THE EFFECTS OF DISPERSION ON THE PROPAGATION AND AMPLITUDE VARIATIONS OF BAROCLINIC ROSSBY WAVES

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1.INTRODUCTION

Chelton and Schlax (1996) provided observational evidence from 4 years of TOPEX/Poseidon data that the phase speed of observed baroclinic Rossby waves was faster than predicted by the standard theory by a factor of up to two to three at mid-and high-latitudes. Tailleux & McWilliams (2001) suggested that the wave speed up was due to the surface intensification of the waves as the result of a combination of rough/steep topography and/or nonlinear effects. At the time the comparison was based on the non-dispersive Rossby wave theory. More than ten years later, the spatial and temporal resolution of SSH data has considerably improved by merging different satellite products, warranting a more detailed investigation of dispersion effects. This poster illustrates the main issues associated with dispersion effects, on the propagation, as well as on the amplitude variations of baroclinic Rossby waves.

2. THE BOTTOM PRESSURE COMPENSATION THEORY OF TAILLEUX AND MCWILLIAMS (2001)

The bottom pressure compensation theory of Tailleux and McWilliams (2001) relies on the observation that oceanic motions are often surface-intensified. This occurs for instance in a two-layer model over rough or steep topography. This is also found in numerical simulations of eddy propagation over a flat-bottom. Our theory explores the consequences of the simplest model of surface-intensification, namely the one consisting in replacing the bottom boundary condition of a vanishing vertical velocity by one of vanishing pressure in the linear standard theory. The theory is found to do much better than the standard theory (Fig. 1) although it is found to systematically over-estimate observations. The zonal mean flow of KCS97 is found in comparison to systematically underestimate observations. The two theories do approximately the same in terms of scatter.

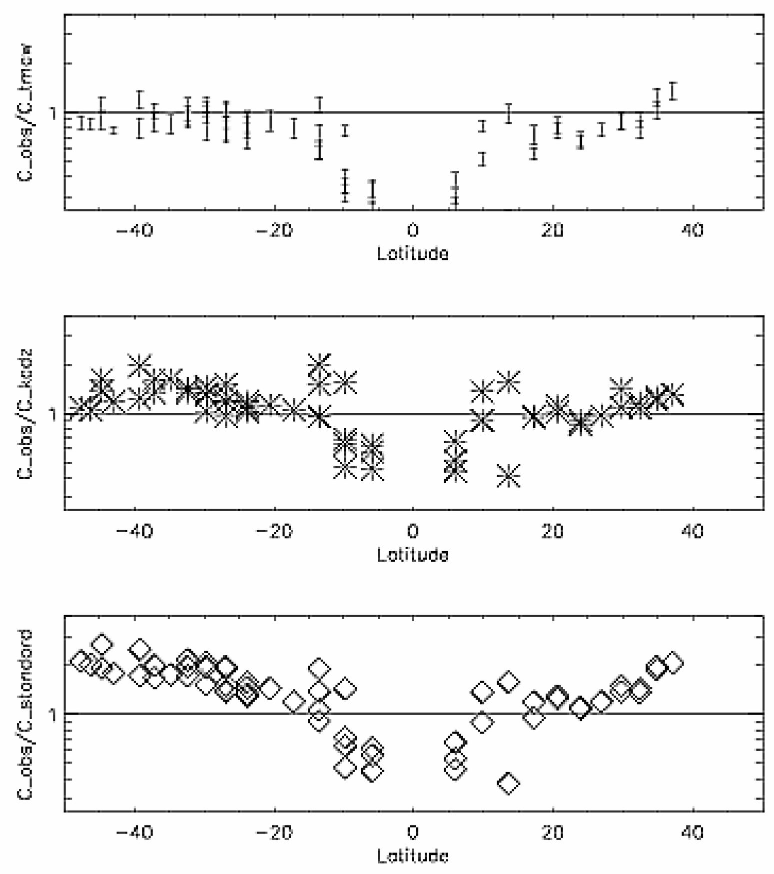

Figure 1: Comparison of nondispersive wave theories predictions for the ratio of predicted to observed phase speeds. TMC01's theory (top), KCS97's theory (middle), Standard theory (bottom).

3. EFFECTS OF DISPERSION ON AMPLITUDE

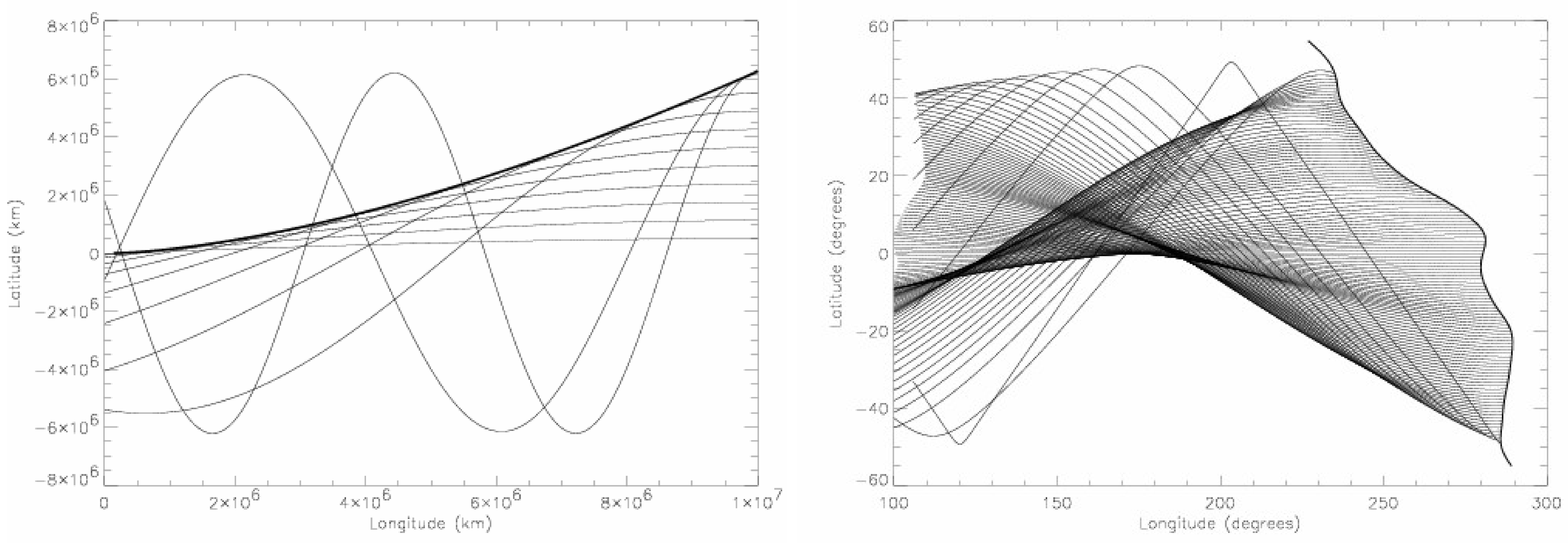

Figure 2: Without dispersion, waves of a given frequency would exist at all latitudes, and could propagate nondispersively across an ocean basin. Dispersion, however, introduces a critical latitude poleward of which a wave of given frequency no longer exists. Near the critical latitude, dispersion strongly distorts the westward pathway of energy propagation. Connected to the critical latitude is a caustics that introduce a natural barrier to the westward penetration of the wave, so that the waves can travel significant distances across an ocean basin only at sufficiently low latitudes. The left figure shows an example of what happens on an idealized beta-plane geometry, whereas the right figure shows what happens for the coast of South America. Dispersion is directly responsible for the beta-refraction pattern characteristics of the waves generated along eastern boundaries. (see also Schopf et al. 1981).

4. DISPERSIVE EXTENSION OF THE BOTTOM PRESSURE COMPENSATION THEORY OF TAILLEUX AND MCWILLIAMS (2001)

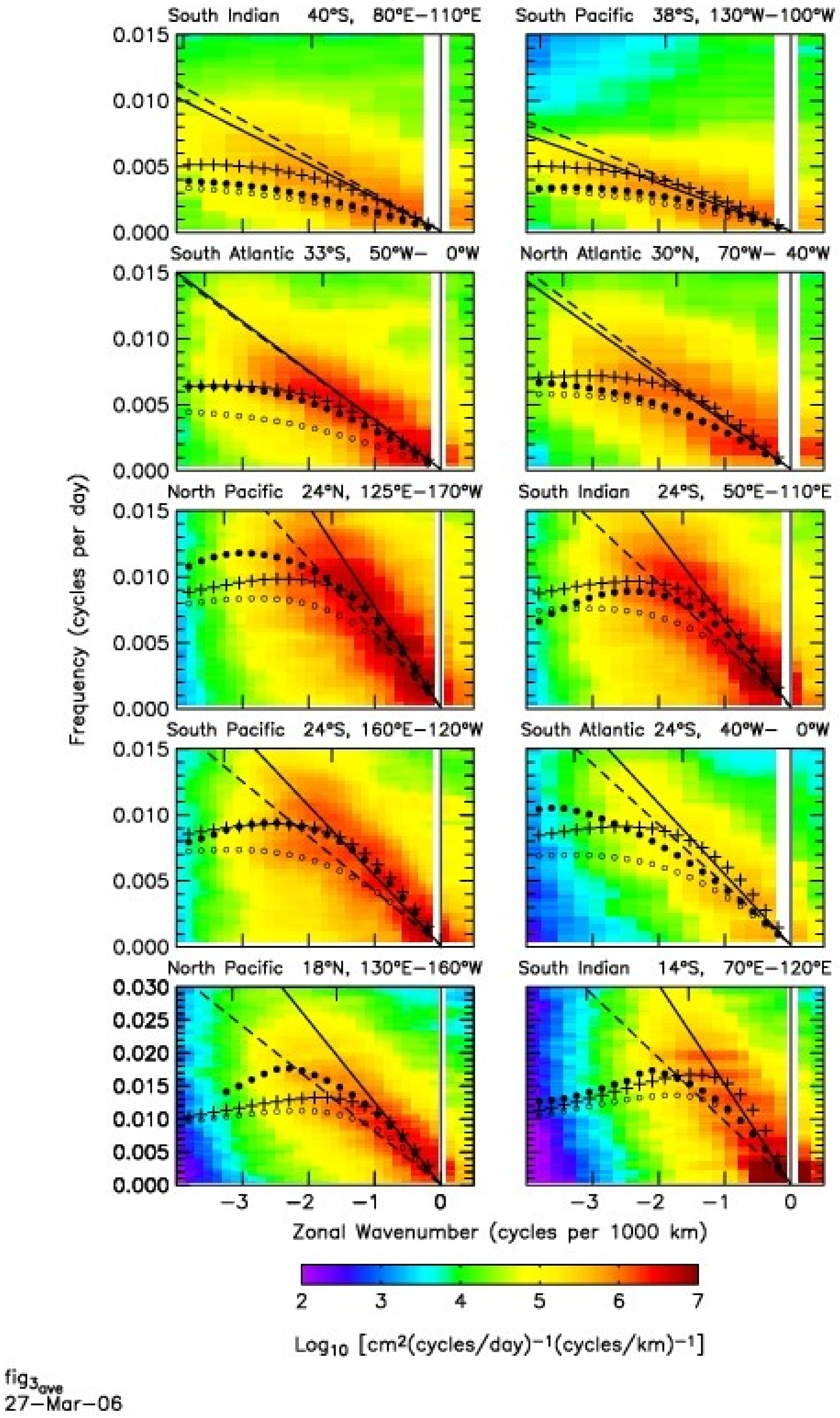

Figure 3: Empirical dispersion relations estimated at selected locations in the oceans (color) superimposed with the predictions of different theories. The plus signs correspond to the dispersive extension of the bottom pressure compensation theory of Tailleux and McWilliams (2001), simply obtained from the following relationship:

$$\omega = -\frac{\beta c_{tmc01}^2 k_x}{f^2(1+R_{tmc01}^2\|\mathbf{k}\|^2)}$$

The white circles correspond to the classical dispersive theory for Rossby Waves over a flat bottom, and in absence of background mean flow. The filled black circles correspond to a straightforward dispersive extension of the zonal mean flow theory over a flat bottom of Killworth et al. (1997).

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References:

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5. CONCLUSIONS: Dispersion is a very important component of linear Rossby wave propagation that affects both the propagation and the amplitude variations of Rossby waves generated along eastern boundaries. Its main implication is that the observed westward propagating signals seen in the ocean interior are therefore unlikely to originate from eastern boundaries. See D. Chelton's talk suggesting that the observed westward propagation seen in the interior should be attributed to nonlinear eddies rather than linear waves