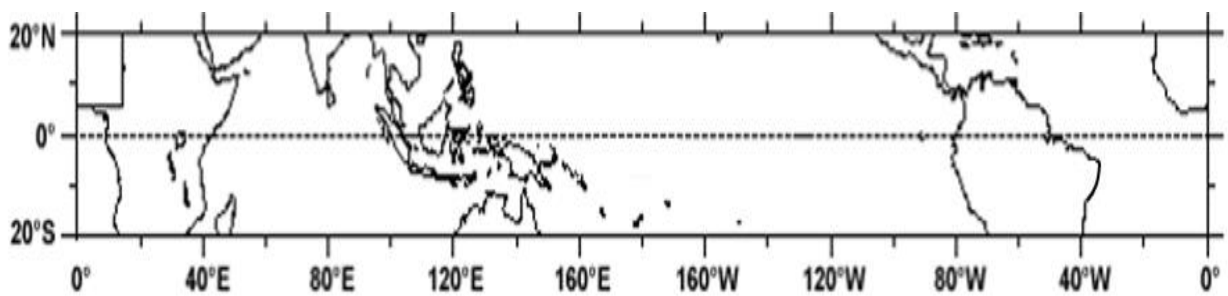
<u>Tropical Meteorology – Homework #2</u>

Due Date: 1 March 2018

Learning Objectives: In this assignment, you will *apply* what you have learned about equatorial wave modes and their resulting kinematic and convective structures to observed events from 2008 and 2011-2018 to *generate* understanding of (a) the contributions of equatorial waves to the total lower-tropospheric kinematic field, (b) equatorial wave climatology, and (c) connections between equatorial waves and other modes of tropical variability such as the El Niño-Southern oscillation.

1. (36 pts) For this question, please refer to Figure 1 at the end of this assignment.

    a. (24 pts) In Figure 1, areas of enhanced and suppressed convection associated with n = 1 equatorial Rossby, Kelvin, and mixed Rossby-gravity waves are depicted. Using this information, please sketch on the figure below the lower-tropospheric wind field resulting from the observed equatorial waves. Please limit your sketch to west of 160°W. You may find it helpful to first sketch on Figure 1 the wind field for each wave type in isolation before blending them together below.



    b. (12 pts) The NOAA/ESRL/PSD website enables daily mean composites of many atmospheric fields to be created using NCEP/NCAR Reanalysis data. This site is available at:

        http://www.esrl.noaa.gov/psd/data/composites/day/

    Choose "Vector Wind" as your variable and "850mb" as your analysis level. Enter a single year, month, and day as 2008 11 18. Choose a plot type of "Mean" and "Custom" as your region. Enter -20 and 20 as your lowest and highest latitude, and 0 and 180 as your western and eastern longitudes. Finally, click on "Create Plot." Right-click on the resulting plot and choose "Save image as…" (or similar) to save it to your computer. Attach it to your completed assignment. How well does this 850 hPa wind analysis compare to your sketch? Please discuss noteworthy areas of agreement and disagreement. Generally speaking, what are some potential causes of disagreement between the figure in (1a) and the NCEP-NCAR Reanalysis data?

2. (64 pts) For this question, please use the Hovmöller plots available on the course website at http://derecho.math.uwm.edu/classes/TropMet/assignments/HW-EW/. There are a total of twenty-nine images in this directory, encompassing the period from 1 April 2011 to 21 January 2018. Images are numbered sequentially in time. All images are courtesy Carl Schreck's webpage at https://ncics.org/portfolio/monitor/mjo/.

   In general, Hovmöller plots include time as one of their axes, commonly the *y*-axis. In the plots available on the course website, time increases moving downward along the *y*-axis, with longitude plotted along the *x*-axis. Please focus only on the portion of each plot above "Begin Forecast." Outgoing longwave radiation anomalies, averaged between 7.5°S and 7.5°N (through July 2015; averaged between 5°S and 5°N thereafter), are shaded per the color bar at the bottom of each image. Negative (positive) values indicate greater (lesser) thunderstorm activity at a given longitude. Contours indicate outgoing longwave radiation anomalies associated with the Madden-Julian Oscillation (blue/black), n =1 equatorial Rossby waves (black/red), and Kelvin waves (green/blue). Solid (dashed) contours indicate an active (suppressed) thunderstorm signal associated with each wave type.

   For parts (b) and (c) of this question, please only focus on waves that last for at least seven days (contours extending between two consecutive tick marks along the *y*-axis) and travel at least 30° longitude (contours extending between two consecutive tick marks along the *x*-axis).

   a. (20 pts) Contours depicting n = 1 equatorial Rossby waves have steeper slope than and opposite sign to contours depicting Kelvin waves. Why do the contours for n = 1 equatorial Rossby waves have steeper slope than do those for Kelvin waves? Why are the contours for n = 1 equatorial Rossby waves sloped in the opposite direction than are those for Kelvin waves?

   b. (16 pts) For this question, please consider only the *convectively active* phase of n = 1 equatorial Rossby waves (solid black/red contours).

      i. (8 pts) Over what range of longitudes are n = 1 equatorial Rossby waves most commonly found?

      ii. (8 pts) During what times of year are n = 1 equatorial Rossby waves most and least common?

   c. (28 pts) For this question, please consider only Kelvin waves (green/blue contours).

      i. (6 pts) Over what range of longitudes are Kelvin waves most commonly found?

      ii. (6 pts) During what times of year are Kelvin waves most and least common?

iii. (16 pts) Archived values of the Oceanic Niño Index, reflecting the three-month-averaged sea surface temperature over the region 5°S-5°N, 120°W-170°W, are available from NOAA. Values greater than +0.5°C denote El Niño conditions, while values less than -0.5°C denote La Niña conditions. Use a plotting program (Excel, GrADS, MATLAB, Python, etc.) to plot the ONI between March-April-May 2011 and October-November-December 2017. Ensure that all axes are appropriately labeled. Attach the plot to the completed assignment.

There are five time periods of interest: July-December 2011 (moderate La Niña); March-August 2012 (weakening La Niña); January-June 2014 (failed El Niño); March-October 2015 (developing strong El Niño); and March-September 2016 (transition from El Niño to a weak La Niña). How does Kelvin wave activity vary between these time periods? Are you able to discern any connection between Kelvin waves and El Niño and/or La Niña? Please speculate on the cause of any connections that you identify.

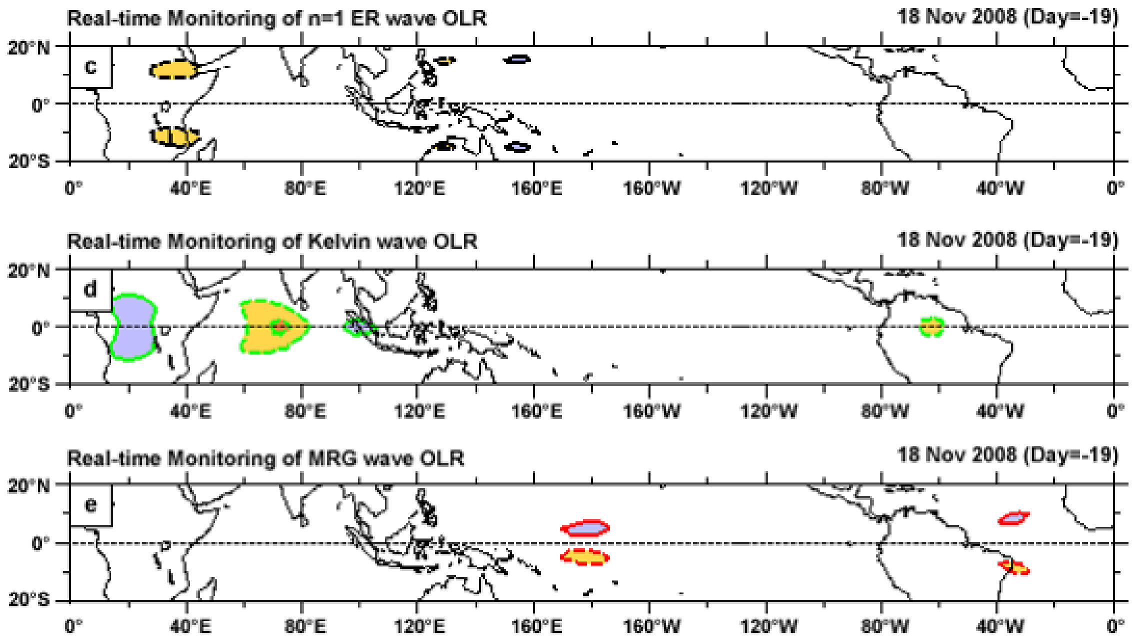


Figure 1. Filtered outgoing longwave radiation anomalies (W m^{-2}, shaded/contoured) for (top) *n* = 1 equatorial Rossby, (middle) Kelvin, and (bottom) mixed Rossby-gravity waves. Blue-shaded and solid contoured areas denote regions of below-normal outgoing longwave radiation and, by extension, enhanced convection. Yellow-shaded and dashed contoured areas denote regions of above-normal outgoing longwave radiation and, by extension, suppressed convection. Figure courtesy of the Australia Bureau of Meteorology, as reproduced in *An Introduction to Tropical Meteorology, 2nd Edition*.