GNSS for Practical Applications, Science, Capacity Building, and Training

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Outline

• Augmentation Systems
• Science applications
• Capacity building
• Training activities and science conferences
• Summary

Augmentation Systems

*Systems that aid GPS by providing improvements that are not part of GPS*

- NDGPS Network
- IGS Network
- U.S. CORS Network
- FAA WAAS System
- Japan’s Geonet
- GDGPS
- Other SBAS systems
  - EGNOS, MSAS, GAGAN
- NOAA operation TEC product
- EUREF
Assimilation of COSMIC-I and -II GNSS Radio Occultation and ground-based GNSS data into NA-TEC and GLO-TEC

NA-TEC
- NOAA’s operational product
- 15-minute cadence, 15 to 30 minute latency, 2-3 TEC unit accuracy (~34-48cm delay at L1 frequencies)
- Target users: Positioning and Navigation Community

In support of NOAA operational products
Scientific Exploration with GNSS

- Biology
- Archeology
- Seismic monitoring
- Tsunami studies
- Ozone layer monitoring
- Climate change
- Gravity fields
- Atmospheric science
  - ground water
  - precipitable water vapor
  - the ionosphere
  - space weather

All using GPS data...
The Low Latitude Ionospheric Sensor Network (LISN)

LISN GPS Network

- To address key questions about the physics of the equatorial ionosphere
- Develop nowcast/forecasts capabilities on the onset of Spread F

- 50+ GPS Receivers
  - TEC, Depletions, TIE
  - Scintillation (~30)

- 5 Ionosondes
  - Virtual height
  - Bottomside density profiles
  - Meridional winds
  - Nighttime capability

- 5 Magnetometers
  - Monitor ionospheric currents
  - Measure Vertical plasma drifts
The Low Latitude Ionospheric Sensor Network (LISN)

LISN GPS Network

Development and Decay of the Equatorial Anomaly
Two channels of high TEC formed over the Americas on August 3, 2010, during a magnetic storm.

High TEC over Central America

![Map of TEC over the Americas on August 3, 2010](image-url)
Ionospheric Storm Studies

Figure courtesy of E. Yizengaw, BC
Ionospheric Monitors in Africa

- Magnetometers (MAGDAS, AMBER/SAMBA)
- >50 units of GPS - IGS, SCINDA, BC/ICTP, ESA
- Many other regional networks

Additional monitors planned:

- VIPIR Ionosondes in Addis Ababa, Ethiopia and Maseno, Kenya (2013 completion anticipated)
- GPS (with new L5 signals)

Data obtained from these facilities are being used to improve our understanding of global space weather as it affects the performance of GNSS.
Overall climatologies agree.
Most activity where magnetic field aligns with the solar terminator.
EPBs outside the bands – especially in May-Aug months. - a curious result
Studies like this not possible without GPS!
Africa’s Science and Technology Plan of Action (1) clearly states Africa’s commitment to develop and use science and technology for socio-economic transformation and full integration into the world economy.

Global Navigation Satellite Systems (GNSS) are a space technology that can address some of these problems and help meet Africa’s goals.

Numerous fields of scientific study: Space weather, geophysics, geography, geology, ecology, biology and more.

IHY/ISWI Instrument Sites

IHY (2007-2008) – to understand planetary environments
ISWI (2009 – present), focuses on space weather
Meet their goals through instrument deployment, data analysis, modeling, education and outreach

Courtesy, Joe Davila and Nat Gopalswamy
IHY/ISWI Instrument Sites

Scientists from developing and developed nations work together
Students and faculty participate at all levels of the instrument project and science
Data gaps closed due to deployment in crucial locations
Heavy focus on Africa, with added schools and workshops

Courtesy, Joe Davila and Nat Gopalswamy
IHY/ISWI Meetings & Schools

2007: IHY/SCINDA Africa Workshop, Addis Ababa, Ethiopia
2009: IHY/SCINDA Africa Workshop, Livingstone, Zambia

2010: First UN/ESA/NASA/JAXA Workshop on ISWI, Helwan, Egypt

2011: Rabat, Morocco; Kinshasa, Democratic Republic of the Congo; Lagos, Nigeria
      ISWI UN/Nigeria Workshop on ISWI, Abuja, Nigeria

2012: AGU Chapman Conference on Space Weather held in Ethiopia
      ISWI/MAGDAS School on Space Science, Bandung, Indonesia
      UN/Ecuador Workshop on ISWI, Quito, Ecuador

2013: MAGDAS School, Abidjan, Cote d’Ivoire
      ISWI/SCOSTEP School, Nairobi, Kenya
      School for Young Astronomers, Jatinangor, Indonesia
      First ISWI School of Maghreb, Bab Ezzouar, Algeria

2014: SCOSTEP/ISWI International School on Space Science, Lima, Peru

2015: Space Weather School in Maghreb, Rabaat, Morocco
      UN/Japan Workshop on Space Weather, Fukuoka, Japan
AGU CHAPMAN CONFERENCE ON LONGITUDE AND HEMISPHERIC DEPENDANCE OF SPACE WEATHER

12-16, NOVEMBER 2012
ECA HALL, ADDIS ABABA
Many opportunities for training  
(just to name a few)

International School on equatorial and low latitude ionosphere – Abuja, Nigeria (14-18 September 2015)

ESA/JRC GNSS School, Barcelona, Spain (31 Aug – 10 Sept, 2015)

International Centre for Theoretical Physics/Boston College schools – GNSS for Scientific Exploration - 6 programs to date

Many other ISWI, ICTP/BC related regional workshops
ICTP and BC

1 Workshop held in Rwanda 2014

Original Goals:
– Provide GNSS education at the university level
– Build a knowledgeable GNSS African workforce
– Encourage the use of GNSS for societal and economic development
– Build GNSS infrastructure
– Establish space weather studies in Africa
– Establish international scientific collaborations

More Recent Goals: Focused on specific applications, hands on training
ICTP-BC Workshop – March 2015

Workshop on Ionospheric Effects on SBAS and GBAS Applications at Low Latitudes + International SBAS IONO Meeting
2 - 13 March 2015
Miramare - Trieste, Italy
5th Workshop – 2014 Kigali, Rwanda
African School on Space Science

GNSS applications and scientific exploration together with a greater focus on space and solar physics and how solar events can affect our technology on Earth – specifically GNSS.
Increasing number of students and young scientists studying space science
Increasing participation by women
Many opportunities for research

Improved imaging of the ionosphere over the equatorial region
  • dense networks
  • 3D tomographic reconstruction techniques

Longitudinal variability of space environment and equatorial spread-F

Improved modeling of space environment

Causes of spread --F

Effects of ionospheric effects on systems – navigation and communication systems
  • Scintillation
  • Ionospheric storms

Studies of traveling ionospheric disturbance

... Many topics covered at the recent ISEA 2015 (Bahir Dar, Ethiopia)
Success Stories – just a few of many

Dr. Babatunde Rabiу
Director NASDRA
President, African Geophysical Society
Recently delivered the 70th inaugural lecture at Federal University of Technology, Akure

Dr. Baylie Damtie
President Bahir Dar University

Dr. Melesseuw Nigussie
Bahir Dar University – first PhD recipient

Recent PhDs
Dr. Joseph Olwendo, Nairobi, Kenya
Dr. Amira Shimeis Helwan University, Egypt
Dr. Ibrahim Salem, Helwan University, Egypt
Dr. Sheetal Karia, National Institute of Technology Surat, India
UPCOMING OPPORTUNITIES

International Centre for Theoretical Physics, Trieste, Italy

BC/ICTP Joint Workshop to follow Beacon Satellite Symposium

URSI Commission F, G and H – workshop in late 2016 or early 2017 prior to URSI General Assembly

ISWI School – Sangli, India, November 2016

Others?
Awards and Recognition

Sunanda and Santimay and Sunanda Basu Early Career Award in Sun-Earth Systems Science
  • For scientists living and working in developing countries

African Geophysical Society Fellowship Awards

  • 2 early career scientists from Africa will be recognized for significant work showing promise of making outstanding contributions to research in Earth and Space Science

Others?
A Simple Summary

GPS has proven to be a valuable utility for both practical applications and scientific exploration.

It is getting even better with new satellites, new signals and improved ground system.

With GLONASS, GALILEO, QZSS, IRNSS and Compass – the best is yet to come!
Thank you for your attention!

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Disclaimer: This presentation was prepared by P. Doherty of Boston College. Materials on the GPS system are based on information obtained from the gps.gov website and other publicly released information.
GPS SPS Signal in Space Performance

Signal in Space User Range Errors have been steadily decreasing since 2001.

This is not the same as the user accuracy. Pseudorange is simply the distance from a GPS satellite to a receiver.

User accuracy depends on uncontrollable factors – including atmospheric effects, sky blockage and receiver quality.

(WWW.GPS.GOV)
User Accuracy from FAA GPS SPS Receivers

(Vertical and Horizontal Position Errors (April – June 2014))

(www.nstb.tc.faa.gov/reports/PAN86_714.pdf)
Global Positioning System (GPS) Overview

- **Worldwide Radio-Navigation System**
  - Developed and maintained by U.S. DoD
  - Original intended use was military
  - Civilian use enabled (SA turned off in 2000)

- **Provide 3D Positioning, Navigation and Time**
  - 24hrs/day, 7 days/week, everywhere!

- **Two Levels of Service**
  - Standard Positioning Service (SPS) - Civilian
  - Precise Positioning Service (PPS) - Military

- **Based on Satellite Ranging**
  - Users determine position by measuring the distance from a group of satellites in space

- **GPS Consists of Three Segments**
  - Space Segment
  - Control Segment
  - User Segment

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<td>10.3</td>
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<td>GPS IIF</td>
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You, me and >200 Million other people
Applications

Annual Commerce in GPS Products and Services > $15billion
>200 Million Users
GPS Modernization – New Civil Signals

Second Civil Frequency (L2C; 1227 MHz)
- Designed for commercial needs
- Combined with L1 C/A – enables ionospheric correction
- Broadcasts at a higher power
- First satellite launched with L2C in 2005 (without data msg)
- Currently 15 SVs broadcasting L2C

Third Civil Frequency (L5; 1176 MHz)
- Designed for safety-of-life transportation
- Broadcasts at a radio band reserved for aviation
- L1 C/A, L2C and L5 – together provide robust service
- First satellite launched with L5 in 2010 (without data msg)
- 8 SVs launched to date

Fourth Civil Frequency (L1C; 1575 MHz)
- Designed for GNSS interoperability
- US and Europe designed as a common signal for GPS and Galileo
- QZSS, IRNSS and Compass – also plan to broadcast L1C
- GPS plans to launch first satellite with L1C in 2016
- Will enhance performance in challenging environments
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