FUTURE CIRCULAR COLLIDER

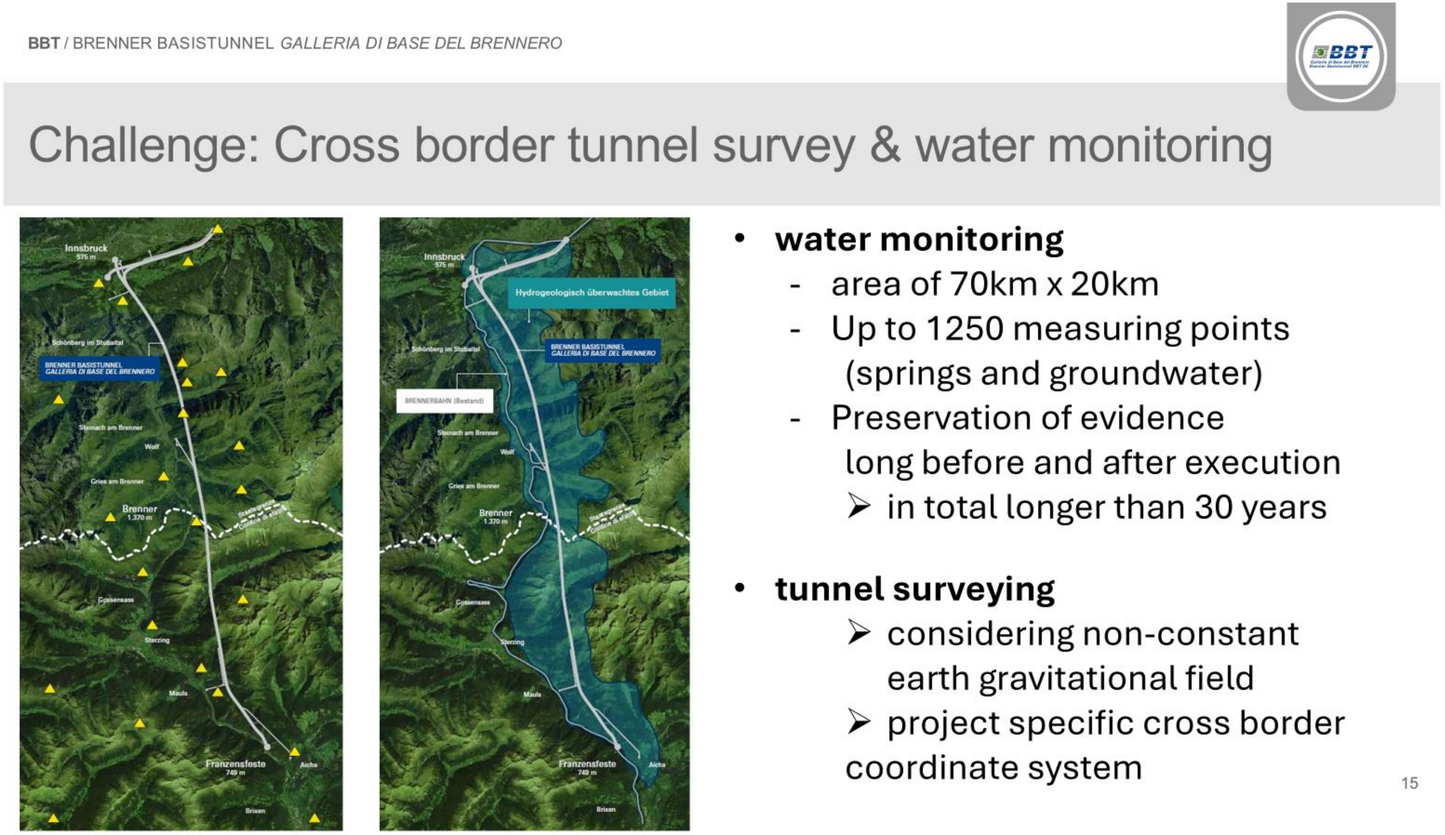
GEODESY UPDATE

22nd May 2025 / FCC Week 2025

Benjamin Weyer

Outline

1. Objective of the geodetic studies
2. Geodetic reference system and frame for FCC
3. Geoid modelling
4. Geomonitoring



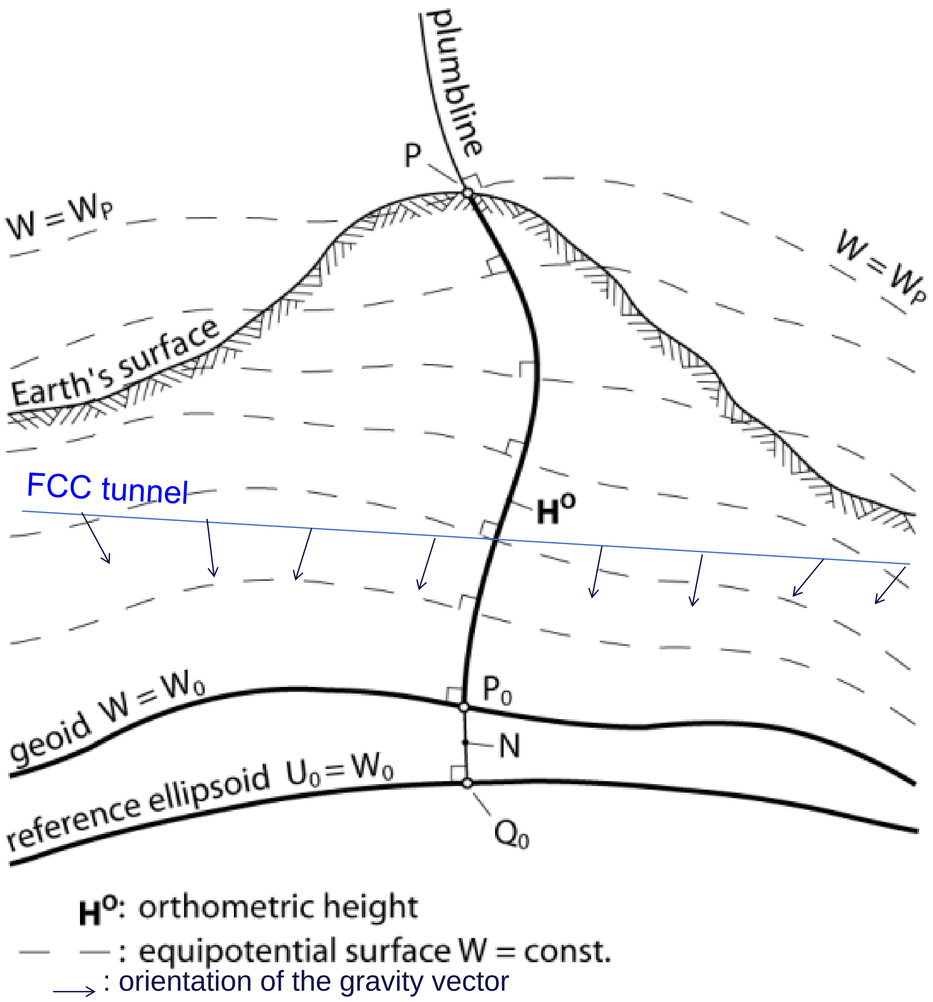
Cross-Border Collaboration: Challenges and Insights from Brenner Base Tunnel (Matthias Hofmann / BBT FCC Week Industry and Technology day 21st of May 2025)

Objectives of the geodetic studies

Establish the geodetic infrastructure for the Future Circular Collider

- Define coordinate reference systems
- Establish the necessary geodetic reference frames
- Study the determination of a high-precision gravity field model for the FCC area

Develop and provide necessary documentation and transformation tools and software



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

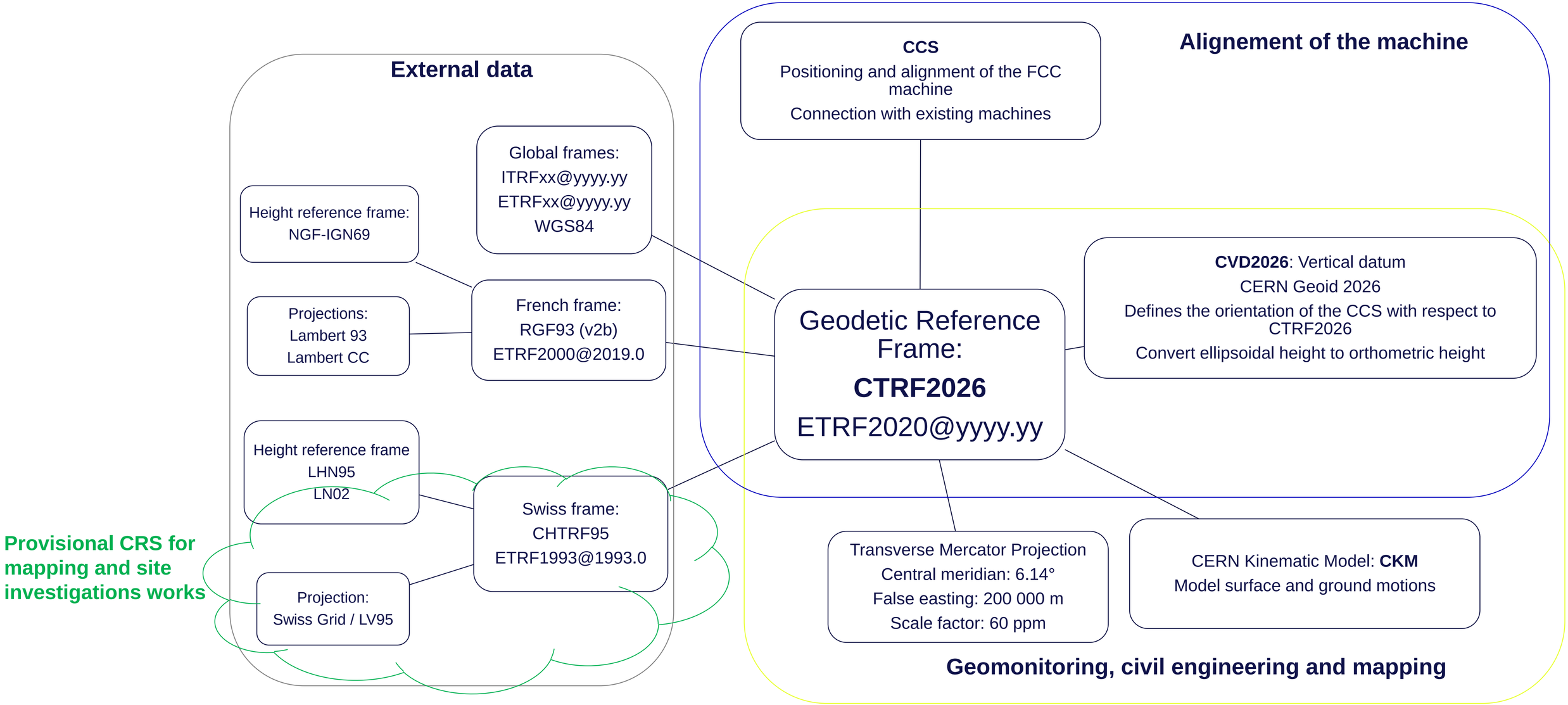
Bundesamt für Landestopografie swisstopo
Office fédéral de topographie swisstopo
Ufficio federale di topografia swisstopo
Uffizi federal da topografia swisstopo

IGN INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

ETH zürich

HEIG VD

Coordinate Reference Systems for FCC

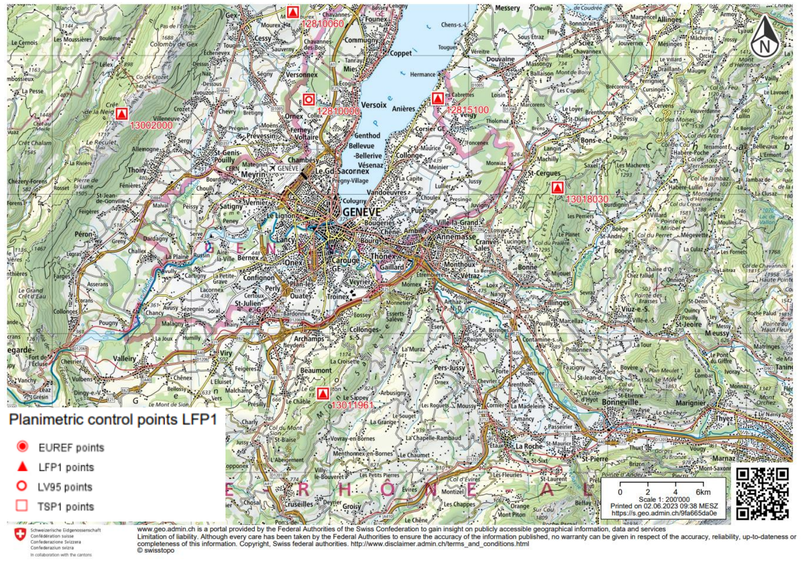


Implementation of the P-SGN

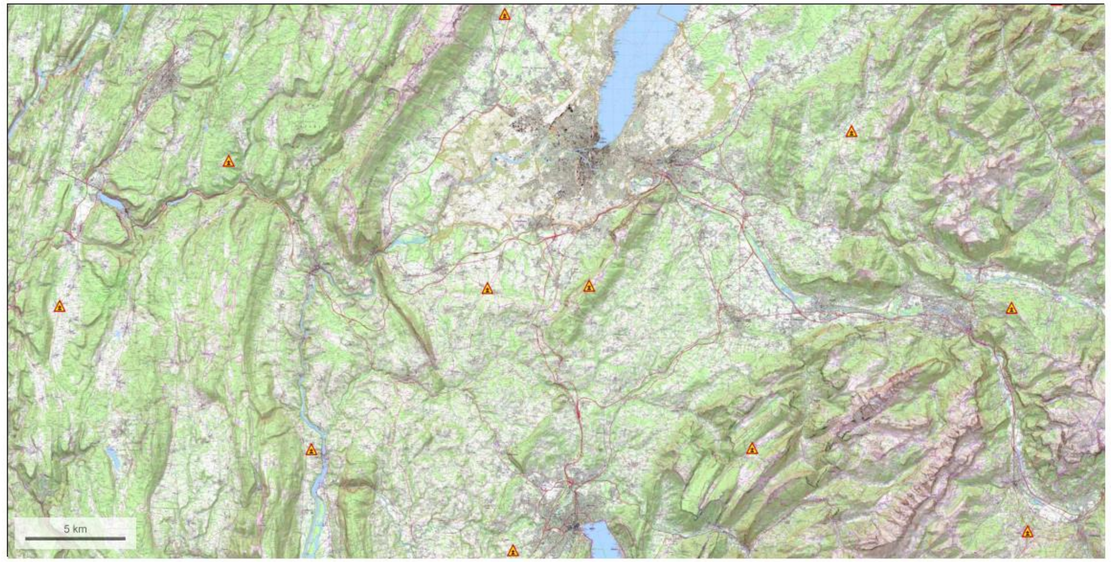
Primary Surface Geodetic Network (P-SGN)

- P-SGN will serve different purposes
  - Materialization of the CERN Terrestrial Reference Frame (CTRF)
  - Civil-engineering and surveying works required for the construction of the FCC tunnel
  - Providing the long-wavelength basis for the later alignment work
  - Providing the reference for the geokinematic monitoring of the FCC area

- Collaboration between CERN, IGN and Swisstopo for a densification of the French and Swiss national geodetic networks around FCC area
  - P-SGN markers will be available for the entire survey community
  - New CORS will be part of the French RGP (Réseau Géodésique Permanent)



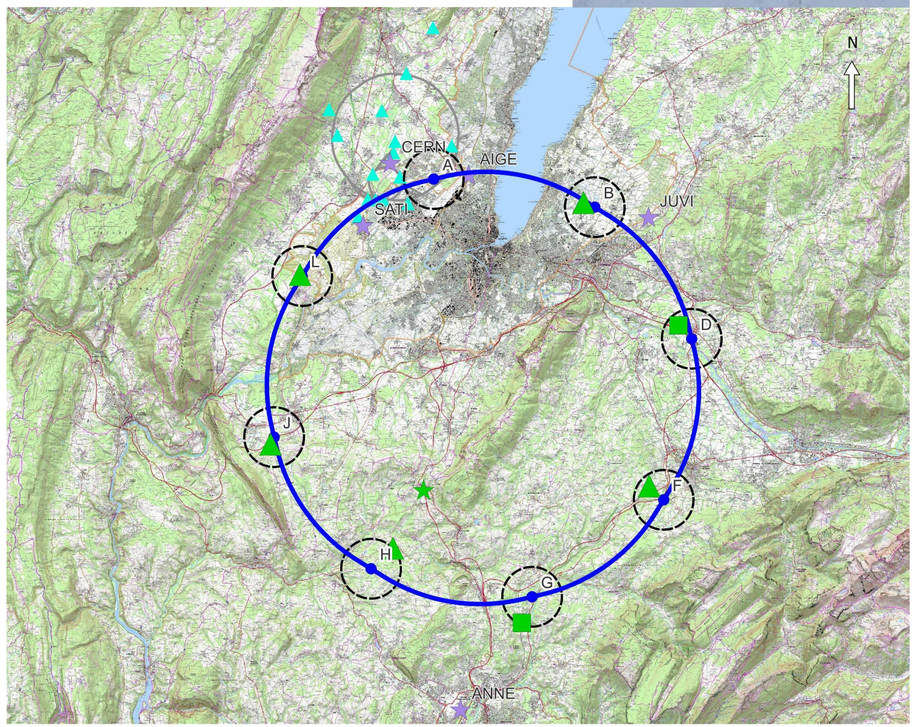
géoportail Réseau de Base Français



Implementation of the P-SGN

Construction of the geodetic pillars

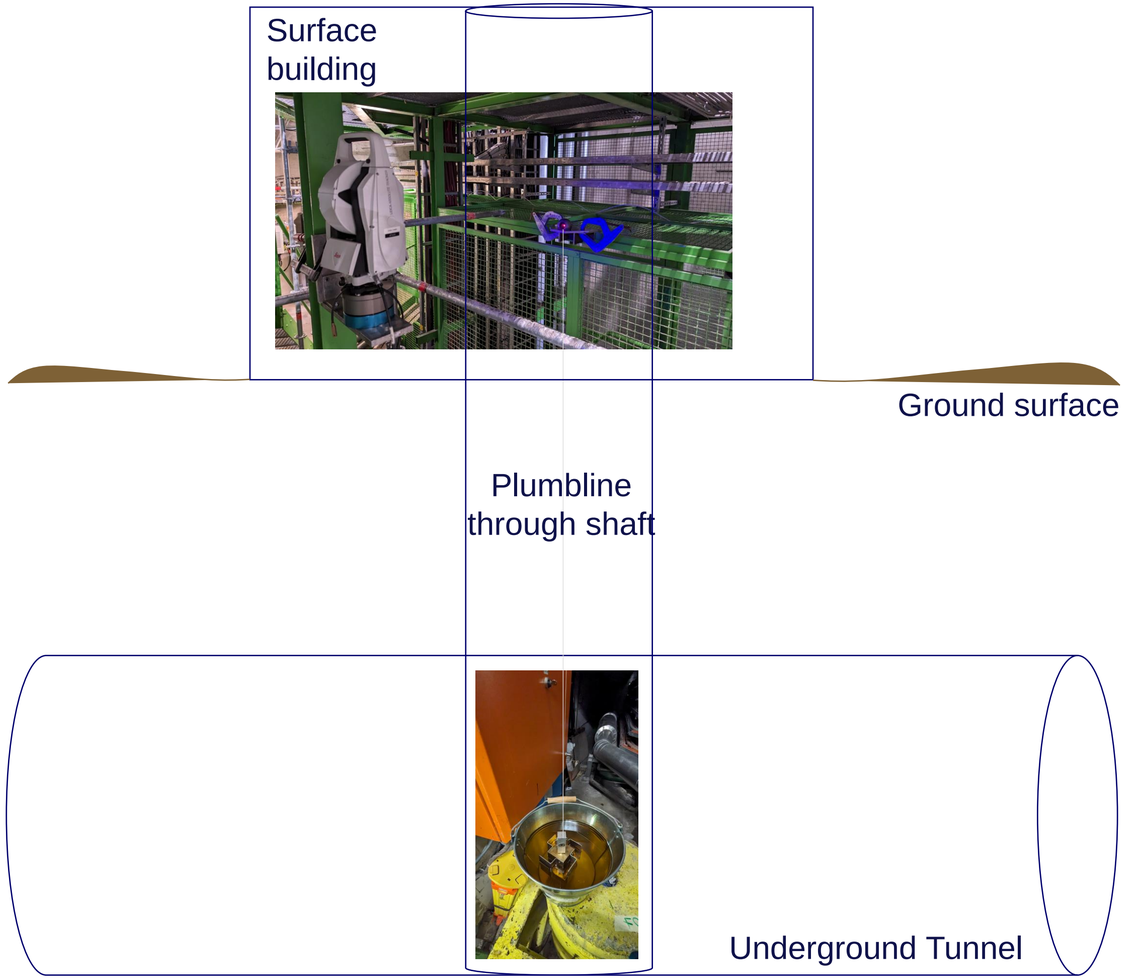
- Swisstopo built 2 new pillars in Choulex (point B) and Dardagny (point L)
- IGN built 4 new pillars in Eteaux, Cercier, Andilly, Dingy-En-Vuache. Construction pending on the French side at point H and D (construction expected at the beginning of the summer)
- GNSS observation of the entire network planned as soon as all pillars built



Test on coordinate transfer methodology

Computation of transformation parameters between CCS and CTRF

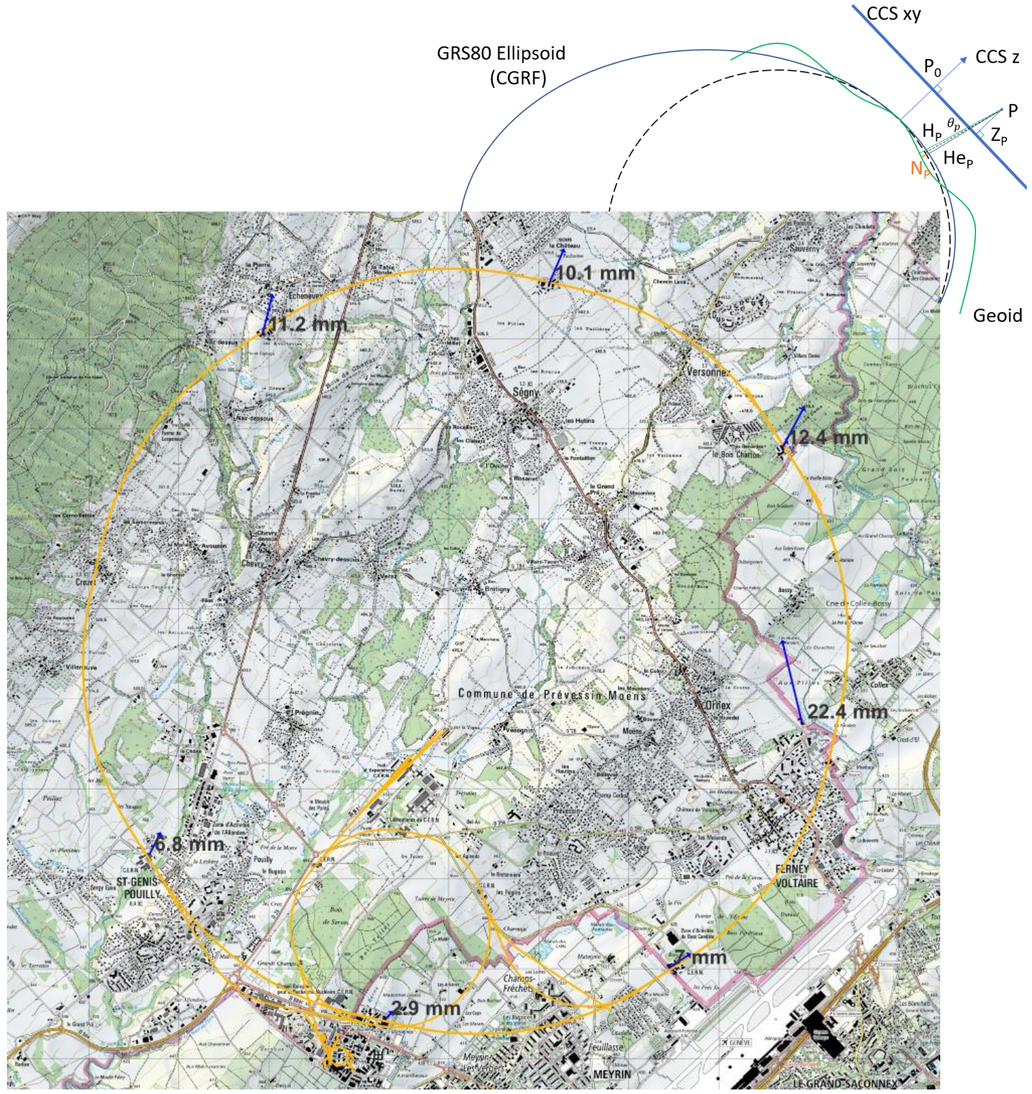
- Weak knowledge of the global accuracy of the coordinates calculated in CCS: Are the coordinates calculated underground consistent with coordinates of the surface reference points?
- We will need to calculate transformation parameters between CCS and CTRF
- Coordinate transfer through 7 LHC shafts were done during YETS 2023 - 2024 and YETS 2024 - 2025 (mechanical plumbing)
- Precision of the calculated coordinates: 1 mm



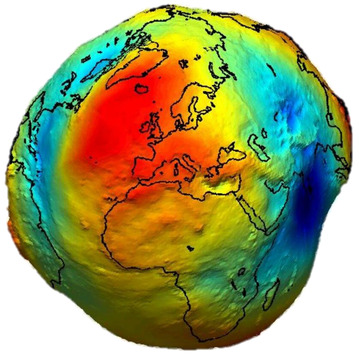
Test on coordinate transfer methodology

Comparison between coordinates of the wire calculated underground and at the surface

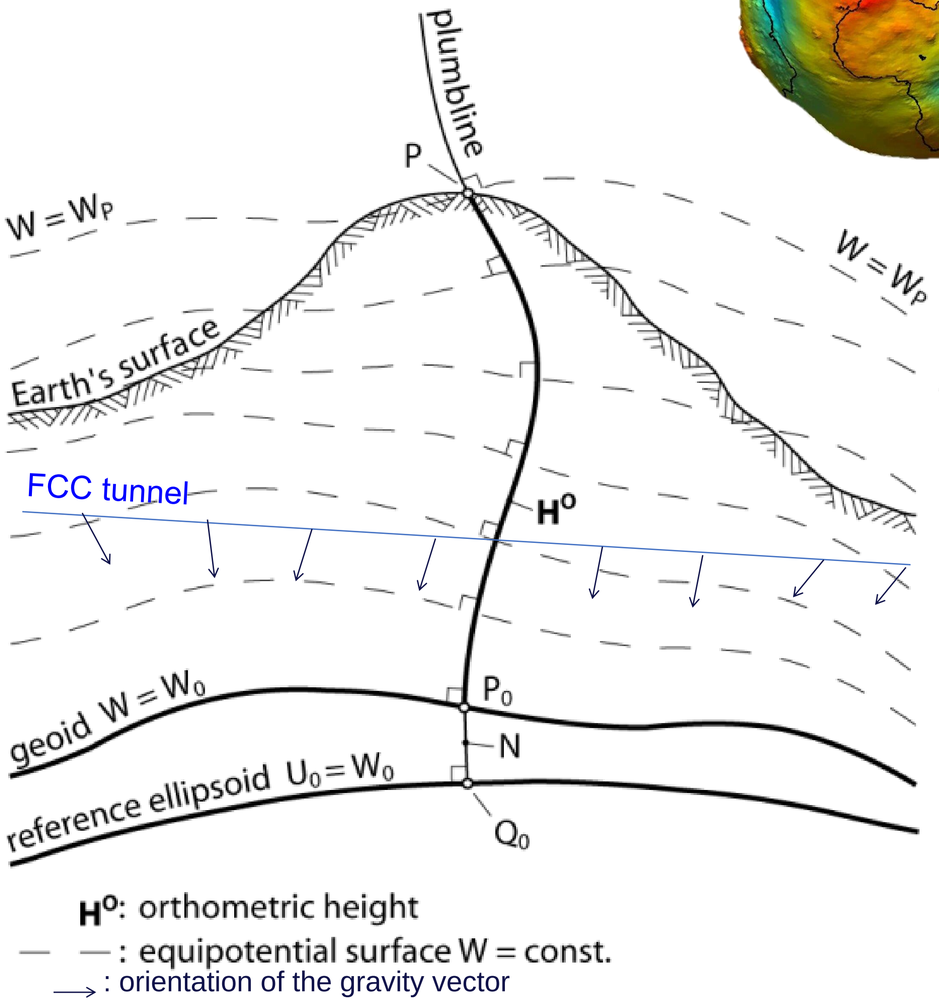
		Delta East LV95 [mm]	Delta North LV95 [mm]
Measured during YETS 2023-2024	Point 1 (depth = 83 m)	2.0	2.1
	Point 2 (depth = 46 m)	3.1	6.0
	Point 6 (depth = 81 m)	5.8	10.9
	Point 7 (depth = 91 m)	-5.3	21.8
Measured during YETS 2024-2025	Point 5 (depth = 73 m)	4.0	9.3
	Point 4 (depth = 125 m)	5.7	10.8
	Point 8 (depth = 86 m)	5.8	3.9



Geoid modelling



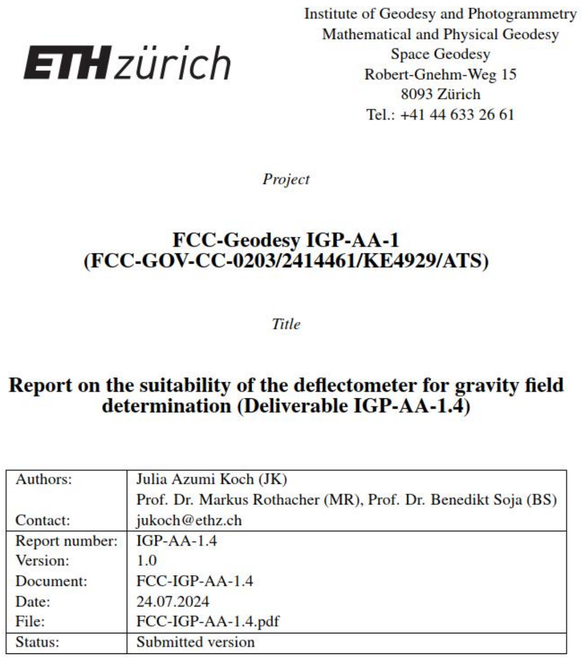
- The geoid is a selected equipotential surface of the earth's gravity field and serves as the reference surface for height determination. It can be considered as an idealised continuation of the mean surface of the oceans beneath the continents.
- Equipotential surfaces are not parallel within the Earth
- Survey observations need to be corrected to take into account variations of the direction of the plumbline (deviation of the vertical) to align accelerator components in an Euclidean plane
- Expected precision of the initial geoid model : 1 cm



Geoid modelling

- Report on the suitability of the deflectometer for gravity field determination
  - Not suitable: uncertainties are too high

- Budget realocated to the development and test of a gravity field closed loop simulator
  - Improve modeled gravity field (lakes, 30m DTM,…).
  - Generate various realistic non-modeled masses (deeper anomalies, Perlin noise density,…).
  - Try different observations strategies (GPS-leveling, DoVs (CODIAC, QDaedalus), gravimetry).



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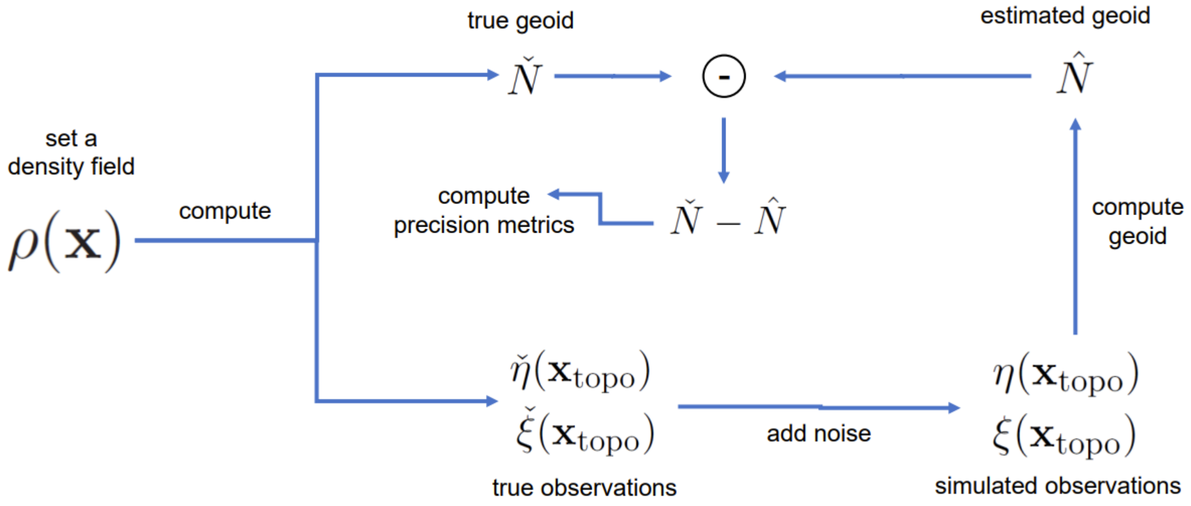
Project

FCC-Geodesy IGP-AA-1
(FCC-GOV-CC-0203/2414461/KE4929/ATS)

Title

Report on the suitability of the deflectometer for gravity field determination (Deliverable IGP-AA-1.4)

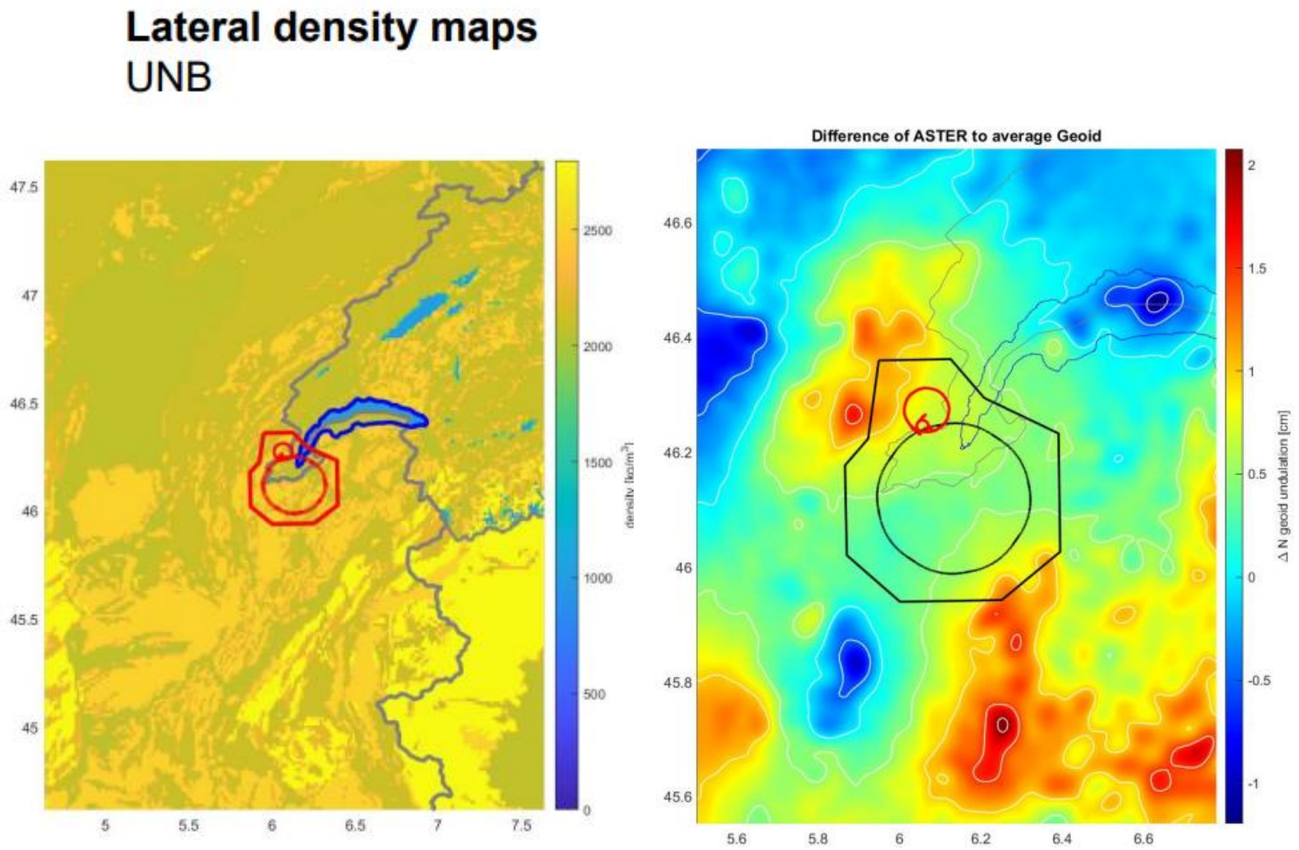
Authors:	Julia Azumi Koch (JK)
	Prof. Dr. Markus Rothacher (MR), Prof. Dr. Benedikt Soja (BS)
Contact:	jukoch@ethz.ch
Report number:	IGP-AA-1.4
Version:	1.0
Document:	FCC-IGP-AA-1.4
Date:	24.07.2024
File:	FCC-IGP-AA-1.4.pdf
Status:	Submitted version



Geoid modelling

Progress on computation of local geoid model

- Gravimetric geoid calculated in GROOPS (TU Graz) fits well to validation data
- Investigation on the effect of digital terrain model and topographic density variations

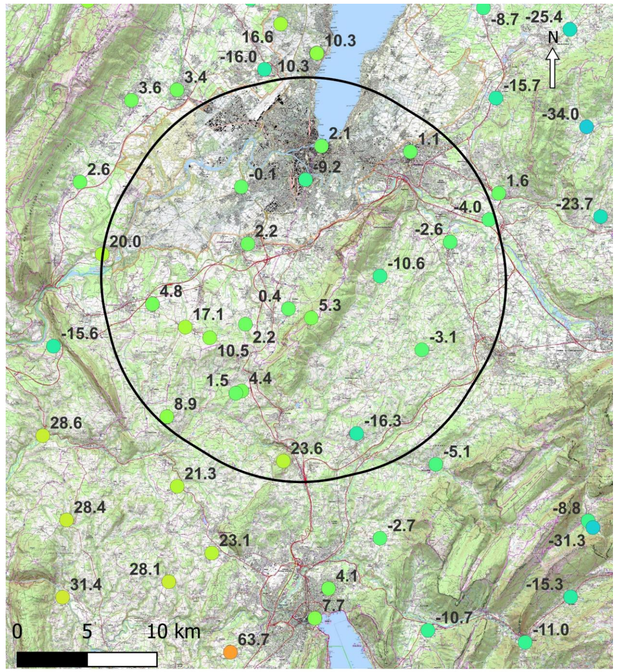


(J. Koch)

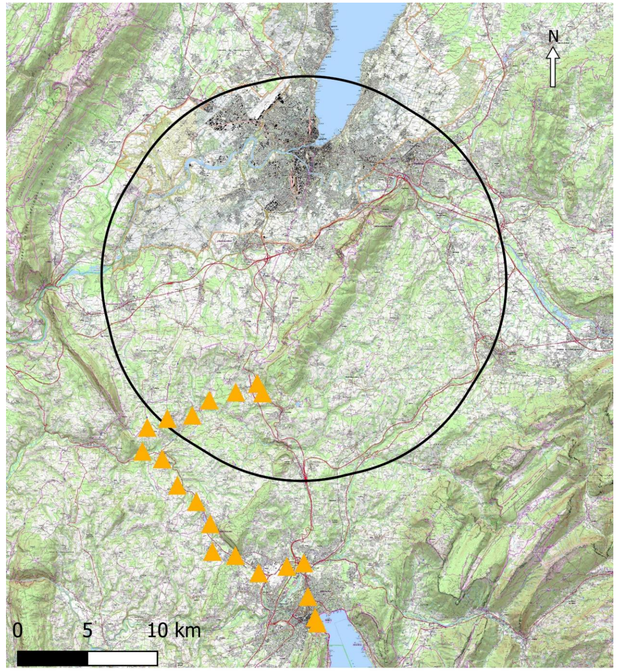
Geoid modelling

Progress on computation of local geoid model

- The uncertainty of the model is bigger in the South-West part
- Planning of new astro-geodetic observation campaign (deflection of the vertical)
  - 5 existing points (qualification of the accuracy of the new PyDaedalus developed at HEIG-Vd)
  - 15 new points (control of the geoid model)



FCC trajectory
GNSS-levellling residuals (mm)
Background map: Carte topographique (IGN Scan25)



Astro-zenithal measurements
FCC trajectory
Background map: Carte topographique (IGN Scan25)

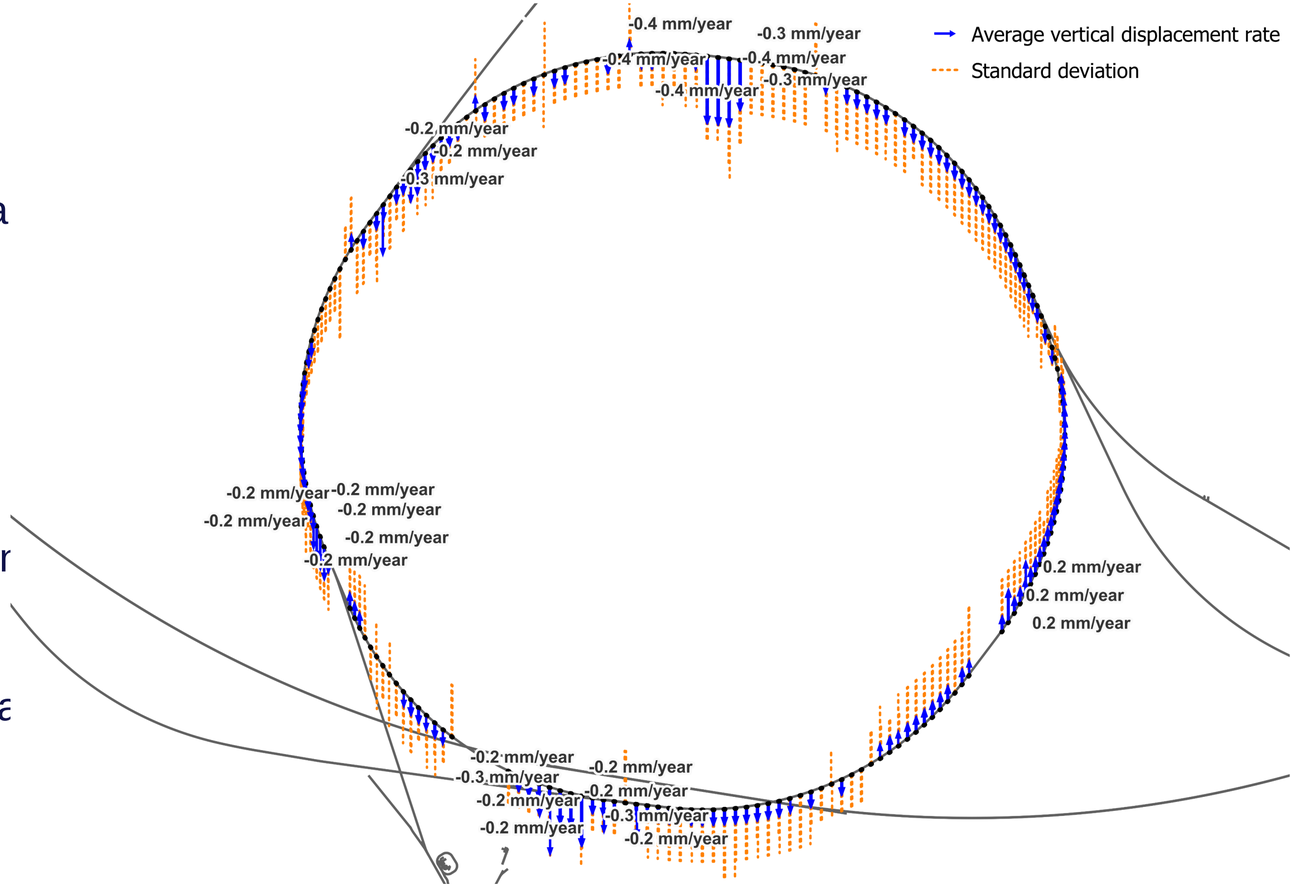
Geomonitoring

Collaboration agreement under signature

- Geodetic study of the surface kinematics of the FCC area to assess potential long-term deformations and study existing ground movements over FCC area

- The study has two major objectives
  - Provide information about the presence/absence of long-term relative surface kinematics (deformations) potentially relevant for the construction, installation, ar operation of the FCC
  - Develop a proposal of how to monitor the surface kinematics during the preconstruction phase, as well a during construction, installation and operation of the FCC.

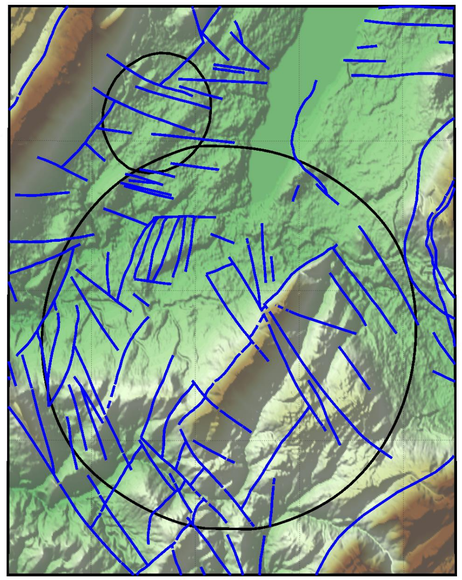
- It includes literature review, study of legacy data, InSAR study



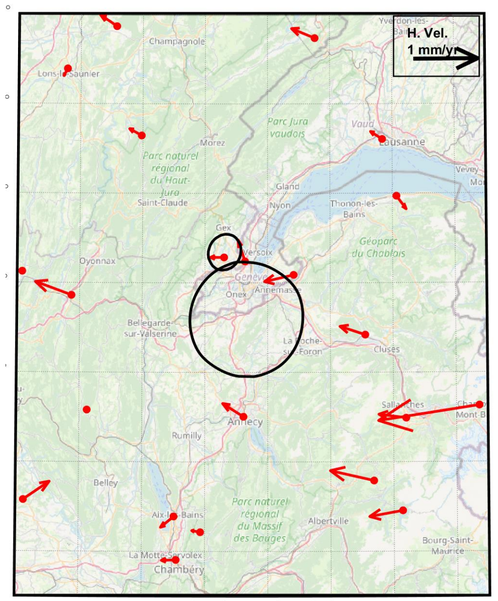
Annual vertical displacement rate of SPS components

Geomonitoring

- Relative surface kinematics are expected to range from 0 to few mm/yr



Geological faults



Surface kinematics

	v_H [mm/yr]	v_U [mm/yr]	σ_H [mm/yr]	σ_U [mm/yr]
CERN	0.2	-0.3	0.2	0.3

Upcoming works

- Computation of the gravity field models required for the FCC and for the implementation of new Swiss height project.
  - Development of a gravity field simulation tool
  - Densification of observations
- Provide comprehensive documentation and develop necessary transformation tools and software
- Prepare densification of the P-SGN (design of the portal network at each access site)
- Alignment requirements baseline and civil engineering requirements must be confirmed (will impact the required accuracy of the different components of the geodetic infrastructure)
- Define locations and buildings for the Calibration Check and Testing (CCT) of geodetic instruments
- Study gravity field errors effects on precise alignment accuracy

Thank you