Schweizerische Eidgenossenschaft
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Confederazione Svizzera
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Status Report
EUREF WG on “European Dense Velocities”

EUREF LAC Workshop 2019, Warsaw

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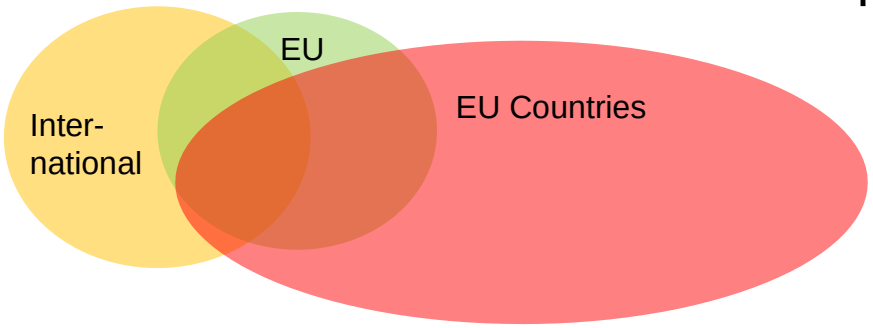
Densification

- International / IGS

~500 sites

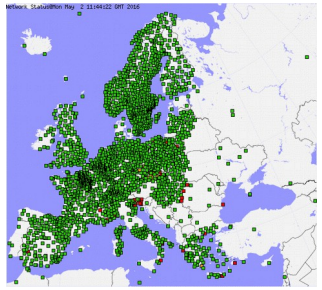
- Continental / European / EUREF



~340 sites

- EU countries

>4000 stations
used in E-GVAP
near real-time
>6000 this project
>8000? totally

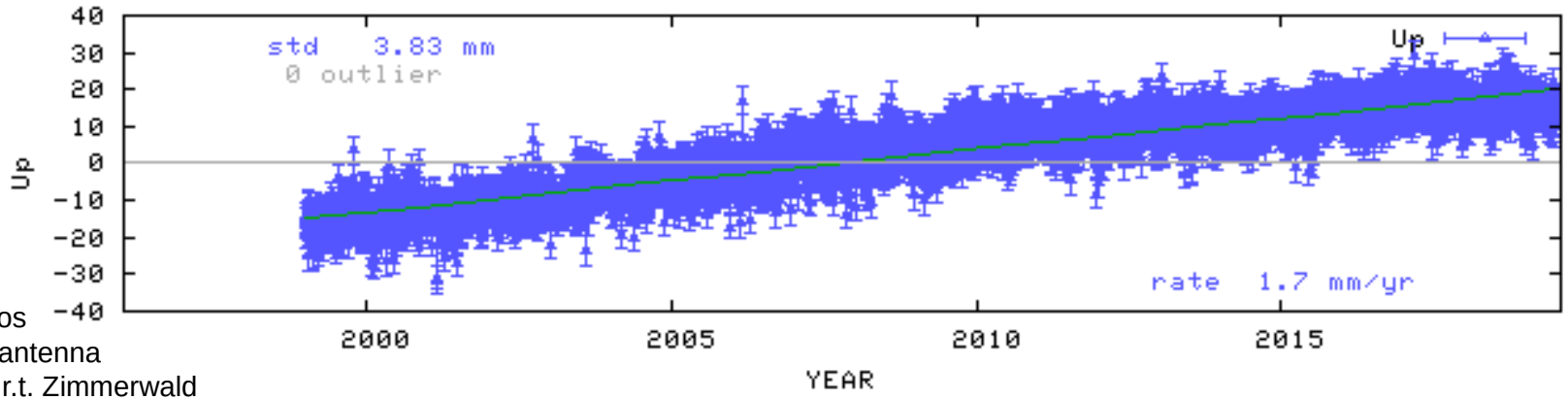


~40-500 sites
per country

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	
498	001	alp08	AlpArray Initiative	Alps
194	002	alps17	BAdW/DGFI (I /doi.org/10.5194/essd-2018-19)	
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	cgn08	Central European GPS (ortium (CEGRN): 2016 campaign com	Central Europe (already combined)
1128	006	cgn14	Central European GPS Geodynamic Reference Network Consortium (CEGRN): 2018 Multi-annual	
213	007	ch08	swisstopo - Permanent stations	
66	008	ch08l	swisstopo - Permanent ing	CH levelling-only
432	009	ch16	swisstopo - Permanent	CH permanent + campaings
237	010	epn14	EPN Reference Frame Coordinator	EPN operational (every 15 weeks)
2014	011	epnd14	EUREF WG on EPN Densification	EPN densification
341	012	esp08	Instituto Geografic l (IGN Spain)	Spain
179	013	gr08	Aristotle University of Thessaloniki	Greece 1
38	014	gref08	Federal Agency for Cartography and Geodesy (BKG)	Germany
21428	015	gsrm14	Global Strain Rate Map , Nevada Bureau of Mines and Geology)	Global
76	016	gurn08	GNSS Upper Rhine Graben Network (GURN)	
1313	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	
663	021	it08	Universita di Padova	Italy
148	022	itrf14	ITRF Coordinator	ITRF14
29293	023	nkg03	Nordic Geodetic Commission (NKG)	Nordic grid
76	024	noqu08	Universite de Montpellier	France
544	025	rgp08	Institut national de l'information geographique et forestiere (IGN France)	
40	026	svn14	Surveying and Mapping public of Slovenia	Slovenia: campaings
164	027	turk14	General Directorate g of Turkey	Turkey
182	028	walp08	Universite de Montpellier	Alps

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

epndmy http://147.162.183.197/EPNDMY

Densification solution Joaquin (October, 4 2019) 1568 sites

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

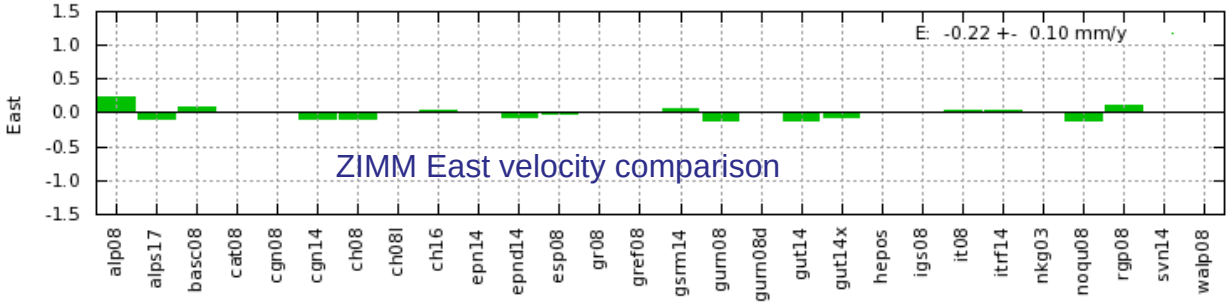
Method

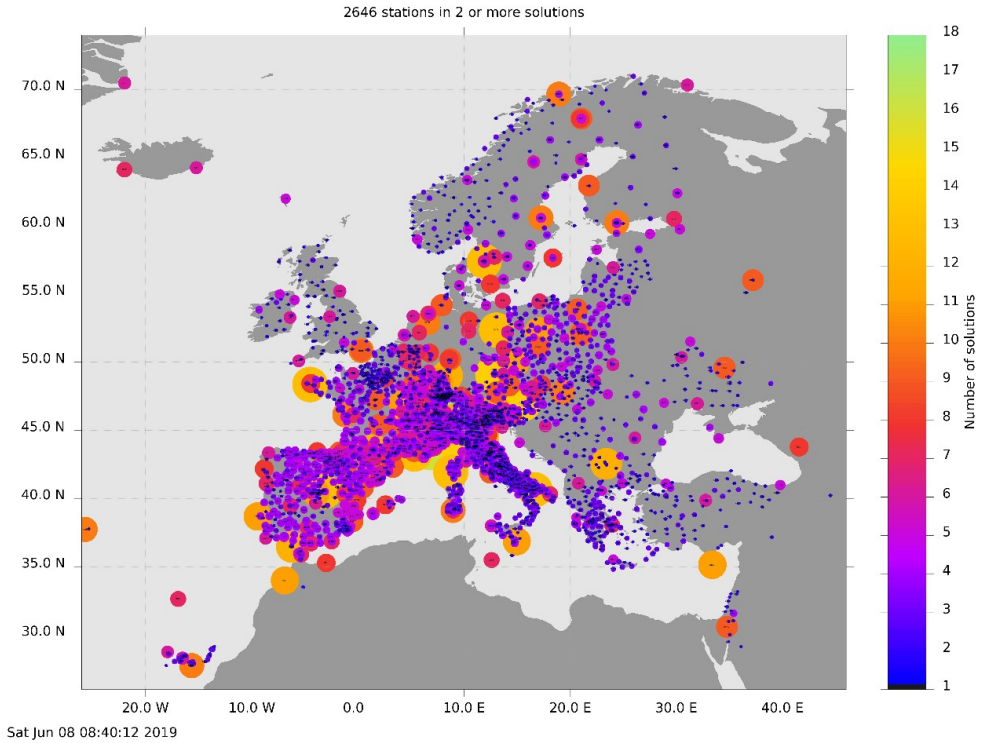
- **Input: velocities aligned to ETRF2000**. No coordinate combination -> no difficulties with different modelling (tropo models, antenna PCVs)
- **Flexible velocity input**: GNSS velocities (permanent + campaigns), levelling, INSAR, velocity grids, … (not possible with SINEX-only input)
- Combination 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 strict guidelines to data processing, no historical 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, …

2805 (October, 4 2019)

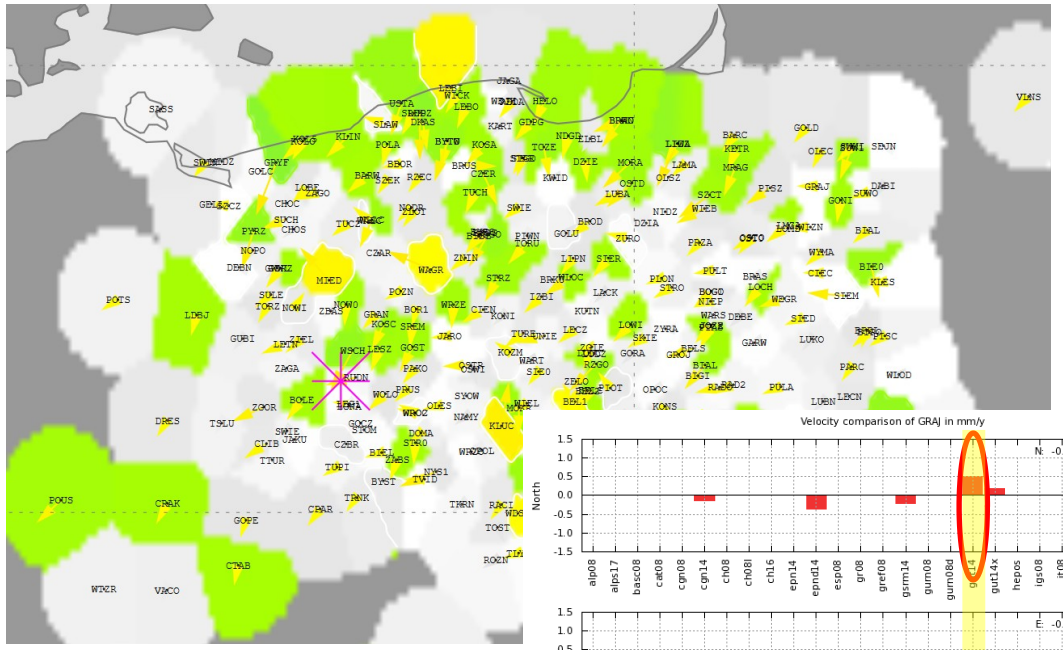


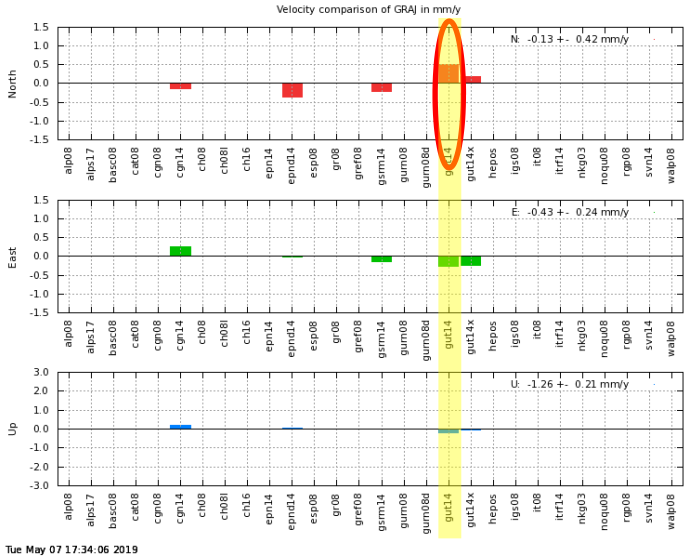


Feedback web page: Example gut14 (Gdansk University, Poland)

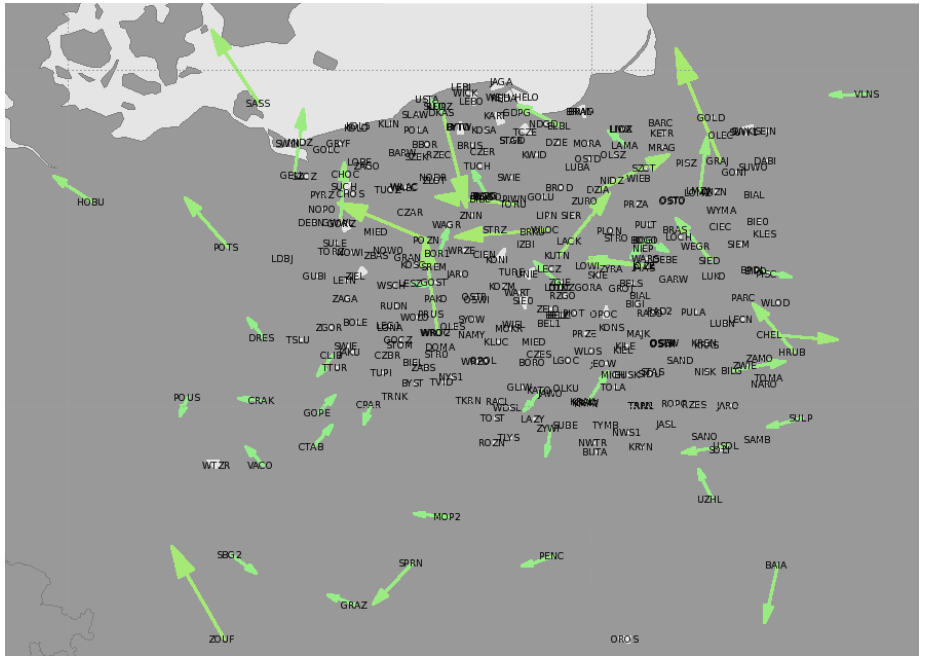
Iterations let to a new contributions gut14x

Input field (gridded background)





Residuals to combination



Neighbour stations

STAT1 -STAT2	L(M) Maps LAT/LON	dVN	dV
[BOGI] [BOGO]	106 [+52.475/+021.035]	0.04	0.3
[BRAN] [BRWO]	15 [+54.385/+019.828]	0.48	-0.3
[BYTO] [BYTW]	45 [+54.157/+017.488]	0.39	0.2

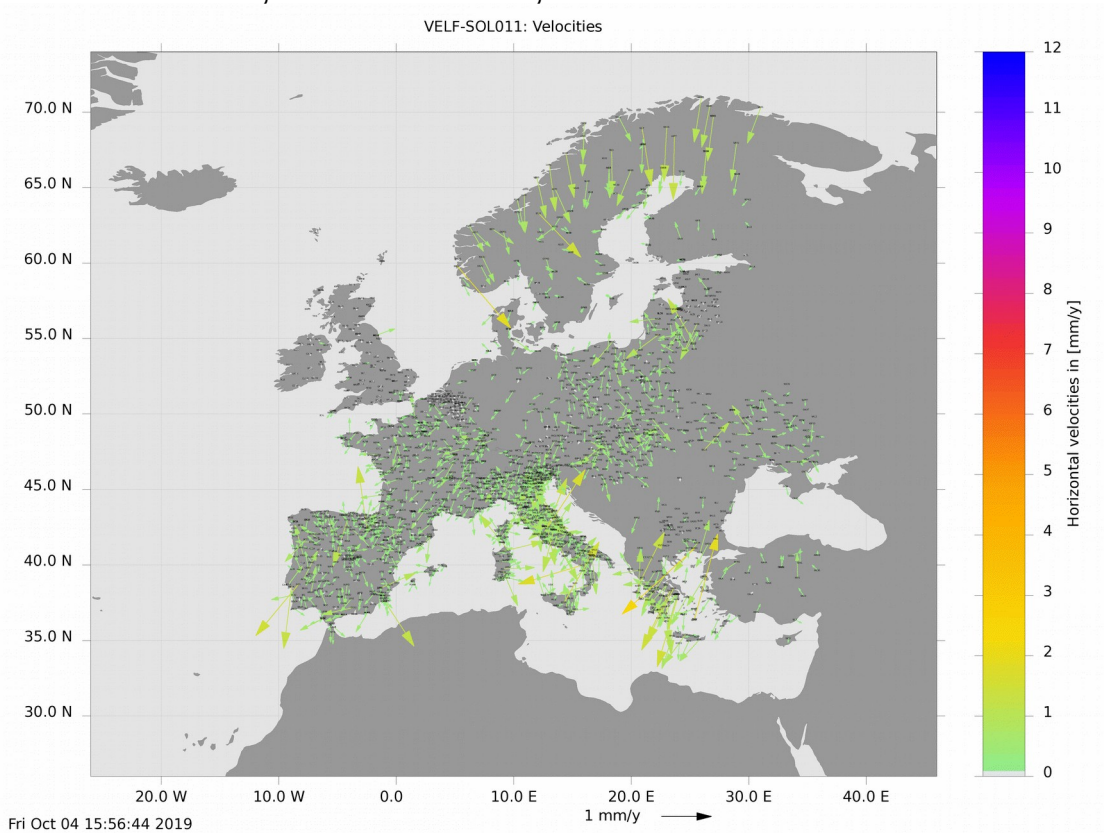
Residuals to combination (sortable table)

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

Residuals to combination (horizontal)

EPND

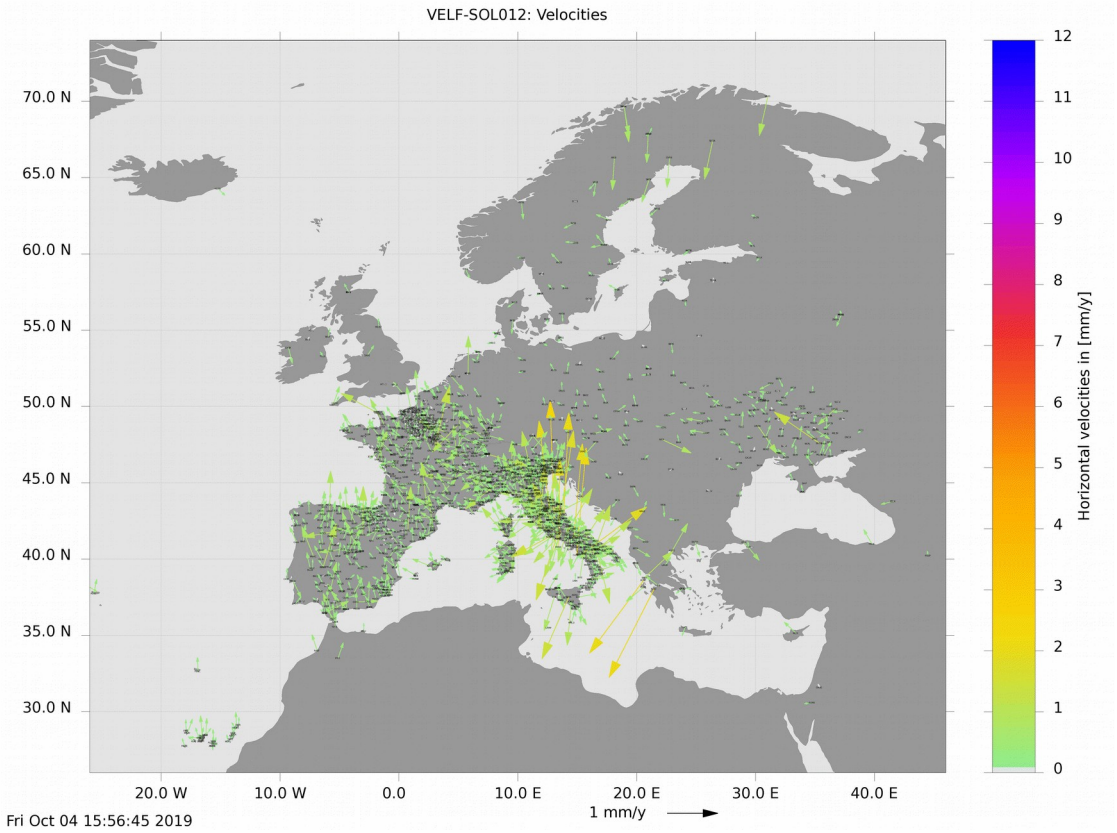
sites: 2014, #sites ok: 1826, #sites combined: 1615



Deletions: 180, Man. Del.: 4, Outliers: 1, Res. 3

EPNDMY

sites: 1568, #sites ok: 1539, #sites combined: 1401



Deletions: 0, Man. Del.: 10, Outliers: 1, Res. 18

Combination statistics

Sorted by std-North

x0 –x000 sites common to combination

Reference frame alignment

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

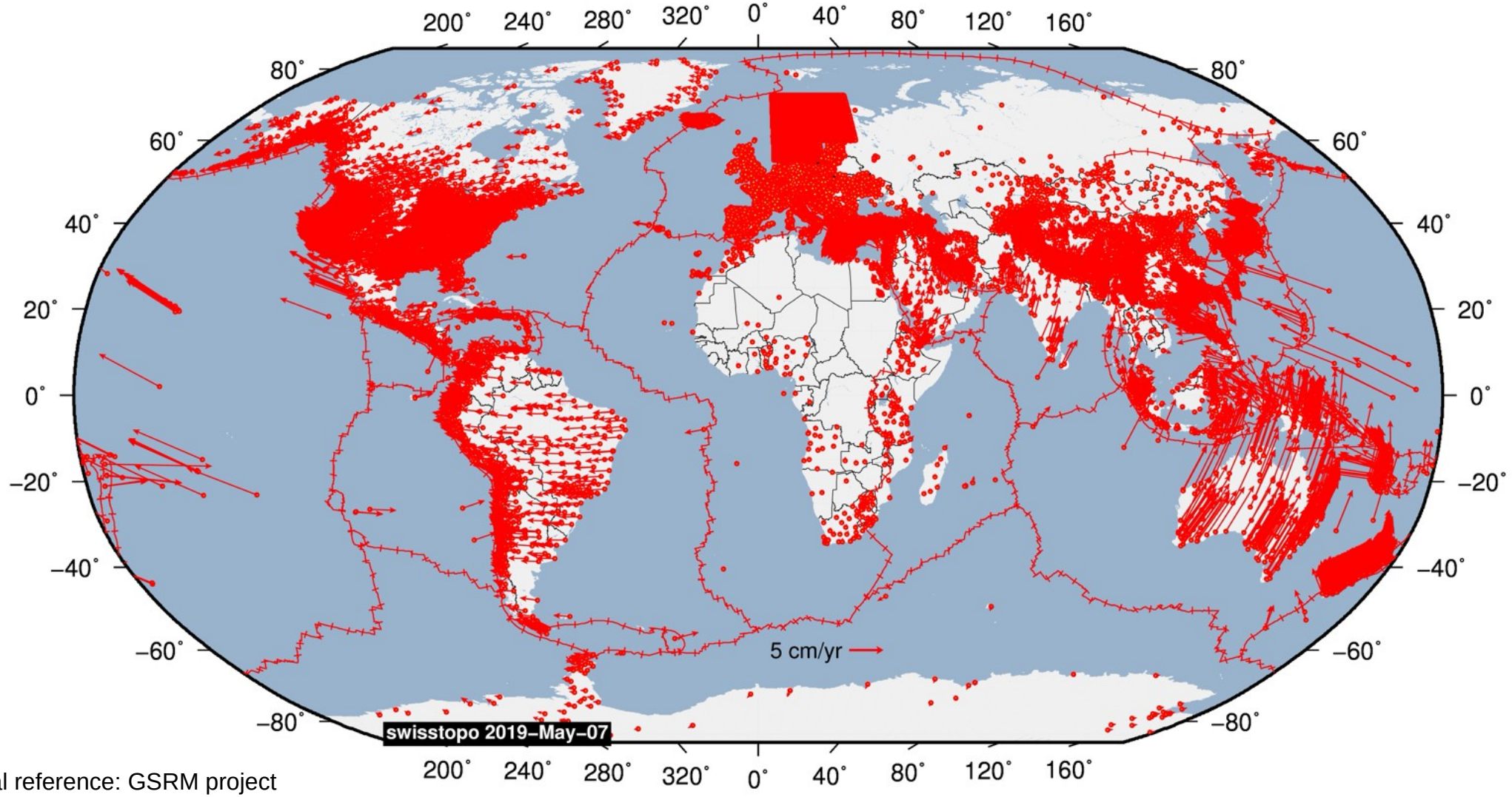
Regions with tectonic signals

NUM	SOLUTION	#INI	#DEL	#ORI	#MAN	#OUT	#RES	#FIN	#CMB	MEAN_N	SIG_N ▾	MEAN_E	SIG_E	MEAN_U	SIG_U	MEAN_H	SIG_H
008	ch08l							63	62	0.00	nan	0.00	nan	0.29	0.31	0.00	nan
023	nkg03							29221	125	0.04	0.06	0.01	0.03	0.09	0.08	0.04	0.07
026	svn14							40	7	0.06	0.06	-0.06	0.09	-0.61	nan	0.09	0.11
017	gurn08d							1313	117	0.02	0.08	0.05	0.11	0.00	0.34	0.05	0.14
009	ch16							428	260	0.00	0.10	0.01	0.13	0.05	0.30	0.01	0.16
027	turk14							161	70	-0.06	0.11	0.03	0.09	0.02	0.24	0.07	0.14
007	ch08							211	211	0.06	0.14	-0.10	0.14	0.06	0.31	0.11	0.20
010	epn14							234	234	-0.00	0.14	0.01	0.11	-0.18	0.31	0.01	0.18
018	gut14x							318	88	0.01	0.14	-0.02	0.17	-0.21	0.41	0.02	0.23
024	noqu08							76	75	0.04	0.14	0.03	0.16	0.45	0.48	0.05	0.21
002	alps17							194	182	-0.03	0.15	-0.13	0.17	-0.14	0.36	0.14	0.23
022	itrf14							139	136	-0.02	0.16	-0.03	0.17	-0.32	0.31	0.04	0.23
004	cat08							144	142	0.06	0.17	-0.02	0.19	0.03	0.43	0.07	0.25
016	gurn08							74	49	0.08	0.18	0.05	0.21	0.00	nan	0.09	0.28
020	igs08							93	91	0.03	0.18	-0.05	0.20	-0.14	0.43	0.06	0.27
028	walp08							178	175	0.20	0.19	0.21	0.28	0.37	0.47	0.29	0.34
014	gref08							38	37	0.04	0.20	0.11	0.17	0.52	0.49	0.11	0.26
005	cgn08							52	51	0.03	0.22	0.03	0.25	-0.08	0.55	0.04	0.34
025	rgp08							355	349	-0.17	0.22	0.02	0.27	-0.10	0.53	0.18	0.35
006	cgn14							1108	1027	0.07	0.24	-0.05	0.23	0.05	0.58	0.09	0.33
011	epnd14							1826	1565	-0.06	0.24	-0.04	0.21	-0.24	0.53	0.07	0.32
001	alp08							493	411	0.11	0.29	0.13	0.25	0.15	0.58	0.17	0.38
003	basc08							315	269	0.07	0.32	0.14	0.34	-0.22	0.60	0.15	0.47
012	esp08							318	290	-0.14	0.32	-0.12	0.28	0.46	0.71	0.18	0.43
021	it08							593	509	-0.14	0.33	0.00	0.26	0.13	0.76	0.14	0.42
019	hepos							59	47	-0.14	0.36	0.28	0.39	-0.88	0.86	0.31	0.54
013	gr08							173	140	0.21	0.43	0.07	0.44	0.47	0.77	0.22	0.62
015	gsrm14							20916	1306	0.05	0.65	0.04	0.55	0.00	nan	0.07	0.85
TOT								53560	2454								

...

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

Global velocities (w.r.t ETRF)



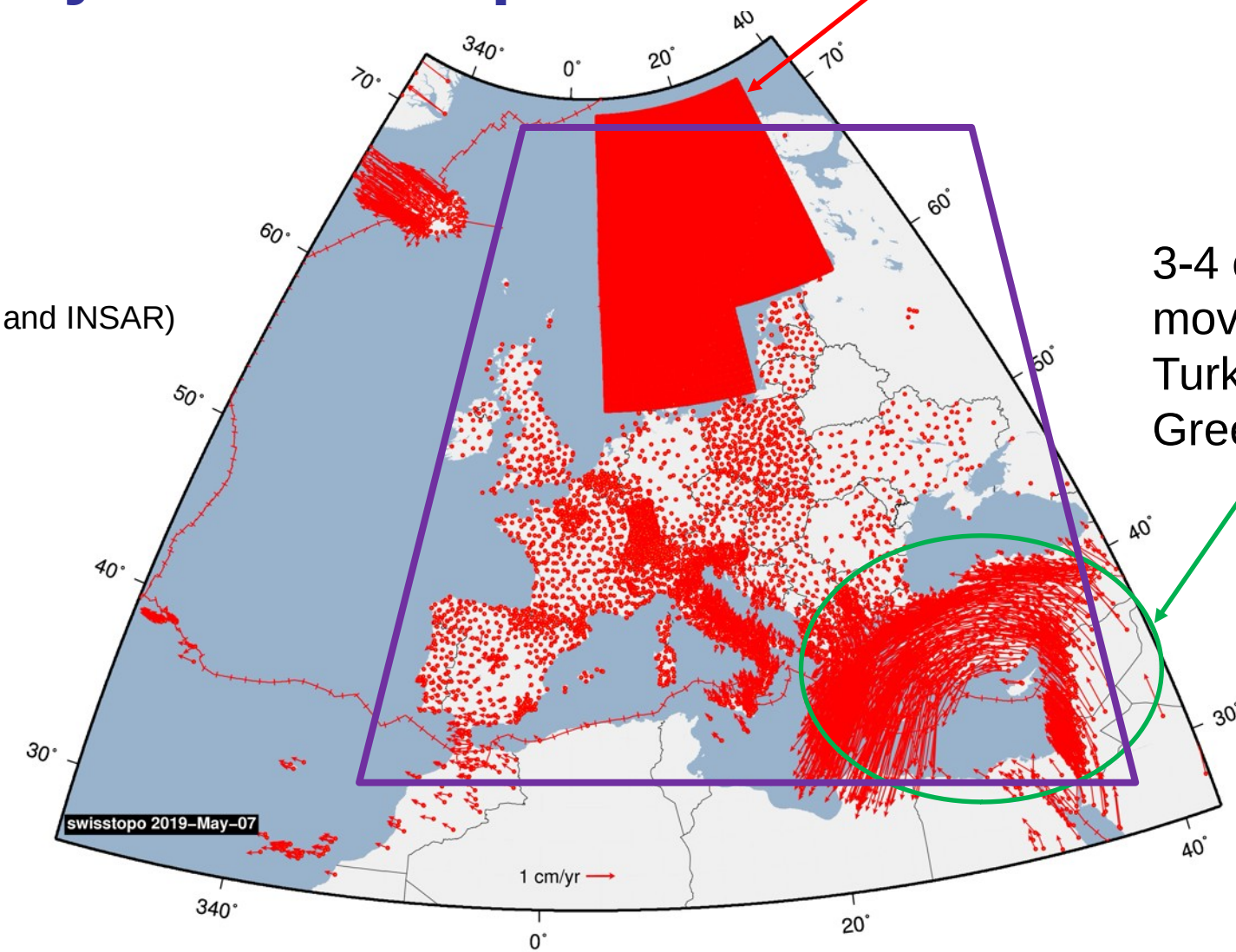
International reference: GSRM project
(Nevada Bureau of Mines and Geology)

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

Velocity field: Europe

NKG velocity grid

6170 sites
(not counting grids and INSAR)



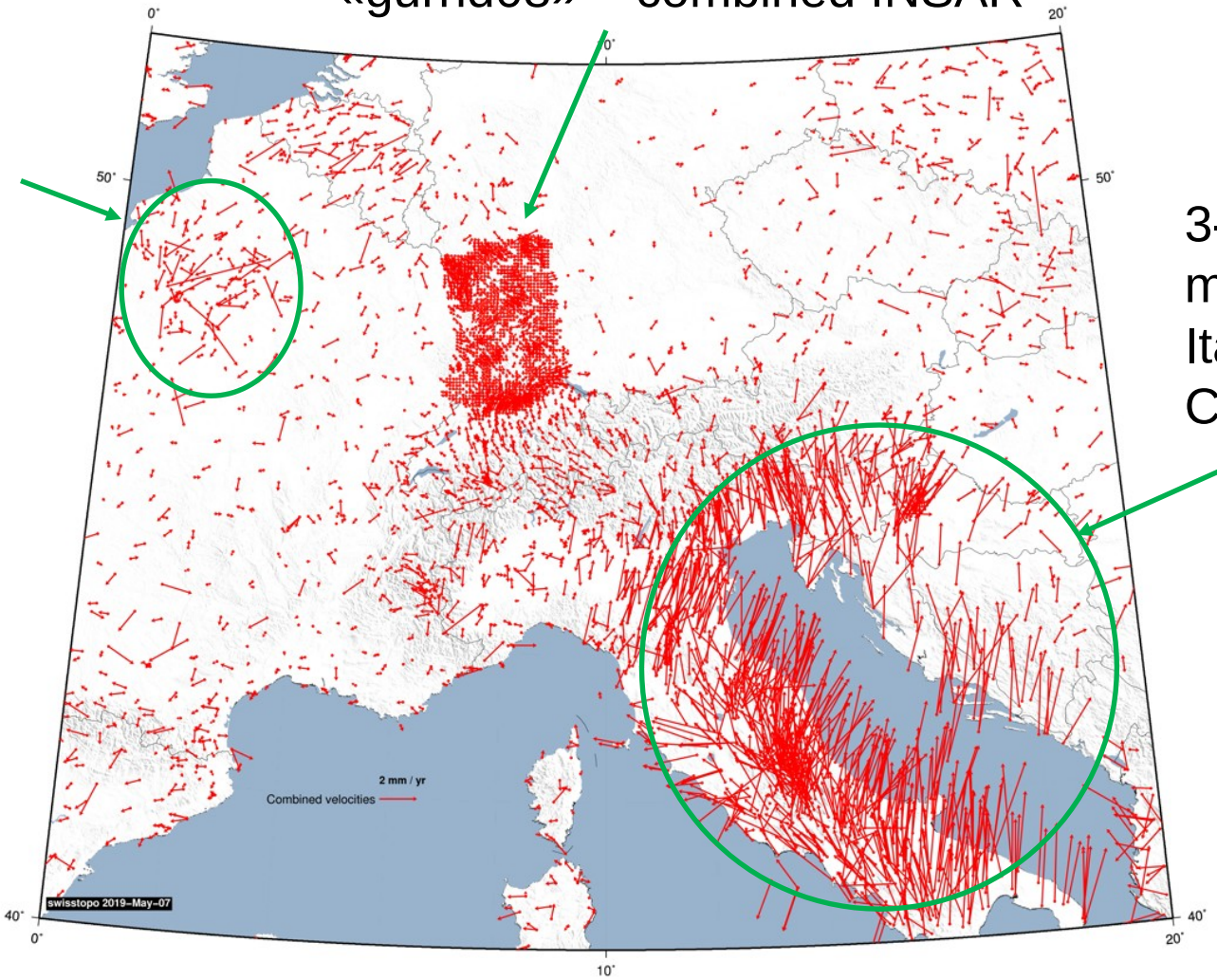
3-4 cm/yr movements Turkey, Greece

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

Velocity field: Zoom Alps

«gurnd08» – combined INSAR

outlier…



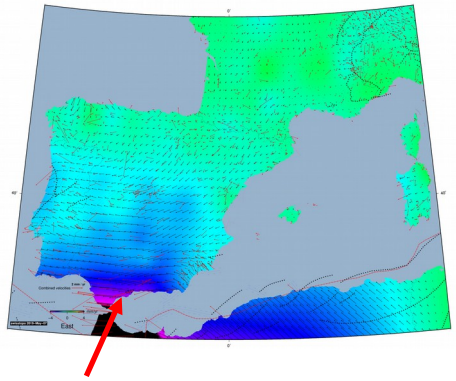
3-4 mm/yr movements Italy, Slovenia, Croatia, …

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

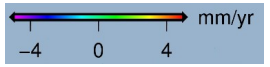


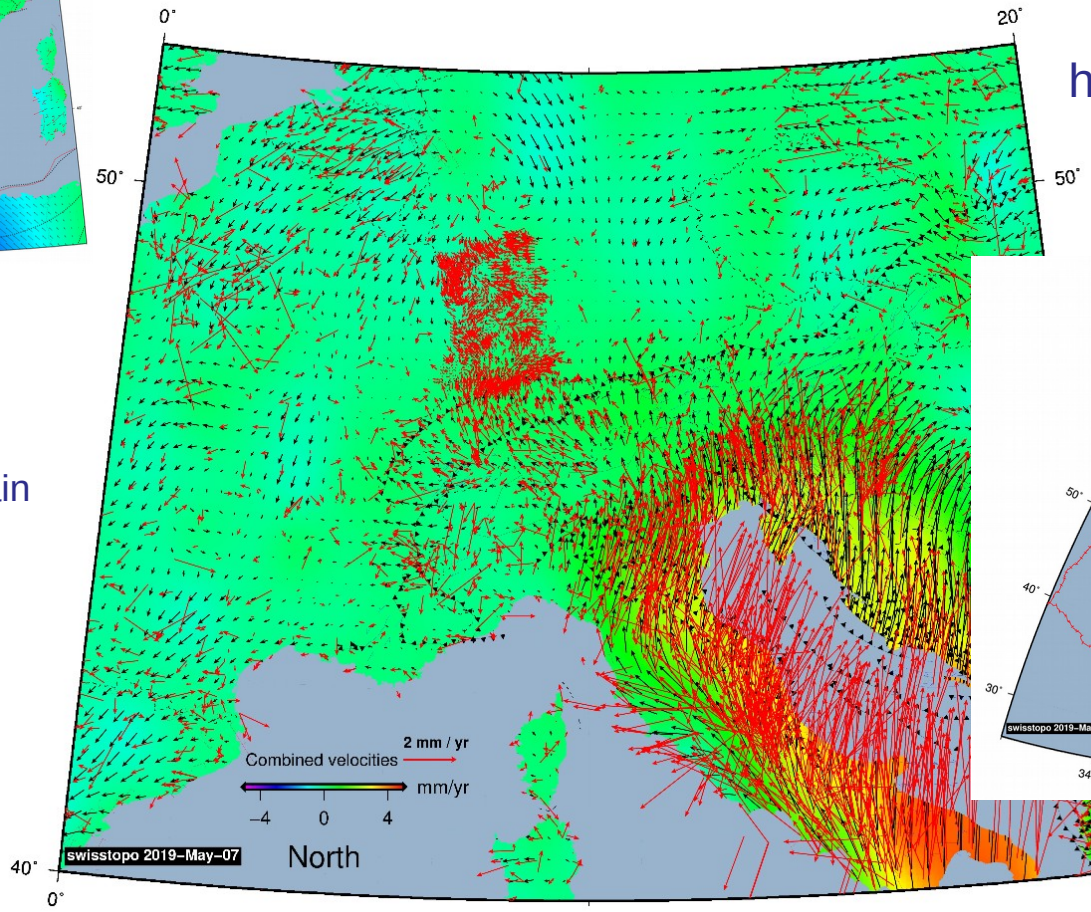
South-Spain

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

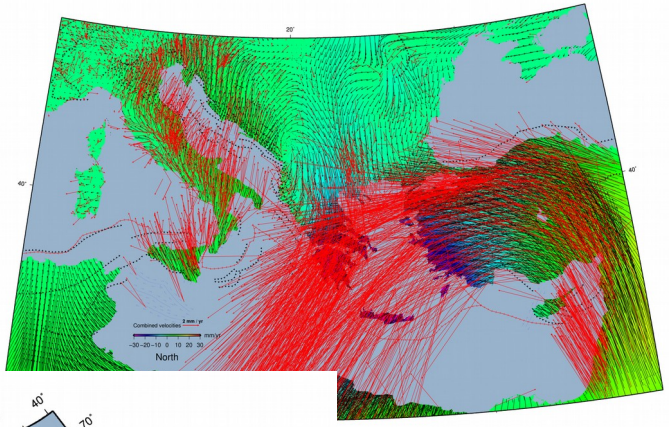
Static reference frame
newly defined
1.1.2017 : < 1 mm
July 2019 : < 10 mm
1.1.2022 : < 20 mm

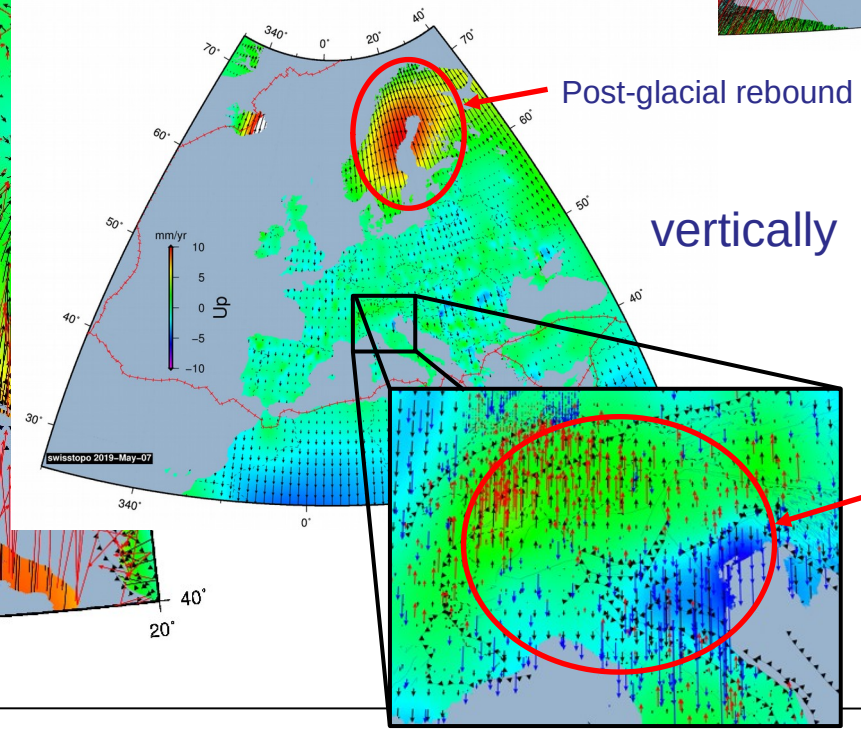
observed
model
colored grid





horizontally





Post-glacial rebound

vertically

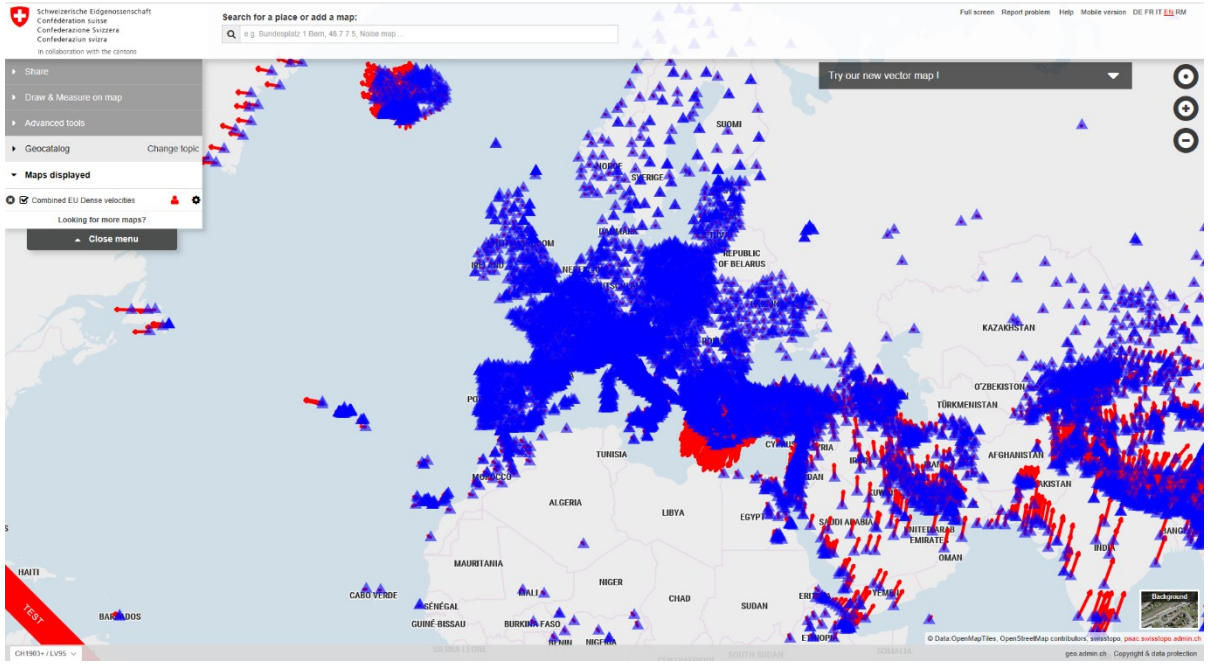
Alpine rise +
Po-basin
subsidence

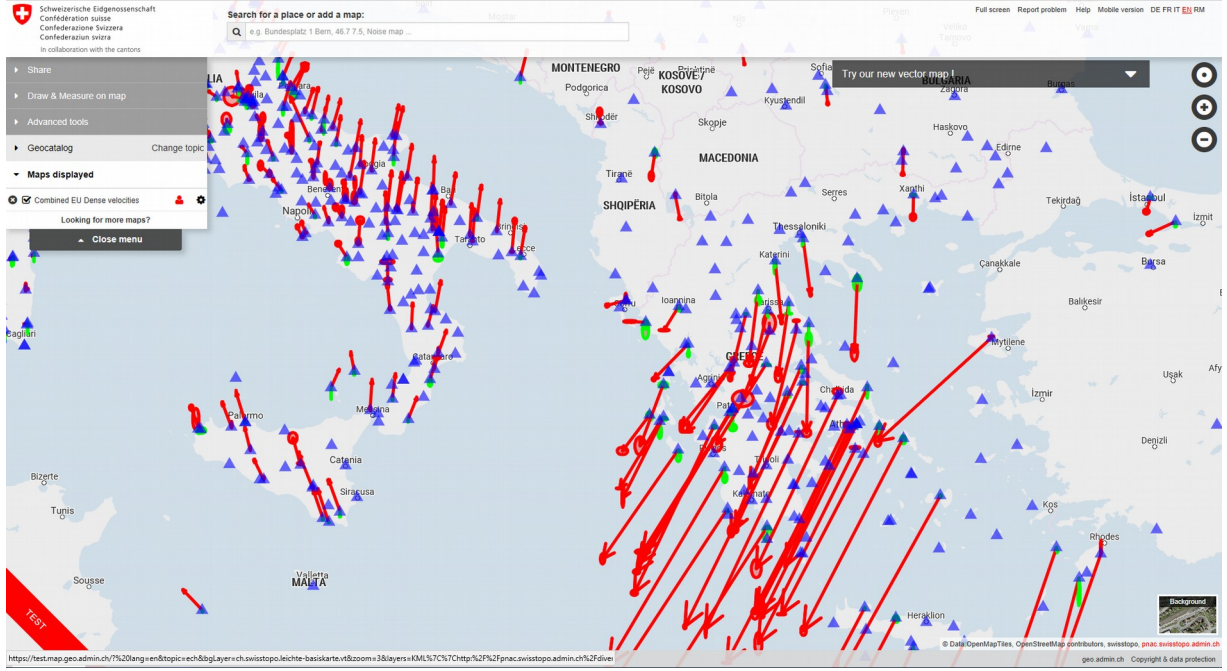
http://pnac.swisstopo.admin.ch/divers/dens_vel/000.html#VELOCITIES

Graphical support: Mercator Viewer

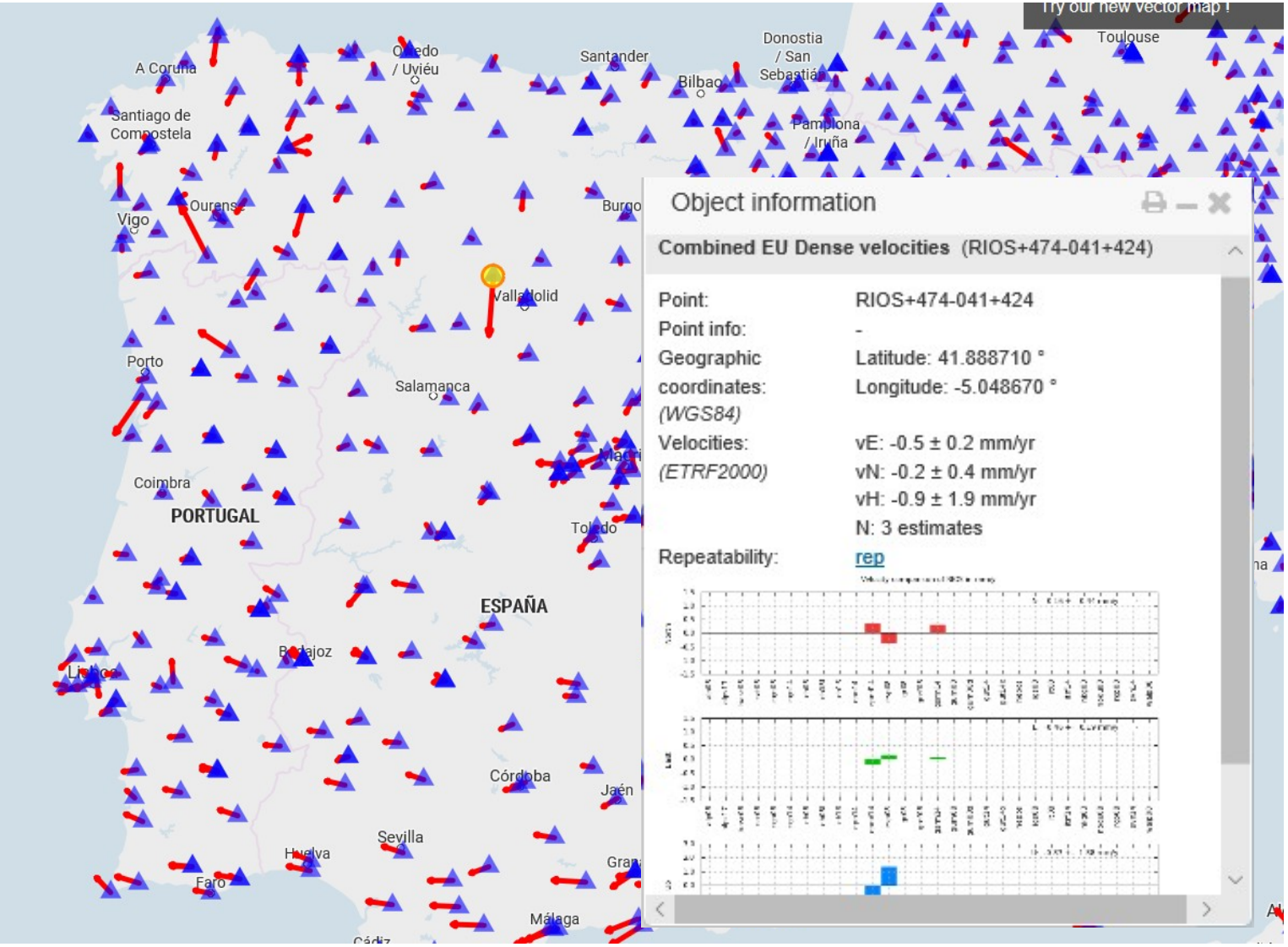
- Swiss data + Openstreetmap data
- Global coverage
- Maps are vector based – you can design your map yourself
- Performance improvements in summer 2019

Stations (>2 ACs)





Mercator Viewer: context information



Mercator View – Example Slovenia

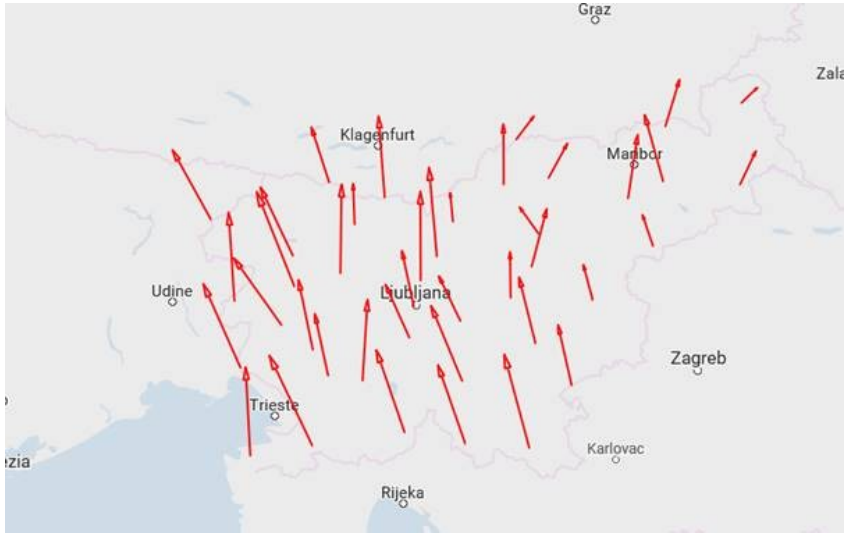
Sandi Berk, Klemen Medved

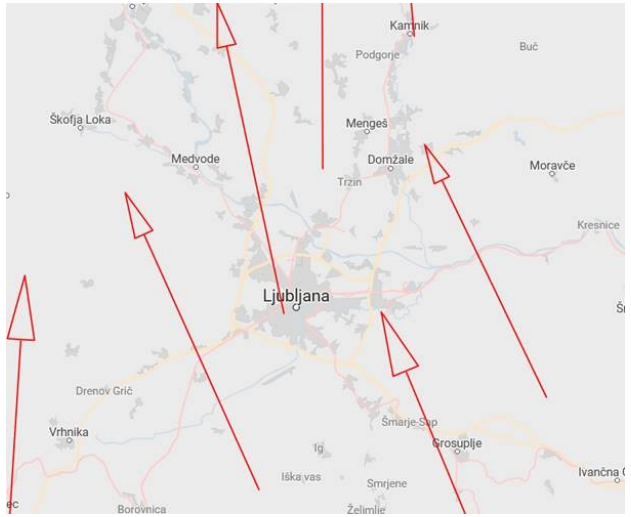
TEST

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%2FSVN_ETRF00_Hz_vel.kml&lon=14.3&lat=46.05&lang=en

WG mail
8.2.2019





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 successfull 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" ("no official product at present"):
  - 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 («IAG WG 1.3.1: Time-Dependent Transformations Between Reference Frames»; use of PROJ as opensource software)
- Data set for a deeper collaboration with Geophysics, Seismology and Geology