

FOR MY LOVE

GREENLAND SEA DIARY

XX

The Beginning

I arrived in Bergen on Saturday noon, 3 September 1988. The flight was packed, but all right. Paul Boutin met me at the airport and took me to the warehouse at the waterfront in downtown Bergen where all the gear was being assembled. This is right at the water front just one block from Haakon Halle, where I received my degree about 15 years ago.

Paul then took me to Ola and Bente Johannessen's house, where we had dinner and I stayed for some days. I spent a lazy Sunday. The Johannessen's very kindly had the entire scientific party of 8 for dinner.

Monday I gave a talk about the Greenland Sea Experiment at Ola's NANSEN INSTITUTE to about 30 people.

The KNORR arrived on Tuesday, held up 2 days by engine trouble associated with having taken on watery fuel in Turkey. (However we were going to be plagued with engine trouble for the rest of the trip. The KNORR was going into drydock immediately afterwards.) I moved aboard the KNORR. After 2 hectic days loading the KNORR to the gills, we left Thursday, 8 September, two days late

The Trip into the Area

We steamed at 10 knots in very good weather. People got their gear in shape, and worked at their software. There must be at least 20 computers in the various laboratories. In the main laboratory aft there is a direct flow from the Woods Hole set up which gets the data from the sonobuoys, to Bruce Howe who gets the position to Ted and Kurt who compute the travel time of ray arrivals to Bruce Cornuelle who is supposed to make sense out of them. Everyone has at least 2 Apollo's or equivalent. I have taken a little desk space in the WHOI corner, with just my little HP handheld

We arrived at SITE 3 in the afternoon of the 12th, and Peter turned on the fathometer. The best available chart had shown a smooth flat seafloor at 3400 m depth. To our chagrin the bottom revealed at 200 m relief with 10% slopes. This is a serious problem since the surface buoy is to be

kept within 10 m of the allocated depth of 100 m, and there is no way of dropping the anchor on exactly the allocated spot. So if we miss the spot by 1 km, then we might miss the depth by 100 m (and have a "floater" instead of a submerged buoy). We searched the area and found that by going 15 nm to the WNW the relief was down to 10 or 20 meters. Unfortunately the entire array of 6 moorings has to retain its geometry, since reception and transmitting times have been preset. Accordingly we steamed 6 hours to #5 in the NW corner, the mooring nearest the ice, to see whether it could be so moved. It turned out that this is barely possible, with the new site being virtually in visual contact with the ice edge. There was smooth bottom at #5, so no trouble with relief. We then steamed 6 hours to the east to have a look at position 1, and the bottom there was fortunately very smooth.

By this time a valuable day had been lost, and we were nervous about the ice edge advancing and closing in on #5. So back we went to #5 to install our first mooring, in the morning of 14 September. It was a smooth sea but somewhat cold. We all wore our exposure suits. I served as timekeeper. John Kemp did his usual professional job, and we were in in 6 hours. We overshot a little, so the mooring is off 1 km, which is acceptable. The depth is perfect. Peter did a wonderful job running the show. The afternoon of the 14th, and all day the 15th was used to survey that anchor position and bottom transponders with GPS. Things all worked out. Unfortunately there was a misunderstanding and Werner in Spitzbergen did not get his associated GPS observations in. These have to be taken simultaneously on land and sea to get the 10 m accuracy we are shooting for. Kurt and Ted took their first sonobuoy recording in the immediate vicinity of the source, and this showed very prominent bottom reflections. I had fun using the simple theory for comparing the recorded arrival with simple ray theory for an adiabatic ocean, and this showed that the two rays (at this close range) differed only by 4 ms and could not be resolved by our 16 ms window.

Bruce C. ran his ray trace program and essentially accounted to the observed arrival pattern. We got underway at 10 pm on the 15th towards station 1 and arrived there by daybreak. Setting mooring 1 took until late afternoon, but things went well. After the anchor is dropped we did the usual thing of listening to the radio transmitter on top of the mooring to go out when it is dragged under (it ends up 60 m beneath the sea surface, out of reach of ice and Soviets.)

Then we listen to the first of the hourly capsule transmissions to see whether it comes in on time. Everything o.k. But then to everyone's amazement Bob Truesdale claims to have heard another transmission just a little later (instead of the next scheduled hour). This is very worrisome. But then it occurs to Peter that we might have picked up capsule 5, 124 km away. At first blush

this seemed impossible. But then Peter reconsiders the signal to noise ratio, allowing for the very calm day, giving 60 dB instead of the assumed 75 dB which allows for waves and ice. We all get ready for the next capsule 5 transmission, 4 hours later. And surely enough there it is, loud and clear. Kurt and Ted pick it up and process it, and get 35 dB on the highest peak. They get a wonderful arrival pattern, the first example of what we expect to have to work with. Bruce C. has to stay up to cut the anchor and transponder satellite positions in, and between hydrophone lowerings he runs his ray trace program to identify arrivals. The outliers are clearly bottom reflections.

I use the morning of the 17th to look at the arrival pattern. The first CTD is taken (our previous attempt failed since the cable on the winch was damaged and John Kemp had to spend an entire days putting a new cable on). It turns out that the the computed soundspeed gradient $C-1.dC/dz = 0.0113 \text{ km}^{-1}$ is very close to the measured one beath 1000 m (the measured averages 0.016, why) but definitely less above 1000 m, e.g. the ocean above 1000 m is warmer than it will be after the winter convection). With this in mind one can compared the measured arrival pattern with the pattern computed for an adiabatic ocean. On this basis I think one can identify each of the distant arrivals. I will bet Bruce a beer for every one I miss. The latter shallow arrivals with turning points well above 1000 m come in early, as expected. This is just as expected. As winter comes, the early arrivals will be retarded and this will give us a measure of just when the cooling occurs, and how fast.

We will have BT and fathometer watch all night while we are underway to #4 mooring, which we will drop tomorrow. From now on I will try to keep this diary going day by day.

18 September

Peter and I took the 0400 watch, fathometer and BT's. We arrived at station 4 at 630. Bottom was pleasantly flat. The capsule drop started punctually at 800, right after breakfast. Everything went very smooth, and the anchor was dropped at 1330. Two down, four to go. I served in my standard capacity as recorder, putting down the time when each item goes overboard. There are about 50 items, of which the cage with the acoustic sources is the largest. Peter had guessed the total depth to the nearest meter, so there was no need for wire rope corrections. Each rope has been carefully measured and tagged to the nearest tenth meter, using a laser distance meter.

This time the anchor was within 1/3 mile of the designated position. This is the best so far, a little bit of an undershoot since we got done so early and did not want to spend too much time dragging the 3 1/2 km behind us as we were heading into the wind.

At 4 this afternoon was transmit time, and we could hear capsules 1,5,and 4 coming over clearly. If the weather stays as good as it is we shall be able to hear all 6 capsules as we leave the area. It is now dinner time, and I shall spend some time working on my omega-kay paper after dinner.

19 September

Peter got up early this morning to do the Satellite navigation for station 4 . I worked all day looking over the arrival patterns Kurt is producing at an increasing pace. They are beautiful, but no one is really looking at them. One puzzle came up. A very close transmission on Julian Day 262 gave no bottom bounces, whereas these had been prominent at other times. The main single spike-like arrival was 42 dB above noise. I looked at Urick's Text Book, and it is pointed out that there is an angle of "intrusion" for which there is zero reflectance. This angle is a function of the ratios of densities and soundspeed, bottom relative to water. The measured inclination is very steep 70.8° relative to the horizontal. The requirement for this angle is that if the density ratio is $1 + \epsilon$ the soundspeed ratio is $1 - \epsilon$. So the soundspeed would have to be somewhat smaller in the bottom than the water (work by Ed Hamilton). By assuming this is what happened at 70.8° , one can calculate the reflectance for another very steep case 55.5° . This gave a reflectance of -18dB., which happens to be the measured weak intensity. I must ask some of our marine seismologists whether this makes sense.

Bruce Cornuelle has produced a beautiful angle-time diagram which will be the proper tool for identification. The records are truly beautiful.

In the afternoon we went on to station 5 to make a BT section, and then to catch up on a CTD at 5 which we previously missed since the cable was found damaged and had to be repaired. We had planned to steam over and look at the ice edge, but it must have retreated with the southerly winds. We shall have another chance when we return with the moving ship tomography work.

In one hour we are off for the central station 6. I have the first BT watch. Then tomorrow we launch the 4th mooring. It has all sorts of equipment in addition to ours. Peter calculates that it is worth \$0,6 million.

20 September

A busy but eventless day. The sun was shining but it remained below freezing. I am lonely for Judy, and sent her a telex asking her to telephone me when she wakes up.

It took from 800 to 1400 to get the mooring set. I had my usual function as recorder. There was some software problem in getting the time set. It seems to me that one has more software problems than hardware problems.

It is now after dinner and I plan to do some work on using tomography to get mesoscale spectra.

21 September

This was an easy day. I slept until breakfast and have been working on and off on my omega-kay notes. Tomorrow we get up at 4 to look over the bathymetry of station 2, and start setting mooring at 8. The weather has gotten a little rougher, so there will be a bit more effort in setting the station. I hope for a smooth bottom.

22 September

Five down and one to go! Everything went smooth and the anchor was on its way at 1331. The only hitch was a test program that threw off the capsule setting.

I got up with Peter at 0330 to help out on the surveying of site 2. It was the only site we had not previously visited and so there was some concern about the nature of the bottom. As it turned out it was totally smooth, and it was easy to make the rope correction (+70 meters) to get the capsule cage to the desired depth of 100 m.

We have been pretty well alone up here, except for the sea gulls. Yesterday at 1700 a plane flew over. The captain says it looked like a DC 10, perhaps the London-Los Angeles flight. But last night about midnight while we were steaming towards the south east from station 5 to station 2 a ship passed within 4-5 miles going northward. According to the first mate (Pat was on watch) it was most unusual because she had a very powerful searchlight shining forwards and visible for 10 miles (she could be noticed when she was still over the horizon). As far as it could be seen the bridge was way forward. Someone thought it might be an ice patrol, but I wonder whether this

still exists in the days of satellite ice mapping. So this is my *flying hollander* on his way to watch us and to steal one of our precious moorings.

Everyone is fine. I am doing double duty by washing my weekly laundry while bringing my diary up to date.

23 September

We had shocking news from Jane. Don Betts has a hanglider accident and broke his arm and pelvis.

Up today at 0300 to cut in the four transponders and the anchor with GPS navigation. It is interesting but wearing.

Tom Curtin of ONR called at 1600. A mooring was set by WHOI and APL Washington at 79° 25.9' N and 2° 58.8'W and is in trouble. Could we pick it up on the way home. The WHOI mooring moves up and down to collect data and then snuggles up beneath the ice to transmit to a satellite through the ice.

We have considered various alternates, most of them involving going into Tromso instead of Iceland. Curt will call back at 7 tomorrow morning and we need to make a decision then. I very much hope this can be worked out. I remember how desperate we were for help when our buoys were in trouble.

24 September (Saturday, we almost forgot)

It is hard to see how our smoothly working expedition could have taken such a deep nose dive so rapidly.

Three things came up all at once. One was the wind. We have been having 30 knot winds with gusts up to 50, and a rather nasty swell from the south. The second thing was the ONR request for the RTEAM mooring at 79° north. The third is that the capsule malfunctioned when we prepared for the launch.

All this is piled upon a very challenging problem. We are back to site 3 where we discovered the rough terrain when we first came into the area. Between midnight and 7 AM we made a major effort at surveying the area near the site. We need to meet all the following criteria. First, we have to be within 2 km of the specified point, in order for all 15 capsule to capsule transmissions to be devoid of overlap. Second, we cannot count on hitting a point better than to within 1 km. Third, we must allow for the depth where the anchor hits bottom to within 10 meters, for otherwise the depth of the capsule will deviate seriously from then allocated depth of 100 m beneath the surface. If the bottom slope is typically 10% then an error on positioning by 1 km will make a depth error of 100 m, instead of the allowable 10 m. If we are too deep, some of the equipment will collapse. If we are too shallow, then the ice might catch the uppermost float and drag it away.

It was just these considerations which made us move the entire array 15 km to the west north west after encountering the hilly array when we first came here. In the new displaced position the terrain is actually smoother, but not enough so. So we looked for a level spot that meets all these considerations. We found one about 1 km sw of the allocated point (which is just tolerable). It is a flat spot about a mile by mile in area, totally smooth as far as one can tell, but with steep edges. I visualize it as a mudflat that has collected all the debris from the sides. The depth is 3780 m within 2 m. Very satisfactory if we can just hit it.

We were ready to go, but then the AVATAR did not check out, so we have just been hanging around which is probably just as well. We needed a break, and then it looks as if the weather is coming around. Peter and Doug have been checking the capsule all day, and I have tried to stay away and not get in their way.

Now with regard to the arctic rescue mission, things look pretty good. I have a 7 Am date for a phone patch with Tom Curtin of ONR to hopefully come to a decision. Last night all the senior scientists met, and I had talked to the Captain, so we had our story straight. Actually Curtis had flown back to the USA, so the call came from Dean Horn of ONR. We are to go to the site at the end of our activity, pick up the capsule in distress, and then steam south to Longyearbyen, Spitzbergen. (I was uncomfortable about the wording of the request, yesterday it was whether we were willing to do it, today it was telling us to do it.) There we will be met by Henry Bertaux with his WHOI group. We disembark, catch a plane to Tromso and Oslo, and then home, actually getting back 2 days earlier since Longyearbyen is so much closer than Reykjavik. Bertaux will either repair and reinstall, or otherwise the RV KNORR just leaves for home with the sick capsule aboard. Four of us (Ted, Kurt, Peter and I) have to fly to Reykjavik to meet our Navy date, and

then get home on Iceland Air. Our connections are lousy and we will probably not get home any earlier.

By tomorrow we will know whether the capsule drop worked.

25 September

Well, we don't know. It seems we have been cut to size for our overconfidence. The weather has turned nasty. When Doug made his final capsule check one of the receivers was noisy. And when he thought he had that one fixed, there was a massive power surge. They now think the trouble is with the transmitter, which is the hardest thing to get to, particularly when the ship is so unsteady.

We spent the day doing XBT and XSV casts, and will continue to do so until tomorrow morning. Then we start on the "moving ship tomography", while Doug and Peter will have another go at the capsule. We thought we had it by the balls, with five down and one to go.

26 September

What an improvement! The important development is that Doug and Peter understand what went wrong in the capsule, and things are now being assembled for launch tomorrow. Jorgen's acoustic current meter has also been fixed (it had blown a fuse) and can now be put on the mooring, which would not have been possible if we had launched yesterday. The winds are down a little, from 30 knots to 25, and the swell is a little less angry. So we will get up for 2 hours of surveying the bathymetry around the site, as an aid in placing the transponders. And at 800, if things go well, the final launch starts.

While the AVATAR and capsule was being repaired, we did 4 more legs of the XBT survey, and have enough data now even if we cannot complete the remaining 3 legs (there are 15 legs connecting all possible transmission paths between the 6 moorings).

But the important thing that happened was the early trial of the moving ship tomography. We had several runs, and the results look stunning. The only negative aspect is that the ship noise is appreciable even though the receiver array is floated several hundred meters away from the ship. Evidently it will be necessary to declutch the ship's rotors while the measurements are being made. But we pick up all the 5 existing sources with a good S/N ratio. Kurt has automated the inclination angle/arrival time display, and this will permit an easy comparison with a similar computed figure

using the sound profile and ray drawing techniques. In this way the identification can be easily made.

There was one minor negative note. The APL group has been showing its Civil Service background by complaining about their quarters, and so Doug and Bob volunteered to trade cabins. Before leaving Bergen they had complained about their cabins, and Paul had purchased them some goodies (like a little bath mat) which they took with them to their new cabins. In perhaps this spirit Bruce Howe issued lengthy and detailed instruction to the bridge and others of what will happen from now on until we sail into Longyearbyen. This goes against our spirit of informal cooperation, and as far as the instruction for the last few days are concerned it violates the responsibility of Peter as chief scientist. I talked to Bruce about this in our cabin, and he took it rather well. Then I went to see the Captain to confirm that Peter was responsible for the scientific decisions. He said that he had not taken the Howe document very seriously; anytime someone programs the work 4 days in advance to the nearest minute, he said, he was inexperienced in work at sea.

So I close on an optimistic note, wishing to know what will be reported tomorrow.

27 September

The good news is that we dropped #3 within 0.2 miles of the selected spot, and that is a bulls eye! The bad news is that the capsule we set 3 days ago is not functioning properly.

The day started at 0300. When Peter and I got up to do the survey, a little note was waiting that mooring 2 had failed to meet its transmission schedule at 2000 and 2400 the previous evening. We decided to put this calamity out of mind and concentrate on today's business. I helped Peter survey the area for where the transponders go. I feel quite intimate with the area 3 1/2 km down below.(I imagine this is the way all marine geologists feel). There is this mile wide flat area at 3780 meters, with steep walls on all 3 sides. Doing the mooring setting is a bit like landing a plane in San Diego.

The actual mooring setting got underway at 8, and was finished at 1:40. At the end we almost ran short of time, which would have meant overshooting the site. It was fairly cold and for awhile it hailed.

We then turned our attention to #2 that had failed. To everyone's amazement it did come in on the noon transmission, but 8 s late.

We all met this evening to decide what to do. The decision is to go back to site 2 (we are now underway) and to recall the Capsule. Then will will go around the entire array, hopefully getting a chance to fix what is wrong, and then set the capsule again at the end. In order not to short change the people who are doing the "moving ship tomography" thing, we decided to ask WHOI for another day of ship time. After talking it over with the captain, I called the WHOI marine supervisor, Joe Coburn, and made the request. He promised to get back with us tomorrow. Travel arrangements at the moment are exceedingly complex, and we had better settle one one plan or another.

28 September

From 8 until 1400 was pull-up time. The sea was friendly, and the weather changed a few times from sunshine to blizzard. But it was really a friendly time. The problem was O rings, believe it or not. This time not a manufacturing error but a homemade one. Another trouble symptom was that in the checkout process the capsule failed to print out its temperature, Peter called our local programer David Horwitt at IGPP to try and solve that particular mystery. It turned out that David had programmed the test so that if the temperature should tread above 40o or below 2o it would not print the result since the instrument was obviously malfunctioning.

It is a good thing station 3 failed so soon. As I understand it, we will probably repair and relaunch first thing tomorrow morning. I would welcome that, just to get one phase of GSP88 (as everything is labeled) out of the way.

29 September

A good day. First I received a message from my family. Then we dropped #2 successfully, in a blizzard no less. Then a message from Jane (SIO delayed delivery of the telefax one day since her name was spelled with an "e" and a single "l") that we should have no difficulty making Iceland on time for the conference and for getting home on Sunday.

It was an 8 to 1345 launch this time. Peter wanted the anchor dropped no later than 1345; it takes 20 minutes for the cage to be pulled under and the cage to be vertical, and this is the preferred orientation for the acoustic transmission. These are scheduled every hour for the first 24

hours, every four hours thereafter for the year. I went up on the bridge to see the upper buoy pulled under. She travelled about 4 knots towards where the anchor is dropped, leaving a white trail. It was easy to follow her, since she was accompanied by hundreds of little white birds who were wondering about this big fast red fish. As soon as she disappeared, so did the birds.

Lots to do. Kurt keeps feeding me more and more data. We used to look at every new record with awe and respect, now I just glance at the records and staple them together.

I will work with Bruce C. identifying ray arrivals, and I had some ideas about the omega-kay theory which I want to follow up. I talk about it with Ted every evening, and this is a great help.

30 September

It has gotten very rough again, big seas, plus a snowy blizzard. All capsules work and we have been doing "moving source tomography". They call it MST and so my anti-acronym effort has failed miserably. But there are some T-shirts that spell it out (I am bringing some home). Just now we cancelled a MST station on account of the weather, the first time this has happened on this trip. The ship is moving so violently that the satellite antenna for international marine calls does not work; I have been calling each day at 1400, wake up time in La Jolla, but there has not been an answer, Judith must be with the children. But today I could not call.

Things seem to be falling into shape with regard to the return trip. Instead of returning to Iceland we shall go into Longyearbyen, Spitzbergen, which is much closer. A party to recall the WHOI buoy is to be there when we arrive, and they will take over the ship. This is on Thursday, the 6th. In the afternoon we fly into Tromso, on to Oslo and Copenhagen. Ted, Kurt, Peter and I then go on to Iceland on Friday to meet with the Navy, and leave for home on Sunday, as originally planned.

1 October

An eventless day. The weather has greatly improved and we started the regular MST stations at 0800. I worked all day on my omega-kay paper but seem to have gotten thoroughly confused.

We are encircling our pentagon in a counterclockwise direction, and have reached the northernmost point on this circle, about 76° north. Peter and I have left word to call us should we get into sight of the ice.

2 October

No ice. Even though we went 30 km north of the site where we had previously seen some floats, there were none last night. I am afraid this was our last chance for seeing the ice edge.

The weather has turned foul again. As all the meteorologists know, you don't get much respite up here between cyclones.

By now we are more than half around the circle, with stations every four hours. This morning I watched from the bridge as we occupied one of the stations. It is amazing how quickly these vague ideas are transformed into a routine. The APL technicians in their bright red exposure suits with APL painted on the back and their last names on the rear of the hard hats know exactly what they are doing. The senior man clearly in charge giving the signals to the winch man and the crane man, 400 m of line paid out on blue and green floats to get away from the noise of the cyclone engines, ten minutes of data taking, and then back in. As if MTS is an old established oceanographic tradition, not something that was vaguely conceived a year ago in the Helen Raitt room.

There is good news on the omega-kay paper. I was ready to give up, but thought I would give it one more try. And then everything worked. Then Ted worked things over in much better and more transparent style. So I am ready to go back for further work.

Bruce Cornuelle is now seriously into trying to do inversions, and produce a map of the Greenland Sea temperature field before we leave the area. That would be something. I have helped with the identification problem. Kurt gets the ray arrivals in angle-traveltime space from the observations, and Bruce gets the same diagram from doing ray constructions using the local CTD data. Both show about 20 dots for each source transmission. For both computed and measured plots, the high intensity arrivals are plotted with big points, the low intensities with small points. I put the two plots on the ship's light table and try to match dots, paying attention to angle, time and intensity. In this way one can identify the path of the measured arrivals, the number of loops, how many bottom reflections, how many surface reflections. Thus +12 means upward at the source with 12 turning points. The figures have a nice pattern, a crescent shape at low angles for the rays

that saw neither surface nor bottom, with two wings for the bottom reflections. The first such drawing was produced by Peter 2 years ago, now we get 6 (one for each source) every 4 hours. That reminds me, I have forgotten to even mention that all 6 sources are functioning.

The ship is rolling so badly that I miss half the keys. You have to decide whether to type with 10 fingers, or use one hand to hold on to the table.

3 October

The bad weather has continued, and we were not able to occupy stations until 1200. Instead of circumnavigating the array 1 1/2 times, as we had hoped yesterday, we shall be lucky if we get around it once. The captain has already warned us that we may not be able to make more than 6 knots on the way to Longyearbyen.

I called our contact point in Iceland, Lt. Howard. First I was delayed because the telephone number had changed, and then she (as it turned out) could not be promptly located. By the time we were through it cost \$135. Anyway she will meet us at the airfield, and she has arranged a BOQ quarter, so I wired Jane to cancel the City Hotel in Reykjavik.

I have been splitting my time between identifying ray ray arrivals and doing another omega-kay draft.

The main laboratory where we are all working is really a remarkable sight. I counted 10 computer work stations, and all the paraphernalia that goes with it, wires all over the place, electronics on the floor, all reasonably secured for the ship's roll and pitch. I am sitting in a little corner way aft that Steve Liberatore offered me when I got to Bergen. Then, going forward, Steve with the WHOI equipment, then Bruce Howe with all the fancy APL gear for tracking the receiver array, then Kurt and Ted for feeding all the data into their computers and coming out with the most beautiful 3D plots of arrival structure, and then at the forward end Bruce Cornuelle for feeding it all into the inversion program and coming up (we hope) with maps of the Greenland Sea waters. But the flow of information is not nearly as unidirectional as this description might convey. Anyway it is a wonderfully busy and exciting place.

Tomorrow is our last full time working day, till midnight.

4 October

Everyone is packing up like mad and Kevin may want to crate the Mac before tomorrow. It was very rough last night, and at one time we had to slow to 1 1/2 knots. Peter and I went on watch at 4 to survey in station 3, the last one (we had to leave it in a hurry when mooring 2 failed). We make stations until 2000, which means we have finished our circumnavigation barely, without overlap, and with some gaps in the southwest. But all in all, I think that things have worked well. Beginning 2000 we are on our way to Longyearbyen, with an expected passage of 35 hours.

I will try to finish most of the omega-kay manuscript before we get off the vessel. Things are progressing well now.

I recited my favorite "keep it up" poem used one cold ski lifts. It fits well into the Greenland Sea atmosphere. Peter wants a copy of it, so here it goes:

Cold as the end of a witches tit
Cold as a pile of penguin shit
Cold as the edge of a cocktail glass
Cold as the rim of a polar bear's ass
Cold as the hinge on an outhouse door
Cold as the heart of an Baltimore whore.

To Peter, courtesy of his Greenland Sea roommate, 4 October 1988

5 October

Well, there is still a chance for a few words. Following the last station at 2000 Peter and I brought our 4 bottles of Norwegian-acquired champagne into the lab, and we drank a series of accelerating toasts. The party went on until 0130 this morning. I quit at midnight to read my new Tom Clancy. Everyone was in the best of mood. This must be one of the most positive adventures of my life time.

When I close this diary, I shall use my newly acquired skills as a word processor to process some words of thanks to the WHOI Marine Department. Especially to the Bosun Jerry Cotter and John Kemp. The first day we set a buoy, with the guard rail removed so that the equipment can be lowered over the fantail, Jerry gave me holy hell (not mincing his words) when I

stood too far aft for safety. I am glad I didn't answer back, for I have greatly enjoyed getting to know him since. About 20 years ago Jerry slipped and fell overboard in northern waters. By the time they lowered a line he was too far gone to grab it, and they had to get a skiff in the water to haul him out.

Jim Lynch suggested we make another try of listening to the sources. So at 1600 we tossed over a sonobuoy, and there they were, all six of them plainly audible even though we were 400 km north of the mooring center. Kurt got a very good analysis of them on his computer, amidst all the disorder and confusion of crating the gear. It was a romantic gesture, waving goodbye from afar: until a year from now.

6 October

The Captain woke Peter and me at 0200 as requested; and there it was, a few lonely lights in the distance; the wind had calmed, and a faint moon suggested the white towering mountains of Svalbard.

It took 4 hours up the majestic Fjord. The Russian coal settlement on our right, and a few scattered huts until Longyearbyen came into sight. Rather like an old Colorado mining town. The dock was filled to capacity with 3 vessels. Andy Heiberg of APL Seattle has been here for 10 days outfitting an arctic experiment. (Judy and I met him in Voss six years ago). He had arranged for the Norwegian's governor's boat to evacuate the vital gear and us and to put the WHOI rescue party aboard, standing off about 1000 feet. We said a quick goodbye to the Captain, the Bosun, and John Kemp. By the time we tied up the KNORR was a distant speck on her way to the rescue mission.

3 DAY SEQUEL

7 October 1988

This is a 3 day sequel that will have to be kept separate. But it needs to be recorded as a remarkable climax to a remarkable month.

I had not told the whole story when I reported that we had waved our six capsules (Jan, Michelle, Nancy, Ken, and two unnamed) goodbye on the way to Reykjavik. We were to hear them once again.

Lt. Howard was waiting at the airport in Reykjavik; we had placed bets as to whether she would be blonde or brunette; in fact she is black.

We checked into an incredibly drab BOQ (\$4/night versus \$150 in town). The security is formidable, and we found it amusing to be in our Hertz Russian-built NISA 1400 four-wheel drive.

Five of the capsules had been heard from for weeks on the regular outputs which are ill suited for the purpose. We calculated the optimum beams, and then hooked Kurt's P.C. on the line which gains another 32 dB by cross correlating with the known transmission code. And here were all of them, loud, clear, and exactly on time. We had flown half way around the North Atlantic, from Longyearbyen to Tromso to Oslo to Copenhagen to Reykjavik for another final look, this one from the South.

We spent two days at the facility to arrange for a continuing update. We will want to know this before we go into the field for a second try at MST.

Two Soviet AGS's (the MARS and the DEVIATOR) are uncomfortably close to our array. They may have been there all the time, but we never saw them. Obviously they have heard us. We are more worried about the U.S. SURTASS vessel INDICATOR which was right on top of our mooring 4. We arranged for an immediate open message asking all vessels to keep 5 nm from our revised positions, and warning them that our moorings came to within 75' of the surface and consist of hefty 3/8" wire rope at 2000 lb tension. We had previously requested such a warning, but it slipped through somehow.

Craig D. had arranged our access, and I never cease to be amazed what a word from the Admiral will do. But it was truly a pleasure working there, with a healthy interest in our work by the officers, and particularly the Chiefs. I must have given 10 pseudo talks on tomography. About a third of the personnel were women (including the CO) and the atmosphere was congenial even at the end of a 12 hour shift.

We had our own 12 hour shift, but found the time Saturday afternoon to visit the Geyser, the frozen waterfalls, and to have an elegant dinner in the old part of Reykjavik. And just before flight departure on Sunday, 9 October afternoon, Peter and I went swimming in the blue lagoon, geothermally heated and adjoining a geothermal power plant. You could see the steam rising for some distance, and when you got into the hot water there was so much steam that you could only vaguely make out the high chimneys and the general lava landscape. Blaring through all this was a loud speaker with rock music. Peter and I were convinced we had been given a preview to what it will look like in hell.

Home in San Diego by midnight. On the plane we had a good snort of Danish Aquavit. It has been a most remarkable month.

5 November 1989

I should add a *finale* to the Greenland Sea epic. All moorings are now safely home. The data return is fair: about 80%. One of the sources quit one month after we had so happily listened to it in Iceland. And one of the receivers quit in the Spring. The villain, as so often before, was connector trouble. Pete and Kevin will now definitely go to a new type of connectors.

We have just returned from a two day Washington meeting where ONR reviewed the Tomography performance since its beginning. The important actors all attended, Craig Dorman (who since has gone from Admiral to WHOI director), Fred Saalfeld and Phil Selwyn (Chief Scientists of ONR and ONT respectively), Art Bisson, Gordon Hamilton, etc, etc. I was given the task of giving the introductory summary for an hour; and Carl gave the conclusions and led a discussion. It all went exceedingly well, with both Fred and Phil going out of their way to say that they were impressed with the progress that had been made. Peter gave the Greenland Sea summary.

Unfortunately the rosy picture of the accomplishments was not echoed in the following executive session where an agreement between ONR and ONT was to be reached on financial support for the next experiment.

Perhaps the most interesting conclusion at this time is that all the moorings were there, no interference from the Soviets as we had feared. Whether Judith's and my brief October visit had anything to do with it, we shall probably never know. Or perhaps there is a chance. Carl Wunsch is going to Moscow next month to do some WOCE planning with the Russians, and at a rather wet and jovial dinner at the Cosmos following the lengthy ONR day I suggested that Carl thank Brekhovskikh for having saved the moorings.



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LA JOLLA, CALIFORNIA 92093-0225

29 June 1989

RADM Craig Dorman, USN (RET),
Director,
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Dear Craig:

You will recall our exchange of correspondence in connection with Judith and my trip to Moscow in November, 1987 to talk to Academician Brekhovskikh in an attempt to avoid any possible interference with our moorings in the Greenland Sea Tomography Experiment.

As you know, the Navy conducted a sea test in the very same area terminating a few days before we left Bergen, Norway to establish our moorings. During the Navy's work, they were followed by Soviet ships; in contrast, during our month at sea we never had any indication of being observed. As far as I can tell, there has been no interference with our moorings. Only two weeks ago, Ted Birdsall reported that five of the six sources could be plainly heard. The sixth source died in May of what appears to be natural causes. (Jim Lynch was the WHOI senior member on this expedition.) It appears as if we have been successful in not having any interference with the moorings, but whether it is related to my trip to Moscow we shall probably never know.

You might be interested in a copy of a letter that came from Brekhovskikh. Starting with paragraph three, Brekhovskikh describes his discovery of the sound channel, quite independently of the work of Maurice Ewing. After describing the work he says in his letter, "...Since this work could principally have military applications its publication was delayed till 1948." Brekhovskikh did not know of Maurice Ewing's work until considerably later.

I hope to catch a glimpse of you on 24, 25 July, when the Navy Panel of the Ocean Studies Board meets in Woods Hole.

With best wishes,

Walter H. Munk

WHM/jrd

Enc.

Prof. W.Munk
Scripps Inst. of Oceanography,
La Jolla, California 92093, A 025
USA

May 5, 1989

Dear Walter,

I have just returned from Atlantic (expedition on a new research ship "Academic Sergey Vavilov") and found your kind letter together with the shipboard report on Greenland Sea experiment and the copy of the paper "An acoustic Measure of Global Ocean Warming". I congratulate you on the success of the Greenland ~~Sea~~ experiment and not less on your new daring idea of acoustical monitoring of Global Ocean Warming. This idea is very exciting indeed.

I and my colleagues are looking forward to see your book on ocean acoustic tomography. Soviet references on this subject are few. However several papers could be mentioned: (Enclosed you will find the list of publications in Russian).

As concerned the history of the sound channel's discovery (Soviet side) it was described in short in my book "Океан и человек. Настоящее и будущее" (Ocean and man The present and the future). There is the chapter "How discoveries are making" in this book devoted to discovery of plate tectonic, synoptic eddies (Poligon-70 experiment) and underwater sound channel. I do not remember whether I have sent this book to you. Enclosed you will find xerocopy of the pages concerning sound channel. In short the history was the following.

In the middle of 1946 certain acoustical expedition was preparing for work in the Pacific (Chief scientist L Rosenberg). The goal of the expedition was such that it must be in the ocean by a specified date. Due to some unforeseen reasons, however, preparations were completed when this date have been elapsed.

For preparation not to be useless it was decided to fulfill very simple experiment with sound waves propagation in Japan Sea. Receiving ship with the hydrophon at a depth 100 m was drifting whereas the other ship was going away from it dropping charges which exploded also at a depth 100m. Something very strange was observed in process of experiment. Peak amplitude of the sound signals received was markedly decreased only up to the first 30 nautical miles whereas at greater distances (maximal distance 300 n.m.) decreasing was hardly noticeable. The acoustical signal's form was also drastically different at different distances. At small ones it resembled shock wave very much whereas at long distances the signal was very weak at the beginning, then increased with the time resembling a thunder in a final stage, then coming to an end abruptly. It was my duty to treat these results. It appeared that the only way (and a very natural) to explain them was to take into account an existence of the acoustical wave guide with its axes at depth about 150 m, formed by the temperature gradient below it. This picture fitted very well to the summer hydrological conditions in Japan Sea. The quantitative theory of this phenomenon was developed also (see waves in layered media, 1st. edition § 39). Its close resemblance to the whispering galleries phenomena in St. Jone in London (explained by Rayleigh) was noticed. Since this work could principally have military applications its publication was delayed till 1948. See papers (reprints are enclosed):

1. L. Brekhovskikh. About sound propagation in a liquid layer with a constant sound velocity gradient. Doklady Akad. Nauk SSSR, 62 469 1948.
2. L. Brekhovskikh. Sound propagation in underwater sound channel. Doklady Akad. Nauk SSSR 69, 157, 1949 and also
3. L. Rozenberg. A new phenomena in hydroacoustics, Doklady Akad. Nauk SSSR, 69, 175, 1949.

Due to the weakened international scientific relations after the World War II we have known about Ewing paper (Bull. Geol.

Soc. Am. 57 909, Oct. 1946) with considerable delay. Four main participants of the work (L. Brekhovskikh - head of the work, L. Rozenberg, B. Karlov, N. Sigachev) were awarded by the State prize of the USSR of 1950 ("Pravda" March, 1951).

I were not shure that my letter wili not miss you in Australia because the mail is very slow. That is why I am sending this letter to La Jolla.

Sincerely yours,

y

academician L.M. Brekhovskikh



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INSTITUTE OF GEOPHYSICS AND
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LA JOLLA, CALIFORNIA 92093

12 October 1988

RADM Craig E. Dorman
Commander, Space & Naval Warfare
Systems Command (PD 80)
Department of the Navy
Washington, DC 20363-5100

Dear Craig:

I was pleased to receive your call this afternoon.

To complete our record, I will report briefly that we successfully set six moorings and then had a go at Moving Ship Tomography around the moored area. It was a very exciting month and things went well.

We saw no ships in the area for the entire month, with one exception. A ship passed us on the night of 22 September at a distance of six miles sailing north. She had very powerful headlights which were pointing forward and were on continuously. Our first mate, who was on watch, was able to notice her coming when she was still well below the horizon. Everyone aboard was puzzled about the nature of that vessel.

When we arrived in Reykjavik on the afternoon of 7 October, we learned that two Soviet AGS' were about 40 miles to the northeast of our array. They were identified as the MARS and the DEVIATOR. We were told that these two ships spend a good deal of time in this area, so their presence might have been totally unrelated to our work, but I am sure they can hear us. I wonder whether it was one of those that appeared on the scene before we got into the area.

I am in the process of making some arrangements that will provide monitoring of our sources. I think this can be done without interference with the tasks of the facility. I have requested that in the case of a sudden drop out of one of our sources that we be informed whether any vessels were in the area.

Thanks again for your encouragement and help.

Sincerely yours,

A handwritten signature in cursive script, appearing to read "W. Munk".

Walter H. Munk

WHM/jrd



DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350-2000

IN REPLY REFER TO
9460
Ser 241/8U576903
29 June 1988

From: Chief of Naval Operations
To: Commander Oceanographic System, Atlantic

Subj: IUSS SUPPORT FOR THE GREENLAND SEA EXPERIMENT (GSE)

Encl: (1) Dr. Munk, Professor of Geophysics, Institute of Geophysics and Planetary Physics, Scripps Institute of Oceanography, University of California ltr of 26 May 88
(2) Dr. Munk, Professor of Geophysics, Institute of Geophysics and Planetary Physics, Scripps Institute of Oceanography, University of California ltr of 6 Apr 88

1. Enclosures (1) and (2) provide a review of the experimental investigations being conducted in the Greenland Sea this summer by Dr. Munk, Professor of Geophysics, University of California, and his colleagues. Part of this effort will include the installation of an acoustic transceiver array to conduct tomographic studies.

2. Dr. Munk is seeking assistance and access to Integrated Undersea Surveillance System assets, specifically Naval Facility, Keflavik, in order to monitor these acoustic transceivers.

3. During earlier discussions, agreement was reached that COM-OCEANSYSLANT would support this extremely important effort. Request points of contact and security clearance requirements be provided to Chief of Naval Operations (OP-24).



I. H. COEN, JR.
By direction

Copy to: (w/o encls)
COMSPAWARSYSCOM (PMW 180)
Institute of Geophysics and Planetary
Physics, Scripps Institute of Oceanography,
University of California
(Attention: Dr. Walter H. Munk)



DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, DC 20350-2000

IN REPLY REFER TO

9460
Ser 241/8U576921
29 June 1988

From: Chief of Naval Operations
To: Commander, Space and Naval Warfare Systems Command
(PMW 180)

Subj: IUSS SUPPORT FOR THE GREENLAND SEA EXPERIMENT (GSE)

Encl: (1) Dr. Munk, Professor of Geophysics, Institute of Geophysics and Planetary Physics, Scripps Institute of Oceanography, University of California ltr of 26 May 88
(2) Dr. Munk, Professor of Geophysics, Institute of Geophysics and Planetary Physics, Scripps Institute of Oceanography, University of California ltr of 6 Apr 88

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2. Request enclosures (1) and (2) be reviewed to determine what associated technical issues, if any, would result in a significant degradation in Integrated Undersea Surveillance System (IUSS) performance.

3. Dr. Munk is seeking assistance and access for his associates to the AT&T Technology Center in Greensboro, North Carolina, in order to discuss the technical issues associated with equipment installations at IUSS activities. Request points of contact and security clearance requirements be provided to Chief of Naval Operations (OP-24).



I. H. COEN, JR.
By direction

Copy to: (w/o encls)
COMOCEANSYSLANT
Institute of Geophysics and Planetary
Physics, Scripps Institute of Oceanography,
University of California
(Attention: Dr. Walter H. Munk)

file



INSTITUTE OF GEOPHYSICS AND
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LA JOLLA, CALIFORNIA 92093

27 May 1988

RADM Craig E. Dorman
Commander, Space & Naval Warfare
Systems Command (PD 80)
Department of the Navy
Washington, DC 20363-5100

Dear Craig:

I will continue to use this correspondence to keep you informed of any new info on Soviet Tomography efforts.

The following senior USSR scientists were visiting Scripps Seismologists, and came to see me on May 16:

Academician Anatoly S. Alexeev (and Mrs. Alexeev)
Director, Computing Center
USSR Academy of Sciences, Siberian Division, Novosibirsk

Prof. A. V. Nikolaev
Chief, Experimental Geophysics Department
Institute of Physics of the Earth
USSR Academy of Sciences, Moscow

Dr. Viacheslav K. Gusiakov
Chief, Tsunami Laboratory
Computing Center
USSR Academy of Sciences, Siberian Division, Novosibirsk

Nikolaev told me that he is chairman of a committee on the application of tomography in a number of fields of science, including seismology and oceanography. I tried to get more precise info, but no luck. My impression was that they are very active.

I am enclosing a copy of my letter to Capt. Coen (following up on our meeting two weeks ago) making specific requests in connection with our Greenland Sea Experiment. We are leaving Bergen on 6 September. I am aware of some intense acoustic activity just preceding our tomography experiment, same area, similar equipment, similar acoustic codes. I have wondered whether our Soviet friends will believe me that ours is an independent scientific enterprise.

I have just returned from a brief equipment cruise with Peter Worcester and Bob Spindel. The purpose was to test some of the equipment to be used in the Moving Ship Tomography this fall. At the moment there are no insurmountable problems.

Sincerely yours,

Walter H. Munk
Walter H. Munk *W.H.M.*

WHM/jrd

Enc. bcc: R. Spindel, P. Worcester



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LA JOLLA, CALIFORNIA 92093

26 May 1988

Captain Ira Hearst Coen, Jr.
Chief of Naval Operations, OP-24
Navy Department Room 5D580, Pentagon
Washington, D.C. 20350-2000

Dear Captain Coen:

Thank you for the opportunity for going over our plans for the Greenland Sea Experiment (GSE). Our updated schedule and acoustic codes are attached. We are sailing from Bergen on 6 September on the Woods Hole vessel KNORR, setting six moorings, then performing a moving ship tomography test, and finally pulling into Reykjavik on 6 October.

We request authorization for the following visits:

1. ATT Technology Gilford Center in Greensboro, N.C. as soon as possible by BIRDSALL and METZGER.
2. Visits of the Keflavík facility during the period 6 to 17 October 1988 by BIRDSALL, METZGER, MUNK and WORCESTER.
3. Possible return visit by the same people in May or June 1989 (prior to the recovery cruise).

The purpose of the above visits is to determine the optimum procedure for monitoring the GSE transmissions with the available resources. Thus we require:

- (i) information on location, orientation and internal geometry.
- (ii) We need to determine the best manner in which to connect our signal processing hardware to the selected resources. Connector types, and pin assignments need to be determined. Our signal processing equipment is relatively compact and will be in place for only a few days. Electrical connection will be made using isolation amplifiers. These amplifiers have been used at a number of similar locations and have proven effective in isolating our signal processing electronics from the signal source electronics.

The connector type and pin assignments need to be determined as soon as possible in order to be able to allow us time to procure parts and construct the required connecting cables, hence the request for visit to ATT center.

Captain I. H. Coen, Jr.
26 May 1988
Page Two

(iii) Visit the site in the period 6 through 17 October 1988 to make the desired measurements and to brief station personnel on the GSE program. At this time we require to have on site precise information about the location, orientation, and internal geometry of the selected resources. We will also require access to the display area. Electrical connection will be made to the signal source electronics with the assistance of site personnel. Measurements will be made over a several day period. All data will be processed in a manner such that the results will be unclassified. Operation will be on a non-interfering basis.

(iv) The feasibility of ongoing monitoring of the GSE transmissions will be determined. If this proves possible, a monitoring schedule will be set up, again on a non-interfering basis.

(v) It may be necessary to return to the site in May or June 1989 and make additional measurements. We will require access to the same information and resources as used in October 1988.

We repeat that all operations will be on a non-interfering basis, and that we shall exercise great care to meet all classification requirements. You are aware that some of us have performed equivalent tasks on previous occasions.

Can you identify a contact person and information on where to send clearances?

Sincerely yours,



Walter H. Munk

WHM/jrd

cc: T. Birdsall
Adm. C. Dorman
K. Metzger
R. Spindel
P. Worcester



INSTITUTE OF GEOPHYSICS AND
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LA JOLLA, CALIFORNIA 92093

17 November 1987

Admiral Craig E. Dorman
Commander, Space & Naval Warfare
Systems Command (PD 80)
Department of the Navy
Washington, DC 20363-5100

Dear Craig:

Judy and I have just returned from Moscow. I would like to use this correspondence to keep you informed, and also for the record.

We arrived in Moscow, Tuesday evening, 3 November, and were met by KAMENKOVICH (a physical oceanographer we first met 24 years ago) and a long black limousine, which remained at our disposal for the entire stay. We were booked at the Hotel of the USSR Academy on Oktyabrskay, just like 20 years ago, but even more shabby.

They had scheduled my talk for next morning at the Institute of Oceanology. It lasted from 10 am to 12:15(!). About 175 people came, many from other laboratories, including KRAVTSOV who is head of Acoustics of the General Physics Institute. BREKHOVSKIKH and KAMENKOVICH translated. I asked to be interrupted for questions, and got plenty. They were good questions. Afterwards Brekhovskikh took six of us to lunch.

As least one thing is now clear: the two vessels we heard about in China are well underway, they are being built in Finland for the exclusive use of the Division of Acoustics of the Institute of Oceanology (not the Acoustics Institute). Brekhovskikh heads this division reporting to the Director of the Institute of Oceanology. In fact, as the only Academician (and besides a member of the Academy Presidium) he calls the shots. The two ships are to be delivered in 1988 and 1989, respectively. The theme is (Soviet) state-of-the-art computing capacity aboard the two vessels.

Skipping ahead, next day Judith and I spent 1 1/2 hours with Brekhovskikh alone in his office. I went over our plans for the Greenland Sea Experiment, September 1988 to September 1989, Brekhovskikh mentioned that the Acoustic Institute (not Brekhovskikh's division) will do an experiment in the Greenland Sea in 1988, but he did not elaborate. As far as Brekhovskikh's division is concerned, their new two ships would be available in August or September 1989. I asked whether they could do some hydrographic sections (our experiment is presently short on this vital component). Brekhovskikh said no, but he would be interested in a possible participation in the acoustic work, preferably any aspect having to do with moving ship tomography inasmuch as he had some experience with precise position keeping of transducers using high frequency acoustics. I inquired whether Brekhovskikh's laboratory had any capability of acoustically tracking deep drifters such as RAFOS or SOFAR floats (another desirable component of our experiment for which there is presently no support). Brekhovskikh said there was no such capability.

Admiral Craig Dorman
17 November 1987
Page Two

Somewhere along this time I brought up the principal purpose of my trip to Moscow. I said, "My partners and I are concerned that coded acoustic signals at intermittent intervals in a strategic ocean area might evoke a response to investigate, and (as he could see) any loss of a mooring would seriously deteriorate the tomographic experiment." He knew exactly what I meant. His answer was something like this: any discussion (as we are having now) and possible collaboration is the best way to insure non-interference, but that, of course, he could not guarantee non-interference since, "I (Brekhovskikh) cannot tell the Navy what to do." In any event, the message has gotten across; whether it will do some good we will not know until next year and we may never know.

Any possible collaboration was left to future consideration. Brekhovskikh told us that Frank Press was coming to Moscow on 5 December to discuss cooperative programs. Brekhovskikh is going to the IAPSO Meeting in Acapulco on 23-31 August 1988 and might come to San Diego for a few days following, if invited, to discuss a possible cooperation. He made the situation very clear: he will have two ships, any tomographic work will have to be "as equal partners" and to compete "with other challenging problems", that he is not interested in "service work like CTD surveys", and that he was particularly interested in tomographic measurements from a moving ship, but has no equipment to do this. He would be glad for us to build it and give it to them to use.

I replied that we were in no position to do so; that we have neither the money, nor the time, nor the people to do anything but get ready ourselves.* So as of now there is no collaborative effort in view. If something comes up, we shall discuss it with you and our sponsors.

Finally, with regard to any USSR capability or experience in tomography, Brekhovskikh told about some work he called "sediment tomography": 10-50 Hz self-noise by a moving ship is recorded on a fixed bottom hydrophone and displayed in f, t -space, and then inverted to give information on the acoustic properties of the sea bed down to 1 km. And KRAVTSOV (head of the Acoustic Institute) said they were doing work on shallow water tomography**. That is all I heard. Yet there is no question that Brekhovskikh and Kravtsov fully understood what ocean acoustic tomography is all about. If they are doing some, they carefully avoided talking about it.

I have made some notes (which I can send you if you wish) on the recent succession to the Directorship of the Institute of Oceanology. There have been only three Directors: Kort, Monin and Yastrebov, and we saw them all.

Sincerely yours,



Walter H. Munk

WHM/jrd

**Enclosed

bcc: P. Worcester, E. Frieman, M. Moss

*For your information, we plan to make an engineering test with a moving ship receiver in September 1988 after having set the moorings, and a further test in August 1989 before pulling up the moorings.



INSTITUTE OF GEOPHYSICS AND
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LA JOLLA, CALIFORNIA 92093

file

13 November 1987
Enroute Amsterdam-New York

Academician Leonid Brekhovskikh
Department of Oceanology
Physics of Atmosphere & Geography
Academy of Sciences of the U.S.S.R.
14 Leninsky Prospekt
Moscow V-71
U.S.S.R.

Dear Leonid:

Here is the manuscript (to be published) by Howe and Cornuelle on the range-dependent information from a single source-receiver pair.

While in Hamburg, I received a telex that we now have available the Woods Hole ship KNORR for the month of September 1988. This means that the installation in the Greenland Sea can start in the very early days of September. Presumably, all participants will assemble in Norway by 31 August 1988. The moorings will be recovered in August 1989, but there are no firm plans for the recovery.

We invite you to visit us in La Jolla prior to your attendance at the Acapulco meeting 23-31 August 1988. Judith and I invite you to be our guest during this visit.

Our four days in Germany, were pleasant and very stimulating. I had the opportunity to review the Greenland Sea Project with Gotthill Hempel at Bremerhaven. Things are on course, though we are significantly short on hydrographic sections. The efforts of Klaus Hasselmann and his associates in Hamburg are noteworthy. Their effort in computer modeling of the global climate is yielding some remarkable results.

I wish to thank you for the opportunity of visiting Russia after so many years. I had hoped that our five day visit would provide also the opportunity for some relaxed discussion of your work and of your views of the future directions of ocean acoustics. Perhaps there will be such an opportunity at a future time.

Judith sends her regards.

Sincerely yours,

Walter H. Munk

WHM/jrd

Enclosure

bcc: C. Dorman, E. Frieman, M. Moss, P. Worcester