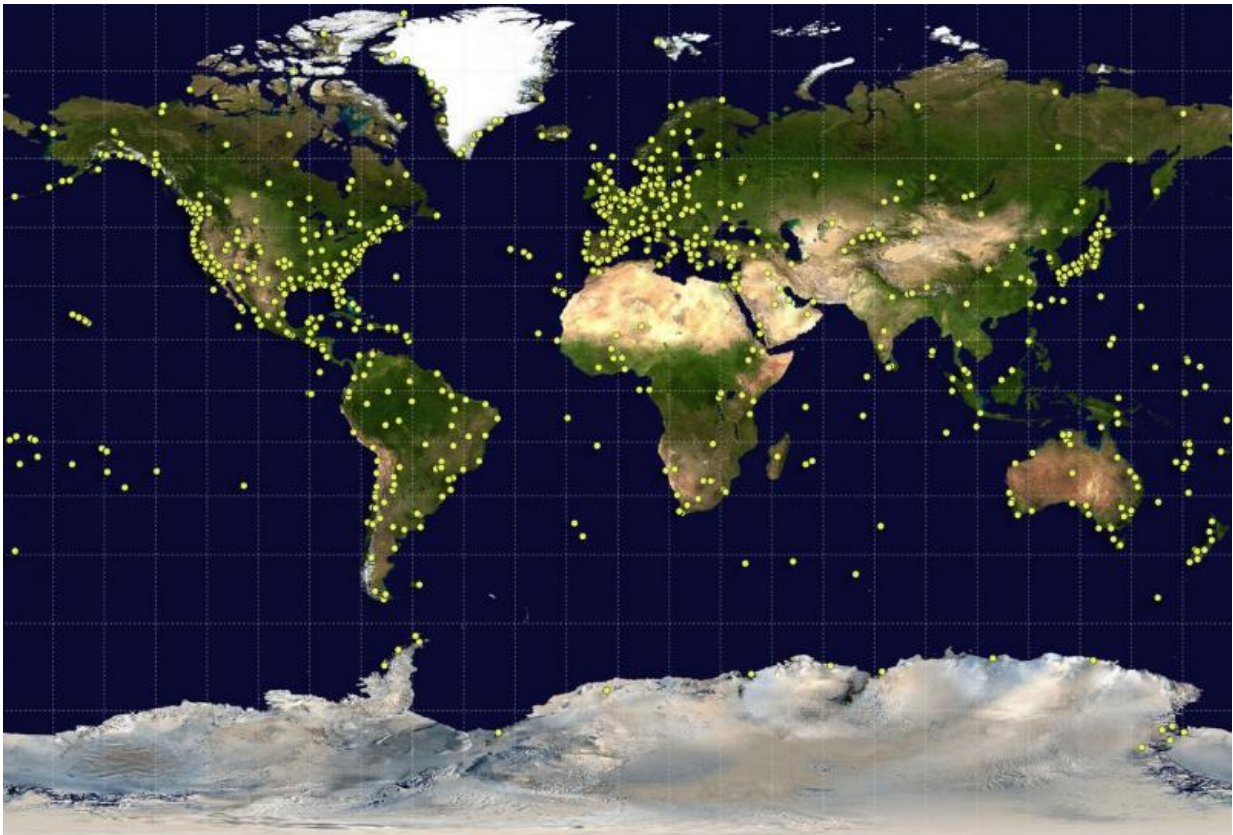


NASA contributes to global standard for navigation, studies of Earth

February 24 2016, by Elizabeth Zubritsky



Sites around the world (yellow dots) contributed data and serve as "landmarks along a trail" for the newest update to a global standard called the International Terrestrial Reference Frame. Each site conducts precision measurements using at least 1 and up to 4 geodetic techniques. Credit: NASA/Earth Observatory/Goddard

The surface of Earth is constantly being reshaped by earthquakes, volcanic eruptions, landslides, floods, changes in sea levels and ice sheets, and other processes. Since some of these changes amount to only millimeters per year, scientists must make very precise measurements of the landscape and ocean in space and time in order to study their evolution and help mitigate their impacts.

The foundation for these precision measurements is the terrestrial reference frame, which serves the same purpose as landmarks along a trail. Earth-orbiting satellites and ground-based instruments make use of this reference system to pinpoint their own locations and, in turn, those of the features they are tracking. It is also the hidden framework relied upon by aircraft to determine their locations and by mobile phone apps that provide maps and driving directions. And it is a fundamental reference for interplanetary navigation of spacecraft.

NASA helps maintain the worldwide standard called the International Terrestrial Reference Frame, or ITRF, and recently contributed to an update issued by the International Earth Rotation and Reference Systems Service's International Terrestrial Reference System Product Center at the Institut National de l'Information Géographique et Forestière, known as IGN, in Paris.

"The new release lays the groundwork for more detailed studies than ever before of global changes in Earth's ocean, ice sheets, land and atmosphere," said Stephen Merkowitz, manager of NASA's Space Geodesy Project at the Goddard Space Flight Center in Greenbelt, Maryland.

Earth-observing satellites—such as the Jason 3 spacecraft, launched in January through a U.S.-European partnership, and the upcoming ICESat-2 mission—will be among the beneficiaries of the new standard.

Officially called ITRF2014, the update released in late January is the ninth ITRF issued since 1992. More than a thousand observing stations run by NASA and other scientific institutions worldwide contributed to it, collecting data through 2014.

Global in nearly every sense of the word, the ITRF is made up of specific geographic positions around the world, along with information about how each one drifts over time. This is important because the positions move relative to each other, with some drifting more rapidly than others. The reference frame includes details about how quickly and in which directions the positions are expected to move.

Some of the drift happens because of the motion of Earth's tectonic plates, which is well understood. Drift motions may also include the gradual rebounding of land that was covered by ice sheets during the last ice age, as well as land subsiding due to climatic effects or human activity, such as withdrawal of groundwater. Less predictable are changes due to earthquakes. Large quakes will cause a sudden shift in position and also may alter the drift rate or direction at that location. Recent versions of the reference frame have started to include these effects.

"An important feature of the latest International Terrestrial Reference Frame is that the model has a more sophisticated way of incorporating the effects of earthquakes," said Chopo Ma, a geophysicist at Goddard who was involved in producing and analyzing data for the latest reference frame.

Helping to improve the ITRF is one of the primary goals of NASA's Space Geodesy Project. Four measurement techniques are used by stations worldwide to collect data for the reference frame.

In Satellite Laser Ranging, or SLR, precise measurements are made by

sending short laser pulses from ground stations to Earth-orbiting satellites equipped with suitable reflectors. The distance is calculated from the time it takes for the pulse to complete the round trip back to the ground station.

The second method is called Very Long Baseline Interferometry, or VLBI. Ground stations spread across the globe observe dozens of quasars, which are distant enough to serve as stable reference points. By carefully timing when the signals from the quasars are recorded by each station, the precise geometry of the antenna network can be deduced, and Earth's orientation in space and its rotation rate can be measured.

The technique known as Doppler Orbitography and Radiopositioning Integrated by Satellite, or DORIS, takes advantage of the Doppler effect, which is what we hear when an ambulance's siren changes pitch as it drives toward or away from us. The frequency of a radio signal from a DORIS beacon experiences the same effect while traveling from Earth to an orbiting satellite. By measuring the frequency change, it's possible to work backward to figure out the distance from the beacon to the satellite.

The final method makes use of the Global Navigation Satellite System, known as GNSS - a network that includes GPS and other navigation satellites. Radio signals are broadcast by GNSS satellites and received at many locations worldwide.

"The big advantage of GNSS is the dense network of stations distributed around the world," said Richard Gross, who manages the Terrestrial Reference Frame combination center at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. "For the reference frame, on the order of a thousand GNSS stations contribute position measurements."

Because there are GNSS receivers at the stations that perform the other three measurement techniques, GNSS also provides a method for tying together all four approaches. And when scientists worldwide want to measure how the ground is moving, they access the reference frame by using GNSS to determine their positions.

In preparation for the new reference frame, research teams worldwide carried out data analysis, looking at between 20 and 30 years of data for each method. Scientists at Goddard and the University of Maryland, Baltimore County, coordinated the data analysis for VLBI, SLR and DORIS, and JPL contributed GNSS data. All of the geodetic data for the reference frame have been archived at the NASA Crustal Dynamics Data Information System, located at Goddard, and distributed to users worldwide.

Looking forward, NASA is upgrading the stations in its Space Geodetic Network. The Space Geodesy Project at Goddard is managing these upgrades, and work is already under way at stations in Hawaii and Texas. The upgraded stations will help fill in geographic gaps in the global system, helping to improve future versions of the reference frame.

In addition, scientists are looking at other possible approaches for combining the four data types to produce an improved reference frame. Research on advancing the ITRF is conducted not only at IGN, but also at JPL's Terrestrial Reference Frame combination center and at a similar center at the Deutsches Geodätisches Forschungsinstitut in Munich. Each center produces its own independent solution, which scientists will compare to see what they can learn from different approaches.

"We renew the International Terrestrial Reference Frame every few years because it's more than a set of geographical positions," said Frank Lemoine, a Goddard scientist involved in producing and analyzing data for the new standard. "It's a projection about what will happen to those

positions in the future, and our ability to extend the [reference frame](#) into the future gets better and better over time."

Provided by NASA's Goddard Space Flight Center

Citation: NASA contributes to global standard for navigation, studies of Earth (2016, February 24) retrieved 19 July 2024 from

<https://phys.org/news/2016-02-nasa-contributes-global-standard-earth.html>

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