GLOBAL 3D FOREST STRUCTURE MAPPING WITH TANDEM-L: MONITORING THE EARTH'S DYNAMICS

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ABSTRACT

Forest biomass plays a crucial role in the quantification of the terrestrial carbon budget. Today, forest biomass is poorly quantified across most parts of the Earth surface due to the great difficulties in measuring biomass on the ground and consistently aggregating measurements across scales. SAR satellites can provide the required information globally and frequent in order to quantify current biomass state and the changes. Tandem-L is a German mission proposal for an innovative interferometric L-band radar mission that enables the systematic monitoring of dynamic Earth processes using advanced techniques and technologies. The mission is science driven aiming to provide a unique data set for climate and environmental research, geodynamics, hydrology and oceanography. Important application examples are global forest height and structure and the derivation of forest biomass. The Tandem-L mission concept consists of two cooperating satellites flying in close formation. The 3 D structure mode provides a unique data source to observe and quantify changes in forest biomass. This paper provides an overview of the potential of using multi-parametric SAR for forest structure estimation with the derivation of forest biomass and suggests a mission for a global acquisition.

SCIENCE EXPLORATION

26% of the land surfaces are covered with forest corresponding to an area of 40 Mio km². Forests play an important role in storing natural resources (ecological and economical aspect) and in the storage of carbon content (climate aspect). The relation between carbon content and biomass is given by the dry matter of the wood; 50 % of the plant dry matter consists of carbon. The role of biomass in the global carbon cycle is determined by two components, the static and the dynamic one. The static is describing the amount of biomass currently existing worldwide. The dynamic one is defined through the biomass change occurring due to forest structure change or forest areas extent change. The dynamic component is the most unknown one, although the estimation uncertainty of the static component has the highest influence in the whole carbon cycle budget error. The dynamic processes of the biomass can be seen as carbon sources and sinks and are also essentially influencing the carbon cycle.

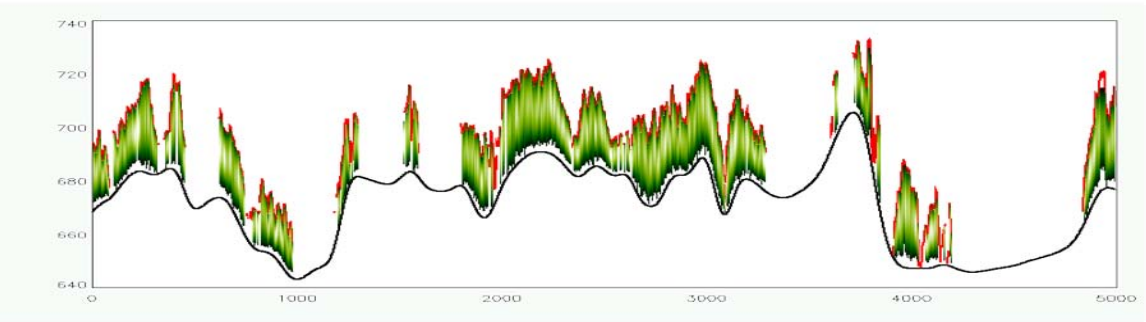

Figure 1: 3-D forest structure profile derived from the Pol-InSAR technique at L-band with DLR's E-SAR airborne system. Ground topography black, forest top height red and vertical forest structure green.

The estimation of above ground biomass can be done indirectly through the knowledge about the 3D forest structure. Fully-polarimetric single-pass SAR interferometric (Pol-InSAR) data (see Figure 2) is an innovative and proven method that is able to estimate the 3D forest structure by resolving different scattering mechanisms in different polarizations along the forest height resulting in a quasi tomographic image of the volume scatterer (see Figure 1). Dependent on the number of acquired baselines several low frequency components of vertical forest structure can be estimated. Then each forest type can be characterized by its specific 3 D structure which is a direct link to the stored biomass.

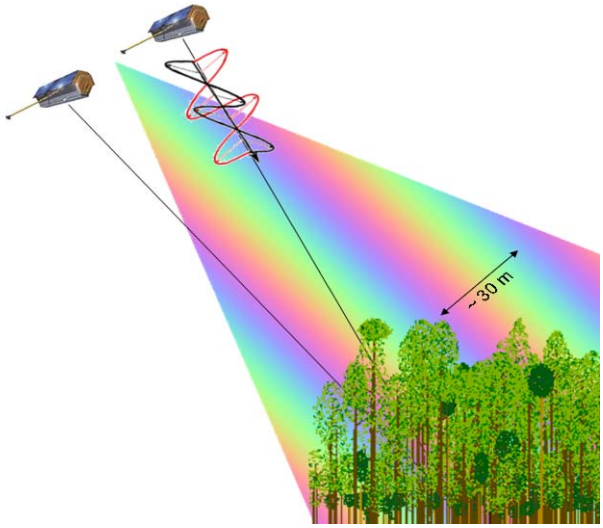

Figure 2: 3-D structure mode using single-pass SAR interferometry

TANDEM-L MISSION CONCEPT

The motivation for this mission proposal comes from the increasing science requirements for a continuous and global monitoring of climate and environmental variables with high resolution and on a reliable way. Examples of the essential variables to be measured by Tandem-L in a systematic way are:

- Above ground forest biomass and its 3-D vertical structure distribution. Observation of changes in forest height and biomass (e.g. due to deforestation or afforestation), changes in biodiversity, etc.
- Earth surface deformation

- Retreat and accumulation in ice and snow covered regions
- Changes in surface soil moisture and land use (high resolution maps).

The estimation of dynamic processes on Earth surfaces requires systematic, long term and continuous observation strategies in order to detect short and long term changes with a sufficient accuracy. Depending on the environmental and/or anthropogenic process to be observed there is a need for having different time intervals in the acquisition plan.

Existing SAR sensors could already demonstrate that radar plays an important role in the parameter estimation related to essential environmental, climate and anthropogenic processes. Today, SAR sensors are mostly covering only small and selected areas and do not acquire data in a long term and systematic way in order to make reliable statements about Earth's processes changes.

One important feature of Tandem-L is therefore to achieve observation intervals of weeks to several months on a global scale with an appropriate sampling to characterize dynamic processes. A second important feature is a systematic acquisition strategy with a global coverage that allows generating consistent time series over at least 5-7 years of mission lifetime. The combination of short observation intervals and systematic data acquisition will enable to observe short term highly dynamic processes like seismic movements as well as long term processes with yearly cycle change like forest biomass growth changes.

Tandem-L will be the first mission that will measure biomass with an accuracy of 20% on a global scale and in addition estimate its yearly change throughout the mission lifetime. With this information the uncertainty in the terrestrial stored above ground biomass will be drastically reduced. Biomass will be derived from the direct estimate of the forest height and 3-D forest structure that will be measured by Tandem-L Moreira 2009.

Due to the need of having Pol-InSAR and D-InSAR modes in the mission concept, one satellite should have a nearly circular and polar orbit within a narrow tube of a few hundred meters for D-InSAR operation, while the second satellite should have an orbit which provides the required baselines for Pol-InSAR. The same helix orbit concept as in the TanDEM-X mission is adopted for the second satellite Krieger 2007.

One most challenging task in the Tandem-L realization is the development of two identical satellites (see Figure 3) with a cost effective implementation approach and at the same time having a high performance in order to fulfill the demanding scientific needs. However, besides an innovative mission concept also new imaging techniques and technologies are needed for fulfilling the science requirements.

Figure 3: Artistic view of a Tandem-L formation with two satellites (preliminary design achieved during a joint DLR and NASA/JPL pre-phase A study).

SUMMARY

The 3D forest structure estimation using polarimetric SAR interferometry is a reliable and innovative technique for biomass derivation and can be globally applied with the proposed Tandem-L mission. Tandem-L is an innovative mission proposal for mapping Earth dynamics with an unprecedented accuracy and capability.

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Keywords: *biomass, forest structure, L-band, SAR, polarimetric SAR interferometry*

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