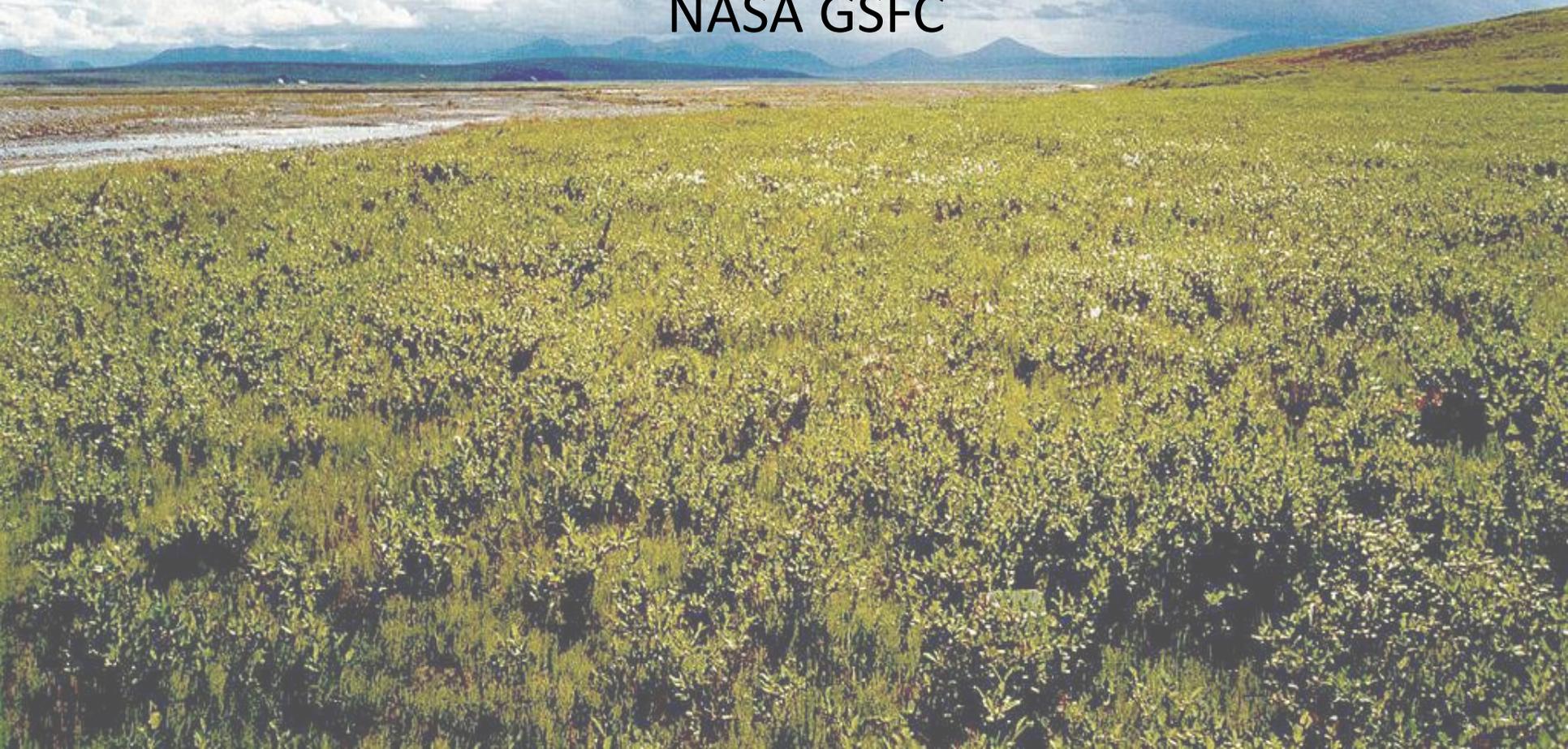


# Landsat NDVI Trend in Canada and Alaska

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# Background

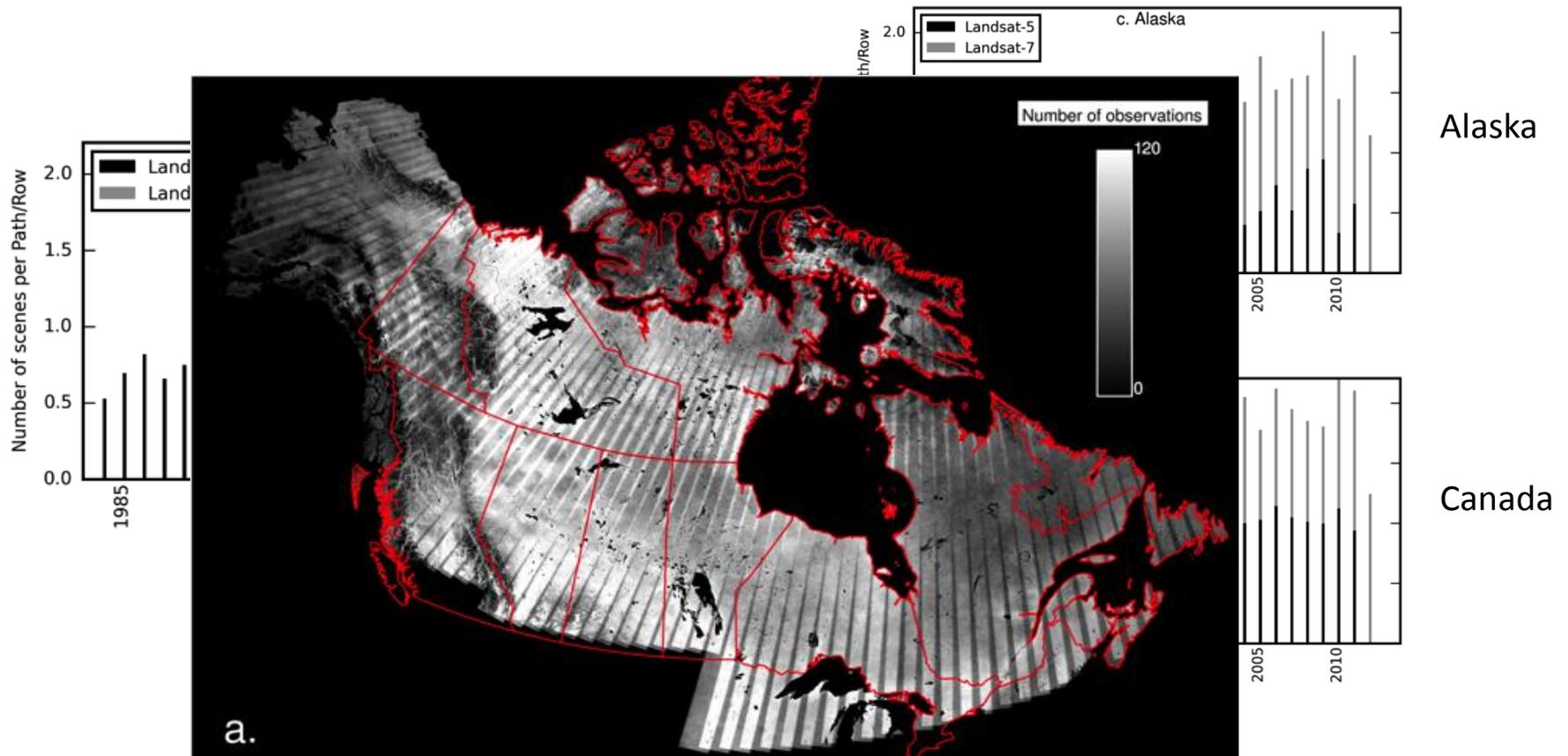
- Multiple studies of high-latitude “greening” from AVHRR datasets
  - *One of our clearest examples of climate-driven vegetation change in unmanaged ecosystems*
- Regional studies with Landsat, air photos, and ground observations
- Objective: prepare a Landsat-based continental assessment of NDVI trend
  - Are the spatial patterns similar to those found with AVHRR?
  - Can finer-resolution Landsat information inform process understanding?

# Methods

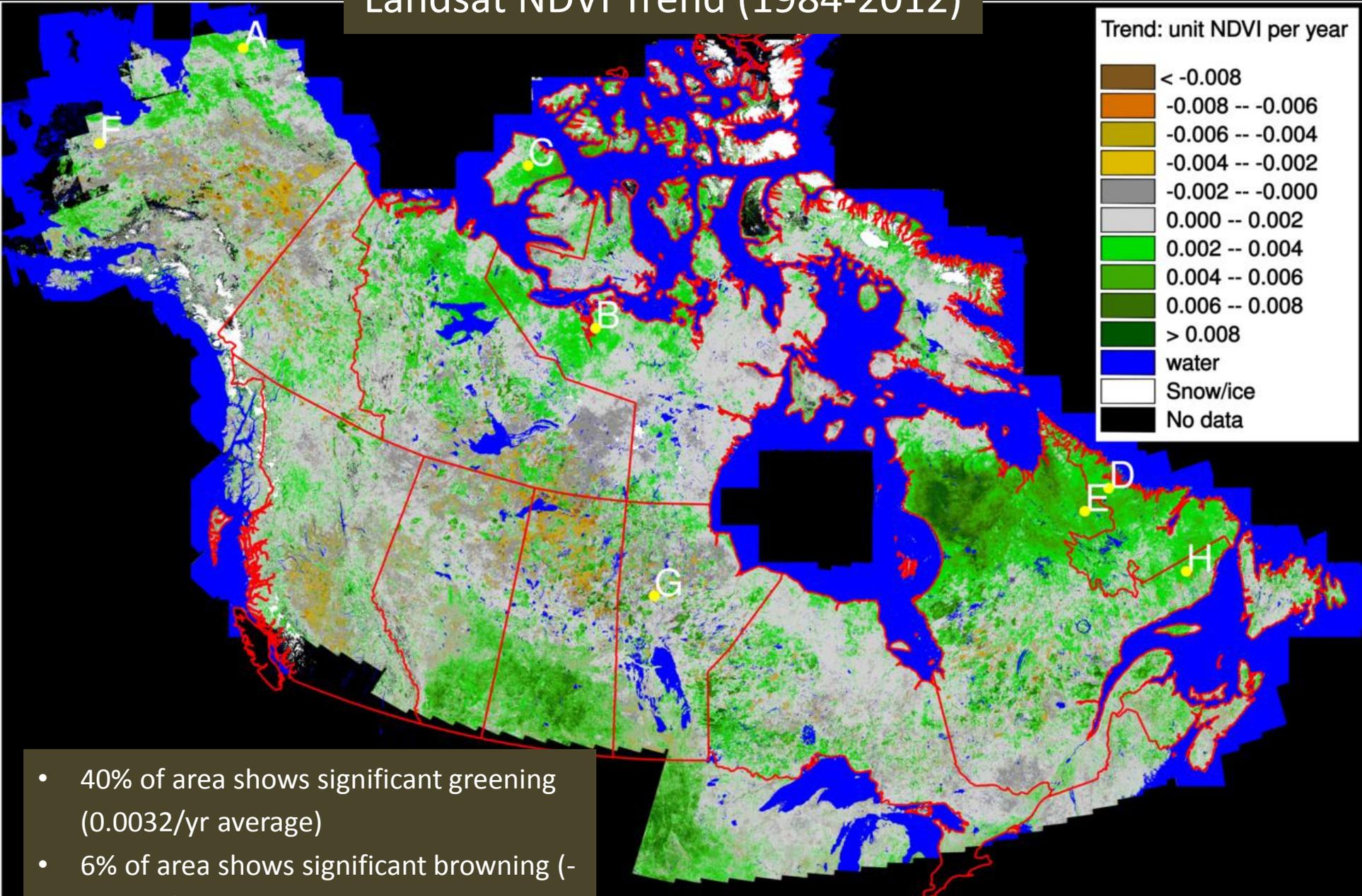
- Assembled per-pixel NDVI time series for Canada & Alaska from Landsat-5, -7 SR data (1984-2012)
  - Mid-summer data (Jul 1- Aug 31)
  - Excluded cloud, shadow, snow/ice
  - Required at least 2 valid observations in each of three sub-segments of time series in order to calculate trend
- Derived temporal trend via linear regression and assessed significance via T-test
- Identical analysis carried out using GIMMS3g AVHRR dataset for comparison

# Landsat Data Availability

- 1295 path/row locations
- All L5, L7 images between July 1 and Aug 31 with < 80% cloud cover
- 55,200 scenes used

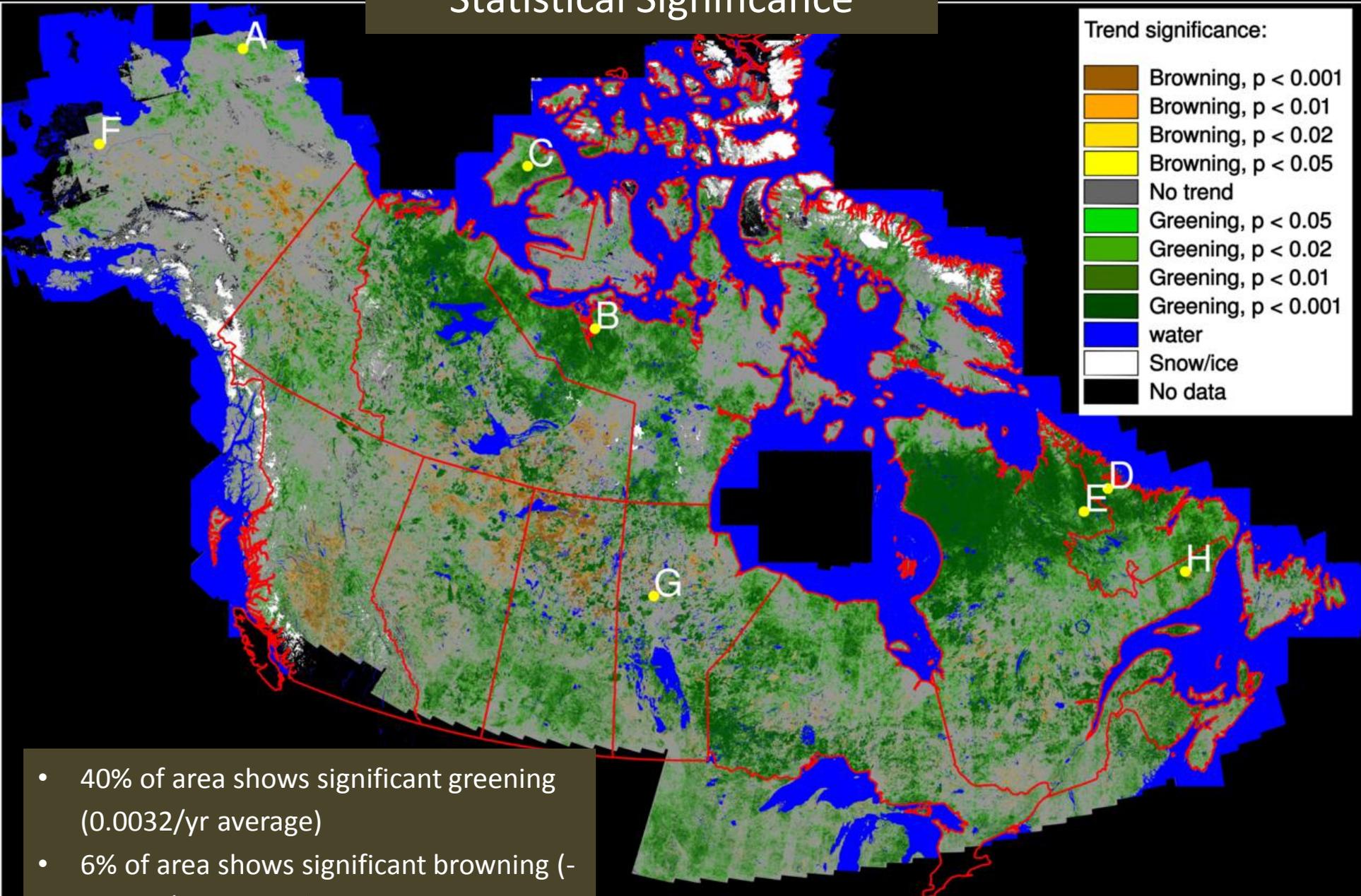


# Landsat NDVI Trend (1984-2012)



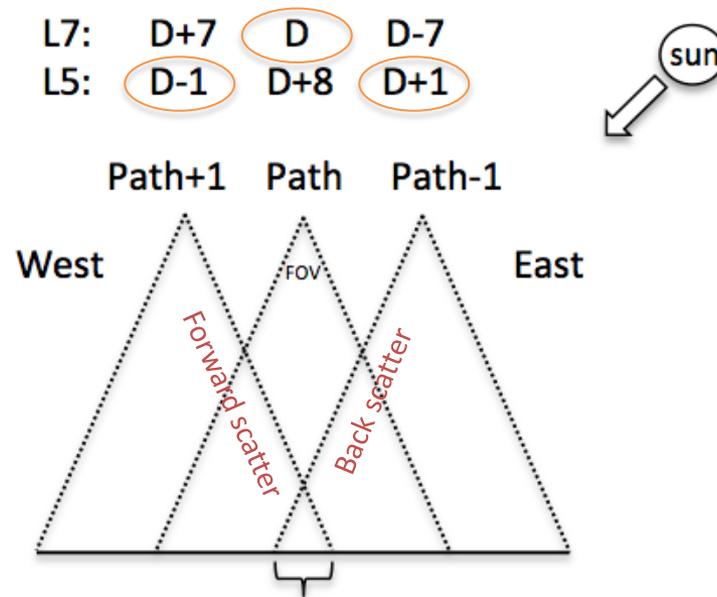
- 40% of area shows significant greening (0.0032/yr average)
- 6% of area shows significant browning (-0.0034/yr average)

# Statistical Significance



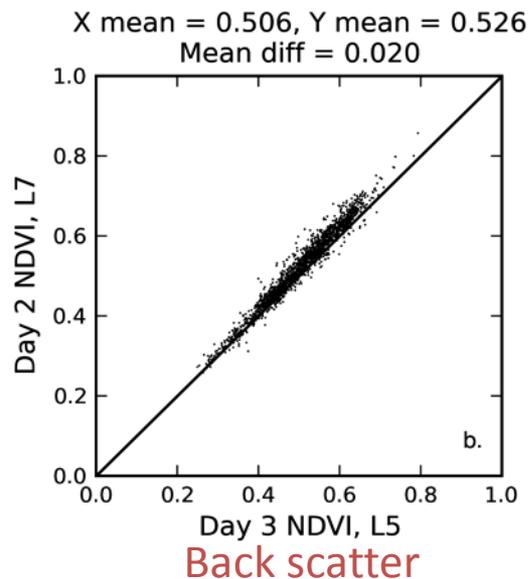
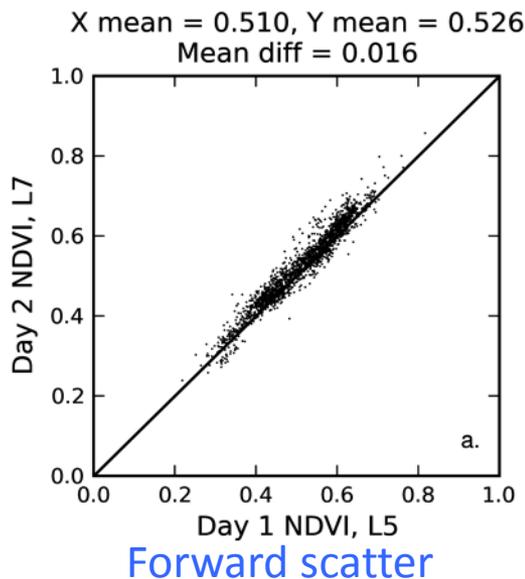
- 40% of area shows significant greening (0.0032/yr average)
- 6% of area shows significant browning (-0.0034/yr average)

# Checking L5/L7 NDVI Consistency: Multi-angle observations from Landsat

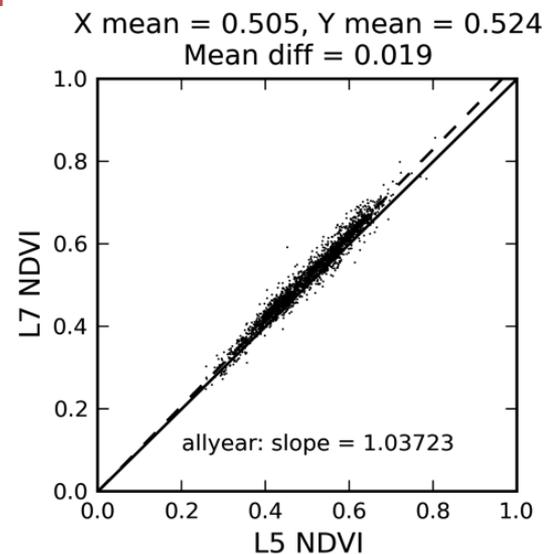


**Figure A1.** An illustration of the possibility of viewing the same ground area on three consecutive days from three contiguous WRS-2 paths by alternating Landsat 5 (L5) and Landsat 7 (L7) approximately above 54° latitude. If L7 overpasses the central path on day D, the ground area directly at nadir can also be observed off-nadir on days D-1 and D+1 from the two adjacent paths by L5. Observations are hence made from forward, nadir and backward scattering directions respectively on three consecutive days, D-1, D, and D+1, by L5, L7, and L5. The alternating satellite sequence can also be L7, L5, and L7. For clearer illustration, the sensor FOV in this diagram is greatly exaggerated; the sensor height and swath width are also not drawn to the scale.

Regardless of forward- or back-scatter direction, Landsat-5 NDVI based on SR is always lower than that of Landsat-7:



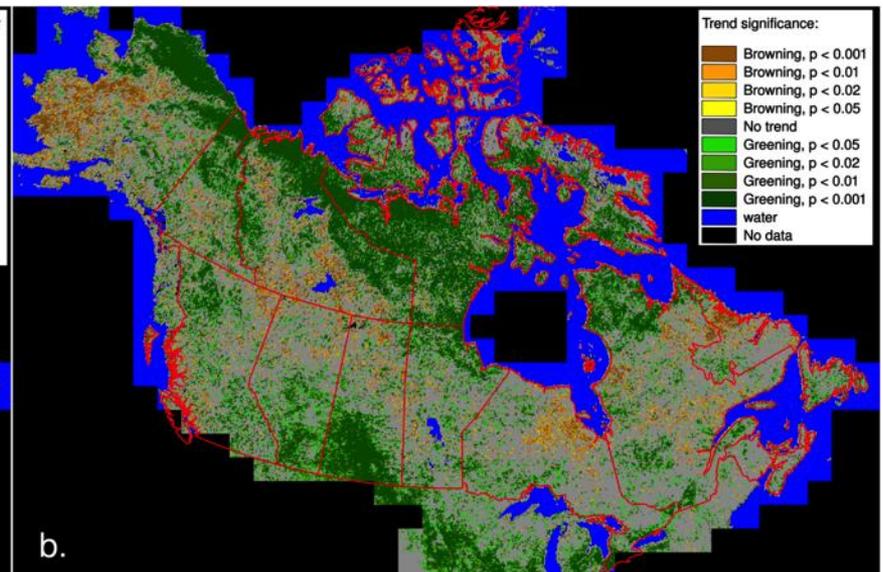
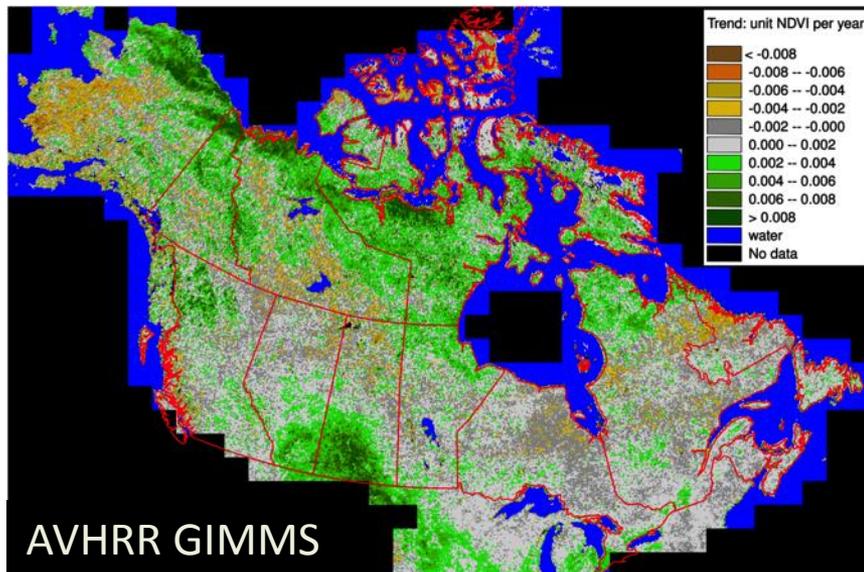
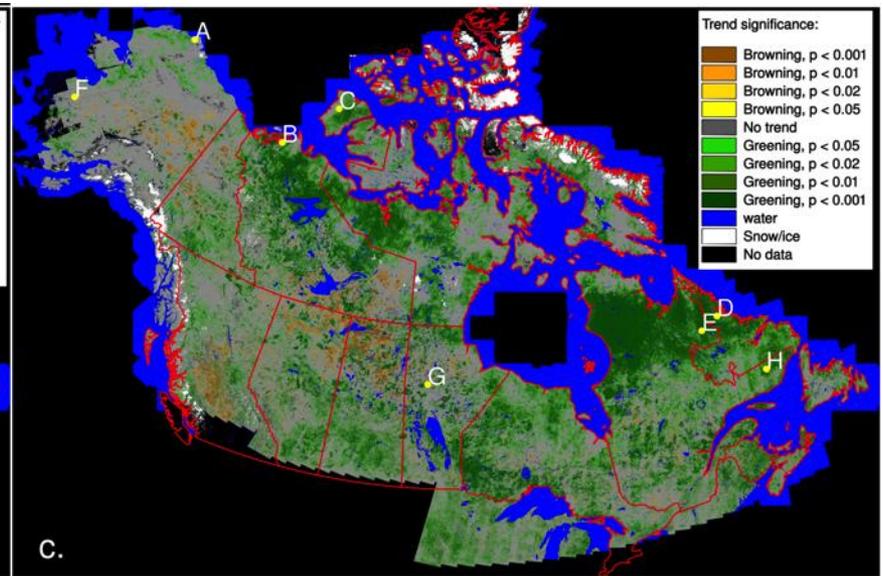
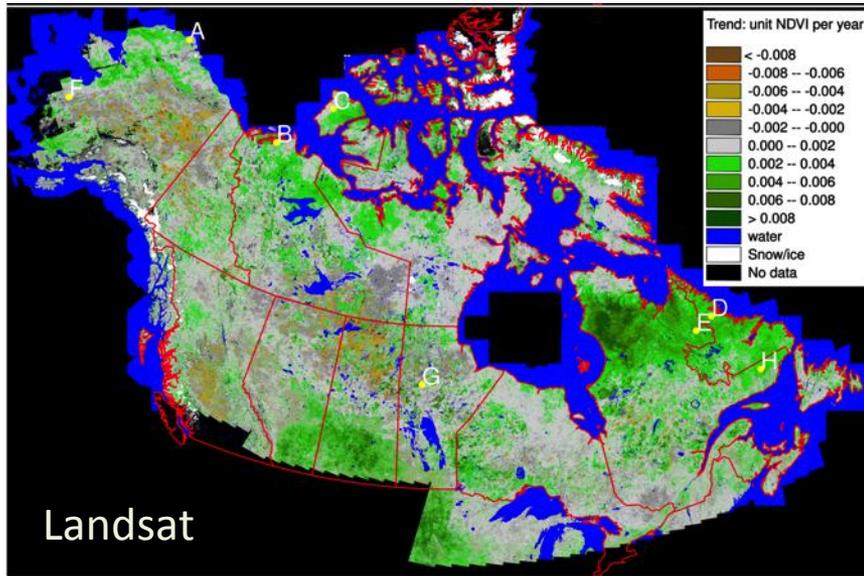
So, we implemented an empirical “gain change” of 1.037 to convert  $NDVI_{L5}$  to  $NDVI_{L7}$



# Comparison with GIMMS3g AVHRR Dataset

Trend

Significance



# A Closer Look...

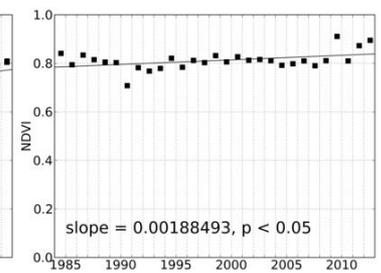
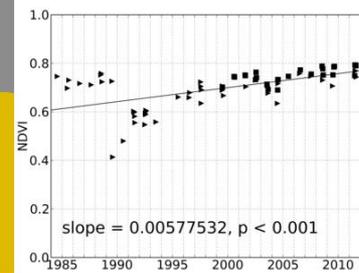
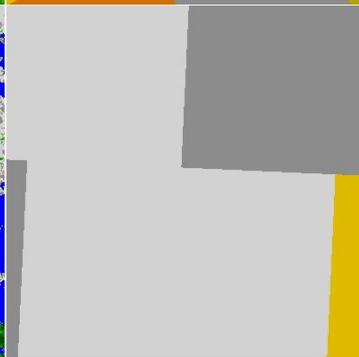
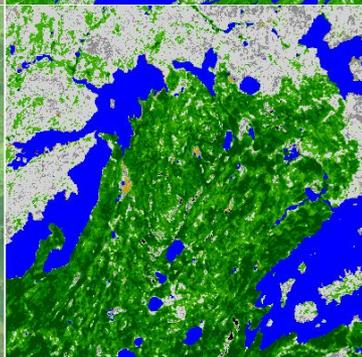
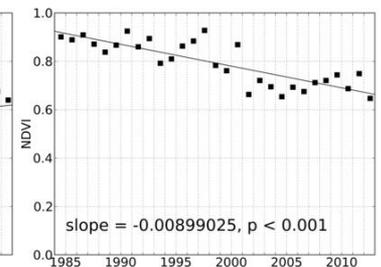
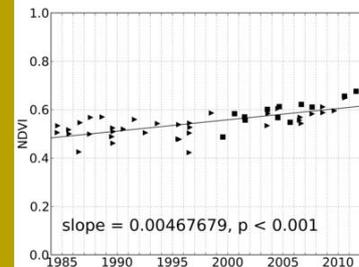
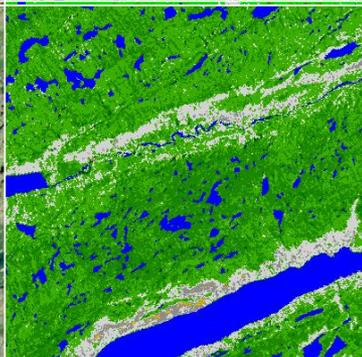
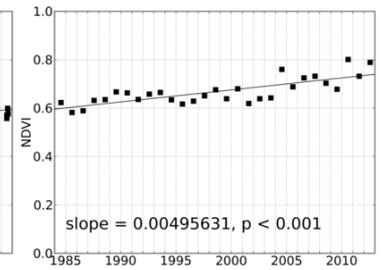
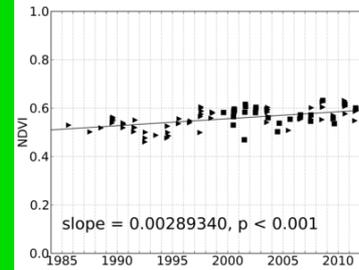
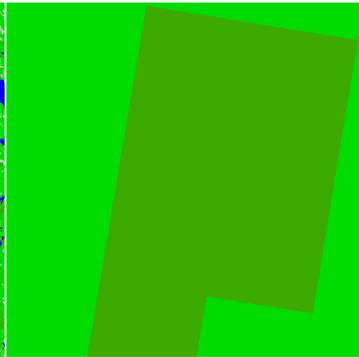
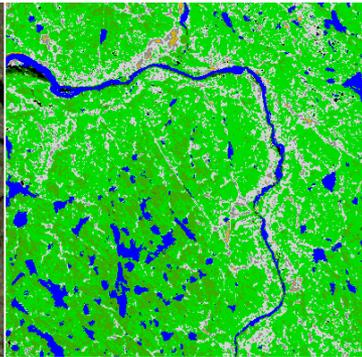
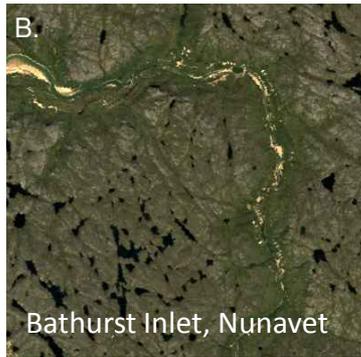
Landsat RGB

Landsat Trend

AVHRR Trend

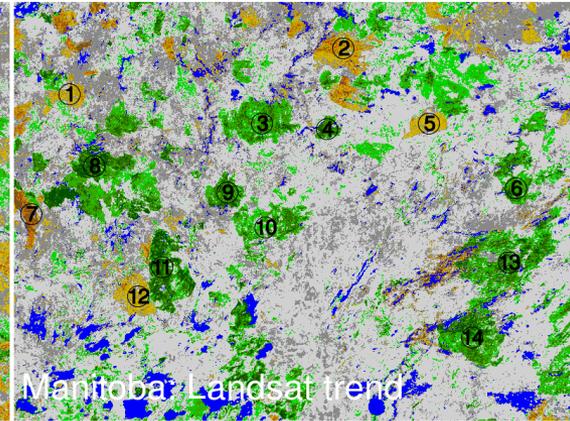
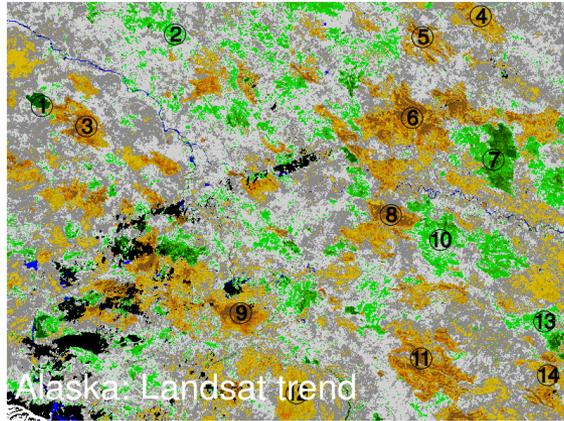
Landsat Trend  
(8km cell)

AVHRR Trend  
(8km cell)

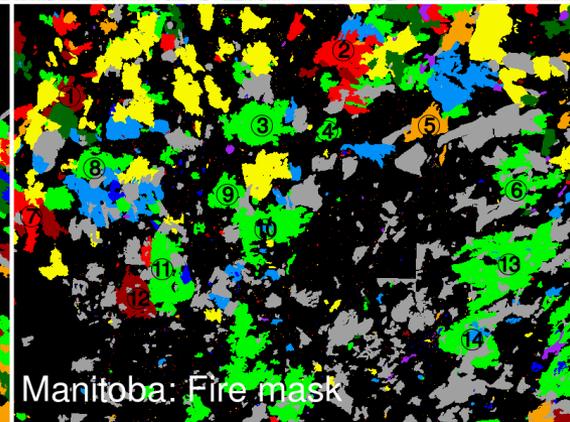
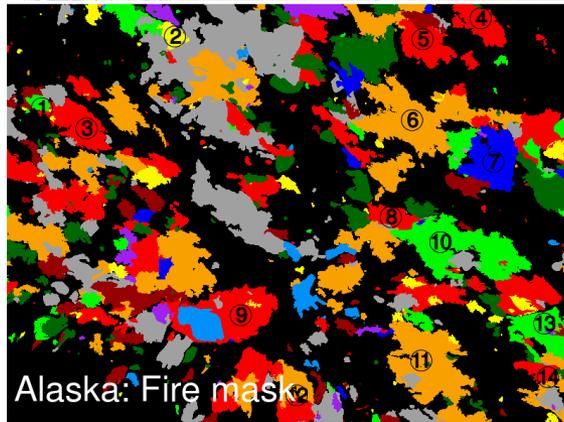


# Boreal Forest Trends Correspond to Burns & Recovery

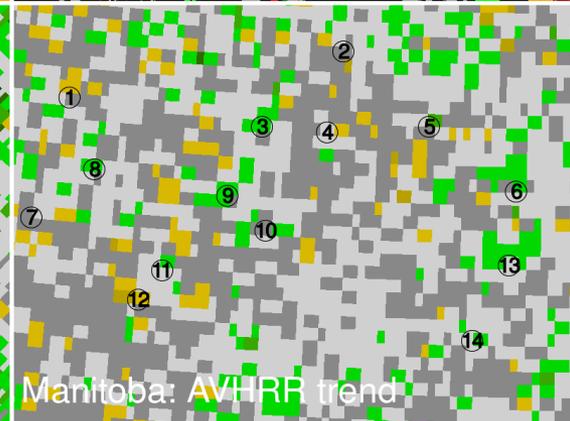
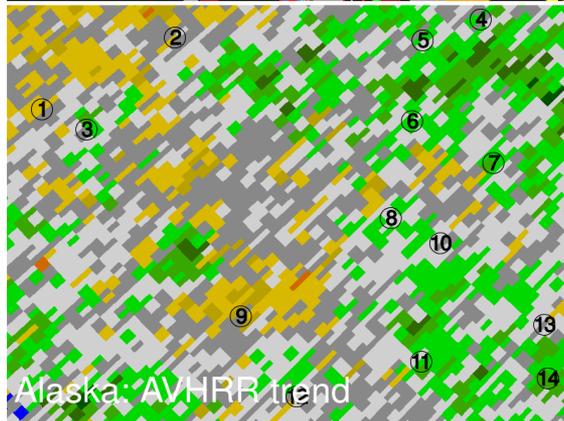
Landsat NDVI  
Trend



Fire History

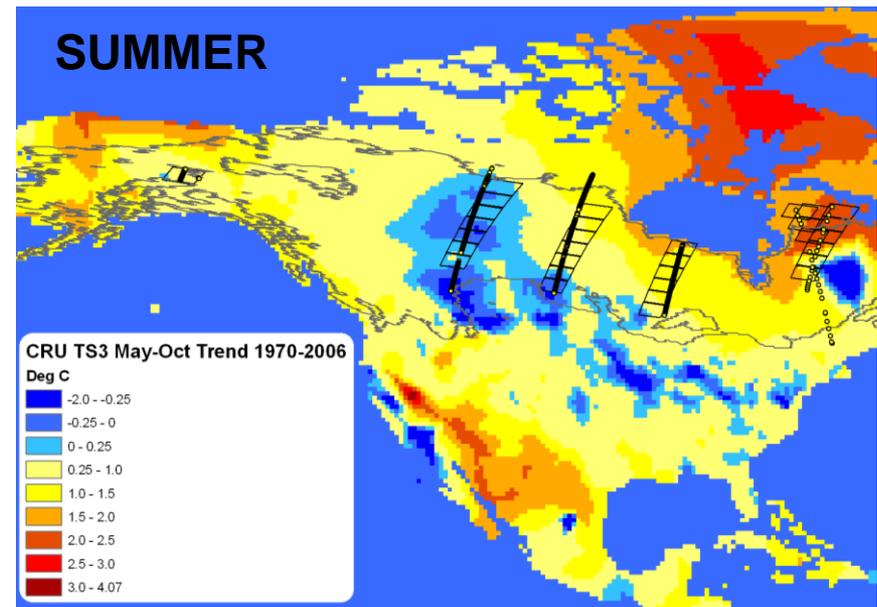
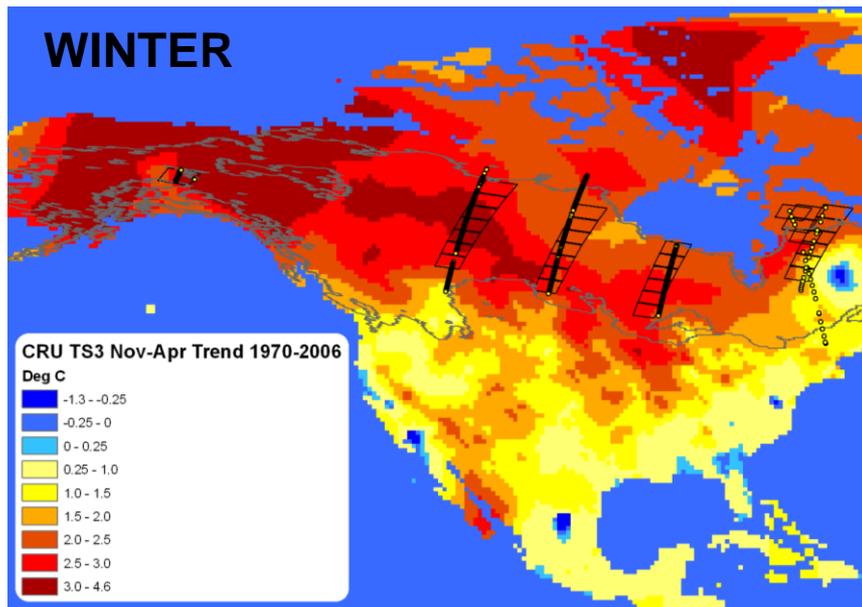


GIMMS3g



# Climate Trends (East Anglia CRU dataset)

- Most of Canada and Alaska has experienced rapid winter warming during the Landsat era (1970-2006)
- Only the area around Hudson Bay and Quebec has also experienced rapid Summer warming



# DGVM Predicted Trends in fPAR: 1972 – 2009

Total fPAR

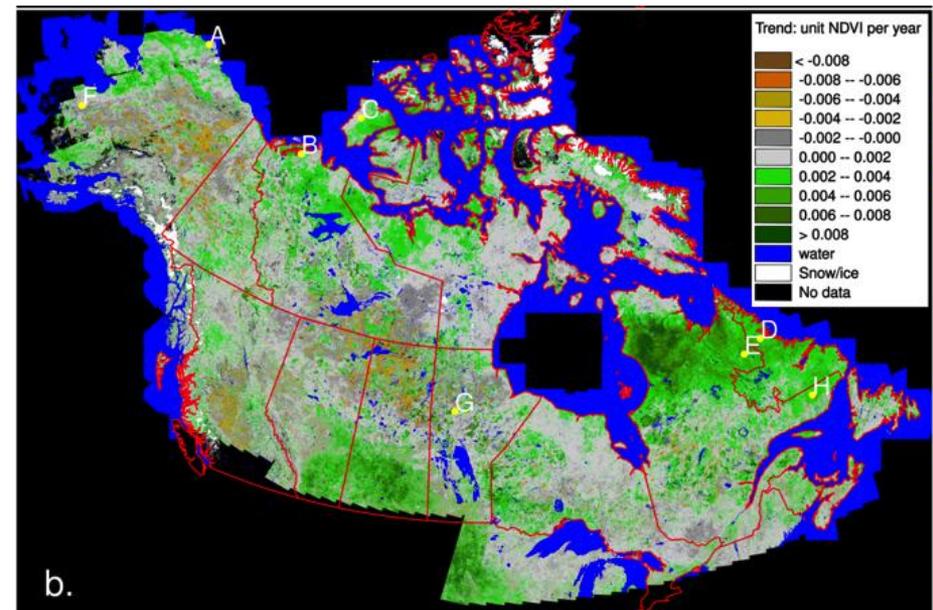
- Trend in total FPAR and individual functional types from Lund-Potsdam-Jena model

C3 Grass

- CRU TS3.1 climatology

Boreal  
Evergreen  
Needleaf

Boreal  
Deciduous  
Broadleaf



# Conclusions

- To first approximation, Landsat NDVI trends are similar to those from AVHRR GIMMS
  - Greening within tundra & agricultural regions
    - aligned with DGVM response to recent climate trends
    - Mid-summer NDVI corresponds to vegetation amount (LAI), not just growing season length
  - Apparent “browning” in Boreal forest mostly due to fire and insects
- But, on closer examination, differences are apparent
  - Rapid changes in Quebec (summer + winter warming?)
  - Less pronounced changes in Alaska & Nunavut

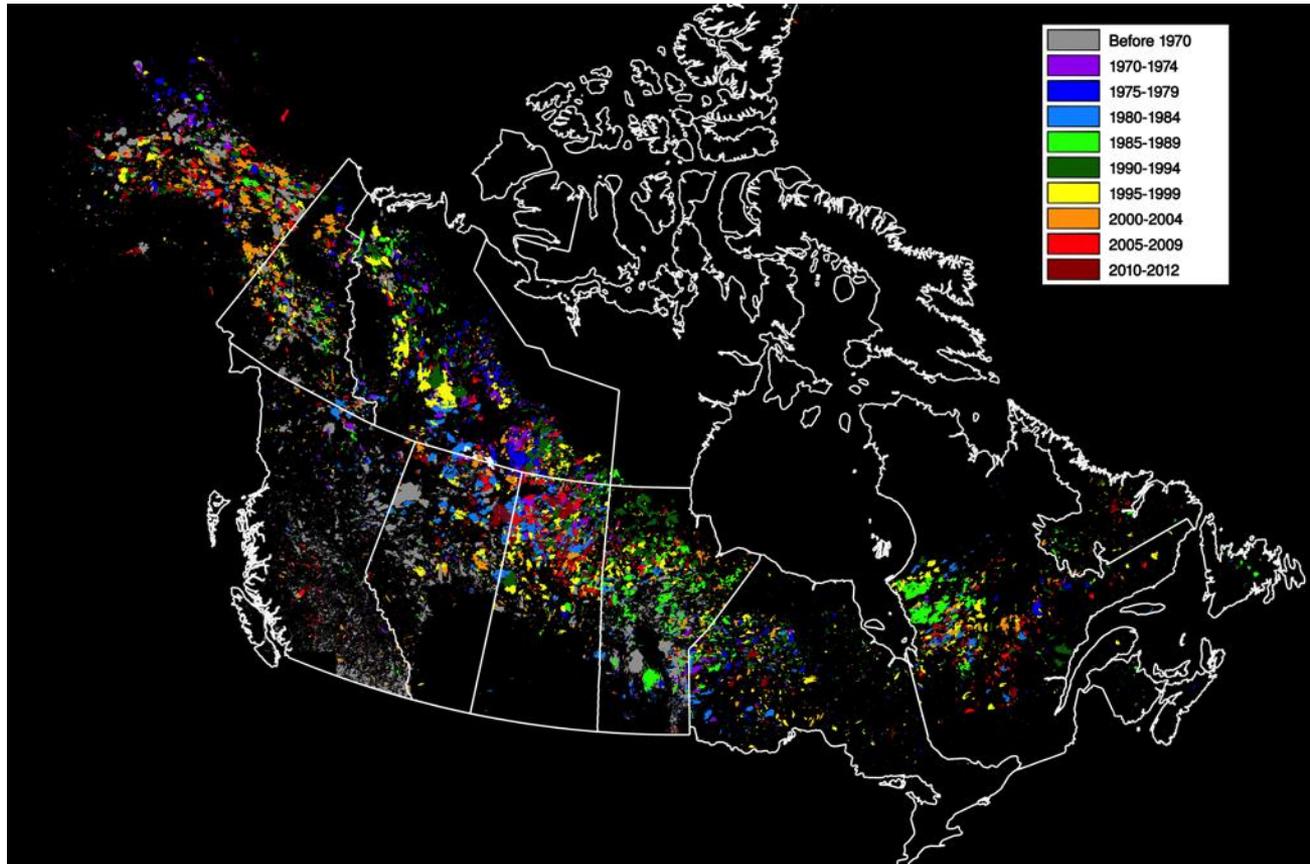
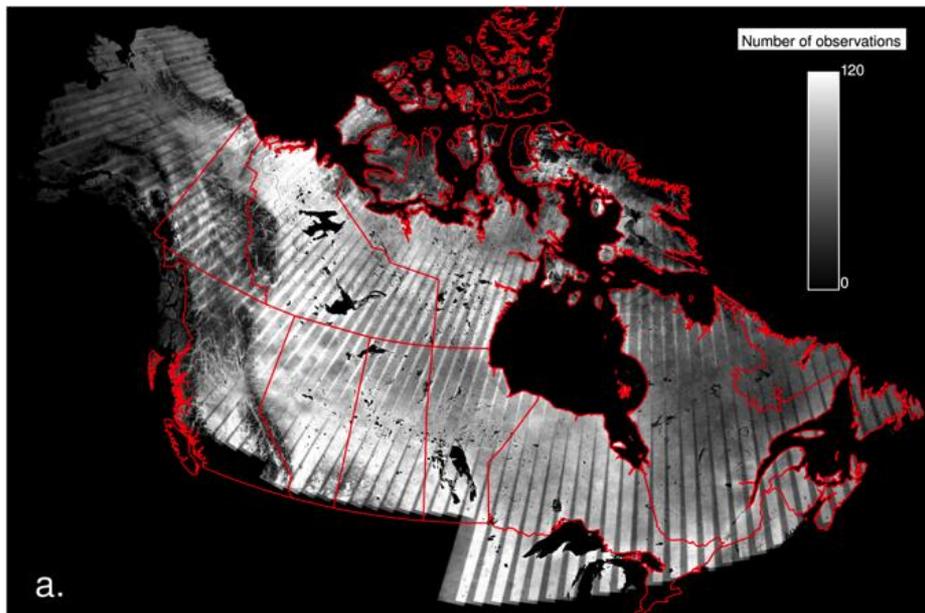


Figure 4. The fire perimeters in the forested area. Dates of fire occurrence were aggregated into 5-year intervals in this illustration. Results are presented as browse images with a 500-m pixel size. Derived from Canadian National Fire Database.

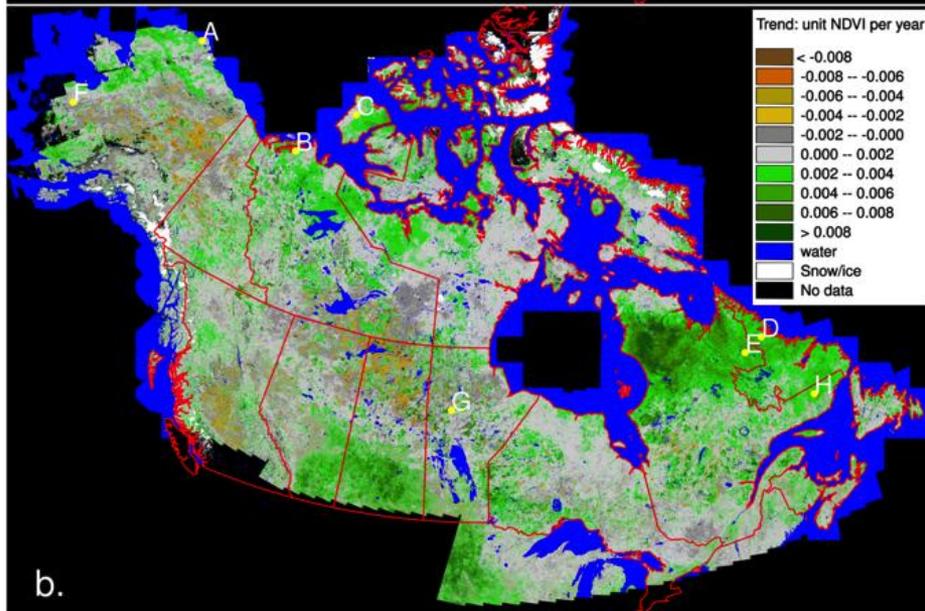
Number of valid observations available (1984-2012)



a.

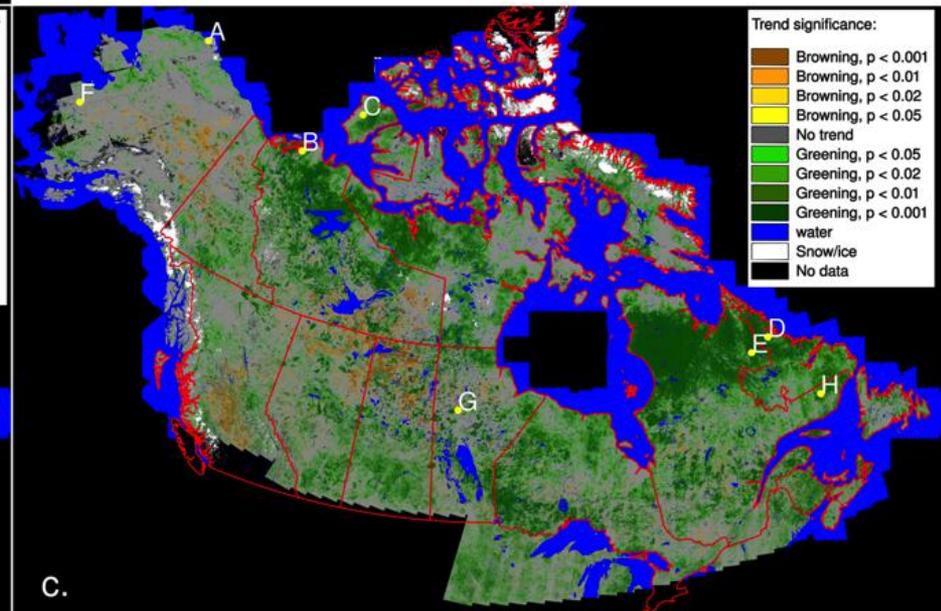
## Landsat NDVI Trends

- 40% of area shows significant greening (0.0032/yr average)
- 6% of area shows significant browning (-0.0034/yr average)
- Coherent Geographic Patterns
  - *Tundra greening*
  - *Mixed/no signal in Boreal forest*
  - *Greening in southern agricultural regions*



b.

Landsat NDVI linear trend (1984-2012)



c.

Statistical significance