GEODESIA SATELITAL – GNSS

(GEOFISICA Y GEOMATICA)

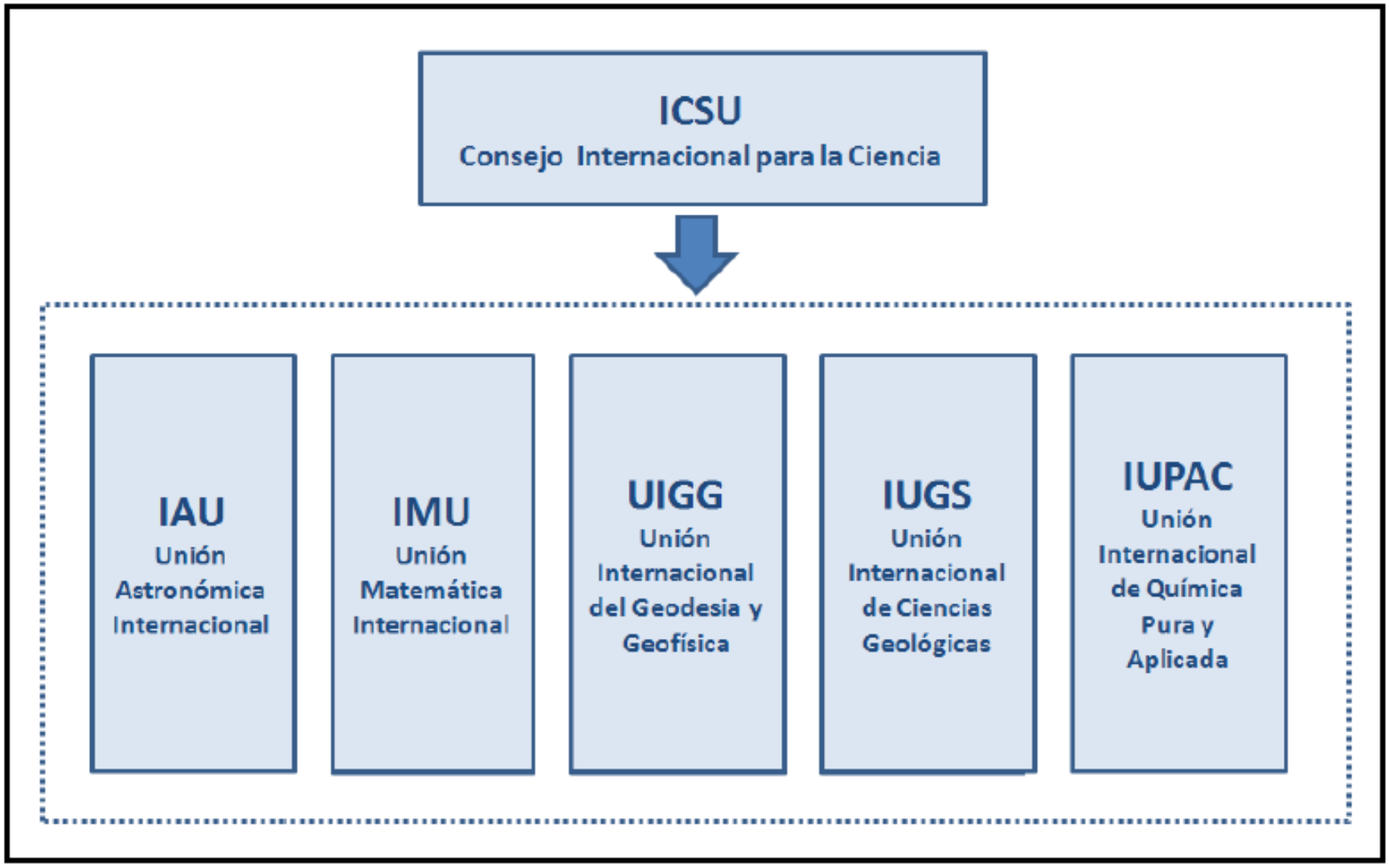
Retos del siglo XXI

Andrés Cárdenas Contreras

CONTENIDO

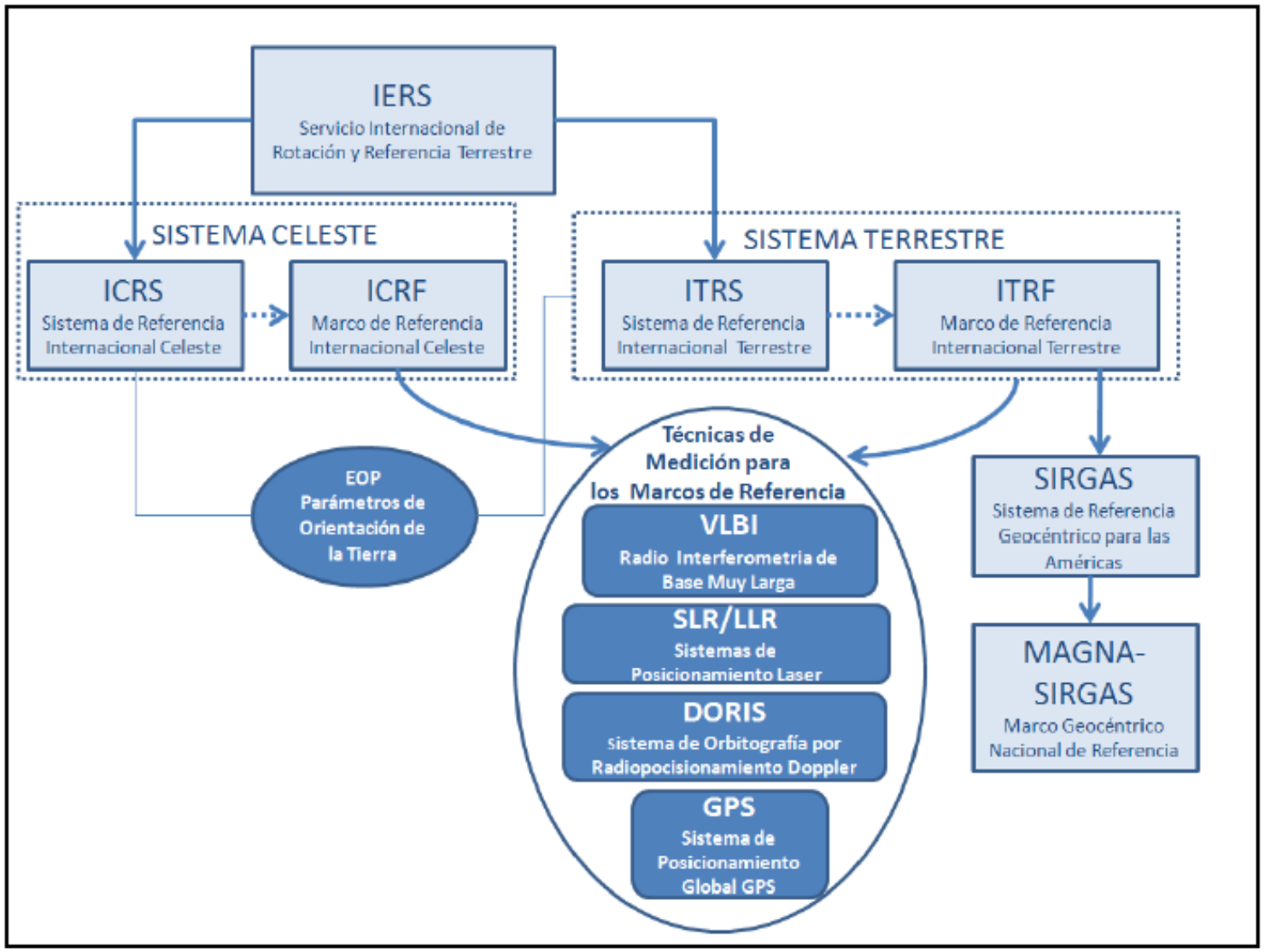
1. Organización Geodesia Satelital y Servicios GNSS
2. Retos de Geodesia Satelital, Geomática y Geofísica en el siglo XXI
3. Fundamentos de GNSS
4. Procesamiento GNSS
5. Ejemplos de Proyectos de Investigación

1. Organización – Consejos - Uniones



Fuente: CIOH, 2009

1. Sistemas y Marcos de referencia



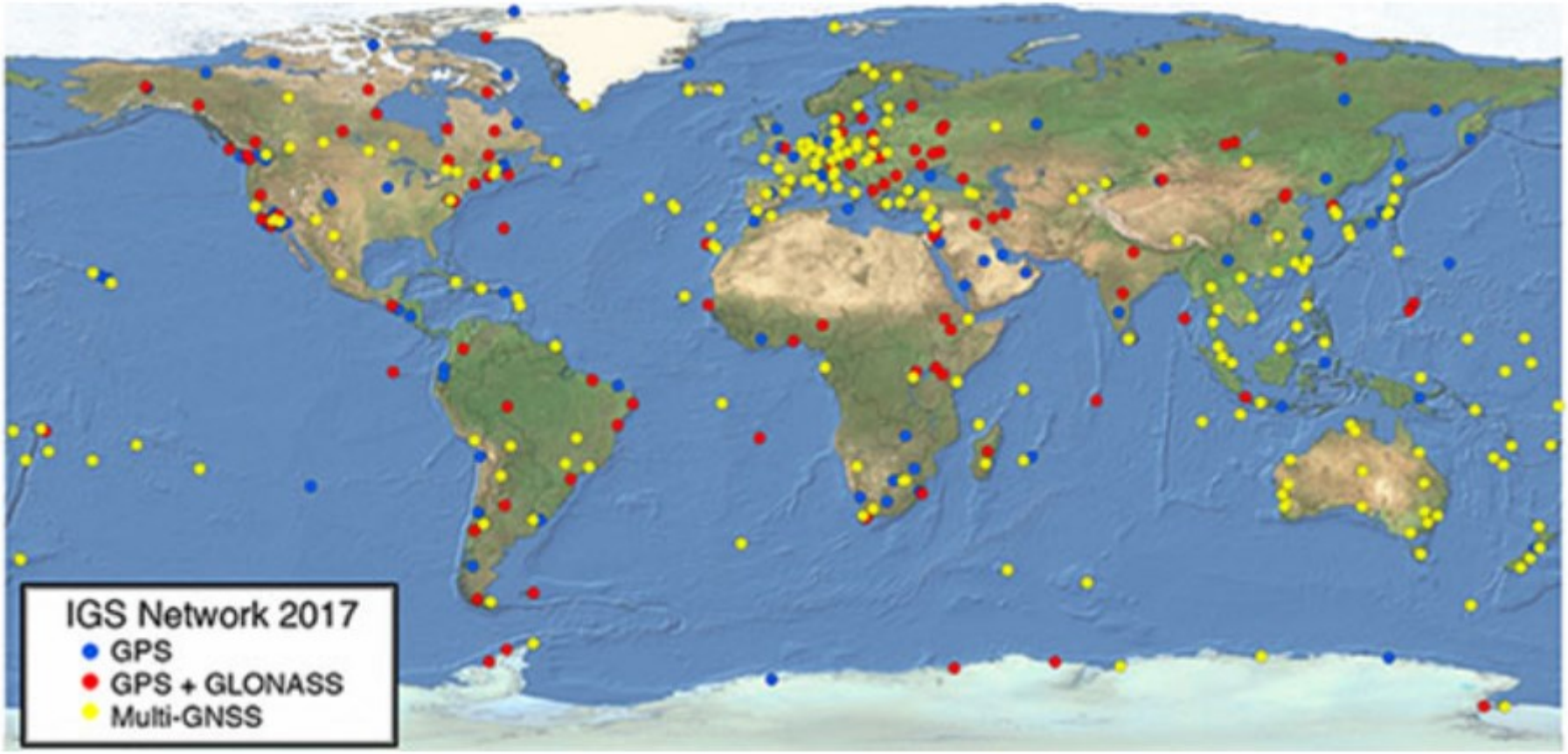
Fuente: CIOH, 2009

1. Servicios IGS

Geometry	IERS:	International Earth Rotation and Reference Systems Service *(ILS in 1899, BIH in 1912, IPMS in 1962, IERS in 1987)*
	IGS:	International GNSS Service *(1994)*
	IVS:	International VLBI Service *(1999)*
	ILRS:	International Laser Ranging Service *(1998)*
	IDS:	International DORIS Service *(2003)*
Gravimetry	IGFS:	International Gravity Field Service *(2004)*
	BGI:	Bureau Gravimetrique International *(1951)*
	IGeS:	International Geoid Service *(1992)*
	ICET:	International Centre for Earth Tides *(1956)*
	ICGEM:	International Centre for Global Earth Models *(2003)*
	IDEMS:	International Digital Elevation Models Service *(1999)*
Ocean	PSMSL:	Permanent Service for Mean Sea Level *(1933)*
	IAS:	International Altimetry Service *(2008)*
Std	BIPM:	Bureau International des Poids et Mesures *(Time 1875)*
	IBS:	IAG Bibliographic Service *(1889)*

Fuente: El Rol de la Geodesia FIG – IAG -, Rizos 2012

1. Servicios IGS – Red de Estaciones



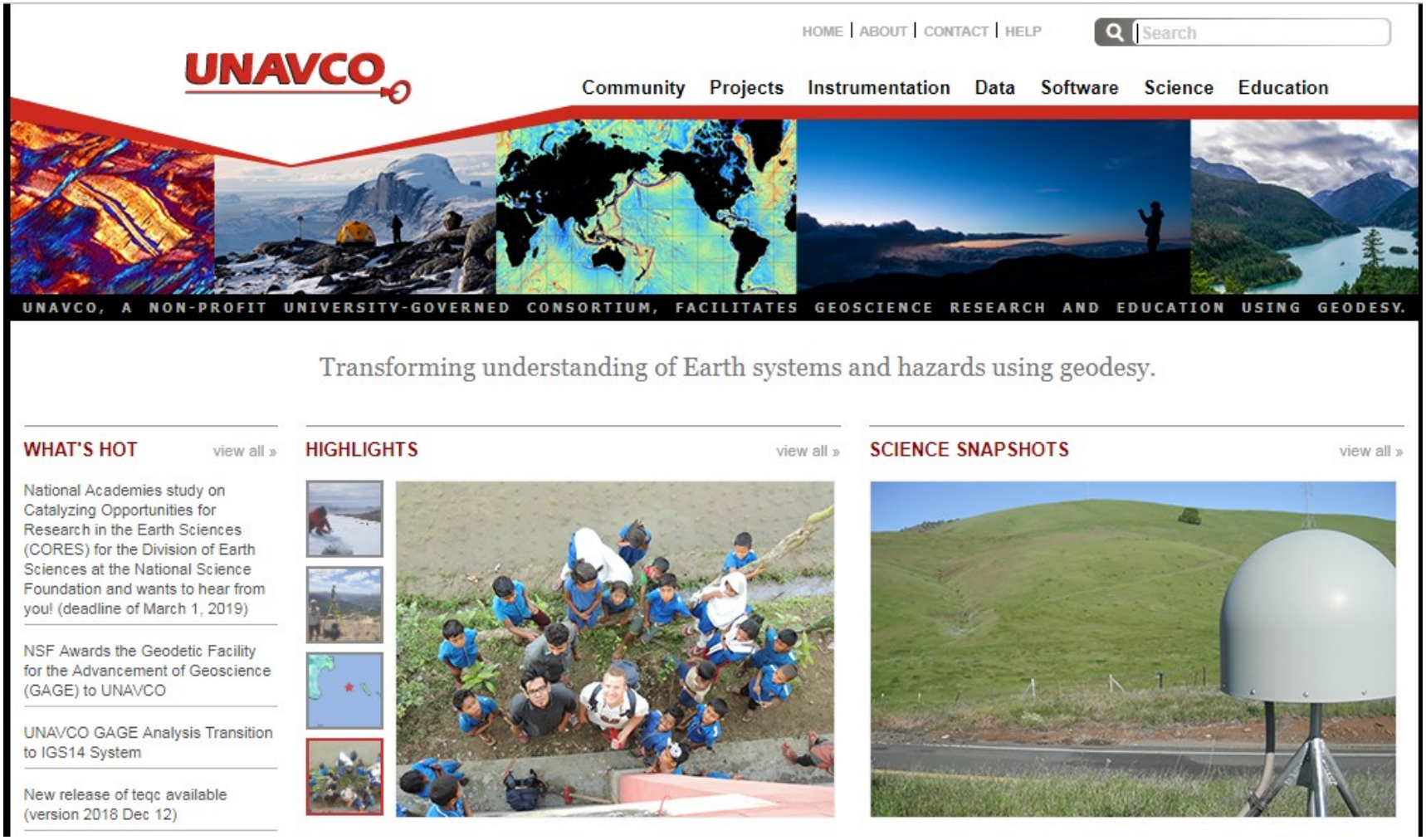
Fuente: https://www.gpsworld.com

1. Servicios IGS – Grupos de Trabajo

Antenna	Est. 2008
Bias and Calibration	Est. 2008
Clock Products	Est. 2003
Data Center	Est. 2002
GNSS Monitoring (IGMA)	Est. 2017
Ionosphere	Est. 1998
Multi-GNSS	Est. 2003
Precise Point Positioning with Ambiguity Resolution	Est. 2018
Real-time	Est. 2001
Reference Frame	Est. 1999
RINEX	Est. 2011
Space Vehicle Orbit Dynamics	Est. 2011
Tide Gauge (TIGA)	Est. 2001
Troposphere	Est. 1998
Multi-GNSS Extension (MGEX)	Est. 2016
Real-time (RTS)	Est. 2001
Low Earth Orbiters (LEO)	2002-2010

Fuente: http://www.igs.org/wg

1. Servicios GNSS - UNAVCO



https://www.unavco.org/

1. Servicios UNAVCO - Productos

- Software
  - Ayuda con Software
- Procesamiento de datos
- TEQC
- Herramientas de pre procesamiento GPS / GNSS
- Hatanaka
- runpkr00
- Preprocesamiento GPSTk
- Herramientas de posprocesamiento GPS / GNSS
- GAMIT / GLOBK /
- GIPSY-OASIS II
- RTKLIB
- Posprocesamiento GPSTk
- Bernese
- Centro de Negocios Trimble
- RTNet
- Software TLS
- Software SAR

https://www.unavco.org/

1. Servicios GNSS – UNAVCO - EDUCACION

UNAVCO

Community Projects Instrumentation Data Software Science **Education**

Help with Education

¿Necesita ayuda con alguno de los temas de educación enumerados a continuación? UNAVCO puede proporcionar orientación y apoyo educativo.

OVERNED CONSORTIUM. FACILITATES GEOSCIENCE RESEARCH AND EDUCATION USING GEODESY

Outreach

UNAVCO publica periódicamente materiales de divulgación tales como páginas, folletos, servicios disponibles y demás material sobre geodesia

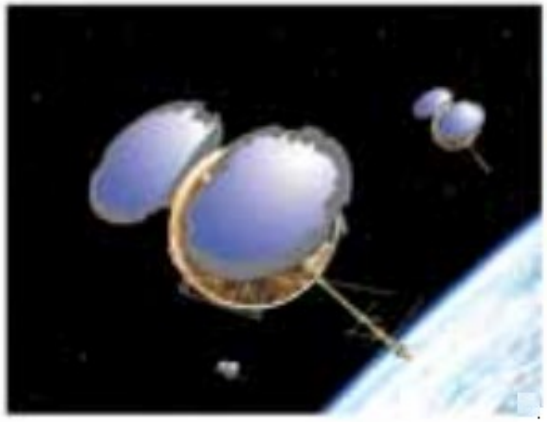
Internships & Opportunities

UNAVCO está comprometido a aumentar la comunidad de profesionales de geodesia y fuerza laboral de geociencias. Enfocamos nuestros esfuerzos en brindar oportunidades en varias etapas de la trayectoria académica / profesional de las geociencias. Hay muchas oportunidades para los estudiantes en UNAVCO, incluidos nuestros programas RESESS, Geo-Launchpad y USIP. Oportunidades adicionales para estudiantes están disponibles a través de la comunidad UNAVCO.

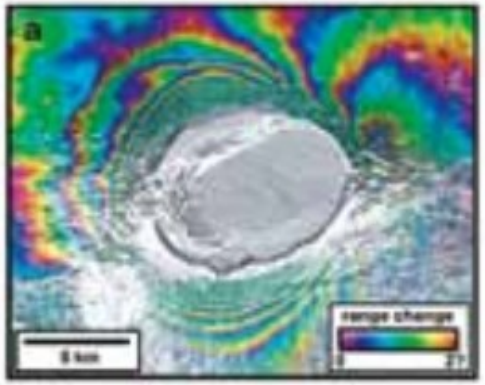
https://www.unavco.org/

2. Retos de la Geodesia Satélital y Geofísica

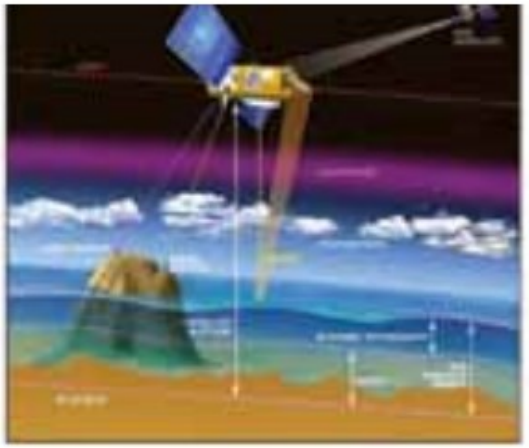
CLIMA Y DINAMICA ATMOSFERICA



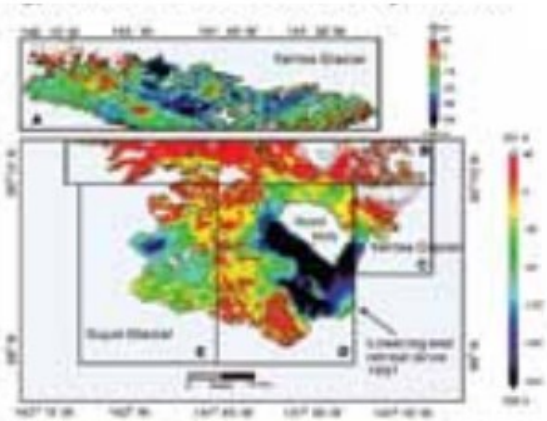
RIESGOS NATURALES



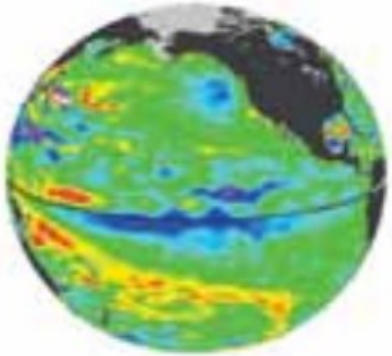
DETERMINACION DE ORBITAS PRECISAS



DINAMICA DEL HIELO Y LOS GLACIARES - CAMBIO CLIMATICO



NIVEL DEL MAR Y DINAMICA DE LOS OCEANOS

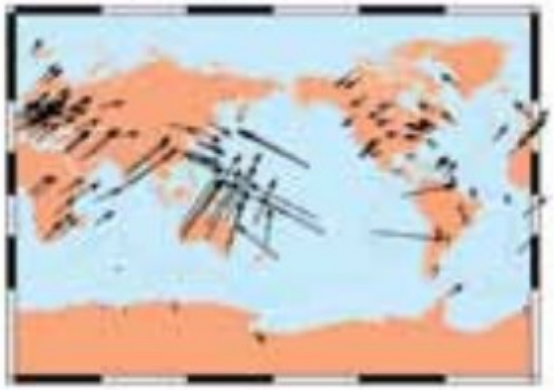


HIDROLOGIA

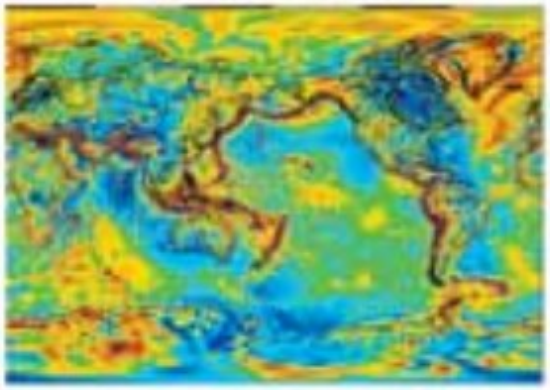
Fuente: Cambios de la Geodesia, UNAVCO 2012

2. Retos de la Geodesia Satélital y Geofísica

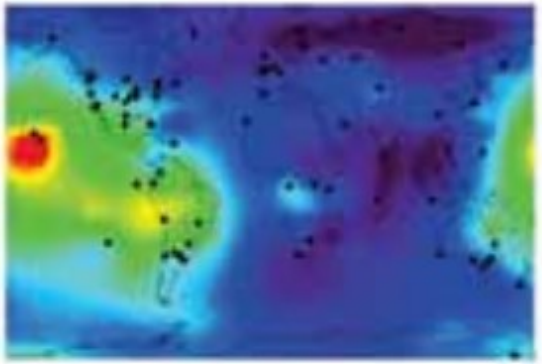
PLACAS TECTONICAS



GRAVIMETRIA LOCAL Y GLOBAL

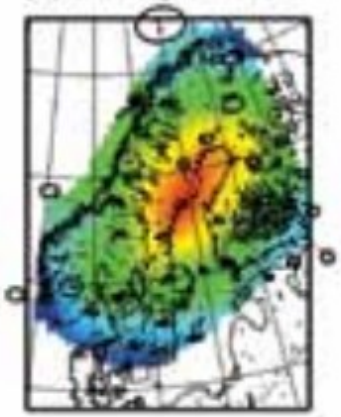


ACTIVIDAD DE LA INOSFERA

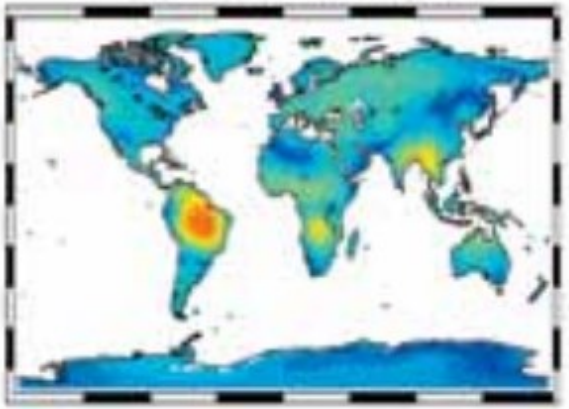


BATIMETRIA Y TOPOGRAFIA

GEODINAMICA



CICLO HIDRICO GLOBAL, REGIONAL Y LOCAL

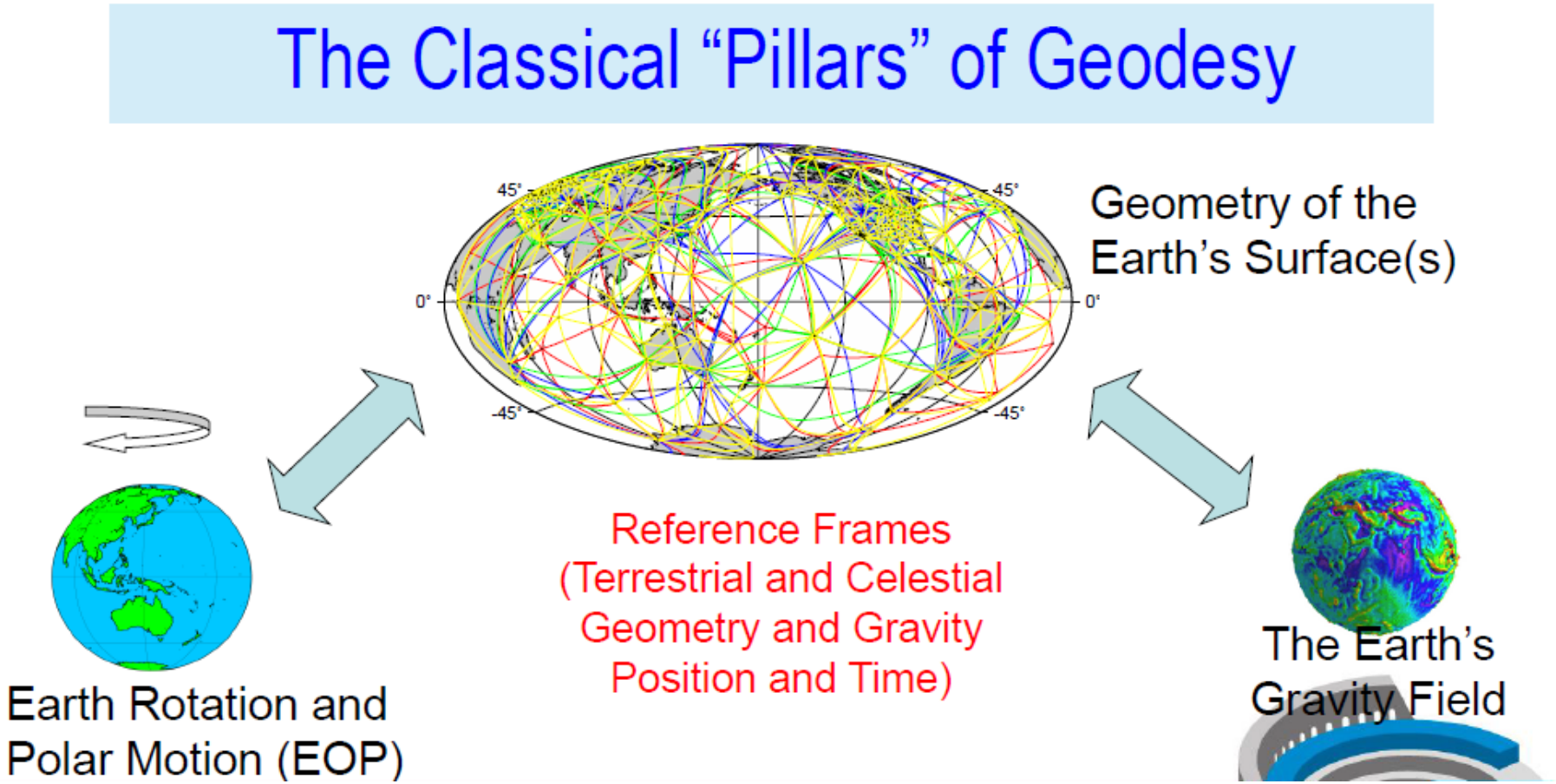


Fuente: Cambios de la Geodesia, UNAVCO 2012

2. Retos de la Geodesia Satélital y Geofísica

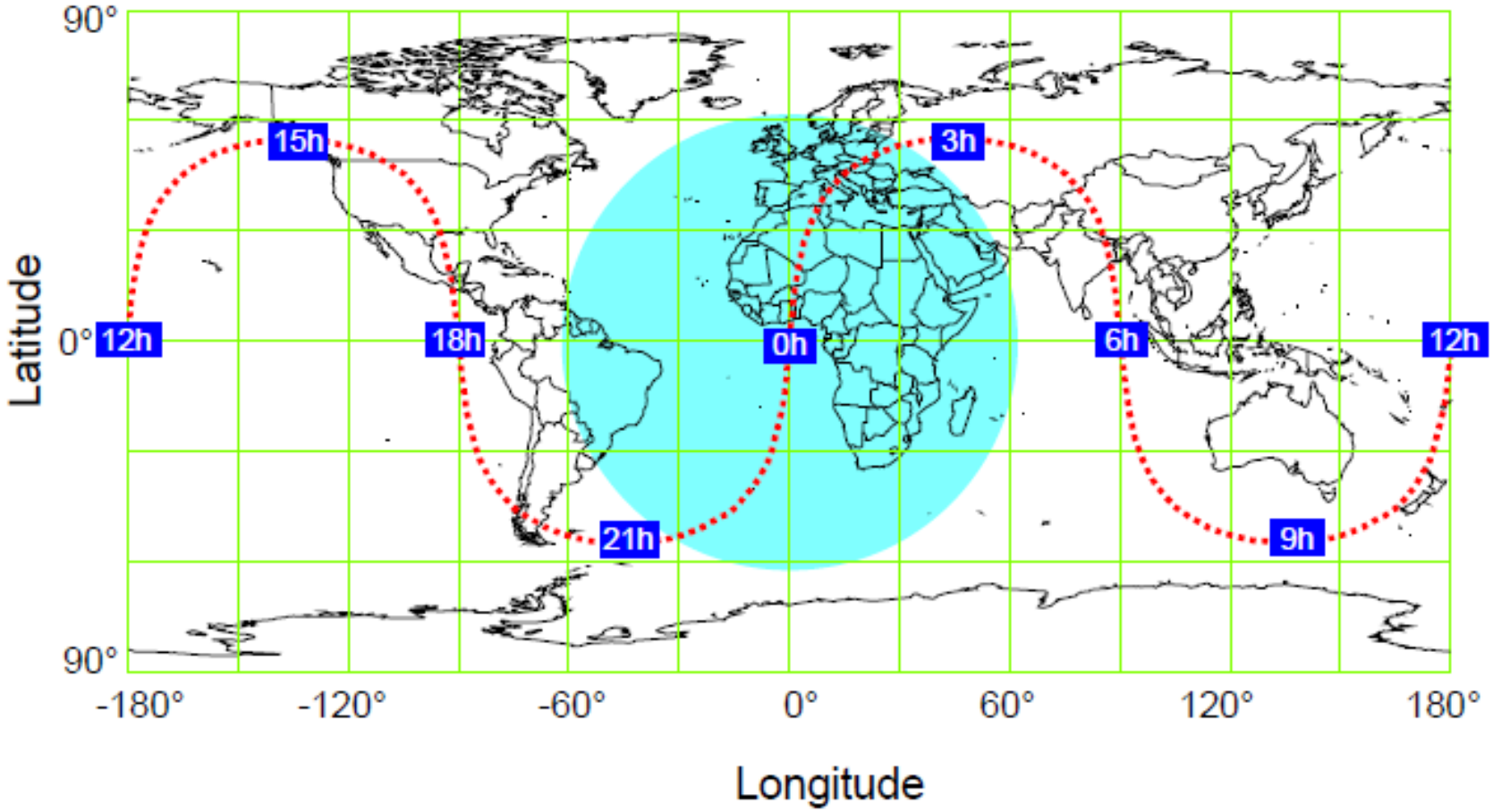
- **Geociencias fundamentales:** Geofísica de la tierra sólida, atmosférica, Procesos criosféricos y oceanográficos, hidrología.
- **Estudios de cambio climático global:** ciclo del agua y transporte masivo, aumento del nivel del mar, monitoreo a largo plazo.
- **Gestión de Riesgos Naturales:** sísmica, volcánica, deslizamiento de tierra, tormentas, inundaciones, tsunamis, clima espacial, sistemas de alerta temprana.
- **Marcos de referencia geodésicos:** ITRF, datos nacionales, gravedad, tiempo.
- **Ingeniería:** Sensores remotos atmosféricos, sensores de georreferenciación, Geodesia operativa y de ingeniería.

3. Fundamentos de GNSS



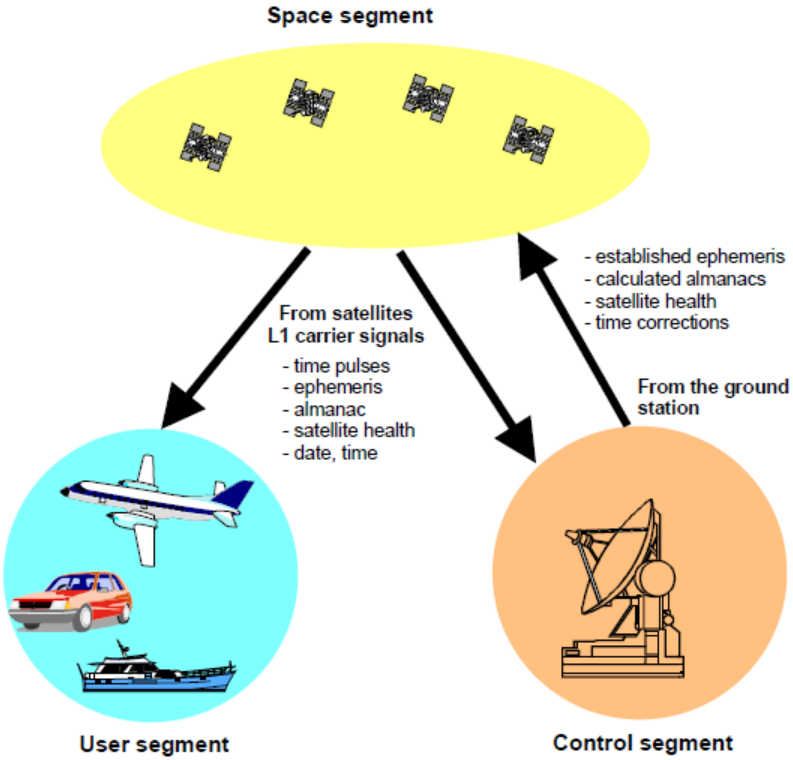
Fuente: El Rol de la Geodesia FIG – IAG -, Rizos 2012

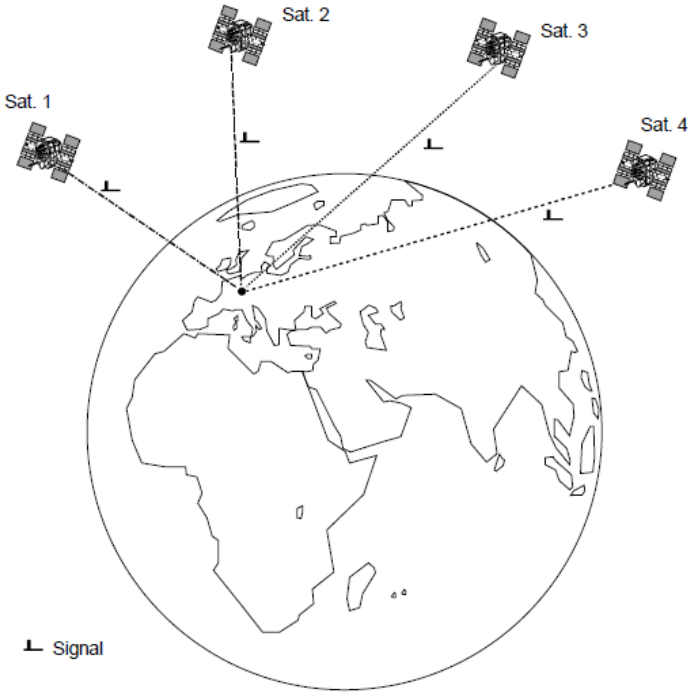
3. Orbita de un Satélite GPS en 24 horas



Fuente: GPS, Zoog JM 209

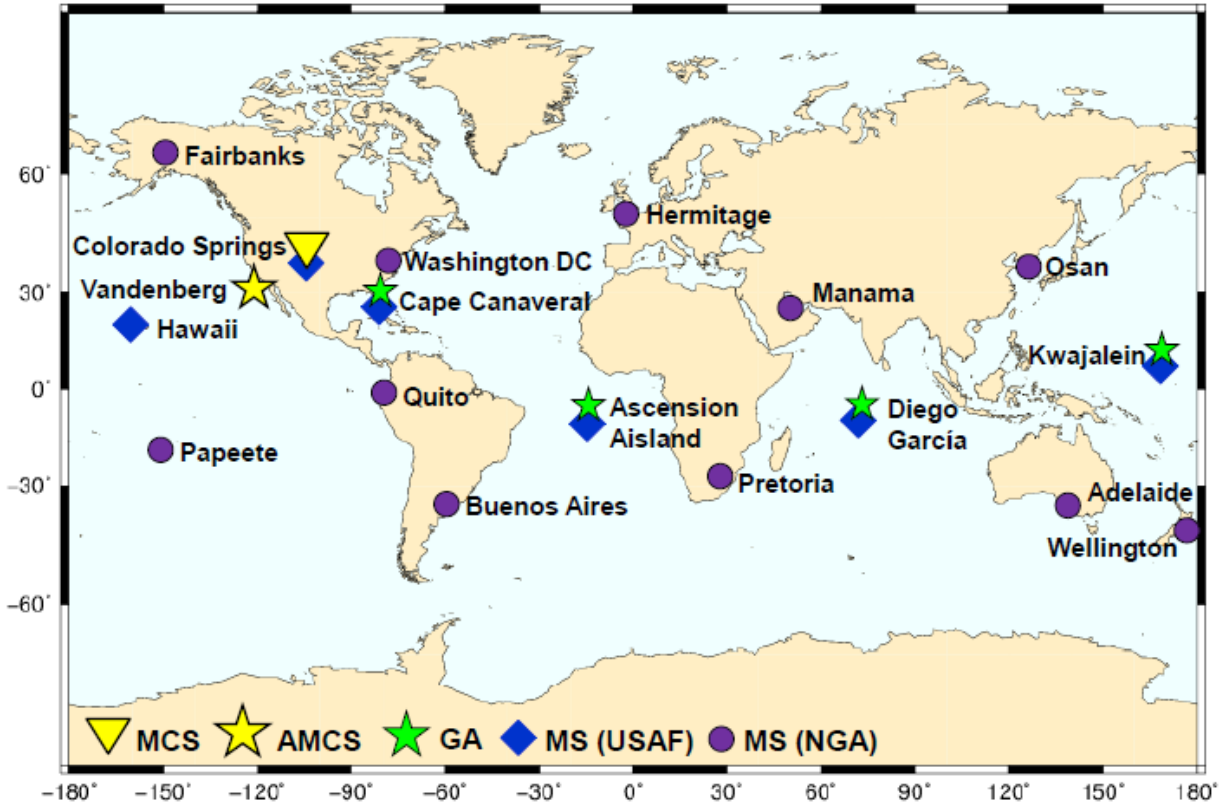
2. Segmentos





Fuente: GPS, Zoog JM 2009

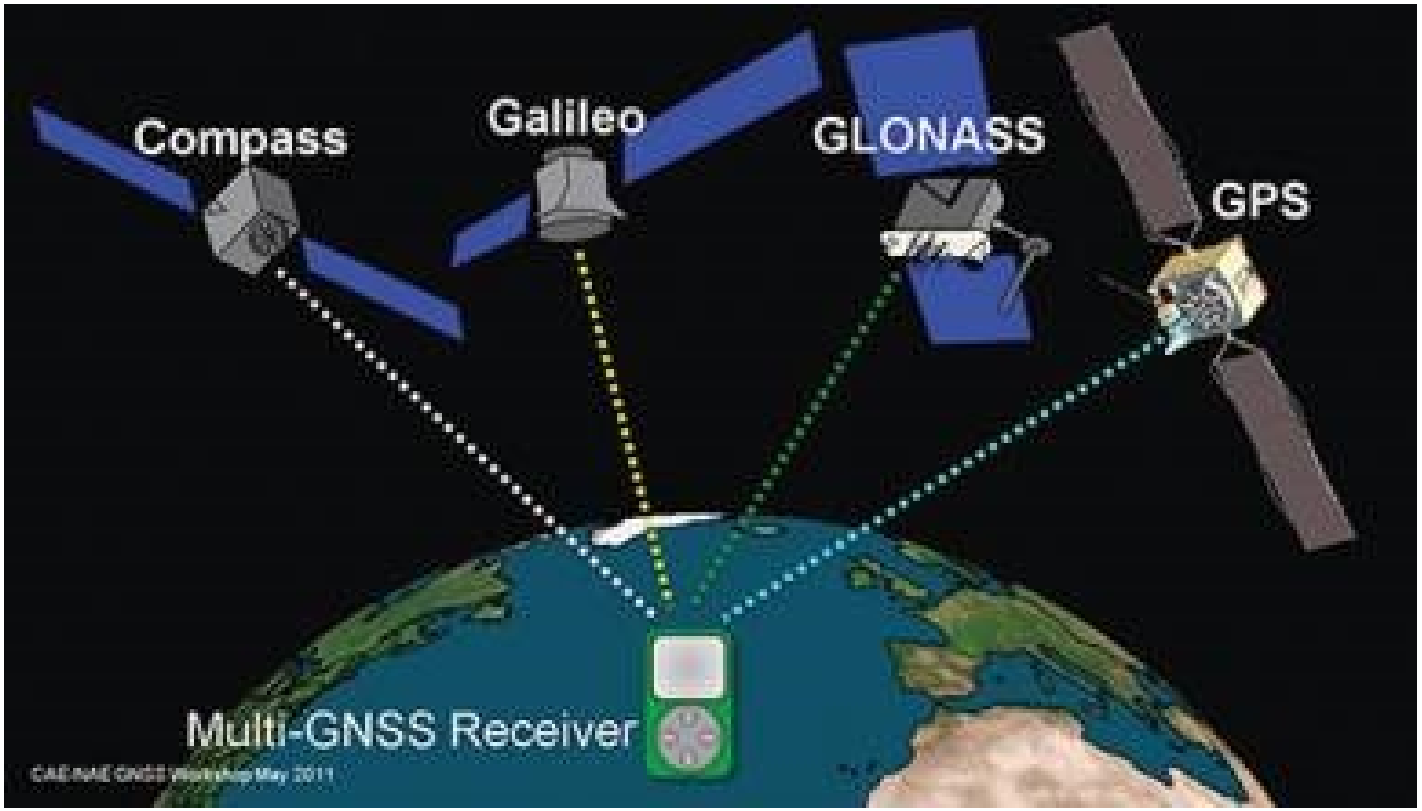
3. Ejemplo de un Segmento Control



GPS ground infrastructure: Master Control Station (MCS), Alternate Master Control Station (AMCS), Monitoring Stations from United States Air Force [MS(USAF)], Monitoring Stations from National Geospatial-Intelligence Agency [MS(NGA)] and Ground Antennas (GA).

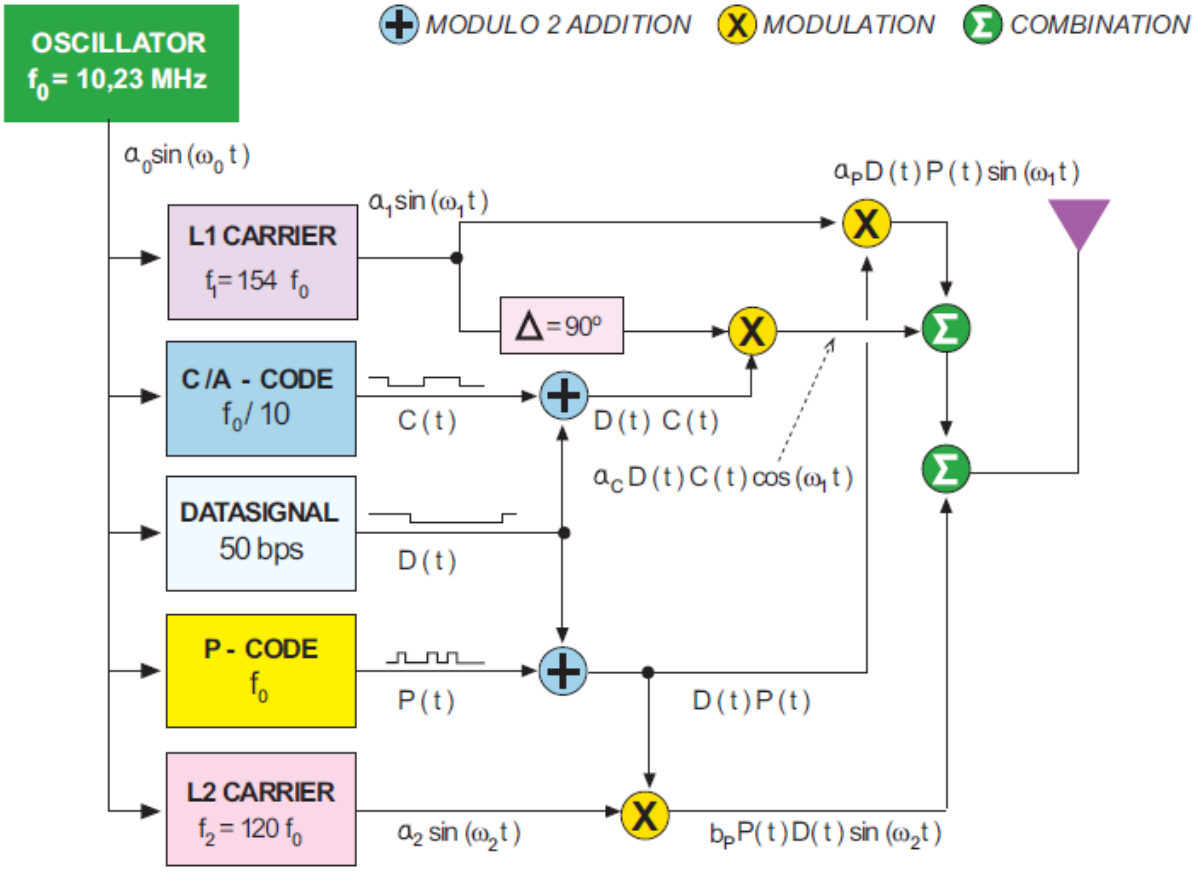
Fuente: ESA, 2013

2. GNSS Constelaciones



Fuente: Inside GNSS, Descargado de Google

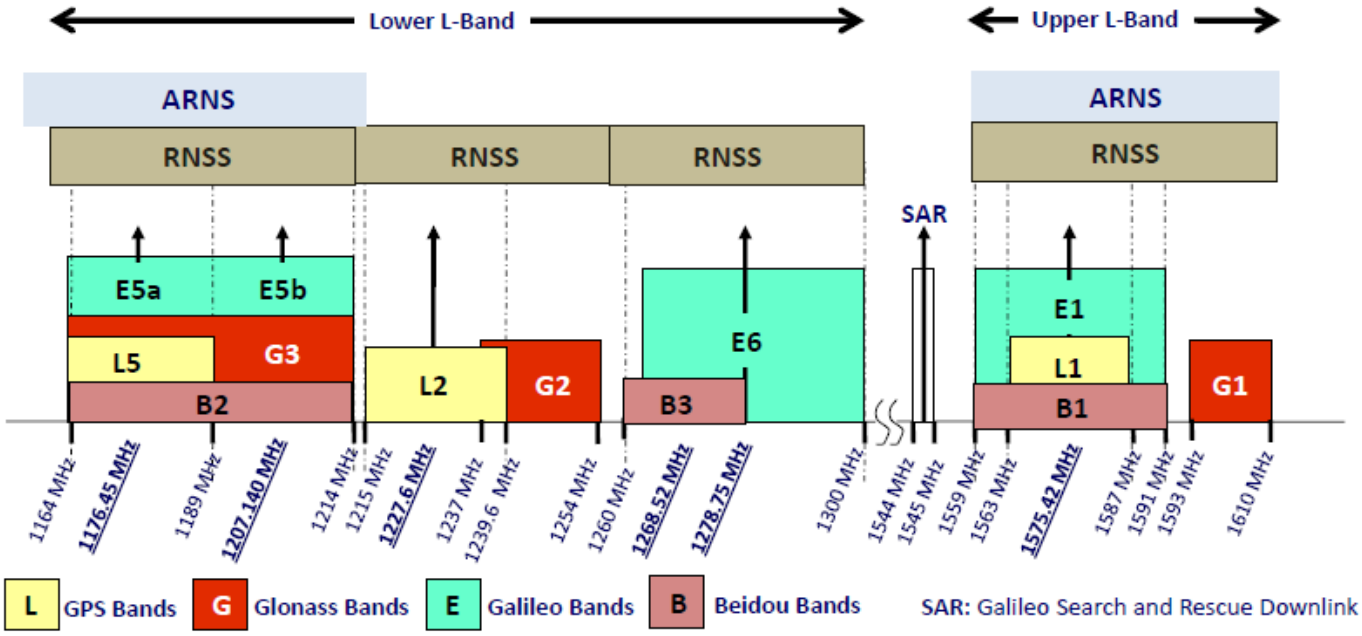
2. Estructura de la Señal GNSS



Legacy GPS signal structure (source [Seeber, 1993]).

Fuente: ESA, 2013 – Modificado de Seeber 1993

3. Señal GNSS



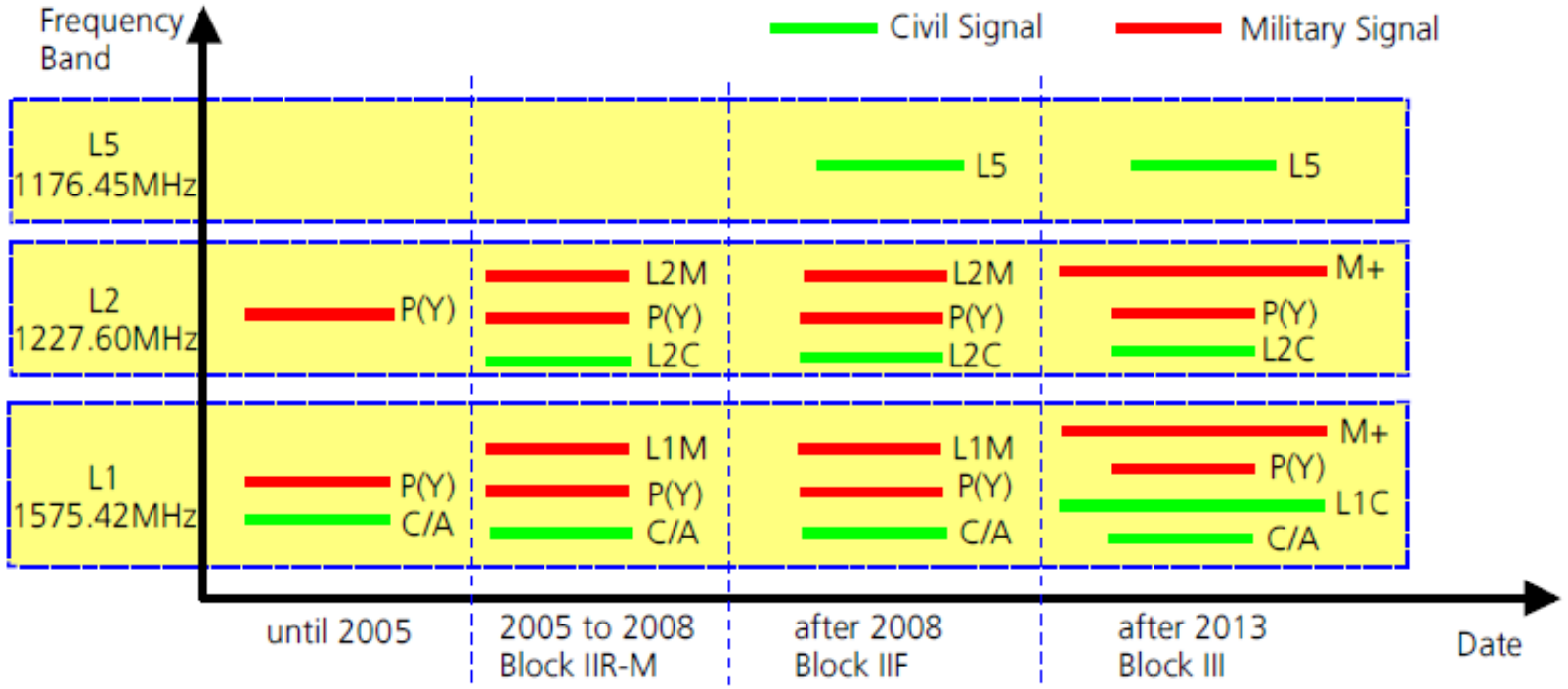
GPS, Glonas
Galileo and Beidou navig
frequency bands.

ARNS: Aeronautical Radio Navigation Service

RNSS: Radio Navigation Satellite Service

Fuente: ESA, 2013

3. Frecuencias de la Señal GPS



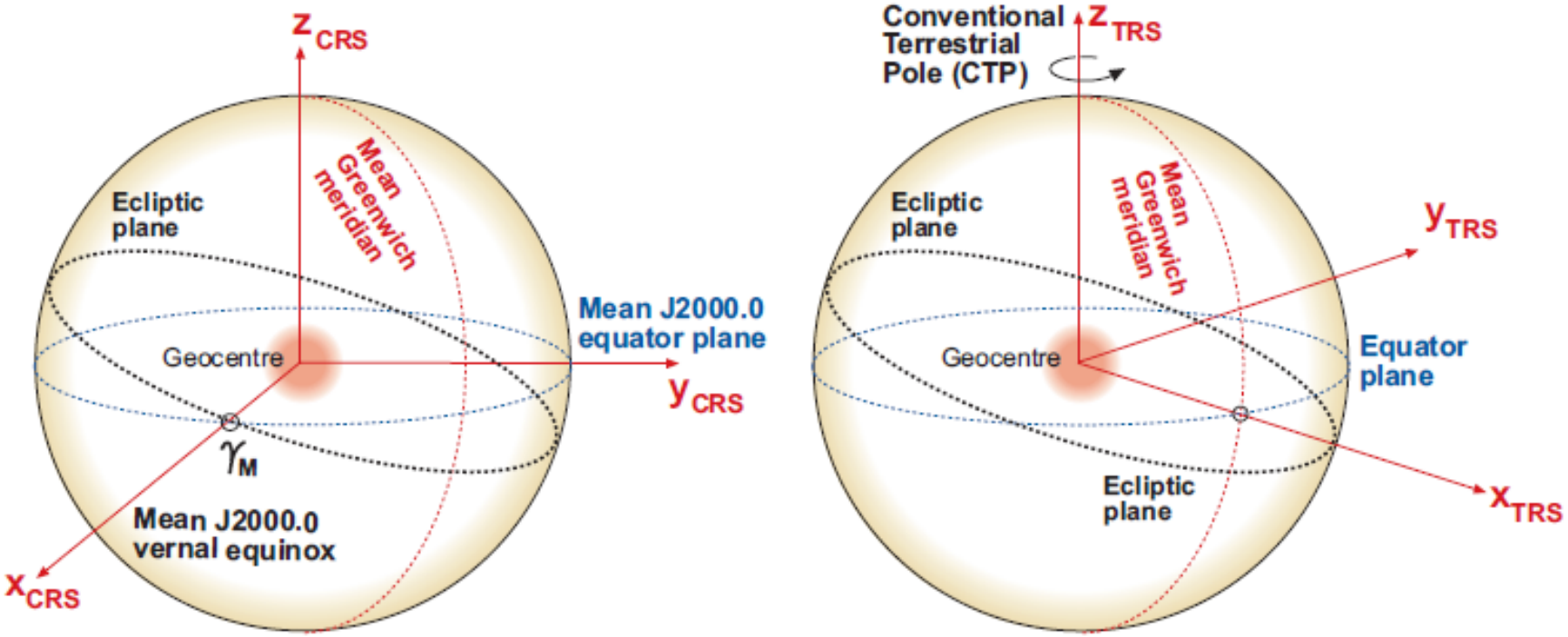
Fuente: ESA, 2013

3. Tiempo en GNSS Diferentes Sistemas

Periodic process	**Time**
Earth's rotation	Universal Time (UT0, UT1, UT2) Greenwich Sidereal Time (Θ)
Earth revolution	Terrestrial Dynamic Time (TDT) Barycentric Dynamic Time (TDB)
Atomic oscillators	International Atomic Time (TAI) Coordinated Universal Time (UTC) GNSS Reference Time

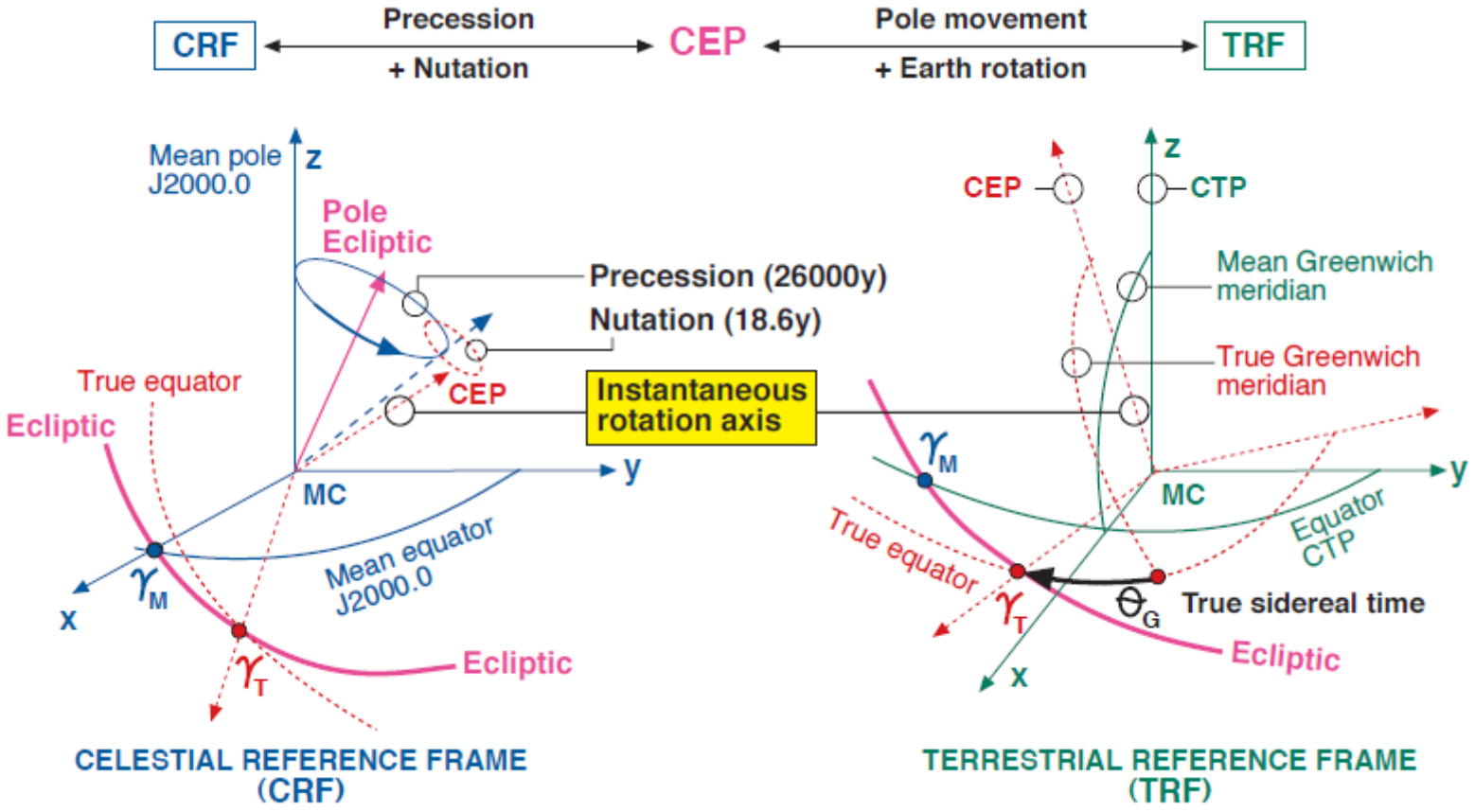
Fuente: ESA, 2013

3. Sistema y Marco de Referencia. CRS vs TRS



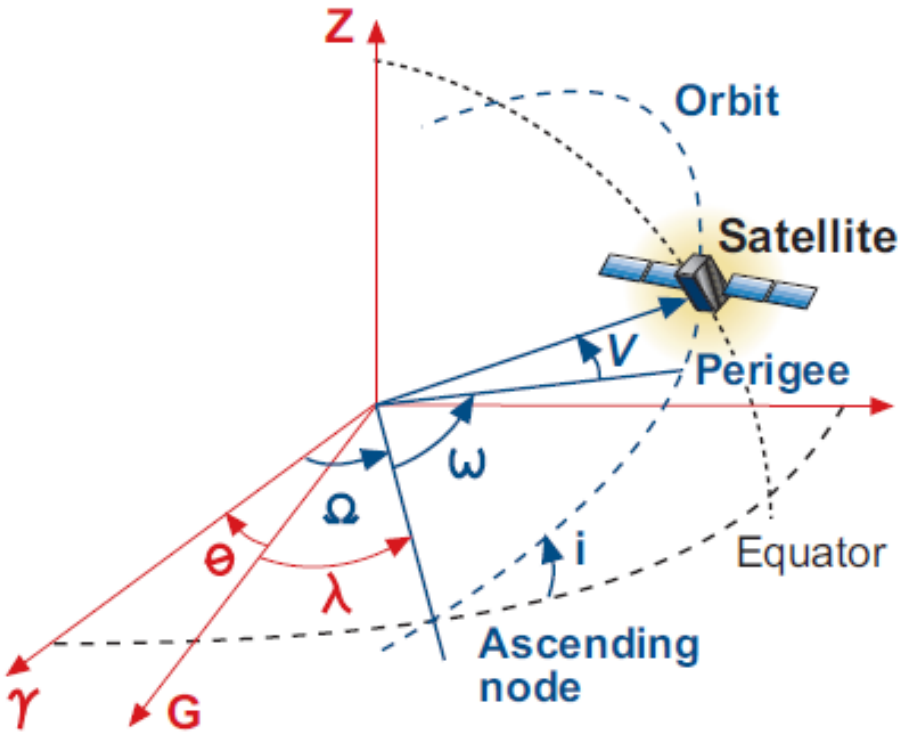
Fuente: ESA, 2013

2. Transformación entre Marcos de Referencia. CRF vs TRF



Fuente: ESA, 2013

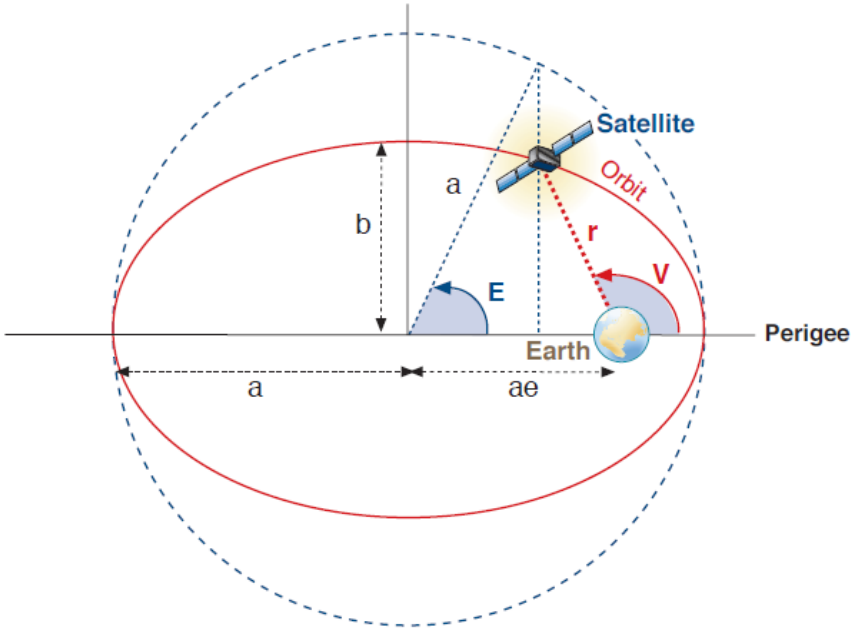
3. Elementos Orbitales GNSS

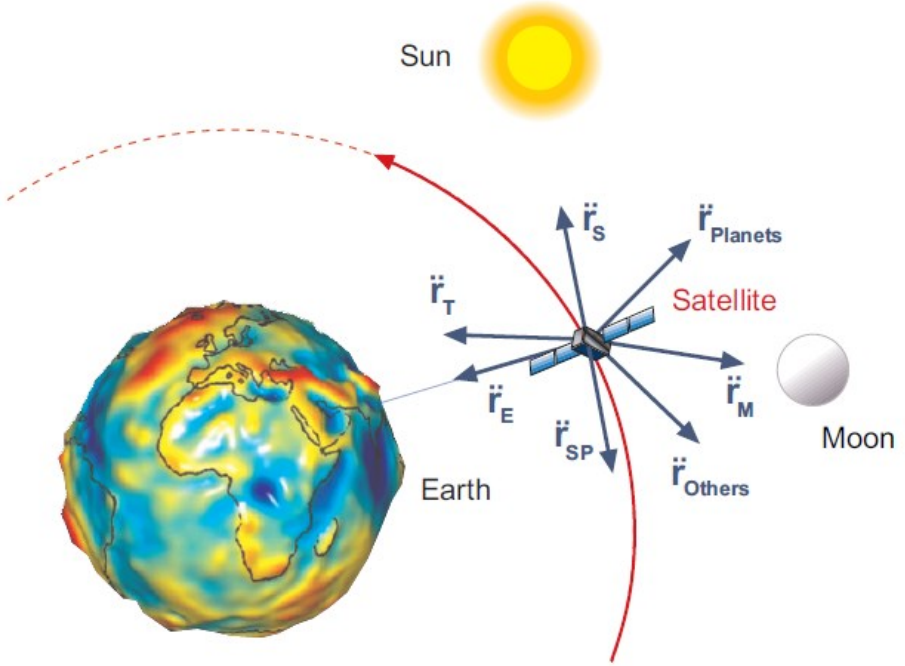


i inclination
ω argument of perigee
Ω arg. ascending node (Aries)
λ arg. ascending node (Greenwich)
V true anomaly
Θ sidereal time
γ vernal equinox
G Greenwich meridian

Fuente: ESA, 2013

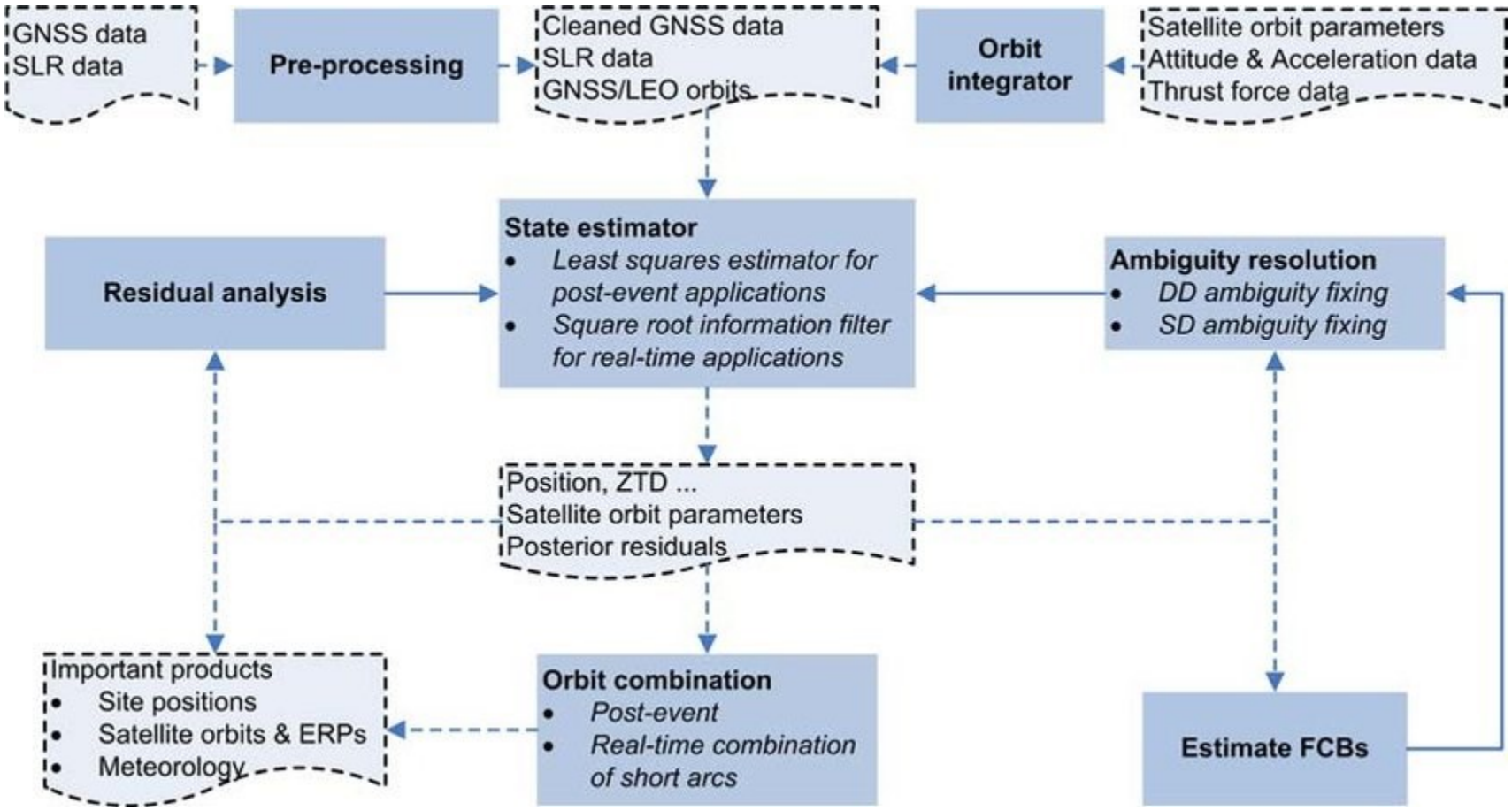
3. Orbita Normal y Perturbada GNSS





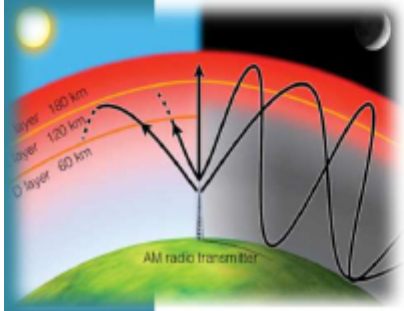
Fuente: ESA, 2013

4. Secuencia de Procesamiento GNSS



Fuente: Software PANDA Procesamiento GNSS

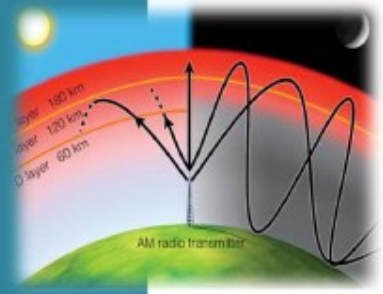
4. Errores Sistemáticos GNSS



SATELITE	• Errores de reloj • Errores de órbita • relatividad • Retardo entre los transportistas en el hadware satélite • Centro de fase de la antena de satélite
PROPAGACION DE LA SEÑAL	• **Refracción ionosférica** • Refracción troposférico • Saldos de Ciclo • Señales de trayectoria múltiple o reflejadas • Rotación de la Tierra

Fuente: Galera, 2008

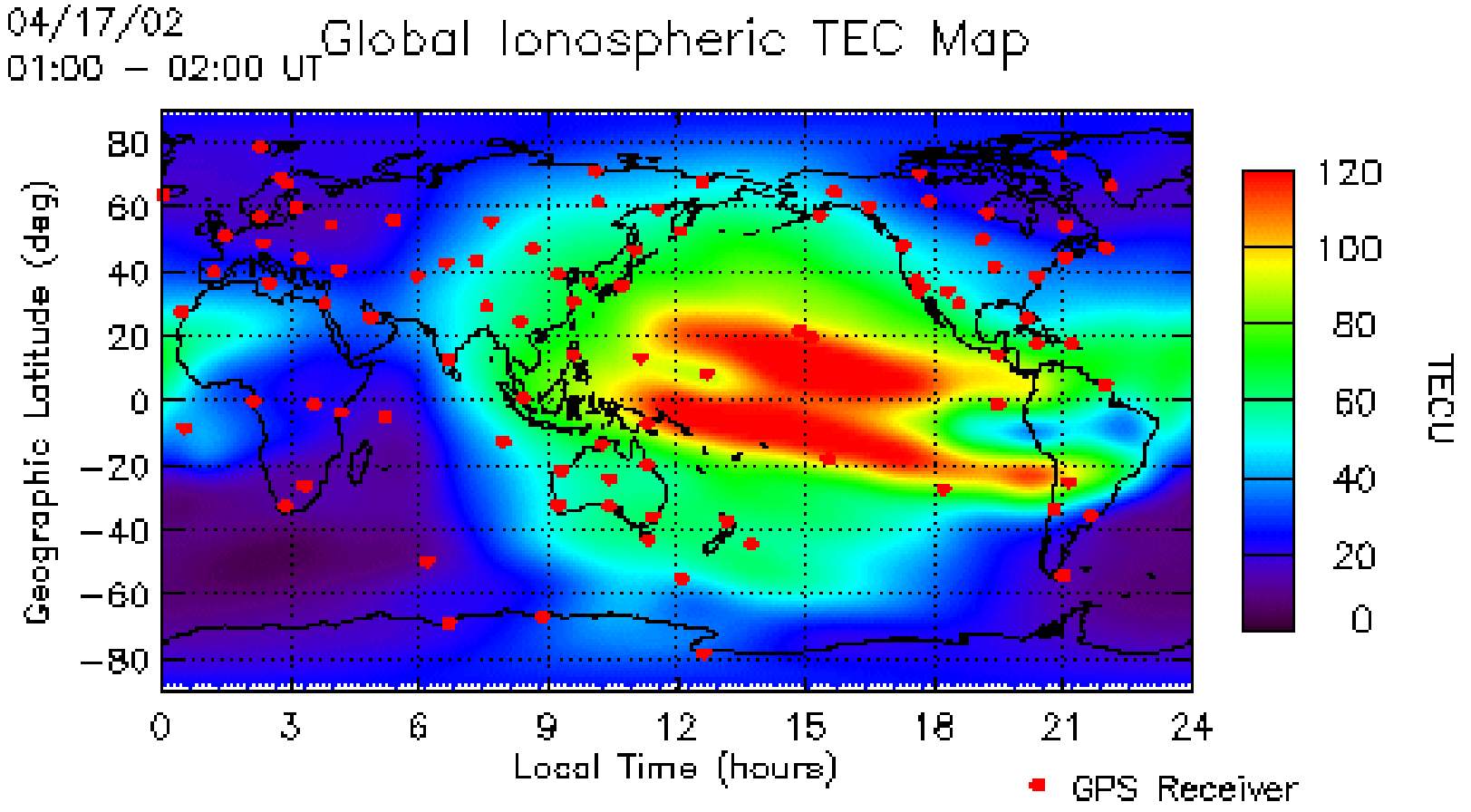
4. Errores Sistemáticos GNSS



RECEPTOR/ ANTENA	• Errores de reloj • Errores entre los canales • Centro de fase de la antena del receptor • Retardo entre las portadoras en el hadware receptor
ESTACIONES CONTINAS (GEODINAMICOS)	• Error en las coordenadas • Señales de trayectoria múltiple o reflejadas • Mareas Terrestres • Movimiento del Polo • Carga oceánicas • Presión de la atmósfera

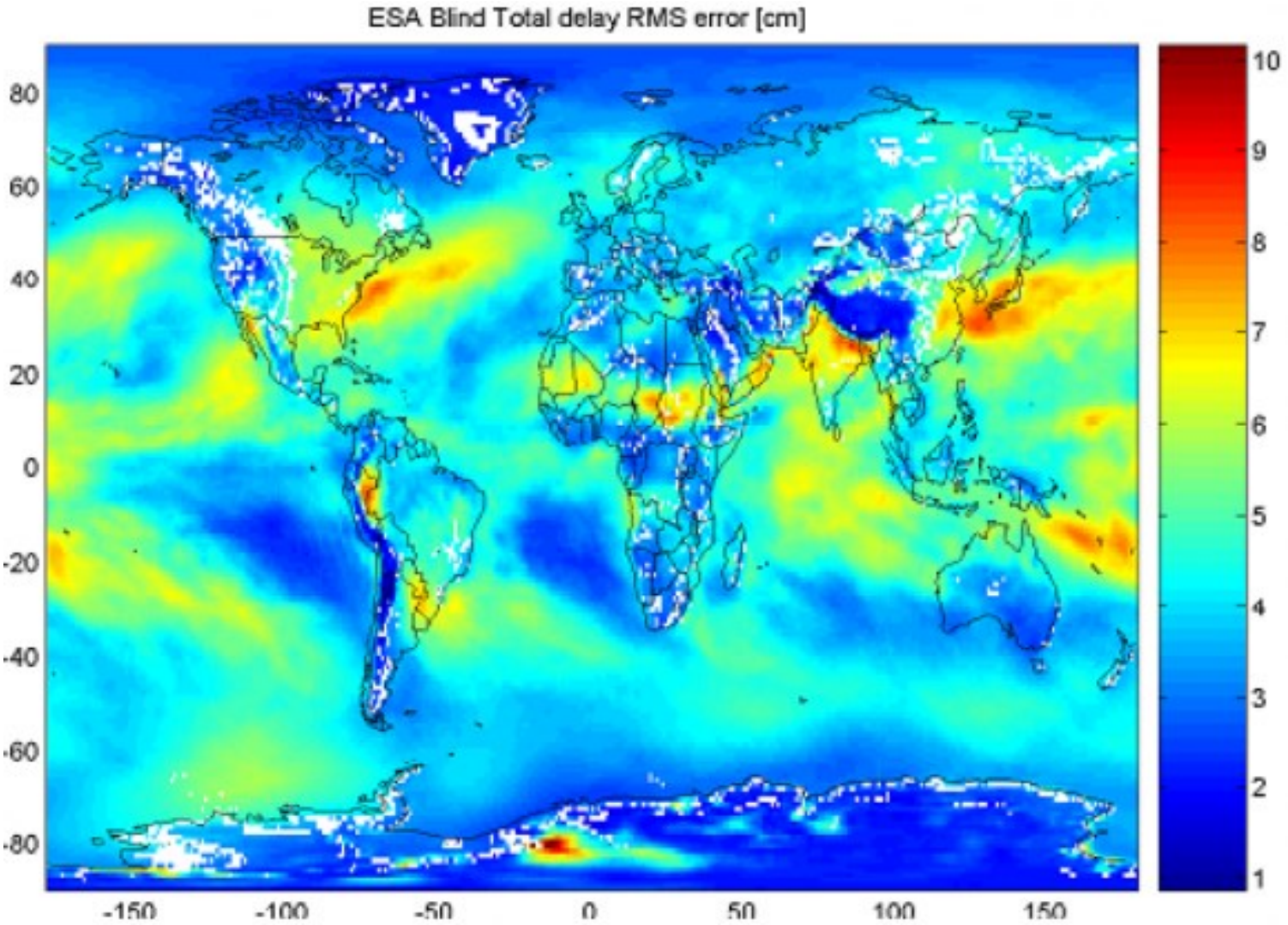
Fuente: Galera, 2008

4. Contenido Total de Electrones



Fuente: JPL, NASA 2002

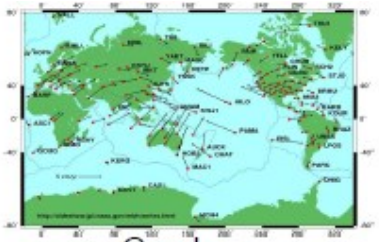
4. Modelo Troposférico



Fuente: ESA, 2014

5. Aplicaciones - GNSS

Building Construction



Geodesy

Monitoring

Rapid Mobile Mapping

Port Operations

Land Surveying

Machine Guidance

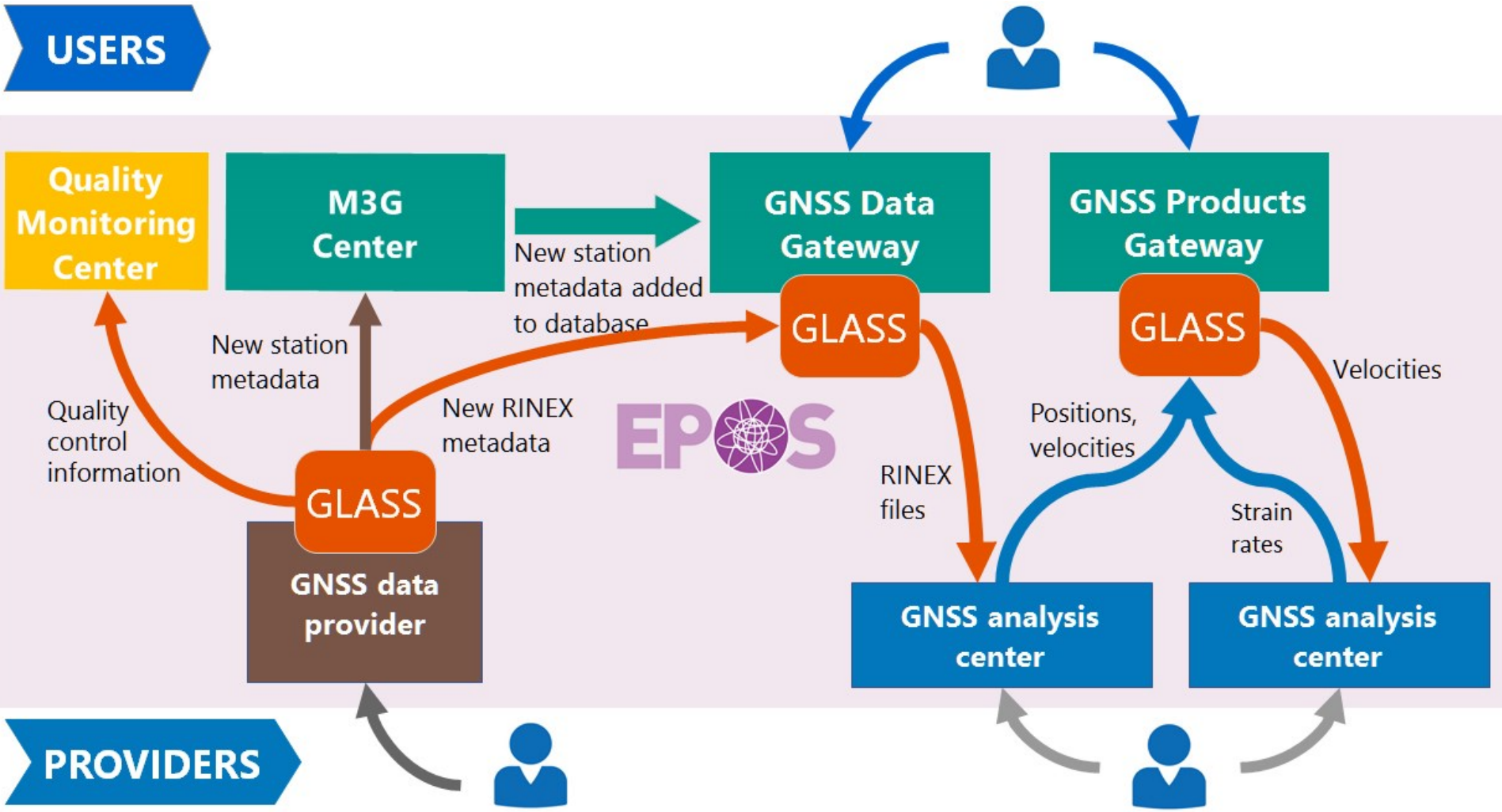
Precision Agriculture

PP GNSS Apps

- Surveying & mapping
- Precise kinematic apps, such as machine guidance/control
- Define/monitor datum, geodesy apps, etc.
- Precise georeferencing of airborne or terrestrial scanning/imaging sensors

Fuente: El Rol de la Geodesia FIG – IAG -, Rizos 2012

5. Aplicaciones - GNSS



Fuente: Sistema Europeo de Observación de la Tierra, 2017

5. Aplicaciones

USGS
science for a changing world

USGS HOME
Contact USGS
Search VHP

Volcano Hazards Program | Find a U.S. Volcano | Assess | Prepare | Forecast | Activity | Products | Observatories | Abo

Volcano Updates | Monitoring | Hazards | Education | Multimedi

- About
- Volcano Updates
- Monitoring
  - Earthquakes
  - Deformation
    - *GPS*
    - *Tilt/Strain*
    - *InSAR*
  - Gas and Water
  - Hydrology
  - Heat/Thermal

Networks of GPS receivers track ground movement at volcanoes.

The Global Positioning System (GPS) consists of a group of Earth-orbiting satellites that orbit the Earth twice per day at an altitude of about 20,000 km (12,500 mi) and continuously transmit information to receivers on the ground. Using these data, it is possible to calculate the exact position of the receiver on Earth at a specific point in time.

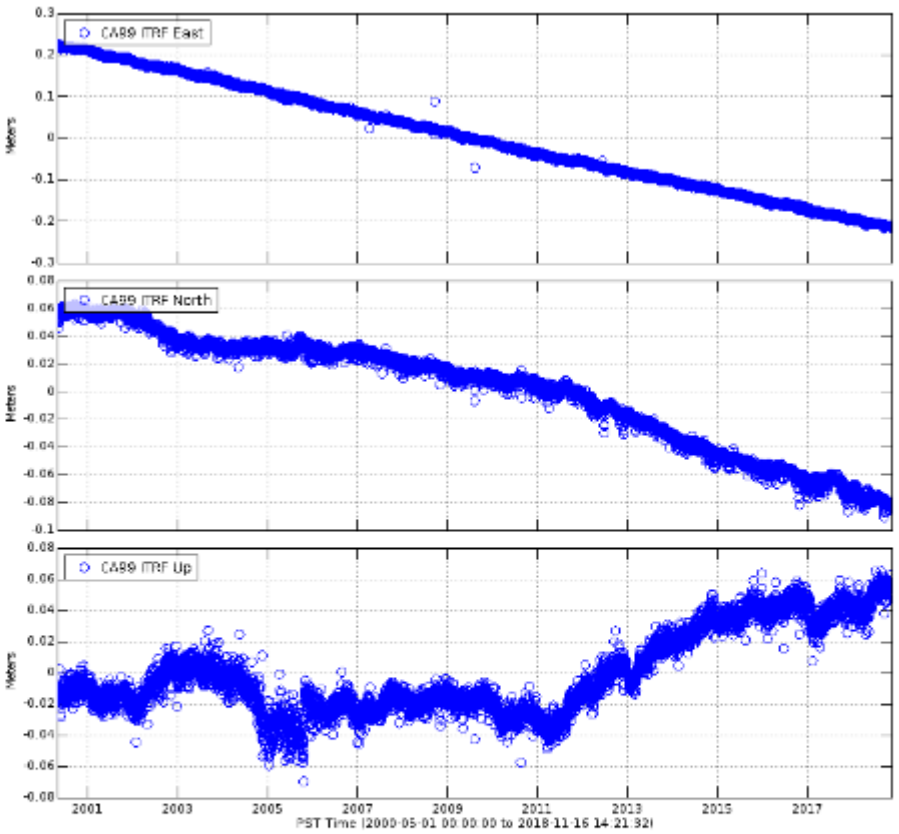
To use GPS data for volcano monitoring, multiple receivers are placed around a volcano as a GPS network. In some locations, instruments are permanently installed and record data continuously. However, sometimes scientists setup a "campaign" GPS network above "benchmarks" (sites with a standard point of reference) where they are left for several days to record data. Campaign-style data are often recorded from the same benchmark sites annually or as needed

Fuente: USGS, 2018

5. Aplicaciones - GNSS

GPS data is accurate to within a fraction of an inch.

Relatively inexpensive GPS receivers, like those in vehicle navigation systems, smart phones, and handheld units, can determine their position on the Earth's surface to within a few meters. With more sophisticated receivers and data-analysis techniques, receiver positions can be determined to less than a centimeter (fraction of an inch), which is very important when applied as a volcano monitoring technique. Networks of GPS sensors can track three-dimensional movements of the ground surface even at rates of less than 1 millimeter (1/25 inch) per year.



GPS data, station CASA, Long Valley Caldera, California

GPS is the name of the satellite navigation system created and maintained by the United States. Other countries have launched their own satellite navigation systems, including GLONASS (by Russia) and Galileo (by Europe), but all follow the same basic principles as GPS. We generically refer to these systems collectively as GNSS (Global Navigation Satellite System). Modern receivers can record data from multiple types of GNSS satellites, which increases the overall accuracy of the calculated positions.

Fuente: USGS, 2018

5. Aplicaciones - GNSS

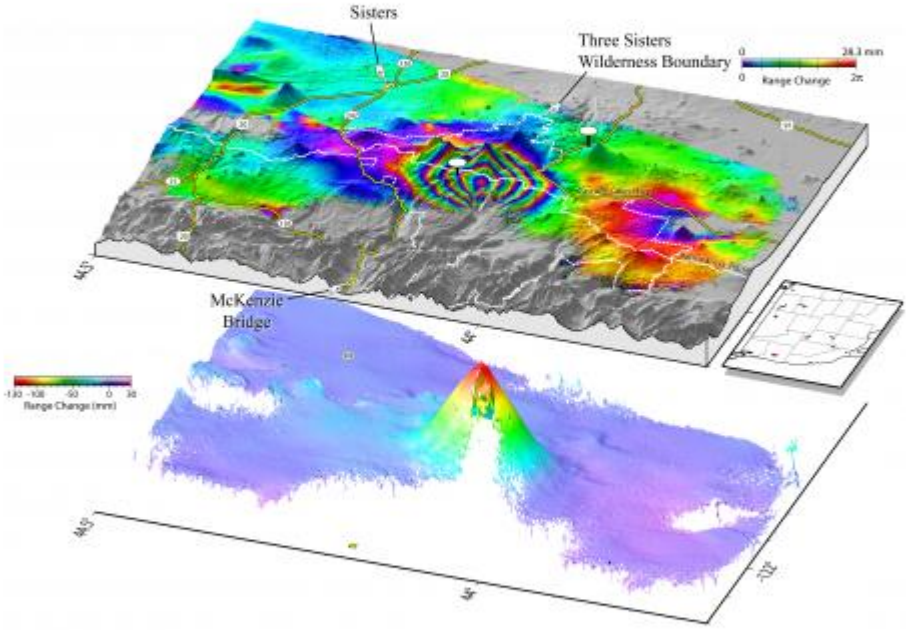
Volcano Updates | Monitoring | Hazards | Education | Multimedia

- About
- Volcano Updates
- **Monitoring**
  - Earthquakes
  - Deformation
    - *GPS*
    - *Tilt/Strain*
    - *InSAR*
  - Gas and Water
  - Hydrology
  - Heat/Thermal
  - Topographic Changes
- Hazards
- Preparedness
- Education

InSAR—Satellite-based technique captures overall deformation "picture"

InSAR (Interferometric Synthetic Aperture Radar) is a technique for mapping ground deformation using radar images of the Earth's surface that are collected from orbiting satellites. Unlike visible or infrared light, radar waves penetrate most weather clouds and are equally effective in darkness. So with InSAR it is possible to track ground deformation even in bad weather and at night – two big advantages during a volcanic crisis.

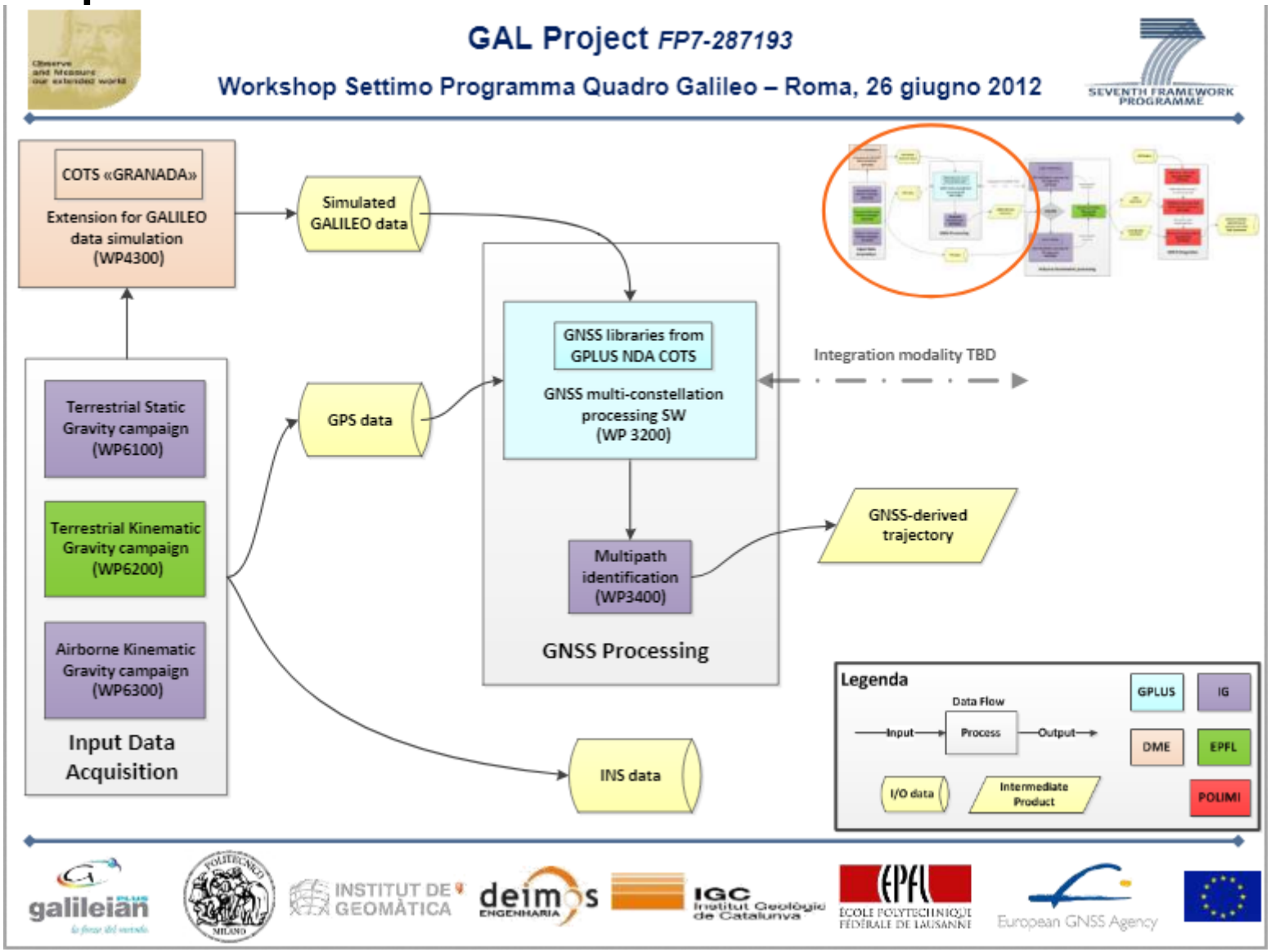
Two radar images of the same area that were collected at different times from similar vantage points in space can be compared against each other. Any movement of the ground surface toward or away from the satellite can be measured and



Interferogram image made from InSAR monitoring, showing 1995-2001 ground-uplift pattern centered 5 km (3 mi) west of South Sister volcano, Oregon. (click for more info)

Fuente: USGS, 2018

5. Aplicaciones - GNSS



Fuente: https://cordis.europa.eu/project

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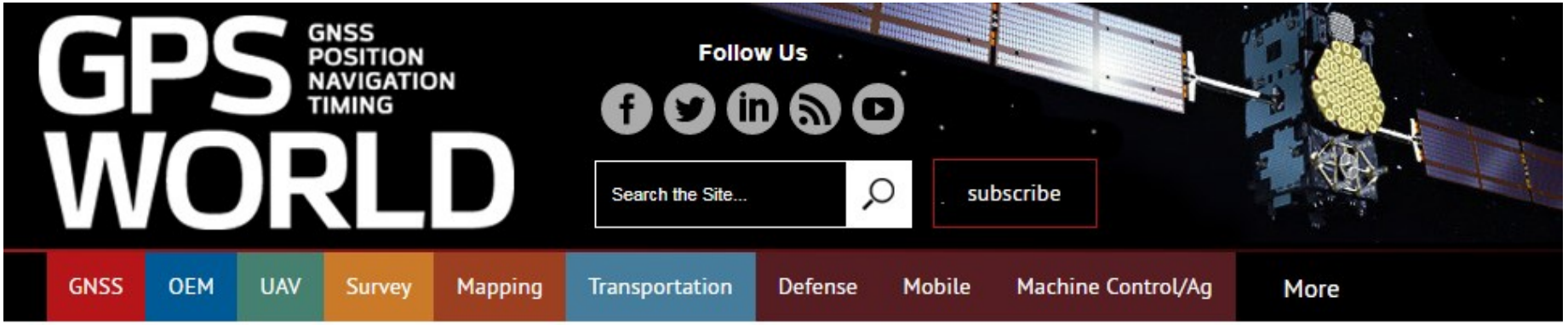

First GPS III launch delayed for rocket issues

Fuente: https://www.gpsworld.com/