Orchestration in time and space of southeast Tibetan faults

view from geodesy

Context & research background

Despite decades of controversy, our understanding of the formation of the Tibetan Plateau remains limited. The role of competing mechanisms, such as distributed crustal thickening versus lateral propagation of thrust faulting at crustal or lithospheric scales, is still poorly understood (Figure 1). In view of the 3D nature and temporal complexity of the involved deformation processes, no numerical model taking into account the role of strike-slip faults in accommodating stepwise evolution of thrust faulting, as well as the interaction between the deep crust and the surface, has yet been implemented. Therefore, it remains difficult to test the mechanical and rheological consistency, and the ability to explain observations, of end-member conceptual models at the scale of the Tibetan Plateau.

Objectives of the project & Description of work

The objective of the project is to use a modelling tool based on geodetic data to provide new quantitative constraints on the deformation of the Tibetan Plateau. Indeed, geodetic observations at a larger scale than geologic studies allow identifying and examining currently active faults (Figure 1). For that, the radar satellite data (InSAR) of the Sentinel-1 (S1) constellation can be used to quantify very small present-day interseismic deformation signals at unprecedented resolution, following an approach that has already proven successful in Tibet (Daout et al., 2016, 2018; Lemrabet et al., 2023). Indeed, InSAR is now a mature technique to investigate such interseismic deformation at large regional scales, allowing to quantify present-day rates of deformation. The method relies on the New Small BAseline Subset (NSBAS) approach that has proven successful in retrieving interseismic deformation signals (Doin et al., 2011, Grandin, 2015). The analysis is already ongoing in the framework of the FLATSIM service developed by CNES and by the French Solid Earth center Form@Ter (https://www.poleterresolide.fr/projets/en-cours/flatsim/).

In the frame of this project, elastic block models will be made to allow inverting for block kinematics and fault coupling (Figure 1). We will focus on the central and eastern edge of the Tibetan Plateau, which is a key location to study the interplay between strike-slip motions and thickening through time. Indeed, at the centre of this region, the Xianshuihe fault is the most seismically active fault in Tibet, while to the north the plateau is present-day actively uplifted. We aim to build a purely elastic rigid block model taking into account block rotations (which cannot be neglected in our study area) as well as elastic loading on active faults (Tdefnode code, McCaffrey 2009). The present-day tectonic loading rates at depth and along-strike variations of slip deficit rate will be inverted and compared with the geodetic data. The analysis of the velocity residuals will help refining block boundaries with respect to GPS-only block models (e.g., Li et al., 2018), detecting potential internal block deformation and constraining thrust-fault dips. The geological and tectonic validity of the block limits will also be evaluated with respect to the active faults identified in the field, providing detailed fault mapping of the study area.

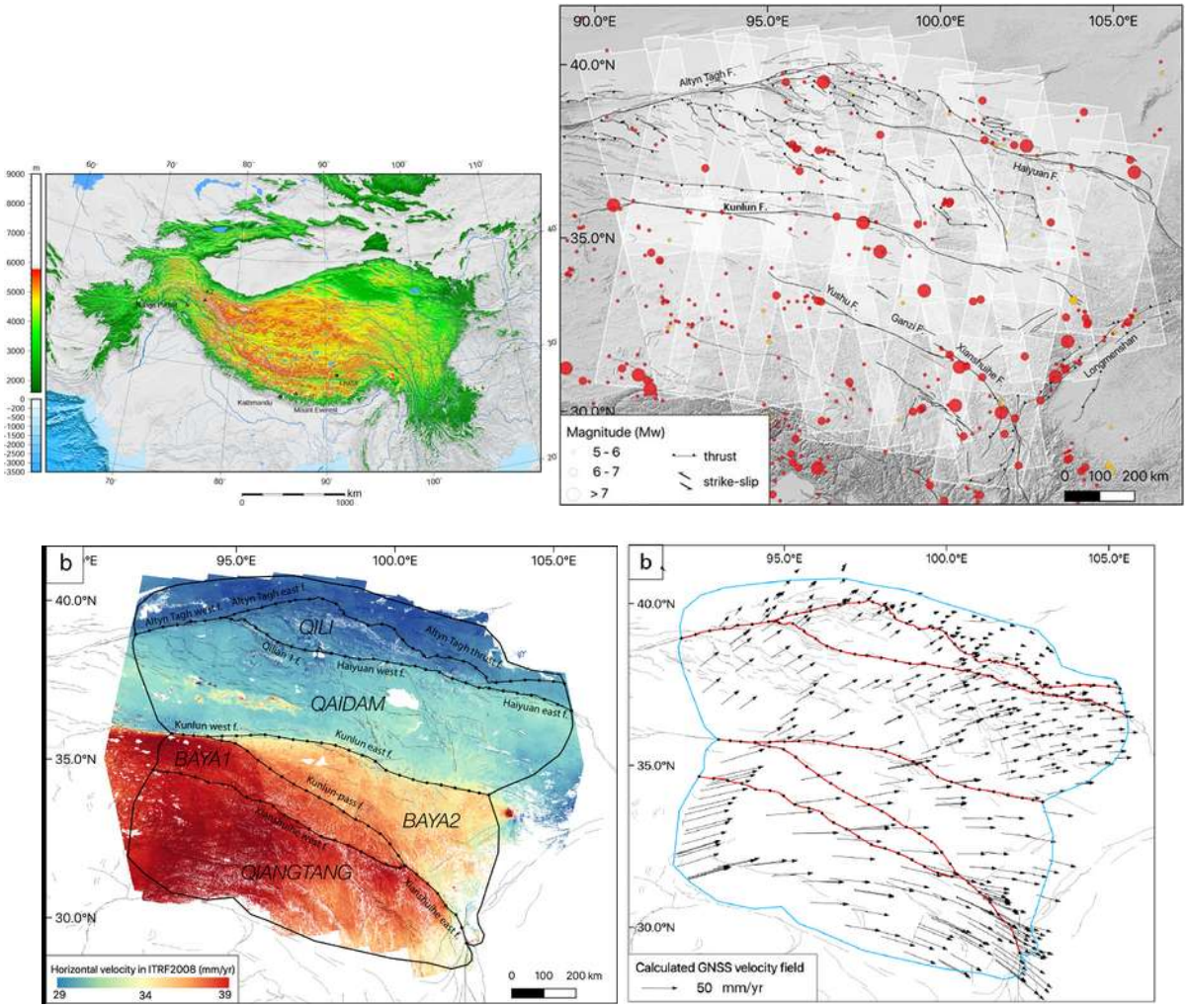

Figure 1: Top left: topographic map of Tibet. Top right: sismotectonic map of Tibet, with main faults and earthquakes. Bottom left: InSAR image with block boundary deduced from fault map. Bottom right: preliminary result for inversion of geodetic data. The goal of the project is to explore in detail this inversion, testing different block geometry.

References

Doin, Guillaso, Jolivet, Lasserre, Lodge, Ducret, Grandin, Presentation of the small-baseline NSBAS processing chain on a case example : the Etna deformation monitoring from 2003 to 2010 using ENVISAT data, Proceedings of the European Space Agency Symposium « Fringe », Frascati, Italy, 2011.

Doin, M.-P., Twardzik, C., Ducret, G., Lasserre, C., Guillaso, S., & Jianbao, S. (2015). InSAR measurement of the deformation around Siling Co Lake: Inferences on the lower crust viscosity in central Tibet. JGR, 120, 5290–5310. Doi: 10.1002/2014jb011768

Daout, Jolivet, Lasserre, Doin, et al., (2016), Along-strike variations of the partitioning of convergence across the Haiyuan fault system detected by InSAR, GJI, doi: 10.1093/gji/ggw028

Daout, Doin, Peltzer, Lasserre, Socquet (2018) Strain partitioning and present-day fault kinematics in NW Tibet from Envisat SAR interferometry, JGR, doi: 10.1002/2017JB015020

Lemrabet, Doin, Lasserre & Durand (2023). Referencing of continental-scale InSAR-derived velocity fields: Case study of the eastern Tibetan Plateau. JGR, 128, doi: 10.1029/2022JB026251

Li, Liu, Wang, Cui, (2018) Present-day crustal deformation and strain transfer in NE Tibet, EPSL, doi:10.1016/j.epsl.2018.01.024

McCaffrey (2009), Time-dependent inversion of three-component continuous GPS for steady and transient sources in northern Cascadia, GRL, doi:10.1029/2008GL036784

Keywords

radar satellite data (InSAR), present-day interseismic deformation, elastic block models, internal block deformation, active faults, Geodesy, Tectonics, Tibet.

Learning outcomes of project

The students will develop and validate a model for a natural phenomenon. They will build an elastic rigid block model including block rotations and elastic loading on active faults using an existing code (Tdefnode code, McCaffrey 2009). The aim of the project is to constrain the tectonic loading rates along the active faults of Tibet by inverting the geodetic data. They will learn both numerical modelling and dealing with natural data which include noise and incertainties. They will have to interact with specialists of geodesy (Marianne Métois, Marie-Pierre Doin, Cécile Lasserre) and of tectonics (Anne Replumaz).

Prerequisite

Ability for numerical modelling, curiosity of natural phenomenon, and ability to read research papers.

Supervisor (with contact information)

Marianne Métois (LGL-TPE, Université Lyon 1), Marie-Pierre Doin (ISTerre, Université Grenoble-Alpes), Cécile Lasserre (LGL-TPE, Université Lyon 1) et Anne Replumaz (ISTerre, Université Grenoble-Alpes).

Location/Laboratory (with link to the website)

ISTerre, Université Grenoble-Alpes, https://www.isterre.fr/