Supplementary Information for

An Energetics Tale of the 2022 Mega-Heatwave over Central-Eastern China

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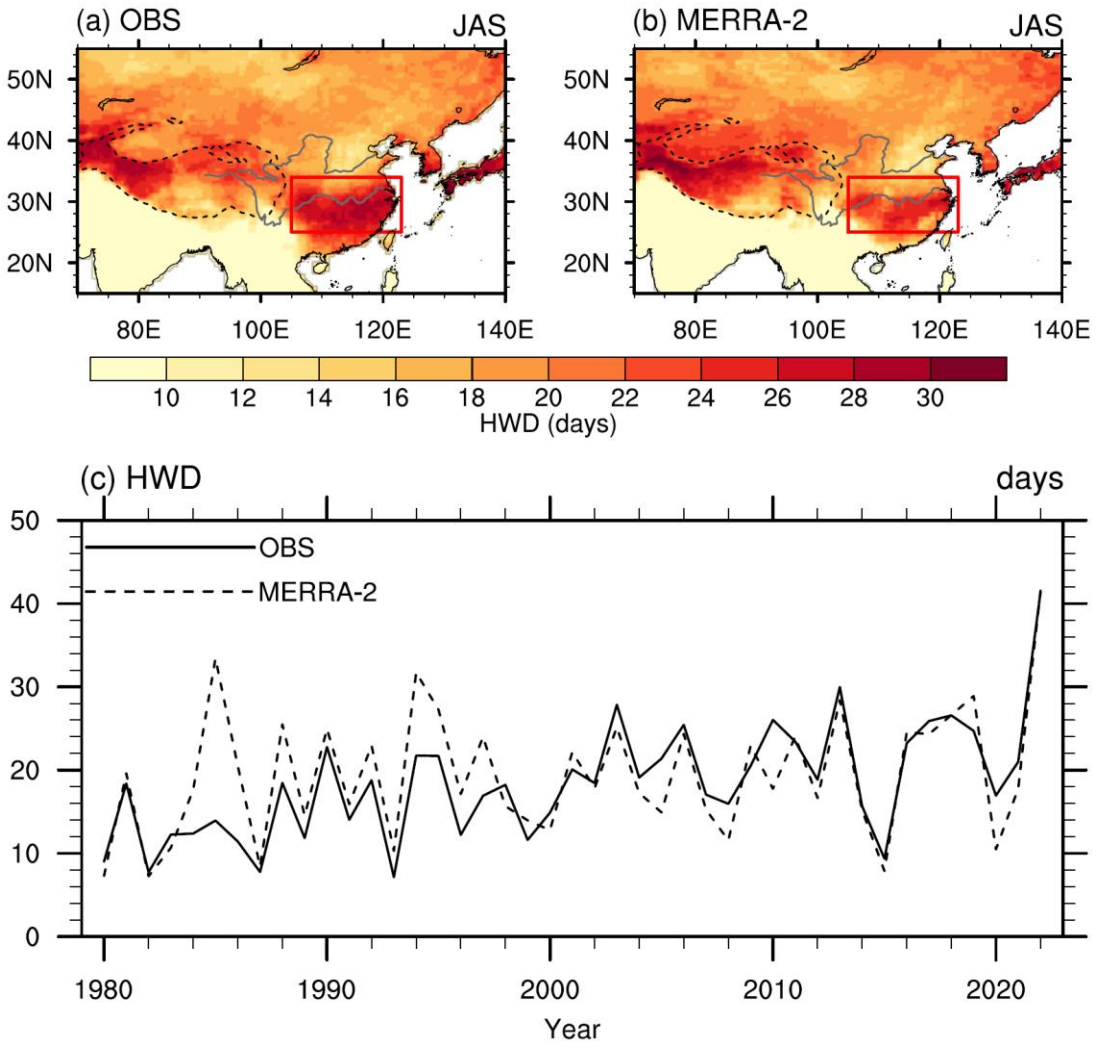
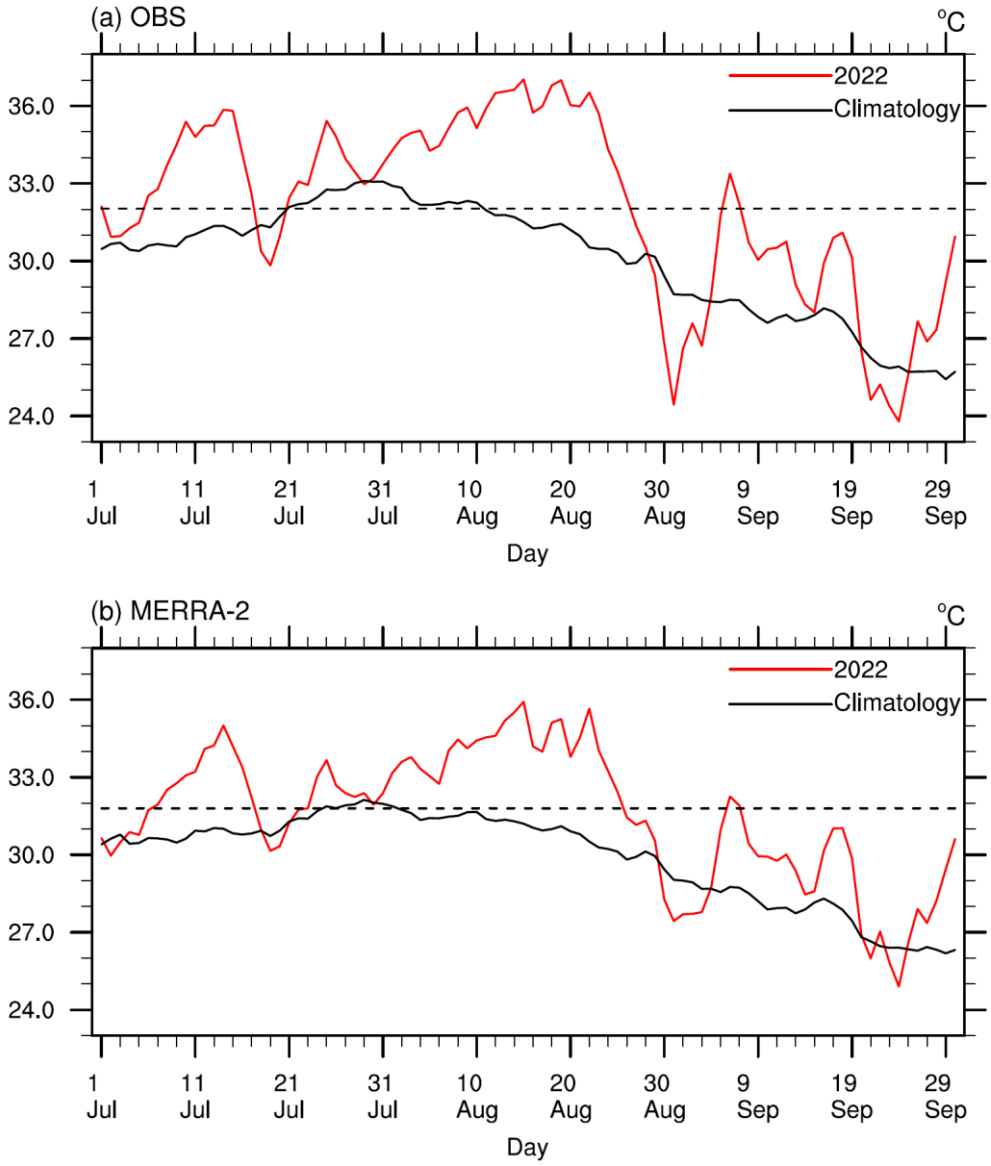
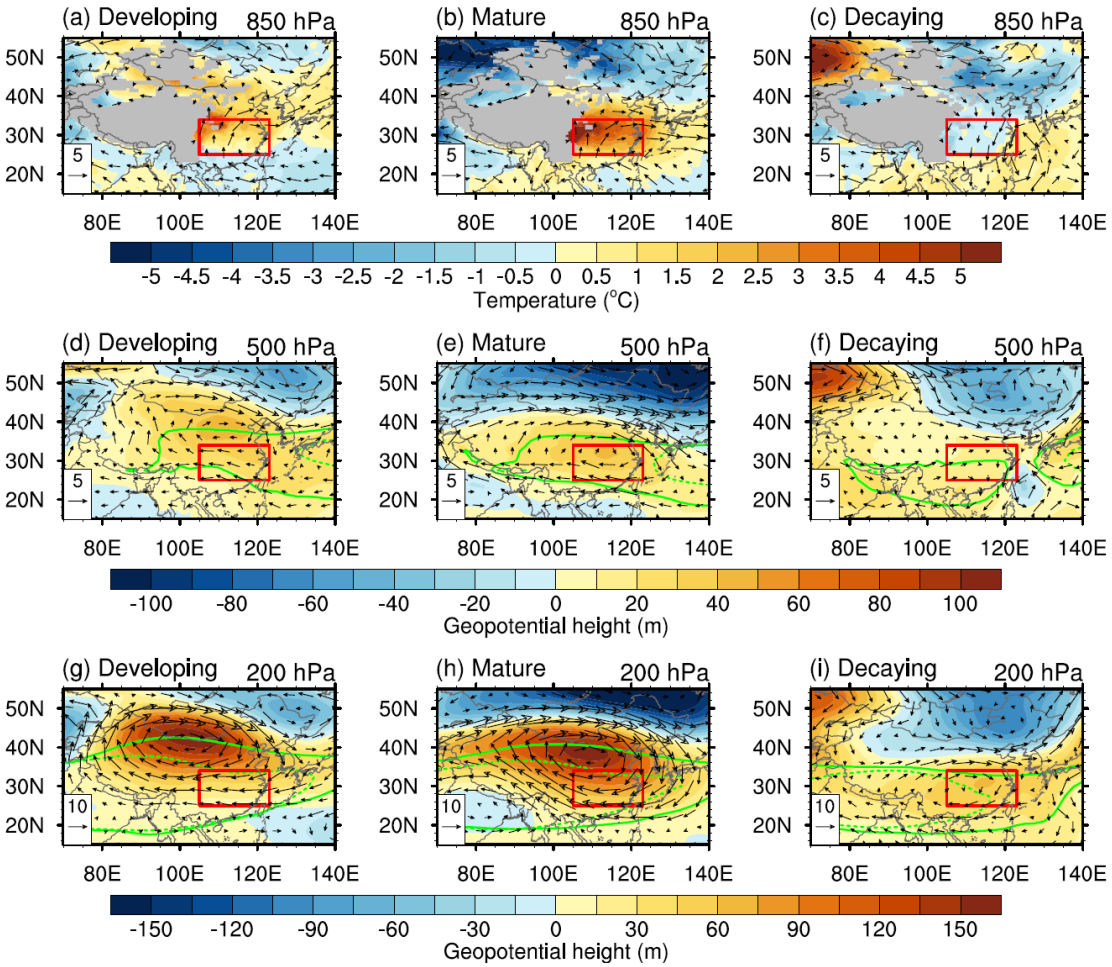


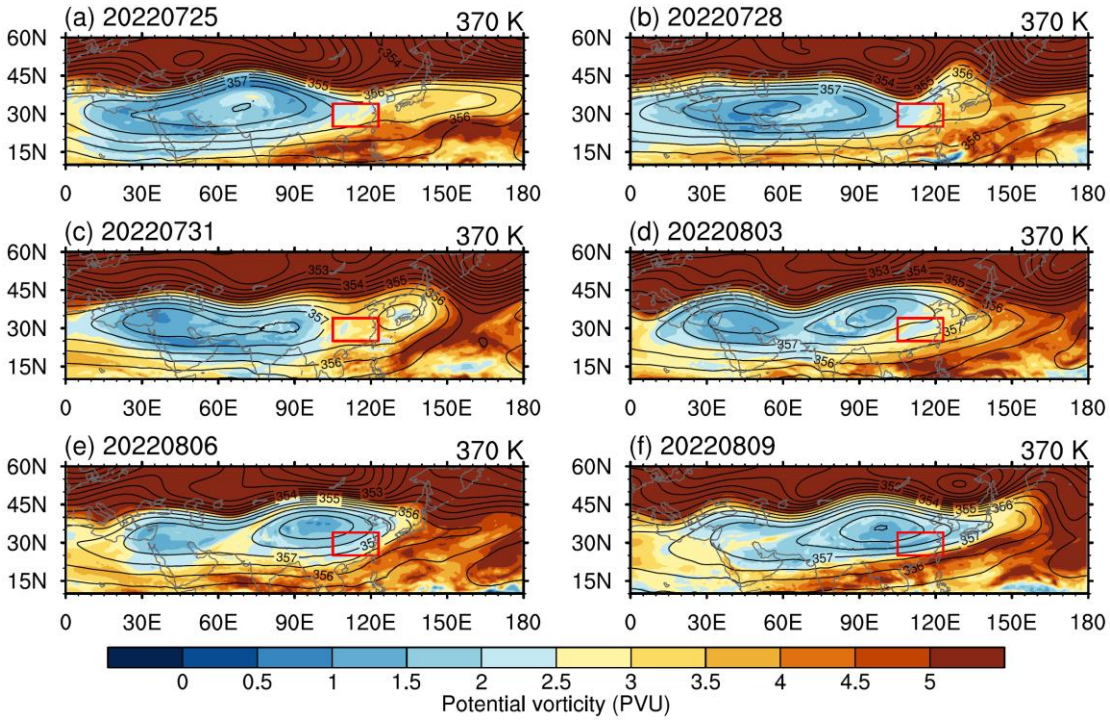
Supplementary Figure 1 | Number of heatwave days in the mid-late summer (July-September) over central-eastern China. Spatial patterns of climatological (2003-2022) heatwave days in (**a**) the Climate Prediction Center Global Unified Temperature dataset and (**b**) the Modern-Era Retrospective Analysis for Research and Application version 2 (MERRA-2) reanalysis. (**c**) Time series of area-averaged heatwave days over central-eastern China from 1980 to 2022. The domain of central-eastern China is outlined by the red box in (**a-b**). The solid and dashed lines in (**c**) denote the results from the Climate Prediction Center Global Unified Temperature dataset and the MERRA-2 reanalysis, respectively.



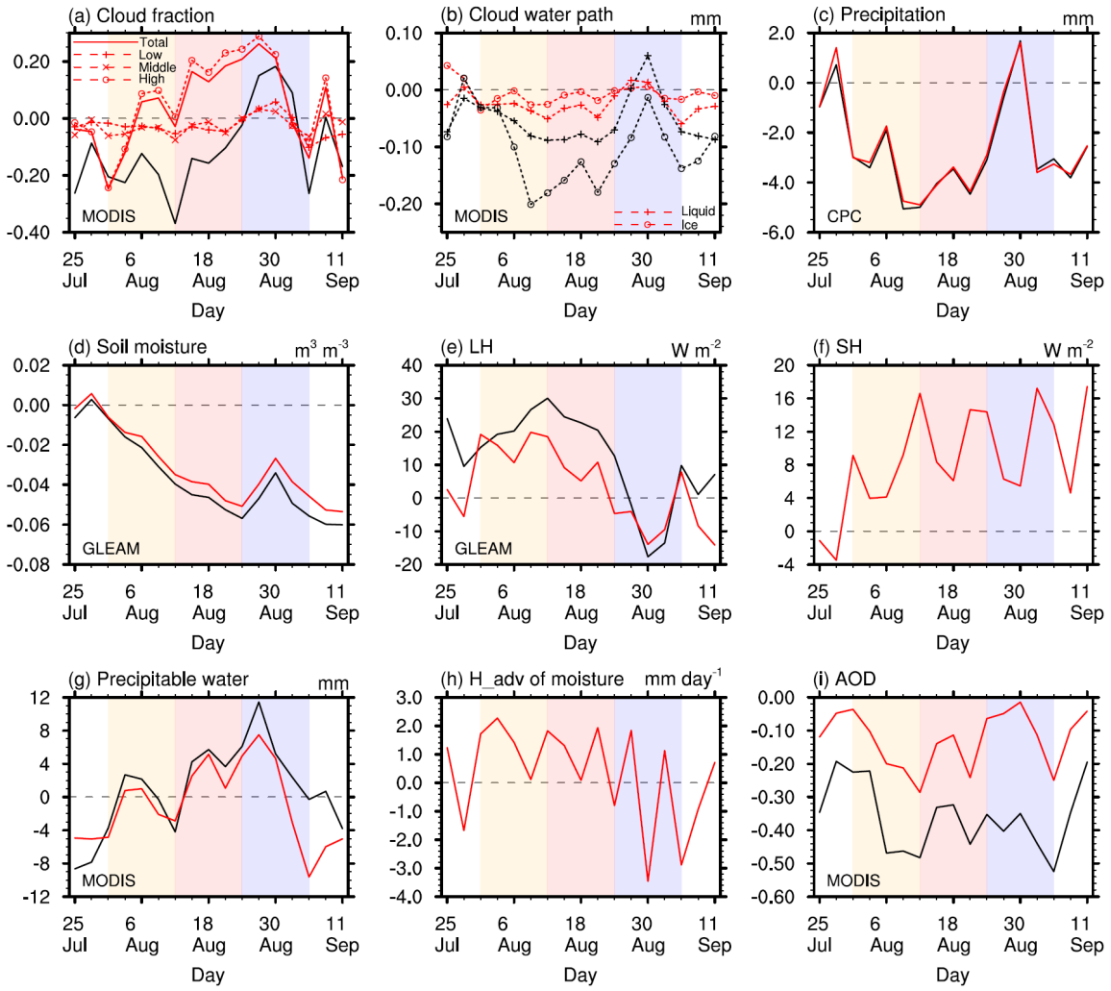
Supplementary Figure 2 | Evolution of temperature over central-eastern China during the mid-late summer (July-September). The results obtained from the Climate Prediction Center Global Unified Temperature dataset and the Modern-Era Retrospective Analysis for Research and Application version 2 reanalysis are presented in (**a**) and (**b**), respectively. The black and red lines denote the area-averaged maximum 2-m air temperature (°C) in climatology (2003-2022) and 2022, respectively. The black dashed line represents the area-averaged 90th percentile of the daily maximum 2-m air temperature in the climatological period of 2003-2022.



Supplementary Figure 3 | Evolution of atmospheric circulations in the life cycle of mega-heatwave. Composite patterns of temperature (°C; shading) and winds (m s^{-1}; vector) at (**a-c**) 850-hPa and composite patterns of geopotential height (m; shading) and winds (m s^{-1}; vector) at (**d-f**) 500 hPa and (**g-i**) 200 hPa during the developing (**a**, **d**, and **g**), mature (**b**, **e**, and **h**), and decaying (**c**, **f**, and **i**) phases of the mega-heatwave. The green solid and dashed lines (5880 m contour) in (**d-f**) mark the position of the western North Pacific subtropical high in 2022 and climatology (2003-2022), respectively. The green solid and dashed lines (12520 m contour) in (**g-i**) mark the position of the Asian monsoon anticyclone in 2022 and climatology (2003-2022), respectively. The domain of central-eastern China is outlined by the red box.



Supplementary Figure 4 | Evolution of eastward shedding eddy during the developing of mega-heatwave. 3-day mean potential vorticity (PVU, 1 PVU = 10^6 K kg^{-1} m^2 s^{-1}; shading) and Montgomery streamfunction (kJ kg^{-1}) on the 370 K isentropic surface on (**a**) 25 July 2022, (**b**) 28 July 2022, (**c**) 31 July 2022, (**d**) 3 Aug 2022, (**e**) 6 August 2022, and (**f**) 9 August 2022. The domain of central-eastern China is outlined by the red box.



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59 **Supplementary Figure 5 | Evolution of the associated variables during the life cycle**

60 **of mega-heatwave.** The anomalies of (**a**) cloud fraction, (**b**) cloud water path (mm), (**c**)

61 precipitation amount (mm), (**d**) soil moisture (m^3 m^{-3}), (**e**) surface latent heat flux (W

62 m^{-2}), (**f**) surface sensible heat flux (W m^{-2}), (**g**) precipitable water (mm), (**h**) horizontal

63 advection of water vapor (mm day^{-1}), and (**i**) aerosol optical depth from 25 July to 11

64 September of 2022. The black lines denote the results from observational datasets, and

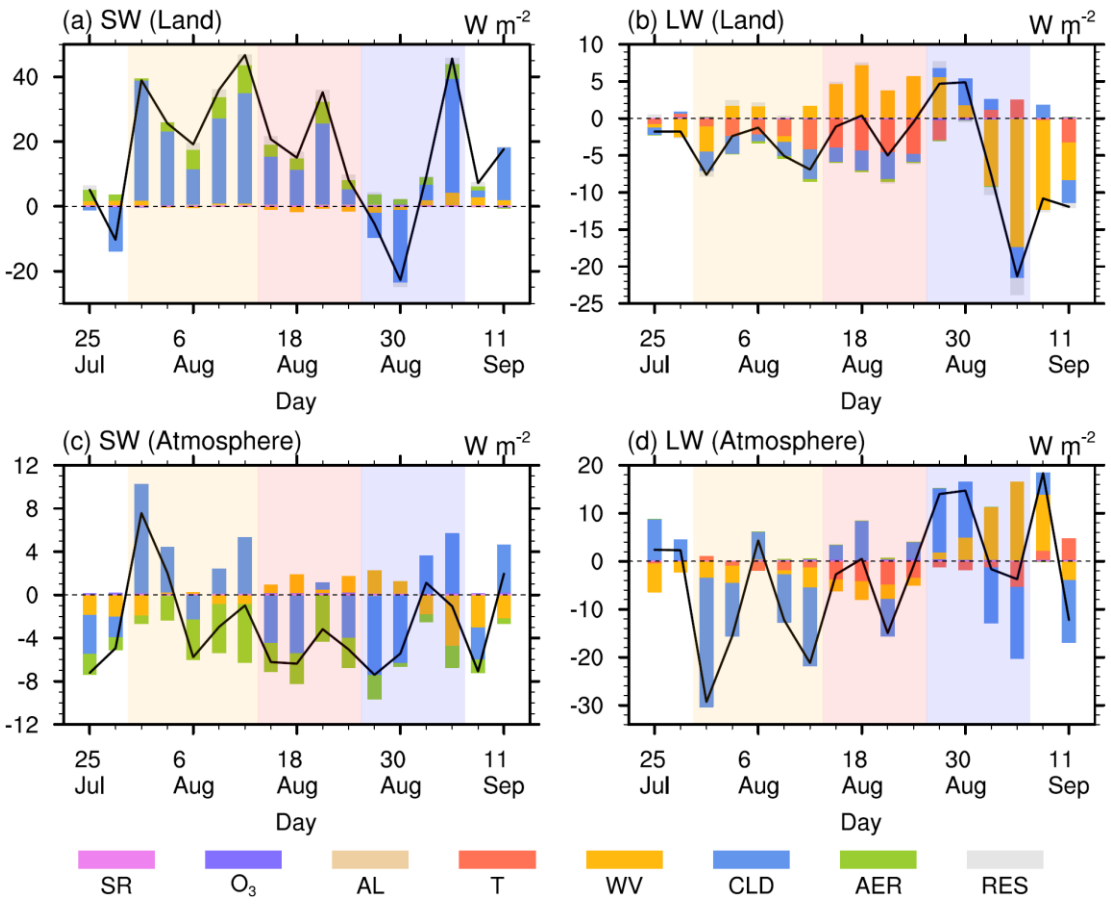
65 the red lines denote those from the Modern-Era Retrospective Analysis for Research

66 and Application version 2 reanalysis. The solid line, dashed line with plus signs, dashed

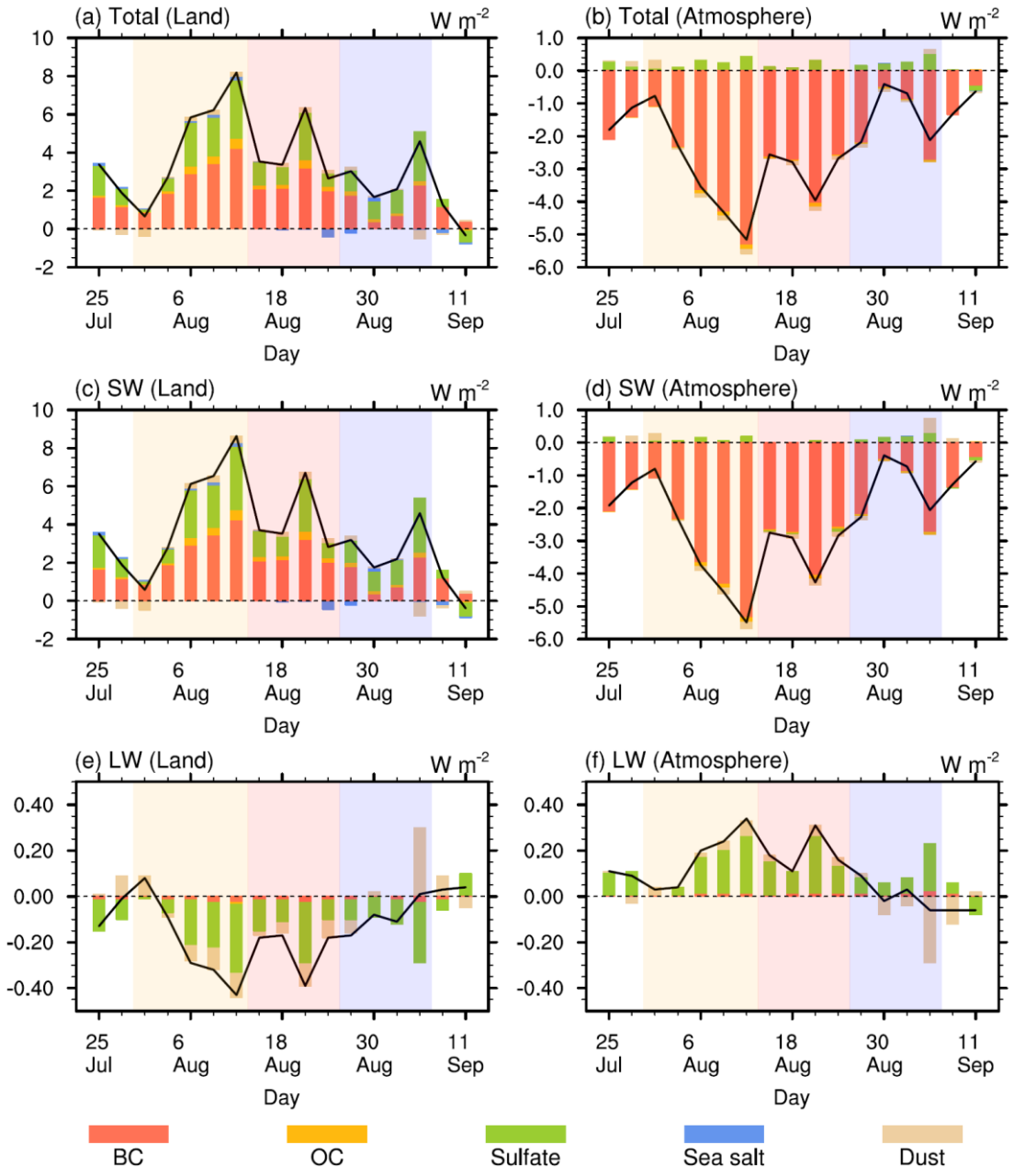
67 line with multiply signs, and dashed line with circles in (**a**) represent total cloud fraction,

68 cloud fraction for low clouds, cloud fraction for middle clouds, and cloud fraction for

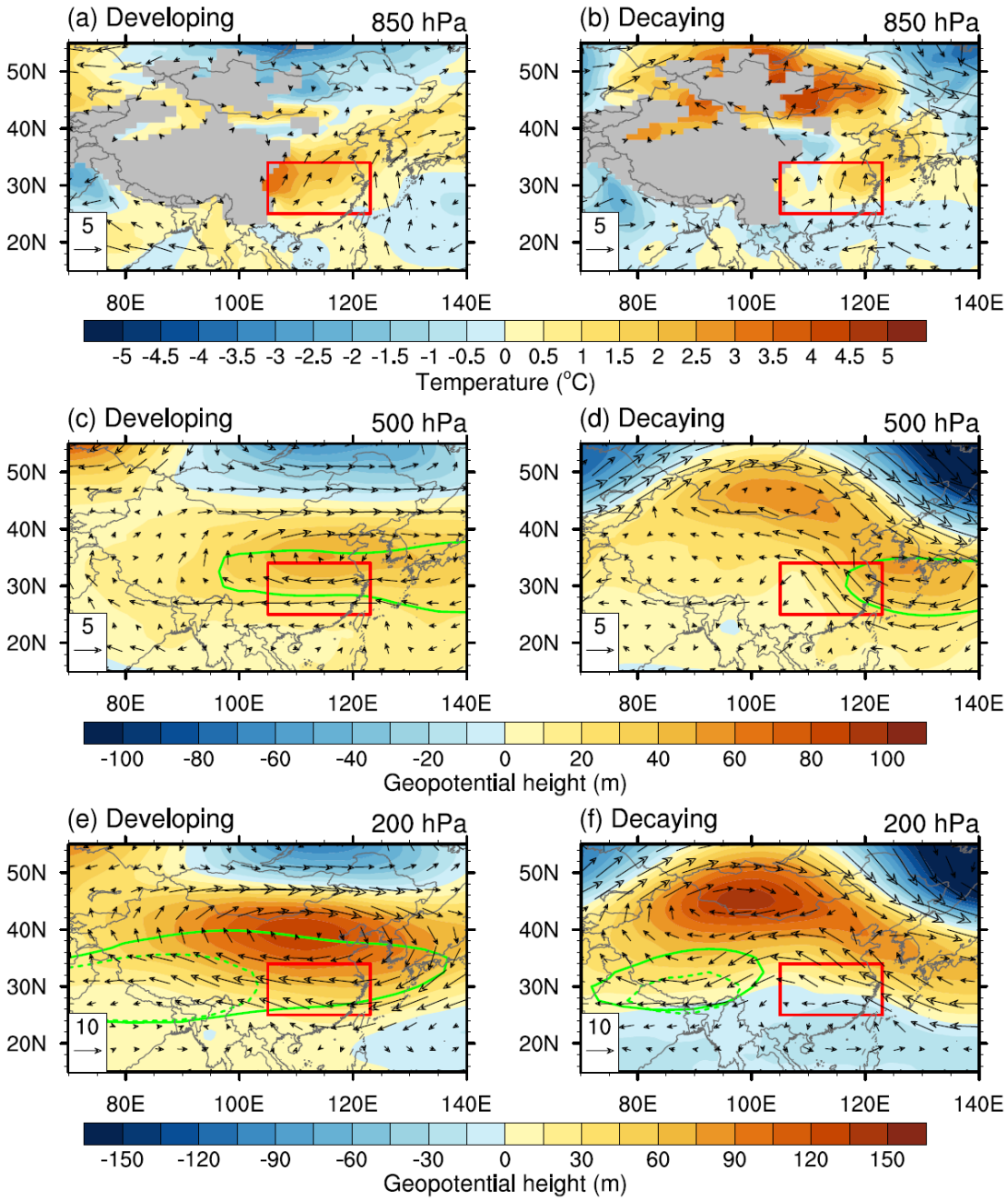
high clouds, respectively. The dashed line with plus signs and that with circles in (**b**) represent cloud liquid water path (mm) and cloud ice water path (mm).



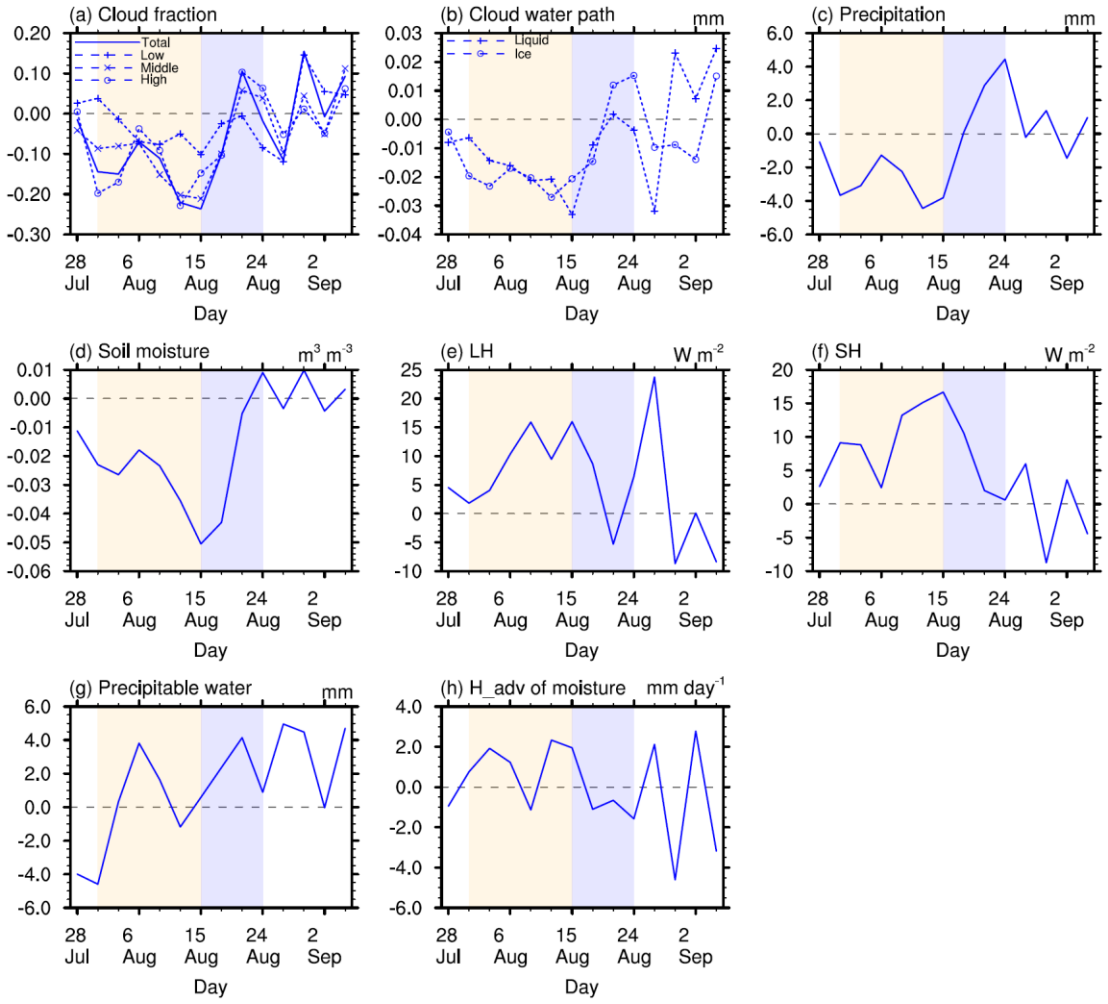
Supplementary Figure 6 | The shortwave and longwave radiative effects associated with different radiative processes. The (**a** and **c**) shortwave and (**b** and **d)** longwave radiative energy perturbations (W m^{-2}) for (**a-b**) land surface and (**c-d**) atmosphere associated with different radiative processes and their sums (black lines). The abbreviations "SR", "O_3", "AL", "T", "WV", "CLD", "AER", and "RES" stand for the processes of changes in solar insolation, ozone, surface albedo, temperature, water vapor, cloud, aerosols, and residual, respectively.



Supplementary Figure 7 | The shortwave and longwave radiative effects associated with the changes in different types of aerosols. The (**a-b**) total, (**c-d**) shortwave, and (**e-f**) longwave radiative energy perturbations (W m^{-2}) for (**a**, **c**, and **e**) land and (**b**, **d**, and **f**) atmosphere associated with the changes in different types of aerosols and their sums (black lines). The coral, orange, green, blue, and grayish yellow colors represent the effects of black carbon, organic carbon, sulfate, sea salt, and dust, respectively.



Supplementary Figure 8 | Prediction of the anomalous atmospheric circulations in the life cycle of mega-heatwave. (**a**), (**c**), and (**e**) are the same as in Supplementary Figure 3a, 3d, and 3g, and (**b**), (**d**), and (**f**) are the same as in Supplementary Figure 3c, 3f, and 3i, except for the results obtained from the Climate Forecast System version 2. The domain of central-eastern China is outlined by the red box.



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98 **Supplementary Figure 9 | Predicted evolution of the associated variables during**

99 **the life cycle of mega-heatwave.** Same as in Supplementary Figs. 5a-h, except for the

100 results obtained from the Climate Forecast System version 2.

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