



Chile National Net: Geodetic Overview

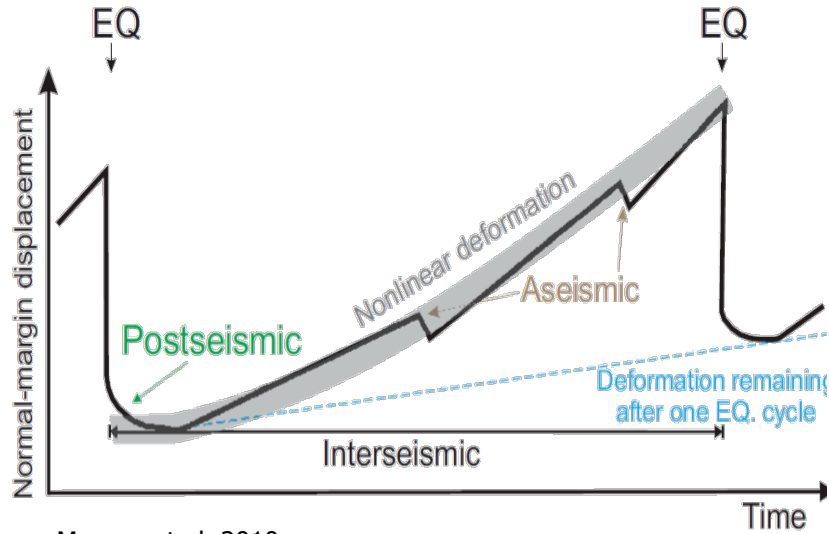
*Juan Carlos Báez - et al.
Centro Sismológico Nacional
Universidad de Chile
jcbaez@csn.uchile.cl*

Outline

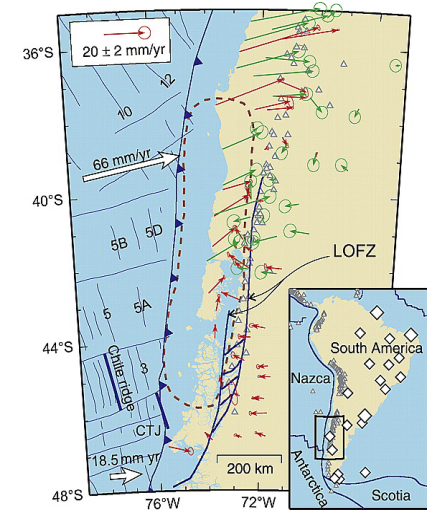
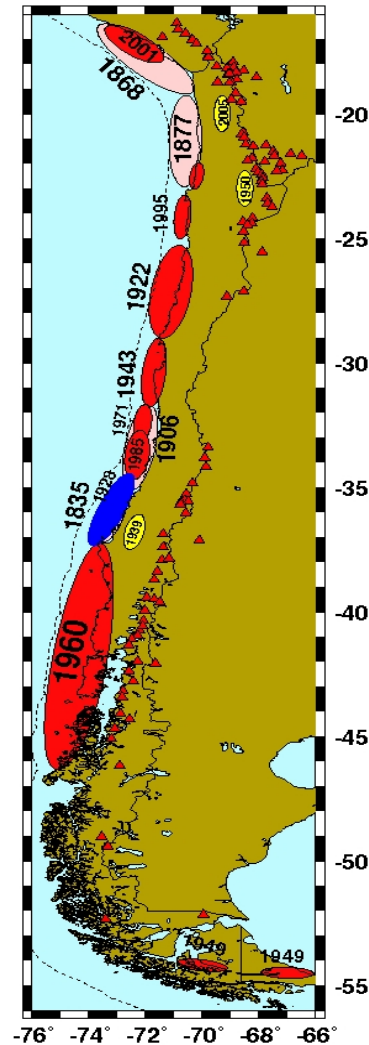


- What we want to observe with C-GNSS?
- Status of all of GNSS network in Chile
 - First stations
 - Scientific networks
 - CSN, current status
 - Monumentation
- Network design for EW
- Schedule of CSN solutions
- Results
- Final remarks

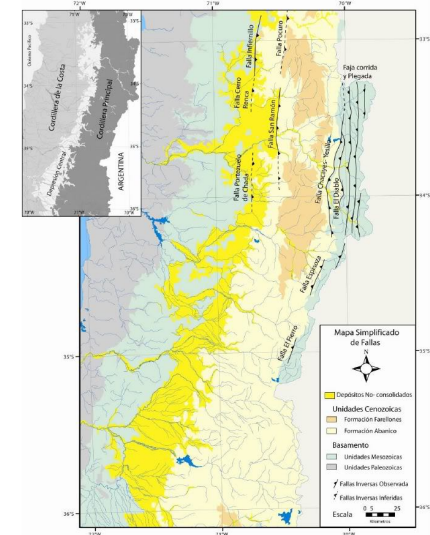
What we want to observe with C-GNSS?



Moreno et al, 2010



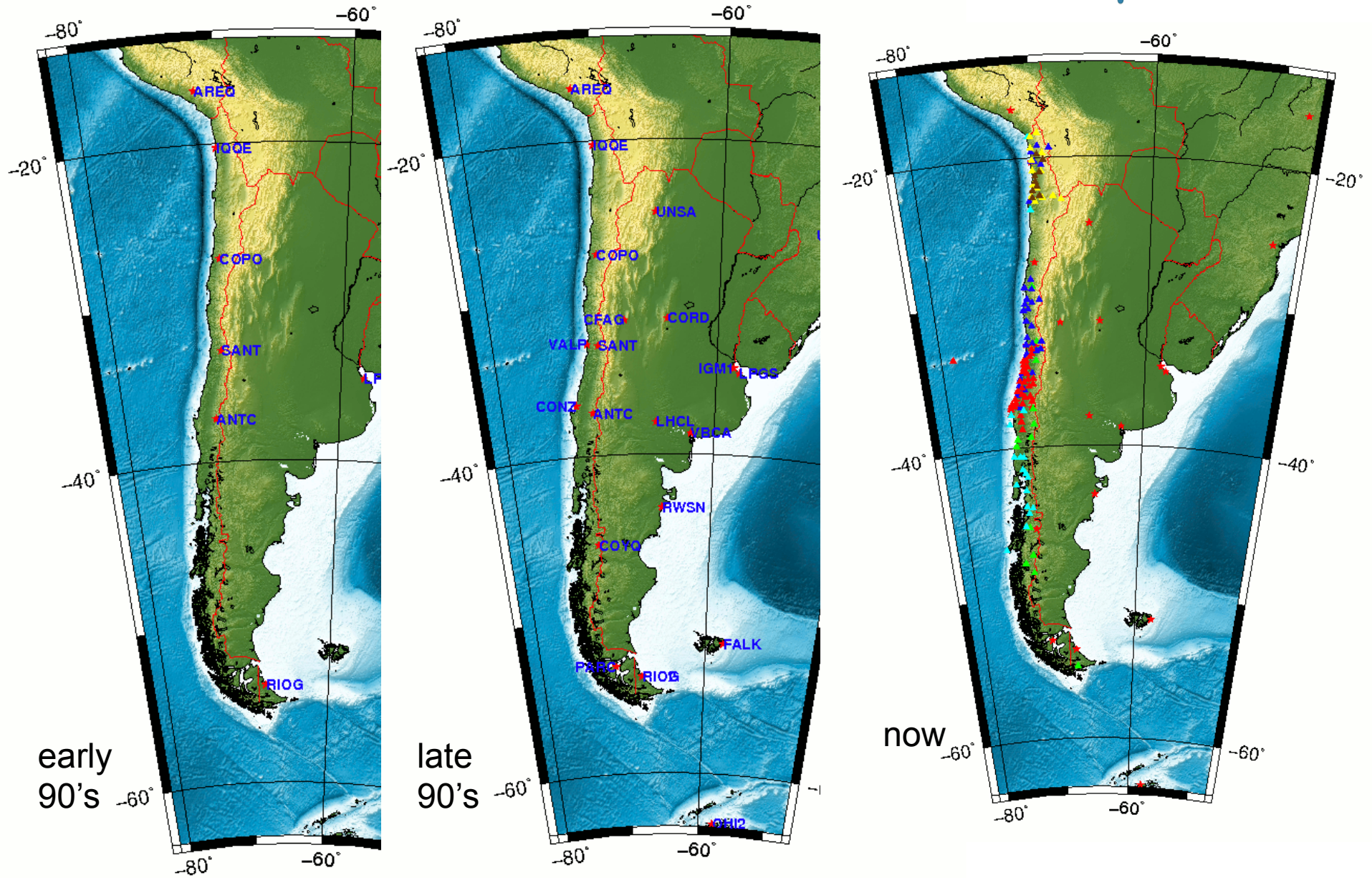
Wang et al, 2007



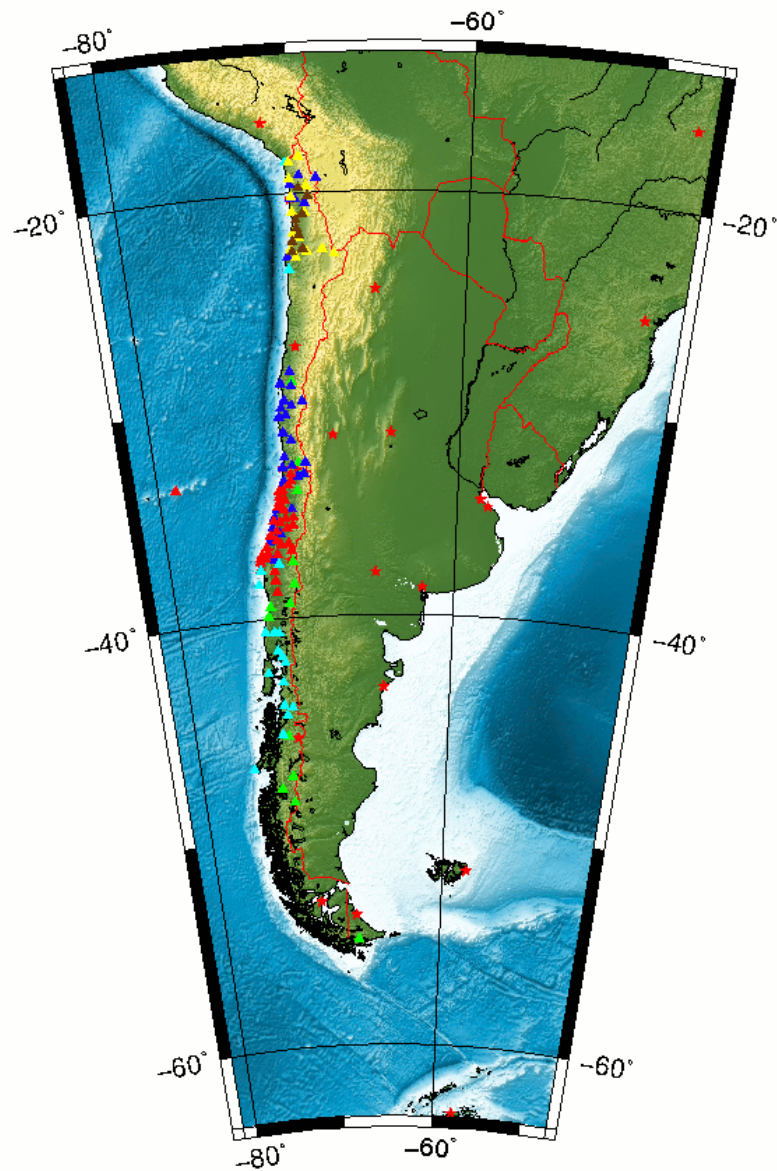
GNSS observation for:

- Seismic cycle
- Intra plate
- Fault systems
- Volcanoes (SERNAGEOMIN)
- Early warning

Status of all GNSS networks in Chile



Status of all GNSS networks in Chile



CAP/IGM/UDEC stations
UDEC/GFZ/IGM stations
IPGP/DFG stations
CALTECH stations
GFZ/IPGP/DGF stations

More than 151 C-GNSS

CSN current status



- 76 stations ready installed
- 54 remaining stations
- 130 in total for this project
- 40 with RTX capabilities
- 4 stations was vandalized
- Not all of them with good communications at the moment
- 92% are stations replaced from IPGP/CALTECH/CAP/FENIX (UNAVCO et al)
- 21 stations will be in a multi-parametric sites (velocities, acceleration and displacement)
- We have a open data policy!!!
jcbaez@csn.uchile.cl

CSN current status



```
jcbaez@jcbaez:~> sftp gpsext@200.9.100.121
gpsext@200.9.100.121's password:
Connected to 200.9.100.121.
sftp> ls RINEX/2015/146/*.*Z
RINEX/2015/146/aeda1460.15d.Z
RINEX/2015/146/chyt1460.15d.Z
RINEX/2015/146/dgfl1460.15d.Z
RINEX/2015/146/mrcg1460.15d.Z
RINEX/2015/146/pcmu1460.15d.Z
RINEX/2015/146/ptr01460.15d.Z
RINEX/2015/146/rcsd1460.15d.Z
RINEX/2015/146/tlgt1460.15d.Z
sftp> ls incoming/???20150526*
incoming/VALN201505260000s.T02
incoming/PTR0201505260000s.T02
incoming/CBAA201505260000s.T02
incoming/PELL201505260000s.T02
incoming/CBAA201505260000s.T02
incoming/PTAR201505260000s.T02
incoming/NAVI201505260000s.T02
incoming/TLGT201505260000s.T02
incoming/SANT201505260000s.T02
sftp> █
```

```
RINEX/2015/146/antc1460.15d.Z
RINEX/2015/146/cmba1460.15d.Z
RINEX/2015/146/futf1460.15d.Z
RINEX/2015/146/navi1460.15d.Z
RINEX/2015/146/pell1460.15d.Z
RINEX/2015/146/qlln1460.15d.Z
RINEX/2015/146/sbll1460.15d.Z
RINEX/2015/146/utar1460.15d.Z
incoming/AEDA201505260000s.T02
incoming/RAD0201505260000s.T02
incoming/FUTF201505260000s.T02
incoming/PAZU201505260000s.T02
incoming/DGF1201505260000s.T02
incoming/MRCG201505260000s.T02
incoming/RCS0201505260000s.T02
incoming/SBLL201505260000s.T02
```

```
RINEX/2015/146/cbaa1460.15d.Z
RINEX/2015/146/crsc1460.15d.Z
RINEX/2015/146/imch1460.15d.Z
RINEX/2015/146/pazu1460.15d.Z
RINEX/2015/146/ptar1460.15d.Z
RINEX/2015/146/rado1460.15d.Z
RINEX/2015/146/srgd1460.15d.Z
RINEX/2015/146/valn1460.15d.Z
incoming/ANTC201505260000s.T02
incoming/PCMU201505260000s.T02
incoming/SRGD201505260000s.T02
incoming/CRSC201505260000s.T02
incoming/QLLN201505260000s.T02
incoming/IMCH201505260000s.T02
incoming/CHYT201505260000s.T02
incoming/UTAR201505260000s.T02
```

```
█ 2.11 OBSERVATION DATA G (GPS) RINEX VERSION / TYPE
teqc 2013Mar15 Juan Carlos Baez 20150527 12:53:44UTC PGM / RUN BY / DATE
Linux 2.4.21-27.ELsmp|Opteron|gcc|Linux x86_64|=+ COMMENT
teqc 2013Mar15 CSN/UCHILE 20150527 12:49:36UTC COMMENT
BIT 2 OF LLI FLAGS DATA COLLECTED UNDER A/S CONDITION COMMENT
UTAR MARKER NAME
0000 MARKER NUMBER
-Unknown- Centro Sismologico Nacional OBSERVER / AGENCY
5229K50867 TRIMBLE NETR9 4.85 REC # / TYPE / VERS
5000112786 TRM57971.00 NONE ANT # / TYPE
2040107.6400 -5696703.5800 -2009987.7400 APPROX POSITION XYZ
0.0000 0.0000 0.0000 ANTENNA: DELTA H/E/N
1 1 WAVELENGTH FACT L1/2
7 L1 L2 C1 P1 P2 S1 S2 # / TYPES OF OBSERV
15.0000 INTERVAL
16 LEAP SECONDS
COMMENT
Centro Sismologico Nacional COMMENT
Universidad de Chile COMMENT
Unidad de Geodesia COMMENT
gps@csn.uchile.cl COMMENT
SNR is mapped to RINEX snr flag value [0-9] COMMENT
L1 & L2: min(max(int(snr_dBHz/6), 0), 9) COMMENT
Forced Modulo Decimation to 15 seconds COMMENT
2015 5 26 0 0 0.0000000 GPS TIME OF FIRST OBS
END OF HEADER
15 5 26 0 0 0.0000000 0 10G30G02G09G03G07G23G05G28G06G10
108046535.07948 84192226.64547 20560543.0864 20560550.7234
50.5004 42.9004
122126686.67147 95163726.09245 23239946.2274 23239951.5784
11.5004 20.5004
```

- RAW data available in 1hz
- RINEX data available in 15 sec

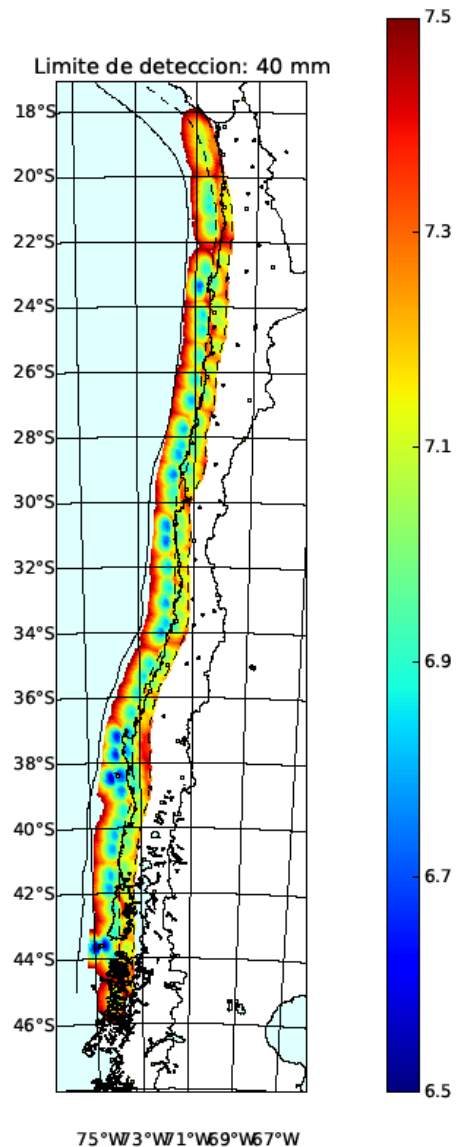
jcbaez@csn.uchile.cl

Status of C-GNSS stations under CSN

Monumentation



Network design for EW

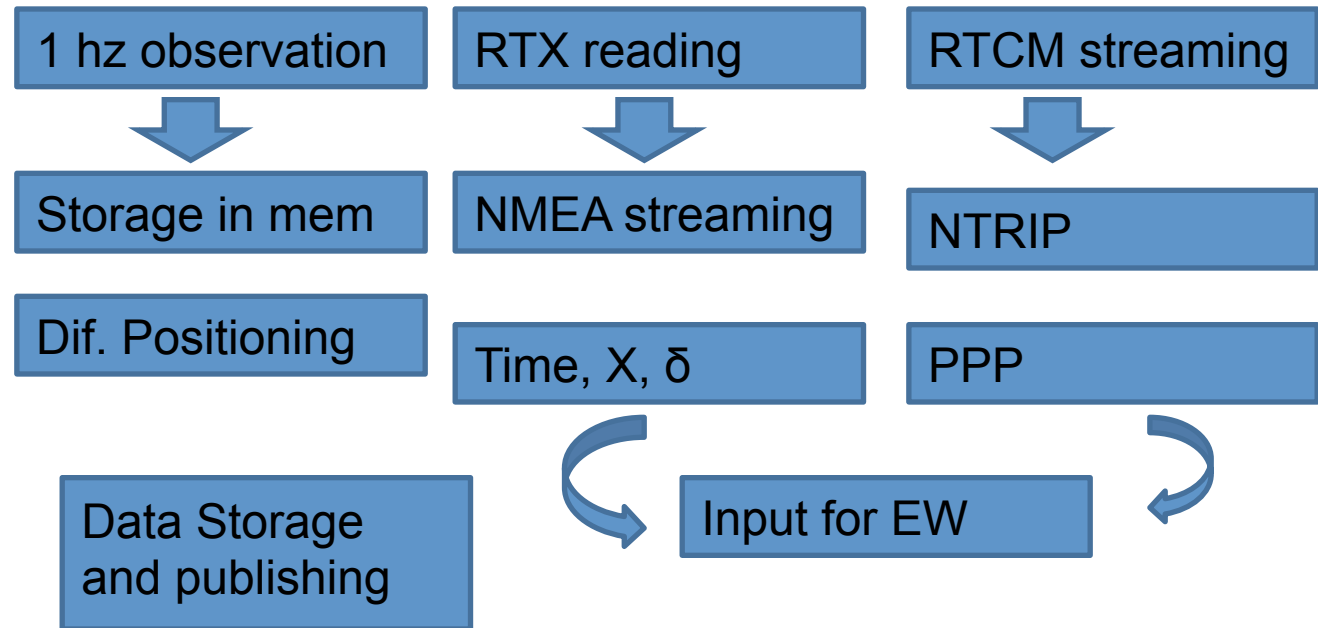


Detectability threshold of actual CSN network.
(Thanks Francisco del Campo)

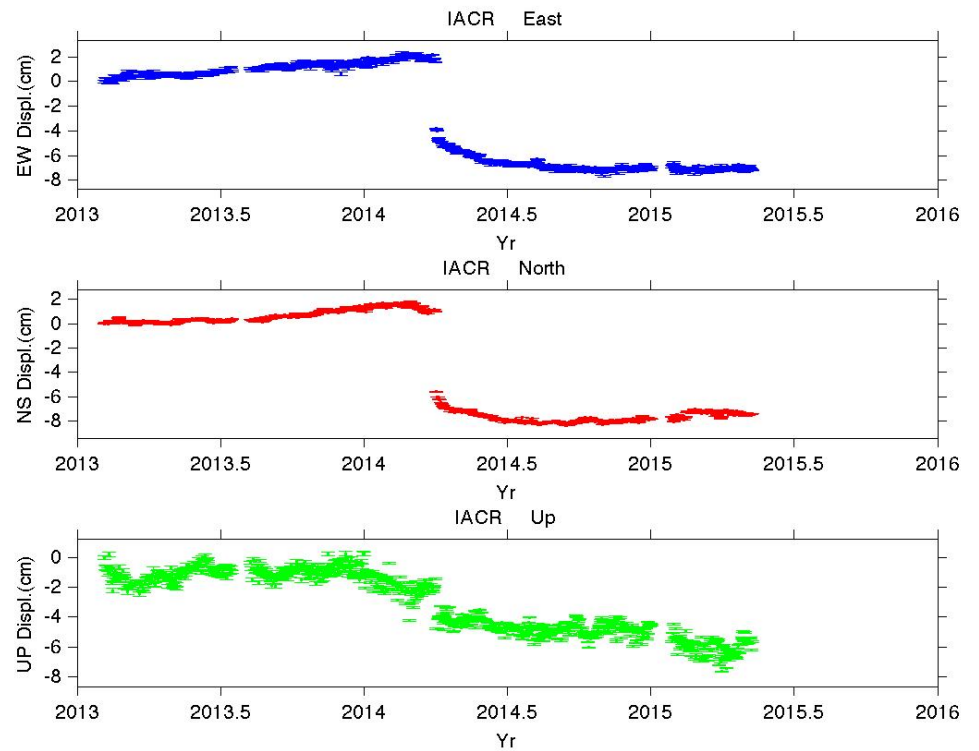
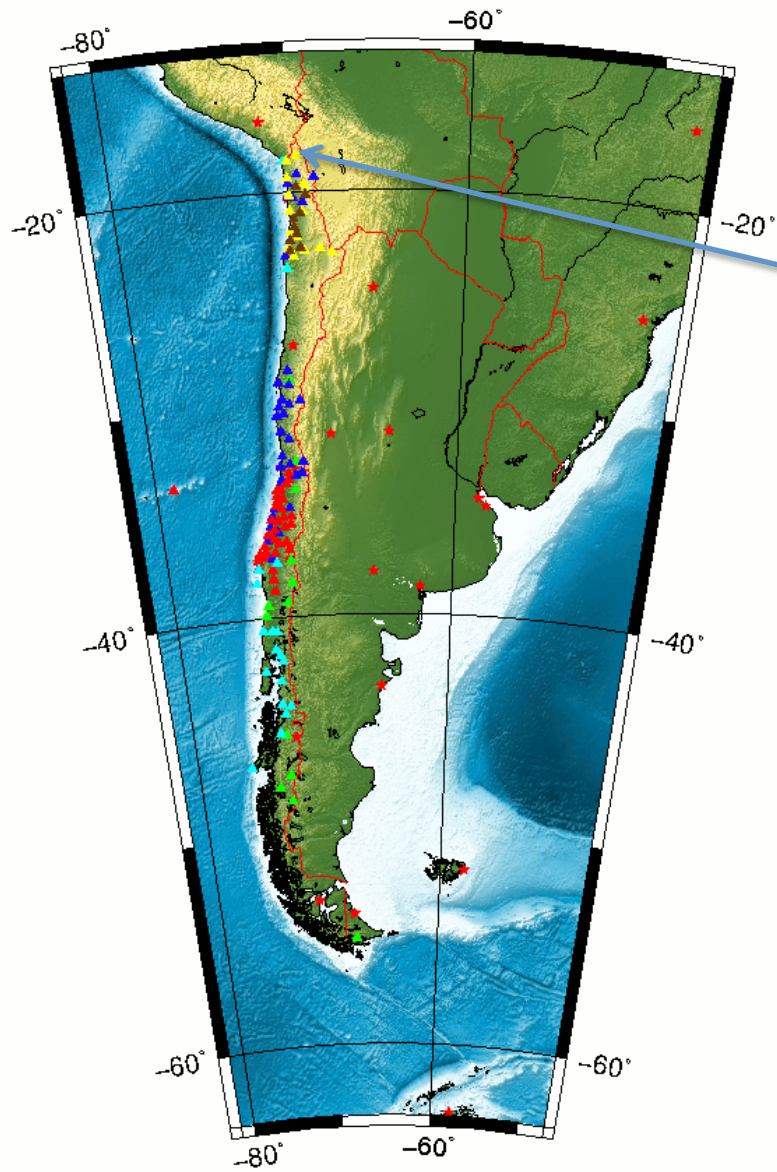
The scale of colors displays the minimum moment magnitude (M_w) to observe a 40 mm horizontal displacement due to an inter-plate earthquake.

- It is clear that coast-stations are more sensitive;
- For great earthquakes (>8.0) coast-stations still have better response, but inland stations become of increasing importance;
- We will increase the number of stations near to coast, to have one every 40 km

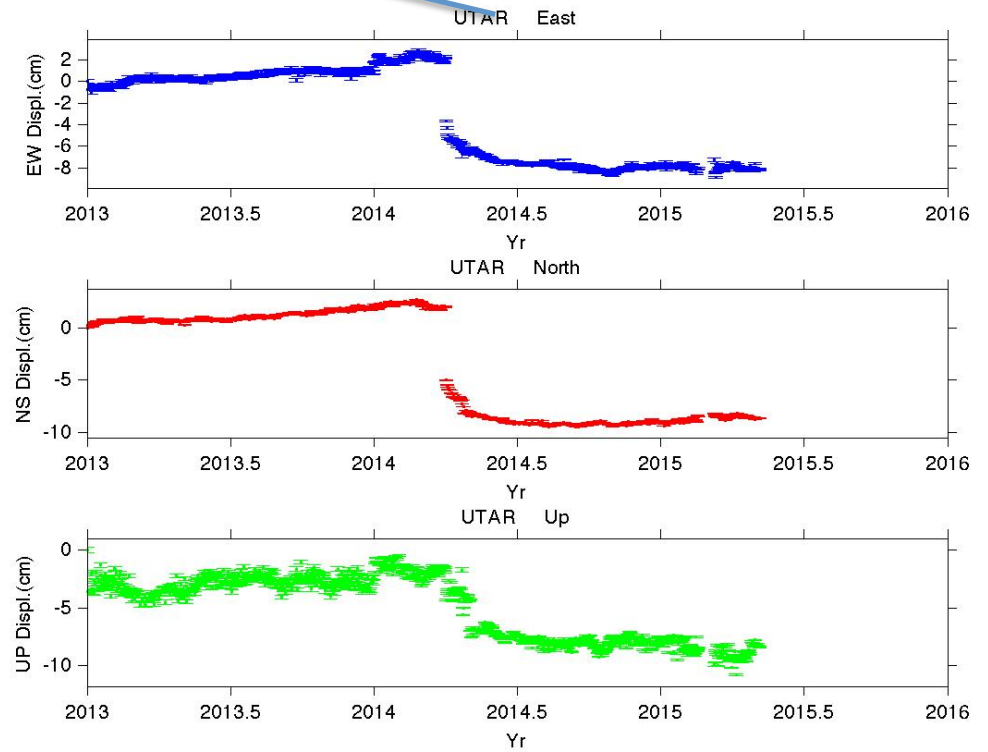
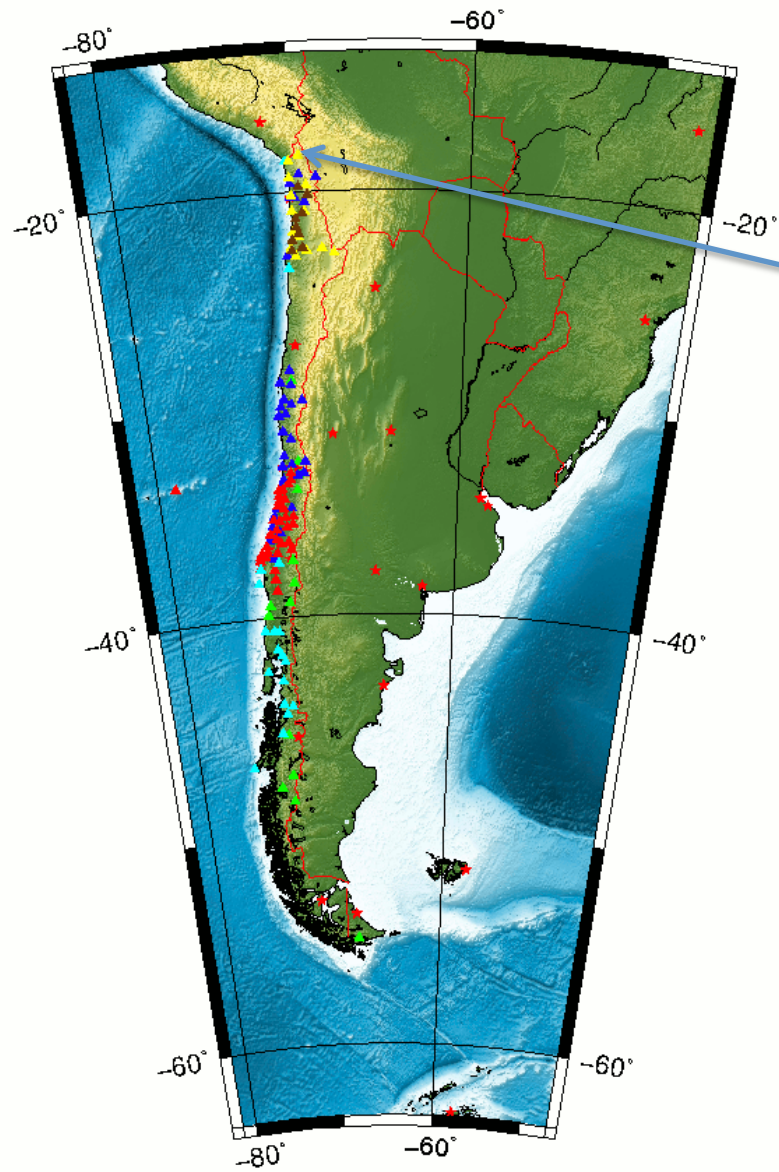
Schedule of CSN solutions



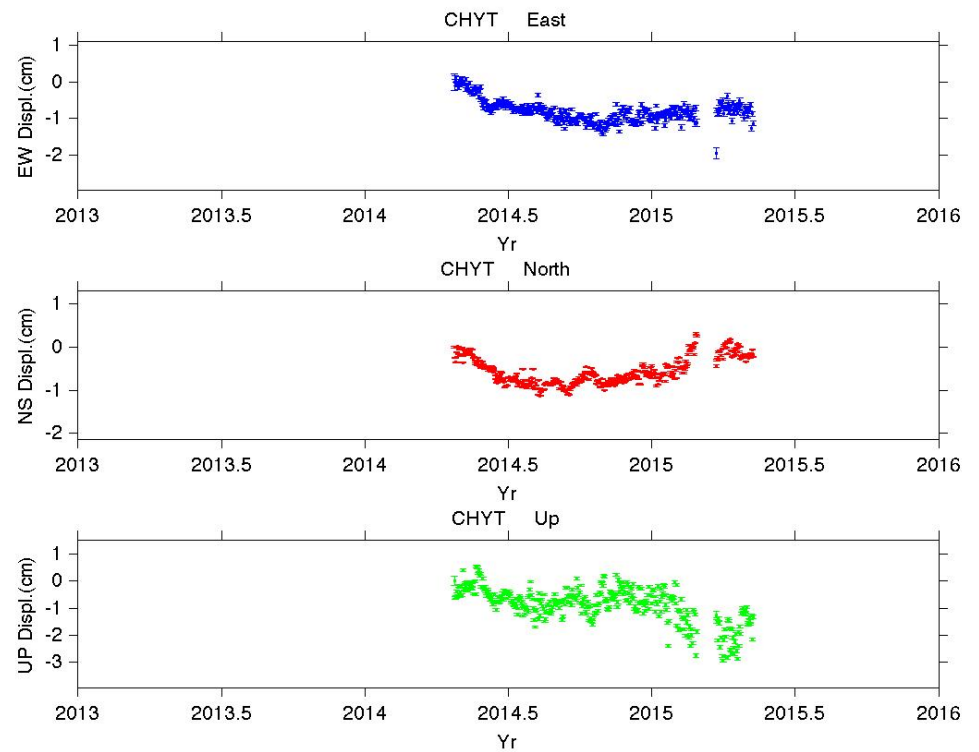
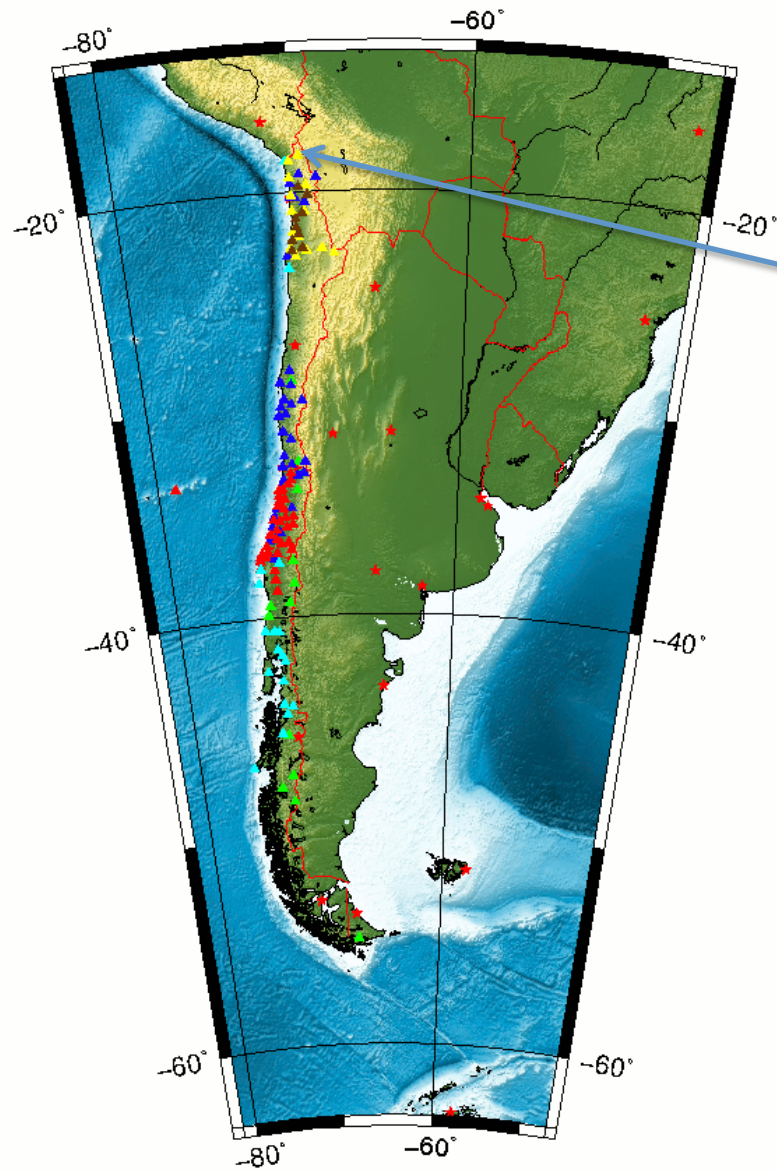
Results from Pisagua EQ 2014



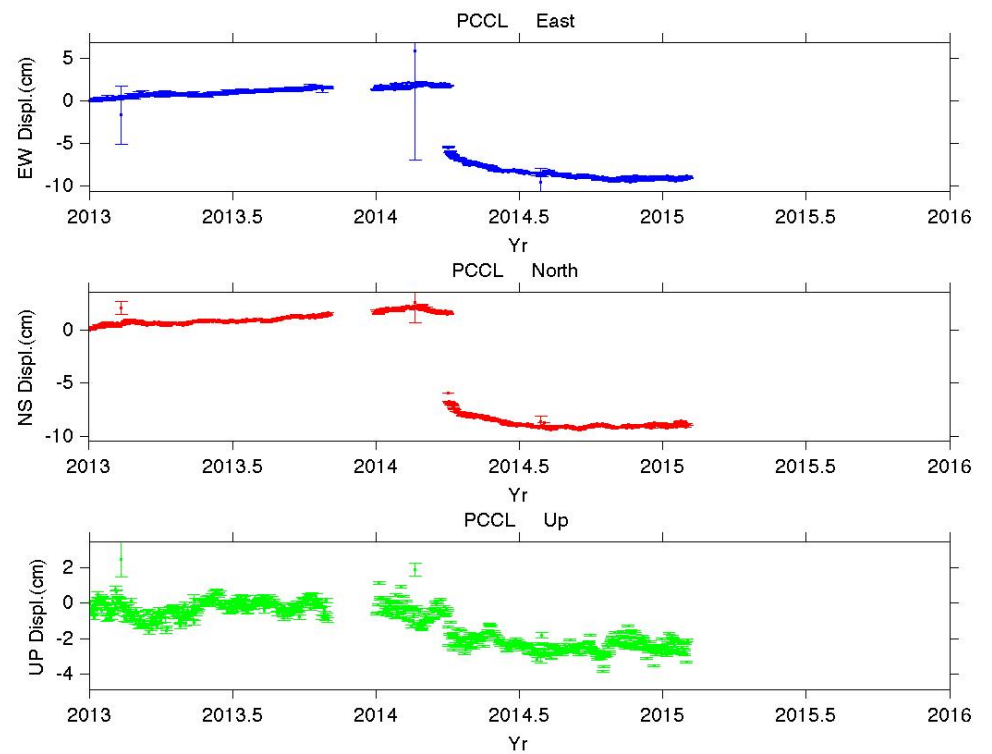
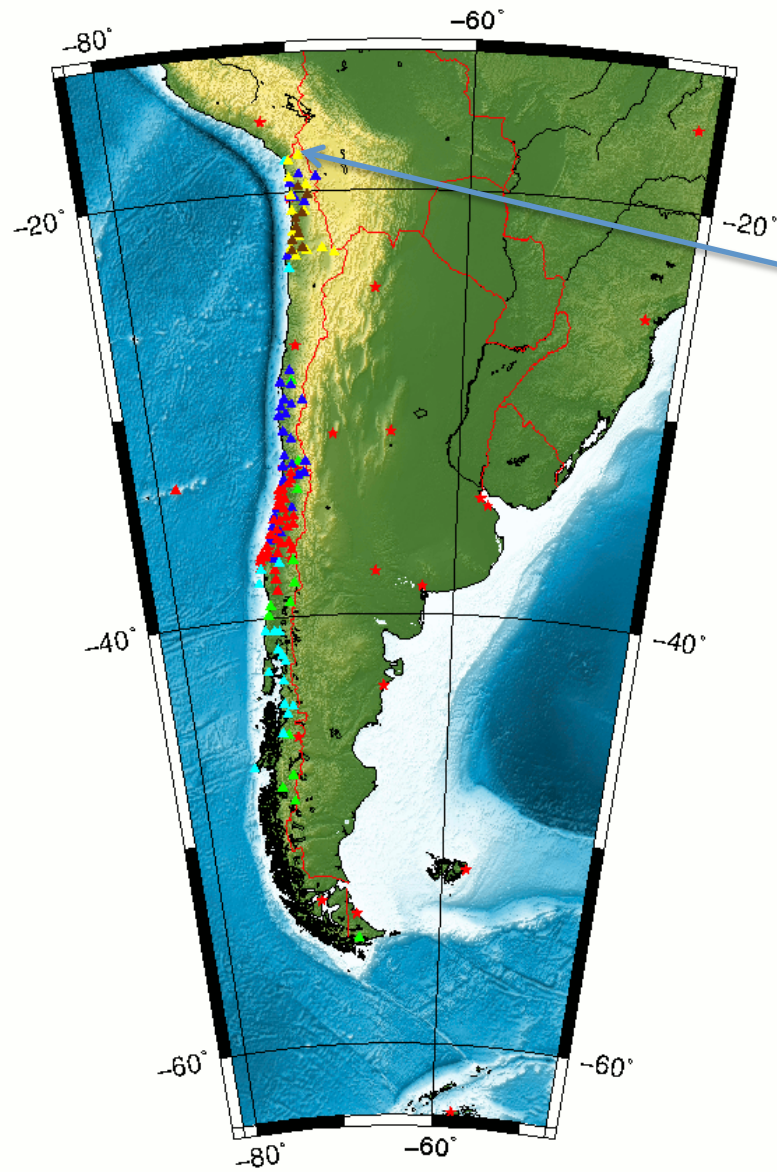
Results from Pisagua EQ 2014



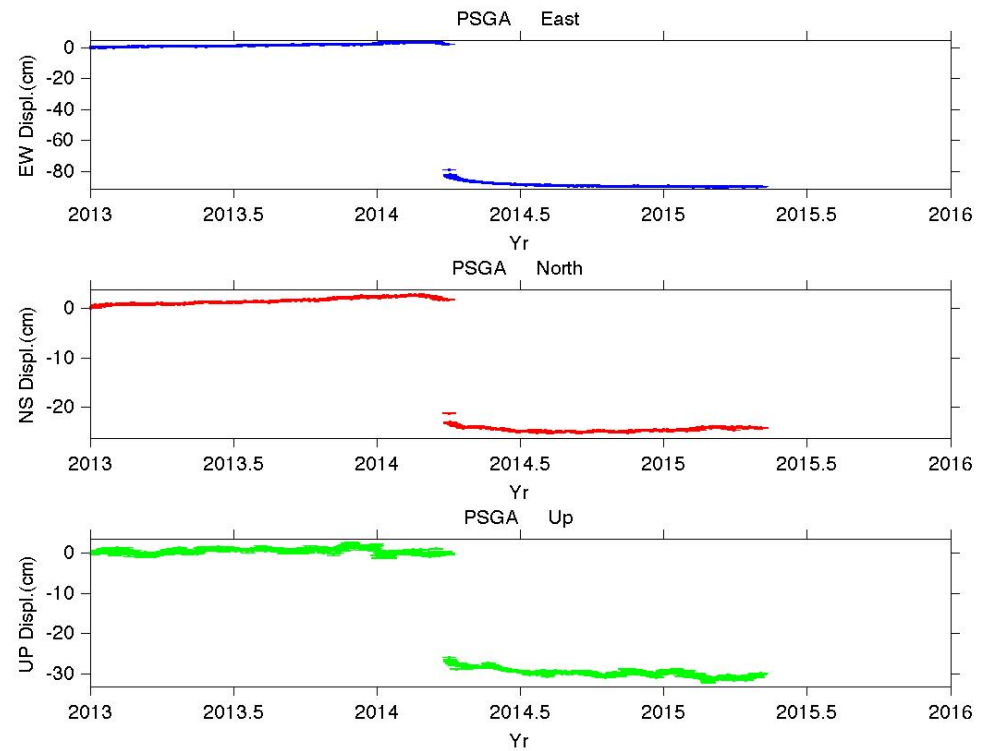
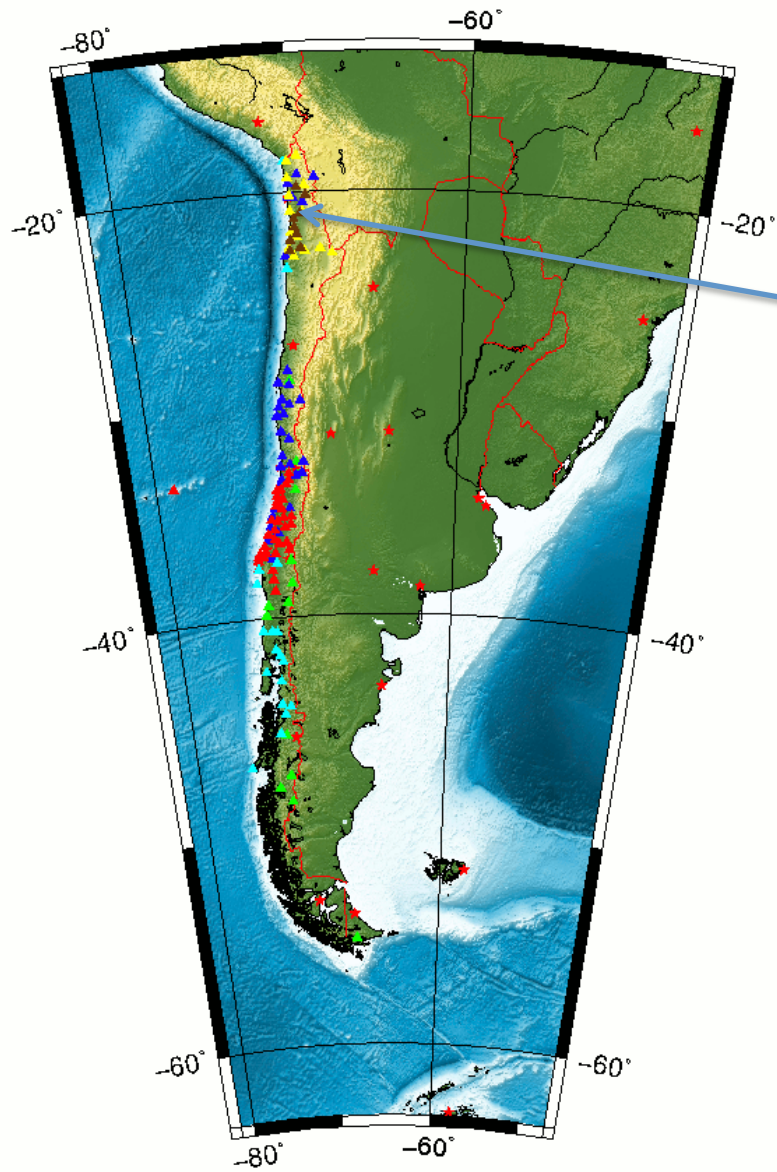
Results from Pisagua EQ 2014



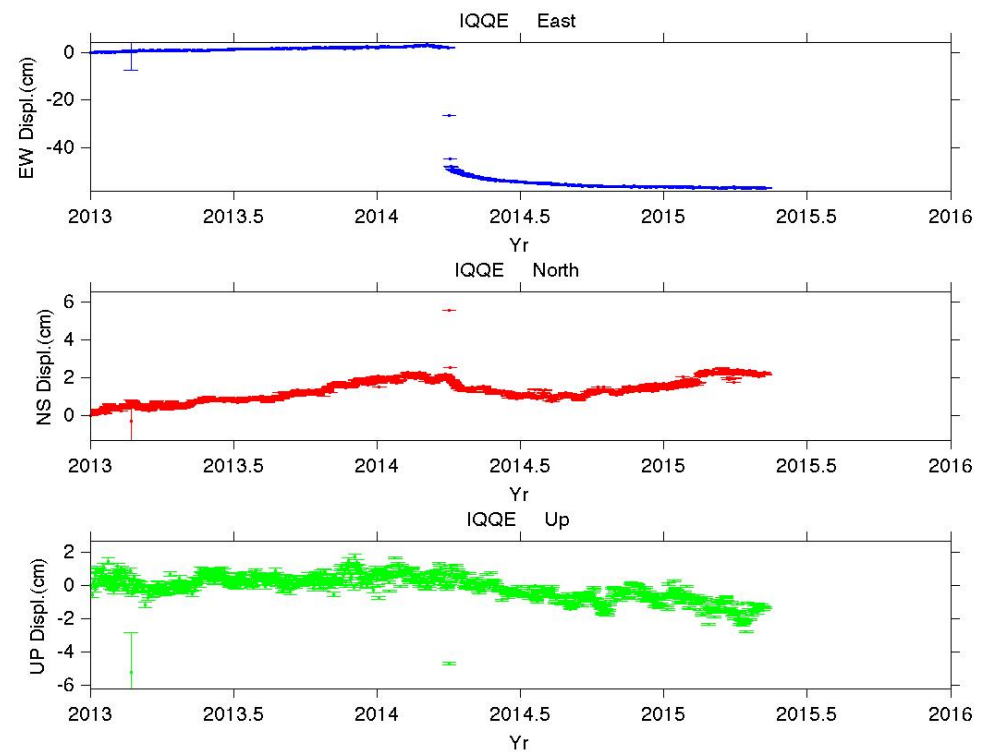
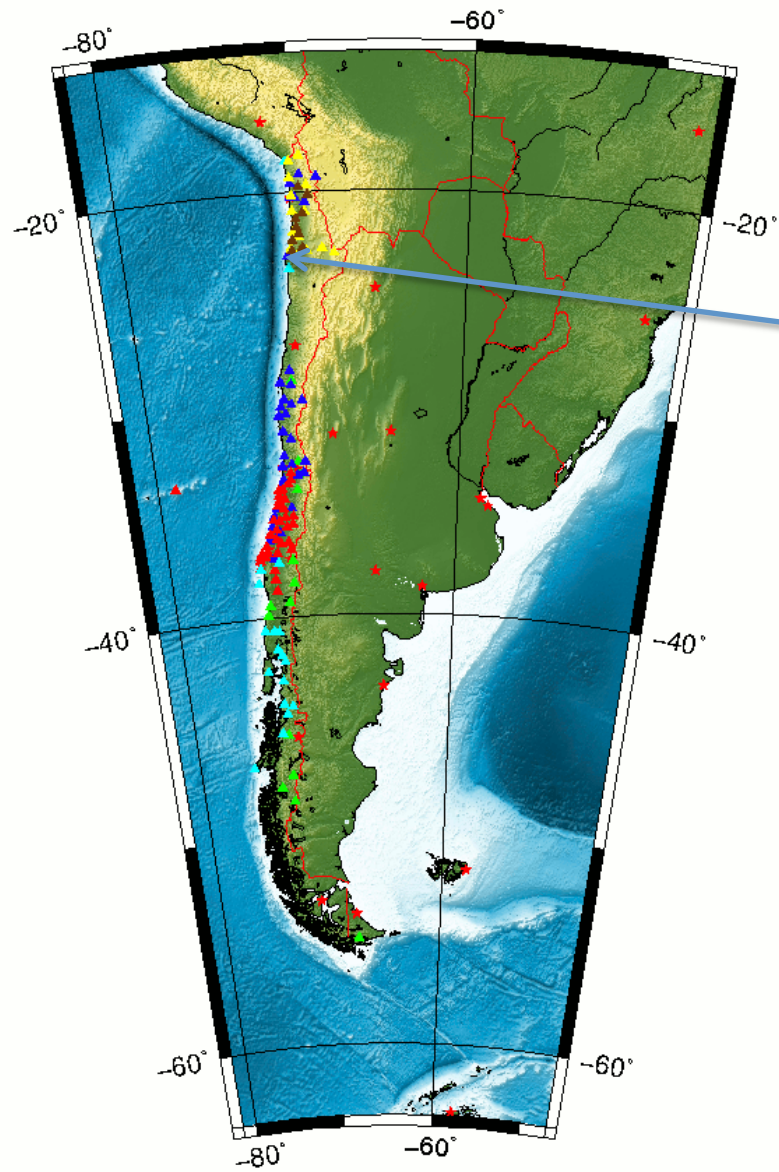
Results from Pisagua EQ 2014



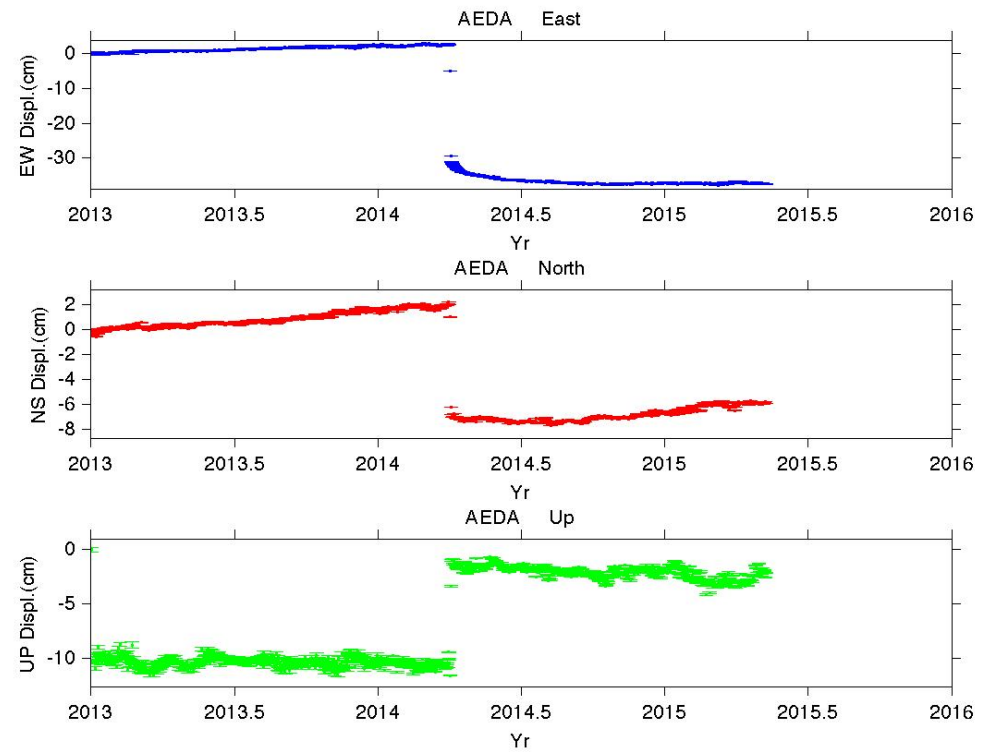
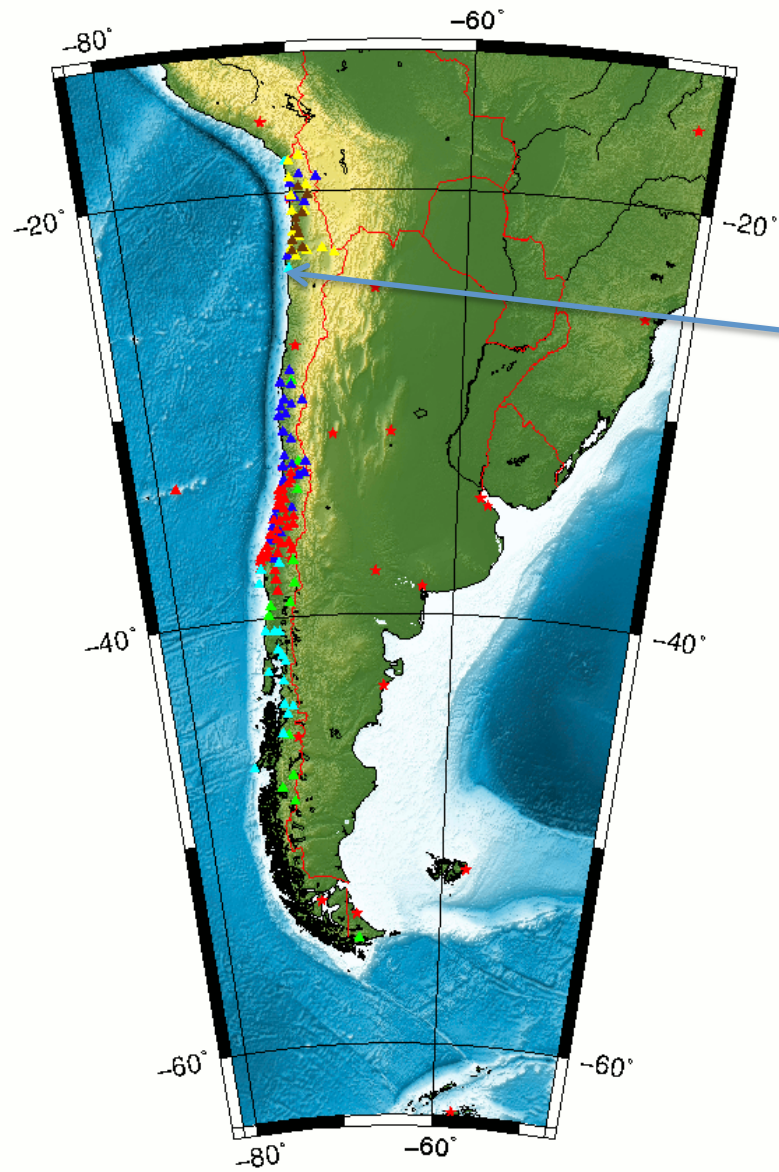
Results from Pisagua EQ 2014



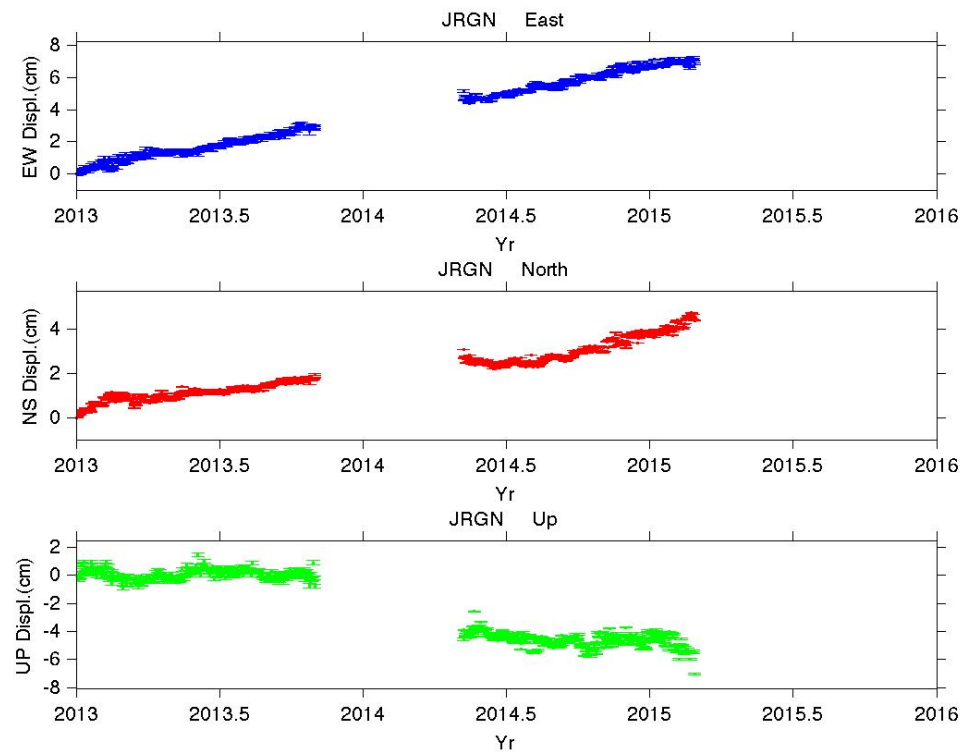
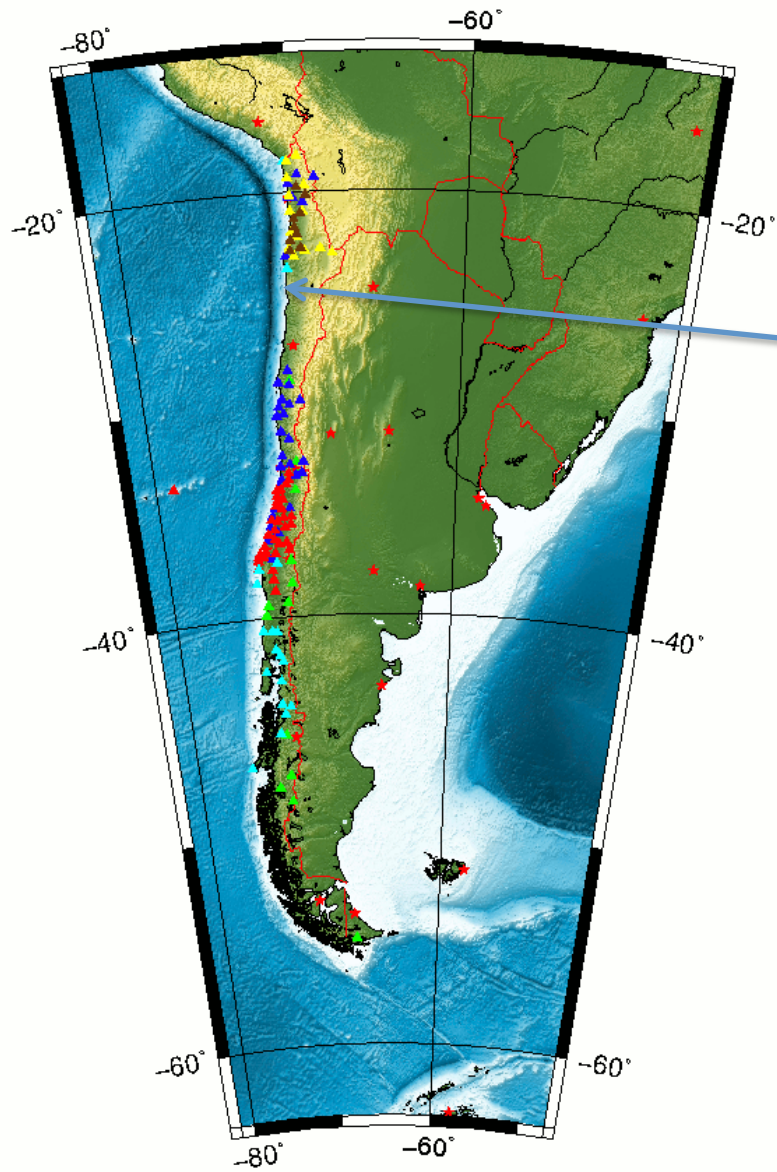
Results from Pisagua EQ 2014



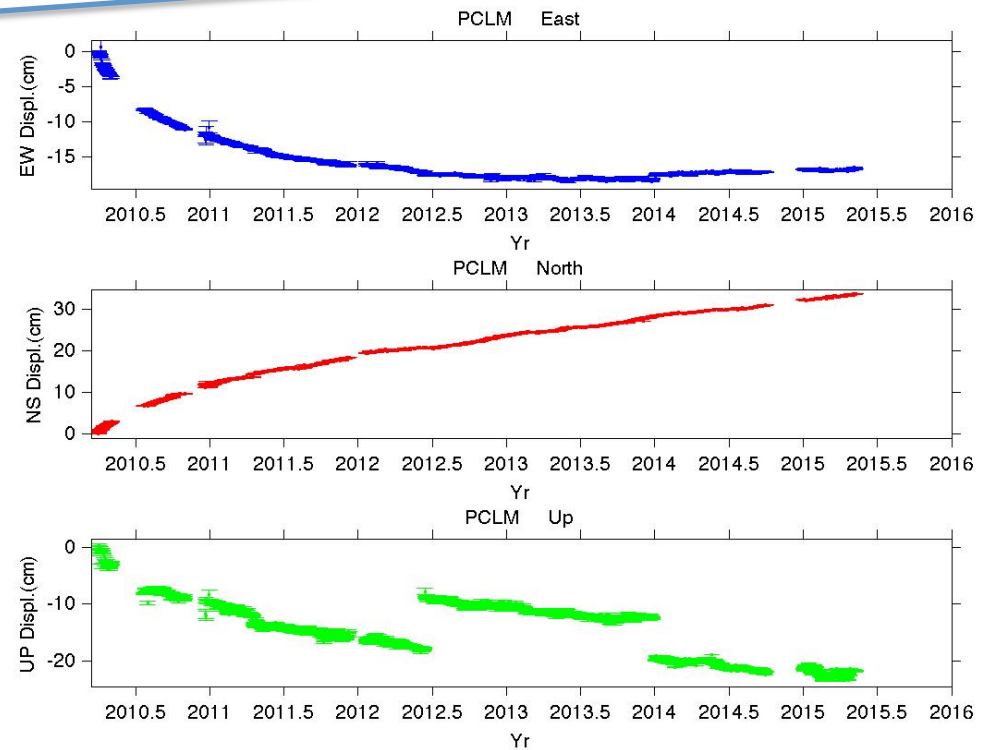
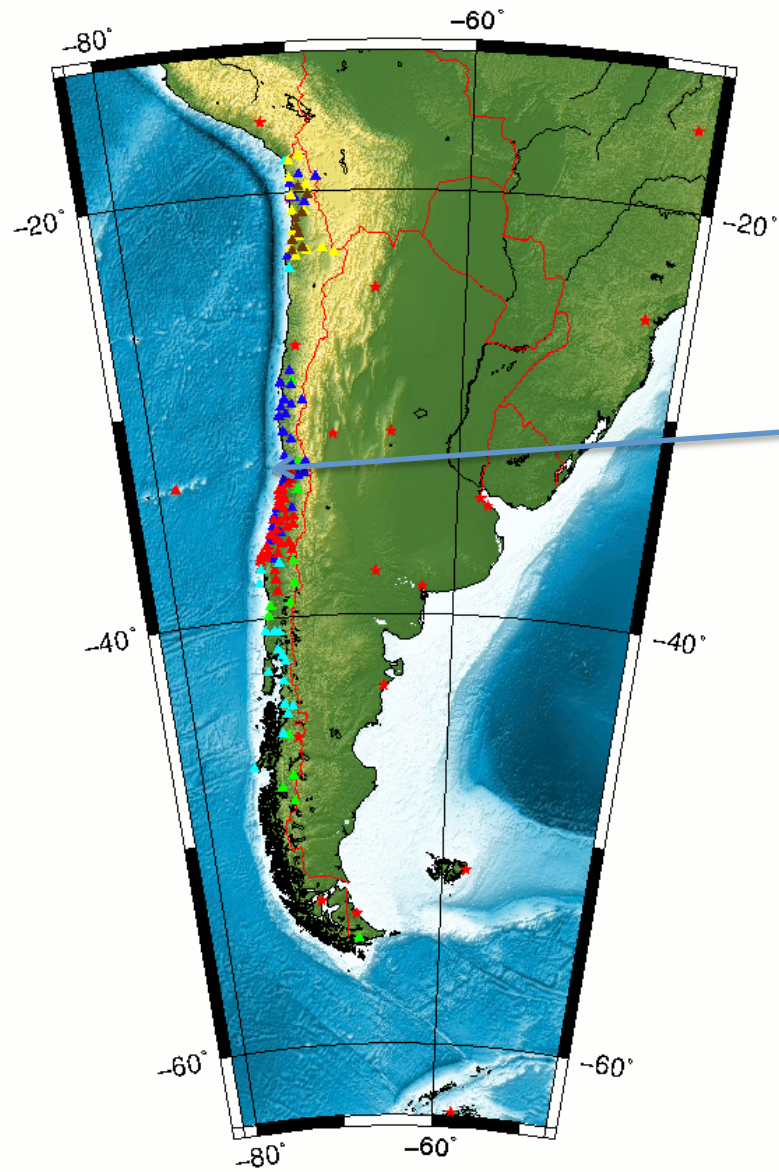
Results from Pisagua EQ 2014



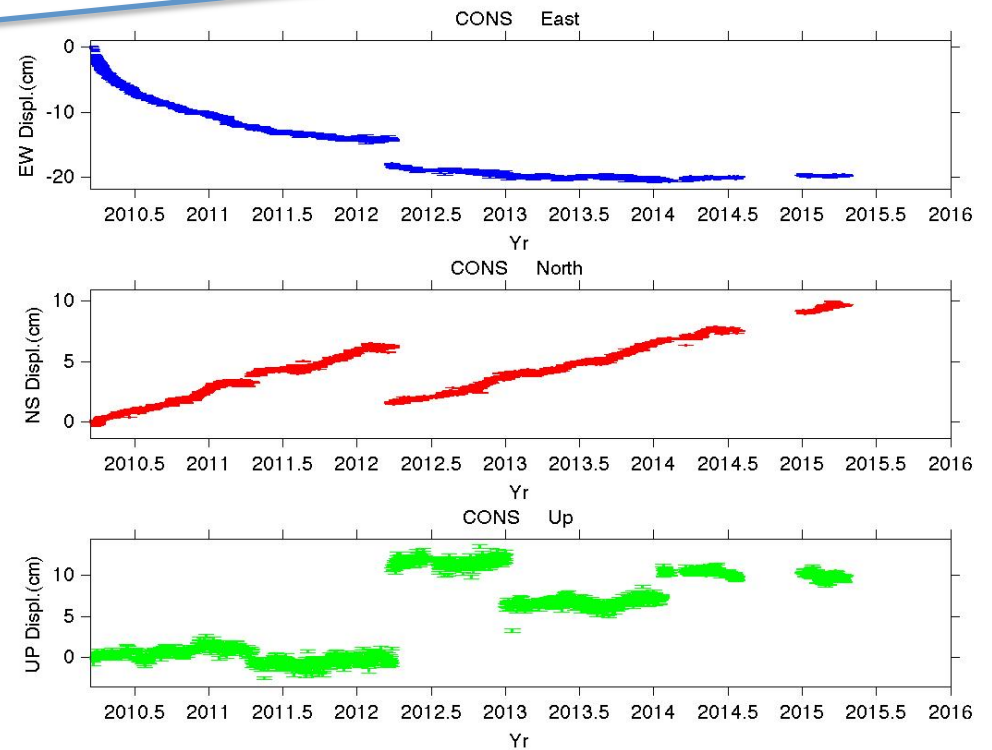
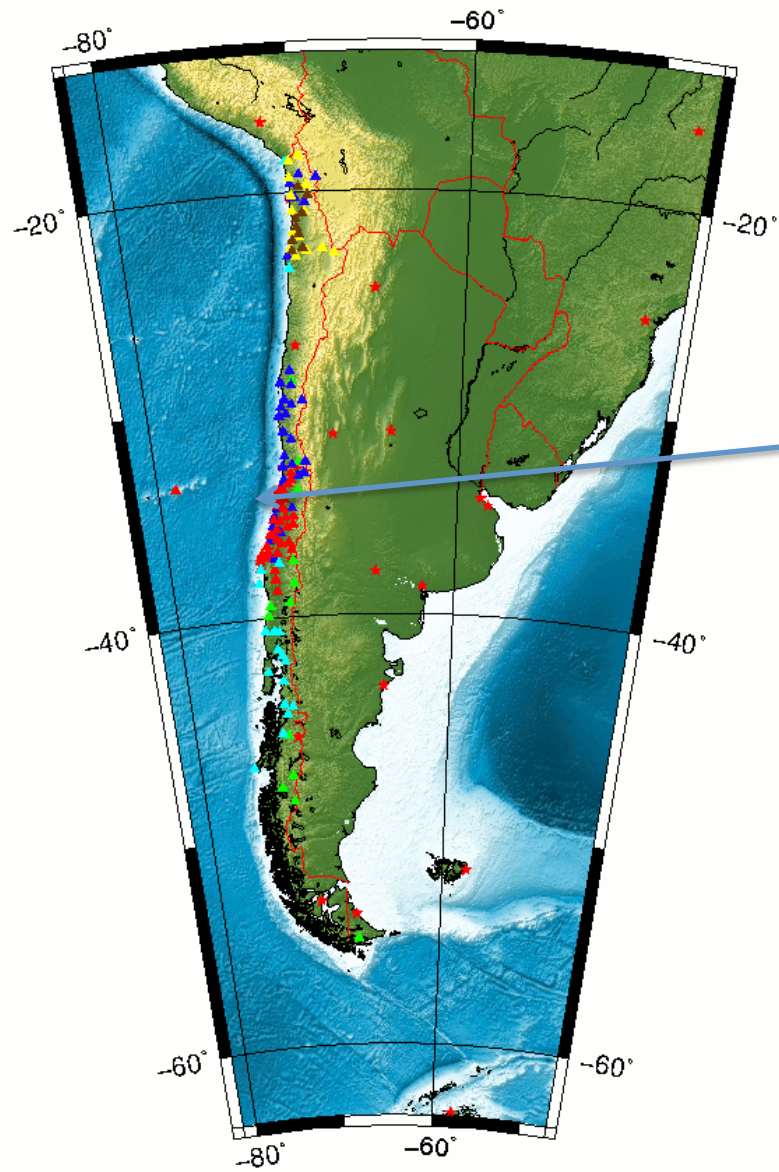
Results from Pisagua EQ 2014



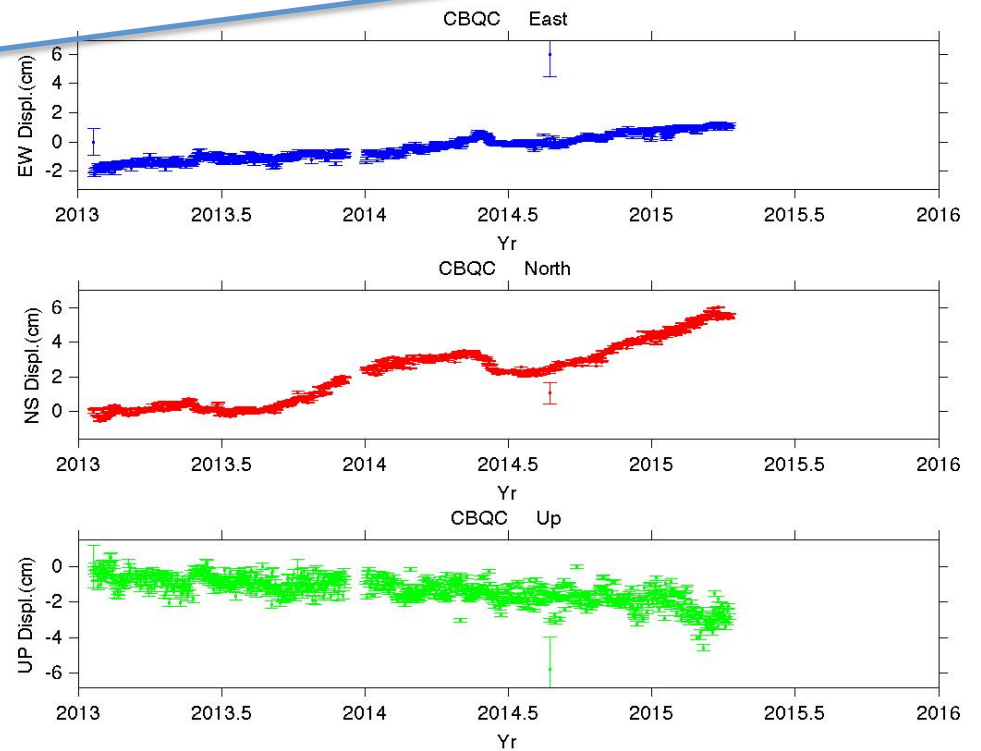
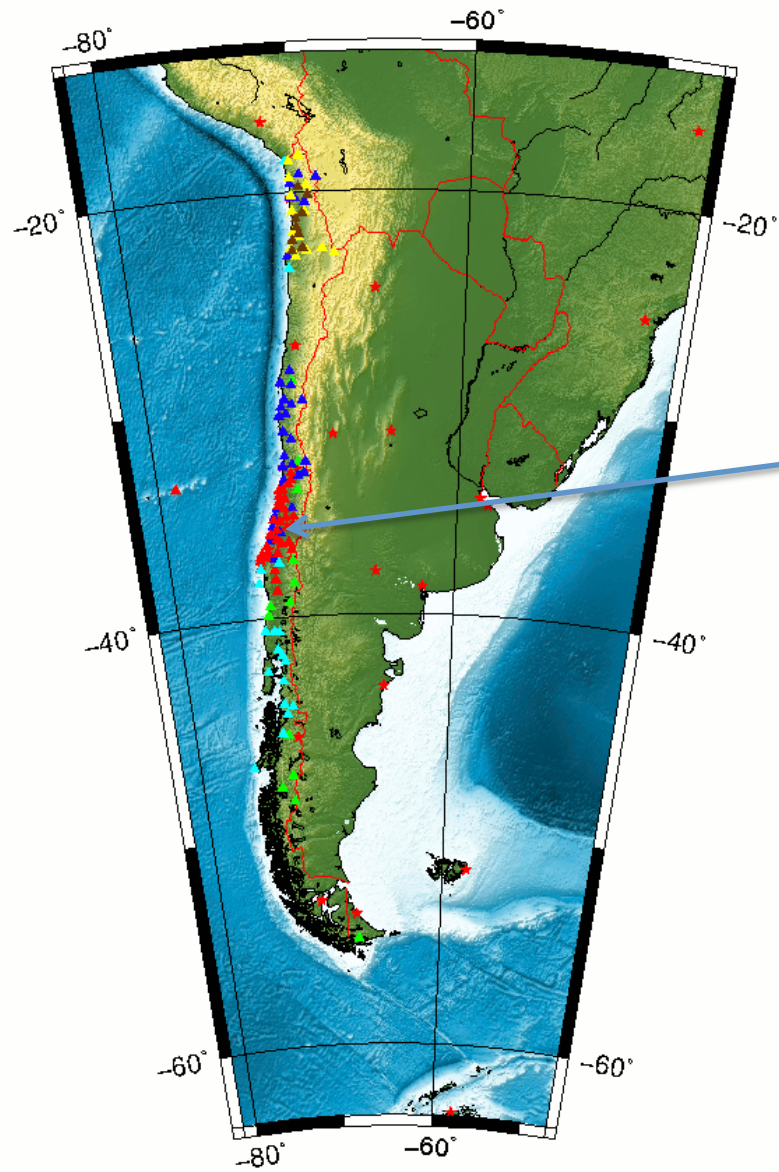
Results from Maule EQ 2010



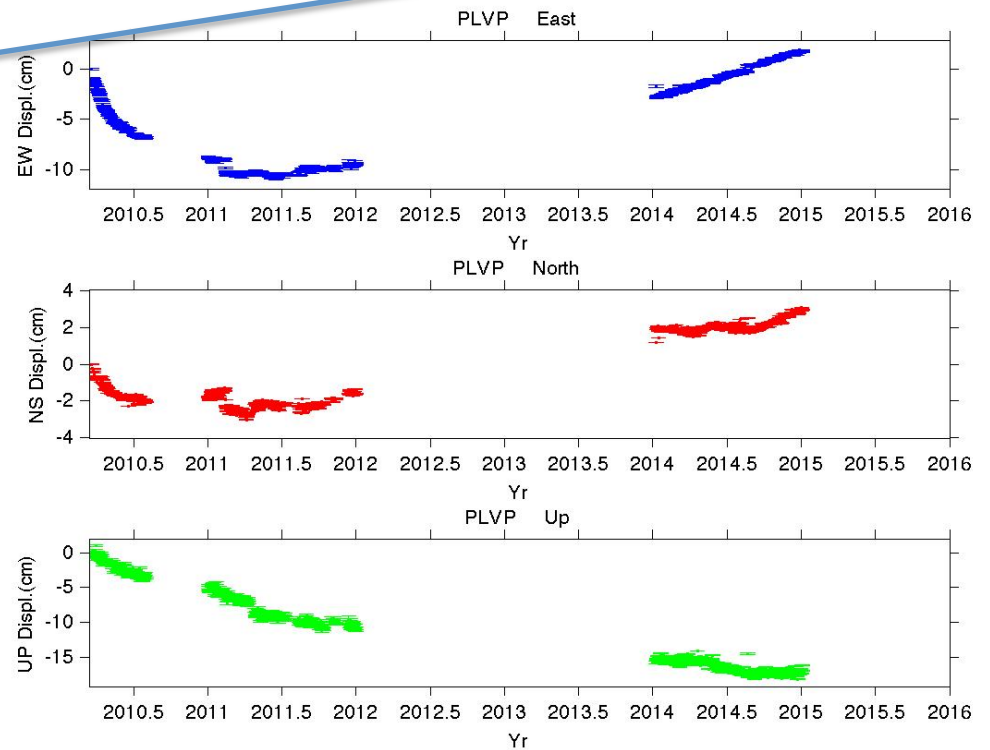
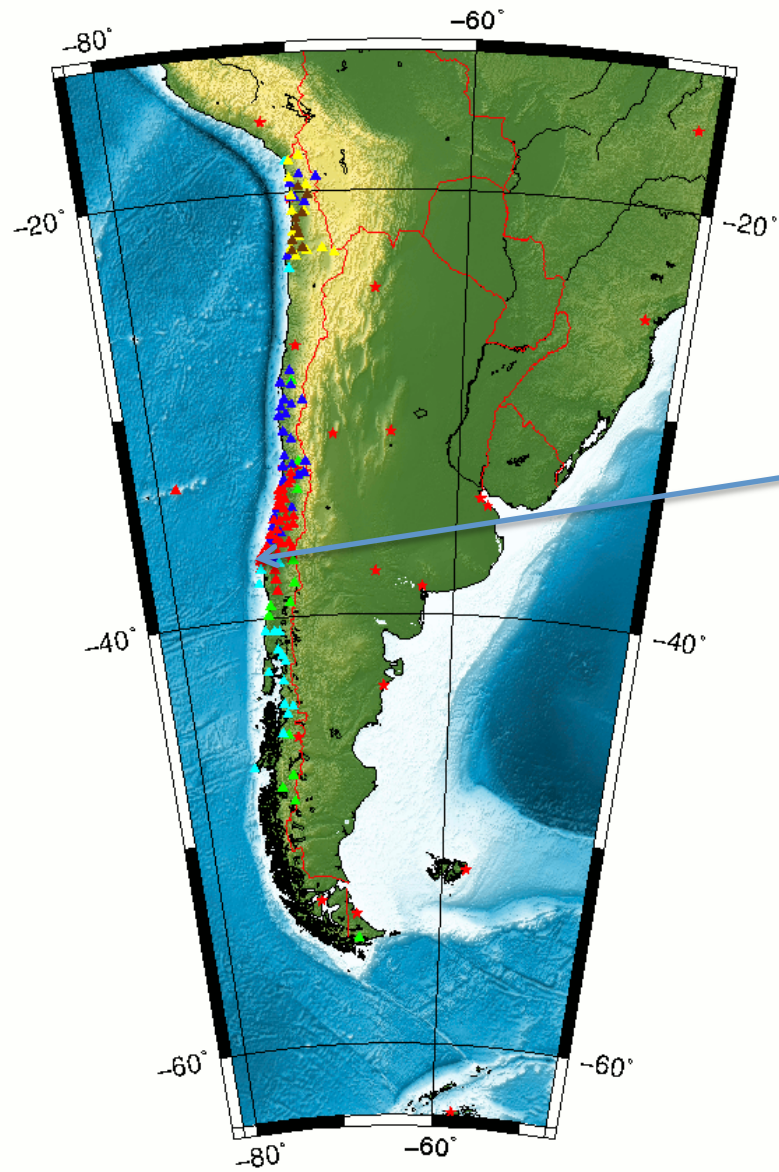
Results from Maule EQ 2010



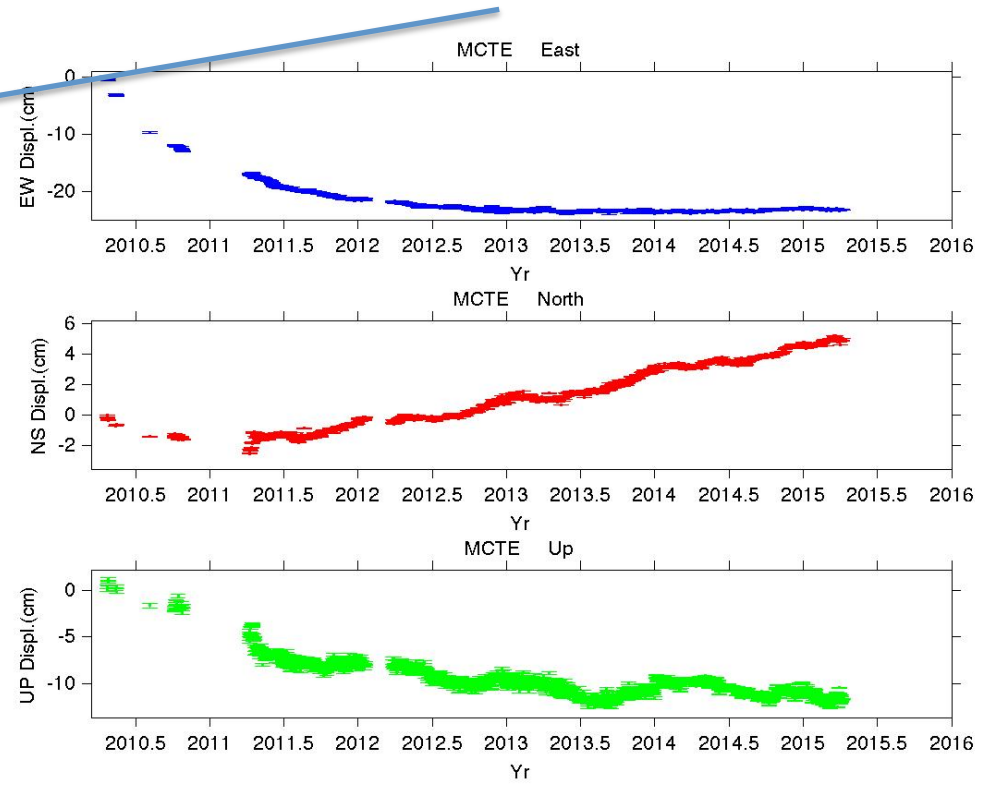
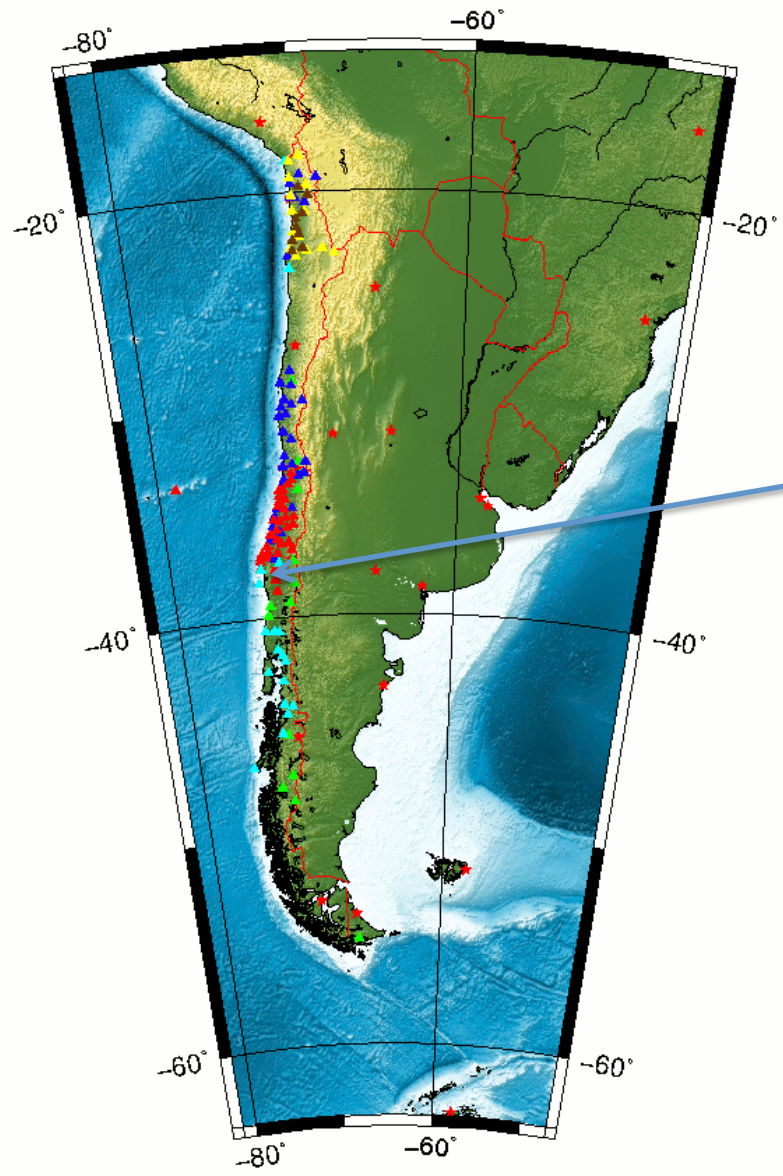
Results from Maule EQ 2010

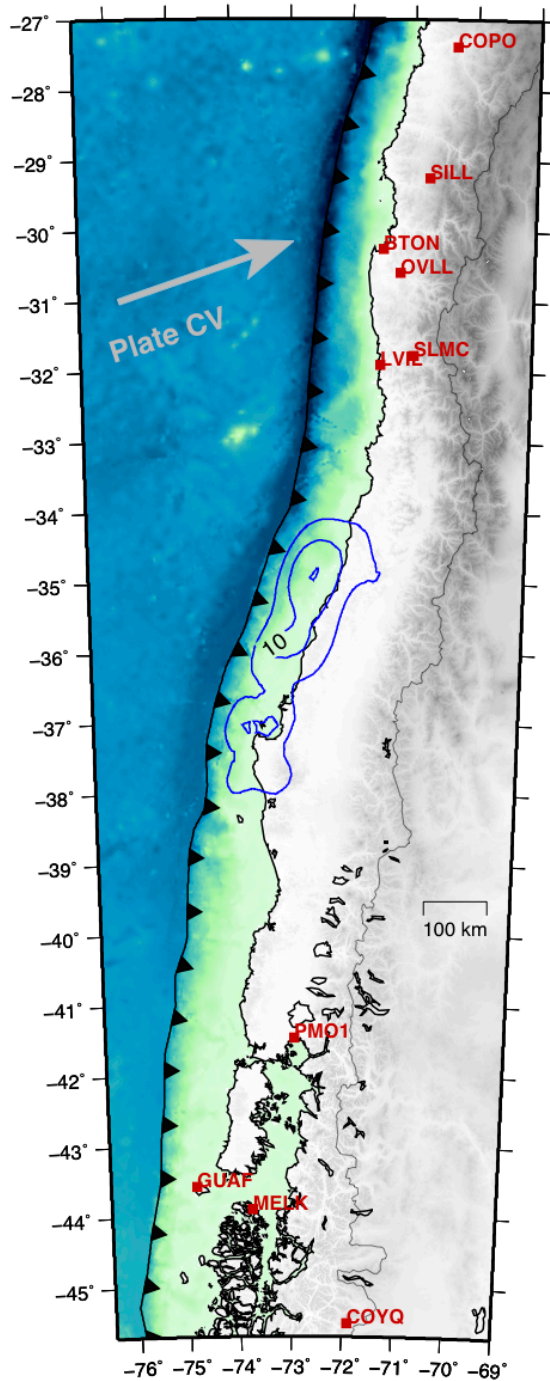


Results from Maule EQ 2010



Results from Maule EQ 2010

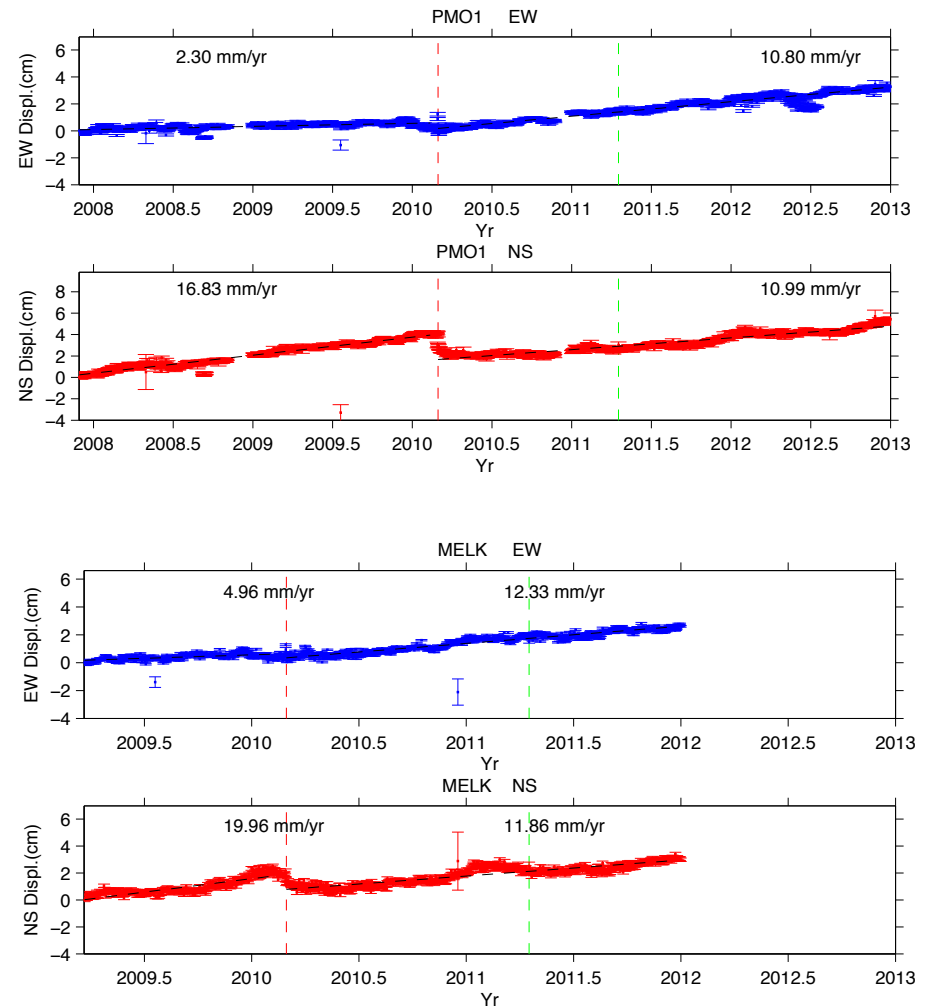
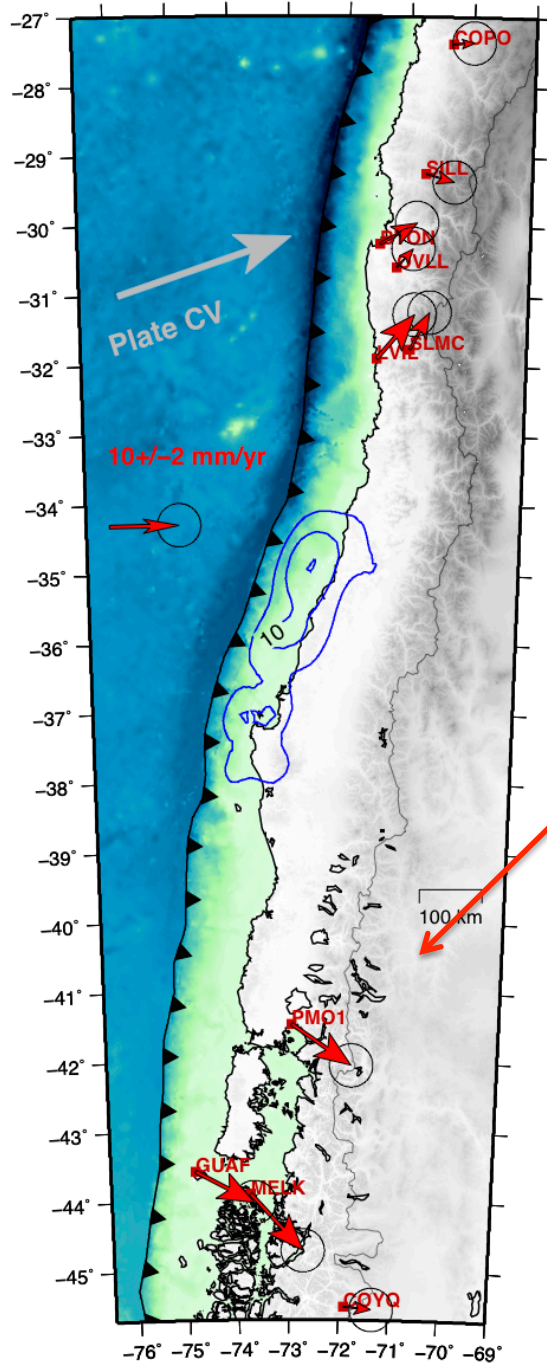




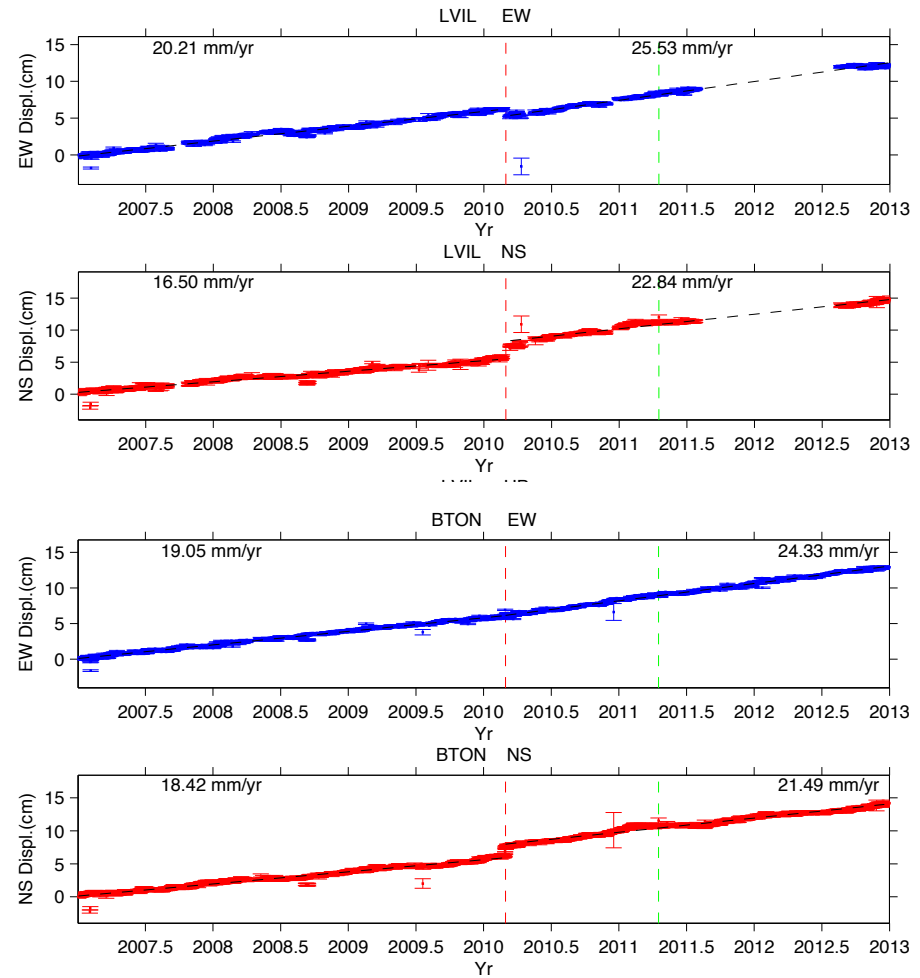
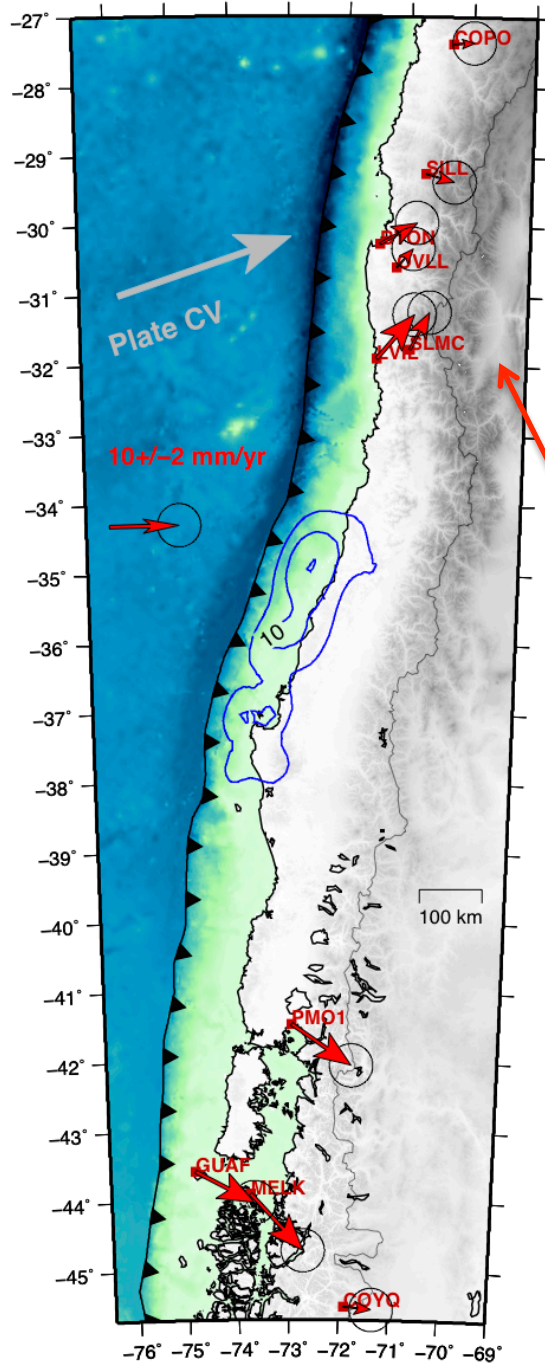
Time-series outside the Maule rupture zone

cGPS stations +700 km from Maule rupture zone

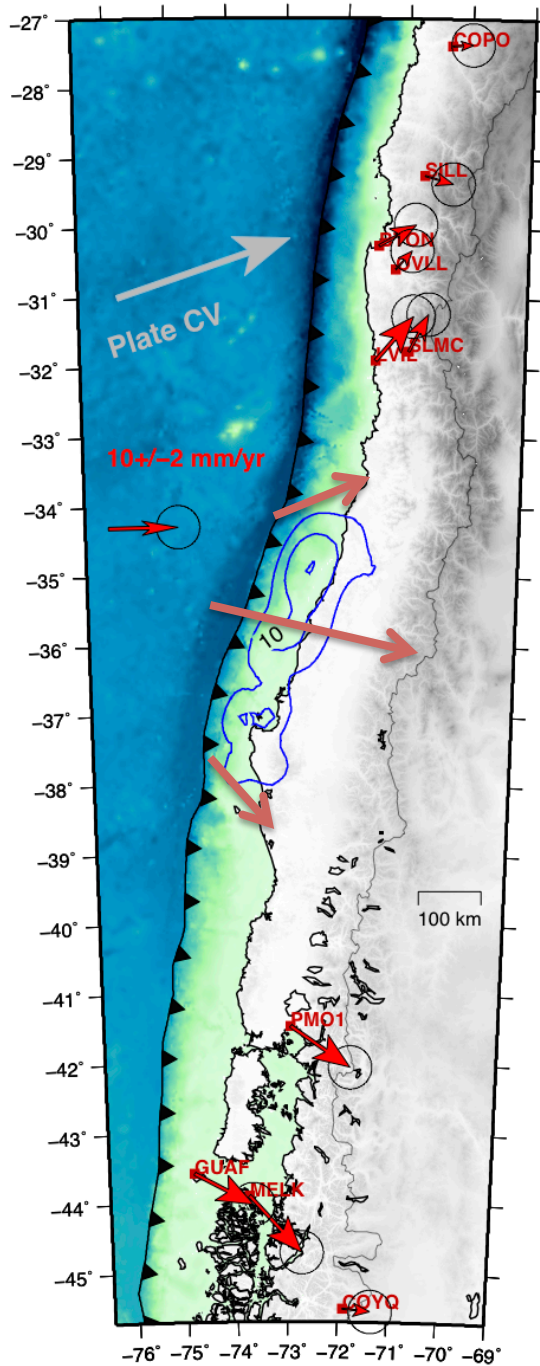
Difference before & after the Maule EQ.



Difference before & after the Maule EQ.



Difference before & after the Maule EQ.



Increase of inter-seismic velocities outside rupture area

Acceleration in the slab velocity after the Maule EQ?

Increase in locking degree at the adjacent segments?

NRT solutions

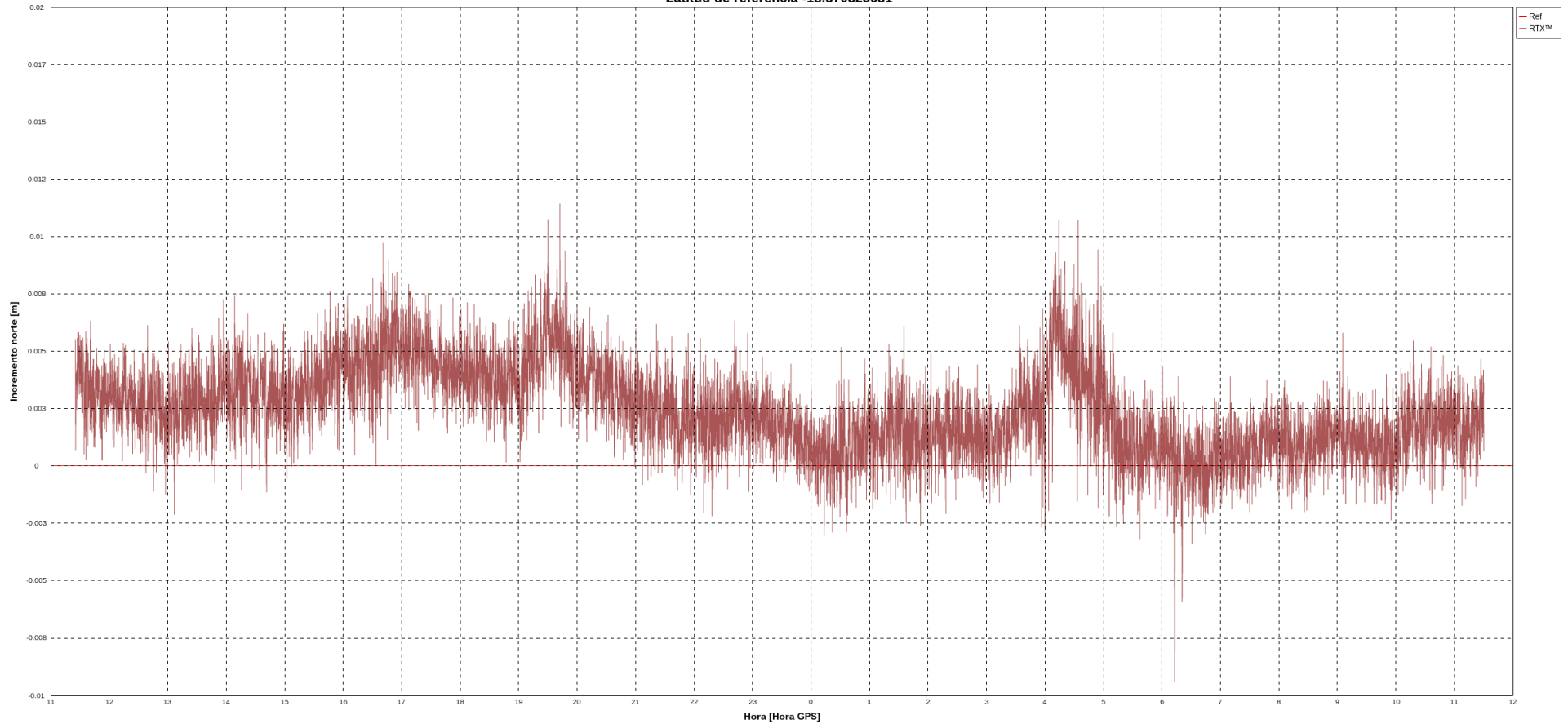


Results

NRT RTX-NMEA streaming

Cargando

Norte: $\mu=0.002$, $\sigma=0.002$ [m]
Latitud de referencia -18.370823681°

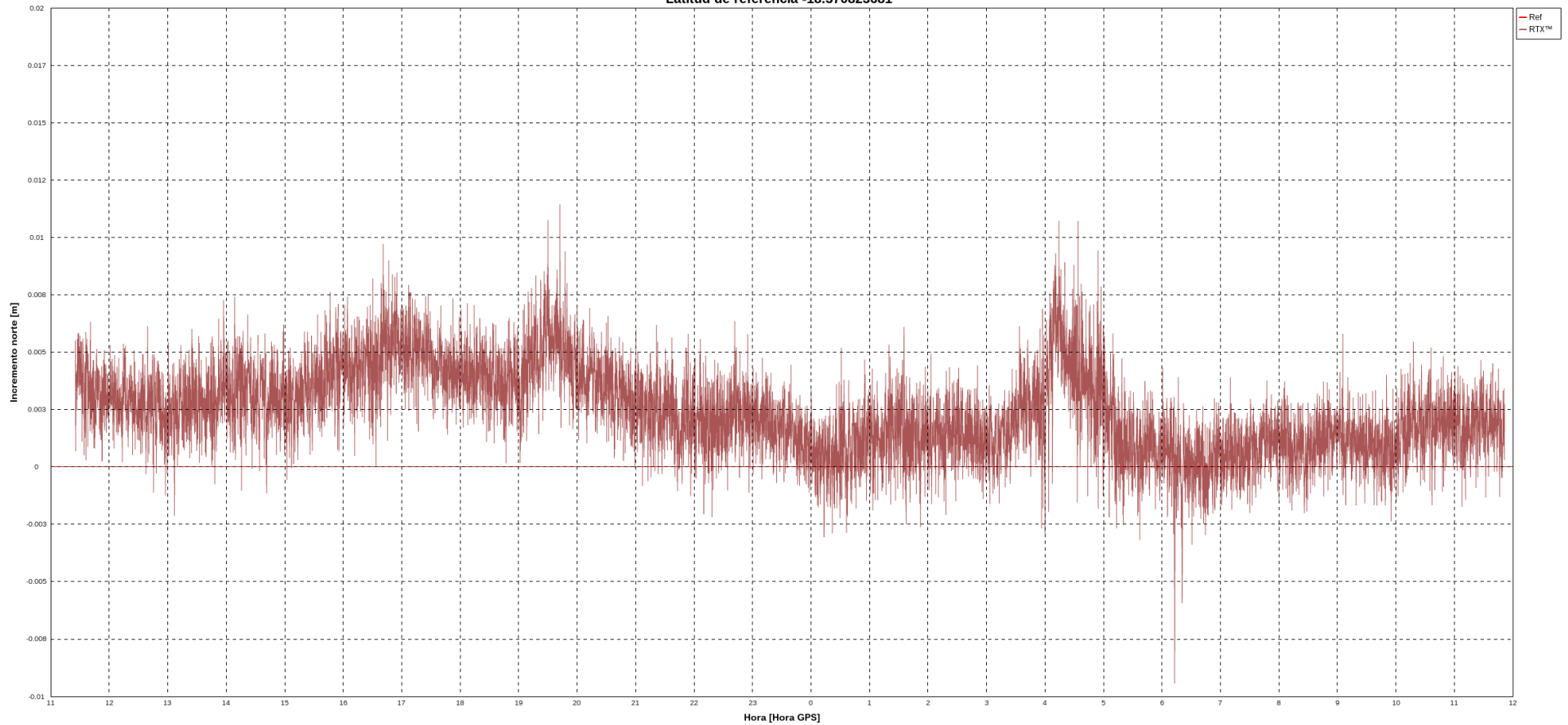


Results

NRT RTX-NMEA streaming

Cargando

Norte: $\mu=0.002$, $\sigma=0.002$ [m]
Latitud de referencia -18.370823681°



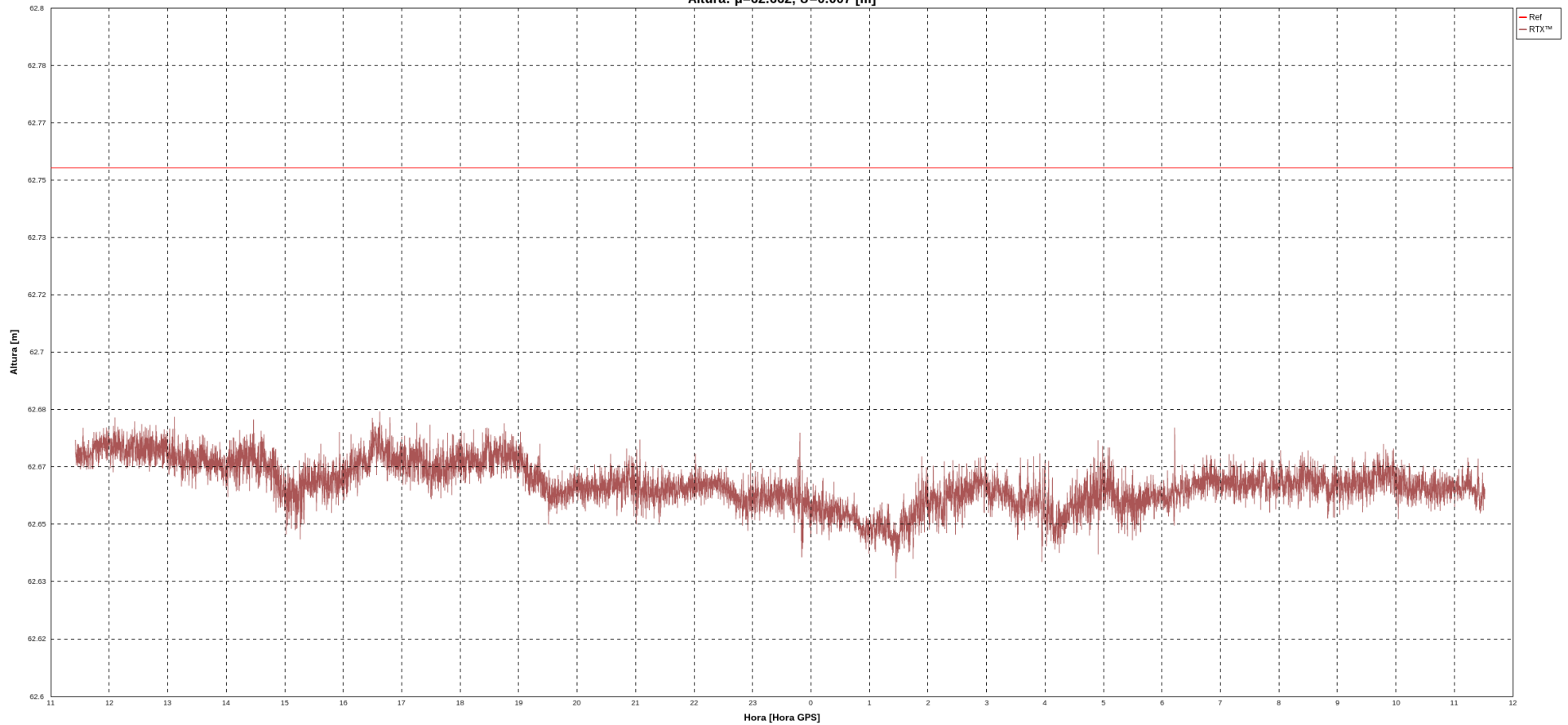
Results (5)



NRT RTX-NMEA streaming

Cargando

Altura: $\mu=62.662$, $\sigma=0.007$ [m]



Results



NRT PPP

The screenshot shows the BKG Ntrip Client (BNC) Version 2.9 interface. The main window is titled "Precise Point Positioning, Panel 2." and contains various configuration options for NRT PPP. The "Antennas" field is set to "/Users/cuentadejuancarlosbaez/Desktop/Bnc2-Mac/108.ATX". The "ANTEX File" is "TRM41249.00 NONE". The "Antenna Name" is empty. The "Basics" section has "Use phase obs" checked. The "Estimate tropo" is checked. The "Use GLONASS" is unchecked. The "Basics cont'd" section has "Sync Corr (sec)" and "Audio response (m)" fields. The "Sigmas" section has "10.0" and "100.0" values. The "XYZ Init" is "100.0". The "Phase" section has "Code" and "XYZ White Noise" (0.1) fields. The "Tropo Init" is "3e-6". The "Tropo White Noise" is empty. The "Streams" section shows a table of active streams:

Streams:	resource loader / mountpoint	decoder	lat	long	nmea	ntrip	bytes
1	kg3-dmz.gfz-potsdam.de:2101/UDECO	RTCM3.0	-37.5	-72.3	no	1	396.372 kB
2	products.igs-ip.net:2101/GS03	RTCM_3.0	50.08...	8.66458	no	1	85.578 kB
3	products.igs-ip.net:2101/RTCM3EPH	RTCM_3.0	50.08...	8.66458	no	1	747.596 kB

The bottom section of the interface shows a "Log" tab with a list of PPP data points. The data points are formatted as follows:

```
15-03-03 23:50:26 UDECO PPP 23:50:41.0 14 1537190.201 +- 0.067 -4829689.386 +- 0.035 -3859233.672 +- 0.028 NEU -0.334 -1.290 0.447
15-03-03 23:50:27 UDECO PPP 23:50:42.0 14 1537190.198 +- 0.067 -4829689.386 +- 0.035 -3859233.667 +- 0.028 NEU -0.331 -1.293 0.442
15-03-03 23:50:30 UDECO PPP 23:50:43.0 14 1537190.197 +- 0.067 -4829689.389 +- 0.035 -3859233.668 +- 0.028 NEU -0.329 -1.295 0.446
15-03-03 23:50:30 UDECO PPP 23:50:44.0 14 1537190.198 +- 0.067 -4829689.394 +- 0.035 -3859233.669 +- 0.028 NEU -0.327 -1.295 0.449
15-03-03 23:50:30 UDECO PPP 23:50:45.0 14 1537190.196 +- 0.067 -4829689.387 +- 0.035 -3859233.669 +- 0.028 NEU -0.332 -1.295 0.444
15-03-03 23:50:31 UDECO PPP 23:50:46.0 14 1537190.195 +- 0.067 -4829689.388 +- 0.035 -3859233.670 +- 0.028 NEU -0.333 -1.297 0.445
15-03-03 23:50:32 UDECO PPP 23:50:47.0 14 1537190.195 +- 0.067 -4829689.392 +- 0.035 -3859233.671 +- 0.028 NEU -0.331 -1.298 0.449
15-03-03 23:50:33 UDECO PPP 23:50:48.0 14 1537190.196 +- 0.067 -4829689.393 +- 0.035 -3859233.672 +- 0.028 NEU -0.330 -1.298 0.450
15-03-03 23:50:34 UDECO PPP 23:50:49.0 14 1537190.196 +- 0.067 -4829689.393 +- 0.035 -3859233.668 +- 0.028 NEU -0.327 -1.297 0.449
15-03-03 23:50:35 UDECO PPP 23:50:50.0 14 1537190.199 +- 0.067 -4829689.395 +- 0.035 -3859233.670 +- 0.028 NEU -0.327 -1.295 0.452
15-03-03 23:50:36 UDECO PPP 23:50:51.0 14 1537190.199 +- 0.067 -4829689.394 +- 0.035 -3859233.667 +- 0.028 NEU -0.325 -1.295 0.449
```


Results



NRT PPP

macOS window: bnc File Help | BKG Ntrip Client (BNC) Version 2.9 | 88% Mar 20:50

Network | General | RINEX Observations | RINEX Ephemeris | RINEX Editing & QC | Broadcast Corrections | Feed Engine | Serial Output | Outages | Miscellaneous | PPP (1) | **PPP (2)** | PPP (3) | Combine Corrections | Upload Corrections | Upload Ephemeris

Precise Point Positioning, Panel 2.

Antennas	/Users/cuentadejuancarlosbaez/Desktop/Bnc29-Mac/108.ATX	ANTEX File	TRM41249.00	NONE	Antenna Name				
Basics	<input checked="" type="checkbox"/>	Use phase obs	<input type="checkbox"/>	Estimate tropo	<input checked="" type="checkbox"/>	Use GLONASS	<input type="checkbox"/>	Use Galileo	<input type="checkbox"/>
Basics cont'd		Sync Corr (sec)		Averaging (min)		Quick-Start (sec)		Max Sol. Gap (sec)	
Basics cont'd		Audio response (m)		Phase		Tropo Init	3e-6	Tropo White Noise	
Sigmas	10.0	Code	0.02	XYZ White Noise	0.1				
Sigmas cont'd	100.0	XYZ Init	100.0						

Streams:	resource loader / mountpoint	decoder	lat	long	nmea	ntrip	bytes
1	kg3-dmz.gfz-potsdam.de:2101/UDEC0	RTCM3.0	-37.5	-72.3	no	1	398.74 kB
2	products.igs-ip.net:2101/IGS03	RTCM_3.0	50.08...	8.66458	no	1	86.178 kB
3	products.igs-ip.net:2101/RTCM3EPH	RTCM_3.0	50.08...	8.66458	no	1	754.332 kB

Log | Throughput | Latency | **PPP Plot**

1.20 m
0.00 m
-1.20 m

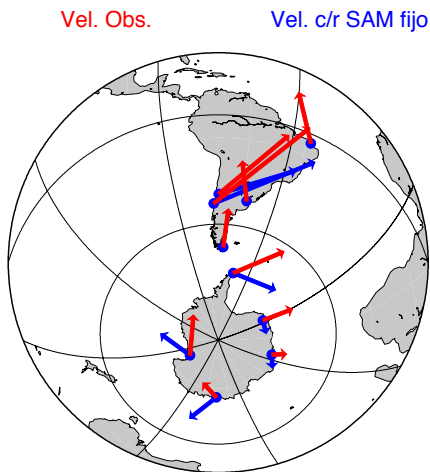
23:46 23:47 23:48 23:49 23:50

NEU UDECO Start 23:32:24

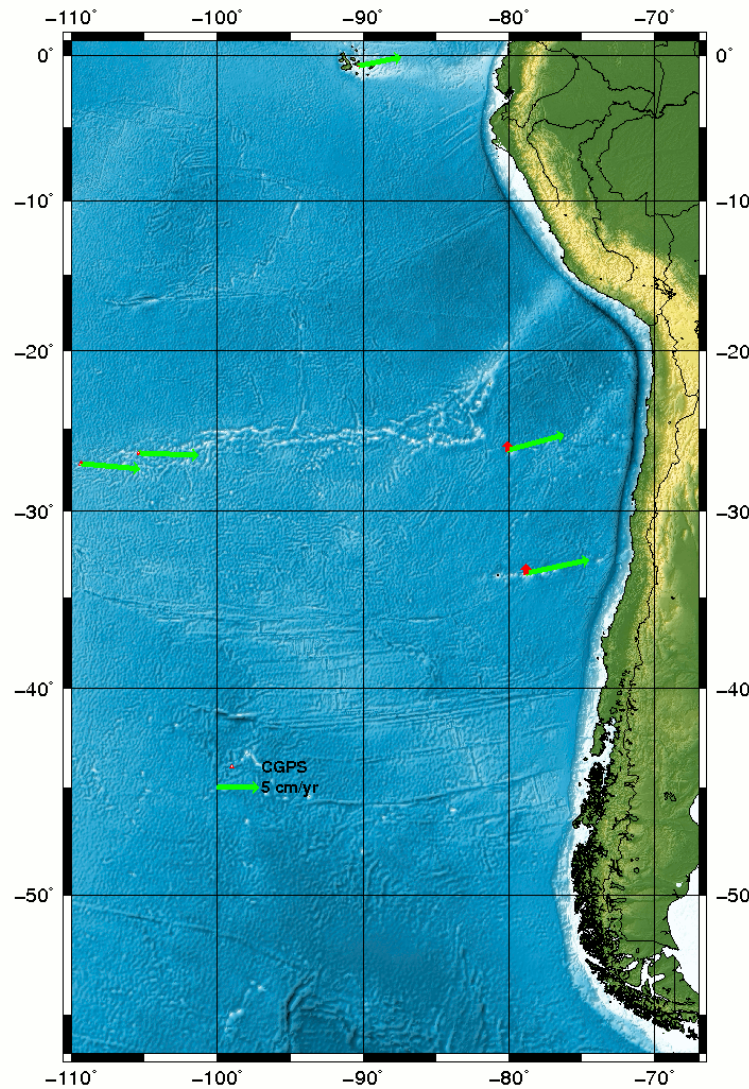
Add Stream | Delete Stream | Streams Map | Start | Stop | Help ?=Shift+F1

Results

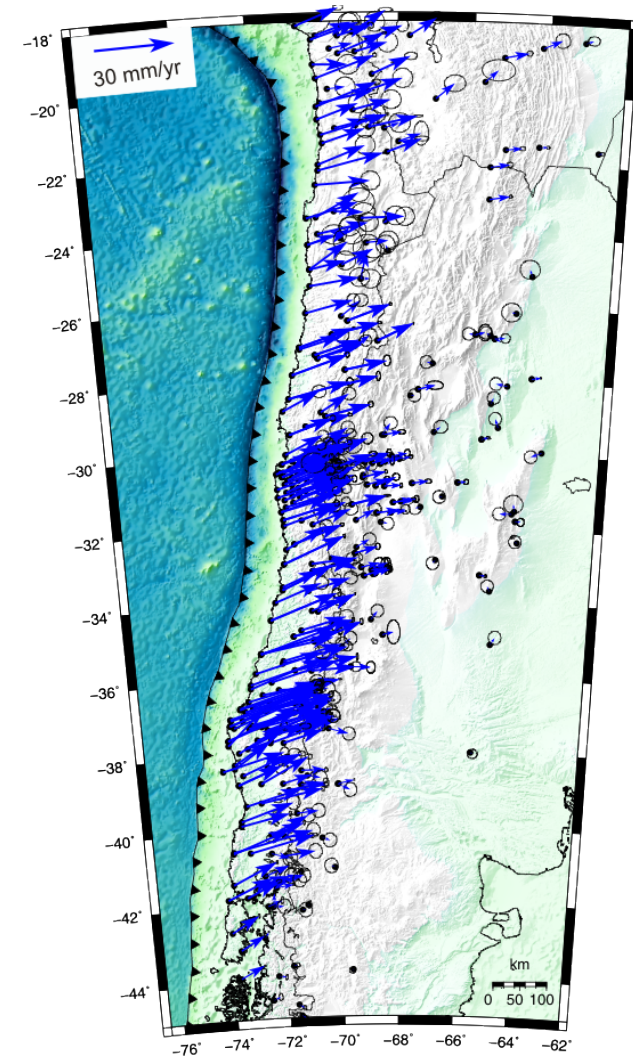
Velocities field of Nazca plate locking rate deficiency



Báez & Bataille 2006

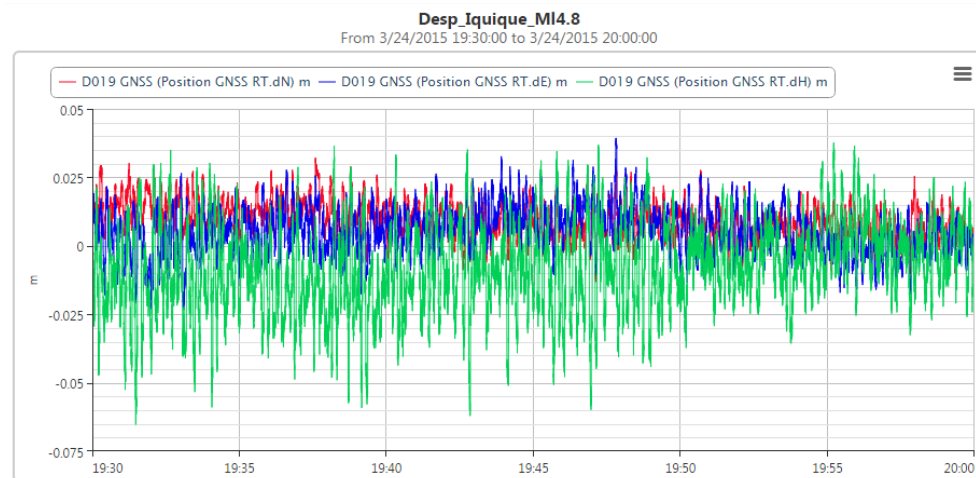
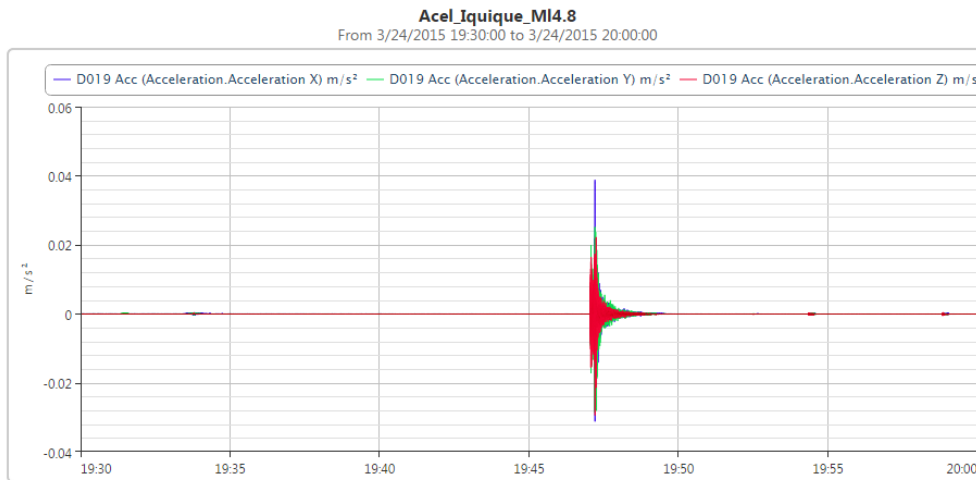


Baez et al 2015 (in preparation)



Results

Acceleration v/s displacement



We have displacement from GNSS and we integrate acceleration to correct displacement measurements Applying Kalman Filtering

(data from Trimble SG160-09)

Final Remarks

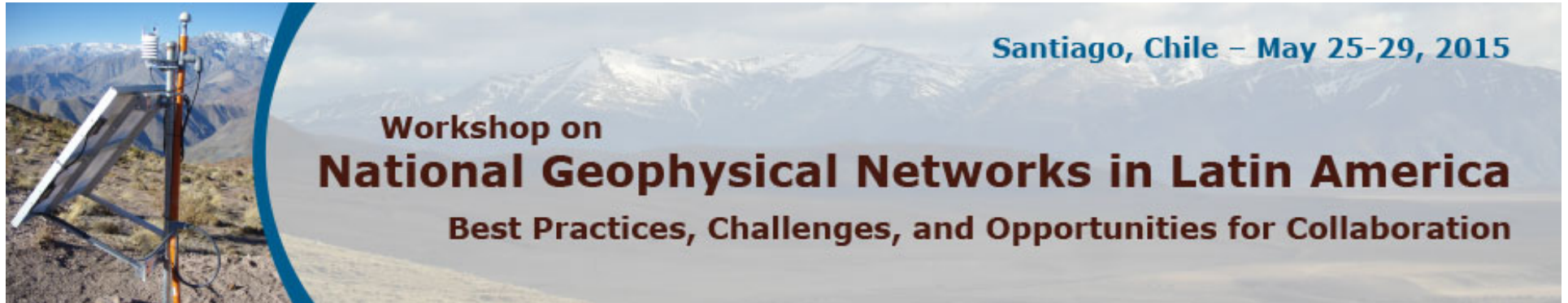


- Network need to be re-designed for EW
- Good communications are still the key of the system
- Redundancy of the system for NRT are strongly necessary (RTX – PPP)
- Filter applications is necessary for false-positive detections
- We need to implement our own software application to eliminate external dependencies
- Integrations of multi-sensor observations are our next step

Thanks to



Thanks you!!!!



Chile National Net: Geodetic Overview

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