



Photo: Katie Orndahl

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Patrick Burns ¹

Rosanne D'Arrigo ⁵

Scott Goetz ¹

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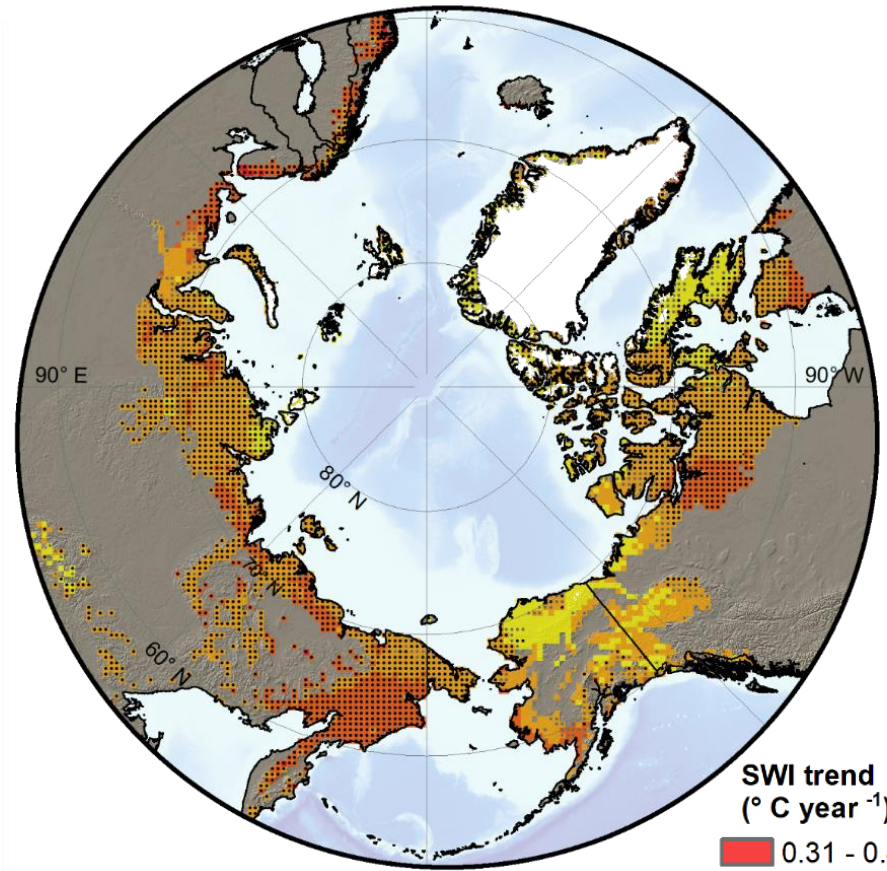
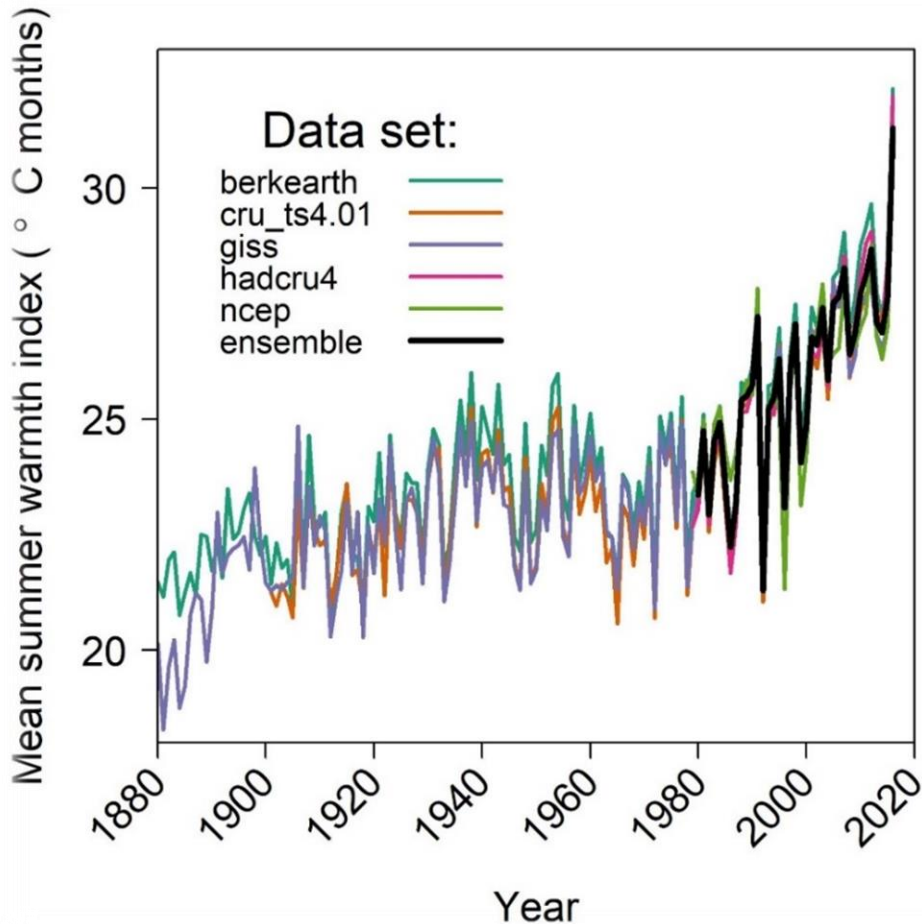
⁵ Columbia University

Greening of the tundra biome

Arctic tundra: cold but rapidly warming

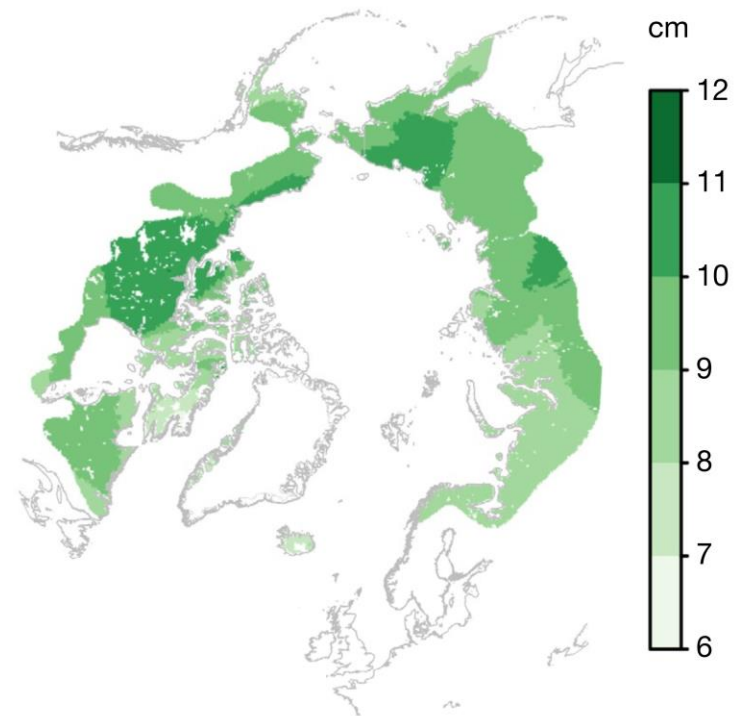
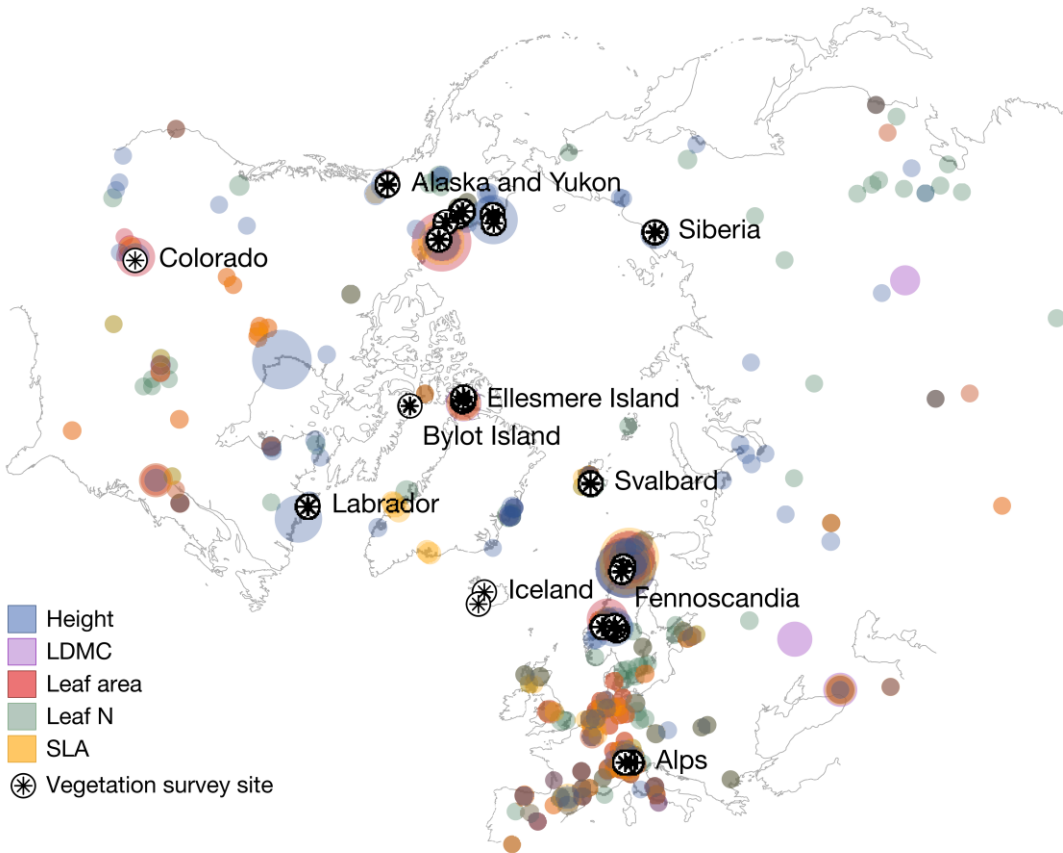
$$\text{Summer warmth index} = \sum T_{avg} > 0^\circ \text{C}$$

Trends from 1982 to 2016



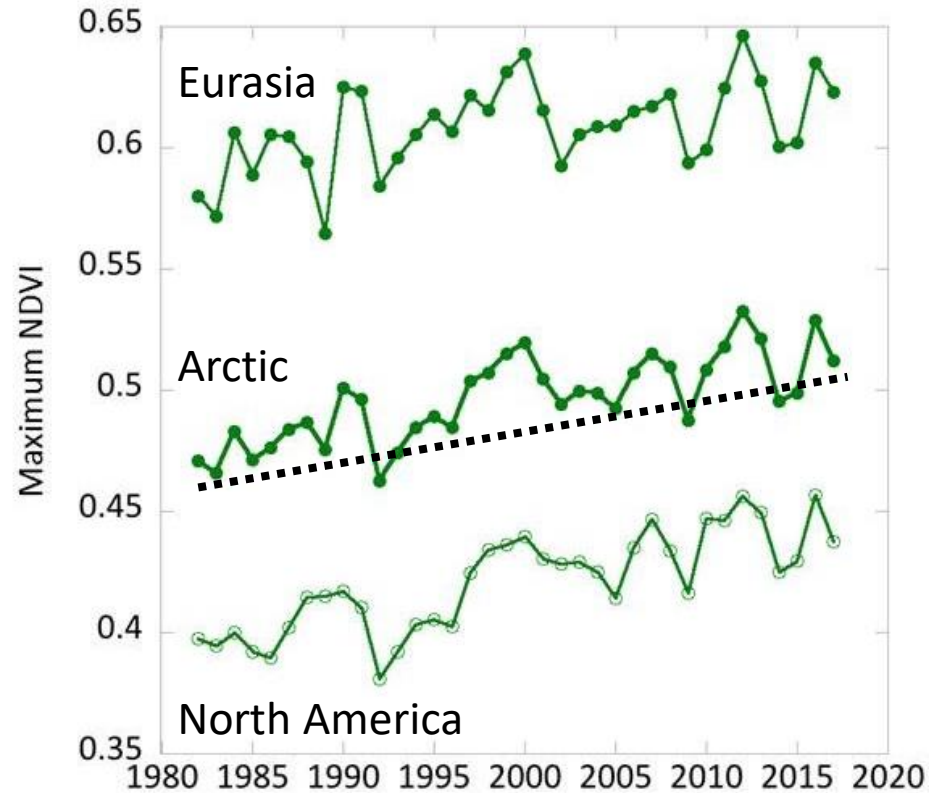
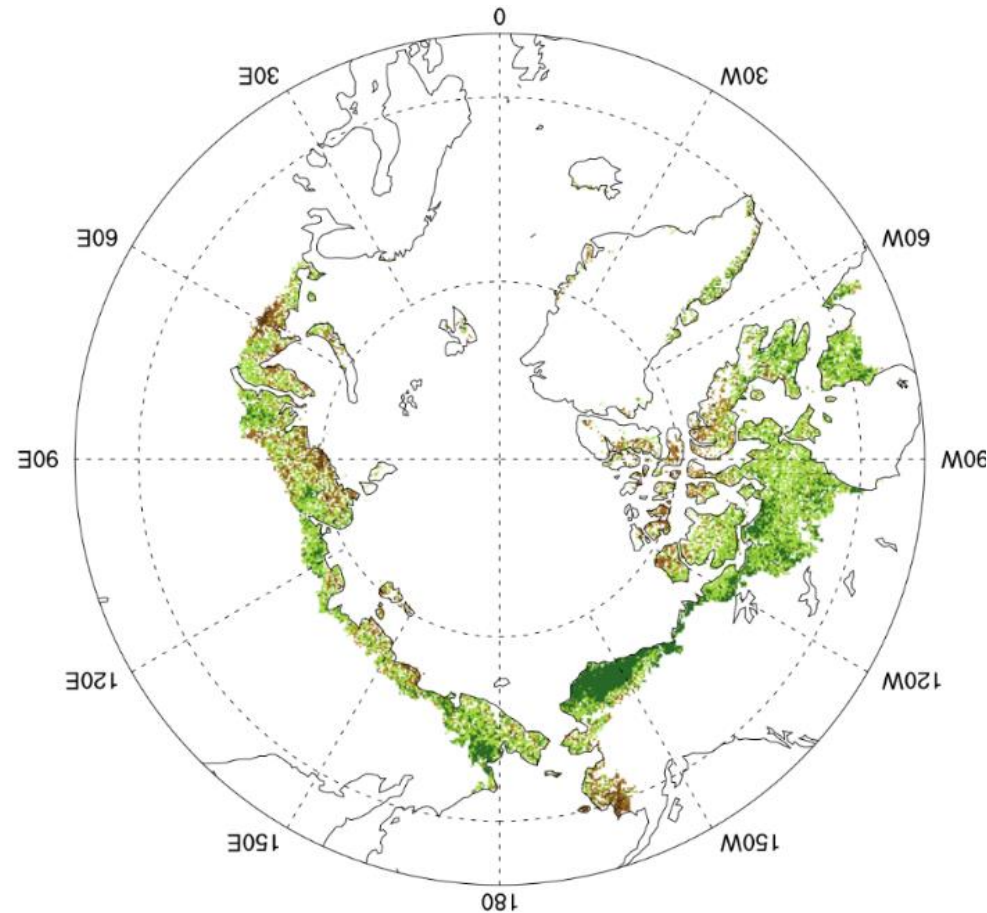
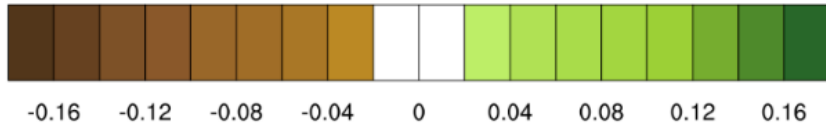
Plant communities growing taller

Predicted changes in plant height from 1979 - 2016



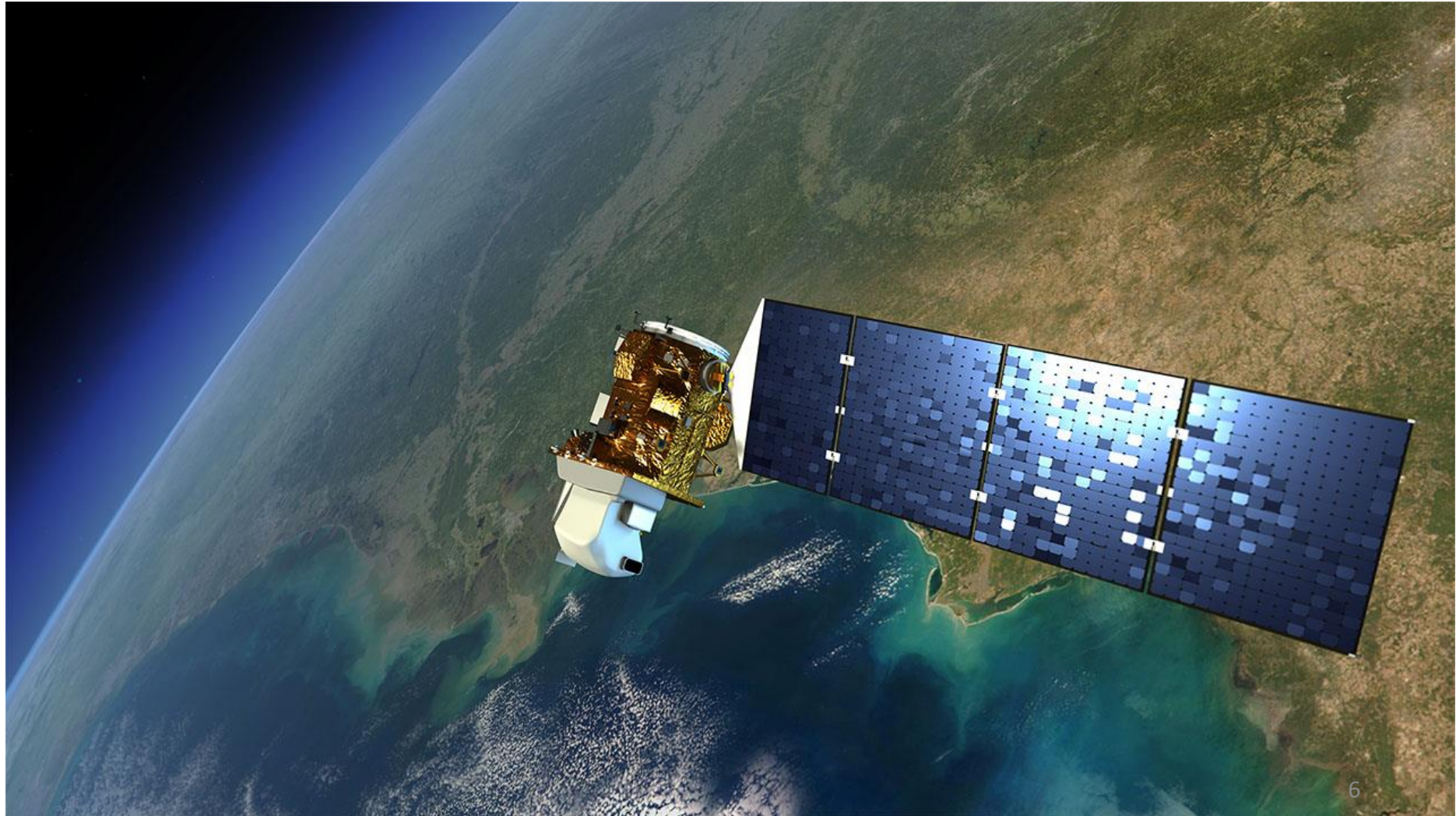
AVHRR NDVI shows *greening* of the Arctic

Change in maximum NDVI from 1982 - 2016



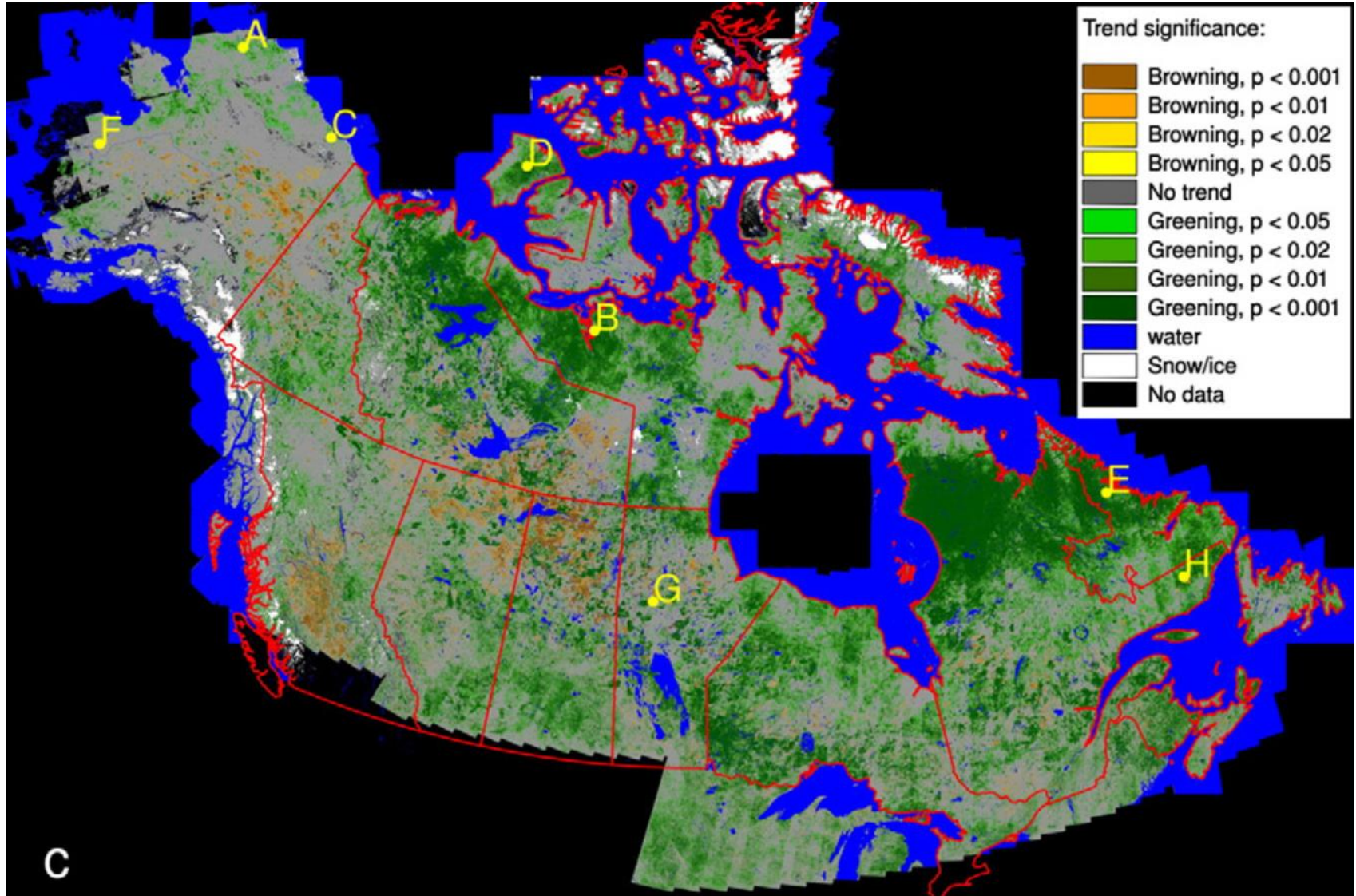
Landsat unleashed

Global vegetation monitoring at 30 m resolution since 1980s



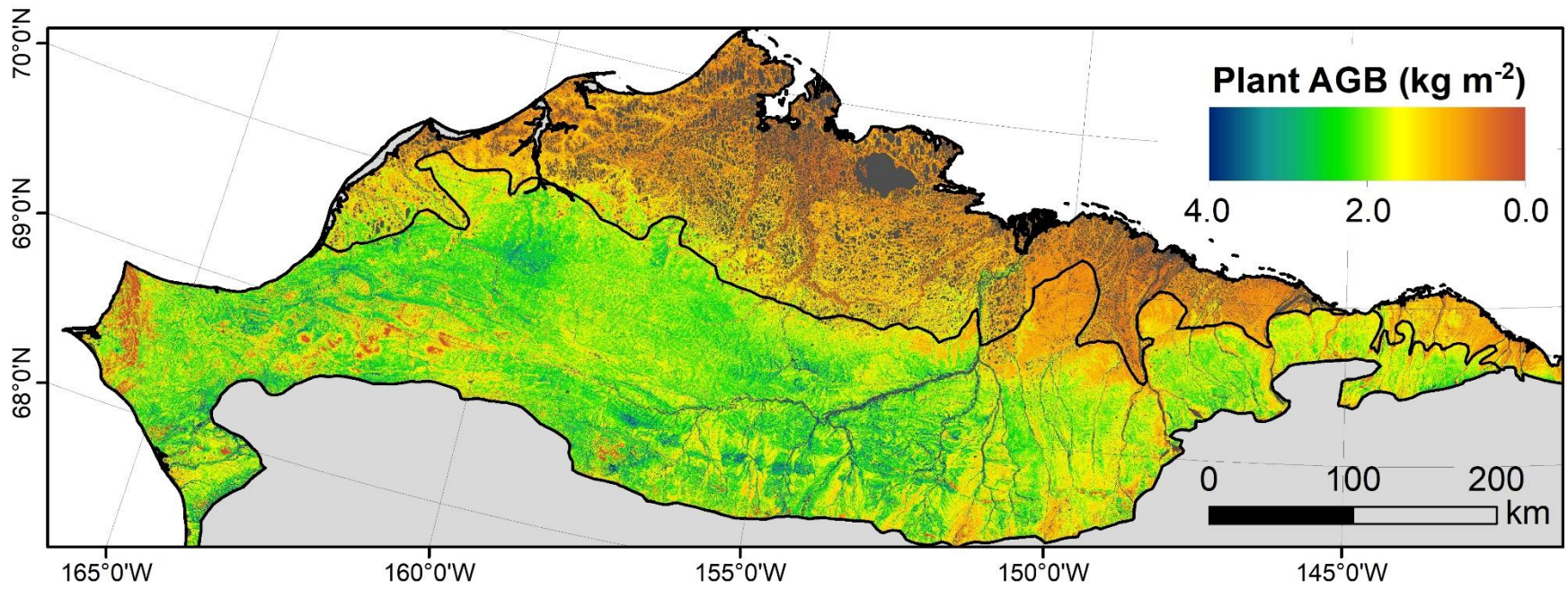
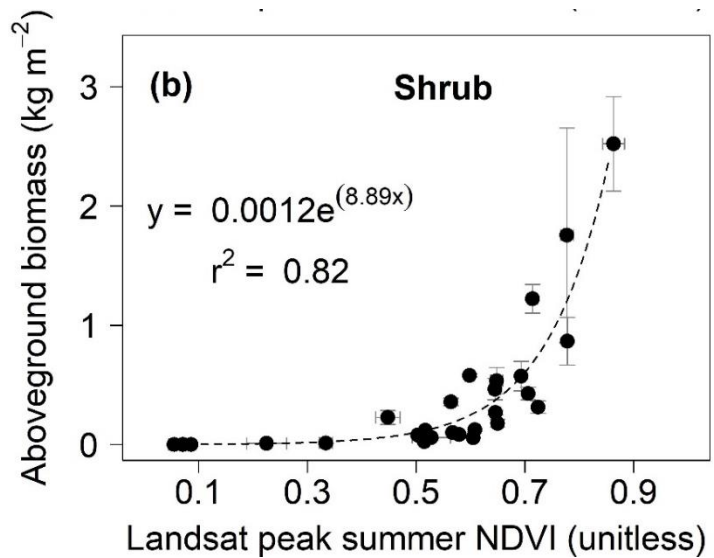
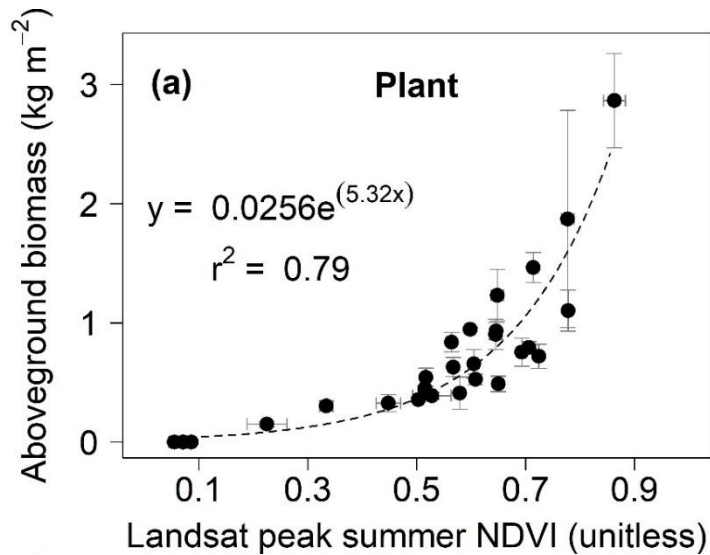
Landsat NDVI trends

Changes in July-August NDVI from 1984 to 2012

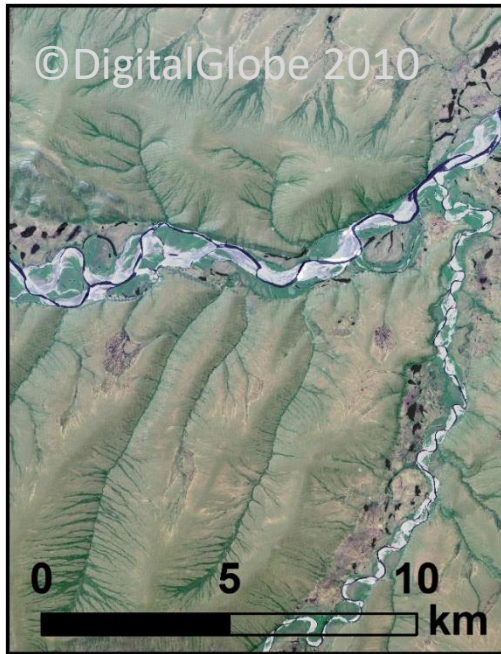


Ju and Masek 2016 RSE

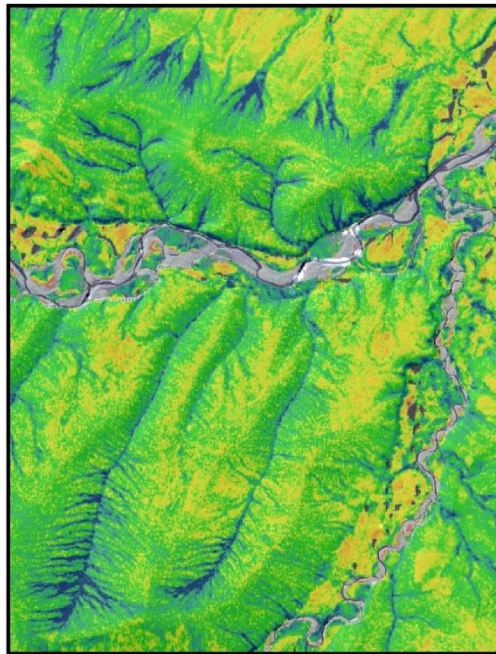
Landsat NDVI tracks tundra plant biomass



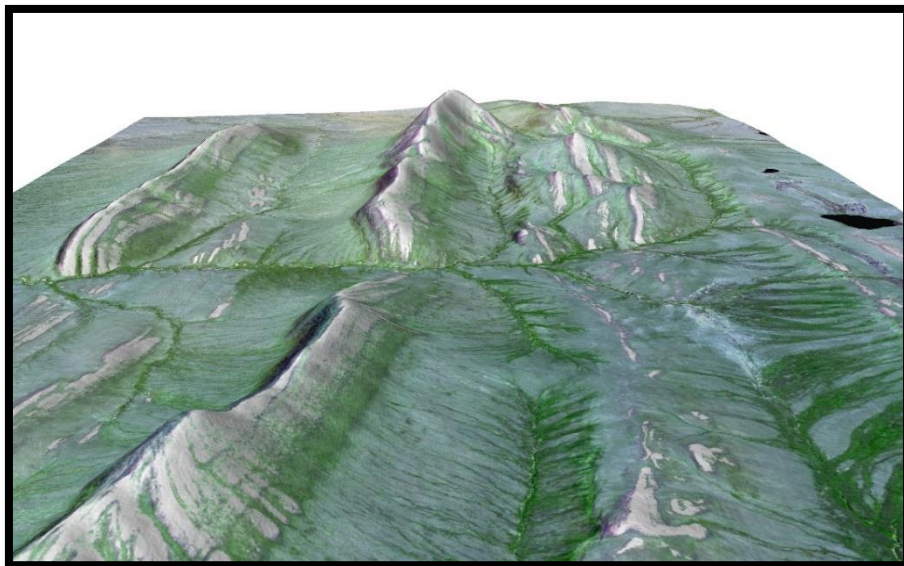
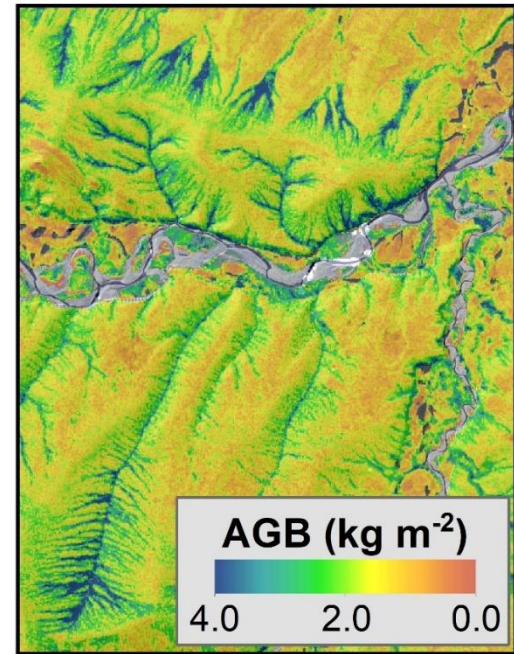
GeoEye-1 image



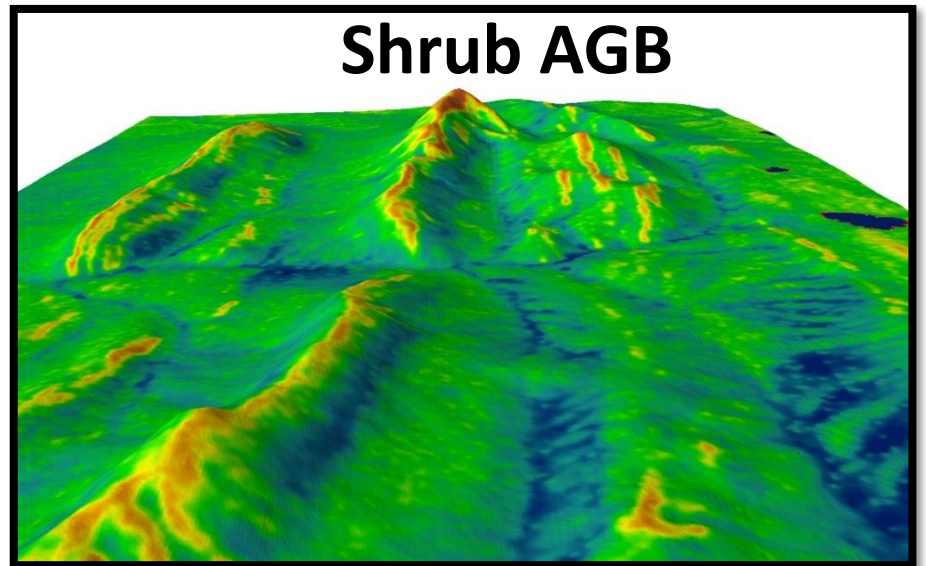
Plant AGB



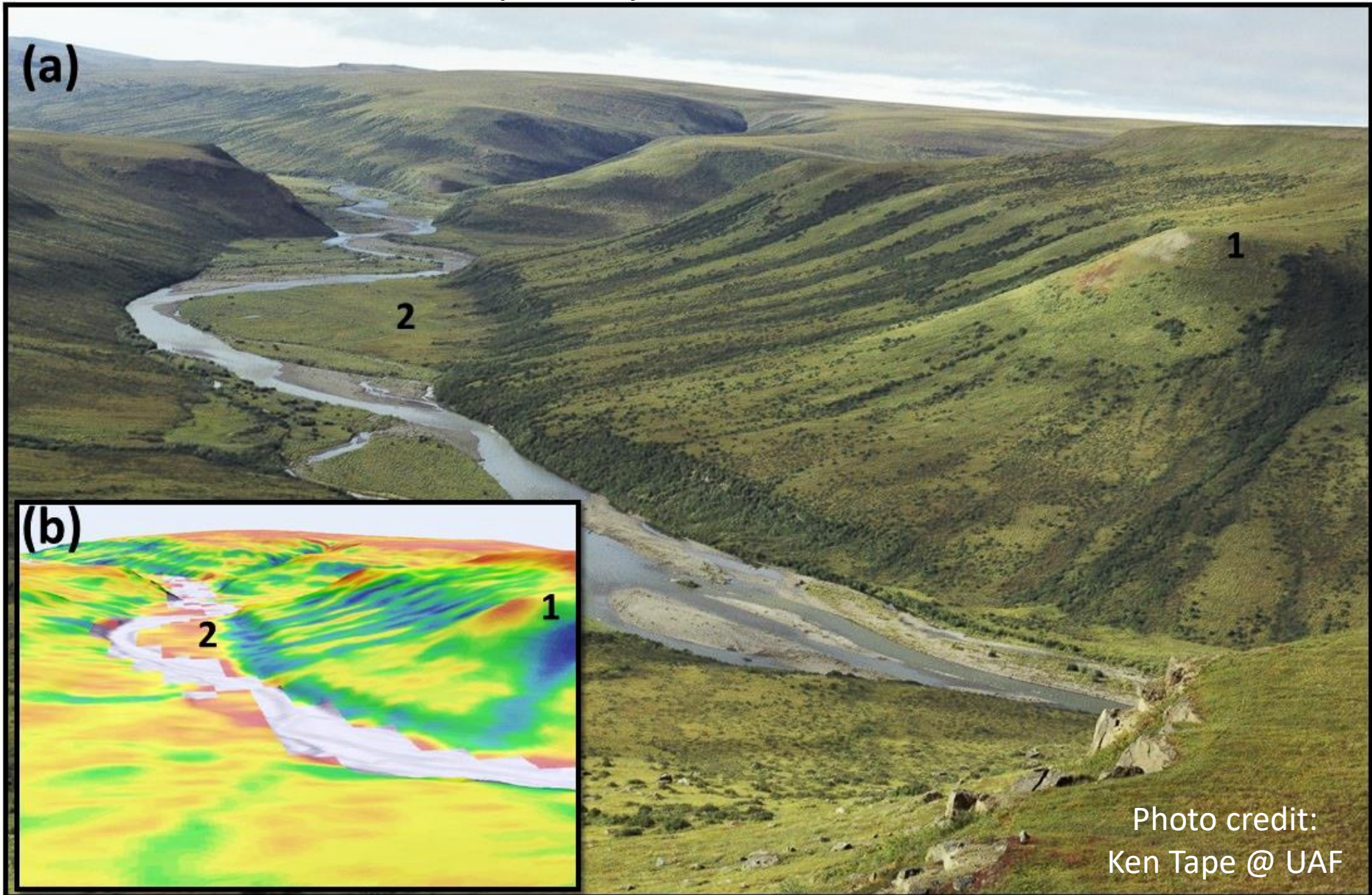
Shrub AGB



Shrub AGB

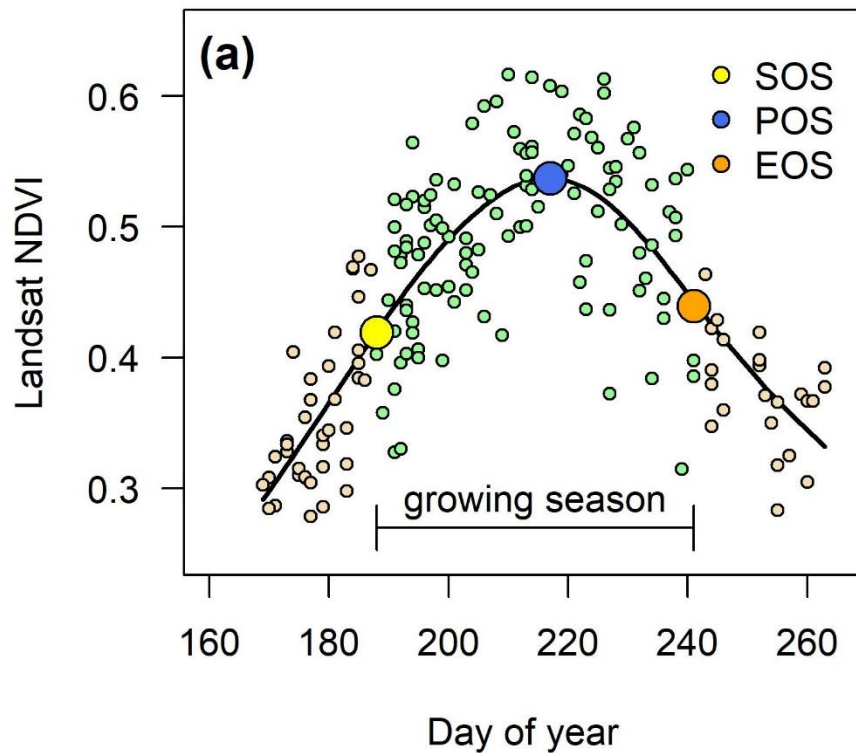


Data set is publicly available on ORNL DAAC

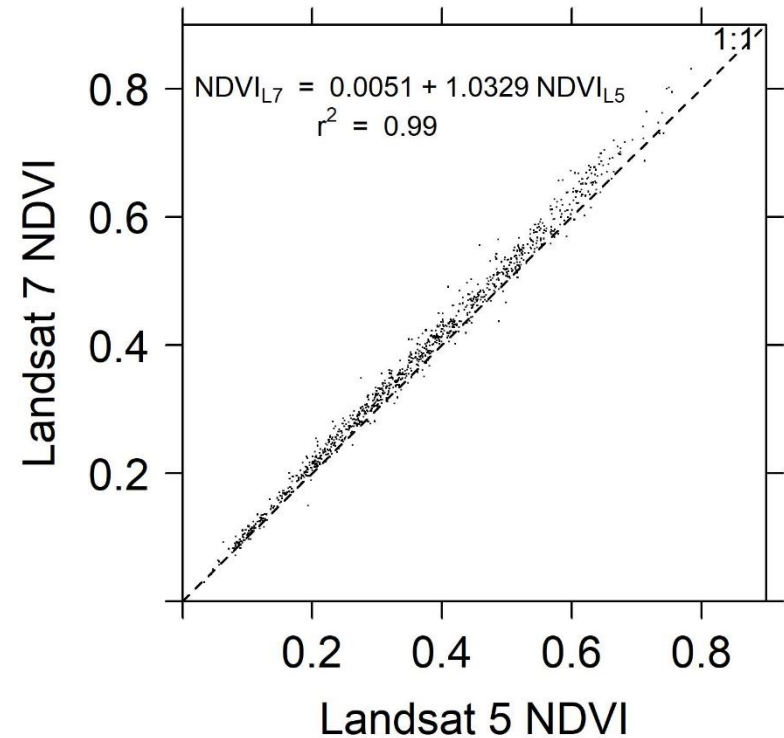


Challenges with Landsat in tundra ecosystems

Shoulder season observations

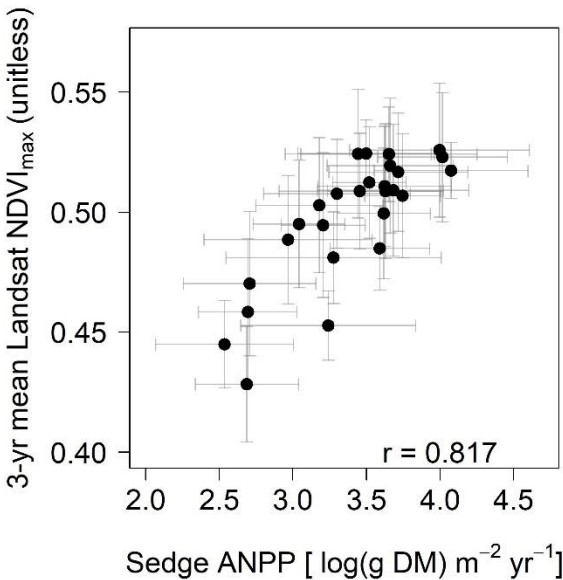


Sensor cross calibration

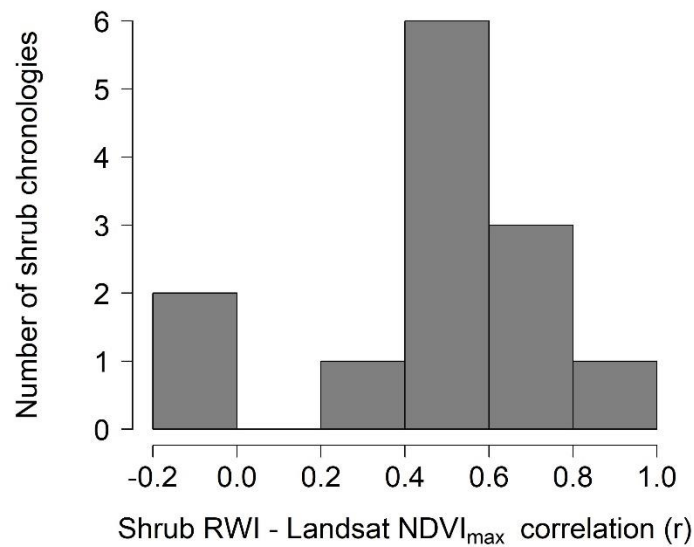
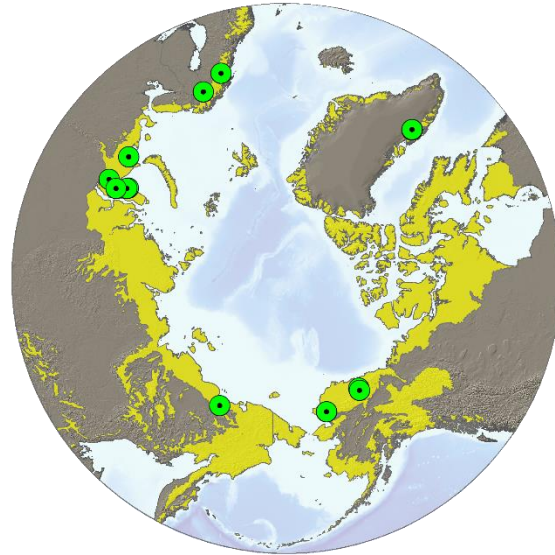


Landsat NDVI_{max} tracks:

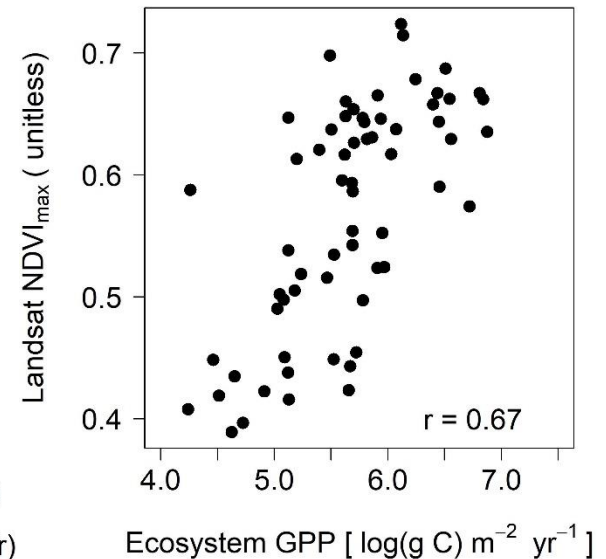
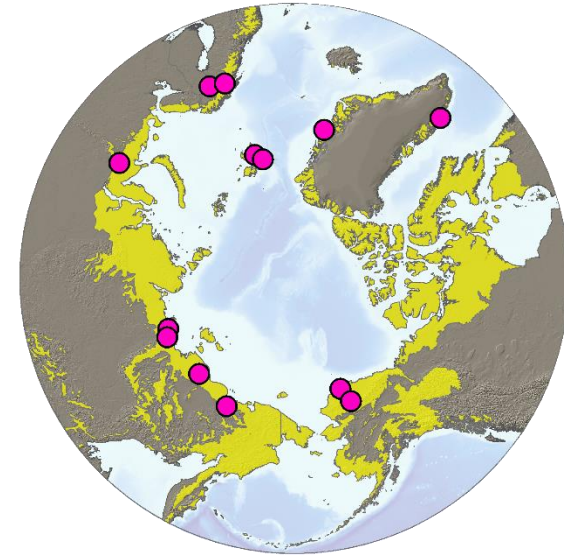
Sedge productivity



Shrub radial growth



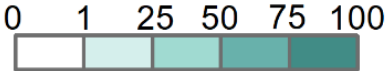
Flux tower GPP



Changes in Landsat NDVI_{max} from 1985 - 2016

Pervasive *greening* of the tundra

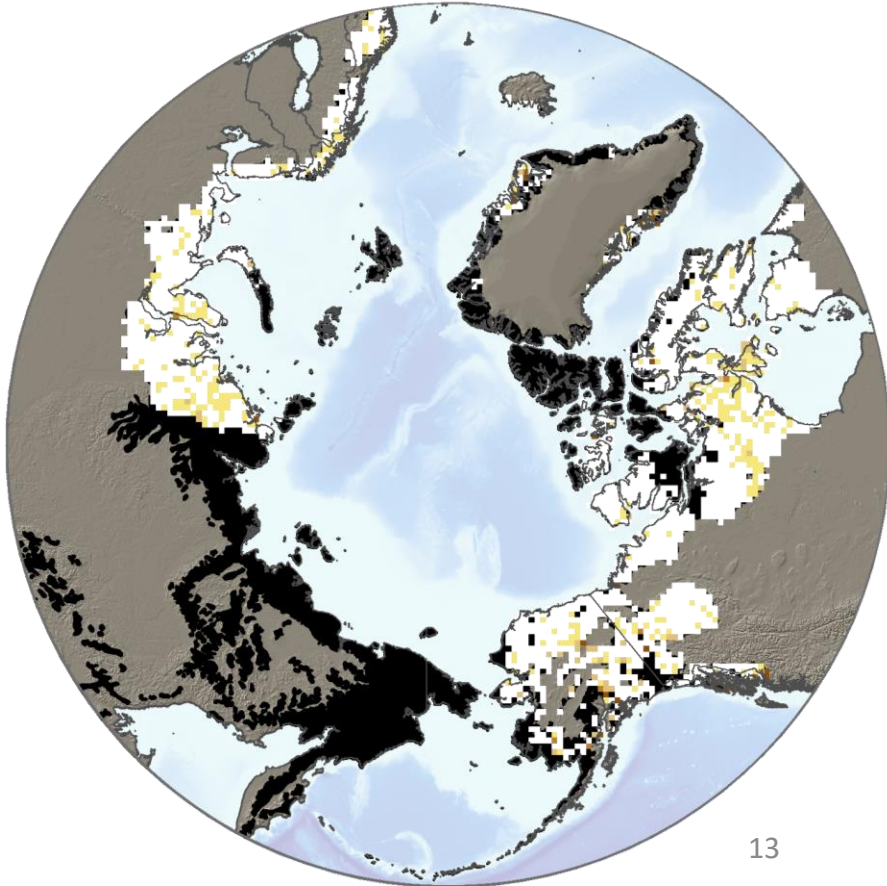
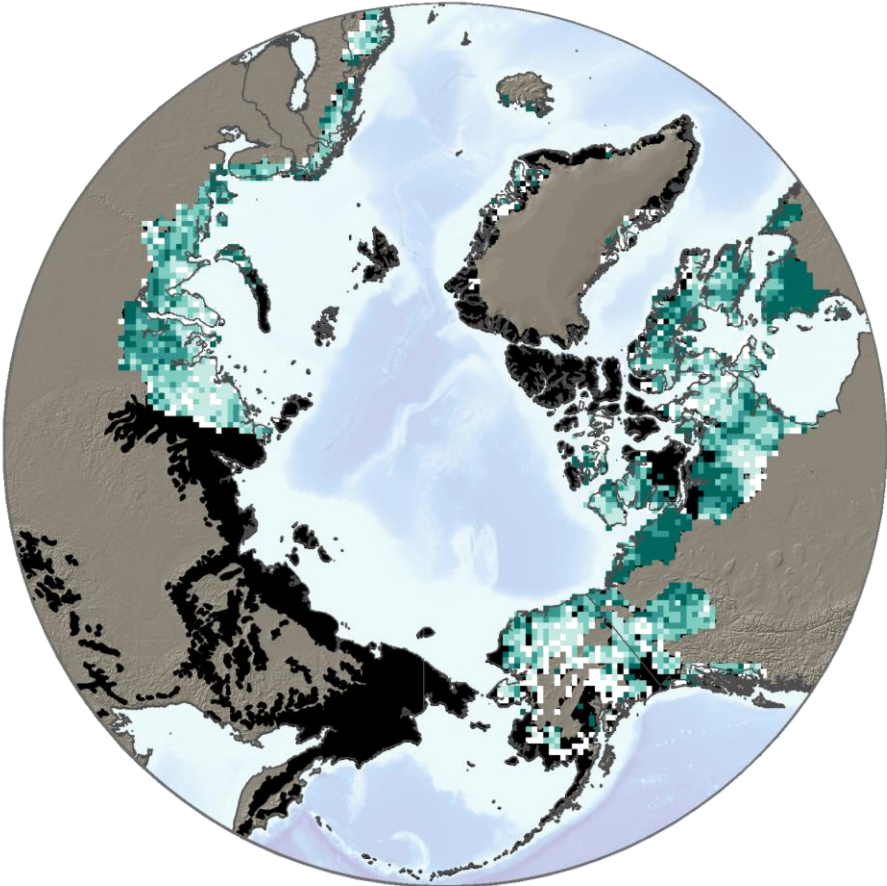
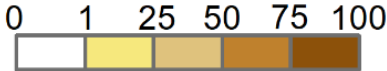
% positive trend



No Data

A solid black square representing areas with no data.

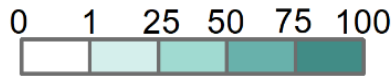
% negative trend



Changes in Landsat NDVI_{max} from 2000 - 2016

Pervasive *greening* of the tundra with scattered browning

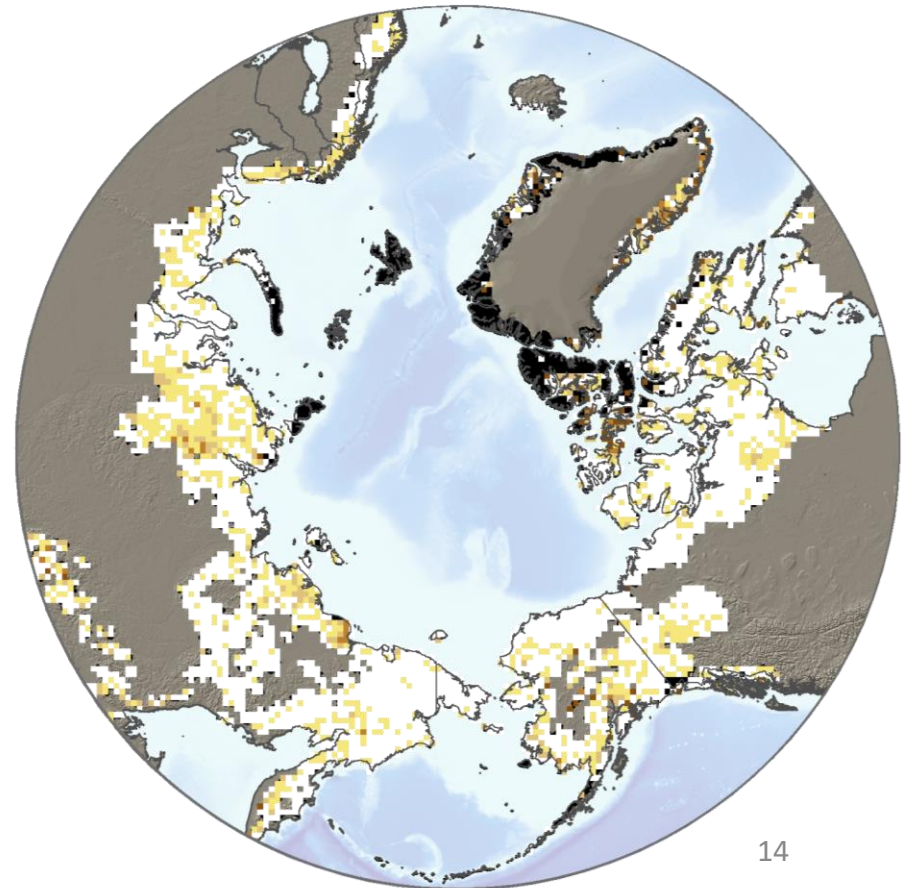
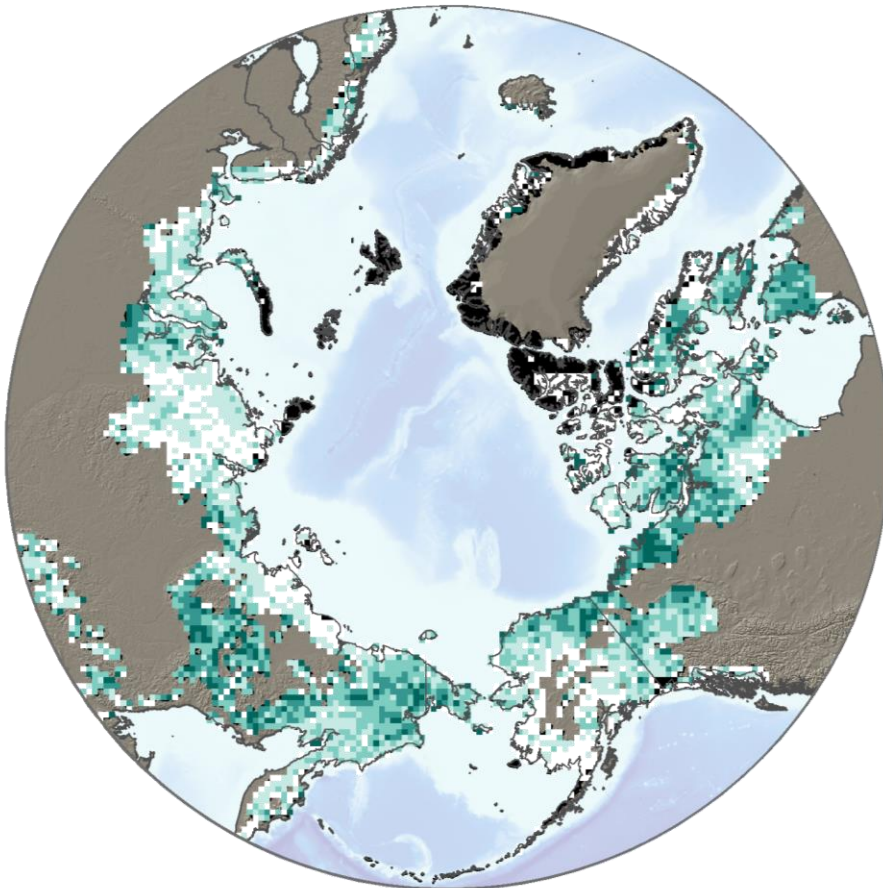
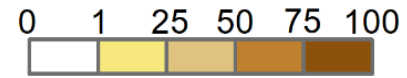
% positive trend



No Data



% negative trend

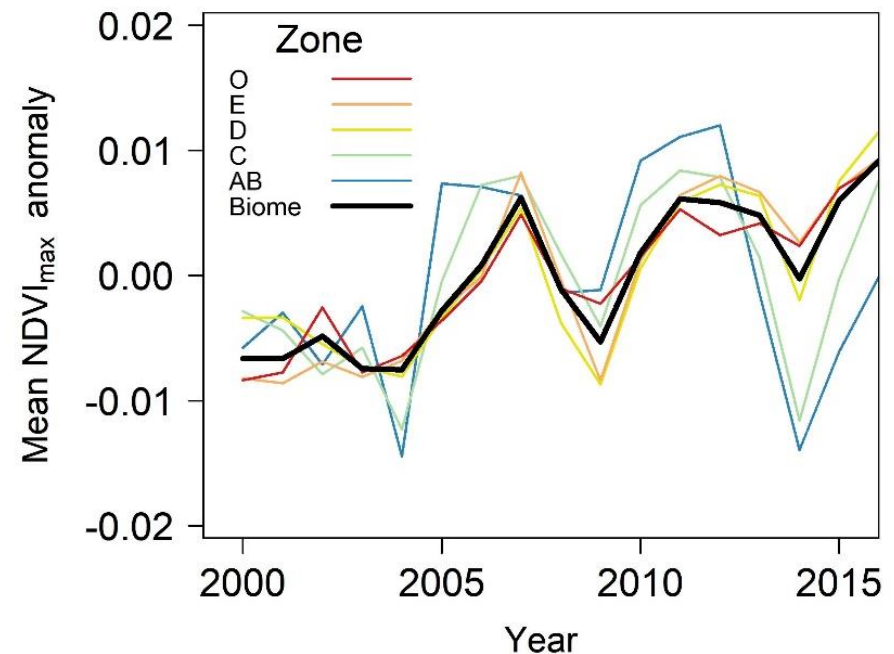
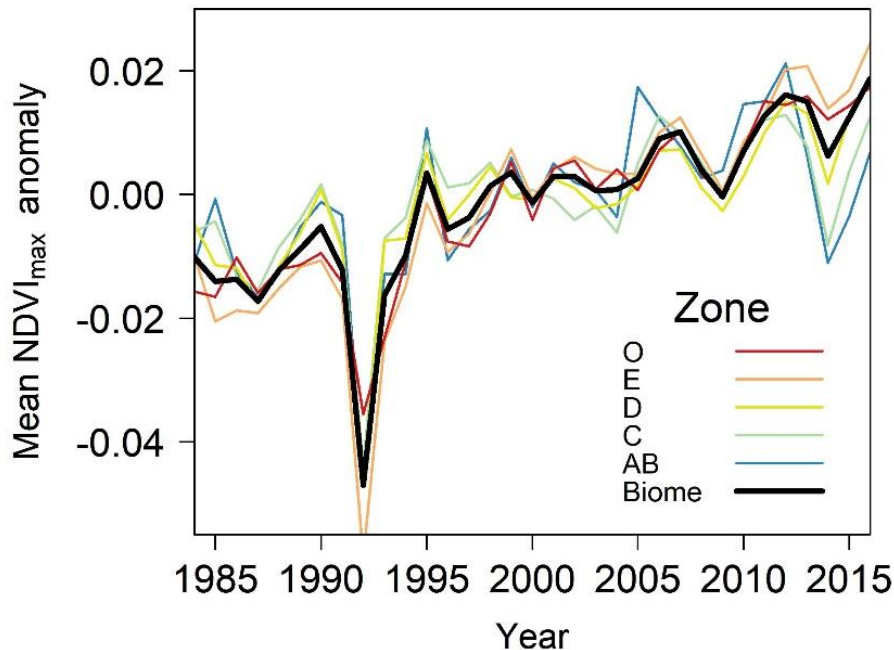
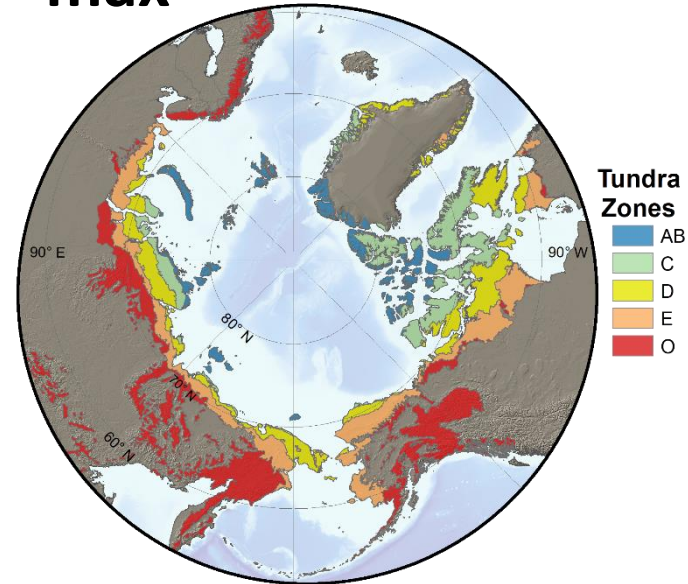


Changes in Landsat NDVI_{max} by zone

Significant *greening* of biome and each bioclimatic zone from 1985 - 2016

Eruption of Mt. Pinatubo in 1991

Significant *greening* of biome and southern zones from 2000 - 2016

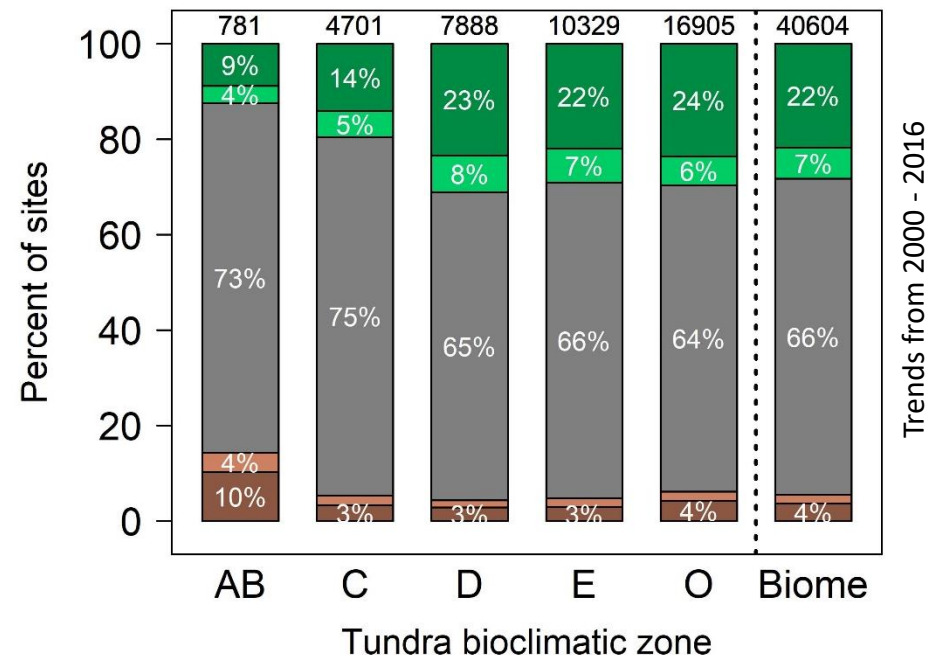
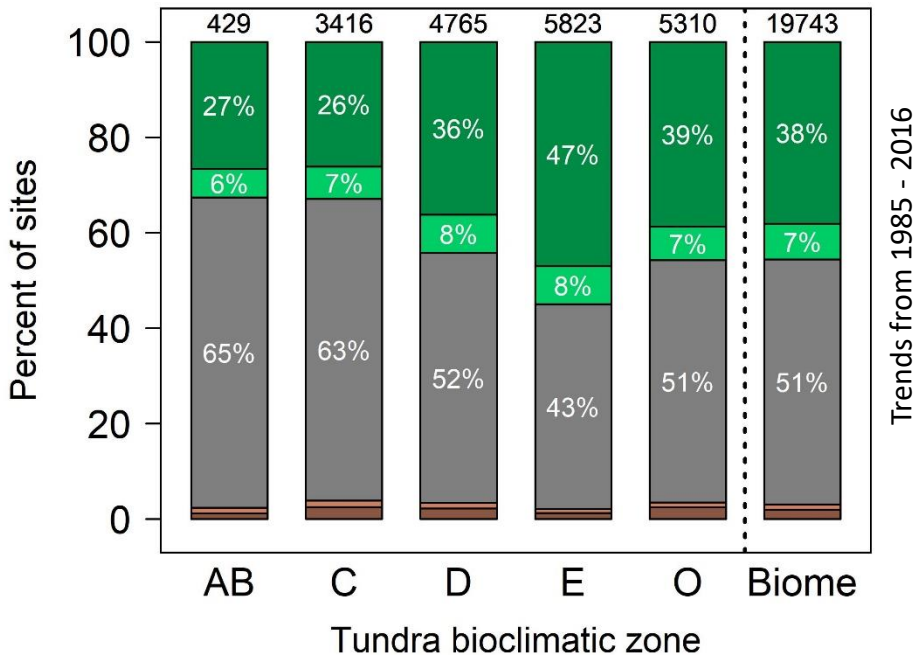
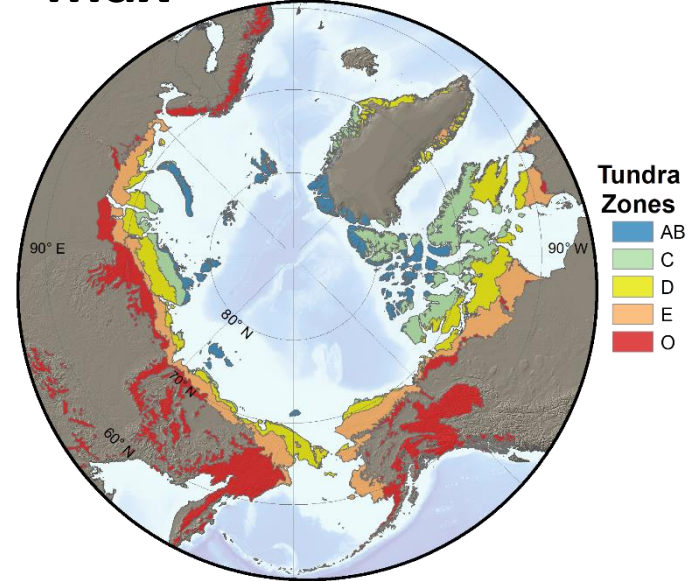


Changes in Landsat NDVI_{max} by zone

NDVI stable across half of domain

Greening more prevalent in southern than northern zones

Greening more prevalent than *browning*

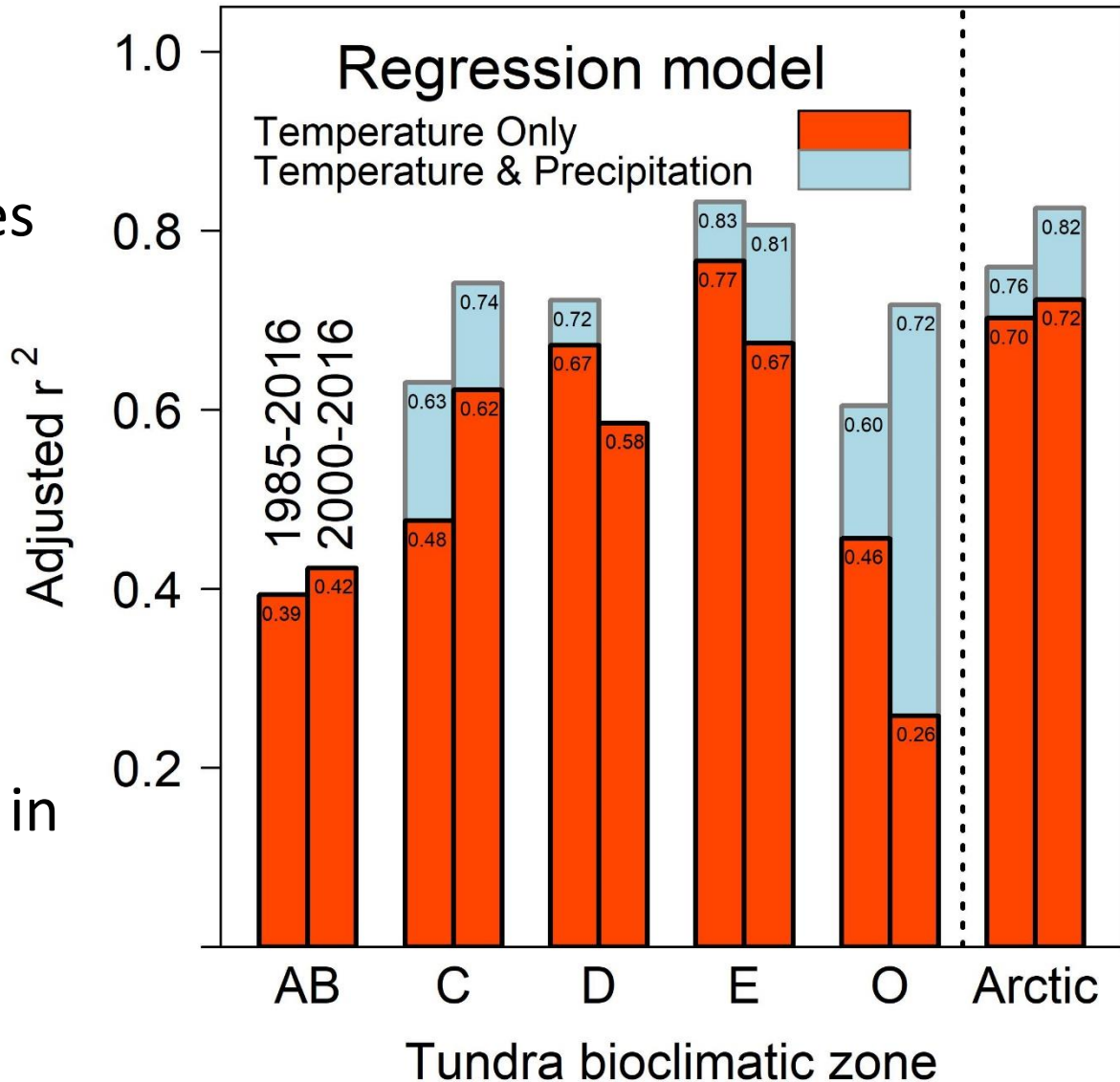


Landsat NDVI_{max} - temperature relations

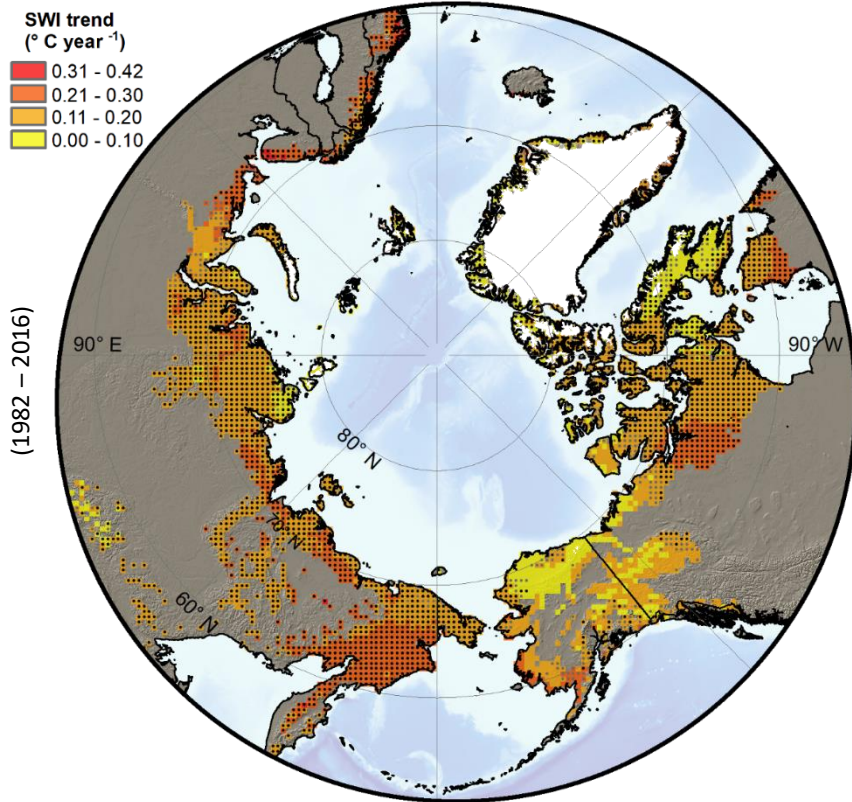
Strong across Arctic,
especially southern zones

Precipitation typically
explains little variance

Recent reductions in
temperature sensitivity in
southern zones

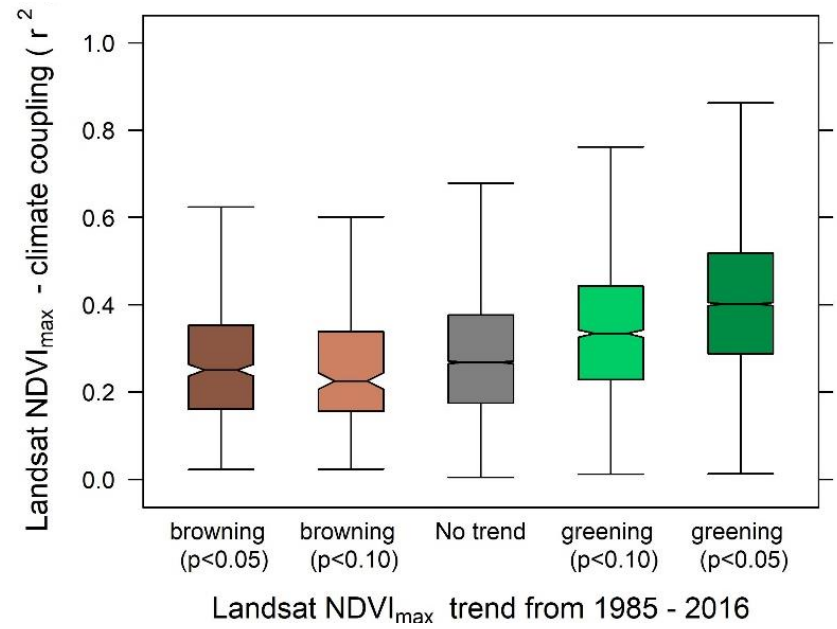
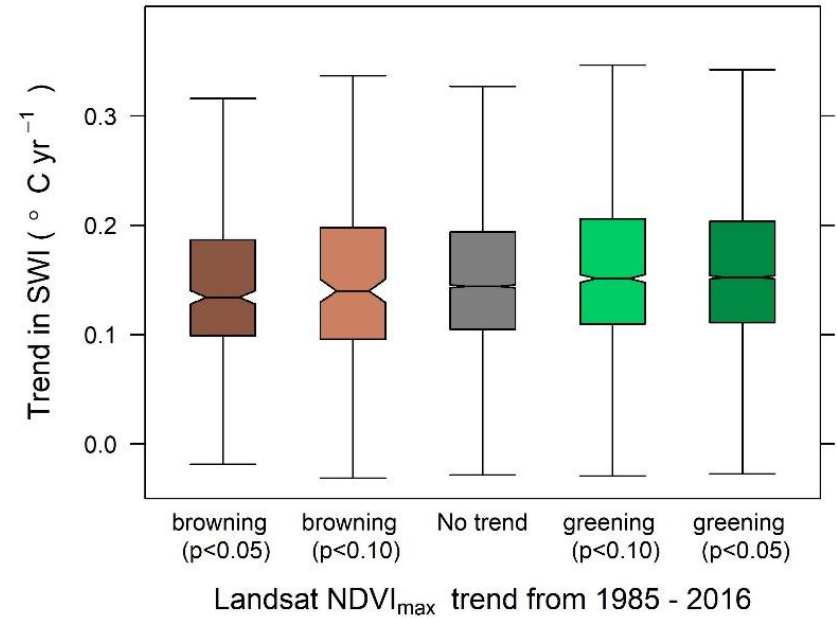


Landsat NDVI_{max} – temperature relations



Many areas warmed
without *greening*

Productivity more closely tied to
climate in areas that *greened*



Takeaway messages

Warming caused (most?) tundra plant communities to become taller and more productivity during recent decades, especially in southern bioclimatic zones.

Absolute changes and current status of plant height, productivity, and biomass remain uncertain, warranting future efforts to couple field and remote sensing measurements (esp. Landsat)

Considerable potential to improve monitoring and modeling of rapidly changing Arctic ecosystems

Thank you!

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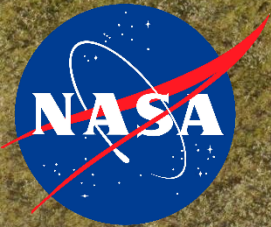


Photo:
Jeff Kerby