EUREF 2018 SYMPOSIUM

AMSTERDAM 30 May – 1 June 2018

High-Rate GPS Positioning for Seismic Event Retrieval

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EPOS - European Plate Observing System

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Priority IV: **INCREASING THE RESEARCH POTENTIAL**
Action 4.2: **DEVELOPMENT OF MODERN RESEARCH INFRASTRUCTURE OF THE SCIENCE SECTOR**

Period of realization: 2016 - 2021
Project value: 61 996 279,64 PLN
ERDF co-financing: 46 632 332,69 PLN

Beneficiary: Instytut Geofizyki Polskiej Akademii Nauk

Consortium members: CYFRONET, GIG, IGiK, Uniwersytet Wrocławski, WAT, Polska Grupa Górnicza

PROJECT **EPOS - EUROPEAN PLATE OBSERVING SYSTEM** IS CO-FINANCED BY THE EUROPEAN UNION FROM THE FUNDS OF THE EUROPEAN REGIONAL DEVELOPMENT FUND (ERDF)

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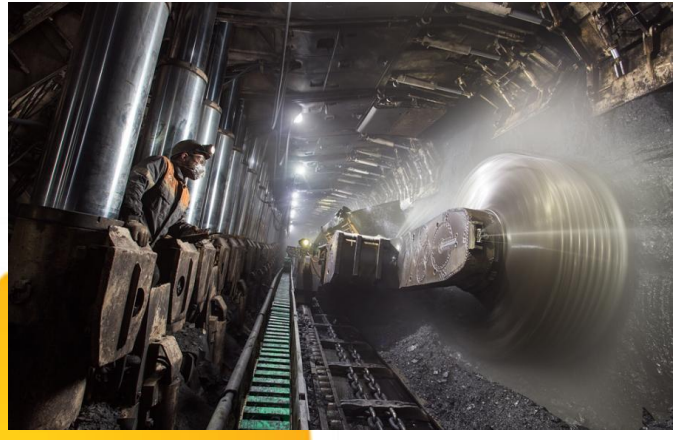
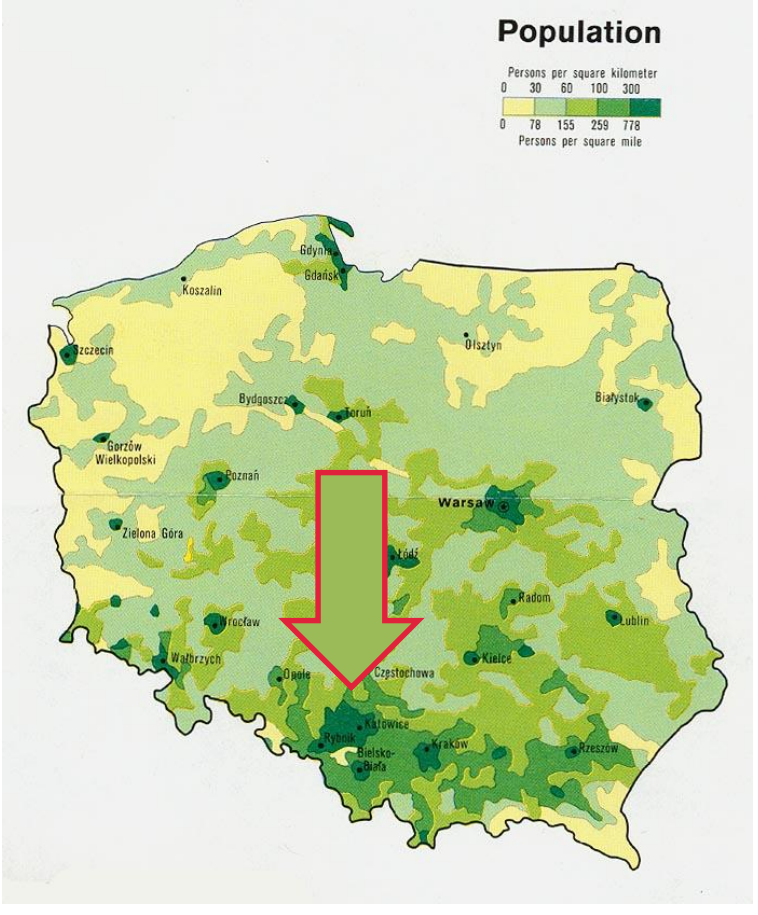
Motivation



POLSKA GRUPA GÓRNICZA



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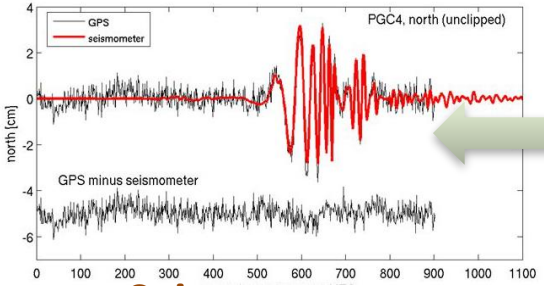
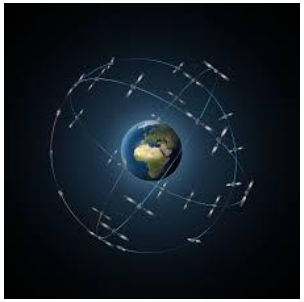
EPOS-PL Observing Techniques

Radiometers

External frequency standard

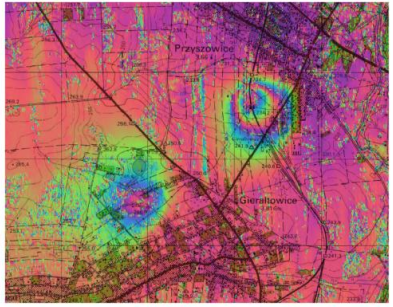


Seismometers



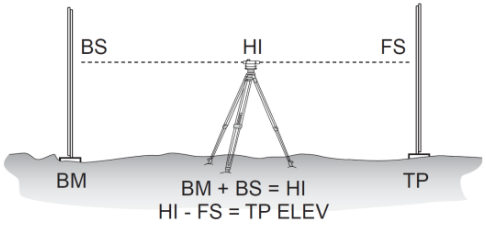
Multi-GNSS receivers

Tidal gravity meters

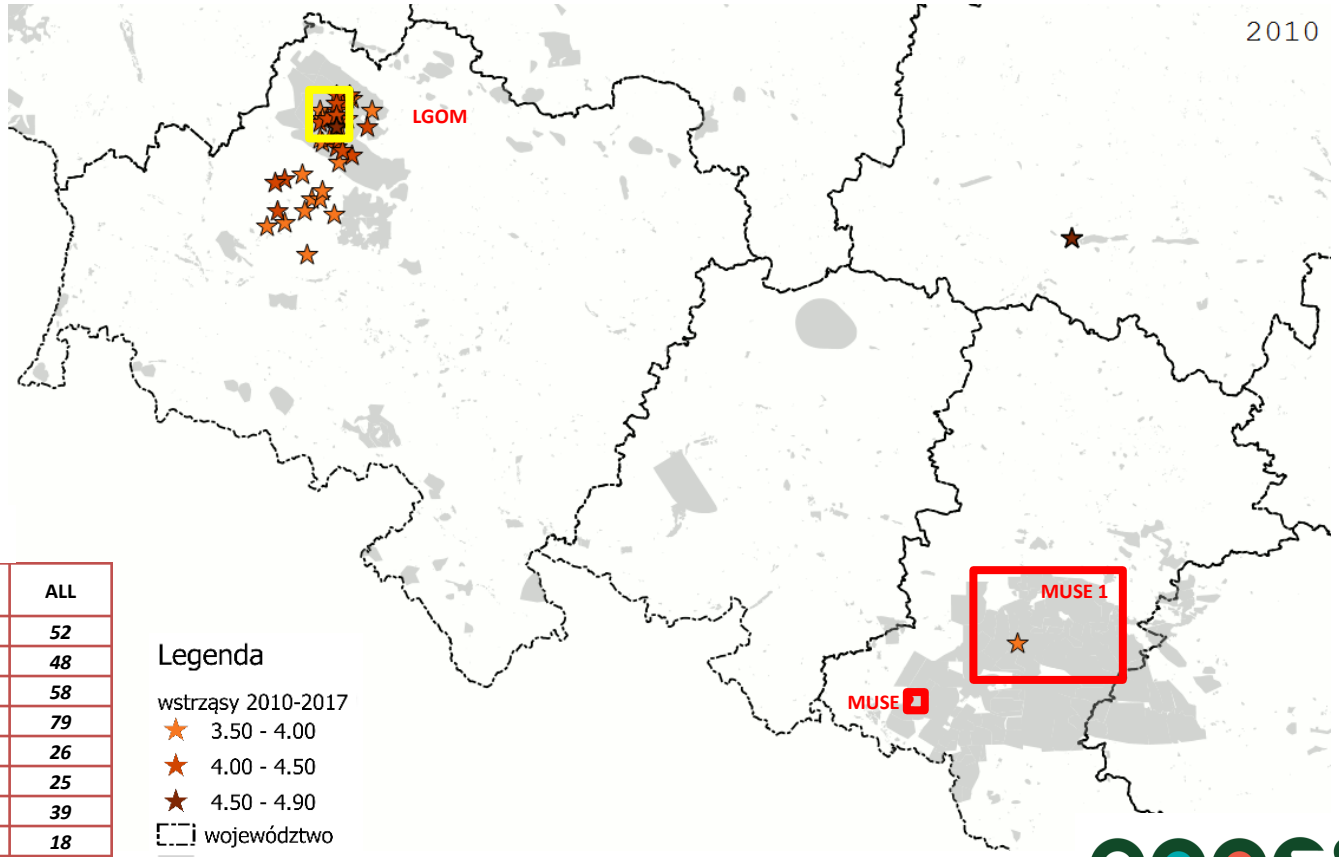


InSAR

Precise leveling



Mining Tremors in Poland Mw > 3.5

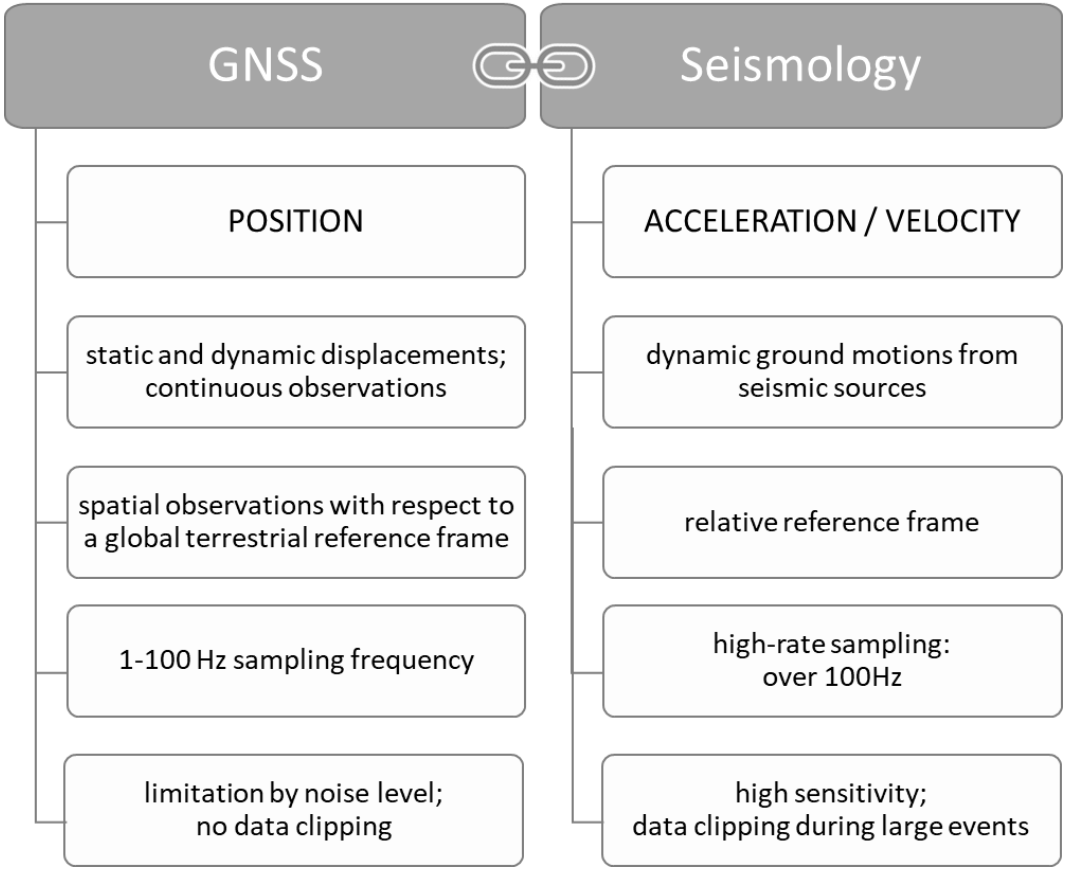


Number of mining tremors in Poland

year\Mw	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	ALL
2010	0	7	19	21	5	***52***
2011	1	5	20	21	1	***48***
2012	10	19	15	14	0	***58***
2013	22	35	14	7	1	***79***
2014	3	8	8	7	0	***26***
2015	1	6	12	6	0	***25***
2016	2	18	12	5	2	***39***
2017	1	9	4	3	1	***18***
Σ	***40***	***107***	***104***	***84***	***10***	**345**

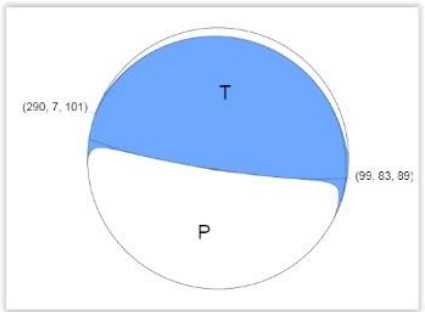
(Based on: http://geofon.gfz-potsdam.de)

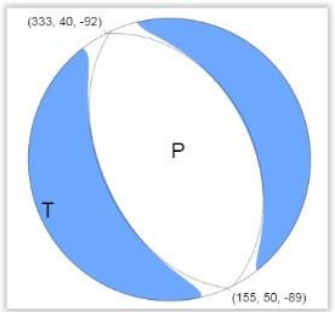
GNSS & Seismology - Complementary Techniques

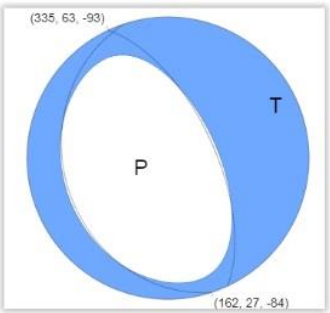


Test cases

NAME	Lamjung / Gorkha	Italy 1 / Visso	Italy 2 / Norcia
DATE	2015-04-25 06:11:25 UTC	2016-10-26 19:18:08 UTC	2016-10-30 06:40:18 UTC
MOMENT MAGNITUDE (MW)	7.8	6.1	6.6
LOCALIZATION	36km E of Khudi, Nepal	3km NNW of Visso, Italy	7km north of Norcia, Italy
EPICENTER COORDINATES	28.231°N 84.731°E	42.862°N 13.096°E	42.956°N 13.067°E
DEPTH	8.2 km	8.0 km	10.0 km
FOCAL MECHANISM	normal thrust	normal thrust	normal thrust







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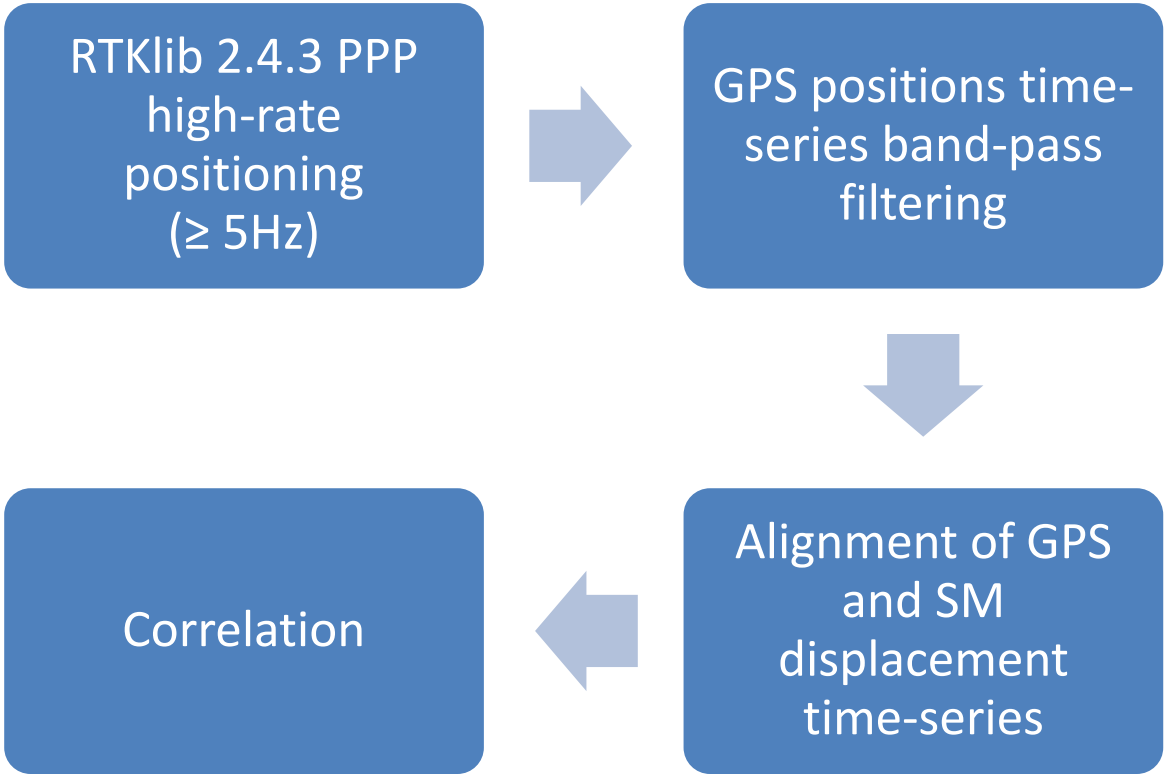
Data processing



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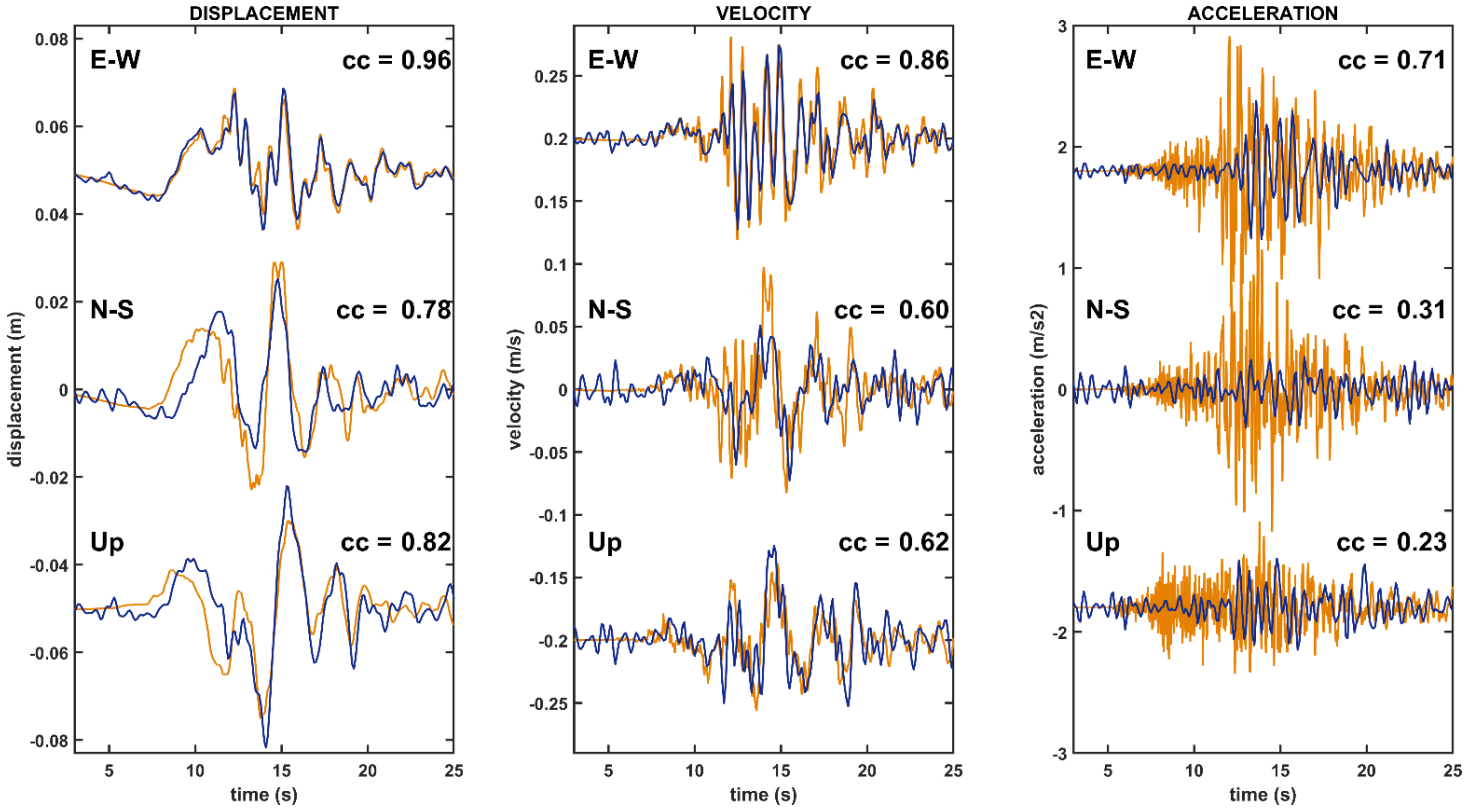
Displacement / Velocity / Acceleration Dilemma

GPS station: GUMA (10Hz); accelerometer: GUMA (200Hz)

Norcia earthquake 2016-10-26 19:18:08 UTC, Mw 6.6

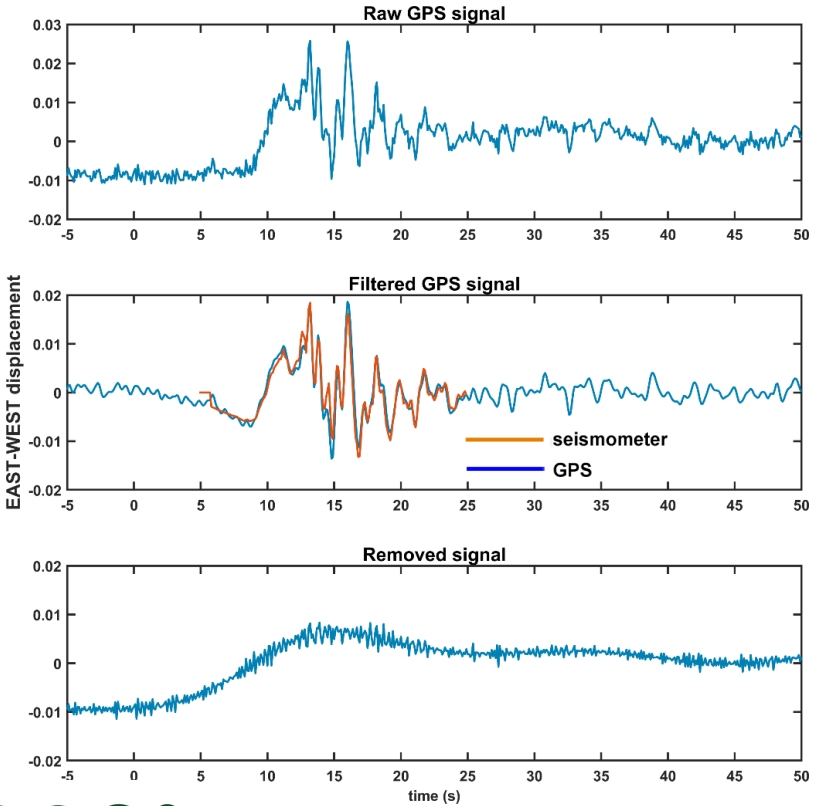
seismometer

GPS



GPS High-Rate Positions Time-Series Filtering

2-order Butterworth band-pass filter cut-off frequency: 0.05-2Hz



GPS station: GUMA (10Hz); accelerometer: GUMA (200Hz)

Norcia earthquake 2016-10-26 19:18:08 UTC, Mw 6.6

correlation coefficient	E	N	U
Raw GPS data	0.87	0.71	0.81
Band-pass filtered GPS data	0.96	0.78	0.82
Percentage change	+9%	+9%	+2%

For other stations and events:
mean+28% change (maximum +72%)

GPS/SM residuals stdev	E	N	U
Raw GPS data	0.004	0.007	0.005
Band-pass filtered GPS data	0.002	0.006	0.005

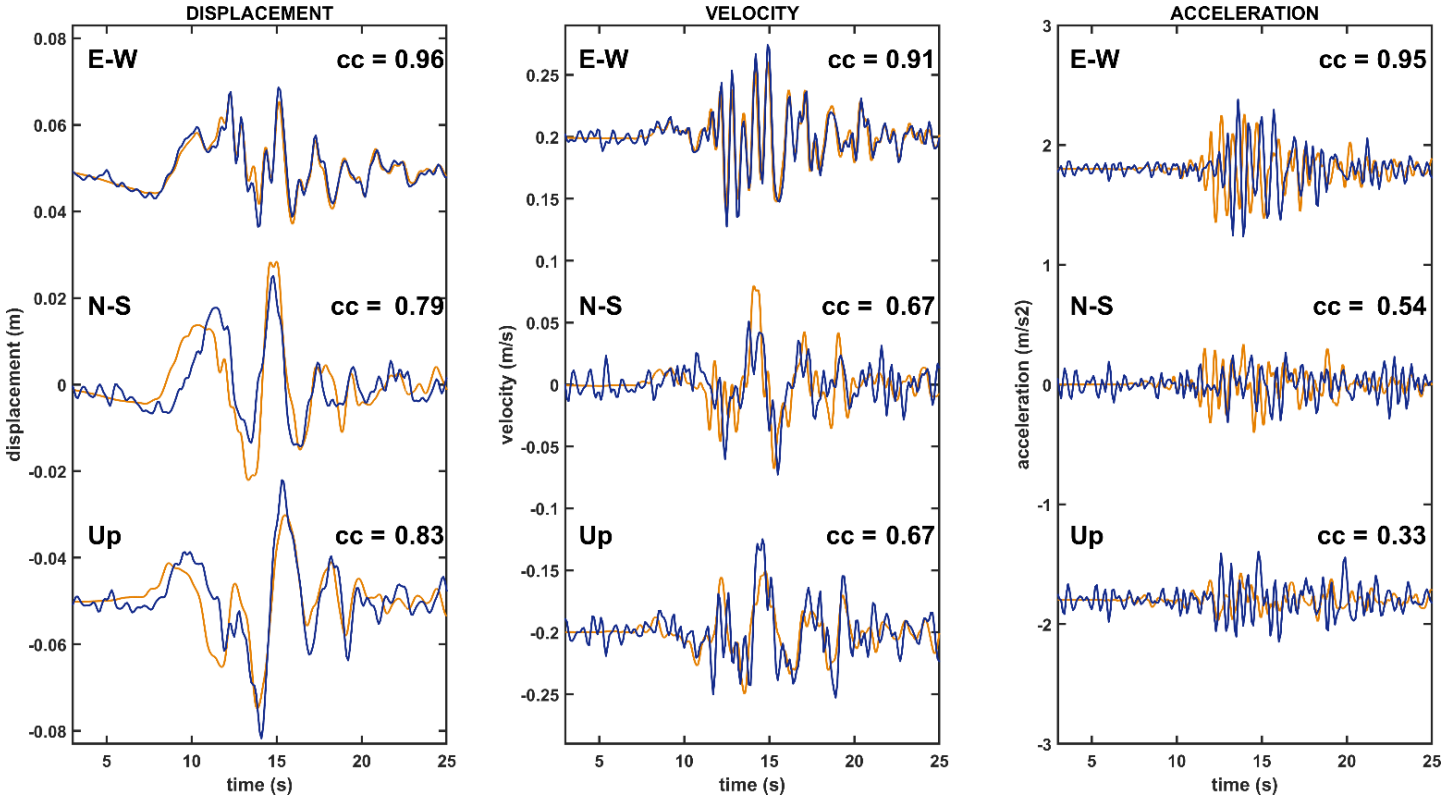
What if we filter also SM data?

GPS station: GUMA (10Hz); accelerometer: GUMA (200Hz)

Norcia earthquake 2016-10-26 19:18:08 UTC, Mw 6.6

2-order Butterworth band-pass filter
cut-off frequency: 0.05-2Hz

seismometer
GPS



GPS vs Seismometer: Correlation

Event	SENSORS	DISTANCE [km]		CUT-OFF FREQUENCY [Hz]		CORRELATION COEFFICIENTS								
						Raw GPS data			Band-pass filtered GPS data			Percentage change		
	GPS/SM	EPICENTRAL	SENSORS	LOW	HIGH	E	N	U	E	N	U	E	N	U
Gorkha	KKN4/KATN	68,00	10,50	0,03	0,40	0,44	0,34	0,43	**0,70**	**0,87**	**0,96**	38%	**61%**	**55%**
	NAST/KATN	81,70	6,30	0,03	0,40	**0,63**	0,40	0,51	**0,79**	**0,90**	**0,92**	20%	**55%**	45%
Visso	ACCU/ACC	25,40	0,08	0,05	2,00	**0,61**	0,27	0,22	**0,95**	0,39	**0,77**	36%	31%	**72%**
	AMAT/AMT	33,70	0,77	0,15	1,50	**0,73**	0,19	0,67	**0,80**	0,52	**0,78**	8%	**63%**	14%
	GUMA/GUMA	24,00	0,49	0,15	2,00	**0,87**	**0,71**	**0,81**	**0,96**	**0,78**	**0,82**	9%	9%	2%
	MTER/RM33	44,90	0,39	0,15	1,00	0,37	0,20	0,33	**0,80**	0,57	0,49	**54%**	**65%**	32%
Norcia	ACCU/ACC	18,50	0,08	0,05	2,00	**0,82**	0,26	0,57	**0,96**	**0,78**	**0,75**	14%	**67%**	24%
	AMAT/AMT	26,80	0,77	0,10	1,50	**0,72**	0,57	**0,66**	**0,77**	**0,67**	**0,67**	7%	15%	1%
	ATTE/ATTE	74,00	0,37	0,05	1,50	**0,89**	0,23	**0,66**	**0,93**	0,34	**0,67**	4%	33%	1%
	CAPE/CPS	81,80	0,05	0,05	1,00	**0,84**	0,59	0,58	**0,94**	**0,72**	**0,72**	11%	18%	19%
	LTNA/LAT	152,40	0,62	0,05	1,00	**0,96**	**0,82**	0,37	**0,99**	**0,90**	0,40	3%	8%	8%
	MUVI/T1216	10,20	2,14	0,05	1,00	**0,62**	0,40	0,31	**0,84**	0,60	0,59	26%	33%	47%

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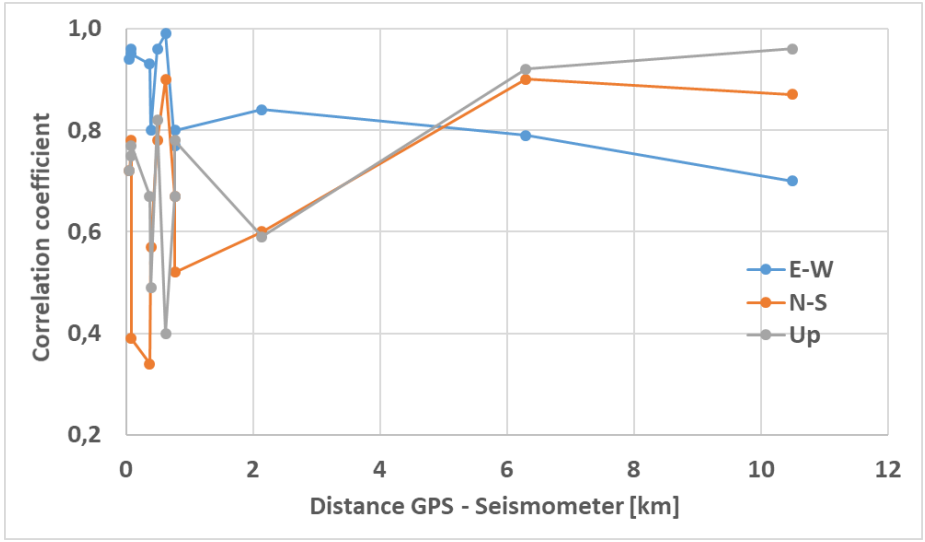
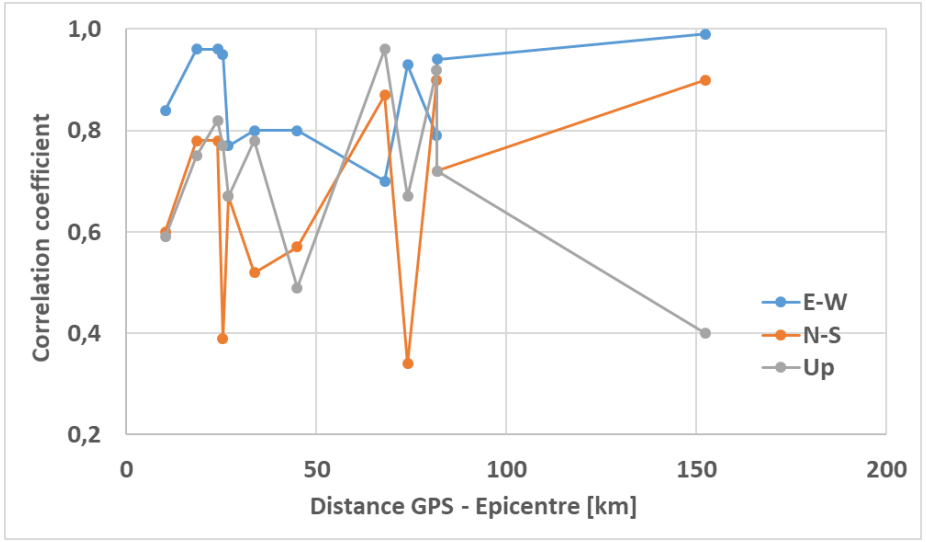
GPS vs Seismometer Correlation is not distance dependent

Co-location distance



Epicentral distance



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Conclusions

- GPS receiver can be successfully used as a seismometer,
- Displacements from GPS and SM techniques reveal the best agreement in terms of correlation,
- The best GPS and SM correlation was obtained with 2-nd order Butterworth band-pass filtering of data with station dependant filter frequencies selection:
  - Low-pass: 0.03 – 0.15 Hz; average 0.08 Hz,
  - High-pass: 0.40 – 2.00 Hz; average 1.28 Hz,
- We are beginning to gather 20Hz multi-GNSS data co-located with SM (distance < 50m) in the Polish mining areas to test the GPS ability of mining tremor retrieval.

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Thank you for attention!

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