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Supplement of

How meteorological conditions influence aerosol-cloud interactions under different pollution regimes

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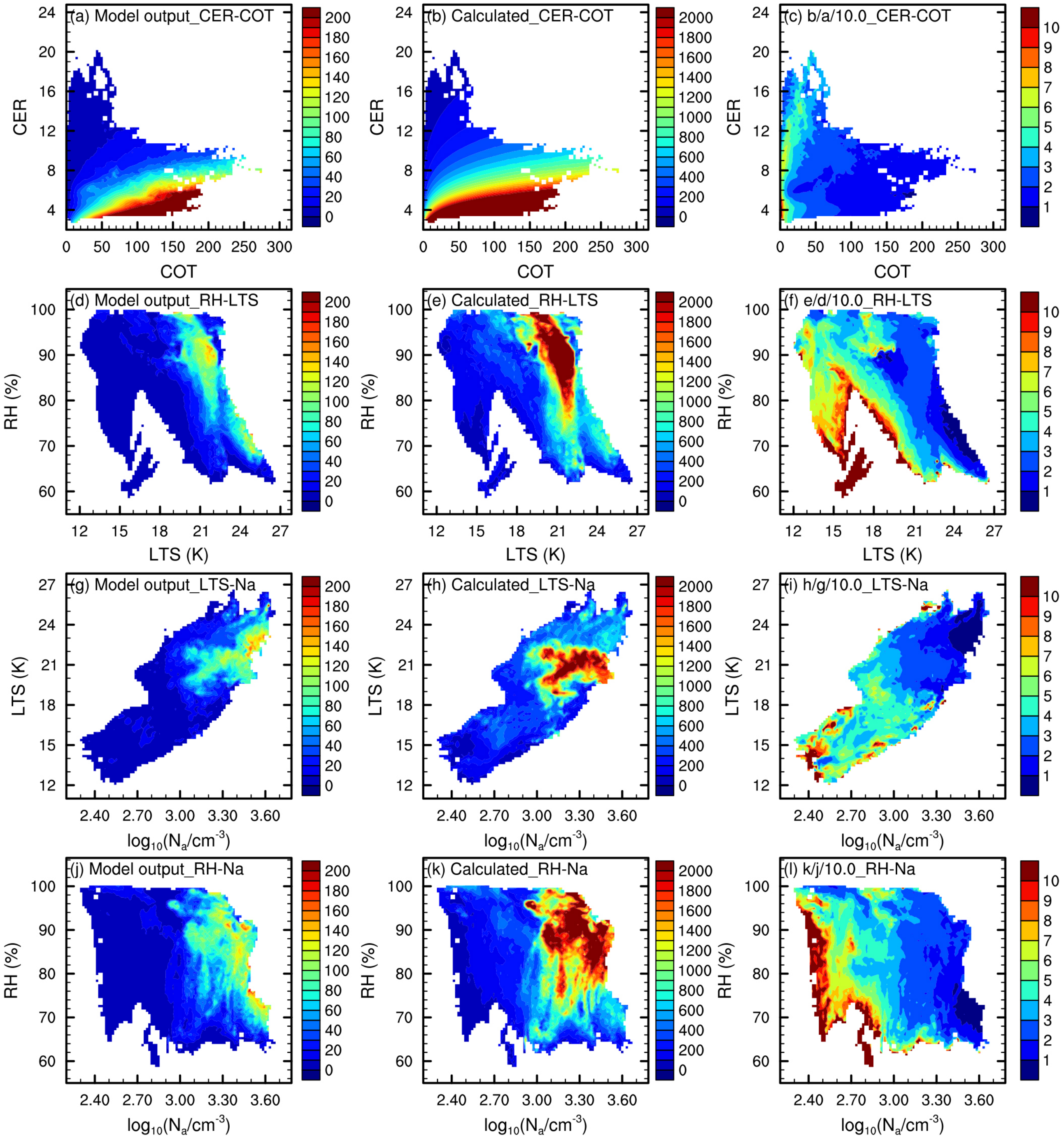

Figure S1. In-cloud mean N_d (Control experiment) derived from direct model output (left column) and empirical formula (Eq. (1) in the main text, middle column), along with the ratio of the empirical formula calculation (after dividing by 10) to the direct model output (right column), as functions of COT and CER (**a–c**), LTS and RH (**d–f**), N_a and LTS (**g–i**), and N_a and RH (**j–l**). The data processing method is the same as that used in Fig. 6.

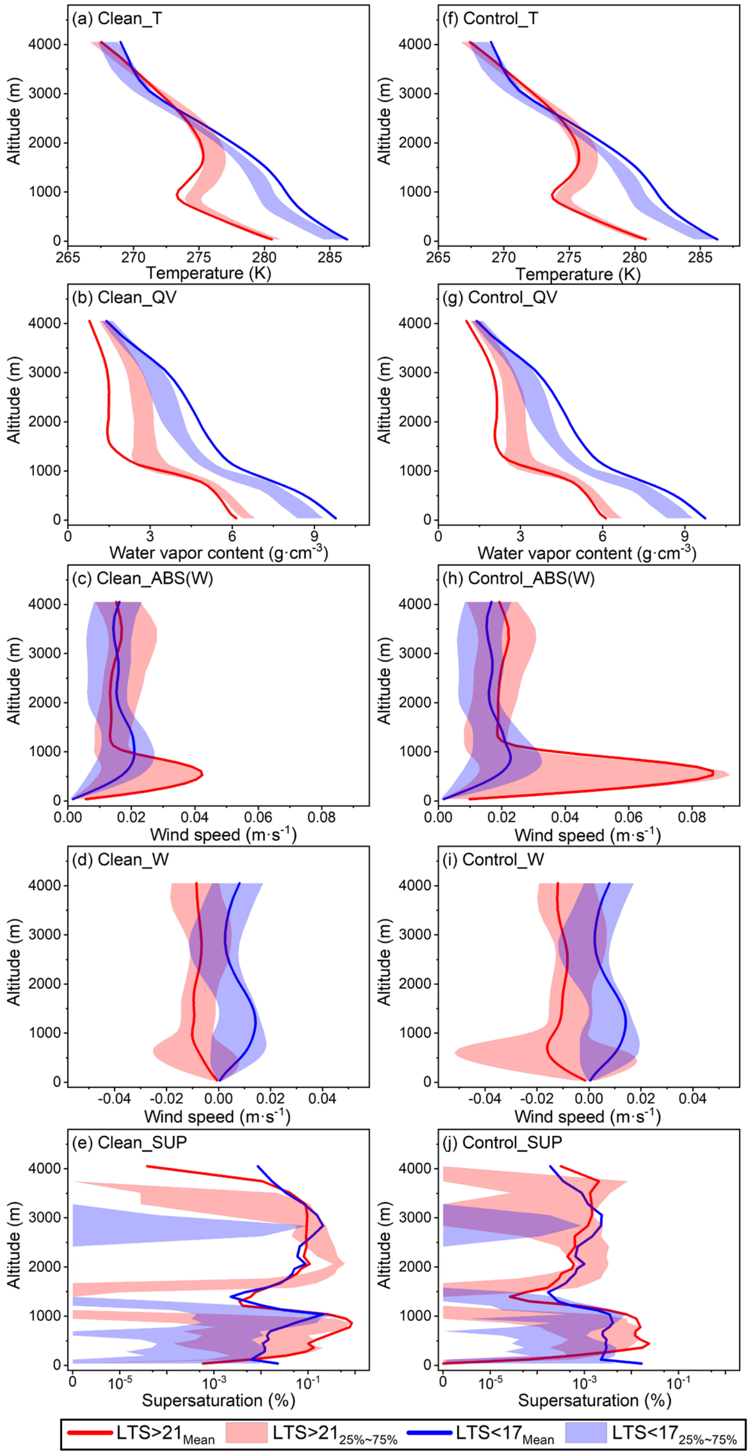

Figure S2. Vertical profiles of average temperature (**a, f**), water vapor content (**b, g**), absolute value of vertical wind speed (**c, h**), vertical wind speed (**d, i**), and supersaturation (**e, j**) over ECO for the Clean (**a-e**) and Control (**f-j**) experiments.

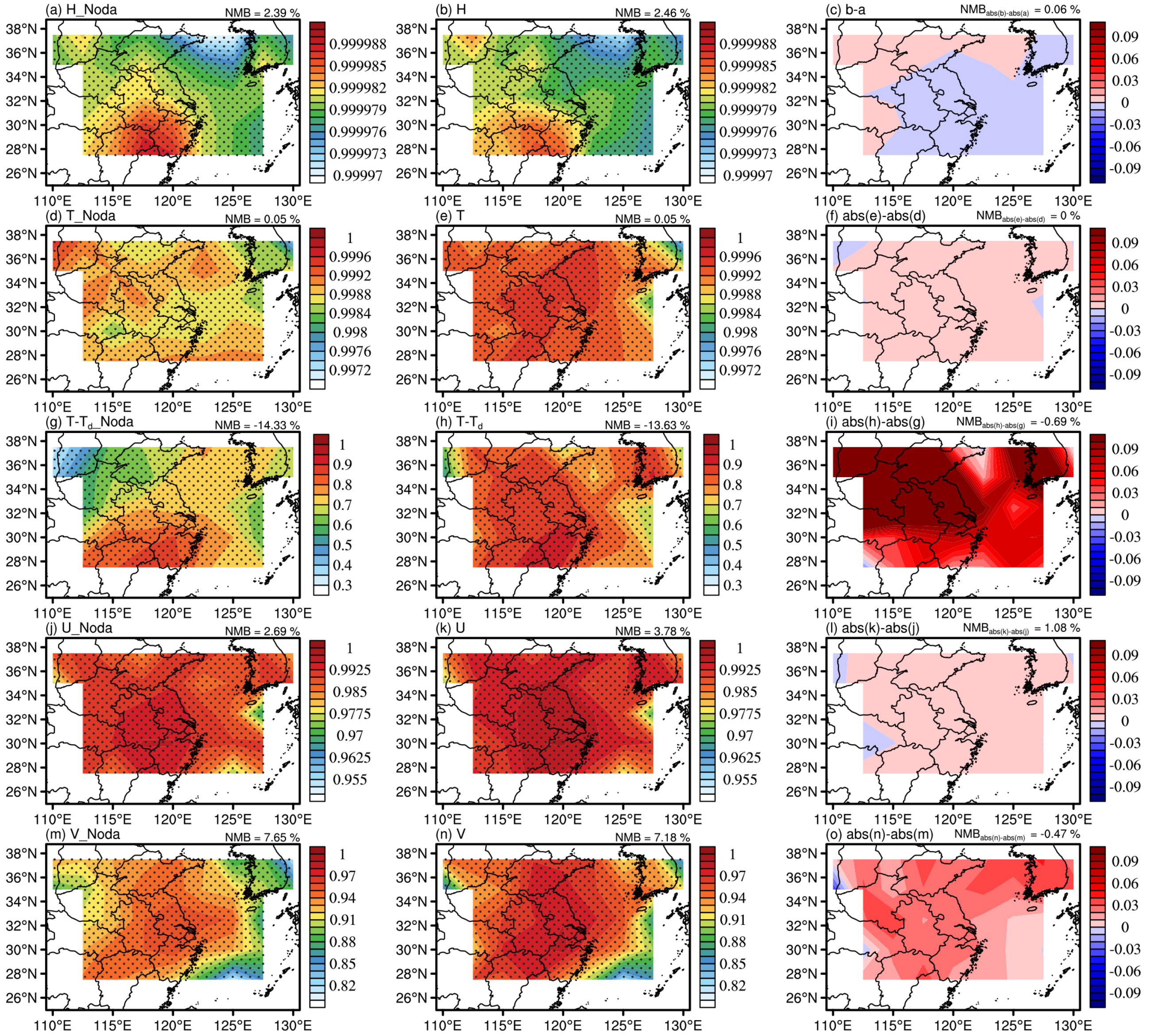

Figure S3. Correlation between the observations and the Control experiment simulations for height (**a-c**), temperature (**d-f**), dewpoint depression (**g-i**), zonal (**j-l**) and meridional winds (**m-o**) without (left column) and with assimilation (middle column), along with their differences (assimilated minus unassimilated, right column). Dotted areas in the figure indicate regions where the correlations pass the 99% significance test. The top-right corner of the left, middle, and right panels shows the Normalized Mean Bias (NMB) of the simulations without and with assimilation relative to observations, as well as their difference, respectively.

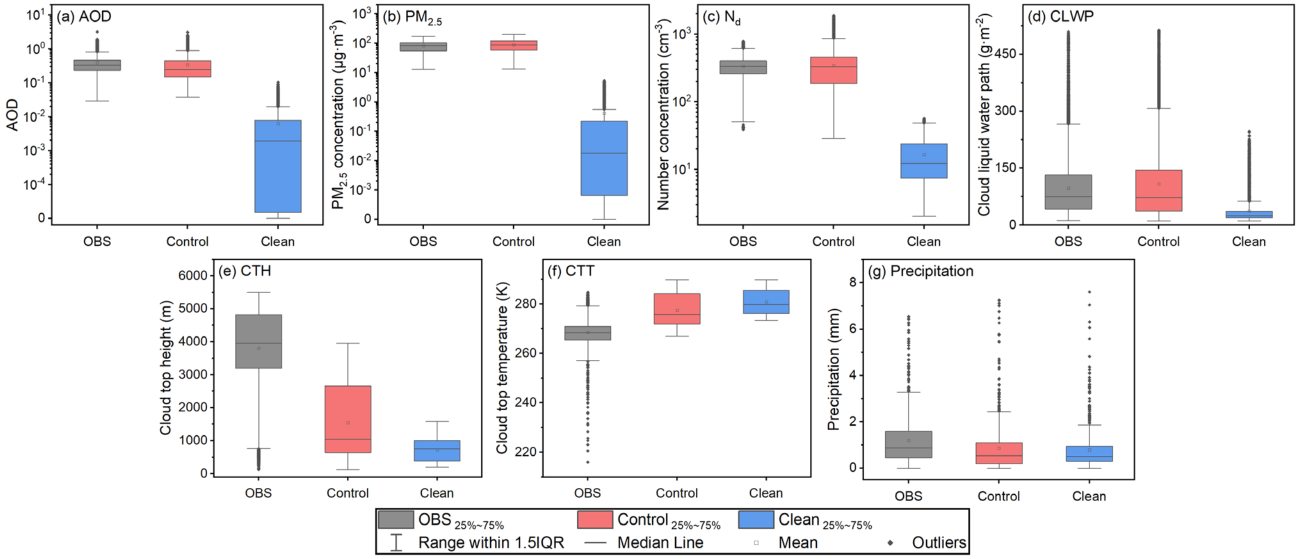

Figure S4. The observed (AOD and cloud properties, near-surface $PM_{2.5}$, and precipitation from MODIS retrievals, near-surface observations, and IMERG, respectively) and simulated (Control and Clean) AOD (**a**) and $PM_{2.5}$ (**b**) of the outer domain and N_d (**c**), CLWP (**d**), CTH (**e**), CTT (**f**), and precipitation (**g**) of the inner domain, including the 25th to 75th percentile range, mean, median, range with 1.5 IQR (Interquartile Range), and outliers.

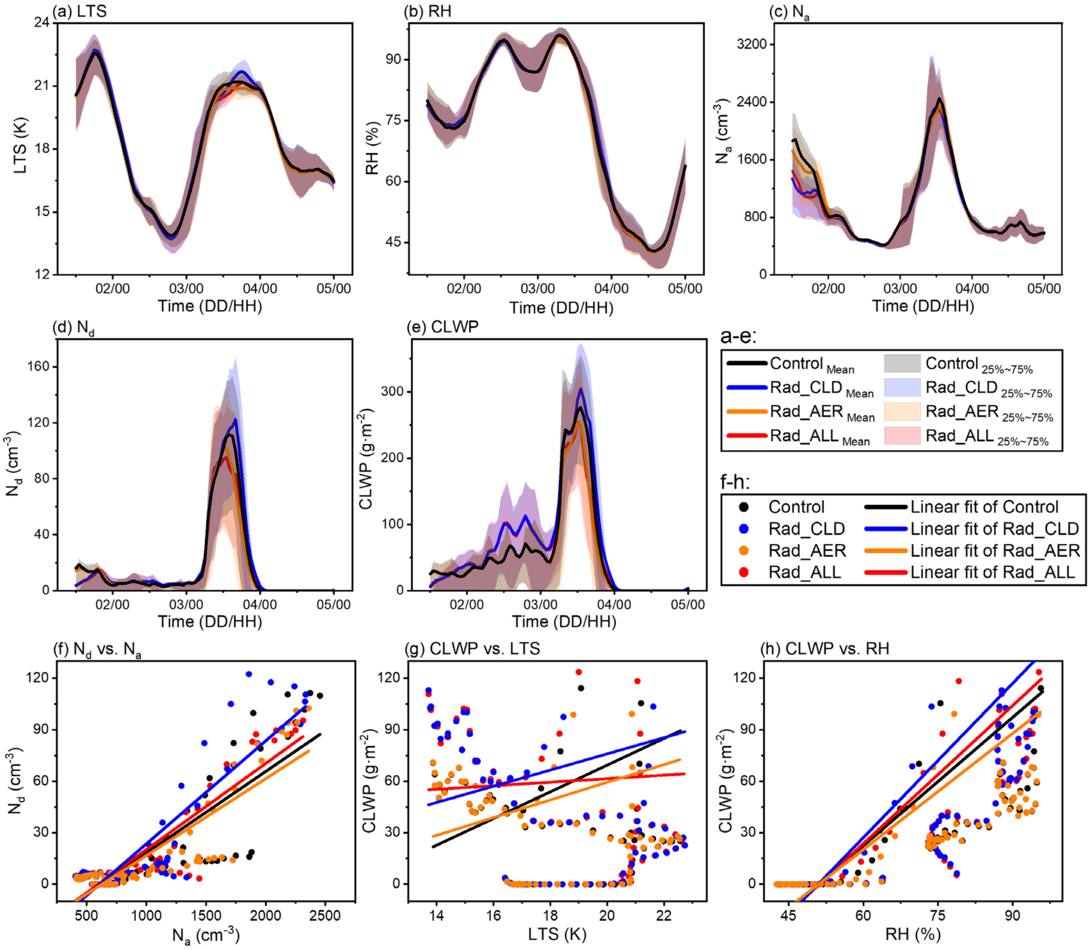

Figure S5. LTS (**a**), RH (**b**), N_a (**c**), N_d (**d**), CLWP (**e**), N_d versus N_a (**f**), as well as CLWP versus LTS (**g**) and RH (**h**) for the Control experiment and each radiative sensitivity experiment (Rad_CLD: cloud radiative effects enabled; Rad_AER: aerosol radiative effects enabled; Rad_ALL: both cloud and aerosol radiative effects enabled), showing data averaged over ECO (RH is the column mean from the surface to 1300 m, and N_d and N_a are in-cloud means).

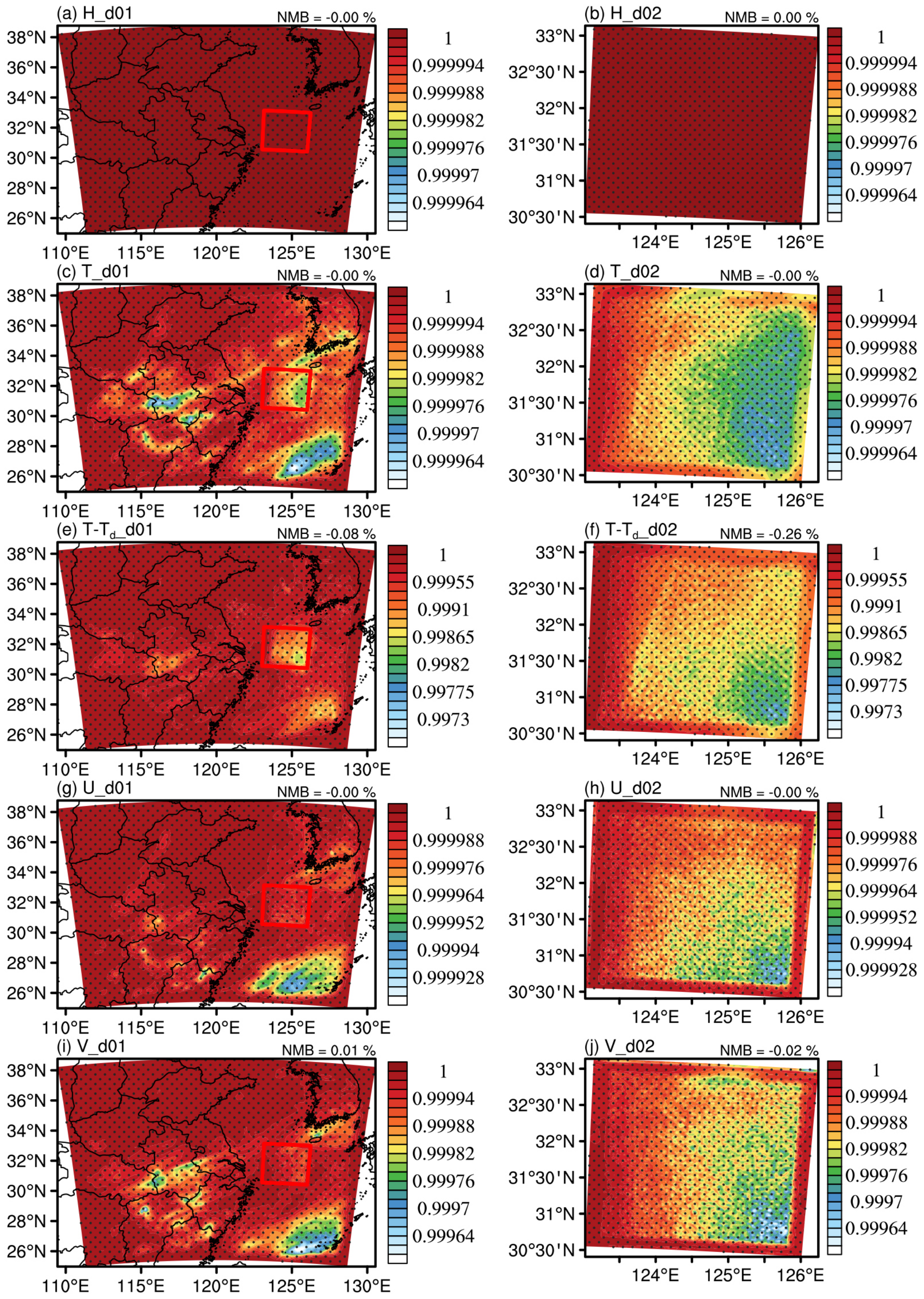

Figure S6. Correlation between the Control and Clean experiments for height (**a-b**), temperature (**c-d**), dewpoint depression (**e-f**), zonal (**g-h**), and meridional winds (**i-j**) in the outer domain (left column) and inner domain (right column). Dotted areas in the figure indicate regions where the correlations pass the 99% significance test. The top-right corner shows the NMB of the Clean experiment relative to the Control experiment.

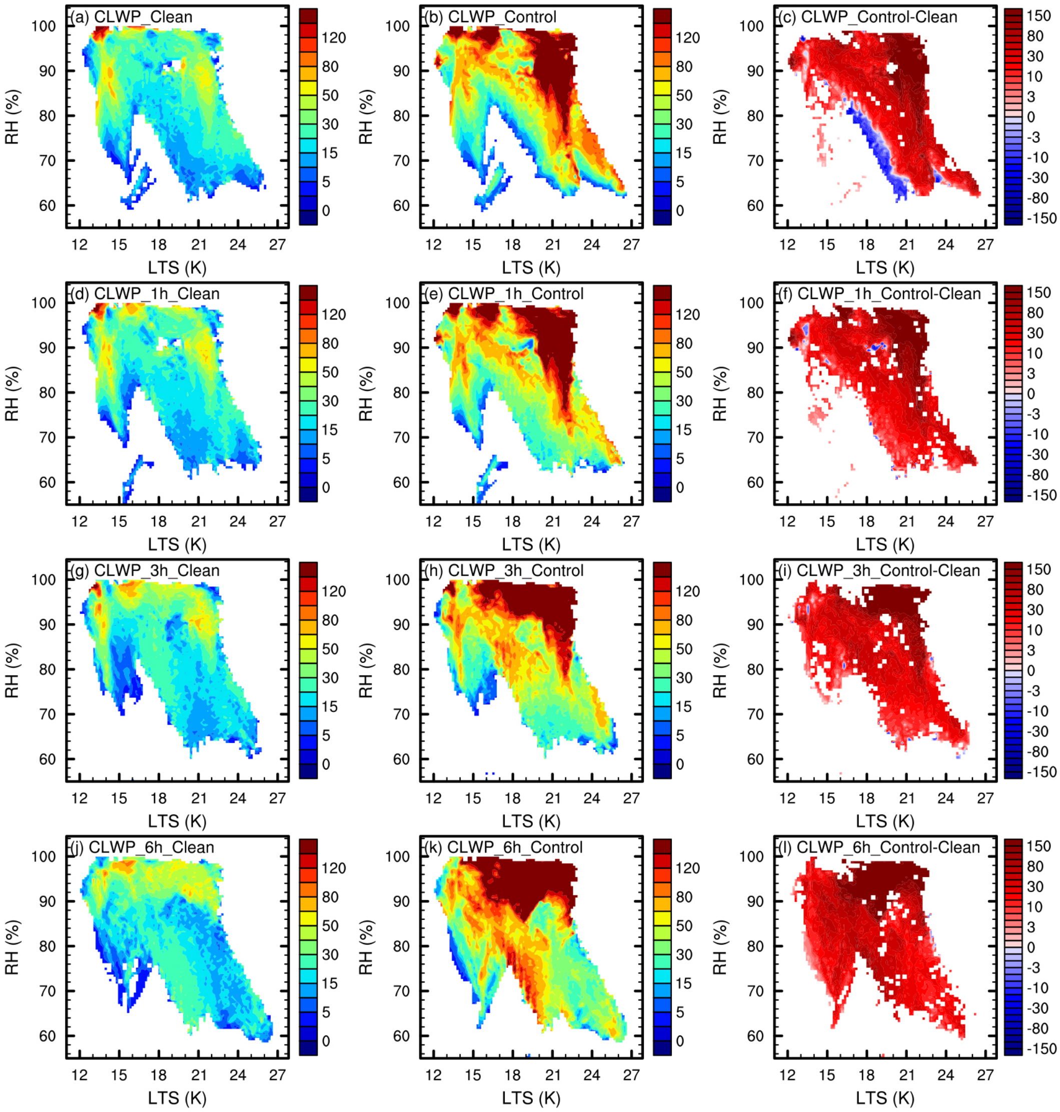

Figure S7. Variations of current (**a–c**), as well as 1 h (**d–f**), 3 h (**g–i**), and 6 h (**j–l**) lagged CLWP (in g m^{-2}) with LTS and RH in the Clean (left column) and Control (middle column) experiments, along with their differences (Control minus Clean, right column). The data processing method is the same as that used in Fig. 6.

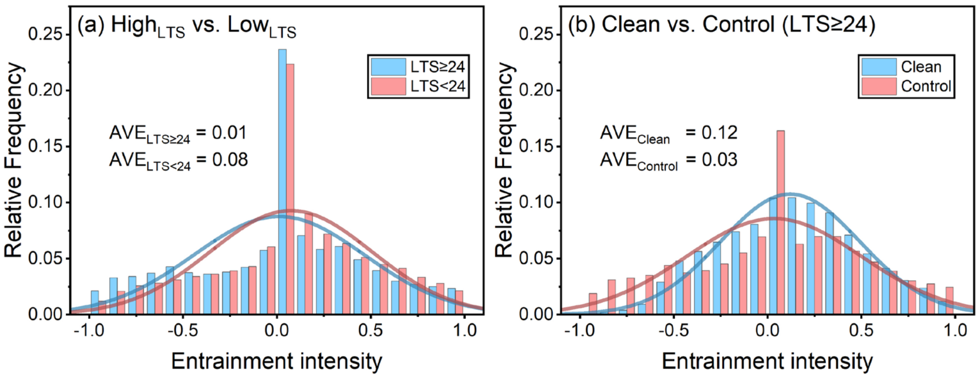

Figure S8. Frequency distribution histograms and fitted curves of entrainment intensity for liquid-cloud samples (CLWP > 1 g m^{-2}) under relatively dry conditions (RH < 80%), showing comparisons between environments with LTS ⩾ 24 K and

LTS < 24 K (**a**, from Control experiment), and between Control and Clean experiments within the LTS ⩾ 24 K environment (**b**).The entrainment intensity is defined, following Jia et al. (2019b) with refinements based on model outputs, as $(CLWC_{non\text{-}entrainment} - CLWC_{entrainment}) / CLWC_{max}$, where the non-entrainment and entrainment zones are the layers immediately below and above the level of maximum CLWC in clouds with CLWP > 1 g m^{-2}.The histograms are obtained by first assigning liquid-phase cloud samples under different conditions to entrainment intensity intervals according to their corresponding entrainment intensity, and then calculating, for each interval, the relative frequency of samples with respect to the total number of samples. The curves represent fitted distributions of these frequencies to better highlight the differences in entrainment intensity under different conditions.

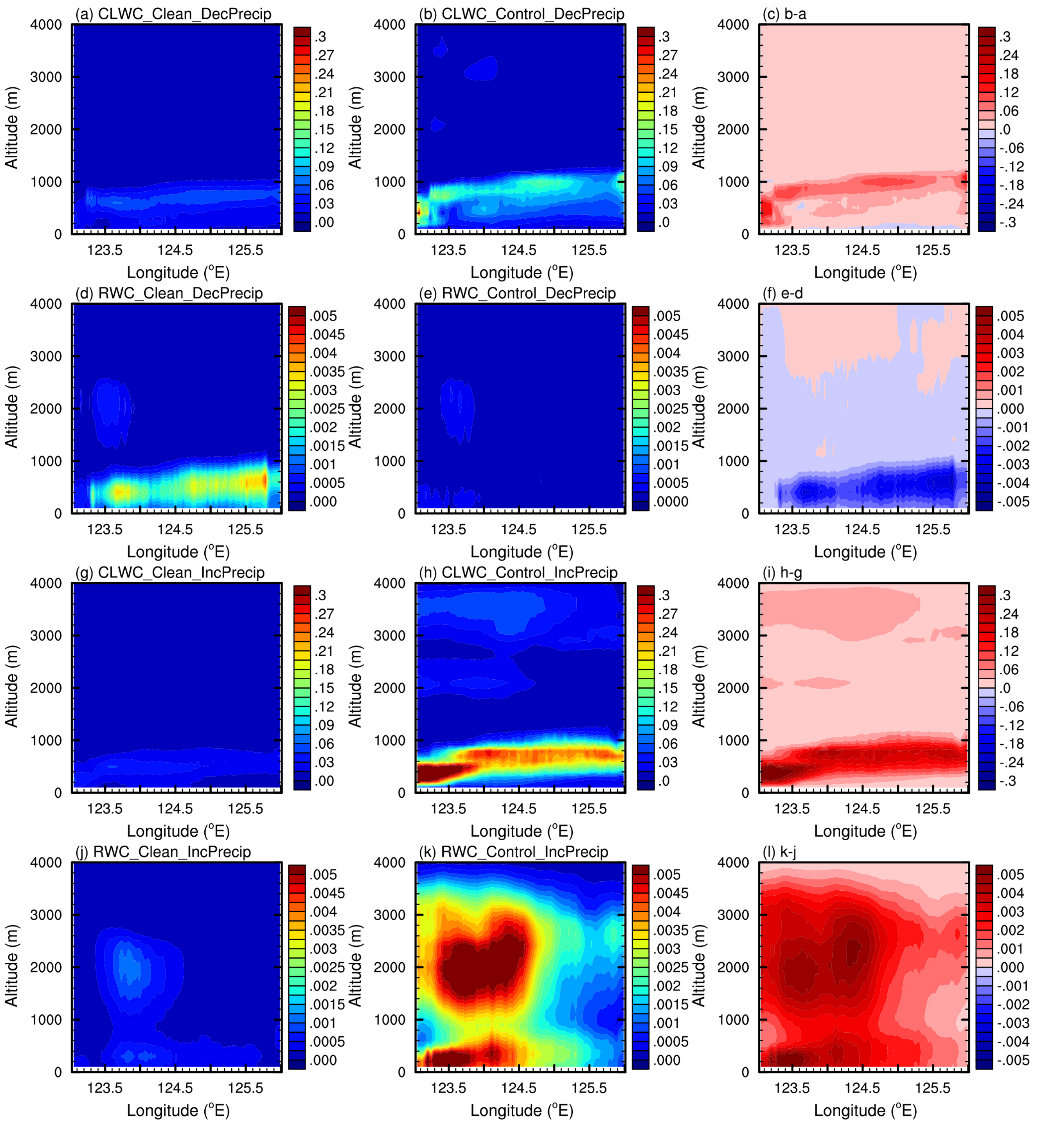

Figure S9. Cross sections of average CLWC (**a–c** and **g–i**, in g m^{-3}) and RWC (**d–f** and **j–l**, in g m^{-3}) for Clean (left column) and Control (middle column) samples showing decreases (**a–f**) and increases (**g–l**) in RWP exceeding 0.001 g m^{-2} under continental aerosol influence (values at each longitude coordinate represent the mean across all latitudinal grids at that longitude), along with the difference between the two experiments (right column).

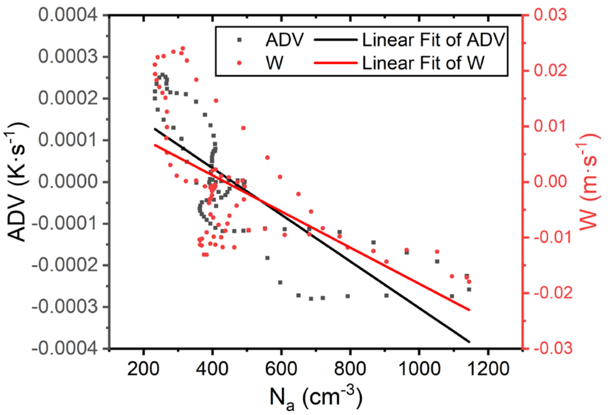

Figure S10. Variations of vertically weighted mean temperature advection (ADV, calculated as $-\left(U\frac{\partial T}{\partial x}+V\frac{\partial T}{\partial y}\right)$) and vertical wind velocity (W) from the near-surface to 1300 m with column-averaged N_a over ECO (the value in the figure represents the ECO average).

Table S1. Correlations between cloud properties (shown in Fig. 9) and LTS or RH (correlations are calculated after averaging cloud property values across all N_a coordinates for each corresponding LTS or RH value).

Property	RH				LTS			
	Clean		Polluted		Clean		Polluted	
	r	p	r	p	r	p	r	p
CER	0.46	<0.01	0.96	<0.01	0.86	<0.01	0.15	0.13
CLWP	0.81	<0.01	0.75	<0.01	-0.54	<0.01	-0.34	<0.01
RWP	0.67	<0.01	-0.14	0.16	0.18	0.07	-0.50	<0.01
$\log_{10}(N_d/N_a)$	0.59	<0.01	0.89	<0.01	-0.33	<0.01	0.28	<0.01
$\log_{10}(\mathrm{CLWP}/N_a)$	0.58	<0.01	0.70	<0.01	-0.14	0.18	-0.82	<0.01
$\log_{10}(\mathrm{RWP}/N_a)$	0.65	<0.01	0.70	<0.01	0.22	0.03	-0.36	<0.01