NATIONAL SURVEY AUTHORITY
MINISTRY OF DEFENCE
SULTANATE OF OMAN

الهيئة الوطنية للمساحة
وزارة الدفاع
سلطنة عمان

LATEST GEOSPATIAL INFRASTRUCTURE IN OMAN : NATIONAL DEVELOPMENT BENEFITS

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- CORS – ONCN SYSTEM
- GEOID MODEL – ONGM SYSTEM
- INTEGRATED ONCN/ONGM SYSTEM APPLICATIONS
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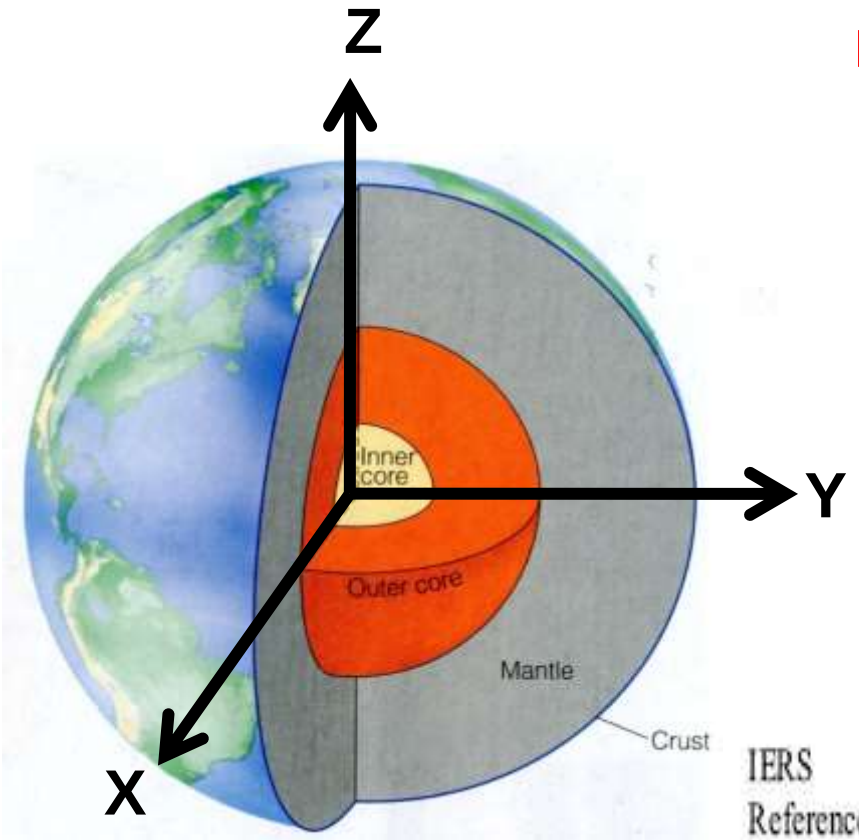
ONGD14/OMAN DATUM 2017

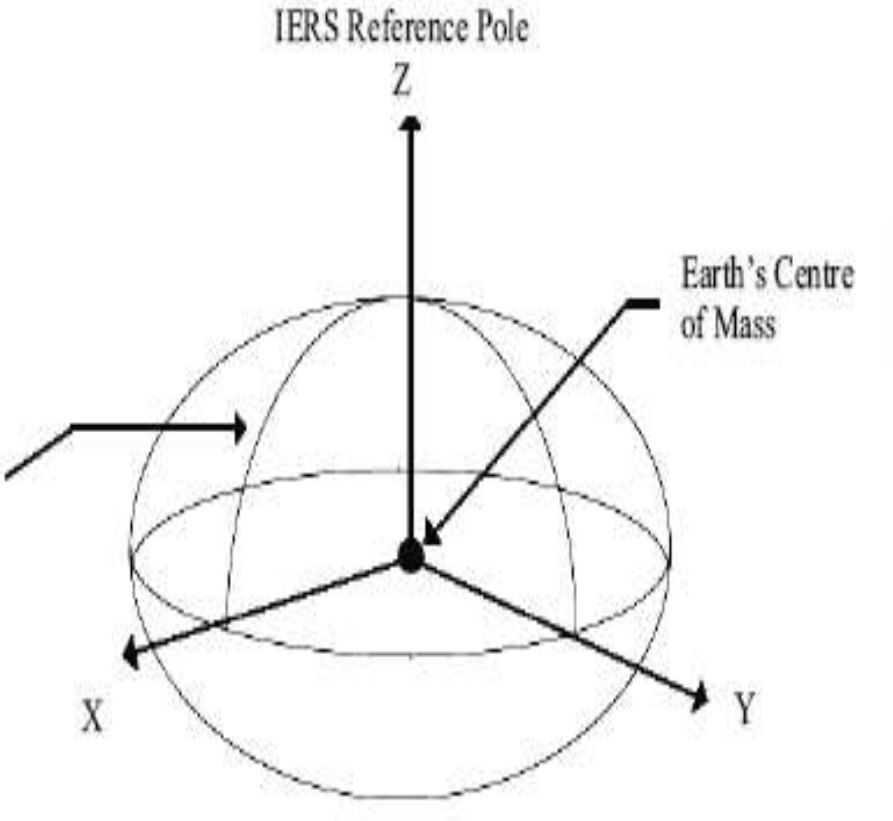
ONGD14 AND OMAN DATUM 2017



IERS (International Earth Rotation Service)

EARTH CENTERED EARTH FIXED (ECEF) CARTESIAN SYSTEM

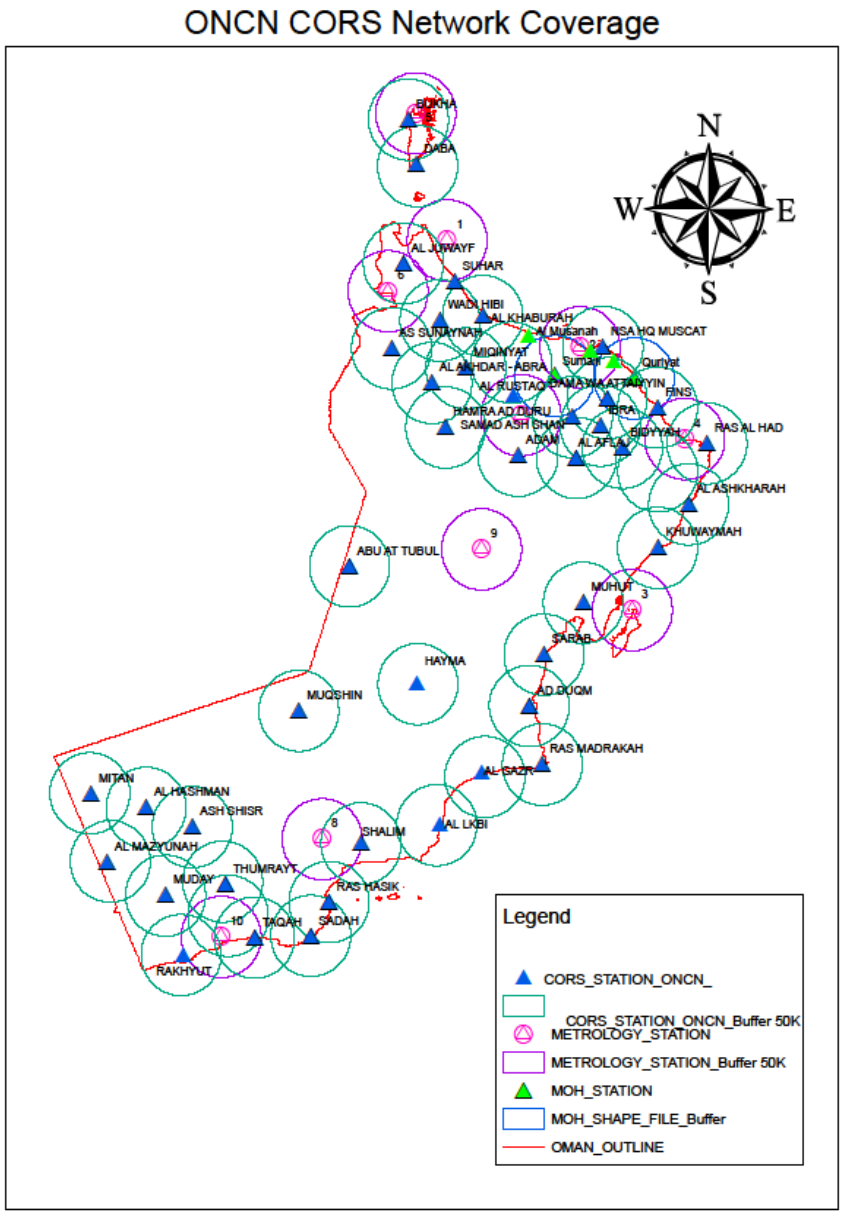
ITRF2008@2014/ITRF2014@2017

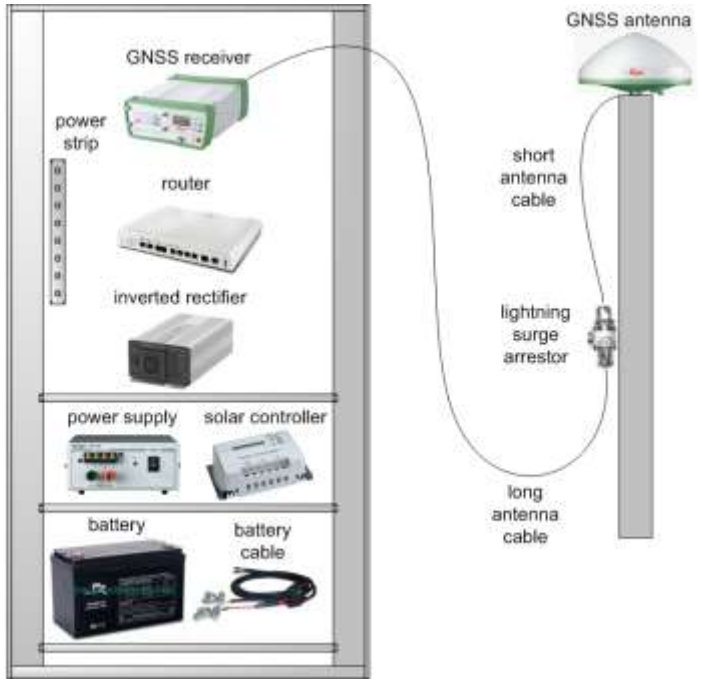


- Recent development in Oman requires latest geospatial infrastructure in particular modern surveying and mapping platforms for providing the country with homogenous horizontal and vertical control.
- **Realization of a national geocentric datum to provide GNSS user community in the country with uniform coordinates in ITRF system**.
- The need for more GNSS-based geodetic control points to sufficiently covering the land areas of the country is inevitable. The **existing First Order GPS control network** is not sufficient to meet present horizontal control requirement in the country.
- This network needs **to be replaced by modern geodetic control infrastructure comprising of CORS stations network** such as ONCN system that will provide control and positioning services throughout the country.

CORS – ONCN SYSTEM

OMAN NATIONAL CORS NETWORK





ONCN CORS

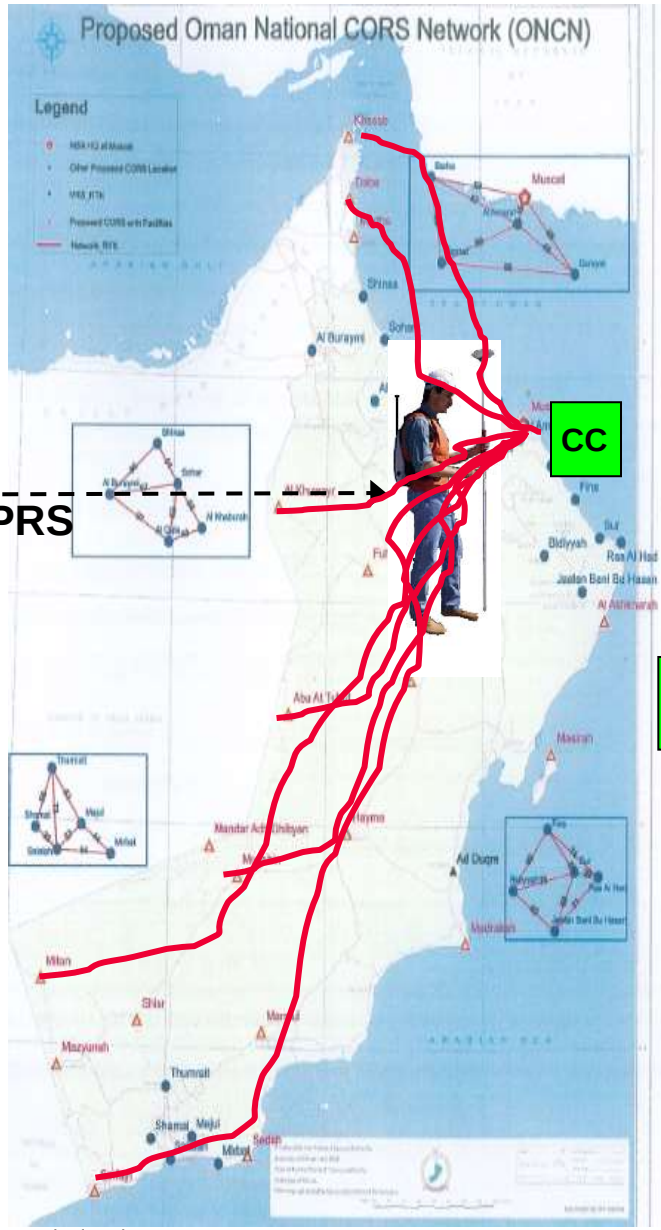
Concept – System Architecture

Site Server :

- **Control & Management of CORS**
- **Collecting measurements in Real-Time**

CORS Network Control-Centre

RTCM corrections via mobile internet / GPRS



Network Server :

- **Processing Network Solution**
- **Creating User Corrections**

RT Proxy Server :

- **Distribution of Real-Time Corrections**
- **Distribution of Web Services (RINEX)**

ONCN CORS

- Continuous Operation 365/24/7
- Provides Data and Corrections in a consistent national datum
- Robust against failure of one Reference Stations
- **Mitigates Distance-dependent Errors that limit conventional GNSS**
- Provides positioning with Higher Accuracy, Reliability and Availability everywhere in Oman
- Allows Central Control and Monitoring of all Stations
- The operation of new ONCN system will indicate the beginning of modern 3-D positioning service era for the country. Integration with new Oman geoid model will enable the practice of GNSS-Leveling application.

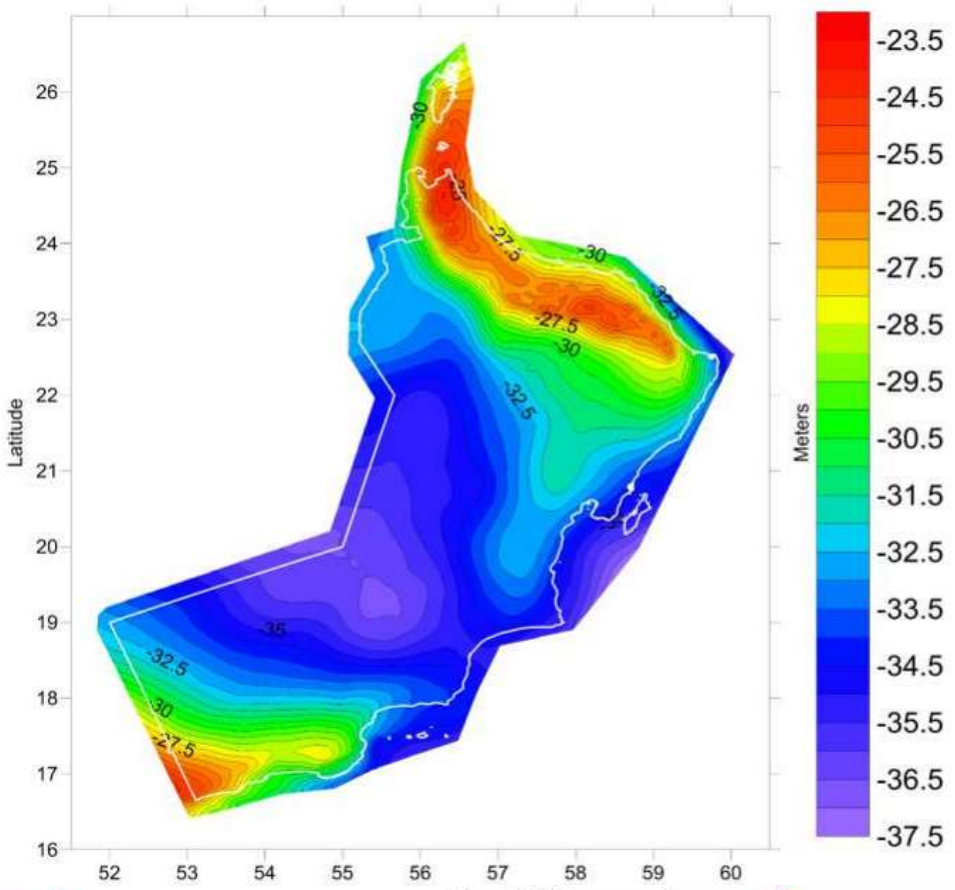
CORS Supports Precise Positioning

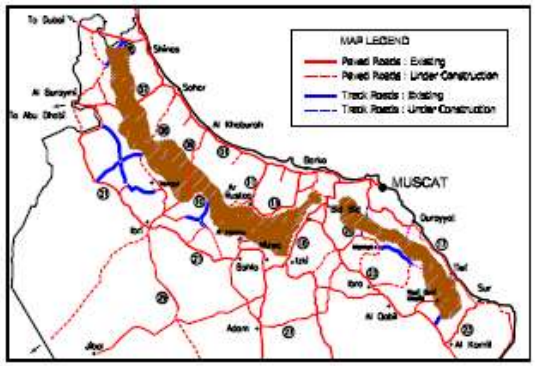
Before CORS: Accurate differential GPS positioning with multi-person field crew.

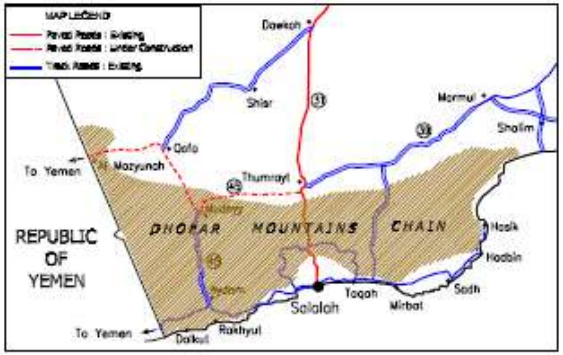
After CORS: Accurate differential GPS positioning with one-person field crew.

GEOID MODEL – ONGM SYSTEM

OMAN GEOID MODEL



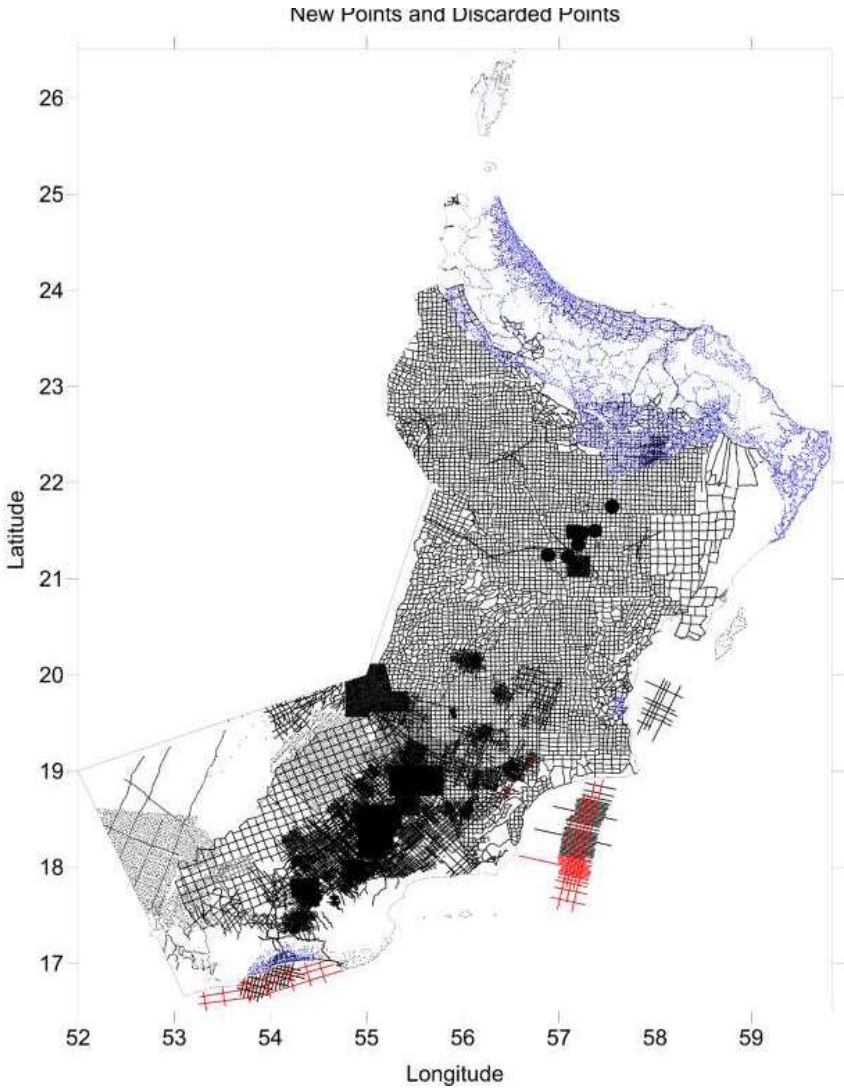


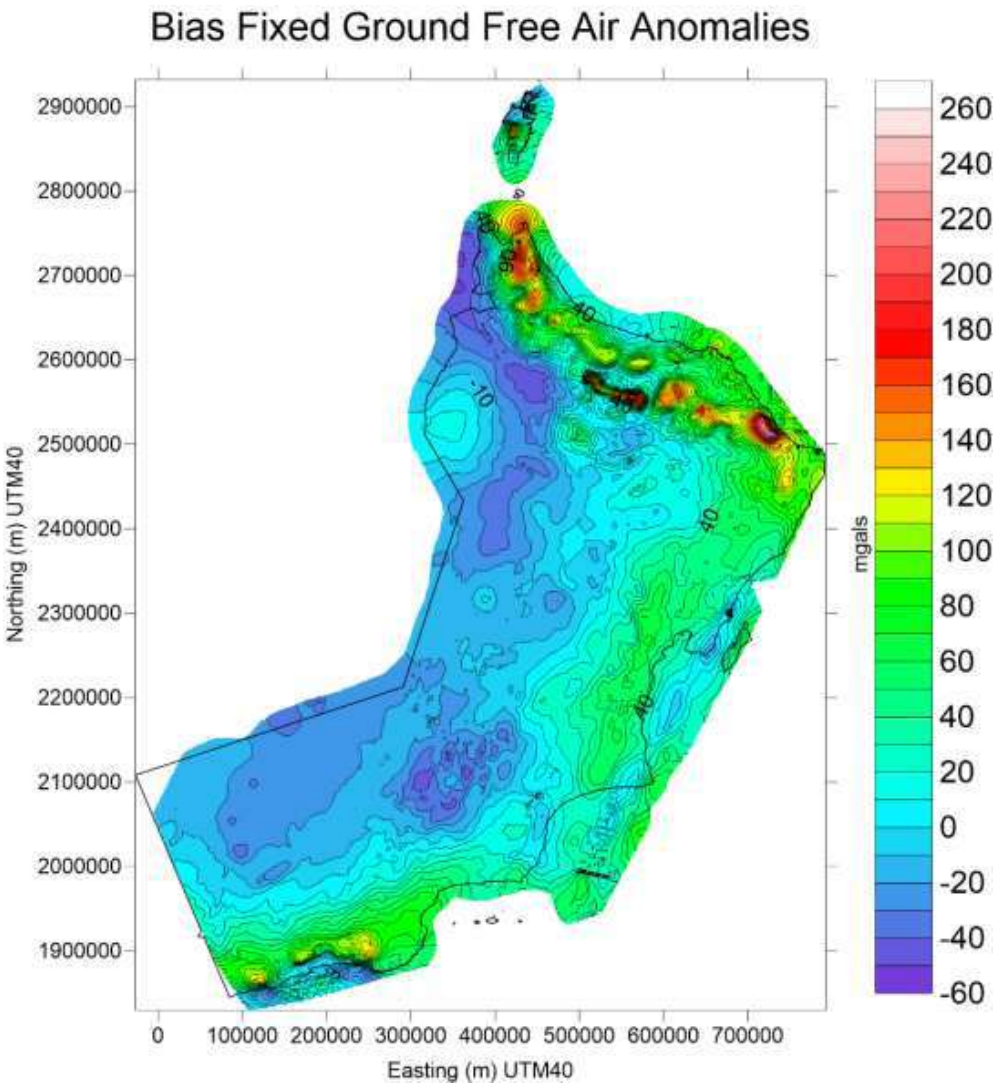


- The new **gravimetric geoid model** has been successfully established within the expected accuracy.
- This model becomes one of the fundamental geodetic layers for the future SDI of the country.
- First version of fitted geoid model has also been produced and delivered with accuracy that could be further enhanced to be **compatible with accuracy of GPS-derived ellipsoidal height**.
- Together with CORS network of ONCN system, this fitted geoid model will serve Real-Time GPS-Leveling applications in the country.

GRAVITY DATABASE

Gravity Data Coverage

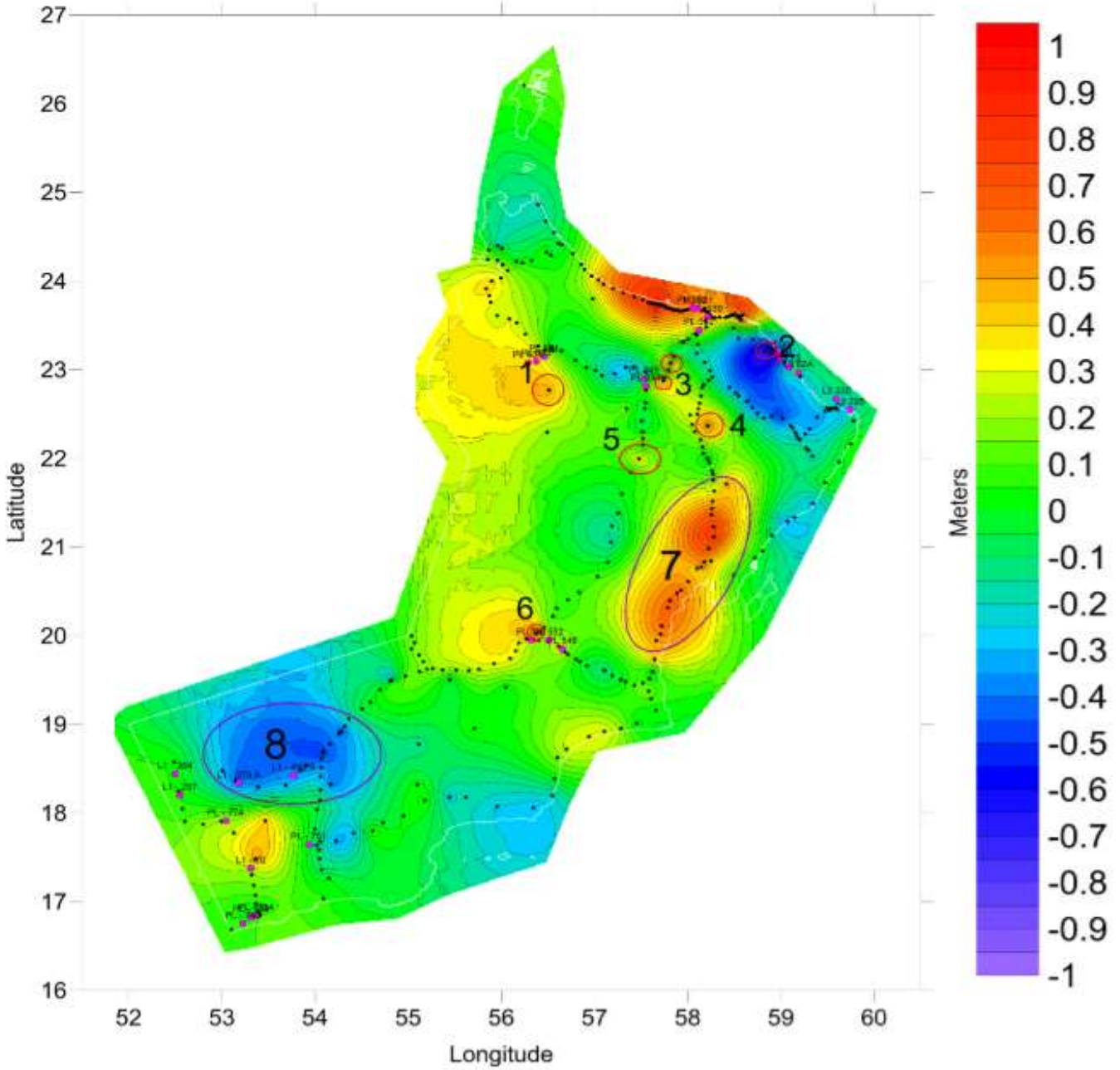




FITTED GEOID MODEL

- Oman gravimetric geoid model has been produced successfully i.e. consistence and compatible with other global geoid models. This model has been produced using enormous combination of extensive ground gravity survey (6,000 points), nation-wide airborne gravity data (5/10km spacing), and nation-wide PDO gravity data-set (~250,000 points).
- In practice, the gravimetric geoid model need to be fitted to local height datum. This has been carried out by **fitting it to over 400 BMs** nation-wide. The quality of the fitting process will really depends on the quality of GPS derived ellipsoidal heights on the BMs. After the fitting, the fitted geoid model shows agreement with local height datum with RMS of 3.8cm nation-wide. This is acceptable considering the size of the country and the outline of PLN.
- Slightly higher fitting discrepancies being observed in three areas which is believed to be due to quality of GPS on BMs values. But this problem could be fixed by re-observing BMs by GPS in that particular areas, and re-fitting the geoid model. This task could be taken as the **continuous enhancement process** of the Oman geoid model after completion of the project.

Benchmark Residuals From -1 to 1



INTEGRATED ONCN/ONGM SYSTEM APPLICATIONS

EVOLUTION OF POSITIONING TECHNOLOGY IN OMAN

CLASSICAL TRIANGULATION SYSTEM

Requires conventional terrestrial measurement techniques (Theodolite, EDM and Total Station).

Control points mostly located at hilltops. Difficult accessibility and limited accuracy. Not practical for establishing large number of control points.

Based on classical local geodetic datum (Fahud Datum 1954).

CONVENTIONAL GPS GEODETIC SYSTEM

Requires two or more GPS receivers for relative positioning technique.

GPS static technique (min 1 hour observation; station separation of 20-30 km; using single or dual frequency receiver).

Rapid static and RTK techniques (min 10-15 minutes observation; station separation of <10km; using dual frequency receiver).

Based on global datum WGS84.

MODERN ONCN SYSTEM

Requires only ONE GPS receiver/rover.

VRS-RTK Technique requires a few minutes of data collection.

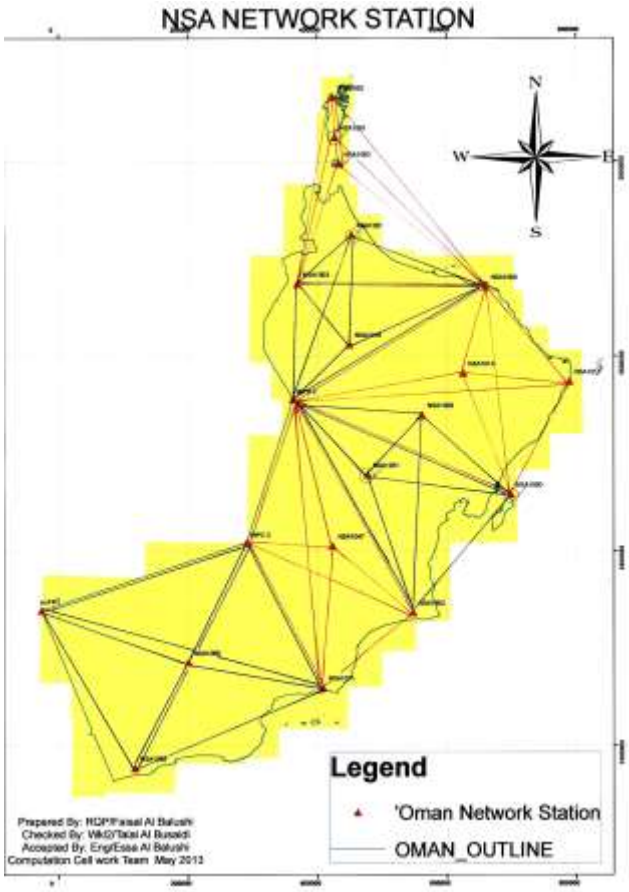
Oman CORS Network (ONCN) is the most modern and accurate control network for disseminating ONGD14 coordinates in Oman.

Oman Geoid Model (ONGM) will be integrated with ONCN for real-time accurate 3-D positioning (**to deliver both horizontal coordinates and Mean Sea Level (MSL) height**).

1. GEOSPATIAL INDUSTRY

- CORS Network has great impact on Surveying and Mapping field and consequently on geospatial industry
- **CORS will improve work performance, reduces inconsistencies and provide efficient utilization of resources**
- CORS provides fast, homogenous and economical means of geospatial positioning
- CORS provides a platform for accurately mapping each and every infrastructure with standardized positioning

- Control Survey
- Topographic Survey
- Route Survey
- Grid Surveying
- Construction Staking
- Site Development
- Pipeline Survey
- Powerline Survey
- Hydrography



2. MODERN HEIGHT

'Height Modernization' in Oman is the **establishment of accurate, reliable heights** using integration of CORS Network technology with precise Geoid Model information.

- Geoid – the equipotential surface of the Earth's gravity field that best fits MSL.
- Ellipsoid – a mathematically-defined surface that defines a reference frame (coordinate system) e.g. real-time GNSS-derived ellipsoidal height using Oman CORS Network (ONCN System).
- Geoid Height – difference between the geoid and ellipsoid e.g. newly established Oman Gravimetric Geoid Model (ONGM System).
- Orthometric Height – height on the surface above the ellipsoid obtained from methods such as leveling e.g. existing Oman PLN.
- There is a separation between the geoid and Oman PLN. This separation has been estimated for most areas, but it is not always accurate.
- After fixing height at 2 tide gauges in the adjustment, Oman PLN reveals SST effect as expected over north-south route of over 1,000km leveling.

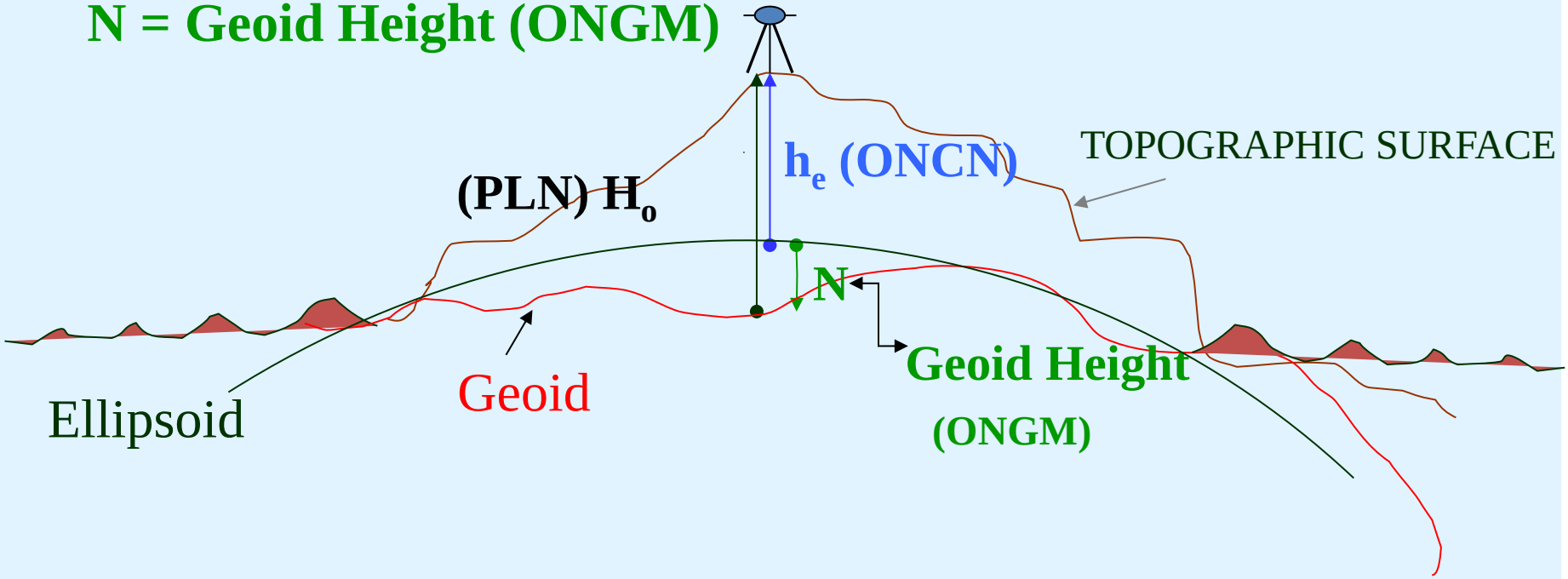
MODERN HEIGHTING CONCEPT

H_o = Orthometric Height (Leveling)

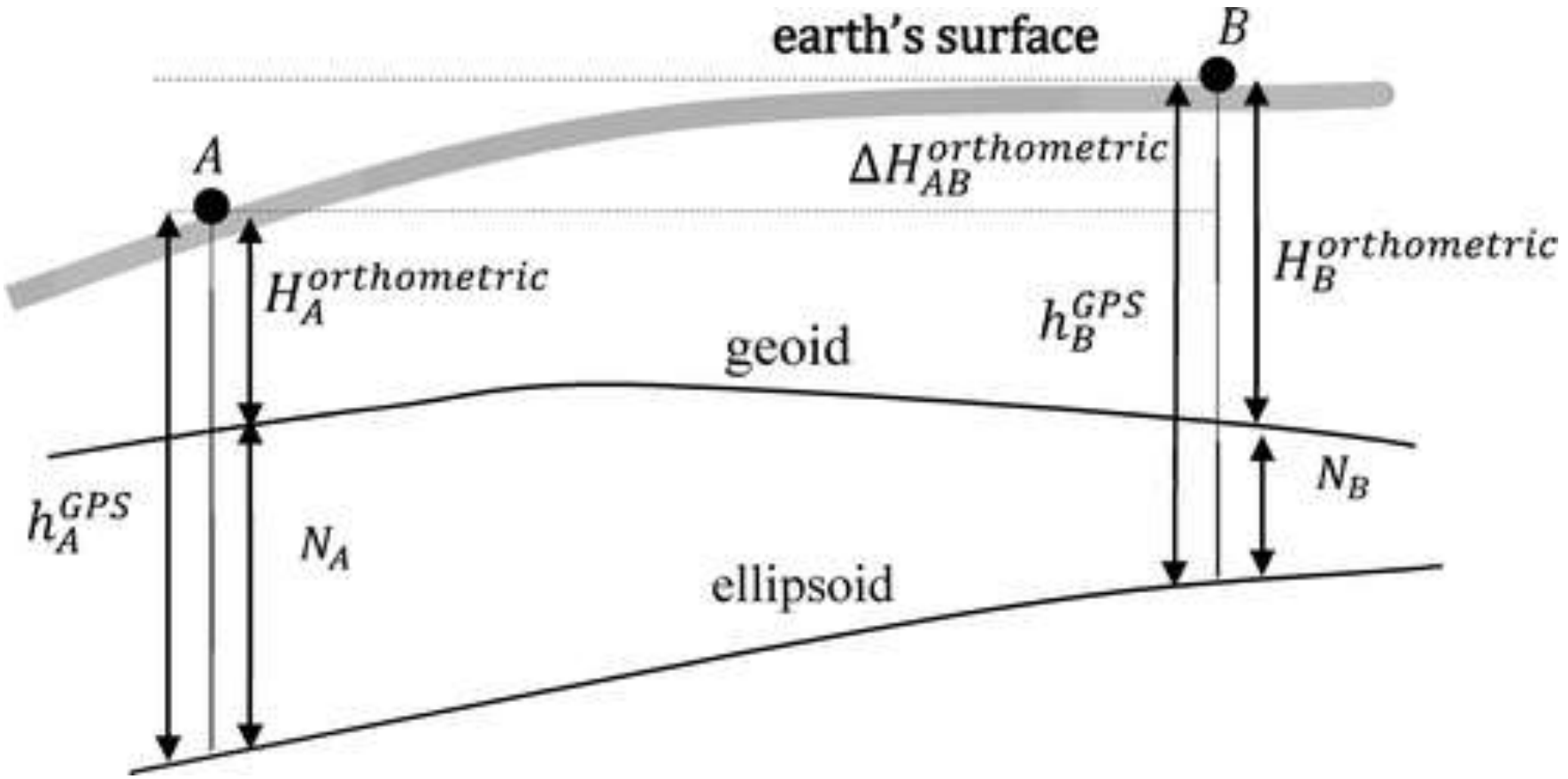
h_e = Ellipsoidal Height (ONCN)

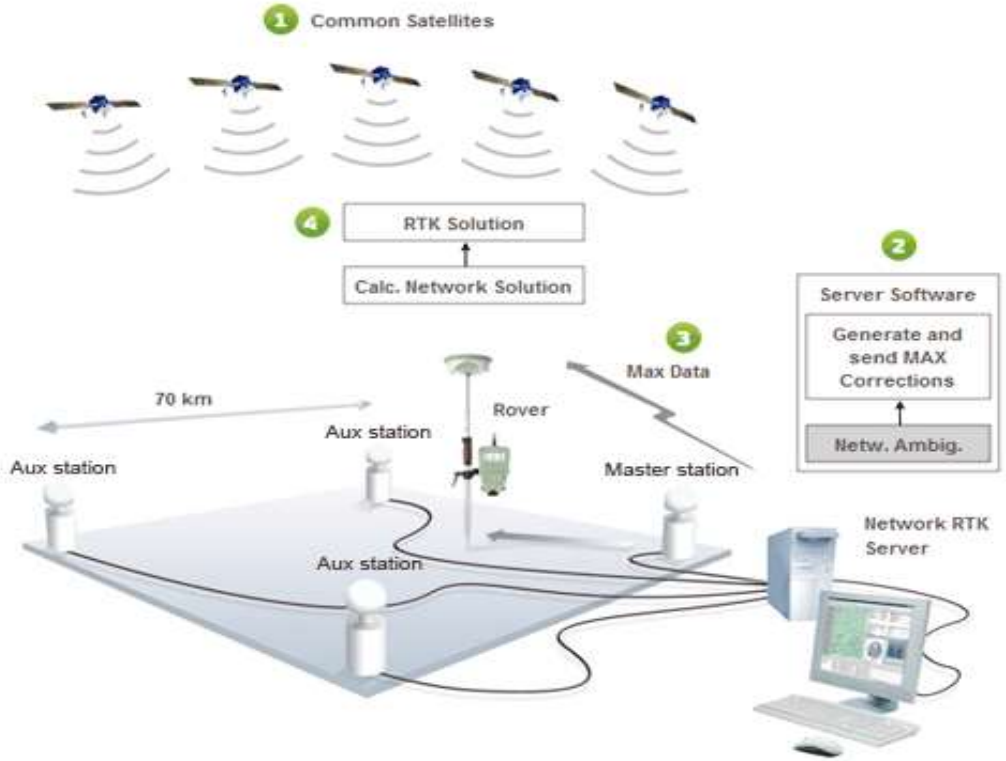
N = Geoid Height (ONGM)

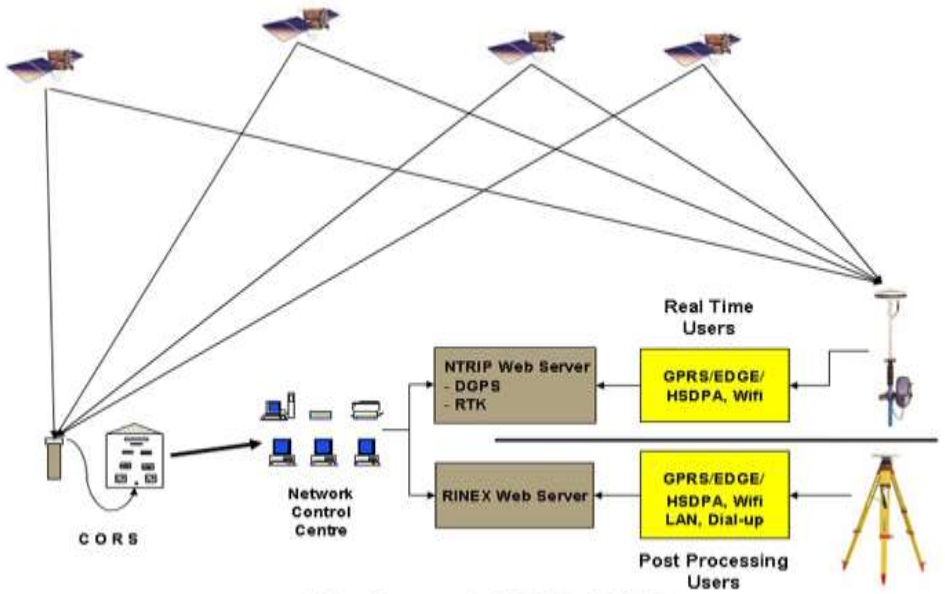
$$H_o = h_e - N$$



GNSS RELATIVE HEIGHTING/LEVELING







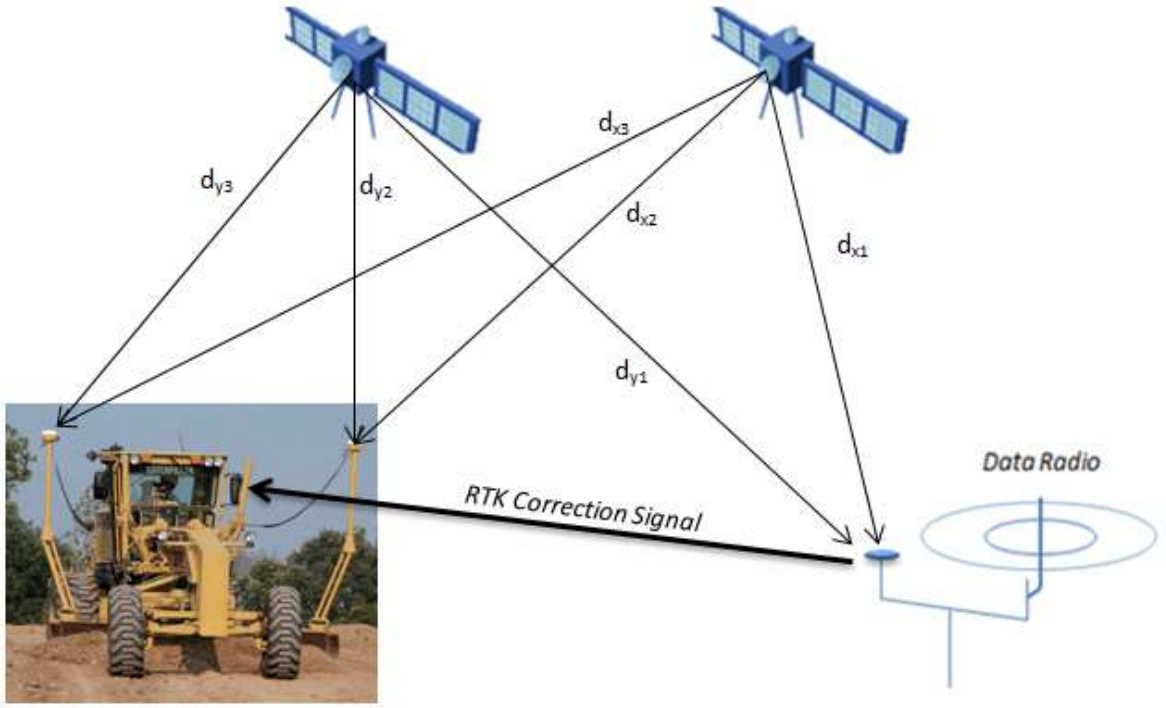
Konfigurasi GNSS-CORS

MODERN HEIGHT

- Flood Management – Creating accurate flood insurance rate maps to help better decide which areas need flood insurance. Elevations are critical to determining possible flood levels.
- Construction Industry – GNSS guided machines using CORS Network (accurate 3D positioning is greatly needed in real-time).
- Water Level Management – Monitoring ground water and surface water levels require accurate height information.
- Transportation Industry – Monitoring of roads, rails, and airways, and guided inland shipping navigation.
- Survey Control Infrastructure - Accurate survey control becomes widely available, which reduces future surveying costs.
- Modern Farming – Combining GIS with accurate location provided by real-time GNSS 3D positioning helps decide amount of fertilizer and pesticide to use. Another benefit is minimized runoff waste.

3. CONSTRUCTION AND CIVIL WORKS

- In civil engineering, **machine guidance delivers significant increases in productivity** and improved on-site safety.
- **GNSS guided machines using CORS Network** (accurate 3D positioning) is greatly needed in real-time.
- E.g. using GNSS machine guidance a motorway was completed ahead of schedule (30% reduction in time required), with a 10% reduction in total project costs.

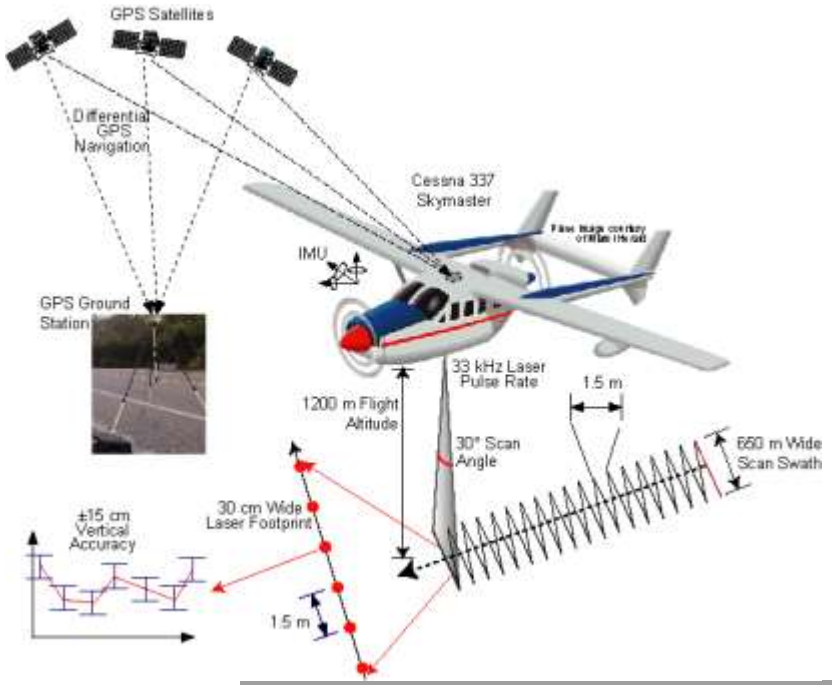


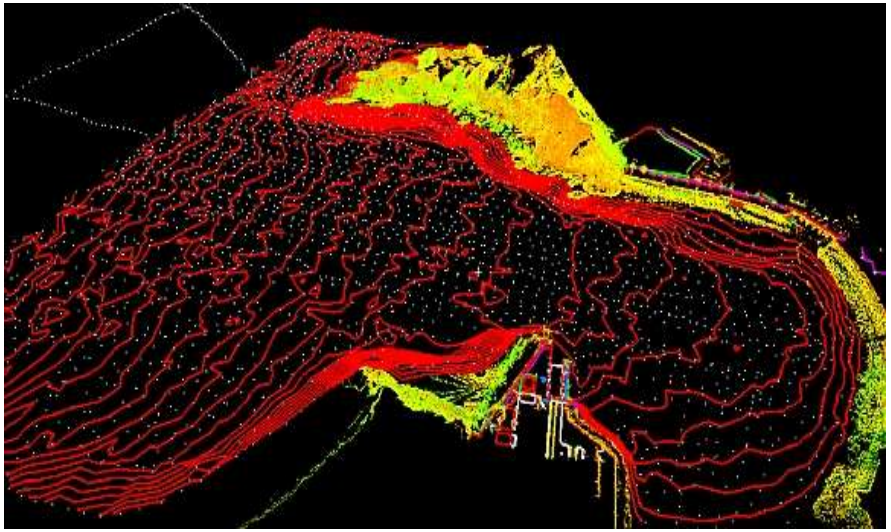
- RTK technique provides statistically compatible results against traditional means of surveying utilizing the total stations. **CORS Network provides efficient means of surveying at construction sites** where frequent surveying is required by reducing the resources.

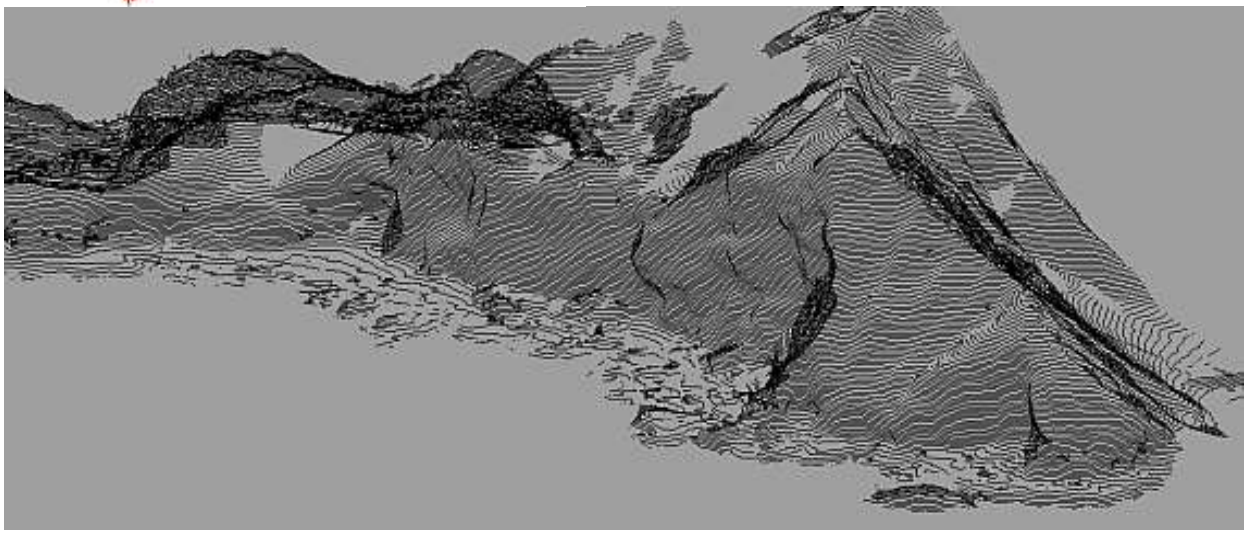
4. GEOLOCATION OF AERIAL PLATFORMS

- Data available from CORS sites has been used in many remote sensing applications. The accurate positioning of aircrafts employed in **aerial mapping** is crucial to improve the reliability of photogrammetric restitution primarily for large-scale aerial survey applications over remote or inaccessible terrain.
- The same concepts implemented for geo-locating landmarks from the air with digital cameras has been extended to a broad array of mapping terrain applications using cutting edge technologies such as **airborne LiDAR, airborne gravity system, and large scale mapping using Drone**.
- The aerial mapping community will certainly benefit from the growing number of CORS sites.

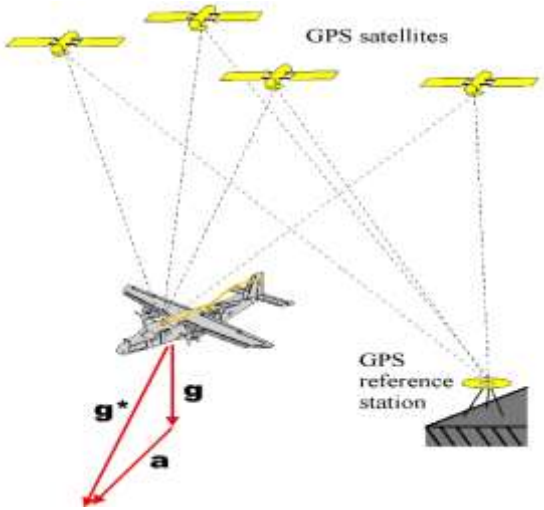
AIRBORNE LIDAR MAPPING IN OMAN

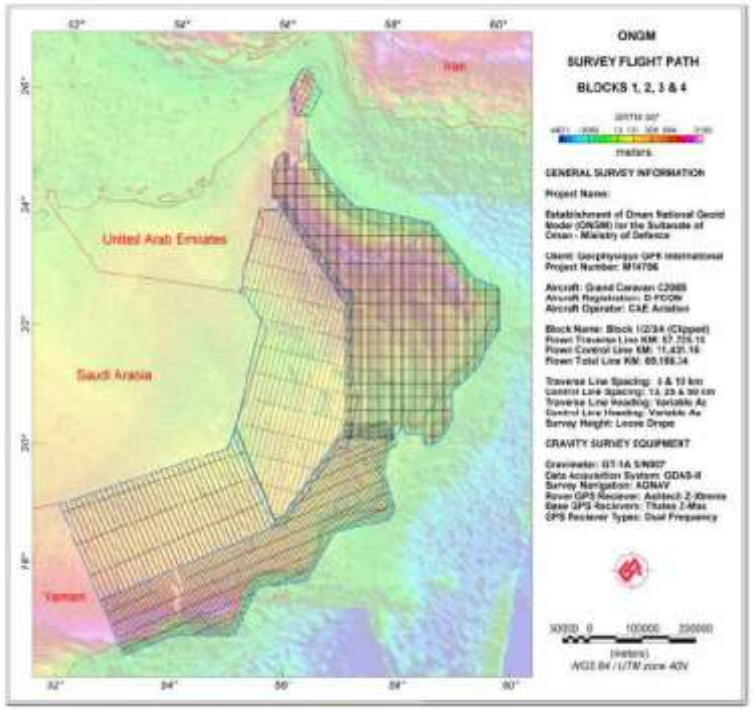


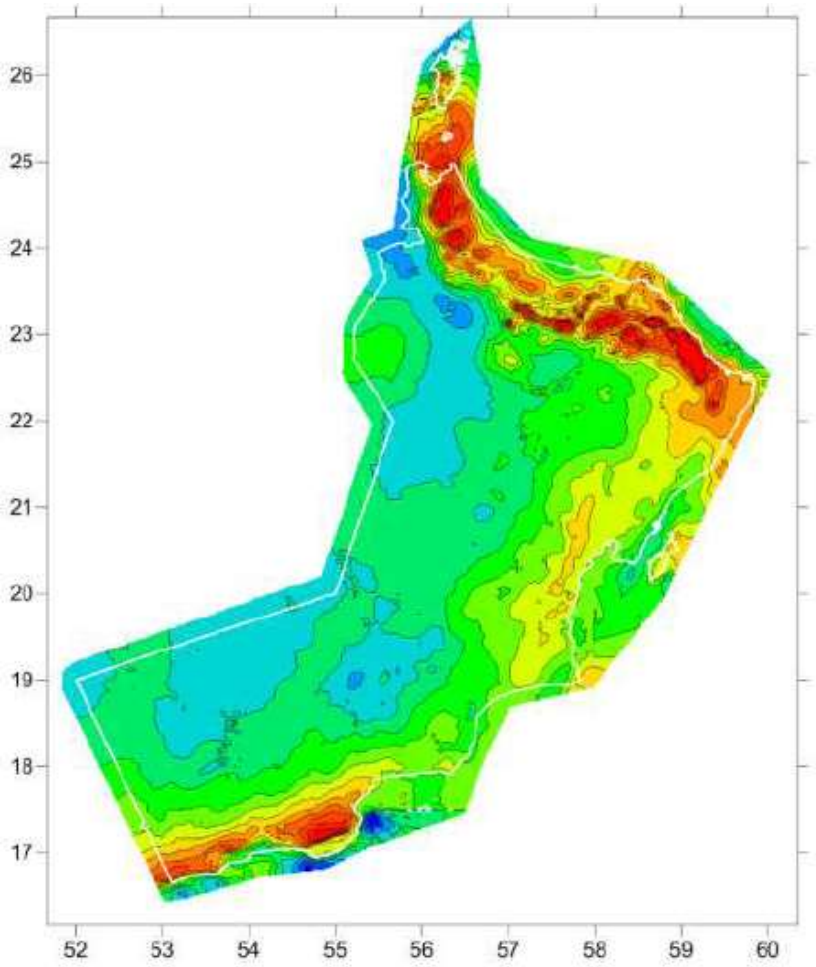




AIRBORNE GRAVITY SURVEY IN OMAN







CAMERA DRONE APPLICATIONS

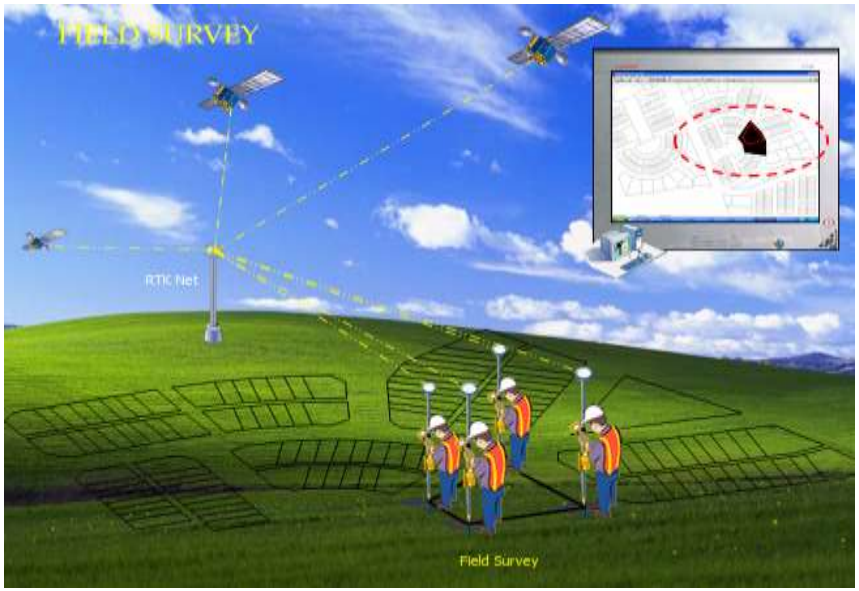
DRONE FOR SEVERE FLASH FLOOD MONITORING

- GNSS based CORS network can be used to provide control for drone mapping.
- **Drone will map the affected area in real-time** in case of severe flash flood for precise monitoring.
- Will support immediate response for **search & rescue operation** and organizing debris removal.

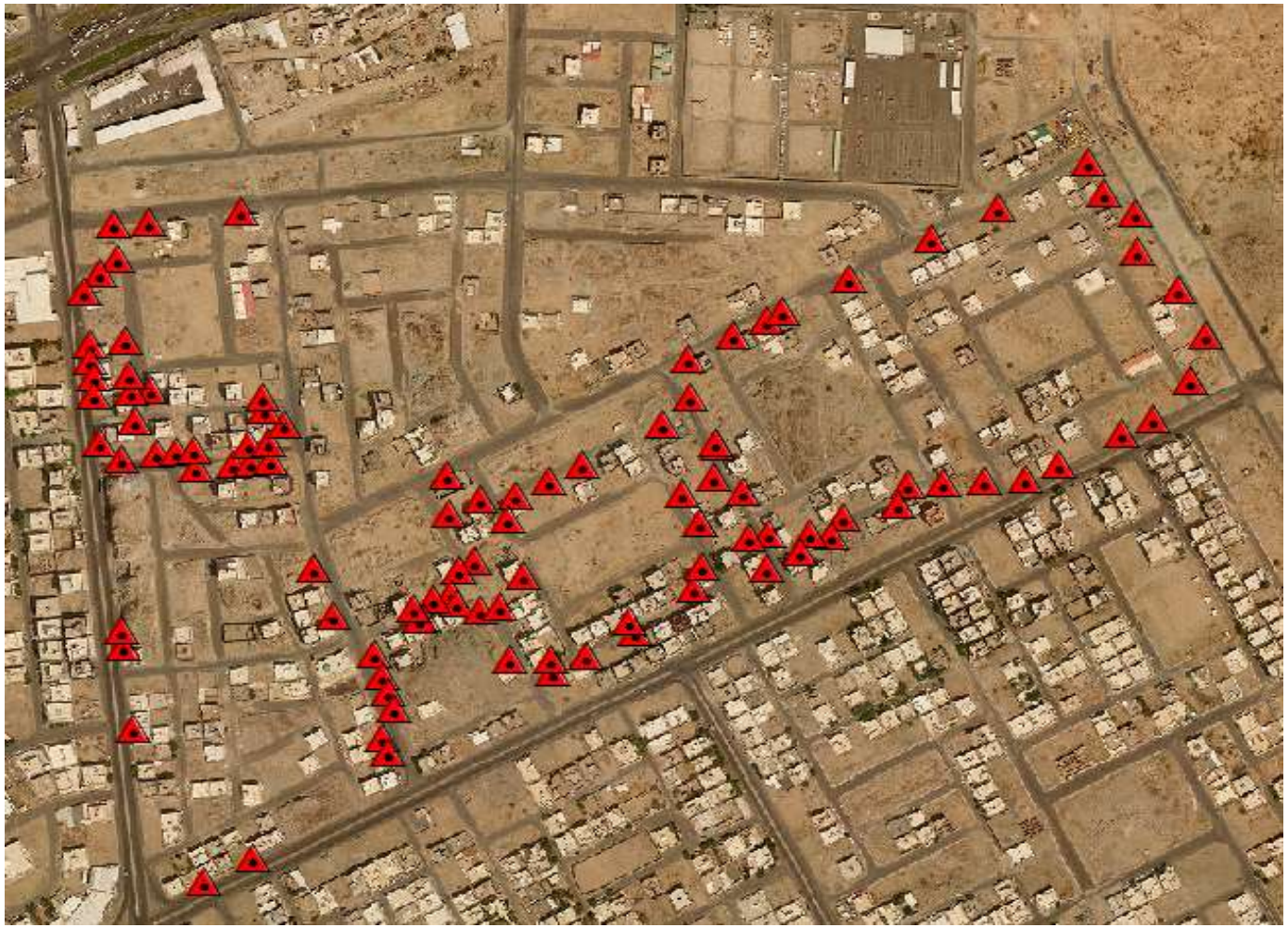
5. SEAMLESS PARCEL DATABASE

- Land property consists almost ¾ of national wealth in any economy
- Government builds land administration system (LAS) for efficient and effective land market
- CORS Network facilitates in developing an efficient LIS for rights and recognition of property, taxation, planning and management through e-government environment
- HOW?

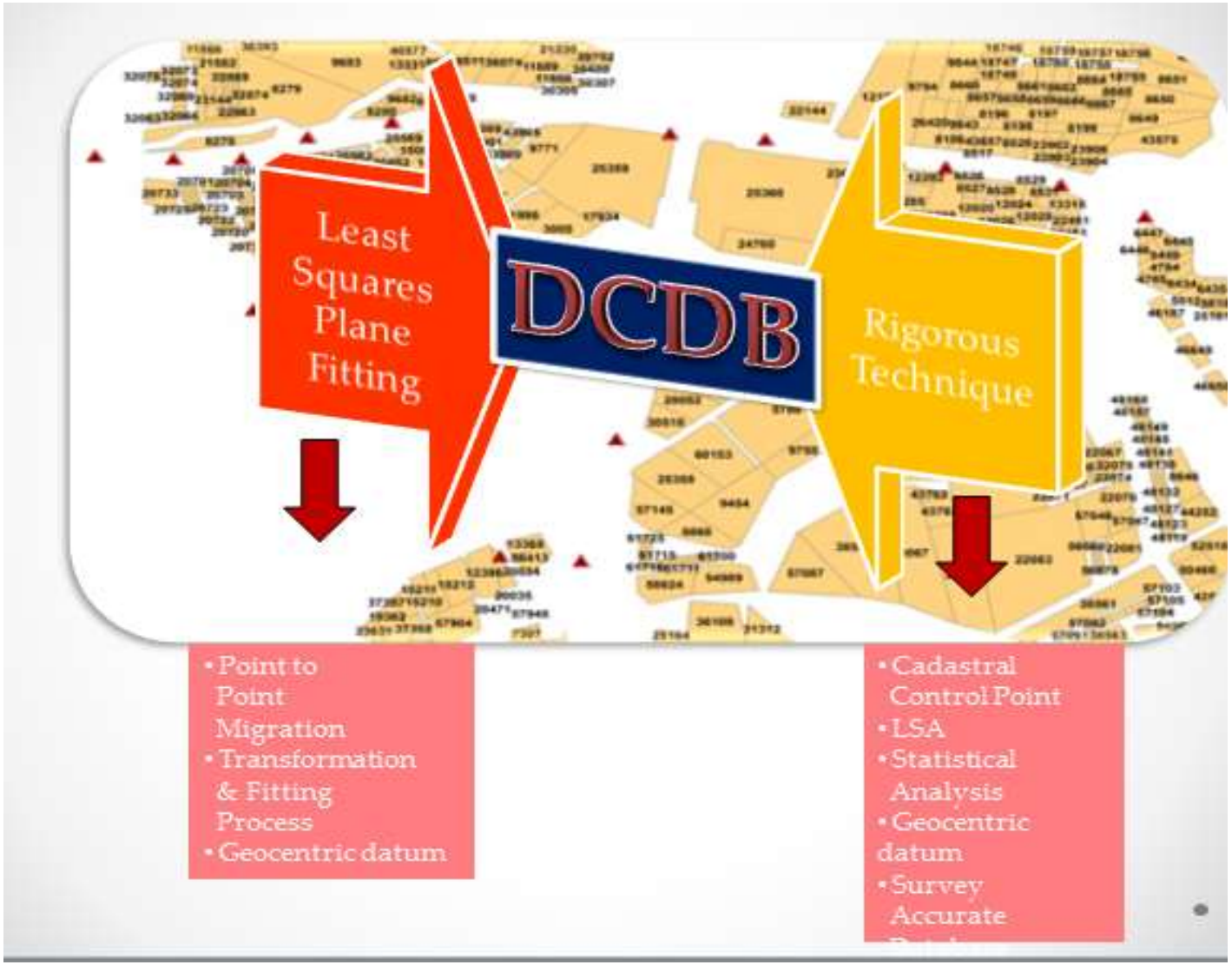
  - ✓ **To establish cadastral control points using CORS** network
  - ✓ To carryout raster to vector **parcels conversion** and migration to new Oman Datum
  - ✓ To do '**spatial adjustment**' of parcels in blocks
  - ✓ To **produce seamless parcels database** for Oman



PARCELS CONTROL POINTS



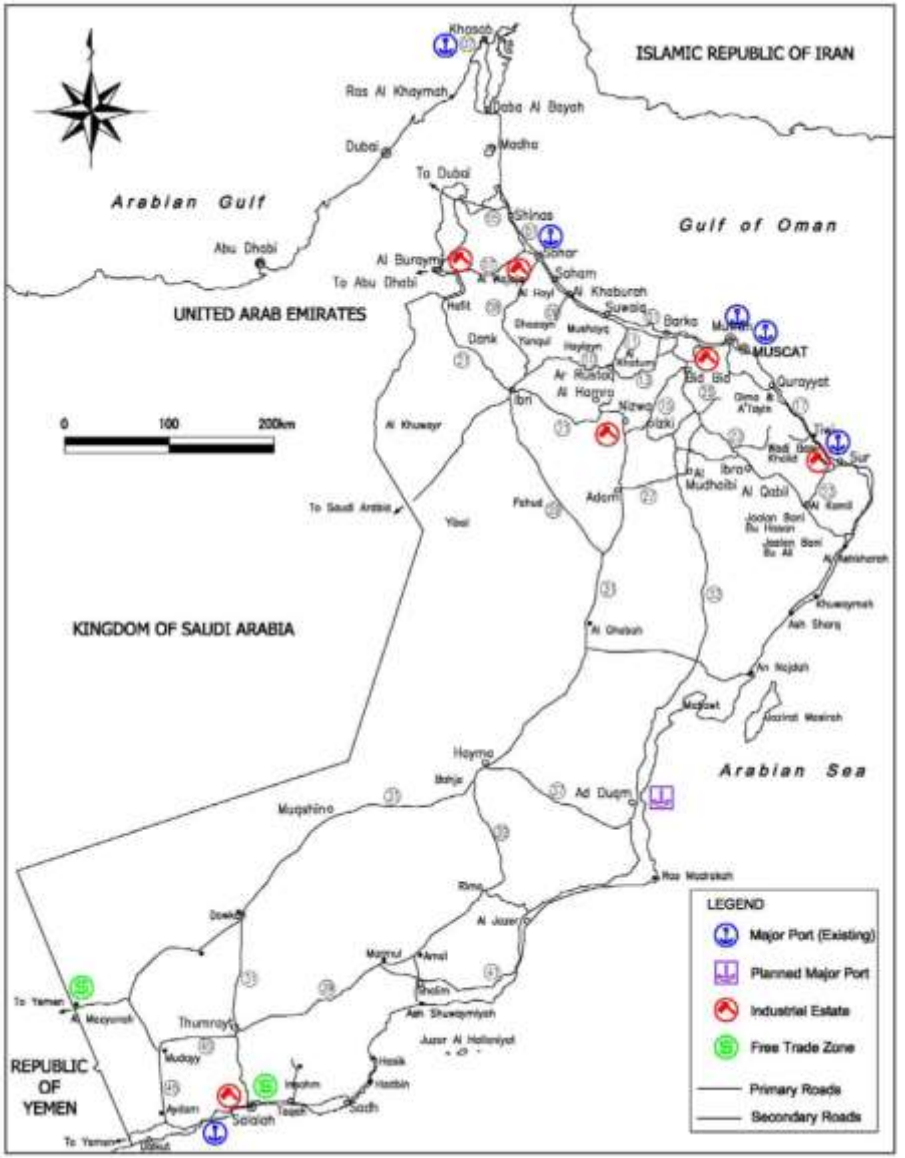
SPATIAL ADJUSTMENT PROCESS



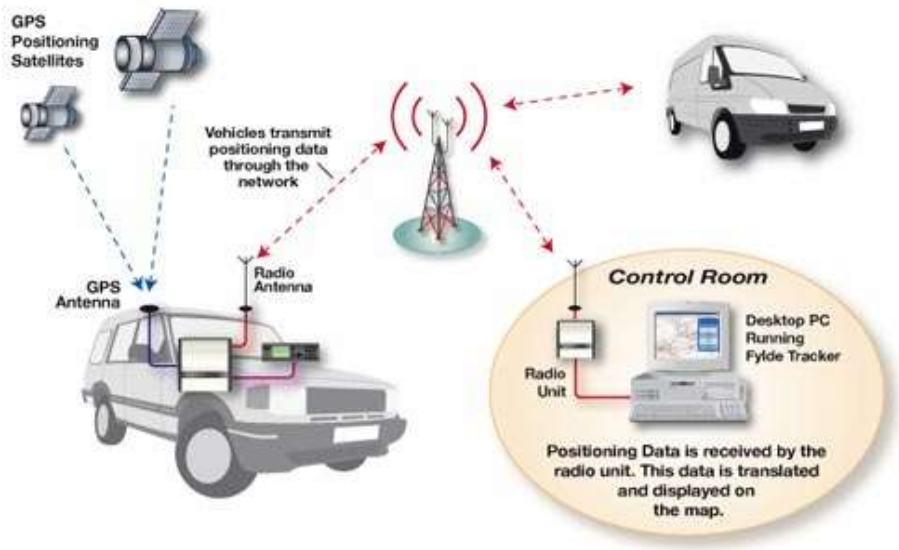
SEAMLESS PARCELS DATABASE

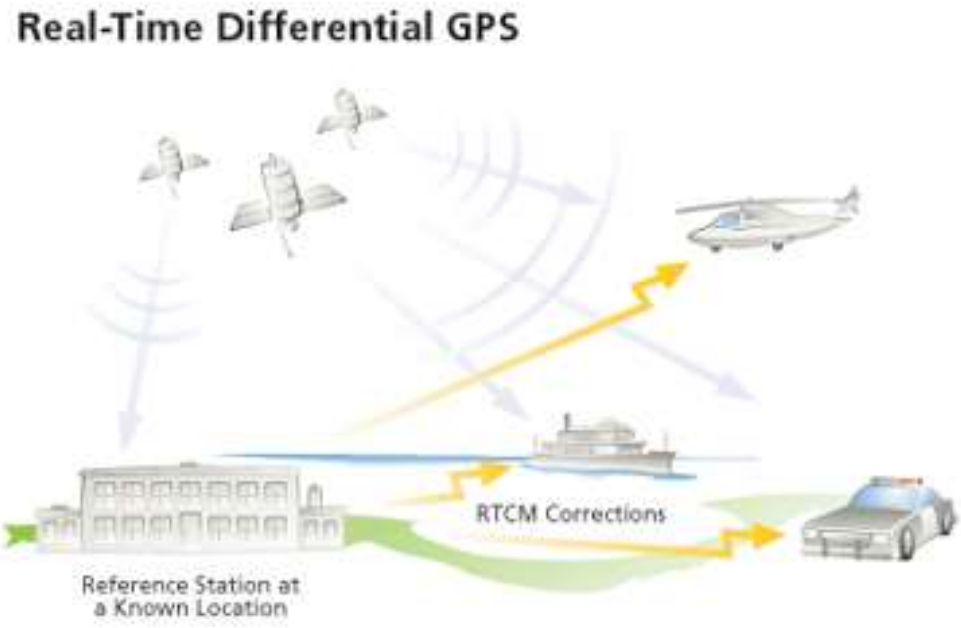
6. TRANSPORTATION INDUSTRY

- CORS could be widely used in tracking of ground moving targets.
- CORS integrated with modern communication technology, computer technology, and mapping technology provides sophisticated real-time location through the Internet and wireless communication network.
- CORS application in **fleet management** (tracking system) could benefit police cars, fire bridged, ambulance and trucking services.



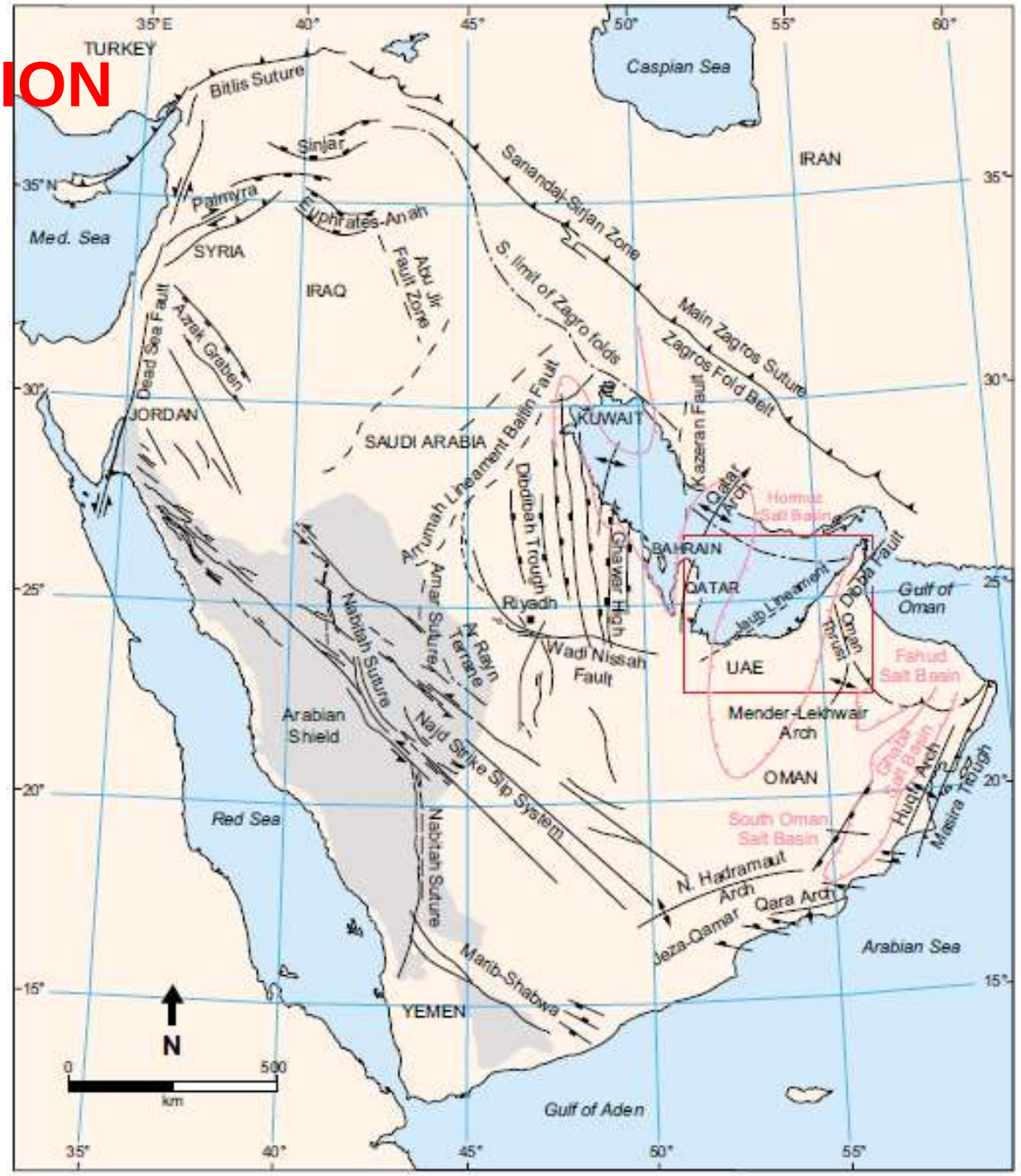
- Vehicle positioning monitoring system takes satellite positioning as the main positioning means, supplemented with inertial navigation, terrain-aided navigation and other technologies **to obtain real-time vehicle location information**, which is then integrated into the mobile GIS technology that can provide vehicle location, path planning, information query and other functions whenever and wherever possible.
- The vehicle navigation system which is integrated with dynamic road traffic information can **guide vehicles according to dynamic traffic information**, so as to avoid the road with congestion and relieve urban traffic jams.

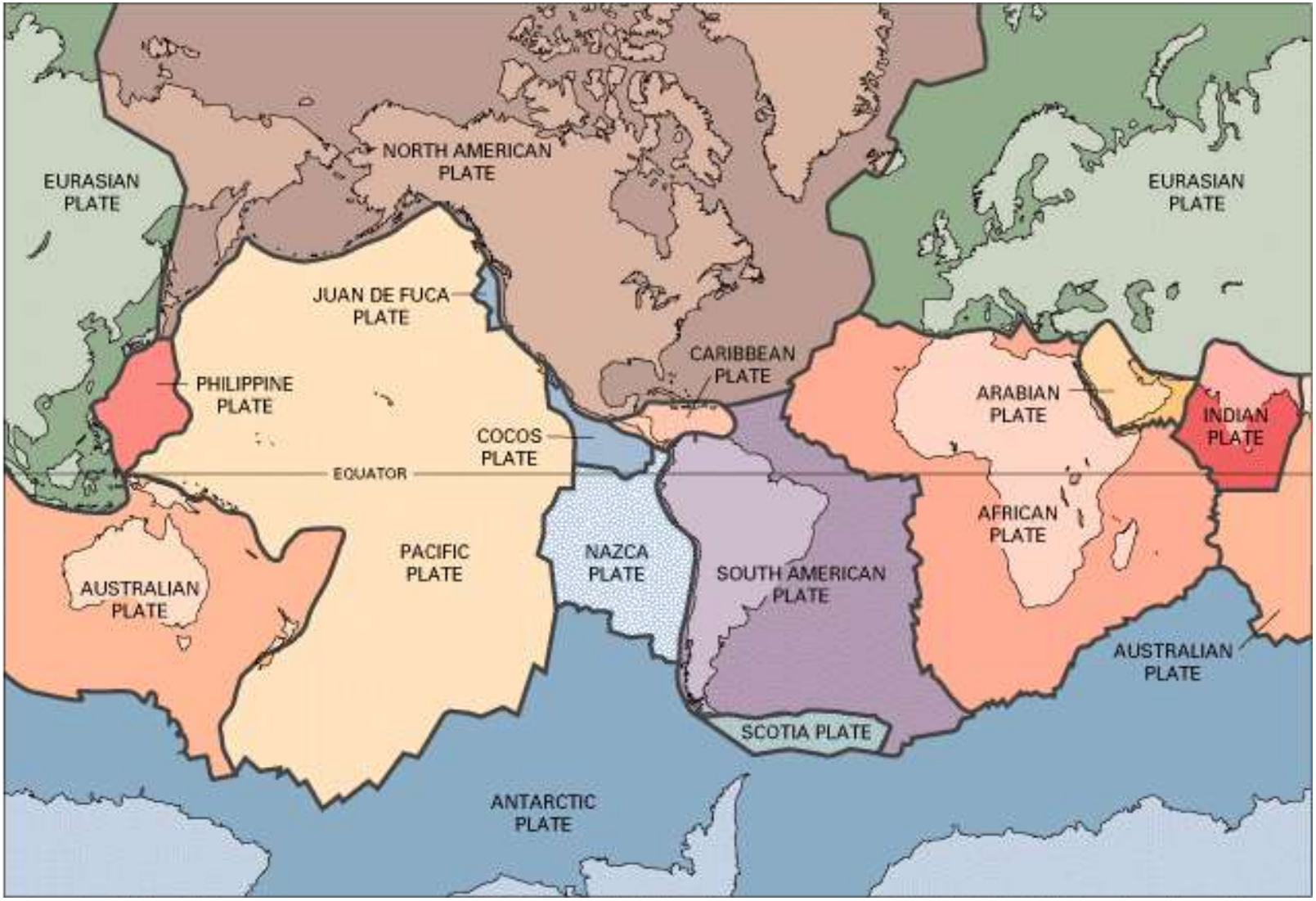




7. CRUSTAL MOTION

- **To estimate station velocity of all CORS sites** in Oman using continuous GNSS data.
- **Estimation of CORS sites velocity** could be carried out in association with crustal movement study in Oman with respect to existing tectonic plate in the region.
- To compute GNSS time series, velocity vectors and error ellipse using 57 CORS sites GNSS data for a selected study period.

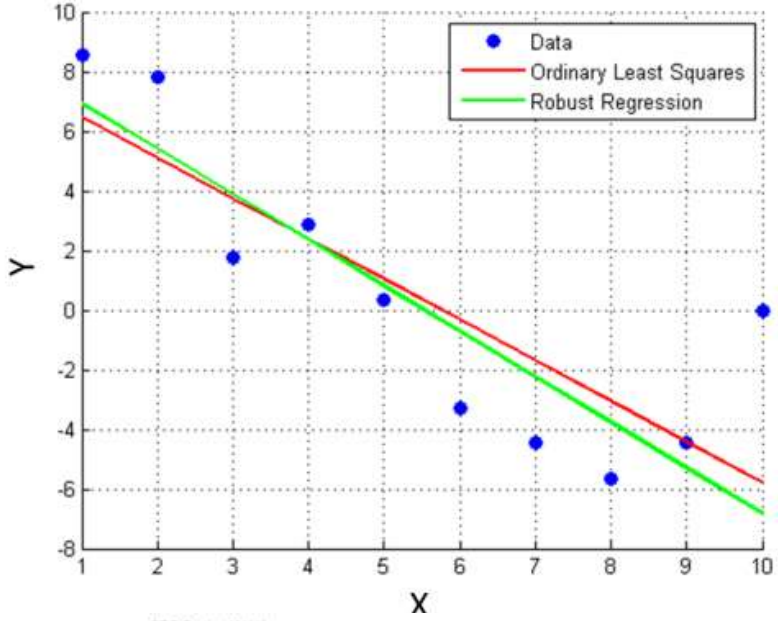


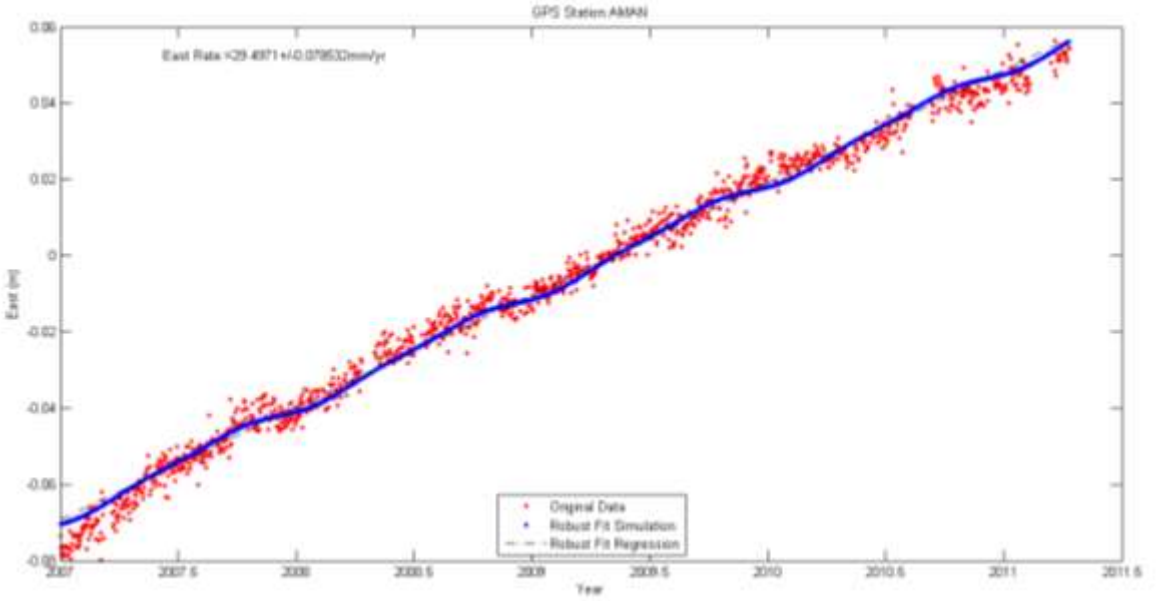


THE EARTH TECTONIC PLATES

RATE ESTIMATION

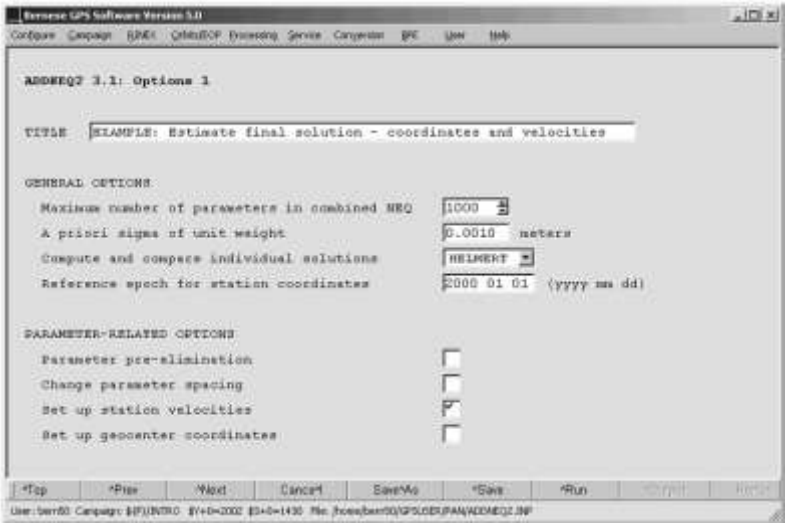
- Robust Fit Regression analysis technique in MATLAB.
- A standard statistical technique that simultaneously deals with solution finding and outliers detection is applied.
- A linear trend is fitted to the **annual horizontal or vertical time series of each station**.

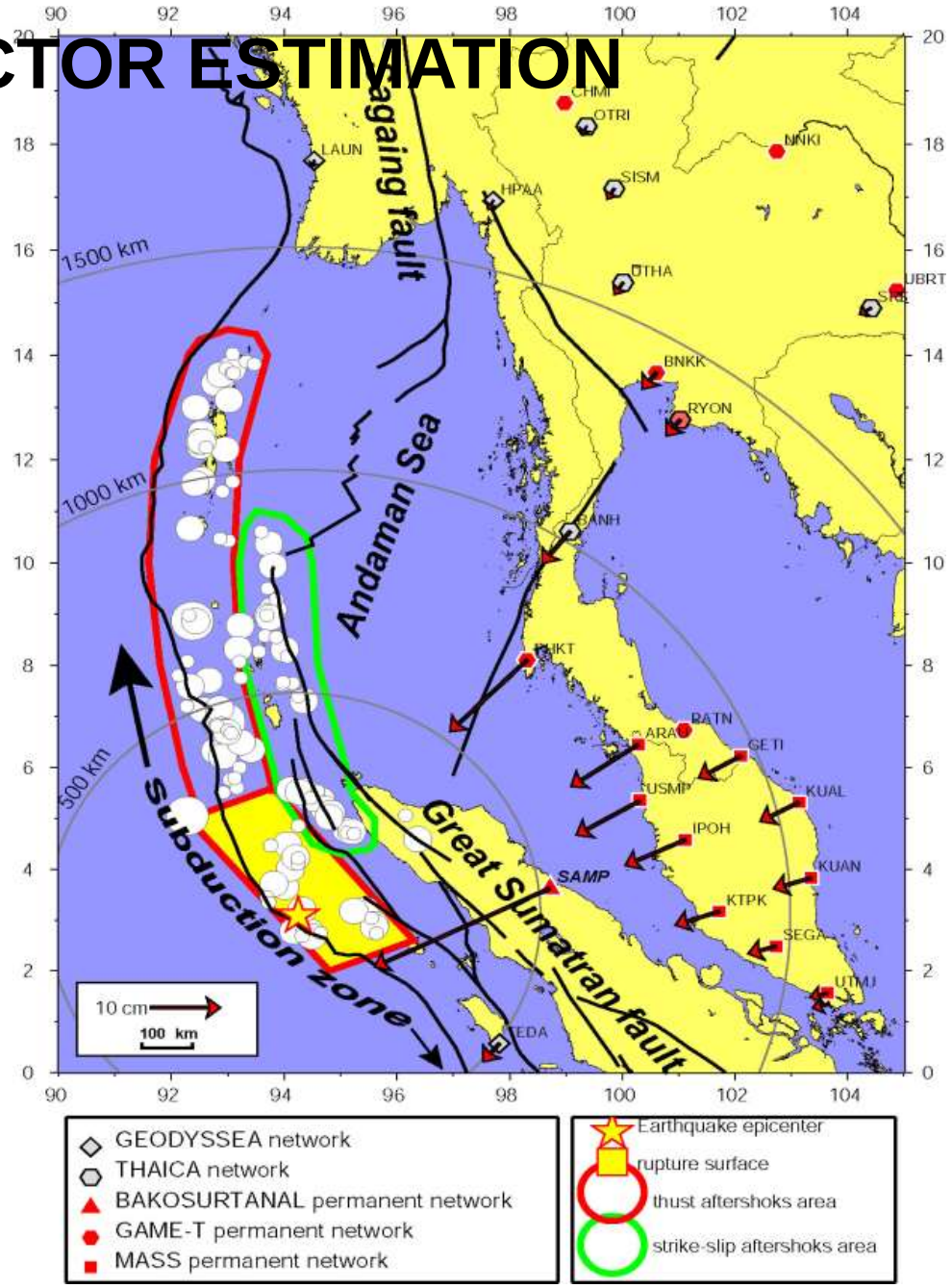




VELOCITY VECTOR ESTIMATION

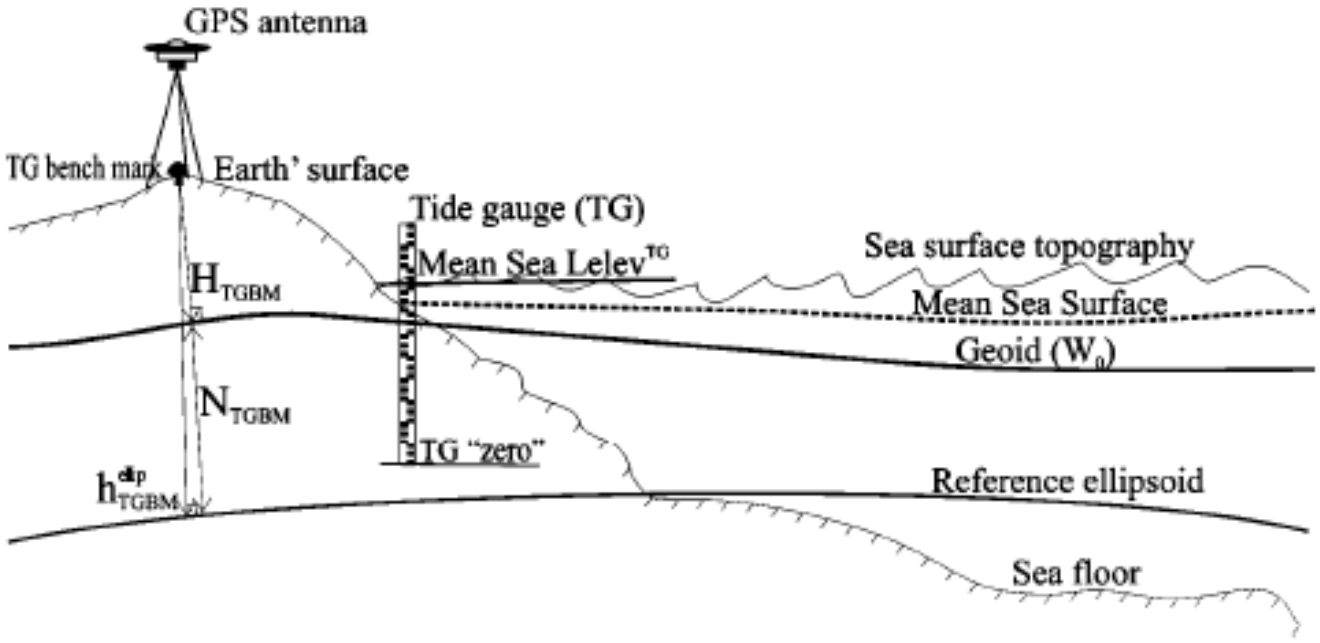
After the 2004 Acheh earthquake/tsunami, the nearest sites from the epicenter showed large co-seismic displacements: 27cm in Phuket Thailand; 17cm in Langkawi Malaysia; 15cm in Sampali Indonesia (Vigny et al., 2005).



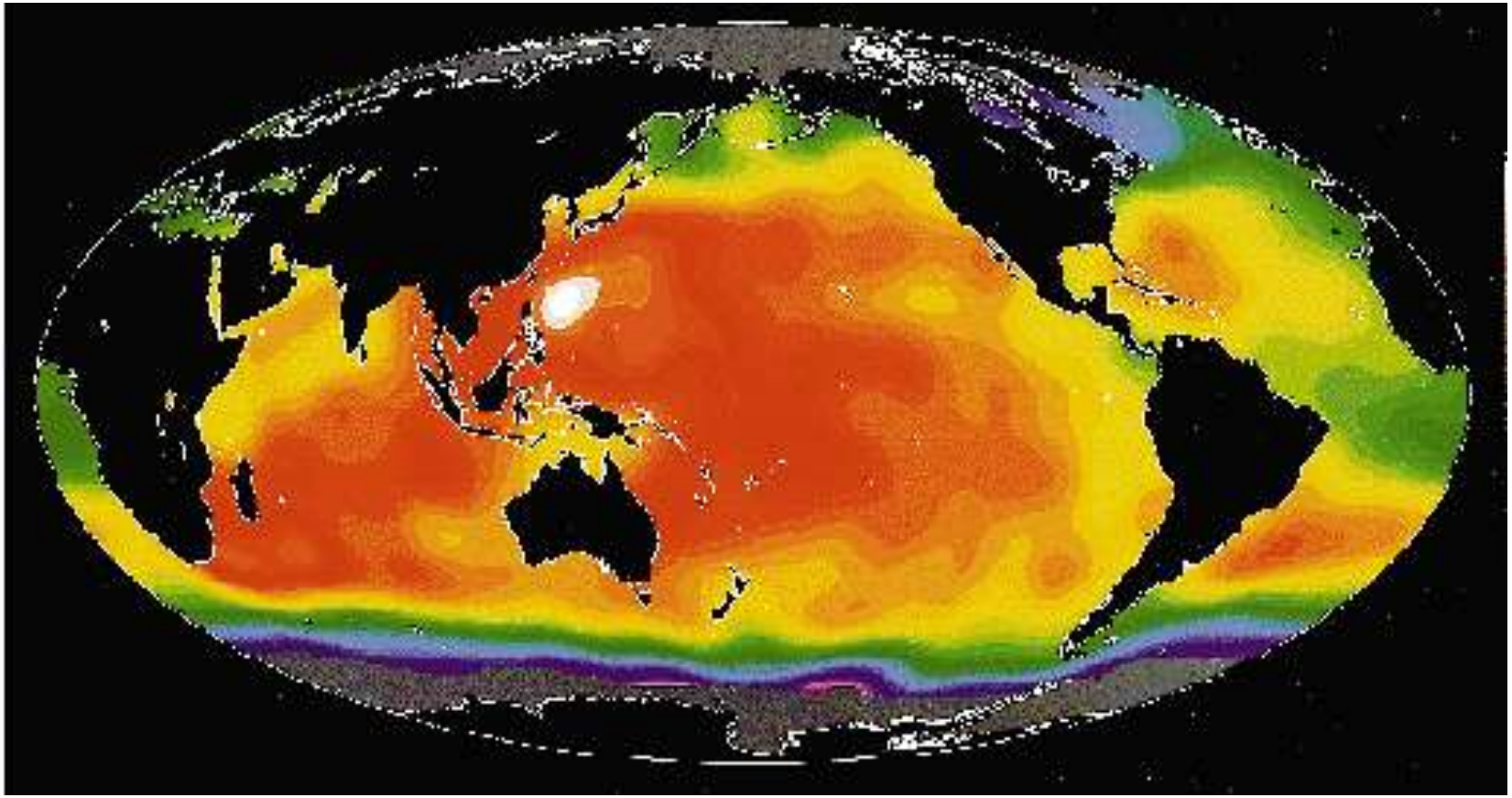


8. SEA SURFACE TOPOGRAPHY

- In practice, MSL determined from the tide gauge data is used as the reference surface for topographic elevation and bathymetric depth.
- National, regional and continental vertical datums are realised using geodetic levelling observations that are constrained to MSL at the so-called 'zero' point.
- Globally, **MSL varies from region to region due to gravity and topography differences** and it (sea surface topography, SST) ranges from **–2.0 to +2.0 m** comparing to the geoid.

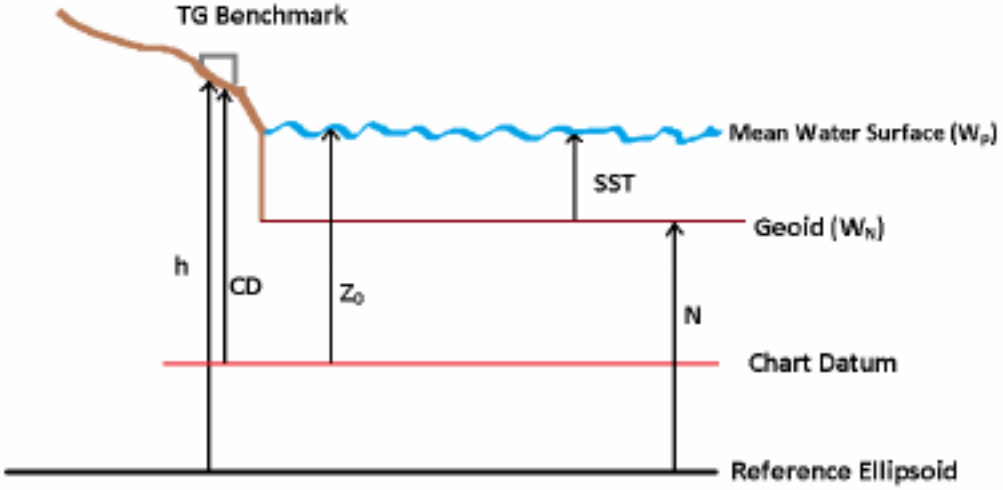


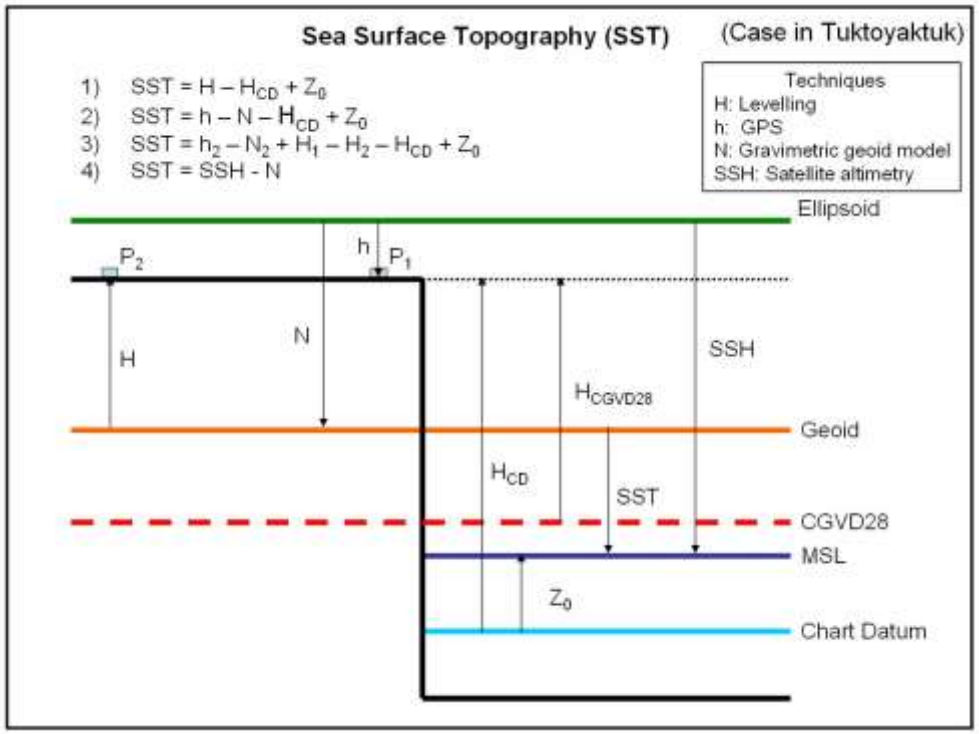
GLOBAL SST



LOCAL SST ESTIMATE

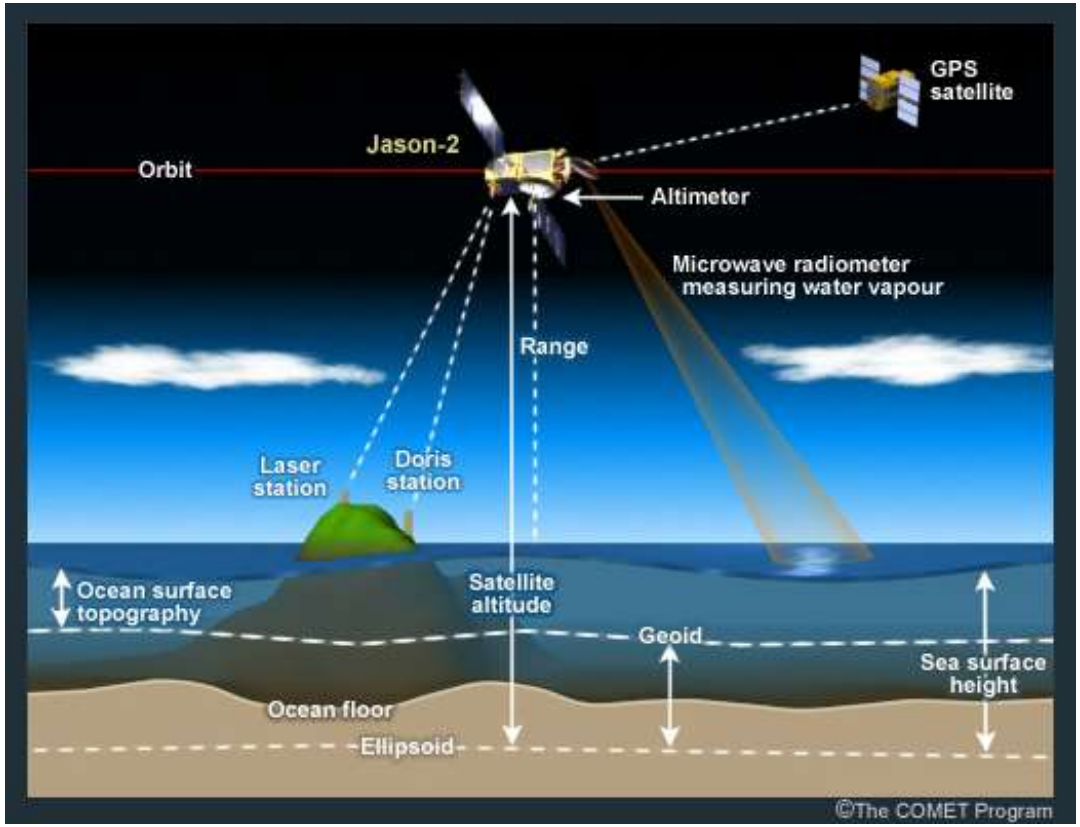
- It has been shown that the Oman gravimetric geoid model is about 14cm lower than the existing MSL datum provided by the PLN. This is due to the effect of the global SST value on MSL in the region. PLN includes over 1000 km levelling route connecting Muscat (north) and Salalah (south). **Different MSL values between two tide gauges will give effect on the PLN** since their MSL values were held fixed during the adjustment process.
- It is necessary **to carry out investigation on the SST along the coast of Oman**. This could be carried out using GPS geodetic campaign connecting tide gauges, existing **gravimetric geoid model**, existing PLN, and Bernese processing.





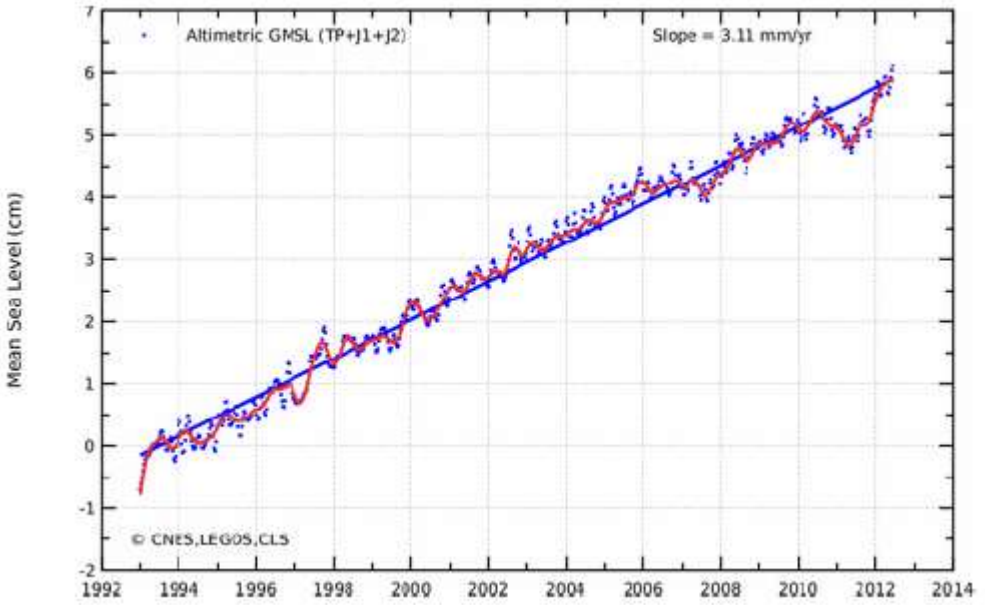
SST FROM ALTIMETRY

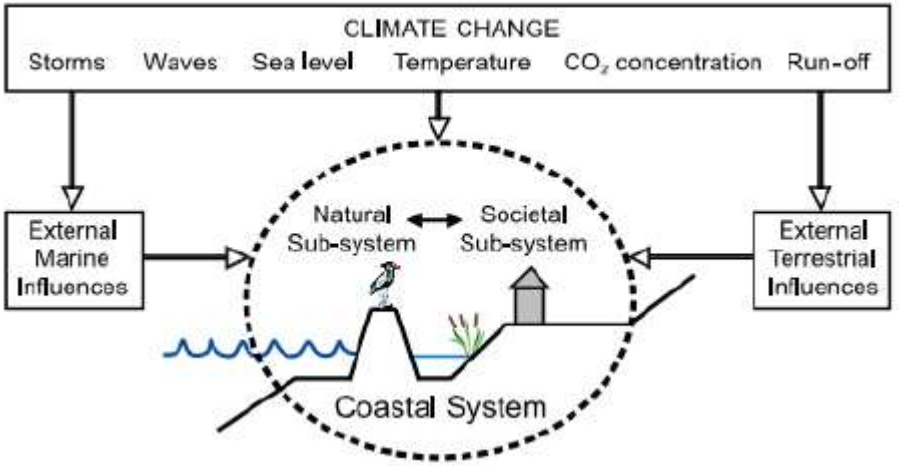
- A radar altimeter measures the altitude of a spacecraft above the sea surface.
- Precision orbit determination measures the altitude of the spacecraft above a reference surface of the Earth.
- The height of sea surface relative to the same reference surface is the difference of the two altitudes.
- **SST is the height of sea surface relative to the geoid**, a surface of uniform gravity.



9. SEA LEVEL CHANGES

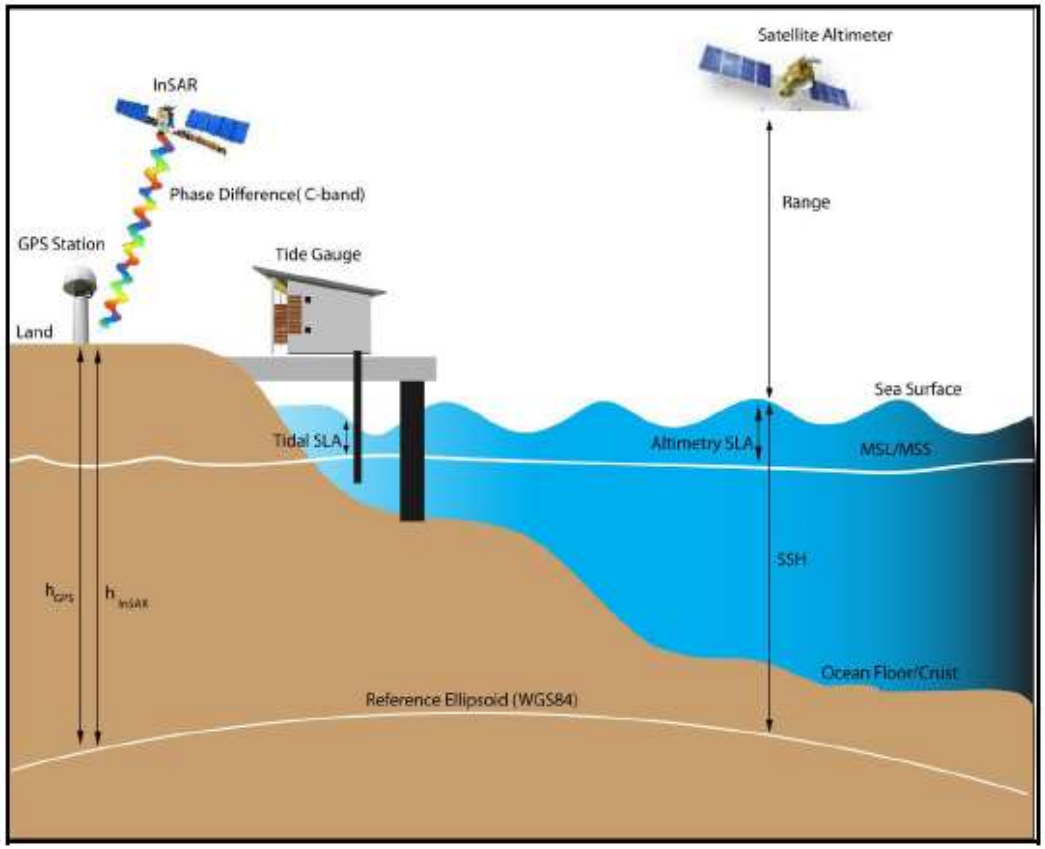
- Scientific research has produced concrete evidence on sea level rise and their consequences on coastal flooding, shoreline erosion, and storm damages.
- **Sea level rise** will impose a substantial impact for a country surrounded by coastlines. Effective mitigation and adaptation measures must be put in place to prevent and compensate for their impacts.
- Since 1993 to 2012, the Global Mean Sea Level (GMSL) has increased to a rate of **3.11 ± 0.6 mm/year** (AVISO, 2013).
- Understanding of past and future changes in sea level and related ocean dynamics are important, especially for coastal management.





LOCAL SEA LEVEL CHANGES

- Oman CORS Network, Geoid Model and PLN will provide very **important components for future study of sea level changes** in Oman.
- Other components required for a comprehensive study are historical tidal records, satellite altimetry data and InSAR measurement.
- **Yearly trend for sea level rise in Oman could be estimated**.



Contributor	Sea Level Rise (mm/yr)	
	Tide Gauge (1961 to 2003)	Sat. Altimeter (1993 to 2003)
Thermal Expansion	0.42 +/- 0.12	1.6 +/- 0.5
Glaciers and Ice Caps	0.50 +/- 0.18	0.77 +/- 0.22
Greenland Ice Sheet	0.05 +/- 0.12	0.21 +/- 0.07
Antartic Ice Sheet	0.14 +/- 0.41	0.21 +/- 0.35
Sum	*1.1 +/- 0.5*	*2.8 +/- 0.7*
Observed	*1.8 +/- 0.5*	*3.1 +/- 0.7*
Difference (Observed – Sum)	*0.7 +/- 0.7*	*0.3 +/- 1.0*

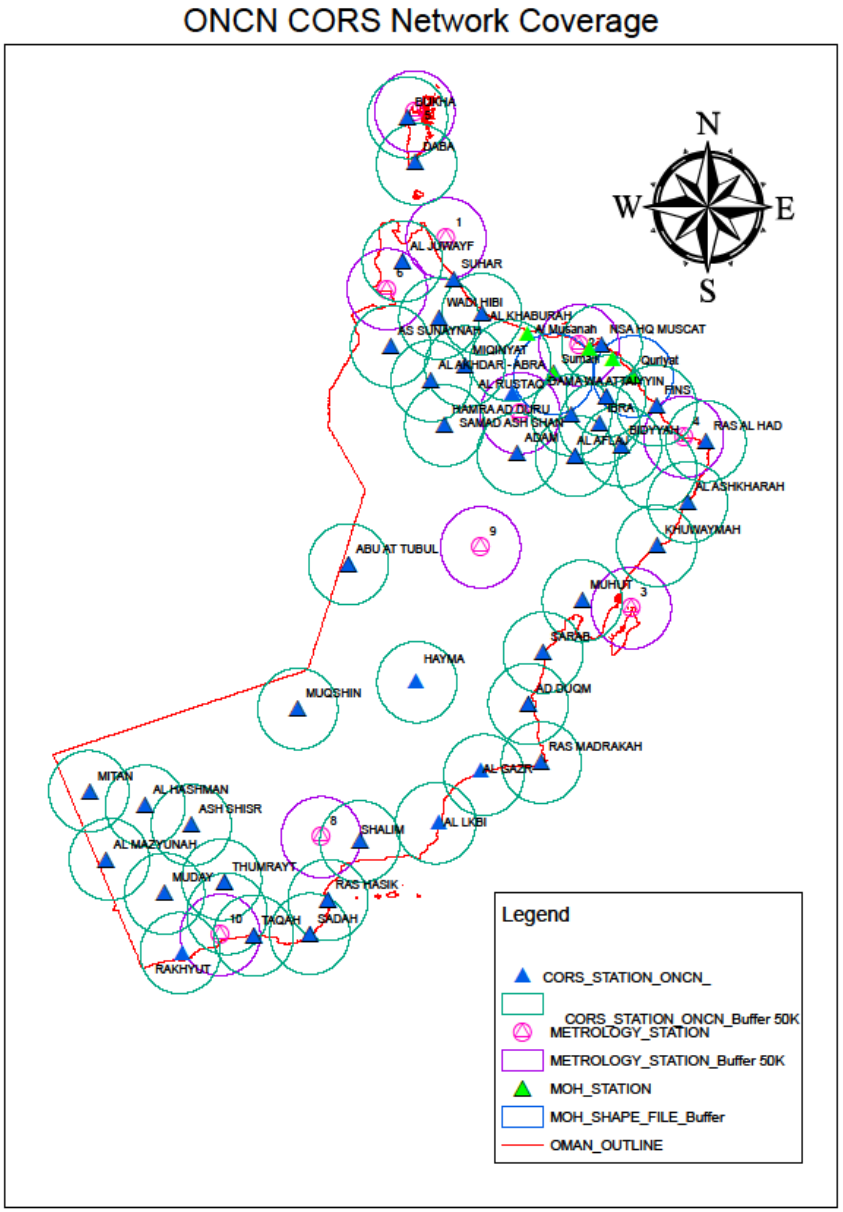
10. GNSS-CORS METEOROLOGY

- The Ministry of Transport and Communications has entered into an agreement to receive images from the European Satellite for the METEOSAT every half an hour. The data has been used in monitoring weather conditions especially over the Arabian Sea.
- 36 automatic stations are being installed to develop the numerical forecast systems. Seasonal forecasts and specialized numerical forecasts have also been introduced to help monitor tropical cyclones in the Arabian Sea.
- The Public Authority for Civil Aviation (PACA) is working on implementing a **Multi-Hazard Early Warning System** in Oman. The project follows Royal Orders after the December 2004 tsunami, and the cyclones that hit Oman in 2007 and 2010.

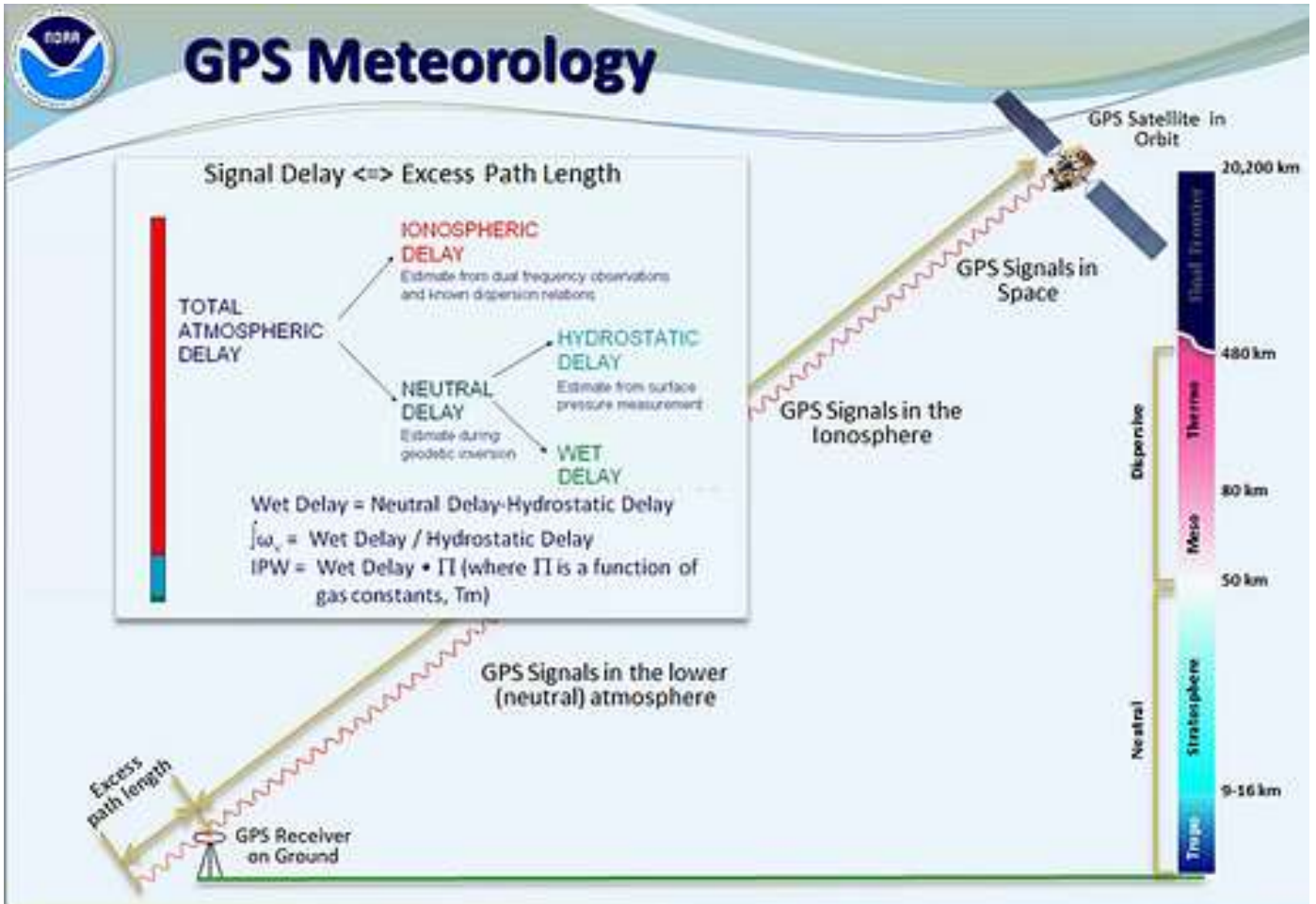
CORS in the vicinity of a Meteorological Site

MULTI-HAZARD EARLY WARNING SYSTEM

- The task includes assessing the dangers of Tsunami at the coastal areas by developing models for simulating Tsunami disasters.
- The task includes setting up 7 sea level monitoring stations connected to PACA in real-time.
- The number of GNSS CORS stations are increased to 10. **Continuous GNSS data could be used to support weather forecasting task**.
- The existing meteorology CORS stations shall be included in the ONCN system for better coverage of forecast modeling.



GPS Meteorology



BENEFITS TO NATIONAL DEVELOPMENT

1. CORS NRTK facilitates cm(s) level accuracy for horizontal and vertical components in homogenous coordinate system applicable for most surveying and engineering purposes. This will **provide GNSS-based surveying tool with standard data format to support various inter-departments engineering projects** for national infrastructure development.
2. Integrated ONCN-ONGM systems (CORS + Geoid Model) provides accurate 3D positioning (ϕ, λ, H=h-N) for various applications in both real-time and post-processing modes. This will **enable efficient project execution and monitoring** of national infrastructure development tasks with optimum cost.
3. The beginning of modern 3-D positioning service era for the country. Integration of CORS with new Oman Geoid Model will enable the practice of GNSS-Leveling ($H_{MSL}=h_{GPS}-N$) for most engineering survey applications. This will replace labourious conventional leveling practice with compatible height accuracy that will **reduce survey crew in the field**.

4. CORS NRTK could provide efficient control for large/medium scale mapping operations such as aerial photogrammetry, airborne LiDAR, airborne gravity survey, and terrestrial scanning tasks. **Modern mapping technologies require real-time and accurate positioning control** in most of their operations in developing geospatial components necessary to support various inter-department projects for national development.
5. CORS support mapping technologies in establishing all geospatial layers and that will make **data sharing** between the users possible. This will **avoid duplication efforts** in producing the geospatial data that will certainly optimizing the departmental data acquisition cost.
6. CORS and Oman Geoid Model are the fundamental components in the establishment of National SDI. Both components will provide accurate and homogenous 3D positioning control nation-wide. **Uniform coordinate reference frame is a primary requirement in developing geospatial components in SDI**.

7. CORS will support GIS activities at municipalities and national levels. Basemap creation is a primary task in all GIS related projects which require field data acquisition. **CORS support GNSS survey for GIS purposes** where spatial data shall be in uniform coordinate reference frame.
8. Parcels basemap is one of the fundamental component in SDI. Many other applications such as planning and housing are very much rely on the quality parcels basemap. **Creation of parcels basemap** is a complex procedure of producing accurate parcels dimensions in vector format. **Major requirement here is uniform coordinates system** which could be realized through control provided by CORS.
9. CORS will **support National transportation and logistics sector**. Fleet management and vehicle tracking systems will get benefit from the CORS. Both systems could support police petrol cars, fire bridged trucks, ambulance and many trucking companies in the country.

10. CORS and Oman geoid model will **support important scientific investigation in Oman including crustal movement, SLC and SST**. Understanding crustal movement relative to other regional crustal plates is possible by using long term continuous GNSS data provided by the CORS. Impact of global sea level rise along the coast of Oman and local SST effect could be quantified using both CORS and geoid model.
11. Contribution of CORS to meteorology is proven internationally. PACA established 10 GNSS-CORS stations to support weather forecasting task in Oman. **NSA CORS stations shall be included for better nation-wide coverage**.

THANK YOU !