

arctic winter, one noontime in January 1597 the explorers were astonished to see the Sun appear two weeks sooner than expected at that latitude. At the time, the Sun's actual position was still about 5° below the geometrical horizon.

This unexpected appearance of the Sun, the Novaya Zemlya effect, is now explained in terms of long-range optical ducting in the lower atmosphere. At the Optical Society of America meeting in Chicago in October, Waldemar Lehn and Borys German of the University of Manitoba in Winnipeg showed what they believe to be the first collection of documented photographs of this polar mirage.

After the original observation of Barents, most scientists were skeptical that it had been seen at all, although Kepler in 1604 did try to attempt an explanation for the effect. During Ernest Shackleton's last expedition to Antarctica, on 8 May 1915, seven days after the Sun had set for the Antarctic winter, he saw the Sun reappear. As had Barents, Shackleton saw the Novaya Zemlya effect a second time during this polar winter.

Last year Lehn analyzed¹ data taken by G. H. Liljequist during a 1951 Antarctic visit; he had seen and sketched several cases of the Novaya Zemlya effect and measured temperature profiles of the lower atmosphere. In one case, he reported a very strong temperature inversion of 25 °C, extending up to 1000 meters elevation. Lehn developed a model to trace rays through the atmosphere for different temperature distributions that reproduced the weird shape seen by Liljequist.

Lehn explains that in the Novaya Zemlya effect, the limit on viewing distance imposed by the Earth's curvature is overcome and the horizon dis-

tance is greatly extended because light rays are trapped beneath a fairly sharp temperature boundary (thermocline) of large horizontal extent. Within the thermocline layer the coefficient of refraction, k , must be greater than one, while above and below it k must be less than one. Then certain rays will return to Earth in a fashion similar to total internal reflection or light being transmitted in an optical fiber. If conditions are right, these rays, trapped in the atmospheric duct, can bounce back and forth between the thermocline and a region close to the Earth many times, provided the ground is very level. The image, however, is completely distorted because individual rays are refracted by different amounts.

The effect is easiest to see in polar regions because the reappearance of the Sun during the winter night is so dramatic. Also in winter the characteristically flat polar regions are ideal for generating the required uniform widespread temperature inversion.

Lehn and German visited Tuktoyaktuk, Canada (69°26'N, 133°02'W) a week before the Midnight Sun was due to begin, essentially reversing the time when Barents made the first Novaya Zemlya observation. The second time they looked, in the early morning on 16 May 1979, they saw the effect—the Sun did not set. It remained above the horizon, within a rectangular strip that is characteristic of the effect. Lehn and German saw an assortment of images. One was essentially a rectangle whose width was 32 min of arc (normal for the Sun) but whose height was 10–14 min of arc. (See the figure.) Another resembled a Big Mac, Lehn told us, with three pancake-thin images, one above the other; in between was no light. From clear superior mirages of distant landmarks in other directions,

the pair knew that the uniform temperature inversion responsible for the effects covered a very large geographical area. (Typical distances were about 100 km.) Using photographs, site surveys and ground-level meteorological data, the pair did a simulation study. They assumed various temperature distributions (strength of the inversion and height of the thermocline) until they duplicated each of the observed solar images.

The same kind of optical ducting has been proposed² by Lehn and Irmgard Schroeder (Manitoba) to explain why Eric the Red, when exiled from Iceland, set out so confidently toward Greenland. The sagas relate that he was seeking some islands seen by Gunnbjorn off northwest Iceland, about 100 years earlier. However, Lehn and Schroeder note, Gunnbjorn's "skerries" (flat rocks projecting just above a water surface) never existed in that location. Instead his skerries have an appearance and location consistent with a ducted image of the Greenland coast that was transmitted to observers in northwest Iceland. —GBL

References

1. W. H. Lehn, *J. Opt. Soc. Am.* **69**, 776 (1979).
2. W. H. Lehn, I. I. Schroeder, *Polarforschung* **49**, 173 (1979).

in brief

NASA has chosen Ford Aerospace and Communications for the negotiation of a contract for the Space Telescope that is to be launched into orbit from the Space Shuttle. Ford is to undertake design engineering of the preliminary-operations and test-support systems that will be located at the Goddard Space Flight Center (Greenbelt, Maryland).

DOE has selected McDonnell Douglas as the builder of the Elmo Bumpy Torus proof-of-principle experimental facility (EBT-P) at Oak Ridge (PHYSICS TODAY, October 1979, page 18). The 4½-year project is expected to cost \$70–100 million. EBT-P will be an upgraded version of the original EBT, a hybrid magnetic-confinement fusion machine in operation at Oak Ridge since 1973.

The Tristan mass separator is now in operation at Brookhaven's High-Flux-Beam Reactor. This facility, said to be the only reactor-based, on-line mass separator in the US, was moved to Brookhaven in 1978 after 12 years of operation at the DOE Ames (Iowa) Laboratory. It is used to study unstable nuclides produced in fission reactions.



Novaya Zemlya effect photographed in the Arctic on 16 May 1979. Because of atmospheric ducting, rays bounce back and forth between a thermocline and the Earth, and a distorted solar image is visible when no image at all is expected. In both images the horizontal extent is 32'. At left, the rectangular image is 13' high at either side and higher in the middle. At right, the stack of three images (Big Mac) is a total of 19' high. Photos by W. H. Lehn, B. German.