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Arctic Investigations

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This afternoon I would like to tell you about the arctic. First, about some early arctic expeditions, then about expeditions and studies made by the atomic submarine last year, and lastly, the future of the arctic. I will also show a few slides.

Historically, the arctic regions have been under investigation for the past 400 years, first by sailing ships, steamships, and icebreakers, and more recently by submarines. The obvious questions are: why do people want to explore these desolate regions, and what discoveries are being made?

Man has shown a special interest in reaching the North Pole. This desire to find a particular geographic position on the earth is hard to explain because the place looks essentially the same as thousands of others near it. (In actual fact, its surface appearance continually changes as the ice moves past)

Many countries, principally Denmark, Britain, and Norway sent explorers to seek a northwest passage over the top of North America from Europe to China. Many of these expeditions tried to get to the North Pole.

The first person accredited with actually reaching the North Pole was Robert Peary on 6 April 1909. Peary's party travelled by means of a ship to northern Greenland and then by dog sleds the rest of the way. On 9 May 1926, Byrd and Bennett crossed the Pole by airplane. A few days later, Amundsen and Ellsworth made the trip by dirigible.

One of the first U.S. endeavors to accomplish this feat was made by the U.S. Navy in 1879 using the arctic steamer, JEANETTE. The JEANETTE went up the Pacific through the Bering Sea into the Chukchi Sea and then attempted to reach Greenland through the ice. Unfortunately, the ship was crushed by the ice and nearly all aboard died. The few who reached safety made their way home by ice, water, and land through Siberia. A significant result of this expedition was that parts of the crushed ship were later found on the coast of Greenland. This led Nansen, a Norweigian explorer, to construct a ship which would not be crushed by the ice, and to repeat the path of the drift of the wreckage of the JEANETTE. So, in 1893, Nansen's ship, the FRAM, was allowed to lodge in the ice off northern Siberia. It drifted with the shifting ice, generally towards the Pole, and after three years emerged in the Atlantic Ocean.

Later, Amundsen wanted to repeat this feat. He constructed a ship similar to the FRAM and called it the MAUD. He and Dr. Har~~o~~ald Sverdrup, former director of the Scripps Institution of Oceanography, and others aboard the ship tried to enter the drifting ice, but failed to do so. They drifted in circles just north of the Bering Strait. After seven years, they abandoned the attempt.

Icebreakers have also been used to explore the Arctic Ocean. By accident, the Russians lodged an icebreaker in the ice and more or less repeated the cruise of the FRAM. Our icebreakers have not been as bold but, nearly every summer since the war, have operated in the ice fringes of the Chukchi and Beaufort Seas north of Alaska and Canada, respectively.

Conventional Submarines

Probably the most farsighted arctic explorer of all was the Australian, Sir Hubert Wilkins. Thirty years ago he believed that a submarine could reach the North Pole by travelling under the polar ice cap. Laboriously he raised money wherever he could. He leased a surplus World War I submarine from the U.S. Navy for the sum of one dollar per year and modified it for arctic operations. By removing the sail or superstructure and mounting large steel sled runners on the top, he proposed to slide on the underside of the ice. He added a hydraulic ram on the bow to ease head-on collisons with submerged ice pinnacles. For safety, he had a "cathead" rotary cutter with which he planned to bore holes through as much as 15 feet of overhead ice. The holes could be used for escape or for snorkeling.

Water samples were obtained by lowering water bottles through a trap door in the bottom of the submarine. When the submarine was at or near the surface, the air pressure in a forward room was increased to equal that of outside water pressure, and the trap door opened for direct access to the open sea below.

On arrival at the edge of the arctic pack, the diving planes were missing. Someone apparently chickened out. The submarine did, however, push for five miles under the ice fringes bumping the overhead ice until it became too rough; it then surfaced in a polynya. (~~Figure 1, NAUTILUS in Ice~~).

The scientific programs, though not numerous, were still highly significant, since they were the first of their kind in this particular region (~~Figure 2, Under-Ice Photo~~).

The idea of a submarine running under the arctic ice pack was made a reality by Dr. Waldo Lyon of the U.S. Navy Electronics Laboratory. After World War II, Lyon and others conducted several under-ice expeditions by submarines and collected oceanographic data in the ice fringes of the Chukchi and Beaufort Sea.

With the advent of nuclear-powered submarines, a major breakthrough was made in the techniques of arctic exploration and oceanographic research. The 1957 cruise of the USS NAUTILUS and the 1958 cruises of the USS NAUTILUS and USS SKATE, and the 1959 cruise of the USS SKATE to the Arctic Ocean clearly demonstrated this. In 1958, the NAUTILUS made the epic cruise from the Chukchi Sea to the North Sea under ice in 96 hours. The SKATE afterwards entered the Arctic from the Atlantic side where the water is deeper, ran to the North Pole, and zig-zagged in order to cover more area. Both ships carried on oceanographic studies.

Before going into the type of studies we made from the submarines, I would like to regress, show some slides, and tell you some features of the arctic.

~~Before taking you under the ice of the arctic ocean, I would like to show some slides about the arctic~~ so as to get a feeling of what is up there (Slide 1, Arctic).

This is a projection of the Arctic Ocean and surrounding land masses. For scale, it is about 1800 miles from Greenland to Siberia, 2300 from Alaska to Scandinavia. The white, as you may surmise, represents ice coverage that is the general ice conditions in summer. There is usually open water along the Siberian, Alaskan, and parts of the Canadian coast.

Aside from the fringe of land-fast ice, in other parts, the entire basin is filled with floating ice.

If all this ice were stacked in a pile, it would be about 20,000 cubic miles. If it had any monetary value, a person could really clean up. However, there would be market and delivery problems.

The arctic basin is mainly full of floating salt-water ice (Slide 2, Block Ice). There are, however, some places which have fresh water ice (glaciers) such as Elsmere Island and northern Greenland.

The first sea ice encountered in summer is in the form of small brash and blocks (~~Slide 2, Block)~~. During this season, the ice melts and larger blocks form grotesque shapes. Icebreakers can penetrate 5 or 6-foot thick of broken ice as shown by this slide (Slide 3, Icebreaker). This ice is fairly well broken. In the winter in the Bering Sea, large sheets of ice are found. However, with wind and swell, these large cakes are broken up and rafted in ridges. Farther north in the ice pack, the ice becomes more compact with about 97 percent cover (Slide 4, Ice).

The important thing as far as submarine activity, is up water or polynyas (Slide 5, Polynyas). Polynya is a Russian word meaning hole in the ice. We have no similar word, so we use theirs. In the summer, the surface snow and ice melt form puddles which drain into the polynyas.

Open water is sometimes reflected in the sky (Slide 6, Ice Blink). Open water is indicated by a haze over it. This haze is not smog.

As shown in previous slides, the arctic basin is nearly all covered with ice. In winter, the ice becomes about 10 or 13-feet thick. In the summer, it melts at the surface and forms pools. As some of the slides show, at this season, the flat ice is only 8-10 feet thick. However, the arctic ice does not remain flat. It becomes hummocked by the wind which rafts it into piles and ridges. In fact, probably 90 percent of the arctic basin is covered with rafted ice (Slide 7, Hummocked Ice).

Now, returning to last year's cruises of the NAUTILUS and SKATE and some of the studies made from these atomic submarines (Slide 8, Tracks). The NAUTILUS, as you may have read in several publications or seen on television, attempted to enter under the ice from the Bering and Chukchi Seas in June but found the ice too thick and the water too shallow, gave up and waited until August. At that time, they again attempted to enter the ice via the Chukchi. Their track is depicted by the blue dashed line. After two attempts, they finally ran along the coast to the Barrow Sea Valley where the water is deeper and thus the head room is greater. From there, they ran directly to the North Pole (the red dot in the upper center) and out to the Atlantic -- a period of 4 days under the ice.

The SKATE, on the other hand, entered the arctic from the Atlantic side where the water is deeper. It ran to the North Pole and zig-zagged around according to the red track shown. In addition, the ship surfaced nine times in polynyas as shown by the red dots. I shall return to this slide later.

Now, let's pretend that we are going under the ice. We encountered the fringe of the arctic ice pack just west of Spitzbergen and immediately dove to 270 feet and headed north. Of course, under the ice, you cannot see anything outside but must rely on electronic instruments.

Our main instruments for determining what was overhead were echo sounders directed upward (Slide 9, Tape). On this tape, the ordinate is depth, the abscissa time or distance. With this acoustic instrument, the sea surface or water-air interface would give a strong echo or dark trace on the tape; whereas, ice gave a weaker echo at a less distance than the water surface. The reason the ice does not give a strong echo is due to its honeycombed surface found in summer melting season and the brine cells in the ice (Slide 10, Honeycomb).

As we proceed farther into the ice pack, the ice becomes thicker and the water spaces fewer (Slide 11, Tape). In this case, waves are apparent on the water-air surface.

The ice protrudes down 35 feet in places. The interesting thing to me is how rough the underside of the ice really is. Although this representation is greatly exaggerated, the thickness fluctuates greatly over a few hundred feet. However, we know that the upper ice surface is rough and that ice protrudes down 5-9 times its distance extended in air, it may not be too surprising.

As we continue under the ice, we keep looking for open water in case it is necessary to surface. A fire, engine trouble, etc. would make it necessary to surface. In addition to the echo sounders, we had an ambient light meter which, by change in light intensity, gave an indication of a hole through the ice (Slide 12, Ice-Light). In the upper right is a cake of sea ice. This picture was taken by a SCUBA diver. You can see that the light intensity under the ice is greatly reduced; it is dark. However, as you come out, the light increases, not only from the direct rays emanating from the sun and sky through the clear water, but this light is reinforced by reflection from the highly reflecting vertical sides of the ice forming the polynya.

A copy of our ice thickness and light thickness record is reporduced in this slide (Slide 13 light & ice). In openings through the ice, the light intensity always increased. If the light intensity increased 10-20 times, there was strong evidence of an opening through the ice. Fortunately, in the summer, it was light above the ice both day and night.

We continued under the ice where we found an opening or polynya in the ice and made preparations to surface. The technique was to plot the polynya by making several passes across from different directions while using an acoustic scanner and echo-sounding equipment. Ice appears as long-jagged projections down into the water, whereas water gives a strong signal on the echo sounder and is flat.

After a polynya has been surveyed, the ship is brought to a position along the long axis and then is moved vertically by pumping out the ballast very slowly. If a polynya was free of ice, the ship surfaced. (Slide 14, In Polynya). Here is the SKATE in a polynya on a calm day. The ice in the foreground appears to extend about 5 feet above water which should make it about 35 below.

In polynyas, it was possible to get out of the submarine and inflate a rubber boat and go ashore (Slide 15, Rubber Boat). On the ice, we sampled ice and water puddles, collected plankton samples, made temperature measurements and recorded the weather (Slide 16, Ice Sampling).

The water in the Arctic Ocean is quite clear. You can see down at least 50 feet or more in most cases. Other ice formations were more easy to collect (Slide 17, Ice Crystals).

In the summertime, the surface ice and snow is melting and forms puddles which drain into the polynyas (Slide 18, Pegs Polynya). Since the water is relatively warm, about 34°F and relatively fresh, about 3‰ of salt, it floats on top of the normal sea water. There is a sharp boundary at about 10 feet, the bottom of the thinnest ice, in which the temperature and salinity changes abruptly. Since the salinity increases and the temperature decreases, a large density discontinuity is created. Below this, the temperature is about 30°F and the salinity about 33 percent. The ice on one side or the other of the polynya is usually rafted. The uneven wind stress may be a factor in creating a polynya. Another summer characteristic is the undercutting by eroding or melting right at the water surface.

While surfaced in the polynya near the North Pole, we radioed also to the International Geophysical Year Station, Alpha, which is located at 86° north and over towards the Bering Strait near the 180° meridian. We asked them if they had any opening near their station. They replied that they had an airstrip (the station is supplied only by air) and that recently this airstrip had opened up; the ice had parted and a polynya was formed right alongside of their station, which consists of about 20 houses.

The technique of finding the station from under the ice was to run an 18-horsepower Johnson outboard motor in their polynya. This they did, and we proceeded in their direction. Within a few miles from this station, we could hear the motor. We homed in on it and came up right alongside their buildings (Slide 19, Alpha). This to me was the greatest feat of the arctic cruise. The IGY scientists came aboard and our scientists went ashore.

At this floating ice station, they were studying weather, ice formation, currents, depth of water, and bottom characteristics. They were even swimming and diving with aqualungs through the holes in the ice and examining the ice and the organisms that live off the ice (Slide 20, Swimming). They also claimed that they had been water-skiing in the polynya with their 18-horse Johnson motorboat. The water was about 32-34° at the surface, becoming cooler as you went down.

This station located on flat ice which drifts with winds and currents. In this particular location, the current has been drifting in a circle (Slide 21, Currents in Arctic).

Most arctic surface currents or ice drift has been obtained by ships drifting across the arctic (Blue = FRAM)(Red = Russian icebreaker)(Orange = Ice Station)(Green = T3 and Alpha).

Variability is apparent from the reversal of drift. Of particular interest is the eddy in the Beaufort Sea and the one off of Elsmere Island. The latter is probably caused by the shallow bottom topography or the Lomonosov Ridge. In general, there is a drift from W to E. There are some variations near the coast as off Siberia and Alaska.

Biological populations in the arctic, from our observations, were extremely sparce. The water was exceptionally clear with visibility down to 50 feet in places. Some plankton were found at the bottom of pools or on the shallow subsurface shelves in polynyas (Slide 22, Plankton in Polynya). At these locations, increased light by reflections from the ice shelf and the vertical ice sides of the pool, as well as the higher temperature in these regions were conducive to phytoplankton production. Older, retarded green algae spores, sometimes in large concentrations, were found in and on the ice, undoubtedly the results of freezing of polynyas and the melting of surface ice which gradually worked this material up to the surface.

As far as large organisms are concerned, there were a few seals in one polynya, a polar bear in another (Slide 23, Polar Bear), fresh tracks in still another. When we went out on the ice any great distance, we carried a gun. Although we were informed that polar bears eat nothing but seals, the bright, glarry ice has apparently affected their eyesight and everything, including people, look like seals to them.

One of our most important measurements from the SKATE as well as the NAUTILUS was a continuous profile of the sea floor by means of an echo sounder aiming downward (Slide 24, Topography). However, most of the data from which this bathymetric chart was prepared comes from the Russians, especially from single soundings from plane landings. Each change in color represents 1000 meters. Light yellow 0-1000 m, dark yellow 1000-2000 m, green 2000-3000 m, light blue 3000-4000, and the darkest blue is 4000 meters. The North Pole, the red dot is near the edge of the deepest basin. The general features of the Arctic Ocean are 3 basins W, C, and E. C and E are separated by the Lomonosov Ridge (L). This ridge is quite shallow and must have an effect on the drift (currents) in the arctic since it nearly cuts the Arctic Ocean in two. The west side is full of submarine canyons. In fact, most of the topography to the east is rough, whereas the east basin is flat. The canyons may have been cut in glacial times in which the melting could have cut valleys on the slopes. The margins around the deeper parts are broad and shallow, less than 1000 meters and colored yellow. It is difficult to enter the arctic from either N. Canada, Pacific, or N. Siberia by submarine. Actually, the only safe way is by the Atlantic. The Nansen Ridge is fairly deep.

The sea floor of the arctic basin varies in relief. The rise between the East and Central Basin is made up of small hills (Slide 25, Hills). The Central Basin is flat (Slide 26, Central Basin) and the southern part of the East Basin contains seamounts rising from the flat bottom (Slide 27, Seamounts).

So much for the past; what of the future operations in the arctic? As far as exploration and scientific studies are concerned, we must expect a continued increase. (Slide 28 Arctic) This is because of military needs for accurate prediction of an open water resupply route to early-warning installations all along the Alaskan and Canadian Arctic. These strategic stations mark the shortest route to Russia over the Arctic Ocean. Further, Russia borders 44% ~~one-third~~ of the 360° sector subtended from the North Pole. The fact that we could travel under the ice virtually to Russia's back door for missile launching makes the arctic basin an important strategic operating area.

Aside from military uses, what can we do with all that ice? The arctic is a liability and has no value. However, if we could melt all that ice, the arctic could be useful for navigation and living conditions would improve. There is some indication that the arctic summers are getting warmer and the open-water area greater off the Alaskan coast. This is true, in general, for the last 10 years. Ships usually experience no great difficulty in reaching Pt. ~~Ft.~~ Barrow during recent years. However, there is no assurance that this will continue and may prove to be only a short-period cycle of a group of warm and cold years.

A continued trend towards still warmer summers, and winters for that matter, would be most desirable in the arctic. The Russians, I have read, have proposed to warm up the Alaskan-Siberian region by building a dam across the Bering Strait and pump warm water across. Such a dam is quite feasible since the water is relatively shallow, only 160 feet on the Russian side and about 180 feet on the American side. But, what would this dam do to the redistribution heat of the region?

At the present time, the Bering Sea is frozen each winter down to the edge of the continental shelf near the Pribilof Islands. (Slide 29 Bering Strait) In the spring, the ice first breaks up off the Yukon River. Here, this initial breakup of ice is believed to be caused by the river runoff and surface heating. When some water becomes ice free, it becomes a better absorber of radiation. Further, any turbid material in the water accentuates the absorption of heat. In accordance with the general circulation, this relatively warm water flows up the east side of the Bay, through the Bering Strait and following near the land as far as Pt. Barrow. The warmest layer is usually below the surface and the water becomes colder with distance from the Bering Sea.

If this flow were blocked at the Bering Strait, the warm fresher, water would accumulate just south of the barrier. Eventually, this would flow souuth along the western side of the Bering Sea along the east Siberian coast and materially improve the summer climate there. The colder flow along northern Siberia would not be affected much since little of it went down through the strait anyway. It would continue over to the Alaskan coast, but being colder than the former Alaskan current, would do nothing beneficial for northern Alaska. The pumping of appreciable water, seems to me, out of the question. The net result of daming the Bering Strait would be a little warmer Bering Sea and a little colder northern Alaska. This Russian proposal of building a dam across the Bering Strait does not appear to be worthwhile, at least for us. A better method would be to increase the size of the Bering Strait thus facilitating the passage of more warm water into the Arctic Ocean and melting some of the ice. This approach is quite feasible since the land is low and cutting a wide channel would be relatively easy.

Still another approach to the improvement of the climate of the Arctic is from the Atlantic side. On the Atlantic side of the Arctic Ocean, the cold arctic water is separated from the relatively warm Atlantic water by the Iceland-Greenland Ridge (Slide ~~28~~ 30, Iceland-Greenland Ridge). The sill depth of this ridge is about 300 fathoms. It has been proposed that, if by some means this ridge were deepened by dredging or blasting, an interchange of water would result.

How would a deeper trench change the climate? First, the cold and heavier arctic water would flow south through the treanch and down along the bottom. This would tend to drain the arctic water from the Arctic Ocean. This cold water would flow towards the equatorial region where it would eventually mix with the warm surface water and cool the hot tropics. To replace the arctic water, relatively warm Atlantic water would flow in to take its place. If the arctic water were heated by only a few degrees, all the ice would melt. This would certainly warm the arctic region and result in a much more equitable climate. The absence of arctic ice pack would allow surface navigation from the Atlantic to Pacific.

These climatic changes would all be favorable, but many side effects may develop. For example, if the land ice glaciers would melt, the sea level would rise. If all land ice would melt, the sea level would rise from 150-300 feet and this could do low coastal cities no good.

Another detrimental factor would be the greater evaporation caused by the lack of ice. Open water evaporates much faster than ice. This would create more clouds and we would have greater rainfall. If the increased snow that falls in high latitudes is greater than the summer melting, it would accumulate and eventually develop into a glacier period. Some of the objectional effects may offset the desirable ones. So, when the trench is cut across the Iceland-Greenland Ridge, a valve should be inserted to turn off the process if it is not the desired one.

Conclusion

Right now, we are in an age of expensive space travel and exploration. I feel, that after we have taken a good look at the moon, we will decide that the earth is not such a bad place after all; but that it might be improved.

Some of us in oceanography feel that we should spend more effort to study the ocean's bottom than the moon's behind.

The greatest improvement to our earth would be in its climate. That is, cool the tropics and, especially, heat the arctic. The most promising method to transport thermal energy would be by large sea currents. The heat-carrying capacity of water is more than 1000 times that of air. If a warm-water current can be diverted from its usual path, either by a change in winds or by the topography of its sea bed, it will have a profound effect on the climate of that region. Even a small diversion would be useful. For example, the warmer water off San Diego for the past 2 or 3 years is undoubtedly the result of a change in meteorological conditions which caused a mass of warmer southern water to be advected into our front yard.

Although we cannot exercise much control on the major wind patterns, there is some possibility of making some changes in sea current. Two possible approaches were mentioned which would affect the arctic. In the future, it is likely that efforts will be directed along similar lines to improve the climate of the earth especially in the arctic.