Operations
National Seismological Center
CSN
Sebastián Riquelme M.
May 25th, 2015
Before we started

• GSN: LVC, LCO, RPN

• GEOSCOPE: PEL, COYC

• CX Network already Installed by GFZ (Günter Asch) 16 stations + 4 IPGP stations.

• C Network: LMEL, ROC1, STL, CL2C, FAR, CHRN.

• GPS Network: CALTECH, IPGP, ENS (Ruegg-Vigny), UDEC (JCBaez), CAP, GFZ.
Kick-off (2012-2013)

- GRO Network (IRIS)
- Analysts 24/7
- Automatic Location and Magnitude (Early Bird)
- Antelope (GRO Stations)
- W-phase

...good

but not good enough for monitoring earthquakes in real-time
To start, what we considered necessary?

• More stations (**we still need more**)

• A place that could collect seismic data: DATACENTER (we still need a few more).

• Robust Communications systems.

• Redundancy on instruments and a satellite hub in our building.

• **Manuals, Procedures and Protocols**

• **Money**... but before, we knew what **we had to do**

• Monitoring Earthquakes as fast and accurate as possible (not perfect).
Evolution of CSN Budget through the years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Anual Budget</th>
<th>Source of Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSN-2010</td>
<td>$500,000</td>
<td>Ministry of Education</td>
</tr>
<tr>
<td>SSN-2011</td>
<td>$666,667</td>
<td>Ministry of Education</td>
</tr>
<tr>
<td>SSN-2012</td>
<td>$833,333</td>
<td>ONEMI + Ministry of Education</td>
</tr>
<tr>
<td>CSN-2013</td>
<td>$3,500,000</td>
<td>ONEMI</td>
</tr>
<tr>
<td>CSN-2014</td>
<td>$6,333,333</td>
<td>ONEMI</td>
</tr>
<tr>
<td>CSN-2015</td>
<td>$3,883,333</td>
<td>ONEMI</td>
</tr>
<tr>
<td>Total</td>
<td>$15,716,667</td>
<td></td>
</tr>
</tbody>
</table>
Initial Plan

• Install 10 to 12 stations per year… but (un)fortunately

• so we have to install faster

from Hayes et al., 2014
• Why fortunately?

• As the government requested to finish the network as soon as possible, this opened up opportunities

• How can we go faster?

• Transportable Array.

• The TA moves 200 to 300 stations every year.
What from the TA could make us to install faster?

- Every station is equal (*essential to build a network*)
- No room for improvisation
- Robust design (\(T^\circ\) and H\%)
- Modular Stations
- Reliable power supply (6W/hr)
- Proven in extreme weather conditions
- Type of soil: Rock or Sediment, it doesn't matter.
- Busby’s rule of thumb “1,5 mt in hard rock, same as 3 mt in sediment”
Temperature Variation

Temperature; Accelerometer in a vault over the ground

Temperature outside a TA type station

Temperature inside the station

Temperature affects LP

Estación Sismológica - Estándar de instalación IRIS

Medidas en mm

Centro Sismológico Nacional - Universidad de Chile

Escala 1:8
Station Building Tasks

Reconnaissance- which may involve office evaluation, field visits, landowner interaction but ends with the selection of a Candidate Site-that is a site for which we will seek a permit. Produces a recon report, which includes the outline of how the specific station will be provisioned including power and communication strategy. **Usually this takes a year before the installation!!!**

Permitting- meaning the negotiation with landowner, paperwork necessary to obtain written permission to access the property and to install a station. Permits and the expertise to acquire them increase in complexity from a simple private landowner agreement, through cooperative ownerships, corporate ownership to state managed lands.

Construction- digging a hole, pouring concrete, trenching cables and erecting a mast. This task can be accomplished by a backhoe operator and a laborer assistant. While construction details are important for good quality data, the task itself does not require scientific expertise.

Installation- installation of electronics, power system, communication system and sensor. Generally ends with data communication back to CSN. This step involves detailed understanding of seismic instrumentation, communications and power electronics and requires at least one highly trained person on site.

Lodges: Luxury Hotels in quiet places (far away from people, roads, towns, communications and electrical towers) mainly located in southern Chile

- Safe from vandalism
- Almost No sources of noise

Most Important:
They want to have a seismic station
**Manuales y Procedimientos**

**ESPECIFICACIONES TÉCNICAS**

**ESTACIÓN SISMOLÓGICA**

Centro Sismológico Nacional – Universidad de Chile

El Centro Sismológico Nacional de la Universidad de Chile, en adelante e indistintamente CSN, el Centro Sismológico Nacional.

**ESPECIFICACIONES TÉCNICAS**

Difundir oportunamente toda la información y características acerca de cualquier fenómeno sísmico que afecte el territorio nacional.

Dada la ausencia de estaciones de monitoreo sísmico en el país, el CSN-UCH considera que la existencia y el aumento de estaciones sísmológicas contribuye significativamente con los fines y objetivos previamente mencionados, como también en resguardar la seguridad del país ante desastres naturales.

La construcción de una estación sísmica tiene impacto directo en la calidad de los datos que registra; es por ello que debe proporcionar protección contra factores externos como humedad, ruido, variaciones de temperatura, vandálico e inundación entre otros; garantizar contacto mecánico apropiado de los sensores sísmicos con el lecho rocoso o el espacio abierto para que acceda una persona a realizar mantenciones esporádicas o permanentes, así como también para que el equipamiento necesario se distribuya de manera óptima.

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**1. Technical Specifications**

- **Technical Specifications**
- **Reconnaissance**
- **Permitting**
- **Installation & Telemetry**
Ahora los sismos en Puerto Natales se pueden medir inmediatamente

En las últimas semanas el Centro Sismológico Nacional (CSN) ha estado instalando nuevas estaciones sismológicas en el sur del país. "Lo hasta entonces no existía", dice el ingeniero del CSN. "La idea es detectar cualquier terremoto a tiempo y alertar al público en el país. En la actualidad no existían muchas estaciones. Ahora instalamos en Puerto Natales y Tapias (Región de Magallanes), y en Los Muermos, Patagonia, y dos en la Cordillera de la Costa y La Segunda, la segunda más activa. Es la última idea de tecnología. Todas medirán el terremoto y permitirá conocer en tiempo real cualquier actividad geológica".

La base de datos recibirá el terremoto en tiempo real, con base para entonces alertar a la población. "Una vez que la corriente de datos llega al servidor lo procesamos y enviamos a la gente", dice el ingeniero. "Eso es crucial para poder tomar medidas preventivas en tiempo real".
Video of Whys?

Learning process is not successful if you don’t internalise explanations.
Communication Variety

- V-SAT 90%
- Radio 1% (topography)
- Radio-Internet 1%
- Radio-DGAC (Internet more reliable) 6%
- 3G (Not reliable) 2%
- Cell modems 85%
- VSAT systems 14%
- Internet via host 1%

www.opensignal.com
Technical problems that we currently face

- Energy: beyond latitude 40°S V-SATs need more batteries and solar panels.
- Time data availability
- GPS incorporation; design and power supply.
- Bandwidth (GPS-RTX)
- Public Offices (Schools, Municipalities) in Chile are not reliable.
- Poor communication system
Restructuration

- Isolated Database
- QuakeML will be the transition format for any requirement
- Software

Dataflow CSN

PDL*  
USGS  
Sharing Data!
Communications by the end of 2015
The 2015 Mw 7.9 Nepal Earthquake recorded by C and C1 networks
Quality Control, Intranet and Dataless

• Noise

• Time Data availability

• Metrics

• “A datacenter collects data, a good datacenter collects good quality data”
Quality Control, Intranet and Dataless

Management

Communications

Metrics Control

Stations
Quality Control, Intranet and Dataless

- Every station has its own dataless
- It has everything we need to know from the station: poles, zeros, sensitivity, gain, start, finish, sensor etc. (header)
- Checked by geophysicist at CSN
- Goes to USGS and IRIS
- Part of CSN public data policy (GPS, BB and SM)
- Multiple Quality Checkers

Data & Products Distribution

Bandwidth limitations...
Tsuni Early Warning

LETTER
doi:10.1038/nature13677

Continuing megathrust earthquake potential in Chile after the 2014 Iquique earthquake

Gavin P. Hayes1, Matthew W. Herman2, William D. Barnhart1, Kevin P. Furlong3, Sebastian Riquelme4, Harley M. Benz5, Eric Bergman3, Sergio Barrientos3, Paul S. Earle6 & Sergey Samsonov3

CSN W-phase Iquique Earthquake 2014
Green Functions v/s Observed

W-phase report goes to SHOA
Installed and Maintained at CSN by S. Riquelme

©2014 Centro Sismológico Nacional (CSN) W-phase centroid moment tensor (CMT) inversion

1Maintained at CSN by Sebastian Riquelme, developed by Hiroo Kanamori and Luis Rivera

2Developed by Hiroo Kanamori, Luis Rivera, maintained in Chile by Sebastian Riquelme
W-phase using cGPS

GPS: a Very LP green “function maker”, that doesn’t saturate in the near-field

W-phase using cGPS 1 sps 2011
Mw 9.1 Tohoku Earthquake

W-phase using cGPS 1 sps 2014
Mw 8.2 (8.35) Iquique Earthquake

W-phase using cGPS 1 sps 2010
Mw 8.8 (9.1) Maule Earthquake

S. Riquelme & F. Bravo
Possible Scheme for Mw > 8

- Hypocenter & Mw (cGPS and SM)
- WCMT cGPS
- WCMT cGPS+BB
- WFFM cGPS
- WFFM cGPS+BB

Next Steps: Include GPS signals.
FFM from cGPS W-phase
Hopefully from RTX technology
Why FFM? provides a better estimation for run-up, pga, damage, economic losses and fatalities.

From Benavente R. & Cummins P., 2013

The 2010 Mw 8.8 Male Earthquake
The 2014 Mw 8.2 Iquique Earthquake
The 2013 Mw 8.3 Oshtok Earthquake
Network Expansion & Earthquake Early Warning (if funding)

- Network expansion up to 900 instruments.
- 2 to 3 Datacenters
- A building.
- 300 MS to monitor crustal faults
- The Nepal Earthquake remind us that we have crustal seismicity.
- Liquiñe-Ofqui (Mw ?) Fiord tsunami
- Magallanes Mw 7.9 1949
- San Ramón potential Mw 7.5 (Armijo et al.)

The problem in EEW, is to communicate seismic data, as fast as possible. milliseconds.
“Life is too short to have crappy data”

Thanks