

Towards a Dense Velocities Field in Europe as a basis for Maintaining the European Reference Frame

IUGG 2019 Symposium

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Densification

- International / IGS

~500 sites



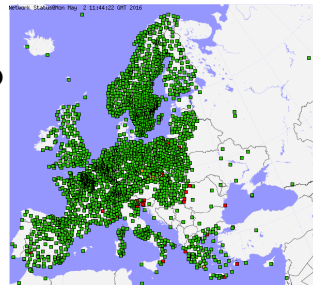
- Continental / European / EUREF

~340 sites

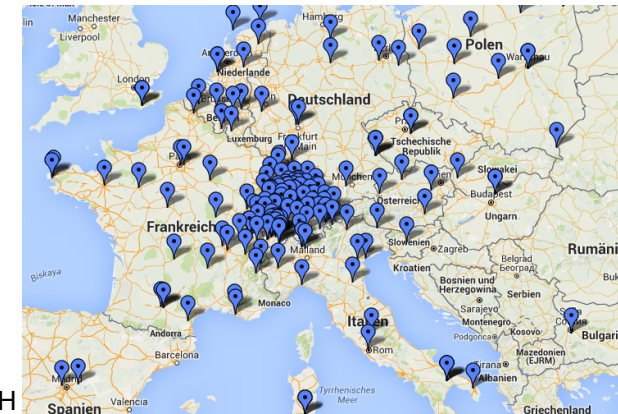


- EU countries

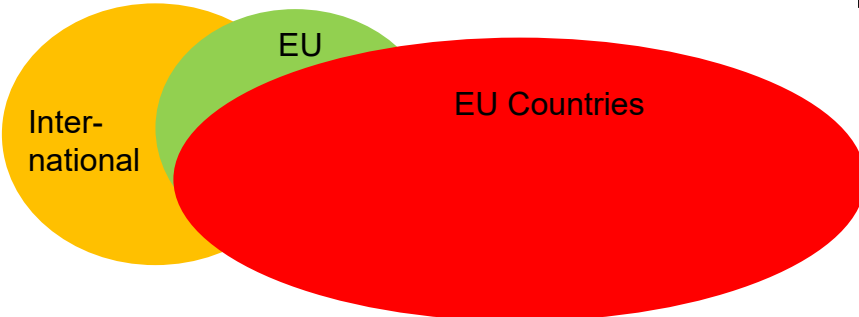
>4000 stations
used in E-GVAP
near real-time
>8000? totally



~40-500 sites
per country



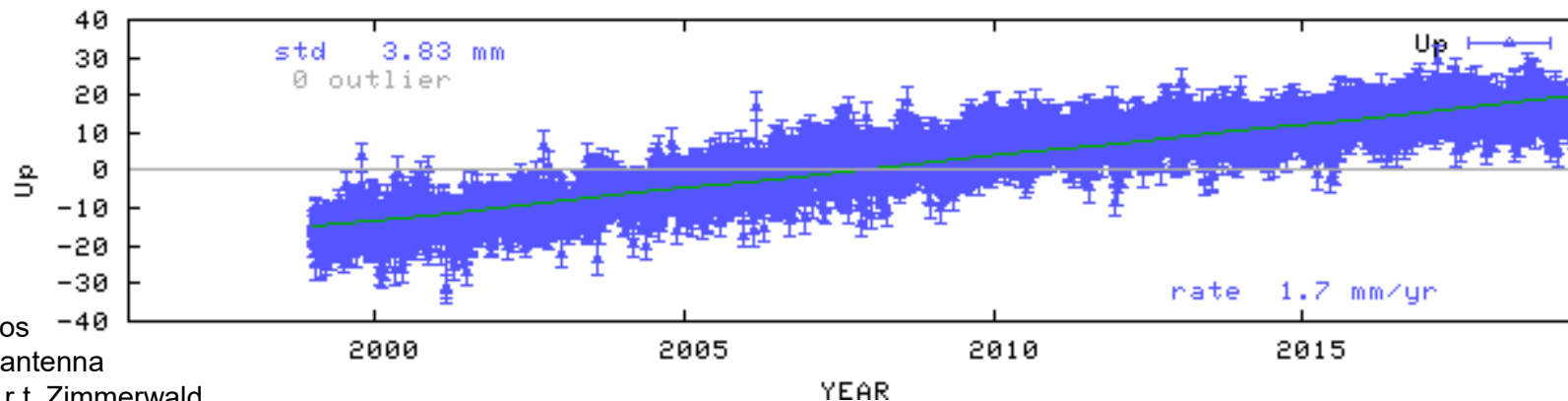
Example CH





Motivation

- Geodata of most (all) European countries are based on **static coordinate reference systems** – aligned to ETRF (70% on ETRF2000)
- Data cover now time spans of several years and analysis precision shows that stations / regions / countries show a **significant movement exceeding 1 mm/yr**
- Mapping agencies responsible for reference frame maintenance (and guarantee quality)



Alpine station Davos
 >20yrs with same antenna
 1.7 mm/yr Uplift w.r.t. Zimmerwald

COU	Frame Name (Static)
AUT	ETRF00
BEL	ETRF2000
BGR	ETRF2000
CHE	ETRF93
CZE	ETRF2000 (R05), ETRF89
DEU	ETRF2000 (R05,R08)
DNK	ETRF92
ESP	ETRF2005
EST	ETRF96
FIN	ETRF96
FRA	ETRF93, ETRF2000 (R05)
GBR	ETRF97, ETRF2000
GRC	ETRF05
HRV	ETRF2000 (R05)
HUN	ETRF00
IRL	ETRF89
ITA	ETRF2000
LTU	ETRF2000
LVA	ETRF2000
MDA	ETRF97
MKD	ETRF2000 (R05)
NLD	ETRF2000 (R05)
NOR	ETRF97
POL	ETRF2000 (R05)
PRT	ETRF97
ROU	ETRF2000
SRB	ETRF2000 (R05)
SVK	ETRF2000
SVN	ETRF05
SWE	ETRF97

Reference frame used in Europe
 (compiled 2016)



Partners in project “EU Dense Velocities”

#INI	Num	Solution	Analysis Centre
	001	alp08	AlpArray Initiative
194	002	alps17	BADW/DGFI (Alps)
326	003	basc08	ARANZADI's Department of Applied Geodesy (ARA) Basc/Spain
187	004	cat08	Institut Cartografic i Geologic de Catalunya (ICGC) Catalonia/Spain
54	005	cg08	Central European GPS Consortium (CEGRN): 2016 campaign com
	006	cg14	Central European GPS Geodynamic Reference Network Consortium (CEGRN): 2018 Multi-annual
213	007	ch08	swisstopo - Permanent stations
66	008	ch081	swisstopo - Permanent CH levelling-only ing
432	009	ch16	swisstopo - Permanent CH permanent + campaigns
237	010	epn14	EPN Reference Frame Coordinator EPN operational (every 15 weeks)
	011	epnd14	EUREF WG on EPN Densification EPN densification
341	012	esp08	Instituto Geografic Spain (IGN Spain)
179	013	gr08	Aristotle University of Thessaloniki Greece 1
38	014	gref08	Federal Agency for Cartography and Geodesy (BKG) Germany
	015	gsrm14	Global Strain Rate Map Global, Nevada Bureau of Mines and Geology)
76	016	gurn08	GNSS Upper Rhine Graben Network (GURN)
	017	gurn08d	GNSS Upper Rhine Graben Network (GURN) - combined InSAR INSAR
319	018	gut14x	Gdansk University of Technology, extended version Poland
60	019	hepos	Hellenic Positioning System (HEPOS) Greece 2
103	020	igs08	IGS Reference Frame Coordinator
	021	it08	Universita di Padova Italy
148	022	itrf14	ITRF Coordinator ITRF14
	023	nkg03	Nordic Geodetic Commission (NKG) - Nordic grid
76	024	noqu08	Universite de Montpellier France
	025	rgp08	Institut national de l'information geographique et forestiere (IGN France)
40	026	svn14	Surveying and Mapping Slovenia: campaigns public of Slovenia
164	027	turk14	General Directorate Turkey g of Turkey
182	028	walp08	Universite de Montpellier Alps

- EUREF Working Group started 2017
- Steadily increasing contributions
- Web page as feedback to contributors started (June 2018)
- Several contributions updated in time

http://pnac.swisstopo.admin.ch/divers/dens_vel/index.html

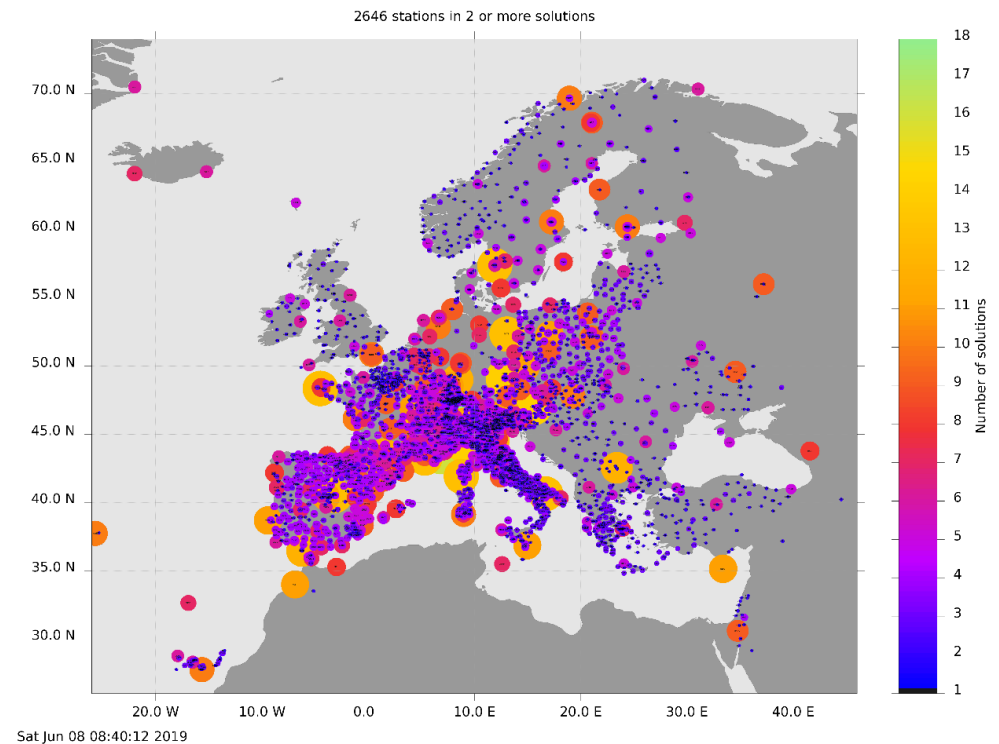
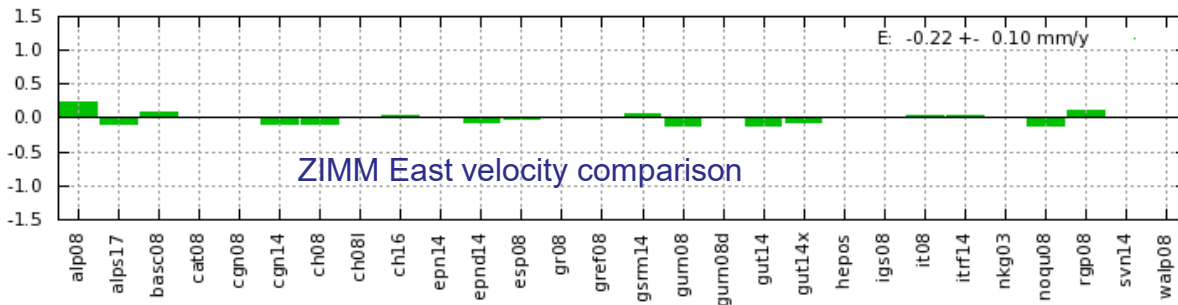
Method



- **Input: velocities aligned to ETRF2000.** No coordinate combination -> no difficulties with different modelling (tropo models, antenna PCVs)
- **Flexible velocity input:** GNSS velocities (permanent + campaigns), levelling, INSAR, velocity grids, ... (not possible with SINEX-only input)
- Combination based on the **classical combination scheme: weighted average**
- **Shared activity** making use of the knowledge of the contributing countries rather than a single central combination agency.
 - No exchange of any site logs, no guidelines to data processing, no original data archives
 - Feedback (frame alignment/outliers) possibility via web service
 - Test contributions possible (no weight for the combined results)

Key parameter: Status July 2019

- 28 contributions
- grids (get weight “10” if used in a country), test solutions no contribution
- Station identification by site name and approximate position (10 km)
- 6170 sites in Central EU (not grids, not INSAR), 2646 sites in ≥ 2 solutions
nice progress 1987: Oct. 2018, 934: May 2018
- Stations in solutions:
ZIMM: 18, GRAS: 16,
GRAZ 15, POTS: 14, ...

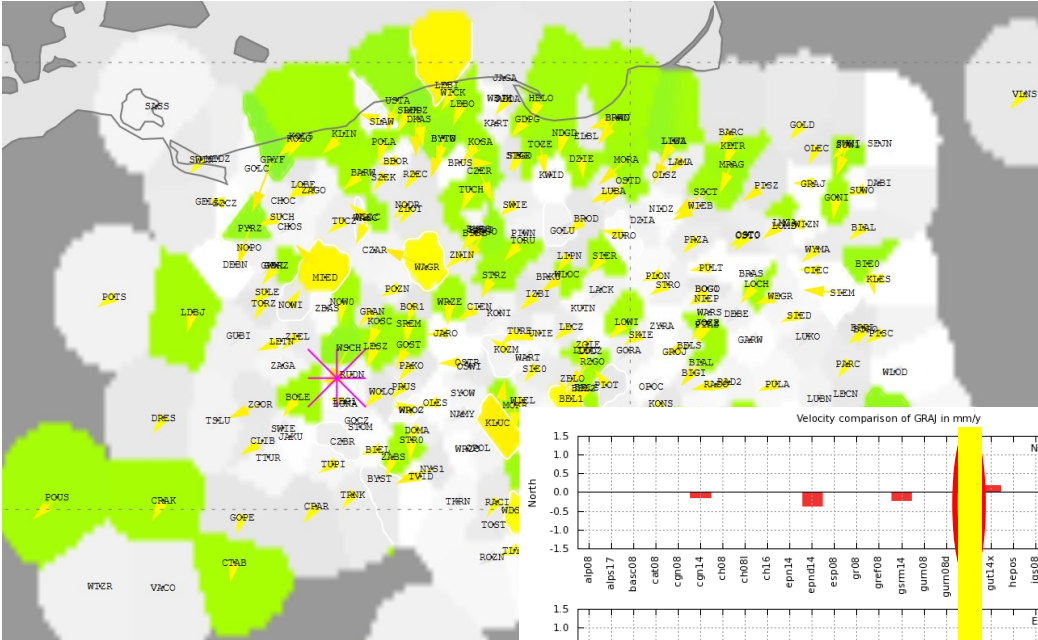




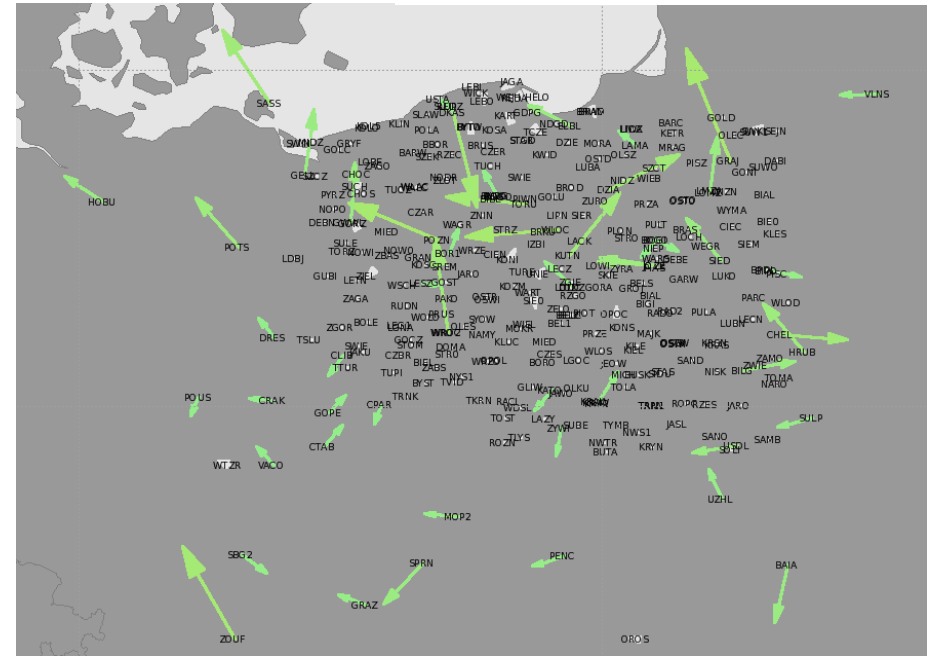
Feedback web page: Example gut14 (Gdansk University, Poland)

Iterations let to a new contributions gut14x

Input field (gridded background)

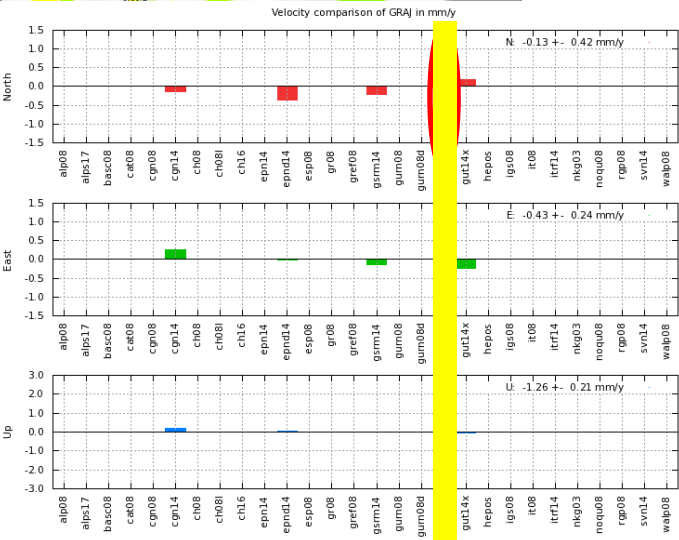


Residuals to combination



Neighbour stations

STAT1 - STAT2	L(M)	Maps	LAT/LON	dVN	dVI
[BOGI] [BOGO]	106		[+52.475/+021.035]	0.04	0.31
[BRAN] [BRWO]	15		[+54.385/+019.828]	0.48	-0.31
[BYTO] [BYTW]	45		[+54.157/+017.488]	0.39	0.21



Residuals to combination (sortable table)

STATION	Maps	LAT/LON	VN	VE	VU	VH	VV	NUM
[TRO1]		[+69.663/+018.940]	-0.61	-0.20	-0.48	0.65	0.48	11
[GRAJ]		[+53.651/+022.455]	0.50	-0.25	-0.22	0.56	0.22	5
[POZN]		[+52.477/+016.866]	0.17	-0.51	0.10	0.54	0.10	5
[WLOC]		[+52.638/+019.149]	-0.03	-0.53	-0.46	0.53	0.46	4



Combination statistics



x0 -x000 sites common to combination

Reference frame alignment



NUM	SOLUTION
008	ch081
023	nkg03
026	svn14
017	gurn08d
009	ch16
027	turk14
007	ch08
010	epn14
018	gut14x
024	noqu08
002	alps17
022	itr14
004	cat08
016	gurn08
020	igs08
028	walp08
014	gref08
005	cgn08
025	rgp08
006	cgn14
011	epnd14
001	alp08
003	basc08
012	esp08
021	it08
019	hepos
013	gr08
015	gsrm14
TOT	

...

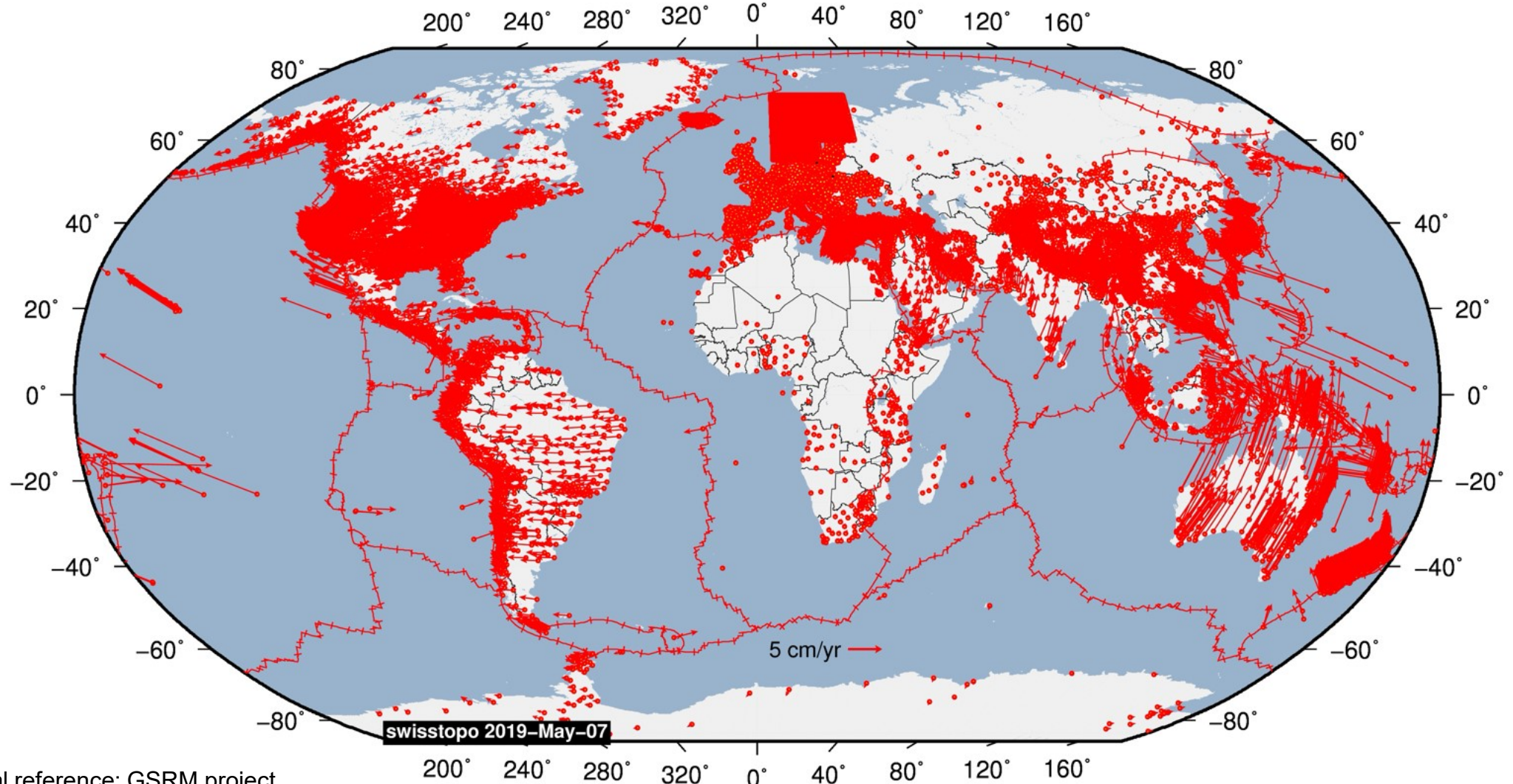
#FIN	#CMB	MEAN_N	MEAN_E	SIG_E	MEAN_U	SIG_U	MEAN_H	SIG_H
63	62	0.00	0.00	nan	0.29	0.31	0.00	nan
29221	125	0.04	0.01	0.03	0.09	0.08	0.04	0.07
40	7	0.06	-0.06	0.09	-0.61	nan	0.09	0.11
1313	117	0.02	0.05	0.11	0.00	0.34	0.05	0.14
428	260	0.00	0.01	0.13	0.05	0.30	0.01	0.16
161	70	-0.06	0.03	0.09	0.02	0.24	0.07	0.14
211	211	0.06	-0.10	0.14	0.06	0.31	0.11	0.20
234	234	-0.00	0.01	0.11	-0.18	0.31	0.01	0.18
318	88	0.01	-0.02	0.17	-0.21	0.41	0.02	0.23
76	75	0.04	0.03	0.16	0.45	0.48	0.05	0.21
194	182	-0.03	-0.13	0.17	-0.14	0.36	0.14	0.23
139	136	-0.02	-0.03	0.17	-0.32	0.31	0.04	0.23
144	142	0.06	-0.02	0.19	0.03	0.43	0.07	0.25
74	49	0.08	0.05	0.21	0.00	nan	0.09	0.28
93	91	0.03	-0.05	0.20	-0.14	0.43	0.06	0.27
178	175	0.20	0.21	0.28	0.37	0.47	0.29	0.34
38	37	0.04	0.11	0.17	0.52	0.49	0.11	0.26
52	51	0.03	0.03	0.25	-0.08	0.55	0.04	0.34
355	349	-0.17	0.02	0.27	-0.10	0.53	0.18	0.35
1108	1027	0.07	-0.05	0.23	0.05	0.58	0.09	0.33
1826	1565	-0.06	-0.04	0.21	-0.24	0.53	0.07	0.32
493	411	0.11	0.13	0.25	0.15	0.58	0.17	0.38
315	269	0.07	0.14	0.34	-0.22	0.60	0.15	0.47
318	290	-0.14	-0.12	0.28	0.46	0.71	0.18	0.43
593	509	-0.14	0.00	0.26	0.13	0.76	0.14	0.42
59	47	-0.14	0.28	0.39	-0.88	0.86	0.31	0.54
173	140	0.21	0.07	0.44	0.47	0.77	0.22	0.62
20916	1306	0.05	0.04	0.55	0.00	nan	0.07	0.85
53560	2454							

Standard deviation
 ~0.2-0.3 mm/yr hor.
 ~0.4-0.7 mm/yr up

Regions with tectonic signals

http://pnac.swisstopo.admin.ch/divers/dens_vel/000.html#STATISTICS

Global velocities (w.r.t ETRF)

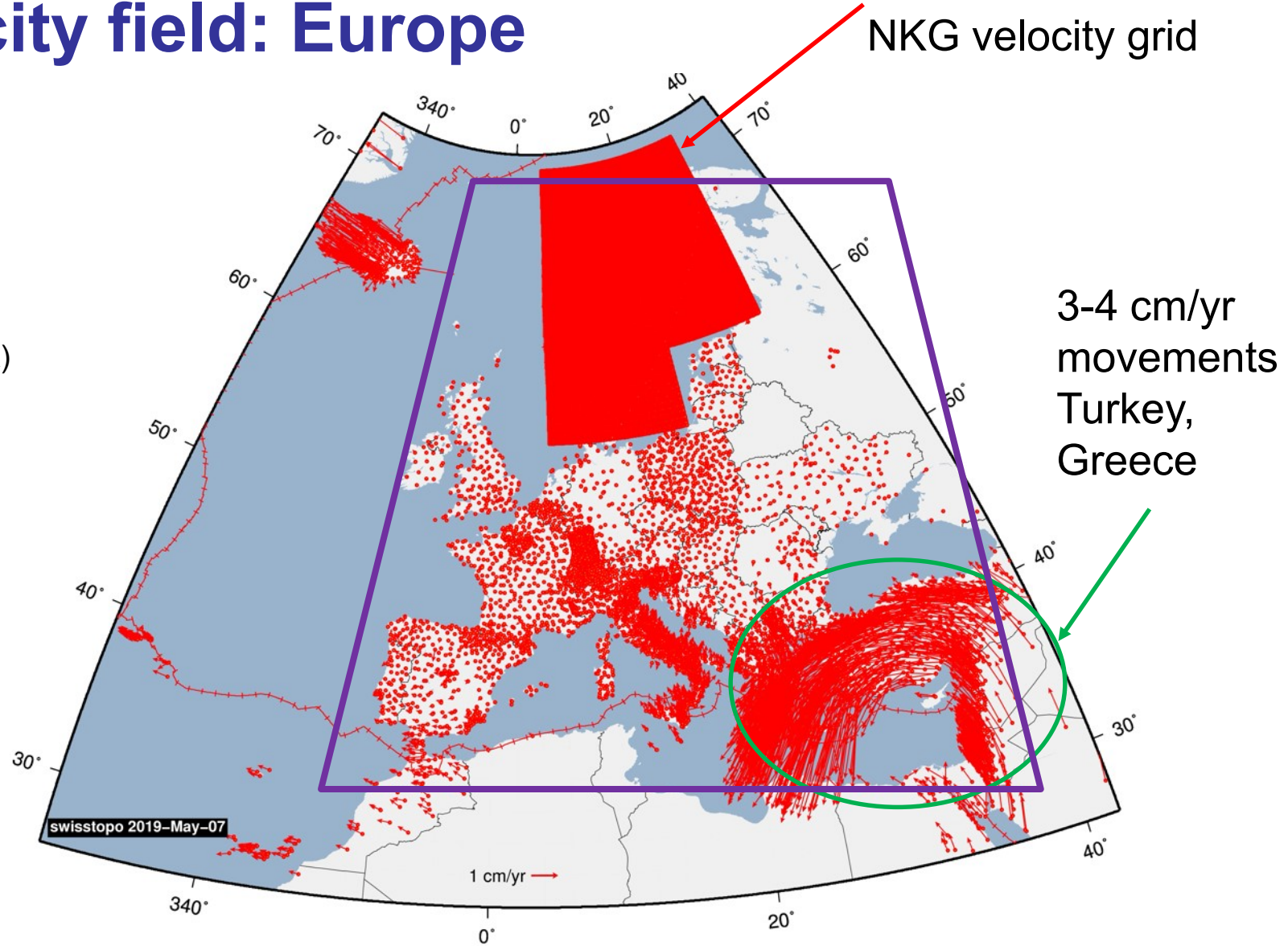


International reference: GSRM project
(Nevada Bureau of Mines and Geology)

http://pnac.swisstopo.admin.ch/divers/dens_vel/combvel_global_all_cmb_basic_dh.jpg

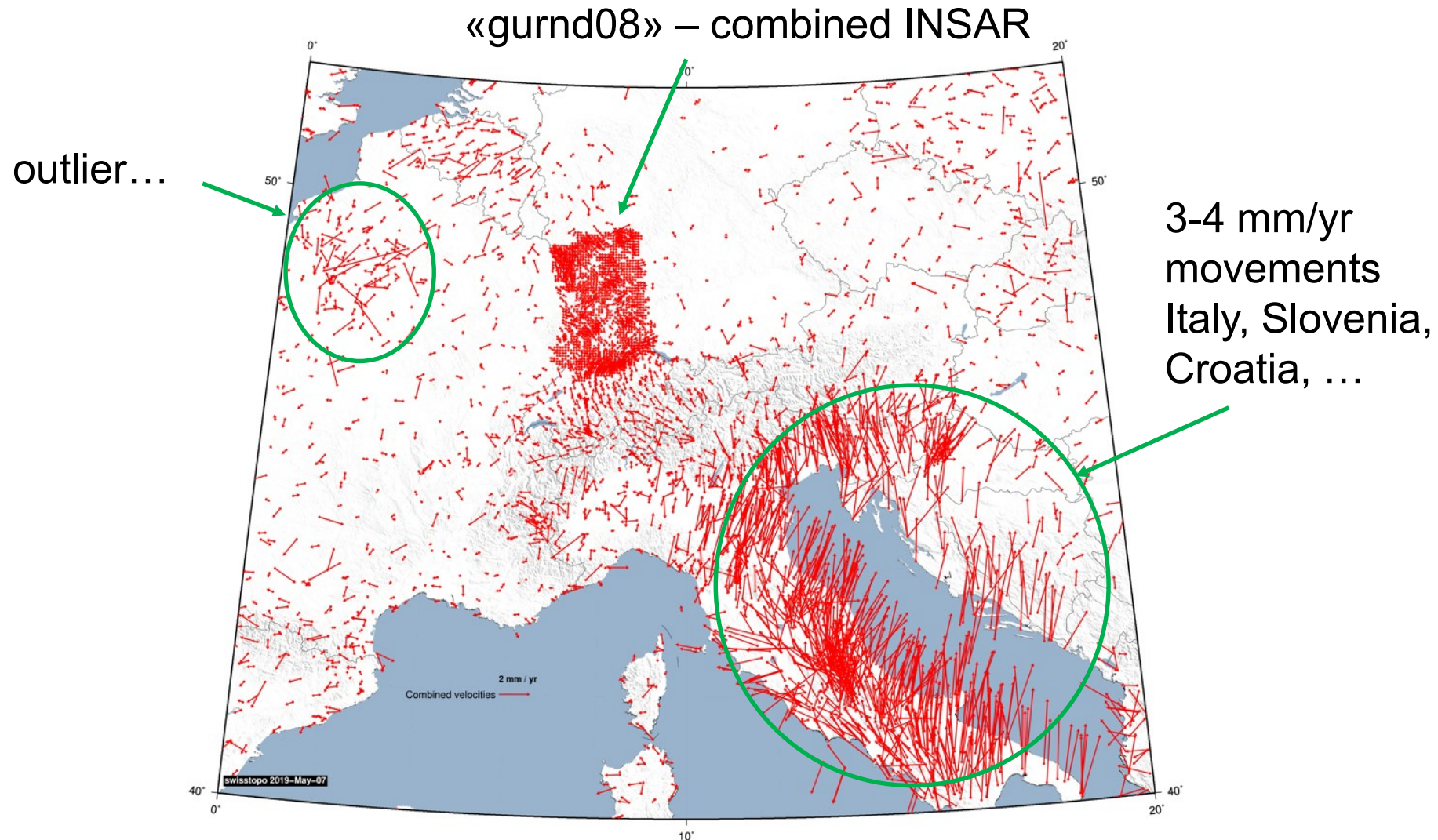
Velocity field: Europe

6170 sites
(no grids, no INSAR)



http://pnac.swisstopo.admin.ch/divers/dens_vel/combvel_eu_all_cmb_basic_dh.jpg

Velocity field: Zoom Alps



http://pnac.swisstopo.admin.ch/divers/dens_vel/combvel_eu_ch_cmb_dh.jpg

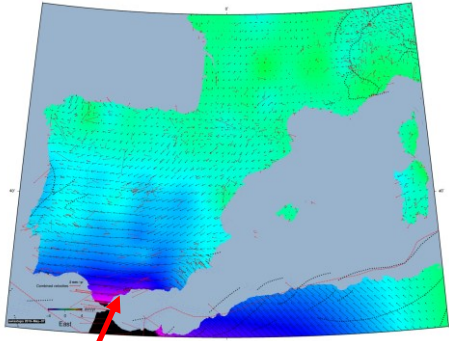
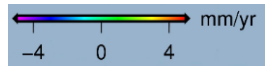


Velocity models

1-D fits by component
(not yet suited as final velocity model
but well for data screening)

horizontally

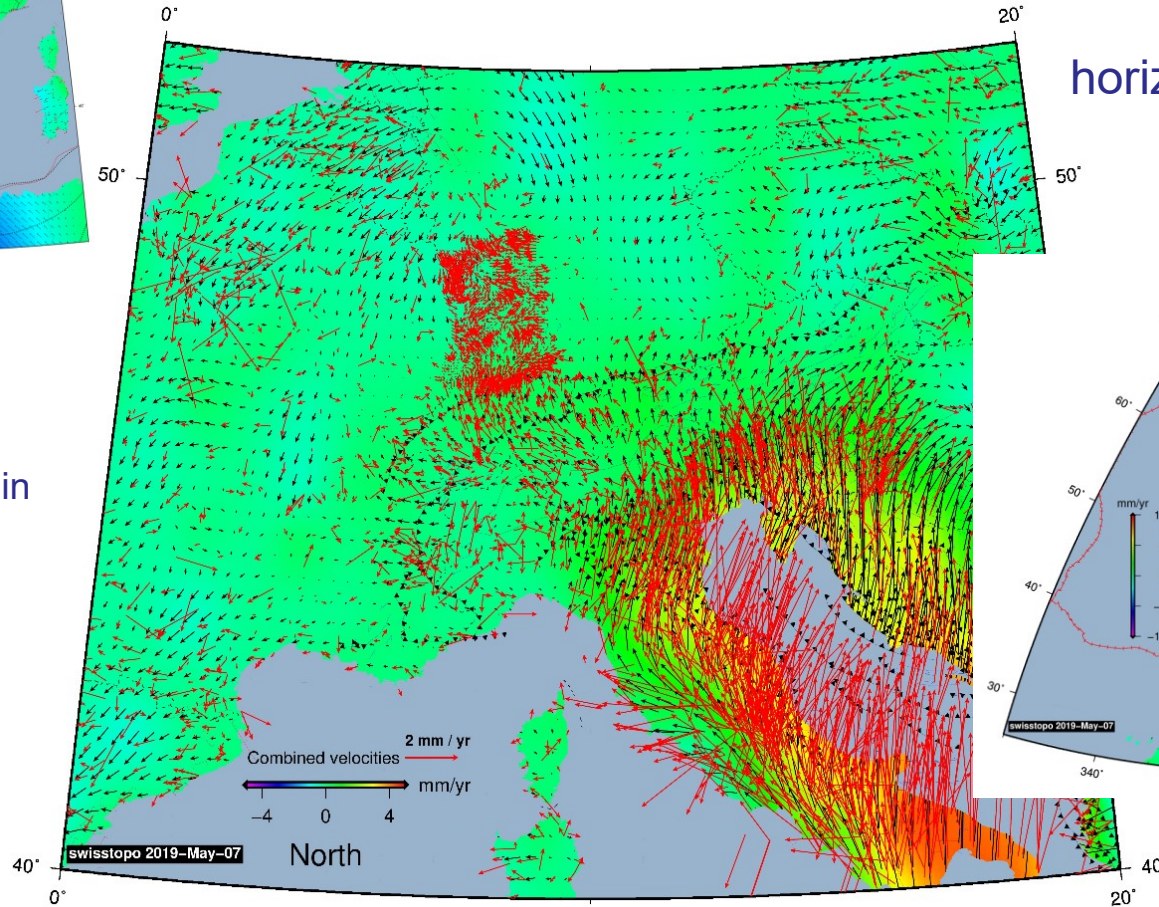
→ observed
→ model
colored grid



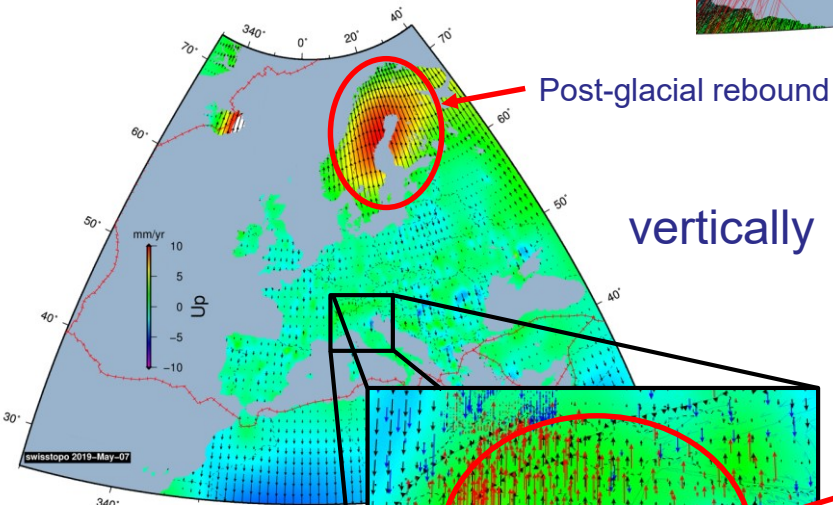
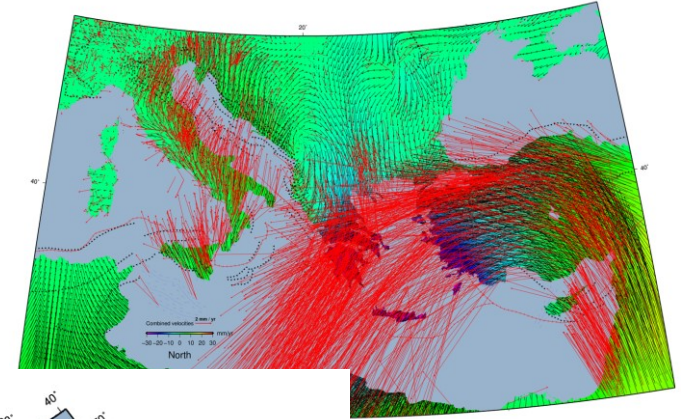
South-Spain

East velocities
~4 mm/yr
w.r.t. ETRF + North Spain

Static reference frame
newly defined
1.1.2017 : < 1 mm
July 2019 : < 10 mm
1.1.2022 : < 20 mm



horizontally



vertically

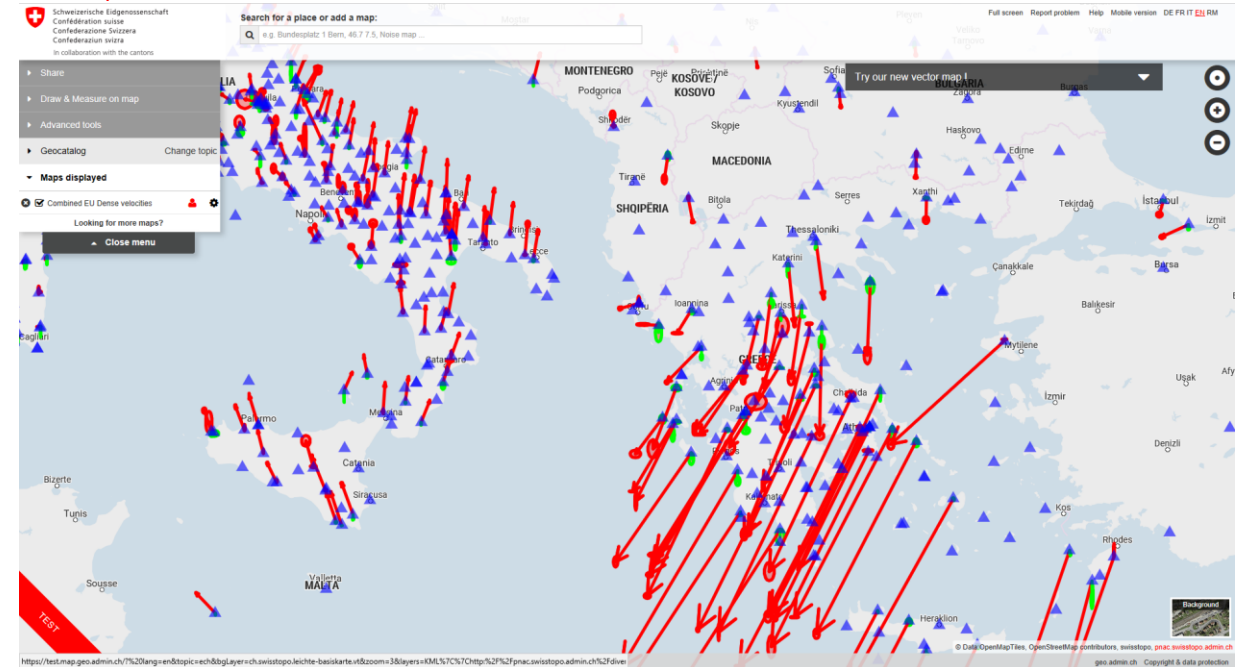
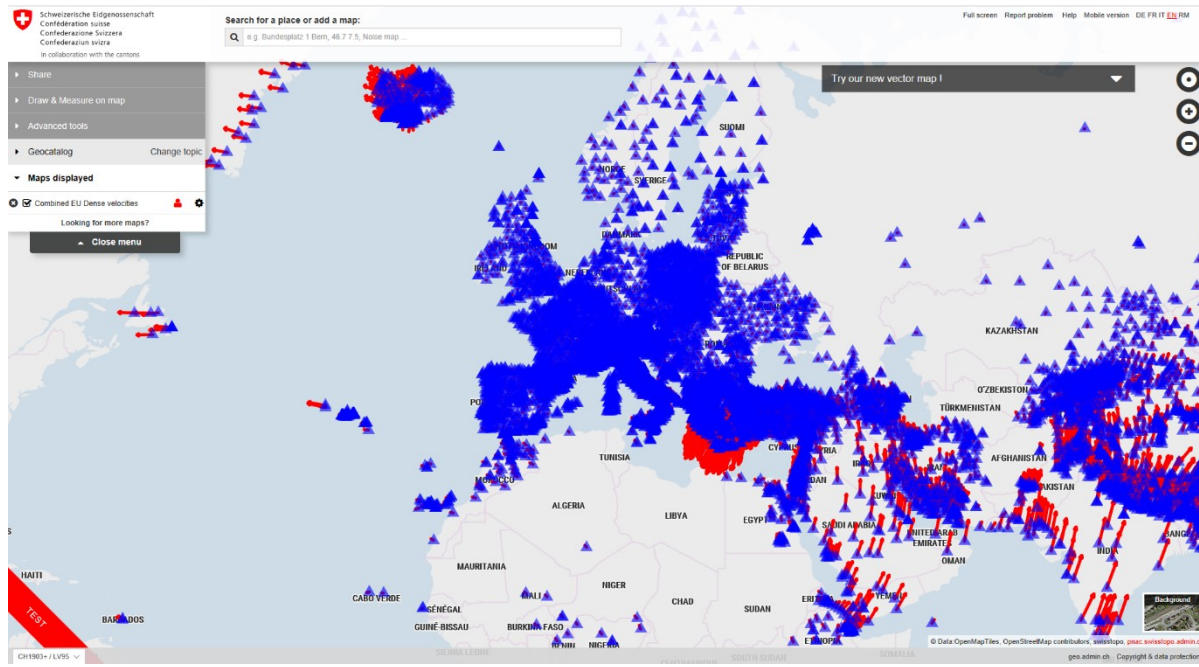
Alpine rise +
Po-basin
subsidence

http://pnac.swisstopo.admin.ch/divers/dens_vel/000.html#VELOCITIES

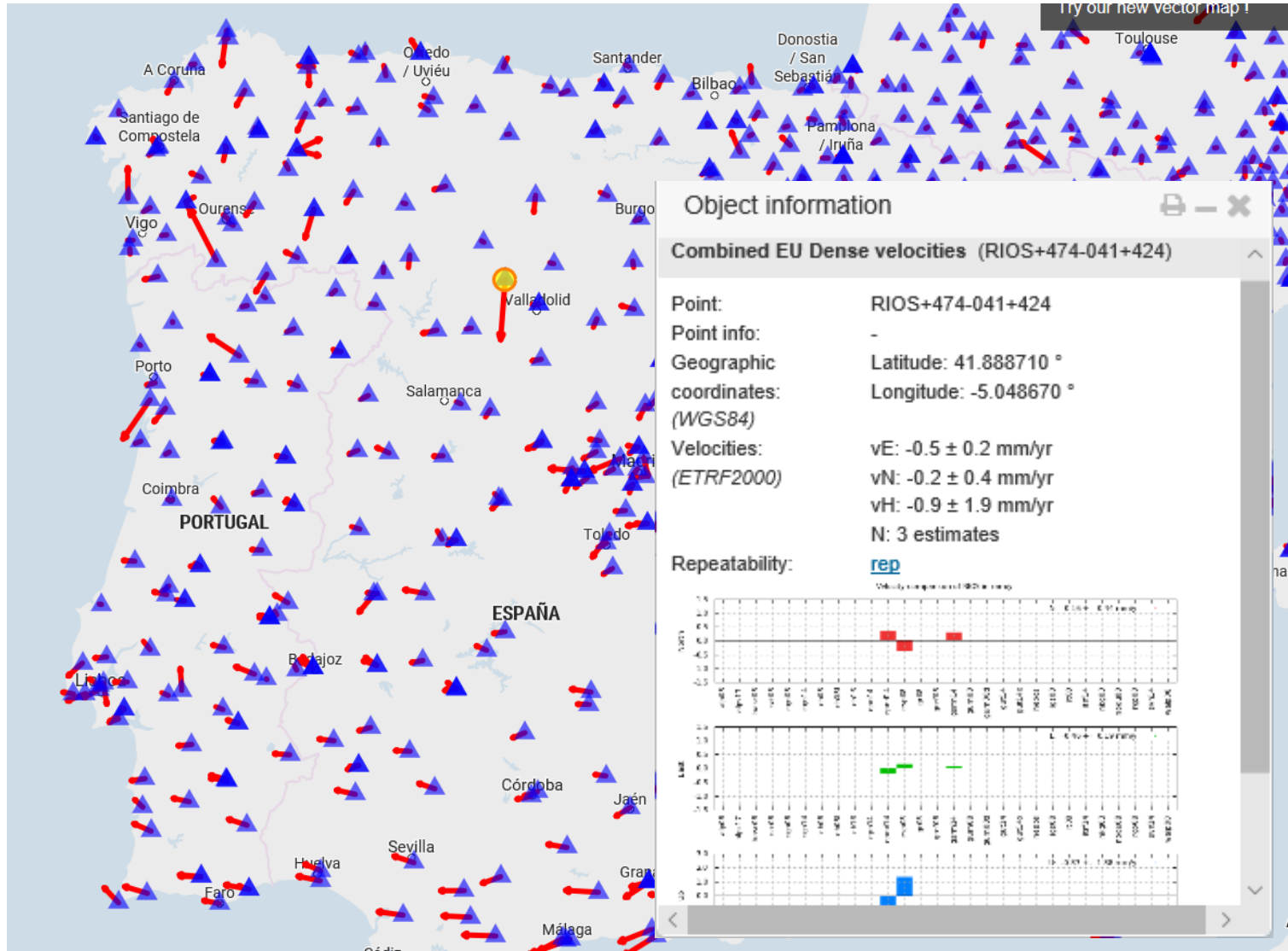
Graphical support: Mercator Viewer

- Swiss data + Openstreetmap data
- Global coverage
- Maps are vector based – you can design your map yourself

Stations (>2 ACs)



Mercator Viewer: context information



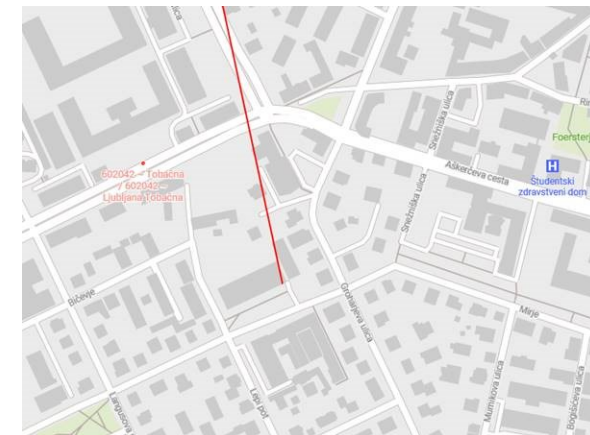
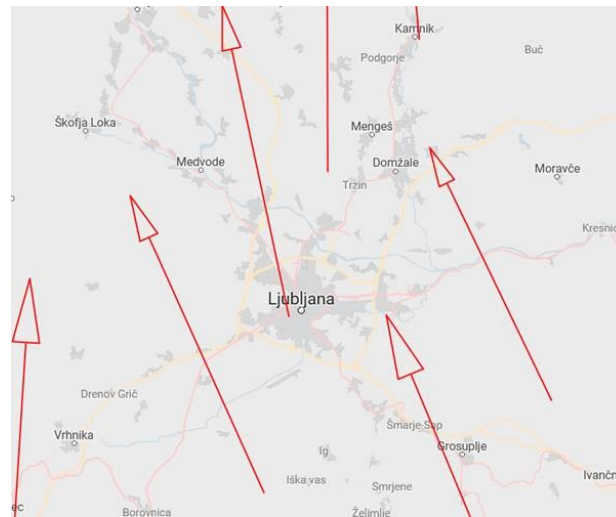
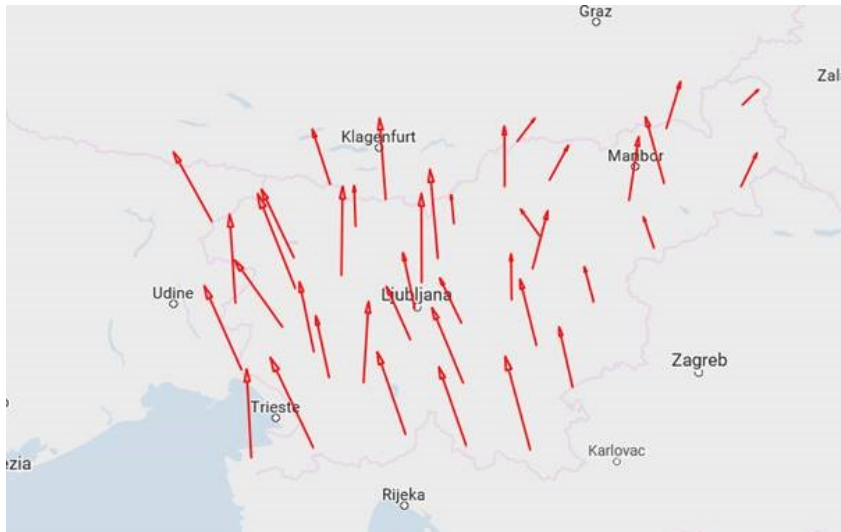
Mercator View – Example Slovenia

Sandi Berk, Klemen Medved



<https://test.map.geo.admin.ch/?layers=KML||your kml on web>

https://test.map.geo.admin.ch/?layers=KML%7C%7Chttp:%2F%2Fpnac.swisstopo.admin.ch%2Fdivers%2Fkml%2FSV_N_ETRF00_Hz_vel.kml&lon=14.3&lat=46.05&lang=en



Summary

- Thanks to the **various individual inputs** (~ 20 institutions) and their good quality a preliminary velocity field for Europe can be generated. Velocities are significant, providers have the know-how and partly have velocity generation automated.
- A **web system is up** and running giving **feedback to the provider** (sortable tables with outliers, plots, grids, etc.). First successful viewing possibilities developed.
- Especially in regions of slow motions, some iterations are necessary to remove outliers, instable stations, differences between provider (mainly task of the provider): “**Validation first**”
Some provider started refinement activities using the web feedback system...
- On a longer view “**Model next**”:
 - acceptance of “**cleaned**” **velocity fields** or **velocity grids** (e.g. if model is already applied in a country)
 - a **velocity model extends the lifetime of the European (and national) reference frames**
 - Making use of synergies with other international partners for handling of intraplate-deformations in reference frame maintenance.
- Data set for a deeper collaboration with Geophysics, Seismology and Geology