High latitude systems:
Synthesis of what we know, don't know, and need to know, pre-ABoVE

SCOTT GOETZ
NASA Terrestrial Ecology meeting
LA JOLLA, CA
MAY 2013
We know: Climate warming & arctic amplification

2011 mean Ta vs longer-term 1881-2011 mean

Goddard Institute for Space Studies (GISS)
Permafrost Carbon Feedback to Climate

Need to know: What is the magnitude, timing, and form of the permafrost carbon release to the atmosphere in a warmer world?

- Fossil Fuel Emissions: 365 Pg
- Land Use Change: 151 Pg

Future (2100) Permafrost Zone C Emissions?
- 7-11% Loss: 120-195 Pg
- Expert Survey (Schuur 2013): (162-288 Pg CO₂-Cₑq)
Know: Permafrost is not well represented in Earth System Models

Climate-scale modeling tasks

Intermediate-scale modeling tasks

Fine-scale modeling tasks

DOE NGEE-Arctic timeline for major modeling tasks
Know: knowledge of permafrost properties over large areas is poor but critically important for magnitude & timing of carbon release

Permafrost extent

Soil carbon in permafrost region

Tremendous heterogeneity within these classes

Hugelius et al. (2013)
CARVE observations of methane bursts as Spring thaw moves across the North Slope

Need to be able to link this variability to surface & subsurface properties
Need to know: How do permafrost landscape properties vary at relatively fine scale (10-100m) across the landscape?

- Not just presence but also substrate properties (e.g. soil moisture & texture, ice content & morphology)
- Vegetation cover & density, surface hydrology & other properties
- Snow cover, seasonality & properties (e.g. SWE)
- Freeze-Thaw state & seasonal variability
- Spatial variability in seasonal depth of thaw

➢ **NASA RS is key to meeting this challenge**
Opportunities to Use Remote Sensing in Understanding Permafrost Ecosystems: A Workshop

National Academy of Sciences

In formulation stage

Planned for 8-9 Oct 2013
Location TBD
Need to know: How does fire disturbance alter active layer / depth of thaw and how does this change in the years post-disturbance?

Photos by Torre Jorgenson

2010 Fire on Tanana Flats, AK
**Need to know:** How can we work this information into meaningful spatial models of subsurface temperature & thaw depth?

**Know:** like Freeze-Thaw, these do not scale linearly with spatial resolution.

*Figure 1. The GIPL-1 model conceptual diagram (A) and schematic profile of mean annual temperature through the lower atmosphere, active layer and upper permafrost (B).*
Know: Satellite microwave detection of northern hemisphere non-frozen season shows increasing trend

Northern Hemisphere Mean Annual Non-Frozen Period Trend (days yr$^{-1}$)

Temperature & vegetation seasonality is shifting HNLs towards more southerly status

Temperature Seasonality through time

Vegetation Seasonality

Xu, Myneni & 19 others 2013
*Know:* satellite observed productivity trends vary with warming as well as drying (drought / high VPD).

These are coupled
Drought Duration

Short
Long

Tree Mortality Threshold

MORTALITY

Drought Intensity

High
Low

Precipitation

Wetter
Drier

Temperature

Cooler
Warmer

Current Climate

NO MORTALITY

Allen et al – 2010
Drought Duration

Short  Long

Drought Intensity

High  Low

Tree Mortality Threshold

Precipitation

Wetter  Drier

Temperature

Cooler  Warmer

Current Climate

Future Climate

MORTALITY

NO MORTALITY

Allen et al – 2010
Recent work supports drought influence on boreal productivity & mortality.
Know: Tree ring data support evidence for satellite observed productivity declines.
Need to know: is a “biome shift” being captured in tree ring & satellite data records?

Boreal tree growth

Juday & D’Arrigo

Summer temperature

(A) cool, moist northern and coastal regions
(B) warm, dry lowlands

positive responders
negative responders

$\text{positive responders}$

$\text{negative responders}$
Know: Alaska tree ring & satellite observations are consistent with a biome shift

Cooler coastal zone greening with warming whereas interior browning
Global vegetation models predict 21st century ‘biome shift’

Lucht et al. 2006

Deciduous woody

Evergreen woody

Non-woody

SRES B1 emissions scenario

SRES A2 emissions scenario

Lucht et al. 2006
Boreal fire is common, widespread and increasingly intense (greater burn severity)

Kasischke & Turetsky 2006 GRL, Turetsky et al. 2011 Nature Geoscience

Know: drought decreases productivity but also intensifies the fire regime.

Need to know: will fire disturbance accelerate a biome shift?
Know: more severe fires burn organic soil, increase depth of thaw & change composition of regrowth.

Burn severity

Post-fire organic layer depth

OL = 10 cm

OL = 5 cm

OL = 2 cm

1983 Minto Flats Burn
Interior Alaska
Alexander and Mack

Kasischke et al. 2010 CJFR and Kasischke & Hoy 2012 GCB
Turetsky et al. 2010 Nature GeoSci.
Know: larger later-season fires, indicative of more severe burning, show successional trajectory shift (captured by MODIS).
**Know:** river measurements & RS observations capture record of fire disturbance in river carbon chemistry

![Map of Arctic Great Rivers Observatory](image)

Absorption is similar out to $\sim$440nm

**Need to know:** the extent to which fire-produced condensed aromatic carbon is exported into rivers and the ocean and, by absorbing light, warms & enhances photochemical processes (compounded by declining sea ice)
Need to know: The influence of insect disturbance on nutrient & carbon budgets

Spruce budworm & aspen caterpillar defoliation in NE Alberta

Photo by Ted Hogg
Know: vegetation & the boreal – tundra transition is not well represented in Earth System Models
Need to know:
How to better represent veg cover in ESMs so albedo & energy balance are more accurately predicted.
**Know**: the future distribution of arctic vegetation will change substantially.

![Map comparison of current vs. future (2050s) vegetation distribution in the Arctic region. The map on the left shows the current vegetation distribution, while the map on the right shows the predicted vegetation distribution for the 2050s. The legend at the bottom identifies different vegetation types: graminoid tundras, prostrate shrubs, erect shrubs, and trees.](image-url)

*Pearson et al. 2013. Nature Climate Change*
Need to know: How will future vegetation distribution alter albedo, energy balance, nutrient & carbon budgets?

Albedo & net solar radiation change under ~2050 vegetation compared to present.

Goetz et al., unpublished
Need to know: How will wildlife & biodiversity will be affected by climate & vegetation change?
The Arctic will become greener within decades as rising temperatures leads to an increase in plant life

- Rising temperatures will lead to an increase in trees and shrubs in the Arctic
- Wooded areas in the Arctic could increase by 50 per cent in a few decades
- Research shows that this dramatic greening will also accelerate climate warming

By JAYMI MCCANN

The Arctic will turn green due to rising temperatures within decades, warns a new study.

The study forecasts that rising temperatures will lead to a massive 'greening' - increase in trees and shrubs - in the Arctic.

Scientists have revealed new models projecting that wooded areas in the Arctic could increase as much as 50 per cent over the next few decades.

Know: we have a communications & public outreach challenge