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Astrogeodetic Test Observation by the Newly Designed Astrogeodetic Camera System Version 2

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1 Why do we need a Digital Zenith Camera System?

The geoid is the equipotential surface of the Earth. Development of geoid modelling is based on geodetic, gravimetric and astrogeodetic techniques. In order to define high precise geoid, deflection of the vertical (DoV) components, that are obtained by the astrogeodetic techniques, can be used. DoV is also very important for providing valuable information on the structure of Earth's gravity field.

After the 2000s, Digital Zenith Camera Systems (DZCSs) were developed which provide high accuracy measurements for DoV components in precise geoid modelling applications. Using the astrogeodetic DoV, geoid height changes between ground stations are determined that lead to the **astrogeodetic geoid** modelling. The use of DZCS could be advantageous in mountainous and coastal regions where geoid heights have larger variations. Implementation of DZCS into the astrogeodetic DoV determination would lead to a new determination of the astrogeodetic geoid profile for Istanbul.

2 Areas of Usage in Digital Zenith Camera System

Gravity Field Determination		Geoid Modelling Studies	
Geophysics and fine structure determination of Earth's gravity field		Local Geodetic Networks - underground survey of the tunnel axis	
Combined gravity field determination	Validation of gravity field models	Validation of gravimetric geoids & GGMs	Geometric - Astronomical levelling
Definition of highly-precise astrogeodetic gravity field		Astronomical - Topographic levelling	Hybrid geoid models
Monitoring of Anomalous Refraction		**Celestial Positioning and Navigation at Sea**	
...		...	

In this study, the Digital Zenith Camera System is used for Geoid modelling.

3 How to obtain 1 cm Differential Accuracy Geoid?

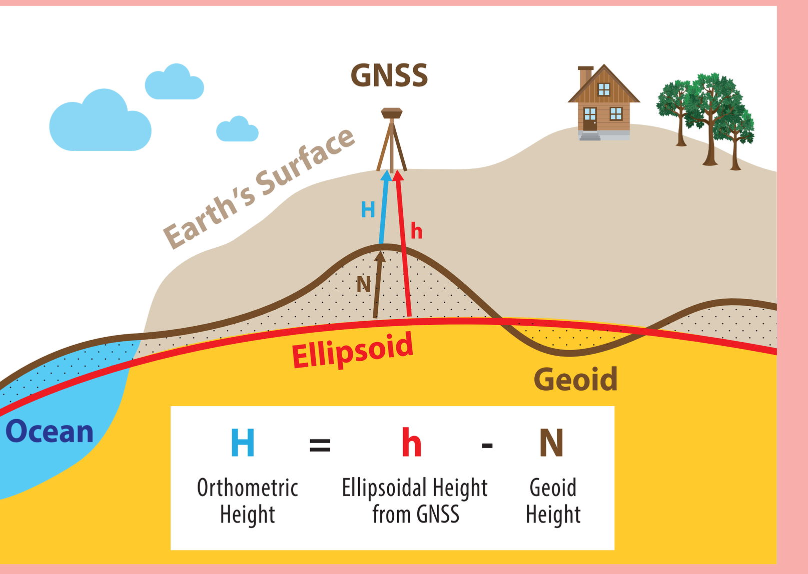
Geoid is the fundamental geodetic infrastructure for the rational use of Global Navigation Satellite System (GNSS) technology.

GNSS/Levelling technique for geoid determination has great significance for to the transformation of GNSS-derived ellipsoidal height (h), into the orthometric height (H), which is used in engineering projects and determined by levelling.

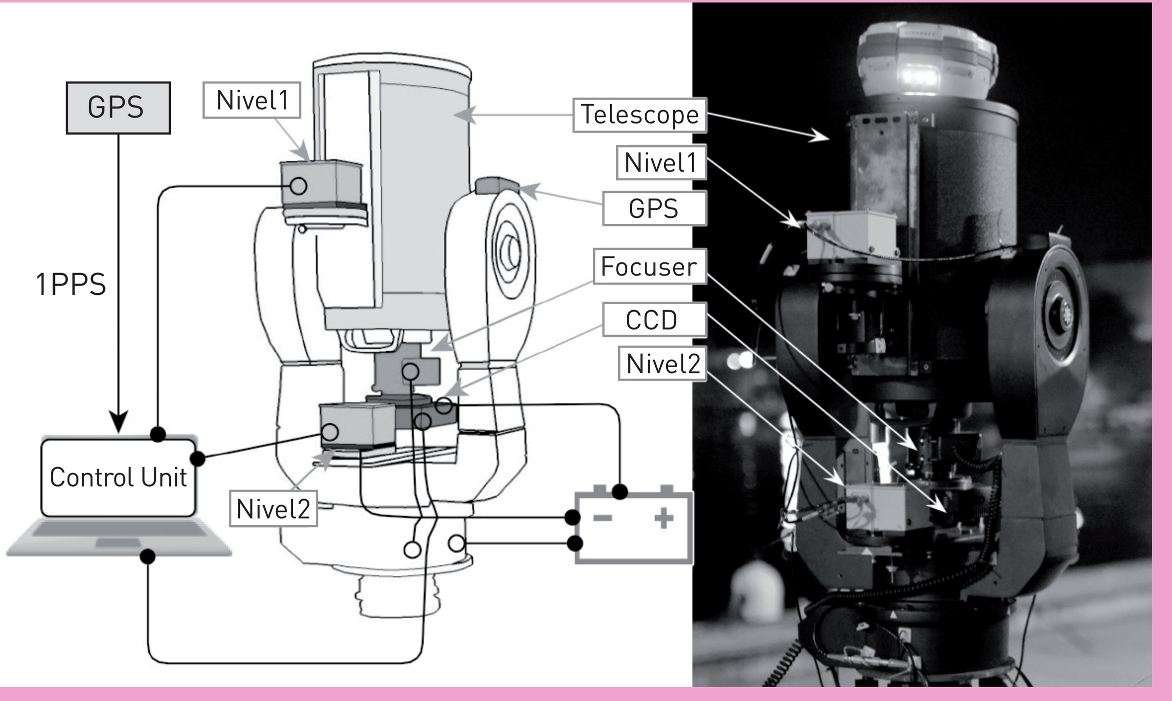
Instead of levelling, which is an expensive and time-consuming method, orthometric heights can be calculated by using a well-defined geoid models.

To obtain 1 cm differential accuracy geoid, these data sets can be used:

- Gravity data (airborne and/or terrestrial)
- Astrogeodetic deflection of vertical data
- GNSS/Levelling data
- Satellite altimetry data
- Satellite gravity data
- Chronometric levelling



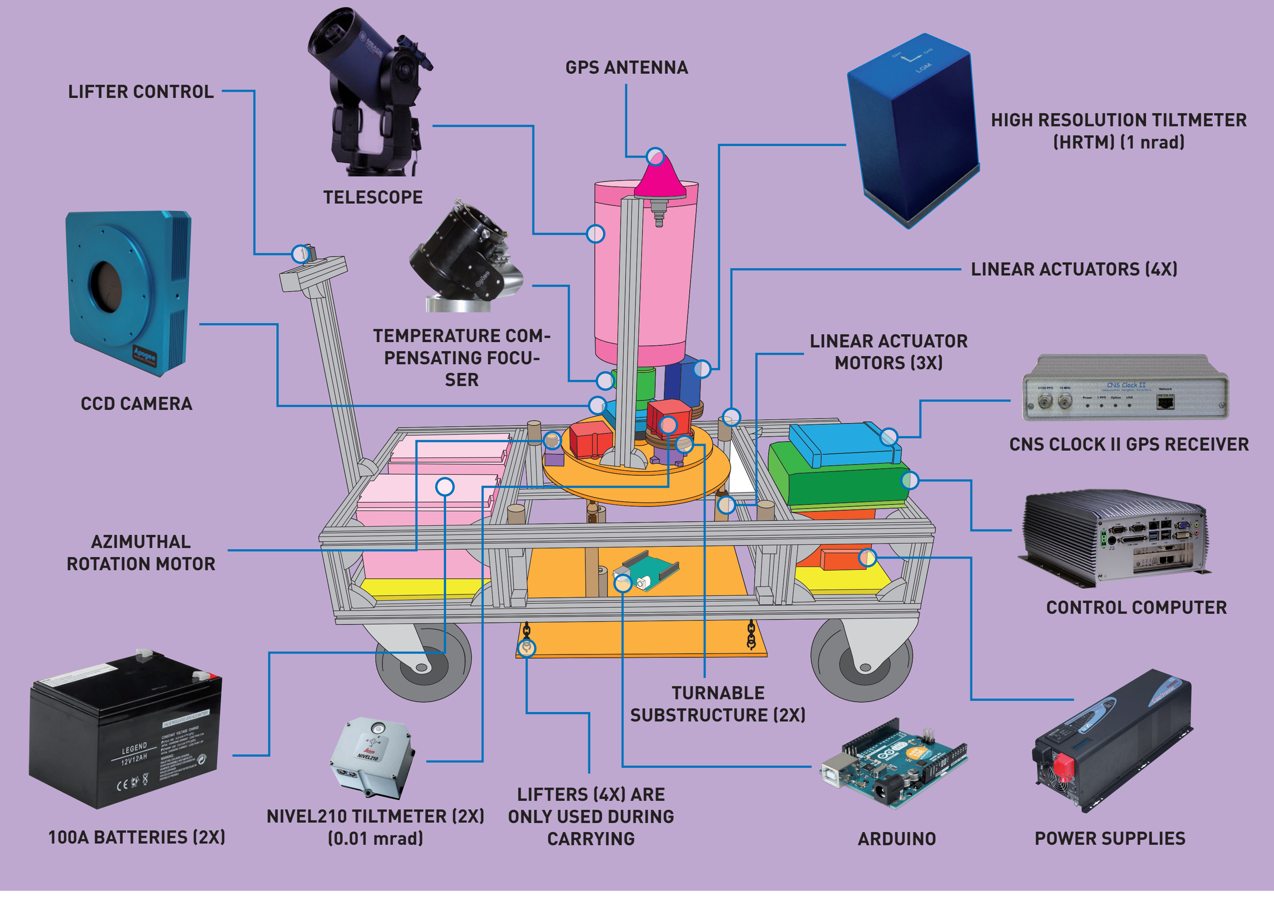
4 The First Digital Zenith Camera System of Turkey "Astrogeodetic Camera SYStem (ACSYS) v.1"



The first DZCS, namely the Astrogeodetic Camera System (ACSYS), was developed in Turkey in 2015. It is capable of obtaining DoV with an accuracy of 0.2-0.3 arc sec, yet it has some limitations in observation duration. Because of the semi-automated mechanical design, levelling the system towards zenith was a time-consuming process .

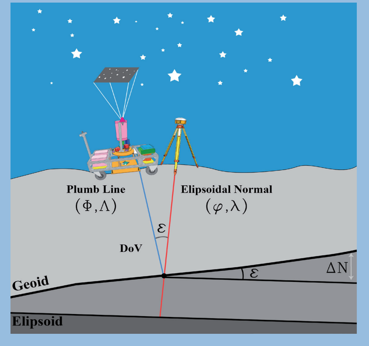
Since the beginning of 2016, the ACSYS has been modernized though upgrading the system with new technological components, hardware and software.

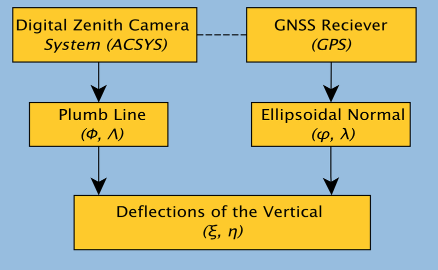
5 Astrogeodetic Camera System Version 2



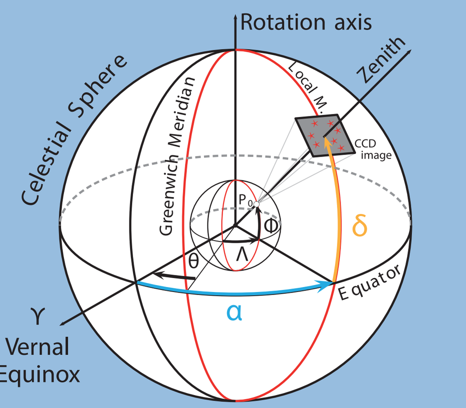
The test and calibration measurements of each component of the system such as the telescope, CCD camera, tiltmeters, the CNS Clock II, that is used for determining the time, and the temperature compensating focuser were completed. These components were re-tested, and their calibration measurements were also completed with the new fully automated substructure supporting the ACSYS v2.

6 Astrogeodetic Measurement Technique





$$\xi = \Phi - \varphi$$
$$\eta = (\Lambda - \lambda)\cos\varphi$$
$$\varepsilon = \sqrt{\xi^2 + \eta^2}$$



Star Located at Zenith

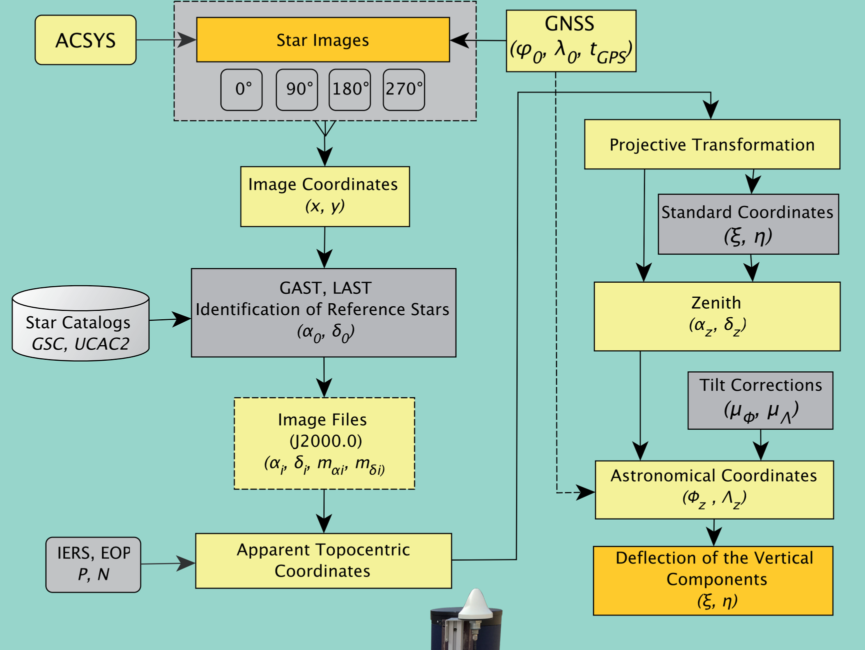
$$\Phi = \delta \quad \Lambda = \alpha - GAST$$
$$\theta = GAST$$

$$\Phi = \delta_z\,(\text{catalog, ERP, x, y, model, refraction}) + \mu_\Phi$$
$$\Lambda = \alpha_z\,(\text{catalog, ERP, x, y, model, refraction}) + \mu_\Lambda - GAST\,(t_{GPS}, ERP)$$

7 The Observation Procedure

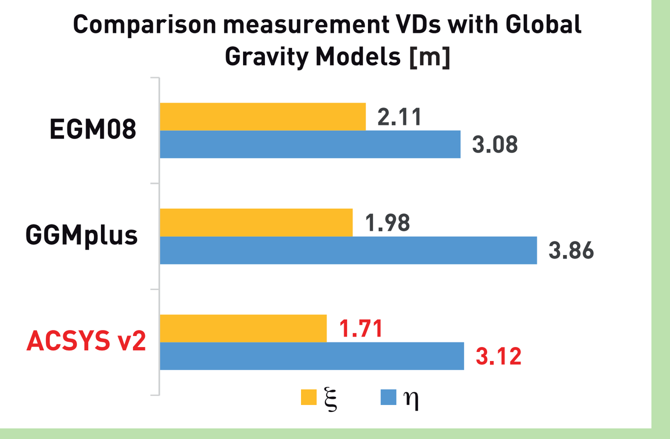
- The tiltmeters are utilized while levelling the system. The biggest problem of ACSYS v1 was that the leveling of the system took 1.5 hours. To reduce the time spent on levelling, the levelling of the system was automatized through linear actuator motor in the ACSYS v2. To increase the accuracy of levelling, the HRTM with one nanoradian accuracy was provided as the system component.
- To determine the coordinates of zenith point through ACSYS v2, observations in different azimuths should be conducted because the images obtained in different azimuths show a radial symmetry around the zenith point. In the previous ACSYS (v1), Azimuth calibration was made manually with 4 different azimuth values which had 90° among each. In ACSYS v2, the azimuth calibration is automatized through a system controlled by Arduino.
- Observation duration is 1-1.5 hour; Shutter time is 300ms, 10 images in each azimuth and 5 series.

8 Evaluation of the Test Data



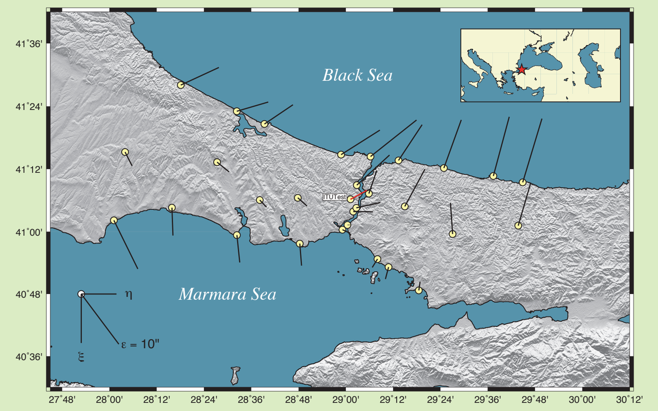
9 The Preliminary Results

- The preliminary astrogeodetic test observations were conducted by The ACSYS v2 in the main station (ITU test point) for 5 nights.
- ITU test point geodetic coordinates:
  41° 06' 12.80635" N   29° 01' 10.82185" E   126.9973 m
- ITU test point vertical deflections (average of 5 nights):
  North-South Component (ξ) = 1.71 m
  East-West component (n) = 3.12 m
- The main motivation in this study was to investigate the system precision with repeated observations. Obtained VDs from ACSYS v2 is compared with Global gravity models such as GGM plus and EGM08.



10 Conclusion and Future Work

- The repeated measurements during 5 nights at the main station have shown that the ACSYS v2 is capable of determining and reproducing deflections of the vertical with high precision.
- The ACSYS v2 will be measured on an Istanbul Astrogeodetic Network (30 benchmarks) with the already known geoid heights.
- This study's aim is to establish an astrogeodetic network and to improve Istanbul local geoid model based on the geoid height changes, obtained after the observations collected at this network, integrated with the current GNSS/Levelling data.
- Geoid height differences will be compared with the ones calculated using GNSS/Levelling, GGM plus and EGM08.
- Contribution to future Global models & local geoid models.



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