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Supplement of

Tracking the global flows of atmospheric moisture and associated uncertainties

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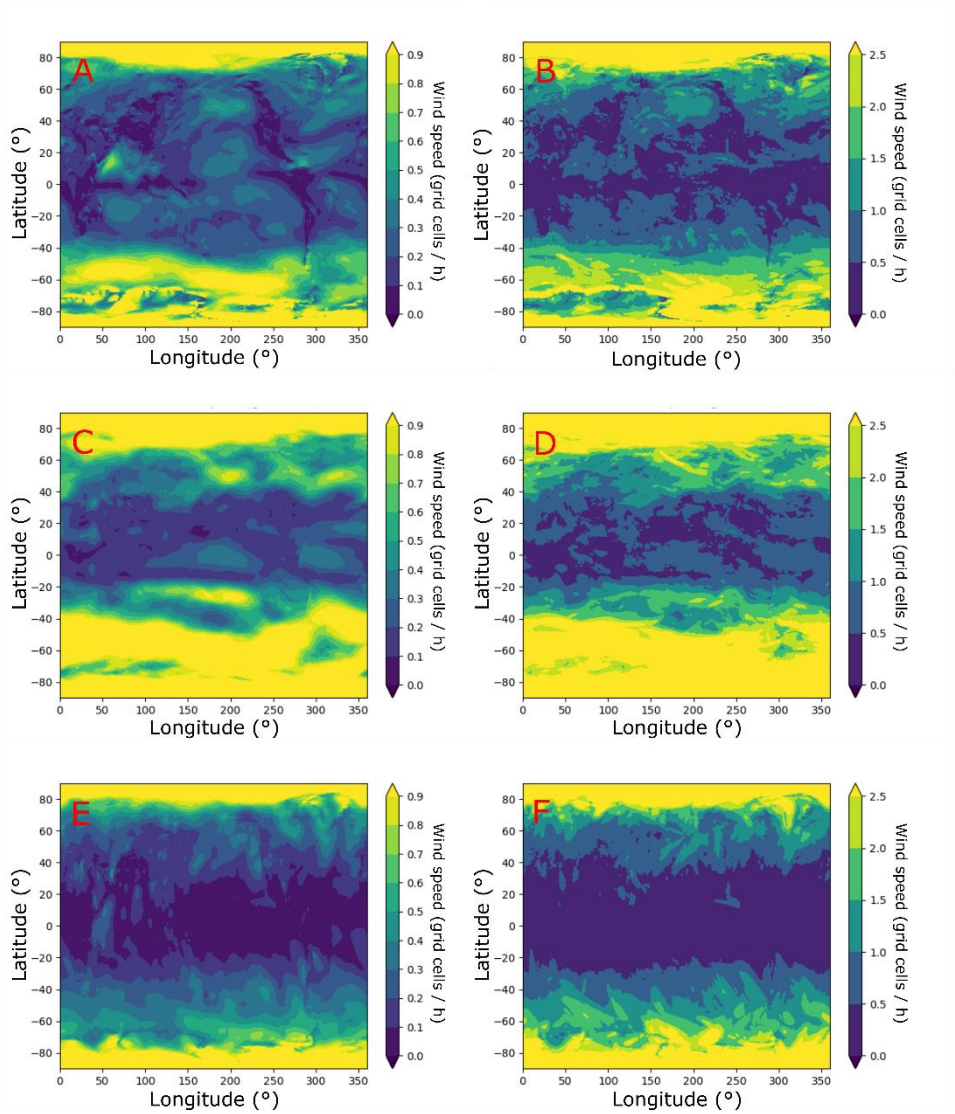

Figure S1: Eastward wind speeds in July 2012 across the globe, given in ERA5 grid cells / h (Courant number). A) Mean eastward wind speeds at 900 hPa; B) Maximum eastward wind speeds at 900 hPa; C) Mean eastward wind speeds at 500 hPa; D) Maximum eastward wind speeds at 500 hPa; E) Mean eastward wind speeds, vertically integrated divided by the precipitable water; F) Maximum eastward wind speeds, vertically integrated divided by the precipitable water.

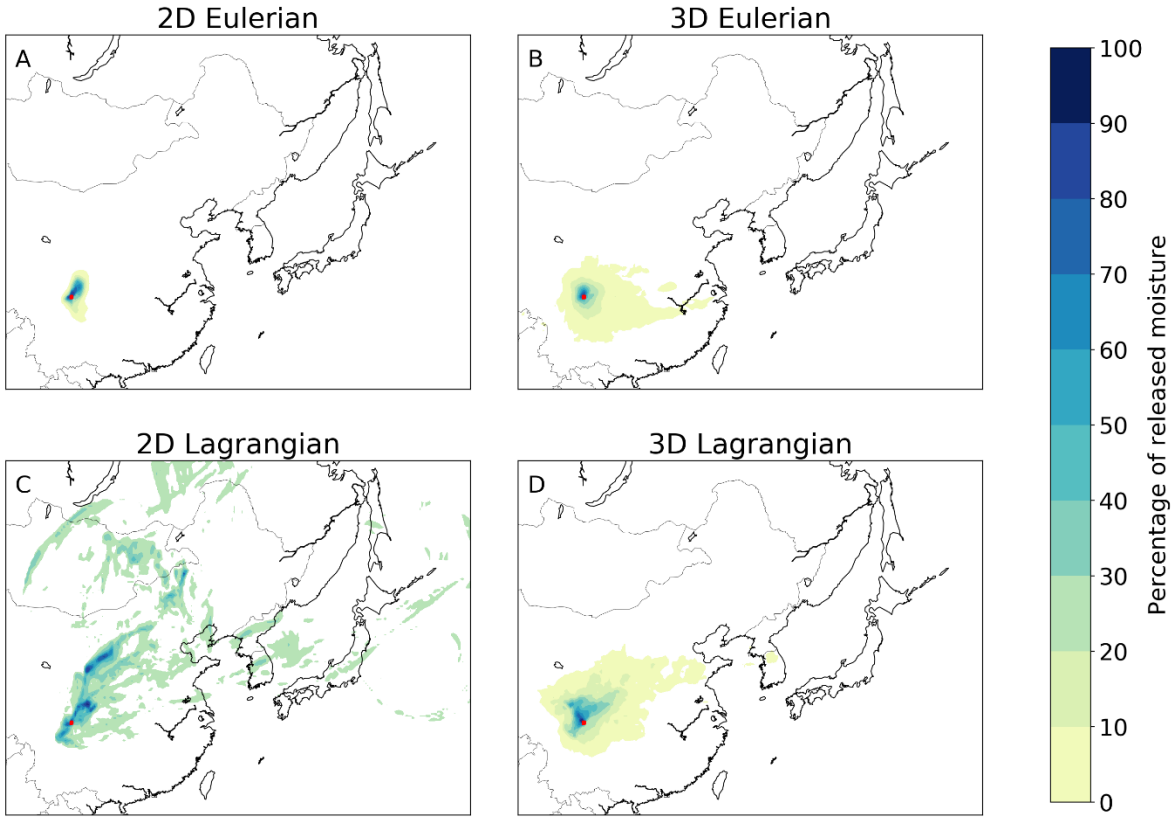

Figure S2: Different footprints of moisture releases from Chengdu in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 0.6° in a northerly direction and mean longitudinal flow of 0.6° in an easterly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 0.1° in a northerly direction and mean longitudinal flow of 0.9° in an easterly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 6.5° in a northerly direction and mean longitudinal flow of 5.6° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction.

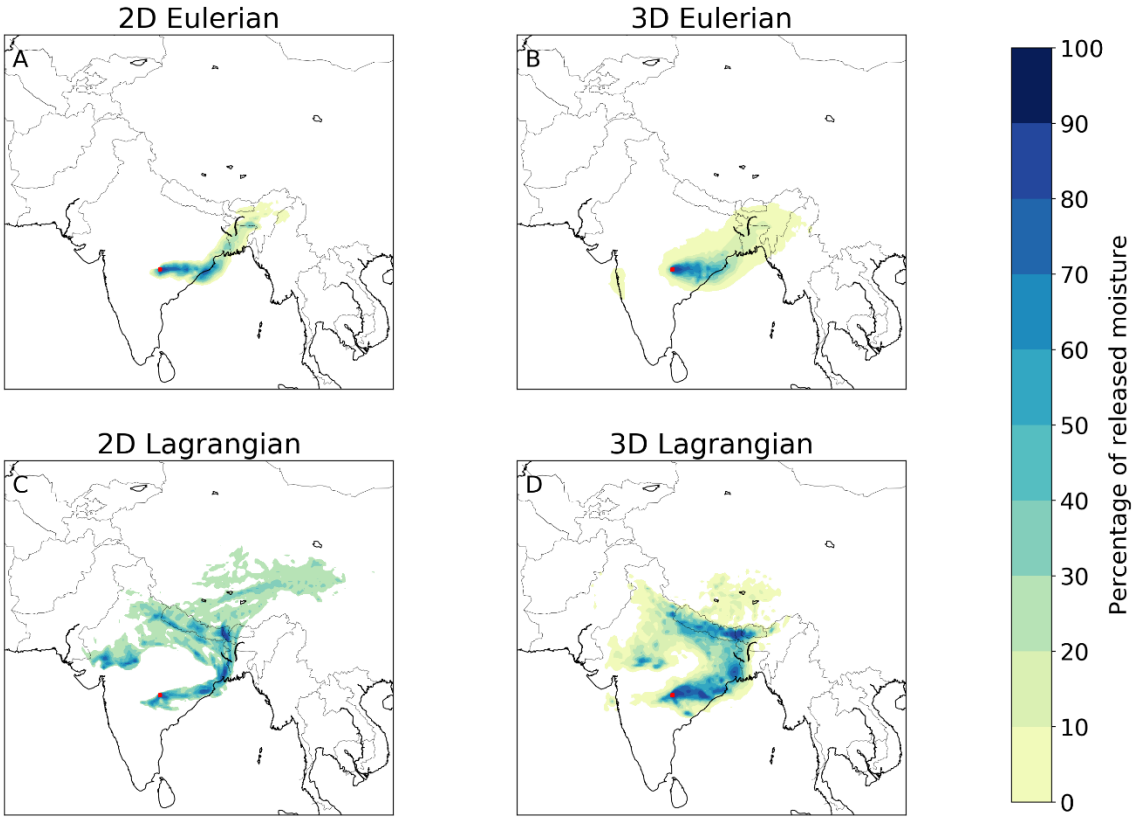

Figure S3: Different footprints of moisture releases from Nagpur in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 5.7° in an easterly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 0.6° in a northerly direction and mean longitudinal flow of 3.8° in an easterly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 5.5° in a northerly direction and mean longitudinal flow of 4.8° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction.

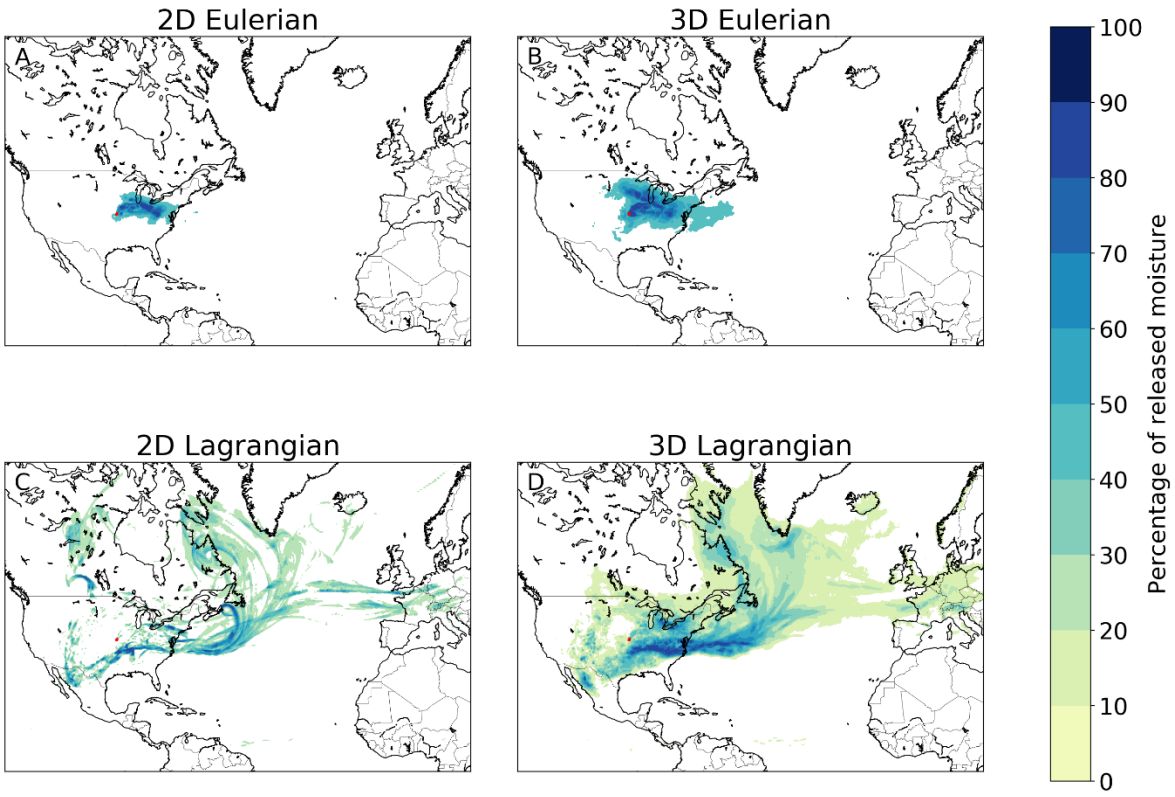

Figure S4: Different footprints of moisture releases from Central Kansas in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 8.5° in an easterly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 1.3° in a southerly direction and mean longitudinal flow of 7.1° in an easterly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 5.4° in a northerly direction and mean longitudinal flow of 14.4° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction.

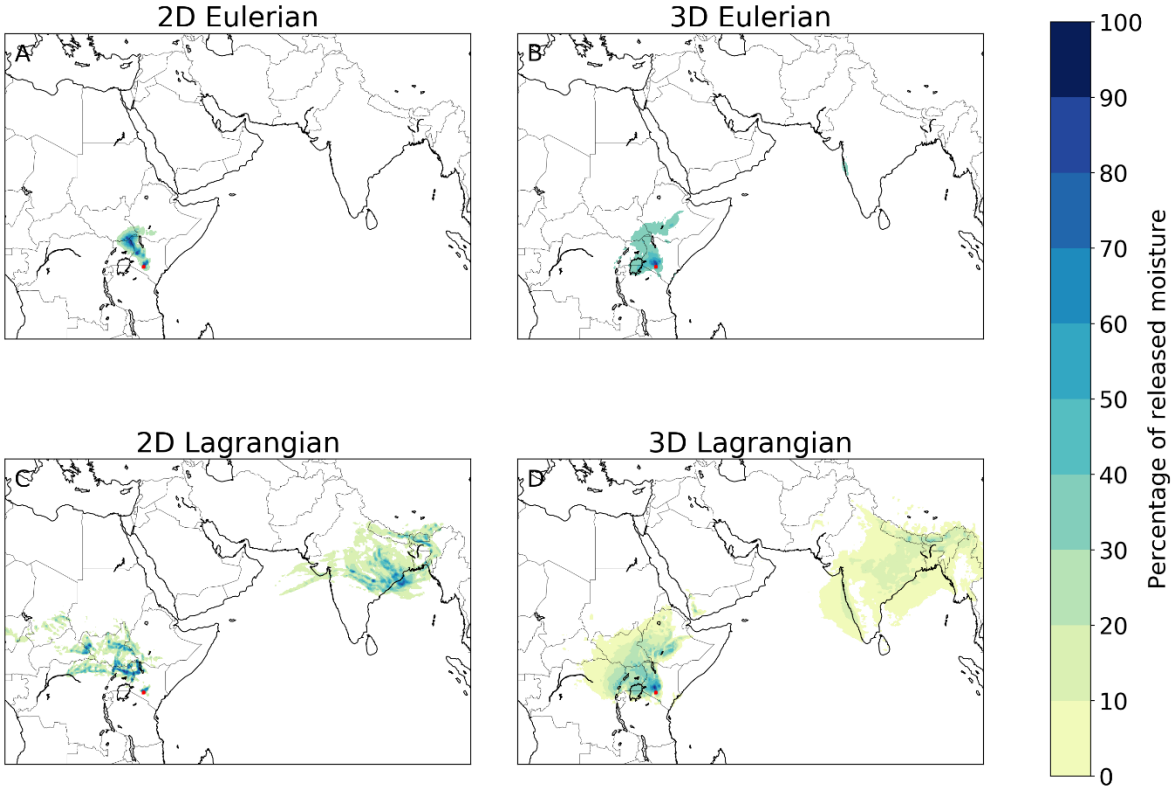

Figure S5: Different footprints of moisture releases from Nairobi in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 1.6° in a westerly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 2.2° in a northerly direction and mean longitudinal flow of 0.8° in an easterly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 14.0° in a northerly direction and mean longitudinal flow of 3.9° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.9° in an easterly direction.

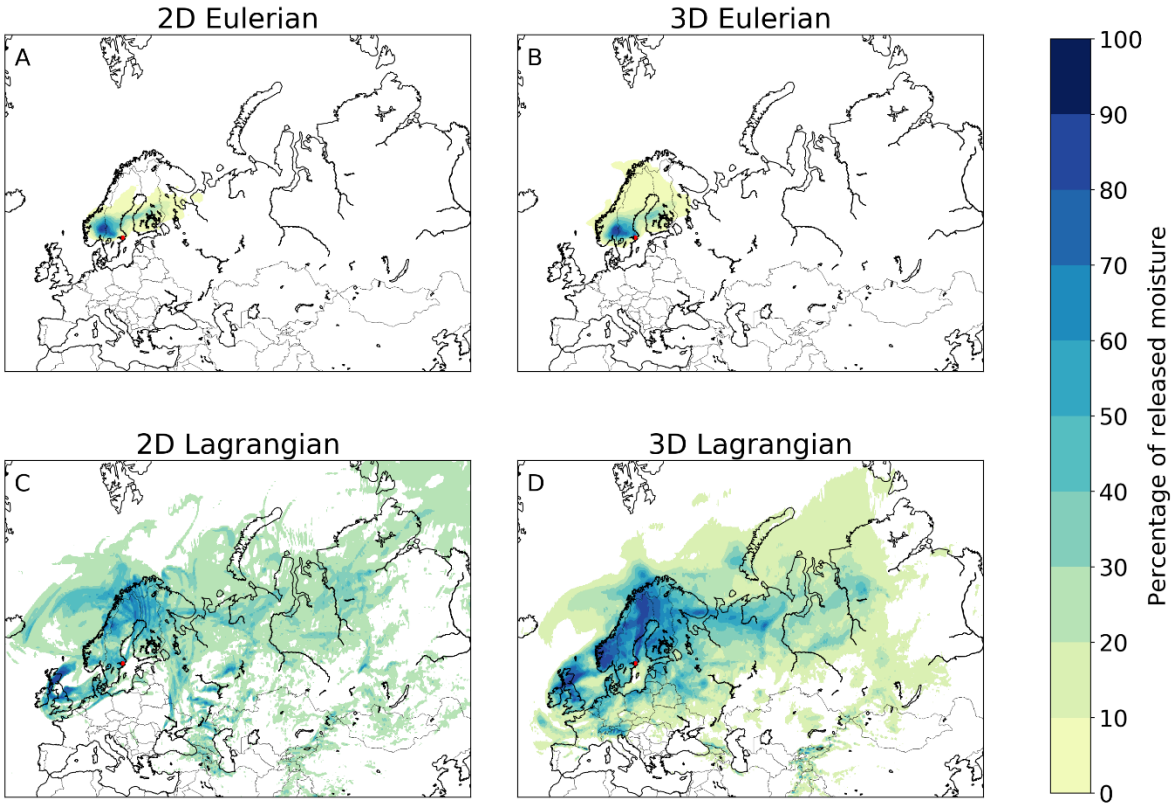

Figure S6: Different footprints of moisture releases from Stockholm in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 2.6° in a northerly direction and mean longitudinal flow of 0.6° in a westerly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 1.4° in a westerly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 0.0° in northerly/a southerly direction and mean longitudinal flow of 13.9° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction.

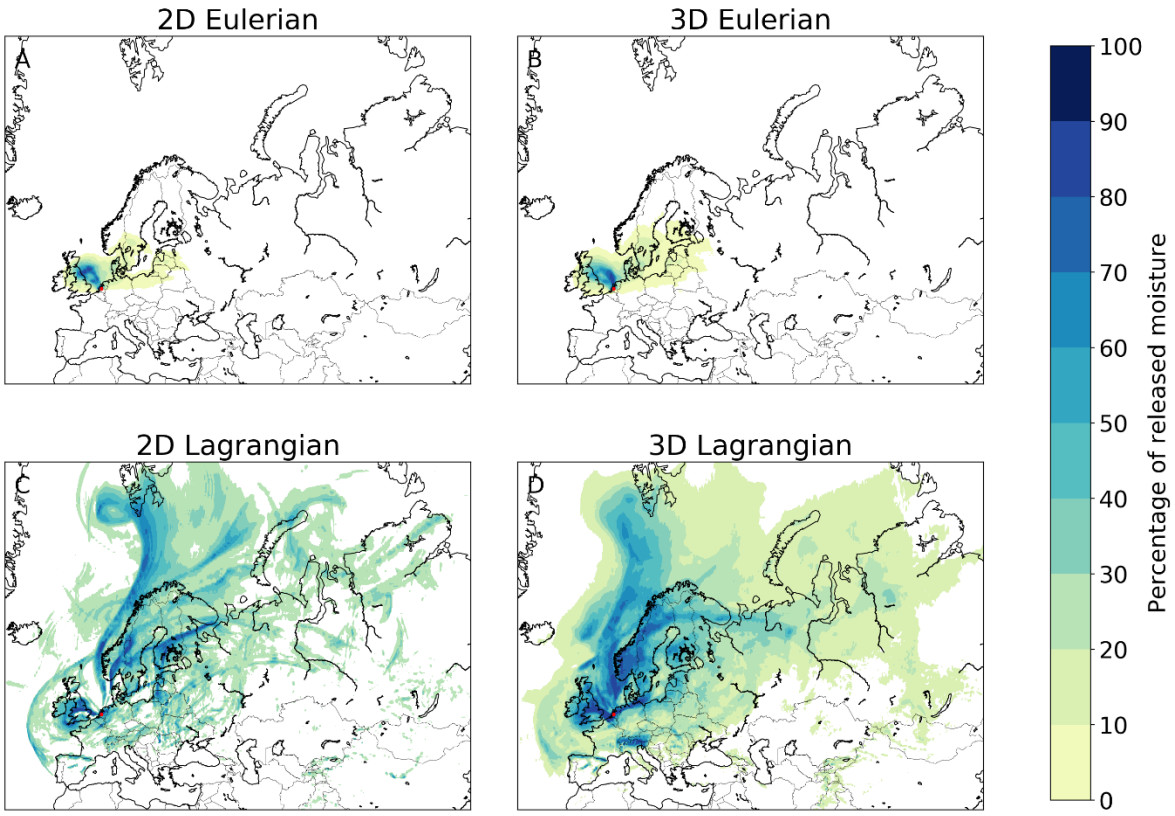

Figure S7: Different footprints of moisture releases from Utrecht in July 2012 in two-dimensional and three-dimensional Eulerian and Lagrangian models. A) Two-dimensional Eulerian, with a mean latitudinal moisture flow of 2.8° in a northerly direction and mean longitudinal flow of 11.3° in an easterly direction; B) Three-dimensional Eulerian, with a mean latitudinal moisture flow of 3.1° in a northerly direction and mean longitudinal flow of 9.8° in an easterly direction; C) Two-dimensional Lagrangian, with a mean latitudinal moisture flow of 8.7° in a northerly direction and mean longitudinal flow of 18.1° in an easterly direction; D) Three-dimensional Lagrangian, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction.

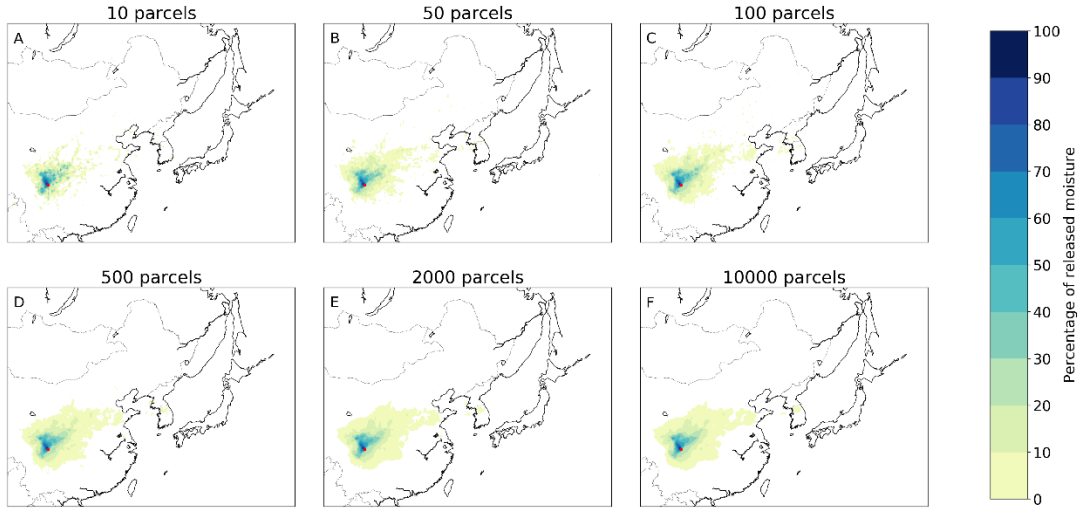

Figure S8: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 2.4° in a northerly direction and mean longitudinal flow of 2.5° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 2.6° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 1.9° in a northerly direction and mean longitudinal flow of 1.8° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 1.9° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction.

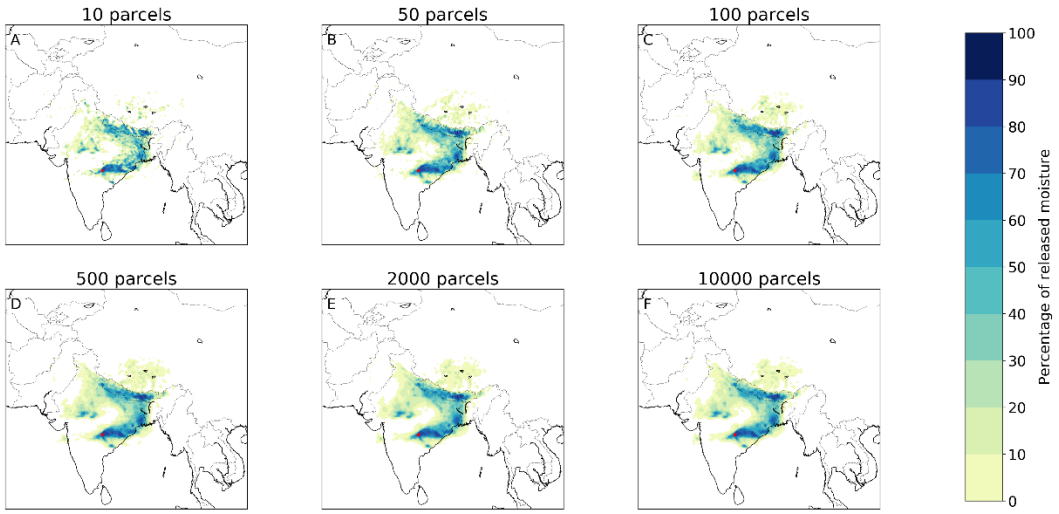

Figure S9: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 5.0° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.5° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction.

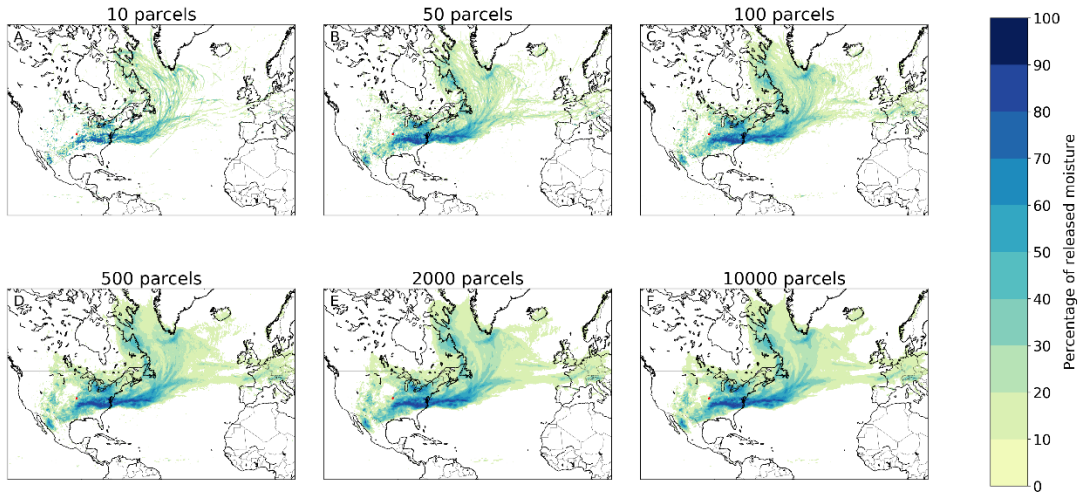

Figure S10: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.2° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 3.9° in a northerly direction and mean longitudinal flow of 15.2° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 4.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction.

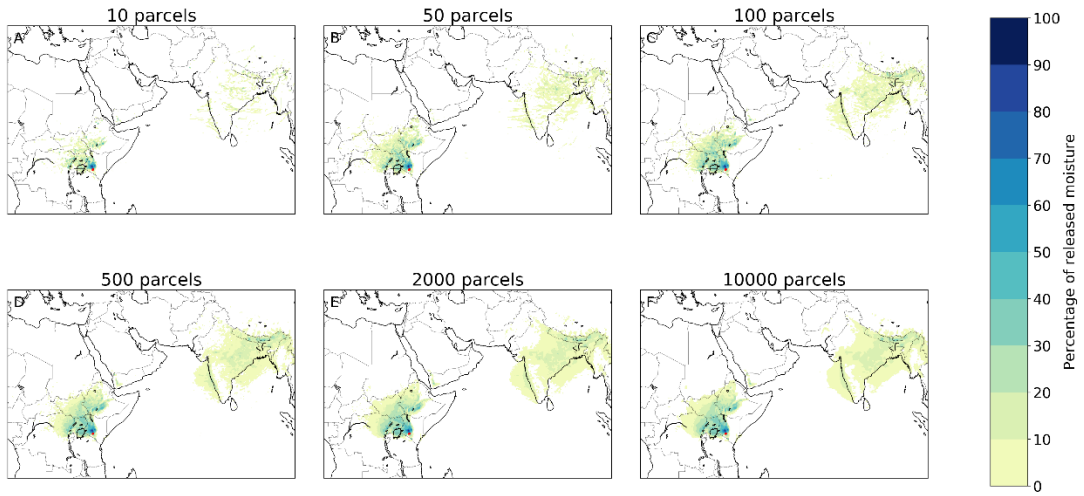

Figure S11: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 7.2° in a northerly direction and mean longitudinal flow of 3.1° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 7.5° in a northerly direction and mean longitudinal flow of 3.1° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 6.7° in a northerly direction and mean longitudinal flow of 2.9° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 6.9° in a northerly direction and mean longitudinal flow of 3.1° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 6.5° in a northerly direction and mean longitudinal flow of 2.8° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.9° in an easterly direction.

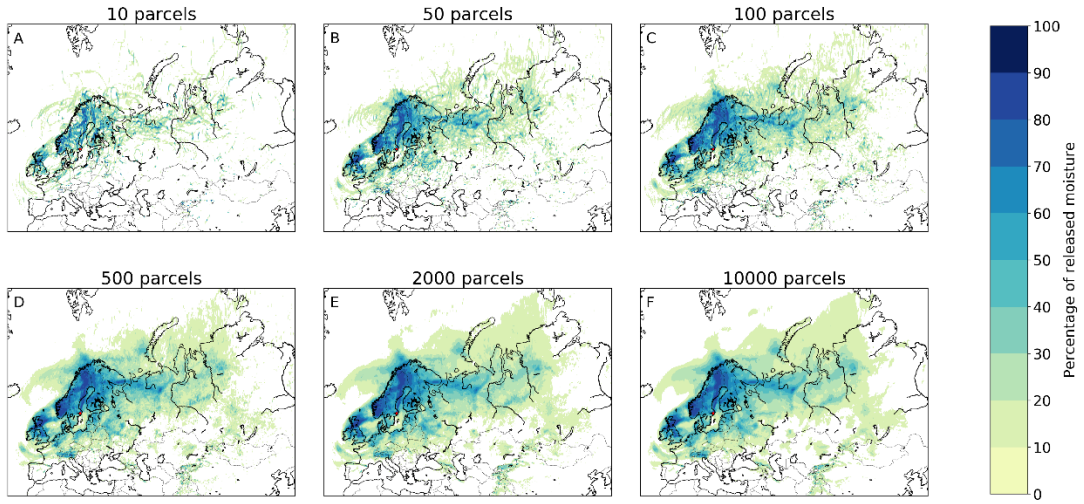

Figure S12: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 11.5° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 0.9° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 1.5° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 1.5° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction.

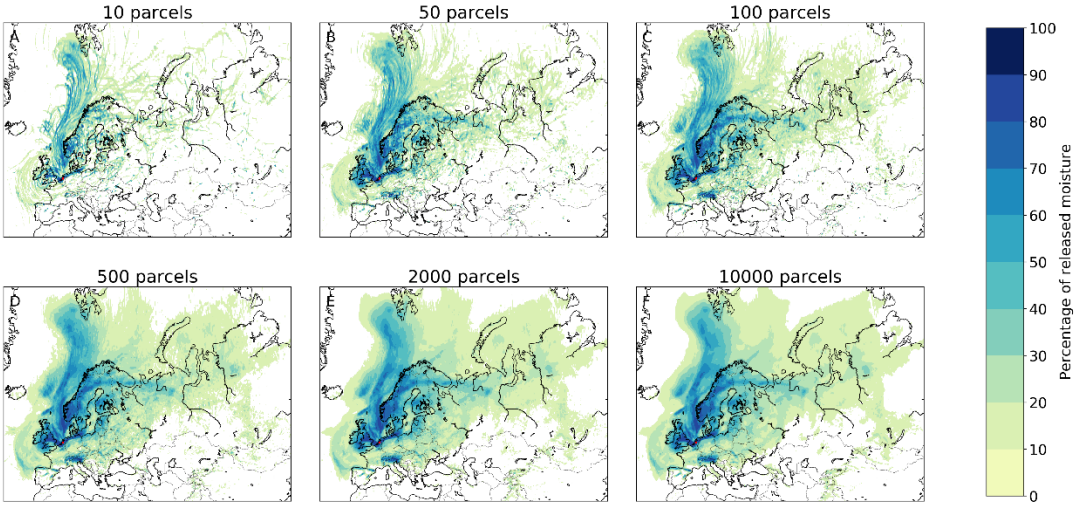

Figure S13: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with 10, 50, 100, 500, 2,000, and 10,000 tracked parcels mm^{-1}). A) 10 parcels, with a mean latitudinal moisture flow of 6.8° in a northerly direction and mean longitudinal flow of 15.5° in an easterly direction; B) 50 parcels, with a mean latitudinal moisture flow of 6.4° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; C) 100 parcels, with a mean latitudinal moisture flow of 6.1° in a northerly direction and mean longitudinal flow of 15.5° in an easterly direction; D) 500 parcels, with a mean latitudinal moisture flow of 6.4° in a northerly direction and mean longitudinal flow of 15.5° in an easterly direction; E) 2,000 parcels, with a mean latitudinal moisture flow of 6.3° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; F) 10,000 parcels, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction.

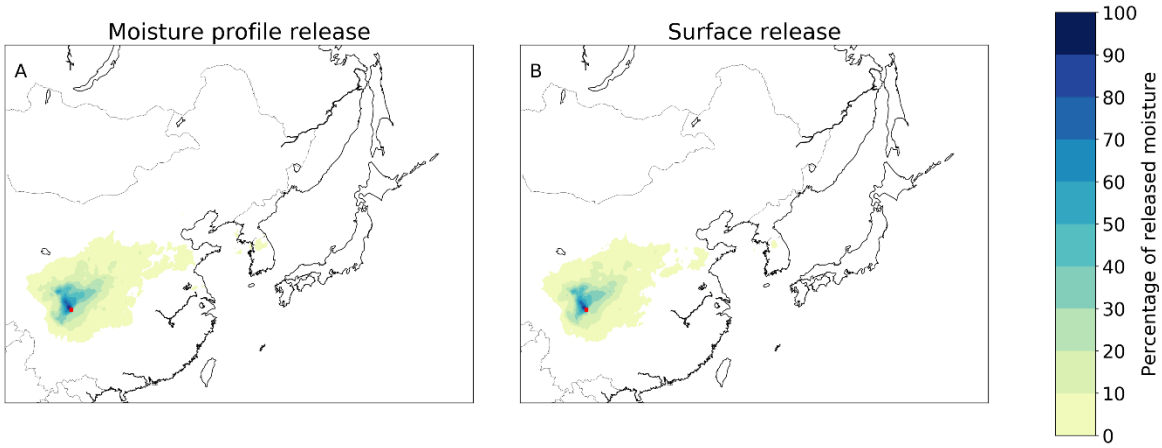

Figure S14: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 2.4° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 2.0° in a northerly direction and mean longitudinal flow of 2.1° in an easterly direction.

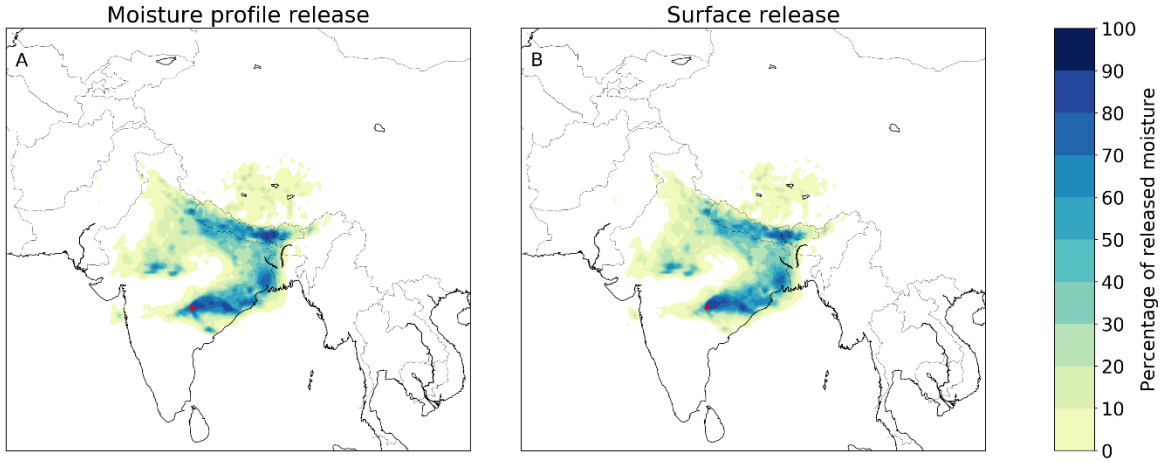

Figure S15: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.3° in an easterly direction.

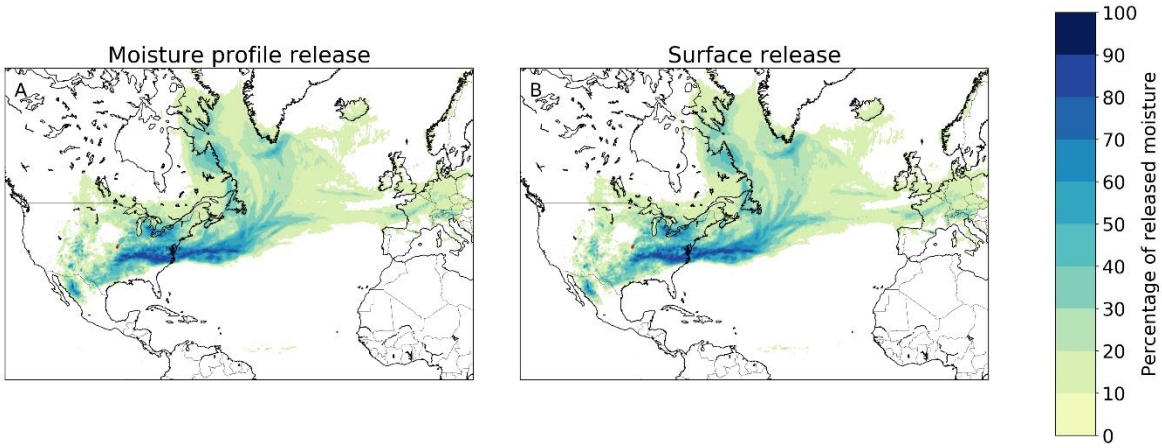

Figure S16: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.2° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction.

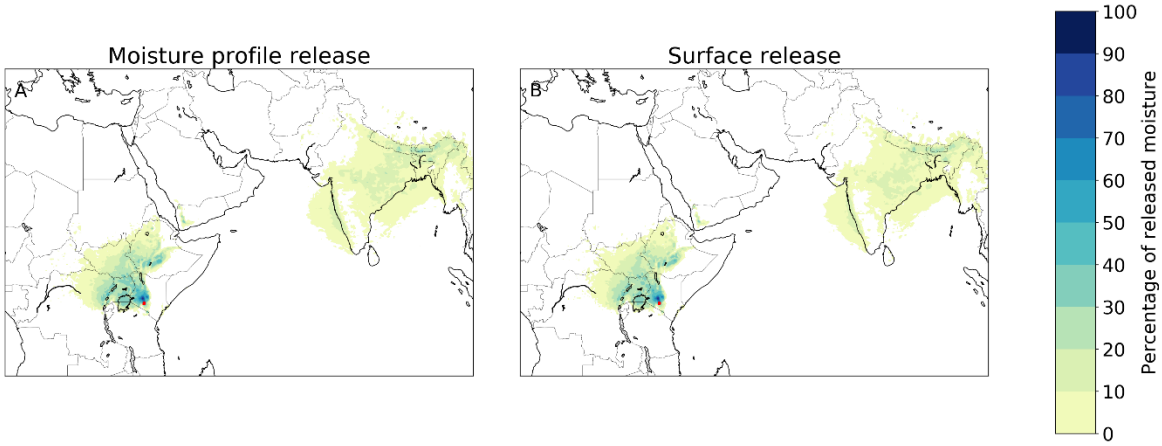

Figure S17: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 7.2° in a northerly direction and mean longitudinal flow of 3.0° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 6.7° in a northerly direction and mean longitudinal flow of 2.6° in an easterly direction.

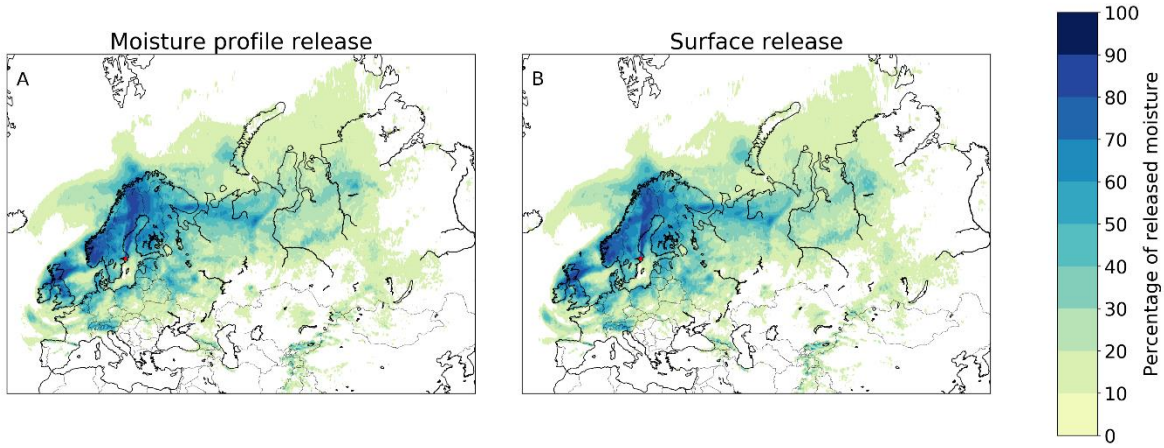

Figure S18: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 10.8° in an easterly direction.

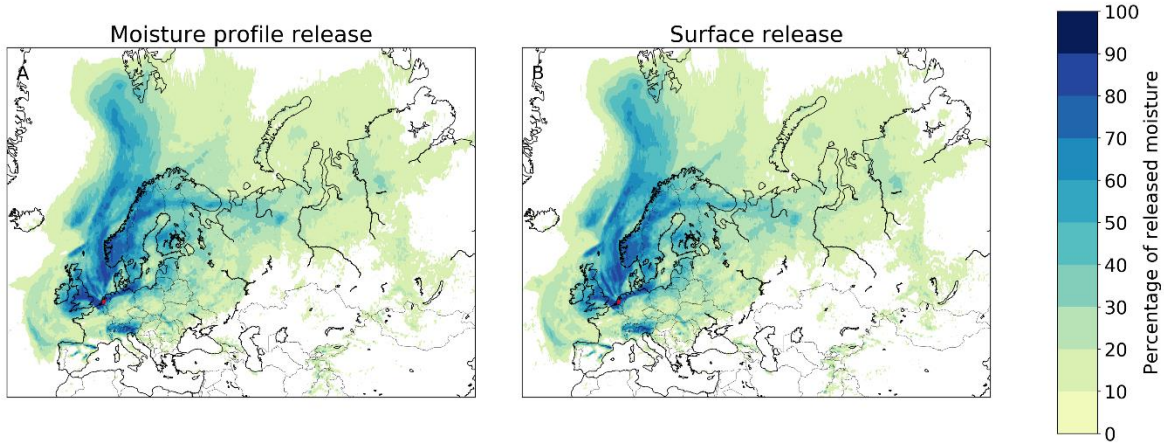

Figure S19: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with moisture released according to the vertical moisture profile of the atmosphere and moisture released at the surface. A) Release according to the moisture profile, with a mean latitudinal moisture flow of 6.0° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; B) Release at the surface, with a mean latitudinal moisture flow of 5.8° in a northerly direction and mean longitudinal flow of 14.6° in an easterly direction.

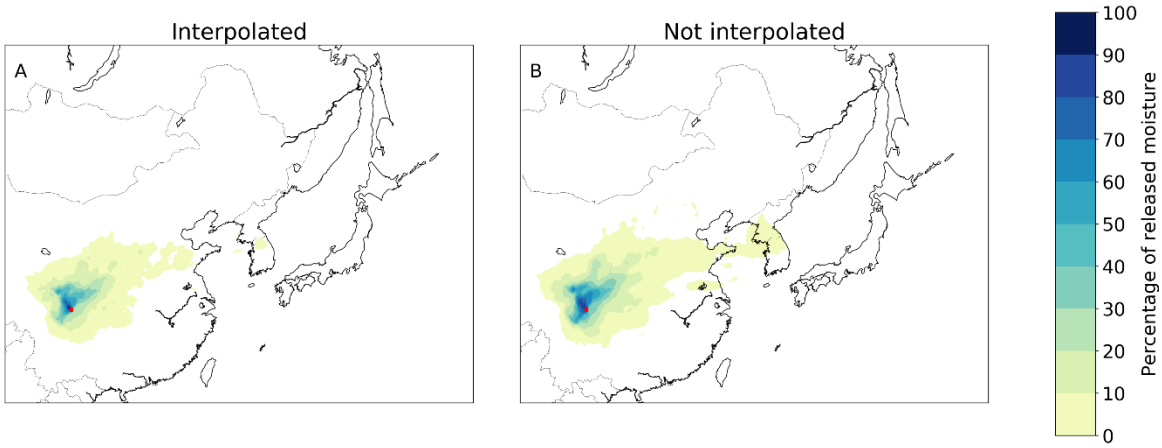

Figure S20: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 2.4° in an easterly direction.

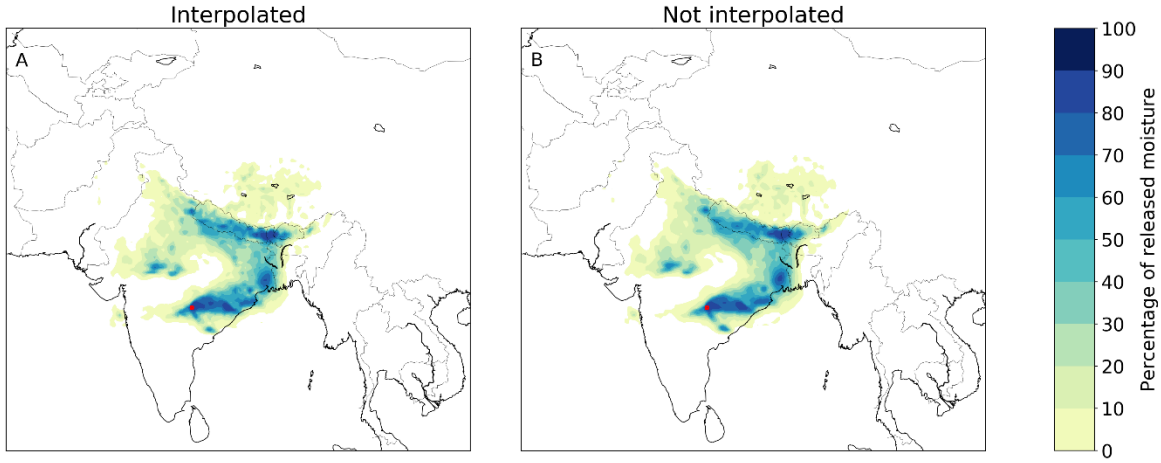

Figure S21: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction.

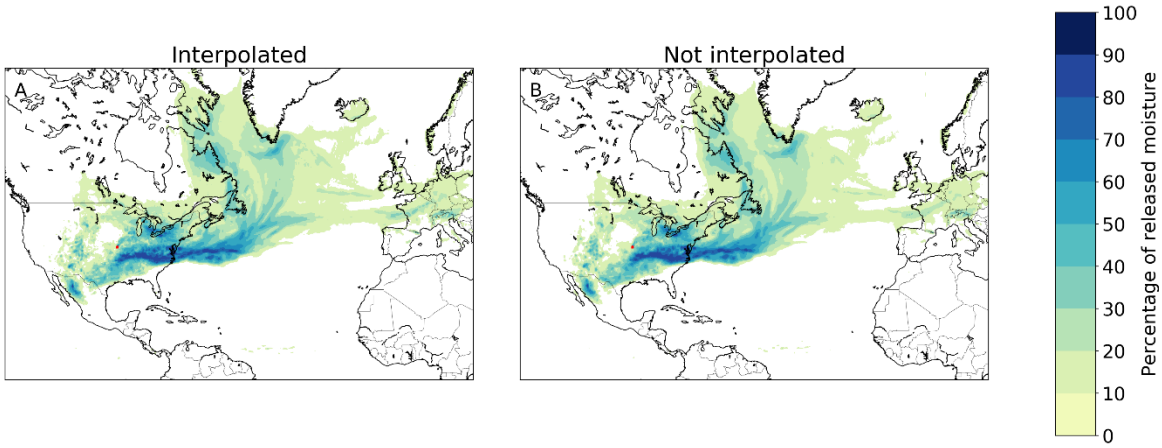

Figure S22: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.2° in an easterly direction.

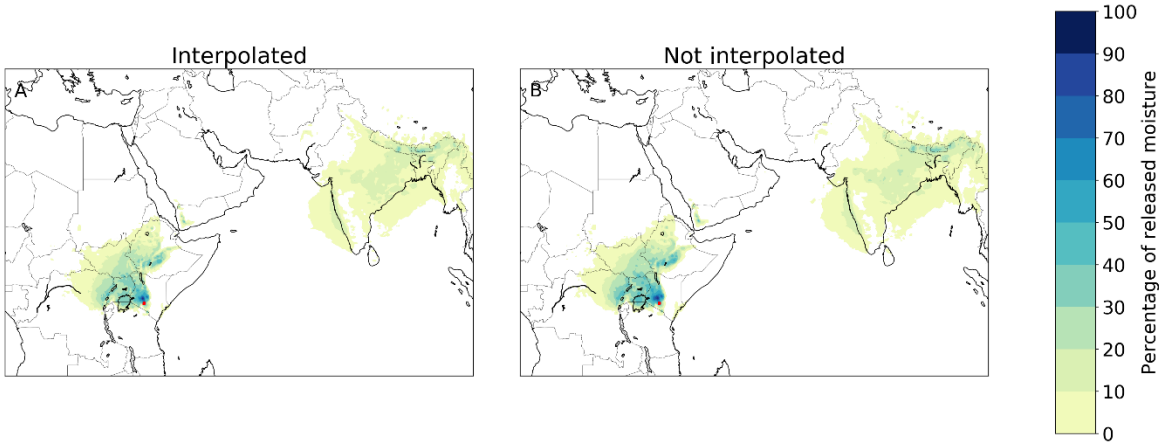

Figure S23: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.9° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 7.2° in a northerly direction and mean longitudinal flow of 3.0° in an easterly direction.

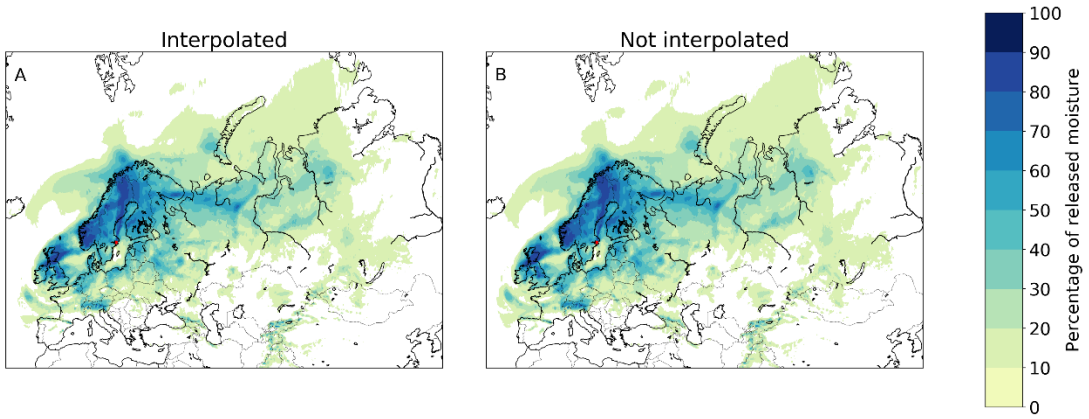

Figure S24: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction.

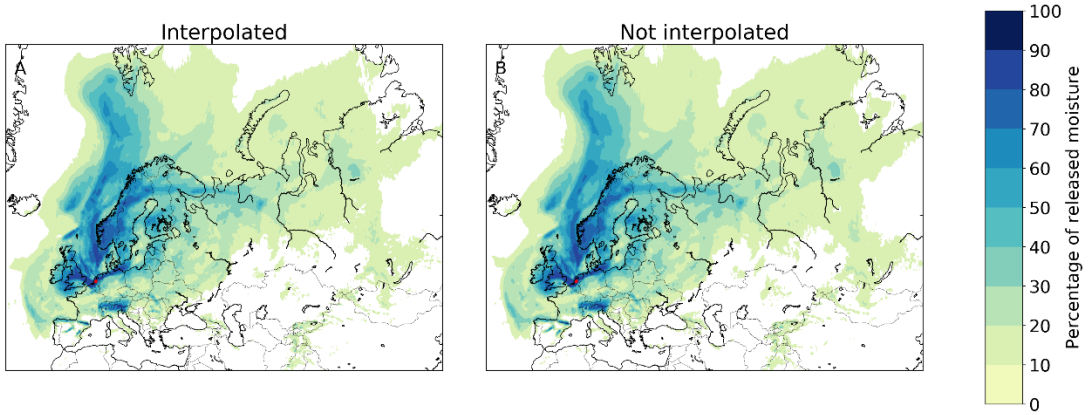

Figure S25: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with and without interpolation of wind speed and directions. A) Interpolated, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; B) Not interpolated, with a mean latitudinal moisture flow of 6.1° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction.

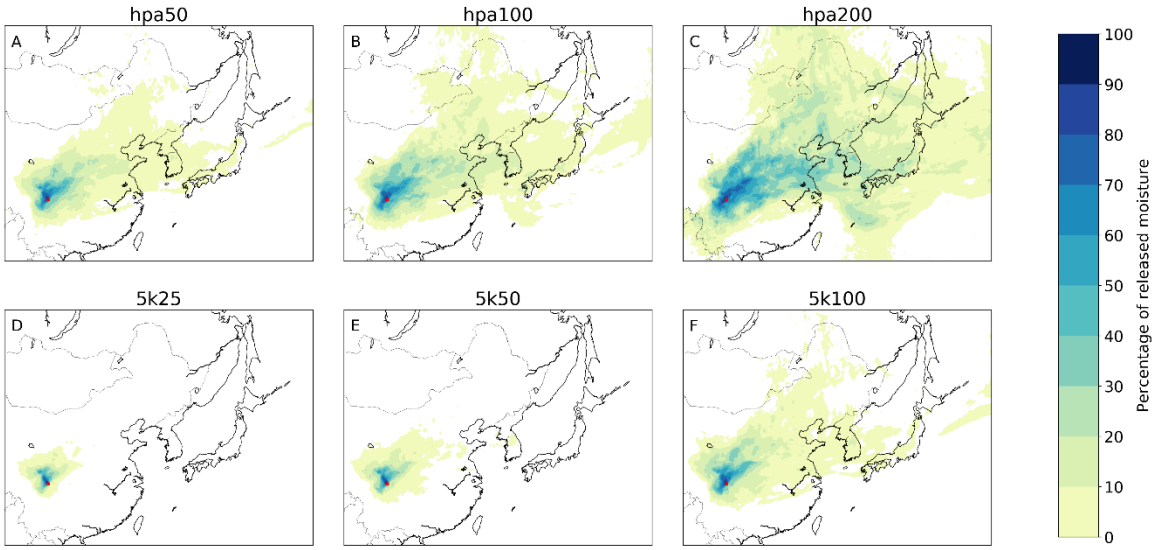

Figure S26: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 3.1° in a northerly direction and mean longitudinal flow of 4.0° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 3.8° in a northerly direction and mean longitudinal flow of 5.7° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 9.2° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 1.6° in a northerly direction and mean longitudinal flow of 0.3° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 2.2° in a northerly direction and mean longitudinal flow of 1.4° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 3.5° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction.

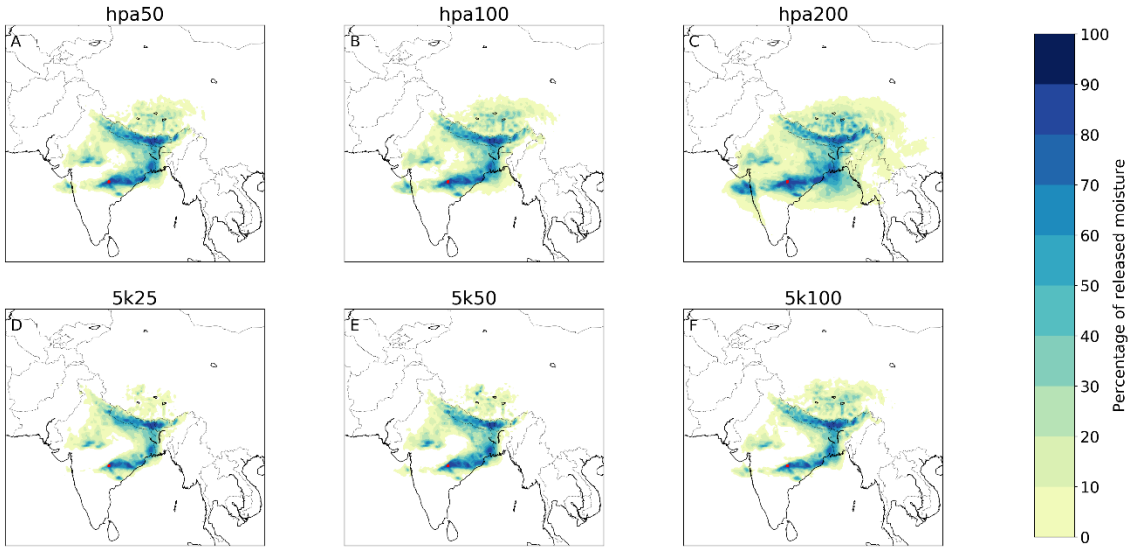

Figure S27: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 4.6° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 4.8° in a northerly direction and mean longitudinal flow of 5.1° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 3.1° in a northerly direction and mean longitudinal flow of 5.1° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 5.0° in a northerly direction and mean longitudinal flow of 4.0° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 4.8° in a northerly direction and mean longitudinal flow of 3.8° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 5.4° in a northerly direction and mean longitudinal flow of 5.6° in an easterly direction.

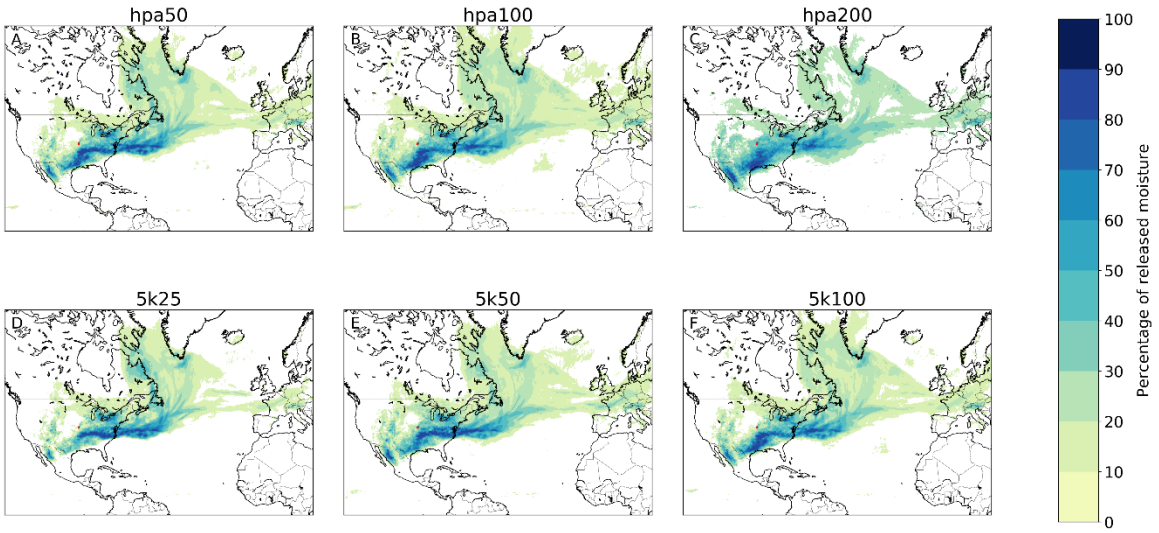

Figure S28: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 2.8° in a northerly direction and mean longitudinal flow of 13.8° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 11.2° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 0.2° in a southerly direction and mean longitudinal flow of 6.6° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 16.7° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 2.4° in a northerly direction and mean longitudinal flow of 11.9° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 2.2° in a northerly direction and mean longitudinal flow of 12.0° in an easterly direction.

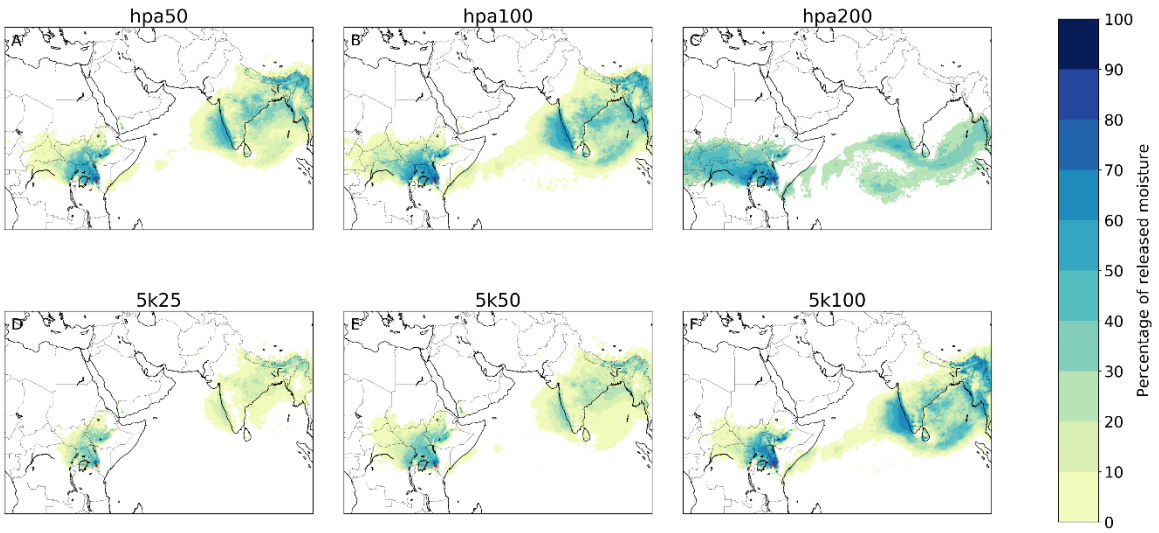

Figure S29: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 11.3° in a northerly direction and mean longitudinal flow of 9.8° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 11.0° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 4.3° in a northerly direction and mean longitudinal flow of 2.7° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 8.6° in a northerly direction and mean longitudinal flow of 5.4° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 8.5° in a northerly direction and mean longitudinal flow of 5.9° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 13.2° in a northerly direction and mean longitudinal flow of 14.1° in an easterly direction.

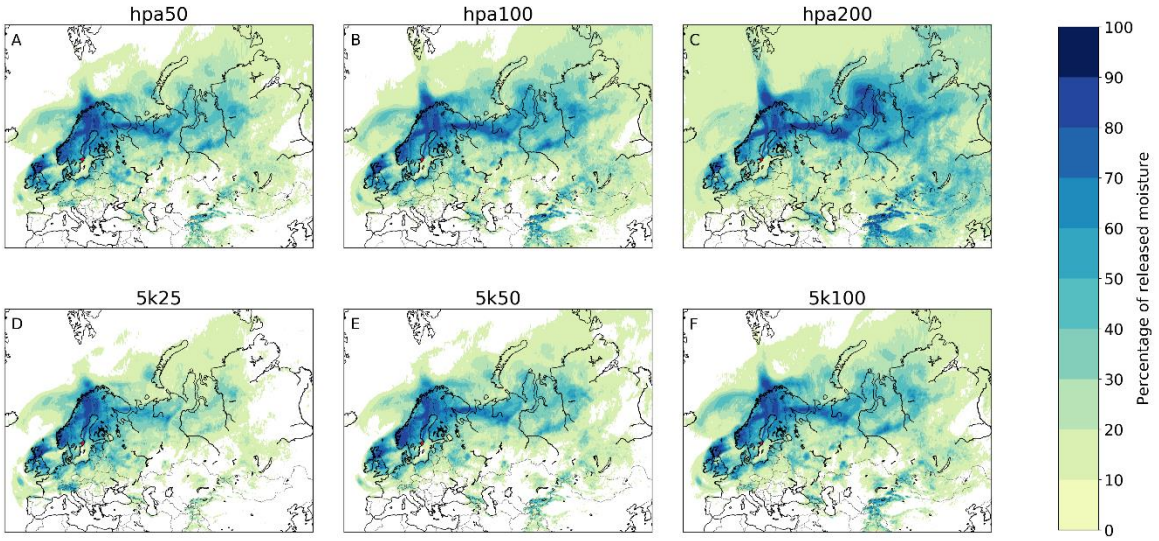

Figure S30: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 1.7° in a northerly direction and mean longitudinal flow of 14.0° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 0.0° in northerly/a southerly direction and mean longitudinal flow of 18.1° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 1.1° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 2.5° in a northerly direction and mean longitudinal flow of 12.9° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 14.4° in an easterly direction.

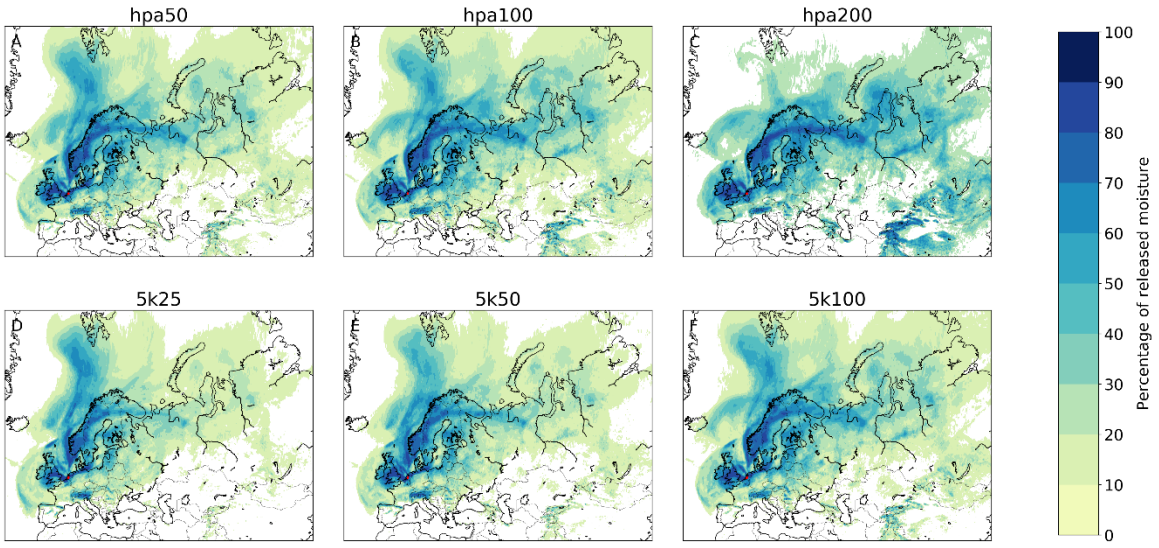

Figure S31: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with different degradations of the vertical moisture profile. A) hpa50, with a mean latitudinal moisture flow of 7.0° in a northerly direction and mean longitudinal flow of 17.9° in an easterly direction; B) hpa100, with a mean latitudinal moisture flow of 6.3° in a northerly direction and mean longitudinal flow of 19.1° in an easterly direction; C) hpa200, with a mean latitudinal moisture flow of 3.8° in a northerly direction and mean longitudinal flow of 21.0° in an easterly direction; D) 5k25, with a mean latitudinal moisture flow of 6.7° in a northerly direction and mean longitudinal flow of 15.7° in an easterly direction; E) 5k50, with a mean latitudinal moisture flow of 7.2° in a northerly direction and mean longitudinal flow of 17.0° in an easterly direction; F) 5k100, with a mean latitudinal moisture flow of 6.7° in a northerly direction and mean longitudinal flow of 18.7° in an easterly direction.

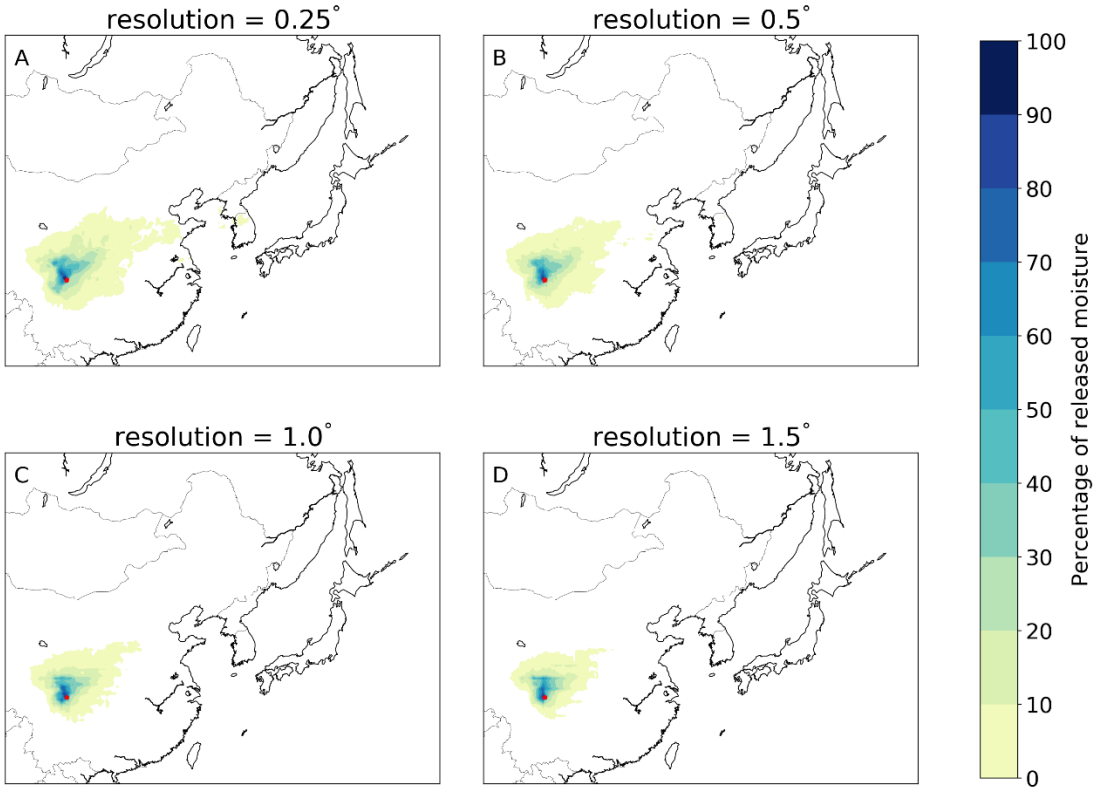

Figure S32: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 1.7° in a northerly direction and mean longitudinal flow of 1.4° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 1.6° in a northerly direction and mean longitudinal flow of 1.2° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 1.6° in a northerly direction and mean longitudinal flow of 1.1° in an easterly direction.

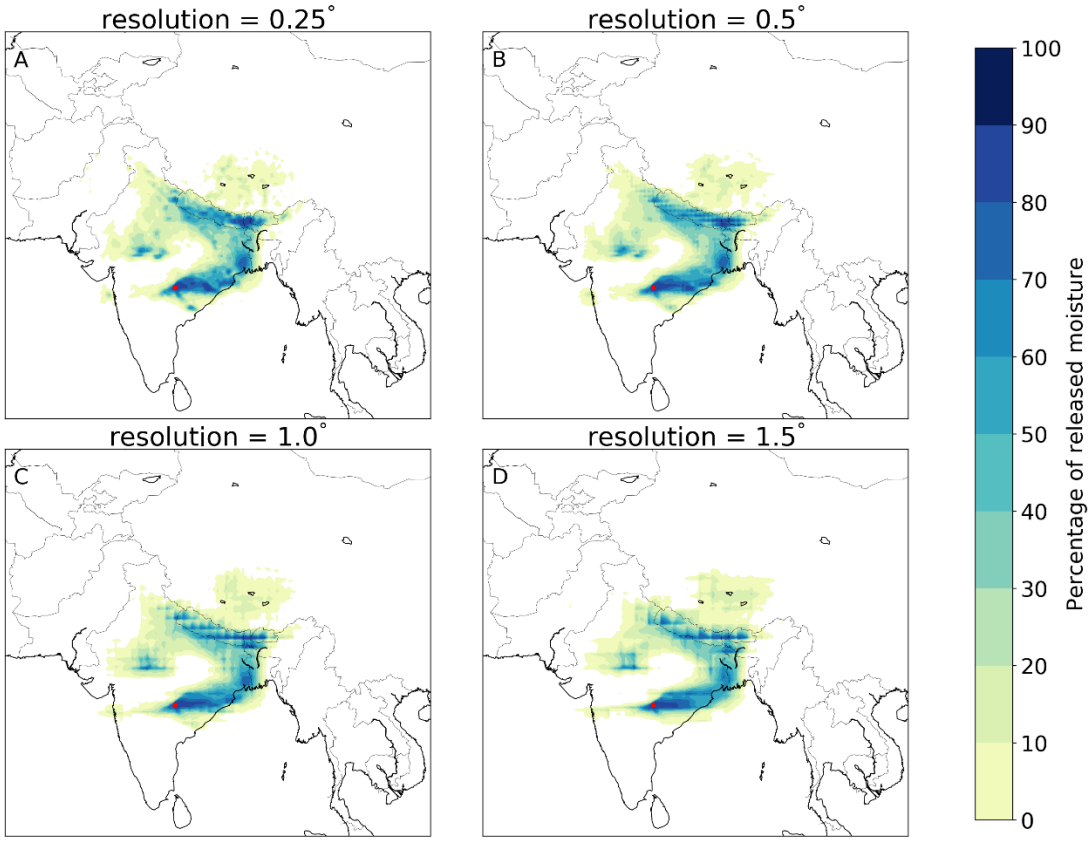

Figure S33: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.9° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 4.6° in a northerly direction and mean longitudinal flow of 4.1° in an easterly direction.

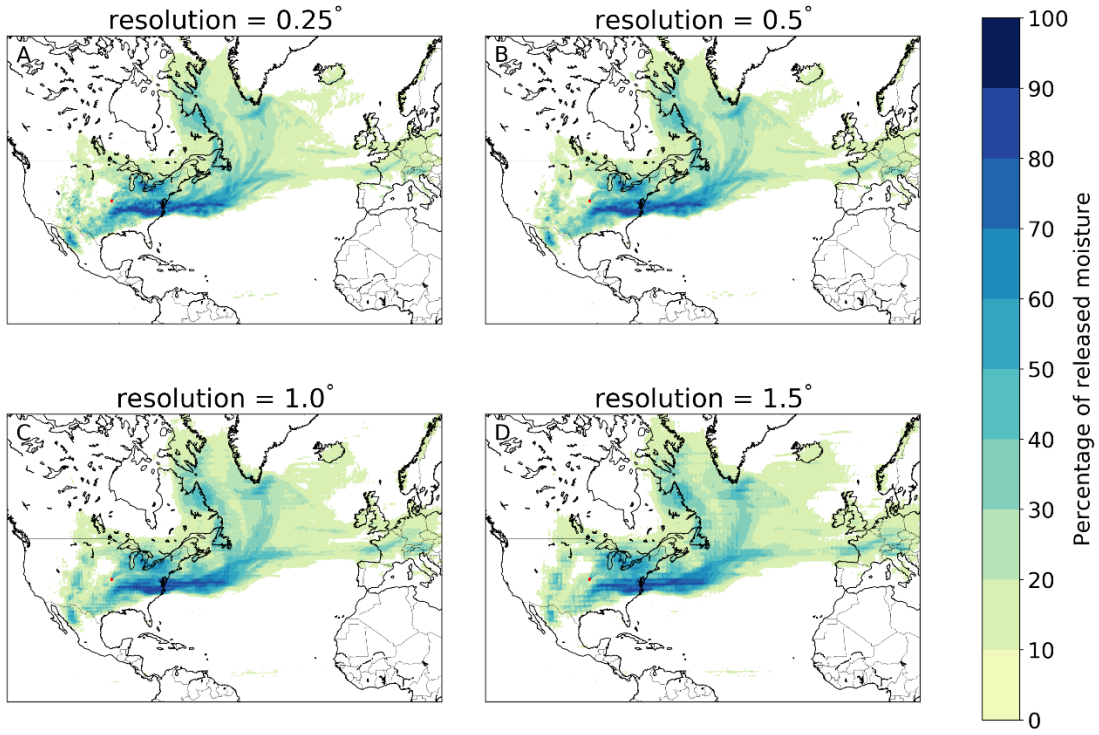

Figure S34: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 4.3° in a northerly direction and mean longitudinal flow of 15.9° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 4.6° in a northerly direction and mean longitudinal flow of 16.2° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 16.3° in an easterly direction.

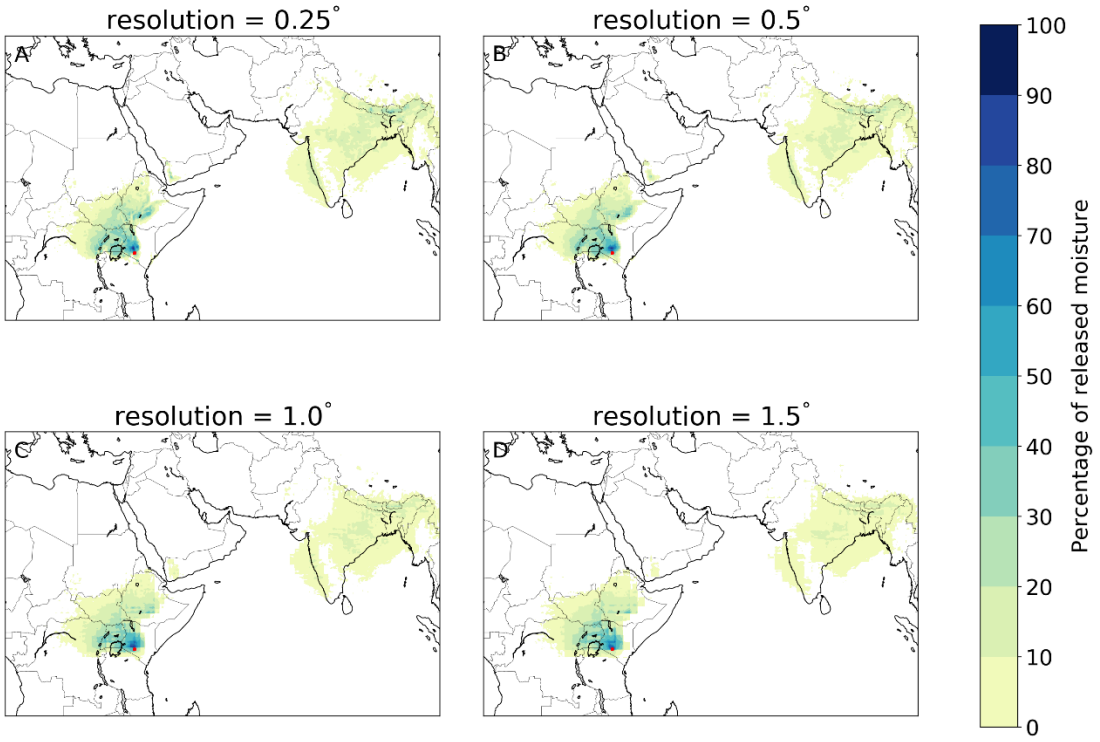

Figure S35: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.9° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 5.9° in a northerly direction and mean longitudinal flow of 2.2° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 5.4° in a northerly direction and mean longitudinal flow of 1.5° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 5.0° in a northerly direction and mean longitudinal flow of 1.2° in an easterly direction.

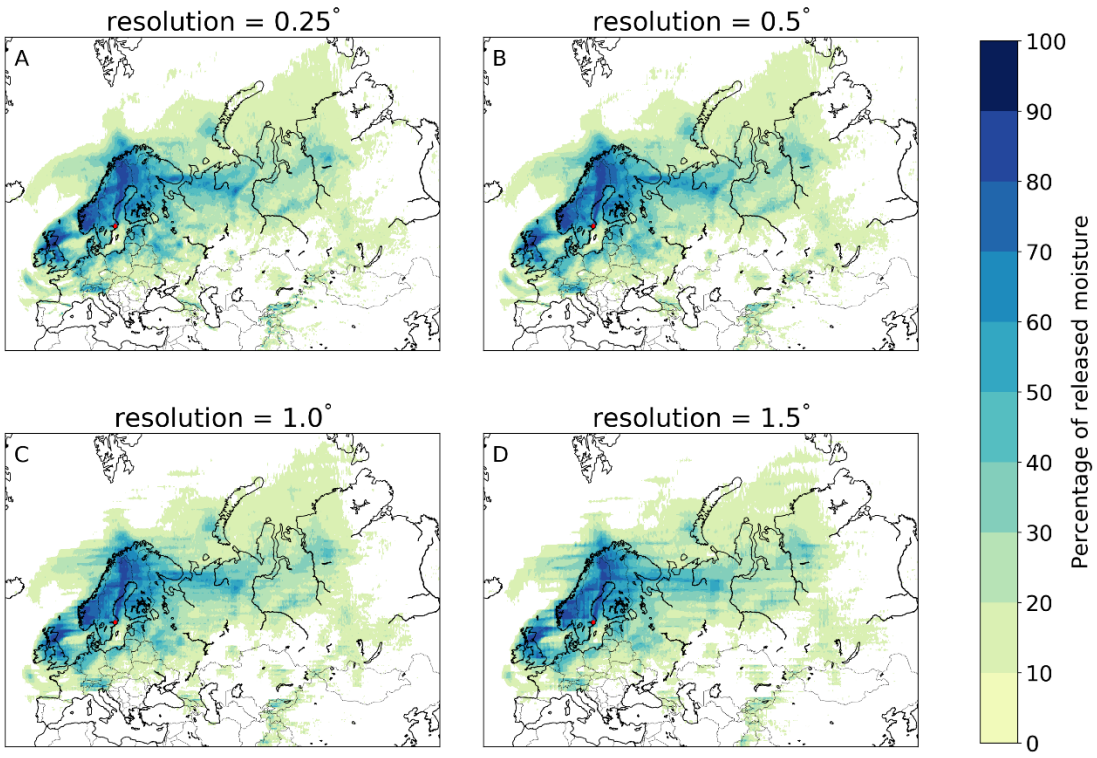

Figure S36: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 1.6° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 10.9° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 2.1° in a northerly direction and mean longitudinal flow of 10.6° in an easterly direction.

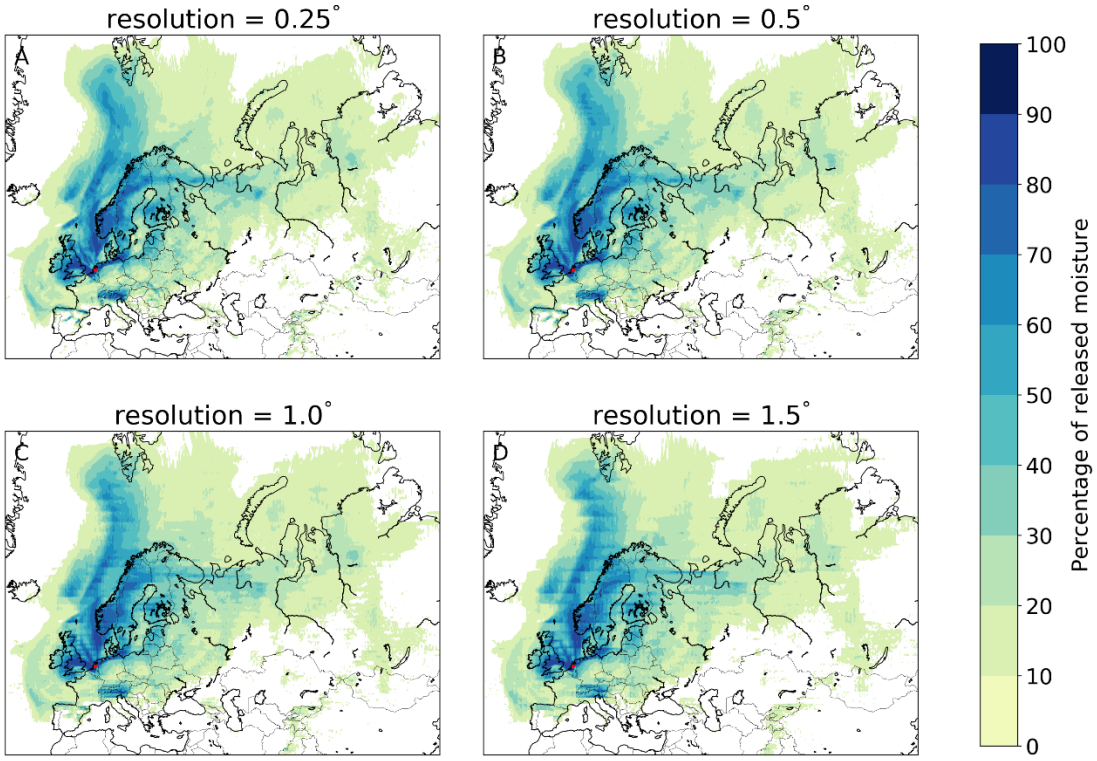

Figure S37: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with different horizontal resolutions. A) 0.25°, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; B) 0.5°, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; C) 1.0°, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; D) 1.5°, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 15.5° in an easterly direction.

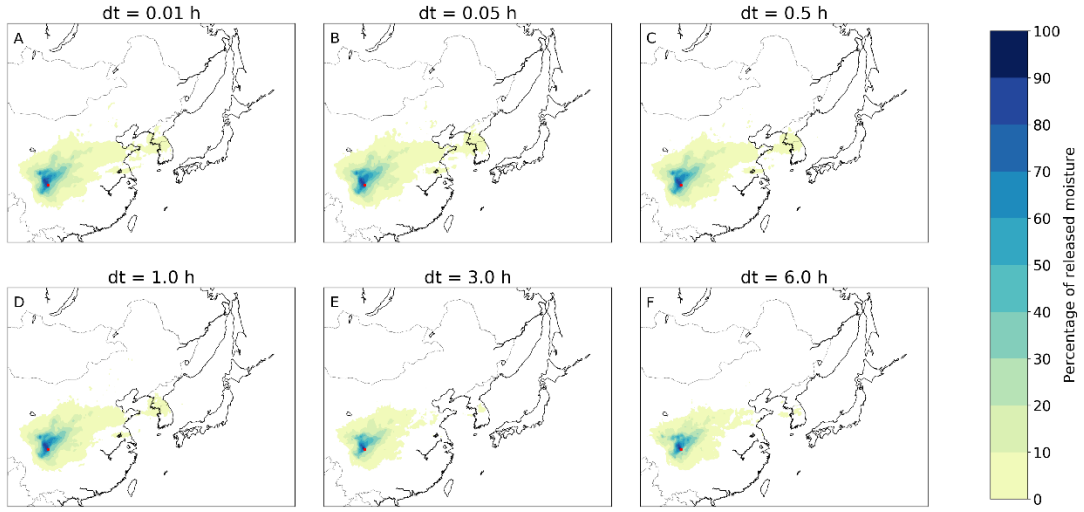

Figure S38: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 2.4° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 2.5° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 2.2° in a northerly direction and mean longitudinal flow of 2.3° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 2.2° in a northerly direction and mean longitudinal flow of 2.3° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.6° in an easterly direction; F) 6.0 h, with a mean latitudinal moisture flow of 1.9° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction.

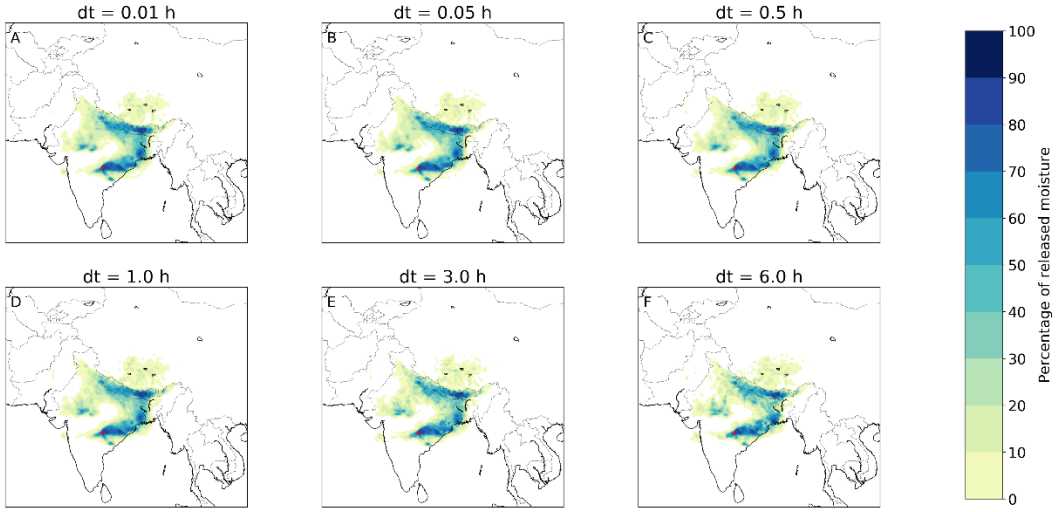

Figure S39: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.8° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 4.8° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction; F) 6.0 h, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.7° in an easterly direction.

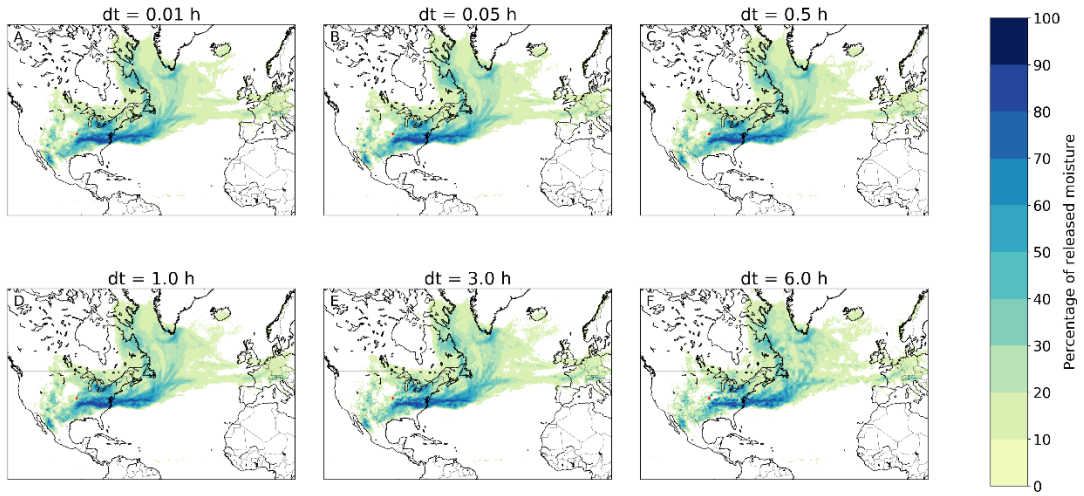

Figure S40: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 3.9° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 3.9° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 4.2° in a northerly direction and mean longitudinal flow of 16.1° in an easterly direction; F) 6.0 h, with a mean latitudinal moisture flow of 4.5° in a northerly direction and mean longitudinal flow of 16.7° in an easterly direction.

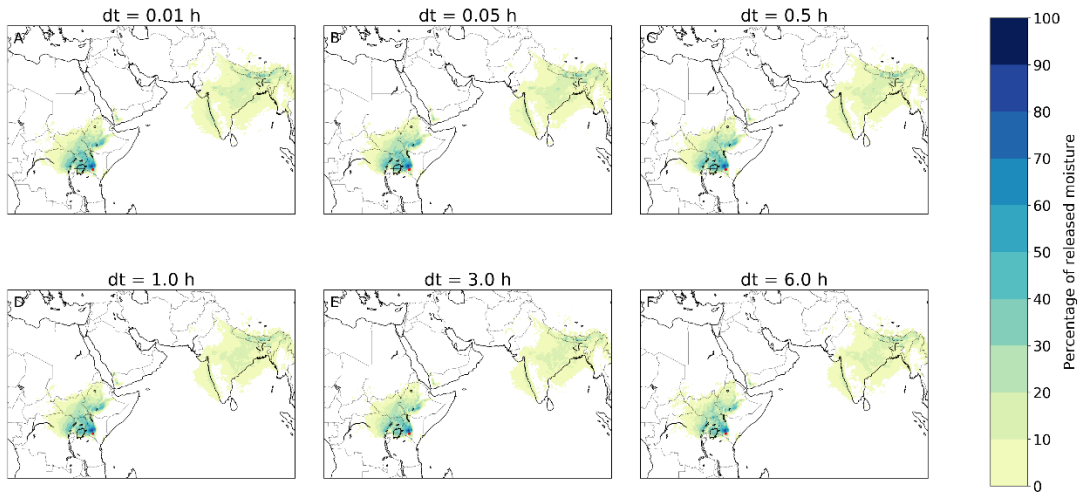

Figure S41: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 7.4° in a northerly direction and mean longitudinal flow of 3.2° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 7.2° in a northerly direction and mean longitudinal flow of 3.0° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 7.1° in a northerly direction and mean longitudinal flow of 2.8° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 6.9° in a northerly direction and mean longitudinal flow of 2.5° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.5° in an easterly direction; F) 6.0 h, with a mean latitudinal moisture flow of 6.6° in a northerly direction and mean longitudinal flow of 2.5° in an easterly direction.

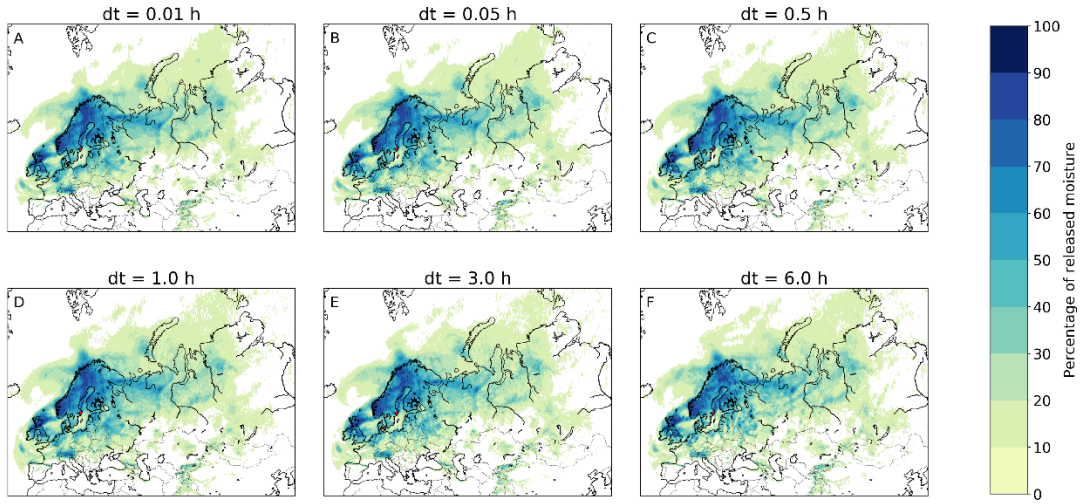

Figure S42: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 1.1° in a northerly direction and mean longitudinal flow of 11.1° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 0.8° in a northerly direction and mean longitudinal flow of 11.2° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 1.1° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; F) 3.0 h, with a mean latitudinal moisture flow of 1.4° in a northerly direction and mean longitudinal flow of 11.5° in an easterly direction.

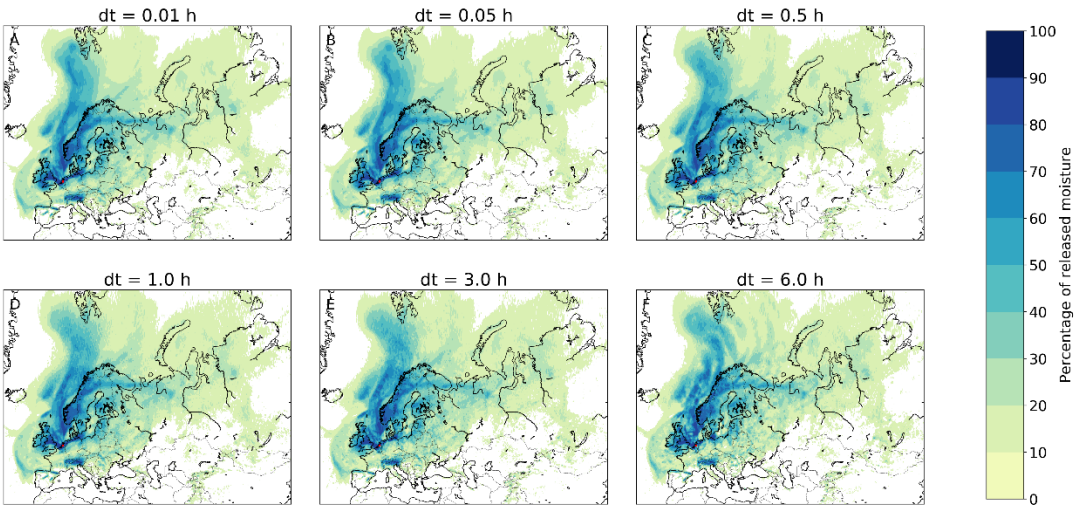

Figure S43: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with different time steps (dt): 0.01 hours, 0.05 hours, 0.5 hours, 1.0 hours, 3.0 hours, and 6.0 hours. A) 0.01 h, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; B) 0.05 h, with a mean latitudinal moisture flow of 6.1° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; C) 0.5 h, with a mean latitudinal moisture flow of 5.9° in a northerly direction and mean longitudinal flow of 15.3° in an easterly direction; D) 1.0 h, with a mean latitudinal moisture flow of 5.9° in a northerly direction and mean longitudinal flow of 15.2° in an easterly direction; E) 3.0 h, with a mean latitudinal moisture flow of 6.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; F) 6.0 h, with a mean latitudinal moisture flow of 6.7° in a northerly direction and mean longitudinal flow of 15.9° in an easterly direction.

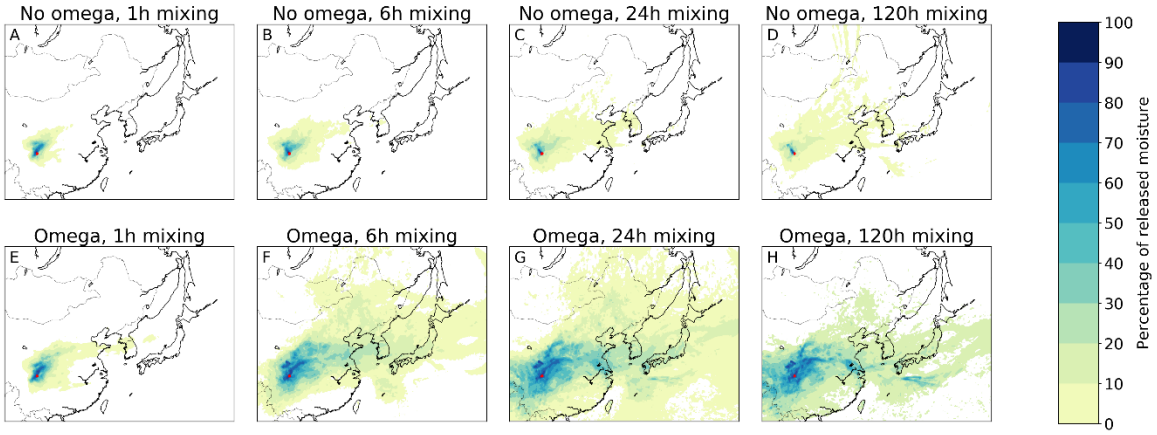

Figure S44: Different footprints of moisture releases from Chengdu in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 1.6° in a northerly direction and mean longitudinal flow of 1.3° in an easterly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 1.8° in a northerly direction and mean longitudinal flow of 1.7° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 2.0° in a northerly direction and mean longitudinal flow of 1.8° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 2.0° in a northerly direction and mean longitudinal flow of 1.6° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 2.4° in a northerly direction and mean longitudinal flow of 3.1° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 3.8° in a northerly direction and mean longitudinal flow of 7.1° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 1.5° in a northerly direction and mean longitudinal flow of 3.8° in an easterly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 0.6° in a southerly direction and mean longitudinal flow of 1.0° in an easterly direction.

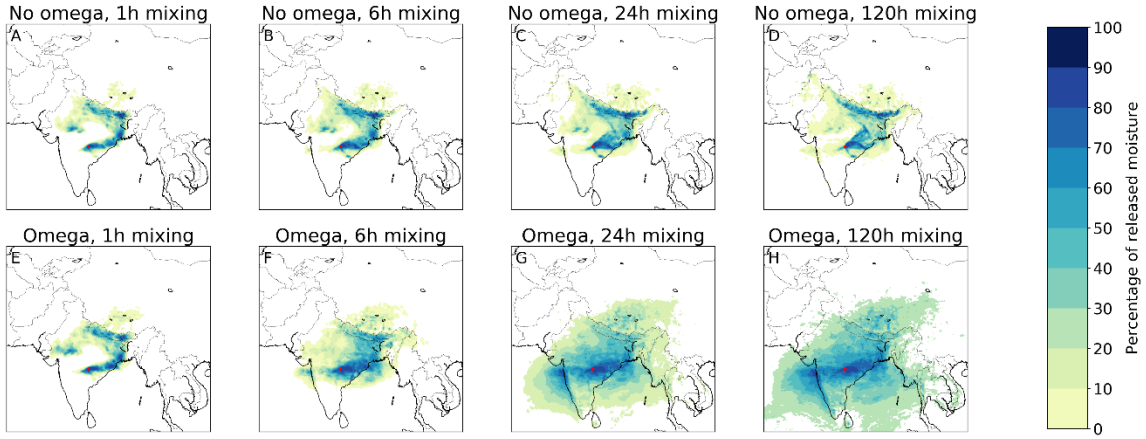

Figure S45: Different footprints of moisture releases from Nagpur in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 4.9° in a northerly direction and mean longitudinal flow of 3.4° in an easterly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 3.6° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 4.6° in a northerly direction and mean longitudinal flow of 3.8° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 4.5° in a northerly direction and mean longitudinal flow of 3.9° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 4.6° in a northerly direction and mean longitudinal flow of 3.4° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 2.7° in a northerly direction and mean longitudinal flow of 3.9° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 1.1° in a southerly direction and mean longitudinal flow of 1.1° in a westerly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 3.7° in a southerly direction and mean longitudinal flow of 0.5° in a westerly direction.

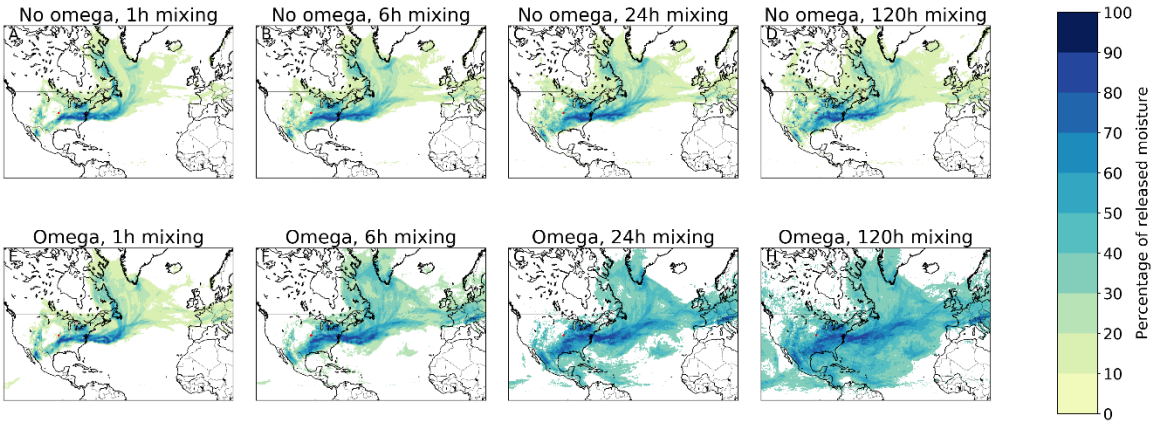

Figure S46: Different footprints of moisture releases from Central Kansas in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 4.3° in a northerly direction and mean longitudinal flow of 16.4° in an easterly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 4.1° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 3.7° in a northerly direction and mean longitudinal flow of 14.6° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 3.3° in a northerly direction and mean longitudinal flow of 13.4° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 4.0° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 5.1° in a northerly direction and mean longitudinal flow of 12.5° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 2.3° in a northerly direction and mean longitudinal flow of 9.2° in an easterly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 1.1° in a southerly direction and mean longitudinal flow of 6.0° in an easterly direction.

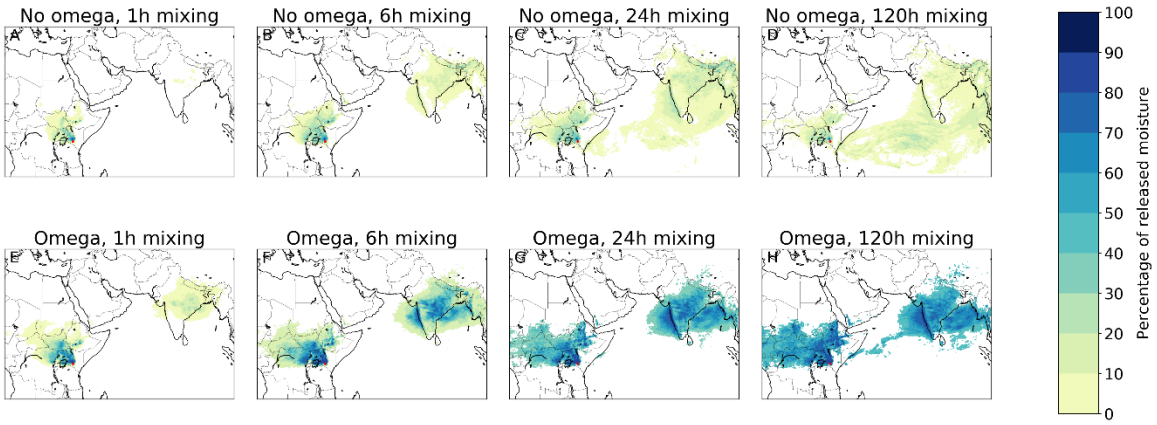

Figure S47: Different footprints of moisture releases from Nairobi in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 3.5° in a northerly direction and mean longitudinal flow of 0.9° in a westerly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 6.5° in a northerly direction and mean longitudinal flow of 2.8° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 6.5° in a northerly direction and mean longitudinal flow of 5.3° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 3.6° in a northerly direction and mean longitudinal flow of 5.4° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 6.9° in a northerly direction and mean longitudinal flow of 0.1° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 12.9° in a northerly direction and mean longitudinal flow of 9.5° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 12.5° in a northerly direction and mean longitudinal flow of 10.2° in an easterly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 11.0° in a northerly direction and mean longitudinal flow of 8.8° in an easterly direction.

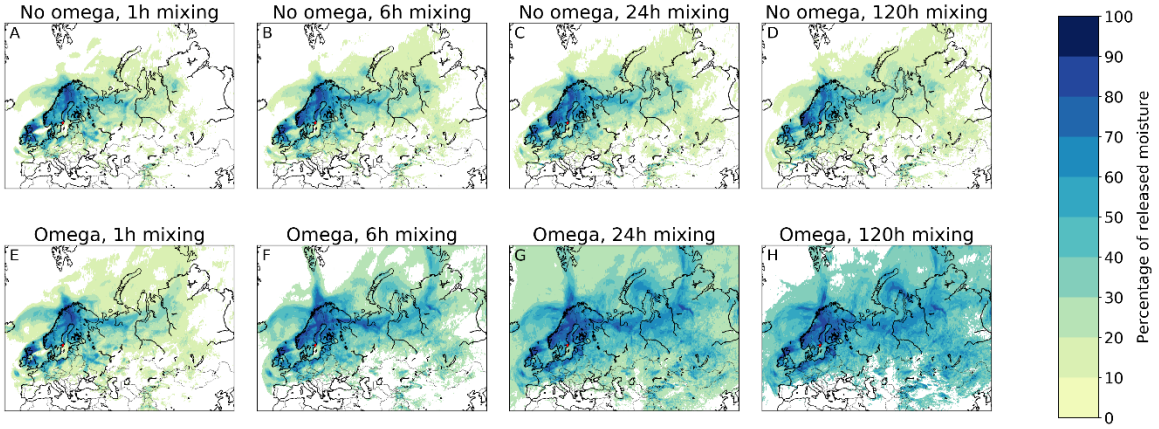

Figure S48: Different footprints of moisture releases from Stockholm in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 1.5° in a northerly direction and mean longitudinal flow of 11.8° in an easterly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 1.5° in a northerly direction and mean longitudinal flow of 11.0° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 1.0° in a northerly direction and mean longitudinal flow of 10.1° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 0.4° in a northerly direction and mean longitudinal flow of 8.3° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 1.3° in a northerly direction and mean longitudinal flow of 12.6° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 1.2° in a northerly direction and mean longitudinal flow of 13.6° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 0.0° in northerly/a southerly direction and mean longitudinal flow of 14.2° in an easterly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 0.8° in a southerly direction and mean longitudinal flow of 14.2° in an easterly direction.

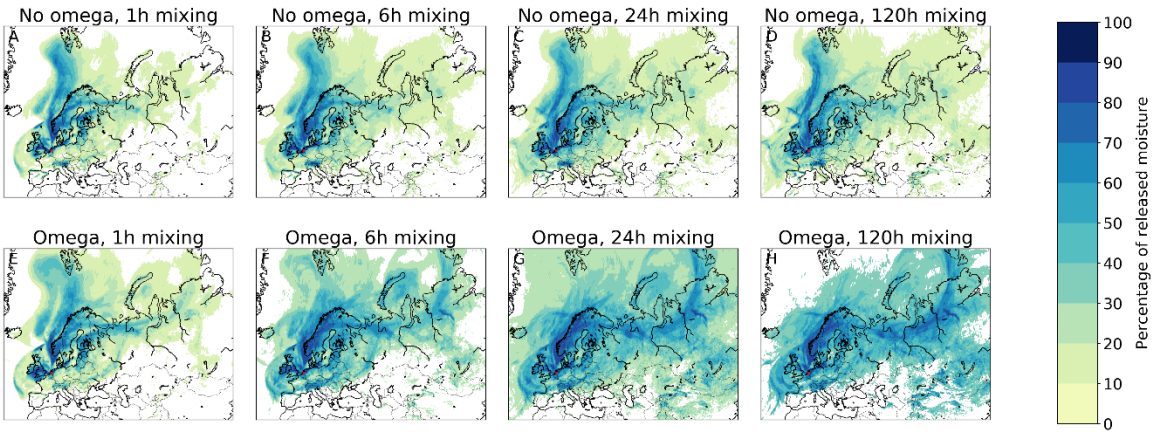

Figure S49: Different footprints of moisture releases from Utrecht in July 2012 in a three-dimensional Lagrangian model with different mixing assumptions: without and with accounting for the three-dimensional moisture flows in the ERA5 data (termed omega), and with different assumptions of additional vertical mixing speed (full mixing every 1 h, every 6 h, every 24 h, and every 120 h). A) Without omega, every 1 h mixing, with a mean latitudinal moisture flow of 8.1° in a northerly direction and mean longitudinal flow of 14.9° in an easterly direction; B) Without omega, every 6 h mixing, with a mean latitudinal moisture flow of 6.3° in a northerly direction and mean longitudinal flow of 15.4° in an easterly direction; C) Without omega, every 24 h mixing, with a mean latitudinal moisture flow of 4.7° in a northerly direction and mean longitudinal flow of 15.5° in an easterly direction; D) Without omega, every 120 h mixing, with a mean latitudinal moisture flow of 3.6° in a northerly direction and mean longitudinal flow of 15.6° in an easterly direction; E) With omega, every 1 h mixing, with a mean latitudinal moisture flow of 8.8° in a northerly direction and mean longitudinal flow of 17.5° in an easterly direction; F) With omega, every 6 h mixing, with a mean latitudinal moisture flow of 6.2° in a northerly direction and mean longitudinal flow of 17.9° in an easterly direction; G) With omega, every 24 h mixing, with a mean latitudinal moisture flow of 4.4° in a northerly direction and mean longitudinal flow of 18.1° in an easterly direction; H) With omega, every 120 h mixing, with a mean latitudinal moisture flow of 3.9° in a northerly direction and mean longitudinal flow of 18.4° in an easterly direction.