Charter

EUREF working group on "Deformation models"

Background

Given the amount of interplate and intraplate deformations present within the EUREF area of interest, the development of a roadmap towards a European velocity model is proposed. This includes crustal deformations such as plate boundary zones, Fennoscandian PGR (Post Glacial Rebound), episodic events such as earthquakes, as well as other surface deformations of known (e.g. volcanic swelling, long-term hydrological changes, compaction in sedimentary basins, anthropogenic influence due to oil or gas extraction, CO_2 sequestration) or not yet known causes.

The goal of this WG is - relying on the known 3D crustal velocities of GNSS reference stations with sufficient detail and accuracy - to obtain velocity models and to significantly improve the prediction of the time evolution of coordinates and overcome the limitations in the use of the ETRS89. A general understanding of the physics behind such a velocity field (PGR, interplate and intraplate deformation, atmospheric effects, etc.) is also part of this WG.

When this initiative proves to be successful, interplate and intraplate deformations could be modelled and corrected for while using the reference frame, which will extend the useful lifetime of a realisation of the ETRS89. Therefore this work is important for applied geodesy.

It is also relevant for scientific activities. Sometimes, ITRF may be utilised in scientific work. However, for scientific studies of geodynamics in Europe, it is handy to remove the plate tectonic motion and use the ETRS89 in order to present velocities relative to "stable Eurasia" in a standardised way.

With the need of increasing precision for national reference frames over time, the European velocity model should fill a gap between the global look on a stable Eurasian Plate defined by ITRF and the more or less stable (or unstable) parts of this plate. It should be noted that national boundaries are not identical to boundary zones and therefore EUREF should offer cross-boundary models for mapping

agencies for consideration to be applied for national realisations of ETRS89. It should be kept in mind from former discussions (e.g. Greece) that some countries need such models to maintain a consistent national reference frame at all.

The first re-processing of EPN has recently been completed successfully (EPN-Repro1) and has significantly improved the quality of the velocities of the EPN stations. Further re-processing initiatives are foreseen. Relying on EPN-Repro1 and the routine EPN analysis, a regularly updated EPN multiyear solution is created and maintained by the EPN Reference Frame Coordinator. In addition a densification (based on weekly SINEX solutions from national densification networks) of this solution is under preparation by the Reference Frame Coordinator. This EPN product can be considered as the backbone for crustal deformation studies in Europe.

On the global scale, the IAG WG on the "Integration of dense velocity fields into the ITRF" is a key initiative towards the elaboration of strategies, procedures on the improved realisation and delivery of velocity products from global to regional level. EUREF and the EPN are also part of this WG and essential work has already been done to realise the European part of the global velocity field.

On a regional scale, the MoU between CEGRN and EUREF also aims to densify the velocities of permanent GNSS stations in Central Europe, with the intent to improve the predictability of future positions of reference stations and, at the same time, to gain a better understanding of Central European geokinematics.

Other initiatives like the European Plate Observing System (EPOS) (www.epos-eu.org) are currently being designed. Such initiatives will probably contribute to the improved understanding of geodynamic processes relevant for Europe.

The dual purposes of this working group

The purposes of this working group are twofold:

- First there are pure scientific interests in improving the knowledge of surface deformations in Eurasia and adjacent areas,
- Second, a velocity model will potentially be a valuable tool in the management and use of the national realisations of the ETRS89. Applications of geodetic reference frames in the presence of crustal deformations will be studied in detail.

Availability of station velocity solutions

Key information for improved knowledge of crustal deformations is observed motions at stations. This includes station velocities, and possible station position shifts for the case of episodic events, where the EPN is considered as the core infrastructure. However, a denser network of GNSS stations than the EPN will be needed to sample the crustal deformations sufficiently. The availability of velocity solutions including additional stations compared to the EPN stations is therefore of high interest for this working group, provided the processing standards used for these solutions comply with the EPN/IGS specifications. The work related to the realisation of improved station velocity solutions are covered by other initiatives and operational procedures of EUREF and will therefore not be done within this WG. Rather, this WG will build on the results from these initiatives.

In this sense the key input to this WG will be expected from the EPN Densification initiated and operated by the EPN Reference Frame Coordinator. The target of that work – in agreement with the IAG WG on the "Integration of dense velocity fields into the ITRF" and the EUPOS Combination Centre - is to integrate the national permanent GNSS sites/networks from possibly all European countries on the weekly (for the future possibly daily) SINEX level, where the EPN serves as the backbone of the combination. The main product of this work will be a combined position/velocity solution.

Proposed activities:

1. ***Evaluation of station velocities***

Observed station velocities will be evaluated in order to determine areas where observations seem to sample the actual crustal deformation with sufficient density. The simplest method for such an evaluation will be to compare observed motions at neighbouring sites, but more refined methods shall be developed and evaluated. We expect that e.g. an uplift or a shear motion will result in correlated velocity anomalies of GNSS stations in the area. Hence the statistical study of the correlation function of station velocities, its amplitude and the decay moving away from the area will provide a first quantitative kinematical model. The goal is to discern between local movements restricted to one station or the local area, and common movements of at least a certain part of the surface, ideally connected with features already known by geology.

2. ***Work towards model(s) of crustal deformations in Europe***

A European velocity model may be some years away, but there are quite some activities that preferably shall start in the near future. The velocity model should be understood as a mathematical or geophysical model (or a combination thereof), where the velocity of an arbitrary point can be derived with some reasonably known and preferably low uncertainty.

The geodynamic processes are of different kind in different areas of Europe, and will need slightly different treatment:

- The Fennoscandia **PGR** seems to be the deformation process that is easiest to treat since it is relatively smooth and continuous, and various models that describe the process to a reasonable degree are already available.
- **Episodic events** (earthquakes) are much more complicated to model and development work will be needed to include episodic events (e.g. from the USGS database) into a useful deformation model. Some special development regarding how to realise computer implementation of also episodic events in gridded velocity models will need special attention.

Handling of episodic events in a spatial model of crustal deformations is considered complicated. Since episodic events of moderate magnitude (typically Mw<5.5 with hypocentral depth >5 km) are considered to affect a limited area, episodic events will not be included in the first version of the model. The correspondence between the fault plane solution resulting from seismic data and the 3D displacement of local GNSS stations will be checked, using elastic dislocation models in a half space, to understand the effect of ground deformation and that of monument instability in the observed changes of coordinates.

- We also have areas in the **boundary zone** of the Eurasian plate where (1) large velocity differences at neighbouring GNSS stations are found and (2) large velocities relative to stable Eurasia (i.e. the area is in principle outside the Eurasian plate), e.g parts of Greece, are determined. Usually also episodic events are common in these areas. A first step will be to compile information on tectonic zone areas. The second step should be to develop a "best practice" for efficient use of ETRS89 in these areas.

3. *Consideration of a deformation model in maintenance and use of national realisations of ETRS89*

Discrete station velocities or an area velocity model could be applied to maintain ETR89 realisations in European countries according to, e.g., national declarations. Various approaches such as (a) re-new the ETRS89 realisation after certain station movements (so-called "lifetime of ETRS89 coordinates" approach), (b) apply local velocities to the frame realisation, or (c) apply model velocities to arbitrary points to reach consistency with the frame realisation will be described in details. Suggestions on the usage of one particular model for areas with various geodynamic activities in Europe will be compiled.

Considerable efforts have been devoted to crustal deformations and geodynamic processes in Europe. A reasonable measure should

therefore be to make an inventory of reported activities. An inventory of the work presented at EUREF Symposia in the last decades will be a reasonable first step.

Membership of this WG:

The WG will be open to scientists interested in the topic

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