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Supplementary Materials for

Orographic evolution of northern Tibet shaped vegetation and plant diversity in eastern Asia

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The PDF file includes:

Supplementary Text
Figs. S1 to S12
Legends for data S1 and S2
References

Other Supplementary Material for this manuscript includes the following:

(available at advances.sciencemag.org/cgi/content/full/7/5/eabc7741/DC1)

Data S1 and S2

Supplementary Text

Select four simulations

We select four key simulations by comparing simulated SDGVM results with paleobotanical data and considering possible Tibetan orogenic development for the key parts of Tibet, including the Songpan-Ganzi, Qiangtang, Lhasa terranes, and the Gangdese Mountains (*3*, *12*, *13*, *21–23*).

The low elevation Tibetan experiments (flat Tibet, 1000 m Tibet, 2000 m Tibet, and half Tibet; fig. S3, B–D and G) indicate broadleaf deciduous forest covered large area of eastern Asia and south Asia (fig. S4, B–D and G), and barren or grassland vegetation (mainly are C3 type) occupied large regions in the north-western part of east Asia. When the Gangdese Mountains (fig. S3J) or Lhasa Terrane uplifted (fig. S3K), the northern Tibet changed from grassland to barren, but the deciduous broadleaf forest still distributed over a large area in eastern Asia, only sparse regions were covered with evergreen broadleaf (fig. S4, J and K). A number of studies suggest that the Gangdese Mountains and Lhasa Terrane already uplifted during the Paleogene (*12*, *21*, *52–53*), therefore we choose the high Gangdese Mountains and Lhasa Terrane, to represent the late Paleogene development of the Tibet.

When the Qiangtang Terrane uplifted, the SDGVM simulations yielded a larger proportion of evergreen broadleaf forest in eastern Asia (fig. S4, L and N) than that from low Tibet (fig. S4, B–D and G) and the Gangdese mountains or Lhasa Terrane uplift (fig. S4, J and K). The paleoelevation in the Qiangtang Terrane remains controversial due to lacking sufficient enough evidence. The oxygen isotope data from the northern Qiangtang Terrane suggested high elevation (>5000 m) from at least the Oligocene in that region (*61*), however recent modelling works argued that paleoaltitudes calculated from stable isotopes are suspectable due to the complex structure of the topography, especially in the north Tibet where the south Tibetan topography can dramatically change the altimetry–isotope ratio relationship by altering atmospheric circulation patterns (*49*). Moreover, recent fossil evidence showed the elevation of northern Tibet was still lower (<2000 m) than the south part of Tibet during the Oligocene, only in that condition can the mammals migrate from north to south (*48*).

The Songpan-Ganzi Terrane uplift (fig. S4, M and O) has larger evergreen broadleaf forest than that of the Gangdese Mountains, Lhasa and Qiangtang terranes uplifts (fig. S4, J–L and N). A number of studies generally agree that this region was still low (< 2000 m) during the Paleogene and may uplift during the Miocene (*12*, *62–63*). Considering fossil and geological data—dry or seasonal dry vegetation was changed to subtropical forests in the east of China from the Paleogene to Neogene, we can infer that the north and north-eastern Tibet may uplift after the Oligocene. So, we choose Qiangtang and Songpan-Ganzi terranes as the post-Oligocene growth regions.

The SDGVM results show the uplifts of Himalaya Mountains, Qaidam Basin and Qilian Mountains, as well as Hengduan Mountains only slightly affected vegetation in eastern Asia (fig. S4, P, Q and R) comparing to the Qiangtang and Songpan-Ganzi terranes. This is consistent with studies that show that the Himalaya and Qilian Mts. may uplift in the late of Neogene (*13*, *64*); while the Hengduan Mts. are still under debate comparing with fossil records (*32*, *46*, *47*), which show there were sub-tropical or temperate forest in this region before the Oligocene. Because the simulated vegetation changed only slightly and it hard to compare with fossil data, so the impacts of the orogeny in these regions are not discussed in this work.

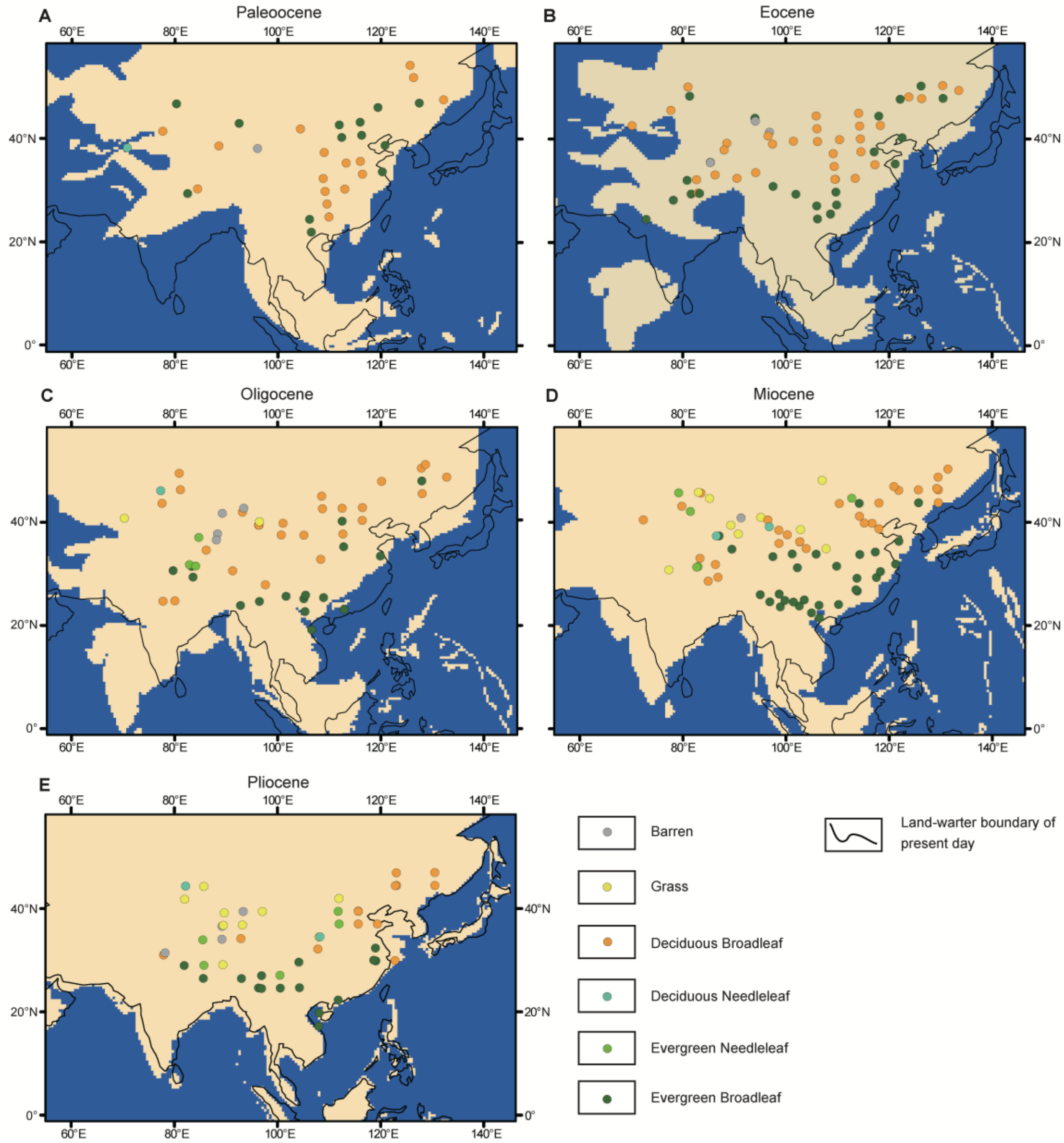

Fig. S1. The Cenozoic vegetation maps defined as the Sheffield Dynamic Global Vegetation Model (SDGVM) in China. Land–sea mask data are derived from Getech Group plc. paleogeographic data (*25*). A detailed description of the fossil data is included in the data S1.

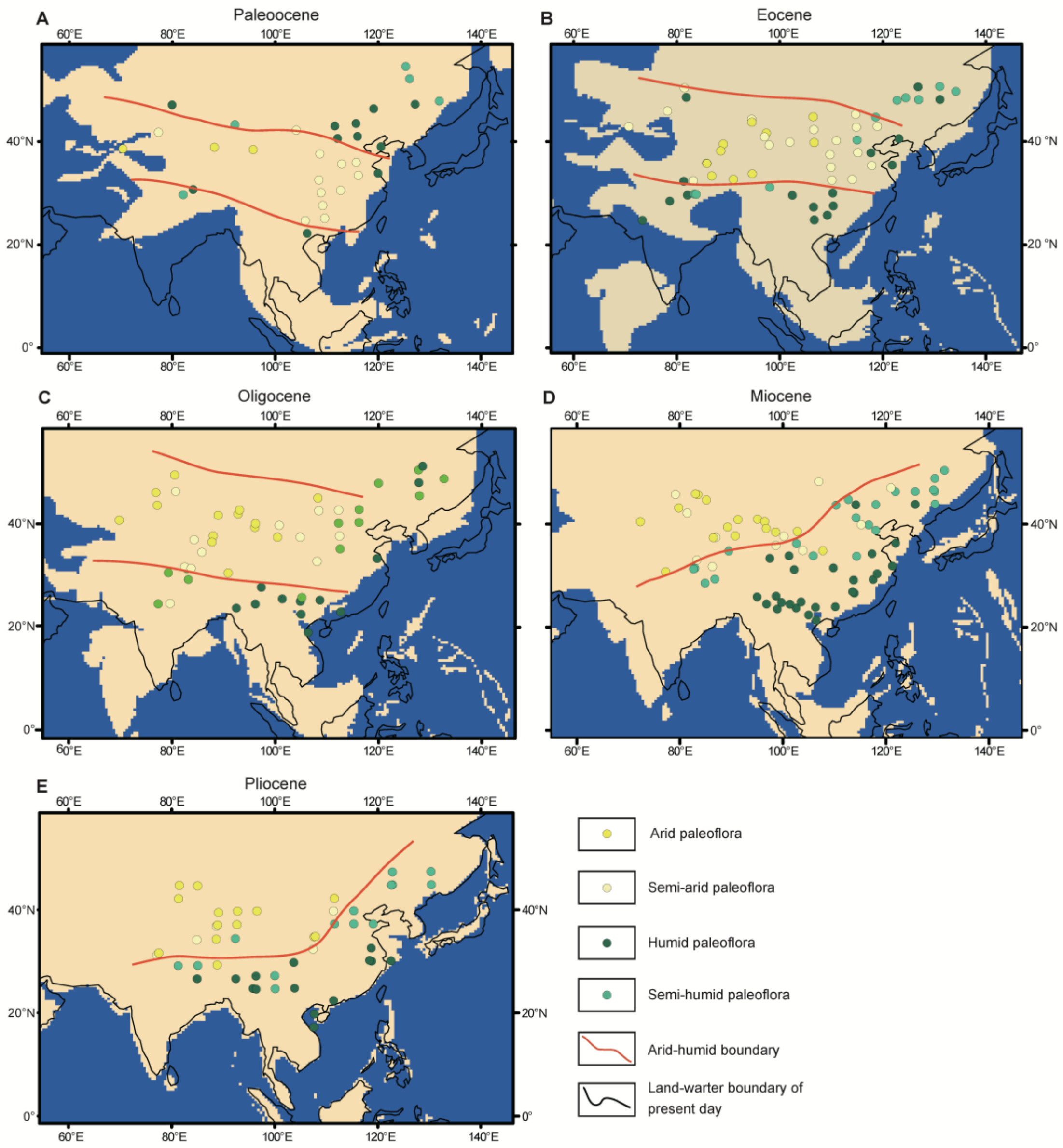

Fig. S2. Simplified maps showing dry-humid boundary of the Cenozoic vegetation changes in China. The vegetation types are defined as arid, semi-arid, humid and semi-humid types. A detailed description of the fossil data is included in the data S1.

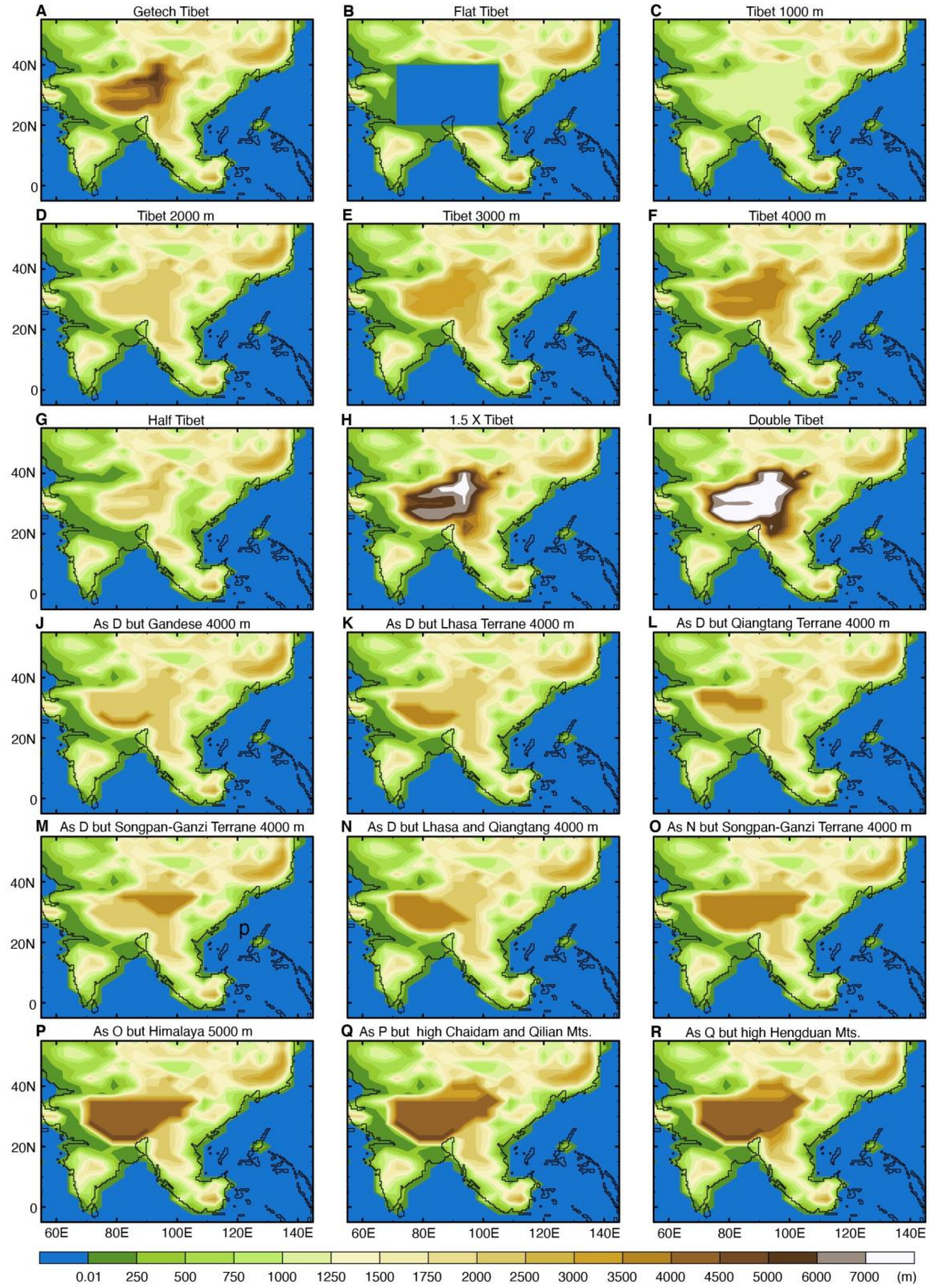

Fig. S3. Designed 18 experiments with different Tibetan Plateau topographies. See data S2 for the details.

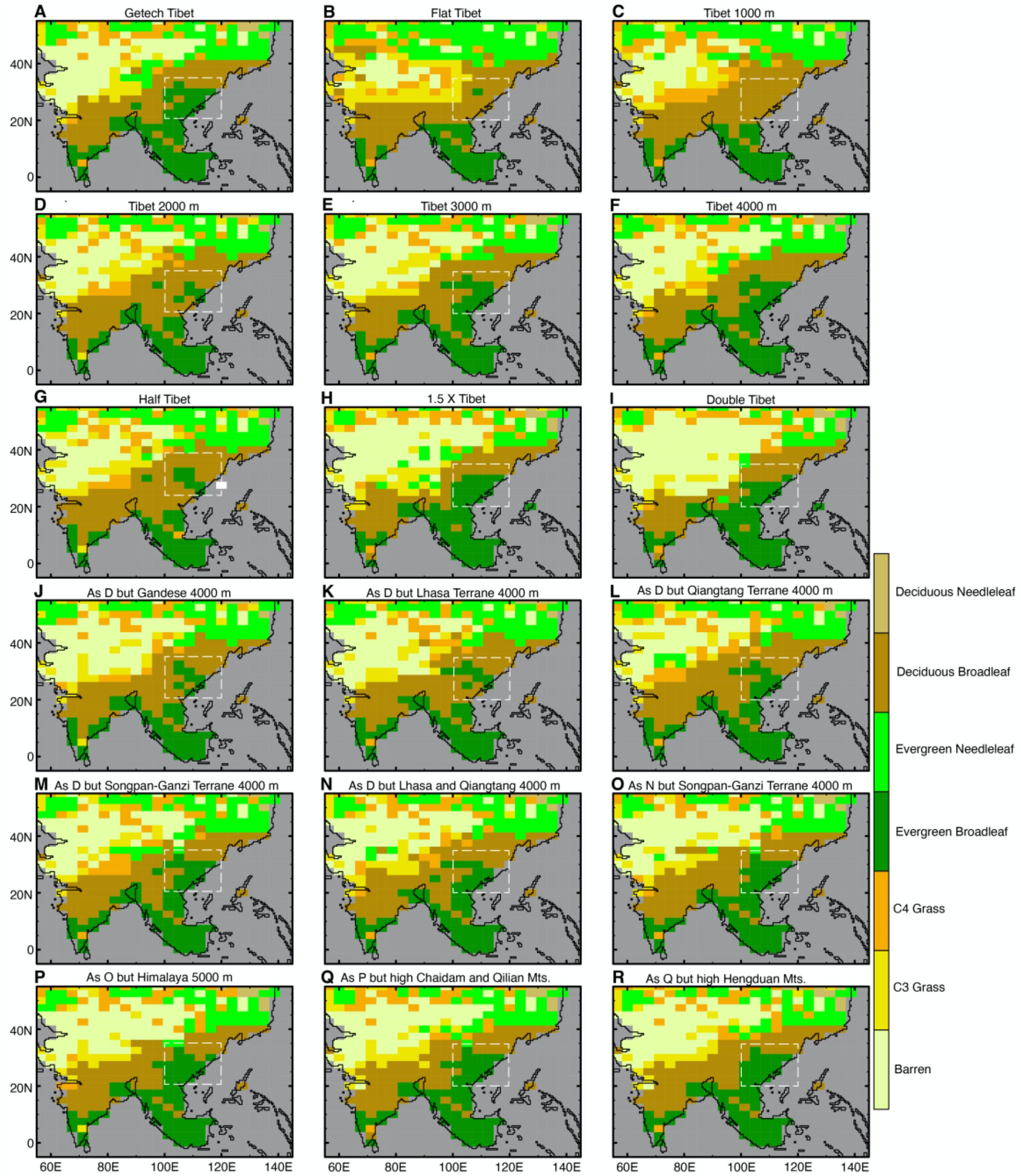

Fig. S4. The Sheffield Dynamic Global Vegetation Model (SDGVM) results are derived from 18 experiments. The white dashed boxes indicate the south-eastern Asia region (100°–120°E, 20°–35°N) discussed in main text. See data S2 for the detailed experiment information.

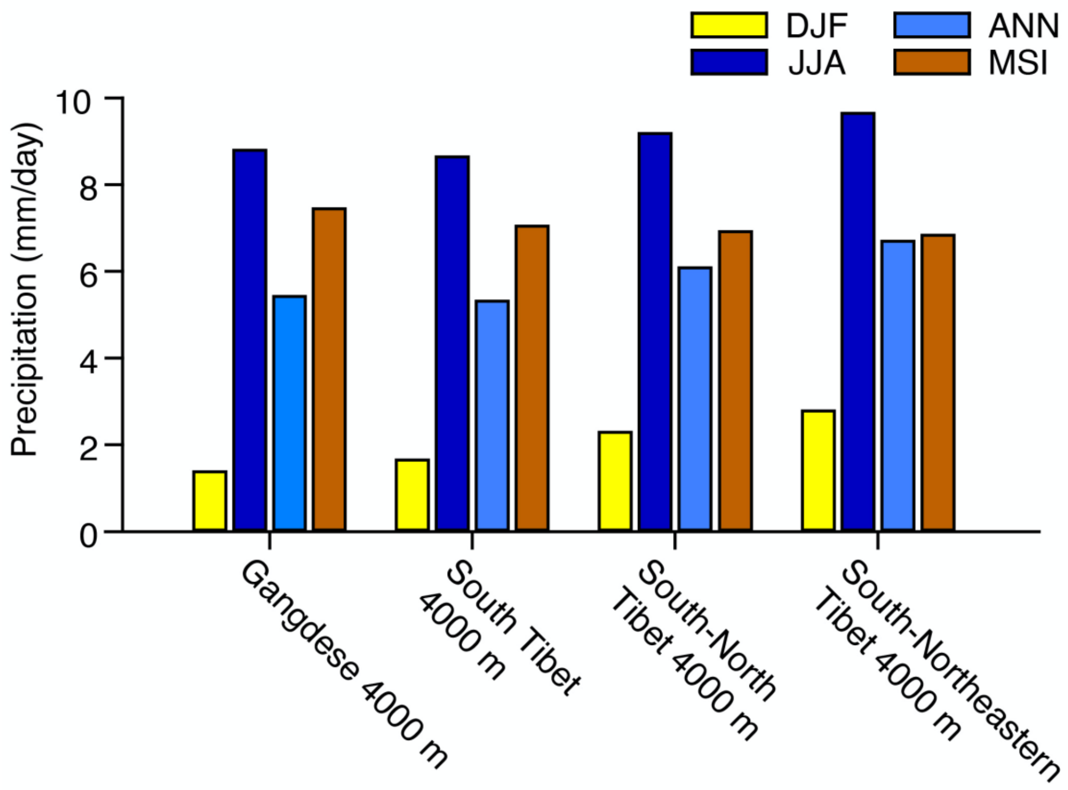

Fig. S5. Precipitation change comparison. The data for the driest season (DJF), wettest season (JJA) precipitation, annual precipitation (ANN) and monsoon seasonality index (MSI; see methods for definition) changes are calculated from south-eastern Asia (the terrestrial region of 100°–120°E, 20°–35°N) from four selected simulations. See supplementary text for details of simulation selection.

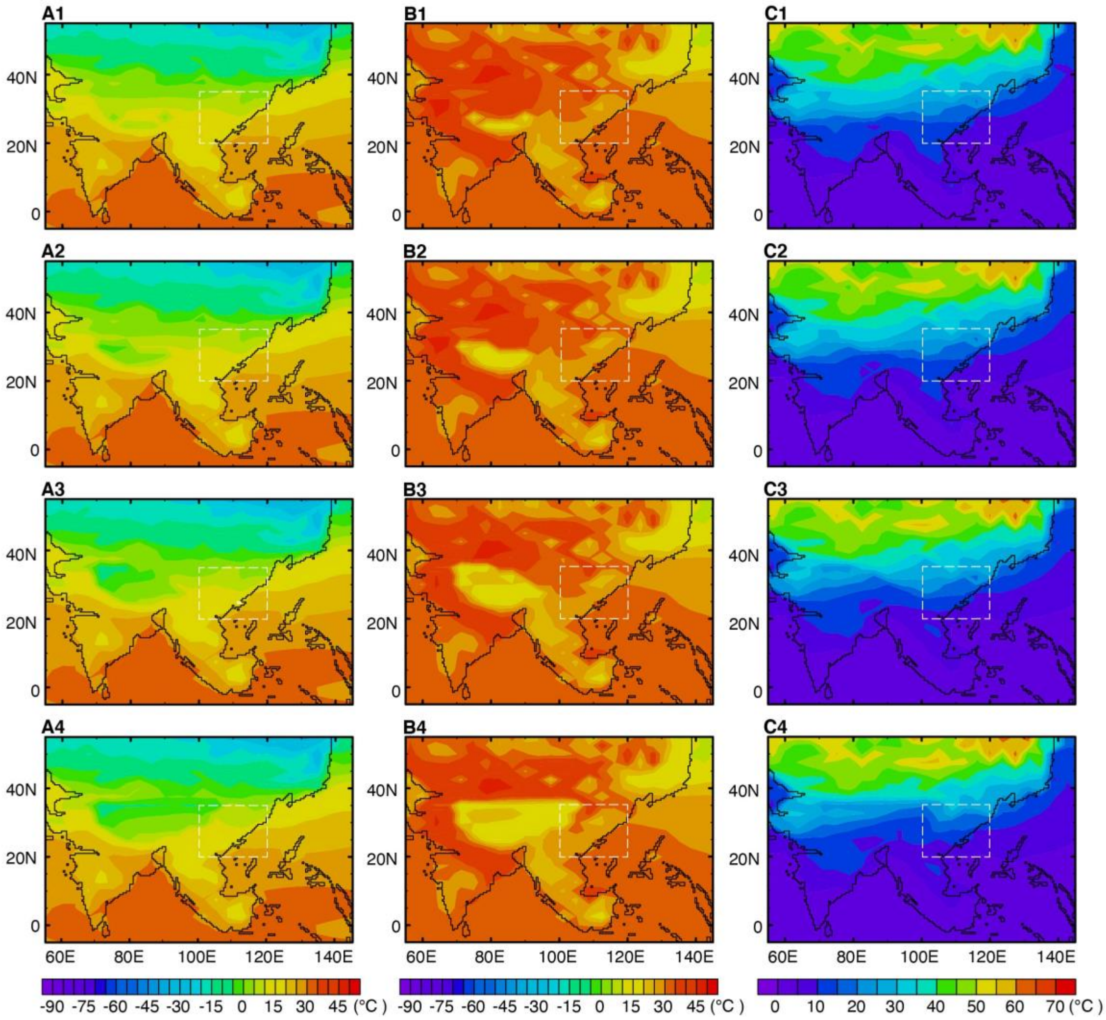

Fig. S6. Simulated temperature results from selected four experiments with different Tibetan Plateau topographies. A1–A4 show the coldest season (DJF, winter) mean surface air temperature; B1–B4 show warmest season (JJA, summer) mean surface air temperature; C1–C4 show temperature seasonality (warmest-coldest season temperature difference). The white color dashed boxes indicate the south-eastern Asia region (100°–120°E, 20°–35°N) discussed in the main text. See supplementary text for more details for the selection of four simulations.

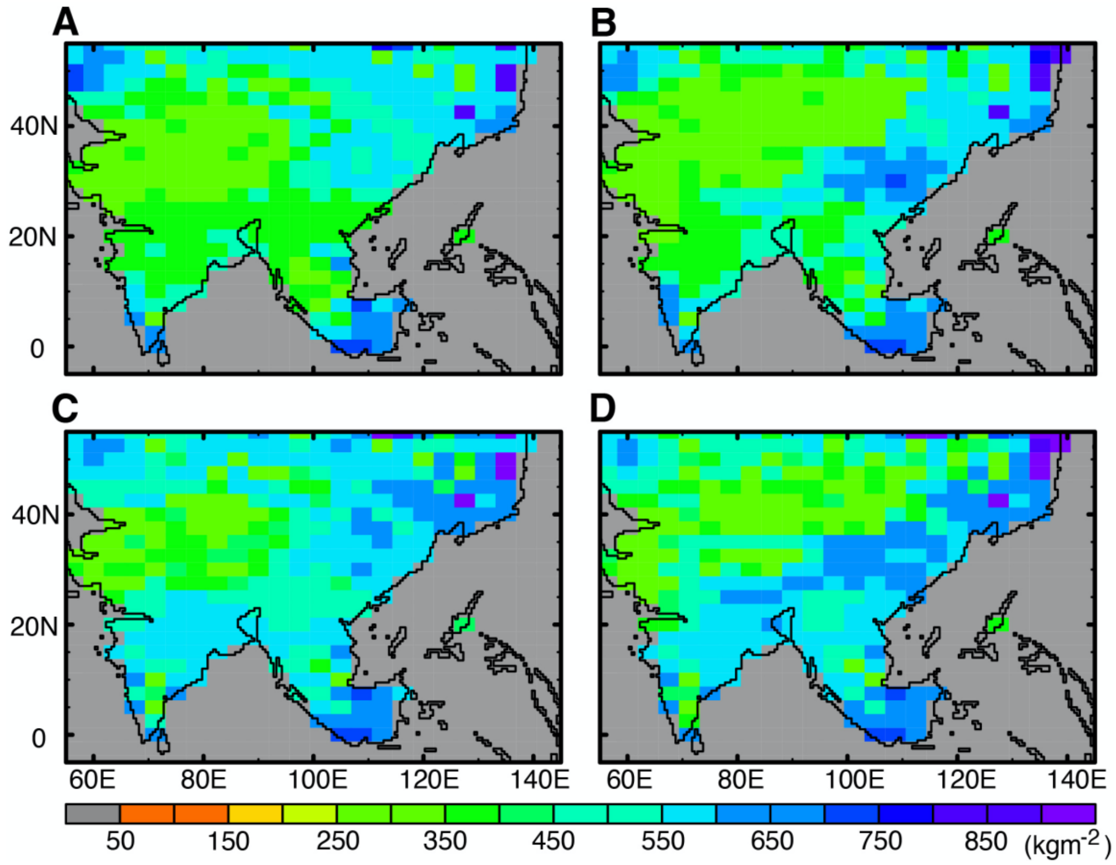

Fig. S7. Simulated soil moisture in dry season (DJF). The top panel show soil moisture in layer 3 (40–100 cm), the bottom panel show soil moisture in layer 4 (100–200 cm), for a low Tibet (1000 m; A, C) and a high Tibet (Lhasa, Qiangtang and Songpan-Ganzi terranes are 4000 m high; B, D) respectively.

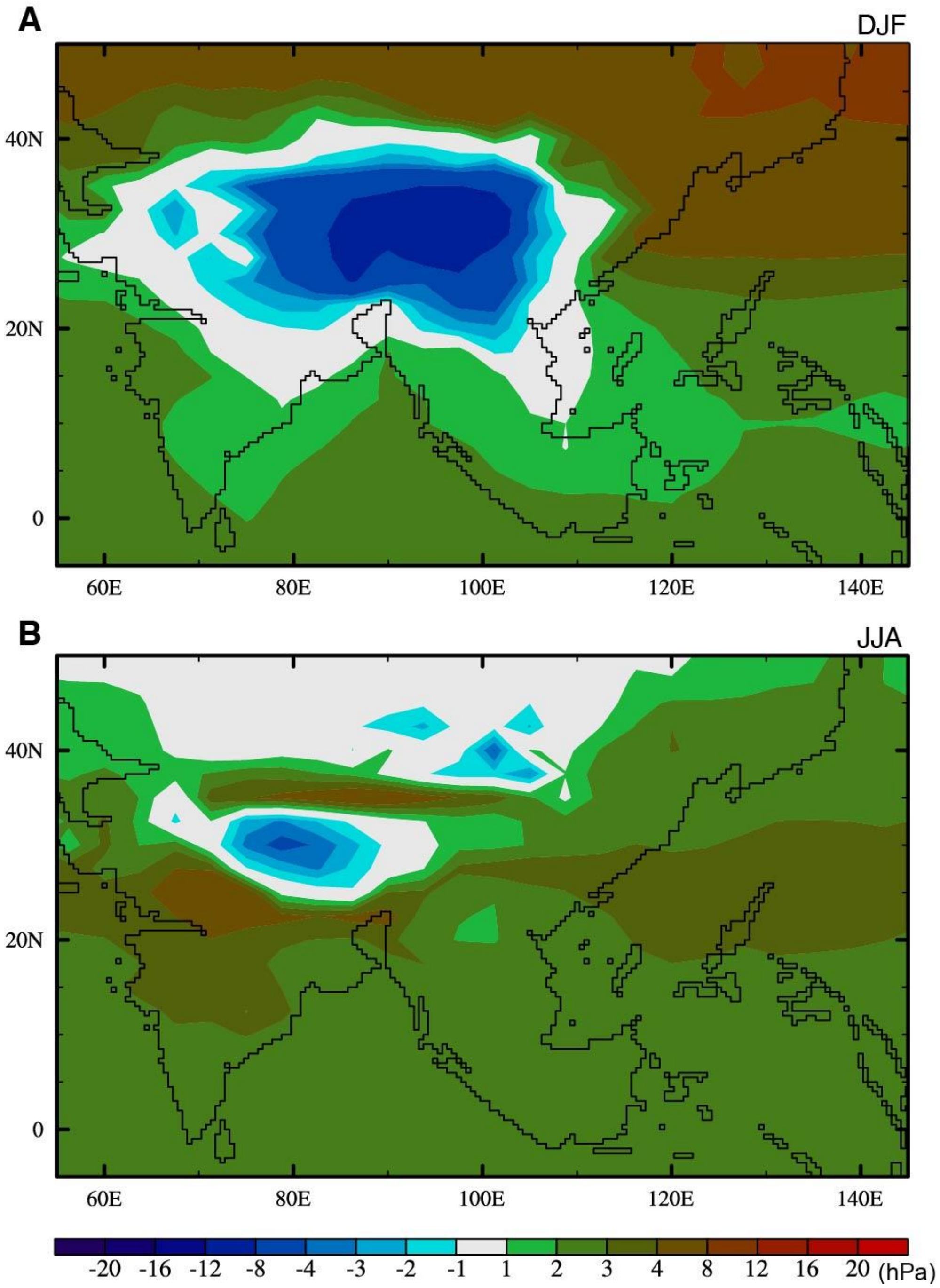

Fig. S8. Anomalies of the mean sea level pressure between high Tibet and low Tibet experiments. The mean sea level pressure anomalies are the differences between a high Tibet (Lhasa, Qiangtang and Songpan-Ganzi terranes are 4000 m high) and a low Tibet (1000 m) in winter (DJF) and summer (JJA) respectively.

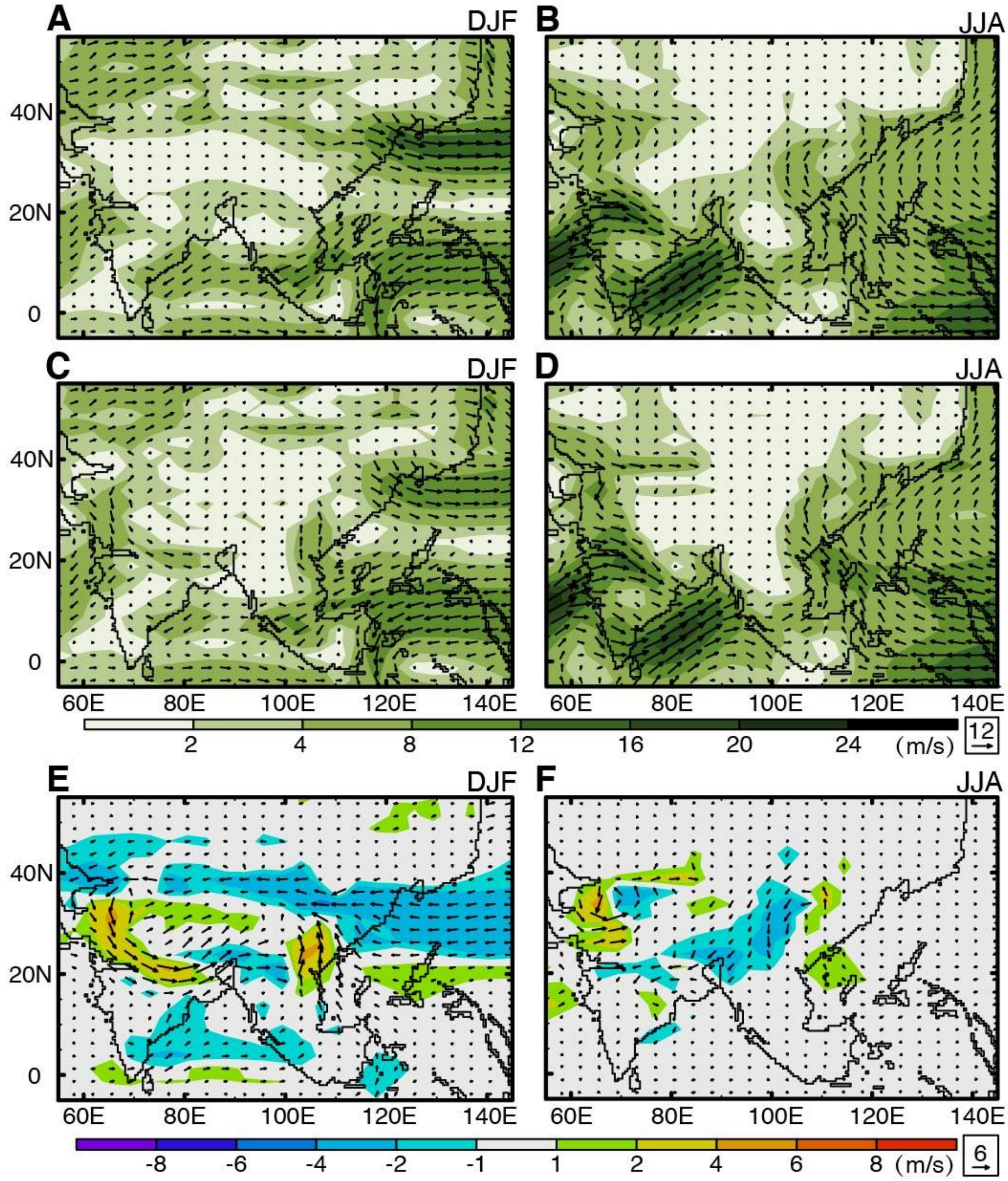

Fig. S9. Tropospheric winds at 850 hPa (in m/s). The top panel (A and B) and middle panel (C and D) show a low Tibet (1000 m) and a high Tibet (Lhasa, Qiangtang and Songpan-Ganzi terranes are 4000 m high) in winter (DJF) and summer (JJA) respectively. The bottom panel (E and F) show the differences between a high Tibet and a low Tibet experiment in winter (DJF) and summer (JJA) respectively.

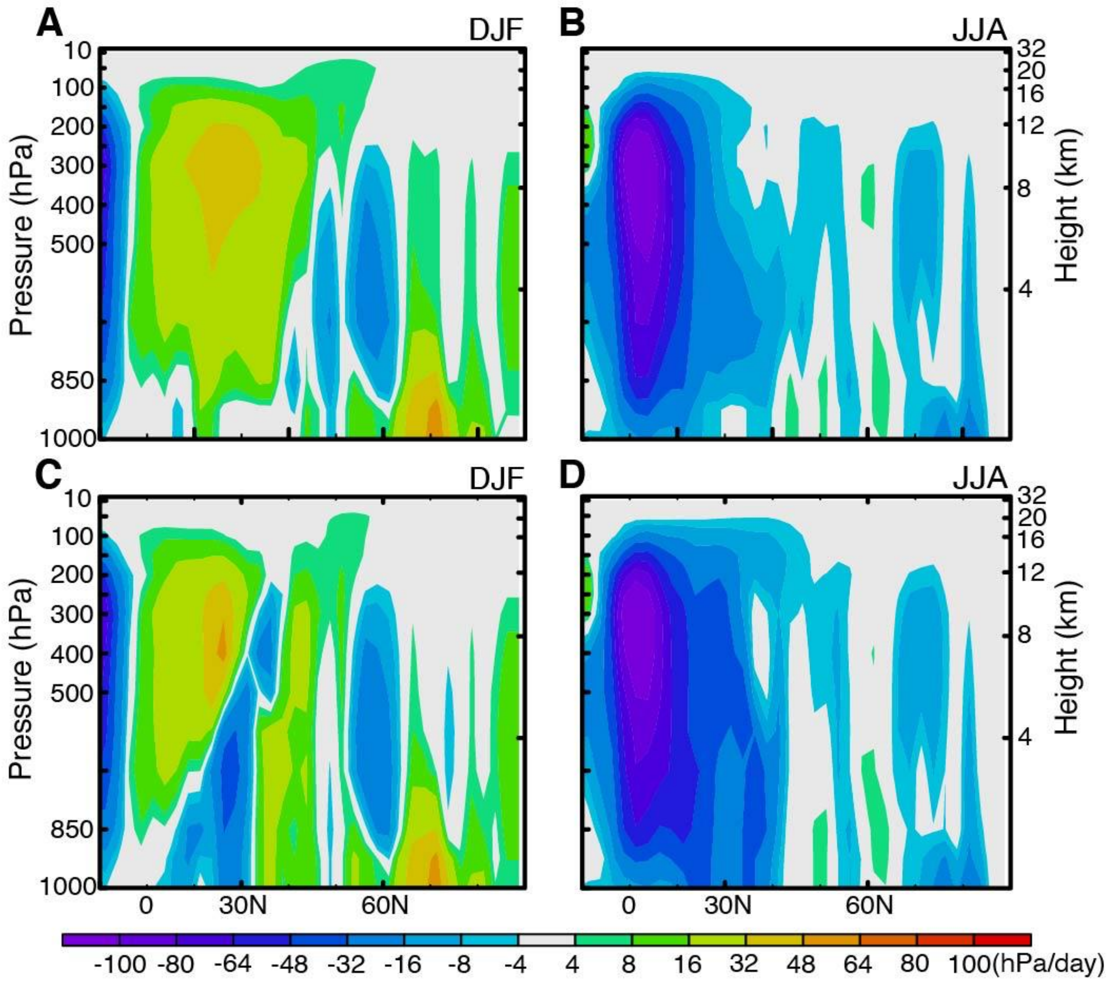

Fig. S10. Vertical velocity (in hPa/day) comparison. The upper panel (A and B) and lower panel (C and D) show a low Tibet (1000 m) and a high Tibet (the Lhasa, Qiangtang and Songpan-Ganzi terranes are 4000 m high) in winter (DJF) and summer (JJA) respectively. The vertical velocity values are calculated from a cross section of mean value of 80°–110°E.

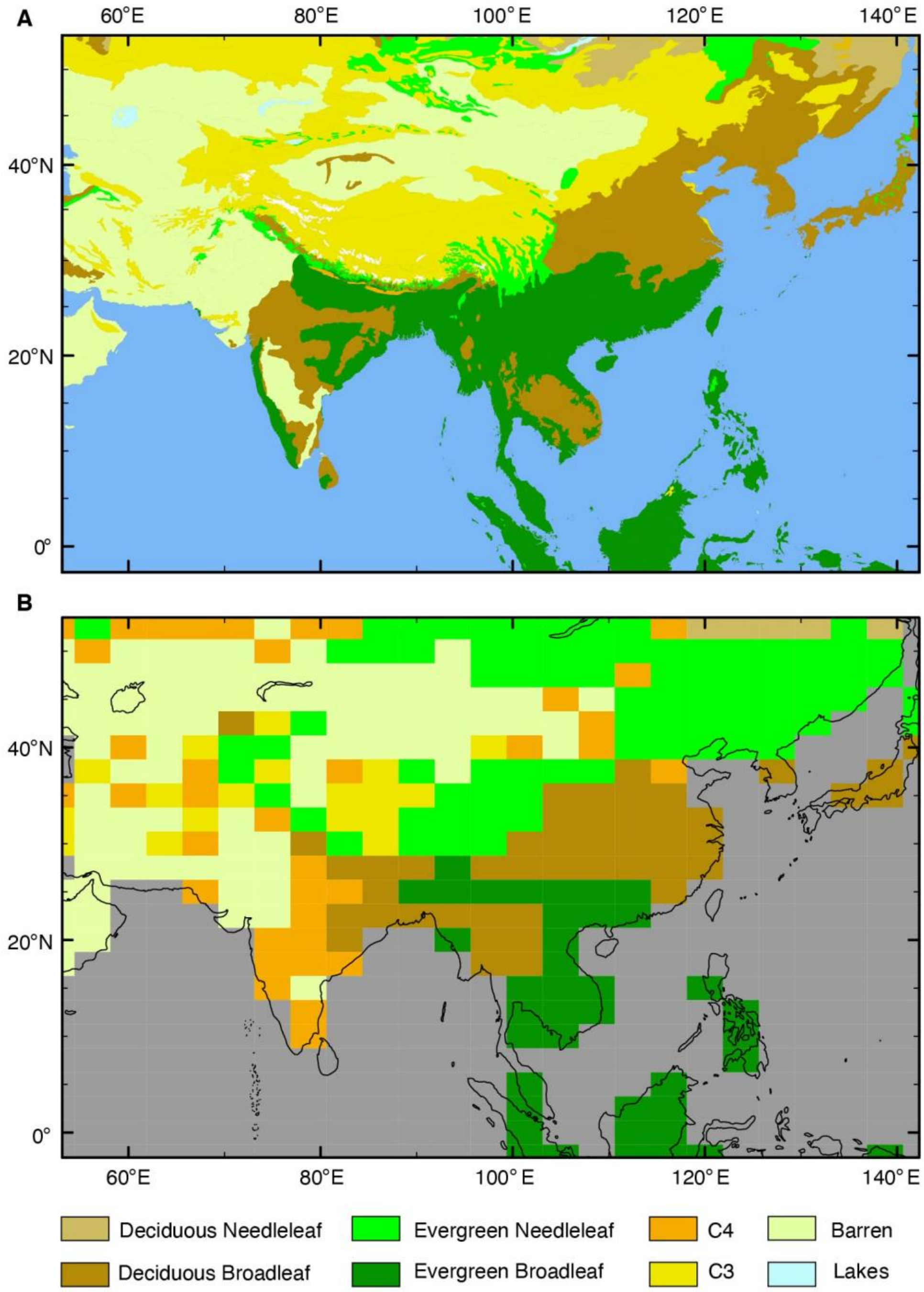

Fig. S11. Comparison of observed vegetation with simulated vegetation pattern in eastern Asia. The observed vegetation data (A) are derived from Terrestrial Ecoregions of the World (*59*). The Sheffield Dynamic Global Vegetation Model results (B) are simulated from a climate simulation (teiha) based on pre-industrial conditions (see data S2 for the details).

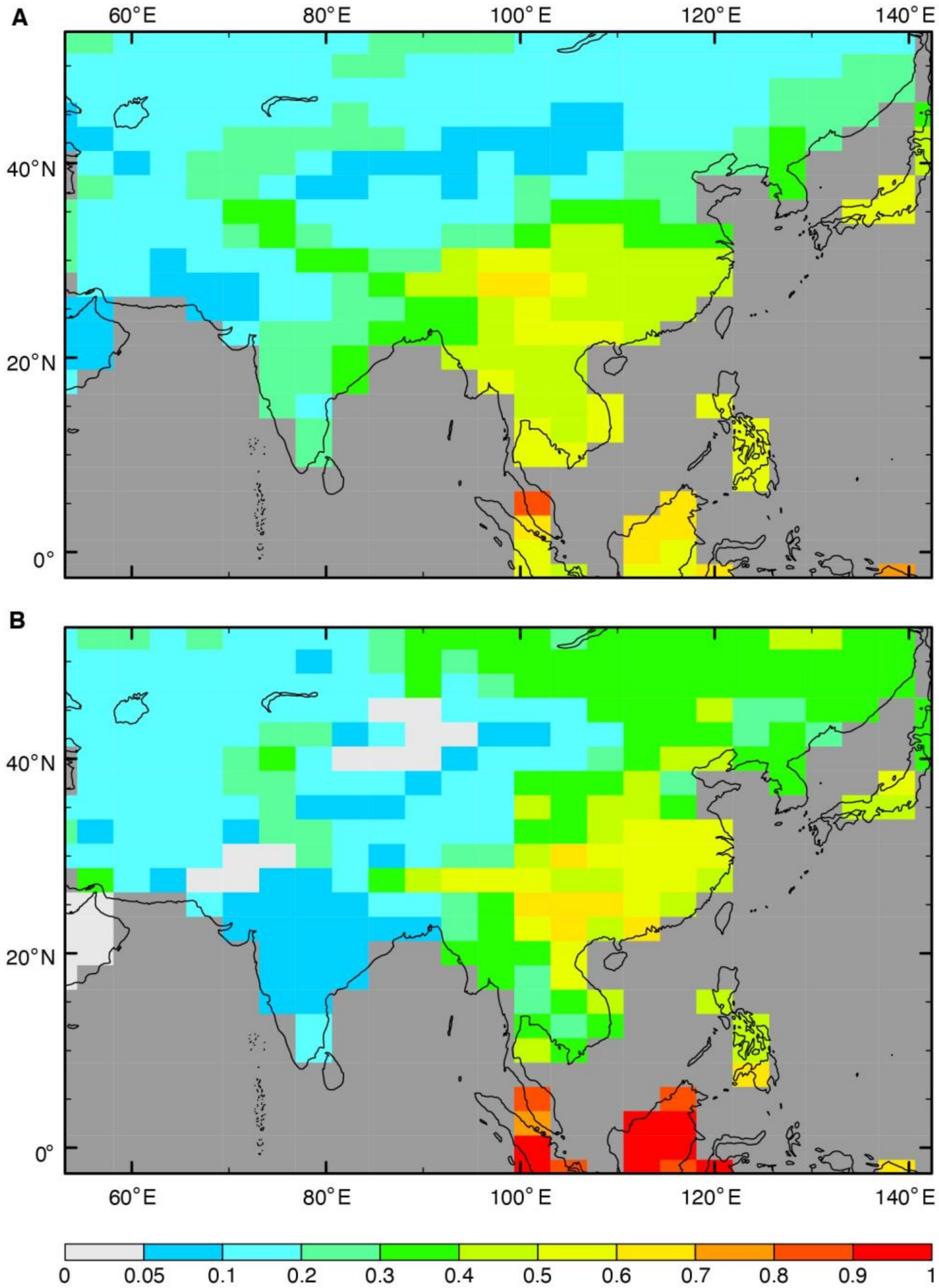

Fig. S12. Comparison of observed plant diversity with simulated plant diversity pattern in eastern Asia. The observed native vascular plant diversity (A) are derived from Ellis *et al*. (*60*). The Jena Diversity-Dynamic Global Vegetation Model (JeDi-DGVM) results (B) are simulated from a climate simulation (teiha) based on pre-industrial conditions (see data S2 for the details).

Data S1. The Cenozoic paleobotanical data in China

Data S2. Simulation description and boundary conditions

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