Figure S1. Vertical profiles of average temperature (a and f), water vapor content (b and g), absolute value of vertical wind speed (c and h), vertical wind speed (d and i), and supersaturation (e and j) over ECO for the Clean (a-e) and Control (f-j) experiments.
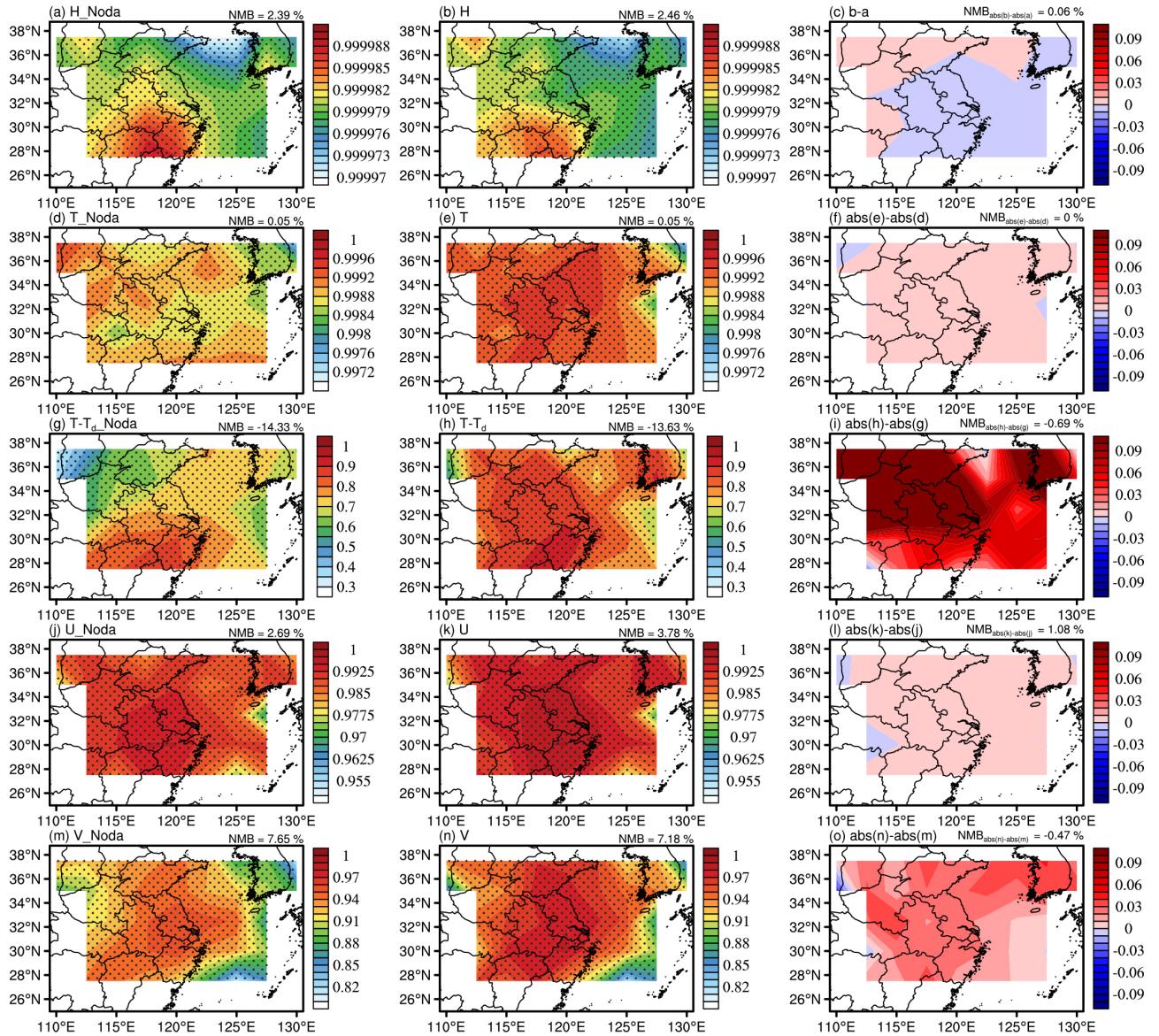
Figure S2. Correlation between the observations and the Control experiment simulations for height (a-c), temperature (d-f), dewpoint depression (g-i), zonal (j-l) and meridional winds (m-o) without (left column) and with assimilation (middle column), along with their differences (assimilated minus unassimilated, 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.
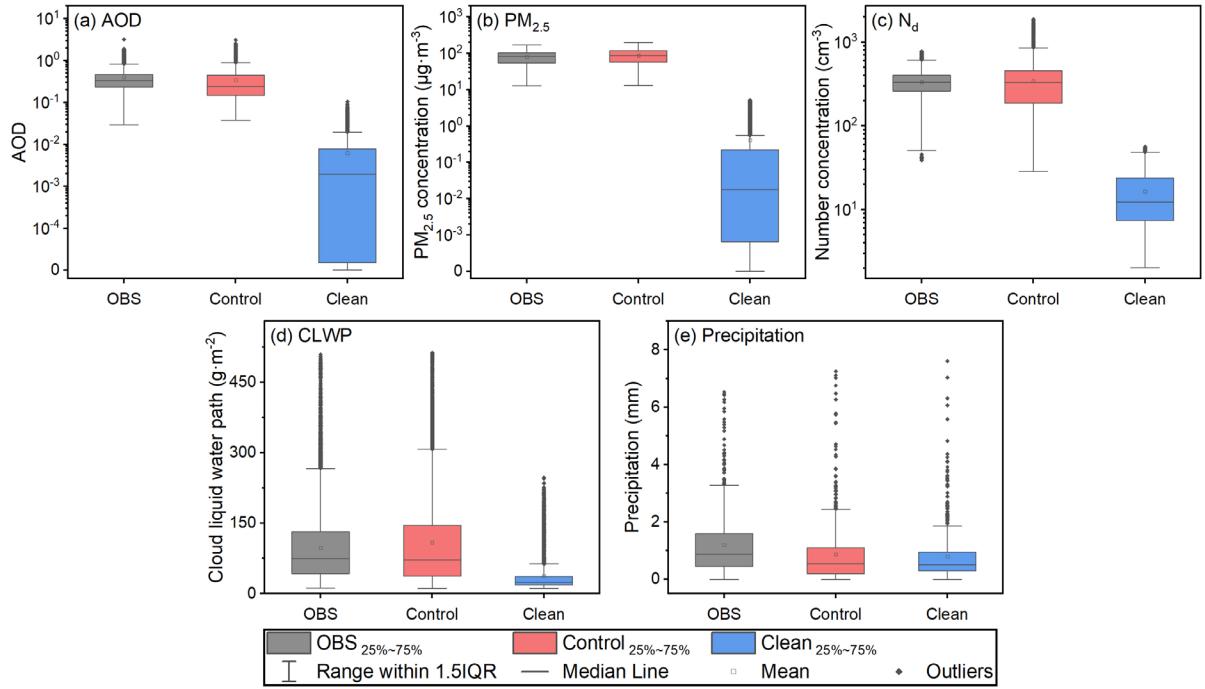
Figure S3. The observed (AOD and cloud properties, near-surface PM$_{2.5}$, and precipitation from MODIS retrievals, near-surface observations, and IMERG, respectively) and simulated (Control and Sen) AOD (a) and PM$_{2.5}$ (b) of the outer domain and N$_d$ (c), CLWP (d), and precipitation (e) of the inner domain, including the 25th to 75th percentile range, mean, median, range with 1.5 IQR (Interquartile Range), and outliers.
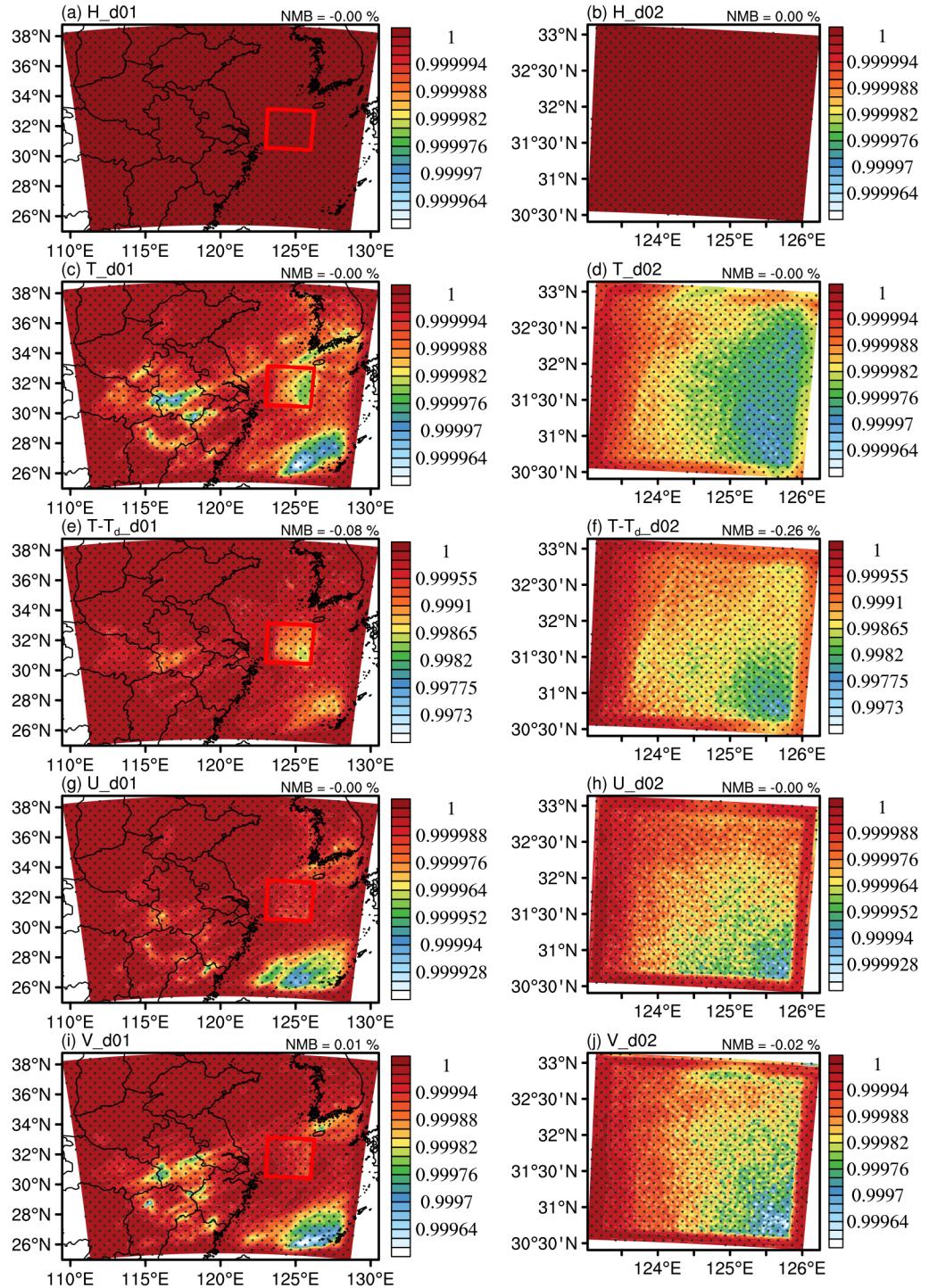
Figure S4. Correlation between the Control and Clean experiments for height (a-b), temperature (c-d), dewpoint depression (e-f), zonal (g-h), and meridional winds (i-j) in the outer domain (left column) and inner domain (right column). Dotted areas in the figure indicate regions where the correlations pass the 99% significance test. The top-right corner shows the NMB of the Clean experiment relative to the Control experiment.
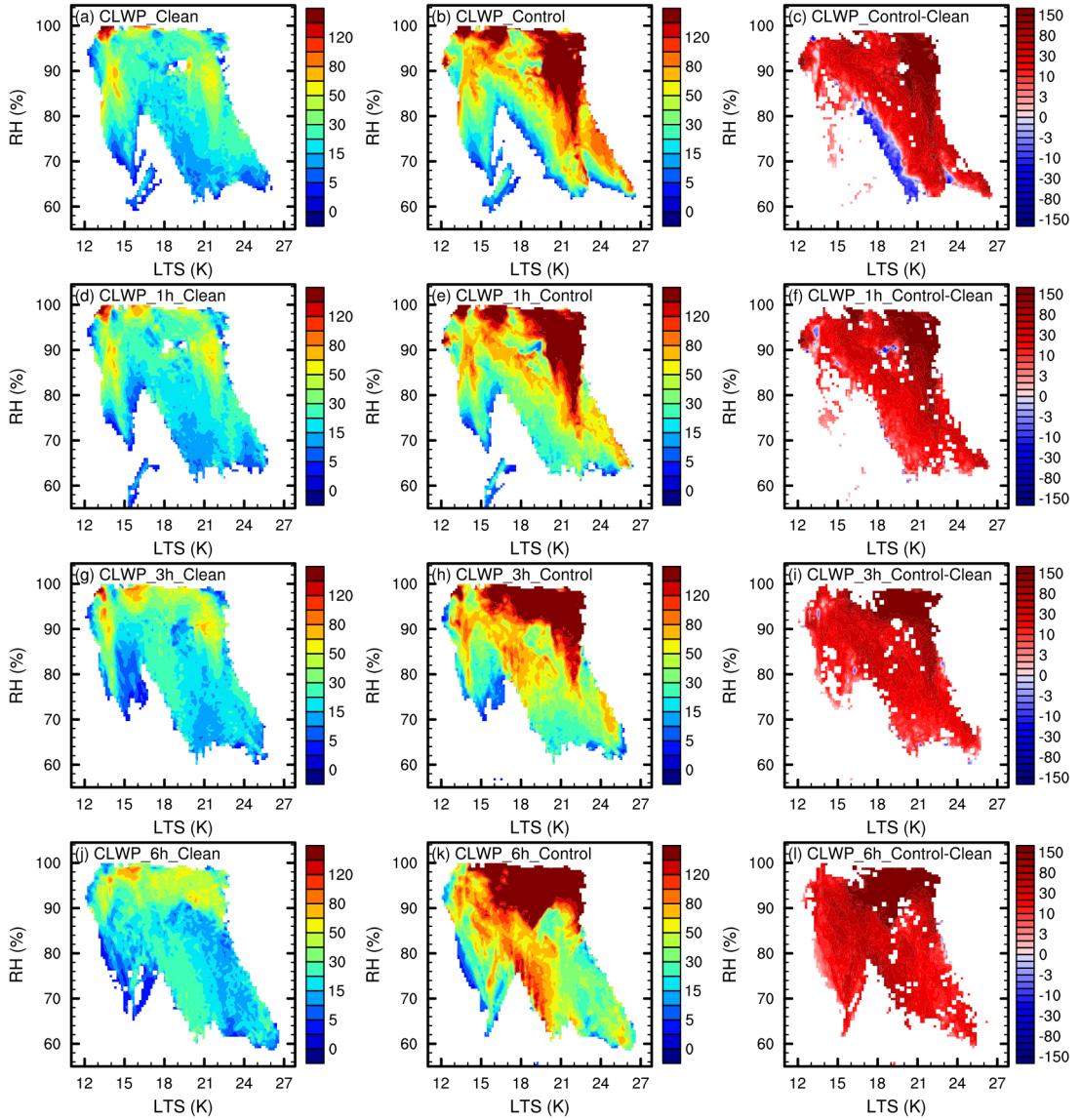
Figure S5. Variations of current (a–c), 1 h (d–f), 3 h (g–i), and 6 h (j–l) lagged CLWP (in g·m^{-2}) with LTS and RH in the Clean (left column) and Control (middle column) experiments, along with their differences (Control minus Clean, right column). The data processing method is the same as that used in Fig. 6.