EVOLUTION OF NONLINEAR INTERNAL WAVES IN CHINA SEAS

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LONG-TERM GOAL

To study nonlinear ocean internal wave processes in the East and South China Seas, and Yellow Sea by using satellite synthetic aperture radar (SAR) imagery, in-situ data, and numerical models.

SCIENTIFIC OBJECTIVES

To Understand the environmental effects (e.g. bottom topography, shoaling, mixing, and current/shear) on nonlinear internal wave generation, evolution, and dissipation.

APPROACH

Synthetic Aperture Radar (SAR) images from ERS-1 have been used to study the characteristics of internal waves northeast and south of Taiwan in the East China Sea, east of Hainan Island in the South China Sea, and in the Yellow Sea in conjunction with moorings and field measurements. The numerical simulations of internal wave evolution on the continental shelf have been performed and compare with SAR observations, especially for the evolution of nonlinear waves and the disintegration of solitons into wave packets. A parametric study for various environmental conditions to assess the nonlinear effects such as bottom topography (across critical depth), shoaling, and dissipation has been conducted.

WORK COMPLETED

Based on the SAR images and hydrographic data, internal waves of elevation have been identified in shallow water due to a thicker mixed layer as compared with the bottom layer on the continental shelf (Liang et al., 1995). The generation mechanisms including the influences of the tide and the Kuroshio intrusion across the continental shelf for the formations of both elevation internal waves and depression waves under various ocean conditions have been investigated. The effects of water depth on the evolution of solitons and wave packets are modeled by nonlinear Kortweg-deVries (KdV) type equation and linked to satellite image observations. The numerical calculations of internal wave evolution on the continental shelf have been performed and compared with the SAR observations. In the South China Sea, both depression and elevation waves were observed in the SAR images during the summer and spring seasons at the same location, respectively. Also, the internal wave packets with more than 15 solitons were observed and measured by the ERS-1 SAR and the thermistor chain from a research ship in the Yellow Sea. Based on the SAR images, these many solitons may be caused by the wave-wave interaction. The comparisons of the characteristics of the

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internal wave evolution in the US East coast water, in the East and South China Seas, and Yellow Sea have been studied. A parametric study for various environmental conditions has been carried out by numerical simulations to demonstrate and to assess the nonlinear effects such as bottom topography, shoaling (across critical depth), dissipation/mixing, and wave-wave interaction on internal wave evolution.

RESULTS

Rank-ordered packets of internal solitons propagating shoreward from the edge of the continental shelf were observed in the SAR images (Liu et al., 1996) in the East China Sea. Based on the assumption of a semidiurnal tidal origin, the wave speed can be estimated and is consistent with the internal wave theory. The effects of water depth on the evolution of solitons and wave packets are modeled by KdV-type equation and linked to satellite image observations. For a case of depression waves in deep water, the solitons first disintegrate into dispersive wave trains and then evolve to a packet of elevation waves in the shallow water area after they pass through a "turning point" of approximately equal layer depths has been observed in the SAR image and simulated by numerical model (Liu et al., 1997). The Kuroshio moving north from Philippine Basin branches out near the south tip of Taiwan. A part of the Kuroshio intrudes into the South China Sea through the Bashi Channel and the Luzon Strait. The internal tides and internal waves have been generated by the shallow ridges in the Luzon Strait. Surface signature pattern of huge internal soliton packets has been observed in the ERS-1 SAR image. The crest of soliton is more than 200 km long and each packet contains more than ten rank-ordered solitons with a packet width of 25 km. These are the biggest internal waves that have been observed in this area. The internal wave amplitude is larger than 100 m based on the CTD casts from Taiwan's research ship during their South China Sea expedition. These huge wave packets propagate and evolve into the deep South China Sea and will reach the continental shelf of southern China. The interaction of nonlinear internal wave packets in the Yellow Sea show the merge of solitons to a larger single wave packet.

IMPACT/APPLICATION

It is clear that these internal wave observations at northeast of Taiwan in the East China Sea, east of Hainan Island in the South China Sea and in the Yellow Sea provide a unique resource for addressing a wide range of processes. Among these the following may be included: the generation of elevation internal waves by upwelling due to the Kuroshio intrusion across the continental shelf; the evolution of nonlinear depression waves through the critical depth; the disintegration of solitons into internal wave packets; internal wave breaking and turbulent mixing on wave propagation; the shoaling effects of variable bottom topography on wave evolution; and internal wave-wave interaction. The inclusion of these physical processes is essential to improve quantitative understanding of the coastal dynamics. The effects of internal wave on acoustic propagation is a very important issue as demonstrated in the Yellow Sea Acoustic/Internal Wave Experiment carried out in August, 1996.

TRANSITIONS

We have collected many SAR images in the Yellow Sea to help the field test planning of an ONR-funded (Ocean Acoustics Program) study in the Yellow Sea in August 1996. We are getting more

SAR images to compare with field test data and try to interpret test results by numerical simulations. Our internal wave evolution model has been used in a NRL/SSC study of internal wave effect on acoustic propagation.

RELATED PROJECTS

Professor Ming-Kuang Hsu of National Taiwan Ocean University has collaborated with us to coordinate the field measurements of internal waves during Taiwan's KEEP-II experiment and to provide the required environmental and current measurements. Regularly scheduled hydrographic surveys by Taiwan's research ship with CTD casts, thermistor chains, marine radar, acoustic echo sounder and long-term direct current observations with four moored ADCP's will be conducted by Prof. Joe Wang of the Institute of Oceanography of the National Taiwan University in the South China Sea and Prof. M.-K. Hsu of the National Taiwan Ocean University in the East China Sea. Dr. John Apel and I also work on the effects of internal wave on acoustic propagation in the Yellow Sea Acoustic/Internal Wave Experiment carried out in August, 1996 in conjunction with the ONR Ocean Acoustics Program. These in-situ stratification and current measurements will provide a check on SAR observations and an input for the numerical simulation of wave evolution on the continental shelf.

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