Long-term behavior of precipitable water vapor over the last 20 years and regionality of atmospheric delay gradient

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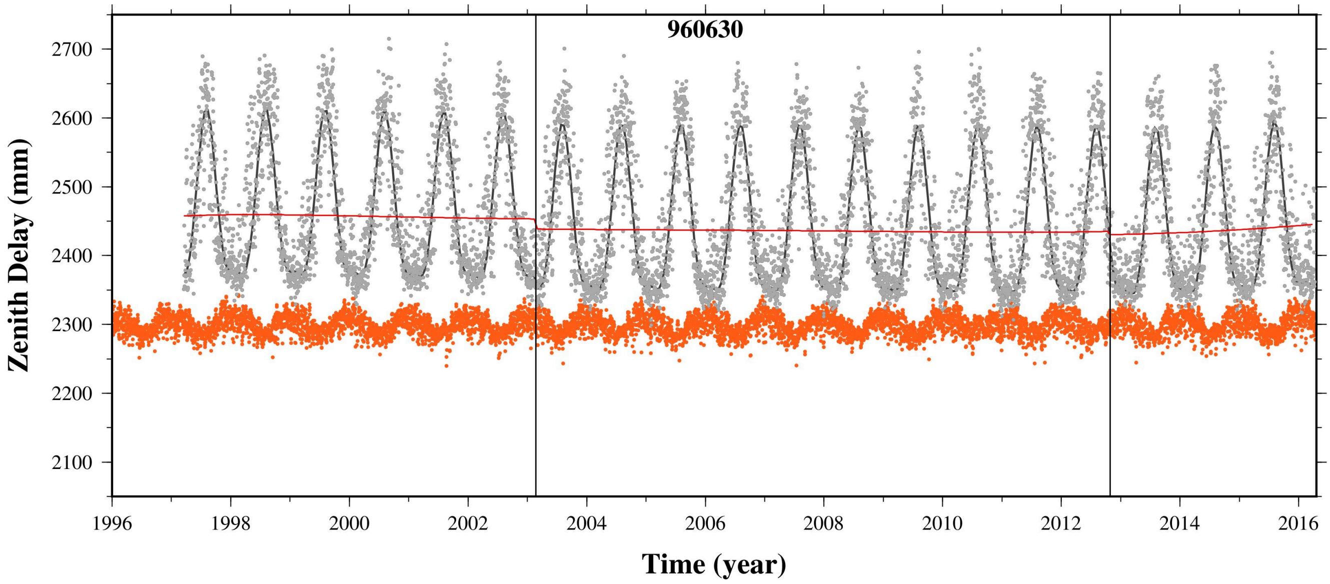
Recent increase of extreme climate events has been a focus of debate all over the world, and they believe that global warming is responsible for the increase. IPCC AR5 (Intergovernmental Panel on Climate Change Fifth Assessment Report) suggested that the average temperature on Earth increased by 0.85℃ from 1880 to 2012 and the average temperature over the last 30 years is higher than any decadal averages since 1850. There is little doubt concerning the reality of the on-going global warming.
It is an important meteorological issue to understand how the changes of atmospheric water vapor influence global warming. By observing the distribution and dynamics of atmospheric water vapor, we can understand its link to the climate change. It will also contribute to improve the accuracy of forecasting precipitation. Precise knowledge of the long-term behavior of water vapor would enable us to predict future climate changes over centuries.
Microwave signals from GNSS satellites experience delays when they propagate the neutral atmosphere. We can infer the amount of wet atmospheric delay (delay caused by water vapor) by subtracting the hydrostatic delay (delay caused by dry atmosphere) from the total delay. In this research, I estimated changes of atmospheric water vapor from 1996 to 2016 by combining the atmospheric delays from the Japanese dense GNSS array GEONET (GNSS Earth Observation NETwork) with the surface atmospheric pressure data from the Japan Meteorological Agency. I then found that the atmospheric water vapor shows complicated inter-annual variations rather than simple monotonous increase. By comparing the behaviors of the atmospheric delays at various points in Japan, I found that multiple factors, e.g. latitude and height, influence the amount of delay.
Atmospheric delay gradient is an important factor to reduce positioning errors when atmospheric delays are not in azimuthal symmetry. In the early days of positioning with GNSS, they assumed that the atmospheric delay depends only on the elevation angle. Now it became standard to model its azimuthal dependence by introducing the atmospheric delay gradient as a new parameter. Estimating the gradients all over the Japanese Islands also made it possible to assess the non-uniform distribution of water vapor not canceled by taking long-term averages. I found several general tendencies in the time-averaged atmospheric delay gradient vectors, e.g. they often show significant southward components, and they are often perpendicular to the coastline and tend from ocean to land.

Keywords: GNSS, PWV, Long term variation


960630
Zenith Delay (mm)
2700
2600
2500
2400
2300
2200
2100
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Time (year)