

Variability of GPS-derived Zenith Tropospheric Delay and Some Result of Its Assimilation into Numeric Atmosphere Model

O. G. Khutorova, G. M. Teptin, V. E. Khutorov, V. V. Kalinnikov, and T. R. Kurbangaliev
Kazan Federal University, Russia

Abstract— The total zenith tropospheric delay (ZTD) is an important parameter of the atmosphere and directly or indirectly reflects the weather processes and variations. This paper presents a hardware and software complex for continuous measurements and prediction of atmospheric thermodynamics and radiowaves refraction index. The main part is a network of ground-based spatially separated GPS-GLONASS receivers, which allows the remote sensing zenith tropospheric delay. GPS-Derived Zenith Tropospheric Delay shows the day to day variation and mesoscale spatial and temporal variability. Comparison with the numerical weather reanalysis fields and solar photometer measurements showed agreement with the relative deviation of less than 10%. Hardware-software complex includes the numerical model of the atmosphere on a computational cluster. A variational assimilation system was used to examine the comparative impact of including satellite derived total zenith tropospheric delay from GPS and GLONASS ground observations. Preliminary results show that the initial field of radiowaves refraction index was improved by assimilating the satellite derived ZTD.

1. INTRODUCTION

Numerical weather prediction is an initial and boundary value problem; the more accurate initial conditions could result in the improvement of forecast skill. Over the past decades, considerable progress has been made in satellite navigation systems monitoring technology, which is significantly increasing the atmospheric information. In the ionospheric investigation the method may be considered as a global tool for radiosounding [1–3]. It is shown that a network of ground receivers GPS — a tool for studying the troposphere with high temporal resolution [3, 4]. Due to the strong spatial inhomogeneity and temporal variability of atmospheric density, especially for water vapor, accurate modeling of path delay in GPS signals is necessary in high-accuracy positioning and meteorological applications (climatology and weather forecasting).

2. RADIOWAVES ZENITH TROPOSPHERIC DELAY AND ITS MONITORING

This paper presents hardware-software complex for continuous measurements and prediction of atmospheric thermodynamics. The main part of the hardware-software complex is a network of ground-based spatially separated GPS-GLONASS receivers. The network of seven GPS-GLONASS receivers arranged to distance from 3 to 35 kilometers in Kazan city (56°N, 49°E) gives a good possibility of the atmosphere remote sensing [7, 8].

All existing theories accept the refraction index as key parameter determining features of distribution of radiowaves in the atmosphere. GPS signals are significantly influenced by the atmosphere, especially the ionosphere and troposphere, along their path from the satellite to the GPS antenna. Dependence of the refraction index of air on height above a terrestrial surface causes a curvature of the radiowaves trajectory. Fluctuations of parameters of the electromagnetic waves extending in an atmosphere are connected to various atmospheric processes. The equation for a parameter of refraction looks like [1, 3]

$$N = 77.6 \frac{P_d}{T} + 72 \frac{e}{T} + 3.75 \cdot 10^5 \frac{e}{T^2}. \quad (1)$$

Here, T is the absolute air temperature, p is the dry-air pressure, and l is the water-vapor pressure.

The resulted factor of refraction of radiowaves in plasma for high frequencies is defined as [1]:

$$N = -\gamma \cdot N_e \cdot f^{-2} \quad (2)$$

Here $\gamma = 40.4$ if electronic concentration N_e is expressed in m^{-3} , and frequency f — in Hz. An additional way of radio waves from the satellite to the antenna associated with refraction in the atmosphere [1, 5]:

$$L_i^j = I_i^j + \Delta L_i^j = 10^{-6} \int_S N(s) ds \quad (3)$$