Lab facilities GRS

Lab facilities of the Department Geoscience and Remote Sensing

The department has a wide variety of lab facilities. The lab facilities within the building of CEG is rather limited. We only have one room (27m2) within the department and some storage/work facilities within the basement of CEG. The single room within the department is very important for easy access of the control facilities.

Facilities:

The main laboratory infrastructure of GRS can be divided in several facilities:
- Observatories
- Measurement equipment
- Computer equipment with data storage facilities, including a GPU grid computer with stereo visualisation tools (VRLAB)

GRS manages several observatories, among them the Fundamental station Westerbork and Cabauw. At Westerbork there is a specifically designed bunker for gravity observations. Other designed observatories are the GNSS lab in Delft (on top of the VSL building), our part of the Dutch Permanent GNSS Array (DPGA) observatories, and our share in the Cabauw Experimental Site for Atmospheric Research (CESAR). The world-class CESAR Observatory in Cabauw (PI Prof. Russchenberg) is widely recognised as one of the most advanced sites for atmospheric studies. TU Delft owns and operates the high-resolution atmospheric radar systems IDRA and TARA. CESAR consists of a large set of instruments to study the atmosphere and its interaction with the land surface. It also serves as a permanent bridge between the participating universities (TU Delft, WUR, TU/e) and research institutes (KNMI, RIVM, TNO, ESA, ECN). Many of the available atmospheric remote sensing instruments located at Cabauw offer unique possibilities for sensor synergy.

Measurement equipment is either permanently located at an observatory site for continuous monitoring or used for long-lasting campaigns (several months or years), or shorter campaigns (days to weeks). The laboratory provides state-of-the-art GPS equipment, theodolites, levelling, and laser distance measurement devices. Terrestrial acquisition is also carried out using digital cameras and a Laser Scanner.
The equipment includes GNSS receivers, four relative gravimeters, one FG-5 absolute gravimeter, a 3D laser scanner, a rainfall radar and various other surveying attributes. The GRS laboratory possesses some powerful computer equipment with data storage facilities. We also use the Sara supercomputing facilities and Oak Ridge Leadership Computing Facility (OLCF). GRS has access to a local cluster, mainly used for traditional HPC applications and a low-latency gridnetwork for special GPU and visualisation applications.

The infrastructure in Westerbork comprises a bunker for gravity observations, a relative gravimeter, GPS equipment, telecommunication and data storage facilities. Moreover, ultra-stable atomic clocks (a.o. a hydrogen maser) are shared with ASTRON.

The data and computer facilities include all specific hardware which has been acquired for the execution of the research program of GRS. This comprises several high-performance computer clusters for the processing of earth observation data and geo-information data bases as well as clusters for brute force calculation of clouds and a GPU grid computer with stereo visualisation tools (VRLAB)

Although out lab facilities are used primarily for research, some of the facilities are regularly being used for educational purposes, e.g., for exercises, labs, homework assignments, and theses in the BSc program Civil Engineering, Applied Earth Sciences and Applied Physics; and the MSc programs Aerospace Engineering, Civil Engineering, Applied Earth Sciences; Applied Physics and Geomatics.

2. GRS Observatories and measurement equipment

For data acquisition in the field, the laboratory provides state-of-the-art equipment for precise positioning, gravity measurements, and 3D-object scanning. The equipment includes sixteen mobile GNSS receivers and antennas for precise positioning, which are used for special projects and special campaigns, two LaCoste-Romberg type relative gravimeters and two Scintrex type relative gravimeters and one FG-5 absolute gravimeter for gravity measurements, and ancillary equipment such as tripods, meteo instruments and a in house developed soil moisture profile sensor for boreholes. A 3D laser scanner is being used for scanning objects indoors as well as outdoors. The equipment is completed by diverse measurement devices for measuring height differences, distances, and angles (levelling instruments, tachymeters, theodolites, laser distance measurement devices); they are mostly used to support the other measurement equipment or for educational purposes..

The GRS lab. maintains a number of important research facilities to support the GRS research program and earth observation research at large. The research facilities are mostly operated in close cooperation with other groups. These research facilities are:

- Dutch Permanent GNSS Array (DPGA)
- Astrometric-Geodetic Observatory Westerbork (WAGO)
- GNSS Laboratory Delft
- Experimental Sites for Atmospheric Research (a.o. Cabauw)

2.1 Dutch Permanent GNSS Array

The Dutch Permanent GNSS Array (DPGA) presently consists of 15 continuously tracking GNSS (Global Navigation Satellite System) receivers in the Netherlands, which are part of the International GPS Service (IGS), EUREF Permanent GPS Network (EPN), the Active GPS Reference System for the Netherlands (AGRS.NL), or the Cabauw Experimental Site for Atmospheric Research (CESAR). The first GPS receiver was installed in Kootwijk in 1992 within the framework of a pilot project, which in 1994 became the International GPS Service (IGS). The IGS consists of about three hundred tracking stations world-wide. It is the only supplier of precise GPS and GLONASS orbits and clocks, and an important contributor to the International Earth Rotation Service (IERS) and International Terrestrial Reference System (ITRS). Westerbork is one of the fifty core stations, which make up the reference frame of IGS. Three stations are co-located with tide-gauges at the North-Sea. One of the tide-gauge station is also equipped with a compact active radar transponder for the Radarsat-2 and Sentinel-1 radar satellites. The DPGA also serves as operational center for the NTUS IGS station in Singapore.

The Active GPS Reference System for the Netherlands (AGRS.NL), a joint effort between the TU Delft, Cadastre and Rijkswaterstaat under the auspices of the Netherlands Geodetic Commission, became operational in 1997. The AGRS.NL forms the backbone of the Dutch geometric infrastructure and is used for scientific research and international collaboration initiatives.

The scientific value of a GPS station depends on collocations with other techniques, such as Satellite Laser Ranging (SLR), Very Long Baseline Interferometry (VLBI), Absolute Gravity measurements (AG), Tide Gauges, Water Vapour Radiometers (WVR), connection to the Dutch Primary Levelling Network (NAP) and the presence of accurate clocks (Maser). The Westerbork, and Cabauw sites are of special significance in this respect because of the Westerbork Synthetic Radio Telescope (WSRT) and the Cabauw Experimental Site for Atmospheric Research (CESAR) providing strong links to astronomy and meteorology.

The permanent GNSS receivers participate in various international networks, such as the IGS, the EUREF Permanent Network (EPN) - European densification of IGS - the Eumetnet EGVAP projectfor near-real time determination of water vapour for Numerical Weather Prediction, forecasting and climate applications , and the IGS Multi GNSS (MGEX)), tide gauge (TIGA), and real-time pilot projects. Delft is also used as a data collection site for the EGNOS System Test Bed (ESTB) in collaboration with Eurocontrol, and houses GNSS tracking stations for the US Jet Propulsion Laboratory (JPL) and Japanese Space Agency (JAXA). The Delft site is also used as a testing site for various new type of receivers to track upcoming satelletie systems (GALILEO, BEIDOU, QZSS)

Data from the Dutch Permanent GNSS Array is processed using two different software packages: GIPSY from JPL and Bernese GPS software. Furthermore, the data is analyses by several international analyisis centers from IGS and EUREF.
Data from the Dutch Permanent GNSS Array is available through a local data center. Data for the IGS and EPN stations is also available through IGS and EPN data centres. The local data center also archives data from two Network RTK providers in the Netherlands, the NETPOS system operated by Kadaster, and 06-GPS operated by a commercial company. These networks are primarily operated for surveying (RTK), but their data is also of scientific interest, such as studies of surface motions and climate studies (water vapour).

A reprocessing of all GNSS data stored at the local data center is planned for 2016 in collaboration with the Kadaster and KNMI.

2.2 Westerbork Astrometric-Geodetic Observatory (WAGO)

The Westerbork Astrometric-geodetic Observatory (WAGO) is the fundamental Dutch reference station, established in 1997. It is located at the premises of the Westerbork Synthesis Radio Telescope (WSRT), an astronomical facility operated by the Netherlands Foundation for Research in Astronomy (ASTRON). New facilities were constructed according to the international standards for fundamental reference stations. They include a permanent GPS station as part of the International GPS service (IGS) and the Dutch Active GPS Reference System (AGRS.NL), and a specially designed stable platform (bunker) for hosting absolute and relative gravimeters. Moreover, ultra-stable atomic clocks (a.o. a hydrogen maser) are shared with ASTRON.

One of the fourteen telescopes can be utilized for geodetic VLBI. The available H-Maser frequency standard makes possible internationally precise time comparisons. The Survey Department of the Ministry of Transport, Public Works and Water Management (RWS/DiD) installed an underground height reference marker, which allows connecting the AGOW with the Dutch first-order-levelling network. A control network has been established and the ties between the different markers are being realized at the millimetre level.

FG-5 absolute gravimeter (left) and gravity bunker at Westerbork (WAGO_) (right).

2.3 GNSS Laboratory Delft

GRS has its GNSS Laboratory, in Delft, in the former Geodesy building. Until 2003 part of GRS was housed in this unique building with specially designed and stabile facilities for earth observation, with a platform for GNSS observations that has been in use since 1989. In 2003 the building was sold to the Netherlands Metrology Institute (VSL), but GRS has secured access to the GNSS observation platform and registration room.

Currently, several GNSS experiments are running in this laboratory. It is home to a real-time IGS station, an EPN station and a receiver for the IGS MGEX pilot, but also it is running a receiver for JPL's Internet Based Global D-GPS network, the Japanese Space Agency (JAXA) and it houses two GNSS receivers to monitor the performance of EGNOS for Eurocontrol. The facilities are often employed for various other GNSS experiments, such as a zero baseline GNSS experiment, using multiple GNSS receivers on the same antenna , to study receiver and inter system biases for a PhD study.
The same facilities are used by NMI for time transfer using their own GNSS receivers. NMI is the official time laboratory for the Netherlands and operates several atomic clocks, GNSS receivers and two-way time transfer system.

2.4 Experimental Sites for Atmospheric Research.

Cabauw Experimental Site for Atmospheric Research (CESAR)

The Delft University of Technology collaborates in 'Cabauw Experimental Site for Atmospheric Research' (CESAR). It consists of a large set of instruments to study the atmosphere and its interaction with the land surface. Cabauw also serves as a permanent bridge between the participating universities (TU Delft, WUR, TU/e) and research institutes (KNMI, RIVM, TNO, ESA, ECN).

The CESAR site is used for

- Monitoring of long term tendencies in atmospheric changes
- Studies of atmospheric and land surface processes for climate modelling
- Validation of space-borne observations
- The development and implementation of new measurement techniques
- Training of young scientists at post-doc, PhD and master level.

The Atmospheric radars at CESAR Observatory used by GRS are a mobile 3 GHz radar system TARA, (annual costs: 25 keuro k€) and a 10 GHz radar system IDRA, (annual maintenance costs: 25 keuro k€)

Many of the available atmospheric remote sensing instruments located at Cabauw, offer unique possibilities for sensor synergy.
For instance, the collocation of a cloud radar with radiometers, lidars, in-situ equipment and nearby radio sondes will improve understanding of cloud-aerosol-radiation interaction, while integrated water vapour estimations from GPS observations will be a valuable input for various system studies and international campaigns to be carried out at Cabauw.

LEOS operates two GNSS receivers at the CESAR site to determine Integrated Water Vapour.. For more information see Cabauw Experimental Site for Atmospheric Remote Sensing (CESAR)--> http://www.cesar-observatory.nl/

Other infrastructure on Atmospheric remote sensing

Other infrastructure on Atmospheric remote sensing are the new to be formed testbed in Rotterdam (as per August 2013: a 10 GHz radar RAINGAIN, annual costs 25 k€) and the 3 GHz system PARSAX (on top of the EWI building). The *TU partners are* CEG: Deps. Water management, Geoscience and Remote Sensing and from EEMCS: Dep. Microelectronics. In

the Netherlands we collaborate with WUR, KNMI, RIVM, ECN, TNO, UU, ESA, City of Rotterdam, Delfland

Furthermore through our cooperation with the KNMI we have access to the KNMI Parameterisation Test Bed (Results of a variety of numerical models, ranging from GPU-Accelerated large-eddy simulations, limited area models and single-column model versions are compared continuously with in-situ data as obtained from the CESAR Observatory) and the OMI satellite instrument (PI: prof. Levelt) and the new TROPOMI instrument (PI: Veefkind, to be launched in 2016) gives detailed information on global trends in regional and global air quality and climate related issues.

Cabauw Site

3. Data and computer facilities

3.1 Dedicated data processing facilities

The processing of the huge amount of earth observation data requires and the design and analysis of space missions require dedicated data processing facilities. Currently, our main processing facility is: complemented by several smaller clusters consisting of a couple of PC's for specific tasks. Also several PC's are used for web based data services. For running and developing GPU accelerated simulations such as DALES and it GPU derivative GALES a GPU computing grid is available. The grid also 3D visualisation facilities ranging from desktop 3D system to a a large 3D screen facility with dedicated rendering hardware.

3.1.1. Cesar-Cluster

Cesar-Cluster has been designed for the processing of satellite, airborne, and ground-based gravity data with main emphasis on the dedicated gravity missions CHAMP, GRACE, and GOCE and for running full-scale simulations for follow-on missions. It consists of one master node and 18 compute nodes. Each node is equipped with two modern Xeon CPU's with 24 cores. The theoretical peak performance is 812 GFLOPS per node. All nodes are equipped with 64 GB RAM A RAID array with a total capacity of ca 30 TB is used for storage. The nodes are connected by an Infiniband network. At the moment we are looking tp expand and improve the storage system. The new storage system should be much faster and saleable in all dimensions (speed, size and number of connected nodes) and will initially have a 250Tb capacity. Part of this cluster is optimized to handle and process radar remote sensing data and consists of a 32 core system with adequate Ram and hard disk space of 130 TB.

Cluster

3.1.2. Clouds and Climate GPU Accelerated Grid for Computation and Visualisation

For the clouds and climate GRID we have a setup of a dedicated 1 GB link to specific workplaces, coupled via a 8 server setup at CiTG and a 3 server setup at EWI. The network is coupled to the VR lab and has a direct link to Sara. It also has a 100TB storage facility. The system is coupled with a 3D visualisation lab, allowing near-immersive visualisations of 3D data sets in stereo. We are looking to expand the visualisation facility with a small, possibly mobile, stereo display and rendering machine.

The grid system is also to become the centre of all incoming data from remote locations such as the systems at Cabauw. For the diverse radar measurements storage is being handled by a control PC at CiTG. Data is stored locally at harddrives.

3.2.2. Data facilities

GRS operates a number of data services for distributing earth observation data, and contributes to several other services of national and international organizations. The largest data services operated by GRS is :GNSS Local Data center

GRS operates a local data center), which includes all current and historic data from the Dutch Permanent GNSS Array, the NETPOS system operated by the Kadaster, and 06-GPS system. Currently data is stored for about 85 sites in the Netherlands, with the oldest data from 1992.The main purpose of thedata is to facilitate research and educational applications, and to provide GNSS data to the International GNSS Service (IGS) (http://igscb.jpl.nasa.gov), the IGS regional data center at BKG, Germany (http://igs.bkg.bund.de), the IGS global data centre at IGN (http://igs.ensg.ign.fr/), the EUREF Permanent GPS Network (EPN) (http://epncb.oma.be/), the NASA Global Differential GPS System (http://gmon2pa.gdgps.net/igdg/monitors/), the EUMETNET GPS Water Vapor Program (E-GVAP) (http://www.knmi.nl/samenw/egvap/validation/ztd_iwv.html), and the Cabauw Experimental Site for Atmospheric Remote Sensing (CESAR) (http://www.cesar-observatory.nl/).

4. Personnel of Lab facilities GRS

For support and maintenance of the GRS lab. facilities, 1.8 fte's are assigned (0,5 fte additional via EWI for the Radar support). The tasks comprise maintenance of the facilities (stations and measurement equipment), site, software and hardware testing and developing, upgrading, organization and execution of field campaigns, and data pre-processing.

One person has a focus on servers, and other ICT hardware/software, 1 has a focus on gravimetric equipment and on geodetic equipment. A third person, working at Electrical Engineering supports the atmospheric radars.