Eurasian Reindeer Pastoralism in a Changing Climate: Indigenous Knowledge & NASA Remote Sensing

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Introduction

The Arctic is home to many indigenous peoples, including those who depend on reindeer herding for their livelihood in one of the harshest environments in the world. For the largely nomadic peoples, reindeer not only form a substantial part of the Arctic food base and economy, but they are also culturally important, shaping their way of life, mythologies, festivals and ceremonies. Reindeer husbandry has been practiced by numerous peoples all across Eurasia for thousands of years. Having learned over generations to live with uncertainties in an Arctic environment, societies that practice traditional reindeer husbandry are good examples of sustainable human communities that are highly interconnected with the ecosystems in which they live. Climate change and variability plus rapid development are increasingly creating major changes in the physical environment, ecology, and cultures of these indigenous reindeer herder communities in the North, and climate changes are occurring significantly faster in the Arctic than the rest of the globe, with correspondingly dramatic impacts. (Oskal, 2008))

Meanwhile, as discussions about the rate and impacts of climate change continue around the world in the scientific and popular press, the reindeer herding community has recently taken leadership in a bold new direction to develop local adaptation strategies based upon their traditional knowledge of the land and its uses – in targeted partnership with the science community - involving extensive collaborations and co-production of knowledge to minimize the impacts of the various changes. This unprecedented new reindeer herder-led initiative has resulted in the development of the international, interdisciplinary collaboration with scientists through the IPY EALAT Consortium (IPY Project # 399 "EALAT, Reindeer Herding in a Changing Climate") and directly addresses the herders' need for better data and information for responding to the global and environmental changes through a variety of different projects (www.EALAT.org).

The IPY EALAT project ("Reindeer Herding in a Changing Climate") was initiated by the Association of World Reindeer Herders (WRH), a circumpolar indigenous peoples' organization with observer status in the Arctic Council. Under the leadership of indigenous reindeer herding community, EALAT is an interdisciplinary, intercultural study that is assessing the vulnerability of reindeer herding, a coupled human-ecological system, to change in key aspects of the natural and human environments, actively involving reindeer herders, linguists, remote sensing scientists, meteorologists, lawyers, anthropologists, biologists, geographers, philosophers (the ethical dimension) as well as indigenous institutions and organizations, relevant industrial enterprises and management authorities. The name of the project, EALAT, which comes from the word "pasture" in the Sámi language, reflects the emphasis of the project on the close connection these cultures have to the environment in which they live. It focuses on the adaptive capacity of reindeer pastoralism to climate variability and change and, in particular, on the integration of reindeer herders' knowledge with scientific research and analysis of their ability to adapt to environmental variability and change. (www.EALAT.org)

The IPY EALAT project partners believe that it is critical to empower indigenous peoples in Eurasia with the best technologies available to combine with indigenous knowledge for achieving a truly sustainable development of the Arctic. The EALAT team also believes it is important that indigenous peoples' traditional knowledge is integrated into the future management and monitoring of the reindeer pastures and their societies. In addition, it is important to remember that building competence locally about land cover land use change, including tools such as satellite observations and geographic information systems (GIS), is one important factor which could increase future adaptive capacity locally in Eurasian reindeer herding societies. Thus, developing training programs as well as EALAT monitoring systems for Eurasian reindeer herders, which will extend well beyond the international Polar Years (IPY) must have a high priority. In the IPY EALAT Consortium, EALAT-monitoring is already endorsed as a future expert monitoring network in the Circumpolar Biodiversity Monitoring Program of the CAFF Working Group of the Arctic Council (CAFF, 2006). The data collected in IPY will be the start of a future place-based monitoring system of reindeer herders' pastures and societies, while at the same time representing a unique opportunity for validation of satellite imagery in cooperation with the NASA LCLUC program.

This chapter provides preliminary results from the IPY EALAT project of the impacts of climate change and industrial development on reindeer husbandry and description of how traditional reindeer herding societies in the Arctic could reduce the risks of change by using modern technology. It also describes the innovative approach by the EALAT project in which indigenous reindeer herders are leading the process of integrating indigenous knowledge with scientific data and other information such as NASA remote sensing data to provide increased capabilities for community monitoring, risk mapping, and surveillance of parameters critical to the characterization of pasture quality and migratory routes, such as forage quality, snow changes, and infrastructure development. This is different from past studies in which traditional knowledge has been added (or not) to scientific studies or studies in which indigenous people have often been a subject of the research; instead, indigenous reindeer herders are leading this study, and have invited scientists and other colleagues to collaborate. The EALAT studies are still in an early stage of field work and data collection, with extensive results expected over this coming year. The purpose of this chapter is to show the value and depth of indigenous knowledge related to reindeer husbandry, demonstrate the importance of true collaboration between indigenous and scientific scholars, help make scientists aware of this new model for collaboration as an important new paradigm for cooperation between indigenous and non-indigenous scholars, and provide some preliminary results from the first year of the EALAT project, including, preliminary studies of some combined uses of NASA data and observations and indigenous knowledge for reindeer husbandry from an earlier NASA LCLUC pilot project, "Reindeer Mapper".

1.1 Reindeer Husbandry across the Arctic – Background and Challenges

Reindeer husbandry has a long history in the Arctic. There are more than 20 different indigenous peoples in the Arctic who are reindeer herders. Reindeer husbandry is practiced in Norway, Sweden, Finland, Russia, Mongolia, China, Alaska, Canada and Greenland. This livelihood involves some 100,000 herders and approximately 2.5 million semi-domesticated reindeer, which graze approximately 4 million square kilometers in Eurasia. While reindeer husbandry is spread across the Arctic and across many cultures, its organization is remarkably similar everywhere, consisting of a nomadic livelihood with family-based working communities and a typical indigenous way of life. For hundreds of years, reindeer herders have managed vast barren circumpolar areas of land that hold little value for others. Herding represents a model for sustainable management of these areas that has developed through generations. In recent years, however, as noted earlier, Arctic reindeer herders increasingly face major challenges, such as climate change, loss of grazing land due to development by humans, and effects of global change in their local societies. (Oskal, 2008)

Figure 1. Eurasian indigenous peoples involved in reindeer herding.

Reindeer/caribou are the very base of the traditional economy for many indigenous northern peoples across the Arctic in Russia, Canada, Scandinavia, and Alaska. Rangifer tarandus, called reindeer or caribou, is the most common large land mammal of the Arctic and SubArctic, which gathers in large herds of tens to hundreds of thousands of animals on their calving grounds during the Arctic summer, and scattering widely in smaller groups for the remainder of the year (Hall, 1989). In Russia, the total number of domesticated reindeer in the region has decreased significantly within the last 100 years with particularly marked change from approximately 2.5 million in 1969 to 1.2 million in 2000 (Jernsletter and Klokov, 2002). This decline in numbers of reindeer in Northern Russia, which has by far the largest share of pasture lands (87%) and about 67% of all reindeer, is causing a serious decline in the reindeer husbandry industry, and, in turn is directly affecting the health and well-being of the indigenous peoples associated with reindeer husbandry (Schindler, D.L., 1994; Jernsletten and Klokov, 2002). This decline is not only causing poverty in the Russian indigenous communities associated with reindeer herding, but also, because reindeer husbandry is the very core of their traditional way of life, the decline is causing serious damage to the ethnic traditions and to the families of nomadic reindeer herders. (Abrjutina, 2003; Jernsletten and Klokov, 2002; Glazovsky et al, 2004).

In Norway, reindeer husbandry is the only industry where the number of people involved has increased over the past 50 years (Eira, A.J., 2001). However, while approximately 40% of mainland Norway is designated reindeer pastureland, there are serious threats to those lands from not only climate changes, but also loss of pastures by encroachment from development, tourism, damming of rivers, cultivation, oil and gas development, and roads and power lines, accompanied by similar impacts as are observed in Russia (Eira, A.J., 2001). In Finmark, which is the northernmost, largest and least populated county in Norway, there are approximately 2000 registered reindeer owners which represent 73% and 75% of semi-domesticated reindeer and Sami reindeer owners in Norway, respectively (Tyler et al, 2007). Reindeer in Finmark are managed in a transhumant method (Skjenneberg, 1989; Paine, 1994). Herds of mixed sex and ages (from hundreds to 10,000 reindeer) live on mountain pastures throughout the year, moving between inland winter pastures and coastal summer pastures (Tyler et al, 2007).

Climate Change and Development

The Arctic Climate Impact Assessment (ACIA), a large climate study initiated by the Arctic council, concluded that climate change is happening faster in Arctic areas than other regions of the world. For example, the study concluded that 10 years of climate change in the Arctic equals 25 years of climate change elsewhere in the world (ACIA, 2004). Reasons for this include reduction of snow and ice-covers and diminishing reflection of solar energy. Ice covered with snow will reflect 85-90 % of the sunlight, while seawater only reflects about 10 % and the earth surface about 20 % (ACIA, 2004). Therefore, ice melting will reduce solar energy reflection and increases Arctic temperatures, which will, in turn, lead to ice melting even faster. The changes in ice cover and increases in temperature have already impacted reindeer husbandry and will continue to do so both directly, for example through changes in food availability, and indirectly such as through changes in human land use. (Oskal, 2008)

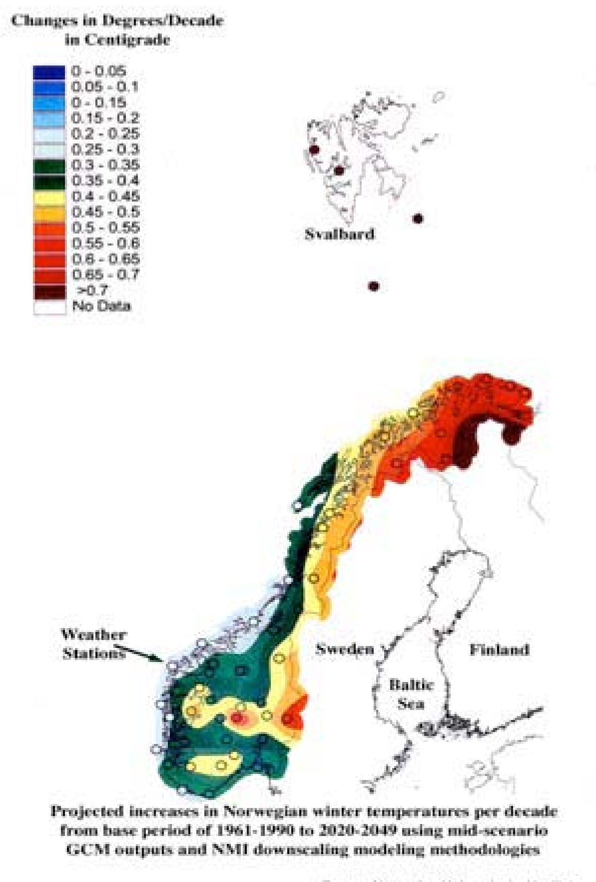

Figure 2. Future warming in Norway showing increased future temperatures in the north and east in region important for reindeer grazing in winter.

Changes in temperatures have already been observed. These changes could cause rivers to freeze later in the autumn and melt earlier in the spring, resulting in challenges for the annual migration of reindeer between different seasonal pastures. Warming-induced changes in freeze-thaw cycles are also creating problems. For example, as river and lake ice thaws earlier in the spring along migration routes, newborne calves can no longer cross the ice surface, but have to attempt crossing open waters, and large numbers of calves have been swept away by currents (ACIA, 2004). Another change that has already been observed is increasing climate variability at a local level. This is especially true during the critical wintertime, where increasingly periods of mild weather accompanied by rain will be followed by colder periods, form ice layers in the snow and block the reindeers' access to food on the ground. As reindeer live only on natural pastures, this often represents a "worst-case scenario" from the reindeer herders' perspective. Increasing precipitation in the form of snow can add to these challenges, while warming would shorten the period of snow cover in any particular year.

A deeper snow pack in winter can also make the reindeer more vulnerable to predator attacks (e.g., wolves) because the lighter wolves can travel on thinner snow crusts that reindeer sink through (Brotton and Wall, 1997). Increased insect harassment, accompanying warmer temperatures, is a second major factor shown to interfere with foraging. The outcome of this harassment is increased energy requirements, and results in a significant decline in body fat and lactation and decrease in calving success (Walsh et al 1992; Brotton and Wall, 1997; Gunn and Skogland, 1997). One example of recent climate impact is the unusually warm winter of 1996-1997, which was associated with a deep snow pack and icing, and which caused about 10,000 reindeer to die of starvation on Russia's far northeast Chukotsk Peninsula(Malcolm, 1996).

Reindeer herders have also observed major changes in biodiversity. A significant example of this is repeated occurrences of certain species replacing others, such as the spreading of shrubs into the barren tundra-areas (ACIA, 2004). Shrubs contribute to a hard packing of snow during the tough winter months, thus making access to food a challenge for reindeer. In addition, important food resources for the reindeer, such as lichens and reindeer preferred species of grasses, in time may disappear partially if not fully due to this shrub encroachment. Changes and/or increases in insect populations could also change reindeer behaviour during the summer by not allowing them to feed long enough in summer pastures due to increased harassment.

Indirect effects of climate change are also being observed, with major implications for reindeer pasture availability and migration routes. Due to the sea ice melting and longer summers, increased accessibility of the Arctic regions for human activities is a growing threat to reindeer herders. Human development and activities represent disturbances with negative effects for the semi-domesticated reindeer herds (UNEP, 2001) and irreversible loss of marginal pasture resources – a serious challenge for reindeer husbandry. In particular, female reindeer and calves will stay away from humans, physical installations and general human activity. In the last 50 years, for example, approximately 25 % of the reindeer pastures of the Euro-Arctic Barents Region have in effect been lost due to human development (Tyler et al, 2007).

Of particular relevance today is the fact that the Arctic is estimated to contain approximately 25 % of the world's remaining undeveloped petroleum resources (Forbes, 2000). For instance, Yamal in Western Siberia holds about 90 % of Russia's gas reserves, while also being the largest reindeer herding area of the world. Activities to access these resources would reduce the grazing lands, and are viewed as another human activity in the Arctic contributing to the reduction of the "available room for adaptation" for reindeer husbandry (Forbes, 2000). In fact, industrial development (e.g., pipelines and oil and gas infrastructure) has increased across reindeer migration routes in Northern Russia, blocking pathways to summer pasturelands (Forbes, 2000).

It is also expected that there will be a sharp increase in the near future in oil and gas development, mining, and other forms of development in the Russian North – accompanied by infrastructure, pollution, and other manifestations of human presence – which will increase future pressure on available pasturelands for the reindeer and the indigenous communities associated with them. (Forbes, 2000; Jernsletter and Klokov, 2002) Furthermore, future reductions in sea ice from global warming recently projected by the Arctic Climate Impact Assessment are very likely to increase the amount of marine traffic and general access to the Arctic and, as a result, significantly increase development as well as serious problems related to sovereignty, social, cultural and other environmental issues, which will directly impact the indigenous reindeer herding community. (ACIA, 2004)

Socioeconomic, Political and Other Pressures

Compounding the problem for the reindeer herding community in Russia, the transition of Russia to a market economy has, over the past few years, resulted in considerable disorder in many parts of the supply and transport systems in remote northern areas. This has resulted in serious disruption of any system of goods, services, and health care to northern Russian indigenous Peoples. (Abrjutina, 2003; Jernsletten and Klokov, 2002) Basic commodities such as paraffin lighting, fabrics, and vegetables or other foods are no longer easily available. The reindeer herders have also been cut off from any health care services at all, and, as a result of these factors combined, there are rapidly deteriorating health and living conditions in the reindeer herder communities, with growing death rates and serious health impacts. (Abrjutina, 2003; Jernsletten and Klokov, 2002)

For all of these reasons, the Arctic Council has called for the full attention of the international community to the situation in the reindeer herding industry and the critical state of the indigenous peoples of the North in Russia. The 2nd World Reindeer Herders' Congress (2003) reported that there is a "real threat of the complete loss of reindeer husbandry in large parts of eastern Russia" and "indigenous peoples connected with reindeer husbandry here face an ethnic disaster". These concerns were echoed once again recently at the 3rd World Reindeer Herders' Congress in March 2005. Since that time, the reindeer herding communities have increasingly continued to develop new partnerships and organizations to improve their collective abilities to respond to the challenges of climate change and development. For example, the Association of World Reindeer Herders in partnership with the Russian Union of Reindeer Herders, the Sami Reindeer Herders Association of Norway, and the Sami Council, were able to successfully launch the interdisciplinary, multi-partner EALAT study to address these many threats to reindeer herding through collaborative efforts to help prepare reindeer herders in Eurasia, their societies, institutions, and management for change, and accordingly, begin to reduce their vulnerability to these changes.

According to Nuttal et al (2008) environmental conditions clearly help to determine the extent to which people enjoy their basic rights to life, health, adequate food and shelter, and traditional livelihood and culture. However, more often then not, the most vulnerable members of society are those who suffer most from environmental problems. In this respect the indigenous peoples of the Arctic are in a central position, since they typically depend on their relationship with a sound environment not only for subsistence but also for the very basis of their cultures.

Socioeconomic adaptation to warming of the Arctic includes development of robust local economies based on the customary rights and traditional knowledge to produce local food for human consumption. The diversity of the food cultures of Arctic societies is rich, and based on local natural resources of high nutritional values. Constraining local food production by not respecting indigenous peoples' traditional food cultures and rights to produce their own food is also a serious threat to the ability of Arctic local societies to adapt to change.

Parts of the Arctic are unique in terms of the political settlements and land claims that have been achieved over the last thirty years or so. The extent of vulnerability and resilience to climate change not only depends on cultural aspects and ecosystem diversity, but on the political, legal and institutional rules which govern social-economic systems and social-ecological systems. On the one hand, climate change has the potential to enhance economic development, but with further climate change, the climate in the Arctic is predicted to become more variable and extreme weather events more frequent and severe, which on the other hand can undermine economic activities. Thus it seems particularly important that attention be given to the management of resources and to the effectiveness of governance institutions, and critical questions must be asked as to whether they can create additional opportunities to increase resilience, flexibility and the ability to deal with change.

Climate change threatens individuals, communities and livelihoods in the Arctic. However, if effective policy responses are to be developed, then the answers to the many questions will depend on a range of factors, including the importance of understanding the nature of the relationships between people, communities and institutions. Since adaptation to climate change is something that primarily takes place on the local level, it is important that indigenous peoples and local societies themselves define the risks related to rapid change. Adaptation to climate change will demand the training of local Arctic leaders in long-term sustainable thinking, based on the best available adaptation knowledge and modern monitoring technology. However, to succeed in developing preparedness and building competencies in local Arctic societies, adaptation to climate change must therefore be a high priority for national and regional governments and indigenous people's institutions and organizations. In addition, national adaptation strategies must recognise minorities, indigenous peoples' traditional knowledge, cultural and linguistics rights. It is important to highlight the need to link research to policy-making, by placing an emphasis on getting research messages to appropriate target groups, linking research to existing local knowledge of climate related hazards and involving local communities in adaptation decision making. In turn, education and awareness creation on climate change among governments, institutions, communities and individuals should be viewed as a necessary step in promoting adaptation to climate change in the Arctic, a region that is already under pressure from climate stresses which increase vulnerability to further climate change and reduce adaptive capacity.

Traditional Knowledge and Adaptation

The challenges reindeer herding communities are facing because of climate change and development are of such magnitude that we the best available knowledge must be used to formulate optimal adaptive strategies. In some cases, this knowledge is scientific, but often, the best knowledge is the experienced-based knowledge of the herders themselves. Reindeer herders and their reindeer live for eight to nine months a year in snow covered environments in constantly changing conditions. Temperatures can vary, for example, from +25 o C down to -65 o C. As both reindeer and herders have adapted to living in these conditions, reindeer herding cultures themselves represent an adaptation to extreme climate variability. Senior Sami reindeer herder and Secretary General of the Association of World Reindeer Herders, Johan Mathis Turi described that adaptation as follows:

> "…We have some knowledge about how to live in a changing environment. The term 'stability' is a foreign word in our language. Our search for adaptation strategies is therefore not connected to 'stability' in any form, but is instead focused on constant adaptation to changing conditions."

Reindeer husbandry involves moving herds of reindeer, which are very docile animals, from pasture to pasture depending on the season. This means herders lead either a nomadic life living in a tent on the Arctic tundra year-round as a family unit, or a semi-nomadic life, having permanent residences for parts of the year and having fewer family members herding on a daily basis. Thus, herders must adapt on a daily basis to find optimal conditions for their herds according to the constantly changing conditions.

Sámi reindeer herders have over 200 analytical expressions for snow and snow change in their language, and over 400 for reindeer, which represent an integral part of reindeer herders' traditional knowledge. When referring to 'traditional knowledge', this knowledge is not outdated knowledge, but rather critical knowledge used by reindeer herders in their everyday lives. Such traditional knowledge both could and should be tested and integrated with scientific knowledge to provide the best possible knowledge foundation for the future. Constraints on use of reindeer herder's traditional knowledge resulting from national legislation is an important challenge when discussing adaptation to climate change. EALAT studies are under way to attempt to capture that knowledge for future strategy-development.

The Arctic has experienced a rapid temperature increase similar to the one which occurred in the 1920s-30s, but with more variation. Figure xx shows historic changes in average air temperatures in the Arctic (Annual average change in near surface air temperature from stations on land relative to the average for 1961-1990, for the region from 60 to 90°N) (ACIA, 2005). There are still reindeer herders alive who have knowledge about how reindeer husbandry adapted during that time and that knowledge is very important for the 21st century and the development of new adaptation strategies.

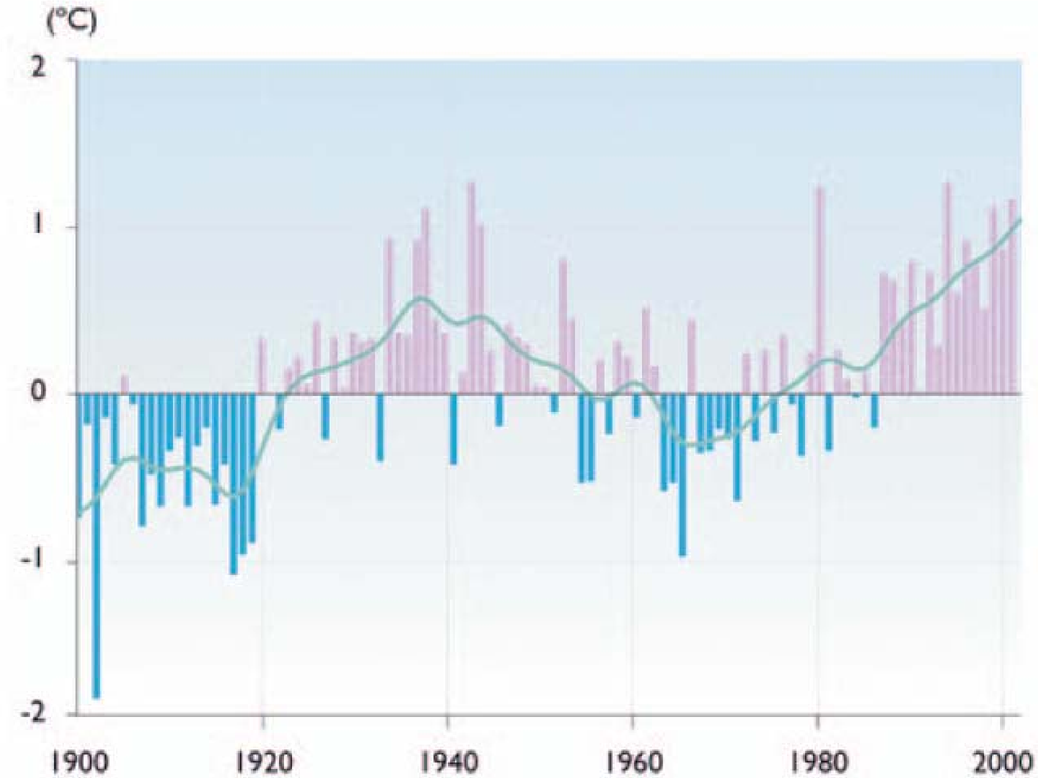

FIG 3: Climate variability in the Arctic, past experience with adaptation

The EALAT Project & Adaptation

Adaptation to climate change is not happening in the corridors of national ministries or in international agencies, but rather at the local level where people are actually facing the changes in their everyday lives. Furthermore, it would be meaningless to discuss adaptation to climate change without societal perspectives, as adaptation is about the human dimension. Hence, as part of the EALAT project, a network study was set up to help prepare the reindeer herders for the changes they are likely to face and the options they have. As noted earlier, it was named "EALAT" – the Sami term "Ealat" means "good pasture" and is connected to "Eallu", meaning "herd", both of which come from the word "Eallin", which means "life". In other words, pastures are the foundation for the reindeer herd, and the reindeer herd is the foundation for the lives of reindeer herding peoples of the North.

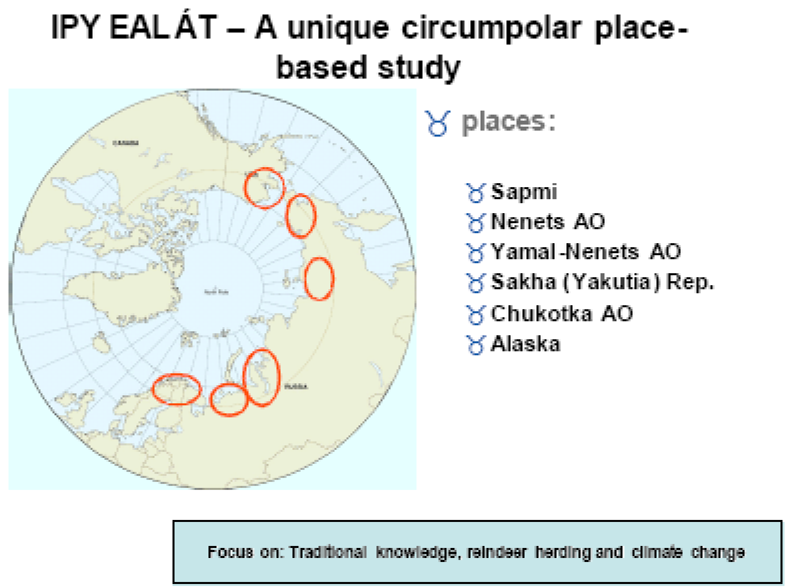

Figure 4. EALAT is a placed based study with a focus on building competence in the local Arctic communities.

Launched in February 2007 and to be concluded by the end of 2010, EALAT is an interdisciplinary study led by reindeer herders and indigenous organizations, together with scientific and other partners. EALAT attempts to understand the wide spectrum of issues related to climate change, reindeer husbandry, and the development of adaptation strategies which will address the enormous challenges of circumpolar reindeer herders in a holistic manner. One of the most critical elements of successful adaptation is the development of local competence and capacity building in indigenous societies. In fact, these are also major objectives of EALÁT, through community-based workshops in local reindeer herding societies, education and development of new communication tools (www.reindeerportal.org, www.reindeerblog.org, and www.ealat.org).

Another critical element of EALAT's adaptation strategy is the use and integration of the best data available – both traditional and scientific – to create optimal adaptation to climate change. For example, air and surface temperatures combined with precipitation data collected by both reindeer herders as well as meteorological institutions are being used to model snow conditions and the formation of compressed snow near the ground. An example of extreme precipitation and compressed snow conditions occurred starting in December 2006 and continued throughout much of the remaining winter. The compressed snow and ice layers constitute a serious challenge for reindeer in accessing food. Reindeer herders have extensive knowledge about such phenomena, explaining and understanding snow conditions with a completely different set of analytical expressions and concepts founded on experience and of great importance for adaptation.

Figure 5 From an EALAT workshop: Adatation to Climate change and loss of grazing land in Topolini, Sakha Jakutia, Russia April 2008.

While the planners of the IPY EALÁT project had hoped to study five different reindeer herding societies across Eurasia, funding limitations forced researchers to concentrate on the two largest reindeer herding cultures in the world: The Sámi, who inhabit Northern Scandinavia, with the Norwegian county of Finnmark representing the centre of the society, and the Nenets, focusing in particular on herders in the Yamal-Nenets Autonomous Region in Russia. A majority of the Sámi participate in the local cash economy (with at least one member of the family having a job) and live in tents only part of the year during the migration period, while a greater number of Nenets still live on the tundra year-round, although this number also seems to be decreasing. Motorized vehicles have made it possible for herders to live further away from their herds for parts of the year, visiting it daily or when needed.

One of the main objectives within the IPY EALÁT project is documenting indigenous knowledge about snow conditions and their perceptions about how they are adapting to changing conditions. A great deal of insight can be gained from centuries-old knowledge from herding societies such as the Sámi and the Nenets. With the numbers of those from traditional reindeer herding communities following more traditional ways of life on the decline, it is important to document this knowledge as much as possible while it still exists.

Indigenous Knowledge and Science for Adaptation

Indigenous knowledge has always helped guide reindeer herders when migrating between summer and winter pastures. However one of the main tenets of the IPY EALÁT project is that just as indigenous knowledge can give insight that can be of use to science, science can also be useful to the indigenous reindeer herding communities. Project members are carrying out field research to obtain data that can help reindeer herders adapt to adverse weather conditions and climate change, especially with climate change making weather conditions more variable and less predictable than before.

For example, the Sámi reindeer herders in Northern Scandinavia usually allow their reindeer to graze on the tundra in coastal areas during the summer months, where they can feast on abundant grasses, bushes, mushrooms and daffodils. After the annual slaughter and the first snowfall, the herders bring their reindeer to over-wintering pastures in the mountains and tundra in the interior part of upper Scandinavia, where reindeer dig through the snow to get to lichens, the primary staple of the winter diet of reindeer. However certain meteorological conditions can sometimes create conditions that "lock out" winter grazing pastures. If a warm period that partially melts the snow is followed by rain and then the temperature drops below freezing, this can create a thick coating of ice in the winter pastures that makes it impossible for reindeer to access their primary food source. This can lead to illness and starvation for the reindeer, which translates into losses for herders.

Accordingly, the IPY EALÁT project is developing a new adaptive strategy for “lock out” prediction to avoid this increasingly difficult problem. Investigators are using both indigenous knowledge together with scientific data to better predict when and where adverse winter grazing conditions might occur so that eventually a service could be set up that would help herders know where winter pastures with bad grazing conditions are so they can avoid them. Meteorologists from the Norwegian Meteorological Institute in Oslo have developed models that try to predict snow conditions in Finnmark by looking at temperature gradients throughout the snow pack. These models are being combined with real-time field observations by herders to verify the predictions the models make, including, the use of some NASA technologies. In fact, in October 2007, a team of researchers from the Sámi University College placed NASA thermochrons (small devices that take daily temperature readings at regular intervals) all over Finnmark along several reindeer migration routes at various depths between the ground and the top of the snow pack. In May 2008 a team took them out and the temperatures they record will be compared with predictions the model has made. Observations will be compared with remote sensing data from NASA and ESA and data shared with collaborators in the NASA Global Snowflake Network (GSN) and History of Winter (HOW). This process will be repeated for three more winters in order to get an adequate data set to compare with the model. Researchers are also examining historical meteorological data taken over the past several decades as well as satellite data, concentrating in particular in years when many pastures were "locked out" due to ice cover.

The Polar View consortium, which runs a variety of earth-observation services for its end-users all over the world, will also be contributing to the study by providing researchers with snow maps created using satellite data. These maps help in giving an overview of the amount of snow cover and snow cover type in the regions being studied in the EALÁT project. These observations will provide useful information on the snow temperature from the ground to the surface of the snow pack because the influences of the temperature of the ground on the snow above it is not fully-understood. These observations will help better understand what happens to the snow above if warming occurs on the ground as well as the questions: what will happen to the snow above it? Will it get wetter? Will it get drier? These answers will help the understanding of how the energy exchange occurs between the ground and the snow above. New data sets will be produced for snow type and distribution as a result of the thermochron study, which will include remote sensing data such as MODIS as well as in situ data from the Norwegian Meteorological Institute and NOAA/NCEP and integrated into indigenous knowledge and observations for that area.

Data from the snow study will be integrated by the Sami reindeer herders into the system which will become part of a special service to be produced by the combination of all observations and a model to predict whether certain pastures will be locked out due to ice in the snow pack, so that herders can avoid these areas. These will constitute a unique dataset for the land-use and land-cover studies for this part of Eurasia and the first “adaptation early warning system” created by and for reindeer herders. All data such as these will be distributed through the International Centre for Reindeer Husbandry as part of this special service to reindeer herders. With increasing temperature variations causing more “freeze-thaw-freeze” cycles resulting in icing of the forage plants, the presence of the larger animals in the herd such as the castrates becomes a potentially critical adaptation tool. In fact, another climate-related adaptation strategy EALAT is studying is reindeer castration, a technique commonly used in reindeer husbandry as a tool for herd structure management. Castrates serve a special purpose in the herd regarding the icing issue because, due to their larger size, they are more able to easily break through ice layers in the snow, facilitating access to food for females and calves. In addition, the presence of castrates calms down female reindeer and calves, making herds easier to control. Therefore, adjusting herd composition through castration might represent a possible strategy for adaptation to future climate change.

Satellite Technologies as Adaptation Tools

Remotely-sensed data and observations are providing increased capabilities for developing adaptive strategies through monitoring, risk mapping, and surveillance of parameters critical to the characterization of pasture quality and migratory routes, such as vegetation distribution, snow cover, infrastructure development, and pasture damages due to fires. This section of the chapter describes a few of the remote sensing capabilities applicable to reindeer husbandry along with some examples from a pilot project of the NASA Land Cover Land Use Change Program, "Reindeer Mapper", a remote sensing and GIS-based system designed to bring together space technologies, ground-based measurements, and indigenous knowledge for sustainable reindeer husbandry. (Maynard et al, 2005) This study preceded the EALAT program as a pilot project to investigate remote sensing technologies for reducing the threats to reindeer husbandry from changes in the climate, environment and human-induced activities and improve community resilience and ability to adapt to these changes by providing usable, timely knowledge from detailed analyses of satellite data to be combined with traditional, local and other data and information. The first task was to identify the most effective sensors for obtaining satellite data for these studies.

Based upon discussions among Reindeer Mapper team members from the reindeer herder community, including discussions and publications such as the Yakutsk Declaration from the Third World Reindeer Herders' Congress in March 2005, a preliminary list of the highest priority environmental measurements was generated. These requirements constitute the primary elements determining pasture quality and state, the most important overall set of parameters for reindeer herders. A summary of these data requirements is listed in Box 1.

High Priority Remote Sensing Observations and Data for Reindeer Husbandry

- Ecological characterization of seasonal pasturelands and migration routes and assessment of their suitability as pasture
- Depth and characteristics of snow cover of pasturelands and migration routes
- Condition of ice on rivers, lakes and other water bodies in migratory routes
- Assessment of anthropogenic impacts on migration routes and pasture lands of interest, including environmental contamination and infrastructure development
- Detection, monitoring, and status of annual forest/tundra fires and associated burned areas in pasture and migration routes
- Monitoring, inventories and tracking domestic and wild reindeer herds
- Meteorological conditions – current and predicted

Summary of Potentially Useful Satellite Technologies

Information for characterization of pasture quality can be derived from data collected in several spatial and temporal scales by a number of the space-borne remote sensing instruments in orbit today as well as archives of historical data. For example, ecological characterization of the pasturelands and migration routes, including human infrastructure, can be accomplished through the use of the extensive suite of land cover and land use change optical space sensors. In fact, there are a number of remote sensing studies, which have been carried out to assess various aspects of the state of reindeer pastures using some of these technologies. A brief summary of some of available technologies for reindeer husbandry is presented in the following section.

Optical sensors for pasture quality

One of the first applications of remote sensing to reindeer husbandry was carried out by George et al., (1977), where an inventory of reindeer-range resources was conducted of wild lands in western Alaska using Landsat data. Since then, a number of in-depth reindeer pasture characterization studies looking at a variety of pasture parameters using optical remote sensing sensors have been carried out in Finland, Sweden, Canada, Alaska, Greenland, and Norway using different combinations of available sensors such as Landsat TM, ETM+, Ikonos, ID-LISS, MODIS, supported by GIS, seasonal maps, digital elevation maps, digital topographic maps, and field data. (A few example are by Colpaert et al., 2003; Tamstorf and Aastrup, 2002; Johansen and Karlsen, 2002; Kitti and Kumpula, 2002; Kumpula et al., 2002; Nieminen et al., 2002; Arseneault et al., 1997; Sandstrom et al., 2003; Rees et al., 2003). These studies were able to use these passive optical remote sensing systems to assess pasture quality parameters such as vegetation type, health and distribution and other land-cover features like water bodies, sand, soil, rock, fires, fire scars and infrastructure. Several recent remote sensing studies addressing vegetation dynamics, phenology mapping, and surface temperature by researchers such as Beck et al, 2006; 2007; Karlsen, et al, 2007; and Raynolds et al, 2008) continue to demonstrate the potential usefulness of optical sensors for reindeer husbandry.

Microwave sensors for pasture quality

Microwave sensing can also be used for assessing pasture quality due partly to that fact that the tundra is a terrain characterized by sparse to moderate vegetation cover and, therefore, a major component of the C-band radar backscatter is the backscatter from soil surface. (Li et al., 1999). It was shown by Wang et al (2004), that radar backscatter is positively correlated to Normalized Difference Vegetation Index (NDVI<0.45), when soil is dry and negatively correlated at higher moisture levels. Soil moisture governs the dielectric constant, which enhances radar signatures from wet soils. Nevertheless, Duguay et al., (1999) noted that the tundra vegetation structure is an important factor explaining the large differences in backscatter with freezing. A SAR study of wet tundra, carried out by Belchansky et al., (1995), has also demonstrated the potential for SAR to discriminate up to four or five tundra land cover classes including water, wet sedge tundra; wet sedge tundra/moist non-tussock-sedge, dwarf-shrub tundra; gravel pads and continuous flooding.

Radio tracking of reindeer herds

A successful means of directly monitoring reindeer is the use of navigation satellites, radio collars, and Geographic Information Systems (GIS). The first such study was carried out by Craighead and Craighead, (1987) with the NOAA/Tiros system. This method makes it possible to gather information about migration movements, rate of travel, seasonal behavior and other habitat features of reindeer herds. An excellent example of a radio tracking study of reindeer movement is Porcupine Caribou Herd Satellite Collar Project (http://www.taiga.net/satellite/index.html) based on the ARGOS (Advanced Research and Global Observation Satellite) system. A useful summary of some important applications of remote sensing for reindeer pasture monitoring and some management support may be found at http://www.szooek.slu.se/dokument/gis_ workshop/gis_workshop.htm.

Fire, snow, and lake monitoring

There are several other different active and passive systems, which could be or are being used to provide useful data and information for reindeer husbandry such as fires, snow, and lake monitoring. For example, forest/tundra fires are the most hazardous natural disaster impacting reindeer husbandry due to fire damage itself as well as the loss of land from pasture use and the interruption of annual migration routes. (Auclair, 1983; Mironenko, 2000) There are various remote sensing systems being used for forest fire detection and monitoring (UNEP, 1999; Liew at al., 2001; Justice and Korontzi, 2001). In addition, SAR is starting to be used more extensively to avoid cloud contamination problems. The MODIS Rapid Response System (MRRS, http://rapidfire.sci.gsfc.nasa.gov/) was created to monitor the global distribution of fires including tundra sub-Arctic and Arctic zones (Justice et al., 2002). On the other hand, snow, one of the most critical parameters to reindeer herds, is an especially important parameter to be able to monitor and assess, particularly as it impacts the herds' ability to find and forage for food. Snow monitoring using optical remote sensing methods for Arctic regions is limited to months with sufficient solar radiation, but passive and active microwave sensors are relatively unaffected by clouds and solar radiation (Tait et al., 2000; Kelly et al., 2004). Space-borne radars with synthetic aperture (SAR) with the ability to acquire images of Earth surface through darkness and cloud cover with the resolution comparable with the optical sensors are especially useful for snow studies in polar regions (Ulaby et al., 1994). There are a number of studies under way on this subject which also investigate the use of SAR for characterizing snow parameters in reindeer pastures. Finally, Arctic and Sub-Arctic lakes are important natural landscape features of the tundra environment and are sensitive indicators of regional climate variability (Hall et al., 1994; Doran et al., 1996). In addition, they can be very important features in the reindeer migration pathways, particularly, because during premature thaws due to climate warming they become serious hazards to the migrating herds as they attempt to cross the melting ice.

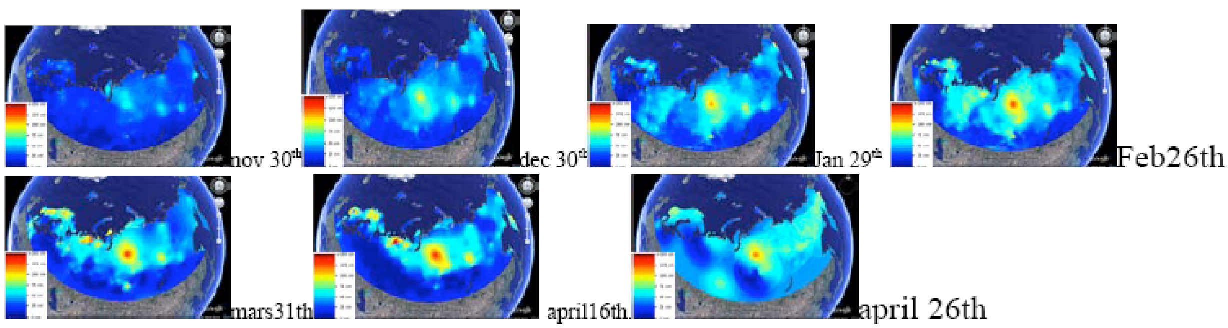

Figure 6. Change of snow depth (cm) on the reindeer pastures in Eurasia nov 2007- April 2008, For more than 9 months of the year snow covers the ground in Eurasia where reindeer graze. Monitoring of snow change will be important to reduce risks related to change in regions where reindeer graze.

SAR Sensors for Pasture Quality

A preliminary examination of the use of SAR for characterizing the quality of reindeer pasture was done because it does not rely on the visible part of the spectrum and, therefore, has the ability to provide data regardless of weather or light conditions. Early studies focused initially on the highest priority measurements/data products identified by the reindeer herders on the team – characterization of "pasture quality' for pastures and migration routes (Box 1). The applications of SAR for characterization of vegetation and measuring snow parameters are not as well-developed as optical sensors. Initial studies of seasonal changes in SAR backscatter from different kinds of land features in two locations (Anadyr River Research Area (ARRA) and Vaegi Village Research Area (VVRA) in Chukotka, Russia, were carried out for the four seasons of the period between the years 2000 and 2004. Site selection was done based on data availability from the Alaska Satellite Facility (ASF) and on the location of typical tundra landscapes on reindeer pasture areas. Based on these criteria, two sites within the Anadyr district of Chukotskiy Autonomous Okrug (ChAO) were selected. The first site is a nature conservation area north of

"Krasnoe" lake along the Anadyr river (Anadyr river research area - ARRA); the second site, a fire risk area south of Vaegi Village (Vaegi Village research area -VVRA).

Results from the first year of the project show (Yurchak and Maynard, 2005), that the SAR data can detect fire scars very well and could be used for fire scar inventory mapping in conjunction with other systems such as the MODIS Rapid Response System and an analysis of tundra lakes' radar properties suggests the possibility for remote assessment of the depth of lakes. It was also possible to observe the snow masking effect (Ulaby et al., 1994) and wet snow (Bagdadi et al., 1997). Studies showed the capability of SAR to delineate different types of tundra species as well as demonstrate seasonal changes in radar backscatter from tussock and mountain tundra in time series studies. The sensitivity of SAR data to vegetation and snow cover over plains and mountain tundra is demonstrated on time series study of a selected area in the north of ARRA, fig.7 and fig.8.

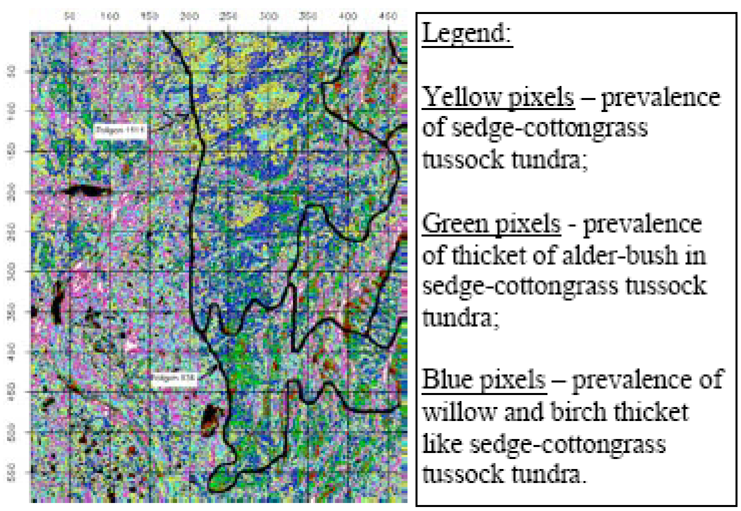

Figure 7. A classified part of SAR low resolution image of ARRA, based on comparison with geobotanical map (courtesy of A. Polezhaev). July 28, 2003. Image size (HxW) ~ 60 x 47 km; image center: $65^0$35'N, $174^0$08'E.

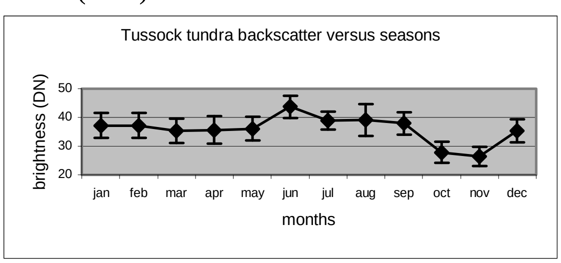

Figure 8. Time series of SAR backscatter from plains tussock tundra and mountain tundra within ARRA.

The results showed clear seasonal changes in tundra radar backscatter. For tussock tundra the backscatter was higher in summer months and dropped to the lowest value in the fall due to decrease of soil (vegetation) moisture because of freezing. The subsequent backscatter increase in the winter could be related to snow cover impact. For mountain tundra, summer backscatter behavior is opposite to that of tussock: it is the lowest. Also, the range of winter-summer decrease is rather high: ~ 60 DN. The reason for such behavior, probably, is different local incidence angles for tussock tundra (~ 23^0) and for the mountain slope (~0^0). Further field validation work was planned for this study. In addition, SAR data were shown to be capable of delineating detailed geobotanic polygons. SAR data were compared with ground-based geobotanic maps and were found to provide a higher resolution set of polygons than aerial surveys. These preliminary results suggest that further development of the methodology as well as its validation and calibration may result in a reliable method for SAR applications to these important environmental parameters. In summary, SAR data can detect fire scars very well and could be used for fire scar inventory mapping in conjunction with other systems such as the MODIS Rapid Response System. Studies showed the capability of SAR to delineate different types of tundra species as well as demonstrate seasonal changes in radar backscatter from tussock and mountain tundra in time series studies. In addition, SAR data were shown to be capable of delineating detailed geobotanic polygons. SAR data were compared with ground-based geobotanic maps and were found to provide an even higher resolution set of polygons than aerial surveys. An analysis of tundra lakes' radar properties suggests that SAR may provide a useful means of remotely assessing the state of lakes. As temperature increases cause earlier melting of lakes along migration routes in springtime, this technique for lake assessment could prove to be very valuable for herders on a real-time basis.

EALAT Remote Sensing and Indigenous Knowledge - IPY Studies

In a continuing collaboration which builds upon EALAT/Reindeer Mapper and early EALAT studies, NASA and university colleagues are now working with the EALAT Sami reindeer husbandry community to help strengthen herder adaptation strategies to changes in the Arctic by providing usable, timely knowledge from detailed analyses of satellite data and information (e.g., Landsat, MODIS, Ikonos, NDVI) combined with indigenous traditional and local knowledge. EALAT and Reindeer Mapper partners are conducting field campaigns as well as image analysis. The team has already established a number of test sites starting with specific Sami reindeer migration routes for 2007-2009, set priorities for data requirements, and have begun analyzing data sets. These direct observations and data are then to be integrated with the indigenous historical knowledge and observations from herder's daily data logs. Emphasis will be on spatial and temporal changes in vegetation, snow, water bodies, and infrastructure together with variations/changes in weather and climate.

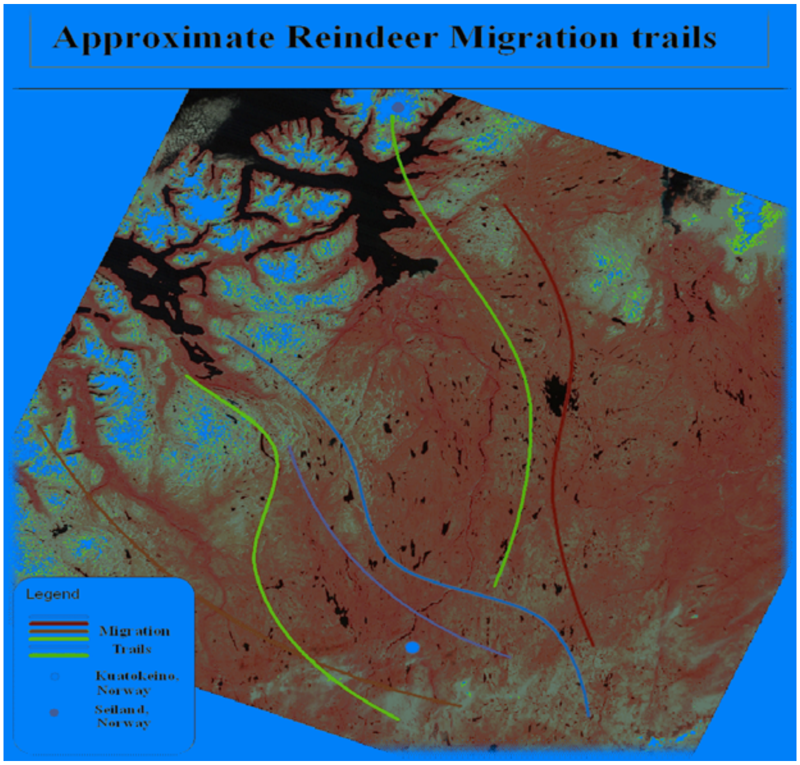

Figure 9. Landsat image from Finnmark, Norway showing the migration routes used by 6 different reindeer herders between winter and summer pastures.

As part of this joint IPY EALAT project, NASA has initiated analyses of several Landsat scenes from the area of the specified Sami migration routes. In addition, a NASA-Sami snow study was initiated in February 2007 at the Indigenous Peoples Opening of the IPY. The primary goal of this initial snow change study is to record temperature differences on and within the snow pack over the entire winter period on the specified reindeer migration routes as part of the NASA Global Snowflake Network (GSN) and History of winter (HOW).

(http://education.gsfc.nasa.gov/how/) The Norwegian Sami EALAT participants have been collecting data along the migration routes under the supervision of Sami University College. NASA supplied thermochrons to the project which were planted in the snow along the migration routes October 2007, collected in May 2008, and compared with NASA snow data at (e.g., MODIS) and meteorological data (NOAA/NCEP and Norwegian Meteorological Institute). The purpose of the thermochron study is to address one of the highest priority climate change impact topics for reindeer herders, the freeze-thaw cycles, which are causing “lock-out” conditions of forage from ice layers in snow pack or over lichens.

In another element of the EALAT project, NASA is creating a unique qualitative and quantitative assessment of multispectral information from remote sensing combined with indigenous data into a GIS environment where impacts of global warming, climate change, and infrastructure development can be shown and mapped as it directly impacts selected areas of reindeer husbandry communities of Northern Norway and Russia. Although the use of optical remote sensing systems in the Arctic has a number of challenges, such as frequent cloud cover, a number of Landsat cloud-free scenes have been located in our areas of interest from 1987, 2000, and 2007 (see figure 10), which provides the opportunity to detect and monitor some of the change along the six pasture routes of the IPY study.

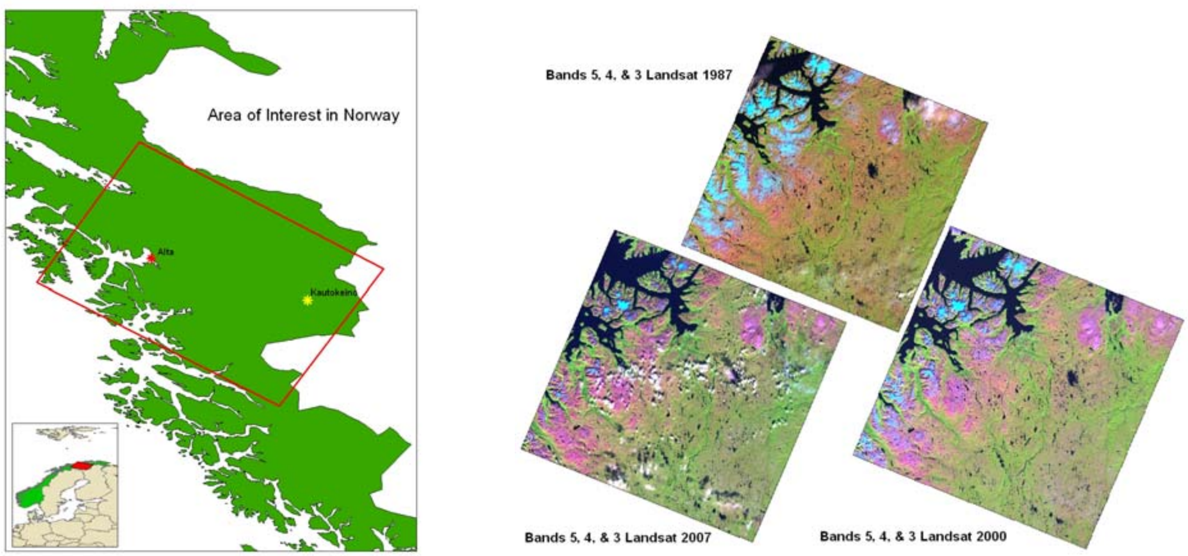

Figure 10. Location map showing area of interest & Landsat scenes of interest 1987, 2000, and 2007

These scenes are presently being processed and will be compared with indigenous observations for the same dates for change analyses. The land cover land use changes being analyzed in these scenes include vegetation changes, vegetation type identification, snow/ice features, urban expansion/growth, and urban feature identification (large roads, platforms). Several other studies have included analysis of NDVI in high latitude areas for biodiversity and vegetation dynamics research but usually at a much coarser spatial resolution using MODIS (Beck et al., 2006 & 2007). Normalized difference vegetation index (NDVI) produced from Landsat Thematic Mapper images is a means of monitoring density and vigour of green vegetation growth using the spectral reflectivity of solar radiation. It is computed as follows: (NIR-RED) / (NIR+RED), where NIR (Near Infra-Red) is the ETM band 4 (0.76-0.9 micrometers) and RED is band 3 (0.78-0.82 micrometers). Using this analysis with Landsat allows us to register changes over time in vegetation vigor at a higher spatial resolution over a refined area of current reindeer pasturelands. Using the aforementioned Landsat dates, we remain consistent in terms of seasonality comparison by varying by years but the images are all acquired within the same 1-2 month period (July/early August).   One particular issue of interest mentioned earlier is the identification of possible shrub area increase from 1987 to 2007. An increase of shrubland area in reindeer grazing area makes food access increasingly difficult so classification of precise locations of these shrubland areas is essential to help reindeer herders lead their herd to more promising grazing areas in terms of food security.

The processing methods for the Landsat scenes are first and foremost to satisfy the following requirements of this project: determine major land cover land use classes, temporal change within those classes (increase or decrease in area), change from one class type to another (grassland to shrubland for example), incorporate ground truth data from herders to increase accuracy of final map products, and collaboratively identify areas of concern with reindeer herders' local knowledge (such as interruption of migration routes from infrastructure or melting lakes/rivers).
To accomplish this, an unsupervised classification was first performed to identify major classes that are spectrally

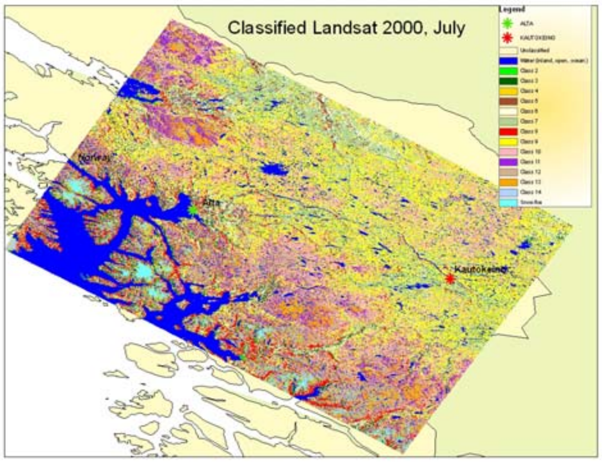

Figure 11. Initial Landsat classification for 2000 using separability analysis technique

separable from each other (Figure 11). Initial results are shown above in Figure 11. This is important to be able to identify separate vegetation communities such as lichen from bare soil or ice from open water or shrubland from coniferous forest. To do this it is necessary to perform a spectral signature evaluation. This is done through a separability analysis, here an analysis called "transformed divergence" is utilized (Jensen, 1996). Separability is a statistical measure of distance between two signatures to determine how different the spectral signatures are from one another. Separability is calculated from the covariances and mean vectors of the class signatures. The transformed divergence statistic was used for this separability analysis (Swain and Davis 1978). Transformed divergence ranges between 0 and 2000. A transformed divergence value of 2000 for a class pair indicates that those classes are exclusively separable, whereas values less than 1700 suggest that those classes are not separable (Jensen, 1996). Transformed divergence was calculated for an initial 30 classes in ERDAS IMAGINE. ERDAS provides a signature separability report, which lists every divergence value for the bands studied for every possible class pair in a cell matrix format. The final number of spectrally separable classes for this region is 15; this result is from the above mentioned initial analysis of separability. An example of the initial classification results is shown here. One of our final goals is to verify classification accuracy with the help of the reindeer herders' on the ground data collection, so not all classes are named here.

In addition several GIS layers are being added for analysis such as roads, utility lines, drainage points, elevation, etc. A sample of this GIS data for this region is shown below in Figure 12.

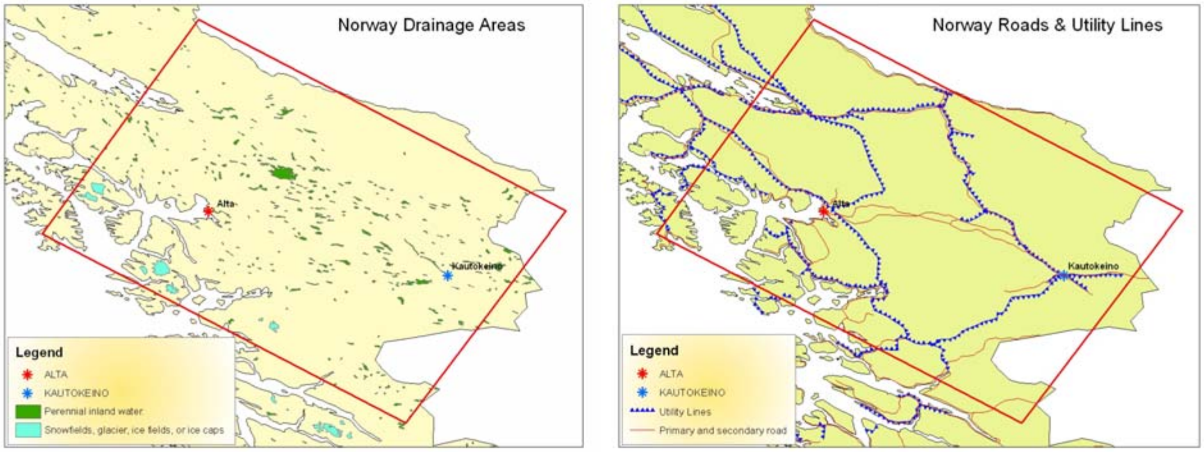

Figure 12. GIS data to be used for value added analysis and ground truth efforts

As the classification of these images and value-added spatial data of the GIS layers progresses, we will combine this spatial data analysis with ground-truthed information acquired with GPS units in the field to help verify the classified land cover maps and increase validity of these methods and help establish the accuracy of the data and results. Additionally, this combination of ground-truth data from the herders will add value to already existing GIS data sets in terms of improved accuracy and locate any errors that the original data may incorporate. Characterization of areas of interest such as shown above which provide information on pasture quality and migration routes, such as vegetation distribution, snow cover, infrastructure development, and lakes are critical to the success of reindeer husbandry in the region. It is clear that information from such sensors as Landsat, Ikonos, MODIS, NDVI integrated into a GIS with other data and disseminated in a timely fashion could assist local and nomadic residents and reindeer herders to carry out far improved decision-making and herd management.

New “co-produced” datasets of combined remote sensing (Landsat, MODIS, AVHRR, and, if available, Ikonos) and indigenous observations of land cover and land use changes (temporal and spatial) in the areas of interest will be created, describing changes in vegetation, snow/ice features, urban expansion/growth, urban features, large roads, platforms, power lines, drainage areas, etc. These data sets will be produced to show the changes as they relate to climate and environmental changes in the region as well as to development influences., and particularly as they impact the Eurasian reindeer husbandry community. NASA resources proposed to be used for this study are as follows: Landsat, MODIS, NASA Landsat library, NASA GIMMS Spot/AVHRR NDVI, and Ikonos. In addition, the EALAT team is considering re-evaluation of the project’s earlier use of NASA’s Radar Research Program use of Alaska SAR Facility resources and SAR data to add the capability to collect data regardless of cloud cover conditions to follow changes in vegetation and other land properties. Data products will be distributed through web sites, locally-appropriate means, and the International Centre for Reindeer Husbandry.

EALAT Information Integration System – Adaptation and Planning for the Future

It is imperative that governments, local reindeer herders, management, policy, and decision-makers include reindeer herders and their traditional local and scientific knowledge in future decision-making. The new monitoring system for reindeer herders must be based on UN Convention of Biological Diversity Art 8, UN Agenda 21 Declaration Ch 26, ILO-169 Convention on Rights of Indigenous Peoples, UN Declaration concerning the rights of Indigenous Peoples 2007, UNESCO’s Convention on Protection and Development of Cultural Diversity, and the Jakutsk Declaration from Third World Reindeer Herders Congress in 2005. In addition, rulings must take into account - on an equal basis - reindeer herders’ traditional knowledge and experience in all future decision-making, which could impact their lands and well-being. The Jakutsk Declaration explicitly stated that reindeer herders should develop their own system to monitor changes of the Arctic natural resources, based on traditional knowledge and modern technology.

Figure 13. Picture of EALAT workshop in Brigade 4 Khanzelan, Chkotka March 2008

At a recent meeting of EALAT (AVE'EN) International Seminar for Reindeer Pastures Sustainable Use and Monitoring in Anadyr, Russia, February 25-March 3, 2008, the serious challenges of pasture degradation and seizure caused by growing development in the region were discussed. Reindeer herders are trying to develop preventative measures against pasture loss and damage from these pressures through collaborative planning between science and indigenous knowledge. The situation is especially difficult in Chukotka, which is uniquely situated at the interface between the two giant continents of Eurasia and North America, in the area called Beringia. The seminar participants applied the extensive knowledge of the Chukotkan peoples about the pastures, snow, reindeer moss, weather and other parameters in the reindeer lands. There is a very large Chutkotkan traditional vocabulary expressing their knowledge to describe differentiation of snow quality for food accessibility and special features important to reindeer husbandry. At that workshop, a project was proposed to document the traditional knowledge of the Chukotkan indigenous peoples and to compare it with the modern scientific and technological data. Funding will have to be found to support this effort. The seminar also recommended that a new center be established for monitoring the reindeer pastures in Chukotka which will conduct monitoring and studies of reindeer pastures, weather, fires, snow cover, and other parameters of interest.

EALAT/Monitoring in cooperation with the NASA LCLUC Program, Reindeer Mapper, is developing an observation program or monitoring system for reindeer pastoralism in place-based studies in the Saami area (Norway, Sweden, Finland and NW-Russia), Nenets AO, Yamal-Nenets AO, Sakha-Jakutia Republic, Chukotka AO. The EALAT/Reindeer Mapper System - being developed at the International Center for Reindeer Husbandry - is a data integration and sharing system to integrate traditional indigenous knowledge together with physical, scientific, and technical data into a common GIS database for improved decision-making and herd management. This georeferenced data sharing system will use secure Internet connections for data collection, management, transmission, analysis, access, and dissemination.

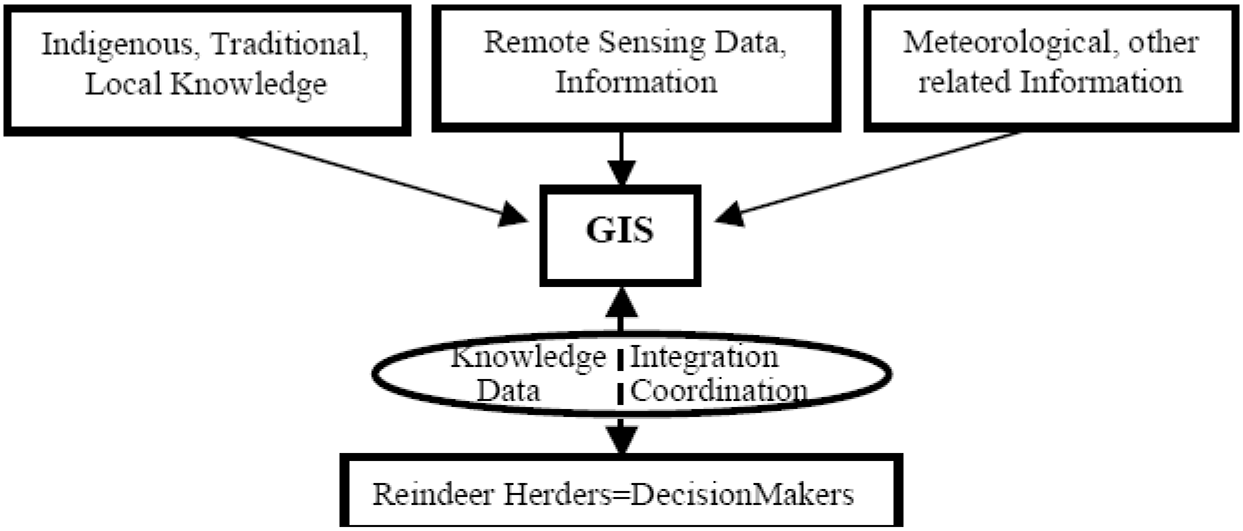

Figure 14. General Concept of the Reindeer Mapper System

The system will function as a portal to link data from a variety of sources and provide that information to multiple herders. The system is being designed, based partly on the PAIRS system of Pennsylvania (Conrad, 2002), specifically to meet the requirements of Northern Eurasian reindeer herders. Observations and information is being integrated into a central GIS data base so that data from all sources such as NASA products, reindeer herder knowledge, observations and maps, ground-based measurements and observations, herd movements can all be inputted, managed, transmitted, accessed and disseminated in real time for herd management. The EALAT/Reindeer Mapper Information System will assist in the ongoing analysis of trends and detection of emerging events and conditions, which affect humans, agriculture, and the environment to enhance early warning and management of responses and adaptation.

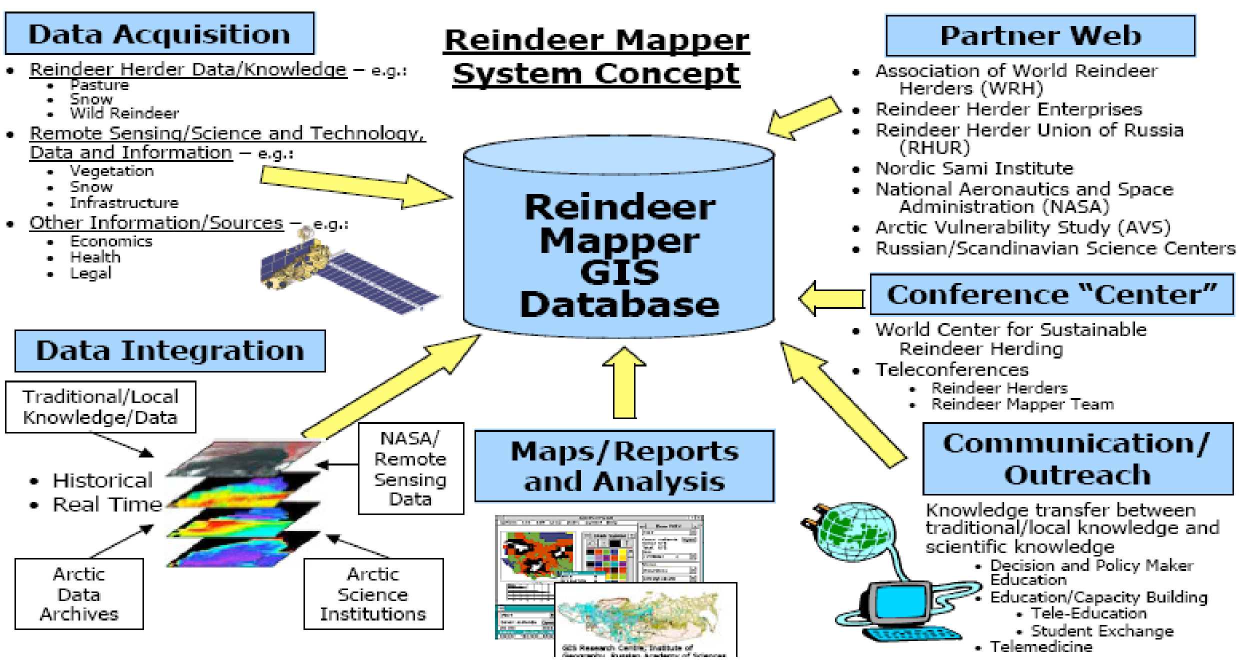

Figure 15. outlines the architecture of the Reindeer Mapper system (adapted from PAIRS, (Conrad, 2002), and shows each major component of the system: (1) data acquisition, (2) data integration, (3) map/report production and analyses, (4) communication and outreach, and (5) conference and knowledge-sharing

It is intended that Reindeer Mapper/EALAT will be able to provide reindeer herders with an efficient tool for managing the real-time movements and migrations of their herds through enabling improved efficiency in linking different members of the herder settlements or communities and providing real-time local, satellite or other data (e.g., ice melt in lakes and rivers, weather events), thus enabling real time adjustments to herd movements to avoid problems such as changing weather/climate conditions, freeze-thaw "lock-out" problems, or take advantage of availability of better pasturelands along migration routes. The system is being designed to incorporate local data to allow users to bring their own data into the system for analysis in addition to the data provided by the system itself. With the local information of the population, up to date environmental data and habitat characteristics, the system could generate maps depicting important features of interest for reindeer managers. One of the products derived from the planned Reindeer Mapper system will be a web-based graphic display that allows analysts to quickly pinpoint areas of interest such as those with large concentrations of reindeer and provide surrounding environmental information. The system could be automatically updated with near-real-time information such as hourly precipitation and snowfall rate and accumulation, daily surface and air temperatures, and vegetation cover conditions. The system could bring attention to the proximity of human and animal populations as part of the need for control response. A local GIS will bring these many layers together with several supporting models, showing only a straightforward graphic of the real-time situation in the field. Because the system proposed will be operating in the Internet environment, it should be virtually accessible from any network computers and wireless remote access from the field. The International Center for Reindeer Husbandry in Kautokeino, Norway, is providing regional and international coordination of and access to data sets and expertise, and will act as overall clearinghouse for EALAT information.

For a sustainable future, reindeer herders themselves are having to define and anticipate risks related to rapid change in their local communities and plan for optimal adaptation strategies. Reindeer herders in Eurasia from the Bering Strait in the east to the Atlantic Ocean in the west will face many challenges related to changes in their grazing lands and their societies due to climate variability and change and Arctic industrial development. Reindeer herders therefore have to prepare themselves, their societies, and management authorities to reduce their vulnerability to change, including, empowering themselves with new technologies to monitor their local communities based on the best knowledge available. Therefore, it is important to develop several special initiatives as soon as possible, starting with the following three: an EALAT reindeer husbandry monitoring program, a special reindeer husbandry "prediction service", and a special Land Cover Land Use Change training program for Eurasian indigenous people. Although elements of each of these initiatives are already planned or in place by members of the EALAT team, a major program needs to be implemented to create the infrastructure within the Eurasian indigenous community necessary to build the adaptation capabilities necessary to adapt successfully to these major changes taking place across the Eurasian North.

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