June 17th 2008, A. Pany

On the impact of turbulence parameters and the scatter in 3D rms error caused by multiplication with random numbers in generation of fake delay observables

To assess the impact of the parameters driving the turbulence (i.e. refractive index structure constant C_n, effective height of wet troposphere H and wind velocity v) on rms of 3D position error, simulation studies using many different values for these parameters were carried out. WZ was chosen as a reference station, i.e. az, el, and time epochs of observations of this station were used for the simulation of fake delay observables. The investigations were carried out for two uniform sky schedules, namely the st16uni_30_6_230 and the st16uni_60_12_230. For each combination of values of C_n, H and v, 250 24-h time series were generated.

Specifications:

schedules: st16uni_30_6_230_X_0_0 (reference station: WZ)
st16uni_60_12_230_X_0_0 (reference station: WZ)

software: PPP KF

zwd: Vienna turbulence
clk: random walk + integated random walk, ASD 1e-14 @ 50 min
wn: 4/sqrt(2) ps per station

variance rates: zwd – random walk, 0.7 ps²/s
grd – random walk, 0.5 ps²/s
clk – deterministic rate + random walk offset, 1 ps²/s

C_n: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 e-7 $m^{1/3}$
H: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000 m
v: 7, 15 m/s in North-East direction

For the results presented here, the PPP was performed with the base solution, i.e. random walk gradients without elevation dependent weighting.

Figure 1 shows rms of 3D position error versus H for all different C_n values and a wind speed of 7 m/s.

Figure 2 shows rms of 3D position error versus C_n for all different H values and a wind speed of 7 m/s. The curves exhibit an almost linear dependence on C_n (at least for large C_n). The slope of the lines is determined by H (and the wind speed as can be seen from Figure 3).

Figure 3 compares rms of 3D position error for wind speeds of 7 (solid lines) and 15 (dotted lines) m/s for three different C_n values. It can be deduced from this plot that the slope and the curvature of the curves is decreasing with increasing wind speed.

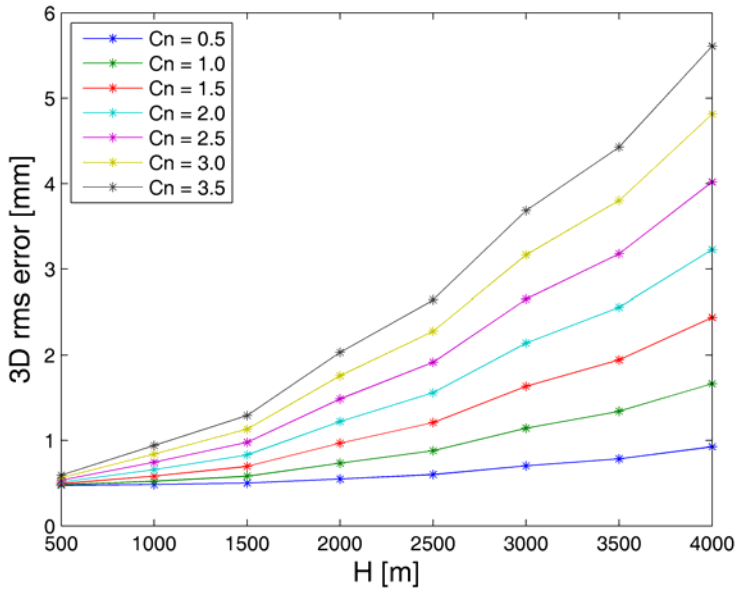

Figure 1: rms of 3D position error versus effective height H of wet troposphere for different values of refractive index structure constant C_n and a wind speed of 7 m/s towards North-East.

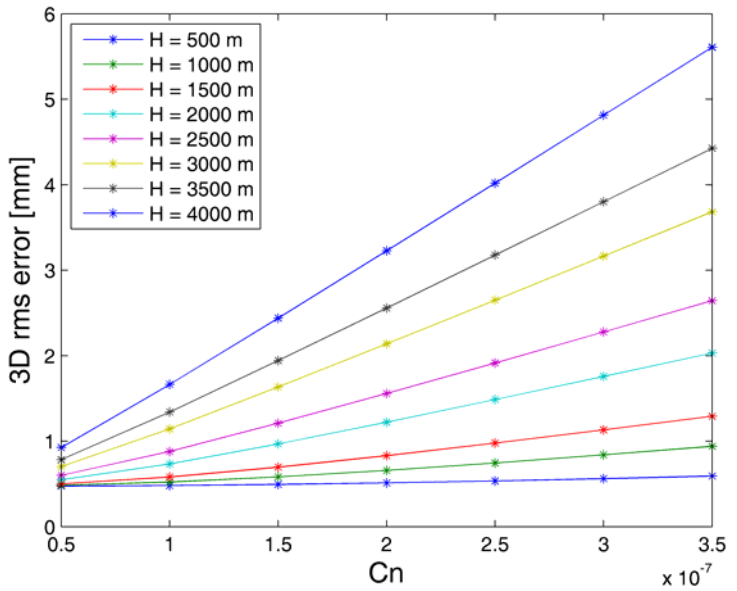

Figure 2: rms of 3D position error versus refractive index structure constant C_n for different effective heights H of wet troposphere and a wind speed of 7 m/s towards North-East.

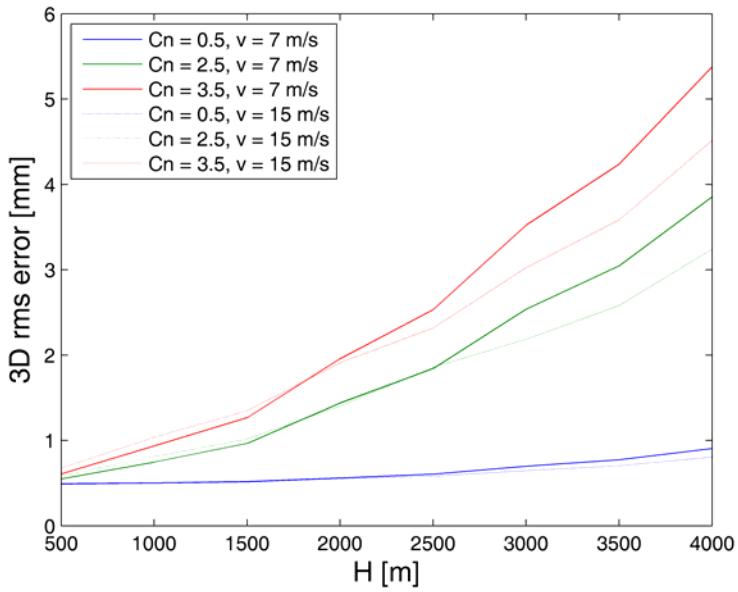

Figure 3: rms of 3D position error versus effective height H of wet troposphere for different values of refractive index structure constant C_n and wind speeds of 7 (solid lines) and 15 (dotted lines) m/s towards North-East.

For these simulations, the same 250 sets of random numbers were used for the generation of fake delay observables for all combinations of C_n and H values. Figure 4 shows scatter plots of 3D position error for two different combinations of C_n and H with a wind speed 7 m/s. The upper plots are for schedule st16uni_30_6, the lower plots show results for schedule st16uni_60_12. The plots on the left (C_n = 0.5e-7 $m^{1/3}$, H = 500 m) are comparable to the least turbulent station in our 16 station test networks (NY, C_n = 0.35e-7 $m^{1/3}$, H = 2173 m). The plots on the right (C_n = 3.0e-7 $m^{1/3}$, H = 2000 m) are comparable to the most turbulent station in the VLBI2010 16 station test networks (BN, C_n = 3.09e-7 $m^{1/3}$, H = 1788 m). It can be clearly seen that there is more scatter for more turbulent stations and more scatter for the schedule with a switching rate of 60 s.

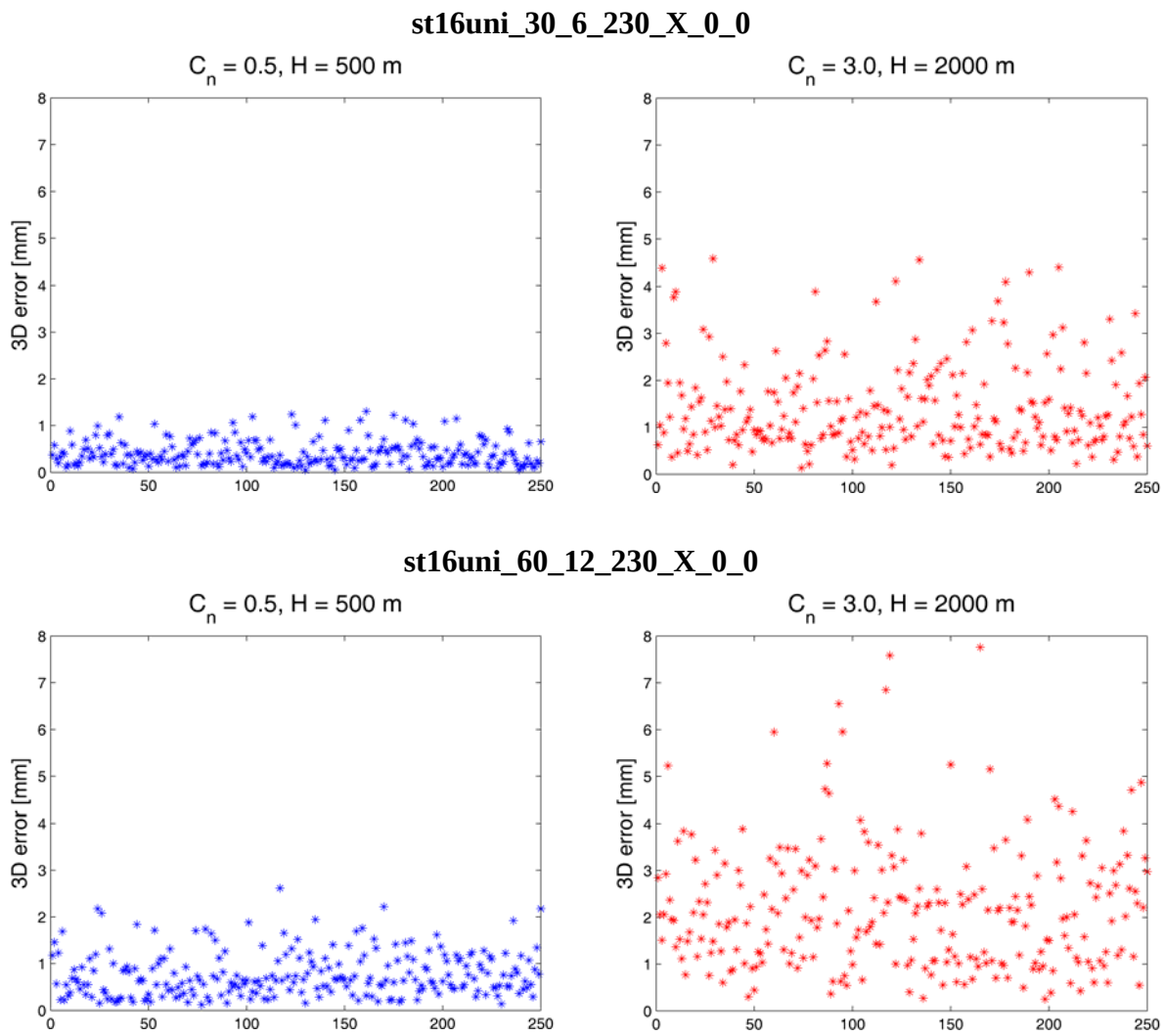

Figure 4: scatter plots of 3D position error for 250 days for two combinations of C_n and H values (wind speed 7 m/s). The upper plots show results of simulations for schedule st16uni_30_6_230, the lower plots for schedule st16uni_60_12_230. The plots on the left are comparable to the least turbulent station in the 16 station test networks, the plots on the right to the most turbulent station.

As can be seen, the scatter is more or less large - depending on the turbulence paramters and the number of observations. In order to assess which scatter is to be expected for the VLBI2010 PPP simulations which use only 25 repetitions, the 250 24-h time series were divided into 10 groups of 25 time series each and for each of the 10 groups a 3D rms error was computed. Results are shown in Figure 5 for the same combinations as are shown in Figure 4.

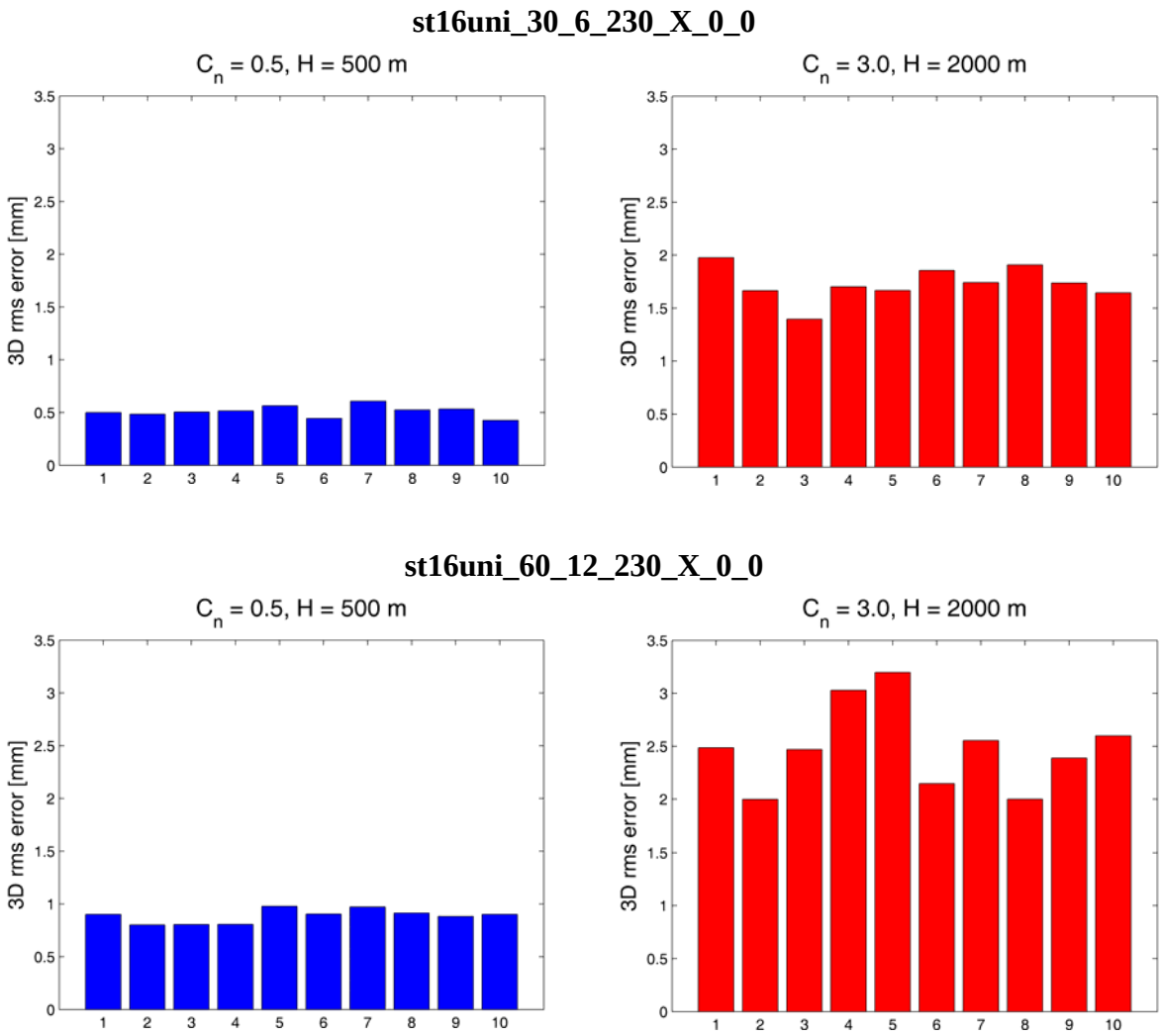

Figure 5: The 250 time series were divided into 10 groups of 25. For each group, a 3D rms error was computed. The upper plots show results for schedule st16uni_30_6_230, the lower plots for st16uni_60_12_230. The plots on the left are comparable to the least turbulent station in the 16 station test networks, the plots on the right to the most turbulent station.

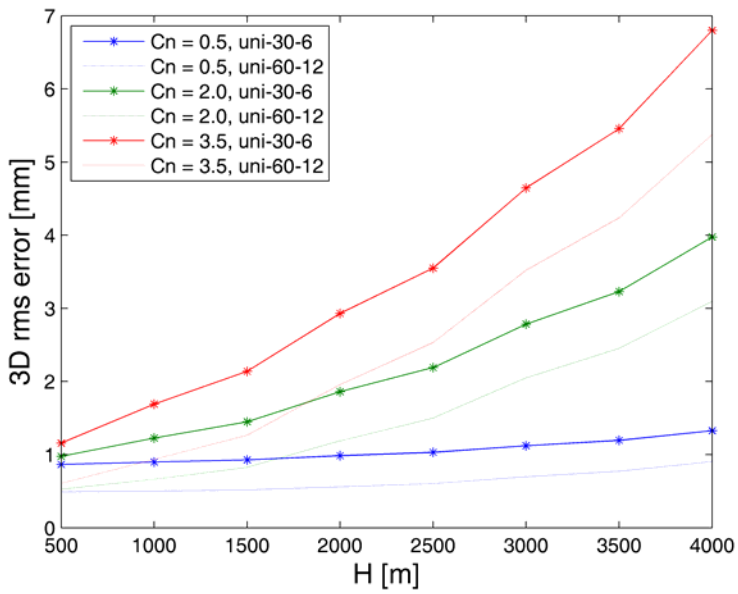

Figure 6: rms of 3D position error versus effective height *H* of wet troposphere for three different values of refractive index structure constant C_n and a wind speed of 7 m/s towards North-East. Solid lines show results for schedule st16uni_30_6_230, dotted lines for schedules st16uni_60_12_230.

It can be seen from Figures 4 and 5 that not only the turbulence parameters but also the observation density has a significant impact on rms of 3d position error. Figure 6 shows 3D rms error versus effective height H for C_n values of 0.5e-7, 2.0e-7 and 3.5e-7 $m^{1/3}$ for a wind speed of 7 m/s for both schedules. It can be deduced from this plot that the observation density mainly causes the curves to shift.

In conclusion it can be stated:

- The refractive index structure constant C_n and the effective height of wet troposphere H have the most significant impact on 3D rms error.
- The dependence of 3D rms error on C_n is almost linear for larger C_n values.
- Beside the turbulence parameters, the observation density also influences the scatter of 3D rms errors.
- C_n, H and wind speed v determine the slope (and the curvature) of the lines in Figures 1-3, the observation density causes shifts (Figure 6).
- 3D rms values computed from only 25 repetitions exhibit scatter which is more or less significant (depending on the turbulence parameters and on observation density). Comparisons between schedules that are carried out with PPP have thus to be interpreted with care.

- Another effect that has not been taken into account in the scope of this investigation is that also the analysis strategy (especially the choice of the variance rates for zenith wet delay and gradients) is likely to have an impact on the results.
- The conclusions drawn here are only valid for PPP and might not hold for OCCAM or Calc/Solve simulations.