

Bulletin No. 8 / May 1971

1971 PILOT-STUDY NARRATIVES

8



AIDJEX BULLETIN

ARCTIC
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AIDJEX BULLETIN No. 8
May 1971
1971 Pilot Study Narratives

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from Alma Johnson

May 12, 1971

CORRECTIONS, AIDJEX BULLETIN No. 8

Because of the rush to get out Bulletin 8, we dispensed with the services of a proofreader--and it shows. Some of the grosser errors should be corrected as follows:

- p. 1, 1st para., 9th line: omit are at end of line.
- p. 9, 11: NASA-Ames Expedition Manager's name is Earl Petersen.
- p. 10, 2nd line from bottom: "...a double-cross pattern be flown..."
- p. 13, 4th line from bottom: "...then a sharp drop..."
- p. 14, under March 15: the name of Dr. R. Roger Evans should be inserted.
- p. 31, 2nd para., last sentence: "...so heat flux meters were placed..."
- p. 34, 2nd para., 2nd line: "...I received word..."

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May 1971

1971 PILOT STUDY NARRATIVES

Arctic Ice Dynamics Joint Experiment
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FOREWORD

Coordinated AIDJEX pilot studies were conducted during March and April, 1971, on the Beaufort Sea. The questions to be investigated, experiment designs, and operating plans were described in Bulletins 4 and 5 prior to the field studies.

This issue, Bulletin 8, contains brief narratives describing how the activities were conducted. Assessment of results and the design of further pilot studies will be discussed at a general AIDJEX coordination meeting in Seattle in mid-June and will be subsequently reported in the Bulletin.

Bulletin 7, "Arctic Data Buoy and Positioning Systems," is now being prepared; it will appear within the next two weeks.

THE CRREL-USGS PROGRAM AT CAMP 200: A POST-OPERATIONS SUMMARY

by

W. F. Weeks and W. J. Campbell

Introduction

The most intensive airborne remote sensing and ground truth investigations ever made of sea ice took place during the 1971 AIDJEX pilot expedition to the Beaufort Sea. Multiple missions over and around the AIDJEX site at 74°N, 131°W were performed by three remote-sensing aircraft: the NASA Convair 990, the U.S. Coast Guard Hercules, and the Navy "Birdseye" Constellation. The ground truth team succeeded in establishing a tellurometer deformation triangle and occupying it during all but two of the aircraft overflights. For the first time the following kinds of data were obtained: (1) sequential synoptic imagery of a given area of sea ice; (2) mesoscale deformations of sea ice; (3) microwave emissivities of sea ice. In short, we believe that this remote sensing and ground truth experiment was a success.

Field Experiment

The following is a chronological narrative of the work on the ice. For a complementary description of what went on in the NASA Convair 990 aircraft, read the report of Ann D. Moen, U.S.G.S., given elsewhere in this Bulletin.

After leaving Hanover and Tacoma on March 3, the members of the CRREL-USGS field party met in Edmonton and proceeded on to Inuvik and Tuktoyaktuk on the 4th. The Twin Otter was loaded with project equipment (roughly 1500 pounds) that evening and left the next morning for Camp 200, with the project personnel following by Single Otter in the afternoon. The weather during the flight was beautiful, allowing us to take a large number of photographs of the ridging. Of particular interest were several clearly defined double ridges and many leads in the marginal zone between

the shorefast ice and the pack ice. The only rubble fields we noted were in the vicinity of the pack-ice fast ice boundary.

We arrived at Camp 200 at 1800. As we approached the camp prior to landing, we could see that, although the camp was located on a large multiyear floe, a number of cracks cut across the floe. The runway itself was situated on first-year ice (2 m thick) that was attached to part of the thicker multiyear floe. On the 6th, we completed our unpacking, checked the tellurometers and our procedures, set up the base camp tellurometer tent on top of the messhall, and made an on-foot reconnaissance of the pressure ridges in the vicinity of the camp. We were able to take several photographs of the lateral profiles of well-developed ridges. It was quite cold, the air temperature about -40°C and the 1 cm ice temperature (no snow) -36°C .

The next day we examined multiyear ridges and hummocks near camp and selected a representative location for detailed study. We decided to focus our studies on multiyear ridges because they were readily available and because, although they have never been studied, they are usually thought to be the most formidable sea-ice obstacle encountered by surface shipping and off-shore structures. We completed a profile of snow- and ice-surface elevations over the ridge (sail height roughly 3 m) and made a one-sonar profile of the side of the ridge (keel depth roughly 14 m). The width of the keel was appreciably larger than the width of the sail, roughly agreeing with the Wittmann-Makarov model. While we were working on the sonar, the wind started to increase and the working conditions became very difficult. This poor weather continued through the next day (March 8) and delayed the establishment of the tellurometer sites.

Although poor visibility continued on the 9th, we established tellurometer site Alpha on a horizontal (5 m diameter, 2 m thick) ice block located in a long, apparently inactive, pressure ridge. We were able to get a good signal from the base camp tellurometer. After setting up our tent at the site, we had to return to base camp because the helicopter had a faulty seal in the hydraulic system.

The first NASA overflight occurred at 1700. During the overflight the lateral visibility was roughly 5 miles. Because of the visibility and

the fact that we had as yet been unable to complete the strain triangle, the aircraft was instructed to fly a four-legged star centered over the base camp. One of the legs of the star was oriented so that the aircraft would fly the line between Alpha and the base camp. During all overflights the following were measured at the tellurometer site at Camp 200: air temperature, wind speed and direction, visibility, ceiling, surface snow temperature, and barometric pressure. The below-surface temperatures and salinities did not vary appreciably, so between flights temperature and salinity profiles were measured in the snow and ice at various sites.

Radio communications with the aircraft via the SSB (single side band) transceiver supplied by the Canadians were generally excellent. All remote-sensing aircraft were able to pick up and home in on the radio beacon. The inertial guidance system in the Convair 990 was of great help to the Camp 200 crew, in that fixes of the camp given from the aircraft allowed the Decca navigational gear, which has an unfortunate propensity for making lane jumps, to be calibrated occasionally. During the afternoon we continued sonar studies of the multiyear ridge. The keel on one side of the ridge appeared to be a nearly vertical wall of solid ice.

On March 10, Site Alpha was reoccupied and Site Beta was established. We attempted to take tellurometer readings all day with very little luck. Even after contact was finally made between the base camp and the Alpha and Beta sites, the readings were contradictory and signals were weak. Contact could not be made between Alpha and Beta even though two different tellurometer locations were used. It was a trying day. A number of overlapping profile photographs were completed of a lateral view of the pressure ridge on which Alpha was located. In the evening we checked the tellurometers over a known distance near camp. They gave satisfactory readings.

March 11 was a beautiful day--calm, clear, air temperature -20°C . We moved Site Beta closer to the base camp, and a good lock was immediately made between Alpha and Beta. The readings between these stations (distance about 8,350 m) were extremely interesting; they indicated a dilation of 102 m (a 1.2% strain) in 6 hours. Thirty-three readings were made during this time period. Once the dilation started, the dilation rate was as high as 0.5 m/sec. Although both Alpha and Beta were able to contact base camp,

the initial tellurometer readings were ambiguous. After the base camp tellurometer was changed, reasonable readings were obtained with Alpha. The readings between base camp and Beta, however, continued to be contradictory.

The second NASA mission was flown during the afternoon. A complete flight sequence was made, including flights over the strain triangle. The high altitude SLAR and photographic mission over an area of 60 x 83 km with Camp 200 at its center preceded the low-level mission on every flight. The mosaic images from these missions will be invaluable in interpreting the strain data and deformation fields. The visibility during the flight was excellent. Because of the low sun angles, the pressure ridges cast extremely sharp shadows. Examination of these shadows on the aerial photographs should provide the first useful information on the longitudinal profiles of pressure ridges. On the helicopter trip back to camp, we noticed that a large number of leads had opened in the annual ice and that a large crack had split the multiyear floe on which the camp was located. We found on landing that a 30 m lead had formed along a pressure ridge roughly 200 m from our living quarters.

When we returned to the tellurometer sites the following morning (March 12), they were still in good condition although many leads and cracks had formed in the vicinity of Beta. Most of the leads observed the previous evening had now closed, forming new pressure ridges. Because of the earlier difficulties with the base camp tellurometer site, we decided to move it to the top of a pressure ridge roughly one km north of camp. With the good readings we obtained from this new site, it was now possible to close the strain triangle. We concluded that either the antenna system or the electronic gear (such as the Decca) in the camp had been interfering with the tellurometer signal. The lengths of the triangle legs were as follows: Base Camp-Alpha, 10728 m; Base Camp-Beta, 5578 m; Alpha-Beta, 8321 m. The good readings continued until 1500, when the batteries at Beta went dead. The third NASA overflight occurred between 1400 and 1630. Unfortunately during this period the visibility was only fair (5 km, stratus at 500 m).

We continued our study of the multiyear pressure ridge on March 13 and 14. The ice in the upper portion of the ridge was both very cold (-24°C) and fresh. At our coring site the ridge was 12 m thick. The ice was massive, and no voids were noted. This is in distinct contrast to first-year ridges. The sonar equipment was working well.

On March 15 we reoccupied the tellurometer sites. A slight compression of 0.2 to 0.3% had occurred since the 12th. Only very slight distance changes were noted during the day (about 2 m). At Alpha a crack had formed under the corner of the ice block on which the tent was located, and water was beginning to flood the area.

The fourth NASA overflight took place that afternoon. Ice fog decreased the lateral visibility and made it difficult for the aircraft to fly exactly over the strain sites. A break in routine occurred during the overflight, when two polar bears attempted to visit Site Beta. We drove them away with yells (LOUD) and smoke bombs. Paw prints measured 28 cm. The bears should show clearly in the aerial photographs.

On March 16, the overcast and light snow so reduced visibility that the helicopters could not fly. We continued our core sampling of the pressure ridge and collected salinity and temperature data from the unridged portions of the multiyear floe and the first-year ice. The last NASA flight began with poor (2 km) visibility; however, during the flight the visibility rapidly improved, and by evening it was excellent. The aircraft flew three low-level passes centered over the base camp.

The U.S. Coast Guard C-130 also flew its combined SLAR-photographic mission on the afternoon of March 16. Pat Welsh mounted four radar reflectors in a variety of patterns during the NASA and Coast Guard overflights. We hope that sufficient data were collected to obtain some quantitative relation between the size of the reflector and the received signal.

During the next four days (March 17-20) the pressure ridge study continued. We tried to photograph the lower portion of pressure ridges by using an underwater camera mounted on extension rods. Detailed low-level aerial photographs were made of the pressure-ridge site by using a hand-held automatic Hasselblad in the helicopters. In addition, we started a survey of ice-surface elevations and snow and ice thicknesses

on the undeformed portion of the multiyear floe. The sampling pattern was a three-armed star with an arm length of 180 m. Snow and ice surface measurements were made at 1 m intervals, while 30 ice thickness measurements were randomly spaced along the star.

The first "Birdseye" overflight (NAVOCEANO C-121) took place on March 21. When we occupied the tellurometer sites on that day, we found that a lead had formed along the pressure ridge at Site Alpha, the ice block supporting the tent had split, and the tent had become incorporated into the underwater portion of the ridge. Fortunately, we were able to establish a new site on the edge of an ice block roughly 2 m from the initial site. Good closures were obtained on the strain triangle. The Birdseye plane was able to make a very precise triangle over the strain net. However, the quality of the air photography may be affected by the development of a low haze layer during the flights. In the evening and during the next day, we continued work on the sonar profiling, the salinity measurements, and strain data compilation.

The last Birdseye overflight was made on March 23. Visibility was excellent, but it was very cold and windy (-29°C and 20 knots). The tellurometer became so cold at the exposed location on the ridge that we could hardly turn the dials, and the readings were contradictory. We, therefore, moved to a new location (which could be located relative to the previous site) where a tent could be set up and the tellurometer kept warm. The readings indicate a compression of roughly 100 m between the base camp and Alpha, and little change in the lengths of the other two sides of the triangle. Examination of a portion of the aerial photography from this mission indicates very **high** quality imagery.

During the stay at Camp 200, the microwave ellipsometer was used on the sea ice for the first time. The work was begun by Al Edgerton of the Aerojet Corporation; when he had to leave Camp 200 after a week, his colleague Don Williams took over. At first, the apparatus failed when kept at low ambient temperatures for long periods. However, after a few days of trouble shooting the ellipsometer worked well until its power supply burned out on March 21.

A number of interesting experiments were performed using this instrument. Since so little is known of the microwave emissivities of sea

ice, we decided to make the early measurements over multiyear and single-year ice at various places in the vicinity of the camp. At these sites, cores were taken from the ice and temperature and salinity profiles obtained. When sufficient data were collected from multiyear and single-year ice, we decided to sample refrozen melt ponds and very thin sea ice. A "bath tub" hole (1.0 m square and 0.7 m deep) was carefully cut in multiyear sea ice and then filled with fresh salt water. The ellipsometer was then mounted over this hole and the microwave emissivities were measured continuously as the ice formed and filled the hole. Unfortunately, as the ice thickened, the "milk bottle" effect took place and the top surface developed a wave form. We then transported the ellipsometer to a fresh lead approximately 0.5 km west of camp and mounted it over a meter square hole in new sea ice approximately 25 cm thick. The microwave emissivities were measured on the new sea ice forming in the hole. Both Al and Don feel that some significant data were obtained.

On March 24, a new lead formed half way between the old lead and the camp (about 100 m). Between the 24th and the 26th, we completed our work on the ridge; determined a number of additional ice temperatures, salinities, and snow and ice densities; completed the ice thickness determinations; collected 125 samples for chemical analysis to study changes in the ion ratios with ice age; and packed. We left Camp 200 for Tuktoyaktuk at 1245 on March 26. We had been on the ice exactly three weeks.

Conclusion

We feel that our program was extremely successful. Much of this success is the result of the cooperation we received from the other projects operating at Camp 200 and the excellent support provided by the personnel of the Polar Continental Shelf Project. Our preliminary analysis of the strain results indicates values similar to those obtained by Thorndike between more widely spaced stations at a longer time interval, and points out the desirability of measuring the strain array on a more continuous basis. The multiyear ridge that we studied proved to be a most formidable piece of ice (massive, cold, low salinity). It is too early to comment on the rest of our work except to state that we were able to collect the

necessary data. A complete assessment of our project results will be possible only when our ground truth observations are coupled with the results of the NASA, Coast Guard, and NAVOCEANO remote-sensing missions.

This program was planned as a joint CRREL-USGS experiment. However, in our varied activities, we were given a great deal of help by members of other organizations. We wish to specifically thank Wilson Goddard (University of California at Davis), Pat Welsh (U.S. Coast Guard), and Don Williams (Aerojet) for their magnificent efforts in helping us with the trying and uncomfortable job of manning the tellurometer stations.

Of course, the *raison d'être* of our program was to provide ground truth data for the aircraft remote-sensing missions, and we wish we could properly express the sense of awe and excitement and appreciation we felt during every overflight. We could fill a page with praises and still fall short of giving proper thanks. We wish to give special thanks to Ann D. Moen (U.S.G.S.), Earl Petersen (NASA-Ames), Olav Smistad (NASA-Houston), Walter Wittmann (U.S. Navy), Lloyd Breslau (U.S.C.G.), Joseph Fletcher (AIDJEX), and certainly to John W. Sherman III (SPOC), who is responsible more than anyone else for getting us involved in the NASA remote-sensing program.

Project Personnel

<u>CRREL</u>	<u>USGS</u>	<u>USCG</u>	<u>Aerojet General</u>
W. F. Weeks	W. J. Campbell	P. Welsh	A. Edgerton
A. Kovacs			D. Williams
W. D. Hibler			
S. Ackley			

REPORT OF NASA CONVAIR 990 REMOTE-SENSING MISSIONS
OVER AIDJEX SITE, MARCH 9-16, 1971

by

Ann D. Moen
U. S. Geological Survey

The five remote-sensing flights by the NASA-Ames Research Center Convair 990 over the AIDJEX pilot study site provided for 15 arctic scientists a unique look at the Arctic sea ice and a first-hand demonstration of the Convair 990 remote-sensing platform. In addition to these observers (a list of which appears at the end of this report), Joe Fletcher, AIDJEX Coordinator, and Ann Moen, Hydrologist with the U.S. Geological Survey, participated in all flights.

The first overflight of the AIDJEX site had been scheduled for March 8, but computer trouble aboard the aircraft delayed the first flight until March 9. This gave Bill Campbell, Willie Weeks, and the other scientists on the ice an extra day to set up the two auxiliary tellurometer stations, but storms on the ice allowed the men to set up only one station before the first overflight.

The first group of observers arrived at Eielson Air Force Base, near Fairbanks, Alaska, on March 8. The temperature was -44°C . That evening, Mr. Earl Peterson, Expedition Manager, called a meeting of all experimenters and observers who would participate in the overflights. Joe Fletcher reported that the AIDJEX base camp had been established March 1 on a 17 x 17 km floe of old ice. Bill Campbell would be on the radio during the overflights for ice-air communication.

On the morning of March 9, Joe Fletcher was in telephone contact with Tuktoyaktuk, and he reported that the latest AIDJEX camp location was $73^{\circ}15'N$, $130^{\circ}51'W$. We soon discovered that the positions determined by the men on the ice differed by as much as 15-30 km from a more accurate position determined by the inertial navigation system on board the aircraft. On each of the overflights, the 990 flew directly over the AIDJEX base camp, marked its position, and radioed the correct position to the ground party.

Bill Campbell had originally suggested that the aircraft fly a triangle pattern at low altitude (300-1000 m) over the ice stations, climb to 10,000 m to fly a north-south grid of 83 x 83 km to obtain overlapping photographs and radar imagery, then return to low altitude to repeat the triangle pattern. This plan required more time and fuel than was available to the aircraft, partly because the ice camp was farther from land than originally planned. The revised flight plan eliminated the first low-level pattern and shrank the high-altitude pattern to 83 x 60 km. Fuel requirements limited flight time to 6 hours. About 1 1/2 hours were required to fly from Eielson to the AIDJEX site, leaving 3 hours over the site on each of the five flights. Eielson AFB is the closest facility equipped to handle aircraft the size of the Convair 990.

Departure from Eielson was delayed two hours on March 9 by maintenance problems on the ground. Shortly after take-off we were flying over clouds which obscured the ground. Only the pilots and radar operators knew when we had crossed the shoreline. When we were able to see down, we were over the Beaufort Sea; visible were fresh, very large parallel leads, or cracks in the ice, oriented approximately east-west, with the north side displaced relatively to the east. This was the only extensive system of fresh leads we saw on this flight. Other, older, leads were seen, but all were solidly frozen with white ice.

When we reached the AIDJEX site, we flew the high-altitude pattern at 12,000 m as an alternating series of ten north and south runs, each 83 km long. The speed required to keep the aircraft aloft at that altitude dictated a turning radius of almost 17 km, and it took almost as long to turn the 990 at the end of each leg as it did to fly the leg itself. This pattern allowed side-looking radar (SLAR) imagery of the 5000 sq. km area centered on the AIDJEX base camp. The RC-8 camera (which takes 22 x 22 cm photographs) was running, but haze and undercast obscured most of the ground area.

During this high-altitude pattern, the pilots established radio contact with Bill Campbell on the ice. He informed us that only one auxiliary tellurometer station was set up and suggested that, instead of the planned triangle pattern, a double-cross pattern be flown at low altitude, with north-south, east-west, northwest-southeast, and southwest-northeast legs. The

cross pattern, which had the base camp at the center, had to be flown at 300 m, lower than planned, because of the low cloud ceiling. The speed of the aircraft (280 knots) made it impossible to use the RC-8 camera at 300 m. Also, we were two hours behind schedule and the sun angle was very low. This made it easier to see the ice features, but the amount of light was almost too low for photography. The suggested length of each run of the cross pattern was 8 km, which at 280 knots was covered in less than two minutes. All experimenters agreed that this length was too short to properly set up the instruments; and since so much time was consumed turning and aligning the aircraft for each run, Earl Peterson decided to extend the low-altitude runs to at least 17 km on future flights.

All other sensors aboard operated normally except the 19.35 ghz microwave scanning radiometer, which did not work after the first few minutes of the flight.

There were no ground delays for the second flight, on March 11, and we left Eielson at 9:00 a.m. When we were free of clouds over the ice, it was obvious that there were more fresh leads and open water since the March 9th flight. Also, the long, wide leads were oriented at right angles to the leads we had observed on the 9th. One wide lead we observed extended about 70 km east along our pattern and at least that far to the west, and leads of that length were not uncommon.

Only four of the ten runs at 12,000 m were good for the cameras. The side-looking radar sees through clouds and so obtained good imagery regardless of the weather below. During the descent for the low-altitude runs, a northeast-southwest line was flown directly over the main camp for the RC-8 camera. Bill Campbell advised by radio that both auxiliary tellurometer stations were operating and manned. He radioed the bearing of each station from the main camp, and the pilots altered the double-cross pattern to fly directly over each station. The auxiliary stations were easily identified by the red smoke bombs they set off. Each leg of the pattern was 17 km long.

All sensors operated normally except the still inoperative microwave radiometer. Walt Brown of Jet Propulsion Laboratory noticed an interesting pattern on his radar scope. On the low-altitude runs when the

aircraft was very stable and the ice fairly uniform, he saw an unusual double radar reflection which seemed to be from the top and the bottom of the ice. If the double reflection was in fact from both surfaces of the ice, it would be the first time that ice thickness had been measured remotely and would be an extremely valuable tool for further ice study.

The third flight was on March 12. The microwave radiometer still was not working. Clouds obscured the area west of the camp, but photography of the eastern half was good. The side-looking radar obtained full imagery of the 83 x 60 km area. During the descent, Walt Brown reconfigured the radar to better see the double reflection. He took several Polaroid photos of it and will fully analyze the data in his lab after he receives some needed ground truth data. On this flight the low-altitude pattern, flown below 700 m because of low clouds, was the triangle as originally planned. The three legs were short (the auxiliary stations were 12 km and 7 km from the main camp), but they were the longest that conditions on the ice would allow. After completing the triangle over each of the ice stations, the aircraft headed toward Eielson, flying much of the distance at an altitude of less than 1700 m. There was good RC-8 coverage. Radiometer operators reported that cloud temperatures were about -15°C and ice temperatures averaged -21°C .

The Coast Guard Hercules aircraft arrived at Eielson late on the 12th. They had tried to fly over the AIDJEX, but they did not have the correct location and could not find the site. On the 13th, the Coast Guard pilot became ill, and the flight was aborted after two hours.

The fourth Convair 990 flight was on March 15. The microwave radiometer had been repaired in Los Angeles over the weekend and operated normally on this flight and on the last. The instrument indicated that multiyear ice is approximately 20°C colder than first-year ice. This was the best day so far for the RC-8 at 12,000 m. On the descent the pilots leveled out at 3,000 m and flew a 17 km leg over the camp. At this altitude the laser profilometer worked intermittently. The low-altitude pattern was flown at 1,200 m, high enough for the RC-8 to obtain good photographs and low enough for the laser to obtain good data. The highest ridges recorded by the laser profiler were 2 to 3 meters.

The Coast Guard aircraft had arrived at the site ahead of us, causing the tellurometer stations, which were not in communication with the base camp and not expecting overflights by two aircraft, to set off the smoke bombs intended for us. Consequently, when we descended our pilots could not locate the two auxiliary sites. The low-altitude triangle was replaced by the cross pattern. The sky was clear during the return to Eielson, so the pilots kept the aircraft at 1,700 m most of the way to the shoreline. This was the first flight with sky conditions good enough for the RC-8 to obtain photographs of the shoreline and tundra.

During the last flight, on March 16, the RC-8 was able to obtain photographs of the tundra and shoreline on the way to the AIDJEX site. While we flew the high-altitude pattern, for which there was complete under-cast, the Coast Guard imaged the area near the ice stations from an intermediate altitude. The microwave radiometers operating at 10 ghz or high seemed to see through the clouds, because they periodically registered drops or rises in temperature of 20C°.

Our low pattern had to be at 600 m because of the clouds, and the clouds shut out much of the sunlight for photography. The pilots corrected the heading toward Eielson, climbed to 1700 m and continued at that altitude until forced to climb over the Brooks Range. For the hour required to reach land, the skies were clear and all sensors operated continuously. Mike Fleming of NOAA was in the belly of the aircraft calling out ice features and structures, which were recorded in the onboard computer for future reference.

As we approached the shoreline, there was a marked change in the appearance of the ice. There was an area several hundred meters wide that seemed to be the result of shearing. The side of this area toward land was very smooth, solid, white ice which contrasted sharply with the rough, broken, gray and white ice on the ocean side. It was difficult to see where the shore ice stopped and the shore began. The laser profiler recorded a gentle rise, than a sharp drop which was presumably the upturned edge of shore ice which had been pushed onto the shore and broken off. The North American Rockwell radiometer recorded an 8C° drop in temperature at this break.

Everyone on board the Convair 990 and the scientists on the ice agreed that the series of five overflights had been a great success. This is the first time that sequential, synoptic imagery of Arctic sea ice had been obtained, and the extensive ground truth measurements will make the data that much more valuable. Some of the RC-8 photographs have been developed and are of excellent quality. The data and experience gained from this mission will be a great help to the detailed study of Arctic sea ice and to the planning of the full-scale AIDJEX expedition in 1973.

Scientific Observers on NASA-Ames Convair 990 Remote-Sensing Flights

March 9

Dr. Frank Danes
University of Puget Sound

Dr. Paul Bock
University of Connecticut

Dr. Kirk Bryan
ESSA Geophysical Fluid
Dynamics Laboratory

March 11

Dr. Norbert Untersteiner
University of Washington

Dr. Gary Maykut
University of Washington

Dr. Gunter Weller
University of Alaska

March 12

Dr. Stanley Murphy
University of Washington

Mr. Roy Marsh
Canadian Telecommunications

Dr. Don Archibald
Canadian Meteorological Services

March 15

Dr. Lawrence Larson
University of Washington

Dr. William Criminale
University of Washington

Dr.
University of Washington

March 16

Dr. Gerd Wendler
University of Alaska

Dr. K. O. L. F. Jayaweera
University of Alaska

Dr. Don Grybeck
University of Alaska

LAMONT OCEAN CURRENT PROGRAM

by

Kenneth Hunkins

The primary purpose of this program was to continue the study of the dynamics of the upper ocean. Current observations were made at different levels during the occupation of Camp 200. Celestial navigation provided a reference azimuth for the current direction. To supplement these observations, more detailed current profiles were taken occasionally. Also, temperature profiles obtained with a thermistor and bridge were used to describe water structure and its changes in the upper layers. The field party, consisting of Kenneth Hunkins and Allan Gill, remained at Camp 200 until April 8.

Gill arrived at Barrow in late February from T-3, where he had been working during the winter. At Barrow, he assisted Dick Tripp with packing equipment before leaving for Tuktoyaktuk with the buildings on March 3. From Tuk, he proceeded to Camp 200 with the Eskimo carpenter crew to oversee camp construction. Hunkins arrived at Camp 200 on March 11 sans equipment. Customs difficulties at Whitehorse had held up the entire shipment, and it did not arrive at the camp until March 17 and 18. In the meantime, there was more than ample opportunity to excavate the two hydro wells they would need and to prepare the buildings.

The Lamont party used two buildings, one as a lab and the other as a combined lab and sleeping hut. Each building was set over a hydro hole cut through 5 or 6 feet of ice. The ice on this old polar floe was quite irregular, with 16-foot thicknesses found only 30 feet from the buildings. Trap doors in the floor gave access to the holes. Timbers placed across the roofs and fastened by eye bolts supported the current meter arrays. A small hole was cut through each roof for manipulating the pipes in and out of the well.

In each hut, an inverted mast was installed for the current meters. Savonius-rotor current meters were set on one mast at levels of 5 m, 7 m, 11 m, and 19 m, and on the other mast at levels of 32 m and 75 m. The

masts were of 1 1/4" aluminum pipe in 10-foot lengths. The zero reference directions of the meters were carefully aligned with each other, and each mast was then oriented to true north by celestial fix and theodolite. This system eliminated the use of a magnetic compass for reference, which can be unreliable in high latitudes. The corrections to the aligned directions were small: 5 m, +8°; 7 m, +1°; 11 m, -1°; 19 m, 0°; 32 m, 0°; 75 m, 0°. Speed and direction outputs were all brought to the surface and into the lab by electrical cables. The signals were processed and converted to analog voltages. Direct visual readout was provided by a panel of meters showing speed and direction continuously at each of the levels. The complete current meter array was in operation on March 21, when hourly logging of currents began.

The multipoint recorder for continuous recording finally began operating on March 28, after an essential gear wheel, which was missing, had been rushed from Lamont. Current speed and direction were then recorded from each level at 30-second intervals until the instruments were dismantled on April 7 at the conclusion of the field work.

Celestial navigation by Allan Gill commenced on March 18. Daily fixes by sun and star were taken thereafter until April 7 except for March 21, when visibility prevented any sights being taken. A Kern DKM-1 theodolite was employed for angular measurement and a Times electronic chronometer set to WWV for time. The "cocked hat" formed by the three or more lines of position was less than 0.1 nautical mile in dimension in almost all cases, and it is likely that the positions are accurate to better than that figure in most cases. The azimuth of an arbitrary reference line on the floe was determined with each sight. Thus the azimuth was highly over-determined, with at least three azimuth determinations for each fix. The azimuth determinations were made to an accuracy of 0.1° and were internally consistent to that accuracy for any fix. The arbitrary azimuth line chosen extended from the theodolite position at the center of the camp compound to the northernmost of the Arctic Submarine Lab micrometeorological masts. A list of the astronomically determined fixes and azimuths follows. Note that times are Greenwich Mean Time. Seven hours must be subtracted from GMT to convert it to the local time used at Camp 200.

Celestial Navigation, Camp 200, 1971.

<u>Date</u>	<u>Time</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Azimuth</u>
18 March	2055z	74°04.5'N	131°23'W	114.6°
19 "	1918z	74°04.3'N	131°24'W	114.7°
20 "	2042z	74°02.8'N	131°26'W	114.8°
22 "	1909z	73°55.9'N	131°23'W	115.1°
23 "	1915z	73°51.1'N	131°30'W	115.1°
24 "	2051z	73°48.3'N	131°22.5'W	115.4°
25 "	1142z	73°46.0'N	131°15'W	
25 "	2038z	73°46.7'N	131°18'W	112.9°
26 "	1933z	73°46.7'N	131°20'W	112.9°
27 "	1143z	73°46.7'N	131°21'W	112.9°
27 "	1955z	73°46.9'N	131°18.5'W	113.0°
28 "	1150z	73°46.4'N	131°21'W	
28 "	1951z	73°46.3'N	131°19'W	114.4°
29 "	1935z	73°45.4'N	131°18'W	114.8°
30 "	0550z	73°44.4 N	131°17'W	114.9°
30 "	1924z	73°44.9'N	131°16'W	114.9°
31 "	0558z	73°44.5'N	131°17'W	114.7°
31 "	1919z	73°44.4'N	131°15'W	114.7°
1 April	0613z	73°44.5'N	131°15'W	114.9°
1 "	1855z	73°45.0'N	131°08'W	115.2°
2 "	0703z	73°45.0'N	131°05'W	114.9°
2 "	1840z	73°44.9'N	131°01'W	115.0°
3 "	1900z	73°44.9'N	131°01'W	115.0°
4 "	1843z	73°45.1'N	131°05'W	114.9°
5	1845z	73°44.8'N	131°06'W	115.0°
6	1843z	73°44.5'N	131°06'W	114.9°
7	1813z	73°44.3'N	131°08'W	115.0°

The station drifted southward almost 20 nautical miles between March 18 and March 25. Thereafter, it drifted very slowly despite some strong winds, making only a few miles of easting on April 1. The azimuth changed through a total range of $2\ 1/2^\circ$. The most sudden changes in azimuth occurred on March 24, coinciding closely with the opening of a lead very near the camp.

Current profiles from the surface to a depth of 100 m were made at 10 m intervals on eleven occasions. The meter was lowered by hand on a cable; the reference was magnetic north. The directions are not considered reliable, but the speeds apparently are. An entire profile usually took one hour, with measurements taken on both descent and ascent to give a measure of the variability of the velocity field.

Temperatures were measured twice daily between March 28 and April 7 at 10 m intervals to 100 m depth. More detailed profiling was generally carried out between 50 and 80 m to better delineate the Pacific Water Mass. The thermistor had previously been calibrated at the Lamont calibration facility. A four-decade Wheatstone bridge was powered by a $1\ 1/2$ V. battery, and null was determined with an electronic galvanometer with 30 navovolts full scale to reduce self-heating effects. Variations of several tenths of a degree Celsius were noted in the core of the Pacific Water over the course of a day or two.

Magnetic declination was measured with a Brunton compass. The following values were obtained:

<u>Hour</u>	<u>Date</u>	<u>Magnetic Declination</u>
1200	April 3	49°E
1000	April 4	53°E
1200	April 5	48°E
1200	April 6	48°E

The speed at 32 m and the direction output at 75 m do not seem to have functioned properly. The other instruments appear to have operated well.

There are two interesting aspects of the current data. The small storm on April 1, when winds reached 20 knots, is probably the most important period for determining water stress. The height of the storm lasted only from about noon to 2100. It may be that stress during this time will be assessable both from the frictional and from the Ekman layer, providing a needed cross check.

The other interesting aspect is the current flow during periods when the ice was essentially stationary. On two occasions, March 25 and April 6, the ice had been stopped, evidently by internal ice pressure, even though north winds continued to blow. During both of these periods, current flow continued to the south with the current maximum at shallow depth, just beneath the ice. This additional water stress in the same direction as the wind on the stationary ice was not predicted; it may be one of the more interesting discoveries of the pilot study.

We are dependent on nature for setting up the experiment in oceanographic experiments of this kind. The variables cannot be manipulated as in a laboratory. Patience is required to set up the instruments and wait for an interesting situation to develop. Development will be on the synoptic scale of meteorology: days to weeks. We were fortunate to have some varied conditions this year, but a longer station occupation would be desirable next year to increase the probability of encountering interesting case histories.

UNIVERSITY OF WASHINGTON OCEANOGRAPHIC STUDIES

by

L. K. Coachman and J. Dungan Smith

The 1971 University of Washington oceanographic study undertook (1) measurement of the time- and space-dependent velocity and Reynolds stress fields in the boundary layer under the ice, with typical topography, using the mechanical current-meter systems of Klink and Smith; (2) current measurements to relate the deeper flows to those in the boundary layer and to determine the horizontal coherence of the flows at various scales up to about 30 miles; (3) hydrographic measurements to determine the approach to geostrophy of the Arctic Ocean flow; and (4) accurate positioning of the stations by Decca-Lambda to permit strain calculations.

Eight prefabricated, insulated, plywood buildings were provided by the Naval Arctic Research Laboratory. PCSP provided longhouse tents and igloo tents for various utility purposes (Fig. 1). One large hole was opened at the main camp for diving and entry of the masts for the boundary layer studies. An unmanned current-meter hole was opened five miles southwest of Camp 200. Two holes, for current meters and hydrographic measurements, were opened at each of three locations: at Camp 200; at a site 20 miles west of the camp; and at a site 10 miles south of the camp. After selecting the sites, holes were opened by charges of CIL 60% Geogel placed in a circle of bore holes. At the Camp 200 site, a hut was constructed over the hydrographic hole; for the outer locations, the huts were assembled at the camp and transported and lowered over the hydrographic holes by helicopter.

Interior Flow Field Measurements (Fig. 2)

At each manned hydrographic location, a wooden rack was installed to hold ten Nansen bottles, each equipped with two protected and three unprotected reversing thermometers. A 3-h.p. winch with tripod raised and lowered the Nansen bottles on 3/32" hydrographic cable. Once into the

hut, the water samples were stored in 8-oz. plastic bottles with plastic-insert caps, then frozen.

Simultaneous casts for temperature and salinity were obtained at the three hydrographic locations four times per day [at 0700, 1200, 1700, and 2200 (+7)] from March 18 through March 31 at depths of 30 m, 60 m, 90 m, 120 m, 150 m, 180 m, 220 m, 260 m, 350 m, and 500 m. To provide a more detailed structure of the vertical column, extra casts with bottles at 5-m intervals were obtained at each of the stations.

The temperature values are now being corrected, and the salinity samples which were frozen in the plastic bottles are being analyzed at the Department of Oceanography. Duplicate salinity samples were drawn from each sample depth, and one set of duplicate samples (from the Camp 200 location) were maintained unfrozen as a check on the freezing procedure.

The uncorrected temperatures showed considerable variation at the time scale measured, particularly in the upper levels. Water of Bering Sea origin, which typically causes a slight temperature maximum (about -1°C) centered at approximately 75 m in the otherwise quite homogeneous and cold layer (about -1.5°C) was noticeably present. During one day, temperatures this warm were observed at 30 m depth.

Current meters were deployed at the three hydrographic sites and at the unmanned current-meter hole. Eight Norwegian (Aanderaa) current meters had been ordered for the project, but they could not be delivered in time. Consequently, we renovated six old Braincon Mod. 316 histogram meters and borrowed three Aanderaa instruments from Dr. Sig Wiggin, Canadian Hydrographic Survey, Victoria, B.C. The Aanderaa meters were placed in the current-meter holes at a depth of 50 m at the manned locations; and three Braincon meters were placed at a depth of 10 m. The other three Braincons were placed at the unmanned site at depths of 150 m, 300 m, and 400 m. All meters were in place one or two days before the series of hydrographic stations began, and were removed one or two days after the series ended. The film records (Braincon) and magnetic tapes (Aanderaa) are now being processed.

Judging from the amount of magnetic tape processed and the number of film frames counted, eight of the nine meters apparently functioned for

full time of their deployment. The Braincon located at the unmanned site at 400 m depth had a slow leak in the O-ring joint at the bottom of the pressure case. We found several inches of water in the meter when it was disassembled. However, the camera (located at the top of the instrument) was dry, and the counter indicated about two-thirds of the number of frames expected for a 15-day run had been advanced.

Navigation

The Decca-Lambda navigation system of PCSP recorded frequent fixes of the Camp 200 location. The positions of the outer hydrographic sites were recorded at least once daily, and that of the unmanned current-meter hole less frequently from the Decca-Lambda equipment in the helicopters. In addition, the pilots noted bearings and distances to the stations from Camp 200.

Boundary Layer Studies

The large hole which we opened at Camp 200 was used for lowering the two instrument masts into the water, for raising and lowering pieces of oceanographic gear, and for diving. We chose a smooth low area (probably a summer lake) for its site, because we felt that the ice would be thinner there. This proved to be the case. In fact, we found it was easy to locate thin areas, because the surface topography of the ice sheet was quite highly correlated with its thickness. Regions of high elevations were regions of thick ice, and regions of low elevation were related to areas of thin ice. This differed from the situation found at the ice camp in 1970, where there was very little surface topography and what there was did not correlate with the under-ice morphology.

The hole was allowed to freeze over between uses. It was reopened by pick and manure spreader at least twice a day.

The diving hut was big enough to also serve as a bunk house for two of the divers and near enough to the instrument hole to be a handy place to keep instrumentation warm until needed in the water. A MAKO Products model KA-13-E electric air compressor was operated inside the

hut. Power for the air compressor came from a portable 5-kw gas generator outside the hut.

The diving program, similar to that for last year which was described in AIDJEX Bulletin 4, was extremely successful. Only two real problems arose. One was the failure of our lift bag technique for moving the frames around under the ice to work. We partially solved this problem by replacing the lift bags with a large plastic fishing float; in the future we will use better lift bags. The other problem was the large amount of time and manpower sapped from the entire experiment by the diving operations. We have not yet found a solution to this problem.

To measure currents, two masts composed of nine 10-foot sections of 3/4-inch-diameter thick wall stainless steel tubing were assembled as described in Bulletin 4. These mast were attached to hangers frozen in the ice so that the top current-meter set was located one meter below the underside of the ice in a known geographic orientation.

The current meters were unbanded versions of those used last year and described in Bulletin 4. They were mounted in triplets on the masts at the following locations beneath the underside of the ice: 1 m, 2 m, 4 m, 8 m, 16 m, and 27 m. Signals were transmitted from each mast to the instrument shed by one of two 22-conductor special Arctic quality instrument cables. The instrument cables terminated in a switching box where various sets of meters could be attached to the 14-channel f.m tape recorders, to a set of monitor oscilloscopes, and to a set of up-down counters which provided an accurate measure of mean current at each sensor.

The masts were first assembled on the surface and then taken apart and lowered into the water, 20 feet at a time, by a hand winch attached to a 24-foot radio tower guyed with 3/32-inch hydrowire. Once the entire mast had been reassembled in the water, a large fishing float was attached to the upper side and a piece of hydrowire was pulled through an eye on the frame hanger and attached to the top of the mast. The hydrowire served to pull the mast over to the hanger, while the fishing float took up most of the weight of the mast. The winch cable served as a safety line. In this way two masts were placed, one on a steep mound and one in a fairly level area. This implantation method worked well, but it took too much time and

manpower to permit moving one of the frames from hanger to hanger, as we had originally planned. We therefore decided to make measurements from two fixed locations.

The two-mast experiment lasted from 2300 on March 21 to 1400 on March 24. During this period, current meters 1 through 6 on both frames were recorded on one 14-track tape recorder; current meters 7 through 18 were recorded from alternate masts on the second 14-track tape recorder. Switching was done manually. Current speed and direction and water temperature and conductivity were recorded on the spare channels at various times throughout the experiment. When a lead opened near the diving hole, we decided to remove one mast and continue recording data from the one which remained.

Wind speed and direction varied during the boundary layer experiment as shown in Fig. 3. Our first current measurements were made in the early evening of March 21, and the flow was found to range from 10 to 12 cm/sec. The wind at that time was blowing from the north at 18 mph. Over the next 28 hours the currents increased to a maximum of about 18 cm/sec, then began to decrease although the wind speed remained high for another twelve hours. On March 24, the wind changed direction from northerly to westerly and picked up in speed until it exceeded 20 mph. The currents picked up more or less in phase with the wind and ranged from 12 to 15 cm/sec at 1400. About this time a large lead opened in the vicinity of the instrument frames. The currents decreased rapidly throughout the rest of the afternoon, and by 2100 the currents were below threshold at nearly all depths. Unfortunately, the winds and currents were both weak during the following six days. This quiet spell was interrupted on April 1 by a storm, during which the surface current speed reach about 10 cm/sec. However, this storm lasted less than 24 hours, and the quiet conditions had returned by the following morning. The currents were below threshold at 0300 on April 2, and we terminated the experiment at 1030 that morning.

Preliminary results indicate the complexity of the boundary layer and suggest that there is much yet to be learned about flow in the upper Arctic Ocean. Moreover, these results suggest that observations of the oceanographic boundary layer with which the ice sheet is interacting may

provide a handle for the gross response of the ice sheet to the wind stress. That is, the so-called water stress studies may be as productive as indicators of ice motion as of regional stress measurements.

Personnel

<u>Name</u>	<u>Title</u>	<u>Project</u>
L. K. Coachman	Assoc. Professor	physical ocean
K. Aagaard	Research Asst. Professor	physical ocean
J. D. Smith	Asst. Professor	boundary layer
R. B. Tripp	Oceanographer	physical ocean
M. Welch	Oceanographer	boundary layer, lead diver
E. J. Klink	Engineer	boundary layer
C. Pearman	Engineer	boundary layer
T. Liffiton	Marine Technician	physical ocean
J. Newton	graduate student	physical ocean
E. Carmack	graduate student	physical ocean
J. Rosenberg	graduate student	boundary layer
S. McGowan		diver
K. Ward		diver
B. A. Morse	Oceanographer	physical ocean, cook
G. Wade	Canadian Hydrographic Service	Commander, C-200
L. Lundgaard (from PCSP)		camp assistant

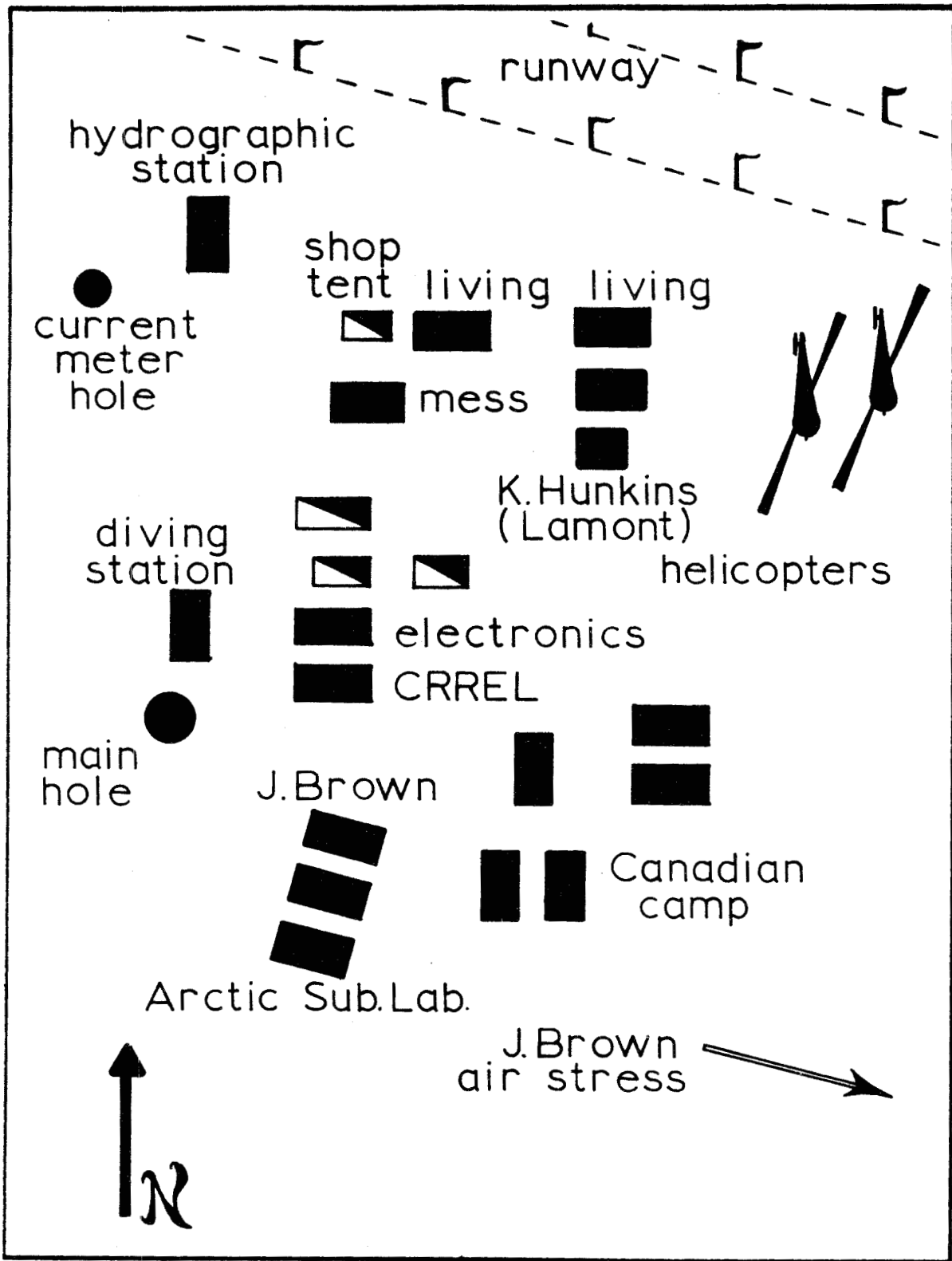


Figure 1. Plan of CAMP-200, 1971

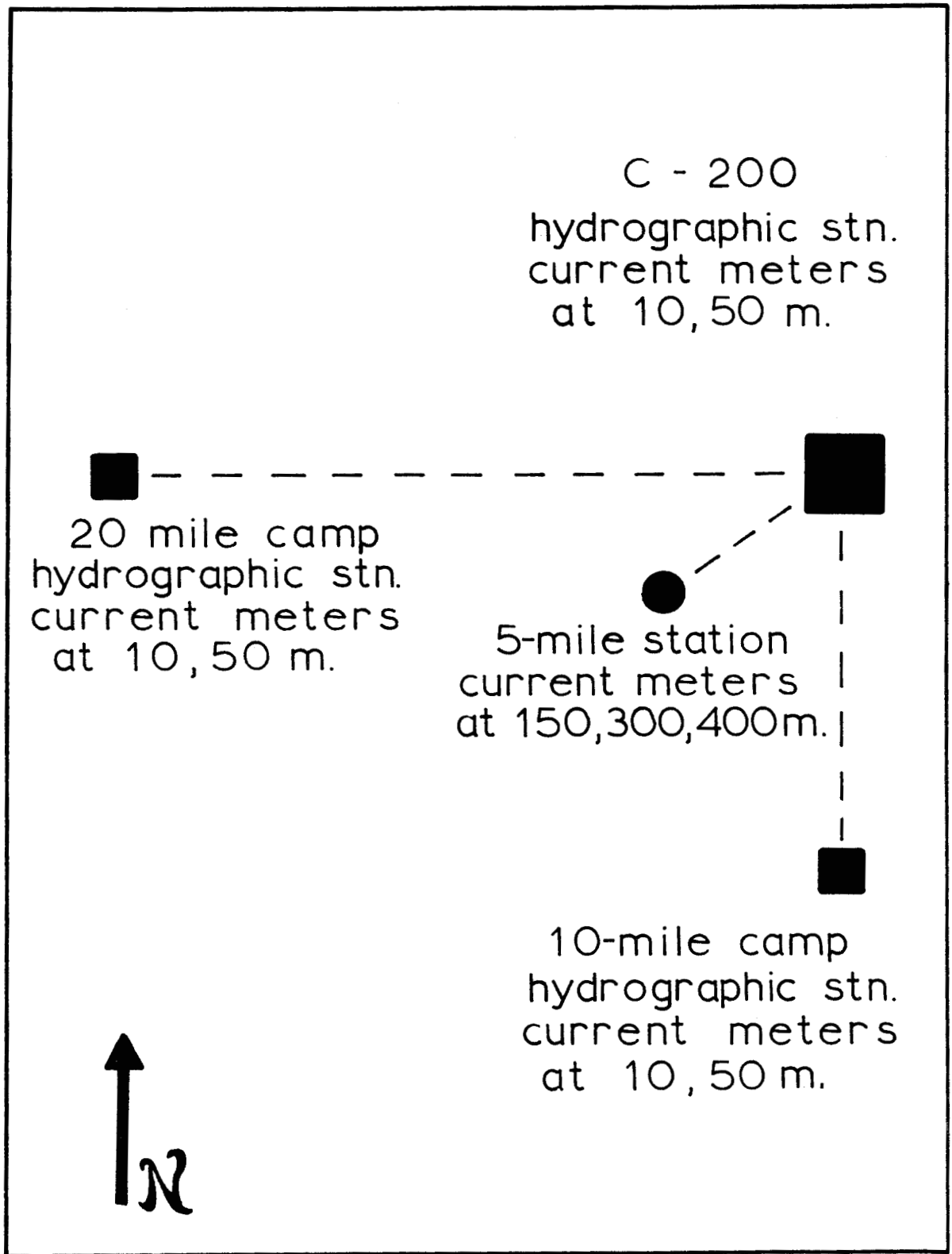


Figure 2. Map of hydrographic and interior flow measurements - 1971

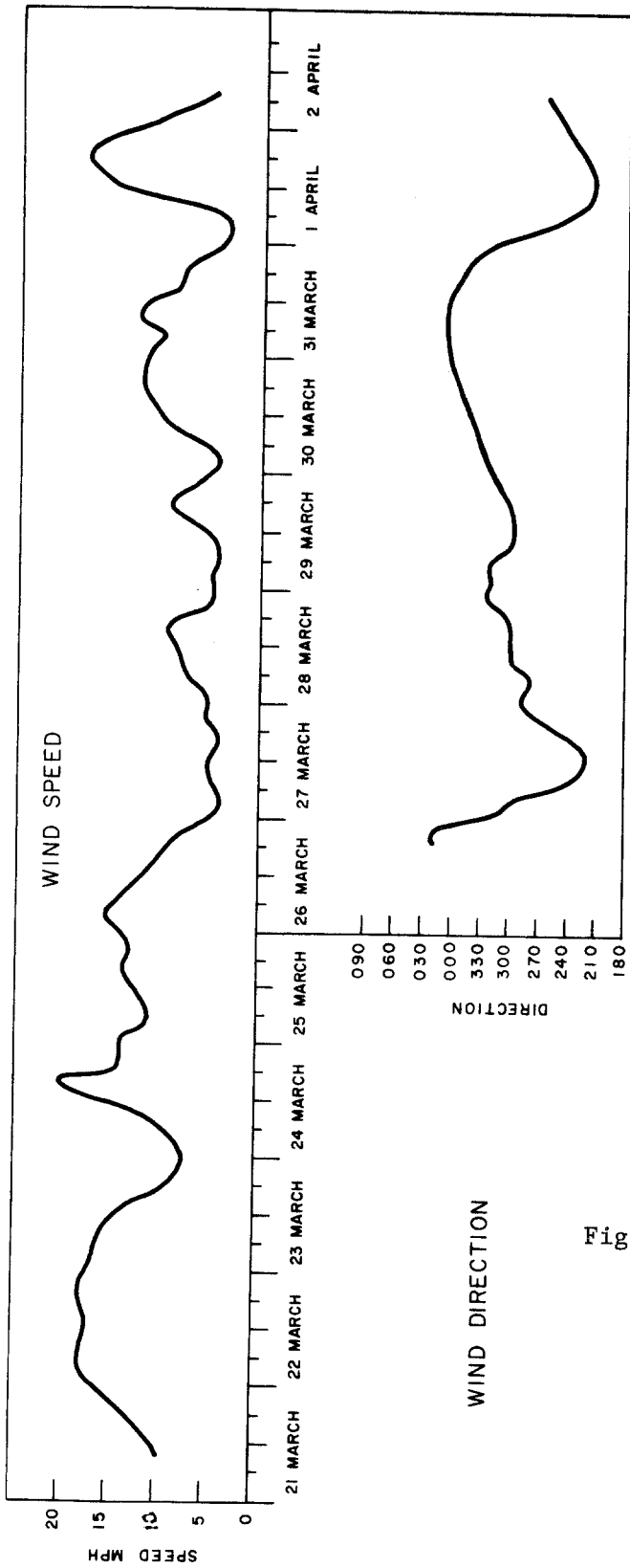


Fig. 3. Wind speed and direction at Camp 200.

1971 ARCTIC ICE FLOE STUDIES
ARCTIC SUBMARINE LABORATORY

by

James H. Brown

The Arctic Submarine Laboratory (ASL) group of eight men spent 33 days at Camp 200. During this period, twenty tons of equipment and instruments were transported to the floe, and data were obtained for a period of 15 days. The main effort was directed towards recording profile boundary layer measurements, which would give detailed information of momentum and energy flux components at the air-ice boundary of a polar ice floe.

The floe was instrumented with approximately three hundred sensors whose outputs were recorded on a high-accuracy data acquisition system. Two masts were instrumented at nine levels (0.25 meters to 10.0 meters) to measure horizontal wind speed, virtual potential temperature, and specific humidity gradients. The direct solar radiation component (filtered and unfiltered) was measured. The shortwave (0.3 μ to 3.0 μ) hemispherical radiation facing upward and downward was measured. The longwave (4.0 μ to 40 μ) hemispherical radiation facing upward and downward was measured. Total spectrum (0.3 μ to 100 μ) hemispherical radiation facing upward and downward was measured. The net radiation was measured at six different locations. Temperature profile measurements in the snow were made at six locations, and in the ice at one location. Twenty heat flux meters were placed at different locations in the snow and ice to measure the conducted heat flux term.

Profile measurements of wind speed, temperature, specific humidity, pressure, and wind direction to heights of 600 meters on three occasions were recorded with the NCAR aerodynamic wing system. A number of problems were encountered with this system which were overcome; however, the leakage of helium from the wings could not be corrected in the field. The helium leakage limited the amount of data obtainable by this system. It is

hoped that this problem can be solved and that quality profiles to greater heights can be obtained in the future.

In addition to the measurements mentioned above, ice salinity and density profile measurements were made at 16 locations to a depth of 0.7 meter. The snow depths at 47 locations were recorded. Ice thickness measurements were made at 20 locations, and ice growth measurements at one location.

An experimental accelerometer system was installed in the ice, and data were recorded. Some improvements in this system will be required for future work. Improvements will also be required in field calibrations and in a method of making system adjustments at low temperatures.

An experimental three-component thermal-probe water-velocity meter was installed, and data were recorded for two days.

It is planned to computer process, analyze, and write a preliminary technical report from the field data in the next two or three months.

LOGISTICS REPORT OF THE 1971 AIDJEX PILOT STUDY

by

Rolf Bjornert
AIDJEX Operations Coordinator

In terms of logistics, the 1971 AIDJEX field activities were a complete success. After a slight delay at the beginning of the operation, the flow of events fitted smoothly into the time schedule that had been set beforehand. The success was due as much to the cooperative spirit of everyone involved as to the luck we enjoyed with good weather, a minimum of mechanical failure, and no accidents.

As has been mentioned in earlier AIDJEX bulletins, the Polar Continental Shelf Project (PCSP) of the Canadian Department of Energy, Mines and Resources provided the major logistic support for the AIDJEX field operations. At the main ice camp this included heaters, fuel, furniture for the living quarters, Parcolls, tents, electrical power, radios, Decca recorders, ice tools, food, and one cook.

All AIDJEX investigators transported their own parties and scientific equipment to Tuktoyaktuk (Tuk), Northwest Territories; from there, PCSP airlifted all personnel and equipment to Camp 200 on the ice. To provide this airlift service, PCSP chartered a Bristol freighter, a Twin Otter, and a Single Otter aircraft. At Camp 200, two helicopters (a Bell 204 and a Bell 205) were used by the PCSP hydrographic team, and AIDJEX was able to schedule 45 hours of helicopter time to establish and man the remote stations and to periodically record the Decca coordinates for them.

The following is an edited version of the diary I kept during the field activities. It will describe the establishment, maintenance, and evacuation of the project.

On February 24 I arrived at Point Barrow, Alaska, where local workmen at the Naval Arctic Research Lab had prefabricated the 14 buildings which were to house the AIDJEX scientific parties at Camp 200 on the ice. The time schedule in AIDJEX Bulletin 5 had called for the arrival of these

buildings at Tuk on February 25. This was a clear impossibility; not only had the Bristol aircraft not yet arrived at Tuk to transport the buildings to Camp 200, but the ice floe on which Camp 200 was to be established had not been found. We were already late.

We tried to find out what was happening at Tuk so that we could help solve whatever problem was causing the delay. Words cannot convey the frustration of communicating questions and answers between Point Barrow and Tuk. A commercial telephone does connect the two points, but by the time a call is routed south through Alaska into central Canada and back up north to Tuk, the signals have all but faded completely. The DEW-line offers another possible telephone connection (it was invaluable in coordinating the remote-sensing overflights from Eielson). Unfortunately, PCSP at Tuk did not have access to this connection, except indirectly. The DEW-line operator at Tuk had to call PCSP and leave word that Point Barrow wanted to talk to them. PCSP had their own troubles, not only organizing their hydrographic group but also preparing for the imminent arrival of the AIDJEX participants; and they were not always able to respond. All we could do was to call down to our groups in the States and delay their departure so that the limited PCSP facilities at Tuk would not be overtaxed.

The buildings and I waited at Point Barrow until March 1, when received word that the ice floe for Camp 200 had been found. Interior Airways C-130 Hercules immediately began making its three flights to Tuk with the buildings and some equipment from the University of Washington group. Dr. Max Brewer of NARL sent along a five-man construction crew to assemble the huts at Camp 200. Without his generosity in providing these carpenters, the establishment of Camp 200 and the initiation of the pilot study would have been severely delayed.

Upon our arrival at Tuk, we discovered that the Bristol aircraft had in fact arrived several days earlier, but had been damaged while being towed out of the hangar. Fortunately, the Twin Otter had already begun transporting the PCSP equipment to Camp 200. It and the Bristol (which was repaired by March 2) were able to finish the Canadian hauling in time for the Bristol to begin carrying AIDJEX buildings and the construction crew to Camp 200 on March 3. It carried two buildings on each flight. The carpenters did an excellent job, assembling the huts as fast as they were delivered.

The airlift operation went well, thanks to good weather and the willingness of the pilots to fly a grueling schedule, sometimes stopping to rest only during aircraft maintenance checks. The Single Otter and the Twin Otter aided the Bristol in shuttling personnel and equipment, and we were able to transfer people with a minimum stay at Tuk. Those who were waiting usually helped to load and unload the aircraft. The DEW-line station manager, Douglas McKay, was very helpful to us. He let us use the DEW-line hangar as a temporary warm storage for all our scientific gear and as a place in which to make the airplane maintenance checks.

The flying weather turned bad and one Bristol engine failed mechanically on March 7. The continued use of the Bristol was critical to the AIDJEX operation. Frank Hunt of PCSP performed the impossible: he obtained a second Bristol for us on March 9. Four days later, the last load of personnel and equipment arrived at Camp 200. By the following day, all prefabricated buildings had been erected. The Bristol returned to home base on March 21, having completed the first phase of flights between Tuk and Camp 200.

During the scientific activities at Camp 200, logistic support went routinely. The Twin Otter flew at least every second day with fuel, food, mail, and spare parts. We always tried to fill it for its return flight with data tapes, water samples, and gear that was no longer needed.

Since only a single telephone line connects Tuk with the outside world, we were glad we had taken along an amateur radio station. It was a low-powered transceiver, and we were able to use two bands (15 and 20 meters). It was a good supplement to the limited phone facilities, because with it we could make contact with other amateur stations in Canada and the U.S., who in turn could connect us to the phone network. The transceiver also performed well at Camp 200.

On March 26, the CRREL-USGS group left Camp 200. From this day through April 16, there was a more or less continuous exodus of gear and people, with parties leaving in the same order they had arrived. Everything was recovered except the prefabricated buildings, which were sealed in the hope that the floe would stay in one piece until next year. A pyramid of empty oil drums was constructed to mark the abandoned campsite for future radar detection. The camp was abandoned on April 16.

The ice around the camp remained in good condition throughout the pilot studies. Leads did begin to open around us in late March, the nearest one about 160 feet from the buildings. It reduced our runway by about 100 feet, but neither this reduction nor the several hairline cracks that developed on the runway prevented the Bristol from completing the evacuation with loads of up to 8,000 pounds.

