Models of Marginal Seas Partially Enclosed by Islands

Roxana C. Wajsowicz
Dept. of Meteorology
University of Maryland
3433 Computer and Space Science Building
College Park, MD 20852
Phone: (301) 405-5396 Fax: (301) 314-9482 Email: roxana@atmos.umd.edu

Award Number: N000140310544
http://www.meto.umd.edu/~roxana

LONG-TERM GOALS

This project represents the next step in my continuing effort to construct simple, theoretical models of western marginal sea-open ocean systems, which explain how large-scale forcing over the open ocean drives a circulation through the sea and how this circulation is distributed through possible straits connecting the marginal sea to the open ocean. A motivating factor for this research is the need to understand how to best represent these systems in 3-D numerical models of the ocean circulation being developed for prediction.

OBJECTIVES

1. To determine how partial enclosing of a marginal sea by islands affects the hydrographic structure of the sea. The effect of islands on the surface winds and the effect of the modified winds on the hydrographic structure and currents will be considered.

2. To identify the parameters which determine the flow structure in a strait connecting a marginal sea to the open ocean, and so identify the regimes in which a countercurrent and/or an undercurrent occur and their locations.

APPROACH

A hierarchy of models is being developed to gain a better understanding of the baroclinic structure of the flow through straits connecting the open ocean and marginal sea and their effect on the hydrographic/potential vorticity structure of the marginal sea. At each level of the hierarchy, a new feature is introduced, for example:

Base Level: Open ocean-marginal sea, no island;

Level 1: Include partially sheltering island, unperturbed wind stress;

Level 2: Include perturbation to wind stress due to island.

WORK COMPLETED

This project was a new start late in FY03. So far, I have extended some earlier research on the scattering of low-frequency coastal Kelvin waves through a gap to multi-gap systems. It unifies and extends the results of Johnson (1991), Killworth (1989) and Wajsowicz (1991), and provides insight on how to interpret temporal variability measured at tide-gauges on island chains, and by current meters in straits, between two basins, *e.g.* Intra-Americas seas and North Atlantic Ocean, and southern Indonesian seas and eastern Indian Ocean.

RESULTS

In the limit of frequency $\sigma \rightarrow 0$, the *net* transport of an ideal fluid through a multi-gap system induced by an incident coastal trapped Kelvin wave (CKW) is determined by the deepest sill depth. It is independent of gap widths and lengths, though the transport through individual gaps in the system may depend on their widths, and those of the gaps on the incident CKW side. This result follows from Johnson's (1991) stratified connection formulae, which traces pressure along coastal isobaths through *conservative* scatterers. The fraction of incident energy flux transmitted *through* the system of gaps into an adjacent basin for an incident CKW of mode M is $1-a_{MM}$, where a_{MM} is the amplitude of the Mth mode continuing past the system of gaps in the incident basin. Examples are given in Fig. 1a for an incident barotropic mode and first two baroclinic modes calculated for a background buoyancy frequency typical of the tropical oceans. The baroclinic modes are surface-trapped, which accounts for the large amount of energy transmitted *through* the system of gaps even for high sill depths. If Lombok Strait were the deepest sill in the system connecting the Indonesian seas to the Indian Ocean, then little of the energy associated with barotropic or 2nd baroclinic mode CKW incident from the Indian Ocean is transmitted *through* the Strait. In contrast, a major fraction of an incident 1st baroclinic mode CKW is transmitted. If Timor Strait were the deepest sill, then a major fraction of all of the low-order mode incident wave energy is transmitted through the system, though not necessarily through Timor Strait itself.

In applying Johnson's (1991) stratified connection formulae for a conservative scatterer, it is assumed that the basins are of infinite extent and unbounded, and also that the fluid is ideal. None of the incident CKW is converted into short, stratified topographic Rossby waves on the sills. Rather, reflected topographic wave energy is converted into baroclinic energy on the downslopes, and propagates away as CKWs. However, Killworth (1989) shows short waves on the downslopes in his numerical 2-layer PE calculations. Also, Wajsowicz (1991) shows barotropic wave energy confined to the sill region in finite basin simulations under the rigid-lid approximation. These findings can be reconciled with the above by noting that in a finite, bounded domain, the barotropic wave energy at least recirculates around the basins, and is subject to further redistribution of its energy by passage over the sills. Also, if σ is small, but not zero, then the large difference in group velocity between the barotropic and baroclinic CKWs suggests a build up of energy in the regions of conversion of barotropic to baroclinic energy, so requiring dissipation. Fig. 1b gives the corresponding results assuming all of the reflected barotropic energy is dissipated. There is little impact on amplitudes of the low-order baroclinic modes, which continue in the incident basin. However, those in the adjacent basin are significantly reduced especially for shallow sills.

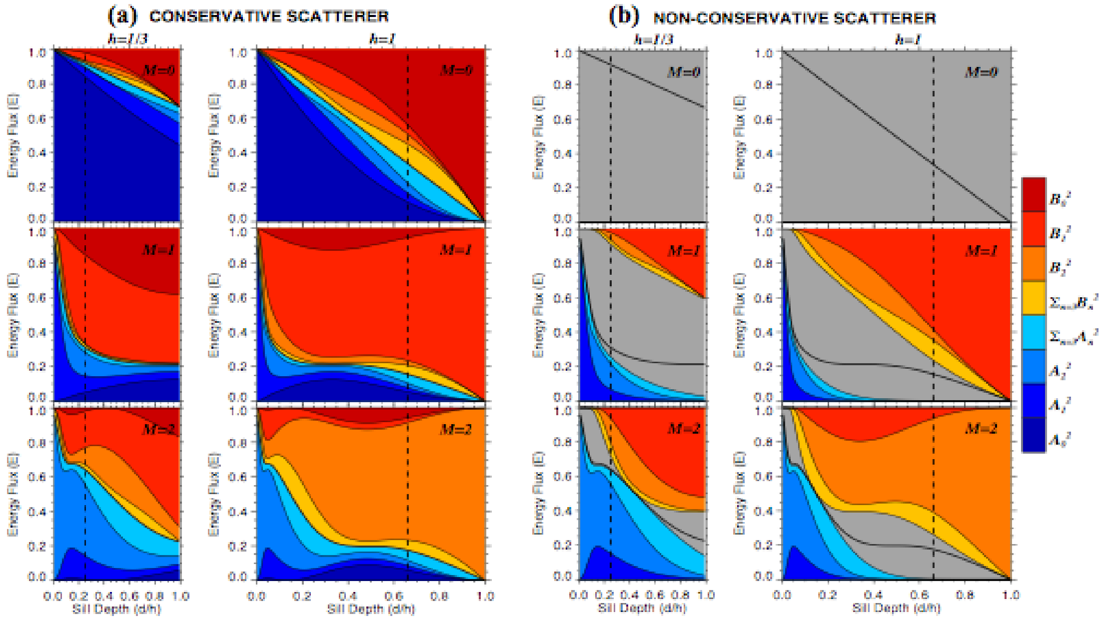

Fig. 1: Transmitted energy fluxes for (a) conservative scatterer, and (b) non-conservative scatterer, as function of sill depth relative to adjacent basin depth (d/h) for adjacent to incident basin depth ratios of h=1/3 (left) and h=1 (right). From top to bottom for incident CKW normal modes M=0,1,2, where baroclinic normal mode structure is surface-trapped as found in tropical oceans. Energy flux transmitted by given normal mode is square of its transmission coefficient. Blue shades denote contributions to flux transmitted **across** ***gap (A_n^2, n=0,1,2,...), red shades to flux transmitted*** **through** ***gap (B_n^2,n=0,1,2,...); key is given on righthandside of plot. Total energy flux dissipated shaded grey. Dashed line on lefthandside plots denotes ratio appropriate to Lombok Strait and on righthandside plots to Timor Strait for CKWs incident from east Indian Ocean.***

IMPACT/APPLICATIONS

As with my previous research, it is expected that the numerical modeling community, in particular those developing 3-D numerical models of the North Atlantic Ocean/Intra-Americas seas circulation, and western Pacific Ocean/south-east Asian seas circulation, will find this fundamental research useful in understanding which features are important to include and how their present models may be deficient.

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