

iii. *Remote Sensing of Snow Covered Sea Ice*: Energy will interact with the snow covered sea ice as a function of the physical characteristics. The basic premise of this work is that if both the state and seasonal evolution of the sea ice and snow microstructure are known, the interaction mechanisms at any wavelength of energy can be estimated. This leads to the idea that transfer functions must exist whereby interactions at one frequency may be used to estimate the interactions of energy at another frequency. Specific research issues being addressed within the *C-ICE* program include:

Visible wavelength extinction properties and those arising due to dielectric changes in the snow volume each arise from the same geophysical conditions, namely: an increase in the water which is in liquid phase; an increase in snow crystal size; and an increase in the brine concentrations within the snow pack. Therefore, inference of shortwave interactions may be possible using micro-wavelength energy.

Estimation of surface temperature, either directly through temperature inversion (thermal and passive microwave wavelengths) or indirectly through the seasonal evolution of active microwave interactions, will be a prime candidate proxy indicator of the state of the major components of the surface energy balance.

Due to atmospheric attenuation of incident visible wavelength radiation during the spring, micro-wavelengths are more appropriate for monitoring the metamorphic state of the snow covered ice surface than are visible wavelengths.

iv. *Ecosystem Studies*: The marine cryosphere provides habitat for a wide diversity of marine and avian species. The ramifications of change and variability must be coupled with adaptation responses of these biota since the biophysical processes are an integrator of the hydrospheric and atmospheric components of the system. Specific research postulates being address within the *C-ICE* program include:

What are the macroscale linkages between sea ice type and extent and their characterization as an ecosystem and how does this definition of an ecosystem change as a function of spatial and temporal scale?

Snow thickness distributions limit epontic primary production. Can remote sensing be used to provide proxy measures of biologically significant snow thickness distributions, either as a direct measure of photosynthetically active radiation transmission or indirectly as a function of ice surface roughness snow catchment area estimation?

Sea ice topography creates specific habitat niches for marine mammals. Can knowledge of ice surface roughness be used in establishing habitat preference?

The *C-ICE* field program provides the surface data required to develop an understanding of the process linkages operating in an environment typical of fast ice conditions in the Canadian Arctic Archipelago. A modelling component within *C-ICE* operates in conjunction with the field activities, although the modelling aspects will assume greater importance as the existing field data are analyzed. The principal objective of this subgroup is to integrate the field data within numerical models of the primary processes operating in our area of interest, for the expressed purpose of 'scaling up' observations to more regional scales.

Agencies participating in *C-ICE'99* include: Centre for Earth Observation Science (University of Manitoba) (lead agency); Canadian Ice Service, Polar Continental Shelf

Project and Energy, Mines and Resources Canada, Environment Canada; Canada Centre for Remote Sensing; Atmospheric Environment Service, Downsview, Ontario; National Research Council, Ottawa, Ontario; Jet Propulsion Laboratory, Pasadena, California; the Winnipeg Climate Centre and Transport Canada.

Malawi Project Executive Summary

This report marks the end of the second and final period of data collection by CEOS in the Lake Malawi Biodiversity Conservation Project. This report is the second volume of a two volume set, and provides a summary and archive of data collected in Malawi from September 98 to July 31, 1999. Data and preliminary results are provided for the aquatic and terrestrial projects described in Barber and Cooley (1997): 1) coastal and littoral habitat 2) sediment plumes, and 3) soil erosion potential. Each is summarized below.

1.0 Biodiversity Atlas

The primary objective of the biodiversity atlas study is to better understand the distribution of cichlid species richness (R sp) among and within littoral habitats in Lake Malawi. In a hyper-diverse and large system, the understanding of the physical processes which influence species diversity can only be obtained at a small number of sites. At the same time, there is a need to understand the patterns of distribution of R sp at regional and lake wide scales for conservation planning. Because a trade-off exists between statistical replication at sites (to gain an understanding of processes) and increasing spatial scale in ecosystem studies (need for a lake wide conservation strategy), a hierarchical scale approach will document habitat and species characteristics at three spatial scales: sites, regions, and system. The hierarchical approach will enable models developed at the site scale to be evaluated at the regional scale, and conditionally implemented at a lake wide scale. This scalar approach will also document our ability to collect and understand map variables from ratio data at sites, to ordinal at the system scale.

1.1 Coastal and Littoral Habitat and Biodiversity

The objective of the 1999 field surveys was to acquire shoreline information for the entire lake, collect regional substratum and depth data from littoral areas within Lake Malawi National Park, and to collect substratum habitat and species richness data at sites. Lake wide shoreline information was collected using aerial video frame surveys for classification of rock, sand, and vegetated coasts. Regional coastal data was collected using optical remote sensing imagery and global positioning system data. Littoral depth and substratum maps were collected using digital sonar coupled to a GPS. Sonar data are used to evaluate the role of wave energy in controlling the distribution of sediment boundaries, and to learn slope thresholds for rock, sand, and deposition classes. The estimates of slope from the detailed depth data are intended for comparison to slopes derived from the more general lake wide bathymetry. Site scale habitat and species

richness data serve to demonstrate the short term temporal variations of species richness at sites, and the effect of habitat complexity on species richness.

2.0 Linthipe River Plume Study

The impact of increased sediment loading on either primary production or littoral habitat depends on the depth in the lake to which the fluvial plume is carried. For the Linthipe River, at least part of the discharge mixes in the near surface waters of Lake Malawi, as is evidenced by the visible surface plume that typically spreads out to the northeast. However, a significant part of the river water plunges and either attains buoyancy and spreads into the lake along density gradients, or continues downward, possibly as turbidity currents. In either case, sediment are swept past the littoral zone with less widespread or persistent effect there than if the river mixed entirely with shallow waters.

The main objective of the sediment plume study is to determine and model the spatial and temporal dynamics of sediment delivery into Lake Malawi from a major river, with particular emphasis on the effects of potential changes in fluvial sediment load and concentration, and the relationship with nearshore lake circulation. The plume of the Linthipe River in Lake Malawi has been mapped during two rainy seasons by CTD-turbidity (conductivity-temperature-depth-turbidity) profiles along transects off the river mouth. During the 1999 rainy season, turbidity and circulation were mapped simultaneously with an Acoustic Doppler Current Profiler. These data will be used to validate a model of the dispersal of sediment discharged by the Linthipe River. Gross sedimentation rates predicted by the model will be mapped over the area of the plume. The model will allow evaluation of impacts for model variables that may be expected to change with increasingly intense land use, i.e. sediment load, sediment concentration, river discharge and river water temperature. Satellite imagery will be used to map surface suspended sediment patterns at the mouths of all major rivers influent to Lake Malawi.

3.0 Soil Erosion Study

Removal of vegetative cover through anthropogenic activities such as deforestation and agriculture, is the likely main cause of accelerated (human-induced) soil erosion in the watersheds of Lake Malawi. Studies elsewhere have shown that the vulnerability of lakes to eutrophication and sedimentation is partly controlled by the way watersheds are exploited. Sediments and nutrients from watersheds are discharged into lakes where they reduce habitat quality, feeding and breeding of ichthyofauna, and reduce primary productivity. It is therefore postulated that sediments and nutrients from Lake Malawi's watersheds also pose a serious threat to the biodiversity of the lake, which is the richest and most diverse in the world. It is further speculated that smallholder and commercial farmers probably employ different soil loss control strategies that are commensurate with their priorities and resources. Therefore, different farming systems are sources of different rates of soil loss.

This study is a Ph.D. thesis research in the Geography Department at the University of Manitoba. The research was conducted under the auspices of the SADC/GEF Lake

Malawi/Nyasa/Niassa Biodiversity Conservation Program (LMBCP), which is a regional research project involving three riparian countries, i.e., Malawi, Mozambique, and Tanzania. The study used a questionnaire survey to ascertain the soil conservation methods used under different farming systems, and verify the link between soil loss and farming practices within Lake Malawi's watersheds. The link, it is hoped, will be useful in identifying critical sources of sediment discharges so that soil conservation efforts can be concentrated on such areas. Too often expensive conservation work has been carried out on areas of land, which were thought to be important sediment sources but in fact were not. The study is also using a predictive soil loss model so that the factors that play major roles in soil erosion are combined to predict rates of erosion under any combination of soil, rainfall, slope and vegetation.

This report summarises the types of data that were collected during the course of the research. It briefly presents the methods used in collecting the data, and the use into which the data will be put. This report serves two purposes. First, it acts as a progress report to all the interested parties, i.e., academic advisor, donors, LMBCP management, fellow students, and the riparian states. Secondly, the report acts as a road map for the thesis research. It helps to identify gaps in the data collected so that they can be filled timely.

GlobeSAR projects- CEOS is partnered with the University of Pariaba and the University of Beunos Airies on two Radarsat related projected relating to climate change impacts in South America. The Space Agency provides funds for academics from the South American Universities to come up to the U of M and for us to travel to their labs.

CEOS is a founding member of the Lake Winnipeg Research Consortium. This summer was the second field season for this group and CEOS actively collected field data for 10 days on the Lake as well as obtaining the remote sensing data for the entire field season of the group. CEOS also provided a portable GPS data collection system for use in vessel tracking on the Lake. CEOS is actively looking for graduate students to join this exciting project.

High latitude climate change research – CEOS continues to lead a longitudinal climate change research programme in the high arctic. We conducted field projects there in the spring of 1998 and 1999. These projects are part of a 10 year dataset on the processes of arctic climate change. Partners in this work are Environment Canada, AES, DFO, CCRS, CSA and NASA.

The project 'Measuring tundra productivity and vegetation structure from cloud-free weather satellite (geocomp-n) data' has completed the first field season in TUKTUK nagate National Park. This project is a research partnership between the Parks Canada Agency and the University of Manitoba. The aim of the present partnership between Parks Canada and CEOS is to improve the interpretation of the GEOCOMP-n satellite data that Parks Canada is currently using as a monitoring tool in its northern parks.

Dr. Barber will lead a research program using archived Landsat MSS data to map the magnitude and interannual evolution of total suspended solids (TSS) within regions affected by the Lake Winnipeg-Churchill-Nelson regulation.

CFI Equipment application for Ship board instrumentation was successful though Laval.

Completed Projects:

North Water Polynya Project – D. Barber was selected (through a national competition) as the Principle Investigator for the Sea ice-climate dynamics subgroup of this Arctic climate change project. The field component of the project was conducted in the NOW region in the spring and summer of 1998. We are currently working towards a special issue of the journal, Atmosphere-Ocean as a contribution from our group to the national NOW initiative. NSERC funded national network program (5 million in NSERC support and 11 million from international partners)

Annual Geomatics Workshop:

This year's focus was GIS and Remote Sensing; the tools to study Climate Change Adaptations and Impacts. This two day workshop was funded by a grant from PARC and was attended by over 100 individuals.

Meetings:

Hosted the National CRYSYS climate change meeting in Winnipeg (March, 2000)

Academic Contributions

Primary Publications

Barber, D.G. and Yackel, J. 1999. The physical, radiative and microwave scattering characteristics of melt ponds on sea ice. *International Journal of Remote Sensing*. In Press (July, 1998)

Perovich, D.K. D. Barber, G. Cota, A.J. Gow, T.C. Grenfell, A.J. Hunt, R.A. Maffione, C.D. Mobley, R.O. Onstott, W.W. Pegau, and C.S. Roesler. Field Observations of the electromagnetic properties of first-year sea ice. *IEEE Transactions on Geoscience and Remote Sensing*. ONR ARI special issue. 36(5):1705-1715.

Barber, D.G., and S.V. Nghiem. 1999. The role of snow on the thermal dependence of backscatter over sea ice. *Journal of Geophysical Research (Oceans)*. In Press (July'98).

Hanesiak, J.M., D.G. Barber and G.M. Flato. The Role of Diurnal Processes in the Seasonal Evolution of Sea Ice and its Snow Cover. *Journal of Geophysical Research (Oceans)*. , 104(C6),13593-13604.

Iacoza, J. and D.G. Barber. Modelling the Distribution of Snow on Sea Ice Using Variograms *Atmosphere-Oceans*. In Press (Sept'98)

Yackel, J. and D. G. Barber. An Examination of the Morphological, Climatological and Microwave Scattering Characteristics of Melt Ponds on Landfast First-Year Sea Ice using RADARSAT-1. *Journal of Geophysical Research-Oceans* (March'99).

Barber, D.G., J. Yackel and J. Hanesiak. 1999. Perspectives on Sea Ice, RadarSat-1, and Arctic Climate Change. ADRO special issue, *Canadian Journal of Remote Sensing*. In Review (April'99)

Hanesiak, J.M, D. G., Barber, R. De Abreu and J.J. Yackel. An Examination of the Role of Melt Pond Broadband and spectral Albedo in Sea Ice Ablation. *Journal of Geophysical Research-Oceans*. (June'99).

Macey, S.M., Smith, G.C. and Watkins, J.F., "Aging and the Aged," In Gaile, G.L. and Willmott, C.J. (eds.), *Geography in America at the Dawn of the 21st Century*, New York: Oxford University Press, in press.

Ingram, G, D.G. Barber and J.M. Hanesiak, 1999: The North Water Polynya: An Overview. *Atmos.-Ocean* (in review).

- Yackel, J.J., D.G. Barber and J.M. Hanesiak, 1999: An examination of the morphological, climatological and microwave scattering characteristics of melt ponds on landfast first-year sea ice using Radarsat-1, *J. Geophys Res.* (in review).
- Hanesiak, J.M., T.N. Papakyriakou and D.G. Barber, 1999: Parameterization schemes of incident radiation in the North Water. (to be submitted to *Atmos.-Ocean NOW* special issue).
- Szeto, K.K., Halvey, I., J.M. Hanesiak, R.W. Crawford, R.E. Stewart and G.W.K. Moore, 1999: The Beaufort mesoscale vortex: Its structure, evolution and occurrence. *Atmos.-Ocean*, in press
- Barber, D.G. and Yackel, J. 1999. The physical, radiative and microwave scattering characteristics of melt ponds on sea ice. *International Journal of Remote Sensing* 20(10):2069-2090.
- Barber, D.G., and S.V. Nghiem. 1999. The role of snow on the thermal dependence of backscatter over sea ice. *Journal of Geophysical Research* 104(C11). 2,5789-25,803
- Hanesiak, J.M., D.G. Barber and G.M. Flato. 1999. The Role of Diurnal Processes in the Seasonal Evolution of Sea Ice and its Snow Cover. *Journal of Geophysical Research (Oceans)*. 104(C6):13593-13604
- Iacoza, J. and D.G. Barber. 1999. Modelling the Distribution of Snow on Sea Ice Using Variograms *Atmosphere-Oceans*. 37: 21-51
- Yackel, J., J. Hanesiak, and D. G. Barber. Melt ponds on sea ice in the Canadian Arctic Archipelago. Part 1 – Variability in morphology and surface radiation. *Journal of Geophysical Research-Oceans* 105(C9): 22,049-22060.
- Yackel, J. and D. G. Barber. Melt ponds on sea ice in the Canadian Arctic Archipelago. Part 2. On the use of RADARSAT-1 synthetic aperture radar for geophysical inversion. *Journal of Geophysical Research-Oceans*. 105(C9):22,061-
- Barber, D.G., J. Yackel and J. Hanesiak. 1999. Perspectives on Sea Ice, RadarSat-1, and Arctic Climate Processes. *ADRO special issue, Canadian Journal of Remote Sensing*. In Press (May'00)
- Hanesiak, J.M, D. G., Barber, R. De Abreu and J.J. Yackel. An Examination of the Role of Melt Pond Broadband and spectral Albedo in Sea Ice Ablation. *Journal of Geophysical Research-Oceans*. In Press (Aug'00).
- Barber. D.G., E. Saczuk, and P. Richard. Examination of beluga-habitat relationships through the use of Telemetry and GIS. *Arctic*. In Press (May'00).
- Hanesiak, J.M., D.G. Barber T.N. Papakyriakou and, P.J. Minnett,. Parameterization Schemes of Incident Radiation in the North Water Polynya. *Atmosphere-Ocean NOW special issue*. In Press (July'00).
- Wilson, K, D.G., Barber, and D. King. Validation and Production of RADARSAT-1 Derived Ice Motion Maps in the North Water Polynya (NOW), January-December 1998. *Atmosphere-Ocean NOW special issue*. In press (June'00).

- Yackel, J., D. G. Barber and T.N. Papakyriakou. On the effect of snow thickness in the temporal evolution of landfast first-year sea ice RADARSAT-1 scattering. *Annals of Glaciology*. International Glaciological Society. In press (July'00).
- Yackel, J. and D.G. Barber and T.N. Papakyriakou. On the Estimation of Spring Melt in the North Water (NOW) using RADARSAT-1 SAR. . *Atmosphere-Ocean NOW special issue*. In press (July'00).
- Mundy, C.J., and D. G. Barber. On the relationship between the spatial and temporal evolution of sea ice patterns and the physical mechanisms creating and maintaining the NOW polynya. *Atmosphere-Ocean NOW special issue*. In Review (August'00).
- Barber, D.G., J. Hanesiak, W. Chan and J. Piwowar. Spatial and temporal patterns of sea ice/atmosphere processes within the NOW polynya between 1978 and 1996. *Atmosphere-Ocean NOW special issue*. In review (August, 2000).
- Barber, D., J. Iacozza, and A. Walker. On the Estimation of Snow Water Equivalent (SWE) using microwave Radiometry over First-Year Sea Ice. *Photogrammetric Engineering and Remote Sensing*. In Review (May, 2000).
- Nghiem, S.V., D.K. Perovich, A.J. Gow, R. Kwok, D.G. Barber, J.C. Comiso. Observation of Sea Ice Surface Thermal States under Cloud Cover. *Journal of Geophysical Research (Oceans)*. In review (June, 2000).
- Wilson, K, D.G., Barber, and D. King. A Case Study in Tracking 1998 Spring Ice Dynamics in the Smith Sound, North Water Polynya Region using RADARSAT-1, *Annals of Glaciology*, International Glaciological Society. In press (August'00).
- Hochheim, K.P. and D.G. Barber, 2001, The seasonal backscatter of agricultural crops as observed by RADARSAT-1. Part I. Wheat. *International Journal of Remote Sensing*. In review.
- Hochheim, K.P. and D.G. Barber, 2001, The seasonal backscatter of agricultural crops as observed by RADARSAT-1. Part II. Canola. *International Journal of Remote Sensing*. In review.

International Field Work

Participated in research in the northwestern Argentina monitoring desertification using RADARSAT and optical satellite data. Work conducted under GLOBESAR-2 in cooperation with the University of Buenos Aires. Feb 29 - Mar 10, 2000.

Presentations/Seminars

Hochheim, K.P. Microwave remote sensing of agricultural crops. Presentation at the University of Buenos Aires, Argentina, March 9, 2000.

PARC RS/GIS Conference. Dave I don't have the details, Title of presentation, name of conference University of Manitoba, June 5, 2000

Current Remote Sensing Technology in Agricultural Monitoring. *Remote Sensing and GIS: The Tools to Study Climate Change, Impacts and Adaptations*, June 8-9. University of Manitoba. Centre for Earth Observation Science, Department of Geography.

Cooley, P. M., 2000. Mapping biodiversity and habitat and its utility to management. State of Current Knowledge on the Lake Malawi/Nyasa ecosystem and its application to Future Management. 4 October 2000, World Bank Group Headquarters, Washington, D.C.

F.X. Mkanda, 2000. Determinants of Soil Erosion and Conservation Options in Malawi Catchment State of Current Knowledge on the Lake Malawi/Nyasa ecosystem and its application to Future Management. 4 October 2000, World Bank Group Headquarters, Washington, D.C.

Conference Papers

Barber, D. 1999. "Geomatics" Presented at the first annual GIS Modelling Workshop, co-sponsored by the Departments of Geography, Botany and Civil and Geological Engineering, University of Manitoba, June 24-25th, 1999

Barber, D. 1999. Snow on Sea Ice. Eastern Snow Conference. IAHS meeting. Fredericton, NB. May '99.

Barber, D. 1999. Response of Sea Ice to Climate Change. Arctic Climate Change Workshop. Victoria B.C. February, 1999.

Kenkel, N. 1999. "Spatial Statistical Analysis in GIS" Presented at the first annual GIS Modelling Workshop, co-sponsored by the Departments of Geography, Botany and Civil and Geological Engineering, University of Manitoba, June 24-25th, 1999

Valeo, C. 1999. "Hydrological Modelling and GIS". Presented at the first annual GIS Modelling Workshop, co-sponsored by the Departments of Geography, Botany and Civil and Geological Engineering, University of Manitoba, June 24-25th, 1999.

Yackel, J.J., 1999. An evaluation RADARSAT-1 for geophysical inversion of melt pond characteristics over sea ice. The 1999 Prairie Division of the Canadian Association of Geographers Annual Meeting, Winnipeg, Manitoba, 24-26 September (oral presentation given)

Yackel, J.J., D.G. Barber and J.M. Hanesiak., 1999. An Examination of the Morphological, Climatological and Microwave Scattering Characteristics of Melt Ponds on Landfast First-Year Sea Ice using Airborne Videography and RADARSAT-1. Proceedings, Fourth International Airborne Remote Sensing Conference and Exhibition/21st Canadian Symposium on Remote Sensing, Ottawa, Ontario, 21-24 June (interactive presentation given).

Yackel, J.J., 1999. Microwave Scattering Characteristics of Melt Ponds on Landfast First-Year Sea Ice using RADARSAT-1. GIS Workshop: From Theory to Application, 24-25 June (oral presentation given).

Yackel, J.J., D.G. Barber and J.M. Hanesiak., 1999. Microwave Scattering Characteristics of Melt Ponds on Landfast First-Year Sea Ice using RADARSAT-1. Proceedings, The Canadian Association of Geographers 1999 Annual Meeting, Lethbridge, Alberta, 1-5 June (oral presentation given)

Smith, G.C. and Sylvestre, G.M., "Locational Aspects of Government-Subsidized Senior Citizen Apartment Buildings in Winnipeg," Annual Spring Symposium, Centre on Aging, University of Manitoba, Winnipeg, Manitoba, May, 1999.

Sylvestre, G.M. and Smith, G.C., "Locational Aspects of Low-Rent Senior Citizen Apartment Buildings in Winnipeg," Annual Meeting, The Canadian Association of Geographers, Lethbridge, Alberta, June, 1999.

Workshops/Meetings

Yackel, J.J. conducted a week long research investigation of Sea Ice Decay at the Canadian Ice Service, Ottawa, Ontario, 13-21 June, 1999.

Yackel, J.J. talked on Arctic Climate Change: A Sea Ice Perspective. Issues in the North Seminar Series, Department of Native Studies, 29 September, 1999.

Cooley, P. M., G. K. McCullough, F.X. Mkanda and R.G. Brook, 2000. CEOS Data Report in Support of the Lake Malawi Biodiversity Conservation Project, Malawi, Africa: Volume II. Centre for Earth Observation Science Data Report 00 -15-1. 189 p.

Cooley, P. M., J. Snoeks, A. J. Ribbink, F. Duponchelle, A.B. Thompson, R.S. Sululu, and P. Hamblin, 2000. A Biodiversity Atlas for Lake Malawi Final Report. Centre for Earth Observation Science Technical Report, 7 - 1 - 00. 71 p.

Sources of Funding

CEOS receives an annual operating grant from the Faculty of Arts. The Department of Geography and CEOS also collaborate on providing teaching and research facilities within the Department. Currently we have one undergraduate lab, and two graduate research labs. The following research grants were obtained within the reporting period.

| Principal Investigator | Grant Description |
|-------------------------------|--|
| Barber, D.G., | Fisheries and Oceans support for establishment of a Centre for Northern Studies at the University of Manitoba |
| Barber, D.G., | Manitoba Conservation support for establishment of a Centre for Northern Studies at the University of Manitoba |
| Barber, D.G., | Prepare and deliver a national workshop on the role of Earth Observations in climate change (PARC) |
| Barber, D.G., | Supplemental funding for CRYSYS'99 funding |
| Barber, D.G. | NSERC Equipment Grant – This is an equipment grant to purchase a UNIX workstation for numerical modelling |
| Barber, D.G. | Meteorological Services of Canada. Research Grant to examine the role of clouds in microwave emission over sea ice. |
| Barber, D.G. | Meteorological Services of Canada. Research Grant to link microwave remote sensing to a one-dimensional thermodynamic model of snow covered sea ice. |
| Barber, D.G. | Support from the Department of Fisheries and Oceans for training of two graduate students (1 PhD and 1 masters) as part of the Lake Malawi Biodiversity Conservation Program |
| Barber, D.G. | Sea Ice/Climate Dynamics subgroup of the North Water Polynya Study (NOW). Research grant from NSERC for a National Network. |

- Barber, D.G. Sea Ice/Climate Dynamics subgroup of the North Water Polynya Study (NOW). Research grant from NSERC for a National Network.
- Barber, D.G. Canadian Climate Centre, Atmospheric Environment Service. Research Grant to develop a technique for estimation SWE over snow covered sea ice.
- Barber, D.G. Canadian Climate Centre, Atmospheric Environment Service. Research Grant to investigate approaches available for linking remote sensing data within numerical climate process models
- Barber, D.G. Canadian Ice Services, Environment Canada, Support in Kind for the NOW polynya study
- Barber, D.G. Canadian Ice Services, Environment Canada, Research Grant to support the NOW polynya study
- Barber, D.G. Arctic Ice Regime Shipping System research project supported by Transport Canada and Canadian Ice Services
- Barber, D.G. National Ice Services, Washington, DC. Research Grant to support the NOW polynya study
- Barber, D.G. Arctic Ice Regime Shipping System research project supported by Canadian Ice Services
- Barber, D.G. Arctic Ice Regime Shipping System (Phase 2 and 3) research project supported by Transport Canada and Canadian Ice Services
- Barber, D.G. NSERC Operating Grant - This is a four year grant for general research support from the Natural Sciences and Engineering Research Council.
- Barber, D.G. NOW sea ice collaborative research with the Canadian Ice Services
- Barber, D.G. Globesar projects for collaborative research work in Argentina, Brazil and Peru. Funds are provided by CCRS for travel between

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| | labs, per diem support and collaboration on field research. |
| Barber, D.G. | Northern Studies Training Program to support the C-ICE'99 experiment |
| Smith, G. | SSHRC research grant (1998-2001). Effects of Local Environments upon the Adjustments of Movers to Senior Citizen Housing. |
| Barber, D.G. | Collaborative research grant from the Centre for International Forest Research (CIFOR) in Indonesia |
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The centre has a reasonably good financial status. Most of the CEOS research support money goes to student stipends and equipment. The operating grant from the Faculty of Arts will have to be increased in the near future if we are to maintain the level of research and funding activity currently enjoyed by CEOS.

Infrastructure

New equipment purchases:

- SUN Ultra 60 UNIX server and 4 SUN Ray remote terminals for data analysis and modeling has been purchased with a NSERC equipment grant (see Barber).
- Paramotor for aerial remote sensing

Research Facilities

Technologically, CEOS considers remote sensing, geographic information systems, image analysis systems, global positioning systems, computer modeling and analytical methods as an integrated set of 'Geomatics' tools.

- Computer Hardware/software:

State-of-the-art network computer facility with modern industry standard software. CEOS through the University of Manitoba is part of a GIS consortium, which has entered into a province wide licensing agreement with ERSI to provide industry standard GIS software to students regardless of which institute they are attending.

- Field equipment:

two vis/NIR spectrometers, differential GPS base station and rover units, surface energy balance and cloud physics instrumentation (radiometers, psychrometers, ceilometers, and an all sky cameras)

Data:

- MOUs between CEOS and the Province of Manitoba (Land Information Branch), NASA, CSA, NASDA, and ESA for access rights to data - with the qualification that these data must be used for research.
- The University of Manitoba Libraries has entered into a licensing agreement with Linnet Geomatics to make the Land Information Navigator data available on campus. CEOS is the repository of one of four University held sets of these data.

Web Address

To be kept up-to-date with the variety of CEOS activities and to be informed of upcoming events, check our World Wide Web page regularly. You can find us at:

www.umanitoba.ca/ceos

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emails: David Barber – dbarber@ms.umanitoba.ca

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