7.3 Session 2b. GNSS format files description

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Objectives

To get familiar with the different format standard(s) involved in the GNSS data sets. To analyse in detail particularities and characteristics of the GNSS systems, evolutions, observables, their modelling through the different data content provided. To provide the user a reliable and powerful tool to learn the standard formats in a very easy and friendly way, aided with explanatory tooltips. These tooltips will be triggered automatically when the mouse is hovered over a field. The explanations include a description of the field, the format in which is written and if applicable, its units.

Files to be used
`LaunchHTML.html`, `Observation_Rinex_v3.01.html`, `Observation_Rinex_v2.11.html`,`Observation_Rinex_v2.10.html`, `GPS_Navigation_Rinex_v2.11.html`, `SBAS_Navigation_Rinex_v3.01.html`, `GLONASS_Navigation_Rinex_v2.11.html`, `SP3_Version_C.html`, `IONEX_v1.0.html`, `ANTEX_v1.3.html`, `RINEX_CLOCKS_v3.00.html`

Programs to use
Any Internet browser (`Firefox` is recommended)

Development

1. **[RINEX Measurement files: v2.10]**
   This standard gathers the GNSS Observations collected by a receiver. This file is divided clearly in two different sections: The Header section and the Observables section. While in the header global information for the entire file is given, the Observables section contains the pseudoranges measures stored by epochs.

   Open file Observation `RINEX v2.10.html` with an Internet browser.

   (a) Hover the mouse over `'Observation RINEX 2.10 Format'` title, where some general information is given. Who was the first institution to develop this format?

   → *The Astronomical Institute of the University of Berne.*

(b) What was the purpose for developing such standard?

→ *The exchange of GPS data from several different GPS receivers.*

(c) Which type of optimisation has been applied to this standard?

→ *Minimum space requirements, keeping the observation records as short as possible.*

(d) What is the maximum record (i.e., line) length?

→ *Files are kept to 81 characters lines.*

(e) The header section contains a set of labels. Where are they located?

→ *The header labels are located between the* `61th` *and the* `81th` *column of each line.*

(f) Where can be found a collection of the currently used formats?

→ *In the International GNSS Service (IGS) website:* `http://igscb.jpl.nasa.gov/components/formats.html`

(g) The header section of this file is dual coloured in order to distinguish the header information from the header labels. Which is the first and the last header label of the header section?

→ *The first label is the* `'RINEX VERSION / TYPE'` *while the last label is* `'END OF HEADER '`.

(h) What is the difference between the `'RINEX VERSION / TYPE'` and the `'COMMENT '` label?

→ *While the first one is a mandatory label, the second one is optional and may not appear in some RINEX files.*

(i) Hover over the first field in the `'RINEX VERSION / TYPE'` line, what is the main advance in this RINEX version?

→ *Version 2 has been prepared to contain GLONASS or other satellite systems observations apart from GPS satellites.*

(j) Where is the antenna located approximately? In which reference system?

→ *The approximate antenna position is (4789028.4701, 176610.0133, 4195017.0310) in the WGS84 system.*

(k) Hover over the first field in the `'LEAP SECONDS'` line, what is the difference between the different Satellite Systems, when counting Leap Seconds?

→ *The GLONASS Time System is tied to UTC, so it does not need to correct Leap Seconds. GPS and Galileo are ahead of UTC, so need to substract the current Leap Seconds.*

(l) How many satellites are present in the current file? Which Satellite System do they belong?

→ *There are* 14 *different satellites:*
14 GNSS Satellites = 10 GPS + 3 GLONASS + 1 SBAS.

(m) Line `'PRN / # OF OBS '` has to be consistent with the observables listed in `'# / TYPES OF OBSERV '` line. Which are these observations? Do all satellites contain the same observables in this example?

→ *The observables are:* `L1, L2, P1, P2, C1, S1, S2`.
GLONASS and SBAS satellites only have: `L1, C1, S1`.

(n) How does the standard indicate the end of the header?

→ *The last field of the header is a record of 60 empty characters.*

(o) The data section of this file is again dual coloured in order to distinguish blocks of data. According two the different colours used, how many epochs are included in this file?

→ *There are two different epochs, each one has a different colour.*

(p) The first line of an epoch contains information of the whole block of measurements. When is the first epoch of the file?

→ *The first epoch corresponds to* `5/3/2010` *at* `00:00:00`.

(q) How many satellites are present in the first Epoch? Is there any particular feature occurring due to this number?

→ *First epoch contains* `14` *different satellites. Because there are more than* `12` *satellites, the list of epoch satellites is divided in two different lines.*

(r) Measurements follow the order stated in `'# / TYPES OF OBSERV'` line. The satellite order is given in the first line of the epoch. Which are the units for the observables?

→ `L1, L2` *: Cycles of the carrier.*
`P1, P2, C1`*: meters.*
`S1, S2`*: Receiver dependent.*

(s) Hover the first L1 measure of satellite G13. The measure is given together with 2 indicators. What are these indicators? What do they represent?

→ *Loss of Lock Indicator: Depending on its value, it can show a cycle slip, an opposite wavelength factor, or an anti-spoofing measurement.*
Signal Strength: Projected into the `[1-9]` *interval.*

2. **[RINEX Measurement files: v2.11]**
   Open file Observation `RINEX v2.11.html` with an Internet browser.

   (a) Hover the records `'WAVELENGTH FACT L1/2'` line records. First line states the default values for the wavelength measures for L1 and L2 frequency. Which satellite system does the default values applies to? Interpret the second line of the `'WAVELENGTH FACT L1/2'` records.

   → *The Default Wavelength Factor applies for GPS only.*
   `3` *Satellites* `(G14, G18, G19)` *have a full cycle factor in the first frequency (L1) and half cycle factor in the second frequency (L2).*

   (b) Hover the first record of line `'# / TYPES OF OBSERV'`. Which observation types are defined in RINEX Version 2.11? In which units are these observations measured? How many frequencies are involved in the different GNSS systems?

   → *Pseudorange measures:* `C` *and* `P` *code [meters]*
   Carrier Phase: `L [cycles of the carrier]`
   Doppler frequency: `D [Hz]`
   Signal to Noise Ratio: `S [receiver-dependent]`
   GNSS systems use `6` *different frequencies.*

   (c) Which value is set in `'RCV CLOCK OFFS APPL'` record? Where can be found the Receiver Clock Offset later in the RINEX file?

   → *It has a value of* `1`*, which means that an offset is applied in the receiver clock. The value of this offset is reported in the last record of the first line of each epoch.*

3. **[RINEX Measurement files: v3.01]**
   Open file Observation `RINEX v3.01.html` with an Internet browser.

   (a) This RINEX version is newer than version 2. At the first glance the header section is larger and the observation data records are reorganised to be column-readable. Which satellite system does this file belongs to? What type of file is it?

   → *This file contains GPS, GLONASS and SBAS observations, so its is a mixed file. It is an observation data file. Please note, the possible values have changed from version.*

   (b) The date record has been also redesigned. What is now the date format? What has changed in versions?

   → *In version 2.11, there was no a strict rule to state the date file creation. In version 3.01, the date has to follow the structure* `Year/Month/Day - Hour/Minute/Second - Timezone`*.*

   (c) A `'MARKER TYPE '` record has been added to the header. What type of marker type would report a station in the North Pole?

→ *The North Pole is located in the middle of the Arctic Ocean, almost permanently covered with constantly shifting sea ice. It suits the* `'FLOATING_ICE'` *marker type.*

(d) An extensive description of the ANTENNA can be now obtained from this new standard. What type of Antenna information is available?

→ *Antenna Number. Antenna Type + Radome identifier.*
Antenna Reference Point (ARP): (Height, East Eccentricity, North Eccentricity)
Antenna Reference Point (ARP): (X,Y,Z) when mounted in a vehicle
Antenna Phase Center: (North, East, North) wrt the (ARP)
Antenna Bore-sight: (North, East, North) or (X,Y,Z)
Antenna Zero-direction: Azimuth or Vector.

(e) A new `'SYS / # / OBS TYPES '` record has been added. Which observations are present for the SBAS satellites?
Hover over the Observation Descriptors. How many pseudorange code descriptors are present for the 6th COMPASS frequency?

→ *GLONASS and SBAS satellites have the same 4 observation types:* `L1C S1C C1C S1C`. *RINEX v3.01 defines* `C6I, C6Q, C6X` *pseudorange code descriptors for COMPASS system.*

(f) A new `'SIGNAL STRENGTH UNIT '` record has been added to standardise RINEX Signal Strength Indicators (SSI). What indicator would have a S/N of 33 dbHz at the output of the correlator?

→ *Following the RINEX table it would present a* `5 SSI` *value.*

(g) Record `'SYS / DCBS APPLIED'` and `'SYS / PCVS APPLIED'` inform if Differential Code Bias (DCB) or Phase Center Variation (PCV) are applied. Which program/files have been used in this file?

→ *DCBs are corrected using* `CC2NONCC` *program with the input file:* `p1c1bias.hist`. *PCVs are corrected using PAGES program with input file:* `igs05.atx`.

(h) Hover over the `'SYS / SCALE FACTOR'` data records. What is the purpose of implementing such a scale factor?

→ *The purpose of the scale factor is to increase the phase observations resolution.*

(i) What is the purpose of giving the `'GLONASS SLOT / FRQ #'` information?

→ *The processing of GLONASS data without GLONASS navigation message files or other sources.*

(j) Find the week number in the `'LEAP SECONDS'` line. What is the reason for the week roll-over? When it did happen first?

→ *Because it is a 10 bit number.*
It happened the 22/08/1999 *at* 00:00:00 *GPS time.*

(k) Hover over any observation data record. Why are there lines of 80 characters, and lines that are longer?

→ *While the epoch headers remain with a record length to 80 characters, the observation record length limitation of RINEX Versions 1 and 2 has been removed.*

4. **[RINEX Navigation files: v2.11 (GPS)]**
The standard navigation messages broadcasted by GNSS satellites gathered here slightly vary from one Satellite System to another. For example, while the GPS Navigation RINEX contains the pseudo Keplerian elements that permit the calculation of the satellite position, GLONASS Navigation RINEX contains the satellite position, velocity and Sun and Moon acceleration in order to integrate satellite orbits using Runge-Kutta numerical method.

Open `GPS_Navigation_Rinex_v2.11.html` with an Internet browser.

(a) As usual, this file is divided in a header section and the data record section. The header section is shorter than in the Observation RINEX. How short can be a GPS Navigation RINEX header?

→ *The shortest header contains just 3 lines:* `'RINEX VERSION / TYPE'`, `'PGM / RUN BY / DATE'`, `'END OF HEADER'`.

(b) Which ionospheric correction are given?
The `alpha0`, `alpha1`, `alpha2`, `alpha3` *and the* `beta0`, `beta1`, `beta2`, `beta3` *coefficients for Klobuchar model.*

(c) How many leap seconds are used in the file? When is recommended to state the number of leap seconds?

→ *15 seconds. It is recommended for mixed GPS/GLONASS files.*

(d) This file contains the ephemeris for two different satellites, each block of ephemeris has a separate colour. Where is it found the satellite identifier? Which satellites are present in the file?

→ *The satellite identifier is found in the first record of the ephemeris block. The two PRN present in the file are* `PRN 6` *and* `PRN 13`.

(e) The first line of each ephemeris block contains three records to compute the satellite clock offset to the GPS time. Which are these three coefficients?

→ *Each space vehicle clock has a bias, drift and drift rate from the GPS time.*

(f) GPS orbits are nearly circular. In the third line, it is found the broadcasted orbit eccentricity. Which are the orbit eccentricities for the file satellites?

→ `PRN 6` *has an eccentricity of* 0.00626740418375.
`PRN 13` *has an eccentricity of* 0.00200239347760.

(g) The last non blank field (second record in the 8th row) states the validity period for each ephemeris block. What is the value if it is not known?

→ *The value is zero if the fit interval is unknown.*

5. **[RINEX Navigation files: v2.11 (GLONASS)]**
Open file `GLONASS_Navigation_RINEX_v2.11.html` with an Internet browser.

(a) How do you identify this file as a GLONASS Navigation message?

→ *The RINEX File Type value is a* `'G'`.

(b) Does this file include any ionospheric information?

→ *The GLONASS Navigation Message does not broadcast ionospheric corrections.*

(c) Which correction has to be applied to correct GLONASS system time to UTC (SU timezone)?

→ $Tutc = Tsv + TauN - GammaN * (Tsv - Tb) + TauC$.

(d) Each of the other lines of GLONASS Navigation files contain 3 records with satellite position, velocity and Sun-Moon acceleration. In which units are given? What information gives the fourth record of each line?

→ *Units are:* km, km/s *and* km/s^2.
Message Frame Time, Satellite Health, Frequency Number, Information Age.

(e) In the third row of each ephemeris block frequency information is found. Which frequency was used by each GLONASS satellite present in the file? What happened to force the range in the frequency number?

→ `R3` *used the* `21th frequency slot`, *so:*

$$1602 + 0.5625 * 21 = 1613.8125 MHz.$$

`R11` *used the* `4th frequency slot`, *so:*

$$1602 + 0.5625 * 4 = 1604.25 MHz.$$

Interference problems with radioastronomy frequency bands and satellite communication services.

(f) In the last row of each ephemeris block the period for each ephemeris block is stated. When was last updated the satellite?

→ *The broadcasted information is 3 days old.*

6. **[RINEX Navigation files: v3.01 (SBAS)]**
Open file `SBAS_Navigation_RINEX_v3.01.html` with an Internet browser.

   (a) The Satellite Based Augmentation System broadcast navigation message is given in a new a version (v.3.01). The first change is observed in the first header line, where the file type and the satellite system are now clearly divided. What is the difference between the older version 2.11 to represent the navigation messages?

   → *In the older navigation message version the satellite system record was unused. In version 2.11, File Type* `N` *or* `G` *would directly represent a GPS or GLONASS Navigation message.*
   In version 3.01, File Type `N` *represents a navigation message, where the satellite system record specifies which of the* `G`, `R`, `S`, `E`, `M` *satellite system(s) is involved.*

   (b) The `'TIME SYSTEM CORR'` line allows to transform the satellite system time to UTC time through a corrections. What are the coefficients for the formula? Which is the augmentation system of this navigation message?

   → *The formula is:* `CORR(t) = a0 + a1*DELTAT`
   Particularised:
   `CORR(t)= 0.1331791282E-06 + 0.107469589E-12*(t-552960)`
   The augmentation system is EGNOS.

   (c) This file contains ephemeris for a geostationary satellite. What is the difference in time between the two records? Where can be found?

   → *The epoch time is located in the the first line of each data epoch.*
   The first epoch corresponds to `18/12/2010` *at* `00:01:04`.
   The second epoch corresponds to `18/12/2010` *at* `00:05:20`.
   So, between them is was elapsed 4 minutes and 16 seconds.

   (d) SBAS navigation files are similar to GLONASS, both contain records with satellite position, velocity and accelerations. What is the flag for a healthy satellite? Which IODN corresponds to the ephemeris present in the file?

   → *A healthy satellite contains a* `0.0 Health flag`.
   The first ephemeris block has an `IODN: 23`.
   The second ephemeris block has an `IODN: 24`.

7. **[Global Ionospheric Map files: IONEX v1.0]**
Using a GNSS tracking network it is possible to extract information about the Total Electron Content (TEC) of the ionosphere on a global scale. The IONEX format is a well defined standard used to exchange ionosphere maps. It follows the same philosophy of the RINEX, even with the organisation of the files into a header and a data section where the maps are allocated.

   Open file `IONEX_v1.0.html` with an Internet browser.

   (a) Hover over the third record of the first line. How many sources can contribute to produce a IONEX map? And how many models?

   → *Several satellite sources can be used, such as:* `Envisat`, `Geostationary`, `GLONASS`, `GPS`, `TOPEX/POSEIDON`, `Navy Navigation Satellite (NNS)` *or* `IRI`. *Two different models are possible: BENt or ERS.*

   (b) This file contain two types of information lines: there are COMMENT Lines and DESCRIPTION Lines. What is the difference between the two records? Which model is used in this IONEX map? When is this map valid?

   → *Description lines give brief description of the technique, model used, while comments can contain any kind of information.*
   The IONEX map model is based on spherical harmonics.
   The ionosphere map is for `Day Of Year (DOY) 288 of 1995`.

   (c) What information would you expect to appear in the `'OBSERVABLES USED'` line when using a theoretical model.

   → *A blank line is stated when a theoretical model is used.*

   (d) After Comments Line(s) the IONEX Map Grid is described. Give details about: The number and dimension of the maps present in the current file with its mapping function. The number of stations and satellites used for the Total Electron Content (TEC) computations. The grid size and the satellite elevation cut-off.

   → *The IONEX file contains five 3-dimension* `TEC/RMS/HGT` *maps with a 1/cos(z) mapping function.*
   80 stations and 24 satellites have been used to produce the map.
   The grid extends from 200 km to 800 km in height with an equidistant increment of 50 km.
   The grid extends from 85^o *to* -85^o *in latitude and from* 0^o *to* 355^o *in longitude in increments of* 5^o.

   (e) There is some auxiliary data in this file. Which type of this information is given, and in which units is given?

   → *This IONEX map gives the Differential Code Biases (DCB) and their RMS for the satellites used in the IONEX map.*

The DCB's are given between the GPS P1 and P2 codes in units of nanoseconds (of L1-L2 delay).

(f) Once the header section ends, the ionosphere maps are detailed. How many ionospheric maps are presented in the current file?

→ *There are 3 different maps: a Total Electron Content map (TEC), a RMS errors map of the associated TEC map, and a final map containing the heights which the TEC values are obtained.*

(g) Hover over the TEC values of the first TEC values. What is the time of this map?

→ *The first map corresponds to* `15/10/1995` *at* `00:00:00`.

(h) How to interpret the exponent values.

→ *The exponent values indicate the 10-exponent to apply to the TEC values:*
Exponent: `-3` *TEC field:* `1000` *TEC value:* $1000 \cdot 10^{-3} = 1 TECU$.
TEC is given in TEC units (TECUs), where 1 TECU corresponds to $10^{16} e^- / m^2$

(i) How would be seen and non-available TEC value?

→ *Non available TEC values are given as* `99999` *value.*

(j) How many TEC values fit in a single line and in which units are given these values?

→ *TEC rows are given in 16 fields per line, until the grid limits.*

(k) Hover over any of the RMS values. What is the default exponent for stating the RMS values of the TEC maps?

→ *The default exponent is* `-1`*:* $10^{-1} = 0.1 TECU$. *Where 1 TECU corresponds to* $10^{16} e^- / m^2$

8. **[RINEX Clocks Files: v3.00]**
The standard files provide station and satellite clock data. Four types of information are given in this format: data analysis results for receiver and satellite clocks derived from a set of network receivers and satellites with respect to a reference clock, broadcast satellite clocks monitoring, discontinuity measurements and calibration(s) of single GNSS receiver.

Open file `RINEX_CLOCKS_v3.00.html` with an Internet browser.

(a) This clock data file starts with a header section as usual. Hover over the first and second comment record. What is the difference among comments? what kind of information does the second comment give?

→ *The first comment is generic, while the second one is a Timescale Re-Alignment comment. This comment is required if* `'Ax'` *data is given (*`AR` *or* `AS`*). In case clock values have been timescale shifted the method applied to all receiver and satellite clocks should be noted.*

(b) Hover over the 'SYS / # / OBS TYPES' records. Which observation descriptors are present in this RINEX Clocks file?

→ *This file contains* 4 *different descriptors from the GPS system:* C1W, L1W, C2W, L2W.

(c) Records 'SYS / DCBS APPLIED' and 'SYS / PCVS APPLIED' describe Differential Code Bias (DCB) and Phase Center Variations (PCV). Which programs are used to apply different corrections?

→ *DCB corrections are applied using* CC2NONCC *program, while PCV corrections are applied using PAGES program.* CC2NONCC *is available at the server* https://goby.nrl.navy.mil/IGStime/cc2noncc/.

(d) Records 'STATION NAME / NUM' and 'STATION CLK REF' give information about the station. Which receiver identifier is present in the file? Which is the external clock of this station used for calibration?

→ *The station name is the United States Naval Observatory (USNO) with a receiver identifier* 40451S003. *The external clock is the USNO, connected via continuous cable.*

(e) Which is the analysis center of this file?

→ *The analysis center is the USNO, using the GIPSY/OASIS software.*

(f) This file uses two different groups of '# OF CLK REF' and 'ANALYSIS CLK REF'. When does each clock reference apply?

→ *The data set is for date* 14/07/1994. *USNO clock reference applies from* 00:00:00 *to* 20:59:59. *After then, the clock reference used is TIDB from* 21:00:00 *to* 23:59:59.

(g) How many receivers are included in the data file? Which reference frame us used to give station coordinates?

→ 5 different stations are used in the file: GOLD (USA), AREQ (Peru), TIDB (Australia), HARK (South Africa), USNO (USA).

(h) The data record section of this file comes right after the 'END OF HEADER' record. Each clock data record starts with a data type identifier. Which are present?

→ *The following clock data records are present:* AR *(Receiver Analysis),* AS *(Satellite Analysis),* CR *(Receiver Calibration),* DR *(Receiver Discontinuities). The only missing record is the* MS *(Satellite Monitor) record.*

(i) Which data records are present for all clock data types? Which data records sometimes are present?

→ *Records* 'Clock Bias' *and* 'Clock Bias Sigma' *are always present. Records* 'Clock Rate', 'Clock Rate Sigma', 'Clock Acceleration' *and* 'Clock Acceleration Sigma' *are only present for the* AR *clock data type.*

9. **[Antenna Phase Center files: ANTEX v1.3]**
These standard files contain satellite and receiver antenna corrections. While satellite data includes satellite and block specific Phase Center Offsets (PCOs). Receiver data includes elevation and azimuth dependent corrections for combinations of antennas and radomes.

   Open file `ANTEX_v1.3.html` with an Internet browser.

   (a) As usual, this file contains a header section. Hover over the record present in line 'PCV TYPE / REFANT'. Which Phase Center Variation (PCV) is used in this file? Which antenna is used as reference?

   → *PCV are relative. This ANTEX file uses* `AOAD/M_T` *antenna as a reference.*

   (b) The different blocks of information are clearly identified using colours. What are the opening and closing records of each block? Which antennas are described in the file?

   → *The antenna blocks start with record* `'START OF ANTENNA'` *and end with* `'END OF ANTENNA'`. *This ANTEX file contains* 3 *different antenna descriptions. First one is from* `GLONASS R08` *satellite, second one is from GPS satellite* `G12` *(modernised block 2) and the third one corresponds to the* `AOAD/M_B` *antenna.*

   (c) Analyse GLONASS antenna record `'TYPE / SERIAL NO'`. How is the satellite code (CNNN) interpreted? When it was launched? How many satellite were launched that year before this one? Repeat the exercise with the GPS satellite.

   → *The GLONASS antenna corresponds to a* `GLONASS (R)` *satellite, numbered* 729. *It was launched during year 2008. According to the ANTEX record, it is the 67th launched satellite. The GPS antenna is aboard the* `58th GPS Space Vehicle (SV)`. *It is the* `52th` *satellite launched during 2006.*

   (d) `'DAZI'` line shows the azimuth increment used to characterise the antenna's azimuth phase pattern. For satellite R08, is the Phase Center Variations (PCV) azimuth dependent? What about the GPS one?

   → *Because a* `DAZI` *value of* 0.0 *is given, the PCVs of* `R08` *and* `G12` *are non-azimuth-dependent.*

   (e) `'ZEN1 / ZEN2 / DZEN'` gives information for both `AZI` and `NOAZI` phase patterns. What satellite grids are used to study the antennas? Is there any difference between receiver and satellite antennas?

   → *Both satellite grids start at* 0.0 *degrees, ends at* 14.0 *with* 1 *degree step. While receiver antennas use zenith, satellite ones use nadir degrees.*

(f) '# OF FREQUENCIES' determines the number of frequencies for each antenna block. Which frequencies are described in the block for each satellite phase pattern?

→ *Two different frequencies are described. GLONASS satellite describes* G1 *and* G2 *frequencies, while the GPS satellites describes* L1 *and* L2.

(g) The frequency section extends from 'START OF FREQUENCY' to 'END OF FREQUENCY' records. Which information is given? Give the eccentricity vector for both satellites. What is the origin of this vector?

→ *The eccentricities of the antenna phase center and the phase pattern values:* R08=(-545.00,0.00,2300.00), G12=(-10.16,5.87,-93.55) *The vector points FROM satellite center of mass TO satellite antenna phase center.*

(h) How many Non-AZImuth-dependent (NOAZI) phase pattern values are specified. Why?

→ *14 different* NOAZI *values are specified, due to the* 'ZEN1 / ZEN2 / DZEN' *definition. Because* DAZI *is set to* 0, *non AZImuth (AZI) dependent phase pattern are specified.*

(i) Third antenna corresponds to a receiver antenna. Which is the calibration method? Which agency has created such corrections?

→ *Calibrations have been converted from file* igs_01.pcv. *The Technischen Universität München (TUM) is the creator of the file.*

(j) This antenna has a non-zero DAZI record for the Phase Center Variations (PCVs). What is the value of this increment? Where else can we see this DAZI?

→ *This antenna block has a 30 degrees azimuth increment for the PCVs. So, this values fill be given from 0 to 360 with increments of 30 degrees.*
Apart from giving the NOAZI *values, this data sets includes the* DAZI *values, both of them using a* 0.0 *to* 90 *grid with a* 5 *degree step.*

10. **[Precise Orbits and clock files: SP3 version C]**
Precise orbital data (Satellite Position and Velocity), the associated satellite clock corrections, orbit accuracy exponents, correlation information between satellite coordinates and satellite clock are available in this format. This information can be observed or predicted simultaneously with those precise orbits.

Open file SP3_Version_C.html with an Internet browser.

(a) The structure of this file is different from the RINEX ones seen until now. Hover the mouse over 'Extended Standard Product

3 Orbit Format' title, where some general information is given. Who was the first author to develop this format? What additional information was included?

→ *Remondi, from the National Geodetic Survey (NGS) Standard Product. Satellite clock corrections, orbit accuracy exponents, comment lines, the GPS week and the first epoch seconds of week.*

(b) What was the main advance in the SP3-b version? Did this change break some previous characteristics?

→ *The version* B *of the* SP3 *files accommodated GLONASS orbits.* SP3-b *modifications were backwards compatible with* SP3-a*, with the exception of the satellite identification records, from a* I3 *field to an* A1,I2*.*

(c) What was the main advance in the SP3-c version? How this was achieved?

→ *Files now include not only clock accuracy information, but also (X,Y,Z) satellite coordinates accuracy information. This new information was added using columns 61 through 80 in each Position and Clock Record.*

(d) How is this format organised? Is there any optional record?

→ *The format of an SP3 file is a Header, followed by a series of epoch times each with a set of Position and Clock Records listed for each satellite. Optional records are: satellite velocities, clock correction rate-of-change, Position and Clock Correlation Record* (EP record)*, and a Velocity and Clock Rate-of-Change Correlation Record* (EV record)*.*

(e) The first line of the SP3 file contains information about the entire file. What is the version of the current file? Which may be the next SP3 version? Which flag mode is set in this file? What time is the first epoch? How many epochs are included in this file? Which type of orbit is used in the file? Which agency has created the file?

→ *The version of the file is* C-version*.* SP3 *versions follow the alphabet, so next one may be* SP3-D *version. The Velocity mode flag is set. This means the records will follow the Order* P,V, P,V... *in case there were additional records, (*EP *or* EV*), those would be in the middle.*
First epoch dates from 08/08/2001 *at* 00:00:00*.*
There are 192 epochs of a maximum of 10 million.
The orbit type is HLM, which means it has been fitted applying a Helmert transformation.
IGS is the agency that has created the file.

(f) What is the symbol to identify the start of the second line? Which GPS week number corresponds this file? Which interval is used in this file? How many days have been elapsed since the start of GPS?

→ *The* ## *symbols.*
This file corresponds to the GPS week 1126*.*
A 900 *seconds interval is used.*
It can be easily found, from the MJD: $52129 - 44244 = 7885$ *days.*

(g) The next block (lines 3-7) states the satellites used in the file. How many have contributed? What does a zero value means? How many different satellites from different satellite systems are identified?

→ 31 *Different satellites.*
The 0 *value indicates all identifiers have been listed.*
Each identifier consists of the Satellite System Indicator followed by a 2-digit integer.

(h) From line 8 to 12, orbit accuracy of the satellites is listed following the previous block order (lines 3-7). How is this accuracy exponents interpreted? Does this orbital error imply any limitation?

→ *For example, if the accuracy exponent is* $13 \rightarrow 2^{13}mm \simeq 8\,m$*. This accuracy represents one standard deviation of the entire file (per satellite). This is problematic when joining orbit files, or when a file contains both observed and predicted data.*

(i) Next block comprises lines 13 and 14. Although is mainly unused, what information is given in the file?

→ *This block states the file type and the system time used in the file.*

(j) Next block comprises lines 15 and 16. What information is given in the file? What is the reason for using such base numbers?

→ *This block contains the floating-point base number used for computing the standard deviations of satellite position, velocity, clock correction and the rate-of-change of the clock correction. Better resolution can be attained using a floating point number different from 2.*

(k) After the comment section, the data records start with the previously seen time of first epoch. What are the symbols to mark the start of comments and new epoch?

→ *Comments start with symbols '/*', while new epoch start with symbol '*'.*

(l) The second epoch line contains the Position and Clock data record. What parameters are given? Which units are used? Explain the different flags applied to the first satellite.

→ *Satellite (X,Y,Z) positions, the clock correction with its correspondent standard deviation exponents. There are 4 final flags.*
Satellite positions are given in kilometres, clock correction in microseconds. The exponents generate millimetres and picoseconds corrections.
First satellite has set: a discontinuity flag between the previous epoch and current epoch, an orbit position and clock prediction flag and a maneuver flag.

(m) The third epoch line contains the Extended Position and Clock Correlation record. What information is given in the first 4 records? What is the difference with the previous line? Which correlation coefficients are given, next?

→ *The standard deviations of the satellite position and clock correction are given with greater resolution than the approximate values given in the Position and Clock Record.*
The correlations between `X/Y`, `X/Z`, `Y/Z` *satellite coordinates, and correlations between* `X/C`, `Y/C`, `Z/C` *satellite coordinates and clock.*

(n) The fourth epoch line contains the Velocity and Clock Rate-of-Change Record. In which units are given satellite velocities, clock rate of change and their deviations? What happens if the deviations are unknown or too big to represent?

→ *Velocities are given in decimeters/second while clock rate of change in microseconds/second. Velocity deviation in millimetres/second while clock rate of change deviation are given in picoseconds/second. A value of 99 means the standard deviation was too large to represent, while a blank means it is unknown.*

(o) The fourth epoch line contains the Extended Velocity and Clock Rate-of-Change Record. Which correlation coefficients are given? Why are the values given greater than one?

→ *The correlations between* `Vx/Vy`, `Vx/Vz`, `Vy/Vz` *satellite velocities, and correlations between* `Vx/Clock`, `Vy/Clock`, `Vz/Clock` *satellite velocities and clock.*
Because they have to be divided by 10^7.