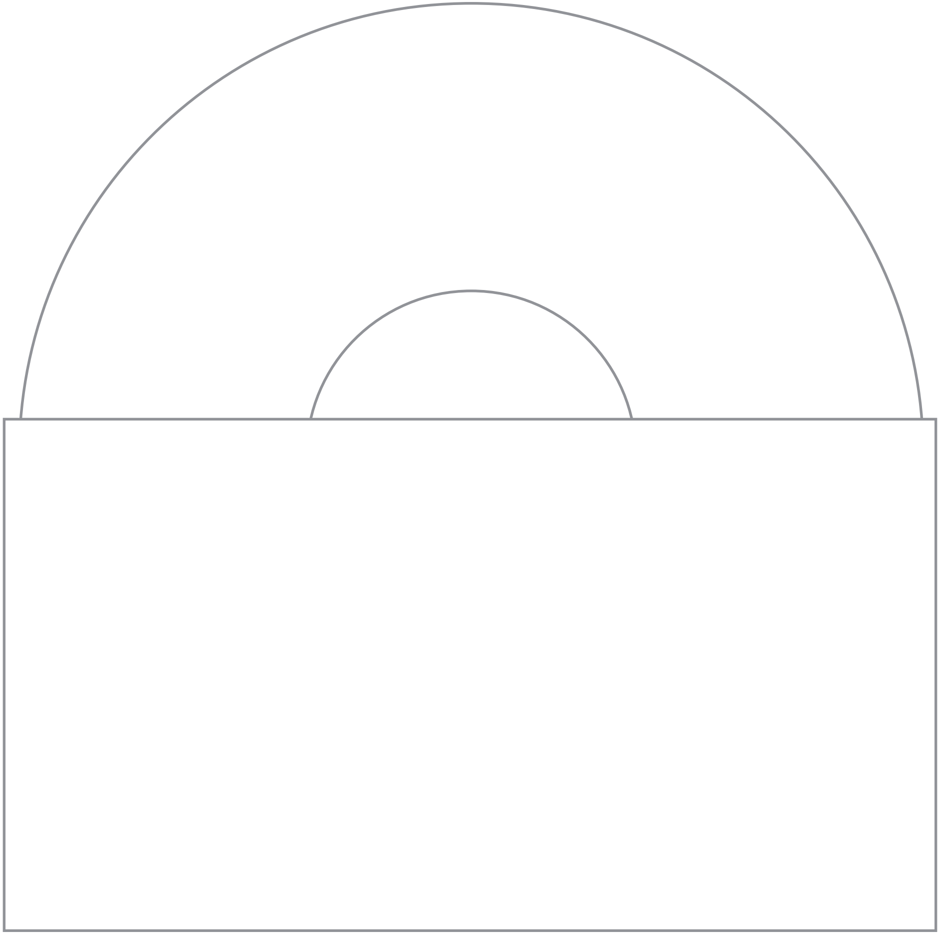
Republic of Croatia | State Geodetic Administration

EUROPEAN UNION – CROATIA PHARE NATIONAL PROGRAMME

CROPOS USERS' MANUAL

CROatian POsitioning System
Hrvatski pozicijski sustav



Republic of Croatia
State Geodetic Administration

CROPOS

USERS' MANUAL

Projekt financira Europska unija
This project is funded by the European Union

Technical assistance to the Integrated Land Administration System – ILAS in the Republic of Croatia

This manual is one of the results achieved through the implementation of the Integrated Land Administration System – ILAS Project contracted within the national PHARE 2005 program which is one of the instruments established for the use of pre-accession European Union funds and intended to finance institutional development as well as economic and social connectedness.

Project Objectives and Purpose

The basic Project purpose is to improve the real estate market in the sense of moderating the current infrastructure limitations which are related to the real property registration system at the municipal courts and cadastral offices. In that sense, the Project provides significant support to the reform of the court system and the strenghtening of the responsible state institutions.

The Project is divided into four different components:

1. development of final project documentation for the modernization of municipal courts and cadastral offices at the level of IT and communication equipment
2. support provided to the implementation of National Spatial Data Infrastructure
3. development of procedures and educational programs for users related to the CROPOS network establishment
4. training and strengthening the capacities of Land Registry Offices (LRO) and cadastre

The Component 3 of the Project refers to the provision of consultant services for the CROPOS (CROatian POsitioning Svstem) Project whose objective is to establish a national network of GNSS stations and which is financed by the PHARE program.

Basic objectives of this component are the following:

- inform the public and future users about the possibilities of CROPOS (types of services that will be offered to users, service accuracy, necessary investments in GNSS equipment, etc.)
- elaborate the procedures and rules for the practical use of CROPOS by users
- establish a system of data quality control management
- provide support to SGA in training the employees for daily system management

PREFACE

Director-General:
Prof. Željko Bačić, Ph.D.

Dear users,

Satellite positioning and navigation have become a daily habit for a great number of professionals and citizens. In order to use satellite systems for positioning and navigation as efficiently as possible, permanent station networks are being developed throughout the world. Their purpose is to register constantly the observations of these satellites and to make this data available to users through mobile communications. This doubles the efficiency of system use, whereas reliability increases several times. In the desire to be in line with contemporary solutions and due to the growing needs of Croatian society, the State Geodetic Administration has established the CROatian POsitioning System - CROPOS service. CROPOS is a national network of reference GNSS stations (Global Navigation Satellite System is the standard term for the satellite positioning systems: the American GPS and Russian GLONASS, i.e. the future European GALILEO and Chinese KOMPASS). The GNSS systems have introduced significant changes and benefits in the entire range of economic activities and systems.

The CROPOS system provides the users with three types of services: DPS, VPPS and GPPS. The difference among these services is in the instruments they use, measured values and methods of determining coordinates, manner of data transfer, accuracy and data format. The type of service you select depends on your needs. VPPS is the most efficient service and that is why we have directed particular attention to it in this manual. The CROPOS VPPS service gives you, dear users, the possibility to determine a position in the so-called real time, with an accuracy better than +/- 2 cm on the entire territory of the Republic of Croatia. This service is intended to be used by all entities of geodetic and cadastral system of the Republic of Croatia, the state administration entities, local governments, all Croatian public systems and economic entities, as well as by all sailors, hikers and backpackers.

With the establishement of CROPOS system, the most contemporary such system in Europe at this moment, the Republic of Croatia has joined the developed countries that provide such services to its economic community and citizens. Regarding the exceptional geodetic and construction activities, Croatia as a transit country in some aspects, tourism and a high level of economic activity, our expectation is that, as economic entities, you will directly benefit from the system because the GNSS technology will be more available and cheaper to you, and you will obtain more accurate and reliable results. Therefore, the CROPOS system represents an infrastructural background for the overall development of different economic activities in Croatia and is becoming a measure of our technologic development.

The purpose of this manual and the attached training video is to provide you, dear users, with basic knowledge in satellite navigation, and with support while registering into the system. Furthermore, we wish to assist you in the planning of your assignments and in you daily use of CROPOS.

The employees of the State Geodetic Administration Sector for State Survey will do their best to provide you with appropriate support in other aspects as well as to justify your trust and expectations regarding the use of CROPOS service.

INTRODUCTION

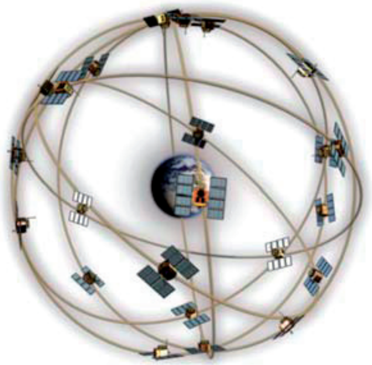
This manual is intended for the Croatian Positioning System – CROPOS users who should obtain through it some basic knowlegde in the area of satellite navigation and its implementation within the national reference network. This is not a technical manual or textbook for satellite geodesy or global navigation satellite systems – GNSS because this is a wide area of expertise and there are many reference materials for this. This manual should primarily provide support to the future users in their work, planning process and development which requires making appropriate investment decisions. GNSS is an overall term for the systems used in the United States of America and Russian Federation. Throuhgout the world, USA are developing and maintaining the widely known GPS system (Navigation System using Time and Ranging Global Positioning System - NAVSTAR-GPS), whereas Russia is developing the GLONASS system (Global Navigation Satellite System). GNSS is a result of a continuous development of navigation system related to the Earth or the satellites such as Transit, Timation, Loran and Decca. The position determining conducted by navigation systems can be affected by errors occurring due to physical, meteorological and ionospheric impact. With the implementation of differential procedures, the errors can be reduced or cancelled, i.e. their size or estimation can be calculated. The procedures for improving the position accuracy in real time are based on the comparison of coordinates obtained from measurements at a permanent GNSS station with its reference coordinates determined by high accuracy geodetic methods. On the basis of the difference between coordinates, the corrective data is calculated and sent through communication devices. A user can, if necessary, receive the corrective data and use it to fix its measured values. The measurement procedure has been developed for civic purposes. With the installation and launching of the national reference GNSS CROPOS network, the Republic of Croatia has enabled the users to implement the system in their daily work.

SYSTEM REVIEW

The GNSS system can be divided into three parts:
• Space Segment – containing active satellites circling around the Earth
• Control Segment – containing stations set up for the overall control and supervision of the system
• User Segment – made up of users receiving and processing the GNSS measurement data

SPACE SEGMENT

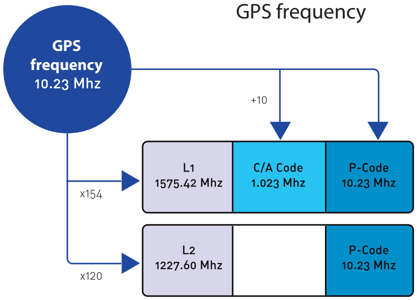
The Space Segment is made up of GNSS satellites located around the Earth, in almost circle-like orbital planes. The altitude of GPS satellite orbit is approximately 20.200 km. The satellites make a circle around the Earth every 11.58 hours, and currently 31 satellites are active. The GLONASS system currently contains 18 active satellites circling around the Earth at the altitude of 19.100 km and they make a circle every 11.15 hours.

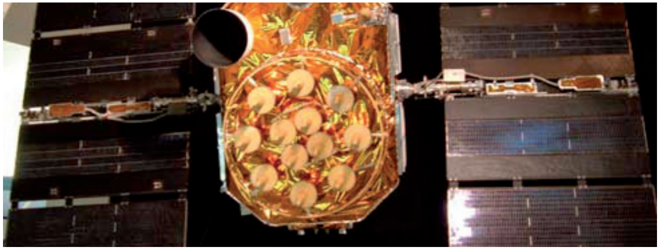


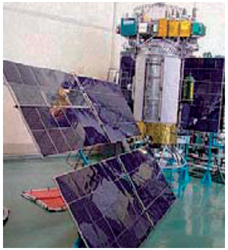
GNSS - Constellation of satellites

Both systems are designed to enable point positioning at any moment or place on Earth and in all weather conditions, which also requires visibility of at least four satellites located above the horizon; Aquisition Code and P-Code (Precision Code). In order to differentiate unambiguously the GPS satellites, different PRN (Pseudo Random Noise) codes are used. The codes can also be used as the basis for measuring pseudo-distances in order to determine point positions.

GPS frequency







GPS satellites transmit the measurement data at two frequency carriers located in L-radio area. The frequency carriers have been developed from the basic frequency generated by the high-precision atomic clock.. On the L1 frequency carrier, two codes have been modulated, C/A-code (Coarse/).

The GLONASS satellites are similar to GPS satellites in the signal structure, however, unlike GPS signals, they always transmit the same code which enables identification of a particular satellite, by attaching an unambiguous frequency pair to each satellite.

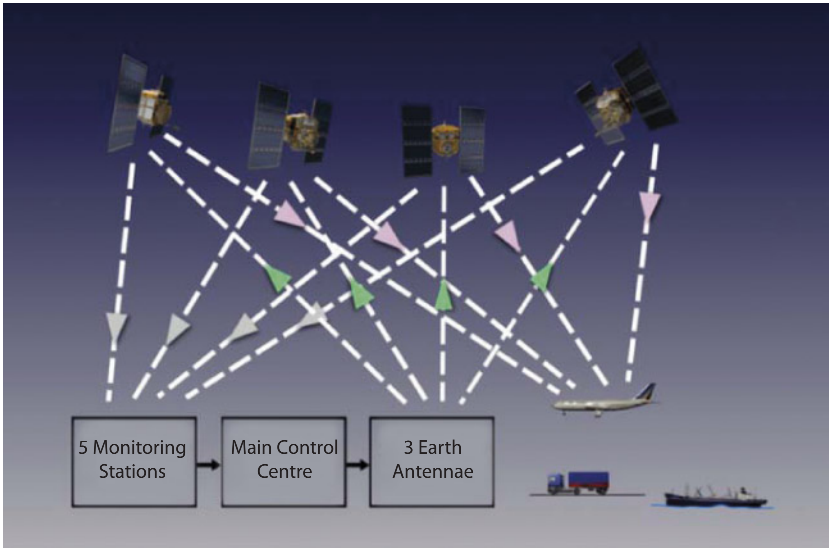
CONTROL SEGMENT

The Control Segment of GLONASS system includes the following:

- main control station
- central station for the harmonization of system operations
- managing and monitoring stations

with the following tasks:

- collecting the measurement data and calculating the satellite ephemerides
- sending the ephemeris data, time data and other information to particular GLONASS satellites
- monitoring and harmonizing the GLONASS time and the UTC time
- controlling the satellite operation, as well as satellite movements and positions
- managing and ensuring the functioning of the entire system



Control segment of GPS system includes the following:

• main control station
• 5 stations for system monitoring
• 3 stations for data transmissions

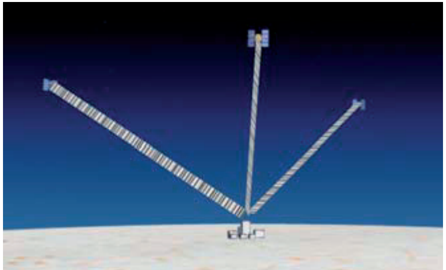
with the following tasks:

• controlling the entire system operations
• monitoring the satellite movements
• monitoring the satellite clock operations
• calculating the ephemerides and satellites times

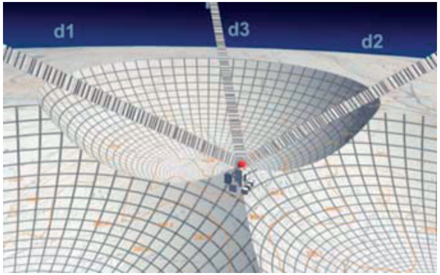
USER SEGMENT

The device for the GNSS measurement data receipt basically consists of the receiver itself and the antenna. The receivers, depending on the producer and accuracy requirements, have a possibility to receive one or two signal frequencies, as well as a various number of channels where they can receive satellite signals. The signals of all satellites located above the horizon are received through the antenna, and the receivers recognize them and register them. On the basis of the received data, the pseudo-distances between the receiver's antenna and the satellite are calculated, and the position of the antenna is determined.

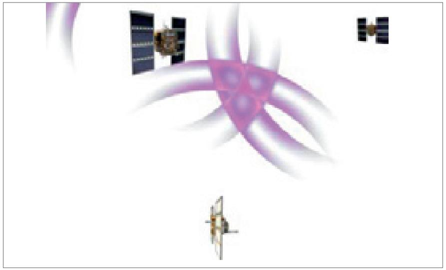
PRINCIPLE OF DETERMINING THE POSITION

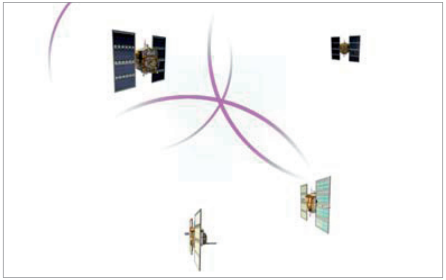


The GNSS receivers receive the satellite signals and calculate the distances on the basis of time difference, from the moment of transmitting until the moment of receiving the signal. If the distances to the three different satellites are known, it is possible through the space intersection to determine the antenna position (3 unknowns: X, Y, Z) in relation to the satellites. The receiver position is not by this unambiguously determined because the satellite and receiver clocks are not harmonized, therefore nor are the measured distances the real distances, but the so-called pseudo-distances. Due to this, it is necessary during the measurements to have at least four pseudo-distances determined in order to calculate the four unknowns (X, Y, Z, ΔT).



Depending on the method of measuring and the available instruments, a user has several possibilities for determining his position:





AGNSS

Absolute position:

Determining the position by using L1 frequency and C/A-code (Coarse-Acquisition Code) but not implementing the corrective data.
The position accuracy is approximately 3-8 m.

DGNSS

Differential positioning (code):

Determining the position by using L1 frequency and C/A-code (Coarse-Acquisition Code) but not implementing the corrective data.
The position accuracy is approximately 3-8 m.

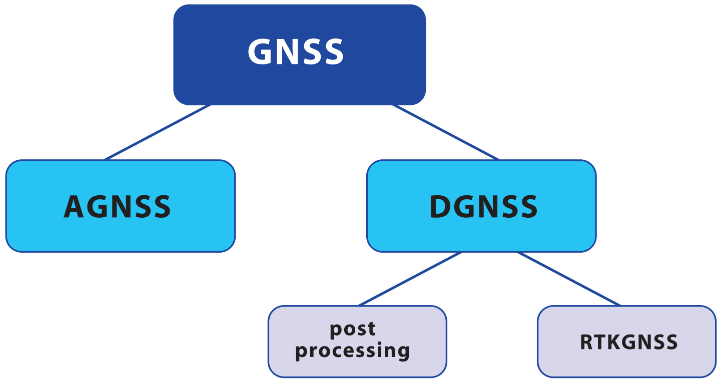
RTK GNSS

Differential positioning (phase):

Determining the position by using L1 and L2 frequencies and C/A-codes, as well as the data of real-time phase measurements with the implementation of corrective data from another independent GNSS receiver.
The position accuracy is approximately 20-50 mm.

Post-processing (phase):

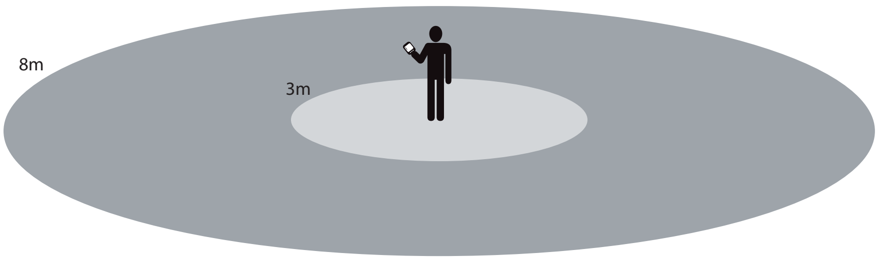
Determining the position by using L1 and L2 frequencies and C/A codes, the phase measurement data, and additionally determined corrective data from another independent GNSS receiver.
The position accuracy is approximately 10-20 mm.



AGNSS

Determining the position by using navigation receivers without applying the corrections of measured values or a particular position, is the basic and most widespread implementation of satellite positioning. This method can be applied by using the so-called manual navigation receivers or receivers installed in cars, ships or planes. The position accuracy of navigation receivers is approximately 3-8 m.

As the case is with all the others, mostly GPS-based receivers, the position calculation is conducted in WGS 84 (World Geodetic System 1984) coordinate system. For position calculation, the C/A code (Coarse/Acquisition Code) is mostly applied. The user has the possibility to transform the coordinates determined in this manner, into the local coordinate system, according to his/her own choice. The exit for the position data and the communication with other devices can be performed, if necessary, through the accepted NMEA (National Marine Electronic Association) format.



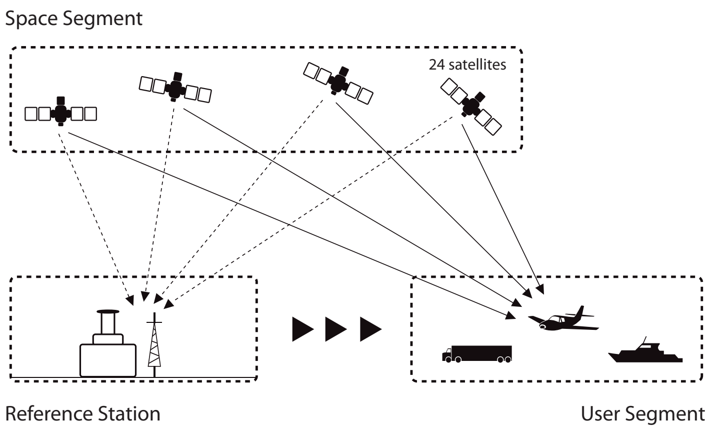
DGNSS

With the implementation of the DGNSS method of measurement, the accuracy of determining the position has been significantly improved due to the implementation of corrective data. The corrective data is calculated within the work of reference network consisting of permanent GNSS stations. The corrective parameters are calculated by using the collected measurement data from the permanent stations and their reference coordinates. The discrepancies in distance measurement and clock errors are calculated by comparing the actual time of signal passage between a known position and a satellite, with the calculated time of signal passage from the currently determined position. These differences are calculated for each satellite from which the signals were received and are available to the users.

The calculation and implementation of data can be conducted under the assumption that the ionospheric and atmospheric conditions at the user's place of measurement and at the place of reference receiver can be compared.

The distance of 50 km is taken as the maximum distance between a user and a reference station. With the implementation of this method, it is possible to achieve the positioning accuracy of 0.5 – 1 m.

The transfer of corrective data is conducted through radiowaves (UKW) or mobile phone system (GSM). The RTCM (Radio Technical Commission for Maritime Services) data format is used for the corrective data transfer. The RTCM 2.0 or RTCM 2.1. formats are mostly used for the DGNSS method.



RTK GNSS

In case the phase measurements are included in the processing of GNSS measurement data and in the calculation of corrective data, the accuracy of real-time positioning will significantly increase. In applying this method, it is possible to achieve the accuracy of determining the position from 2 to 5 cm in real-time, for the data that can be downloaded from the server of the reference GNSS network.
The data downloaded from the server are in RINEX (Receiver Independent Exchange) format. The RTCM 2.2, RTCM 2.3, RTCM 3.0 i RTCM 3.1 formats are used for the transfer of corrective data.
The objective of processing and equalizing the phase measurement data is determining the ambiguities of phase measurements, i.e. determining the number of full wave lengths of phase measurements, by which the accuracy and reliability of real-time positioning is increased.

Post processing

In case the corrective data receipt is not possible in real time in the field during measurements, a user can conduct a measurement data processing in his/her office, using the measurement data collected in the field and the data that can be downloaded from the server of reference GNSS network. The data downloaded from the server is in RINEX (Receiver Independent Exchange) format.
The GNSS systems consist of several parts: the space segment in the space area close to the Earth, the control segment and user segment on Earth. Due to a large number of various external influences on the satellite movement orbit and the signal path of measurement, errors occur from the satellite to the receiver, influencing the accuracy of determining the position. Determining a position through the GNSS measurement method requires accurate data on the time, satellite position and signal delay during its passage from the satellite antenna to the receiver antenna. The point positioning is influenced by the attractive force of the Sun and Moon, but also from other planets, which creates tidal waves at seas, oceans and land. During the measurement data processing, the models are used in order to reduce the external impact on the measured values and determining the point coordinates. The differences and linear combinations of original measurements are used for the cancellation of system errors.

ERROR IMPACT

SYSTEM ERROR IMPACT

Satellite orbit error

Orbit errors and orbit accuracy have a direct impact on determining the measured point position. In order to complete the navigation assignment, a user must have a real-time access to data on satellite position and satellite system time. This data is contained in the broadcast message which is an integral part of the measurement signal. The broadcast message is defined within the satellite system control segment, and then transmitted to the satellites. The establishment of IGS (International GPS Service for Geo-dynamics) service in 1994, made a significant contribution to the further development of the GNSS measurement method applied in geodesy. On the basis of measurement data of about 400 reference points, the IGS service defines a precise orbit and corrections of satellite clocks which are available to users. The accuracy of IGS orbit is greater than 5 cm.

Receiver clock error

Due to the incompliance between the satellite clock and receiver clock, the wrong time is attached to the measured value, therefore it is not the actual lengths that are determined, but the so-called pseudo-distances.

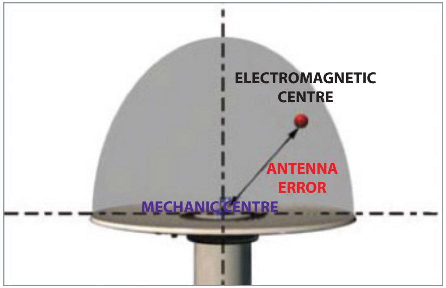
IMPACT OF RECEIVER ERRORS

Receiver's measured noise

The impact of receiver errors are discrepancies of measured signals from real values (measured noise). The errors appearing at the signal receipt, enter into pseudo-distance of up to 10 cm.

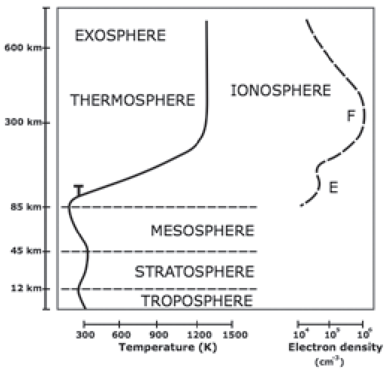
Antenna phase centre

Variations of the antenna phase centre that the GNSS measurements refer to, can be changed in their amount, and they depend on the satellite position, i.e. its elevation and azimuth. In general, the phase centres of L1 and L2 measurements are not identical and their distance must be specified and known for the antennas used for high-accuracy measurements. In order to fix this impact, during the measurement data processing it is necessary to implement the model of antenna phase centre variations where the positions of phase centres of L1 and L2 measurements are defined in relation to ARP (Antenna Reference Point).



IMPACT OF THE IONOSPHERE

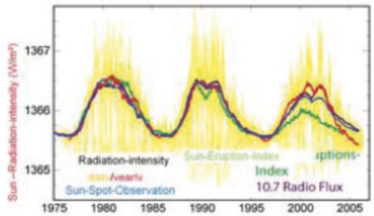
Ionosphere is part of Earth's atmosphere containing a significant share of ions and free electrons. In the space closer to the Earth, the ionosphere starts at the altitude of about 70 km, and at the altitude of about 1000 km it becomes plasmasphere. The highest concentration of ions and free electrons is at the altitude of about 300 km. The acronym for the number of electrons in the atmosphere is TEC (Total Electron Content). This value usually varies between 5 and 25, and depends on the activity of the Sun.



The activity of the Sun reaches its maximum every 11 years.

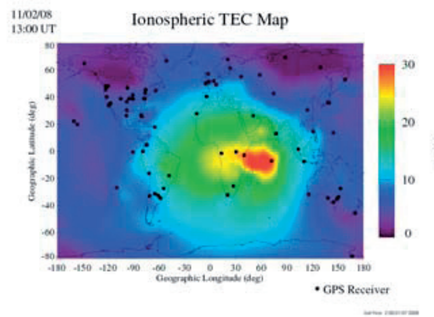
GNSS systems – causes of inaccuracies
Environment

Solar activity (11-year cycle of solar activity)

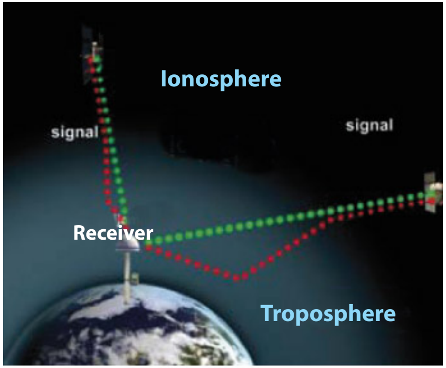


During a solar storm and while the activity of the Sun is maximal, TEC can reach values greater than 200.

The impact of the ionosphere , i.e. TEC value, significantly reflects on the accuracy of determining the position by the GNSS measurement method. Therefore, the Sun's activity is very important during the satellite measurement, and this can particularly be seen when this method is applied in real time.



The state of ionosphere can be monitored on the internet. Due to the above-mentioned influences, the satellite signal breaks in the ionosphere, and therefore it is delayed. The influences affect differently various frequencies. By using the receivers that can receive two frequencies (L1 and L2) and applying the appropriate linear measurement combination it is possible to cancel out the impact of the ionosphere. Regarding the receivers which use only one frequency for positioning, the impact of the ionosphere can be reduced with the implementation of the appropriate model of the ionosphere.



For the satellites in zenith, under favourable conditions, it is possible to conduct calculations with errors from 3 m (by night) to 15 m (by day). The accuracy is furthermore affected by the length of the signal passage through ionosphere. By increasing the elevation angle over the horizon, the signal passage through ionosphere will be shorter.

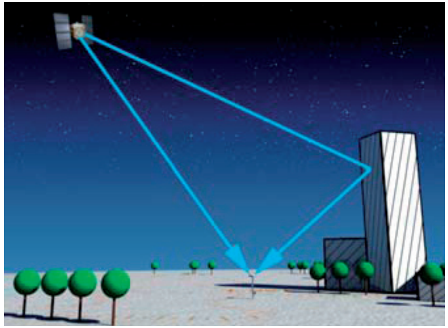
For the satellites which are 5 degrees above the horizon during measurements, the measurement error is greater, from 10 m (by night) to 50 m (by day).

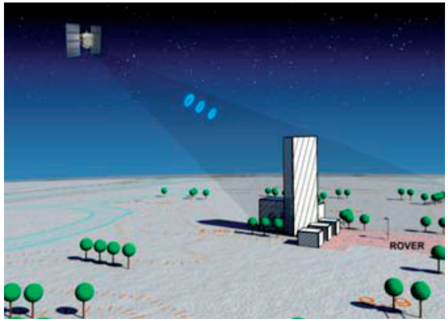
IMPACT OF THE TROPOSPHERE

Due to the changes in air pressure, humidity and temperature, the impact of the troposphere does not depend on frequency, and cannot be cancelled by applying linear measurement combination. The impact of troposphere on satellite signals can be defined by applying models which must correspond, meteorologically and in time, to the area of measurement. The impact also depends on the elevation angle of the satellite. When models are not applied, the error of measuring the distances of satellites in zenith is about 3 m, and for satellites which are 10 degrees above the horizon, the error is about 10 m. The models can help reduce this error to about 1 meter.

MULTIPATH SIGNAL DISSEMINATION

A longer period of time necessary for the signal to go from satellite to receiver's antenna, can be caused by the impact of ionosphere and troposphere, but also by reflexions from constructions and objects appearing in the vicinity of GNSS antenna. A user can receive here the same signal several times which leads to different length results. In general, compared to the direct waves, the reflected waves are very suppressed. This limitation also refers to the

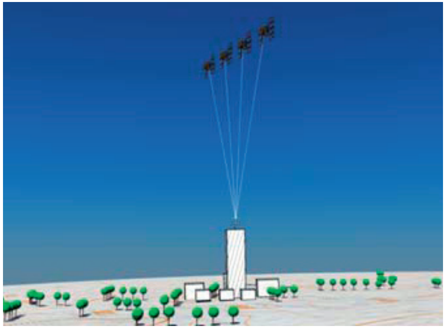




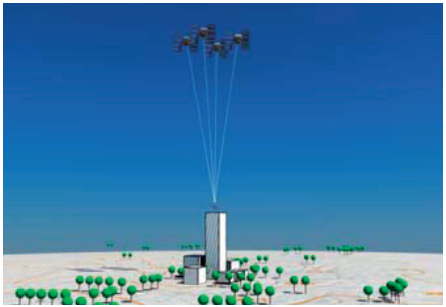
signals received under a small elevation angle. The resulting error can be from 1 m to several hundreds of meters. During the measurement data processing, such impact can be cancelled or reduced by applying appropriate algorthms, but with a longer time period for measurement. It is very important here to take this impact into consideration during RTK measurement because the measurement time period is relatively short.

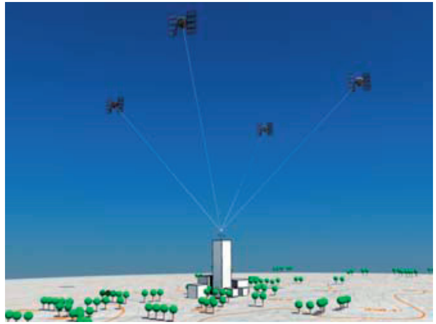
GEOMETRICALLY CONDITIONED ERROR IMPACT

It is important to emphasize that value 1 ensures the best possible satellite constellation, value 6 ensures a good one, whereas values over 10 present a satellite constellation where processing is no longer possible. Determining a position is based on spatial intersection which can be obtained from the measured lengths. Since the measured lengths are burdened with errors, consequently the position determined on the basis of these lengths is burdened with errors. A graphical display of these mistakes looks like a rhomb and the possible positions of a measured point are within it. The size of a rhomb depends on the size of an error of the measured length and the



elevation angle of the satellite. Therefore, the position error is smallest when the elevation angle of the satellite above the user is 90 degrees.





PARAMETERS OF ACCURACY

The accuracy of determining the position through the GNSS measurement method depends on two factors:
1. The accuracy of determining particular pseudo-distance expressed through User Equivalent Range Error or through the attached standard deviation.
2. Geometric configuration of available satellites.

The quality of satellite geometry is assessed through the DOP (Dilution of Precision) parameters.
It is important to emphasize that value 1 ensures the best possible satellite constellation, value 6 ensures a good one, whereas values over 10 present a satellite constellation where processing is no longer possible.

RTCM FORMATS

The corrective data is sent to the users in standardized RTCM format. The RTCM format has been developed throughout many years, therefore today there are several formats in use, differing primarily in the scope of data (number of messages) that can be transferred to users. The following are the descriptions of particular RTCM formats, emphasizing the most important messages which are transmitted through them.

RTCM

1 Differential GPS corrective data (pseudo-distances and speed, max. 12 satellites)
2 Corrected pseudo-distances, in relation to the old orbit data (max. 12 satellites)
3 Reference station coordinates (ECEF X, Y, Z) 6 Initial message, used as time record
16 Specific message (max. 90 characters – ASCII-text)

RTCM 2.1

9 GPS partial corrections (max. 3 satellites per message)
17 GPS ephemerides (1 satellite per message)
18 RTK phase measurements, uncorrected
19 RTK pseudo-distances, uncorrected
20 RTK phase measurements – corrective data
21 RTK pseudo-distances – corrective data

RTCM 2.2

14 GPS time, GPS week
22 Additional parameters of reference station
31 Differential GIONASS correction (otherwise type 1)
37 GNSS System Time of set (seconds of merging)

RTCM 2.3

23 Antenna code (title, ID, antenna serial number)
24 Antenna height and Antenna Reference Point (ARP) data

RTCM 3.0

1001 GPS L1 measurements
1002 GPS L1 measurements (additional information 1)
1003 GPS L1+L2 measurements
1004 GPS L1+L2 measurements (additional information 1)
1005 Reference station coordinates (ECEF XYZ)
1006 Reference station coordinates (ECEF XYZ and additional information 2)
1007 Antenna type
1008 Antenna type (additional information 3)
1009 GLONASS L1 measurements
1010 GLONASS L1 measurements (additional information 4)
1011 GLONASS L1+L2 measurements
1012 GLONASS L1+L2 measurements(additional information 4)
1013 System parameters, list of transmitted messages

The RTCM 3.1 format can also include the transformation parameter data used for the transformation of coordinates between the coordinate systems (geodetic datums).

RTCM

1014 Coordinate differences between the auxiliary and main station
1015 Ionospheric correction for all satellites between one auxiliary and the main station
1016 Geometric correction for all satellites between one auxiliary and the main station
1017 Combined ionospheric and geometric correction for all satellites between one auxiliary and the main station (the same contents as with the 1015 and 1016 messages together, but of a smaller size)
1018 RESERVED for additional ionospheric corrections
1019 GPS ephemerides
1020 GLONASS ephemerides
1021 Helmert/Abridged/Molodenski transformation
1022 Molodenski/Badekas transformation
1023 Transformation- Residual Message, ellipsoidal grid representation
1024 Transformation- Residual Message, plane grid representation
1025 LCC2SP, OM Projection
1026 Lambert Conic Conformal (LCC2SP) Projection
1027 Oblique Mercator (OM) Projection
1028 RESERVED for Global to Plate Fixed transformation
1029 Text in UTF8-format (max. 127 Multibyte – codes and max. 255 Bytes)
1030 GPS Network Residuals 1012 GLONASS Network Residuals
1032 Reference station coordinates (ECEF XYZ)
1033 Description of GNSS receiver and antenna
1034 GPS FKP corrective data

DATA TRANSFER METHODS

The transfer of corrective data can be conducted in several ways, depending on the possibilities and needs of users, in real-time or for additional measuement data processing

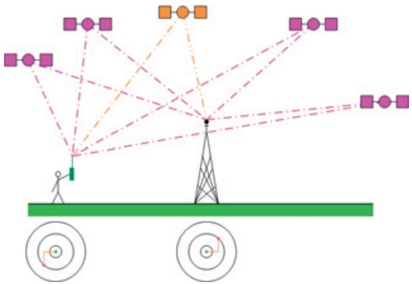
REAL TIME DATA TRANSFER

Radiowaves

At the beginning of real time data transfer implementation, the method used for the transfer of corrective data was through the own temporary base station at different wave lengths (e.g. in Germany 70 cm, 2 m or 4 m). The advantage of this system was in the good regional applicability, reasonable costs and speed of data transfer. The disadvantage of this system was in the insufficient range and dependence on the terrain configuration. In order to cover a larger territory, the corrective data was transferred through a radio transmitter in the area of short, middle and long waves.

Satellite systems

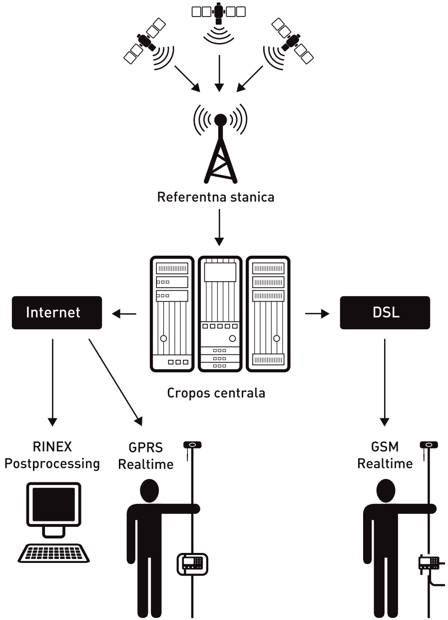
For the global transmission of corrective data, the so-called SBAS (Satellite Based Augmentation System) services are used. Such services are the following: EGNOS (European Geostationary Navigation Overlay Service), MSAS (Multifunctional Satellite Augmentation System) and the planned GAGAN (GPS Aided Geo Augmented Navigation) or the commercial OmniSTAR, which send the corrective data through geostationary satellites. The corrective data for DGPS are mostly sent in RTCM formats. The available accuracy of non-commercial services is 1 to 3 m, and regarding the OmniSTAR commercial service, the accuracy is about 0.1 m. However, these services do not support the RTK GNSS measurement method.



Mobile phone systems

The GSM (Global System for Mobile Communications) defines a standard for mobile networks which cover Europe and are available to users. The GSM standards represent the second digital generation of mobile networks. The range of digital transmission of data is from several hundreds of meters in cities up to 35 km in mutual line of sight of transmitters. The capacity of data transfer for the second generation GSM standards is between 9,8 kbit/s and 220 kbit/s. Meanwhile, the third generation standards have occurred, enabling a transfer of large quantities of data in a short period of time. The first increase of tranfer capacities to 150 kbit/s - 200 kbit/s was enabled through the EDGE (Enhanced Data Rates for GSM Evolution) system. Further development of this standard has been enabled by the UMTS (Universal Mobile Telecommunications System) with the data transfer speed of 384 kbit/s to 7,2 Mbit/s, as well as the further development of HSDPA (High Speed Downlink Packet Access) system which enables data transfer from 3,6 Mbit/s to 13,98 Mbit/s.

This manner of data transfer requires the existance of permanent connection between the user and corrective data service provider. Furthermore, the so-called package-oriented data transfer methods have been developed, such as GPRS (General Packet Radio Service). Regarding these services, only the actual transfer or exchange of data is calculated, not the duration of the established connection between user and service provider.



Internet

NTRIP (Networked Transport of RTCM via Internet Protocol) is a procedure developed in Bundesamt für Kartographie und Geodäsie (BKG, Frankfurt am Main) with the objective to send corrective data through Internet. A user has access to the Internet through GPRS or UMTS technology. The NTRIP enables data transfer and data availability simultaneously to thousands of users. As a method of corrective data transfer, it has become a world standard.

DATA TRANSFER FOR ADDITIONAL MEASUREMENT DATA PROCESSING

Near Real Time

When the corrective data is not available in real time, a user can conduct the measurement data processing immediately in the field, having completed the measurement process, and using the measurment data as well as the data that can be obtained from the server of reference GNSS network. The data taken from the server is in RINEX (Receiver Independent Exchange) or VRS RINEX (Virtual Reference Station RINEX) format. The advantage of this method is a fast verification already in the field, of the success of conducted measurements.

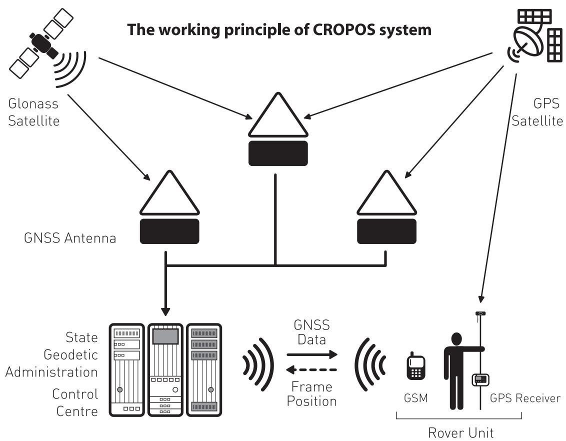
Post-processing

If there is no need to take over the data in the field, a user can take the necessary RINEX or VRS RINEX data through the Internet in the office, and conduct the measurement data processing.

THE CROPOS SYSTEM

CROPOS (Croatian Positioning System) is a national network of GNSS reference stations of the Republic of Croatia. The objective of CROPOS system is to enable real time positioning with an accuracy of 2 cm horizontally, and 4 cm vertically, on the entire Croatian territory.

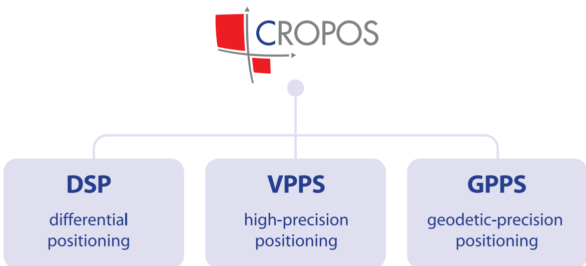
The CROPOS system consists of 30 reference GNSS stations placed at the distance of 70 km one from another and distributed in such a way to cover the entire territory of the Republic of Croatia. The objective is to collect the data of satellite measurements and calculate the correction parameters which are available to the users in the field through mobile internet (GPRS/GSM).



THE CROPOS SERVICE

The users can access three CROPOS system services which are different in terms of the solution method, data transfer method, time of availability, positioning accuracy and data format. The standard formats (RTCM, RINEX i VRS RINEX) are used for the transfer of corrective data and measurement data. The users can access corrective data in real time through mobile internet, whereas the data for post-processing is available through standard internet.

CROPOS SERVICES	METHOD SOLUTIONS	DATA TRANSFER	ACCURACY	DATA FORMAT
DSP	Network solution of code measurement in real time	Wireless Internet (GPRS, UMTS) NTRIP protocol GSM	±0.3 do ±0.5 m	RTCM
VPPS	Network solution of phase measurement in real time	Wireless Internet (GPRS, UMTS) NTRIP protokol GSM	±2 cm (2D) ±4 cm (3D)	RTCM
GPPS	post-processing	Internet (FTP, e-mail)	±1 cm (2D, 3D)	RINEX

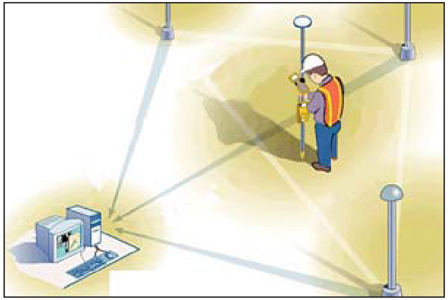


DSP

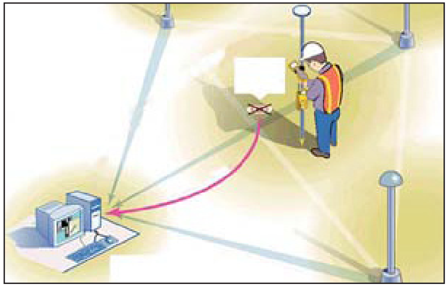
In order to use the DSP service, the following conditions are required:

a) be a registered CROPOS user
b) have a GNSS receiver which can read the RTCM 2.3 data format or its advanced version
c) establish a connection through mobile Internet
d) receive signals from an adequate number of satellites, at least 4, in order to calculate own position

When these conditions are met, the only thing you need to do is to connect yourselves to the CROPOS system and in that way you will receive the correction data.
Only a few seconds later, your receiver will transfer from the navigation mode to the differential mode. This is the way in which submeter accuracy is achieved.



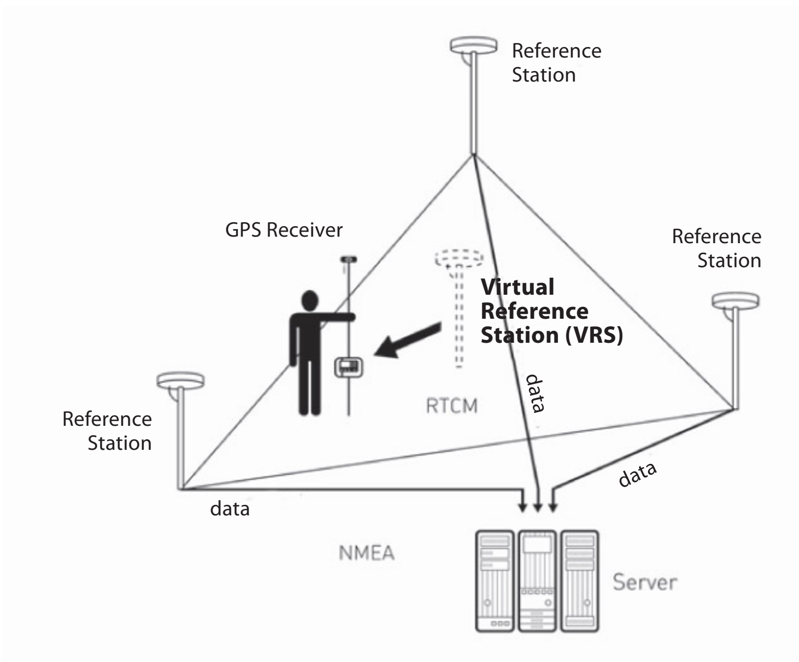
1. Established connections:
a) mobile internet
b) CROPOS

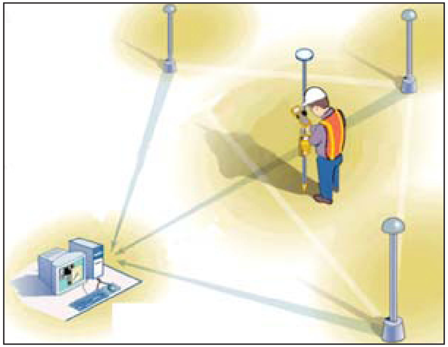


2. A user obtains corrective data in RTCM 2.3 format through mobile internet

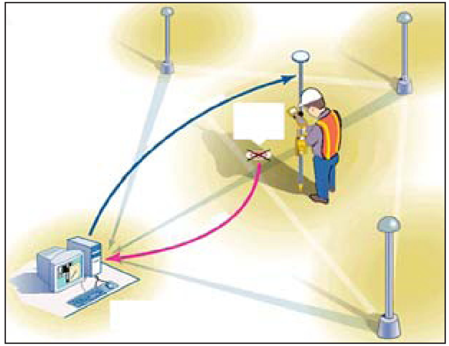
VPPS

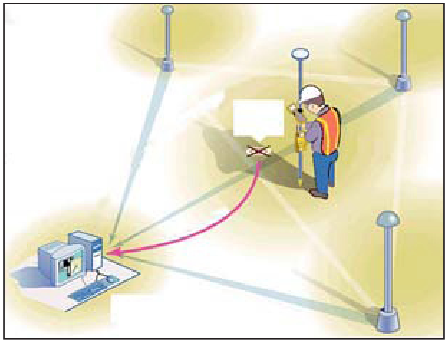
On the basis of data and an approximate position of user, the system determines a real-time virtual reference station which is „located" at the distance of several meters from the user's receiver in the field. The measurement data of the CROPOS system reference GNSS stations network is used to determine virutal reference stations and correction parameters. The measurement data cancels out the negative external influences which affect the accuracy of real time positioning.





1. Established connections:
a) mobile internet
b) CROPOS





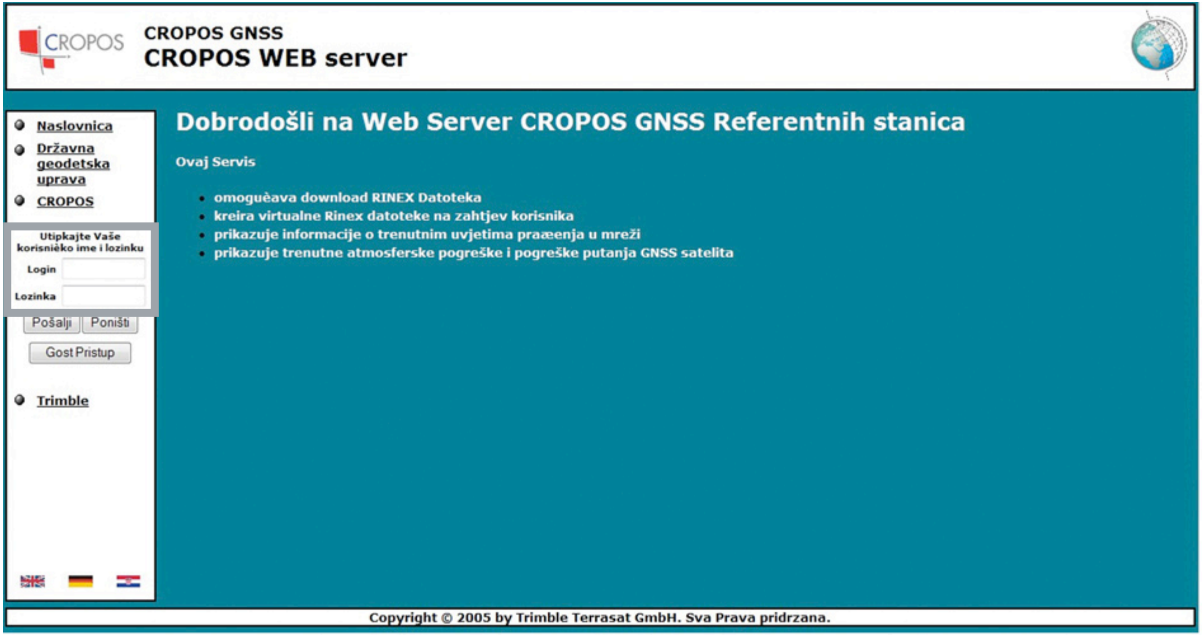
2. A user obtains corrective data in RTCM 2.3 format through mobile internet

GPPS

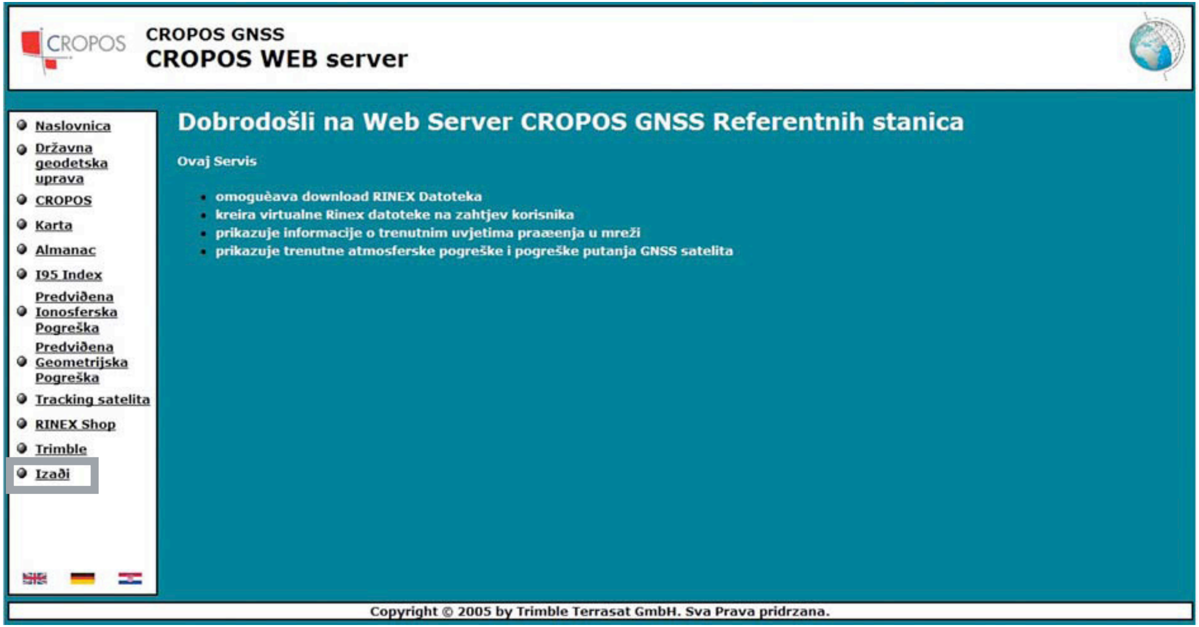
Post-Processing:
Individual reference station

If it is not possible to obtain the corrective data in real time for the high precision implementation, it is possible to prepare the data after the measurements have been conducted. One possibility is to take over the measurement data of an individual reference station in RINEX (Continuously Operating Reference Station - CORS) format. When applying this measurement method, the distance between a measured point and the CROPOS system reference station is very important. The required time of measurement depends on the distance between the user and the used reference station. The recommendation is to select the closest reference station(s) to the measured point.

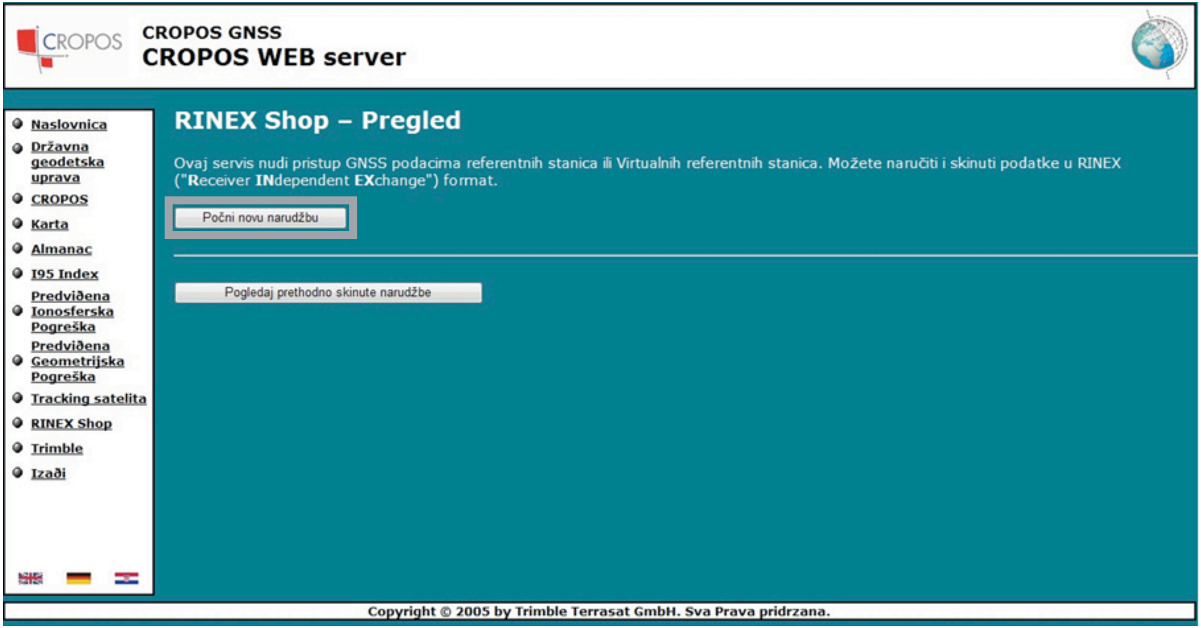
For point positioning, it is necessary to have the measurement time at a new point of at least 20 min plus 2 min for each kilometer. The achieved accuracy of obtained coordinates depends on the external influences and distance from the reference station. When the measurement time is 20 min and the length of base line is 20 min, the expected positioning accuracy is 20 mm. With the extension of base line for one kilometer, the positioning accuracy is decreased by 2 mm per kilometer. The measurement data processing and coordinate calculation are conducted through the program for subsequent processing – post-processing. It is always possible to conduct the control of determining the point coordinates by involving additional reference stations. The efficient control is achieved by repeating the measuring of a point after at least 2 hours. The CROPOS system RIHEX-shop enables the users to obtain the reference station measurement data.



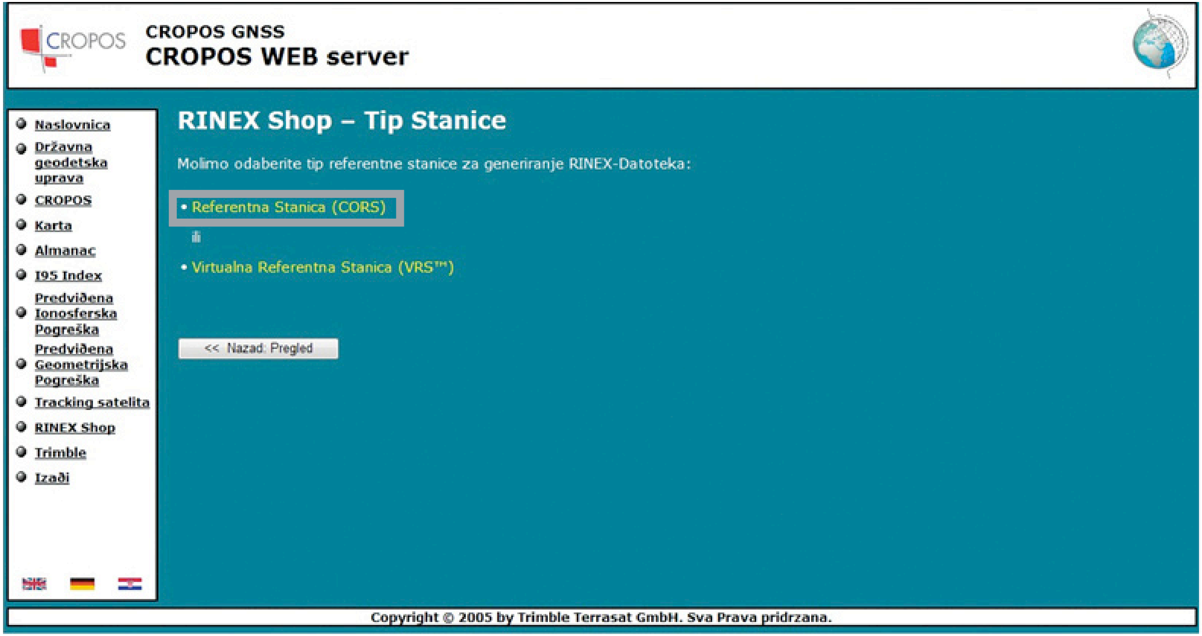
After entering username and password, it is possible to access RINEX-shop and services of CROPOS GPPS.



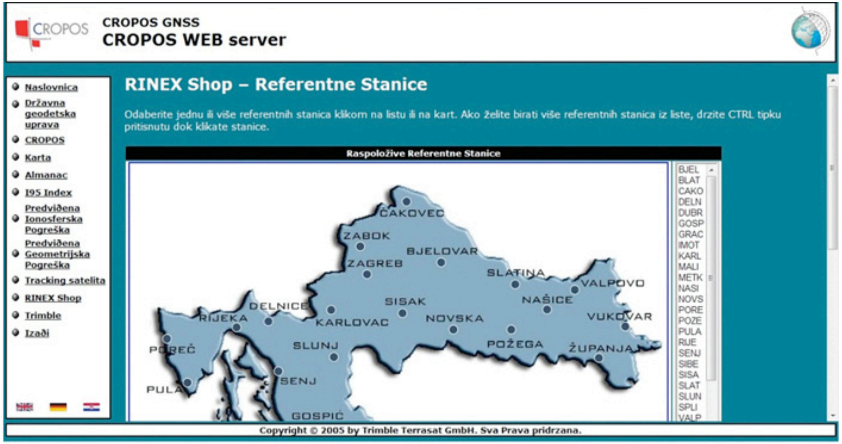
Beginning of RINEX-shop request.



Beginning of new order.

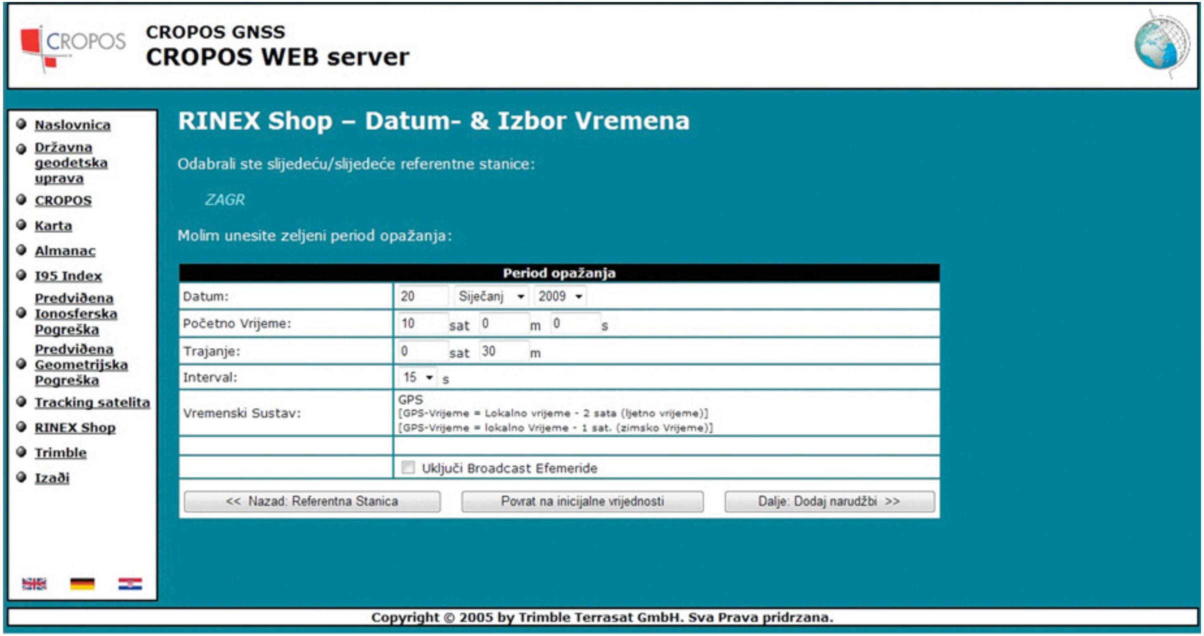


Select a reference station (CORS).

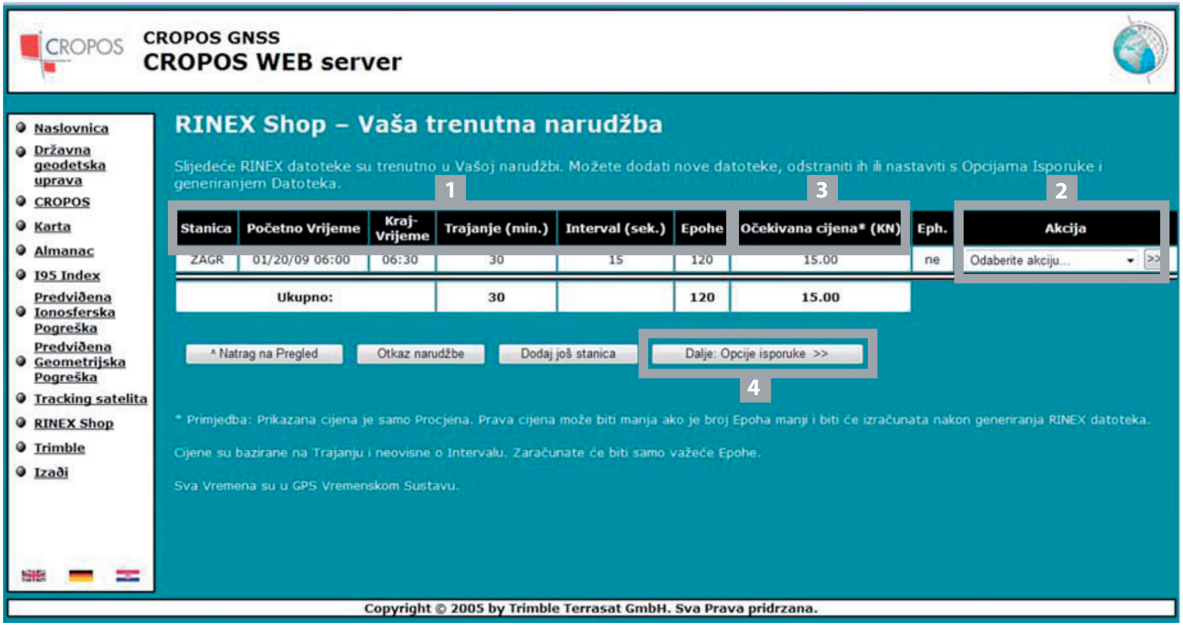


Select a reference station of your preference.

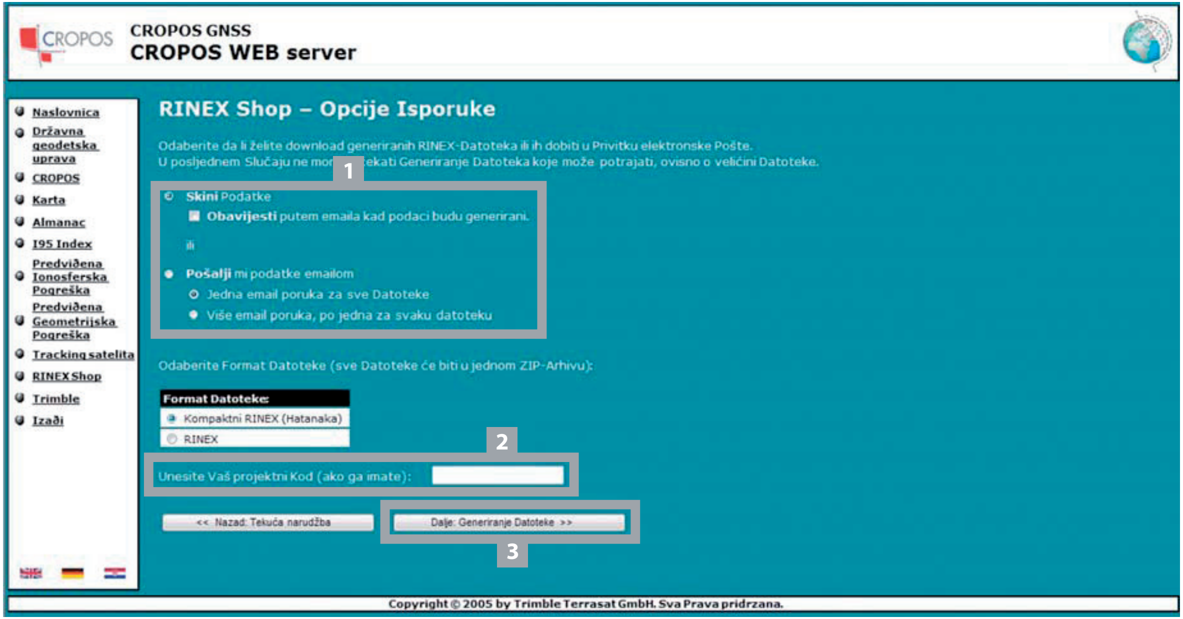
Select „Measurement time selection" at the bottom of the page.



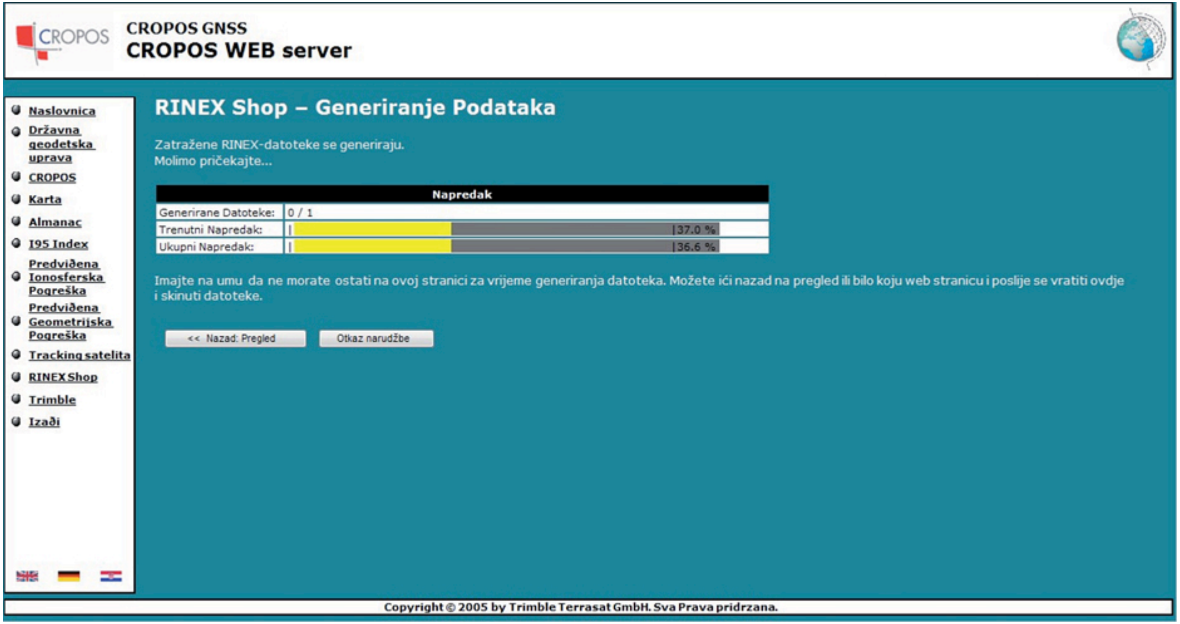
Enter date, start time, duration and measurement interval for the selected reference station.
Data on the date, start time and duration must correspond to the measurement time in the field.



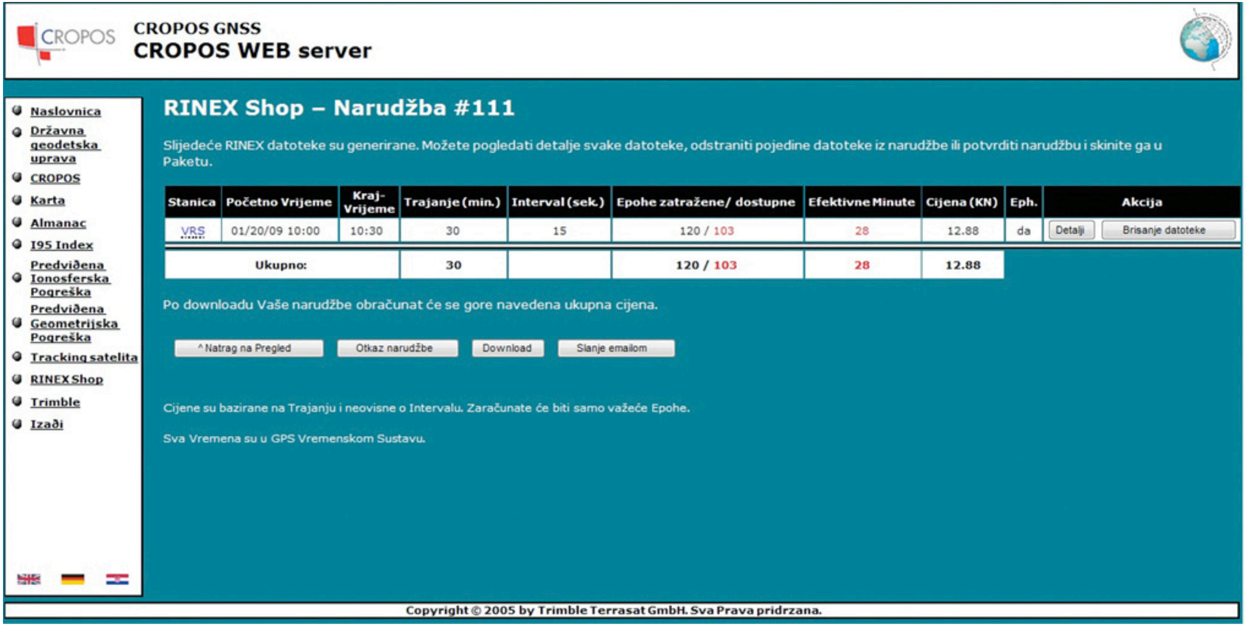
1. Review of entered data.
2. If you wish to change the data, it is possible to select different options.
3. Estimated prices of the requested data are also shown.
4. If you accept the proposed order, select „Continue: Delivery options“.



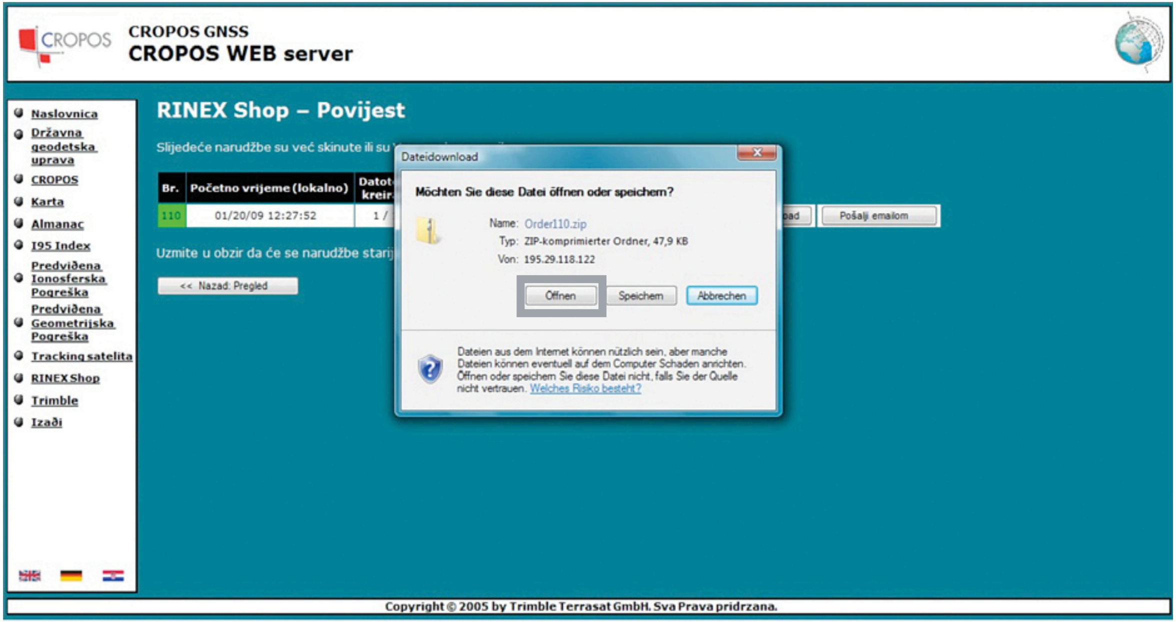
1. You can select the option to receive the data through Internet or e-mail.
2. In order to identify a project, you can enter the code of your project.
3. If you agree, select to generate RINEX file.



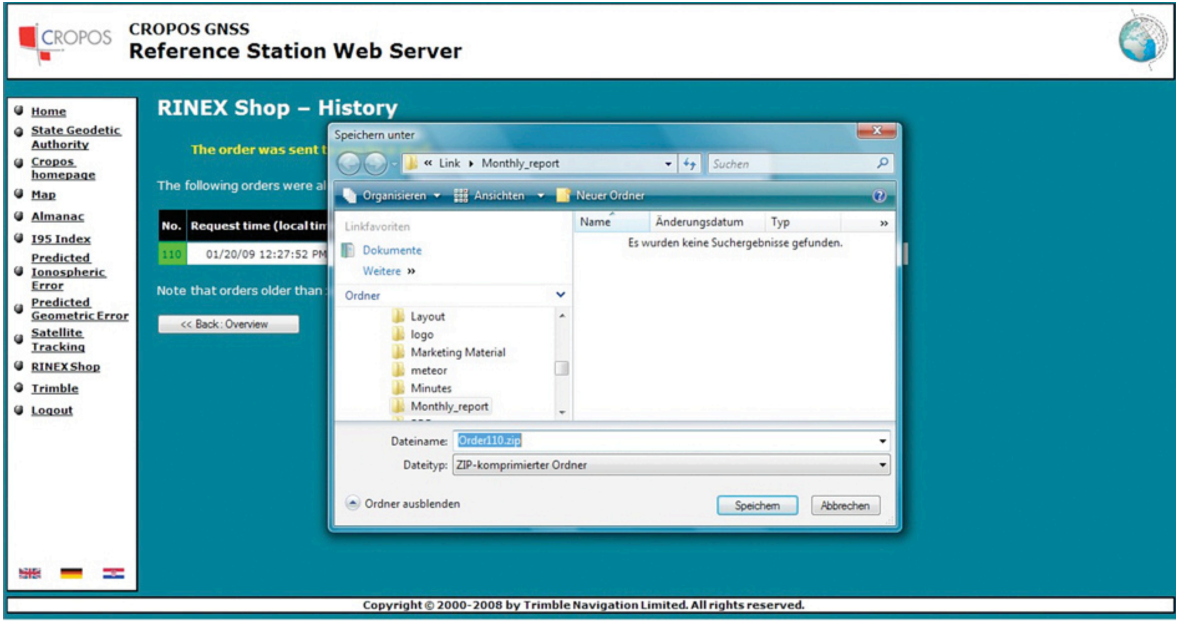
Preparing and generating measurement data.



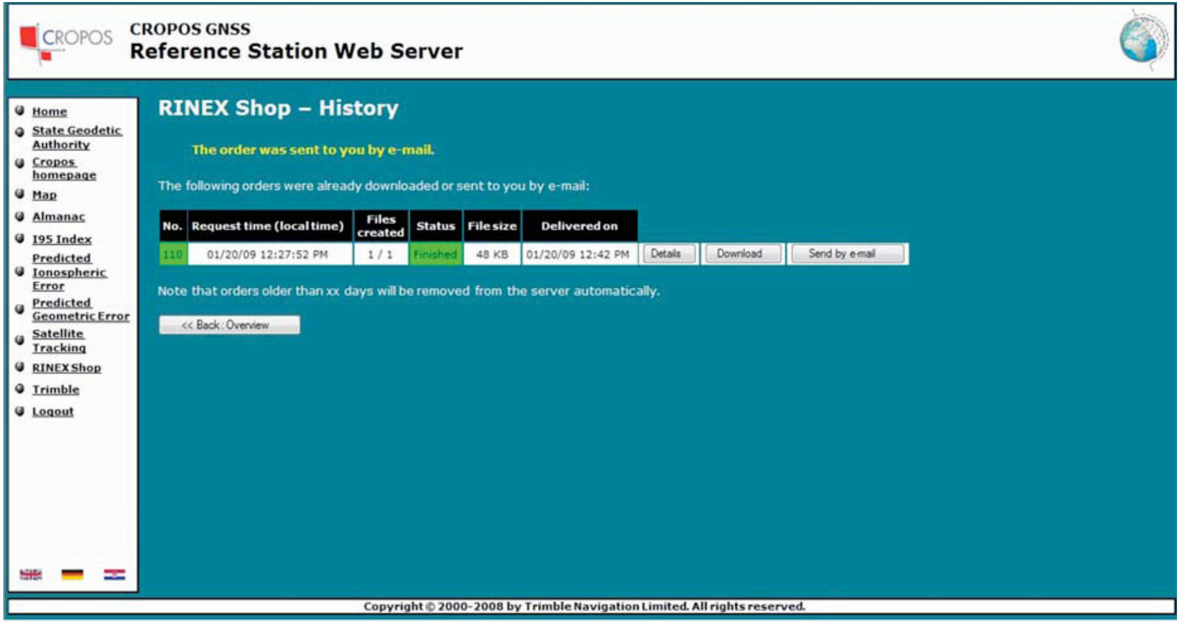
Having generated the data, the review of data and its estimated price are shown.
Again you can select to receive the data through Internet or e-mail.



Beginning of data download.



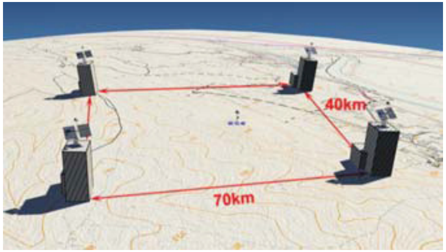
Select where you wish to save the data on your computer.

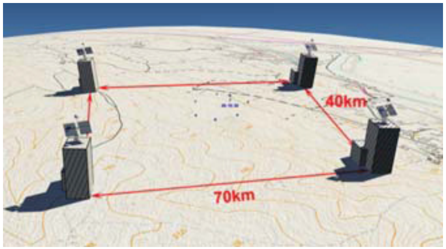


At the end, the program shows a review of your orders.

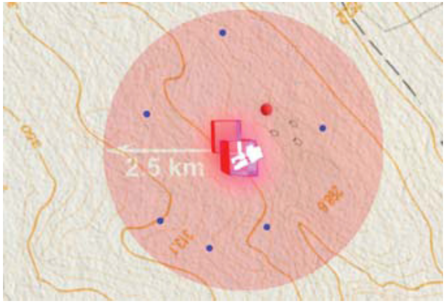
GPPS

Post-Processing:
Virtual reference station



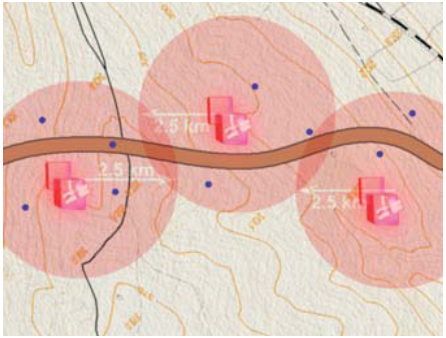


Together with the measurement data of individual reference stations, CROPOS also provides the users with the preparation of measurement data of Virtual Reference Stations (VRS) for post-



processing, the co-called VRS RINEX. Unlike for the implementation of individual reference station measurement data, the location of user in the network during measurement is not important.
The virtual reference station data is generated on the basis of data from the entire network.
The distance between an individual virtual reference station and the new point should not exceed 5 km. In case a user moves in the areas of greater distances, it is necessary to generate more virtual reference stations.
The measurement time of new points (blue within circles) depends on the used post-processing software. Minimal time period of measurement on a point is 15 min.

The coordinates of virtual reference station necessary for calculations are not entered, but taken from the file of VRS RINEX station (red outside circles). The control of measured points can be conducted through other virtual reference stations. However, the best control is an independent second measuring of the points and the repeated preparation of virtual reference stations after at least 2 hours.



The prodedure of preparing the virtual reference station measurement data can be compared with the procedure of preparing the data of an individual reference station. After having accessed the system with a username and password and having selected the options of virtual reference station data, it is necessary to enter the coordinates of a point for which the virtual reference station measurement data wishes to be created.

Having selected the options of virtual reference station, its approximate coordinates need to be set.

It is possible to select the setting of virtual reference stations in geographic or geocentric coordinate system. Then follows the same procedure as for the individual reference station (see p. 38).

CORS or VRS?

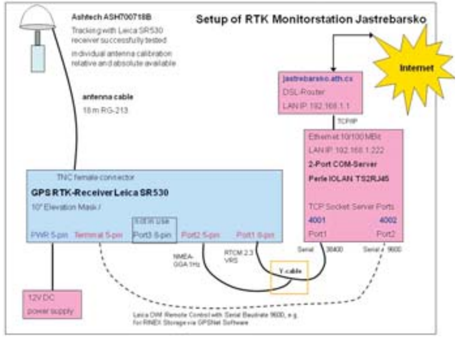
Using the virtual reference stations significantly shortens the necessary time of measurement. The individual reference stations are used for determining the higher rank points, with the appropriate duration of field measurements. When applying the GNSS measurement method for determining permanent points of geodetic basis, the procedure of measurement and measurement data processing is defined by the Rules and Regulations on the manner of conducting basic geodetic works.

CROPOS QUALITY MANAGEMENT

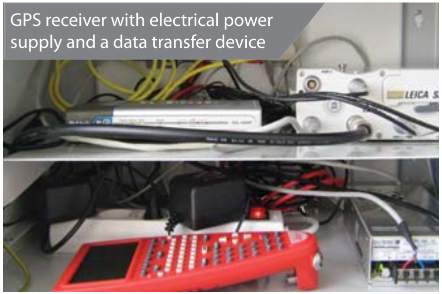
The system operation is continuously supervised by the State Geodetic Administration. In order to obtain at any moment the information on the system operation quality in relation to the initialization time as well as the accuracy and availability of the system, two independent permanent control stations have been established in Jastrebarsko and Nova Gradiška which simulate the work of users in the field.

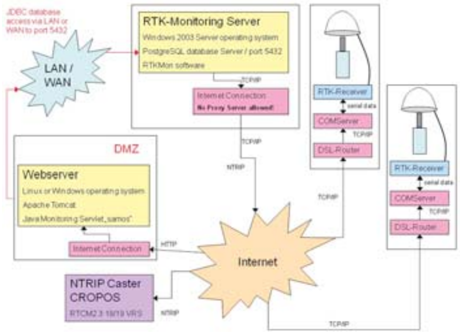
Every 10 seconds, the control stations connect to the CROPOS system and use the VPPS service for determining the position.

On the CROPOS system web site (www.cropos.hr), the users can see the parameters of work and impact of control stations.




GPS antenna - calibrated


GPS receiver with electrical power supply and a data transfer device



RTK impact of GPS receivers

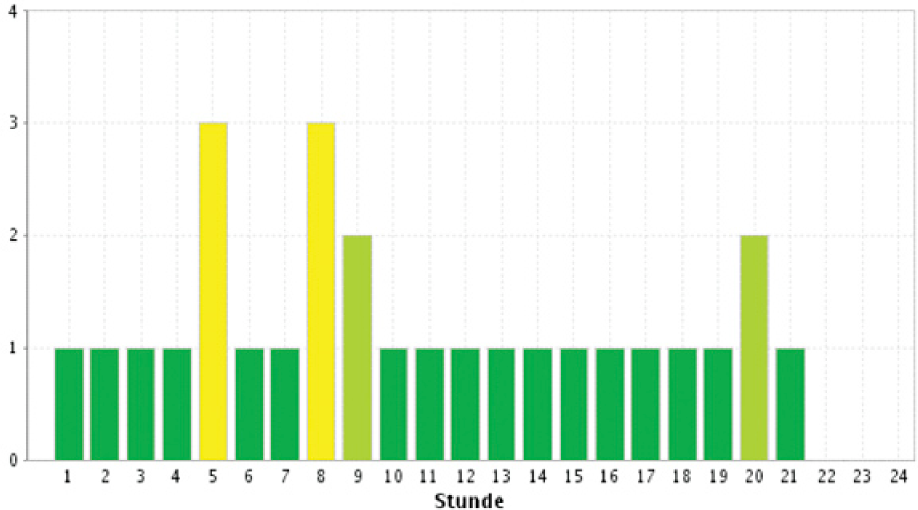


Diagram shows RTK impact of control stations of every clock through 4 indicators:

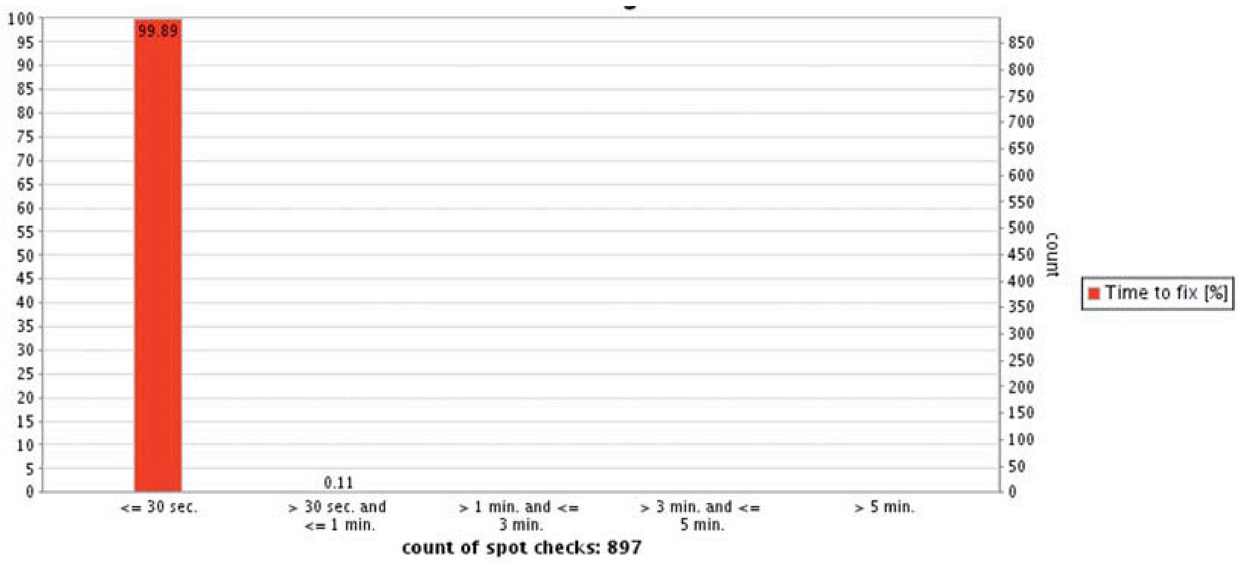
GREEN = VERY GOOD, for at least 90% of measured values: position error ≤ 2 cm and altitude error ≤ 3 cm i TIME TO FIX ≤ 1 min,

BRIGHT GREEN= VERY GOOD, for at least 90% of measured values: position error ≤3 cm and altitude error ≤ 5cm and TIME TO FIX ≤ 3 min,

YELLOW=SATISFACTORY, for at least 67% of measured values: position error ≤3 cm and altitude error ≤ 5 cm and TIME TO FIX ≤ 3 min,

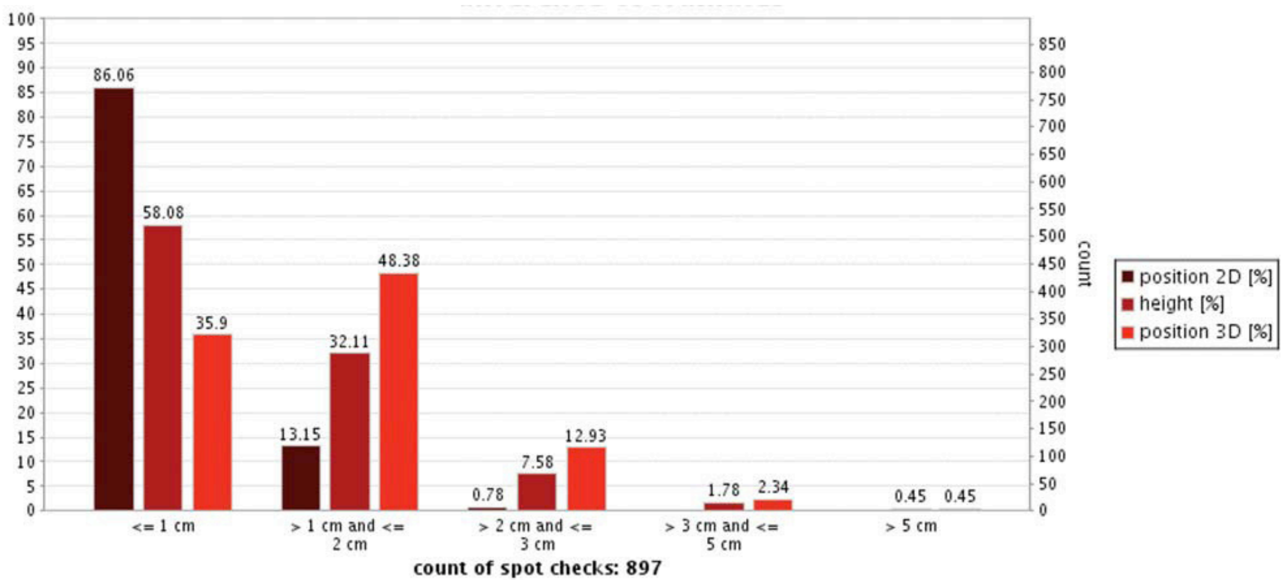
RED = INSUFFICIENT, for > 33% of measured values: position error > 3 cm or altitude error > 5 cm or TIME TO FIX > 3 min

Initialization time



The diagram shows the time necessary for the initialization of receiver. Every day the receivers at control stations will start and stop the measurements several hundred times, and will measure the time necessary for the initialization, i.e. time of applying the received correction parameters necessary to determine the position in real time.

Accuracy of coordinates



The diagram shows the measured point positioning accuracy allocation.

CROPOS LIMITATIONS AND ADVANTAGES

LIMITATIONS OF THE SYSTEM

When applying the GNSS measurement method, it is necessary to ensure that the antenna for the satellite signal receipt has a free horizon.

Also, it is necessary to take into consideration that the measurements are not conducted near constructions that can cause multipath, i.e. a multiple receipt of the same signal.

It is difficult to conduct the GNSS measurement method in cities or forests. In order to apply the RTK GNSS measurement method in real time, it is necessary to ensure the connection with the CROPOS system control centre for the receipt of corrective data, which, of course, depends on the extent to which the territory is covered by the GSM signal.

WHY GNSS?

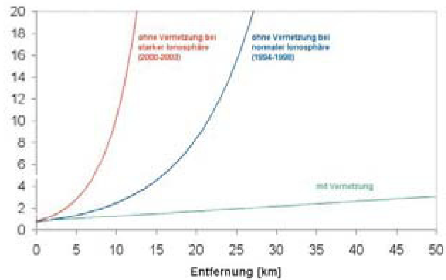
The GNSS measurement method has numerous advantages in relation to classical methods:

1. Line of sight between points is not necessary.
2. Can be applied at any time of day or night, in all weather conditions.
3. High accuracy results are obtained.
4. More work can be conducted in a shorter period of time, with less people.

WHY CROPOS?

System advantages:

1. Own base is not necessary when applying RTK measurement method, which reduces the number of necessary GNSS devices.
2. Field measurements are shortened because it is not necessary to search for the reference points in order to set up the base device.
3. There is no risk that the base device might be stolen or damaged.
4. No limitations due to the range of radio-device for the transmission of correction parameters.
5. Much less time necessary for the rover initialization
6. Measurement homogeneity on the territory of the entire state
7. Increased accuracy and reliability of measurements.



FREQUENTLY ASKED QUESTIONS

1. Does the CROPOS system cover the entire territory of the Republic of Croatia?
The CROPOS system services are available to users in the entire Republic of Croatia.

2. Where does a user register in order to access the CROPOS system services?
The State Geodetic Administration has established the CROPOS system of reference stations and is responsible for managing the control centre, supervising the functioning of reference stations and assigning the user names and passwords which allow access to the system services. The user name and password which permit access to the CROPOS system services, are assigned to the user on the basis of a Request sent to the State Geodetic Administration. The request to use the CROPOS system services can be downloaded from the www.cropos.hr web site.

3. What kind of equipment is necessary to access the CROPOS system services?
In order to receive the real time correction parameters of the VPPS and DPS services, the user needs a GNSS receiver with a possibility to establish a GSM, GPRS or UMTS connection and also needs to have a contract with a mobile operator that provides one of the above-mentioned connections. Furthermore, the receiver needs to support the RTCM 2.3 or RTCM 3.1 formats of correction parameters and also must have a possibility to transmit the NMEA GGA position message in case the user wants to use the VRS service. In order to use the GPPS service, the user needs to have access to the Internet so that he can download the measurement data in RINEX or VRS RINEX format.

4. What does the availability of CROPOS system services depend on?
The availability of the CROPOS system services depends mostly on the availability and reliability of GSM/GPRS signals. Since the system is designed for transmitting the correction parameters via mobile Internet, it is important to have a reliable GSM/GPRS signal so that the user can connect to the CROPOS system. Also, it is necessary to be able to receive the satellite signal, as is the case for any other GNSS measurements.

5. Where can I work with the CROPOS system?
The CROPOS system reference stations are placed at the distance of 70 km one from another, and they are distributed in such a way to cover the entire territory of the Republic of Croatia. The CROPOS web site shows the network of reference stations and the area within a radius of 70 km that it covers. As it is shown, the CROPOS system is available in any point of the presented area. The availability of GSM/GPRS signal is the key component of the system, necessary for its functioning. Without a reliable GSM/GPRS signal, it is impossible to connect to the system and use its resources in real time.

6. In what coordinate system are the coordinates of points, measured in CROPOS system, expressed?
The coordinates of reference stations are calculated in the ITRF2005 coordinate system, 2008.83 epoch of measurements (GPS week 1503), then they are transformed into ETRF00 (R05) system (ETRS89), therefore the coordinates of points measured by CROPOS system, are expressed in that system. ETRS89 (European Terrestrial Reference System 1989) represents the official position datum for the area of Europe. GRS80 (Geodetic Reference System 1980) is then used for the reference ellipsoid.

7. What causes the differences in the coordinates of a measured point?
The differences in the coordinates of a point that has been measured several times, occur most often due to the badly determined ambiguities in the system. This is caused by the intensified activitiy of ionosphere which is expressed by the I95 ionospheric index. The intensified activity of ionosphere influences mostly the short measurements, and not so much the longer measurements. The diagram of ionospheric index I95 for different time periods can be seen on the CROPOS system web site.

8. At what elevation do the GNSS measurements need to be conducted?
The GNSS measurements are conducted at the elevation of 5° to 15°, depending on the type of works.

9. What if during the CROPOS system measuring, it is not possible to achieve initialization?
Before measuring, it would be useful to check on the CROPOS system web site the actual conditions of work (ionospheric index I95, anticipated ionospheric error, anticipated geometric error, satellite monitoring, effect of control stations, etc.). In case the initialization cannot be achieved, together with the above-mentioned, it is necessary to check the connection between the receiver and antenna, then the connection with the CROPOS system, all possible obstacles on the horizon, and also check the settings in the cotroller. If all these actions have no result, it is necessary to contact the customer support service.

10. Can several receivers use the same user name and password?
With one user name and password, a user can at the same time have the service provided by using one GNSS device.

11. Is the subscription to CROPOS linked to a specific rover or a measuring device?
No. The CROPOS subscription is not linked to a specific device. When the connection to the CROPOS system is established through GPRS/UMTS mobile internet, the authorization is obtained by

assigning the user name and password, which enables measuring for several field teams with different devices (but not simultaneously). When the connection to the CROPOS system is established through GSM modem, the authorization is obtained through the number of GSM modems.

12. Can there be any system breakdowns?
The CROPOS system has been designed to be optimally available and is supervised 24/7 in order to ensure a continuous work of the system with as few breakdowns as possible. The system will be temporarily unavailable during the maintenance works, and the users will be notified about it in advance. Furthermore, it is important to have a good GSM/GPRS/UMTS signal in the area where measuring is conducted in order to be able to access the system services in real time.

13. What is the duration of licence?
The licences for the use of CROPOS system services are provided in a form of annual subscription for the VPPS and DPS services, and also according to the time period of use (the billing control unit is 1 minute) for the VPPS and GPPS services.

14. Is it necessary to sign the contract with a specific mobile operator?
No. The contract can be signed with any mobile operator because the CROPOS system supports GSM, GPRS and UMTS connection. Any mobile operator offering adequate coverage of the target territory and the stated telecommunication standards, can be used to connect to the system.

15. How often does the rover in the field receive the corrections from the system?
The CROPOS system has been designed to send the corrections to the rover every second. However, it is possible for the corrections to be late, depending on the availability of the signal of the mobile operator in the area where the works are conducted.

16. What types of corrections does CROPOS provide?
CROPOS provides the following types of corrections:
CROPOS VRS, single base RTK and DGNSS.

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