Relative abundance and behavior of marine mammals exposed to transmissions from the Heard Island Feasibility Test

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8:25

6UW2. Ocean signature of greenhouse warming. Walter Munk (Inst. of Geophysics and Planetary Physics, Scripps Inst. of Oceanography, Univ. of California at San Diego, La Jolla, CA 92093)

The Princeton GFDL coupled ocean–atmosphere global climate model (GCM) of greenhouse warming yields estimates of ocean temperature change from 1990–2000 as a function of position and depth. These estimates have served as a basis for computing changes in acoustic travel time between Heard Island and various receiver sites. (I am greatly indebted to S. Manabe for computing these changes.) The results differ from ocean basin to ocean basin and from gyre to gyre. A typical result is a reduction in travel time by 2 s per decade over a 10 000-km path. Mesoscale eddies produce a month-to-month variability of 0.5 s rms. Gyre and basin variability are more troublesome. The goal is to deploy a reasonable network of acoustic sources and receivers with gyre scale resolution and mesoscale suppression.

8:50

6UW3. The Heard Island global program: Today Heard Island, tomorrow the world. M. G. Briscoe (Office of Naval Res., 800 N. Quincy St., Arlington, VA 22217)

The objective of the Heard Island global program is to develop and implement a global acoustic network for the detection of climatic variability in the ocean, using the principle that sound travels faster in warmer water. The first phase was the Heard Island feasibility test, which showed in January 1991 that *m*-sequence coded acoustic signals transmitted 18 000 km could easily be heard and that their travel times could be measured to a few tens of milliseconds; this is sufficient to detect potential ocean warming against background oceanic fluctuations after about ten years of monitoring. The second phase of the global program (FY92–94) will prepare for the implementation of acoustic sources and receivers at sites around the world. The preparations consist of the development and testing of improved sources and receivers, of a network design that takes into account global models of greenhouse warming and ocean response, and of working with the marine mammal research and protection communities so that the acoustic programs can also provide much-needed information on the response of marine mammals to low-frequency sounds. The third and fourth phases of the global program are the actual implementation of the acoustic network (FY94–97) and the operation of the network for at least a decade (FY95–05). The implementation will first take place in a sparse network configuration for broad ocean monitoring that is global, starting in the Atlantic, the Indian, then the Pacific Ocean, followed by implementation of higher-resolution regional (mapping) networks.

9:15

6UW4. HIFE signals and general results. Kurt Metzger, Jr., Theodore G. Birdsall, and Matthew A. Dzieciuch (CSPL, EECS Dept., Univ. of Michigan, Ann Arbor, MI 48109-2122)

HIFE transmitted for 28 full hours and 8 half hours, repeating the same signal continuously for each transmission. HIFE had a repertoire of cw, Pentaline, and four different phase-coded time-resolving signals based on *m* sequences. The several purposes of each signal will be explained. Receptions were processed on line at 14 sites at ranges of 200 to 18 000 km; to date, the digital tapes from 8 sites have been processed at CSPL. The feasibility questions concerning power, stability, time resolution, and dispersion were answered, and a thorough study of the receptions begun. Examples of the on-line processing and selected frequency domain and travel-time-domain time series will be presented and discussed. An extraordinary look at the phase stability of the propagation was revealed through comparison of (1) the diagonal ship surge deviation from a uniform path measured at the transmitter, and (2) the integrated autocorrelation phase (IAP1) after constant Doppler correction measured at a 9000-km distant receiver.

9:40–9:50

Break

9:50

6UW5. Observations on the abundance and behavior of marine mammals exposed to the Heard Island source transmissions. Ann E. Bowles (Hubbs-Sea World Res. Inst., 1700 S. Shores Rd., San Diego, CA 92109), Mari Smultea, Bernd Würsig (Texas A&M Univ.), Douglas P. DeMaster, and Debra Palka (Natl. Marine Fisheries Service, Southwest Fisheries Ctr.)

Marine mammal density and behavior were measured in a 70-×70-km square centered on the site of the Heard Island feasibility test 4 days before and throughout the transmissions. Observers were stationed on

two large vessels; they conducted line-transect surveys, and monitored marine mammal behavior during transmissions. Observers surveyed 590 nm of tracklines before and 598 nm during transmissions; they made 123 h of observations before and 149 h during. Transmission source characteristics are described elsewhere. Forty schools of cetaceans and 18 pinnipeds were sighted before the transmissions; 40 schools and 25 pinnipeds were sighted after. Sightings of endangered cetaceans were equally common before and during transmissions (3 schools each), but the number of hourglass dolphin (*Lagenorhynchus cruciger*) schools increased and schools of midsized whales, chiefly southern bottlenose whales (*Hyperoodon planifrons*) and minke whales (*Balaena acutorostrata*), decreased. These changes could be explained by the transmissions, the survey vessel, or unknown natural factors. Cetacean school size may have changed during transmissions, but there were no consistent changes in direction of travel or calling behavior. Endangered whales showed changes in respiration rate and rate of reorientation. However, these whales were able to aggregate and probably feed during transmissions.

10:15

6UW6. The Ascension Island listening station. D. R. Palmer (NOAA/AOML, 4301 Rickenbacker Cswy., Miami, FL 33149), T. M. Georges, J. J. Wilson (NOAA/WPL, Boulder, CO 80303), L. D. Weiner, J. A. Paisley (NOAA/AOML, Miami, FL 33149), R. Mathiesen, R. R. Pleshek, and R. R. Mabe (CSR Co., Patrick AFB, FL 32925)

Ascension Island is located in the South Atlantic Ocean 9100 km, or about one quarter of the distance around the globe, from Heard Island. It is the location of one of the U.S. Air Force's missile impact locating system (MILS) sites. All HIFE transmissions were recorded on at least 8 MILS hydrophones and many more were recorded on 11 hydrophones, using both digital and analog systems. The hydrophones are located at the depth of the sound channel axis or somewhat deeper. Preliminary indications are that most, if not all, of the data are of high quality. Typical signal-to-noise ratios for the hydrophones south and southeast of the island were 20 to 30 dB in a 1-Hz band. Late, reverberative arrivals were observed for up to twenty minutes after termination of the direct arrival. These and other general characteristics of the Ascension data set will be discussed.

10:40

6UW7. Vertical array resolution of the normal modes from the Heard Island signals. A. B. Baggeroer (MIT, Cambridge, MA 02139), K. Lashkari (Monterey Bay Aquarium Res. Inst., Monterey, CA 93950), J. Miller, C. S. Chiu, G. Froger (Naval Postgraduate School, Monterey, CA 93950), P. N. Mikhalevsky (Sci. Appl. Intl. Corp., McLean, VA 22217), and K. von der Heydt (Woods Hole Oceanographic Inst., Woods Hole, MA 02543)

A 32-element, 1.3-km vertical array was deployed off Monterey, CA from the R/V POINT SUR during the signal transmission from Heard Island. The signals were received with an SNR on a single channel of approximately -10 dB *re*:1 Hz. Narrow-band filtering to 15 mHz improves this to $+5$ dB. The suspension system was designed to minimize array motion and array tilt and depth were monitored at two locations in the array. The multichannel data have been decomposed into normal modes using a time varying least-squares representation. Initial processing of the data indicates the first four modes can represent 75% of the energy of the average projection over a 180-s window. The time-varying structure of the representation and the effect of array tilt and Doppler spread will also be discussed. [Work supported by Dept. of Energy, Monterey Bay Aquarium Res. Inst. and the Commander, Naval Postgraduate School.]

11:05

6UW8. Heard Island feasibility test: Long-range sound transmission from Heard Island to Krylov underwater mountain. S. V. Burenkov, A. N. Gavrilov, A. Y. Uporin, and A. V. Furduev (Acoust. Inst., Acad. of Sci. of the USSR, Moscow, USSR)

On 26–31 January 1991, the "AKADEMIK NIKOLAI ANDREEV" research vessel anchored at Krylov underwater mountain (17.5° north, 30° west) received the low-frequency signals at a distance of 12.5 thousands kilometers from the source disposed at Heard Island. All transmitted signals were received by two omnidirectional hydrophones at the SOFAR axis and 200-m depth, sampled, and collected on the cartridge tapes by the data acquisition system. All three types of signals—continuous wave 57 Hz, pentaline, and phase coded (*M* sequence)—have been primarily processed in the time and frequency domains. The purposes of data processing were to determine what the intensity of signals are, the signal/noise (S/N) ratio and temporal variation of the signal phase and magnitude, what is the time structure of the multimode signal, and how time stable is this structure. On most of the transmissions the S/N ratio was about 10–15 dB in 1-Hz band at the carrier frequency 57 Hz, and then it decreased to 0–5 dB on last transmissions. Both temporal variation of Doppler shift and phase fluctuation dominantly depended on the nonuniformity of ship's motion. GPS data of both ships were compared with the phase variance of some received signals. The distinction between GPS and phase estimations of distance variance is about 10–15 m on an average. The cross-correlation processing of the phase-coded signal enabled one to identify the periodical groups of pulse