Global Ocean Internal Wave Database

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LONG-TERM GOALS

Our long-term goal is to develop a global database of ocean internal waves observed primarily from spacecraft. This database will be publicly accessible and can be used for various purposes including understanding the statistical properties of internal waves and upper ocean dynamics in any ocean area of interest.

OBJECTIVES

Our objectives are to extract information on ocean internal waves from Space Shuttle photographs and satellite SAR, to construct a database containing the information for global oceans and to make the database publicly accessible via the Internet. We will demonstrate the use of the database by performing statistical analysis of internal wave features and dynamic analysis of their evolution under continental shelf boundary conditions.

APPROACH

The global database of ocean internal waves has two major sections, one for Space Shuttle images and a separate section containing SAR imagery from ERS-1, 2, Radarsat, and other spacecraft. The images will be accompanied by interpretation maps and text describing oceanographic properties of the imaged features. The database includes a home page, offers a standard format and is accessible to Internet users.

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WORK COMPLETED

We searched NASA and our own Space Shuttle archives to extract nearly 200 cases of ocean internal waves observed in various parts of the globe. A separate section of the database was set up for SAR images of internal waves, provided by various investigators. The radar section includes 50 SAR images. Interpretation maps and text describing oceanographic properties of the imaged features have been prepared to accompany one third of the images. A demonstration study for using the database has been performed, including statistical analysis of ocean internal wave features and dynamic analysis of the evolution of ocean internal waves under continental shelf boundary conditions.

RESULTS

Based on the data contained in the database, one can conclude that ocean internal waves are common and can be observed by spaceborne SAR and visible imagery in all ocean regions, including the Atlantic, Pacific, Indian Oceans and major seas. In the open ocean their wavelengths have a Gaussian distribution, while closer to shore the distribution is skewed (Raleigh). Most of the internal waves were generated by the interaction of the semidiurnal tide with the edge of the continental shelf. Tests showed that all internal wave images and interpretations maps in the database can be downloaded and accessed via the Internet. Adding a SAR section has significantly expanded the database to a total of about 250 scenes. Examples of a Space Shuttle image and a SAR image are shown in Figures 1 and 2, respectively.

Thermocline shoaling and deepening cause changes in the phase speeds of internal waves as described by linear wave theories. On the other hand, the ocean area where internal waves have variable phase speeds may be treated as a dynamically inhomogeneous medium. In this case, theories of nonlinear dispersive-wave propagation in inhomogeneous media may stand. We used these theories to analyze the evolution of ocean internal solitary waves passing over a seamount in the Gulf of Aden. The results indicate that a surprisingly sharp recess of an internal solitary wave packet, imaged by the space shuttle *Discovery*, is a signature of spatial phase delay caused by thermocline shoaling over the seamount. Soliton fission due to thermocline shoaling was also observed in the imagery. The observed number of transmitted solitons over the seamount agrees with theoretical predictions. Relative soliton amplitudes measured from the imagery also agree qualitatively with predictions.

We derived a theoretical model of a radar image for a KdV type ocean internal soliton, and validated the model using ocean internal wave signals taken from ERS-1 SAR and RadarSat SAR images. The results indicate that the model perfectly simulates ocean internal soliton signatures with double sign variations of radar backscatter. On the basis of the model, we developed the curve fitting method and the peak-to-peak method for determining the internal soliton characteristic half widths, which then were used to calculate the internal soliton amplitudes. The test results indicate that ocean internal soliton amplitudes derived by the two methods agree with in situ data acquired on the Portuguese Continental Shelf and the South China Sea with a reasonable accuracy. The role that wind fields play in ocean radar remote sensing was also analyzed. Finally, the modulation ratio of ocean internal waves on radar images was quantitatively estimated.

IMPACT/APPLICATIONS

When completed, this Internet-accessible database will represent the largest collection of internal wave imagery observed by spacecraft over most of the globe. The sample size will be large enough for scientists to evaluate the general statistical properties of internal waves in various parts of the oceans. Furthermore it will be possible to test models and obtain detailed descriptions of internal waves at specific ocean sites.

TRANSITIONS

A dozen scientists from several countries have already requested imagery from our internal wave database. Nine papers using the data from this database have been published (or submitted) in scientific journals and conferences.

RELATED PROJECTS

We have been working closely with various investigators, including Drs. John Apel (Global Ocean Associates), Antony Liu (NASA/GSFC), Tim Donato (NRL), etc. who have provided us with SAR imagery and performed some of the internal wave analysis.

PUBLICATIONS

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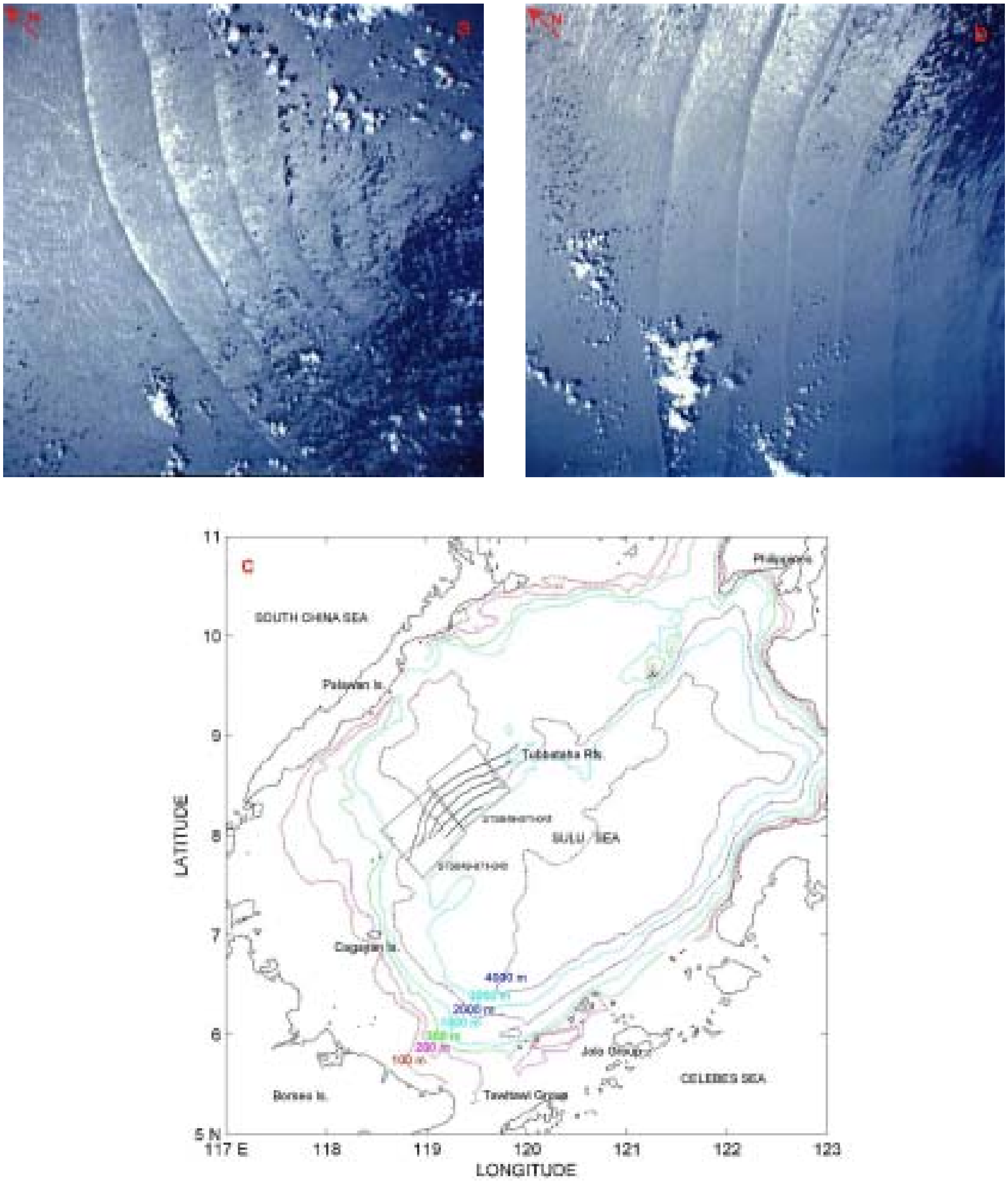

Figure 1 Space shuttle images of internal waves in the Sulu Sea
a) STS049-071-040 b) STS049-071-041 c) Interpretation map

Two photographs were sequentially taken on May 8, 1992. The grouped curves are images of ocean internal waves in the Sulu Sea. There are six solitons in the wave packet. The observed portion of the leading wave crest is 190 km. The wavelength is about 10 km.

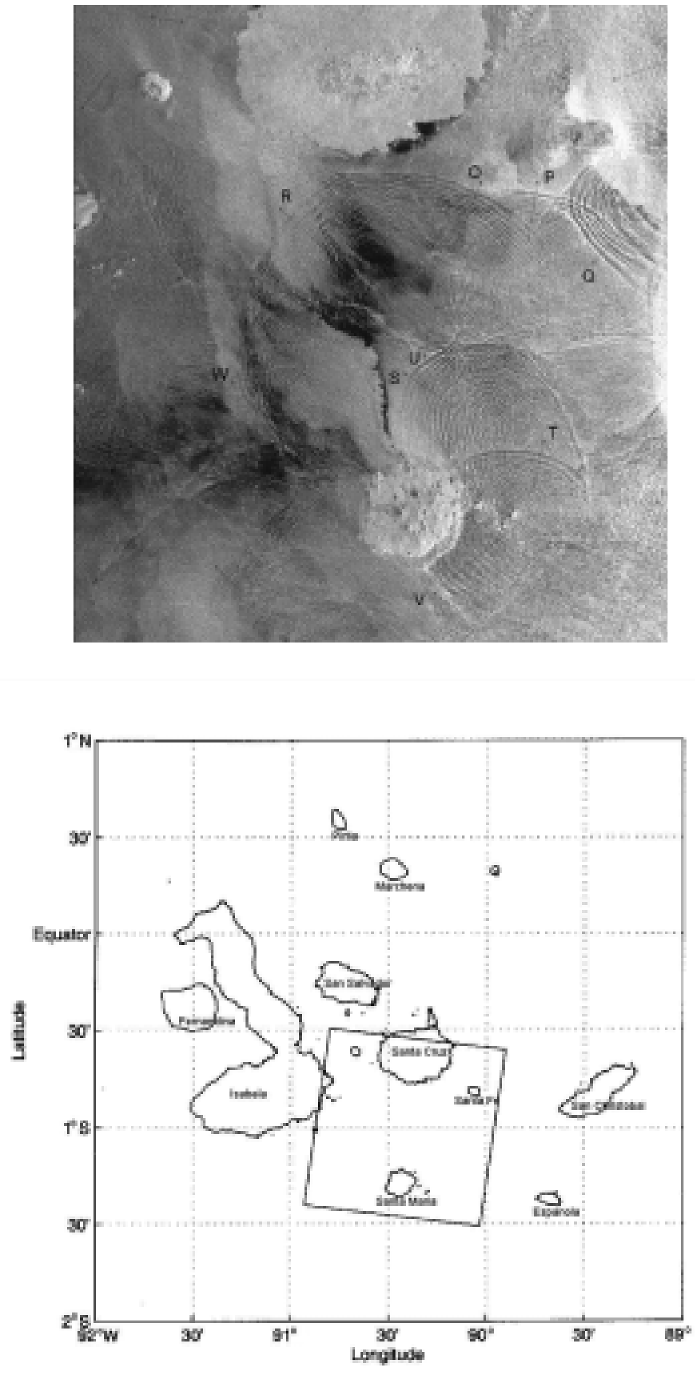

Figure 2 ERS-1 SAR image of internal waves near the Galapagos Islands

The ERS-1 SAR image was taken at 16:20 (GMT) Nov. 18, 1992. The coverage of the image is 100 km $\times$ 100 km. The grouped curves are surface signatures of ocean internal waves. One internal wave packet contains 8 to 15 solitons. The wavelength ranges from 0.8 km to 1.5 km. The internal waves are generated by the tidal current flowing over seamounts or underwater volcanic craters.