Seismic Cycle, Lithosphere Rheology and Continental Deformation from time series analysis of InSAR data in China

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We use radar images acquired by the ERS and Envisat satellites over the northeastern and southern margins of the tibetan plateau and central Tibet to constrain the present-day behavior of major active faults in China and probe the short-term rheology of the lithosphere.

We build a processing chain, that goes from a series of raw SAR data to the time-series analysis of interferograms. The chain is based on ROI_PAC modules (rearranged and complemented) and a small baseline approach. Range-dependent spectral filtering and DEM-based SLCs coregistration help improving coherence in interferograms with long spatial baselines and strong topographic gradients. Corrections for DEM error, stratified tropospheric phase delays (using the ECMWF, ERA-Interim reanalysis), and residual orbital errors are also included.

Envisat SAR data are used to map and model the space and time variations of the interseismic velocity field along the left-lateral Haiyuan fault system (HFS), at the north-eastern boundary of the tibetan plateau. We evidence a narrow, 35 km-long zone of high velocity gradient, corresponding to shallow creep, in between two fully locked sections of the fault : the eastern end of the 'Tianzhu' seismic gap, and the rupture zone of the M~8 1920 earthquake. The creep rate is ~5 mm/yr in average, on the same order as the estimated loading rate at depth. Temporal variations in this creep rate are detected (creep bursts locally reach a rate of 9-10 mm/yr, with a clear rate increase between 2006 and 2007), associated with microseismicity fluctuations. The analysis of the relationships between the space and time evolution of the surface aseismic slip and the surface fault geometry reveals a direct control of the fault roughness on the creep behavior.

ERS and Envisat data are similarly processed to detect the crustal flexure associated with the increase of the Siling Co lake load on the lithosphere in central Tibet (bowl-shaped subsidence at a rate of ~ 5 mm/yr near the lake shores, as a response to a ~ 1m/yr lake level increase since 2000). The subsidence modelling brings constraints on the lithosphere visco-elastic behavior at short time scales.

Finally, the developped processing chain allows to measure by InSAR the interseismic uplift velocity in a very challenging area, the Himalaya, at the India-Asia collision southern front (marked by a ~5000 m topographic step). The uplift profile on a test transect across central Nepal allows to model the present-day slip-rate of the Main Himalayan Thrust (~18-20 mm/yr). Comparing present-day versus long-term deformation across the range also gives insights on the mountain growth processes and evolution.

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基于InSAR时间序列方法分析中国大陆的地震周期，岩石圈流变和大陆构造变形

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我们应用欧空局的ERS和Envisat存档卫星数据，分析青藏高原东北部、南部边界和中部的形变，约束中国大陆主要活动断层的现今运动，探测岩石圈的短期流变特征。我们建立了InSAR数据处理系统，将原始雷达信号处理成用于时间序列分析的干涉结果。该系统基于ROI_PAC模块（经过重组织和补充）和SBAS方法。Range依赖的谱滤波和基于DEM的SLC图像配准改善了长基线和地形复杂地区的干涉相干性。DEM误差校正，大气分层对流层雷达信号延迟，以及剩余轨道误差校正等功能也融合了进来。Envisat数据被用于提取青藏高原东北边界左旋走滑海原断裂的震间速度场，并建模分析其时空变化特征。我们发现了一条35km长的高速滑动带，表明断层浅部蠕滑活动，它处在两个完全锁定的断层段之间，即天祝地震空区的东端和1920年海原地震破裂带西端。其平均蠕滑率为~5mm/y，接近断层深部加载的量级。我们也发现了该段蠕滑率的时间变化特征（局部蠕滑达到了9-10 mm/y，在2006-2007年间明显速率增加明显）与微震波动有关。通过分析无震蠕滑和地表断层的时空演化关系可知，断层粗糙度直接控制着其蠕滑行为。用类似的方法处理ERS和Envisat数据，我们监测到了地壳的绕曲变形与西藏中部色林错湖对岩石圈的加载作用的增加有关（湖岸~5mm/y的碗形沉降是对2000年以来~1m/y湖水位增加的响应）。沉降建模为短时间尺度的岩石圈粘弹性行为模型提供了约束。我们发展的InSAR处理方法也能测量地形复杂地区的震间抬升速率，如印度-亚洲碰撞带南端的喜马拉雅地区（存在~5000m的地形梯度）。在跨越尼泊尔中部的抬升测试剖面中，我们建模发现喜马拉雅主逆冲带的现今滑动率为~18-20 mm/y。比较该高海拔地区的现今和长期变形过程，可以为山脉隆升及其演化过程提供新的认识。