HYDROSTATIC UNBAB MAPPING FUNCTION MODITIFICATION FOR TROPOSPHERIC DELAY

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ABSTRACT – There are many mapping function models in the form of continued fractions which need many operations in calculation. The mapping function need to be modified to allow faster calculation. UNBab mapping function needs 7 mathematical operations for getting the mapping function value. The UNBab mapping function is chosen to be modified due to its ability to calculate mapping function value down to 2 degree of elevation angle. Regression method can be used to modified the mapping function model and also can produce the same result. The calculation of sum of errors shows that the deviation of the modified models from the original models is not significant.

1. Introduction

Marini (1972), the founder of mapping function in term of continued fraction, states that the elevation angle ε dependence of any horizontally stratified atmosphere can be approximated by expanding in a continued fraction in term of $1/\sin\varepsilon$ [3]. The mapping function values is used for getting the total tropospheric delay due to its function as the coefficient of zenith hydrostatic delay and also zenith non hydrostatic delay as given in equation (1) below [4]:

$$TD = ZHDm_h(\varepsilon) + ZWDm_w(\varepsilon) \qquad (1)$$

where:

ZHD - zenith hydrostatic delay (m)

ZWD - zenith wet delay (m)

$m_h(\epsilon)$ - hydrostatic mapping function

$m_{nh}(\epsilon)$ - non-hydrostatic mapping function

2. Process of UNBab Mapping Function Modification

Guo (2003) from the University of New Brunswick has established the $UNBab(E)$ mapping function model. This model has 7 operations in a form of continued fraction. The hydrostatic component of $UNBab(E)$ is written as [1]:

$$UNBab_h(E) = \frac{1 + \dfrac{a_h}{1 + b_h}}{\sin E + \dfrac{a_h}{\sin E + b_h}} \qquad (2)$$

where, E: elevation angle

The parameters a_h and b_h for the hydrostatic function are:

$a_h = (1.53804 - 0.039491H + 0.17020\cos\phi)/1000.$

$b_h = (50.0724 - 0.814759H + 2.35232\cos\phi)/1000.$

where $H = 0.1\text{km}$ and ϕ is 45 degrees.

The mapping function for the original $UNBab_h(E)$, named as P shown in Figure 1.

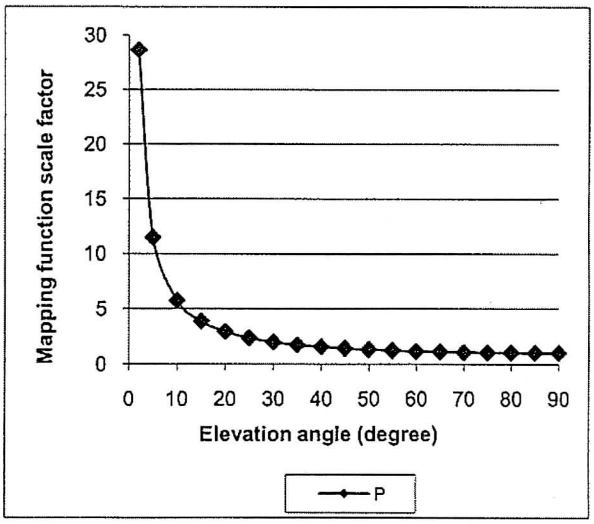

Figure 1: Graph of mapping functions for P

The mapping function give a shape of hyperbola and equation (2) can be modified as:

$$P1(E) = AE^{B} \qquad (3)$$

where,

$P1(E)$:simplified $UNBab_h(E)$

A, B : constant

E : elevation angle (degree).

In logarithm scale, equation (3) can be written as:

$$\log_{10} P1 = B \log_{10} E + \log_{10} A \quad (4)$$

By linear regression method, equation (4) becomes:

$$\log_{10} P1 = -0.8924 \log_{10} E + 1.6604 \quad (5)$$

where, B = -0.8924 and $\log_{10} A$ = 1.6604 which gives A = 45.751.

Therefore, equation (5) becomes:

$$P1(E) = 45.751 E^{-0.8924}. \quad (6)$$

By regression method, polynomial equation, log P2 can be generated from the original model (log P) in a form of quadratic equation as given below:

$$\log_{10} P2 = 0.1575(\log_{10} E)^2 - 1.2761(\log_{10} E) + 1.8509 \quad (7)$$

The graphs of P, P1 and P2 can be shown in Figure 2.

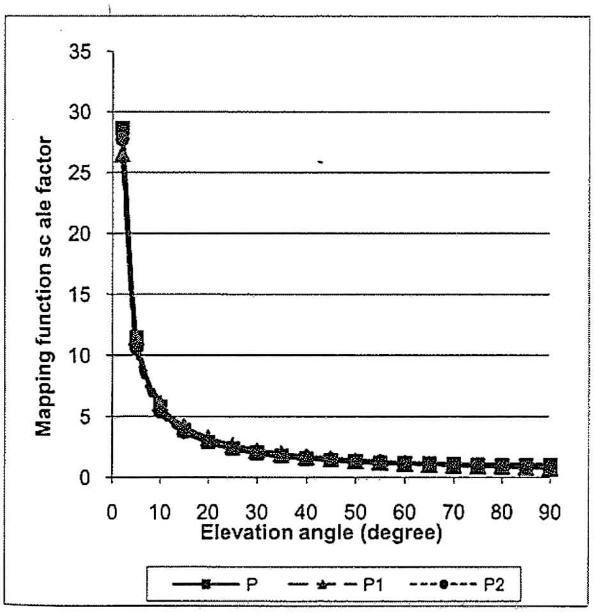

Figure 2: Graphs of P, P1 and P2 for $UNBab_h(E)$ mapping function

3. Calculation of Sum of Error For $UNBab_h(E)$

Sum of error (SOE) method can be used to show how the modified models deviate from the original model. Smaller deviation is better, which shows that the modified model is closer to the original model.

Table 1: Sum of error between $UNBab_h(E)$, P and modified models P1 & P2

E	P	P1	ABS (P-P1)
2	28.628	24.646	3.982
5	11.470	10.880	0.590
10	5.758	5.861	0.103
15	3.863	4.082	0.218
20	2.924	3.157	0.234
25	2.366	2.587	0.221
30	2.000	2.199	0.199
35	1.743	1.916	0.173
40	1.556	1.701	0.145
45	1.414	1.531	0.117
50	1.305	1.394	0.088
55	1.221	1.280	0.059
60	1.155	1.185	0.030
65	1.103	1.103	0.000
70	1.064	1.032	0.032
75	1.035	0.971	0.065
80	1.015	0.916	0.099
85	1.004	0.868	0.136
90	1.000	0.825	0.175
TOTAL	71.625	68.135	**4.87%**

Table 1 shows that the percentage of the sum of error is only 4.87% which shows that the modified model is closer to the original model. Therefore, the difference of mapping function between the original model and the modified model is not significance. (less than 5% mapping function)

4. Computation Time For $UNBab_h(E)$

The computation time for calculating (100,000 cycles) the original model and also the modified model for $UNBab_h(E)$ can be shown using CodeGear C++ Builder 2007 software [2].

Table 2: Comparison for the computation time

Model	Computation time for original model (ms)	Computation time for modified model (ms)	Reduction of computation time. (times)
$UNBab_h$	281	110	2.6

Table 2 shows that the computation time between the original model and modified model shows that the modified $UNBab_h(E)$ model is 2.6 times faster than the original model.

Table 3: Reduction percentage of the number of model operations

Model	Number of operations (Original model)	Number of operations (Modified model)	Opera-tion reduction	Percen-tage of reduction
$UNBab_h$	7	2	5	71.4

From Table 3, the modified $UNBab_h(E)$ model can reduce the number of operations up to 71.4 percent compared to the original model.

5. Conclusion

The modified $UNBab_h(E)$ mapping function model can be used to replace the original model due to its simpler model, smaller sum of error values and also the shorter computation time compared to the original model.
This study has a commercial value by replacing the continued fraction algorithm into either hyperbolic or linear form for its mapping function algorithm.

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