Complexity revealed in the greening of the Arctic

Myers-Smith, I.H, et al, *.Nat. Clim. Chang.* 10, 106-117 (2020) https://doi.org/10.1038/s41558-019-0688-1

Background: The greening of the Arctic is among the world's most important large-scale ecological responses to global climate change; however, the underlying causes and future dynamics of Arctic greening and browning trends are more complex, variable and inherently scale-dependent than previously thought.

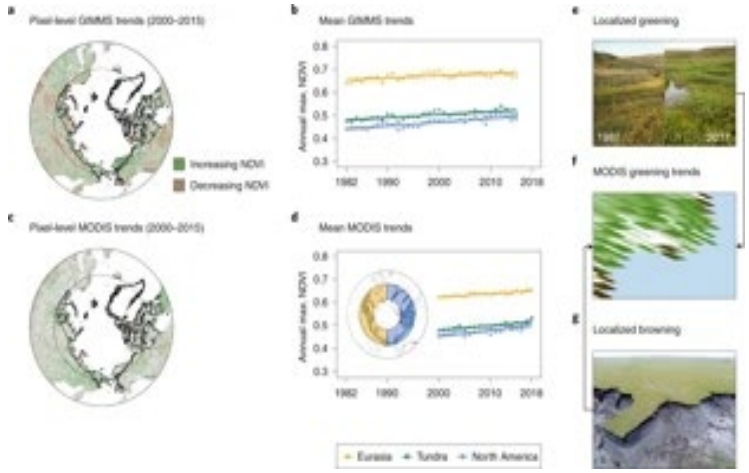
Methods: Using data from publicly available remote sensing and ecological datasets and publically available code, the authors review complexities in observing and interpreting high-latitude greening with the goal of identifying priorities for future research.

Results: Many complexities were discussed, including but not limited to:

- NDVI trends across satellite datasets do not necessarily directly correspond with one another and no one sensor or vegetation index combination corresponds directly with in-situ vegetation change.
- Paired comparisons of changes in growing season length and advances in plant phenology using both satellite and ground-based datasets do not always correspond.
- Uncertainty remains over whether satellite-derived changes in circumarctic phenology represent a longer snow-free period uncoupled from the vegetation response or an actual longer growing season of plants.
- Definitions of spectral greening and browning events vary and cause confusion.

Significance:

- While new sensors and better access to legacy data are improving the ability to remotely sense vegetation change, new data alone will not provide solutions to many of conceptual and technical challenges.
- Improvement is needed to clarify the definitions of widely used terminology associated with greening and browning phenomena.
- Understanding of the strengths and limitations of vegetation indices when making ecological interpretations must be promoted.
- Different scales of observation and uncertainty in analyses of changing tundra productivity and phenology must be accounted for and incorporated in future studies.



Satellite records indicate greening trends across the circumpolar Arctic. Apparent Arctic greening, which varies across space and time and among satellite datasets, is driven both by actual in-situ change and, in part, by challenges of satellite data interpretation and integration. a–d, Trends in maximum NDVI vary spatiotemporally, and the magnitude of changes depends on what satellite imagery is analyzed (a and c, data subsetted to temporally overlapping years; b and d, data from the Global Inventory Modeling and Mapping Studies dataset from AVHRR (GIMMS3gv1) 1982 to 2015, and MODIS MOD13A1v6 2000 to 2018). e–g, Regional trends may summarize localized greening, for example shrub encroachment (e) and browning such as permafrost thaw (g) occurring at the pixel scale on Qikiqtaruk–Herschel Island in the Canadian Arctic (f). NDVI trends (a and c) were calculated using robust regression (Theil–Sen estimator) in the Google Earth Engine130. Dashed line indicates the Arctic Circle, and the black outlined polygon (a and c) and green 'tundra' line (b and d) indicate the Arctic tundra region from the Circumpolar Arctic Vegetation Map (www.geobotany.uaf.edu/cavm/). The inset map in d indicates the regions for the mean trends for yellow 'Eurasia' and blue 'North America' polygons.