EARTH OBSERVATION TO INVESTIGATE THE CHARACTERISTICS AND CHANGES OF THE CRYOSPHERE IN HIGH MOUNTAIN ASIA (EOCRYOHMA)

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

Topic Nr.	PIs	Title
32437_1	*Dr.TobiasBolch, Prof. Tandong Yao*	***Mapping of (rock)glaciers and observation of glacier area and volume changes in High Mountain Asia using earth observation data (EOGlacHMA)***
32437_2	*Prof. Noel Gourmelen, Prof. Shiyin Liu*	***Observation of surface velocity over ice covered terrain with microwave and multispectral imager***
32437_3	*Prof. Roderik Lindenberg, Prof. Tao Che*	***Observation of extent and characteristics of snow and permafrost in High Mountain Asia (EOSnoPeHMA)***

EXECUTIVE SUMMARY

The cryosphere in high elevation regions is a very sensitive indicator of climate change and meltwater from the cryosphere is a significant fraction of fresh water resources in many parts of the world, particularly in China and in the countries receiving waters from the Tibetan Plateau. Cryosphere and hydrology questions should be linked towards better science on the terrestrial water cycle across a range of spatial and temporal scales. This leads to the need of connecting regional and global analyses of water resources. Fully integrated use of satellite, ground observations and hydrological distributed models is necessary to support water resources management and to clarify the roles of the interactions between the land surface and the atmosphere over the Tibetan Plateau in the Asian monsoon system.This project is part of an integrated response to the Call Theme Hydrology & Cryosphere with the projects "Multi source hydrological data products to monitor High Asian River Basins and regional water security (MUSYCADHARB led X. Li and M. Menenti) and Earth Observations tools for Water resource and quality monitoring in Yangtze wetlands" (EOWAQYWET, Y. Wang and H. Yesou).We will generate an (rock)glacier inventory and assess both area and volume changes for benchmark regions in High Mountain Asia (HMA) taking advantage of the synergies of European and Chinese optical and microwave space-borne observation systems. Similar advantage will be taken to investigate the flow velocity of (rock)glaciers and their changes over time, to map snow cover and their evolution and to map permafrost and its evolution and assess the possibilities to map and monitor the active layer.We will also assess temporal and regional trends of glacier elevation changes of entire HMA by altimetry missions. The generated data will be instrumental for forcing, calibration, validation and data assimilation in basin scale glacio-hydrological models.This project is structured in three sub-projects. In all, we plan to exploit specific synergies of ESA and Chinese satellites, such as the combination of ESA S1 SAR data with Chinese microwave radiometers or the high spatial and spectral resolution of Sentinel 2 with the data acquired CBERS-04. We also aim to fully exploit the capabilities of ICESat-1, the forthcoming ICESat-2 and CryosSat-2 data.The combination of the advantages of the different data is especially useful to further automate the (rock)glacier mapping. We also aim to use information about the surface displacements/glacier flow for this task. The velocity will be detected by feature tracking or SAR interferometry. Glacier volume changes will be assessed by differencing of digital elevation models and altimetry data. For snow retrieval, the assimilation of multi-source images in a combined product is expected to enable the investigation of snow properties at finer spatial resolution and higher temporal intervals. In a similar way, the combination of active and passive microwave remote sensing images is expected also to enhance the detection of ground freezethaw states. We will concentrate our investigations on five selected benchmark regions located in different climatic regions in HMA. In-situ measurements and very high resolution data sets will be used to calibrate and validate the remote-sensing derived results. All Lis, PIs and co-PIs will dedicate some of their time to the Dragon project. Moreover, all partners are leading relevant projects, have some funding available and supervise students in relevant subjects who can be active in the Dragon 4 project. Specifically mentioned should be the Glaciers_cci and the GlobPermafrost projects funded by ESA. European partners have several relevant projects funded by other funding agencies such as the national funding (SNF, DFG, BMBF) as well as the Chinese partners (e.g. projects by MOST or NSFC). T. Yao is the leading scientist of a CAS Strategic Priority Program.

ABSTRACT 32437_1: "Mapping of (rock)glaciers and observation of glacier area and volume changes in High Mountain Asia using earth observation data (EOGlacHMA)"

European Principal Investigator	*Chinese Principal Investigator*
Dr. Tobias Bolch (Univ. of Zurich,Switzerland)	Prof. Tandong Yao (ITPCAS,CHINA)

Global warming caused significant changes of glaciers with on average clear glacier mass loss. However, recent studies revealed also regions with balanced mass budgets especially in parts of High Mountain Asia (HMA). These heterogeneous changes significantly influence the hydrology, i.e. regionally they alter the river run-off and cause the rise of endorheic lakes on the Tibetan Plateau and globally they affect the sea-level. Glaciers are a major contributor of sea-level rise and affect population that rely on fresh water from glaciers. Rock glaciers have so far only rarely been investigated in HMA but may also of hydrological importance.
The purpose of this sub-project within the more general cryosphere project is to generate an up to date glacier and a rock glacier inventory for selected benchmark regions located in different climatic settings in HMA. Glacier mapping will be based both on optical and radar imagery distributed by the Chinese and European Space programs and combine information about surface flow (as derived in the subproject 2), surface reflectance and backscatter. The generated outlines will be compared to existing ones of previous periods for area change assessments. As area changes are only indirectly related to climate and hydrology, we will also investigate glacier mass changes using digital elevation models from different time periods (DEM differencing) and altimetry data. Both data sources are complimentary in regard to their spatiotemporal coverage. We will apply ICESat and Cryosat-2 altimetry data to investigate the trends over the whole of HMA and apply DEM differencing in the benchmark regions using existing DEMs (e.g. SRTM, ASTER or TanDEM-X) or DEMs derived from stereo data. Field measurements and high resolution data will be employed to validate and calibrate the remote-sensing derived results.
The outcome of this project will be improved methodologies for glacier mapping and glacier change assessments and a better knowledge about rock glacier occurrence, the spatial and temporal variability of glacier area and mass changes in HMA, its influence on hydrology and its control by local and climatic forcing. This will be realised thanks to the large archive of satellite data available via Dragon, data available from other sources and thanks to the coordinated effort of the several institutions partnering in the project. The link to hydrology, local and climate forcing will be investigated within this subproject via data assimilation into mass balance models, interaction with the two other sub-projects under the umbrella of cryosphere, and via interaction with the hydrology consortium.
Available funding:
All Lis, PIs and co-PIs will dedicate some of their time to the Dragon project. Moreover all partners are leading relevant projects, have some funding available and supervise students in relevant subjects who can be active in the Dragon 4 project.
T. Bolch (UZH) is leading a project about the cryosphere in the Tarim Catchment, NW-China and he is supervising an already funded PhD-student for the next 3 years who deals with glacier remote sensing. It is also intended to attract students for the specialized master to write their thesis within the Dragon project. T. Bolch is involved in the ESA Glaciers_cci project led by F. Paul, a Co-PI of this subproject. T. Strozzi (GAMMA) is involved in the ESA Glaciers_cci and ESA GlobPermafrost projects. This intended Dragon 4 project will benefit from synergies with the Glaciers_cci and GlobPermafrost projects.
Tandong Yao (ITP) is leading 2 NSFC-funded projects relating to glacial energy balance and melting process on the Tibetan Plateau. He is also the leading scientist of CAS Strategic Priority Program (B) on Tibetan multiple spheres. In his group, 2 associate professors and 2 PhD-students focus on glacier changes in HMA by using remote sensing data and one associate professor focus on the glacier modelling. Available in-situ data will provide the ground truth.
Shiyin Liu (CAREERI) is leading a project from MOST about monitoring of glacier mass changes in representative areas in China. He is supervising 2 PhD students funded by this project. Other team members are leading grants from Natural Science Foundation of China in related topics and supervising master degree students.
Chang-Qing Ke (Nanjing University) is leading a NSFC project about glacier elevation and mass balance change by the integration of multi-source remote sensing data.
R. Lindenbergh is leading the TU Delft contribution to the FP7 IQmulus project on a high-volume fusion and analysis platform for Geospatial Point Clouds, Coverages and Volumetric Data Sets. This project currently pays for 2 Postdocs.

ABSTRACT 32437_2: "Observation of surface velocity over ice covered terrain with microwave and multispectral imager"

European Principal Investigator	***Chinese Principal Investigator***
Prof. Noel Gourmelen	Prof. Shiyin Liu
(University of Edinburgh noel,UK)	(Chinese Academy of Sciences,CHINA)

Global warming over the 20th century has caused significant changes in mountain glaciers.Observations have revealed on average a clear glacier retreat, and mass loss. However,recent studies showed the existence of regions with balanced mass budgets especially in the Western and Central parts of High Mountain Asia (HMA). These heterogeneous changes significantly influences the hydrology, i.e. regionally alters the river run-off and causes the rise of most endorheic lakes on the Tibetan Plateau and affect globally the sea-level.Mountain glaciers and ice caps are currently a major contributor of non steric sea level rise and affect population that rely on fresh water from glaciers or that are exposed to glaciers risk.The purpose of this sub-project 'Glacier velocity' within the more general Cryosphere projectis to robustly quantify ice velocity of glacier on HMA from remote sensed imagery distributedby the Chinese and European Space programs. Ice velocity is directly linked with local conditions (e.g. slope, basal friction, surface properties) and climatic conditions i.e. surface mass balance; studying ice velocity can therefore inform about these conditions and changes of these conditions.The outcome of this project will be a better knowledge of the spatial and temporal variability of ice velocity and of its control by local and climatic forcing. Ice velocity will be quantified such that patterns of spatial and temporal changes can be analysed with respect to climaticand local forcings. This will be realised thanks to the large archive of satellite data available via Dragon and thanks to the coordinated effort of the several institutions partnering in the project. The link to local and climate focing will be investigated within this subproject via data assimilation into mass balance models, interaction with the 2 other sub-projects under the umbrella of cryosphere, and via interaction with the Hydrology and Cryosphere consortium. The European lead Tobias Bolch has an assistant position at University of Zurich (UZH) andcan dedicate 10% of his time to the intended Dragon 4 project. He is leading one DFG funded project about the glaciers and hydrology in the Aksu-Tarim Catchment, NW-China. In addition, he is supervising one PhD-Student (N. Mölg) for the next three years who deals with glacier mapping and especially geodetic glacier mass balance assessment and is already funded by University money. It is also intended to attract students for the newly established specialized master at UZH to write their thesis in the framework of the Dragon 4
project. T. Bolch is also involved in the ESA Glaciers_cci project which is led by Frank Paul, a Co-PI of this subproject. This intended Dragon 4 project will benefit from the synergies with the Glaciers_cci project. In addition, some funding is available to host Chinese scientists for
their intended exchange stay in Zurich. Shiyin Liu is now leading a project from the Ministry of Science and Technology (MOST,
2013-2018) for the monitoring of mass changes of glaciers in some representative glacierized areas in western China. He is now supervising two PhD students who is working under the MOST project and will be working together with the Dragon 4 project. Other team
members are leading grant from Natural Science Foundation of China for related topic. They are supervising 3 master degree students who can be active in the dragon 4 project. Noel Gourmelen has a permanent position at the University of Edinburgh and can allocate
5% of his time to this project. Gourmelen is funded through the STSE CS+Mountain Glacier for the analysis of CryoSat over Mountain Glaciers. The University of Edinburgh receives funding for ~25 PhD students a year, bids to hire PhD students will be made each year via
this scheme. Gamma will be supported by the recently funded ESA GlobPermafrost project (P.I. ZAMG, Austria) to be kicked of on February 1, 2016 for a total duration of three years.

ABSTRACT 32437_3: "Observation of extent and characteristics of snow and permafrost in High Mountain Asia (EOSnoPeHMA)"

European Principal Investigator	***Chinese Principal Investigator***
Prof. Roderik Lindenberg	Prof. Tao Che
(TU Delft,Netherlands)	(CAREERI, CAS,CHINA)

One of the main characteristics of High Mountain Asia is its high altitude which makes it prone to permafrost and snow cover. At the same time it is generally assumed and also proven at a number of occasions that climate change has its effects on precipitation patterns and surface temperature which affects the distribution and active layer of permafrost and influences the yearly snow cover variations. Still these effects are only sparsely known, while there impact on the South East Asian water cycle is potentially large. The main goal of this subproject is therefore to use the great potential of newly available remote sensing data from notably Chinese and ESA missions to strongly improve the quality of existing High Mountain Asia snow cover and permafrost products.

To do so, use will be made from for example high temporal resolution Sentinel 1 and 2 data, which will make it possible to make snow cover and permafrost products with much smaller pixel sizes of down to 10 m then for example MODIS derived products, while the temporal resolution could be kept at the same high weekly. In addition, the newly available S1 and S2 data will be used to study if it is possible to differentiate between dry and wet snow and if parameters describing albedo and roughness can be co-estimated within an extended snow product.

Initial results of this efforts will be validated in different ways. By comparison to existing products, by validation in local studies using very high resolution data, by comparisons to outcomes of permafrost and snow cover model results and by local in situ validations. The different results of these validations will be used to further improve the permafrost and snow cover products in the second half of the project.

An important set of activities is also the direct use of the new permafrost and snow cover products in a number of applications. These applications have in common that at first the permafrost and snow cover products are applied to separate satellite data from other sensors in the classes available in the products. This allows, in a second step, to characterize how these signals behave over homogeneous areas, which, finally will enable in future to directly assess these properties from the separate satellite data itself.

Within this subproject it is proposed to apply this scheme for analysing elevation changes induced by large scale thaw and freezing of the ground. These elevation changes can be estimated using InSAR techniques (S1), ICESat 1 and 2 laser altimetry and maybe Cryosat-2 radar altimetry data.

A similar scheme can be used to refine the estimation of glacier elevation changes by differentiating at individual shot level between elevations over snow and ice. As a final application the mapping of snowline extent over glaciated areas will be studied as a simple proxy to monitor glacial evolution.

To summarize, the expected results will directly push forward the knowledge on snow cover and permafrost distribution, while this knowledge will be applied within the project to extend knowledge on particular satellite signals and to extend knowledge on glacial change and the effects of permafrost variations over High Mountain Asia. The provided results will be of high importance to better understand the glaciers' behaviour and provide important input data for the hydrological modelling. We will therefore interact closely with the two other sub-projects under the umbrella of cryosphere and the hydrology consortium.

Available funding

All Lis, PIs and co-PIs will dedicate some of their time to the Dragon project. Moreover all partners are leading relevant projects, have some funding available and supervise students in relevant subjects who can be active in the Dragon 4 project. Specifically, the PIs Dr. Tao CHE, is responsible for the Heihe Remote Sensing Experimental Research Station that can be a platform for the education of young scientists. He is involved in the China State Key Basic Research Project "Remote sensing of snow in complicated condition and snow changes in multi-scales and "Study on key processes of the rapid changing cryosphere " These two projects are related with the remote sensing of snow and ice in regional and global scales. Dr. Lindenbergh has a faculty assistant professorship position at the Delft University of Technology in the Dept. of Geoscience and Remote Sensing, that has a strong focus on observing and modeling meteorological and surface processes in the Cryosphere . He is the project leader of the TU Delft contribution to the FP7 IQmulus project on a high-volume fusion and analysis platform for Geospatial Point Clouds, Coverages and Volumetric Data Sets. This project currently pays for two Postdocs. Dr. Tobias Bolch is leading a project about snow and permafrost investigations in the Tarim catchment, while Lin Liu is involved in the GlobPermafrost project together with T. Strozzi with GAMMA RS (co-PI of two other subprojects).