Greening of the Arctic: Spatial variation of biomass and NDVI along two Arctic transects and the Circumpolar Arctic

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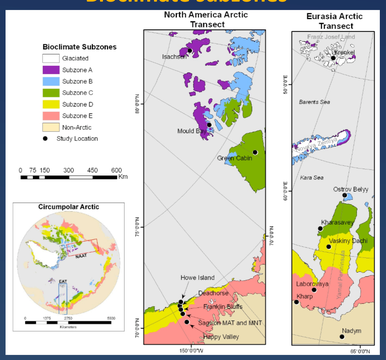
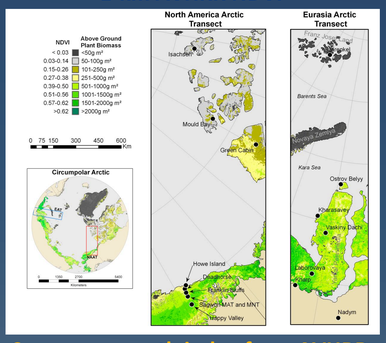
Abstract: Although it is often assumed that a strong correlation exists between tundra biomass and NDVI (e.g. Goetz et al. 2004), such a relationship has not been previously demonstrated at a biome scale for the tundra or any other biome. We sampled aboveground plant biomass (phytomass) at representative zonal sites along two long Arctic transects in North America and Eurasia. The transects were both about 1800 km long and traversed all five Arctic bioclimate subzones. Both transects exhibited a remarkably similar relationship between total aboveground phytomass and the average maximum Normalized Difference Vegetation Index (NDVI), an index of vegetation greenness derived from Advanced Very High Resolution Radiometer (AVHRR) data from NOAA satellites. The regressions was almost identical for North America and Eurasia, and for NDVI data sets using 1-km (r^2 = 0.91) and 8-km (r^2 = 0.94) pixels. The NDVI-phytomass relationship was used to make an aboveground phytomass map of the tundra biome, a valuable tool for monitoring Arctic vegetation change. The methods use a new, more consistent NDVI data set for the Arctic (GIMMS3g) and a sampling protocol that employs a consistent methods for site selection, clip harvest, sorting and weighing of plant material, and extrapolation of the results in a way that is meaningful for zonal landscape-level interpretation.

The Two Arctic Transects

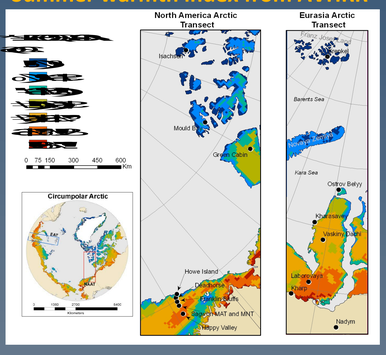
Bioclimate subzones



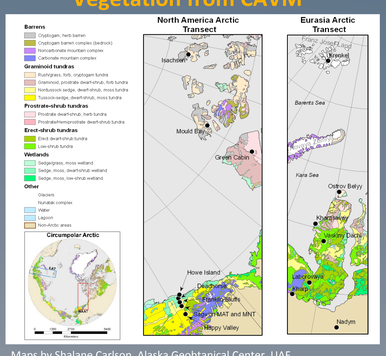
1-km AVHRR NDVI



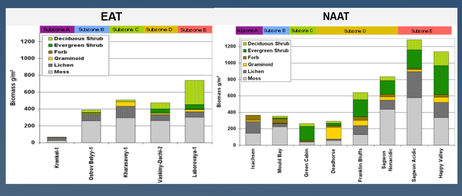
Summer warmth index from AVHRR

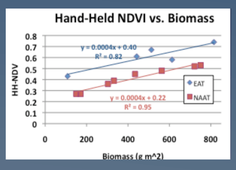


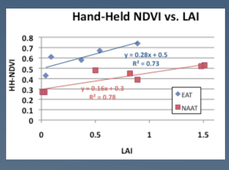
Vegetation from CAVM

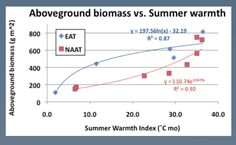


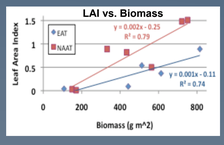
Maps by Shalane Carlson, Alaska Geobtanical Center, UAF.

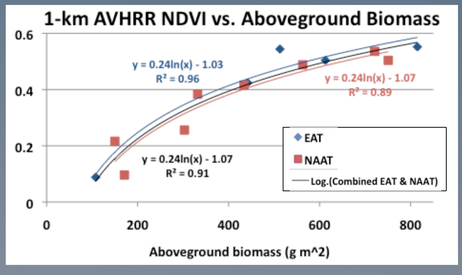












Landscape-level zonal biomass:

Compared to NAAT, EAT has:

- Less biomass in subzone A . (Wetter, much colder).
- More biomass in subzone C. (Wetter, unglaciated land-scapes along the EAT.)
- Much more biomass in subzone E (Warmer?).
- Fewer evergreen shrubs and lichens. (Reindeer grazing effect?)

300,000 reindeer graze the Yamal Peninsula each year (Forbes et al. 2009).

Field measurements of NDVI and LAI:

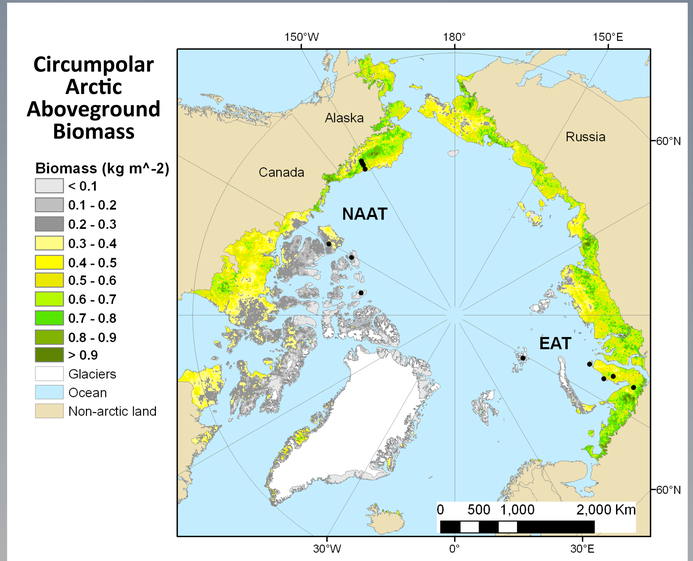
- For equivalent amounts of biomass and LAI, the HH-NDVI readings were much higher along the EAT.

Biomass, LAI relationships along transects:

- Distinctly different biomass in relation to temperature. An equivalent amount of biomass has consistently much higher LAI values along the NAAT than along the EAT and the difference increases at higher biomass values.
- Reflects the different structure of the vegetation along the two transects. Higher proportion of the total biomass is non-green along the NAAT (more wood, standing dead, hairy leaves, brown moss, evergreen shrubs and lichens).

1-km AVHRR NDVI vs.zonal landscape-scale biomass:

- Nearly identical regression between AVHRR NDVI and biomass for both transects and the combined data set.



This study has shown:

1. The feasibility of studying and monitoring zonal landscape-level biomass and NDVI across the full Arctic bioclimate gradient.
2. It is essential to use careful and consistent methods of biomass harvest and extrapolation to broader landscapes (Raynolds et al. 2011 submitted).
3. Broad similarities in biomass between North America and Eurasia along the Arctic temperature gradient, but also major differences in canopy structure related to different disturbance regimes, geology, and precipitation patterns.
4. Very good correlation between AVHRR NDVI and zonal landscape-level biomass.
5. It would be highly desirable to establish permanent biomass harvesting sites across the whole arctic using standardized sampling protocols.

REFERENCES CITED:

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Goetz, S.J., Bunn, A.G., Fiske, G.J., and Houghton, R.A., 2005, Satellite-observed photosynthetic trends across boreal North America associated with climate and fire disturbance: Proceedings of the National Academy of Sciences, v. 102, p. 13521-13525.

Raynolds, M.K., Walker, D.A., Epstein, H.E., Tucker, C.J., and Pinzon, J.E., 2011 submitted, A new estimate of tundra-biome phytomass from trans-Arctic field data and AVHRR NDVI: *Geophysical Research Letters*.