

UN Croatia Workshop on GNSS Applications

University of Zagreb
Faculty of Electrical Engineering and Computing
Department of Wireless Communications

Scientific research:

Recent research achievements in the field of satellite navigation in Croatia

Prof. dr.sc. Tomislav Kos, FRIN



Agenda

- *Motivation*
- *Aim of the project*
- *Project team*
- *Project description*
- *Obtained results*
- *International collaboration*
- *Conclusion*

Motivation – project “Environment for Satellite Positioning”

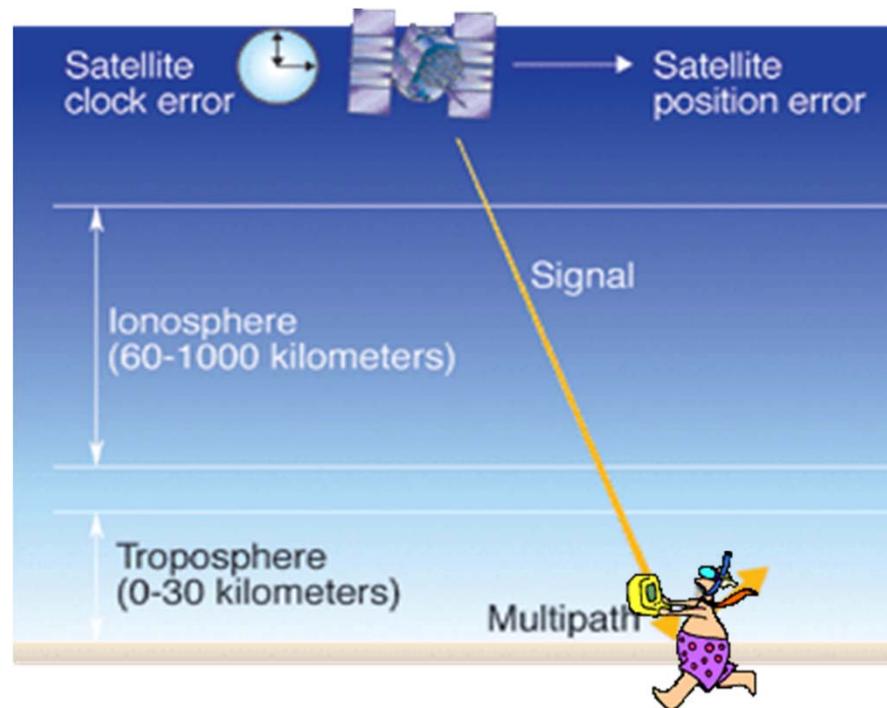
- *Increased importance of satellite positioning systems requires analysis and control of GNSS performance*
- *Satellite signal propagation environment is the major source of positioning errors*
- ***Ionospheric, tropospheric and multipath impacts give the largest contribution to satellite positioning error budget and satellite positioning reliability***
- *Existence of local ionospheric processes, dynamics and patterns is confirmed*
- *No local satellite positioning ambient error model for Croatia and south-eastern Europe exists so far*

Project team

- *Prof. Tomislav Kos, PhD FRIN, Faculty of Electrical Engineering and Computing, University of Zagreb – leading scientist*
- *Prof. Ivan Markežić, PhD MRIN, Faculty of Traffic and Transport Sciences, University of Zagreb*
- *Renato Filjar, PhD FRIN, Faculty of Maritime Studies, University of Rijeka*
- *Jakov Kitarović, MSc MRIN, Faculty of Maritime Studies, University of Rijeka – PhD student*
- *Prof. Ante Tićac, Faculty of Maritime Studies, University of Rijeka – retired professor*
- *Mladen Viher, PhD, Croatian Air Force Headquarter, Expert collaborator in atmospheric physics, meteorology and remote sensing research*

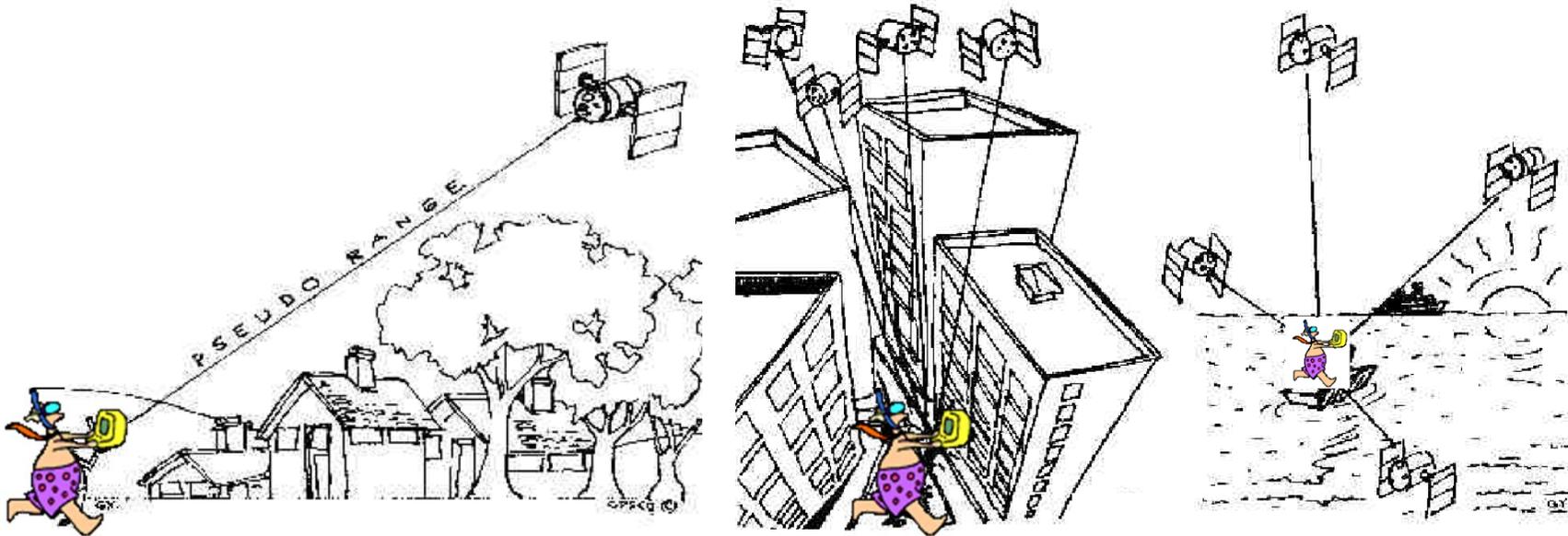
Aim of the project

- *Identification of particularities of local GNSS signal propagation environment in Croatia and surrounding region that make impact on the quality of satellite positioning in the area*
- *Focus on ionospheric, tropospheric and multipath propagation*



Aim of the project

- *Proposal, development and validation of local and regional ionospheric, tropospheric and multipath error correction models for satellite positioning (GPS, GLONASS, Galileo)*



Project procedures

- *Experiments, field campaigns*



- *Numerical analysis of experimental data sets*
- *Computer simulations*
- *Knowledge transfer*

Research protocol

- *Development of local ambient correction models for satellite positioning*
- *Verification of models through computer simulations and by comparison with experimental data sets*
- *Knowledge transfer*
 - *Student and young researcher education, students diploma work in GNSS related topics*
 - *Professional advancement*
 - *Seminars and workshops*
 - *Consultancy*

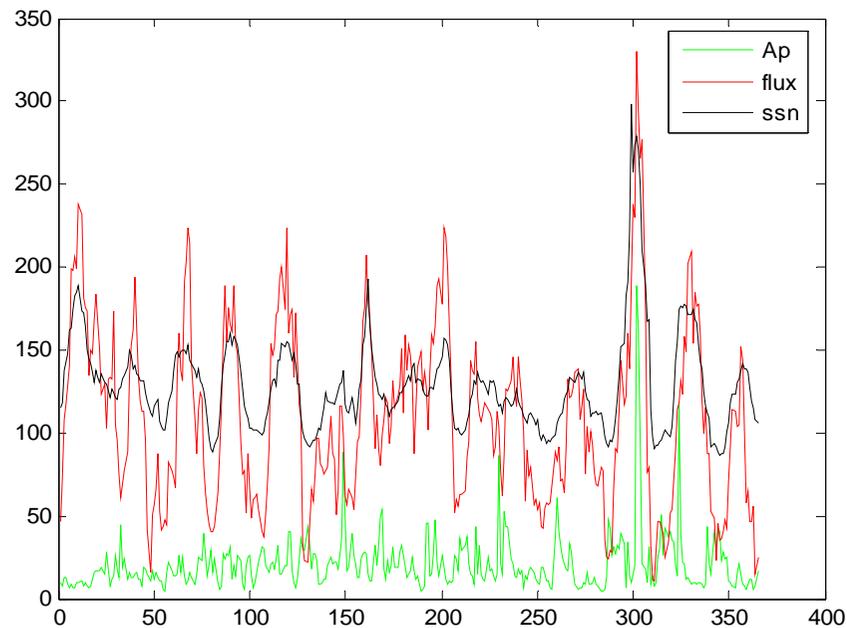
Research protocol

- *Research papers*
 - *Journal papers (Journal of Navigation)*
 - *Conference papers (NAV, ENC, ICECom, ELMAR, Baska GNSS Vulnerabilities and Solutions conference)*
- *Project presentation*
 - *Technical reports*

Research results

Ionospheric research

- *Definition of related space weather indices and ionospheric behaviour*



Time series of space weather indices in 2003

A HALLOWEEN EVENT CASE STUDY

ssn – sunspot number,

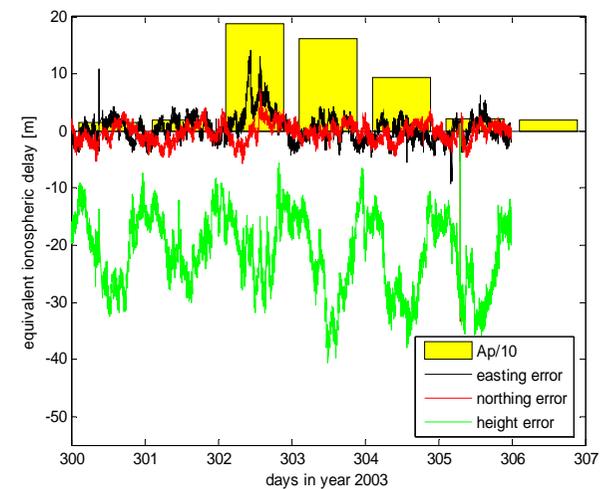
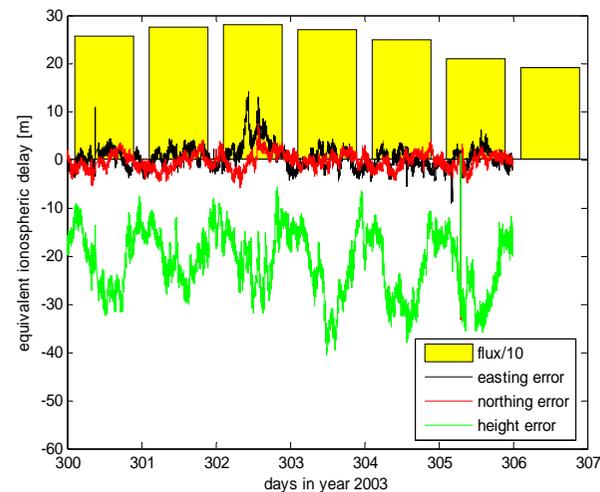
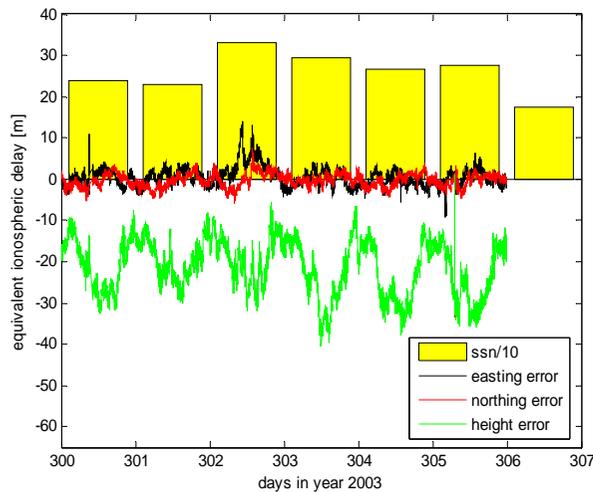
flux – solar flux,

Ap – planetary geomagnetic Ap index)

Research results

Ionospheric research

- Correlation between the space weather indices and GPS positioning error



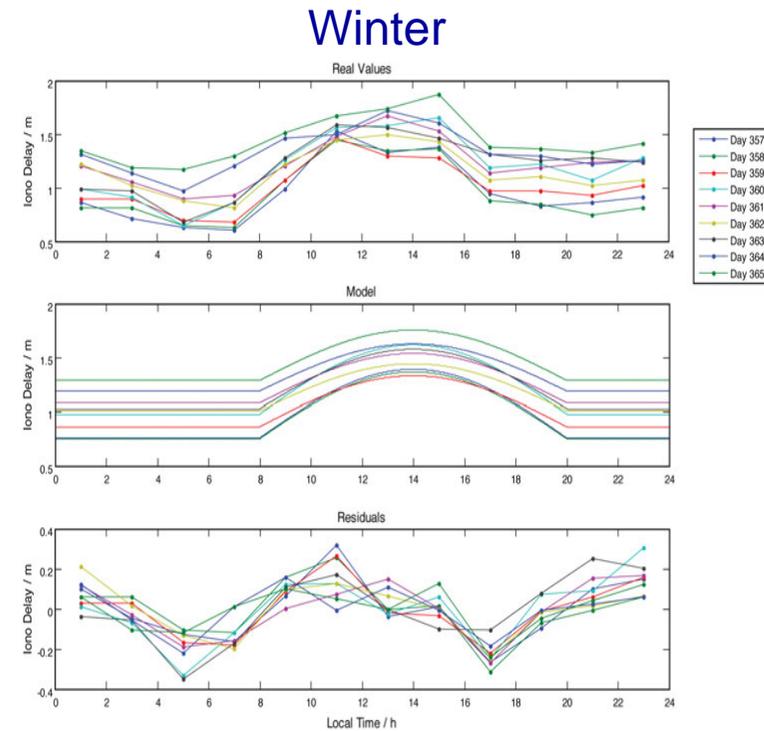
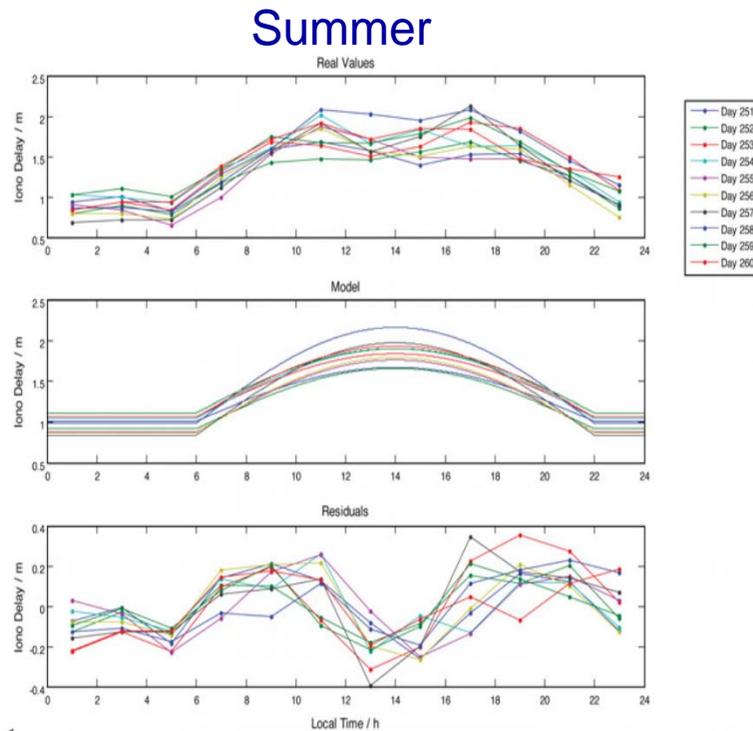
Research results

Ionospheric research

- *Daily dynamic of ionospheric delay with seasonal effects in periods of quiet space weather conditions for a Croatian coastal region of the northern Adriatic in 2007*

Modification of a Klobuchar-like approach for quiet space weather conditions was proposed

- *night-time GPS ionospheric delay is not constant, but rather modelled by a linear function with the minimum during dawn*
- *the width and the amplitude of the cosine component is linearly related to the season of the year*



Research results

Tropospheric research

- *Analysis of available models for tropospheric delay*

Two types of tropospheric delay models exist

Models that use actual meteorological data

- **Saastamoinen model**
- **Hopfield model**

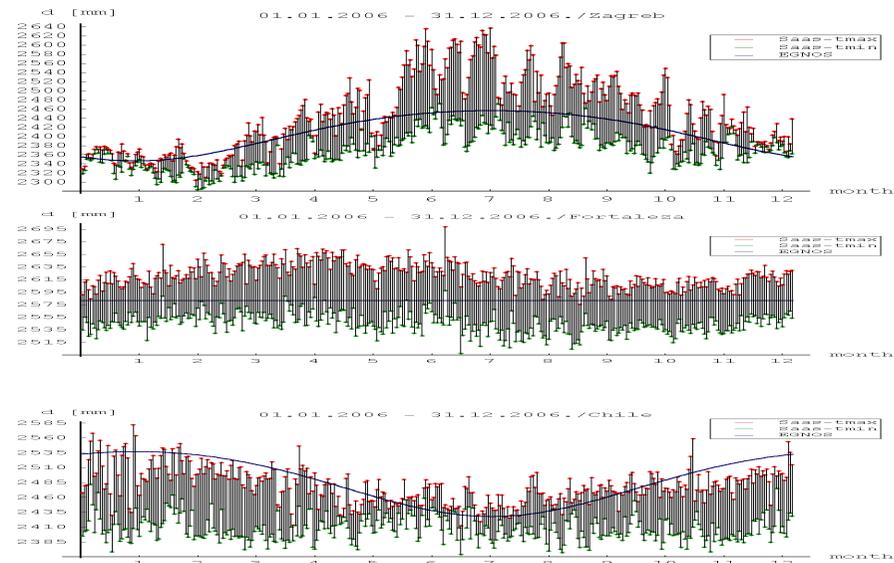
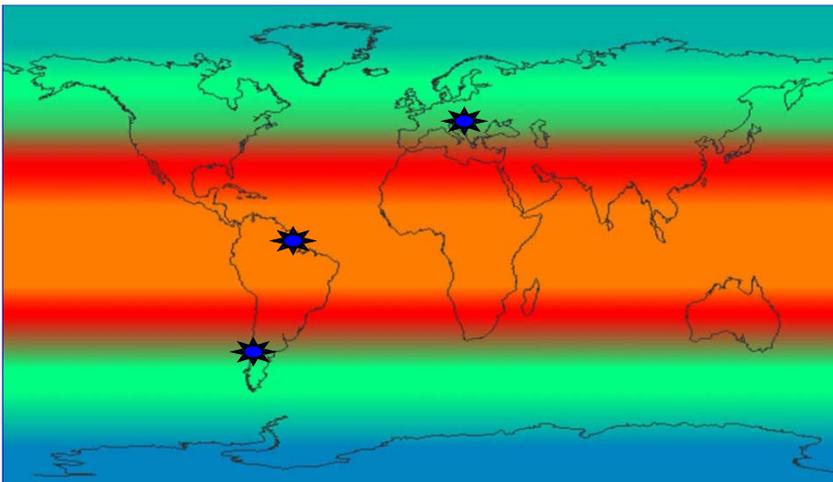
Global models that use yearly averages of meteorological data and their seasonal variation data

- **WAAS/EGNOS model**

Research results

Tropospheric research

- *Analyses of annual tropospheric delay changes at different latitudes*
- WAAS/EGNOS parameters are dependent on the receiver's height, latitude and day-of-year



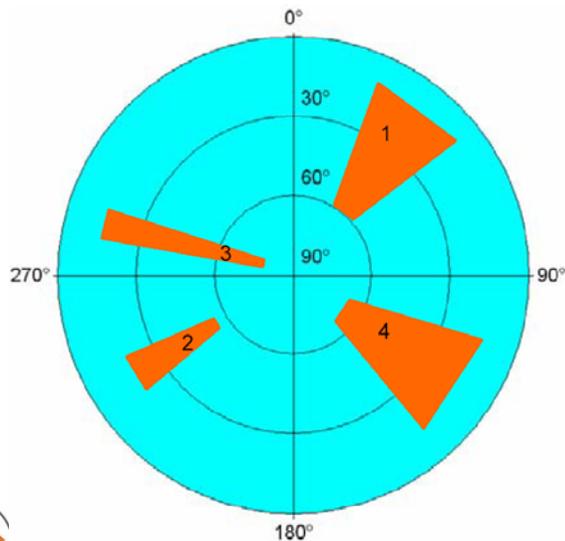
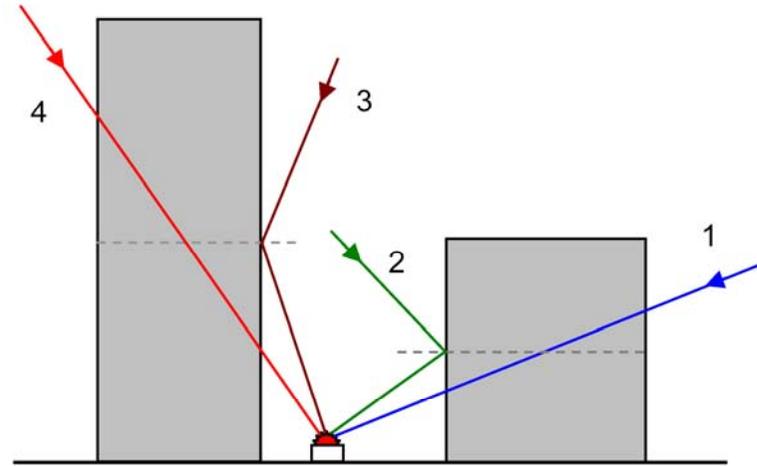
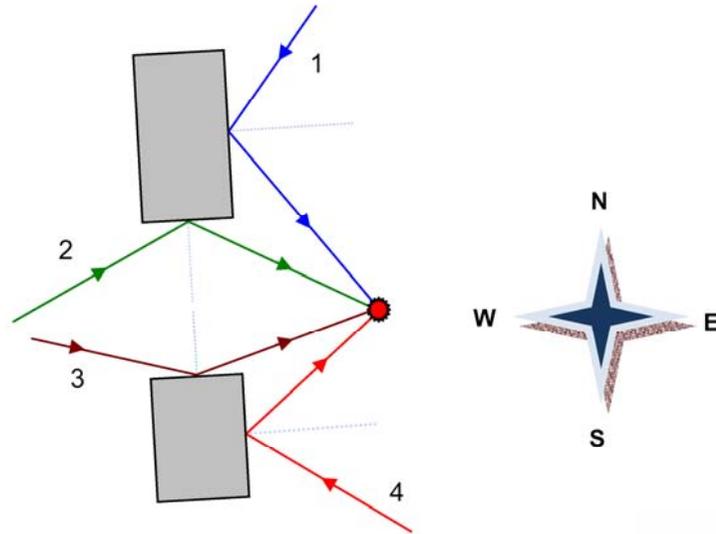
Research results

Multipath propagation effects

- *Analyses of positioning performance in a typical urban environment*



Research results

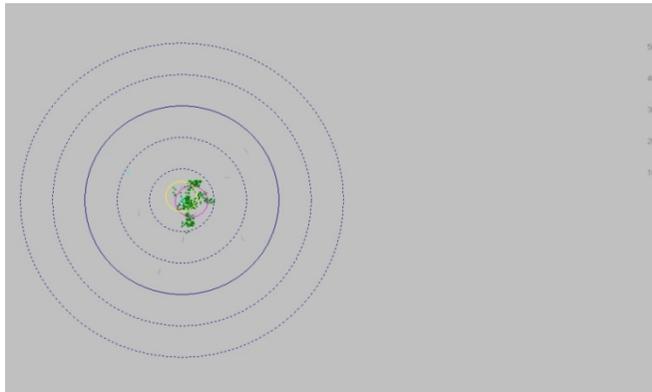


	1	2	3	4
Azimuth min	21°	230°	288°	113°
Azimuth max	49°	244°	300°	144°

	1	2	3	4
Elevation min	10°	10°	10°	10°
Elevation max	61°	52°	82°	80°

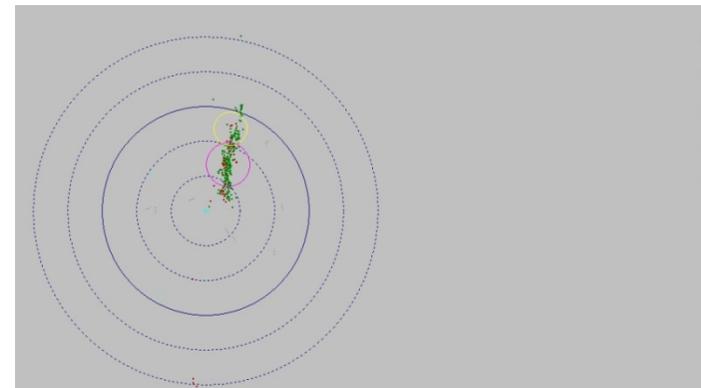
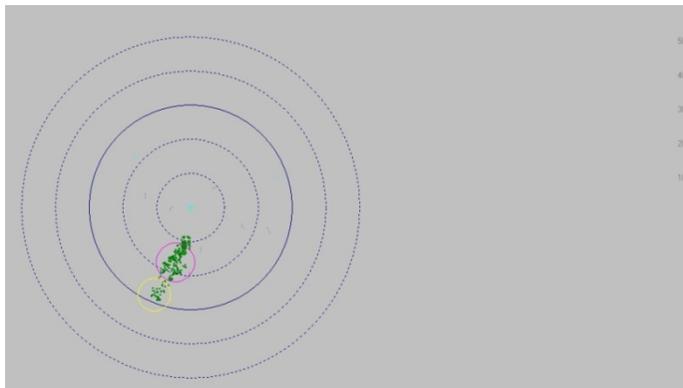


Research results



Typical intervals without multipath:
DOP factor < 6
95% positions within 10 to 15 meter

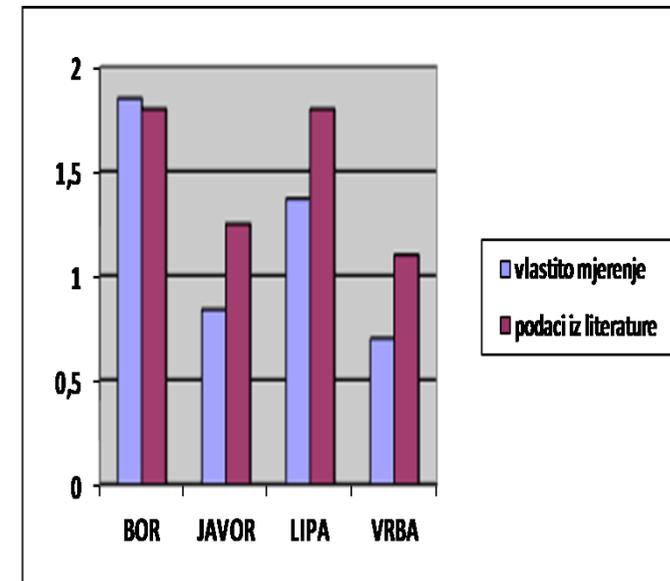
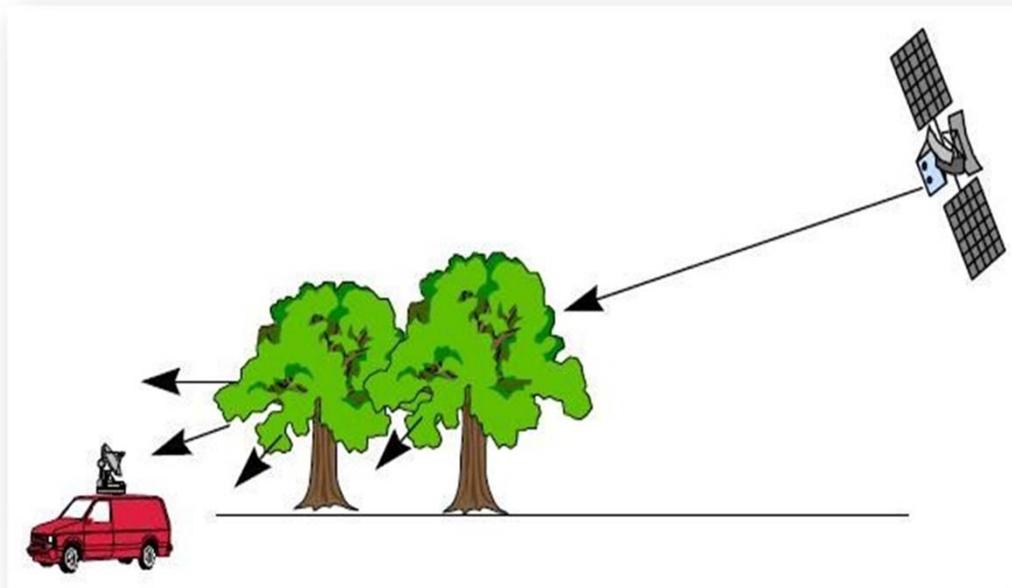
Typical intervals with multipath :
DOP factor < 6, position shift by 30-35 meter



Research results

Student diploma works

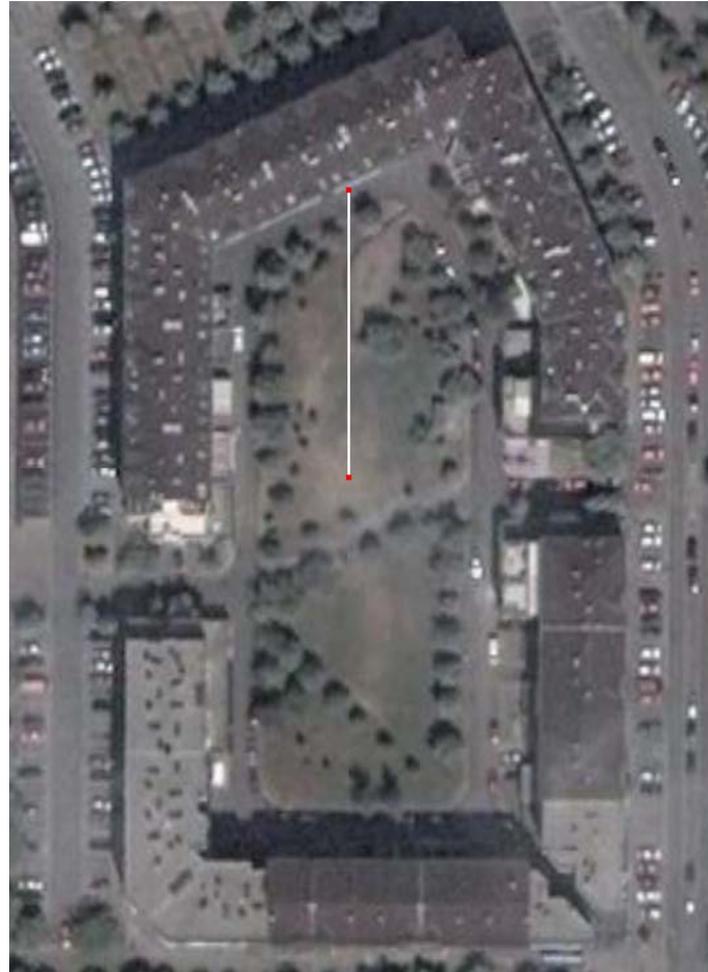
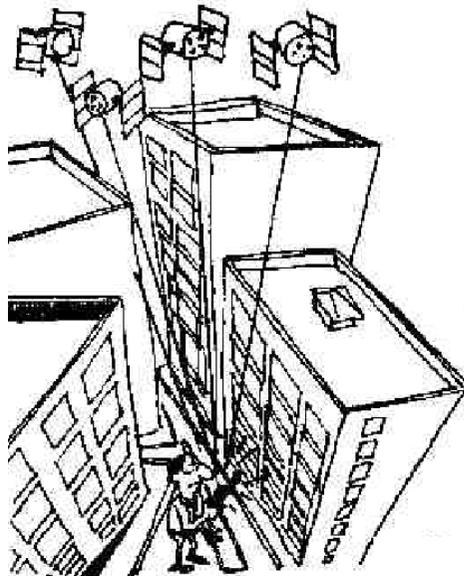
- *Attenuation of GNSS signals by different kind of trees*
- *Comparision with the data from similar published measurement results*



Research results

Student diploma works

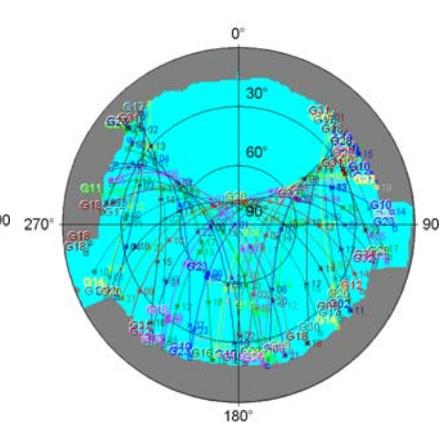
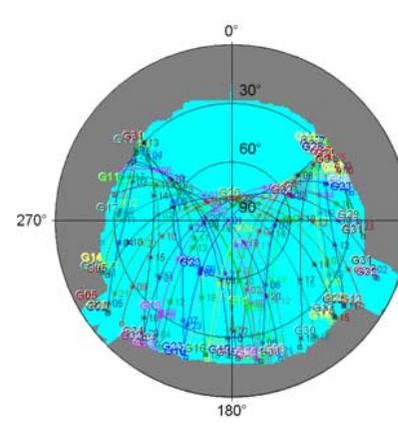
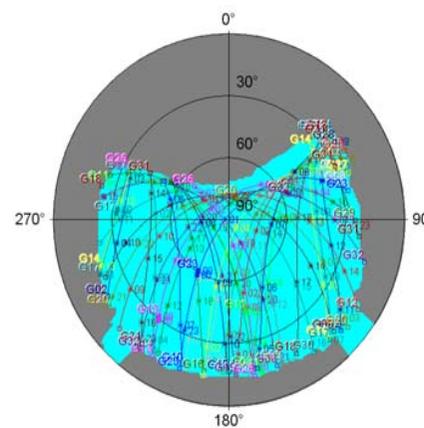
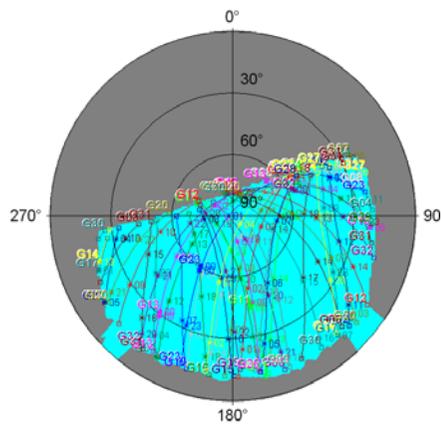
- *Influence of urban environment*



Research results

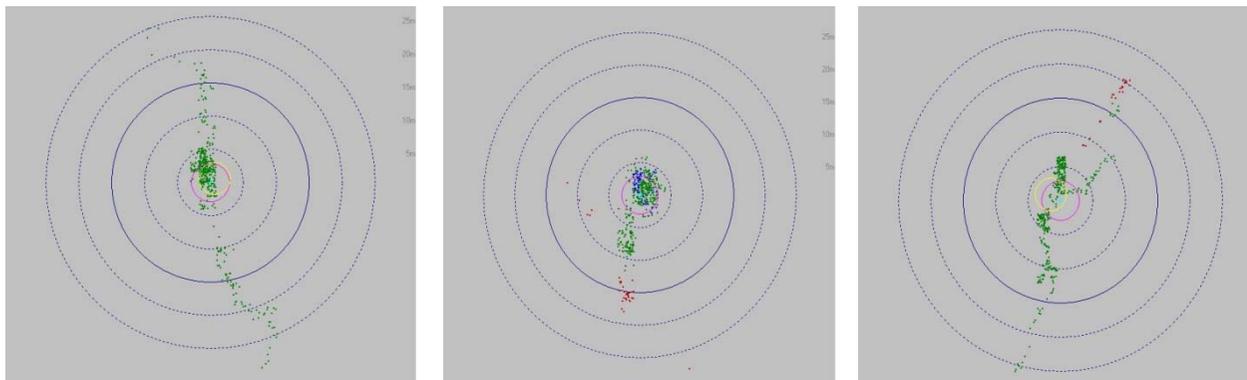
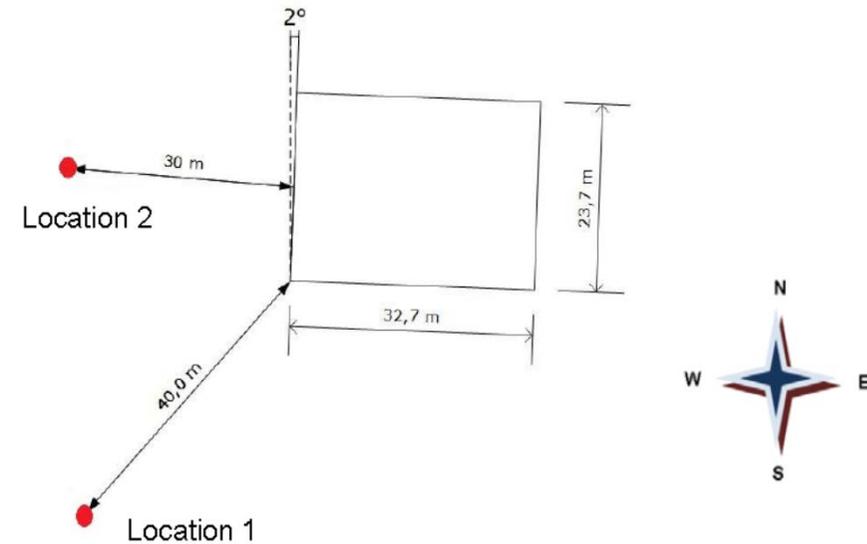
Student diploma works

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Research results

Student diploma work



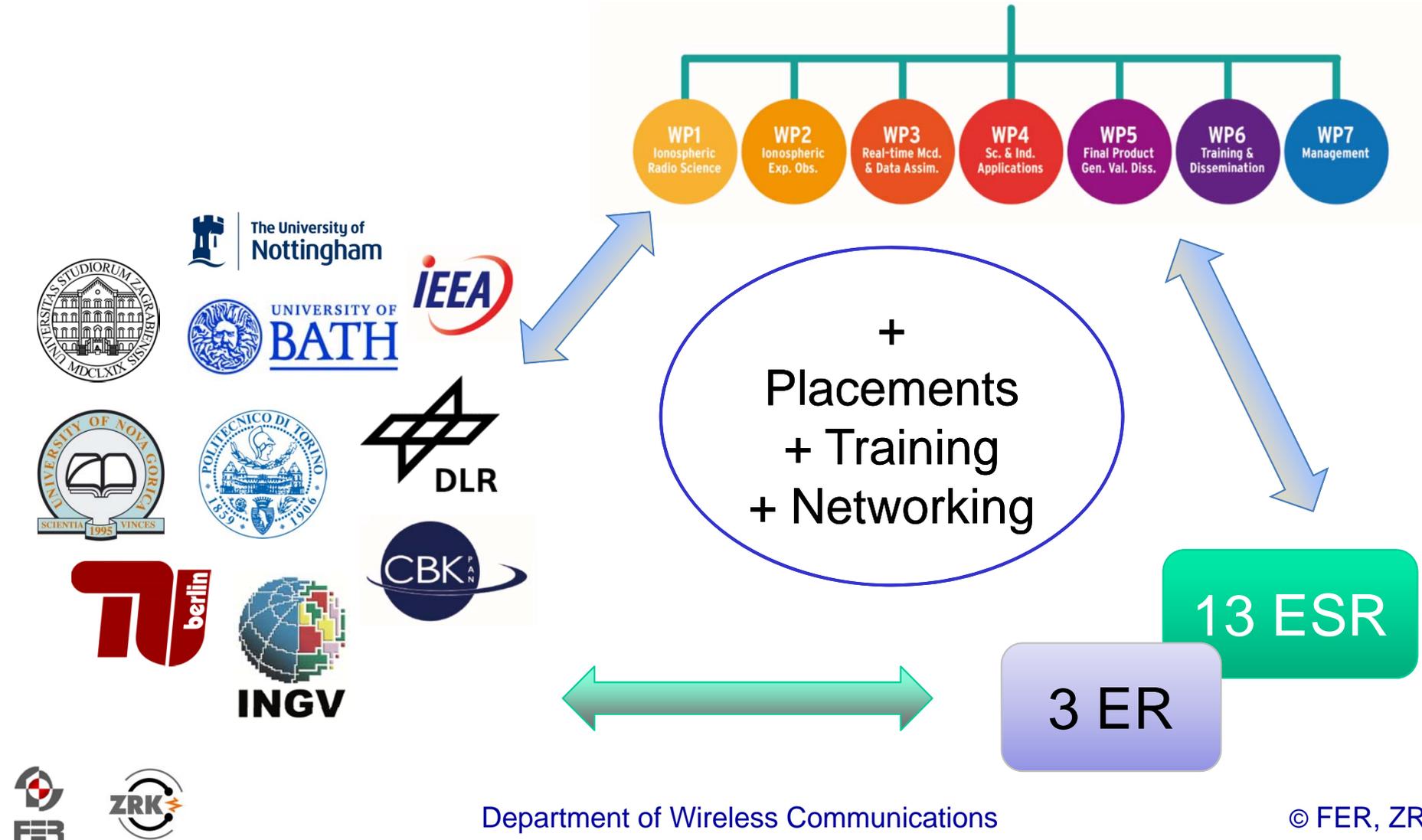
Positioning performance with
multipath propagation

International collaboration

- *Joining the COST 296 MIERS (Mitigation of Ionospheric Effects on Radio Systems) in 2008*
- *Published journal and conference papers*
- *Organisation of annual GNSS Vulnerabilities and solutions conference every year since 2007*
- *Participation on FP7- PEOPLE-2010-ITN project TRANSMIT (Training Research and Applications Network to Support the Mitigation of Ionospheric Threats) – Marie Curie Actions – Initial Training Network*
- *Scientific researcher exchange*

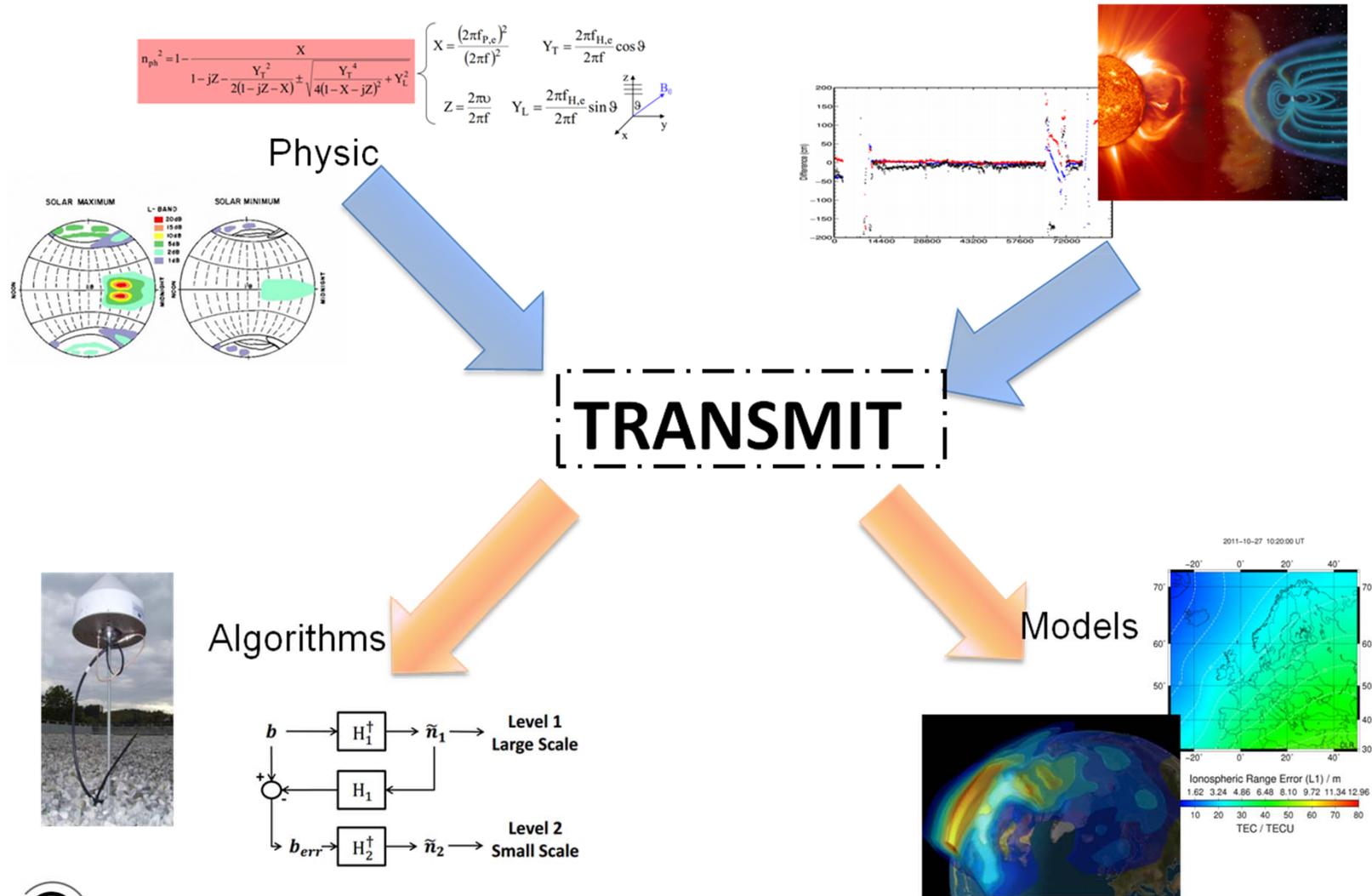
International collaboration

- TRANSMIT (*Training Research and Applications Network*)



International collaboration

- TRANSMIT (.....to Support the Mitigation of Ionospheric Threats)



Conclusion

- *This was the first project in Croatia aimed to systematically research the local ionospheric impact and other environmental influences on satellite positioning quality*
- *A competent project team developed and validated local and regional ionospheric and tropospheric error correction models and multipath influence on GNSS positioning performance*
- *We successfully extended the project towards international collaboration*



Thank you for your attention

