Theory of free and forced planetary waves in a realistic ocean: Towards a physically-based quantitative interpretation of satellite altimeter and SST data

Remi Tailleux (CSAG-University of Cape Town) – Dudley Chelton (COAS-Oregon State University)

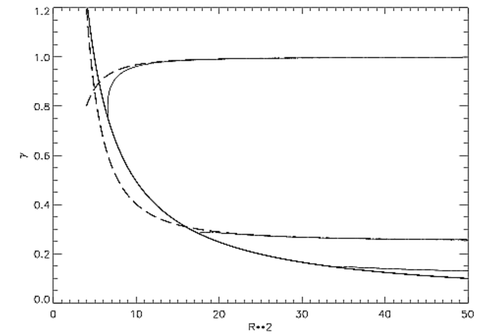
MOTIVATION

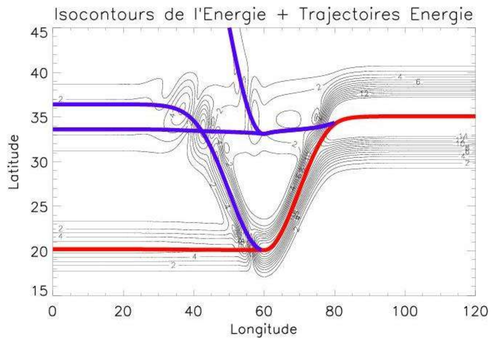
The shortcomings of the linear standard theory were recently demonstrated by Chelton and Schlax (1996). The failure of the linear standard theory is also expected from a number of theoretical arguments.

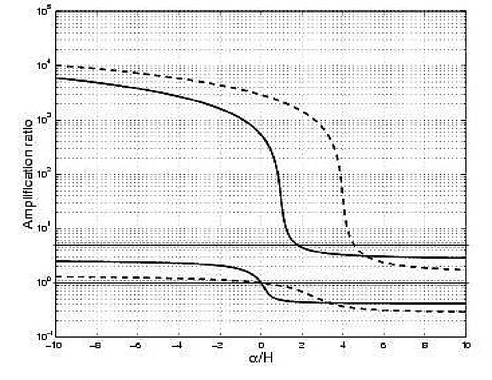
Standard linear Rossby waves	Realistic planetary waves
Infinite number of discrete vertical normal mode, all stable	Only a discrete number of vertical modes + continuous spectrum solutions + baroclinically unstable waves
No bottom trapped mode	Bottom trapped solutions
All modes are linearly stables	Modes may be stable or unstable
The modes propagate independently of and do not exchange energy with each other	The modes exchange energy with each other and with the background mean flow

SCIENTIFIC OBJECTIVES

•Achieve a better theoretical understanding of the roles of topography, mean flow, dispersion, and nonlinearities on the nature and structures of oceanic planetary waves
•Use improved theoretical knowledge to improve existing diagnostics and design new methods of extraction of physical characteristics of planetary waves from SSH and SST data
•In parallel, investigate a-priori decompositions of the SSH and SST anomalies by combining such methods as direct and inverse Radon and Fourier transforms, Hilbert transform, and Continuous Wavelet analysis, which are close to the WKB formalism used in the theoretical work
•In parellel, investigate the signatures of planetary waves in various dynamical fields simulated by high-resolution OGCM (CLIPPER)







MEAN FLOW EFFECT
(Colin de Verdiere and Tailleux, JPO, 2004, in press)

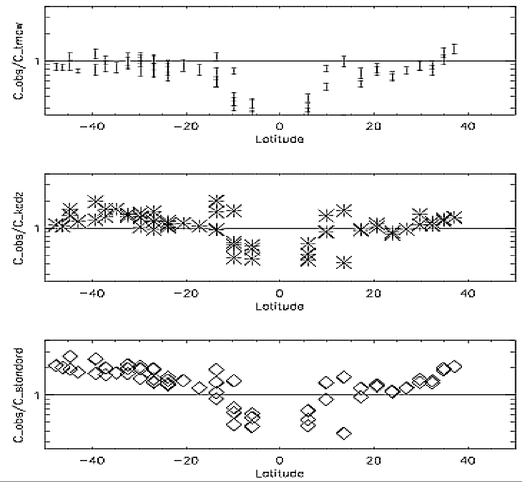
Fig 1:Phase speed of the first three baroclinic modes as a function of the inverse of a dimensionless constant shear.
An increasing shear progressively destroys the discrete baroclinic modes, the higher modes being destroyed first, when the mean flow becomes equal to the phase speed.

TOPOGRAPHIC EFFECTS ON ENERGY PROPAGATION
(Tailleux and McWilliams, JFM, 2002)

Fig 2: Amplitude of a periodic Rossby wave generated along the eastern boundary, with WKB rays superimposed (red=classical theory, blue=mode conversion theory).
Over topography, the classical barotropic and baroclinic modes become bottom and surface intensified modes, and split energy at so-called `mode conversion points'.

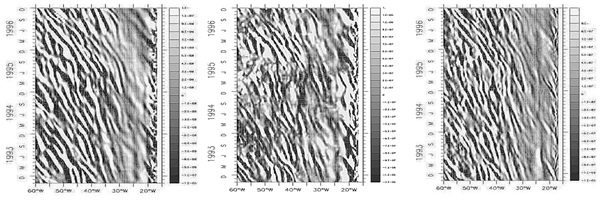
SLOW-DOWN AND SPEED UP OF THE BAROTROPIC & FIRST BAROCLINIC MODES BY TOPOGRAPHY
(Tailleux, JPO, 2003)

Fig 3: Phase speed of the barotropic and first baroclinic modes as a function of the topographic parameter, for two different stratifications (solind and dashed lines).
The two straight lines define the observed speed-up range of observed Rossby waves, in which both barotropic and baroclinic waves can be found.



BOTTOM COMPENSATION THEORY
(Tailleux and McWilliams, JPO, 2001)

Fig. 4: Ratio of observed to theoretical phase speeds. Top: TMC01 theory. Middle: Killworth et al (1997). Bottom: Standard theory (after Chelton & Schlax,96)
Various theoretical and numerical works suggest that topography, nonlinear processes and friction surface-intensify planetary waves, thus speeding-up RWs.



LINKS BETWEEN SST, SSS, and SSH?
(Tailleux, Lazar, Reason, JPO, submitted)

Fig. 5: Hoevmuller diagrams for d/dx surface salinity, temperature, sea level height (from L to R)
•SST (SSS) potentially better to observe higher baroclinic modes?
•SST+SSH: better info about wave amplitudes?
•Phase differences between SST and SSH: related to air-sea interactions, but also to spiciness amplitude variations?

Collaborations:
James C. McWilliams – University of California Los Angeles
Alain Colin de Verdiere – LPO – Universite of Bretagne Occidentale
Alban Lazar – LODYC – Universite Paris 6
Chris Reason – Oceanography Dpt – University of Cape Town