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## The Kingdom of Saudi Arabia Geodetic and Vertical Reference Frames – the main Components of National Spatial Reference System

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# OUTLINES



> 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 Vertica Datum (NVD) 1D
- National Vertical Network (NVN)
- National Gravity Network (NGN) and gravity observations on NVN benchmarks

#### National Vertical Datum – 3D

- KSA-GEOID17
- Airborne Gravity
- GPS/GNSS for ellipsoidal height determination over KSA
- ROLE OF 3D KSA-VERTICAL DATUM AS A LINK BETWEEN KSA-GRF & KSA-VRF
- > CONCLUSIONS AND RECOMMENDATIONS





- It is combination of Spatial Reference System and 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).







- 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 geospatial products are reference to it.
- □ NSRS consists of following geodetic components:
  - National Geodetic Reference Frame (NGRF)
  - National Vertical Reference Frame (NVRF)
  - National Geoid Model
- these geodetic components are defined based on data and information from different 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 Geodetic Networks includes:

- National CORS Network
- National Vertical Network
- National Gravity Network
- National Tide Gauge Network
- Primary Geodetic Network

National Geodetic Networks				
Geodetic Network	National Tide Gauge Network	National Gravity Network	National Vertical Network	National CORS Network
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### NATIONAL GEODETIC REFERENCE FRAME KSA-GRF17



#### KSA-GRF17

- 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 the latest ITRF (currently 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:



#### **KSA-GRF17 CORS STATIONS**



$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{KSAGRF17}(t) = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{ITRF2014}(t) + \begin{pmatrix} 0 & -\dot{R}_z & \dot{R}_y \\ -\dot{R}_z & 0 & -\dot{R}_x \\ \dot{R}_y & \dot{R}_x & 0 \end{pmatrix} \times \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_{ITRF2014}(t) \cdot (t - 2017.0)$$

For station position at any epoch *t*:



### NATIONAL GEODETIC REFERENCE FRAME KSA-GRF17



#### KSA CORS NETWORK -THE CORE OF KSA-GRF17 DISSEMINATION

GENERAL PROJECT DESCRIPTIONTOTAL NUMBER OF STATIONS:325TYPES OF STATIONS & THEIR ROLE2

- GROUND TYPE (GT) & ROOF TYPE (RT): for SANSRS definition & precise positioning services
- **The fundamental CORS-RTK infrastructure:** 
  - Network Control Center (NCC) and
  - a network of GNSS Reference Stations (RS)





### NATIONAL VERTICAL REFERENCE FRAME KSA-VRF14



#### NATIONAL VERTICAL NETWORK (KSA-NVN)

#### Main task

According to the GCS mandate - to define, establish and maintain the NSASRS - the KSA-VRF (as a significant component of SANSRS) should provide a precise and unified vertical datum (height reference frame /a vertical reference surface ) 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  $\pm 1.03 \text{ mm/km}$ .

Finally, the established and observed NVN has an accuracy better than Second order/Class I







### NATIONAL VERTICAL REFERENCE FRAME KSA-VRF14



#### NATIONAL GRAVITY NETWORK (NGN) AND GRAVITY OBSERVATIONS ON NVN BENCHMARKS

#### Main task

The main task: to establish Gravity Reference System of KSA as part of the NSASRS 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 excenter points;

#### **NGN Class 2:**

- Primary Gravity Network (PGRN) 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) 12 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).



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### NATIONAL VERTICAL REFERENCE FRAME KSA-VRF14



#### KSA-VRF14:

□ *FULL NAME:* KSA Vertical Reference Frame Jeddah'2014 (KSA-VRF14)

KSA-VRF14 is based on:

- Tide Gauge Record Analysis;
- Satellite Altimetry Data Analysis for 15 years & Global DOT/SST Models;
- Global Earth Geo-potential Model Analysis;
- Least-Squares Adjustment (LSA) of precise geodetic leveling data together with observed gravity information for derivation of Geopotential numbers/Orthometric Heights above Mean Sea Level at GCS Jeddah TG station





### NATIONAL VERTICAL DATUM – 3D



#### 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 new (GCS) and older (ARAMCO) data sources;
  - The geoid is fitted to the new 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 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;
- Expected Accuracy: ~0.7 mGal







### NATIONAL VERTICAL DATUM – 3D



### GPS/GNSS FOR ELLIPSOIDAL HEIGHT DETERMINATION OVER KSA

- □ MAIN TASK: To determine 'hybrid' KSA-GEOID;
  - The current regional model of the Kingdom fitted to GPS/GNSS/Leveling data linked to KSA-VRF14 and KSA-GRF17;
  - Also, the new 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 cmaccuracy;
  - Observation coverage: Entire NVN, TG Networks, Absolute Gravity stations and Gravity Calibration Baseline
  - Outputs: Ellipsoidal height of all BMs, TG, AG, Grav. stations and GCB with better than 2 cm accuracy.





#### **ROLE OF 3D KSA-VERTICAL DATUM**







### **CONCLUSIONS AND RECOMMENDATIONS**





**GEODETIC APPLICATIONS** 



GEODETIC DATA AND INFORMATION STACK HOLDERS



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

All geodetic activities at General Directorate of Geodesy (GDG), General Commission for Survey (GCS) 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 stack holders.
- □ Different forms of cooperation between GCS 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.



المملكة العربية السعودية KINGDOM OF SAUDI ARABIA





