

VEGETATION STRUCTURE AND BIOMASS FROM PALSAR, AVNIR-2, AND PRISM

Robert N. Treuhaft, Jet Propulsion Laboratory,
California Institute of Technology
Gregory P. Asner, University of Colorado,
Boulder
Beverly E. Law, Oregon State University
Paul R. Siqueira, Jet Propulsion Laboratory,
California Institute of Technology

ABSTRACT

The global remote sensing of forest vegetation structure, for the determination of biomass and disturbance history, is a key component of monitoring global change. The combined use of multibaseline radar interferometry and polarimetric interferometry, plus optical radiometric data will play an important role in vegetation structure remote sensing. ALOS will provide one of the first opportunities to use an effective combination of sensors to measure forest structure. Multibaseline interferometry is proposed, although the baseline plan for ALOS is a single interferometric baseline repeating every 45 days. Either this baseline can be modified or perhaps the addition of Cartwheel in the future will provide the multibaseline interferometric capability. Test sites in Oregon and Brazil have been identified as areas to test the spaceborne remote sensing of forest structure.

OBJECTIVES

The broad objective of this research is to develop and demonstrate methods for estimating forest geometric structural parameters, leaf area density (LAD), and biomass with unprecedented accuracy, utilizing combined microwave and radiometric observations. The specific objectives are to 1) estimate unnormalized structural profiles from multibaseline, interferometric (possibly polarimetric interferometric) radar (PALSAR, eventually with the Cartwheel enhancement), 2) estimate leaf area index (LAI) from radiometric data (AVNIR-2), 3) combine the parameters estimated from each data type to extract LAD, 4) demonstrate a novel approach to estimating biomass from the above-extracted structure and LAD parameters, and 5) validate all of the above remote sensing measurements with field measurements.

SIGNIFICANCE

The structural parameters, for example tree height, height-to-base-of-live-crown and leaf area density (LAD, leaf area per unit volume of space as a function of the vertical coordinate), derived in this proposal bear on land-surface, biogeochemical, and climate modeling efforts [e.g. Asner et al. 1998]. Variation in vegetation structure (in both space and time) can indicate land-cover/land-use impacts, hydrological and phenological change, and other processes deemed important in modeling efforts. Geometric structural parameters relating canopy height to volume are important in land-surface models used in calculating aerodynamic resistance and evapotranspiration [e.g. Betts et al., 1998; Cooper et al., 1997]. These parameters are also being incorporated in regional and global climate models [e.g. Pielke et al., 1998; Sud et al., 1998]. The spatial and temporal variability in LAD is an important aboveground structural parameter for constraining fine-scale models of carbon and water vapor exchange [e.g. McMurtrie et al., 1994]. Biomass is an important vegetation characteristic, which can be inferred from the above structural parameters. Foliage and wood biomass and LAI are used to parameterize biogeochemical models that are applied in a spatially explicit mode with remotely sensed data to estimate net primary production, photosynthesis, and evapotranspiration across regions [e.g. Running et al., 1994; Kimball et al., 1997].

METHODS

The following methods will yield measurements applicable at global spatial scales. The PALSAR component of the project will produce approaches to acquisition and analysis which will maximize the potential of this spaceborne radar. The AVNIR-2 component of the project represents an ongoing effort in the use of spaceborne multi-spectral instruments to improve estimates of forest LAI. The results of this project will aid data fusion and physical modeling approaches.

The data will be used to estimate geometric structural parameters and leaf area density from microwave and spectral remote sensing data [Treuhaft et al. 2001]. It has been shown that multibaseline radar interferometry and polarimetry can be used to estimate profile characteristics. [Treuhaft et al., 1996; Treuhaft and Siqueira, 2000]. However, multibaseline L-

band data, with sufficiently large baseline-to-altitude ratios are rare. PALSAR could provide such data, and we choose to study a Pacific-northwestern site and a Brazilian tropical site to span the world's forest vegetation types. The profile information attainable from microwave remote sensing depends on assumptions about the scattering characteristics. These assumptions, for example random vegetation orientation, will be tested with PALSAR data. The surface topographic measurements from the PRISM instrument will also be used in estimating vegetation characteristics. While the PALSAR data could also be used to estimate topography, using PRISM will strengthen the parameter estimation performance.

Multibaseline interferometry is the natural extension of single-baseline interferometry for vegetation structure measurements. A given interferometric baseline corresponds to a Fourier transform of the vertical vegetation distribution, at a given spatial frequency. Just as multibaseline interferometry yields structure information of celestial objects, multibaseline radar interferometry will yield the structure of terrestrial vegetation. Currently, ALOS is planning only one repeat-pass baseline of approximately 1 km. Additional longer baselines of approximately 2-9 km will be essential for global monitoring of vegetation structure, but if this is not possible, perhaps the passive Cartwheel will eventually supply the missing baselines [Massonnet et al. 2000].

The visible and near-IR channels on AVNIR-2 provide a means to estimate forest canopy LAI, which will be used to normalize the relative profiles from PALSAR and produce LAD. The strength of the absorption of the red channel and the reflectance of the near-IR channel can be interpreted using a canopy radiative transfer model. Without higher spectral resolution data, such as from imaging spectrometers, some increased uncertainty in the interpretation of the multi-spectral ALOS data will occur. However, our previous analyses with similar Landsat ETM+ optical data indicate that LAI can be estimated to within 20% accuracy using inverse modeling techniques. It has been demonstrated that LAI can be quantified using a radiative transfer inversion approach with radiometric data [Asner et al., 1998a]. Inverse modeling techniques are preferable over vegetation index approaches (e.g. NDVI) because they require no calibration with ground data, eliminate the complicating effects of solar and viewing geometry (BRDF), provide a means to

incorporate ecological knowledge (e.g. leaf angle distributions), and allow estimation of errors in the retrieved parameters [Goel 1988; Asner et al., 1998].

Specific activities include:

- 1) Acquire multibaseline, perhaps fully polarimetric PALSAR interferometric microwave data and acquire AVNIR-2 data. Test data for internal consistency and calibration integrity.
- 2) Estimate leaf area index, leaf area density, foliage biomass and aboveground wood biomass from field in Central Oregon and the eastern Amazon Basin.
- 3) Estimate geometric structural parameters such as vegetation height and leaf area density (only if multibaseline available) from the combined microwave and radiometric remote sensing data.
- 4) Estimate biomass by regression to physical structure parameters.
- 5) Compare remote sensing estimates of the structural parameters and biomass with field measurements.

ALGORITHMS

The algorithm, which will estimate LAD from data from all three ALOS sensors, is described in Treuhaft et al. 2001 and is schematically represented below:

$$\begin{pmatrix} \text{LAD} \\ \text{Other} \\ \text{Structural} \\ \text{Parameters} \end{pmatrix} = M^{-1} \begin{pmatrix} \text{Coh}_i \\ \text{Phase}_i \\ \text{Pol} \\ \text{Radiances} \\ \text{Topo} \end{pmatrix} \text{ where}$$

re Coh_i represents the radar interferometric coherence from the i^{th} baseline and polarization from PALSAR. Phase_i is the interferometric phase, and Pol is the zero-baseline standard polarimetric set of observations. Radiances is the AVINIR-2 data, and Topo is the topography product from PRISM.

TRUTH DATA

Two test sites will be used, one in Central Oregon near Black Butte and one in the eastern Amazon Basin near Cauaxi, Brazil. In each site, plots will be established in a range of forests with different stand densities, biomass and LAI

along the flight path. In Central Oregon, this will include ponderosa pine forests of different ages and densities and juniper/sagebrush ecosystems where extensive field data on structure, biomass, LAI, and LAD exist, and ecosystem studies are in progress [Law et al. 2001]. In Brazil, we have an ongoing project to study the effects of varying forest-logging intensity on satellite remote sensing signals. Our experimental design includes replicated 1 x 1 km logging treatments, which, over time, have resulted in a replicated gradient of forest structure and biomass. These ecosystems will provide a good test of the 3-dimensional structure and LAD approaches.

The research described in this report was carried out in part by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration, NASA OES RTOP 622-93-63-40

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