Figure S1. Measurement locations and instrumentation during the campaign. (a) Location of Seoul. (b) Measurement stations within Seoul. Secondary inorganic aerosols, OC and EC were measured at Korea University (KU). $PM_{2.5}$, PM_{10}, O_3 and NO_2 were measured at a site approximately 1 km south of KU, while TVOCs and PBLH were measured at a site approximately 2 km southwest of KU. Aerosol particle data were provided by the National Institute of Environmental Research (NIER), and meteorological data were obtained from the Korea Meteorological Administration (KMA).
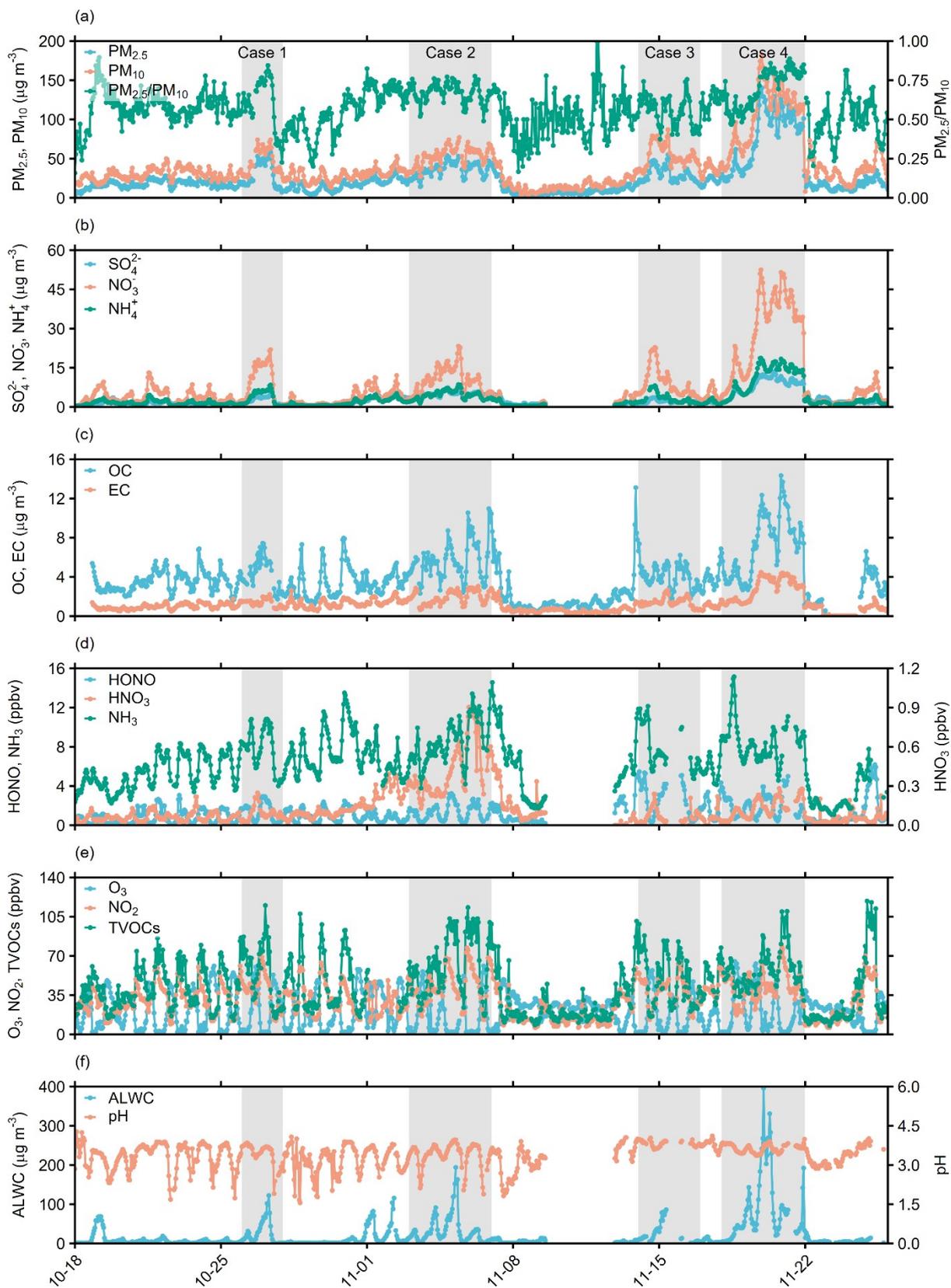
Figure S2. Time series of PM$_{2.5}$, PM$_{10}$, chemical components and related variables in Seoul.

(a) PM$_{2.5}$, PM$_{10}$ and the PM$_{2.5}$/PM$_{10}$ ratio. (b, c) Major PM$_{2.5}$ components. (d, e) Precursor

gases. (f) ALWC and pH, calculated using the ISORROPIA II model. Data were collected between 18 October and 25 November 2021. Shaded areas indicate the four major high-$PM_{2.5}$ events.
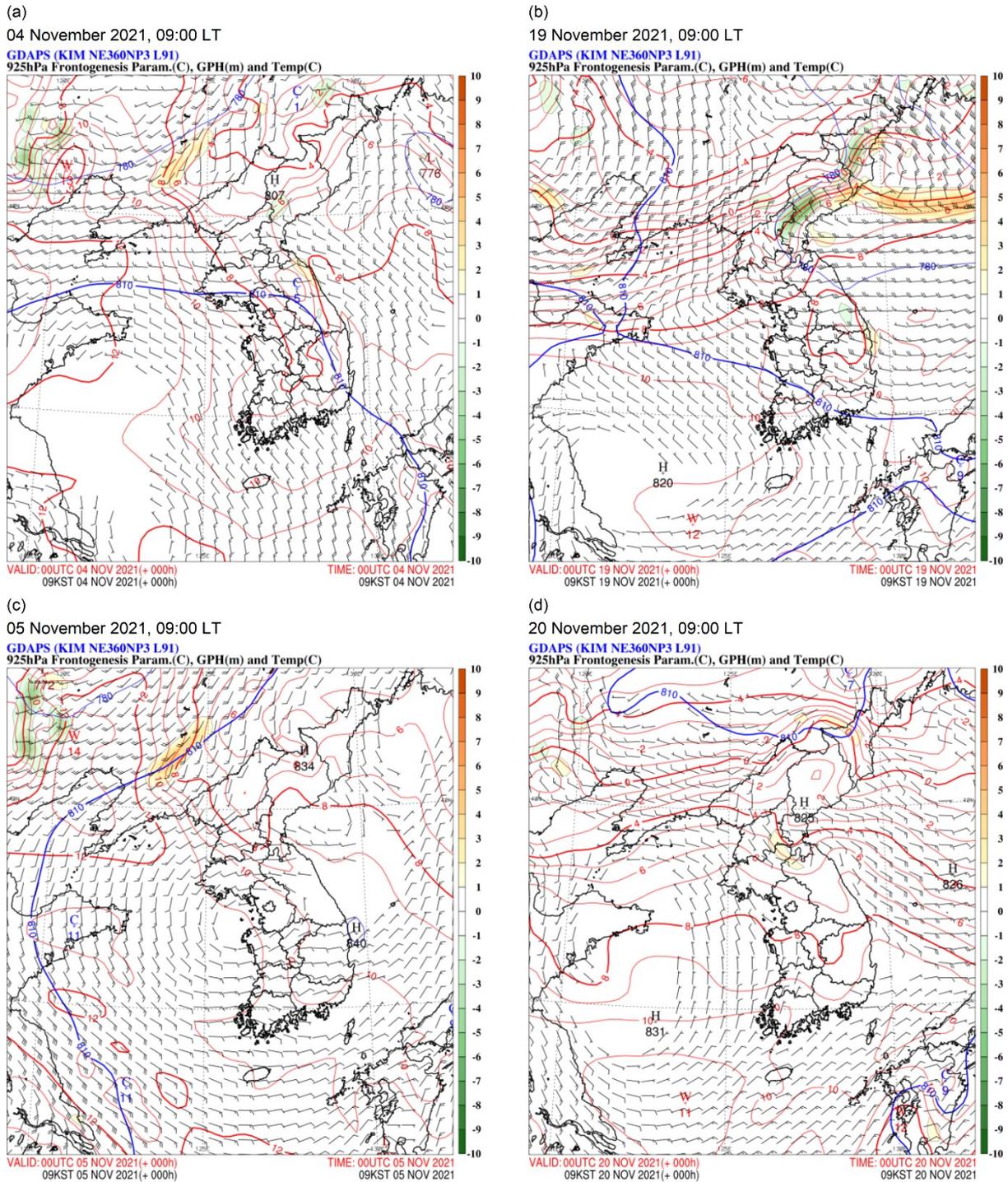
Figure S3. Global Data Assimilation and Prediction System (GDAPS) 925 hPa weather charts for Cases 2 and 4. The left and right columns show Cases 2 and 4, respectively. (a, b) Early-stage weather charts. (c, d) Mid-stage weather charts.
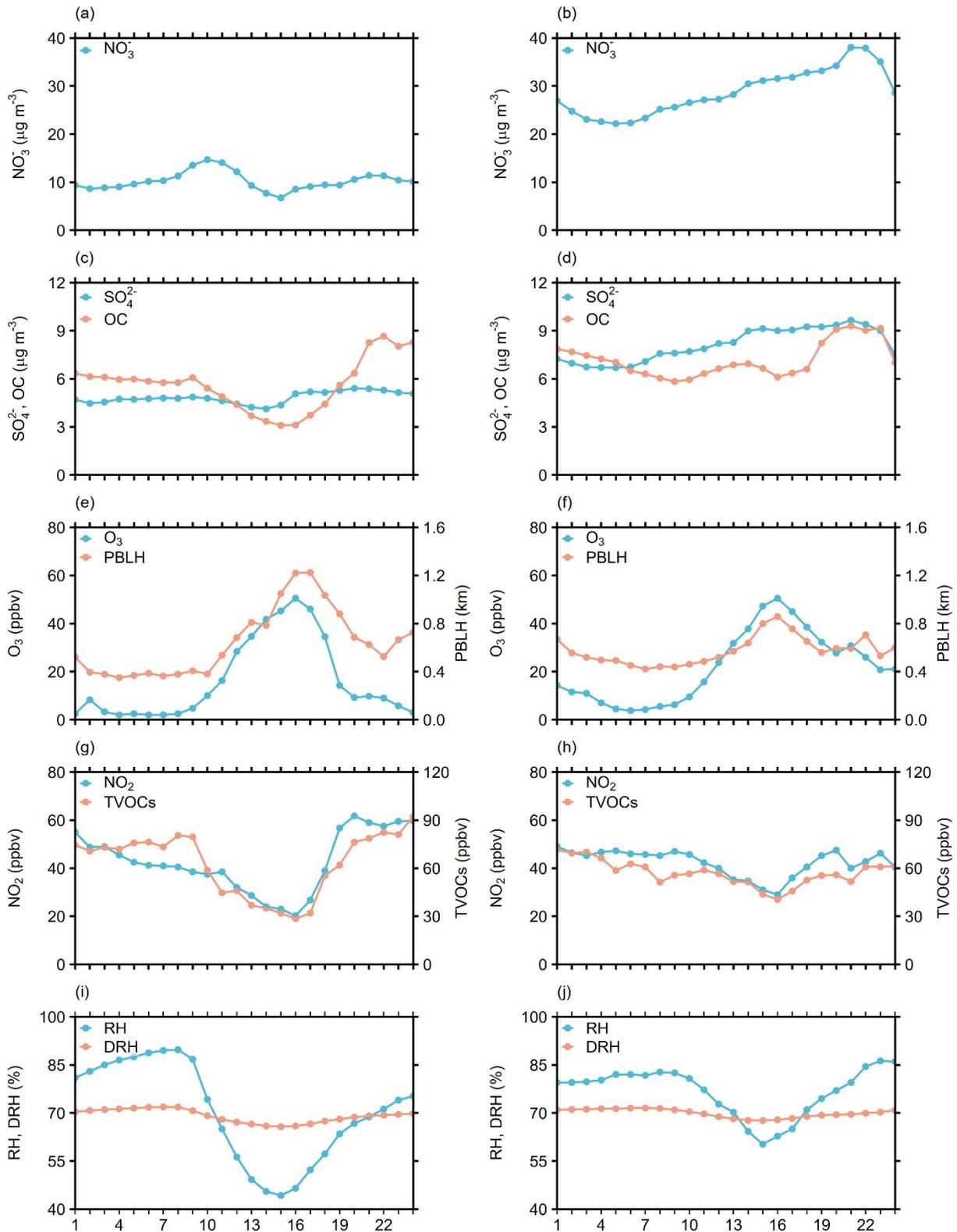
Figure S4. Averaged diurnal variations of NO$_3^-$, SO$_4^{2-}$, OC, O$_3$, PBLH, NO$_2$, TVOCs, RH and DRH. The left and right columns show Cases 2 and 4, respectively.

Table S1. Peason correlation coefficient between PM$_{2.5}$ composition. Only the upper triangle of the Pearson correlation matrix is shown because of symmetry.

Species	NO$_3^-$	SO$_4^{2-}$	NH$_4^+$	OC	EC
PM$_{2.5}$	0.96	0.93	0.97	0.81	0.88
NO$_3^-$	-	0.90	0.99	0.72	0.81
SO$_4^{2-}$	-	-	0.94	0.68	0.81
NH$_4^+$	-	-	-	0.72	0.83
OC	-	-	-	-	0.89