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Using smartphones for monitoring atmospheric tides

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ABSTRACT

By 2020 there will be more than 6 billion smartphones around the globe, carried by the public. These smartphones are equipped with sensitive sensors that can be used to monitor our environment (temperature, pressure, humidity, magnetic field, etc.) In this paper we use the pressure sensor (barometer) within smartphones to study atmospheric tides. These tides are produced by the absorption of solar radiation by water vapor in the troposphere, and by ozone in the stratosphere. The strongest tides are the semi-diurnal tides (period of 12 h) with maximum pressure at 9am/9pm and minimum pressure at 3am/3pm. Given the proliferation of smartphones around the globe, this source of environmental data may become extremely useful for scientific research in the near future.

1. Introduction

Similar to tides in the oceans, the atmosphere also has tides. However, unlike tides in the oceans driven by gravitational forcing of the Sun and moon, atmospheric tides are thermally driven by the periodic absorption of solar radiation throughout the atmosphere, primarily the absorption of ultraviolet (UV) radiation by stratospheric ozone (~ 30–50 km altitude) and of infrared (IR) radiation by water vapor in the troposphere (0–15 km altitude) (Chapman and Lindzen, 1970; Hong and Wang, 1980; Forbes and Groves, 1987; Dai and Wang, 1999). Variations in the global distribution and density of these species results in changes in the amplitude of the atmospheric tides.

Migrating atmospheric tides are sun synchronous – from the point of view of a stationary observer on the ground they propagate westwards with the apparent motion of the sun. As the migrating tides stay fixed relative to the sun a pattern of excitation is formed that is also fixed relative to the Sun. While we would expect the 24 h diurnal solar heating to have the largest signal, it is actually the semi-diurnal (periodicity of 12 h) tides that are the most common in numerous data sets (Dai and Wang, 1999). The two maxima in pressure are often observed around 9am and 9pm, while the minima in pressure occur close to 3am and 3pm. Changes in the tides observed from a stationary viewpoint on the Earth's surface are caused by the rotation of the Earth with respect to this fixed pattern. Seasonal variations of the tides also occur as the Earth tilts relative to the Sun and so relative to the pattern of excitation. Generally atmospheric tides are observed and monitored in the upper atmosphere in different atmospheric parameters from winds, airglow, chemistry, gravity waves and electron density (Hagan and Forbes, 2003).

With the development of sophisticated smartphones in the last decade, and the reduction in their costs, there are now more than four billion smartphones around the globe (Ericsson Mobility Report, 2017). It took over five years to get the first billion smartphone subscribers in 2012, and less than two years to get the next billion subscribers. These numbers, together with the quality of the sensors, are only expected to increase in the next decade, while the cost of the phones is expected to decrease dramatically. By 2020 it is expected that the number of smartphone subscriptions will double again to more than 6 billion around the globe, each one with a suite of sensitive micro-sensors. The largest increase will be seen in the Middle East and Africa, where smartphone subscriptions will increase by more than 200% in the next six years, while the largest increase in number will occur in Asia, with an increase of 1.7 billion smartphone users over the next 5 years.

Smartphones contain several sensors which monitor different atmospheric parameters such as pressure, temperature, humidity and magnetic field. In the past few years there are more and more research groups attempting to use smartphone data for scientific research. In the Netherlands smartphones have been used to study air pollution (Snik et al., 2014) while in the United States smartphone pressure data have been used to improve weather forecasts (Mass and Maduas, 2014), and in the UK smartphones have been used to map temperature variability (Overeem et al., 2013). In California a seismic network MyShake has been developed using the accelerometers in smartphones (Kong et al., 2016). However, this is the first study to investigate the ability of smartphones to study and monitor atmospheric tides.

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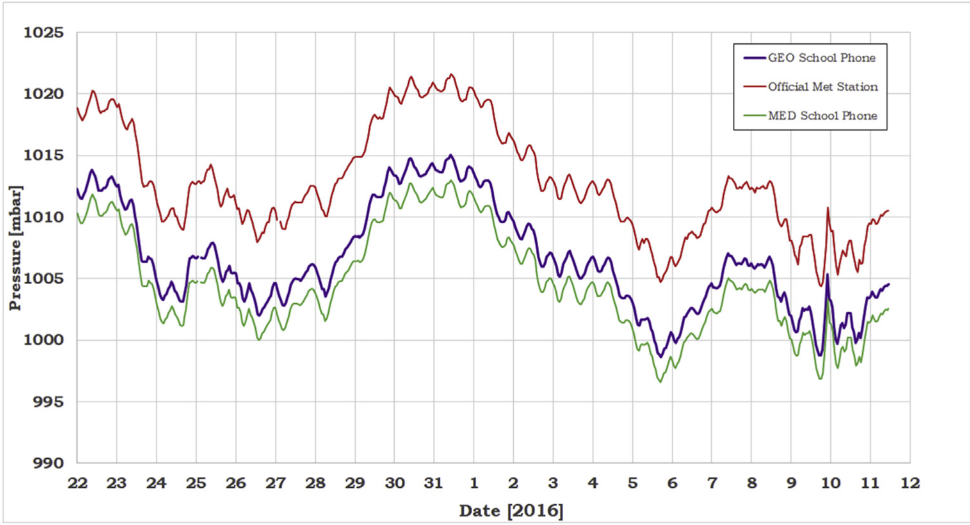

Fig. 1. Time series for pressure data taken from two smartphones and the official Meteorological station during March and April 2016.

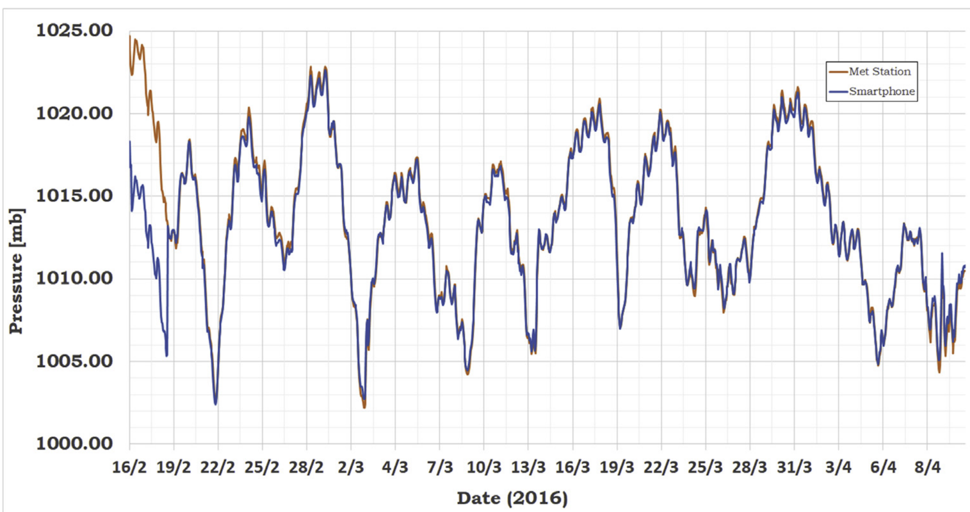

Fig. 2. The pressure time series over two months for the official weather station and a single smartphone. Calibration between the MeteoTAU reading and the smartphone reading was performed on 19/2/2017 00:00.

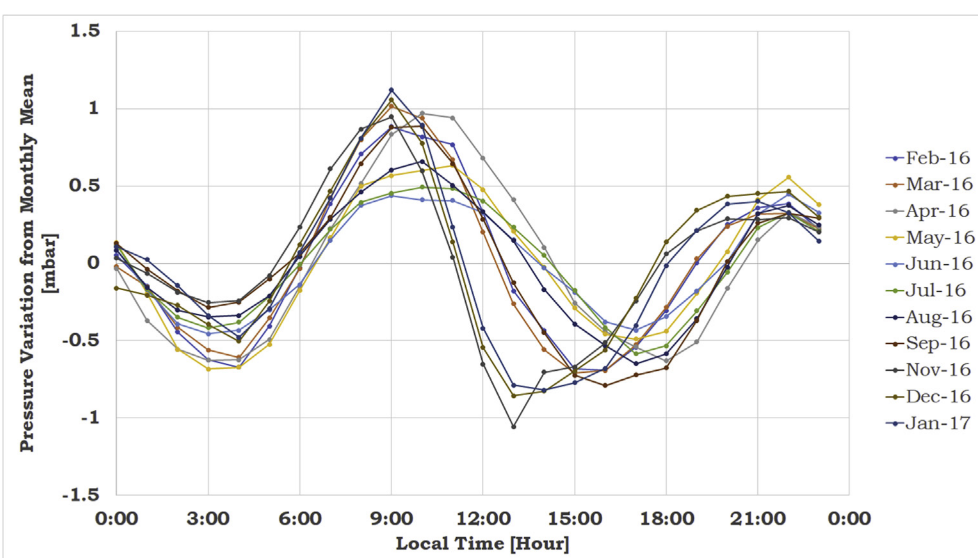

Fig. 3. Pressure anomaly from monthly mean pressures, for each month (data from a single smartphone).