

# 3D GPS velocity field and its implications on the present-day postorogenic deformation of the Western Alps and Pyrenees

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Review by E. Brockmann, swisstopo

## General comments

The paper is well written. For analyzing the velocities a suited data set was used. The conclusions are mostly well proved by the results (exceptions explained later). Furthermore, one should analyze, how many of the sites are setup properly to conclude from time series to tectonic processes (are roof-top installations suited)?

I collected recently some velocity fields in Europe and compared it. The presentation was held end of May at the EUREF symposium in San Sebastian (...the area of the paper ...) Presentation is available under: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/Brockmann\\_16\\_Dens\\_Vel.pdf](http://pnac.swisstopo.admin.ch/divers/dens_vel/Brockmann_16_Dens_Vel.pdf)

I also integrated the velocities as documented in table 3 (assuming that your datum definition is quite close to the ETRF2000 reference frame; your estimates are in color "corale"). The velocity fields with three different zooms to different areas can be viewed under:

EU horizontally: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_all\\_cmb\\_dh.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_all_cmb_dh.jpg)

EU vertically: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_all\\_cmb\\_dv.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_all_cmb_dv.jpg)

EU-SE: horizontally: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_se\\_all\\_cmb\\_dh.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_se_all_cmb_dh.jpg)

EU-SE: vertically: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_se\\_all\\_cmb\\_dv.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_se_all_cmb_dv.jpg)

EU-SW: horizontally: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_sw\\_all\\_cmb\\_dh.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_sw_all_cmb_dh.jpg)

EU-SW: vertically: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/vel\\_eu\\_sw\\_all\\_cmb\\_dv.jpg](http://pnac.swisstopo.admin.ch/divers/dens_vel/vel_eu_sw_all_cmb_dv.jpg)

Numerical values for the Swiss Velocities (in ETRF2000) are available:

CH-EU horizontally: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/ch08\\_hor.vel](http://pnac.swisstopo.admin.ch/divers/dens_vel/ch08_hor.vel)

CH-EU vertically: [http://pnac.swisstopo.admin.ch/divers/dens\\_vel/ch08\\_ver.vel](http://pnac.swisstopo.admin.ch/divers/dens_vel/ch08_ver.vel)

From the plots I recognized that you also have many sites processed outside the region. Agreement with other estimates in these Non-Alp-regions are mainly quite good, too (e.g. good agreement also in Scandinavia).

**Most interesting is the EU-SW plots – generally quite good agreement. Swiss results nicely gives answer how e.g. the vertical velocities are looking further north and may also contribute to a possible conclusion (vertical velocities not only a function of height).**

**Vertical Differences with the Swiss Velocity estimates e.g. for BLG2 / BLGN. We both have 4-5 years of data. Might be you can check your time series for BLGN (showing -3.4 mm vertical velocities, which seems questionable when comparing with surrounding sites).**

Here some information how you can access our results:

[http://pnac.swisstopo.admin.ch/pages/en/qsumblg2.html#REP\\_LONG](http://pnac.swisstopo.admin.ch/pages/en/qsumblg2.html#REP_LONG)

or [http://pnac.swisstopo.admin.ch/resplt/blg2\\_vel.gif](http://pnac.swisstopo.admin.ch/resplt/blg2_vel.gif)

(all links work for other stations by replacing the 4-char name with another station).

Stations processed by us: <http://pnac.swisstopo.admin.ch/pages/en/pnac-monitoring.html> (see first section with 4 different region plots).

Further online info for specific stations in our processing:

<http://pnac.swisstopo.admin.ch/pages/en/agnes-status.html>

**Generally, I fully support the paper. It can be published after checking some details mentioned below and might re-formulate the conclusions taking into account some recommendations I gave.**

Below, the text given in **bold** fonts, indicate comments which I regard important to consider a review.

## Specific comments

Page 1, 11	Environmental noise is no network-wide bias. Please specify more clearly, what you mean.
Page 1, 18	Correlation of velocity with elevation might be visible – but can you follow from this that post glacier rebound is the (only) reason and explanation of your finding. <b>The conclusion must be reconsidered! See also comments later in this table.</b>
Page 3, 10	Why 10 degree elevation – this is a quite old standard. Today, GNSS data are analyzed with 3 of 5 degrees cut-off. Please specify the reason and please mention that that is not current standard.
Page 3, 15	Choice of troposphere model: please specify what you mean (only apriori Model, which models)? Next sentence only addresses the Mapping Function, only.
Page 4, 26	The filter -> 3 parameters per day? time correlation? please specify more clearly
Page 5, 9	0.1 and <b>0.2</b> -> 0.1 and <b>0.3</b> (is probably closer to the numbers you show in table 2) better than -> in the order of about
Page 6, 10 ff	Did you considered the transformation of the velocities to ETRF2000(R08) instead of using 61 sites and define a sum=0 condition? Please formulate more precise, what you mean with “minimize 61 velocities”. Would nice to explain, why ETRF2000 is not used (e.g. ETRF2000 frame mainly is used at mapping agencies but for this scientific work we only analyze differential velocities in the Western Alps).
Page 6, 13	Figure 6 – error ellipses? How computed, from coordinate repeatability (and subtraction of the model)? Formal error? Multiplied by an empirical factor?
Page 7, 17	Station elevation are a good proxy of the mean elevation of the surrounding area – this is very rough and probably not true – station are partly too low (easy accessible, bad signal collection) or up in the mountains (bad access but good data). <b>Please re-formulate.</b> <b>Also correlation with elevation – probably too easy – is probably a function of location (not elevation only) – also in the Western Alps there is a different uplift (higher in North than is South) – would not be visible in you f(elevation) graph.</b>
Fig 10	

	<b>Might be a profile plot N-S (e.g. function of latitude) for the vertical velocities is better suited than a function of elevation plot for the Alps and an W-E profile (function of longitude) for the Pyrenees.</b>
Page 8, 21	Conclusion is not ok (so also comments above (p7, 17; Fig 10). <b>Please re-formulate after further detailed studies</b>
Fig 3	Partly still big differences. E.g. Difference forward – backward after 4-5 years in North is still 1 mm/yr. Seems big compared to the generally good agreements with a “zero-velocity field” and conclusion that 5 years are already acceptable.
Fig 4	Conclusion from these Whisker plots are not much discussed in the paper. Conclusions? Eventually skip?
Fig 5/Fig 7	<b>Error ellipses? See comment above? Furthermore, normally not that extremely E-W shaped ellipses? Please comment on that.</b> <b>Fig 7: here, it seems other way round: uncertainty seems to be for quite some sites bigger in N-S. Please check carefully.</b>
Fig 8	<b>Easier readable with country borders</b>
Fig 9	<b>Quite some stations in green as outliers to surrounding stations visible. E.g. in the northern western Alps were we see 2 mm/yr rise. It’s unrealistic that a station next to it moves downwards by -1 mm/yr (or is sledging, or time series still has un-modelled jumps. Please check station residuals more carefully and try to detect still problems (evt. remove stations not suited for velocity estimation).</b>

## Technical corrections

Page 1,11	processing options -> processing parameters; troposphere delay -> troposphere modeling
Page 3, 31	Decomposed by -> modelled by (eventually)
Page 3, 32	Skip: <del>as well as visual inspection</del>
Page 4, 1	inverted -> adjusted; best-fit -> best-fitting
Page 4, 4	a function of the...positions -> depend on the position repeatability
Page 4, 5	presence of -> introduced
Page 4, 23	consists in removing -> removed
Page 4, 24	The residuals of the time series -> the coordinate time series residuals
Page 4, 24	Stacking the residuals ... might be you can mention: daily residuals
Page 4, 24	(post ... cf. section 3.1) -> (once the original time series and once after modelling the time-series as explained in section 3.1)
Page 5, 2	on going -> going on
Page 10, 2	Proceedings missing (saw by accident – no check of the other references)
Fig 1 / Fig 7 / Fig 10	Just a suggestion: normally green means “ok” and red “warning”. Might be you can turn the color code accordingly. Not essential.