Land-Atmosphere-Ice Interactions

LAII

Terry Chapin
University of Alaska

Talk overview

- LAII program objectives
- Summary of accomplishments and uncertainties
- Visions for the future
  - Integration of terrestrial research with other ARCSS components
    - Requires input from this workshop
  - Relationship to new and planned initiatives

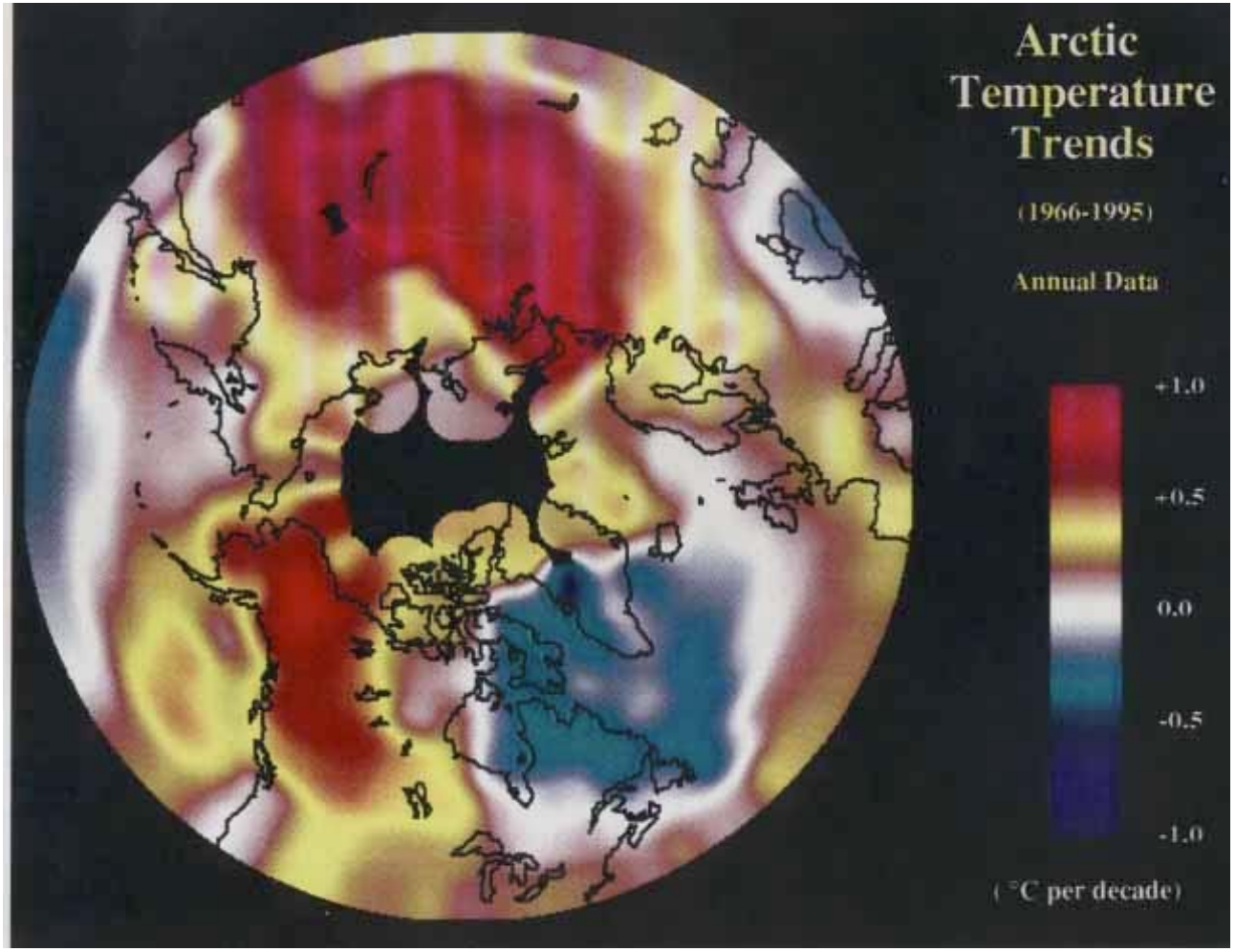
LAII program objectives

- **Detection and analysis of arctic change**
- **Pan-arctic extrapolation of terrestrial feedbacks to climate**
- **Past and future changes in the Arctic System**
- **Sustainability of the Arctic System under global change**

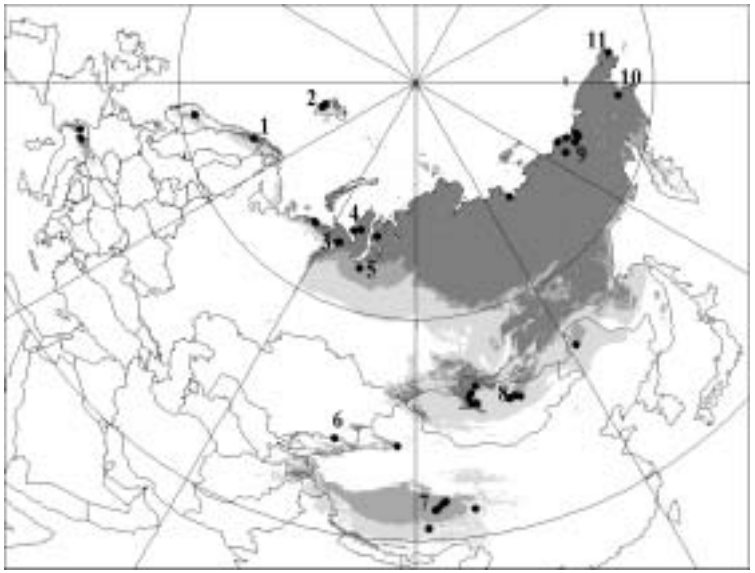
LAII approach

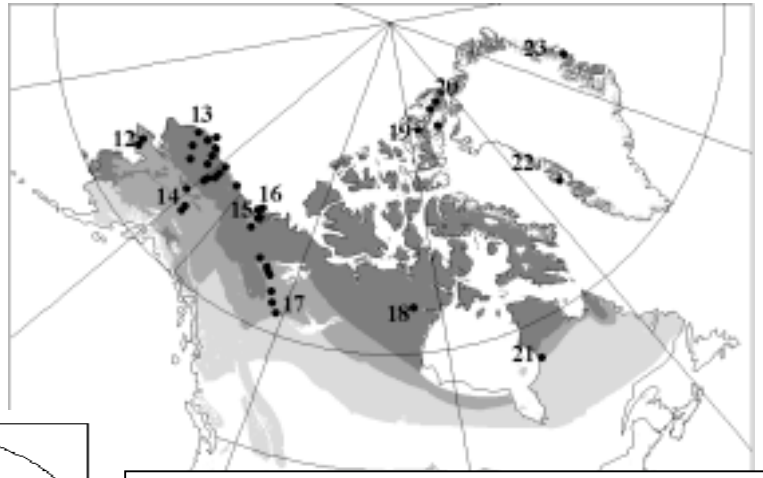
- **Measurement of key processes**
  - **Document spatial and temporal variation**
- **Development of process-based models**
- **Extrapolation in time and space**
- **Testing of predictions in new locations**

Rapid Climatic Change



Serreze

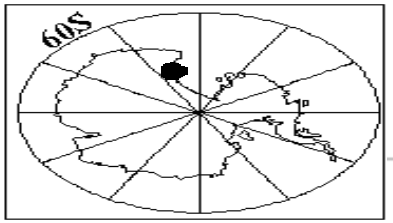




1 Abisko
2 Longyearbyen
3 Vorkuta
4 Marre Sale
5 Nadym
6 Bol'shoe Almatinskoe Ozero
7 Tuotuohe
8 Bayan-Gol
9 Ost Oloj
10 Anadyr'
11 Mys Uelen

12 Nome
13 Barrow
14 Fairbanks

15 Inuvik
16 Tuktoyaktuk
17 Fort Simpson
18 Baker Lake
19 Eureka
20 Alert
21 Kuujjuarapik
22 Upernavik
23 Danmarkshavn

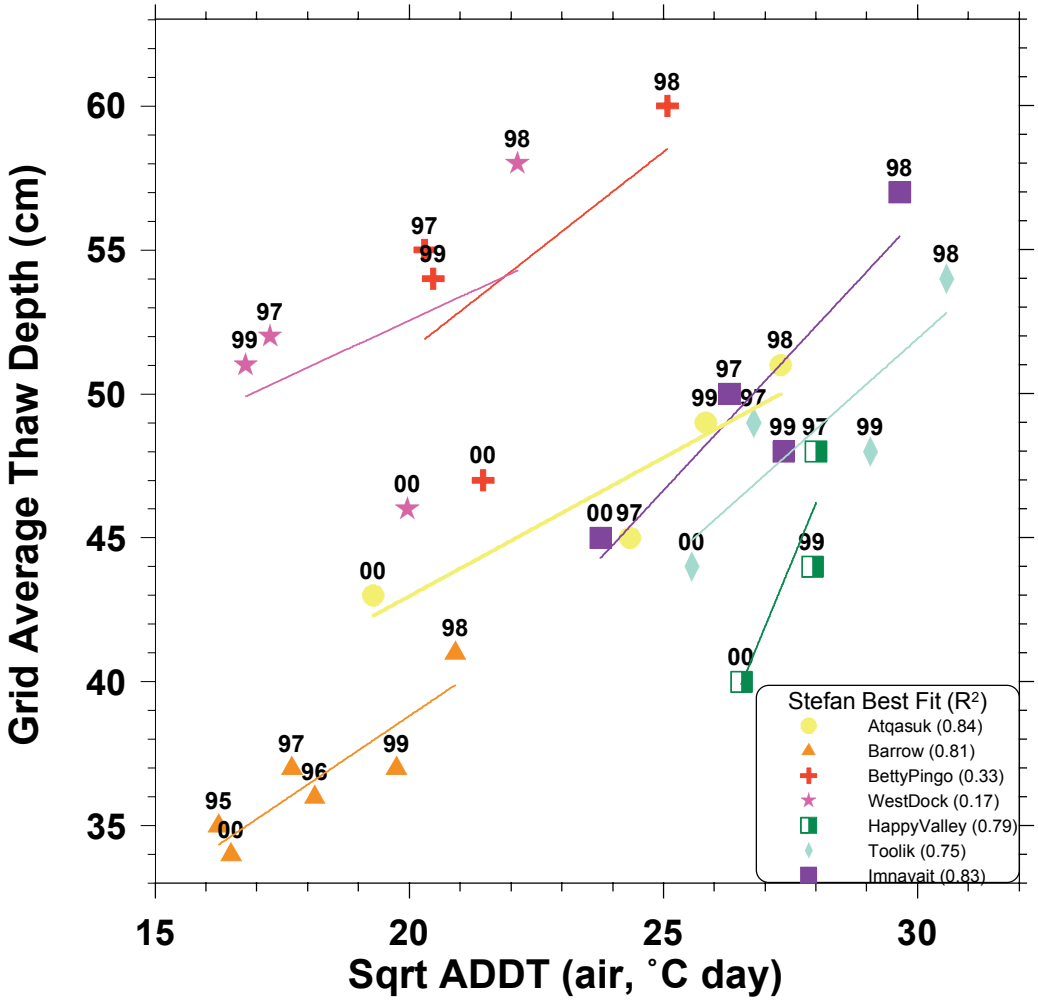


Permafrost Zones

Continuous
Discontinuous
Sporadic

• *Active CALM sites*
#s *represent Climate Stations*

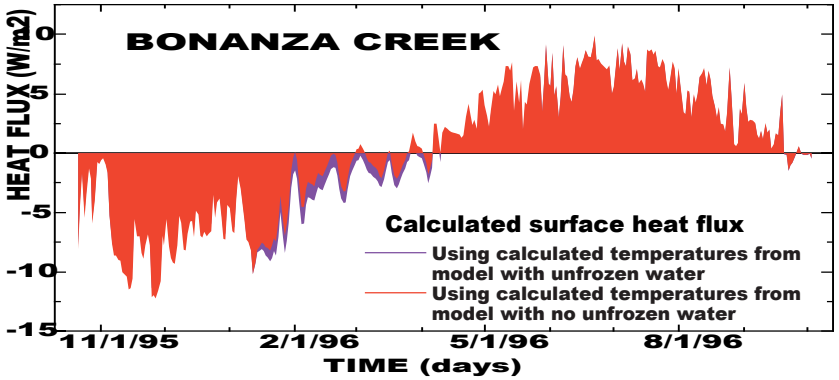
Hinkel, Brown and Nelson



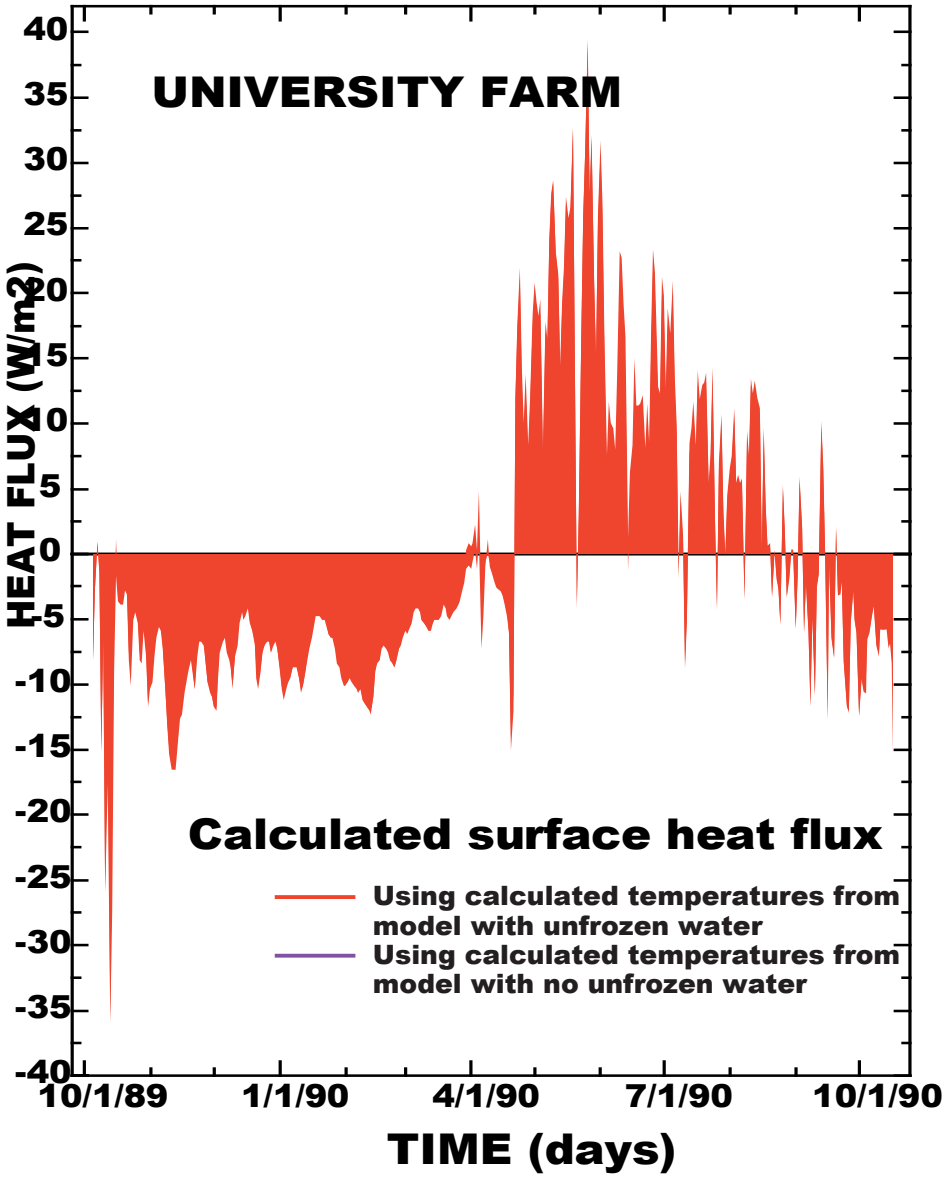
Hinkel, Brown and Nelson

Vegetation influences soil heat flux

Moss-dominated

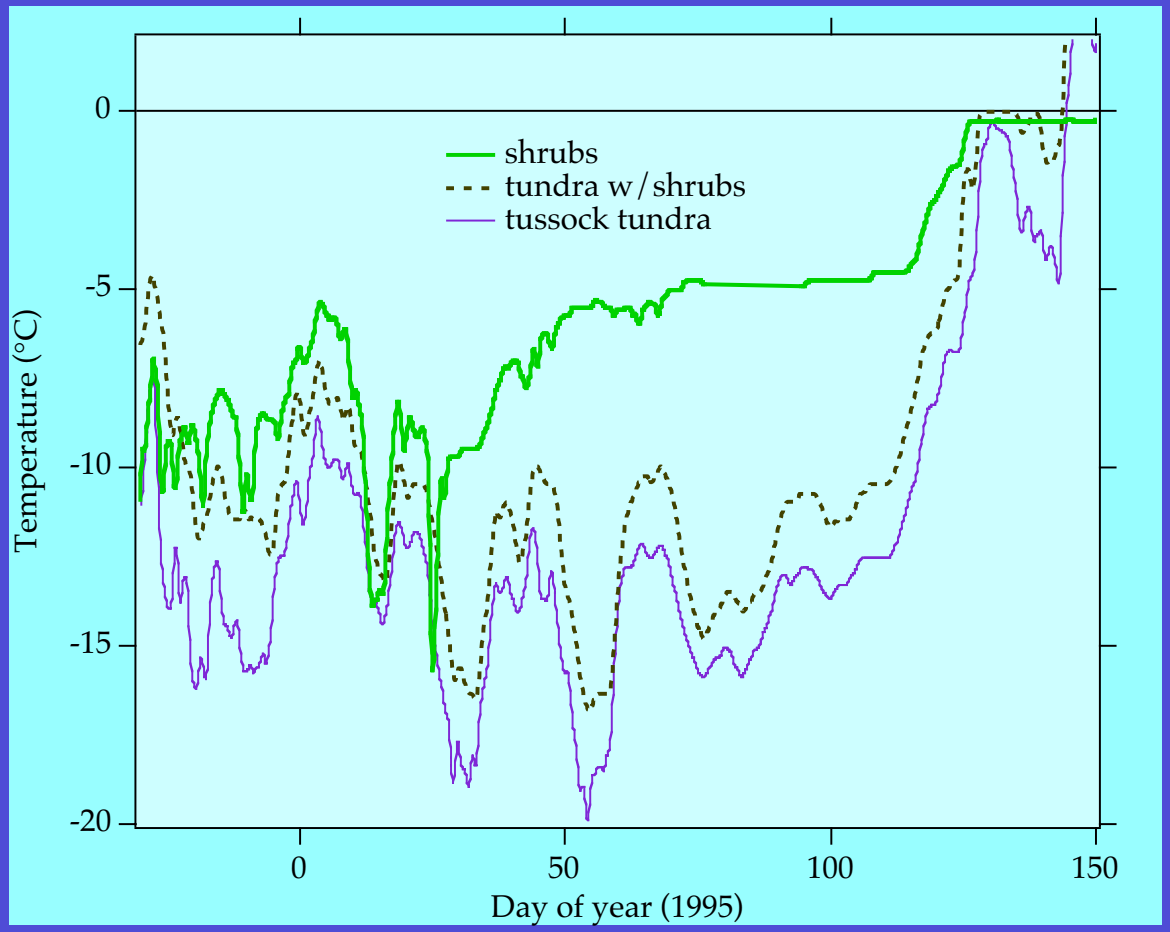


Unvegetated



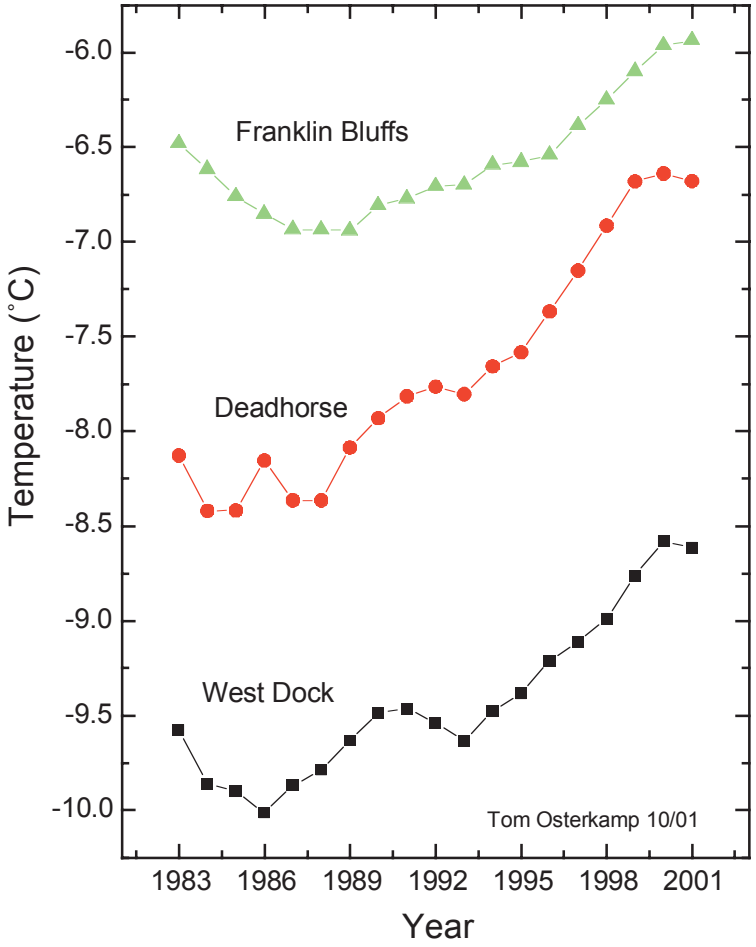
Romanovsky

Shrubs Dramatically Alter Winter Soil Surface Temperatures in Tundra



Sturm

Permafrost temperatures are warming



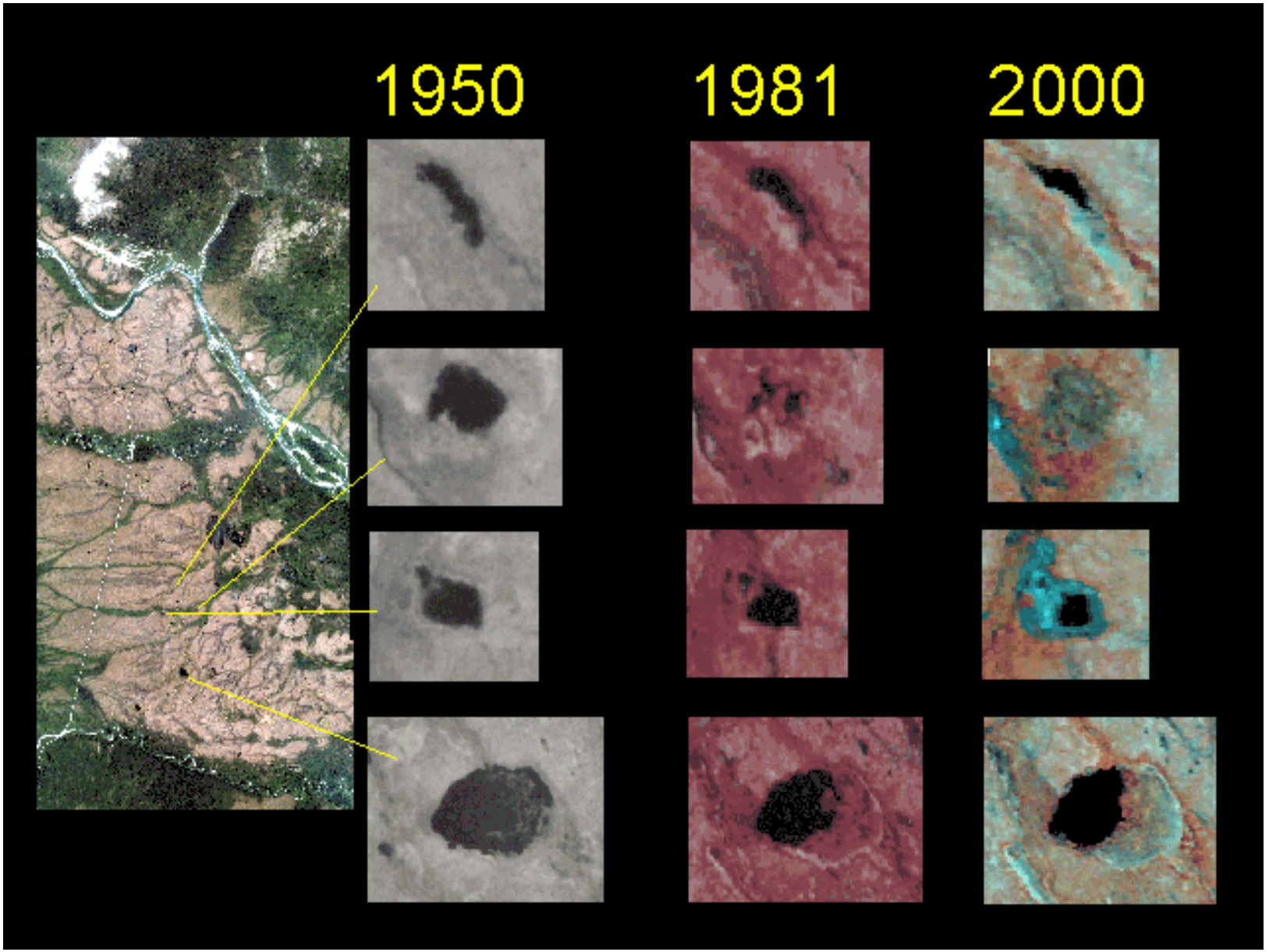
Temperatures at the 20 m depth on a N-S transect across the coastal plain of Northern Alaska

Osterkamp and Romanovsky

Remaining uncertainties: Permafrost

- Ecosystem controls over soil heat flux
  - Snow?
  - Vegetation?
  - Snow-vegetation interactions?
- Variable consequences of thermokarst

Hydrology is changing



Hinzman

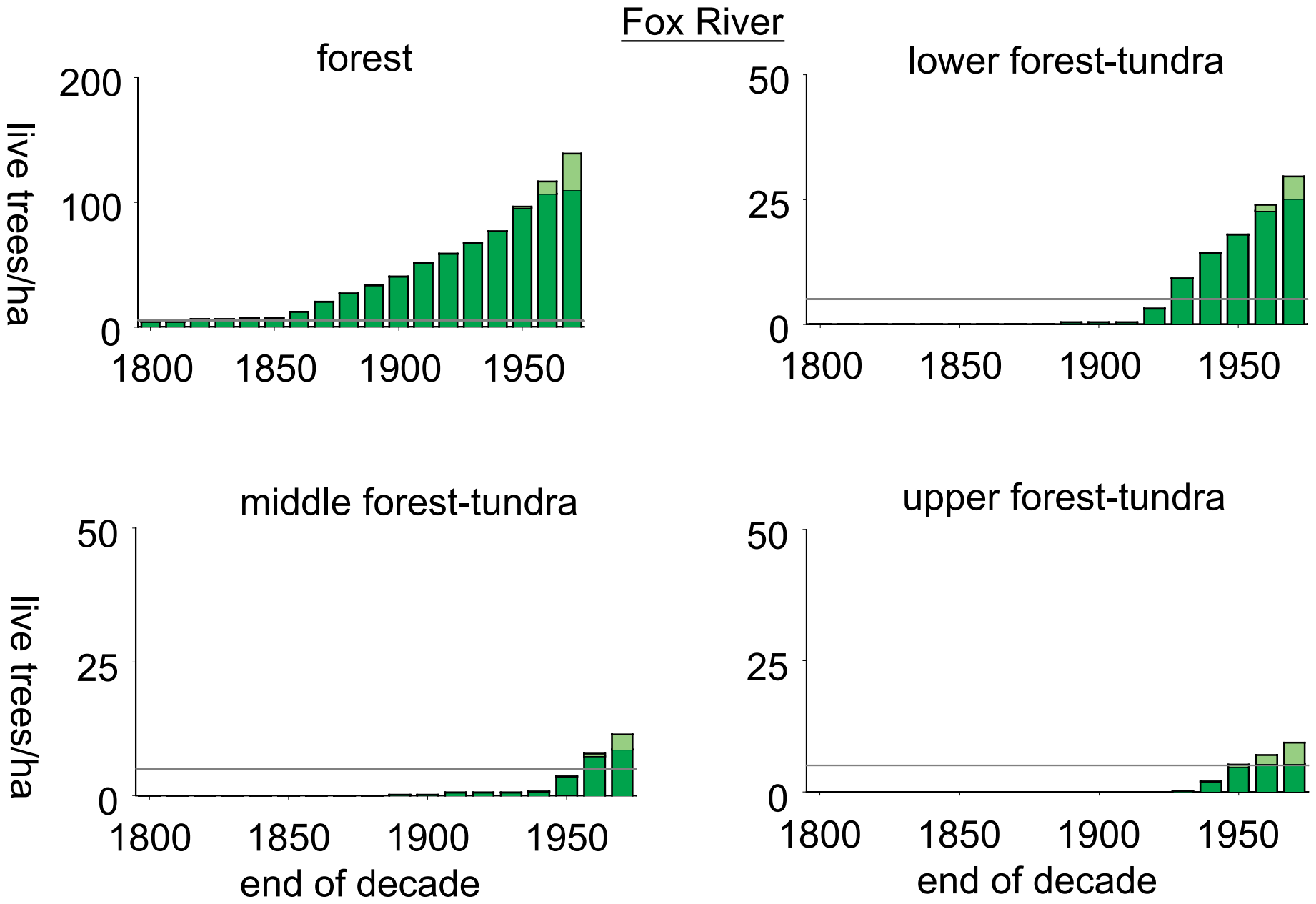

Hinzman
2.23.1999 17:49

Remaining uncertainties: Hydrology

- Why is arctic river discharge increasing
  - Climate?
  - Land-surface change?
  - Interaction?
- Ecosystem effects on evaporation, runoff and precipitation
  - 25% of ppt comes from recycled water
- Future snow cover and properties?

Area burned in W. North America has doubled in last 20 years

Kasischki



Lloyd and Fastie

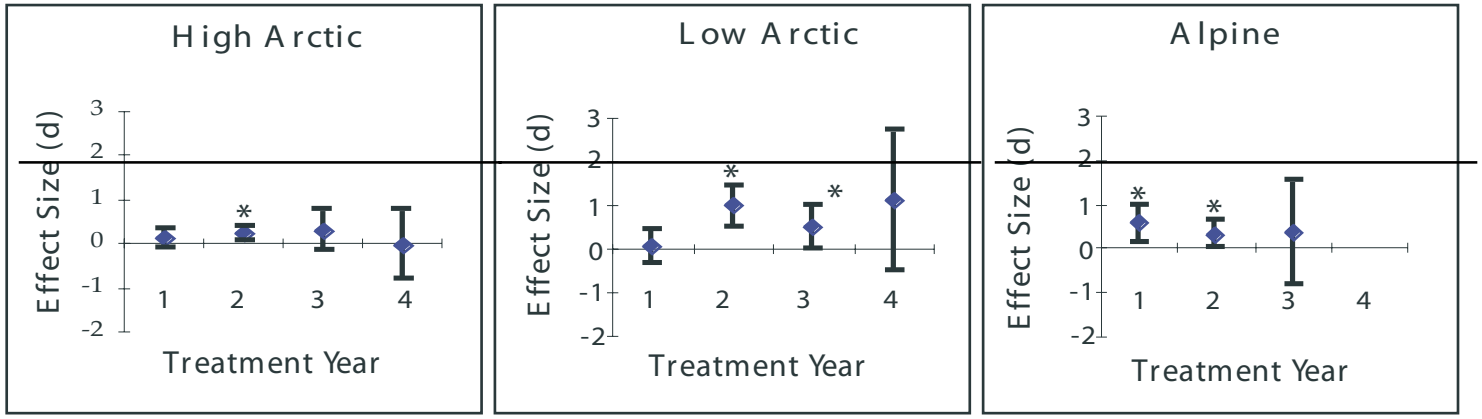
1949

Shrub density has increased

2000

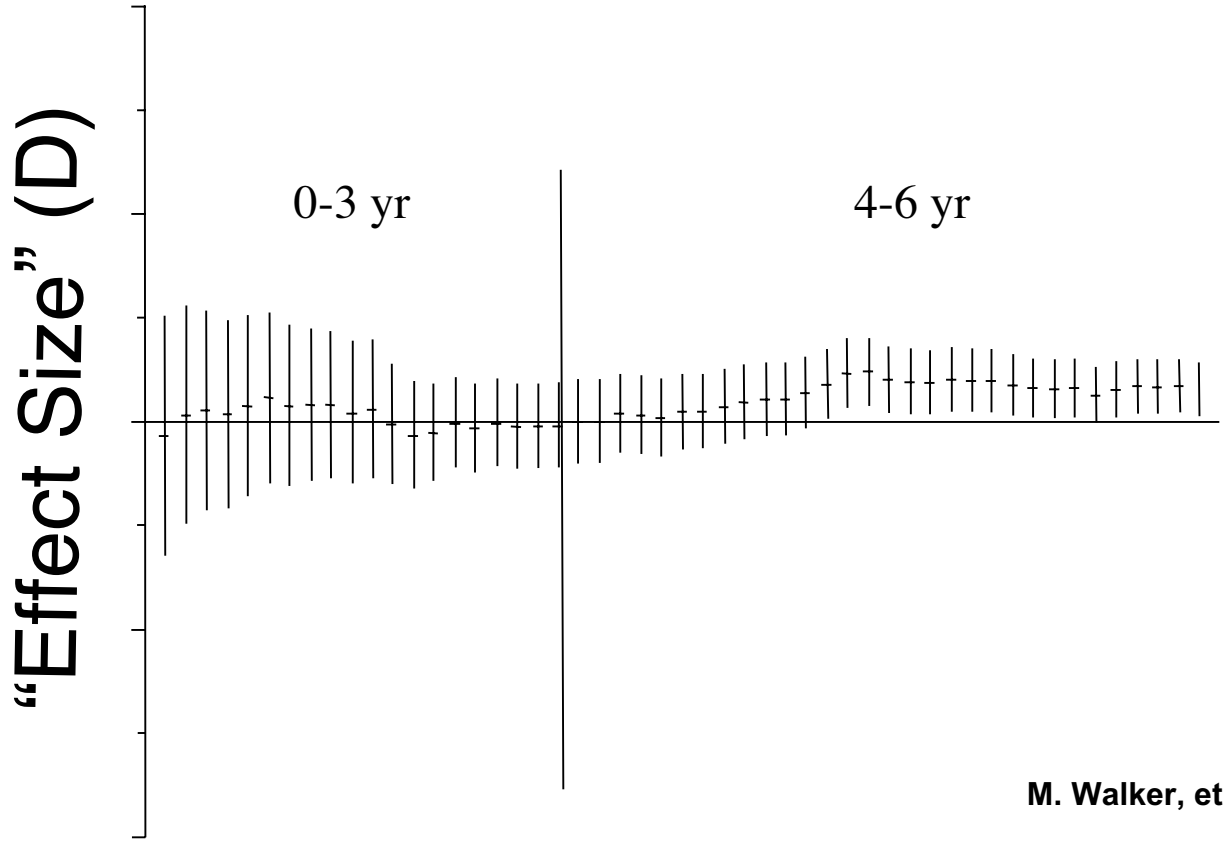
Sturm

Growth responses to warming



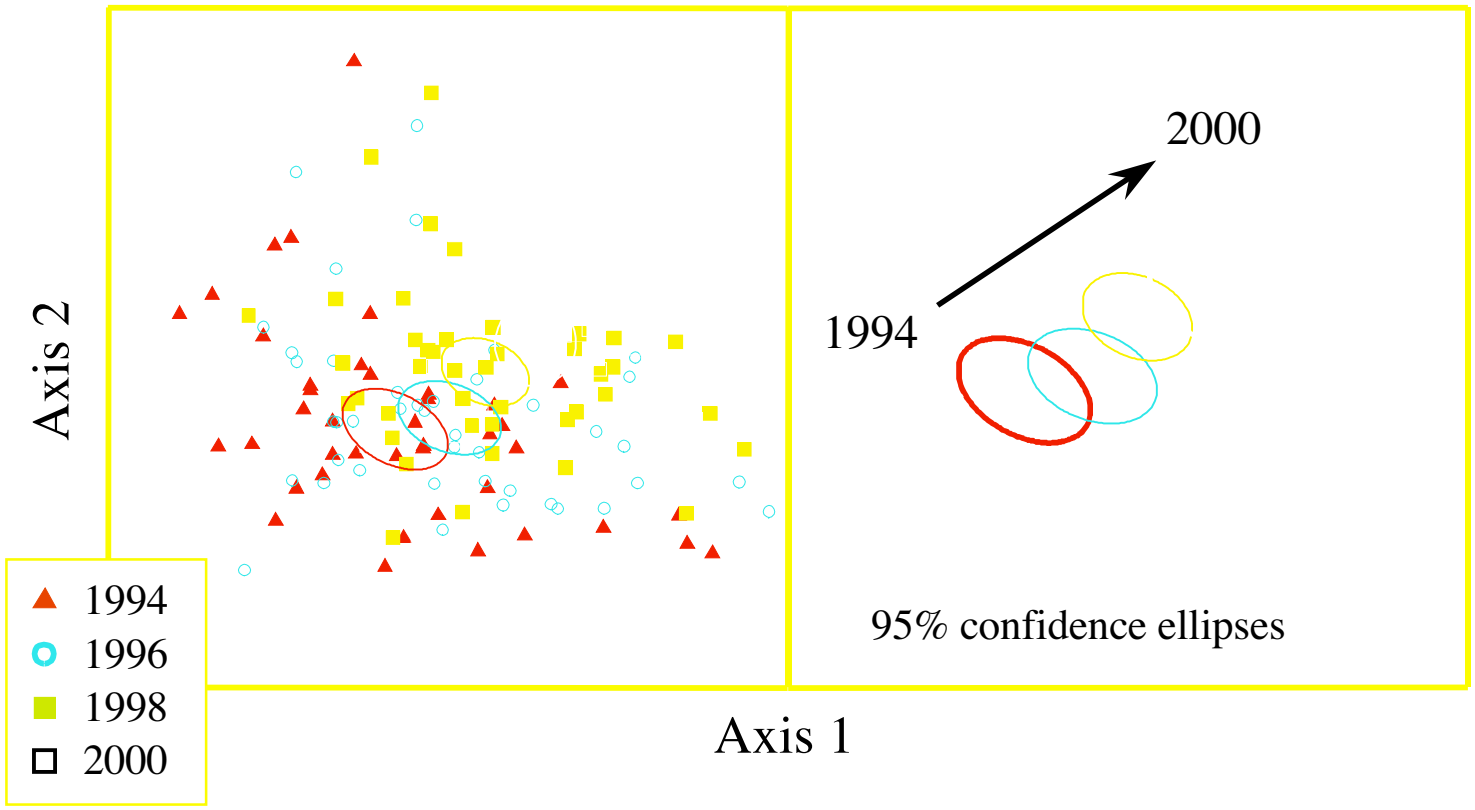
Arft, M. Walker, et al.

Change in deciduous shrub cover



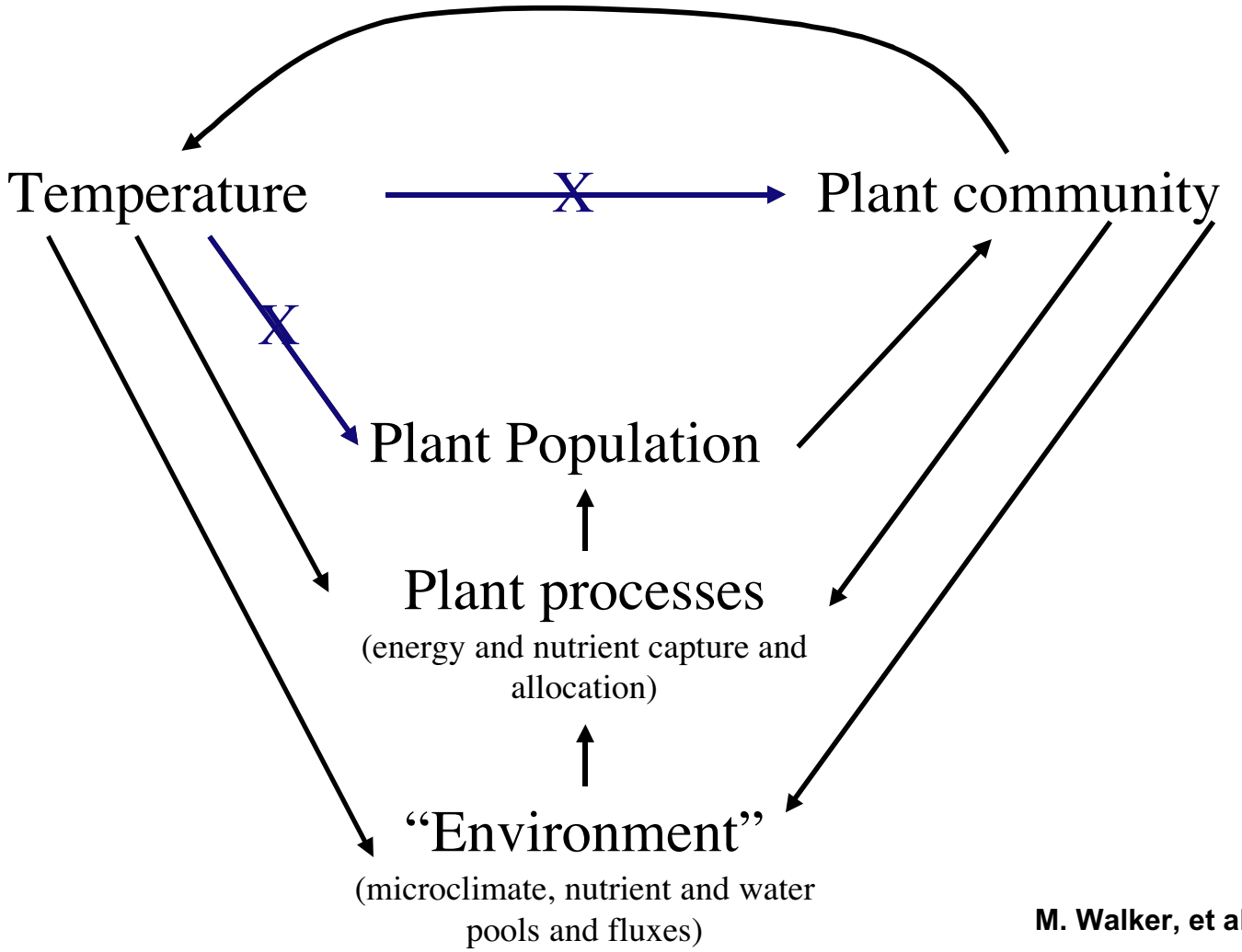
M. Walker, et al.

Whole Community Response

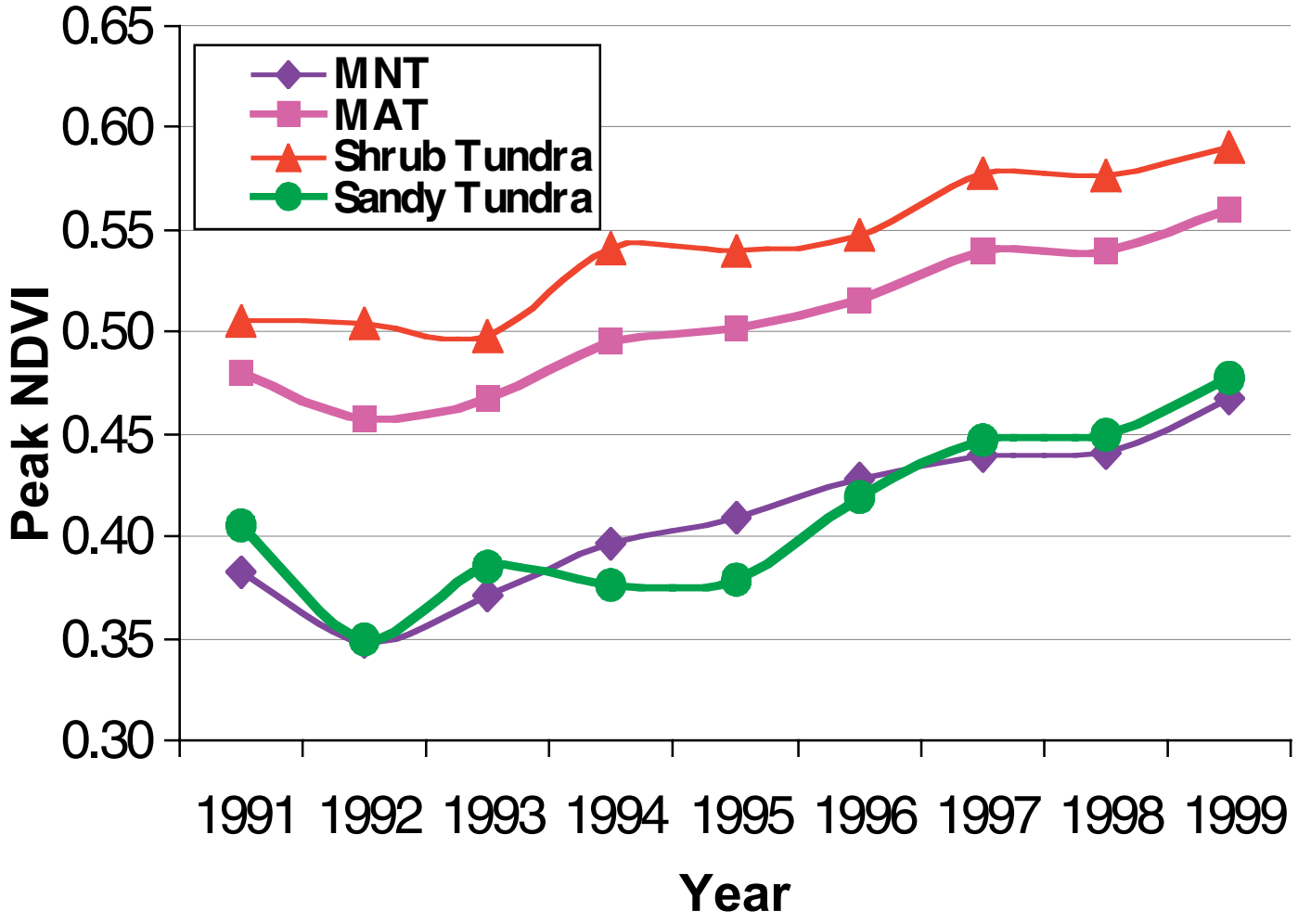


M. Walker, et al.

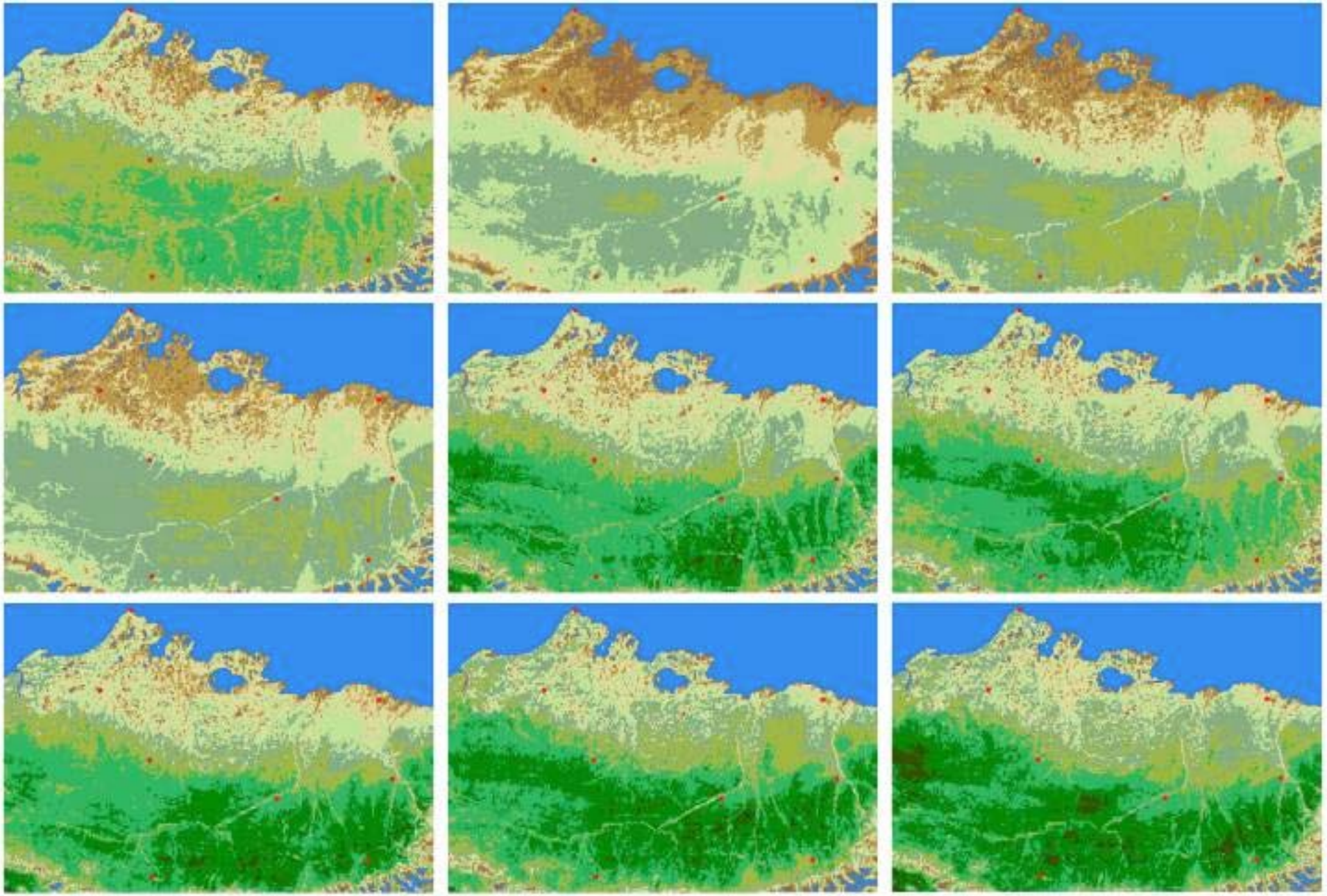
Effect of temperature



M. Walker, et al.



Epstein and Walker



Time Integrated NDVI
Epstein and Walker

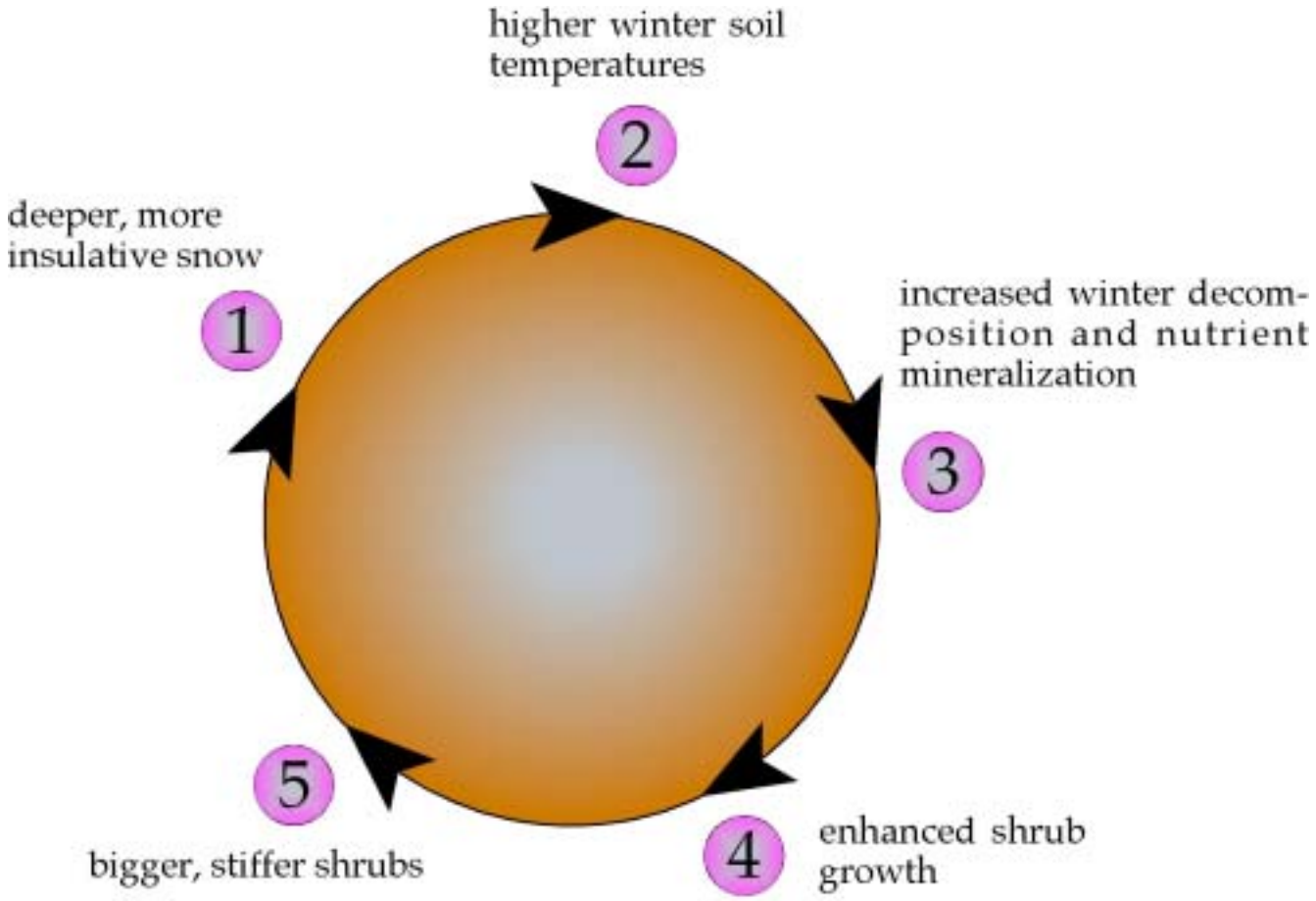
91	92	93
94	95	96
97	98	99

Low ◄——————————► High

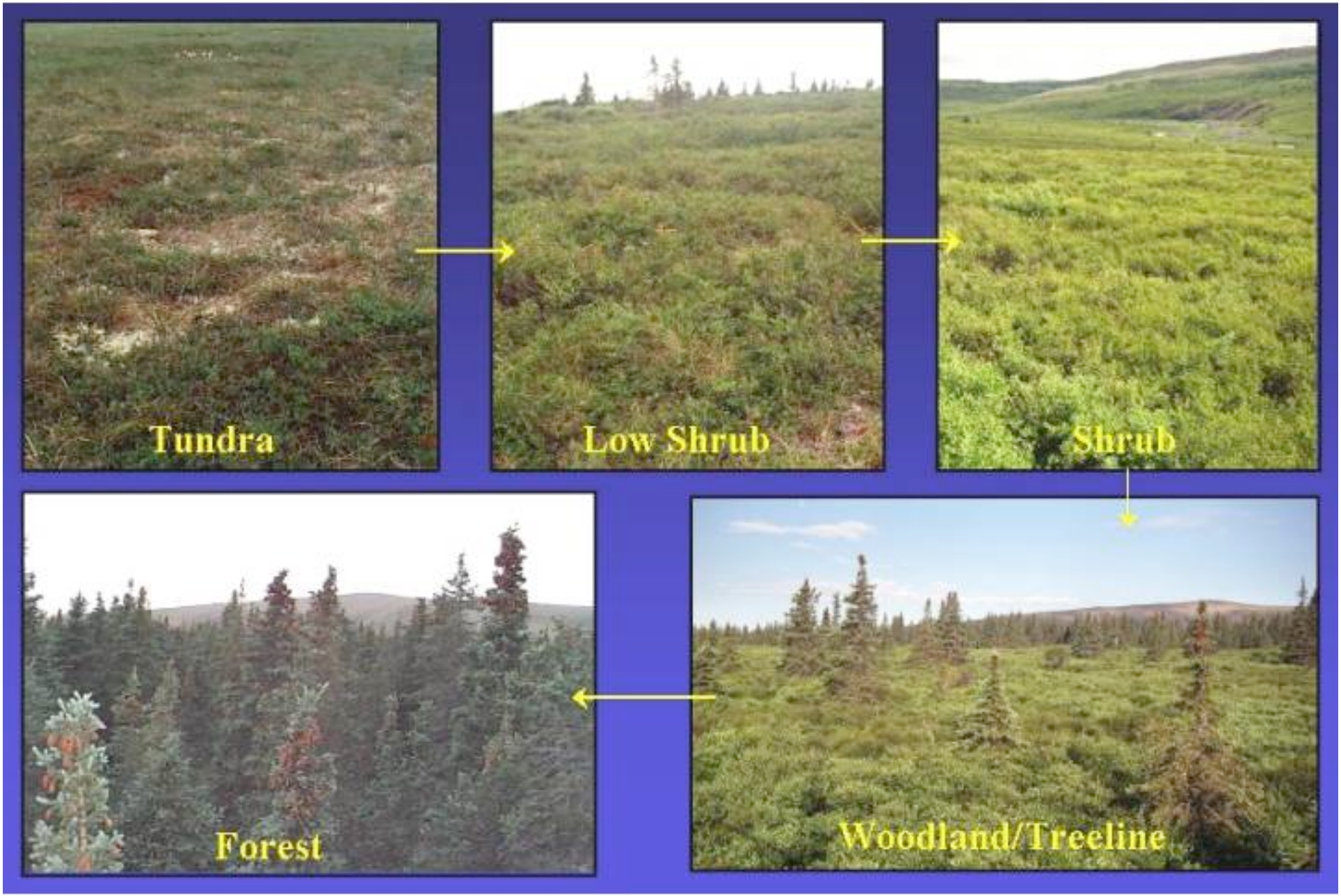
Remaining uncertainties: Land-surface transitions

- Rates and trajectories of land-surface properties
  - Why are there thresholds?
  - What will be the new assemblages?
- Consequences of land-surface change
  - Climate feedbacks
  - Impacts on animals
  - Impacts on ecosystems and society

Climate feedbacks from shrub expansion



Sturm

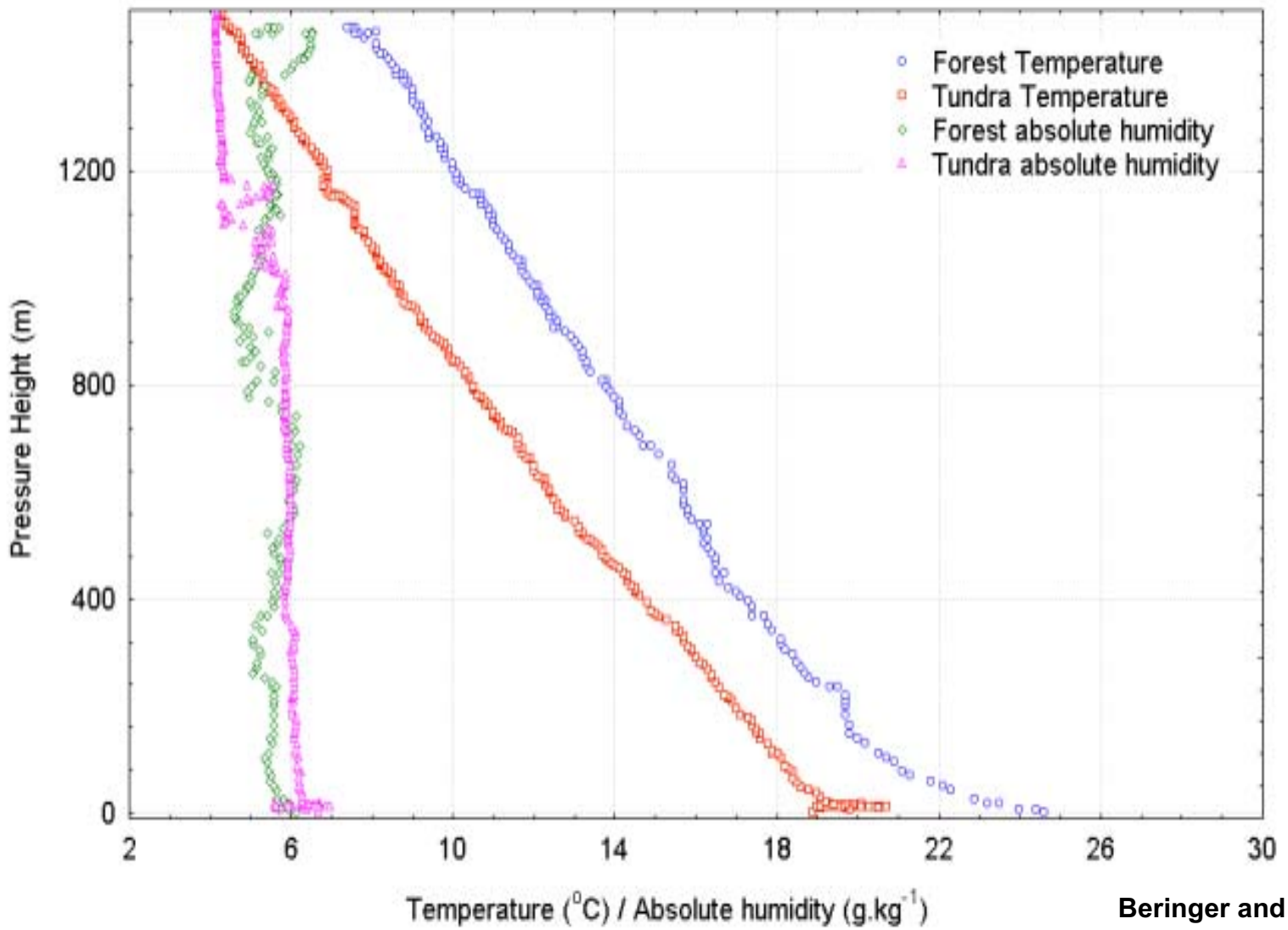


Beringer and Chapin

Comparison of Tundra and Spruce energy exchanges

Beringer and Chapin

Air over forest is warmer and more humid at any give height



Beringer and Chapin

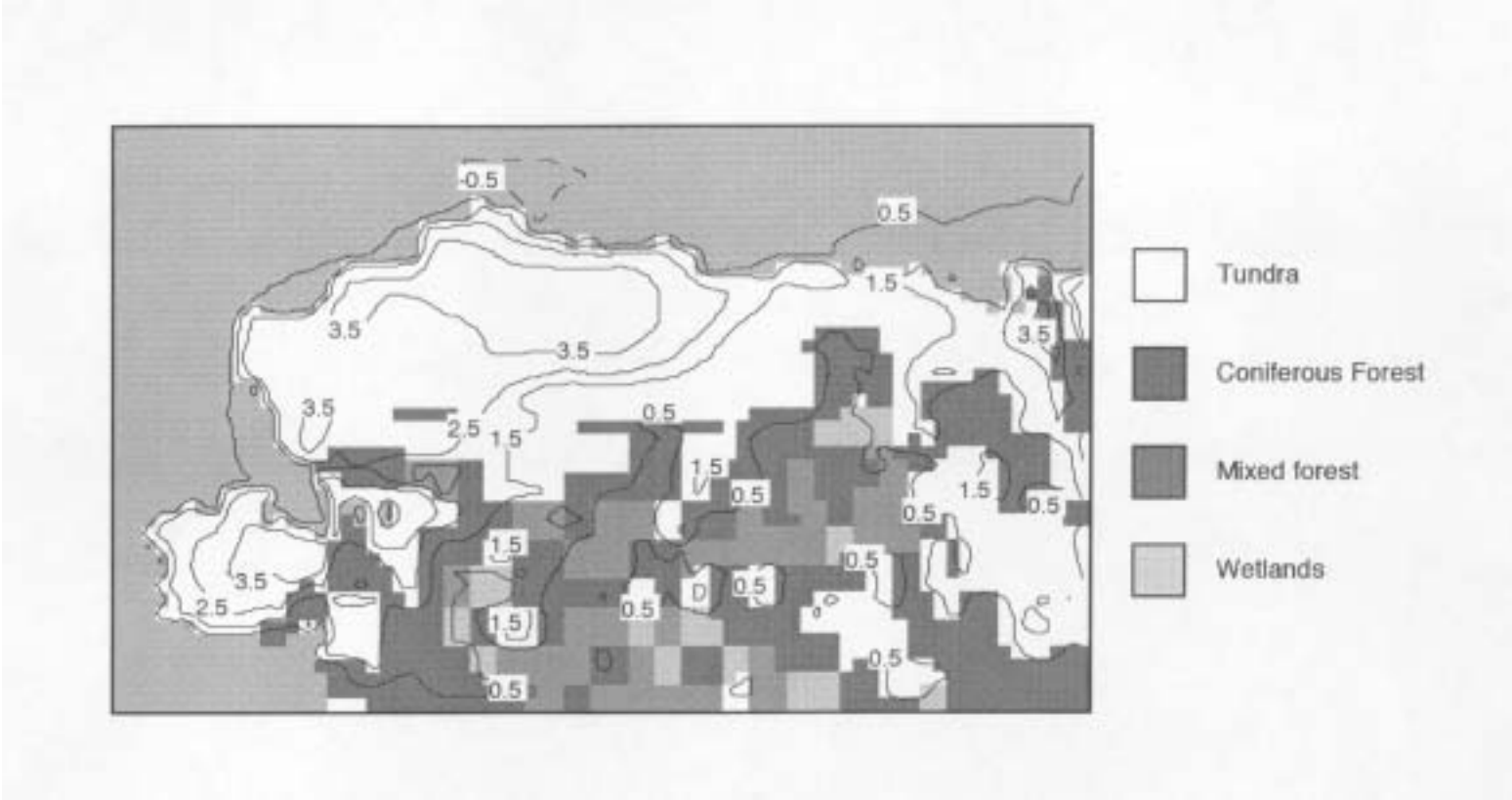
Energy budget feedbacks to regional summer climate

- **Feedbacks from vegetation change**
  - **Tussock to shrub transition: 3.9 W/m2**
  - **Tundra to forest transition: 5.0 W/m2**

- **2% change in solar constant: 4.6 W/m2**
  - **(glacial to interglacial change)**
- **Doubling atmospheric CO2: 4.4 W/m2**

Chapin and McFadden

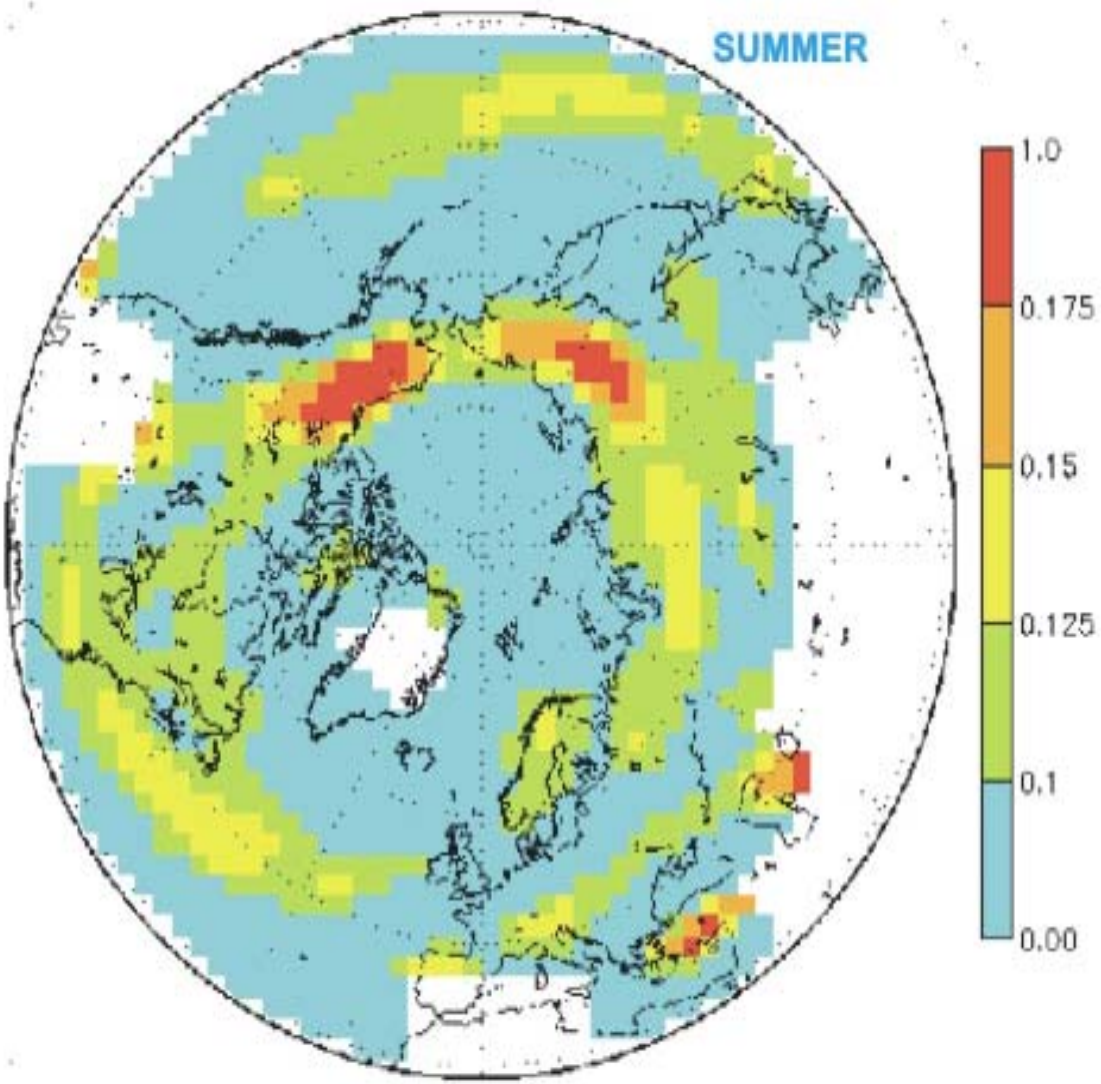
Increase in July temperature due to shrub expansion



Chapin , Lynch et al.

Synoptic analysis

Land-ocean heating contrasts determine location of Arctic Front



Topography focuses frontal activity

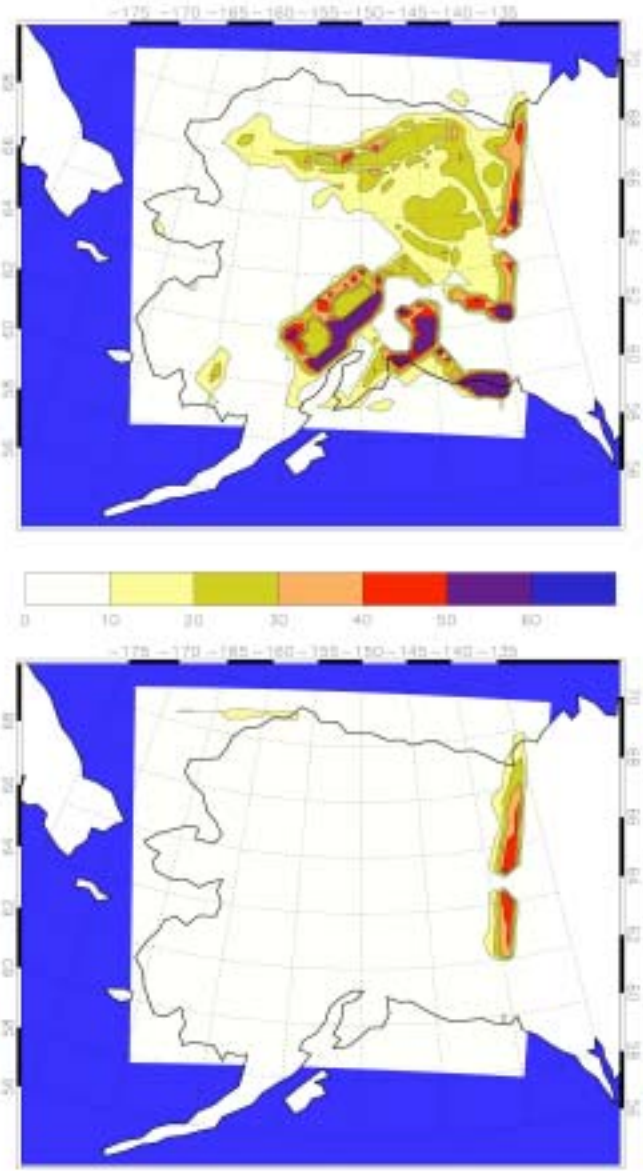
Serreze

Thermal Front Parameter Counts

Counts per Month
Summer, 1995

$$-\nabla\left|\nabla T_{850}\right| \bullet n$$

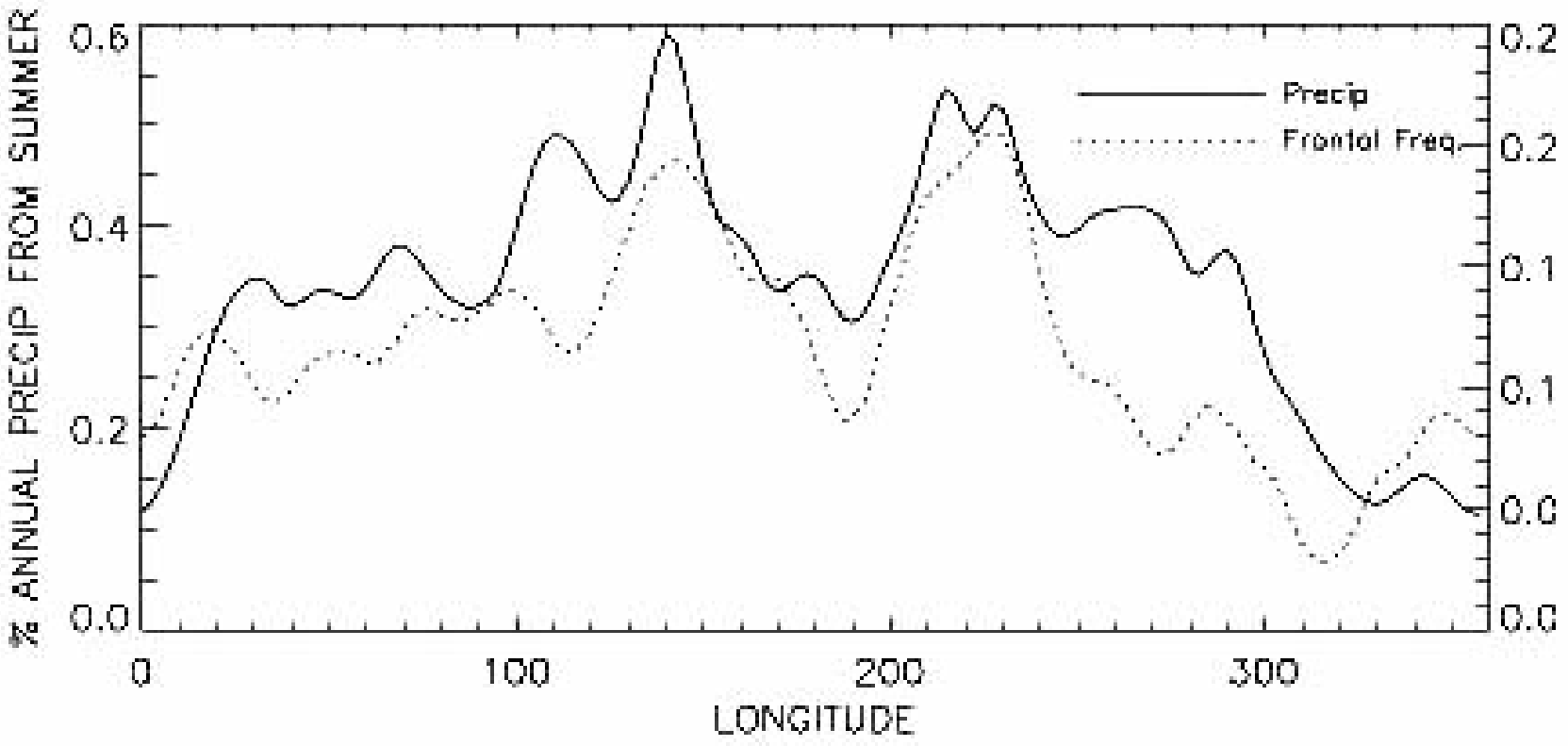
With Topography



No Topography

Lynch

Summer precipitation is greatest in areas where topography focuses frontal frequency

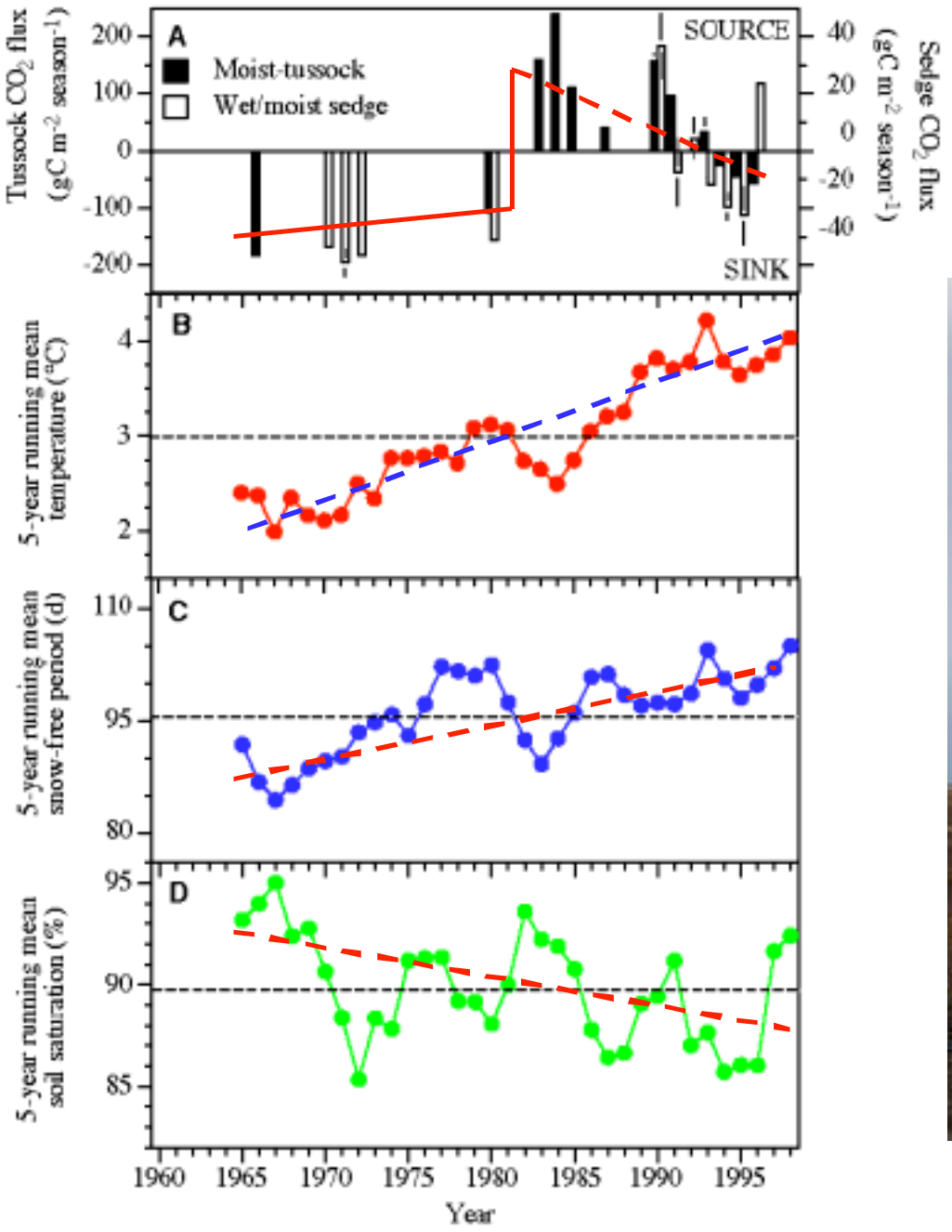


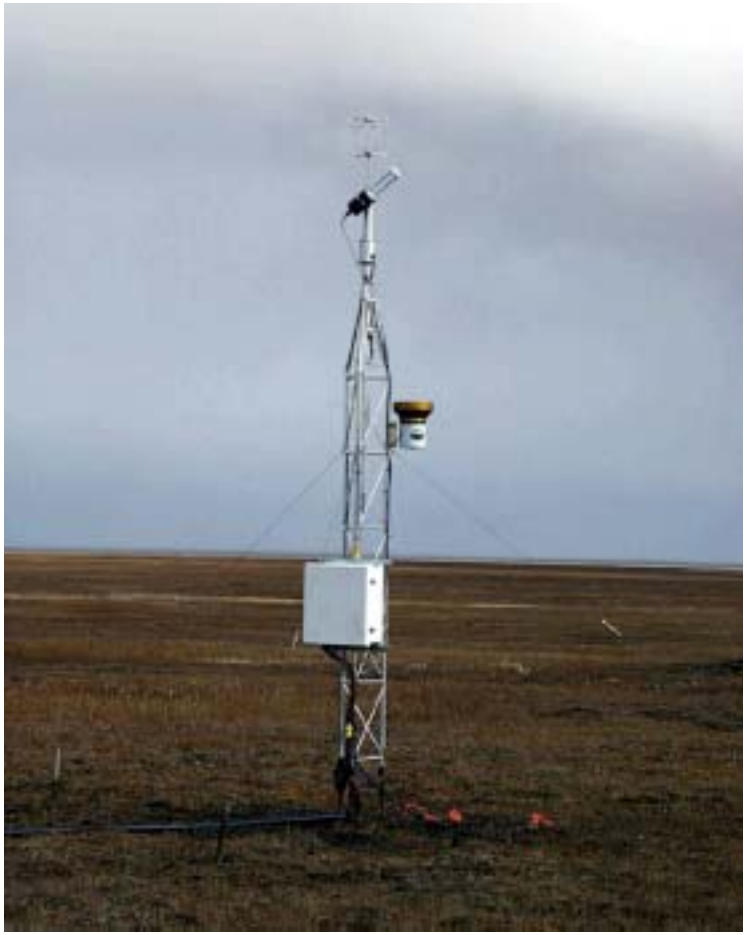
Serreze

Remaining uncertainties: Energy-budget feedbacks

- Rates and patterns of land-surface change
  - Do feedbacks alter thresholds of climate change?
  - New assemblages?
  - Altered snow-cover?
- Consequences of land-surface change
  - Climate feedbacks
  - Impacts on ecosystems and society

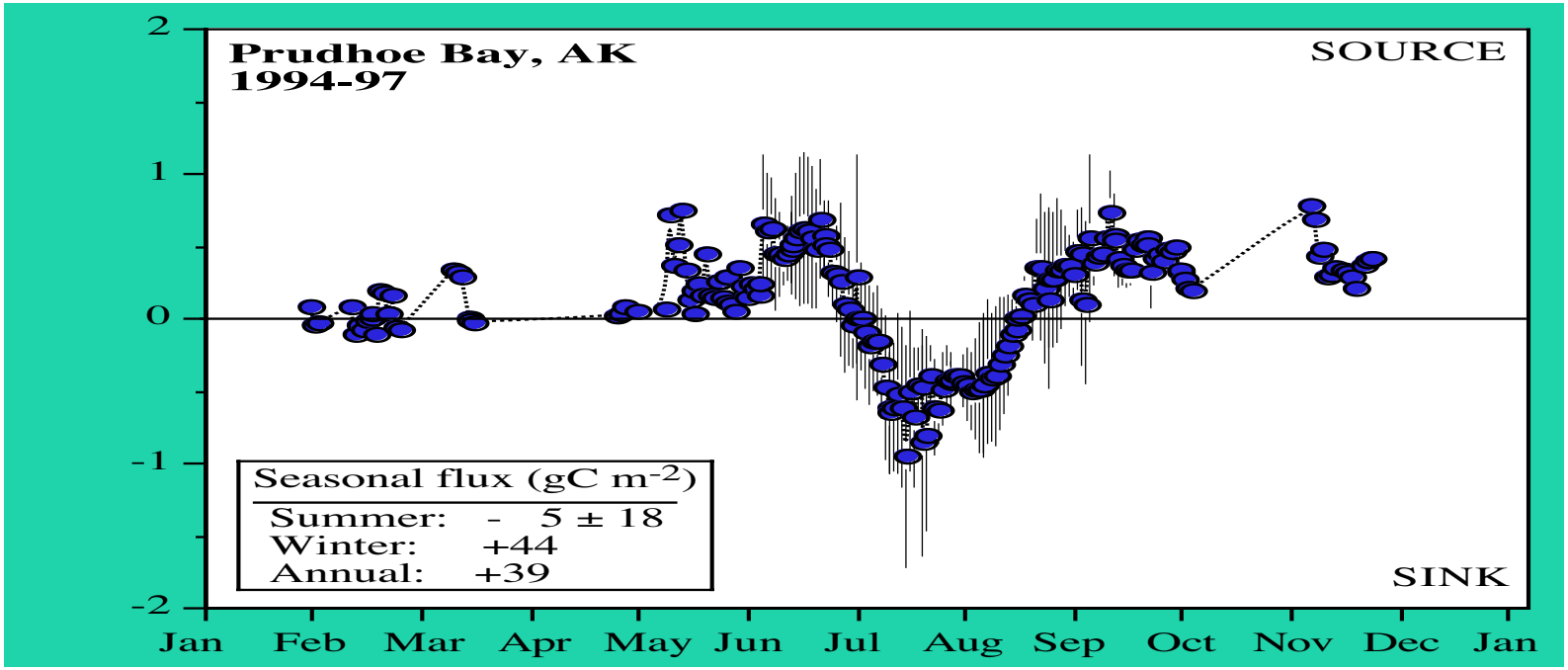
Recent Response of Net Ecosystem Carbon Flux to a Secular Change in Climate



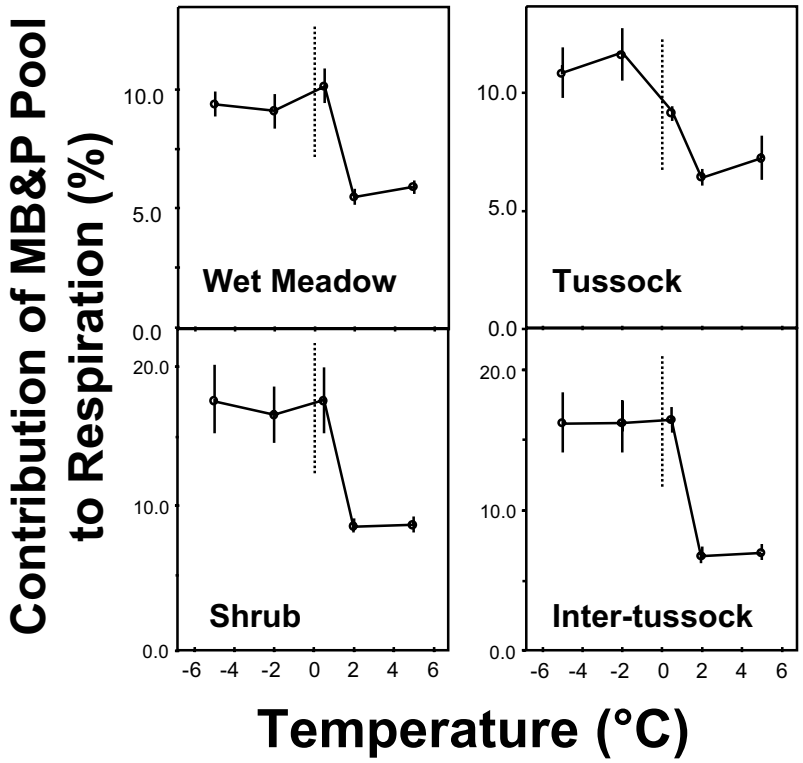


Oechel *et al.* Nature August, 2000

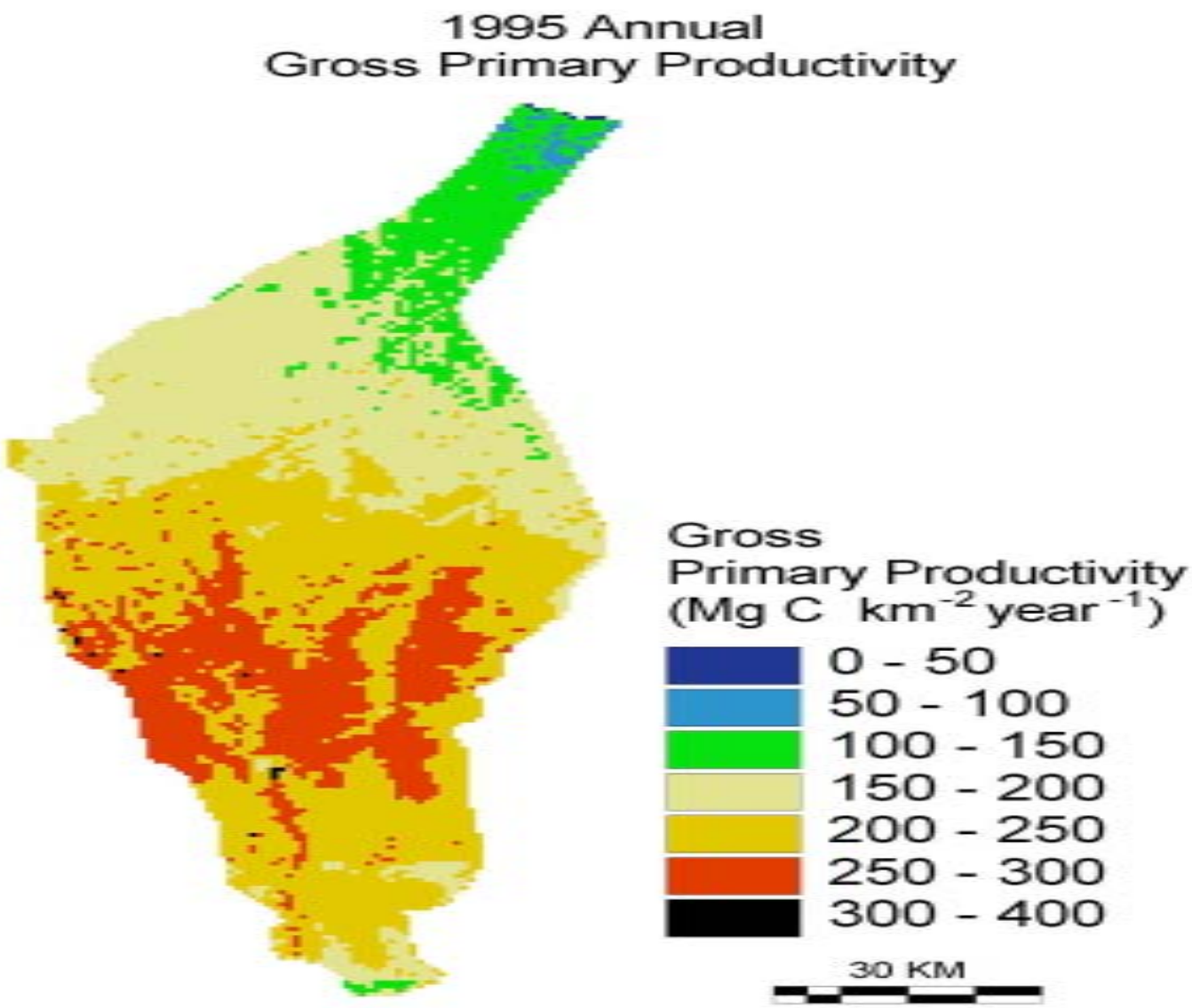
Winter CO_2 efflux: an important component of net carbon balance



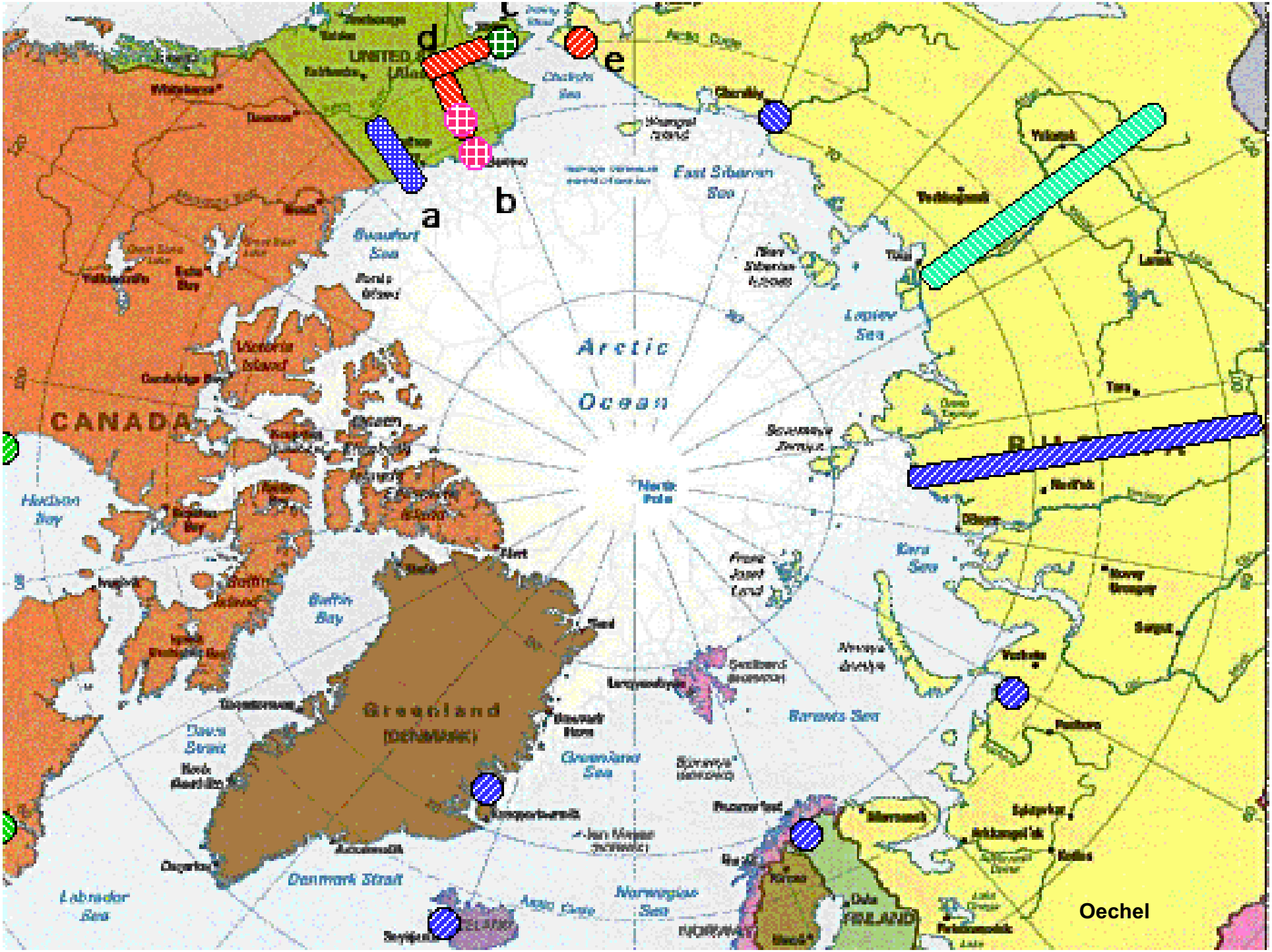
Oechel

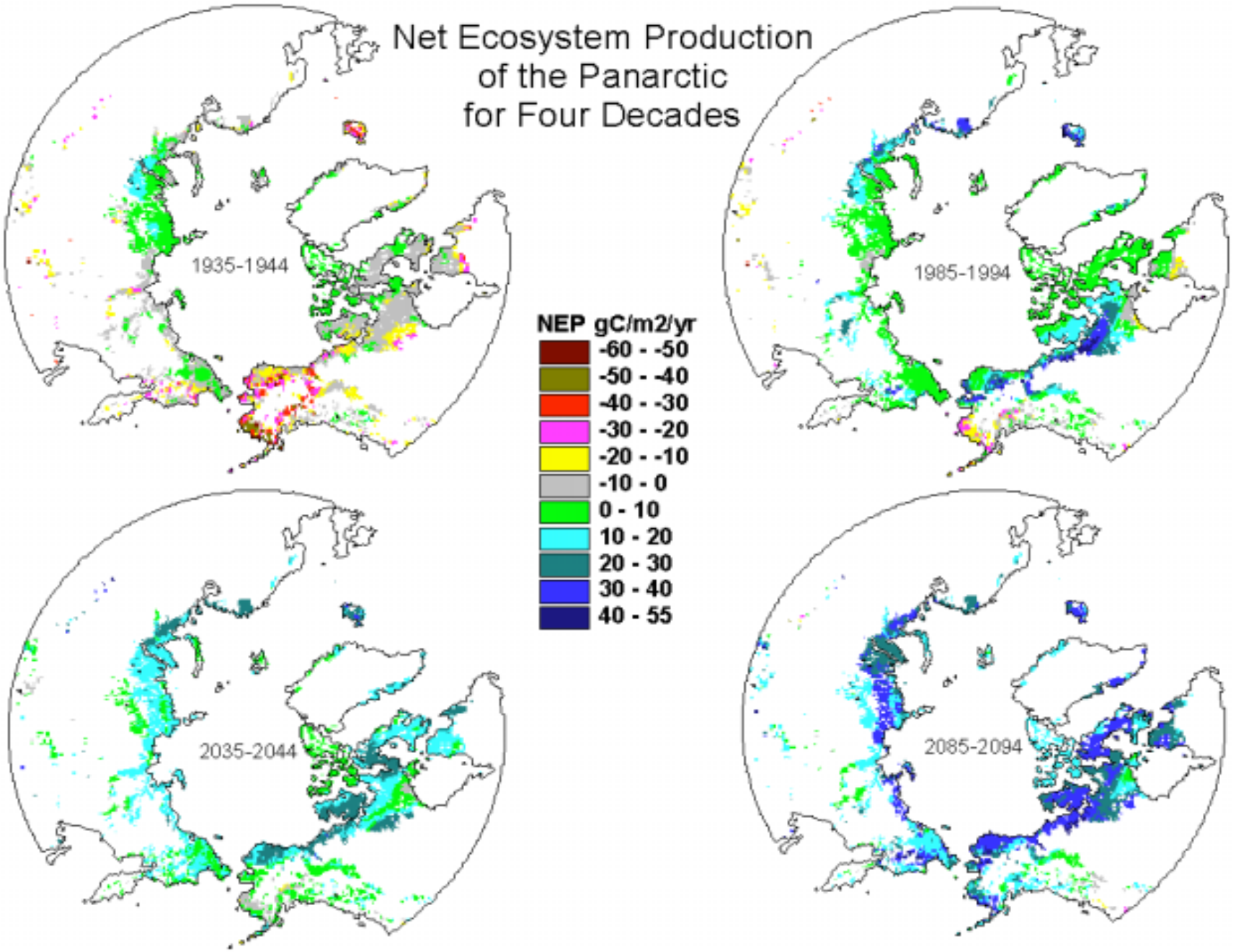

Contribution of MB&P Pool to Respiration (%)
Wet Meadow
Tussock
Shrub
Inter-tussock
10.0
5.0
0.0
20.0
10.0
0.0
-6 -4 -2 0 2 4 6
Temperature (°C)

Schimel



Williams, Rastetter and Hobbie

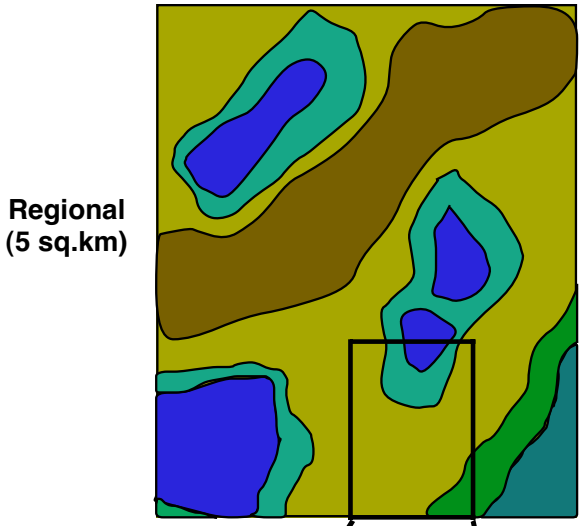

a
b
d
e
Arctic Ocean
East Siberian Sea
Laptev Sea
Kara Sea
Barents Sea
Beaufort Sea
Chukchi Sea
Greenland Sea
Norwegian Sea
Baffin Bay
Hudson Bay
Davis Strait
Denmark Strait
Labrador Sea
CANADA
Greenland (DENMARK)
FINLAND
Oechel


Net Ecosystem Production
of the Panarctic
for Four Decades
1935-1944
1985-1994
2035-2044
2085-2094
NEP gC/m2/yr
-60 - -50
-50 - -40
-40 - -30
-30 - -20
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
30 - 40
40 - 55

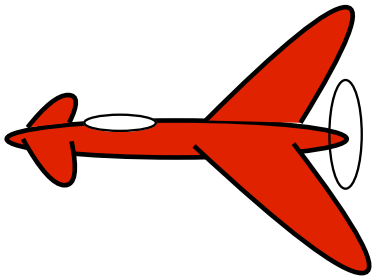
McGuire

Remaining uncertainties: Trace-gas feedbacks

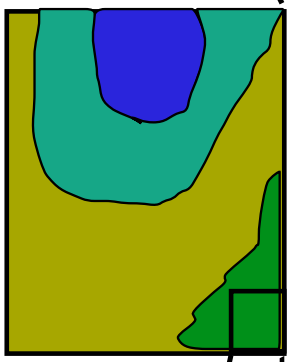
- Rates and patterns of land-surface changes
  - Thresholds, time lags and feedbacks?
  - Marine fluxes?
  - Paleoreconstruction of fluxes?
  - Policy implications: carbon credits?
- Hydrologic sensitivities
  - Thresholds?
  - Incorporation of landscape controls at pan-arctic scales



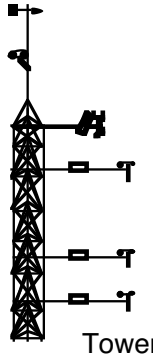
Regional
(5 sq.km)



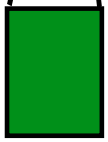
Aircraft-based
eddy covariance



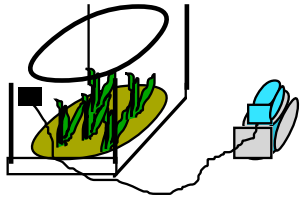
Landscape
(2-3 ha.)



Tower-based
eddy covariance

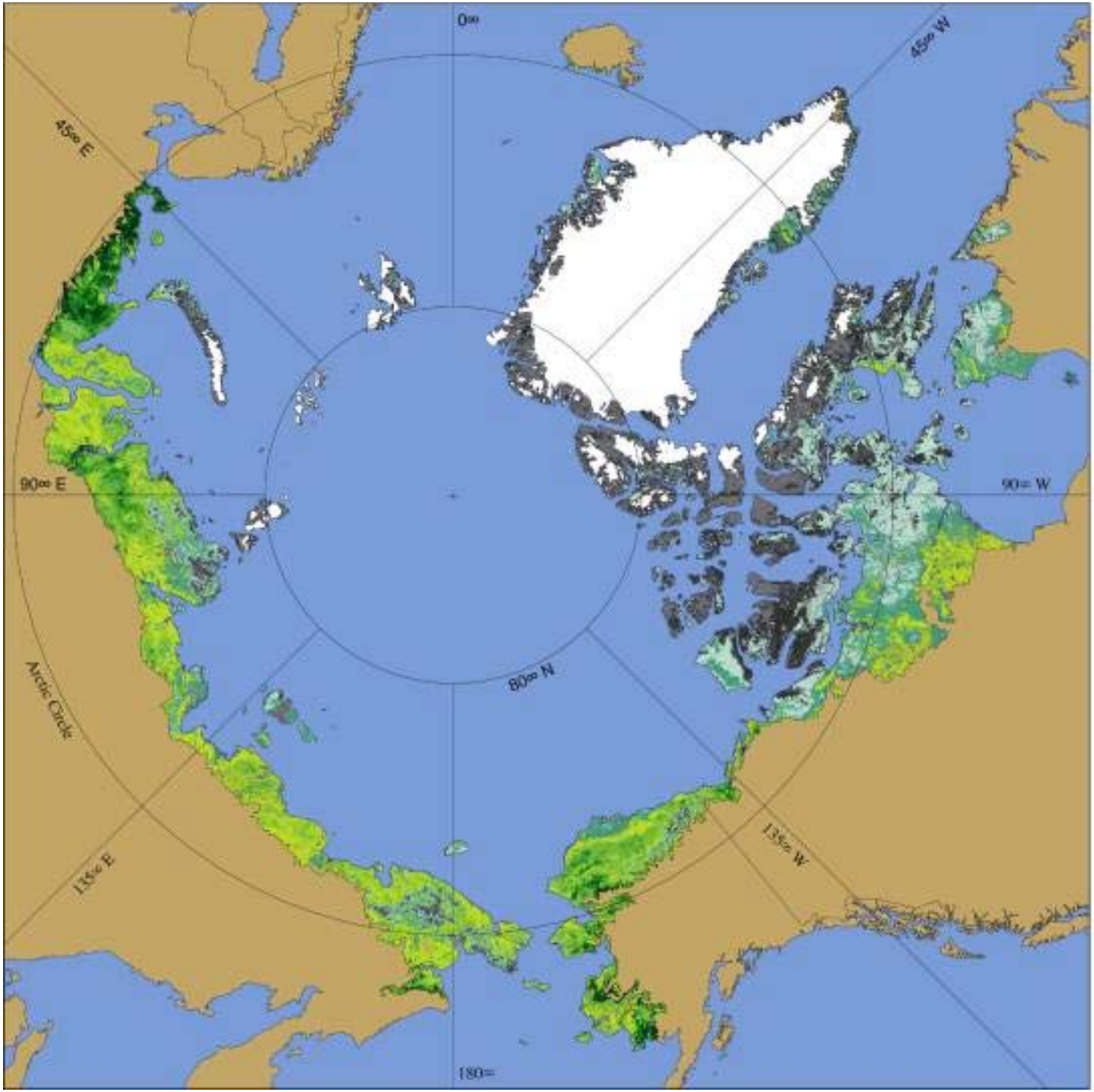


Patch
(0.5 sq. m)



Chamber

Oechel



Phytomass Density

<= 50

<= 100

<= 250

<= 500

<= 1000

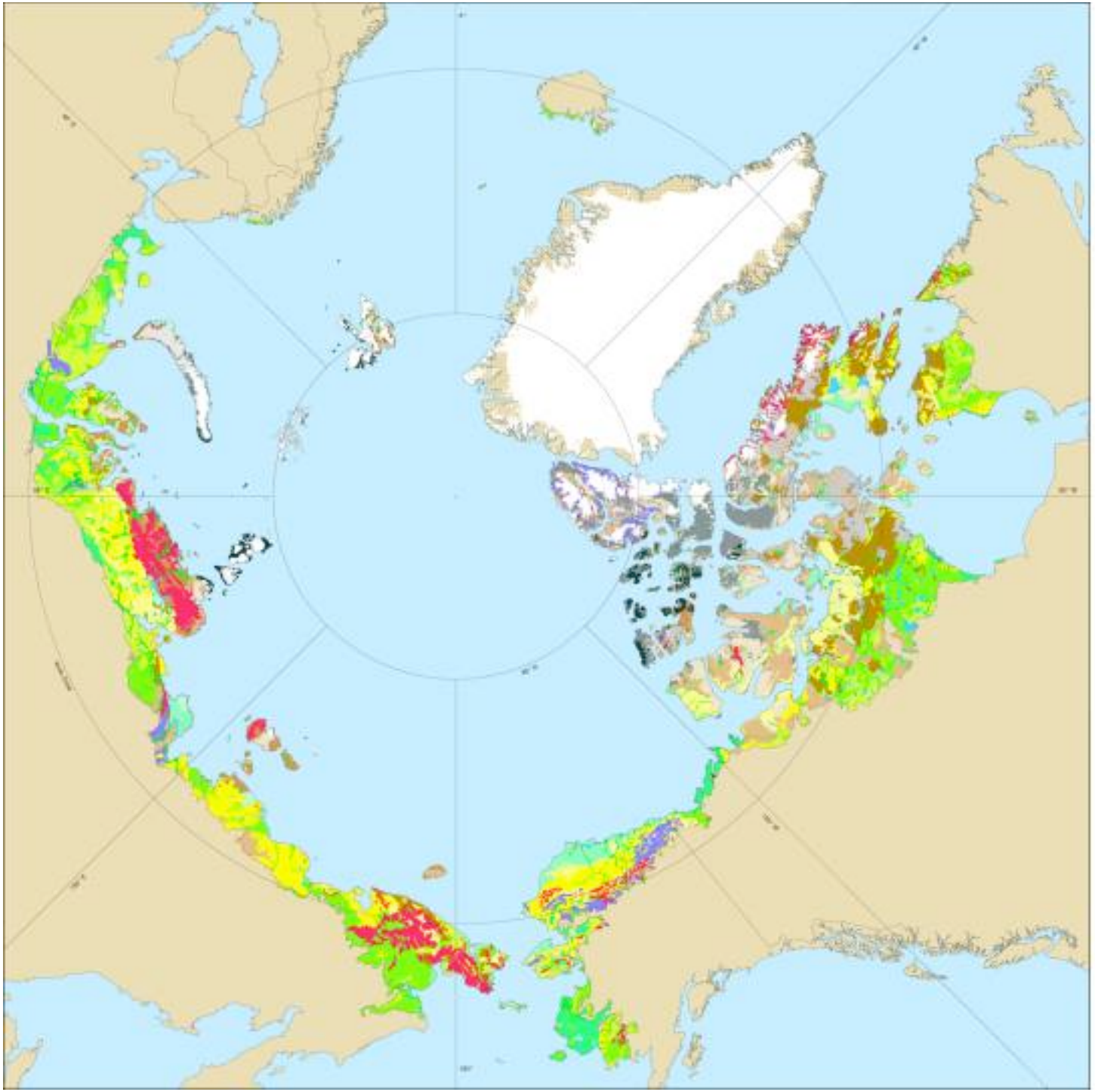
<= 1500

<= 2000

> 2000

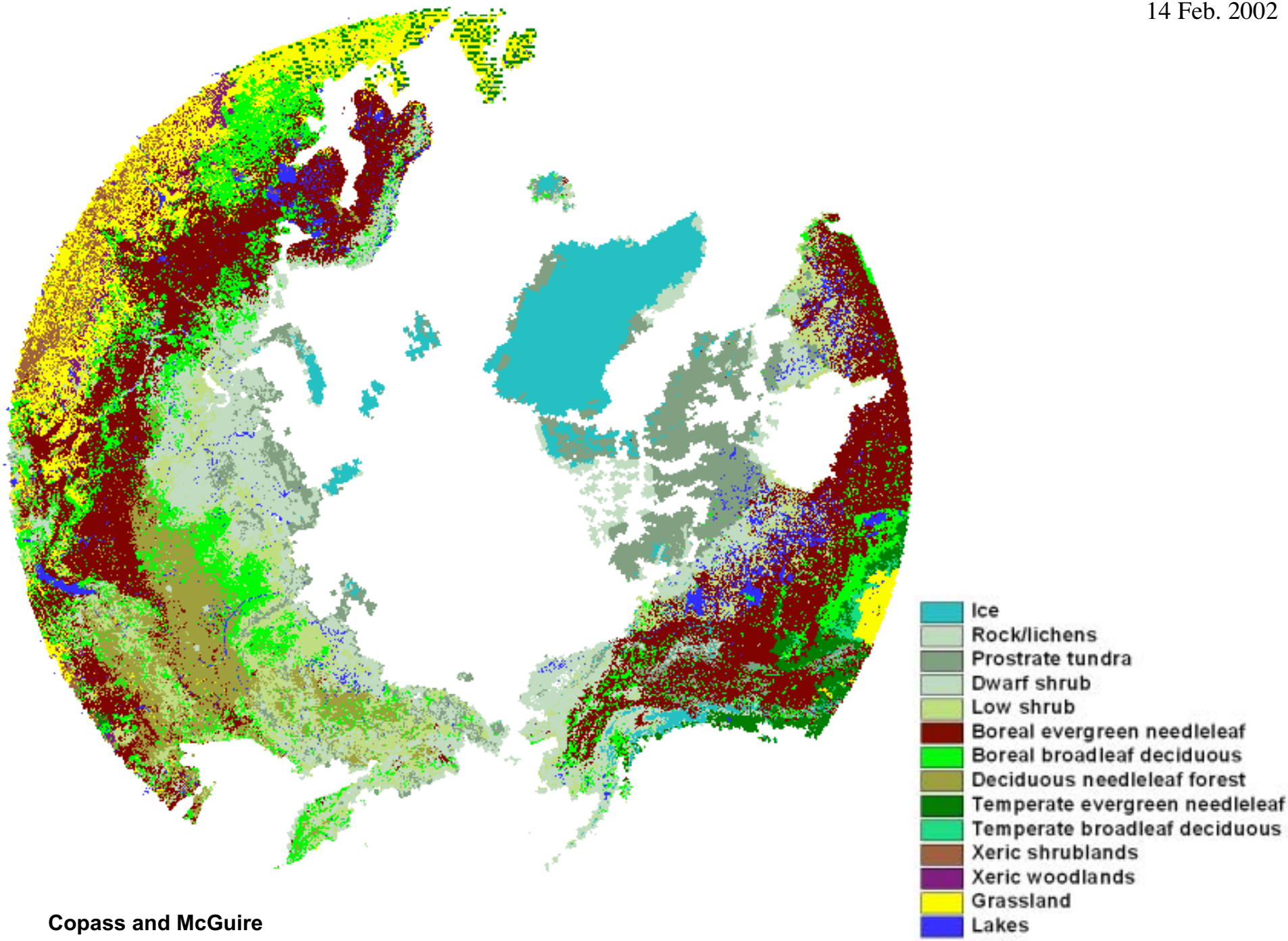
Walker

Circumpolar Vegetation: 1st Draft



S. Walker

14 Feb. 2002



Copass and McGuire

Changing way of doing science

- Increasingly interdisciplinary, for example
  - Snow physics and vegetation
  - Ecosystem flux and climate modeling
- Integration across scales
  - Plot-level process studies linked to pan-arctic synthesis through modeling
  - Increasing interactions with paleoecology

Changing way of doing science (contd)

- **Increased emphasis on data archival**
  - **100% inventory of LAII data sets**
    - **Searchable on line**
  - **>60% of LAII data sets are archived**
  - **LAII data sets constitute 65% of ARCSS data sets archived at JOSS**
  - **Data archival used as mechanism to promote synthesis and outreach (Ivotuk CD prepared by JOSS)**

Changing way of doing science (contd)

- **Synthesis integrated into all research stages**
  - **Guides research design**
  - **Integrates across projects and programs**
  - **Pulls things together at end**

Changing way of doing science (contd)

- Outreach is integrated into science
  - Involvement of local high school students in research
  - Involving teachers in research (TEA)
  - School visits
  - Real time climate data available to communities
  - Video of science process for public TV and schools

Involvement of local residents in LAII research

School visits

Remaining challenges in the scientific process

- Effective integration across ARCSS programs to address the Arctic as an integrated system that interacts with the rest of the globe
- Cross-program synthesis
- Involvement of residents in designing and conducting science
  - Time to go beyond outreach

LAII research directions
Long-term strategy

- **REGIONAL BIOCOMPLEXITY**
- **CHAMP**
- **SEARCH**
- **OTHER INITIATIVES**

REGIONAL BIOCOMPLEXITY

- Complexities associated with the biotic skin of the arctic regional system
- Pan-arctic variability and sensitivity
- Vulnerability to change
- Interaction of humans with other components of the arctic and global systems
- Challenges (scaling, heterogeneity, feedbacks and response to change)

Interfaces with CHAMP

- Biotic regulation of freshwater inputs to oceans
- Impacts of hydrologic change on the biosphere and society
  - Trace-gas fluxes and feedbacks to regional and global climate
  - Changes in animal populations and subsistence
- Landscape evolution

Interfaces with SEARCH

- Process-based understanding of vulnerability and sustainability
- Development of biotic metrics of significant change in surface processes
- Role of biotic feedbacks in future system change

Relationship to existing programs

- PARCS
- HARC
- LAII
- OAII