CHART Scientific Report

FCC Geodesy – Surface Kinematics

(FCC Geodesy 2)

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1. Introduction / Original goals of this project

Surface kinematics, i.e., displacements of surface points relative to each other over time are caused by a variety of natural and man-made processes including e.g., tectonics, gravitational mass movements, activity of geological faults, changes of ground water level, construction activities, earthquakes, and others. While some of these causes may result in unpredictable and sudden deformations others may accumulate gradually over time and be predictable for some time into the future as functions of location and time based on sufficiently long time-series of past observations. Geodetic deformation models allow dealing with both types of deformations in the context of coordinate reference frames.

Surface kinematics over the wider FCC area (see fig. 1) must be known with sufficient precision and spatial resolution to assess potential underground deformations relevant for the FCC. These are deformations affecting the access shafts, the FCC tunnel, the alignment, or CERN's coordinate reference frames (CRFs) and occurring over sufficiently long time spans such that their prediction over a few months to a few years is possible. If such deformations exist, they will have to be considered for the maintenance of the CRFs, e.g., by using a geodetic deformation model, and for the detailed design of the alignment. During the FCC-Geodesy study it has become clear that the presence/absence of relevant surface kinematics and their relation to underground structure has not yet been geodetically investigated.

The proposed project aims at filling this gap. It has two main objectives, namely to

(i) provide information about the presence/absence of long-term surface kinematics (deformations) potentially relevant for the construction, installation, and operation of the FCC; and
(ii) to develop a proposal of how to monitor the surface kinematics in the pre-construction phase, and during construction, installation and operation of the FCC.

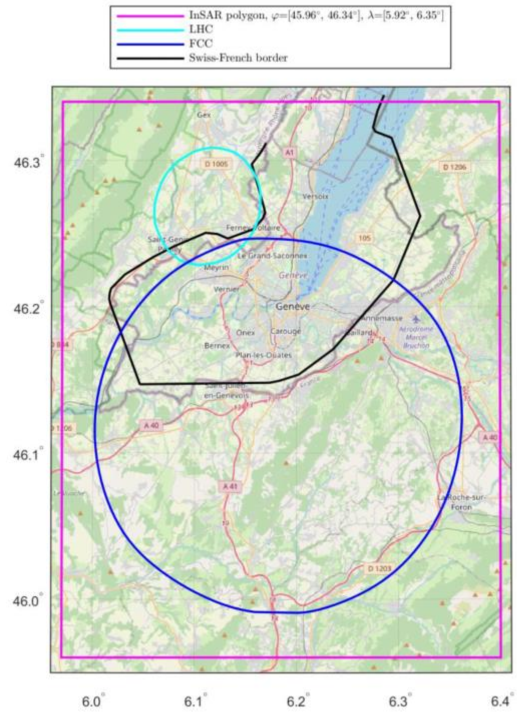

Fig. 1: Study area comprising the surface in the vicinity of the FCC and the LHC.

2. Realisation

Assessing surface kinematics in terms of local subsidence rates, horizontal displacement rates or other parameters, requires time series of coordinates or measurements which are long enough to discriminate unavoidable noise and actual displacements. Typically, such measurements require the implementation of a bespoke monitoring concept with carefully chosen instruments, measurement points, measurement schedule, and processing pipeline. The proper choice of all these components is based on prior knowledge about the spatial extent and magnitude, and character of the kinematics.

In the first phase of the project we focus on collecting and synthesizing such prior knowledge, based on a review of the literature, collection of data sets and geodetic products representing surface kinematics, and processing of accessible legacy data, i.e., data collected in the past, most likely for other purposes. Such data comprise precision levelling data from national surveys, GNSS/GPS data from permanent stations or from a sufficient number of repeated epoch-wise measurements, and time series of displacements obtained from PS/DS InSAR analyses covering approximately the time span from 2014-2026.

Through past alignment, civil engineering and surveying work at CERN, differential subsidence or heaving over relatively short distances have been noticed in a couple of locations within the current CERN premises. Most of these anomalous deformations occurred only during specific times and were likely related to nearby civil engineering works. However, there is an unstable sector (7-8) of the LHC which seems to be subject to continuing small deformations resulting in yearly need for adjustment, and there are unstable sectors along the Super Proton Synchrotron (SPS). Levelling data (hydrostatic and/or geometric) are available over a relatively long time span, but have not yet been consistently analysed. We will use these data to investigate whether the displacements are accompanied by related surface displacements. We will assess how well the deformations within the tunnels could, in the past, have been predicted forward in time based only on the geodetic observations.

We will synthesize all these findings to achieve objective (i) and ideally generate a map of the area showing where relevant long term deformations have been found, where they are absent, and where the legacy data and literature are not sufficient to provide an information. Based on this, we will finally develop a proposal for monitoring the region in the future.

3. Results / Conclusions / Deliverables

So far we have completed the literature review. The FCC region is situated within a structurally complex basin at the transition between the Jura Fold-and-Thrust Belt and the Molasse Basin. Faults in this area are confined to the detached sedimentary cover above a Triassic décollement at 3–4 km depth and are organised into two conjugate systems: NNW-SSE and approximately E-W strike-slip faults. The most significant seismotectonic feature is the Vuache Fault Zone, a left-lateral strike-slip fault with a long-term slip rate of 0.15–0.4 mm/yr, associated with recurrent moderate seismicity including the ML 5.3 Epagny earthquake (1996). Stress analysis reveals that NNW-SSE strike-slip faults and their E-W conjugate counterparts are near-critically stressed under present-day conditions, implying that currently presently inactive faults could be reactivated by fluid pressure disturbances.

Regarding deformation rates, absolute horizontal motion is dominated by the northeastward translation of the Eurasian plate (20–25 mm/yr), while residual intraplate deformation in the FCC region is consistently ≤ 0.4 mm/yr. Deformations of this order of magnitude may be good to know for optimizing alignment in the long turn but are not critical for the FCC. Localized strain rates of up to $40 \cdot 10{-}9$ yr−1 near the Jura-Alps transition correspond to differential displacements of approximately 0.1 mm/yr over baselines of a few kilometres, i.e., likely negligible.

Vertically, the Molasse Basin is largely stable (0–0.5 mm/yr), but because the southeastern sectors of the FCC ring approach the Alpine front, a differential vertical displacement of up to about 1 mm/yr across the full ring diameter cannot be excluded. The literature does not suggest any surface kinematics that would negatively impact the tunnel construction. However, the vertical deformation components could be relevant for the alignment of the accelerator over its multi-decadal operational lifespan. The literature does not provide enough information for this area. We expect that the cross-validation between GNSS, leveling, and InSAR data will help us to reduce this knowledge gap.

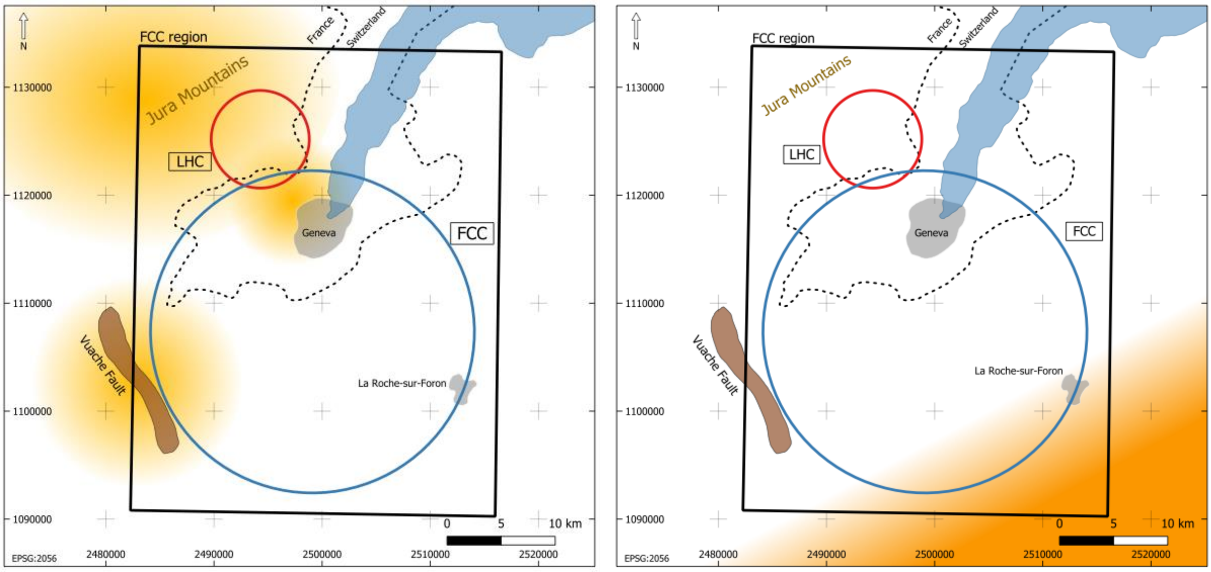

Fig. 2: Qualitative visualization of the results from the literature review. Left: Horizontal deformation across the FCC region, ranging from negligible to relevant (0.1–0.4 mm/yr). Sources of surface deformation include the Jura Mountains and fault systems in the Geneva Basin. Right: Vertical displacement rates due to Alpine uplift in the southeast of the FCC region, ranging from negligible to potentially critical for long-term alignment solutions (0.1–2.5 mm/yr).

4. Publications and Outreach

The project has just started. There are no publications yet.