Boreal Forest 3D Structure, Site-Index and Ecosystem C-Flux

NASA ROSES NNH16ZDA001N-CARBON A.5 Carbon Cycle Science

Principal Investigator: Dr. Christopher S.R. Neigh, NASA GSFC, Greenbelt, MD
Science PI: Dr. Ben Poulter, NASA GSFC, Greenbelt, MD
Institutional PI: Dr. Joseph O. Sexton, UMD, College Park, MD

Co-Investigators:
Dr. Paul Montesano, Science Systems App. Inc., Lanham, MD
Dr. Min Feng, UMD, College Park, MD
Mr. Saurabh Channan, UMD, College Park, MD

Collaborators:
Dr. Jeffrey Masek and Dr. Daniel Duffy, NASA GSFC, Greenbelt, MD
Dr. Matthias Forkel, Tu Wien, Vienna, Austria and Dr. Nuno Carvalhais, MPI, Jena, Germany

2016 Kotuy River Expedition, Krasnoyarsk Russia
Photo by: Chris Neigh

Project Objectives

3.1.2 Carbon Dynamics in Arctic/Boreal Terrestrial Ecosystems

We will provide site index (SI) for DGVMs using Landsat disturbance history and forest structure from WorldView stereo imagery.

We will extend the NASA Global Forest Cover and Change (GFCC) dataset and incorporate it into DGVMs to understand environmental constraints on canopy structure and to predict impacts of environmental change on vegetation cover and C stock & flux.

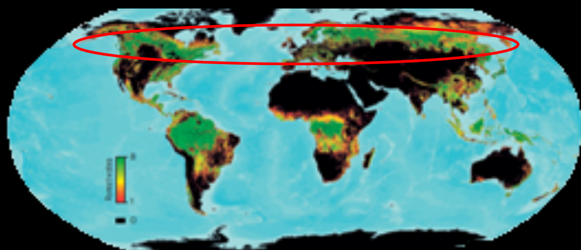
Our objectives are to:

Produce a stand-history/forest-age map: using a time-series of forest cover at annual, sub-hectare resolution spanning the entire Landsat archive pan-boreal, from 1972 to present;

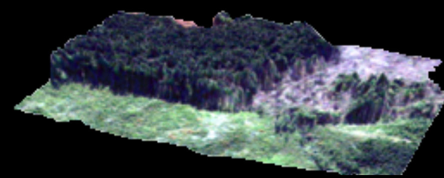
Model and estimate forest growth potential: using a chronosequence of tree-canopy cover and height from samples of WorldView-1, 2, and 3 stereo imagery to estimate height-growth potential as the forest Site Index (SI); and

Estimate pan-boreal forest net C-flux: by incorporating stand age and SI into the process-based Lund-Potsdam-Jena (LPJ) DGVM.

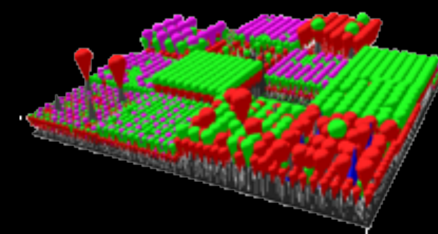
Landsat 1972+
Pan-boreal 60 m
Forest Cover Change
(FCC)/stand history



WorldView Pan
Stereo
2007+ ~2m
Forest Structure



LPJ DGVM
Forest Age
Structure
C storage & flux



2100

LPJ Site Index

1900

Cal/Val

Initialization
Optimization

Benchmarking

Stand Age

Site Index

Urgency

Knowledge of the spatial patterns, rates, and controls of forest growth across the higher northern latitudes is needed for two reasons:

(1) C turnover rates are one of the main sources of divergence between DGVMs (Friend *et al.* 2014) and
(2) annual forest growth is strongly linked to long-term vegetation productivity potential (Forkel *et al.* 2016).

Spatially explicit estimates of forest growth potential from remote sensing (as SI) throughout the boreal forest will serve as a global benchmark and will reduce DGVM uncertainty by constraining model processes.

2016 Kotuy River Expedition, Krasnoyarsk Russia
Photo by: P. Montesano

Remote Sensing

Landsat (UMD) Sexton, Channan & Feng

Project Title:
Multi-source imaging of time-serial tree and water cover at continental to global scales
PI: John Townshend, NASA LCLUC
July 2015 – June 2018

Hi-Res DigitalGlobe Constellation (GSFC) Neigh, Montesano & Wooten

Project Title: A high-resolution circumpolar delineation of the forest-tundra ecotone with implications for carbon balance
PI: K. Jon Ranson, NASA CCS
July 2014– June 2017

Project Title: Linking Remote Sensing and Energy Balance Models for a Scalable Agriculture Insurance System for sub-Saharan Africa
PI: Chris Neigh, NASA IDS
Feb 2014-Jan2017

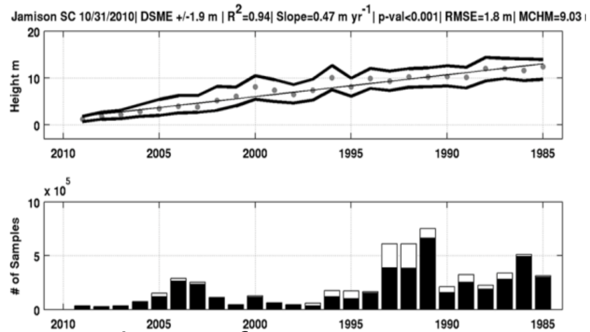
Project Title: High Mountain Asia and Beyond: Regional Changes in Climate, Glaciers and Water Resources
PI: Batuhan Osmanoglu, NASA Cryo
Oct 2016-Sep 2019

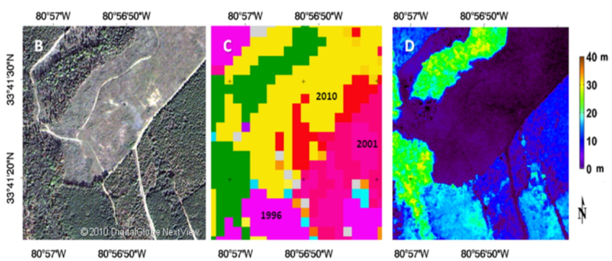
Site Index (SI) from space

Site index From Wikipedia, the free encyclopedia

Site index is a term used in forestry to describe the potential for forest trees to grow at a particular location or "site." Site is defined as "The average age of dominate and/or codominate trees of a even-aged, undisturbed site of intolerant trees at a base age";[1] furthermore, the word site is used in forestry to refer to a distinct area where trees are found.[2] Site index is used to measure the productivity of the site and the management options for that site and reports the height of dominant and co-dominant trees in a stand at a base age such as 25, 50 and 100 years.[2] For example, a red oak with an age of 50 years and a height of 70 feet (21 m) will have a site index of 70. Site index is species specific. Common methods used to determine site index are based on tree height, plant composition and the use of soil maps.

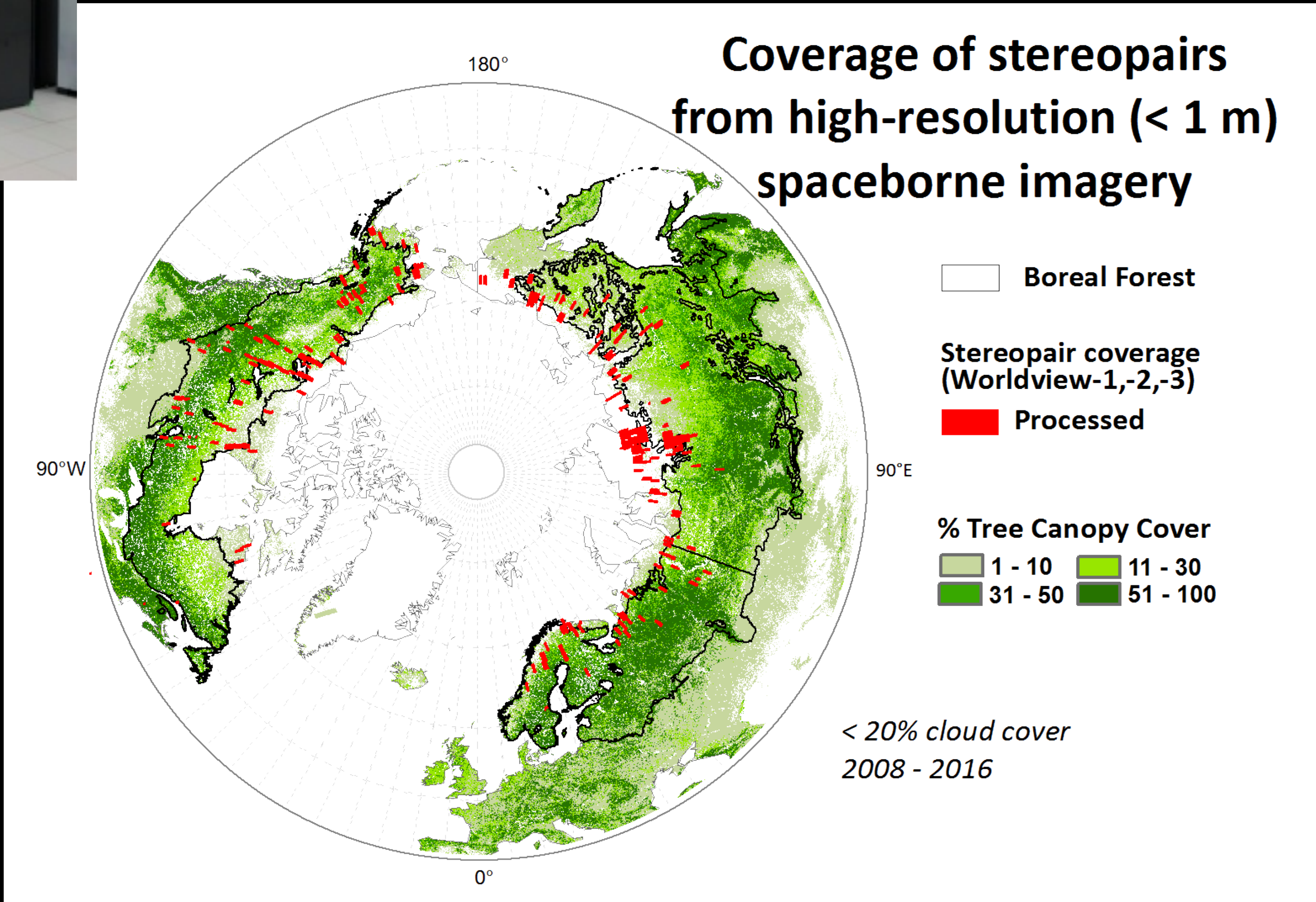
SI is difficult to estimate in situ and to our knowledge no studies have attempted to estimate SI for large areas





(Left) Example of 1-m stereo IKONOS pan-sharpened image from prior NASA CCS research in Jamison South Carolina.
(Center) We found 0.47 m per year growth, by using a space-for-time swap.
(Right) true color image of the same area; Landsat VCT annual disturbance history; and Canopy Height Models derived from stereo IKONOS (Neigh et al. 2014, Neigh et al. 2016).

WorldView DEM processing



Recent Results

The use of sun elevation angle for stereogrammetric forest height in open canopies
Paul M. Montesano, Christopher Neigh, Guoqing Sun, Laura Duncanson, Jamon Van Den Hoek & K. Jon Ranson *submitted RSE*

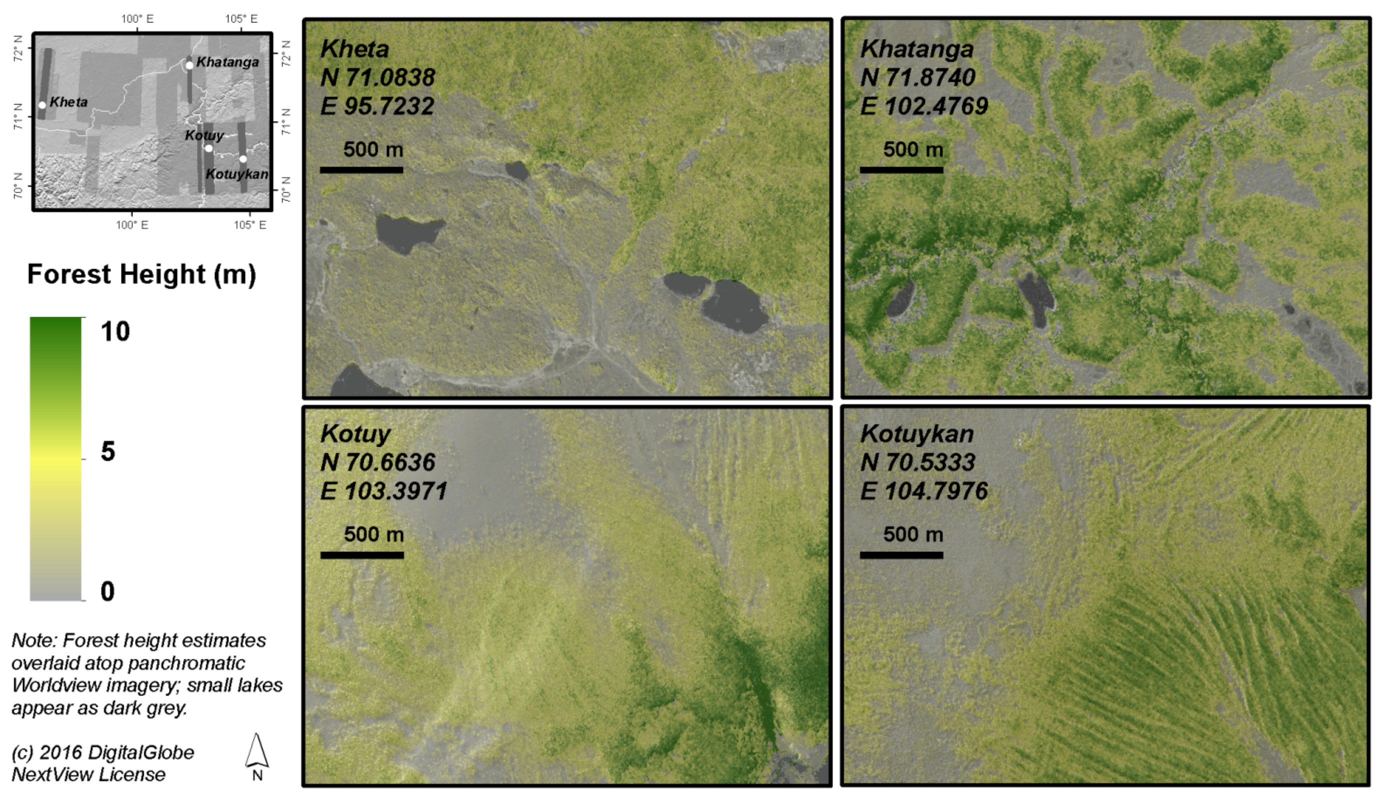


Figure 7. Mapped examples of forest heights at 2 m spatial resolution from image-level DSM differencing applied after vertical co-registration of DSM pairs at each study site.

Modeling

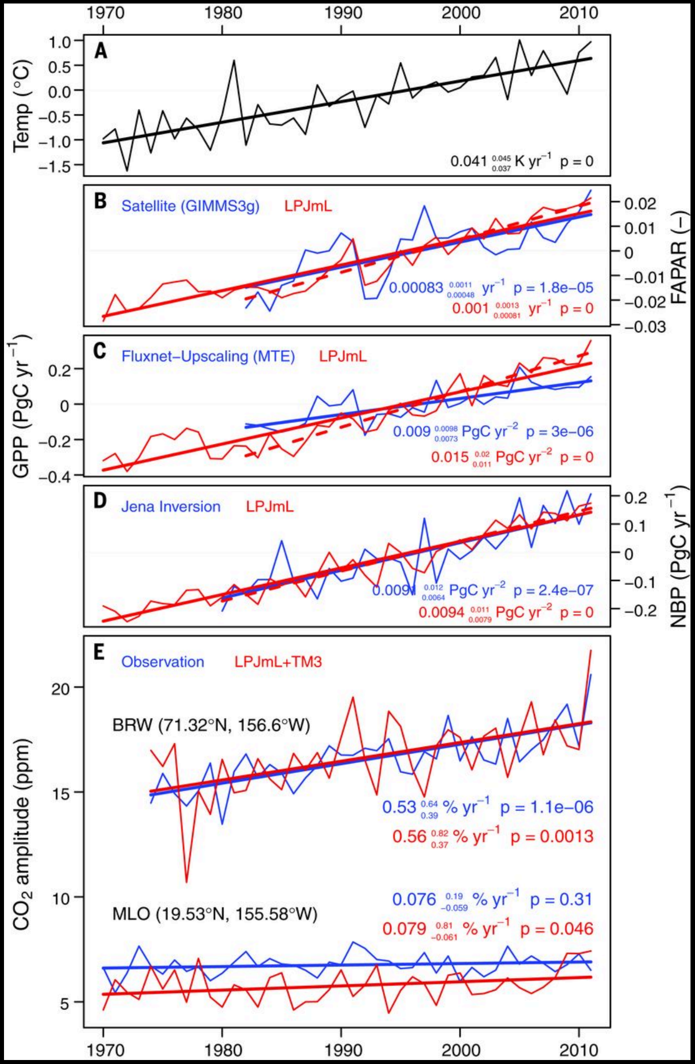
LPJ-WSL - (GSFC) Poulter, Collaborators (MPI) Carvalhais & (WI) Forkel

Project Title: Collaborative Research and NEON: MSB Category 2: Paleon – a PaleoEcological Observatory Network to assess terrestrial ecosystem models
Source of Support: National Science Foundation
Jan 2013 – Dec 2018

Project Title: Full Optimized and Reliable Emissions Tool (FOREST)
Source of Support: European Union Center for Innovation (KIC)
Jan 2014-Dec 2016

Project Title: Fire Vegetation People and Climate: Late Holocene Dynamics Along a Forest-Steppe Ecotone
Source of Support: National Science Foundation
Jan 2015-Dec 2018

Fig. 1 Amplification of plant activity in the northern biosphere



What's Driving it?

✓Disturbance
✓Forest Age Composition
✓SI

Matthias Forkel et al. Science 2016;351:696-699

Take Away Points?

We will:

1) **Characterize the spatial age patterns of northern forests** using sub-meter stereo imagery and Landsat-based forest disturbance history (Objective 1).

2) **Develop and publish methods for estimating SI based on remotely sensed data**, specifically for the use of sub-meter stereo optical data and Landsat disturbance history as a benchmarking tool for characterization of vegetation growth for use in DGVMs (Objective 2).

3) **Provide a pan-boreal map of SI** using a *space-for-time* chronosequence with height information from stereo sub-meter data and Landsat-based disturbance history (Objective 2).

4) **Estimate forest cover and biomass change** in intensive study site transects using sub meter stereo satellite data, available field and aircraft observations, and allometry (Objective 2).

5) **Estimate pan-boreal C-flux** by feeding resulting data layers into LPJ (Objective 3).

Thank You

References:

2016 Montesano, P.M., Neigh C.S.R, Sexton J., Feng M., Channan S., Townshend J., and Ranson, K.J. Improved uncertainty estimates of Landsat tree cover in the taiga- tundra ecotone. Remote Sensing, Special Issue “Validation and Inter-Comparison of Land Cover and Land Use Data”, *in review*.

2016 Neigh, C.S.R., Masek, J.G., Bourget, P., Rishmawi, K., Zhou, F., Huang, C., Cook, B., and Nelson, R.F. Regional rates of young US forest growth estimated from annual Landsat disturbance history and IKONOS stereo imagery. *Remote Sensing of Environment*, 173:282-293.

2015 Sexton, J., Noojipady, P., Song, X., Feng, M., Song, D., Kim, D., Anand, A., Huang, C., Channan, S., Pimm, S., & Townshend, J. (2015). Conservation policy and the measurement of forests. *Nature Climate Change, in press*

2015 Sexton, J.O., Noojipady, P., Anand, A., Song, X.P., McMahon, S., Huang, C.Q., Feng, M., Channan, S., & Townshend, J.R. A model for the propagation of uncertainty from continuous estimates of tree cover to categorical forest cover and change. *Remote Sensing of Environment*, 156:418-425.

2014 Neigh, C.S.R., Masek, J., Bourget, P., Cook, B., Huang, C., Rishmawi, K., & Zhao, F. (2014). Deciphering the Precision of Stereo IKONOS Canopy Height Models for US Forests with G-LiHT Airborne LiDAR. *Remote Sensing*, 6:1762-1782.

2014 Montesano, P.M., Sun, G., Dubayah, R.O., Ranson, K.J. (2014). The Uncertainty of Plot-Scale Forest Height Estimates from Complementary Spaceborne Observations in the Taiga-Tundra Ecotone. *Remote Sensing*, 6:10070-10088.

2013 Sexton, J., X. Song, M. Feng, P. Noojipady, A. A and, C. Huang, *et al., "Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS vegetation continuous fields with lidar-based estimates of error," International Journal of Digital Earth, 6:1-22.*

2013 Neigh, C.S.R., Nelson, R.F., Ranson, K.J., Margolis, H.A., Montesano, P.M., *et al., "Taking stock of circumboreal forest carbon with ground measurements, airborne and spaceborne LiDAR," Remote Sensing of Environment, 137:274-287.*

2013 Neigh, C.S.R. J. G. Masek, and J. Nickeson, "High-Resolution Satellite Data Open for Government Research," *EOS Transactions, vol. 94, pp. 121-123.*

2011 Ranson, K.J., Montesano, P.M., & Nelson, R. 2011. Object-based mapping of the circumpolar taiga-tundra ecotone with MODIS tree cover. *Remote Sensing of Environment*, 115:3670-3680.

2009 Montesano, P.M., Nelson, R., Sun, G., Margolis, H., Kerber, A., Ranson, K.J. MODIS tree cover validation for the circumpolar taiga-tundra transition zone, *Remote Sensing of Environment*, 113:2130-2141.