

**United Nations/United Arab Emirates/United States of America  
Workshop on the Applications of  
Global Navigation Satellite Systems**

**Dubai, United Arab Emirates, 16 - 20 January 2011**

**SPACE WEATHER EFFECTS ON GNSS  
PERFORMANCE AND OPERATION: A  
FUNDAMENTAL COMPONENT OF GNSS  
CURRICULUM**

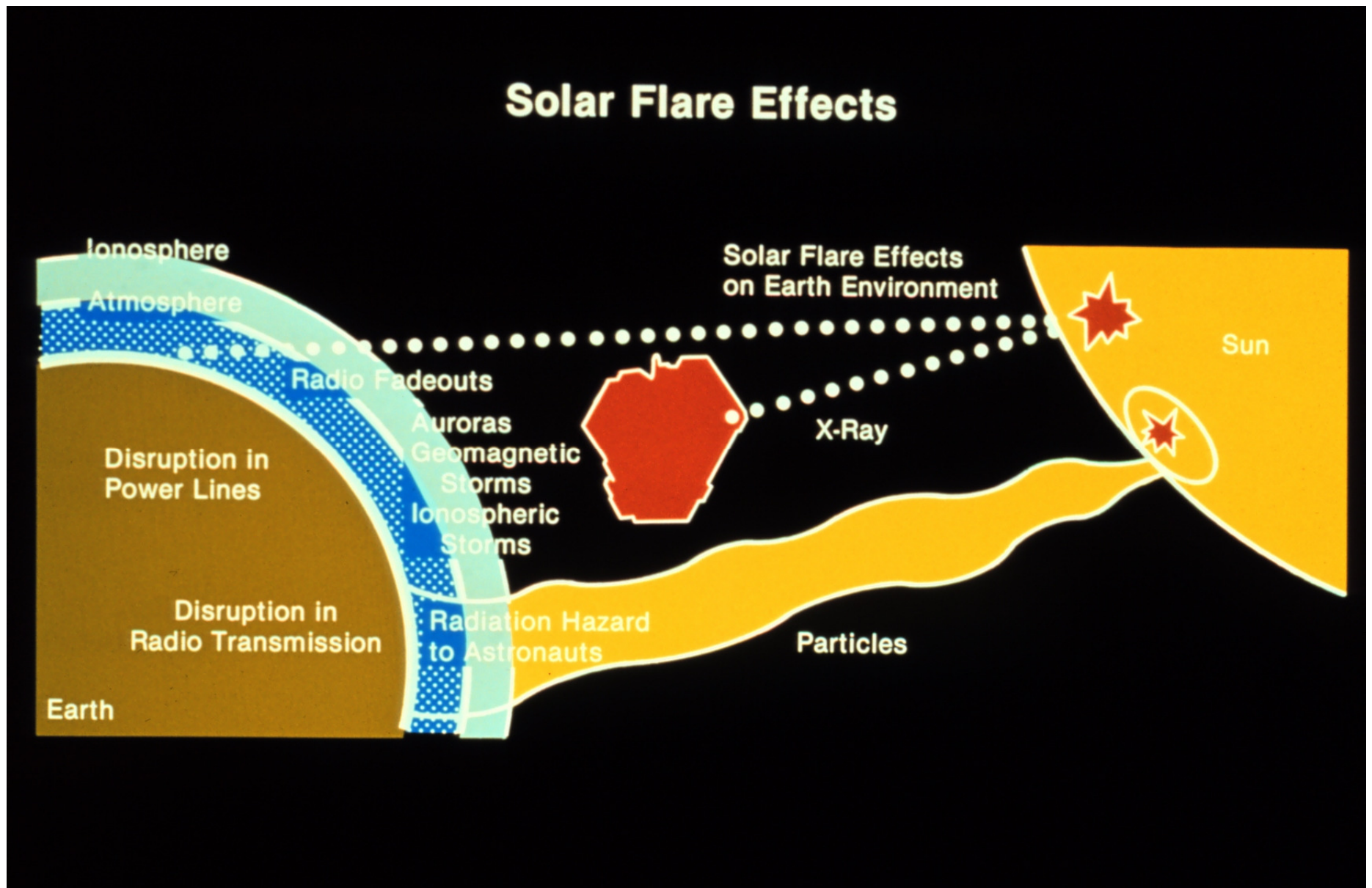
**RENATO FILJAR (University College of Applied Sciences, Bjelovar, Croatia),  
Serdjo Kos (Faculty of Maritime Studies, University of Rijeka, Croatia)**

# Filjar, Kos: Space weather effects on GNSS performance and operation: A fundamental component of GNSS curriculum

- Content of presentation:
  - Introduction
  - Aim and methodology
  - Course programme
  - Resources
  - Conclusion

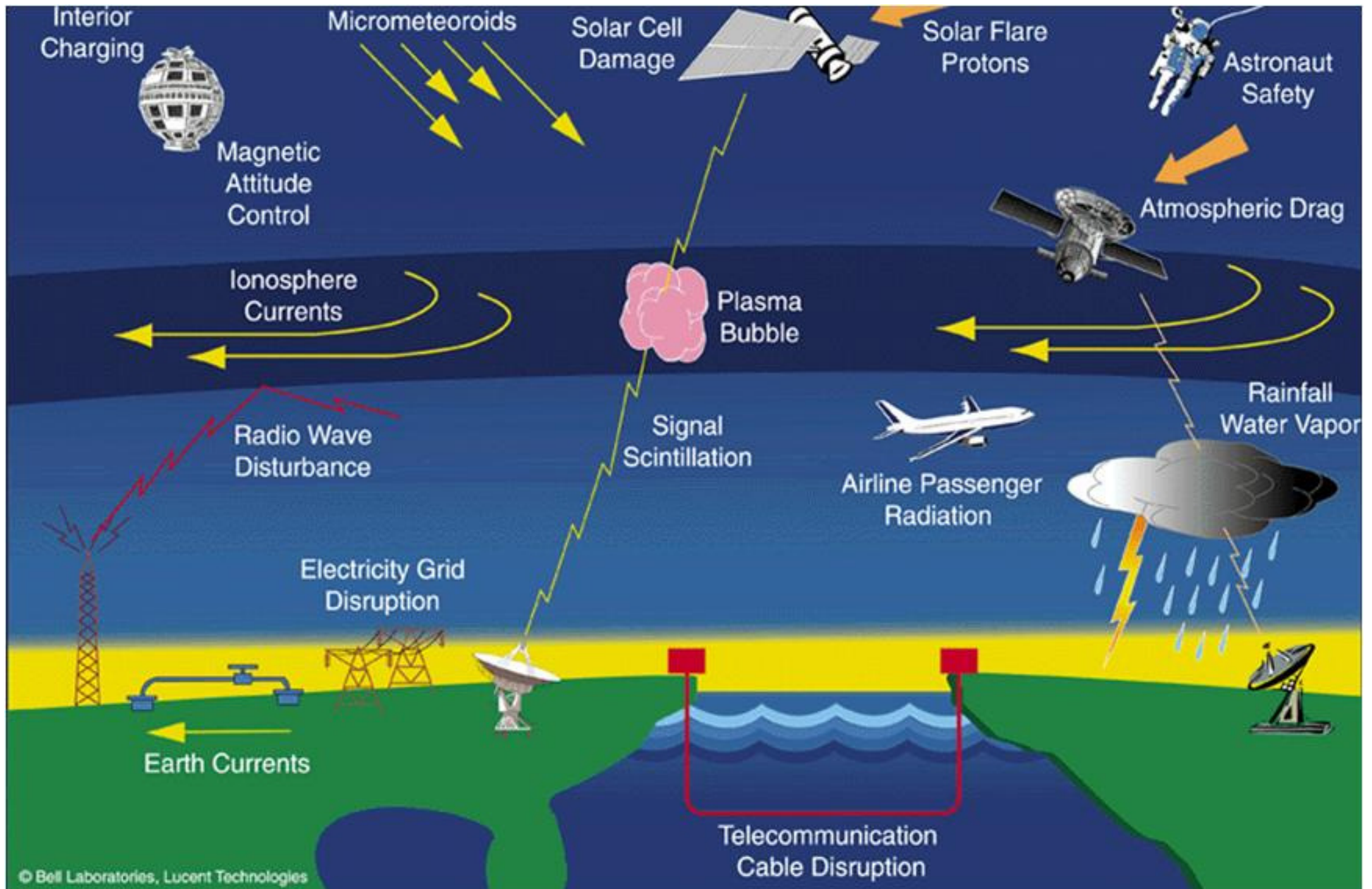


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Courtesy: NOAA

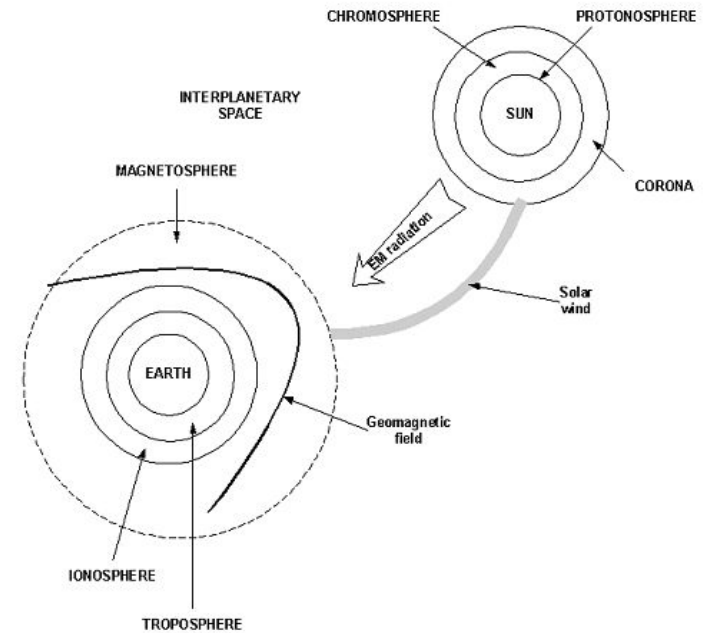
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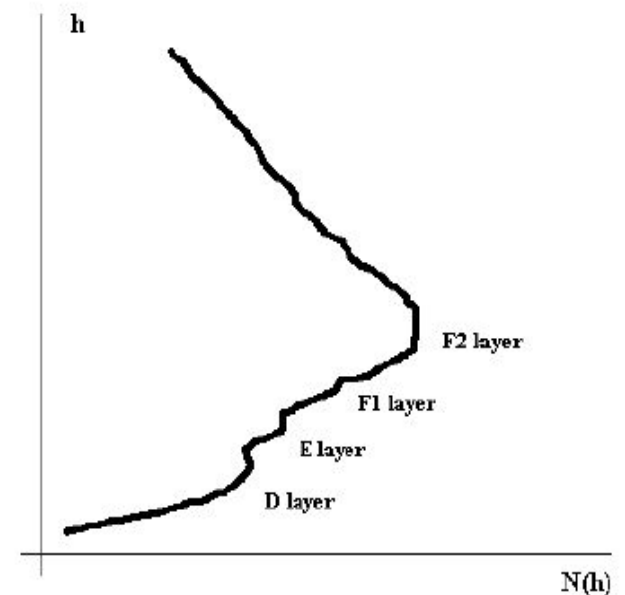
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## • Introduction

- Space weather
- Earth-related environment
- SW effects on GNSS

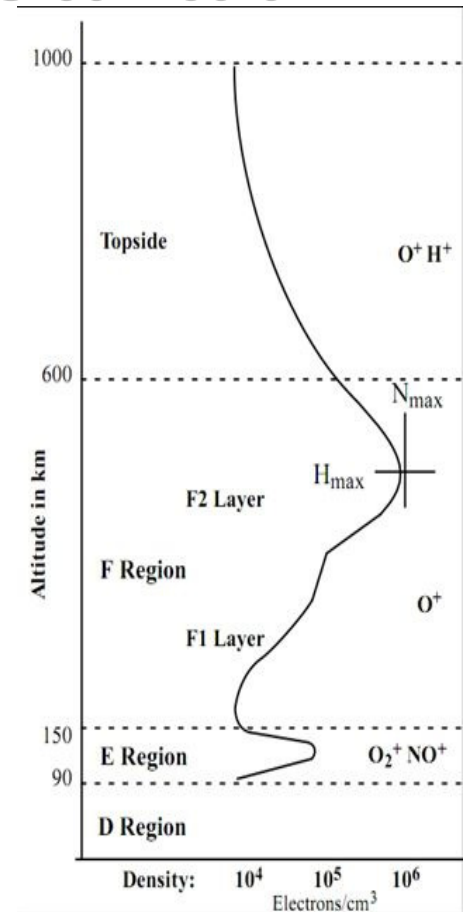


Error source	Equivalent positioning error (bias – random - total) [m]
<i>Satellite and control component errors</i>	
Satellite ephemeris error	2.1 – 0.0 – 2.1
Satellite clock error	2.0 – 0.7 – 2.1
<i>User component errors</i>	
Multipath	1.0 – 1.0 – 1.4
Receiver noise	0.5 – 0.2 – 0.5
<i>Propagation media errors</i>	
Ionospheric delay	4.0 – 0.5 – 4.0
Tropospheric delay	0.5 – 0.5 – 0.7



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- Aim and methodology
  - More detailed understanding of the subject among the GNSS professionals
  - More successful mitigation of space weather and ionospheric effects on GNSS and GNSS-based systems performance and operation
  - Methodology of work: lectures and practical (experimental field) work - an university course



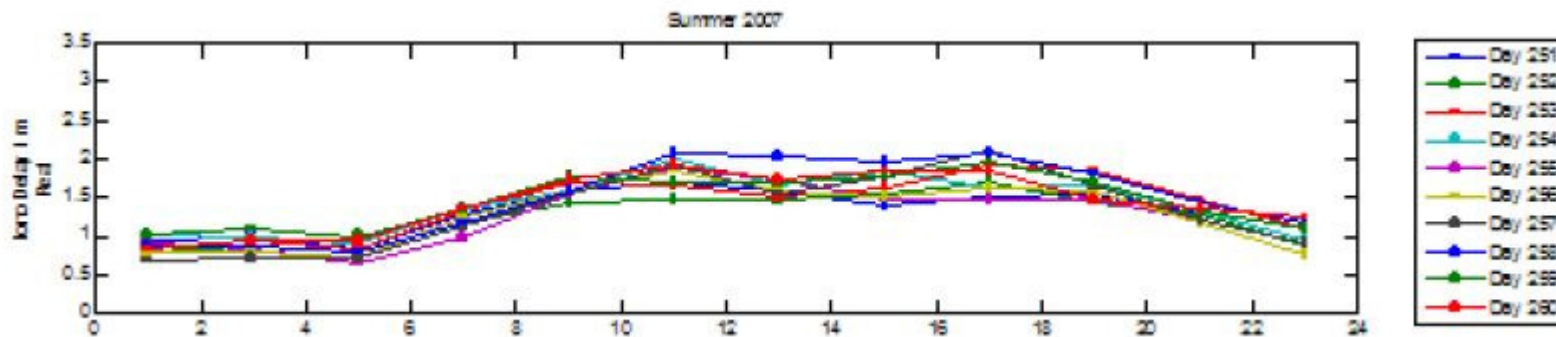
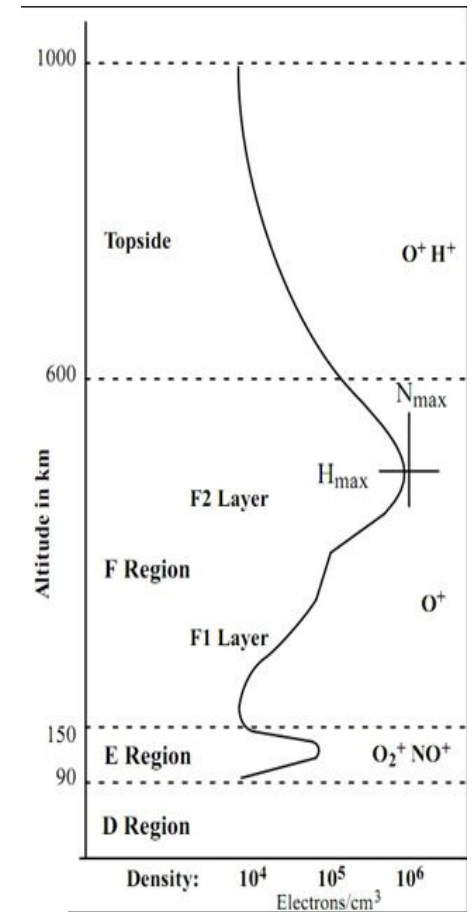
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- Course programme - general outline
  - Space weather
  - Space weather effects on GNSS operation
  - Space weather effects on GNSS performance
  - GNSS-related space weather monitoring
  - Mitigation of space weather effects on GNSS



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- Course programme - Space weather
  - Nature and origins of space weather
  - Solar-terrestrial relationship
  - Geomagnetic environment
  - Ionosphere
  - Modelling the ionosphere





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- Course programme - Space weather effects on GNSS operation
  - GNSS architecture
  - Satellite component
  - Control component
  - Propagation media

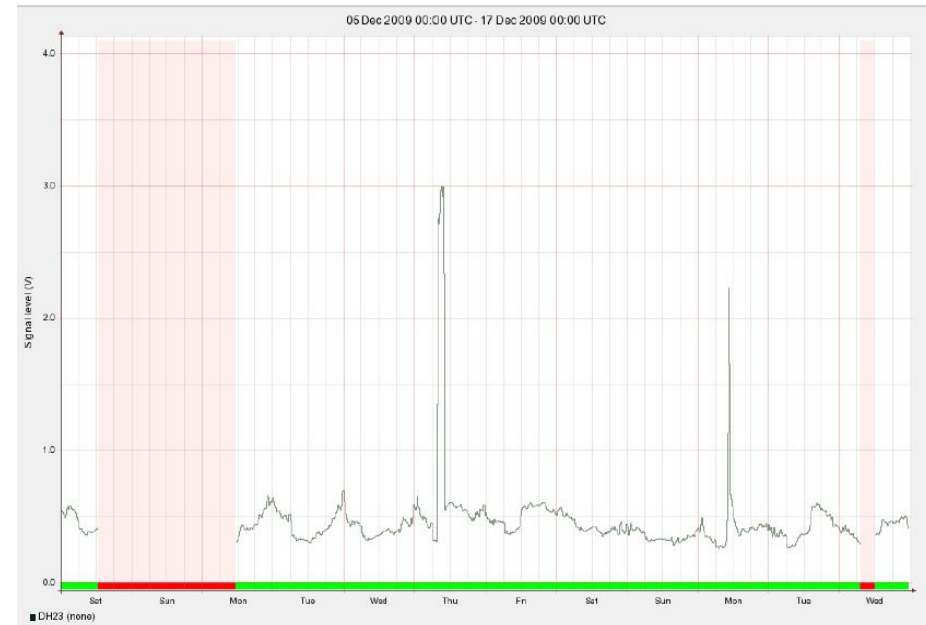


Courtesy: NASA

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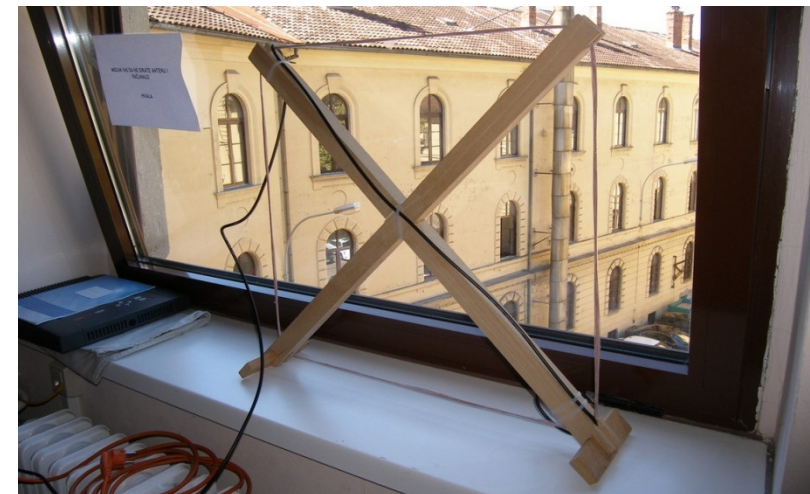
- Course programme - Space weather effects on GNSS performance

- GNSS ionospheric error
- GPS ionospheric delay
- Ionospheric scintillation
- Local ionospheric dynamics
- Other sources of GNSS performance disruptions



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- Course programme - GNSS-related space weather monitoring
  - Essential space weather parameters
  - Instrumentation
  - Satellite observations
  - Terrestrial observations
  - Internet archives of observables
  - Data analysis principles



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- Course programme - Mitigation of space weather effects
  - Modernised GNSS
  - Advanced DSP
  - Assisting and augmenting systems
  - Identification of service disruptions
  - Correction models
  - Alerts and notifications



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- **Resources - Books**

- Davis, K. (1990). Ionospheric Radio. Peter Peregrinus Ltd. London, UK.
- Schunk, R and A Nagy. (2009). Ionospheres: Physics, Plasma Physics and Chemistry (2nd ed). Cambridge University Press. Cambridge, UK.
- Parkinson, B W and J J Spilker, Jr (eds). (1996): Global Positioning System: Theory and Applications (Vol. I.). AIAA. Washington, DC.
- Capderou, M. (2005). Satellites, Orbits and Missions. Springer Verlag France. Paris, France.
- Shumway, R H, D S Stoffer. (2011). Time Series Analysis and Its Applications (with R examples) (3rd ed). Springer Verlag. New York, NY.

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## • Resources - Internet materials

- Zogg, J-M. (2010). GPS: Essentials of navigation (Compedium). u-blox AG. Thalwill, Switzerland. Available at: <http://bit.ly/fhT71T>
- Hapgood, M and A Thomson. (2010). Space weather: Its impact on Earth and implications for business. Lloyd's 360<sup>o</sup> Risk Insight. London, UK. Available at: <http://bit.ly/9Pjk9R>
- Zucchini, W and O Nenadić. (2011). Time Series Analysis with R - Part I. University of Goettingen, Germany. Availbale at: <http://bit.ly/HsiVH>
- Kuhnert, P and B Venables. (2005). An Introduction to R: Software for Statistical Modelling & Computing. CSIRO Mathematical and Information Sciences. Cleveland, Australia.
- Earth-prints. Internet repository of scientific papers. Available at: <http://www.earth-prints.org/>

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- Resources - Space weather and GNSS observables data on internet
- International GNSS Service (NASA). Available at: <http://igscb.jpl.nasa.gov/>
- European Position Determination System (EUPOS). Available at: <http://bit.ly/hPxPLa>
- Space Physics Interactive Data Resource (NOAA). Available at: <http://bit.ly/fOA26E>

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- Resources - Tools
- The R project for statistical computing and graphics (free software, manuals and tutorials). Available at: <http://www.r-project.org/>
- GPStk (GPS Toolkit, University of Texas in Austin). Available at: <http://bit.ly/JMGpy>
- teqc (The Toolkit for GPS/GLONASS/Galileo/SBAS Data, Unavco Facility). Available at: <http://bit.ly/hxDeGn>



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## • Conclusion

- Space weather has considerable effects on GNSS operation and performance
- Importance of proper education and professional advancement of GNSS professionals
- Course programme presented with a detailed list of references - suitable for graduate studies and professional advancement



A scenic view of a coastal town with a harbor, a large mountain in the background, and buildings in the foreground. The water is bright blue and shimmering. A large white ferry is docked at a pier on the left. The town is built on a hillside, and the mountains are covered in green vegetation.

**THANK YOU FOR YOUR ATTENTION!**

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**[rfilejar@vtsbj.hr](mailto:rfilejar@vtsbj.hr)**