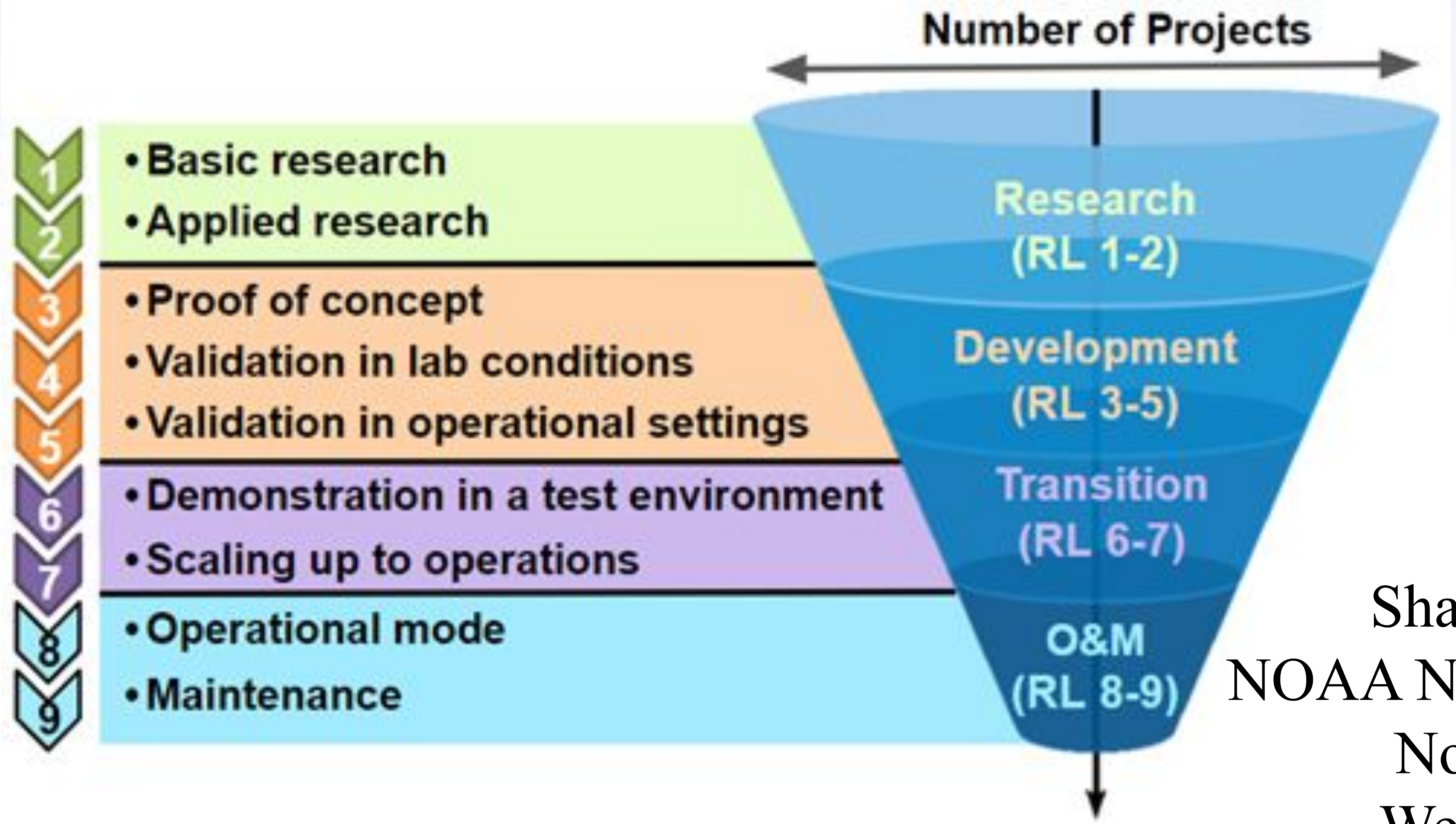
NGS Research Plan



Shachak Pe'eri, Ph.D.
NOAA National Geodetic Survey
November 9th, 2023
Webinar presentation

Outline

- **Overview - Situational awareness**
- **NSRS modernization - Short term research plans**
- **NGS long-term research plans:**
  - Develop the next generation of NSRS
  - Enhance marine and riverine geodesy
  - Advance space geodesy
  - Develop a national deformation model
  - Enable cyberinfrastructure
- **Increase academic and industry engagements**

NGS Research Plan 2024

- **Overview of the Program Office and the research to operation process in NOAA**
- **Linking the NOAA's five Essential Enabling Capabilities to NGS Research**
- **NGS' short-term research efforts**
- **NGS' long term-research efforts**
- **Linking NGS research to NOAA's Weather, Water, Climate Strategy.**

The NGS Research Plan is accessible via:
https://geodesy.noaa.gov/web/about_ngs/info/documents/ngs-research-plan-2024-final.pdf

The road so far…

The primary focus of a <u>strategic plan</u> is competitiveness. It is designed to respond to change and future opportunities in a way to find advantage.

The primary focus of an <u>operational plan</u> is efficiency. Operational plans are designed to roll out strategy via internal department programs developed by, for instance, HR, IT, marketing, and manufacturing.

This <u>research plan</u> provides is situational awareness. Technological context in current research trends and opportunities to support the vision (strategy) and the workflows (operations).

The Mission defined in the 2019-2023 NGS Strategic Plan -
"To define, maintain, and provide access to the National Spatial Reference System (NSRS) to meet our nation's economic, social, and environmental needs."

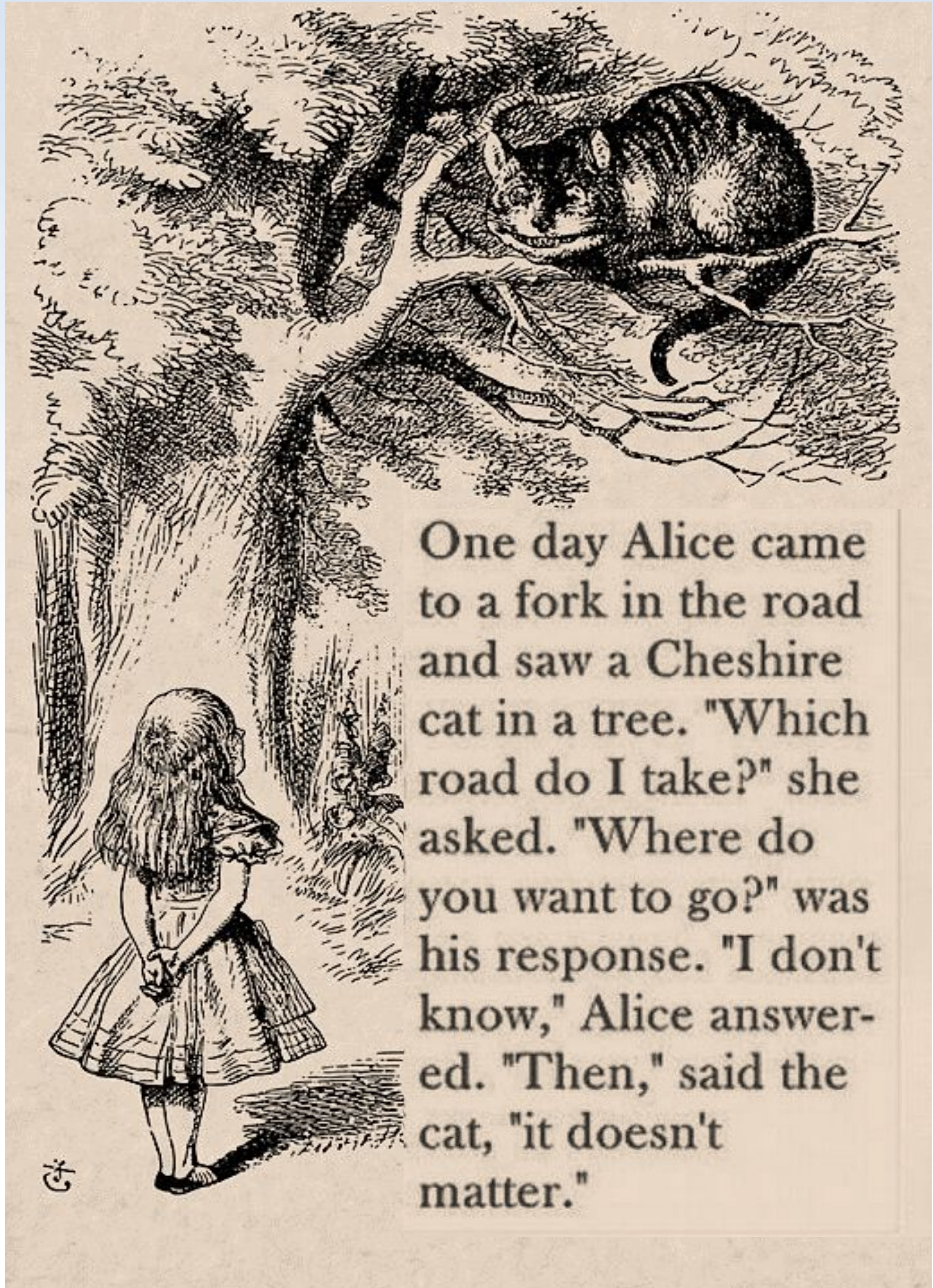
What do we expect in a research plan?

- Aligning with NOAA's **strategy/implementation plans**.
- **Communication tool** to our stakeholders
- **Background material** for academic/industrial partners. (and for anyone interested working at NGS)

Strategy is positioning an organization, whether it is a business, government agency, or a nonprofit entity, with respect to the competitors*.

(Strategic Planning should be a Strategic Exercise, Graham Kenny, Harvard Business Review, 2022)

*** Before you protest - All organizations have competitors - for customers, for staff for resources.**



Aligning with the administration

- Service Delivery
- Decision Support
- Modeling and prediction
- R&D and Engineering
- Observations and Data

Research plan as a recruiting tool

AAGS | The American Association for Geodetic Surveyin

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The Geodesy Crisis

by AAGS | posted in: News | 0

10 FEB 2022

Geodesy is the fundamental science of geospace. It supports and drives innovation in geospatial technology, the ~ $ 1 trillion/year geospatial economy, and the geospatial systems of nearly all military platforms and activities. In the early 1990s the U.S. government, especially the Department of Defense (DOD), largely disinvested in academic research and education in geodesy. In contrast, the countries of the European Union that contributed the most to the development of geodesy in the preceding centuries have maintained healthy academic training and research programs, which is also the case in Japan, Canada, Australia and New Zealand. Furthermore, in the early 2000's, China began to make large and ever-growing investments in geodetic training and research. It now has more Ph.D. geodesists than the rest of the world combined. During this time period the greatest national collapse in geodetic capability occurred in the U.S., as its geodesists steadily retired, and most were not replaced. The Chinese military and defense industries now have access to hundreds of Ph.D. geodesists. Perhaps the most shocking example of the U.S. decline relative to China is that the number of Ph.D. geodesists in the entire DOD, including the National Geospatial-Intelligence Agency (NGA), is now approaching zero. The same is true of the U.S. defense industry. The U.S. is on the verge of being permanently eclipsed in geodesy and in the downstream geospatial technologies. This threatens our national security and poses major risks to an economy that is strongly tied to the geospatial revolution, on Earth and, eventually, in space.

Search

Recent Posts

- Slate of candidates for upcoming 2023 AAGS e officers
- LSU Center for GeoInfor Hiring
- Lecturer or Teaching Assis Professor – Geomatics
- FIG Foundation Student Grant

FGDC.GOV
FEDERAL GEOGRAPHIC DATA COMMITTEE

NATIONAL GEOSPATIAL ADVISORY COMMITTEE – RESOLUTION ON GEODESY

"The decline of geodetic academic programs in the United States and the resulting shortage of practicing geodesists threatens our international technological competitiveness in Earth and space science, affecting our economic health and security. The National Geospatial Advisory Committee (NGAC) supports the findings, which include challenges, threats, and opportunities, outlined in the "Geodesy Crisis" white paper[1] authored by Dr. Michael Bevis et al. and discussed with NGAC members.

The NGAC strongly recommends that these serious national challenges be addressed immediately through an ambitious program of educational support, research funding, and government agency action including:

- Address the challenges and opportunities for augmenting geodesy capabilities in support of the National Spatial Reference System and within relevant Federal Geographic Data Committee (FGDC) agencies.
- Promote understanding within FGDC agencies and across the geospatial community about how geodesy expertise advances socio-economic, environmental, ecological, intelligence, and military programs to advance national security and economic growth.
- Augment budgets to sponsor academic training and research work in geodesy and allied geospatial fields (the NGAC commends the National Geospatial-Intelligence Agency for providing its leadership and financial commitment to this effort).
- Act expediently."

(Adopted by the NGAC on December 7, 2022)

GPS WORLD — GNSS POSITIONING NAVIGATION TIMING
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GNSS OEM Autonomous Survey Mapping Transportation Defense Mobile Machin

The inverted geospatial pyramid shows our vulnerability

November 1, 2022 - By David B. Zilkoski | Est. reading time: 14 minutes

Last year I was privileged to be part of a Blue-Ribbon Review Panel for an American Society of Civil Engineers (ASCE) surveying publication. The book is *Surveying and Geomatics Engineering: Principles, Technologies, and Applications*. I recently received my copy of the published book in the mail and decided to highlight some sections. While preparing this column, the chapters reminded me of how geodesy has expanded into so many different disciplines.

I first mentioned this in my July 2020 article for the "First Fix" column of *GPS World*, where I stated that the shortage of American trained geodesists poses a significant economic risk for the United States. In that column, I mentioned how geodetic science and technology now underpin many sciences, large areas of engineering (such as driverless vehicles and drones), navigation, precision agriculture, smart cities and location-based services. That is why I believe understanding geodesy is more critical today than ever. In January 2022, Mike Bevis, collaborating with others, prepared a white paper titled "The Geodesy Crisis," documenting the concern about the lack of trained geodesists in the United States.

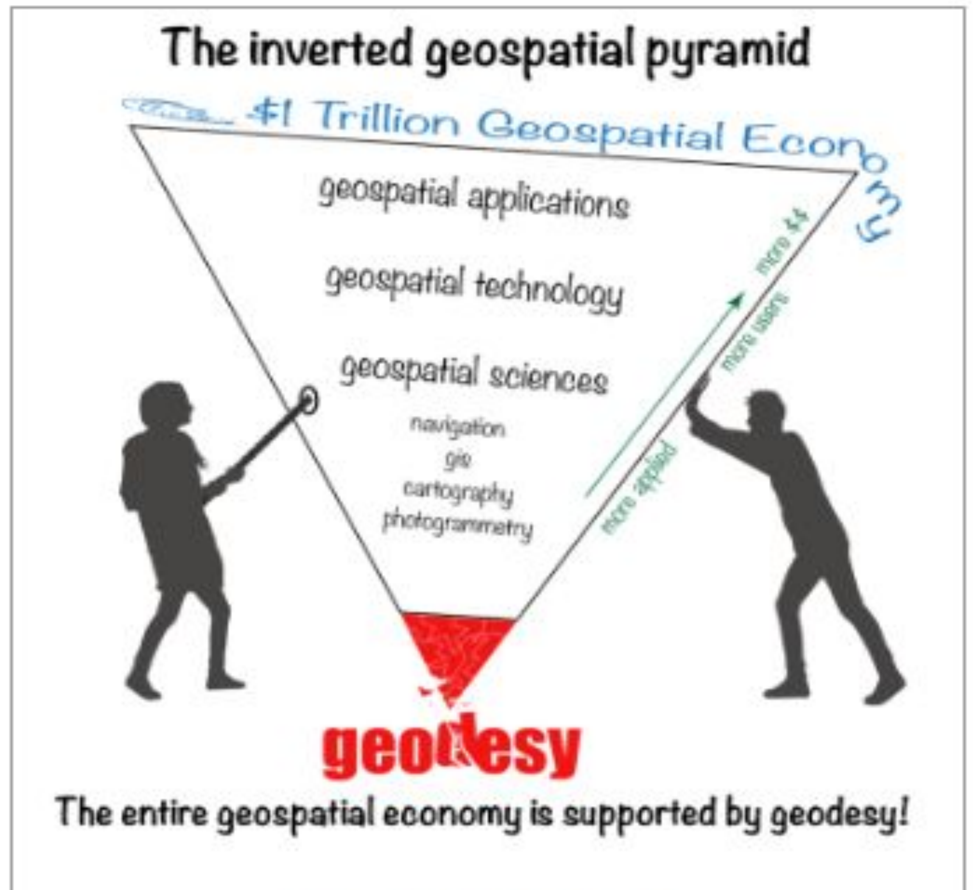


Image: Dana Caccamise II

You are here!


NOAA Administration
National Ocean Service (NOS)
NWS
OAR
OMAO
NESDIS
NMFS
National Geodetic Survey (NGS)
OCS
CO-OPS
IOOS
NCCOS
OCM
ORR
ONMS
Budget and Administration
Research
Reference Systems
Data Analysis
Coastal Mapping
IT

NGS engagement with Federal, State, and local communities

USACE

NGA

USAF

Navy

USCG/FEMA

USGS

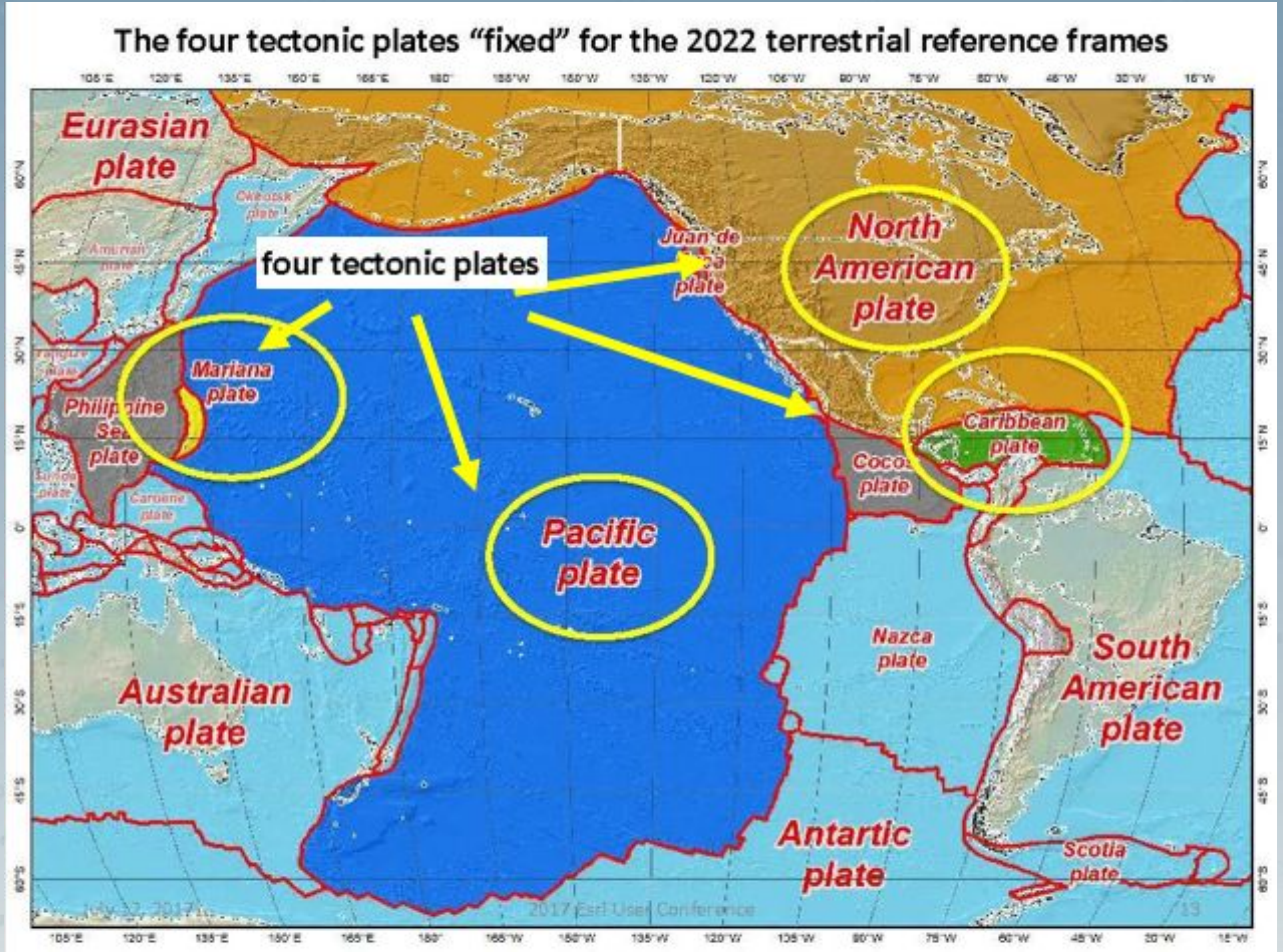
DoT

NASA

Coming soon
(NSRS Modernization)

NSRS Modernization - Geometric

End users will have tools and service to calculate three-dimensional positioning from 4 plate-fixed reference frames that cover the U.S. and its most populated territories (i.e., the ability to determine latitude, longitude and height coordinates relative to an ellipsoid model of Earth)



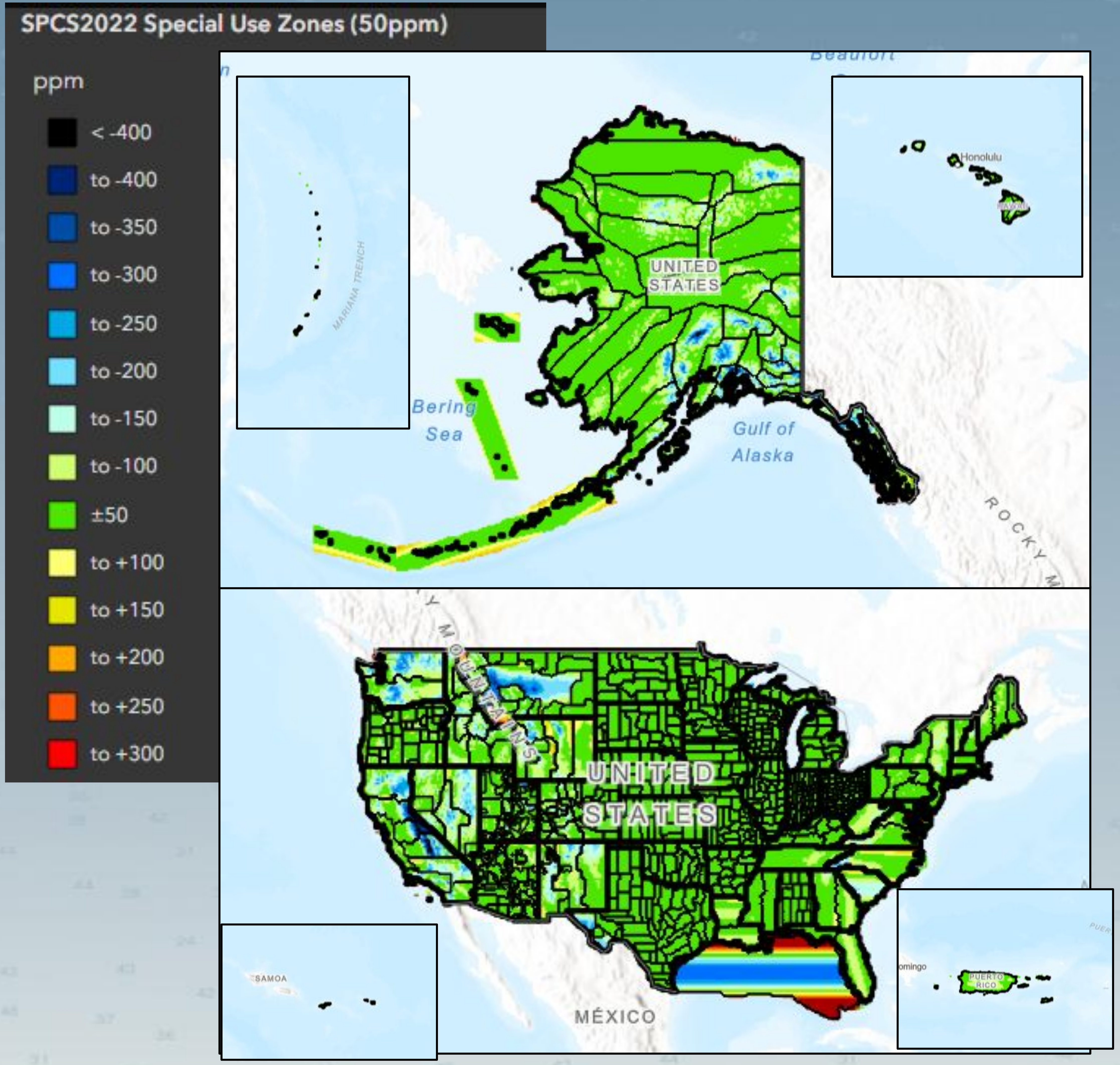
The new reference system will be linked to a global dynamic reference system (i.e., ITRF).

The old		The new
– NAD 83 (2011)	➡	– NATRF
– NAD 83 (PA11)		– CATRF
– NAD 83 (MA11)		– PATRF
		– MATRF

State Plane Coordinate System of 2022 (SPCS2022)

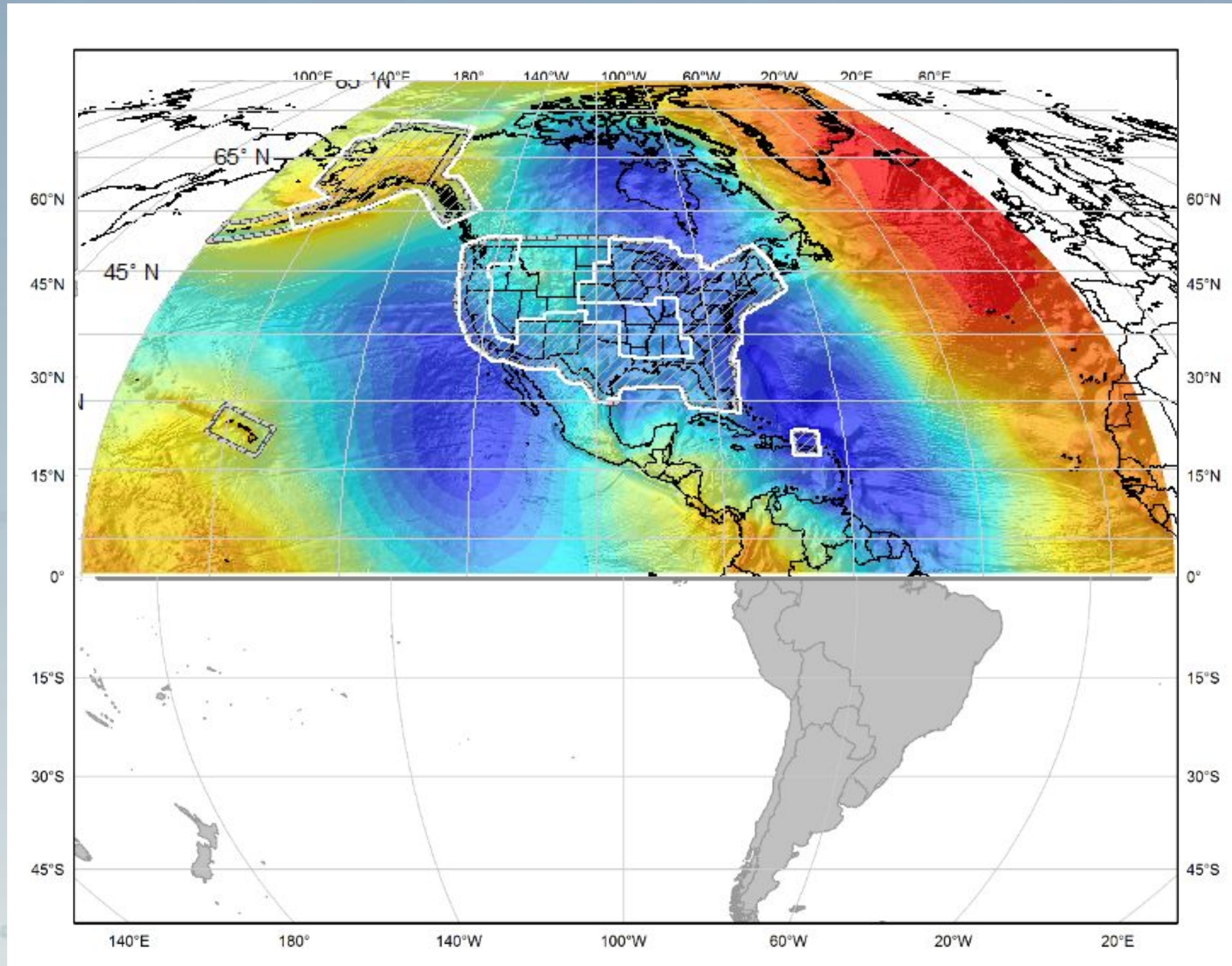
SPCS2022 is the third generation of the State Plane Coordinate System (SPCS). SPCS2022 will be referenced to the **four 2022 Terrestrial Reference Frames**.

SPCS2022 will have up to three zone layers in each state, and the number of zones will vary greatly between states. Every U.S. state and territory will have a statewide zone.

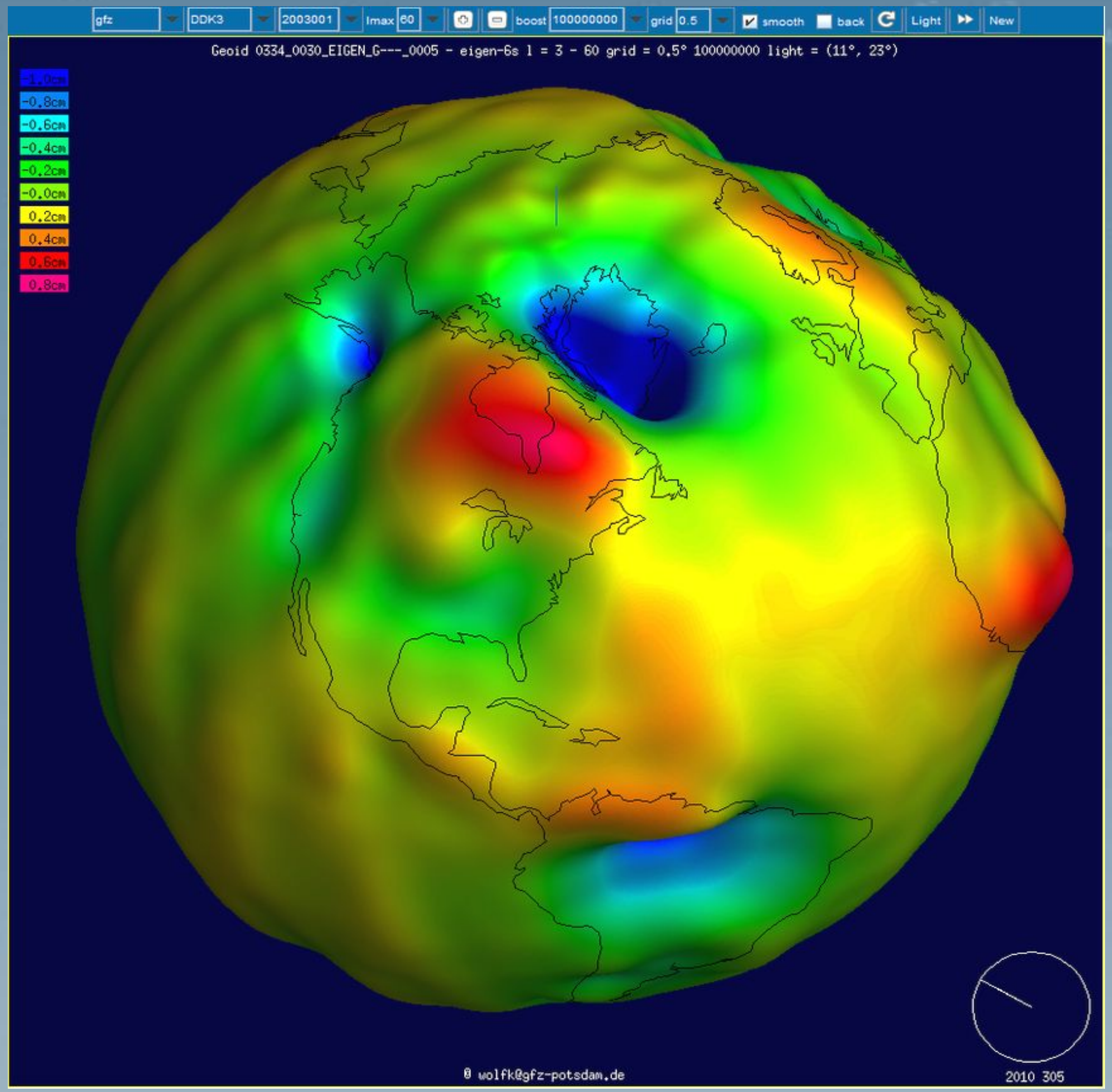


North American – Pacific Geopotential Datum of 2022 (NAPGD2022)

A new geopotential datum using a vertical reference system calculated from gravity observations. **The geopotential surface does not take into account oceanographic processes, such as tides and currents**.



“North American region”
- ¼ of the Earth



GGM derived from EIGEN-6c2 model Provided on ICGEM website

This geopotential is of particular importance at the coast where it is necessary to ensure that **geophysical and oceanographic observations**, **and resulting coastal models**, can be consistently aligned with terrestrial applications.

Long-term Research

Short-Term plans

Modernizing the NSRS

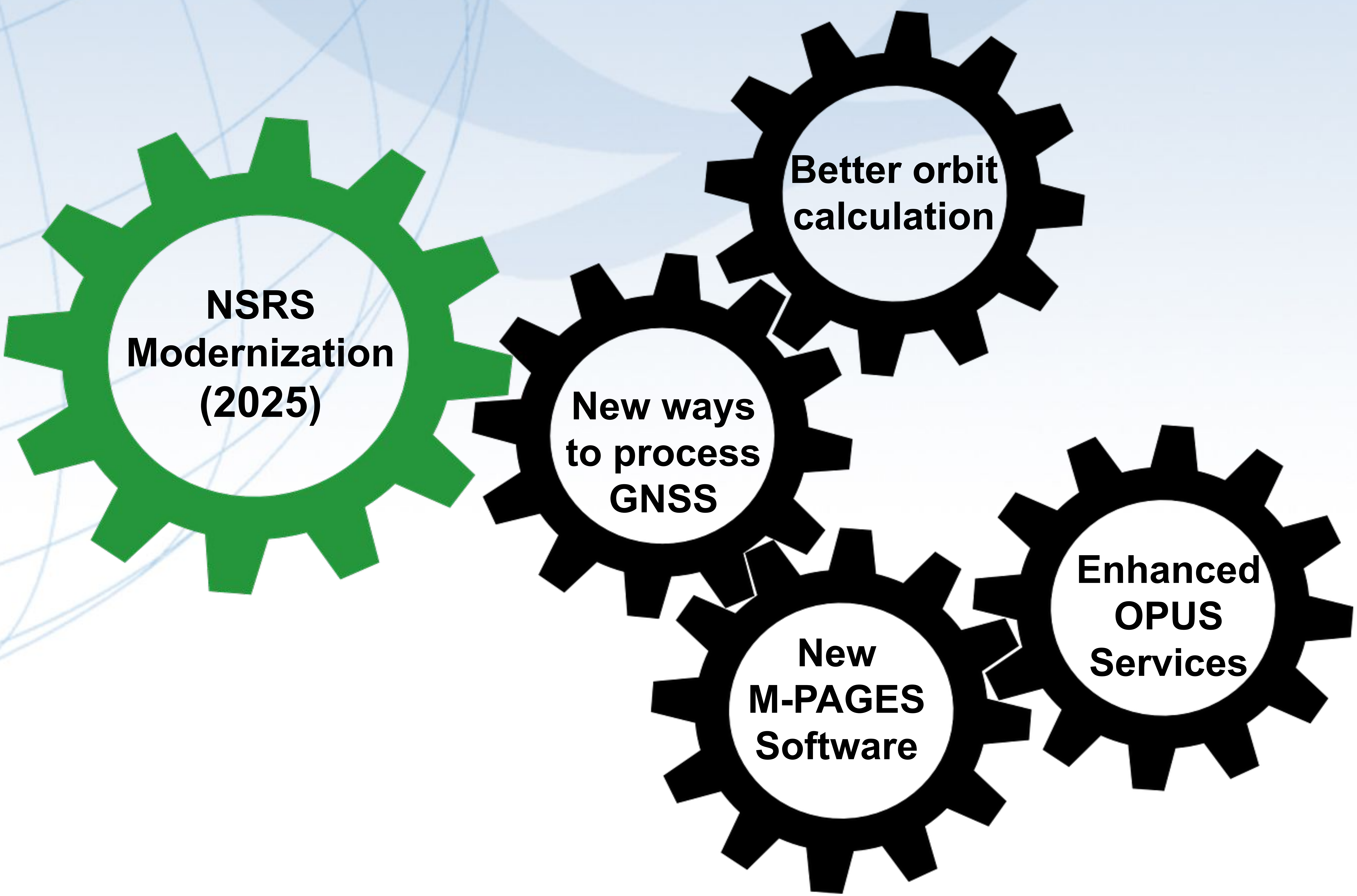
- Geometric
- Geopotential
- Campaigns
- IT Infrastructure

Tools and Services

- OPUS/CORS/Orbits
- Transformations and adjustments

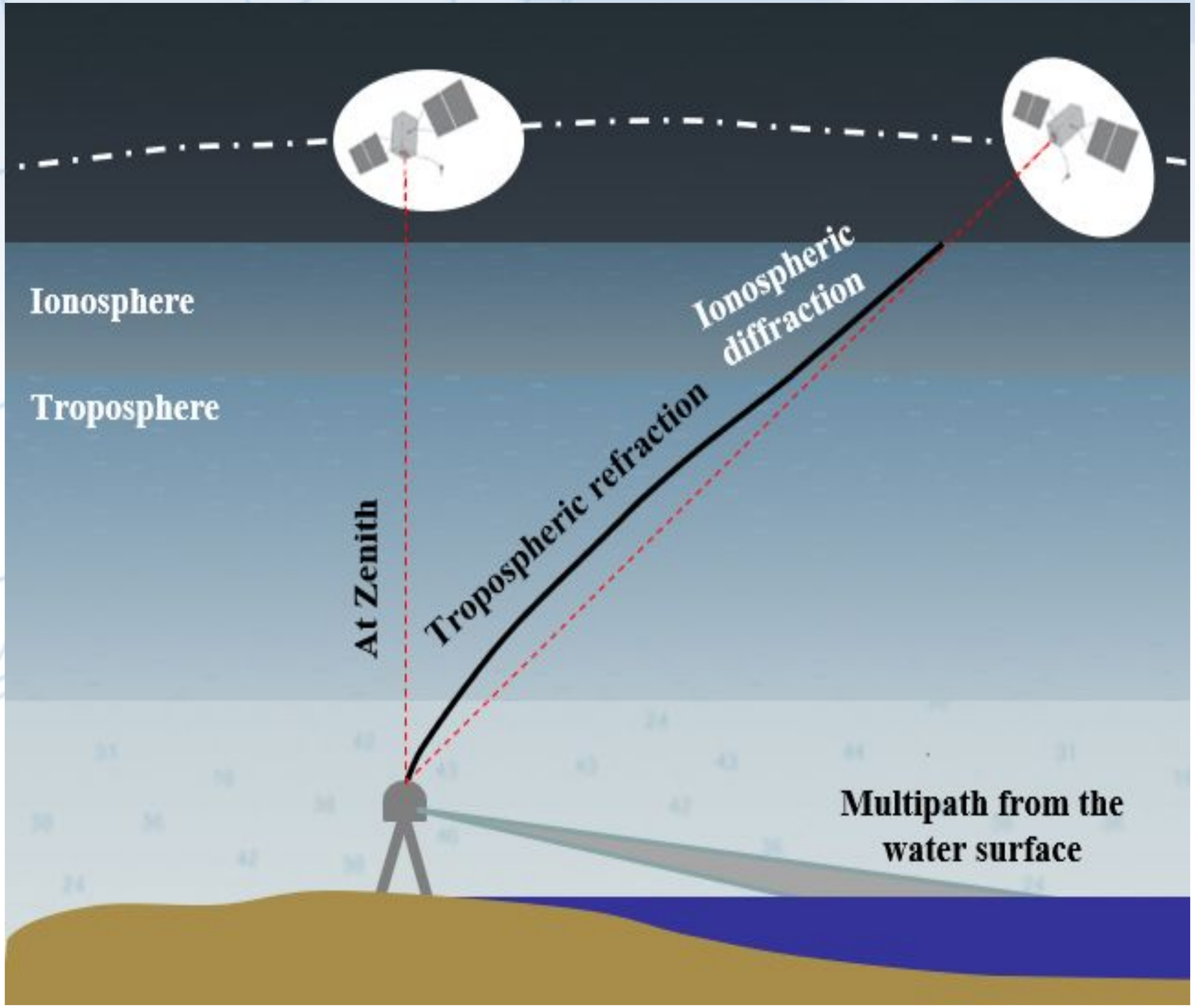
Updating and expanding the CMP

International engagement


NSRS Modernization (2025)
Better orbit calculation
New ways to process GNSS
New M-PAGES Software
Enhanced OPUS Services

Advance space geodesy

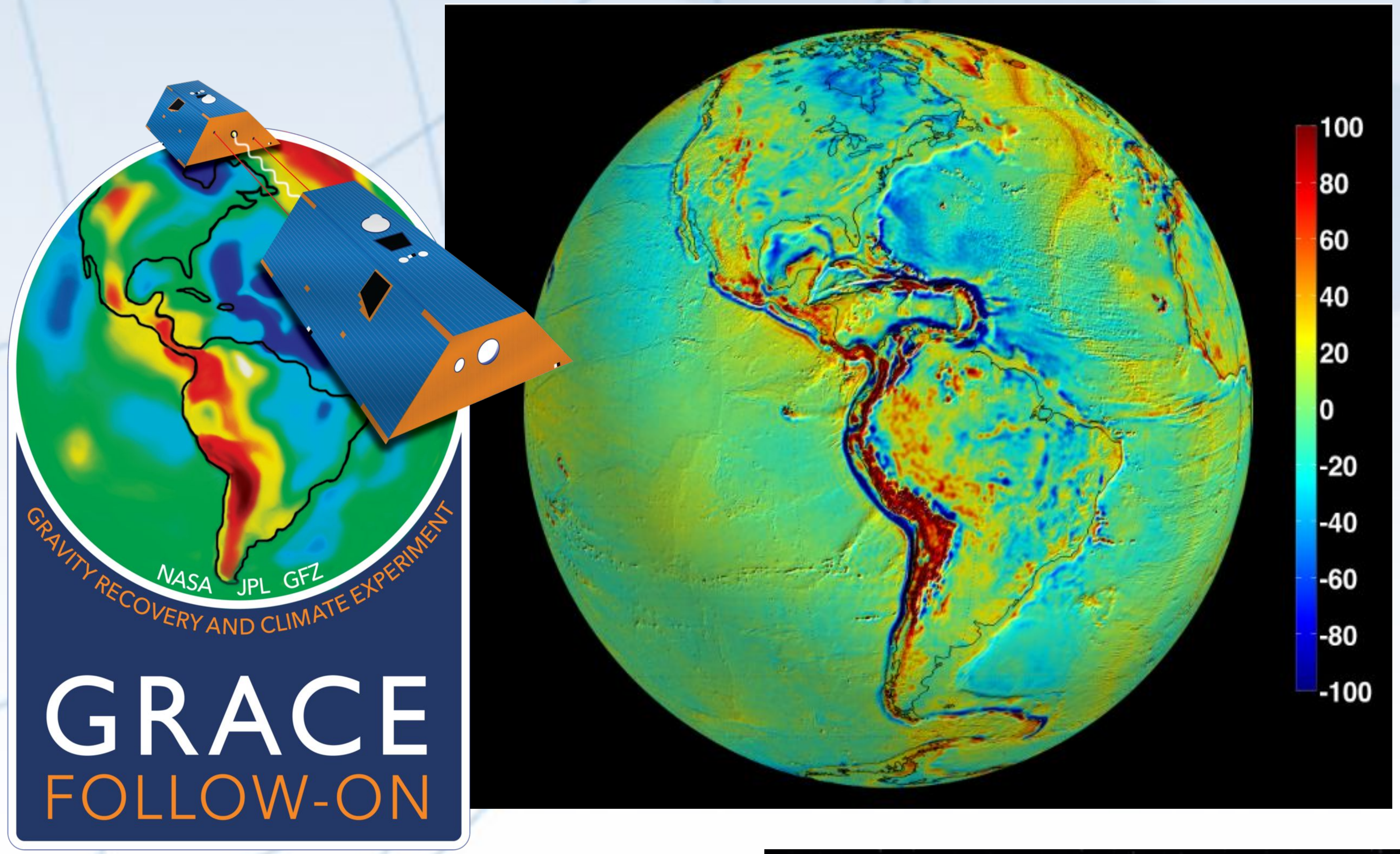
Observing and monitoring Earth

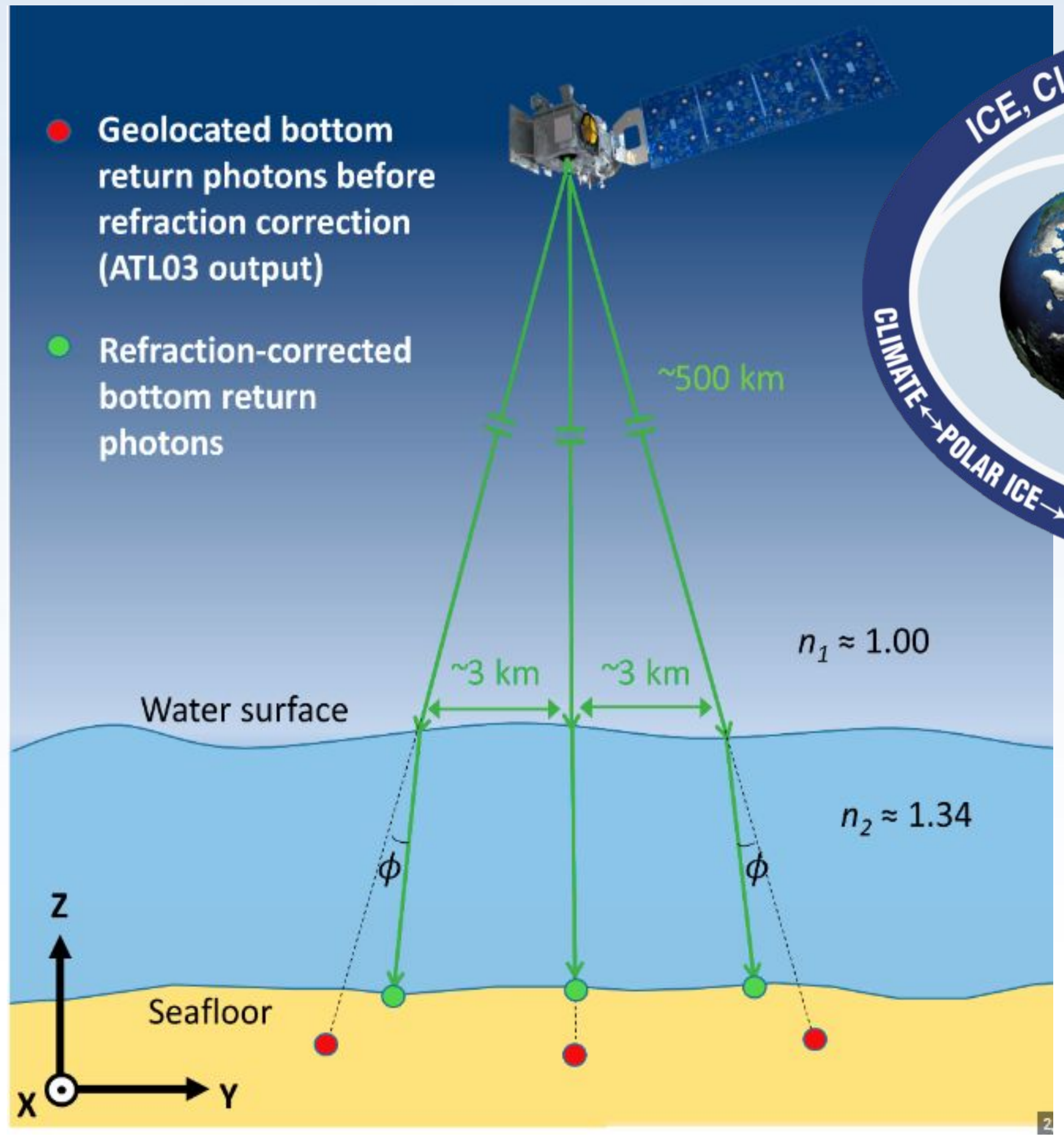


Learning about Earth systems through geodetic observations:

- Land elevation (e.g., PPP)
- Water surface (e.g., GNSS-R)
- Water vapor (GPS-MET)
- Total Electron Content (GPS-ION)
- Orbit calculations
- Clocks

Space missions supporting geodesy

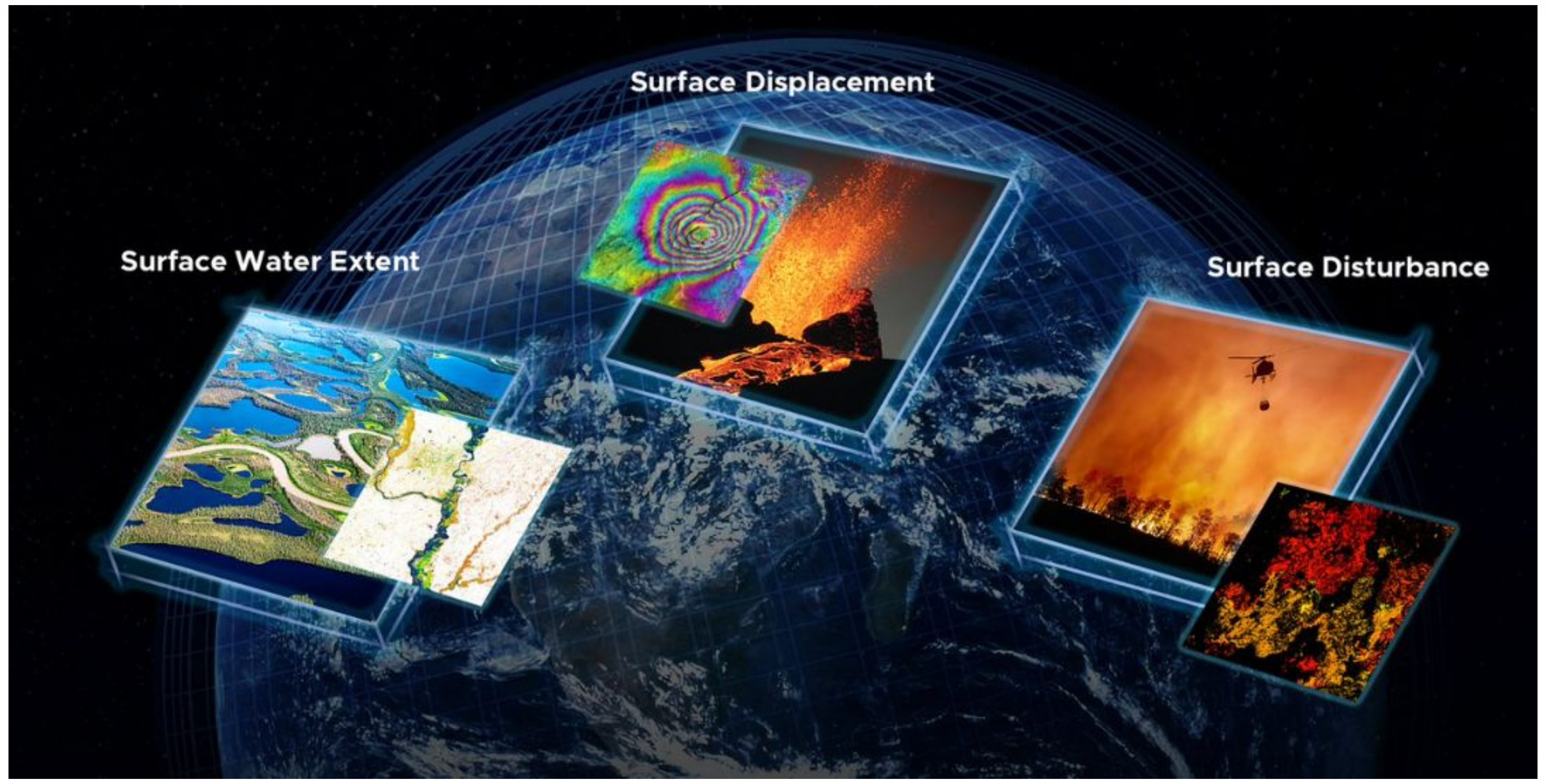




ICE, CLOUD, & LAND ELEVATION SATELLITE

ICESAT

NASA



Observational Products for End-Users from Remote Sensing Analysis (OPERA) project (April, 2021)

Surface Water and Ocean Topography (SWOT) (Launched: 12/16/2022)

SWOT

SURFACE WATER & OCEAN TOPOGRAPHY

Develop the next generation of NSRS

Ideas???

Leveraging legacy datasets

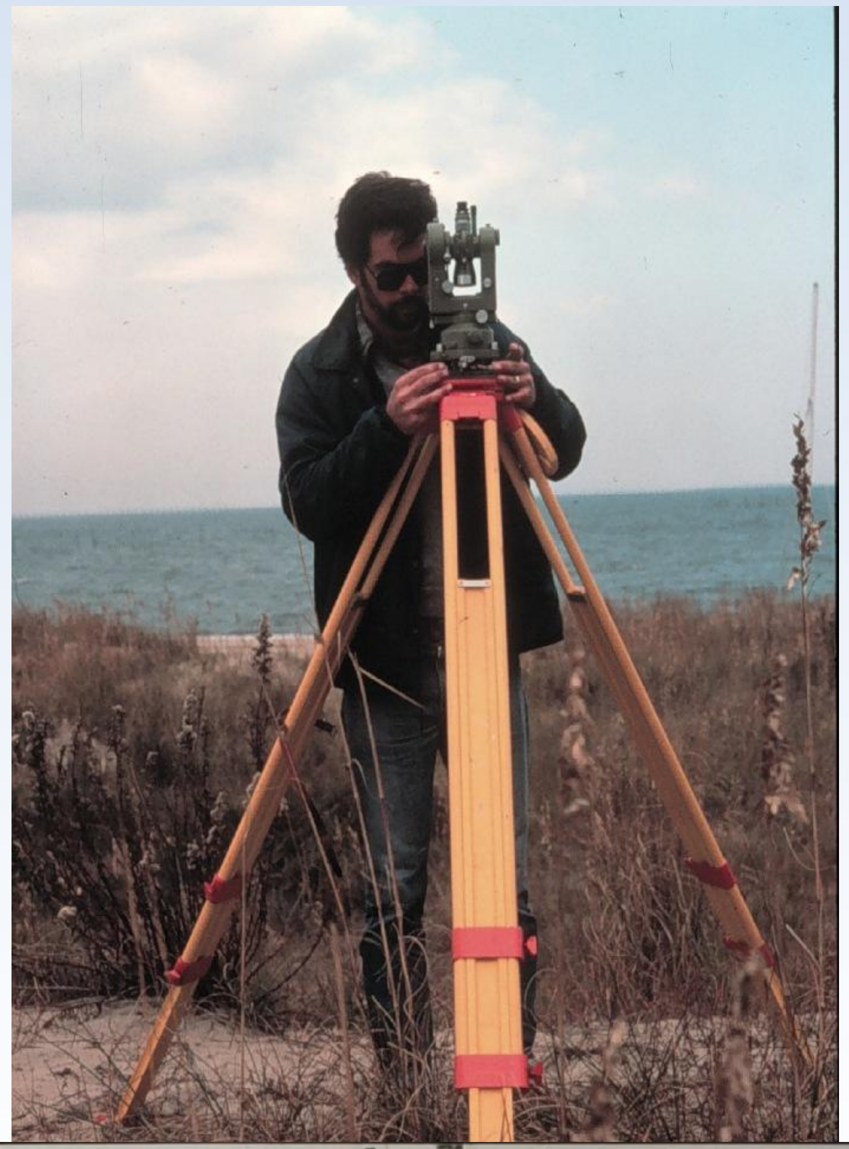
By correct attribution, it possible to leverage the 200 years of observations* to supplement modern-day observations:

- Dynamic observation of the geometric and geopotential surfaces.
- Climate-scale observations and monitoring.
- Change detection.

* Requires metadata

Theodolite (1922)

Theodolite (1990)



Sextant Target (1916)

Shoreline Mapping

Utilizing all geodetic observations

GNSS

- Network solutions
- GNSS ION/MET
- GNSS-R

Coastal mapping

- Imagery (Aerial/Satellite)
- Shoreline mapping
- Topo-bathy LIDAR

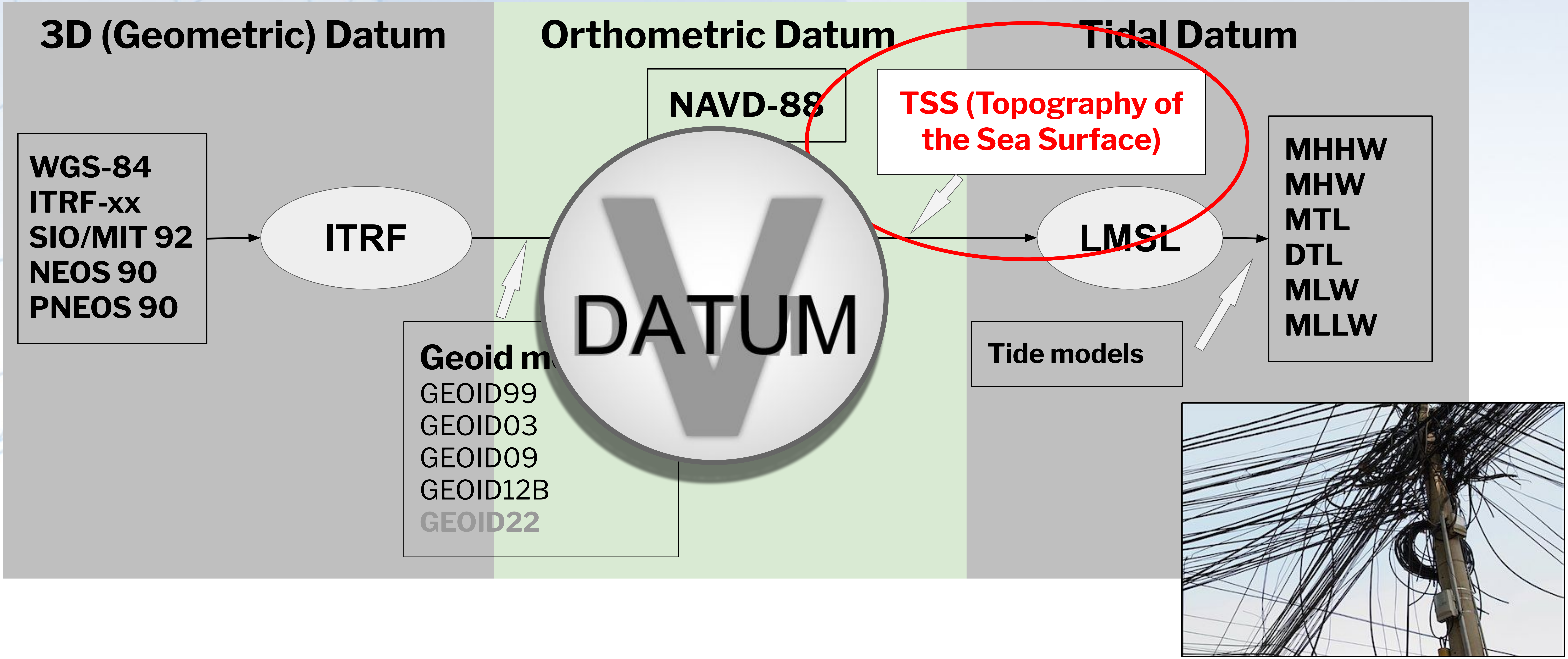
Gravity observations

- Absolute gravity (Terrestrial)
- Relative gravity (Terrestrial)
- GRAV-D (Aerial)
- Satellite (GRACE/GOCE)

Field operations

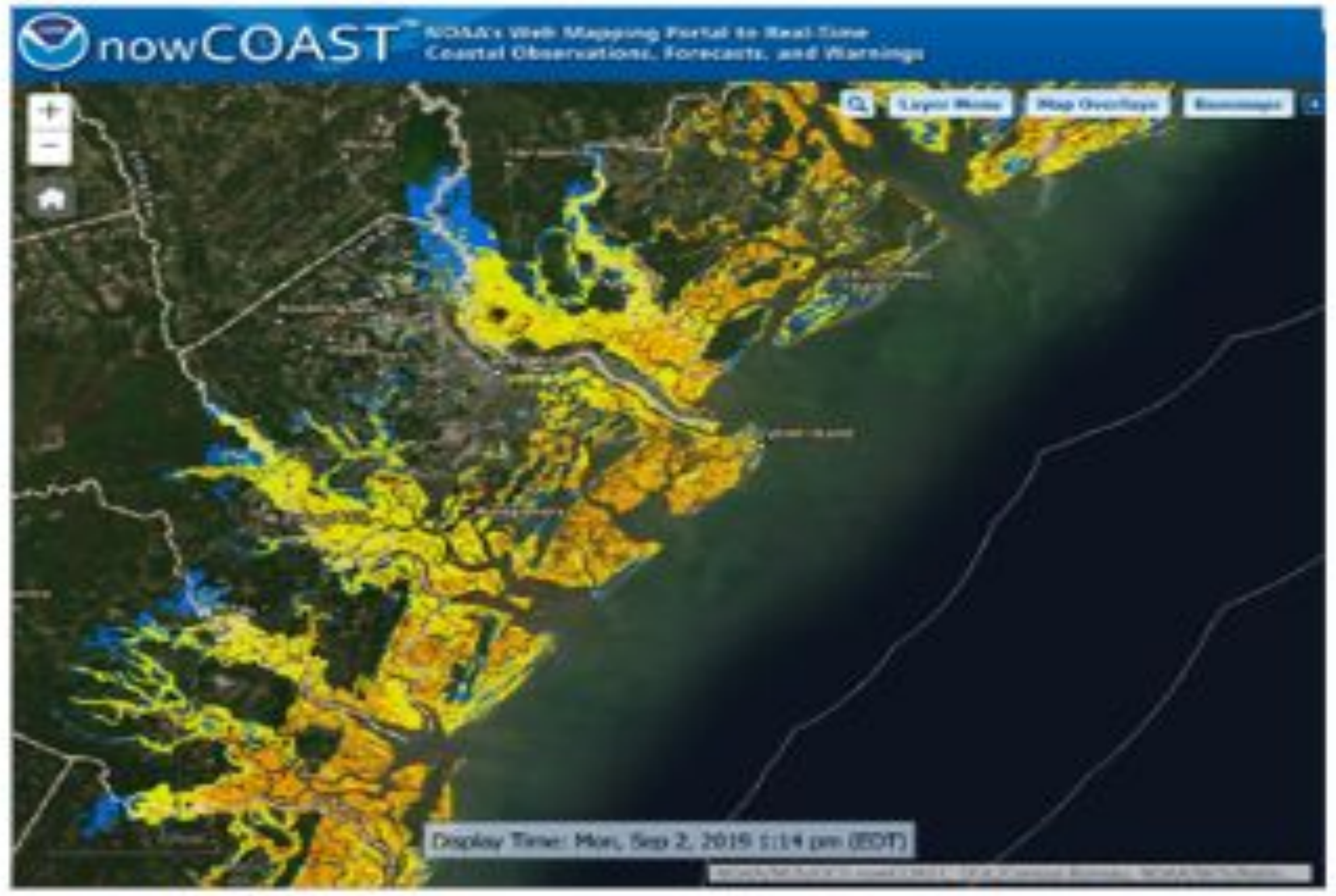
- Leveling
- Lever-arm calculations

More reference systems?
VDatum it!



Why should we care about developing and maintaining reference systems?

(Depositphotos.com)

Safe, Efficient Navigation	Risk Reduction	Total Water Level
		
Schematic illustration of S-1XX and S-4XX layers (IHO.int)	Aftermath of Hurricane Michael in Mexico Beach, FL. (AP Photo/Gerald Herbert)	NWS Potential Storm Surge Flooding Map for Hurricane Dorian (NowCOAST - 9/2/2019)

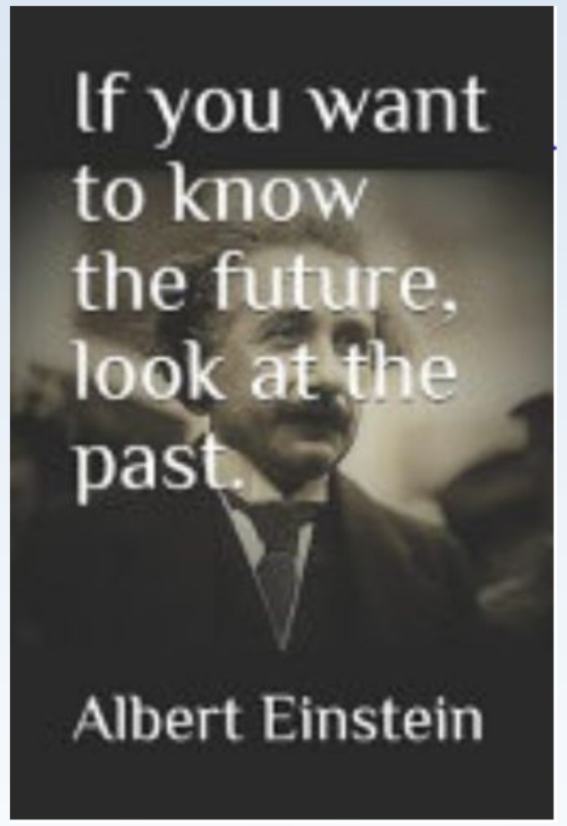
Important note!

All elevation data should be processed to the <u>same</u> horizontal and vertical reference system

https://stock.adobe.com/

Alternate positioning, navigation, and timing (PNT)

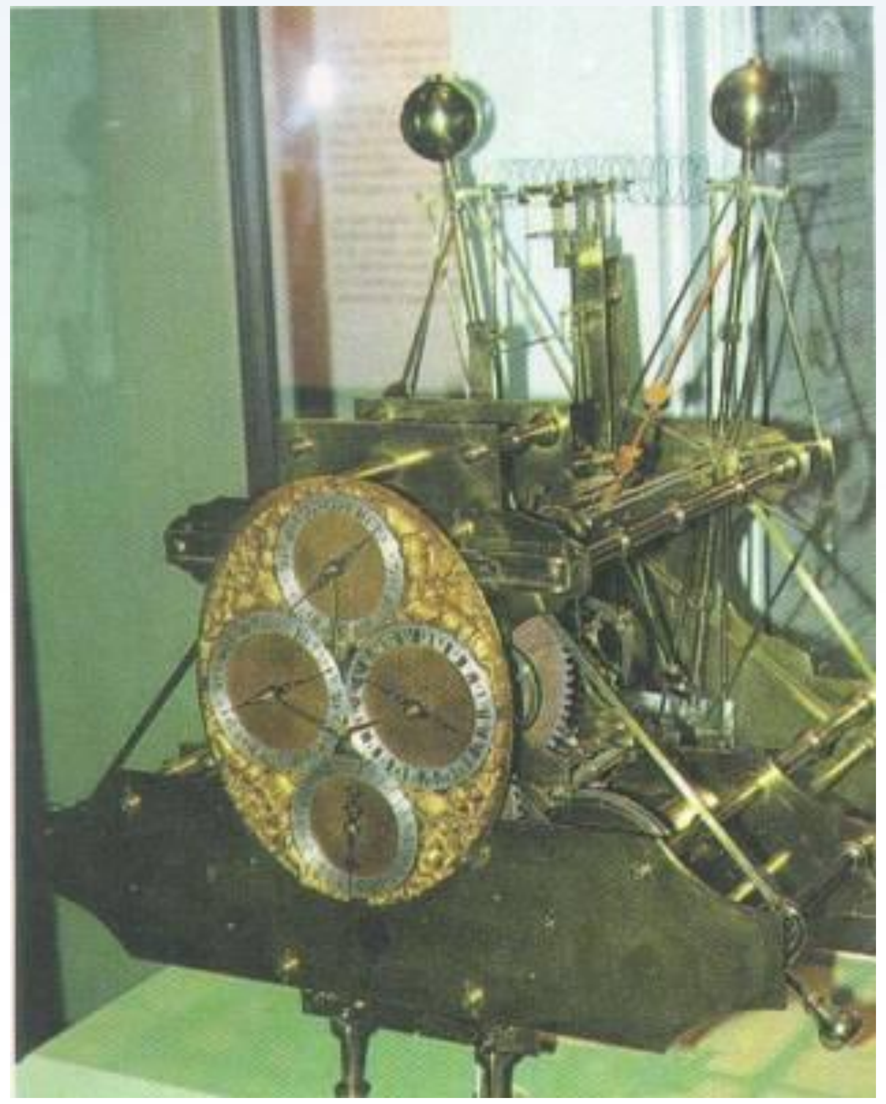
"You have to know the past to understand the present." (Carl Sagan, 1980)



Latitude

Phoenicians used the constellation Ursa Minor to determine their latitude (~600 BC). Arabs were known to measure the Altitude of the sun at noon in order to determine their latitude.

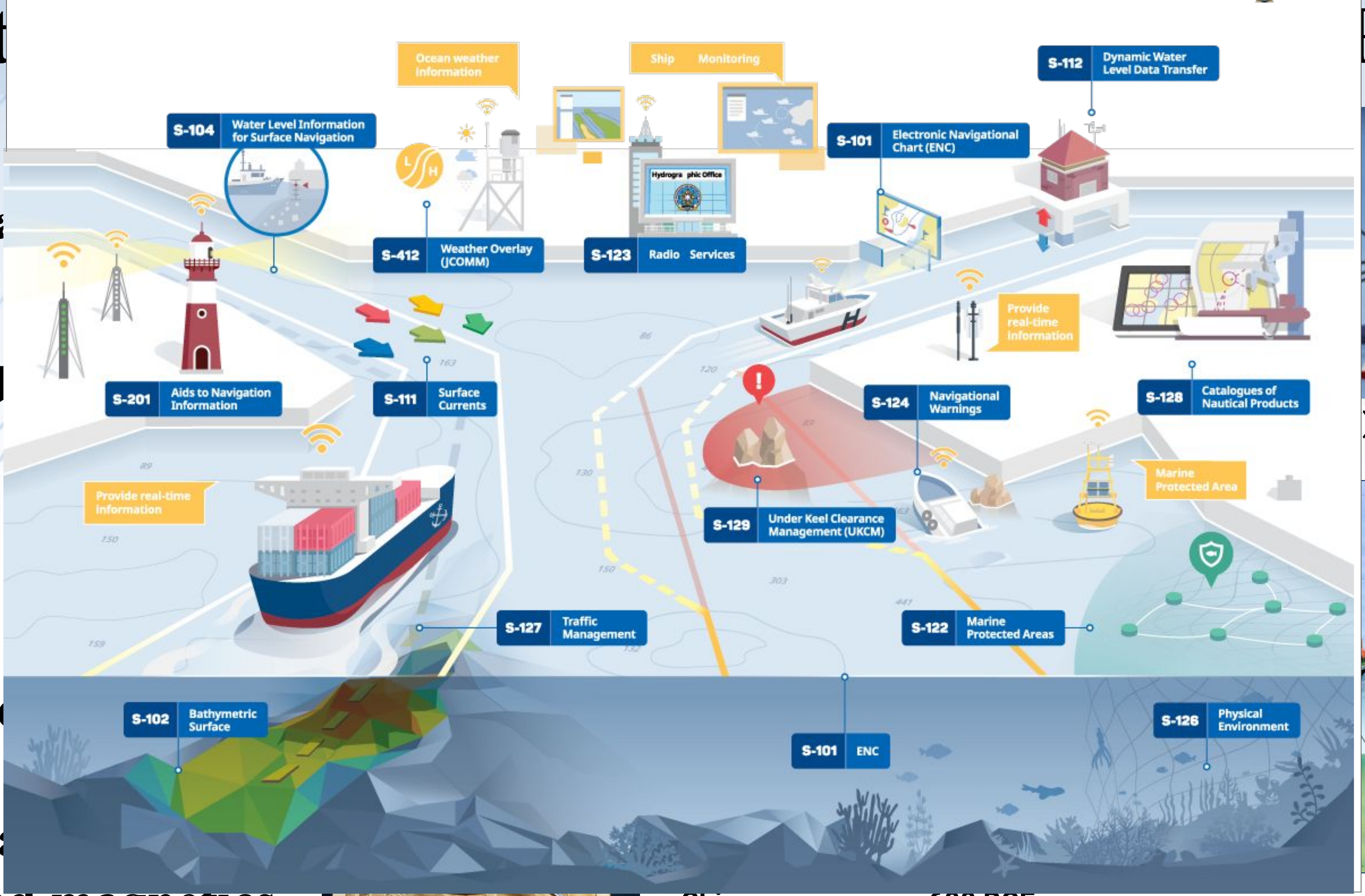
Longitude



"It was impossible to determine longitude out of sight of land until the development of accurate and reliable chronometers" (Harrison's clock, 1736). With the advent of chronometers seafarers began to chart the geography of the oceans (Magellan - early 1500's, Cook - 1770's, etc).

Alternat ... PNT)

Schematic illustration of S-1XX and S-4XX layers (Source: IHO.int)



Ground-Ba

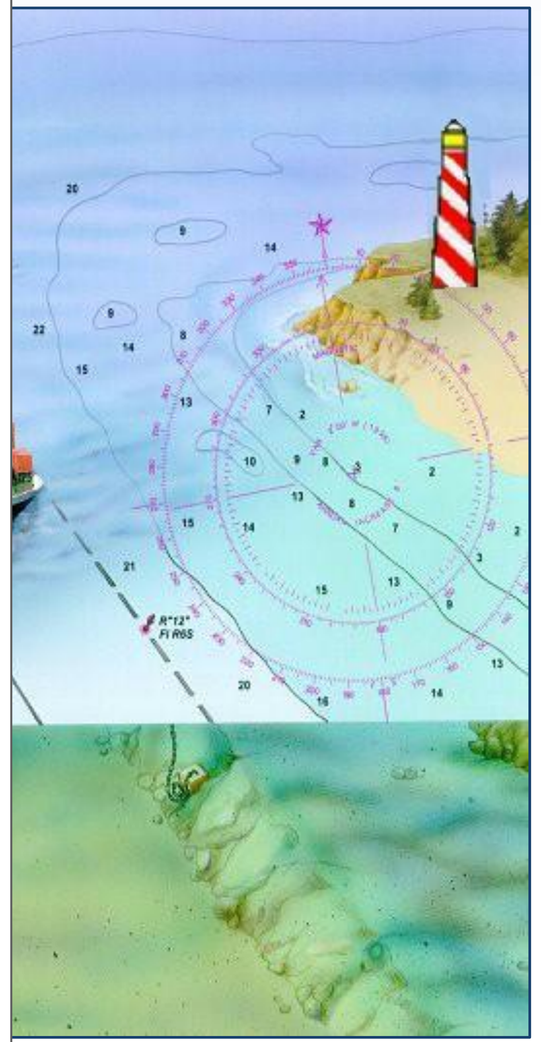
Celestial o

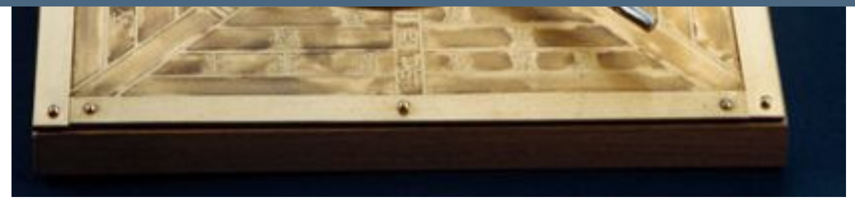
DEM

Feature re

Geophysic

Gravity and magnetics





Chinese compass - 600 BCE
(www.smith.edu/hsc/museum/ancient_inventions/compass2.html)

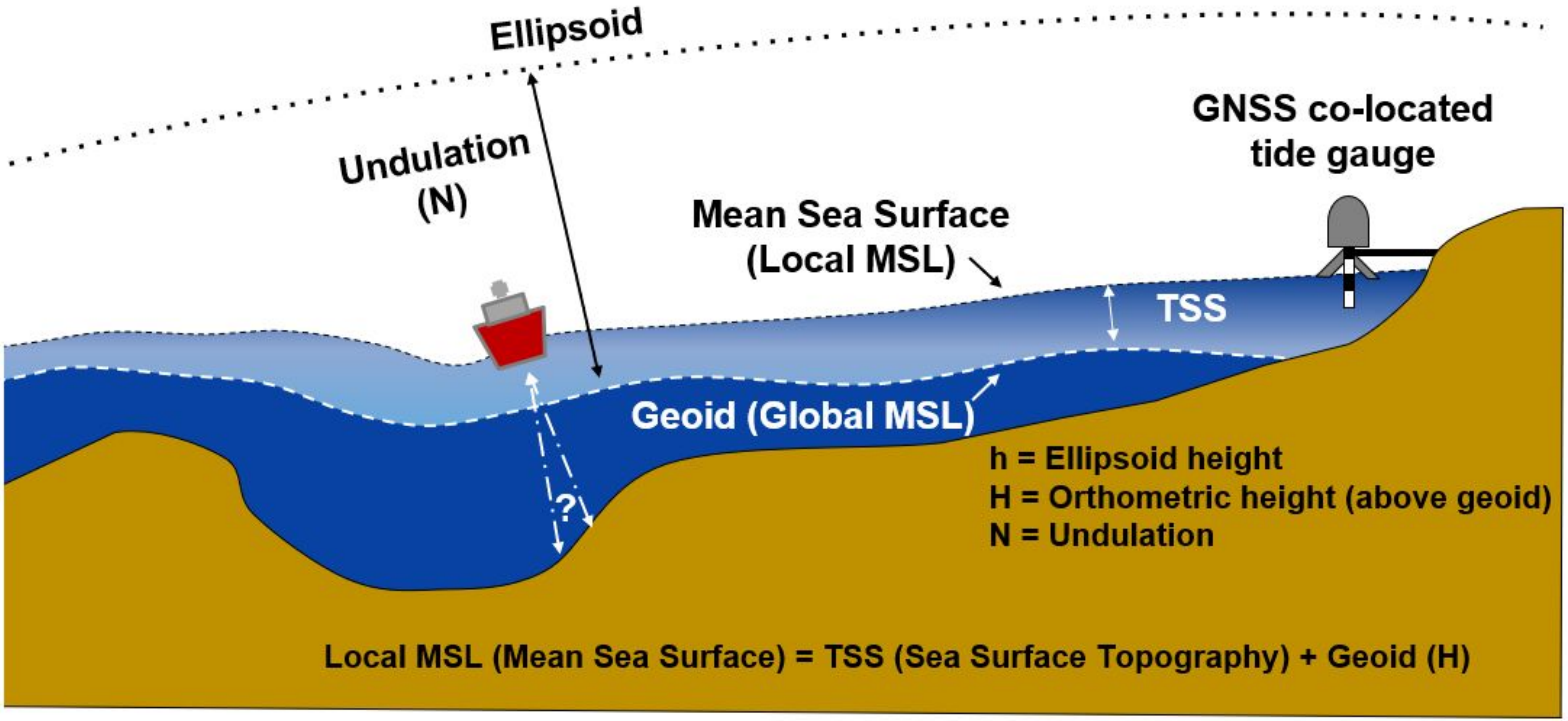
Enhance marine and riverine geodesy

Safe Efficient Navigation - Geodetic control

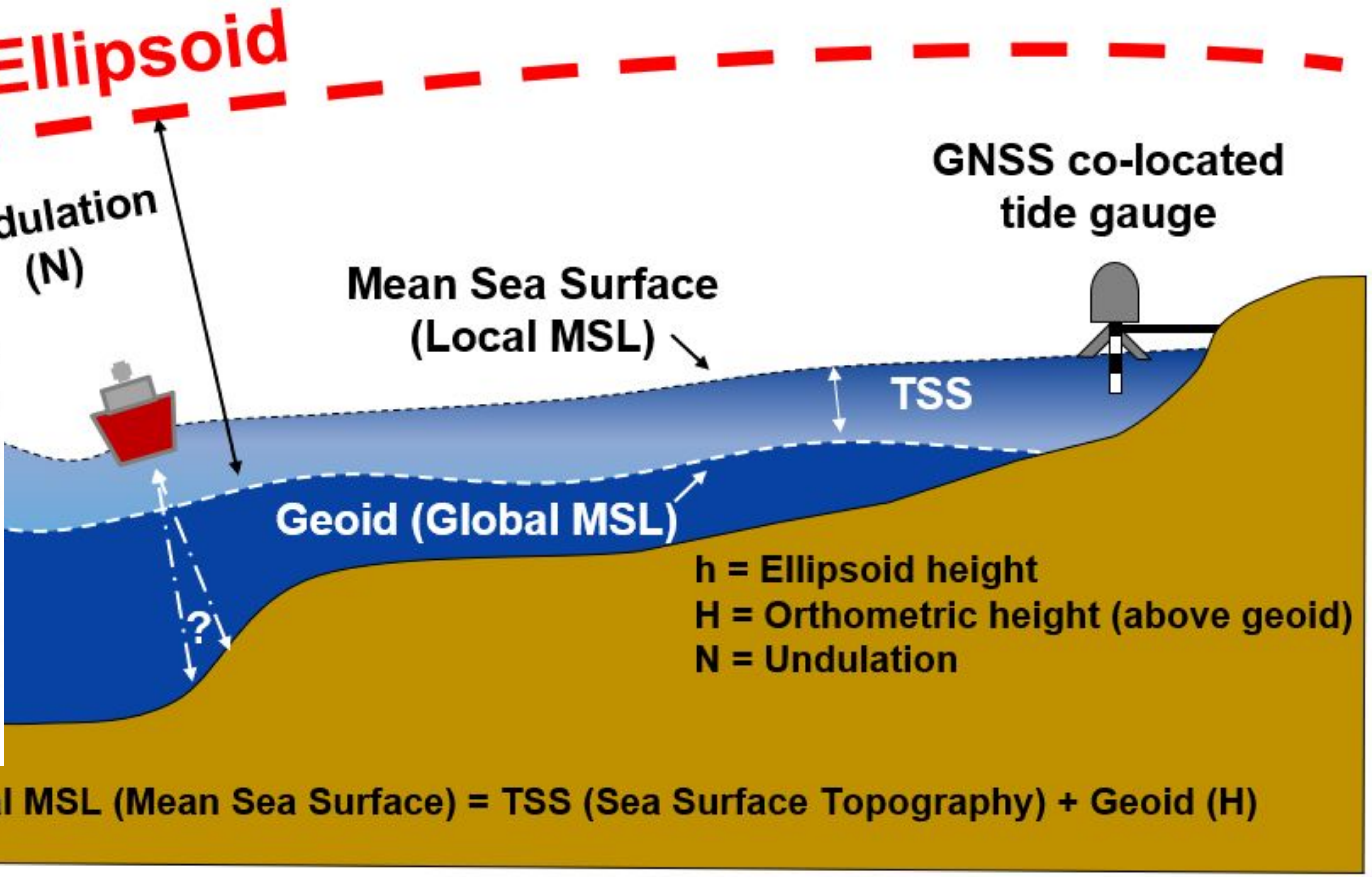
Safe, Efficient Navigation

Schematic illustration of S-1XX and S-4XX layers (IHO.int)

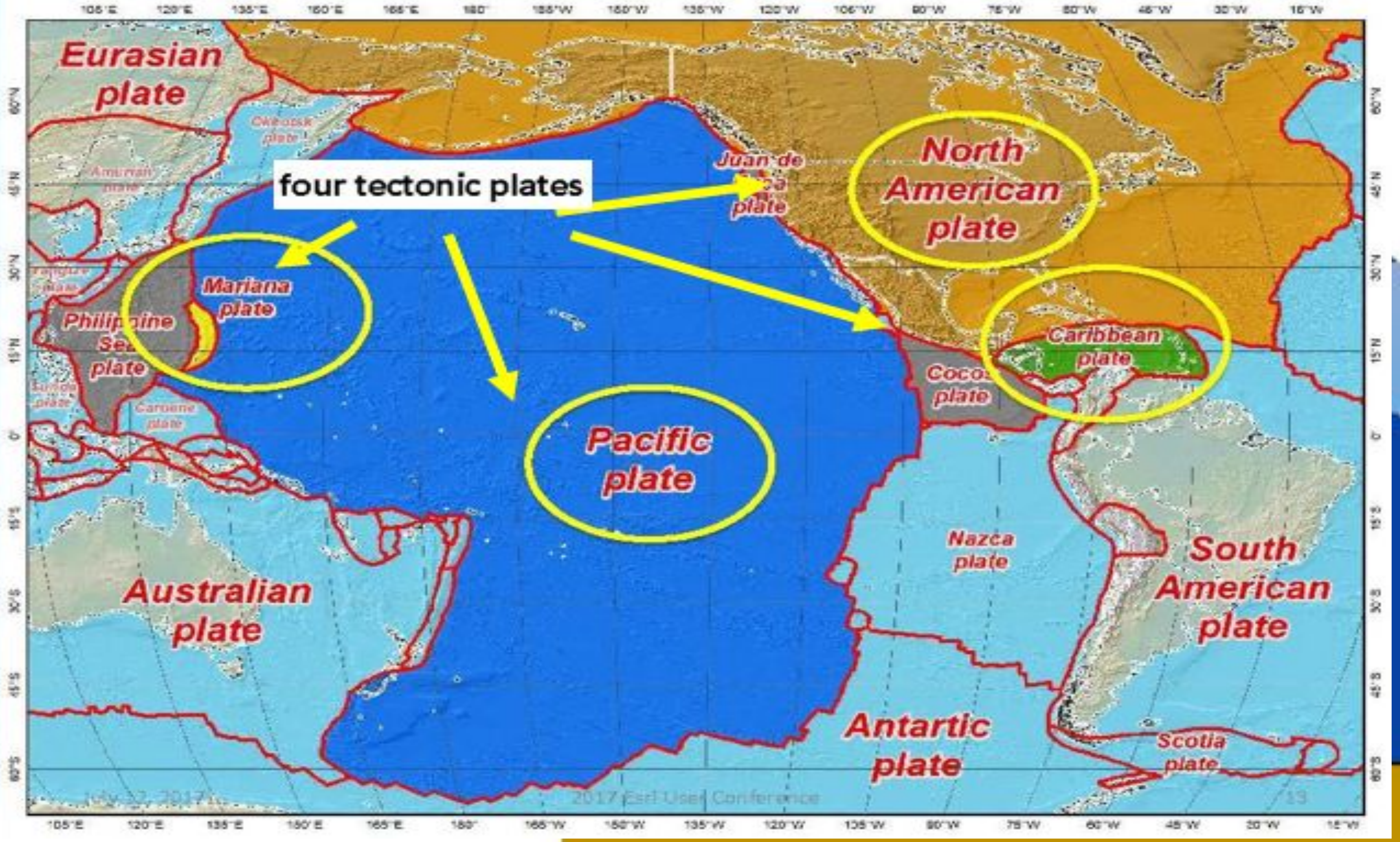
Height relationships



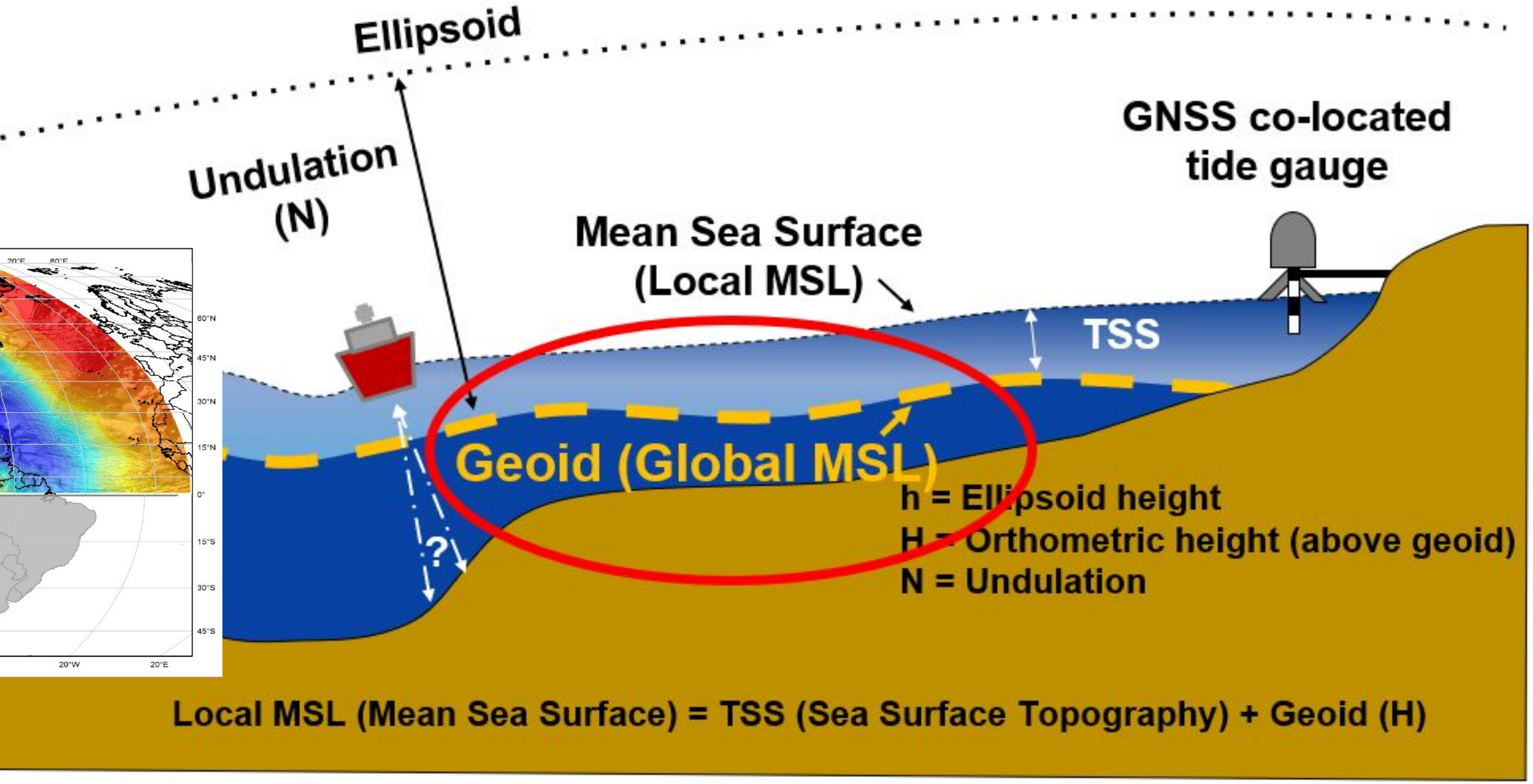
Height relationships

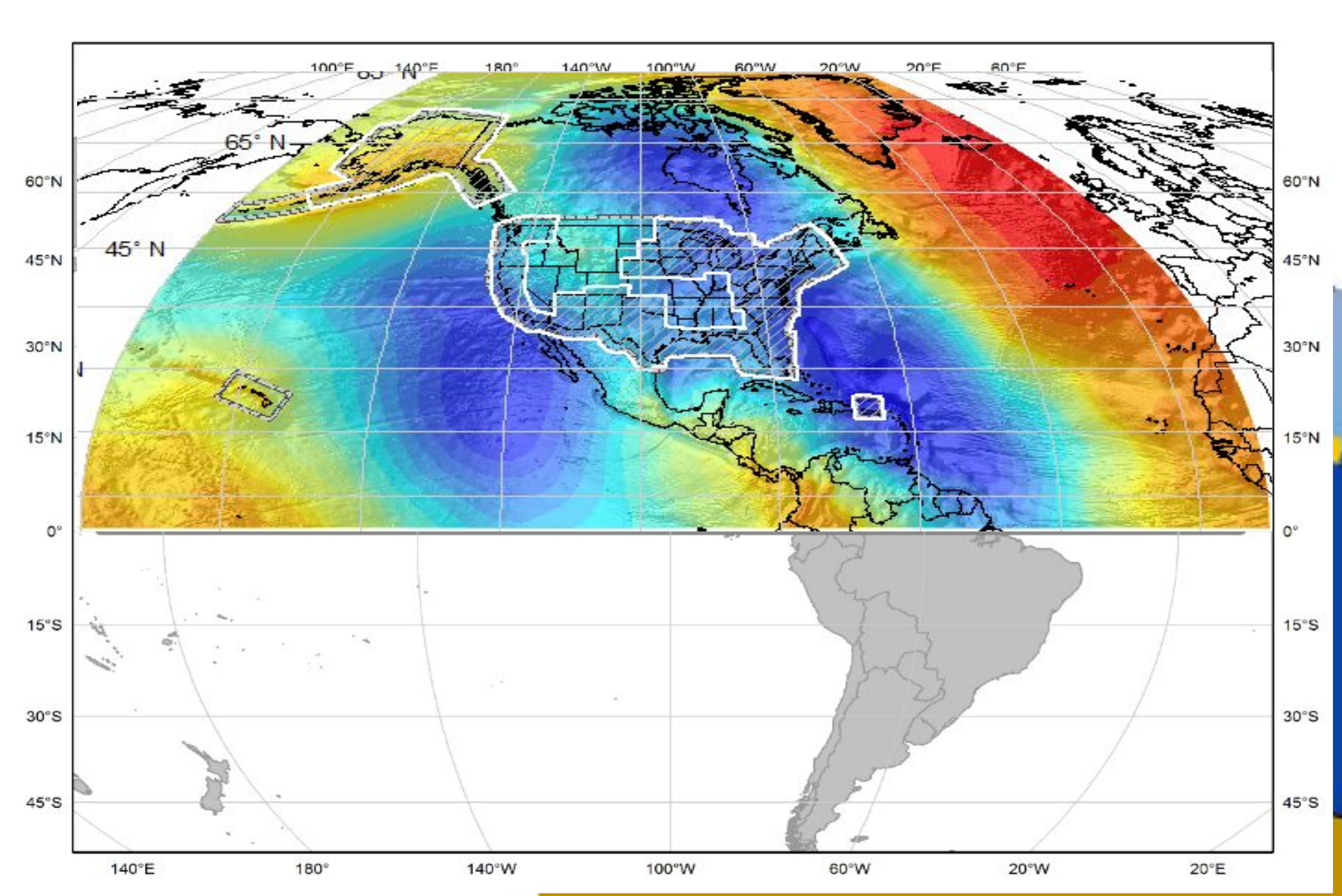


The four tectonic plates "fixed" for the 2022 terrestrial reference frames



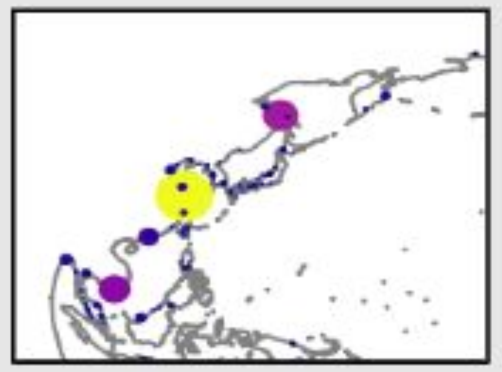
Height relationships



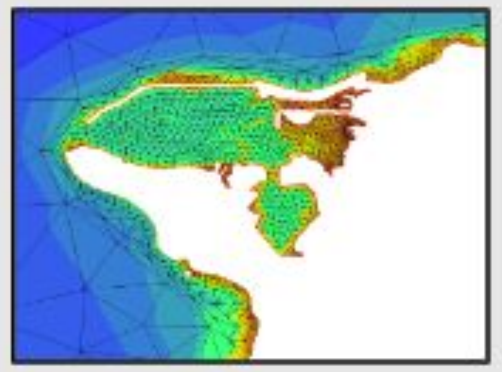


Height relationships

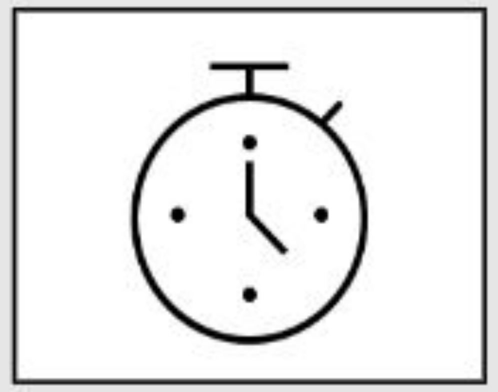
Regional coverage at high resolution circulation models



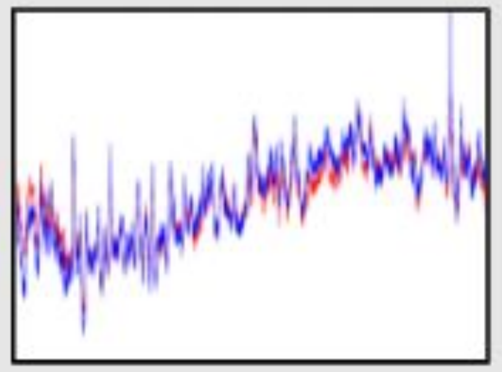
Implementation



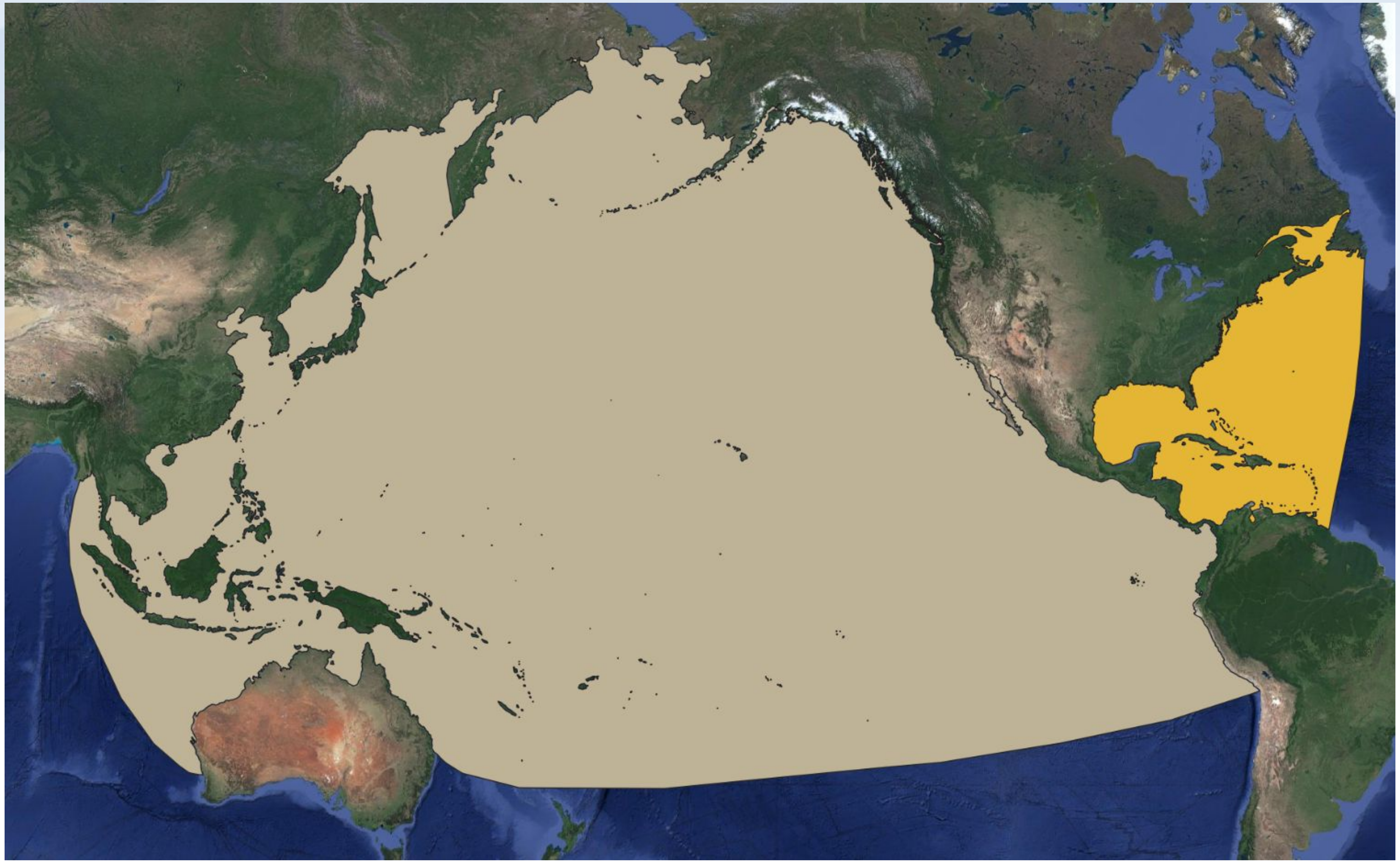
High resolution



Computational efficiency



Water levels



Images courtesy of OCS/CSDL/CMMB

Height relationships

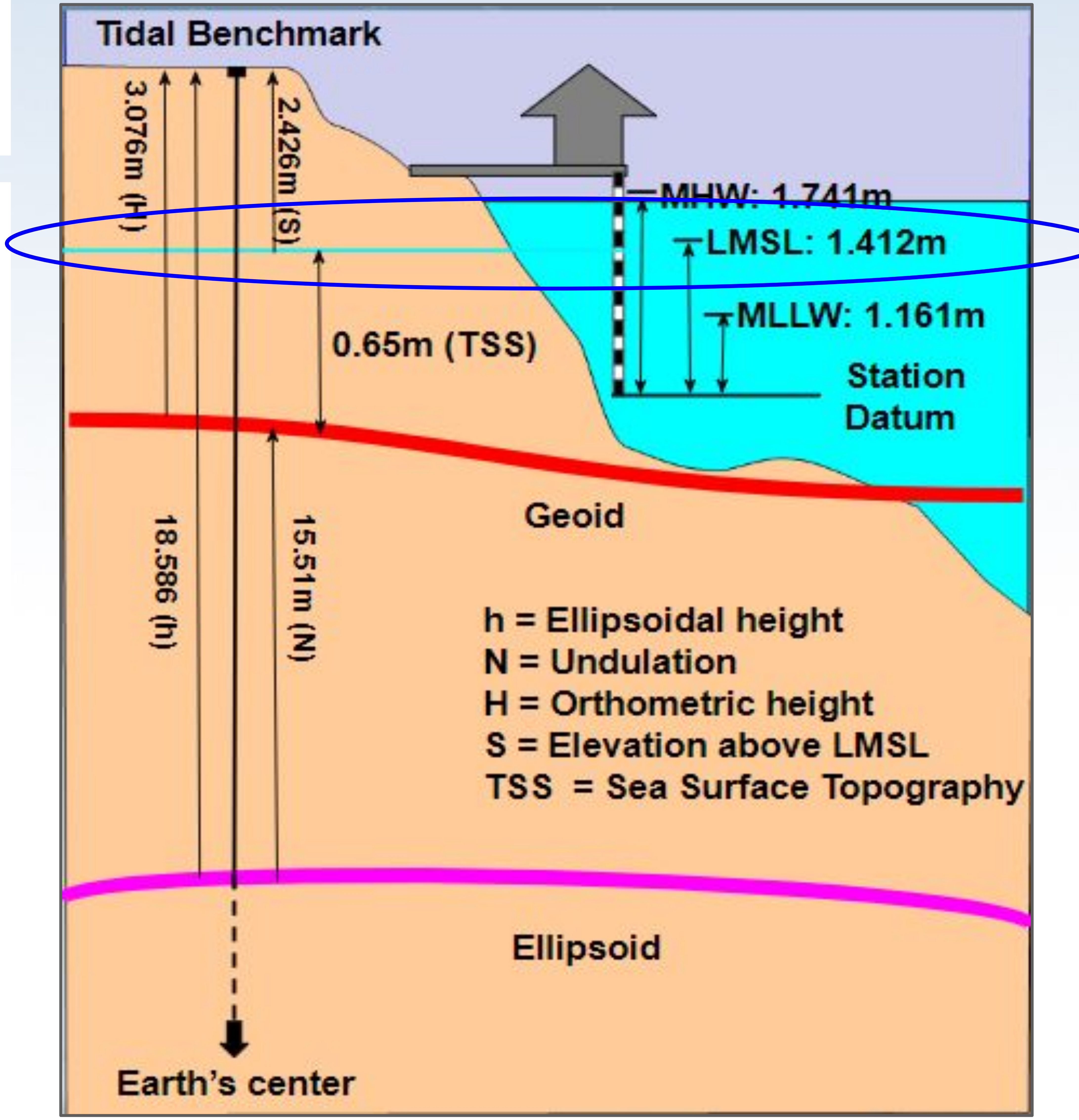
Referencing the circulation models to Tidal Datum

Will additional observations improve the TSS products and the VDatum results overall?

Using a **co-located GNSS water level observation**, it is possible to reference the water level information directly to the ellipsoid with knowing the deformation model (e.g., tidal loading) of the benchmark.

As such, three key component are needed to evaluate the **total propagated uncertainty (TPU)** of the observation:

- **Accuracy of the sensor**
- **Geodetic control**
- **Length of observation**



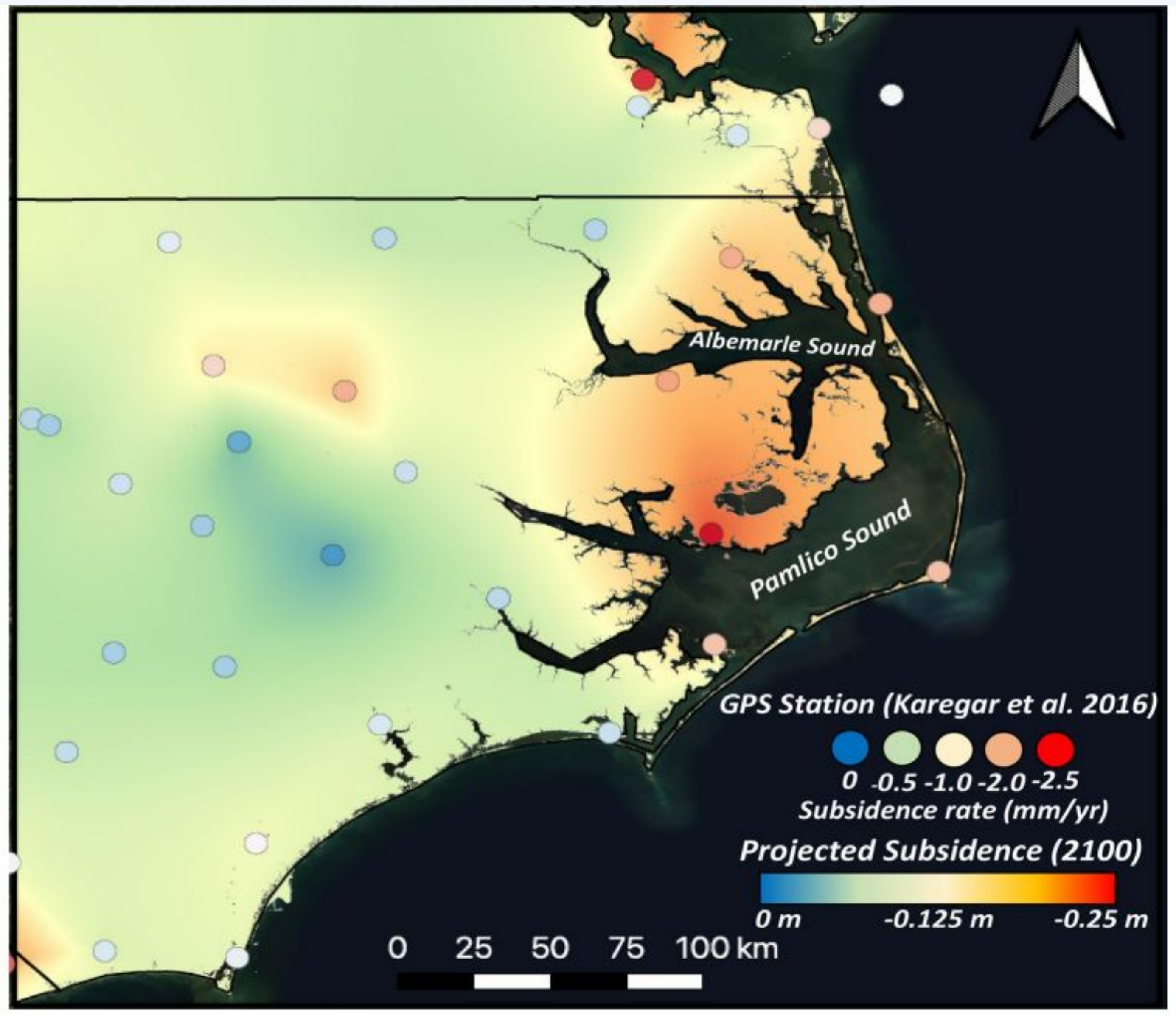
Develop a national deformation model

Vertical Land Deformation

Land deformation monitoring (also known as, **Intra-Frame Deformation Model, IFDM**) is needed for updating the passive benchmark network. This has traditionally be done using GNSS and leveling campaigns.

This vertical land deformation models, VLMs, can also be used:

- **Syncing inter-agency geohazard monitoring (plate tectonics)**
- **Linking into ground water activities (subsidence)**
- **Calculating Sea Level Rise (decoupling the land signal)**

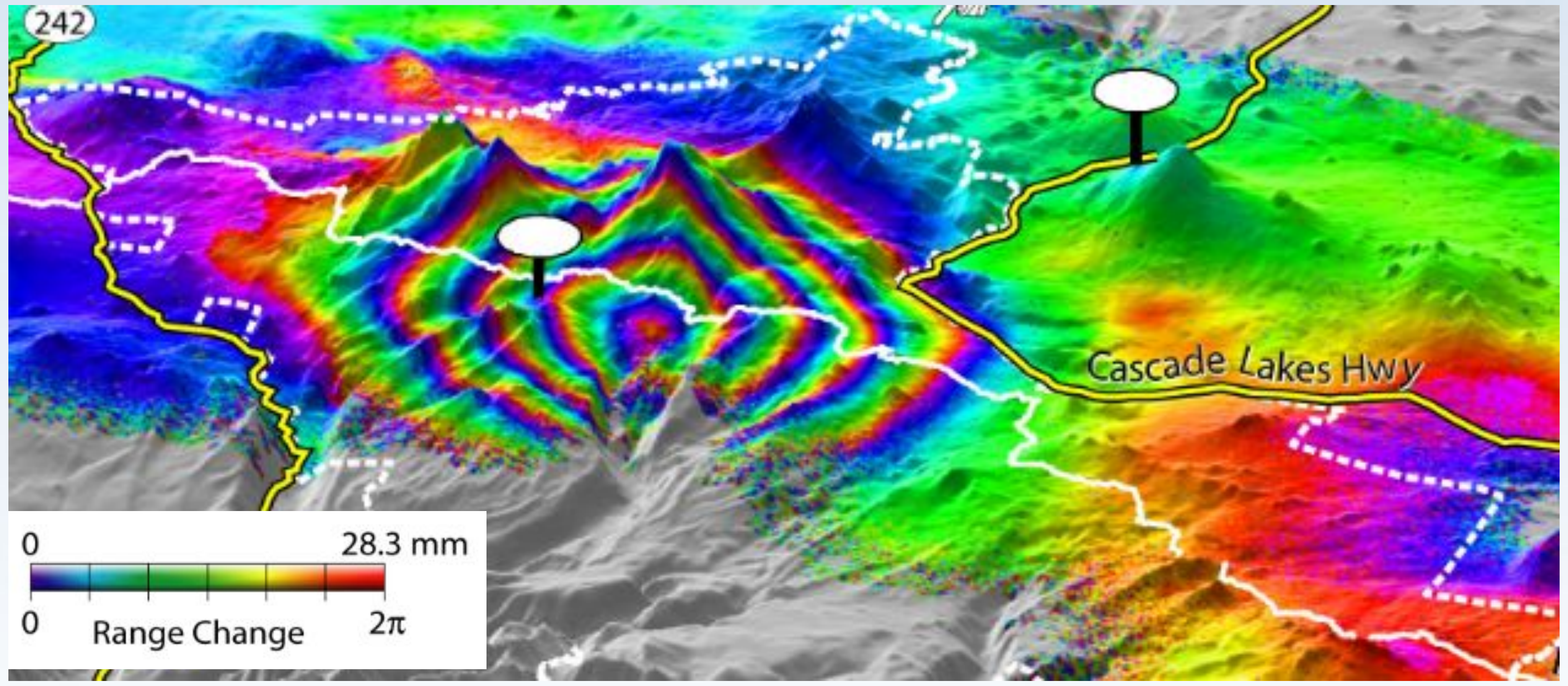


Groundwater management (Johnston et al., 2021)

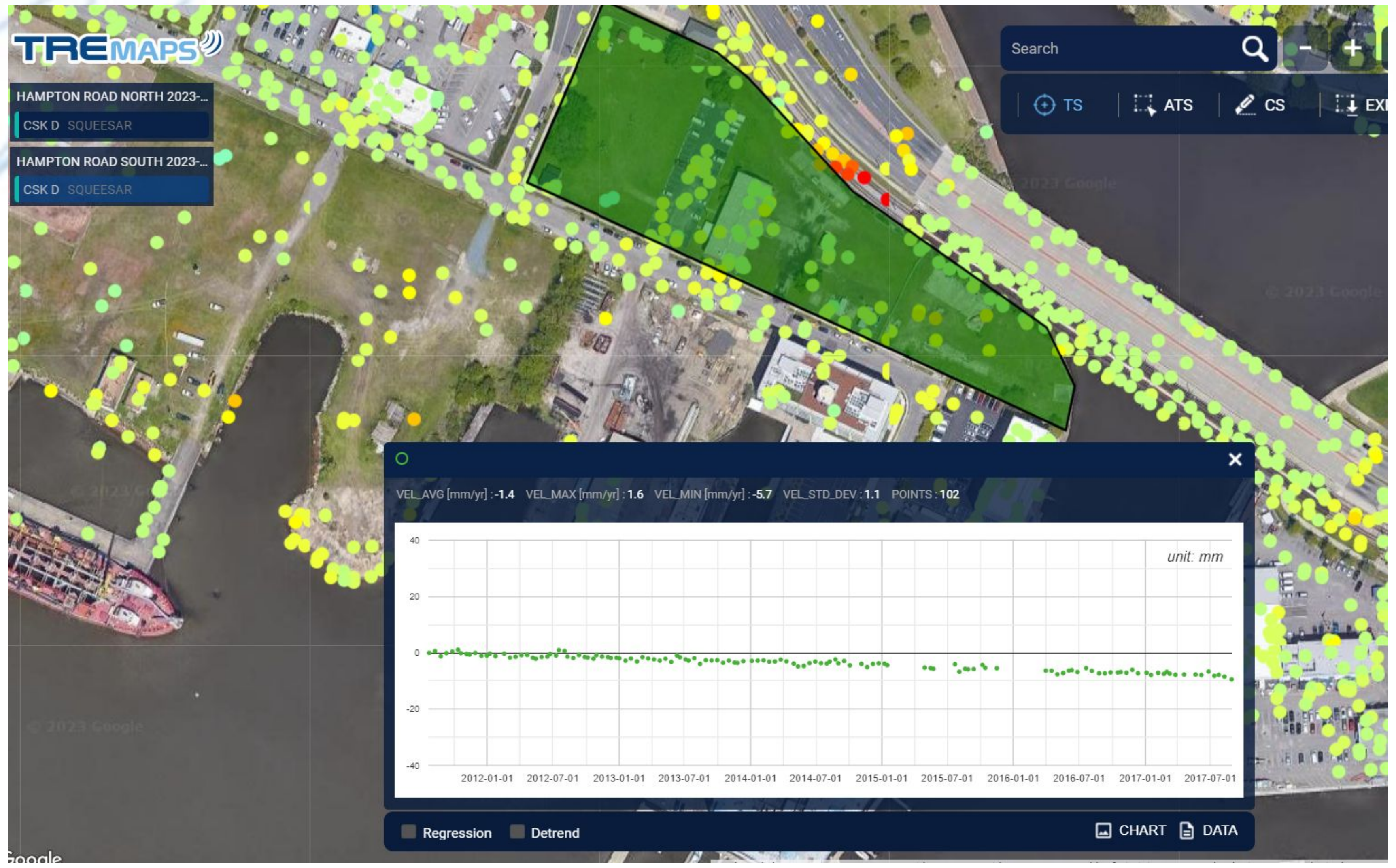
Interferometric Synthetic Aperture Radar and more

Monitoring land deformation models can be done using various technologies:

- **Leveling**
- **GNSS observations**
- **Interferometric Sythetic Aperture Radar (InSAR)**



Wicks, C.W. et al., 2002



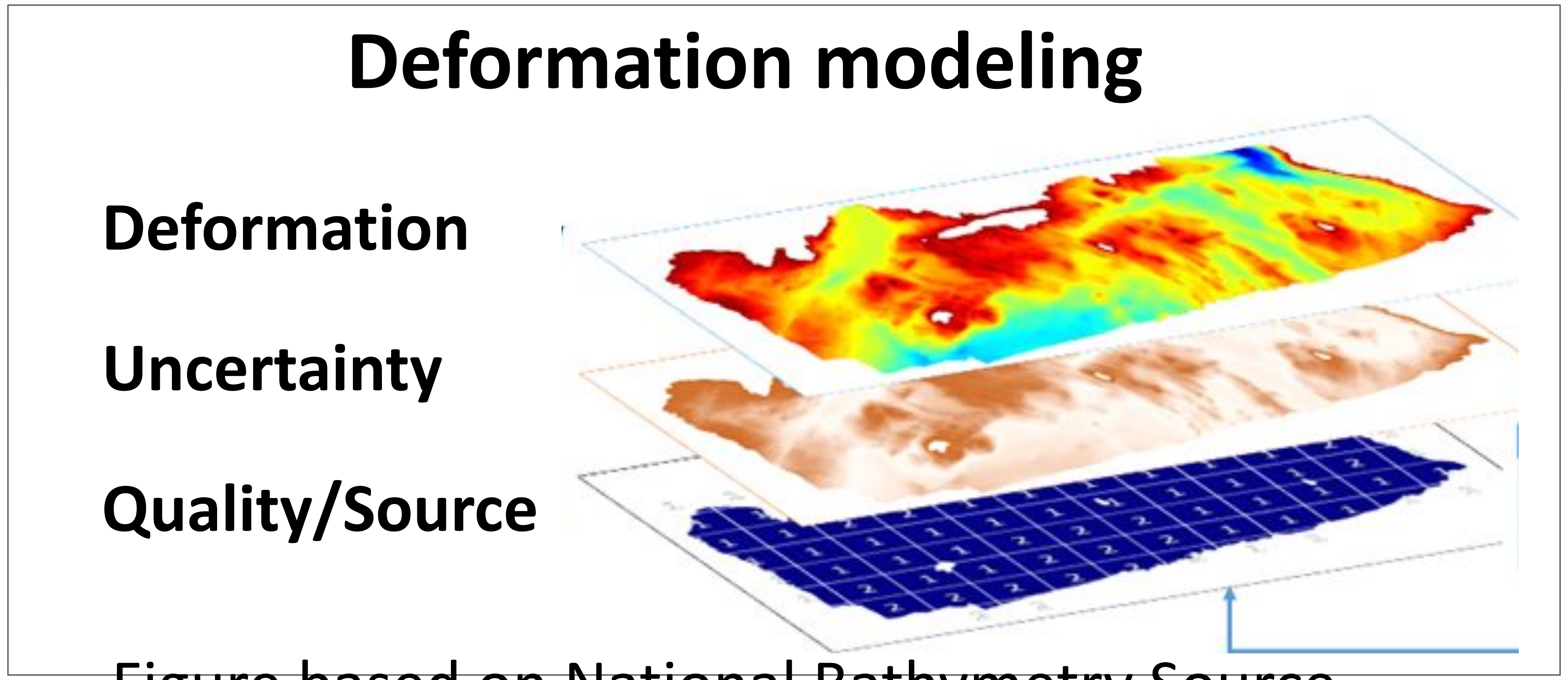


Figure based on National Bathymetry Source (NOAA/OCS)

Seafloor geodesy

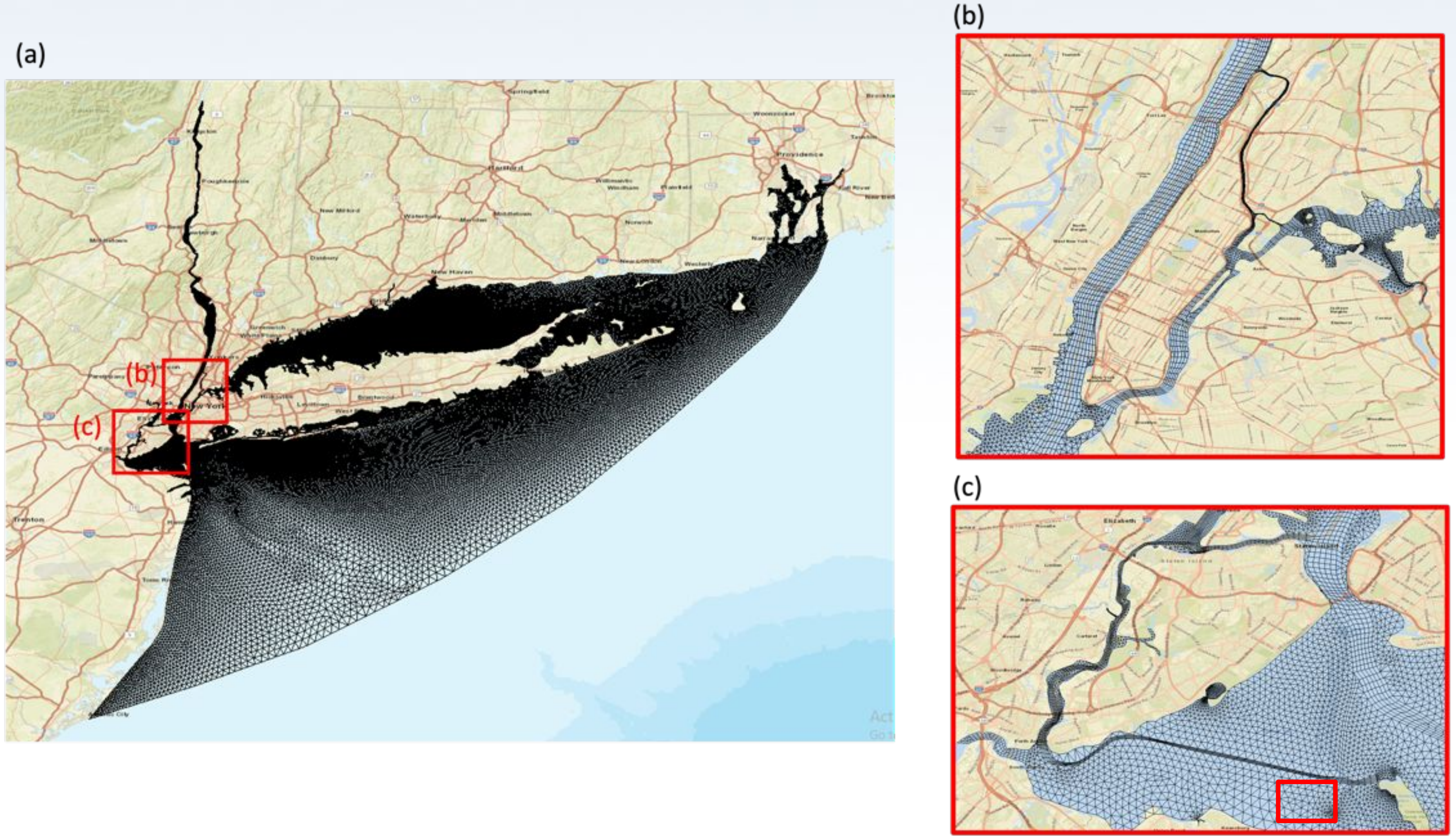
Enable Cyber-Infrastructure

HPC as a resource

UT Austin's **Texas Advanced Computing Center (TACC)** designs and operates powerful computing resources. The center's mission is" *to enable discoveries that advance science and society through the application of advanced computing technologies*".

1. Conventional HPC support
2. Cloud sandbox for collaborative development
3. Data-sharing and collaboration infrastructure

Illustration of a network



SCISM mesh for calculating water levels, currents, temperature and salinity using circulation models.

Cyber-Infrastructure

Emerging opportunities

High Performance Computing (HPC)
Parallelization
Clustering

Artificial Intelligence
Machine Learning
Deep Learning
Digital Twins

Code management
Language
Profiling
Architecture

Sandbox collaboration environment

Increase
Academic and Industry Engagements

Academic and Industry Engagements

Technology - Are we aware of new systems and software that are now available or being developed?

Capacity -Do we have the knowledge and the skillset?

Education - What is needed to train the next generation of geodesists?

Technology

Pop quiz - Name that brand (15 seconds!)

GNSS Technology

Trimble

Javad

Ashtech

U-Blox

Topcon

Laser scanners

Sick

Hoyuko

Velodyne

Icihigo

Naruto

Kenpachi

Goku

Capacity - recruitment

Government job series:

- **Physical Scientist (ZP-1301)**
- **Land Surveyor (ZP-1373)**
- **Geodesist (ZP-1372)**
- **Cartographer (ZP-1370)**

Academic background

- **Minimum of B.Sc. in Earth Sciences, Engineering, or Physics.**

What are the core classes required/recommend… d for a Geodesy 1372 series?

- Geometric Reference Systems
- Physical Geodesy
- Satellite Geodesy
- Geodesy and Geodynamics (C… and remote sensing)
- Adjustment Computatio… …ast Square adjustments
- Numerical Methods
- *Theoretical ge… …y/Magnetic field theory)*
- *Oceanogr…*
- Time … analysis, Statistical approaches, including F… …lysis
- …ing Geospatial Data Structures and databases
- …surveying
- …asic coding - Python, Fortran, or C++ programming

Does Human Resource departments supporting recruitment understand these requirements?

Education material - availability and delivery

Topic/Element	Content
F1.1 Physical geodesy	
F1.1aThe gravity field of the Earth *(B)*	(i) Newton's law of gravita (ii) Centrifu (iii) Gravity (iv) Gravity (v) Level or
F1.1b Gravity observations and their reduction. *(B)*	(vi) The Geo (vii) Normal models (viii) Gravity (ix) Gravity
F1.1c Height systems and height determination *(B)*	(i) Dynami (ii) Orthom (iii) Normal (iv) Level el (v) Theoret leveling
F1.1d Geopotential and geoidal Modelling *(I)*	(vi) Geopote (vii) High res local ge (viii) Deflecti

F1.2a Coordinate Systems for Positioning *(I)*
F1.2b Datum transformation techniques *(A)*
F1.2c Geodetic computations or the ellipsoid *(I)*
F1.2d Three-Dimensional Geodetic Modeling

INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE FOR CATEGORY "A" HYDROGRAPHIC SURVEYORS

Publication S-5A
First Edition
Version 1.0.2 - June 2018

rhumb gles and	Apply plane and spherical trigonometry to surveying problems.
bservation y related lity on ce rtainty in h multiple e	Differentiate between accuracy, precision, reliability and repeatability of measurements. Relate these notions to statistical information. Apply the variance propagation law to a simple observation equation, and derive an estimate uncertainty as a function of observations covariances.
ble vation res are cit ated estimate (x) Internal and external reliability	Solve geodetic problems by least squares estimation. Determine quality measures for least square solution to geodetic problems, to include reliability and confidence levels.

CAT-A in Hydrography
https://iho.int/uploads/user/pubs/standards/s-5/S-5A_Ed1.0.2.pdf

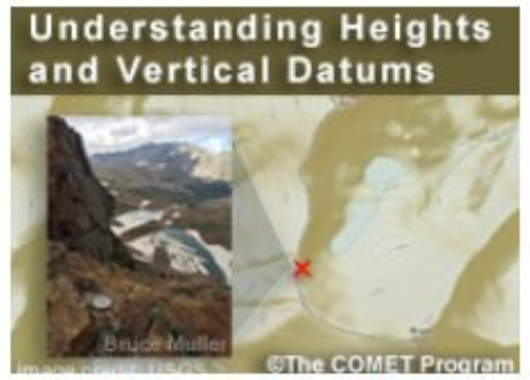
Education material - availability and delivery

Online Lessons

NGS, in partnership with **The COMET Program**, has developed a series of self-paced lessons on geodetic and remote sensing topics. **Create a free user account** to gain access to the courses below and **many others that may be of interest**. You will have the option of printing out a certificate upon successful completion of the quiz at the end of each lesson.

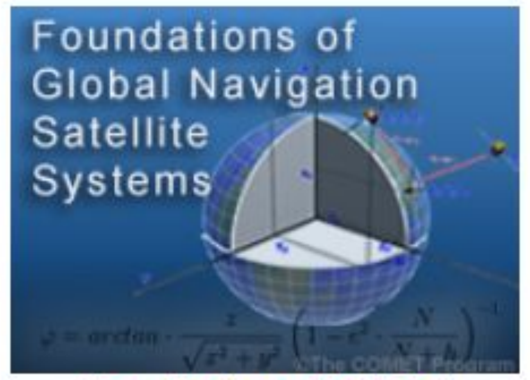
These lessons are rated by skill level:

- **0** = Suitable for non-scientists
- **1** = Requires basic scientific literacy
- **2** = Requires some prior knowledge of the topic

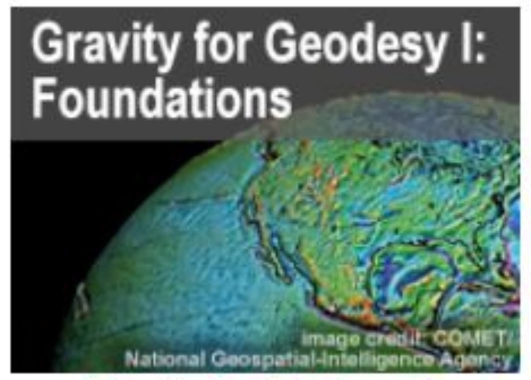


Understanding Heights and Vertical Datums
Skill Level: 0
Français | Español

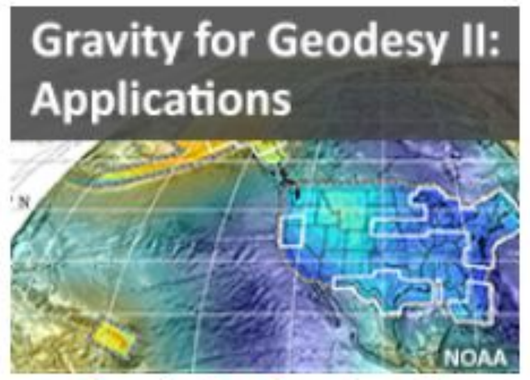
GNSS Positioning: Survey Planning and Data Acquisition
Skill Level: 1



Foundations of Global Navigation Satellite Systems
Skill Level: 2



Gravity for Geodesy I: Foundations
Skill Level: 2
Español



Gravity for Geodesy II: Applications
Skill Level: 2
Español

For additional lessons designed to supplement existing curricula at the middle and high school levels visit the **National Ocean Service Lesson Plan Library**.

geodesy.noaa.gov/web/science_edu/online_lessons/index.shtml

VIRTUAL GPS ASSIGNMENT SEPTEMBER 2003

Computational Problem Set:
Being a Virtual GPS receiver

September 2003 version

Dave Wells
10 August 2003

Courtesy of Prof. Dave Wells, University of New Brunswick, Canada

VIRTUAL GPS ASSIGNMENT SEPTEMBER 2003

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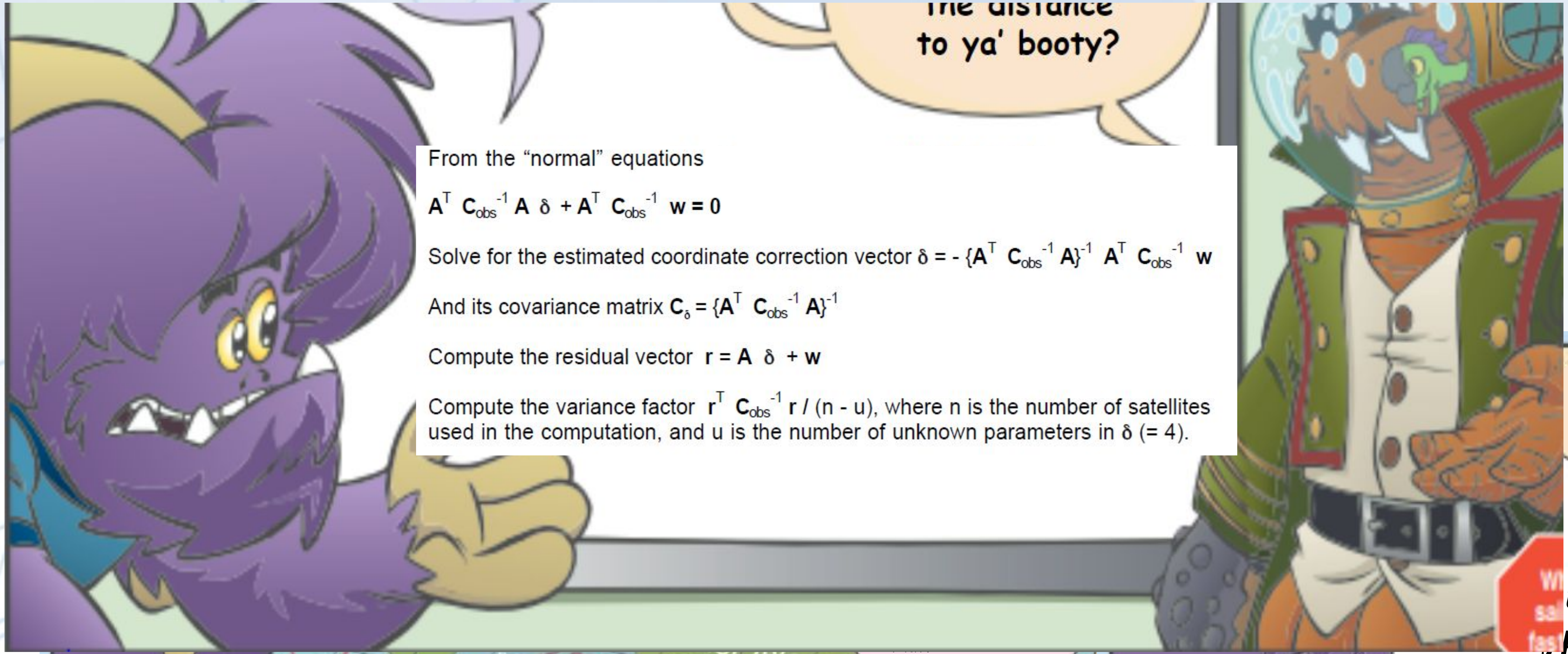
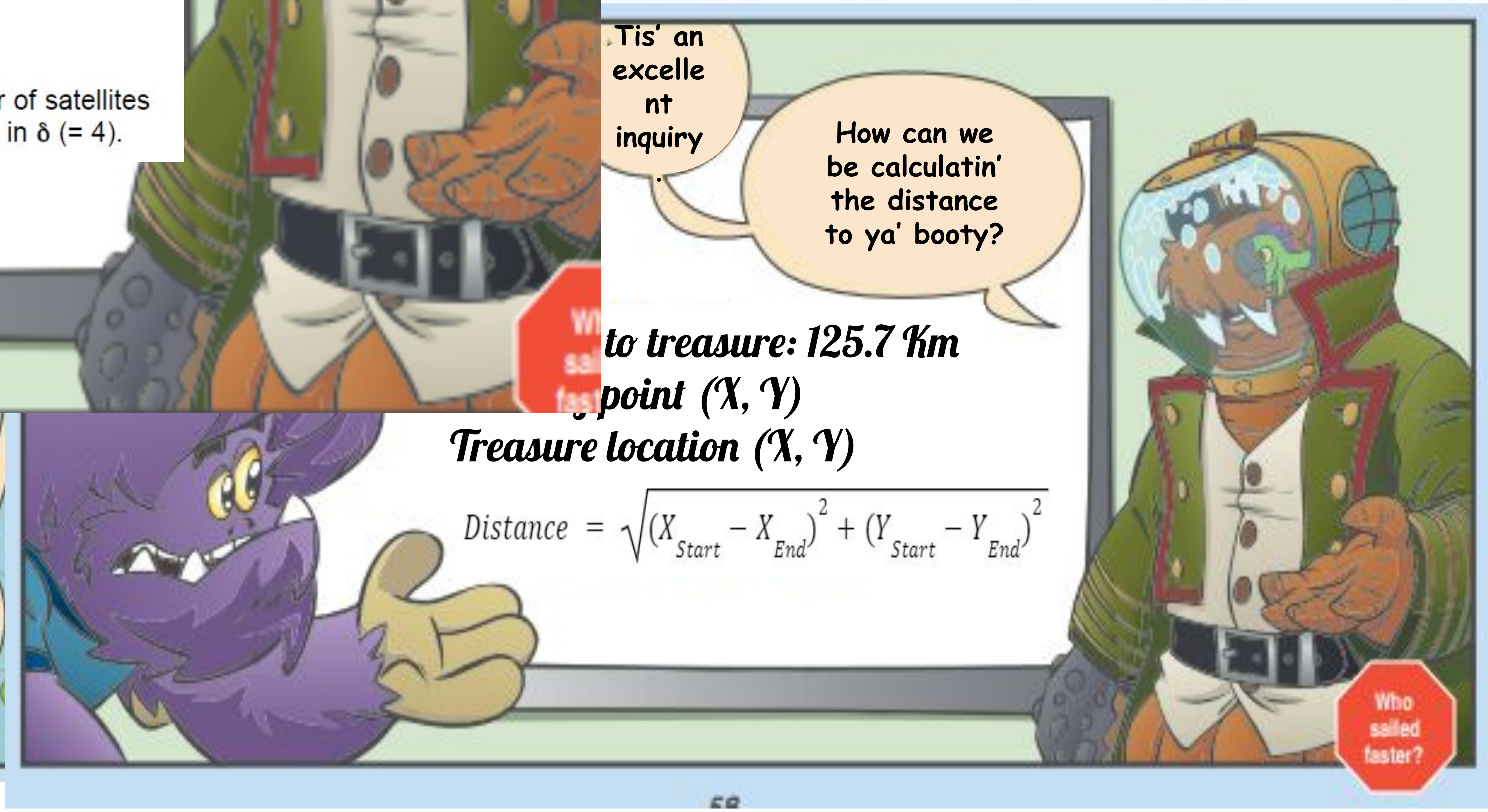
What if?



Images from AoPS Beast Academy (https://beastacademy.com/)



It takes a village to raise a child

geodesy.noaa.gov

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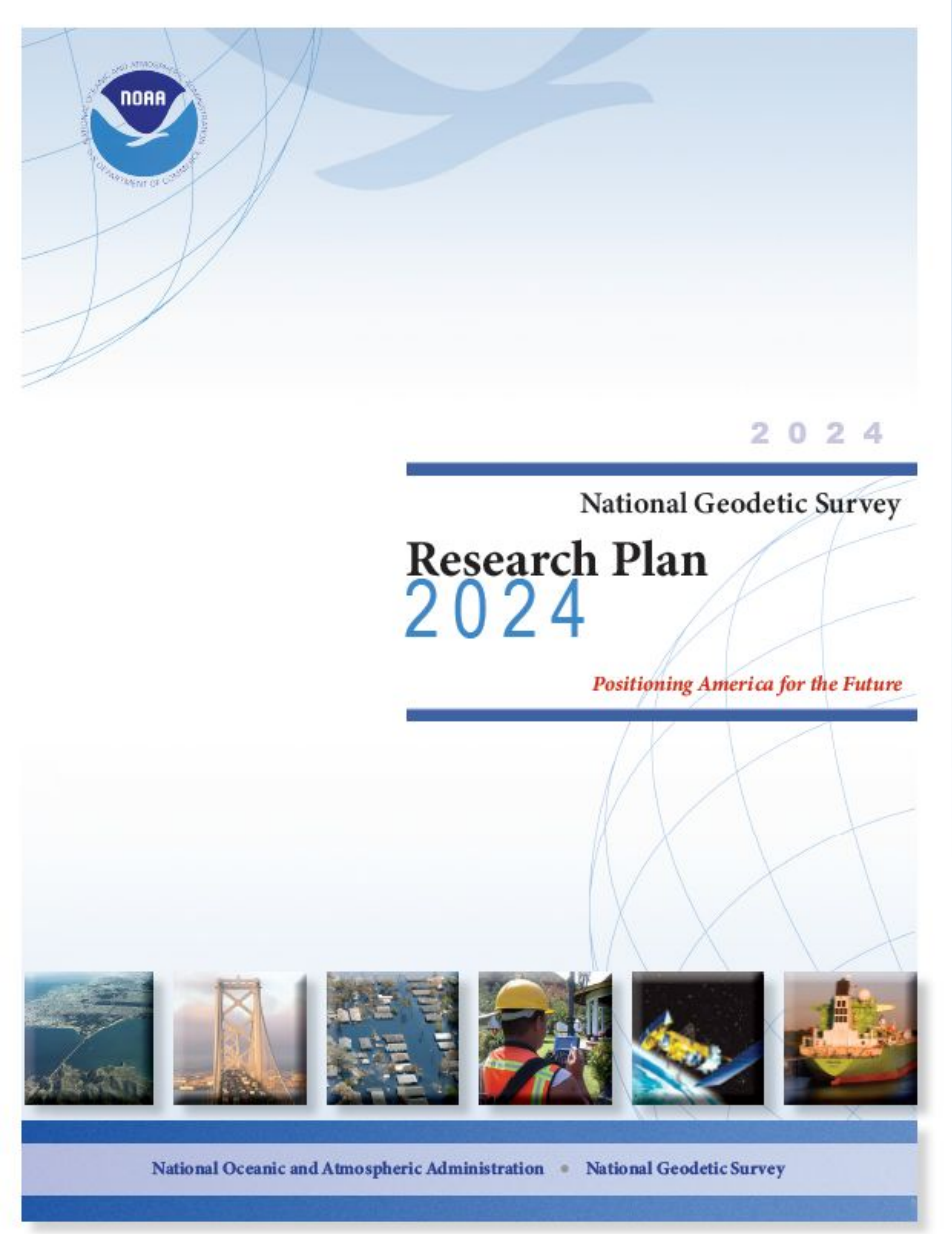
VT Blacksburg
West Virginia University

Summary

- The goal of this presentation was to communicate the NGS commitment to research and vision for investment on the long-term (i.e., next decade) research planning horizons.
- Providing long-term research themes allows governmental partner agencies, academic collaborators, and commercial industry insight into NOAA's plans to prepare and address the nation's geodetic control needs for the next 10–15 years.
- The long-term research activities are based on the outcomes of the current short-term research projects that are mainly focused on establishing, preserving, and improving the NSRS: including high-resolution geoid models, precise satellite orbits, and continuously updated national shoreline service



The research plan is accessible via:

https://geodesy.noaa.gov/web/about_ngs/info/documents/ngs-research-plan-2024-final.pdf

Thank you for attending this Webinar!