Investigation on the Coordinates of the Permanent GPS Station VENE (Venice)

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History of the VENE site

According to the log file archived at the EUREF CB, the VENE site is active since March 23, 1995 (GPSweek 827). The antenna is installed on the roof of the ancient palace Papadopoli, on the Canal Grande, which houses the Istituto per la Ricerca sulla Dinamica delle Grandi Masse (Research Institute for the Dynamics of Large Masses) of the National Research Council in Venice. The equipment is owned and remotely operated by the Centro di Geodesia Spaziale of the Agenzia Spaziale Italiana in Matera (Figure 1).

Figure 1: the antenna of VENE .

The monument is a metallic mast on the wooden terrace on the roof of the building. The geological characteristics of the foundations are sand and clay. Overall, the area has been subsiding in the 60's and 70's. The subsidence is reported to have very nearly stopped.

The equipment history is summarised as follows.
The earliest available solution refers to week 864 (March 1996). At that epoch the antenna was modified by adding a metallic ring, with the intent of reducing R.F. interference. From week 867 to week 872 the site was inactive. On May 14, 1996 (week 872), the metallic ring was modified to the

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configuration that is valid at present. On week 926 (1 October 1997) a new receiver and antenna were installed. Since week 926 no hardware replacement is reported in the logbook.

Data Quality Analysis (QC)

Four weeks of data (1068-1072) corresponding to the month of July 2000 have been analyzed with the program TEQC developed by UNAVCO, running in full QC mode.

Figure 2 shows that on average 15000 valid data are collected daily, out of expected 20000. The code multipath is on average 0.3 m on L1, and 0.8 m on L2. Also the number of observations per cycle slip is nominal and nearly constant. It is necessary to understand why QC deletes on average 5000 data point for every daily session.
Figure 3 shows that the breakdown of the ca. 5000 edited data points consists of typically 1500 data being taken below the elevation mask of 15 degrees, and the rest of data with no L2 phase.

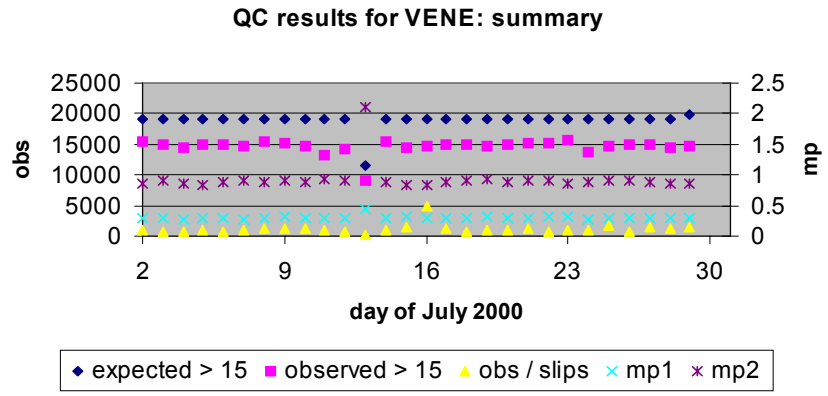

Figure 2: QC statistics of VENE data for July 2000.

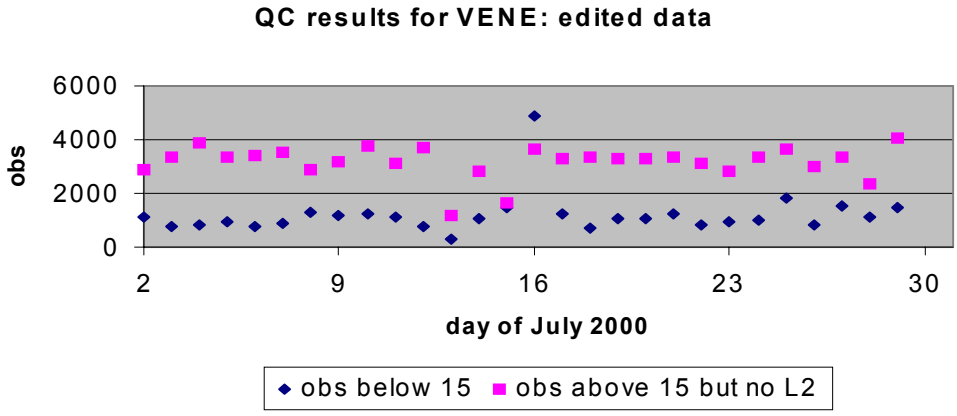

Figure 3: breakdown of the QC- edited data for VENE during July 2000.

Further analysis of the outputs of QC on several test days indicates that the receiver performs nominally, as to code multipath and number of cycle slips. Figure 4 refers to doy 198 (July 16, 2000) as an example. It shows that the problem is that the L2 data are missing at medium to low elevation, regardless of the satellite. Figure 5 shows that the data on the same day were quite nominal at the nearby station UPAD.

The combined solution for VENE

The EUREF CB home page provides plots of time series of individual stations of the EPN, resulting from the combined solution computed weekly by BKG. The plots for VENE (Figure 6) indicate an oscillatory pattern within a range of +/-10 mm for the horizontal components, and an irregular, systematic pattern within a range of –40/+20 mm for the vertical coordinate.

Comparing the time series with the logbook, we notice that the series starts at week 864, and exhibits a gap around week 926, when a new receiver and antenna were installed. The solution for the vertical component seems to be biased upwards of roughly 20 mm. There is an additional break at week 1020, always for the up component, but this does not correspond to any physical change in the equipment. This epoch correlates with the shift from CODE to BKG for the combined solution. However this could well be a coincidence, since the time series of other stations of the network do not show any break at that particular epoch.

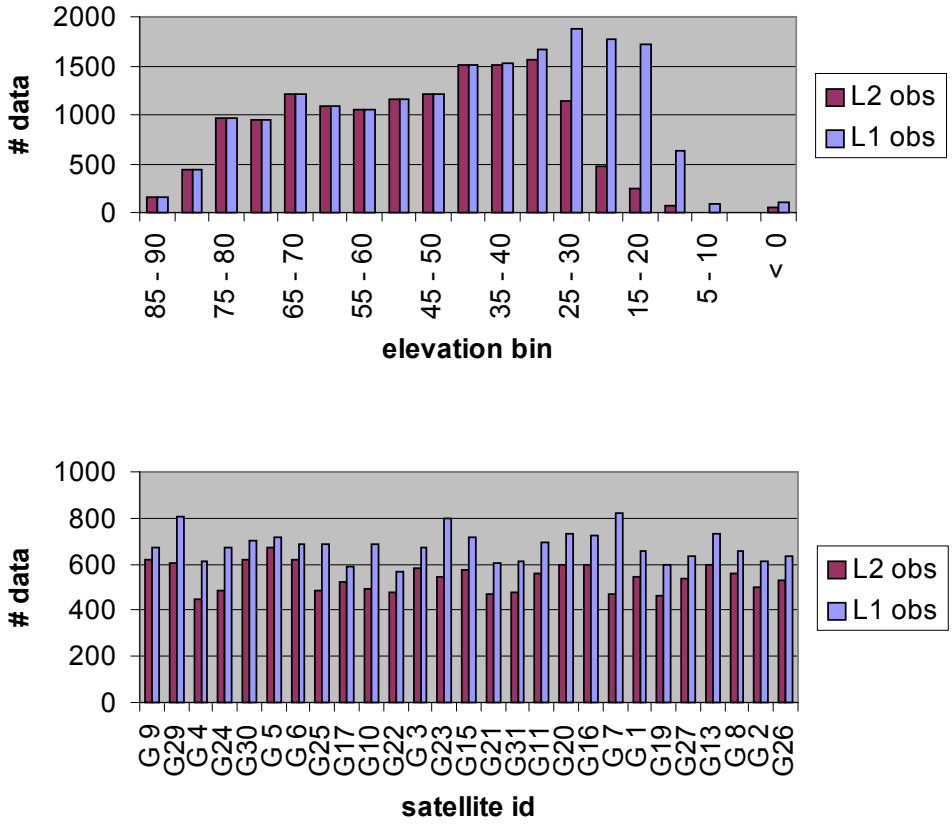

Figure 4: distribution of L1/L2 data per satellite and elevation bin for station VENE, doy 198.

We finally remark that:

- The ring change on the antenna, which is reported on week 972, does not seem to have affected the combined solution at that epoch
- The combined solution of the nearby (35 km) station UPAD for the up component shows a smoother pattern than for VENE. The pattern consists of a secular part with a slow, negative slope, superimposed to an oscillatory part with annual period. Altogether the range is +/- 10 mm.

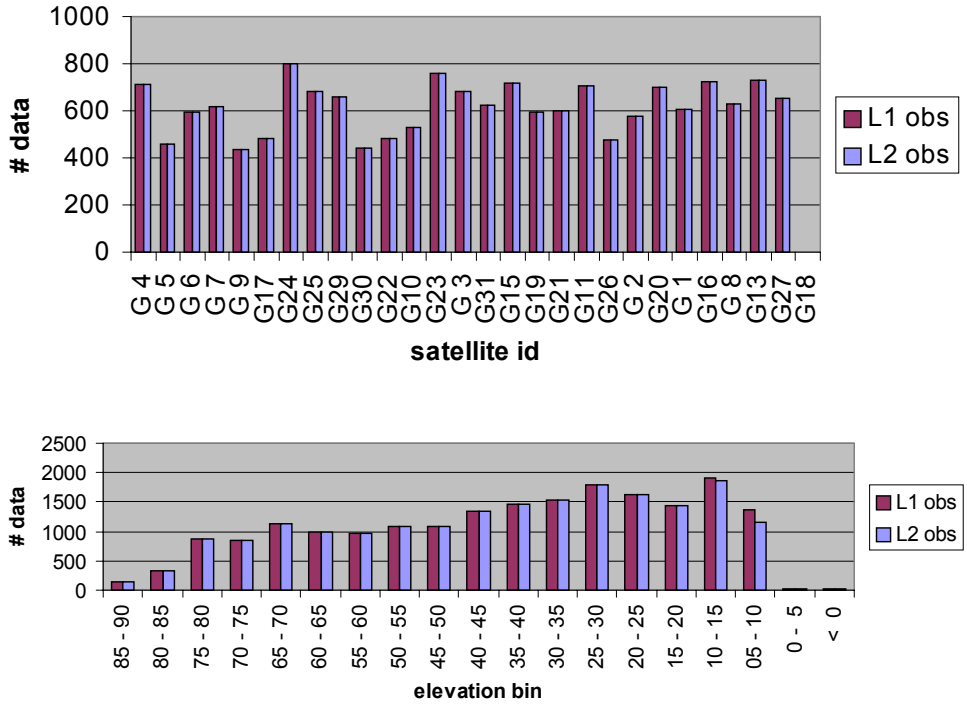

Figure 5: distribution of L1/L2 data per satellite and elevation bin for station UPAD, doy 198.

This lack of spatial coherence between the "up" time series of VENE and UPAD supports the hypothesis that the discontinuities, and more generally the non-random noise in the height time series of VENE are local, i.e. not related to regional phenomena or to analysis procedures.

Weekly solutions for VENE of individual LAC's

Venice data are processed by the following four LAC's:

1. ASI, Agenzia Spaziale Italiana, Matera (Italy); SW: Microcosm 9800.
2. BEK, Bayerische Erd Kommission, Munich (Germany); SW: Bernese 4.x
3. OLG, Observatory Lustbuehl Graz, Graz (Austria); SW: Bernese 4.x
4. UPA, University of Padova, Padova (Italy); SW: Bernese 4.x

The setup for the analysis of daily data sets are:

- ASI: elevation cutoff at 15°, sampling at 120 sec; editing criterion: 3*rms criterion, where rms is the rms of the previous iteration. Basic observable: L1 and L2 in iono free combination. Ambiguities are estimated as real valued numbers.
- BEK: elevation cutoff at 15°, sampling at 180 sec; editing criterion: 0.02 m fixed; a priori sigma for abs/rel tropo parameters: 5m/0.10 m. Basic observable: L1 and L2 in iono free combination; Ambiguities: estimated as integer with the QIF technique, then back-substitued. Since week 1041 Ocean and Solid Earth Tides are applied. SD files defined by the OBS-MAX criterion.
- OLG: elevation cutoff at 15°, sampling at 180 sec, editing criterion unknown; a priori sigma for abs/rel tropo parameters: 5m/0.10 m. Ambiguities: in a first step, L5 integer ambiguities are determined with fixed coordinates and using a model ionosphere; in a second step L1 and L2

integer ambiguities are determined using L3 and L5 ambiguities; SD files formed on fixed baselines: in particular VENE is paired to SBGZ

- UPA: elevation cutoff at 15°; sampling at 240 sec; a priori sigma for abs/rel tropo parameters: 5m/5m. Outlier detection: 3sigma; Ambiguities: QIF method in baseline mode, then backsubstitute. SD files formed with OBS-MAX criterion.

Weekly solutions are constructed out of daily solutions as follows:

- ASI: uses a module of GIPSY to stack daily neq's and produce a weekly SNX file
- BEK, OLG, UPA: use ADDNEQ with minimal and removable constraints on the coordinates.

To understand the peculiarities of the individual weekly solutions of the various LAC's, we have formed the plots in Figure 7 on the basis of the report issued weekly by the BKG . The time series span approximately one year of data. We note that:

- The horizontal solution of ASI shows a random scatter considerably higher than the other three solutions.
- The vertical solutions exhibit a positive bias (ASI,OLG) which very nearly compensate the negative bias (OLG, UPA). Thus we are in presence of non negligible systematic errors.

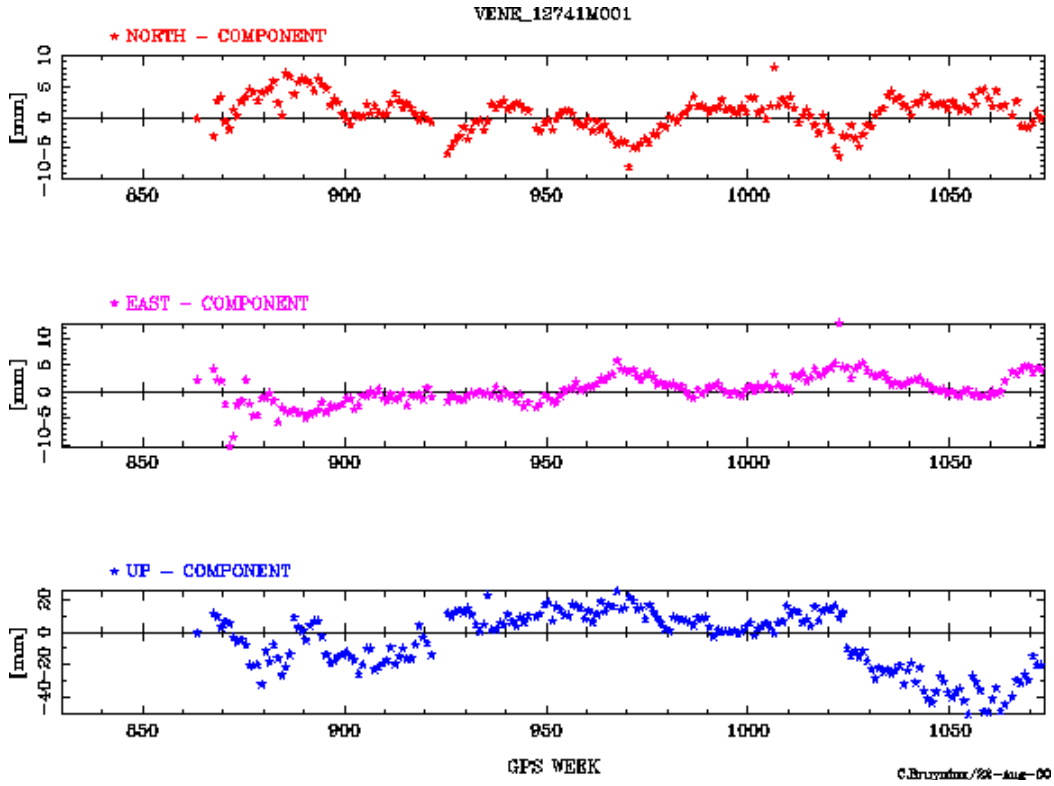

Figure 6: time series of the coordinate residuals of the combined solution for VENE, available at the EUREF CB.

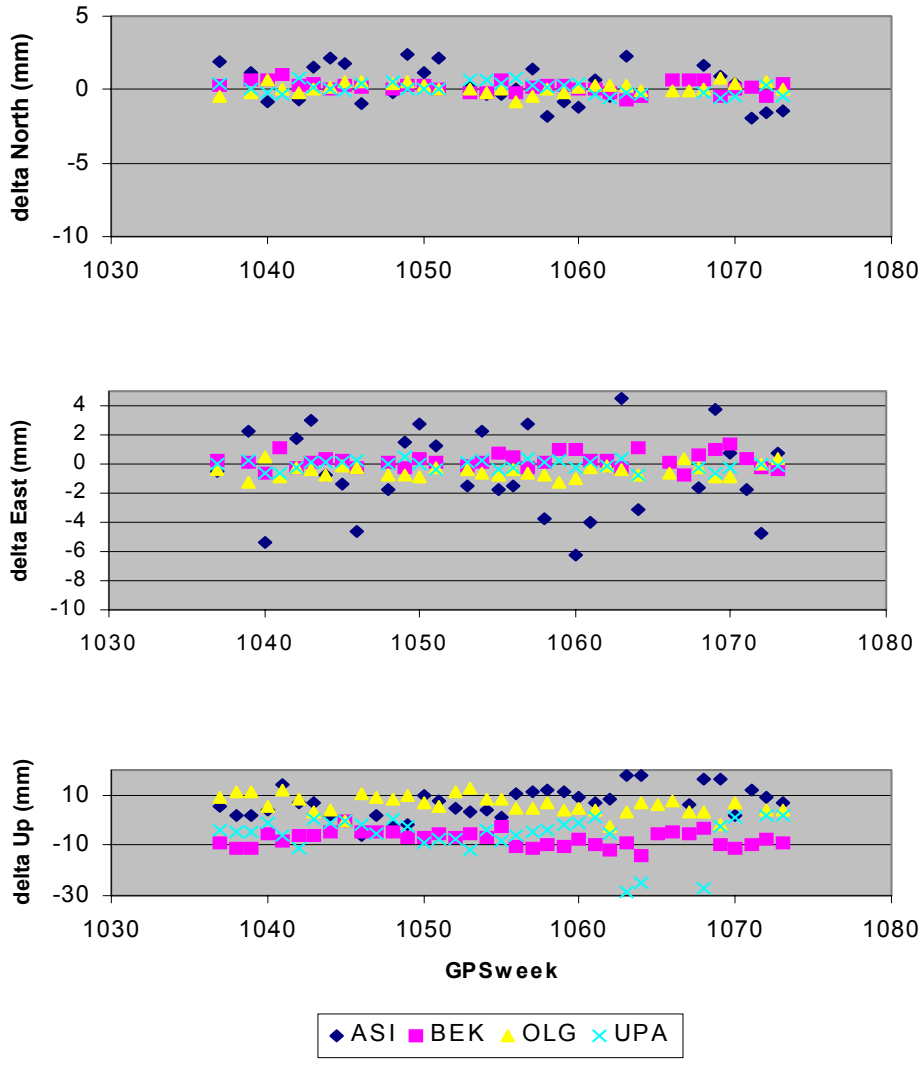

Figure 7: weekly residuals for VENE relative to combined solution, for the individual LACs.

Daily solutions of VENE of individual LACs

Daily estimates of the height of VENE by the various LAC's have been constructed on the basis of printouts of the network run of GPSEST, that is the run where the ambiguities, however computed, are kept fixed to integers. The work could be completed for the BEK, OLG and UPA solutions, due to the homogeneous format.
An important issue here is the minimum elevation angle. By inspection of the printouts supplied by the LAC's it turns out that, for a given day, different LAC's report different minimum angles. For a given LAC, the minimum elevation angle varies from day to day. This variation ranges from 15 to over 20 degrees and produces systematic changes in elevation.

The correlation between minimum elevation and height residuals is described in Figure 8. In general, the higher the minimum angle, the lower the height, roughly –1 cm/degree. This is true for all the sites, thus regardless of the baseline pair. In Figure 9 we further note that UPA tends to have a higher minimum elevation angle than BEK and OLG. This could well be caused by the higher sampling time, which is equivalent to a change in cutoff.

Furthermore, there exist LAC's which process the same baseline on the same day, but report different minimum elevation angles. This could be due to different edit criteria.

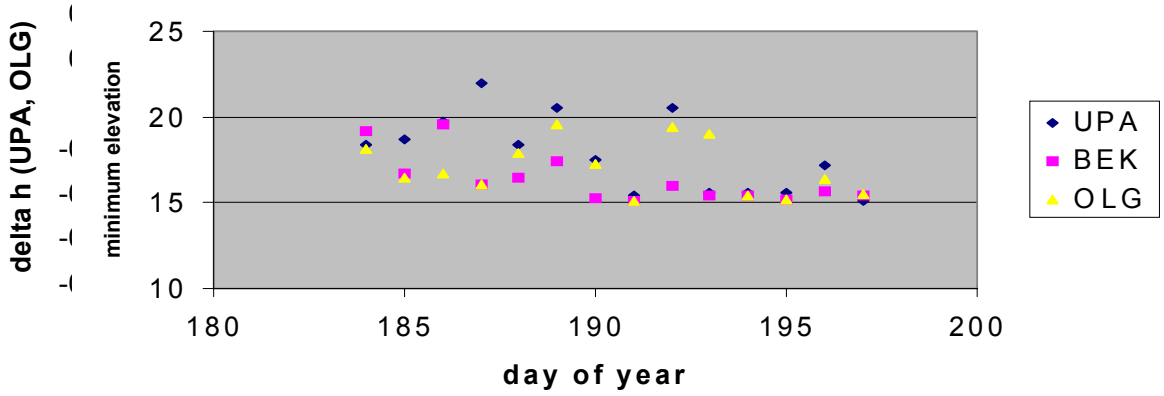

Figure 9: minimum elevation angle of individual daily solutions.

Conclusions and Recommendations

In conclusion, we report :

- A considerable noise in the L2 data produced in VENE, resulting in unpaired L1 and L2 phase data, beginning from moderate elevations (30°-35°). We attribute this to a noisy environment and, presumably, to a mechanical modification of the choke ring antenna resulting in a unknown PCV.
- In the daily solutions, a considerable unevenness in minimum elevation angle among the various LAC's, within a day and from day to day. We attribute this unevenness to a combination of (at least) two independent causes: different editing criteria, and different sampling rate.
- Considerable random noise in the daily solutions of ASI. We tentatively attribute this to the lack of the attempt to constrain ambiguities to integers. Noise in the horizontals could well map into noise in the vertical.

If the above interpretation is correct, then we expect that the daily solutions of VENE, and consequently the EUREF combined weekly solution, could be improved following this strategy:

1. Replace the antenna/receiver equipment in VENE with one more resistant to RF interference and multipath;
2. ASI: adopt ambiguity fixing strategy (e.g. like OLG, if QIF is not implemented in MicroCosm)
3. All: use same editing criteria
4. All: use same sampling rate.