The Effects of Equatorial Kelvin and Mixed-Rossby Gravity Waves on the Mesoscale Structure of Tropical Oceanic Convection

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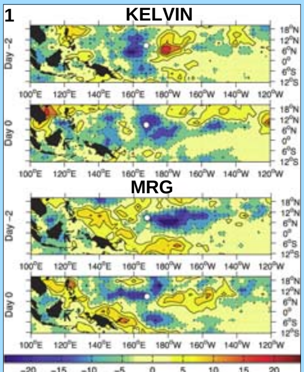
MOTIVATION and DATA

Large-scale tropical deep convection is associated with several types of synoptic disturbances. Kelvin and mixed-Rossby gravity (MRG) waves are convectively coupled equatorial waves with distinct phase speeds and signatures in the outgoing longwave radiation (OLR) frequency-wavenumber spectrum. **This study investigates whether these synoptic differences result in differences in radar-observed mesoscale precipitation structures near Kwajalein Atoll (Republic of the Marshall Islands) in the western Pacific** (see Fig.1 for map)**.**

Using an OLR anomaly method from Wheeler and Kiladis (1999), Swann et al. (2006) identified 26 separate convectively coupled Kelvin events (59 days) and 19 MRG events (38 days), spanning the rainy seasons of 1999-2002 (Fig. 1). These events lasted from 0.5 to 5 days, with no difference in length distribution between wave types.

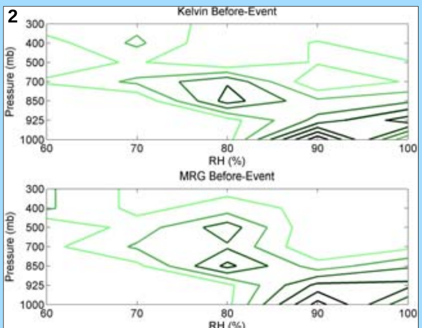
Operational twice-daily upper-air soundings from Kwajalein are analyzed. S-band Kwajalein radar volumes were obtained at 10 min. intervals for the wave events. Radar data are quality controlled, interpolated, and separated into convective and stratiform precipitation components as per Yuter et al. (2005). Radar volumes utilized have horizontal and vertical grid spacings of 2 km.

1

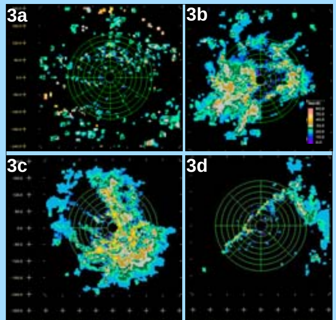


Composite OLR anomaly maps for Kelvin (top) and MRG (bottom) events. Days -2 and 0 are shown for each, with OLR values shaded with contour intervals of 3.4 Wm^{-2} (negative is dotted, positive is solid) to a maximum of 27.1 Wm^{-2}. Kwajalein is identified by a white dot (Swann et al. 2006).

2



Joint frequency distributions of observed relative humidity (RH) for upper-air soundings launched 12 h prior to the wave events. The bin size is 10% RH. For midlevels (700-400 mb), Kelvin events exhibit a wider distribution of values than MRG, with some Kelvin prestorm environments near 90% RH. Soundings for Kelvin and MRG for time periods during and after the events have smaller differences than the pre-event soundings.



Low-level reflectivity maps to 240 km range. **(a)** 1524 UTC on 22 Sept. 1999, **(b)** 1054 UTC on 23 Sept. 1999, **(c)** 2212 UTC on 11 Aug. 1999, **(d)** 1412 UTC on 02 Sept. 1999. Scattered and disorganized mesoscale precipitation structures in (a) and (b), a Kelvin event, were more common for both wave types than the more organized patterns of (c) and (d).

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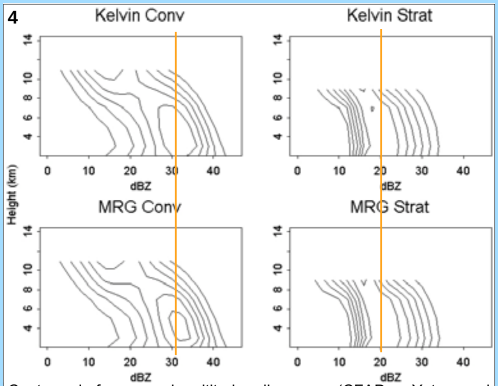
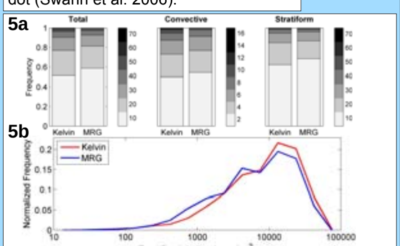


Contoured frequency-by-altitude diagrams (CFADs, Yuter and Houze 1995) of reflectivity for indicated subsets of wave events. All Kelvin and MRG events are used in these ensemble CFADs for each wave type. Contour interval is 12.5% of data dBZ^{-1} km^{-1}. Vertical lines are drawn for comparison. 3D reflectivity structures of convective and stratiform precipitation components for Kelvin and MRG events are very similar.



(a) Fraction of Kelvin and MRG volumes corresponding to different precipitation areas indicated by shadings (values x1000 km^2). The shading scale for convective differs from total and stratiform. **(b)** Frequency distributions of total precipitation area, plotted on a logarithmic scale. The distributions are roughly log-normal. Kelvin events can attain greater precipitation areas than MRG.

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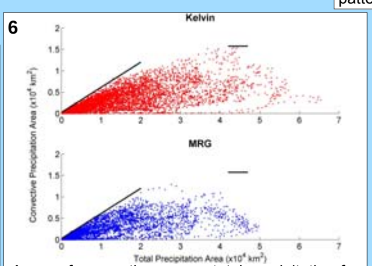

Areas of convective versus total precipitation for the Kelvin and MRG radar volumes. The short horizontal line on the Kelvin graph (top) indicates the maximum convective precipitation area and is superimposed onto the MRG graph (bottom). Larger Kelvin storms are able to sustain greater convective precipitation area than MRG. The angled line on each graph roughly indicates maximum convective area per total area.

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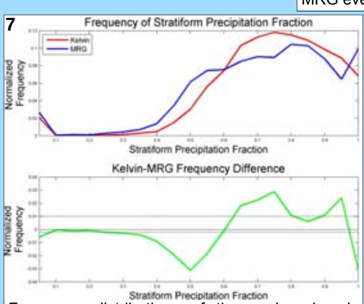
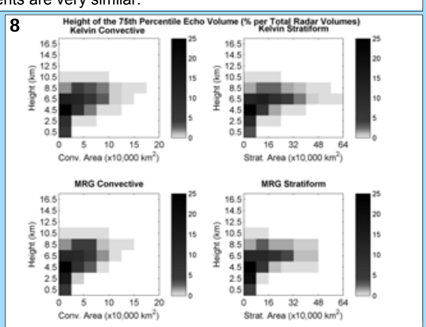


Frequency distributions of the each volume's stratiform precipitation fraction of total area. Data are binned by 0.05. The Kelvin-MRG distribution difference is also shown, and differences greater in magnitude than the dotted lines are significant to 95% using a 10,000 member Monte Carlo test.

8



Height below which ≥75% of echo volume is present for convective and stratiform precipitation components of each volume. Shading is % data per total number of radar volumes. The pattern for Kelvin is similar to MRG except that Kelvin waves can have larger precipitation areas.

RESULTS

Low-level reflectivity maps show that precipitation structures within Kelvin and MRG events rarely exhibit highly organized mesoscale structures such as leading-line convective precipitation with trailing stratiform precipitation. The structures are often scattered or have convective lines simultaneously in multiple orientations.

The distribution of precipitation areas is roughly log-normal for both wave types, in agreement with previous studies of tropical oceanic precipitation. Echo height distributions are similar between wave types.

Convective precipitation area versus precipitation area has a wide range of observed values likely related to different stages of storm evolution in the 97 day sample of mesoscale precipitation events. Kelvin events more often display a greater stratiform precipitation proportion than MRG.

Similarities between characteristics of Kelvin and MRG wave types:

- –Three-dimensional reflectivity distributions of total echo volume and convective and stratiform components
- –75th percentile echo volume heights of convective and stratiform components
- –Maximum observed convective area for a given precipitation area size for precipitation areas < 15,000 km^2

Differences between Kelvin and MRG:

- –Kelvin events can reach larger maximum areas than MRG events, can sustain more convective precipitation per unit total precipitation area, and more often have greater stratiform precipitation fractions than MRG storms. These characteristics suggest more organized mesoscale circulations in the larger Kelvin events.
- –There are differences in mid-level moisture in the pre-storm environments, with some Kelvin prestorm vertical profiles reaching greater values of relative humidity than observed with MRG.

SUMMARY

The precipitation area sizes, stratiform area fractions, and three-dimensional structures of tropical oceanic mesoscale precipitation systems associated with Kelvin and MRG waves near Kwajalein exhibit large variability among individual events.

However, the differences in the synoptic characteristics of Kelvin and MRG waves do not yield systematic differences in the mesoscale structures of precipitation between the two wave types.

There is a limit to the relative proportion of convective area to total precipitation area that a mesoscale storm near Kwajalein can sustain (~0.60 for total areas <15,000 km^2, steadily decreasing to ~0.35 by 40,000 km^2, rapidly approaching 0.0 for the largest areas). This observed characteristic can be used as a metric to evaluate the realism of numerical model output for this oceanic region.

FUTURE WORK

We will examine the size distributions of cells, cell motion, and cell orientation. We will analyze the sea-surface temperatures across the area for these events and explore ECMWF reanalyses of the larger-scale flow. Upper-air sounding observations will be further analyzed.

ACKNOWLEDGEMENTS

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