TROPICAL CYCLOGENESIS IN ASSOCIATION WITH EQUATORIAL ROSSBY WAVES

John Molinari, Kelly Canavan, and David Vollaro

Department of Earth and Atmospheric Sciences

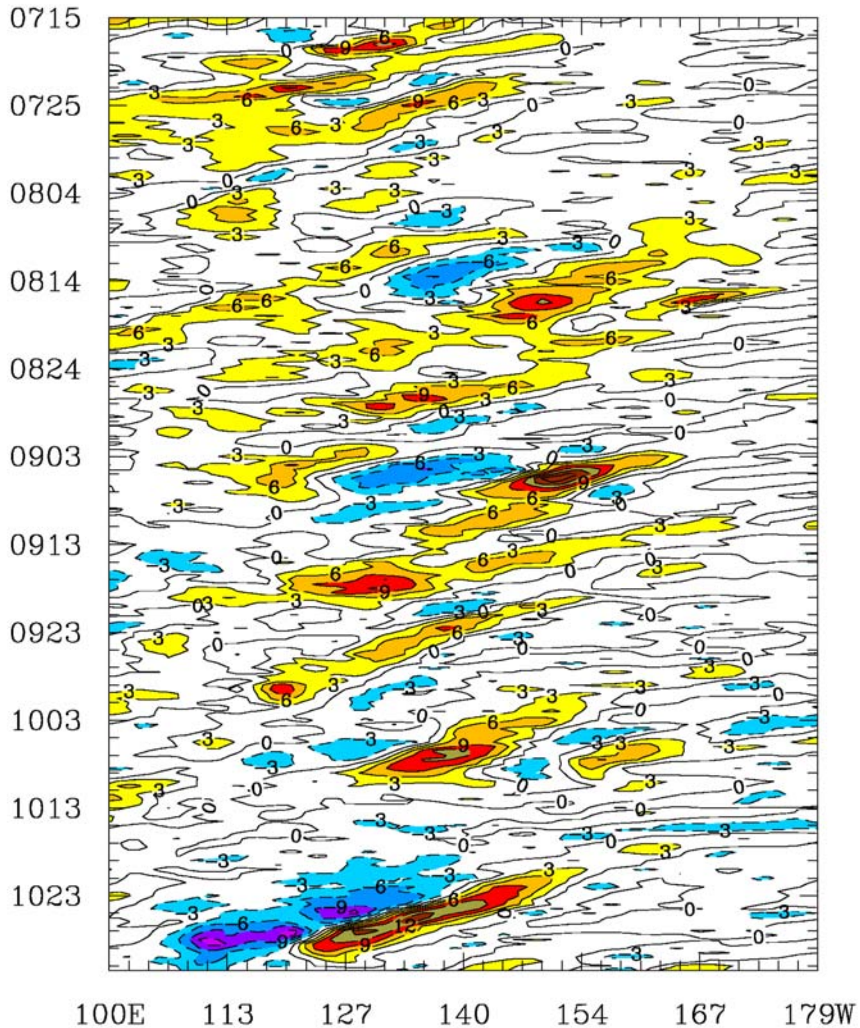
University at Albany, SUNY

ORGANIZATION

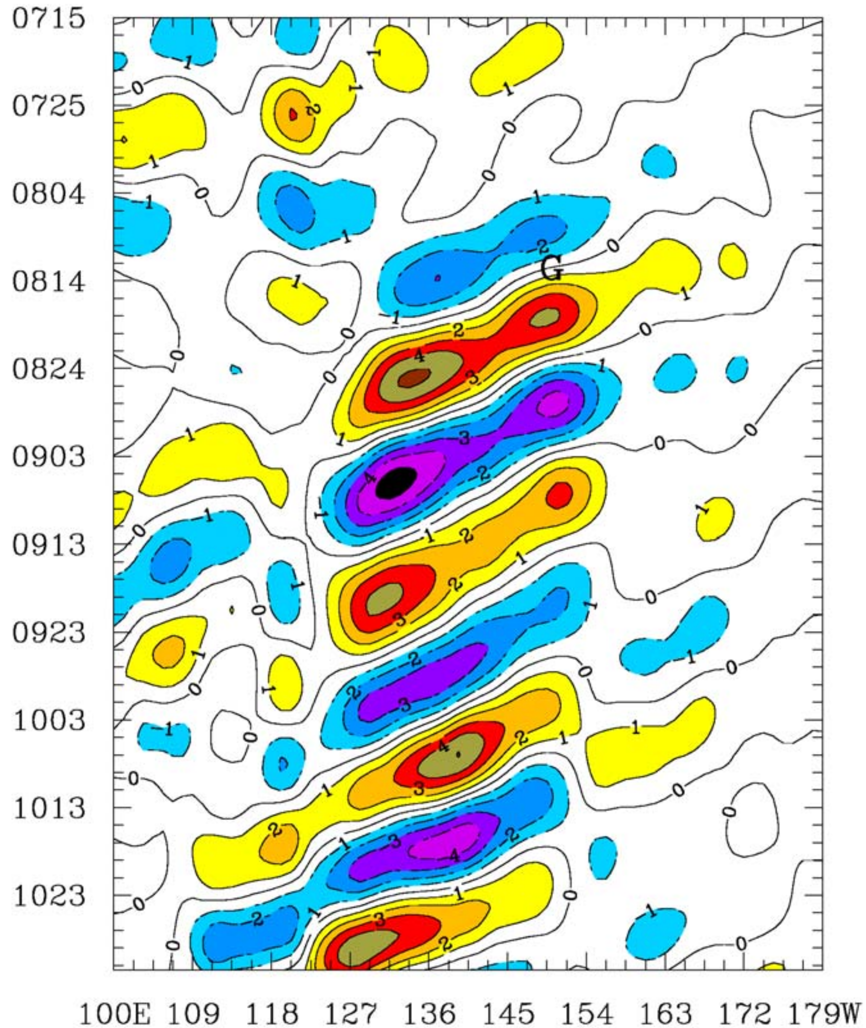
1. Structure and evolution of waves in the packet

2. Environment of the packet

3. Tropical cyclogenesis within the packet



Longitude-time series of unfiltered 850 hPa meridional wind, averaged 5ºN-20ºN, for the period 15 July - 31 October 1991. Contour increment 3 m s^{-1}. Shading in warm (cool) colors represents southerly (northerly) components exceeding 3 m s^{-1}.



As in the previous figure, but bandpass-filtered (15-40 d). Contour increment 1 m s^{-1}. Shading in warm (cool) colors represents southerly (northerly) components exceeding 1 m s^{-1}. The "G" indicates the initial location of what Lander (1994) identified as a "monsoon gyre".

Characteristics of waves in the packet

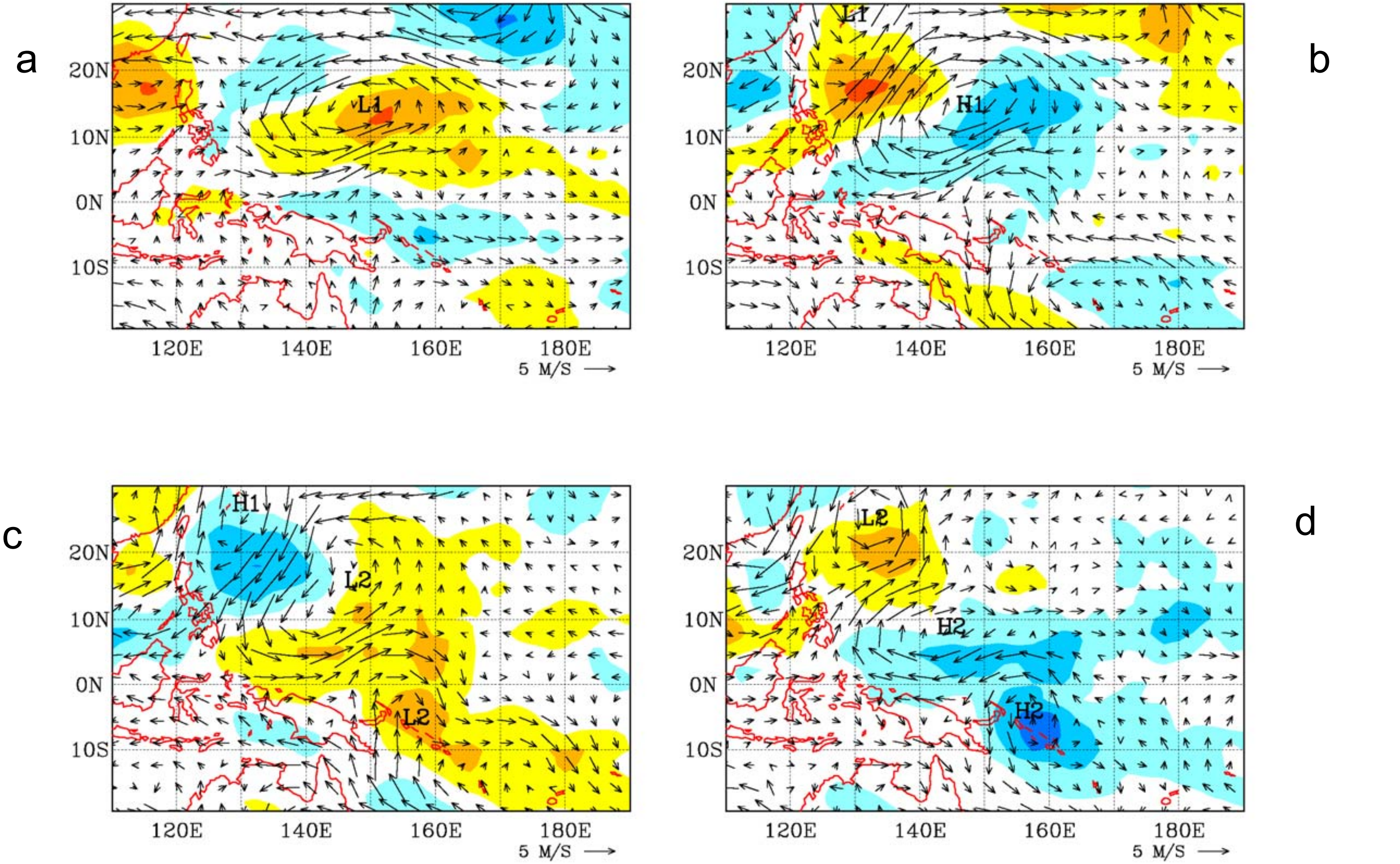
Period 22 d

Wavelength 3600 km

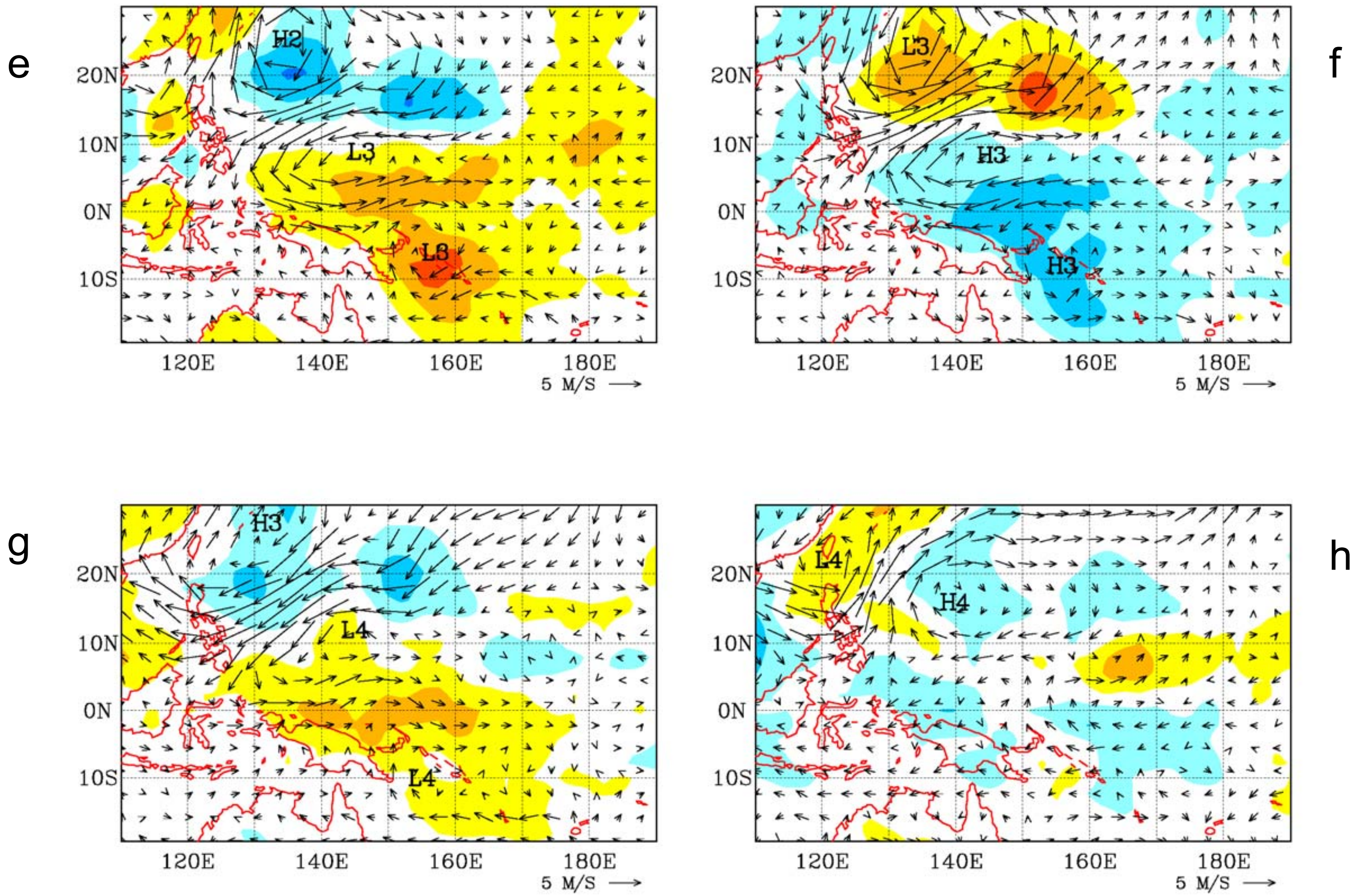
Phase speed -1.9 ms

Group speed ~0

Phase and group closely follow the linear shallow water dispersion relation for equatorial Rossby waves of the observed wavelength for an equivalent depth between 12 m and 25 m, assuming background zonal flow of 1 ms^{-1}.



Evolution of bandpass-filtered (15-40 d) 850 hPa wind vectors and OLR (shaded), shown every 11 days (i.e., increments of one half period) during August-October 1991. Each panel is valid at 0000 UTC. (a) 14 August; (b) 25 August; (c) 5 September; (d) 16 September. Warm colors indicate OLR anomalies of -10, -30, and -50 W m^{-2}. Cool colors represent OLR anomalies of 10, 30, and 50 W m^{-2}.



(continued) (e) 27 September; (f) 8 October; (g) 19 October; (h) 30 October.

Characteristics of the waves in x-y space

Propagate westward, then northward, shrinking in scale as they do so

Southern Hemisphere representation: disturbances are weaker, smaller in scale, and shifted eastward.

The equatorial Rossby waves thus do not resemble linear shallow water structure. But they are very similar to the composite ER waves of Wheeler et al. (2000).

Wave amplitude is large between 5-15N, 125-150E

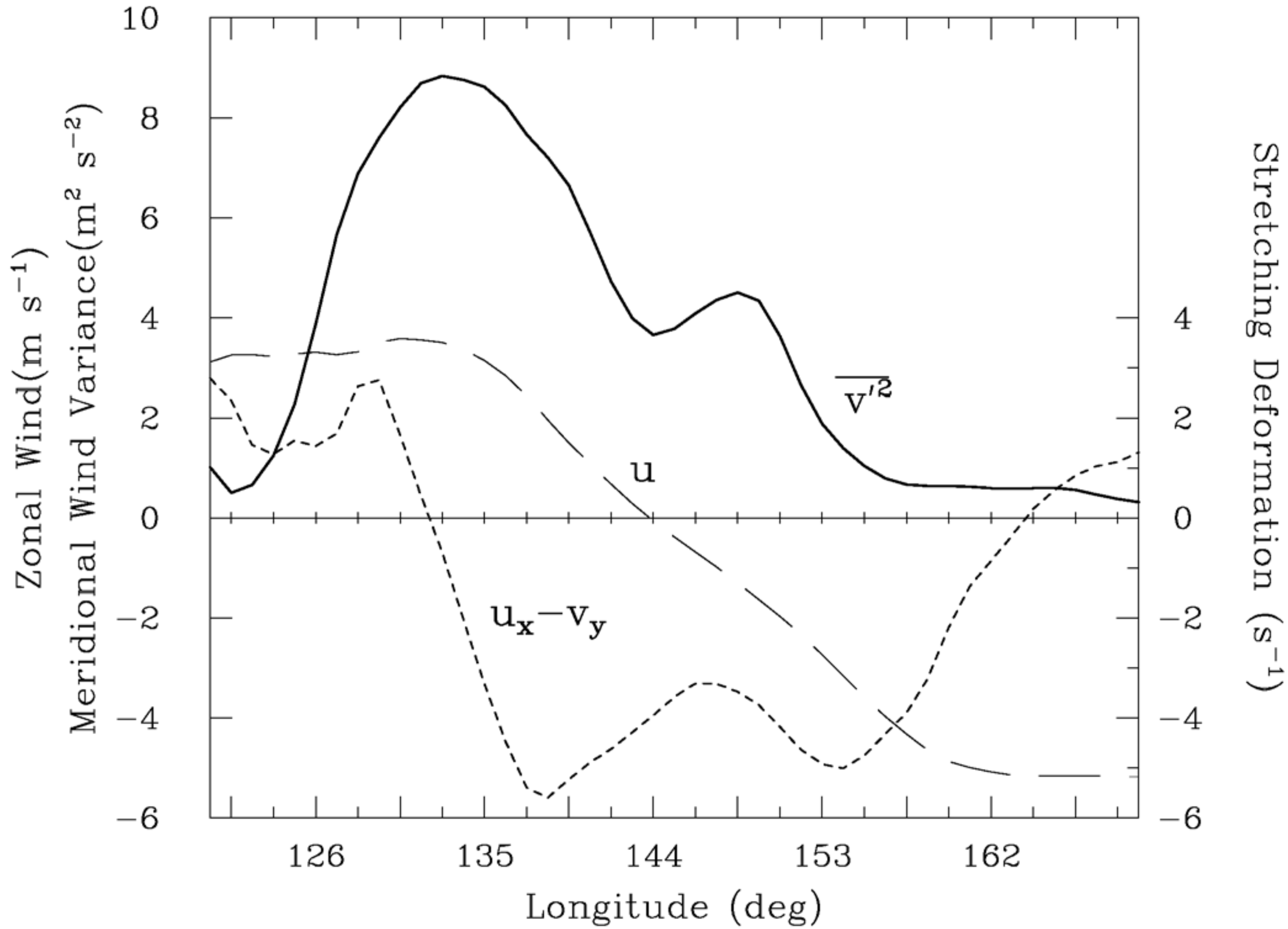
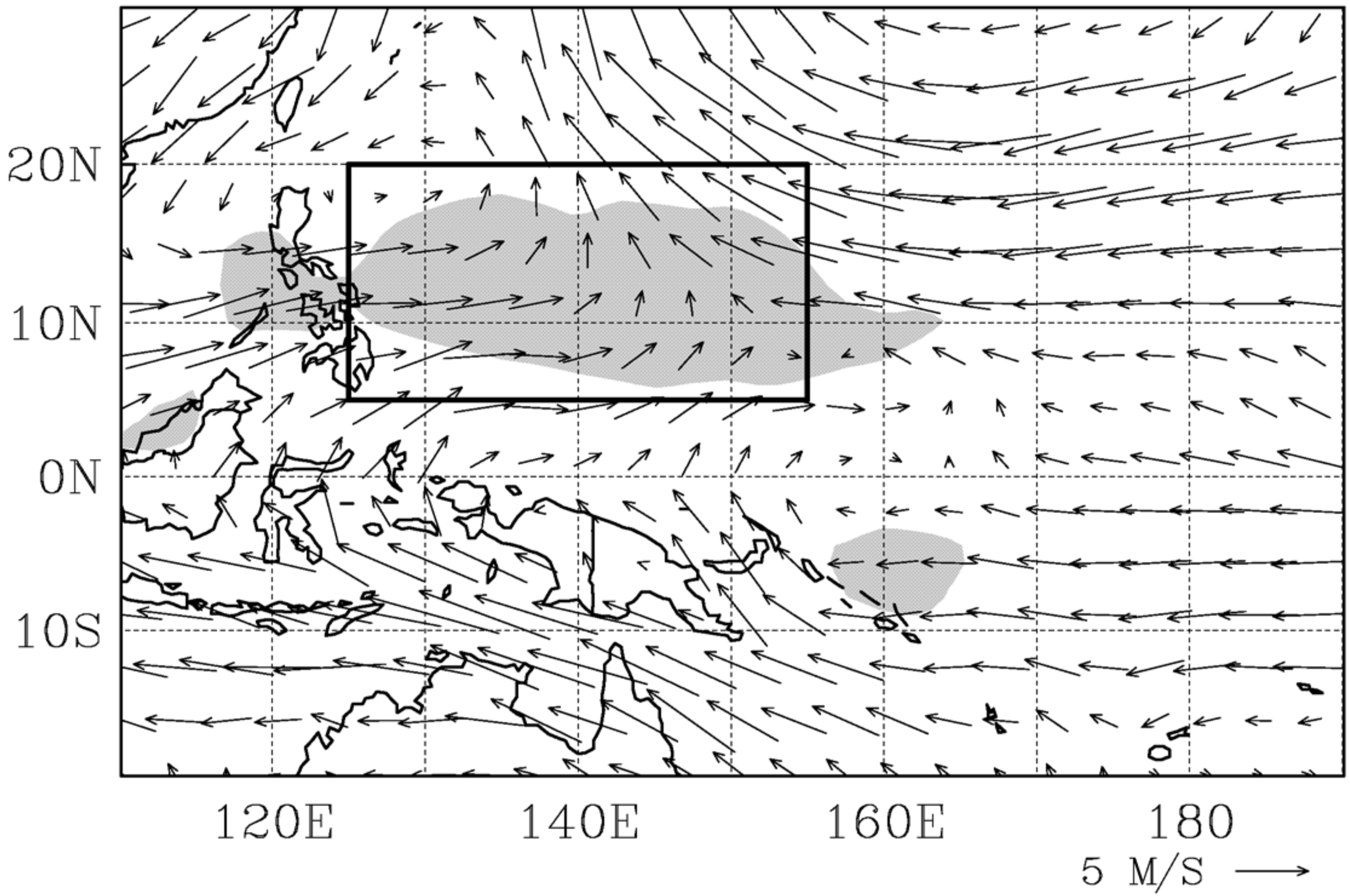
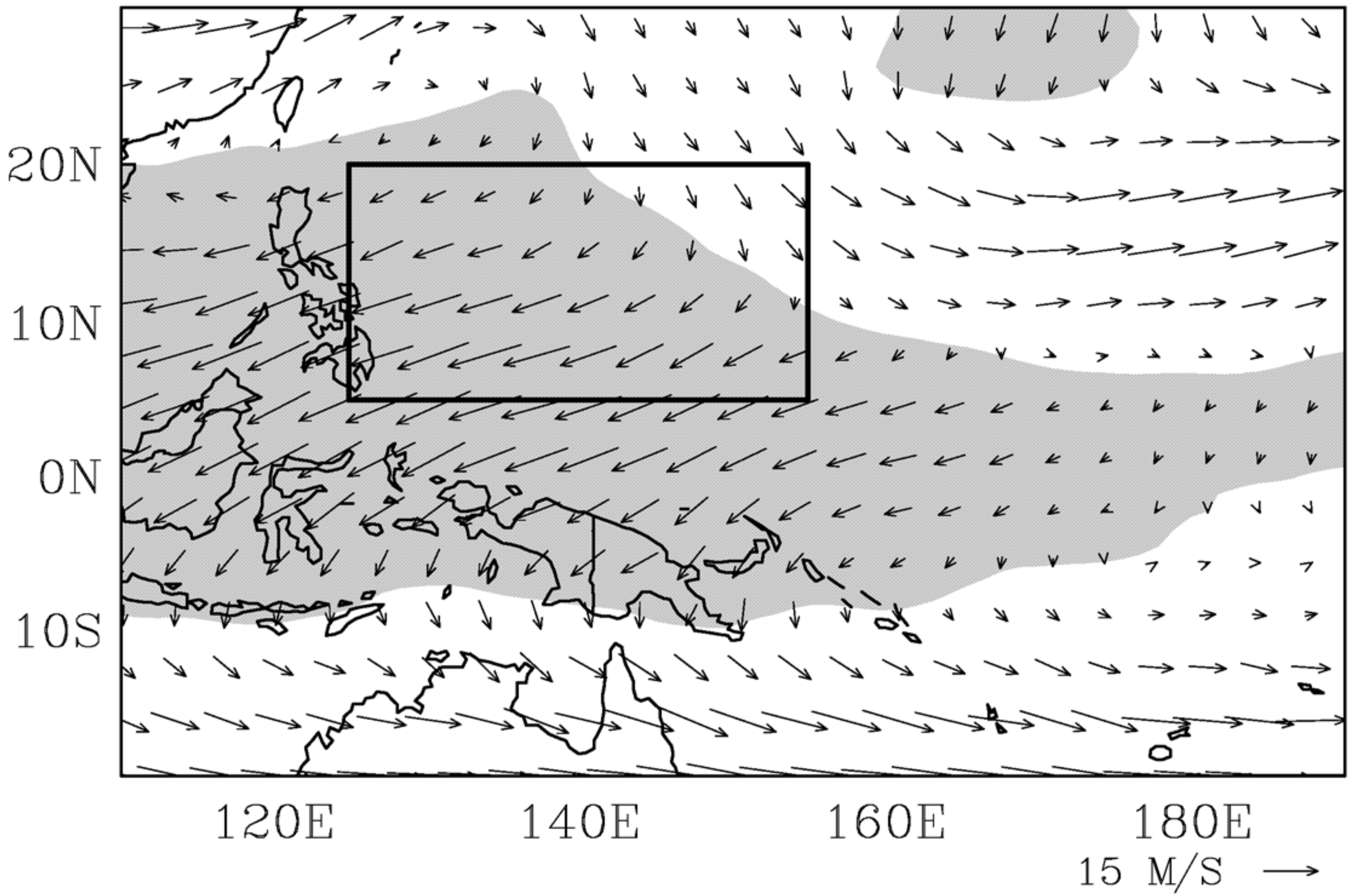


Figure 6. East-west variation of background zonal wind (large dashes), stretching deformation u_x-v_y (small dashes), and 15-40 day bandpass-filtered meridional wind variance (solid), each time-averaged over the life of the ER wave packet, from 8/14/91 to 10/30/91.



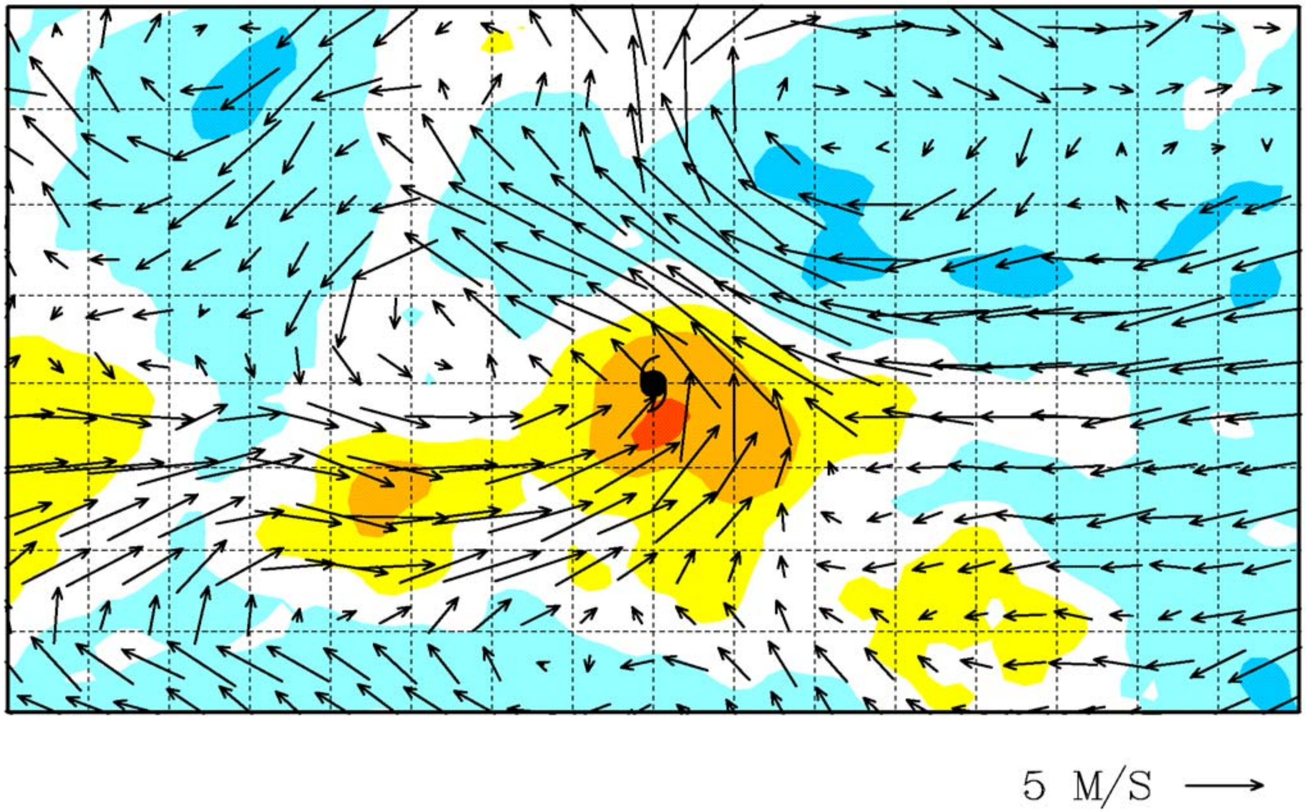
Background wind vectors at 850 hPa and OLR, each time-averaged over the life of the ER wave packet from 8/14/91 to 10/30/91. Shading represents OLR ≤ 210 W m^{-2}.



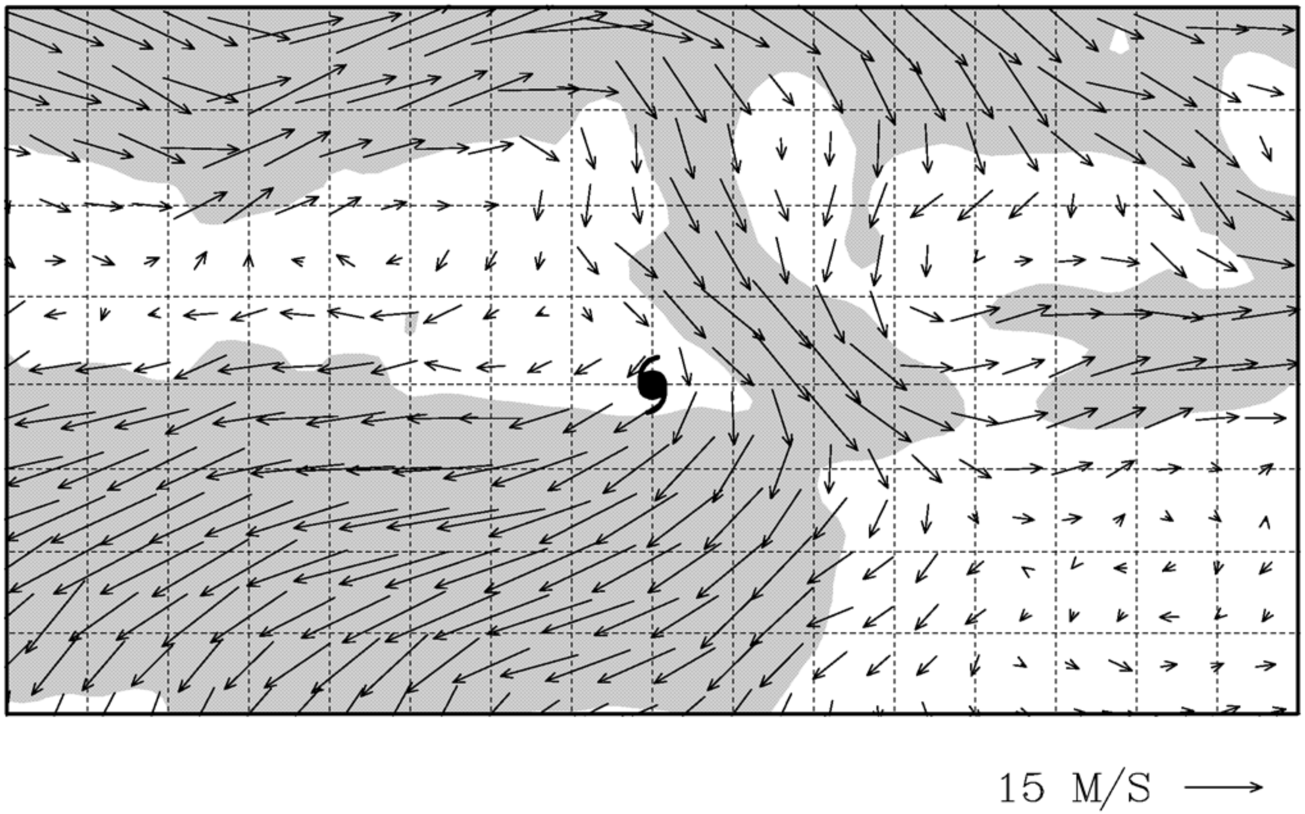
As in the previous slide, but for time-averaged vertical wind shear vectors between 850 and 200 hPa. Shading indicates the regions in which the background vertical wind shear contained an easterly component.

Summary of the packet environment

1. Negative stretching deformation across the packet, largely as a result of confluent zonal flow associated with a region of persistent convection.
2. Easterly vertical wind shear over the packet.
3. In the Southern Hemisphere poleward of 10ºS, there is neither easterly shear nor negative stretching deformation. The ER waves did not grow in that region.
4. Waves in the Northern Hemisphere grow within a region that contains both negative stretching deformation and easterly vertical wind shear.
5. The wave accumulation theory of Lighthill (1978) (see Webster and Chang 1986) seems to be supported, as well as the role of easterly vertical wind shear postulated by Wang and Xie (1996).



Unfiltered wind at 850 hPa and OLR, composited with respect to the genesis location of 8 tropical cyclones that formed in association with ER waves south of 20ºN. The mean genesis point lies at 14.3ºN, 152.5ºE. OLR shading: red: ≤ 150 W m^{-2}; orange 150-180 W m^{-2}; yellow 180-210 W m^{-2}; light blue: 240-270 W m^{-2}; dark blue > 270 W m^{-2}.



Vertical wind shear vectors between 850 and 200 hPa, composited with respect to the genesis location of 8 tropical cyclones. Shading represents regions in which the vertical wind shear magnitude exceeded 10 m s^{-1}.

Summary of tropical cyclogenesis within the waves

Occurs east of the ER wave lows, consistent with the location of linear shallow water theory convergence in the waves.

Occurs in a convectively active region that also has vertical wind shear < 10 ms^{-1}.

Overall summary

ER waves grow within a relatively small region of negative stretching deformation (does not satisfy WKB condition!)

Background deformation is associated with persistent convection in a manner consistent with Gill (1980)

The background convection itself might represent the western Pacific monsoon trough, which is almost always present in some form.

ER waves dominate the OLR variation in the western Pacific, 10-20N, in Northern Hemisphere summer and fall (Roundy and Frank 2004)

Thus ER waves may represent a major pre-cursor to tropical cyclone formation in the western Pacific.

Given the results of Dickinson and Molinari (2002) and others, equatorial wave modes in general may play a major role in tropical cyclogenesis in the western Pacific.