Loads on the Earth Lithosphere at Different Spatial and Temporal Scales: Constraints from Space Geodesy and Satellite Imagery

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With several major faults capable of producing devastating earthquakes, a large and high plateau bounded by prominent mountain ranges, and a fast rate of development, China is a rather unique place to study fault seismic cycle, continental deformation, tectonic-climate interactions, as well as human impact on ground deformation. Global, remote sensing data are well adapted to survey such phenomena with a wide variety of spatial wavelengths and temporal behaviors. The recent evolution toward higher resolution and time series analysis in satellite imagery and space geodesy (GPS, InSAR) provides new key observations that allow to refine or even revise our views on the lithosphere response to tectonic, hydrological or anthropic-related loading variations. Although covering only the past decades, space data also allow to jointly analyze short-term and long-term deformation and reconcile them through integrated models. We now stand at a turning point, with more progresses to expect from the new generation of satellite data. This project builds on the experience gained from the past 2 Dragon projects (2577 and 5305), with both methodological and geophysical goals. The objective is to provide the most precise measurements of ground surface displacement, combining different, complementary techniques (high resolution optical images, GPS and InSAR), to constrain models of the lithosphere response to (WP1) stress and strain variations throughout the seismic cycle or to (WP2) nontectonic sources of load.

In (WP1), we aim in particular at detecting and analyzing lateral variations of coupling during the interseismic stress build up period along selected faults. This is important as coupling variations may influence not only earthquakes patterns on each fault (nucleation zone, rupture extent and arrest) but also the regional stress field, up to large distances from the fault. Starting from detailed InSAR studies at the scale of a fault system, we will merge GPS and InSAR data, exploiting at best their own specificities in terms of space and time resolution, into regional maps and models of the present-day elastic/anelastic deformation. More emphasis will be given on what's going on at the margins of the Tibetan Plateau, where a lot of efforts were already focused on during Dragon 2. In addition, to help documenting how coseismic slip distribute along faults, how it relates to fault segmentation, how it may evolves from one earthquake to another (paleoseismology from space), we intend to use high-resolution optical imagery to map all ranges of offsets of preserved morphological markers. This would complement any other co- (and post)- seismic studies of any event that would occur during this Dragon 3 project.

In (WP2), we propose to extract from the WP1 InSAR time series non tectonic signals related to hydrology (permafrost melting, aquifer pumping, water table changes), mining, or crustal rebound (due to ice sheet melting or lake water level fluctuations). This is critical for properly correcting thus interpreting GPS and InSAR-derived small displacement rates . It also brings information on the lithosphere rheology, that in turn can be used to model fault behaviour during the seismic cycle (WP1). We will primarily focus on the monitoring and modelling of the vertical deformation induced by water level fluctuations of large lakes in Tibet.

Most work will be done continuing to exploit the present archive of ERS, Envisat and ALOS SAR data, and available high resolution optical and multispectral imagery. Further improvement will be made to our own Small Baseline interferometric chain and time series analysis (NSBAS, Doin et al., 2011) to get prepared for the next step for InSARists:

"absorbing" much larger data sets to come from Sentinel and ALOS-2. Funding will be from French PNTS and ANR and Chinese NSF.

不同时空尺度下岩石圈应力加载作用：基于卫星大地测量和卫星图像的观测研究

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中国存在一些能够发生大规模破坏性地震的大型活动断层，拥有独一无二而的青藏高原，同时经济高速发展，因此研究中国大陆的断层周期变形、大陆变形、构造-气候交互作用，以及人类活动导致的地面变形，具有得天独厚的优势。全球覆盖的遥感数据为监测这些现象的多种空间尺度和时间演化提供了很好的机会。最近发展的高分辨率卫星数据和大地卫星测量时间序列技术（GPS，InSAR），为深化、甚至改变我们对岩石圈的构造、水文和人类活动加载响应的认识，提供了新的观测依据。尽管观测数据只有十多年的历史，但是它能够使我们通过统一的模型进行联合分析，并协调短期及长期变形过程。我们现在正处在一个继往开来的转折点上，期待利用新一代的卫星数据获得岩石圈变形过程研究的新认识和新进展。本项目基于前期的两个龙计划项目(Dragon 2577 和 Dragon 5305), 以发展卫星数据的分析方法和地球物理应用为目的。目标是提供高精度的地表变形观测数据，合并不同且互补的技术（高分辨率光学卫星图像，GPS和InSAR等），约束地震周期中岩石圈对应力应变变化的响应模型（WP1），以及岩石圈对非构造加载源的响应模型（WP2）。

在WP1中，我们主要专注于监测和分析震间期一些断层应力耦合积累的侧向变化。其重要之处在于它不仅影响断层上地震发生的模式（成核区域，破裂范围和终止），也会影响距离断层很远的区域应力场。从详细的单个断层尺度的研究开始，我们将合并GPS和InSAR数据，最大限度利用它们各自的时空分辨能力，使之反应区域形变并适应现今弹性/非弹性形变模型。我们主要关注青藏高原周缘的形变过程，此前的龙计划项目中我们已经做了相当多的工作。另外，为了帮助积累同震断层滑动分布数据，断层分段情况，地震周期演化情况（古地震的空间技术研究），我们将利用高分辨率光学图像监测各种尺度范围的地形学位错标志，补充本项目期间发生地震的同震和震后研究。

在WP2部分，我们将提取InSAR时间序列中的非构造信号，如水文（冻土融化、含水层抽水、水位变化等）、开矿和地壳回弹（冰川融化和湖水水位起伏变化）引起的形变。这有助于校正和正确解释GPS和InSAR得出的细微位移变化率。它也会带来岩石圈的流变信息，进而又为地震周期变形的研究（WP1）提供模型约束。我们主要监测和建模西藏地区大型湖泊的水位变化引起的垂直形变。

我们主要利用ERS、Envisat和ALOS存档数据，以及高分辨率光学和多光谱图像开展工作。进一步发展我们自己开发的时间序列分析技术(NSBAS, Doin et al., 2011)， 处理更大量的数据如Sentinel和ALOS-2。我们的研究经费主要来自于法国的PNTS和ANR，以及中国的国家基金项目等。