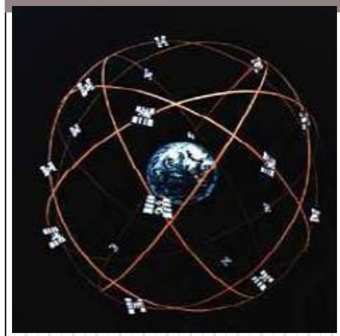
MAPPING AND SURVEYING USING GNSS



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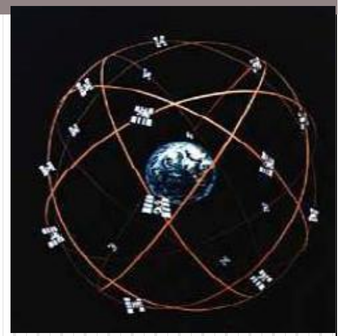


Second Workshop on Satellite Navigation Science and Technology for Africa 6-24,April, 2010, Trieste, Italy

Global Navigation Satellite Systems

- GPS = Global Positioning System (United States)
- GLONASS = Global Orbiting Navigation Satellite System (Russian Federation)
- Galileo = European (Commission's) Proposed Satellite Navigation System
- Beidou/Compass = Satellite Navigation and Positioning System (People's Republic of China)
- QZSS= Quasi-zenith Satellite System(Japan)

Satellite-based positioning

Satellite-based positioning is divided into three main categories:

- Transmitting and receiving optical signals to/from satellites (artificial and natural) SLR/LLR
- Transmitting radio signals to satellites (DORIS)
- Receiving radio signals from satellites (GNSS)

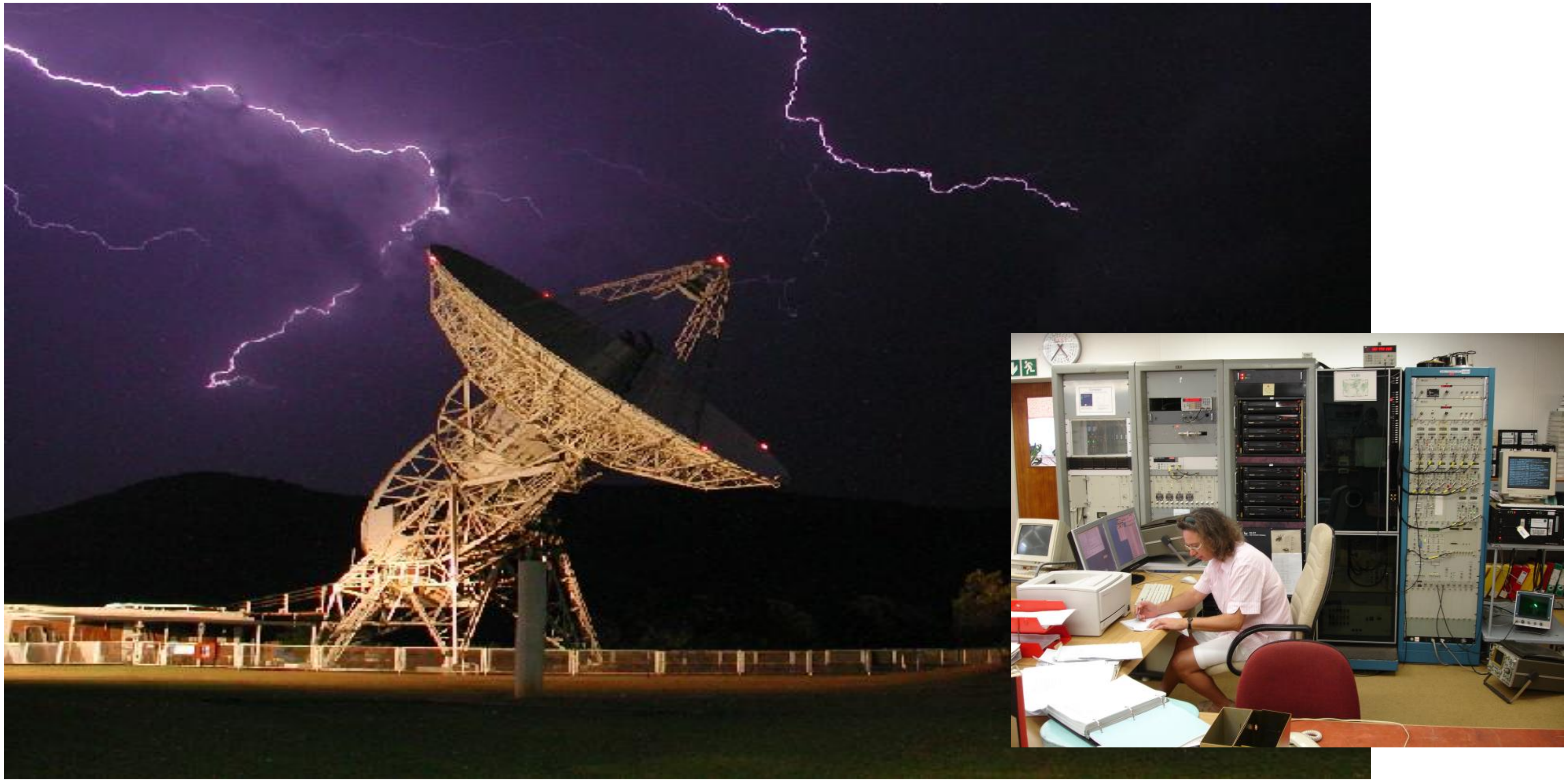
Advantages

- VLBI: very accurate determination of inter-station baselines, rotation rate of Earth, Earth's axis wobble, only absolute system etc.
- SLR: very accurate determination of vertical component and ranges to satellites, no ionospheric refraction.
- DORIS: precise orbits for specific satellites and permanent tracking stations

Disadvantages

- Very expensive to set up and maintain.
- Not suitable for surveying applications.

VLBI instrumentation



SLR instrumentation

GPS observations

Pseudo-range(code range) measurement

- Ancillary observations
- Resolving ambiguities
- Repairing cycle slips during the pre-processing stages of advanced GPS analysis

Carrier phase measurement

- Noise level of a few millimeters and very precise
- High precision GPS positioning and GPS meteorology

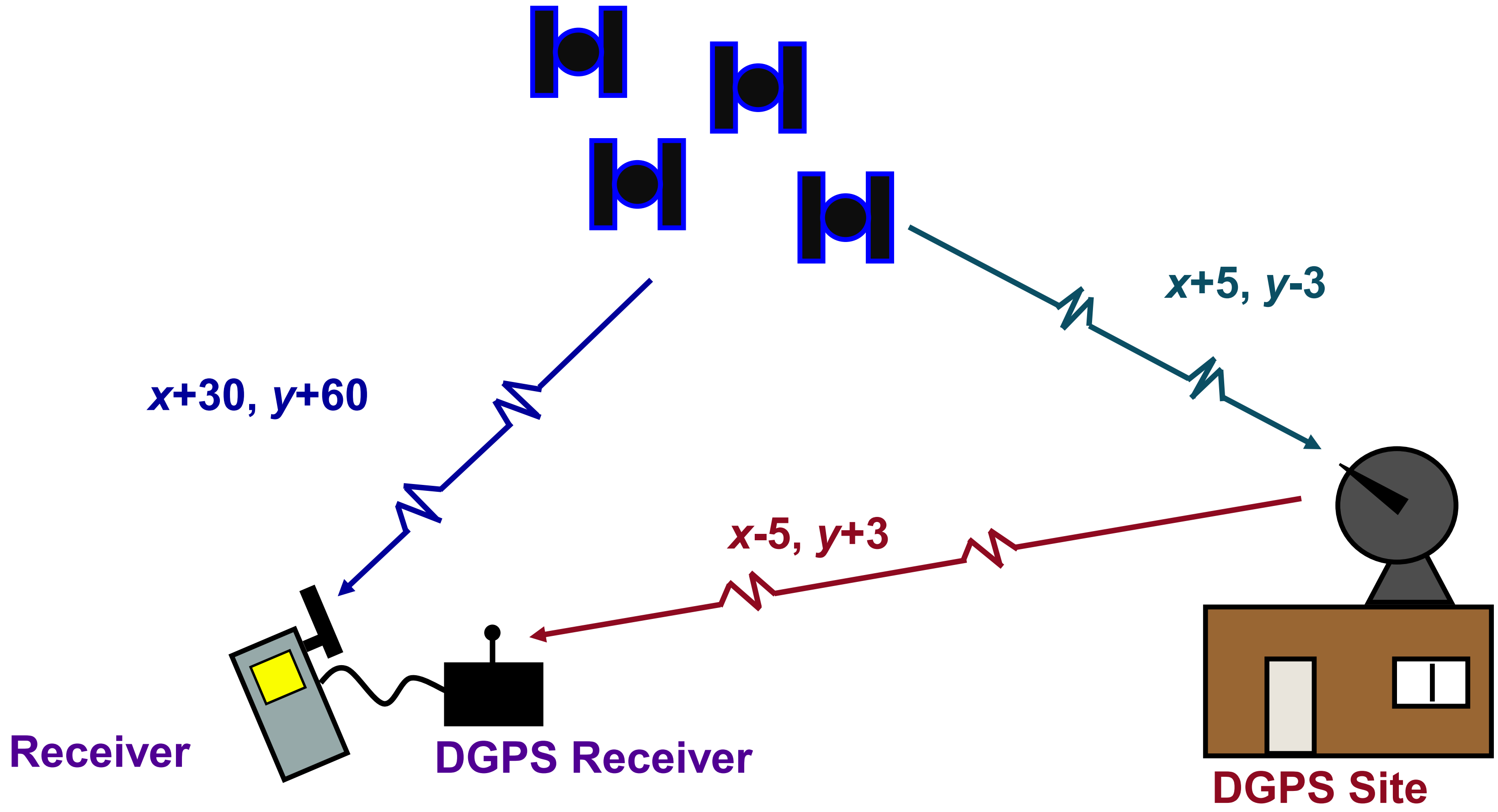
GPS observations(contd)

- $ZD = L = R - \lambda N - \Delta ion + \Delta trop + \Delta clk + \Delta hw + \Delta syn + \Delta orien + \Delta pcv + \Delta rel + e$
- *Combined phase measurement can be written as*

$$L_{12} = a_1.L_1 + a_2.L_2$$

$$\sigma_{12}\left(noise\ level\right) = \sqrt{\left(a_1.\sigma_1\right)^2 + \left(a_2.\sigma_2\right)^2} = \sigma\sqrt{a_1^2 + a_2^2} = F_\sigma.\sigma$$

Concept of Differential GPS



True coordinates = *x*+0, *y*+0

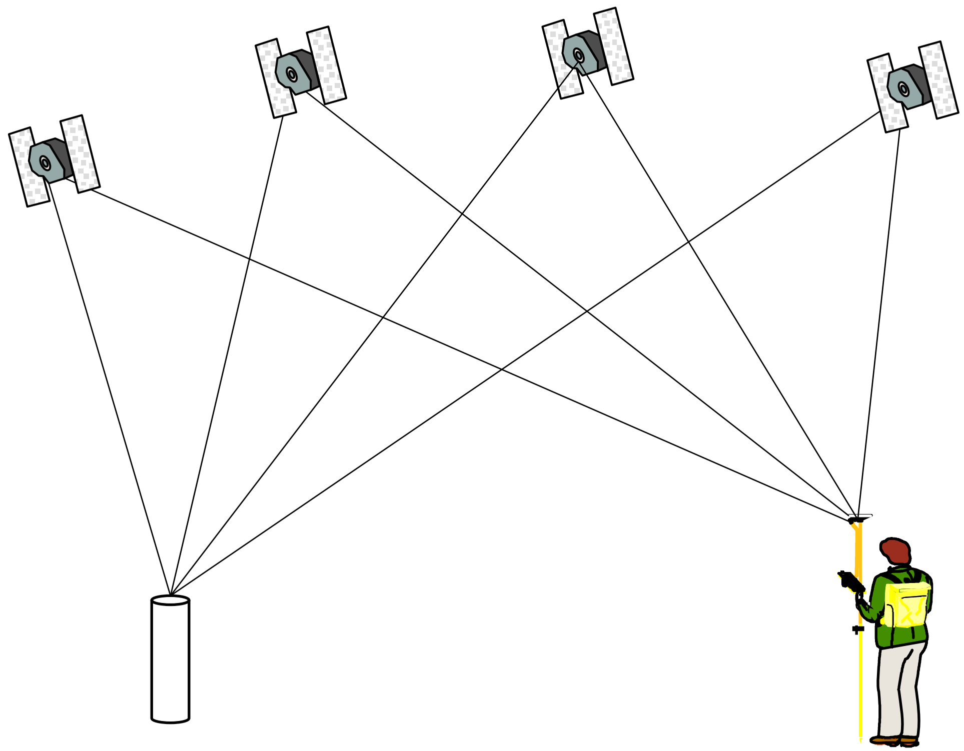
Correction = *x*-5,*y*+3

DGPS correction = *x*+(30-5) and *y*+(60+3)

True coordinates = *x*+25, *y*+63

Differential positioning

The motivation: *Most errors are spatially correlated and can be reduced or eliminated by differencing.*



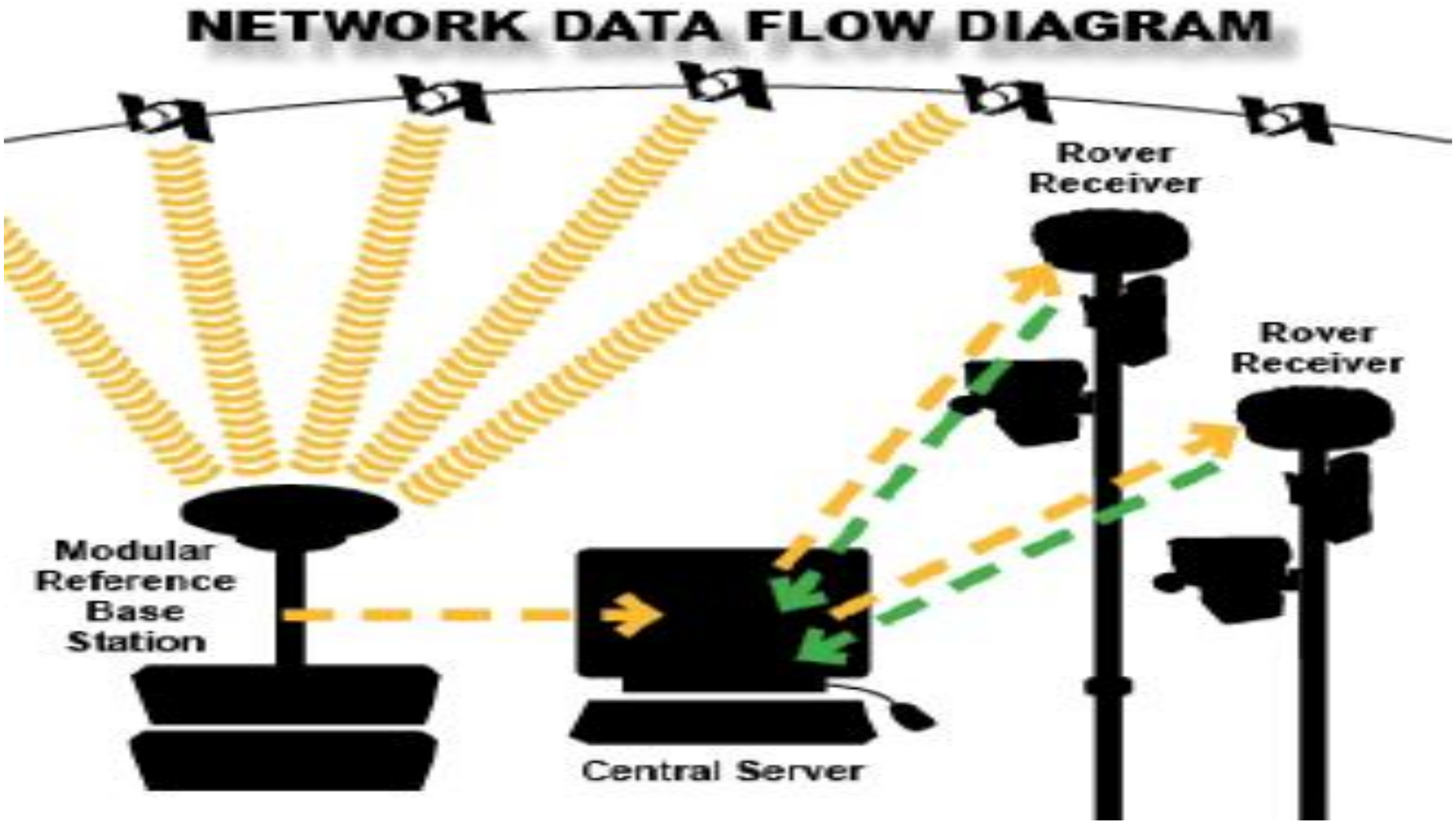
GPS Observations (Contd)

Linear Combinations of the L1 and L2 Observations						
Carrier	a_1	a_2	$\lambda(\mathrm{mm})$	F_{ion}	F_σ	Description
L_1	1	0	190	1	1	Original l1 signal
L_2 L_C	0 $f_1^2/(f_1^2-f_2^2)$	1 $-f_2^2/(f_1^2-f_2^2)$	244	1.65	1	Original L2 signal
L_G			190	0	2.98	Ionosphere free
L_W	1 $f_1/(f_1-f_2)$	-1 $-f_2/(f_1-f_2)$		-0.65	1.41	Geometry free
L_N	$f_1/(f_1+f_2)$	$f_2/(f_1+f_2)$	862	-1.28	5.74	Wide lane
			107	1.28	0.71	Narrow lane

Achievable accuracy with DGPS

Sources of error	Error without DGPS	Error with DGPS
Ephemeris data	2.1m	0.1m
Satellite clocks	2.1m	0.1m
Effect of ionosphere	4.0m	0.2m
Effect of troposphere	0.7m	0.2m
Multipath reception	0.5m	0.5m
Total RMS value	5.3m	1.5m

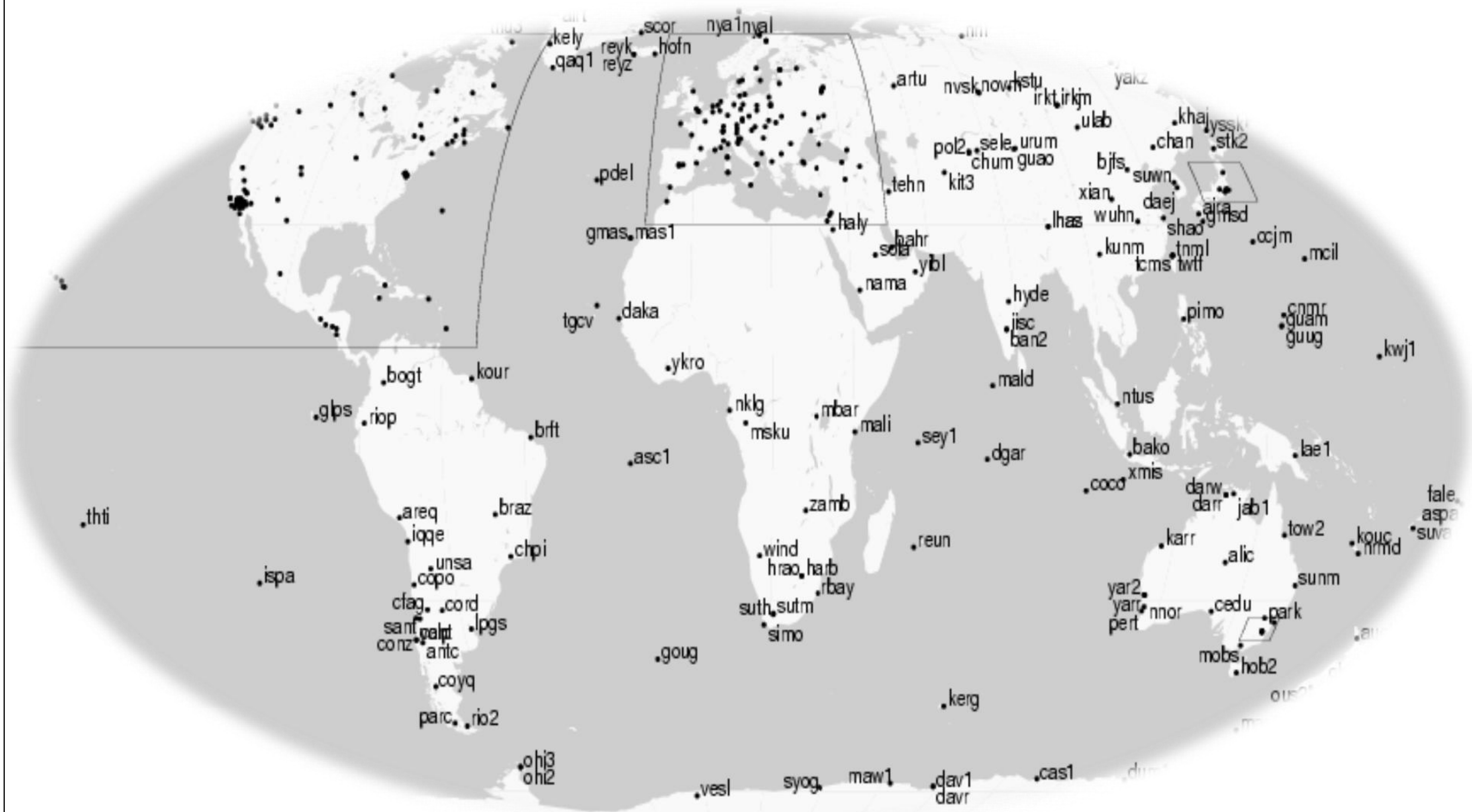
Requirement for GNSS network data exchange and processing



Differences between near real time and post data processing

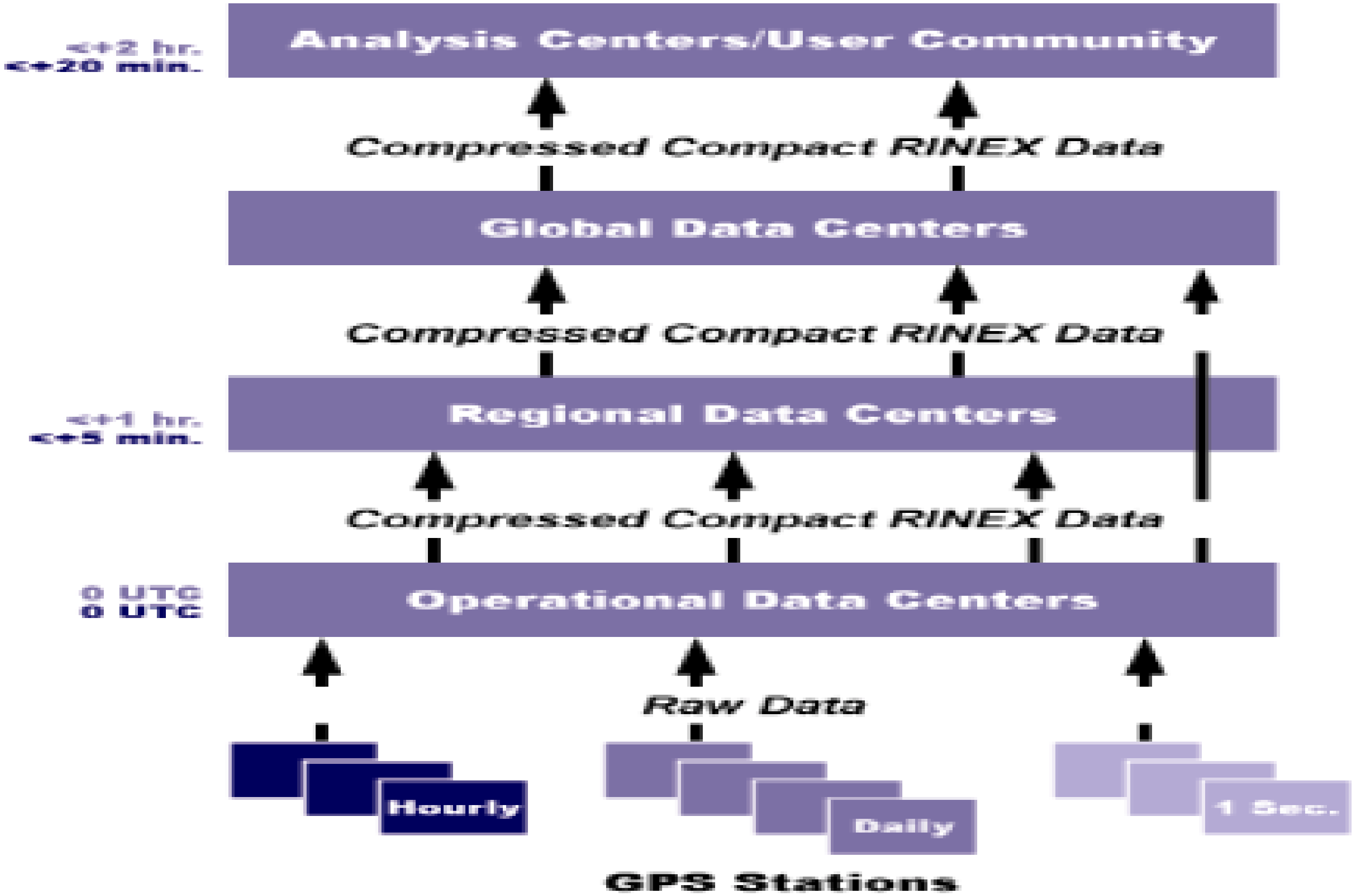
Solution	Near real time processing	Post processing
Data organized and processed	Hourly	Daily
Orbits used	Ultra-rapid /predicted	Rapid/final
delay	1-2 hours	1-10 days
period	Last 24 hours	24 hours of current day
Solutions per day	24	1
ZTD resolution	5-30 minutes	5-30 minutes
Purpose	Rapid mapping, engineering, Meteorological applications	Geodetic and Climate applications

GNSS CORS NETWORK



Nigerian National Meeting on Global Navigation Satellite System(GNSS) 16-19,Nov,2009, Abuja, Nigeria

IGS DATA and products



IGS file naming conventions

GPS (30-second sampling) RINEX observation file:

- ssssddd#.yyo

  (ssss = site code, ddd = day-of-year, yy = last 2 digits of year, # = code)
- for e.g. site "ABUZ", 3rd April 2010, the filename is abuz1230.10o
- When downloaded, the naming convention typically is ssssddd#.yyd.Z

  (use crz2rnx to uncompress to ordinary RINEX)

IGS file naming conventions

GPS 24-hour “combined” RINEX navigation file:

- brdcddd0.yyn or autoddd0.yyn
  (ddd = day-of-year, yy = last 2 digits of year)
- for e.g. 3rd April 2010, the filename is brdc1230.10n or auto1230.10n
- When downloaded, the naming convention typically is brdcddd0.yyn.Z or autoddd0.yyn.Z
  (use gunzip to uncompress to ordinary RINEX)

IGS file naming conventions

GPS 24-hour ECEF orbit and clock correction files:

- igxwwwwd.sp3 and igxwwwwd.clk
  (x = orbit latency (u, r or **s**), wwww = GPS week, d = day-of-week (0 to 6))
- for e.g. Thursday 2 August 2007, the filename of the precise orbit is igs14384.sp3
- When downloaded, the naming convention typically is igxwwwwd.sp3.Z and igxwwwwd.clk.Z
  (use gunzip to uncompress)

More information about the RINEX and IGS file formats

Consult e.g. this website for more information about the format of the contents of the discussed files:

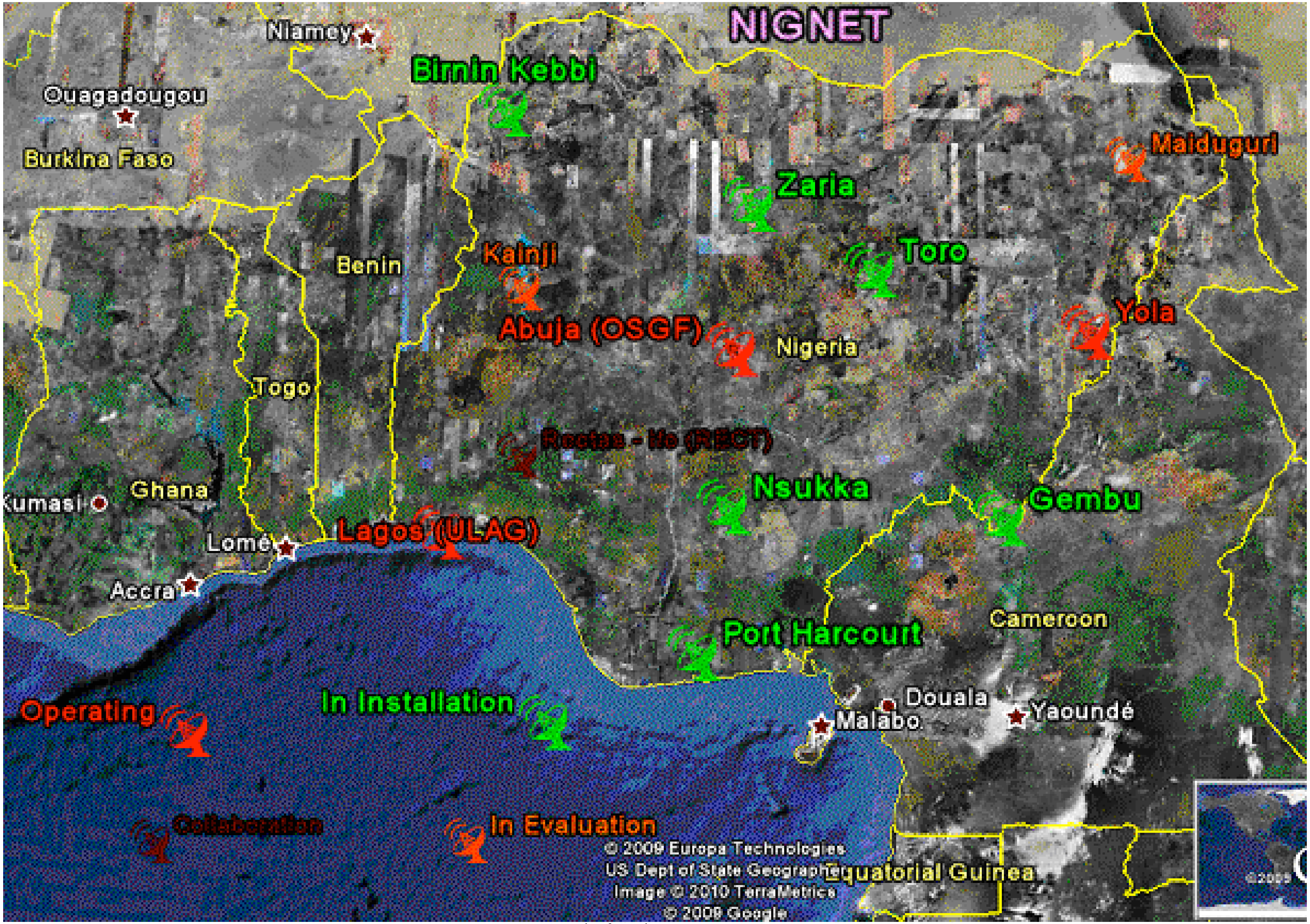
- http://igscb.jpl.nasa.gov/igscb/data/format/rinex211.txt

GPS SATELLITE ORBITS AVAILABLE FROM IGS

Product	Accuracy		Latency	Updates
	Orbits	Sat clocks		
Broadcast	$\sim 200cm$	$\sim 7ns$	Real time	-
Ultra-Rapid (predicted half)	$\sim 10cm$	$\sim 5ns$	Real time	Twice daily
Ultra-Rapid (observed half)	$< 5cm$	$\sim 0.2ns$	Real time	Twice daily
Rapid	$< 5cm$	$0.1ns$	17hours	daily
Final	$< 5cm$	$< 0.1ns$	$\sim 13days$	weekly

THE NEW NIGERIAN PERMANENT GNSS NETWORK OF NIGERIA (NIGNET)

- ITRF SOLUTION (2005)
- CONTRIBUTION TO AFREF
- RTK POSITIONING IN SINGLE AND NETWORK NODES



NIGNET
Niamey
Birnin Kebbi
Ouagadougou
Burkina Faso
Maiduguri
Zaria
Toro
Benin
Kainji
Yola
Abuja (OSGF)
Nigeria
Togo
Rectas - Ile (RECT)
Nsukka
Gembu
Kumasi
Ghana
Lagos (ULAG)
Lomé
Accra
Cameroon
Port Harcourt
Douala
Operating
In Installation
Malabo
Yaoundé
Collaboration
In Evaluation
© 2009 Europa Technologies
US Dept of State Geographer
Equatorial Guinea
Image © 2010 TerraMetrics
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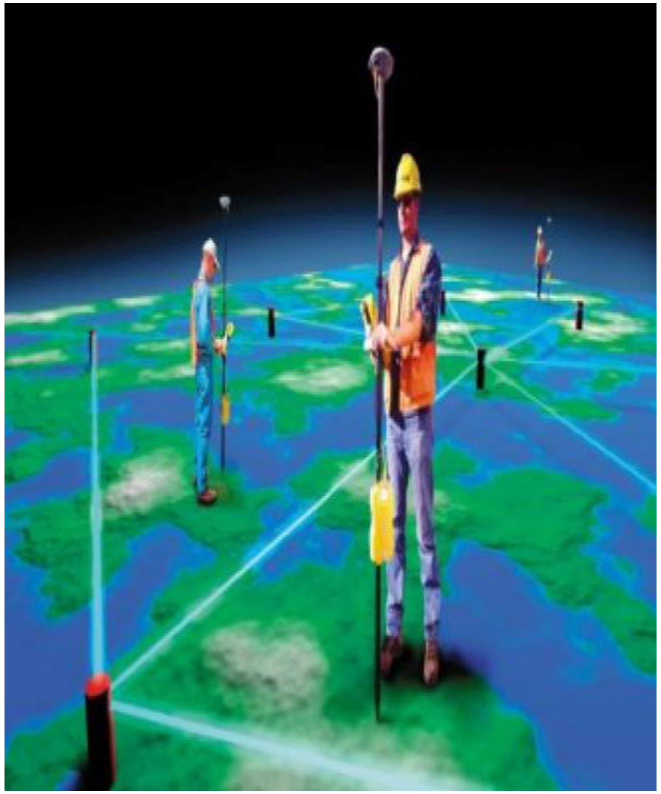
SCINDA RECIEVERS AND PRIVATELY OWNED CORS
Niamey
N'Djamena
Benin
Togo
Illorin
Ife
Akure
Abuja
Nigeria
Nsuka
Lagos
Porto-Novo
Mahin Canyon
Cameroon
Douala
Yaoundé
288 mi
© 2010 Europa Technologies
US Dept of State Geographer
© 2010 Google
Image © 2010 TerraMetrics
9°04'55.20" N 8°40'31.00" E elev 1368 ft
Eye alt 905.39 mi
©2009 Google

CORS / VRS ADVANTAGES



- 3-dimensional.
- Users do not need to recontrol points.
- Users do not need to set up instruments at control points.
- CORS positional coordinates are more accurate than those of other control points.
- Direct tie to National Spatial Reference System.
- CORS positions and velocities are available in ITRF coordinate systems.
- CORS positions are continuously monitored and will be updated if the site moves.

Services from VRS

SERVICES	METHOD SOLUTIONS	DATA TRANSFER	ACCURACY	DATA FORMAT
DSP	Network solution of code measurement in real time	Wireless internet (GPRS, UMTS) NTRIP protocol GSM	±0.3 to ±0.5m	RTCM
VPPS	Network solution of phase measurement in real time	Wireless internet (GPRS, UMTS) NTRIP protocol GSM	±2cm(2D) ±4cm (3D)	RTCM
GPPS	Post	Internet	± 1cm (2D,	RINEX

ON-LINE GNSS PROCESSING SERVICES

- **Auto Gipsy(JPL)**-service provided by JPL
  http://milhouse.jpl.nasa.gov/ag/
- **AUSPOS**(Geoscience Australia)-service provided by Geoscience Australia
  http://www.ga.gov.au/geodesy/sqc/wwwgps/
- **OPUS**- service provided by NGS, USA
  http://www.ngs.noaa.gov/OPUS/
- **SCOUT** (SOPAC)- service provided by SOPAC, USA
  http://sopac.ucsd.edu/cgi-bin/SCOUT.cqi
- **CSRS-PPP**(NRCAN GSD)- service provided by natural Resources of Canada
  http://www.geod.nrcan.gc.ca/ppp_e.php

GPS HEIGHTING

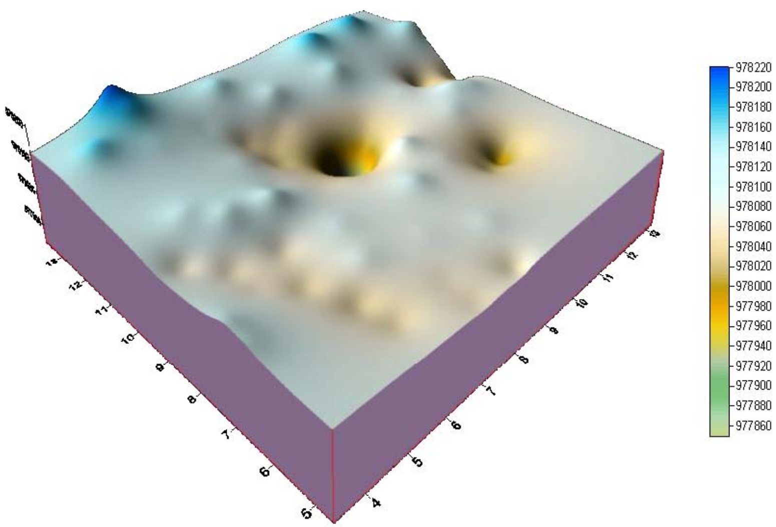
Well established geodetic framework, apart from being the backbone of any national surveying and mapping systems, also enhances the reliability of geographic data used in spatial information systems for resource planning and enhancing sustainable development. One of the components of a geodetic framework is the height component. Orthometric height, a height component referred to the geoid, is required for engineering projects and other applications. The classical geodetic levelling method, used to determine this quantity is tedious, time consuming and expensive. The method is almost impracticable in some parts of Nigeria, where the terrain is swampy and hostile

Importance of height

- *Geodetic/Topographic applications*: Heights are used for geodetic research such as gravity study; the study of gravity has many applications in sciences, secular upheaval or depression. Other applications include ground subsidence monitoring or deformation studies, tidal observations, study of mean sea level variations, change in the rotational axis of the earth, computing geoidal heights, evaluating global geopotential models, determining atmospheric parameters, and other geophysical investigations.

Importance of height (Contd)

- *Engineering uses*: Height information are usually required for engineering works which includes; the determination of the altitudes of different important points on a hill or to know the reduced levels of different points on or below the surface of the earth. These information are used to prepare contour map for fixing sites for reservoirs, dams, barrages, etc., and to fix the alignment of roads, railways, irrigation canals, sewer, pipelines and soon .


978220
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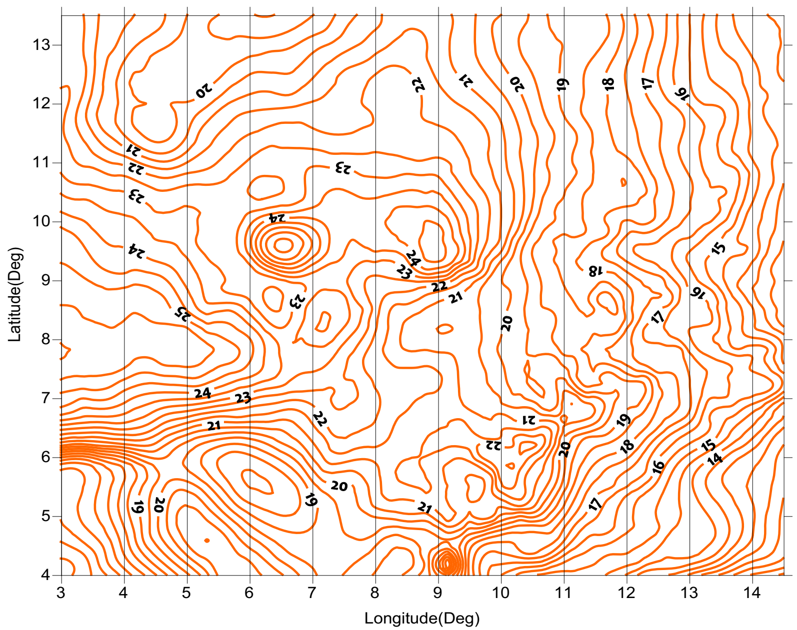

Latitude(Deg)
Longitude(Deg)
13
12
11
10
9
8
7
6
5
4
3
4
5
6
7
8
9
10
11
12
13
14

Errors sources affecting GNSS-determined heights

Error of the GNSS measurement

- Vertical dilution of precision(VDoP)
- Satellite ephemeris and GNSS baseline length
- Ionosphere delay
- Troposphere delay
- Multipath
- Electromagnetic interference and signal attenuation
- Error in measurement of the antenna height

Error due vertical datum

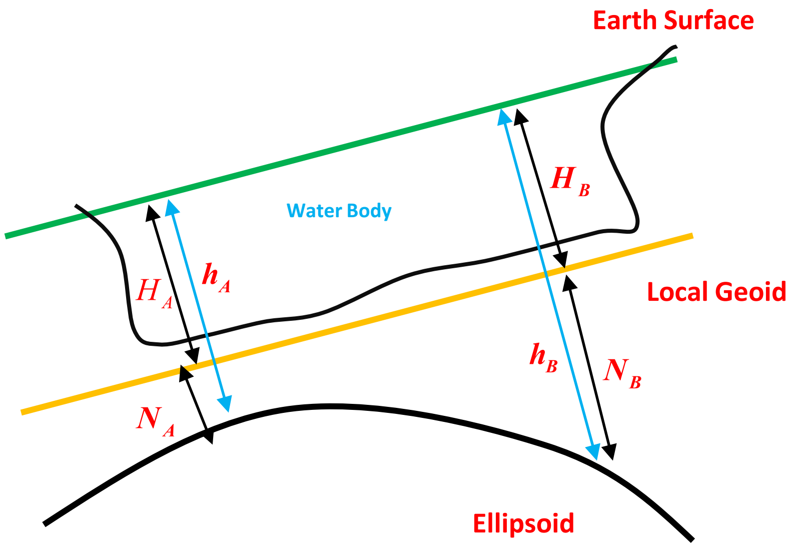
Error due available geoid model

Possibilities and limitations of GPS heights

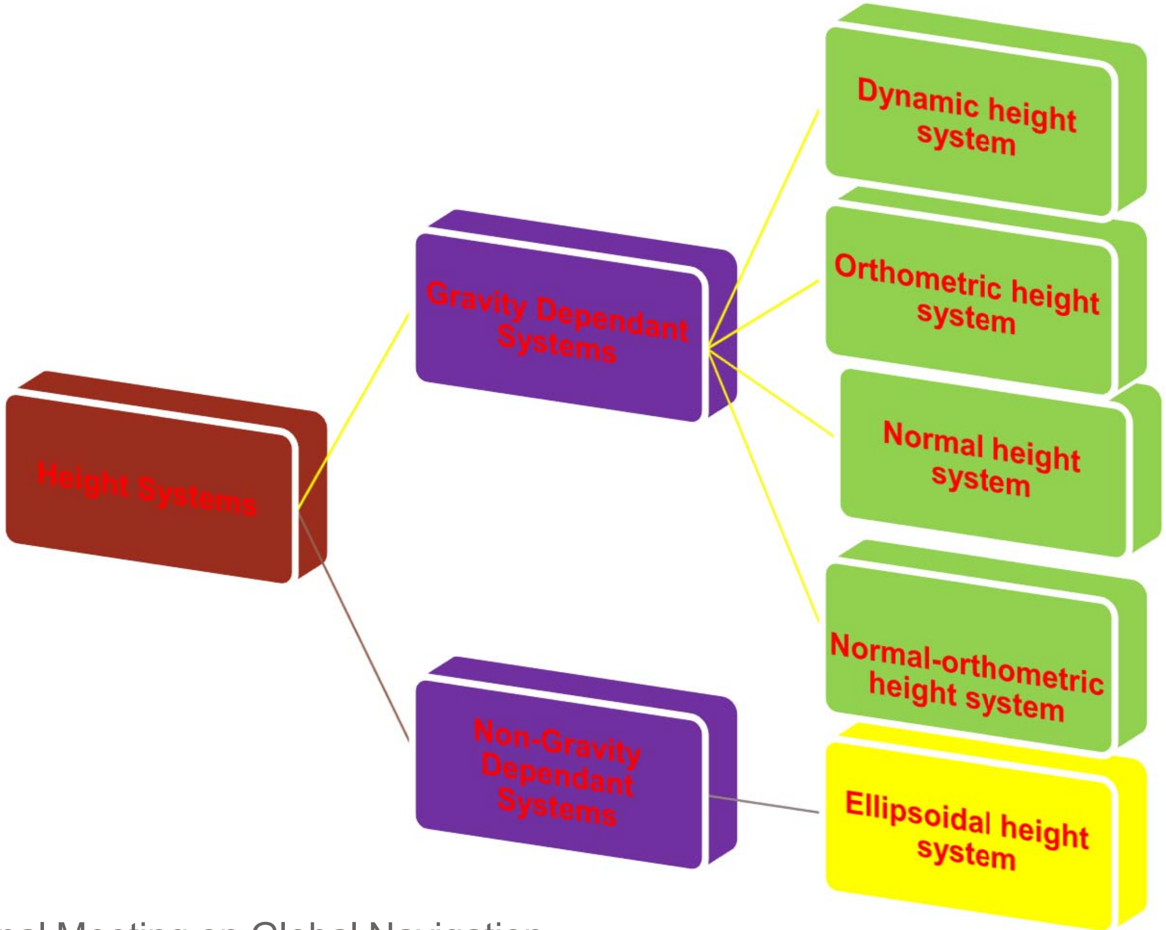
Possibilities

- Deformation monitoring
- Machine monitoring and guidance

Limitations



Height system: physical vs. geometric



Height system: physical vs. geometric(Contd)

Normal height

- Molodenksy normal height

Dynamic height

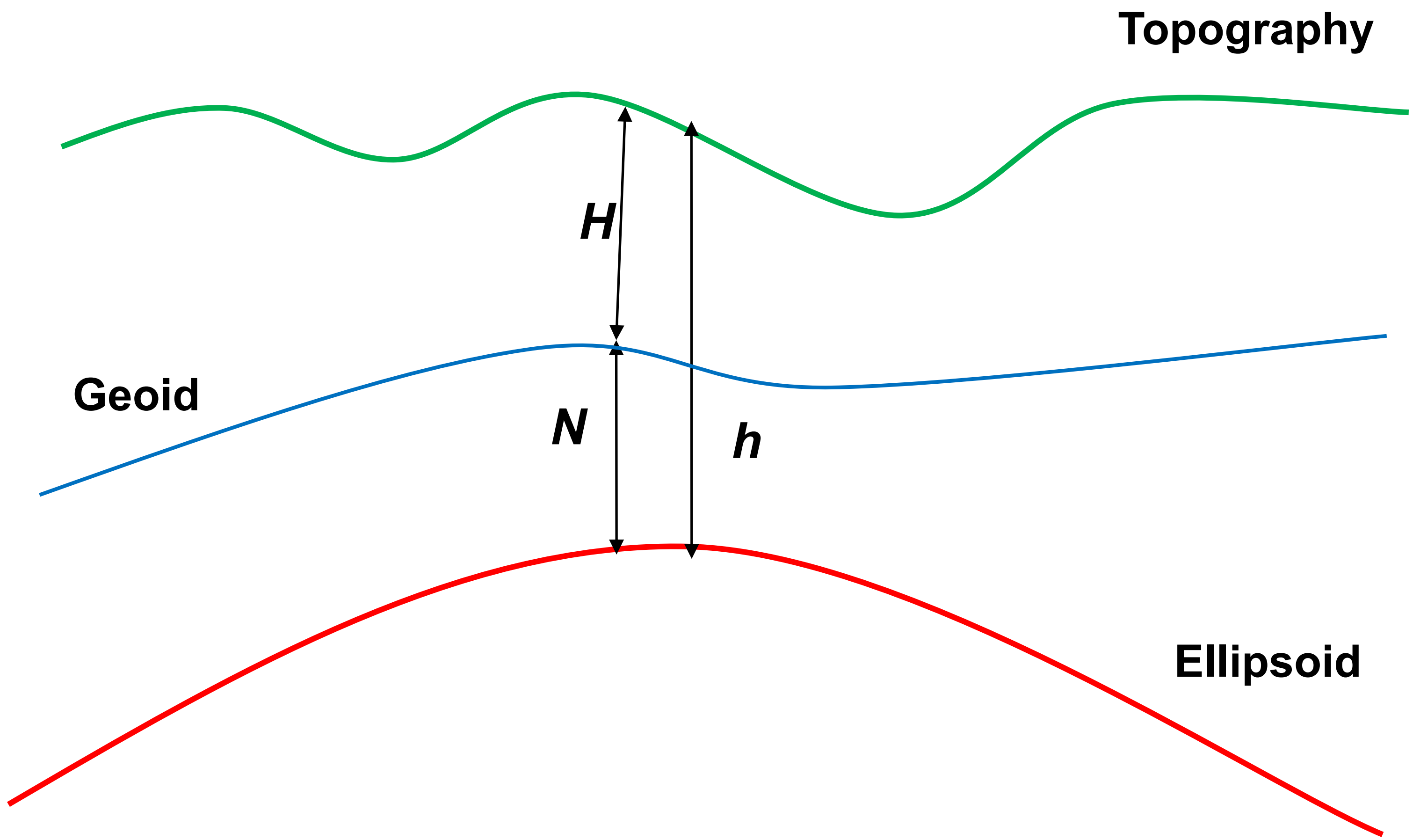
Orthometric height

- Helmert orthometric height
- Ramsayer orthometric height
- Vignal orthometric height
- Baranov orthometric height
- Ledersteger orthometric height

Normal orthometric height

- Rapp's normal orthometric height

Relation between physically meaningful height(orthometric) height and geometric height



Relation between physically meaningful heights and geometric height (contd)

$$h - H - N = 0$$

$$h - H_N - \eta = 0$$

(contd)

- Random errors in the derived heights *h* , *H* , and *N*
- Datum inconsistencies inherent among the height types, each of which usually refers to a slightly different reference surface
- Systematic effects and distortions primarily caused by long-wavelength geoid errors, poorly modelled GPS errors (e.g., tropospheric refraction), and over constrained levelling network adjustments
- Assumptions and theoretical approximations made in processing observed data, such as neglecting sea surface topography effects or river discharge corrections for measured tide gauge values in determining sea level. This category of errors is already known to exist at the Lagos tide gauge
- Approximate or inexact normal/orthometric height corrections
- Instability of reference station monuments over time due to geodynamic effects and land subsidence/uplift

Geoid models

- Geometric geoid models(modelling geoidal height using different trend surface algorithms i.e., The Inverse Distance to a Power Method, Kriging Method, Minimum Curvature Method, Modified Shepard's Method, Nearest Neighbour Method, Natural Neighbour Method, Polynomial Regression Method(Simple Planar Surface, Quadratic Surface, Cubic Surface), Radial basis Function Method(Inverse Multiquadric function, multiquadric function, Natural Cubic Spline, Thin Plate Spline), Moving average Method, Triangulation with linear Interpolation Method, Method, local polynomial method(1^{st},2^{nd}, and 3^{rd} Polynomials).
- Gravimetric geoid models (are computed from collocation or FFT techniques are computed by national bodies)
- Global geoid models (A GGM is typically computed as a series of spherical harmonic expansions to a maximum degree and order. The most recent GGM (EGM08)use an expansion to degree and order 2160. other are OSU91A, EIGEN2/EGM96, GGM02s, PGM2000A, EGM96 to mention but a few

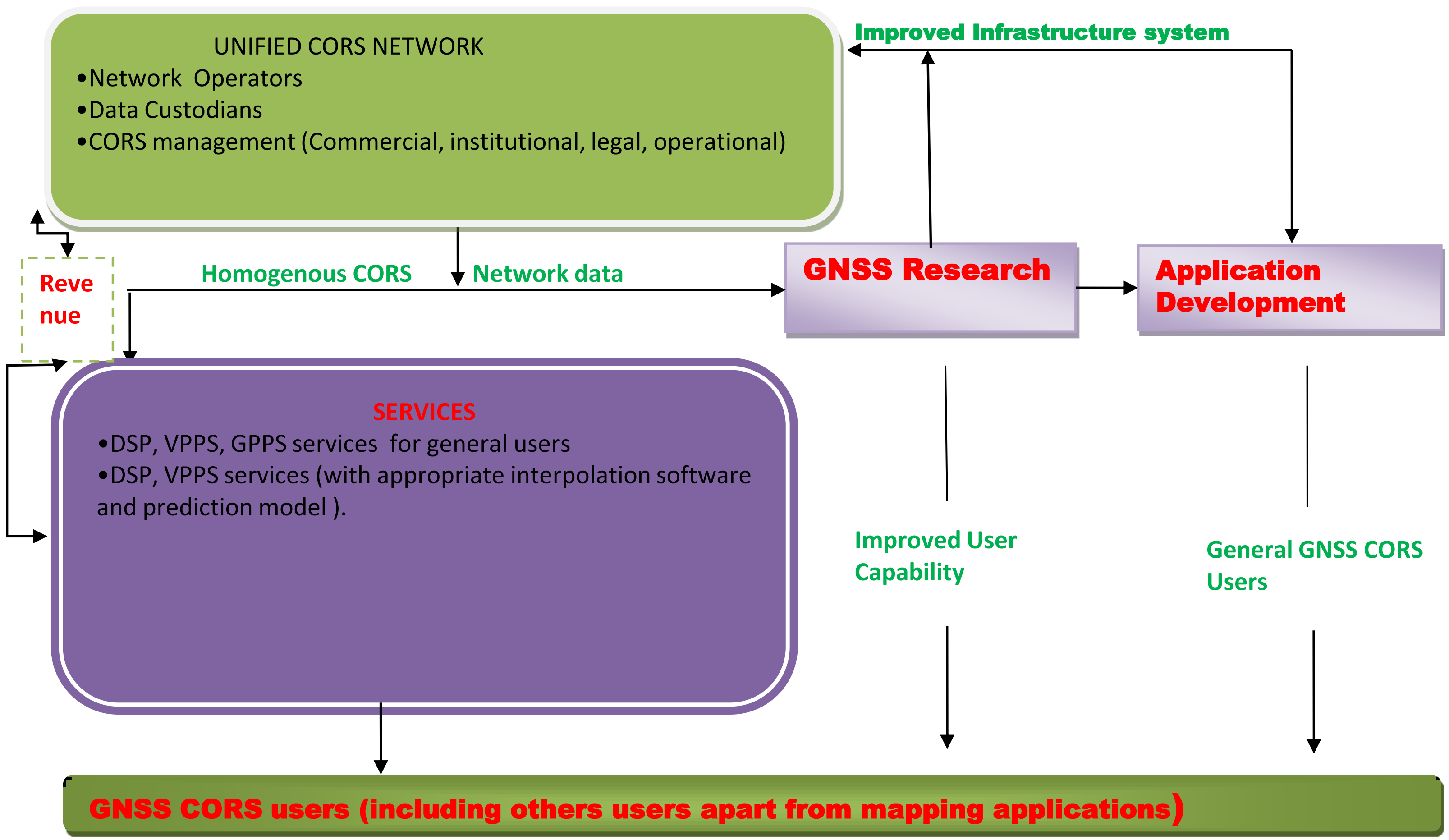
organizations in obtaining orthometric height from GNSS

- American example
- Canadian example
- European proposal
- Australian example
- Global vertical datum and the concept CORS
- Lagos state mapping example
- Researches on obtaining orthometric from GNSS at Ahmadu Bello University

The Nigerian scenario

- Quality of existing conventional levelling data
- Multiple datum problem
- Insufficient or poor terrestrial gravity information
- Absence of a national gravimetric geoid for the country
- Absence of GPS/levelling collocated points at national scale
- Accuracies of global earth model

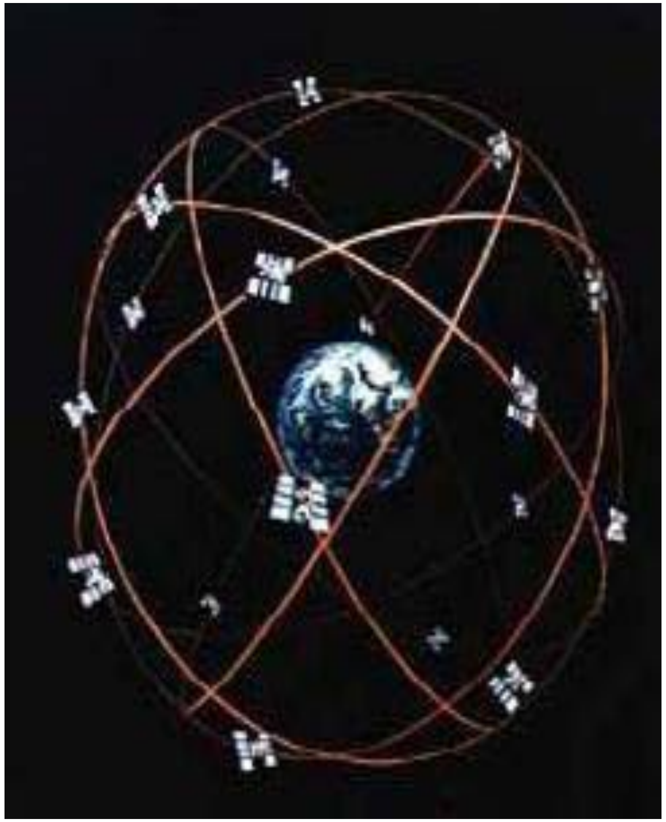
A proposed model for multimodal application of GNSS in Nigeria



Future impact of CORS on mapping operation in Nigeria

- Geodetic control for cadastral mapping
- Cadastral boundary point measurements
- Crustal motion studies
- GIS database, fundamental data set for the NSDI
- National topographic GIS data
- Dynamic cadastre/ three dimensional cadastre
- Coordinate based cadastre
- Dawn of new surveying regulations

THANK YOU FOR YOUR ATTENTION



- "GNSS is an enabling technology that can make major contributions to economic growth and societal betterment. It is a key to scientific exploration"
- . . . ..P. Doherty 2010