



Recent progress in capacity building in Space Weather in Nepal and Pakistan

Christine Amory-Mazaudier

christine.amory@polytechnique.fr

*Sorbonne Université, Ecole polytechnique, Institut Polytechnique de Paris, Université Paris Saclay, Observatoire de Paris, CNRS, Laboratoire de Physique des Plasmas (LPP), 75005 Paris, France
T/ICT4D, ICTP, International Centre for Theoretical Physics, Italy*

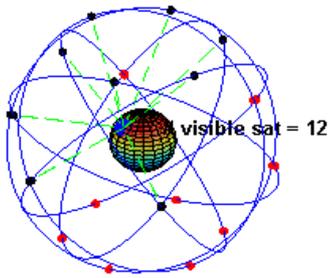


ICG-15 meeting, Vienna 27september-1st October 2021



Outline

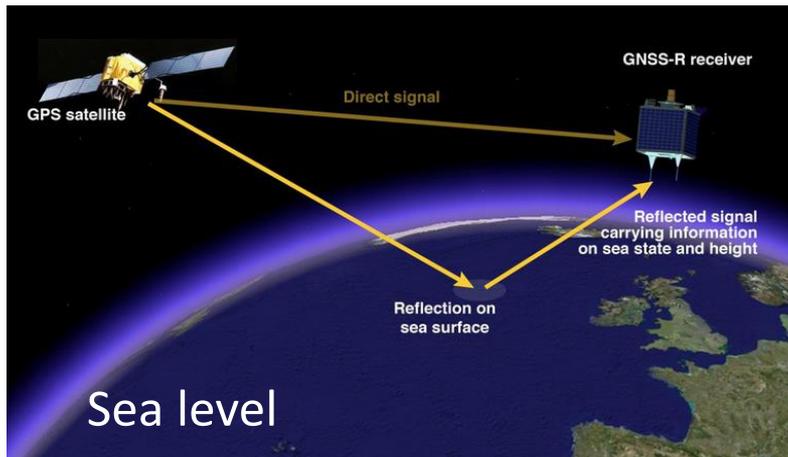
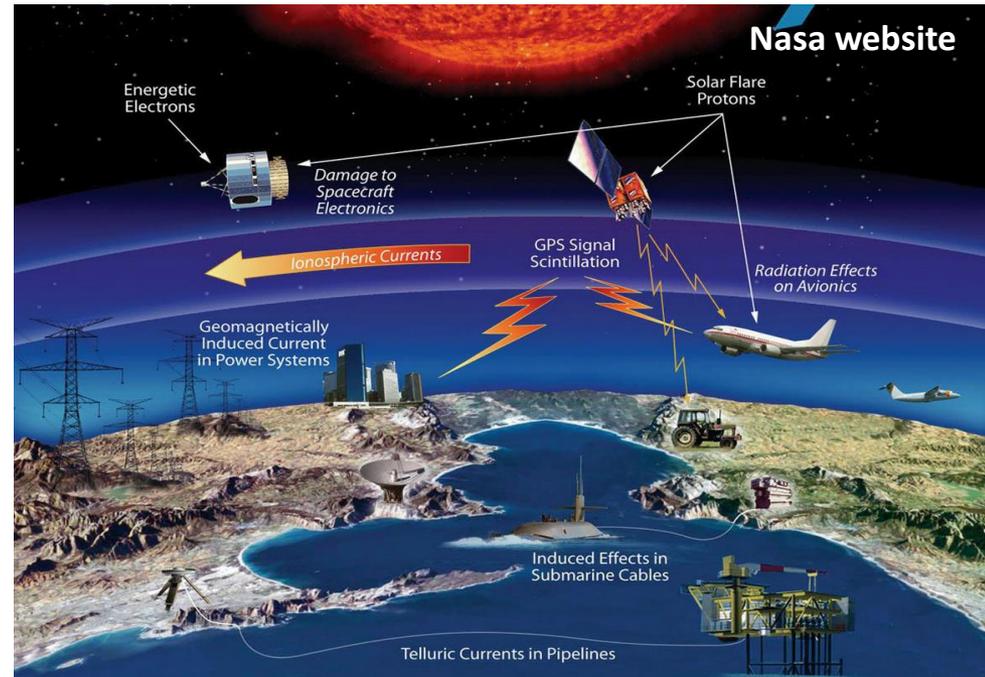
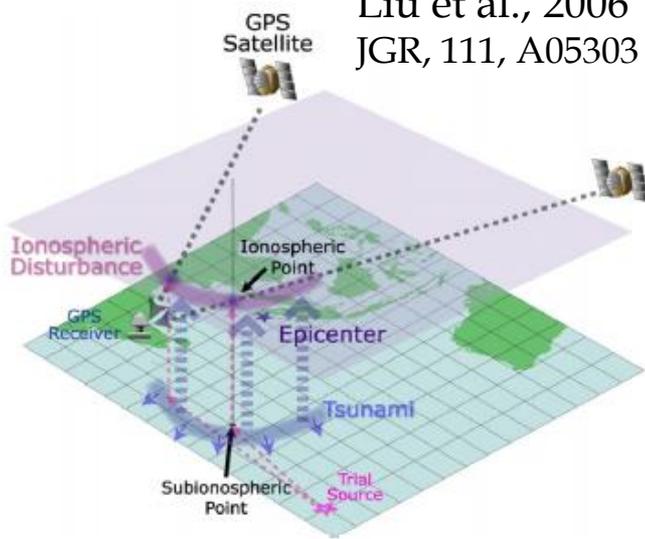
- GNSS for research
- ISWI scientific network : importance of synergies between institutions and international organizations
- Capacity building in Nepal
- Capacity building in Pakistan
- On the necessity of systemic approach of the Sun Earth system



Use of GNSS for research

ionosphere is the largest source of perturbations for GNSS signals

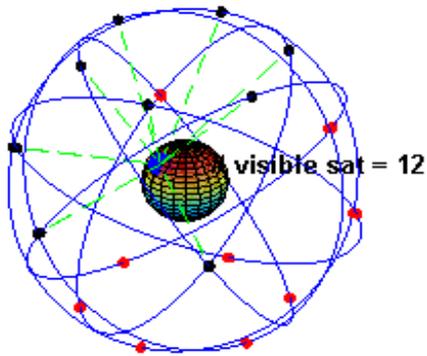
Liu et al., 2006
JGR, 111, A05303



GNSS receivers are cheaper than radar, lidar and other scientific instruments and can be easily installed on the ground.

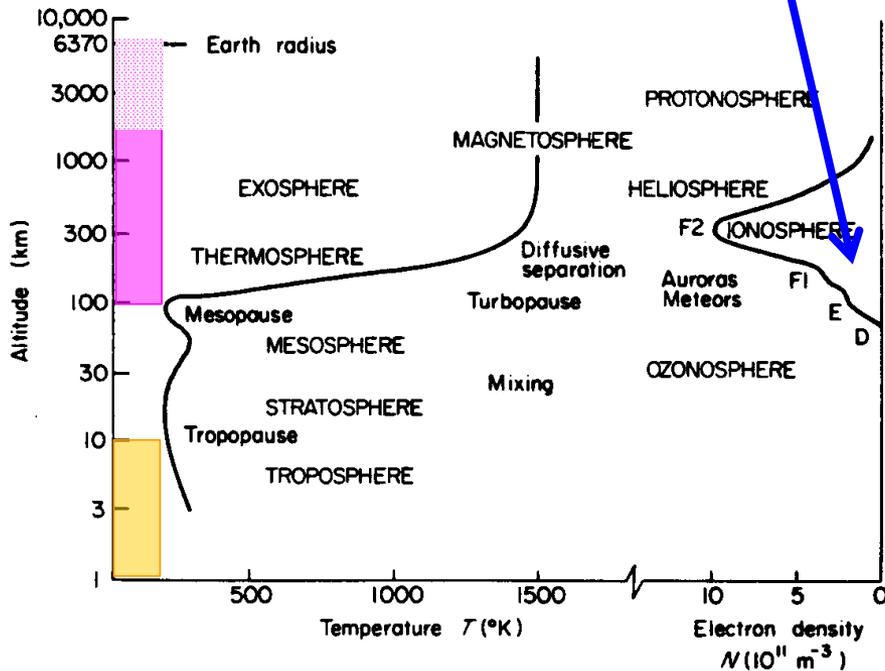
GNSS receivers are the most common instruments on the globe some tens of thousands.

The satellite signal is strongly modified by ionosphere and troposphere



TEC

Total electron content



LAYERS

> 600 km **EXOSPHERE**
few collisions, Particles follow ballistic orbit

80-600 km **THERMOSPHERE**
Ionization by the solar X-EUV radiation
IONOSPHERE

30-80 km **MESOSPHERE**
Absorption of the radiation UV by the ozone layer

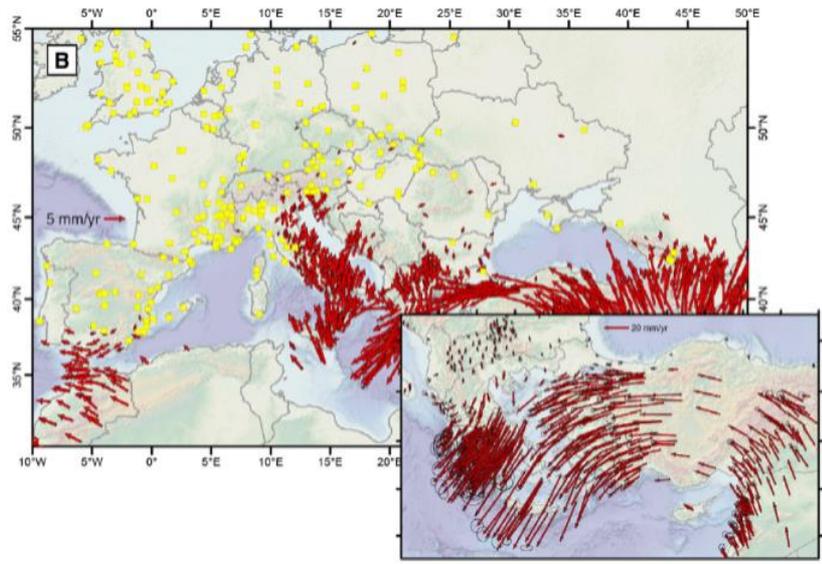
11-30 km **STRATOSPHERE**
Turbulence

0-11 km **TROPOSPHERE**
Meteorological phenomena

There is a strong interest to use GPS for meteorology

GNSS a universal tool for research and many applications in everyday life

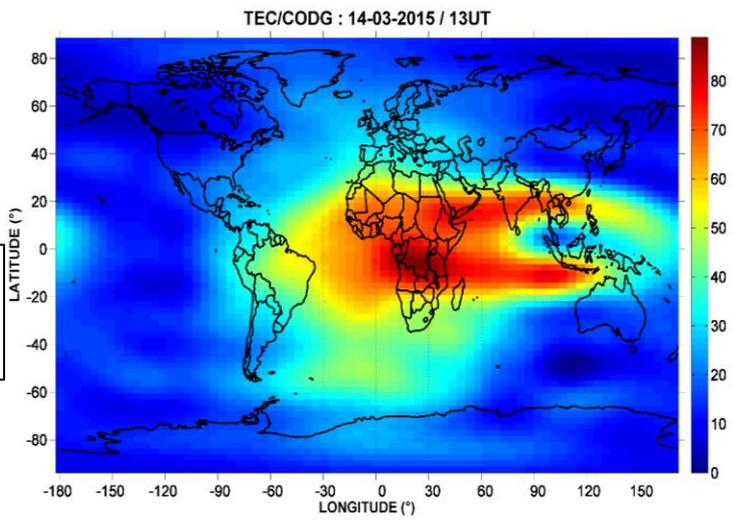
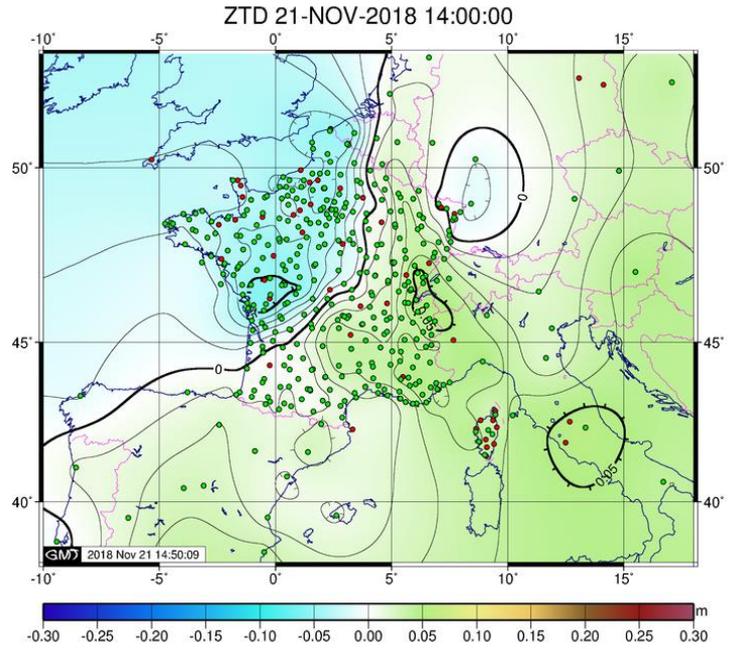
Nocquet (2012) GPS velocity field from the Euro Mediterranean region, relative to Eurasia. Yellow squares indicate velocities below 1 mm/yr. The inset illustrates the westward movement of Anatolia relative to Eurasia.



Post-processed ionospheric map of TEC from CODE on 14/03/2015 at 15UT

Figures and references in the paper Amory-Mazaudier, C. R. Fleury, F. Masson, S. Gadimova, E. Anas, Sun and Geosphere, Vol 14/1, pp. 71-79, 2019

ZTD values over France on 21/11/2018 at 14:00UT
Zenithal Hydrostatic Delay, ZHD



After UNBSSI (1991-2012) the scientific ISWI network

(ISWI : International Space Weather Initiative)



1. Distribution of scientific tools
2. Training schools / GNSS and Physics of the Sun Earth's System
3. PhD => position in the country
4. Curricula in Universities



DECEMBER 2016

This workshop gave me two opportunities





FIRST OPPORTUNITY

Scientific conference at the
University of TRIVANDRUM

Conference organized by
Professor Narayan CHAPAGAIN



Space Weather, from the Sun to the Earth, the key role of GNSS

The goal of this paper is to give a clear view of the Sun Earth relationships that are complex. The phenomena acting at large scales and essentially related to dynamic and electromagnetic physical processes have been addressed. Besides physics, the work done to develop the training in Space Weather by focusing on Global Navigation Satellite Systems has also been presented. We present this paper as a series in two parts. In this issue the focus is on physics of the relationships Sun, Earth and Meteorology of Space. In March issue, GNSS training and capacity building would be discussed



Dr Christine Amory-Mazaudier

Senior Scientist,
University Pierre and
Marie Curie and Staff
Associate at ICIP.
Recently awarded Marcel
Nicolet Medal for her
work in Space Weather



Dr Roland Fleury

Associate Professor,
Microwave Department
of the TMT Atlantique
School of Engineering,
Brest campus, France



Sharafat Gadimova

Programme Officer, the
United Nations Office
for Outer Space Affairs,
leads the organization
of the activities
on GNSS and the

development of the International Committee
on Global Navigation Satellite Systems



**Professor
Abderrahmane Touzani**

Director, African
Regional Centre for
Space Science and
Technology Education
- in French Language

(DRASTE-LE), Rabat, Morocco

was Professor in University
Mohammed V, Rabat, Morocco

This paper presents a study made for the Seminar on Space Weather and its effects on GNSS held in conjunction with United Nations/Nepal workshop on the applications of GNSS held in Kathmandu, 6 to 12 December 2016. The Seminar focused on cross-cutting area, in particular resiliency, the ability to depend on space systems and the ability to respond to the impact of events such as adverse space weather.

The aim is to give an outline of the Space Weather and its effects on GNSS receivers, and this in relation to the international organizations in charge of the harmonization of the various GNSS systems.

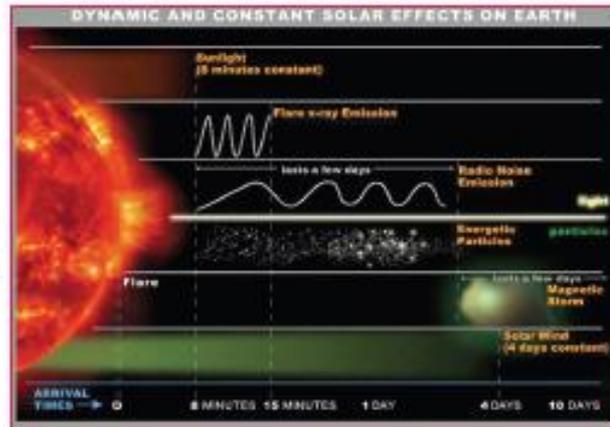


Figure 1: <http://www.nasa.gov/sites/default/files/thumbnails/image/fsc26.jpg>

This article is composed of 3 parts:
Part I: Physics of the relationships Sun Earth and Meteorology of Space, Part II: GNSS teaching and parameters that can be deduced from GNSS receivers, Part III: Building capacity of developing countries in using GNSS technology for sustainable development.

From the Sun to the Earth, Space Weather and its effects

Emissions from the Sun

The sun is our star and it influences the terrestrial environment according to different channels,

Amory-Mazaudier, C., R. Fleury, S. Gadimova, A. Touzani (Feb.2017), Space Weather, from the Sun to Earth, the key role of Global Navigation Satellite Systems, [Part I : From the Sun to the Earth, Space Weather and its effects](#), Coordinates a monthly magazine on positioning, navigation and beyond, <http://www.mycoordinates.org>

SOLAR DISTURBANCES AFFECT GNSS

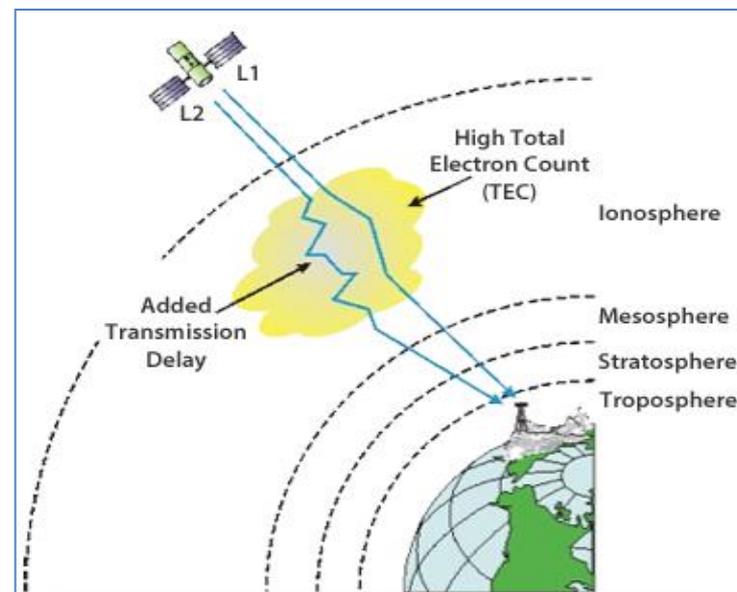


Figure from <http://reflexions.ulg.ac.be>

Space Weather, from the Sun to the Earth, the key role of GNSS

The goal of this paper is to give a clear view of the Sun Earth relationships that are complex. The phenomena acting at large scales and essentially related to dynamic and electromagnetic physical processes have been addressed. Besides physics, the work done to develop the training in Space Weather by focusing on Global Navigation Satellite Systems has also been presented. Readers may recall that we published the first part of this article which focused on physics of the relationships Sun, Earth and Meteorology of Space. In this issue, aspects of GNSS training and capacity building are discussed



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Sharafat Gadimova
Programme Officer, the
United Nations Office
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Leads the organization
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on GNSS and the
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**Professor
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Director, African
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Space Science and
Technology Education
- In French Language

(CRASTE-LF), Rabat, Morocco
was Professor in University
Mohammed V, Rabat, Morocco

Part II: Training on daily Global Positioning System (GPS) data

This training was organized in the African Regional Centre for Space Science and Technology - in French Language (CRASTE-LF) in February 2015 and January 2017 and in school Mines-Télécom in 2011, 2012, 2014, 2015, 2016 and next in February 2017.

This training is centered on the use of GPS for ionospheric studies. It is composed of several courses. The content of this training is given below:

- Ionosphere
- Space Weather
- solar wind
- GPS system
- propagation through the ionosphere

- VTEC
- ROTI index, proxy of scintillation

In this part we will focus the GPS system, propagation through ionosphere, VTEC and ROTI index.

The standard format for the GPS data is the RINEX format. The first training is an introduction for processing the RINEX file. We use the example of ykoi3500.09dLZ (site of Yamoussoukro/Cote d'Ivoire on 16 December 2009). In the rest of this section we show all the parameters that the students can deduced from the GPS data during the training.

The GPS constellation

Two exercises make it possible to understand the relative complexity of the

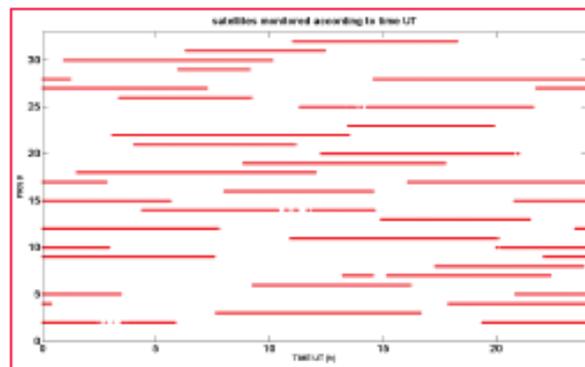


Figure II.1: Satellites PRN monitored during that day at YKRO

Amory-Mazaudier, C., R. Fleury, S. Gadimova, A. Touzani (March 2017), Space Weather from the sun to the Earth, the key role of Global Navigation Satellite Systems- Part II: Training on daily global positioning system GPS data

Coordinates a monthly magazine on positioning, navigation and beyond, <http://www.mycoordinates.org>,

Nepal has an important network of GPS

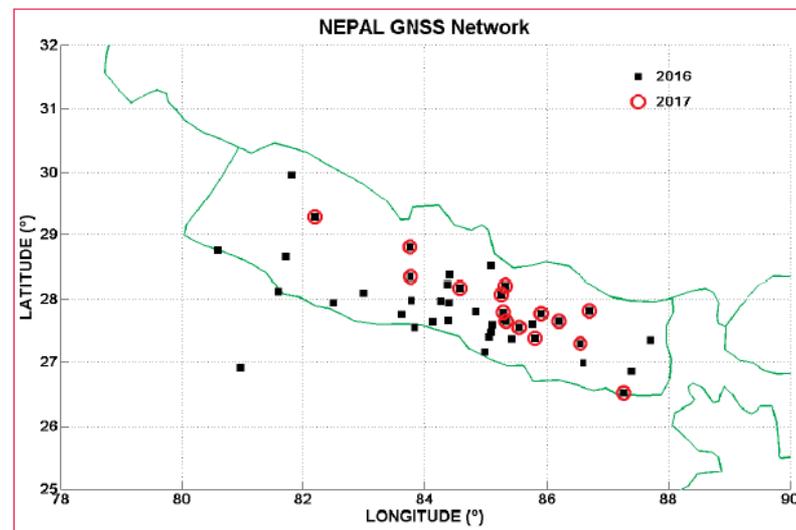


Figure II.10: Network of GPS in Nepal (UNAVCO)



The Abdus Salam
International Centre
for Theoretical Physics



**Workshop on Space Weather and Upper Atmosphere Physics (WSWUAP)
Kathmandu, Nepal, September 23 – 27, 2019 organized by the Dept. of Physics,
Amrit Campus, Tribhuvan University, Kathmandu, Nepal and The Abdus Salam
International Centre for Theoretical Physics (ICTP), Trieste, Italy.**



TEAM of RESEARCH at KATHMANDOU/NEPAL



Professor Narayan CHAPAGAIN
Tribhuvan University, Amrit
Campus, Thamel,



Dr Rolland FLEURY
National school Telecom

SENIOR SCIENTISTS



Dr Christine AMORY-MAZAUDIER
Sorbonne Universités



Dr. Binod ADHIKARI Lecturer and
Research Coordinator St. Xavier's
College, Maitighar

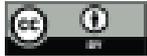


Drabindra PANDIT



Basudev GHIMIRE

2 PhD Students of the Institute of Science
and Technology ,Tribhuvan University.
and Lecturers : St. Xavier's College,



Climatology of ionosphere over Nepal based on GPS total electron content data from 2008 to 2018

Drabindra Pandit^{1,6}, Basudev Ghimire^{1,6}, Christine Amory-Mazaudier^{2,3}, Rolland Fleury⁴, Narayan Prasad Chapagain⁵, and Binod Adhikari⁶

D. Pandit et al.: Climatology of ionosphere over Nepal

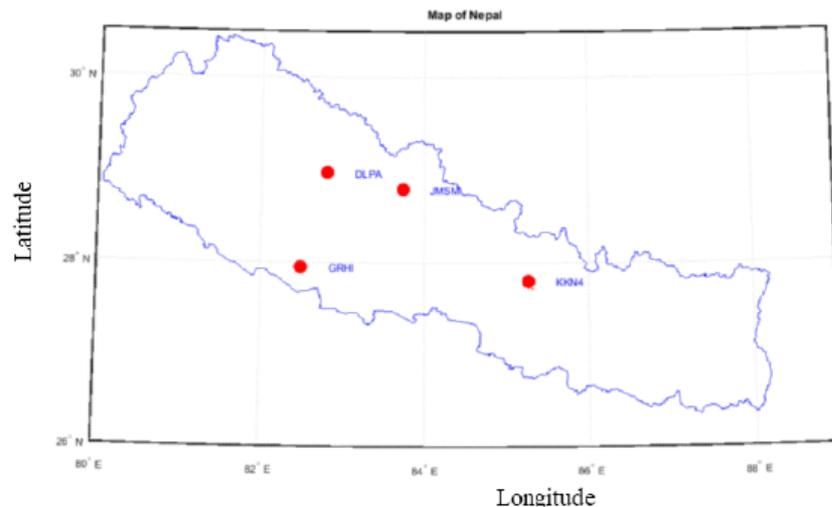


Figure 1. A map of Nepal showing locations of GPS stations used in our study.



The 2 students Drabindra Pandit and Basudev Ghimire participated to workshop organized by ICTP (2018 – 2019)

First paper published
2 other papers are submitted

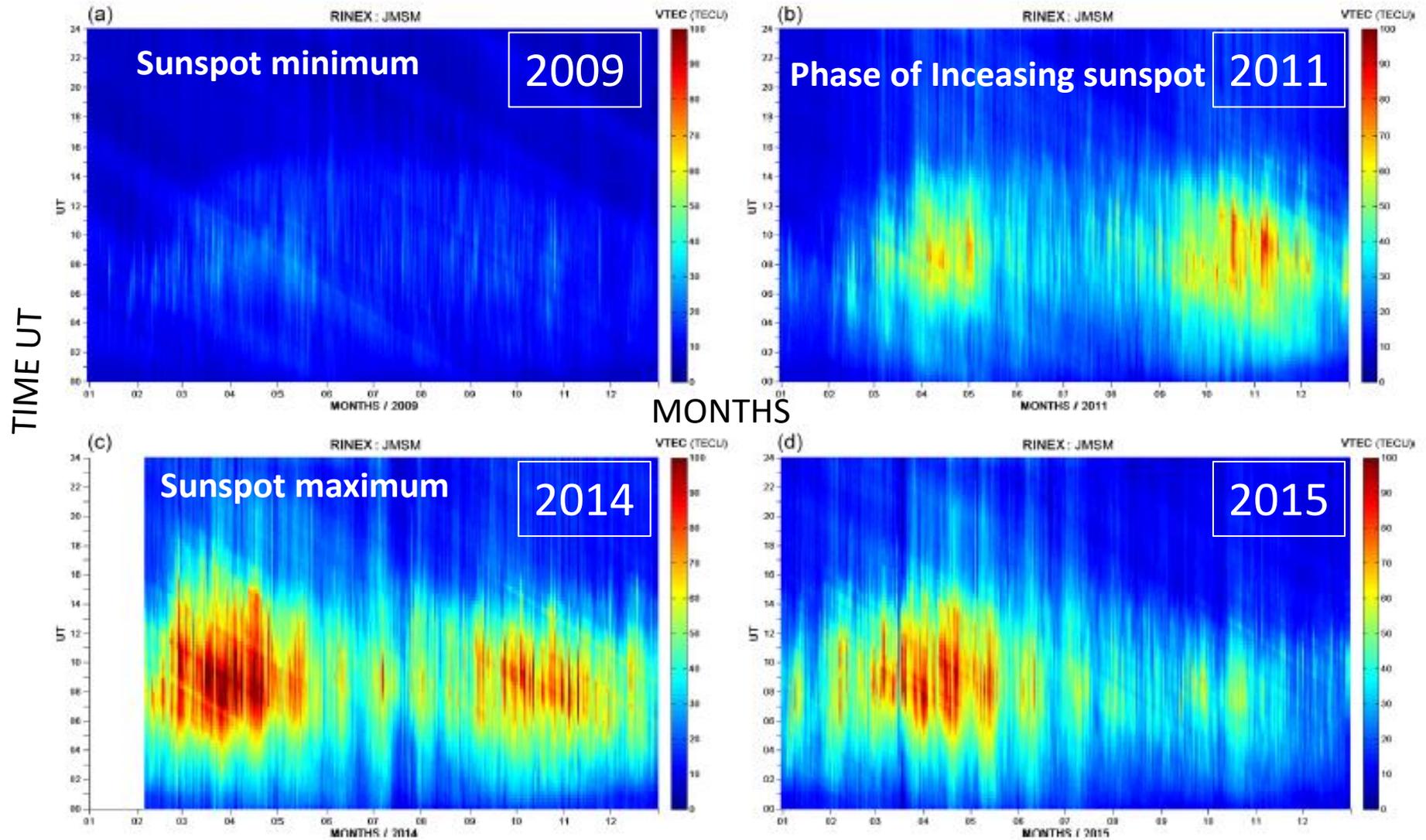


Figure 5. (a–d) A two-dimensional (2D) variation in vertical TEC according to UT at the JMSM station for one of the years of the minimum (2009), ascending (2011), maximum (2014) and descending (2015) phases of solar cycle 24.



Dr. Najam ABBAS NAQVI (Associate Professor)
Institute of Space Technology, Islamabad, Pakistan
Organized the colloquium ICASE , Islamabad/Pakistan, November 2019

I was invited and during this conference the student Waqar YOUNAS with whom I was already working organized a workshop on space weather



MASTER on GNSS
in which it is possible
to add a space
weather option



TEAM OF RESEARCH IN PAKISTAN



Dr. Majid KHAN
Associate Professor (Tenured)
Department of Physics, Quaid-i-Azam
University, Islamabad, Pakistan.



PhD student :Waqar YOUNAS
"Quaid-i- Azam University Islamabad, Pakistan«

JGR Space Physics

RESEARCH ARTICLE
10.1029/2020JA027981

Special Section:
Equatorial Aeronomy: New
results from the 15th
International Symposium on
Equatorial Aeronomy (ISEA-
15) and beyond

Ionospheric and Magnetic Signatures of a Space Weather Event on 25–29 August 2018: CME and HSSWs

W. Younas¹ , C. Amory-Mazaudier^{2,3} , Majid Khan¹, and R. Fleury⁴

¹Department of Physics, Quaid-i-Azam University Islamabad, Islamabad, Pakistan, ²LPP, CNRS/Ecole Polytechnique/Sorbonne Université/Université Paris-Sud/Observatoire de Paris, Paris, France, ³T/ICT4D, The Abdus Salam International Centre of Theoretical Physics, Trieste, Italy, ⁴Lab-STICC/CNRS-UMR 6285, IMT-Atlantique Brest, Brest, France

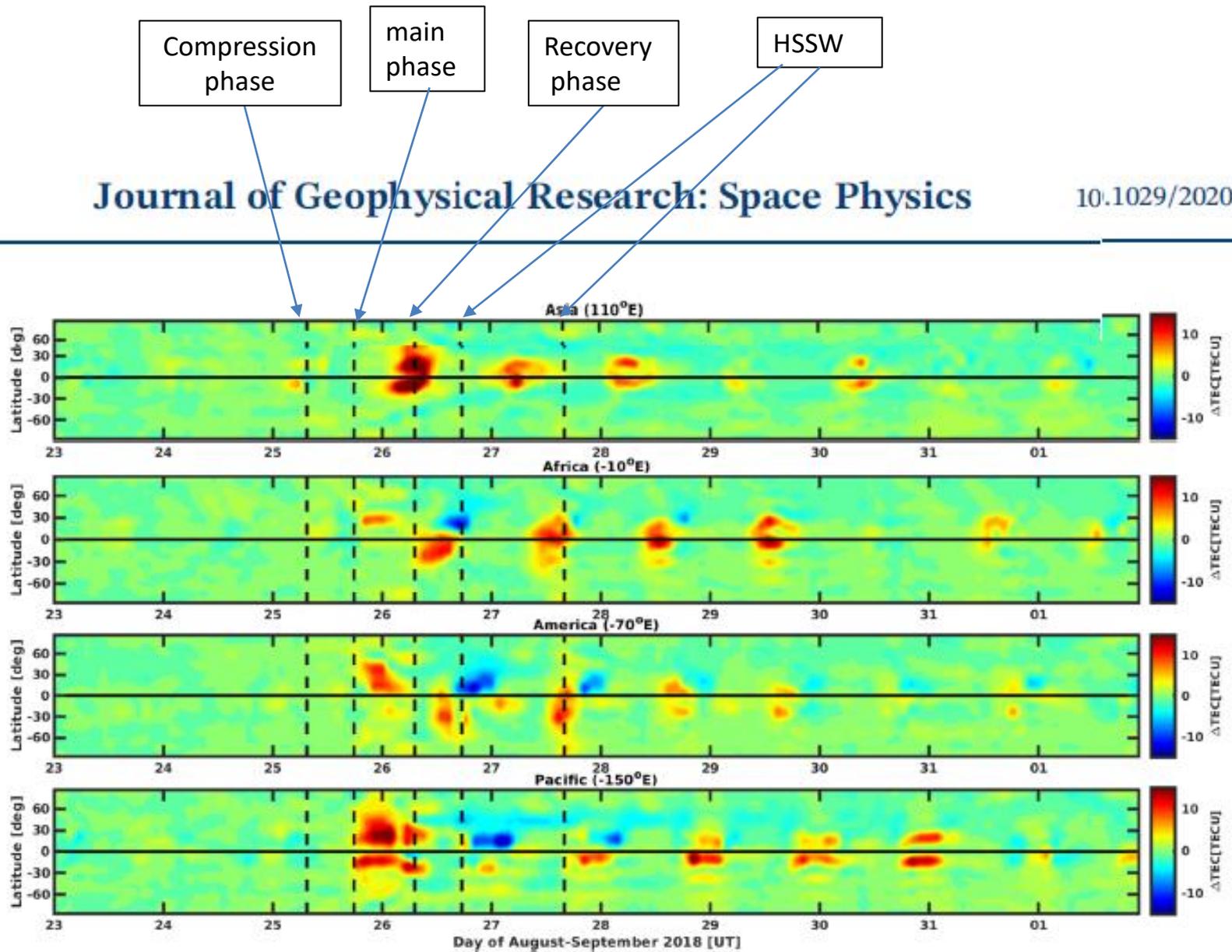


Figure 4. $\Delta VTEC$, in four longitudinal sectors (from top to bottom) Asia, Africa, America, and the Pacific from 23 August to 1 September 2018.

MAGNETIC STORM

COOPERATION WITH VIETNAM



Dr Minh LE HUY, Distinguished researcher
Institute of Geophysics, Vietnam Academy of
Science and Technology



Space Weather

RESEARCH ARTICLE

10.1029/2021SW002825

Key Points:

- A least-square fitting method has been used to evaluate the magnetic signatures disturbance dynamo electric fields
- Differences in the magnetic signatures of CME and high-speed

Magnetic Signatures of Ionospheric Disturbance Dynamo for CME and HSSWs Generated Storms

Waqar Younas¹ , C. Amory-Mazaudier^{2,3} , Majid Khan¹, and M. Le Huy⁴

¹Department of Physics, Quaid-i-Azam University Islamabad, Islamabad, Pakistan, ²Laboratoire de Physique des Plasmas (LPP), CNRS, Sorbonne Université, Université Paris Saclay, Observatoire de Paris, Ecole polytechnique, Institut Polytechnique de Paris, Paris, France, ³T/ICT4D, The Abdus Salam International Centre of Theoretical Physics, Trieste, Italy, ⁴Institute of Geophysics, Vietnam Academy of Science and Technology, Hanoi, Vietnam

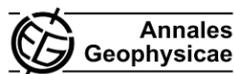


CAPACITY BUILDING DURING IHY and ISWI (UNBSSI)

IHY [2007-2009] : International Heliophysical Year
ISWI [2010-2012]: International Space Weather Initiative

Dr Le Huy Minh trained 6 PhD students

Ann. Geophys., 24, 3313–3327, 2006
www.ann-geophys.net/24/3313/2006/
© European Geosciences Union 2006



Sun-Earth System Interaction studies over Vietnam: an international cooperative project

C. Amory-Mazaudier¹, M. Le Huy², Y. Cohen³, V. Dombia^{4,*}, A. Bourdillon⁵, R. Fleury⁶, B. Fontaine⁷, C. Ha Duyen², A. Koba⁴, P. Laroche⁸, P. Lassudrie-Duchesne⁶, H. Le Viet², T. Le Truong², H. Luu Viet², M. Menvielle¹, T. Nguyen Chien², A. Nguyen Xuan², F. Ouattara⁹, M. Petitdidier¹, H. Pham Thi Thu², T. Pham Xuan², N. Philippon^{10,*}, L. Tran Thi², H. Vu Thien¹⁰, and P. Vila¹

Ionospheric irregularities causes
scintillations of GNSS signal

Vietnam Journal of Earth Sciences, 1-20, <https://doi.org/10.15625/2615-9783/16502>



Vietnam Academy of Science and Technology
Vietnam Journal of Earth Sciences
<http://www.vjs.ac.vn/index.php/jse>



Thanh PHAM XUAN
PhD – physics
On Climate change
pxthanh@igp-vast.vn



Hong PHAM THI THU
PhD- 2012
On ionosphere and geomagnetism
phamhongigp@gmail.com



Hung LUU VIET
PhD – 2011
On telluric currents
viethungluu0510@gmail.com



Lan TRAN THI
PhD - physics
on scintillations/GPS
lanttigp@gmail.com



Thanh LETRUONG
PhD - physic , 2015
On Equatorial Electrojet
igpthanh@gmail.com



Chien Thang NGUYEN
PhD - physics , 2015
On MSTD/ Demeter satellite
thang045@gmail.com

Characterization of ionospheric irregularities over Vietnam and adjacent region for the 2008-2018 period

Dung Nguyen Thanh^{1,2}, Minh Le Huy^{1,2}, Christine Amory-Mazaudier^{3,4}, Rolland Fleury⁵, Susumu Saito⁶, Thang Nguyen Chien¹, Hong Pham Thi Thu^{1,2}, Thanh Le Truong¹, Mai Nguyen Thi¹

COOPERATION WITH NIGERIA

Study on TEC ((IRI model)



Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research xxx (xxxx) xxx

**ADVANCES IN
SPACE
RESEARCH**
(a COSPAR publication)

www.elsevier.com/locate/asr

Comparison of ionospheric anomalies over African equatorial/low-latitude region with IRI-2016 model predictions during the maximum phase of solar cycle 24

Paul O. Amaechi^{a,*}, Elijah O. Oyeyemi^b, Andrew O. Akala^{b,c}, Mohamed Kaab^{d,e}, Waqar Younas^f, Zouhair Benkhaldoun^d, Majid Khan^f, Christine-Amory Mazaudier^{g,h}

Dr. Paul O. AMAECHI
Department of Physical Sciences,
Chrisland University
Abeokuta, Nigeria.

Study on the ratio O/N₂ (CTIPe model) paper in revision



Advances in Space Research

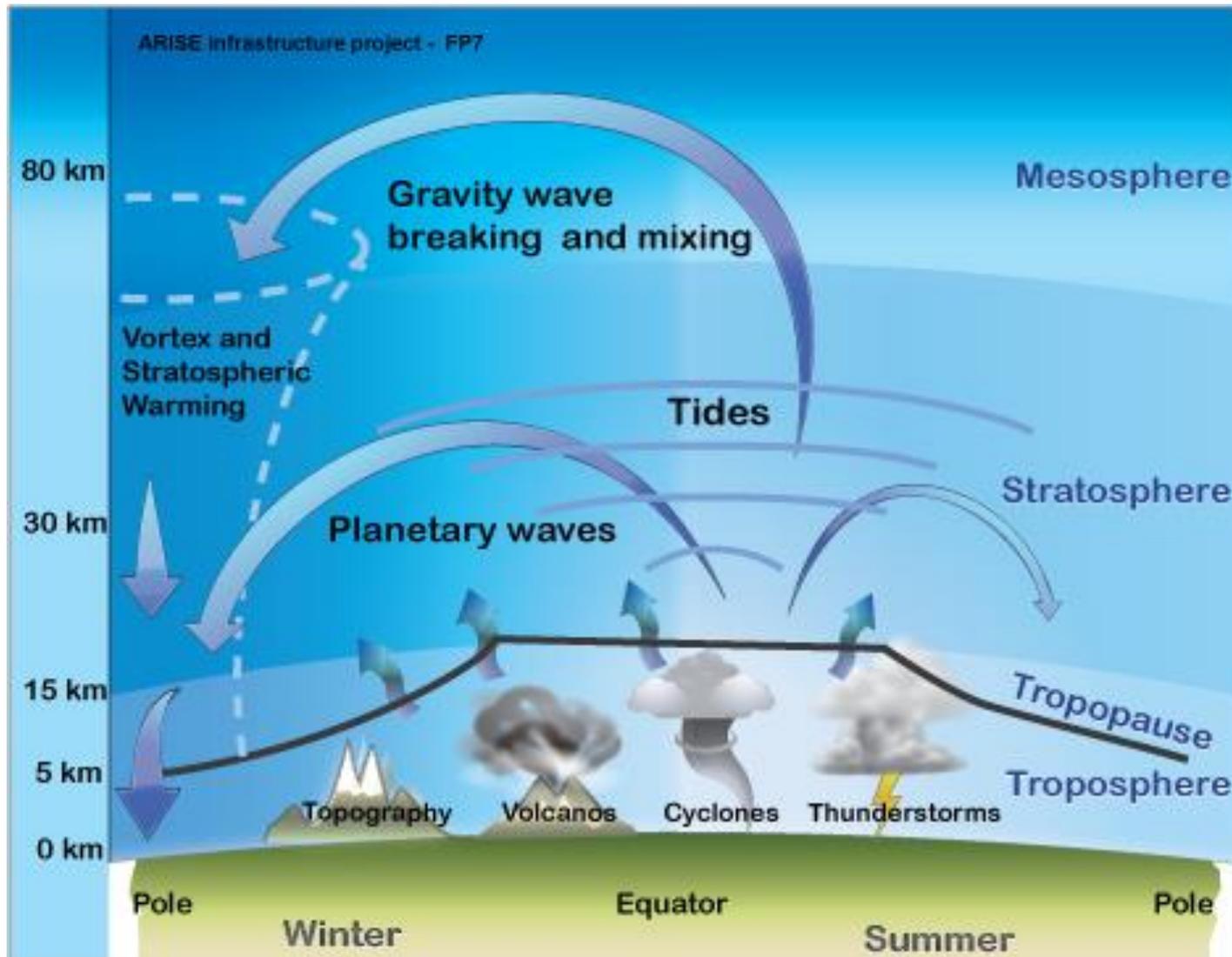
Global Hemispheric differences in thermospheric O/N₂ at Middle- and Low-Latitudes during the Intense Magnetic Storms of Solar Cycle 24

--Manuscript Draft--

Authors

Younas W., M. Khan, C. Amory-mazaudier, P. Amaechi, R fleury

SPACE WEATHER IS ALSO FROM THE EARTH TO ATMOSPHERE AND IONOSPHERE



Published: 22 September 2021

A Lithosphere–Atmosphere–Ionosphere Coupling Phenomenon Observed Before M 7.7 Jamaica Earthquake

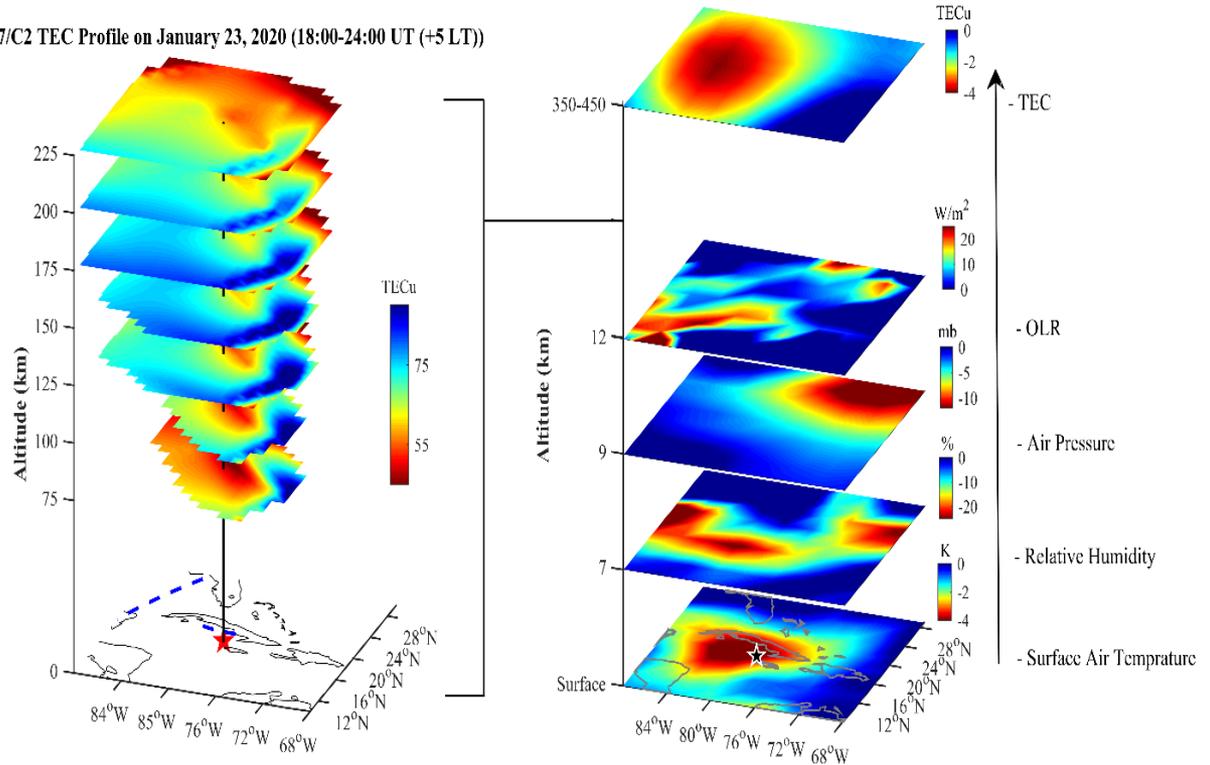
Muhammad Arqim Adil , Erman Şentürk, Sergey Alexander Pulinets & Christine Amory-Mazaudier

Pure and Applied Geophysics (2021) | [Cite this article](#)

On the necessity of systemic studies



F7/C2 TEC Profile on January 23, 2020 (18:00-24:00 UT (+5 LT))



Muhammad Arqim ADIL, Research Assistant,
Department of GNSS, Institute of Space Technology,
Islamabad, Pakistan

Conclusion

- Increasing in research capacity in Space weather
 - Space weather requires knowledge in different disciplines (solar physics, magnetosphere, ionosphere, solid earth)
 - Only the research network structure makes it possible to bring together all the skills
 - It is also of interest, for each country to develop Space Weather, to know the local ionosphere and improve the use of GNSS
- Method
 - Training in workshop (ICTP, ICG)
 - Schools in the countries organized by SCOSPEP; ISWI, GIRGEA in cooperation with the scientific of the countries
 - PhD
 - Cursus at University
- Needs
 - More GNSS receivers in some places in the world => necessity to built very cheap GNSS receivers

conclusion

ARTICLE IN PRESS



Available online at www.sciencedirect.com

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Advances in Space Research xxx (xxxx) xxx

**ADVANCES IN
SPACE
RESEARCH**

(a COSPAR publication)

www.elsevier.com/locate/asr

New results of ionospheric total electron content measurements from a low-cost global navigation satellite system receiver and comparisons with other data sources

Daniel Okoh^{a,b,*}, Aderonke Obafaye^a, Babatunde Rabi^{a,b}, Gopi Seemala^c,
Anton Kashcheyev^d, Bruno Nava^e

^aCentre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria

^bInstitute for Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria

^cIndian Institute of Geomagnetism, Navi Mumbai, India

^dUniversity of New Brunswick, Fredericton, Canada

^eThe Abdus Salam International Centre for Theoretical Physics (ICTP) TIICT4D, Trieste, Italy

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