IGM
INSTITUTO GEOGRÁFICO MILITAR
Cartografía Oficial del Estado de Chile

SURFACE DEFORMATIONS ANALYSIS THROUGH GNSS TECHNOLOGY CHILE 02-27-2010

Friday, May 17, 2013

Content

Introduction

Seismic cycle

Use of GPS technology

Chile Feb 27 2010

Conclusions

Objective

Explore the different uses of the GNSS system beyond high accuracy positioning.

How GNSS data is used to study all the phenomena related to the occurrence of major earthquakes, and how the products obtained from this analysis helps to better understand them.

Introduction

1906 San Francisco earthquake (Reid 1910).

Basis of the seismic cycle.

Study and understanding the seismic cycle could lead to a way to predict them.

SEISMIC CYCLE

Describes the interaction of tectonic plates in 4 different stages (deformations).

Involves all the physical phenomena that take place between 2 consecutive major earthquakes (M>6)

Co-seismic

Post-seismic

Inter-seismic

Pre-seismic

Co-seismic stage

The release of the accumulated energy during the earthquake.

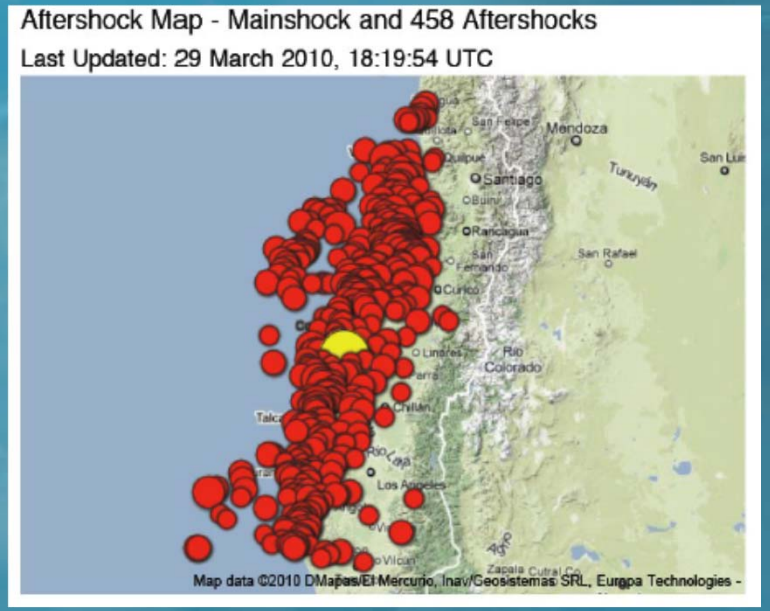
The major deformations take place during this time.

Post-seismic stage

Is the stage that follows.

All the aftershocks take place during this stage

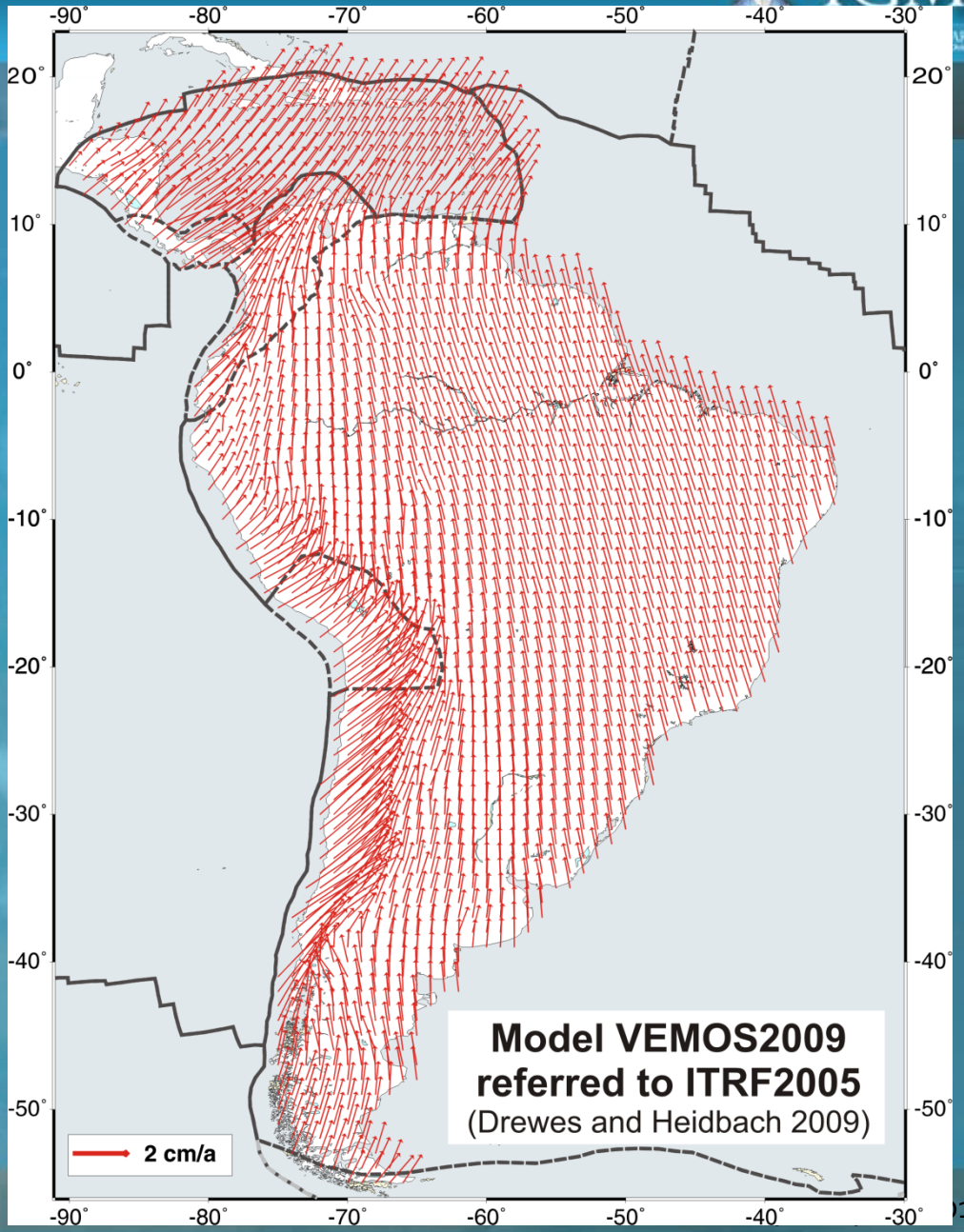
Can last from a month to a couple of years.



Inter-seismic stage

Corresponds to the slow accumulation of energy.

Is 90% of all of the seismic cycle.

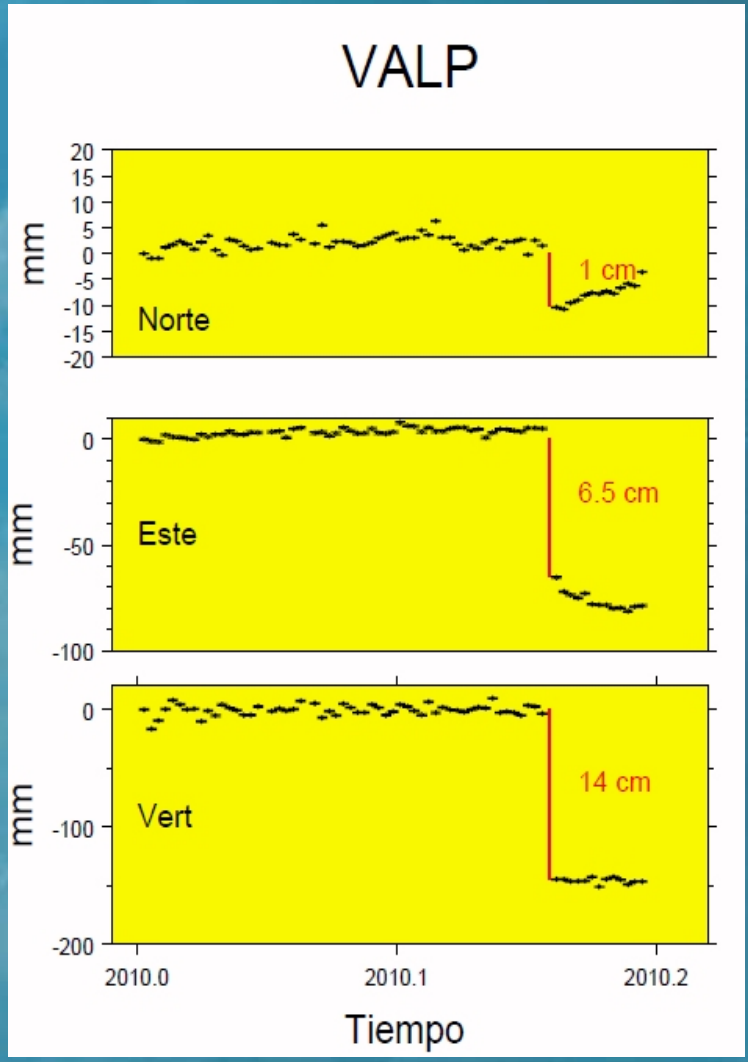


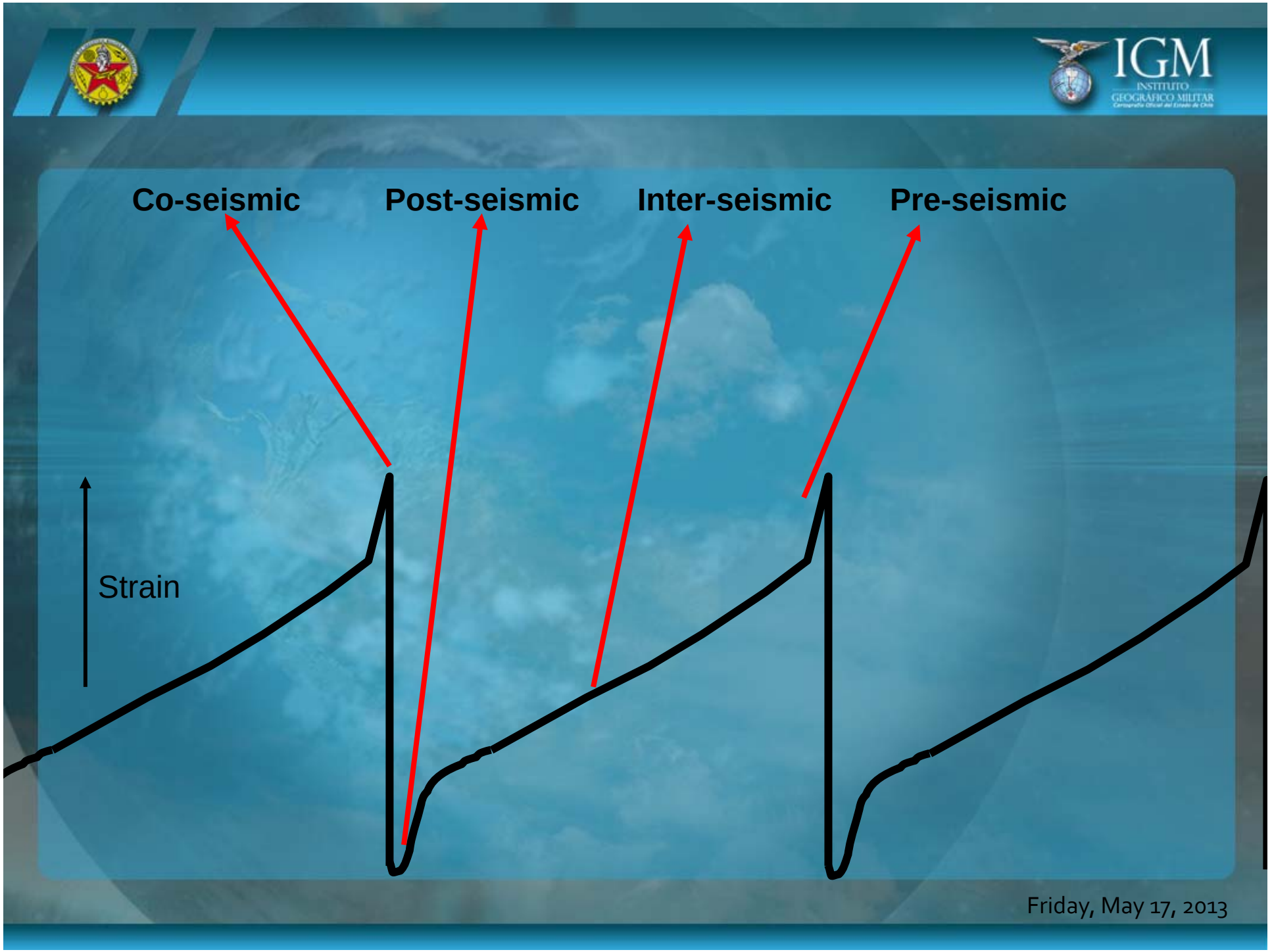
Pre-seismic stage

Strange or unusual behavior before the next Co-seismic stage.

Slow or fast deformation.

Increase in the seismicity.




Co-seismic
Post-seismic
Inter-seismic
Pre-seismic
Strain

Use of GNSS technology

The study of surface deformations related to the seismic cycle requires high precision metrology, in order to measure very small deformations over very large areas, specially in the Inter-seismic stage.

Even though there are other systems that can also be used for this purpose, GPS is almost the only one used due to costs, transportability and energy reasons.

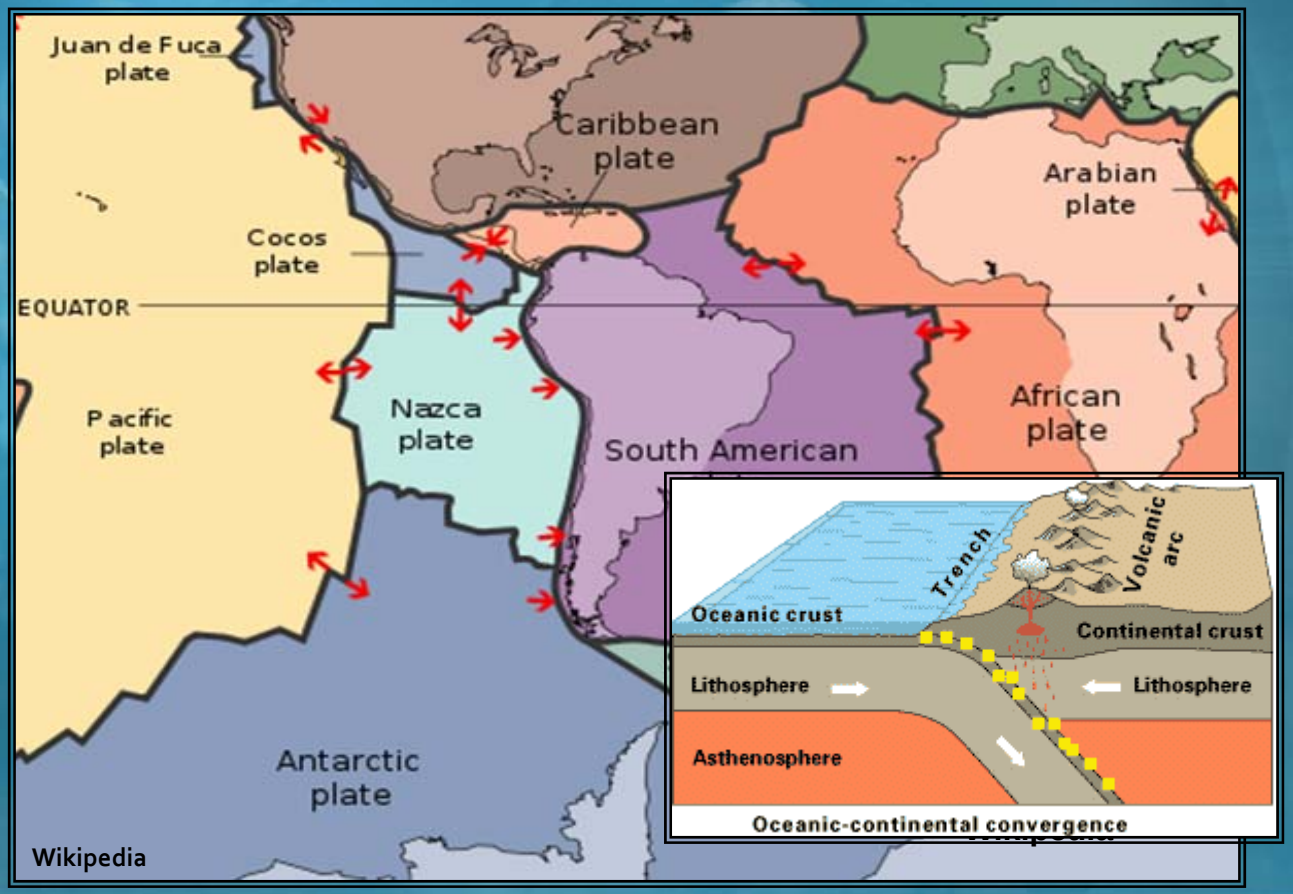
Measure ➡ Displacement

Where ➡ Chile

When?

Chile Feb 27 2010

Geographical and tectonic situation



Chile Feb 27 2010

Geodetic situation – Reference frame

Sirgas-Chile

Datum ITRF2000 epoch 2002.0

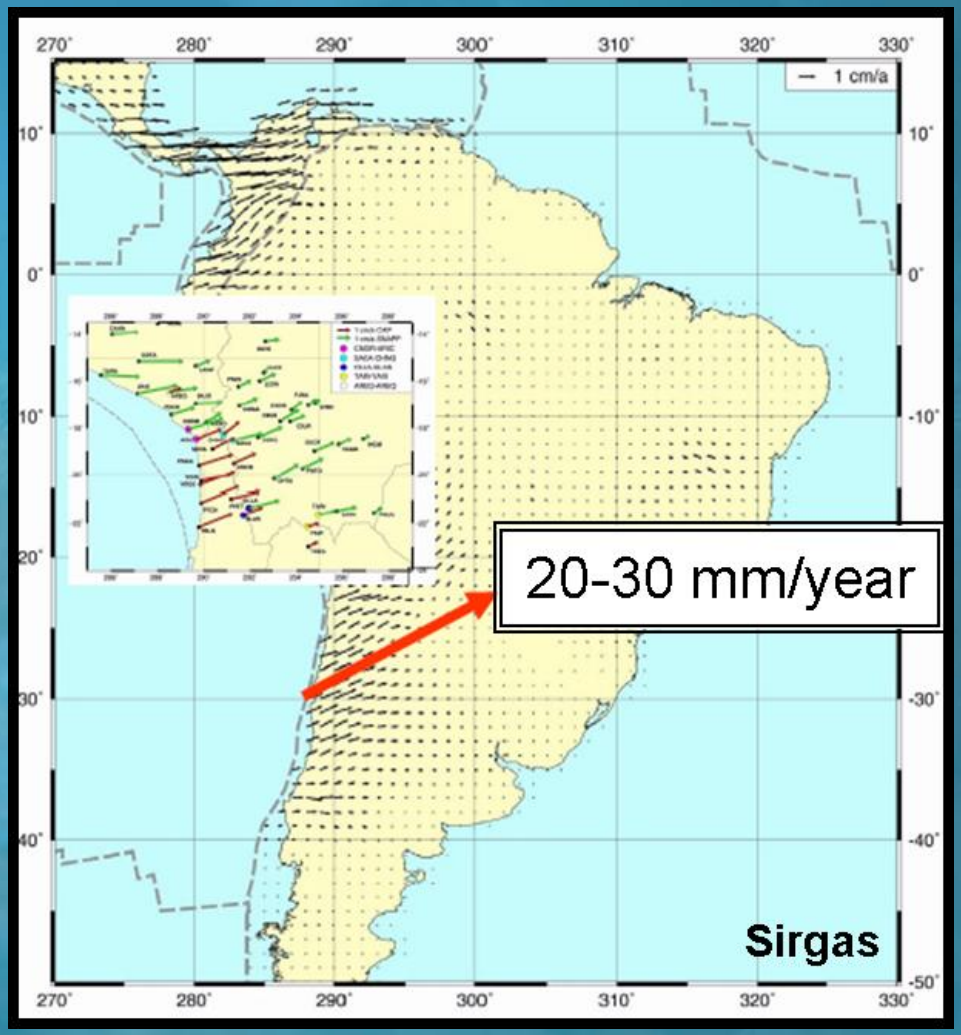
Ellipsoid GRS80

22 CGPS

680 land marks

Chile Feb 27 2010

Inter-seismic stage situation



Chile Feb 27 2010

Feb. 27 2010 03:34 hr

Increment of CGPS

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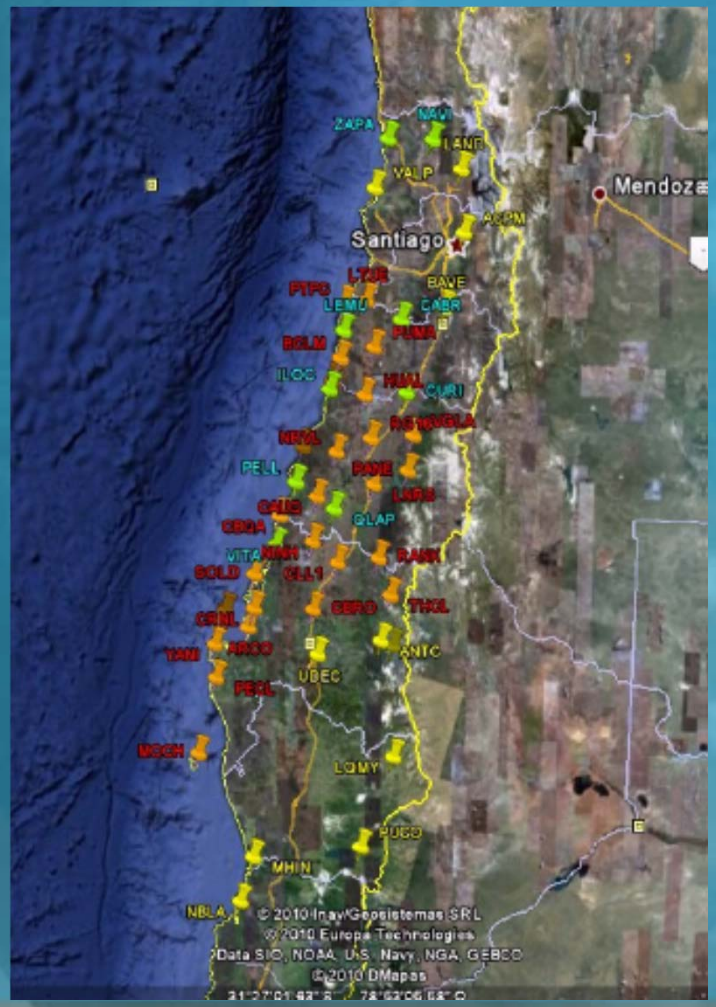


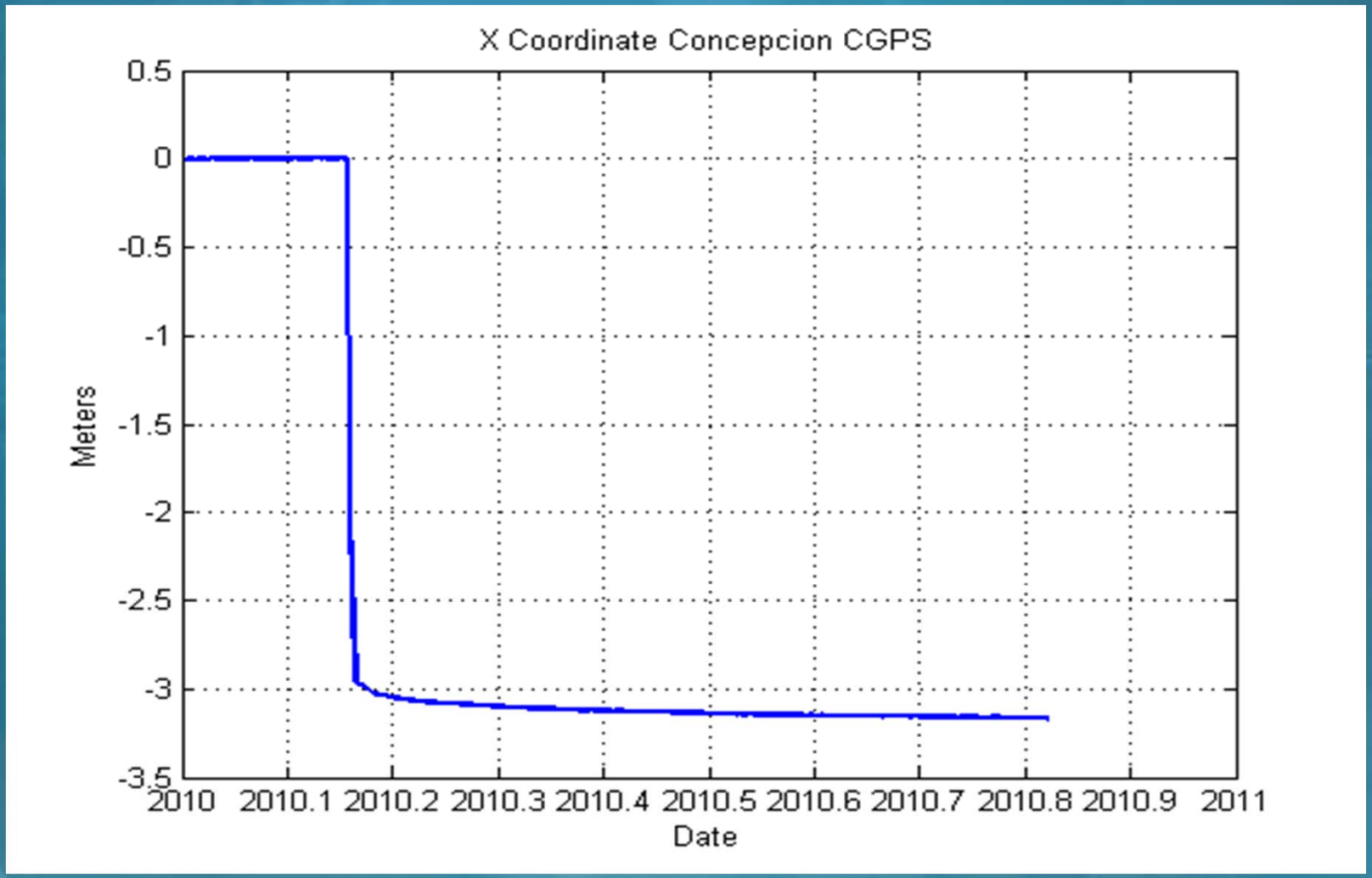
IGM-CAP 11 (Pre- EQ)

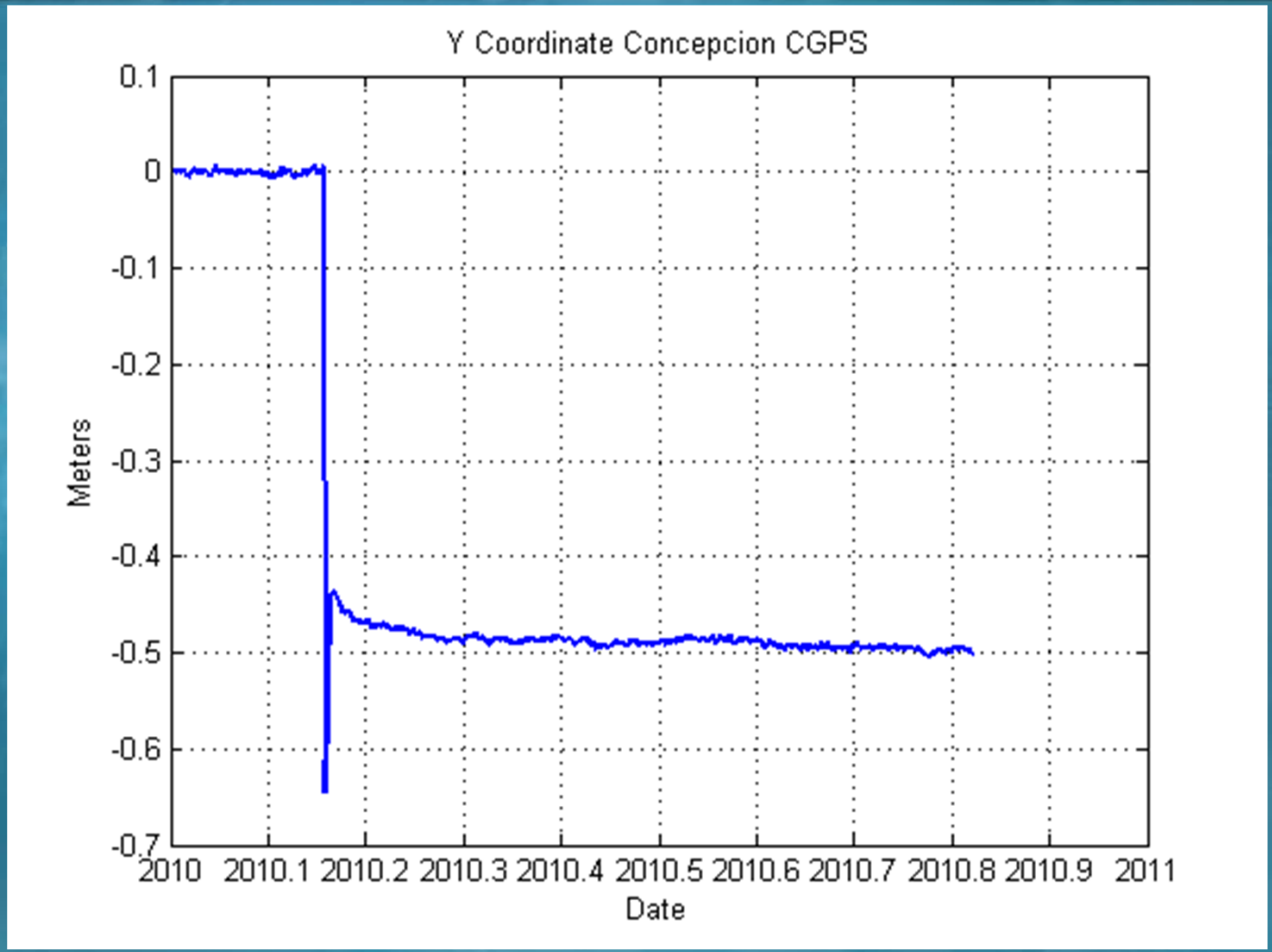
IGM-CAP 39 (Pos-Eq)

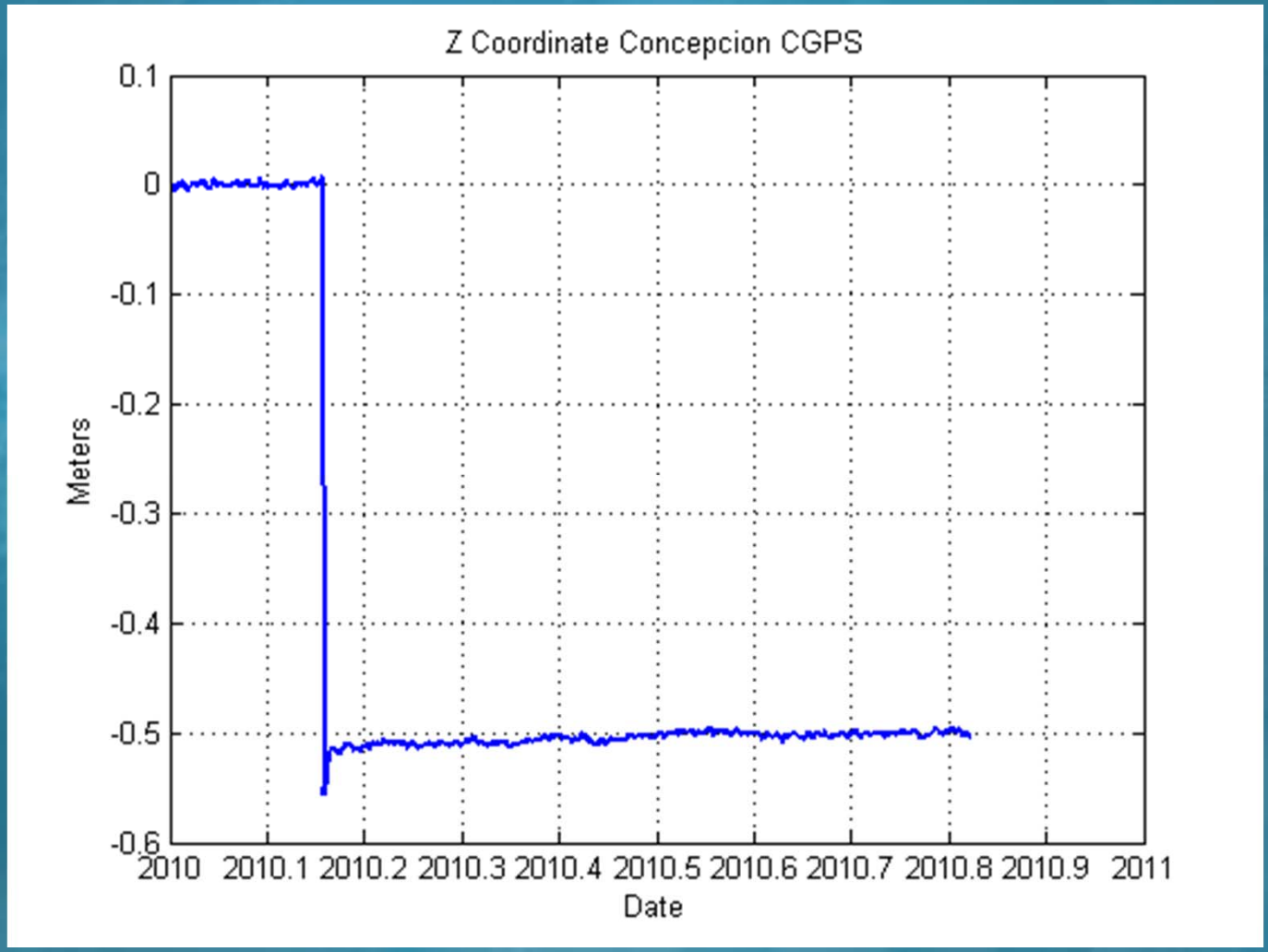
France 9 (Pos-Eq)

GPS Products

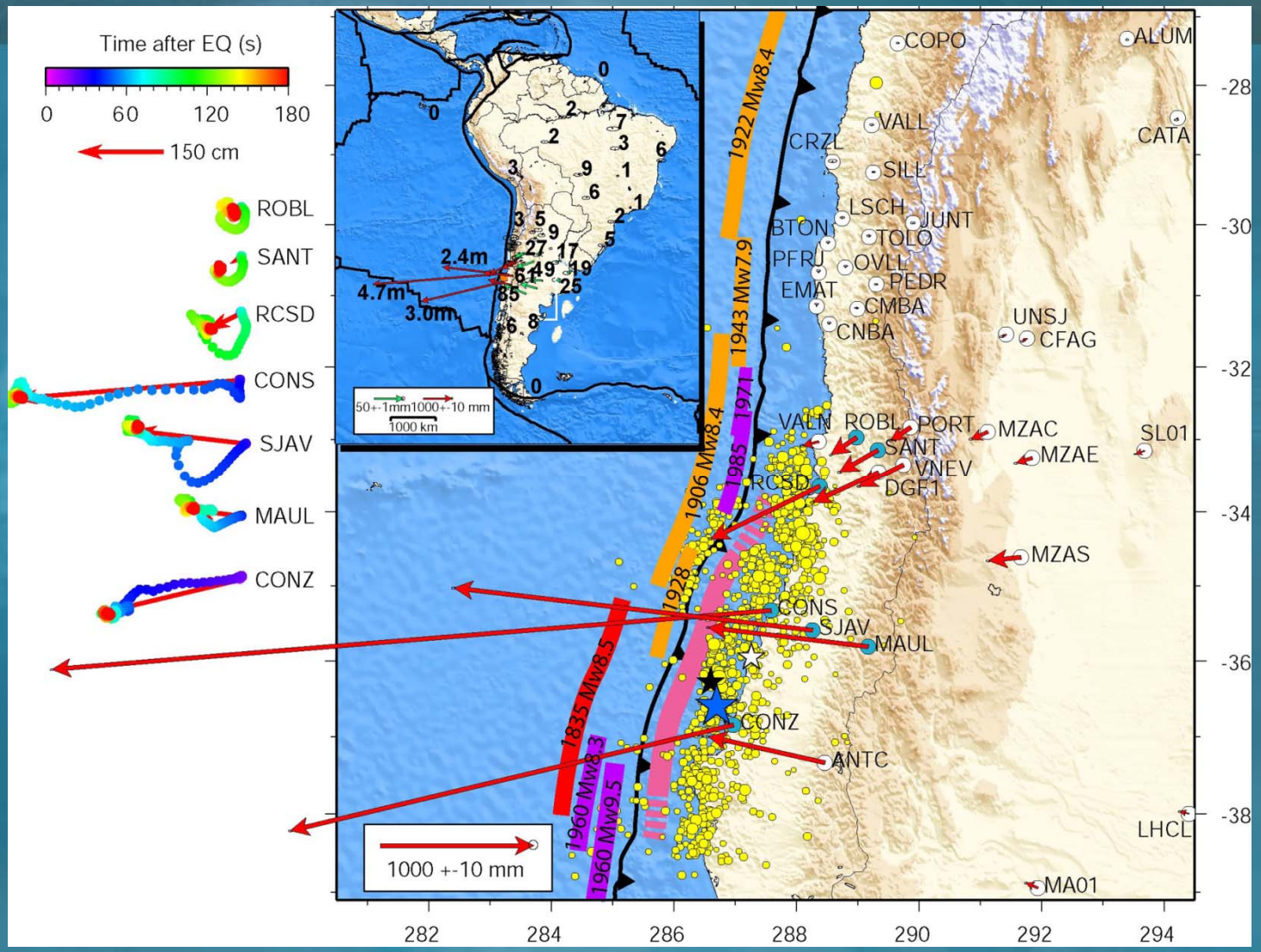
2010.0027	2010	1	1537193.27640	0.0006	-4829688.42260	0.0001	-3859233.51840	0.0006
2010.0055	2010	2	1537193.27530	0.0006	-4829688.42380	0.0001	-3859233.51970	0.0006
2010.0082	2010	3	1537193.27350	0.0007	-4829688.41890	0.0001	-3859233.51550	0.0007
2010.011	2010	4	1537193.27430	0.0007	-4829688.41960	0.0001	-3859233.51590	0.0007
2010.0137	2010	5	1537193.27410	0.0007	-4829688.41830	0.0002	-3859233.51290	0.0007
2010.0164	2010	6	1537193.27450	0.0007	-4829688.42000	0.0001	-3859233.51470	0.0007
2010.0192	2010	7	1537193.27550	0.0006	-4829688.42650	0.0001	-3859233.51880	0.0006
2010.0219	2010	8	1537193.27420	0.0007	-4829688.42000	0.0001	-3859233.51530	0.0007
2010.0246	2010	9	1537193.27490	0.0007	-4829688.42110	0.0001	-3859233.51610	0.0007
2010.0274	2010	10	1537193.27340	0.0007	-4829688.41930	0.0001	-3859233.51560	0.0007
2010.0301	2010	11	1537193.27520	0.0008	-4829688.41610	0.0002	-3859233.51540	0.0008
2010.0329	2010	12	1537193.27270	0.0007	-4829688.41120	0.0002	-3859233.50940	0.0007
2010.0356	2010	13	1537193.27750	0.0007	-4829688.42070	0.0001	-3859233.51530	0.0007
2010.0383	2010	14	1537193.27500	0.0001	-4829688.41790	0.0003	-3859233.51460	0.0001
2010.0411	2010	15	1537193.27420	0.0007	-4829688.41720	0.0001	-3859233.51340	0.0007
2010.0438	2010	16	1537193.27560	0.0007	-4829688.41840	0.0001	-3859233.51460	0.0007
2010.0465	2010	17	1537193.27420	0.0006	-4829688.41770	0.0001	-3859233.51500	0.0006
2010.0493	2010	18	1537193.27610	0.0007	-4829688.41970	0.0001	-3859233.51600	0.0007
2010.052	2010	19	1537193.27610	0.0006	-4829688.41740	0.0001	-3859233.51330	0.0006
2010.0548	2010	20	1537193.27800	0.0007	-4829688.42060	0.0001	-3859233.51680	0.0007
2010.0575	2010	21	1537193.27700	0.0007	-4829688.42090	0.0001	-3859233.51480	0.0007
2010.0602	2010	22	1537193.27710	0.0006	-4829688.42240	0.0001	-3859233.51730	0.0006
2010.063	2010	23	1537193.27660	0.0006	-4829688.42070	0.0001	-3859233.51580	0.0006
2010.0657	2010	24	1537193.27580	0.0007	-4829688.41840	0.0001	-3859233.51450	0.0007
2010.0684	2010	25	1537193.27400	0.0007	-4829688.41330	0.0001	-3859233.51100	0.0007
2010.0712	2010	26	1537193.27550	0.0007	-4829688.41870	0.0002	-3859233.51570	0.0007
2010.0739	2010	27	1537193.27800	0.0007	-4829688.41930	0.0002	-3859233.51220	0.0007
2010.0767	2010	28	1537193.27200	0.0007	-4829688.41720	0.0002	-3859233.50970	0.0007
2010.0794	2010	29	1537193.27480	0.0007	-4829688.41720	0.0001	-3859233.51440	0.0007
2010.0821	2010	30	1537193.27800	0.0007	-4829688.41820	0.0001	-3859233.51400	0.0007
2010.0849	2010	31	1537193.27560	0.0006	-4829688.41920	0.0001	-3859233.51520	0.0006
2010.0876	2010	32	1537193.27490	0.0007	-4829688.42070	0.0001	-3859233.51560	0.0007


X Coordinate Concepcion CGPS
Meters
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
2010
2010.1
2010.2
2010.3
2010.4
2010.5
2010.6
2010.7
2010.8
2010.9
2011
Date


Y Coordinate Concepcion CGPS
Meters
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
2010
2010.1
2010.2
2010.3
2010.4
2010.5
2010.6
2010.7
2010.8
2010.9
2011
Date


Z Coordinate Concepcion CGPS
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Meters
2010
2010.1
2010.2
2010.3
2010.4
2010.5
2010.6
2010.7
2010.8
2010.9
2011
Date

General View Cose-ismic displacement



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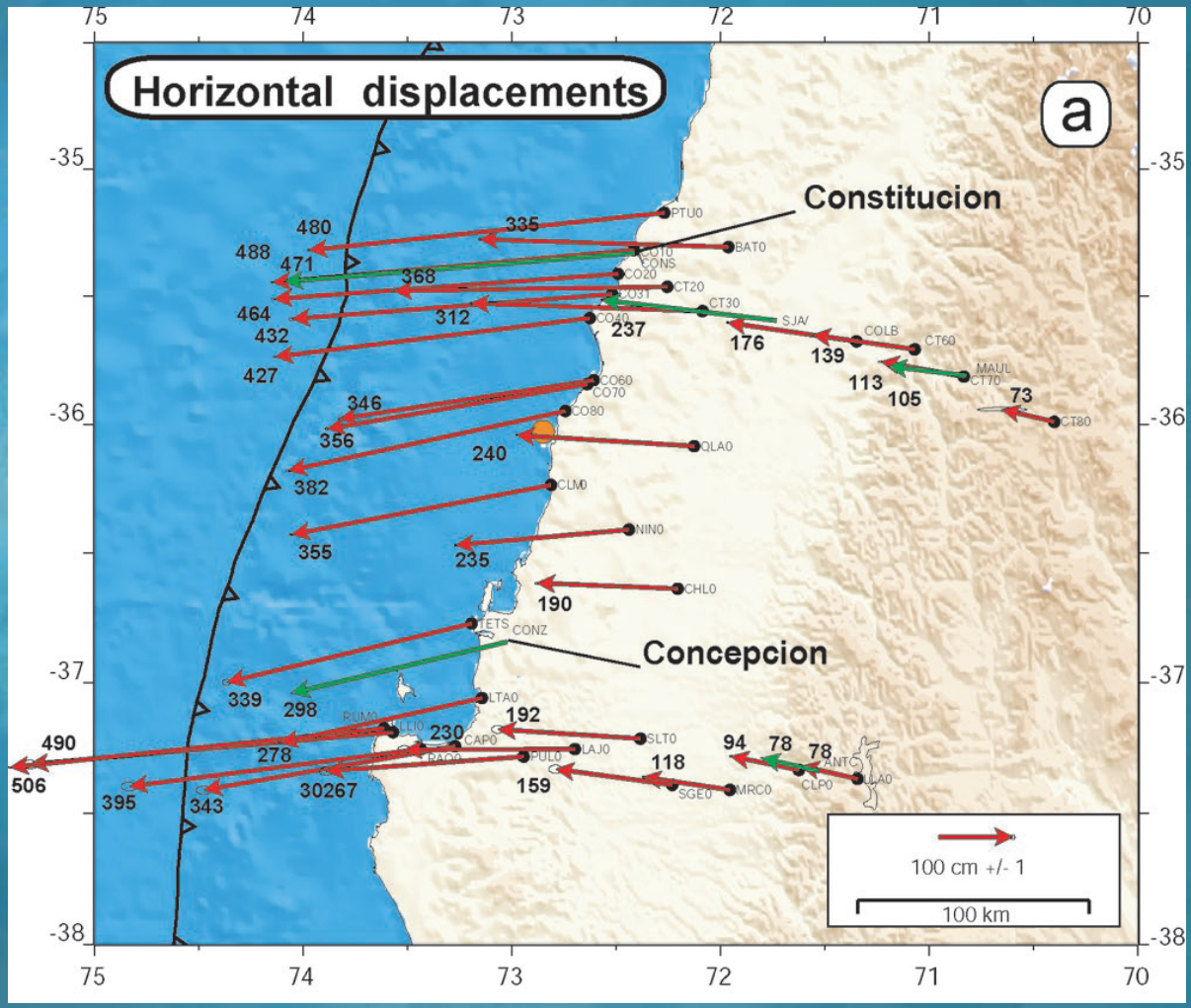
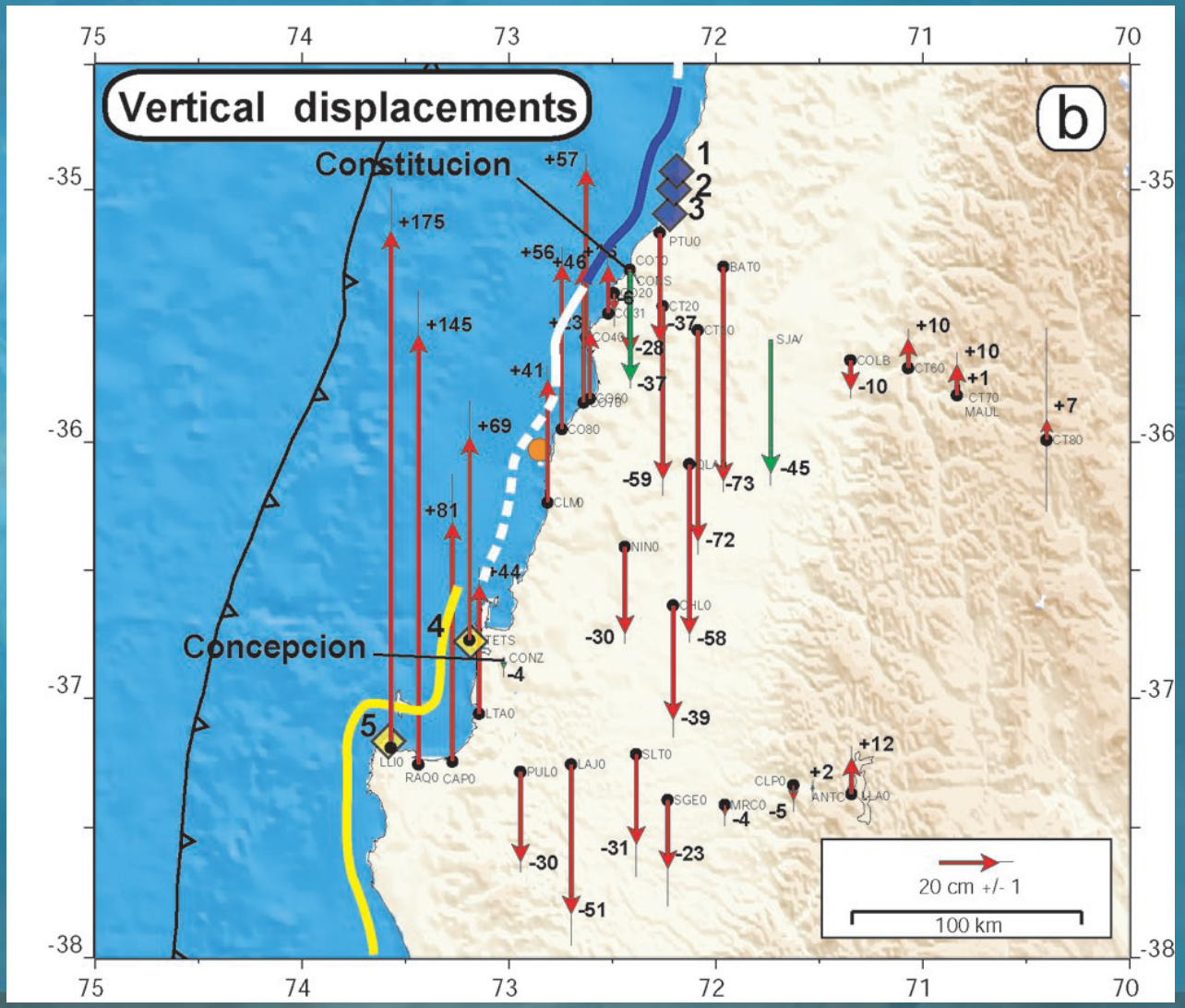
Co-seismic displacement



Co-seismic displacement



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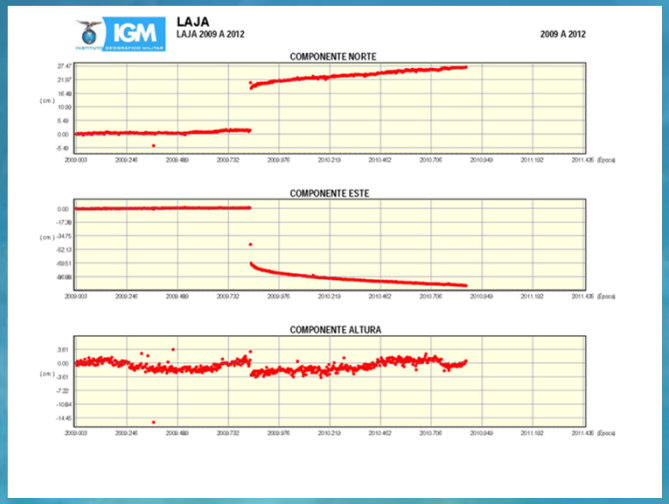
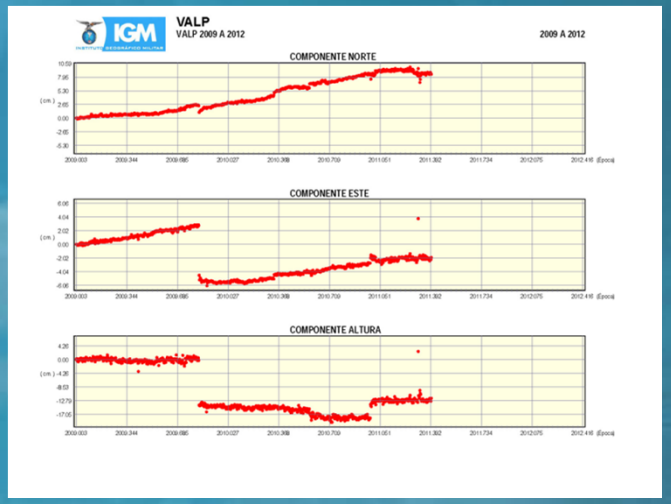
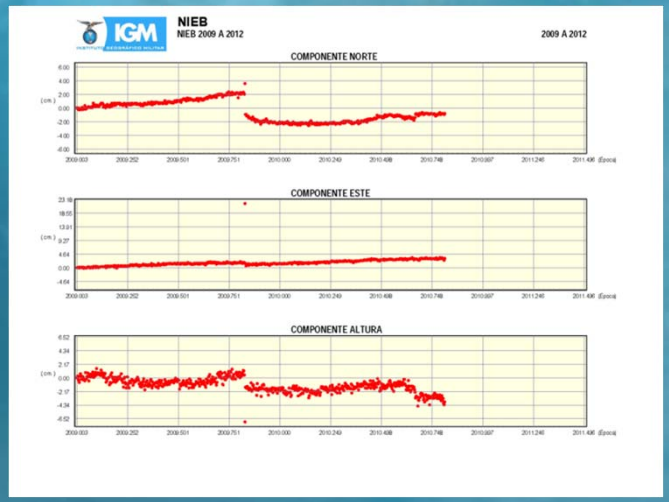
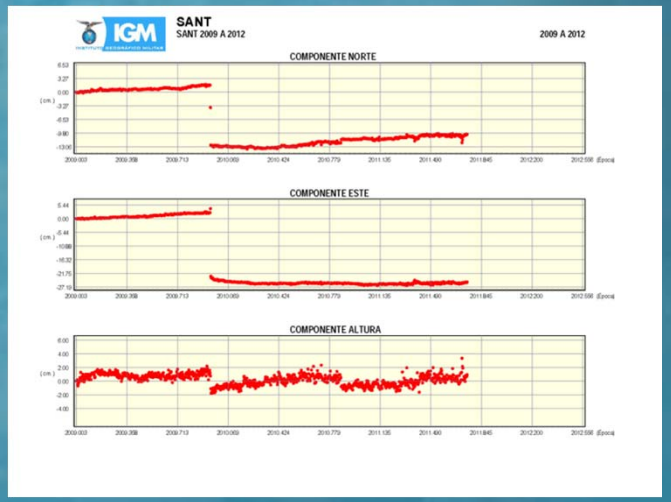
Post-seismic stage

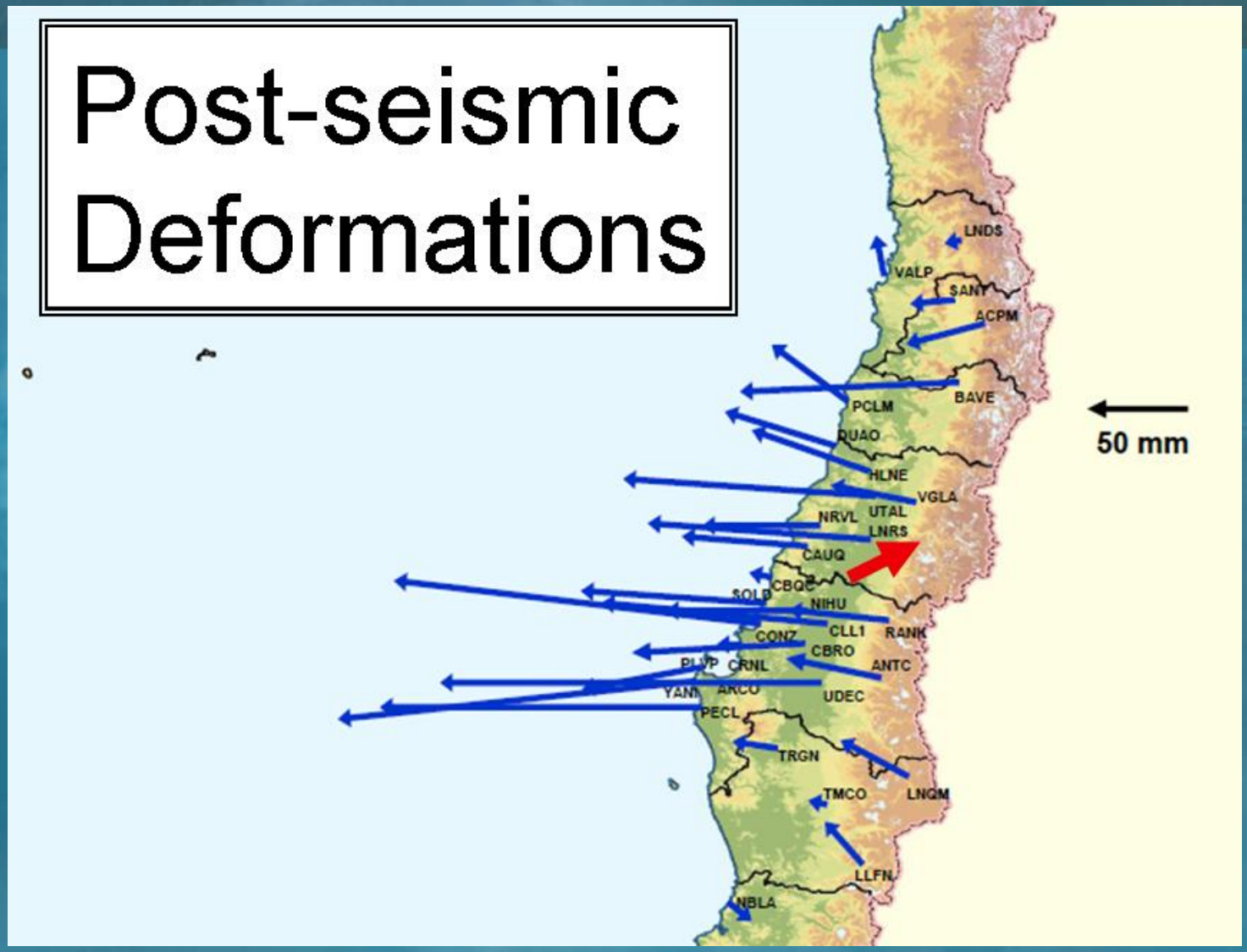






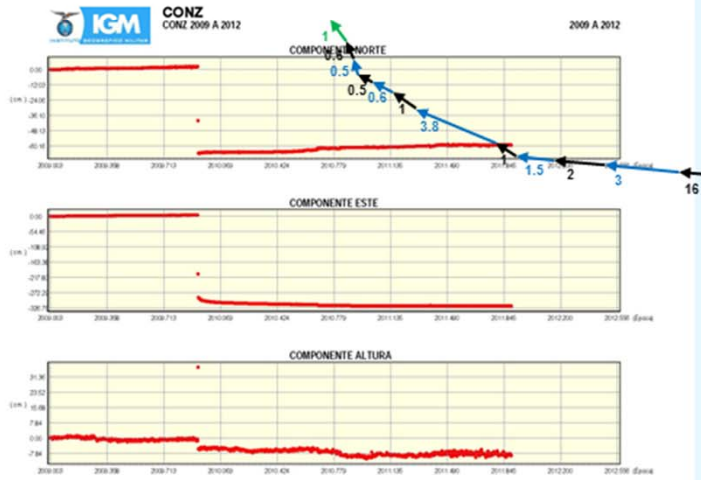


Post-seismic Deformations



CONZ (Concepción)

Mar 2010 - 2012



Co-sísmico: 303,9 cms.

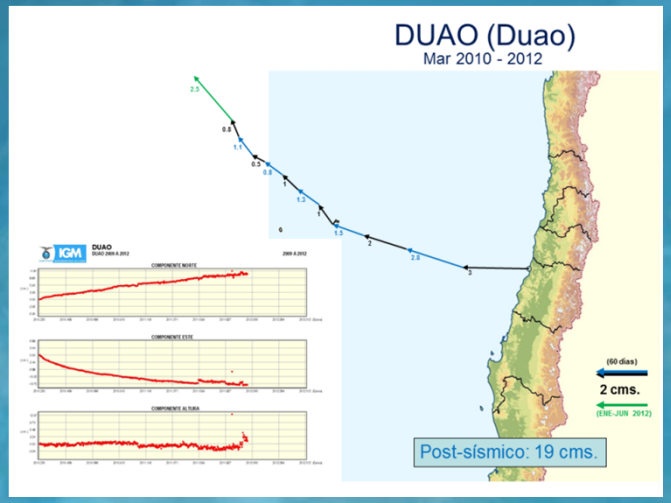
100 cms.

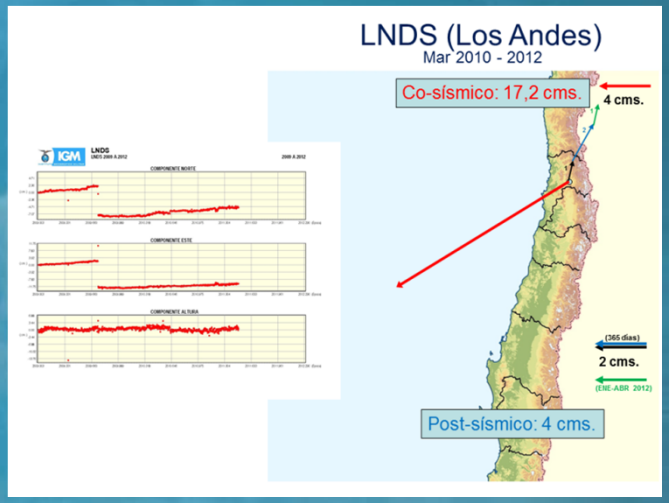
(60 días)

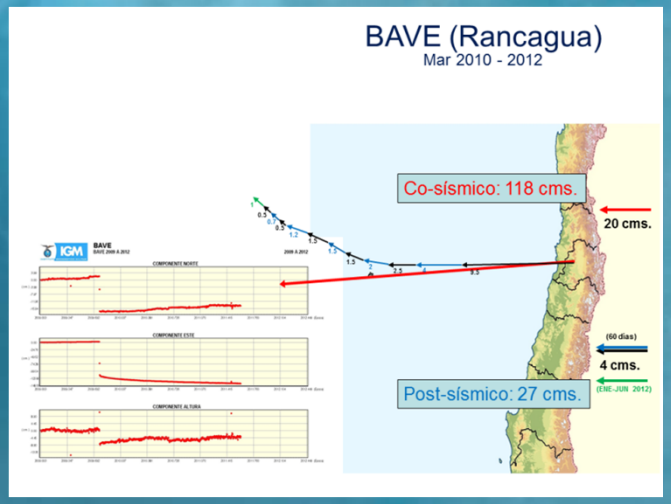
6 cms.

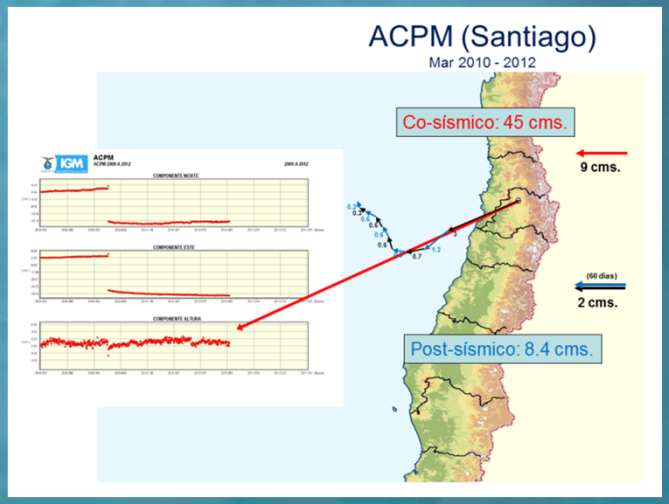
(ENE-JUN 2012)

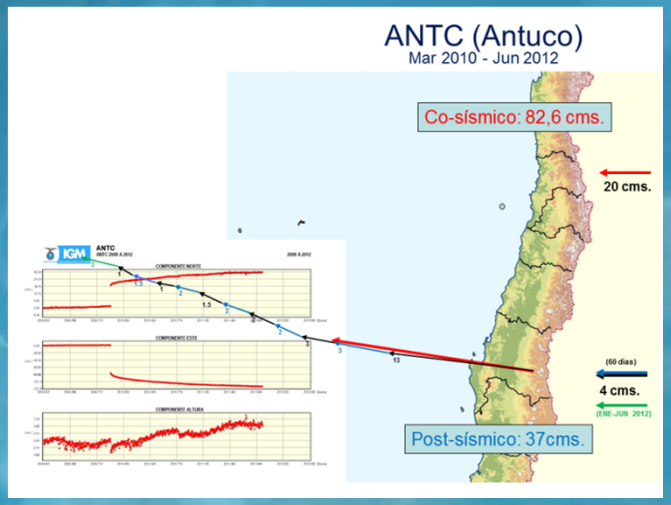
Post-sísmico: 31,5 cms.

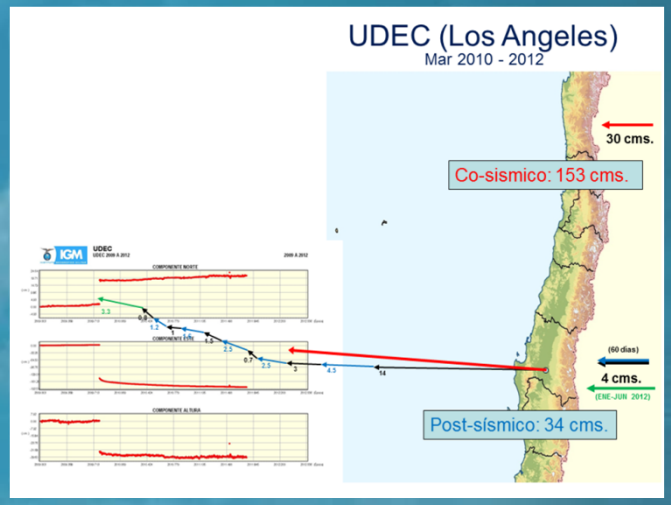

DUAO (Duao)
Mar 2010 - 2012
(60 dias)
2 cms.
(ENE-JUN 2012)
Post-sísmico: 19 cms.

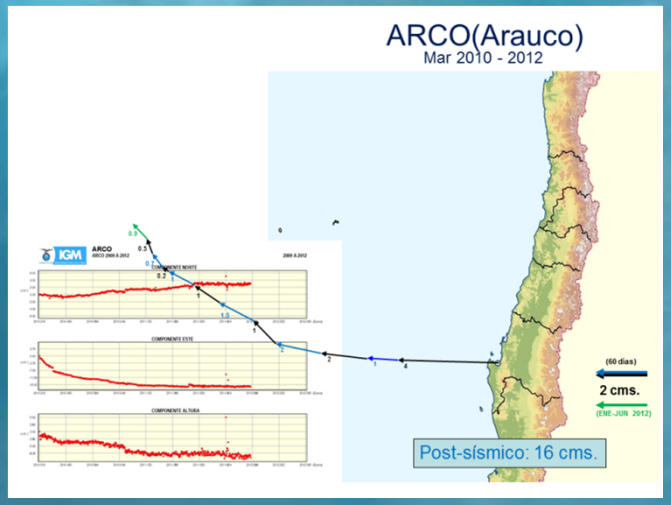

LNDS (Los Andes)
Mar 2010 - 2012
Co-sísmico: 17,2 cms.
4 cms.
(365 dias)
2 cms.
(ENE-ABR 2012)
Post-sísmico: 4 cms.

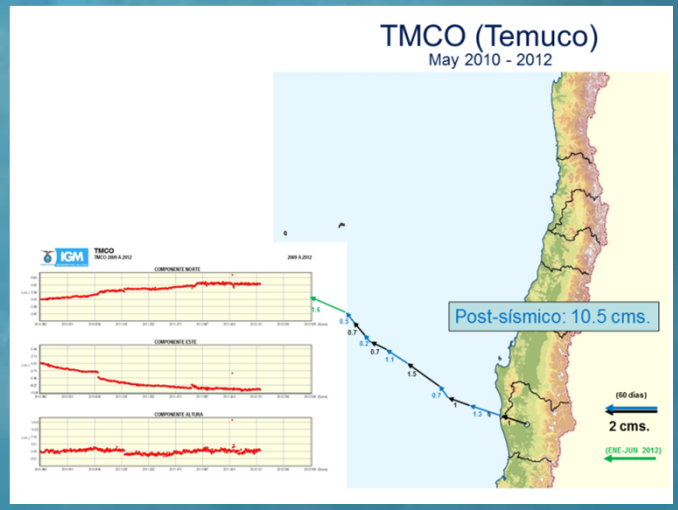

BAVE (Rancagua)
Mar 2010 - 2012
Co-sísmico: 118 cms.
20 cms.
(60 dias)
4 cms.
(ENE-JUN 2012)
Post-sísmico: 27 cms.


ACPM (Santiago)
Mar 2010 - 2012
Co-sísmico: 45 cms.
9 cms.
(60 dias)
2 cms.
Post-sísmico: 8.4 cms.


ANTC (Antuco)
Mar 2010 - Jun 2012
Co-sísmico: 82,6 cms.
20 cms.
(60 dias)
4 cms.
(ENE-JUN 2012)
Post-sísmico: 37cms.


UDEC (Los Angeles)
Mar 2010 - 2012
30 cms.
Co-sismico: 153 cms.
(60 dias)
4 cms.
(ENE-JUN 2012)
Post-sísmico: 34 cms.


ARCO(Arauco)
Mar 2010 - 2012
(60 dias)
2 cms.
(ENE-JUN 2012)
Post-sísmico: 16 cms.


TMCO (Temuco)
May 2010 - 2012
Post-sísmico: 10.5 cms.
(60 dias)
2 cms.
(ENE-JUN 2012)

Conclusions and Challengs

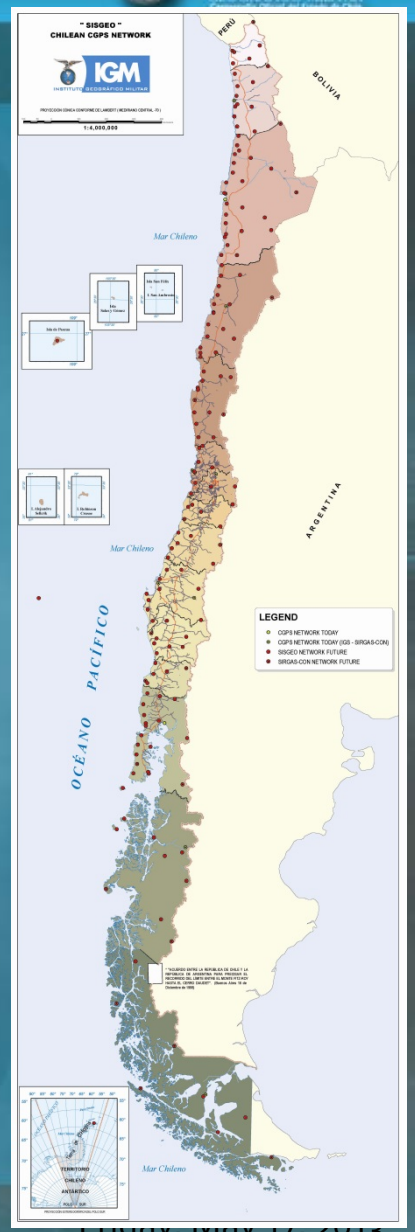
GPS is the only viable tool to study seismic deformations.

Availability is an important Issue. Specially previous to the earthquake.

Information obtained from GPS is used to detect earthquakes where there are no GPS receivers.

Reference frame must be rebuilt, but when?

New network specially for this type of events.



REFERENCES

Crustal Deformation and earthquakes: application to the seismic cycle study in the Northern Chile. J.C. Ruegg.

Geometric reference Systems in Geodesy. Christopher Jekeli.

The 2010 Mw 8.8 Maule Mega-Thrust Earthquake of Central Chile, Monitored by GPS.

Analysis center for SIRGAS, Jan 2011.

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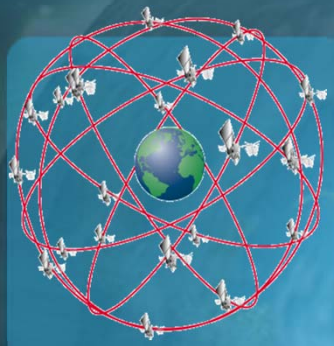
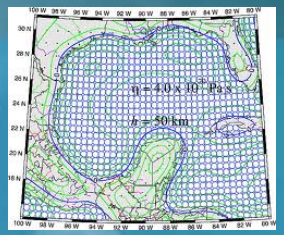
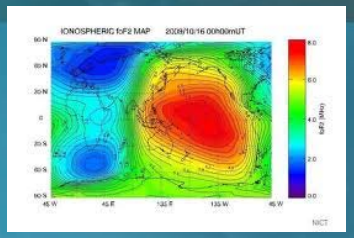
www.sirgas.org

http://www.meteored.com/ram/1161/terremotos-y-el-sistema-gps-la-ionosfera-como-amplificadoras-de-ondas-ssmicas/

Seismological service of Chile (U de Chile)







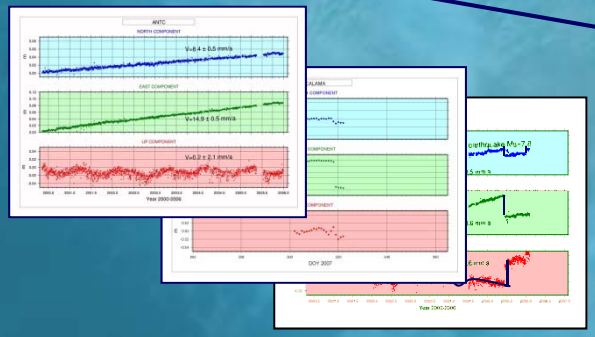
Satellite orbits

Continiuous reference stations

Oceanic loads

Ionospheric models

Earth rotation parameters



BERNESE V5.0
SIRGAS - CHILE

Coordinates

National Geodetic network SIRGAS – CHILE www.sirgaschile.cl	*Geodetic database*	*SIRGAS Solutions*	*Cientific projects and publications*

THANK'S

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Military Geographic Institute
Chile

Absolute values for phase center of the GNSS antenna
http://igscb.jpl.nasa.gov/igscb/station/ general/pcv_archive

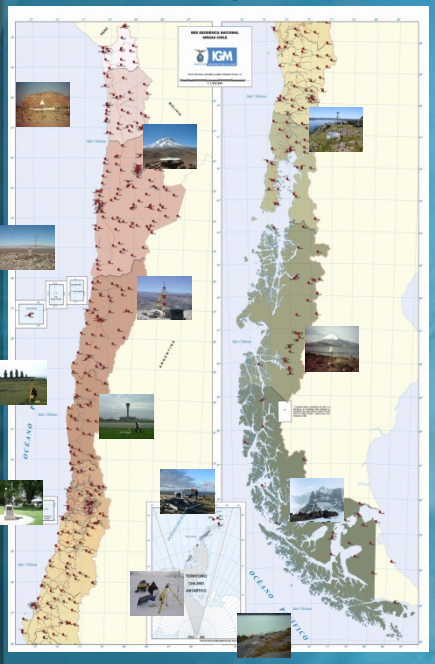
Final IGS solution (orbit, clocks and terrestrial orientation parameters)
http://igscb.jpl.nasa.gov/omponents/prods_cb.html

Ionosphere Model
ftp://ftp.unibe.ch/aiub/CODE/2011/

Correction for the tide displacement
http://www.oso.chalmers.se/~loading

Chilean Geodetic Networks

Red Densificada



- *RGN. SIRGAS-Chile.*
- *ITRF 2000, época 2002.0*
- *650 puntos*

Red CGPS

- *50 estaciones.*
- *Estudios científicos*
- *Apoyo a usuarios*
- *Internet, MODEM, manual.*
- *apoyo a SIRGAS-CON*
- *Base geodésica para RGN*

Red de Nivelación

- *12.000 kilómetros nivelados*
- *NMM.*
- *Conexiones internacionales*

Red de Gravedad

- *54 puntos G. absoluta*
- *70 puntos G. relativa*
- *NGA - IRD - IBGE – USP*
- *Aporte de datos a los modelos geoidales mundiales*