Detecting Seismic Anomalies from Satellite Data with Multiple Parameters Using Pattern Analysis and Statistical Methods

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A series of earthquakes recently occurred in many countries across the world have resulted in massive devastation and loss of lives, and caused enormous economic damage. Some of them include the 2008 Wenchuan earthquake, the 2010 Chile earthquake, the 2011 Christchurch earthquake in New Zealand, and the 2011 Japan earthquake and subsequent tsunami, and the extremely violent Haiti earthquake of January 2010, which killed more than 220,000 people. Although scientists believe a mixture of seismic precursors occur prior to earthquakes, it is commonly recognized that earthquakes are notoriously difficult to predict. Yet a reliable shortterm earthquake forecast could save thousands of lives.

The evolutionary process of earthquakes is rich of complex features, from stochastic to chaotic or pseudo-periodic dynamics, often depending on the different geo-tectonic regime and focal mechanisms. A wide range of fundamental research in the lithosphere, such as from fault rupture mechanics to seismic wave propagation, has been undertaken on different regions in past decades. Many case studies show there are some seismic anomalies before earthquakes and associated phenomena after earthquakes in respect of ground deformation, active faults (slip rates and geometry), tectonic stress fields and geomagnetic fields, but systematic understanding of preparation process of earthquakes and their seismic cycles is very limited to date. There is no pragmatic approach to predicting earthquakes.

Earth observation (EO) building on satellites provides the enormous capability of observing regional and global areas of our planet. It records a wide range and huge volumes of spatial temporal measurements, which capture a variety of activities occurring on the earth and in its interior. Meanwhile, EO provides new possibilities for scientists to investigate the earthquake behaviour by using a broad range of abnormal phenomena reflected in ionosphere and ground displacement activities observed from space and improve understanding of preparation process of earthquakes from the world scale and the perspectives of coupling ionosphere with lithosphere.

The project is aimed to investigate space borne SWARM, ENVISAT/ASAR and other satellite data for detecting a range of precursors in ionosphere and lithosphere, before large earthquakes and to assess correlations between the selected precursors and seismic cycles. The specific objectives are to:

- Review the studies of thermal infrared anomalies using CBERS-01&02, FY 2C, ERS1&2,
- RADARSAT, Sentinel-3; be familiar about spatial-temporal profiles of ground deformation and active fault features using ERS, ENVISAT/ASAR, ALOS/PALSAR(TPM) satellites and GPS;
- improve our understanding on ionospheric perturbations and abnormal changes in electromagnetic emission density and electron density using SWARM;
- develop effective methodologies based on data mining, statistical methods and existing methods
- developed for handling ground deformation and thermal infrared spectrum to extract anomalies;
- define a uniform entropy measure to transform the detected anomalies to a uniform representation;

- carry out fusion on unified anomalies and examine the divergence among combined results and select convergent anomalies for further analyses;
- detect possible coherent acceleration in time of some physical parameters related to seismic strain release behaviour before large seismic events;
- analyze correlations and coherences between the anomalies from satellite and ground data and seismic cycles and;
- develop a model based on Bayesian probability and Theory of Belief Functions to estimate possibilities of potential seismic activities in a given region.

基于多个卫星参数的特征分析和统计技术探测地震异常

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近年来世界范围发生的一系列地震产生了重大灾害和人员伤亡，造成巨大经济损失。例如，2008年5月12日的中国汶川地震、2010年2月27日智利大地震、2011年2月22日新西兰的基督城地震以及2011年3月11日日本地震和海啸等，其中2010年1月12日灾难性的海地地震使22万多人丧生。虽然一些科学家认为地震之前存在地震的综合前兆信息，但是地震预报异常困难确是人们的共识，然而地震之前的短临预报却可以拯救成千上万人的生命。

地震的孕育演化是从随机无序到视周期性动力学的含有丰富信息的复杂过程，常常与不同的地质构造和震源机制有关。过去几十年，已经在不同的地区开展了关于岩石圈基本问题的广泛研究，例如从断层破裂机制到地震波的传播的研究。大量研究表明，地震之前存在异常，震后出现一些现象，它们与地球变形、活断层（滑动速率和几何学）、构造应力场和地磁场等有关，但是对于地震的孕育过程和地震周期至今仍然没有系统的认识，没有一种成熟的预报地震的技术。

本项目的目的是研究SWARM, ENVISAT/ASAR和其它卫星的观测资料，探索大地震前的电离层和岩石圈的前兆，以及一些前兆和地震活动性的关系。

具体研究内容包括：

1. 调查和分析CBERS-01&02, FY 2C, ERS1&2的热红外异常已有研究；
2.收集和分析目前ERS, ENVISAT/ASAR, ALOS/PALSAR(TPM) 卫星和GPS在获取地球变形和活断层的时空特征的应用;
3. 用SWARM电磁辐射和电子密度资料来研究和提高关于电离层扰动和异常变化的认识，并基于数据挖掘、数理统计方法等已有方法开发有效的异常特征提取方法；
4.开发用于地球变形和热红外谱异常的提取方法
5. 定义统一熵度量，将识别的异常转换为统一的表示
6. 开展异常信息融合，检验融合结果的分散特点，选择收敛异常并进一步分析。
7. 研究大地震前与地震应变释放有关的某些物理参数在时间域的可能增强变化
8. 分析卫星和地面异常及其与地震活动性的相关性
9. 研究基于贝叶斯概率和证据理论的不精确或不确定性模型，评估给定区域潜在地震的可能性