United Nations/ICTP Workshop on the Use of Global Navigation Satellite Systems (GNSS for Scientific Applications)
ICTP, Trieste, Italy – 1 - 5 December, 2014

The GeoRED Project: GPS/GNSS Geodetic Infrastructure in Colombia, South America, for Multipurpose Research

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MINMINAS

SERVICIO GEOLÓGICO COLOMBIANO

TODOS POR UN NUEVO PAÍS
PAZ EQUIDAD EDUCACIÓN

The GeoRED Project:
GPS/GNSS Geodetic Infrastructure in Colombia, South America, for Multipurpose Research

OUTLINE

- Tectonic setting and main structural elements
- Space Geodesy in Colombia
- GPS/GNSS GeoRED Network Implementation
- Preliminary Results
- Challenges
- Conclusions

THE COLOMBIAN GEOLOGICAL SURVEY

The Colombian Geological Survey is an institute of Science and Technology, committed to the socioeconomic development of the country through the integral management of all geoscientific knowledge of the subsoil of its national territory, nuclear and radioactive research and the distribution of information by means of:

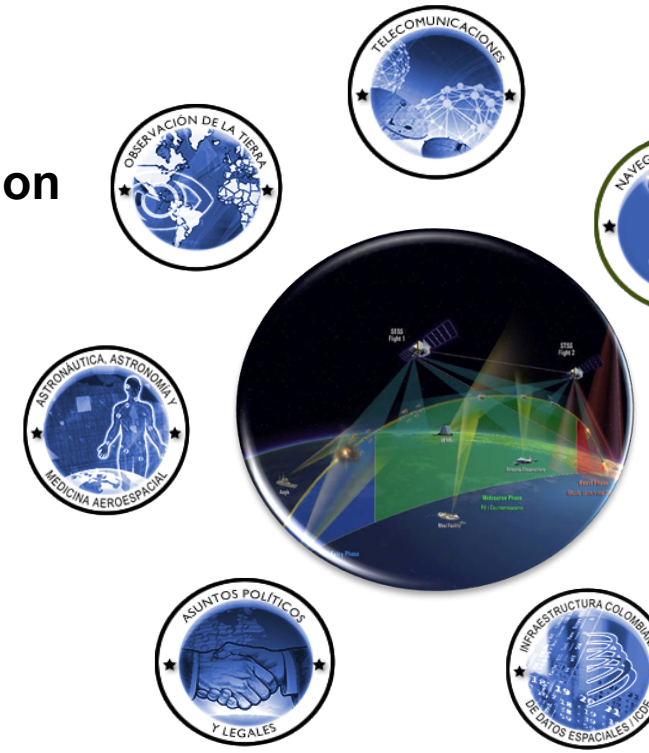
- Research in basic geoscience.
- Research in the potential resources of the subsoil.
- Research, evaluation and monitoring of geological hazards.
- Integral management of geoscientific knowledge of the subsoil.
- Research and application of nuclear technologies, control of the use and disposal of nuclear and radioactive materials.

The availability of a staff of expert and competent public servants committed to continuous quality improvement, the availability of an adequate infrastructure, and the application of modern communication technology that permits the fluent interaction with and a prompt response to the needs of many different interest groups is the best guarantee for the fulfillment of the institute´s mission.

COLOMBIAN SPACE COMISSION

Working Groups

Earth´s Observation Group



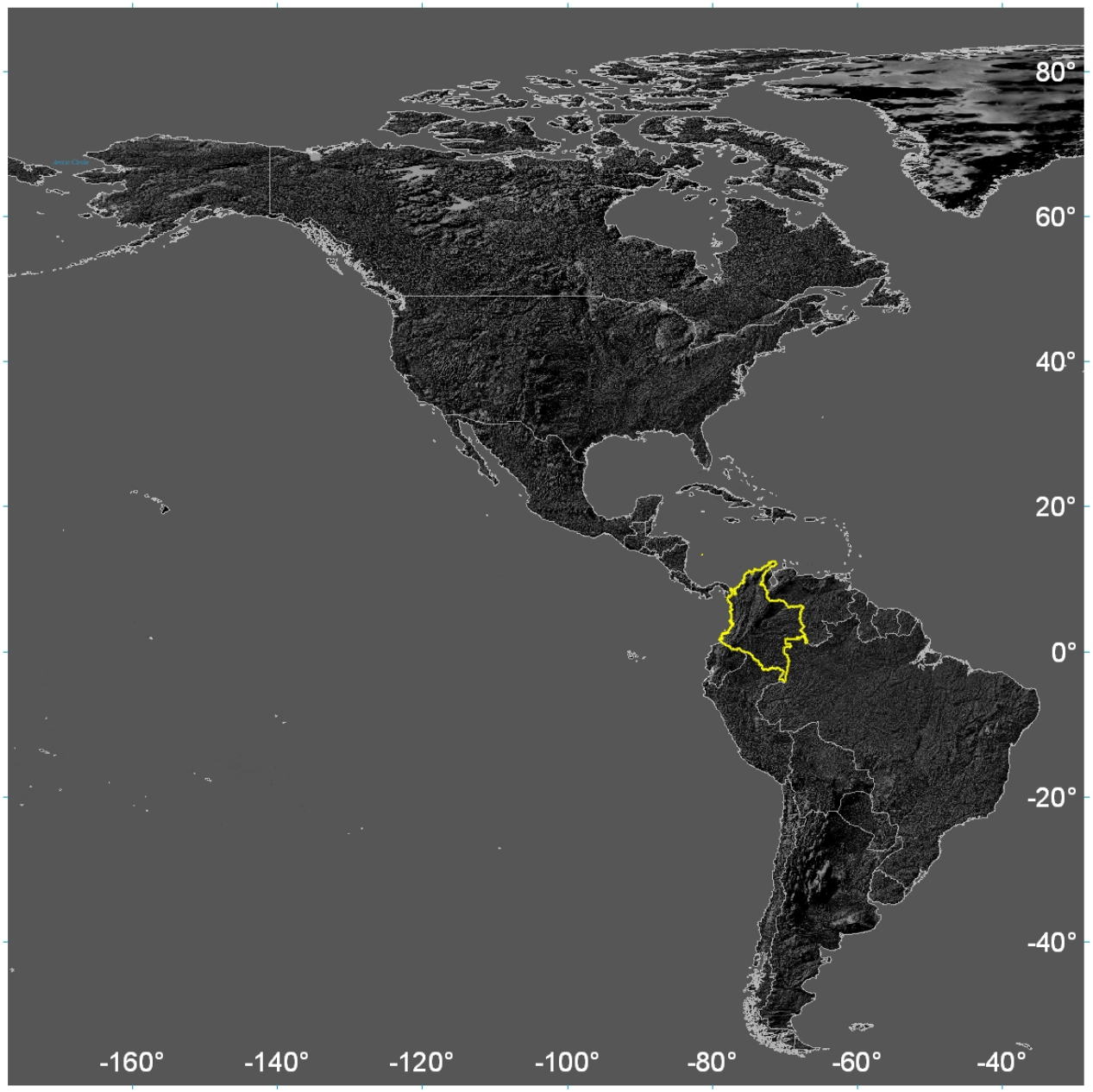
Satellite Navigation

Research and Knowledge

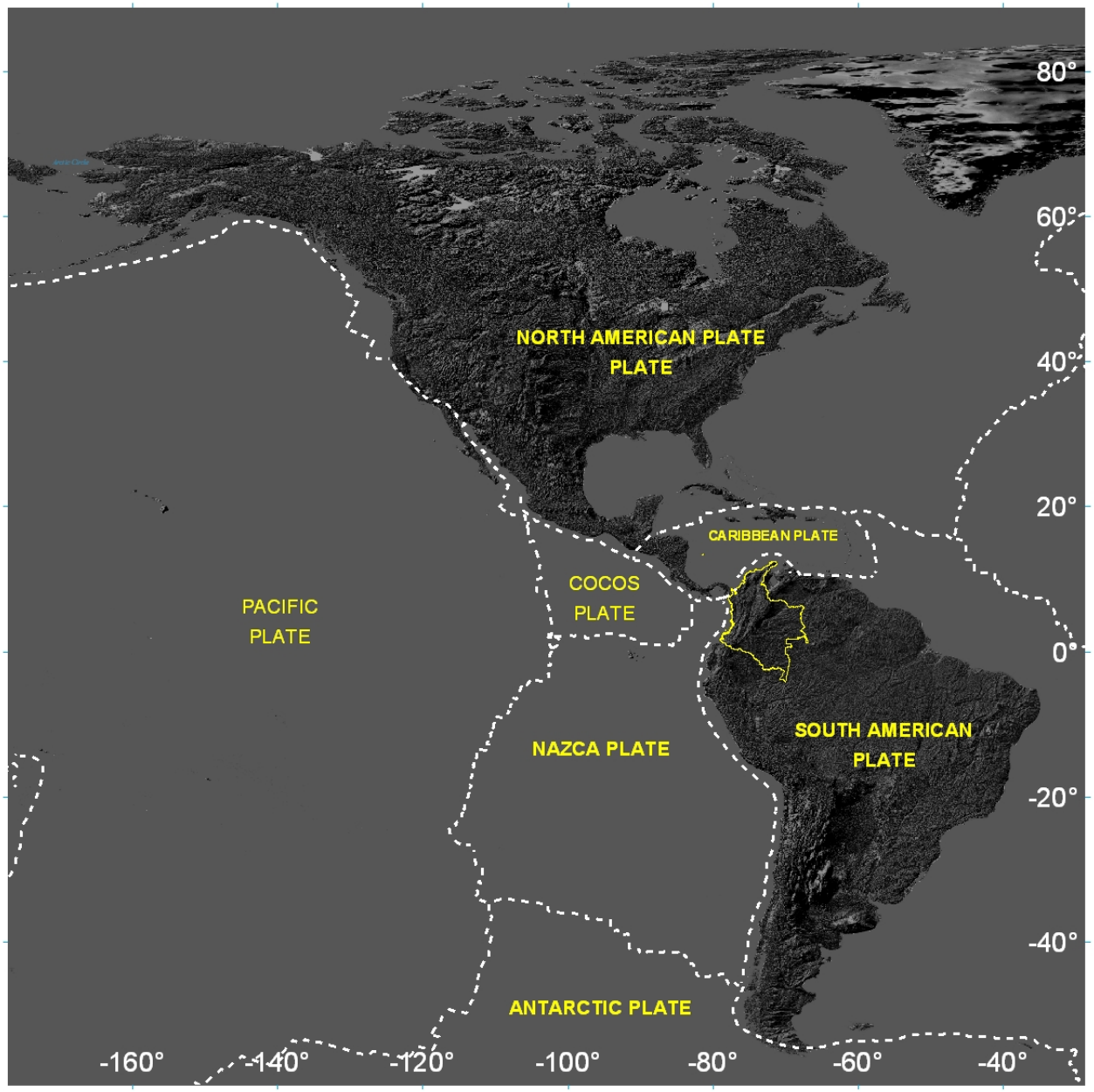
National Geospatial Data Infrastructure

Tectonic setting and main structural elements

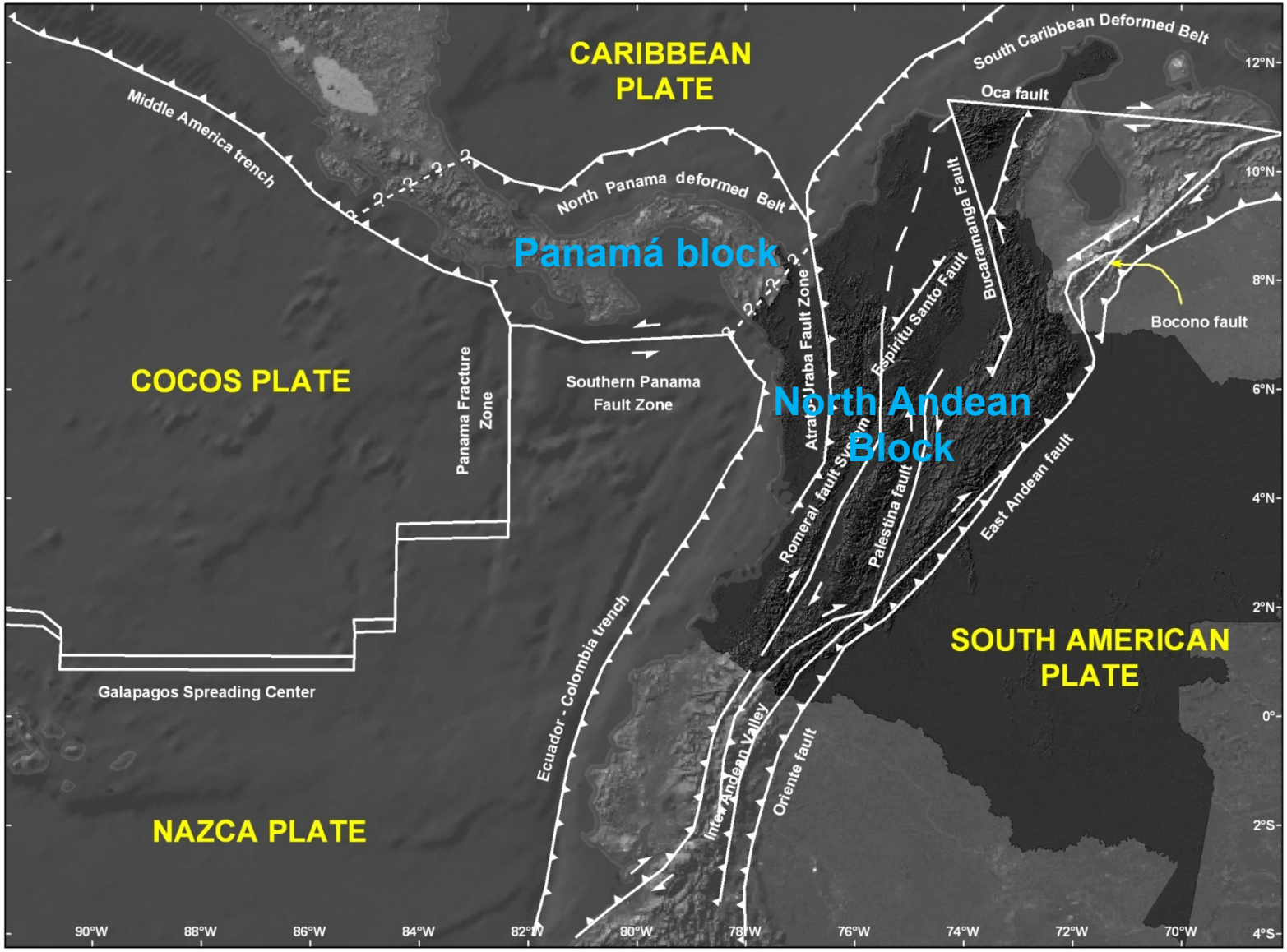
TECTONIC SETTING AND MAIN STRUCTURAL ELEMENTS



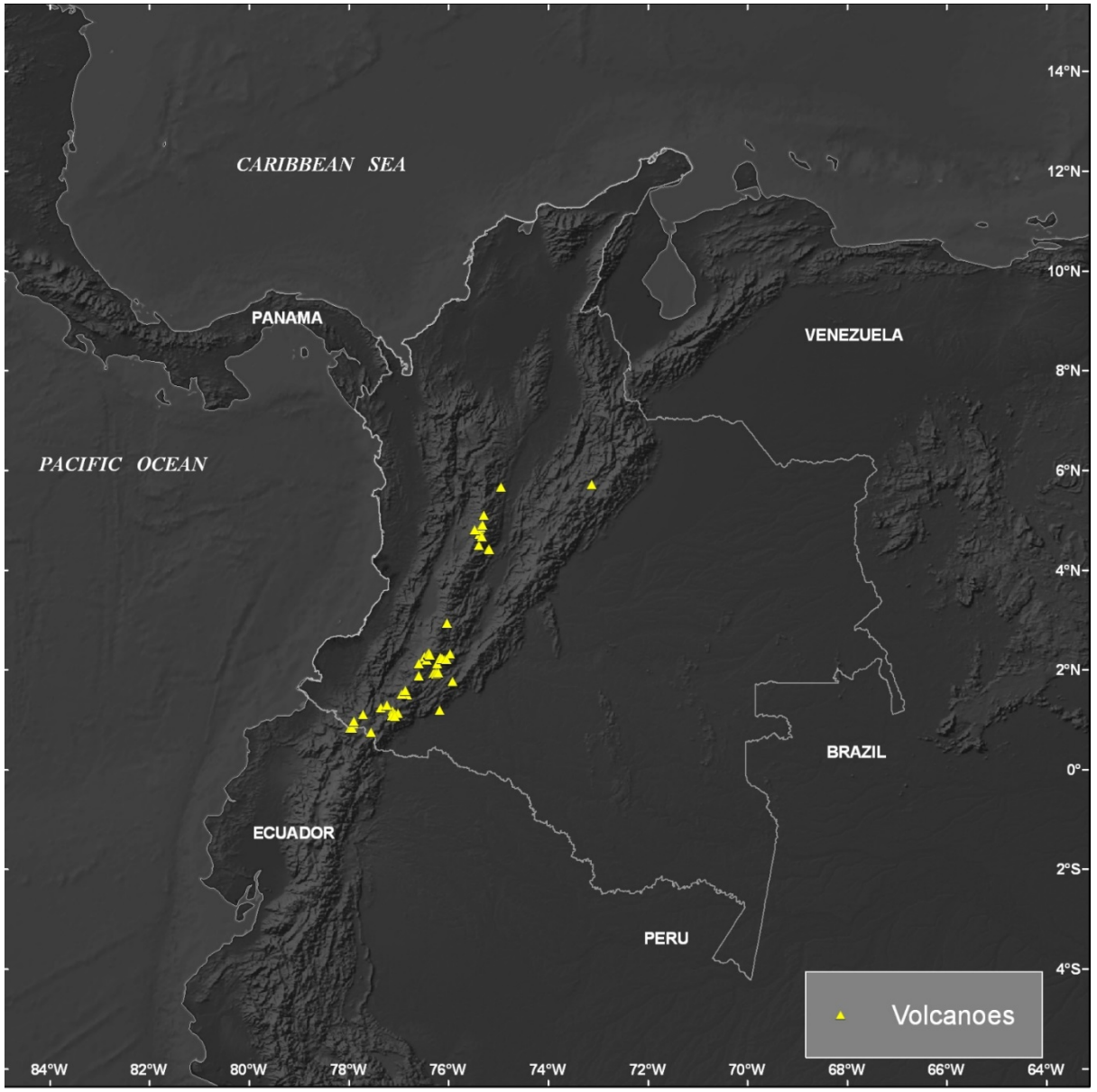
TECTONIC SETTING AND MAIN STRUCTURAL ELEMENTS



TECTONIC SETTING AND MAIN STRUCTURAL ELEMENTS



TECTONIC SETTING AND MAIN STRUCTURAL ELEMENTS

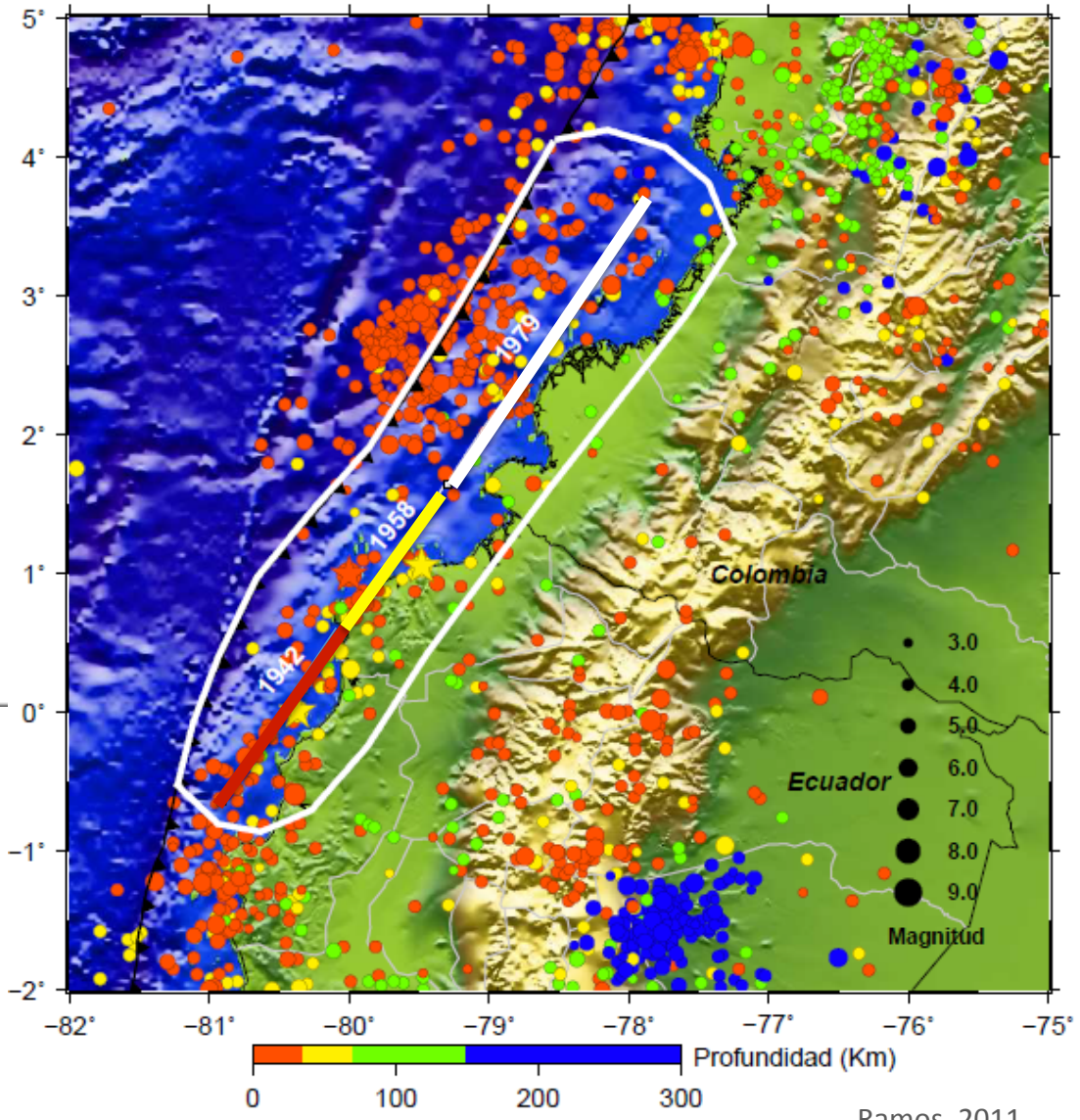


MAIN EARTHQUAKES, 20th. CENTURY, (1900-1980)
Colombia-Ecuador Subduction Zone

1906 Ecuador-Colombia earthquake

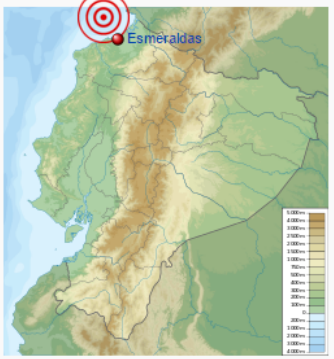
Date	January 31, 1906
Magnitude	8.8 Magnitude M_w
Epicenter	1.0°N 81.5°W
Areas affected	Ecuador, Colombia
Tsunami	Yes
Casualties	~1,000

1942
Mw = 7,6



Ramos, 2011

1958 Ecuador-Colombia earthquake

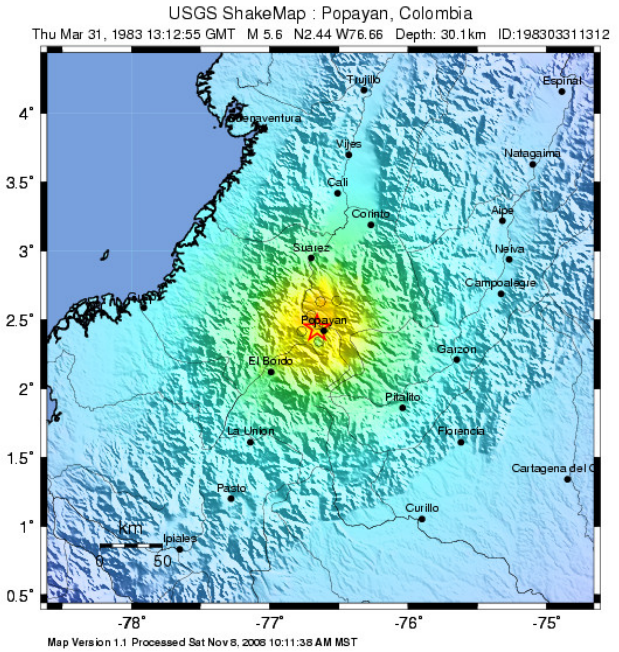


Date	January 19, 1958
Magnitude	7.6 Magnitude M_w
Epicenter	1.5°N 79.5°W
Areas affected	Ecuador, Colombia
Tsunami	Yes
Casualties	111

1979 Tumaco earthquake

Date	December 12, 1979
Magnitude	8.2 M_w[1]
Depth	33 km[2]
Epicenter	1.598°N 79.358°W[2]
Areas affected	Ecuador, Colombia
Tsunami	Yes
Casualties	~600

EARTHQUAKE AND VOLCANIC ERUPTION



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

1983 Popayan Earthquake

1985 Nevado del Ruiz Volcano eruption
25,000 people killed

NATIONAL DISASTERS PREVENTION INSTITUTION AND SCIENTIFIC INSTRUMENTATION
1988

EARTHQUAKES

1875 Cúcuta earthquake

Date	18 May 1875
Magnitude	7.5
Epicenter	7.9°N 72.5°W
Areas affected	Colombia
Casualties	~10,000

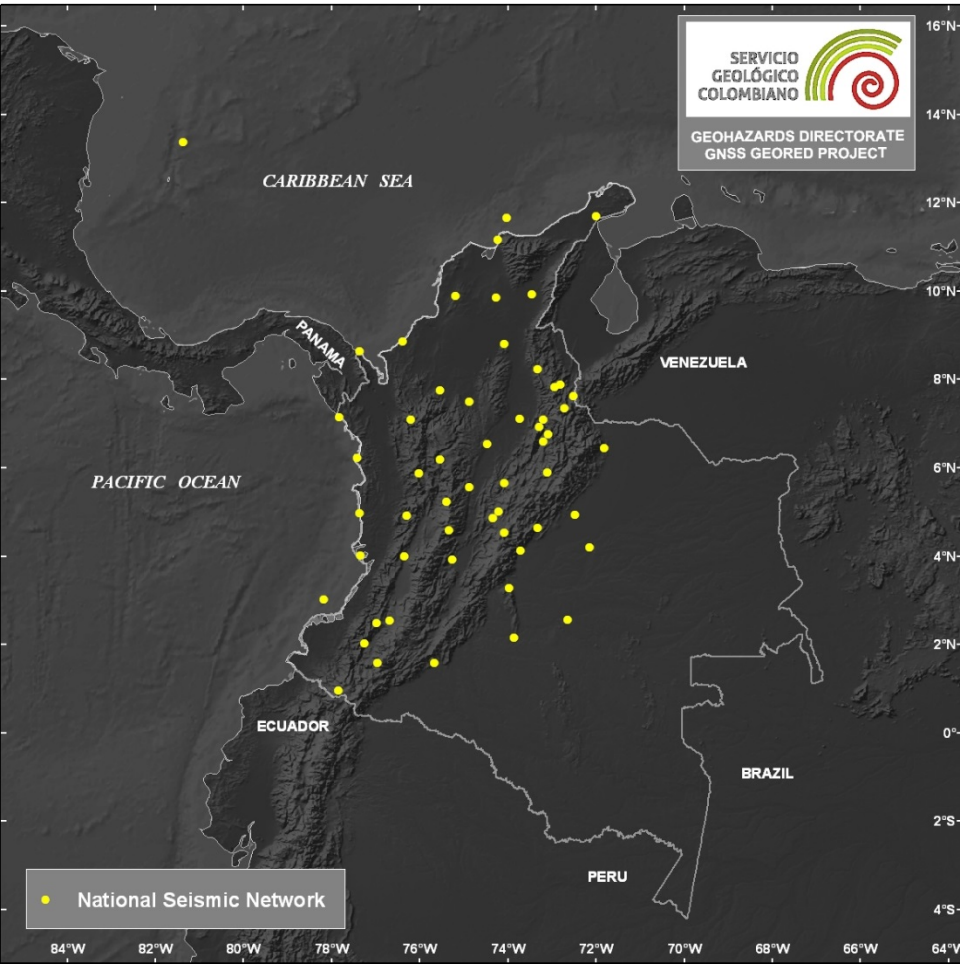
1994 Paez river earthquake

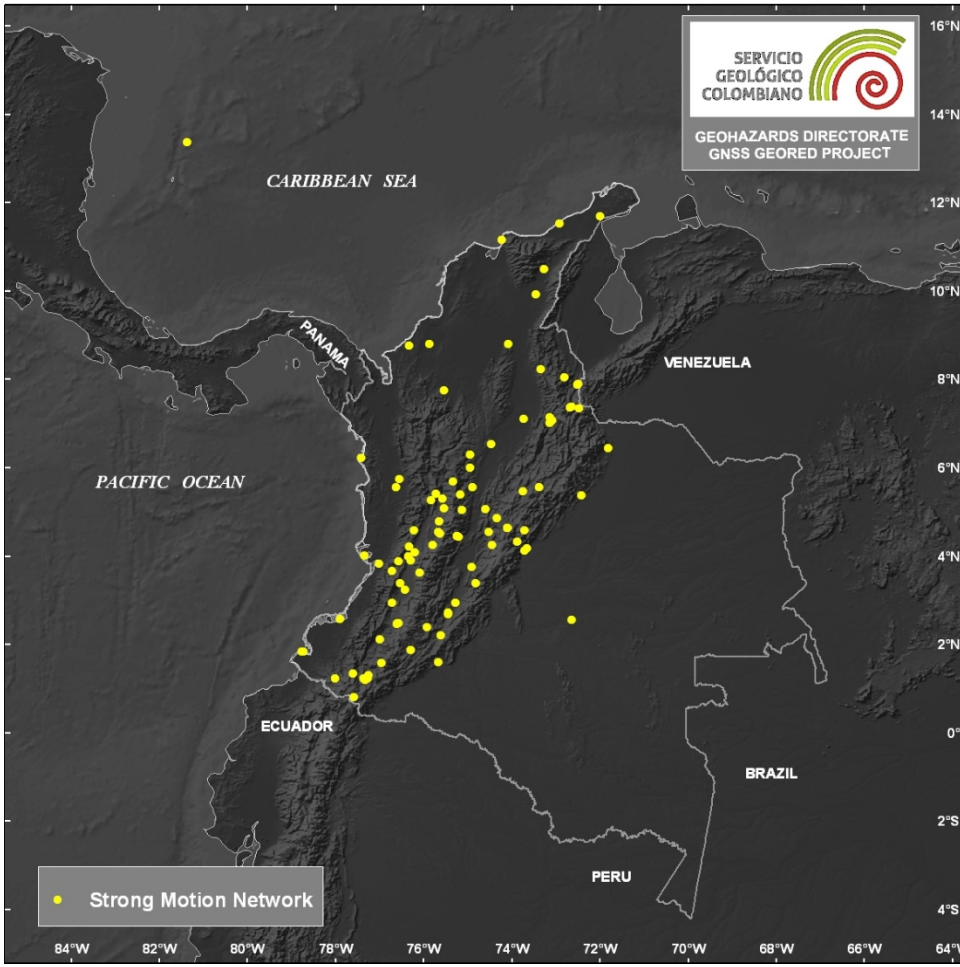
Date	June 6, 1994
Magnitude	6.8 M_w [1]
Depth	12 km [1]
Epicenter	2.917°N 76.057°W [1]
Areas affected	Colombia
Casualties	~1,100

1999 Armenia, Colombia earthquake

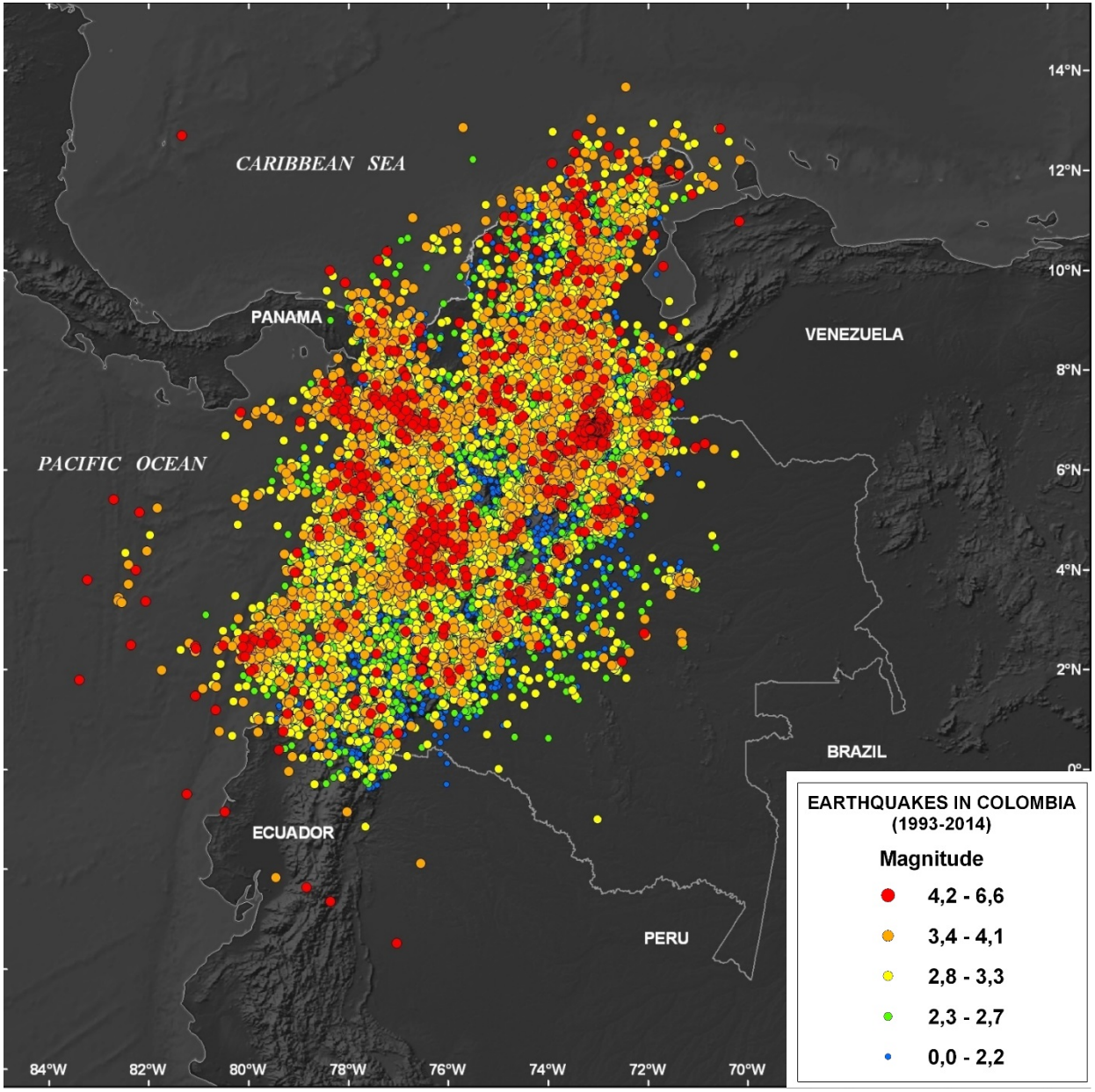
Date	January 25, 1999
Magnitude	6.2 M_w [1]
Depth	17 km (11 mi) [2]
Epicenter	4.5°N 75.7°W [1]
Areas affected	Colombia
Peak acceleration	0.55 *g*
Casualties	1,900 dead [1]

NATIONAL SEISMIC AND STRONG MOTION NETWORKS





SEISMICITY IN THE COLOMBIAN TERRITORY



RSNC, 2014

Space Geodesy in Colombia

Central And South America GPS Project

NSF – NASA – UNAVCO – JPL - USC

James N. Kellogg – Timothy Dixon

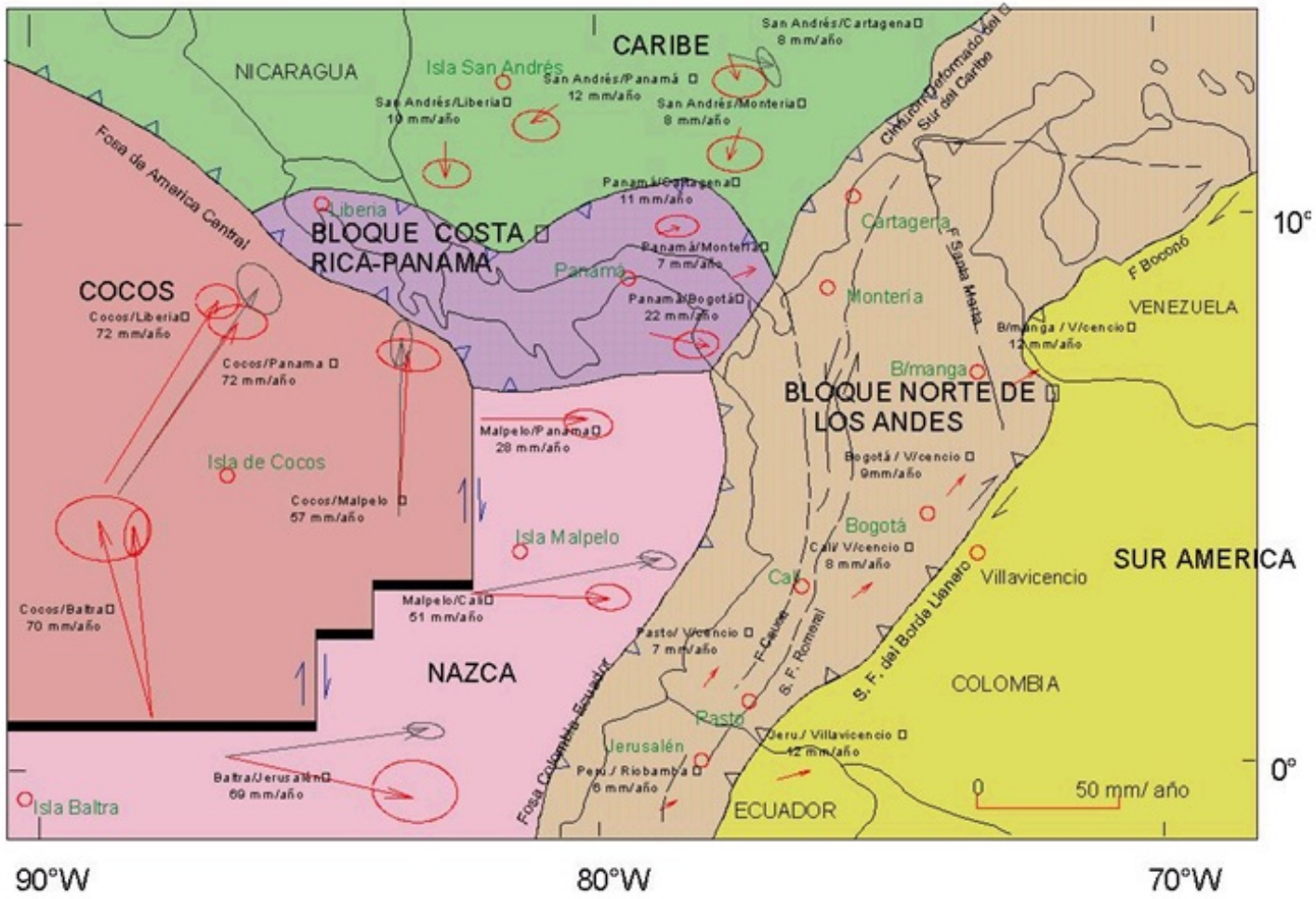
1988 – 1998

43 GPS receivers collected approx. 590 station-days of data in Colombia, Costa Rica, Ecuador, Panama, Venezuela, and American Samoa, Australia, Canada, New Zealand, Norway, Sweden, USA, West Germany

It was the beginning ……

It was the first civilian effort implementing a global GPS satellite technology network

CASA GPS RESULTS



:

Freymueller and Kellogg, (1991)

Mora (1995)

Vega y Kellogg, (1995)

Baselines

GPS/GNSS GeoRED Project

GeoRED, the acronym for "**Geo**desia: **R**ed de **E**studios de **D**eformación" has been adopted for the project "Implementation of the National GPS/GNSS Network for Geodynamics." Initiated in 2007 by the Colombian Geological Survey- CGS, formerly INGEOMINAS, GeoRED is a research and development project based on spatial geodesy technology which takes a multifaceted approach to cataloging and defining the geodynamics of Northwestern South America in order to reduce the associated hazards within a wide plate margin deformation zone (*Mora, 2006)*

Hence, GeoRED is a essential tool for determining interplate and intraplate continental deformation, and for understanding the current seismic cycle. Our current endeavors are focused on the acquisition of high quality GPS/GNSS data to be shared by intergovernmental institutions and university research centers within Colombia as well as collaborative international research efforts including reciprocal data sharing between the neighboring countries of Panama, Venezuela, Brazil, Peru and Ecuador.

GeoRED takes into consideration political relevance, economic importance, social bearing, along with scientific, and technical pertinence, as an appropriate approach to cataloging, understanding and defining the geodynamics of northwestern South America

It is a research and development project financed by the Colombian Government and executed by the CGS under the BPIN code 0043000220000 of the National Planning Department

OBJECTIVES AND SCOPE

The general purpose of the GeoRED Project is to "Improve the technical, scientific and operational capabilities in Colombia for ***analysis, interpretation and policy formulation regarding phenomena related to crustal deformation in Colombia, using GNSS satellite technology***".

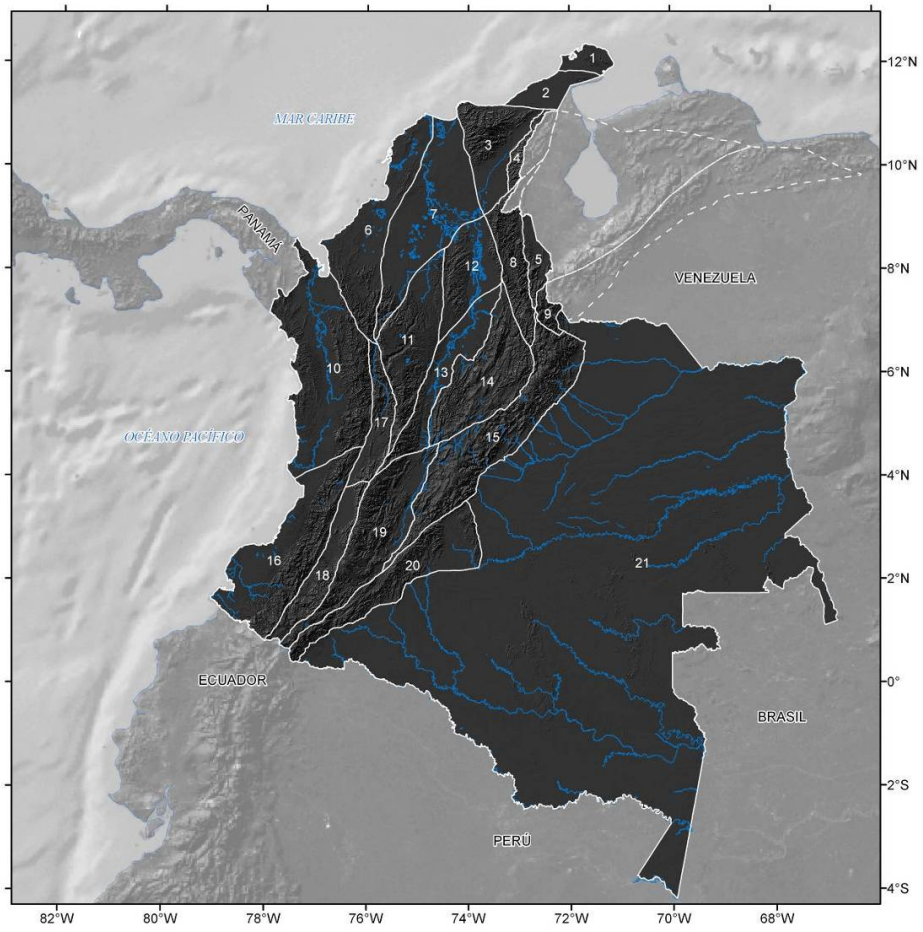
GeoRED is also designed to meet the following specific objectives:

- To implement an Active National GNSS Permanent Network for geodynamics with data transmission to an information-gathering center.
- To create GNSS mobile teams for campaign style data acquisition (passive network) - (active faults studies, post-seismic assistance, volcanic crisis assistance, mass movements monitoring, etc).
- To generate information about horizontal and vertical displacements as an essential input for the studies of crustal deformation.
- To establish a high precision geodetic reference frame for the multipurpose activities within the Colombian Geological Survey
- To provide information within the CGS as well as to other government institutions toward the execution of research and development projects using GNSS data. (*Mora, 2006)*

GPS/GNSS GeoRED Network Implementation

CRUSTAL SEGMENTATION OF THE NORTH ANDES WITHIN COLOMBIA

Beginning in 2007, discussions within the GeoRED group led to a master plan for the distribution of the base permanent GPS/GNSS stations array and specific areas of interest for campaign site construction. The use of previously identified active faults as preferred structures along which stresses are transferred through the deformational area led to the idea of segmentation of the North Andes within Colombia into 20 tectonic sub-blocks.



(López and Mora, 2009)

These sub-blocks were determined taking into account some generalizations:

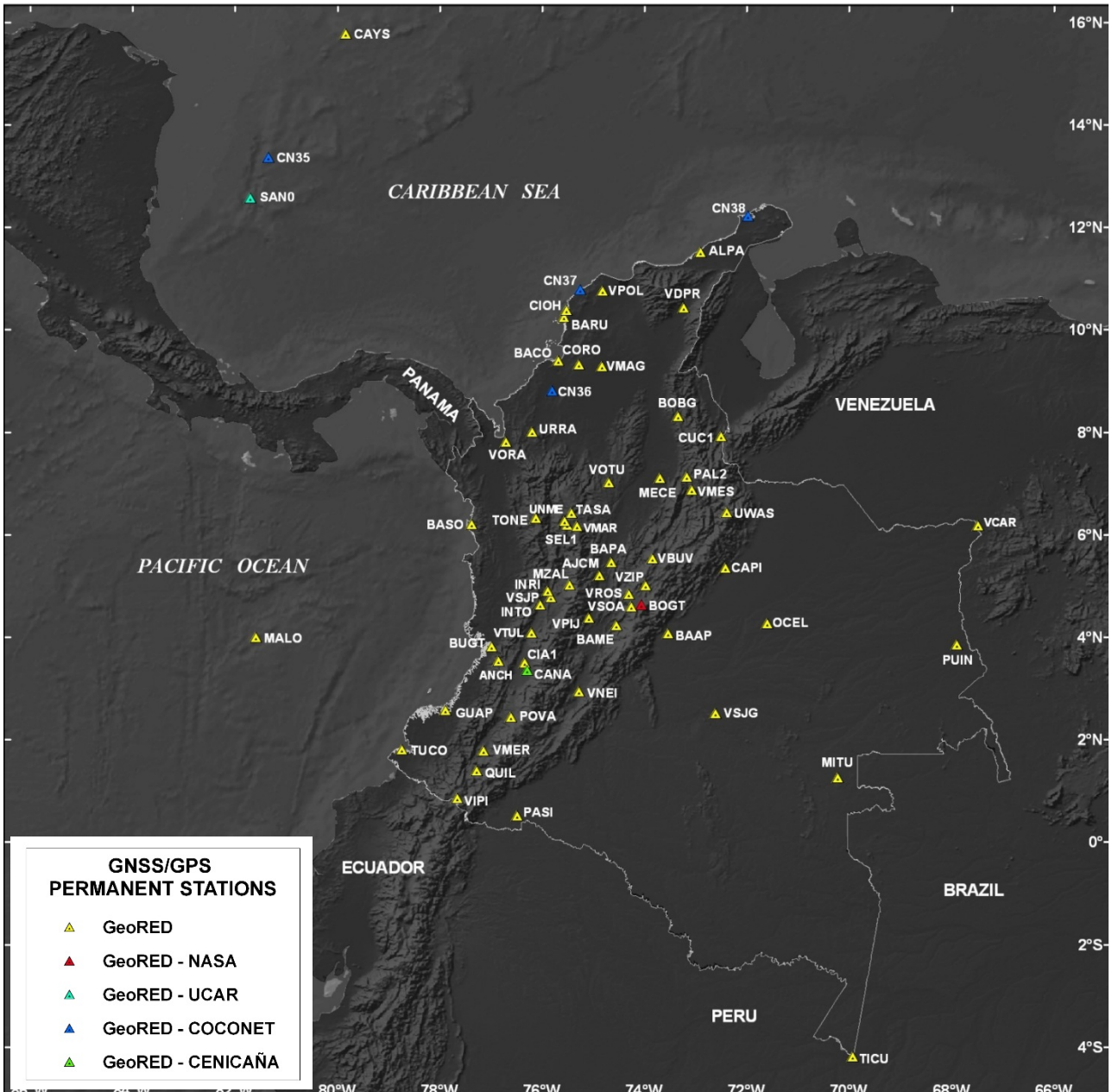
- *A tectonic sub-block represents a homogeneous crustal entity limited by the main active faults, and it is thought to possess a characteristic pattern of internal deformation;*
- *At some fault segments, current kinematics, rupture dimensions and terminations remains unclear; moreover, detailed palaeoseismological and neotectonic studies are yet scarce. Due to this, it has been necessary to make some general assumptions about fault extension, geometry and sense of slip from geophysical interpretation, geological maps and reports;*
- *Some regions at plate interfaces are expected to be more heterogeneous and to have higher sub-block segmentation. But, owing to the fact that some of those places have not been studied in depth and are difficult to access, the polygons of the sub-blocks are only approximately outlined.*

GeoRED GNSS NETWORK IMPLEMENTATION

Each of the 20 sub-blocks is expected to have, at least, 3 – 4 permanent GPS/GNSS stations within the block, and the construction of campaign sites along the boundaries of the blocks.

65 permanent installations and more than 290 campaign style constructions have been funded until now

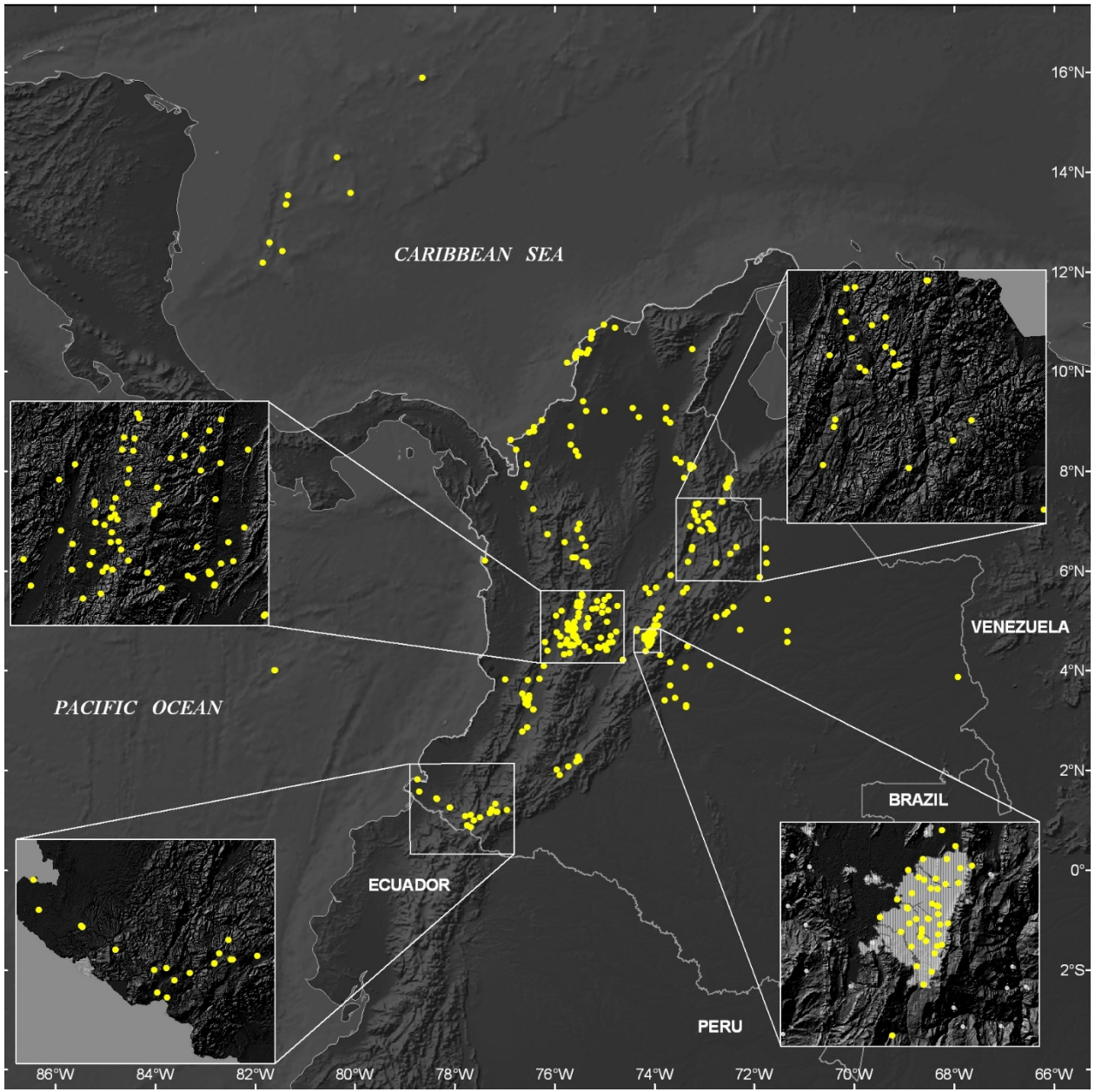
GPS/GNSS PERMANENT STATIONS NETWORK

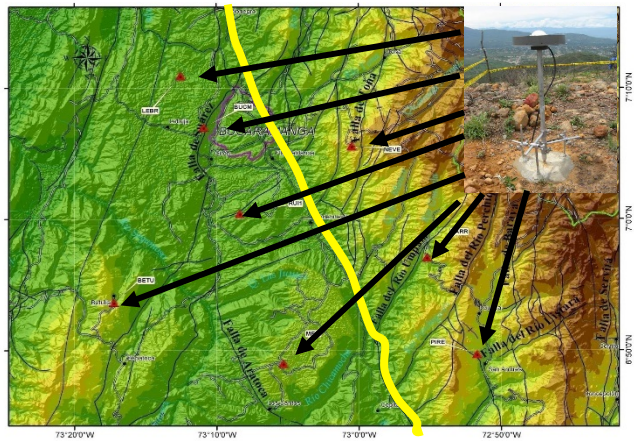


65 stations

Status Dic. 2014

GPS/GNSS FIELD STATIONS NETWORK



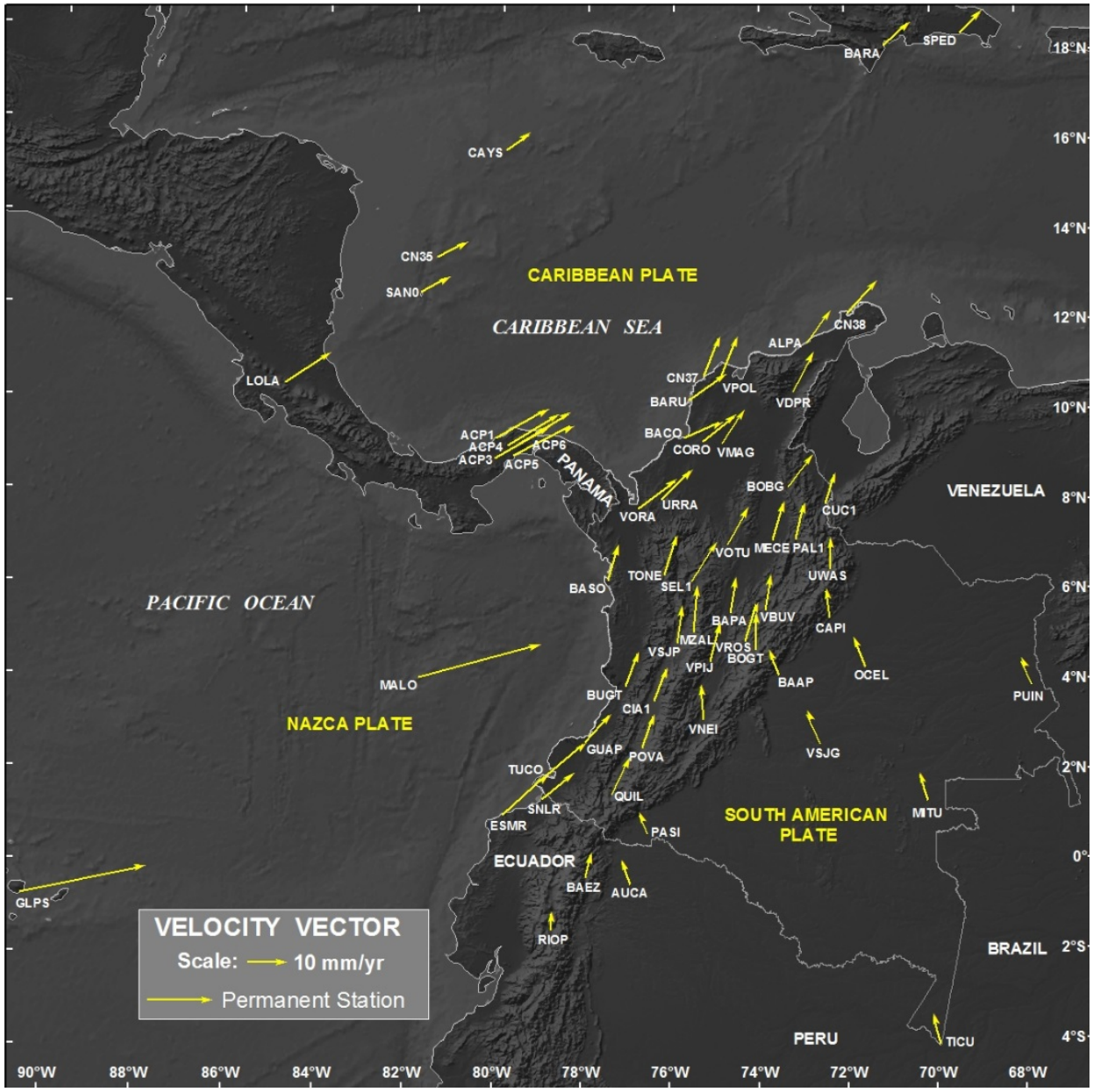


293
stations

Status
December 2014

Preliminary Results

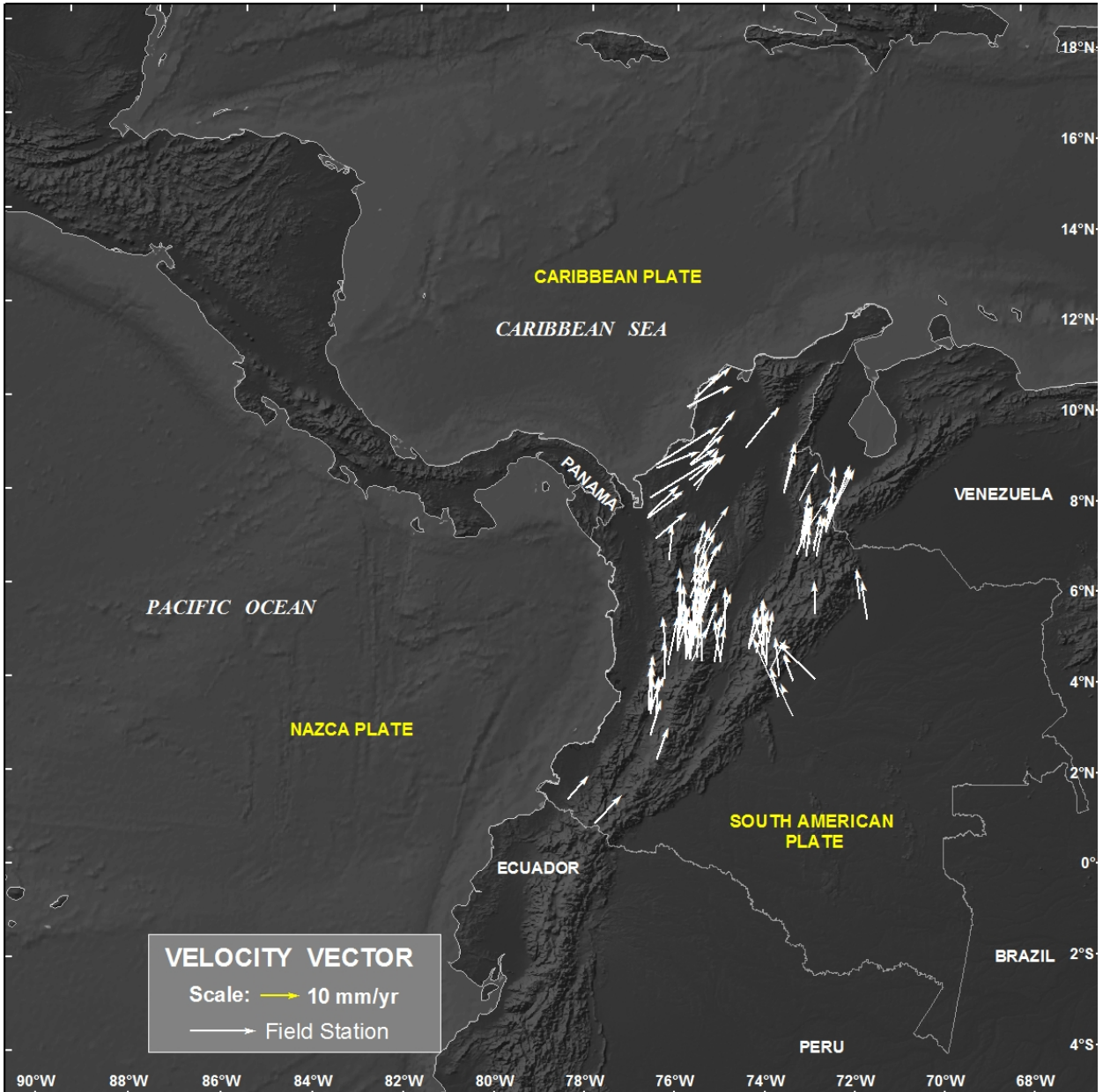
GPS VELOCITIES – Permanent stations



GIPSY-OASIS

NASA JPL Jet Propulsion Laboratory California Institute of Technology

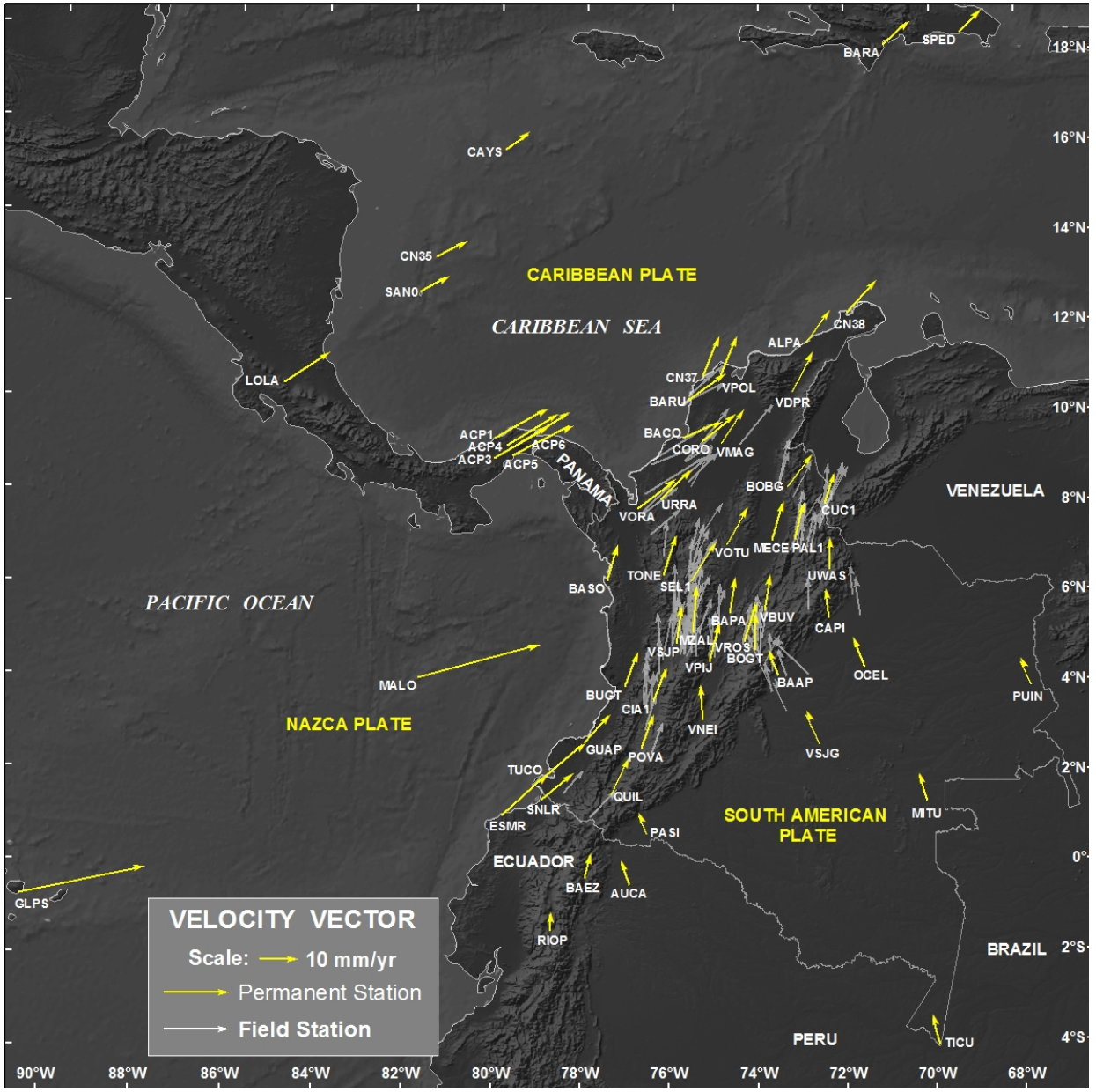
GPS VELOCITIES – Field stations



GIPSY-OASIS

NASA JPL Jet Propulsion Laboratory California Institute of Technology

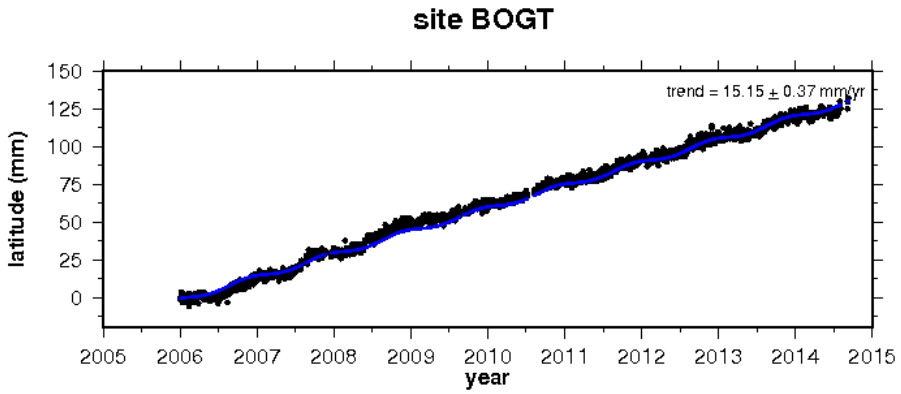
GPS VELOCITIES – Field stations

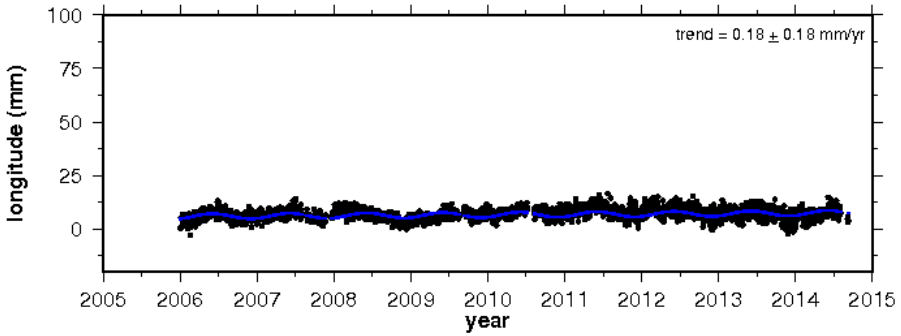


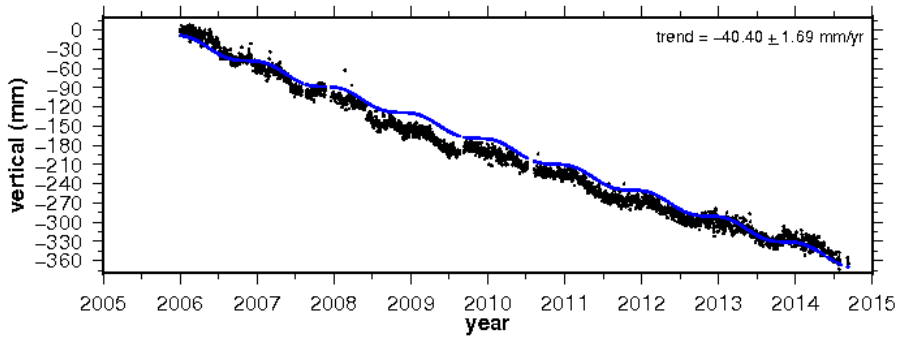
GIPSY-OASIS

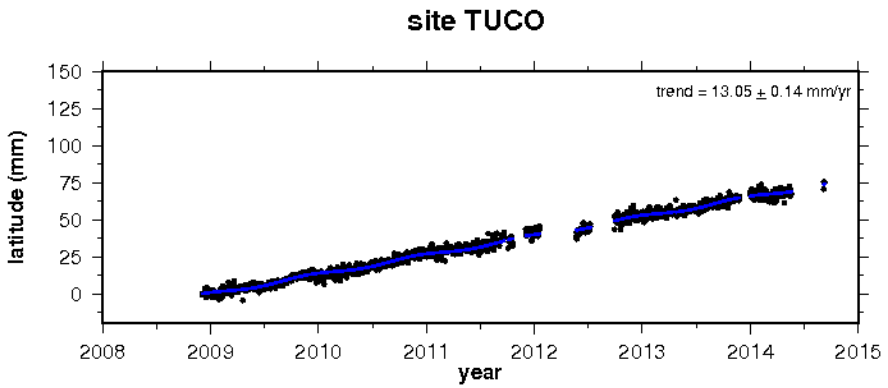
NASA JPL Jet Propulsion Laboratory California Institute of Technology

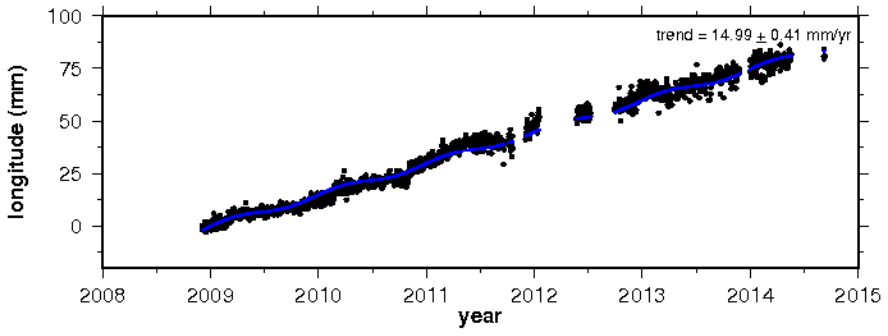
GPS TIME SERIES

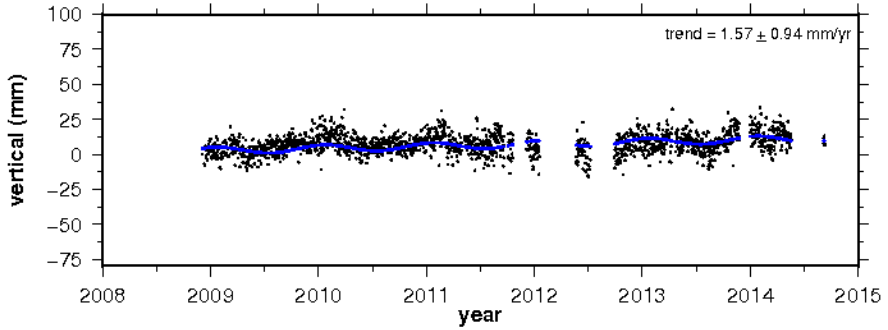




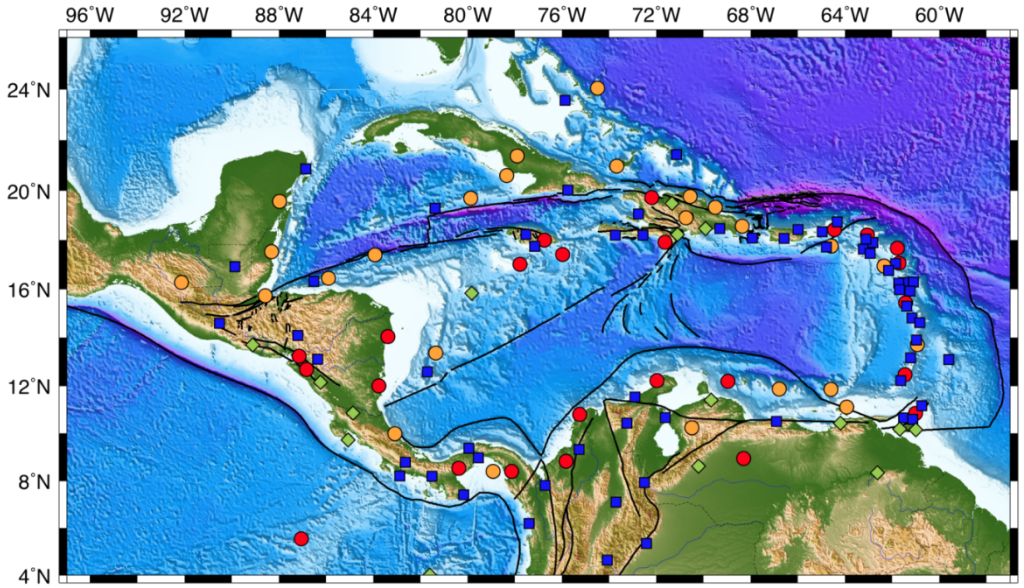








INTERNATIONAL COLLABORATION

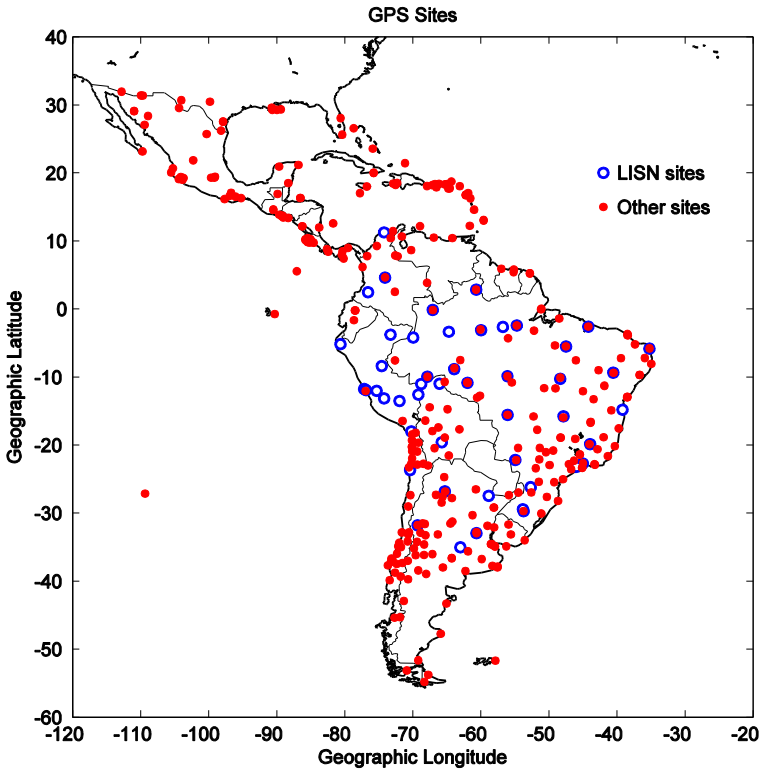


LISN
Low Latitude Ionospheric Sensor Network

Boston College
ISR
Institute for Scientific Research

COCONet
Continuously Operating Caribbean GPS Observational Network

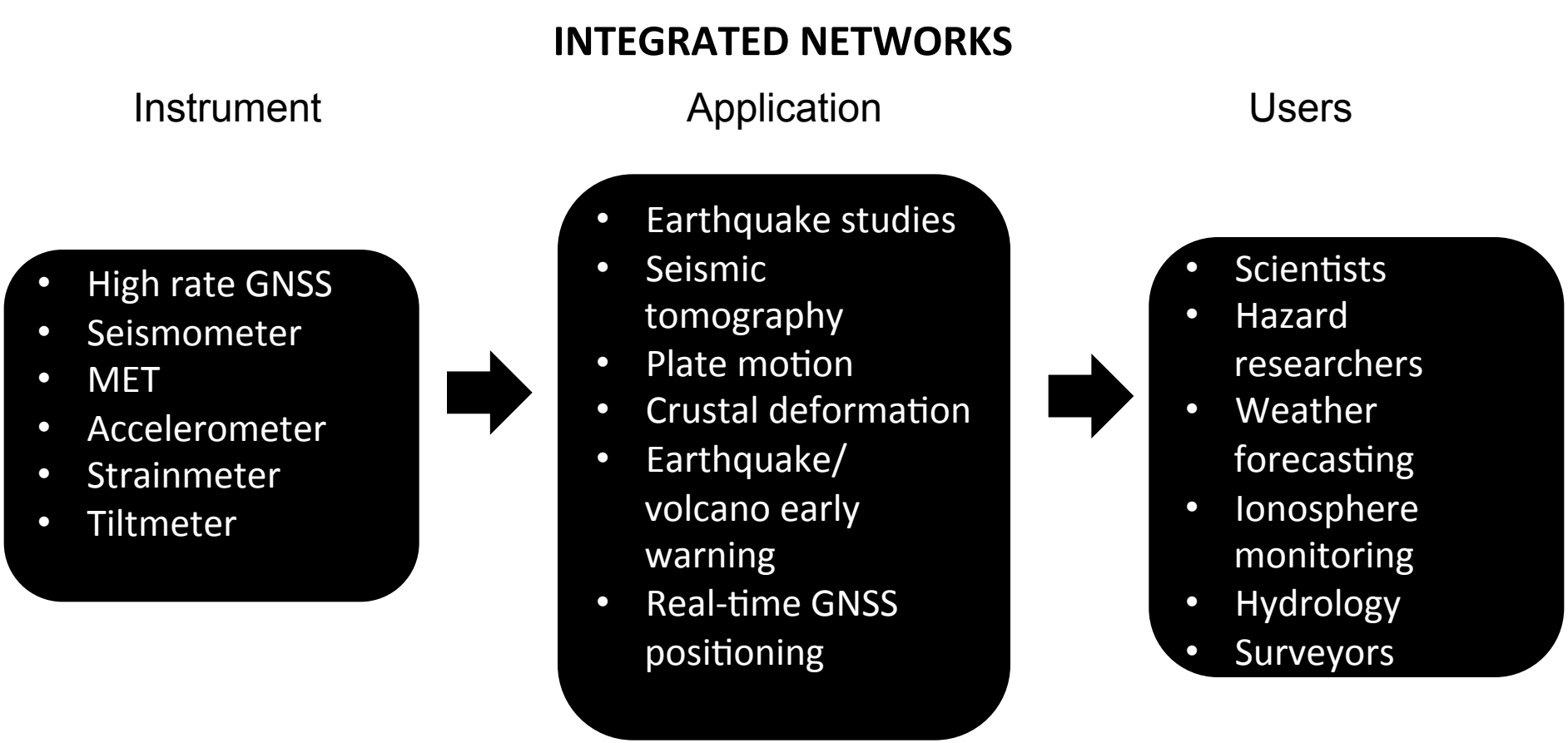
UNAVCO



CHALLENGES

CHALLENGES

INTEGRATED NETWORKS



MAIN CHALLENGES

GNSS Geodesy has great relevance to all aspects of Earth Science research as it is practiced at the Colombian Geological Survey as it involves the application of new technology that permits the active observation and study of crustal and atmospheric dynamics that shape the land and controls innumerable processes at depth and at surface that are of vital importance to mankind. For that reason, it is very important to increase the knowledge of the current crustal deformation stage at Colombia.

- *To obtain geodetic rates of fault displacements, as well as to characterize the kinematics of active faults and their seismogenic potential;*

- *To generate crustal sub-block and regional deformation models to the Colombian territory, through the integration of geodetic, geological and geophysical data;*

- *To establish an operative and dense geodetic network with geodynamic purposes: it is expected to have installed 100 permanent stations and more than 350 field stations for episodic campaigns (tectonic geodesy), and also to continue the implementation of several permanent GNSS local networks to monitor ground deformation on active volcanoes (volcano geodesy)*

MAIN CHALLENGES

To study and understand the ionosphere behaviour and its relationship with other phenomena such as earthquakes (lithosphere-atmospheric coupling, tsunamis, etc)

To provide support to atmospheric, ionosphere, subsidence and mass movement studies and different applications (navigation, surveying, etc)

To continue doing the geodetic connection of the tide gauges in a collaborative work with the Colombian Navy to support the sea level studies

Collaboration should involve data exchange, comparison of geodetic processing procedures and reference frame analysis, as well as fostering international cooperation on geoscience research in the fields of Geodynamics and Atmospheric Science – (COCONet, LISN) among others

Colombian investigators should also cooperate and interchange with international organizations such as the IGS, UNAVCO, among others.

CONCLUSIONS

CONCLUSIONS

The Colombian Geological Survey through the GeoRED Project is creating a high-quality GNSS infrastructure that serves as an essential framework for the study of crustal and atmospheric dynamics of the entire Colombian territory, and at the same time sharing data and research results with neighbouring countries.

Data products will include raw GNSS observations, and data of atmospheric water vapor, that facilitate the construction of time series of high precision daily geodetic positions, that in turn permit the compilation of surface velocity fields that register crustal dynamic behaviour that is of direct relevance to geohazards in earth and atmospheric sciences.

It is intended to achieve a greater density of the national GNSS network in an effort to address specific geoscience aspects such as plate kinematics and crustal dynamics, the registration of active fault slip rates, and plate boundary interaction and deformation, including the understanding of earthquake cycle processes

CONCLUSIONS

- The GPS time series of daily station positions give fundamental information for both regional and local geodynamics studies.

- Until now, we have obtained 113 quality vector velocities for Colombia, 34 of them as part of the permanent network.

- The GPS/GNSS stations are located on the three major plates that interact within the Wide Plate Margin Deformation Zone including existing permanent installations on IGS Galapagos and GEORED Malpelo Islands on the Nazca Plate, and San Andres, Providencia Islands and Serranilla Cay on the Caribbean plate.

- The velocity vectors confirm the oblique subduction of the Nazca Plate and Carnegie aseismic ridge collision processes at the Colombia-Ecuador trench which are assumed to be the mechanism for the transpressional deformation and the “escape” of the North Andes Block (NAB).

- The North Andes block (NAB) is a hypothesized tectonic block that migrates (escapes) north-northeast relative to a stable South American reference frame.

Thank you very much for your attention

http://geored.sgc.gov.co