GNSS meteorology

The concept of GNSS Meteorology was suggested by Bevis (*Bevis et al.*, 1992). As the GNSS signal travels trough the atmosphere its propagation is affected by atmospheric gases and in particular water vapour. The magnitude of the atmospheric effects depends on the elevation angle of the satellite and on the current atmospheric situation. There are three major effects, caused by the atmosphere: ionospheric group delay; group wet and dry delay, caused by the troposphere and the stratosphere and the signal attenuation in the troposphere and the stratosphere (*Parkinson et al.*, 2005).

The ionosphere is the highest part of the atmosphere, between 100 and 500 km from the Earth's surface, and consists mainly of ionized gases. The ionosphere has a highly noticeable daily fluctuation, because it is very sensible to sun and space radiation. The refraction index of the atmosphere depends on the wavelength of the signal, but it can be accurately calculated by using the main two frequencies (L1 and L2) of every GNSS.

The troposphere, the bottom 12 km of the atmosphere, can be described as a combination of dry air and water vapour. Nitrogen, oxygen, argon and carbon dioxide are the gases, which create the troposphere. From them, mainly oxygen refract the GNSS signals. The signal refraction in the troposphere is the main error source in GNSS. The total tropospheric delay of GNSS signal in direction zenith is called Zenith Total Delay (ZTD). ZTD is a result of two major delay factors- the wet and hydrostatic delays.

The Zenith Hydrostatic Delay (ZHD) is the largest of the two and is caused primarily by oxygen and nitrogen. ZHD causes about 2.1 meters of uncertainty in positioning at sea level and varies with temperature and pressure in a predictable manner. The ZHD is calculated, using this formula:

$$ZHD = (2.2768 + 0.0024)\frac{p_s}{f(h,\theta)} \tag{1}$$

$$f(h,\theta) = 1 - 0.00266cos(2\theta) - 0.00028h \tag{2}$$

where p_s is local surface pressure and $f(h,\theta)$ is a factor, dependent on height h and the latitude variation of the gravitational acceleration θ.

The second delay is caused by the water vapour and is called Zenith

Wet Delay (ZWD). ZWD is much smaller, than the ZHD and adds from 1 up to 80 cm to the uncertainty in positioning. Unlike the ZHD it has a large variation in a short time, due to its dependence of temperature, soil moisture and local conditions, which makes it highly unpredictable. The ZWD is defined by:

$$ZWD = ZTD - ZHD. \tag{3}$$

The Integrated Water Vapour (IWV) can be extracted from this formula:

$$IWV = \frac{10^6}{(k_3/T_m + k_2')R_v}ZWD \tag{4}$$

where k_2, k_3 and R_v are constant and T_m is the weighted mean atmospheric temperature.

References

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