Verification of the meteorological observations on the EPN stations

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Abstract

The EUREF Permanent Network (EPN) consist of 200 stations, almost 40 % of these stations have meteorological equipment. The observations obtained from meteorological packages could be used to estimate the tropospheric delay. The fluctuations in meteorological parameters cause fast changes of the tropospheric delay, as a correlated value, and in consequence difficulties in GPS heights determination. The meteorological parameters from meteorological equipment on the EPN stations and the additional reference data from World Meteorological Organization were two in situ data sources. The values from WMO server consist of the daily mean value of the most important weather characteristics. Among these data also appears: the pressure, the temperature and the humidity. These data and values obtained from Global Pressure and Temperature (GPT) model were used as basis for the meteorological data verification on EPN/IGS stations. The accuracy and the reliability of the meteorological data sets were estimated. This paper presents the procedures and the results of meteorological data verification on the all EPN stations equipped with meteorological packages .

Key words: GPS for meteorology, EPN stations, precise GPS positioning.

INTRODUCTION

The GPS signal during its passage through the atmosphere is subjected to distortions. The magnitude of these distortions is a function of meteorological parameters: pressure, temperature, water vapour. The meteorological observations on the EPN stations are carried out in order to provide additional data source for tropospheric errors corrections. With the use of pressure *p* [hPa] it is possible to calculate Zenith Hydrostatic Delay (ZHD) and with the use of temperature *t* [°C] and humidity H [%] Zenith Wet Delay (ZWD). Both ZHD and ZWD might be used in the process of EPN solution. The observations are being made on the vicinity of the GPS antenna, with the use of different producers sensor's and different field configuration. The precision and reliability of the obtained temperature and pressure observations were subjected to verification. The humidity data were not processed due to strictly local characteristics of this phenomena. The verification process was based on meteorological synoptic stations located in the vicinity. Also the log files, RINEX meteo files and Global Summary Of the Day files completeness and correctness have been assessed. These activities were possible to carry out thanks to list of common station: synoptic and GPS.

METEOROLOGICAL PARAMETERS SOURCES

The set of basic meteorological parameters consists of temperature t [$^{\circ}$C], pressure p [hPa], and humidity h [%]. These parameters, according to log files, have been measured at 53 GPS stations (figure 1.).

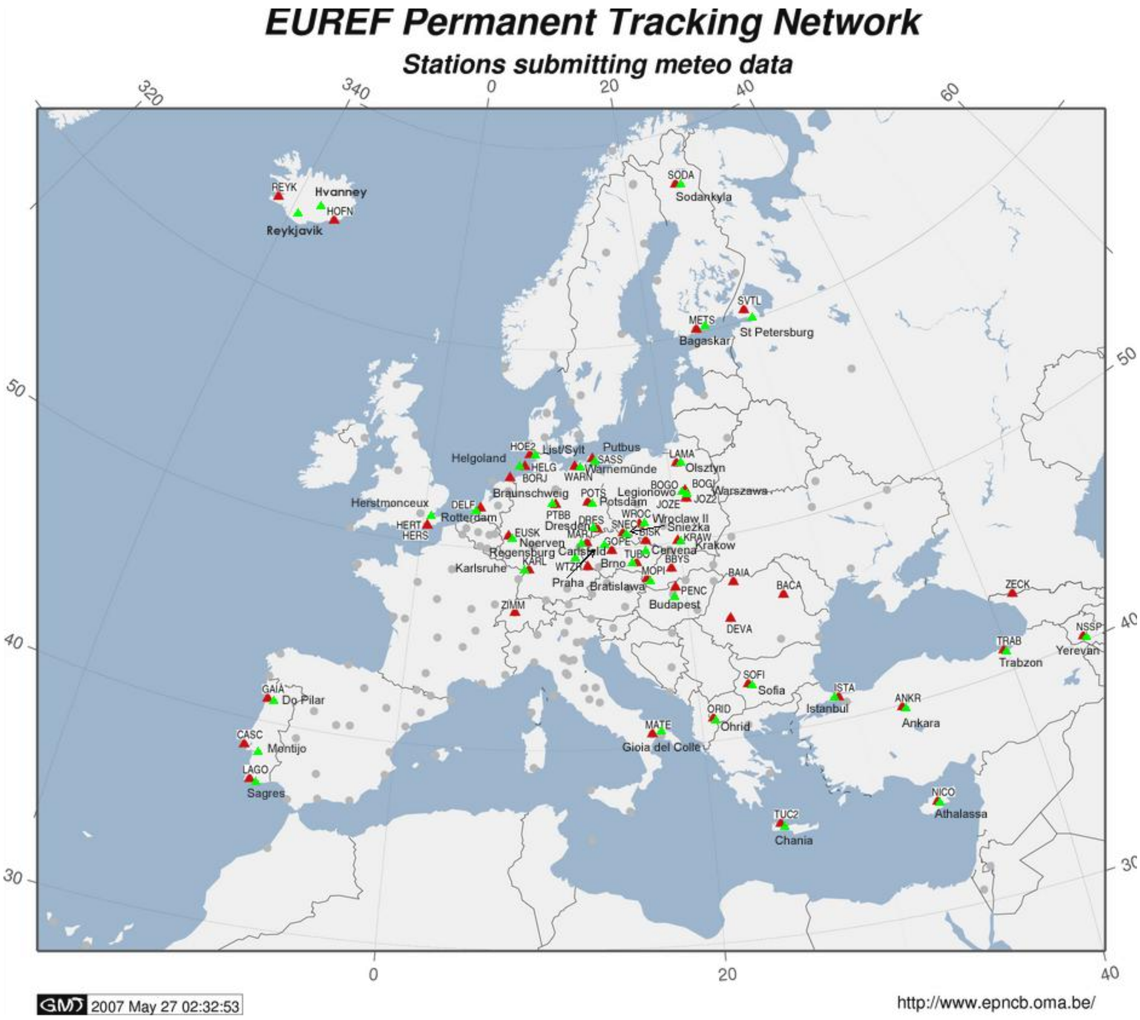


Fig. 1. Couples of GPS (red triangle) and synoptic stations (green triangle)

The measurement equipment consist of barometer, hygrometer and thermometer most commonly as an united device – meteorological lab. At the meteorological stations govern by national meteorological administrations the precise of measurements should conform guidelines of World Meteorological Organization (WMO). The sensors assumed precision is presented in the table 1. The WMO guidelines also define time resolution which is at least four measurements per day, each six hours, with starting hour at 0 GMT.

Table 1. The meteorological data precision

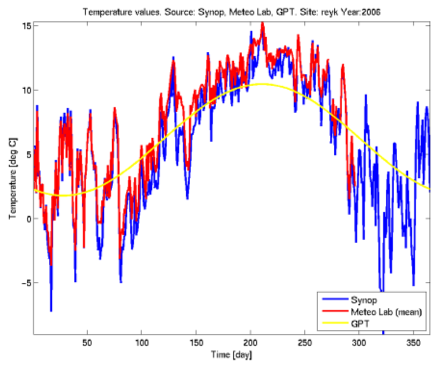
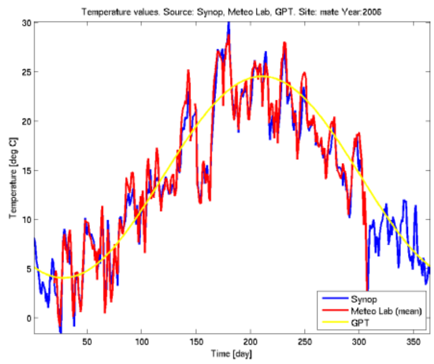
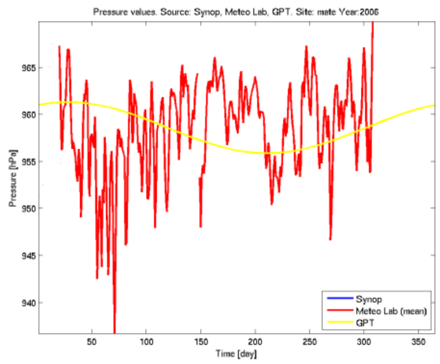
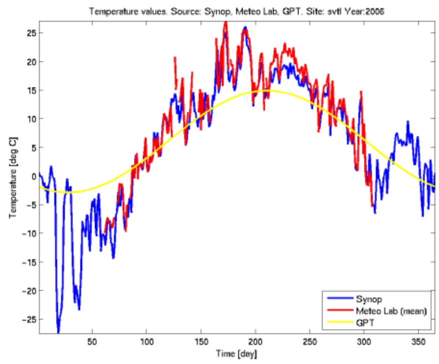
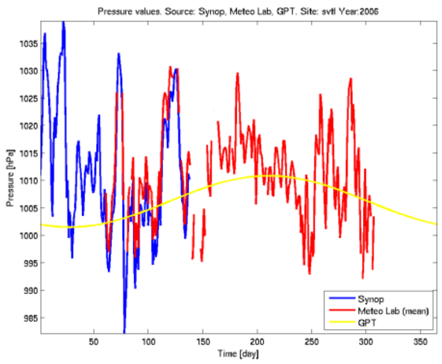
Quantity	Meteorological labs	IMGW or CHMU	GPT model
• pressure p[hPa]	0.3 – 0.5	0.2	5.0
• temperature t [^{0}C]	0.3 – 0.5	0.2	3.0
• humidity H [%]	3.0 – 5.0	2.0	

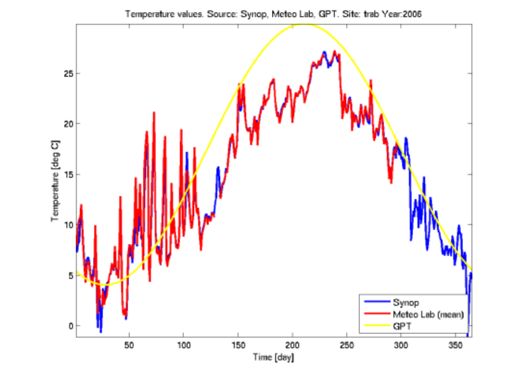
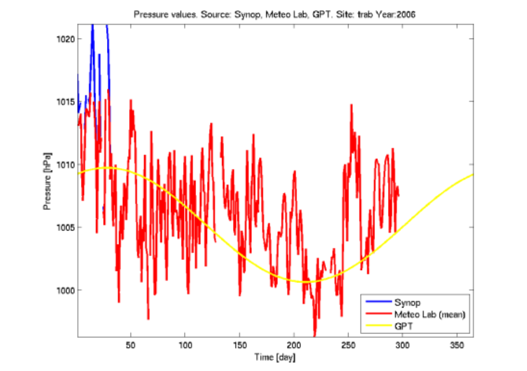
The main data storage facility for WMO data are NOAA servers, which provide Global Summary Of the Day (GSOD) files for free. The additional data source is Global Pressure and

Temperature (GPT) model *(Boehm, 2006)* which is able to determine the pressure and temperature using geodetic coordinates (*φ, λ*), ellipsoidal height (*h*) and day of the year.

STATIONS IN DIFFERENT CLIMATIC ZONES

On the European continent several climatic zones are found, based on the Köppen classification, almost whole West Europe is assigned to group of temperate climates (C), with types: Mediterranean (*Csa*, *Csb*), humid subtropical (*Cfa*), maritime temperate (*Cfb*), maritime subartic (*Cfc)*. In the most of the East Europe continental group of climate (D) are found like: warm summer continental (*Dfb*), Subartic or Boreal (*Dfc*), also on the very north of Europe Polar climates (E) are to be found , on the opposite side of temperature scale also dry climates (B) are found. Finally mountain type of climate (H) is also present on the areas with greater elevation. The EPN as an Pan European network enclose almost all of these climatic zones which is easy to observe on the temperature and pressure plots (figure 2).

Climate type at station	Temperature *t* [^{0}C] for whole 2006	Pressure *p* [hPa] for whole 2006
Cfc Reykjavik (REYK)		not available
Cfa Matera (MATE)		
Dfb Svetloe (SVTL)		

<table>
<tr><td>Cfa
(close to
H)
Trabzon
(TRAB)</td><td></td><td></td></tr>
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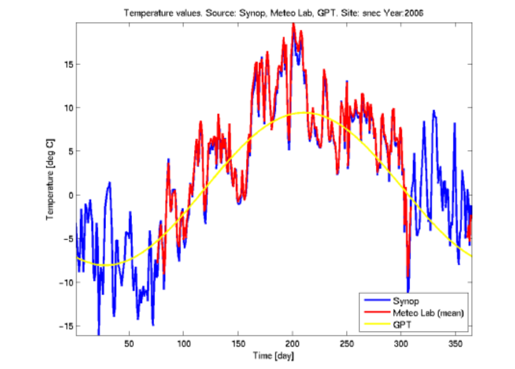
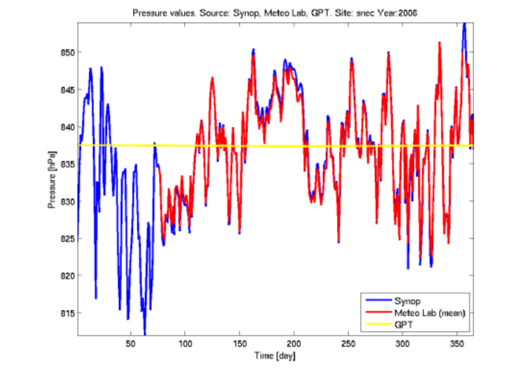
Śnieżka
(SNEC)</td><td></td><td></td></tr>
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Fig. 2 The meteorological parameters (temperature and pressure) from several EPN stations located in different climatic zones

METEOROLOGICAL DATA COMPARISON

The first step was construction of "parameters matrix", the structural table with meteorological and EPN station couples *(Wecker, 2006)* and the basic information from log files. The process of reading the data from log file was complicated due to large amount of blunders in log production. The log file construction should be based on the reference file provided at EPN server. In most cases it is not. The first fault is the not consistence definition of "Height Difference to Antenna" which sometimes denote the pressure sensor below antenna as an positive value (KARL) and on the other hand negative (TUBO). The reference log clearly stating that sensor interval must be in second, while i.e. at the HERS station is in minutes and with unnecessary description. Another problem is writing units just after the values not before the colon, which not helps in machine reading. The following problem is that stations with inscription of meteorological data sensor are not transferring such kind of data.

Concerning the data from couple list *(Wecker, 2006)* at station HERT, PTBB, REYK the height are in meters above the ellipsoid not over the mean sea level as stated.

After "parameters matrix" construction, data reading was consecutive step. There were a several problems Firstly at station NSSP huge gaps in both pressure and temperature were found, secondly at station SVTL humidity value was not present, thirdly at station KRAW data were in odd order, fourthly at stations located on the territory of United Kingdom the values of pressure were in mbar and values of temperature in Fahrenheit degrees.

The process of comparison is parallel to this used in previous calibration of EPN stations located in the vicinity of Karkonosze Mountains *(Rohm and Bosy 2007)*. The main steps of procedure are presented on the figure 3. The three different data source utilized in comparison are produced in non similar time resolution.

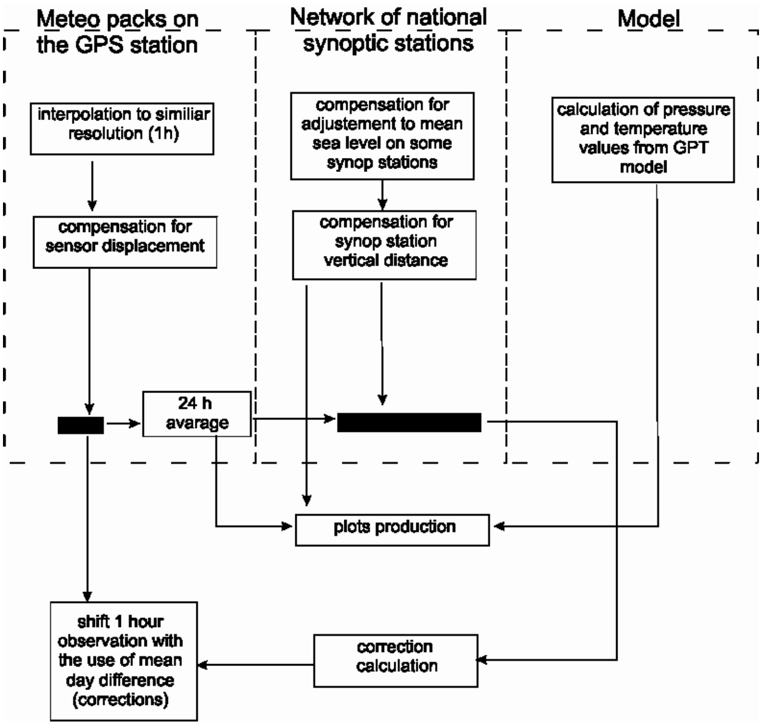


Fig. 3. *Data comparison and calibration flow scheme.*

The comparison result is presented in the table 2. The bias value is a mean difference between calibrated and not calibrated data, while error value is a standard deviation of difference between calibrated and not calibrated data. Stations BISK, LAMA, ISTA, POTS, KRAW, PDEL, SVTL, NICO shows significant bias in term of temperature or pressure.

Table.3.The overview of the meteorological data precisions.

station	bias press (hPa)	STD press (hPa)	bias temp (^{0}C)	STD temp (^{0}C)
bisk	23.95	1.27	0.79	1.03
casc	0.46	0.37	0.17	0.87
delf	-0.02	0.33	0.10	0.42
eusk	-0.25	0.87	-0.66	1.14
gaia	0.06	0.58	0.65	0.68
gope	-0.98	1.03	0.11	0.71
helg	-0.35	0.37	0.04	0.13
hers	0.09	0.50	0.63	0.43
hert	-0.02	0.51	0.65	0.51
ista	-2.08	0.50	-0.09	0.65
joz2	0.91	0.49	0.17	0.42
karl	-0.22	0.41	0.10	0.34
kraw	-0.94	1.92	0.70	0.74
lama	7.57	11.27	-0.38	2.38
mate	0.69	0.00	0.20	0.56
mets	-0.72	0.57	0.17	0.85
nico	-0.12	0.42	-1.13	0.65
orid	-0.22	0.37	0.33	0.41
pdel	0.47	0.53	1.75	0.38
pots	2.33	0.47	0.35	0.34

ptbb	-0.92	0.48	0.12	0.45
reyk	NaN	NaN	0.48	0.54
sass	0.42	0.30	0.30	0.33
snec	-0.07	0.39	0.21	0.37
sofi	-0.33	0.91	0.15	0.70
svtl	2.15	0.62	0.51	0.93
trab	-0.66	0.56	0.08	0.31
tubo	-0.02	0.67	0.30	0.32
warn	0.24	0.79	-0.23	0.49
wroc	0.98	0.74	0.79	0.57
wtzr	-0.52	1.16	0.54	0.71

The BISK station pressure sensor performs poorly – the bias (almost 50 hPa) might be the result of a lightning stroke *(Frantisek Mantlik personal communication)*. At the figure 4, one can find the pressure from synoptic station depicted in blue and corresponding value from the deterministic model GPT as an yellow line, while values obtained at the BISK station are those in red.

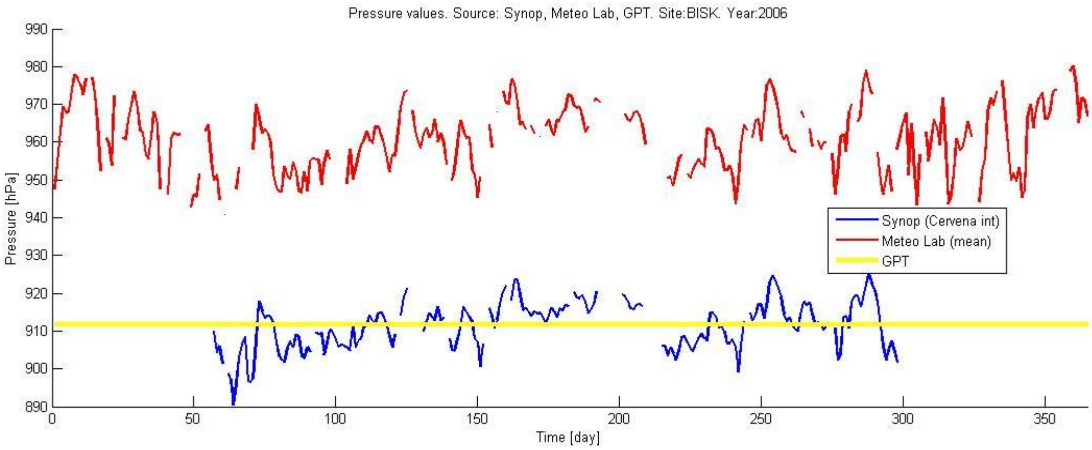
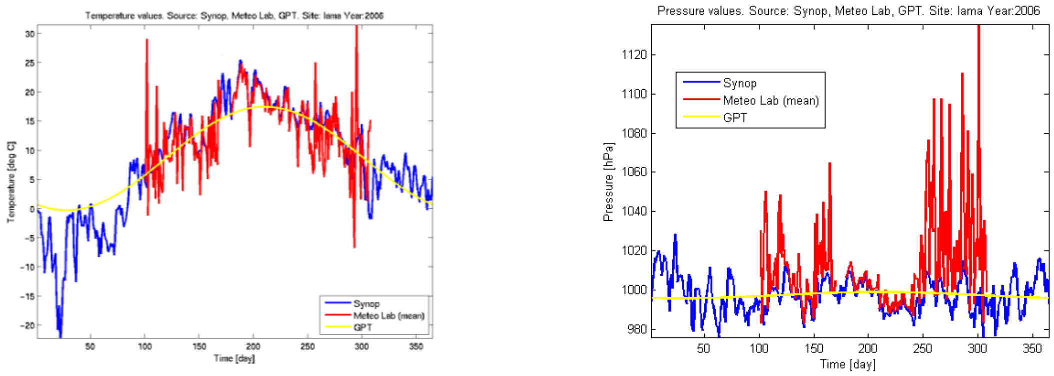


Fig.4. Pressure data problems at the BISK station.

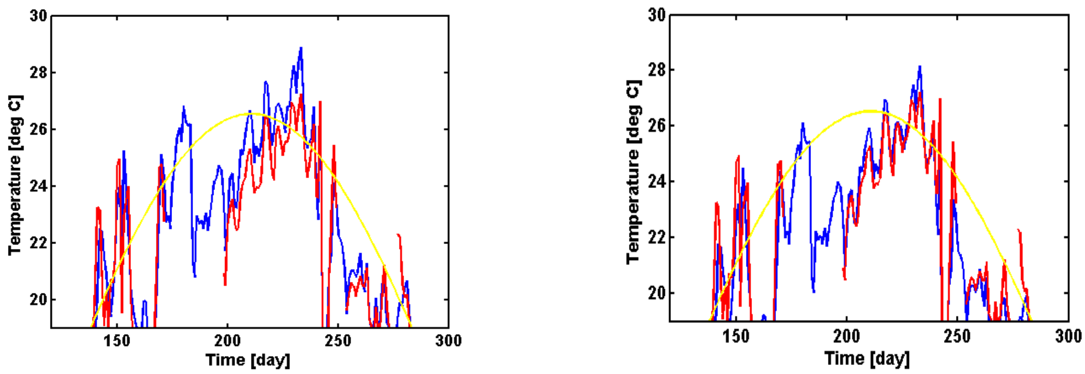
The LAMA station is probably subjected to some seasonal processes (i.e. rain), which is the reason of data picks in the pressure and temperature series. The figure.5.a) and 5.b) shows temperature diurnal and seasonal variability, again in red data from meteo lab at the LAMA station, in blue the data from reference synoptic station and yellow the GPT model values. Between day 100 and approximately day 160 and between day 250 and day 300 one can see the large scatter in meteorological parameters. The part of data positively and strongly correlated with reference parameters is this from summer.



a) b)

Fig.5.a) The temperature at the LAMA station. b)The pressure at the LAMA station.

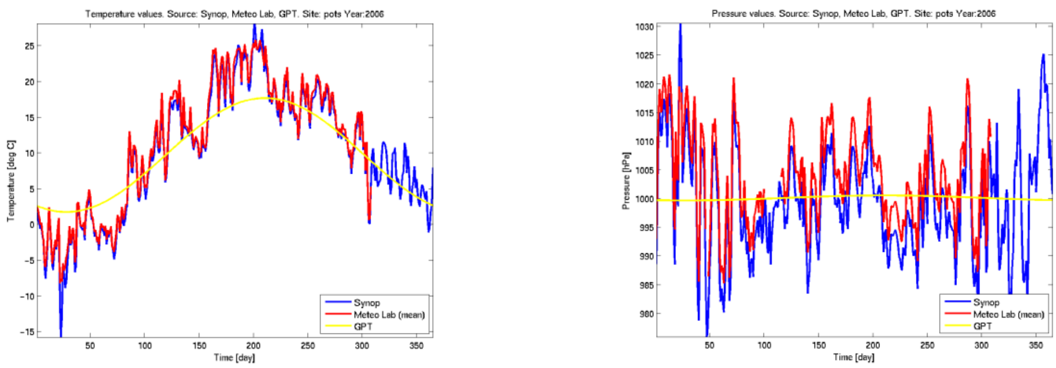
Concerning ISTA station the significant bias is the result of arbitrary laps rate choice. The wet laps rate 0.68 ^{0}C / 100m (figure 6.a)) was used at all stations due to typically frontal weather regime over Europe, with large amount of clouds and large amount of water vapour in the air. It is not the case at ISTA station where the weather is mainly driven by anticyclones from central Asia, thus the air is dehydrated and the dry laps rate 1.00 ^{0}C/100m perform better(figure 6b)).



a) b)

Fig.6. The temperature at the ISTA station a) wet laps rate used. b)dry laps rate used.

Concerning the data reported by WMO, problems occurs while the temperature and pressure reduction is being calculated and the mean sea level height reported by WMO is not appropriate. The result of such miss measurement is observed at POTS station (figure 7.) and with smaller magnitude at WROC station. Other, not investigated problems occur at PDEL (figure 8.) and NICO stations.



a) b)

Fig.7. The temperature at the POTS station a). The pressure at the POTS station b).

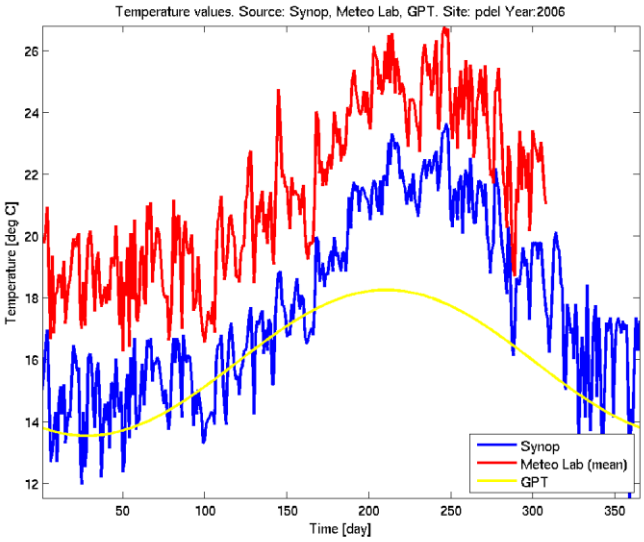


Fig.8. The temperature at the PDEL station.

The STD value of 1.92 hPa at KRAW station is probably the information that the pressure sensor should be swap because the present sensor performs poorly.
The meteorological sensors at the EPN stations, except detailed above, are reporting reliable and precise data, which can be used in network solutions or in the weather applications.

CONCLUSION

There are 31 stations (from all number of 184) transferring meteorological data to EUREF that have been verified with the use of synoptic stations data. Some stations have problems with sensors (BISK, LAMA, KRAW). Most of the station logs are not easily machine–readable, an effort has to be made for the log's unification. Some data from synoptic stations are not available. Moreover, there might be a problems with height measurements at synoptic stations (see pressure bias POTS, NICO).
Pressure data precision varies from almost zero bias and zero STD to bias 23.95 hPa at BISK station and STD 11.27 hPa at LAMA station Temperature data precision varies from almost zero bias and 0.10 ^{0}C error to bias 1.75 ^{0}C at PDEL station and STD 2.38 ^{0}C at LAMA station Some biases have unclear source (NICO, PDEL) and need to be investigated in the future.

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