Comparison between PPP and DD processing techniques using Bernese 5.2 Computation of displacements and velocities of Marussi FVG and FredNet GNSS networks and visualization on GeoServer: first results

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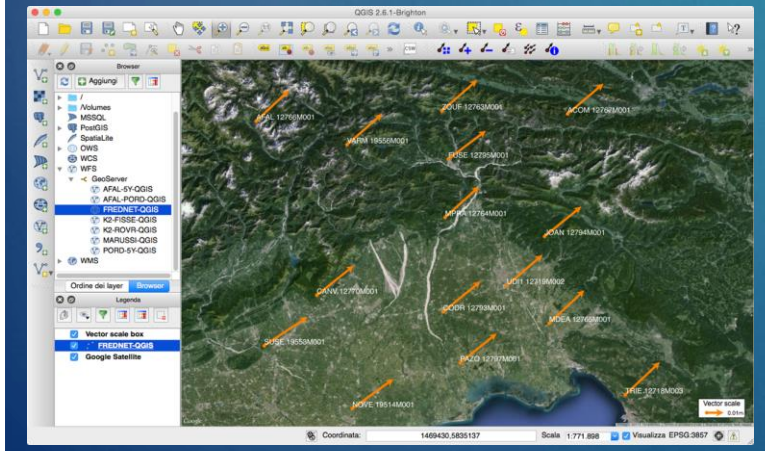
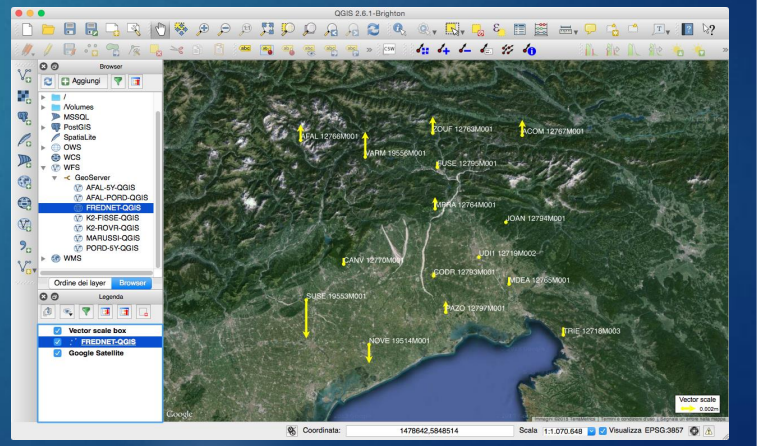
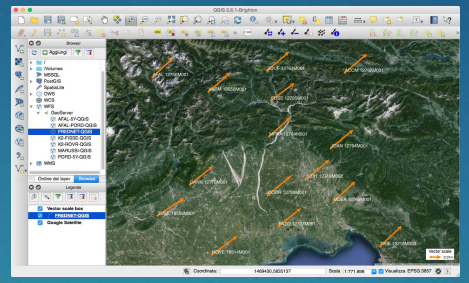
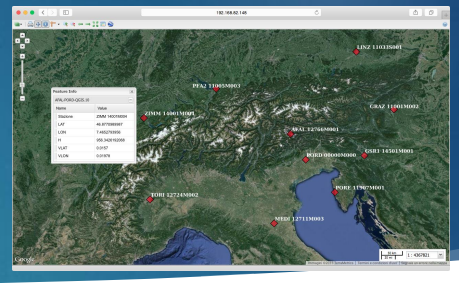




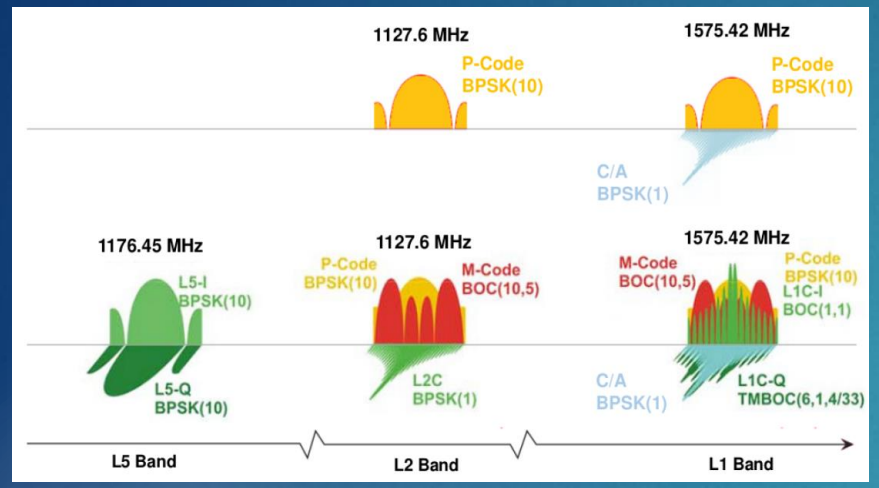
Summary





- **Modernization of GNSS Systems**
- **Scientific Bernese Software** – main features
- **Implementation of a WebGIS on a GeoServer platform**
- **Case studies**
  - Applications on computation of displacements and velocities
    Marussi FVG and FredNet GNSS networks
  - Analysis on different temporal series

GNSS – GPS, GLONASS



GPS (Global Positioning System):

- New civil codes: L2C – L1C (interoperability GNSS) – L5C.
- New military code: M
- New signals: L5

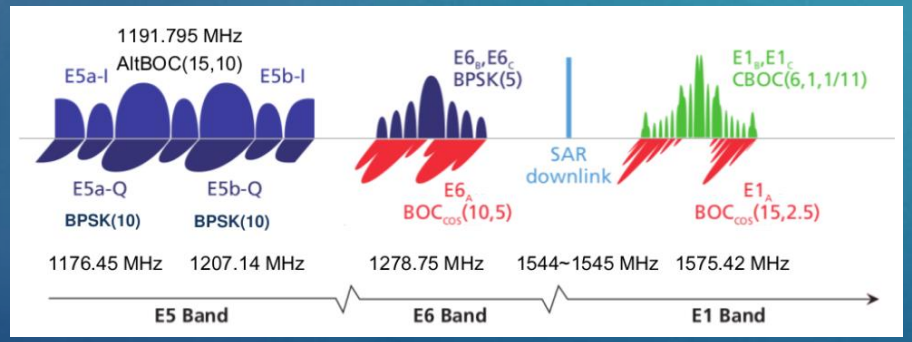
GLONASS (GLObal NAvigation Satellite System):

- New civil codes: L1OC, L2OC, L3OC
- New military codes: L1SC, L2SC
- New signals: G3

Satellite	FDMA Signals		CDMA Signals		
	L1	L2	L1	L2	L3
Glonass-M	L1OF L1SF	L2OF L2SF	-	-	L3OC (2014+) 7 SVs
Glonass-K	L1OF L1SF	L2OF L2SF			L3OC
Modernized Glonass-K	L1OF L1SF	L2OF L2SF	L1OC L1SC	L2OC L2SC	L3OC

GNSS – GALILEO

Band	Carrier freq. (MHz)	Channel or sig. comp.	Services
E1	1575.420	E1-A data	PRS
		E1-B data	OS, CS, SoL
		E1-C pilot	
E6	1278.750	E6-A data	PRS
		E6-B data	CS
		E6-C pilot	
E5a	1176.450	E5a-I data	OS
		E5a-Q pilot	
E5b	1207.140	E5b-I data	OS, CS, SoL
		E5b-Q pilot	



- 27 satellites on 3 orbits equidistant inclined of 56°, "Medium Earth Orbit (MEO)" approximately 23.222 km.
- Experimental phase (2005-2008): satellites GIOVE-A and GIOVE-B, PhaseIOV (In-Orbit-Validation): constellation increasing (since 2012), Phase FOC (Full Operational Capability): full working (2019-2020).
- Open Service (OS), Public Regulated Service (PRS), Commercial Service (CS), Search and Rescue (SAR), Safety-of-Life (SoL).

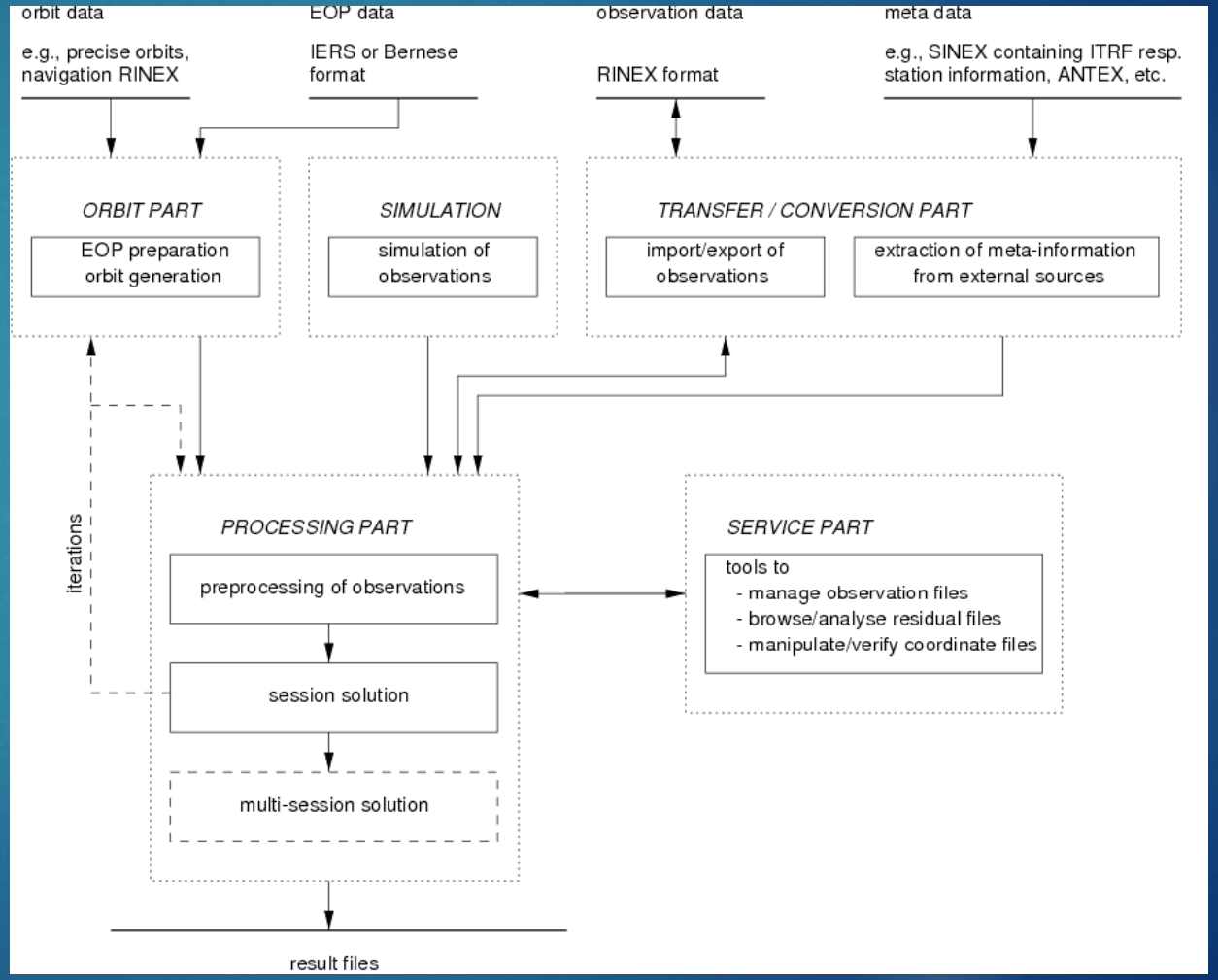
BERNESE – Introduction

Bernese GNSS Software
Version 5.2

Main features:

- Elaboration of GNSS (GPS, GLONASS, GALILEO) code and phase data
- Automatic elaborations of networks and permanent stations
- Phase ambiguity resolution with baselines longer than 2000 km
- Monitoring of ionospheric and tropospheric data
- Satellite orbits determination, clock errors and Earth parameters estimation

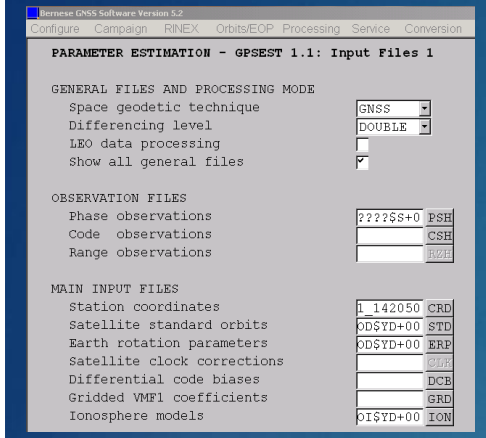
BERNESE – Structure

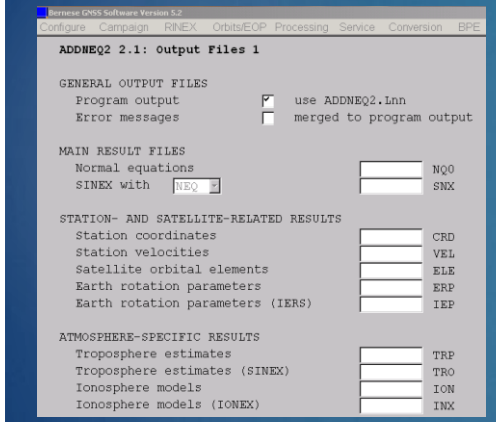


UNIVERSITÄT BERN

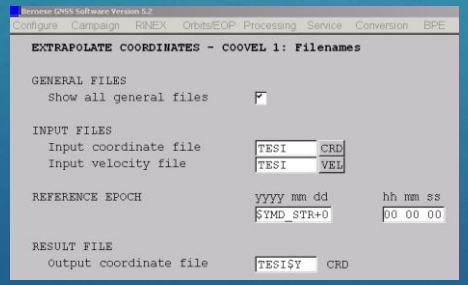
Bernese GNSS Software
Version 5.2

BERNESE – Structure





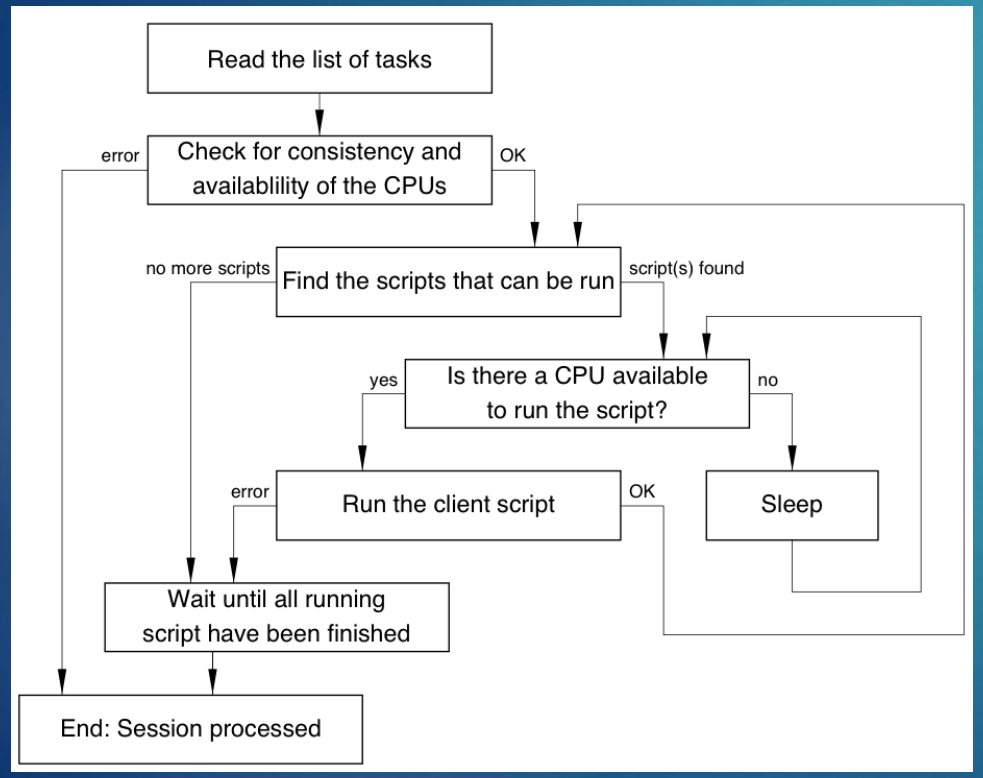
- **GPSEST** – "Menu > Processing > Parameter estimation": main function for parameter estimation based on Ordinary Least Squares (coordinates, ambiguities, troposphere, ionosphere, orbital elements…).
- **ADDNEQ2** – "Menu > Processing > Combine normal equation system": function to elaborate many Normal Equation (NEQ) from GPSEST (coordinates and velocities estimation on temporal series).
- **COOVEL** – "Menu > Service > Coordinate tools > Extrapolate coordinates": function to spread coordinates from a reference epoch to a custom epoch, using station velocities.

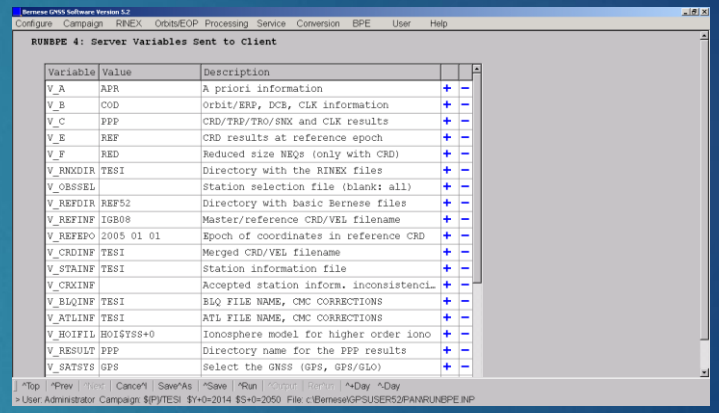


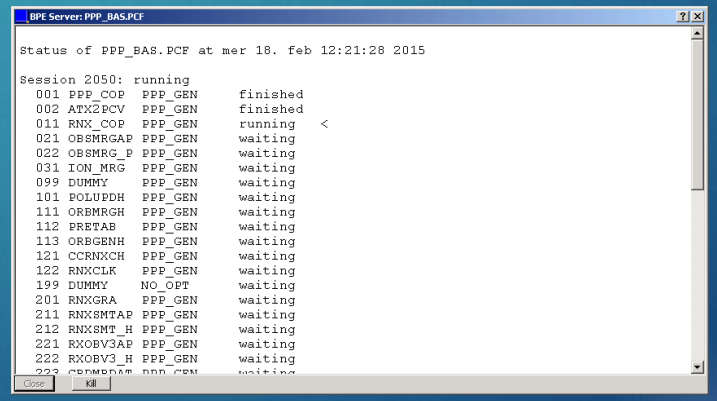
BERNESE – BPE

BPE (Bernese Process Engine): function to automatize processes using scripts from RINEX observations to results.

possible to configure a cluster to realize parallel computations.

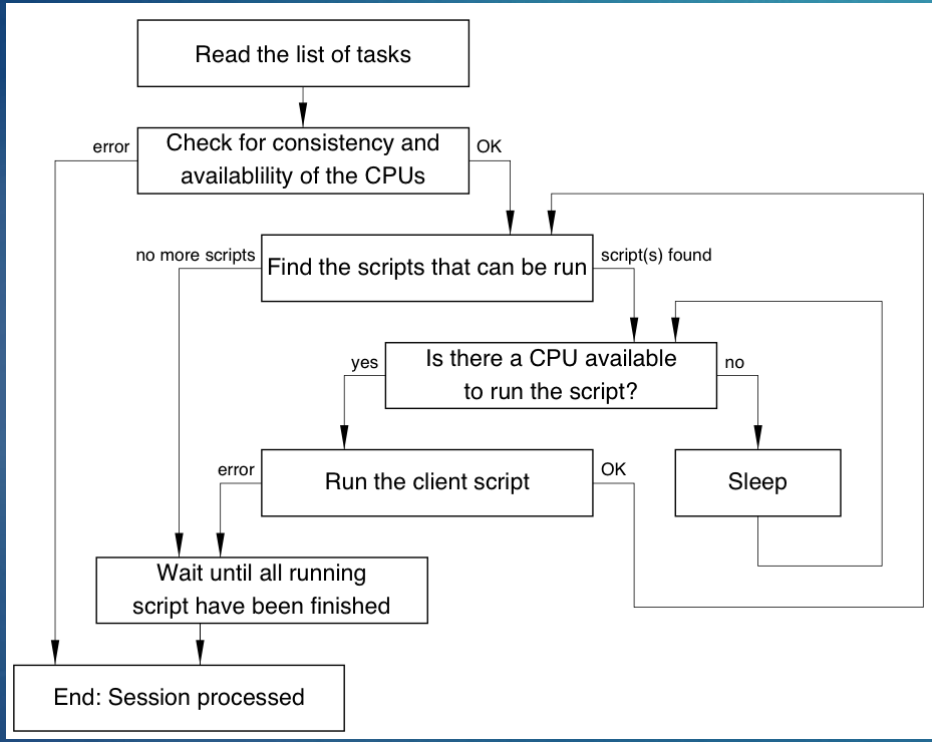


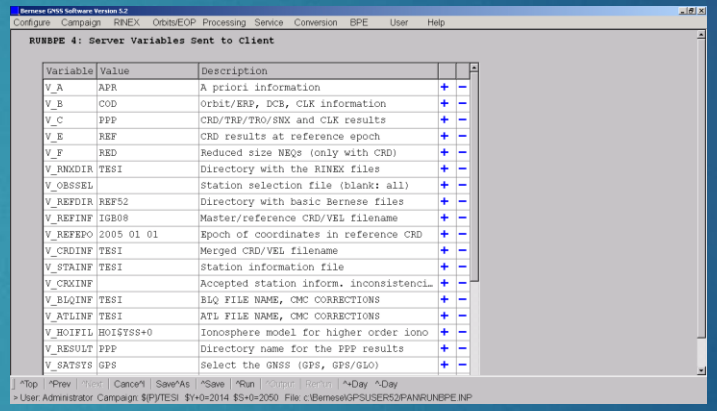


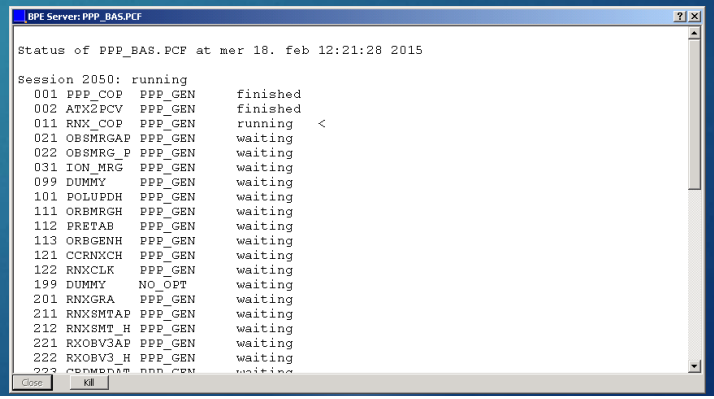


BERNESE – BPE

BPE (Bernese Process Engine): function to automatize processes using scripts from RINEX observations to results. It is possible to configure a cluster to realize parallel computations.







Marussi and **FredNet** GNSS data processing

- Precise Point Positioning (PPP) and Double Differences (DD) processing techniques were used on different set of geodetic GNSS data, relative to some vertexes belonging to Marussi FVG and OgS FredNet **GNSS permanent networks**, using **Bernese 5.2** software.
- **Marussi PORD** (Pordenone, Italy) vertex
- OgS **FredNet AFAL** vertex

Data processing - strategy

- The recorded data sets have been divided in **different time intervals**:

  - a daily subdivision relative to December 2014

  - a weekly subdivision relative to the first week of December from 2010 to 2014 and

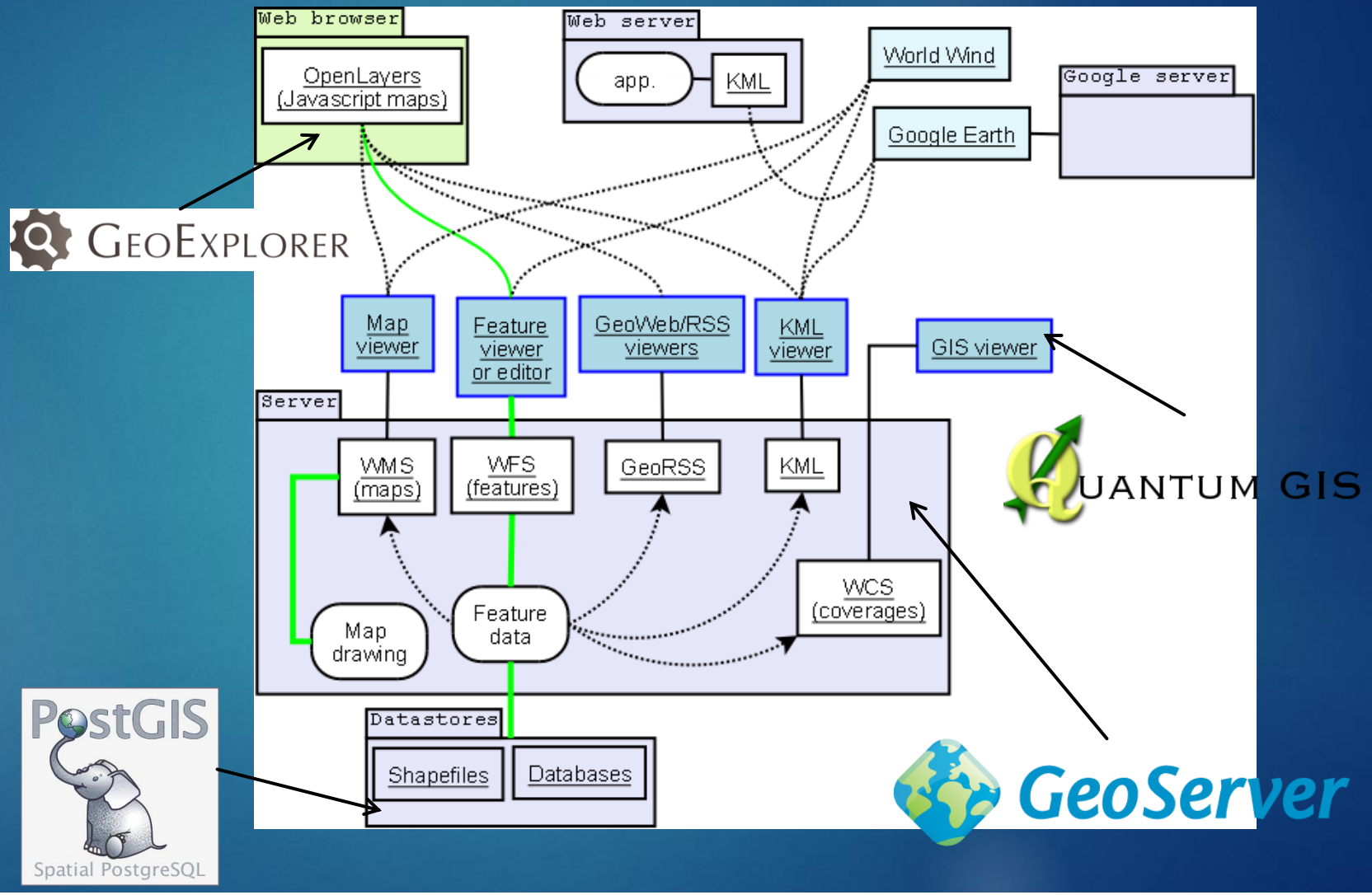
  - yearly for the data from 31th December 2003 to 31th December 2014.

GNSS Data Processing & GIS tools

- FredNet vertexes velocities were obtained to respect to the Euroasiatic Plate
- The coordinates of the network vertexes were computed in the **ITRS2000 Reference System**.
- Data analyses, storing, visualization and sharing were performed using GIS tools:

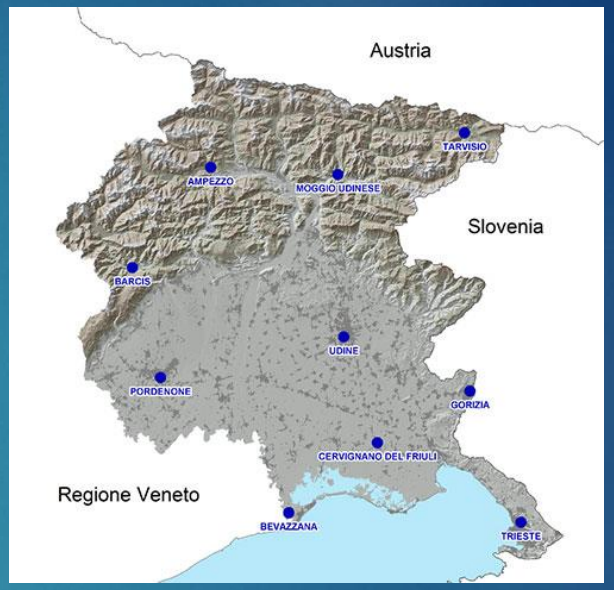
  QGIS for geographical data processing, **GeoServer** for geographical data sharing, **PostGIS** for the database linking and **GeoExplorer** for data visualization.

WebGIS Structure

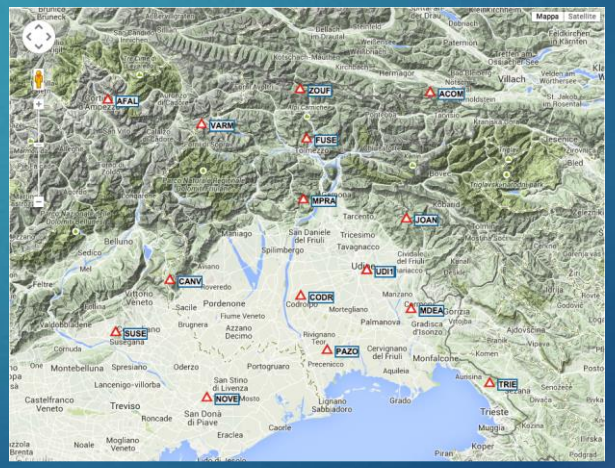


Case studies - Permanent Station Networks

"The GNSS permanent network **Marussi** (Regione Friuli Venezia Giulia), composed by **10 stations** and realized in order to provide assistance for determination of geographical elements, useful in regional cartography."



"The OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Sgonico) **FReDNet** network (Friuli Regional Deformation Network) is a monitoring system for Earth crustal deformation over the Friuli - Venezia Giulia region"



PPP Technique - Precise Point Positioning

- **Precise Point Positioning** is a “zero-difference” technique, using which it is possible to calculate an absolute position using code measurements smoothed with phase and errors modeling.
- In order to obtain high precision measurements (centimetric accuracy), it is necessary to use satellite ephemeris, Earth parameters and satellite clock offsets.
- Final precision is less than “Double Difference Technique”, because of impossibility to solve phase ambiguities.

Case studies - Precise Point Positioning

MARUSSI NETWORK – SESSION 274 – YEAR 2014

Stazione	X (m)	Y (m)	Z (m)	RMS X (m)	RMS Y (m)	RMS Z (m)
AMPE	4296007.30367	975953.18647	4597595.82541	0.00128	0.00087	0.00116
BARC	4317307.32533	962154.87588	4580512.84990	0.00132	0.00094	0.00118
BEVA	4348870.20640	1009567.92283	4539875.32428	0.00101	0.00080	0.00088
CERV	4331989.87248	1027163.47100	4551982.74835	0.00094	0.00078	0.00084
GORI	4317947.00982	1046521.50951	4560977.94593	0.00103	0.00080	0.00093
MOGG	4289567.95607	1005971.73690	4596811.82742	0.00143	0.00087	0.00125
PORD	4333820.33103	973585.78345	4561967.66597	0.00098	0.00078	0.00086
TARV	4275304.71100	1033723.67232	4604417.64174	0.00115	0.00087	0.00116
TRIE	4336817.71260	1064245.99895	4539078.53170	0.00122	0.00083	0.00101
UDIN	4316422.83078	1014589.12712	4569607.46509	0.00095	0.00080	0.00086

Stazione	$V_X(m/year)$	$V_Y(m/year)$	$V_Z(m/year)$
AMPE	-0.01408	0.01806	0.00932
BARC	-0.01399	0.01811	0.00938
BEVA	-0.01404	0.01817	0.00941
CERV	-0.01413	0.01812	0.00936
GORI	-0.01421	0.01809	0.0093
MOGG	-0.01417	0.01803	0.00928
PORD	-0.01398	0.01814	0.00941
TARV	-0.01427	0.018	0.00921
TRIE	-0.01421	0.01813	0.00933
UDIN	-0.01413	0.01809	0.00933

Data shown as geocentric cartesian coordinates and displacement velocities from .OUT file.

Case studies - Precise Point Positioning

FREDNET NETWORK – SESSION 274 – YEAR 2014

Stazione	X (m)	Y (m)	Z (m)	RMS X (m)	RMS Y (m)	RMS Z (m)
ACOM 12767M001	4273810.59610	1027226.83304	4608635.09633	0.00094	0.00086	0.00088
AFAL 12766M001	4298652.85808	927400.68424	4607414.50804	0.00108	0.00082	0.00096
CANV 12770M001	4334208.20577	955715.26724	4566582.92841	0.00096	0.00088	0.00089
FUSE 12795M001	4292558.56362	991105.82071	4597527.99720	0.00114	0.00082	0.00104
JOAN 12794M001	4303674.15707	1026554.90195	4580287.22651	0.00094	0.00092	0.00086
MDEA 12765M001	4322832.16796	1032685.78772	4559530.83370	0.00451	0.00557	0.00411
MPRA 12764M001	4306530.03012	993265.89612	4584380.60696	0.00155	0.00107	0.00129
NOVE 19514M001	4357459.15023	973082.83176	4539605.18133	0.00324	0.00496	0.00273
PAZO 12797M001	4338789.75611	1005881.22696	4550256.90845	0.00111	0.00111	0.00102
SUSE 19553M001	4349256.52934	941019.62208	4554352.10761	0.00120	0.00085	0.00111
TRIE 12718M003	4333581.56013	1061504.76041	4543010.75134	0.00105	0.00094	0.00097
UDI1 12719M002	4317298.06377	1016829.08562	4568247.98856	0.00101	0.00087	0.00089
ZOUF 12763M001	4282709.88310	986659.61751	4609469.90969	0.00099	0.00083	0.00088

Stazione	$V_X(m/year)$	$V_Y(m/year)$	$V_Z(m/year)$
ACOM 12767M001	-0.01426	0.018	0.00922
AFAL 12766M001	-0.01395	0.01807	0.00937
CANV 12770M001	-0.01394	0.01815	0.00943
FUSE 12795M001	-0.01412	0.01804	0.0093
JOAN 12794M001	-0.01419	0.01806	0.00929
MDEA 12765M001	-0.01416	0.0181	0.00933
MPRA 12764M001	-0.0141	0.01808	0.00933
NOVE 19514M001	-0.01393	0.01819	0.00947
PAZO 12797M001	-0.01406	0.01814	0.00939
SUSE 19553M001	-0.01386	0.01818	0.00948
TRIE 12718M003	-0.01422	0.01812	0.00933
UDI1 12719M002	-0.01413	0.01809	0.00933
ZOUF 12763M001	-0.01414	0.01803	0.00928

Data shown as geocentric cartesian coordinates (above) and displacement velocities (left) from .OUT file.

Case studies - Comparison

SESSION 274 – YEAR 2014 – 24 HOURS – PPP AND DD

Marussi Network

Stazione	ΔX (mm)	ΔY(mm)	ΔZ(mm)
AMPE	-7.13000	0.96000	-6.12000
BARC	-11.12000	-1.43000	-9.92000
BEVA	-5.11000	3.50000	-4.45000
CERV	-2.62000	2.24000	-3.08000
GORI	-5.81000	2.18000	-5.84000
MOGG	-2.66000	1.28000	-4.83000
PORD	-4.64000	1.10000	-2.56000
TARV	-6.49000	1.25000	-6.88000
TRIE	-4.71000	1.48000	-3.94000
UDIN	-8.01000	2.48000	-5.09000

FredNet Network

Stazione	ΔX (mm)	ΔY(mm)	ΔZ(mm)
ACOM 12767M001	-3.72000	0.53000	-3.57000
AFAL 12766M001	-6.93000	2.92000	-6.48000
CANV 12770M001	-4.09000	2.05000	-4.00000
FUSE 12795M001	-5.74000	0.62000	-6.12000
JOAN 12794M001	-2.56000	0.82000	-2.32000
MDEA 12765M001	-8.47000	4.29000	-7.09000
MPRA 12764M001	-1.96000	1.13000	-3.93000
NOVE 19514M001	7.12000	-16.01000	13.67000
PAZO 12797M001	3.97000	-3.47000	0.73000
SUSE 19553M001	-8.68000	-3.50000	-9.47000
TRIE 12718M003	-2.23000	0.74000	-3.87000
UDI1 12719M002	-0.00043	-0.00289	-0.00181
ZOUF 12763M001	-0.00635	-0.00090	-0.00528

Precise Point Positioning and Double Difference processing DIFFERENCES. Maximum difference is **16 mm**.

Case studies – AFAL and PORD

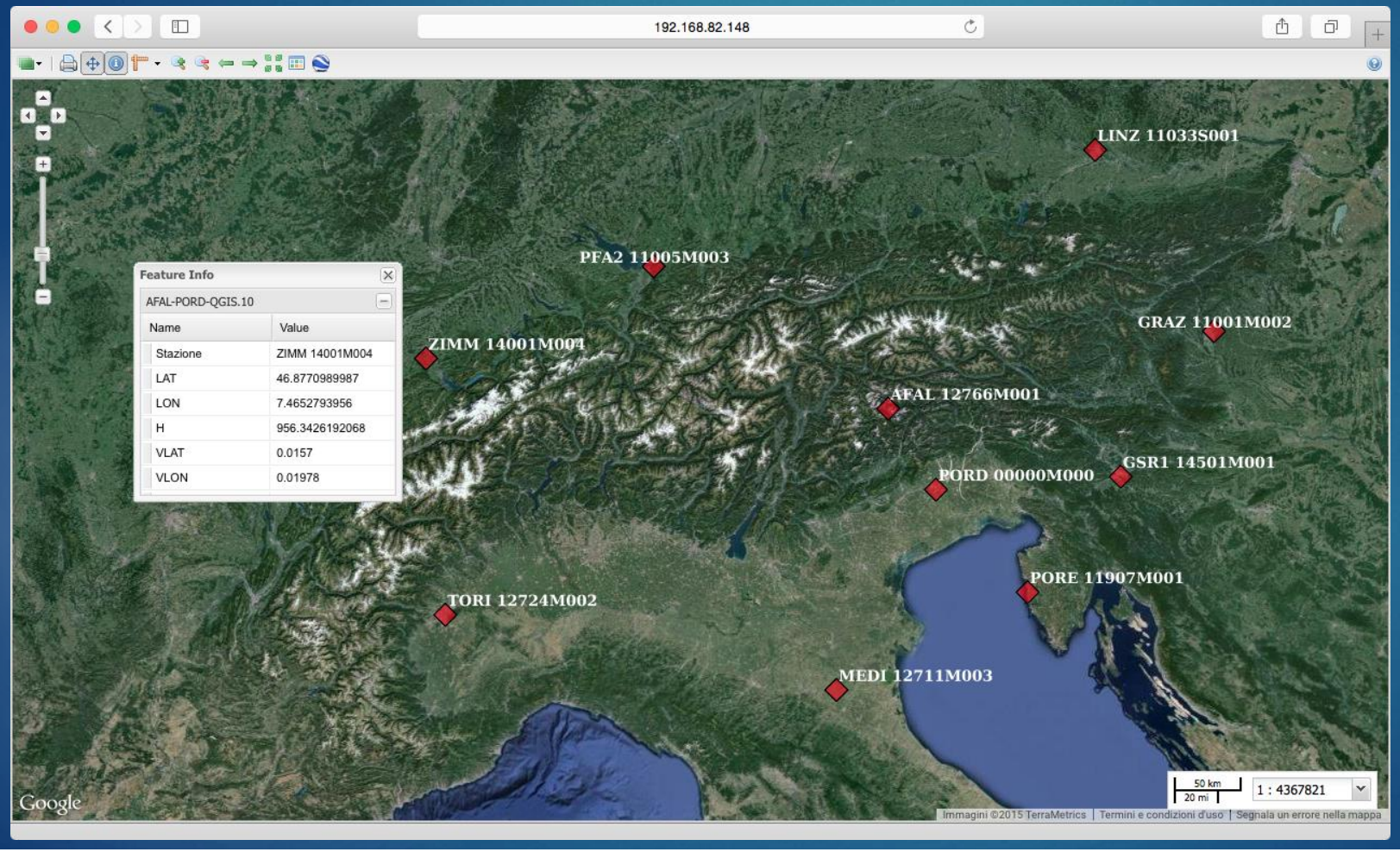
Stazione	Informazioni	Latitudine (gradi)	Longitudine (gradi)	Quota (ell.)	RMS Latitudine (m)	RMS Longitudine (m)	RMS Quota (m)
AFAL 12766M001	Alpe Faloria, Cortina d'Ampezzo (BL)	46.5271447387	12.1745183079	2284.095	0.00013	0.00011	0.00045
PORD 00000M000	Pordenone (PN)	47.0671313989	15.4934831062	538.294	0.00009	0.00008	0.00031
GRAZ 11001M002	Graz (Austria)	46.0481351842	14.5437183690	351.680	0.00013	0.00011	0.00043
GSR1 14501M001	Ljubljana (Slovenia)	48.3097837757	14.2830637391	335.048	0.00012	0.00010	0.00041
LINZ 11033S001	Linz (Austria)	44.5199589268	11.6468176957	50.014	0.00011	0.00009	0.00037
MEDI 12711M003	Medicina (BO)	47.5153300219	9.7846668760	1090.114	0.00013	0.00011	0.00042
PFA2 11005M003	Bregenz (Austria)	45.9567769004	12.6612073696	81.762	0.00014	0.00012	0.00049
PORE 11907M001	Porec (Croazia)	45.2260180029	13.5950477541	66.201	0.00013	0.00011	0.00044
TORI 12724M002	Torino (TO)	45.0633689794	7.6612838615	310.745	0.00013	0.00012	0.00046
ZIMM 14001M004	Zimmerwald (Svizzera)	46.8770989987	7.4652793956	956.343	0.00011	0.00010	0.00038

Data obtained from daily data of December 2014, using Double Difference technique and referred to 01/02/2015 (COOVEL).

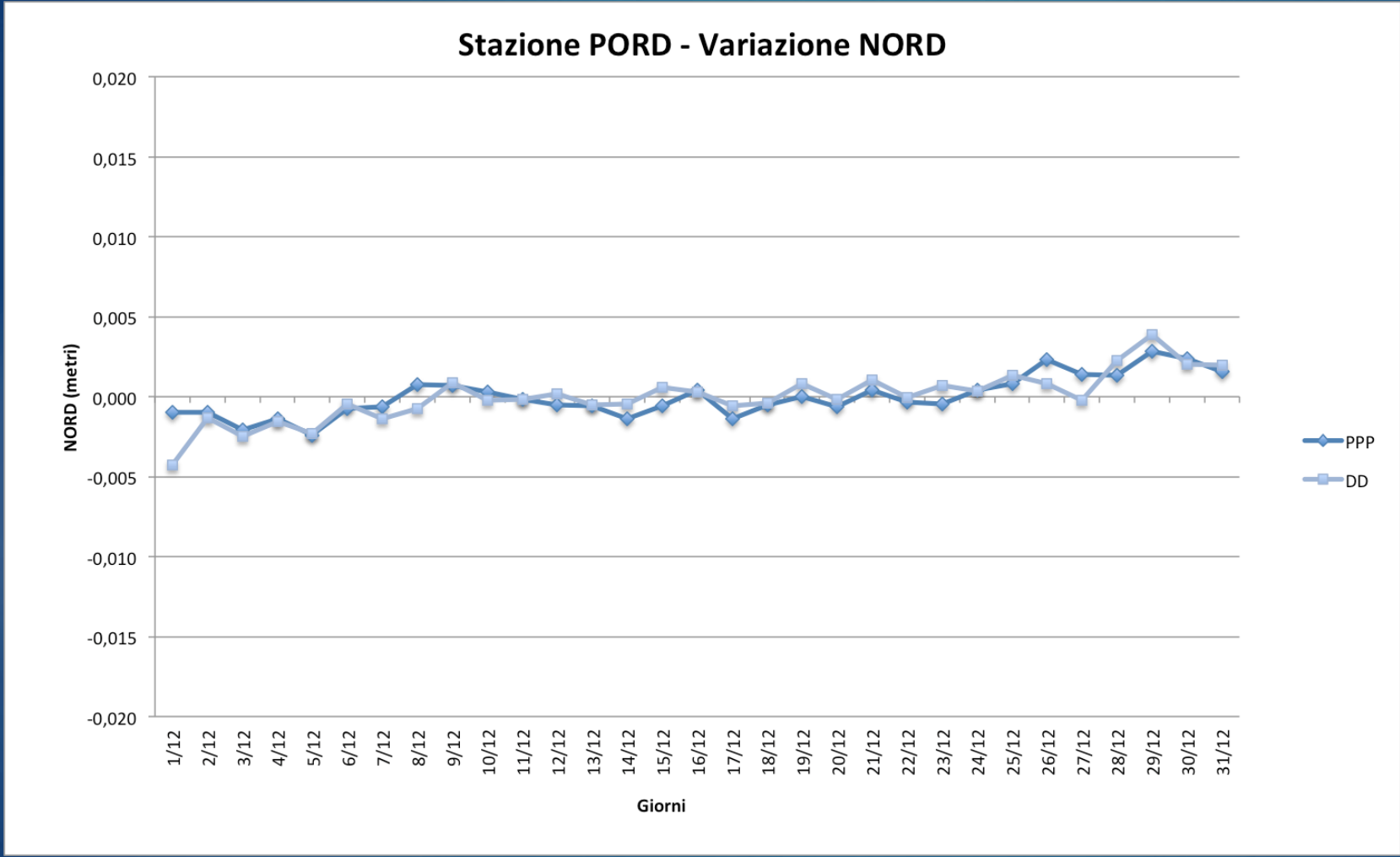
1) Daily elaborations from 1st to 31th of December 2014
2) Weekly elaborations, period 2010 – 2014

Case studies – AFAL e PORD

AFAL AND PORD – IGS/EUREF NETWORKS



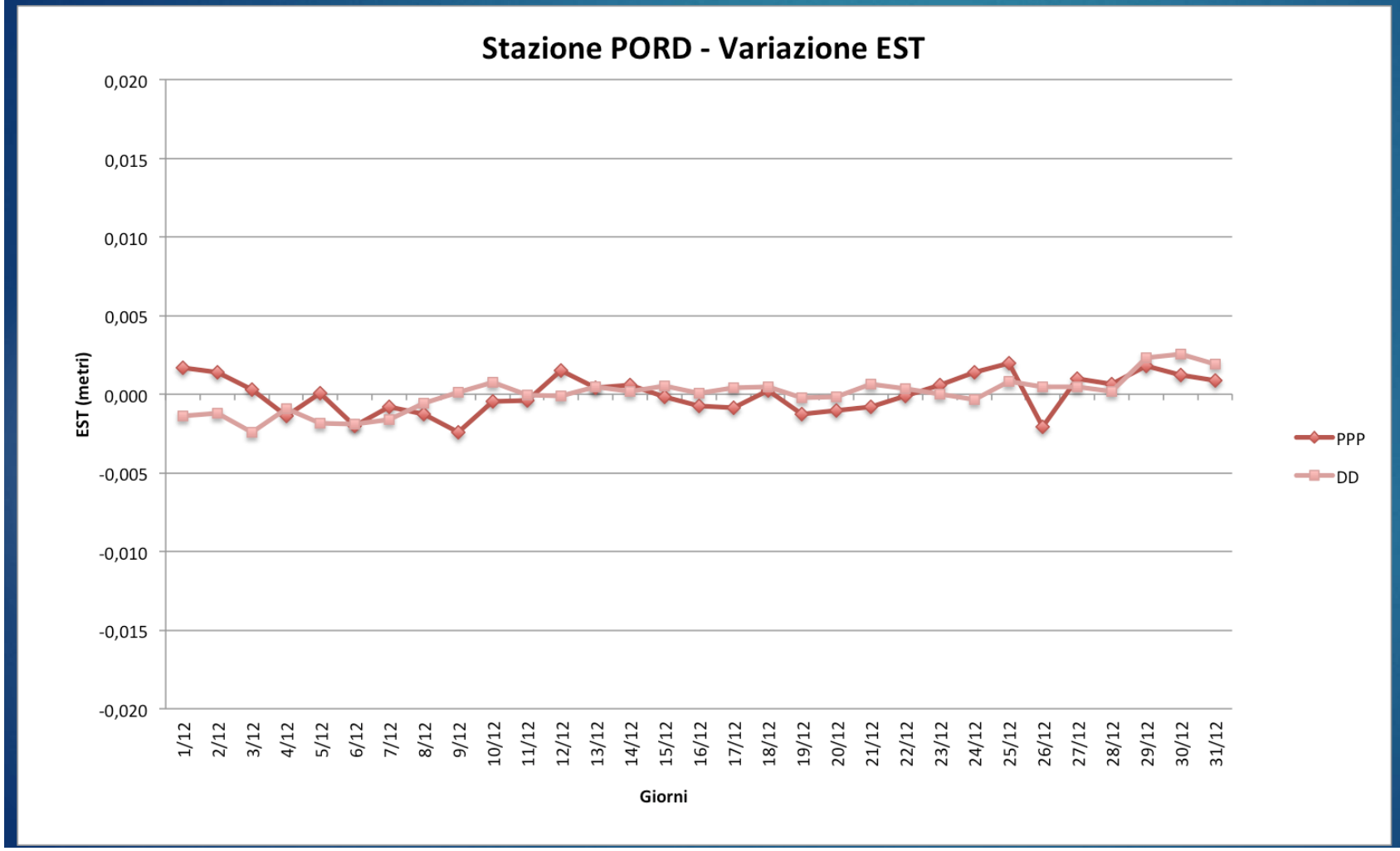
Case studies – 30 days



PORD STATION

DECEMBER 2014
PPP AND **DD**

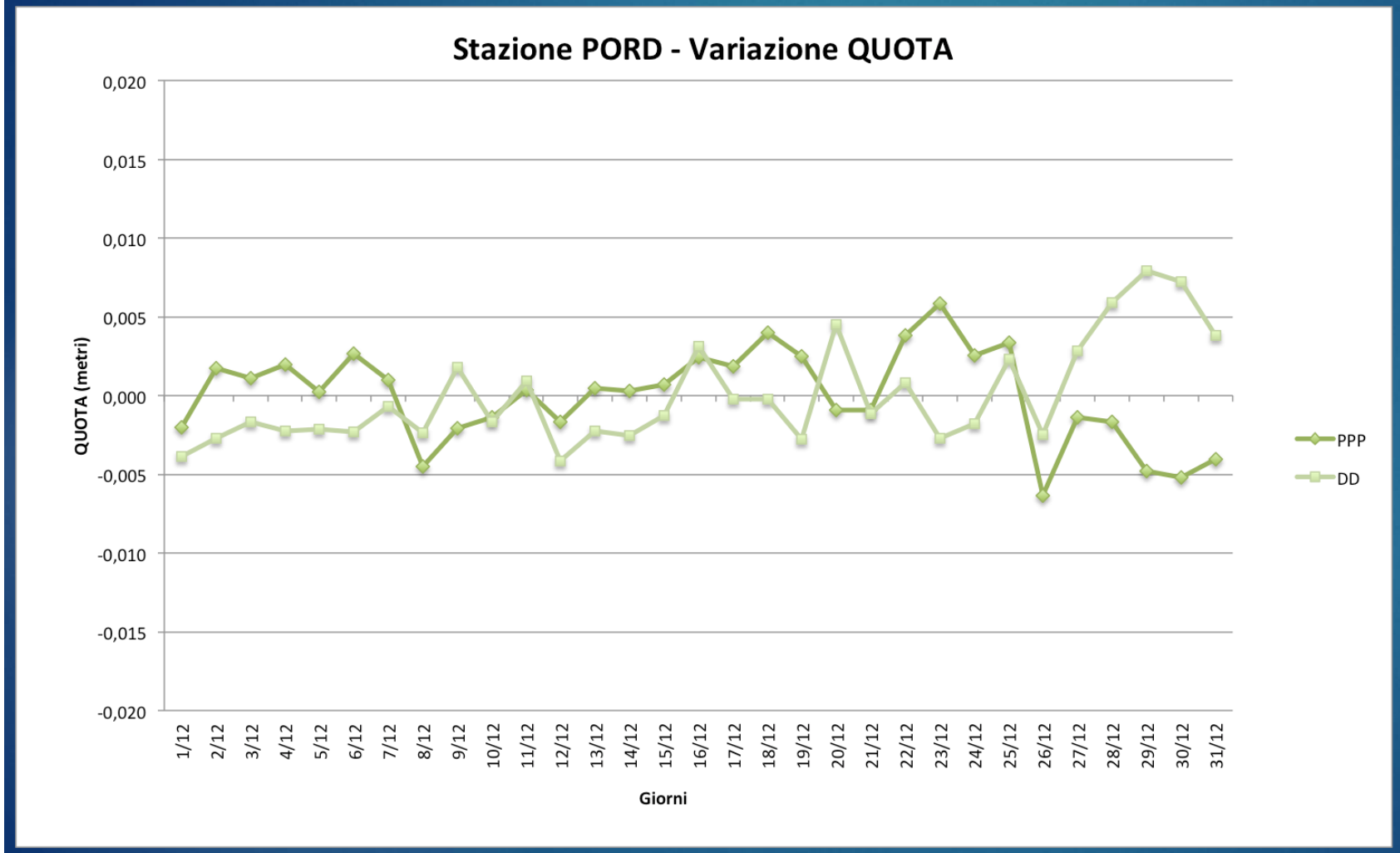
Case studies – 30 days



PORD STATION

DECEMBER 2014
PPP AND DD

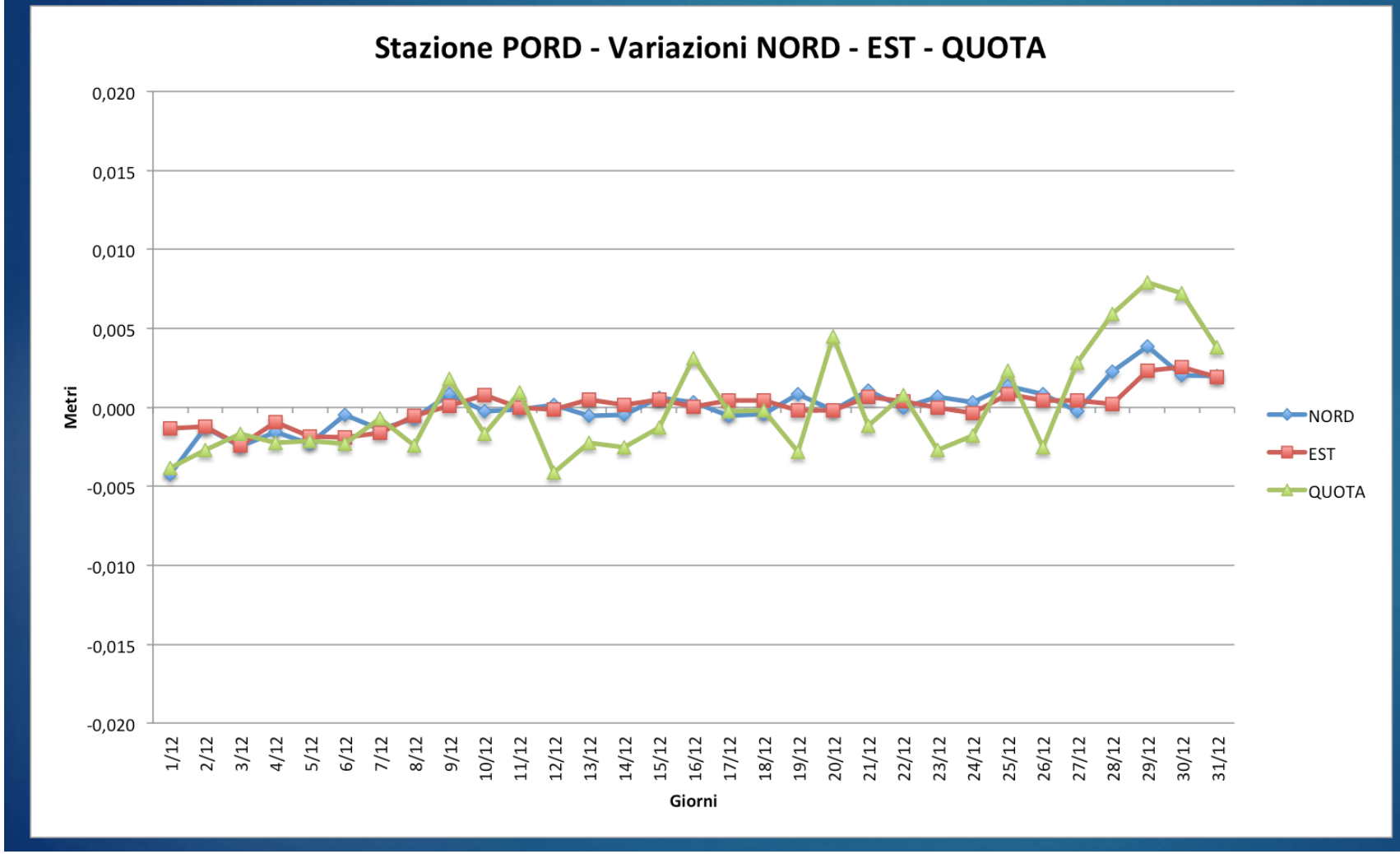
Case studies – 30 days



PORD STATION

DECEMBER 2014
PPP AND DD

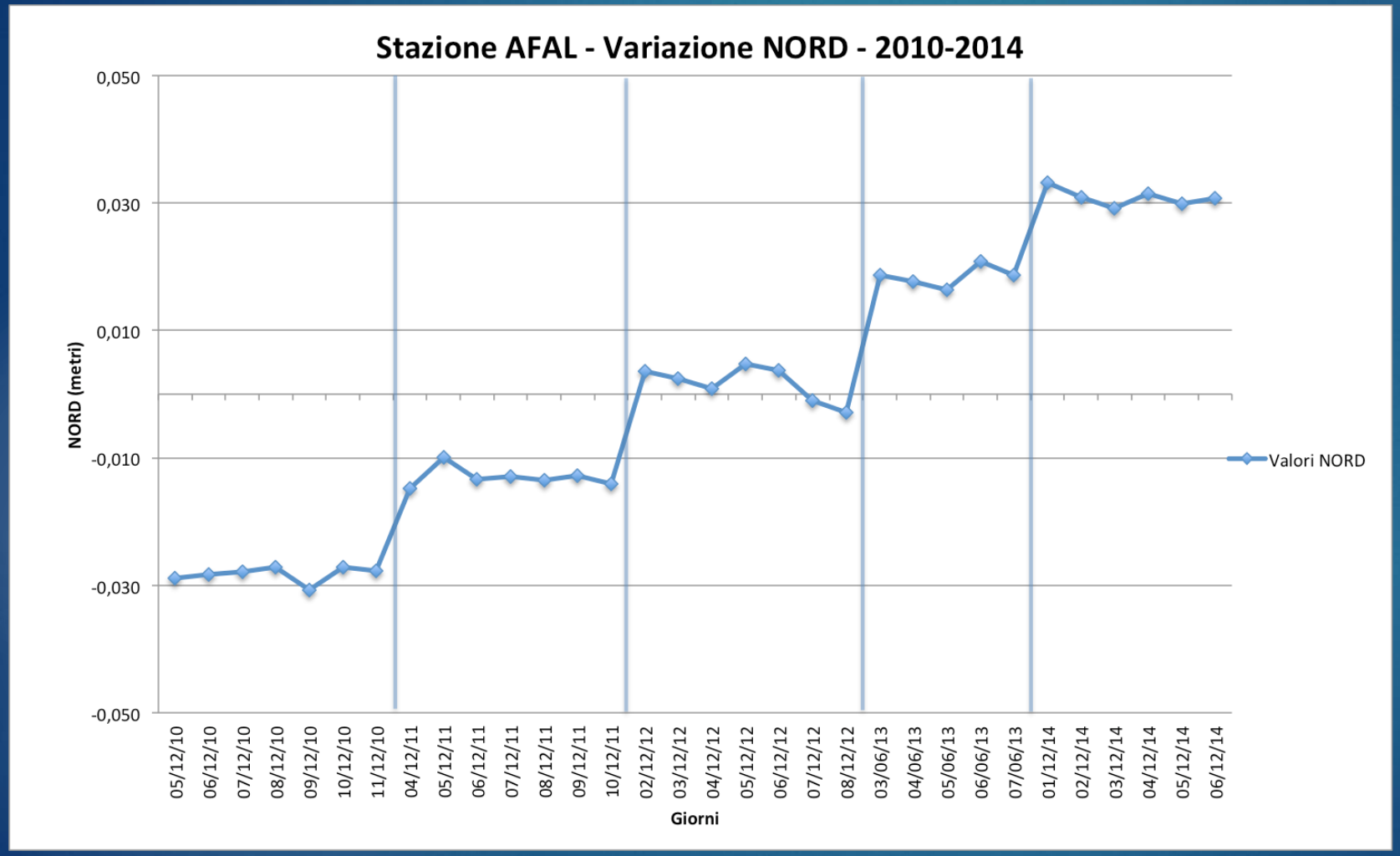
Case studies – 30 days



PORD STATION

DECEMBER 2014

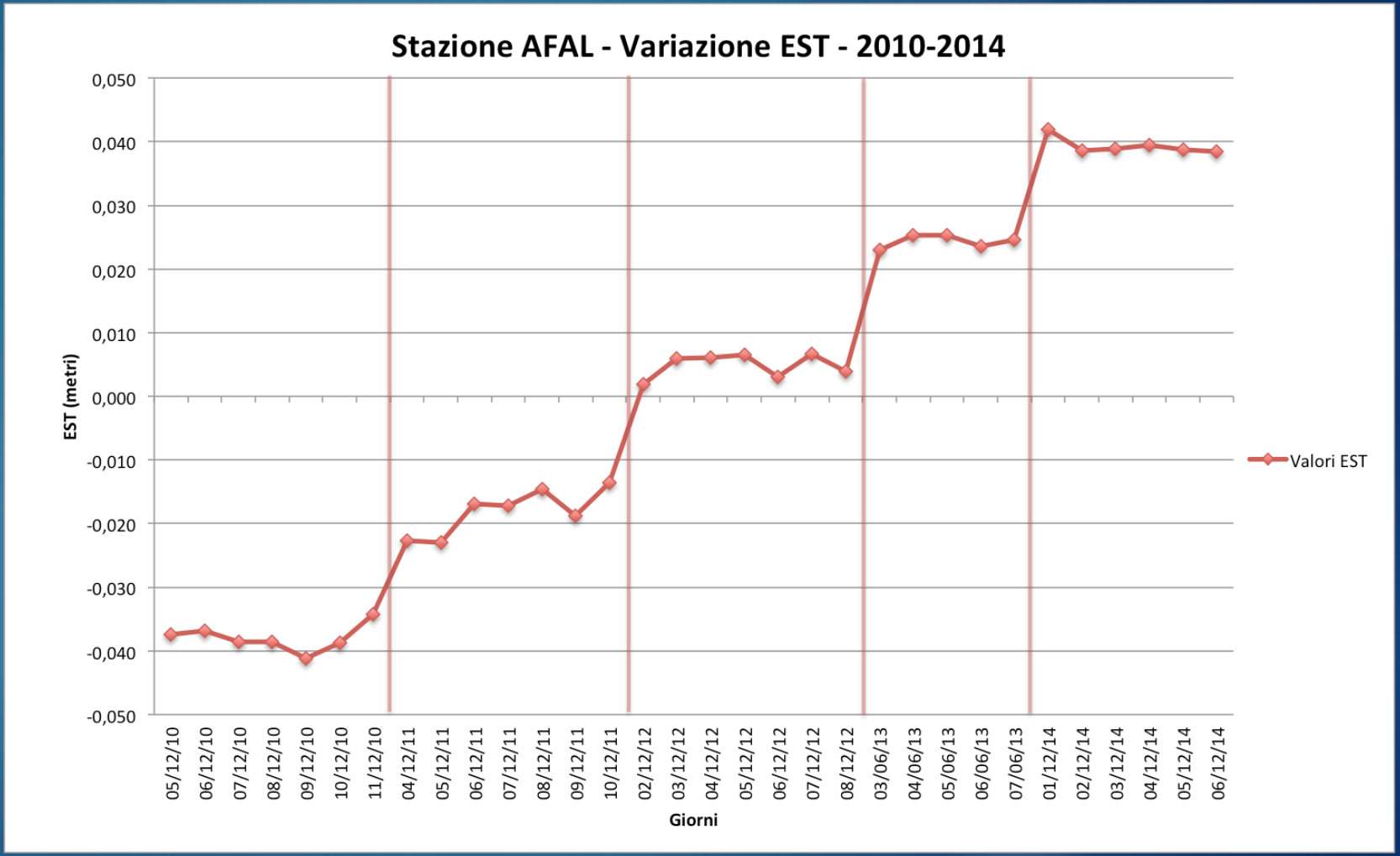
Case studies – 2010-2014



AFAL STATION

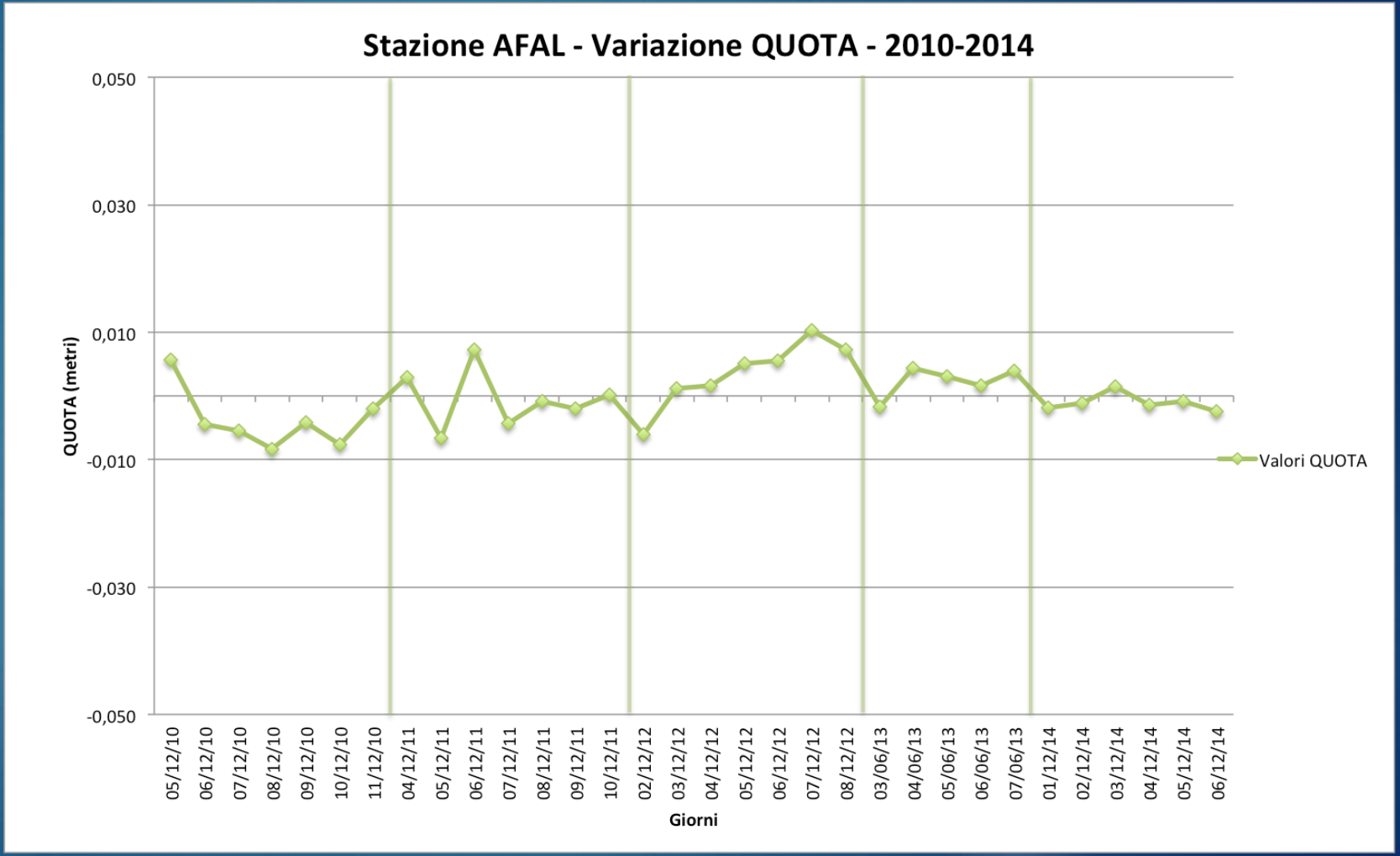
Case studies – 2010-2014

AFAL STATION



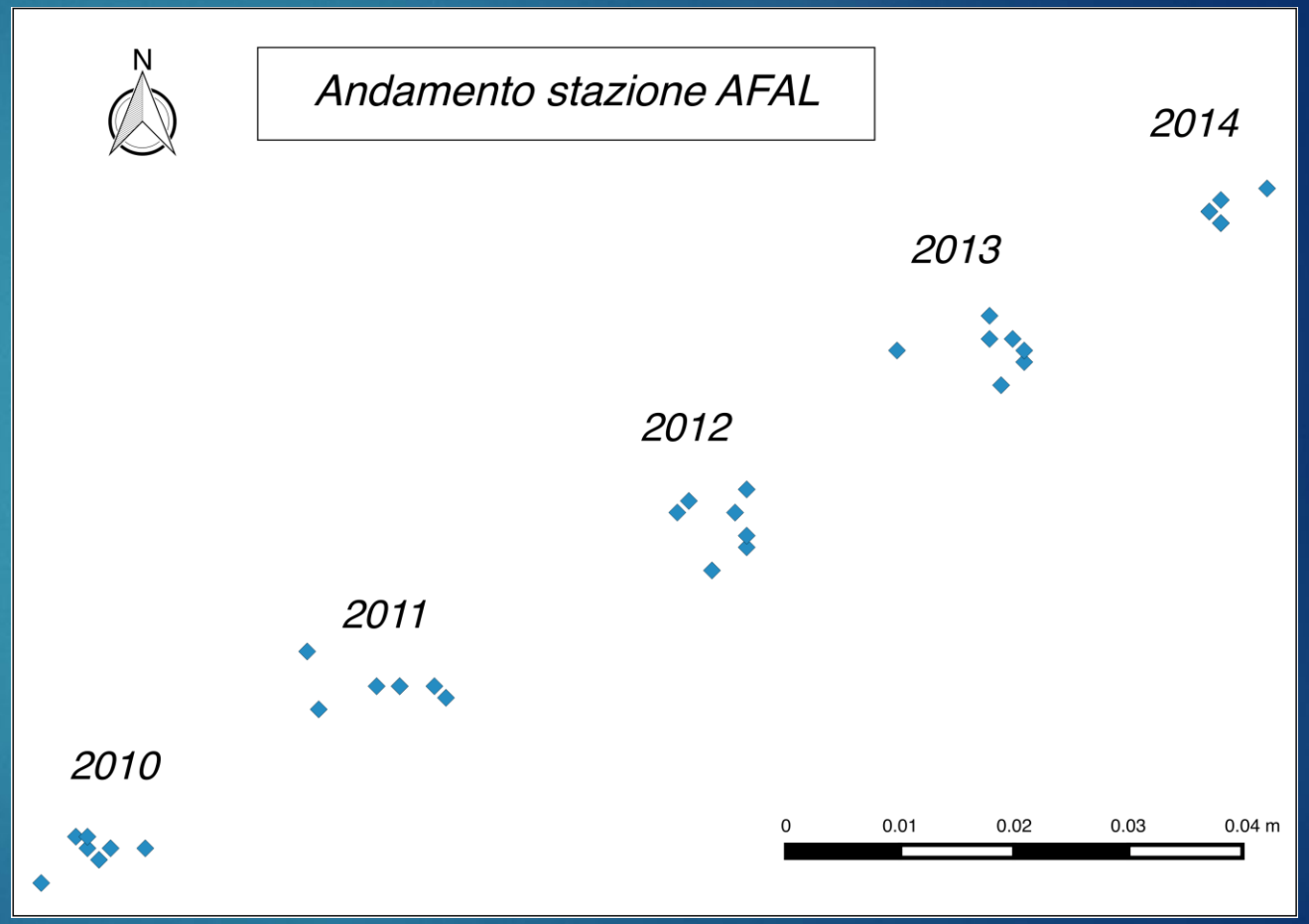
Case studies – 2010-2014

AFAL STATION



Case studies – 2010-2014

AFAL STATION



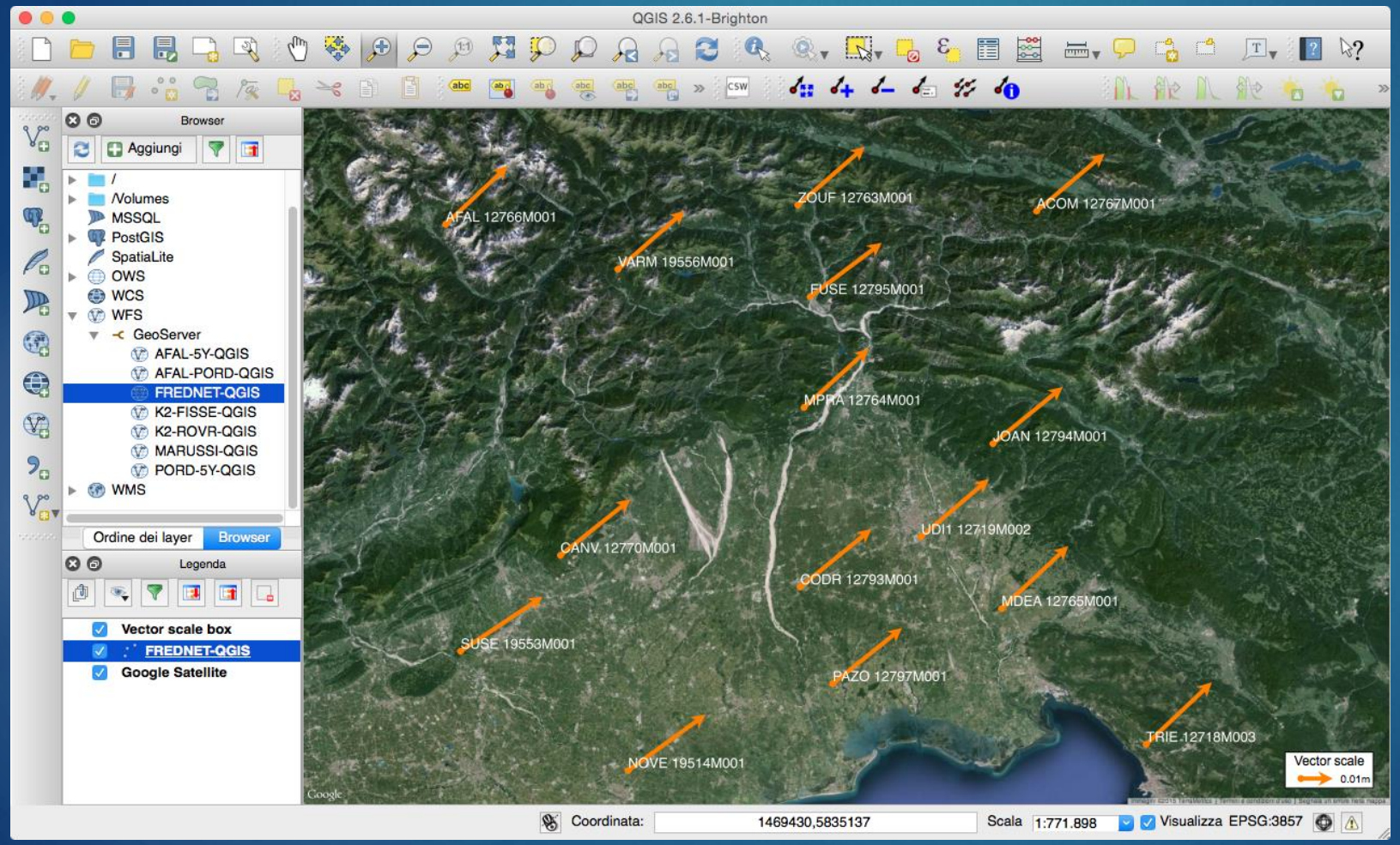
QGIS presentation of AFAL movement, period 2010-2014.

Case studies – 2003-2014

Stazione	N (metri)	E (metri)	Quota (metri)	$V_N(metri)$	$V_E(metri)$	$V_{Quota}(metri)$
ACOM 12767M001	5156001.151	386146.467	1774.682	0.01773	0.02101	0.00232
AFAL 12766M001	5156498.541	283307.955	2284.081	0.01804	0.01917	0.00239
CANV 12770M001	5098168.120	301419.830	965.918	0.01731	0.02164	0.0009
CODR 12793M001	5091425.864	343401.049	91.871	0.01783	0.0219	0.00051
FUSE 12795M001	5142005.847	346384.600	581.908	0.0166	0.0221	0.00082
JOAN 12794M001	5115706.605	377759.808	1190.451	0.01746	0.02147	0.0002
MDEA 12765M001	5086845.485	378703.651	165.700	0.01924	0.02057	0.001
MPRA 12764M001	5122765.630	344860.344	808.565	0.01811	0.01997	0.00179
NOVE 19514M001	5060038.110	312154.770	47.850	0.01721	0.0239	-0.00283
PAZO 12797M001	5074306.618	348678.617	50.084	0.01717	0.02137	0.00173
SUSE 19553M001	5081950.431	283295.693	221.714	0.01682	0.02524	-0.00571
TRIE 12718M003	5062543.922	403757.511	323.406	0.01913	0.02026	0.00111
UDI1 12719M002	5099695.477	364819.551	149.285	0.01782	0.02088	0.00003
VARM 19556M001	5147715.557	313040.295	2121.450	0.01798	0.02059	0.00378
ZOUF 12763M001	5157956.471	344671.940	1946.505	0.01802	0.02067	0.00248

Data shown in table were obtained on 365 (366) day, period 2003 - 2014, using Double Difference technique and referred to 01/02/2015 (COOVEL).

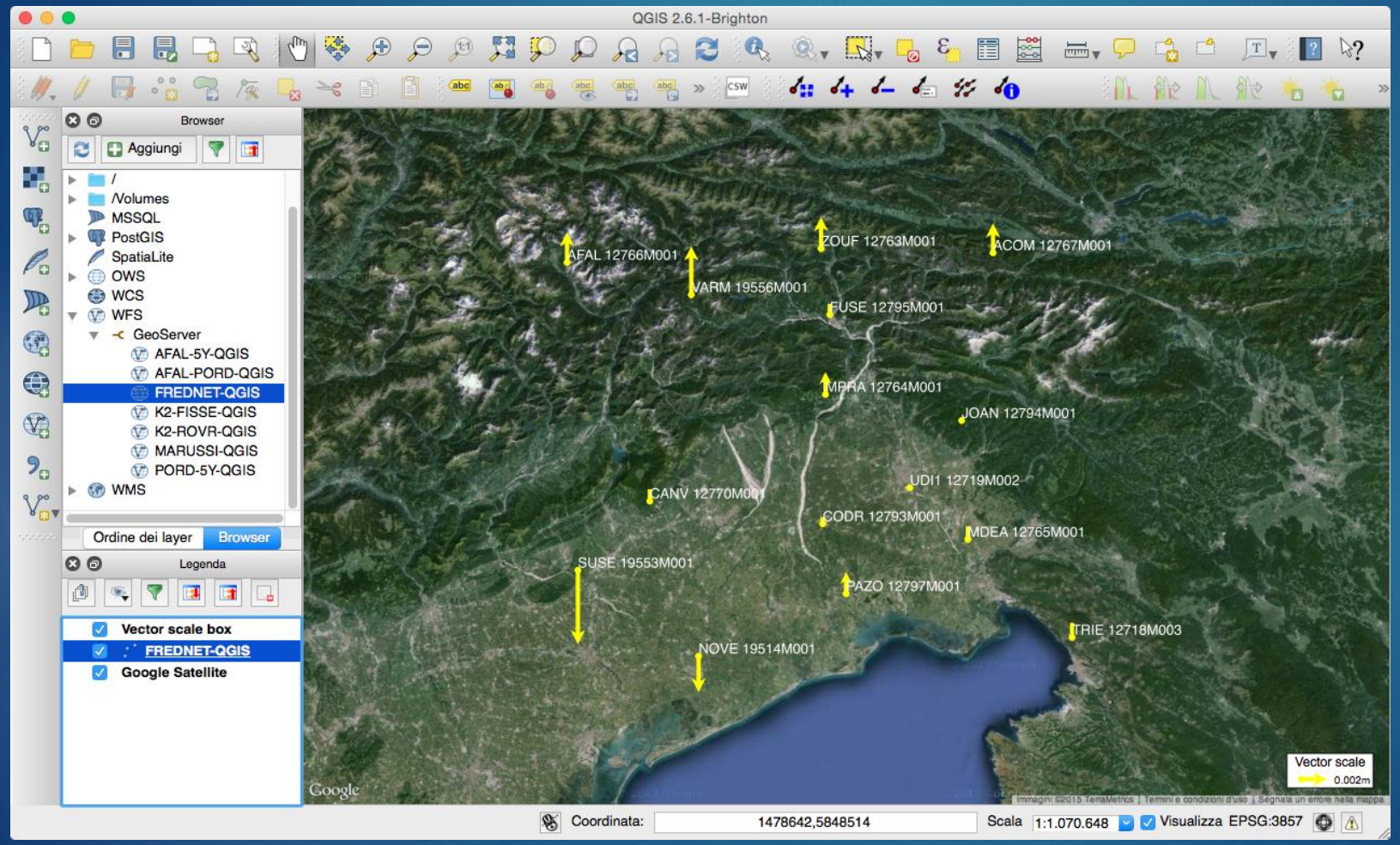
Case studies – 2003-2014



FREDNET NETWORK

PLANIMETRIC VELOCITIES

Case studies – 2003-2014



FREDNET NETWORK

ALTIMETRIC VELOCITIES

Conclusions

"Bernese" GNSS scientific software is a powerful tool to analyze geodetic GNSS data.

In this Research work (**eng. Federico Morsut Degree Thesis**), it was used for:

- Computation of station positions using **displacement velocities** and precise observations.
- Confirmation of experimental convergence between **Precise Point Positioning** and **Double Difference** (24 hours data).
- **Confirmation of displacement velocities** of FReDNet Network, in comparison with OGS official data.

- **WebGIS** are a powerful tool to share and to understand geodetic data, using different overlays on digital cartography and graphical visualizations.

THANKS FOR YOUR ATTENTION!

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NEW ADVANCED GNSS AND 3D SPATIAL TECHNIQUES
APPLICATIONS to CIVIL and ENVIRONMENTAL ENGINEERING, GEOPHYSICS, ARCHITECTURE, ARCHEOLOGY and CULTURAL HERITAGE

In memory of Professor Giorgio Manzoni