**Effect of Meridional Shear on Equatorial Waves - Revisited**

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### Motivation

SSH Standard Deviation

Chelton et al. 2003 showed that the quasi-annual Rossby wave is highly asymmetric about the equator across much of the equatorial Pacific. They also showed that when the shallow water equations are linearized about a background current system representative of the upper 250m, the numerically calculated SSH eigenfunctions of the first meridional mode Rossby wave bear a striking resemblance to the corresponding first sets of altimeter observations.

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### Research Goal

In order to use equatorial wave theory effectively to explain the observations, we first seek a comprehensive understanding of how the equatorial current system affects the equatorial wave spectrum:

- Source(s) of dispersion and structure modification?
- (Advection, background pv anomalies, layer thickness anomalies)

Why are different modes affected differently?
- Is complementary modification of mode structures/dispersion relations inevitable or fortuitous?

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### Perturbation expansion solution

After Ripp and Maringone 1983

Shallow water equations linearized about weak, geostrophic, mean zonal currents

- \( u = u_0 + \delta u \)
- \( v = v_0 + \delta v \)
- \( h = h_0 + \delta h \)

\( \beta \) is the Coriolis parameter.

- \( u_0 \) is the basic state (mean) zonal current in the upper layer.
- \( v_0 \) is the mean meridional current.
- \( h_0 \) is the mean depth of the upper layer.

Three modes when meridional mode 1 is meridional 80 (black) and surface layer zonal wind field (dashed)

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### Phase speed modification

\( \frac{dn}{d\lambda} = -\frac{1}{2} f \left[ \frac{1}{2} \delta u \left( \frac{1}{2} \delta v \right) \right] \)

- \( \delta u \) is the deviation of the zonal current from the mean.
- \( \delta v \) is the deviation of the meridional current from the mean.
- \( f \) is the Coriolis parameter.

\( \frac{dn}{d\lambda} = -\frac{1}{2} \beta \left[ \frac{1}{2} \delta u \right] \)

- \( \beta \) is the Coriolis parameter.

\( \delta u \) and \( \delta v \) are the deviations of the zonal and meridional currents from the mean.\n
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### Eigenfunction modification

Expressed in terms of Hermite solutions:

\( A_A = \frac{1}{\sqrt{2\pi \sigma}} \int_{-\infty}^{\infty} \exp \left[ -\frac{1}{2} \sigma^2 \left( u - \mu \right)^2 \right] \mathrm{d}u \)

- \( A_A \) is the amplitude of the ith Hermite function.
- \( \mu \) is the mean of the distribution.
- \( \sigma \) is the standard deviation.

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### Modifications to mode-1 long Rossby wave h structure

- \( U(y) = 0.3 \, U(140W,y) \)

Mode 1 advected primarily by Equatorial Undercurrent, and also slowed down by negative pv-gradient anomaly produced by negative Uyy on flanks of undercurrent.

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### Contributions to long Rossby wave anomaly

- Mode 1, \( k = 1 \) and \( k = 2 \)
- Doppler effect

Mode 2 advected primarily by South Equatorial Current, and also sped up by positive pv-gradient anomaly produced by negative Uyy at peak of undercurrent.

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### Higher order solution

Required to accurately predict structure and phase speed for full-strength currents. \( \partial u \) solution correctly predicts trends.

Empirically derived expansion coefficient (right) show that eigenfunction modified by full-strength currents can still be approximated with minimal number of Hermite modes.