Atmospheric Potential Gradient Measurements from a Rooftop in Bangkok

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Abstract. Atmospheric potential gradient measurements at 1 Hz (averaged to 1 minute samples) were taken on the roof of a 6th floor building, approximately 100 m from a busy toll road in Lak Si, northern Bangkok. The measurement period covered the transition from hot season into rainy season. The heavy monsoon rains and heavy traffic can both be significant disruptors of the fair weather atmospheric potential gradient. Heavy traffic increased potential gradient due to aerosol loading, while rain storms increased the magnitude, but also changed the sign of the field due to charge processes within clouds. Increasing relative humidity led to a decrease in potential gradient, implying a lack of hygroscopic growth. Cross correlations of aerosol number in different size fractions showed that aerosols with a D50 value of 155 nm had the strongest correlation. A strong diurnal signal is present in frequency domain analysis of potential gradient.

1. Introduction

The atmospheric potential gradient (PG) arises through global thunderstorm activity transporting charge to the ionosphere, which is then dissipated back to ground through the atmosphere. The atmosphere is weakly conducting due to the presence of ions caused by ground-based radiation and cosmic rays. PG measurements are often used to provide information about atmospheric physics and meteorology \cite{1,2} but have also been used to infer information on pollution due to the reduction in atmospheric conductivity caused by atmospheric ion attachment to aerosol \cite{3,4}. Aerosol are a health concern in SE Asia, and PG measurements may provide new information on their properties.

PG is related to the aerosol content within the air as aerosols act as a sink of ions, reducing air conductivity $\lambda$. PG is related to air conductivity through the current density ($J$):

$$PG = J/\lambda$$

The ion-aerosol attachment coefficient $\beta$ describes the rate at which ions attach to aerosols. This factor increases with increasing aerosol radius ($R$), equation (2), where $k_B$ is the Boltzmann coefficient, $T$ the temperature, $\mu_m$ the mean ion mobility and $e$ the elementary charge \cite{5}. An effective aerosol attachment coefficient can be found as a function of $\beta$ and the aerosol number concentration and would typically result in a peak attachment effect at 200-300 nm \cite{6}.

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Relative humidity (RH) can cause aerosol size to change due to hygroscopic growth, with increasing RH increasing $\beta$. Silva et al provide a formulation, equation (3), that relates the PG with number concentration of aerosols ($Z$), the dry radius ($R_d$) and a hygroscopicity parameter that would depend on the constituents of the aerosol ($\kappa$), where $q$ is the ion production rate [3].

$$PG \approx \frac{4\pi k_b T \mu_m e^2}{e^2 q} Z R_d \left(1 + \kappa \frac{RH}{1-RH}\right)$$ (3)

2. Experimental methodologies
The study took place in Lak-Si, a northern district in Bangkok, the measurement site was on the roof of the Chemistry department of the Chulabhorn Research Institute, a 5 floor building. The site has a toll road and a railway to the East. To the West is built-up area, include new building developments. The Don Muang airport is to the North and the city centre is approximately 15 km to the South.

A JCI 131 electric field mill (JCI Chilworth) was used to measure the atmospheric PG, the field mill was placed on a 2 m pole on the roof of the Chemistry building within the Chulabhorn Research Institute. Output was recorded to data logger at 1 second sampling intervals and averaged to one minute. PG was recorded from 8th March to 12th April, 19th April to 21st May and 24th May to 14th September 2018.

Weather conditions were measured using a GMX501 weather station measuring temperature, pressure, humidity, solar radiation and wind speed and direction, and a separate GMX100 measuring rainfall using an optical method (Gill Instruments). Both weather measurements were recorded at 1 s interval to a portable computer. Weather measurements were taken continuously between 5th March 2018 to 17th November 2018, except for the week between April 10th and April 17th 2018.

Throughout March 2018, aerosol particle number concentrations (PNC) were obtained with a Condensation Particle Counter (CPC Model 5.403, Grimm Aerosol). For 6 days in March, aerodynamic size distribution was recorded using an Electrical Low Pressure Impactor (ELPI; Dekati). The ELPI measures size distribution on 12 impaction stages at 1 second sampling intervals. Aerosol samples were drawn through an inlet on the 5th floor on the side of a building facing the toll road.

3. Results and Discussion
The measurements were separated into dry season (8th March to 26th May 2018) and rainy season (26th May to 14th September 2018). Figure 1(a) shows the measured PG for the two time periods and figure 1(b) shows rain rate and temperature in Bangkok between March and October, 2018.
associated with charged clouds [2]. However, histograms of rainy season against dry season shows a broader distribution of field values in dry season (figure 2), and the time series shows increased disturbed activity in May. This may reflect increased electrical activity in the hotter months.

Hygroscopic growth at high RH was posited to increase aerosol size, and therefore reduce PG as RH increases (equation (3) [3]). Figure 3 shows box plots of PG in Bangkok that decreases with increasing RH in contradiction to this prediction. However, experimental data from Portugal also showed a decrease in PG with increasing RH when aerosol came from more polluted sources, but not from marine sources [3]. Hydrocarbons from combustion sources are less hygroscopic, and it may be that the high combustion related pollution levels in Bangkok results in less hygroscopic growth. The large extent of PG at the highest humidity (90 -100%) is likely due to rainfall and disturbed weather.

Figure 2. Normalised histogram of PG measured in the rainy and dry seasons.

Figure 3. Box plots of PG with increasing RH

Figure 4 plots the cross-correlation coefficients between PG and aerosol number concentration measured by each impaction stage of the ELPI, excluding the filter stage and the sizes larger than 3 μm. Sizes larger than this did not show correlations. The best correlation was at zero lag, implying that aerosol increases affect ion concentrations within a timescale of minutes. A correlation with aerosol concentration preceding PG by up to 2.5 hours may indicate a longer-term predictive effect of high aerosol concentration reducing ion concentrations that is not shown when PG precedes PNC. The size range with the highest cross-correlation had D50 values between 155 and 262 nm (aerodynamic diameter), which was the highest concentration shown within the size distribution (figure 5). As would be expected, the coarse size fractions with D50 values greater than 1 μm (higher than PM1) show much reduced correlation as the number concentration is much lower at these sizes.

Figure 4. Cross correlation coefficient between PG measured on the roof of a building and PNC measured at each stage of the ELPI.

Figure 5. Aerodynamic size distribution of particle number concentration measured by the ELPI.
The daily average cycle of PNC measured in March 2018 exhibits a double diurnal cycle, which is not shown in the PG averaged signal from March, but, the PG signal is more stable overnight during times of low PNC. Lomb-Scargle periodograms have been used successfully to identify periodic trends in atmospheric PG, including diurnal traffic signals when there are incomplete datasets [7,8]. Figure (7) shows a periodogram of PG with a clear daily, and possible half daily and quarterly cycles.

**Figure 6.** Daily averaged cycle of aerosol concentration (blue) and PG (orange) measured in March 2018.

**Figure 7** Lomb-Scargle periodogram from hourly averages of PG measured in 2018.

4. **Conclusions**

Atmospheric PG was measured from a rooftop in Bangkok, where it was affected by both disturbed weather and heavy traffic from a nearby toll road. Aerosol disruption of PG was most effective in the sub-micron range and showed a daily cycle consistent with traffic. Global effects are clearly often masked by local and regional impacts such as particulate pollution and weather conditions, and the Bangkok site with frequent heavy rain due to the monsoon climate (Figure 1) and the high aerosol content, even at weekends (Figure 6). Therefore, extracting useful information on the global circuit would require significant effort in data processing to remove the local and regional influences. However, a plurality of contrasting sites can enable local and global effects to be investigated, and Bangkok measurements may act as a useful comparator to better ‘fair weather’ sites around the globe.

5. **References**

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