Geospace Research in Ethiopia: Implication for Scientific and societal opportunities of AMISR

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Outline

1. Historic Development of Space Observation and Current Observational Networks
2. Tomography of Ionosphere Over Eastern Africa
   - 2D Tomography of Electron Density of the ionosphere and its limitation
   - 3D Tomography
3. Space Observation for Lower Atmospheric Sounding: Precipitable Water
4. Conclusion
1. Historic Development of Space Observation and Current Observational Networks

- Space Observation started long time by Jesuit priests in the early 1950s;
- A number of PhD research including;
  - discover of counter electroject was made possible from measurements at AAU observatory
1. Historic Development of Space Observation and Current Observational Networks

- Currently we have:
  - Various magnetometers (Inter-magnet (60 years), MAGDAS (Japan), AMBER, Boston College)
  - GPS (GPS for Tectonic study, SCINDA, Ethiopian mapping agency)
  - Interferomter for lower atmosphere trace gases measurements (in collaboration with KIT, Germany)
  - High performance computing facilities for running various models; we now run GCM, RCM for climate research (ICTP, Italy)
  - VIPIR, recently deployed (in collaboration with Boston College and AFRL, USA).
1. Historic Development of Space Observation and Current Observational Networks

Figure: Some ionograms taken on 20120105, 20120206, 20120806.
2. Tomography of Ionosphere Over Eastern Africa

- TEC time series at some sites:

**Figure:** Daily mean value of VTEC plotted versus GPS days for 2008 and 2009 for GPS receivers at NAZR and ASMA. Peak VTEC occurs at around equinox dates.
2. Tomography of Ionosphere Over Eastern Africa: contd.

- TEC in terms of electron density:

\[ TEC = \int_{\text{raypath}} N(\vec{r}) \, d\vec{r} \]

where \( N(\vec{r}) \) is the electron density
Discretizing the previous relationship for a GPS satellite to receiver ray path,

\[ y_i = \sum_{j=1}^{n} A_{ij}x_j + e_i \]

For TEC measurements along many ray paths,

\[ y_{m\times1} = A_{m\times n}x_{n\times1} + e_{m\times1} \]

where \( y \) is column matrix of \( m \) TEC measurements, \( x \) the electron density in \( n \) pixels. \( A \) is the coefficient matrix with \( A_{ij} \) distance traveled by \( i^{th} \) GPS satellite’s ray in the \( j^{th} \) pixel.
2. Tomography of Ionosphere Over Eastern Africa: contd.

The electron density $x$ that minimizes

$$\|Ax - y\|_2^2 + \alpha^2 \|Lx\|_2^2$$

is given by

$$x_{\alpha,L} = (A^T A + \alpha^2 L^T L)^{-1} A^T y$$

The solution $x$ is a function of the regularization parameter $\alpha$ and Tikhonov difference operator $L$. 
2. Tomography of Ionosphere Over Eastern Africa: contd.

- 2D Geometry of raypaths over Ethiopia:
2. Tomography of Ionosphere Over Eastern Africa: contd.

- 3D Geometry of raypaths over Ethiopia for selected GPS receivers:
2. Tomography of Ionosphere Over Ethiopia: contd.

- Validation of 2D algorithm:
2. Tomography of Ionosphere Over Ethiopia: contd.

- Validation of 3D algorithm:
2. Tomography of Ionosphere Over Eastern Africa: Variability along meridian IED at 28°, 36° (top); at 40°, 48° (bottom) East
2. Tomography of Ionosphere Over Eastern Africa: Variability along a given latitude

IED at 1°, 5° (top); at 10°, 20° (bottom) North:
2. Tomography of Ionosphere Over Eastern Africa: Diurnal variation at 34° East

- IED at UT: 3, 6, 9 (top); at 12, 16, 17 (bottom):
2. Tomography of Ionosphere Over Eastern Africa: Diurnal variation at 40° East

- Implication for AMISR:
  - There is both strong desire and skill to do up-to-date space science in Africa
3. Space Observation for Lower Atmospheric Sounding: Precipitable Water

- Correlation of PWV from GPS with Climate model at 2 GPS stations: Addis Ababa and Alemaya:
Correlation of PWV with model at Addis Ababa: Annual time series for 2008:
3. Space Observation for Lower Atmospheric Sounding: Precipitable Water

- Correlation of PWV with model at 2 GPS stations: Addis Ababa and Alemaya:

![Correlation of PWV with model at 2 GPS stations](image)

- Implication for AMISR:
  - There is strong desire in Africa to do good science
  - There is critical mass of scientists that can make use of observation of Geospace environment along with the global scientific community
4. Conclusion

- In Africa, we can contribute to research and education in space science;
- We have critical mass of scientists;
- There is also institutional support; and
- We can use the opportunities provided by AMISR deployment to strengthen existing education and research in Africa.
Some of our experiences on the field: Installation to Celebration
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THANK YOU!!!