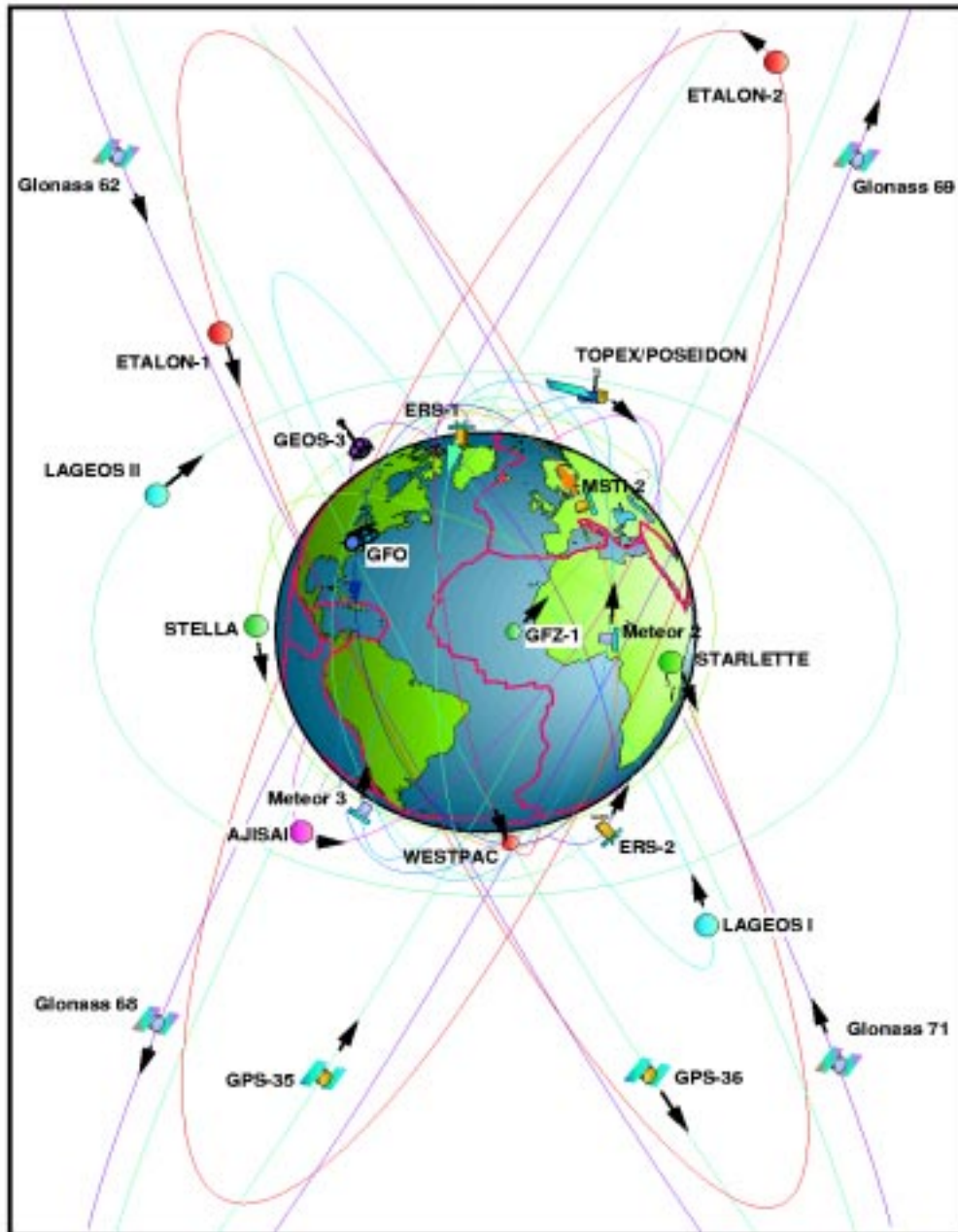


SATELLITE LASER RANGING AND EARTH SCIENCE



Current constellation of satellites supported by SLR



NASA SPACE GEODESY PROGRAM



SATELLITE LASER RANGING

In Satellite Laser Ranging (SLR) a global network of stations measure the instantaneous round trip time of flight of ultrashort pulses of light to satellites equipped with special reflectors. This provides instantaneous range measurements of millimeter level precision which can be accumulated to provide accurate orbits and a host of important science products.

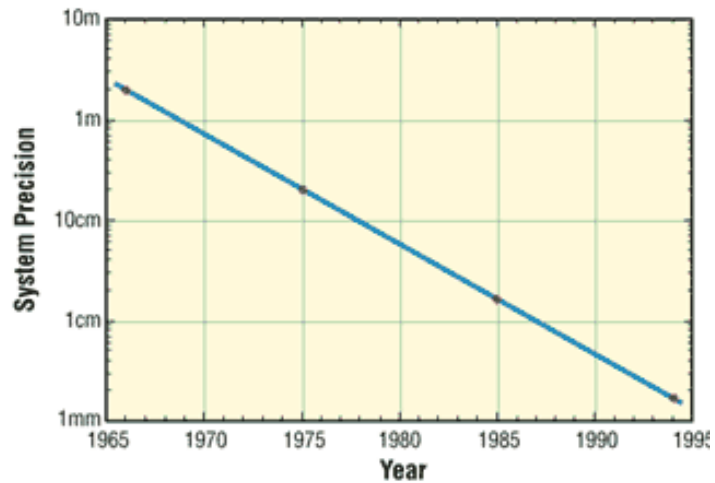


- Satellite Laser Ranging is a proven geodetic technique with significant potential for important contributions to scientific studies of the Earth/Atmosphere/Oceans system.
- SLR is the most accurate technique currently available to determine the geocentric position of an Earth satellite, allowing for the precise calibration of radar altimeters and separation of long-term instrumentation drift from secular changes in ocean topography.
- SLR's ability to measure the temporal variations in the Earth's gravity field and to monitor motion of the station network with respect to the geocenter, together with the capability to monitor vertical motion in an absolute system, makes it unique for modeling and evaluating long-term climate change by:
 - Providing a reference system for post-glacial rebound, sea level and ice volume change
 - Determining the temporal mass redistribution of the solid Earth, ocean, and atmosphere system
 - Monitoring the response of the atmosphere to seasonal variations in solar heating.
- SLR provides a unique capability for verification of the predictions of the Theory of General Relativity.
- SLR stations form an important part of the international network of space geodetic observatories, which include VLBI, GPS, DORIS and PRARE systems.
- On several critical missions, SLR has provided failsafe redundancy when other radiometric tracking systems have failed.
- The cost effectiveness of SLR operations are improving through increased standardization, configuration control, and automation. NASA is vigorously pursuing the development of SLR 2000, a stand-alone, low-cost, subcentimeter SLR system.
- The International Laser Ranging Service has been formed by the global SLR community to enhance geophysical and geodetic research activities (ilrs.gsfc.nasa.gov).



SLR CONTRIBUTION TO EARTH SCIENCE

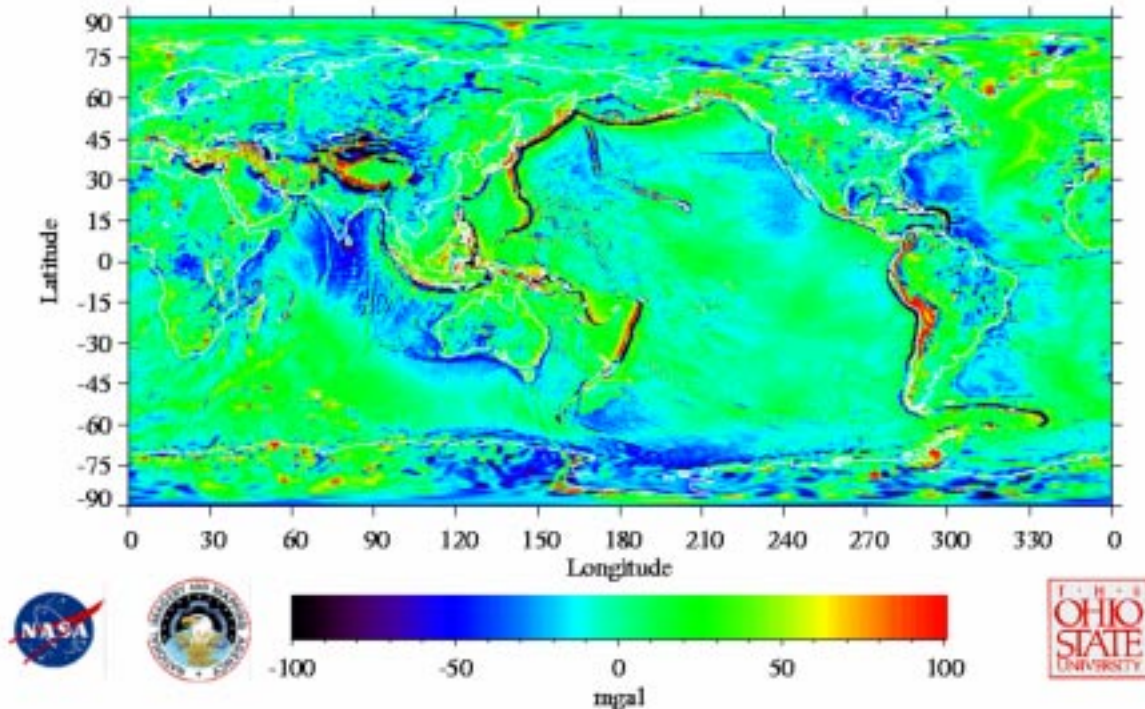
Laser ranging to a near-Earth satellite was initiated by NASA in 1964 with the launch of the Beacon-B satellite. Since that time, ranging precision, spurred by scientific requirements, has improved by a factor of a thousand from a few meters to a few millimeters.



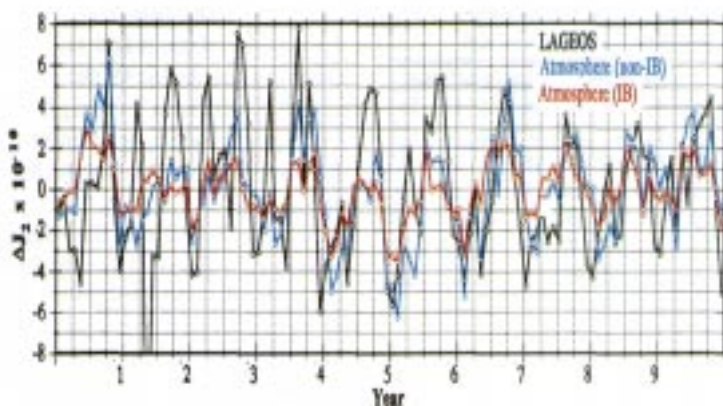
During the past three decades, the global Satellite Laser Ranging (SLR) network has evolved into a powerful source of data for studies of the solid Earth and its ocean and atmospheric systems. In addition, SLR provides precise orbit determination for spaceborne radar altimeter missions mapping the ocean surface (which are used to model global ocean circulation), for mapping volumetric changes in continental ice masses, and for land topography. It provides a means for subnanosecond global time transfer, and a basis for special tests of the Theory of General Relativity.



SLR SUPPORTS THE STUDY OF THE ATMOSPHERE-HYDROSPHERE-CRYOSPHERE- SOLID EARTH SYSTEM



Twenty-five years of SLR data has provided the standard, highly accurate, long wavelength gravity field reference model which supports all precision orbit determination and provides the basis for studying temporal gravitational variations due to mass redistribution. The height of the geoid has been determined to less than ten centimeters at long wavelengths less than 1500 km. Thirty-second mean gravity anomalies from the EGM96 model show the fine detail.

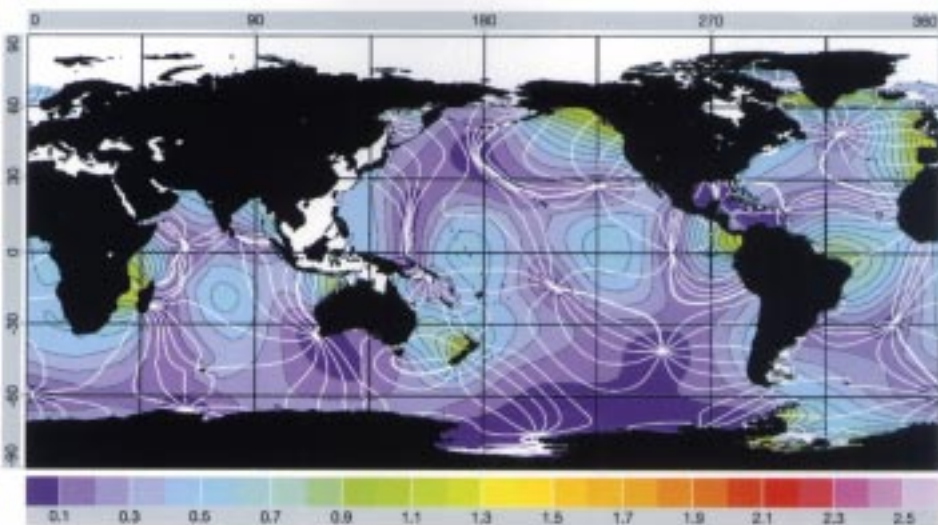


From temporal changes in the gravity field, SLR measures the effects of mass redistribution in the total Earth system. A decade of SLR-determined monthly values of the second zonal harmonic of the Earth's gravity provide independent verification of the mass redistribution implied by global atmospheric circulation models used to predict global climate change.

SLR SUPPORTS

DIRECT SENSING OF SURFACE ELEVATIONS

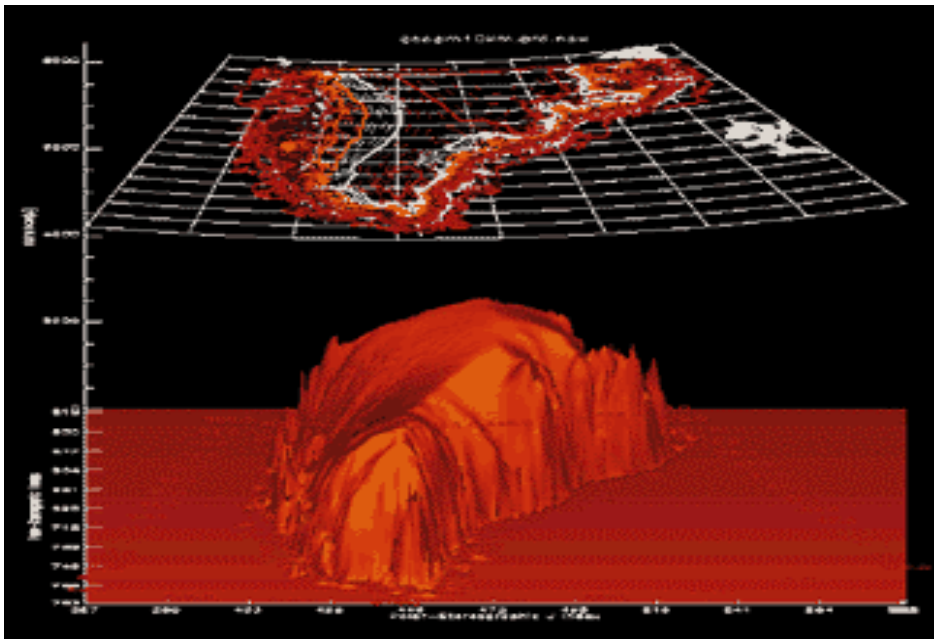
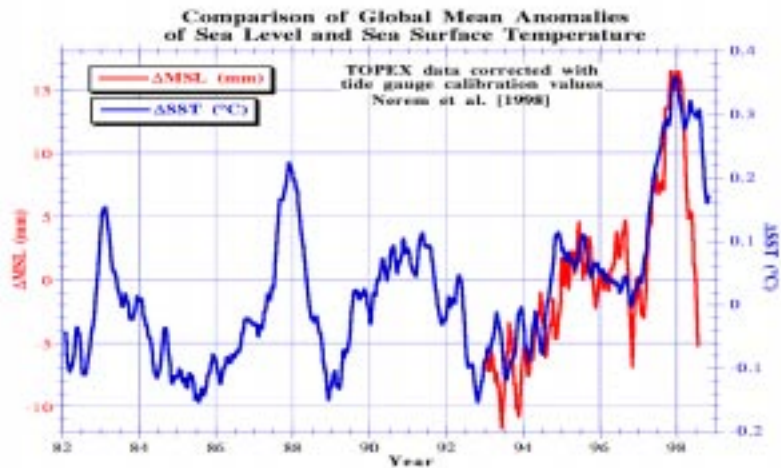
SLR provides direct, unambiguous measurement of altimeter satellite height and permits effective separation of altimeter system drift from long-period ocean topography changes at the sub-cm level. This calibration is essential for the measurement of global mean sea level changes of a few mm/yr and the mapping of ice field topography used to estimate ice volume changes.



Satellite altimeters were used to compute the cotidal map of the main lunar M2 tide. Understanding the nature of tidal dissipation and ocean bottom friction requires a more detailed knowledge of ocean tides. Better tide models are also required to support ocean tidal loading models needed to analyze precise gravimetry.

SLR CONTRIBUTES TO SEA AND ICE LEVEL MONITORING

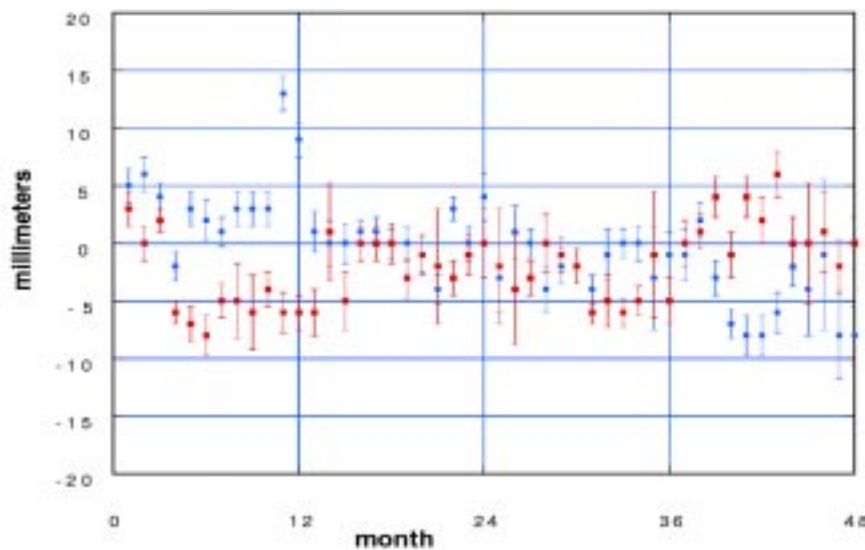
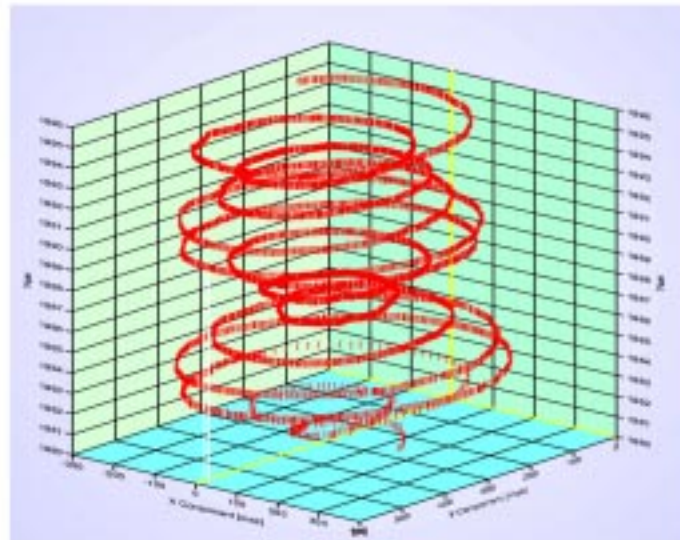
SLR contributes to the monitoring of sea level change in two ways. First, by supplying tracking data for orbit determination, SLR assures excellent radial orbital knowledge of altimeter satellites. Second, by improving knowledge of mm/yr-level secular changes in the height of coastal observing sites, SLR helps to resolve ambiguities in the tide gauge record. Variations in mean sea level from TOPEX/Poseidon match sea surface temperature measurements which indicate El Nino- Southern Oscillation events.



The topography (and its changes) of the Earth's ice sheets are mapped using satellite altimeters and precision orbits based on SLR and SLR-based force models.

SLR Measures the Long Term Dynamics of the Solid Earth, Oceans and Atmosphere

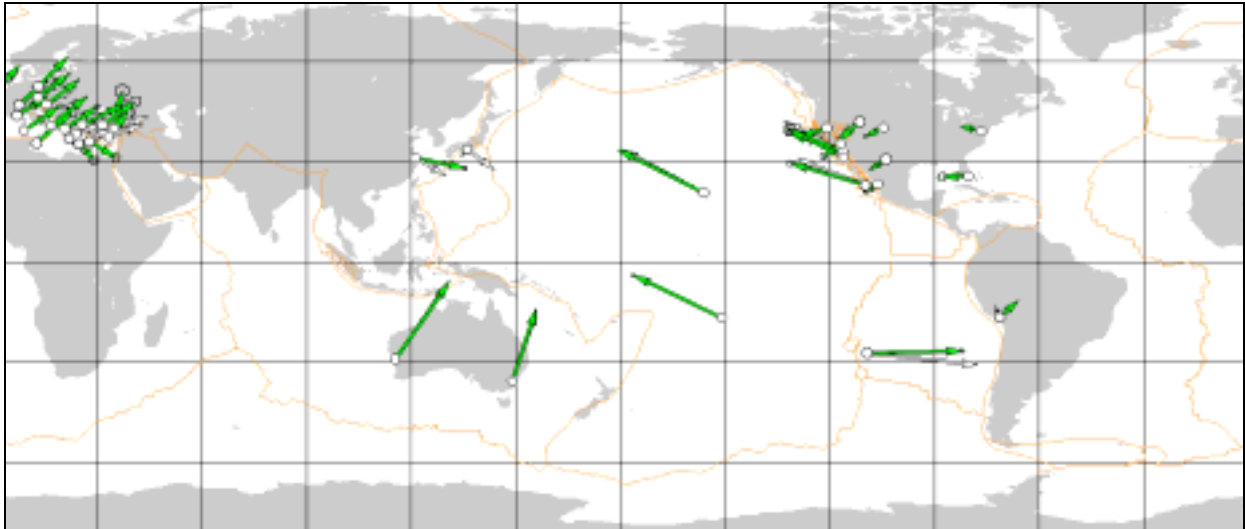
SLR determinations of the Earth's rotation and orientation reveal changes in the distribution of mass and exchange of angular momentum in total Earth system.



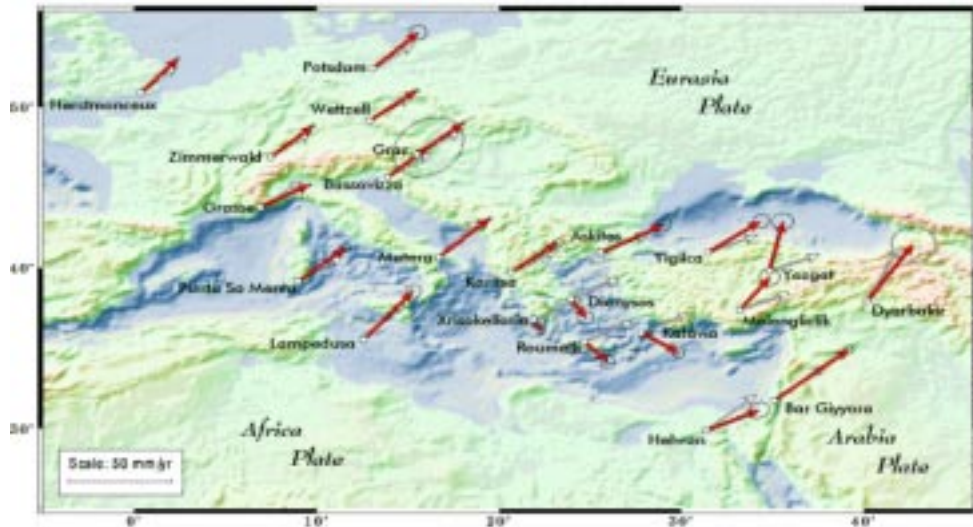
SLR determination of the changes in the geocentric height of stations coupled with determination of the motion of the station network with respect to the geocenter at the few mm level provides a reference for studies of sea level variations and post-glacial rebound. The apparent changes in the X and Y components of the geocenter can be monitored at the millimeter level.

SLR SUPPORTS STUDY OF TECTONIC MOTION

SLR provides mm/yr accurate determinations of station motion on a global scale in a geocentric reference frame. Combined with gravity models and decadal changes in Earth rotation, these results contribute to modeling of convection in the Earth's mantle by providing constraints on related Earth interior processes. The velocity of the fiducial station in Hawaii is 70 mm./year and closely matches the rate of the background geophysical model.

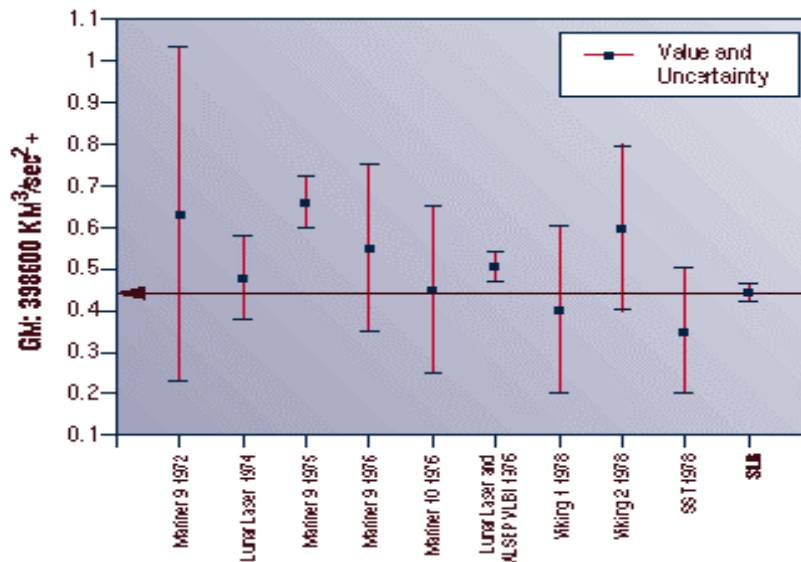
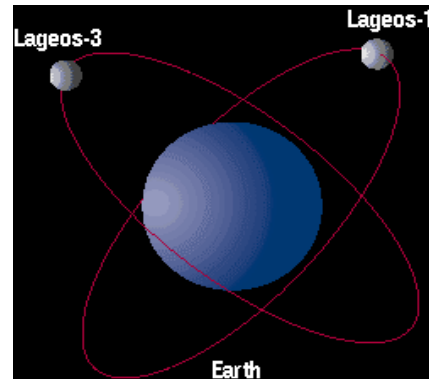


The horizontal motion of a global network of SLR sites in the Mediterranean has shed critical insight into the nature of contemporary plate tectonics.



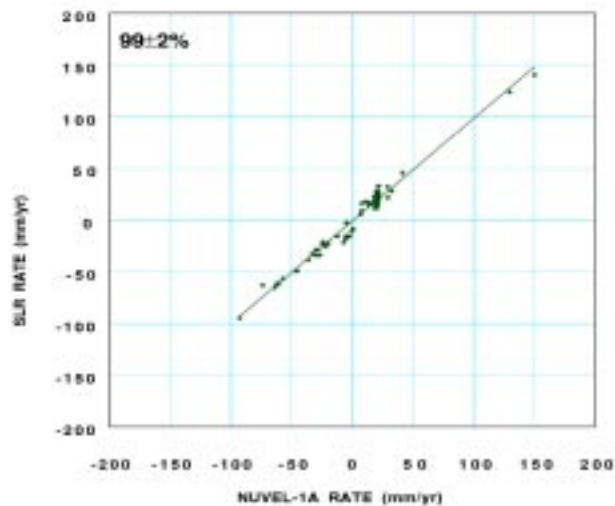
SLR SUPPORTS RESEARCH IN FUNDAMENTAL PHYSICS

LLR tracking of corner cube retroreflectors on the moon has verified the Equivalence Principle of General Relativity. SLR measurements LAGEOS 1 and 2 have measured the Lense-Thirring “drag” of the reference frame. A third LAGEOS-type satellite has been proposed for relativity studies.



SLR measurements of Lageos have provided the most accurate measurement of GM , the product of the gravitational constant and the mass of the Earth, and have confirmed that it does not change secularly.

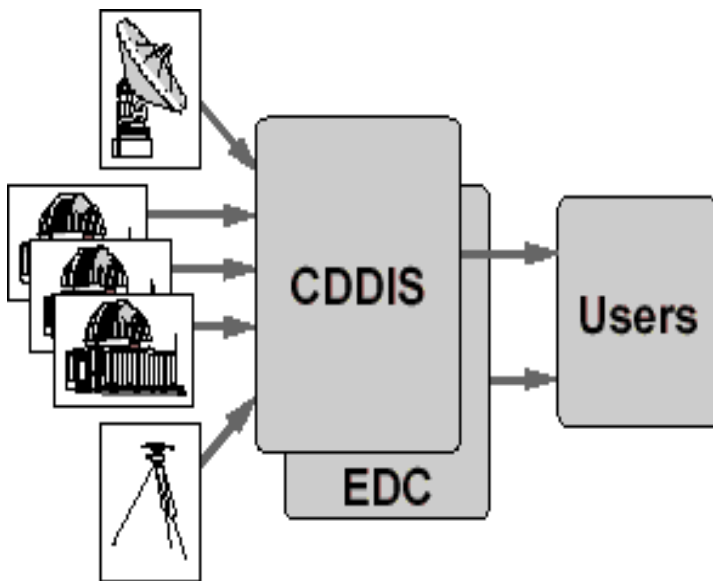
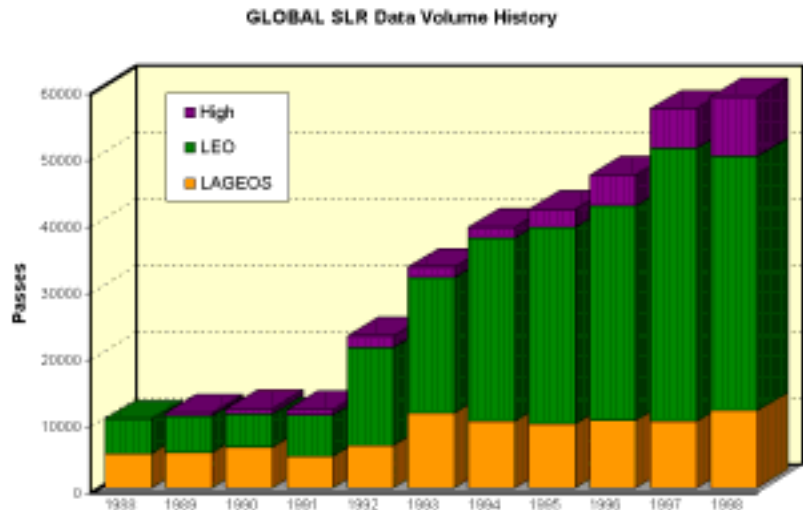
The speeds between SLR stations on stable plate interiors helped to support the tectonic plate model based on a revised paleomagnetic time scale.



SLR OPERATIONS ARE STEADILY IMPROVING

SLR data yield has improved through:

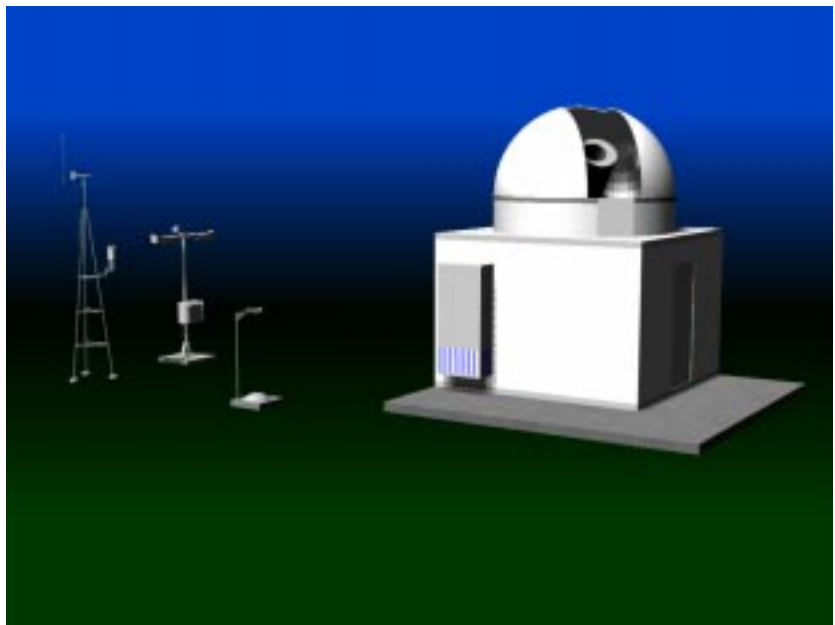
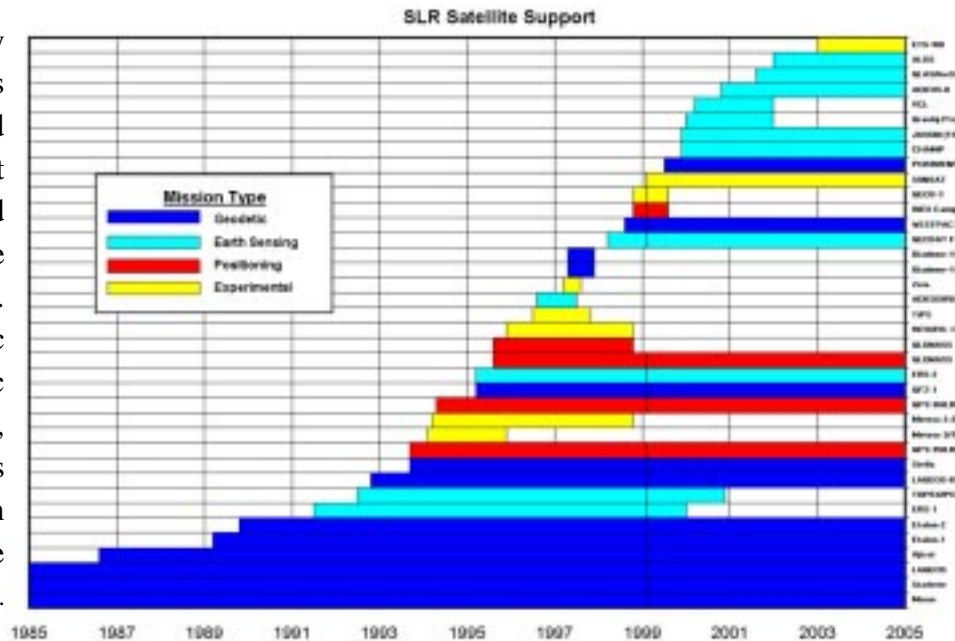
- Real-time data processing,
- Satellite pass interleaving,
- System upgrades,
- Additional operating, and
- Additional Satellites.



The Crustal Dynamics Data Information System (CDDIS), located at NASA GSFC, is the main repository for the global space geodesy data set, which is also available from the European Data Center in Germany. The SLR data are provided via electronic access and/or magnetic tape.

SLR TECHNOLOGY IS RAPIDLY ADVANCING

Mission support by the SLR Network has expanded dramatically in recent years, and the need for SLR will continue to grow in the future. A variety of geodetic and geodynamic missions are planned, as well as applications in Earth sensing and satellite positioning.



NASA's next generation SLR station, currently under development, is fully automated, unmanned, inherently eyesafe, and will operate 24 hours a day to the full suite of artificial satellites. The SLR2000 design is expected to greatly reduce station construction, operating and engineering maintenance costs. The low energy, high repetition rate, photon counting approach represents a quantum technological leap over prior low repetition rate, high signal-to-noise ratio designs.