Greening of the Arctic: A transect to monitor terrestrial change across the full Arctic bioclimate gradient

Skip Walker, Institute of Arctic Biology

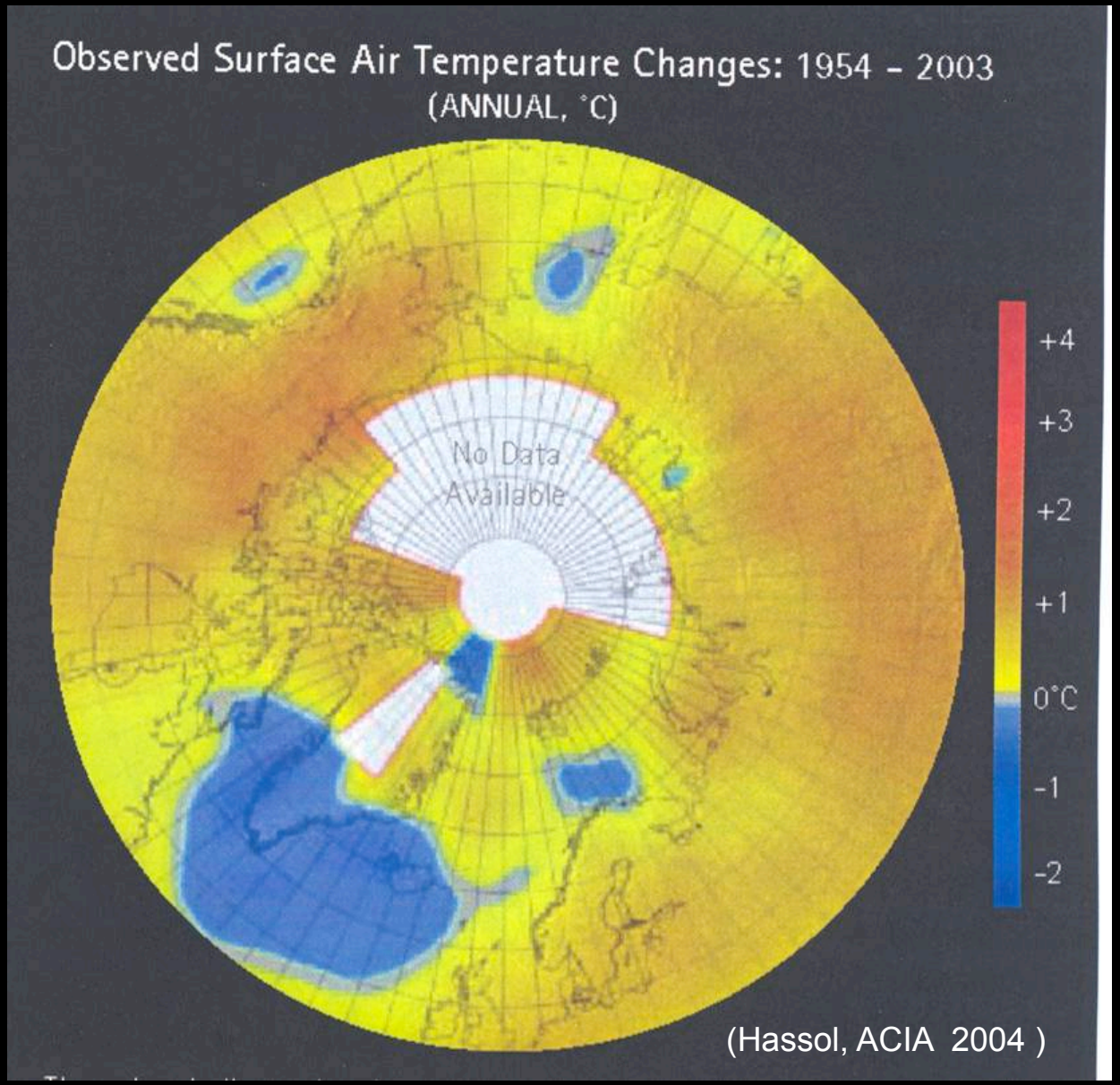
IPY Workshop, Geophysical Institute, 29 November 2004

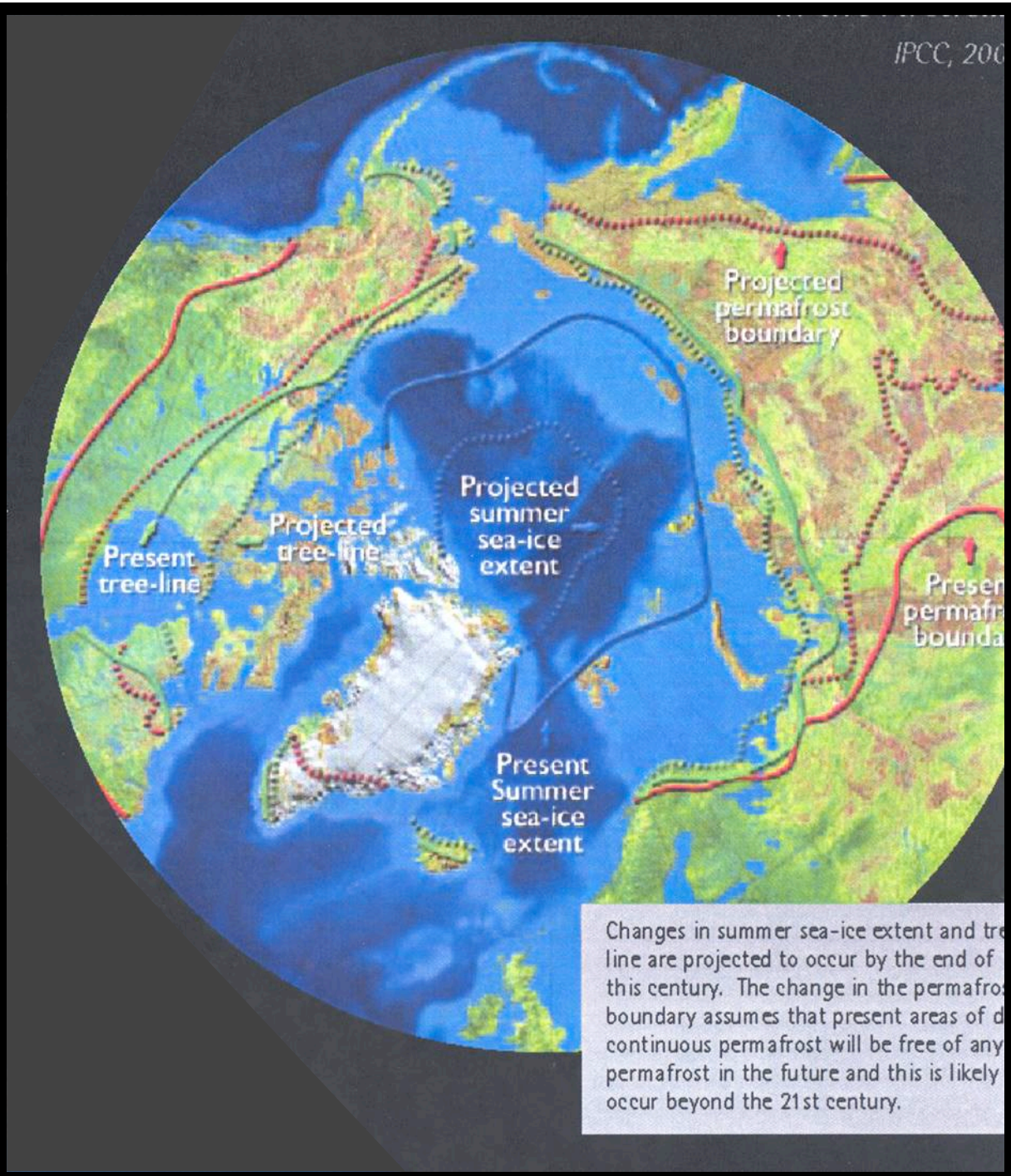
Two themes of IPY

- Document present environmental status of the polar regions.
- Quantify and understand past and present natural environmental and social change in the polar regions, and improve projections of future change.

Study of the effects of climate

One of the key goals of IPY will be to document the rapid and dramatic changes to terrestrial systems that are expected to occur across the circumpolar Arctic as a result of climate change.



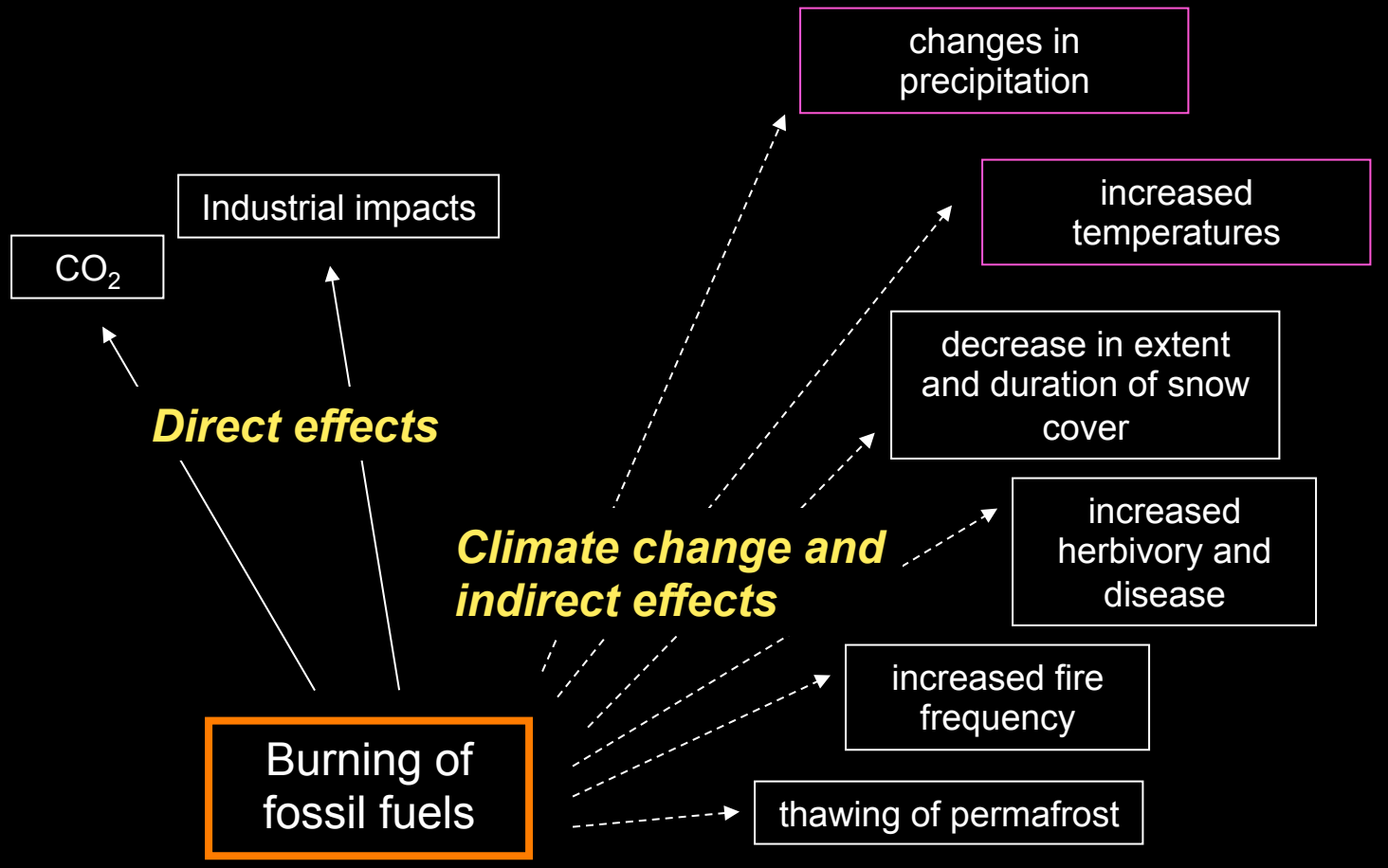


Changes expected by the end of the century

- Poleward movement of
  - permafrost boundary
  - treeline
  - sea ice extent
- General Arctic-wide increase in biomass

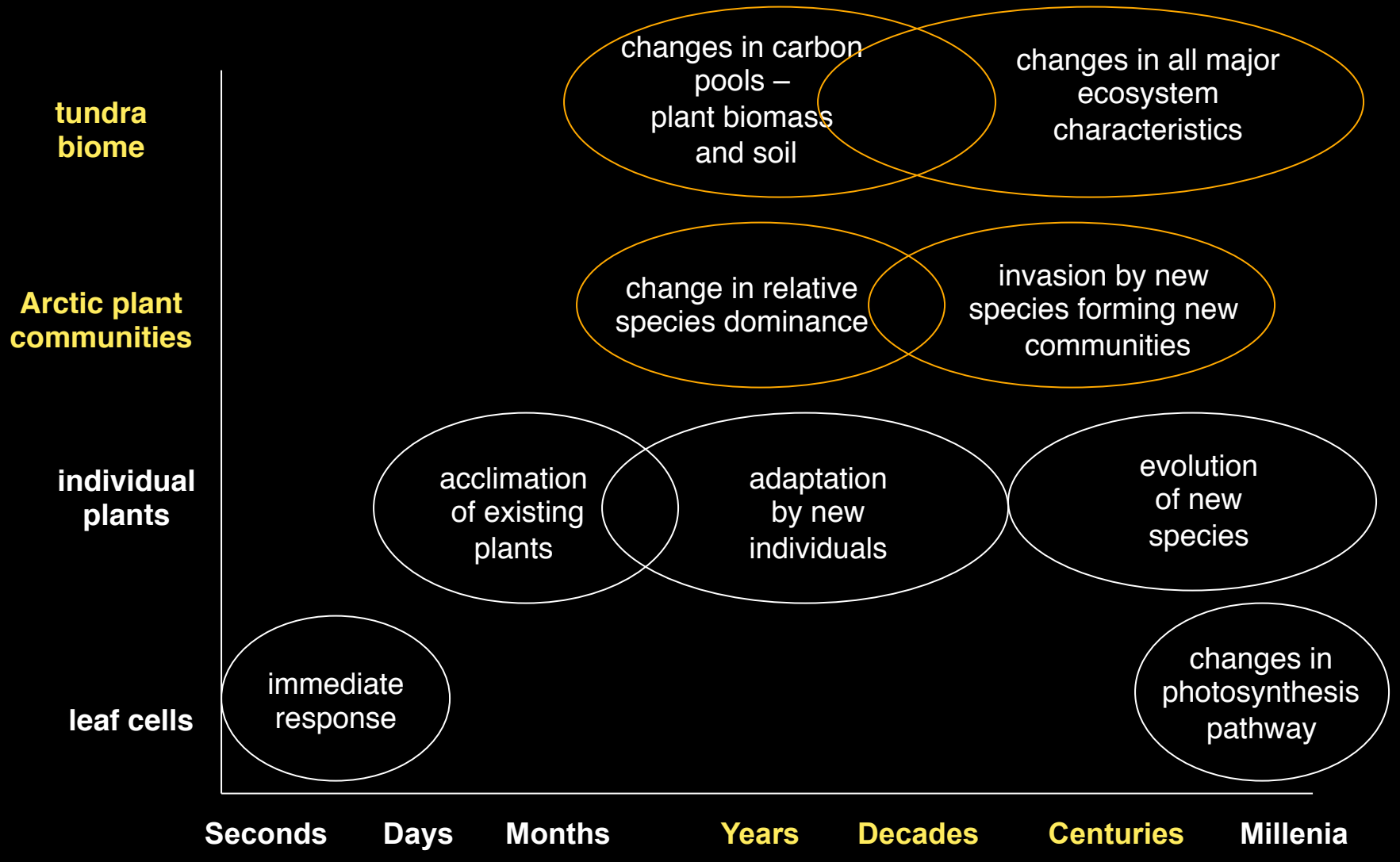
(Hassol, ACIA 2004)

Numerous causes of change to terrestrial Arctic vegetation



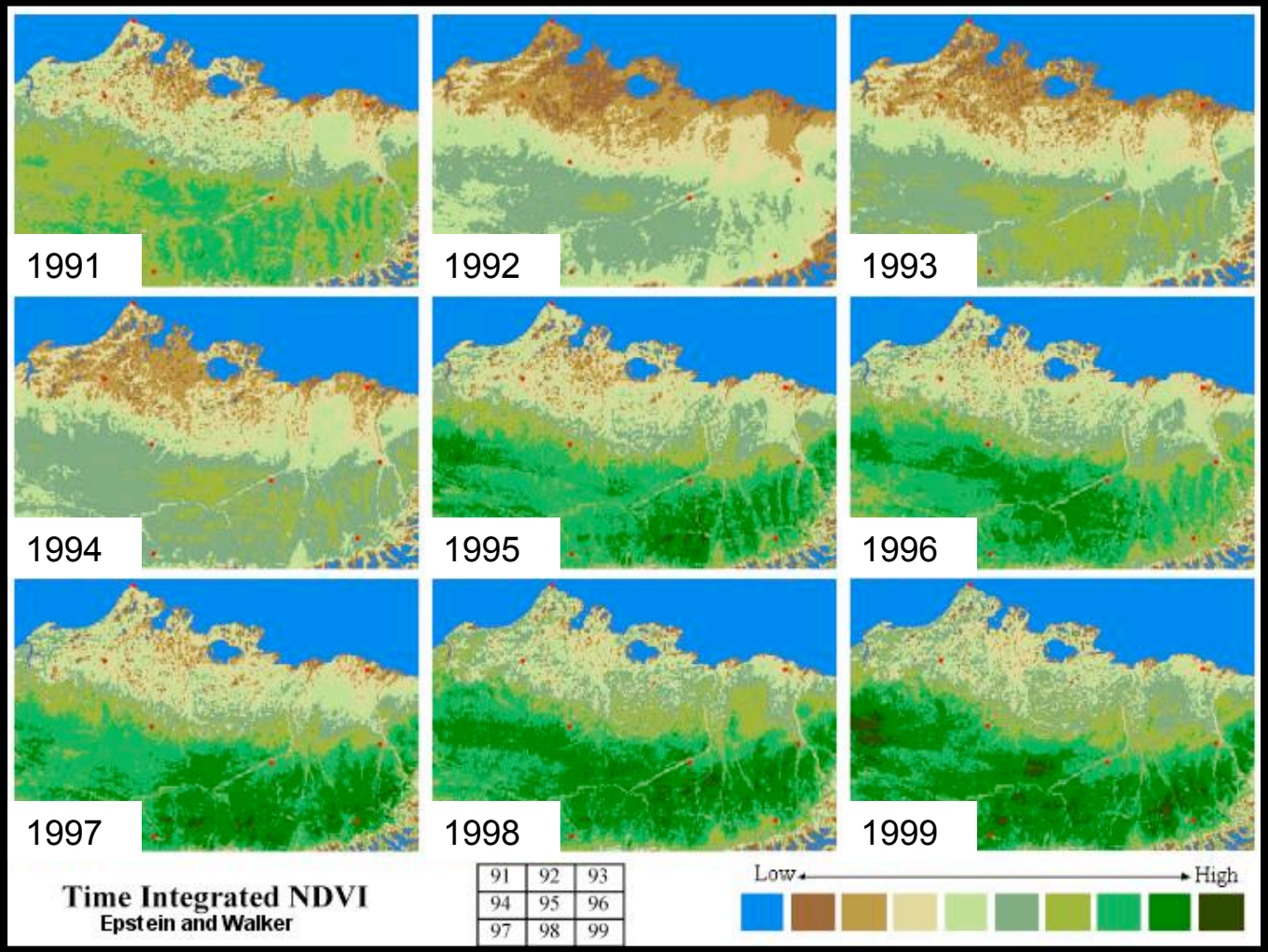
Graphic: M.K. Raynolds

Different spatial and time scales of responses of plants to increased CO_2 and global warming



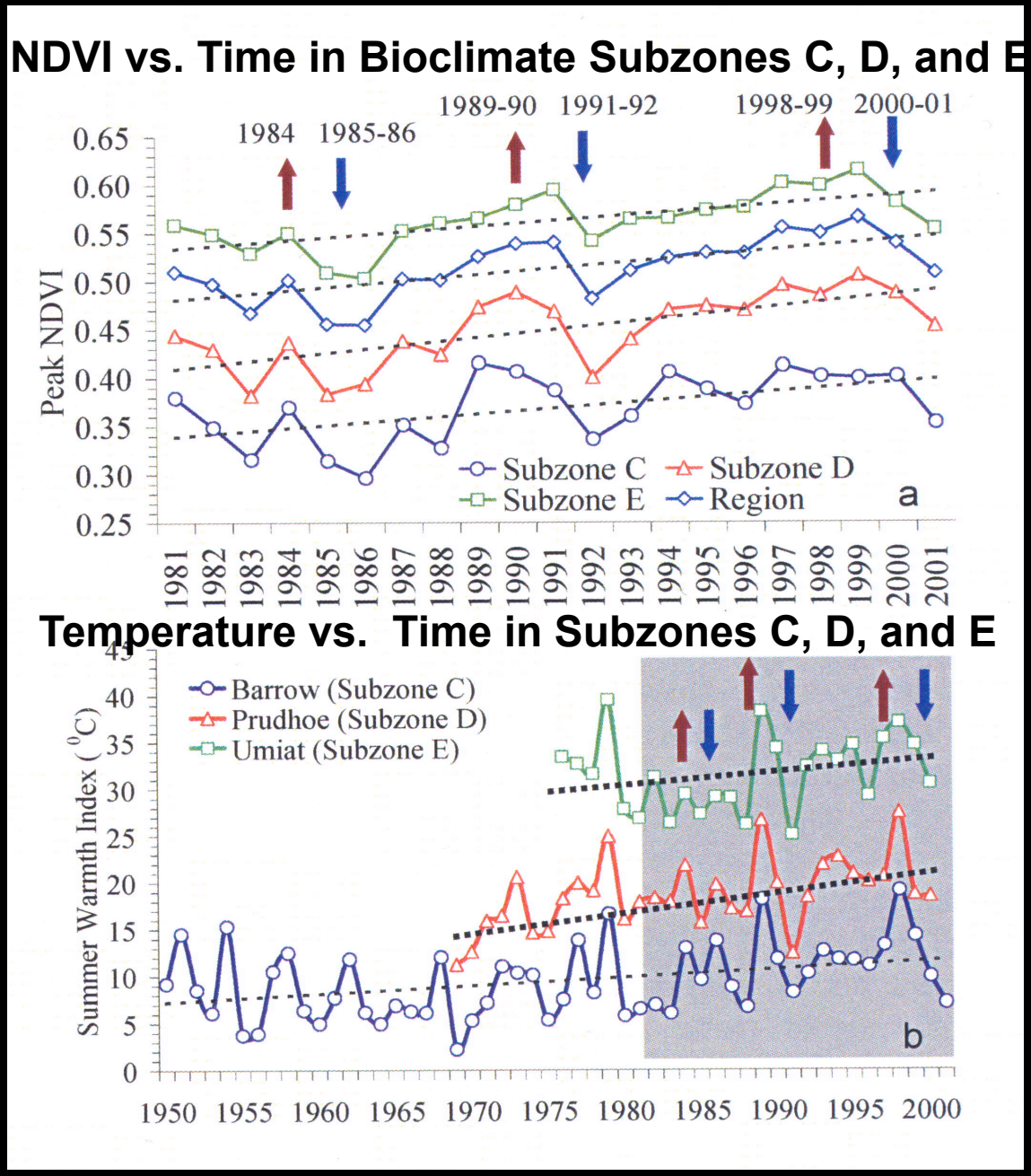
Graphic: M.K. Raynolds

Trend of increased NDVI in northern Alaska 1981-1999



NDVI (normalized difference vegetation index) compares absorption in the spectrum where chlorophyll absorbs most (red, 0.5-0.68 μm) to the portion where it absorbs least (near-infrared, 0.725-1.1 μm).

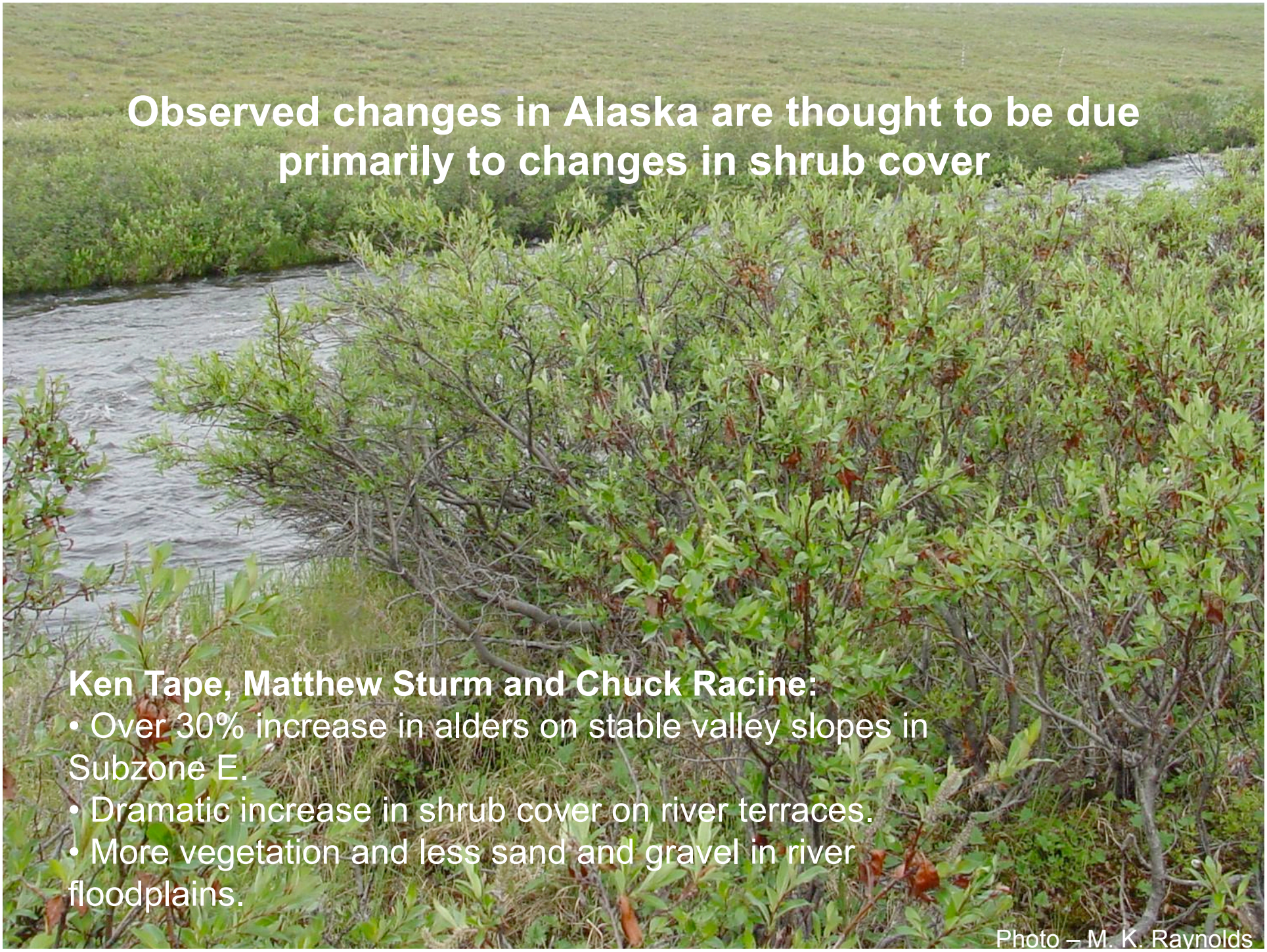
Images of the North Slope of Alaska show changes in summer NDVI between 1991-1999. (Jia et al. 2003)



Jia et al. 2003 *Geophysical Research Letters.* 30: 2067.

Time series of peak NDVI for northern Alaska (1981-2001)

- 17 ± 6% increase in NDVI from 1981-2001.
- Corresponds to about an 170 g m^{-2} average increase in biomass.
- Changes in NDVI follow yearly changes in temperature and long term increase.
- Currently unknown if similar changes have occurred across the entire Arctic bioclimate gradient.



Observed changes in Alaska are thought to be due primarily to changes in shrub cover

Ken Tape, Matthew Sturm and Chuck Racine:

- Over 30% increase in alders on stable valley slopes in Subzone E.
- Dramatic increase in shrub cover on river terraces.
- More vegetation and less sand and gravel in river floodplains.

Photo – M. K. Raynolds

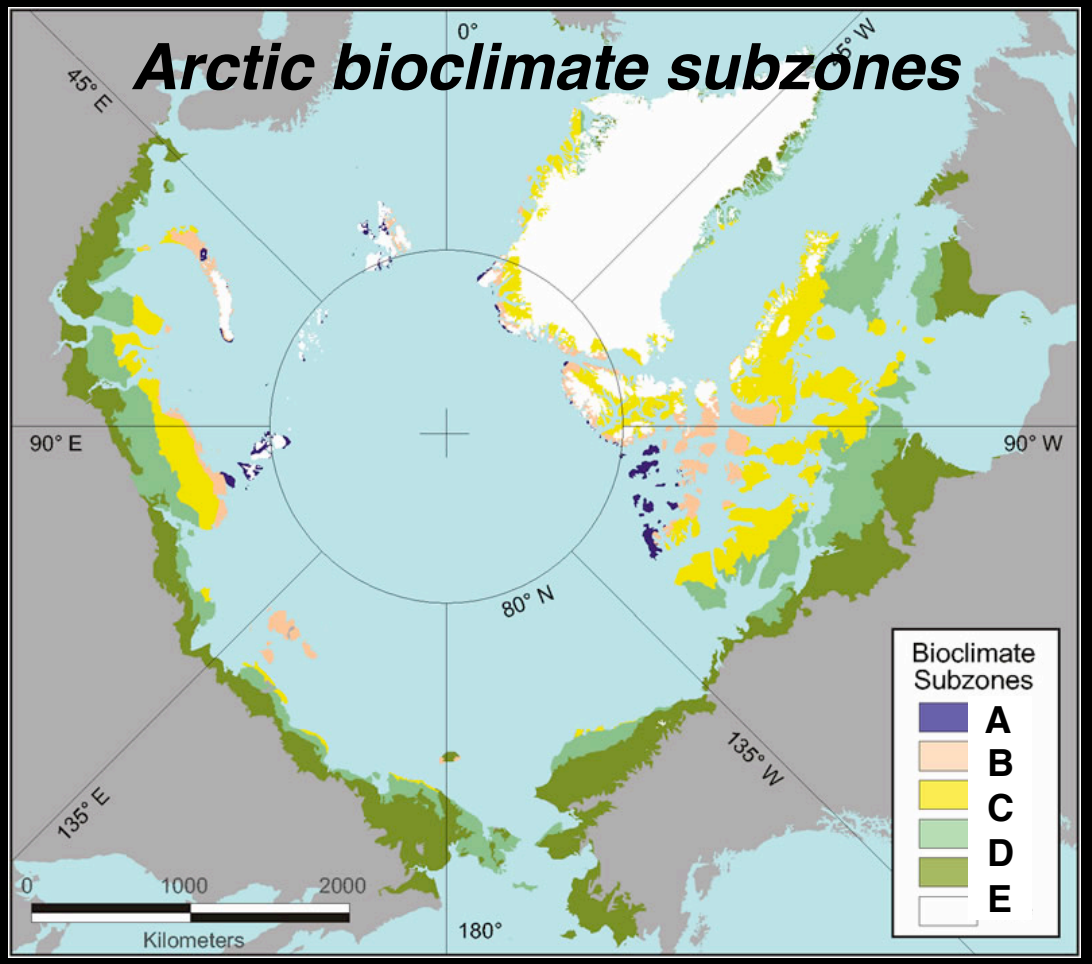
Two large gaps in detecting change to Arctic vegetation

1. There are no long-term biomass data or plant community data that support the changes detected from space. (Most evidence to date is from experimental studies, remote-sensing studies, or modeling studies.)
2. There is very little data from the High Arctic, particularly Subzone A.

Photo – M. K. Raynolds

Nearly all the monitoring of change in Arctic terrestrial systems are in the Low Arctic

Sub-zone	Mean July temp (˚C)	Dominant plant growth forms
A	2-3	Cushion forbs, mosses, lichens
B	3-5	Prostrate dwarf shrubs
C	5-7	Hemi-prostrate dwarf shrub, sedges
D	7-9	Erect dwarf shrubs, sedges mosses
E	9-12	Low shrubs, tussock sedges, mosses



From the *Circumpolar Arctic Vegetation Map*, 2003.

The Low Arctic is distinctly different than the High Arctic

- Tussock tundra and shrub tundra.
- Peaty soils.
- Occupies about 66% of the non-glacier Arctic.

Kuparuk River, Alaska. Photo; D.A. Walker

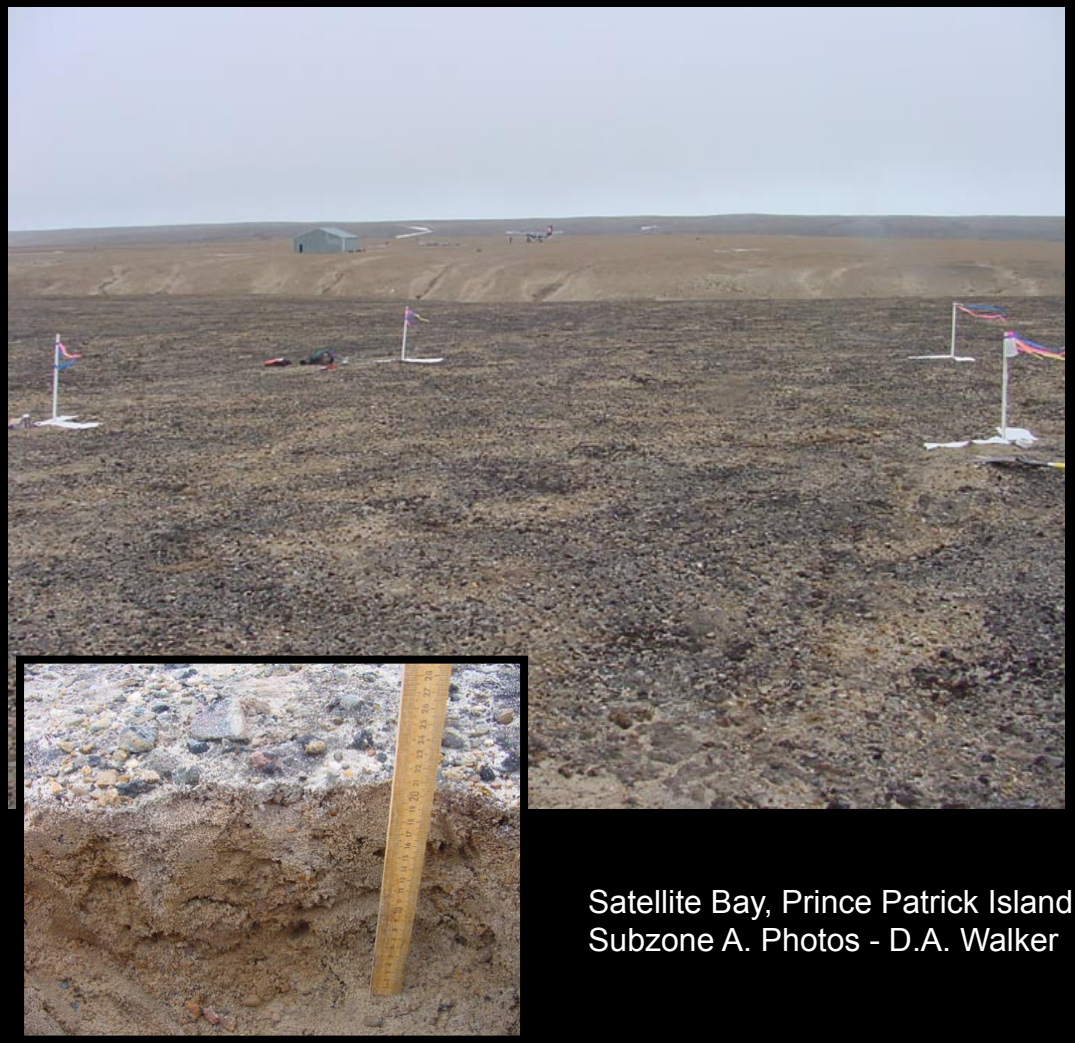
Large changes can also be expected in the High Arctic

- Some of the largest percentage increases in biomass could occur in the coldest parts of the Arctic.
- There may be strong linkages between changes in terrestrial greening and the amount of sea-ice cover.

Bundy Fiord, Axel Heiberg Island.
Photo D.A. Walker

Especially little data from Subzone A

- Coldest subzone.
- Unique extreme environment.
- Very sparse vegetation.
- Total vascular flora of 60 species.
- No woody plants or sedges.
- 2% of the Arctic.
- Could be displaced or eliminated if warmed by 2˚ C

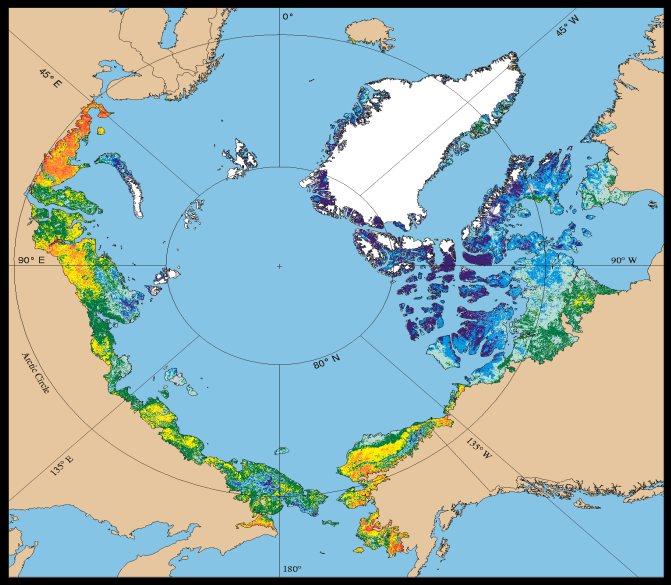


Satellite Bay, Prince Patrick Island, Subzone A. Photos - D.A. Walker

Main research question address:

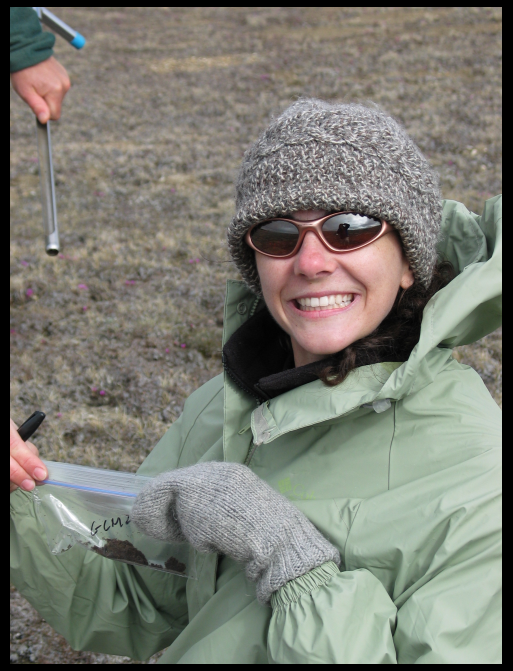
- Temporal patterns of NDVI in relationship to time series of ground surface temperatures, sea-ice patterns, and Arctic Oscillation.
- Spatial NDVI patterns in relationship to average summer climate and regional geobotanical attributes.
- Long-term trends in aboveground biomass, species composition and other key ecosystem properties.

Components of an IPY project to monitor trends in Arctic greening



- NDVI patterns

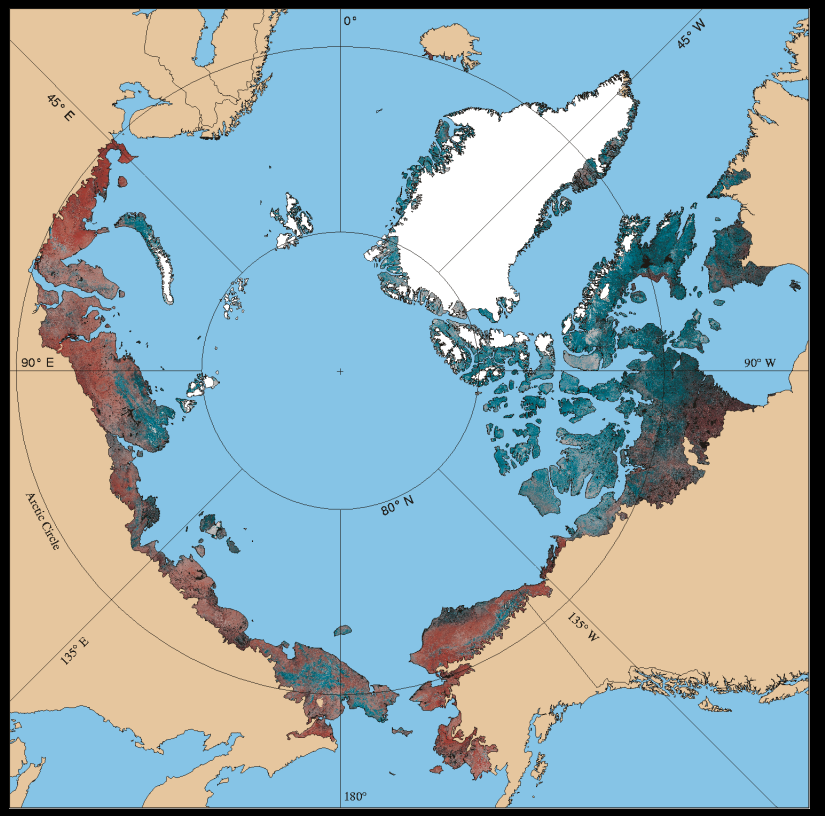
- Arctic ecosystem transect



- Education

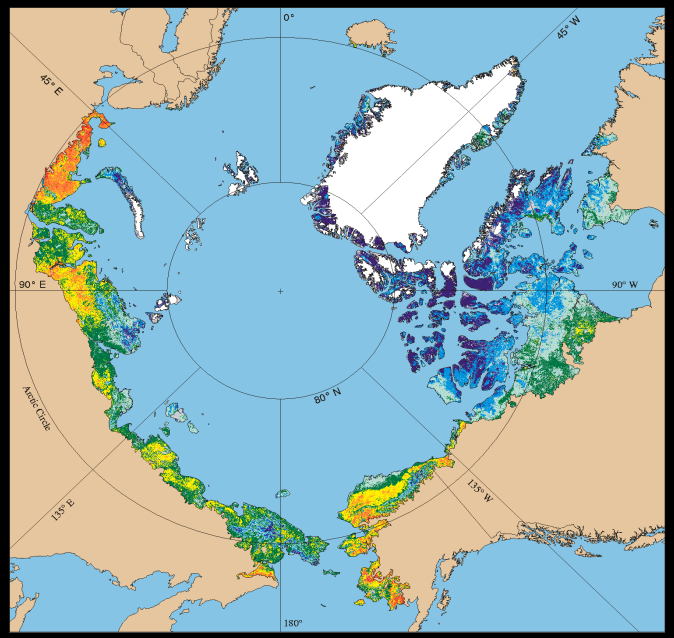
1. Detailed examination of the terrestrial NDVI record.

- Max NDVI, time-integrated NDVI
- 24-year time series, 8-km data
- Time series of NDVI will be analyzed according to:
  - Variation in land surface temperatures (MODIS LST)
  - Sea-ice distribution patterns



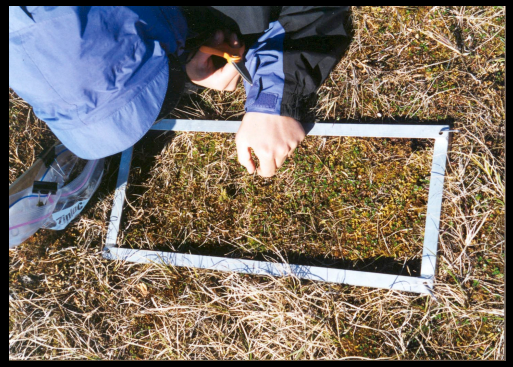
CAVM Team 2003

Circumpolar NDVI and phytomass patterns



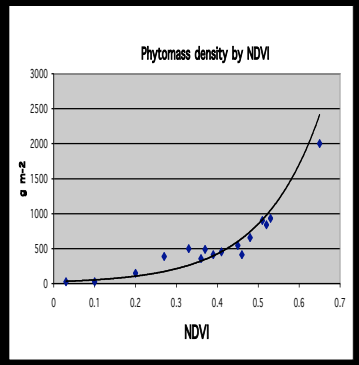
Max NDVI

+



Phytomass harvests

=

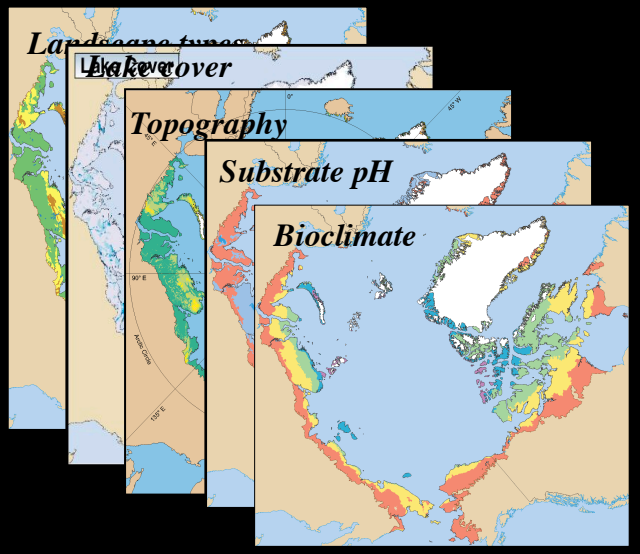


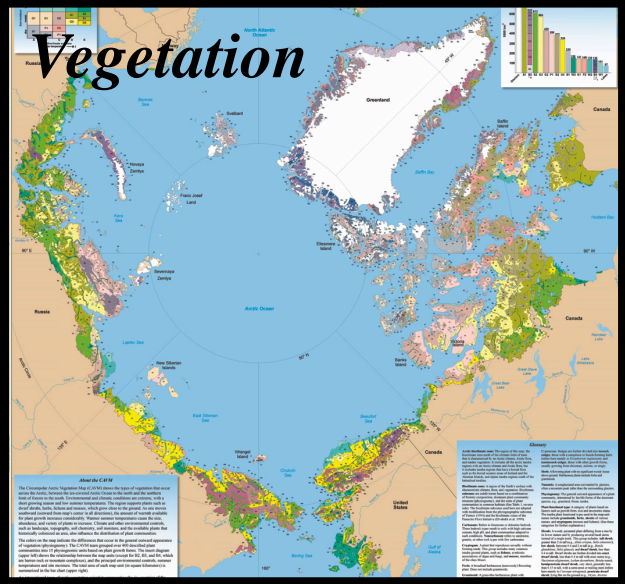
NDVI-phytomass relationships

Aboveground phytomass maps

Spatial patterns of NDVI

- Long term NDVI and phytomass patterns will be analyzed by:
  - Bioclimate subzone
  - Glacial and sea-level history
  - Elevation
  - Parent material (pH and soil type)
  - Vegetation type
- Models to predict vegetation response to climate change in different climate and geobotanical regions.





GIS databsse of the CAVM

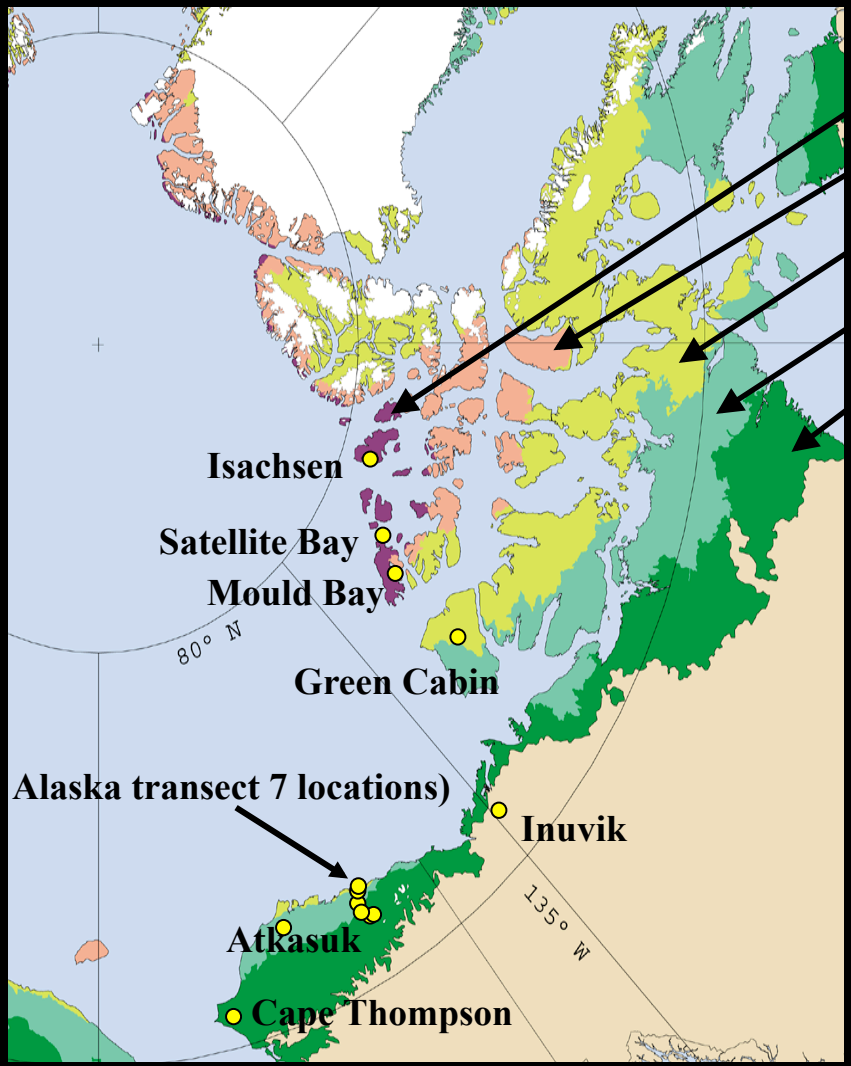
2. Ground-based studies along Arctic Transects

- Examine key ecosystem properties to relate to NDVI patterns.
- North American and Russian transects.

Photos – M. K. Raynolds and D.A. Walker

North American transect would follow an existing transect developed as part of an NSF Biocomplexity project.

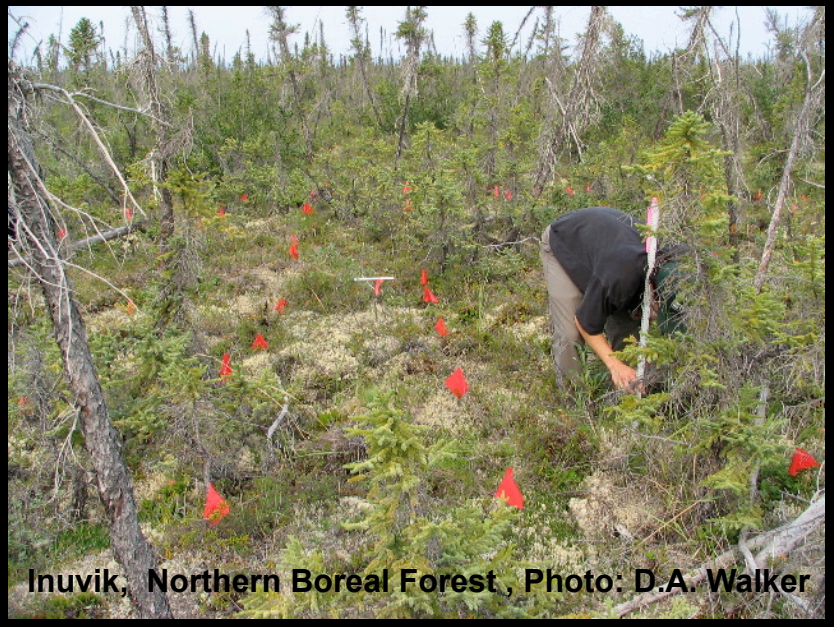
- 20 research grids in Alaska and Canada.
- Spans 5 Arctic bioclimate subzones + northern boreal forest.
- Plan to monitor key sites every 5 years for biomass and ecosystem trends.



Research Grids in all 5 bioclimate subzones

- Zonal sites on fine-grained parent material.
- Data will be part of the Circumpolar Active Layer Monitoring (CALM) project.
- Seeking endorsement from IPA.

Mould By, subzone B. Photo: D.A. Walker



Inuvik, Northern Boreal Forest , Photo: D.A. Walker

Other ecosystem studies

- Climate and permafrost
- Active-layer monitoring
- Vegetation biomass and composition
- Soil processes
- Invertebrate populations
- Other studies could be added.

3. Educational Component

- Arctic Field Ecology Course
- Dr. Bill Gould, University of Minnesota
- Students work with the scientists and develop there own IPY-related projects.

Camp logistics would duplicate those used in the Biocomplexity project

- High-Arctic camps in subzones A, B, and C (Green Cabin, Mould Bay, Isachsen).
- VECO supported.
- Good runways and long-term climate records at each site.

VECO-supported camp
Mould Bay, Prince Patrick Island
Photo: D.A. Walker

Proposed participants

- ***Vegetation:*** D.A. Walker, et al.
- ***Vegetation modeling:*** H.E. Epstein,
- ***Remote sensing:*** G. Jia, M.K. Raynolds
- ***Sea-ice remote sensing:*** U. Bhatt,
- ***Climate and permafrost:*** V. Romanovsky,
- ***Soils:*** C. Tarnocai, C.L. Ping, G. Michaelson,
- ***Invertebrates:*** G. Gonzalez
- ***Education:*** W.A. Gould
- ***Russian transect:*** N. Matveyeva, N. Moskalenko, E. Melnikov

Dietrich River, AK, Photo – J. A. Knudsen