# FOREST BIOPHYSICAL RETRIEVALS AND LAND COVER DYNAMICS USING MULTI-TEMPORAL, MULTI-SENSOR (SAR-OPTICAL-LIDAR) AND MULTI-RESOLUTION EO SENSORS FOR CHINA AND SELECTED ASIAN REGIONS (FOREST DRAGON 4)

| ***European Leader Investigator*** | ***Chinese Leader Investigator*** |
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**List of Principal Investigators (PIs)**

| Topic Nr. | PIs | Title |
|---|---|---|
| **31470_1** | *Prof.Christiana Schmullius, Prof. Zengyuan Li* | ***Forest biophysical retrievals using multi-temporal, multi-sensor (SAR-optical-LiDAR) and multi-resolution EO sensors for China and selected Asian regions (FOREST Dragon 4)*** |
| **31470_2** | *Prof. Laurent Ferro-Famil, Prof. Erxue Chen* | ***3-D geo-physical characterization of vegetated areas, including forests and cultivated areas, using polarimetric SAR tomography: techniques and applications*** |
| **31470_3** | *Prof. Peter Krzystek, Prof. Yong Pang* | ***Synergistic 3D mapping and characterization of diverse forested areas with multi-source remotely sensed data*** |

## *EXECUTIVE SUMMARY*

The overall goal of the FOREST DRAGON 4 project is to advance understanding in forest ecosystems mapping within China and neighbouring regions. In addition, methodological developments towards the synergy of different spaceborne and airborne LiDAR sensors and techniques are proposed. The ten objectives of the FOREST DRAGON 4 project are 1) the investigation of scaling effects in forest ecosystem mapping with SAR data, 2) the long-term analysis of forest GSV and forest structure, 3) linking forest DRAGON products with existing land use, land cover and/or fire products (e.g. GlobBiomass, CCI Land Cover, US and Chinese products), and 4) the synergy of optical and radar data for mapping forest ecosystems, 5-6) adapt current forest mapping algorithms to Eastern Russia and Continental Southeast Asia, 7-10) canopy height inversion based on multiple data source, forest change detection using canopy height models, forest response from airborne profiling radar (so called FGI-Tomoradar) in Evo, Finland, and DOM, DTM, DHM mapping in 1 to 2 test areas in China.

The project will deliver theoretical results as well as wall-to-wall maps of forest parameters for China and neighbouring countries. As a result of Objective 1, a thorough analysis of scaling effects in forest structure mapping and forest GSV mapping at different spatial resolutions will be delivered. The outcome of Objectives 2 and 3 includes validated forest GSV and GSV change maps for the years 1995-2005-2010 and 2015. The products will be generated in close cooperation with and will be exchanged with other DRAGON 4 teams involved in vegetated ecosystems analyses. In addition, methodological procedures for (i) improving and/or validating Forest DRAGON maps with other DRAGON products or several land use or land cover maps and (ii) for validating forest GSV change by means of fire emission data will be presented. This work can be linked to other DRAGON 4 proposals, such as rice and crop mapping, fire monitoring and atmospheric pollutants. The deliverables for Objective 4 include methodological procedures (i.e. a Sentinel-Procedure) for monitoring forest ecosystems using different sensors (optical, radar) synergistically at different temporal and spatial scales in accordance with GEOSS requirements. Objective 5 and Objective 6 include the analysis of algorithms for forest change detection in tropical forest, the forest GSV and coverage maps, forest change analysis in Eastern Russia and Continental Southeast Asia. The time period will include 1995-2015. Objectives 7-10 develop very high resolution approaches and algorithms for forest GSV and biomass estimation from 3D forest structure models. Two sub-proposals complement the ecosystems theme:

1) Ferro-Famil & Chen, 3-D geo-physical characterization of vegetated areas, including forests and cultivated areas, using polarimetric SAR tomography: techniques and applications. Objectives: 1) Development of physical parameter retrieval methods for the quantitative 3-D characterization of vegetated areas, 2) Development of innovative vector signal processing techniques for high-resolution 3-D imaging, PolSARpro Software v5.0 is a polarimetric SAR data processing and educational tool developed under contract to the European Space Agency. It is proposed in this project to include all the new algorithms and scientific procedures that will be developed during the DRAGON-4 project.

2) Krzystek & Pang, Synergistic 3D mapping and characterization of diverse forested areas with multi-source remotely

sensed data. Objectives: 1) the investigation of upscaling and adaptation models and algorithms for 3D multi-functional and scales forestry inventory using spaceborne data by using airborne data and products as basis, 2) the synergy of optical and 3D forest models derived from LiDAR/Radar data for precise mapping of forest ecosystems, 3) use the Sentinels-½ or Tandem-X/Tandem-X data and ENMAP/Rapideye satellite for forest map updating and vitality checking based on calibration and validation tools obtained by terrestrial and airborne observations.

**ABSTRACT 31470_1: "Forest biophysical retrievals using multi-temporal, multi-sensor (SAR-optical-LiDAR) and multi-resolution EO sensors for China and selected Asian regions (FOREST Dragon 4)"**

| ***European Principal Investigator*** | ***Chinese Principal Investigator*** |
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| Prof. Christiana Schmullius | Prof. Zengyuan Li |
| (University Jena,Germany) | (Chinese Academy of Forestry,CHINA) |

The overall goal of the FOREST DRAGON 4 project is to advance understanding in forest, cultivated and natural grassland ecosystems mapping within China and neighbouring regions. In addition, methodological developments towards the synergy of different spaceborne and airborne LiDAR sensors and techniques are proposed. The ten objectives of the FOREST DRAGON 4 project are 1) the investigation of scaling effects in forest ecosystem mapping with SAR data, 2) the long-term analysis of forest GSV and forest structure, 3) linking forest DRAGON products with existing land use, land cover and/or fire products (e.g. GlobBiomass, CCI Land Cover, US and Chinese products), and 4) the synergy of optical and radar data for mapping forest ecosystems, 5-6) adapt current forest mapping algorithms to Eastern Russia and Continental Southeast Asia, 7-10) canopy height inversion based on mutiple data source, forest change detection using canopy height models, forest response from airborne profiling radar (so called FGI-Tomoradar) in Evo, Finland, and DOM, DTM, DHM mapping in 1 to 2 test areas in China.
The grassland part of this proposal covers the following three objectives: 1) Development of physical parameter retrieval methods for the quantitative 3-D characterization of vegetated areas. The proposed research activities that will be conducted in this topic will aim at developing vegetation parameters extraction methods based on the complementary aspects of PolSAR and PolTomSAR, for volumetric land-cover (including the topics of scattering modelling, decomposition, segmentation …) characterization and at investigating the potential time-series analysis. Among the many descriptors of vegetated areas, key ecosystem parameter for biomass stock successions, and growth dynamics, such as forest structure and Above Ground Biomass will be addressed, as well as classical indicators like tree height. Special attention will be dedicated to the estimation of the underlying ground dielectric and roughness properties.
2) Development of innovative vector signal processing techniques for high-resolution 3-D imaging. The recent history of SAR tomography shows that the possibilities for characterizing 3-D environments using Multi-Baseline Pol-inSAR data are highly linked to both the quality of the signal processing techniques used to perform 3-D focusing and to the acquisition configuration. During this project, several options, related to original CS- and Wavelet-CS based imaging solutions will be tested, and original configurations, like multi-temporal Tandems, Bistatic Tomographic pairs, will be analyzed and explored at various application scales.
3) PolSARpro Software v5.0 is a polarimetric SAR data processing and educational tool developed under contract to the European Space Agency. It is proposed in this project to include all the new algorithms and scientific procedures that will be developed during the DRAGON-4 project.
The project will deliver theoretical results as well as wall-to-wall maps of forest parameters for China and neighboring countries. As a result of Objective 1, a thorough analysis of scaling effects in forest structure mapping and forest GSV mapping at different spatial resolutions will be delivered. The outcome of Objectives 2 and 3 includes validated forest GSV and GSV change maps for the years 1995-2005-2010 and 2015. The products will be generated in close cooperation with and will be exchanged with other DRAGON 4 teams involved in vegetated ecosystems analyses. In addition, methodological procedures for (i) improving and/or validating Forest DRAGON maps with other DRAGON products or several land use or land cover maps and (ii) for validating forest GSV change by means of fire emission data will be presented. This work can be linked to other DRAGON 4 proposals, such as rice and crop mapping, fire monitoring and atmospheric pollutants. The deliverables for Objective 4 include methodological procedures (i.e. a Sentinel-Procedure) for monitoring forest ecosystems using different sensors (optical, radar) synergistically at different temporal and spatial scales in accordance with GEOSS requirements. Objective 5 and Objective 6 include the analysis of algorithms for forest change detection in tropical forest, the forest GSV and coverage maps, forest change analysis in Eastern Russia and Continental Southeast Asia. The time period will include 1995-2015. Objectives 7-10 deal develop very high resolution approaches and algorithms for forest GSV and biomass estimation from 3D forest structure models.

**ABSTRACT 31470_2: "3-D geo-physical characterization of vegetated areas, including forests and cultivated areas, using polarimetric SAR tomography: techniques and applications"**

| ***European Principal Investigator*** | ***Chinese Principal Investigator*** |
|---|---|
| Prof. Laurent Ferro-Famil | Prof. Erxue Chen |
| (IETR/University of Rennes 1,France) | (IFRIT/Chinese Academy of Forestry,CHINA) |

Based on the experience accumulated and gained during the DRAGON-1 to -3 projects, we intend, under the DRAGON-4 project to strengthen the established and already fruitful collaborations between European and Chinese partners and experts in polarimetric, interferometric and tomographic SAR (Pol-TomSAR) and quantitative characterization of vegetated areas, including forest, cultivated areas and grassland. Due to the successful already launched spaceborne polarimetric radar sensors and to the availability of ESA sponsored airborne SAR campaigns, it is now shown that the accelerated advancement of PolSAR and Pol-TomSAR techniques is of direct relevance and of priority to local-to-global environmental monitoring of the terrestrial covers.

The proposed project contains 3 main scientific topics with the following objectives:

1) Development of physical parameter retrieval methods for the quantitative 3-D characterization of vegetated areas. Information on the land cover is of paramount importance for monitoring and management of the environment on a local, regional and global scale. In natural areas, land cover presents complicated structures and highly complex scattering responses, due to various scattering contributions, dielectric and shape properties and volumetric structures. The proposed research activities that will be conducted in this topic will aim at developing vegetation parameters extraction methods based on the complementary aspects of PolSAR and PolTomSAR, for volumetric land-cover (including the topics of scattering modelling, decomposition, segmentation …) characterization and at investigating the potential time-series analysis. Among the many descriptors of vegetated areas, key ecosystem parameter for biomass stock successions, and growth dynamics, such as forest structure and Above Ground Biomass will be addressed, as well as classical indicators like tree height. Special attention will be dedicated to the estimation of the underlying ground dielectric and roughness properties, over both wild and cultivated areas.

2) Development of innovative vector signal processing techniques for high-resolution 3-D imaging. The recent history of SAR tomography shows that the possibilities for characterizing 3-D environments using Multi-Baseline Pol-inSAR data are highly linked to both the quality of the signal processing techniques used to perform 3-D focusing and to the acquisition configuration. During this project, several options, related to original CS- and Wavelet-CS based imaging solutions will be tested, and original configurations, like multi-temporal Tandems, Bistatic Tomographic pairs, will be analyzed and explored at various application scales.

3) PolSARpro Software v5.0 is a polarimetric SAR data processing and educational tool developed under contract to the European Space Agency. It is proposed in this project to include all the new algorithms and scientific procedures that will be developed during the DRAGON-4 project. It will thus increase the great collection of well-established algorithms and tools designed to handle PolSAR and Pol-InSAR data from airborne and spaceborne sensors. The PolSARpro software could thus become also an important communication tool, advertising the international Geoscience and Remote Sensing community for promoting the most important scientific developments conducted during the DRAGON-4 project.

The funding of the project in general and of the Young Scientists in particular is not problematic at all since both European and Chinese partners are used work on the topic proposed in this project and can, through national or regional funding, guarantee that the project will not suffer from a lack of human or material resources

**ABSTRACT 31470_3: "Synergistic 3D mapping and characterization of diverse forested areas with multi-source remotely sensed data"**

| ***European Principal Investigator*** | ***Chinese Principal Investigator*** |
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| Prof. Peter Krzystek<br>(Munich University of Applied Sciences,Germany) | Prof. Yong Pang<br>( Chinese Academy of Forestry,CHINA) |

The goal of the project is to advance the 3D precise mapping and characterization of forest ecosystem by synergistically using multi source remotely sensed data within China and Europe. In addition, methodological development is focused on the synergic use of airborne LiDAR techniques and satellite sensors to enable large-scale 3D intelligent and precision forestry. Furthermore, a solid study will be carried out, in which a system will be built up to provide decision-support on the multi-functional inventory of cross-scale ecosystems integrating space and airborne remote sensing techniques and results. The three objectives of the project are 1) the investigation of upscaling and adaptation models and algorithms for 3D multi-functional and scales forestry inventory using spaceborne data by using airborne data and products as basis, 2) the synergy of optical and 3D forest models derived from LiDAR/Radar data for precise mapping of forest ecosystems, 3) use the Sentinels-½ or Tandem-X/Tandem-X data and ENMAP/Rapideye satellite for forest map updating and vitality checking based on calibration and validation tools obtained by terrestrial and airborne observations. Underlying airborne/terrestrial models will be the benefit to spaceborne remote sensing and existing spatial geo-data to enhance forest information estimation. The project will deliver theoretical models as well as cross-scales wall-to-wall maps of 3D forest structural parameters for China and European countries. This will be pursued through a case study in pilot region(s) in E and NE China and Bavarian national forest Park in which airborne and terrestrial observations and reference are fully available. As a result of Objective 1, an analysis of scaling effects in mapping 3D forest structure at different spatial resolutions by combing forest geometry and optical spectral models will be delivered. The outcome of Objectives 2 and 3 includes validated 3D forest change maps. In addition, methodological procedures for calibrating and validating forest structure maps by means of airborne and terrestrial data will be presented. This work will be linked to other proposals for GSV change mapping, natural biodiversity /productivity monitoring. The deliverables for Objective 2 include methodological procedures for monitoring forest ecosystems using different sensors (optical, LiDAR, Radar) synergistically at different times and spatial scales. Objectives include the development and analysis of algorithms for forest change detection in forest understory and tropical forest, the forest composition and change analysis. Objective 3 deals with algorithms for object-level forest parameter estimation and forest vitality mapping using Radar and hyperspectral data, updated forest GSV and regeneration coverage maps. The system developed will trigger a data fusion-based management tool for large-scale forest resources.