# Measurement and Modeling of Deep Water Ocean Acoustics

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## LONG-TERM GOALS

The long-term goal of this research is to understand deep-water propagation, with particular emphasis placed on the passive quiet target detection problem. Focus is on the spatial/temporal structure of acoustic paths for moving sources and moving receivers. This research seeks to understand the impact that mid-ocean variability (internal waves, surface scattering and mixed layer variability) and seafloor scattering have on the detection problem.

## OBJECTIVES

The objectives of the FY13 effort were to combine measurements with novel acoustic signal processing and acoustic modeling techniques to further understand the impact of environmental variability on sonar performance.

## APPROACH

The CRAM model (a c-language re-structuring of the Range Dependent Acoustic Model (RAM)) was re-written with a new simplified environmental interface that efficiently handles very large 4D environments. This new model is called Peregrine. Peregrine interprets the environment as needed and permits the user to do slices, Nx2D, array-to-everywhere and full 3D computations with minimal user entry. In particular, Peregrine uses a geo-located coordinate system permitting the use to simply enter source/receiver coordinates (or grids). Sound speed (World Ocean Atlas or NCOM), bathymetry (ETOPO or DBDBV) and geo-acoustics (BSDB) are mapped to memory from an Oasis Ocean File (oof) format. With access to the 4D environment as well as the split-step Pade propagation kernel, Peregrine was extended to full 3D acoustics. This extension was applied to very-low frequency long-range acoustics (CTBTO problems) as well as mid-frequency shallow water cases. An example of a120 Hz 3D propagation computation in the Salish Sea near Whidbey Island is shown in Figure 1. The strong 3-dimensional effects of refraction and diffraction are clearly visible.

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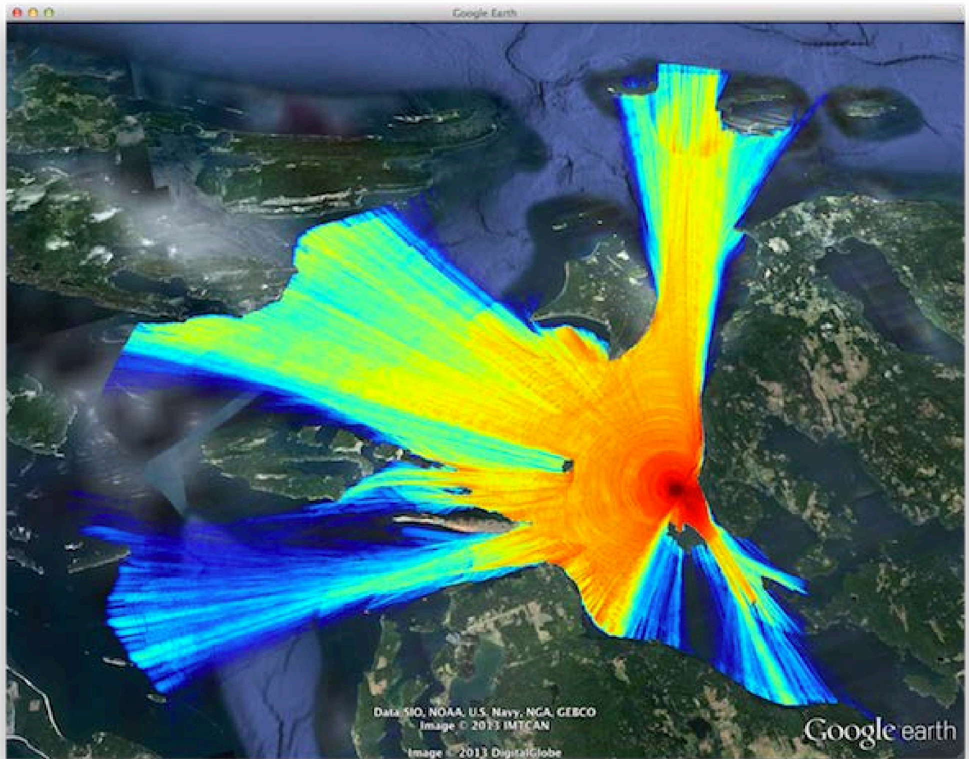


***Figure 1. Full 3-dimensional propagation near Whidbey Island WA, showing the acoustic field complexity due to the bathymetry. Note the refraction in the center of the image as well as diffraction effects.***

The Peregrine algorithm does not compute, and save the tri-diagonal matrix that is stored in RAM. RAMGEO 1.5 computes this tri-diagonal every range step and RAM 2.0 only does it when the sound speed field changes. The latter can be on the order of 3 times faster when computing the field in range-independent environments. Peregrine's efficient implementation makes it on the order of 1.7 times faster than RAMGEO and it is much more memory efficient. Without this increase in memory efficiency, 3D computations would be prohibitive. For most problems of interest to Parabolic Equation modeling, we believe the piece-wise constant in range approximation of RAM 2.0 is not appropriate.

**WORK COMPLETED**

During this period of performance the data analysis of FY12 was completed and 2 papers were submitted to JASA for the special issue on Deep Water Acoustics. Dr. Heaney and Campbell co-authored 4 other papers. The primary focus of this year has been the development of Peregrine, which is on it is way to OAML and transition to the fleet.

**RESULTS**

**Under-Ice Propagation**

Peregrine permits a moving surface interface with arbitrary shape. This has been applied to modeling the scattering of sound off of a surface gravity wave field. This general approach was applied to the propagation of sound under the ice. By placing a deterministic ice sheet with a morphology generated using a measured roughness spectrum, a hard, attenuative rough layer was placed at the top of the water column. Peregrine also permits a rough ice-air interface. This model handles well the rough surface interfaces, but neglects shear. A cyro-acoustic inversion was performed from measured TL to estimate an approximate acoustic parameterization for sea-ice. Volume attenuation of the sea-ice is used as a proxy for shear conversion loss. An example of broadband computations under ice to 200km at a set of frequencies is shown in Fig ##. Note that at 40 Hz, the field is nearly independent of the sea-ice scatter. At frequencies of 150 Hz and higher, individual ray paths are scattered and there is significant incoherent energy from the rough surface scattering.

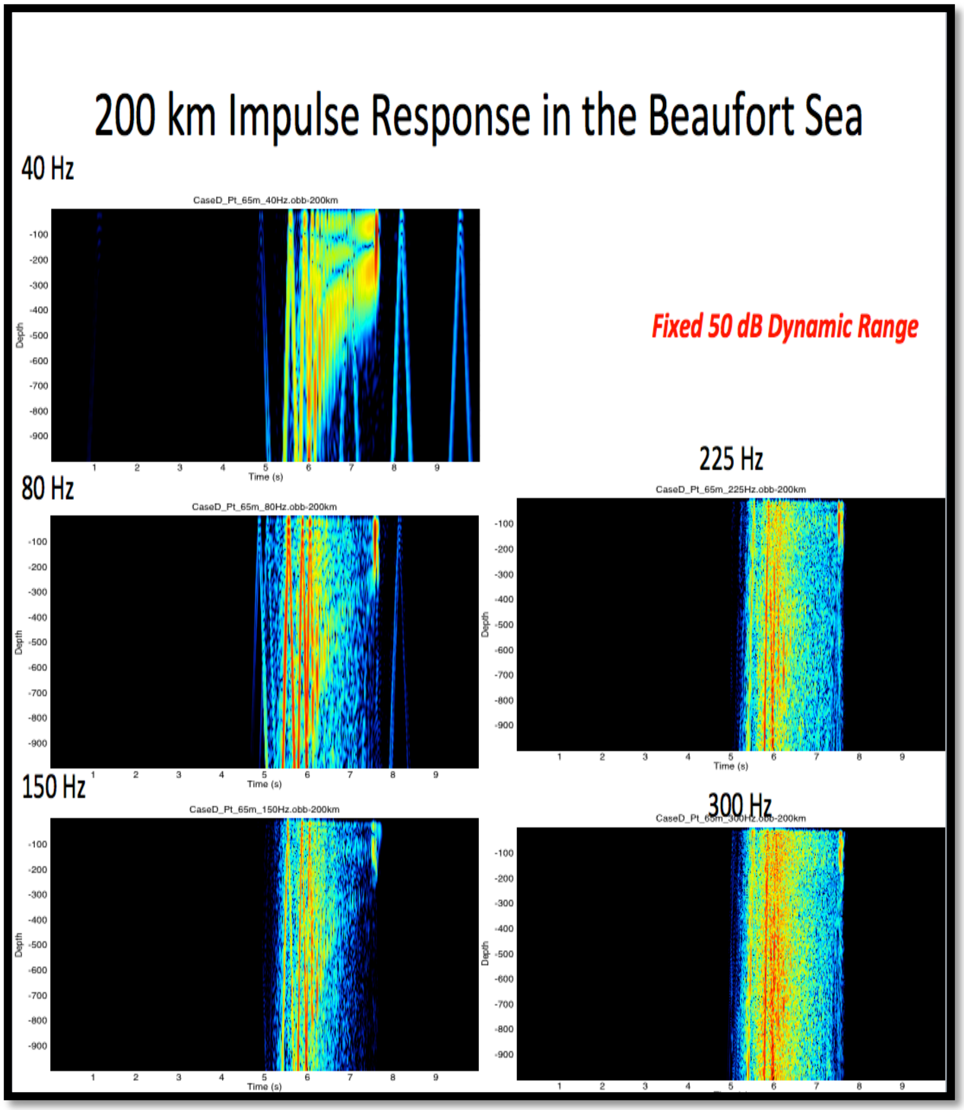


***Figure 2. Broadband under-ice propagation to 200km using Peregrine with an effective ice layer.***

**Basin Scale Acoustics**

The Peregrine 3D model was used to evaluate the coverage of several of the Comprehensive Test Ban Treaty Organization (CTBTO) hydro-acoustic stations and to investigate the impact of 3D acoustics on coverage. It was found that diffractive effects, which reduce the size of acoustic shadows behind seamounts, ridges and islands, increased the coverage by 20-30% for large source level events. OASIS is investigating the localization error induced by presuming 2D propagation.

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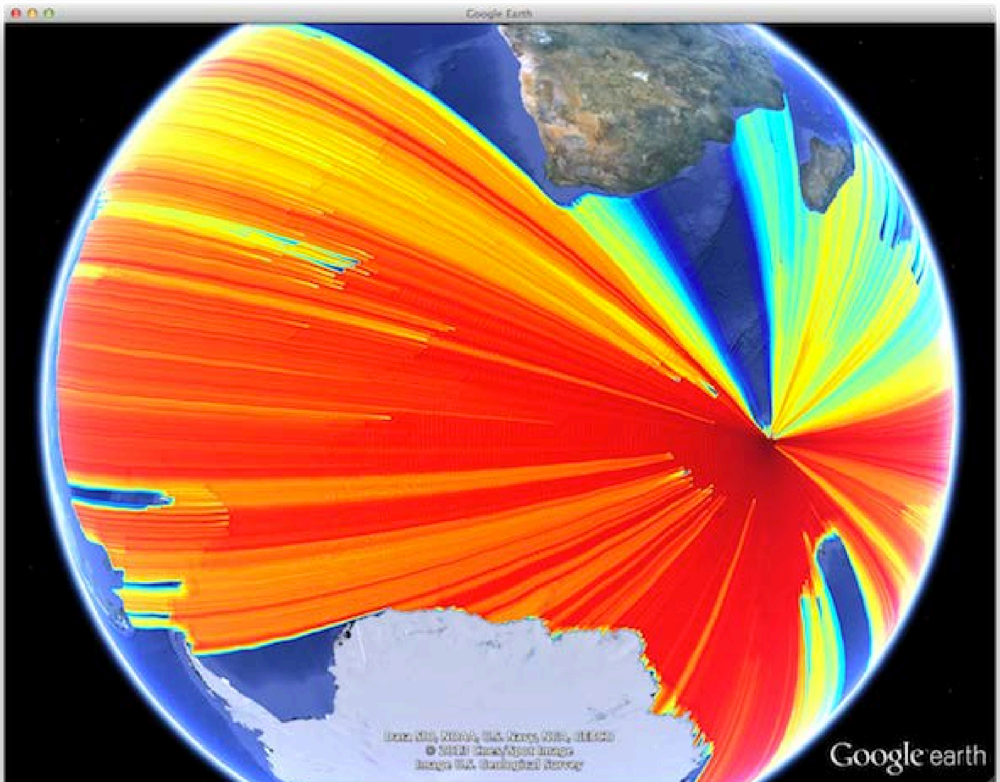


***Figure 3. Basin scale full 3-dimensional acoustic computation at 8 Hz using Peregrine. The source is south of the Ile de la Possession in the Crozet Islands. This is the position of a CTBTO station that deployed in the early 2000s. Note the diffractive filling of the shadow behind islands in the south Atlantic.***

## IMPACT/APPLICATIONS

We believe Peregrine is the next generation naval acoustic propagation engine. The speed increase on a single radial is small (~2x) but the reduction in memory mapping and the efficiency of computing the field from a source (or array) to every position in the water column permits much more rapid passive sonar performance computations.

## TRANSITIONS

Peregrine, developed jointly by this Long-Range Acoustics project and the ONR Persistent Littoral Undersea Surveillance (PLUS) program, has been integrated into the Mission Planning Tactical Decision Aide for the PLUS system. SPAWAR has funded OASIS to begin the submission process for OAML approval. Interest has been shown by both the Submarine Tactical Decision Aid (STDA) and the Submarine Mission Planning Application (MPA) for use of Peregrine within their submarine systems.

## RELATED PROJECTS

This project benefits from work done in the Arctic under an ONR STTR and from integration into the fleet via a mission planner via the NAVSEA PMW-406 UOES program.

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