The Arctic LTER Project at Toolik Lake

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Toolik as an LTER Site*

- History of collaborative research (Barrow IBP, RATE, others since 1975; ARC started 1987)
- Tundra as a Model Landscape
  - Low diversity
  - Permafrost, hydrology, watersheds, and land-water
  - Geology and site age
  - Low stature, fine grain heterogeneity
  - Sampling and manipulations—advantages
- Tundra as a unique landscape
  - Permafrost
  - Photoperiod
- Landscape components
  - Terrestrial
  - Lakes
  - Streams
  - Land-Water interactions
- Monitoring, Manipulations, & Modeling

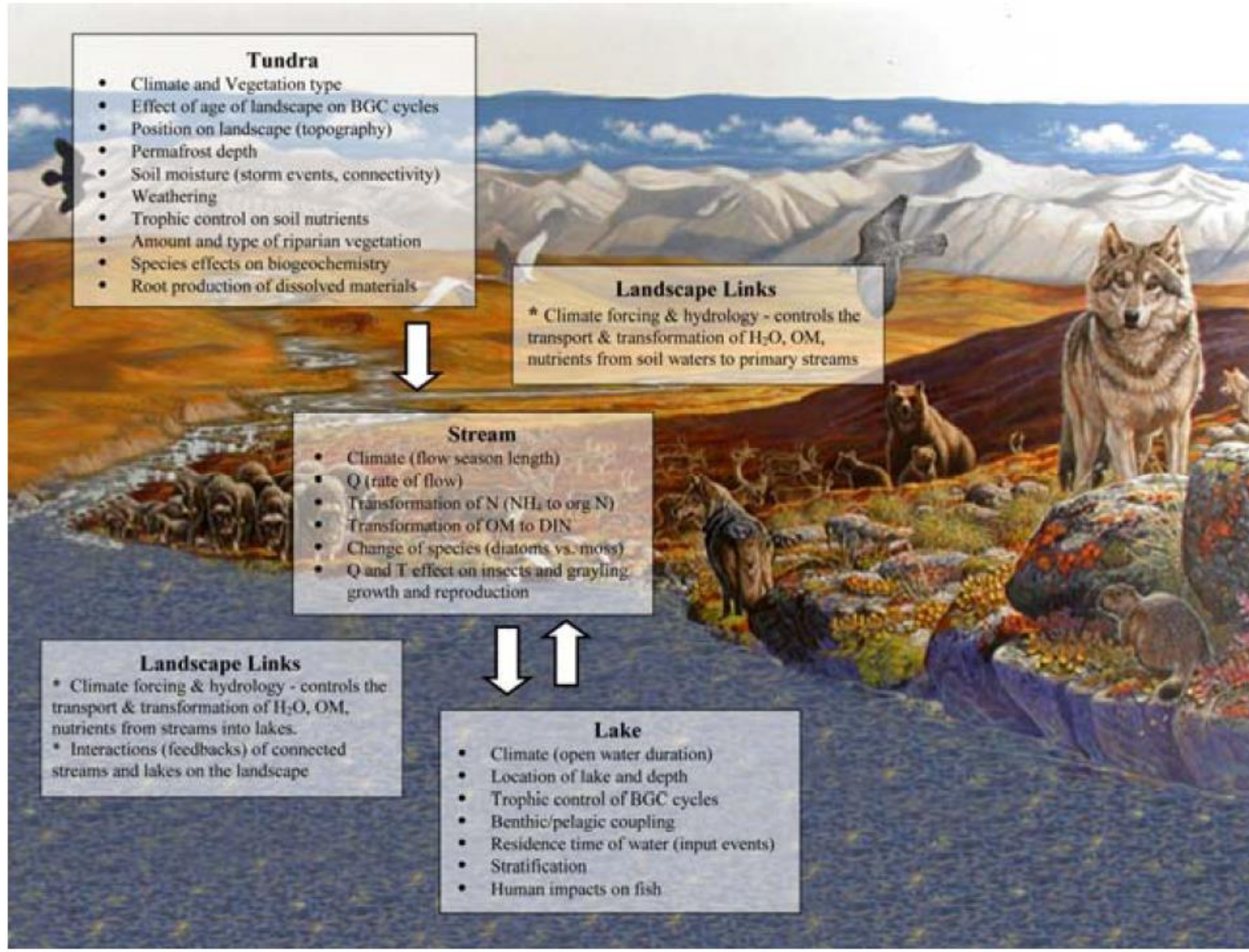
* "Where the hand of man has never set foot"
(D. Schindler ca. 2008)

Science Questions and Time Scales

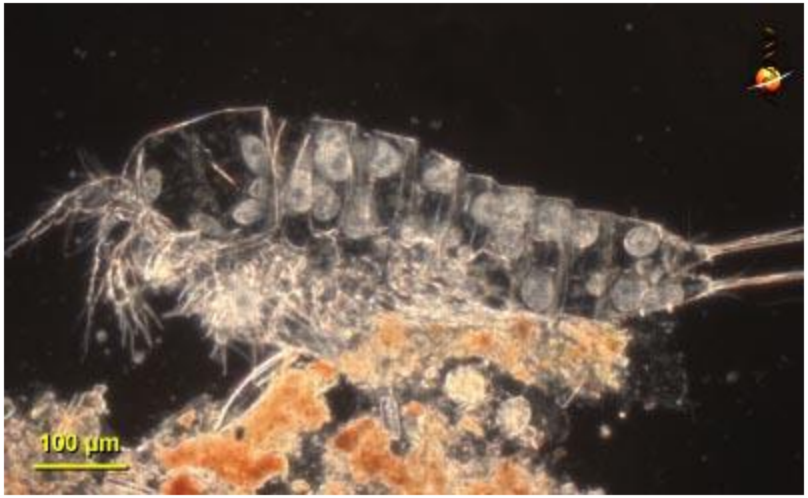
Historic view:

- LTER I (1987-1992): Descriptions of tundra, stream, and lake ecosystems; Long-term change versus short-term controls on ecosystem components
- LTER II (1992-1998): Ecological variability and long-term change; top-down versus bottom-up controls on tundra, streams, and lakes
- LTER III (1998-2004): Prediction of the future characteristics of arctic ecosystems and landscapes; controls on ecosystems by physical, climatic, and biotic factors
- LTER IV (2004-2010): Understanding changes in the Arctic system at catchment and landscape scales through knowledge of linkages and interactions among ecosystems.
- LTER V (2010-2016) : Goal is to understand changes in the arctic system at catchment and landscape scales as the product of: (i) Direct effects of climate change on states, processes, and linkages of terrestrial and aquatic ecosystems, and (ii) Indirect effects of climate change on ecosystems through a changing disturbance regime.

Fig 2-1. Research of the ARC LTER involves multiple landscape components and processes. For management purposes the research is divided into terrestrial, lake, stream, and landscape interactions components. Here, this structure is shown against a background of the foothills and mountains at Toolik Lake (modified from U.S. Postal Stamp Series Nature of America # 5); examples of research by each component are in the boxes. In 2010-2016 we will add a fifth component, focused on subsistence land use and impacts of climate change and on Native communities.

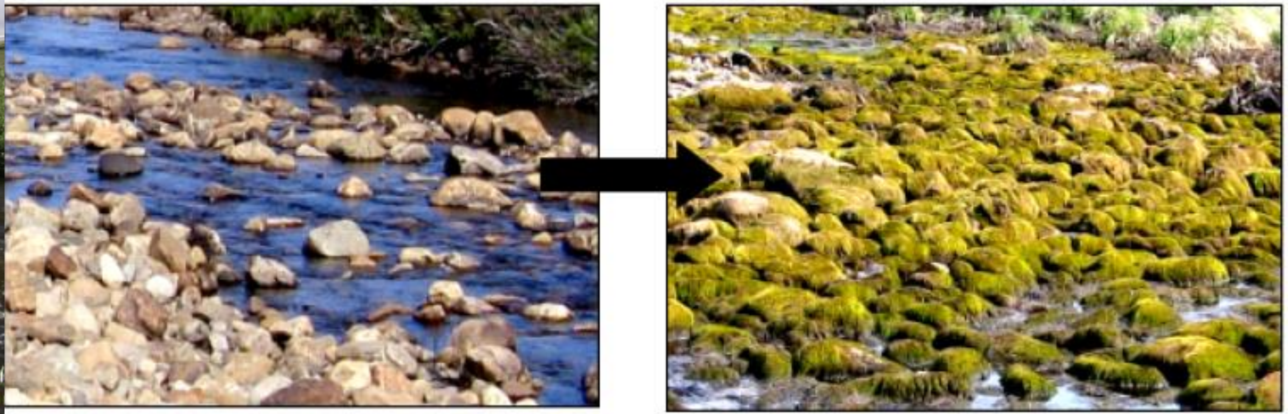


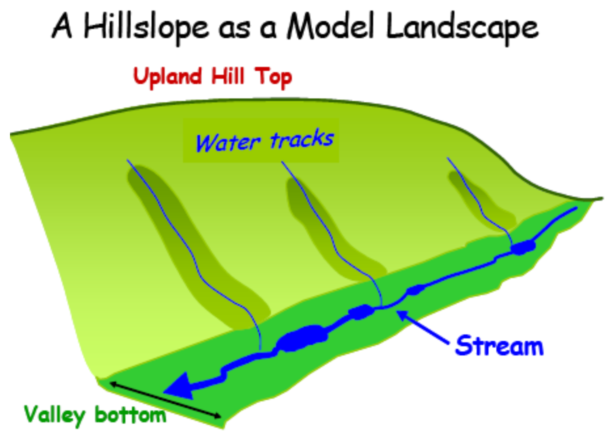
	Surface Area (ha)	Max Depth (m)	Sampling Frequency (per summer)
Toolik	149	25	10
E1	2.6	11	1
Fog 2	5.9	20.3	2
Fog 4	1.9	4.4	2
NE9b	.4	6	1
NE12	8.2	17.1	1
N1	4.3	14.2	1
S6	1.1	5.2	1
S7	.8	2.9	1
S11	.3	9.5	1
I Series	2.1-17	3.1-15	3
E5	11.3	12.7	5
E6	1.9	3.2	5
N2	1.6	9.7	2
Dimple	10.6	9.0	3
Horn	35.8	5.0	3
Luna	4.75	2.5	3
Perched	15.1	12.0	3
North	32.9	2.0	3









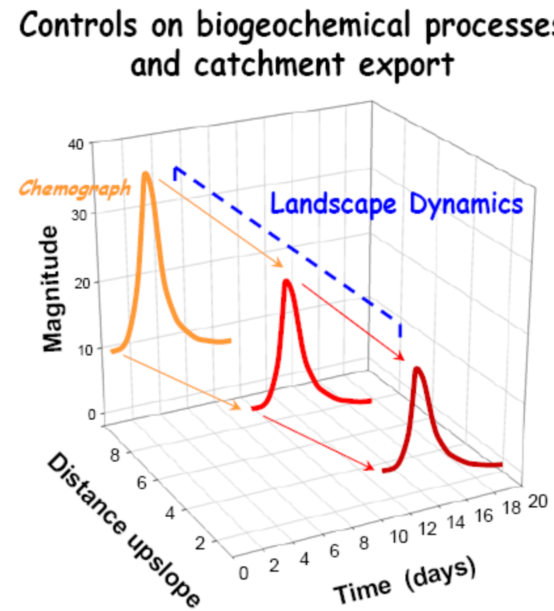


Figure LW-8. The hillslope *(above)* as a representative landscape model, with landscape components represented by the toposequence from upland heath to mid-slope tussock tundra to valley wet sedge vegetation. Landscape dynamics *(right)* can be represented by changes in patterns or processes (e.g., soil water chemistry) moving from upslope to downslope and through time.

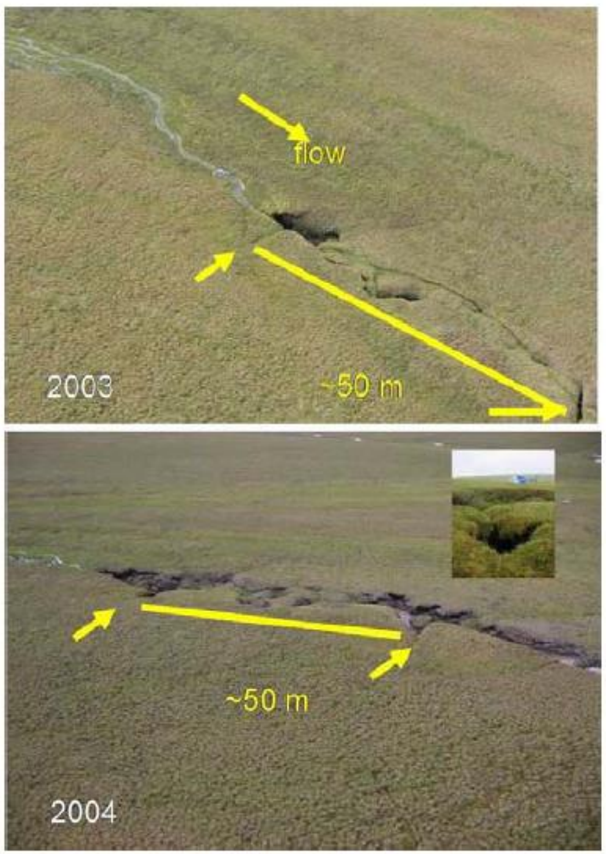
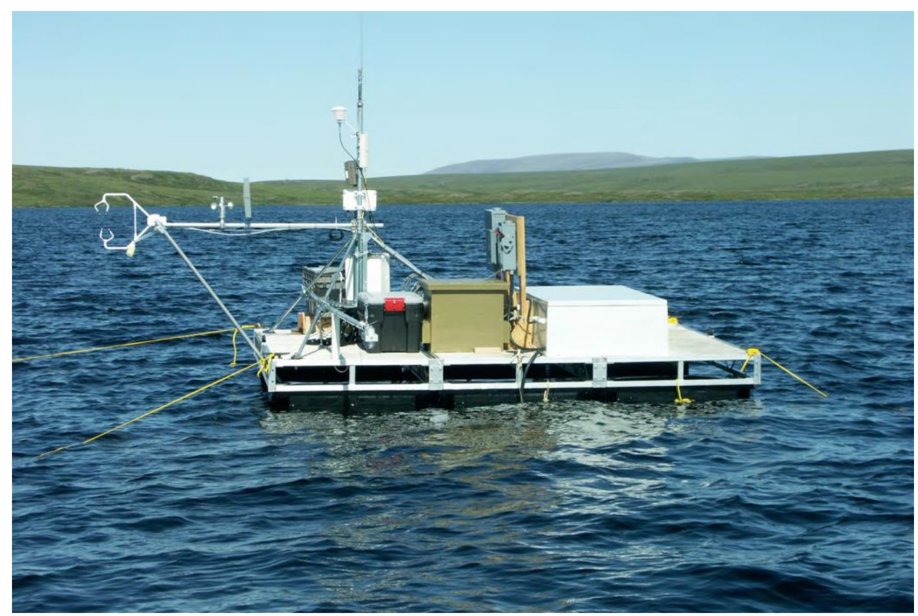


Figure S4. The TRTK site in 2003 shortly after it formed and in 2004, showing expansion. Inset in 2004 shows a helicopter for scale. (photo credits: Bowden)



Science Questions and Time Scale

Three Current "Organizing Questions" addressed by lakes, streams, terrestrial, land-water groups:

- *How does climate control ecosystem states, processes, and linkages?*
- *How do disturbances change ecosystem states, processes, and linkages?*
- *How do climate and disturbance interact to control biogeochemical cycles and biodiversity at catchment and landscape scales?*

Importance of Collaborations

- Virtually all components of ARC research involve collaboration with one or more independently-funded projects. ARC provides help with monitoring, sampling, chemical analyses, access to experiments, and data management. Collaborating projects typically focus on individual processes and components; ARC provides whole-system context
- ~35 currently-funded collaborating grants in 2010 (includes several NSF Collaborative projects); total funding ~ $24M. Funding "Leverage" from collaborations is ~4-8 fold
- Additional international collaborations, arctic research networks (AON, IPY, ISAC, SAON)
- ARC provides startup support for new projects/new investigators
- Annual winter meeting plays a key role in promoting collaborations and synthesis

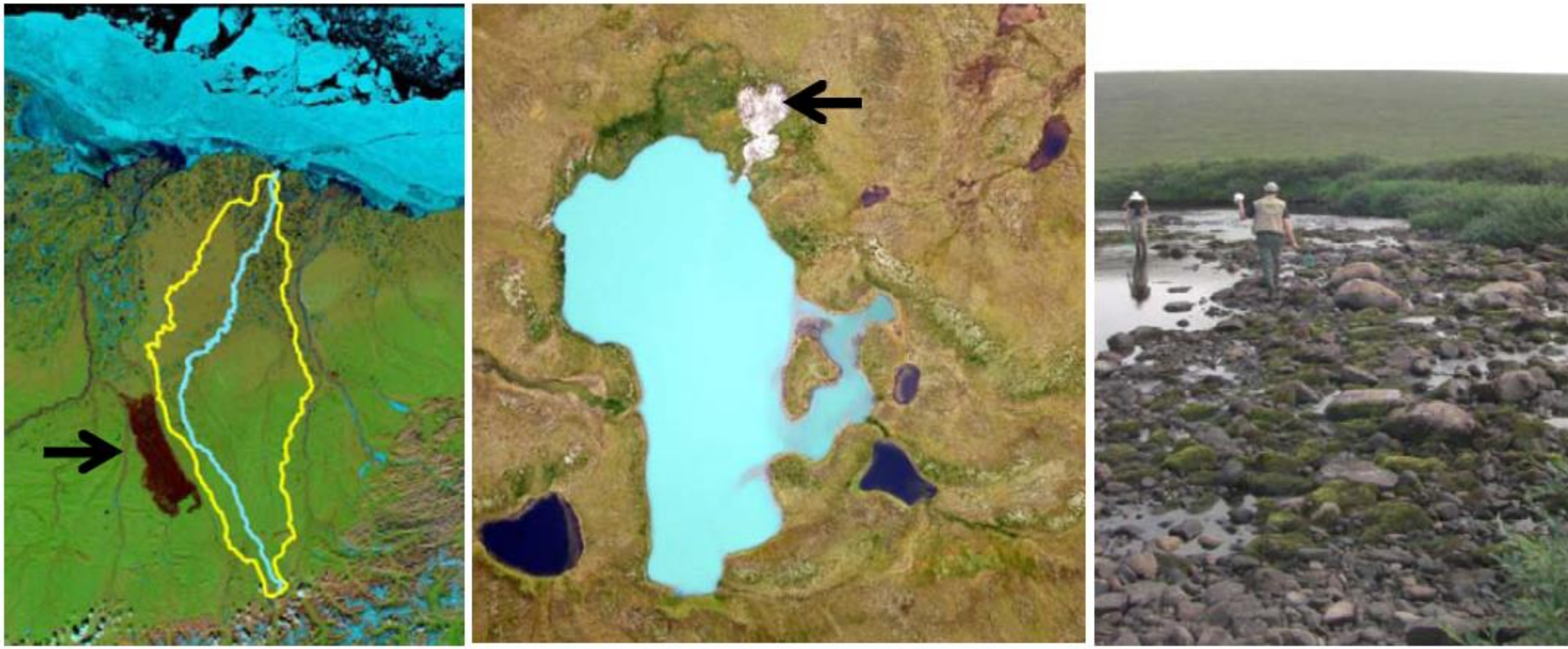


Fig 2-4. Disturbances create patches of dramatically different biogeochemistry and environmental conditions that can dominate the C or energy balance and community dynamics of much larger areas. LEFT: 1000 km^2 Anaktuvuk River Burn (arrow) adjacent to the 9200 km^2 Kuparuk River watershed. CENTER: <1 ha thermokarst (arrow) on the shore of 25 ha Lake NE-14. RIGHT: Extreme low water in the Kuparuk River caused by occasional drought blocks fish migration to headwater lakes 10 km away.

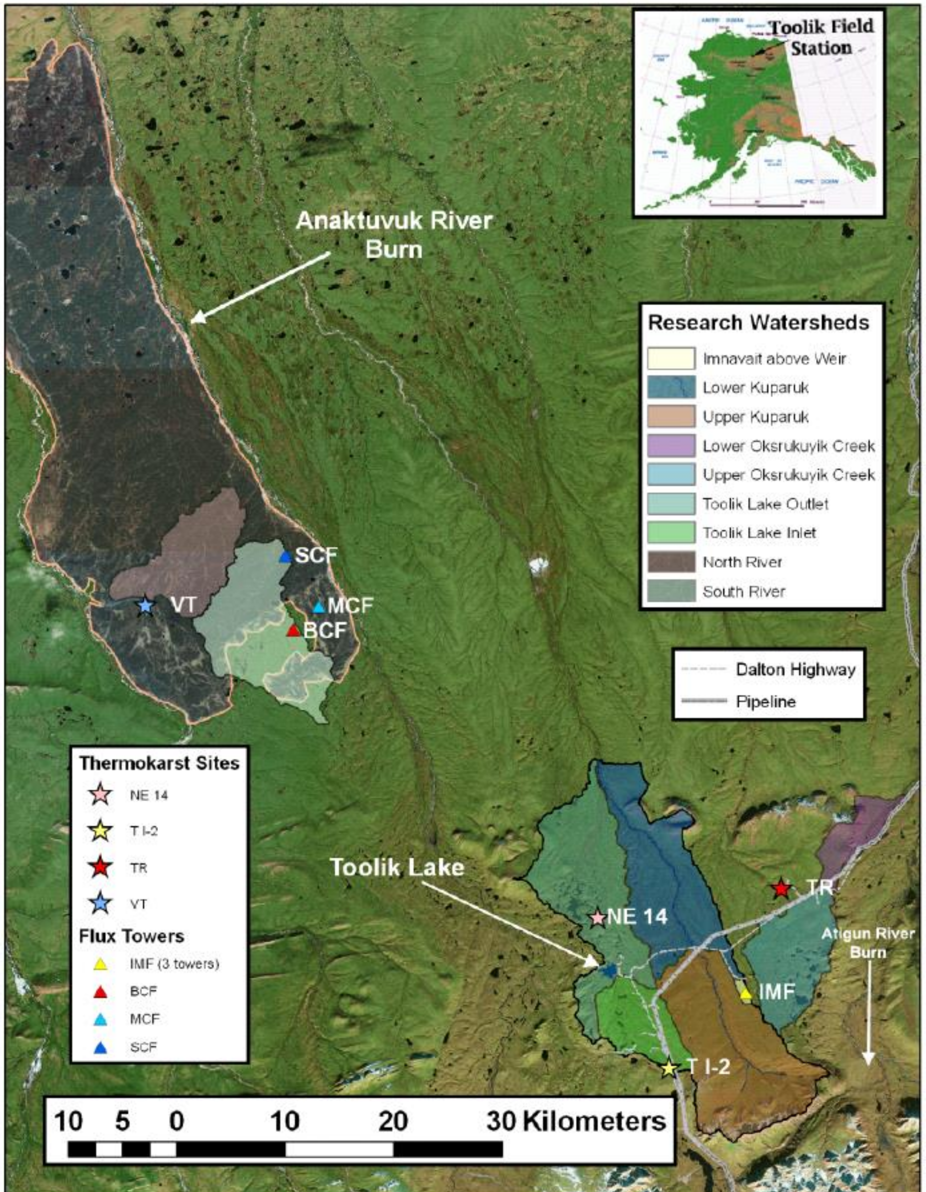


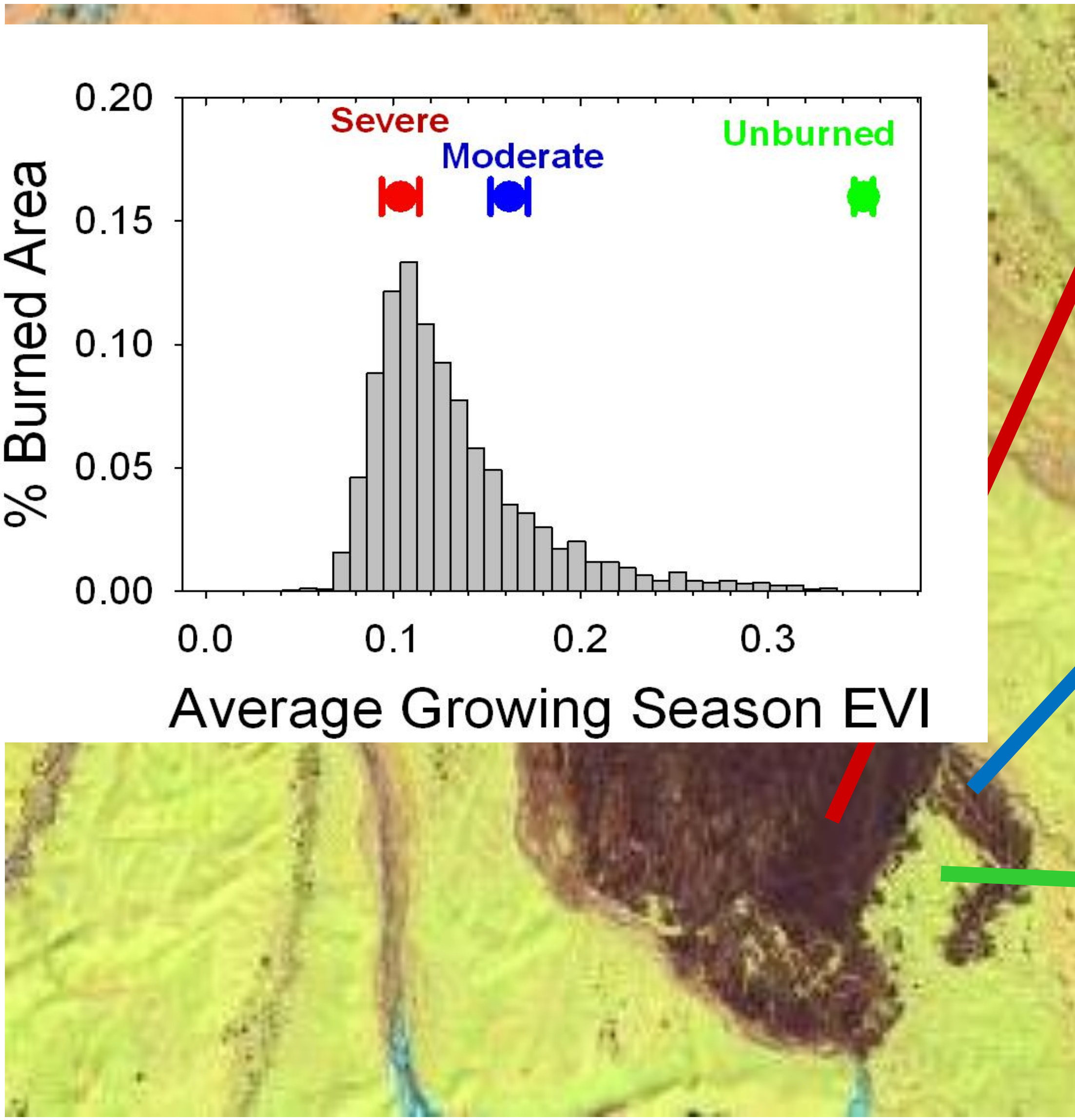
Fig 2-2. Major research sites and place names. The main Arctic LTER research site includes the drainage basin enclosing the two branches of the headwaters of the Kuparuk River (including Toolik Lake and its drainage basin, the upper Kuparuk River, and Imnavait Creek). The ARC LTER research also includes sections of Oksrukuyik Creek, lakes and springs in the mountains and foothills near Toolik Lake (not on this map), the 2004 Atigun River Burn (not shown) and the 2007 Anaktuvuk River Burn 40 km to the northwest.

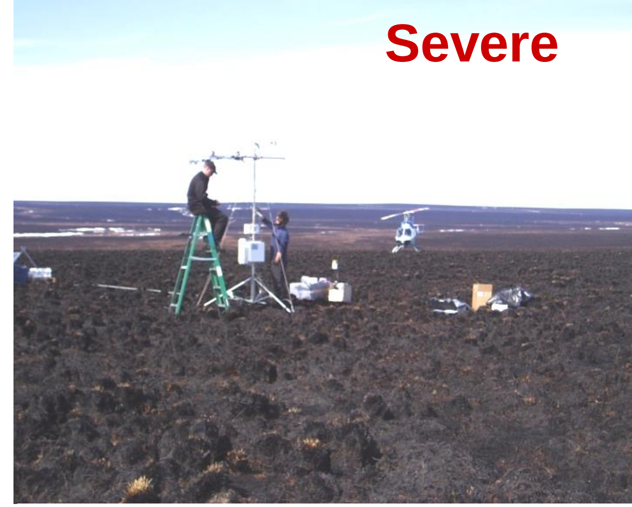
Key to thermokarst and flux sites:

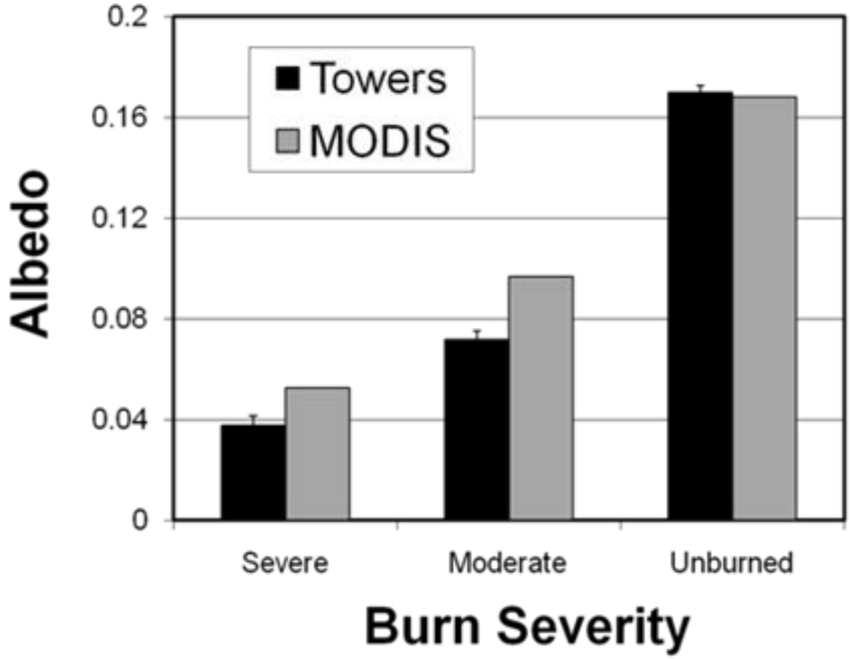
NE-14 = glacial thermokarst on lake shore; TI-2 = Toolik Inlet thermokarst; TR = Toolik River thermokarst; VT = Valley of Thermokarsts; IMF = Imnavait Creek flux towers (3); BCF=unburned control flux tower; MCF=Moderate burn flux tower; SCF=severe burn flux tower.

Anaktuvuk River Fire

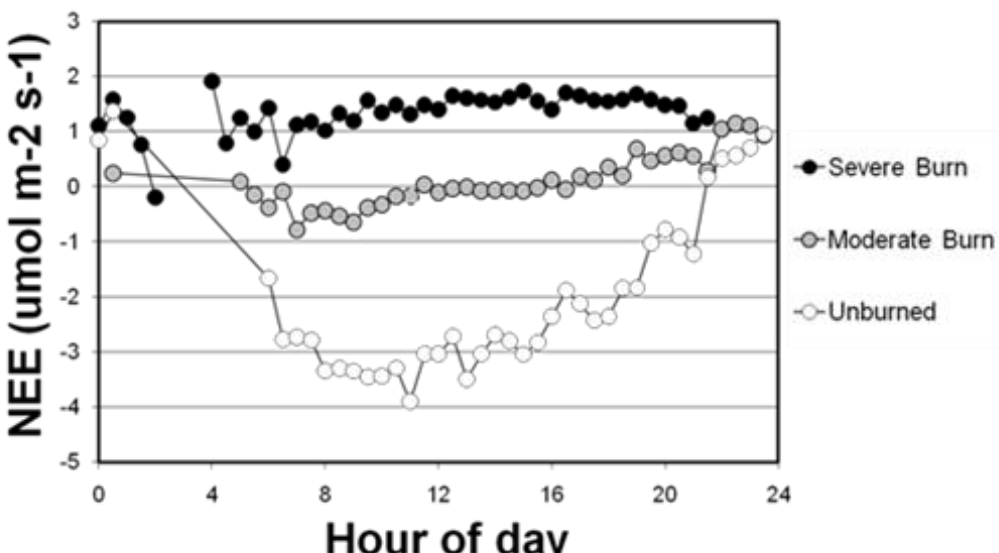
Area burned : 1039 km2
C released : ~2.16 Tg







Net Ecosystem Exchange of CO_2



Summary of initial changes in C balance due to climate change and fire

	Yearly NEE	Change in NEE in 1 year due to:			
	(mean predicted)	Warming	Combustion	Recovery	Aquatic loss
Area:			2007	2008	2008
one m2	-15 gC	< -1 g C	2.02E+3 gC	80-140 g C	1-2 g C
AR Burn	-15.6E+09 gC	<-1.04E+09 g C	2.09E+12 gC	1.25E+11 g C	1-2E+09 gC
N Slope	-2.8E+12 gC	<-1.88E+11 g C			

Combustion losses/m2 were opposite in sign and ~100x annual NEE; combustion losses were >2000x expected gains due to warming alone; losses on AR Burn were >2/3 the yearly C gain of the entire N Slope (200x larger area) and >10x predicted gains due to warming only

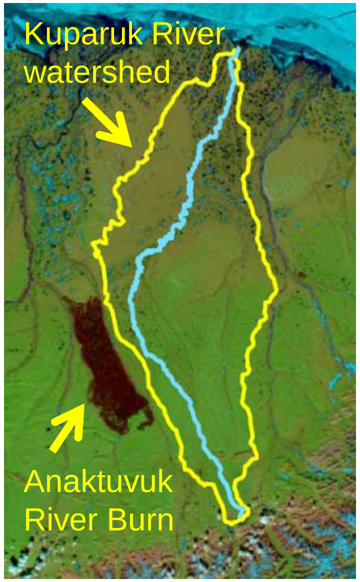
In summer 2008, increased NEE (C loss) in recovering vegetation was 5-9 x predicted gains as annual NEE and >100x changes in NEE due to warming in equal area, and similar (but opposite in sign) to warming gains on entire N Slope

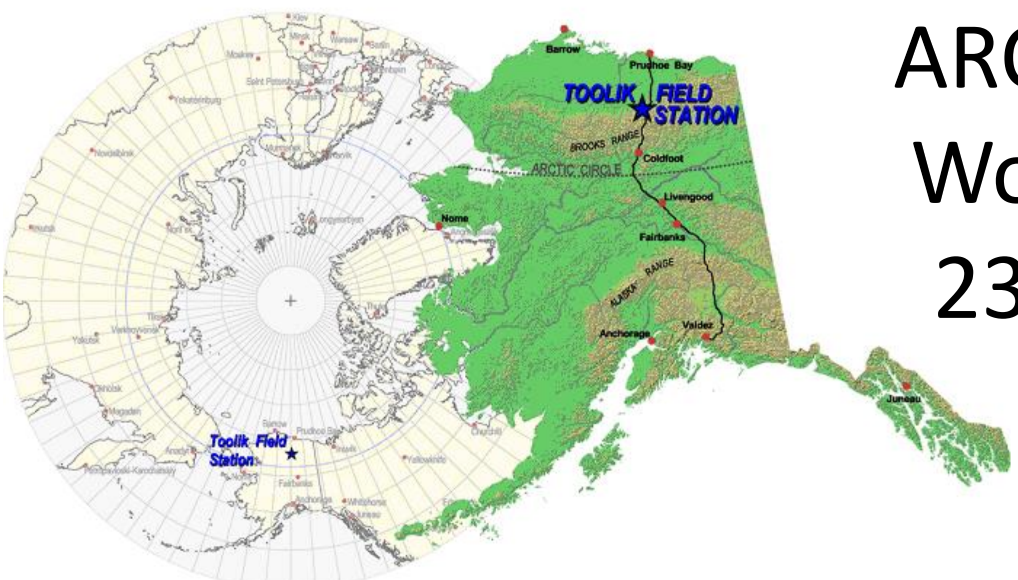
In summer 2008, aquatic losses in burned catchments were10% of unburned NEE and ~1-10x NEE gains due to warming

Science Support Needs

- Laboratories
  - More and better lab space; new kinds e.g., animal holding, microbial hoods
  - More basic, widely-used equipment (ovens, balances, pH, hand held instruments) but NOT specialized equipment (autoanalyzers, flux towers, gene sequencing, mass specs)
- Equipment maintenance/repair/fabrication
- Shared logistical support away from TFS
  - Boardwalks, remote power, trucks, helicopters
  - Permitting is a major problem
- Data and information
  - Data base, data access, general info, weather and climate
  - Communications: data servers, real-time communications with field instruments, autonomous systems

North Slope of Alaska:	188,000 km2
Kuparuk River watershed:	9200 km2
Anaktuvuk River Burn:	1003 km2
Kuparuk Headwaters:	143 km2
Toolik Inlet:	43 km2
Imnavait Creek:	4 km2





LTER Network 30 Year Review
ARC LTER Site Visit
Woods Hole, MA,
23-24 Sept 2010

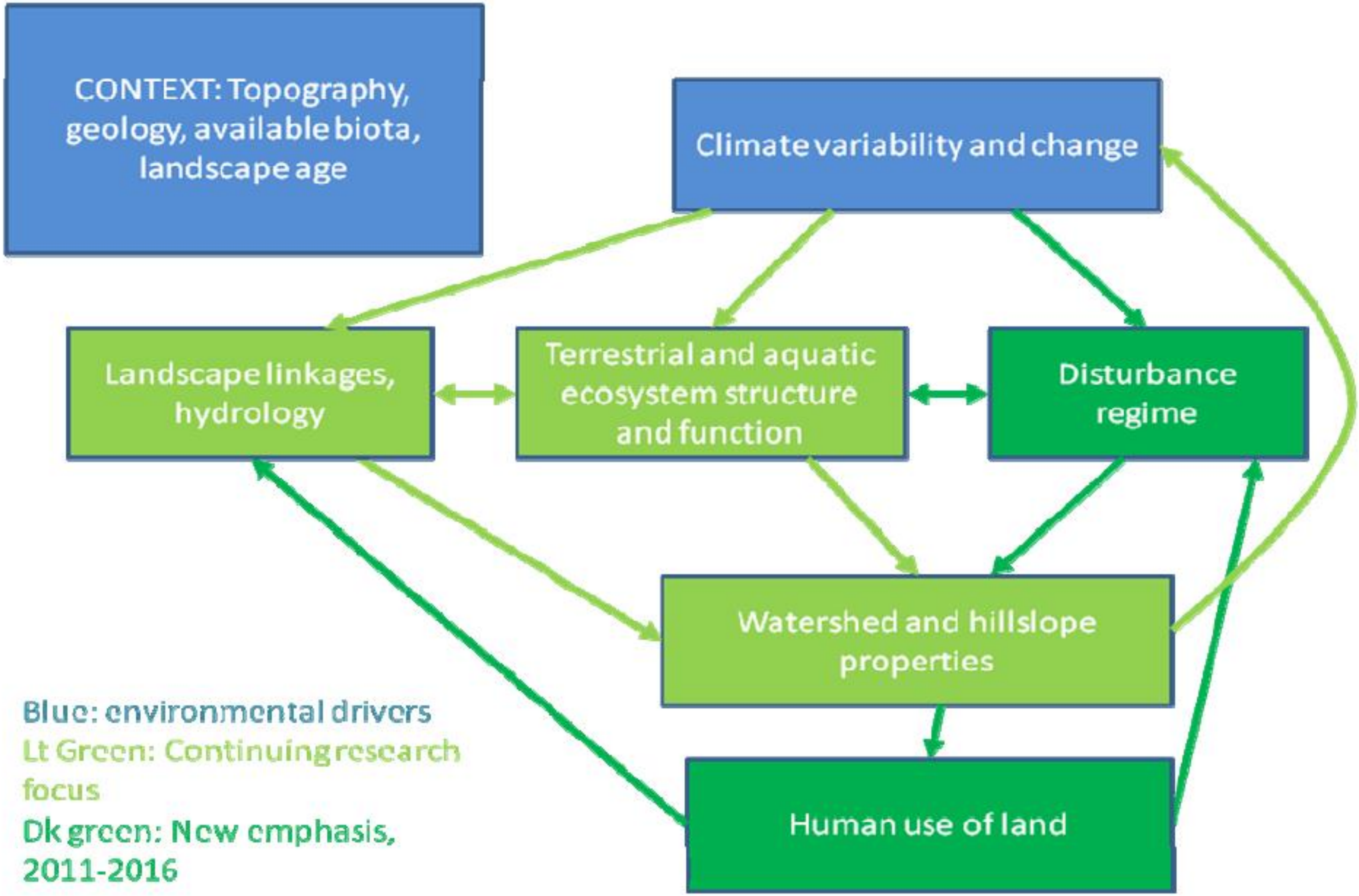


Fig 2-3. Conceptual Framework for 2011-2016. (see text for explanation).





Toolik Field Station
GIS
Inst. of Arctic Biology
University of Alaska Fairbanks
To The Dalton Hwy.
Manager Cabin
ATCOs 3 & 4
Sunrise Cabin
Cotton-Grass
Cold Storage
Cabinex
WeatherPORT Housing
Outhouse
ATCOs 1 & 2
Helipad
Porta Potties
Winter Quarters
Community Center
Towers 1
Loader Tent
Resource Pile
EMT Shack
THC
Dorms 18 & 19
Dining Hall & Main Office
Hazmat Shack
Towers 2
Diesel/Unleaded Fuel
Whalen Trailer
Shipping & Receiving
Bike Tent
Kitchen
Generator Modules
Tool Shop
Showers & Laundry Module
Tire Shop
Dining Over-flow
Water Trailer
Incubation Facility
Wet Lab
Lab 6
Lab 1
Met Station
Lab 5
Dry Lab
Towers 3
GIS Office
Herbarium
Winter Lab
Lab 2
Meeting Trailer
EDC Trailer
Main Dock
Pub Tent
Lab 3
Lab 4
Stable Isotope Lab
Social Circle
Tent City
Well
Sauna
06 . 29 . 2009

Science Questions and Time Scale

Relation to Project Structure:

- *Lakes, streams, terrestrial, and land-water interactions groups receive equal resources (1 RA, 1 Summer RA, 1 PI 1 mo/y, travel, logistics)*
- *Each group's research includes monitoring/observing components and long-term experiments*
- *Collaboration with separately-funded projects complements LTER research, by coordinated sampling, analysis, and data integration and archival*

Time and space scales:

- *Variable sampling schedules but all research is carried out with a view toward interpretation of results at a scale of years to decades*
- *Collaborating projects tend to focus on one time or space scale (often short-term, small area) but work in ARC sites to take advantage of interpreting their results in the context of large-area, long-term data sets from same sites*