United Nations

United Nations Global Geodetic Centre of Excellence

POLICY BRIEF NO002

Geodesy is critical to climate science

Did you know that many of the sciences used to monitor and measure the causes and effects of climate change are dependent on geodesy?

Authors: Sarah Kowal and Nicholas Brown, United Nations Global Geodetic Centre of Excellence, UN DESA.

INTRODUCTION

Geodesy is the science of measuring and understanding Earth's shape, gravity field, and orientation in space, which is critical to climate science. Without accurate, reliable, and continuous measurement of the Earth's shape, gravity field, and orientation, it is impossible to track and understand the indicators of change in Earth's climate, including sea level, vertical land motion, ice mass loss, ocean currents, and atmospheric circulation.

The global geodesy supply chain which enables the accurate, reliable and continuous measurement of the Earth is at risk of degradation or failure (UN-GGCE, 2024). The weaknesses in the supply chain threaten the capacity of the climate science community to monitor changes in the Earth's climate and the ability of policy makers to mitigate the effects of climate change.

Key Messages

- The science of geodesy is critical for accurate measurements needed to track and understand sea level change, vertical land motion, ice mass loss, ocean currents and atmospheric circulation.
- For satellites serving the climate science community to operate accurately and reliably, their 'place in space' and Earth's 'place in space' need to be observed and analysed constantly. This information is provided through the global geodesy supply chain.
- The global geodesy supply chain is not robust. The weaknesses in the supply chain threaten the capacity of the climate science community to monitor changes in the Earth's climate and the ability of policy makers to mitigate the effects of climate change.
- Constant updates to the geodetic products are needed because the Earth and satellites are always moving.
- The UN-GGCE have worked with Member States and partners to create the 1st Joint Development Plan for Global Geodesy describing how they will work together to strengthen the supply chain.
- Key activities for Member States include strengthening national awareness and governance in geodesy, recognizing the global geodesy supply chain as national critical infrastructure and increasing funding for geodetic infrastructure and capacity development.

ESSENTIAL GEODETIC PRODUCTS

Consistent Reference Frame

Like measuring the growth in a child's height as they stand against a doorframe, climate scientists measure changes in the Earth's land, sea and ice height over time. Measuring and monitoring these changes is only possible by comparing the measurements over time with respect to a consistent reference frame.

Known as the International Terrestrial Reference Frame (ITRF), this geodetic product is the best estimate of the Earth's shape and serves as a stable and globally consistent base for comparing sea, ice and land measurements. To ensure it remains accurate and reliable, new versions of the ITRF need to be created every few years based on the most accurate and up-to-date information from geodetic instruments located at observatories around the world including Very Long Baseline Interferometry and Satellite Laser Ranging.

Place in Space

The range of positioning, imagery, altimetry and gravity satellites serving the climate science community to measure and monitor changes on Earth are reliant on constant updates about their 'place in space' (satellite orbit information) and the Earth's 'place in space' (shape, orientation, gravity field, and coordinate reference frame).

These Earth and satellites 'place in space' information are geodetic products which need to be constantly updated because the Earth and satellites are always moving. Without updates to these geodetic products, satellite applications that climate scientists rely on, and all the benefits they provide would degrade or fail.

Global Geodesy Supply Chain

The geodetic products are created through the global geodesy supply chain which includes:

- Ground observatories and scientists constantly observe the movement of the Earth and satellites. It is critical to have geodetic "supersites" located all around the world

which are ground observatories hosting Very Long Baseline Interferometry, Satellite Laser Ranging and Global Navigation Satellite System equipment. These geodetic techniques are complementary, which means having them collocated enables geodesists to develop the most accurate reference frame possible.

- Data centres and data centre operators who quality check the data from observatories and make it available to the global geodesy analysis community.
- Analysis centres, combination centres, correlation centres and analysts who translate the raw data into geodetic products.

CAUSE AND EFFECT

Investment in geodesy is required to ensure climate scientists have a consistent reference frame and place in space information essential for monitoring both the causes and the effects of climate change. These measurements are essential for making informed predictions and developing climate adaptation strategies. Below are some examples of essential areas of climate science which are dependent on geodesy.

Sea level monitoring

"Satellite altimetry and tide gauge records, supported by geodetic techniques, are essential for detecting long-term sea level trends and distinguishing between global sea level rise and regional variations due to land movement."

– IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), 2019.

Global sea levels are rising at an average rate of approximately 3.6 mm per year (The Royal Society, 2020). The rate of sea level rise has been accelerating in recent years due to increasing ice sheet melt (primarily from Greenland and Antarctica) and thermal expansion of seawater as it warms due to climate change.

The accuracy of these measurements is only possible due to satellite altimeters which provide high-resolution, near-global coverage of changes in sea surface height over time by bouncing radar signals off the ocean surface and calculating the distance between the satellite and the sea surface. These observations are dependent on satellites having accurate place in space information, and long-term monitoring of global and regional sea level changes over time requires a consistent reference frame.

Vertical land monitoring

"Accurate assessment of vertical land motion using geodetic techniques, such as GPS, is necessary to distinguish between land subsidence or uplift and sea level rise, particularly in coastal and island regions vulnerable to climate change."

– IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), 2019.

Satellite altimeters measuring sea level change observe *absolute* sea level with respect to the Centre of the Earth, whereas tide gauges measure *relative* sea level with respect to a local reference point. For example, at a tide gauge which measures 5 mm/yr sea level rise, it is not possible to know whether it is because the land to which the tide gauge is connected is subsiding at 5 mm/yr, sea level is rising 5 mm/yr or if it is a combination of both.

By measuring the vertical motion of tide gauges using the Global Navigation Satellite Systems, which operate in the same reference frame as the satellite altimeters, it is possible to distinguish between absolute and relative sea level change.

This provides valuable insights for climate scientists and people developing disaster risk reduction or mitigation plans. For example, in Samoa, between 2011 and 2022, a tide gauge has subsided at a rate of -7.8 mm/yr rise (Geoscience Australia, 2023) which is more than twice the global average of sea level rise. This subsidence compounds the relative sea level rise impact.

Understanding vertical land motion is critical for climate science, disaster risk reduction mitigation and infrastructure planning.

Ice sheet and glacier monitoring

"Geodetic measurements from satellite gravity missions, such as GRACE and GRACE-FO, are crucial for quantifying ice mass loss from the Greenland and Antarctic ice sheets, providing critical input to sea level rise projections."

– IPCC Fifth Assessment Report (AR5), 2014.

Geodetic satellites, such as GRACE (Gravity Recovery and Climate Experiment), track changes in Earth's gravity field and the redistribution of mass, which helps quantify ice mass change in polar regions. This data is critical for assessing the contribution of melting ice to sea level change.

Atmospheric and Oceanic Circulation

> "Geodetic data, including gravity measurements, are essential for understanding mass redistribution on Earth's surface due to ice melt, ocean dynamics, and land hydrology changes, all of which are influenced by climate change."
>
> *– IPCC Sixth Assessment Report (AR6), 2021.*

Atmospheric and oceanic circulation play a crucial role in regulating the Earth's climate, distributing heat, moisture, and nutrients across the planet, as well as influencing weather patterns and ocean currents.

Atmospheric and oceanic circulation depend on Earth's orbit around the sun, the Earth's tilt and the precision of the wobbling axis of the Earth.

Geodesy helps track changes in the shape and rotation of the Earth, which are linked to shifts in atmospheric and oceanic circulation patterns. These changes can be influenced by climate events like El Niño and La Niña.

CALL FOR ACTION

Measuring the causes and effects of climate change would not be possible without the global geodesy supply chain which provides:

- the place in space information about the Earth and the satellites which accurately describe the relationship between satellites and Earth at the time the measurements are made;
- precise measurements of changes to the Earth's ocean, ice and land; and
- a consistent frame of reference in which the measurements are made and analysed.

A future with accurate and reliable climate data requires accurate and reliable geodetic products provided by a robust global geodesy supply chain. The current global geodesy supply chain is not robust. It suffers from inadequate governance, lack of capacity and lack of awareness which have led to a lack of resourcing.

The UN-GGCE have worked with Member States and partners to create the 1st Joint Development Plan for Global Geodesy (UN-GGCE, 2025). This plan describes how – together – they will work to strengthen the global geodesy supply chain with actions to:

- Grow awareness of geodesy so it is recognized as being essential to science and society.
- Strengthen global geodesy governance arrangements internationally and country-level geodesy working groups nationally.
- Recognise the global geodesy supply chain as national critical infrastructure.
- Increase funding for geodetic infrastructure and capacity development.

REFERENCES

Geoscience Australia, 2023, Vertical motion of Pacific Island tide gauges, https://dx.doi.org/10.26186/148937, accessed 7 January 2025.

IPCC, 2014, Fifth Assessment Report (AR5), https://www.ipcc.ch/assessment-report/ar5/, accessed 7 January 2025.

IPCC, 2019, Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), https://www.ipcc.ch/srocc/, accessed 7 January 2025.

IPCC, 2021, Sixth Assessment Report (AR6), https://www.ipcc.ch/assessment-report/ar6/, accessed 7 January 2025.

The Royal Society, 2020, How fast is sea level rising? https://royalsociety.org/news-resources/projects/climate-change-evidence-causes/question-14/, accessed 7 January 2025.

UN-GGCE, 2024, Hidden Risk, https://ggim.un.org/UNGGCE/documents/20240620-Hidden_Risk_Report.pdf, accessed 7 January 2025.

UN-GGCE, 2025, 1st Joint Development Plan for Global Geodesy, in preparation for publication.