Lasers for Earth Observation

The device’s ability to measure distances, to detect compositions in the atmosphere and transmitting data has provided possibilities to use lasers for a number of tasks connected to the earth observation fields. Several existing and new satellites use the system, and the sensitivity and accuracy are steadily increasing.

The ADM - Aeolous. Photo credit:ESA

Composition of the atmosphere

The atmospheric lidar instrument, Geo-science Laser Altimeter System (GLAS) on the ICESat satellite was the first satellite-based lidar that was able to investigate the Earth’s cloud from space. Experiences so far from this satellite, launched in 2003, provide further development of a similar instrument for the French/American Cloud-Aerosol Lidar and the Infrared Pathfinder Satellite Observations (CALIPSO) mission. Lidars are ideal for detecting thin cirrus and aerosol layers, while the radar is ideal for probing optically thick clouds that are impenetrable by the lidar. A combination is the best, and CALIPSO thus form a part in the so- called A-train formation, where several satellites, with different characteristics, follow the same track over Earth’s surface with a short time interval. The complementary satellite in the formation is Cloud, and equipped with radar, the satellite “spots” the phenomena CALIPSO cannot detect.

Measuring distances

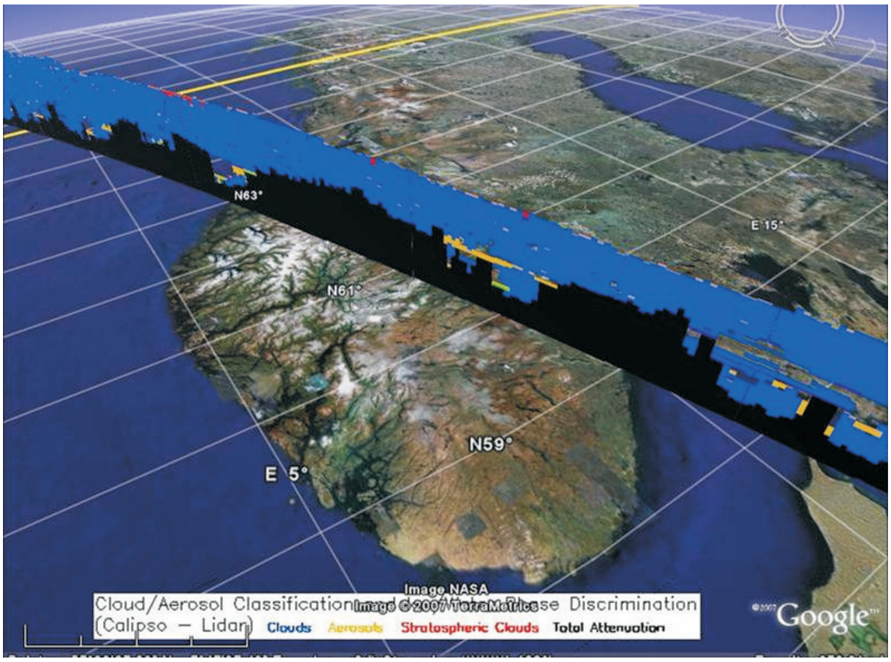
The European Earth Explorer Satellite CryoSat-2 is dedicated to give necessary data for calculation the volume of the free floating ice in polar areas. For this reason, the difference between the ocean floor and top of the sea ice is the main interesting measuring object, not only directly beneath the satellite, but along a 250 metres’ wide strip. Radar pulses every 50 milliseconds give measuring strips each 250 metres. Knowledge about the height over the sea floor of the free floating ice floe and the ice’s specific weight is the necessary data for calculation of the total ice thickness. To be able to calculate this height, and simultaneously be able to detect where, CryoSat-2 carries two devices onboard, a radio receiver and a laser retro reflector that measures the Doppler shift in receiving radio signals from several ground stations, as well as carries out a preliminary calculation onboard. However, in addition, the satellite is equipped with small laser reflectors attached to the underside of the satellite. This little device has seven optical corner cubes, that reflect light in the exactly the same direction it came from. A global network of laser tracking stations fires short pulses at CryoSat-2 and times the interval before the pulse arrives back. These stations are relatively few, but their position is very accurately known. In addition, a star tracker onboard provides the position for the satellite, referenced to stars in the sky.

Measuring Wind Speed

The Doppler Effect at a Lidar beam can also be used to detect the wind speed in the atmosphere. The theory has been known for a long time, but the technology has not been fully developed until now. The first satellite that will utilize the technique is the European ADM-Aeolous (Atmospheric Dynamic Mission) wind mission. Aeolous will orbit the Earth at an altitude of about 400 km. Measurements will be taken orthogonally to the flight direction at an angle of 35 degrees off-nadir. For every 700 laser pulses, over which time the satellite moves forward 50 km, one wind profile will be obtained and the data transmitted to ground station when the satellite is on sight for this. The instrument is called ALADIN (Atmospheric Laser Doppler Instrument) and consists of a powerful laser system, a large telescope to collect the backscattered light and a very sensitive receiver to analyze the Doppler shift of the signal from different layers of the atmosphere.

Communication Through Terrestrial Laser Fibre

A fibre laser is a laser where the active gain medium is an optical fibre doped with rare-earth elements such as erbium, ytterbium etc. That has shown to be the most effective way to transmit data in a terrestrial network. An example of effective communication is the connection between the mainland in Norway and the satellite receiving station Svalsat at Svalbard. This has successfully increased the data transfer capacity from Svalbard considerably and contributes to range the Svalsat ground station to one of the world's largest receiving stations for earth observation satellites in polar orbits.



CALIPSO *(Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) Vertical data at* Google *Earth. The profile shows the actual situation over Denmark, Skagerak and the Southern Norway. Photo credit. NASA.*

Transmitting Data

Through a laser beam it is possible to transmit data between satellites in orbit, or from satellites that orbit the Earth. That has been successfully demonstrated for the first time between the French Spot 4 satellite and the experimental Artemis communication satellite in November 2001. Through the laser link, images taken of Spot 4 could be transmitted in real time to the ground station, via a communication satellite in geosynchronous orbit, in spit of the satellite was out of sight for the station.

The system the satellites use is that Artemis scans the areas where Spot 4 is expected to be. When contact is made, Spot 4 responds by sending its own laser beam to Artemis. When contact is established the scanning stops and data transmitting begins. Near real time data from Spot 4, with a speed of 50 Megabits per second (Mbps), can therefore be transmitted to the main ground station in Europe even if the satellite monitor is on the other side of the Earth.

This system for data transmission, called Silex, secures real time data from Spot 4 from almost all the places of the Earth except the short time interval at every orbit when the Earth will be placed between the two satellites.

The Doppler Effect – Simple and Useful

The principle Doppler Effect has been used in many applications, not only in connection to space. To be caught in a speed control on the road is possibly the most uncomfortable knowledge about the effect for most people. The Doppler Effect (or Doppler shift), named after Austrian physicist Christian Doppler who proposed it in 1842, is the change in frequency of a wave moving relatively to the source of the wave. It is commonly heard when a vehicle sounds a siren or horn when it approaches, passes, and recedes from an observer. The received frequency is higher (compared to the emitted frequency) during the approach, it is identical at the instance of passing by, and it is lower during the recession.

The Doppler Effect for electromagnetic waves such as light is of great use in astronomy and results in either a so-called red shift or blue shift. It has been used to measure the speed at which stars and galaxies are approaching or receding from us, that is, the radial velocity. This is used to detect if an apparently single star is, in reality, a close binary and even to measure the rotational speed of stars and galaxies.