Observations for SEARCH: Data Integration for Arctic Reanalysis and Change Detection

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Introduction

Study of Environmental Arctic Change (SEARCH) program researchers need long-term and pan-arctic observations in order to detect change and to put change in context within space and time. The goal of this project has been to assess what data are relevant to SEARCH reanalysis and change detection activities, collect these data from a wide variety of sources, and facilitate the SEARCH research community's access to the data. This project, NOAA SEARCH Element 5, supports NOAA SEARCH Element 6: Arctic Change Detection, and NOAA SEARCH Element 7: Initiation of an Arctic Reanalysis Activity in SEARCH.

Work began in June, 2003. At NSIDC, the team consisted of F. Fetterer, lead, K. Knowles, scientific programmer and developer for sea ice products, M. Parsons, developer of frozen ground products, B. Raup, scientific programmer and developer for snow and precipitation products, and M. Savoie, scientific programmer and developer for snow and greenness products. Also contributing were K. Pharris, Web site design, and L. Ballagh, data set publication. We sought review and advice from NSIDC scientists as needed. M. Serreze, T. Zhang, and R. Armstrong provided guidance.

When the project began in 2003, we listed parameters that NSIDC could facilitate access to, and evaluated these based on their importance to the Reanalysis and Change Detection teams. We concluded that cataloging and obtaining precipitation data would yield the greatest return on our investment for the reanalysis team. This is because the cataloging effort revealed that existing precipitation data sets have many gaps. Increasing the spatial density of the network of precipitation stations is linked to improving the accuracy of the reanalysis approach to assimilating precipitation.

While continuing work with precipitation data, in 2004 and 2005 we began work on providing data streams for change detection. This new focus resulted from discussions at NSIDC in March 2004 with J. Overland, and others involved in the Arctic Change Detection project. At the May 2004 NOAA SEARCH review and workshop, held in

Boulder, we briefed the group on our plans for the products that now make up the Arctic Cryospheric Climate Indicators Web site. This site aims to:

- Characterize, at a glance, some of the changes that are occurring while putting changes in a spatial and historical (within limits) context
- Allow a non-specialist to quickly comprehend arctic change without hiding its temporal and spatial complexity
- Meet a need for near-real-time graphical products that can be used in research

Three of the products (sea ice, greenness, and snow off day) are based on satellite data, One, soil temperature, is based on in situ data. We found that while satellite data products require a greater initial investment in terms of algorithm development and processing routines, they are economical to maintain thereafter. In contrast, the soil temperature site has proved difficult to maintain and is not currently up to date.

In 2005, the NOAA Arctic Research Program began planning for the International Polar Year. We shifted some effort to assisting with this planning, coordinating the IPY Expression of Intent titled NOAA's Data, Information, and Change Detection Strategy for the IPY (NOAA Data Management and Change Detection - ID 879), for example.

This report is a summary. For more detailed information see the NOAA at NSIDC “SEARCH and IPY” page (http://nsidc.org/noaa/search/) and linked material.

Precipitation Data Acquisition

Precipitation is a difficult measurement to make. Observed values depend on gauge type and placement. In the Arctic, blowing snow and overall low annual precipitation make obtaining accurate precipitation values especially difficult.

Bias corrections should be made for three types of errors: *Wind induced undercatch* is more severe for snow than for rain, and can reduce measured participation by 50% or more, depending on wind strength and gauge type. *Trace precipitation* is precipitation in amounts too small to be resolved by the collecting gauge (usually less than 0.1 mm) Corrections are made by adding in a set amount for each day on which trace precipitation was recorded. (Trace precipitation can be a significant part of overall precipitation in Arctic regions.) *Wetting loss* occurs when a gauge is emptied into a measuring device. The small amount of precipitation that remains behind in the gauge (sticking to its sides) is the wetting loss. The size of this loss depends on how often the gauge is emptied, as well as on the type of gauge data can be very large.

Creating homogenous precipitation data sets for change detection, using measurements from different countries, or even from different sources within one country, is a task best left to experts. Fortunately, precipitation data are useful for reanalysis even if not highly corrected and homogenized with other data. Station density is important.

To document the contents of existing data sets so that station data not already in use could be acquired, we first compiled an inventory of available precipitation data sets that included arctic stations. This is a table of 25 data sources covering Russia or the former Soviet Union, Canada, Alaska, Greenland, and northern Europe. The table includes information on whether the data are adjusted, whether they are monthly or daily data, the number of stations, and what other data sets a particular data set shares stations with.

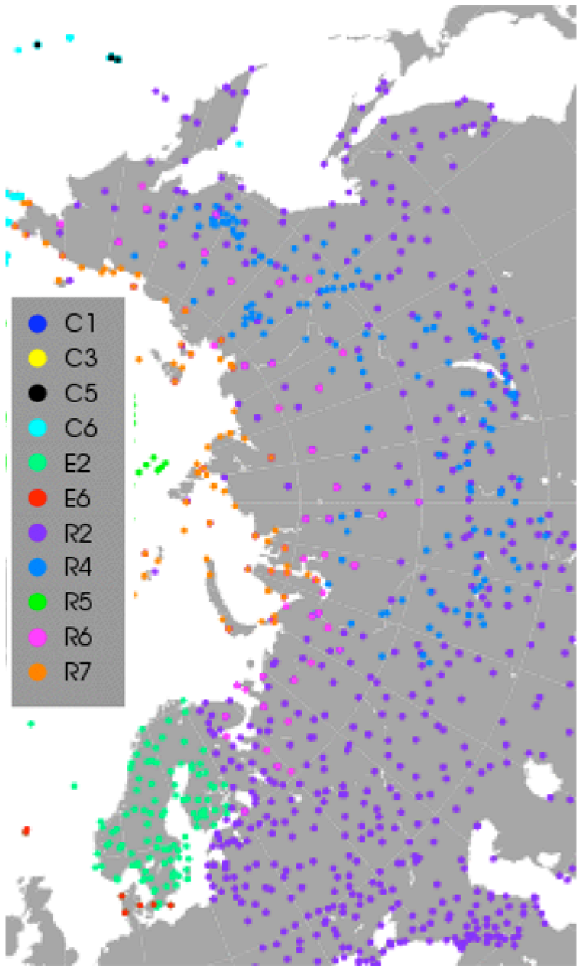

Figure 1. A map (North is to the left) showing the locations of stations in precipitation data sets of particular interest to the reanalysis team. The legend has the NSIDC reference abbreviation for data sets in the Precipitation Dataset Inventory document.

Next, station lists were prepared in a common format: tab delimited longitude, latitude, abbreviation (matching the "NSIDC Reference" column in the Precipitation Dataset Inventory document table), country, station number, station name, and year range. A search for duplication between data sets was performed by searching first for stations having the same station number, and then searching based on proximity. About 1000 station entries from north of 45 degrees were searched.

The Precipitation Dataset Inventory document, station lists, and files showing overlap are available from the NOAA at NSIDC SEARCH and IPY Web page.

The results of the data set overlap analysis guided our acquisition of precipitation data. Three new data sets with precipitation were published: *Monthly mean precipitation sums at Russian Arctic stations, 1966-1990* (http://nsidc.org/data/g02170.html*);* *Meteorological data from the Russian Arctic, 1961-2000* (http://nsidc.org/data/g02141.html*)*; and *Daily precipitation sums at coastal and island Russian Arctic stations, 1940-1990* (http://nsidc.org/data/g02164.html*)*. These added over 200 new stations, considerably increasing the density of stations in the Russian arctic.

Cryospheric Indicators

The Cryospheric Climate Indicators in the Arctic Web site (http://nsidc.org/noaa/search/indicators/) contributes to meeting the goals of the NOAA Arctic Change Detection site, to which it links. The material provides non-scientists with a deeper understanding of the interrelated changes that are happening, and meets a need for near-real-time graphical products that can be used in research. Ideally climate indicators are long records that are kept up to date. They combine characteristics of climate data records (NRC, 2004) from which trends can be derived, and operational products. This combination is difficult to achieve. We hope to continue working on the Cryospheric Indicators until this ideal is realized.

Snow

While warmer temperatures would seem to imply less snow, climate change may bring more precipitation, which may fall as snow. The response of snow cover to climate change is complicated by the timing and amount of precipitation. Is the snow starting to melt earlier than it used to, on average? Does it melt away faster? Is a trend detectable? Is the pattern of snow melt the same everywhere? Is snow covering less of the Arctic than it used to? These are the types of questions snow indicator products can answer.

We developed a passive microwave derived “snow off day” product. The time series of day of year values begins in 1978 and ends in 2005 (the product will be updated in October for 2006). This choice of product and data source was made for practical reasons. Other products that can be added to make a suite of snow indicators are the day melt begins, snow cover duration, and snow covered area.

We initially hoped to use existing algorithms for snow melt onset. When snow gains liquid water in the spring as melt begins, the change has a strong signal in passive microwave data. We found that validating a true melt onset product would require additional time, however, and so stopped after developing a snow off data (SOD) product. The algorithm uses snow water equivalent (SWE) derived from passive microwave data. The SWE algorithm and data used are those described in the documentation for the NSIDC data set *Global monthly EASE-Grid snow water equivalent climatology* (http://nsidc.org/data/docs/daac/nsidc0271_ease_grid_swe_climatology.gd.html). This recently available product has been validated for both SMMR (1978-1088) and SSM/I (1988-present) passive microwave data.

Our SOD algorithm is only used for the area north of treeline, because the forest canopy can depolarize the passive microwave signal and result in inaccurate SWE values. However limiting the algorithm to north of treeline is probably overly cautious and we plan to expand the domain.

The approach of the algorithm is as follows: As snow begins to melt, the value for SWE becomes invalid. A threshold is applied to a time series of SWE, and a flag is set for the days the threshold is crossed. This would give melt onset day, but the transition is not smooth. SWE may cross and re-cross a threshold. Therefore the melt flag time series is filtered with a 15-day low pass filter, and apply a half-power-point threshold to the resulting low-pass filtered series. In 15 days (generally less), all the snow has melted away, so the day on which the half power point is exceeded is in a window within which snow will have melted.

To validate the product, we compared the results with ERA-40 reanalysis surface temperature fields, with a product based on NOAA's visible band satellite snow cover data set (*Timing and Statistics of Autumn and Spring Annual Snow Cover for the Northern Hemisphere*) and with surface temperature from Baker Lake, Nunavut. The results supported our use of the SOD series for trend analysis. Results are detailed in a technical report (Fetterer and Savoie, in preparation), and in a poster presented at the IEEE TGRS Symposium, Denver, 2006.

Data are processed to a 25 km EASE-Grid, and the SOD data field for each year is used to create the figures on the Web page. These are color mapped average SOD, most recent SOD, and SOD anomaly (first five years of data minus mean, and last five years minus mean) The mean is calculated for 1979-2000, to be consistent with the Sea Ice Index product.

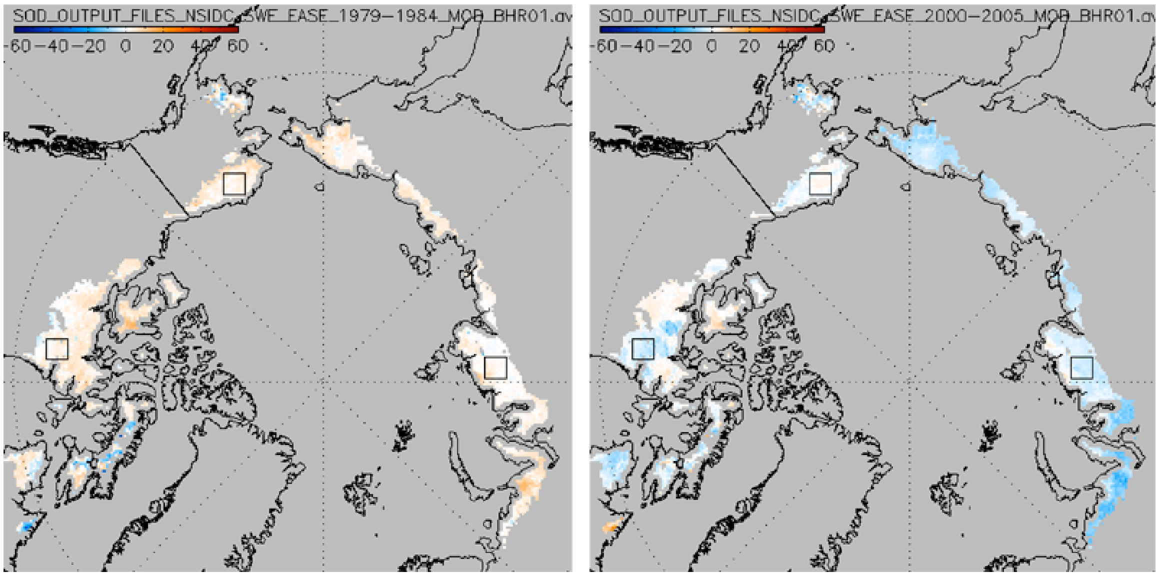

Figure 2. SOD anomaly products (first and last five year averages differenced with the mean) show that overall, snow is melting away earlier now than it used to (as shown by the preponderance of brown tones in the left, earlier image, and blue tones in the right, later, image), but there is considerable spatial variability. Five year averages are used to make the results more meaningful, because the temporal variability is quite large).

The anomaly maps (Figure 2) show spatial variability and a general indication of the trend in snow melt over a large area. To look at variability on a smaller scale, time series of SOD and SOD anomaly are plotted for three regions in Canada, Alaska, and Russia (Figure 3). Variability is high, but there is a negative trend (toward earlier snow melt) in all of the areas, although it is only significant at the Canadian site, where it is –3.7 days per decade.

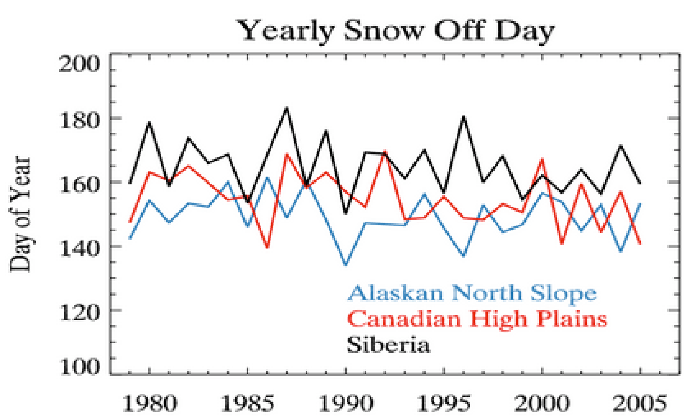

Figure 3. SOD time series for the areas marked by the squares shown in Figure 2.

While the greenness and sea ice indicator products include a great deal of interpretive text and documentation, the snow products are presented without explanation. This discrepancy should be addressed in future versions of the product.

Greenness

Rising temperatures and increasing carbon dioxide favor increasing photosynthetic activity. This can be measured from space using visible and near-IR band data expressed in the Normalized Difference Vegetation Index (NDVI). Using NDVI as the basic measurement of greenness, we derive seasonally integrated NDVI (Figure 4), peak NDVI, and nascence (the day, within the resolution of the satellite image compositing period, that NDVI exceeds a threshold as the growing season begins).

NDVI values accurate and consistent enough for trends to be derived require carefully calibrated satellite data sets corrected for sensor degradation and orbital drift. At high latitudes, patchy vegetation, snow, small leaf area, a short growing season, low sun angle, and persistent cloudiness compound the difficulty of obtaining good NDVI values. For these reasons, and based on advice from researchers in the field, we chose the NOAA/NASA Pathfinder NDVI data set derived from AVHRR data. We planned to continue the Pathfinder data record, which ends in 2001, with a MODIS NDVI product. Contrary to expectations, however, we found that this cannot be done without a cross calibration effort that is beyond the scope of the project. We include the MODIS data, but cannot yet use it as part of a long NDVI series for trend analysis.

Comparisons of Pathfinder and MODIS data, details on how we processed data to create the graphical products, and references for the data sources are on the greenness indicator page. In brief, MODIS and Pathfinder source data are re-projected to an 8 km EASE-Grid prior to processing. Source data use different compositing periods (16-day for MODIS, 10-day for AVHRR Pathfinder). They are interpolated so that SINDVI and Peak NDVI can be determined in a consistent way.

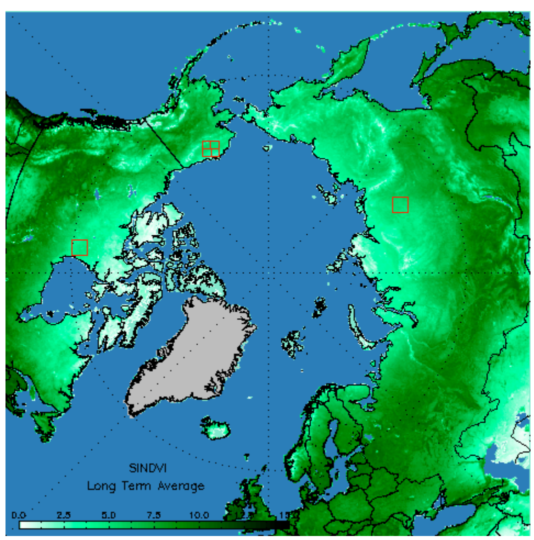

Figure 4. Average seasonally integrated NDVI, over the Pathfinder data set period of 1982-2001. NDVI is a unitless number. In general, lower SINDVI values correspond with higher elevations and higher latitudes.

Researchers (cited on the greenness indicator pages) have noted a trend toward increasing greenness and earlier spring greenup in the Northern Hemisphere. Our products are consistent with that general trend but reveal the spatial variability in greenness changes (Figures 5 and 6).

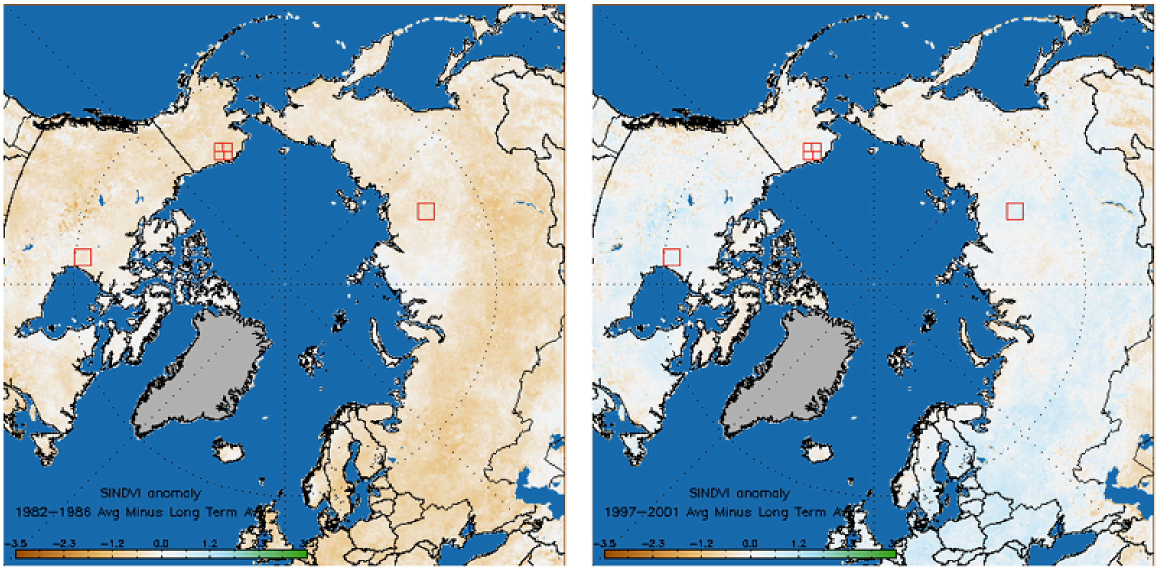

Figure 5. Seasonally integrated NDVI anomaly for the first five years of the Pathfinder data set (left) and the last five years (right). The preponderance of blue in the later data show that on average, the Arctic is getting greener, but there are some areas (such as the Yenisey river basin in central Russia north of 60 degrees) where this trend is not as strong.

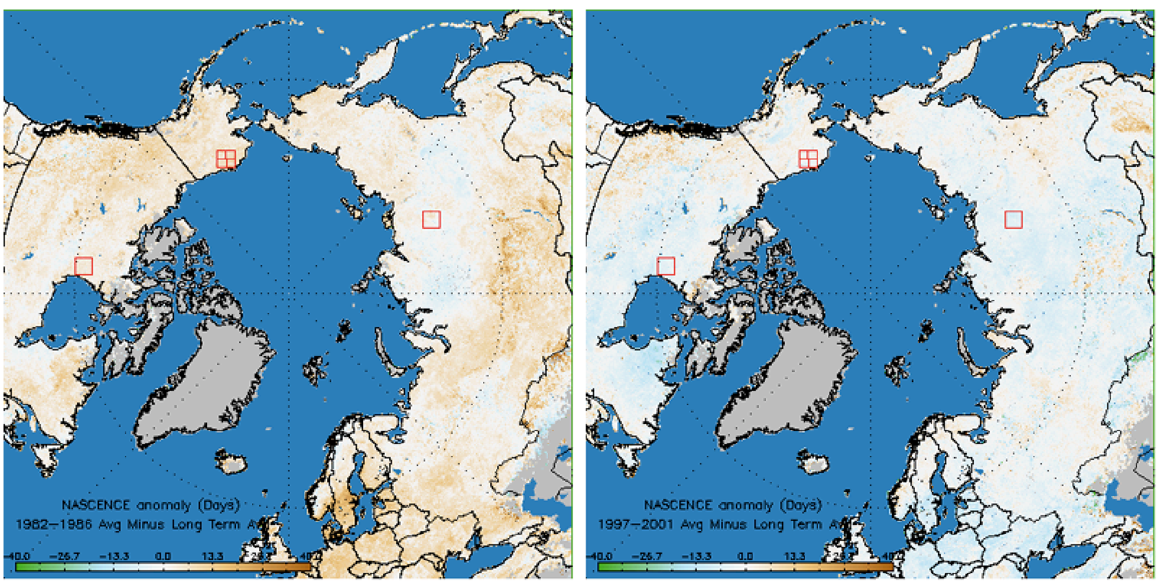

Figure 6. Nascence anomaly images for the first five years of the Pathfinder data set (left) and the last five years (right). These show a trend toward earlier greenup (blue colors in the image on the right) over much of the Arctic in the last five years of the Pathfinder data record when compared with the first five years (this figure).

Time series of SINDVI and nascence (Figure 7) for three regions show that changes seem to be well correlated from place to place for SINDVI but with a greater tendency to vary from place to place for nascence. This difference in the greenness indicators may help in attributing the sources of greenness changes.

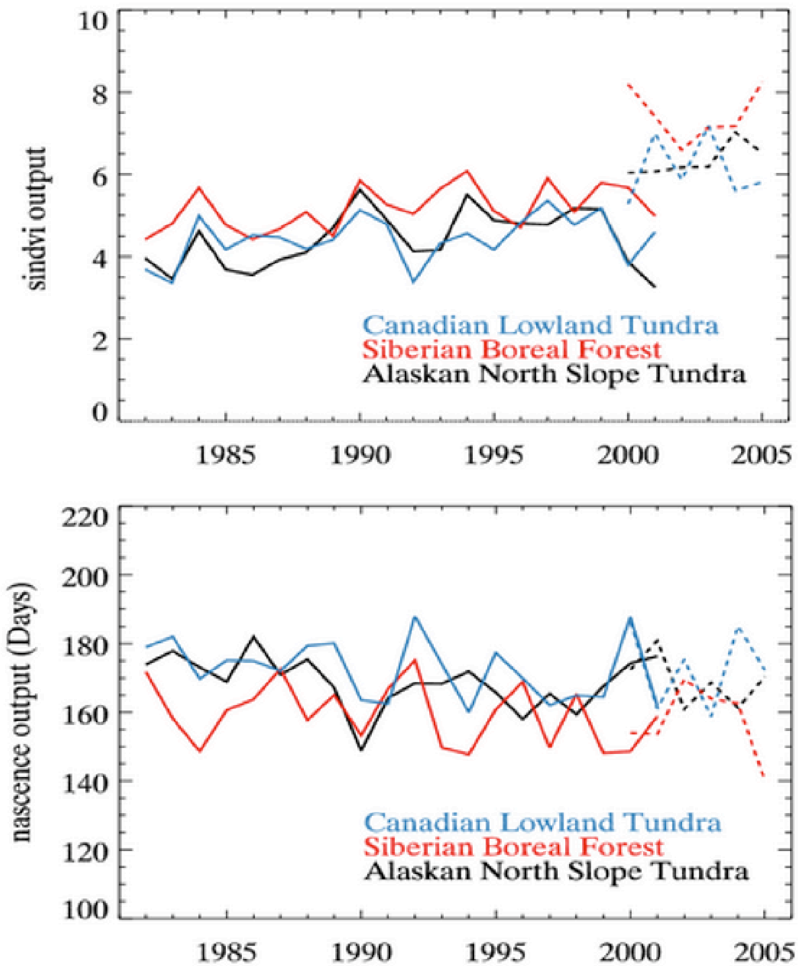

Figure 7. Time series of seasonally integrated NDVI (top) and nascence (bottom) averaged over three areas. Seasonally integrated NDVI is trending higher, and nascence is trending lower (toward earlier greenup), but these trends are not significant in the Pathfinder data. The dashed lines are data from MODIS. A review of the scientific literature comparing the relatively new MODIS product with the Pathfinder product suggests that MODIS is more sensitive and accurate than AVHRR. Cross calibration will be difficult because of the short overlap period.

The type of land cover present can affect how NDVI responds to climate change. In order to sample from homogenous areas for the time series plots, we chose three areas guided by a biome map: a boreal forest biome in Siberia, a lowland tundra area in Canada, and a lowland tundra area on Alaska's North Slope. The North Slope area is complex, however, with factors such as tundra acidity influencing NDVI response. A finer division of biomes is called for here, so the North Slope area is further divided into areas of coastal and higher elevation tundra (Figure 8)

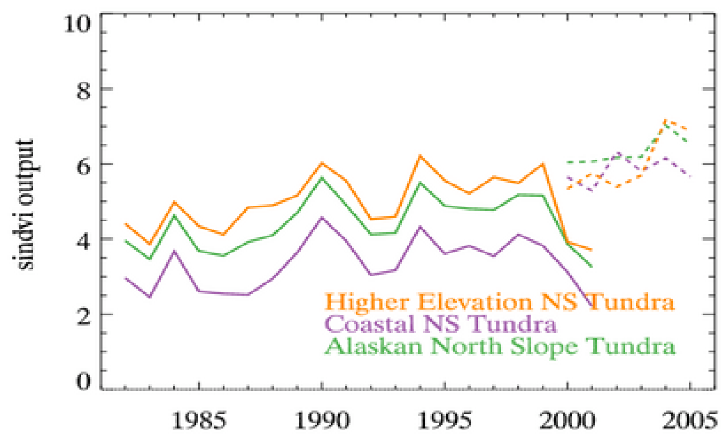

Figure 8. Coastal and higher elevation North Slope tundra have statistically different NDVI distributions, so they are plotted separately as well as together. Coastal tundra SINDVI differs from inland higher elevation tundra SINDVI by a factor of 1 to 2. The large number of lakes near the coast is one reason for the difference, but other reasons are differences in soil and vegetation type. Despite these differences, the regions respond to changes similarly. The higher resolution and more accurate MODIS data give a different impression, however, and point to the potential benefit of more work with MODIS data.

With all of the greenness indicators, we can explore questions such as: Is there more photosynthetic activity now? Do the leaves come out earlier now? Is a trend detectable? Is the pattern of changes in greenness the same everywhere? To answer more questions about plant growth, we would need to add indicators such as senescence, leaf area index, and vegetation cover by type. These are either unavailable in near real time, or require data that are more highly processed than is practical.

More information, including a statistical analysis, can be found on the greenness indicator pages.

Sea Ice

The Sea Ice Index predates the other indicator products. Under this project (in 2004) it was extended back so that the sea ice concentration time series upon which the products are based begins in 1979. This longer record (before, the product covered only the SSM/I satellite passive microwave series beginning in 1988) makes the product much more useful, because trends derived from the series are more likely to be significant.

Sea Ice Index products are updated monthly. Monthly products are used because daily variability in passive microwave derived sea ice concentration can be large, so monthly products give a better picture of trends and anomalies. In addition to the products illustrated by Figures 9 and 10, text files of extent and area data are available, along with archived images. The Web site includes products for Antarctica as well.

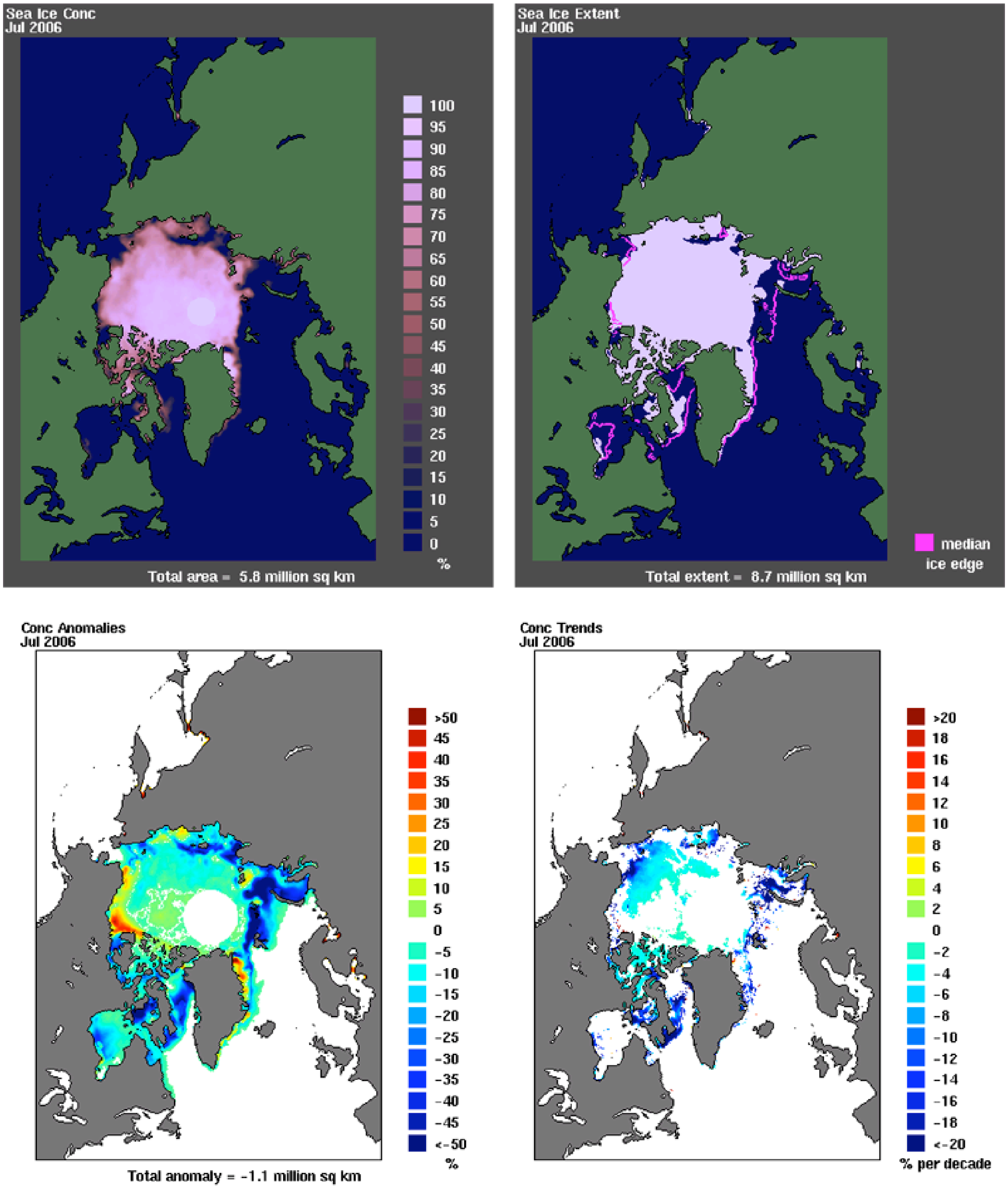

Figure 9. Sea Ice Index products include views of ice concentration (upper left) , ice extent with the median extent for the month (upper right), concentration anomalies (lower left) and trends in concentration (lower right).

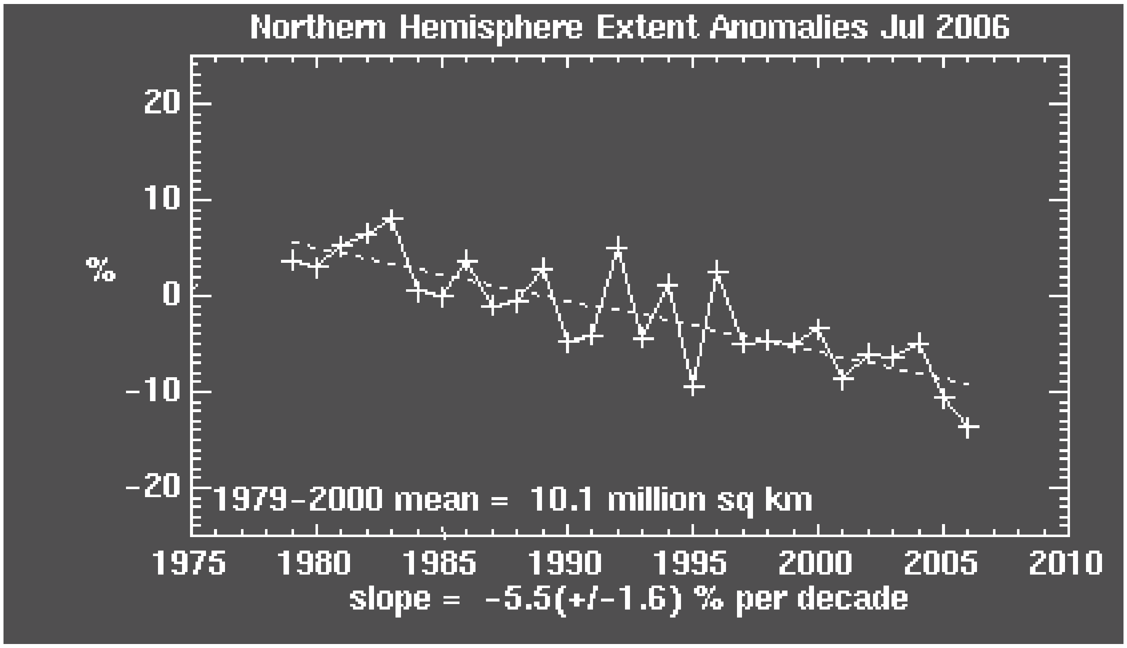

Figure 10. Extent anomaly plots are shown with a 95% confidence interval.

The site includes a tool for animating images. Another tool (Figure 11) makes it easy to compare months, years, and parameters quickly. This tool makes it easy to see, for example, that the Odden sea ice feature off Greenland has failed to appear in the February monthly mean for the last five years, and that the trend in Antarctic sea ice, while positive, is not significant for any month of the year. (See the NOAA Arctic Theme Page for a description of the Odden).

The Sea Ice Index Web site discusses at length how the numbers, images and figures were derived. A section on “Resources for Interpreting Sea Ice Trends and Anomalies” gives the non-scientist user background on sea ice variability, linear regression, and algorithm validation so that they may more fully understand a trend in sea ice extent, for example.

Images are updated monthly and trends are shown with uncertainty intervals (e.g. Figure 10). The figures are presented without comment, although a section titled References on Trends in Arctic Sea Ice gives a short overview of how others have interpreted trends.

Images from the See Ice Index have been widely used in the press, and also in articles and books (e.g. Field Notes from a Catastrophe: Man, Nature and Climate Change, by E. Kolbert, Bloomsbury Publishing 2006). The National Climatic Data Center uses it for climate summaries. There have been as many as 6500 distinct users visiting the site in a month, with 40,000 site “hits”. Based on URL reference logs for the products and requests for permission to use product images, we know that the site is reaching its intended audience of non-scientists as well as scientists. A Digital Library for Earth

System Education Web site for educators has a page that features the Sea Ice Index (http://serc.carleton.edu/dev/usingdata/datasheets/NationalSnowIceDC.html) .

To extend the reach of the product further, we included it in a Google Earth demonstration project (Figure 12).

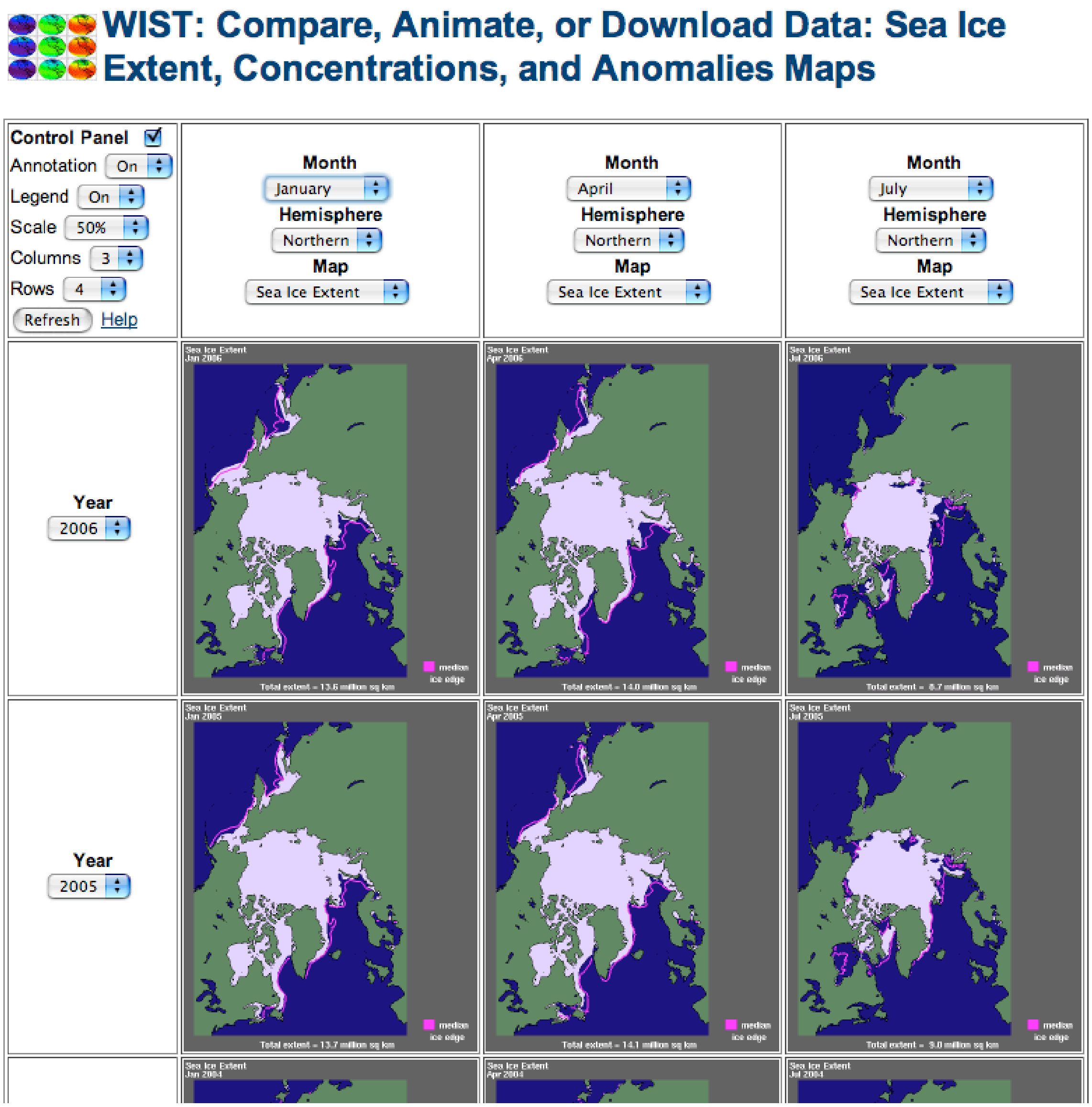

Figure 11. A tool allows users to quickly display Sea Ice Index products side by side, making it easy to compare seasons or years. The Web Image Spreadsheet Tool (WIST) was developed at the NOAA National Geophysical Data Center.

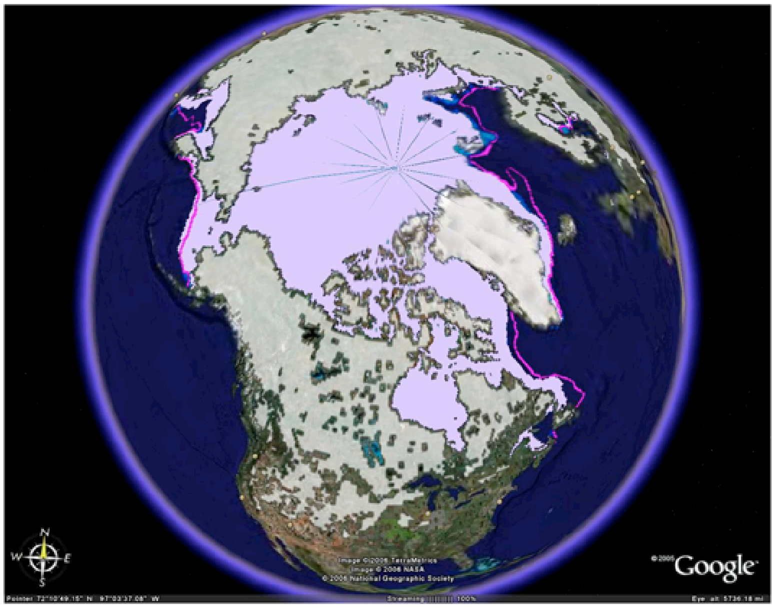

Figure 12. Sea Ice Index products can be incorporated in Keyhole Markup Language (KLM) files to display in Google Earth.

Soil Temperature

Soil temperature responds to changing air temperatures but with a lag in time that depends on soil depth. Changes in surface conditions take years to propagate through the soil: decades or longer to propagate deeper than 10 m. Soil temperature is an excellent climate indicator because it acts as a low pass filter, filtering out short-term noise in the climate signal. However, soil temperature behavior over time at any one location depends on many site-specific factors. The soil temperature indicators show examples of variability in soil temperature behavior. Web pages include profiles of soil temperature over depth, and plots of daily air temperatures and soil temperatures at a level deep enough to remove the diurnal temperature cycle. A time series of normalized monthly soil temperature is shown as well to facilitate comparing different sites. Sites in Alaska and Russia are included.

Data for the soil temperature indicator products are from the NSIDC Frozen Ground Data Center. A lack of funding for this center has contributed to our inability to keep the data series up to date.

In general, the soil temperature plots reflect warming trends. Figure 13, showing the profile product from the Russian site, is a dramatic example.

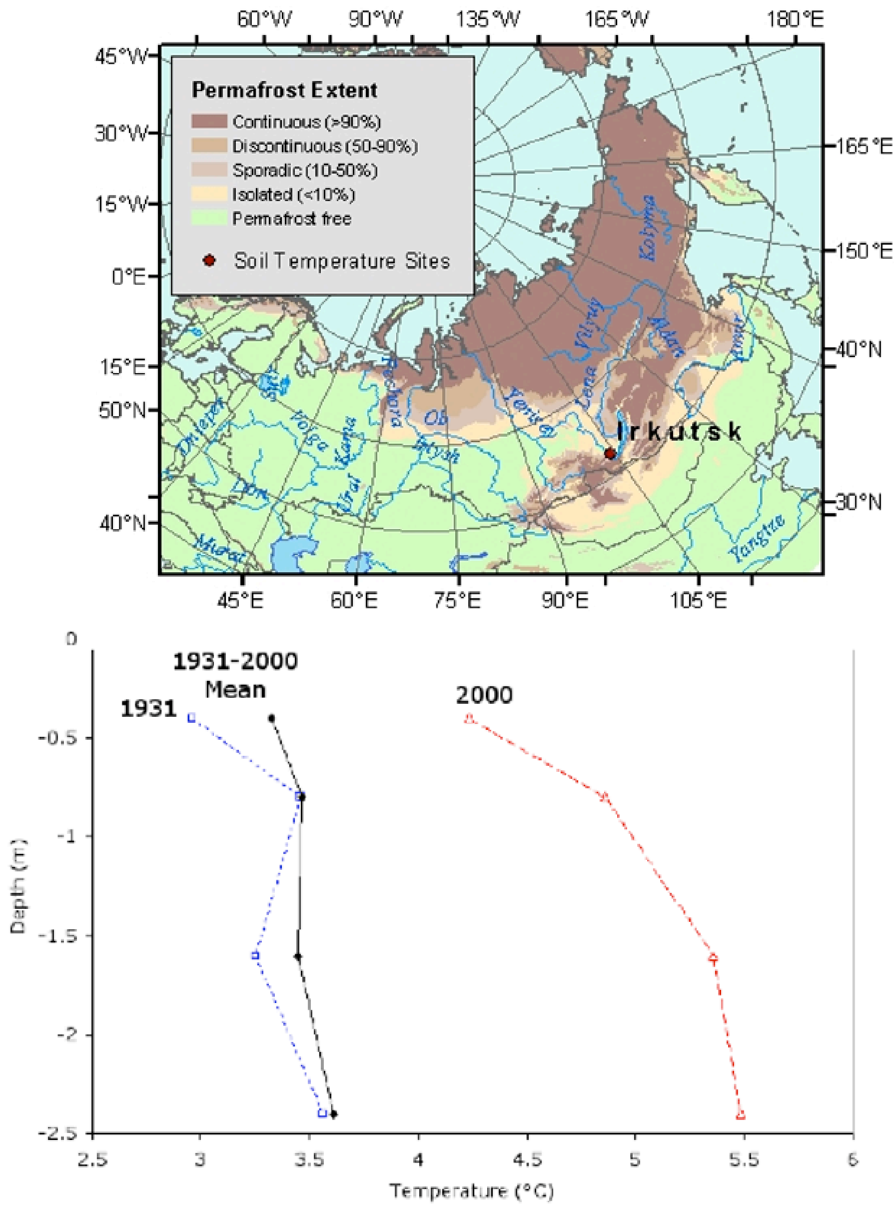

Figure 13. Soil temperature profiles (bottom) with a locator map (top) for Irkutsk, from the soil temperature indicator Web site.

Needed Improvements

Currently, the Cryospheric Climate Indicators in the Arctic Web site is uneven in its presentation. The amount of documentation and interpretation as well as its technical level varies between indicators. The NSIDC Science Communications group reviewed the site and made suggestions for improving site navigation and content. These have not been implemented. If the project continues, the next steps would be to make these improvements, cross-calibrate sensors for the Greenness site, update the Soil Temperature site, and add other indicators to Google Earth.

Data Management for SEARCH and IPY

NSIDC has proposed an IPY Data and Information Service (IPYDIS) that will be an international federation of data centers, archives, and networks working to ensure proper stewardship of IPY and related data (see the NSIDC IPY Web site, http://nsidc.org/ipy/). The NOAA program at NSIDC (http://nsidc.org/noaa/) is in a good position to coordinate data management for NOAA SEARCH and IPY investigators by working with the larger IPYDIS, should it be funded. To date, efforts have been limited to discussing data management needs with Boulder area NOAA SEARCH International Arctic System for Observing the Atmosphere (IASOA) investigators, and coordinating a data management strategy for NOAA IPY that was written up as an IPY Expression of Intent (NOAA's Data, Information, and Change Detection Strategy for the IPY, short title NOAA Data Management and Change Detection - ID 879). This was done in cooperation with several NOAA offices. Fetterer is a member of the SEARCH Data Management Working Group that formed in February 2006.

Impacts

The Sea Ice Index products are reaching scientists, educators, and the public; other indicator products will have similar impacts when fully developed with longer time series. Leading the NOAA IPY Expression of Intent for data management helped connect the diverse and far-flung NOAA Arctic community. This initial planning effort has the potential to grown into a truly collaborative cross-NOAA IPY effort. Participation in the SEARCH Data Management working group ensures that NOAA interests are represented, and provides a link between the SEARCH science program and NOAA or NOAA-affiliated data centers where research program data will ultimately be archived. Participation in the Integrated Ocean Observing System (IOOS) Data Management Advisory Committee (DMAC) Archive Expert Team and the Global Climate Observing System (GCOS) SST and Sea Ice Working Group also helps connect NOAA arctic research with data management.

Data Sets Published

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National Snow and Ice Data Center, compiler. 2006. *Monthly mean precipitation sums at Russian Arctic stations, 1966-1990*. Boulder, Colorado USA: National Snow and Ice Data Center. Digital media.

National Snow and Ice Data Center. 2003. *Meteorological data from the Russian Arctic, 1961-2000*. Compiled by V. Radionov. Boulder, CO: National Snow and Ice Data Center. Digital media.

Radionov, V.F., Ye. I. Aleksandrov, P.N. Svyashchennikov, and F. Fetterer. 2004. *Daily precipitation sums at coastal and island Russian Arctic stations, 1940-1990*. Boulder, CO: National Snow and Ice Data Center. Digital media.

Web Sites

SEARCH and IPY (http://nsidc.org/noaa/search/) summarizes SEARCH data integration and management activities at NSIDC funded by the NOAA Arctic Research Program

Cryospheric Climate Indicators in the Arctic (http://nsidc.org/noaa/search/indicators/index.html) with pages for Soil Temperature, Snow Cover, Sea Ice and Greenness indicators.

Publications and Presentations

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Fetterer, F., and I. Smolyar. 2005. On the Creation of Environmental Data Sets for the Arctic Region, in *Arctic Research of the United States*, NSF05-39, Vo1. 19, 15 pp.

Overland, J., J. Calder, F. Fetterer, D. McGuire, J. Morison, J. Richter-Menge, N. Soreide, and J. Walsh. 2003. SEARCH Workshop on Large-Scale Atmosphere-Cryosphere Observations, *Bulletin of the American Meteorological Society*, *DOI: 10.1175/BAMS-84-8-1077* (August), 1077-1082.

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Fetterer, F. and M. Savoie. 2006. Observations for SEARCH: Data Integration for Change Detection. Presented at the joint CliC/IGS/ICSI International Symposium on Cryospheric Indicators of Global Climate Change. Cambridge, England, 21-24 August.

Soreide, N.N., J. Calder, J.E. Overland, and F.M. Fetterer. 2005. Arctic change detection website. In *The 21st International Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology,* The 85th AMS Annual Meeting, San Diego, CA, 9–13 January.

Poster presentations

Fetterer, F., M. Savoie, and B. Raup. 2006. A passive microwave derived snow melt onset product for the Arctic north of treeline. Poster at the IEEE Int. Geoscience and Rmt Sensing Symposium, Denver, Colorado. 31 July – 4 August.

Fetterer, F., K. Knowles, J.C. Stroeve, M.C. Serreze, J. Maslanik, C. Oelke, and T.A. Scambos. 2003. Recent Arctic Ice Extent Minima Observed with the Sea Ice Index, Poster at the SEARCH Open Science Meeting, Seattle, WA, 27-30 October.

Raup, B. H. F. Fetterer, Mark Parsons, Matt Savoie, Ken Knowles. 2005. SEARCH Climate Indicators: Melt Onset and Other Cryospheric Data Products, in AMS 8th Conference on Polar Meteorology and Oceanography, San Diego, CA.

The following were not funded by NOAA SEARCH, but are related to the Sea Ice Index work and are included here to show the scope of that work.

Fetterer, F., K. Knowles, J. Stroeve. 2002. NSIDC Sea Ice Index Product Reveals Anomalously Low Arctic Ice Extent in Summer, 2002. American Geophysical Union Fall Meeting, 6-10 December 2002. Abstract Reference Number: 3582, U72A-0011.

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Funding

A total of 270K over three years was provided. Funding was spent almost entirely on labor, as show in the table below. (Not shown is $3000 for the purchase of precipitation data. This was paid for from the Reanalysis SEARCH funding.)

In the first two years of the project, Fetterer's contribution was subsidized by NESDIS base funding to the NOAA data management program at NSIDC (described at nsidc.org/noaa/). This "joint funding" allowed us to publish more data sets than we would have otherwise. For example the Sea Ice Index work was started with NESDIS funding, but extending the product back to 1979 was the result of NOAA SEARCH funding.

Note – work actually began in June 2003, when the University fiscal year begins.

Data Integration for Arctic Reanalysis and Change Detection – Funding and Level of Effort

	Labor in Months			
Name	**FY04**	**FY05**	**FY06**	**Total**
Ken Knowles (Scientific programmer)	1.25	1.5		2.75
Mark Parsons (Data management)	1	1.5		2.5
Bruce Raup (Scientific programmer)	1.25	1.45		2.7
Matt Savoie (Scientific programmer)	0	2.46	7.25	9.71
Florence Fetterer (Project lead)			7.2	7.2
Kara Pharris (Web design)			1	1
Total	**3.5**	**6.91**	**15.45**	**25.86**

Non-Labor Charges	Amount
Computer Disk	489
IEEE Conference for Savoie	363
Fedex and Other Misc Charges	65
Total	916