Witness The

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Arctic Research at the Cold Regions Research and Engineering Laboratory (CRREL)

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), located in Hanover, New Hampshire and Fairbanks, Alaska, is an internationally renowned center for cold regions science and engineering. CRREL's single focus as a cold regions research and development (R&D) organization is to provide expertise to the Department of Defense, other federal, state and local agencies, and the private sector. This strategy results in an internationally recognized center of expertise with unique state-of-the-art facilities and a cost-effective capability. Many of the projects described below are either fully or partially funded by outside agencies. CRREL has earned an international reputation of excellence that is sustained by its exceptional technical and support staffs and by emphasis on a balance of theoretical, experimental, laboratory and field work. The hallmark of its experience and expertise is the direct interaction of its research staff with the environment in the Arctic, Antarctica, Alaska and the other northern states, northern Europe and Korea.

CRREL maintains facilities in Hanover, New Hampshire (above) and Fairbanks, Alaska. Researchers conduct field work in the Arctic, Antarctica, Alaska and other northern states, northern Europe and Korea (photo courtesy of CRREL).

Ice Coring

CRREL researchers have been involved in deep ice coring since the 1950s in Greenland. This expanded to Antarctica in 1957 and has continued most recently with the Greenland Ice Sheet Project (GISP2) core funded by NSF. In the earlier cores, CRREL was involved in drill development (electromechanical drill), logistics and science. CRREL researchers also initiated comprehensive ice-core analysis, as it is known today.

With the GISP2 core, researchers have been involved primarily with physical properties and age dating of the core. Properties studies include ice density, ultrasonic velocity, air bubbles, gas content, fabrics and ice structure/deformation. Researchers from CRREL led development of the depth–age scale for the core. A combination of several annual parameters, including visible stratigraphy, electrical conductivity, laser light scattering of dust, oxygen isotopes and chemistry, and non-continuous parameters including volcanic signals, were used for the depth–age scale. This is the longest, most continuously dated record using so many parameters.

For more information on the GISP2 core, see the feature article in this issue of *Witness the Arctic*.

(continued)

Sea Ice

CRREL researchers have been involved in every major arctic sea-ice initiative, from the Arctic Ice Dynamics Joint Experiment (AIDJEX) to the newly planned Surface Heat Budget of the Arctic Ocean (SHEBA) project (see *Witness*, Autumn 1996). Characterizing ice properties and processes contributes to understanding the interaction of ice with the ocean and atmosphere.

CRREL's participation in recent major programs includes the Office of Naval Research Sea Ice Mechanics Initiative (SIMI), Electromagnetic Properties of Sea Ice (EMPOSI), and the 1994 U.S./Canada Arctic Ocean Section (AOS-94) (see *Witness*, Autumn 1995).

During SIMI, CRREL researchers, in collaboration with the National Oceanographic and Atmospheric Administration Pacific Marine Environmental Laboratory, measured *in-situ* ice stress over a six-month period at selected edge and center sites on a multiyear floe. Concurrent measurements of stress and deformation were made to provide a direct (rather than implicit) evaluation of ice-dynamics models and to improve those models. The stress records clearly indicate that:

- ice stresses are caused by changes in air temperature as well as ice motion, and
- these components can be identified and separated.

EMPOSI was a multidisciplinary, multi-institution effort aimed at relating the electromagnetic properties of ice to its physical state and structure. CRREL's contributions included:

- hosting the laboratory portion of the effort,
- providing qualitative and quantitative characterization of physical properties of the ice,
- determining dielectric constants for the ice, and
- measuring optical properties of the ice.

An important part of the properties documentation included statistical characterization of brine and air pockets in the ice. Researchers investigated the optical properties of sea ice from the ultraviolet to the near infrared (280-1000 nm) by making spectral measurements of albedo, bi-directional reflectance, reflected light polarization and transmittance.

CRREL researcher measures the albedo of the sea-ice cover off Barrow, Alaska during the Office of Naval Research Electromagnetic Properties of Sea Ice (EMPOSI) field program. The objective is to monitor spatial and temporal variability in the reflected, absorbed and transmitted light as a function of ice conditions including ice that is snow-covered, bare, sediment-laden, bio-laden, melting and/or ponded.

On AOS-94, researchers characterized ice and snow properties across the Arctic Ocean, measured the albedo of a variety of ice surfaces, and documented melt pond and floe size distribution using precise aerial photography. Chemical properties of the ice were also characterized; measurements included major ions and nutrients. Additionally, investigations of ice-borne sediment were carried out to determine processes of incorporation, likely source areas and levels of radionuclide contamination.

Areal Distribution of Snow Properties in the Arctic

The goals of this project are to:

- understand the role of snow cover in governing winter heat and mass exchange between the ground and atmosphere, and
- develop the ability to predict snow distribution from landscape features and meteorology.

Measurements of the snow cover have been made during five over-snow traverses in the Kuparuk Basin of northern Alaska. Measurements of snow depth, density and snow water equivalent have been made at over 100 stations, and a sled-mounted FM-CW radar has been used to measure an additional 250,000 snow depths.

The results are being used to develop empirical relationships describing how the snow cover is related to the regional climate, topography, landscape and vegetation. Using these relationships, preliminary end-of-winter snow-distribution maps for the Kuparuk Basin have been prepared.

A physically based snow-distribution model that requires precipitation and wind data has been developed in collaboration with Glen Liston of Colorado State University. The model can evolve and distribute a snow cover over the landscape, allowing for wind transport and sublimation. A relational model, developed from observed patterns of snow deposition and topographic features, has also been developed to estimate snow distribution where meteorological data are sparse.

Extensive measurements of snow thermal conductivity and snow/ground interface temperatures are being used to investigate the role of snow cover in controlling winter heat losses from the ground and snow-covered vegetation. A close positive relationship between snow thermal resistance and the local amount of shrubs has been observed.

Scientific Disciplines

- Snow, ice and frozen ground
- Polar operations/logistics
- Non-destructive subsurface geophysical exploration
- Facility design, construction and maintenance
- Winter mobility
- Deep ice coring/climate change
- Environment quality
- Sea-ice geophysics
- River-ice management
- Low-temperature instrumentation

Snow–Atmosphere Exchange Processes

In polar regions, gaseous chemical species found in the atmosphere become incorporated into the snow and firn; decades of snow accumulation compact the firn into glacial ice. Ice cores from polar regions provide a record of changes in concentrations of chemical species over time scales ranging from seasonal to decadal. The process of air-to-snow transfer can filter, and potentially distort, atmospheric signals before they can be preserved in the glacial record.

CRREL researchers are examining the physical processes that affect the manner in which heat, vapor and chemical species in air are incorporated into snow and polar firn. These processes control the rate at which reactive and non-reactive chemical species in the atmosphere become incorporated into the snow, firn and polar ice and, thus, affect interpretation of the polar ice-core data. The objectives of the research are to:

- define the magnitude and extent of these transfer processes, and
- develop a process-level understanding and modeling capability for the snow and firn.

Findings to date show that the firn at Summit, Greenland is very permeable and that layering is important in controlling diffusion and advection within the firn. Significant subsurface air movement in the firn is likely to occur under conditions of sustained winds, and large lateral flow can occur in buried hoar layers. ∎

Acoustic Aircraft Detection Over Polar Snow

The objectives of this research were to:

- measure acoustic aircraft signatures on the Greenland Ice Cap, and
- conduct basic acoustic measurements of parameters needed to model this environment.

Field studies during this program obtained actual signature measurements on a military aircraft as well as basic scientific information characterizing acoustic propagation, so that the effect of this environment could be assessed. The project provided information needed to assess the feasibility of acoustic detection of aircraft, cruise missiles or ground vehicles by unattended ground sensors in areas with a permanent polar snow cover.

Measurements of sound levels and spectral signatures of LC-130 Hercules fixed-wing aircraft were obtained during normal operational flybys, takeoffs and landings at Dye 2 in the center of the Greenland Ice Cap. Measurements were also made of controlled acoustic pulses propagating horizontally over the snow surface. Aircraft recordings were obtained under both calm and high-wind conditions. High winds significantly decreased the aircraft detection range, especially at low frequencies.

Controlled pulse experiments showed that surface conditions in these areas can change quite rapidly. The experiments provided information that will be used to construct an accurate propagation model. This information can be used in the design of new surveillance sensors and estimation of sensor performance in polar regions. ∎

Ground-Penetrating Radar and Northern Hydrology

Ground-penetrating radar (GPR) has been used to find useful water supplies on arctic floodplains in winter and important aquifers beneath permafrost in central Alaska year round. Most arctic river channels freeze completely by late winter. Those that don't freeze usually have ice blisters, caused by pressure from the confined water below the channel. Under all channels, thaw regimes containing water under pressure occur within the frozen alluvium.

Bottom and sub-bottom water has been profiled with high-resolution GPR operating at 500 MHz and has been verified by drilling. Excavations into the blisters have found hundreds of thousands of gallons of water. Some thaw regimes remain until mid-April and, therefore, probably never freeze completely. The regimes appear to be partially frozen but permeable, and they can produce limited flow for hours.

In central Alaska, within the broad Tanana Valley floodplain, permafrost is distributed discontinuously. At Fort Wainwright, deep aquifers, which can develop where permafrost does not extend into bedrock, transport water westward toward Fairbanks. Accidental spills and pipeline leaks can contaminate these aquifers by passing between zones of permafrost. CRREL researchers have used GPR to map sub-permafrost groundwater and frozen bedrock and to site monitoring wells. In many cases, the groundwater appears to be eroding the permafrost.

GPR has been used to define the top of the permafrost, groundwater within perennial thaw above permafrost, and intrapermafrost zones with high percentages of ice or organics. GPR at frequencies above 100 MHz best defines the near-surface features, while GPR near 50 MHz defines the deeper features. ∎

A Winter Concreting Breakthrough

Until recently, there have been no portland cement concrete mixtures that could reliably gain strength and resist frost damage when placed in below-freezing weather. Fresh concrete had to be kept warm by covering it with insulation or enclosing it within a heated shelter. The U.S. concrete industry spends an estimated $800 million every year to combat the cold. By adding chemicals that depress the freezing point of water and accelerate the hydration rate of cement, it is possible for concrete with an internal temperature below 0°C to gain strength at the same rate as additive-free concrete that is kept warm. The challenge was to find an effective combination of chemicals that would not harm the concrete.

Two prototype formulations were developed by W.R. Grace and Master Builders, respectively. Each prototype is capable of protecting concrete down to -5°C, while allowing the cold concrete to gain strength as if it were somewhere between 5° and 10°C. Additionally, the chemicals:

- did not corrode steel,
- did not react with siliceous aggregate,
- did not affect concrete workability, and
- did not reduce concrete durability.

Both prototype admixtures performed well in tests at the Soo Locks in northern Michigan during the winter.

Concreting with these new admixtures cost one-third less than concreting using conventional practice. ∎

Ilisagvik College

Recently, officials from CRREL traveled to Barrow, Alaska, taking the initial steps to enter into an educational partnership with Ilisagvik College (see *Witness*, Autumn 1996).

The mission of Ilisagvik College is to provide post-secondary academic, vocational and technical education to residents of the North Slope Borough, preparing them for employment and assisting them to live with dignity and economic independence while perpetuating and strengthening Inupiaq language, culture, values and traditions. (Ilisagvik translates in Inupiaq as “a place to learn.”)

Ilisagvik College is located on the North Slope of Alaska. This region, including the Bering, Beaufort and Chukchi seas are among the areas in which CRREL researchers have been working for many years investigating the physical, chemical and mechanical properties of snow and sea ice.

Students will have the opportunity to work and gain academic credits by filling varied roles in real-life projects. Other benefits to the college include equipment use and the possibility for faculty and students to work on-site at the Hanover and Fairbanks facilities; the laboratory staff will be available to act as mentors as well as assist in teaching and course development. CRREL will benefit by having a work force on the North Slope. Given the present impacts of downsizing, these and other working relationships with academia are seen as valuable assets for CRREL.

Partnership in Education

- Women in Science and Engineering Internships
- Disability Awareness
- High School Apprenticeship Program
- Junior Solar Sprint
- Ilisagvik College

NUWC's Off-Site Office

In 1994, the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island and CRREL jointly established a Naval Liaison Scientist Position at CRREL. The purpose is to:

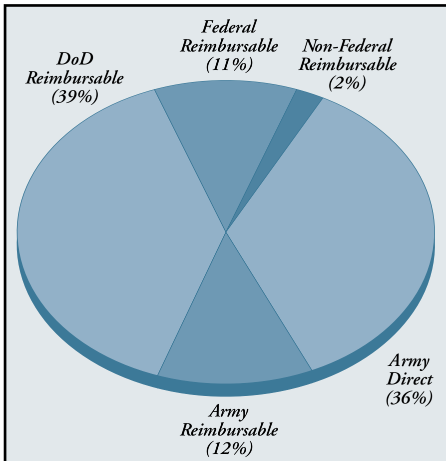
- sustain research and development capabilities associated with arctic-related issues that are of interest to both CRREL and NUWC, and
- foster technical exchange between two significant R&D organizations.

Since the establishment of this office, the two agencies have worked jointly on seven unique research efforts, including topics such as:

- a desalination process that occurs beneath the Antarctic ice shelves,
- the wetting process associated with geotextiles, and
- atmospheric icing of communications antennas.

In addition, an exchange technical lecture series enables scientists from each organization to visit and lecture at the host agency.

The intent of these combined efforts is to complement and enhance individual capabilities for current research and to attract future research projects.



Sources of CRREL research dollars for FY96: CRREL receives approximately one-third of its research budget directly from the Army. The rest comes from individual reimbursable programs based on written proposals. Most of the reimbursable money comes from Department of Defense (DoD) organizations and other federal agencies (e.g., NSF, NOAA, NASA, FAA, FHA).

The Cold Regions Center of Expertise

The Cold Regions Center of Expertise (CRCX), an organizational element of the U.S. Army Corps of Engineers, is a joint venture between the Corps' Alaska District operations in Anchorage, Alaska and CRREL in Hanover, New Hampshire.

Established in 1996, the CRCX effectively integrates the unique R&D expertise at CRREL and the practical technical knowledge and experience of the Alaska District to accomplish applied research, engineering, construction and operations in cold regions of the world. This partnership is based on a team approach with free and open exchange of information and technology, and an emphasis on technical excellence and customer orientation.

The CRCX maintains state-of-the-art facilities and technical expertise for developing research and engineering knowledge and for managing the design and construction of projects that are affected by the special demands of the cold regions.

Unique Facilities

- Ice Engineering
  - ice tank
  - flume
  - hydraulic model basin
- Frost Effects Research Facility
  - 12 test cells
  - 8 frost cycles per year
  - 24 cold laboratories (-35°F)
- Class 100 Clean Rooms
- Sleepers River Watershed
- Sea-Ice Ponds
- Remote Sensing/GIS Center
- Geophysical Research Facility
- Permafrost Research Site
- Research Permafrost Tunnel
- Cold Regions Science and Technology Information Analysis Center

For more information,
visit the CRREL Home Page on the Internet at:
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