Combined lab report for L3 and L4

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1 Assignment 3 – Models for correction of atmospheric effects

1.1 Troposferic delay

We started the laboratory task by determining the tropospheric delays(Δ^{Trop}). To do this, we used the Saastamoinen model. This model provides us the required tropospheric delay.

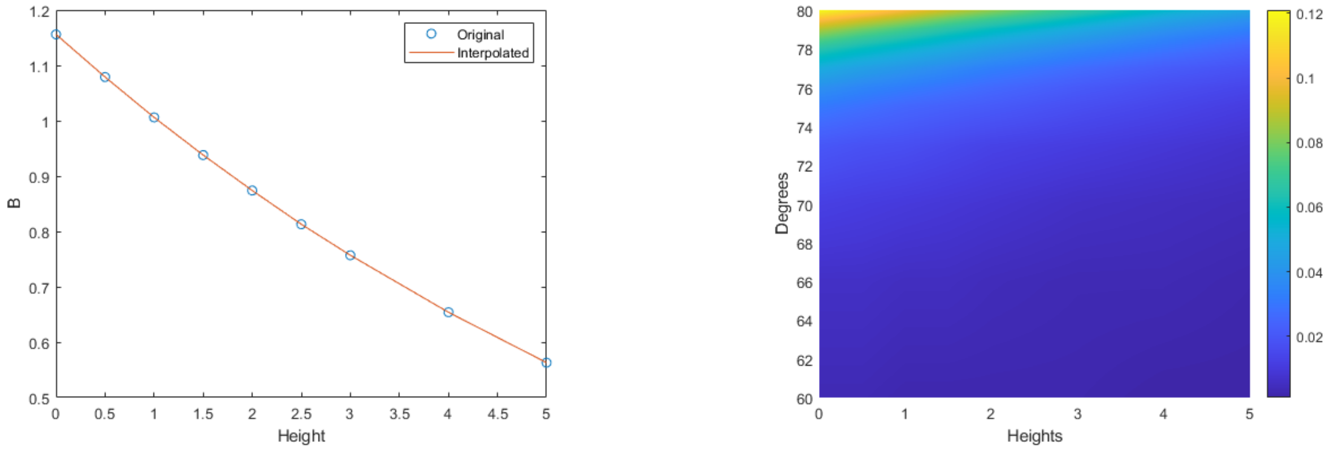
$$\Delta^{Trop} = \frac{0.002277}{\cos z}\left[p + \left(\frac{1255}{T} + 0.05\right)e - \tan^2 z\right] \tag{1}$$

as a function of z, p, T and e. Where z denotes the zenith angle of the satellite, p the atmospheric pressure in millibar, T the temperature in kelvin, and e the partial pressure of water vapor in millibar what can be calculated from $e = 6.108 \cdot RH \cdot \exp\left(\frac{17.15T-4684}{T-38.45}\right)$.

However we can further refine this model by using two correction factors, as shown on the following equation.

$$\Delta^{Trop} = \frac{0.002277}{\cos z}\left[p + \left(\frac{1255}{T} + 0.05\right)e - B\tan^2 z\right] + \delta R \tag{2}$$

where B (only height dependant) and δR (height and zenith angle dependant) both interpolated from a table provided us from the used book. The results for the interpolations are visible on figure 1.



(a) Interpolated B values

(b) Interpolated δR

Figure 1: The correction parameters after interpolation

Testing of utilised model

The book provided us a test-case for the model, what we can use to check if our model works correctly. The provided parameters are $p = 1013.25$ millibar, $T = 273.16$ kelvin, and $e = 0$ millibar and this should results in a tropospheric zenith delay of about 2.3 m. After running the Matlab script, we got the same value.

Next up we investigated the change in Zenith Tropospheric Delay (ZTD) caused by the changing temperature and relative humidity. The investigated temperature range was between $\pm 30°C$,the humidity between 0% and 100%. Our results are visible on figure 2.

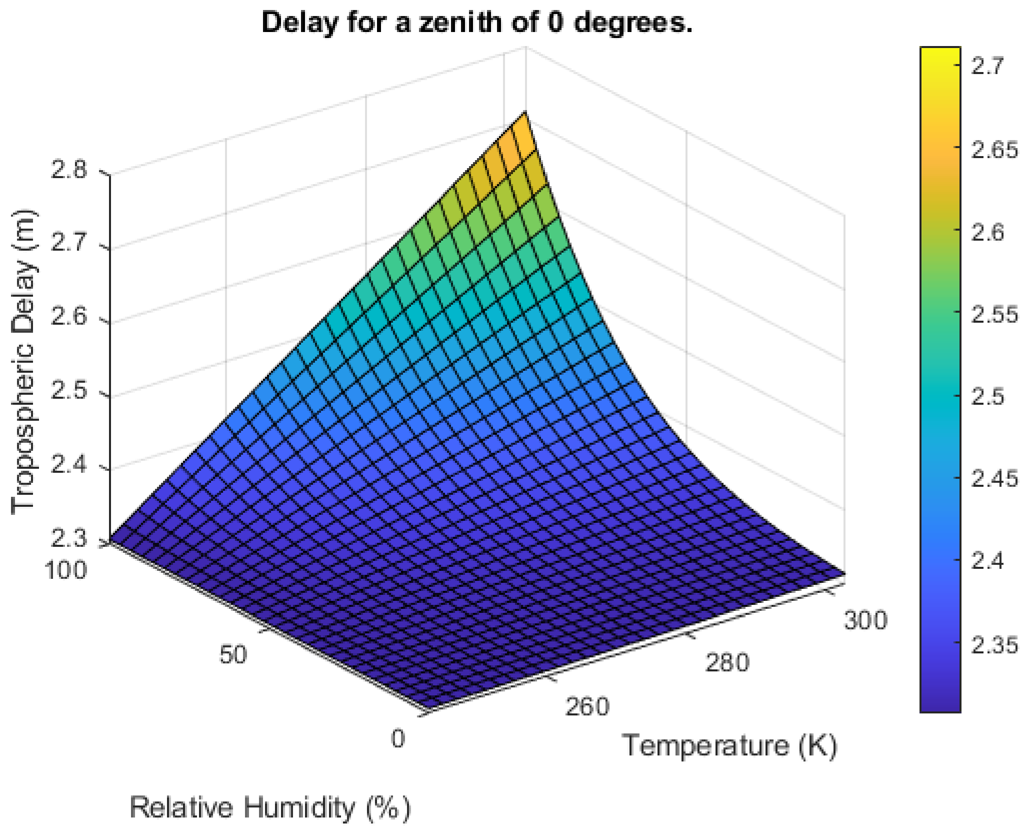


Figure 2: ZTD, function of temperature and humidity

The resulting figure shows the change in tropospheric delay as a function of temperature and relative humidity. Further effects of weather are discussed in subsection 1.4.

1.2 Ionospheric delay

We continued with the calculation for the ionosperic delay (d_g)

$$d_g = \frac{40.3}{f^2} TEC \times OF_\zeta \tag{3}$$

$$OF_\zeta = \left[1 - \left(\frac{R_E \sin\zeta}{R_E + h_I} \right)^2 \right]^{-\frac{1}{2}} \tag{4}$$

where f is the carrier frequency and OF can be calculated as in the equation above in which h_I is the mean ionospheric height, 350 000 m, R_E is Earth mean radius, 6 371 000 m, and ζ is the zenith angle.

TEC was received from International Reference Ionosphere(IRI) using the proper values.

1.3 Results

After implementing the functions for the delays. We calculated the delays in meter for each visible satellite. Our results are shown in table 1 below.

PRN	Elevation	d_trop (m)	d_ion (m)
24	9.038288	13.717186	2.447673
13	28.535584	4.880571	1.554456
8	65.059664	2.578564	0.938836
21	10.248383	12.590363	2.387883
29	27.640849	5.024890	1.584887
26	10.442263	12.389184	2.378069
10	58.988247	2.727461	0.986185
17	25.400914	5.431975	1.666164
2	14.900386	8.989861	2.145725
28	10.421440	12.408705	2.379125
3	12.598842	10.514911	2.266310
27	64.723361	2.585638	0.941109

Table 1: The calculated delays for the visible satellites

The results obtained are as expected. First of all, we can see that a lower elevation angle is associated with a higher delay in both cases.

1.4 Weather effects on troposferic error

Weather variations in the form of temperature, humidity, pressure, and precipitation can all have an impact on the troposphere's refractive index and, consequently, the degree of tropospheric error. For instance, as temperature rises, the troposphere's air density falls, forcing the GPS signals to move more quickly and resulting in a shorter signal route length. The GPS measurement becomes positively biased as a result of this effect.

Similar to this, high humidity levels can raise the amount of water vapor in the air, slowing down GPS signals. Due to the lengthening of the signal route as a result, the GPS measurement is biased negatively. The troposphere's refractive index can be impacted by variations in pressure and precipitation, which can modify the amount of the tropospheric error.

2 Assignment 4 – Models for correction of atmospheric effects

First of all, the approximate receiver position is in the RINEX observation file, which is X=310429.453m, Y=998383.982m, Z=5463290.508m. Then we calculate include the satellite clock errors (in assignment 2), and atmospheric-related delays are calculated (in assignment 3), we can use them to update our pseudo range calculation. Then we use the Least Squares adjustment (LSQ) to do the correction on observation. It is required to have redundant observations to do the LSQ correction. Since we have 12 visible satellites, we can use the LSQ method.

Xr	Yr	Zr	sX(m)	sY(m)	sZ(m)	clock error (s)	PDOP
3.104218e+06	998382.983312	5463291.076406	0.925004	0.729550	1.502340	5.1987140270e-04	1.261715

Table 2: The calculated position for the receiver

PRN	L	X	Y	Z	P1	Sat_clk_err
24	155852.386167	23421962.768253	-12587454.896122	999742.383390	25001256.679430	1.1048527150e-06
13	155853.383137	7552200.217497	22602205.127100	11771799.884814	23106630.269430	-3.1371136900e-05
8	155854.553847	19782985.994349	3245004.088496	17378780.211023	20664230.285440	3.7422564250e-04
21	155855.587847	-11894220.659913	-10766056.106128	21172793.129070	24835459.142430	7.1724874450e-05
29	155852.342390	11084174.963659	-17544452.684560	16816661.064318	23250719.148430	2.1948794090e-04
26	155854.538111	8280837.764110	-21834331.763553	11796587.646937	24278147.404430	4.3836492140e-04
10	155854.617018	16224653.041200	-6015356.853298	20186062.202443	21075046.643440	3.8757988290e-05
17	155851.663687	16522611.971790	-16233816.069106	12453389.868238	23040156.096430	1.5821624890e-04
2	155853.268161	-13921125.846576	10520857.515700	20752900.007543	25021425.825430	-2.6770091050e-04
28	155855.018802	23778312.686953	11792190.075152	-2950541.181966	24944089.654430	1.7561425910e-05
3	155852.251786	-12326721.423382	15206582.112152	17758735.430672	24444981.725430	8.2553296640e-05
27	155852.696986	9544631.970904	12516502.645353	21878718.757285	20946850.748440	9.0430446640e-04

Table 3: The visible satellite information

2.1 Discussion

Our satellite clock errors didn't have enough of the presented digit at first, which will resulting significant errors in pseudo-range calculation. In the observation equation, there is a term related to satellite clock error, which is $c * \delta^s_{L1}$. Since it needs to multiply the speed of light, if the number of digits is not enough then it will lead to an error in the scale of 10^1 meters.

PDOP is a measurement of how the satellite is distributed in the sky, it is better when it has better value. Our results indicate that we have a good PDOP value which is between 1 and 2.

There are some possibilities that we have slightly different results than the provided SPPResult file. When trying to compare the provided result file with our calculated result, the only difference is the value of L matrix, which is related to our pseudo-range equation construction. Therefore, there might be a possibility that we are using different models or methods to calculate the Tropospheric delay and the Ionospheric delay. But since we have a smaller deviations, we will have better results.