The NASA LCLUC Program: Arctic Land Cover/Use Change

Garik Gutman, NASA HQ
LCLUC is an interdisciplinary scientific theme within NASA’s Earth Science program. The ultimate vision of this program is to develop the capability for periodic global inventories of land use and land cover from space, to develop the scientific understanding and models necessary to simulate the processes taking place, and to evaluate the consequences of observed and predicted changes.

• Drivers of LCLUC
  - Natural Drivers
  - Anthropogenic Drivers
    - Socio-Economic Drivers
    - Landscape Modification

• Impacts of LCLUC
  - Carbon Cycle
  - Surface Hydrology
  - Atmosphere
LCLUC Program Content

~280 projects since Program’s inception
Each year:
~40 3-yr projects
>230 researchers

Impacts - 33%
(Carbon+Water+Eco)
Monitoring – 27%
LU Modeling – 14%
Drivers – 11%
LCLUC- Climate interactions - 6%
Synthesis – 5%
Vulnerability/Adaptation – 4%

http://lcluc.hq.nasa.gov
Arctic Land Cover and Land Use In a Changing Climate: Focus on Eurasia

- NASA LCLUC Program contribution to IPY - a compilation of the studies focused on the Arctic region of Northern Eurasia
- The region of interest is land ecosystems north of 60° latitude, specifically transitional forest-tundra and tundra zones
- Twelve chapters written by international teams including US, Russian, and European scientists
- Published by Springer in 2011
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Vegetation of Zonal Patterned-Ground Ecosystems Along the North America Arctic Bioclimate Gradient

- Donald A. Walker (Institute of Arctic Biology, University of Alaska Fairbanks), Patrick Kuss, Howard E. Epstein, Anja N. Kade, Corinne M. Vonlanthen, Martha K. Raynolds & Fred J.A. Daniels
- Question: How do interactions between the physical environment and biotic properties of vegetation influence the formation of small patterned-ground features along the Arctic bioclimate gradient?
- Different growth characteristics of plants growing in northern and southern parts of the gradient have an important effect in stabilizing highly frost-active soils. A conceptual model has been developed to represent the interactions between vegetation and patterned-ground morphology along the Arctic climate gradient.

Study locations along the North American Arctic Transect. The bioclimate subzones are from the Circumpolar Arctic Vegetation Map (CAVM Team 2003).
Climate change studies

• Uma Bhatt, Skip Walker, Martha Raynolds, Jiong Jia, Howie Epstein, Jorge Pinzon, Joey Comiso
• U. Alaska, U. Virginia, NASA GSFC, Finland
• Strong correlations between coastal summer sea-ice trends, land-surface-temperatures, and vegetation greenness were found for the circumpolar Arctic as a whole
• Differences of temperature and NDVI trends in Eurasia vs. North America.
Trends in Sea Ice and Summer Warmth

• Until recently, trends in sea ice retreat have generally corresponded with increases in summer warmth and tundra greening in most regions of the Arctic
• Extending analysis to 1982-2011 yields several notable differences from the earlier period particularly for land surface temperatures.
• There is a larger area of cooling over western Eurasia and there is cooling over the southern tundra areas in North America, which had been warming in the earlier period.
• Open water during summer has increased everywhere in the coastal Arctic with the largest increases in Bering and Kara-Barents seas
• The NDVI has generally increased over the Arctic domain from 1982-2011
Spring Sea Ice and Summer Warmth Index: 1982-2011

Eurasia

Spring Sea Ice and Summer Warmth Index

North America

Sea Ice Concentration (%)
Max NDVI and Time-Integrated NDVI

- **Trends are largest for North America while the mean is larger in Eurasia**

- The trends are not constant over time and change after 2001

- Intra-seasonal analysis suggests that midsummer temperatures are cooling and analysis thus far suggests a link to changes in summer convection

- AVHRR GIMSS3g+ MaxNDVI and TI-NDVI during summer from 1982 to 2011 over the full tundra domains.
Human Dimensions: Land Management

- Human population of the Arctic and their associated livelihood will be impacted and will need to adapt (ACIA 2004)

- Imperative that governments and the associated management, and policy- and decision-makers include reindeer herders and incorporate traditional local and scientific knowledge in future planning

- Specially designed systems, such as the EALAT Reindeer Mapper Information System will assist in the ongoing analysis of trends and detection of emerging events and conditions

- Systems like this will enhance early warning and management of responses and adaptation to external stresses

Reindeer herding: adapting to global change in the Arctic

Maynard et al.
Landscape effects under multiple stresses

- Industrial development (mainly roads and pipelines) is creating serious barriers to animal migration corridors and limiting the areas of summer pasture.

- Herders currently view the threats from industrial development to be much greater than threats from climate change. Land withdrawals by industry, increasing local populations, and larger reindeer herds are putting increasing pressure on the rangelands.

- However, the locals have an overall positive view of gas development because of increased local economic and social advantages.

Direct impacts of industrial activities are currently local and limited in extent but...this is changing rapidly as extensive gas fields are developed and land- and sea-transportation corridors are developed to transport the gas to market.
Polluting the Arctic

- Environmental pollution originating from oil and gas exploration and extraction activities in the Arctic is expected to increase considerably

- Increased contamination by heavy metals, persistent organic pollutants, and petroleum hydrocarbons

- Heavy metal, SO2 and sulphate deposition originating from non-ferrous metal smelting and mining activities are the main threat to the prevailing land cover

- Increasing mercury pollution in the Arctic poses a considerable threat to animal life in the region, and therefore may also have long-term, indirect effects on the land cover

Derome and Lukina
Compound Effect of Climate Change and Pollution

• Global warming may aggravate the effects of environmental pollution on land cover, and the extent and mechanisms through which pollutants can amplify climatic stress

• Temperature increase =>
  – accelerate soil mineralization and decomposition processes =>
  – increased mobility/availability of heavy metals & radionuclides =>
  – higher concentrations in mushrooms, berries, reindeer, fish, birds

• Precipitation increase =>
  – increase the deposition of pollutants, and associated leaching, even though there is an overall decrease in emissions =>
  – increased accumulation of pollutants, including heavy metals and radionuclides, in traditional foodstuff.
  – Higher pollutant availability will also be one consequence of their release from permafrost
Aerosols in Northern Eurasia

- Northern Eurasia world’s largest sources of major aerosol types and air pollutants => strong regional and global signals (via long-range transport, teleconnection)
- The Arctic haze phenomenon is a manifestation of long-range transported air pollutants originating in the mid-latitudes or within the Arctic
- Can persist for long periods due to slow removal processes in the Arctic
- Caused by plumes released from biomass burning and wildfires
- 2008 Spring: Chemical analysis, particle dispersion models and satellite data showed that most of the plumes were emitted by forest fires in the southern Siberia/Lake Baikal region and by agricultural burning in Kazakhstan and southern Russia
- Can directly affect Arctic climate

- Slow down of the hydrological cycle (Ramanathan et al.)


Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming (Jacobson et al.)

Sokolik et al.
Characterizing the Water Cycle

- Increase of fresh water flux into the Arctic Ocean

- Remote sensing is limited in terms of resolution and sub-surface penetration
  - For sub-surface processes, large-scale hydrologic models should be used via assimilation of remotely sensed data
  - The lack of glacier dynamics in most large-scale hydrologic models present challenges
  - Improvements in these models depend on better in situ and remotely sensed observations

Eurasian River Discharge 1936-2006

Annual River Discharge (km$^3$/year)

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<th>Year</th>
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<th>Linear Trend Line</th>
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Rivers: Ob’, Yenisey, Lena, Severnaya Dvina, Pechora, Kolyma

slope = 2.4 ± 0.6, p = 0.0002

Shiklomanov et al.
**NASA LCLUC-relevant Missions**

*Systematic Missions* - Observation of Key Earth System Interactions

- **Landsat 7**
  - 4/15/99

- **Terra**
  - 12/18/99

- **Aqua**
  - 5/3/02

- **Suomi-NPP**
  - 10/28/11

- **Landsat 8**
  - 2/11/13

*Exploratory Missions* - Exploration of Specific Earth System Processes and Parameters and Demonstration of Technologies

- **SRTM**
  - 2/11/00

- **EO-1**
  - 11/21/00
Synergistic Use of Optical Remote Sensing

**VIIRS**
- 3300 km swath
- Spatial resolution: 400/800m (nadir (Vis/IR))
- Global coverage: 2x/day/satellite

**AVHRR/MODIS**
- 2048 km swath
- Spatial resolution: 250m, 500m, 1000m
- Global coverage: 2 days
- Seasonal global coverage

**MISR**
- 360 km
- Spatial resolution: 275m, 550m, 1100m
- Global coverage: 9 days

**Landsat**
- 183 km
- Spatial resolution: 15m, 30m
- 16 day orbital repeat
- Seasonal global coverage

**ASTER**
- 60 km
- Spatial resolution: 15m, 30m, 90m
- 45-60 day orbital repeat
- Global coverage, years

**Commercial Systems**
- ~ 10 km
- Spatial resolution ~ 1m
- Global coverage, decades, if ever
Land Monitoring at Moderate Resolution: Near-Term Solutions

- Landsat data are accessible free of charge

- Landsat observations from one system are often insufficient for applications, which require more frequent, intra-monthly observations (use of 2-3 Landsat systems would help)
  - Landsat-7 is old and has issues with image quality
  - Landsat-8 is functioning well (some issues in thermal IR)
  - Landsat-9 is not foreseen within at least 5 years

- International data cooperation is needed for monitoring on landscape scale (20-30 m)

- Non-US sensor data accessibility issues
  - Sentinel data will be accessible and free of charge but other sensors present challenges
This project is aimed at producing a merged surface product from the Landsat and Sentinel-2 missions to ultimately achieve high temporal coverage (~2 days repeat cycle) at high spatial resolution (20-60m).

The goal is to achieve a seamless/consistent stream of surface reflectance data from the different sensors.

Cross-calibration, atmospheric corrections, spectral and BRDF adjustments, gridding.
Conclusions and future steps

• Methodology for merging products well in place
• Accuracy assessment technique for merged products is mature
• Landsat suite of SR product has been developed and Sentinel 2 SR needs to be prototyped before launch
Open Solicitation

- **ROSES-2014: LCLUC amendment** (no LCLUC call was issued)
  - NOI due Oct 1, proposals due Dec 1
  - Selections May 2015; start projects in July 2015
  - Selections to form Multi-Source Land Imaging (MSLI) Science Team, possibly with international partners
  - Prototyping algorithms and high-level products using multi-sensor approaches