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NAVAL POSTGRADUATE SCHOOL
Monterey, California

WORKSHOP REPORT
The Asian Seas International Acoustics Experiment (ASIAEX)
Final Planning Meeting
Kailua Kona, Hawaii, June 21-23, 2000

by

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June 2001

Prepared for:
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The final planning meeting prior to the Asian Seas International Acoustics Experiment (ASIAEX) was held from June 21-23, 2000 in Kailua Kona, Hawaii. Approximately sixty representatives from seven countries attended to work out the details of the two field programs to take place during spring and early summer 2001. The first focuses on acoustic reverberation from the surface, bottom, and sub-bottom in shallow (less than 100 m) water, while the second focuses on volume interaction of low frequency (200-400 Hz) sound propagating up the continental slope and shelf. The reverb experiment will take place in the East China Sea (ECS) in the same region studied during the spring 2000 pilot study, that is, in the region bounded by 28°–30°N, 126° 30'-128°E. The location of the volume interaction experiment was undetermined at the time of the workshop: It could be in the same region as the reverb experiment noted above, or on the Chinese continental shelf in the South China Sea (SCS).

The workshop began with scientists reporting on the preliminary data analysis from the spring 2000 pilot study cruises in the East and South China Seas. In the afternoon of the first day, formal plans from the participating nations were heard. On the second day, breakout groups were formed to focus on the reverb and volume interaction experiments. On day three, the summary reports for the two groups were presented by the group chairpersons, and a to-do list of action items was presented to prepare for the spring 2001 experiments. All the major objectives of the workshop were accomplished.

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ABSTRACT

The final planning meeting prior to the Asian Seas International Acoustics Experiment (ASIAEX) was held from June 21-23, 2000 at the King Kamehameha Hotel in Kailua Kona, Hawaii. Approximately sixty representatives from seven countries attended to work out the details of the field programs to take place during spring and early summer 2001. Two experiments are planned: The first focuses on acoustic reverberation from the surface, bottom, and sub-bottom in shallow (less than 100 m) water, while the second focuses on volume interaction of low frequency (200-400 Hz) sound propagating up the continental slope and shelf. The reverb experiment will take place in the East China Sea (ECS) in the same region studied during the spring 2000 pilot study, that is, in the region bounded by 28°–30°N, 126° 30'-128°E. The location of the volume interaction experiment was undetermined at the time of the workshop: It could be in the same region as the reverb experiment noted above, or on the Chinese continental shelf in the South China Sea (SCS). The SCS location is the one proposed during July 1999 at the Alyeska, Alaska workshop, namely 21°-22° 30'N, 117°-119°E. The site choice depends on research vessel clearances and was an action item for the workshop.

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Introduction

The final planning meeting prior to the Asian Seas International Acoustics Experiment (ASIAEX) was held from June 21-23, 2000 at the King Kamehameha Hotel in Kailua Kona, Hawaii. Approximately sixty representatives from 7 countries attended to work out the details of the field programs to take place during spring and early summer 2001. Two experiments are planned: The first focuses on acoustic reverberation from the surface, bottom, and sub-bottom in shallow (less than 100 m) water, while the second focuses on volume interaction of low frequency (200-400 Hz) sound propagating up the continental slope and shelf. The reverb experiment will take place in the East China Sea (ECS) in the same region studied during the spring 2000 pilot study, that is, in the region bounded by 28°–30°N, 126° 30'-128°E (Figure 1). The location of the volume interaction experiment was undetermined at the time of the workshop: It could be in the same region as the reverb experiment noted above, or on the Chinese continental shelf in the South China Sea (SCS). The SCS location is the one proposed during July 1999 at the Alyeska, Alaska workshop (Denner et al., 2000), namely 21°-22° 30'N, 117°-119°E (Figure 2). The site choice depends on research vessel clearances and was an action item for the workshop.

The workshop began with scientists reporting on the preliminary data analysis from the spring 2000 pilot study cruises in the East and South China Seas. In the afternoon, formal plans from the participating nations were heard. On the second day, breakout groups were formed to focus on the reverb and volume interaction experiments. On day three, the summary reports for the two groups were presented by the group chairpersons, and a to-do list of action items was presented to prepare for the spring 2001 experiments. This workshop report is organized in similar fashion: The pilot study results are presented in section 2, followed by the national plans in section 3. The breakout group report summaries for the reverb and volume interaction experiments are presented in sections 4 and 5 respectively, and a meeting summary follows. The attendee and report distribution list are presented as Appendix 1.

Dr. Jeffrey Simmen, Program Manager for Ocean Acoustics at the Office of Naval Research, formally opened the meeting and welcomed the participants. He assured the participants that the program is alive and well in Washington, and will go forward as planned. The balance of Dr. Simmen's remarks were devoted to presenting a memorial plaque to Mrs. Margie Denner, commemorating the outstanding work of her late husband, Dr. Warren Denner, who co-founded and laid the groundwork for the ASIAEX program. Prof. Qihu Li, the Director of the Institute of Acoustics, Chinese Academy of Sciences, Beijing, also presented a gift to Mrs. Denner in honor of Warren's outstanding work and friendship. The presentation of these awards was accompanied by an extended standing ovation by the workshop participants.

Pilot Study Reports

Dr. David Tang and his postdoctoral investigator, Dr. Yiing-Jang Yang opened the session with a report on their physical oceanography moorings in the South China

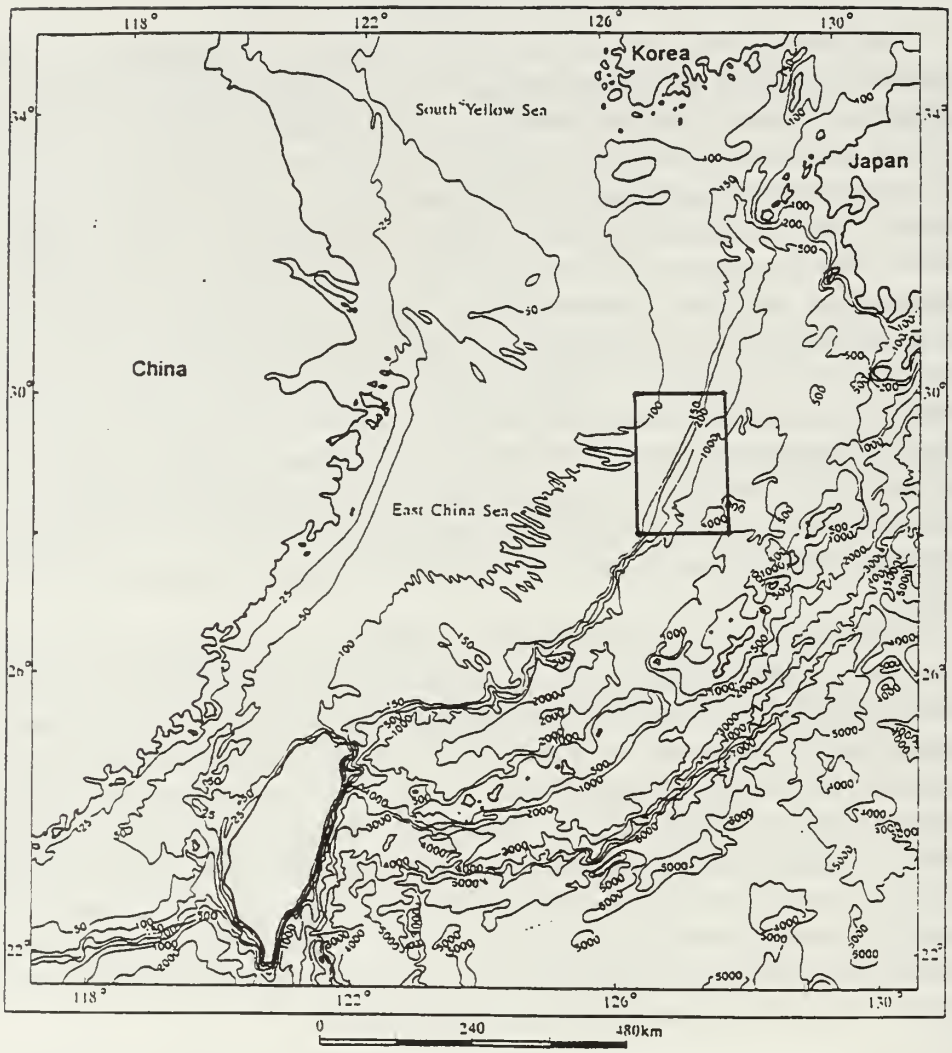

Figure 1. The box indicates the study region for the REVELLE pilot study cruise of April – May 2000 and the planned site for the reverberation experiment during spring 2001. The site is also one of two possible sites for the volume interaction experiment, also planned for spring 2001.

Sea. This and many of the other pilot study reports devoted considerable time to logistics, so we could see what we are up against for the main field program in spring 2001. Three out of four temperature chain moorings were lost to fishing activity: Anything with a surface expression is in trouble. The temperature sensors on the surviving mooring failed also due to suspected vibration problems. Trawl resistant bottom mounts (TRBMs) are highly recommended for all acoustic Doppler current profiler (ADCP) moorings during spring 2001.

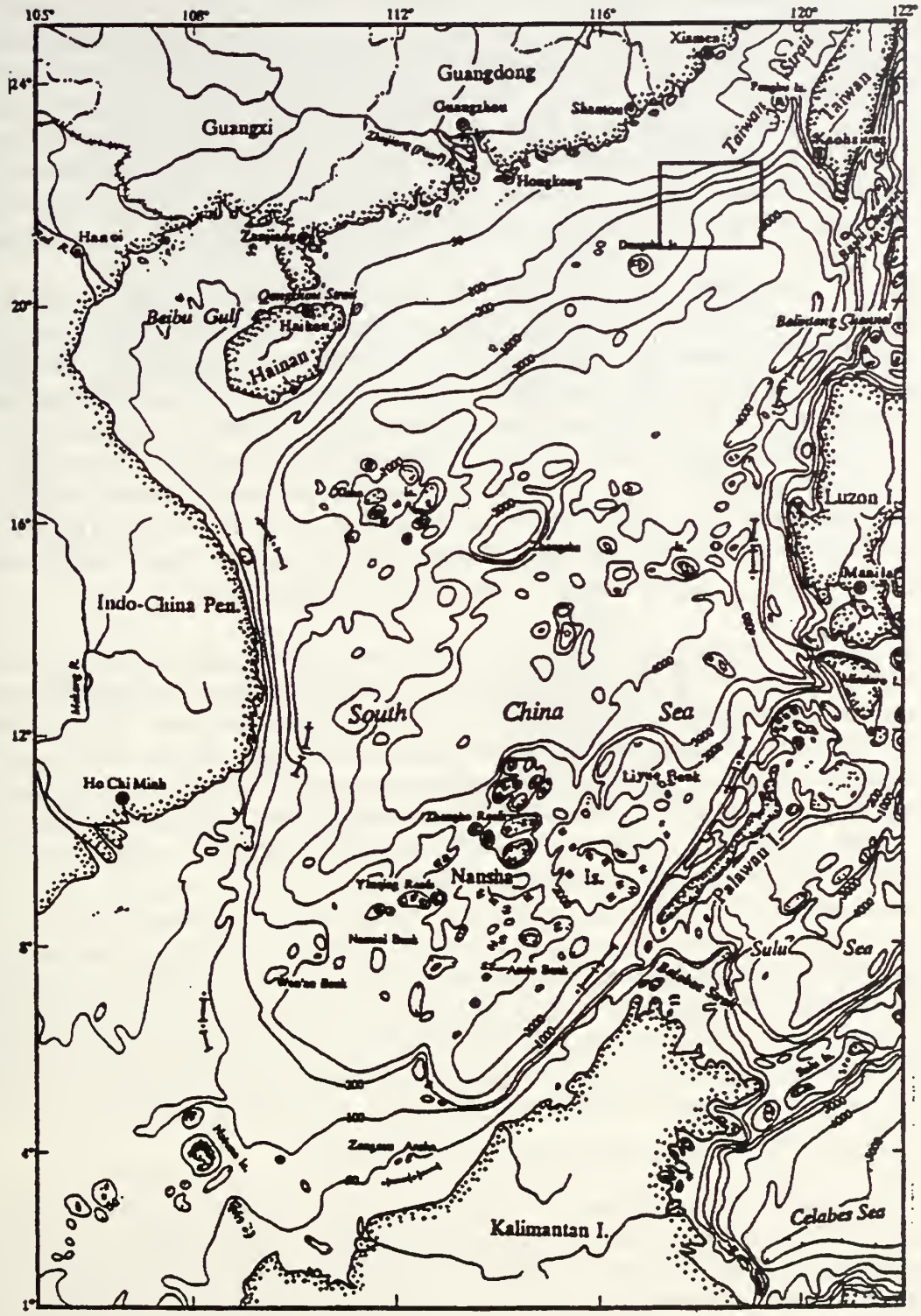

Figure 2. The box indicates an alternative site in the South China Sea for the volume interaction experiment planned for spring 2001.

There were a number of very interesting "spikes" in the broadband ADCP data from the SCS which are not yet understood. These look like some sort of instrument problem but could possibly be real. Investigators at National Taiwan University (NTU) are still looking into the problem. The data are rich with non-linear internal waves and solitons, with amplitude around 200 cm s^{-1} opposing in the upper and lower layer. The sea level data show mixed tides, sometimes semidiurnal and sometimes diurnal. Three data reports have already been published by NTU (Yang et al., 2000a, b, c). The data are also available on CD ROM and on their web site at: http://duck2.oc.ntu.edu.tw/asiaex/.

The research vessel OCEAN RESEARCHER I (ORI) conducted a CTD and Seasoar operation in the SCS, reported on by Joe Wang and Glen Gawarkiewicz. They found fairly uniform sea surface temperatures (SSTs) with less than 2°C change over the study region. The surface gradients went from cold/fresh over the continental shelf to warm/salty over the basin, due to the influence of the Kuroshio intrusions. The intrusions were most obvious in the form of a salinity maximum (S=34.65) at 150 m depth. The large scale circulation in the deep basin was anticyclonic around a warm eddy filling up the northeast quadrant of the deep water with a scale of about 300 km. This and other data suggest the Kuroshio intrusion occurred mainly in winter. Prof. Wang presented a nice schematic of the summer vs. winter circulation (Figure 3).

Dr. Gawarkiewicz reported very steep topography in the proposed ASIAEX region, not only across-shelf, but also in the alongshelf direction, and highlighted the need for better bathymetric surveys prior to the main field program. The many canyons crossing the continental shelf and slope influenced the hydrography, with strong T and S anomalies over the canyons. The isopycnal slope over the canyons indicates that topographic steering is important. The exact extent of these canyons is unknown. Using all the available data, the spatial decorrelation scale in the SCS was about 10 km. This statistic will be very useful in setting up the sampling grids for next year. Some of the shipboard ADCP data for the cruise was also presented. This generally tended to support the implications of the hydrography. One interesting feature of the current field was a cross-shelf flow reversal over the shelf in the dense water just below the thermocline. The audience felt this could be aliasing due to the internal wave field, and the feature demands additional study. The data from this cruise, including the shipboard ADCP data, are included in the aforementioned data reports from NTU, as well as on their web site. In addition to the NTU site, the cruise report and data can also be found via WHOI at http://matisse.whoi.edu/scs/report/or1c581home.html.

The next series of talks presented results from a cruise on the R/V ROGER REVELLE in the East China Sea (ECS) during April 8 – May 4, 2000. The actual research phase of the cruise was confined to April 11 – 26 in a region bounded by 28°–30°N, 126° 30'-128°E. The rest of the time was spent making port calls in Shanghai, Naha, and Kaohsiung. The cruise goals were to obtain a preliminary assessment of the physical oceanography and bottom structure in the region proposed for 2001's reverberation experiment.

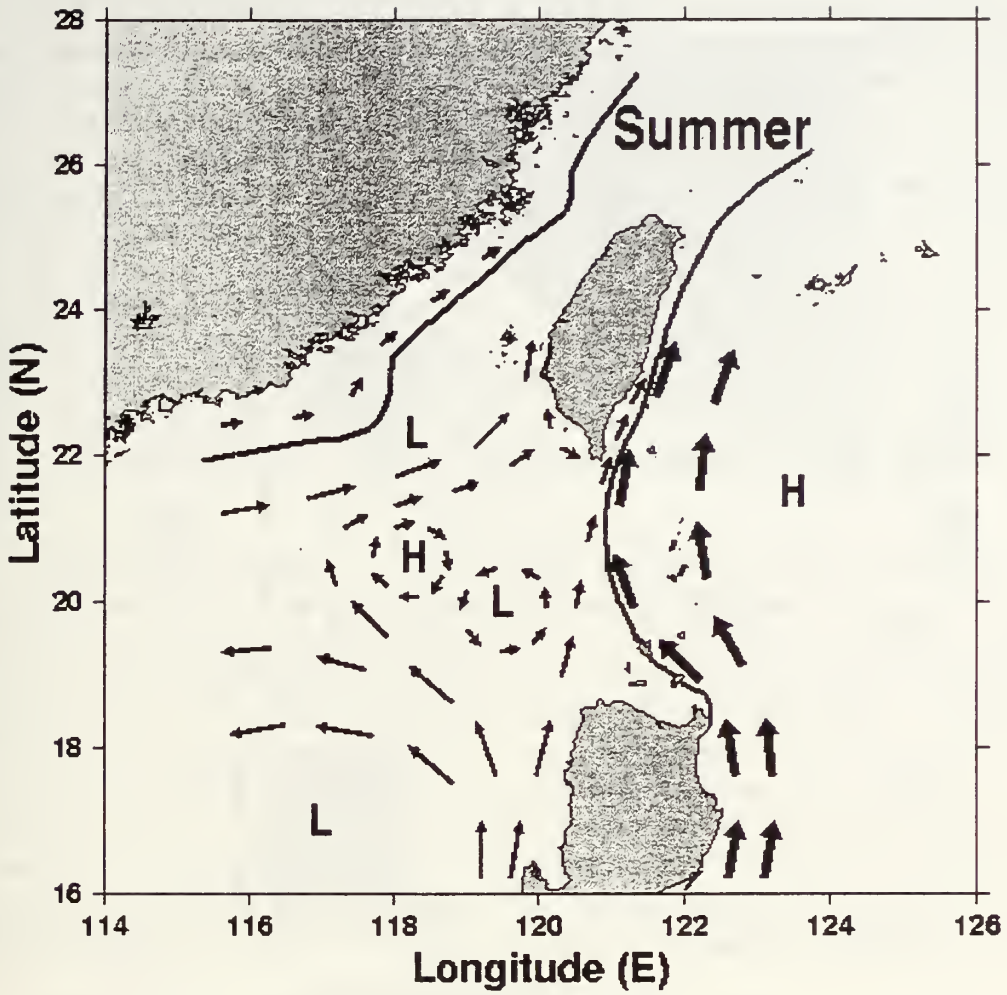

Figure 3a. Schematic drawing of the summer circulation in the northeastern South China Sea. The blue arrows represent Kuroshio water, the red South China Sea water, and the black (inside the green boundary) coastal water. Pressure gradients developed by the SW monsoon tend to prohibit deep intrusions of the Kuroshio water into the SCS. (Figure courtesy Joe Wang, National Taiwan University).

Chief Scientist Jim Lynch gave an introduction to the cruise, including some of the logistical problems encountered (Lynch, 2000). The fishing activity in the area was very heavy, with 150-200 boats sometimes visible on the radar screen at once. The side-scan sonar indicated that trawl marks were the dominant source of bottom roughness. Two conventional moorings and two Low-Cost (LOCO) moorings were lost to fishing activity during the cruise. This indicates that some sort of additional precautions will be required for next year's main field effort. Considerable discussion followed on possible strategies to deal with the fishing activity. This included conducting the program during a different time of year, and hiring some sort of "guard boats" to watch over the moored gear. The suggested boats ranged from fishing boats to research boats to "official" boats of some kind. Researching this topic was ultimately left as an action item for later.

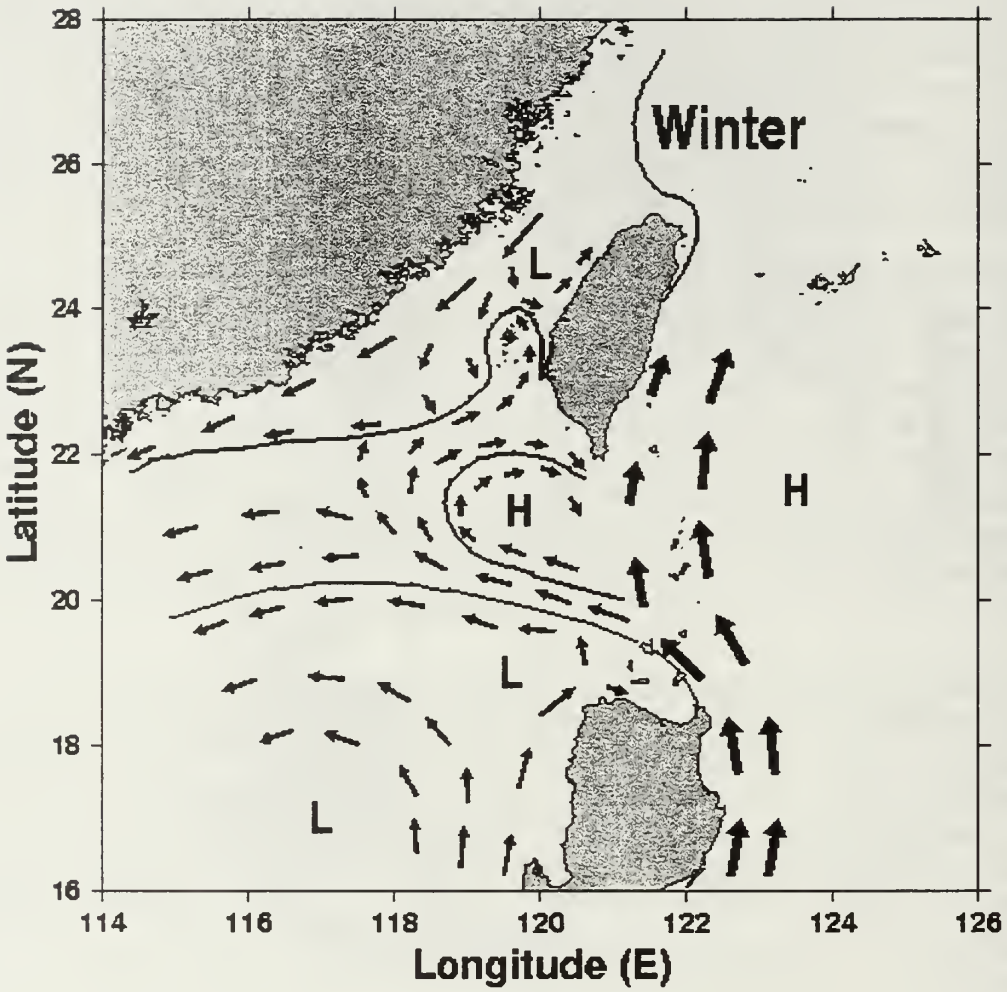

Figure 3b. Schematic drawing of the winter circulation in the northeastern South China Sea. The blue arrows represent Kuroshio water, the red South China Sea water, and the black (inside the green boundary) coastal water. The coastal current has reversed with respect to summer under the influence of the NE monsoon, which also encourages the Kuroshio intrusions deeper into the SCS. [Figure courtesy of Prof. Joe Wang, National Taiwan University.]

Prof. Jim Miller presented a brief talk on the coring activities on the cruise. About 24 cores were obtained, ranging in length from about 6 to 18 inches. The cores were shallow due to a very hard upper layer which was difficult to penetrate. Much better coring gear is required to get longer (deeper) cores. This may possibly be done from the Korean vessel ONNURI some time between now and next spring. Dr. Miller also presented some shot inversion data from the New England Shelfbreak PRIMER Experiment, illustrative of what he plans to do during the ECS main field program.

Profs. Steve Ramp and Rob Pinkel next presented an overview of the physical oceanography in the proposed ECS region based on data collected during the spring 2000 cruise. The data used included SST from satellites, CTD sections, shipboard ADCP data, shipboard sonar data, and moored temperature and velocity data. The dominant feature in the region is the Kuroshio current, which flows southwest to northeast along the topography in the study region. The cruise sampling did not extend into the core of the current, but alongshore currents at the edge of the flow exceeded 100 cm s^{-1} using the ships ADCP. The close proximity of the current to the continental slope in this region precludes large-scale meandering, but several small-scale "splinters" or "shingles" were observed breaking off the current onto the continental shelf, both in the remotely-sensed data and the across-shelf hydrographic sections. These features produce temperature anomalies of about 2°C and may influence acoustic propagation in the area. The gradients at the edge of the Kuroshio are extremely strong, producing a step-like thermal jump of 4°C and an increase in surface roughness that is easily observed with the naked eye.

Oceanographic moorings were deployed at two sites during the cruise. As previously stated, all equipment at site one was lost to fishing gear, however a five-day record with 30 second sampling was obtained at site two, located on the continental shelf just inshore of the Kuroshio. This mooring, SAR imagery (see next talk by Tony Liu) and hull mounted Pinkel sonar all observed internal solitons in the region. The mooring showed about eight waves in the packet with amplitude of about 50 cm s^{-1}, opposed in the surface and lower layers in classic mode-1 style. These (depression) waves appear to be generated by path fluctuations in the Kuroshio, combined with the usual tidal forcing. The barotropic tide in the region was also about 50 cm s^{-1}. Prof. Pinkel's 160 kHz hull-mounted sonar produced stunning images of the internal wave field across the shelf and slope. Plans are underway to deploy this equipment on next spring's cruises as well.

Most of the time during the spring 2000 REVELLE pilot study was dedicated to geophysics, namely chirp sonar and sub-bottom profiling. Dr. Lou Bartek reported next on these results. He began with a brief tutorial on how a meandering river creates sediment facia which are further modified by sea level variations on glacial time scales. Many of the results obtained during the cruise can be understood within this context since most of the Yellow and northern East China Sea floor was exposed during previous ice ages. Dr. Bartek obtained the seismic stratigraphy from towing two instruments at 4 knots, a chirp sonar in the 500-15,000 Hz range, and a seismic profiler operating within 200-2,500 Hz. There was an extensive thin veneer 2 – 4 m thick over the entire area. Below this was a very complex structure of incisions and slumps along the transactions. These data are essential to understand the reverberation (bottom interaction) problem, and it is therefore important that next year's field program be conducted in the same region as the pilot study.

The pilot reports finished up with Dr. Tony Liu describing the internal wave field in the South and East China Seas from synthetic aperture radar (SAR) data. Tony collected 30 images during the April 2000 cruise and their quality and resolution are impressive. Tony has also been working with Tang et al. at NTU to correlate the SAR

data with the in-situ data (current and temperature observations). The combined results so far indicate the largest solitons are being generated in the Luzon Strait with 50 – 80 m thermocline displacements. There may even be examples of solitons generating other solitons! The ECS internal wave field in the proposed ASIAEX region is weaker than the SCS, but still energetic enough to impact the acoustics. Since the June data was only just obtained at the time of the meeting, his analysis of this data was still in progress. A recent paper by Dr. Liu describes soliton generation by a combination of upwelling (by the Kuroshio) and the barotropic tide (Hsu et al., 2000). This may be what was observed by the in-situ sensors during the REVELLE cruise.

Having heard the physical oceanography (PO) data reports, it was time for the acousticians in the audience to predict the impact of the PO on the acoustic propagation in the ECS and SCS. Prof. Ching-Sang Chiu led off this discussion by presenting some acoustic model runs using the anchor station and across-shelf transect CTD data from the REVELLE ECS cruise. The model runs were designed to investigate important questions concerning the bottom and volume interaction acoustic experiments of 2001, namely:

- Is the water-column variability in the northwest quadrant of the ECS survey site robust enough to permit unambiguous observations of the acoustic effects caused by the ocean bottom, if the bottom interaction experiment is to take place there?

- What is the optimum source depth, receiver range, and frequency in a slope-to-shelf transmission, in the event that the volume interaction experiment is moved to the vicinity of the shelfbreak inside the ECS survey site?

To explore the answer to the first question, the yo-yo CTD time-series collected on 9 April 2000 were used to estimate the temporal variability of the transmission loss along the water-sediment interface inside the northwest quadrant. Being far away from the Kuroshio Current and with a minimal stratification in spring, the measured time-series show a very small sound speed variation as anticipated, only 3 m/s over a 4-hour span and was mostly confined in the top layer. However, the calculated transmission loss surprisingly shows moderate temporal fluctuations of ± 4 to 5 dB along the interface. These calculations were performed for a frequency of 1 kHz and a nominal source depth of 20 m. Chiu went on to illustrate that the transmission loss fluctuations are reducible by local spatial averaging, i.e., trading resolution for a reduced uncertainty. However, he cautioned that depending on the accuracy and resolution requirements for studying bottom parameters and their acoustic effects, *adequate water-column monitoring can be important for a clear separation of bottom and volume effects in the bottom interaction experiment.*

The second question was examined by Prof. Chiu using the two cross-front CTD sections, obtained on 18 and 24 April 2000, respectively. The acoustic wavefields simulated in a slope-to-shelf geometry for a sound source located at the 300-m isobath reveal that

- The optimum source depth is near the bottom where sound speed reaches its minimum (Figure 4).
- The optimum frequency band is broad, up to at least 1 kHz, and it peaks at about 200 Hz.
- Receiver ranges with adequate signal-to-noise ratio exceed 70 km.

Furthermore, based on the transmission loss calculations using the two CTD sections obtained on the different days, Chiu found appreciable changes of ± 15 dB due to frontal variability.

Prof. Chifang Chen conducted an acoustic modeling study to examine acoustic propagation conditions in the South China Sea (SCS) site using CTD data obtained from the ORI SCS pilot survey which was led by her colleague, Prof. David Tang. Similarly, Prof. Chen found favorable propagation ranges in both the along- and across-shelf orientations for frequencies below 1 kHz. In addition, she expressed that her main research interest in ASIAEX is the investigation of three-dimensional environmental effects on sound propagation which include horizontal refraction and azimuthal coupling of sound energy.

NRL's planned participation in the Water Column/Acoustic Propagation portion of the ASIAEX experiment is directed to obtaining experimental confirmation of recent model calculations of acoustic propagation in an environment with an anisotropic water column, according to Steve Wolf and Marshall Orr. The predictions suggest that horizontal acoustic coherence will be strongly affected by anisotropy of the ocean induced by an internal soliton field. In the spring of 2000, NTU conducted a "pilot experiment" in the South China Sea (SCS) to acquire environmental information needed to design the acoustic experimental arrangement for the Spring 2001 experiment. NRL used some of these "pilot" measurements and other information available from other sources to: (1) assess the suitability of the SCS site for the NRL experimental objectives, (2) refine the plans for acoustic equipment deployment and (3) further define the environmental sampling strategy needed to support the 2001 acoustics experiment. It was found that the SCS site has sufficient internal-soliton-induced anisotropy to produce a measurable and scientifically interesting effect. The acoustic arrays proposed for use are suitable in their present design form, but may need to have their planned positions and orientations adjusted. Satellite SAR observations made in the spring of 2000 provided indications of internal-wave "point sources" which were not consistent with archival bathymetric information but were consistent with new bathymetric information reported by NTU and WHOI at the Kona meeting. Details of the acoustic calculation results and their connection to environmental issues were given in the NRL talk.

Later in the workshop (Friday morning) the schedule was adjusted to allow Ruth Preller of NRL to make a stunning presentation of the latest NRL numerical modeling results for the South China Sea. The NRL is experimenting with some exciting new visualization packages, and several of these were presented by Dr. Preller (Figure 5). The best way to experience these results in on their web site at:
http://www7320.nrlssc.navy.mil/npacnfs_www

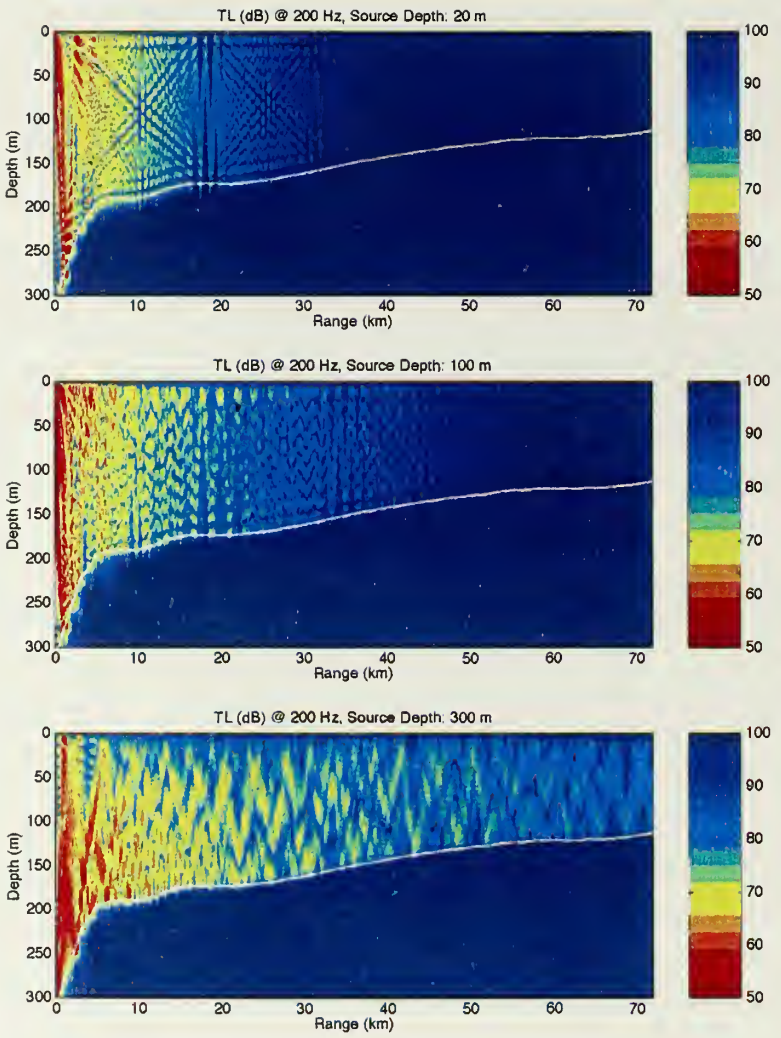

Figure 4: Slope-to-shelf transmission loss at 200 Hz for three different source depths, 20 m (top panel), 100 m (middle panel) and 300 m (bottom panel) calculated based on an across-shelf CTD section obtained during the REVELLE ECS pilot survey. The plots show a general increase in the distance of sound energy penetration onto the shelf as the depth of the source increases. This dependence on source depth is common to most downward refracting sound channels. [Figure courtesy of Prof. Ching-Sang Chiu, U.S. Naval Postgraduate School.]

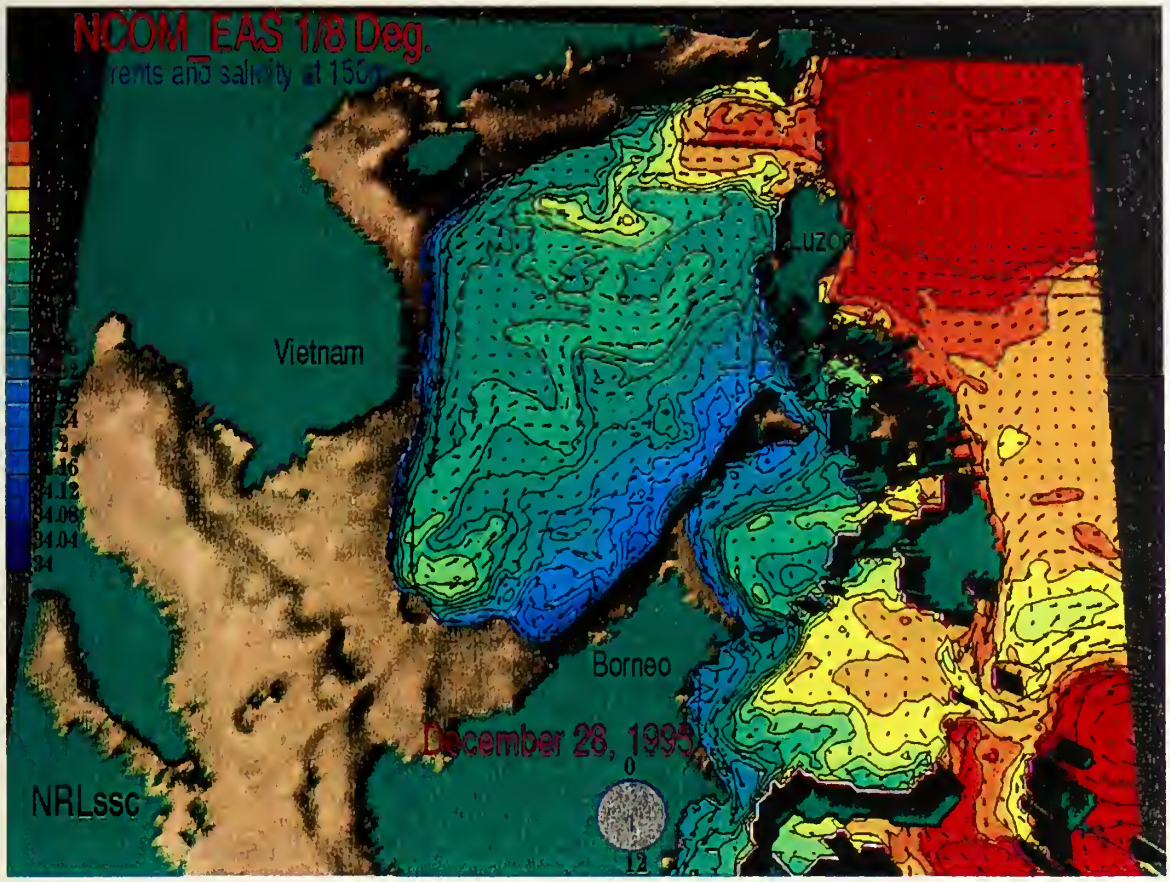

Figure 5. Model output of the salinity (color) and current vectors (arrows) at 150 m depth from the NRL NCOM Northeast Pacific 1/8° numerical model. This is a winter scene from December 28, 1995. Note the similarity in the Kuroshio intrusion with Figure 3b from Prof. Wang, which was based entirely on oceanographic data. [Figure courtesy of Dr. Ruth Preller, U.S. Naval Research Laboratories.]

Progress Reports and Plans

Dr. Weidong Yu began the afternoon sessions with a report on the PRC National Basic Research Program (2000-2004), "Studies on the Mechanism and Numerical Simulation of the Chinese Continental Shelf Circulation." The program is funded by the Ministry of Science and Technology of China and includes extensive continental shelf work in the East and South China Seas. The key scientific problems to be addressed include:

- The interaction between the Kuroshio and Chinese shelf circulation
- The effect of buoyancy introduced by freshwater inflow
- The formation of monsoon circulation and its variability
- The deep and bottom water circulation
- The mesoscale processes
- The extreme shallow water circulation

The methodology to achieve these objectives includes:

- Reanalysis of historical data bases
- Special observation projects for crucial current systems
- Establishment of a database for shelf circulation

A few special projects which have been worked on so far:

- Examine the Yellow Sea cold water
- Seasonal variation of the cold eddy
- Study of an extreme outflow event of the Yangtze River, 1998
- Studies of the Kuroshio mesoscale variability
- Variability of the Kuroshio branch north of Taiwan

Plans for future projects include a shelf survey between Hainan and Dongsha, which will include some shelf moorings, more in-depth dynamical studies, and development of a numerical model which is still under construction. Some goals are more practical, such as improved management of the fisheries and natural resource management in the Bohai Gulf.

The final phase of the presentation was dedicated to an 18-month current (ADCP) time series obtained from an oil platform on the Chinese continental shelf off Hong Kong. An empirical modal decomposition (EMD) shows the tides to be 180° out of phase between the upper and lower layer in 45 m of water.

Prof. Renhe Zhang presented some of his thoughts on bottom interaction studies and showed example data sets and results from past shallow-water acoustic experiments carried out by his institute in China's adjacent seas. He expressed that his institute is primarily interested in the acoustic inversion of bottom parameters, the directional properties of the noise field, the depth dependence of reverberation, the interaction of internal waves and acoustics, and the acoustic impact of circulation features. He hopes to include these studies in ASIAEX.

The emphasis from our Japanese collaborators has been on acoustic tomography. Prof. Arata Kaneko showed results from the Coastal Acoustic Tomography System (CATS). The CATS has been used in the Japanese inland seas to identify the circulation for mariculture purposes. Prof. Kaneko described the inversion technique, then presented comparisons with an array of ADCPs which look quite favorable. He is now proposing a tomography experiment around the shelfbreak front in the ASIAEX region, a 10 x 10 km array to be deployed for 7 days, with the goal of observing the small scale structure along the front and its temporal variation. Some additional funding from ONR would be required and this will be decided in future discussions with program managers.

Prof. David Tang summarized Taiwanese plans in terms of the historical, year 2000 pilot study, and plans for the 2001 main program. Part of the historical work has been to pull together a composite of all shipboard ADCP data around the island of Taiwan. These data show that there is always some intrusion of Kuroshio water into the

SCS in all seasons. Most of the key 2000 results were already reported during the morning sessions. Dr. Tang noted that site IW4 (21.99°N, 117.23°E) is logistically quite difficult to get data from due to fishing activity. The plans for 2001 are in keeping with the existing plan and are included in the breakout group reports later on in this report.

Ships are an important issue for ASIAEX 2000. Taiwan will make several of their ships available for the program. These are: OCEAN RESEARCHER I (OR1) which can accommodate 12 scientists for 20 days; OCEAN RESEARCHER III (OR3), 4 scientists for 30 days; FISHERIES RESEARCHER I (FR1), which holds 10 scientists, can be made available for deploying and recovering heavy gear; and DA-KUAN, a military research vessel, no foreigners allowed. The issue of ship time was revisited later in the breakout groups using these facts and figures. An additional outstanding issue was whether any of these ships could handle the very large NRL receiving array package. The FR1 was the most likely candidate.

Dr. Seong-Ryul Kim reported that Korea is taking ASIAEX very seriously and is modifying their national plans to participate. They have lots of very good Geology and Geophysics (G&G) data, including the ASIAEX ECS study region. The research vessel ONNURI has superior coring equipment to that on board the REVELLE during the pilot study. Negotiations are under way to use the ONNURI to get some better cores. Dr. Jim Miller of the U.S. is planning to participate in this cruise.

Dr. Victor Akulichev described a propagation and tomography experiment in the Japan (East) Sea. He described an experiment carried out during October 1999 using sources near Peter the Great Bay broadcasting at carrier frequencies of 150, 260, 366, 406, and 634 Hz. Several autonomous receivers were moored in the JES, some as far away as the Yamato Rise. The data were sufficient to detect internal waves with a period of about 20 minutes.

The Singapore report was divided between Drs. John Potter (acoustics) and Eng-Soon Chan (physical oceanography). The acoustics effort has been scaled back somewhat and the NUS group will mainly support other investigators and the web page. Two possible equipment contributions include a mini-PANDA for ambient noise detection and a prototype "Thinarray." The 8 mm Thinarray can be operated without dedicated deck gear by one person. It has 8 elements separated by 10 m on a 200 m towed cable and operates in the 100 Hz to 20 kHz range.

Dr. Chan continues his SCS numerical modeling efforts using the Princeton Ocean Model (POM) and is also acquiring an "Acrobat" towed vehicle. The Acrobat is a very light towed undulating system that can carry various sensors and profile to around 80 m depth. To start it will be equipped with a Seabird CTD. This vehicle could be available to the program and could possibly be towed off the Taiwanese ship OR3 while the OR1 and a U.S. ship conduct Seasoar operations. The Acrobat would be limited to shallow water and would obtain very high resolution profiles of the surface mixed layer desired by the acoustics group at the U.S. Naval Research Laboratory.

A report was also received *in absentia* from Prof. Xian-Yi Gong on behalf of the Hangzhou Applied Acoustics Research Institute in Hangzhou (HAARI). They intend to participate in ASIAEX and will contribute both equipment and scientific expertise to the endeavor. The following equipment can be made available:

- A moored vertical line array (32-64 elements, 50-100 meters long, working frequency 100-3000 Hz, attached tilt/temperature/depth combined sensors), transferred to inboard recording and processing instruments by optical cable.
- A drift horizontal line array (32-64 elements, 300-500 meters long, working frequency 60-1600 Hz, attached depth /temperature sensors), transferred to inboard recording and processing instruments by optical cable.
- A moored source (frequency range 500-5000 Hz, source level of 205 dB re 1 μ Pa at 1m at 900-5000 Hz), driven from inboard transmitter by electrical cable.

The HAARI scientific interests include:

- Normal mode/multipath ray structure research in the ocean waveguide (internal wave field and bottom characteristics effects on mode/ray structure by measuring wavefront and mode decomposition using the vertical and horizontal arrays).
- Temporal and spatial coherence research in the ocean waveguide (fluctuations due to internal wave and bottom effects on temporal and spatial coherence through measuring time-space correlation matrices and array gain of the vertical and horizontal arrays).
- Bottom parameters inversion research (putting emphasis on joint sediment and column inversion).

Reverberation Experiment

Thursday and part of Friday morning were devoted to breakout groups focusing on the reverberation and volume interaction (VI) experiments separately. The reverberation group was chaired by Dr. Bob Spindel and Prof. Renhe Zhang, and the VI group was chaired by Dr. Marshall Orr and Prof. David Tang. The charge to each group was to lay out the scientific goals, implementation plan, equipment contributions, equipment needs, and ship schedules for each experiment. Each group produced a summary report which was presented to the plenary session on Friday morning. These two reports are summarized below.

The goal of the reverberation experiment is to "*Develop models that can predict the mean reverberation level and fluctuations using measured environmental parameters.*" Specific issues to be addressed in a field program include:

- The gap in data and understanding at low- to mid-frequencies
- Modeling the sea bottom
- Frequency dependence of reverberation
- The relative contribution of bottom interface roughness and sub-bottom structure to the scattered field
- The extent to which sea bed reverberation level and fluctuation statistics are determined by sea surface conditions.

The program should:

- Obtain experimental data for model development and validation. This should include the surface wave field as well as bottom roughness and sub-bottom structure.
- Extend matched-field inversion methods from low (<400 Hz) to higher (800 to 4 kHz) frequencies
- Focus primarily on the mid-frequency band (1kHz-10kHz) to discover a) how applicable the results are to low frequency reverberation, and b) if low frequency inversions for bottom parameters (<100 Hz, which we do now) can be applied to mid-frequency reverberation.

The experiment will have two components, one to focus on short to mid-range (1 to several bounces, mid-frequency) and the other on long range (several bounces to 30 km, necessarily low-frequency) reverberation. The primary hypothesis of the short to mid-range (high grazing angle) experiment is that *Bragg scatter is the main mechanism by which bottom roughness and sub-bottom inhomogeneities affect the acoustic propagation loss*. The experiment will investigate a) the physics of a single bottom bounce with significant bottom penetration (steep angle); and b) the role of surface scattering in reverberation mean and variance. The primary hypothesis of the long range (low grazing angle) experiment is that *interaction with the sea bottom interface is the primary mechanism, with volume interaction effects also playing a significant role.* The long-range experiment will investigate a) the role of sea surface and sea bed forward scatter; b) role of multiple bounces c) low grazing angles d) azimuthal dependence; and e) sea surface interaction.

The short range experiment requires 3 to 4 sites located within 500 m of each other (Figure 6). These will be located in the ECS within the region where the bottom was well surveyed during the ASIAEX 2000 pilot study (28° to 30°N, 126° 30' to 128°E). The elements of the experiment include:

- A vertical receiving array working with a towed source at 1-10 km range, to look at forward scatter in the 800-4000 Hz band using matched field inversion techniques.
- Vertical monostatic source/receive arrays with 29 channels to study backscatter in the 850 and 3500 Hz range.
- The UW/APL In-situ Measurement of Porosity (IMP) instrument
- The UW/APL MORAY (Moored Receiving Array). This 8-element VLA will listen to a ship-deployed source capable of operating between 1-20 kHz. The goal is to obtain 5 to 10 24-hour data sets.
- The UW/APL BASS (Broadband Acoustic Source System)
- One or more buoys to observe the surface wave field

The long-range configuration consists of a circle 30 km in radius with the receive arrays located near the center (Figure 7). The circle will be located in shallow water (<125 m) in the ECS within the previously surveyed region described above. The source ship (Shi Yan 2) will tow sources around the perimeter and drop SUS charges along the way. Both horizontal and vertical (several 16 and 32 element) receive arrays will be used, listening to SUS charges detonated at 7, 18, and 25 m.

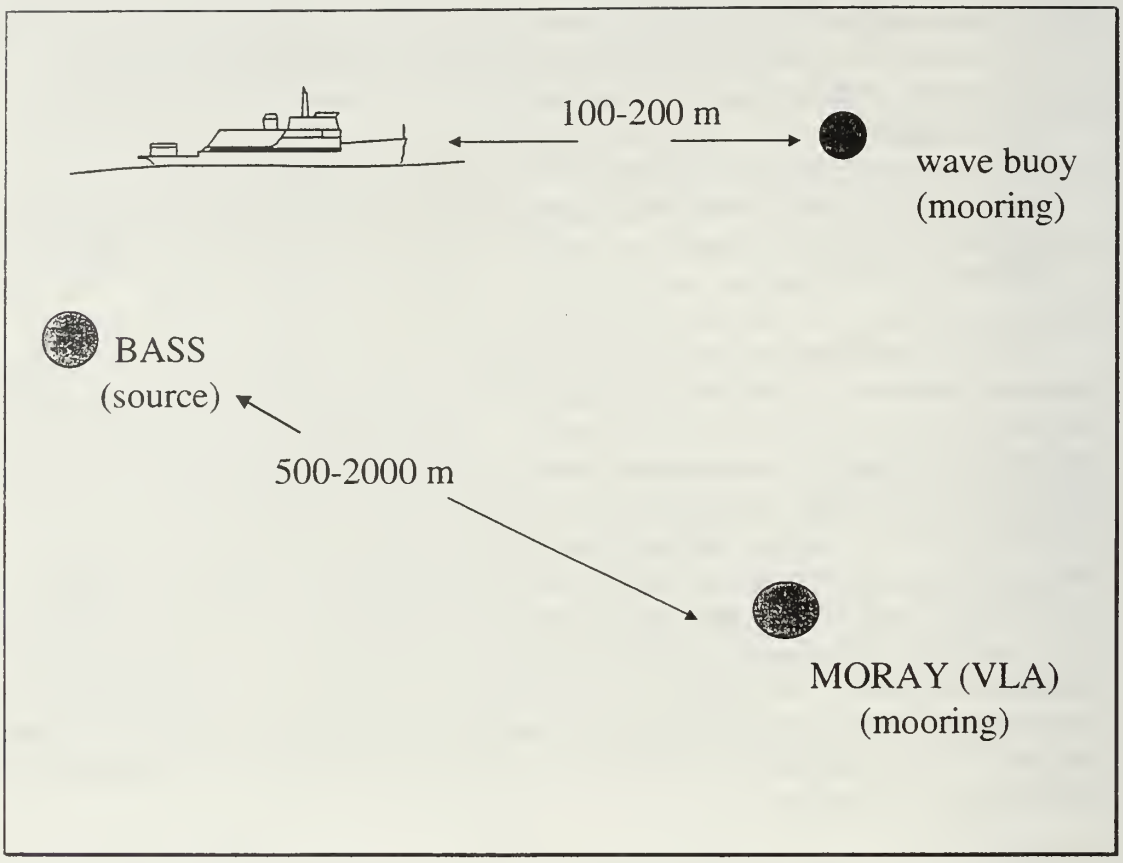

Figure 6. Schematic drawing of the asset configuration for the short-range reverberation experiment. BASS = Broadband Acoustic Source System; MORAY = Moored Receiving Array. [Figure courtesy of Dr. Peter Dahl, UW Applied Physics Laboratory.]

As implied above, the reverberation experiment as proposed is a multi-ship operation. The primary U.S. vessel will be the R/V MELVILLE operated by the Scripps Institution of Oceanography. The two Chinese ships will be the SHI YAN 3 and SHI YAN 2. The anticipated number of ship days includes 21 for the MELVILLE and about 14 each for SHI YAN 2 and 3. The MELVILLE will deploy, monitor, and recover the wave buoy, the MORAY, and the IMP; and will also lower a new Russian source off the fantail. The source is capable of both narrowband (100, 300, 500 Hz) and 1 – 10 kHz wideband transmission. The SHI YAN 3 is the Chinese "command" ship and will deploy receiving arrays directly from the ship as it is very quiet and the ship's machinery can be completely shut down. The SHI YAN 2 will be the source deployment ship. The MELVILLE and SHI YAN 3 will both collect environmental data (CTD, ADCP, XBT, bathymetry) throughout the experiment. Most of the bottom and sub-bottom data have already been taken, but some additional deep sediment cores are still required. Plans are underway to obtain these cores from the Korean research vessel ONNURI prior to May 2001. The time period of choice for the reverberation experiment is May 2001, followed closely by June 2001. Fishing effort is certainly an issue where the safety of the

equipment is concerned. There may be less fishing effort during June as a result of a proposed moratorium that month as a result of over fishing. Several members of the workshop audience will continue working this issue with the PRC and Japan.

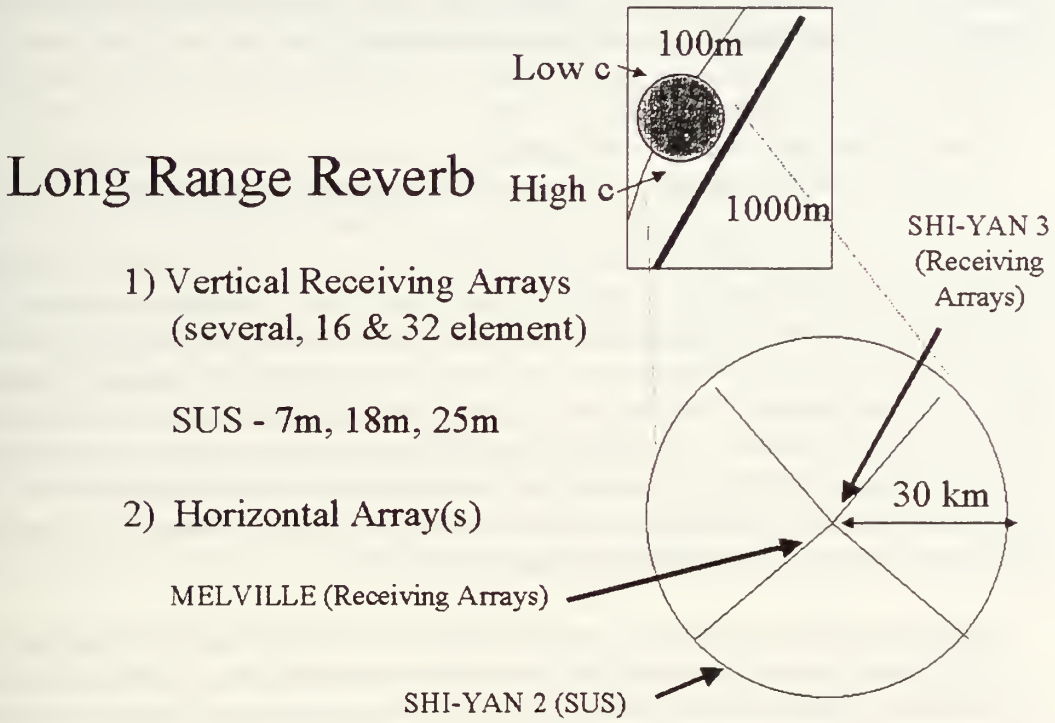

Figure 7. Schematic drawing of asset configurations for the long-range reverberation experiment. A three-ship operation is envisioned, with the SHI-YAN 2 deploying SUS charges around a 30 km radius, and the MELVILLE and SHI-YAN 3 deploying receiving arrays near the center. [Figure courtesy of Dr. Robert Spindel, UW Applied Physics Laboratory.]

Volume Interaction (Shelfbreak) Experiment

The volume interaction working group was chaired by Dr. Marshall Orr and Prof. David Tang. This group had more options to weigh due to the uncertainty at this writing as to where the experiment will actually take place. The two candidate choices are in the South China Sea from 21.0° to 22.5°N, 117.0° to 119°E, and in the East China Sea between 28.0° to 30.0°N, 126° 30' to 128°E. The first box describes a portion of the continental shelf break between Dongsha and Taiwan. The second is the same region as the reverberation experiment, already surveyed during the pilot study of spring 2000. As a result of this ambiguity, much of the discussion was kept rather general to describe an experiment that could be successfully executed in either location. The ECS site makes extensive use of the U.S. research vessel MELVILLE while the SCS site makes use of

several Taiwanese ships, including the OCEAN RESEARCHER I, OCEAN RESEARCHER III, AND FISHERIES RESEARCHER I. The physical oceanography of both regions was described in the ASIAEX Alaska workshop report (Denner et al., 2000) and earlier in the present document. Both sites span the continental shelf break, that is, they contain flat shallow water less than 100 m depth, some steep topography, and some deep ocean. In any case the over-arching goal of the volume interaction experiment is *to understand acoustic propagation through shallow water when strong oceanic variability is present.* This variability primarily takes the form of:

- Strong temperature/salinity (T/S) fronts
- Thermocline displacements (due primarily to internal waves and solitons)
- Variations in the thickness of the surface and bottom boundary layers

The effects of bottom and sub-bottom structure on acoustic propagation can of course not be ignored, but the emphasis of the shelfbreak experiment is on the strong water column variability, rather than on the bottom structure. This variability is recognized to be range dependent, anisotropic, nonstationary, and intermittent making it extremely difficult to observe and understand. The time scales vary from seconds to days, and the space scales from meters to kilometers. This high variability necessitates an intense observational program at least a fortnight (14 days) long with continuous observations of the 3-D physical oceanography in addition to the acoustic propagation. Some of the specific objectives of the ASIAEX shelfbreak study include:

- Investigate 3D low-frequency sound propagation along and across a complex shelf-slope frontal system, emphasizing the dependence on frequency, source/receiver placement in relation to the water column, and bottom and sub-bottom structures.
- Investigate horizontal array coherence, as well as vertical and temporal coherence.
- Investigate the scattering effects of the linear and non-linear internal waves.
- Investigate high frequency acoustic fluctuations in relation to small scale ocean dynamics, and the statistics of frontal structures and internal solitons.
- Investigate the forward scattering properties of bottom inhomogenieties.
- Investigate the feasibility of moving-ship tomography.
- Study the feasibility of joint sediment-water-column tomography.
- Investigate higher frequency coastal acoustics ($f > 1$ kHz).
- Investigate the broadband and narrowband mode interference structures.

The requisite environmental questions related to the acoustics above are:

- What are the cross- and along-shelf temperature and salinity gradients, and over what space and time scales do they vary?
- What is the strength and temporal and spatial variability of the thermocline?
- What is the thickness and variability of the surface and bottom boundary layers?
- What are the dynamics that control these features?
- What effect does the alongshelf current structure have on the acoustic propagation?
- What are the kinematics and dynamics of the non-linear internal waves frequently observed in both the potential study regions?

The guiding concept of the ASIAEX shelfbreak experiment is *to make simultaneous, mutually-located observations of both the acoustic propagation and physical oceanography which will allow the propagation to be understood at a level not previously achievable with existing observations*. The high importance of the tidal signals and their strong variability over the spring/neap cycle demands that the experiment be in the water for a minimum of 14 days. At the other end of the spectrum, internal waves with periods from 15-20 minutes are common in both study areas, which demands very high frequency sampling. A generic sampling plan (Figure 8) includes the following elements:

- Moored (< 1 kHz) sound sources
- Multi-element horizontal and vertical acoustic receiving arrays
- Towed sources
- Ambient noise sensors
- Continuous towed CTD (Seasoar, Acrobat) observations
- Deep (>350 m) CTD observations
- Ship-mounted current (ADCP) observations
- Custom ship-mounted sonars to study internal waves
- Moored current, temperature, conductivity and pressure (TCP) instruments
- A complete suite of meteorological observations at a minimum of one location
- Satellite remote sensing to include SST, ocean color, and surface roughness (SAR)

The source/receiver pairs will be positioned to observe both along- and across-shore propagation. Likewise, adequate numbers of moored TCP strings will be positioned to observe the directional frequency/wavenumber spectrum of the incoming internal waves as well as the strength and position of the T/S fronts. The data thus obtained will be able to establish cause and effect between the arrival time variability and the water column variability in between the source and receiver.

A complete picture of the geology and geophysics is also necessary to understand the acoustic propagation. As the bottom rate of change is very slow, this need not necessarily take place concurrently with the acoustics and PO observations. The required observations include a chirp sonar in the 500-15000 Hz range and a seismic profiler operating within 200-2500 Hz. Much of the ECS region was already mapped during the pilot study (see report by L. Bartek, this document). However, coverage over the continental slope was not adequate for the volume interaction experiment. Thus, if the experiment were in the ECS, some additional G&G work would be necessary. The bottom mapping in the SCS has not been done, and some additional cruise time must be planned there to obtain the necessary data.

The ship contingencies are as follows: If most of the work is to be done from the MELVILLE, about 30 days of ship time is required. Multiple legs are required due to inadequate deck space to house everything at once. The ship thus requires 4 days to deploy moorings, 3 days in/out, 16 days Seasoar, 3 days in/out, and 4 days to recover the moorings. Under option B, the Seasoar work and most of the mooring work would be

done from the OR1 (20 days). The FR1 would be used only for very heavy equipment which cannot be handled for the OR1. The OR3 (30 days available) would be used for deep CTDs, towing the (Singapore) Acrobat vehicle, and possibly as a "guard ship." The moored receive arrays require protection from fishing activity which lead to extensive discussion of the "guard ship" concept. This ship would position itself over the arrays for the duration of the experiment, for the purpose of fending off potential conflicts with trawlers and long-liners. The ship might be a chartered fishing boat (or boats), a small research vessel, or some other kind of "official" boat. The issue of how to best accomplish this was unresolved at the meeting. Several people agreed to work the issue and report back at a later time.

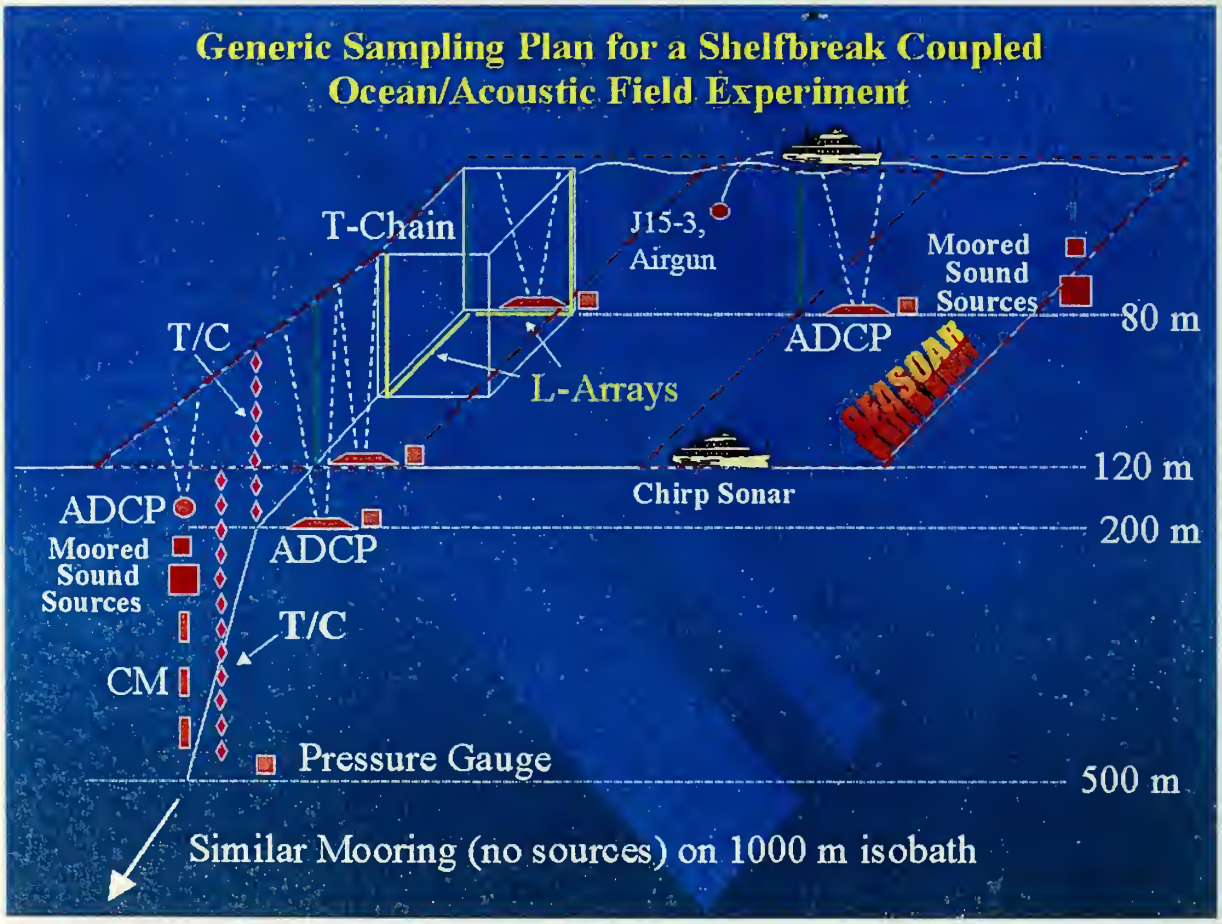

Figure 8. A schematic drawing of the instrument deployment plan for a shelfbreak volume interaction experiment. The L-shaped acoustic receive arrays are in yellow (both VLAs and HLAs), temperature chains in green, sound sources as red squares, current meters and ADCPs in trawl-resistant bottom mounts in orange. A bottom pressure gauge (orange squares) accompanies each ADCP/TRBM. Ship tracks for towing the SEASOAR undulating profiler are indicated as dotted red lines. [Figure courtesy Prof. Steven R. Ramp, Naval Postgraduate School.]

There was near unanimous agreement that an ECS reverberation experiment should be staged from Naha, Okinawa, and that the volume interaction experiment should also be staged from Naha if in the ECS and from Kaohsiung, Taiwan if in the SCS. The equipment storage and warehousing needs are extensive, including six 40-foot vans, two 20-foot vans, several racks of electronic gear, and air conditioned space to set up the instrumentation and check it out before loading and deployment. The WHOI acoustics group was tasked with finding and arranging adequate staging facilities.

Data distribution and publication issues

As the workshop came to a close, Dr. Jim Lynch and Prof. John Potter led a discussion on data distribution and publication issues, including the function of the ASIAEX web site, maintained by the National University of Singapore. Rose Dufour clarified that all the data needn't be distributed within 30 days, but rather a *plan* must be in place to describe how it will all be done in 30 days. Most of the data have already been distributed, since everyone was provided with a CD of the cruise data upon disembarking from the R/V ROGER REVELLE. The U.S. State Department has other data distribution requirements formalized in the vessel clearance request. This requires that the preliminary cruise report and the data be routed through the State Department to the embassies of the various nations so that they know the requirements have been met. This was done by Jim Lynch and Steve Ramp immediately following the workshop.

An exception to the above (data which have not been distributed) are the G&G data collected by Dr. Lou Bartek. The problem is due to the extremely large volume of data which would fill many CDs and even several hard drives (hundreds of gigabytes). Formulation of a plan for distribution of this data was tabled. In the meantime, if anyone wants a specific subset of the data, a request may be made to Dr. Bartek who will provide the data in some acceptable medium.

Prof. John Potter will continue to maintain the central ASIAEX web site. The URL for this web site is: http://arl.nus.edu.sg/asiaex. Certain parts of this web site containing actual data are password protected, but it is mostly open to the public. The site serves as a central clearing house for all the related ASIAEX web sites, and has (or will have) hot links to all the sites at other institutions. There are many interesting links there already and all ASIAEX participants are strongly encouraged to visit the site and link their own web sites to this site. It was agreed that given the wide diversity of the data sets collected, no "standardized format" for data exchange was likely to work. Therefore, people are encouraged to use whatever format is most appropriate for their data, sticking to standard and easily available formats whenever possible (netcdf, matlab, etc.).

Some scientists are already thinking of publishing some short articles containing summaries and hot results from the pilot study program. A program description could be appropriate for the AGU weekly publication EOS. For scientific results, the Technical Notes section of the IEEE J. of Oceanic Engineering, Geophysical Research Letters (GRL) or even Science or Nature for very strong results of general interest might be

appropriate. It is premature to consider a "special issue" of some other refereed journal at this time. This will likely happen some time after the main field effort has been completed.

Summary

All the primary goals of the Kona workshop were met. The Office of Naval Research was well represented by several program officers. They were all pleased by the turnout, the ASIAEX accomplishments to date, and by the direction the program is moving in. A clear set of goals has been established for both the reverb and volume interaction experiments, a rough time line established, and vessels and ports chosen. The Chief Scientists were named for the 2001 MELVILLE cruises: Dr. Peter Dahl for the reverb cruise and Dr. Jim Lynch for the volume interaction. A high level of enthusiasm for the program is being maintained by all the participants, and we are looking forward to the main field program during spring 2001 with high anticipation.

Acknowledgements

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