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Divergence or Submission?: The Extremals of Global Wireless Technology

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Abstract--**Real-time location applications with the aid of wireless sensor networks (WSNs) have climaxed at indoor navigation. However, the predictions and estimations of descriptors of such WSNs have defined the isoperimetric problems and degeneration of patterns under circumstances of symmetry. Further, points of discontinuity and weak variations of signals of ubiquitous positioning necessitate the characterization of vulnerabilities and susceptibilities of various business models. Therefore, on the horizon of emerging technologies, this paper presents (1) the L1 band ensembles of an indoor scenario of A-GPS+GLONASS, (2) the spectral analysis of the observables, and (3) the transitions, vicissitudes and techno-economic implications of the developments in global WSN industries. Evidences of improved measurements and performance metrics of drifting signals are crucial initiatives toward sustainable management of innovative WSN technology age.**

I. DEVELOPMENTS IN GLOBAL WIRELESS SENSOR NETWORKS (WSNS): AT A GLANCE

The developments on the timeline of global wireless technology have not been without upheavals. Ostensibly, from the concept of application specific integrated micro-instruments (ASIM)—microelectronics, integration of micro-electromechanical systems (MEMS), miniaturization, and signal conditioning—to the development of small satellite technologies, WSNs have witnessed challenges of signal vulnerabilities, susceptibilities and interferences. However, upturns of event at the peak of WSN evolution have nurtured a new era of mitigation techniques, over a span of applications: cellular or mobile networks and personal communication service (PCS), terrestrial microwave to satellite communication, environmental monitoring, disaster detection and mitigation, healthcare, oil and gas, transport and logistics, mapping, tracking and geographic positioning, location-based services (LBS), Wi-Fi local area networking—to mention a few. Of course, by definition WSNs are wireless mesh networks that 'self-heal' or 'self-organize' to enable remote observations, monitor and control of processes or systems, over radio frequency communication channels.

Historical developments indicated that ubiquitous WSN signal evolution is a multifunction of not only dynamic environmental features but also of active space and terrestrial transmission. Notably, the Institute of Electrical and Electronics Engineers (IEEE) have developed and maintained a group of terrestrial wireless standards for a variety of applications. Based on IEEE802.11 platforms, concerted efforts in wireless sensor technologies have extended diverse solutions—The main concept and architecture have been directed toward security, autonomous deployment of sensor nodes, reliability, intelligence, flexibility, and energy efficiency [1]. Despite susceptibility to interference, the 802.11 'family' has provided a set of media access control (MAC) and physical layer (PHY) specifications of implementing wireless local area network (WLAN) in the 2.4-2.5GHz, 4.915-5.825GHz, and 60GHz spectra bands (the most popular is defined by 802.11b/g protocols), sustained by the IEEE local and metropolitan area network (LAN/MAN) Standards Committee (IEEE 802). Even so, not be overlooked are bevies of innovative, proprietary WSNs technologies focused on major portfolios in the industries to maintain competitive advantage. Figure 1 illustrated the composite WSNs technology features, topology models, geographic distributions and revenues. In fact, the industrial WSN (IWSN) business market would worth $944.92 million in 2020 at a continuous annual growth rate (CAGR) of 12.96% from 2014, toward a growth of $1.8 billion by 2024 [2]. The IWSNs are the plethora of networks of various sensors placed across industrial plants and fields for remote measurements of phenomena and events. Further, the glimpse of the potential of IWSN market had been classified based on these categories: sensors (temperature, pressure, level, flow, humidity and others), technology (Bluetooth, Wi-Fi, WirelessHART, and Isa.100.11a), applications (oil and gas, energy and power, automotive, and food and beverage) and geographic trends. In short and medium terms, WirelessHART would be the key to applications in the process industries and ZigBee-related solutions to home automation.

The timescale of WSN revolution has promulgated Global Navigation Satellite System (GNSS) modernization programs: Galileo, Global Positioning System (GPS) III or next generation satellites, Globalnaya Navigazionnaya Sputnikovaya Sistema (GLONASS) and BeiDou satellites (BDS), despite the clamors over malfunctions and wrongly placed satellite vehicles (SVs), insufficient budget, loss of signals and late release of interface control documents (ICDs). On February 10, 2015 the Galileo in-orbit validation (IOV) was achieved with 4 satellites, to obtain navigation fixes—with dual-frequency positioning performance average of 8m horizontal and 9m vertical (95% of the time) with an average timing accuracy of 10 nanoseconds [3]. In addition, the €5 billion Galileo program had proposed developments to augment the accuracy and robustness of the system, advance the capabilities to adapt to all signal and message standards, improve mitigation techniques of signal interferences and Galileo's receiver resilience to intentional jamming potentials. Above all, in efforts to accelerate the programme schedule to full operational capability (FOC), six Galileo satellites have been planned for 2015 launch—funded and managed by the European Commission (EC) and its

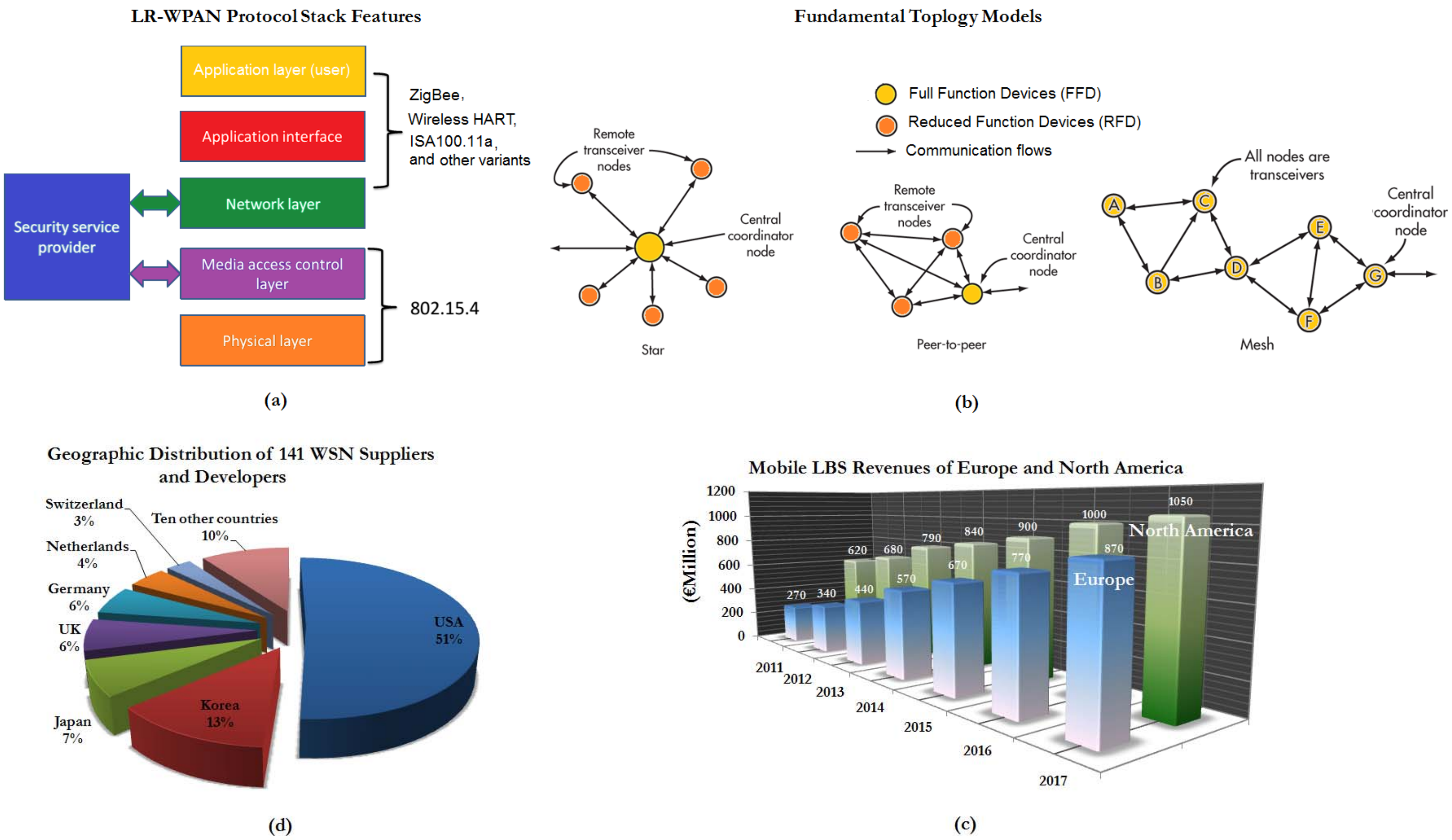


Fig.1. (a) The Low Rate WPAN protocol stack features; (b) The fundamental star, P2P, and mesh topology models; (c) The trends of mobile LBS revenues of Europe and North America between 2011 and 2017; (d) The geographic distribution of 141 WSN suppliers and developers in 2010.

delegated design and procurement agent, the European Space Agency (ESA). The four Galileo satellites in orbit performed the first fix on March 12, 2013, though the complete operational and ground infrastructure of Galileo is expected to be deployed during the FOC phase and despite setbacks. Besides, the third and fourth Galileo FOC satellites, FM3 (Galileo 7) and FM4 (Galileo 8), were set to lunch on Soyuz by March 27, 2015 after rigorous analysis and fit checks. In the meantime, on the downstream sector, avalanches of receiver products have revolutionized the consumer market in various areas of applications to meet the upstream evolution. Notably, in personal tracking, the emergence of machine to machine (M2M) Radionova M10478-A3 integrated full receiver and multi-GNSS antenna module has been designed to receive Galileo + GPS + GLONASS + BeiDou + QZSS, and satellite-based augmentation systems (SBAS) signals [4]. Further, with a patented external matching technique, the module is suitable to application from wearable technology to smartphones and asset trackers. While in wireless and location base services, several software solutions to implement satellite navigation functionalities, upgrade to future satellite systems, and designed to deliver a seamless GNSS experience in hostile environment, have appeared on the global scene. Consider the software based GNSS receiver from Galileo Satellite Navigation (GSN) available on Tensilica ConnX digital signal processor (DSP) core for implementation of wireless mobile applications—it runs on a Cadence ConnX BBE16 DSP, consumes as little as 10mW on a 40-nm process, and delivers high-sensitivity tracking, for ultra-low-power mobile scenarios at low cost of deployment [5]. On the other hand, the u-blox Galileo-ready NEO-M8 chip has added impetus to the consumer OEM horizon, for optimized cost-sensitive applications in automotive industry. The NEO-M8 series have been designed to offer high sensitivity within minimal acquisition time, maximum performance based upon a sophisticated RF-architecture in harsh GNSS environment, and an internal Flash that allows simple upgrades to additional GNSS systems [6].

Likewise, the Global Positioning System (GPS) constellation in ‘Expandable 24’ is a composition of 8 Block IIA satellites, 12 Block IIRs, 7 Block IIR-Ms and 4 Block IIFs. The IIF generation would form the backbone of the GPS constellation configuration for the next 15 years, with greater navigational accuracy from improvements in atomic clock technology, the new and robust third civil signal, L5 (for commercial aviation and safety-of-life applications), and a second civil signal, L2C (for the dual-frequency GPS receivers by means of improved anti-jam capabilities), for military and civil users around the world. In addition to the sustainability of the constellation, GPS civil users would have access to the L2C and L5 signals that broadcast the civil navigation message (CNAV) [7]. Meanwhile, the late broadcast of the CNAV messages on L2C and L5 were alluded to additional time for the schedules of assessments and verification prior to activation. Though, the initial broadcast would meet GPS Standard Performance of Standard Positioning Services (SPS) standards, maximum level of accuracies would not be achieved, until full implementation. However, current location technologies have driven GPS and GPS-enabled technologies to a peak of interoperability with Galileo, GLONASS, and BeiDou/Compass, to achieve a multi-constellation fix mode of higher reliability and accuracy, especially in urban canyons (where tall buildings reduces or reflect line-of-sight (LOS) signals) compared to GPS alone. More than that, the epic of the voyage of the evolution have transited to ubiquitous indoor positioning system (IPS) and LBS— owed to indoor and outdoor hybrid positioning technologies and emerging sensor fusion currently exploited in mobile devices and smartphones. A hybrid technology fuses signal measurement from cellular, Wi-Fi and Bluetooth network signal with data delivered by integrated inertial sensors in mobile devices such as accelerometers, gyroscopes, compasses, magnetometers, barometric height sensors and altimeters [8],[9]. The big impacts of the hybridization were evident in the volume shipment of smartphones, assisted GPS (A-GPS) and A-GNSS chipsets (A-GLONASS is at the horizon), and developments in Wi-Fi connectivity of embedded and near field communication (NFC) systems. These have enabled GPS/GNSS product at large to reposition its leadership in a technology-centered driven toward M2M and the Internet of Things (IoT). Unquestionably, the Industrial IoT (also known as Industrial Internet and Industry 4.0) market grew in 2013 to $181.29 billion, and is projected to $319.62 billion on a CAGR of 8.15% from 2014 to 2020[10]. This new era of economic growth and competitive edge have seen annual revenues of A-GPS servers, passive location platforms, and middleware for GPS/GNSS indoor positioning deployed by mobile operators on trajectory of €14.2 million p.a., from €190 million in 2012 to reach €275 million in 2018, worldwide. Even so, the growing concerns of GPS community to continuous vulnerability of GPS signals to interferences, jamming potentials and spoofing attacks remain unabated (the LightSquared L-Band scenario), neither have the emerging hybrid solutions been augmented unto a common platform or standard; the evolution and implementation of the hybrid positioning technology solutions were still very fragmented and proprietary.

However, BeiDou/Compass and GLONASS by China and Russia respectively have opened up services for global availability at an acceptable reliability and accuracy levels to users. The BeiDou Navigation Satellite System (BDS) is a constellation of five (5) geostationary orbit (GEO) satellites, 27 medium Earth orbit (MEO) satellites with mean period of 12.89 hours, and five inclined geosynchronous orbit (IGSO) satellites inclined at angles 55°, intended for China, Asia-Pacific and global users[11]. By 2020, approximately 40 satellites were expected to have been launched into orbits with improved and enhanced performance over present configuration: Carrier-phase differential accuracy of about 3cm, timing accuracy of 50ns, and single-frequency horizontal, vertical and 3D positioning accuracy of 10, 10, and 14m, respectively. For a constellation with an inception since 1980, the role of BDS to satellite navigation and LBS in

China is estimated to be $13.2 billion in 2012, an equivalent of 8% of the global sector. Moreover, at the end of first quarter of 2014, more than 2 million BDS chips had been sold in China, with over 300,000 vehicles equipped with BDS, and about 20 domestic brands in BDS-related car navigation, beside consumer products (Samsung Galaxy note 3 tablets and Huawei smartphone B199). Conversely, extensive efforts were directed toward GLONASS expansion and sustainment, in spite of signal outages and disruptions (April 2014), by development of new generation of GLONASS-M satellites planned for launch between 2014 and 2015. The new navigation satellite GLONASS-M series would provide navigation services for user with frequency-division multiple access (FDMA) on L1 and L2 signals, and code-division multiple-access (CDMA) on L1(1602MHz), L2(1246MHz) and L3(1202MHz) signals. In addition to the current 24 healthy satellites, a budget of $38 million had been made available in year 2014 to finance the production of GLONASS-K1 navigation satellites. By 2020, 25 more GLONASS satellites are planned: These include 11 GLONASS-M, 10 GLONASS-K1, and 4 GLONASS K2 [12]. Recently, the BDS ICD for the Open Service Signal was released (December 2014), with a new signal B2I signal defined on 1207.140MHz. Hence, BeiDou impulsions toward multi-constellation and hardware developments of integrated radiofrequency (RF) front-end receivers is a step from reality. Early application of such developments is underscored by the new quad-constellation Teseo-3 receiver which featured an RF front-end integrated with digital silicon and flash memory, that enables simultaneous reception of Galileo, GPS, GLONASS and BeiDou signals. By 2020, four (4) global constellations would be on the same band, over 100 satellites would be made available, and with a clear sky, about 30-40 satellites simultaneously could be tracked using multi-frequency receivers. At that point, the concept of ‘any four’—any four satellites from different constellations—would be a heuristic multi-system on the verge of global realization.

Beyond that, the Indian Space Research Organization (ISRO) launched the IRNSS-1C, the third satellite out of the 7 IRNSS satellites on October 16, 2014. The independent regional navigation satellite system (IRNSS) system would consist of 3 GEO and 4 IGSO satellites. The ISRO released the version 1 of IRNSS Signal in Space (SIS) ICD for the Standard Positioning Signal Service in September 2014. The released document—which summarized the IRNSS signal structures, modulation techniques, frequency bands, power levels and data structures and their interpretations, and user algorithms— facilitated research and development (R&D) and aided the commercial use of the IRNSS signals for navigation-based applications. The IRNSS would provide two type of services—the Standard Positioning Services (SPS) to all users and Restricted Services (RS) to authorized users from about 15 or more ground stations [13]. It is expected to provide a position accuracy of about 20m in the primary service area. The entire IRNSS constellation is planned for completion in the year 2015. Table 1 showed a succinct overview of the GNSS spectrum.

II. GNSS, GLOBAL POSITIONING SYSTEM AND WSNS: SIGNALS, MEASUREMENTS AND PERFORMANCES

Prediction and estimation of navigational signal descriptors are necessary, especially as satellites signals become unreliable or noisy. Therefore, variations of position signals are functions of satellite signal strengths. In addition, high quality, position data—devoid of noise—must have sufficient SNR. The spatial data analysis offers a number of possible interpretations especially with regards to atmospheric propagation and environmental effects. In GNSS applications, signal delays, multipath anomalies, and drifts are daily occurrences, which necessitated accurate representation of reference positions over time. In addition to extreme climatic conditions and loss of satellite coverage, the drifts and errors are attributed mainly to tropospheric delays and ionospheric signal refractions. Figures 2 and 3 illustrated the stochastic error model and the satellite geometry models of a typical GPS base station ensembles with coordinates: 7.5319ºN, 4.5393ºE at altitude 281.2594m above mean sea level (MSL) [14].

Recently, however, odd twists in the global economy have stimulated Earth observation science toward economical satellites for environmental monitoring and greenhouse gas mitigation, monitored power plants with carbon capture storage (CSS), resolved complex mission operations, and initiated cost-effective climate modelling. Of course, the GPS industry had matured alongside these developments with emphases on avionics, transportation, wireless communication and location-based services, in conjunction with integrated GPS/GNSS-related technologies for numerical weather prediction (NWP), global circulation models (GCM) and climate modelling—by means of application specific integrated micro-instruments (ASIMs). Obviously, developments in GNSS: Galileo, GPS, GLONASS, and currently BeiDou and associated satellite based augmentation systems (SBAS), should develop unique combinations of high-resolution sensors to meet the measurement requisite. These sensors were expected to operate at various wavelengths to measure the global natural change and anthropogenic impacts, and consequences of fluxes (heat, radiation, geochemical eruptions, ozone depletions, volcanic plumes etc.). However, the challenges of faster response time (< 5min.), high repetition rate (< 15min.), and improved spatial resolution (< 15m); the difficulty of modelling uncertain and potentially time-changing environmental correlations, using available remote sensing satellites, are ongoing researches. Future trends revealed in the climate change key indicators—rising sea level, increasing carbon dioxide (CO_2) concentration, global surface temperature, melting land and arctic sea ice—have disclosed alarming global warming scenarios. Comprehensively, the current key indicators: increasing levels of CO_2 concentration (399.73ppm), rising sea levels

(3.18 mm per year), widespread melting rates of land (258 billion tons per year) and arctic sea ice (decline of 13.3% per decade), and progressive increases in global temperature (1.4°F average temperature since 1880) are deterministic factors, in earth observation time series, that corroborated the scientific theory of greenhouse effects [15]-[17] (See Table 2).

Consequently, observations of earth atmosphere, investigation of global circulation models, and climate change scenarios were typical reflections of historical data acquired by satellites over time via remote sensing techniques. As instances, BIRD (Bi-spectral InfraRed Detection) satellites have established the feasibility studies of pattern recognition and quantitative characterization of terrestrial High Temperature Events (HTE) since 2001. The SPOT/LANDSAT were high-resolution satellites whose multispectral panchromatic images were in the optical wavelength range for real-time monitoring of flood, tropical cyclones, and storms. The El Nino phenomena were detected with scatterometers (microwave sensors) in ERS satellite series; and as part of disaster alert systems, ERS Synthetic Aperture Radar (SAR) instruments are active monitors in evaluation of precursor models of earthquake prediction, volcanic activities, and geo-chemical eruptions. Further, the ENVISAT satellites (2002) assessed environmental pollution situations and future protection measures. The ENVISAT sensors include: An Advanced Synthetic Aperture Radar (ASAR), operating at C band, the wave mode of the ERS-1/2 AMI (active microwave sensor) and, a radar altimeter 2 (RA-2). The ASAR ensured continuity with the image mode (SAR), while the RA-2 is for determining the two-way delay of the radar echoes from the surface of the Earth to a very high precision (less than a nanosecond). Other notable sensors include: the microwave radiometer (MWR)—for detection of the integrated atmospheric water vapor column and cloud liquid water content, as correction terms for the radar altimeter signal, and the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS)—a Fourier transform spectrometer for the measurement of high-resolution gaseous emission spectra in the troposphere and stratosphere. Moreover, global Earth observation satellite (EOS) inventory revealed SPOT 4 and 5 satellite series—launched between 1998 and 2002—which were equipped with high-resolution geometrical (HRG), high-resolution visible (HRV) and its modification high-resolution visible infrared (HRVIR) instruments for geological reconnaissance, vegetation surveys, and surveys of snow cover. In addition, the LANDSAT 5 and 7 ETM+, launched between 1984 and 1999, featured thematic mapper (TM), multispectral scanner (MSS), and enhanced thematic mapper plus (ETM+), designed to observe the surface of the Earth in 7-8 bands—from visible to infrared region—with about 400GB solid state recorder (SSR) for bathymetric mapping along coastal areas, soil-vegetation differentiation, and characterizing forest types [18].

TABLE 1. THE OVERVIEW OF THE GNSS SPECTRUM

Constellation Type	No. of Healthy Satellites	Full Operational Capability (FOC)	Comments
Galileo **E1(1575.42MHz)** **E5a(1176.45MHz)** **E5b(1207.14MHz)** **E6(1278.75MHz)**	**4**	**30**	Galileo is a joint initiative of the European Commission (EC) and the European Space Agency (ESA). The Galileo System Test Bed (GSTB) V2/A satellite, or Galileo In-Orbit Validation Element-A (GIOVE-A) and GSTB V2/B or GIOVE-B were decommissioned on June 30, 2012. Galileo begun transmission of valid navigational messages on January 17, 2013, and the system underwent an upgrade between September 11 and October 17, 2013.
GPS **L1(1575.42MHz))** **L2(1227.6MHz)** **L5(1176.45MHz**	**31**	**31**	The current active GPS constellation consists of 8 Block IIA satellites, 12 Block IIRs, 7 Block IIR-Ms, and 4 Block with 5 reserves. The GPS constellation is in the 24+3 (or “Expandable 24”) configuration. Antispoofing (AS) was activated on all Block II satellites on January 31, 1994.
GLONASS **L1(1602MHz)** **L2 (1246MHz)** **L3(1207.14MHz)**	**24**	**-**	The current consists of 23 GLONASS-M satellites, and 1 GLONASS-K1 satellite. The last successful GLONASS launch was on April 26, 2013. GLONASS channel allocations were introduced September 1993 to reduce interference to radio astronomy.
BDS **B1(1561.098MHz)** **B2(1207.14MHz)**	**14**	**37**	BeiDou Navigation Satellite System (BDS or simply BeiDou, known formerly as Compass) started the initial constellation of 4 geostationary Earth orbit (GEO) satellites between 2003 and 2007. The FOC would include 5 GEO satellites, 27 medium Earth orbit (MEO) satellites, and 5 inclined geosynchronous orbit (IGSO) satellites. The constellation was declared operational for use in China and surrounding regions on December 27, 2011 and would provide global coverage by 2020. The BDS ICD for the Open Service Signal released on December 2014 has defined the B2I signal on 1207.140 MHz.
IRNSS **L5(1176.45MHz)** **S(2492.028MHz)**	**3**	**7**	The last IGSO satellite on test transmission, IRNSS-1C, was launched from the Satish Dhawan Space Centre on October 16, 2014. IRNSS constellation would consist of 3 GEO satellites located at 34°E, 83°E, and 131.5°E, 2 pairs of IGSO satellites with nodes at longitudes of 55°E and 111.5°E with an orbital inclination of 29°.

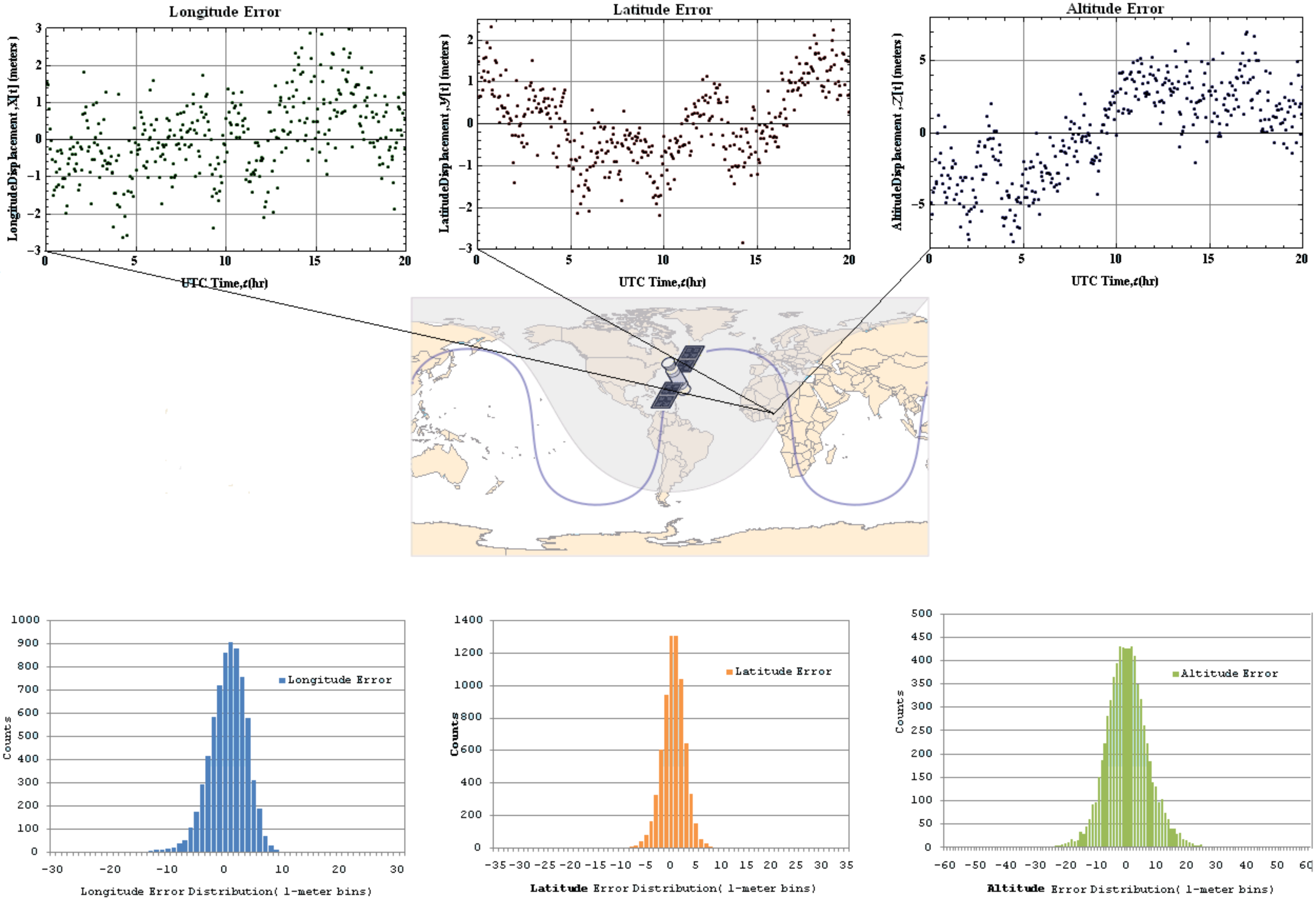


Fig. 2. The stochastic error model of GPS ensembles at 7.5319° N, 4.5393° E and altitude 281.2594m.

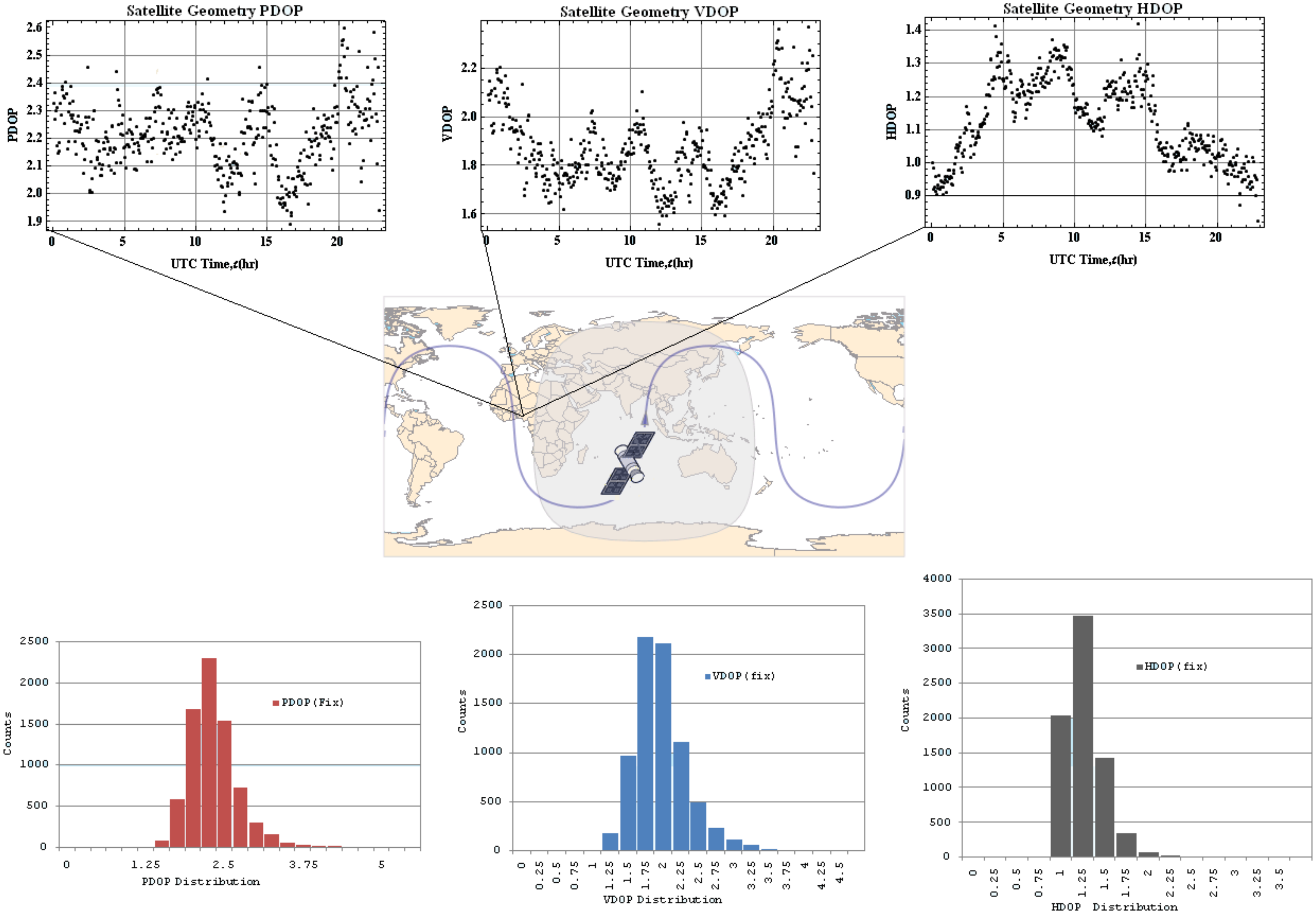
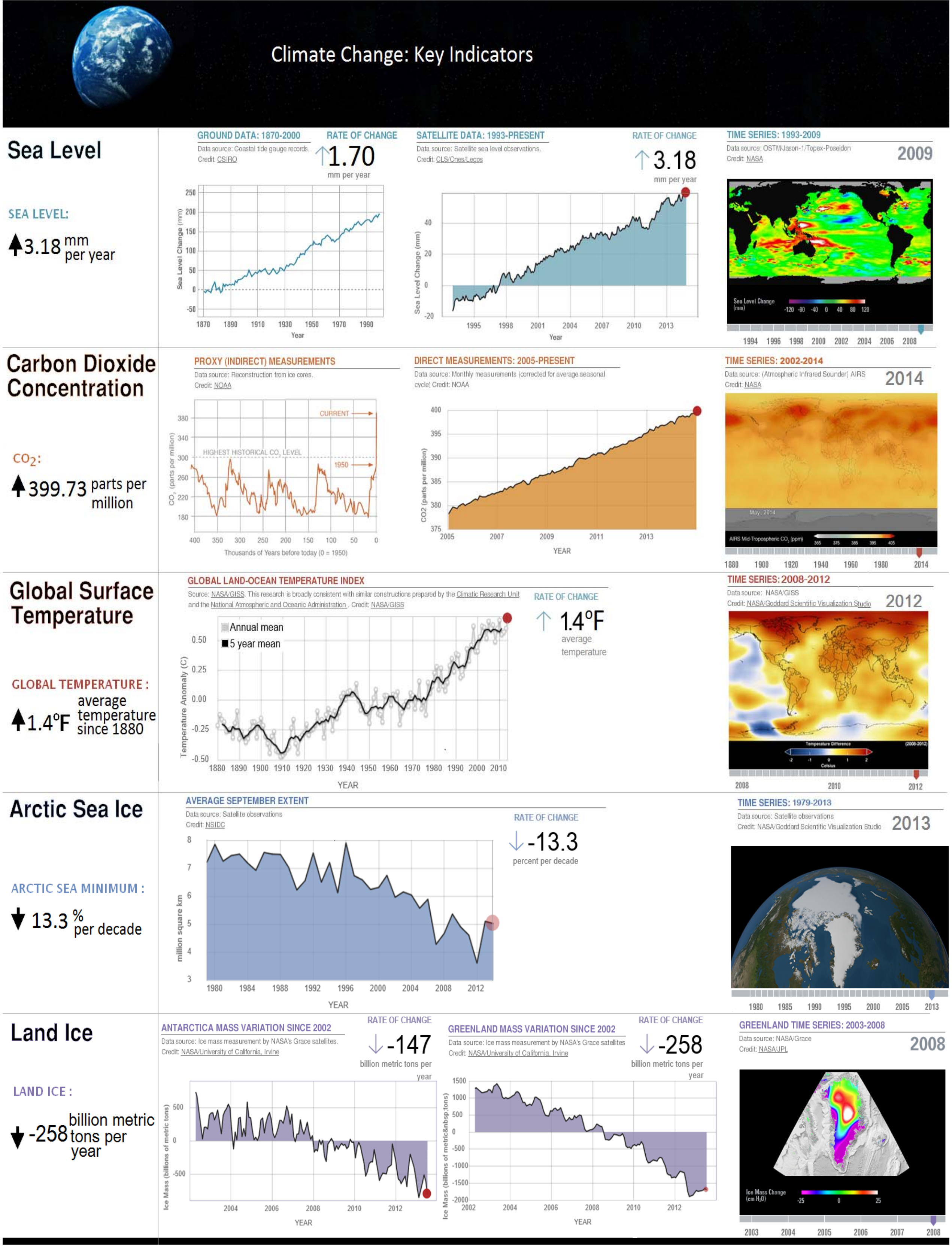


Fig. 3. The stochastic error model of GPS satellite geometry ensembles at 7.5319°N, 4.5393°E and altitude 281.2594m.

TABLE 2. EARTH OBSERVATION AND TIME SERIES ENSEMBLES: THE CLIMATE CHANGE KEY INDICATORS AND CLIMATE VARIABILITY PROJECTIONS (SOURCE: NASA)



Climate Change: Key Indicators

Sea Level

SEA LEVEL: ↑3.18 mm per year

GROUND DATA: 1870-2000 — RATE OF CHANGE ↑1.70 mm per year

Data source: Coastal tide gauge records. Credit: CSIRO

SATELLITE DATA: 1993-PRESENT — RATE OF CHANGE ↑3.18 mm per year

Data source: Satellite sea level observations. Credit: CLS/Cnes/Legos

TIME SERIES: 1993-2009 — 2009

Data source: OSTM/Jason-1/Topex-Poseidon. Credit: NASA

Carbon Dioxide Concentration

CO_2: ↑399.73 parts per million

PROXY (INDIRECT) MEASUREMENTS

Data source: Reconstruction from ice cores. Credit: NOAA

DIRECT MEASUREMENTS: 2005-PRESENT

Data source: Monthly measurements (corrected for average seasonal cycle) Credit: NOAA

TIME SERIES: 2002-2014 — 2014

Data source: (Atmospheric Infrared Sounder) AIRS. Credit: NASA

Global Surface Temperature

GLOBAL TEMPERATURE: ↑1.4°F average temperature since 1880

GLOBAL LAND-OCEAN TEMPERATURE INDEX

Source: NASA/GISS. This research is broadly consistent with similar constructions prepared by the Climatic Research Unit and the National Atmospheric and Oceanic Administration. Credit: NASA/GISS

RATE OF CHANGE ↑1.4°F average temperature

TIME SERIES: 2008-2012 — 2012

Data source: NASA/GISS. Credit: NASA/Goddard Scientific Visualization Studio

Arctic Sea Ice

ARCTIC SEA MINIMUM: ↓13.3 % per decade

AVERAGE SEPTEMBER EXTENT

Data source: Satellite observations. Credit: NSIDC

RATE OF CHANGE ↓-13.3 percent per decade

TIME SERIES: 1979-2013 — 2013

Data source: Satellite observations. Credit: NASA/Goddard Scientific Visualization Studio

Land Ice

LAND ICE: ↓-258 billion metric tons per year

ANTARCTICA MASS VARIATION SINCE 2002 — RATE OF CHANGE ↓-147 billion metric tons per year

Data source: Ice mass measurement by NASA's Grace satellites. Credit: NASA/University of California, Irvine

GREENLAND MASS VARIATION SINCE 2002 — RATE OF CHANGE ↓-258 billion metric tons per year

Data source: Ice mass measurement by NASA's Grace satellites. Credit: NASA/University of California, Irvine

GREENLAND TIME SERIES: 2003-2008 — 2008

Data source: NASA/Grace. Credit: NASA/JPL

In 2008, the PSInSAR (Permanent Scatterer Interferometric SAR) technique was exploited in the detection of CO_2 plume or flux estimations around gas wells and in subsurface reservoirs at In Salah gas development CO_2 storage sites. The time-lapse inversion satellite data—observations from remote SAR systems(ALOS PALSAR, JERS-1 SAR, ERS1/2 AMI, ENVISAT ASAR and Radarsat SAR), were utilized for mapping of surface deformation[19],[20]. These results demonstrated compelling evidences of the applicability of GNSS to global climate change issues. To that end, several international EOS missions by CNES, ESA, EUMETSAT, NASA, NOAA—Aura, Aqua, Grace, Ocean Surface Topography Mission (OSTM)/Jason-2, Jason-1, Terra and Topex/Poseidon—were joint mission efforts and collaborations that have continuously investigated key climate parameters and atmospheric phenomena. Additionally, FORMOSAT-3/COSMIC (Taiwan/USA), METOSAT MTG (EU), and RESOURCESAT-2 (India), were remote sensing satellites from international collaborations—developed to revolutionize weather predictions, environmental monitoring, ionospheric and meteorological researches. However, the weather and climate-related satellite data, images delivered and methods utilized were without deficiencies or monumental failures.

III. INTEROPERABILITY AND INTERCHANGEABILITY OF WSNS: DIVERGENCE OR SUBMISSION OF BUSINESS MODELS?

The GPS/GLONASS receivers in comparison with GPS-only receiver have featured many benefits (see Figure 4). This ranges from availability of more active satellites, to the issues of signal availability in urban canyon environment. Moreover, the varieties of advanced techniques in signal processing techniques have offered a significant improvement in the availability of position solutions when GLONASS was added. The result is termed GNSS interoperability. GNSS interoperability is synonymous to the concept of “interchangeability” which suggest a wider mix of common attributes, common code families, common navigation data format, and common geodetic and time reference systems. GNSS compatibility practically means the prevention of harmful interferences with the use of individual services. Notably, every navigation signal ‘leaks’ into adjacent signals in the same band. This is as result of spreading symbol and transmission bandwidth of a GNSS system upon reception in a GNSS receiver. Consider the case of GALILEO signals which are clearly overlapped by the main lobes of GLONASS on L1. However, such interferences are regulated and managed by the ITU. Clearly, it is understood that compatibility is a fragment of the key elements to ensure interoperability between the Regional Navigation Satellite Systems (RNSS). To that end, the availability of satellites from a multi-constellation would not only be an outstanding issue, but also the biases (of receiver RF and space satellite intersystem) due to interoperability. Another significant challenge would be the integration of the front-end with assistance data (Wi-Fi and Bluetooth) and inertial navigation system (INS) sensors for indoor location that requires the third generation partnership project (3GPPP) infrastructure standard. The eventuality of a multi-system GNSS would be the capacity of enhanced compatibility of satellites.

Yet, several objections and modifications are still under review by the International Committee on Global Navigation Satellite Systems (ICG) Working Group on Compatibility and Interoperability. For instance, in November 2013, the WG-A deliberated on further actions on the comparative identification of parameters and open service performance templates by System Providers [21]. Invariably, this translate into the fact that a combination of measurements from different satellite systems would propagate errors into the CNAV messages. A case in point: The GPS is referenced to coordinated universal time UTC (USNO), Galileo to UTC (INRIM), GLONASS to UTC (SU), Beidou to UTC (NTSC), and QZSS is referenced to UTC (NICT). The side effects are collectively termed the satellite intersystem biases—due to different constellation master clocks referenced to different realizations of UTC. Evidently, the GLONASS UTC (SU) differs from other realizations by 3 hours and to circumvent the time-induced intersystem biases, the time offsets must be resolved. Apart from this, the compatibility Subgroup recognized the concerns on the protection of RNSS spectrum from potential harmonic interferences (1300-1400, 1518-1559, and the 1610-1660.5MHz bands). Therefore, mitigation of non-RNSS emissions into the RNSS spectrum must be emphasized, such that the benefits of interoperability might not be overshadowed by reduced performance.

Then, too, consider the dispute over divergences of the concepts of interchangeability and interoperability that must be brought to the fore on commercial implementations. In this, privacy concerns, understandings of interferences and perceptions of jamming potentials to must be redefined on the altar of collaborative efforts and future integrations of satellite system. In addition, submissions to the goal of a seamless global coverage is centered on open service information sharing and active service performance monitoring. To scoff at the idea of spectrum protection at the moment seem unimaginable, however, the grasp of interoperability presentations are predicated on the integrity of data tracking and acquisition across adjacent multiple bands. The endpoint, of course, would be an accurate and reliable GNSS receiver front-end based upon signal interchangeability, to establish positions both in indoor and open sky scenarios.

To achieve a seamless transition, therefore, from outdoor to an indoor event, the field of extremals of the WSNs should not be restricted to weak variations. The availability of positioning signals (urban canyon or extreme hostile

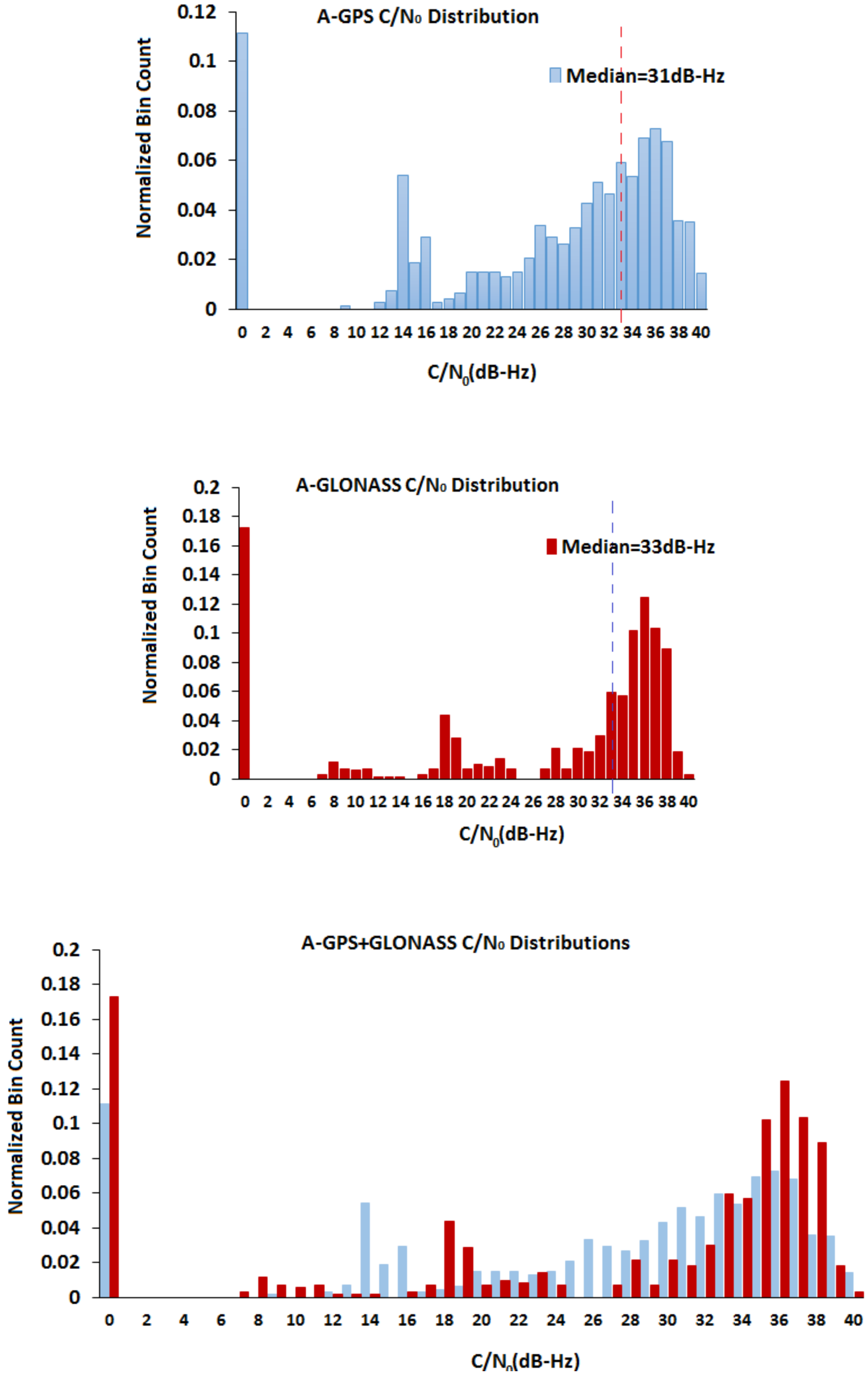


Fig. 4. The cumulative histograms of C/N$_0$ of A-GPS, A-GLONASS and A-GPS+GLONASS acquired at 7° 31’ 11.3’ ’ N, 4° 31’ 16’ ’ E.

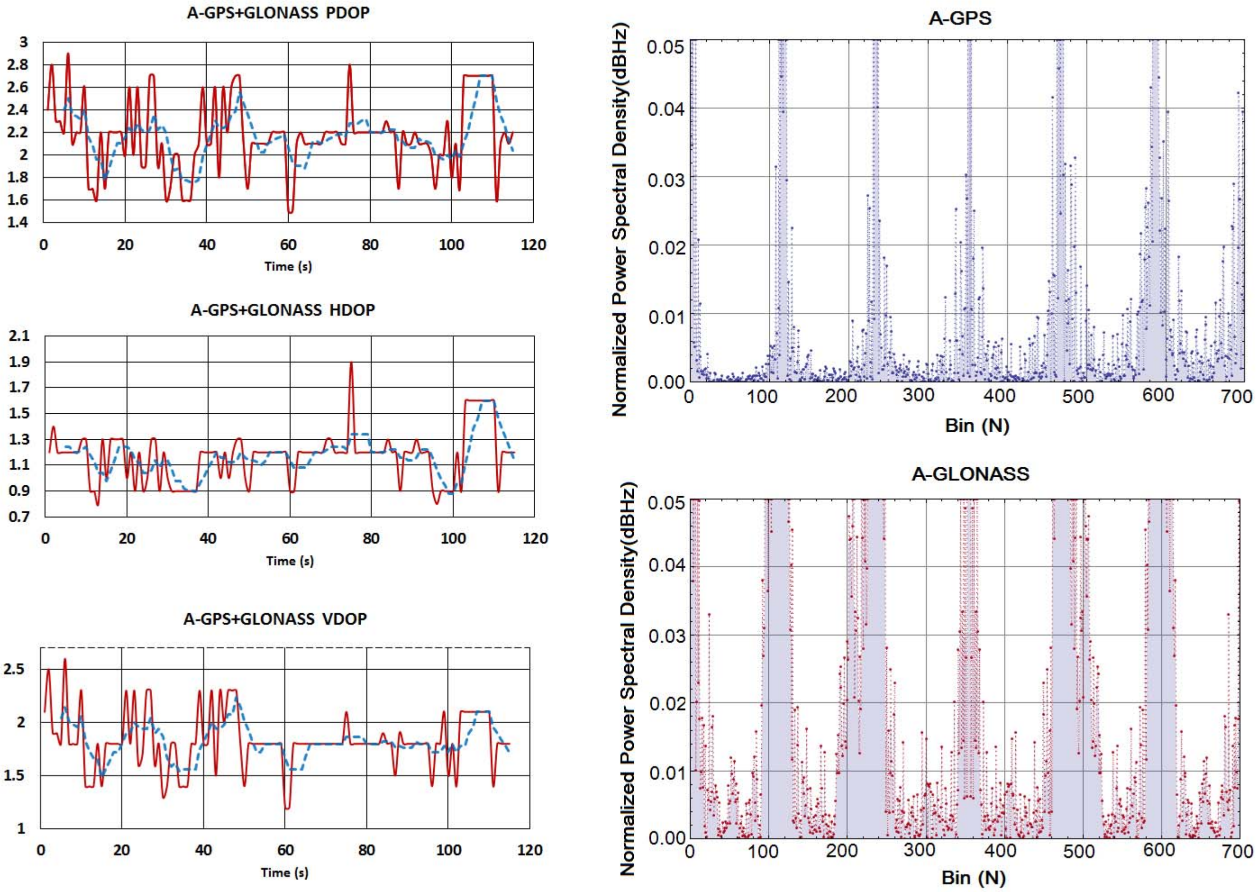


Fig.5. The spectral analyses of the A-GPS+GLONASS observables and the satellite geometry (PDOP, HDOP and VDOP) of the outdoor position location at 7° 31'11.3''N, 4° 31'16''E

environment), could transit piecewise differentially along minimized curve (admissible function), given sufficient conditions of the scenario. Consider Figure 5 that illustrated the satellite geometry (DOPs) measurements and the spectral analysis of the A-GPS+GLONASS observables at the position location 7° 31' 11.3''N, 4°31'16.0''E in open sky surrounded by 3-floor buildings. The NMEA data recorded a coverage of 12 GPS and 6 GLONASS satellite with a mask angle of about 13° within the period of data acquisition. Further, the DOP trends substantiated the levels of accuracy: The PDOP ranged from 1.4 to 3.0 within a period of about 120s, the HDOP between 0.7 and 1.5, and the VDOP 1 and 2.5. The A-GPS normalized spectral density confirmed the transmission pattern of $154f_0$ on the L1 band, where f_0 is the common frequency 10.23MHz, while the A-GLONASS normalized spectral density suggested the transmission pattern of $120f_0$ on the G3 band. Further, the transition into the indoor scenario of the topmost floor is shown in Figure 6. The NMEA data recorded, from a coverage of 13 GPS and 7 GLONASS, wide transient variations of DOPs: The PDOP rescinded from 1.4 to 7.0 in about 40s and achieved stability over the 100s, the HDOP similarly dropped from 0.8 to 3.4 over the same time, while VDOP lowered from 1.5 to 7. The smudge in the spectral components of the A-GPS and A-GLONASS spectrum were evidently attributed to the loss of coverage from transition. Hence, it is imperative that GNSS error estimations and measurements are utilized in the predictions of local accuracies to appreciably correlate international standards and measurements, especially in tropical environment. In long-term evolution, methods such as Observed Time Difference of Arrival (OTDOA)—an advanced cellular positioning technology—should be improved to augment A-GNSS to provide a more accurate location fix.

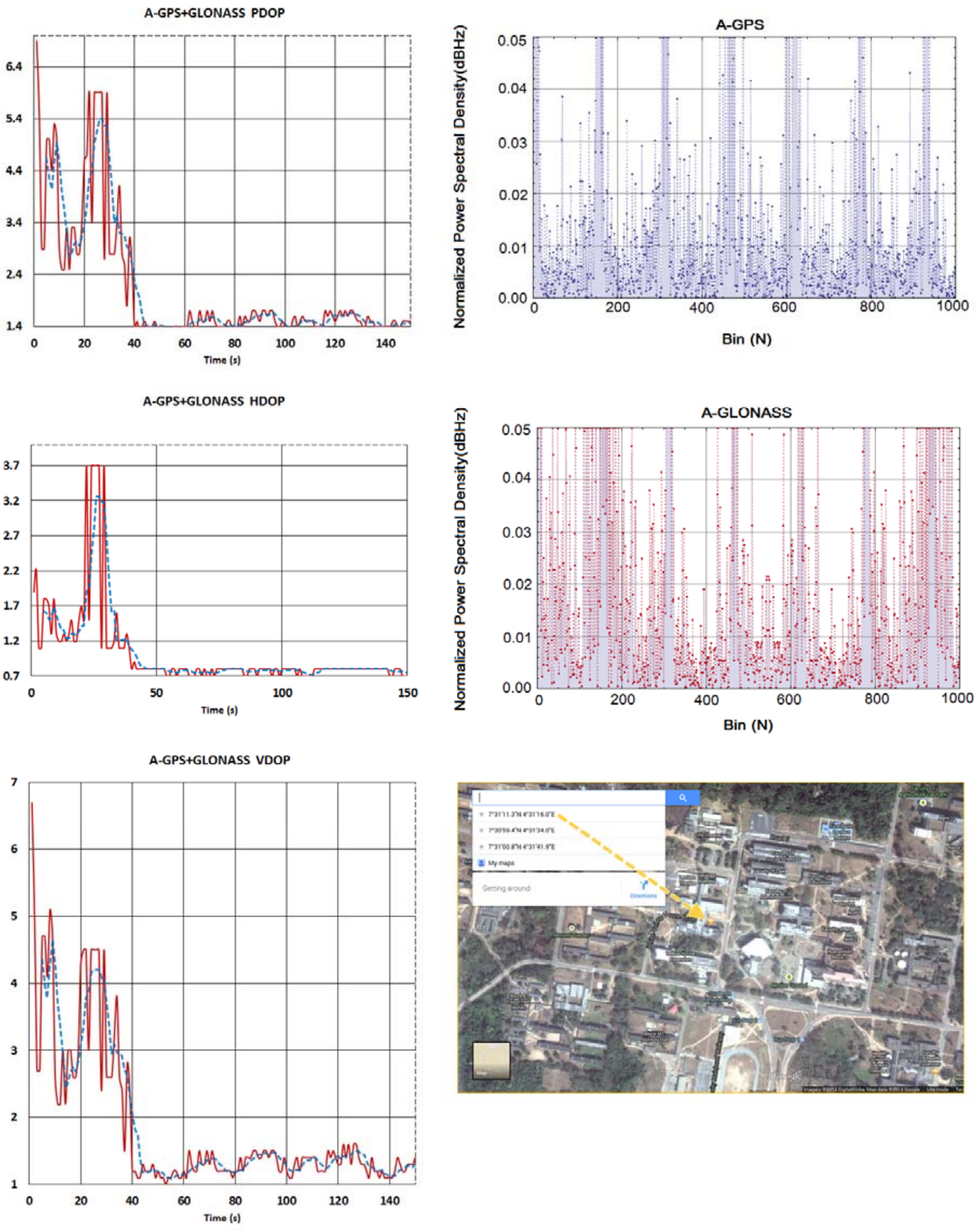


Fig.6. The spectral analyses of the A-GPS+GLONASS observables and the satellite geometry (PDOP, HDOP and VDOP) of the indoor position location at the proximity of 7° 31'11.6''N, 4° 31'16''E

IV. THE FUTURES OF GLOBAL WIRELESS TECHNOLOGY: THE STRANGE ATTRACTORS

As it is, the current GNSS is not immune to interferences, vulnerabilities and failures. The worst case scenarios portend fragmentation in global wireless world over common standard platforms, receiver technologies, and yet-to-be integrated satellite navigation systems. These challenges would dictate to a large degree the pace of techno-economic growths of indoor WSNs toward seamless integration of data networks, to meet various developments and consumer demands. However, the optimistic overview of global WSNs present the compact pictures of reshaped limits of the socio-economic impacts of positioning devices. The outreach stretches from the development of mobile apps, smartphone visualization of real-time project, management of information, enhanced capabilities of alerts (to warn users of potential outages), toward research and developments of possibilities of low-power, low-cost, multi-band, GNSS monolithic chip fabrication. Of course, the RF front-end frequency plan of future receivers would tackle tasks of wideband signal processing, which offers robustness and mitigation of ionospheric biases. Nonetheless, whatever grim stance the interoperability and interchangeability of GNSS signal might bring on the horizon of sustainable management of global wireless technology, the turns of the strange attractors reveals *ad infinitum* an upward spiral of innovations and amalgamation of insights of technologies, into a new age of modernized global wireless navigation systems.

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