National Snow and Ice Data Center

Supporting Cryospheric Research Since 1976

Contemporary Cryosphere Changes in Northern Eurasia: A Few Examples

R. L. Armstrong,

Cooperative Institute for Research in Environmental Sciences (CIRES)

University of Colorado at Boulder

Terrestrial Cryosphere

- Snow Cover
- Seasonal Frozen Ground/Permafrost
- Glaciers

-as monitored by both in situ and remote sensing

Snow Cover
In situ/station data at NSIDC

Former Soviet Union Hydrological Snow Surveys

– 1966-1996, updates pending

– 1345 sites, depth and water equivalent along transects

Historical Soviet Daily Snow Depth Version 2 (HSDSD) – 1881-1995

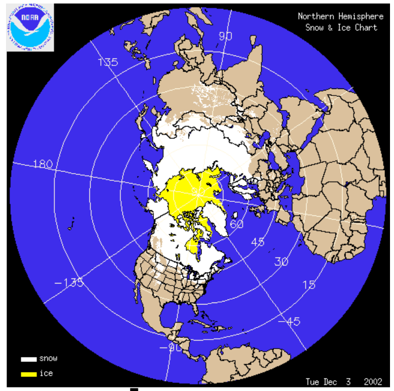
- 284 WMO sites, depth, percent cover, snow and site characteristics

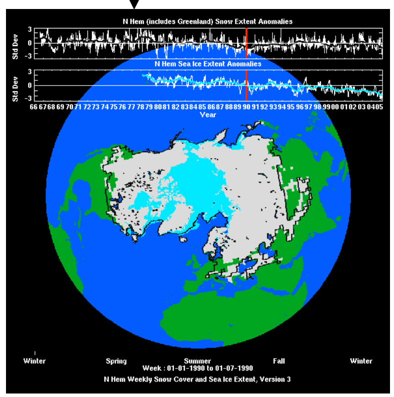
http://nsidc.org/data/g01170; -- /g01092.html

“Visible”-derived snow data

NOAA weekly snow charts, (1966-2007) + Robinson QC, regridded to…

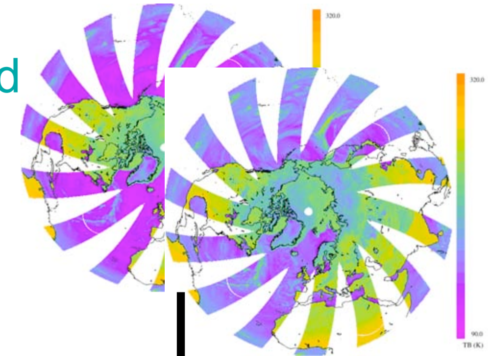
…Northern Hemisphere EASE-Grid, aggregated into monthly average snow-covered area.





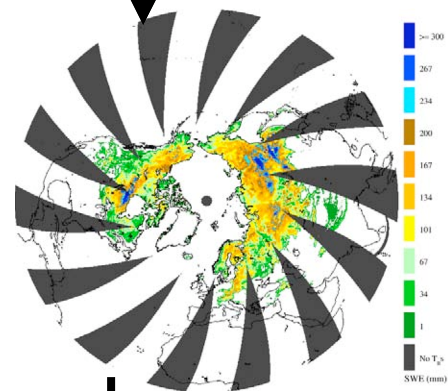
Microwave-derived snow data

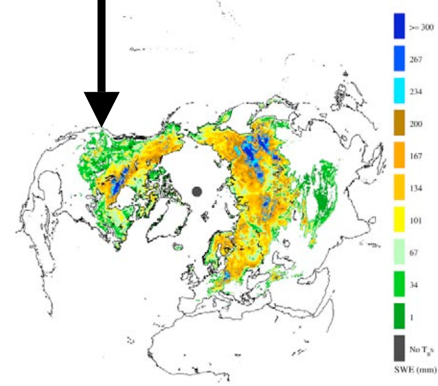
EASE-Grid daily SMMR-SSM/I TBs (1978-2007)…

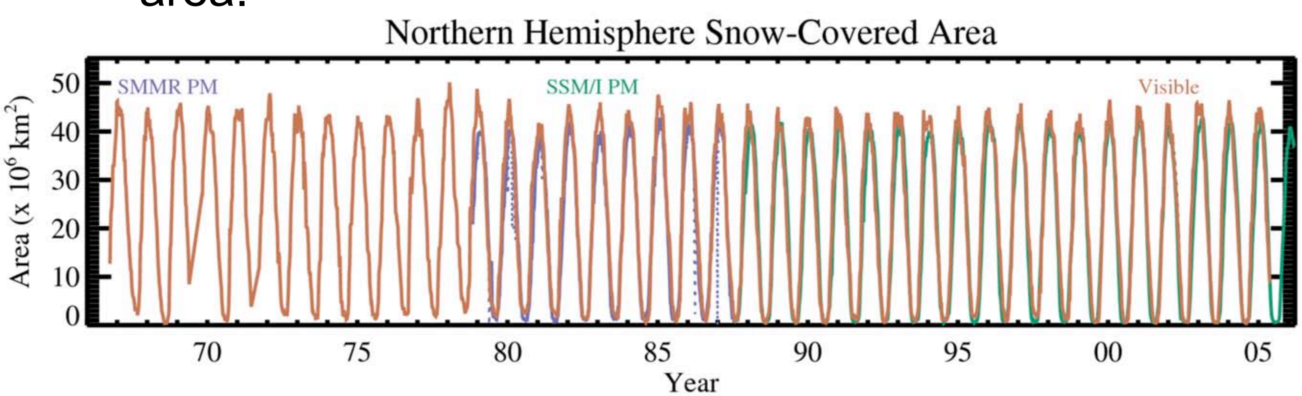


…to derive daily SWE…

…combined into weekly maximum SWE maps, and monthly average SCA.



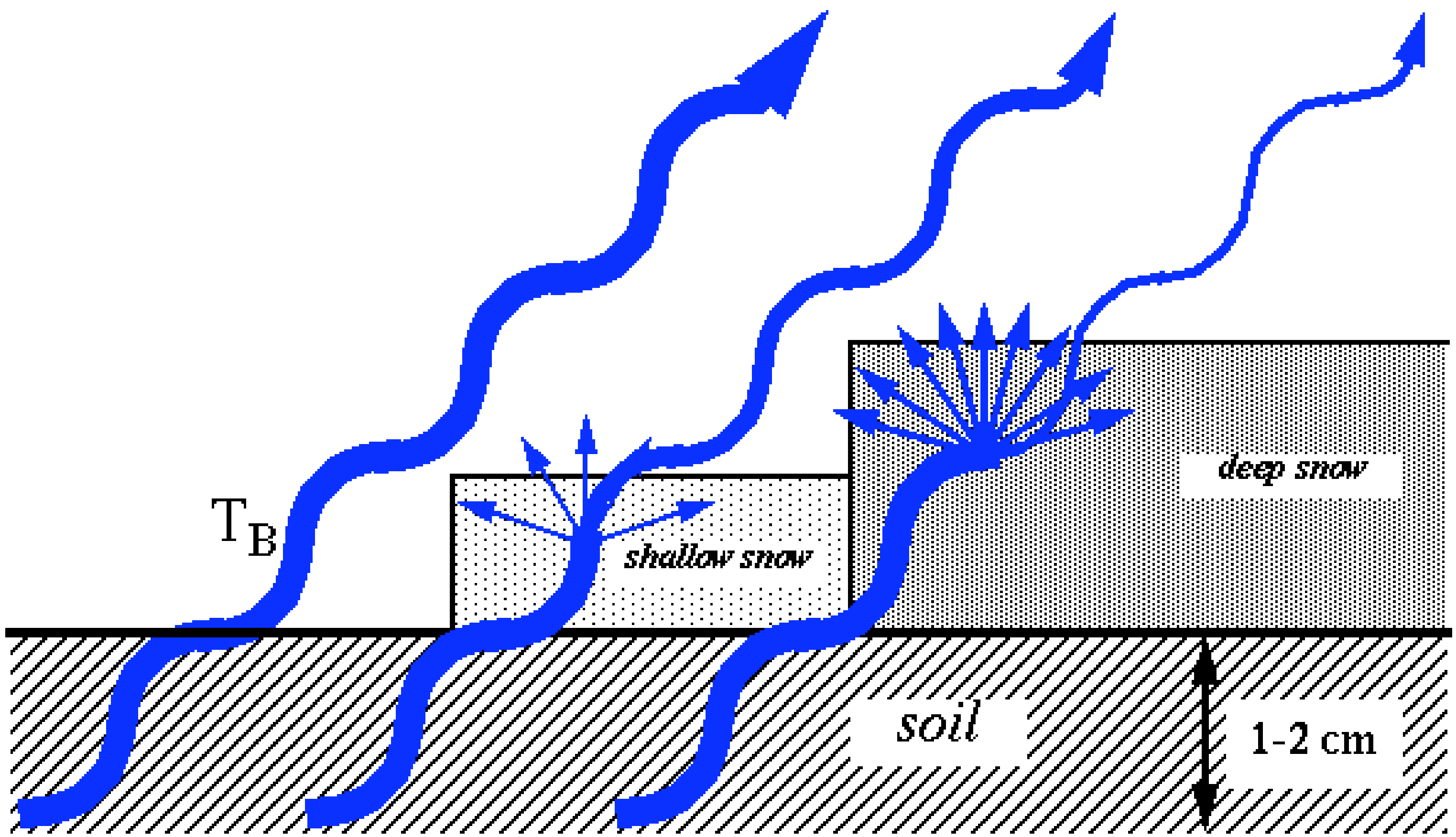




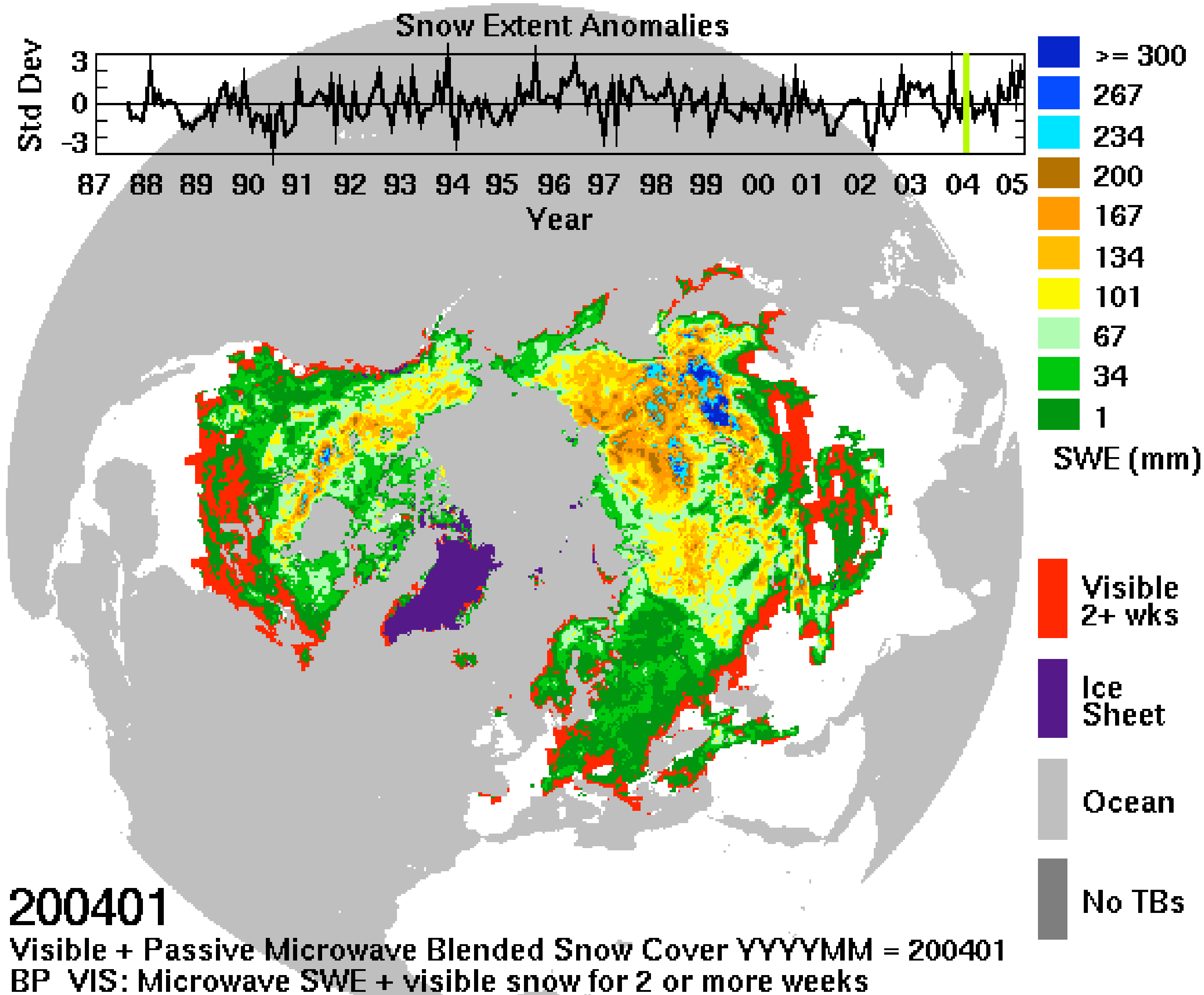
nsidc.org

Passive Microwave Remote Sensing of Snow

- Radiation emitted from the soil is scattered by the snow cover
- Scattering increases in proportion to amount (mass) of snow
- Brightness temperature decrease, negative spectral gradient

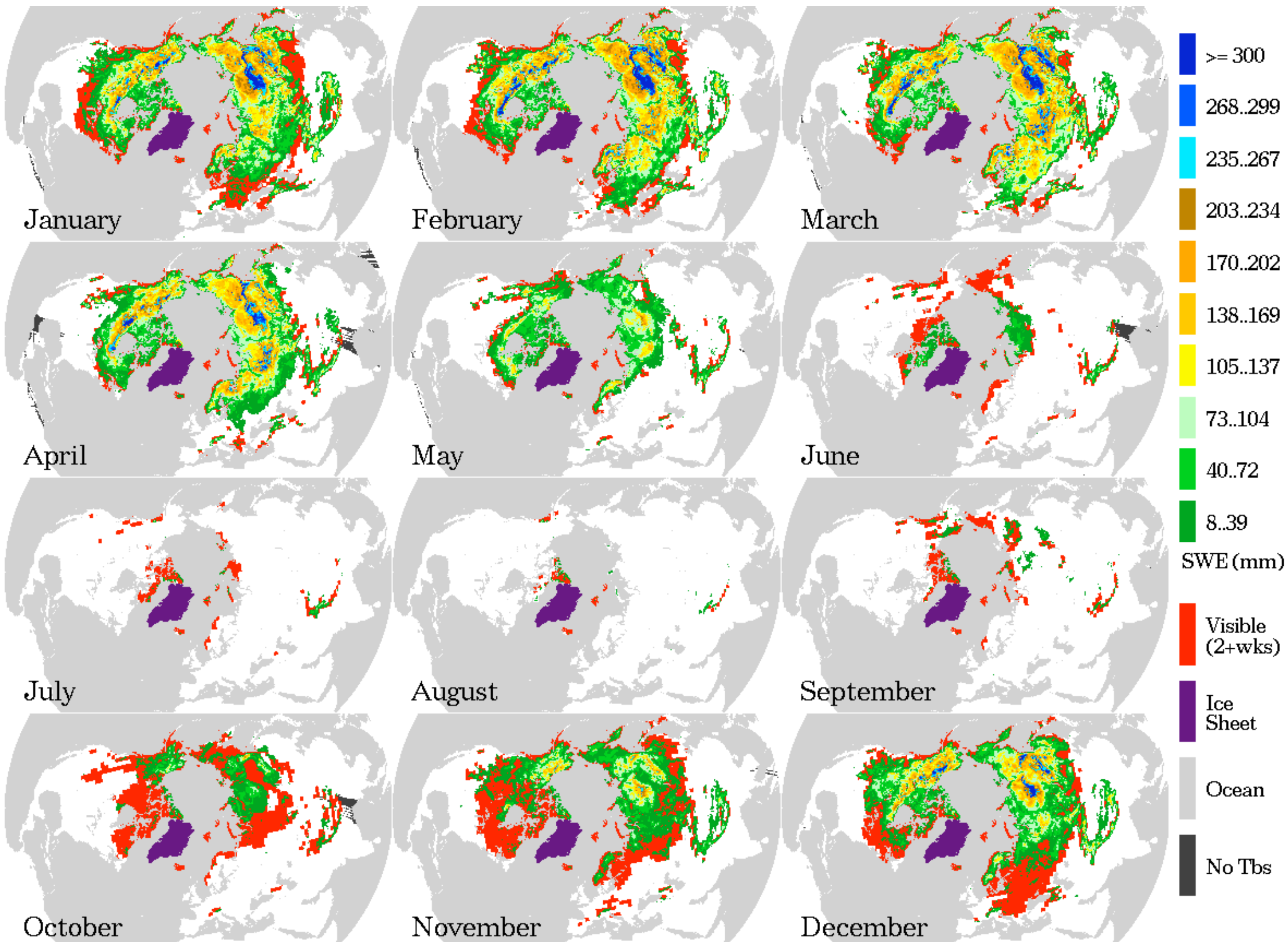


NSIDC Global Monthly EASE-Grid Snow Water Equivalent Climatology



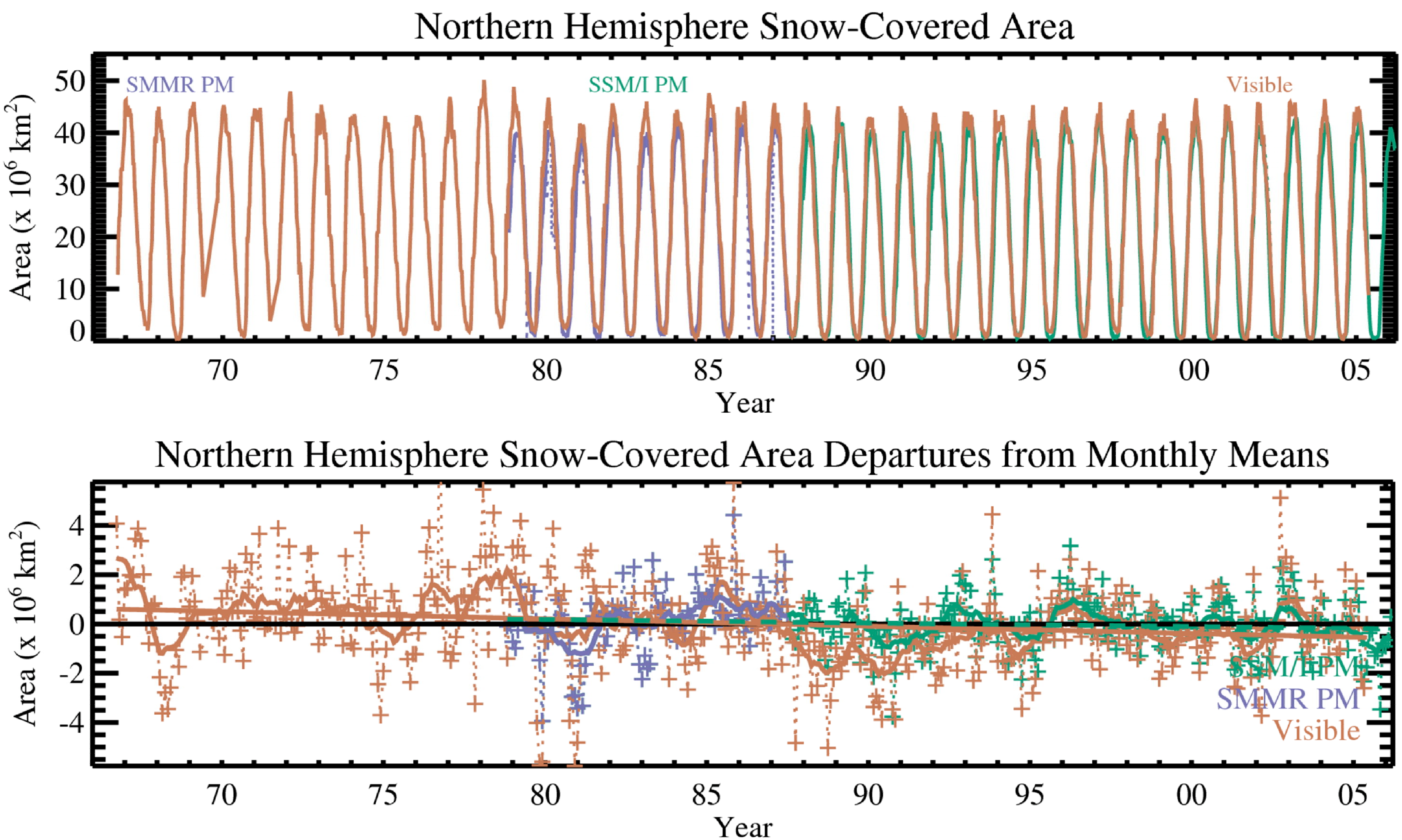
Combines visible (NOAA, MODIS) and passive microwave (SMMR.SSM/I, AMSR-E)

Blend of visible and microwave – monthly climatologies



Mean monthly snow extent and SWE for 1978-2006 from a blend of passive microwave (SMMR & SSM/I) and visible (NOAA) data

Snow-covered Area (SCA) Time Series
Visible (1966-2006) vs. Passive Microwave (1978-2006)

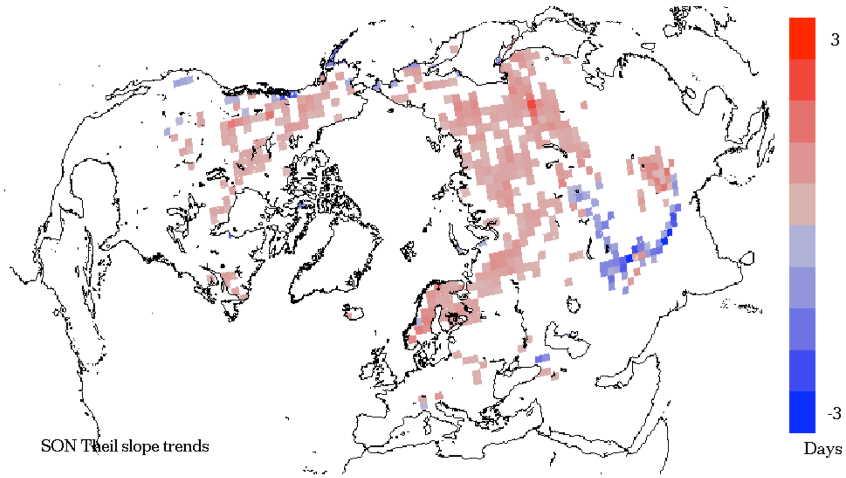


Visible – 1.3%/decade*
Microwave – 0.7%/decade

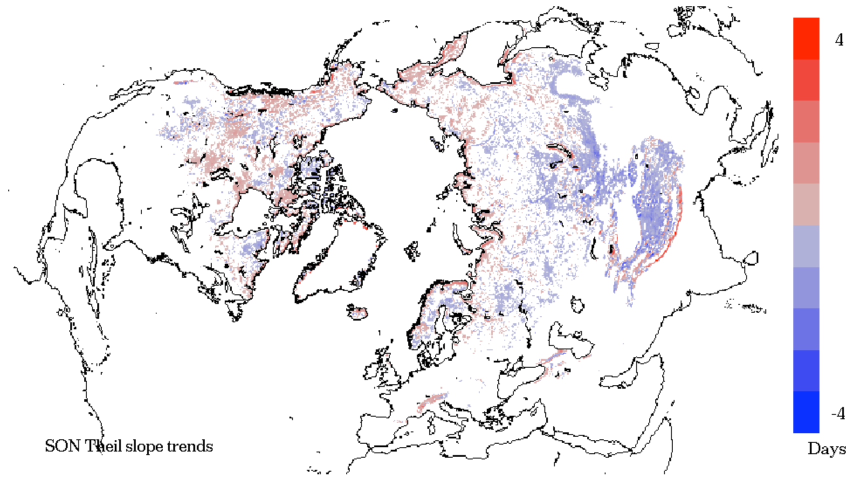
Trend fit: (phi= 0.51*), (-1.330 +/- 0.569%/decade*), required yrs > 25
Trend fit: (phi= 0.48*), (-0.697 +/- 0.640%/decade), required yrs > 50

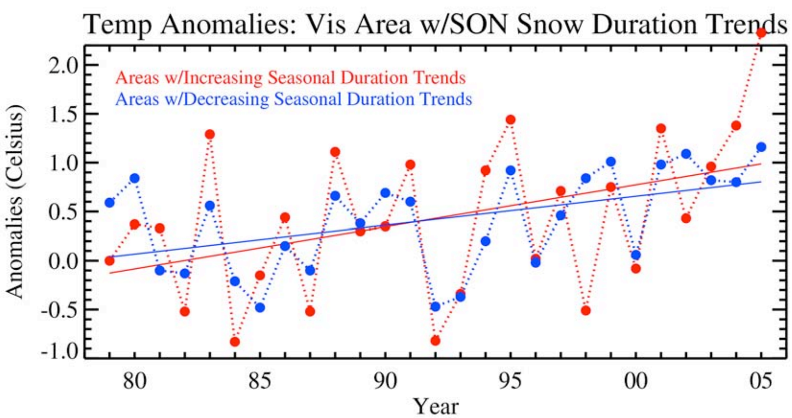
Autumn Duration of Snow Cover vs. NASA GISS Temperature Anomalies

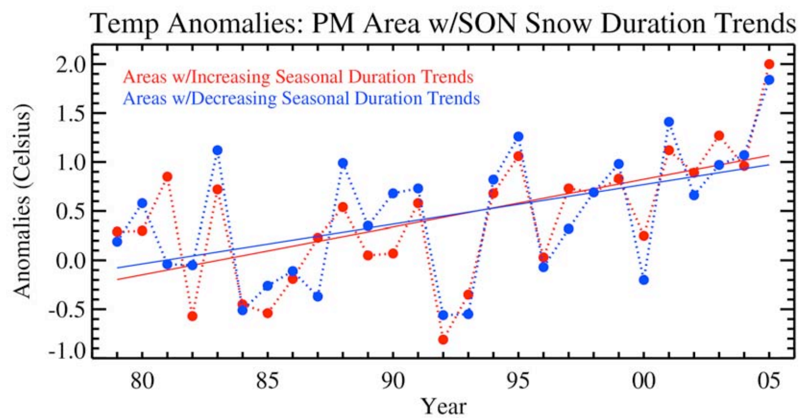
Visible



Passive Microwave

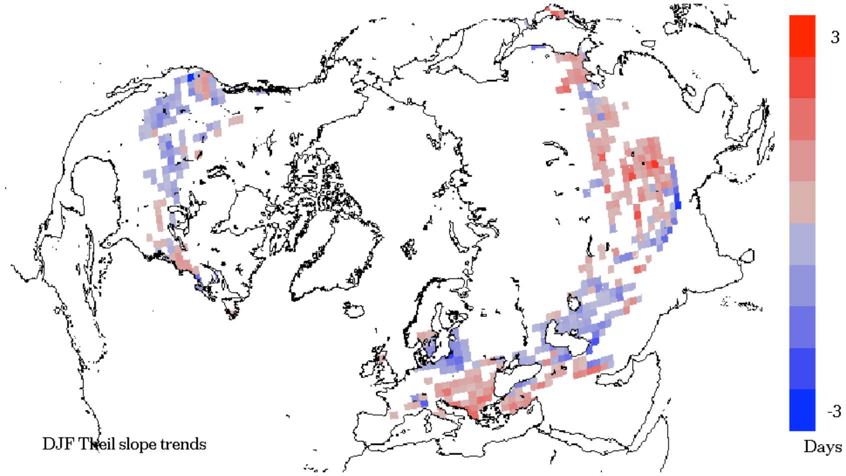




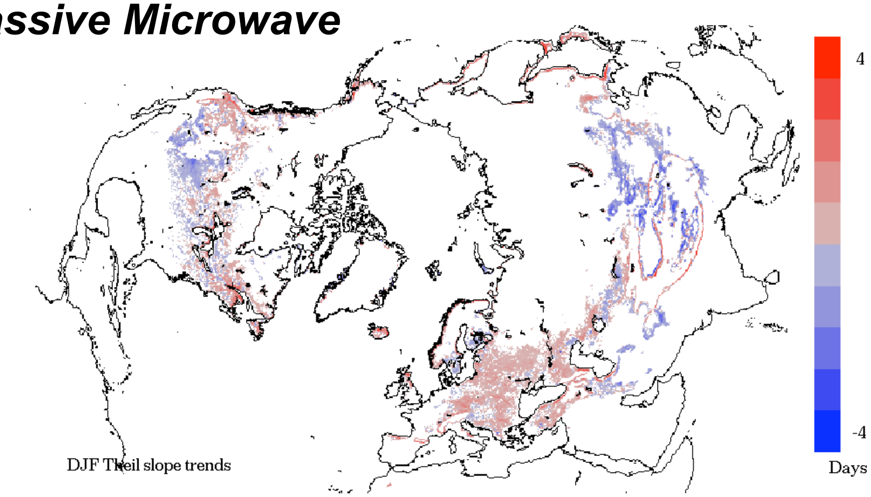


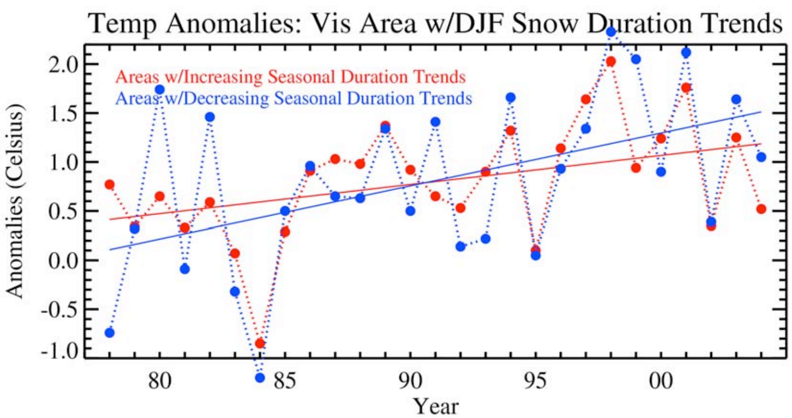
Winter Duration of Snow Cover vs. NASA GISS Temperature Anomalies

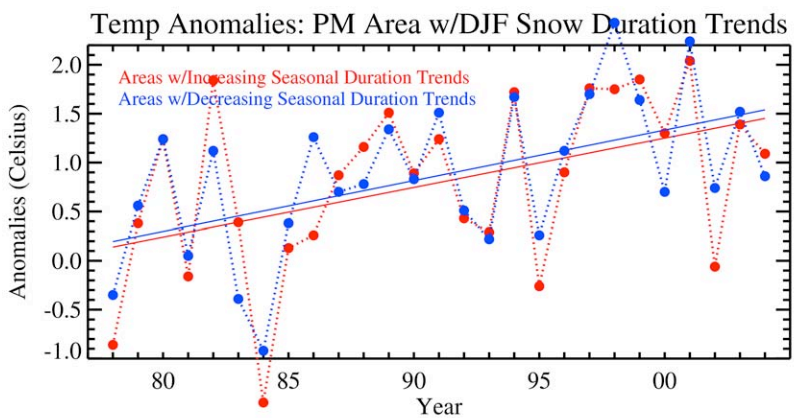
Visible



Passive Microwave

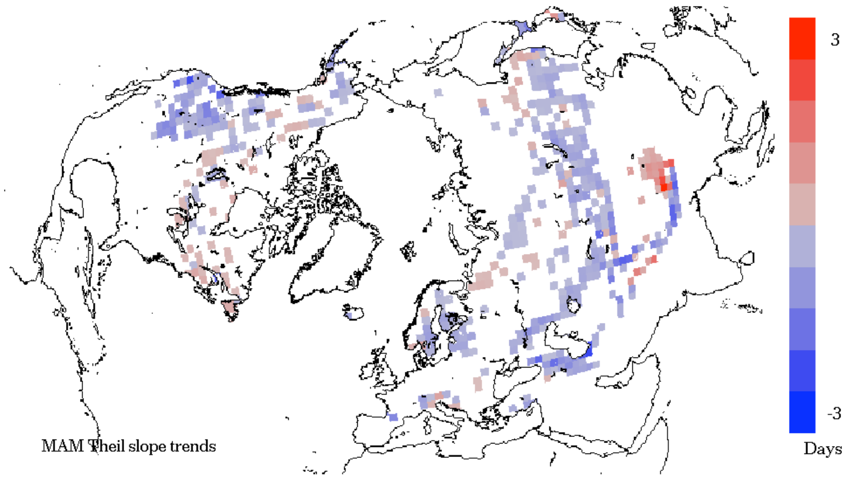




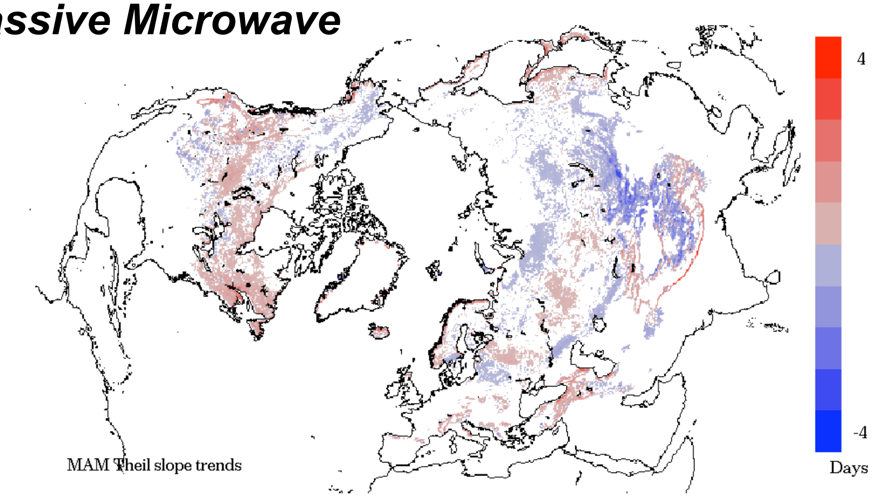


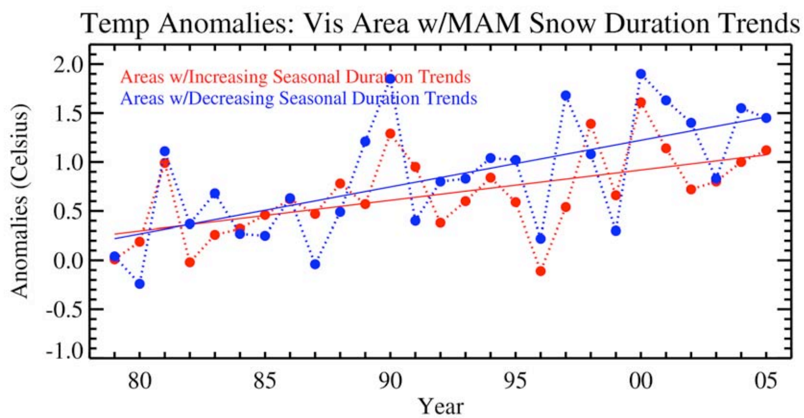
Spring Duration of Snow Cover vs. NASA GISS Temperature Anomalies

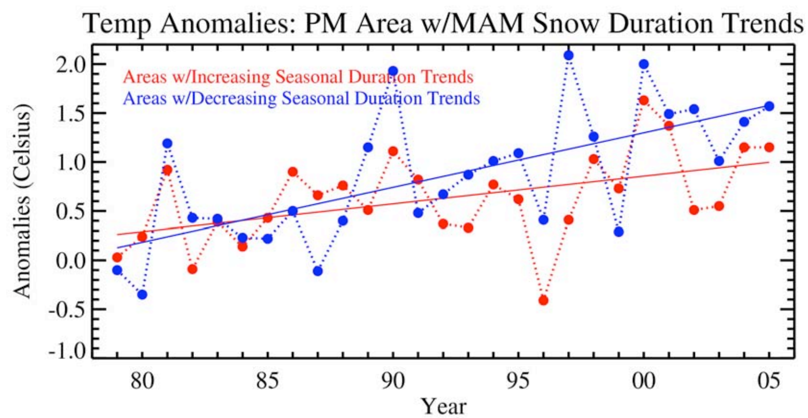
Visible



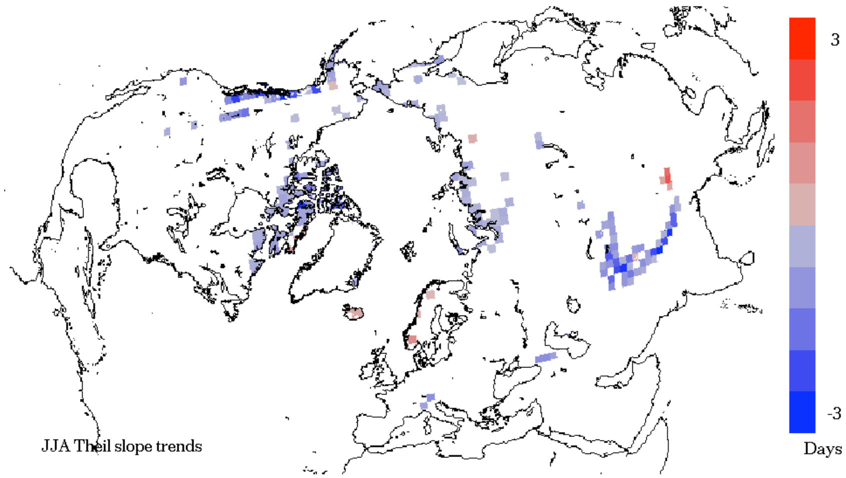
Passive Microwave

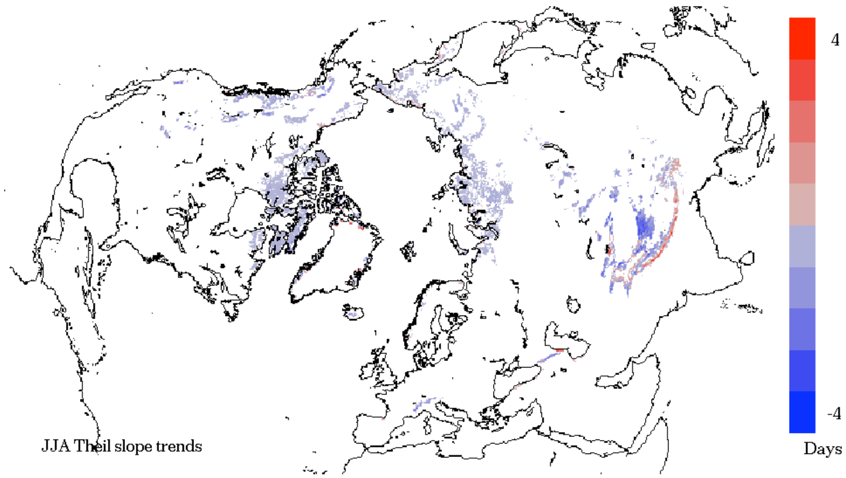


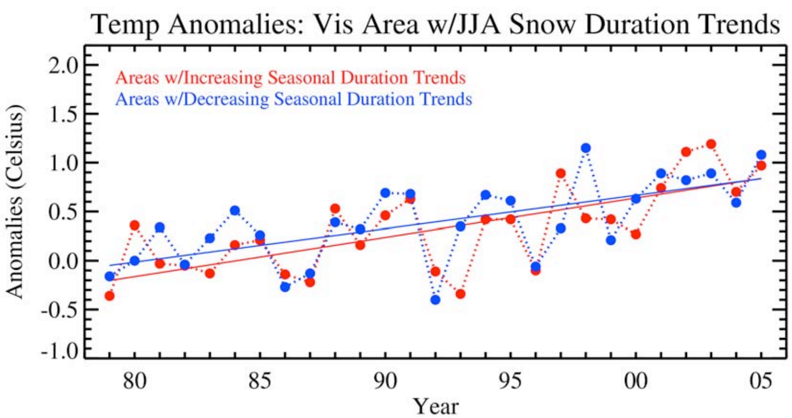


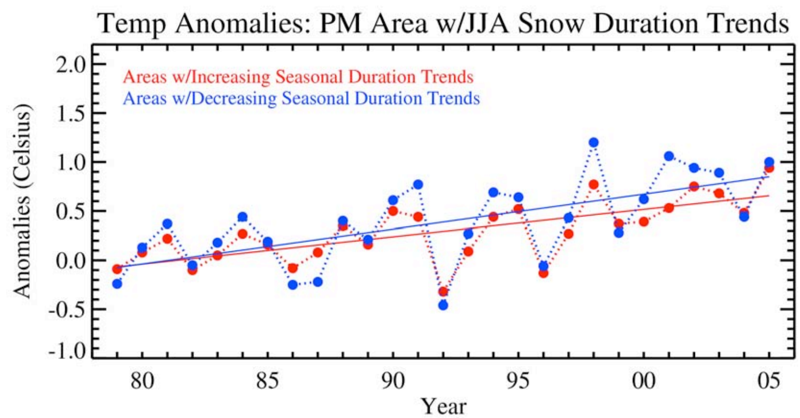


Summer Duration of Snow Cover vs. NASA GISS Temperature Anomalies



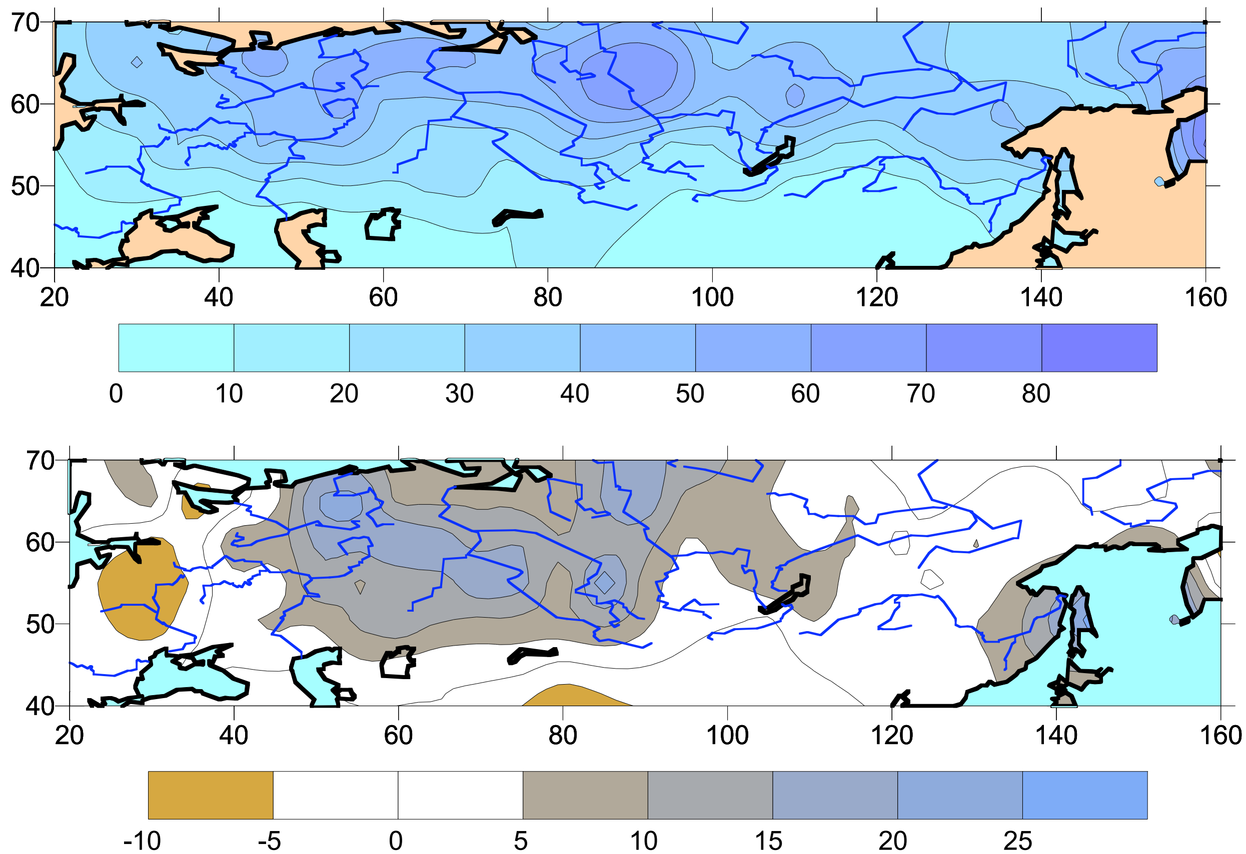






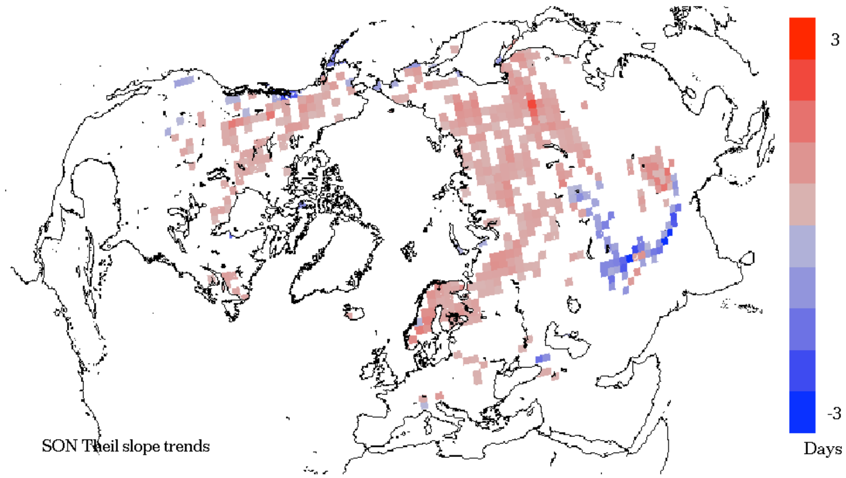
The snow depth in Eurasia is increasing in most areas, and decreasing in the west only

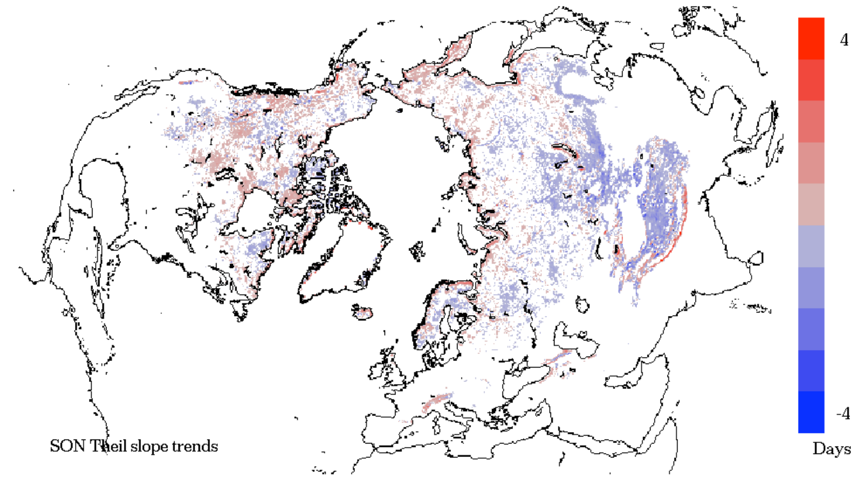
A.B. Shmakin

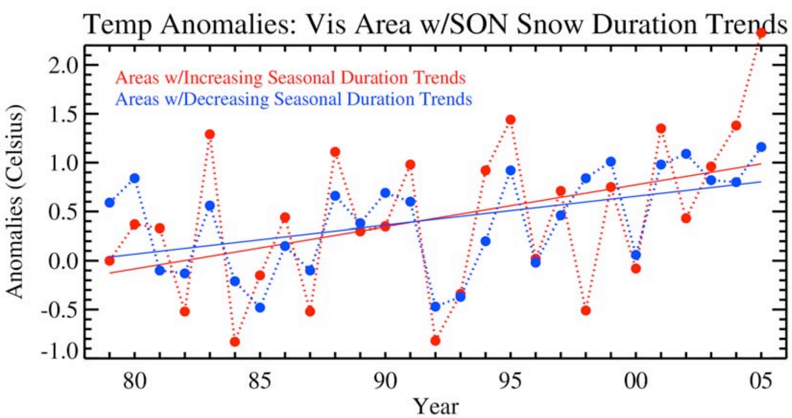


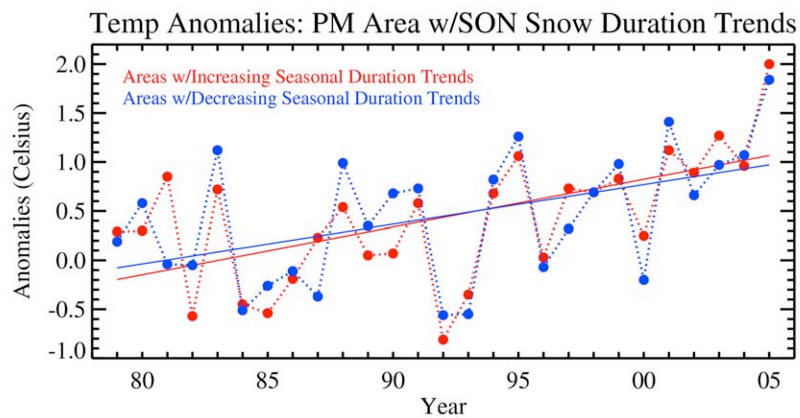
Mean February observed snow depth in Eurasia in 1951-80 (cm, top),
and its change in 1989-2001 as compared to 1951-80 (cm, bottom) from Schmakin.
(J. Cherry, IARC concurs, in situ data shows snow falls earlier and heavier in Siberia)

Autumn Duration of Snow Cover vs. NASA GISS Temperature Anomalies

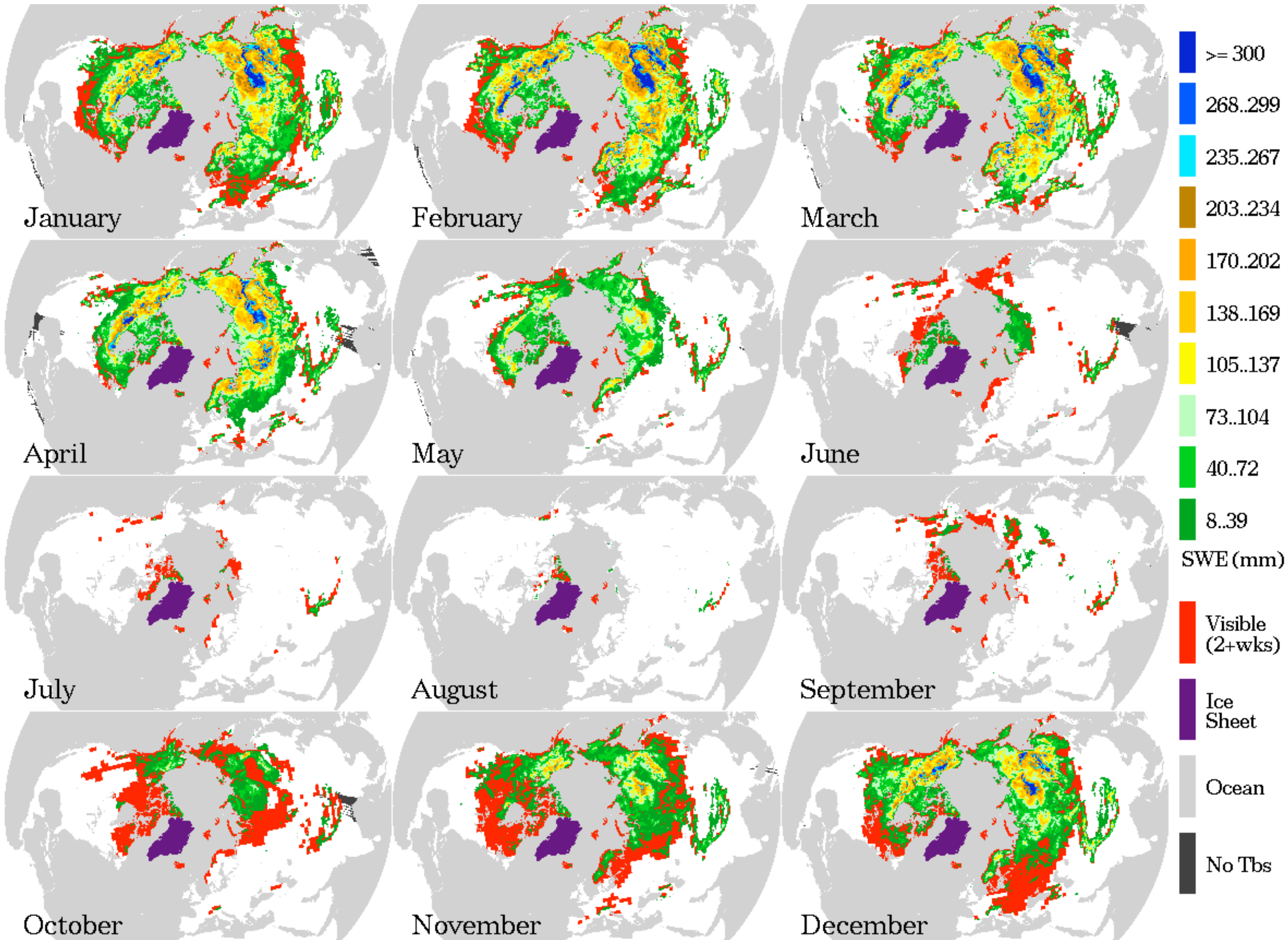






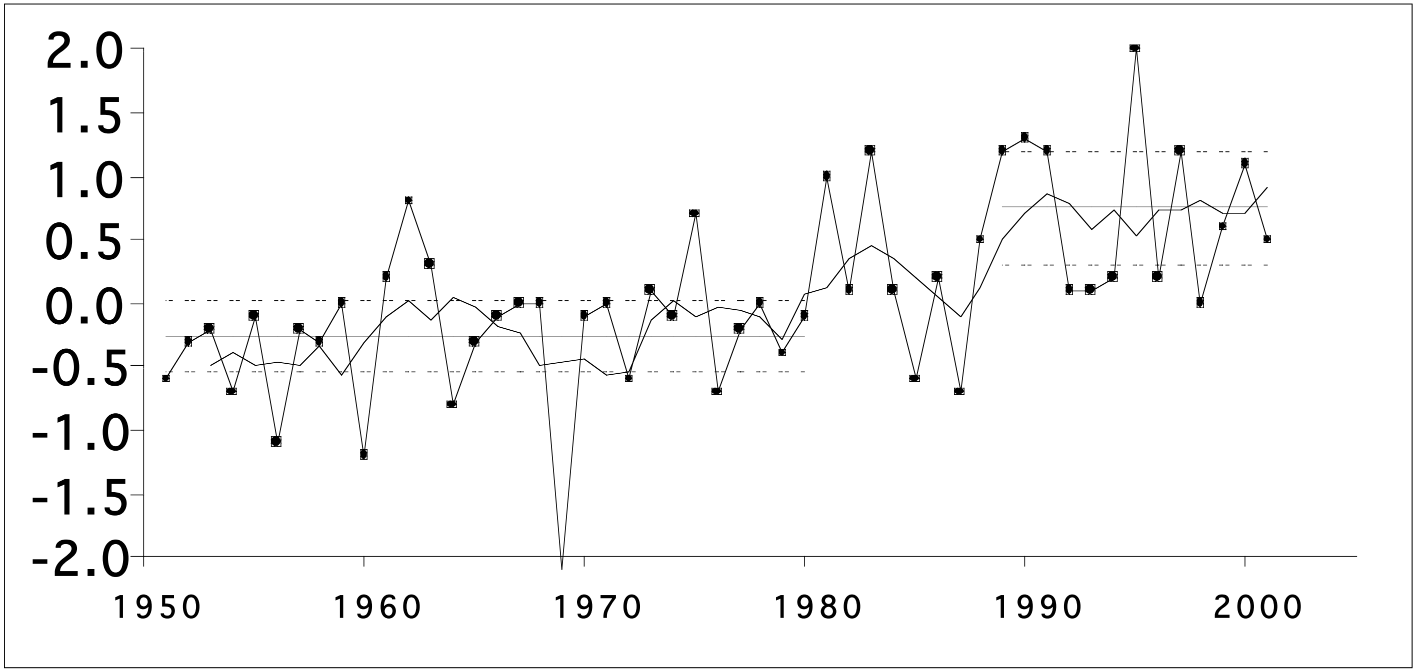


Blend of microwave and visible data – pre-NASA EOS



Mean monthly snow extent and SWE for 1978-2006 from a blend of passive microwave (SMMR & SSM/I) and visible (NOAA) data

Schmakin



Mean annual air temperature, averaged over Russia (anomalies from 1961-1990 mean). The horizontal lines indicate mean values for 1951-80 and 1989-2001; the dotted lines show 99% confidence levels. The two periods differ statistically by about 1°C. The mean annual temperatures are from Gruza et al. (2002).

Basin Scale Studies

*** A.B. Shmakin and V.V.Popova:**

- runoff from Eurasian rivers is not correlated across basins, continental scale variations in snow depth are dependent on several large scale mechanisms, e.g. NAO and Scandanavian

*** Daqing Yang et al. (JGR, 2007)**

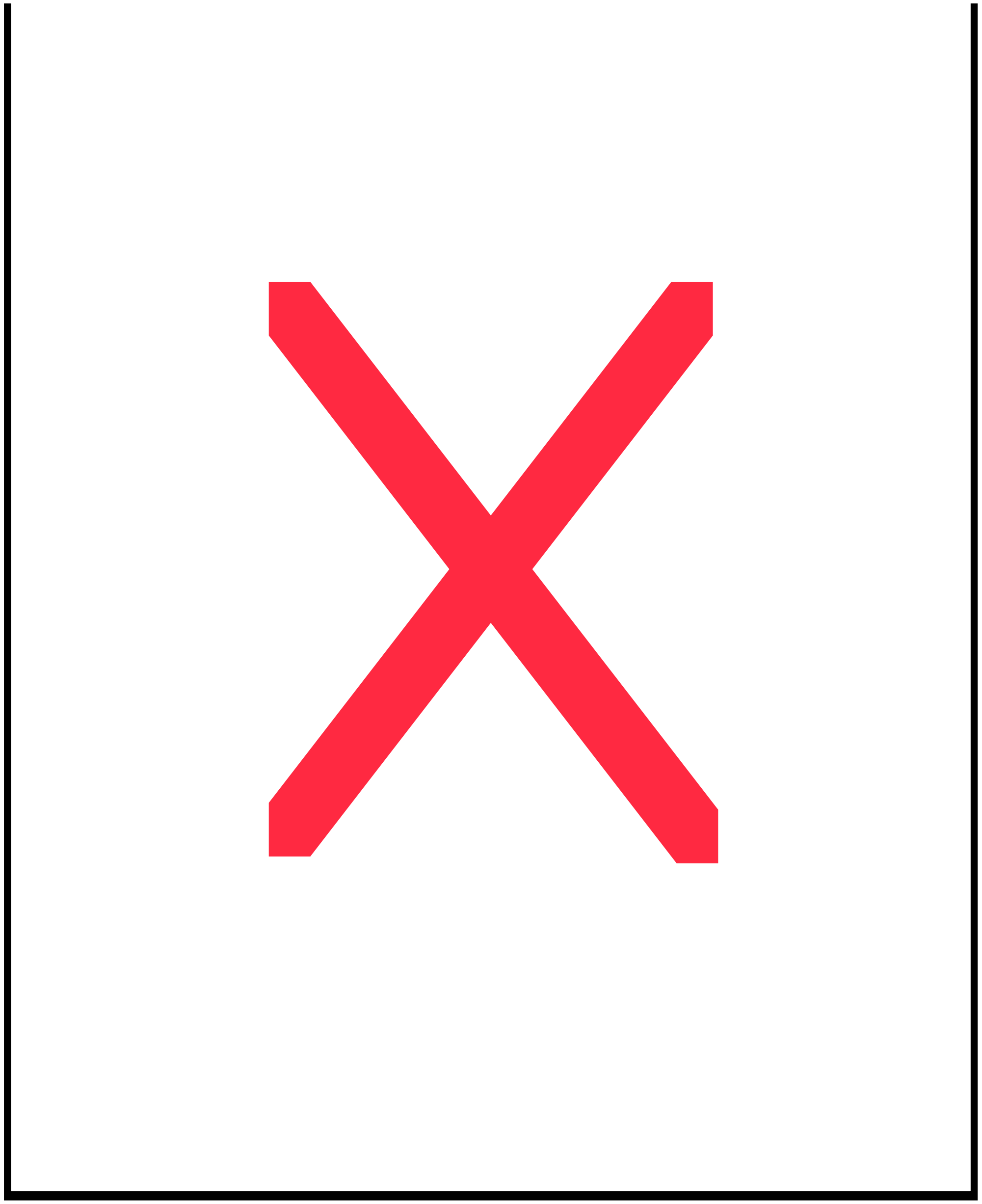
- strong relation between stream flow and snow cover mass change (in situ and satellite) and also notes lack of strong correlation between basins (Ob, Yenisei, Lena) for patterns of winter precipitation, total snow cover mass and runoff.

Modeled Snow Cover - Siberia
HadCM3 vs ERA40 and Satellite
Debbie Putt – IUGG 2007

Environmental Systems Science Center, Reading UK

- **Distribution of SWE within HadCM3 did not agree with remotely sensed data or ERA40**
- **Snowfall events over Siberia cease too early in the season**
- **Biases in snow amount over Siberia could be due to systematic errors in general circulation**
- **The differences between these two data sets must be understood to produce accurate model analysis and to use snow in seasonal and decadal forecasting**

Permafrost – Circumpolar Extent




Permafrost in the Arctic
Prepared (mostly) by
Vladimir Romanovsky
Photo by V.Romanovsky

Major drivers of changes in permafrost

- Changes in Climate (most importantly, changes in air temperature, wind, and precipitation, first of all, snow)

- Changes in Land Cover/Land Use (both naturally occurring and as a result of human activities)

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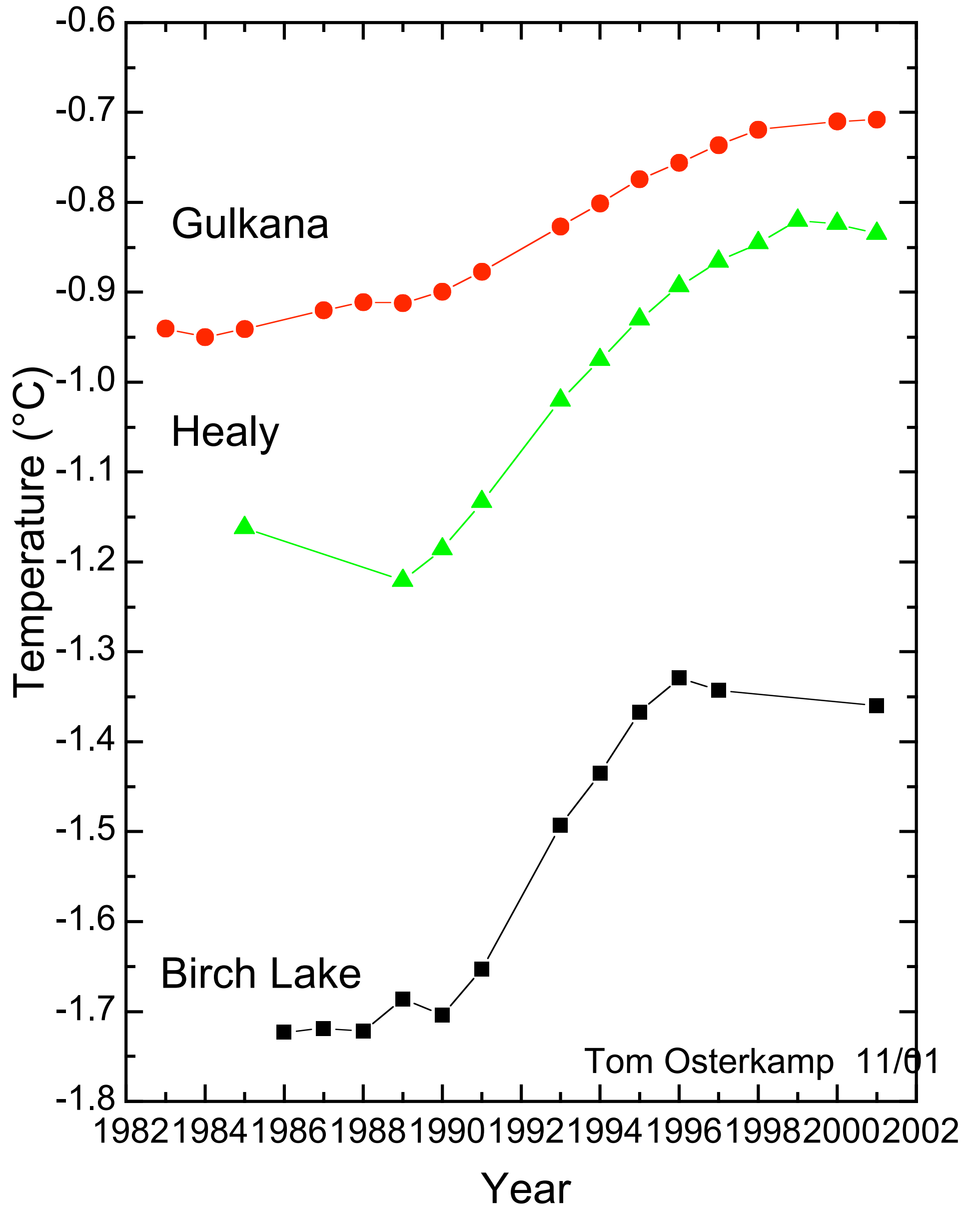
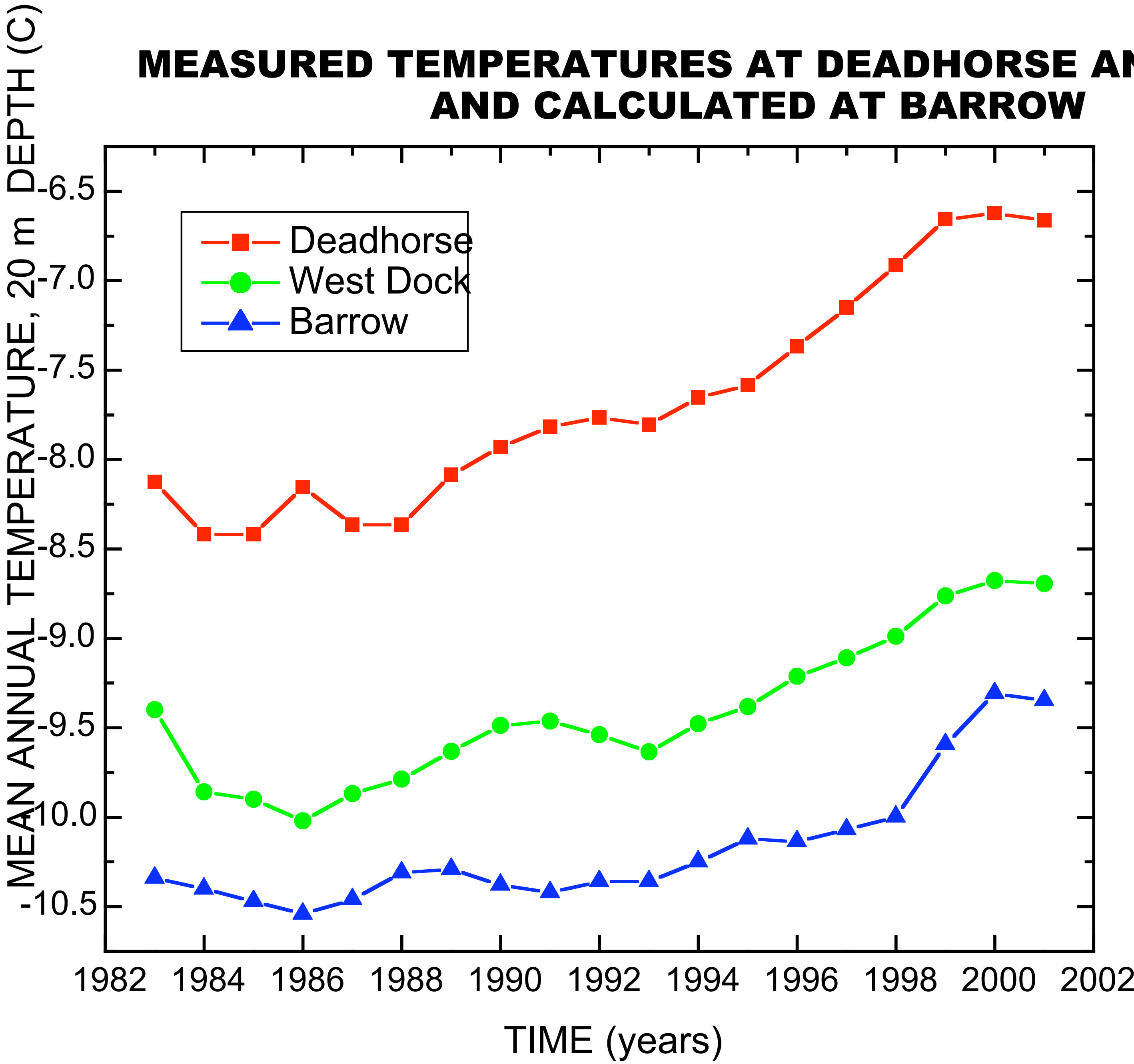
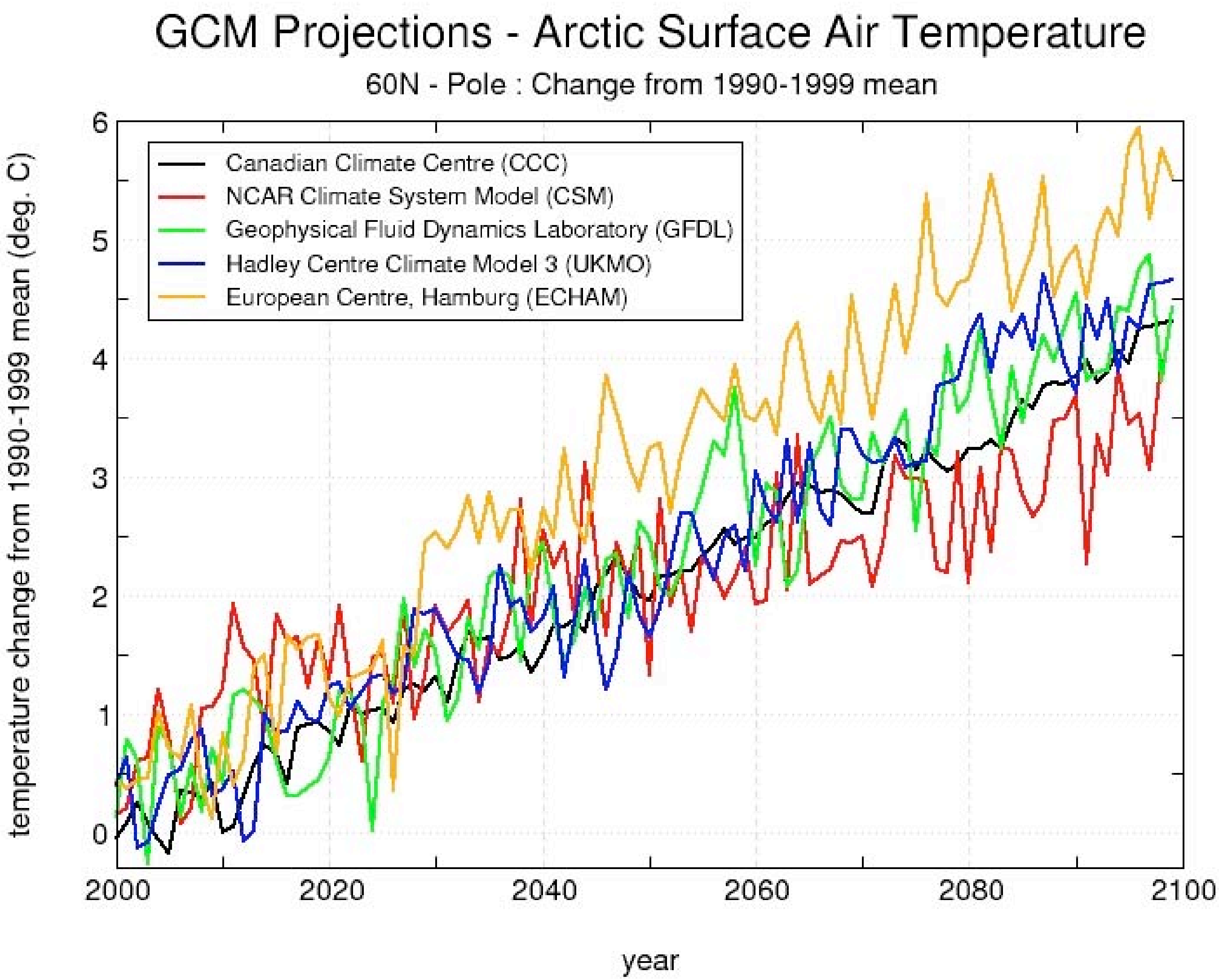
Impact on infrastructure



Temperatures at the 20 m depth in discontinuous permafrost in Interior Alaska.

MEASURED TEMPERATURES AT DEADHORSE AND W
AND CALCULATED AT BARROW




GCM Projections - Arctic Surface Air Temperature
60N - Pole : Change from 1990-1999 mean
Canadian Climate Centre (CCC)
NCAR Climate System Model (CSM)
Geophysical Fluid Dynamics Laboratory (GFDL)
Hadley Centre Climate Model 3 (UKMO)
European Centre, Hamburg (ECHAM)
temperature change from 1990-1999 mean (deg. C)
0
1
2
3
4
5
6
2000
2020
2040
2060
2080
2100
year

Permafrost Data Sets
Frozen Ground Data Center/NSIDC

- There are 48 data sets related with permafrost and the active layer at the Frozen Ground Data Center, NSIDC, over the NEESPI study areas
- All of these data sets are available at: http://nsidc.org/fgdc/ or contact: nsidc@nsidc.org
- **For more information contact Tingjun Zhang at NSIDC**

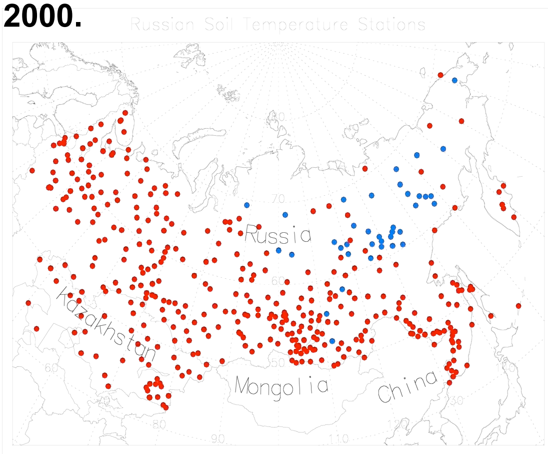
Permafrost Data Sets
NSIDC Frozen Ground Data Center

1) Seasonal freeze-thaw from satellite & in situ, 2) permafrost, 3) active layer thickness, 4) model output

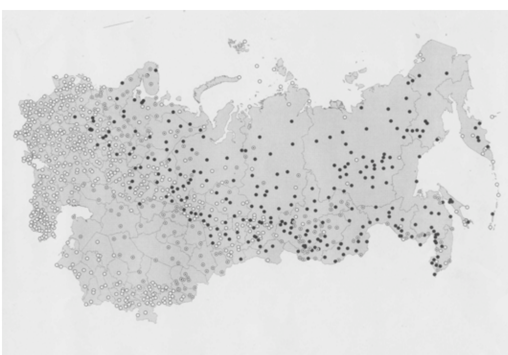
- **Arctic EASE-Grid Freeze and Thaw Depths, 1901 – 2002**
- **Arctic Soil Freeze/Thaw Status from SMMR and SSM/I**
- **Circumpolar Active-Layer Permafrost System (CAPS)**
- **Global Annual Freezing and Thawing Indices**
- **Model Output of Active Layer Depth in the Arctic Drainage Basin, 1979-2001**
- **Modeled Daily Thaw Depth and Frozen Ground Depth**
- **Northern Hemisphere EASE-Grid Annual Freezing and Thawing Indices, 1901 - 2002**
- **Northern Hemisphere Seasonal and Intermittent Frozen Ground Areas 1901-2001**
- **Time Series of Active Layer Thickness in the Russian Arctic, 1930-1990**

Changes in Freeze-Thaw Cycle and Permafrost Dynamics and Their Hydrological Implications over the Russian Arctic Drainage Basin

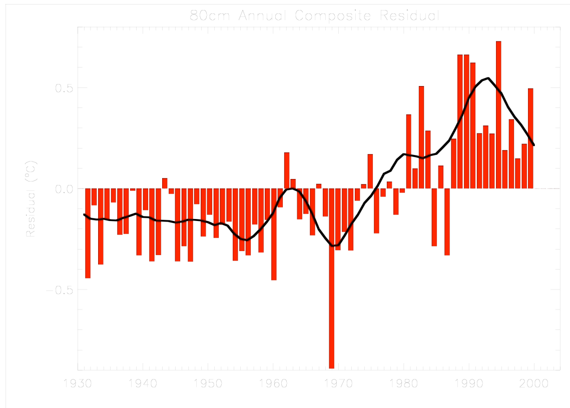
Monthly soil temperature data from about 418 stations with 39 permafrost sites across Russia up to 2000.

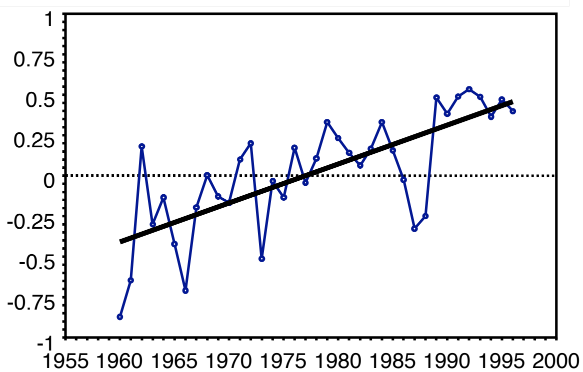


Soil temperatures were measured at >900 stations across Russia.

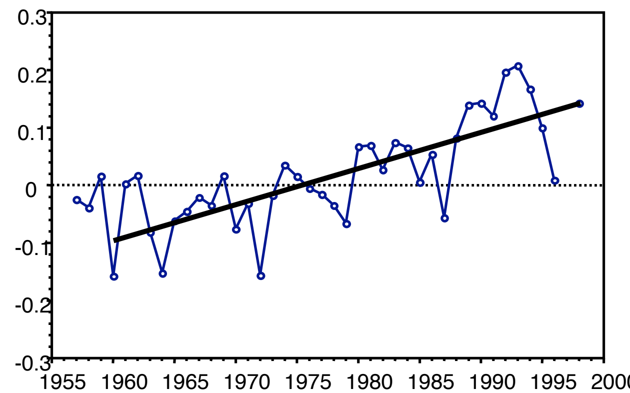


Significant increase in soil (1930s to 2000) and permafrost temperatures (1960 to 2000).





Active layer thickness increased significantly and talik might have been formed in considerable fraction of permafrost regions.



Ground ice meltwater, due to increase in active layer thickness and talik formation, may have contributed to river runoff, while ground water storage may also have increased.

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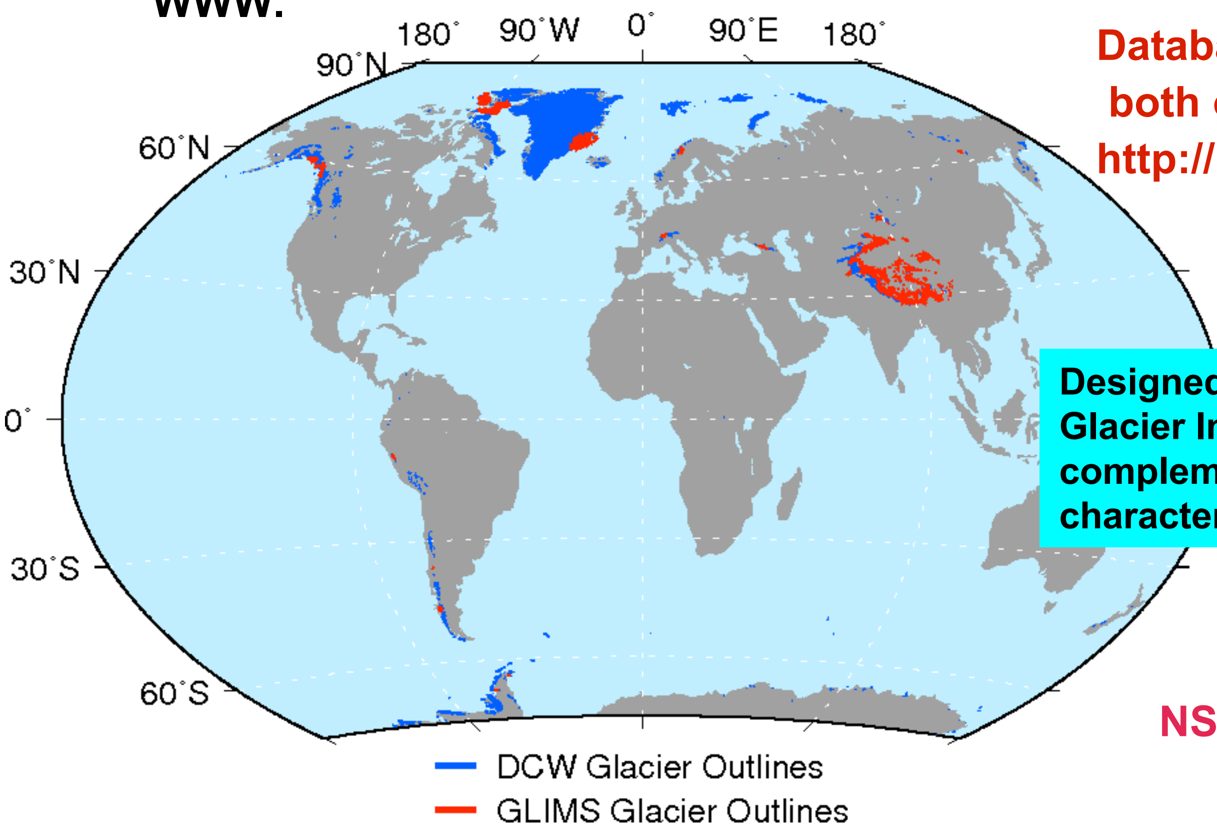
Glaciers

As studied at various scales – global to individual glaciers – e.g. eastern Siberia

GLIMS – Global Land Ice Measurements from Space

The GLIMS project is creating an inventory of the majority of the world's estimated 160 000 glaciers and mapping their extent and rate of change, using primarily ASTER, Landsat and SPOT imagery. GLIMS is an international project with participation from more than 60 institutions in 28 nations worldwide. Each institution (called a Regional Center, or RC) oversees the creation and analysis of data for a particular region appropriate to their expertise.

The GLIMS project provides a GIS data base and mapserver useable via the WWW.

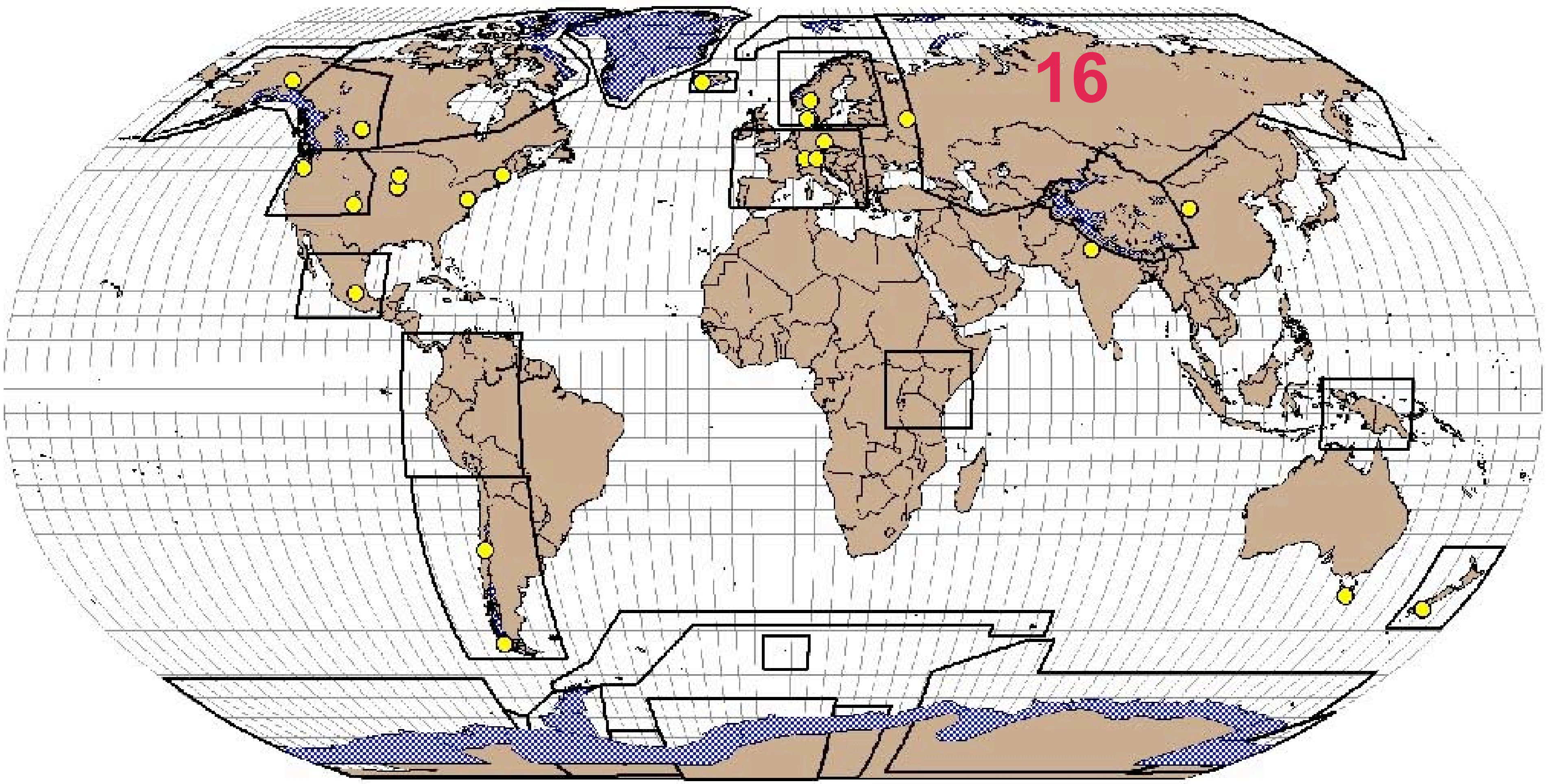


Database and Mapserver are both operational at NSIDC: http://glims.colorado.edu/glacierdata/

Designed to be a logical extension of the World Glacier Inventory of the WGMS, includes full complement of WGMS-defined glacier characteristics, i.e. databases are linked.

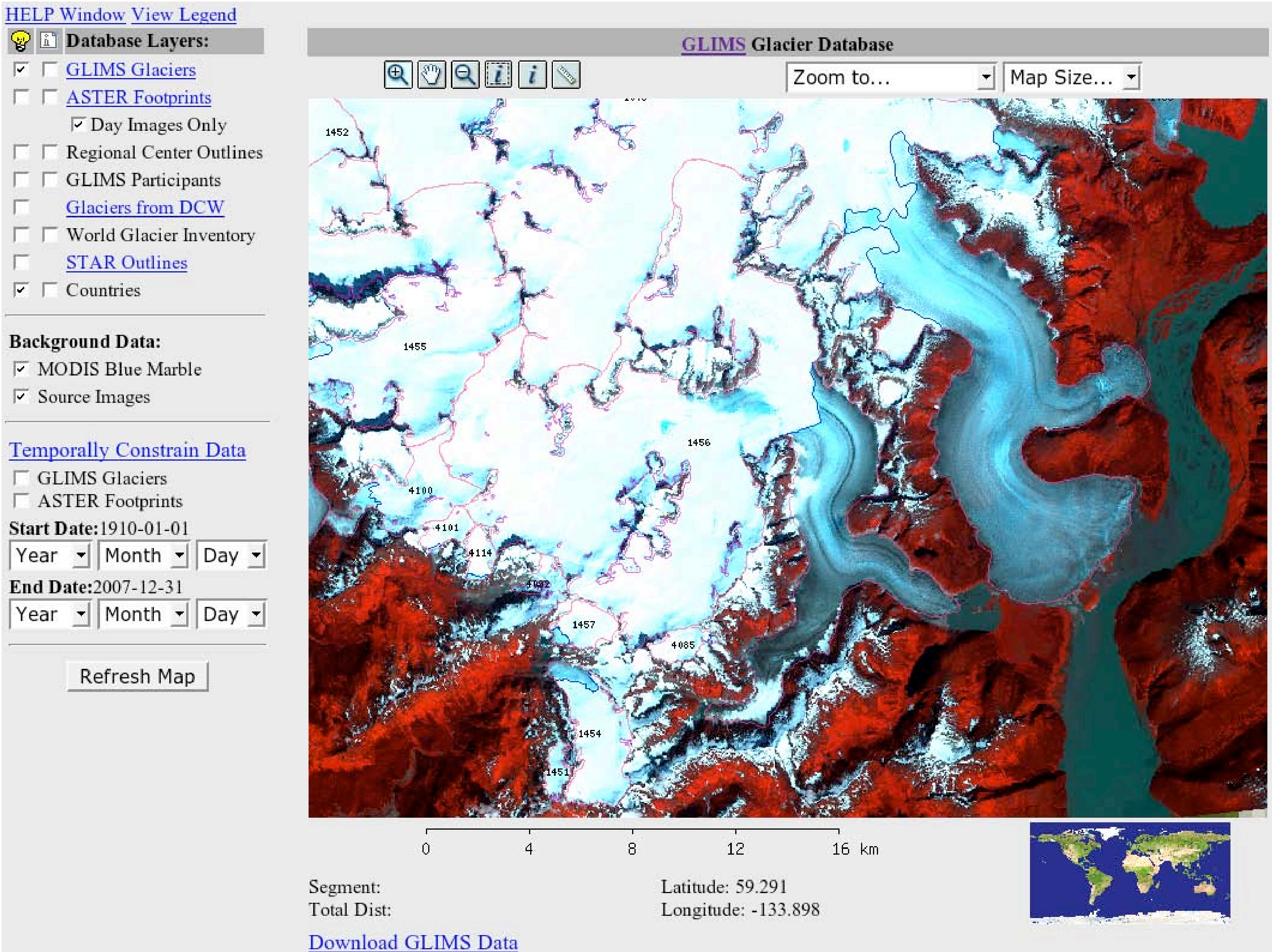
NSIDC funding from NASA EOS

GLIMS Regions and Regional Center locations



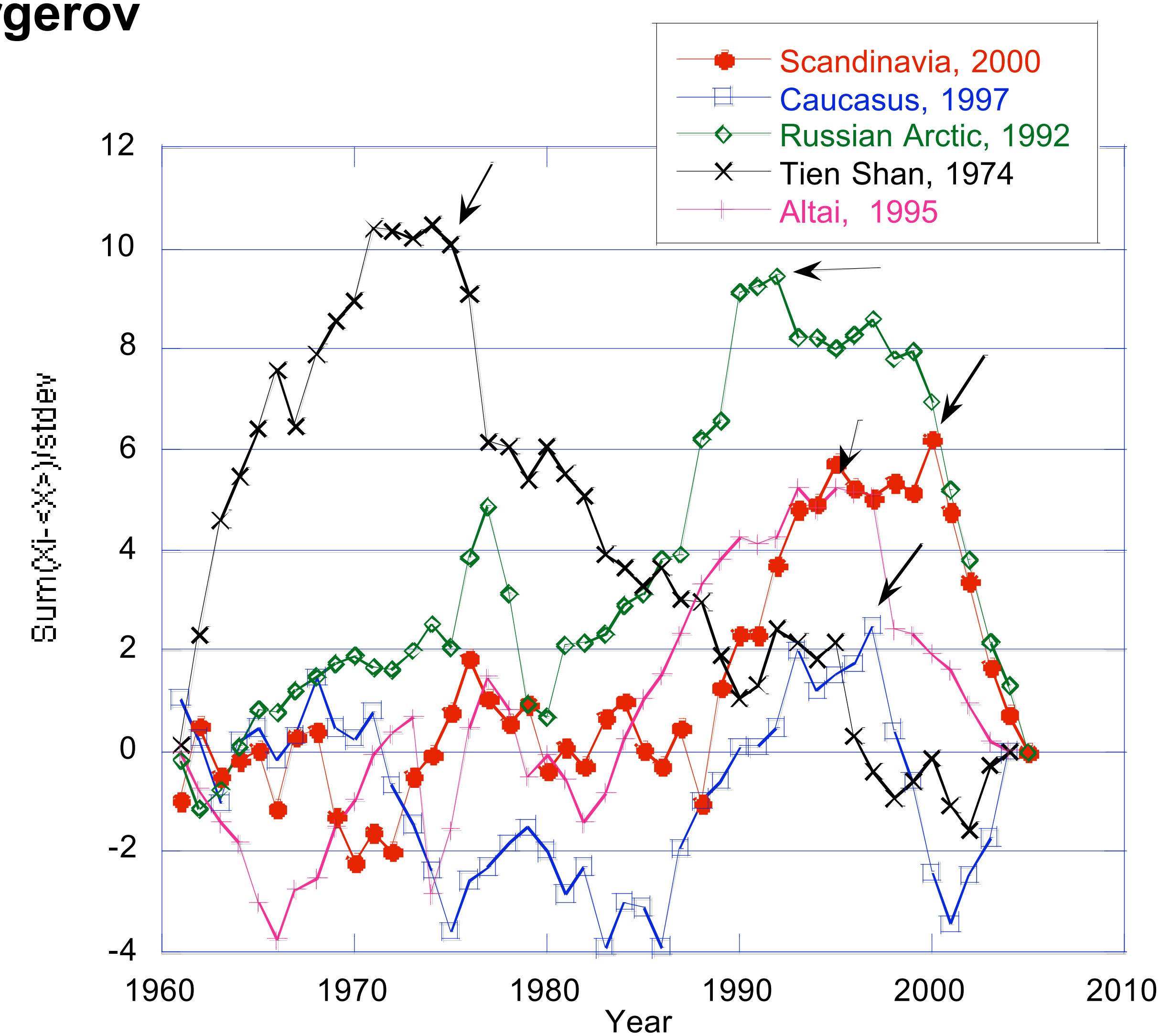
RC 16 - Geographical Institute, Moscow,V. Kotlyakov, T. Khromova, G. Nosenko

Tien Shan, Caucasus, Pamir, Karakorum, Altay, Suntar Khayata and Chersky mountain ranges (nearly 6000 glaciers mapped and in GLIMS data base)



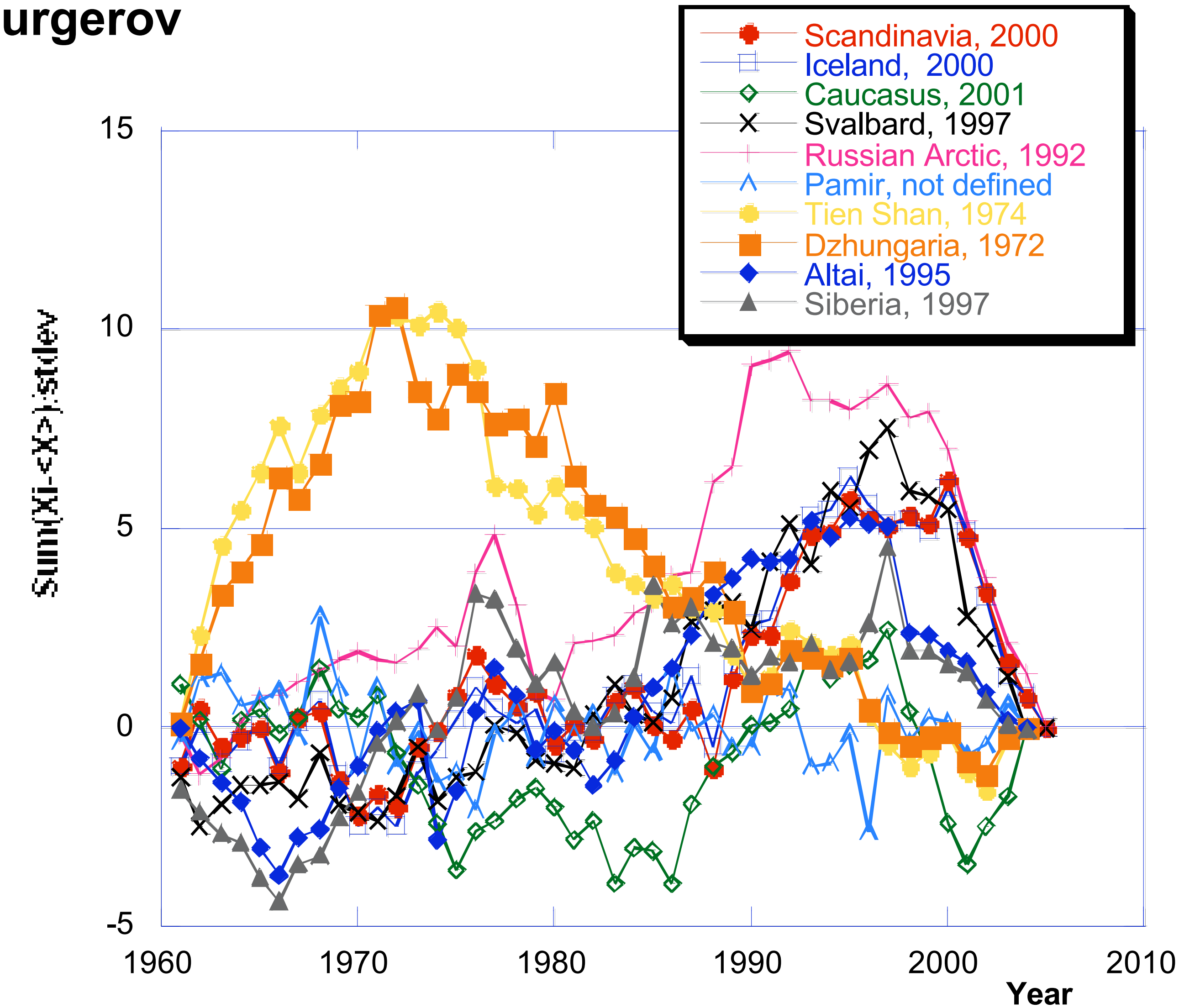
Screenshot of GLIMS MapServer showing database layers and options for temporally constraining data.

M. Dyurgerov



Volume change calculated as the weighted values by the area of individual glaciers and by glacier systems (archipelagos, mountain ranges). The timing of glacier regime changes given in the legend (years and arrows) from more stable to the acceleration of wastage). The results presented as the cumulative standardised departures

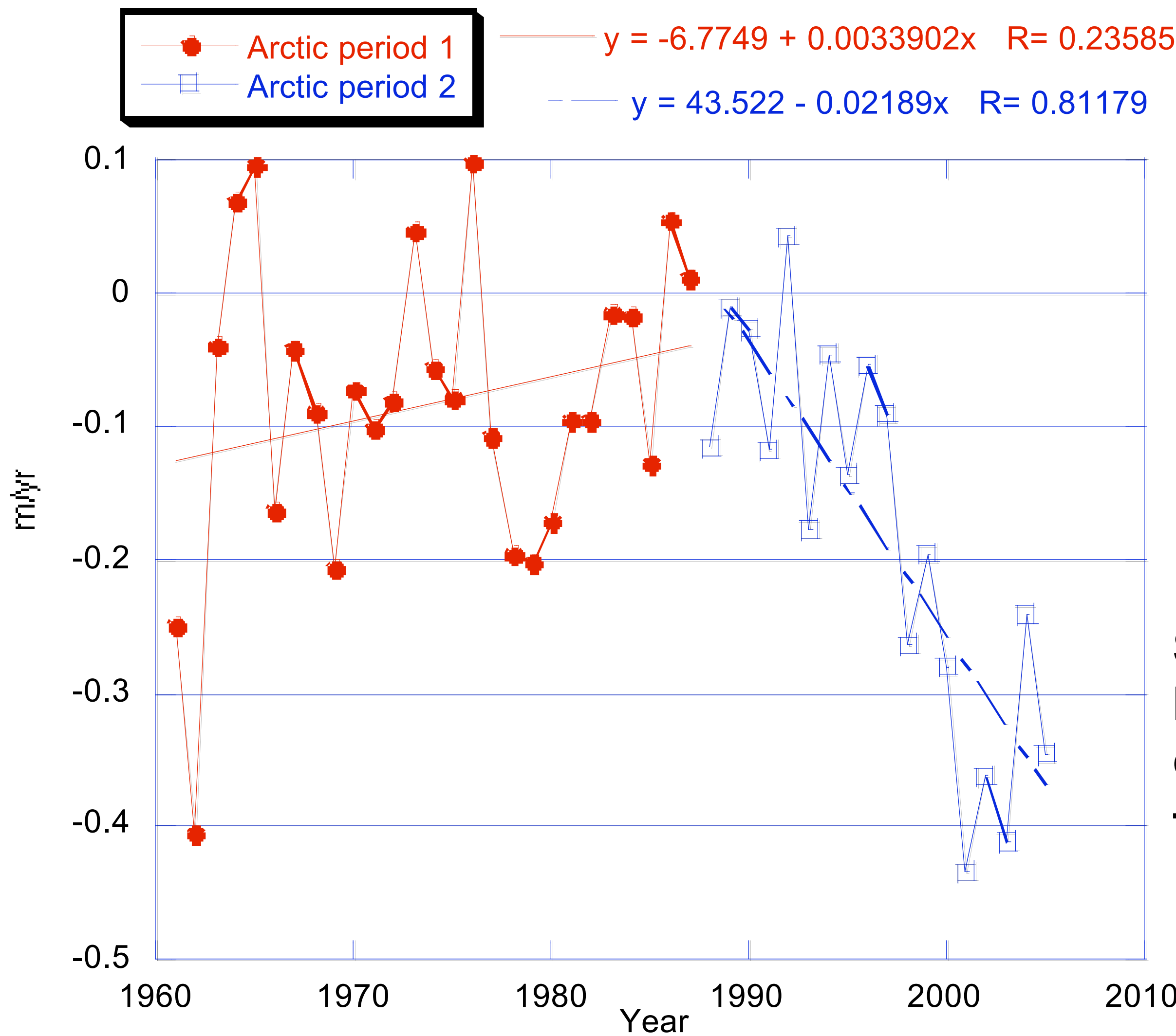
M. Dyurgerov



Volume change calculated as weighted values by the area of individual glaciers and by glacier systems (archipelagos, mountain ranges). The timing, years, of glacier regime changes given in the legend (from more stable to the acceleration of wastage). For some regions such a shift have not been found, e.g., Caucasus. The results presented as cumulative standardised departures

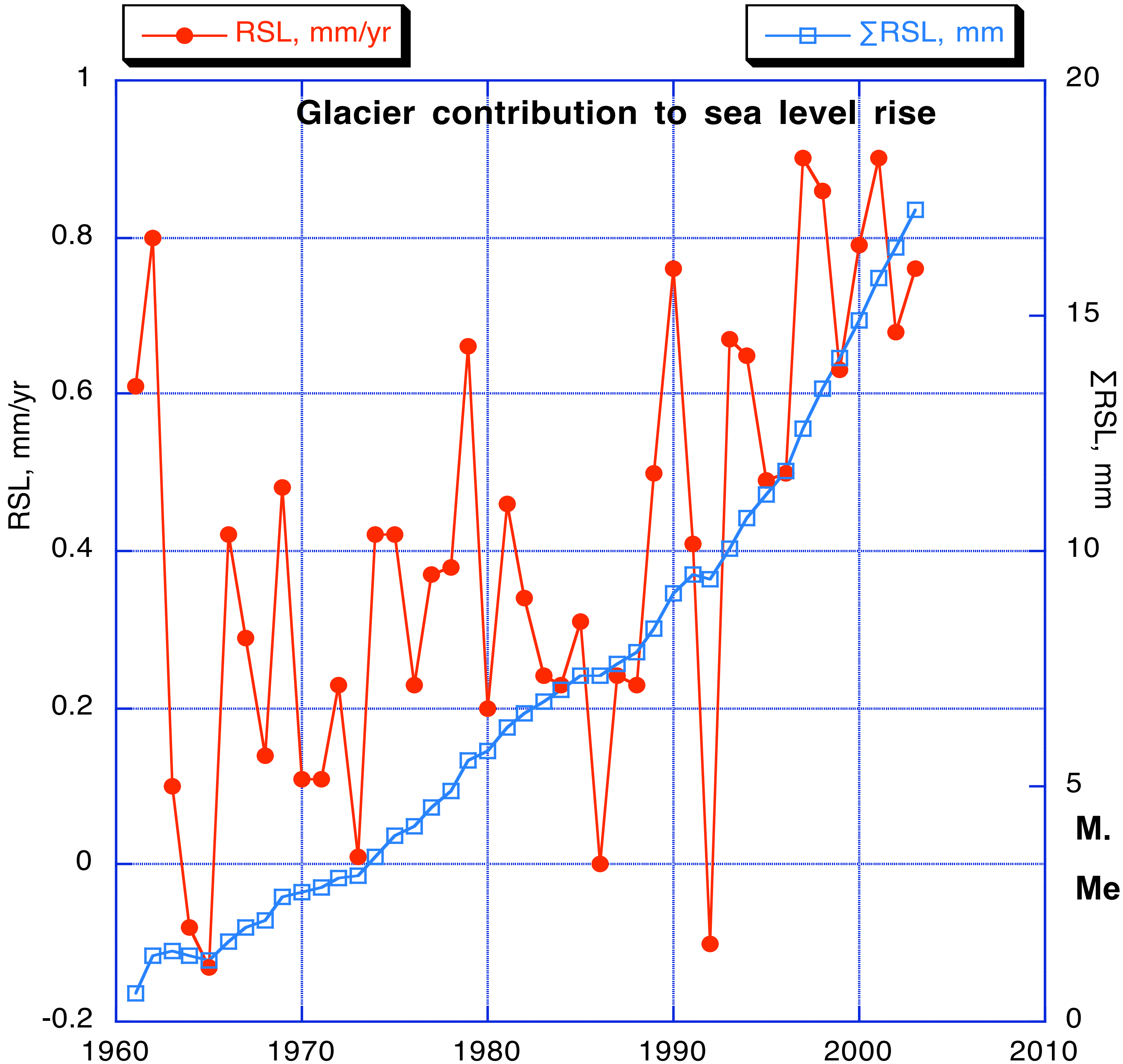
M. Dyurgerov

Arctic Glaciers



Short story = less variability, consistent negative trends

Mass balance of Arctic glaciers show shift towards acceleration mass loss from 1988
(mass balance is in m of water equivalent)



M. Dyurgerov 2004

Meier et al. 2007

Armstrong - Aspen Global Change Institute – Northern Eurasia Terrestrial Processes2007