and 9 km, and wet aggregates and graupel near the melting level (~5 km). Graupel occurred mainly in actively convective towers, while the wet aggregates occurred almost exclusively in the stratiform regions of mesoscale convective systems (MCSs). During each of the three multi-week MJO active phases, the maximum rainfall occurred in short bursts lasting a few days. Each multiday rainy period began with deepening convective elements and a concurrent increase in occurrence of dry aggregates, which maximized just prior to organization into MCSs. The peak rainfall occurrence coincided with the maximum coverage of the radar domain by MCSs, reflecting large stratiform regions that exhibited the most frequent occurrence of wet aggregates. During the December active MJO phase, however, the MCSs were shallower and had a slightly lower tendency for wet aggregates in the stratiform regions and, therefore, generally weaker brightbands.

Year 3

In Barnes and Houze (2014) we used composite analysis of mature near-equatorial oceanic mesoscale convective systems (MCSs) during the active stage of the Madden-Julian Oscillation (MJO) to show where different hydrometeor types occur relative to convective updraft and stratiform midlevel inflow layers. A particle identification algorithm (PID) was applied to radar data to identify the dominant hydrometeor type in each radar sample volume. Combining Doppler velocity data with the PID demonstrated that hydrometeors have a systematic relationship to the airflow within mature MCSs. In the convective region, moderate rain occurs within the updraft core; the heaviest rain occurs just downwind of the core; wet aggregates occur immediately below the melting layer; narrow zones containing graupel/rimed aggregates occur just downstream of the updraft core at midlevels; dry aggregates dominate above the melting level; and smaller ice particles occur along the edges of the convective zone. In the stratiform region, rain intensity decreases toward the anvil; melting aggregates occur in horizontally extensive but vertically thin regions at the melting layer; intermittent pockets of graupel/rimed aggregates occur atop the melting layer; dry aggregates and small ice particles occur sequentially above the melting level; and horizontally oriented ice crystals occur between –10°C and –20°C in turbulent air above the descending midlevel inflow, suggesting enhanced depositional growth of dendrites. The organization of hydrometeors within the midlevel inflow layer is insensitive to the presence or absence of a leading convective line.

Rowe and Houze (2015) showed that AMIE radar observation distinguished three active Madden-Julian Oscillation (MJO) events that were separated by suppressed periods characterized by shallower, more isolated convection and relatively little rainfall. The radar data showed the initiation and organization of both nonprecipitating and precipitating clouds. Early in the suppressed periods, shallow nonprecipitating clouds occurred in shear-parallel lines along apparent boundary layer rolls during early morning. Once some of the clouds began to precipitate, small cold pools formed below the showers. By afternoon, the lines all but disappeared with nonprecipitating clouds instead forming along the edges of cold pools. All such convection was limited in depth early in suppressed periods. As the suppressed environment gained moisture, the nonprecipitating clouds were able to grow to larger size, with the deepest precipitating clouds occurring in clusters at intersections of cold pool boundaries by afternoon. Upscale growth into mesoscale convective systems was observed as the suppressed periods transitioned into active MJO phases, contributing to overnight precipitation during the later part of the suppressed period. This study demonstrates the need for models to accurately represent the organization and evolution of nonprecipitating clouds in association with boundary layer dynamics under suppressed conditions of the MJO, prior to the occurrence of precipitating clouds and their cold pools.

Powell et al. (2015) developed an algorithm used to classify precipitation echoes by rain-type without interpolating radar data to a constant height is detailed. The method uses reflectivity data without clutter along the lowest available scan angle so that the classifications yield a more accurate representation of the rain-type observed at the surface. The algorithm differs from previous convective/stratiform separation algorithms by executing the separation within a polar-coordinate system. An additional procedure allows for more small, isolated, and/or weak echo objects to be appropriately identified as convective. Echoes in the immediate vicinity of convective cores are included in a new transition category, which consists mostly of echoes for which a convective or stratiform determination cannot be confidently made. The new algorithm more effectively identifies shallow convection embedded within large stratiform regions, correctly identifies isolated shallow and weak convection as such, and more often appropriately identifies periods during which no stratiform precipitation is present.

Powell and Houze (2015) used AMIE data to analyze anomalies of eastward propagating large-scale vertical motion with ~30 day variability over the primary AMIE site in the Maldives. The anomalies were found to move into the Indian Ocean from the west, and they are implicated in Madden-Julian Oscillation (MJO) convective onset. Using ground-based radar and large-scale forcing data derived from the sounding array, typical profiles of environmental heating, moisture sink, vertical motion, moisture advection, and Eulerian moisture tendency were computed for periods prior to those during which deep convection is prevalent and those during which moderately deep cumulonimbi do not form into deep clouds. Convection with 3–7 km tops is ubiquitous but present in greater numbers when tropospheric moistening occurs below 600 hPa. Vertical eddy convergence of moisture in shallow to moderately deep clouds is likely responsible for moistening during a 3–7day long transition period between suppressed and active MJO conditions, although moistening via evaporation of cloud condensate detrained into the environment of such clouds may also be important. Reduction in large-scale subsidence, associated with a vertical velocity structure that travels with a dry eastward propagating zonal wavenumbers 1–1.5 structure in zonal wind, drives a steepening of the lapse rate below 700 hPa, which supports an increase in moderately deep moist convection. As the moderately deep cumulonimbi moisten the lower troposphere, more deep convection develops, which itself moistens the upper troposphere. Reduction in large-scale subsidence associated with the eastward propagating feature reinforces the upper tropospheric moistening, helping to then rapidly make the environment conducive to formation of large stratiform precipitation regions, whose heating is critical for MJO maintenance.

Products

Collaborations fostered:
During this research we have begun to collaborate with Zhe Feng and Samson Hagos at PNNL. Note the Feng et al. paper.

Techniques
We have used generally standard techniques but applied them in new ways, as in using regional modeling and satellite data to begin to generalize the results of AMIE to wider applicability.

Publications for Award Number DE-SC0008452/ER-65460 (9/2012 – 8/2015)

Publications: www.atmos.washington.edu/~houze/pubs

Powell, S. W., and R. A. Houze, Jr., 2015: Effect of dry large-scale vertical motions on initial MJO convective onset. *J. Geophys. Res. Atmos.*, **120**, 4783-4805,doi:10.1002/2014JD022961

Powell, S. W., R. A. Houze, Jr., and S. R. Brodzik, 2015: Rainfall-type categorization of radar echoes using polar coordinate reflectivity data. *J. Atmos. Oceanic Technol.*,revised.

Rowe, A. K., and R. A. Houze, Jr., 2015: Cloud organization and growth during the transition from suppressed to active MJO conditions. *J. Geophys. Res. Atmos.*, **120,**10,324–10,350, doi:10.1002/2014JD022948.

Feng, Z., S. Hagos, A. K. Rowe, C. D. Burleyson, M. N. Martini, and S. P. de Szoeke, 2015: Mechanisms of convective cloud organization by cold cools over tropical warm ocean during the AMIE/DYNAMO field Campaign. *JAMES,* **7**, 357–381. doi**:** 10.1002/2014MS000384

Barnes, H. C., and R. A. Houze, Jr., 2014: Precipitation hydrometeor type relative to the mesoscale airflow in oceanic deep convection of the Madden-Julian Oscillation. *J. Geophys. Res. Atmos.*, **119**, 13,990–14,014, doi:10.1002/2014JD022241. *("AGU Editors Research Spotlight" Radar Shows Where Water and Ice Occur in Large Storms,* EOS, *Vol. 96, No. 7, 15 April 2015.)*

Rowe, A. K., and R. A. Houze, Jr., 2014: Microphysical characteristics of MJO convection over the Indian Ocean during DYNAMO. *J. Geophys. Res. Atmos.*, **119**, 2543-2554, doi:10.1002/2013JD020799. *("AGU Editors Research Spotlight" Peering into the microphysics of the Madden-Julian Oscillation*, EOS, *Vol. 95, No. 35, 2 September 2014.)*

Barnes, H. C., and R. A. Houze, Jr., 2013: The precipitating cloud population of the Madden-Julian Oscillation over the Indian and West Pacific Oceans. *J. Geophys. Res.*,**118**, 6996-7023, doi:10.1002/jgrd.50375.

Powell, S. W., and R. A. Houze, Jr., 2013: The cloud population and onset of the Madden-Julian Oscillation over the Indian Ocean during DYNAMO-AMIE. *J. Geophys. Res. Atmos.*, **118**, 11,979-11,995, doi:10.1002/2013JD020421.

Yuan, J., and R. A. Houze, Jr., 2013: Deep convective systems observed by A-Train in the tropical Indo-Pacific region affected by the MJO. *J. Atmos Sci.*, **70**, *465–486. (For figure corrections contact Robert A. Houze, Jr.)*

Presentations

"The DYNAMO/AMIE International Field Campaign: Cloud Population of the Madden-Julian Oscillation," 16th International Conference on Clouds and Precipitation, Leipzig, Germany; 2 August 2012 (Powell)

"The DYNAMO/AMIE International Field Campaign: Cloud Population of the Madden-Julian Oscillation," DYNAMO Radar Workshop, Seattle, 22-24 August 2012. (Houze)

"The Precipitating Cloud Population of the MJO and its Relation to Large-Scale Atmospheric Conditions," 2012 AGU Fall Meeting San Francisco, Monday, 3 December 2012 (Barnes)

"Comparison of Mesoscale Convective Systems During DYNAMO," 2012 AGU Fall Meeting San Francisco, Monday, 3 December 2012 (Barnes)

"Evolution of Precipitating Convective Systems over the Equatorial Indian Ocean in Active Phases of the MJO," 2012 AGU Fall Meeting San Francisco, Monday, 3 December 2012 (Zuluaga)

"Tropical Convection: A Half Century Quest for Understanding," Bjerknes Memorial Lecture, AGU, San Francisco, 4 December 2012. (Houze)

"Are Equatorial Kelvin Waves Chickens? An Updated Paradigm for MJO Onset," Atmospheric Sciences Dynamics Seminar, University of Washington, Seattle, 7 February 2013. (Powell)

"The Precipitating Cloud Population of the Madden – Julian Oscillation over the Indian and West Pacific Oceans." Atmospheric Sciences Dynamics Seminar, University of Washington, Seattle, 24 January 2013. (Barnes)

"Microphysical Characteristics of the MJO Cloud Population during DYNAMO," Atmospheric Sciences Dynamics Seminar, University of Washington, Seattle, 21 February 2013. (Rowe)

"Convection in TOGA COARE—& other tropical field projects," DYNAMO Workshop," Hapuna Beach, Hawaii, 4 March 2013. (Houze)

"Nonprecipitating Phenomena Seen by the S-PolKa Radar in DYNAMO," DYNAMO Workshop, Hapuna Beach, Hawaii, 4 March 2013. (Houze)

"The Cloud Population and Onset of the Madden Julian Oscillation over the Indian Ocean during DYNAMO-AMIE," DYNAMO Workshop, Hapuna Beach, Hawaii, 4 March 2013. (Powell)

"An Improved Algorithm for Radar-derived Classification of Convective and Stratiform Precipitation Echoes." DYNAMO Workshop, Hapuna Beach, Hawaii, 4 March 2013. (Powell)

"Evolution of the Population of Precipitating Convective Systems," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Zuluaga)

"The MJO Precipitating Cloud Population over the Central Indian Ocean as seen by the TRMM PR," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Barnes)

"Hydrometeor characteristics from S-Pol," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Rowe)

"Microphysics of 2-Day Rain Events During the Active Stage," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Barnes)

"Evolution of Precipitating Convective Systems over the Equatorial Indian Ocean in Active Phases of the MJO," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Zuluaga)

"Hydrometeor Characteristics of the Cloud Population during DYNAMO," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Rowe)

"Kinematics and Microphysics of 2-Day Rain Events During the Active Stage," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Barnes)

"An Improved Algorithm for Radar-derived Classification of Convective and Stratiform Precipitation Echoes. DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Powell)

"Evolution of Tropospheric Humidity and Convection Prior to MJO Onset," DYNAMO Workshop, Hapuna Beach, Hawaii, 5 March 2013. (Powell)

"Nonprecipitating Phenomena Seen by the S-PolKa Radar in DYNAMO," DYNAMO Workshop, Hapuna Beach, Hawaii, 6 March 2013. (Houze)

"Effects of Large-Scale Waves and Humidity on Convective Depth." DYNAMO Workshop, Hapuna Beach, Hawaii, 6 March 2013. (Powell)

"Tropospheric Humidification and Cloud Microphysical Structure Observed over the Indian Ocean during AMIE," ASR Science Team Meeting, Potomac, MD, 19 March 2013. (Powell and Rowe)

"Observations of Convection in the MJO—TOGA COARE, TRMM, & DYNAMO," MJO Workshop, George Mason University, Fairfax, Virginia, 9 June 2013. (Houze)

"Global Variability of Deep Convection," University of Illinois Atmospheric Sciences Seminar, 16 October 2013. (Houze)

"Global Variability of Deep Convection," University of Colorodo Atmospheric and Oceanic Sciences Seminar, 1 November 2013. (Houze)

"Global Variability of Deep Convection," University of Washington Atmospheric Sciences Colloquium, 1 November 2013. (Houze)

"The use of multi-frequency radar measurements for investigating microphysical processes during DYNAMO/AMIE", ASR Fall Working Group Nov 2013, Rockville, MD, 5 Nov 2013. (Rowe)

"Radar-based and Large Scale Views of Convection and Humidity during AMIE-DYNAMO", ASR Fall Working Group Nov 2013, Rockville, MD, 5 Nov 2013. (Powell)

"Characteristics of Mesoscale Convective Systems during DYNAMO/AMIE", ASR Fall Working Group Nov 2013, Rockville, MD, 5 Nov 2013. (Rowe)

"MJO Modulation of Lightning in Mesoscale Convective System", 2013 AGU Fall Meeting, San Francisco, CA, 11 Dec 2013. (Virts)

"Radar-Based and Large-Scale Views of Convection and Tropospheric Humidity during DYNAMO/AMIE", 2013 AGU Fall Meeting, San Francisco, CA, 11 Dec 2013. (Powell)

"The Hydrometeor Structure of Mesoscale Convective Systems During the MJO Active Phases in DYNAMO", 2013 AGU Fall Meeting, San Francisco, CA, 11 Dec 2013. (Barnes)

"Scales of Convective Activity in the MJO", 2013 AGU Fall Meeting, San Francisco, CA, 11 Dec 2013. (Houze)"

"The structure and organization of clouds under suppressed conditions observed by S-PolKa during DYNAMO", 2013 AGU Fall Meeting, San Francisco, CA, 11 Dec 2013. (Rowe)

"Global Variability of Intense Convection", Univ. of CA Berkeley, Berkeley, CA, 28 Jan 2014. (Houze)

"Microphysical characteristics of MCSs observed during the MJO over the Indian Ocean", 2014 AMS Annual Meeting, Atlanta, GA, 4 Feb 2014. (Rowe)

"Convective Onset of the Madden-Julian Oscillation", 94th AMS Annual Meeting, Atlanta, GA, 5 Feb 2014. (Powell)

"Global Variability of Intense Convection", University of Manchester, Manchester, UK, 17 Feb 2014. (Houze)

"Global Variability of Intense Convection", University of Reading, Reading, UK, 20 Feb 2014. (Houze)

"The Role of Upper-Tropospheric Dynamics in MJO Convective Onset", ASR Science Team Meeting 2014, Potomac, MD, 11 Mar 2014. (Powell)

"Shallow cloud structure and organization under suppressed conditions in AMIE/DYNAMO", ASR Science Team Meeting 2014, Potomac, MD, 13 Mar 2014. (Rowe)

"Shallow Structure and Organization under Suppressed Conditions in AMIE/DYNAMO", ASR Science Team Meeting 2014, Potomac, MD, 14 Mar 2014. (Rowe)

"Cloud structure and organization under suppressed conditions during DYNAMO/AMIE/CINDY2011", 31st Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 1 Apr 2014. (Rowe)

"Evolution of Humidity and Convection Prior to MJO Onset and Their Sensitivities to Upper-Tropospheric Equatorial Wave Dynamics", 31st Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 1 Apr 2014. (Powell)

"A Conceptual Model for the Hydrometeor Structure of Mesoscale Convective Systems during the MJO Active Stage", 31st Conference on Hurricanes and Tropical Meteorology, San Diego, CA, 2 Apr 2014. (Barnes)

"Latent Heating Associated with the MJO in the Central Indian and West Pacific Oceans", poster, 2014 NASA Precipitation Measurement Missions Science Team Meeting Baltimore, MD 4 – 8 August, 2014. (Barnes"Extreme Convection of the Near-equatorial Americas, Africa, and Adjoining Oceans as Seen by TRMM: Climatological rainfall contribution", poster, 2014 NASA Precipitation Measurement Missions Science Team Meeting Baltimore, MD 4 – 8 August, 2014. (Zuluaga)
"2014 NASA Precipitation Measurements Missions (PMM)", Science Team Meeting, Embassy Suites - Grand Historic Venue, Baltimore, MD, 5 August 2014. (Barnes)

"Extreme Convection in the Equatorial Zone as Seen by 16 Years of TRMM PR", PMM Science Team Meeting, Baltimore, 7 August 2014. (Zuluaga)

"A Conceptual Model for the Hydrometeor Structure of Mesoscale Convective Systems during the MJO Active Stage", Department of Meteorology, The Pennsylvania State University, State College, PA, August 15, 2014. (Barnes)

"Anvil Clouds of Mesoscale Convective Systems", ASR Science Team Meetings, Bethesda, 20 November 2014. (Houze)
"Cloud structure under suppressed conditions during DYNAMO", AMS 95th Annual Meeting, Phoenix, AZ, 5 January 2015. (Rowe)

"S-Pol observations", AMIE/DYNAMO Session ASR Science Team Meeting, Tyson's Corner, VA, March 17, 2015. (Rowe)

"AMIE/DYNAMO Observations of Clouds During the Transition from Suppressed to Active MJO Conditions", poster, ASR Science Team Meeting, Tyson's Corner, VA, March 17, 2015. (Rowe)

""Understanding Convection in Relation to the Non-aerosol Environment, ASR Science Team Meeting, Tyson's Corner, VA, March 17, 2015. (Houze)

" Polarimetric observations in the Tropics: Challenges and successes in identifying cold pools", Radar Polarimetry Breakout Session ASR Science Team Meeting 2015 Vienna, VA, 18 March 2015. (Rowe)

"Relating Large-Scale Vertical Motions to MJO Convective Onset Observed by TRMM Radar", poster, EGU General Assembly, Vienna, Austria, 17 April 2015. (Powell)

"Dry Large-Scale Vertical Motions and MJO Convective Onset", EGU General Assembly, Vienna, 17 April 2015. (Powell)

"Validation of the Simulated Microphysical Structure within the Midlevel Inflow Region of a Tropical, Oceanic Squall Line", 37th Conference on Radar Meteorology, Norman, OK, 14 September 2015. (Barnes)

"Polarimetric radar observations of nonprecipitating echo during DYNAMO/AMIE", 37th Conference on Radar Meteorology, Norman, OK, 15 September 2015. (Rowe)

"The Organization of Microphysical Processes in Mesoscale Convective Systems over the Central Indian Ocean", PNNL Seminar, PNNL, Richland, WA, 1 October 2015. (Barnes)