GNSS Related Activities to Ionospheric and Tropospheric Studies in Cyprus

Website: http://cyirg.frederick.ac.cy/

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Frederick University

United Nations/Finland Workshop on the Applications of Global Navigation Satellite Systems
23 - 26 October 2023, Helsinki, Finland

UNITED NATIONS
Office for Outer Space Affairs

Frederick University At a glance

Campuses in 2 cities
Nicosia and Limassol

50+ **Years of education experience**

High quality teaching

25+
years of
Research Experience

5 **schools**

80+
Accredited and fully recognized Programs of Study

Covering a wide spectrum of academic domains, including engineering, sciences, the arts, education, humanities, health sciences and architecture

Students from 45+ countries

One of the most reputable Universities of the region

Programs of Study

School of Engineering

Undergraduate

- Architect Engineer *(5 year Diploma – Integrated Master)*
- Civil Engineering
- Electrical Engineering
- Computer Science
- Computer Engineering
- Mechanical Engineering
- Automotive Engineering

Postgraduate

- Structural Engineering
- Electrical Engineering
- Web and Smart Systems
- Manufacturing Engineering Design
- Conservation & Restoration of Historical Structures & Monuments
- Energy Engineering
- Marine Engineering and Management

PhD

- Electrical Engineering
- Computer Engineering
- Computer Science
- Mechanical Engineering
- Civil Engineering
- Architecture

School of Business and Law

Undergraduate

- Business Administration
- Accounting and Finance
- Maritime Studies
- Law

Postgraduate

- Master of Business Administration (MBA)
- International Trade and Shipping Management
- Maritime Law & Shipping Management
- Health Management*
- Public Law

PhD

- Management
- Law

School of Arts, Communication and Cultural Studies

Undergraduate

- Visual Communication
- Interior Design
- Fashion and Image Design
- Journalism and Media
- Communication*

Postgraduate

- Visual Arts

PhD

- Art and Design Practices

School of Education and Social Sciences

Undergraduate

- Physical Education and Sport Sciences*
- Primary Education*
- Pre-Primary Education*
- Psychology*
- Social Work*

Postgraduate

- Education for Sustainable Development and Social Change
- Educational Studies: Curriculum & Instruction
- Special Education*
- Educational Administration and Leadership*
- Adult Education*
- Social Work and Social Administration*

PhD

- Education*
- Social Work, Social Policy and Administration*

School of Health Sciences

Undergraduate

- Nursing*
- Pharmacy *(5 years – Integrated Master)**

Postgraduate

- Advanced Health Care*
- Health Management*
- Advanced Cosmetic Science and Natural Health Products

PhD

- Health Sciences*
- Pharmacy

Distance Learning programs

Undergraduate

- Business Administration*

Postgraduate

- Adult Education*
- Special Education*
- Educational Administration and Leadership*
- Educational Studies: Curriculum & Instruction*
- Education for Sustainable Development and Social Change
- Health Management*
- Community Health Care*
- MBA
- MBA with Specialisation in Public Policy and Management*
- International Trade and Shipping Management
- Maritime Law and Shipping Management
- European Law*
- Web and Smart Systems
- Intercultural Studies and Greek as a 2nd Language*
- Conservation & Restoration of Historical Structures & Monuments

**This program of study is offered in Greek*

Research & Innovation

Links with

- **680** Universities
- **250** Research Centers
- **728** Companies
- **796** Public Authorities & NGOs

200+ RDI projects in the last 10 years

40+
Research Units

Active in research areas
- Arts, Education & Culture
- Civil Engineering & Architecture
- Electrical and Electronics Engineering
- Energy, Environment & Sustainable Development
- Health Sciences & Biotechnology
- Information & Communication Technologies
- Mechanical Engineering
- Social Sciences & Economics

50+ new RDI projects running in 2021/22

44+ Successful Projects implemented

€12 Million Total Budget

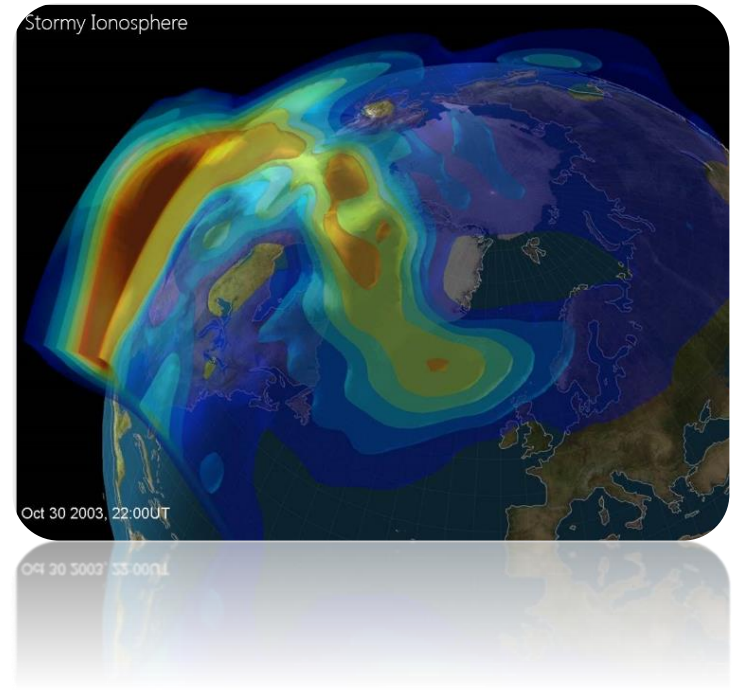
25+ Years Of Research Experience

Cyprus Ionospheric Research group (CyIRG) research scope

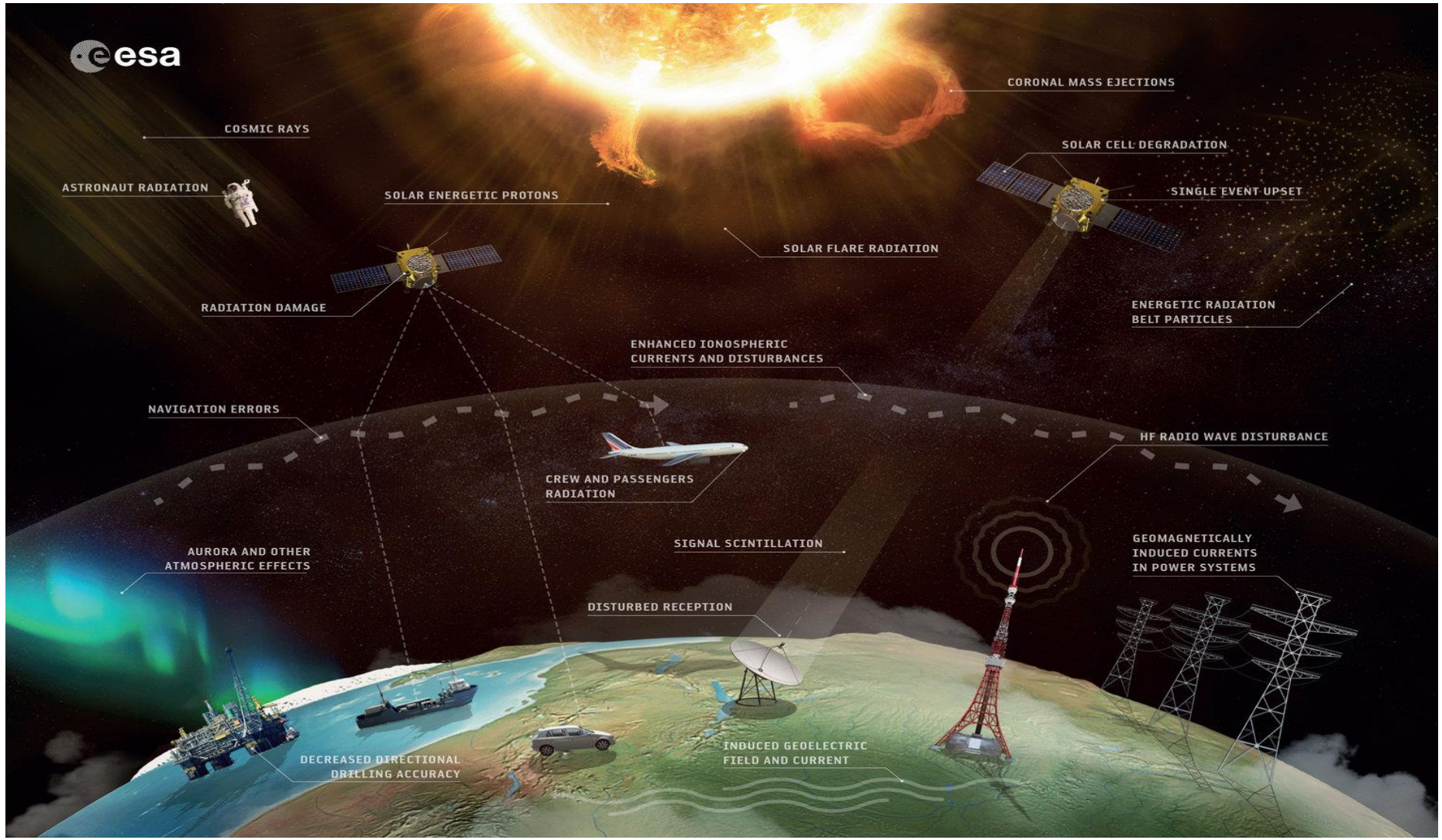
- The research activity of the Cyprus Ionospheric Research group lies in the context of the study and mitigation of ionospheric effects on radio systems.

- It is in the position to pursue this aim by means of its infrastructure that facilitates continuous remote sensing of the state of the ionosphere, within various parts of the electromagnetic spectrum.

- Detrimental ionospheric effects on radio systems usually have their origin on the disturbed state or natural variability of the Sun and therefore the group has a genuine research interest on Space Weather and its subsequent impact on the Upper Atmosphere.



Cyprus Ionospheric Research group (CyIRG) research scope



Permanent Cyprus Ionospheric Research Group researchers

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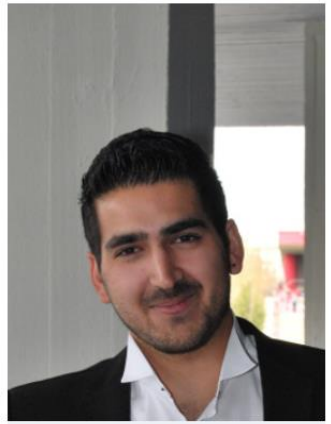
Cyprus Ionospheric Research Group Post-doctoral researchers

Dr. Arun Kumar Singh
Cyprus Ionospheric Research
Group Post-doctoral researcher



Dr. Christos Giannaros
Cyprus Ionospheric Research
Group Post-doctoral researcher

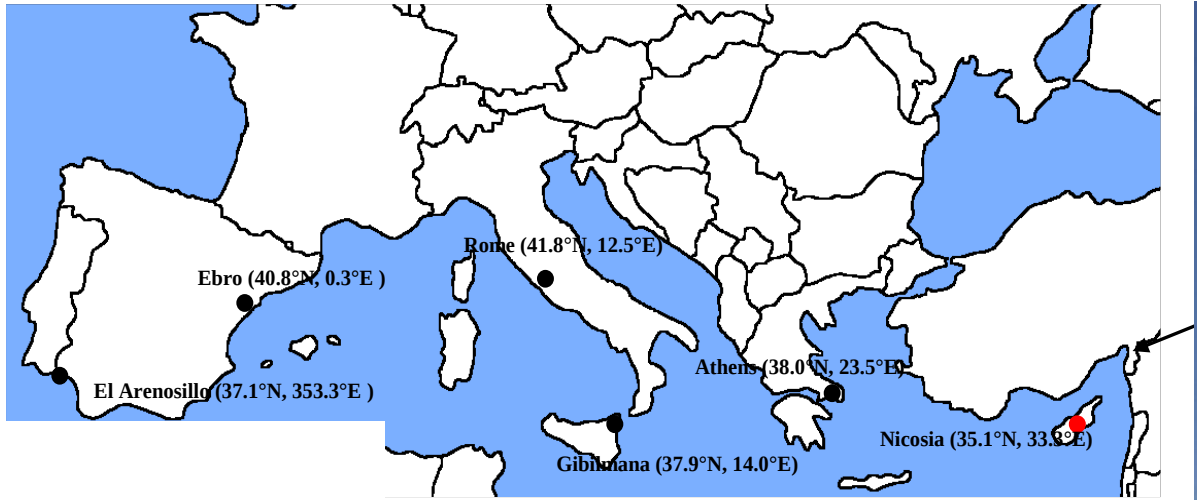
Dr. Antonios Constantinides
Cyprus Ionospheric Research
Group Post-doctoral researcher

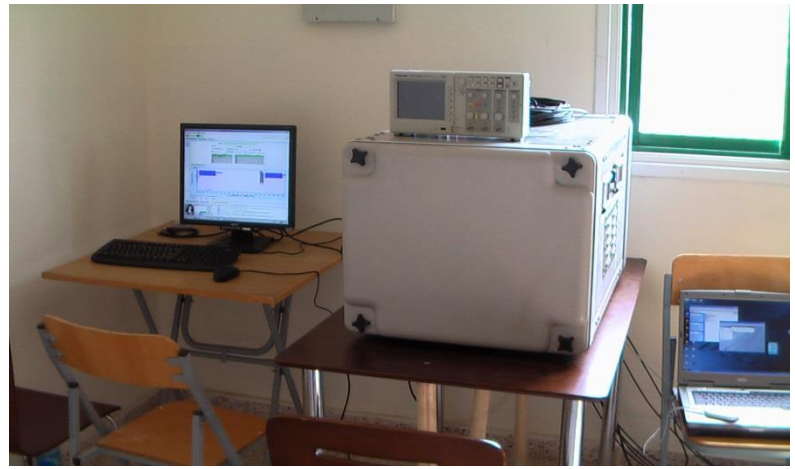
Dr. Krishnendu Paul
Cyprus Ionospheric Research
Group Post-doctoral researcher

Dr. Md Golam Mostafa
Cyprus Ionospheric Research
Group Post-doctoral researcher

CYPRUS DIGITAL IONOSONDE

More than 15 ground-based ionosondes are currently available covering European ionosphere. The recently started Nicosia DPS-4D ionosonde station is expected to introduce new opportunities for real-time ground based ionospheric operations in the Mediterranean area.





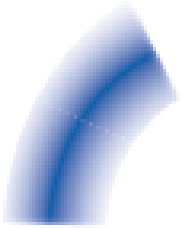
SERVice for ImproviNg Galileo operation over Cyprus (SERVING)

Specific Scientific and Technological Objectives:

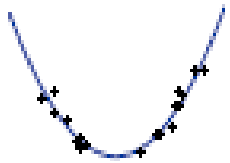
- ✓ Explore techniques to improve and optimize the Galileo single frequency users' positioning algorithm in a context of assisted GNSS driven by a regional and therefore more accurate ionospheric representation

Basic idea

- ✓ On a long-term scale this improvement is achieved through updating of the long-term median ionospheric characteristics (in the form of 12 files)
- ✓ On a short-term scale this improvement is enhanced by driving the NeQuick-G algorithm with a more accurate estimation of the ionisation level obtained with a GNSS receiver in Cyprus on a local scale as opposed to a less accurate global scale estimation which is applied in the context of Galileo



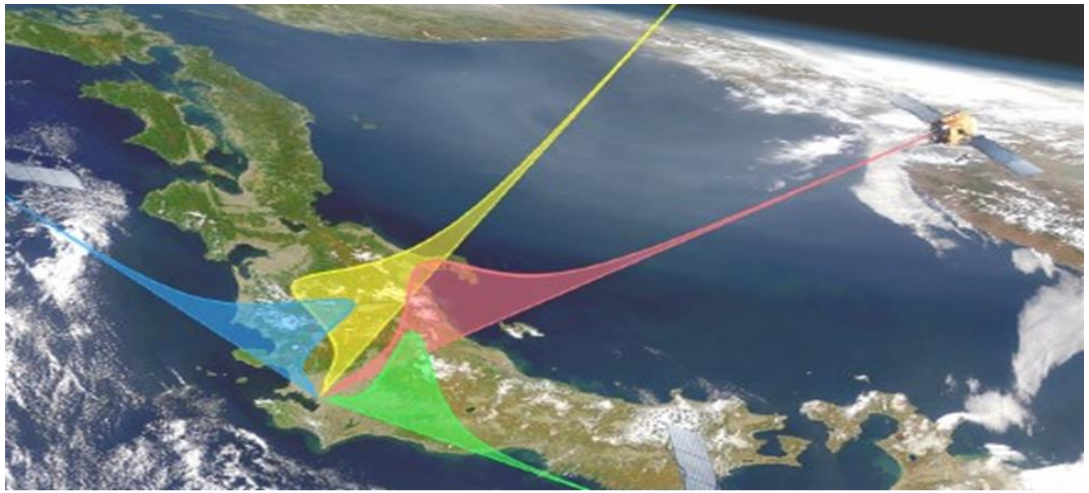
Measure sTEC

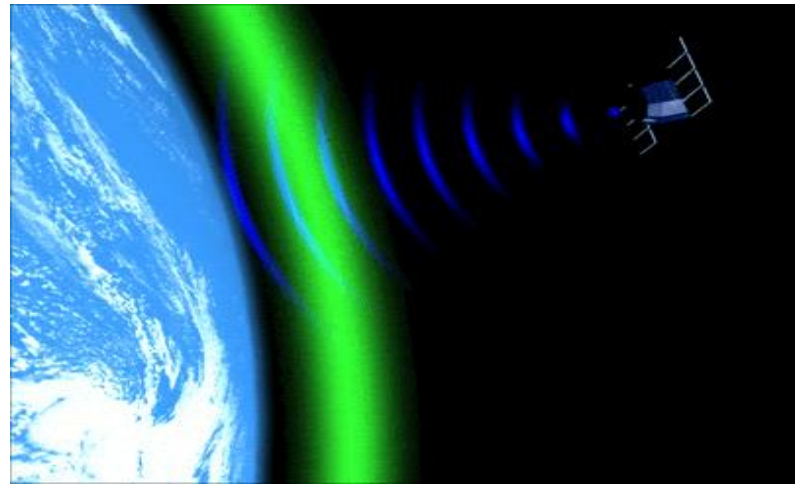


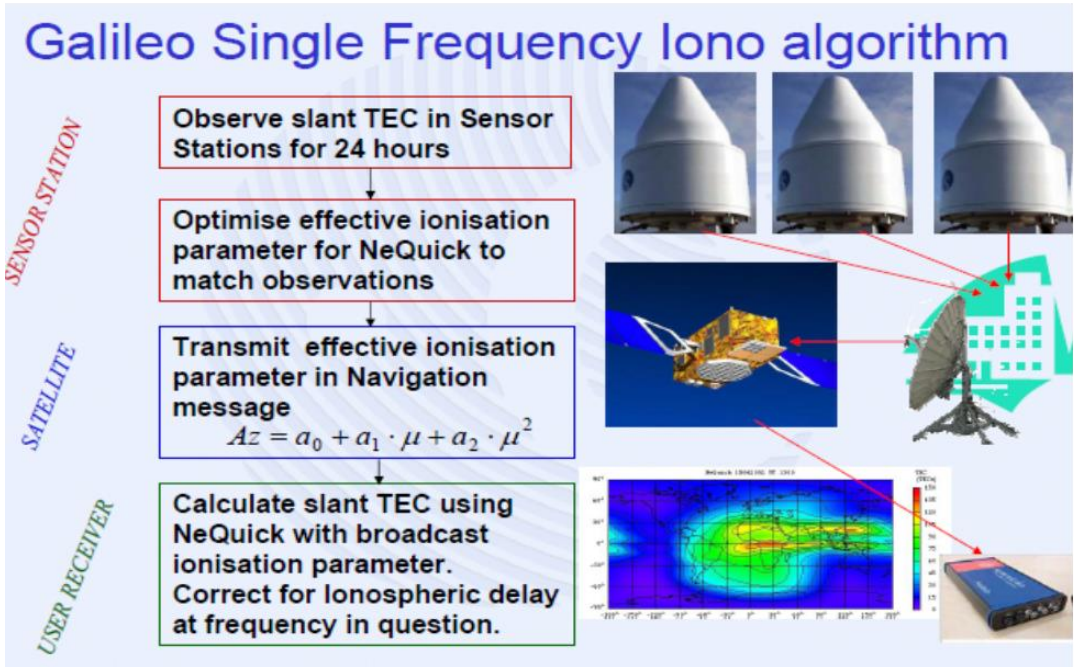
Optimise *Az(μ)*

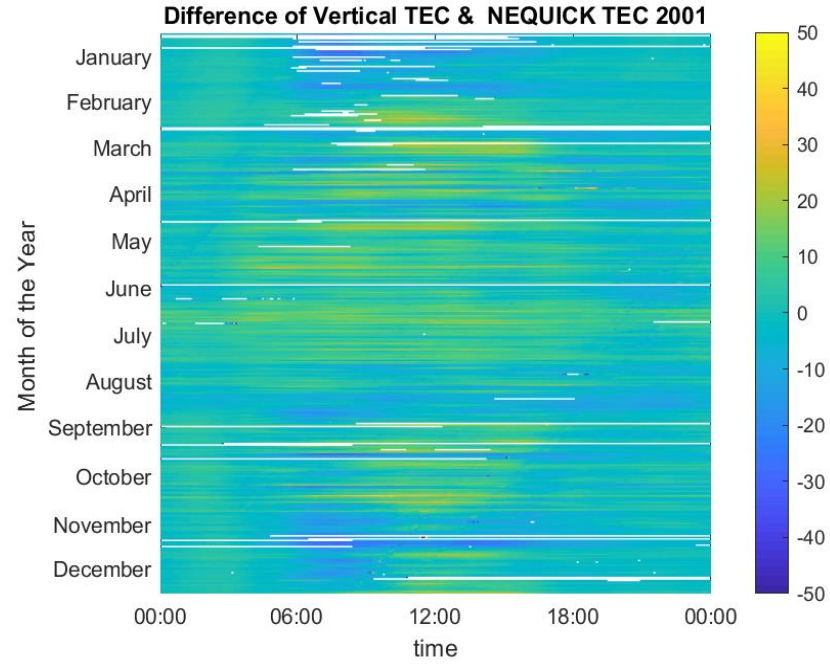
Run NeQuick

SERVice for **I**mprovi**N**g **G**alileo operation over Cyprus (**SERVING**)

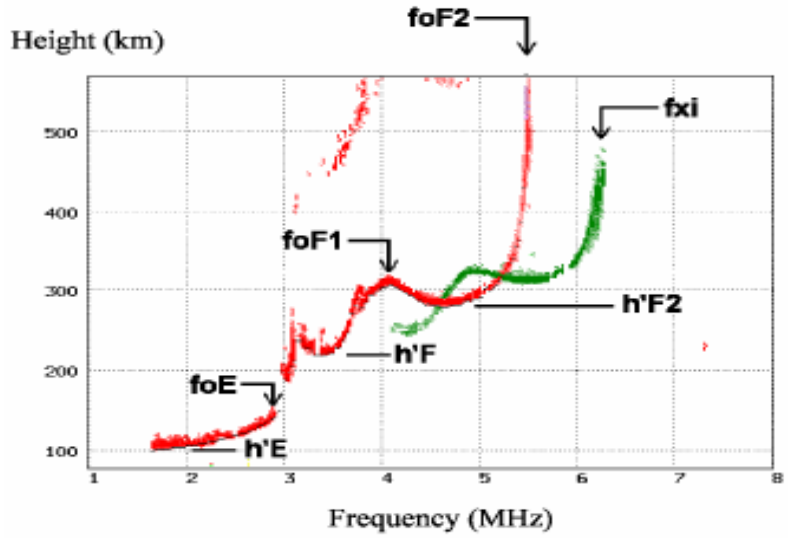


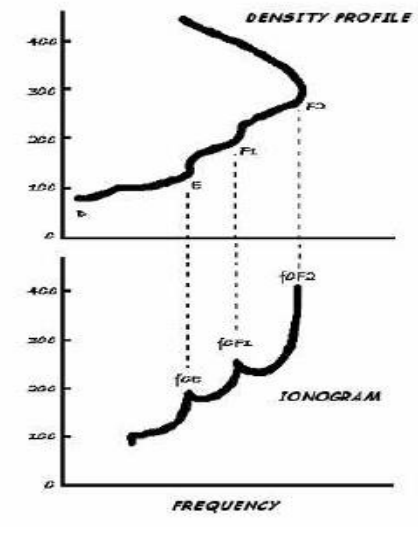


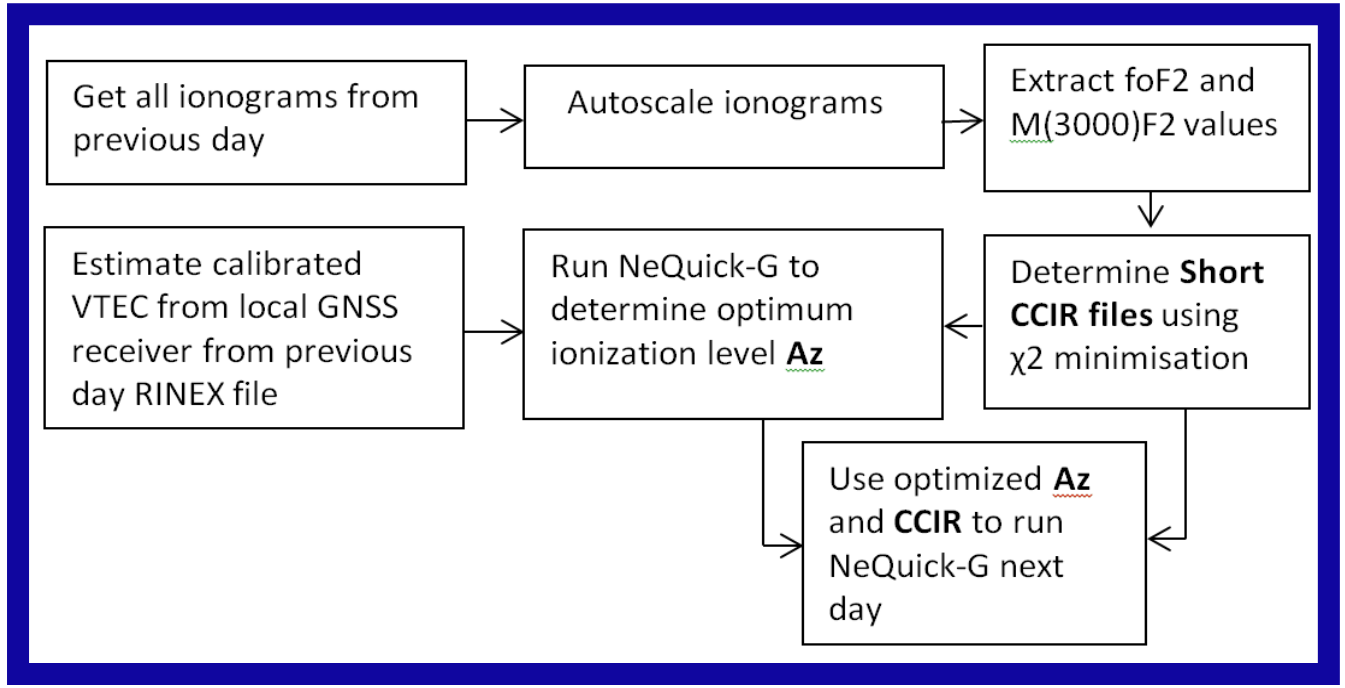




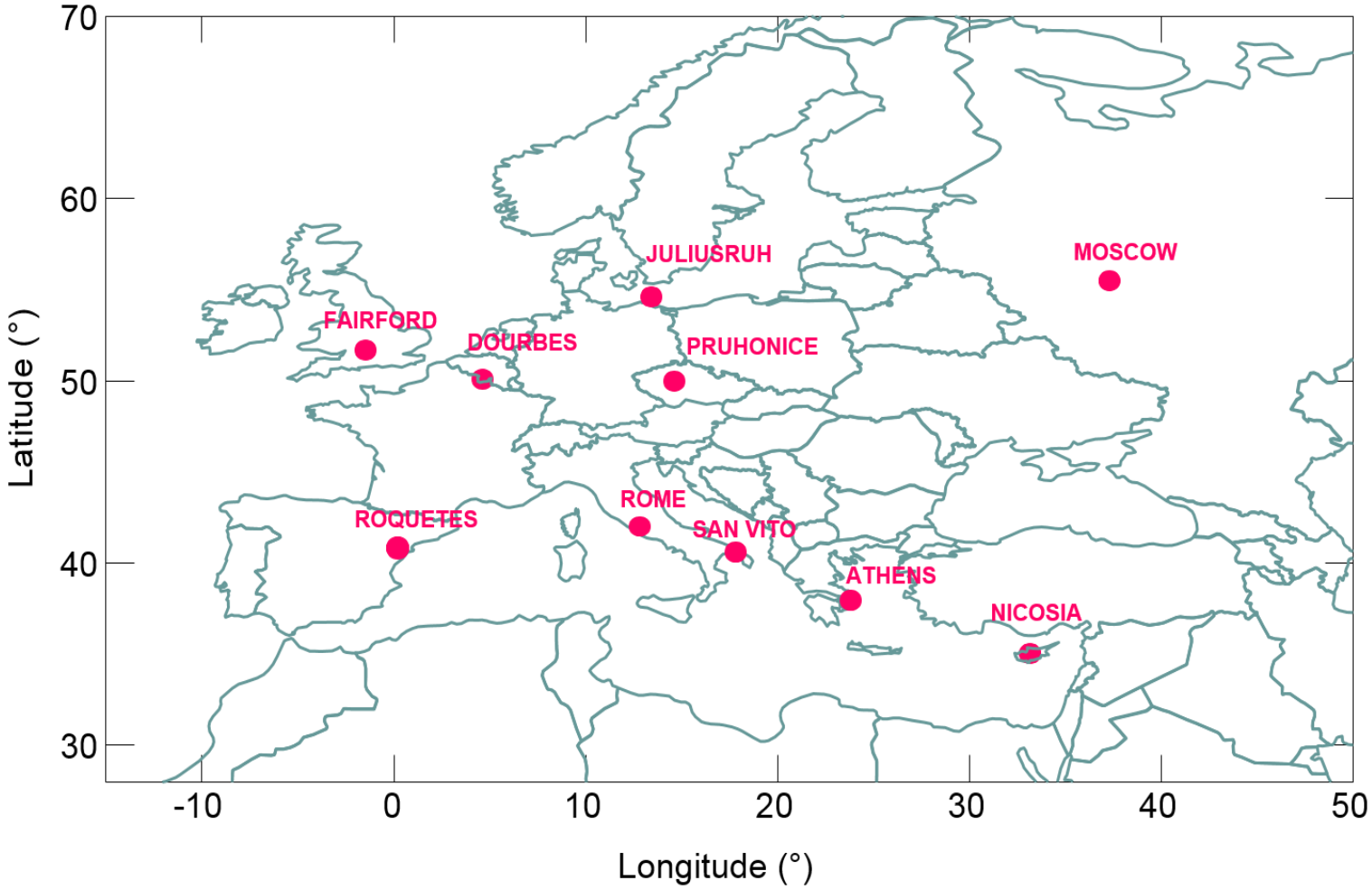
SERVice for **I**mprovi**N**g **G**alileo operation over Cyprus (**SERVING**)







SERVING prospects over Europe

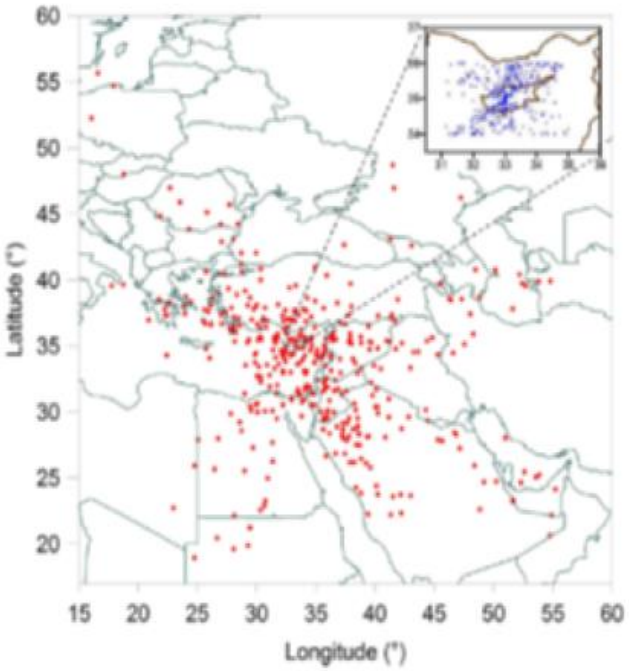


We can apply the SERVING concept over Europe with good ionosonde coverage

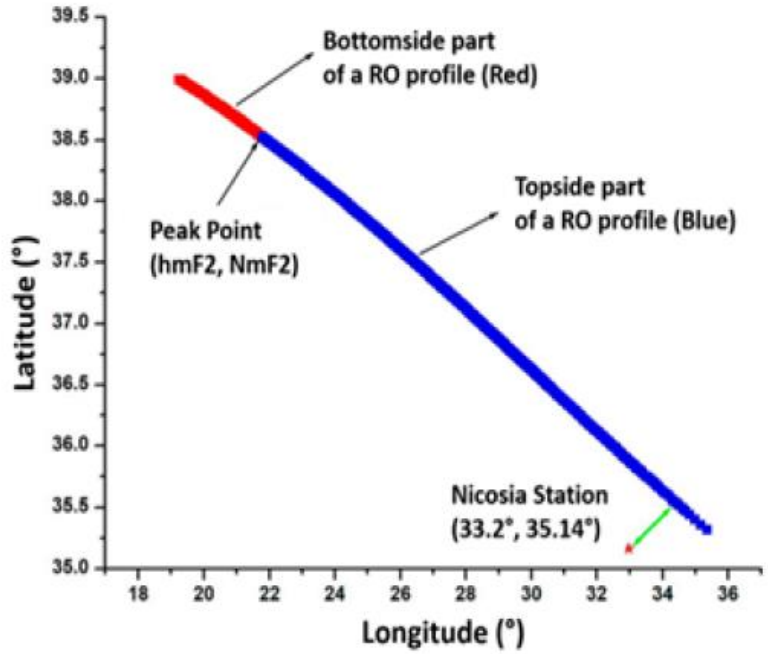
SERVING prospects on a global scale

We can apply the SERVING concept in any part of the world that operates an ionospheric sounder (within a radius of 1000 km)

Potential Enhancements in Ionospheric Monitoring under SSA (PEIMSSA ESA PECS activity)



(a)

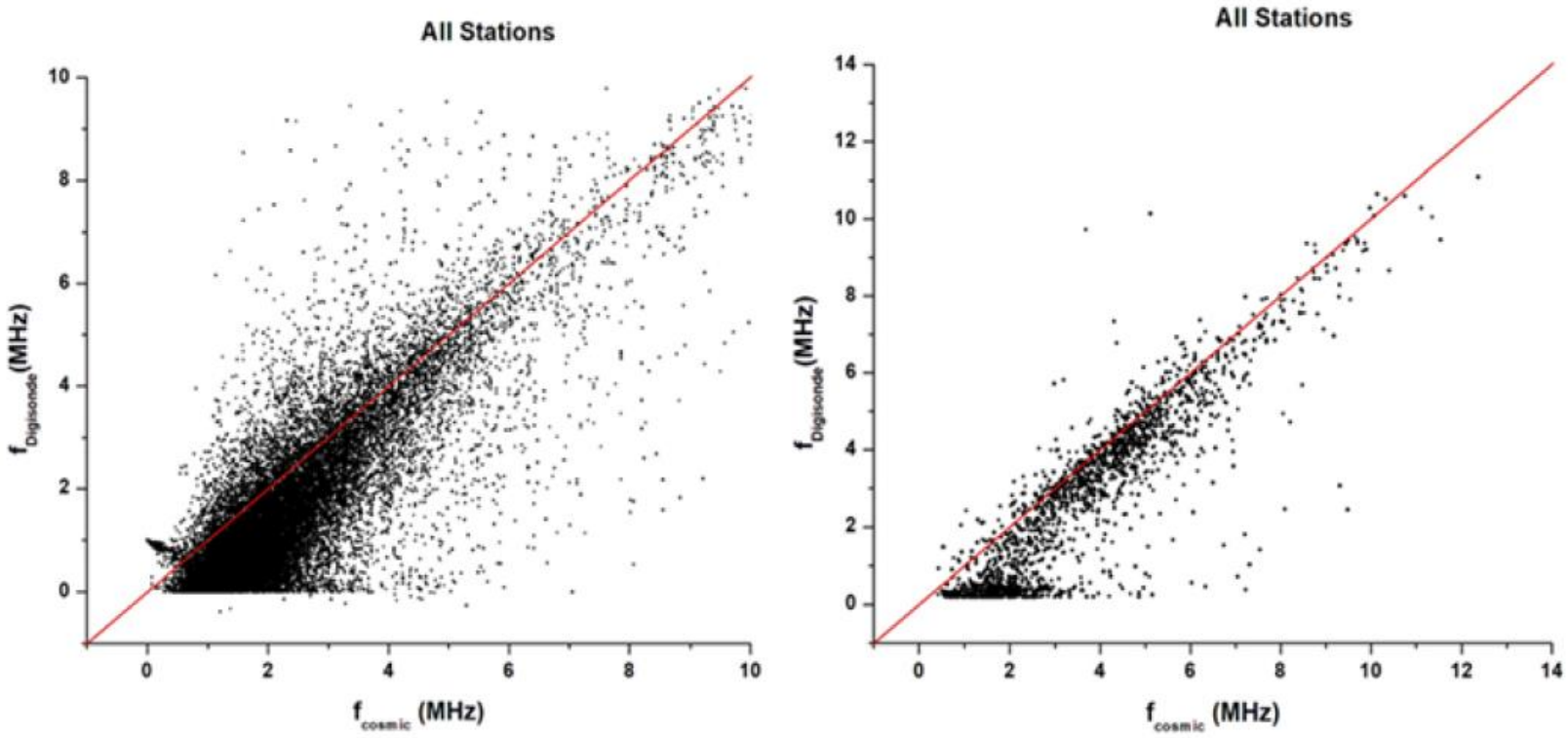


(b)

RO-Digisondes topside-bottomside difference investigation

(a) *Position of F3/C RO EDP NmF2/hmF2 (Red) and corresponding topside EDP Ne (Blue) nearest to Nicosia ionosonde* ***(b)*** *F3/C RO EDP ground projection with respect to latitude and longitude around Nicosia.*

Potential Enhancements in Ionospheric Monitoring under SSA (PEIMSSA ESA PECS activity)

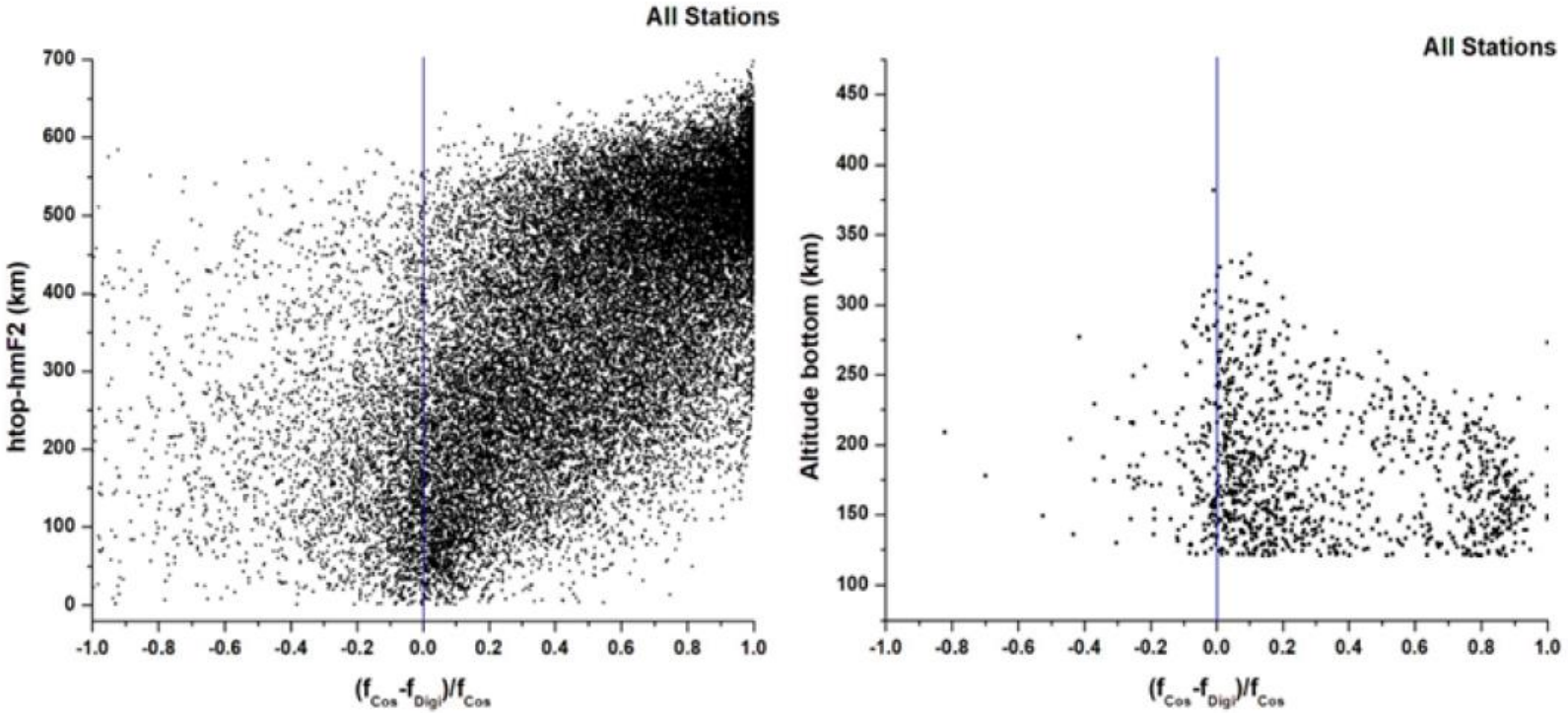


(a) Topside (b) Bottomside

***(a)** Topside and **(b)** Bottomside scatter plots of ionosonde vs F3/C plasma frequency for all European stations.*

RO-Digisondes topside-bottomside difference investigation

Potential Enhancements in Ionospheric Monitoring under SSA (PEIMSSA ESA PECS activity)

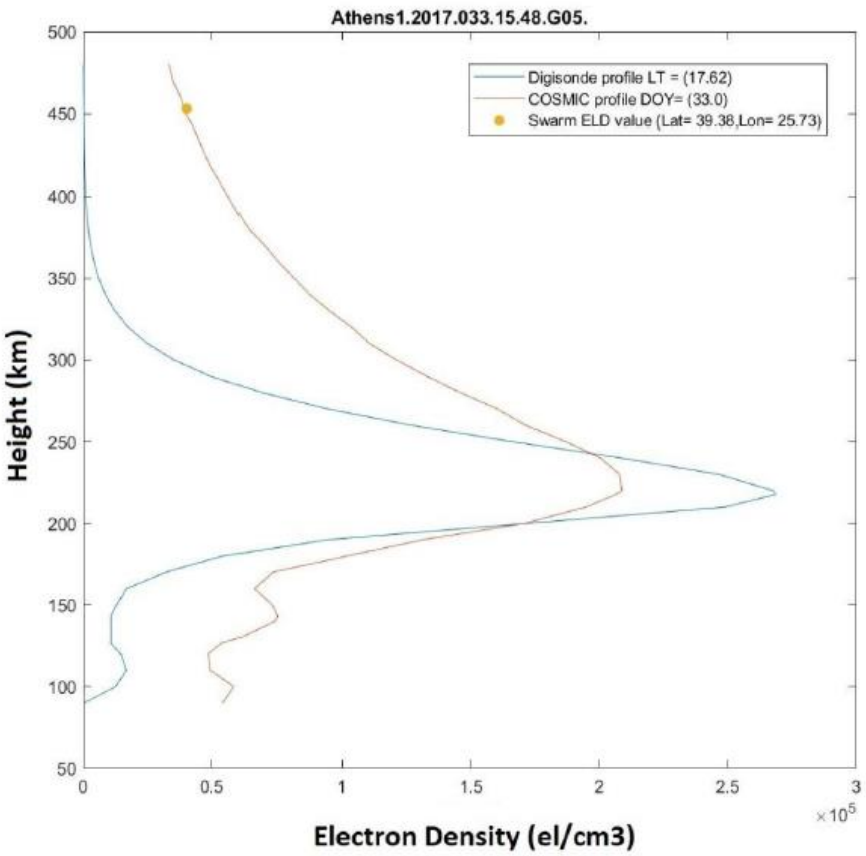


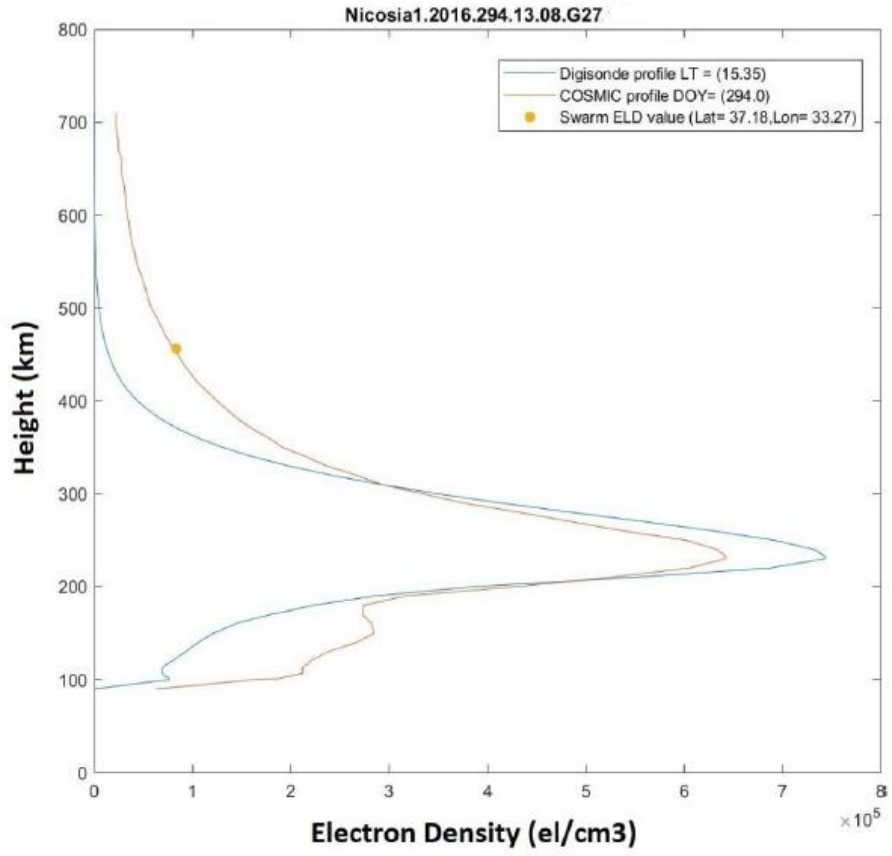
(a) Topside (b) Bottomside

(a) *Topside and* ***(b)*** *Bottomside plasma frequency relative difference from colocated ionosonde and F3/C RO EDPs over all stations.*

RO-Digisondes topside-bottomside difference investigation

Potential Enhancements in Ionospheric Monitoring under SSA (PEIMSSA ESA PECS activity)

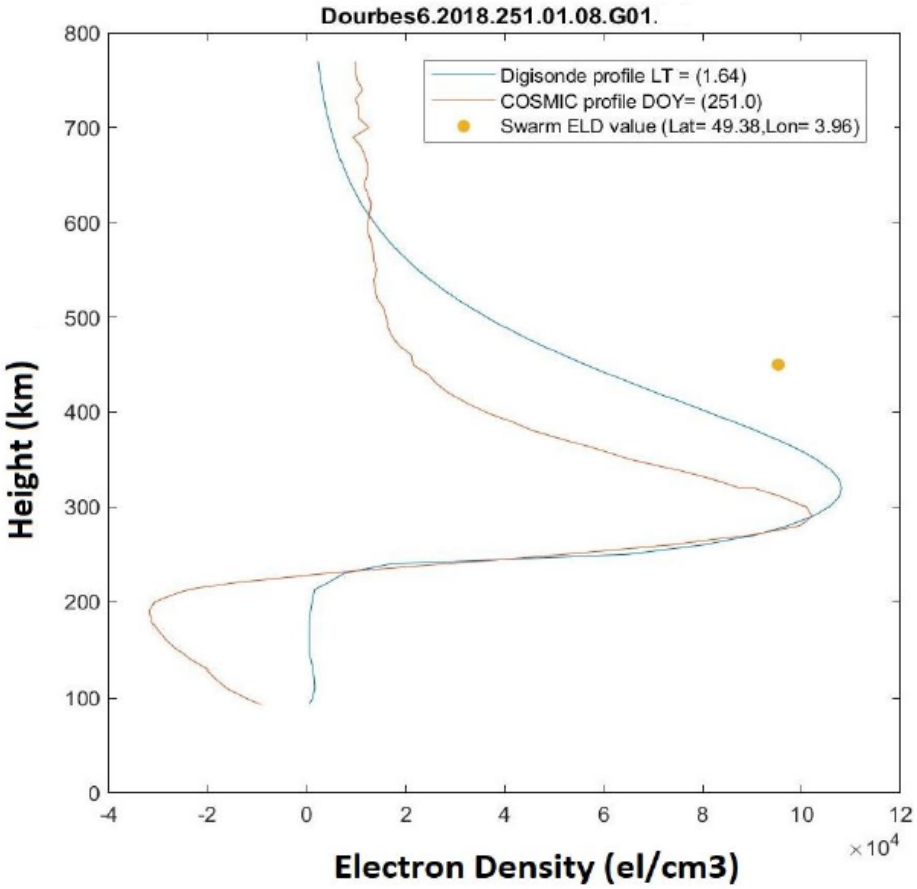


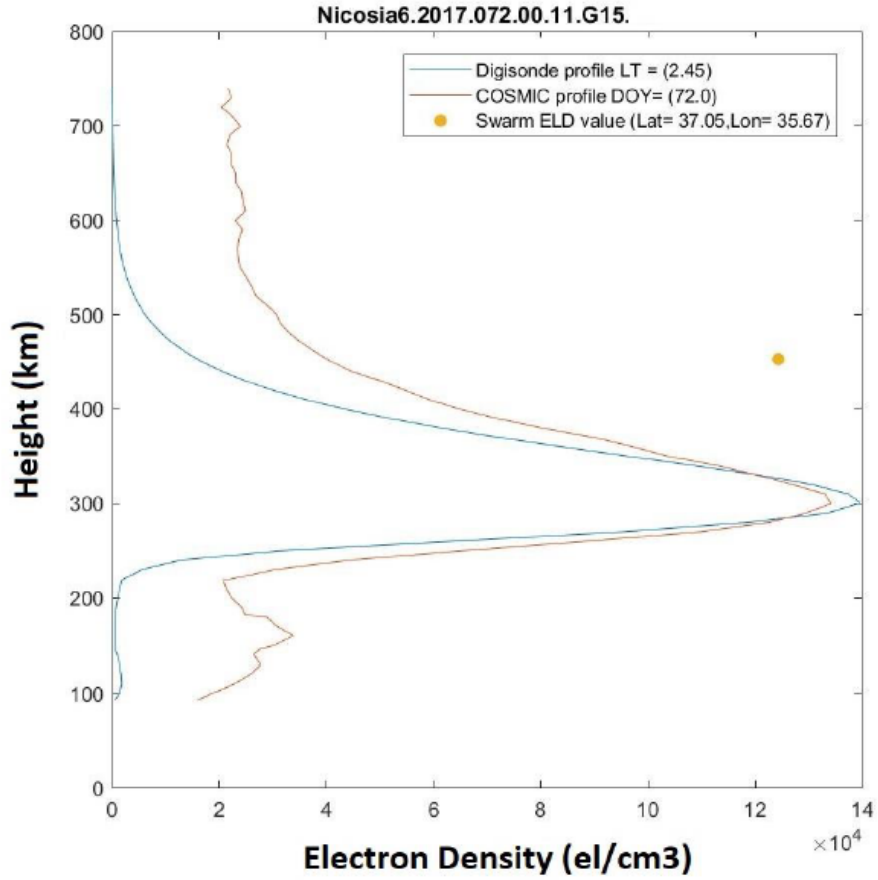


RO-COSMIC-Digisondes topside difference investigation

Colocated EDPs in space and time from COSMIC and Digisondes and Swarm Ne

Potential Enhancements in Ionospheric Monitoring under SSA (PEIMSSA ESA PECS activity)





RO-COSMIC-Digisondes topside difference investigation

Colocated EDPs in space and time from COSMIC and Digisondes and Swarm Ne

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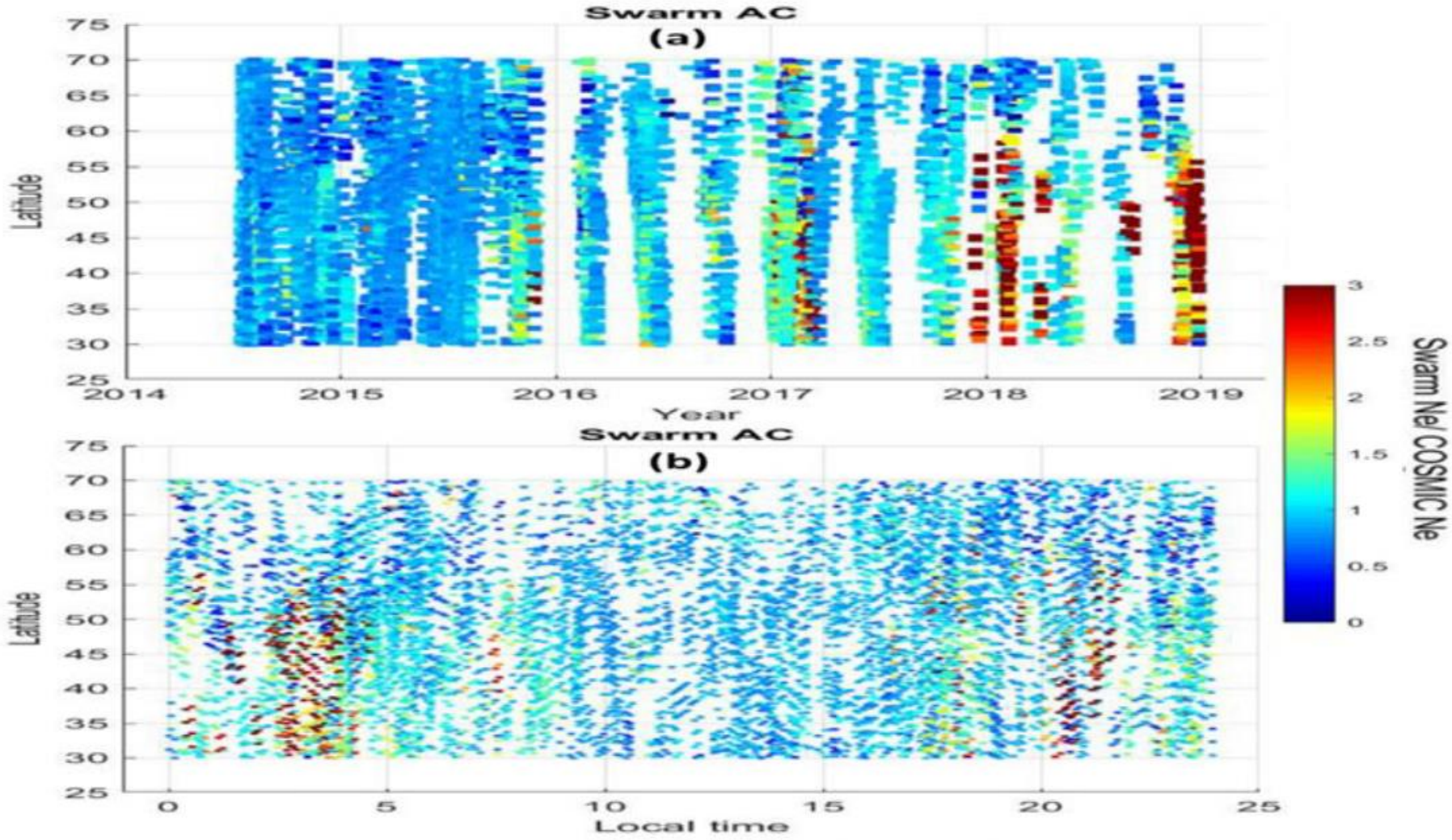
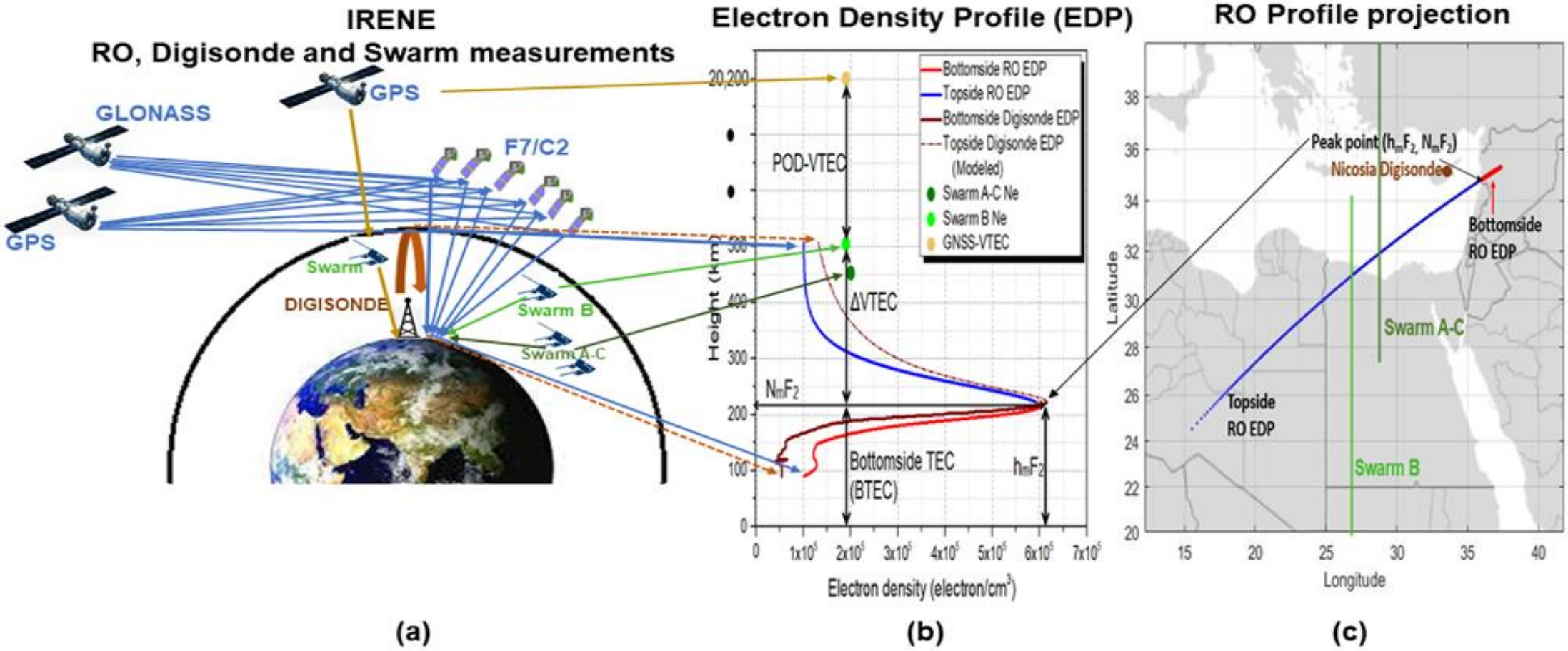
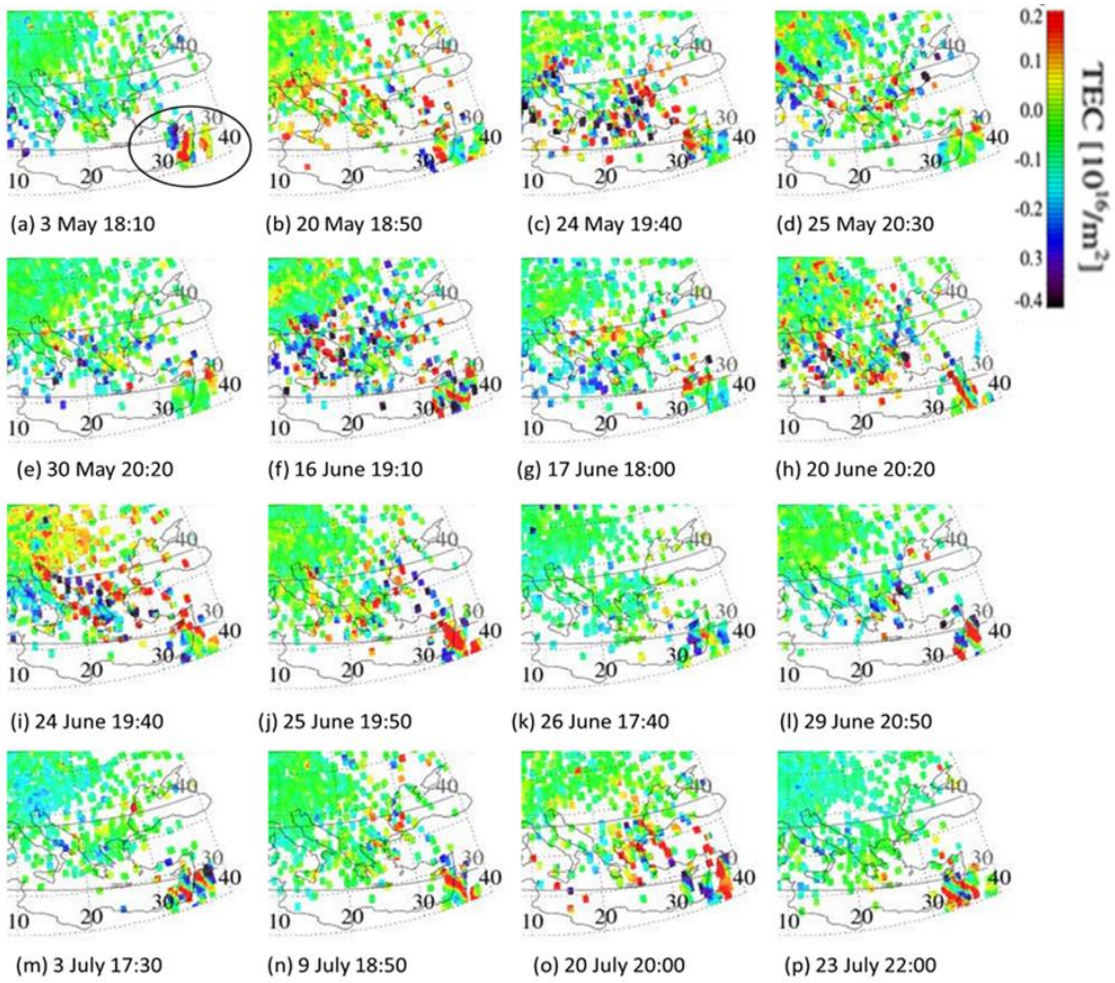


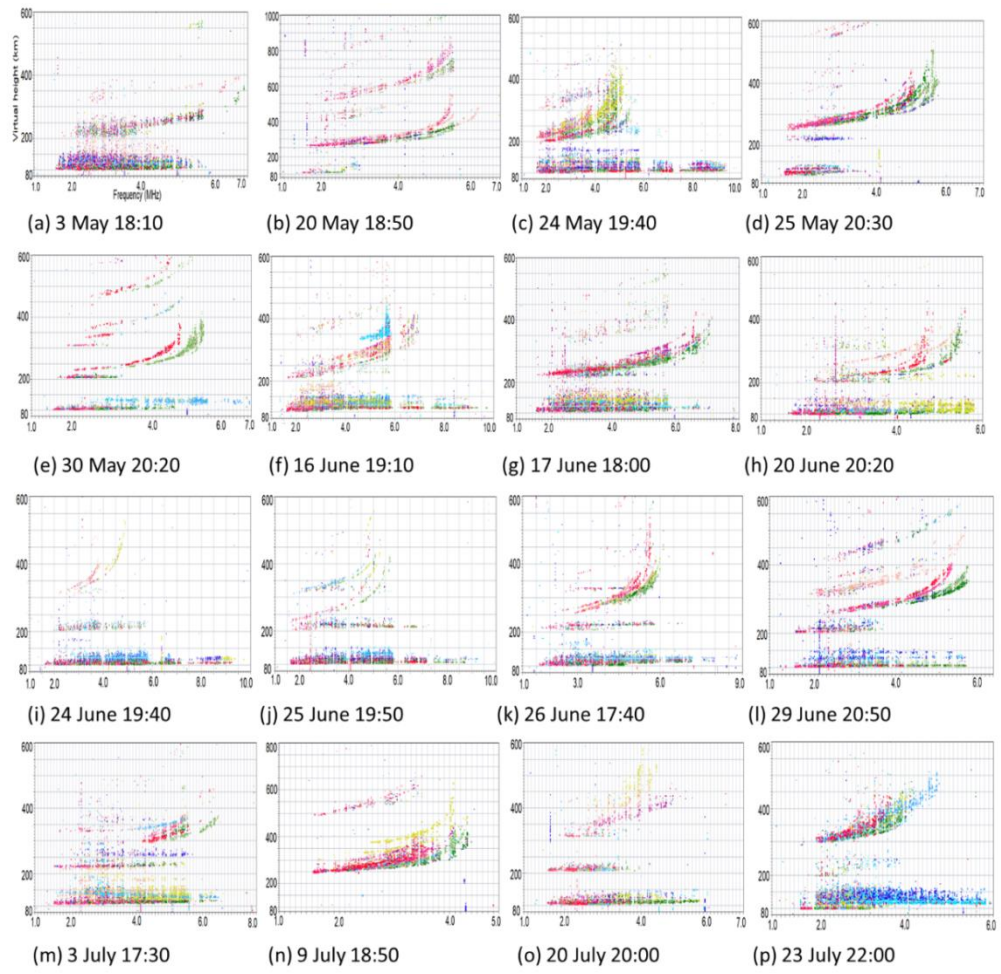
Latitude variation of the ratios of Swarm AC Ne to F3/C Ne at 460 km and their variation w.r.t. ***(a)*** *Year and* ***(b)*** *Local Time over the European region for years 2014-2018.*

Ionospheric topside studies (IRENE ESA PECS activity)



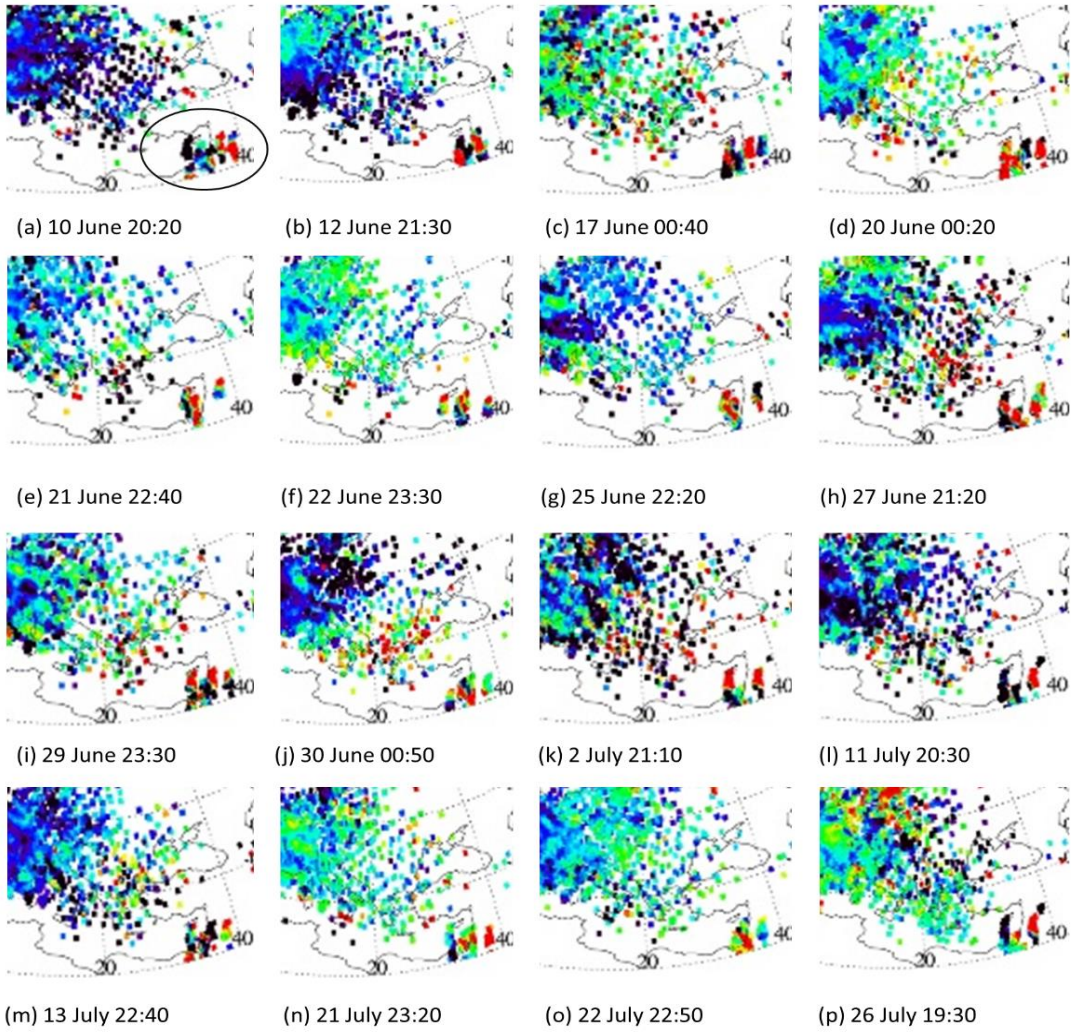
DRAWING maps indicating MSTID activity during every spread F event over Cyprus (indicated with a circle on the top left) during Summer of 2009 (low solar activity)

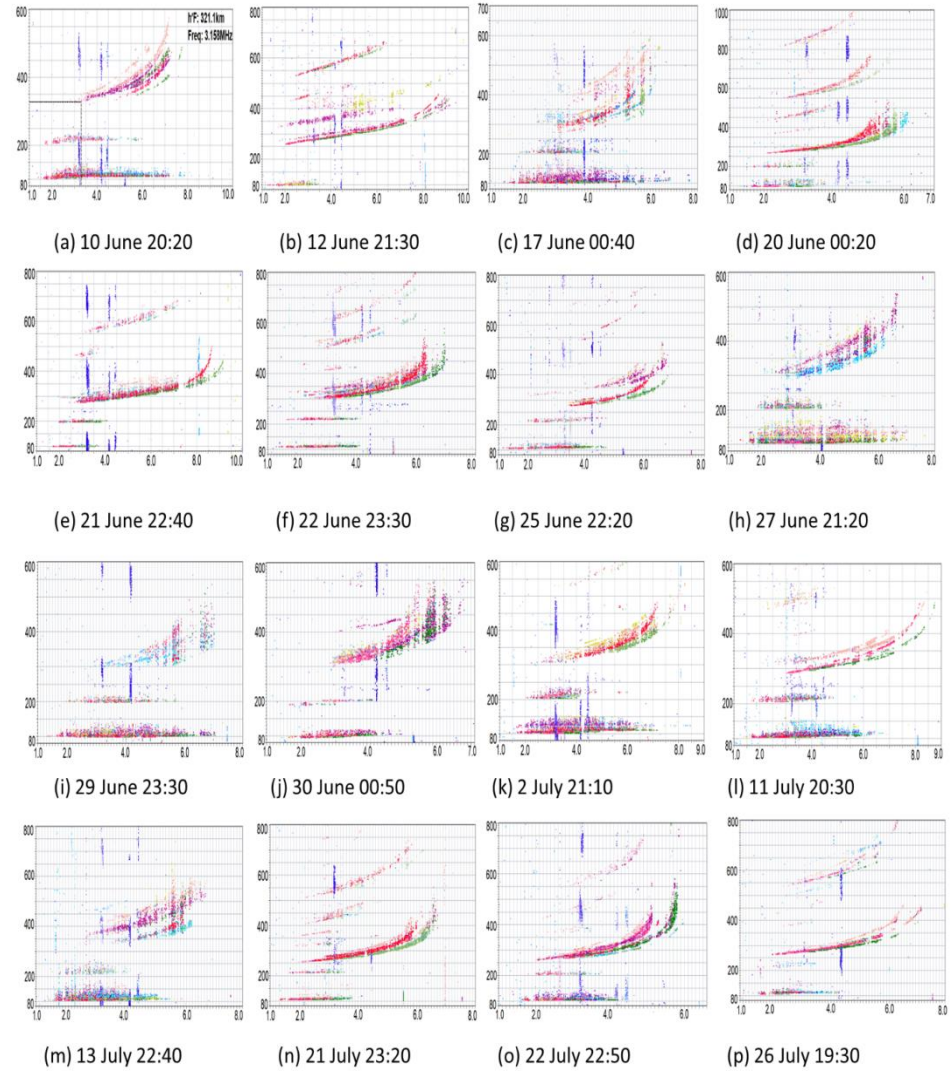




DRAWING maps indicating MSTID activity during every spread F event over Cyprus (indicated with a circle on the top left) during Summer of 2009 (low solar activity)

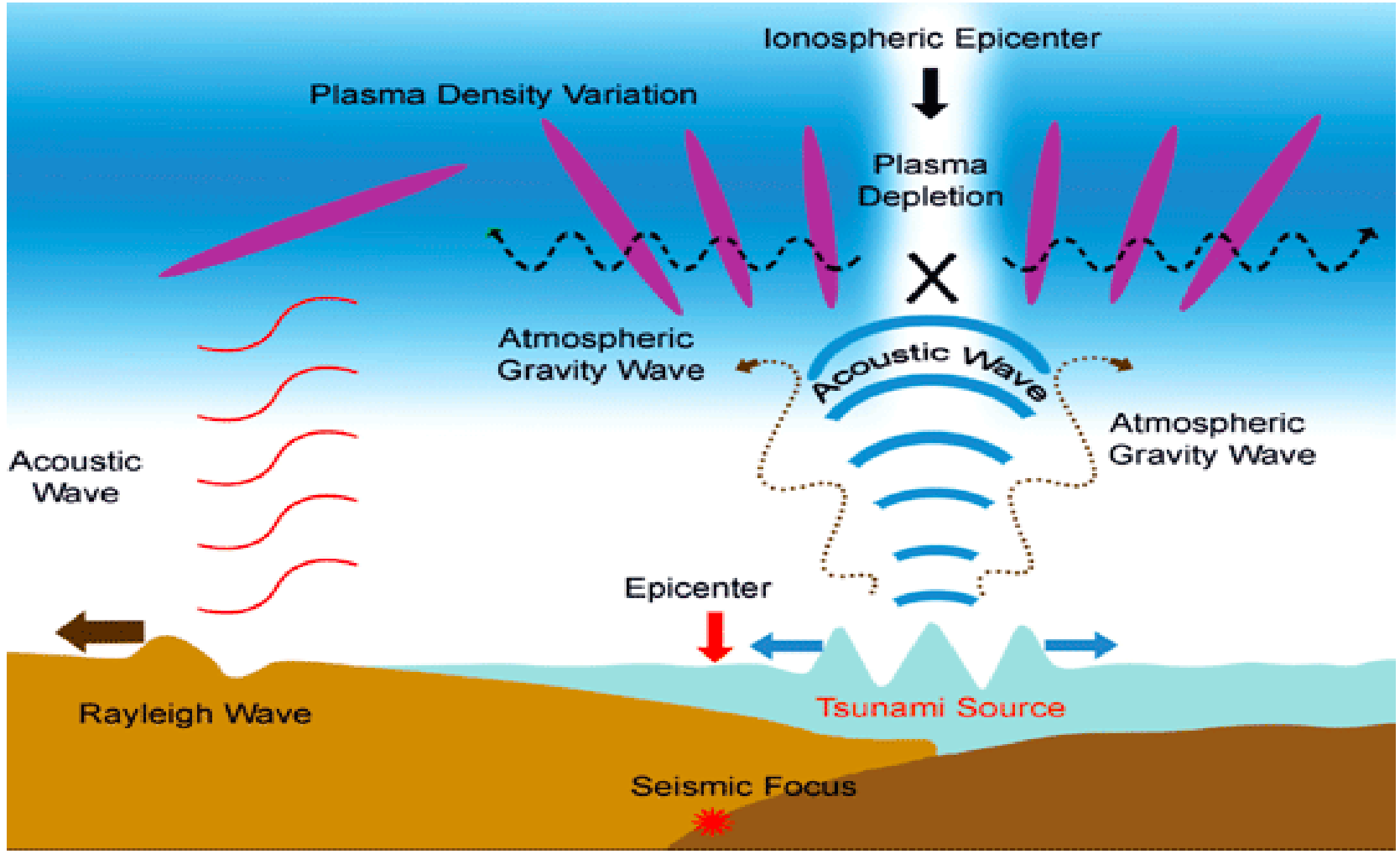
DRAWING maps indicating MSTID activity during every spread F event over Cyprus (indicated with a circle on the top left) during Summer of 2014 (high solar activity)



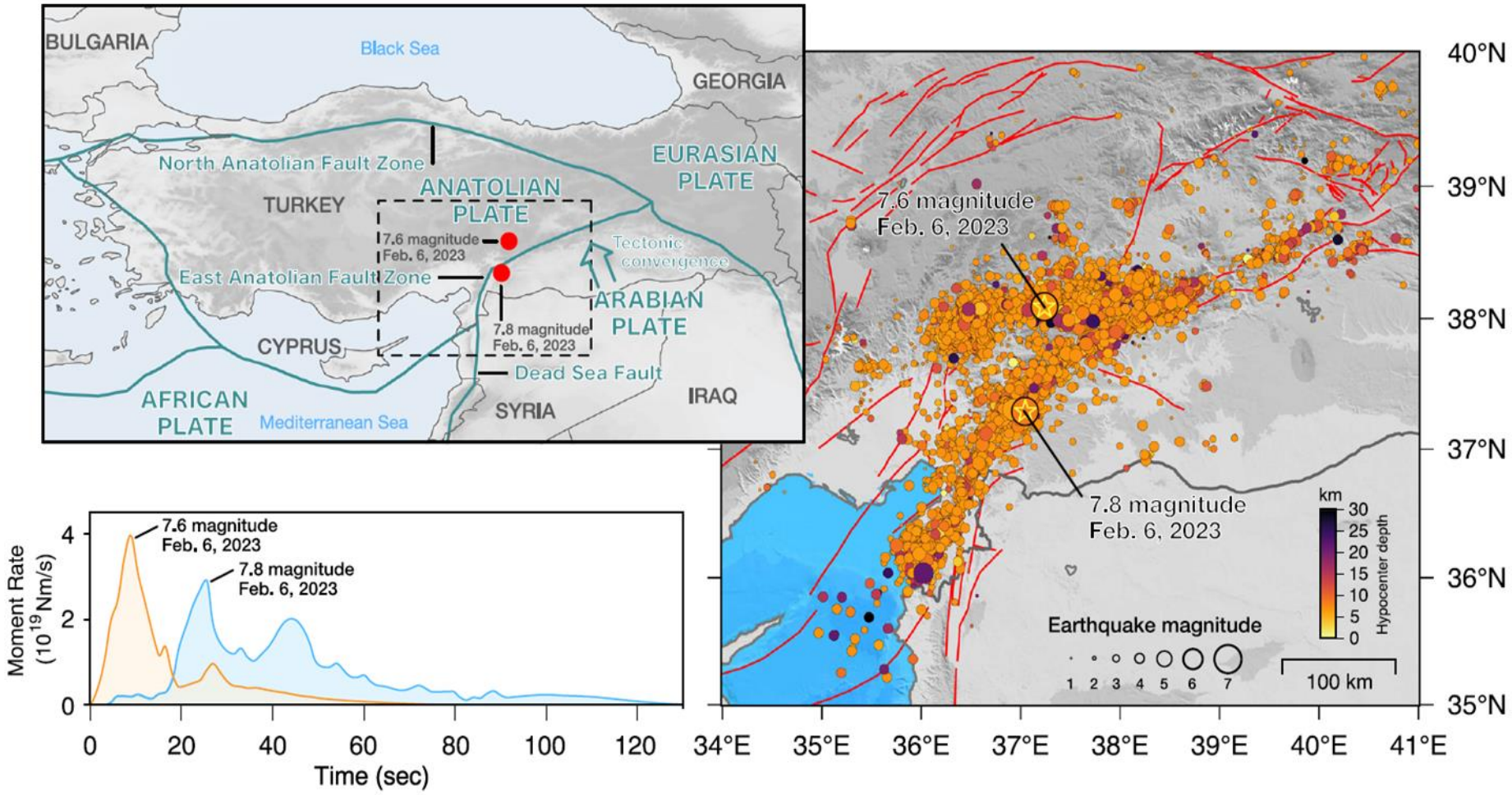


DRAWING maps indicating MSTID activity during every spread F event over Cyprus (indicated with a circle on the top left) during Summer of 2014 (high solar activity)

Co-seismic ionospheric signatures



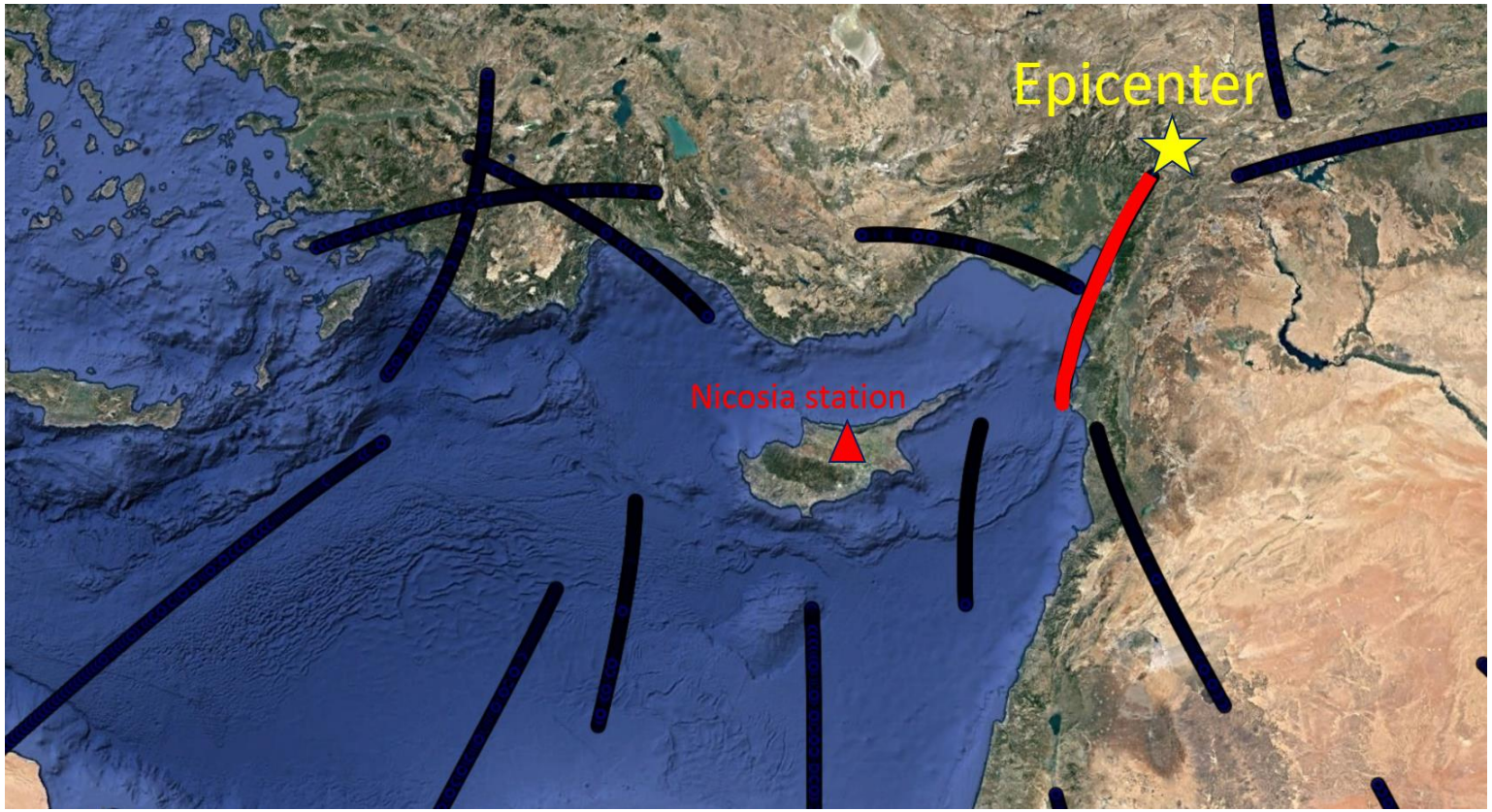
Kahramanmaraș Earthquake Sequence

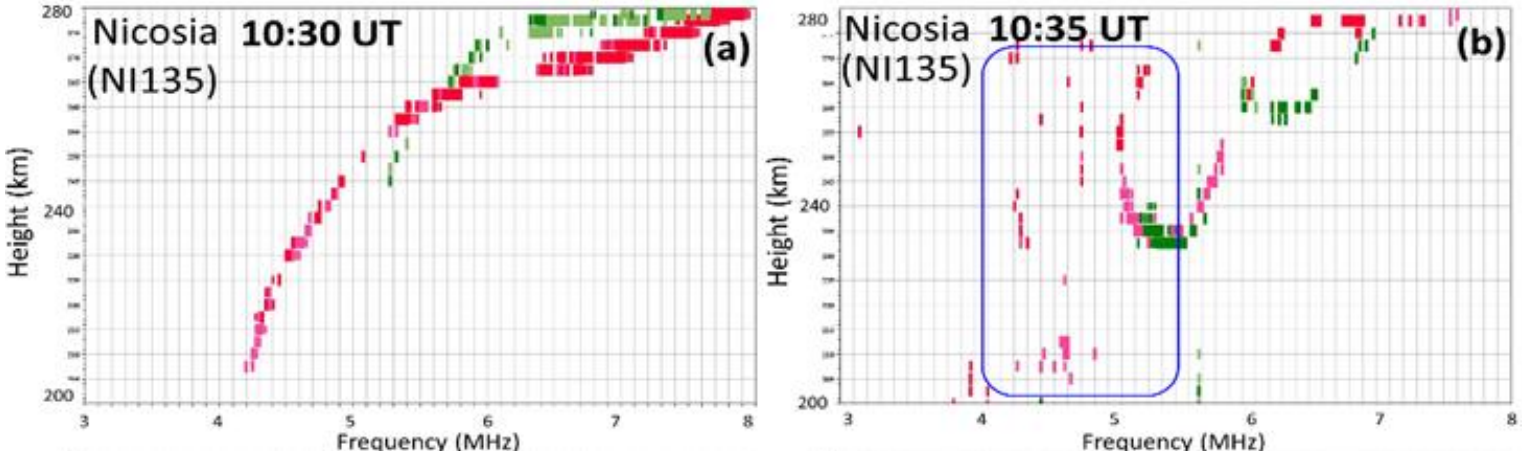


Tectonic setting and seismicity caused by the 2023 Kahramanmaraș Earthquake Sequence

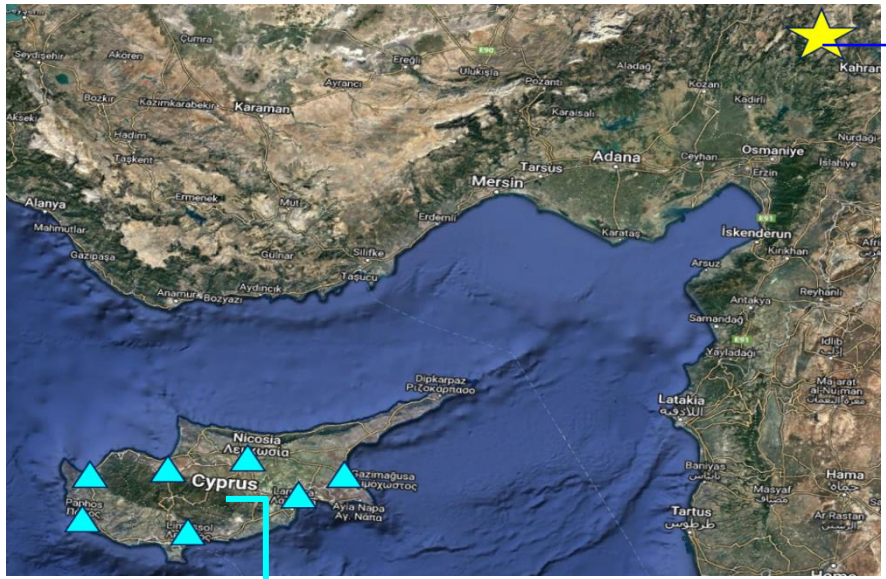
(Luca Dal Zilio & Jean-Paul Ampuero Communications Earth & Environment 2023)

GPS and GLONASS IPP tracks





Ionospheric signatures Cyprus GNSS network

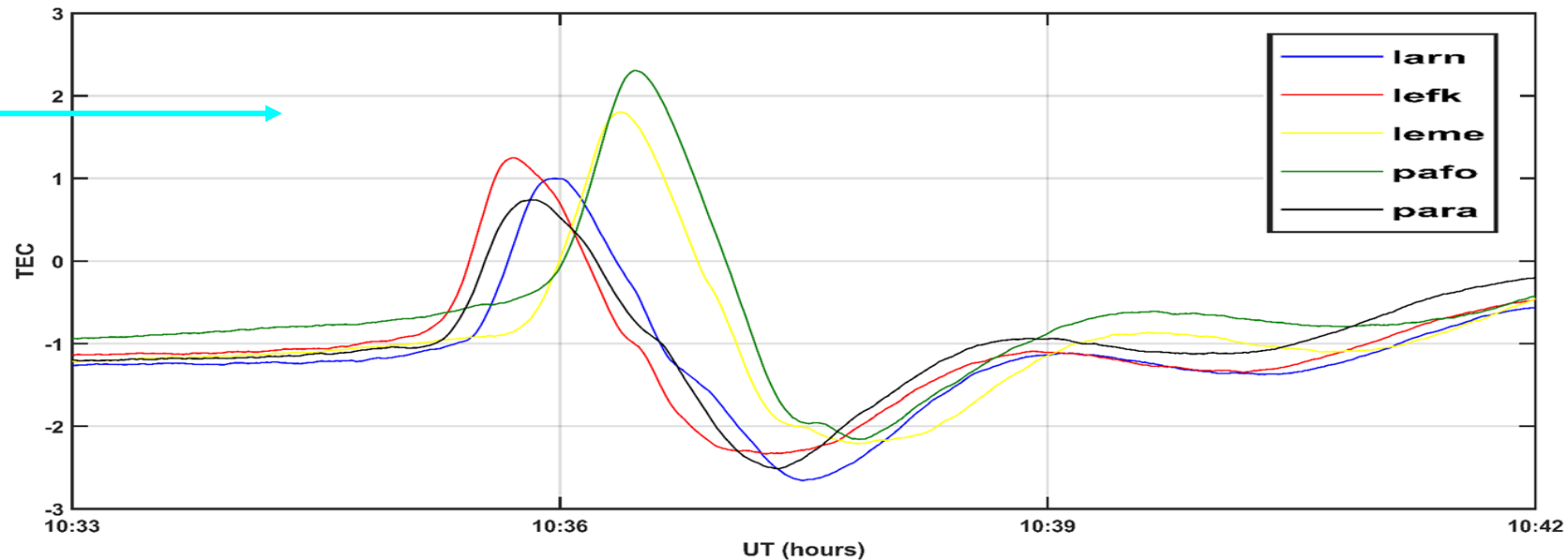


Kahramanmaras earthquake sequence

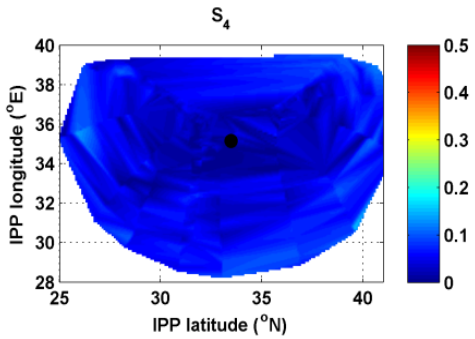
6 Feb 23, 1:17 UTC
M 7.8

6 Feb 23, 1:28 UTC
M 6.7

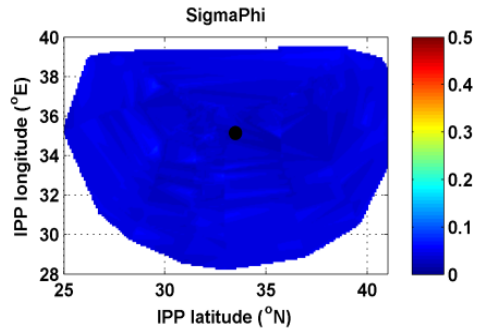
6 Feb 23, 10:24 UTC
M 7.5

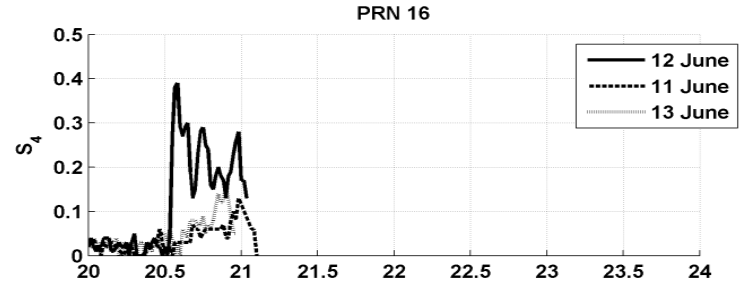


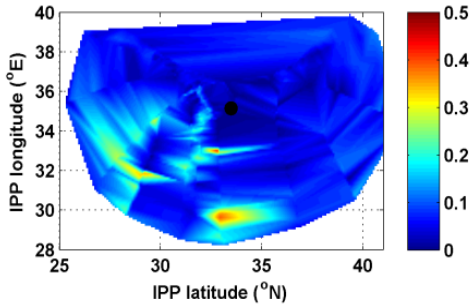
Ionospheric scintillations over Cyprus



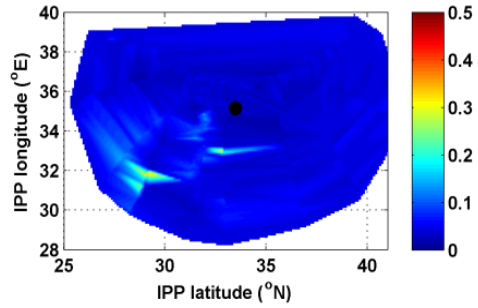
11 June

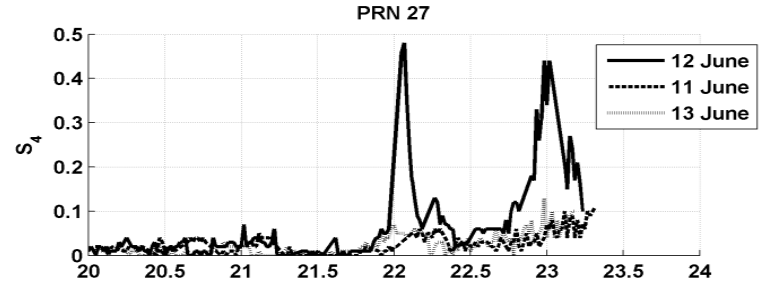


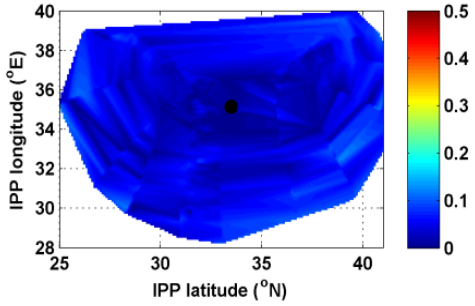




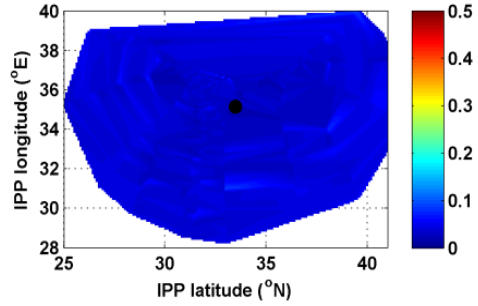
12 June

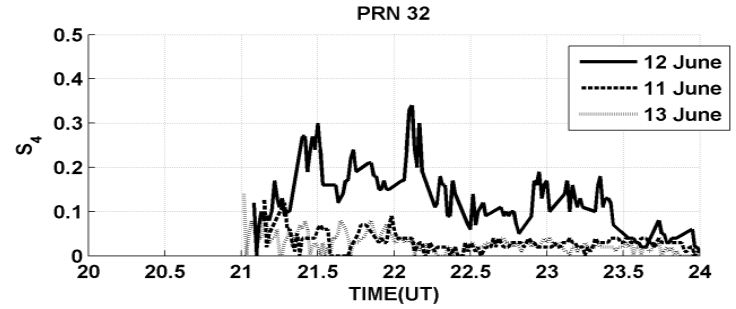




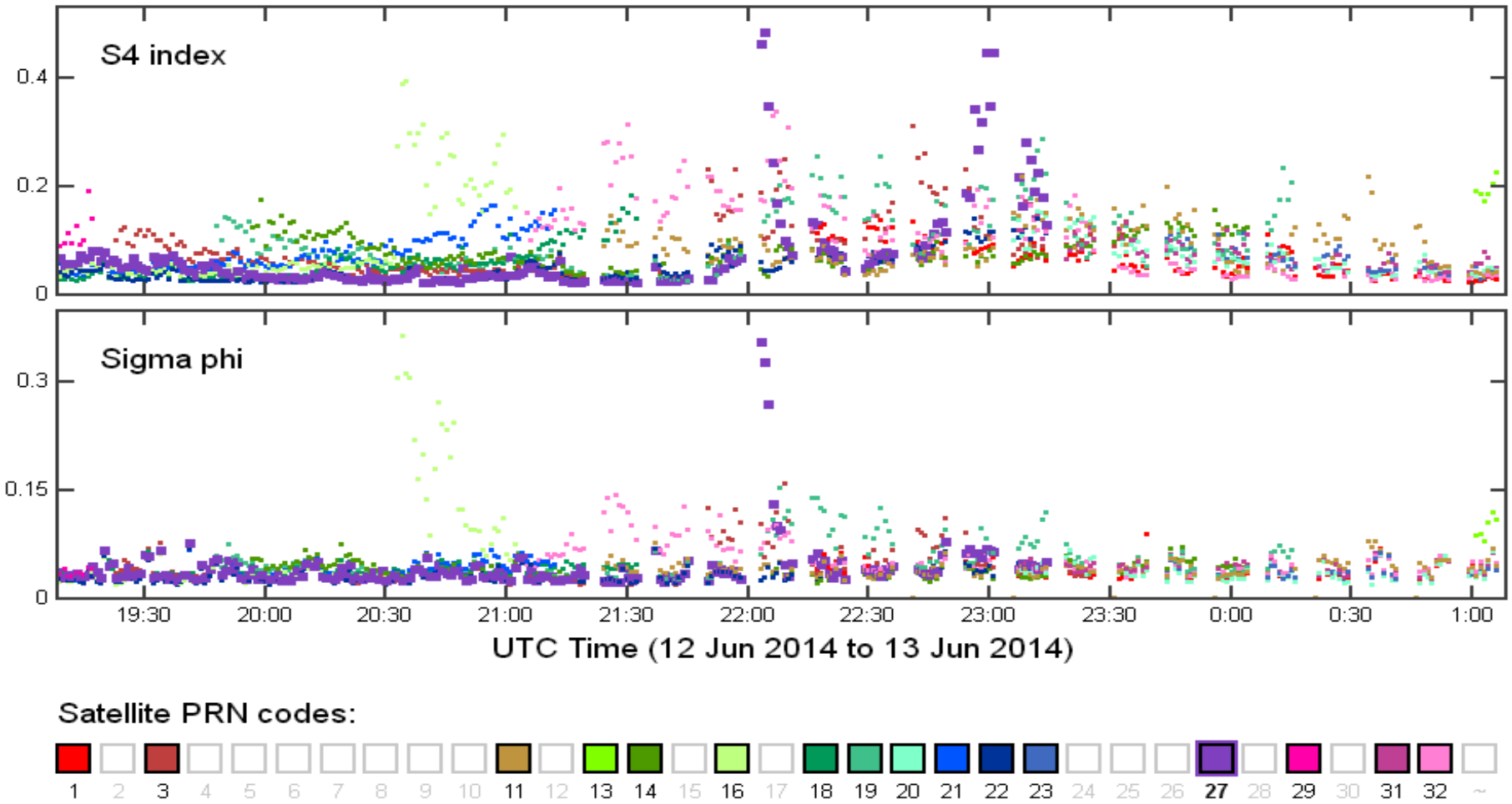


13 June

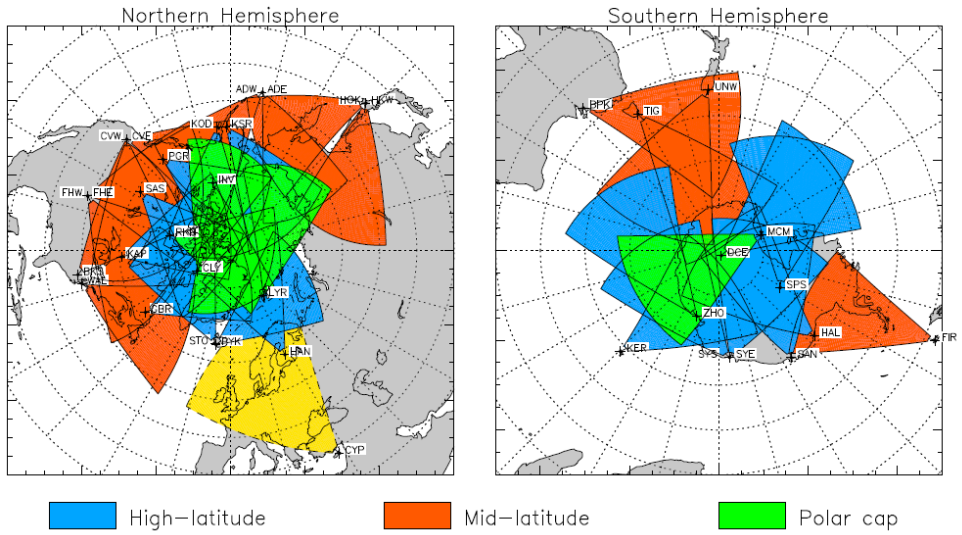


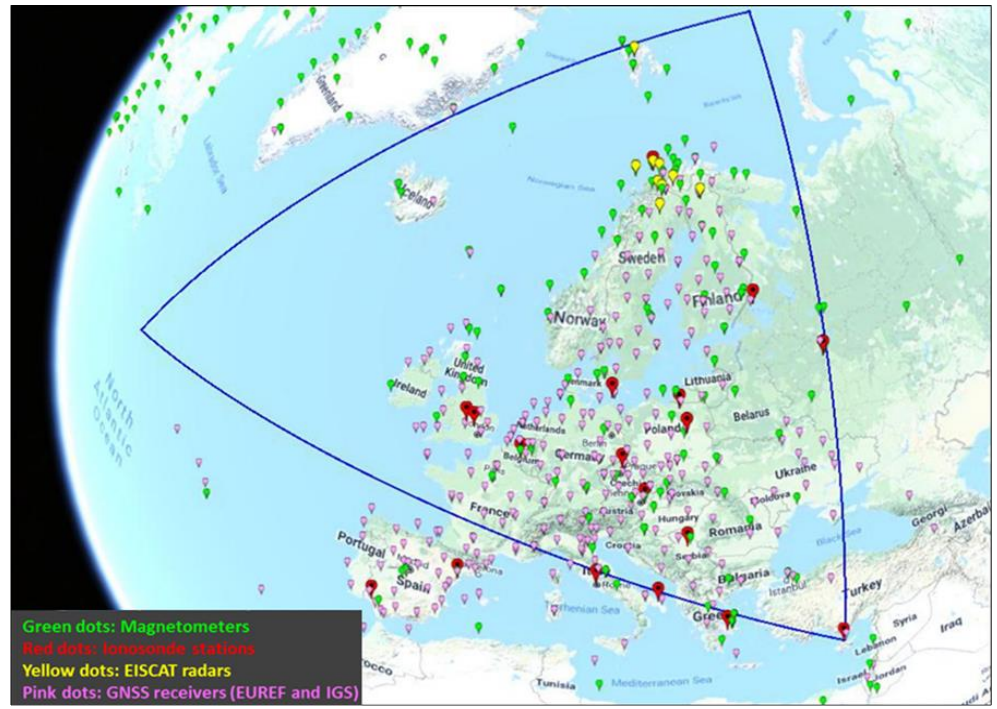


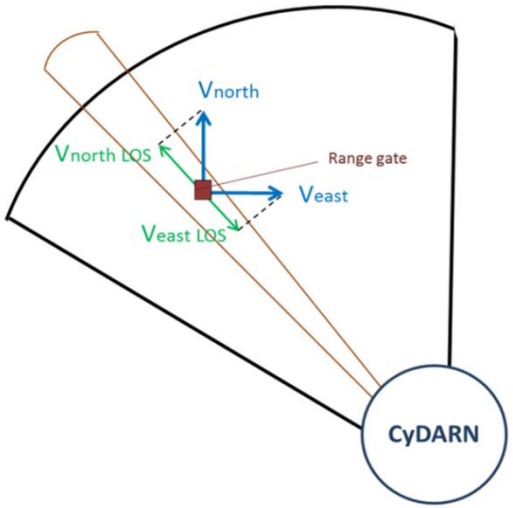
Ionospheric scintillations over Cyprus

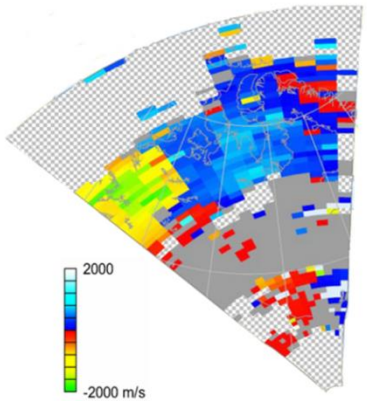


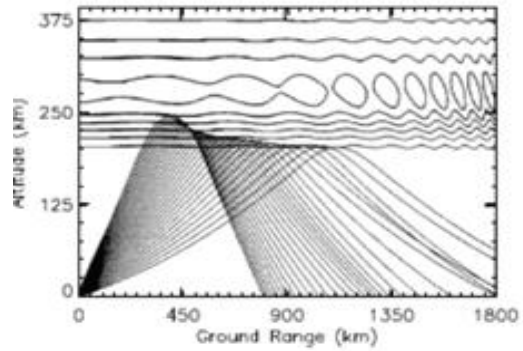
CYprus Radar for Ionospheric Space Situational Awareness
CYRISSA

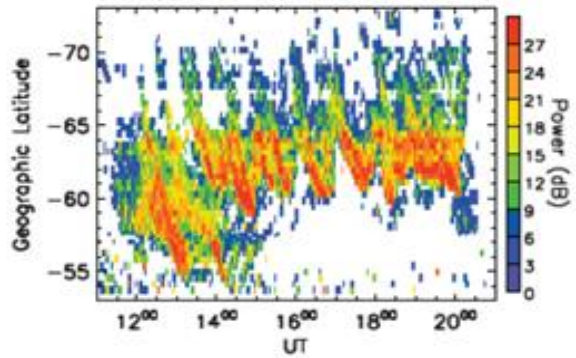




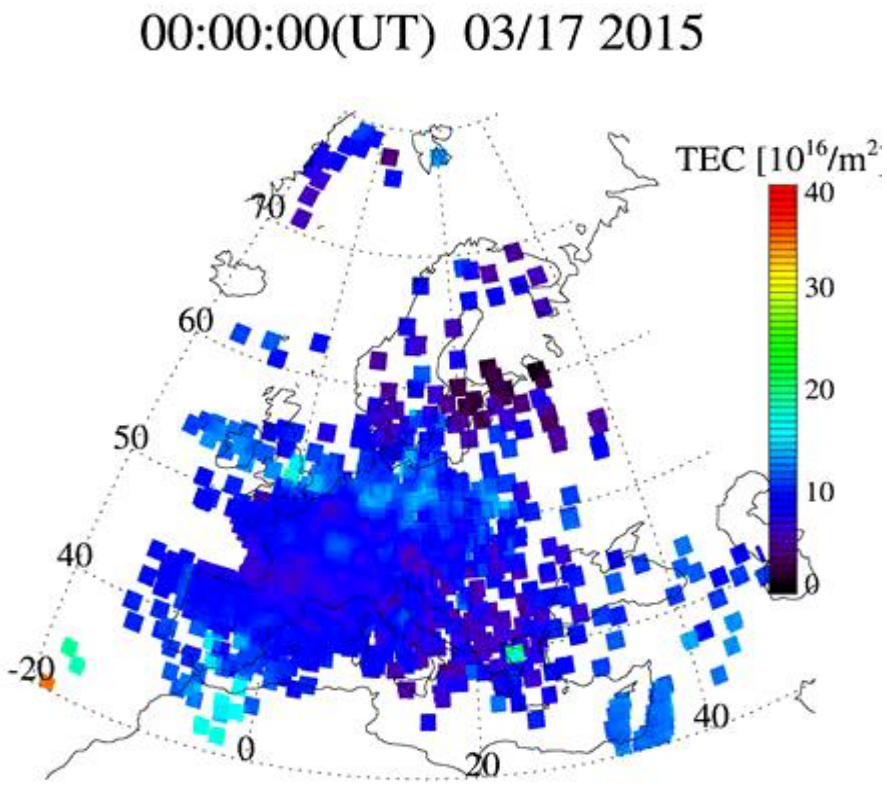


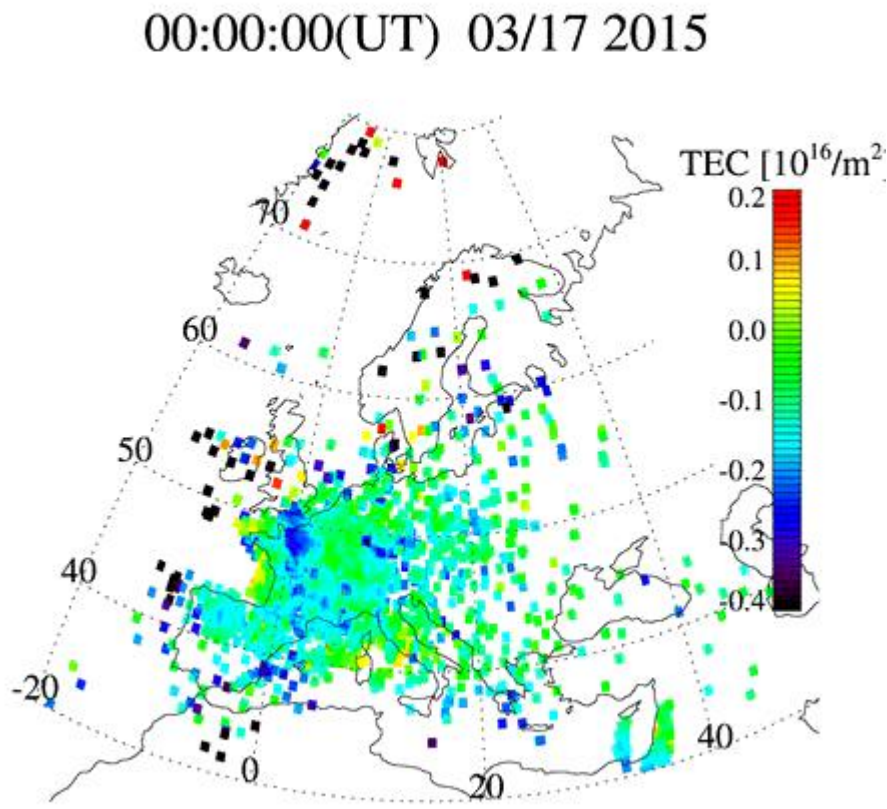






Radar for Ionospheric Space Situational Awareness significance
CYRISSA





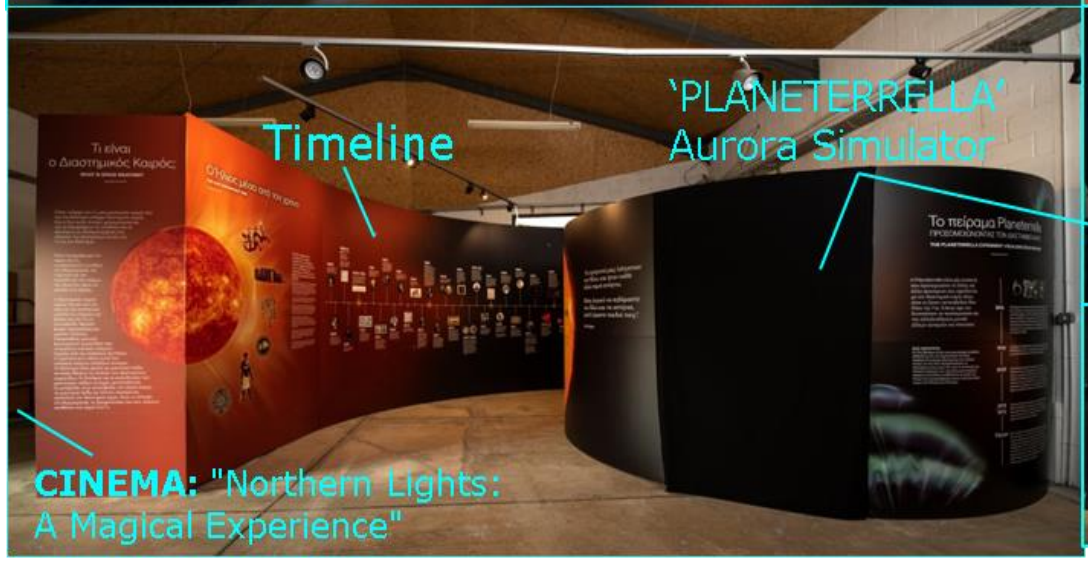
Strong equatorward plasma convection on 17 March 2015 (left plot) and Travelling Ionospheric Disturbances (right plot) as shown on Total Electron Content DRAWING maps

The Sun and Us

Space weather exhibition

–ESA funded project

Enhancing Space Awareness in Cyprus through Space Weather Studies (ESA PECS activity)



Climate change - Extreme precipitation events

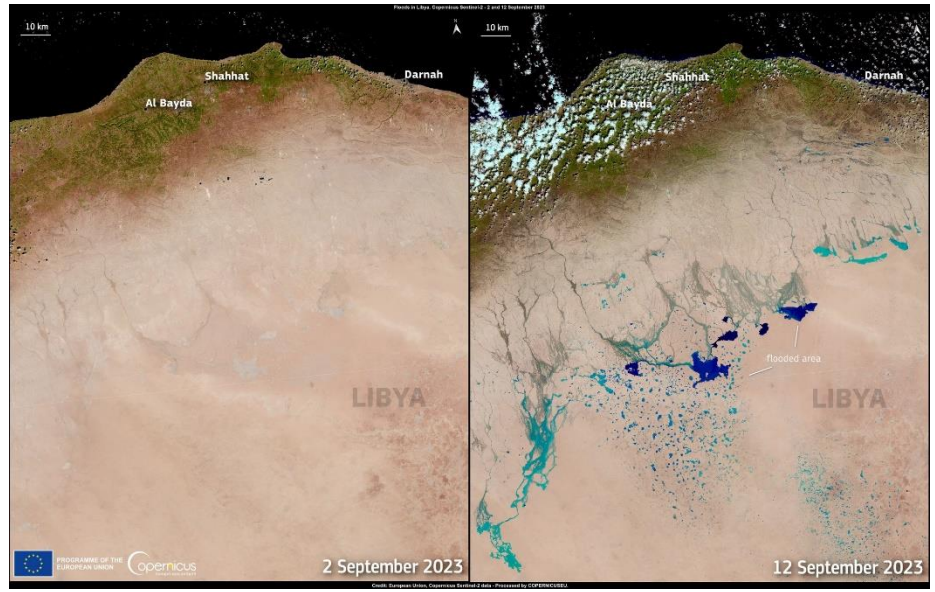
Extreme precipitation weather disasters

- **Daniel 2023** **>11,000 deaths** Greece & Libya
- 1998 - 2017 **500,000 deaths** & €3.47 trillion loss globally
- 2019 €300 billion loss in USA
- 2021 €10 billion in Central Europe

Frequency and intensity of extreme rainfall events is predicted to increase by a factor of 5-50 between 2025 and 2075

*Storm **'Daniel'**, September 2023, Greece*

*Storm **'Daniel'**, September 2023, Libya*

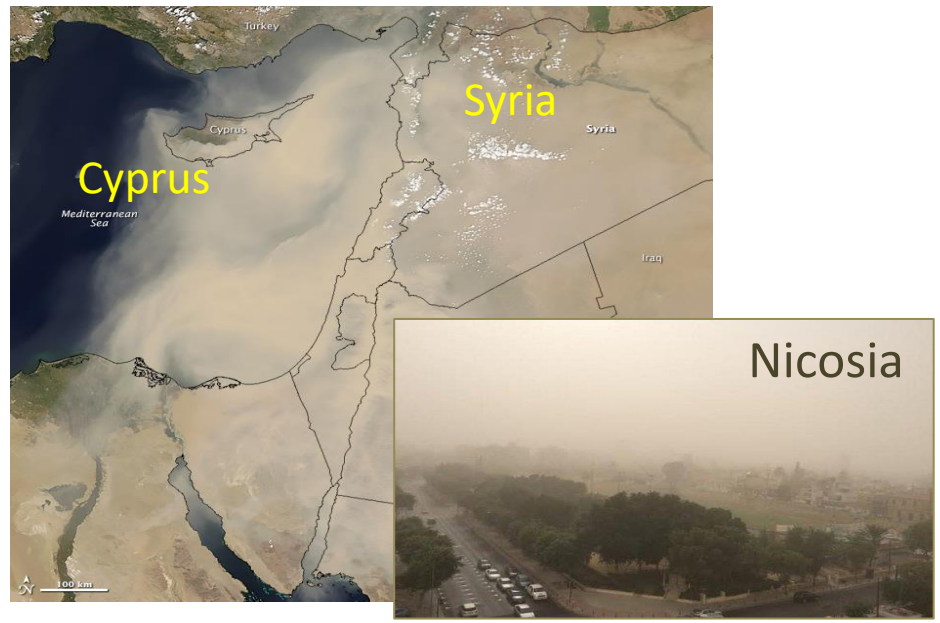


Severe LOCAL weather events in Cyprus

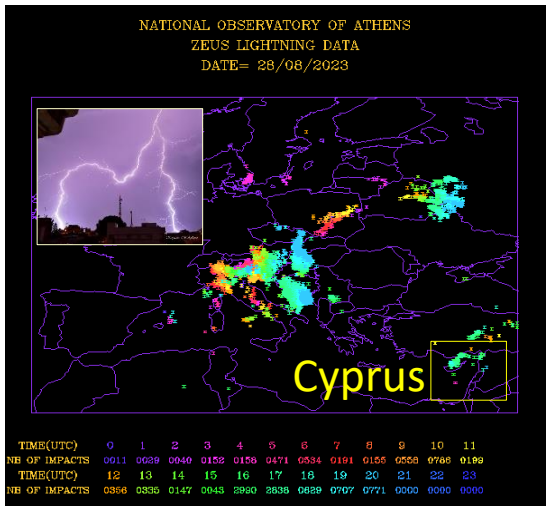
- **Dec 2018** **4 deaths** from flood
- Jan 2023 Rare floods in Ayia Napa
- Aug 2023 Extreme lighting activity & rainfall – Unusual storm trajectory not predicted by NWP models
- Sept 2015 **> 90** people in hospital (Breathing difficulty) from dust storm in EM
- 1966 -now **6 deaths** from Tornadoes
  126 cases of tornadoes

Flood, January 2023, Ayia Napa, Cyprus

Dust storm, September 2015, Cyprus

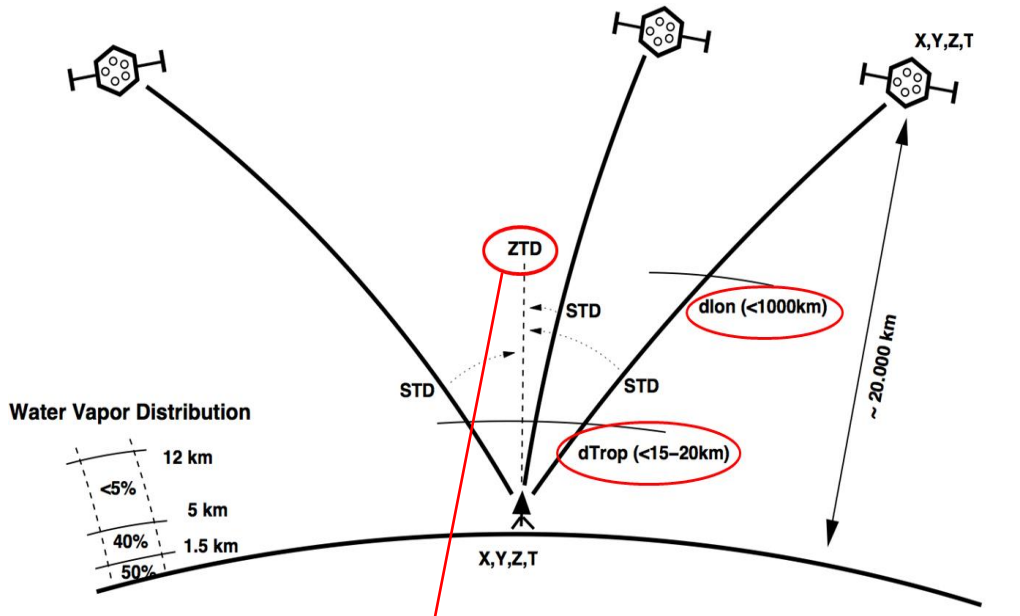


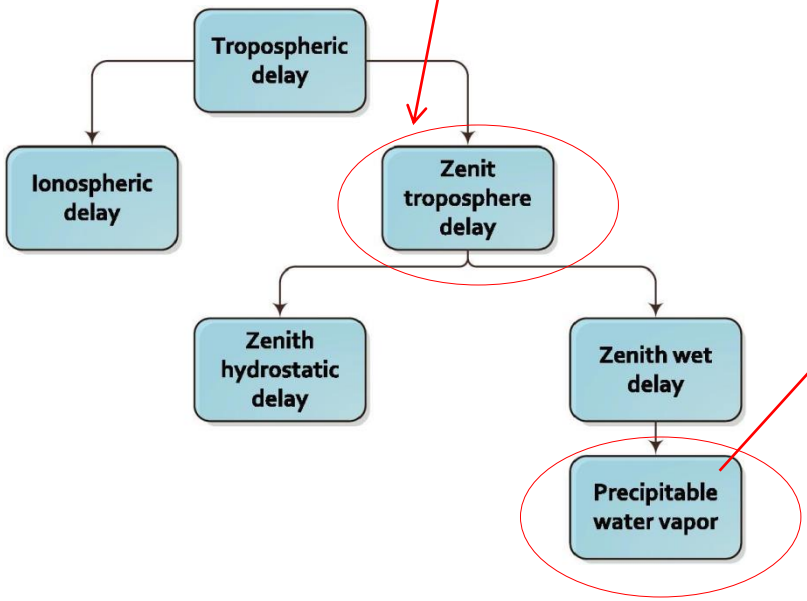
Lightning over Nicosia, August 2023



Tornadoes in Cyprus

BalkanMed real time severe weather service
BeRTISS





- Radio signals transmitted on two L-band frequencies from GNSS satellites are delayed by the neutral part of atmosphere (whose lowest portion is troposphere) before being received on earth surface by GNSS antennas.
- This zenith tropospheric delay (ZTD) consists of the hydrostatic (dry) component which is caused by dry air gases in the atmosphere and accounts for the greatest part of delay and of the wet component which is caused by the water vapor of the atmosphere:

$$ZTD = ZHD + ZWD$$

$$ZHD = (0.0022768 \pm 0.0000005)\frac{P_{GNSS}}{f(\varphi(h)}$$

Surface Pressure

with f (φ, h) = 1 − 0.0026 cos 2φ − 0.00028 h, where φ is the latitude and h is the height (km)

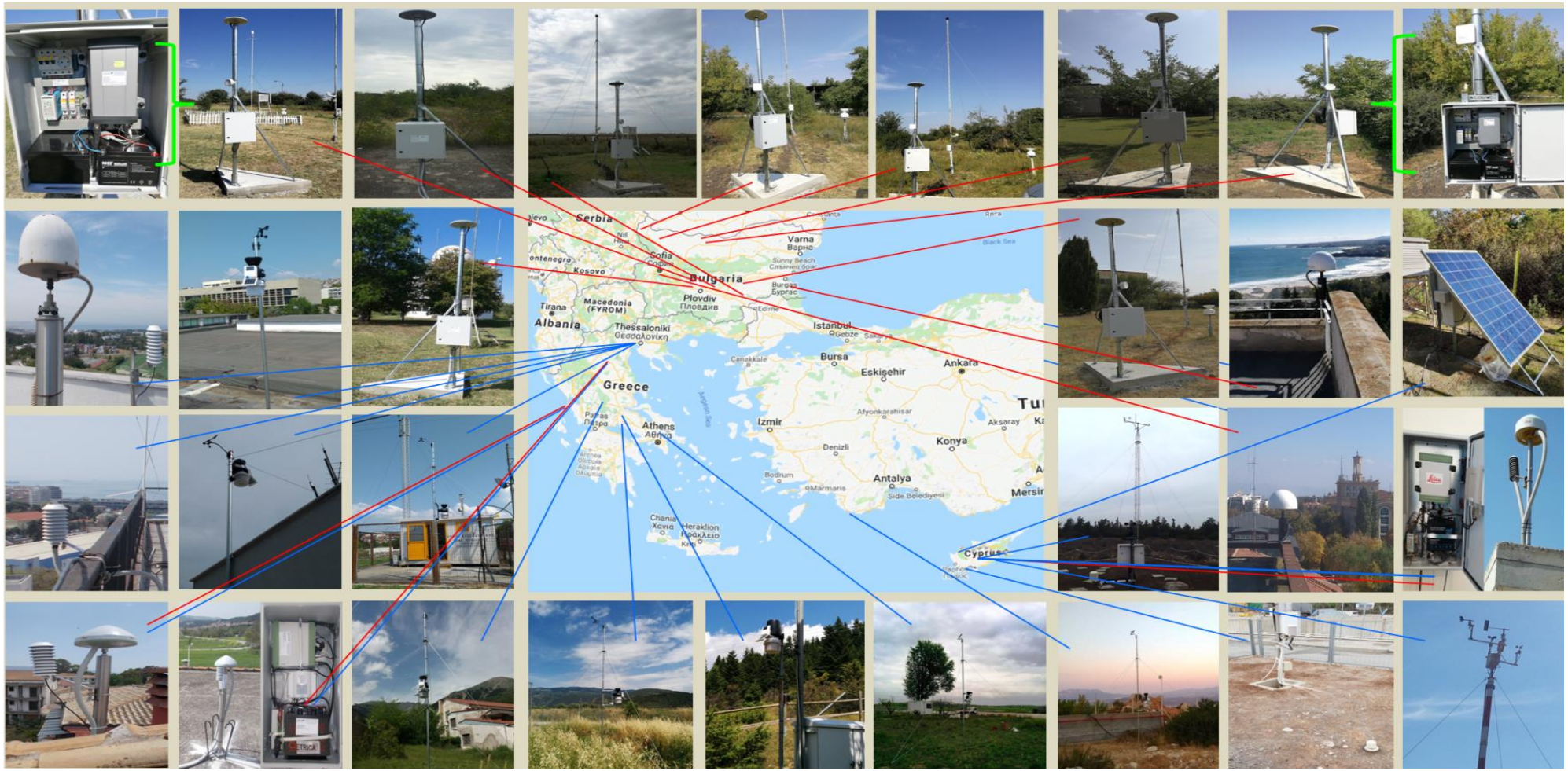
$$PWV = \frac{ZWD}{Q}$$

$$Q = 10^{-6}\rho\frac{R_0}{M_W}(k'_2 + \frac{k_3}{T_m})$$

Surface Temperature

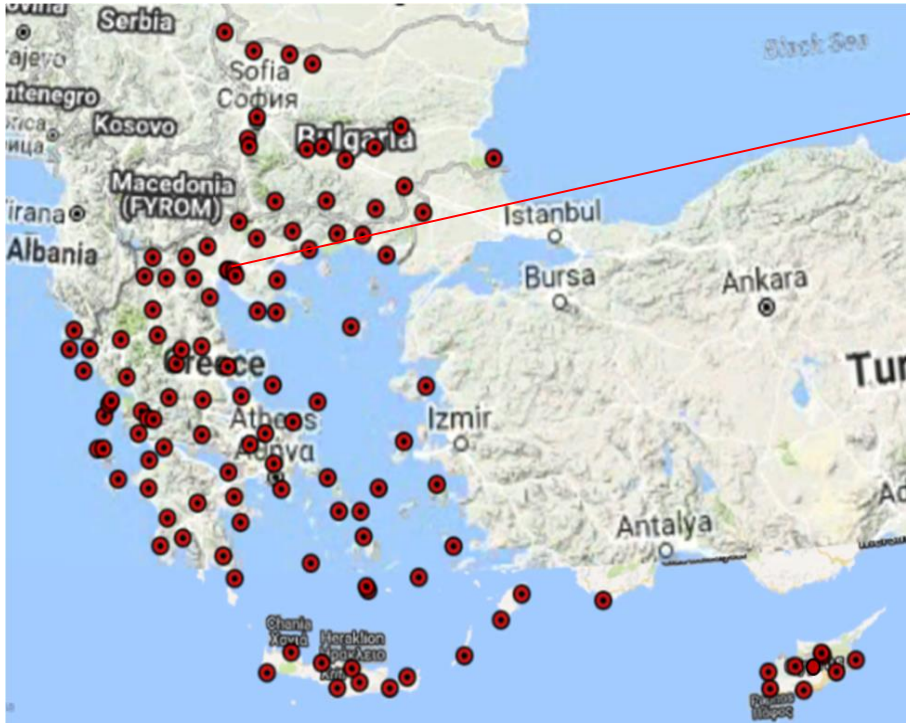
*the **Q factor** depends on surface temperature:*
where ρ is the density of liquid water, R_0 is the universal gas constant, M_W is the molar mass of water vapor and T_m is the weighted mean temperature of the atmosphere in [K]. The physical constants $k'_2 = 17\ Kmb^{-1}$ and $k_3 = 3.776 \cdot 10^5\ Kmb^{-1}$.

BalkanMed real time severe weather service
BeRTISS



- **15 new GNSS stations** were installed in Bulgaria (12), Cyprus (1) and Greece (2) (red lines)
- **25 new Meteorological stations** were installed in Bulgaria (3), Cyprus (8) and Greece (14) (blue lines)

BalkanMed real time severe weather service
BeRTISS



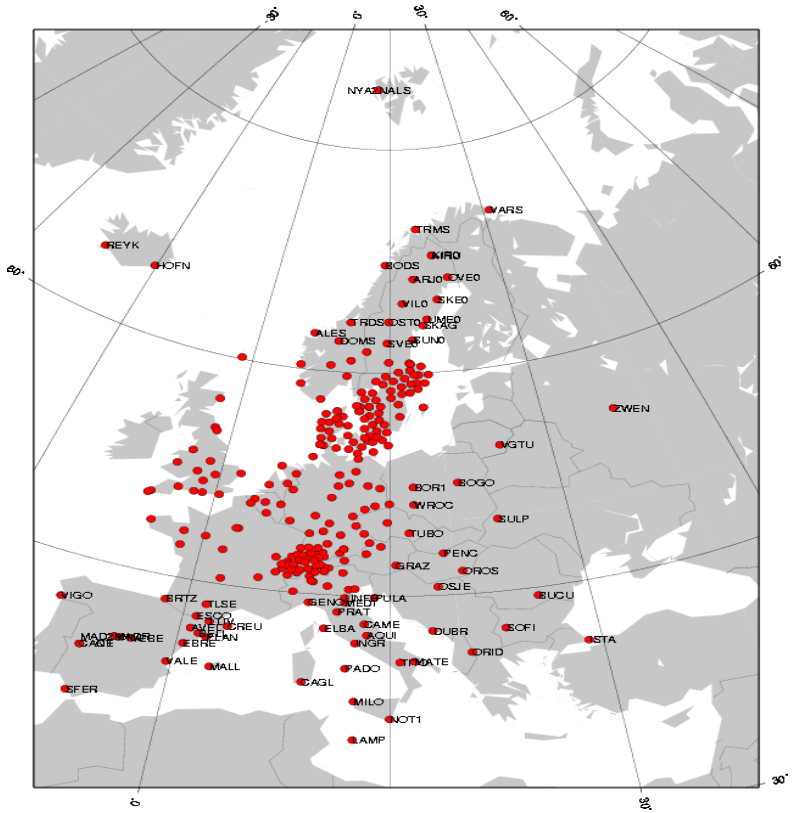
Permanent GNSS stations located in Greece, Bulgaria and Cyprus used at BeRTISS

GNSS and Meteo-stations Config. & Installation

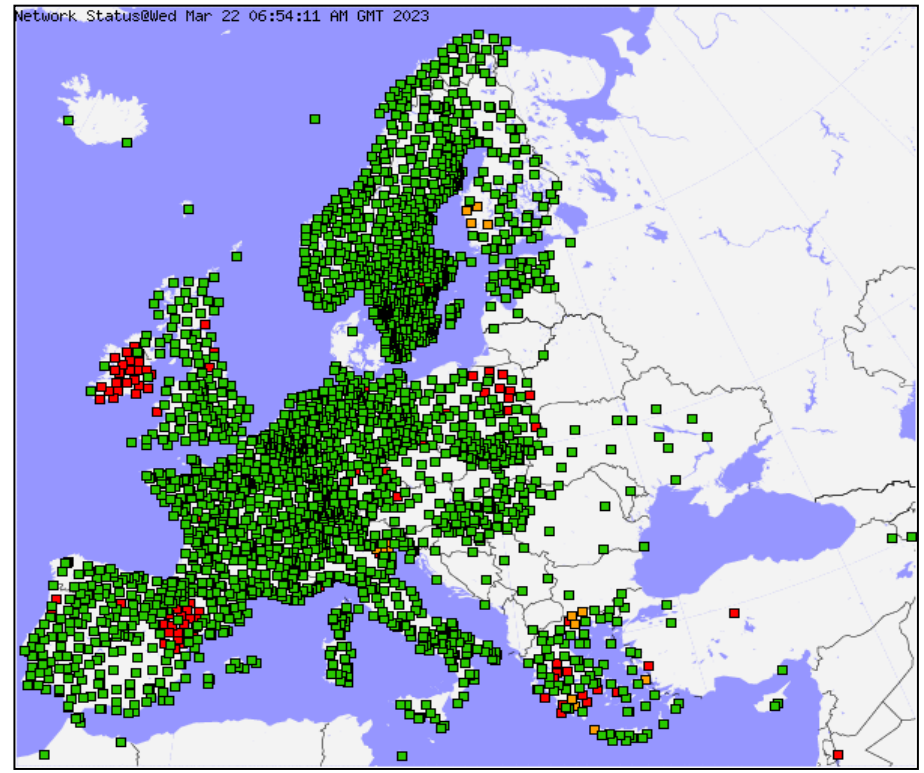
COST ACTION 2013 -2017

ES1206 - Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC)

E-GVAP **2003**



E-GVAP **2023**



EUMETNET Programme E-GVAP:

The GNSS **water vapour programme** was set up, in April 2005, to provide its **EUMETNET** (European National Meteorological Services) GNSS delay and water vapour estimates for **operational meteorology in near real-time**

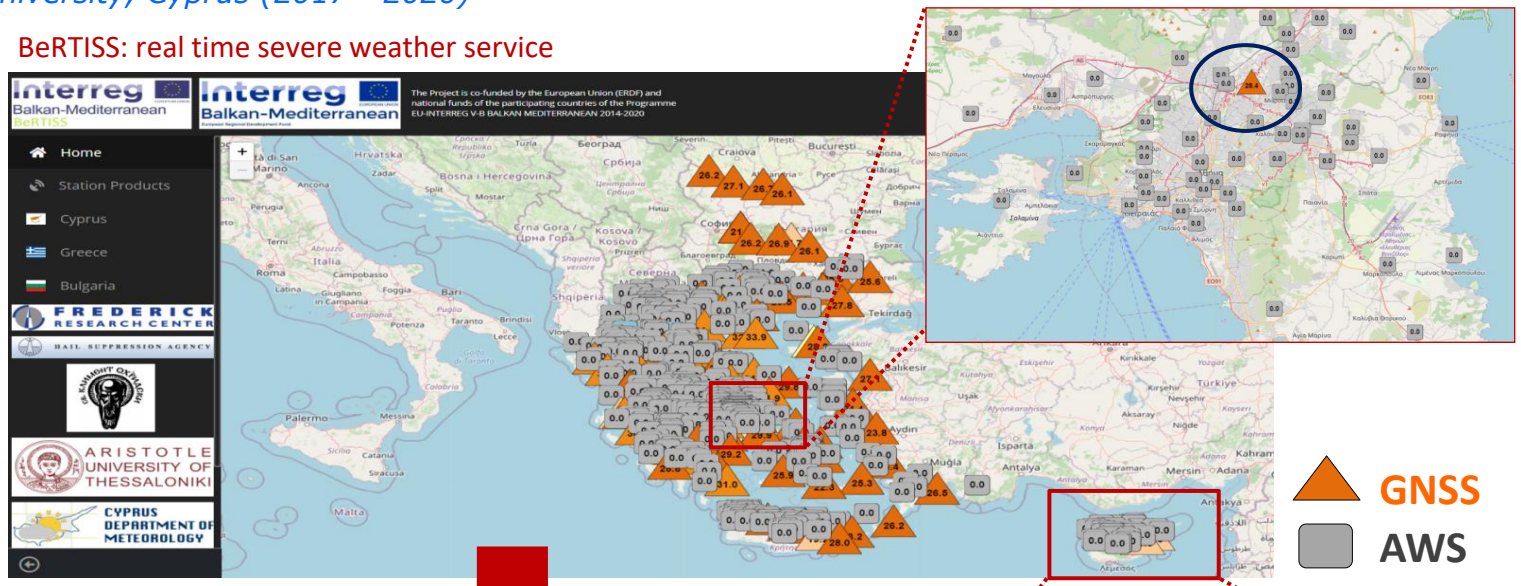
http://egvap.dmi.dk

BalkanMed real time severe weather service
BeRTISS

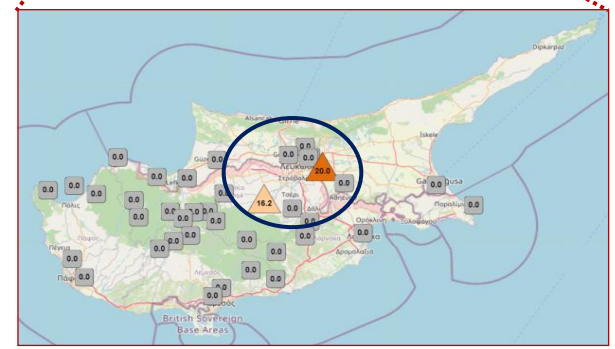
Project Coordinated by Frederick University, Cyprus (2017 - 2020)

- Low spatial resolution of geodetic GNSS networks (~ 80 km)
- Low temporal resolution of real time Water Vapor data (hourly)
- Expensive existing geodetic GNSS receivers > 10,000 €

BeRTISS: real time severe weather service

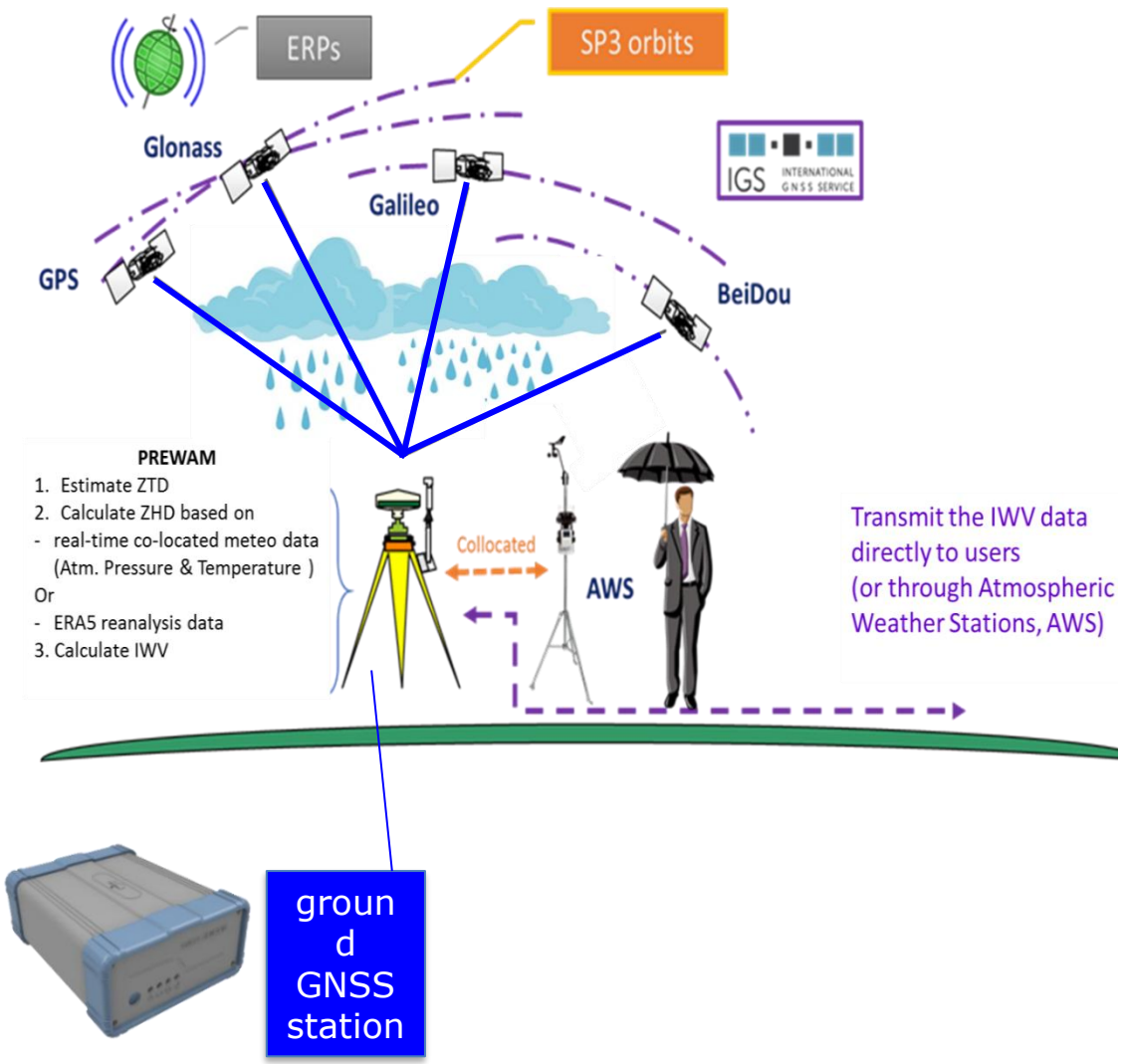


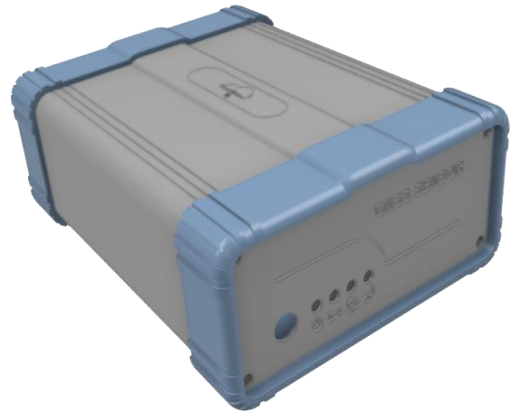
BeRTISS : 15 new GNSS geodetic & 25 AWS stations



http://app.bertiss.eu/home

CyMETEO infrastructure – **GNSS network**





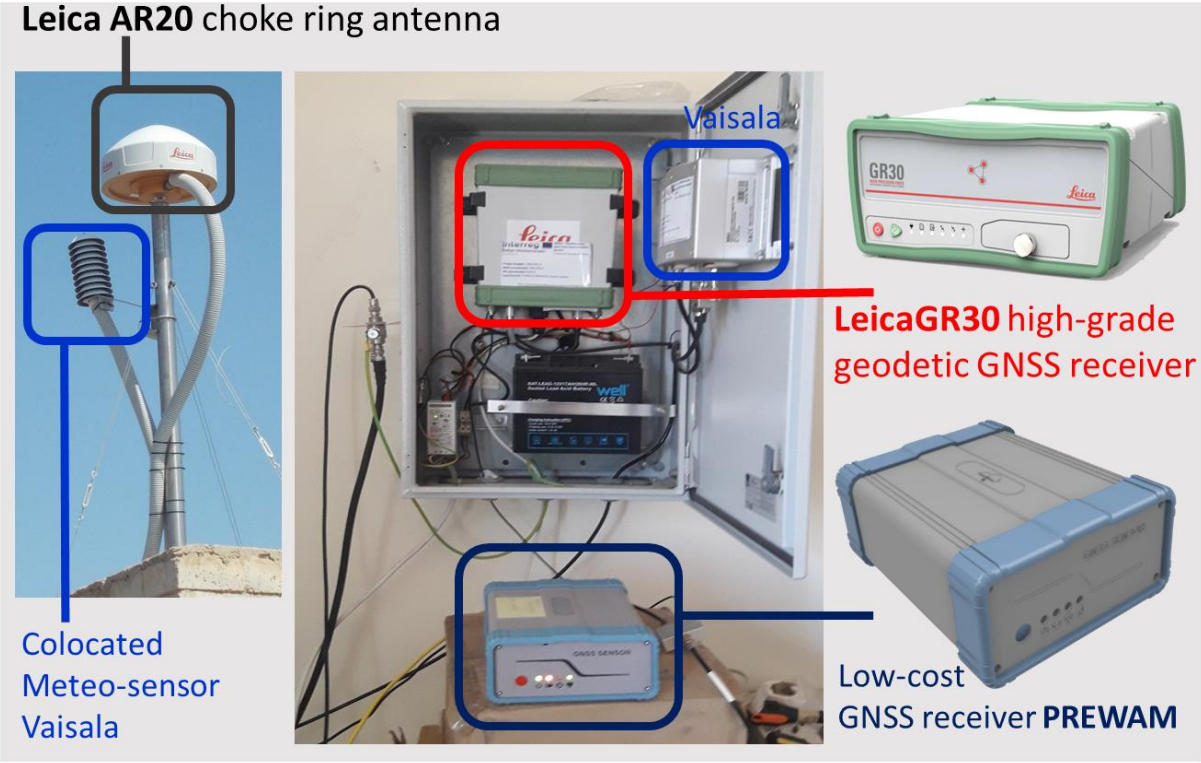
PREcipitable WAter vapour Monitor

'PREWAM'
Developed by Cloudwater ltd

CloudWater

- ✓ **Low-cost GNSS receiver** for near-real time estimation of PWV with high-resolution
- ✓ Takes fully advantage of all GNSS satellite systems: GPS, GALILEO, GLONASS and BeiDou
- ✓ Constructed by 3D Printing technology
- ✓ Can be embedded to AWS stations (Cambell, Vaisala, Davis, etc)

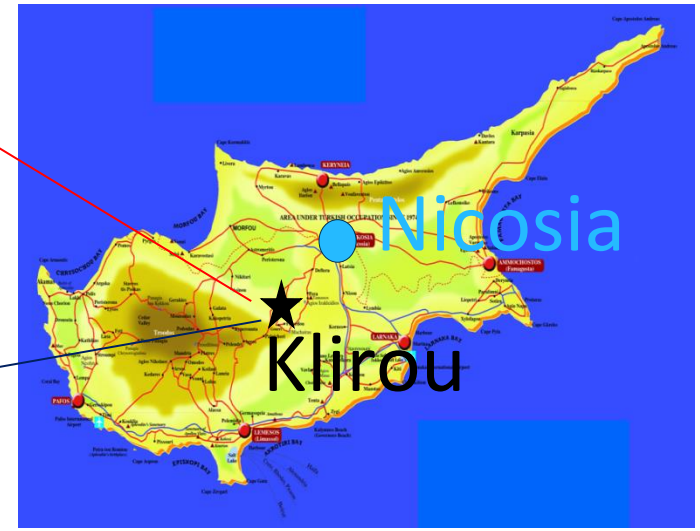
Comparison BeRTISS (Geodetic Leica receiver) – **CLOUDWATER** (Low-cost PREWAM receiver)



Klirou station

KLIR (BeRTISS)

KLIC (CLOUDWATER partner)



High-grade geodetic receiver **LeicaGR30** and low-cost **PREWAM** receiver used for **PWV estimation**
Period of study: October 2022 – December 2022

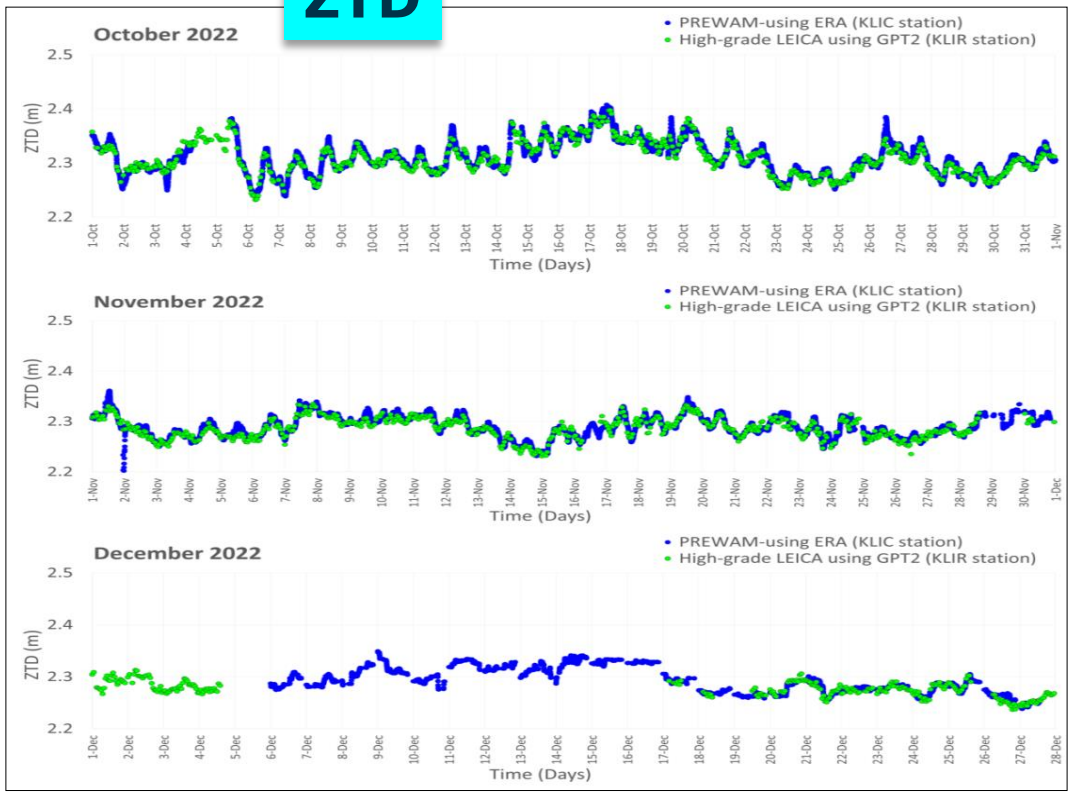
Comparison BeRTISS (Geodetic Leica receiver) **– CLOUDWATER** (Low-cost PREWAM receiver)

- **Leica GR30 geodetic receiver KLIR**
- **PREWAM low-cost receiver KLIC**

- Leica GR30 geodetic receiver – KLIR
Using empirical blind model GPT2w
- PREWAM low-cost receiver – KLIC
Using ERA5 empirical model for P,T estimation

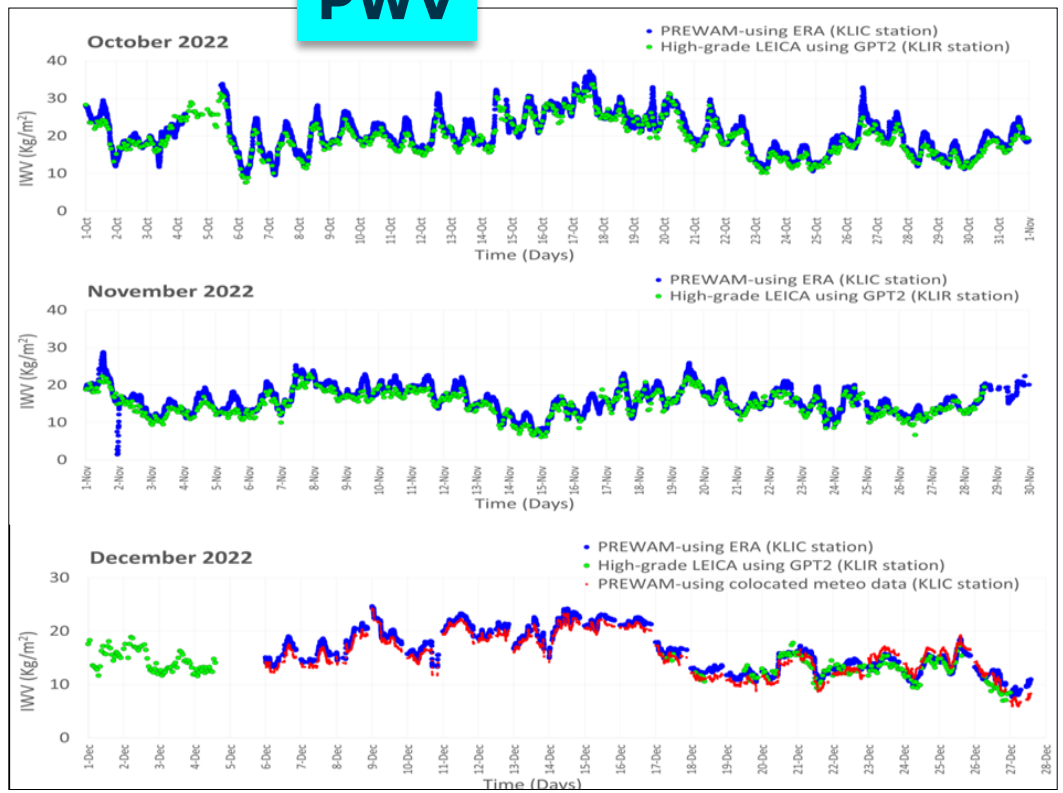
ZTD

Correlation Coefficient R = 0.96



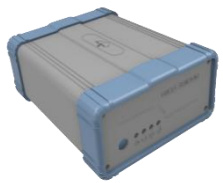
PWV

R = 0.95



FIRST POTENTIAL CLIENTS INTERNATIONAL

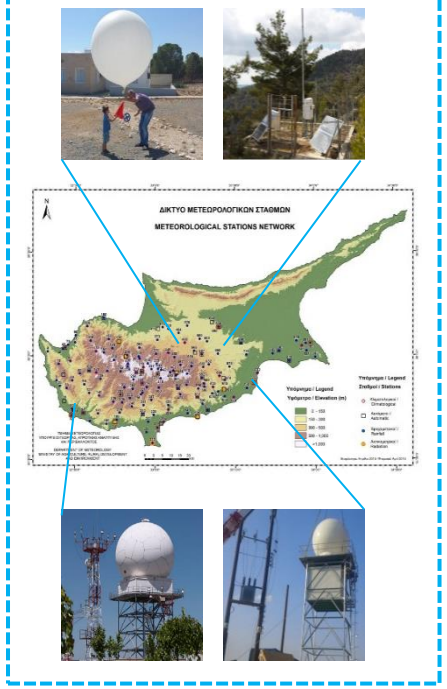
12 Letters of Interest



Project Objective - proposed Solution

CyMETEO infrastructure & service

Existing Meteo system



- 2 Weather RADAR (Humidity)
- 1 Radiosonde (Humidity)
- 500 Meteo stations

5 Lighting detectors network

Radar wind profiler **RWP**

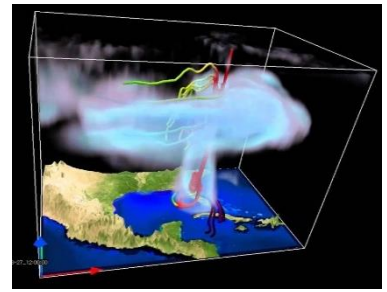
Microwave Radiometer **MWR** Water Vapor profiles

GNSS network Densification Integrated Water vapor

Observational Component

Observational Data Assimilation (DA) In NWP model (first time in Cyprus)

CyMETEO Web-portal



'WRF' NWP model used by Cyprus Dep of Meteorology

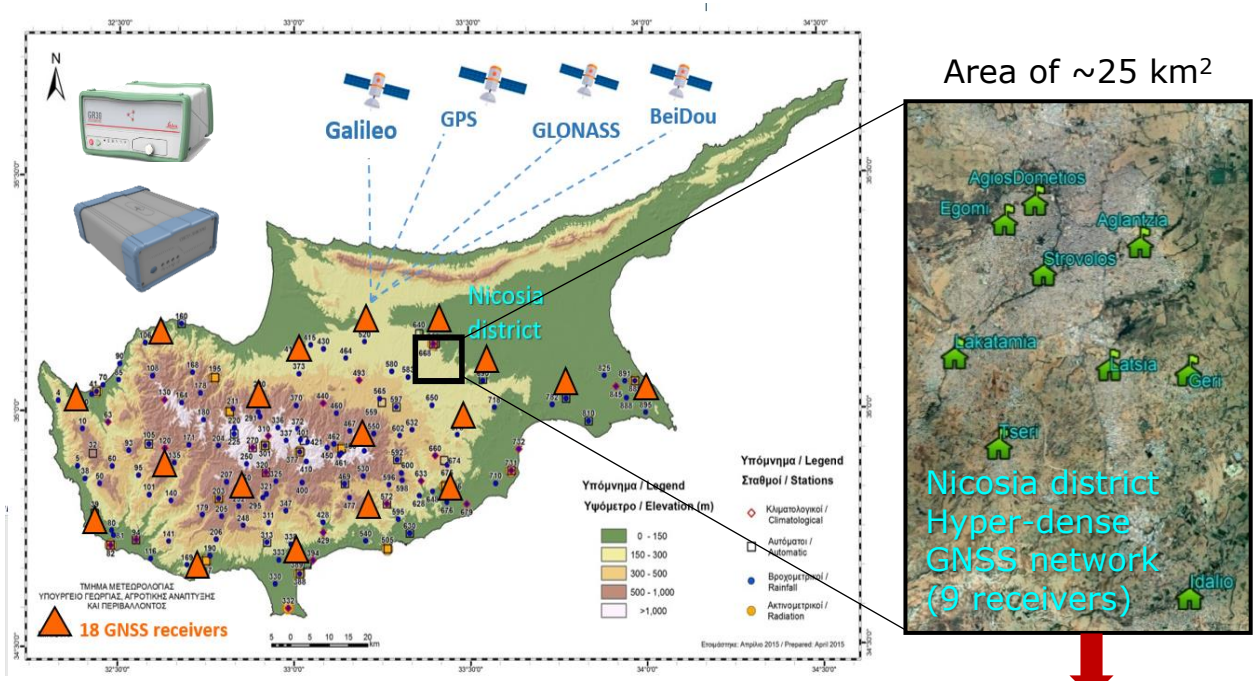
New supercomputer for DA

Modelling Component

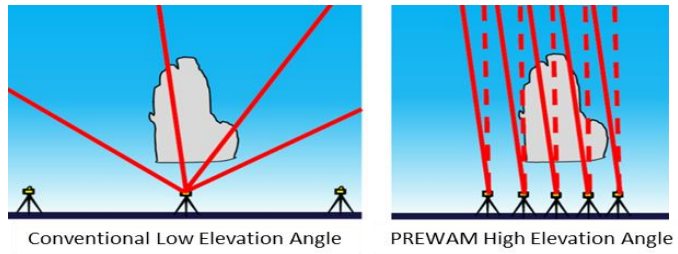
CyMETEO infrastructure – GNSS network densification

Precipitable Water Vapor PWV

- ✓ Deliver high, spatial & temporal, resolution of PWV, Slant & Zenith Tropospheric Delay (STD &ZTD)
- ✓ PWV data Assimilation into NWP model
- ✓ Research on PWV climatology (long-term)



Area of ~25 km²



NEW GNSS receivers Equipment

9 low-cost PREWAM GNSS receivers
(Nicosia district Hyper-dense GNSS network)

3 geodetic Leica GR30 GNSS receivers
(with AR20 Choke Ring antennas)

✚

Existing Equipment

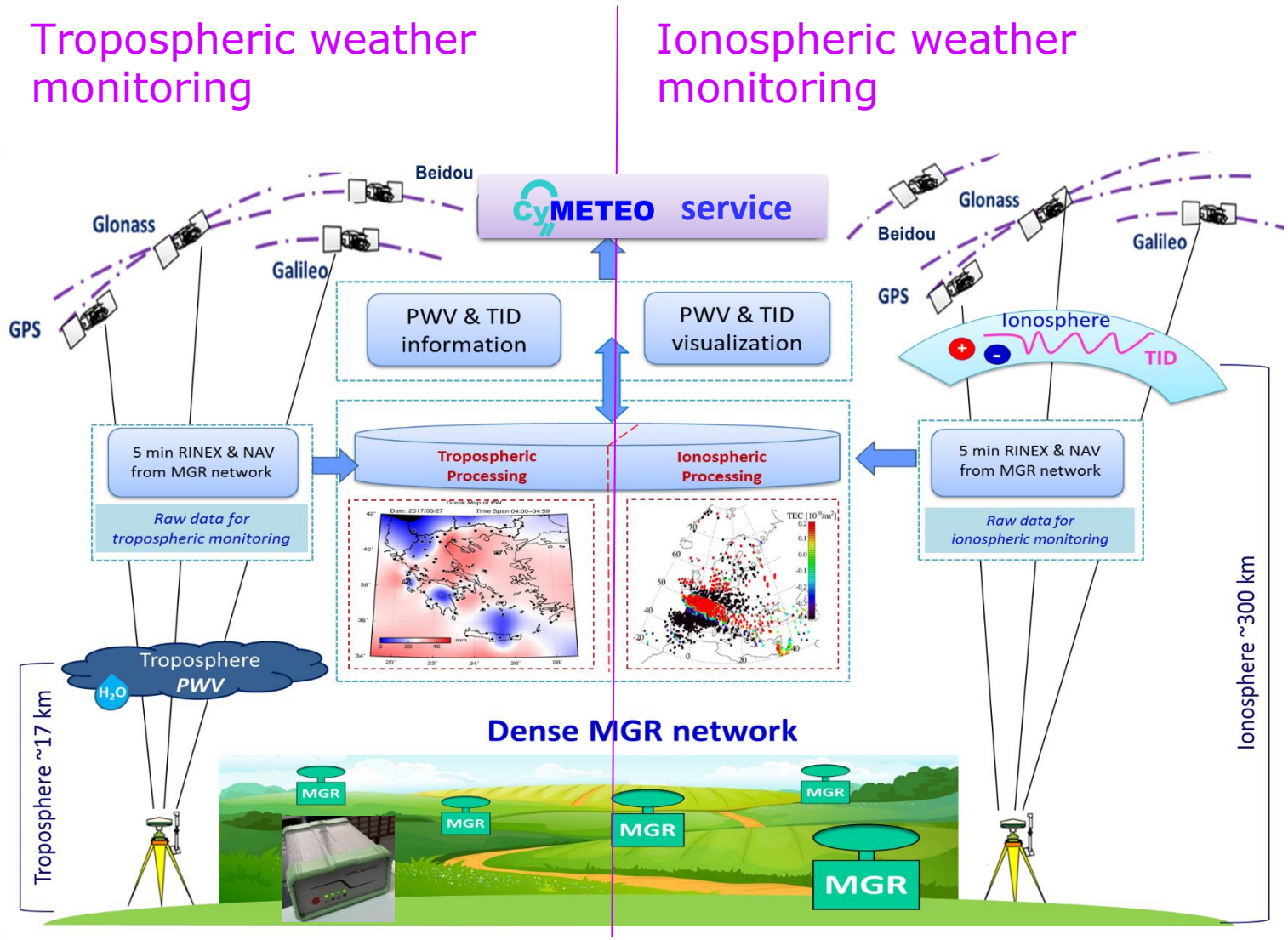
7 CYPOS system of the Dep. of Lands and Surveys (DLS) GNSS stations

4 high-grade LEICA receivers of Coordinator Project partner (FRC)

4 low-cost PREWAM GNSS receivers of Cloudwater Ltd partner

CyMETEO Further Expansion Opportunities

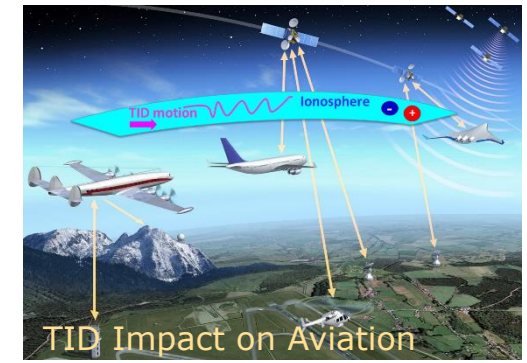
Dense GNSS network for Ionospheric space weather monitoring



- **Expand system with:**

a) **Tropospheric weather monitoring**

b) **Ionospheric weather monitoring**



Near-real time detection of TIDs: Travelling Ionospheric Disturbances

Use Multi-Purpose GNSS receiver: MGR (by Cloudwater Ltd)


Thank You!
Contact
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eng.hh@frederick.ac.cy