ESTIMATION OF FOREST BIOMASS CHANGE FROM FUSION OF RADAR AND LIDAR MEASUREMENTS

S. Saatchi[1], R. Dubayah[2], D.B. Clark[3], R. L. Chazdon[4], D. Hollinger[5]

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA
2. Department of Geography, University of Maryland, College Park, MD 20742 USA
3. International Center for Tropical Ecology, University of Missouri, St. Louis, MO 63121 USA and La Selva Biological Station, Costa Rica
4. Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT 06269 USA
5. USDA Forest Service, Northern Research Station, 271 Mast Rd.Durham, NH 03824 USA

1. Introduction

Radar and Lidar instruments are active remote sensing sensors with the potential of measuring forest vertical and horizontal structure and the aboveground biomass (AGB) (Saatchi et al., 2007). In this paper, we present results from a fusion analysis of radar and lidar data to quantify changes of forest biomass accumulated over 3-5 years. The overall goal of this study is to assess the capability of DESDynl's active sensors to detect changes in aboveground vegetation biomass in temperate and tropical forests, without necessarily estimating the biomass stock. Our research will focus on two study areas covering a range of ecosystem structure and stages of disturbance and biomass accumulation to assess DESDynl in a global perspective(Chazdon et al., 2003). We use data fusion methodology and change detection algorithm by combining radar measurements from ALOS PALSAR, AIRSAR and UAVSAR imagery, and airborne lidar (LVIS) with extensive field measurements to address two questions: 1. Can changes of biomass be detected from fusion of L-band radar and multi-beam lidar from space? 2. What are the spatial and temporal resolutions and specific measurement requirements for DESDynl?

2. Methodology

Study Areas: The La Selva Biological Station is located near the Sarapiquíı River in northeast Costa Rica. Over its 46-year history, La Selva has become one of the most heavily studied tropical forests in the world. This 1536-ha area is comprised of a mixture of lowland old-growth and secondary Tropical Wet Forest abandoned pasture, current and abandoned plantations, and agroforestry plots (Clark and Clark, 2000). Because of the variety of land cover types and the wealth of ancillary data (e.g., soil, topography, forest structure) available, La Selva is an excellent site for assessing variation in forest biomass over a variety of land use history types. Permanent field inventory plots have been established in the study area to provide more than 5 years of changes of forest structure and biomass.

The Howland Research Forest is located in central Maine, USA in the transition zone between boreal conifer and northern hardwoods forest. The central core consists of unmanaged, mature spruce-hemlock-fir stands approximately 20 m in height, surrounded by similar vegetation managed for commercial forest products. The topography of the region varies from flat to gently rolling, with a maximum elevation change of less than 68 m within 10 km. The site is well documented in terms of historical characterization of forest structure and biomass.

Approach: The measurements include radar polarimetry at L-band (25 cm wavelength) acquired by the NASA/JPL airborne synthetic aperture radar (AIRSAR) system in 2004, L-band UAVSAR in 2009 and 2010, ALOS PALSAR imagery from 2007-2010, and Lidar data by large footprint airborne scanning Lidar known as the Laser Vegetation Imaging Sensor (LVIS) (Drake et al., 2002; Saatchi et al., 2007; Baltzer et al. 2003; Rowland et al., 2002). The overall schematic of the fusion algorithm is shown in a flowchart in figure 1. In summary, the approach follows several steps: 1. Lidar samples coincident with the radar image acquired in year one will provide statistics of backscatter differences at different polarizations with respect to the biomass differences associated with lidar shots, $P(\Delta\sigma^0|\Delta B)$. We assume, lidar shots with 2 or more height metrics such as maximum, average, or height of medium energy (HOME) will estimate the aboveground biomass with a reasonable precision. At this point the precision for estimating absolute value of biomass is less important than the precision in biomass difference. 2. We will use the Baysian estimation to acquire the first estimate of change between year 1 and year 2, by using the backscatter change statistics $P(\Delta\sigma^0)$ between the two images. 3. This estimate will then be used as the input to the next iteration to recalculate $P(\Delta\sigma^0|\Delta B)$ until an optimized value of biomass change is obtained and uncertainties are calculated.

The next steps will follow as radar images for the subsequent years and the new lidar shots are accumulated for the area of the study. The procedure has three specific characteristics: 1. The area covering lidar shots is not the same size as the radar pixel, allowing for larger areas to be used for developing better statistics of lidar measurements within a forest patch (many km^2). 2. Iterations within the procedure for estimating biomass change depend on $P(\Delta\sigma^0|\Delta B)$ that can be improved every time new lidar shots are available for the forest patch, developing improved results as the sensors collect more data. 3. The final biomass change detection depends how well $P(\Delta\sigma^0)$ statistics between two images represent the true changes. We will include the multi-looking of radar speckle in the model to assess the resolution suitable for biomass change detection.

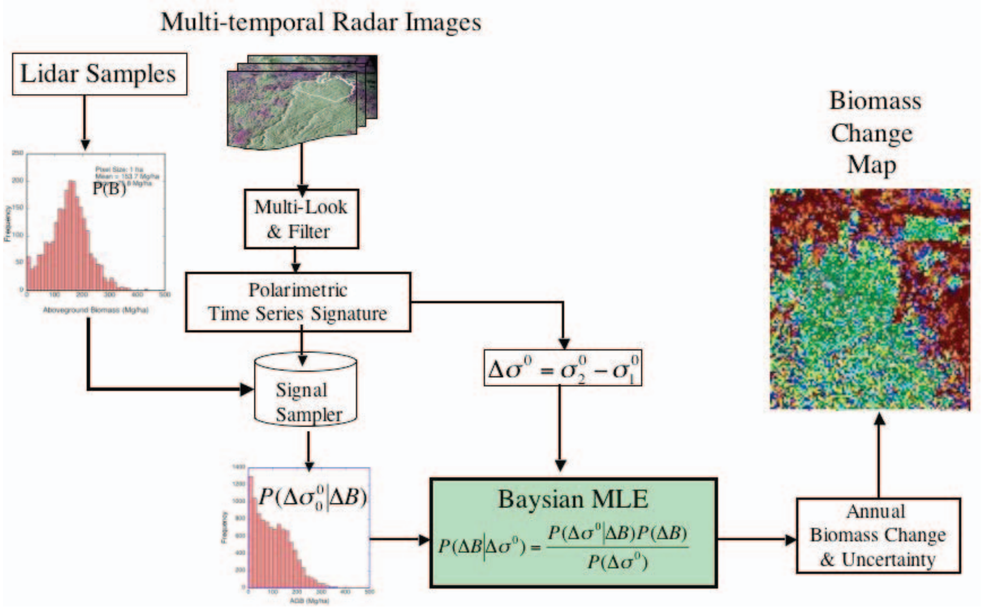

Figure 7. Flowchart of lidar and radar fusion algorithm to estimate biomass change from a Baysian estimation routine. The input data layers are lidar samples over a patch of forest and the multi-temporal radar backscatter images.

References

Balzter, H., Skinner, L., Luckman, A., and Brooke, R. (2003): Estimation of tree growth in a conifer plantation over nineteen years from multi-satellite L-band SAR. *Remote Sensing of Environment* 84, 184- 191.

Chazdon, R. L. 2003. Tropical forest recovery: legacies of human impact and natural disturbances. Perspectives in Plant Ecology Evolution and Systematics 6: 51-71.

Clark, D.B. and Clark, D.A., 2000. Landscape-scale variation in forest structure and biomass in a tropical rain forest. Forest Ecology and Management 137, pp. 185–198.

Drake, J. B., Dubayah, R. O., Clark, D. B., Knox, R. G., Blair, J. B.,Hofton, M. A., Chazdon, R. L., Weishampel, J. F., & Prince, S. (2002). Estimation of Tropical Forest Structural Characteristics Using Large-footprint Lidar. Remote Sensing of Environment, 79, 305– 319.

Rowland, C., Balzter, H., Dawson, T., Luckman, A., Skinner, L. and Patenaude, G. (2002). Biomass estimation of Thetford forest from SAR data: potential and limitations. ForestSAT, Edinburgh, 5-9 August 2002, Forest Research, Forestry Commission, CD-ROM.

Saatchi, S., Despain, D. Halligan, K., Crabtree, R. Yu, Y. 2007. Estimating forest fire fuel load from radar remote sensing, IEEE Geoscience and Remote Sensing, vol. 45:1726-1740.

This work is performed partially at the Jet Propulsion Laboratory, California Institute of Technology, under contract from National Aeronautic and Space Administration.