

# Natural Hazards and Disasters

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Why are you taking the class?

What is the relevance of natural hazards and disasters for you?

# Natural Hazards and Disasters



## Guest Opinion: Finding our way back to the wilderness

Robert C. Koehler  
For Peacevoice  
August 30, 2018

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The science gets ever more dire. The politics runs the other way.

We've claimed hold of the planet, but cluelessly, like the sorcerer's apprentice. Welcomed to the Anthropocene: the age of humanity intertwined with nature.

"Climate change is not a problem we have to make go away, in a sense that you don't make adolescence go away," astrophysicist Adam Frank said to Chris Hedges. "It is a dangerous transition that you have to navigate... The question is, are we smart enough to deal with the effects of our

own power?"

The planet itself is transitioning, to God knows what. There may be no human race on the other side of that transition, but maybe there will be. Either way, we have to reach well beyond ourselves.

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*But we have not learned to wield the  
power wisely!*

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The sorcerer's apprentice

Plag, 2010

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*Having gained the power to change Earth, we need to take a new look at humanity and ask the question who we are*

The sorcerer's apprentice

Plag, 2010



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## Class 1: Introduction to the Course and Basic Concepts (continued)

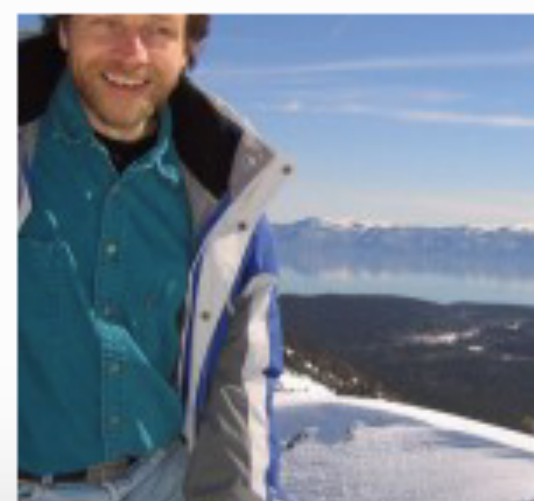
- Practicalities
- Course Contents
- The Earth's Life-Support System and Sustainability
- Hazards, Vulnerabilities, and Disasters
- Concept of Risk
- Thresholds
- Resilience
- Disasters and Sustainability

## ON THE EDGE

# The Year 2015: The Start of a New Decade of Making it Right?

Building a global resilient community

Posted by [Prof. Hans-Peter Plag, PhD](#) on October 3, 2014 in [Columns](#), [Fall 2014](#), [On the Edge](#)



Finally, in August this year it was published: "The Collapse of Western Civilization – A View from the Future".<sup>1</sup> Taking the view of a historian in the Second Peoples Republic of China, who in 2393 looks back and analyzes why 300 years earlier the western culture collapsed, Naomi Oreskes and Erik M. Conway (yes, the same authors who worked together on Merchants of Doubt)<sup>2</sup> paint a beautifully scary picture of what might happen in

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## Sendai Framework for Disaster Risk Reduction 2015 - 2030



## Sendai Framework for Disaster Risk Reduction 2015-2030

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## What is Disaster Risk Reduction?



**DISASTER RISK REDUCTION (DRR)**  
**There is no such thing as a 'natural' disaster, only natural hazards.**  
Disaster Risk Reduction (DRR) aims to reduce the damage caused by natural hazards like earthquakes, floods, droughts and cyclones, through an ethic of prevention.

Disasters often follow natural hazards. A disaster's severity depends on how much impact a hazard has on society and the environment. The scale of the impact in turn depends on the choices we make for our lives and for our environment. These choices relate to how we grow our food, where and how we build our homes, what kind of government we have, how our financial system works and even what we teach in schools. Each decision and action makes us more vulnerable to disasters - or more resilient to them.

### Disaster risk reduction is about choices.

Disaster risk reduction is the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction.



The Third World Conference on Disaster Risk Reduction took place in 2015.

afghanistan algeria andorra armenia australia azerbaijan bahrain bangladesh bhutan brunei darussalam cambodia china cook islands cyprus korea, dem people's rep of fiji georgia india indonesia iran, islamic rep of iraq israel japan jordan kazakhstan kiribati kuwait kyrgyzstan lao people's democratic republic of lebanon libya madagascar maldives mali marshall islands mauritius mexico morocco myanmar nepal new zealand netherlands new york oman pakistan palau papua new guinea philippines qatar korea, rep of samoa saudi arabia singapore solomon islands sri lanka syrian arab republic tajikistan thailand timor-leste tonga turkey turkmenistan tuvalu united arab emirates uzbekistan vanuatu viet nam yemen niue american samoa

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## What is Disaster Risk Reduction?



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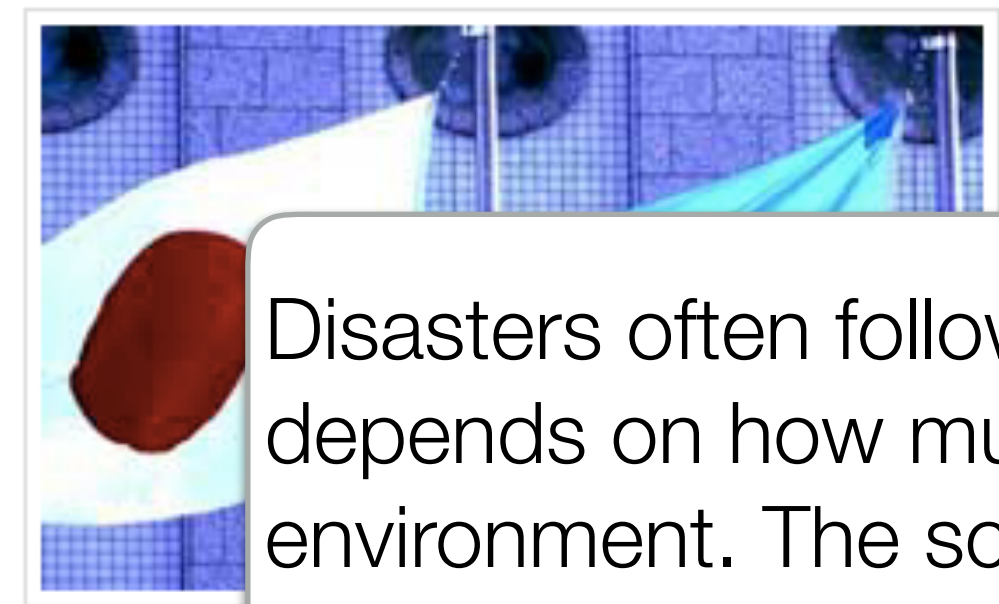


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The Third V... Reduction

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- Indonesia
- Iran
- khstan
- Kiribati
- Maldives
- Oman
- Pakistan
- Korea, Rep. of
- Sri Lanka
- Syrian Arab Republic
- Tajikistan
- Thailand
- Timor-Leste
- Tonga
- Turkey
- Turkmenistan
- Tuvalu
- United Arab Emirates
- Uzbekistan
- Vanuatu
- Viet Nam
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Our region

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**Disaster risk reduction is everyone's business.**

Disaster risk reduction includes disciplines like disaster management, disaster mitigation and disaster preparedness, but DRR is also part of sustainable development. In order for development activities to be sustainable they must also reduce disaster risk. On the other hand, unsound development policies will increase disaster risk - and disaster losses. Thus, DRR involves every part of society, every part of government, and every part of the professional and private sector.

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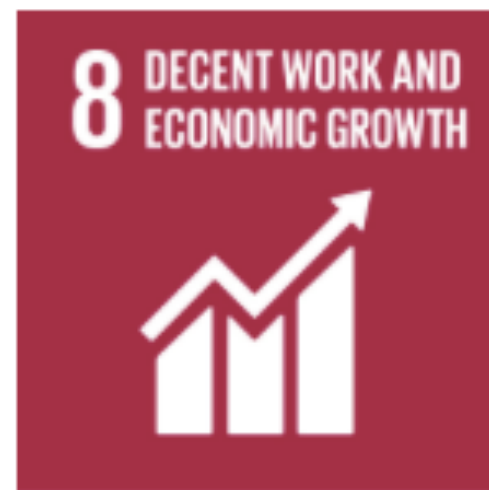
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# SUSTAINABLE DEVELOPMENT GOALS



## SUSTAINABLE DEVELOPMENT GOALS



Each Goal comes with up to 10 Targets and each Target with up to 2 Indicators.

Only Goal 11 addresses disaster risk in three Targets.

## Sustainable Development Goal 11: Sustainable Cities and Communities

“Make cities and human settlements inclusive, safe, resilient and sustainable”

Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations

Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

Target 11.c: Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

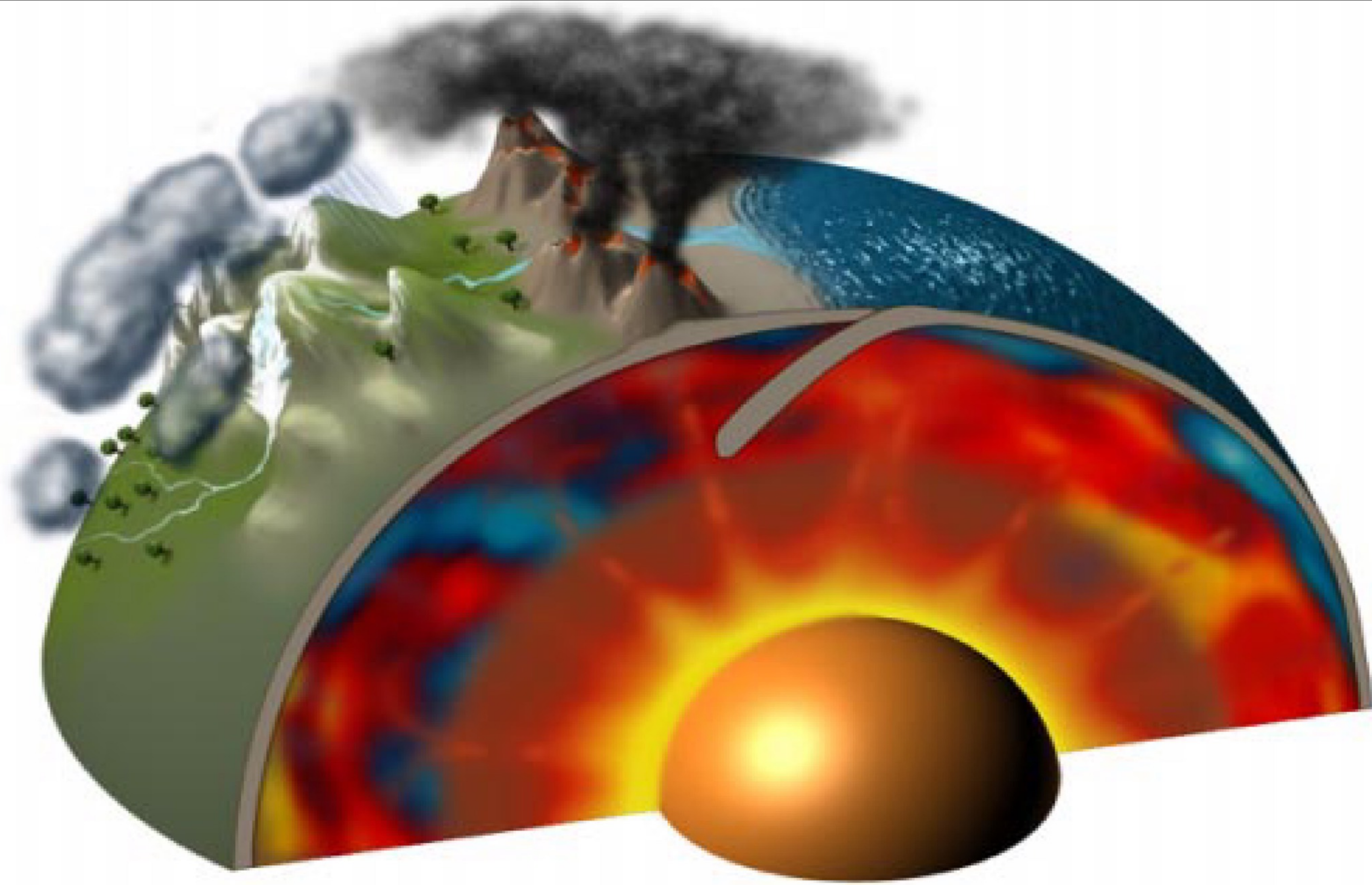
# Natural Hazards and Disasters



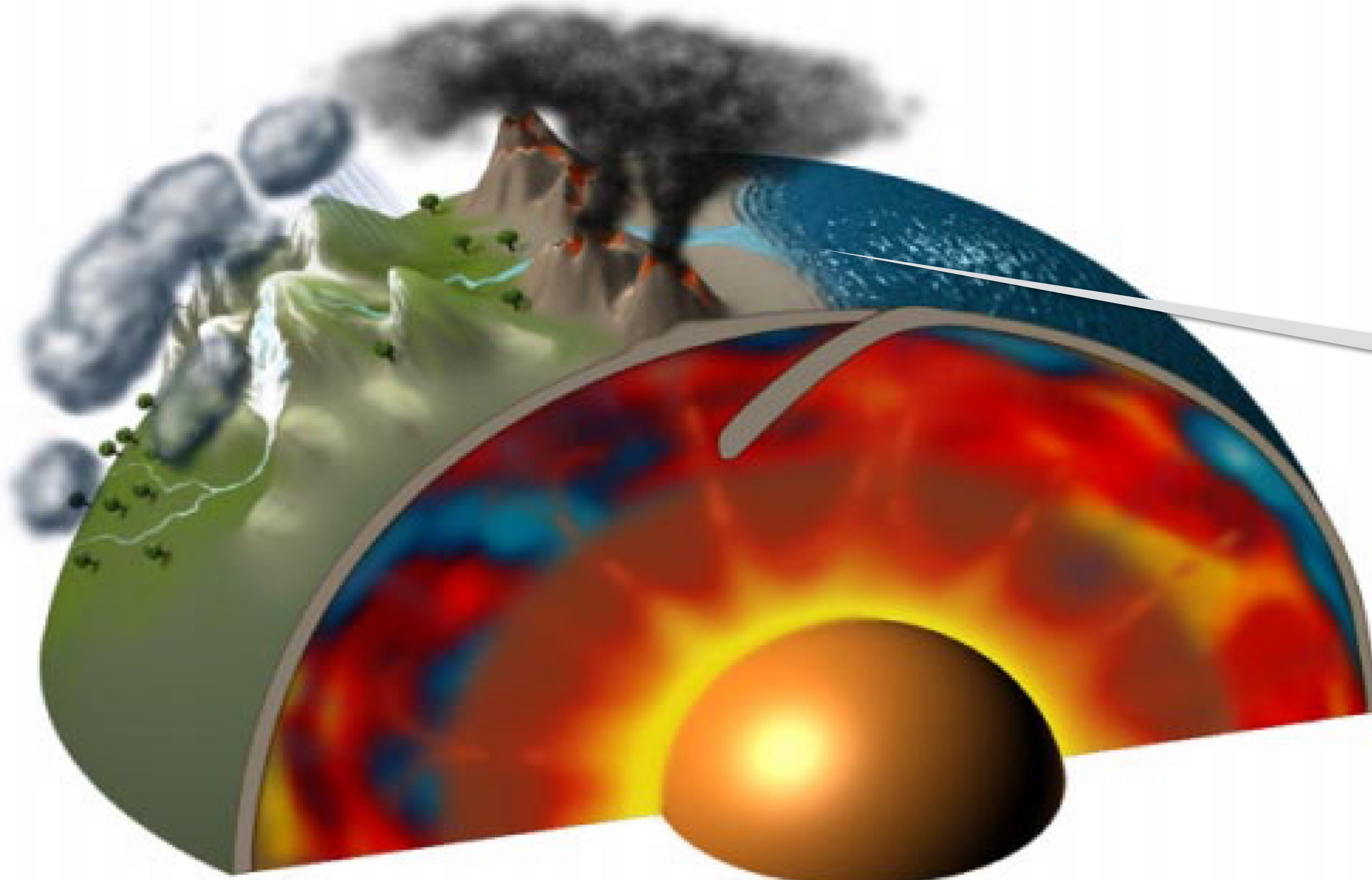
## Class 2: Observing Hazards and Disasters

- A dynamic Planet
- Observing Systems for a Dynamic Planet
- Reference Systems and Frames
- Monitoring Small Changes

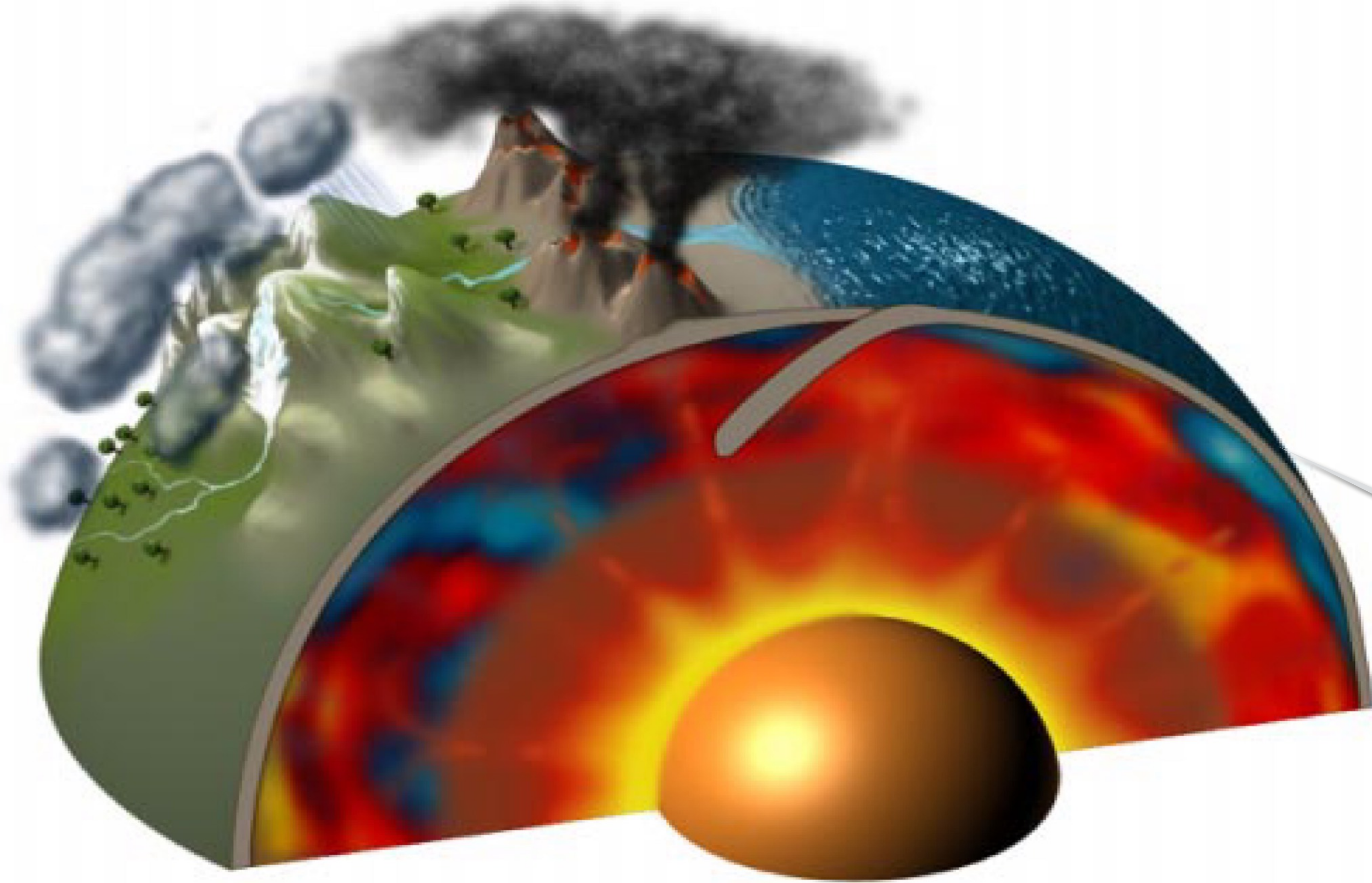


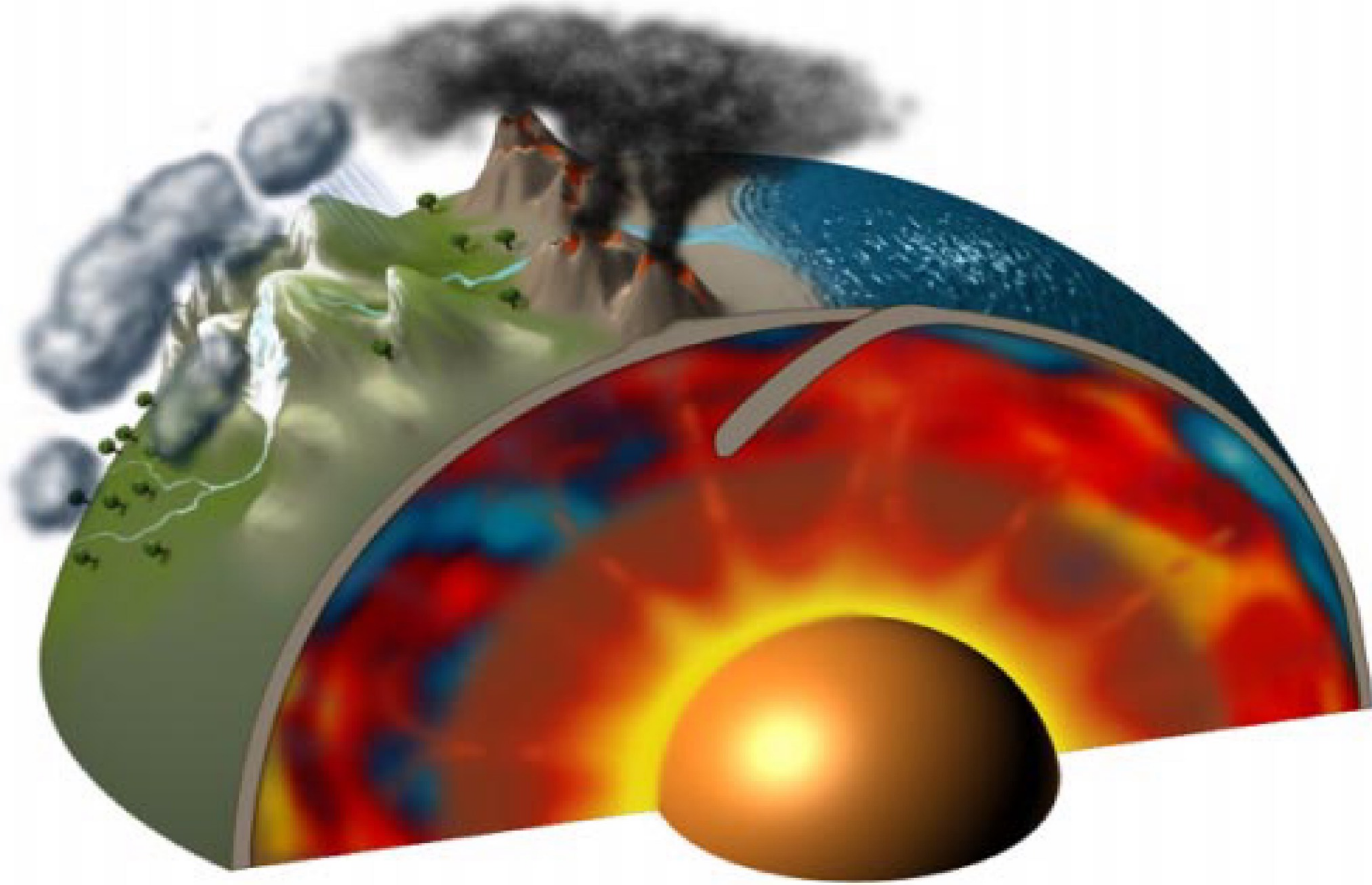




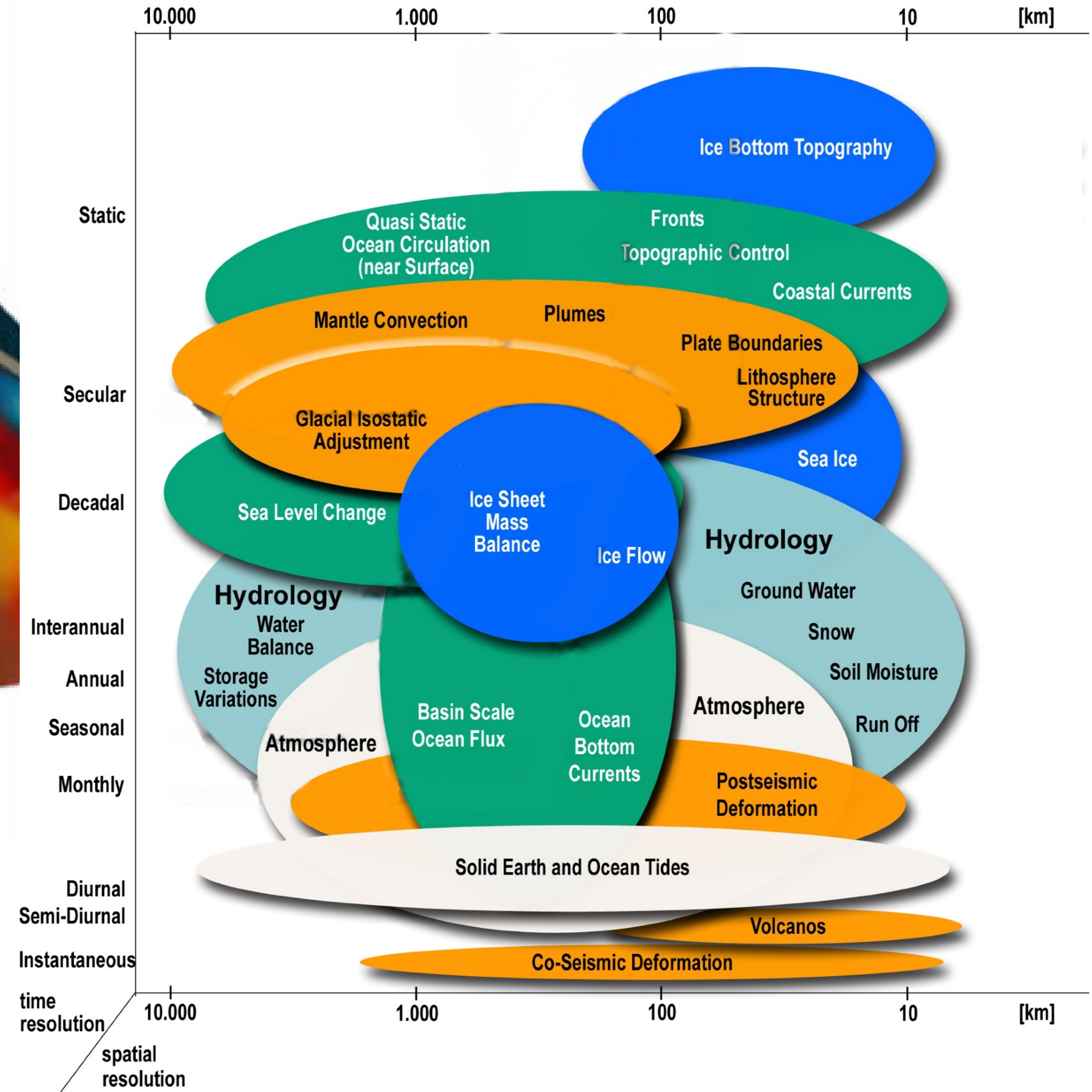
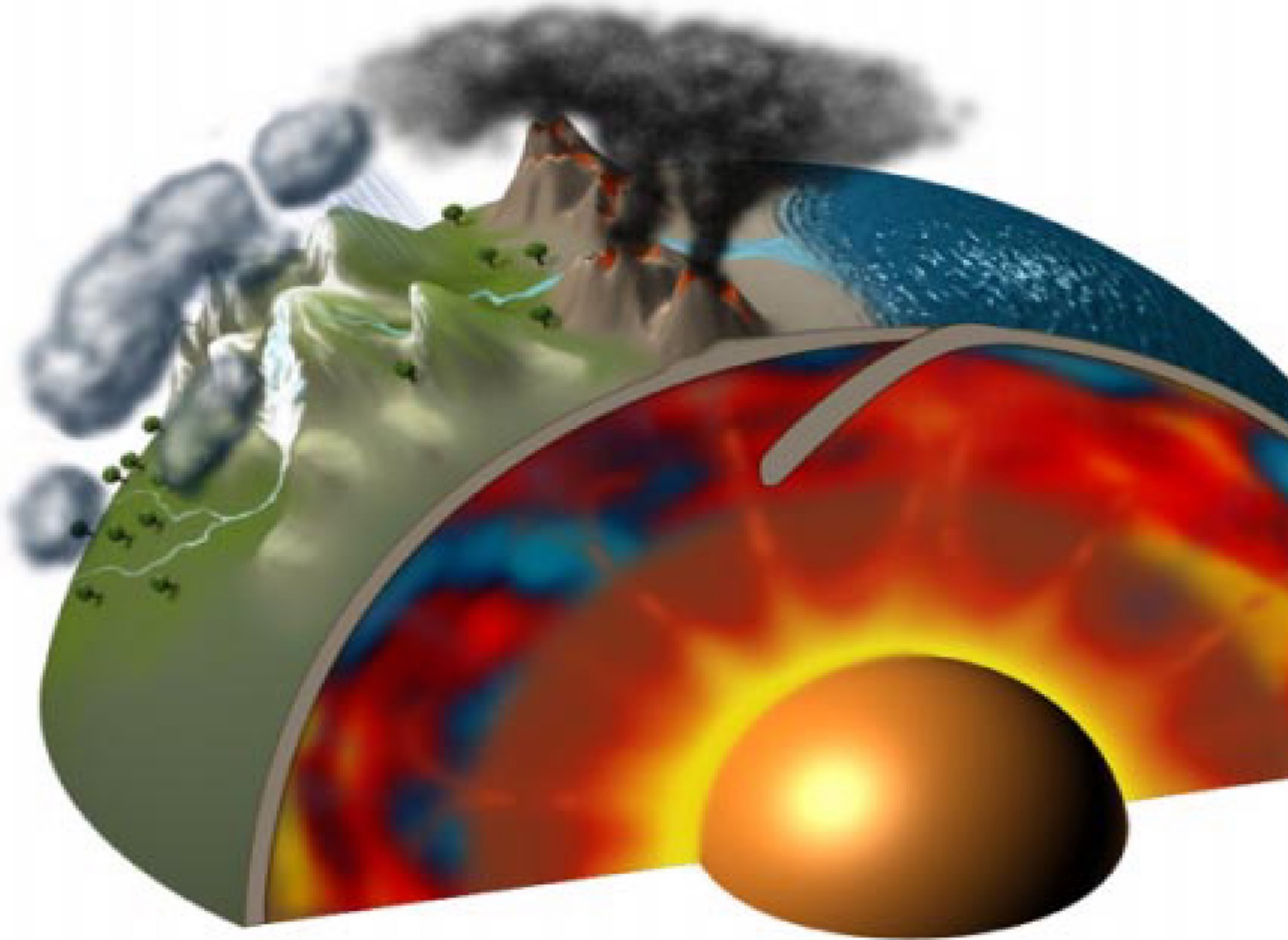


# A dynamic Planet

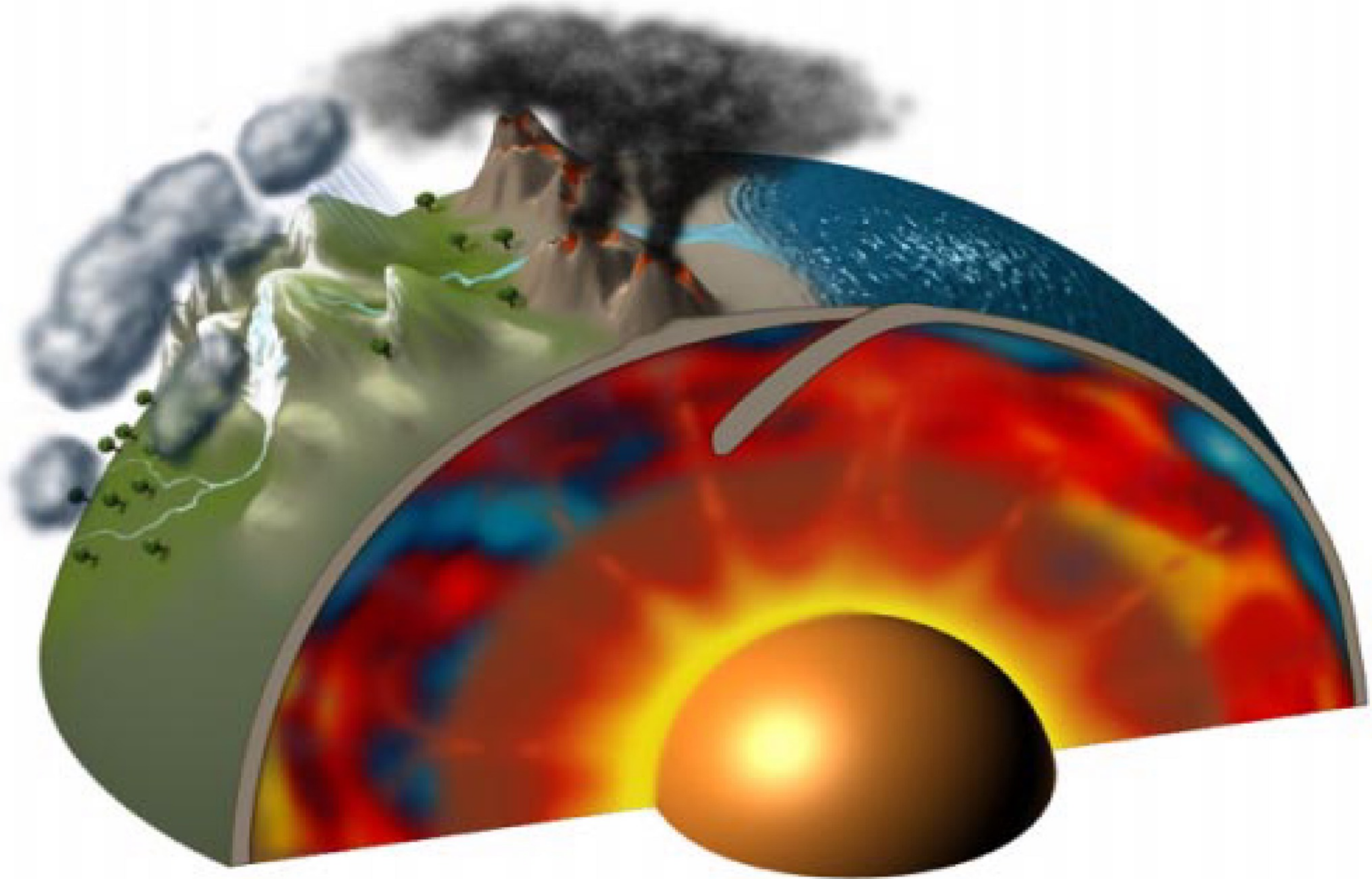


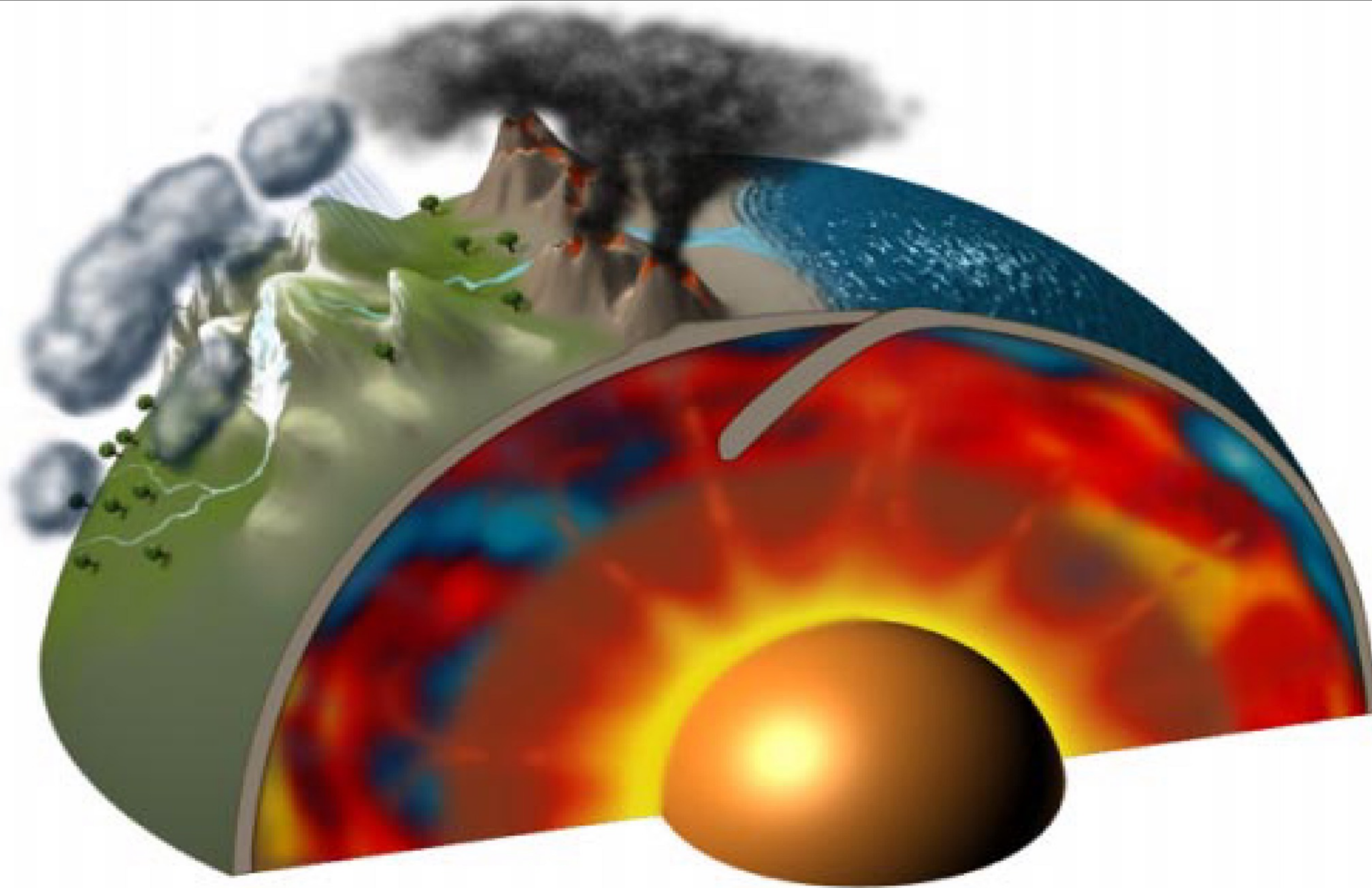


# A dynamic Planet



# A dynamic Planet





Science questions relevant for hazards:

- Plate tectonics: location of and processes at plate boundaries;
- Ice sheets/glaciers: ice load history, including present-day changes;
- Sea level: quantification of different contributions;
- Hydrological cycle: better quantification of fluxes; groundwater movements; land water storage;
- Earthquakes: strain/stress accumulation and earthquakes; physical processes;
- Volcanoes: location, state,

*Modified from Rummel et al., 2009*

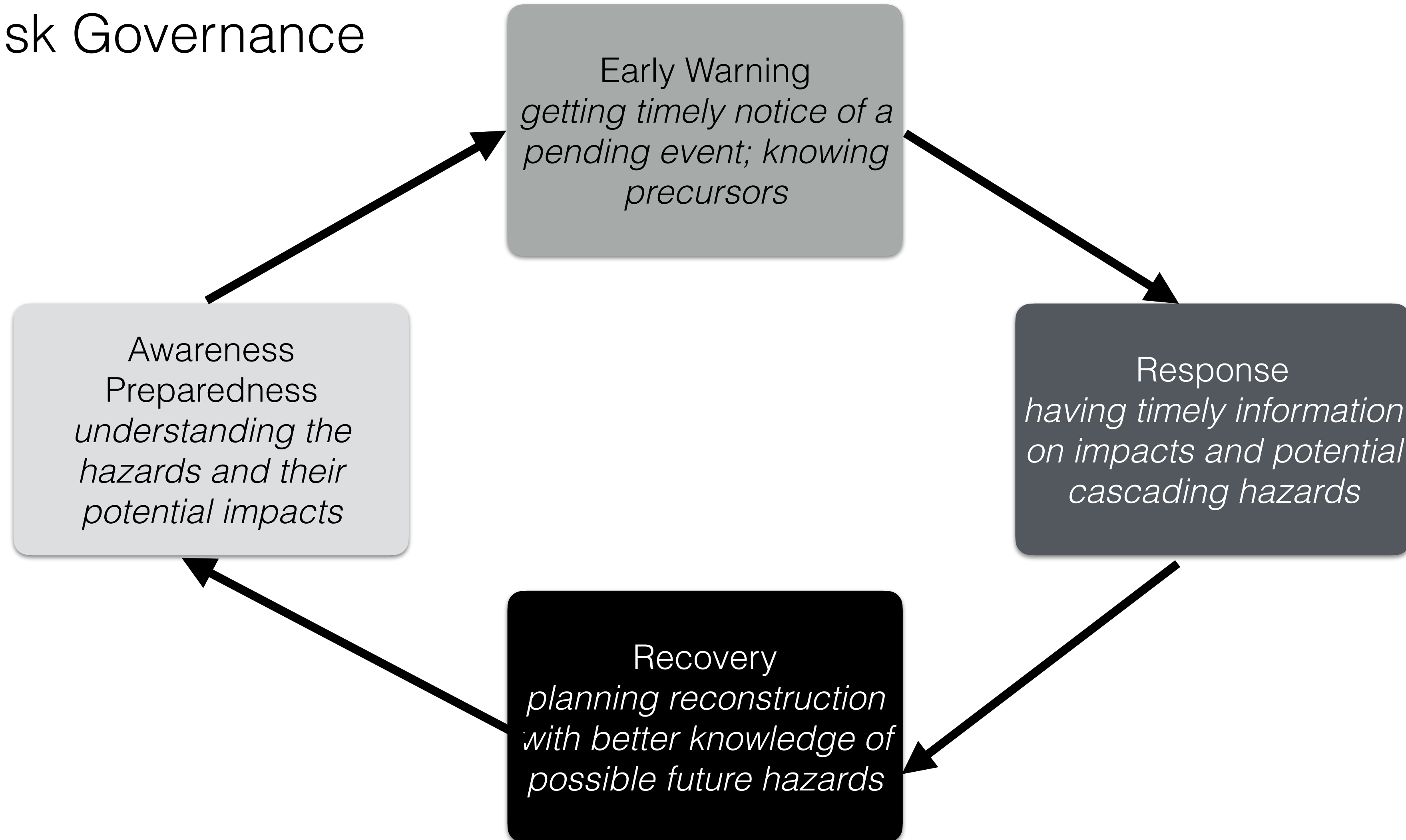
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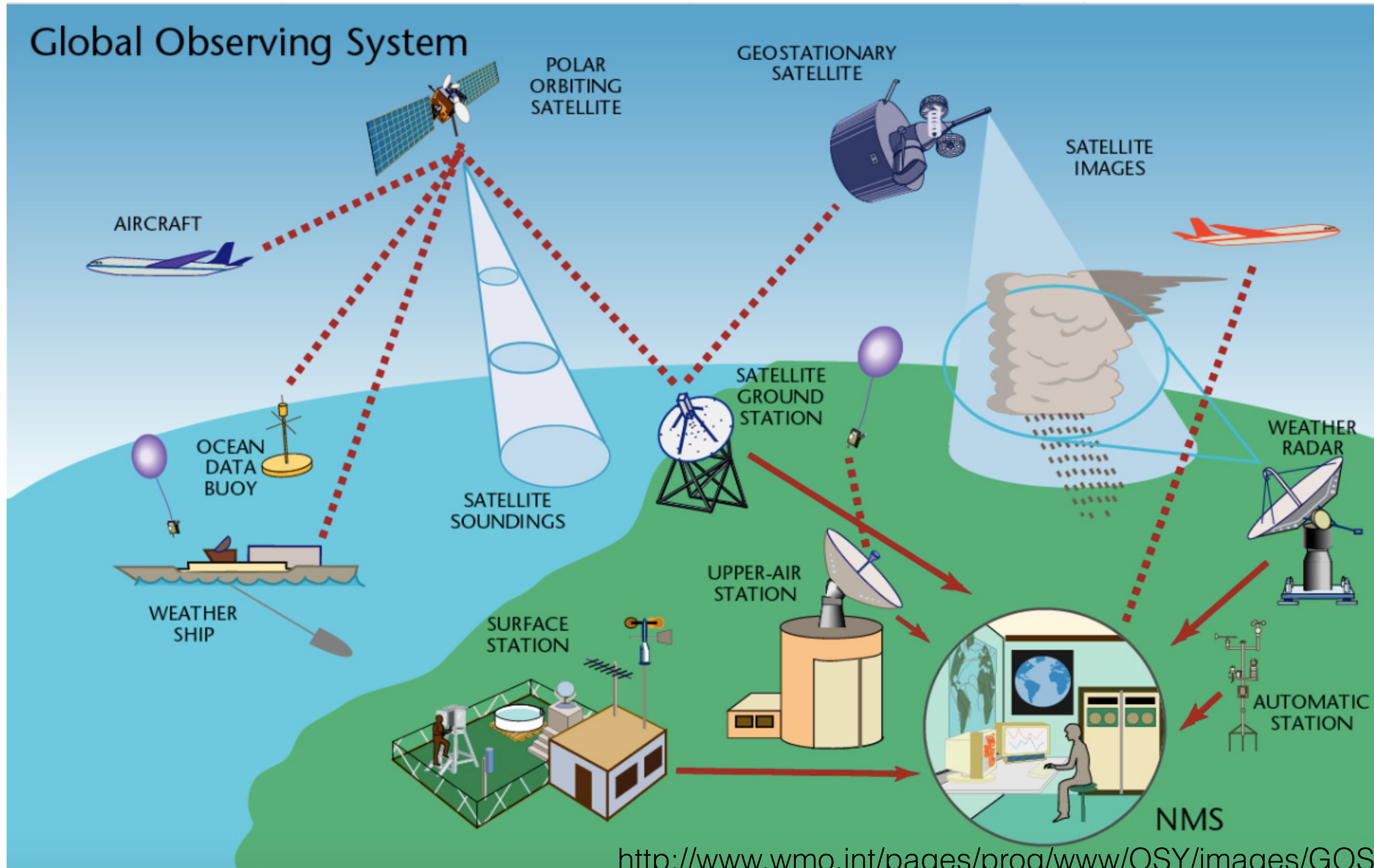
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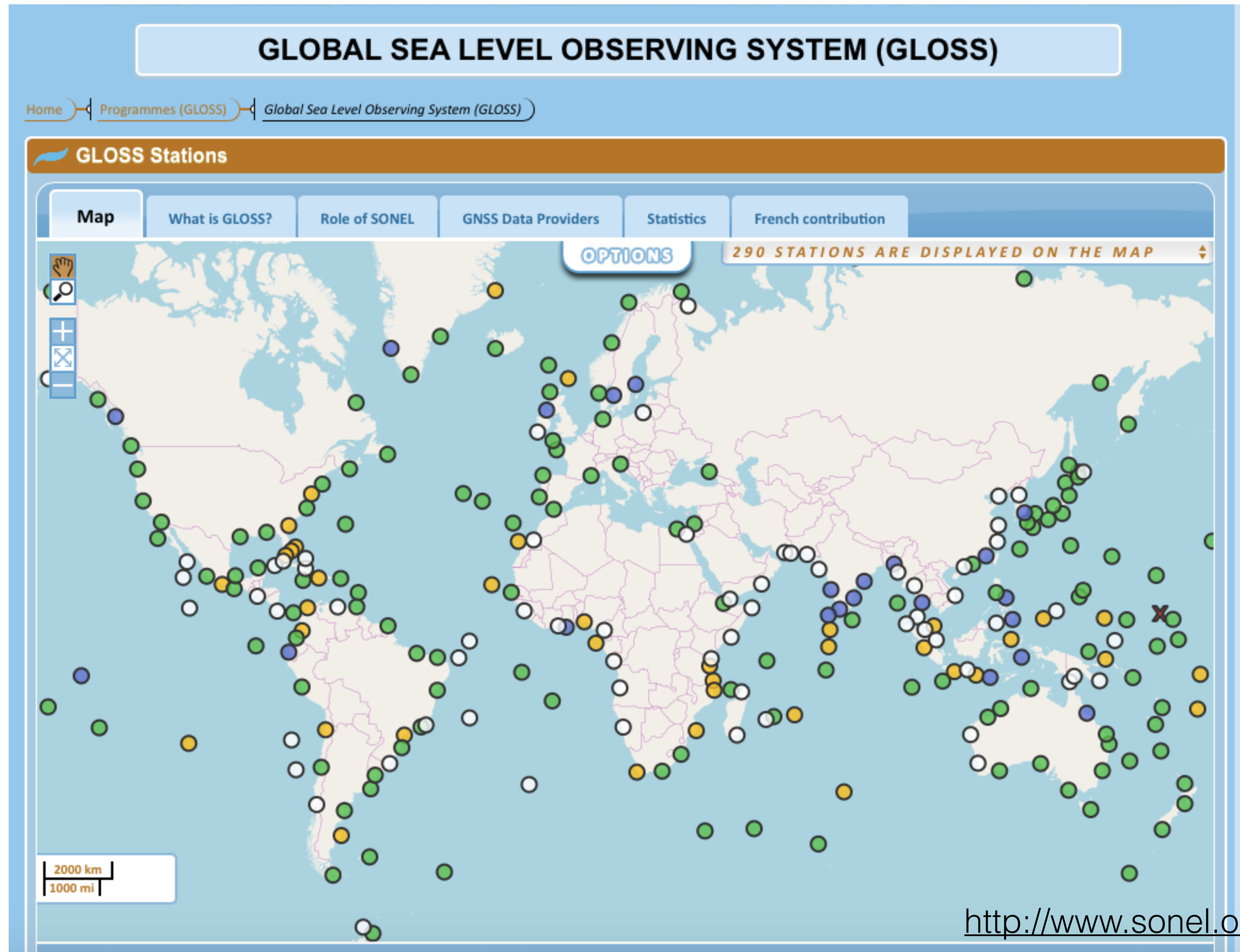
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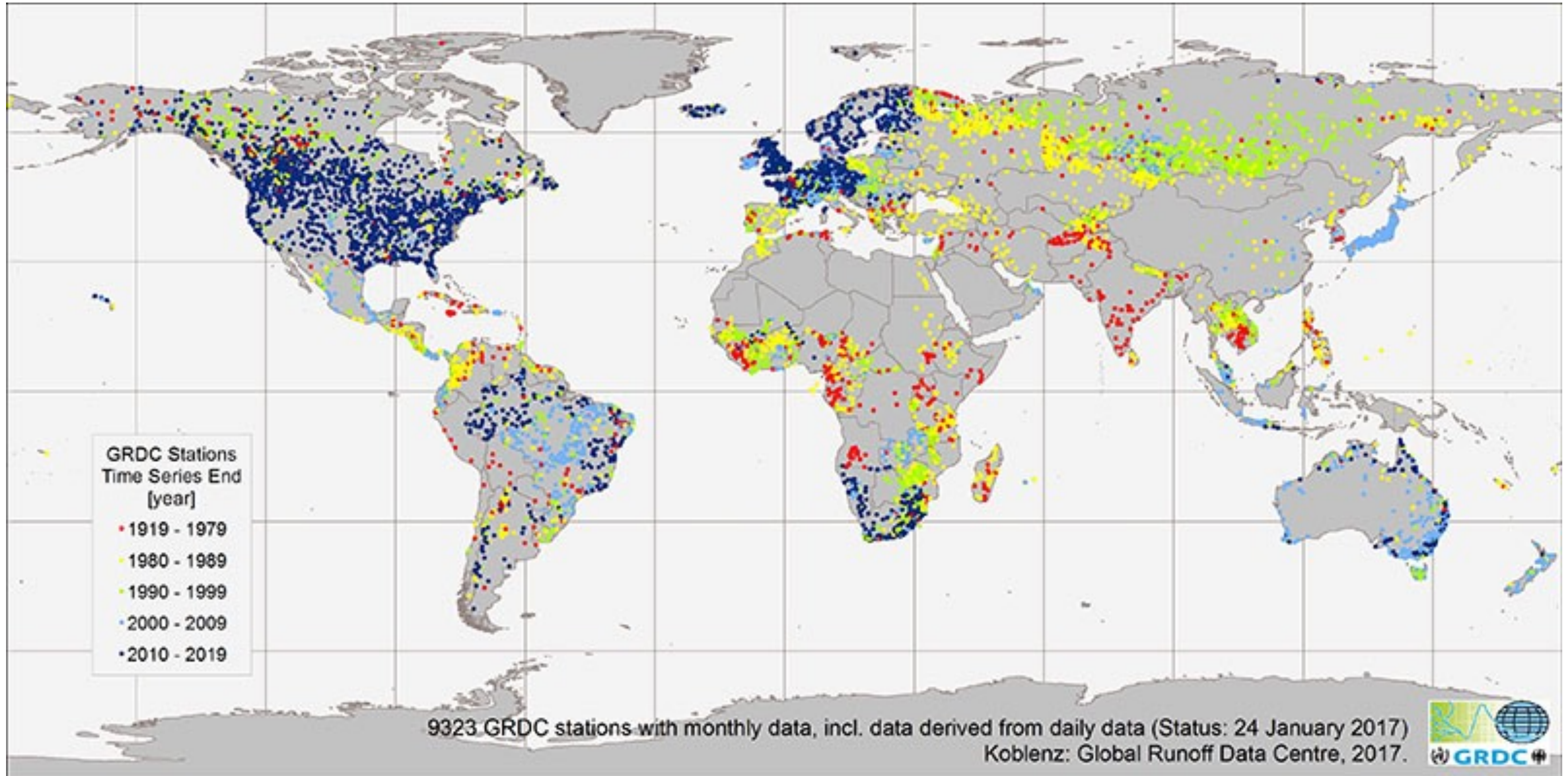
## Disaster Risk Governance















## Earthquake Hazards Program

← Monitoring

### GSN - Global Seismographic Network

National Earthquake Information Center-NEIC

ANSS-Advanced National Seismic System

**GSN-Global Seismographic Network**

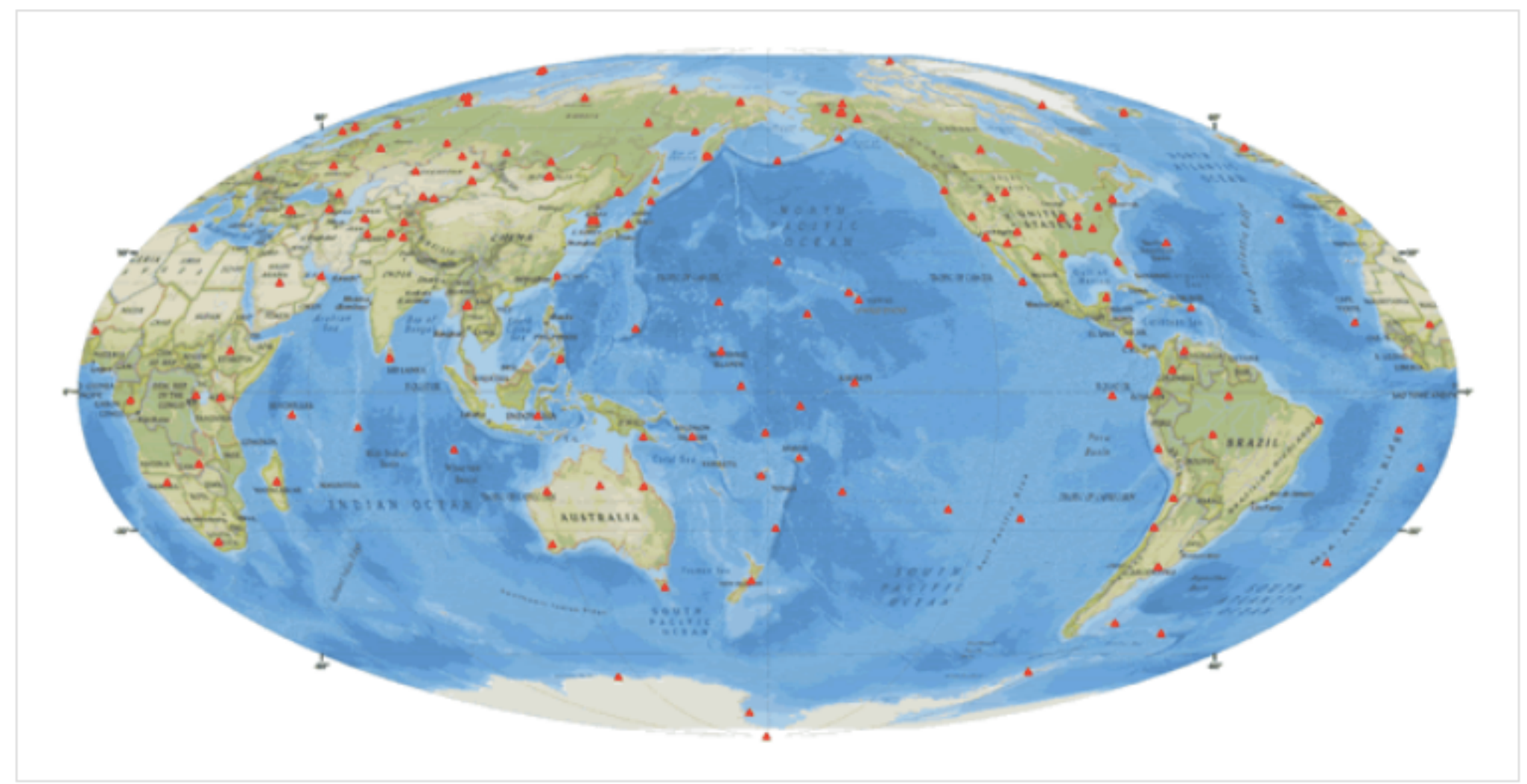
Volunteer Monitoring

Seismogram Displays

Earthquake Monitoring of Structures

NSMP-National Strong Motion Project

Crustal Deformation Monitoring



The Global Seismographic Network is a permanent digital network of state-of-the-art seismological and geophysical sensors connected by a telecommunications network, serving as a multi-use scientific facility and societal resource for monitoring, research, and education. Formed in partnership among the USGS, the [National Science Foundation \(NSF\)](#) and the [Incorporated Research Institutions for Seismology \(IRIS\)](#), the GSN provides near-uniform, worldwide monitoring of the Earth, with over 150 modern seismic

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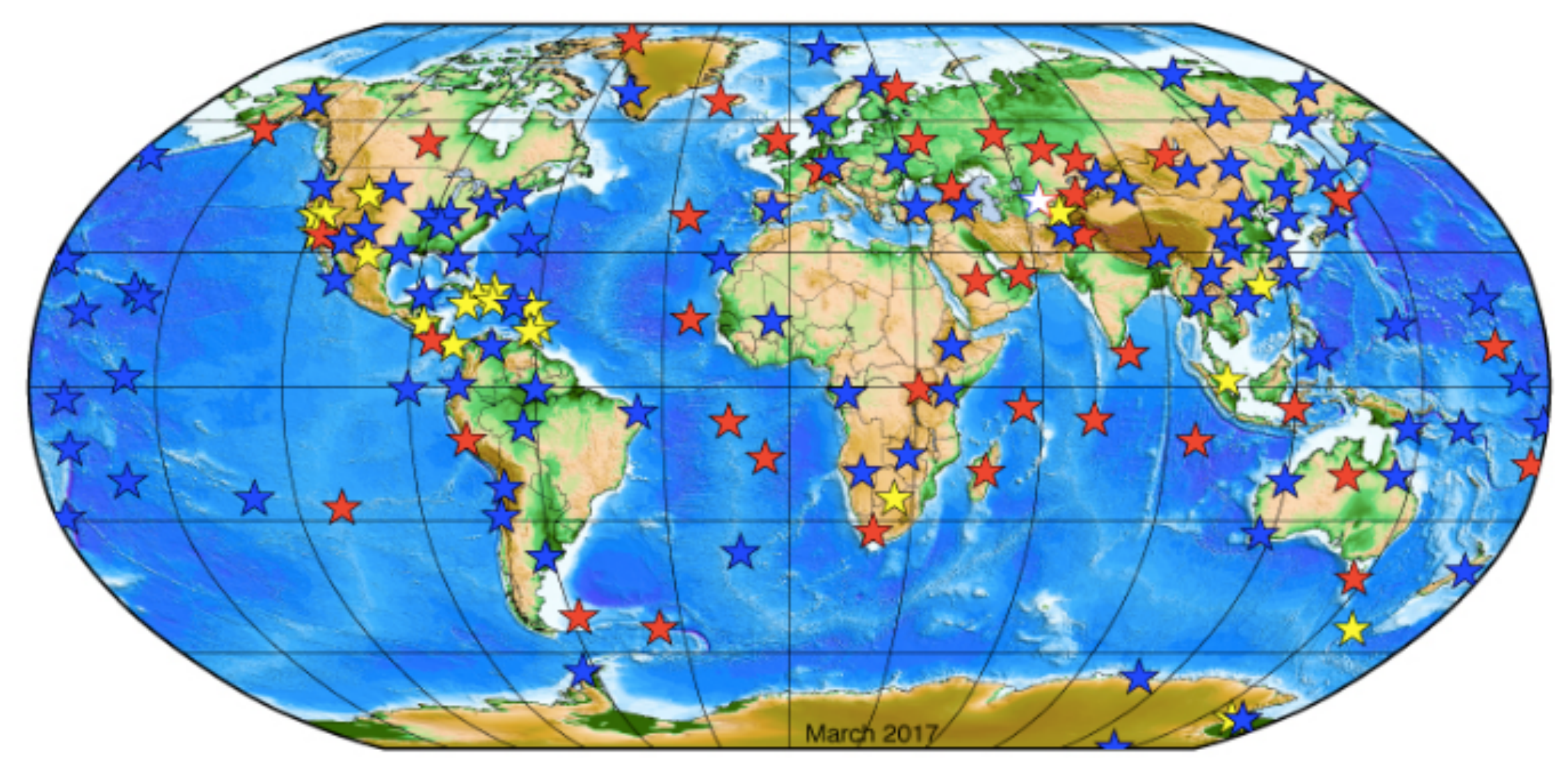
- ← **Monitoring**
- National Earthquake Information Center-NEIC
- ANSS-Advanced National Seismic System
- GSN-Global Seismographic Network**
- Volunteer Monitoring
- Seismogram Displays
- Earthquake Monitoring of Structures
- NSMP-National Strong Motion Project
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  - GSN Review 2015
  - GSN Standing Committee
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- > **The Ocean Bottom Seismograph Instrument Pool**
- > **Transportable Array**
- > **Magnetotelluric Array**
- > **Polar**
- > **Greenland Ice Sheet Monitoring Network**
- > **Global Reporting Observatories in Chile (GRO Chile)**

## Global Seismographic Network



★ IRIS/IDA Stations   
 ★ IRIS/USGS Stations   
 ★ Affiliate Stations  
★ Planned Stations

The Global Seismographic Network (GSN) is a 150+ station, globally distributed, state-of-the-art digital seismic network that provides free, realtime, open access data through the IRIS DMC. The map above shows the distribution of the current station network with respect to [network operations](#).

Earthquake Hazards Program

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## International Federation of Digital Seismograph Networks

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### About the FDSN

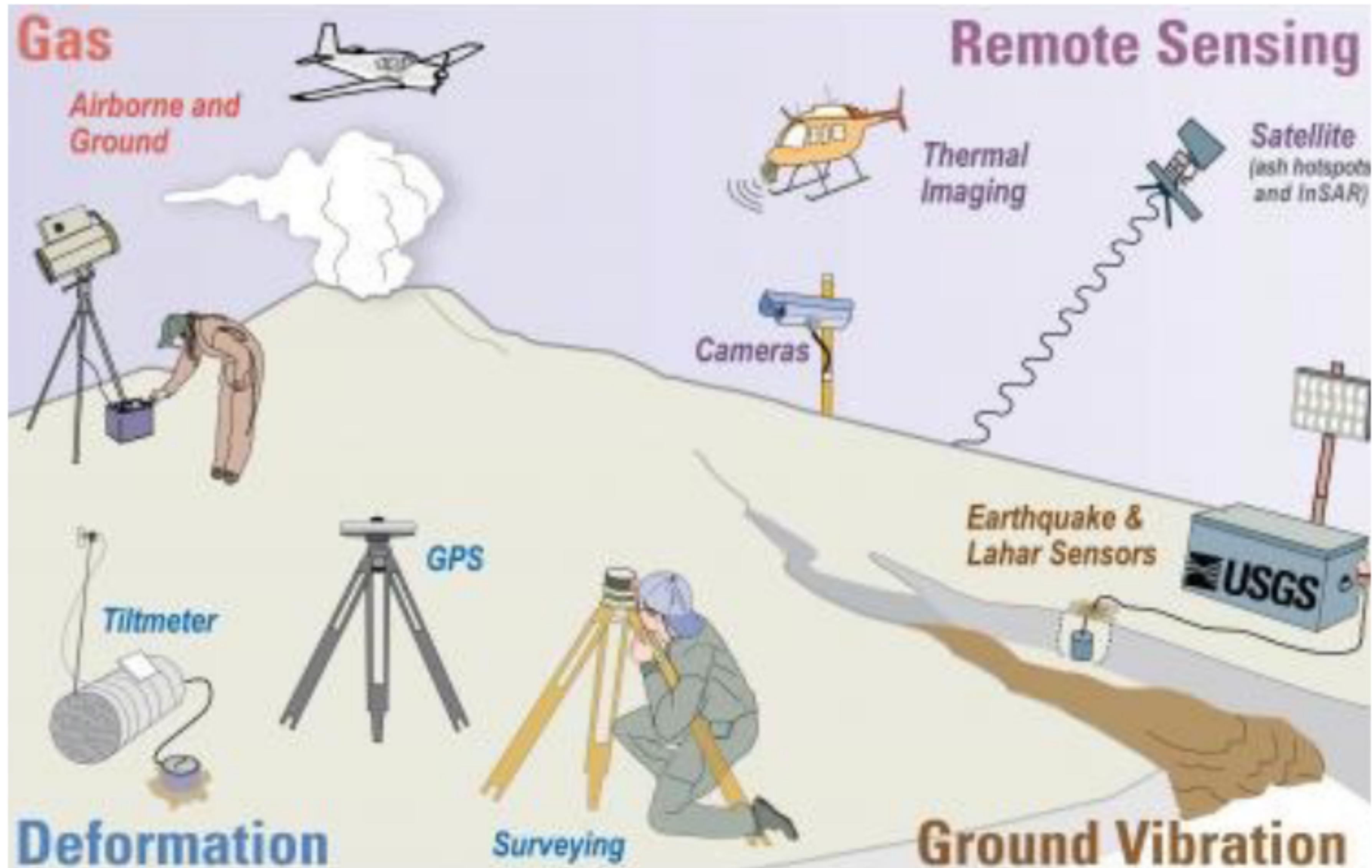
The International Federation of Digital Seismograph Networks (FDSN) is a global organization. Its membership is comprised of groups responsible for the installation and maintenance of seismographs either within their geographic borders or globally. Membership in the FDSN is open to all organizations that operate more than one broadband station. Members agree to coordinate station siting and provide free and open access to their data. This cooperation helps scientists all over the world to further the advancement of earth science and particularly the study of global seismic activity. The FDSN also holds commission status within IASPEI.

The FDSN goals related to station siting and instrumentation are to provide stations with good geographic distribution, recording data with 24 bits of resolution in continuous time series with at least a 20 sample per second sampling rate. The FDSN was also instrumental in development of a universal standard for distribution of broadband waveform data and related parametric information. The Standard for Exchange of Earthquake Data (SEED) format is the result of that effort.

### Network Codes

Network codes are also assigned by the FDSN in order to provide uniqueness to seismological data streams. Network operators request these unique codes for both permanent and temporary networks. Network Code request forms are [here](#).

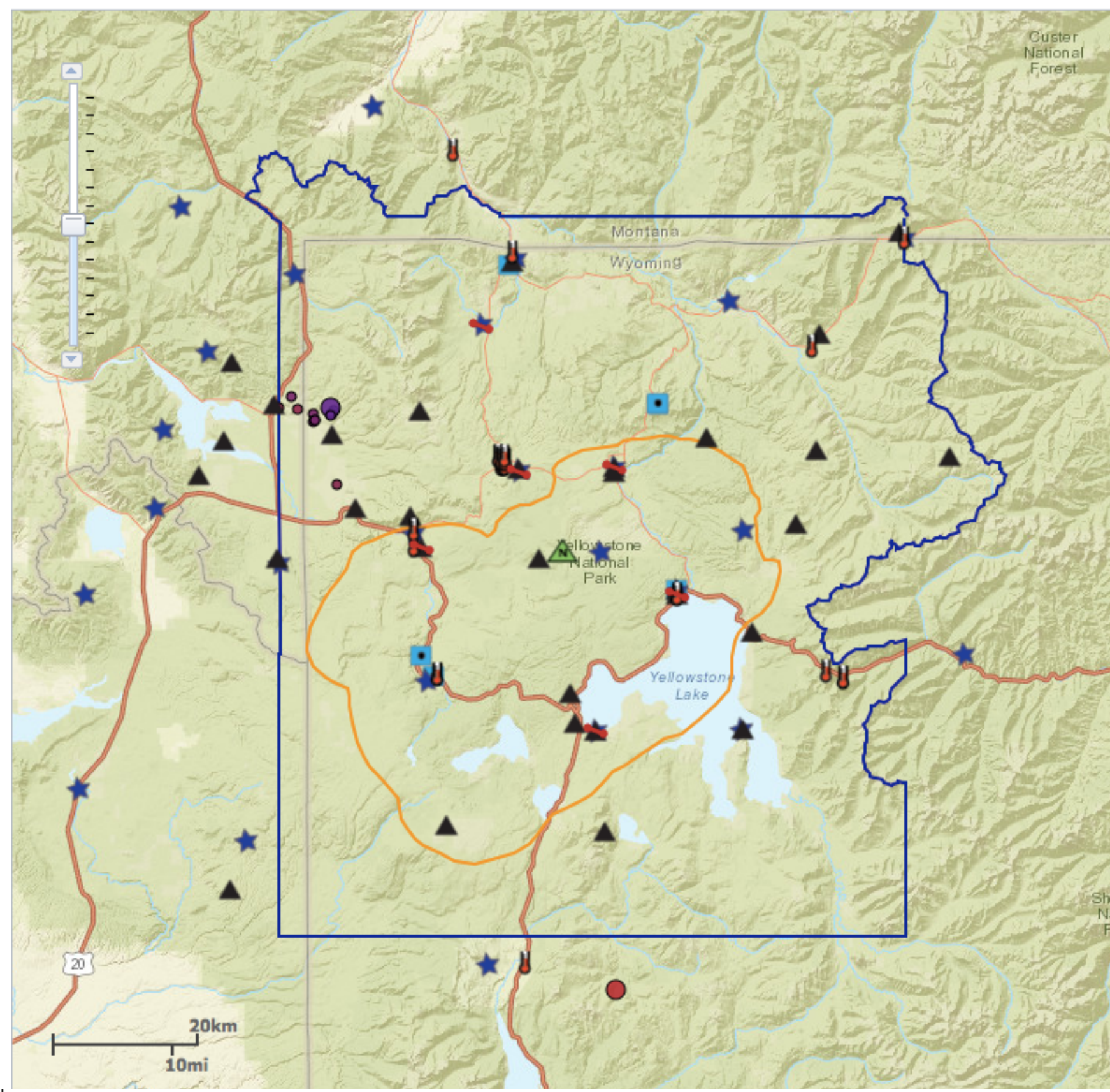
[FDSN historical information](#)



USGS Monitoring System for Geohazards



# Observing Systems for a Dynamic Planet



**Legend** [Help](#)

**Instruments**

- Camera
- GPS Receiver
- Seismic Station
- Temperature
- Tiltmeter

Show All   
Hide All

**Show Available Quakes**

Magnitude (range): -1 - 5

Days ago (range): 0 - 6

**14 Earthquakes In Region**  
(Within magnitude and date range.)

Mag	Date/Time (UTC)	Depth (km)
0.36	09/02/2017 19:36:39	9.94
0.44	09/02/2017 14:27:36	11.01
0.15	09/02/2017 13:43:54	9.35
1.97	09/02/2017 13:40:46	11.09
0.62	09/02/2017 12:06:00	10.12
0.65	09/02/2017 06:37:28	6.37
0.88	09/01/2017 20:25:16	8.73
0.83	08/31/2017 17:24:59	6.71
0.53	08/31/2017 15:36:17	8.29
0.69	08/31/2017 12:06:22	8.08
0.7	08/31/2017 04:18:30	9.21

Depth (km) scale: -2, 2, 6, 10, 20, 40, 50

Magnitude scale: 0, 1, 2, 3, 4, 5, 6, 7, 8

**USGS**  
science for a changing world

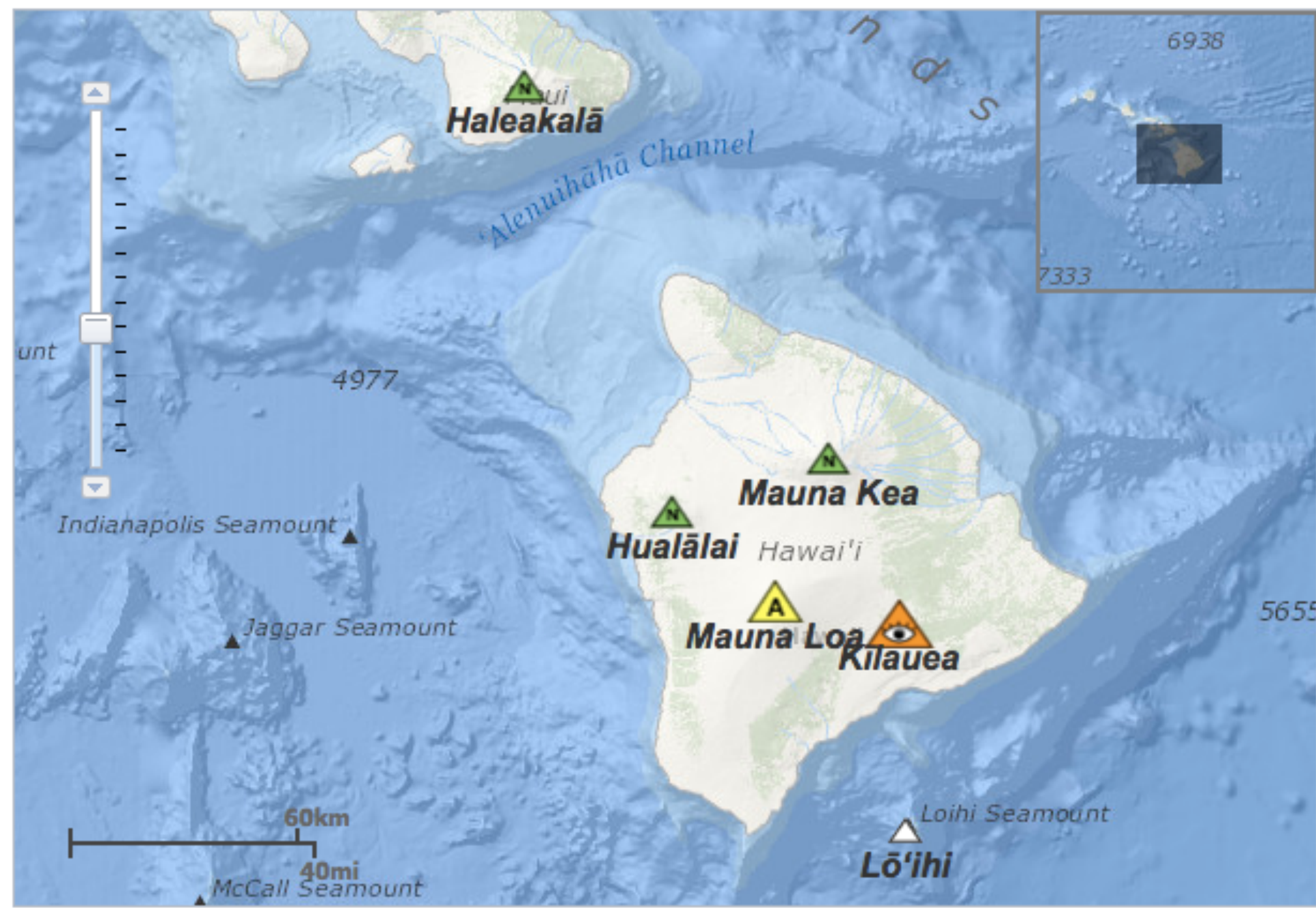
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**Volcano Hazards Program**

**Hawaiian Volcano Observatory (HVO)**

About HVO | Volcanoes | Earthquakes | Hazards | Monitoring | Learn | Multimedia | FAQs



**Kilauea**  
ORANGE WATCH, 2017-09-04 18:52:27 UTC  
Update | Monitoring | Photos | Maps | Webcams  
Deformation | Air Quality | Videos

**Mauna Loa**  
YELLOW ADVISORY, 2017-08-31 19:59:40 UTC  
Update | Monitoring | Photos | Webcams  
Deformation

**Quick Links**

- Volcano Watch
- FAQs
- Publications
- Newsroom
- Volunteer
- Report Felt Earthquake
- Vog Dashboard

**Hawaiian Volcano Observatory's mission**  
HVO monitors the active volcanoes in Hawaii, assesses their hazards, issues warnings, and advances scientific understanding to reduce impacts of volcanic eruptions.

**HVO News** (archive)

**New USGS Open File Report: Hawaiians and scientists discuss Kilauea volcanism**  
July 05, 2017

Co-editors Jim Kauahikaua and Janet Babb recently published *Conversing with Pelehonuamea—A workshop combining 1,000+ years of traditional Hawaiian knowledge with 200 years of scientific*

**Active Volcanoes in Hawaii<sup>1</sup>**

**Hualālai**



Smithsonian Institution  
National Museum of Natural History  
Global Volcanism Program

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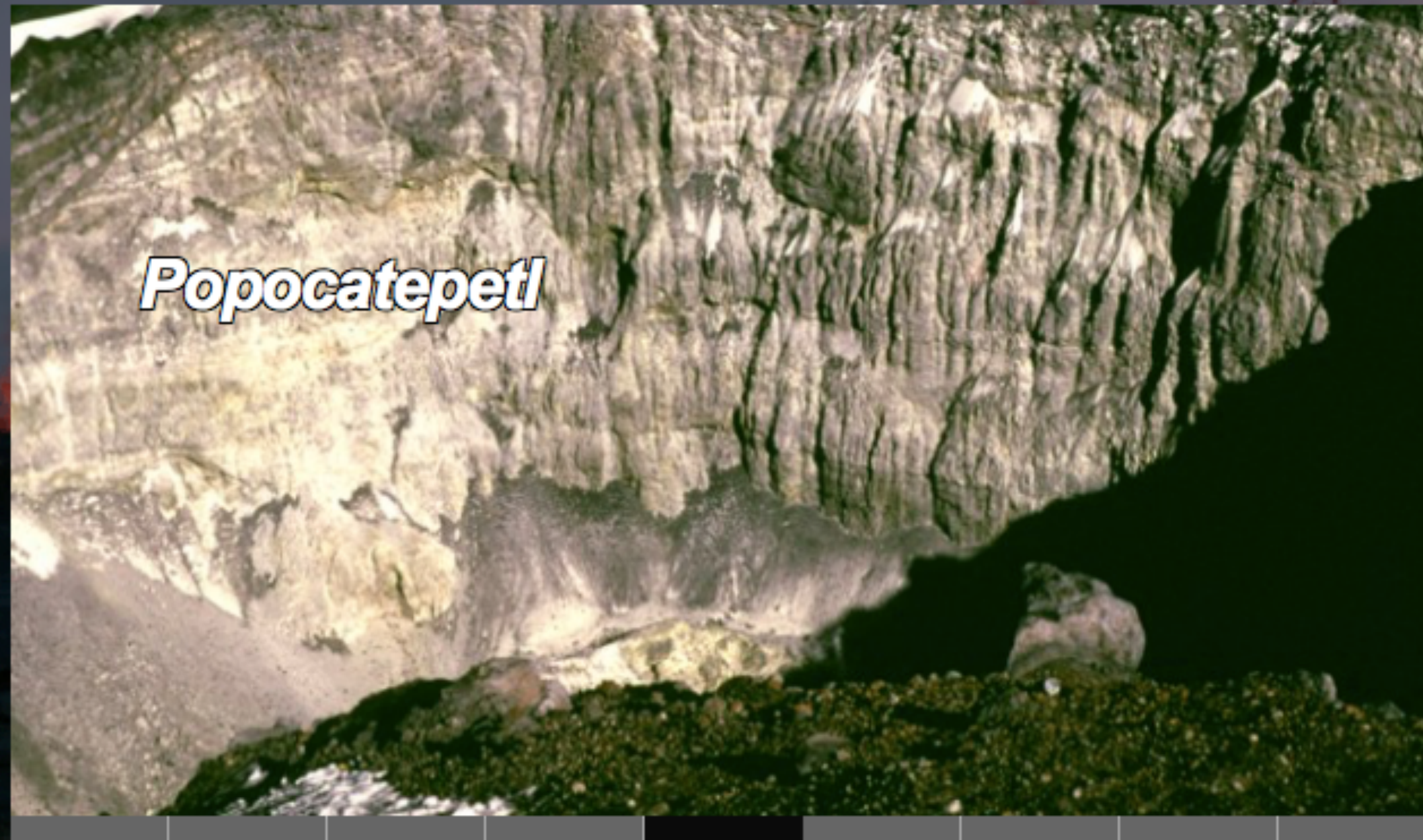
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### New Activity / Unrest

 [Pacaya](#)

Guatemala

 [Sangay](#)

Ecuador

 [Ibu](#)

Indonesia

 [Fuego](#)


Guatemala


 [Klyuchevskoy](#)

Russia

 [Report for 23 Aug-29 Aug 2017](#)

### Recent Bulletin Reports

 [Erta Ale](#) | Persistent lava lake; crater rim overflows; new fissure eruption begins in January 2017

 [Piton de la Fournaise](#) | Intermittent effusive episodes during February-October 2015; May and September 2016; and

## Welcome to the Global Volcanism Program

### "10,000 years of volcanic activity at your fingertips"

[Site & Database News](#)

7 August 2017

[E3 Web Application](#)

The "Eruptions, Earthquakes, & Emissions"



**Figure 2.** Geographical location of the volcanoes involved in the NOVAC project as of April 2009. The project is open to participation by any interested institution, so the network may be expanded in the future. Also see Table 1. (© Google 2009 and Europa Technologies 2009.)

# Observing Systems for a Dynamic Planet

**NIED National Research Institute for Earth Science and Disaster Resilience**

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About NIED Research Departments Research Activities **Experimental Facilities**

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**Experimental Facilities**

- ▶ Large-scale Earthquake Simulator
- ▶ Large-scale Rainfall Simulator
- ▶ Cryospheric Environment Simulator
- ▶ Three-Dimensional Full-Scale Earthquake Testing Facility

**Facility utilization**

- ▶ NIED library
- ▶ Access

**Experimental Facilities**

- Large-scale earthquake simulator**
- Large-Scale Rainfall Simulator**
- Cryospheric Environment Simulator (CES)**
- 3-D Full-Scale Earthquake Testing Facility**

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home → projects → major projects → pbo

## EarthScope - Plate Boundary Observatory (PBO)

### Overview

The [Plate Boundary Observatory \(PBO\)](#) component of the [EarthScope](#) precisely measures Earth deformation resulting from the constant motion of the Pacific and North American tectonic plates in the western United States.

The GAGE Facility, operated by [UNAVCO, Inc.](#), is responsible for instrument installation, ongoing maintenance, communications, data archiving, data processing, and data availability for the geodetic instruments that comprise the Plate Boundary Observatory.

The Principal Investigator (PI) for for the Plate Boundary Observatory is [UNAVCO President](#), Dr. M. Meghan Miller ([meghan@unavco.org](mailto:meghan@unavco.org)) and the Co-PI is Director of UNAVCO Geodetic Infrastructure, Dr. Glen Mattioli ([mattioli@unavco.org](mailto:mattioli@unavco.org)).



<https://www.unavco.org/projects/major-projects/pbo/pbo.html>

### Science

A primary objective of the PBO is to quantify three-dimensional deformation and its temporal variability across the active boundary zone between the Pacific and North American plates.

Centimeter to millimeter-level measurements of surface and near surface motion through Global Positioning System (GPS) stations, borehole geophysics, laser strainmeters, accelerometers, and geodetic imaging has far reaching implications regarding earthquakes, volcanic unrest, subsidence, landslides, extraction or injection of fluids, loading or unloading of water, ice or snow, and other Earth processes.

### Projects

- Help with Projects
- **Major Projects**
  - **EarthScope PBO**
    - Overview
    - Science
    - History
    - Instrumentation & Networks
    - Maintenance
    - Data
    - Documentation

### Related Links

- [EarthScope Science](#)
- [PBO Instrumentation](#)
- [PBO Network Monitoring](#)
- [PBO GPS Core Data](#)
- [PBO High Rate Data](#)
- [Custom Data Request](#)
- [SINEX format at IERS](#)

# Observing Systems for a Dynamic Planet

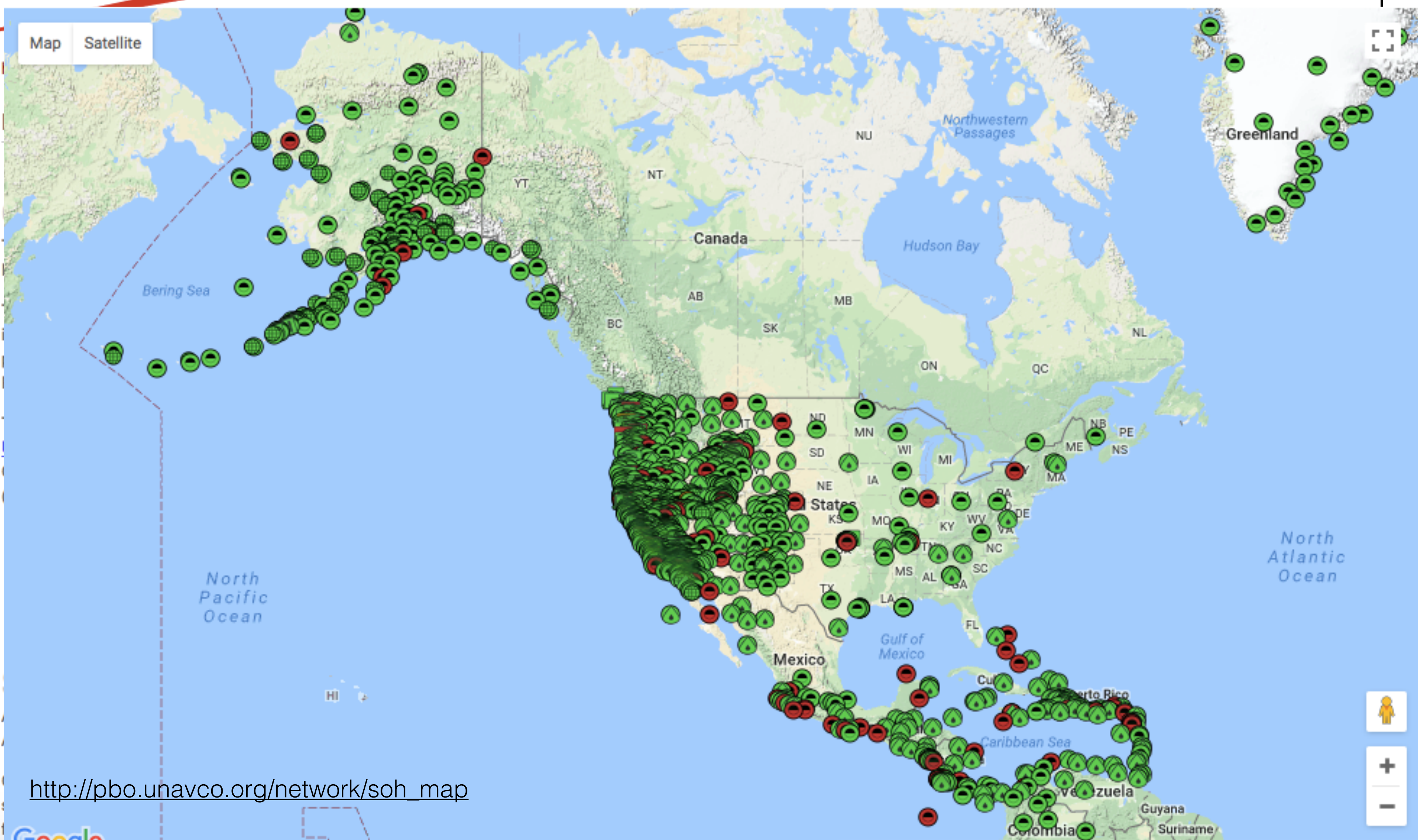


## Projects

- Help with Projects
- **Major Projects**
  - **EarthScope PBO**
    - Overview
    - Science
    - History
    - Instrumentation & Networks
    - Maintenance
    - Data
    - Documentation

## Related Links

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- [PBO Network Monitoring](#)
- [PBO GPS Core Data](#)
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- [SINEX format at IERS](#)



[http://pbo.unavco.org/network/soh\\_map](http://pbo.unavco.org/network/soh_map)

# Observing Systems for a Dynamic Planet

EUROPEAN RESEARCH INFRASTRUCTURE ON SOLID EARTH

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EVENTS



EPOS and ECCSEL ESFRI Research Infrastructures collaborative framework - The two research infrastructures have identified an initial list of topics of common interest and have set up a working group to elaborate a roadmap for establishing a...

MORE NEWS

<https://www.epos-ip.org>



## EPOS THEMATIC CORE SERVICES



SEISMOLOGY



NEAR FAULT OBSERVATORIES



GNSS DATA AND PRODUCTS



VOLCANO OBSERVATIONS



SATELLITE DATA



GEOMAGNETIC OBSERVATIONS



ANTHROPOGENIC HAZARDS



GEOLOGICAL INFORMATION AND MODELING



MULTI-SCALE LABORATORIES



GEO-ENERGY TEST BEDS FOR LOW CARBON ENERGY



EPOS and ECCSEL ESFR infrastructures have identified a group to elaborate a road map

### EPOS for integrated data provision

Easy-to-find data and data products, tools for visualization, processing and analysis will drive research and science forward

[Read more](#)

### EPOS for geo-hazards

EPOS will give scientists, decision makers and the public better access to the latest information for hazard assessment and risk mitigation

[Read more](#)

### EPOS for geo-resources

EPOS will simplify and streamline access to multidisciplinary Earth science data, products and services for Geo-resource management

[Read more](#)



# Observing Systems for a Dynamic Planet



GPS: Global Positioning Service



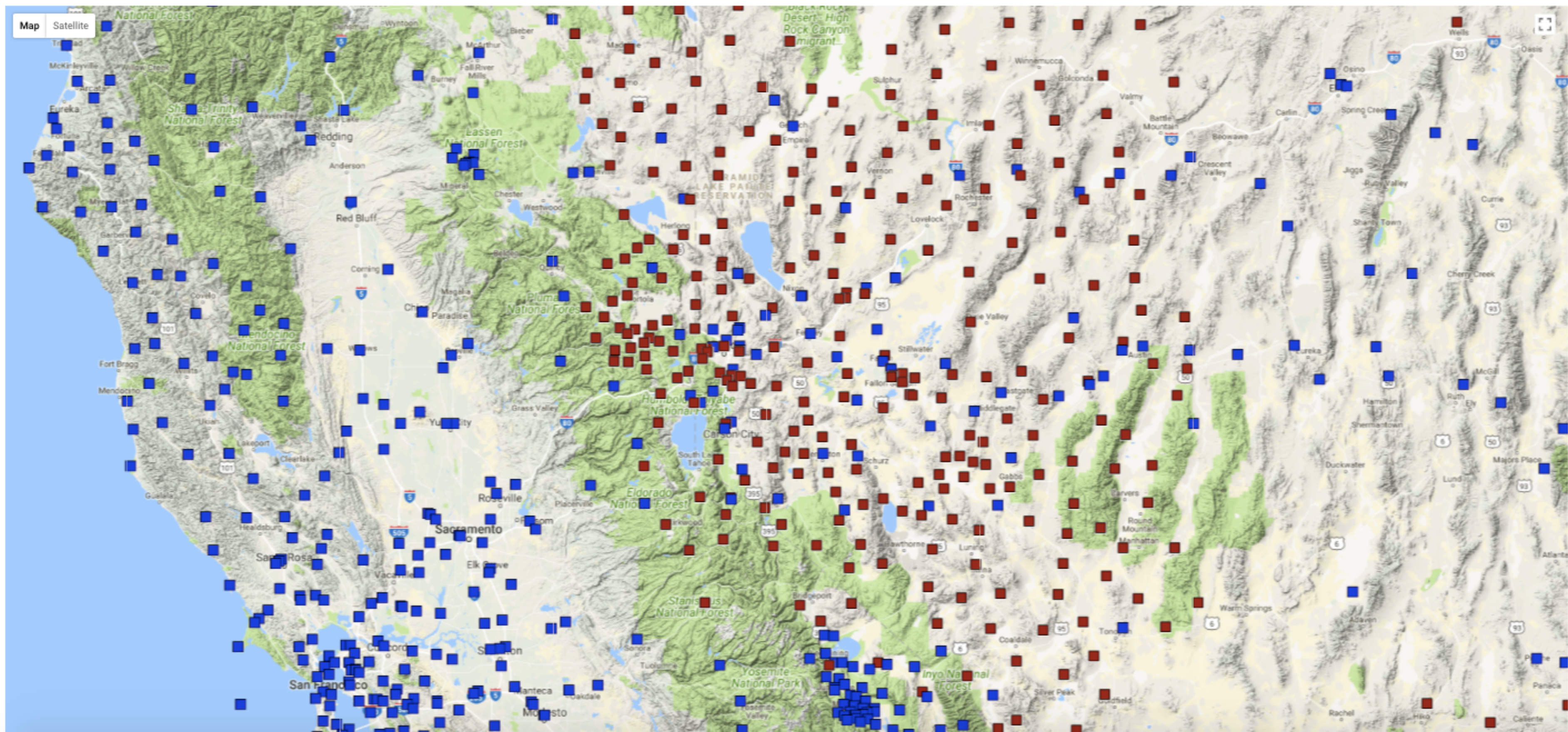
# Observing Systems for a Dynamic Planet



**MAGNET + Other GPS Networks Map**

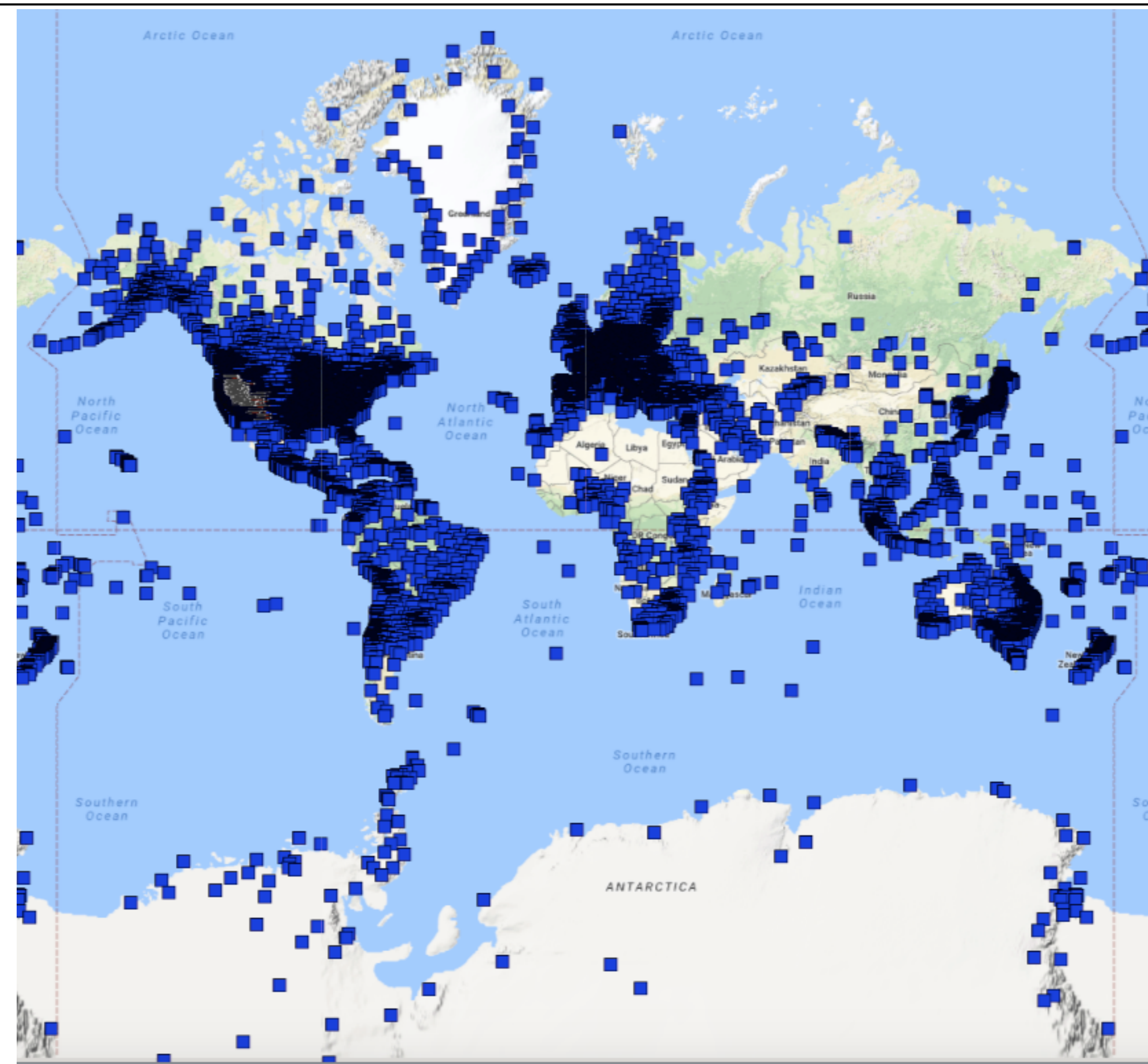
[Click on Site for more information.](#)

■ MAGNET GPS Network  
■ All Other GPS Stations

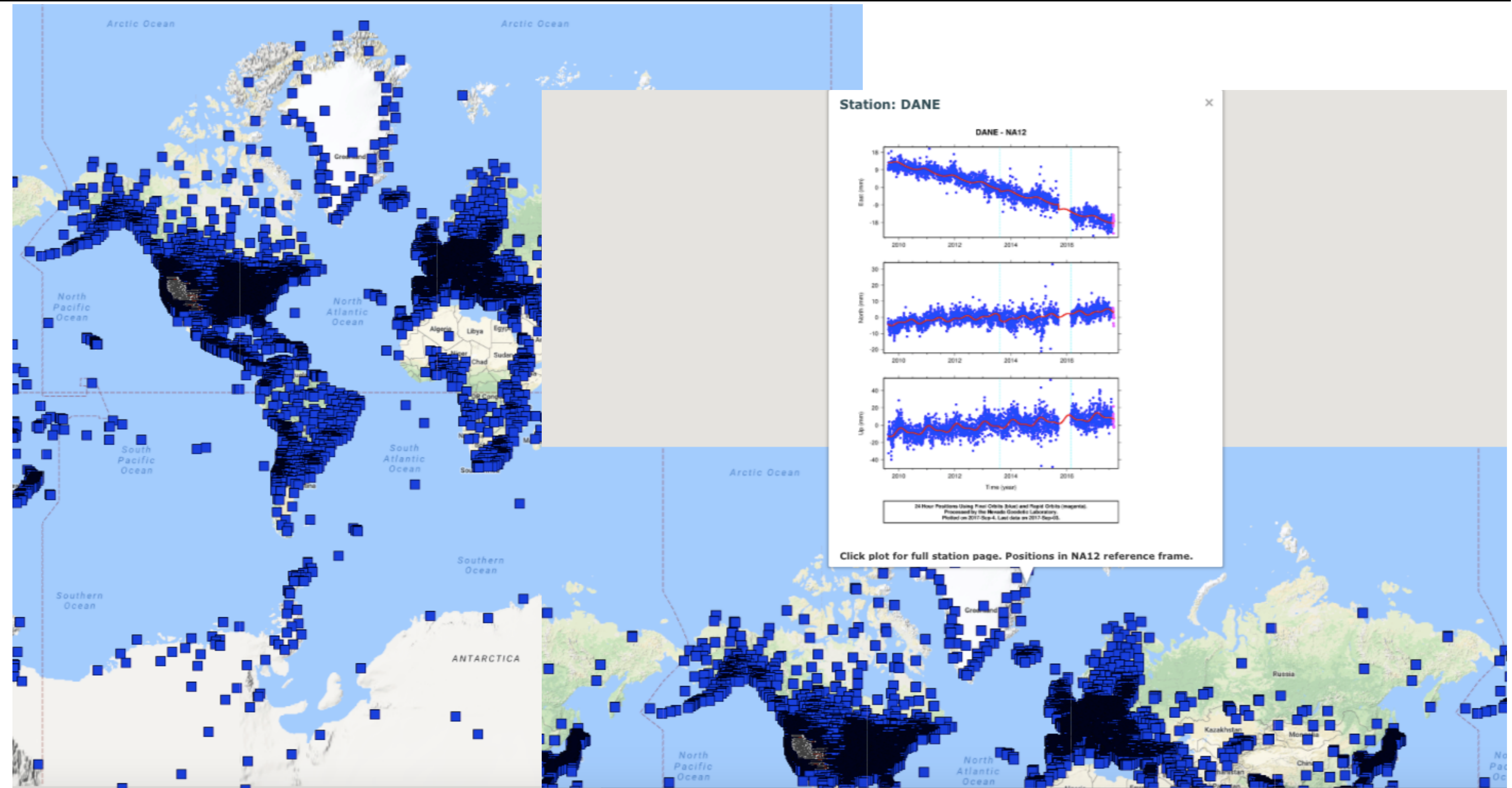


GPS: Global Positioning

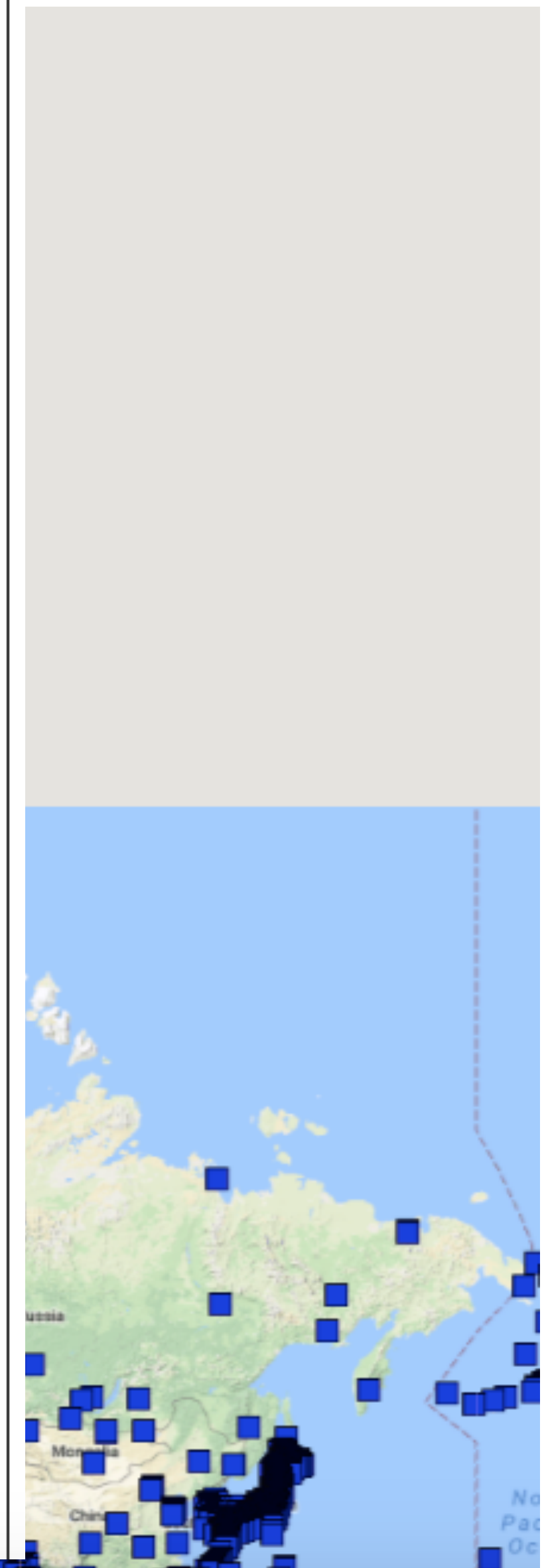
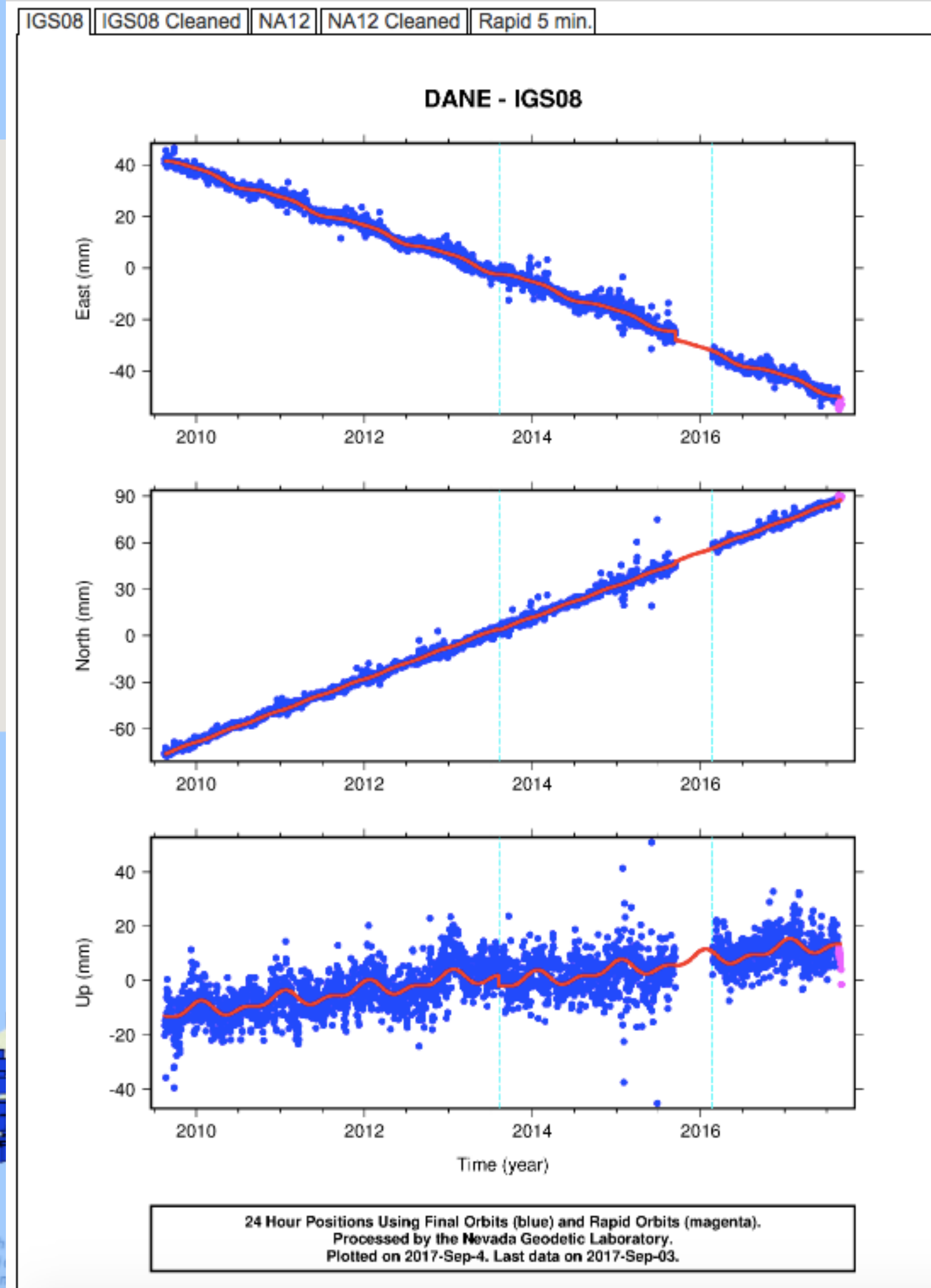
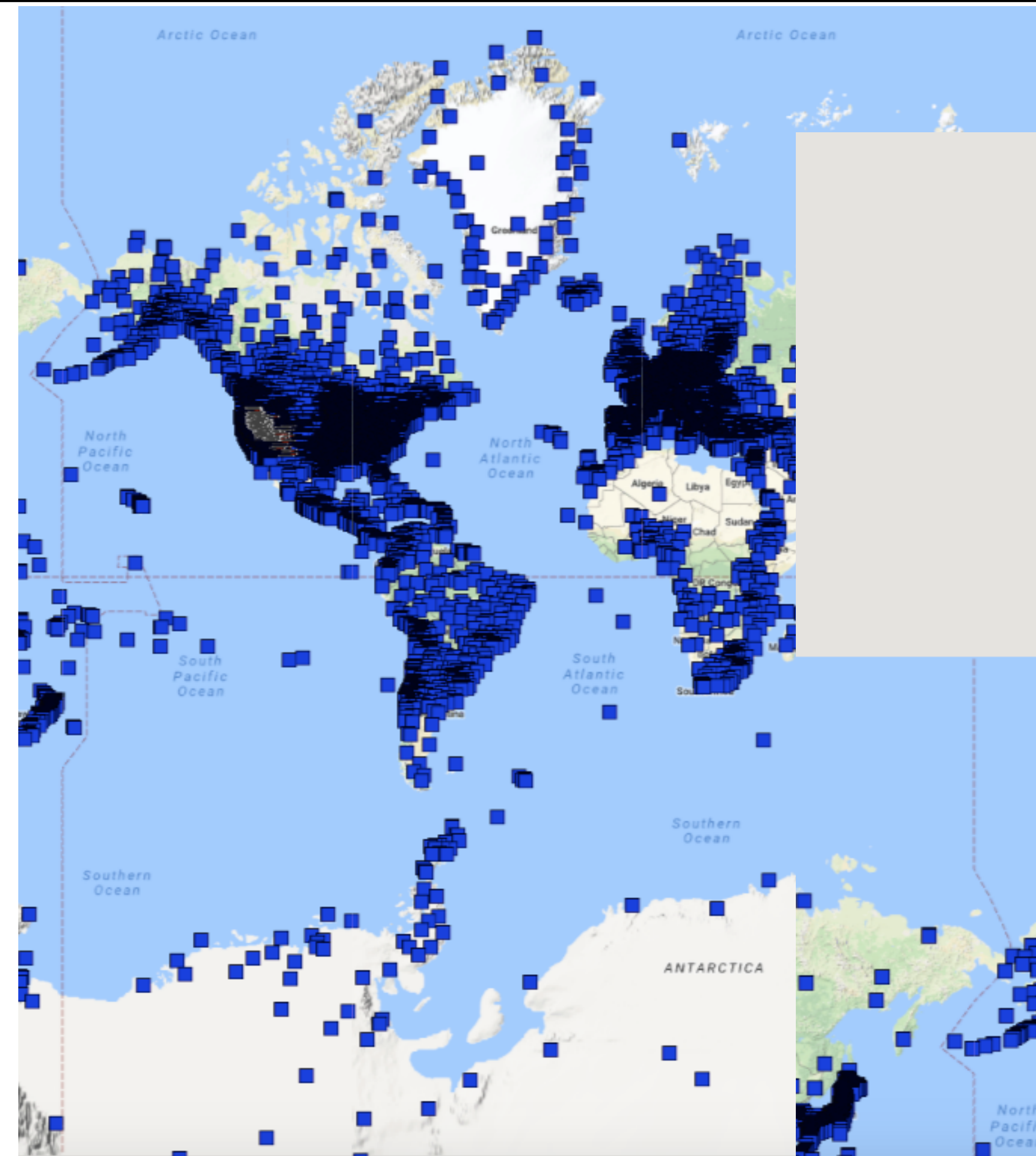
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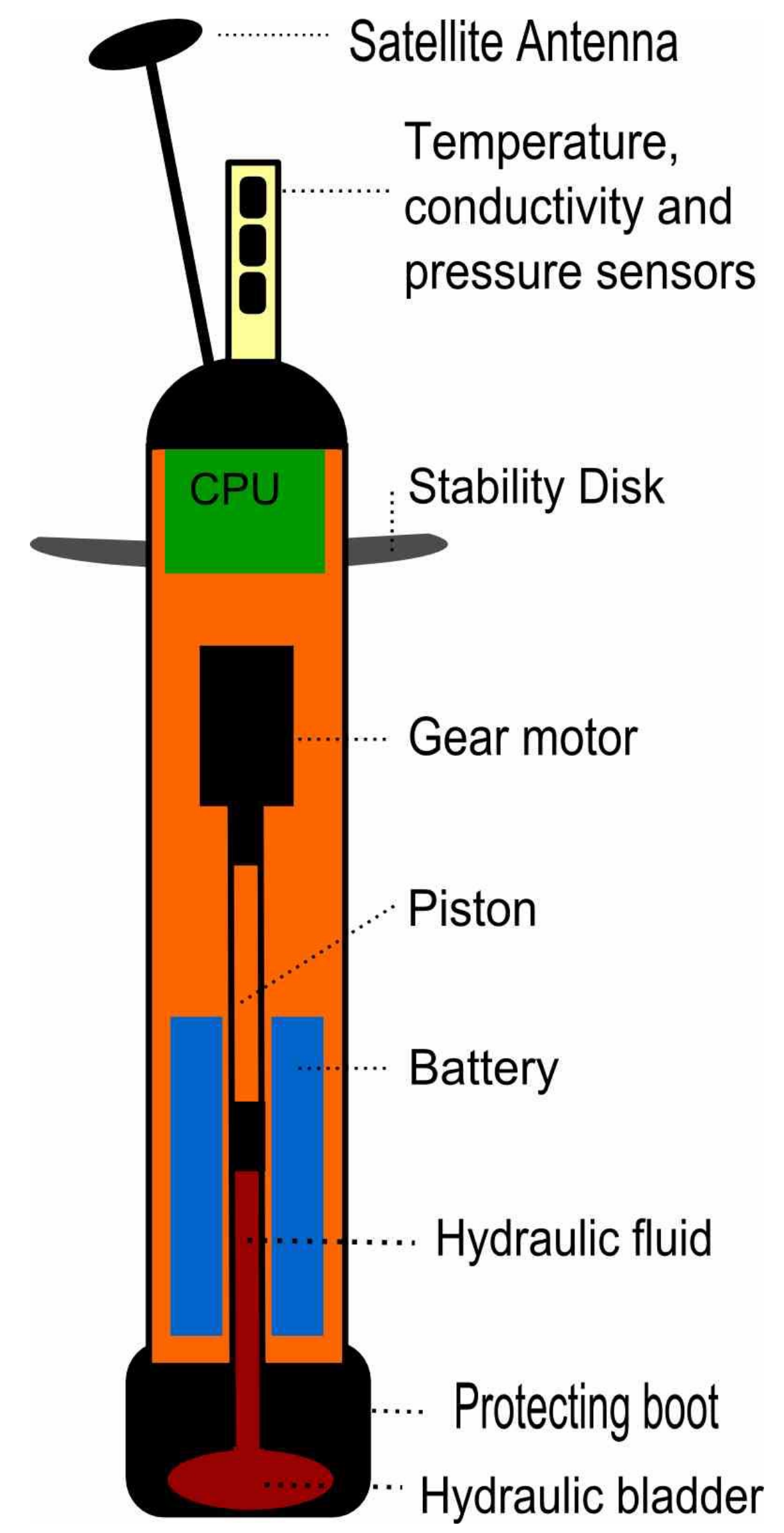
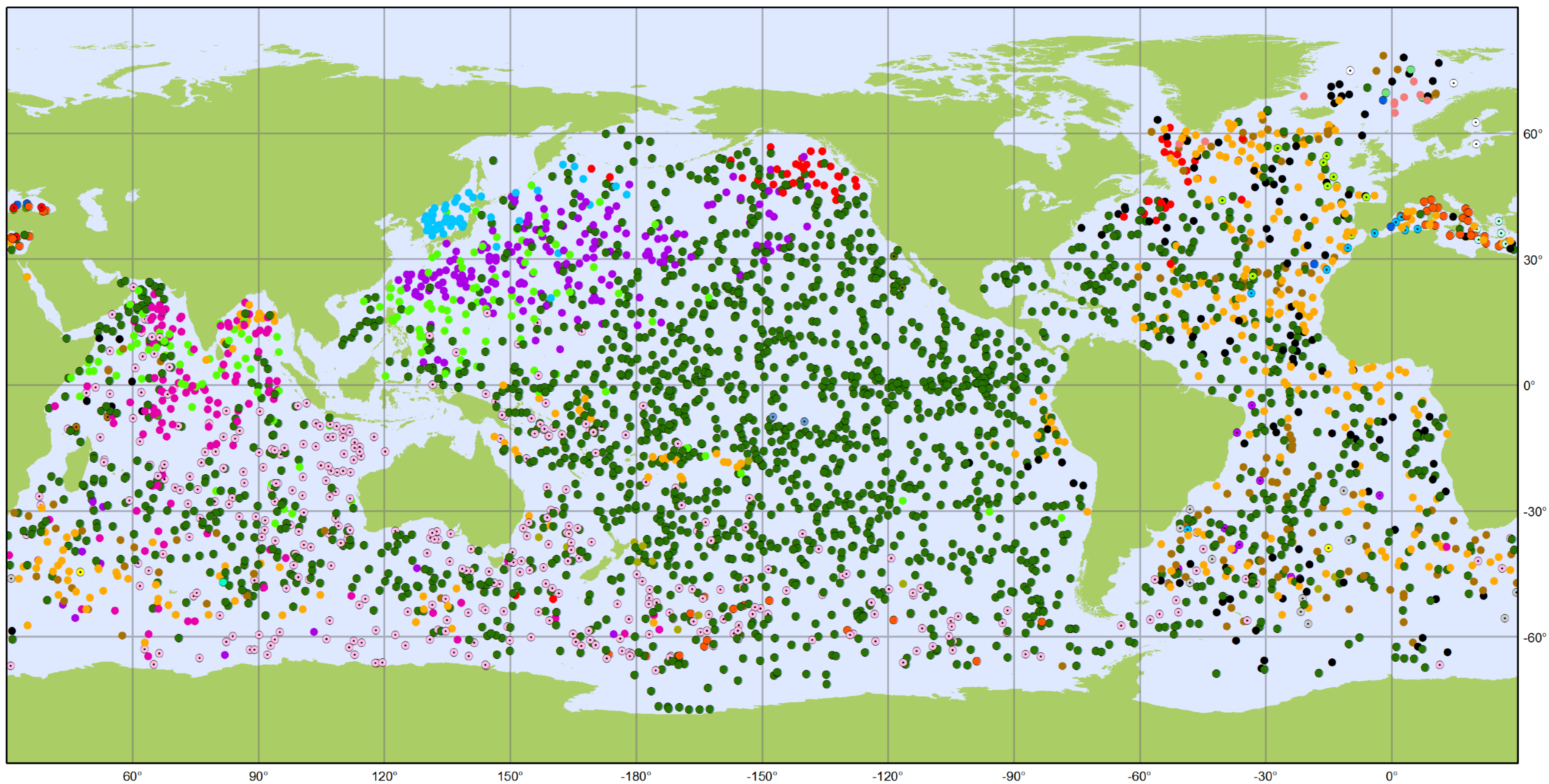
# Observing Systems for a Dynamic Planet



# Observing Systems for a Dynamic Planet

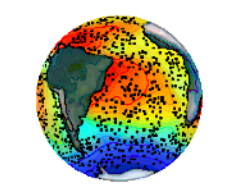


# Observing Systems for a Dynamic Planet

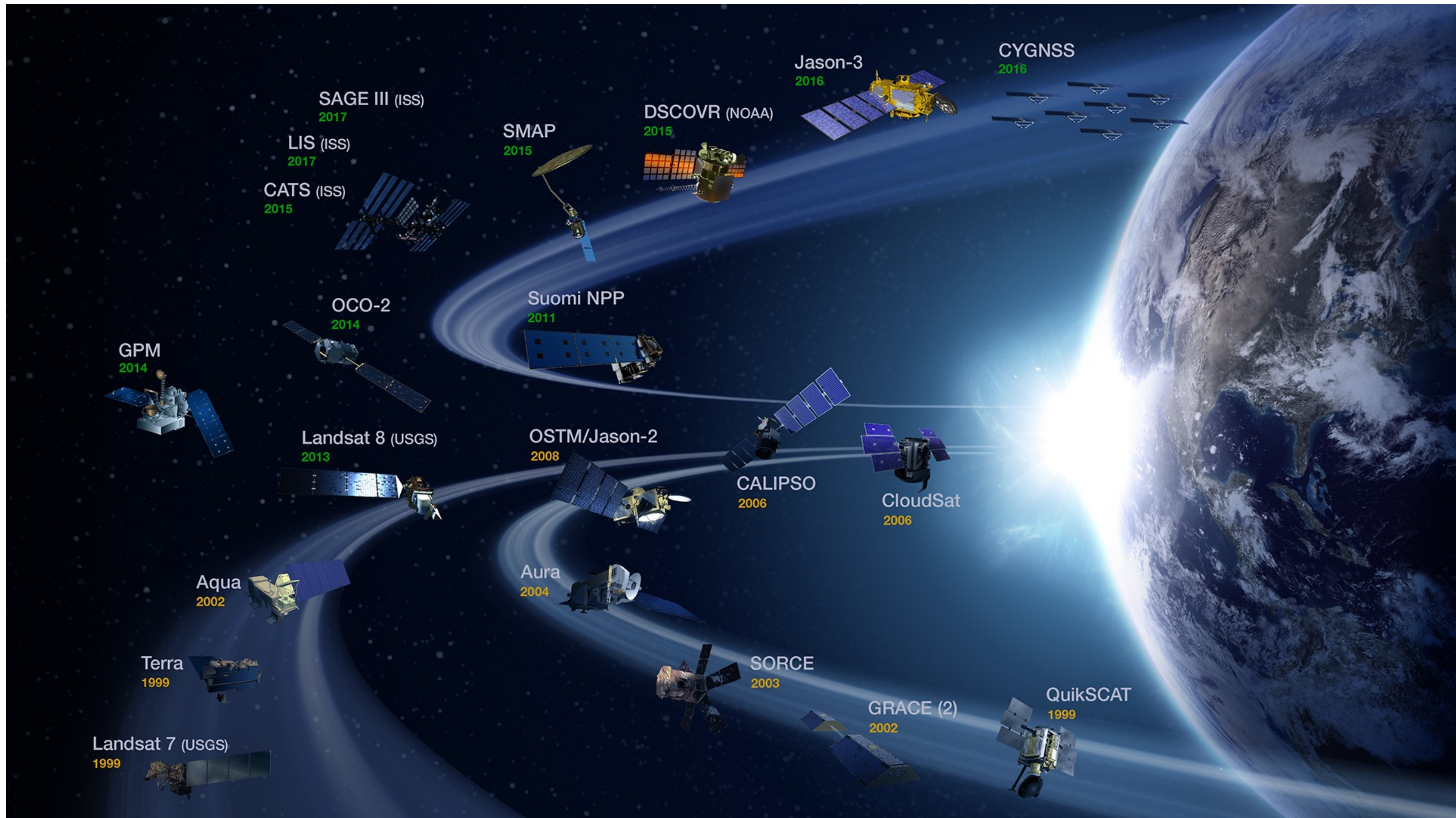


**Argo** National contributions - 3829 Operational Floats April 2016  
 Latest location of operational floats (data distributed within the last 30 days)

- |                   |                |                 |                           |                    |              |
|-------------------|----------------|-----------------|---------------------------|--------------------|--------------|
| ● ARGENTINA (2)   | ● CHINA (149)  | ● GERMANY (133) | ● JAPAN (189)             | ● NETHERLANDS (12) | ● SPAIN (9)  |
| ● AUSTRALIA (380) | ● ECUADOR (2)  | ● GREECE (7)    | ● KENYA (1)               | ● NEW ZEALAND (12) | ● TURKEY (3) |
| ● BRAZIL (10)     | ● EUROPE (6)   | ● INDIA (124)   | ● KOREA, REPUBLIC OF (52) | ● NORWAY (10)      | ● UK (134)   |
| ● BULGARIA (2)    | ● FINLAND (5)  | ● IRELAND (10)  | ● MAURITIUS (3)           | ● POLAND (3)       | ● USA (2138) |
| ● CANADA (58)     | ● FRANCE (328) | ● ITALY (46)    | ● MEXICO (2)              | ● SOUTH AFRICA (1) |              |



# Observing Systems for a Dynamic Planet



From: <https://eospso.gsfc.nasa.gov>

See also: [https://eospso.gsfc.nasa.gov/files/mission\\_profile.pdf](https://eospso.gsfc.nasa.gov/files/mission_profile.pdf)

# Observing Systems for a Dynamic Planet

→ EUROPEAN SPACE AGENCY ABOUT US OUR ACTIVITIES CAREERS AT ESA FOR MEDIA FOR EDUCATORS FOR KIDS

observing the earth

ESA OBSERVING THE EARTH UNDERSTANDING OUR PLANET SECURING OUR ENVIRONMENT BENEFITING OUR ECONOMY

## EARTH OBSERVATION MISSIONS



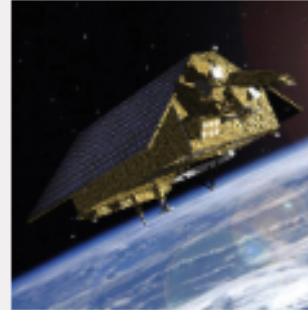






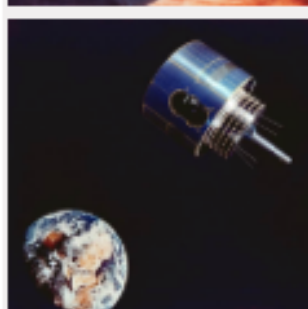

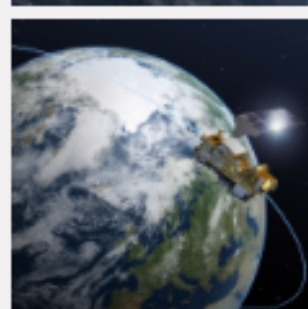


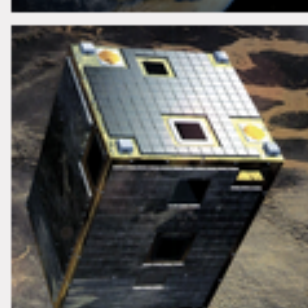
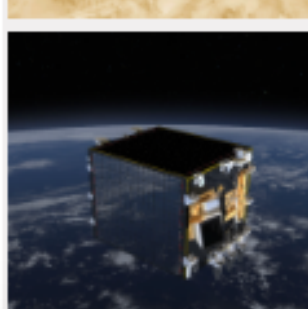


ESA has been dedicated to observing Earth from space ever since the launch of its first Meteosat weather satellite back in 1977. With the launch of a range of different types of satellites over the last 40 years, we are better placed to understand the complexities of our planet, particularly with respect to global change. Today's satellites are used to forecast the weather, answer important Earth-science questions, provide essential information to improve agricultural practices, maritime safety, help when disaster strikes, and all manner of everyday applications.

The need for information from satellites is growing at an ever-increasing rate. With ESA as world-leader in Earth observation, the Agency remains dedicated to developing cutting-edge spaceborne technology to further understand the planet, improve daily lives and support effect policy-making for a more sustainable future.

[Back to the homepage](#)

 <b>Aeolus</b> Wind mission From 2018	 <b>Biomass</b> Forest mission From 2020	 <b>Copernicus Sentinel-1</b> Radar vision 2014–present
 <b>Copernicus Sentinel-2</b> Colour vision 2015–present	 <b>Copernicus Sentinel-3</b> Bigger picture 2016–present	 <b>Copernicus Sentinel-4</b> European air monitoring From 2020

[http://www.esa.int/ESA/Our\\_Missions](http://www.esa.int/ESA/Our_Missions)

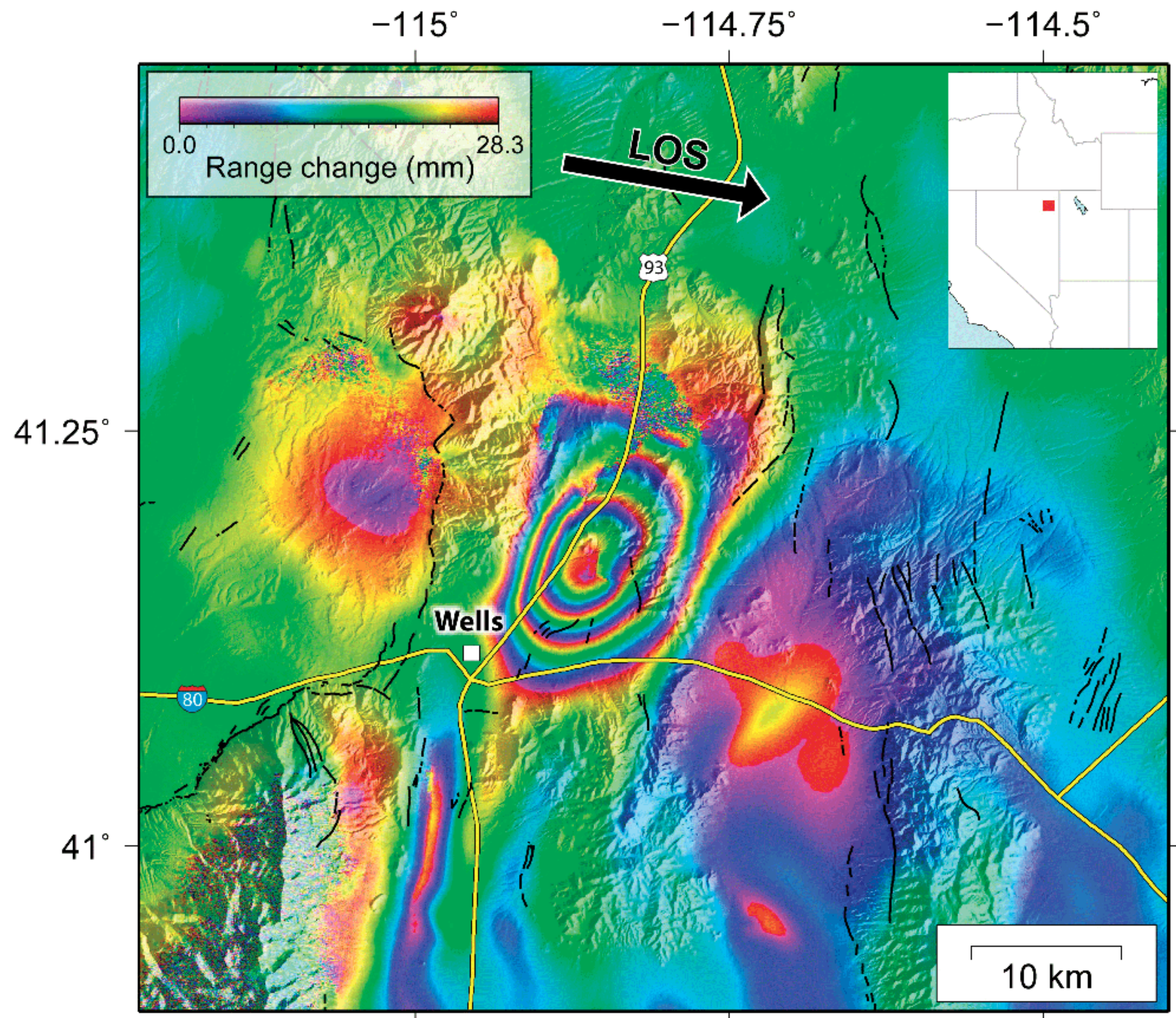
 <b>Copernicus Sentinel-5</b> Global air monitoring From 2021	 <b>Copernicus Sentinel-5P</b> Global air monitoring 2017 (to be launched)	 <b>Copernicus Sentinel-6</b> Surfing the seas From 2020
 <b>CryoSat</b> Ice mission 2010–present	 <b>EarthCARE</b> Cloud and aerosol mission From 2019	 <b>Envisat</b> Environmental monitoring 2002–12
 <b>ERS</b> European Remote Sensing 1991–2011	 <b>FLEX</b> Fluorescence mission From 2022	 <b>GOCE</b> Gravity mission 2009–13
 <b>Meteosat series</b> Weather satellites 1977–2017	 <b>MetOp series</b> Weather satellites 2006–present	 <b>MetOp-SG series</b> Weather satellites From 2021
 <b>MSG series</b> Weather satellites 2002–present	 <b>MTG series</b> Weather satellites From 2021	 <b>Proba-1</b> Technology demonstrator 2001–present
 <b>Proba-V</b> Vegetation monitoring 2013–present	 <b>SMOS</b> Water mission 2009–present	 <b>Swarm</b> Magnetic field mission 2013–present

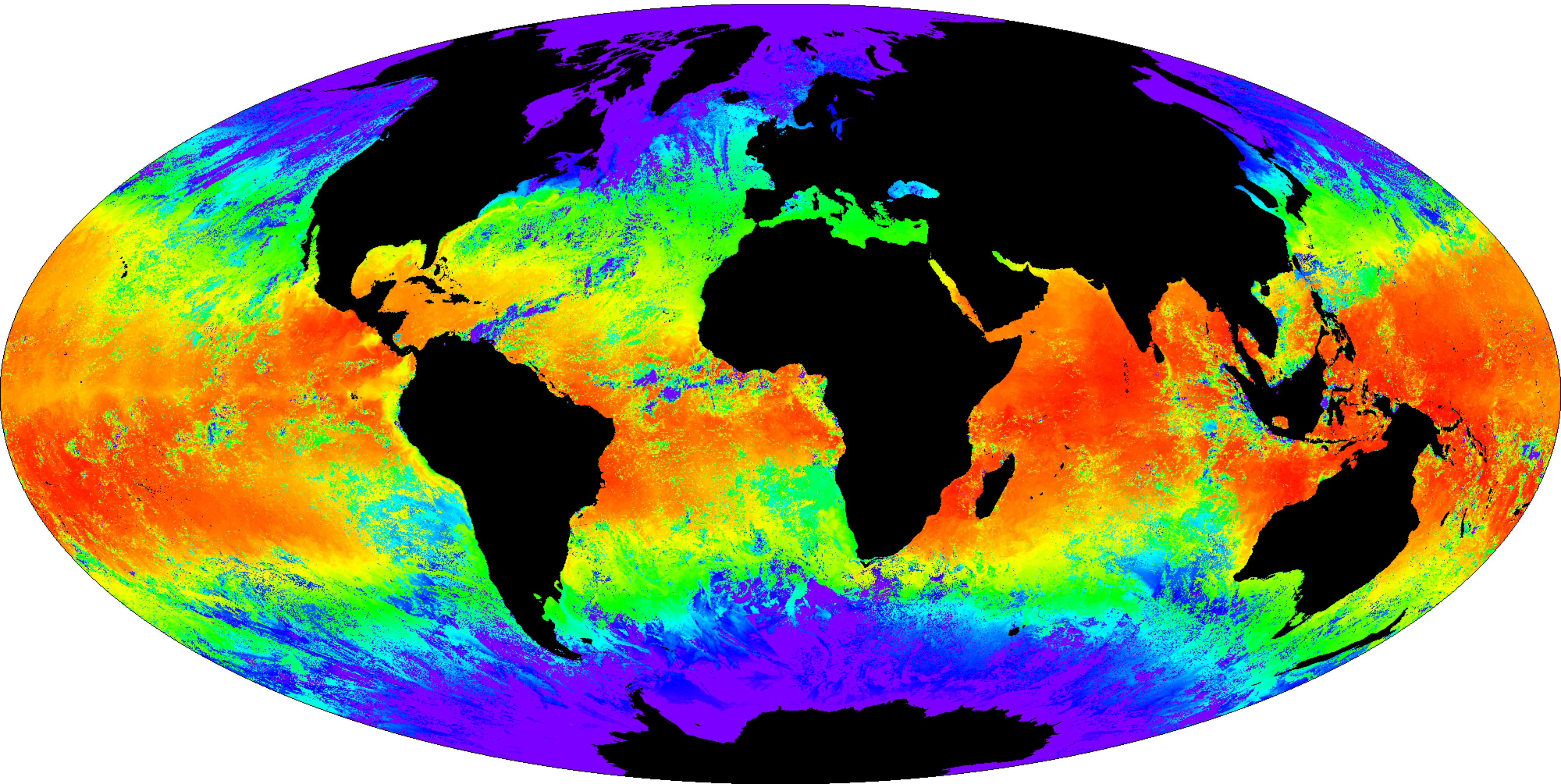


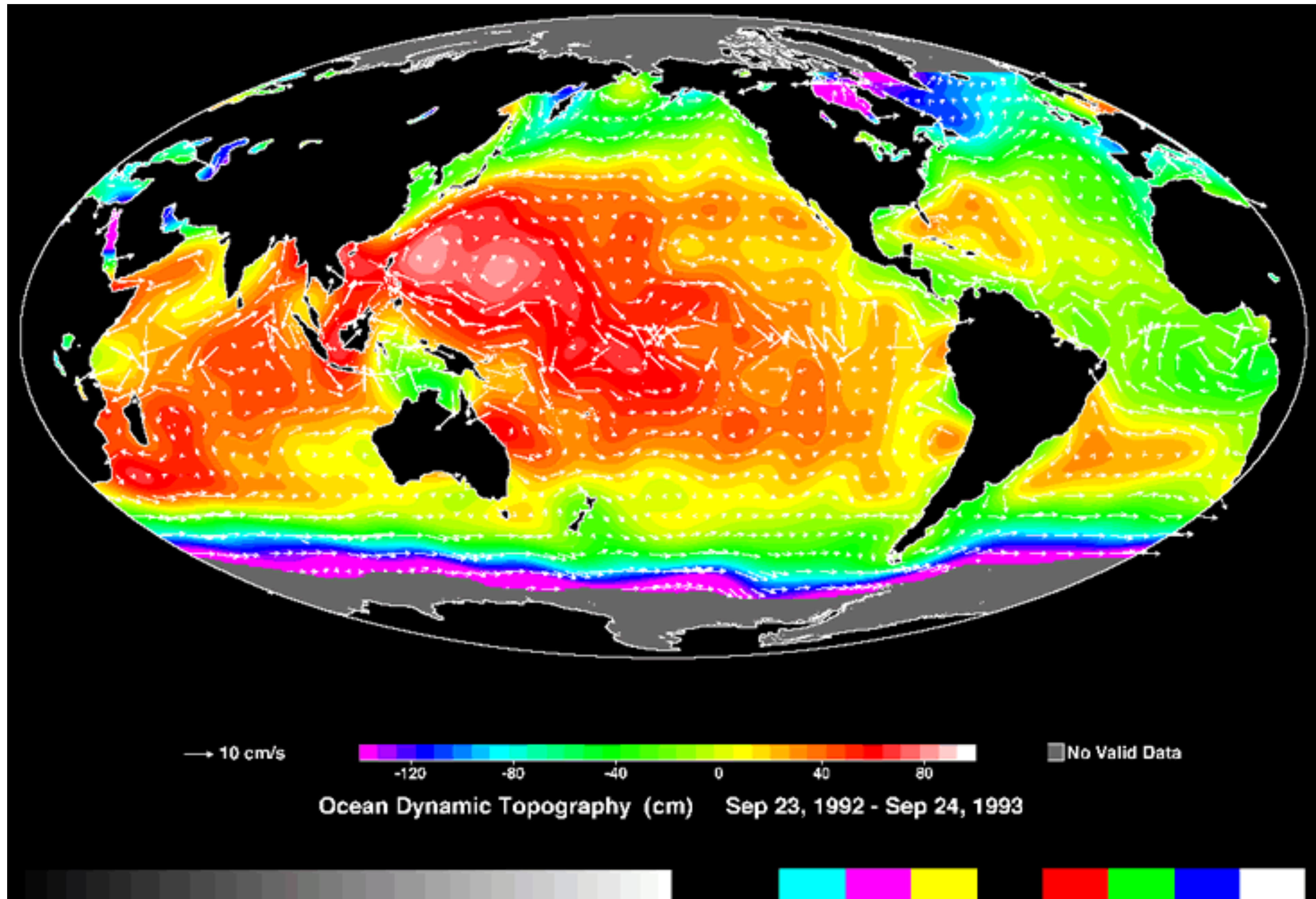


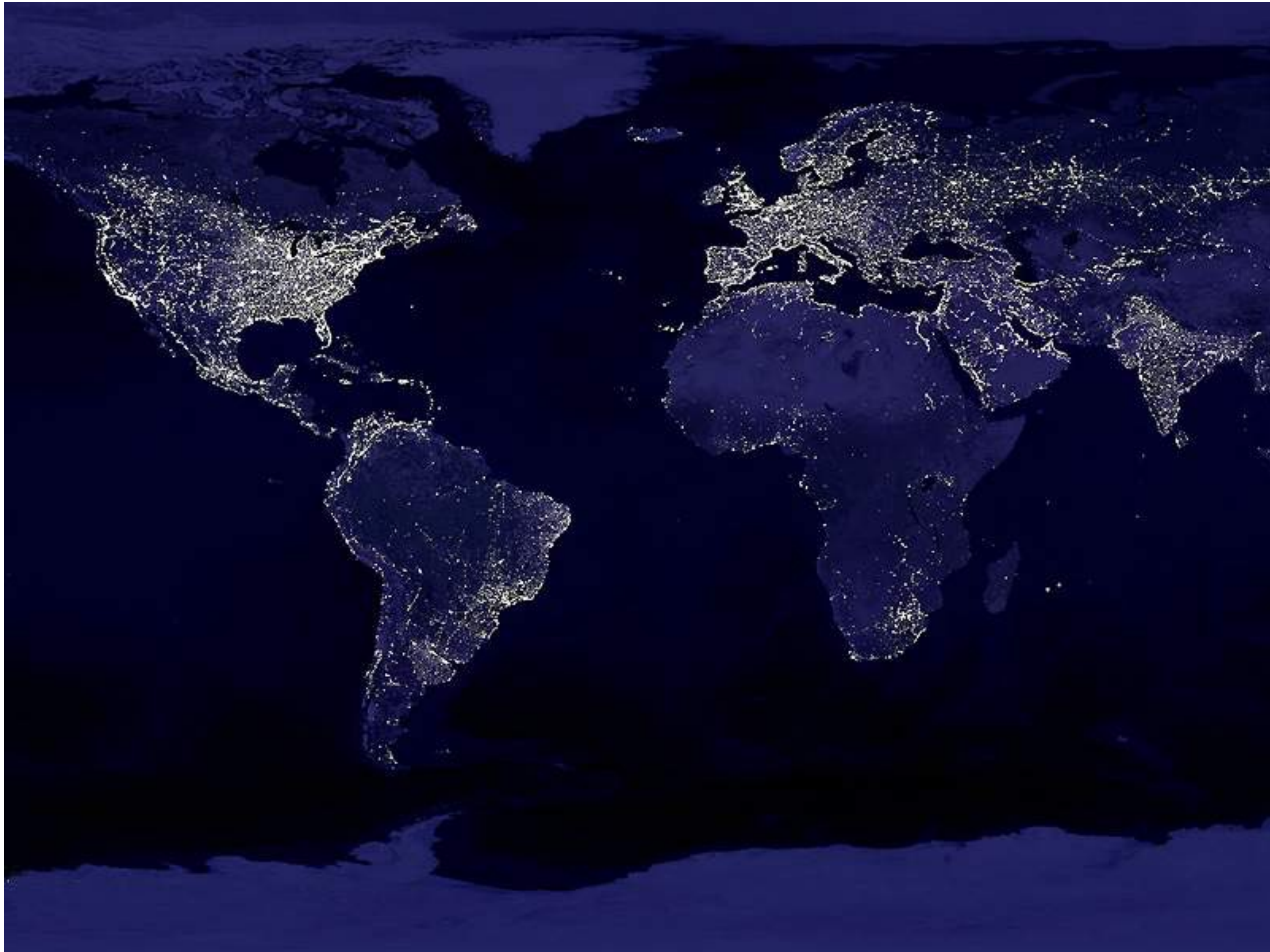


Satellite imagery shows Category 4 Hurricane Irma approach the Bahamas, followed by Hurricane Jose approaching the Leeward Islands. Hurricane Katia spins in the southwestern Gulf of Mexico.









# Observing Systems for a Dynamic Planet

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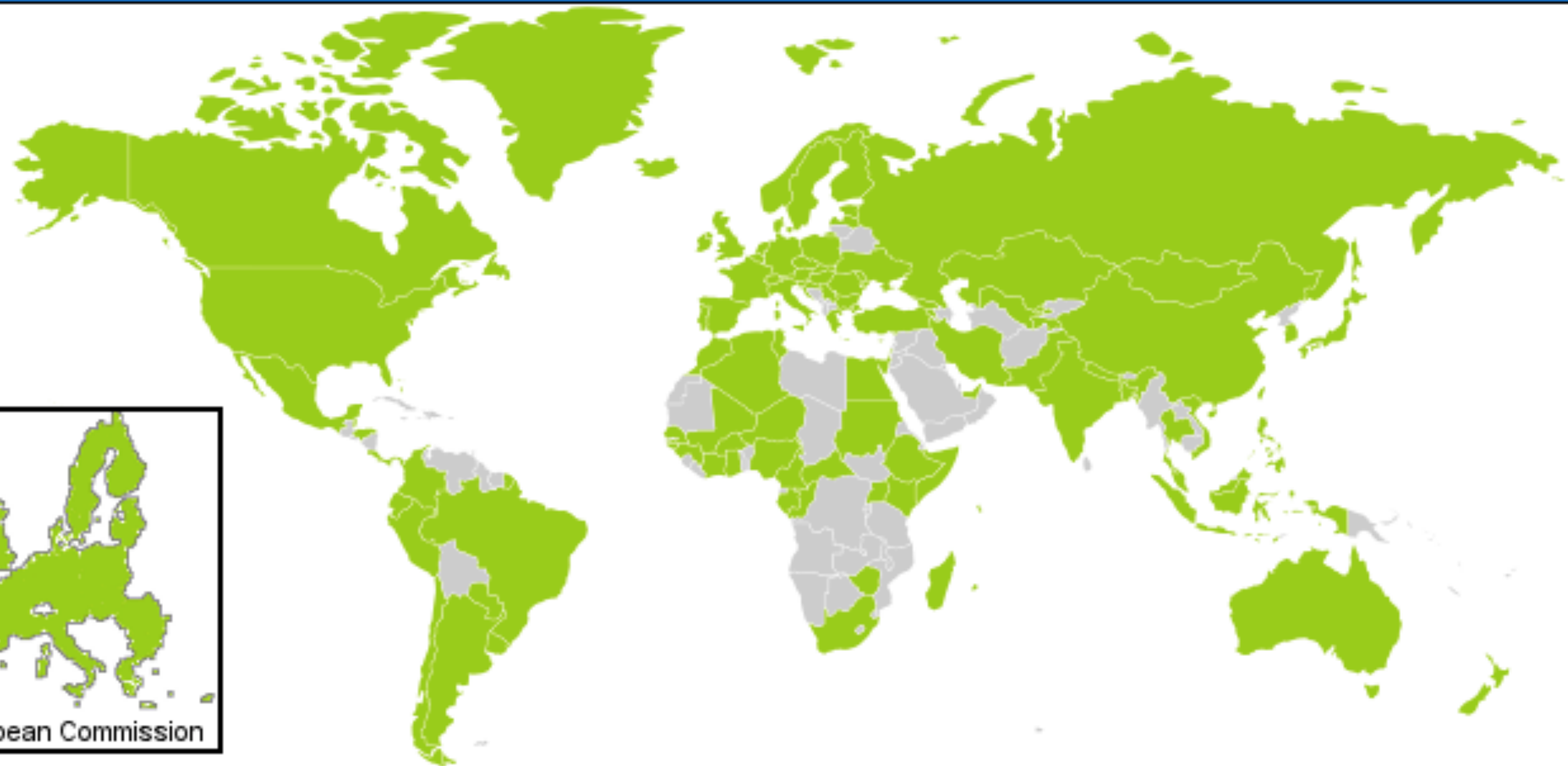
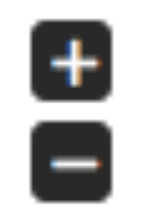
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[Member map](#) [Member list](#) [Member charts](#)

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## Member Country info



Click on a country to view it's information

# Observing Systems for a Dynamic Planet

## THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS



search our site here

resources ▾ how to get involved contact

Member Country info

---



# Observing Systems for a Dynamic Planet

## THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS



## Observation types:

### (1) Sensor-based:

- In situ: observations of ambient conditions (e.g., thermometer)
- Remote sensing: Using a signal to sense something in the distance (e.g., radar)

### (2) Sample-based:

- in situ
- in laboratory
- counting, assessing

## Observation Mode:

- on the Earth surface (fixed and moving);
- satellite-borne
- dedicated air-borne, ship-borne
- opportunity (ships, airplanes, ...)
- balloons, robots, drones (within atmosphere, ocean, ...)
- citizen scientists
- Big Data

# Natural Hazards and Disasters



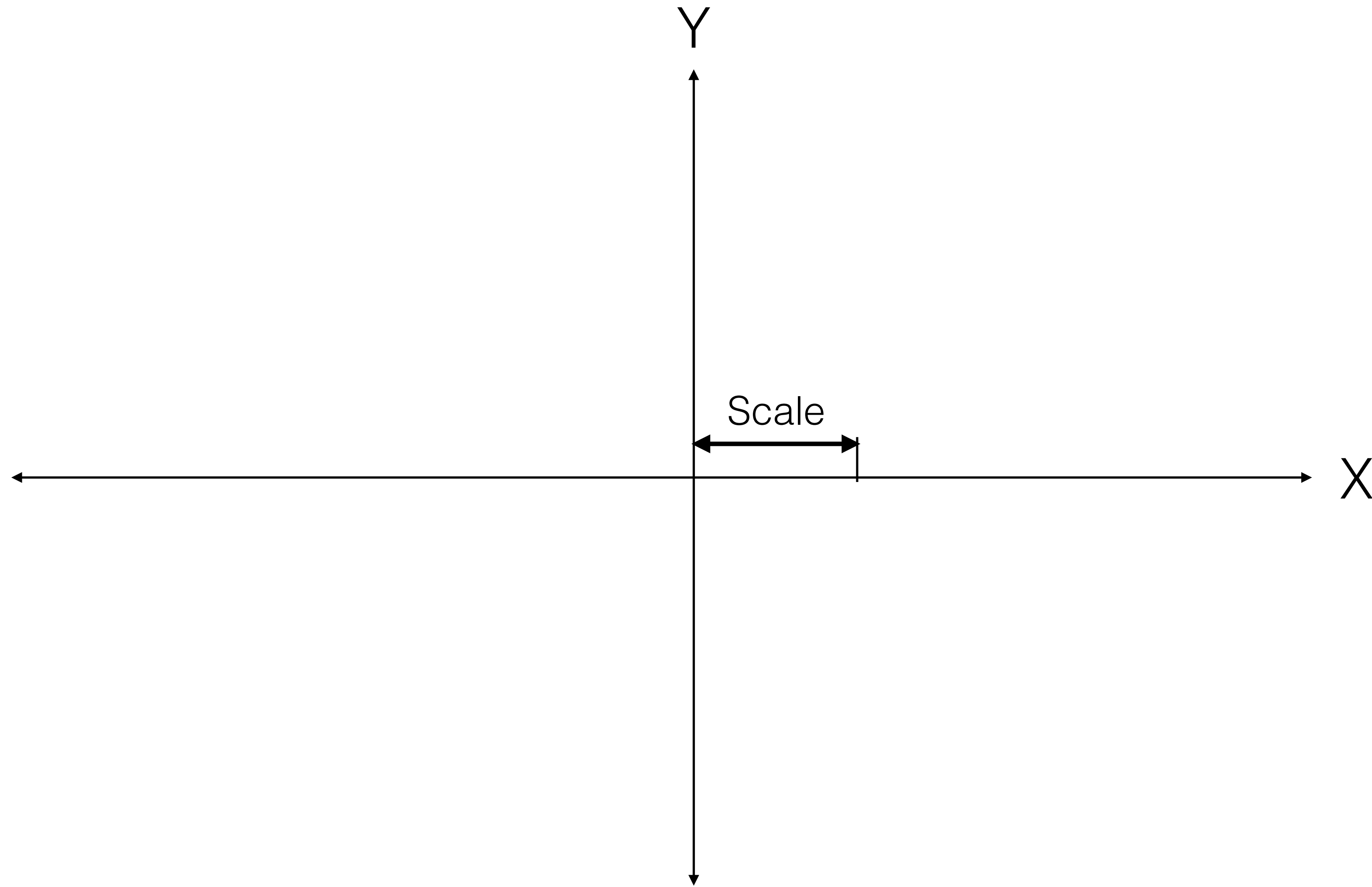
## Class 2: Observing Hazards and Disasters

- A dynamic Planet
- Observing Systems for a Dynamic Planet
- Reference Systems and Frames
- Monitoring Small Changes



Measuring position and motion requires a coordinate system:

Measuring position and motion requires a coordinate system:



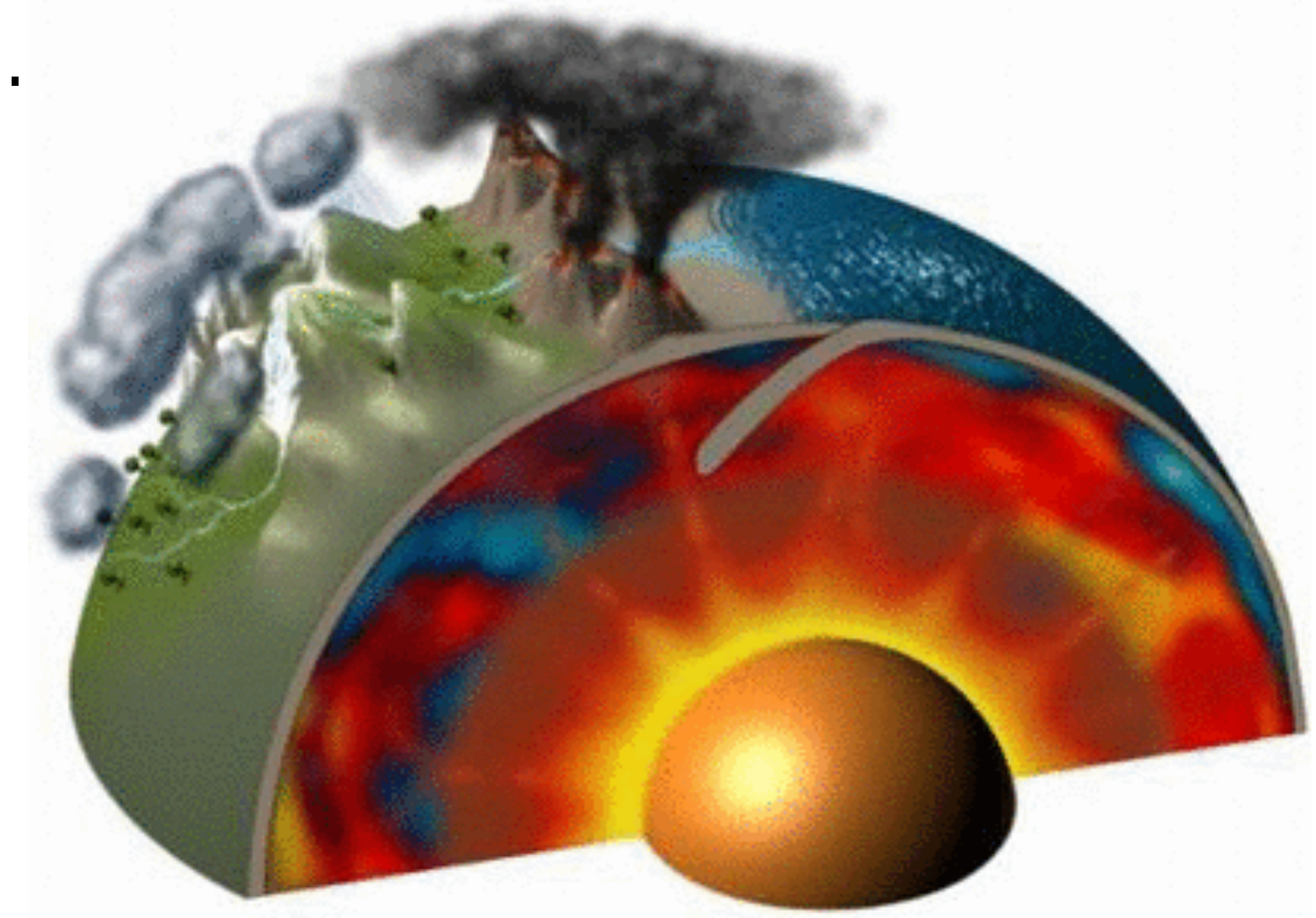


Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.



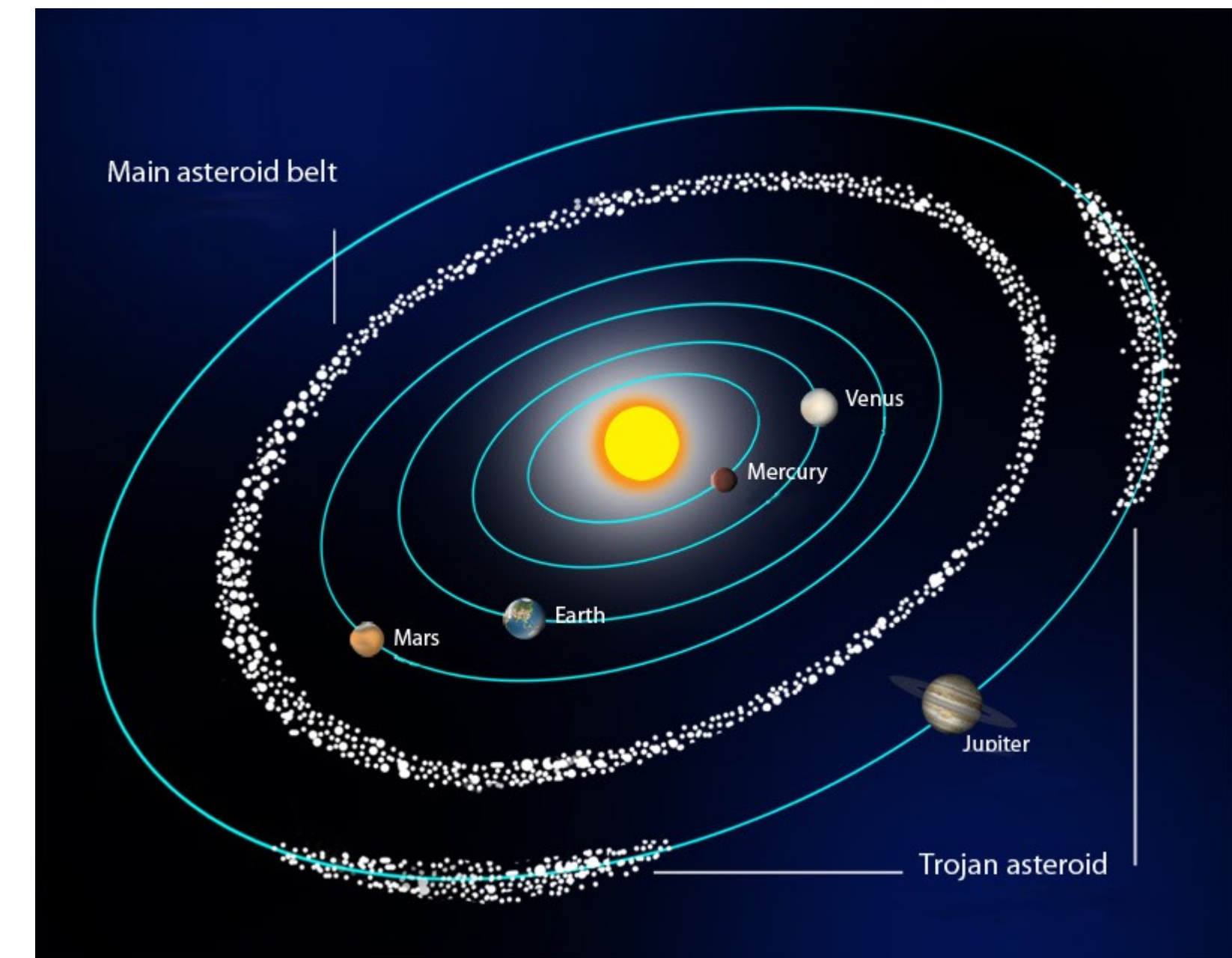
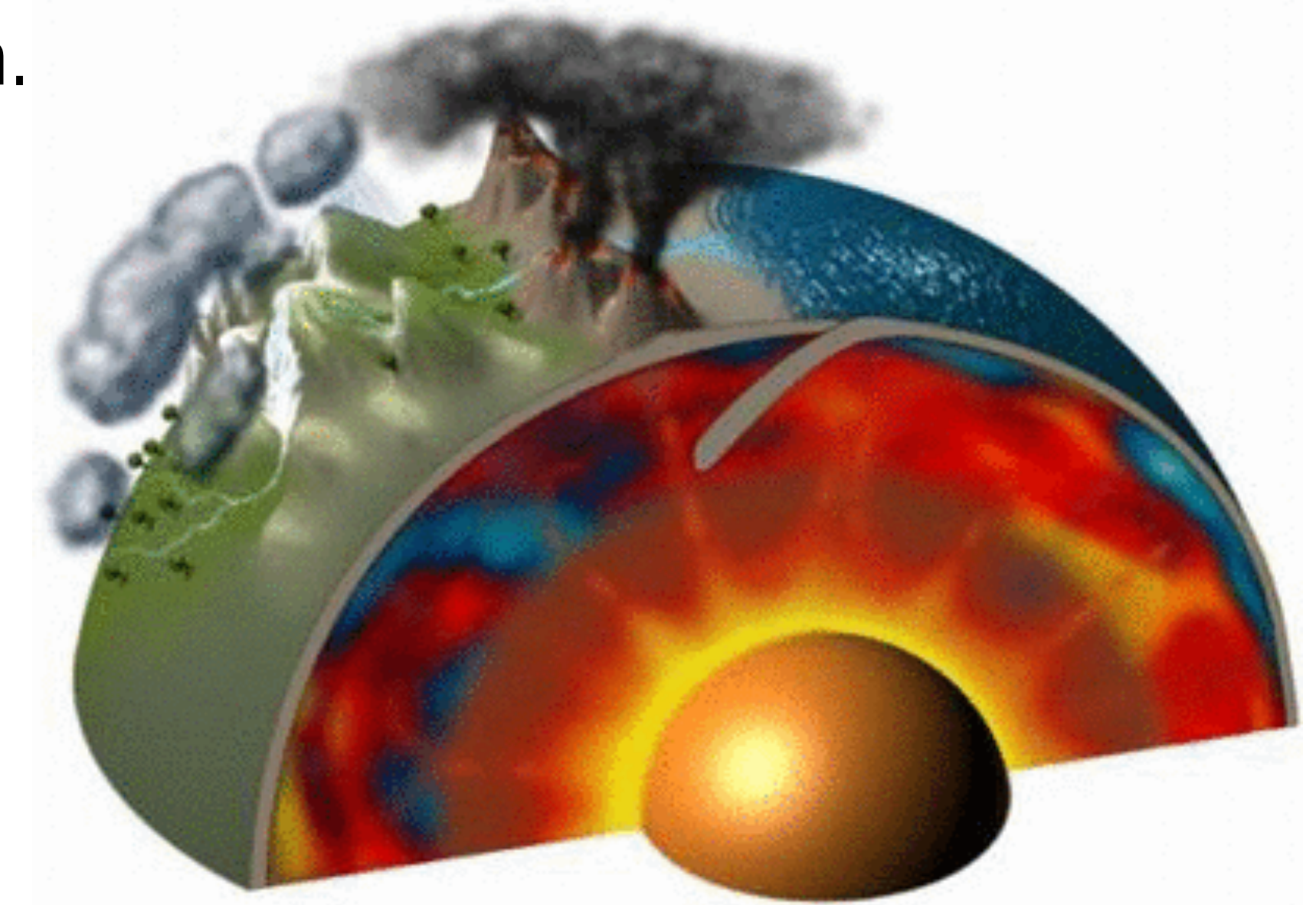
# Reference Systems and Reference Frames

Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.



# Reference Systems and Reference Frames

Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.

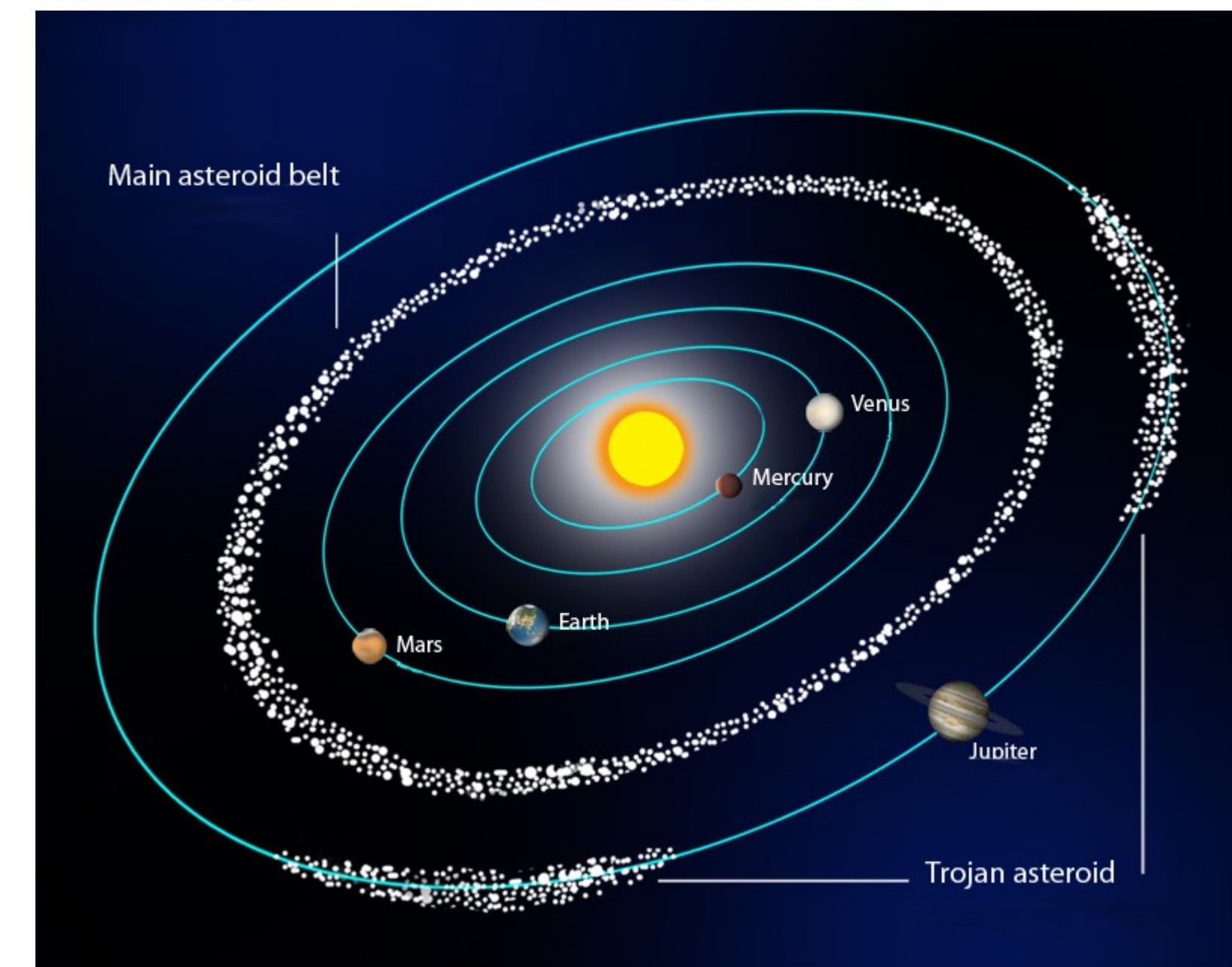
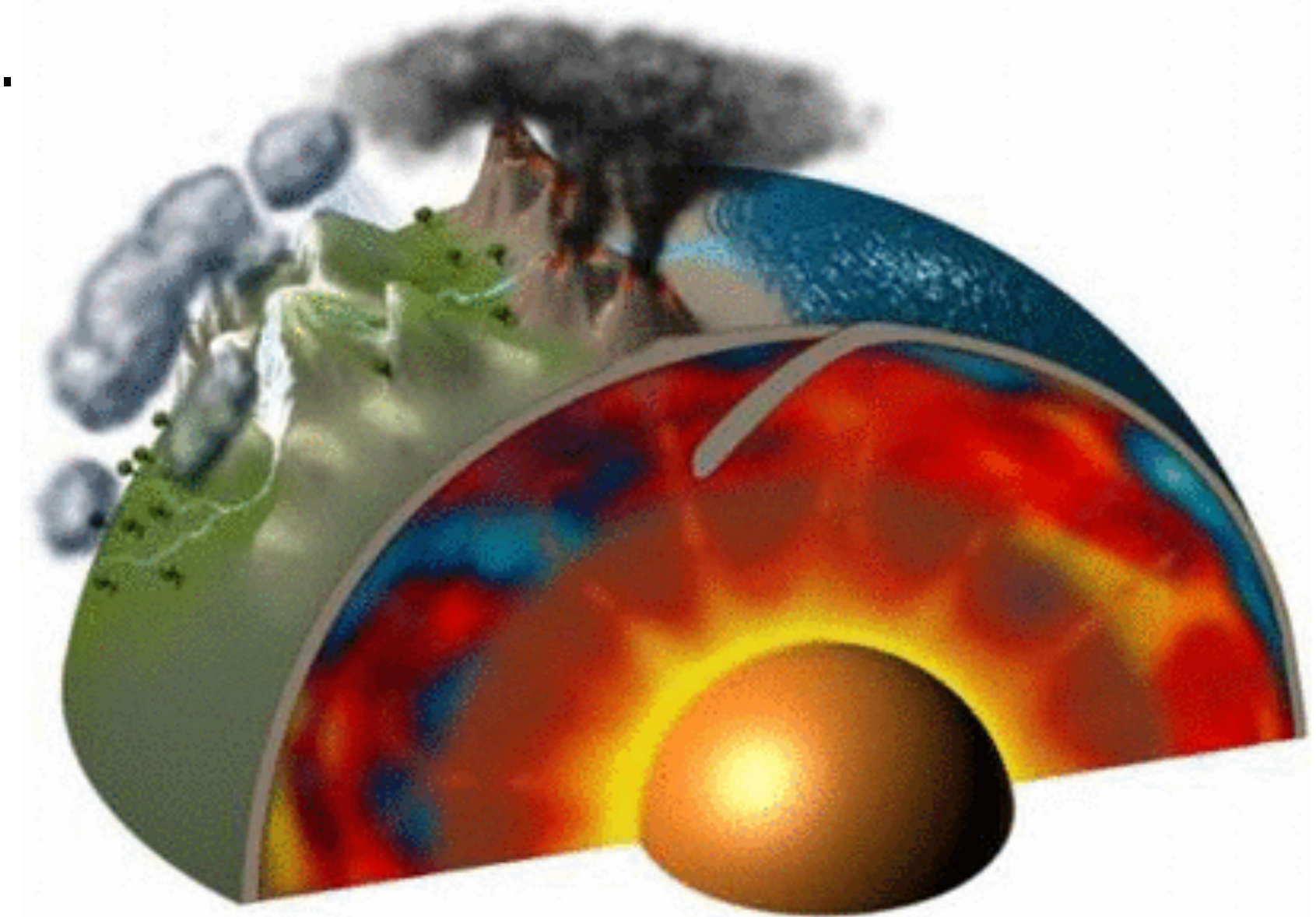


# Reference Systems and Reference Frames

Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.

For this purpose, two reference systems are intrinsic in geodesy:

- International Celestial Reference System (ICRS)
  - International Terrestrial Reference System (ITRS)
- and these are connected through Earth Rotation.



# Reference Systems and Reference Frames

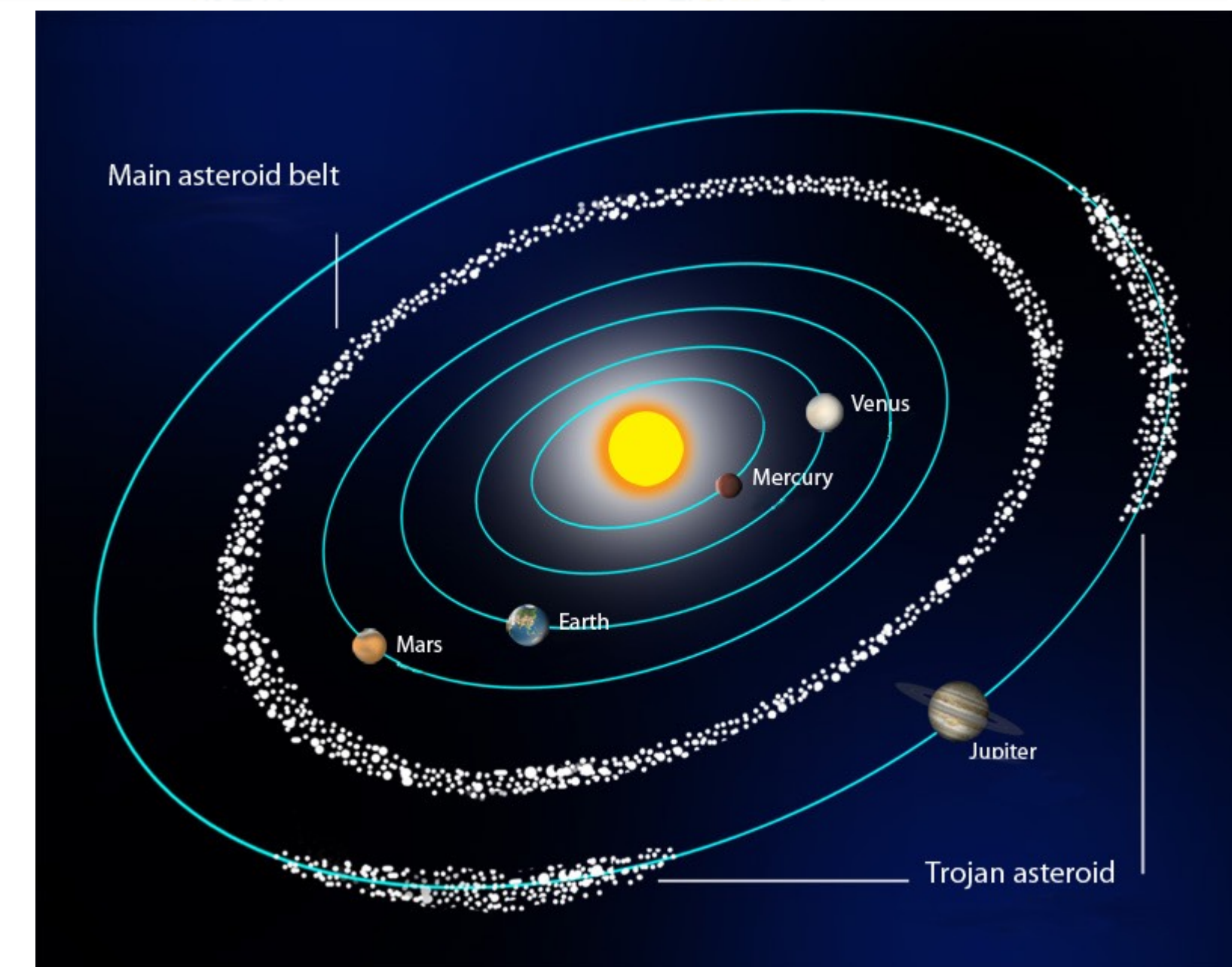
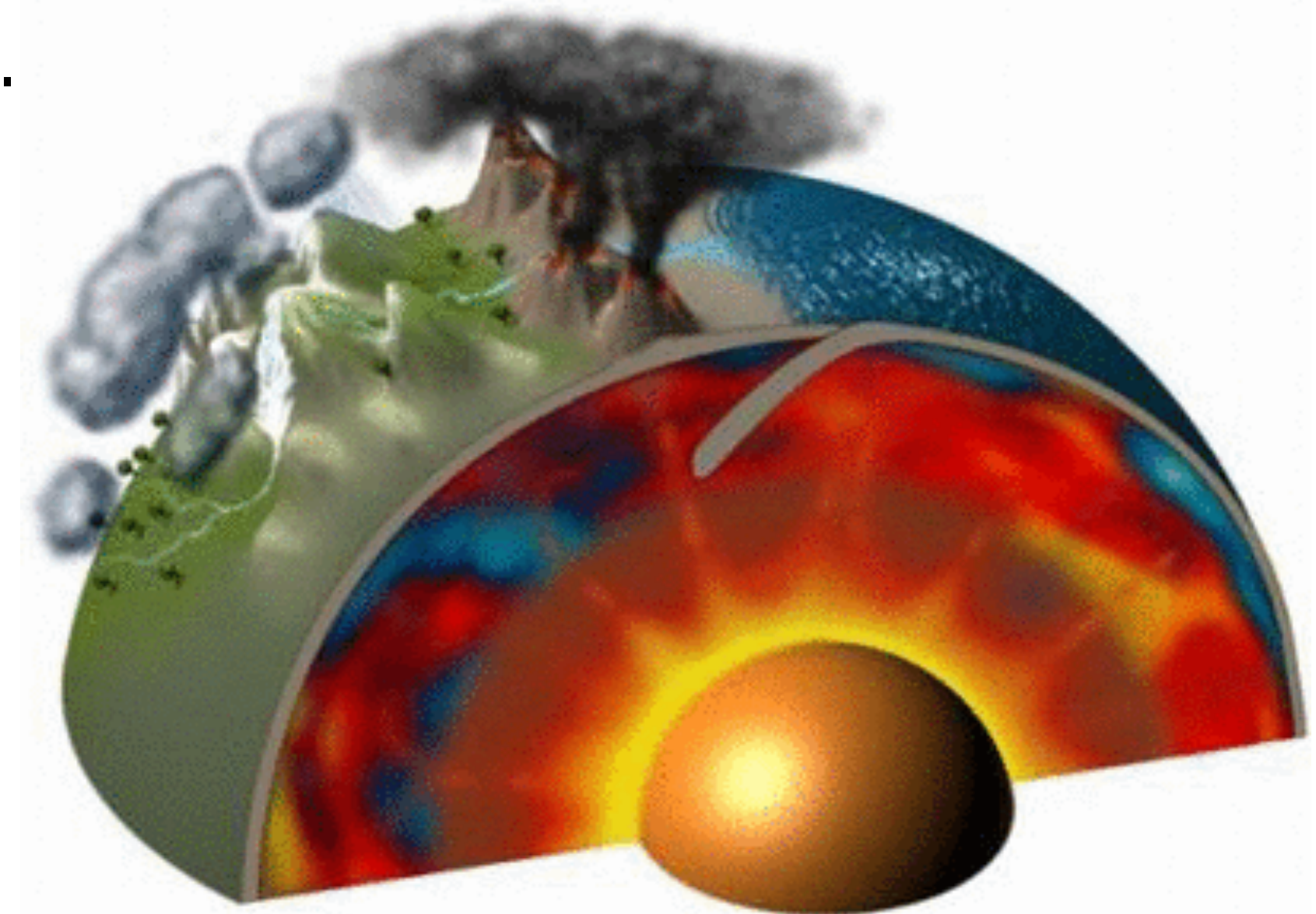
Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.

For this purpose, two reference systems are intrinsic in geodesy:

- International Celestial Reference System (ICRS)
  - International Terrestrial Reference System (ITRS)
- and these are connected through Earth Rotation.

The two reference systems are realized through reference frames:

- International Celestial Reference Frame (ICRF)
  - International Terrestrial Reference Frame (ITRF)
- and the connections is provided by the
- Earth Orientation Parameters (EOPs).



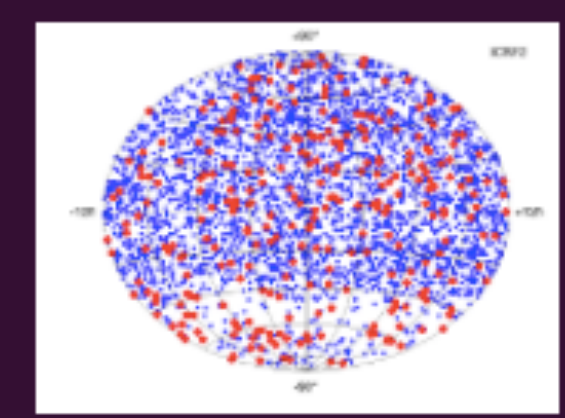
# Reference Systems and Reference Frames



This pages provide data of successives realizations of the International Celestial Reference Frame (ICRF) by VLBI. Please, refer to the article (link to ADS) or to the ReadMe files for more informations on each realization.

## ICRF2

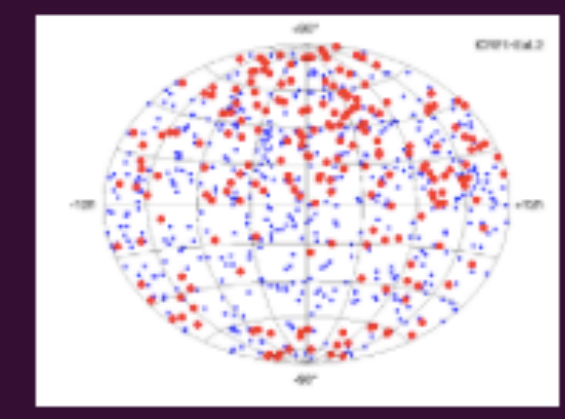
Data (.txt) [Fey et al. \(2015\) \(link to ADS\)](#) [ReadMe](#)



3,414 objects

## ICRF1 Extension 2

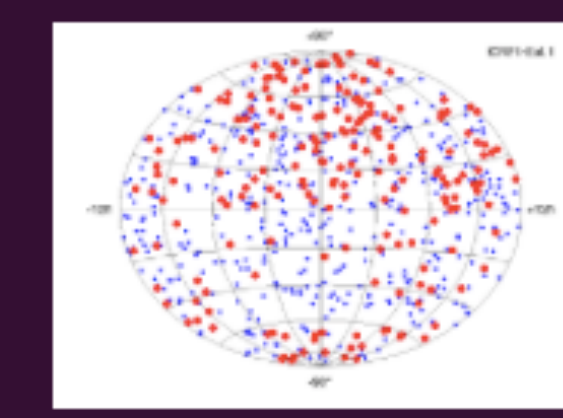
Data (.txt) [Fey et al. \(2004\) \(link to ADS\)](#) [ReadMe](#)



717 objects

## ICRF1 Extension 1

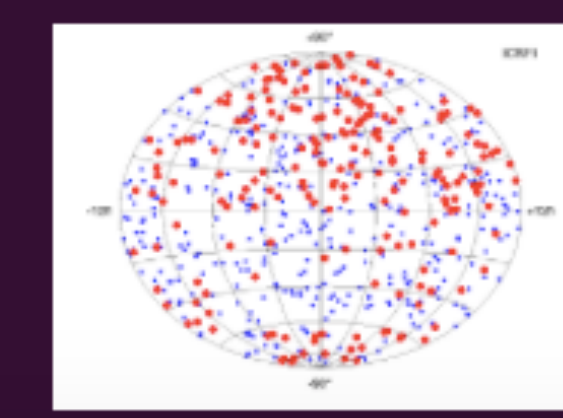
Data (.txt) [Gontier et al. \(2002\) \(link to ADS\)](#) [ReadMe](#)



667 objects

## ICRF1

Data (.txt) [Ma et al. \(1998\) \(link to ADS\)](#) [ReadMe](#)



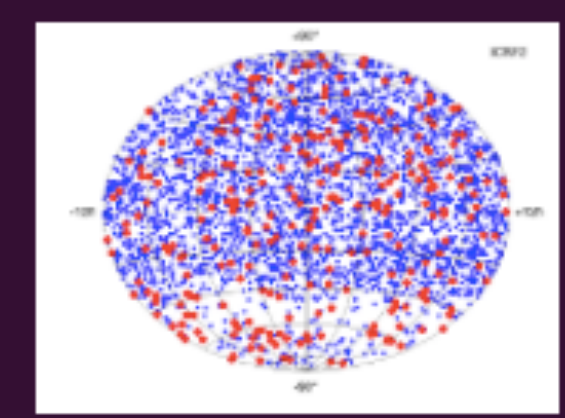
608 objects



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## ICRF2

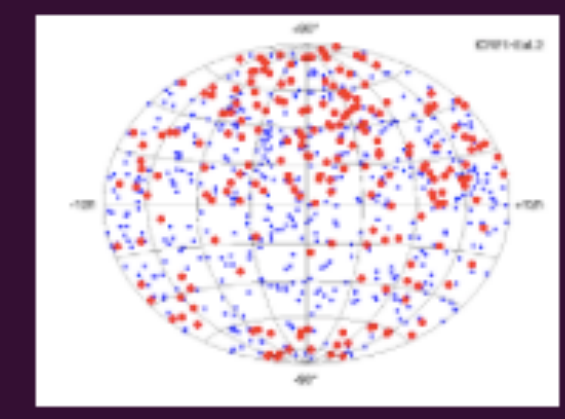
Data (.txt)    Fey et al. (2015) (link to ADS)    ReadMe



3,414 objects

## ICRF1 Extension 2

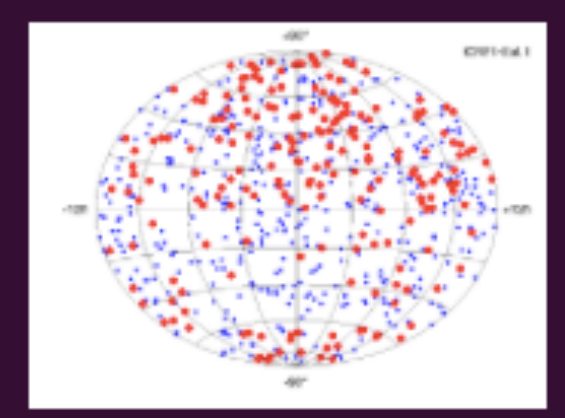
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717 objects

## ICRF1 Extension 1

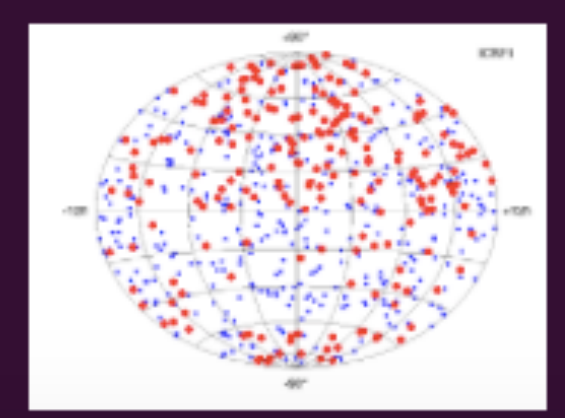
Data (.txt)    Gontier et al. (2002) (link to ADS)    ReadMe



667 objects

## ICRF1

Data (.txt)    Ma et al. (1998) (link to ADS)    ReadMe



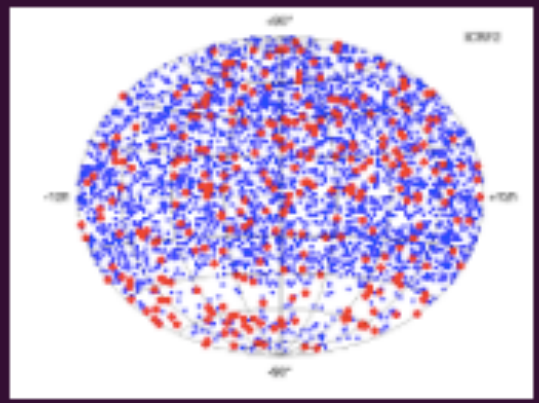
608 objects



This pages provide data of successives realizations of the International Celestial Reference Frame (ICRF) by VLBI. Please, refer to the ReadMe files for more informations on each realization.

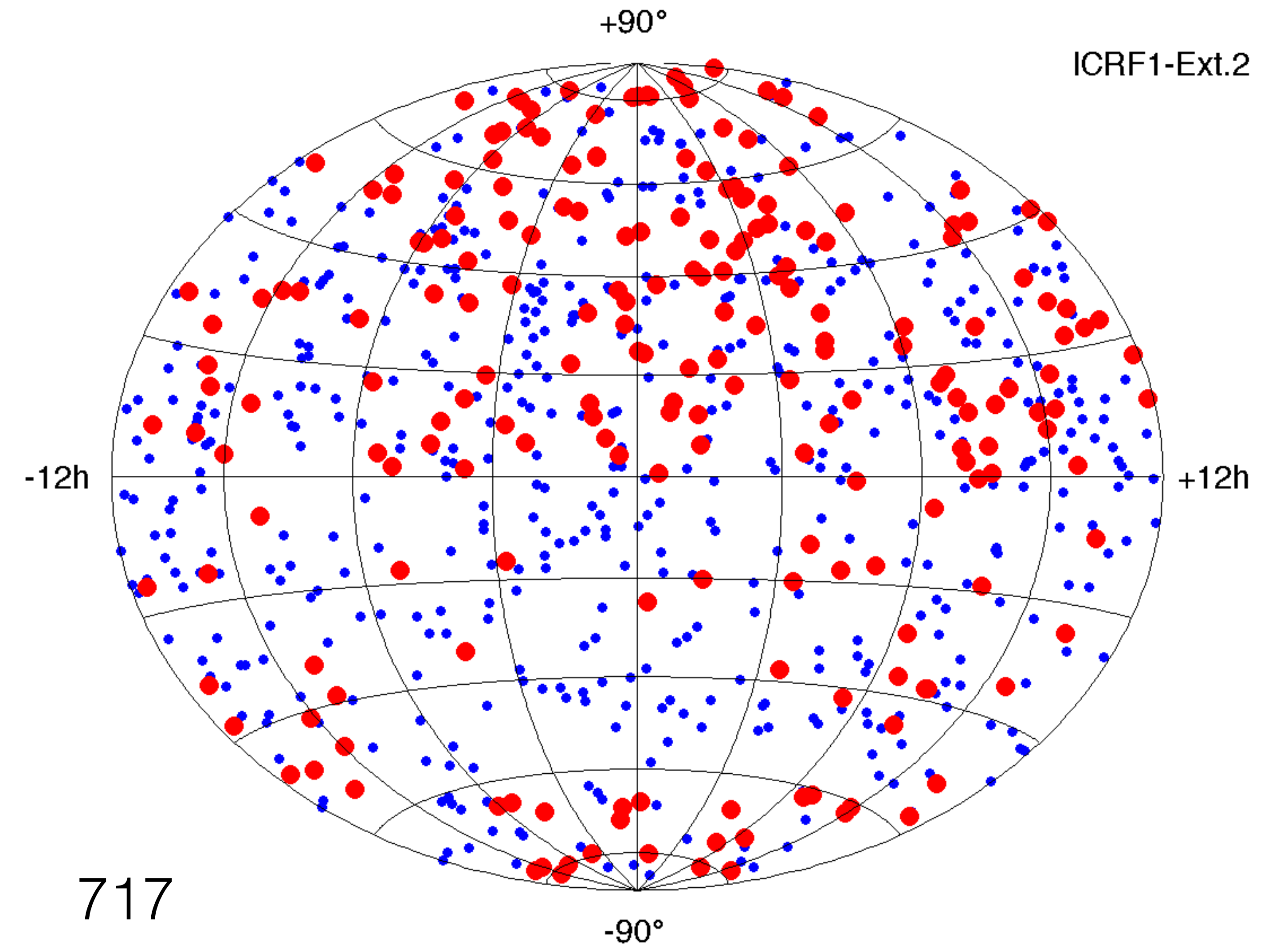
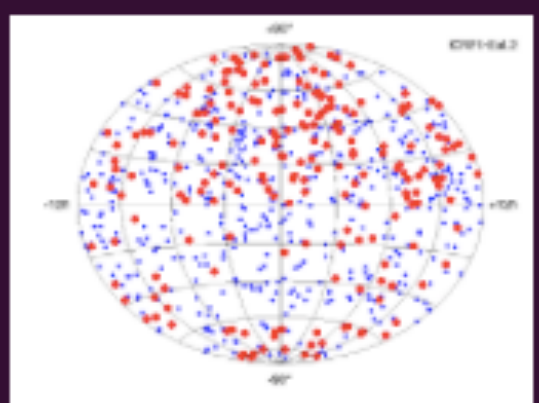
## ICRF2

Data (.txt)    Fey et al. (2015) (link to ADS)    ReadMe



## ICRF1 Extension 2

Data (.txt)    Fey et al. (2004) (link to ADS)    ReadMe



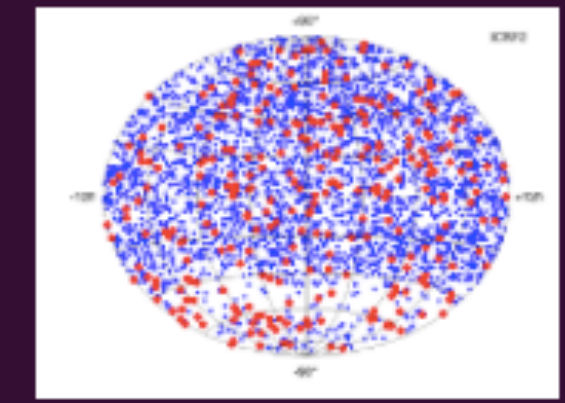
# Reference Systems and Reference Frames



This pages provide data of successives realizations of the International Celestial Reference Frame (ICRF) by VLBI. Please, refer to the ReadMe files for more informations on each realization.

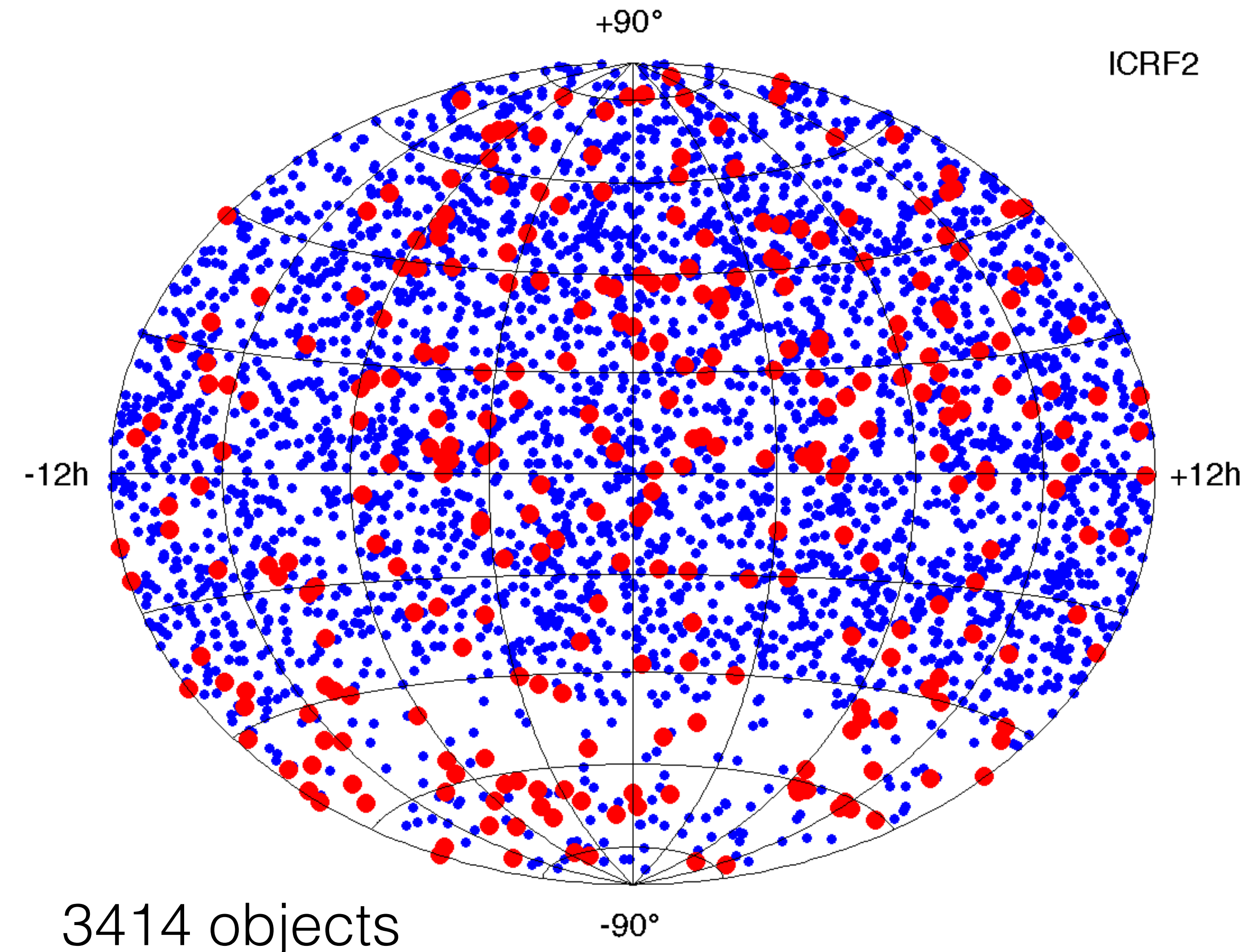
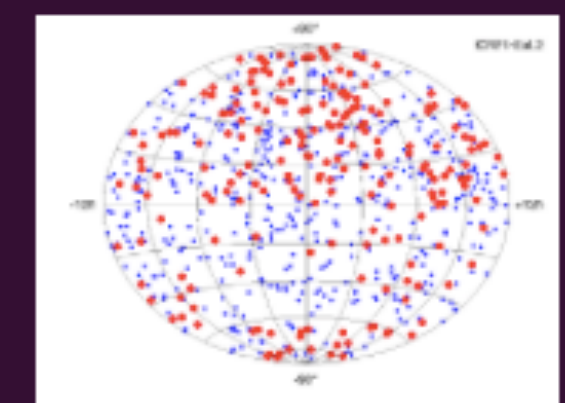
## ICRF2

Data (.txt) Fey et al. (2015) (link to ADS) ReadMe



## ICRF1 Extension 2

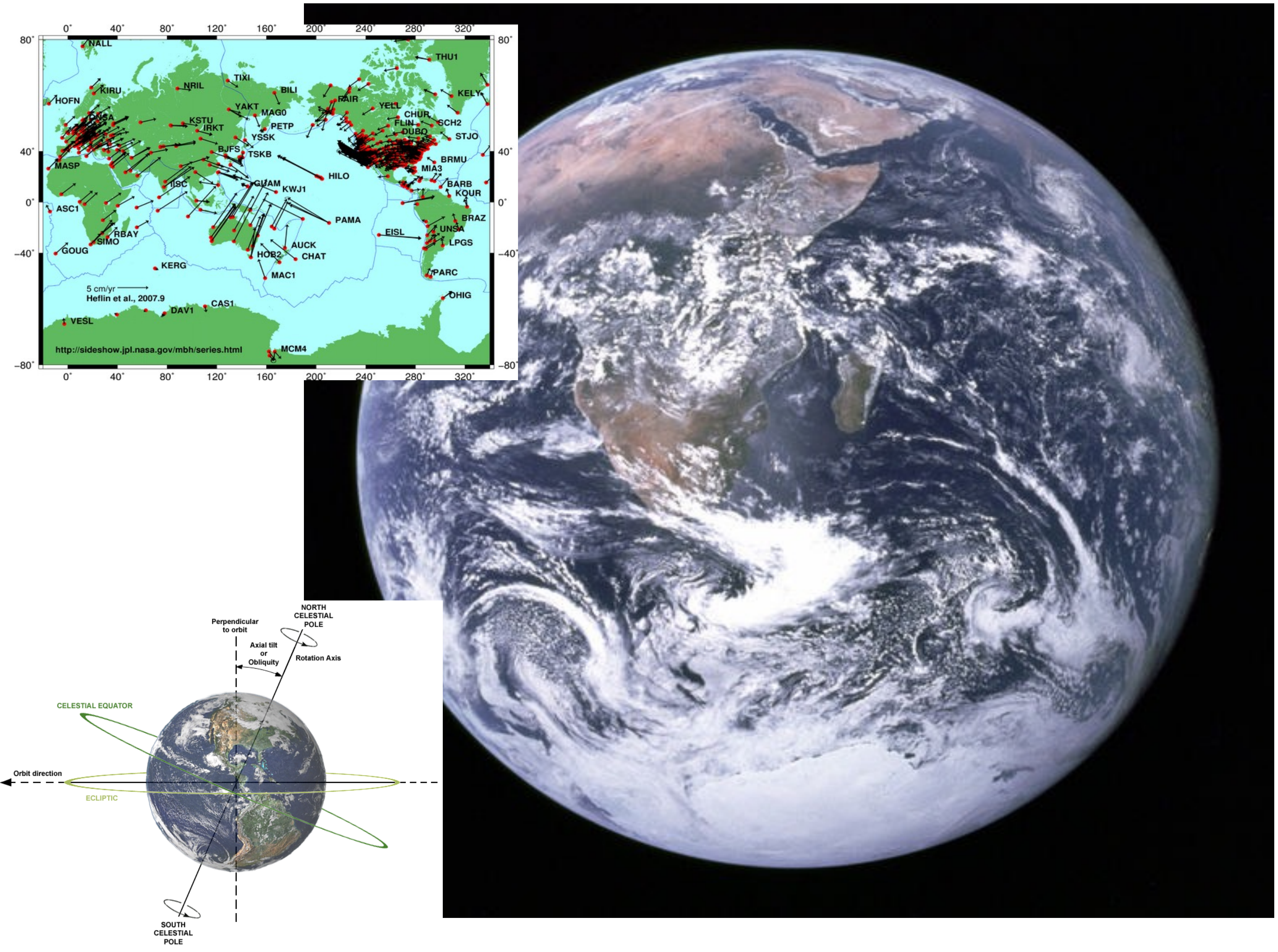
Data (.txt) Fey et al. (2004) (link to ADS) ReadMe





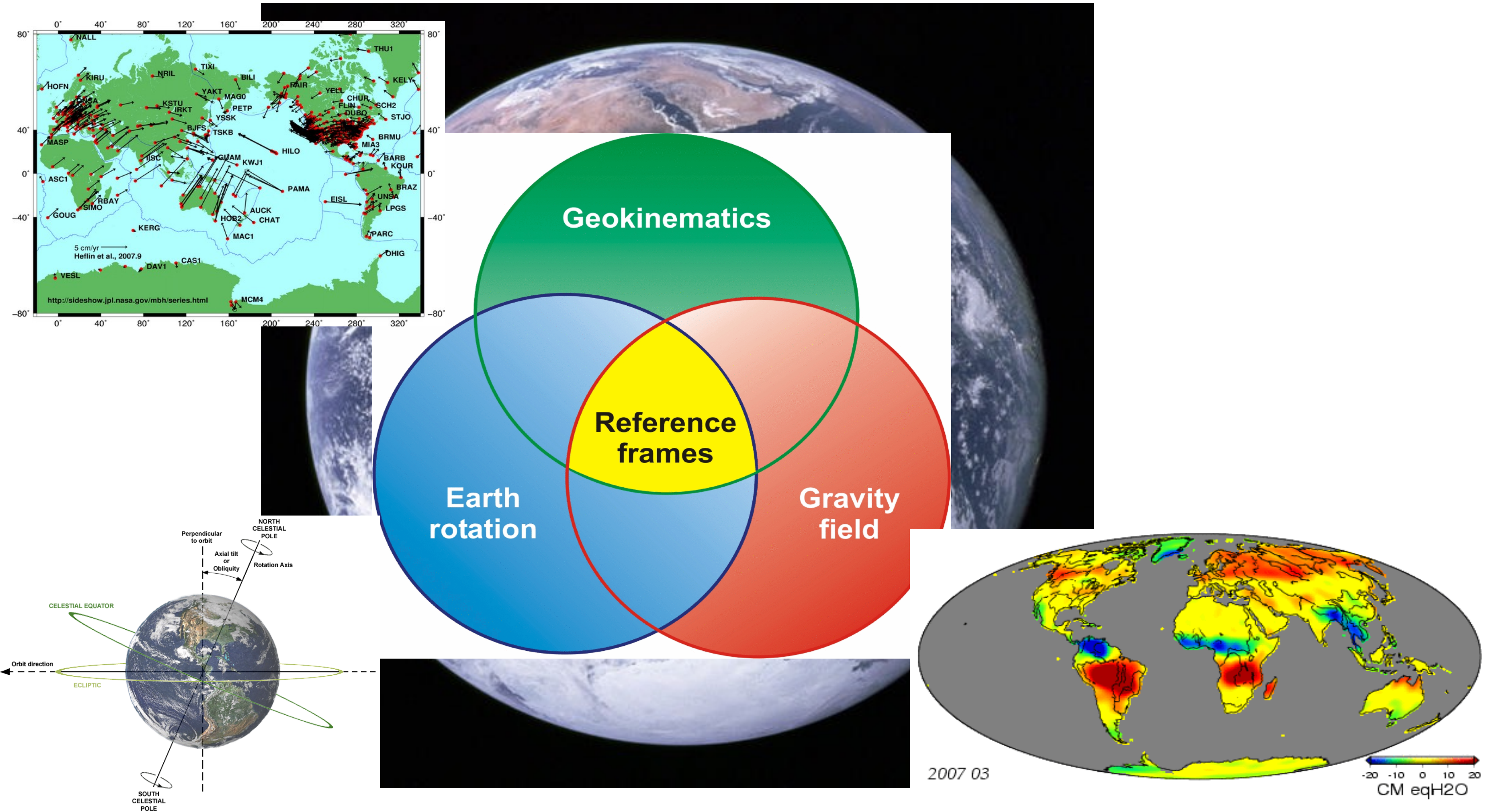
# Reference Systems and Reference Frames

Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.



# Reference Systems and Reference Frames

Assigning coordinates to points and objects on Earth, and to describe Earth's motion in space, we need to measure Earth's shape, gravity field, and rotation.



# Reference Systems and Reference Frames

Component	Objective	Techniques	Responsibility
<b>I. Geokinematics</b> (size, shape, kinematics, deformation)	<i>Shape and temporal variations of land/ice/ocean surface (plates, intra-plates, volcanoes, earthquakes, glaciers, ocean variability, sea level)</i>	<i>Altimetry, InSAR, GNSS-cluster, VLBI, SLR, DORIS, imaging techniques, leveling, tide gauges</i>	<i>International and national projects, space missions, IGS, IAS, future InSAR service</i>
<b>II. Earth Rotation</b> (nutation, precession, polar motion, variations in length-of-day)	<i>Integrated effect of changes in angular momentum and inertia tensor (mass changes in atmosphere, cryosphere, oceans, solid Earth, core/mantle; momentum exchange between Earth system components)</i>	<i>Classical astronomy, VLBI, LLR, SLR, GNSS, DORIS, under development: terrestrial gyroscopes</i>	<i>International geodetic and astronomical community (IERS, IGS, IVS, ILRS, IDS)</i>
<b>III. Gravity field</b>	<i>Geoid, Earth's static gravitational potential, temporal variations induced by solid Earth processes and mass transport in the global water cycle.</i>	<i>Terrestrial gravimetry (absolute and relative), airborne gravimetry, satellite orbits, dedicated satellite missions (CHAMP, GRACE, GOCE)</i>	<i>International geophysical and geodetic community (GGP, IGFS, BGI)</i>
<b>IV. Terrestrial Frame</b>	<i>Global cluster of fiducial point, determined at mm to cm level</i>	<i>VLBI, GNSS, SLR, LLR, DORIS, time keeping/transfer absolute gravimetry, gravity recording</i>	<i>International geodetic community (IERS with support of IVS, ILRS, IGS, and IDS)</i>

# Reference Systems and Reference Frames

**Navigation Tools**

ZOOM + ZOOM - CENTER - Zoom to continent -

OK SELECT SITES ? INFO SITES - Zoom to country -

**ITRF Network**

- ★ Four Techniques
- Three Techniques
- ▲ Two Techniques
- GPS Sites Only
- DORIS Sites Only
- SLR Sites Only
- VLBI Sites Only
- Other points

**Velocity Vector**

2005

- Horizontal
- Vertical
- uncertainty

**Tectonic Plates**

None

Latitude Longitude   GO

(Decimal degrees)

By default, all points are displayed

ITRF Solution:  05  00  97  96  94

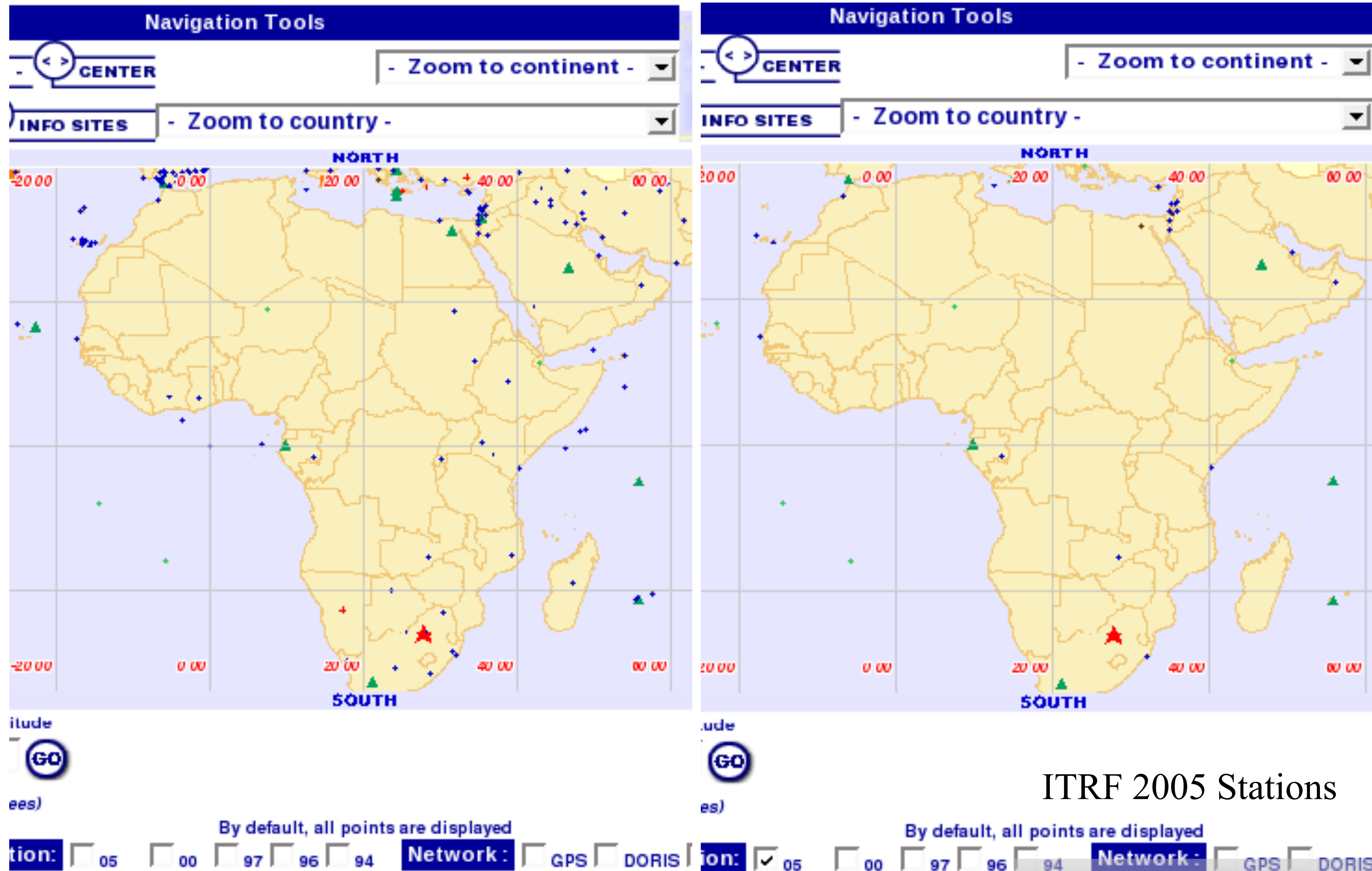
Network:  GPS  DORIS  SLR  VLBI

OK UPDATE

ITRF 2005 Stations

<http://itrf.ign.fr/GIS/>

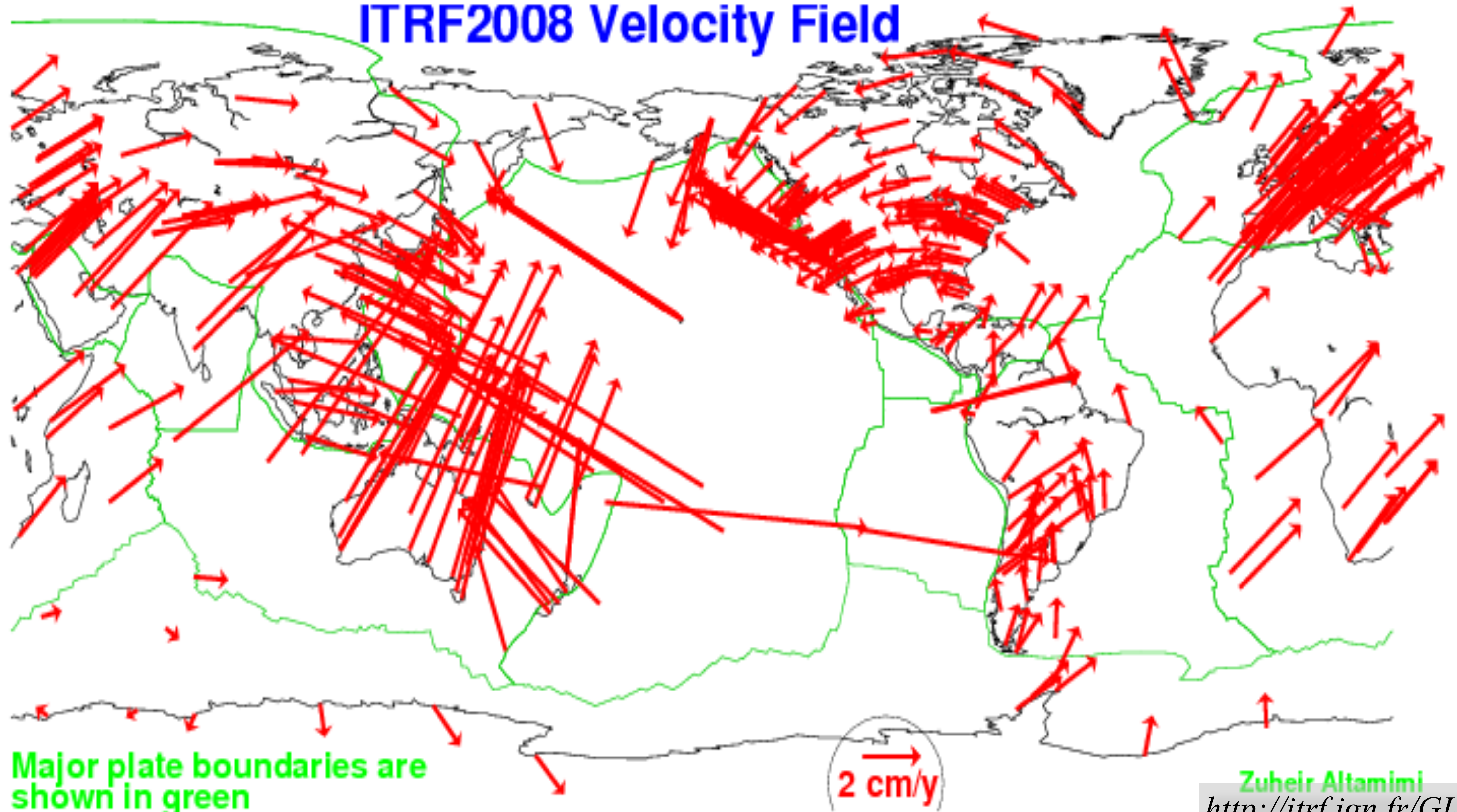
# Reference Systems and Reference Frames



ITRF 2005 Stations

<http://itrf.ign.fr/GIS/>

## ITRF2008 Velocity Field

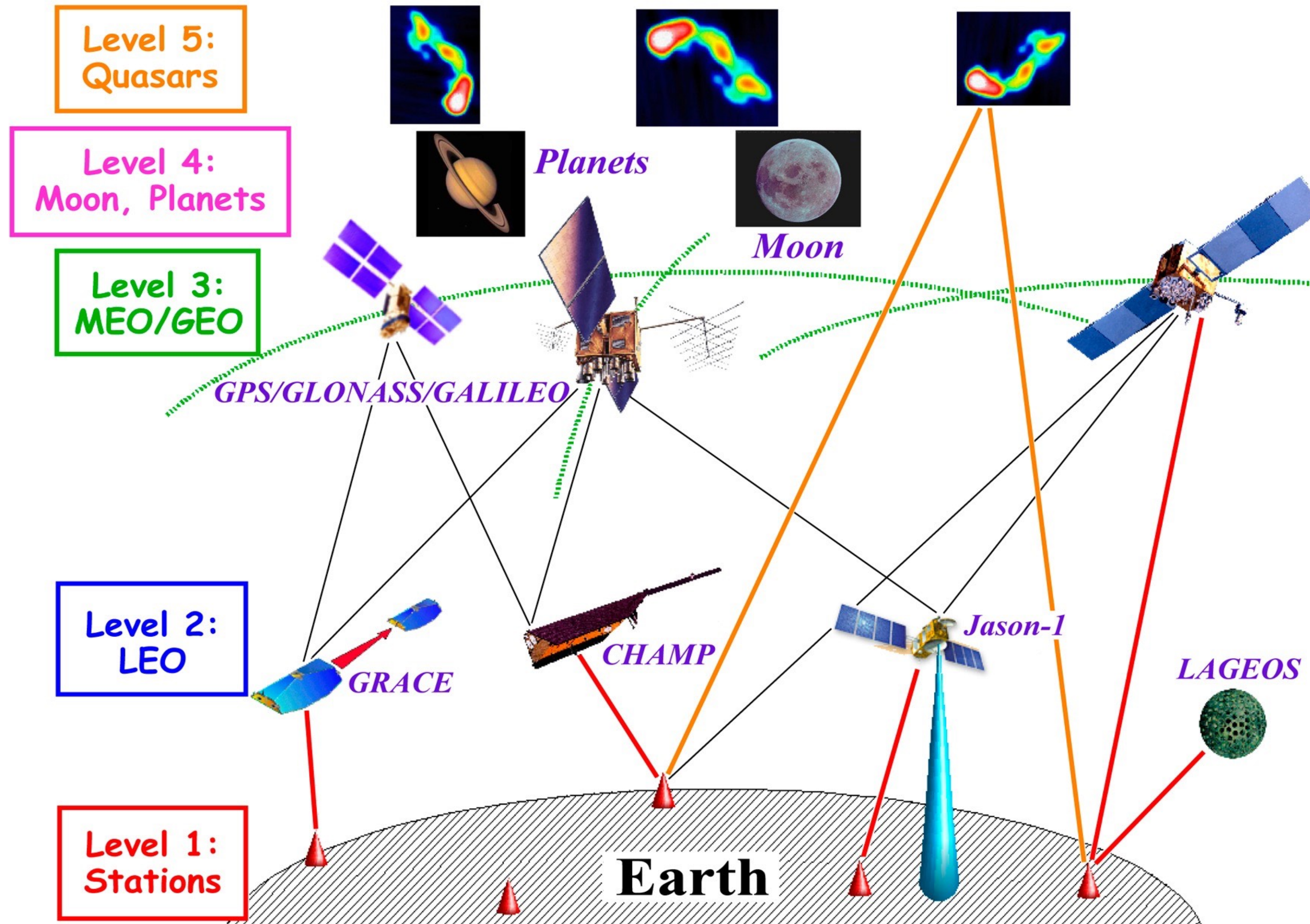


Major plate boundaries are shown in green

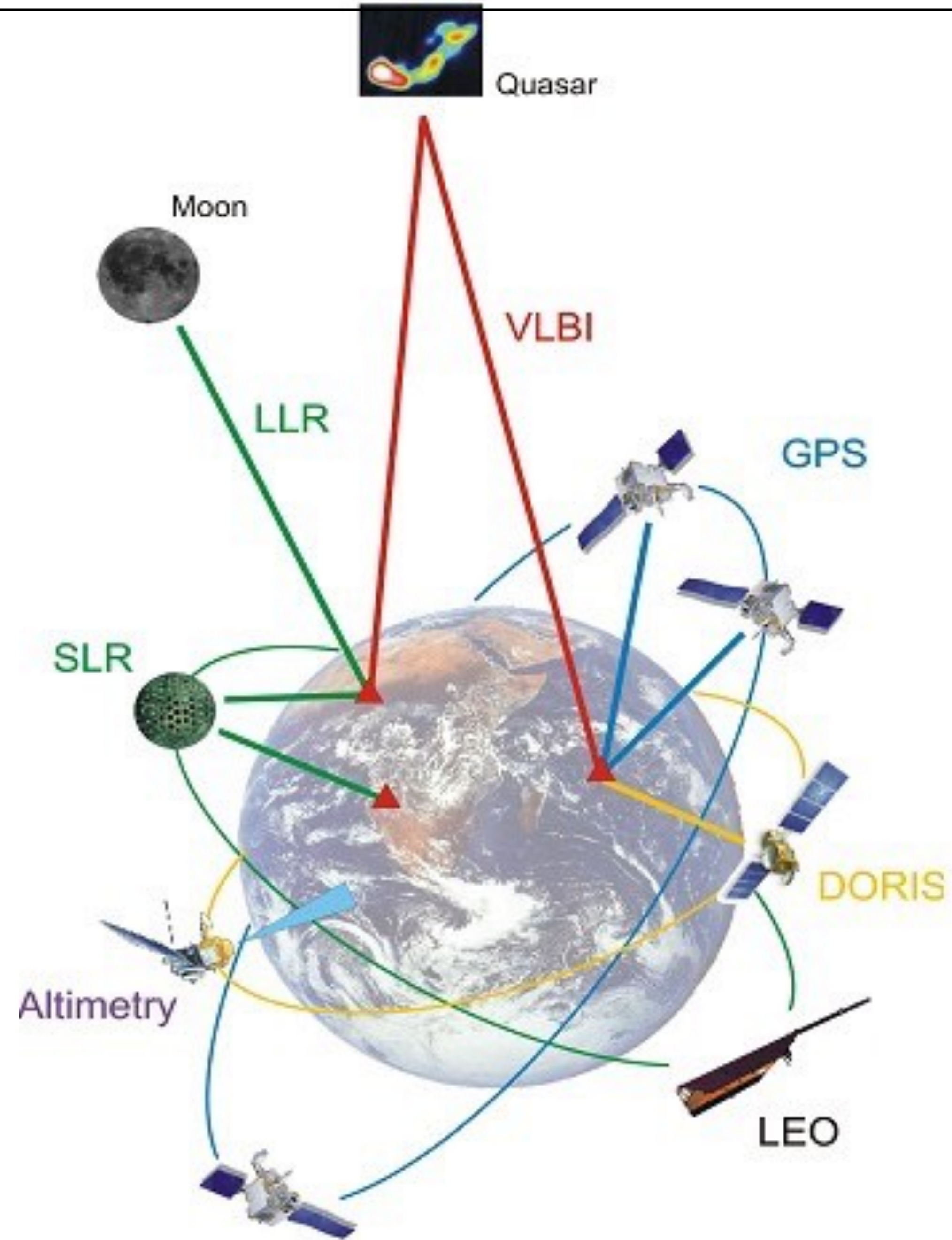
2 cm/y

Zuheir Altamimi  
<http://itrf.ign.fr/GIS/>

# Reference Systems and Reference Frames



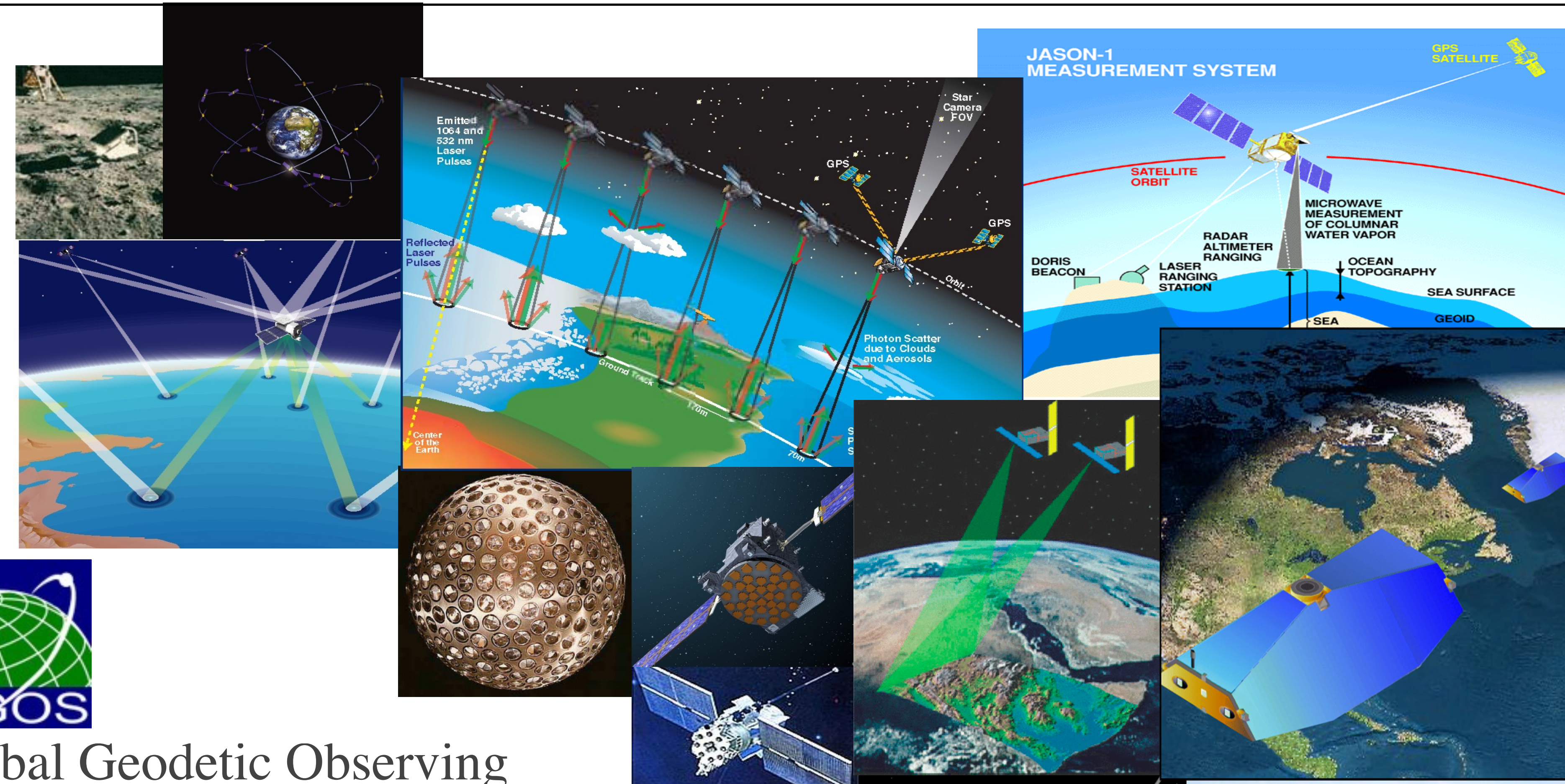
# Reference Systems and Reference Frames



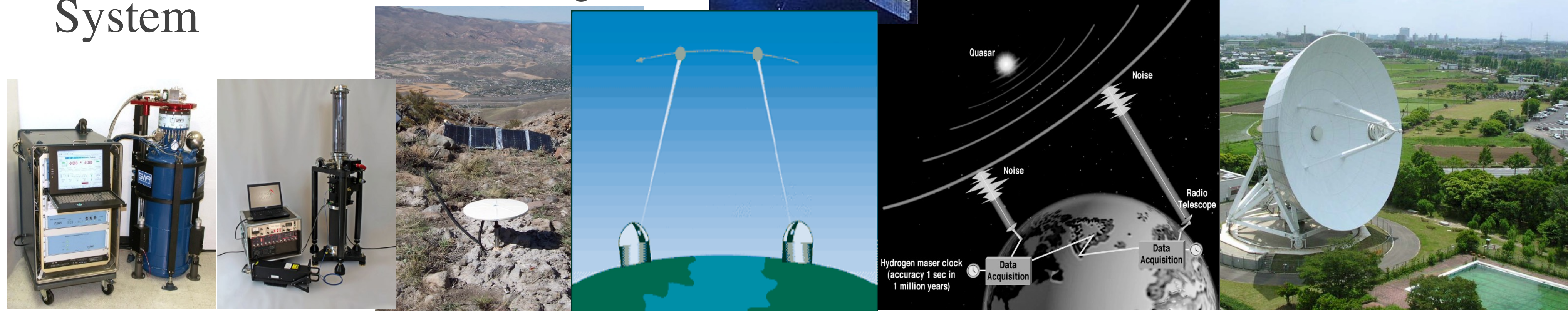


# Reference Systems and Reference Frames

Measuring land motion with respect to the center of mass of the Earth requires a stable, global reference frame well tied to the center of mass.

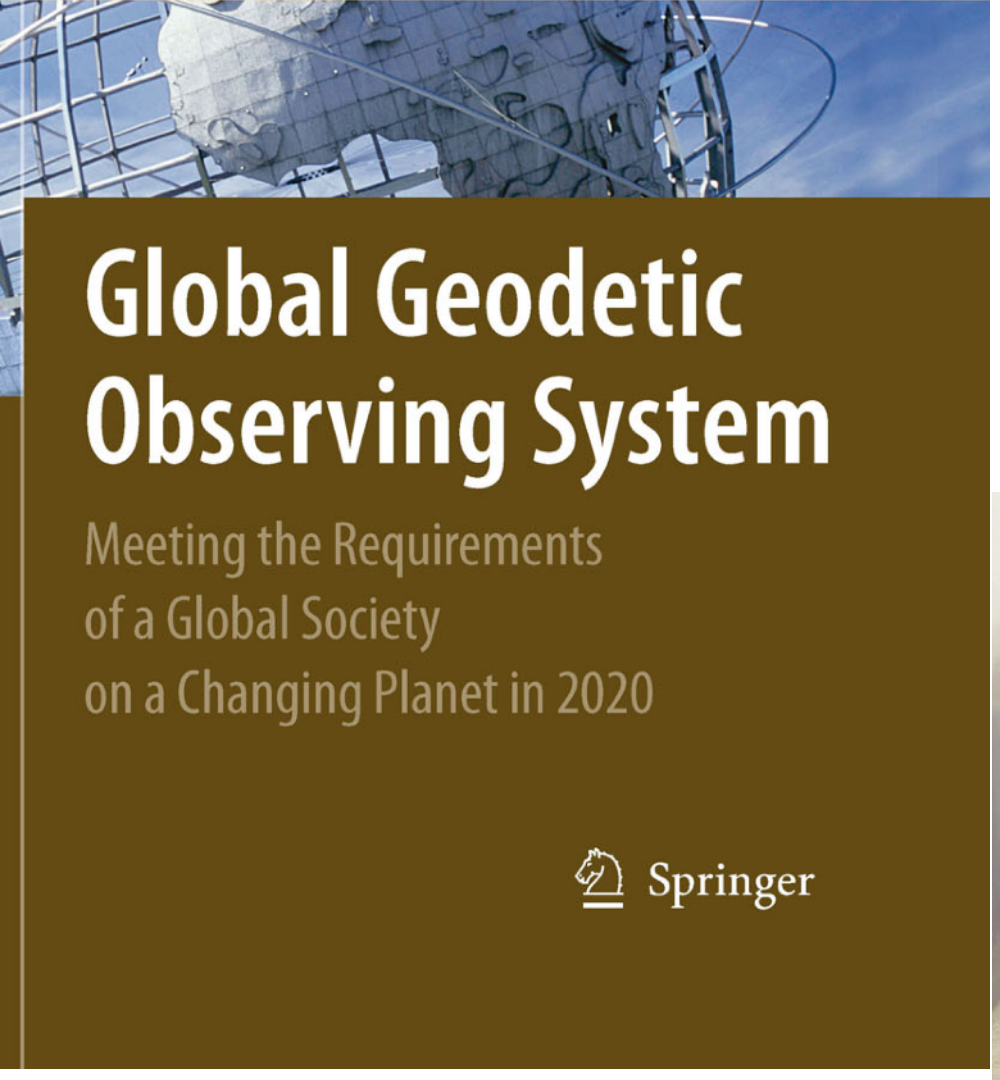
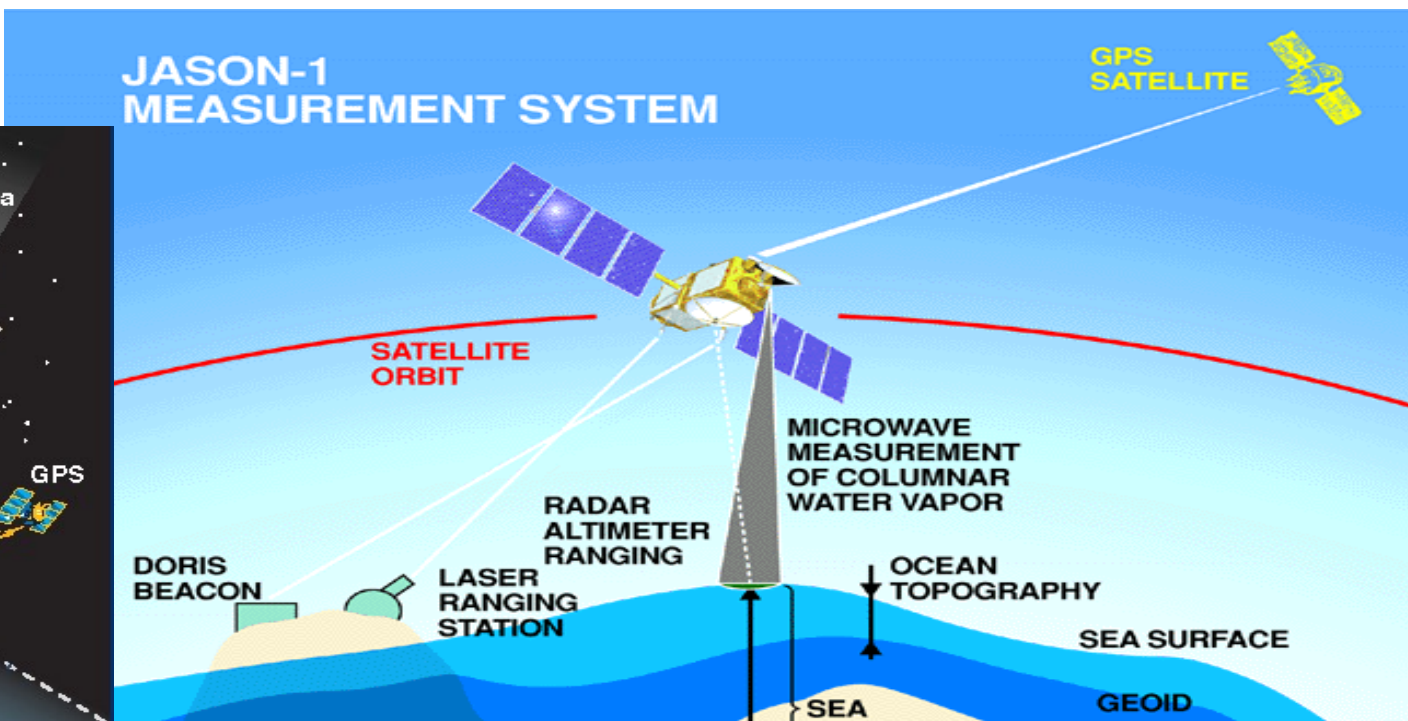
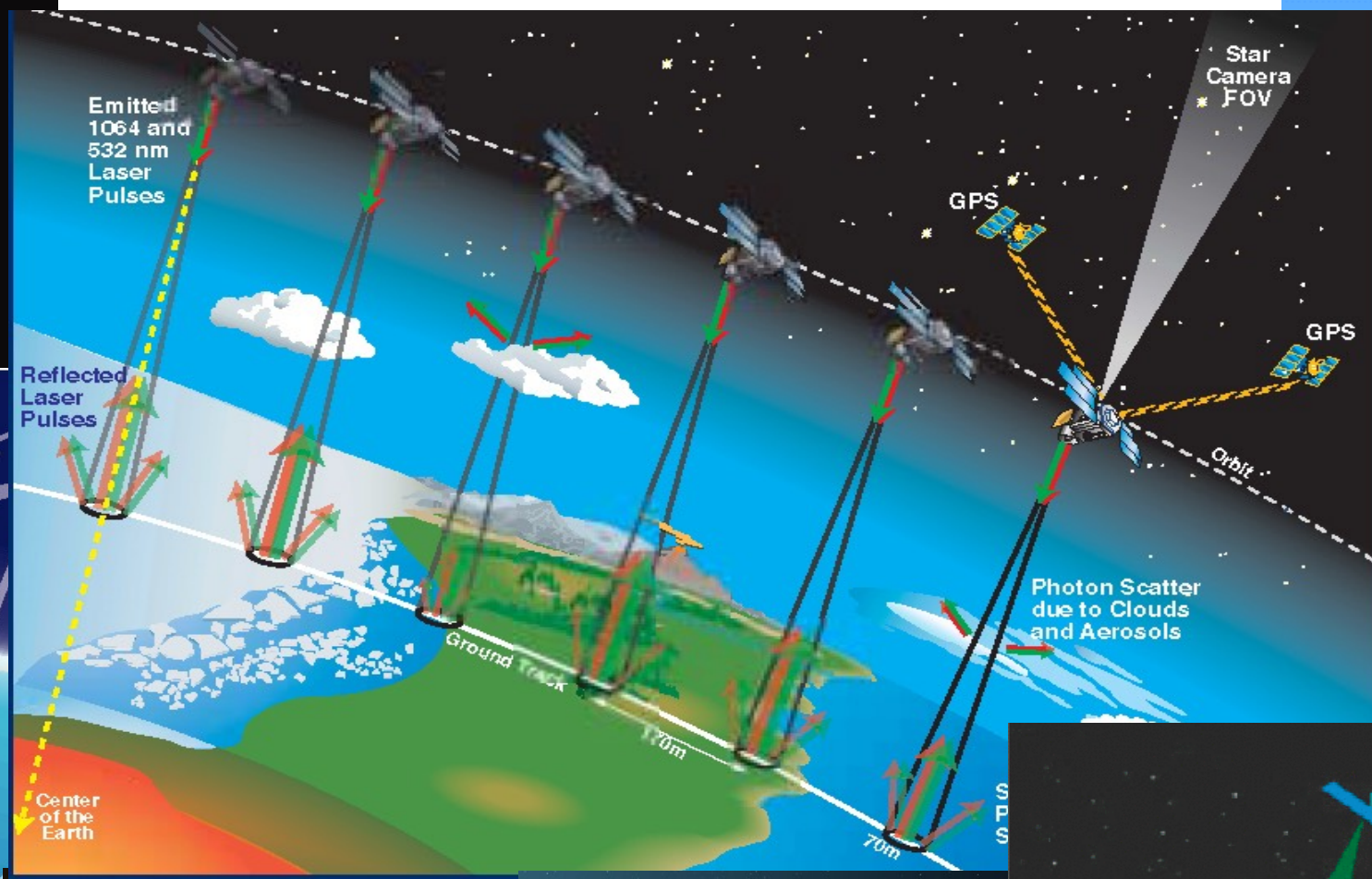
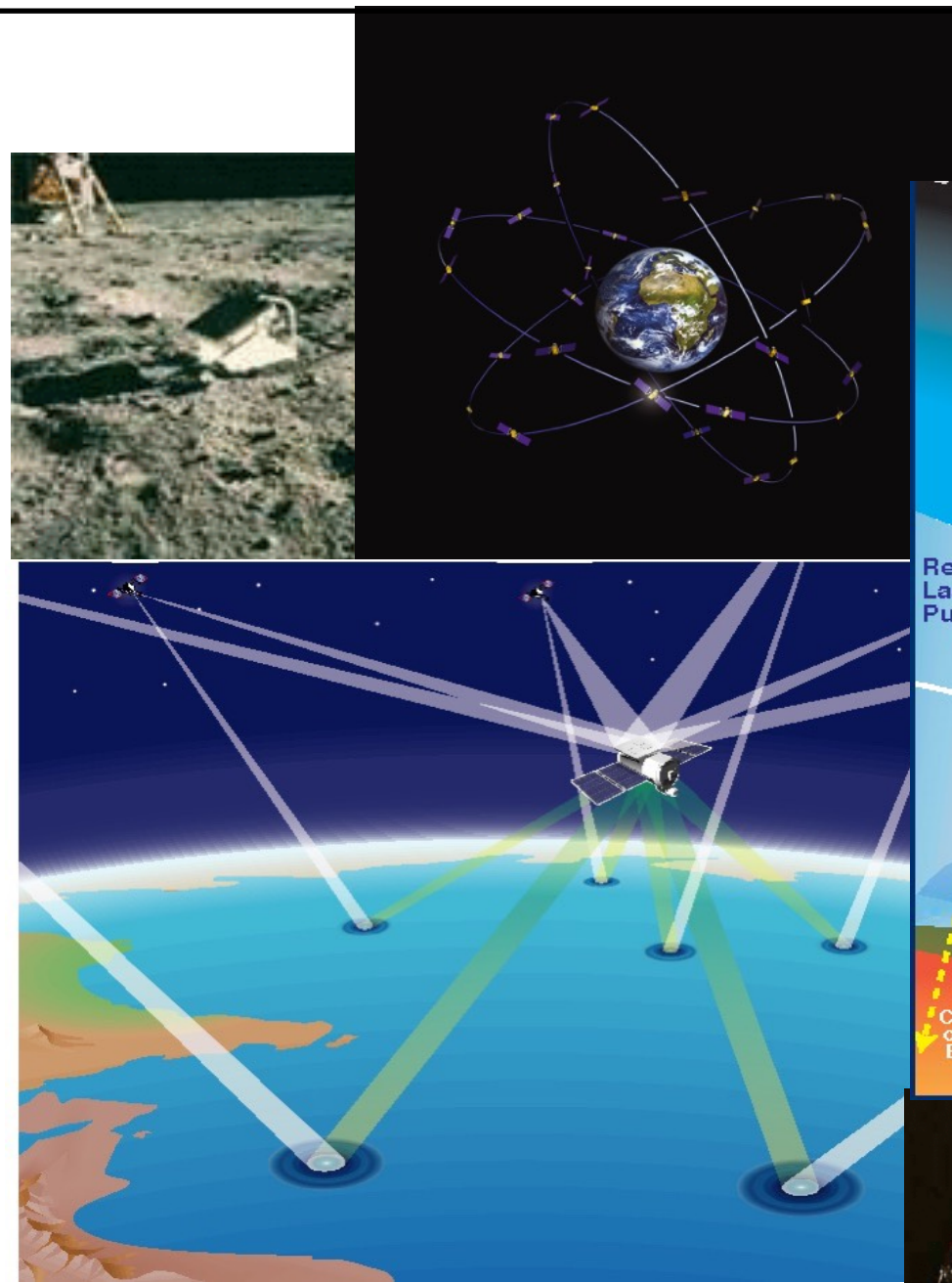


## Global Geodetic Observing System

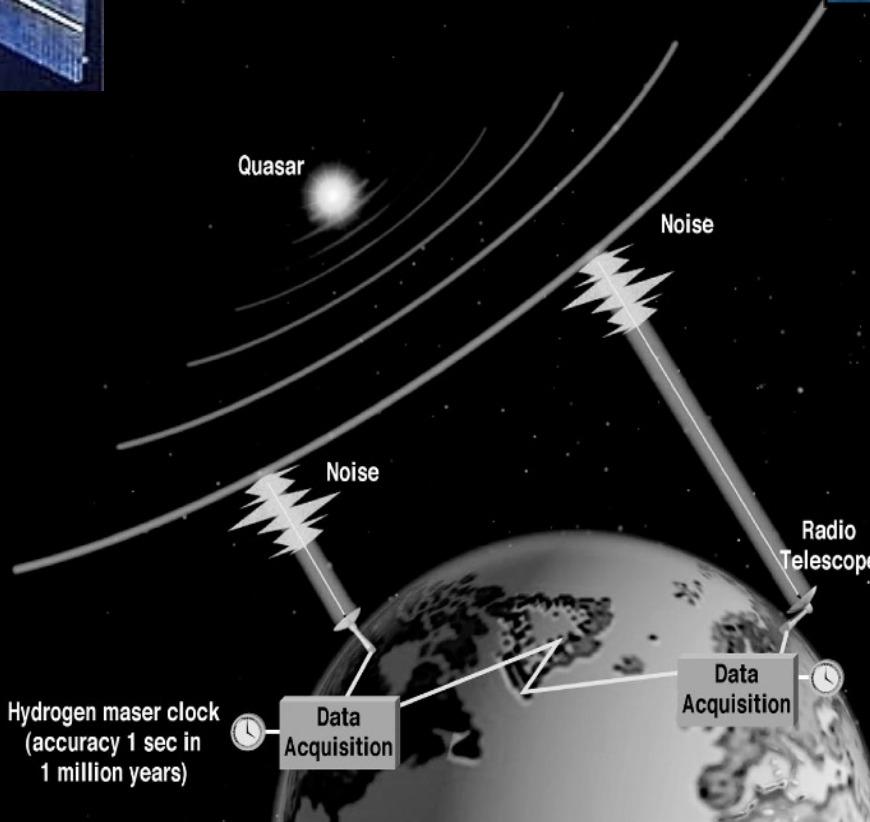
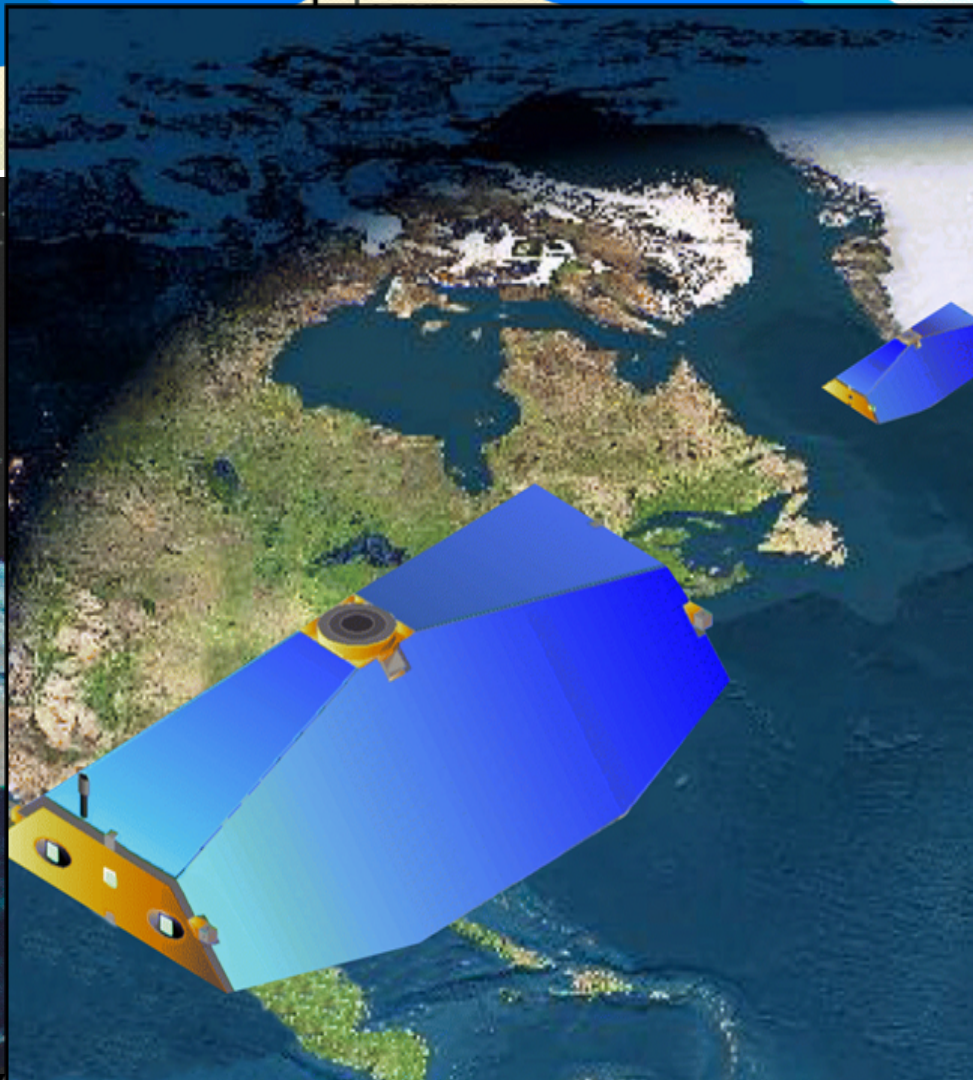
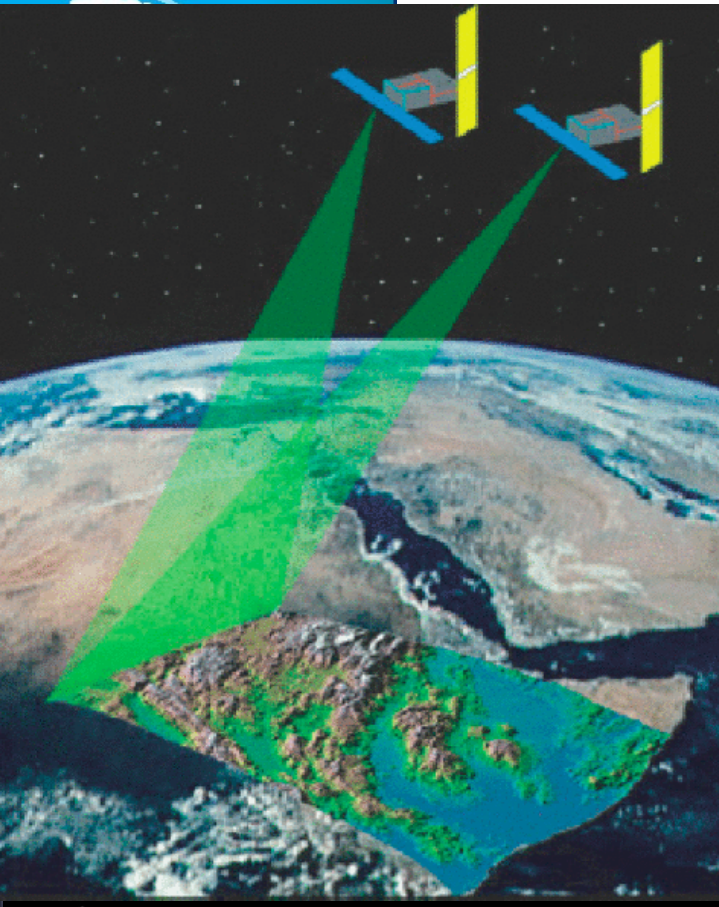


# Reference Systems and Reference Frames

Measuring land motion with respect to the center of mass of the Earth requires a stable, global reference frame well tied to the center of mass.



## Global Geodetic Observing System



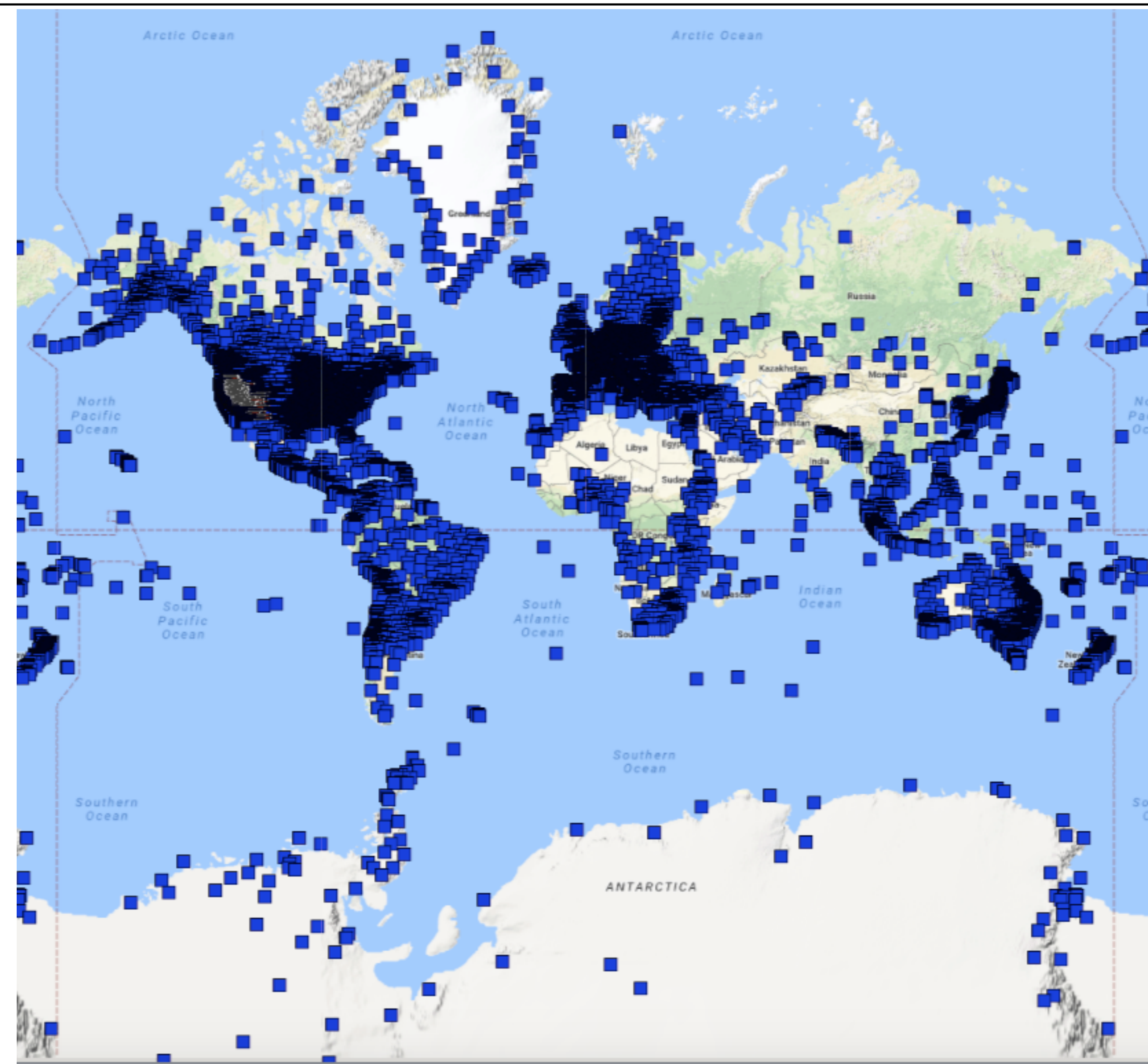
# Natural Hazards and Disasters



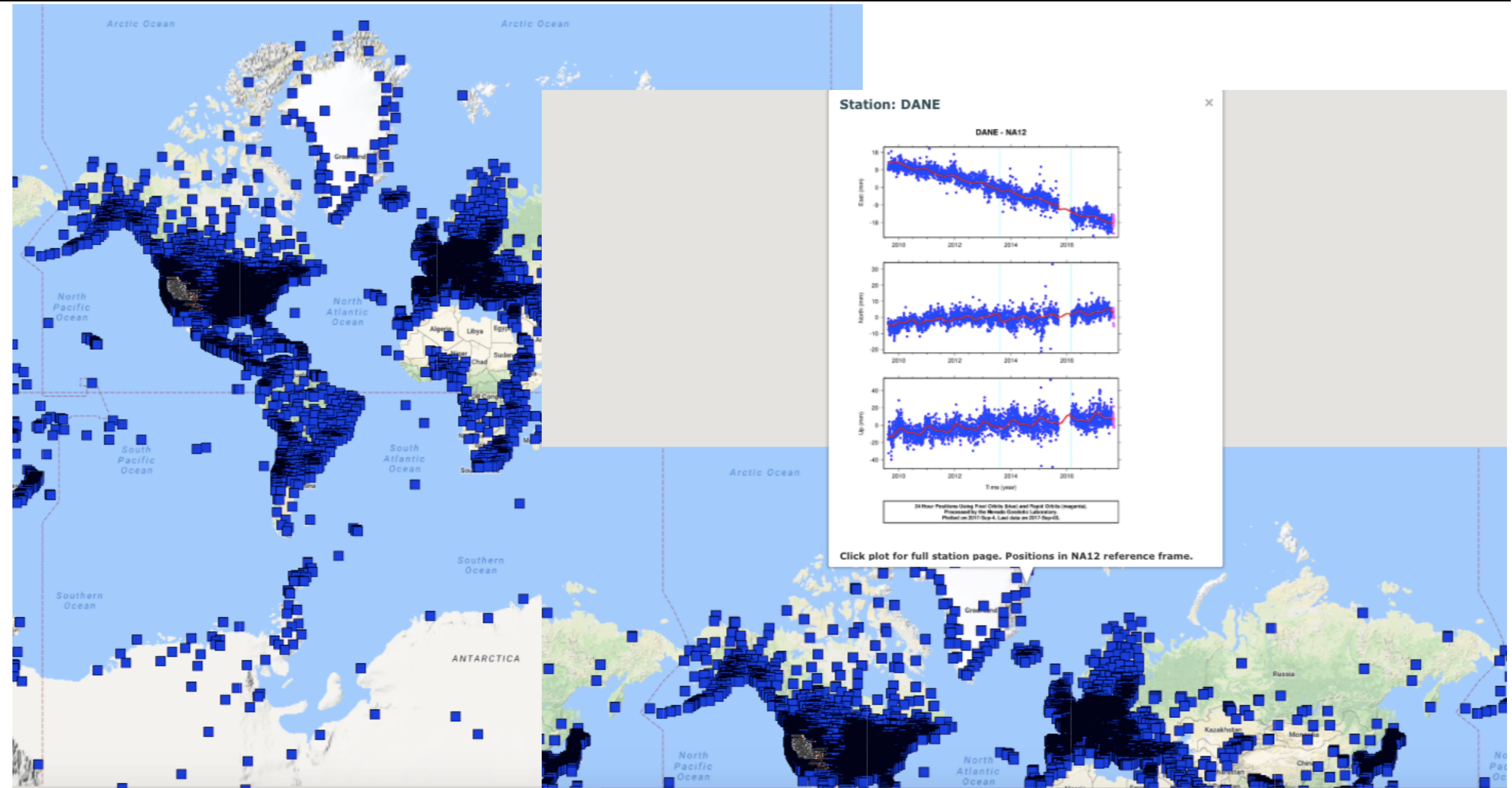
## Class 2: Observing Hazards and Disasters

- A dynamic Planet
- Observing Systems for a Dynamic Planet
- Reference Systems and Frames
- Monitoring Small Changes

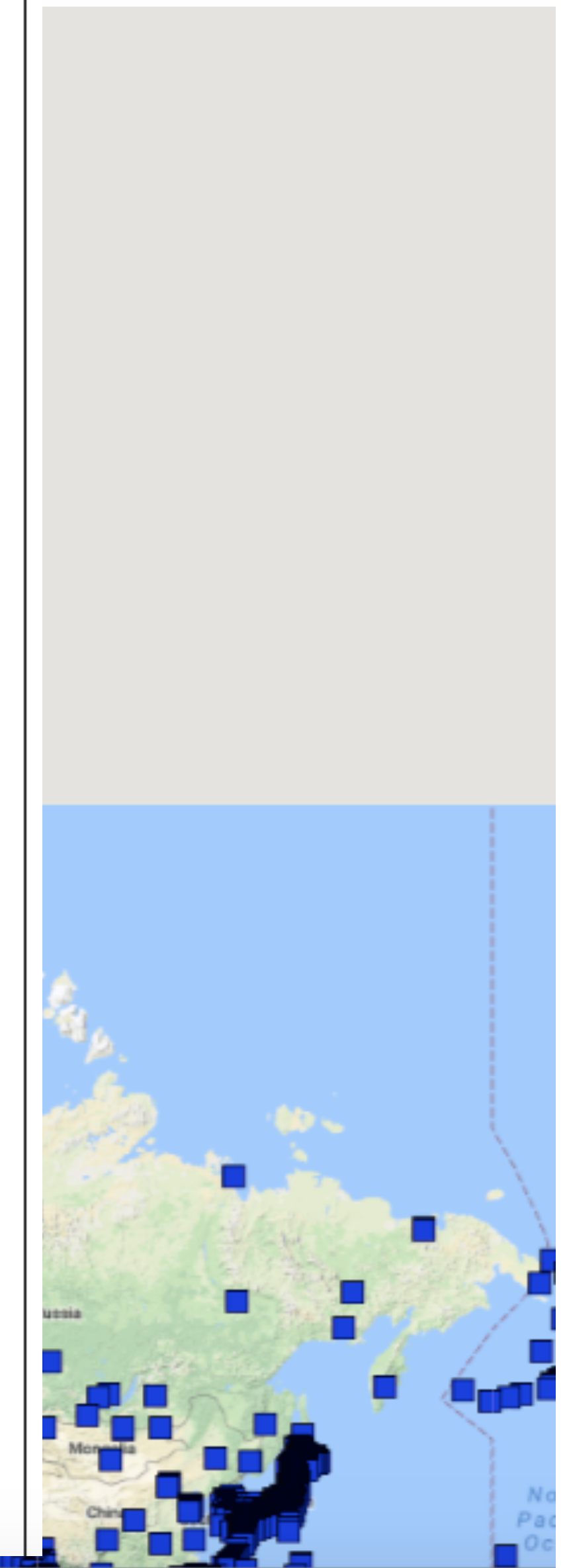
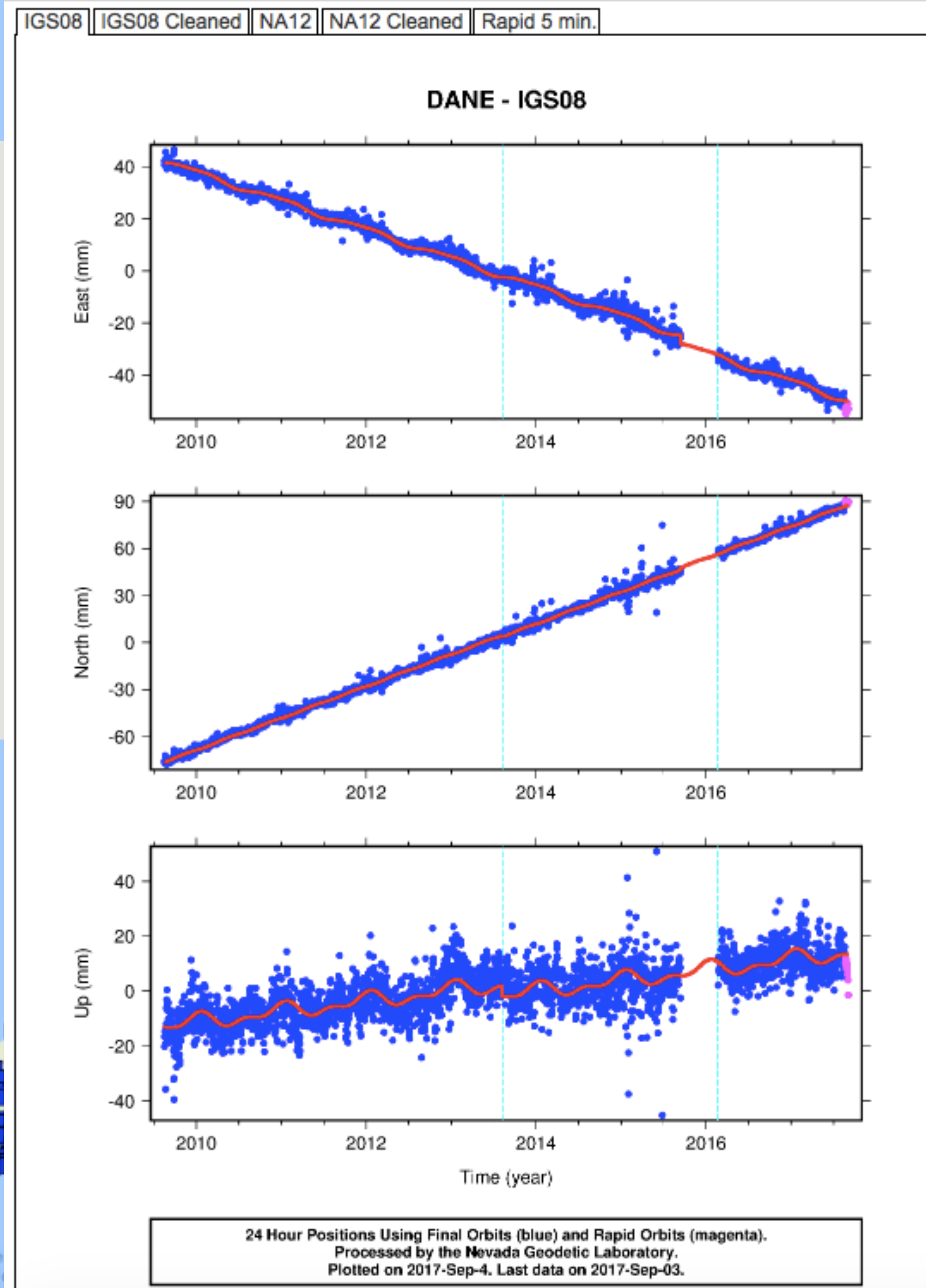
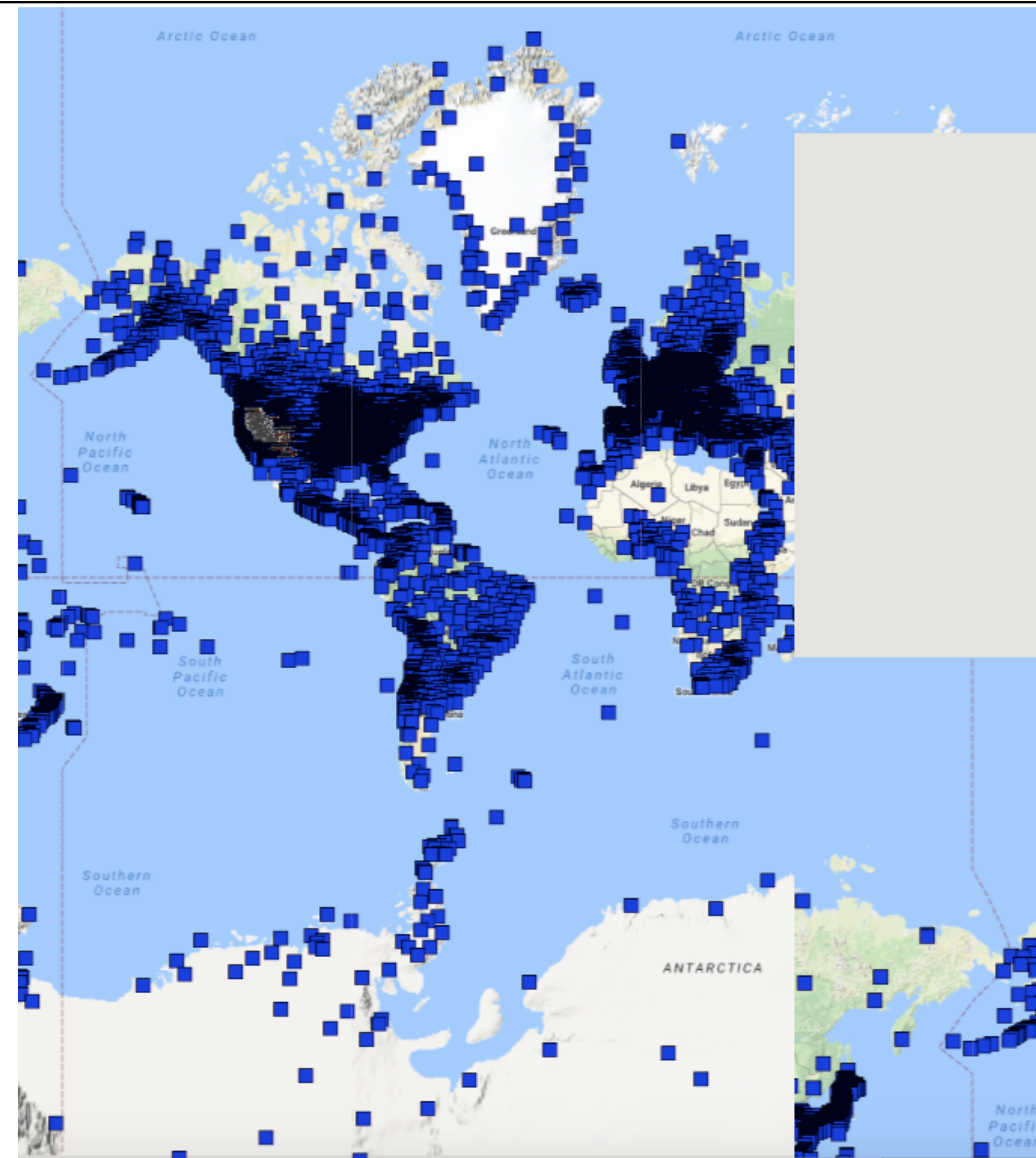
# Monitoring Small Changes



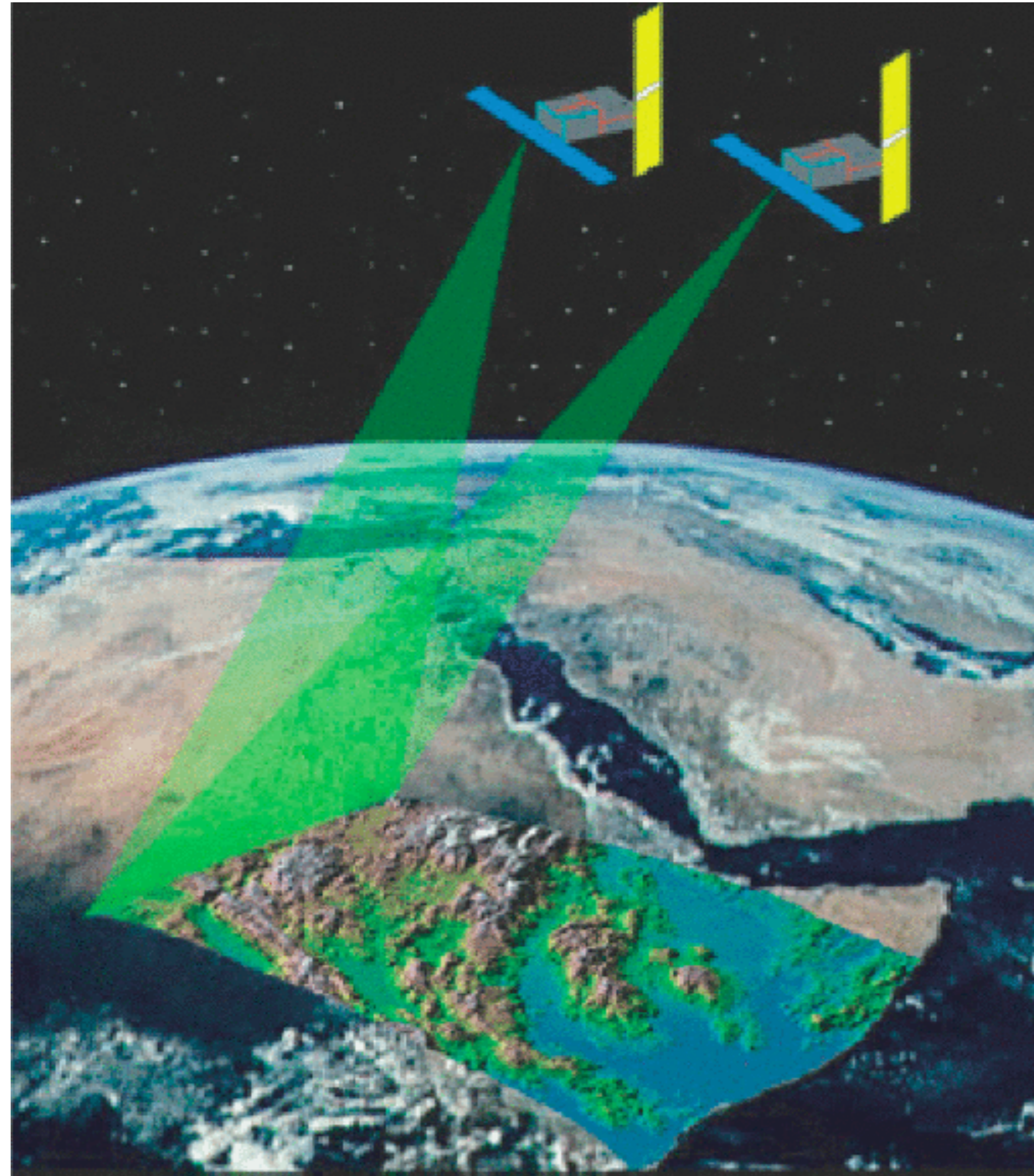
# Monitoring Small Changes



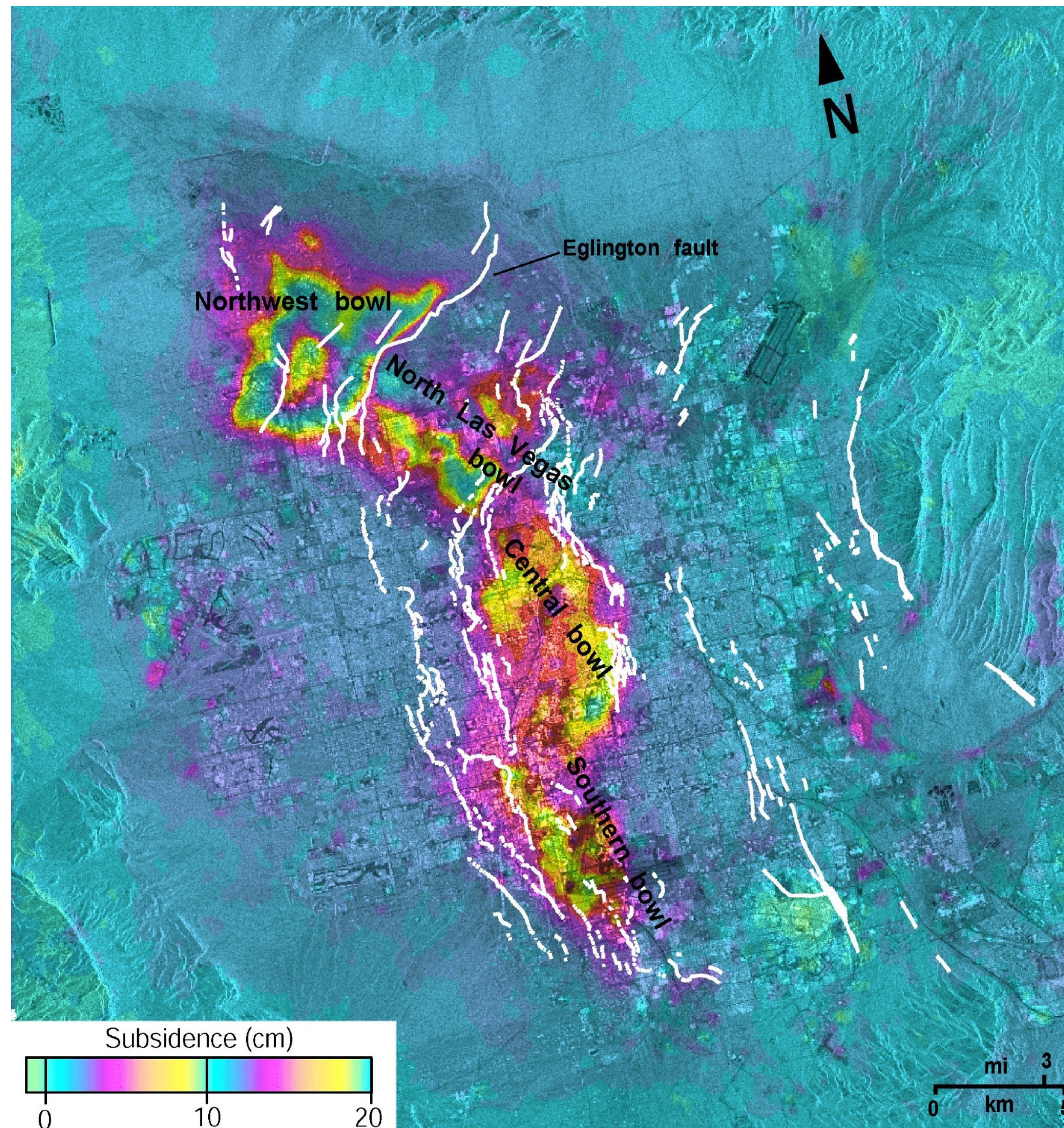
# Monitoring Small Changes



Interferometric Synthetic  
Aperture Radar (InSAR)  
Spatial scales: order 25 m  
Temporal scales:  $< \sim 10$  days



## InSAR-Determined Surface Displacements



### Subsidence 1992-1997

Four subsidence bowls

Aquifer system response strongly controlled by faults

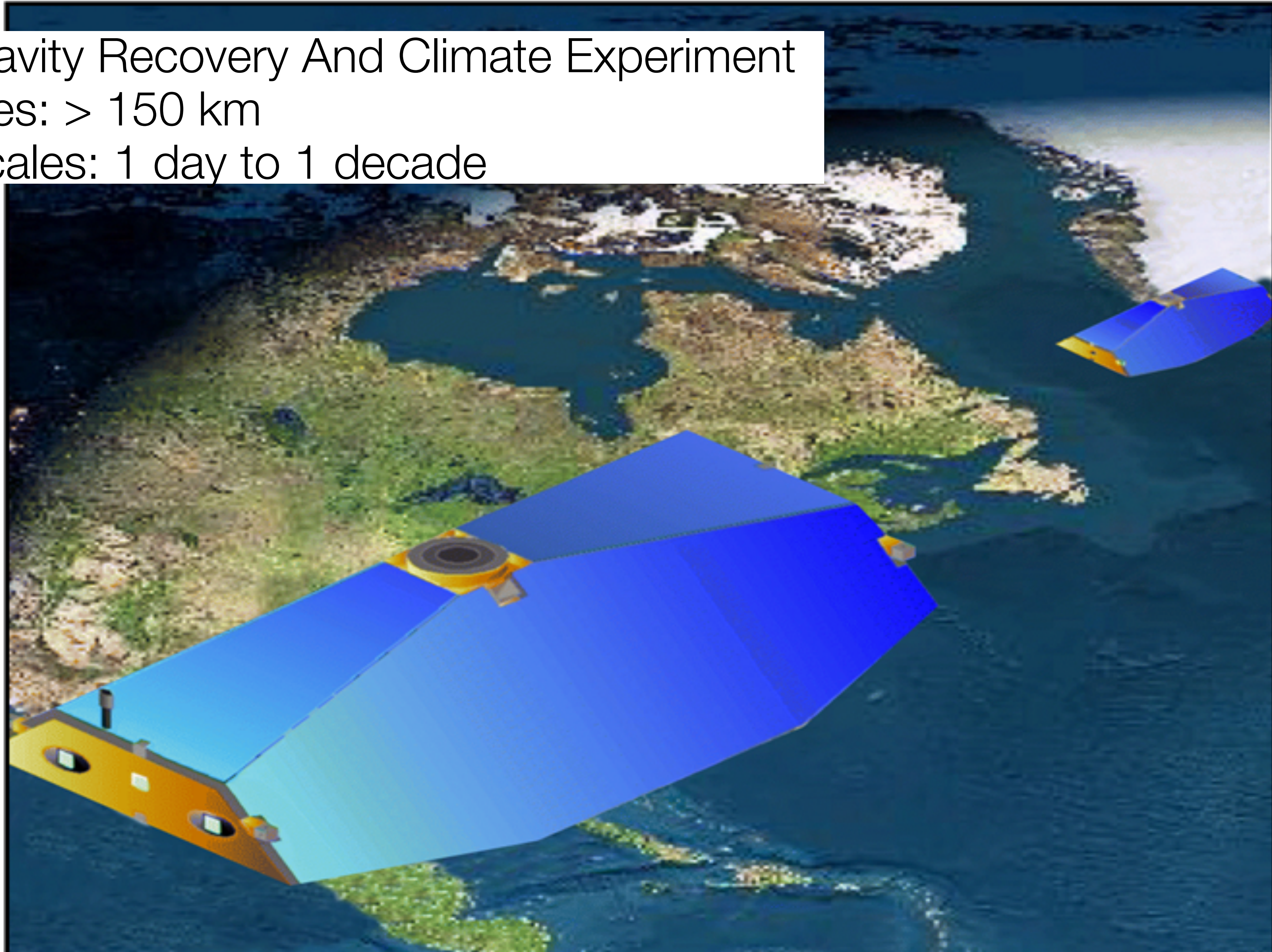
Faults are subsidence barriers

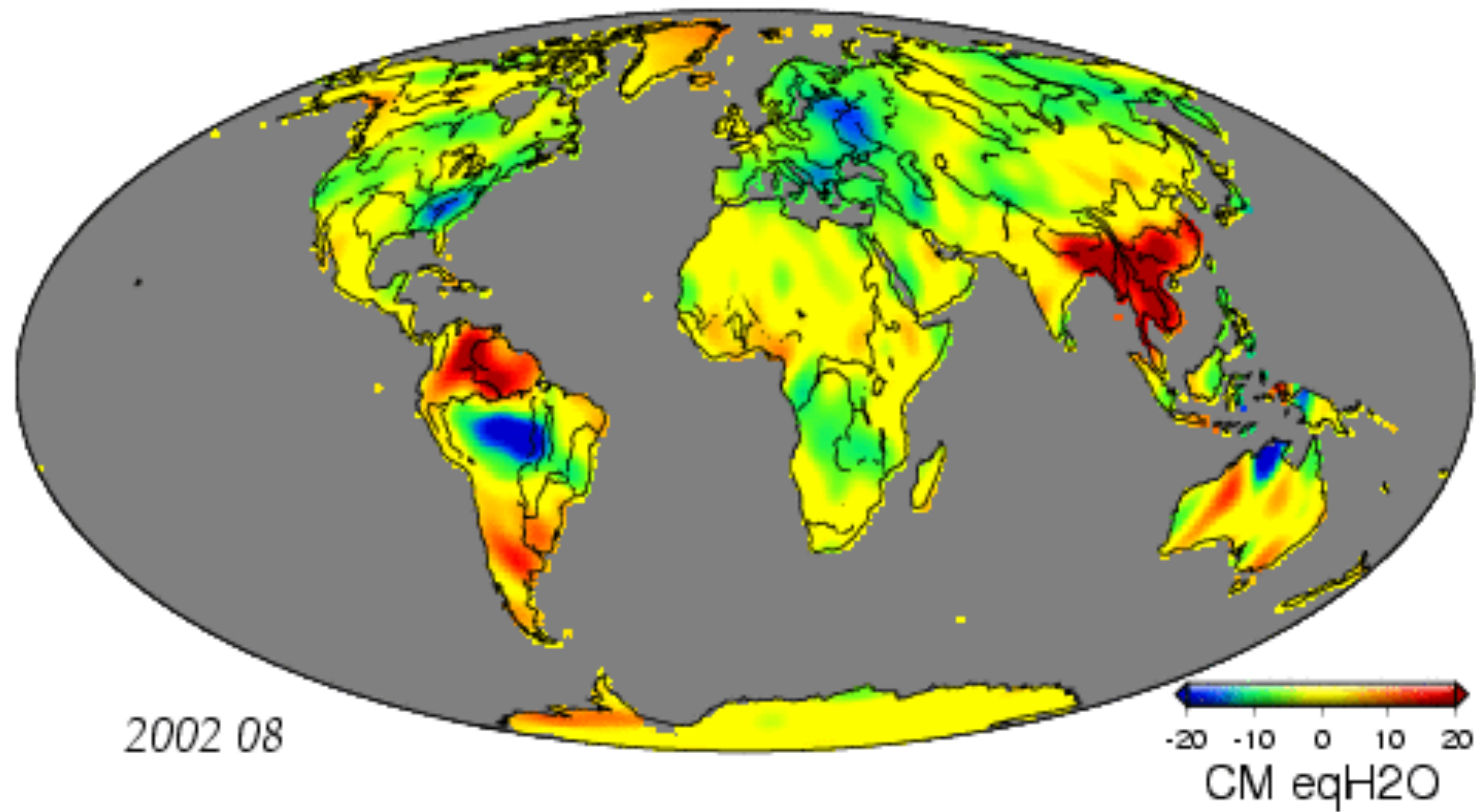
Subsidence rate is decreasing

Amelung et al., 1999



GRACE: Gravity Recovery And Climate Experiment  
Spatial scales:  $> 150$  km  
Temporal scales: 1 day to 1 decade

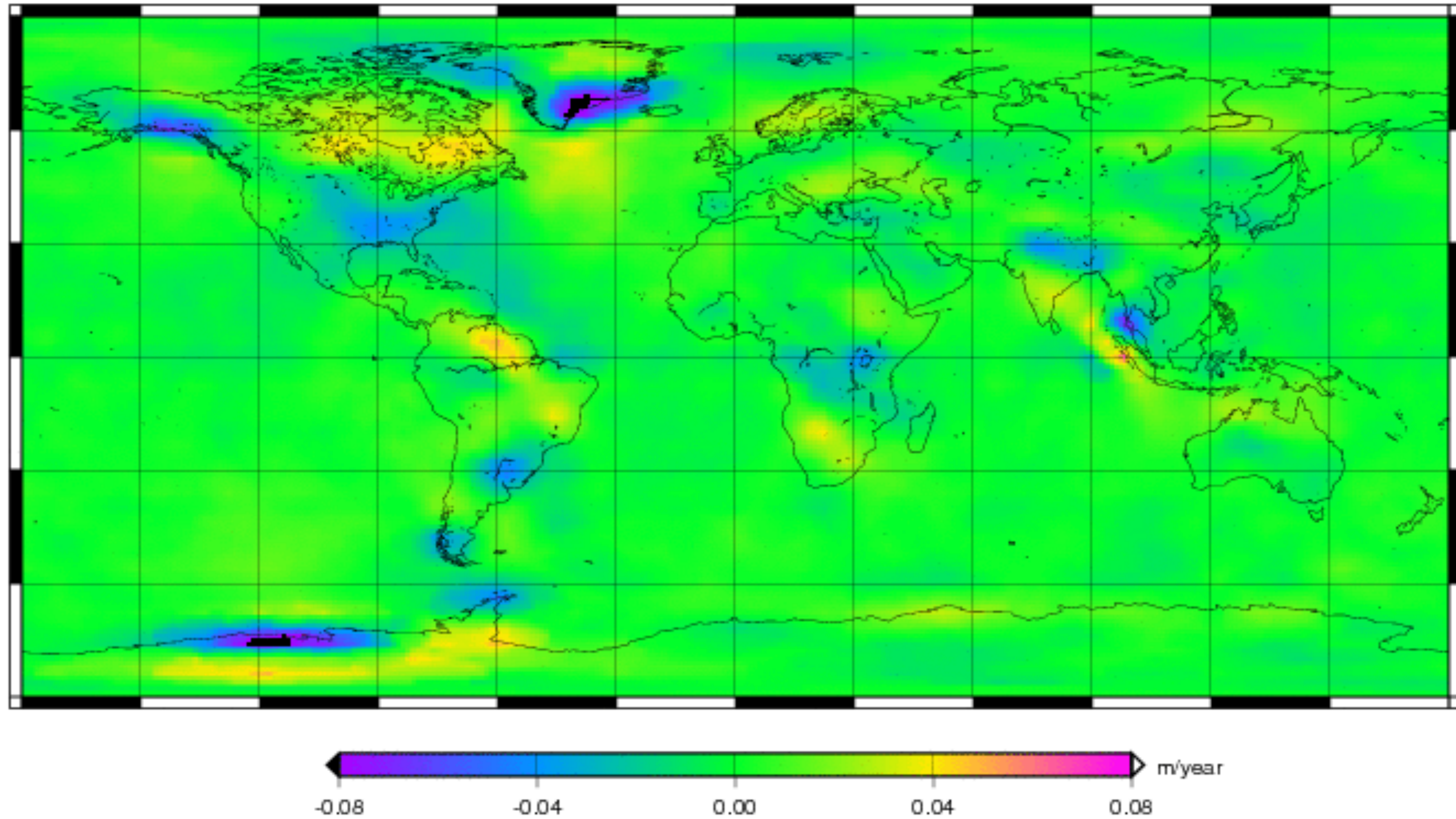




<http://grace.jpl.nasa.gov/information/>

*Satellite Gravity Missions (GRACE)*

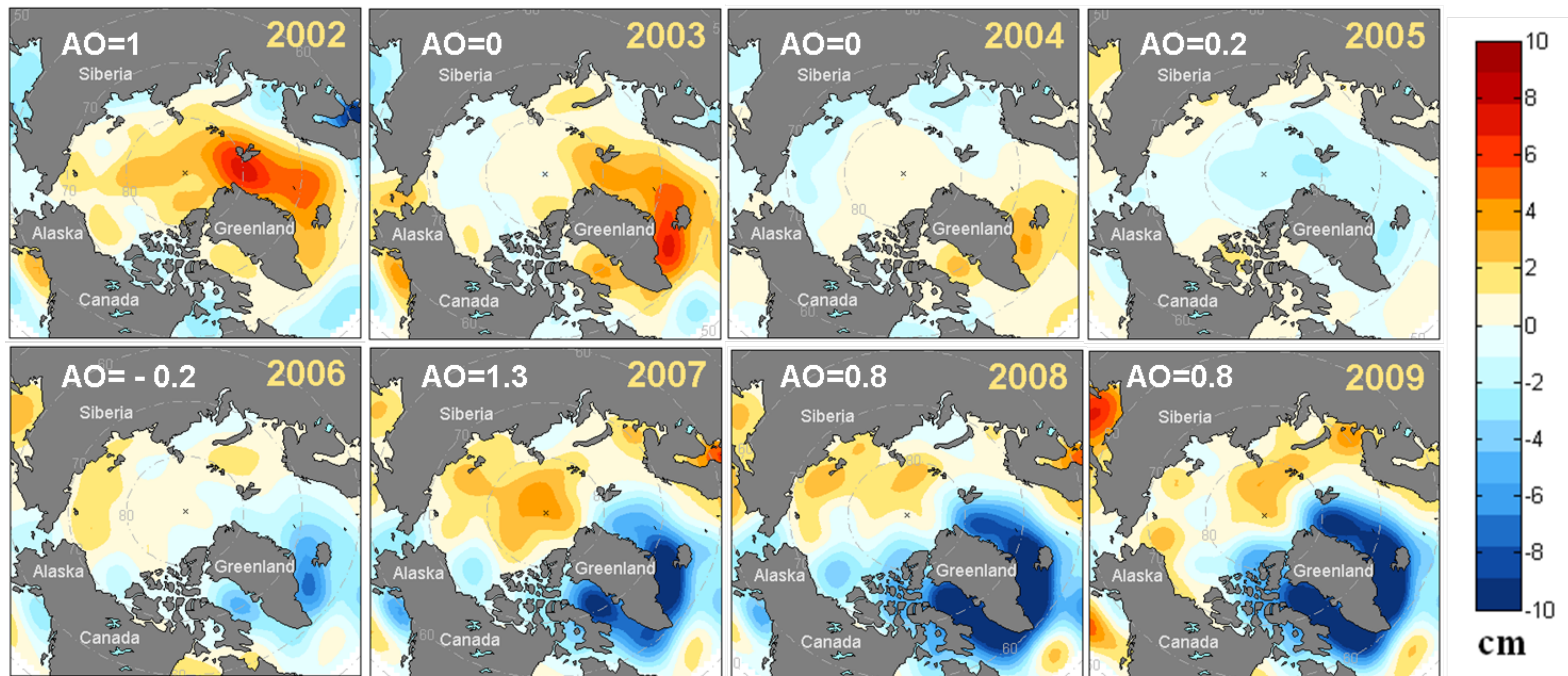
## Hydrology: Secular trends in Land Water storage



JPL MASCON, secular trends 2003-2007, Watkins, 2008

## GRACE Reveals Changes in Arctic Ocean Circulation Patterns

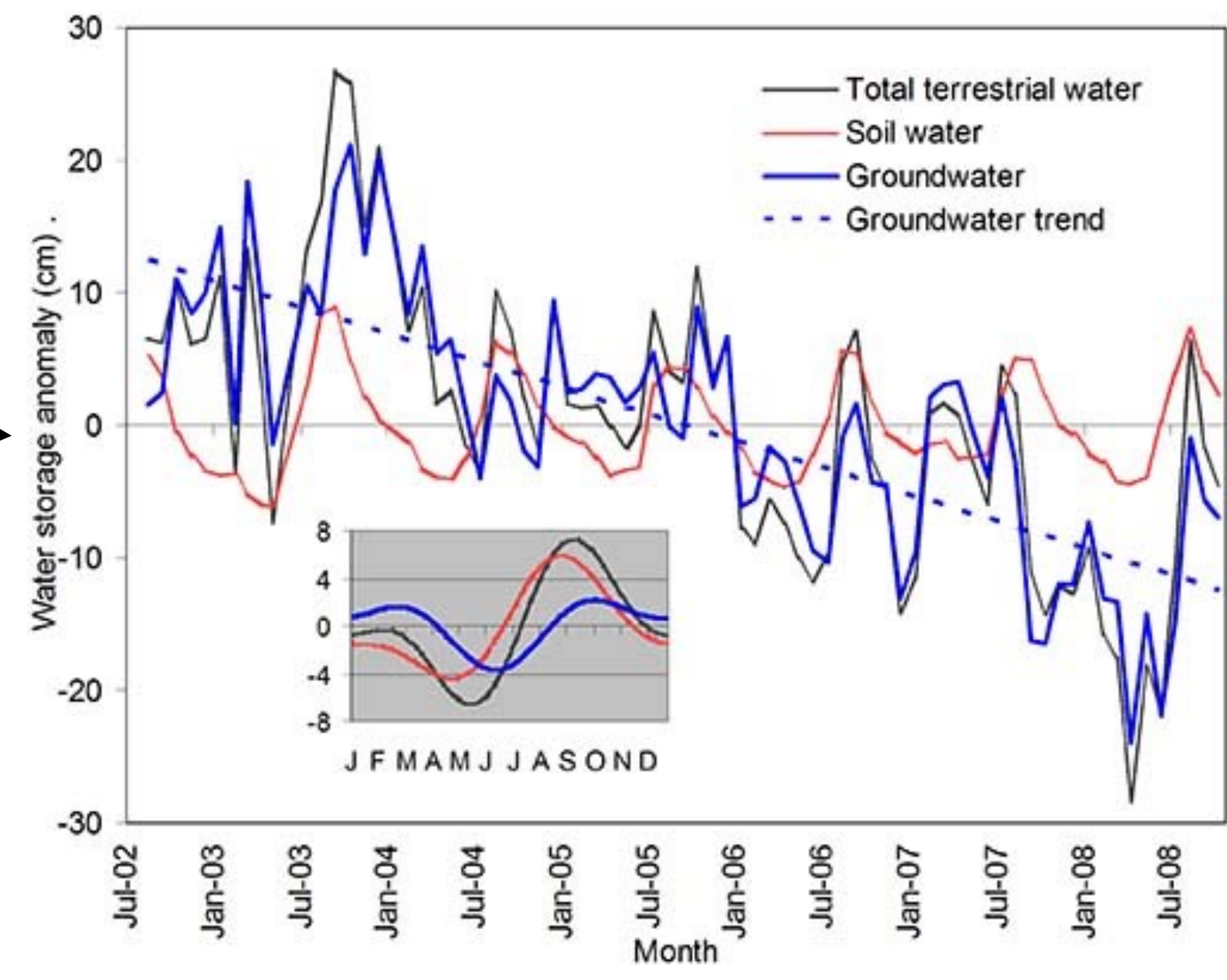
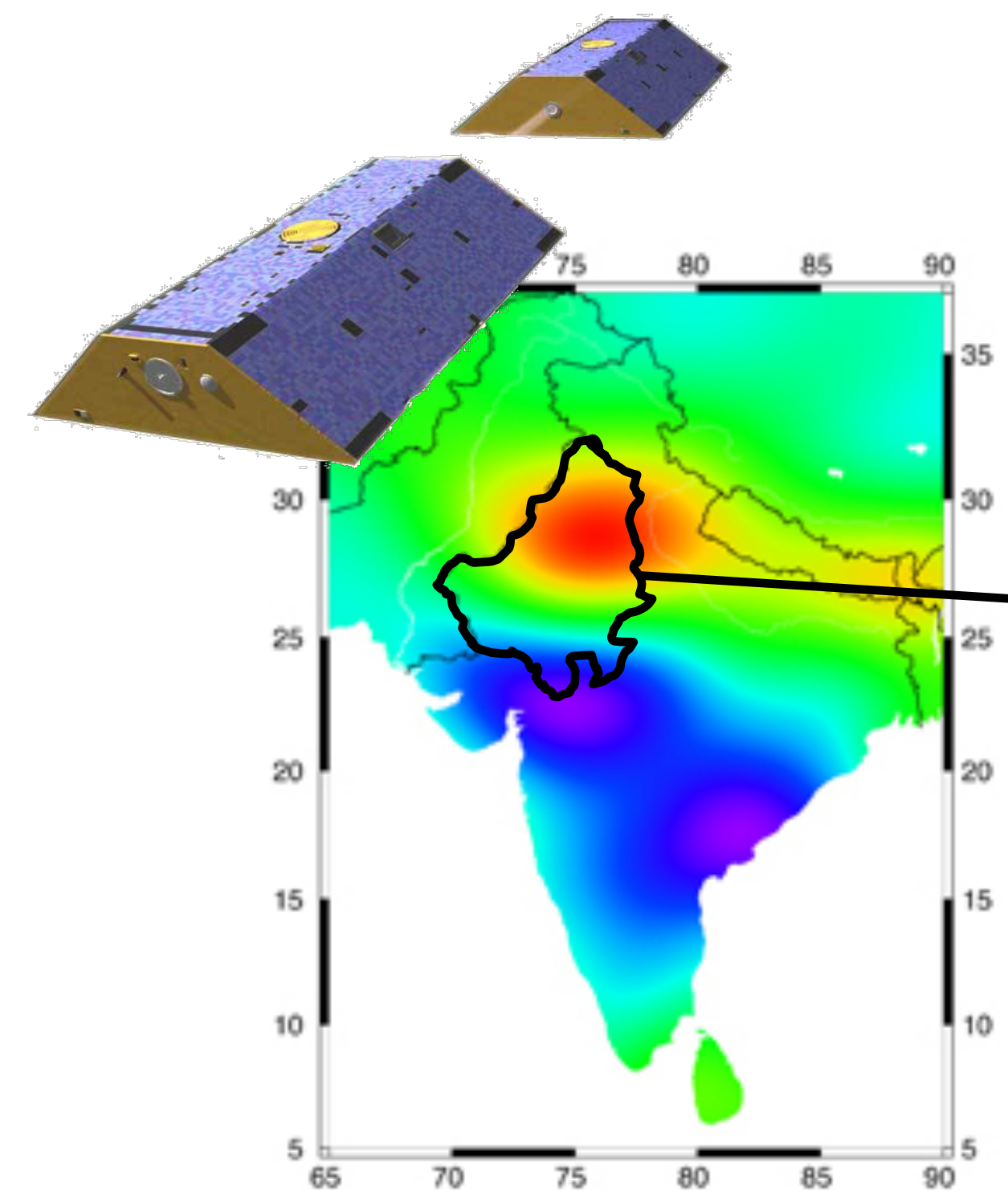
Variations in the Arctic Ocean circulation are associated with clockwise and counterclockwise shifts in the front between salty Atlantic-derived and less salty Pacific-derived upper ocean waters. Orientation of the front is climatically important because it impacts sea ice transport.



## GRACE Quantifies Massive Depletion of Groundwater in NW India

The water table is declining at an average rate of 33 cm/yr

GRACE is unique among Earth observing missions in its ability to monitor variations in all water stored on land, down to the deepest aquifers.



Trends in groundwater storage during 2002-08, with increases in blue and decreases in red. The study region is outlined.

Time series of total water from GRACE, simulated soil water, and estimated groundwater, as equivalent layers of water (cm) averaged over the region. The mean rate of groundwater depletion is 4 cm/yr. Inset: Seasonal cycle.

During the study period, 2002-08, 109 km<sup>3</sup> of groundwater was lost from the states of Rajasthan, Punjab, and Haryana; triple the capacity of Lake Mead

## GRACE Detects Accelerated Ice Mass Loss in Greenland and Antarctica

During the period of April 2002 to February 2009 the mass loss of the polar ice sheets was not constant but increased with time, implying that the ice sheets' contribution to sea level rise was increasing.

- Greenland:
- mass loss increased from 137 Gt/yr in 2002–2003 to 286 Gt/yr in 2007–2009
  - acceleration of  $-30 \pm 11 \text{ Gt/yr}^2$  in 2002–2009.
- Antarctica:
- mass loss increased from 104 Gt/yr in 2002–2006 to 246 Gt/yr in 2006–2009
  - acceleration of  $-26 \pm 14 \text{ Gt/yr}^2$  in 2002–2009.

