Overview of state-of-the-art methods and applications for boreal and temperate forest monitoring and availability of remote sensing data

Curtis Woodcock, Boston University

With slides from:

- Matt Hansen et al.
- Warren Cohen et al.
- Jeff Masek et al.
- Mike Wulder et al.
- Alan Strahler et al.

Current Trends: Applications and Methods

1. Exciting Time!! Lots of new applications
2. Use of multiple sensors (notion of sampling)
3. Integration of remote sensing in management of forests
4. Focus on trends and change – more comprehensive perspective and longer histories
    1. Human activity – harvest, land use change
    2. Fires
    3. Insect damage
    4. Regrowth
    5. Climate change

Data for Characterizing Land Cover and Change: Availability, Spatial and Temporal Detail

- MODIS – now a decade of data
- Landsat – progression to free data
  - GLS datasets
  - Opening of the US Archive
  - Ensuring access to all Landsat data
    - ground receiving stations
    - centralized (and consistent) processing
- High Resolution – commercial providers (samples)
  - growing number of providers
- Lidar – lots of use despite lack of a space mission

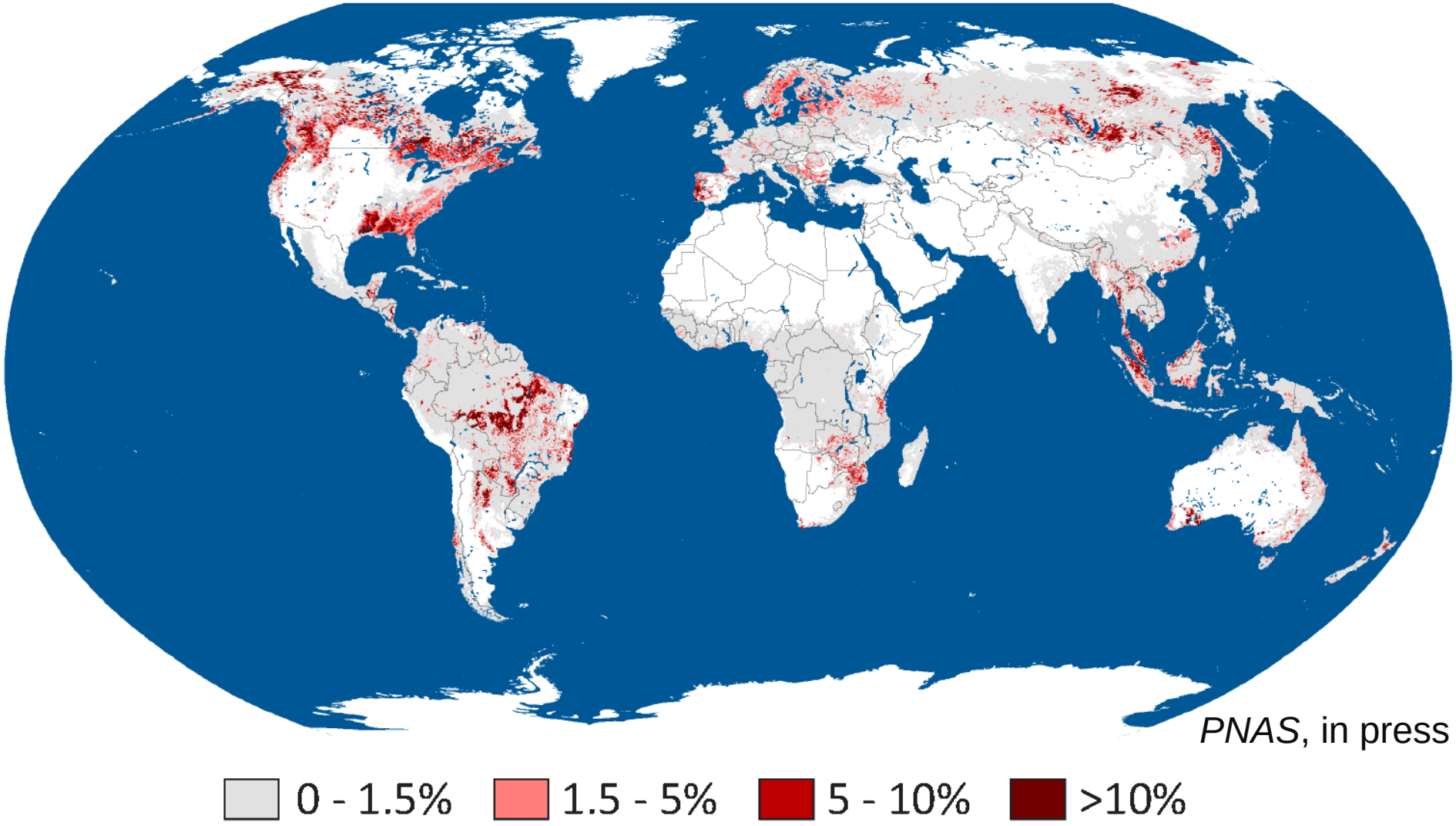
Easy access to Landsat data is changing the ways we use it – both in terms of studying larger areas and by using richer time series

Slides from Matt Hansen, South Dakota State University

Data requirements for global forest monitoring

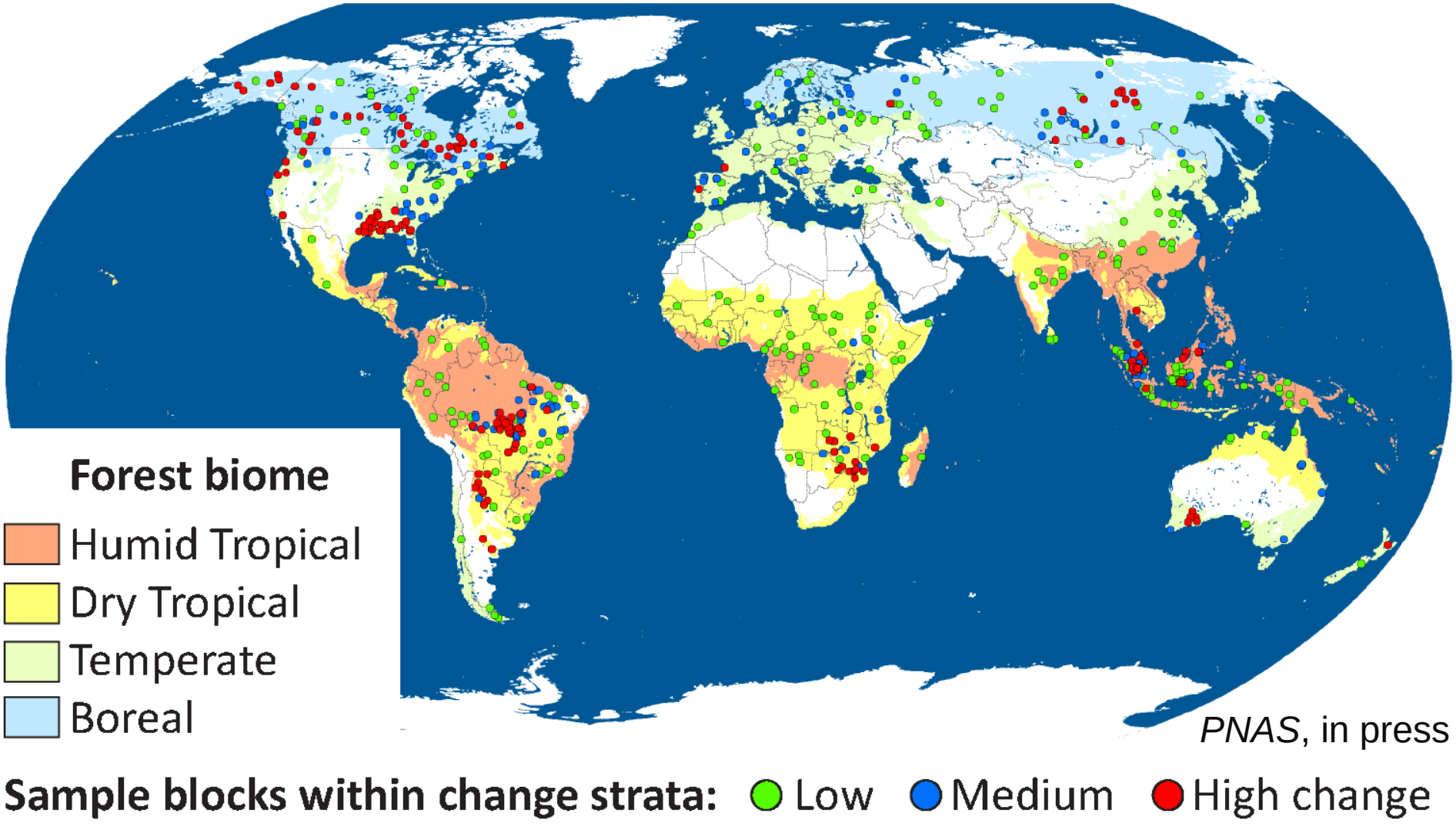
- Systematic global acquisitions
- No/low cost
- Easy access
- Minimal pre-processing required

Percent gross forest cover loss, 2000 to 2005

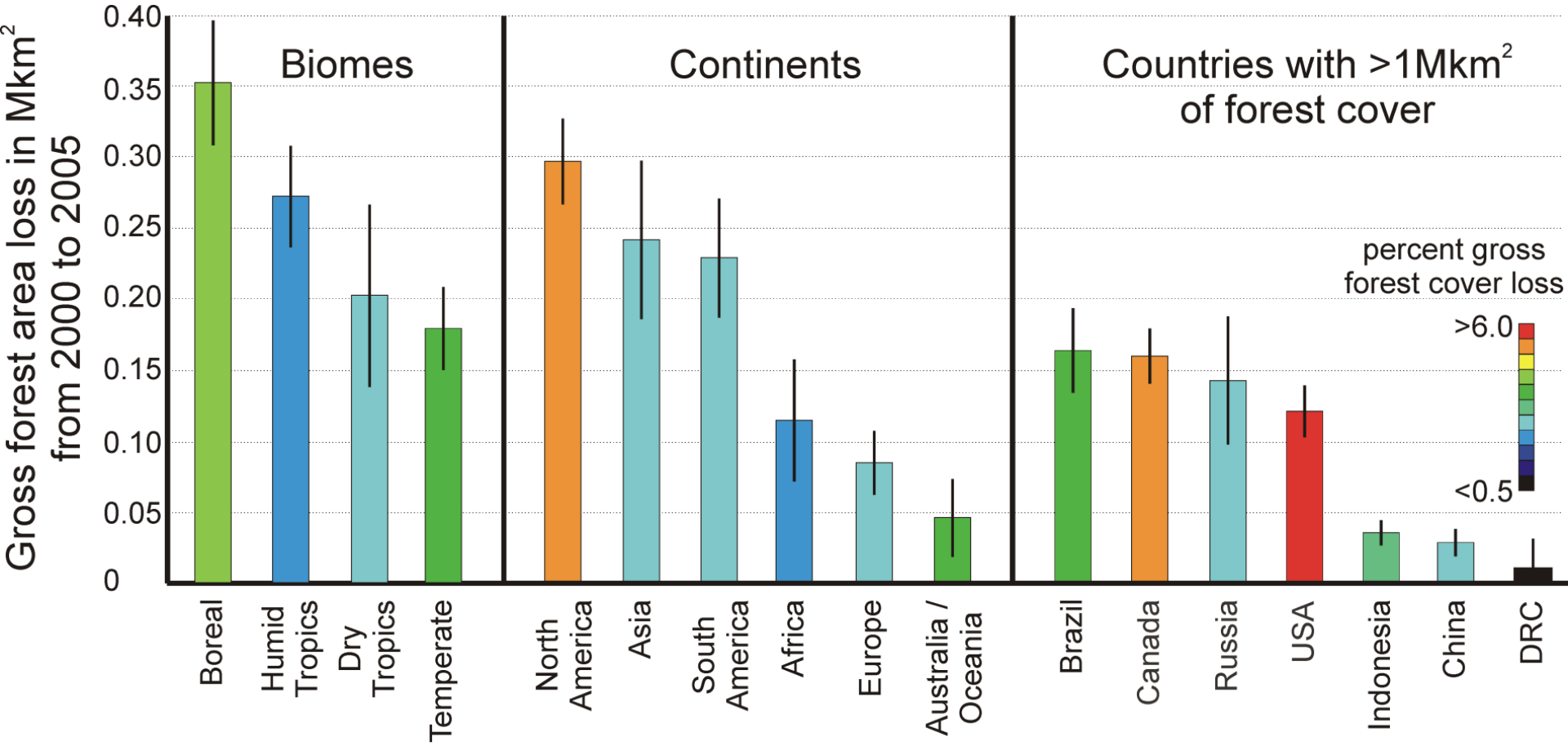


PNAS, in press

MODIS-stratified Landsat samples



Global gross forest cover loss, 2000 to 2005

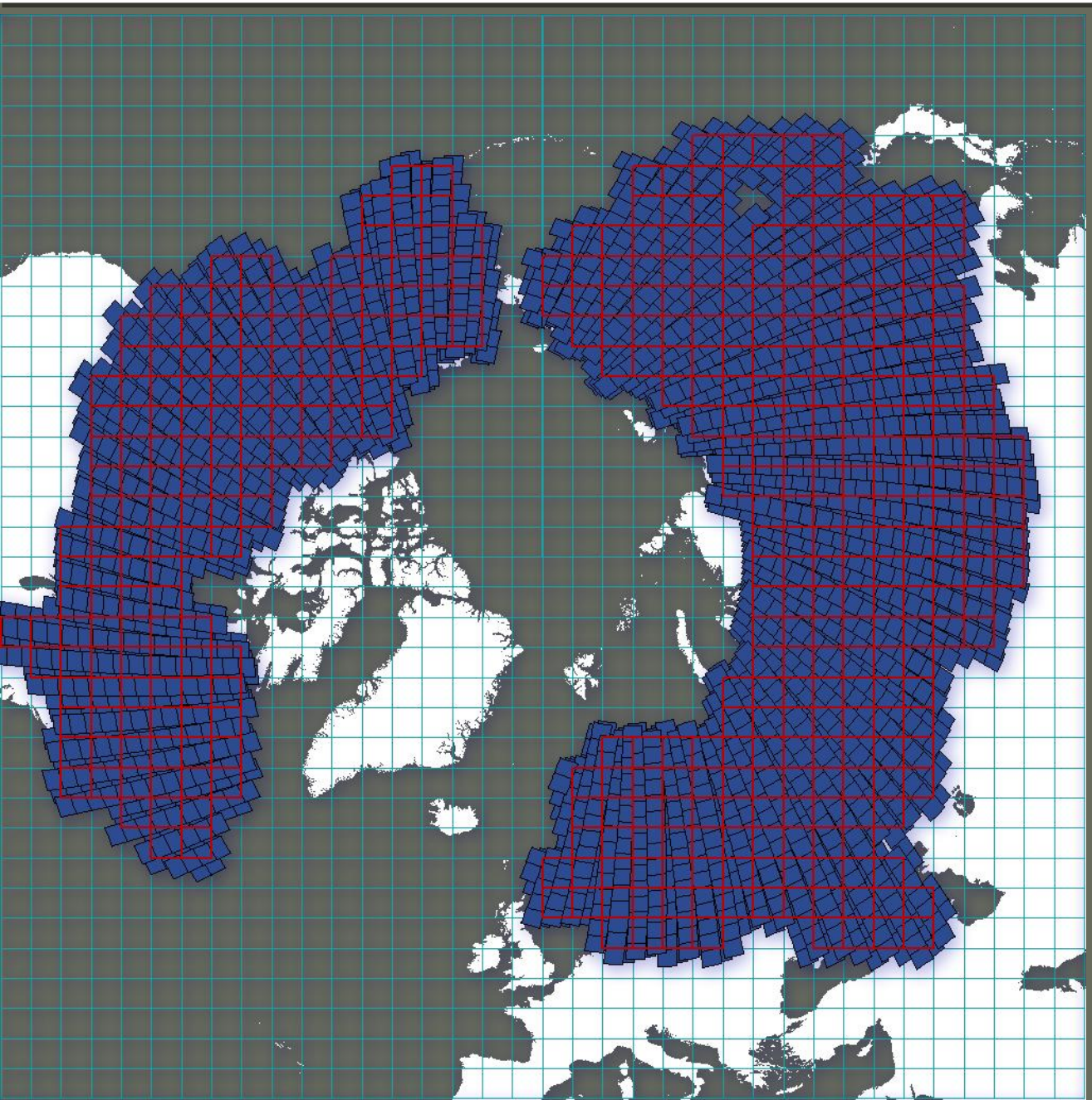


PNAS, in press

Landsat boreal forest cover monitoring

SDSU

Image selection



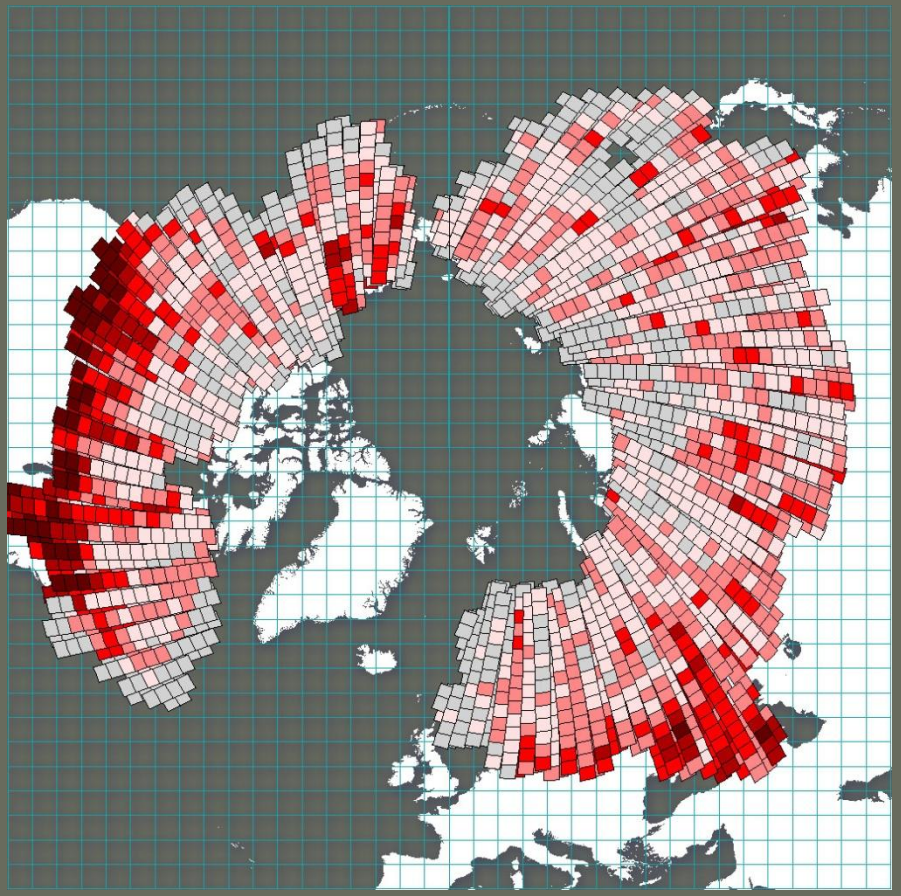
All selected WRS2 path/row (3154)

SDSU

Image selection

Landsat image selection criteria

- Date
  - Circa 2000 composite



Available Landsat images for year 2000

(within growing season, with cloud cover below 50%)

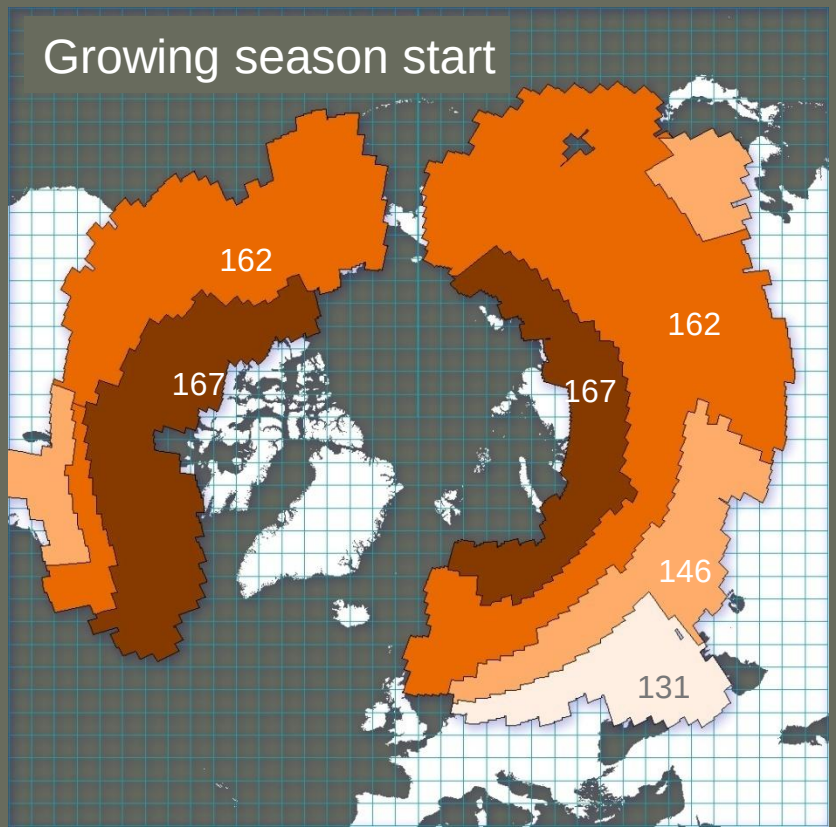
	Images per path/row	Percent of all path/row
	0	23
	1	38
	2	26
	3	8
	4	3
	5 and more	2

SDSU

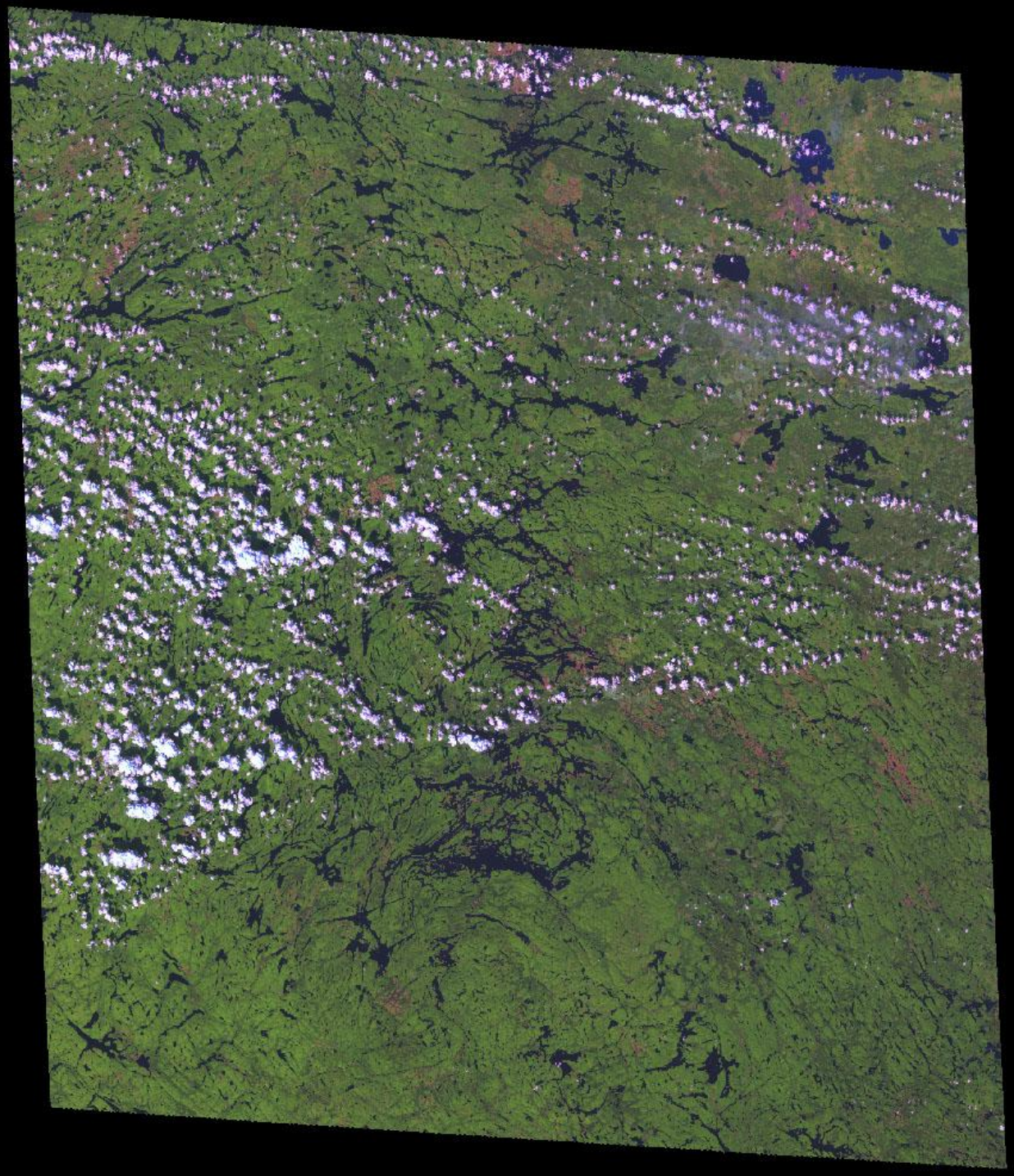
Image selection

Landsat image selection criteria

- Dates
  - Circa 2000 composite: 1999-2002 slc-on data
  - Circa 2005 composite: 2003-2007 slc-off data
  - Within growing season



SDSU

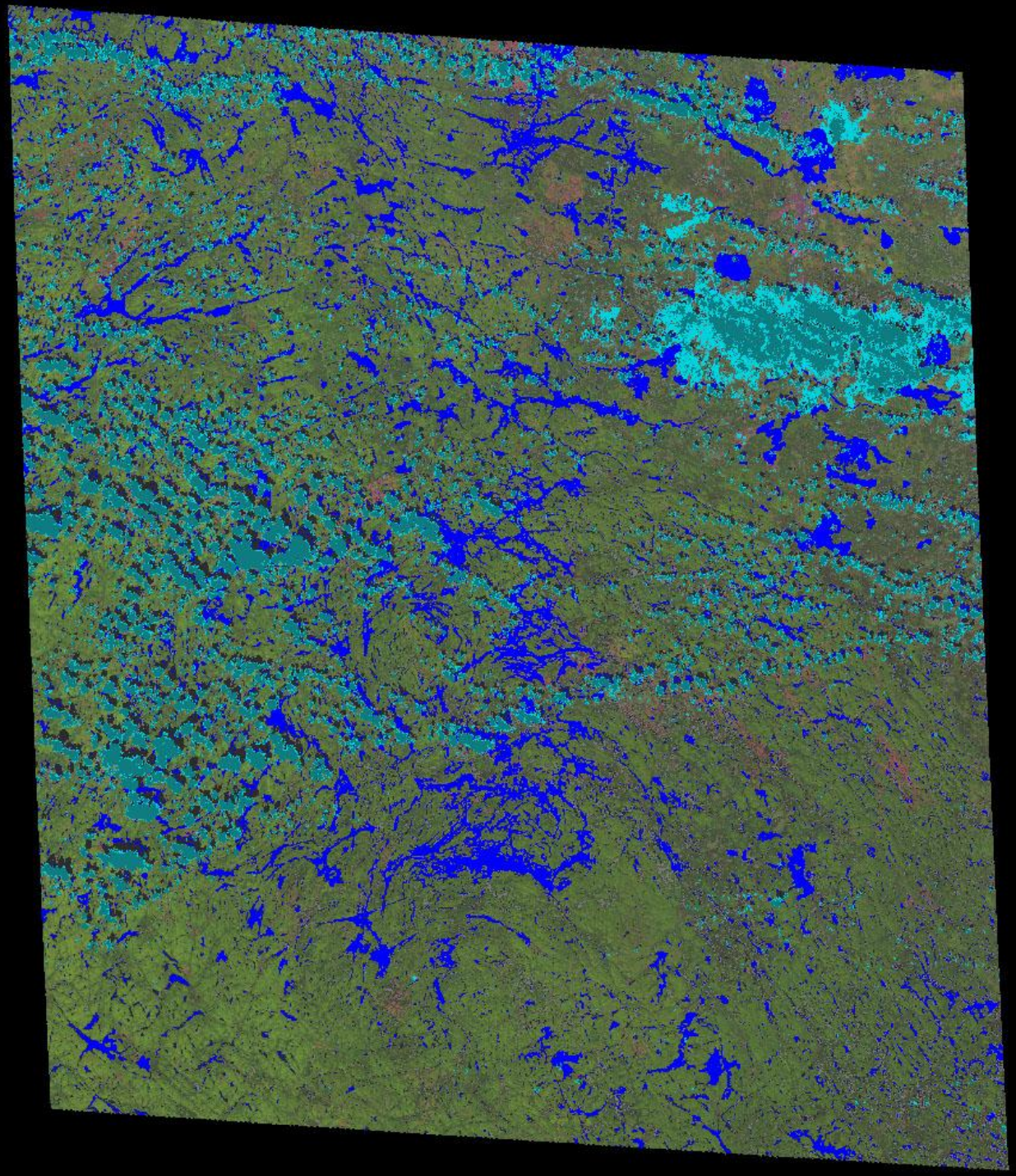


Source imagery

Quebec (P17R27)

1999/08/27
2000/06/26
2000/07/12
2000/08/13
2001/06/13
2001/07/31

SDSU



Quality assessment flags

Cloud likelihood

- 50-90%
- >90%

Shadow likelihood

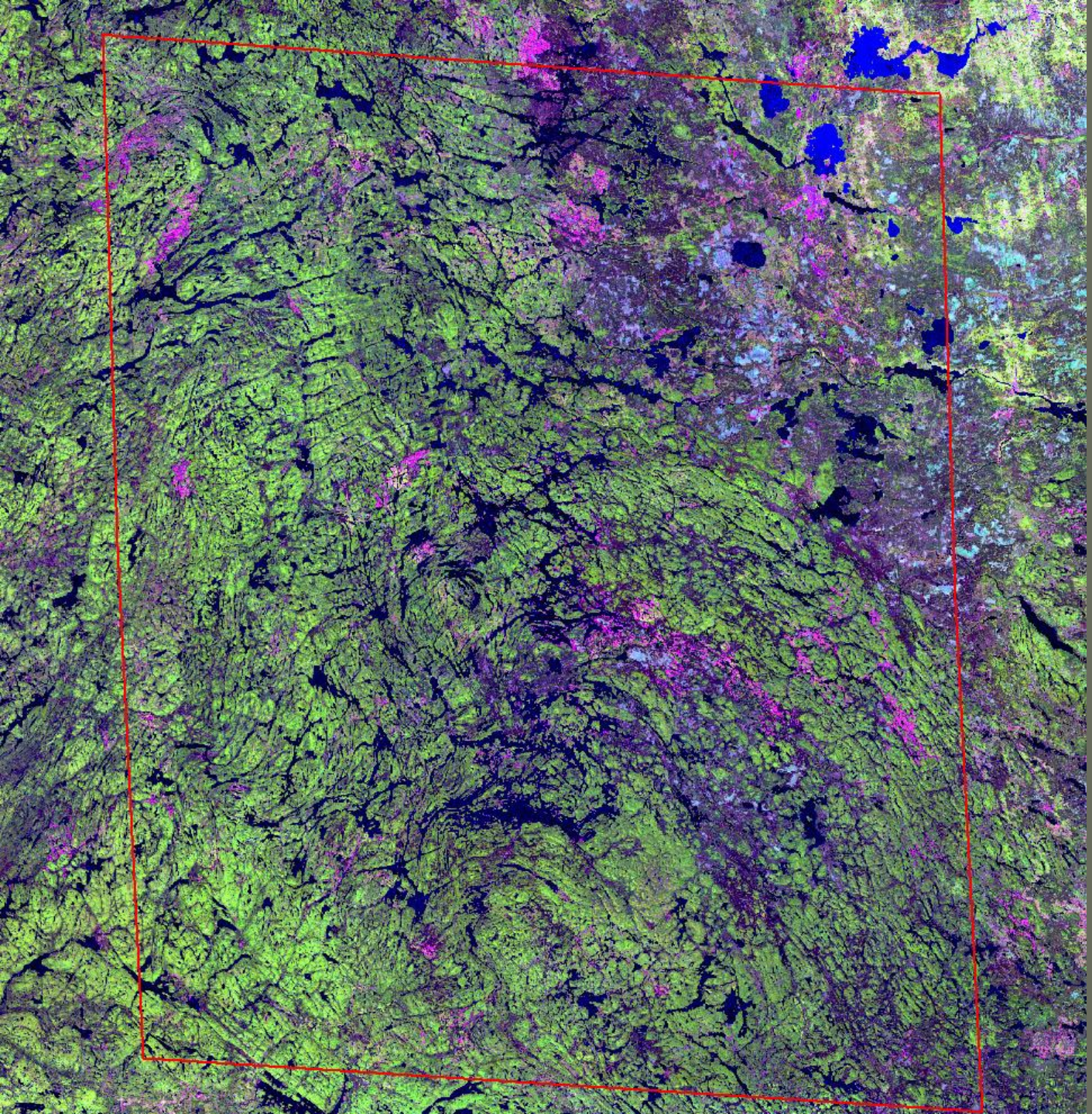
- 50-90%
- >90%

Water likelihood

- >50%

1999/08/27
2000/06/26
2000/07/12
2000/08/13
2001/06/13
2001/07/31

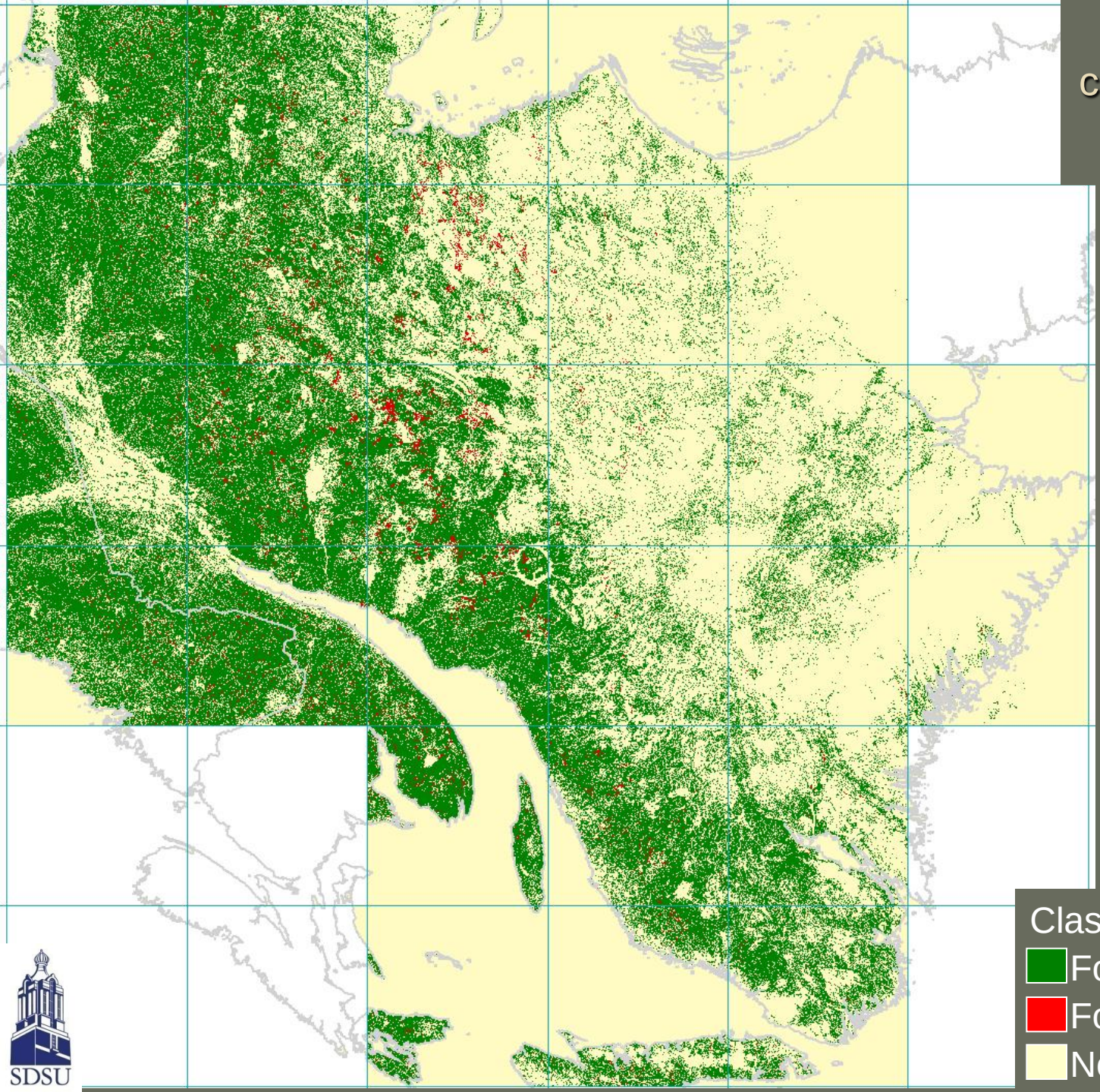
SDSU



Composite image
for circa year 2000

SDSU

Quebec, Canada classification results



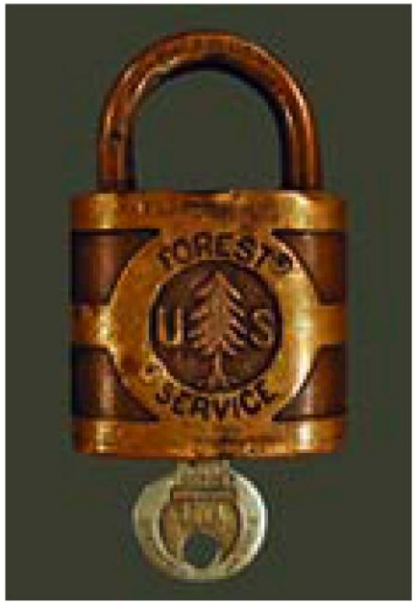
N

Classification results

- Forest 2000
- Forest loss 2000-05
- Non-forest 2000

SDSU

Landsat Happenings in the US Forest Service: *Just how important is Landsat to the USFS?*

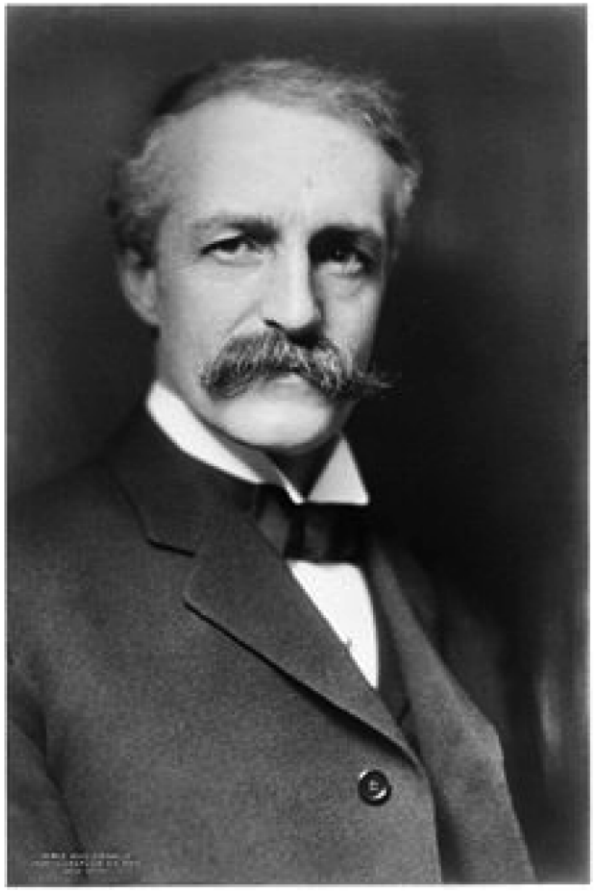


Warren B. Cohen
USFS, PNW Research Station, Corvallis, OR

Landsat Science Team Meeting, Boise ID – 15-17 June 2010

Contributions from:

Ken Brewer, John Coulston, Sean Healey, Eileen Helmer, Andy Hudak, Robert Kennedy, Paul Maus, Ron McRoberts, Gretchen Moisen, Mark Nelson, Janet Ohmann, Todd Schroeder, Brian Schwind, Nancy Thomas, and others



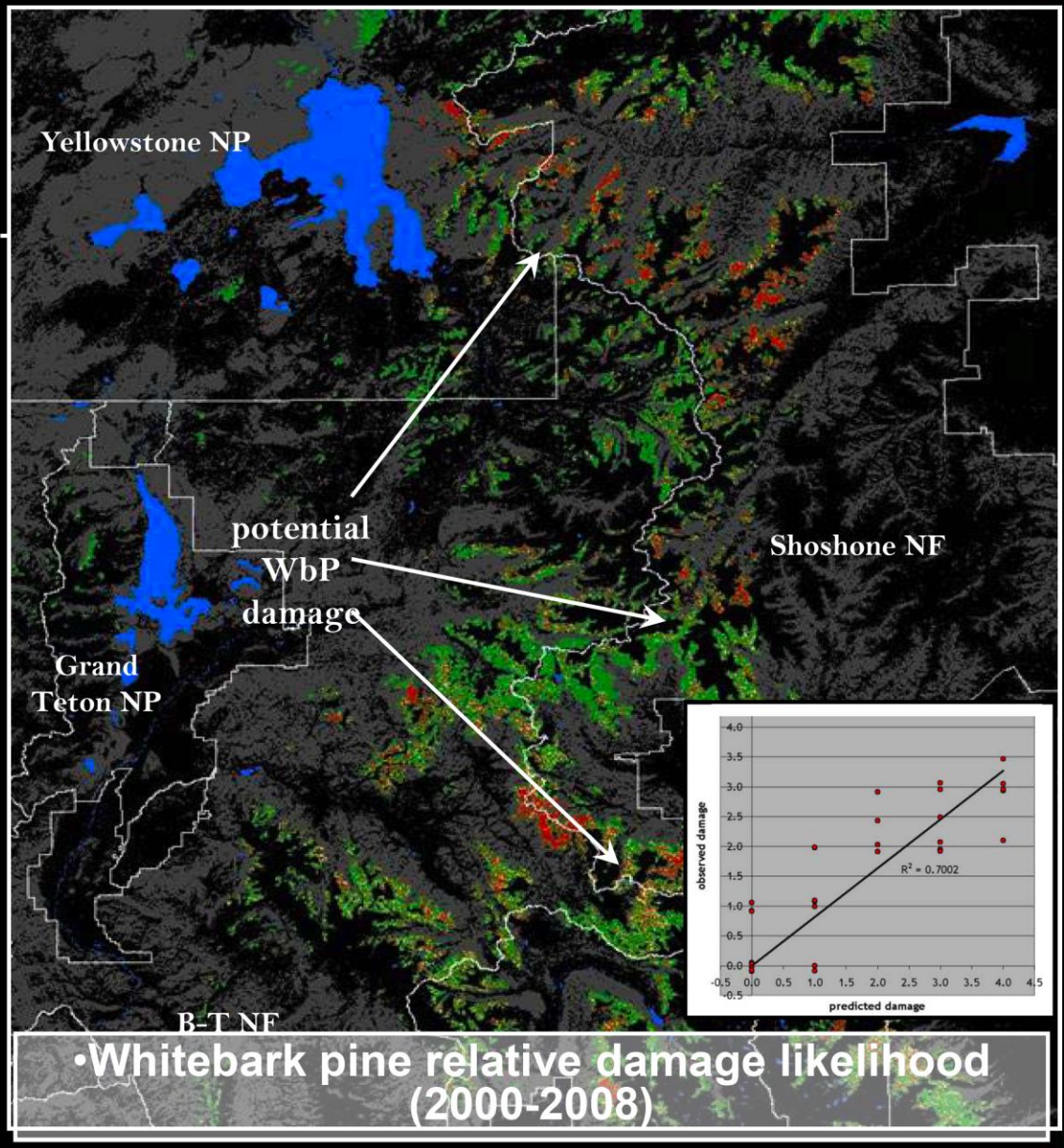
Gifford Pinchot, 1st Chief

More Recent & Current Landsat Happenings in the US Forest Service (examples)

- Fire mapping & modeling
- Insect & disease
- Wildlife habitat
- Statistical estimation of forest conditions & change
- NLCD tree cover
- Regional assessments
- Partnership with NASA Applied Sciences Program

Whitebark Pine Decline Assessment

- Assessed changes in whitebark pine across the GYA between 2000-2008
- WBP is key habitat for T&E species including grizzly bear
- Develop regression between field plots and changes in NDVI
- Used 5 path/rows covering the Greater Yellowstone Area

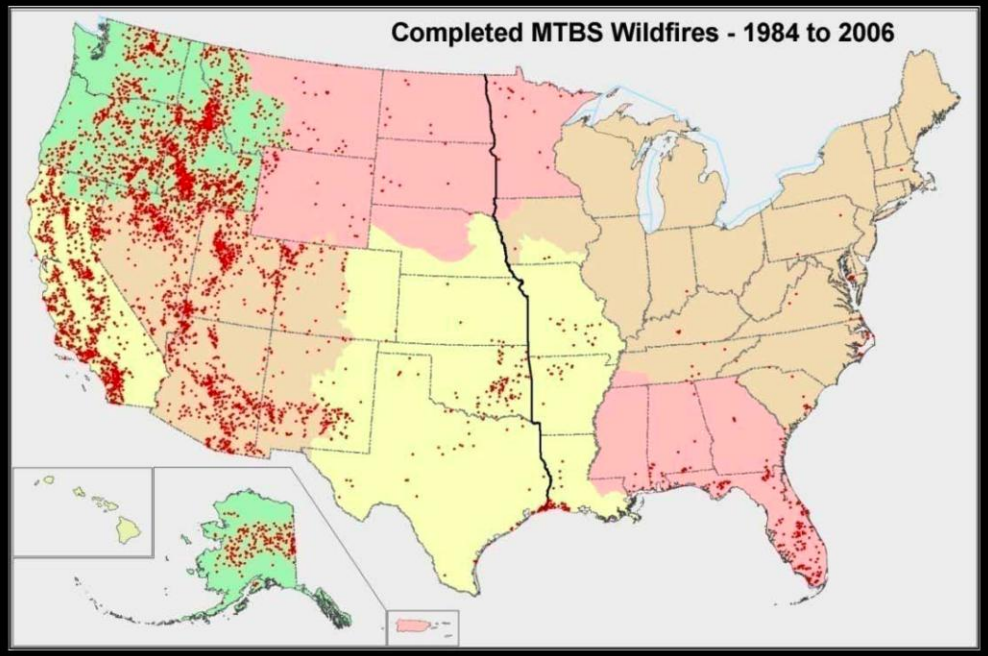


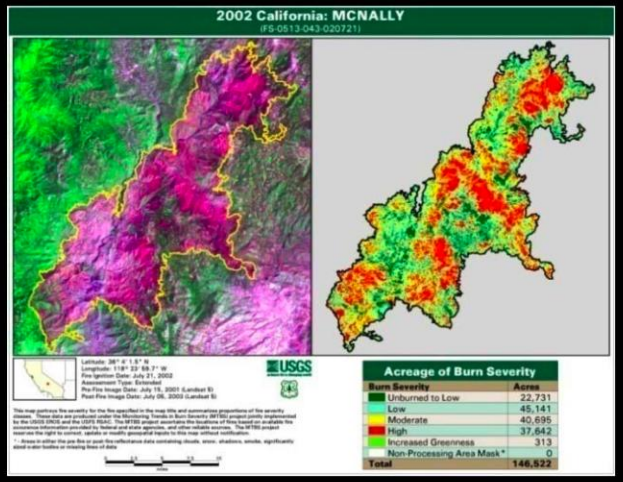
•Whitebark pine relative damage likelihood (2000-2008)

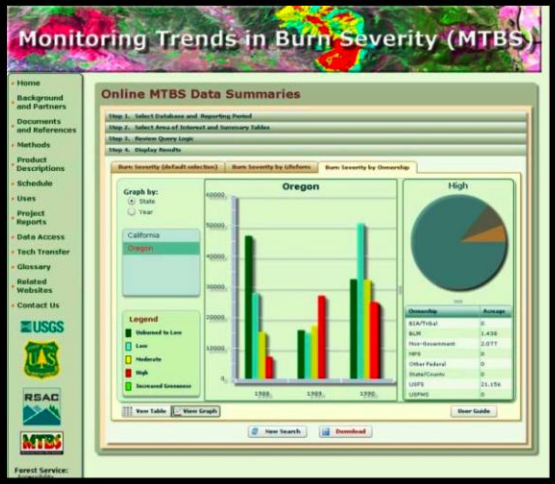
Monitoring Trends in Burn Severity (MTBS)

http://www.mtbs.gov

- Consistently map burned areas and associated severity of large fires on all US lands (1984-2010)

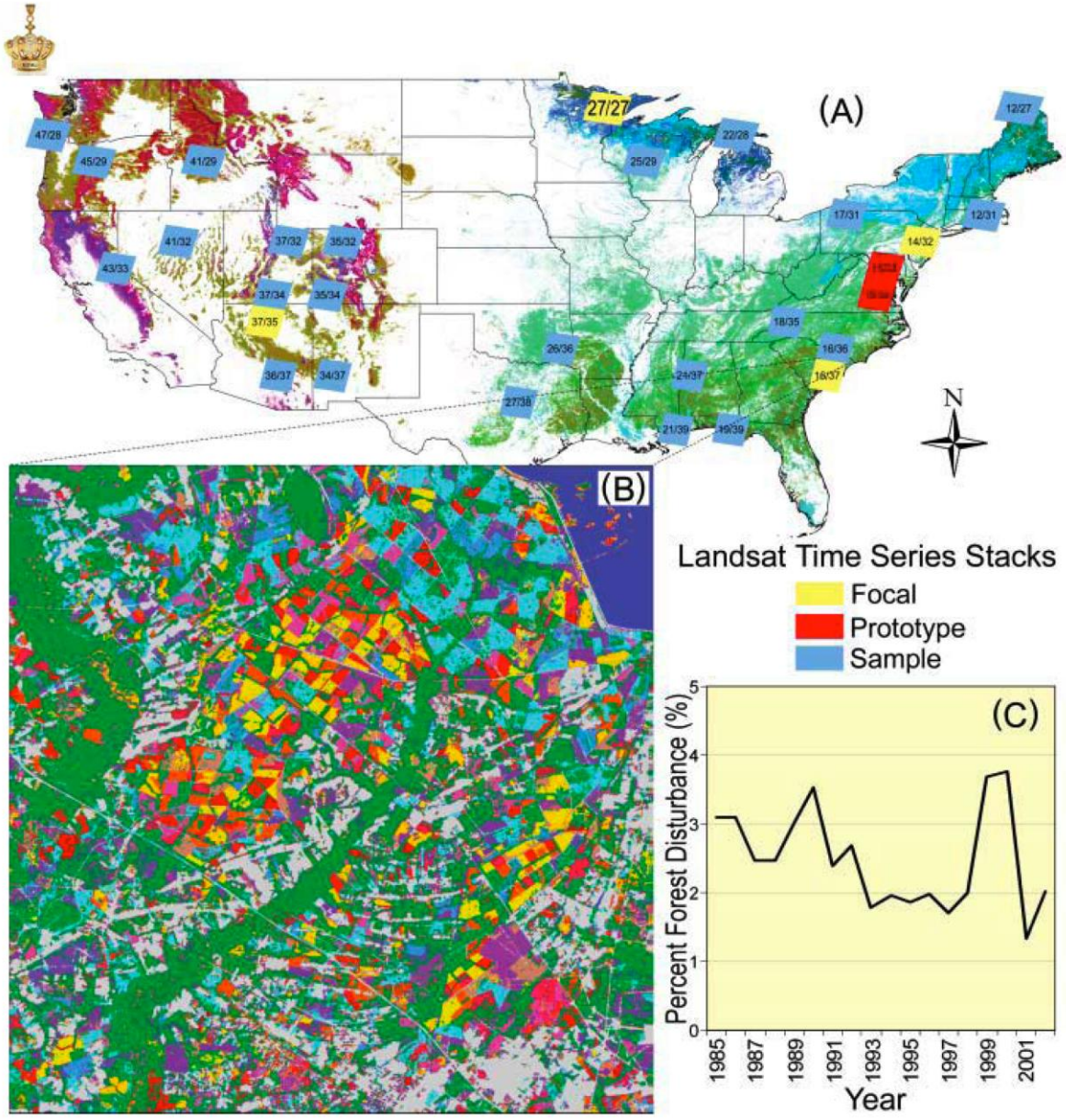






- Sponsored by Wildland Fire Leadership Council
- Implemented jointly by USFS RSAC and USGS EROS
- Strategy to monitor the effectiveness of NFP and HFRA
- Distribute geospatial data via web-based portals
- Over 6400 Landsat images processed covering 10K fires

North American Forest Dynamics (for NACP)

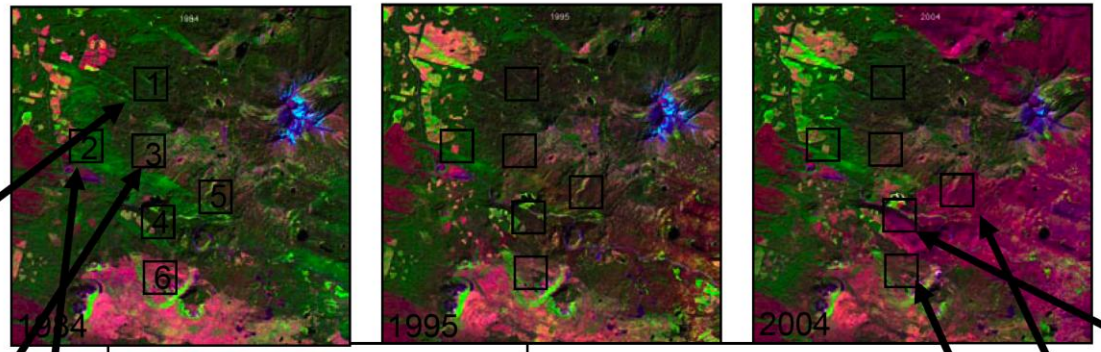


Estimation of forest disturbance rates (VCT)

NASA-funded to UMD, GSFC, USFS

(Goward, Masek, Moisen, Cohen, Huang, Wulder, Kennedy, Powell, Healey, and several others)

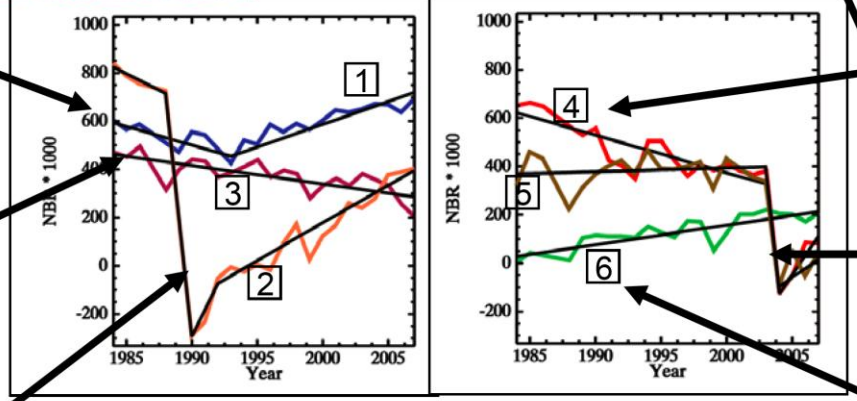
Disturbance year, magnitude, agent, regrowth rates



1: Insect, then regrowth

3: Insect-related mortality

2: Harvest, then regrowth

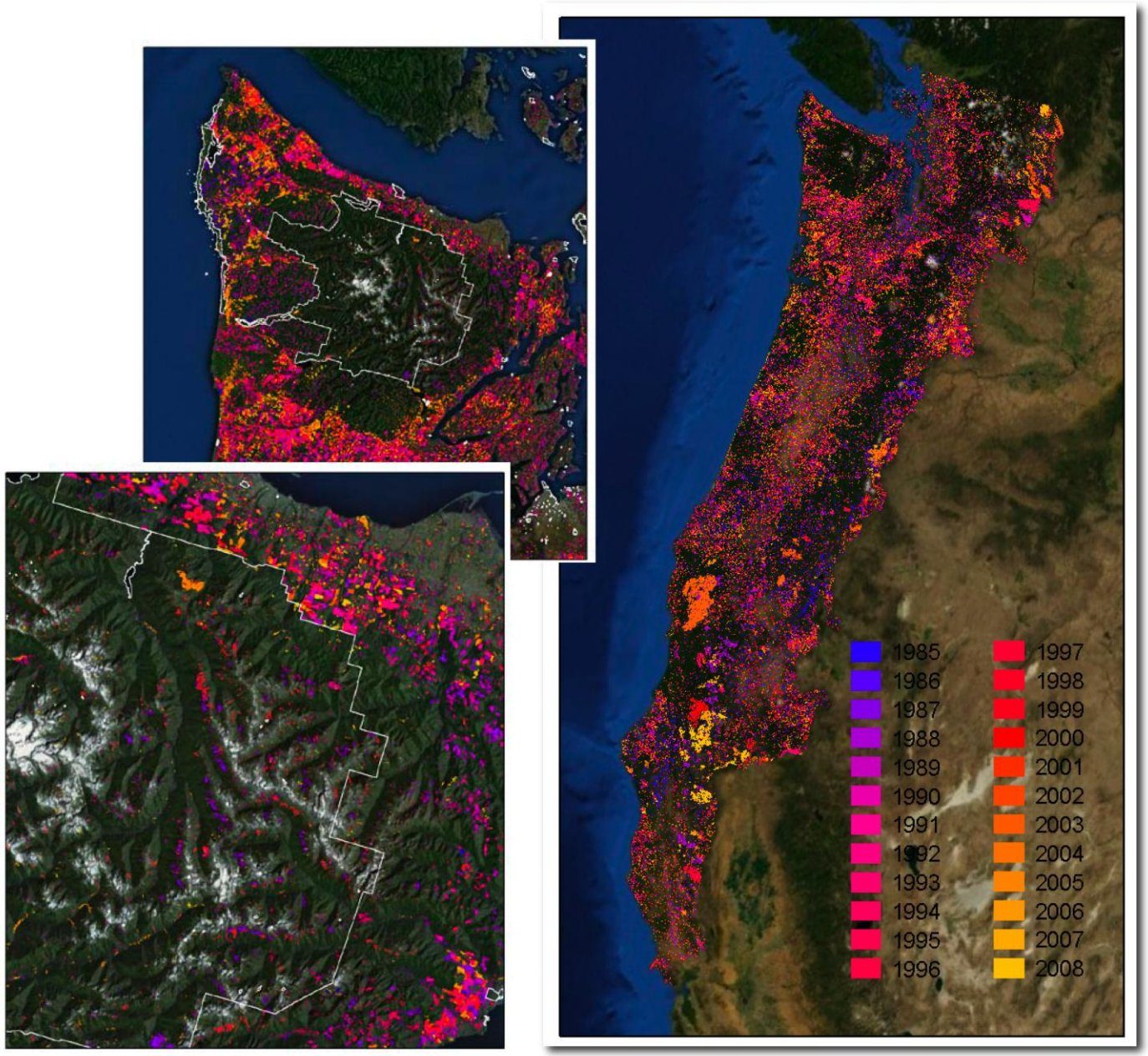


4: Insect, then fire

5: Growth, then fire

6: Growth

LandTrendr – Kennedy et al.



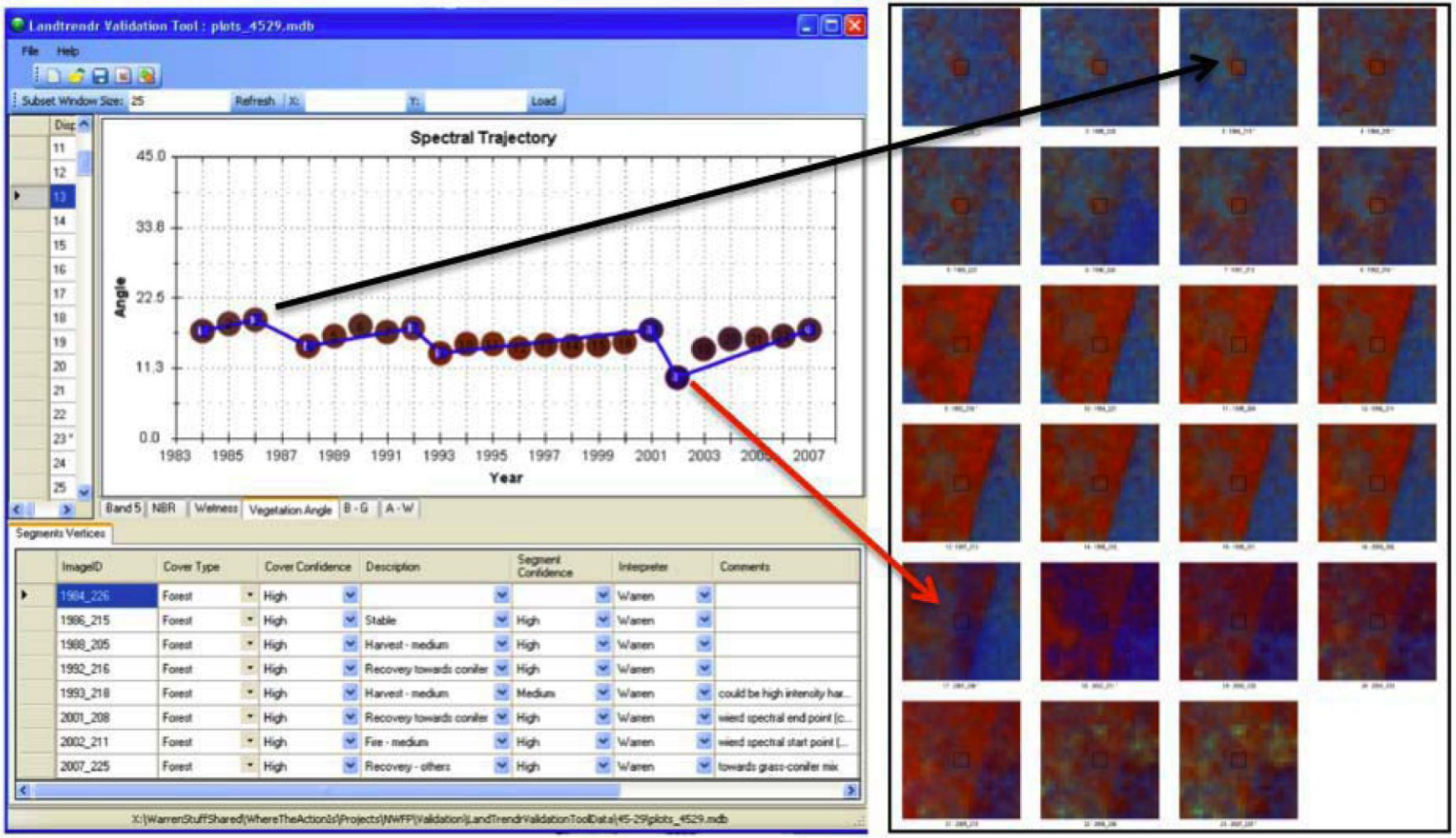
Project: Region 6 Effectiveness Monitoring Program for the Northwest Forest Plan (NWFP)

Data: > 500 individual Landsat images

LandTrendr – Kennedy et al.

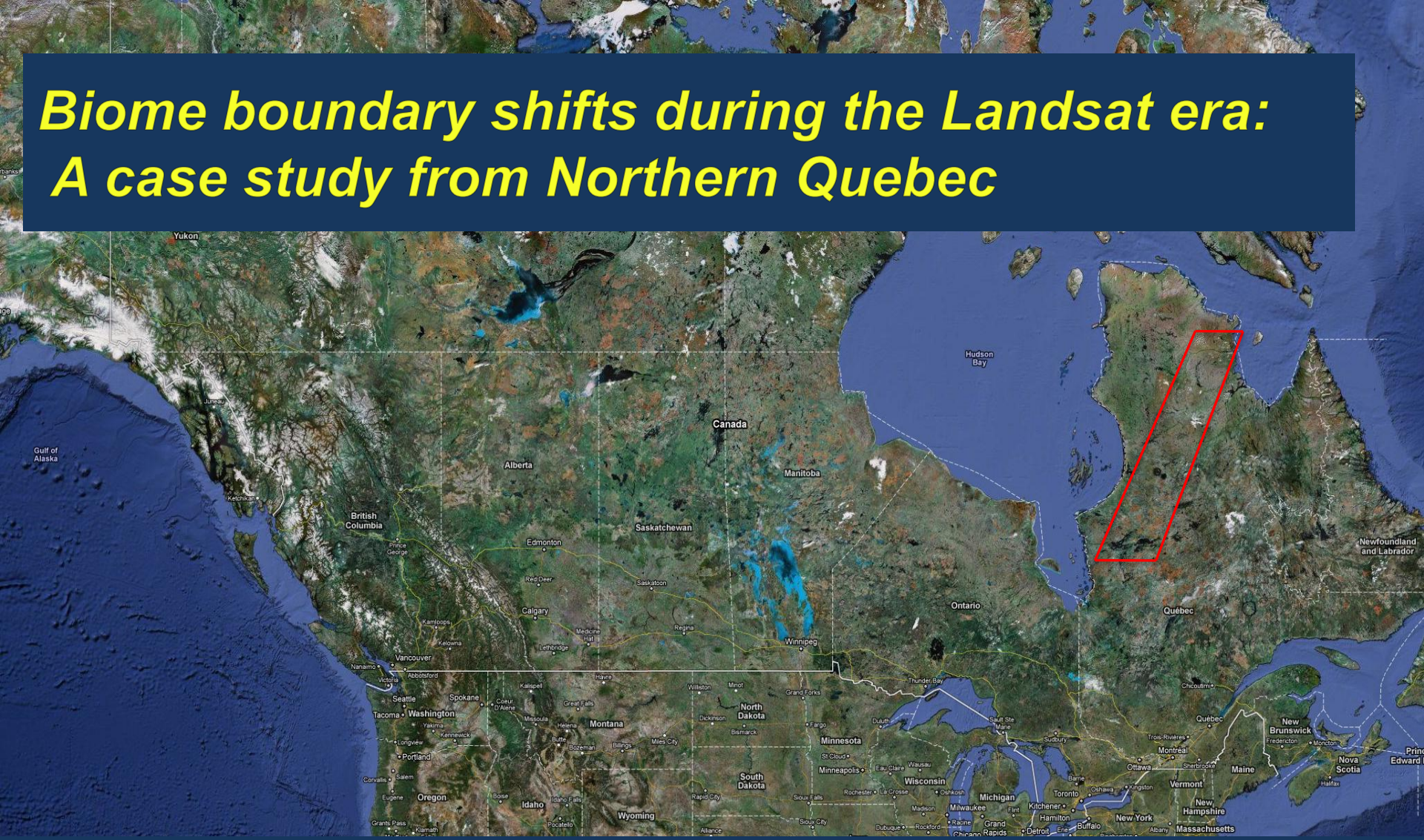
Funding from USFS, NASA, NPS, DOE, and others

Error Assessment via TimeSync



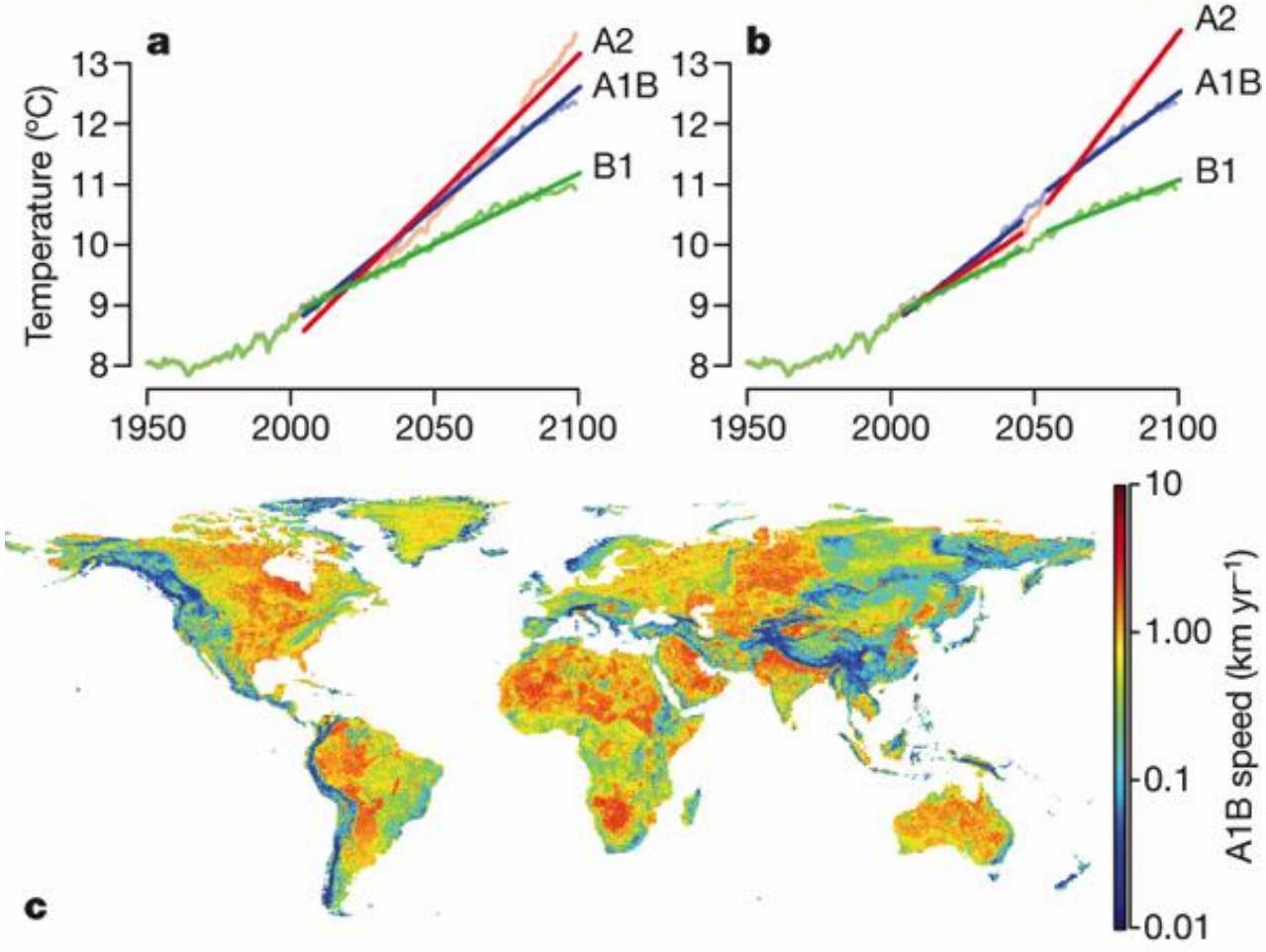
Cohen et al.

Biome boundary shifts during the Landsat era: A case study from Northern Quebec



D.C. Morton[1], J.G. Masek[1], D Wang[2], J. Sexton[2], J. Nagol[2], K. McManus[1]
[1]NASA Goddard Space Flight Center, [2]University of Maryland, College Park

Global Warming will Likely Force Biome Migration (aka "The Velocity of Climate Change")…
But how fast? And when?

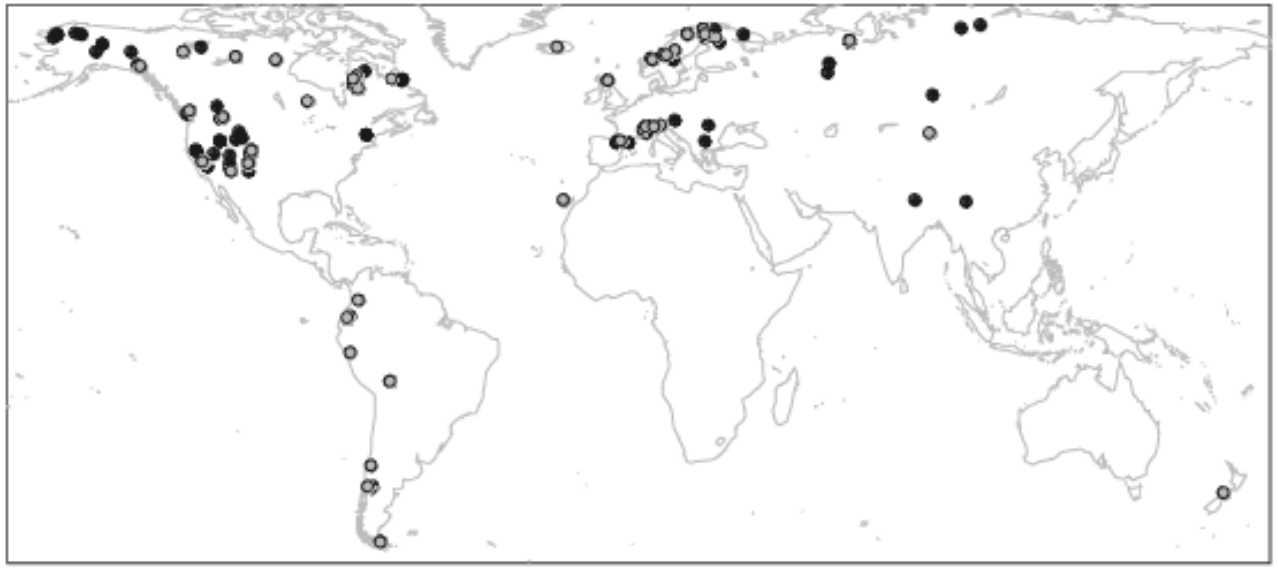


SR Loarie *et al. Nature* **462**, 1052-1055 (2009) doi:10.1038/nature08649

Observations of current biome shifts are ambiguous…

Harsch et al., 2009, Are treelines advancing? A global meta-analysis of treeline response to climate warming, Ecology Letters

Figure 1. The location of the 166 treeline sites across the globe analyzed in this study grouped according to whether they are advancing (black circles) or not advancing (grey circles).



Reported observational evidence for…

- Shrub advance into tundra (Alaska)
- Pine replacing larch (Siberia)
- Aspen dieback (Rockies, S. Canada)
- Altitudinal treeline advance (Rockies, Siberia)
- Pinyon-Juniper dieback (or temporary disturbance?) (SW US)

GSFC/UMD Biome Boundary Shift Project

Do we see “early” evidence of biome migration from Landsat time series?

Focus on areas with…

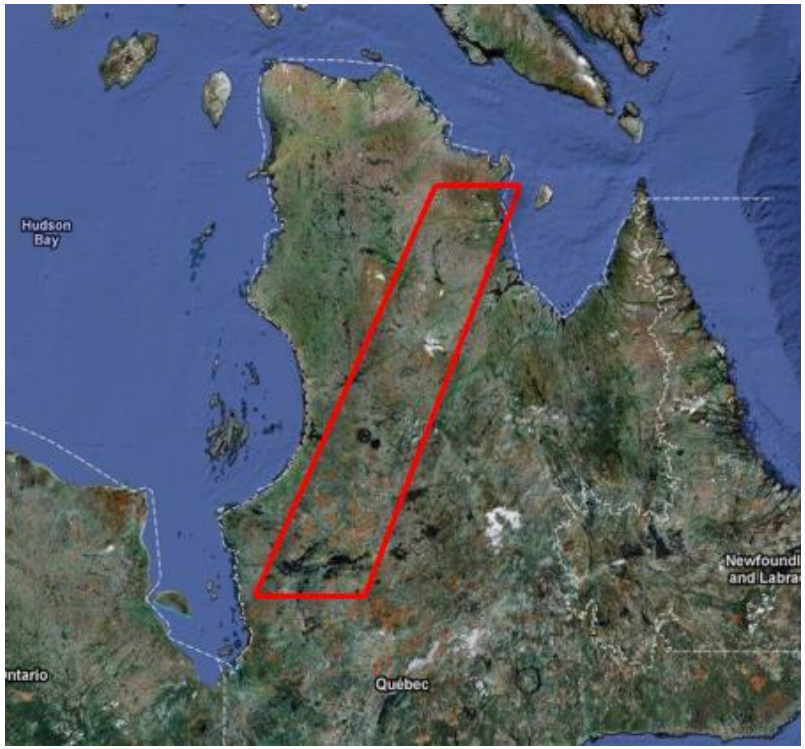
- significant climate trends during Landsat era
- minimal human impact on vegetation

1. Northern Quebec Transect

- rapid summer warming
- transect through tundra/shrub/forest
- overlap with PALS lidar data (Nelson)

2. Central Canadian Boreal

3. Southern Brazilian Amazon

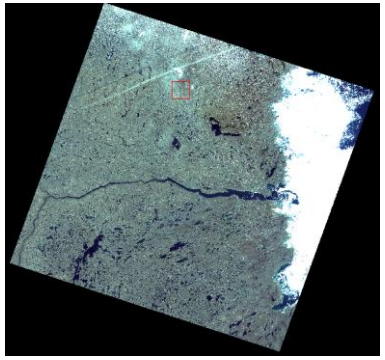


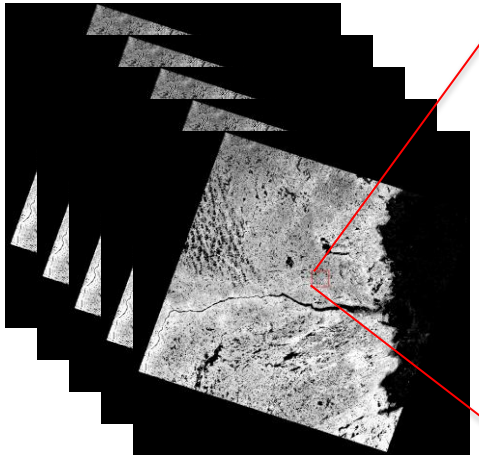
Landsat timeseries analysis: NDVI trends

- calculated using least square regression (N_{min}= N-1)

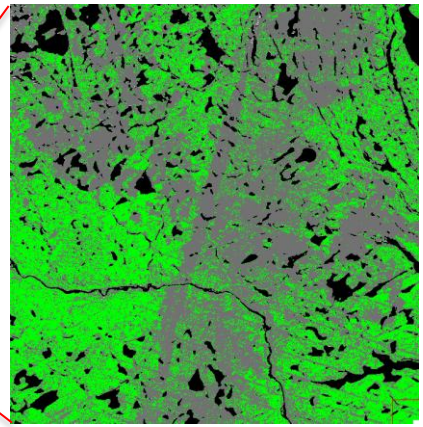
-Signficance assessed with T test (T = slope/std error; p=0.05)

Scene 17-18: 1986- 2009

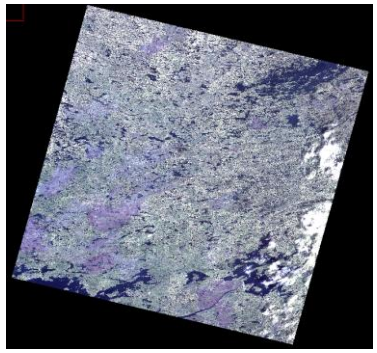


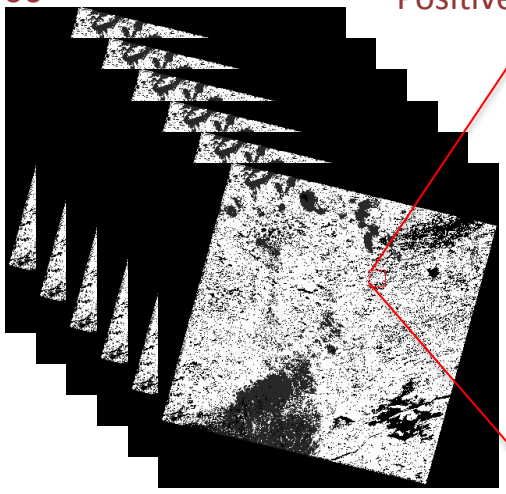


Positive Δ NDVI, 1986-2000 (Green)

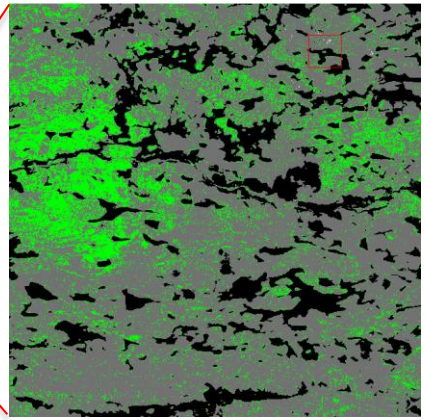


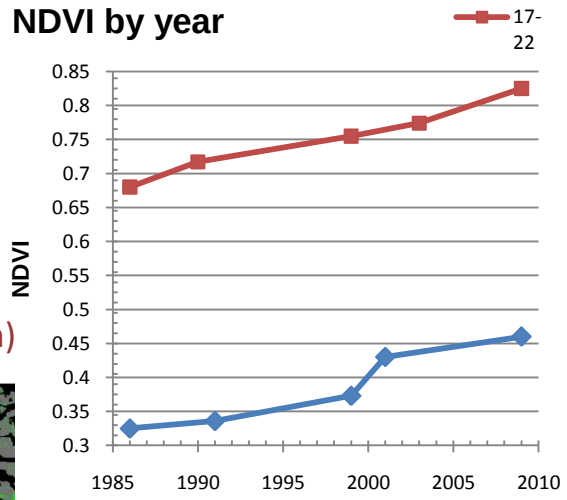
Scene 17-22: 1986- 2009





Positive Δ NDVI, 1986-2000 (Green)



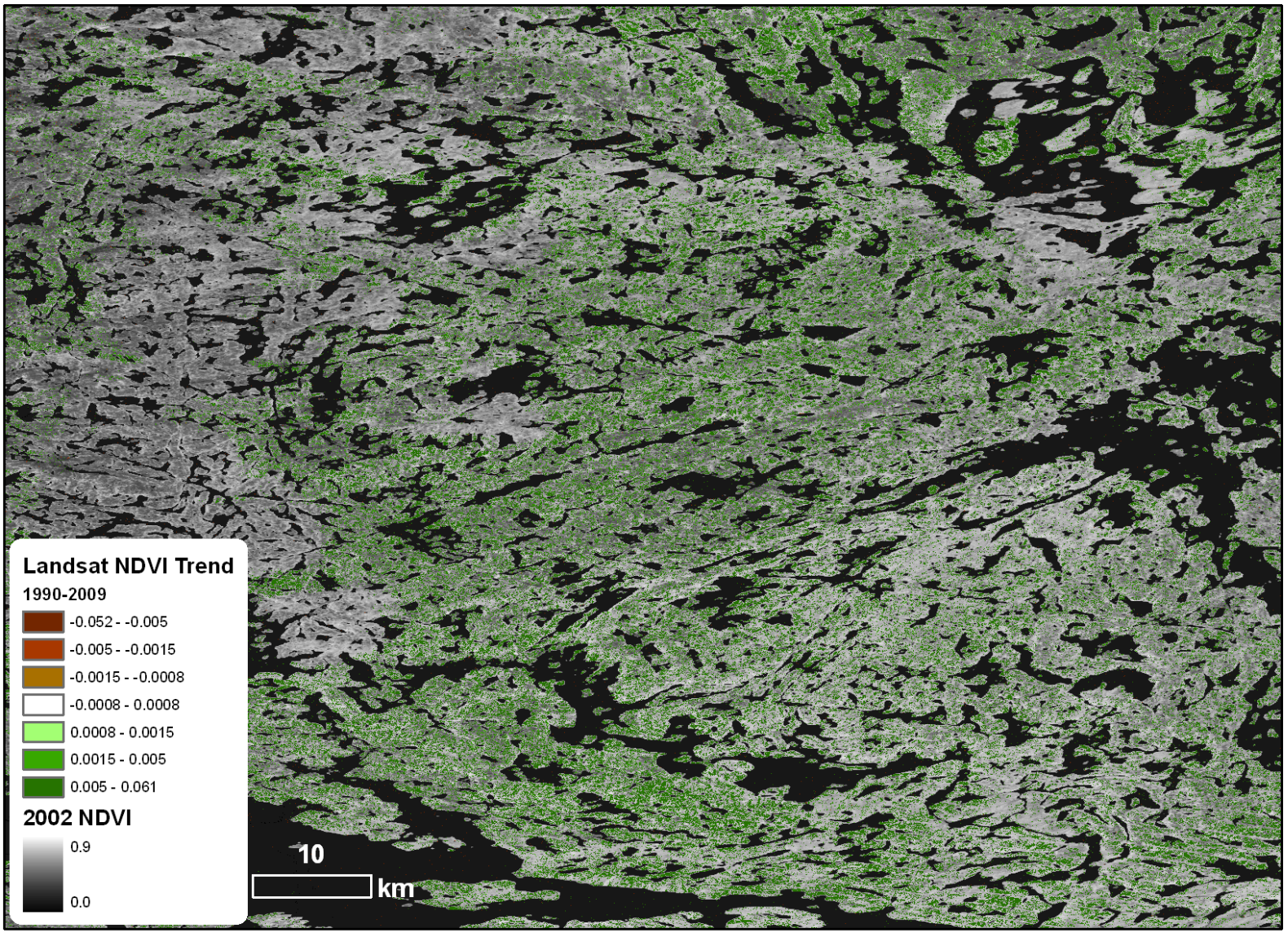


Mean positive Δ NDVI/yr by scene:

17- 18: 0.0064

17-22: 0.0074

NDVI trend, p18 r19, mid-August 1990, 2002, 2008, 2009



Do We See the Same Trends in MODIS?

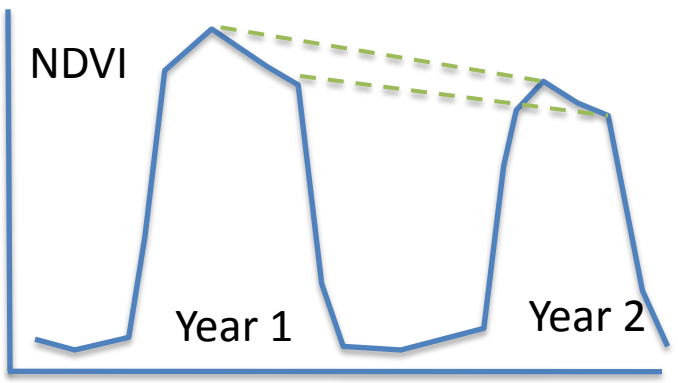
- NBAR (MCD43A4) products for h14v3
  - Years: 2000-2009; DOY: 201, 209, 217, 225, 233 (July 20 – August 29)

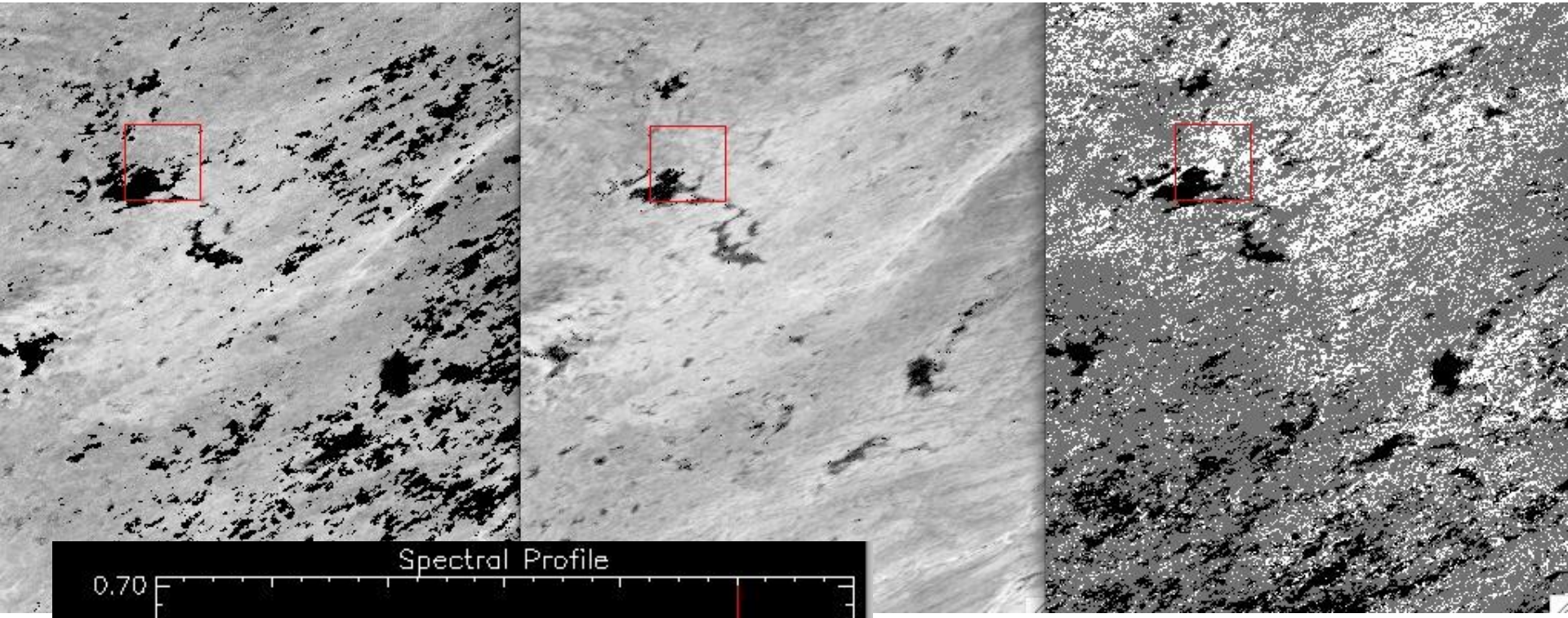
- Masked out "poor" data (QA > 2), calculated NDVI

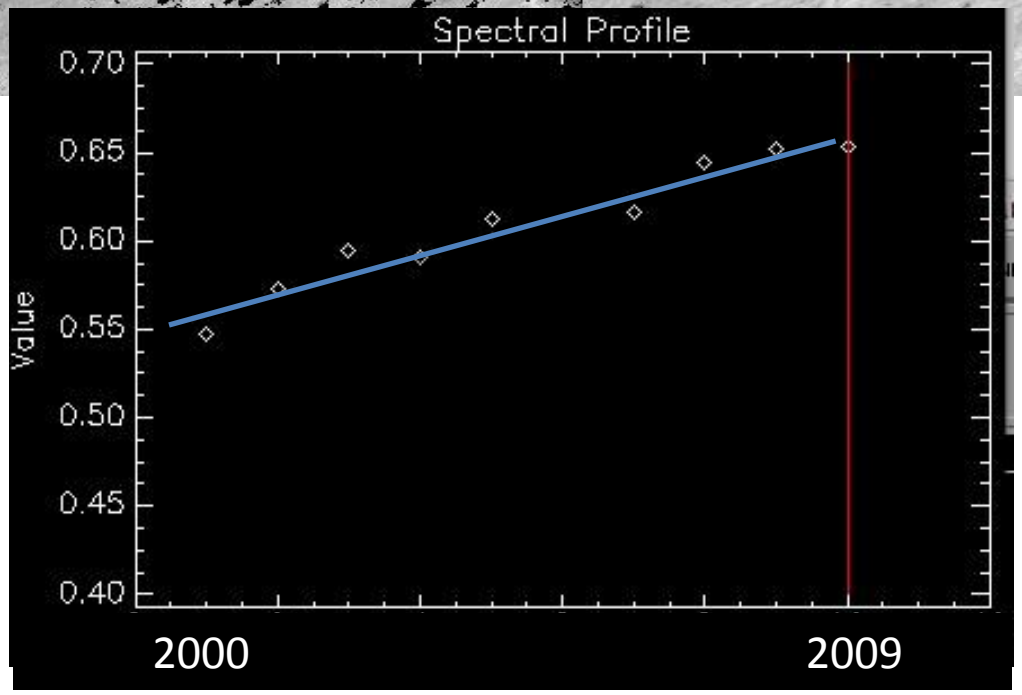
  0 = best quality, full inversion
  1 = good quality, full inversion
  2 = magnitude inversion (number of observations > 7)
  3 = magnitude inversion (number of observations >=3 & <7)
  4 = fill value

- Used LINFIT to calculate per-pixel regression through 2000-2009 NDVI
  - Assessed each DOY epoch separately
  - Required at least 7 out of 10 valid observations in time series
  - Statistical significance assessed with T-test
  - T statistic for trend = (slope) / (std_error)
  - Assessed confidence at p=0.05 level

- Aggregated significant trends into single map



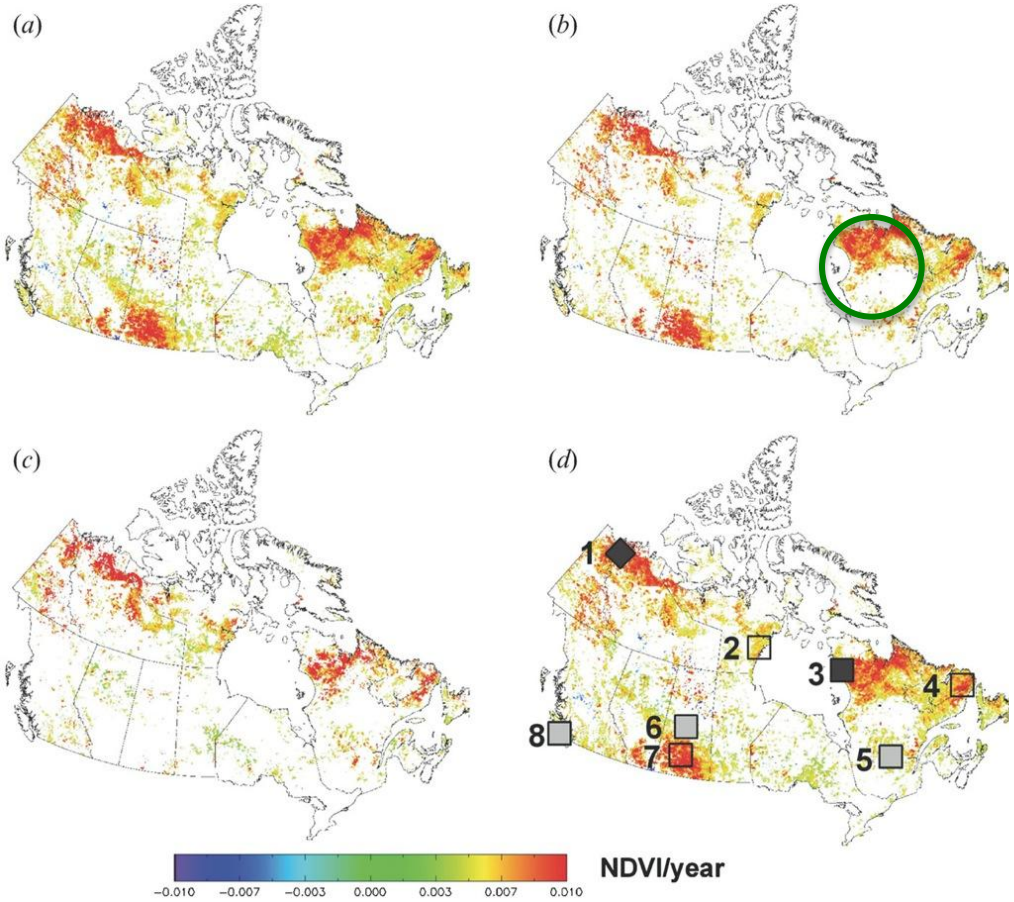




MODIS NBAR NDVI

~ 0.01 NDVI/yr

Pouliot et al., Trends in vegetation NDVI from 1km AVHRR over Canada for the period 1985-2006, IJRS, 30, 149-168



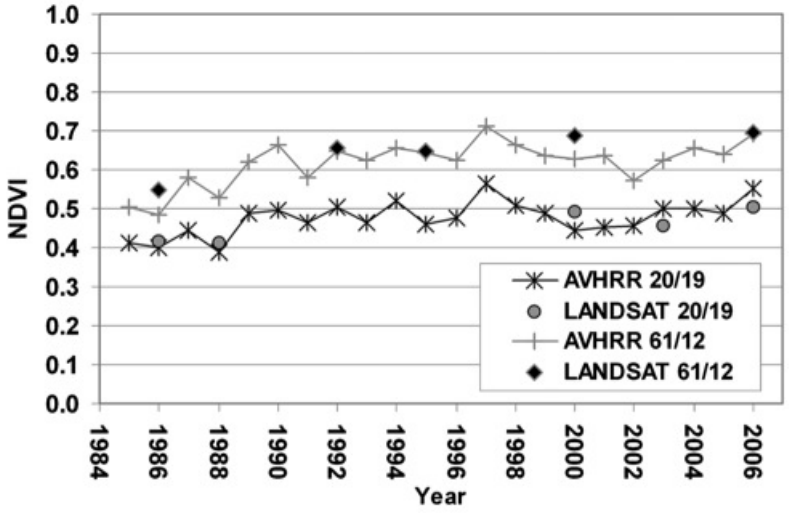
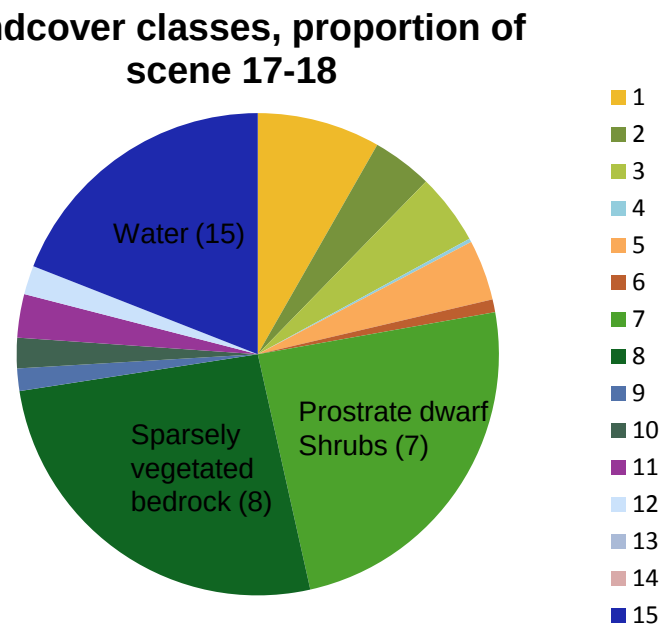
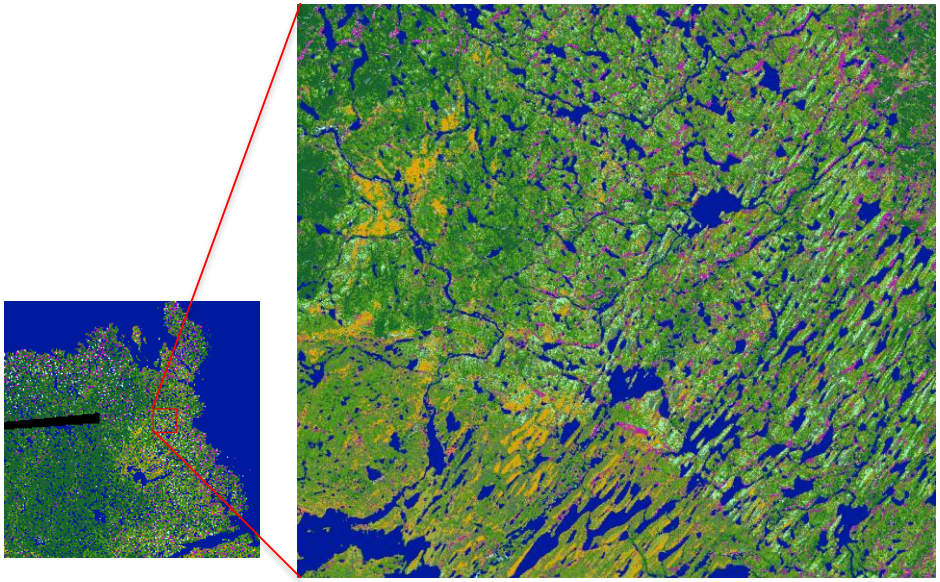
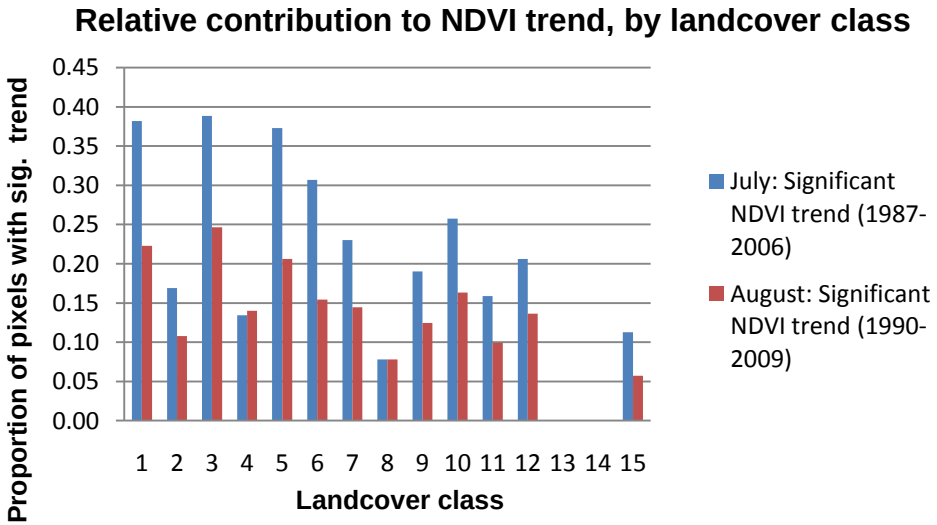


Figure 3. Statistically significant trends in NDVI/year. (a) MK test at 90% confidence, (b) MK test at 95% confidence, (c) t-PST test at 95% confidence, and (d) areas that were analysed to evaluate the influence of climate and land cover change on trends. Dark grey identifies areas where an atmospherically corrected Landsat time series was available. Light grey identifies areas where a land cover time series was available.

Preliminary analysis: NDVI trend by landcover class







CCRS Northern Land Cover Classification Legend

I. Graminoid dominated
- 1 Tussock graminoid tundra (<25% dwarf shrub)
- 2 Wet sedge
- 3 Moist to dry non-tussock graminoid/dwarf shrub tundra
- 4 Dry graminoid prostrate dwarf shrub tundra

II. Shrub dominated (.25% cover)
- 5 Low shrub (<40 cm; >25% cover)
- 6 Tall shrub (>40 cm; >25% cover)
- 7 Prostrate dwarf shrub

III. Sparse vegetation (2-10% cover)
- 8 Sparsely vegetated bedrock
- 9 Sparsely vegetated till-colluvium
- 10 Bare soil with cryptogam crust- frost boils

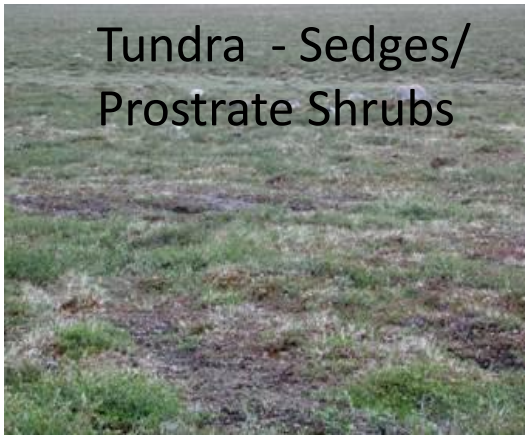
IV. Wetlands
- 11 Wetlands

V. Non-vegetated
- 12 Barren
- 13 Ice/snow
- 14 Shadow
- 15 Water

So What's Going On…

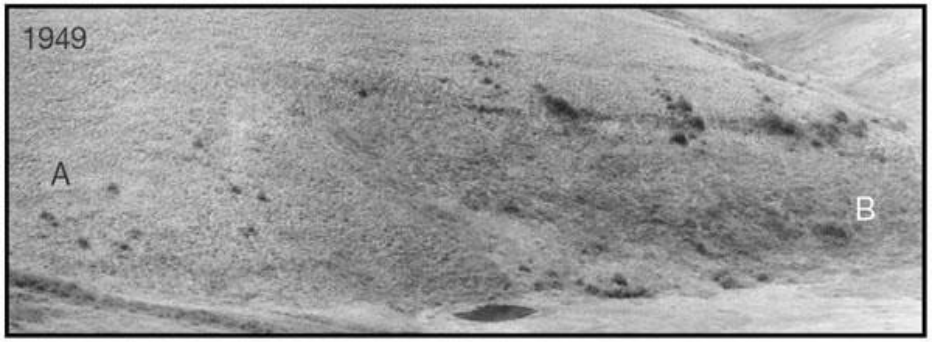
Increased mid-summer cover and/or LAI in both grass- and shrub-dominated regions

Hypothesis: Shrub expansion into tundra; has been observed in Alaska and Europe



courtesy CCRS

Shrubs =
deeper winter snow
= greater insulation
= earlier root/microbal activity
+ albedo feedback => earlier snowmelt



Sturm, M., Racine, C., and Tape, K. (2001) Increasing shrub abundance in the arctic. Nature, 411: 1251-1256.

Conclusions

Landsat + MODIS + AVHRR provide strong evidence for recent greening in northern Quebec

- Peak-summer phenomenon (not just phenology or snow)
- Rates up to 0.01 NDVI/yr (0.005 more typical)
- Increased cover and/or LAI of both grasses and shrubs
- Possibly related to shrub encroachment into tundra?

The Landsat archive, when combined with other RS and field data sources, provides a critical tool for characterizing climate-driven shifts in global vegetation patterns