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Synergy SLR in Latin America

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Workshop SLR - SIRGAS 2017

South American SLR network within ILRS

International Laser Ranging Service (ILRS)

SLR global network distributed in over 30 countries, with fixed and mobile stations.

The ILRS Global SLR Network is made up of three regional networks:

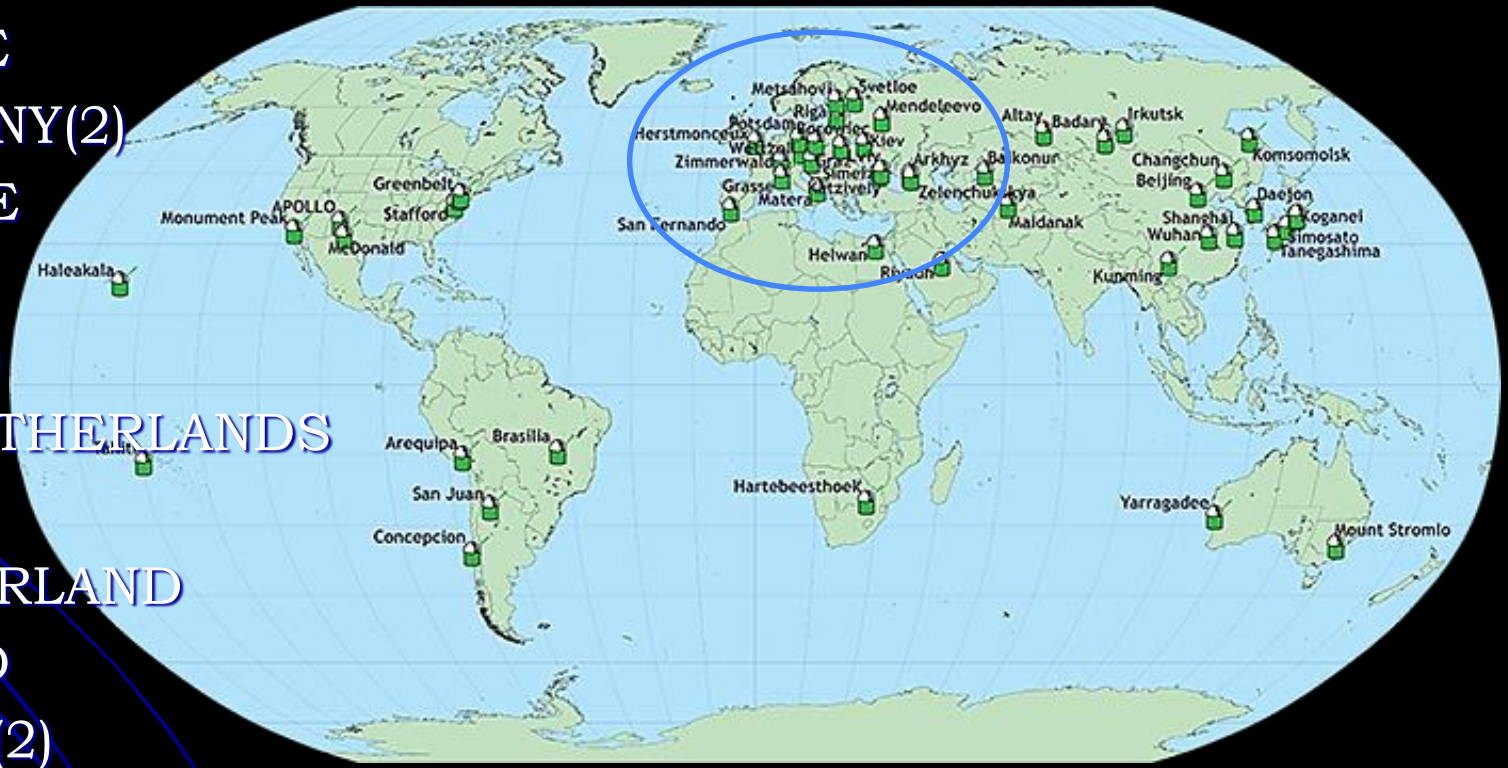
- **EUROLAS** (European Laser Network) encompassing the European stations

- **NASA** Network encompassing North America, and some stations in South America, South Africa and the Pacific

- **WPLTN** (Western Pacific Laser Tracking Network) encompassing Japan, China, Eastern Russia and Australia

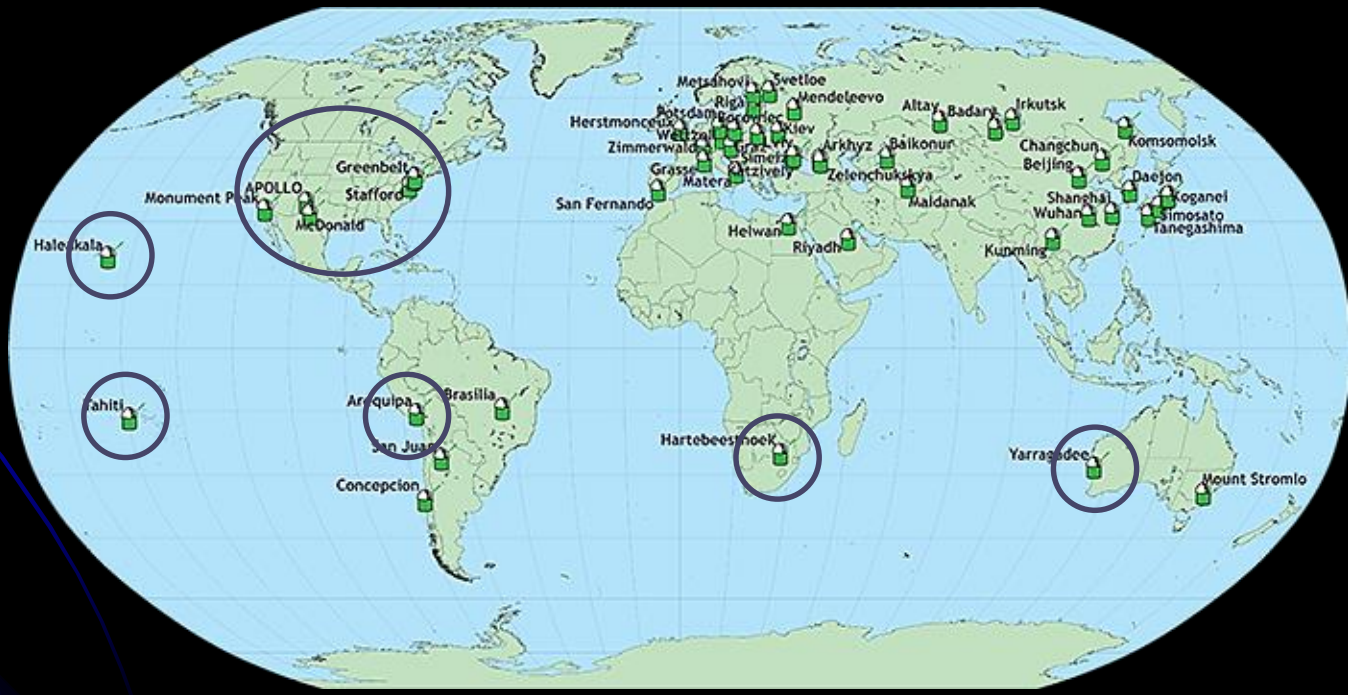
EUROLAS (1989)

- AUSTRIA
- CZECH REPUBLIC
- FINLAND
- FRANCE
- GERMANY(2)
- GREECE
- LATVIA
- ITALY(2)
- THE NETHERLANDS
- SPAIN
- SWITZERLAND
- POLAND
- RUSSIA(2)
- UK
- UKRAINE



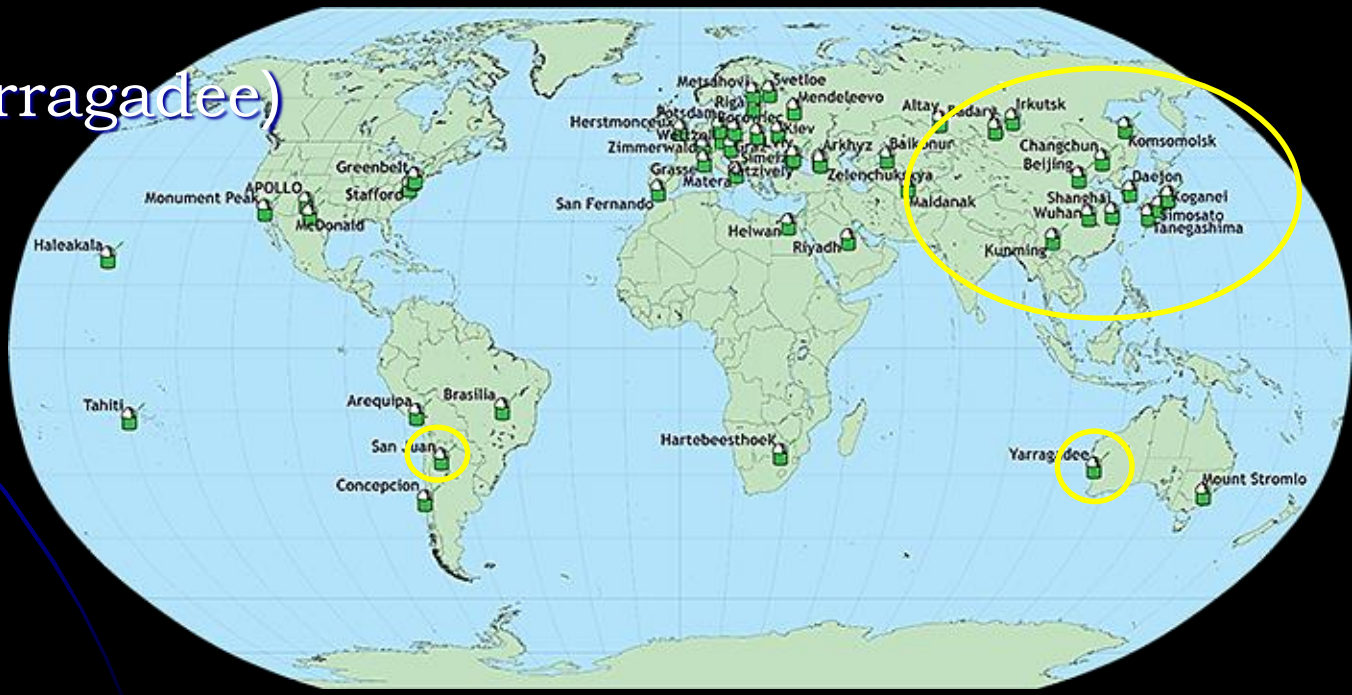
NASA NETWORK

- MOBLAS-4 & 7 (Monument Peak, California y Greenbelt) USA
- MOBLAS-5 (Australia Yarragadee)
- MOBLAS-6 (South Africa Hartebeesthoek)
- MOBLAS-8 (Tahiti French Polynesia)
- TLRS-3 (Arequipa Peru)
- HOLLAS (Hawaii USA)
- MLRS (Texas)



WPLTN - Western Pacific Laser Tracking Network (1994)

- Japan
- China
- Saudi Arabia
- Russia
- India
- Australia(Yarragadee)
- Argentina



SLR South American stations

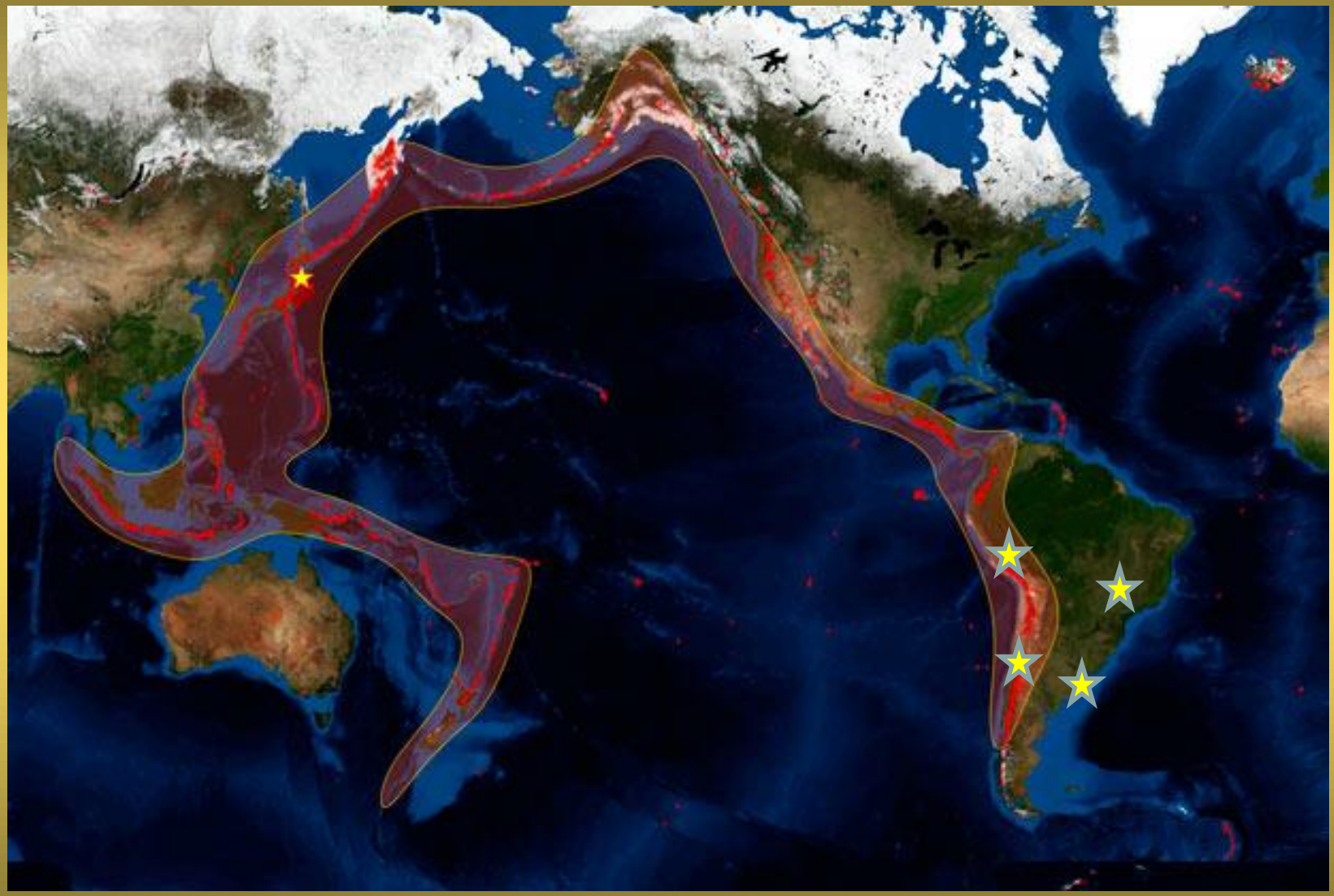
South American stations:

- 7403 Arequipa (1989)
- 7406 San Juan (2006)
- 7407 Brasilia (2014)
- 7405 AGGO (2015)
  TIGO (2002)

Next challenges - Future Network Projects:

- Seismicity in South America
- Short Arc
- Tracking GNSS
- Time
- ……

Pacific Ring of Fire

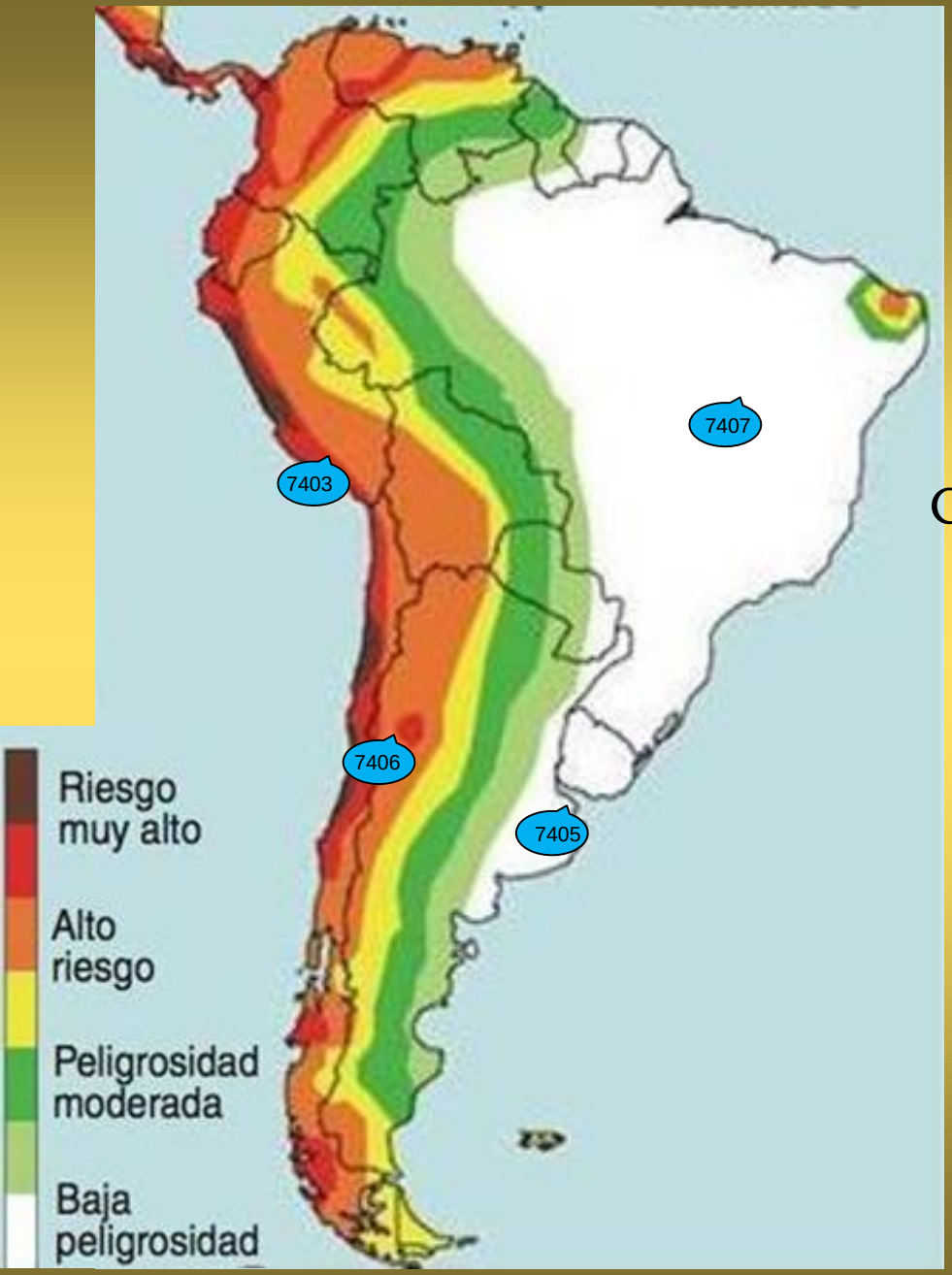


At the **Pacific Ring of Fire** around 90 % of the world seismic activity is recorded.

The Nazca plate is denser and is moving towards the east thus subducting below the western edge of the South American plate.

Seismic Risk in Latin America

Latin America is considered one of the most active seismic region of the world, in which the earthquake danger threatens, within large portions of the continent, all human life.



ILRS → Monitoring of Tectonic Movements

Global Analysis of the ILRS Network

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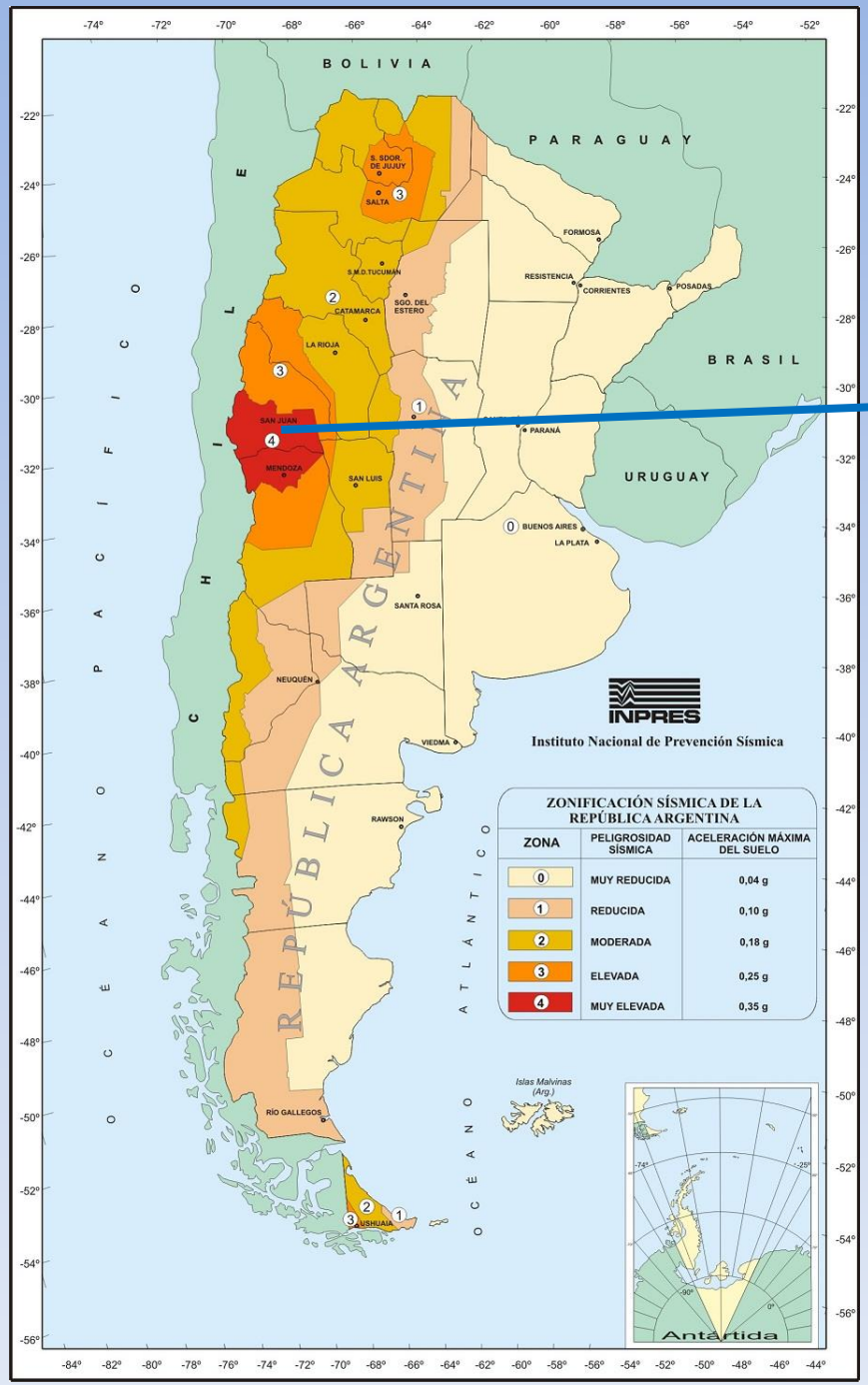
Is it the best way to research local phenomena?

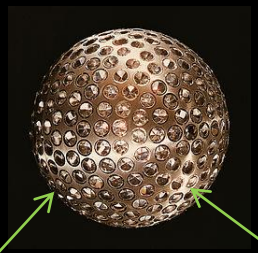


SLR 7406 OAFA station

MAXIMUM LEVEL
OF SEISMIC HAZARD

Short-Arc Method

This technique consists of the possibility of tracking the same satellite simultaneously from two (or more) SLR stations and process only the simultaneous data.



Baseline AGGO-OAFA

Principle of analysis Short-Arc

DR = RAGGO, real (t) – R SJ, real (t)

All common errors are discarded
(e.g. residual errors on the satellite's orbit)

The baseline between stations may be determined with high precision through a minimum squares analysis

"double difference" **δ*DR*** represents the signal of the data displacement

At the third stage of the analysis, the partial derivatives of the differential distances regarding the geocentric coordinates (X, Y, Z) of each station are calculated numerically.

$$\frac{\partial DRn}{\partial X_{AGGO}} = \lim_{(\Delta x \to 0)} \frac{DR\,(X_{AGGO}, tn) - \Delta DR\,(X_{AGGO} + \Delta X, tn)}{\Delta X}$$

$$A = \begin{pmatrix} \frac{\partial DR1}{\partial XAGGO} & \frac{\partial DR1}{\partial YAGGO} & \frac{\partial DR1}{\partial ZAGGO} & \frac{\partial DR1}{\partial XSJ} & \frac{\partial DR1}{\partial YSJ} & \frac{\partial DR1}{\partial ZSJ} \\ \frac{\partial DR2}{\partial XAGGO} & \frac{\partial DR2}{\partial YAGGO} \cdots & \frac{\partial DR2}{\partial ZAGGO} & \frac{\partial DR2}{\partial XSJ} & \frac{\partial DR2}{\partial YSJ} & \frac{\partial DR2}{\partial ZSJ} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \frac{\partial DRN}{\partial XAGGO} & \frac{\partial DRN}{\partial YAGGO} \cdots & \frac{\partial DRN}{\partial ZAGGO} & \frac{\partial DRN}{\partial XSJ} & \frac{\partial DRN}{\partial YSJ} & \frac{\partial DRN}{\partial ZSJ} \end{pmatrix}$$

Starting from the approximate coordinates, corrections are iteratively calculated according to the equation:

$$\begin{bmatrix} X_{AGGO,\,n+1} - X_{AGGO,\,n} \\ Y_{AGGO,\,n+1} - Y_{AGGO,\,n} \\ Z_{AGGO,\,n+1} - Z_{AGGO,\,n} \\ X_{SJ,\,n+1} - X_{SJ,n} \\ Y_{SJ,\,n+1} - Y_{SJ,n} \\ Z_{SJ,\,n+1} - Z_{SJ,n} \end{bmatrix} = (A^T * A)^{-1} * A^T \begin{bmatrix} DR_{m1} - DR_{c1} \\ DR_{m2} - DR_{c2} \\ DR_{m3} - DR_{c3} \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ \cdots\cdots\cdots\cdots \\ DR_{mN} - DR_{cN} \end{bmatrix}$$

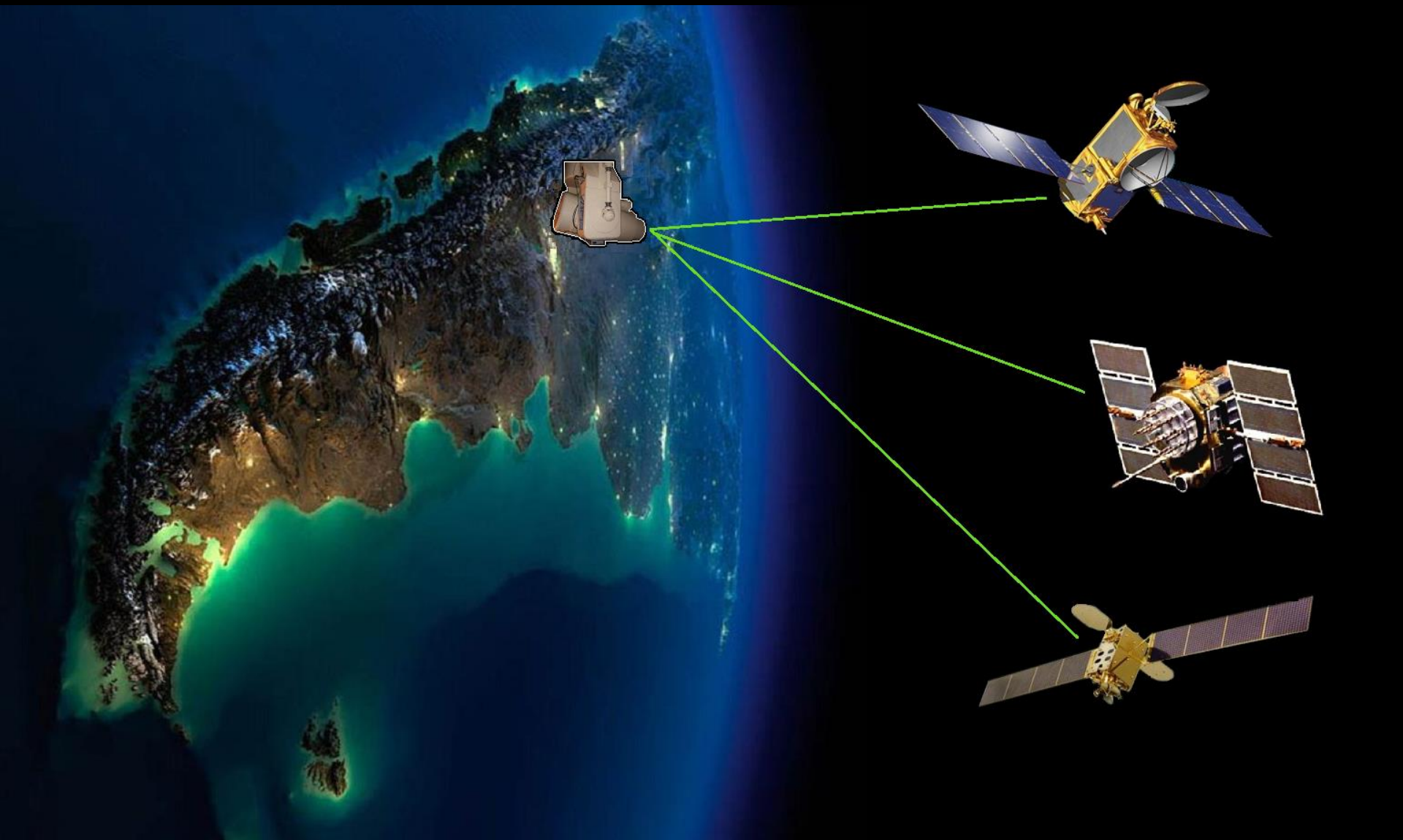
Sinclair and Appleby showed that this technique has great potential for accuracy, especially for monitoring the **baseline** between participating stations.

EUROLAS ⇨ precision of 2-3 mm in the length of the base lines.

However, the estimates of the coordinates of the stations in the frame of reference seem more robust the analysis of the complete network (analysis of the distances between the stations)

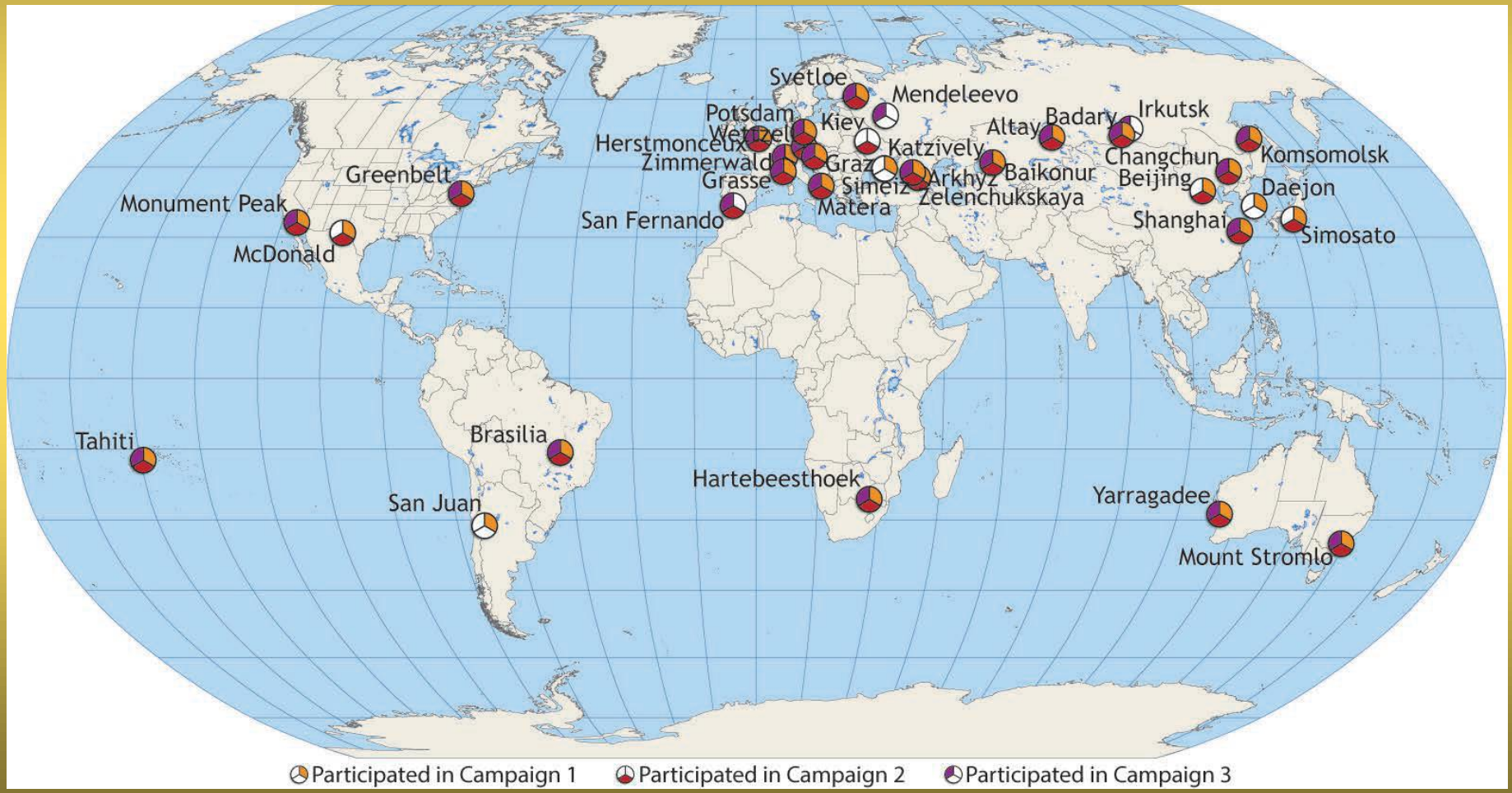
	Approximate distance	order of precision
OAFA - LA PLATA	1050Km	mm
AREQUIPA - OAFA	1700Km	mm
LA PLATA – BRASILIA	2300Km	.....
BRASILIA – AREQUIPA	2500Km	.....

Why is SLR tracking important to GNSS constellations?

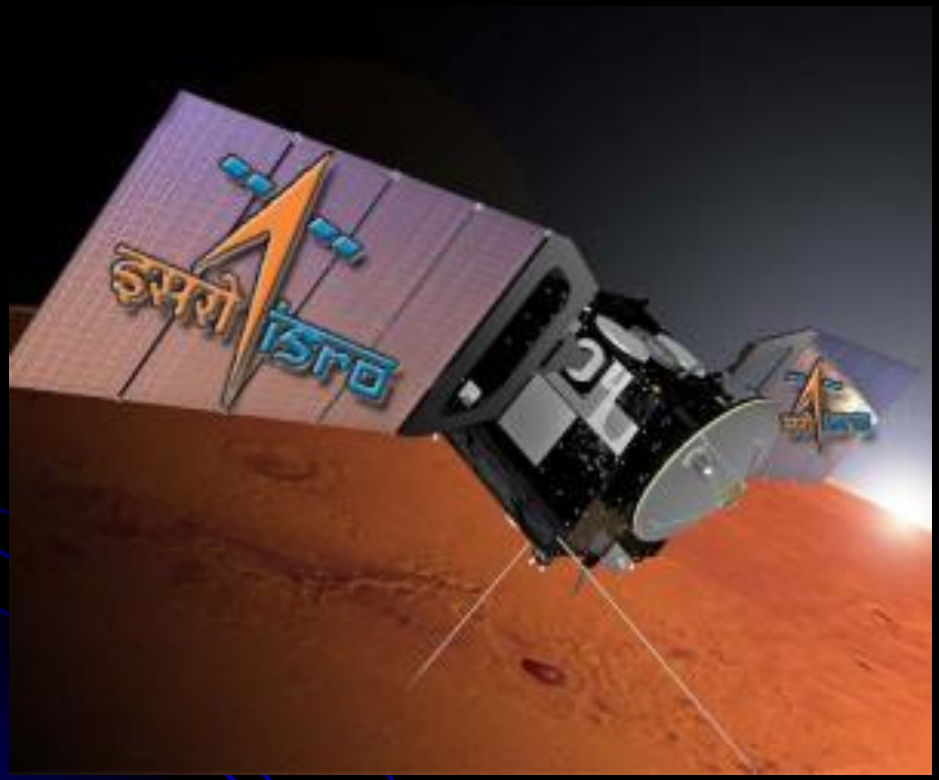


ILRS Network Participation

Campaigns 1, 2, 3



Indian Regional Navigation Satellite System (IRNSS)



Next challenges : Tracking IRNSS 1A, 1B, 1C,1D

(H = 42 164Km)

Future Center of SLR data processing

Processing of the SLR observable (NP):

- GEODYN II
- UTOPIA
- NAOC SLR
- BERNESE
- GAMIT-GLOBK
- .....

Viability of SLR and GNSS data processing with Bernese

In Argentina, the possibility of processing GNSS and SLR data with Bernese software is currently being studied, with the idea of including the OAFA and AGGO stations to the SIRGAS network.

CONCLUSION and Future Perspectives

- **Seismicity of the South American network:**
  - Eastern stations (AGGO and BRASILIA).
  - Western stations (OAFA and AREQUIPA)

*Taking into account that these stations are included in the current international ITRF 2008 and ITRF 2014 frames of reference, the **constant monitoring of their coordinates is absolutely crucial** due to them being located at the highest seismic activity zone of South America.*

- SHORT_ARC method → it provides daily solutions, whereas the ILRS network delivers weekly solutions

- **Critique: Stations crowded together** → improved

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Brasilia and AGGO

At the 2017 ILRS Technical Workshop, held in October in Riga, Latvia, the participants overwhelmingly supported a resolution:

Recognizing:

- The requirement for a global distribution of SLR stations to support the improvement in the reference frame and precision orbit determinations for active missions;
- The current lack of accurate SLR data from South America;
- The plans by the Changchun Station to upgrade the SLR station in San Juan, Argentina

Objectives and future perspectives of the South American SLR network

a) Set up the first bonds

b) Get to know the South American SLR stations (affiliations, personnel, equipment, functions, limitations, etc.)

c) Motivate the union and cooperation among the members for the making of joint works. Coordinate the important tasks for the network.

d) Coordinate and promote the participation of the South American SLR group in international programs.

e) Promote the network development of our own investigations and publications (Michael Hafner: Journal of Geodesy on Laser Ranging).

f) Promote the training and interchange of scientists, observers and students. Attend international meetings as a bloc.

g) Have our own Data Processing Center, sharing software development, progress of each station, technical innovations, etc.

"The secret of success does not consist of strengthening our weaknesses, but of boosting our strengths"