Saudi Arabia National Spatial Reference System - SANSRS

SULTAN AL-SHAHRANI
General Authority of Survey and Geospatial Information (GASGI), Saudi Arabia
اللهم حم يوم حم
OUTLINE

➢ National Geodetic Infrastructure

➢ Saudi Arabia National Spatial Reference System Components

❑ National geodetic reference frame KSA-GRF17
  ▪ KSA-CORS network and primary geodetic network

❑ National Vertical Reference Frame KSA-VRF14
  ▪ National Vertical Network (NVN)
  ▪ National Gravity Network (NGN) and gravity observations on NVN benchmarks
  ▪ National Vertical Datum – 3d
    ▪ Current KSA-GEOID17
    ▪ Airborne Gravity
    ▪ GPS/GNSS for ellipsoidal height determination over Saudi Arabia
    ▪ New KSA-Geoid Development
    ▪ Role of 3D KSA-Vertical Datum as a link between KSA-GRF & KSA-VRF

❑ Transition from STATIC to DYNAMIC/TIME VARYING Reference System

➢ Conclusions and Recommendations
National Geodetic Infrastructure
National Geodetic Infrastructure

It is combination of Spatial Reference System and Geodetic Networks which contribute in establishing and supporting positioning applications in horizontal and vertical directions with high quality & accuracy and national coverage

It is considered the foundation of National Spatial Data Infrastructure (NSDI)
National Geodetic Networks

They are a group of different geodetic networks – major components KSA-GRF and KSA-VRF - which were established to provide the necessary geodetic data for different projects and land surveying activities in KSA.

National CORS Network

National Vertical Network

National Gravity Network

National Geodetic Networks were established based on International Standards

Spatial Reference System (SRS) is a regional or global reference system which is used in all positioning applications in both dimensions - horizontal and vertical - and also all existing geo-spatial products are reference to it. SANSRS is a national geospatial reference for use in all survey, mapping, locational and positioning services.

These geodetic components are defined based on data and information from different geodetic networks.
It is combination of Spatial Reference System and Geodetic Networks which contribute in establishing and supporting positioning applications in horizontal and vertical directions with high quality & accuracy and national coverage.

It is considered the foundation of National Spatial Data Infrastructure (NSDI)
Saudi Arabia National Spatial Reference System Components
National geodetic reference frame KSA-GRF17

KSA-CORS network and primary geodetic network

National Vertical Reference Frame KSA-VRF14

National Vertical Datum (NVD) – 1d

National Gravity Network (NGN)

National Vertical Datum – 3d

Current KSA-GEOID17

Airborne Gravity

GPS/GNSS for ellipsoidal height

KSA-GEOID21 NEW GEOID
KSA-CORS network - the core of KSA-GRF17 Dissemination

Network Control Center (NCC): to control and monitor KSA-CORS network.

Ground type (GT) & Roof type (RT): for SANSRS definition & precise positioning services
Recently, the Kingdom of Saudi Arabia established the unified National Geodetic Reference Frame KSA-GRF17.

KSA-GRF17 was computed based on ITRF2014/IGS14 epoch 2017.0 using observations of 51+14 IGS stations used also in definition of ITRF2014.

Defined in such way that: it coincides with ITRF2014 at epoch 2017.0.

➢ it is moving consistently with the stable part of the Arabian tectonic plate.
➢ general transformation formula linking KSA-GRF17 to the ITRF2014, for station positions is given by the following equation:

\[
\begin{pmatrix}
X_{KSA-GRF17} \\
Y_{KSA-GRF17} \\
Z_{KSA-GRF17}
\end{pmatrix}(t) = \begin{pmatrix}
X_{ITRF2014} \\
Y_{ITRF2014} \\
Z_{ITRF2014}
\end{pmatrix}(t) \times \begin{pmatrix}
1 & -R_z & R_y \\
-R_z & 0 & -R_x \\
R_y & R_x & 0
\end{pmatrix} \times \begin{pmatrix}
X_{ITRF2014} \\
Y_{ITRF2014} \\
Z_{ITRF2014}
\end{pmatrix}(t - 2017.0)
\]

For station position at any epoch \( t \):

where: \( R_x, R_y, R_z \) are the three components of the Arabian plate rotation pole (or angular velocity) expressed in ITRF2014.
NATIONAL VERTICAL NETWORK (KSA-NVN)

- **Main task**
  
  Provide a precise and unified vertical datum for Orthometric heights determination over the KSA.

- **KSA-NVN**
  
  Number of BMs: 3893;
  Number of level lines: 88;
  Distance between the BMs: 6 km;
  Total length of NVN: 22869 km;

- The a priori accuracy - NGS standards for Second order/Class I double run precise geodetic leveling.

- The provisional accuracy for double run - for entire NVN ±1.03 mm/km.

*NVN has an accuracy better than Second order/Class I according to NGS Standard*
NATIONAL GRAVITY NETWORK (NGN) AND GRAVITY OBSERVATIONS ON NVN BENCHMARKS

- Main task
to establish gravity reference system of KSA as part of the SANSRS and to support the realization of gravity standard over the KSA

- NGN class 1: gravity base network (GBN) - absolute gravity observations on 41 stations with center and ex-center points;

- NGN class 2:
  - Primary Relative Gravity network (PRGN) - densification of the absolute gravity sites (mostly 250 BMs from KSA-NVN apart each other 60 km);
  - National vertical network gravity measurements at BMs, TG BMs and PGNs (3504);

- Service: Gravity Calibration Baseline (GCB) – 14 AG (with center and ex-center points) with achieved average accuracy for relative gravity values: 1.2 μGal (center points); 1.6 μGal (ex-center points). And relative gravity linking them

**NGN has an accuracy better than Second order/Class I according to NGS Standard**
KSA-VRF14

KSA Vertical Reference Frame Jeddah’2014

KSA-VRF14 is based on in-situ observations from tide gauge stations, precise levelling, gravity data, satellite altimetry and GOCE data.

KSA-VRF14 is the latest realization of National Vertical Reference System (NVRS). The main characteristics of KSA-VRF14 are as follows:

| Height system type:                  | Helmert-orthometric Above Mean Sea Level at JEDDAH Tide Gauge |
| Least-Square Adjustment type:        | Fixed geo-potential number above MSL of Jeddah TGBM-B         |
| Physical Realization Benchearks:     | National Vertical Network                                     |
| Physical Realization Grid Interpolation: | KSA-GEOID17/KSA-GRF17                                         |
| Tidal system:                        | Tide Free                                                     |
| Primary Benchmark:                  | Jeddah TGBM-B                                                 |
| Latitude:                            | 21.49981 [degree]                                             |
| Longitude:                           | 39.16161 [degree]                                             |
| Fixed height above Mean Sea Level of Jeddah TGBM-B | 1.7446 [m]                                                   |
| Epoch:                               | 2014.75 year                                                  |
NATIONAL VERTICAL DATUM – 3D

Current KSA-GEOID 17

- The current KSA-GEOID 17 model is based on a gravimetric geoid, which is utilizing:
  - EGM *EIGEN6C4* reference field (incorporating GOCE and GRACE satellite data);
  - New *DTU15* satellite altimetry data offshore;
  - More than 500,000 gravity data points from both (GASGI) and older (ARAMCO) data sources;
  - The geoid is fitted to the *KSA-VRF14* through a set of 280 GPS/levelling points along the *NVN*

- Geoid accuracy:
  - better than 2 cm in area with gravity data
  - 15-20 cm in areas without gravity data and gravity related information

National Vertical Reference Frame KSA-VRF14

NATIONAL VERTICAL DATUM – 3D

AIRBORNE GRAVITY

- **Main task**
  - New gravimetric KSA- GEOID to be computed by filling large gaps with centimeter Accuracy;
  - Survey area coverage: ~1,320,000 square km;
  - Accuracy: ~0.7 μGal
NATIONAL VERTICAL DATUM – 3D

GPS/GNSS FOR ELLIPSOIDAL HEIGHT DETERMINATION OVER KSA

- **Main task**
  - to determine 'hybrid' KSA-GEOID;

- The KSA-VRF needs to be utilized over the territory of KSA by application of GPS/GNSS/leveling technique providing ellipsoidal height with better than 2 cm-accuracy;

- The current regional model of the kingdom fitted to GPS/GNSS/leveling data linked to KSA-VRF14 and KSA-GRF17;

- Observation coverage: entire NVN, TG networks, absolute gravity stations and gravity calibration baseline

- Outputs: Ellipsoidal height of all BMs, TG, AG Stations and GCB with **better** than 2 cm
NATIONAL VERTICAL DATUM – 3D

KSA-GEOID21 (NEW KSA-GEOID)

Main task

- Determination of a new high-accuracy (1-2 cm) and high-resolution gravimetric geoid model over the territory of KSA
- Determination of a new high-accuracy (1-2 cm) and high-resolution hybrid geoid model over the territory of KSA
NATIONAL VERTICAL DATUM – 3D

ROLE OF 3D KSA-VERTICAL DATUM AS A LINK BETWEEN KSA-GRF & KSA-VRF

KSA-GEOID: LINK BETWEEN KSA-GRF & KSA-VRF
Transition from STATIC to DYNAMIC/TIME VARYING Reference System - Currently, GASGI is working on developing a concept for transition from static to dynamic/time varying SANSRS & the following SANSRS components will be considered:

- **Transition of KSA Geodetic Reference Frame (KSA-GRF)** - from static reference frame w.r.t. to Arabic plate to reference frame including interplate and areas with natural & technogenic motions
- **Transition of KSA Vertical reference frame (KSA-VRF)**
  - National Tide Gage Network (TGN) - monitoring the effect of Mean Sea Level and its rate on changes in geo-potential of TG stations
  - National Vertical Network (NVN) – monitoring the effect of geometric movements of Tide Gauge stations, Ground CORS stations and specific areas of interest (Tectonic and technogenic active zones, seismic active, subsiding areas and etc.) on geo-potential changes and separation of pure geometrical movements from physical gravity field changes;
- **Transition of KSA Geoid**
  - National Gravimetric Network – campaign based and permeant Absolute gravity observation
  - Time varying gravity field from old, current and future satellite gravity mission
  - Dynamic KSA Geoid – determination and validation
- **Developing new geodetic earth observation applications over KSA (InSAR, SLR, VLBI and etc.), supporting the transition to time varying SANSRS and those utilizing it**
- **The Concept of transition from static to dynamic/ Time varying SANSRS - part of the National Geodetic Program (NGP), currently under development by GASGI- GDG**
3 Conclusions and Recommendations
All geodetic activities at General Directorate of Geodesy (GDG), General Authority of Survey and Geospatial Information (GASGI), and its up to date infrastructure can be considered as a very good background start, which could support different geodesy-linked activities:

**KSA-GRF/KSA-VRF/KSA-GEOID is the common geodetic infrastructure** for applications linked to Geo-referencing, the Earths’ gravity field, geophysics, oceanography, hydrography, hydrology, water flow studies, surveillance of coastal areas and etc.

- General and specific issues regarding future cooperation with different governmental/international organizations, professional and scientific communities – geodetic data and information stakeholders.
- Different forms of cooperation between GASGI and other communities can be established – bilateral or multi-partner working groups.
- Different joint activities (workshops, seminars, common projects and etc.) during major conferences and meetings can be planned.
- In Future; SANSRS includes transforming from Static (3D) to Dynamic (4D) System, which will allow any product, service or application described time wise.

http://www.nature.com/nclimate/journal/v3/n10/full/nclimate1908.html