Reconstruction of droughts in India using multiple land surface models (1951-2015)

Vimal Mishra1, Reepal Shah1, Syed Azhar1, Harsh Shah1, Parth Modi1, Rohini Kumar2

1Civil Engineering, Indian Institute of Technology (IIT) Gandhinagar, Gujarat, 382355

2UFZ-Helmholtz Centre for Environmental Research, Leipzig, Germany

*Correspondence to*: Vimal Mishra ([vmishra@iitgn.ac.in](mailto:vmishra@iitgn.ac.in))

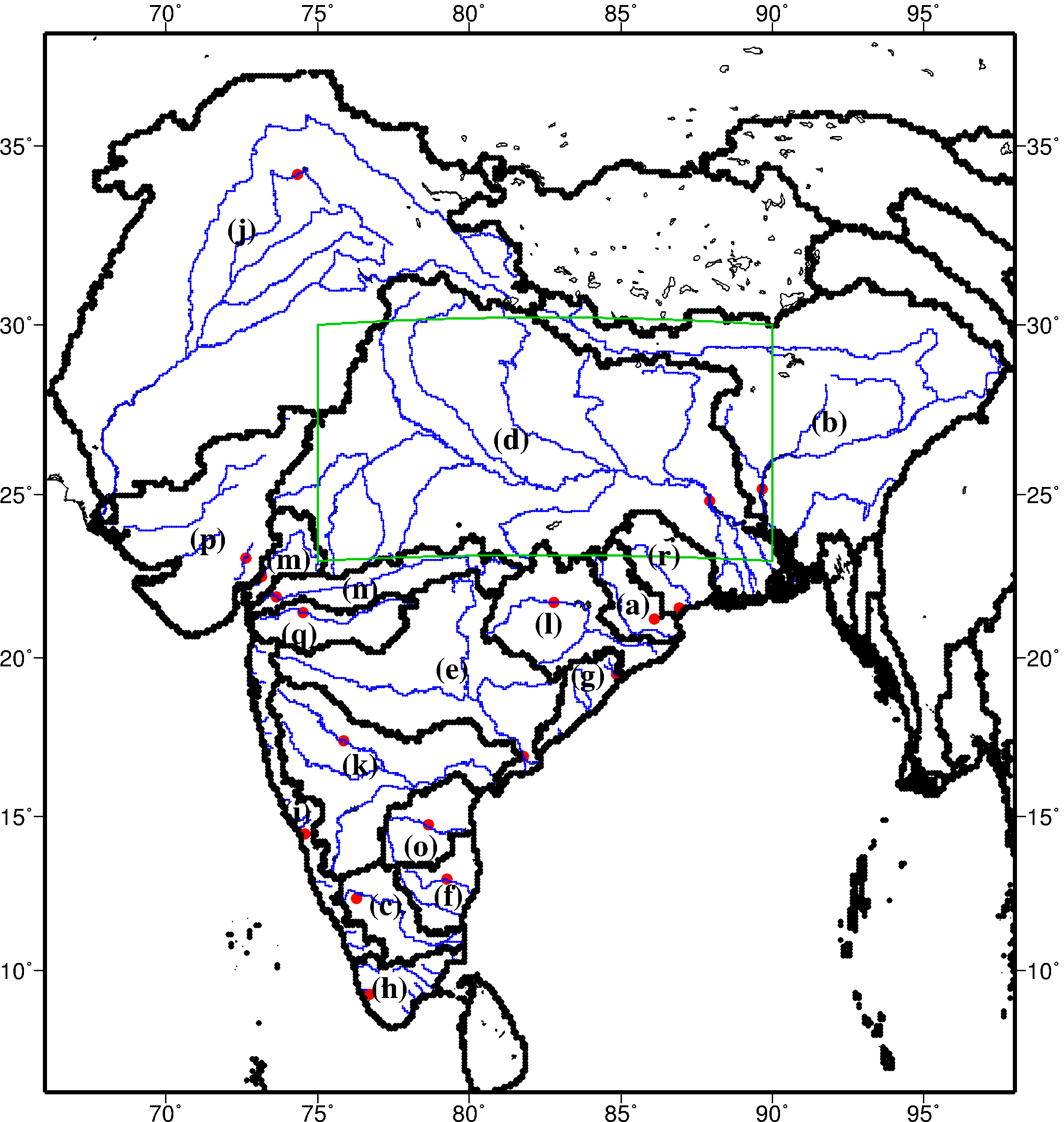


Figure S1: Map of gauge stations used for calibration and validations of models (shown with red color filled circle), river network (shown with blue color line) and basins (bordered with black color line, Refer basins name in Table S2) of India. Boundary of India is shown with grey color. Green color box represents the Indo-Gangetic plain used in this study.

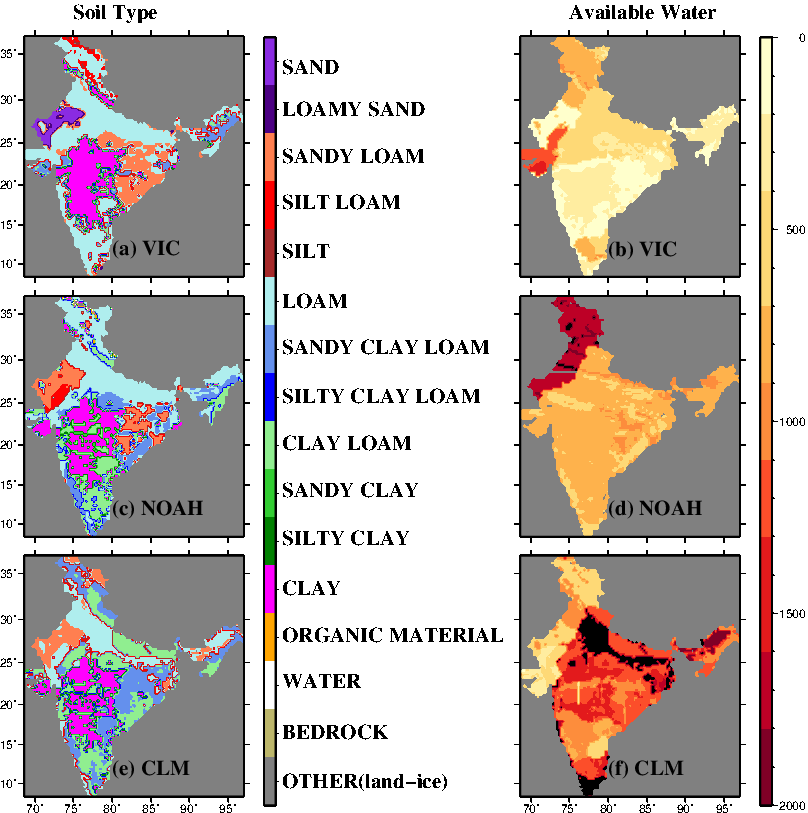


Figure S2. Soil texture used in different models (a,c,e) and available water in total soil column (b,d,f).

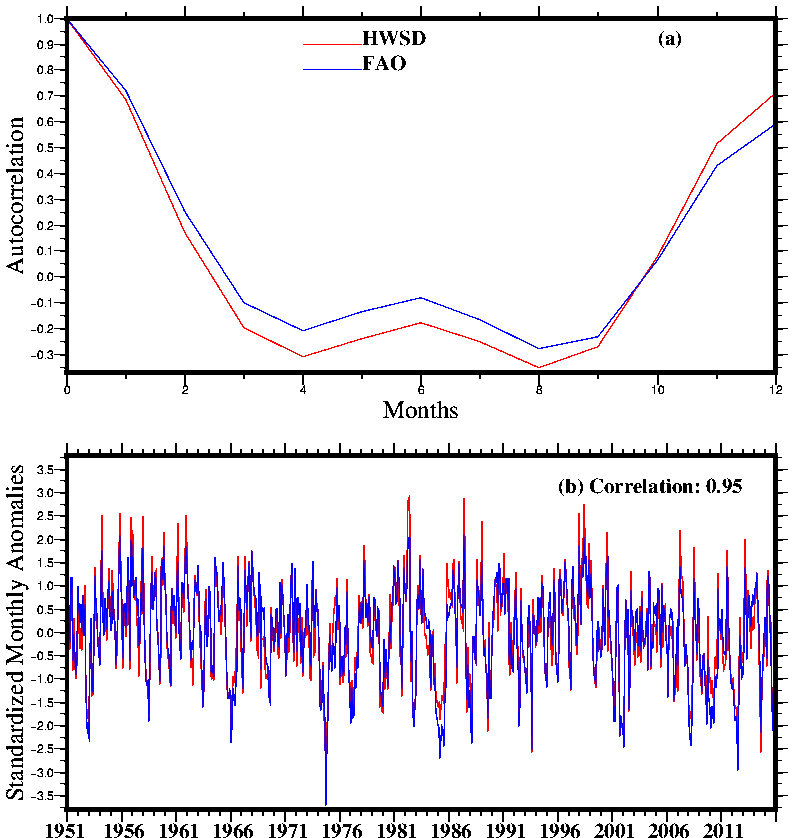


Figure S3: Impact of change in soil parameters on soil moisture simulated using the VIC model. (a) Comparison of autocorrelation in 60 cm soil moisture for soil parameters due to different soil parameters based on FAO and HWSD for grid cell at 30.125°N and 77.125°E. (b) Same as (a) but for soil moisture monthly anomalies.

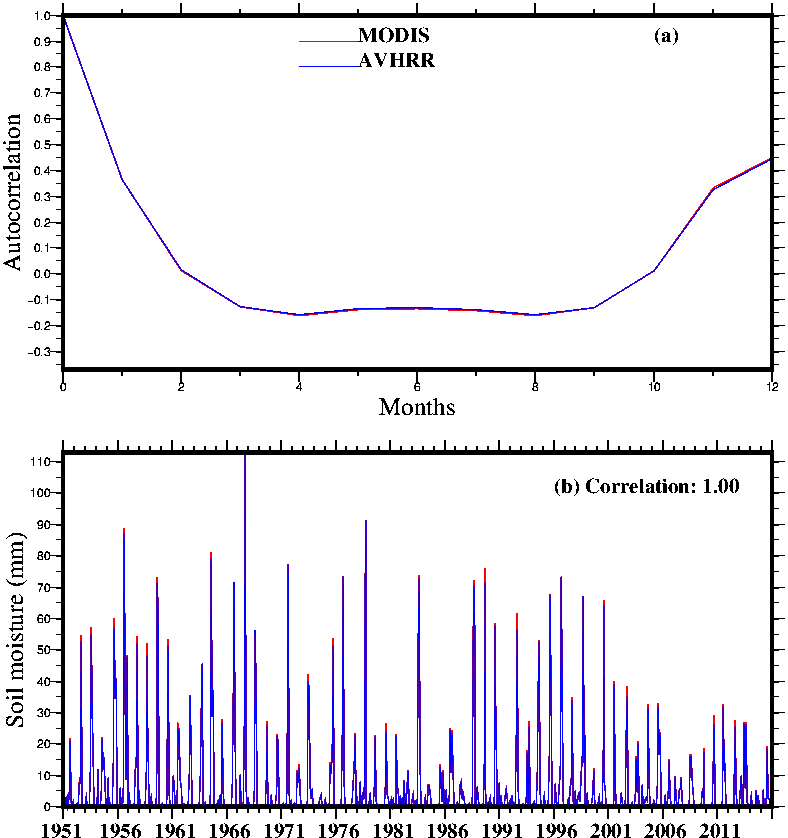


Figure S4: Impact of change in vegetation cover on soil moisture simulated using the NOAH. (a) Shows comparison of autocorrelation in 60 cm soil moisture due to different vegetation parameters based on MODIS and AVHRR. (b) Same as (a) but for soil moisture.

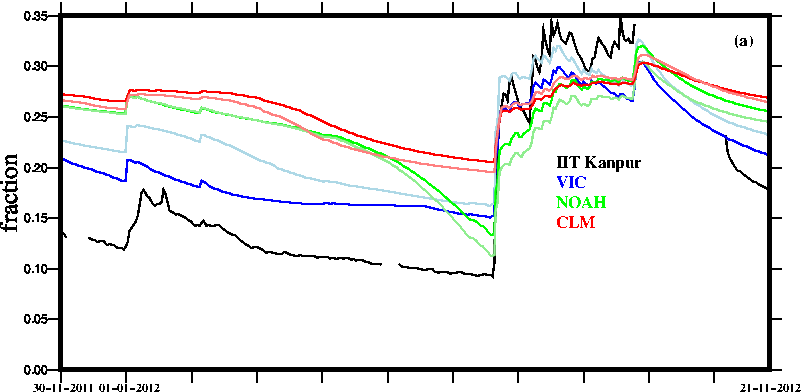


Figure S5. Weekly dynamics of 60 cm simulated soil moisture compared with observations from the IIT Kanpur station. Black line shows the observed soil moisture, while the blue, green and red lines show the simulated soil moisture from the VIC, Noah, and CLM, respectively under the control (un-calibrated) condition; whereas light blue, light green and pink color lines depict the simulated soil moisture after calibration from the respective models.

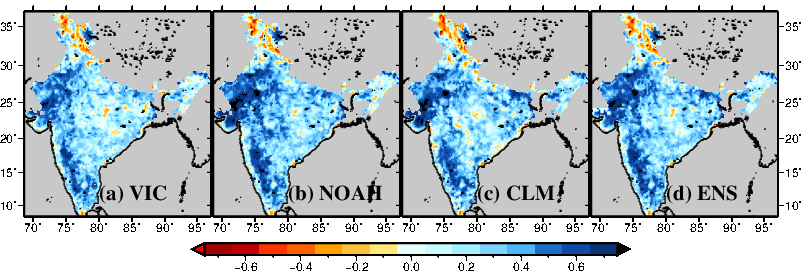
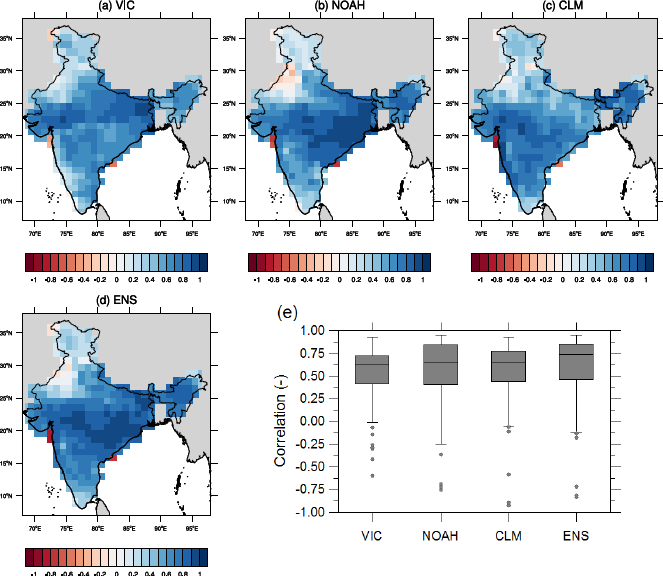


Figure S6: Correlation of the annual top-layer soil moisture simulated using three LSMs and their ensemble mean (ENS) with a top few cm soil moisture derived from ESACCI during the period 1979-2012.

Figure S7: Correlation between monthly anomalies of the terrestrial water storage (TWS) from GRACE and the simulated total column soil moisture anomalies from the (a) VIC, (b) NOAH, (c) CLM models for the period 2002-2015. Additionally the correlation plot for the ensemble mean (ENS) corresponding to three models average monthly anomalies is shown in panel (d). The summary of the correlation plots is shown as the box-whisker plot in panel (e).

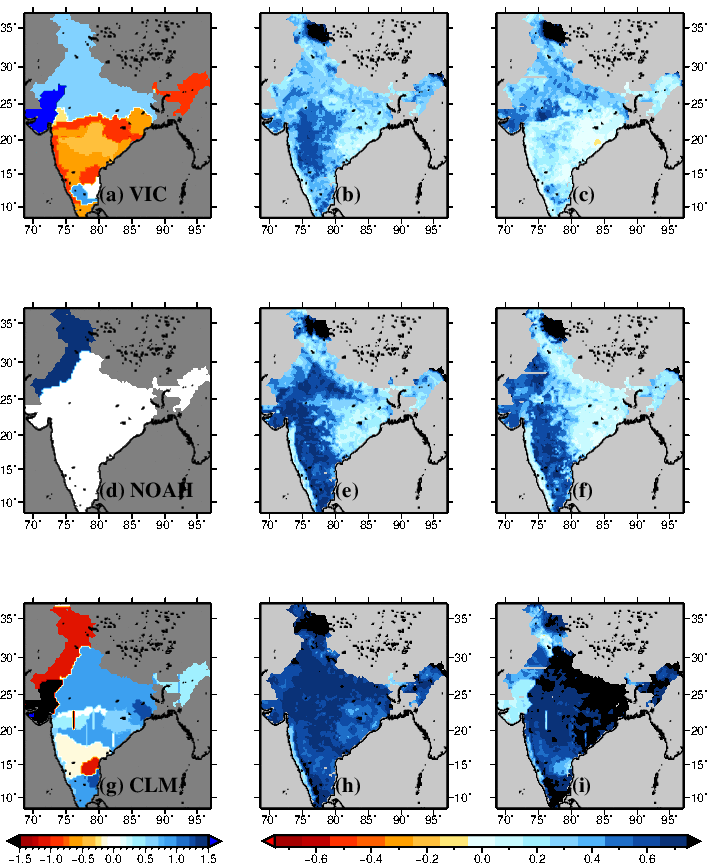


Figure S8: Comparison of persistence before and after calibration. (a,d,g) show change in total depth of first two soil layer after calibration. Panels (b,e,h) show persistence in 60 cm soil moisture before calibration; and (c,f,i) the same but after the model calibration.

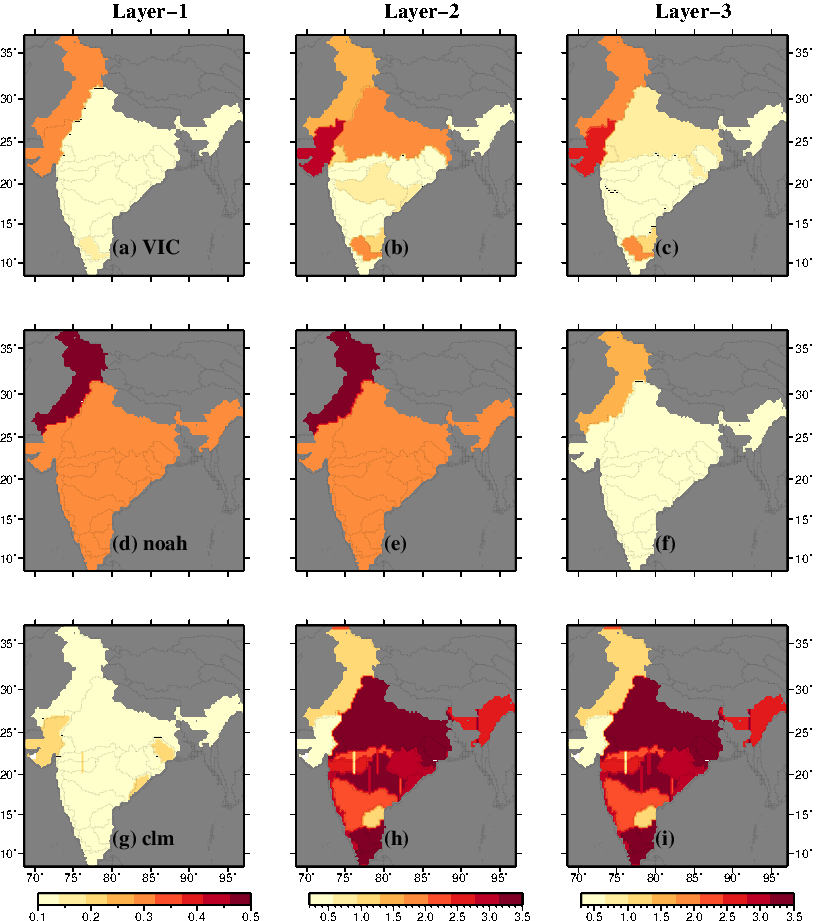


Figure S9: Soil layer thickness (m) for the first three layers of the VIC (a,b,c), NOAH (d,e,f) and CLM (g,h,i).

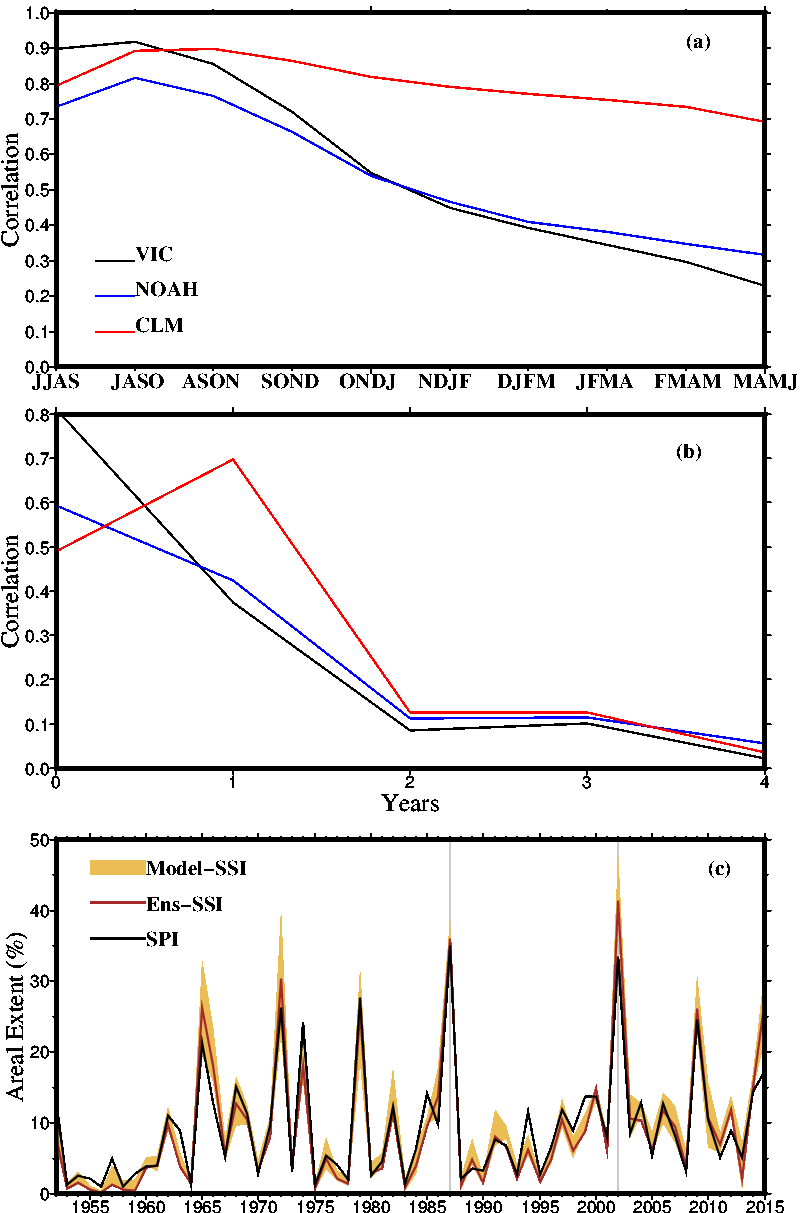


Figure S10: (a) Correlation between 4-month SPI at the end of the monsoon season (JJAS) and 4-month SSI (root-zone soil moisture) at different leads. (b) Correlation of 12-month SPI at the end of December with 12-month SSI at lead varying from 0-48 months. (c) Uncertainty in areal extent of root-zone soil moisture drought based on the lead time for which 4-month SSI shows the highest correlation with the 4-month SPI at the end of the monsoon season. Black line in (c) shows 4-month SPI at the end of the monsoon season. Shaded area shows inter-model uncertainty estimated using one standard deviation. Gray lines show major drought events.

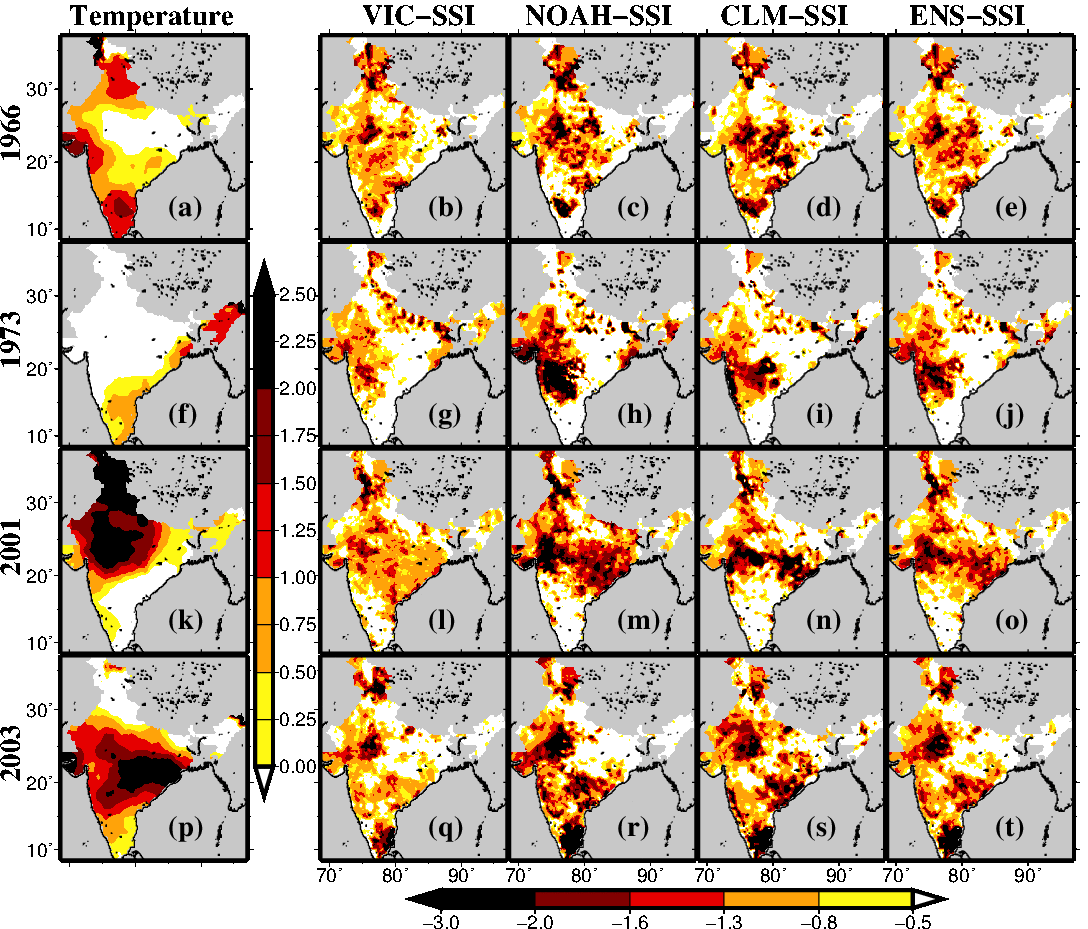


Figure S11: Reconstruction of the Rabi season (November through January) drought events of (a-e) 1966, (f-j) 1973, (k-o) 2001, and (p-t) 2003. (b,g,l,q) 4-month SSI at the end of February estimated using root-zone soil moisture from the VIC model, (c,h,m,r) 4-month SSI simulated using the Noah model, (d,i,n,s) 4-month SSI simulated using the CLM, and (e,j,o,t) ensemble mean of 4-month SSI simulated using the VIC, Noah and CLM. (a,f,k,p) Air temperature anomaly during the Rabi season for the respective years.

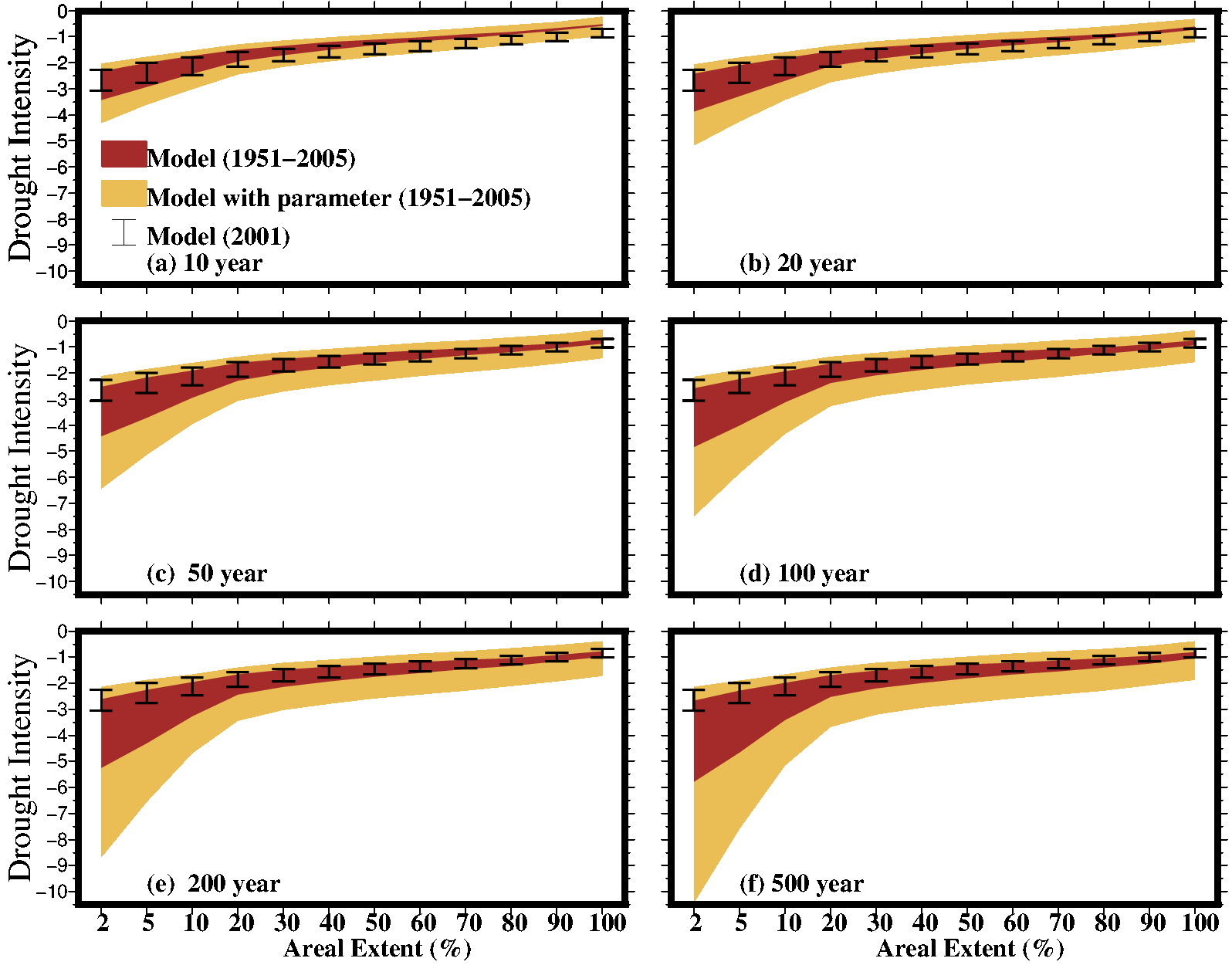


Figure S12: Uncertainty in Intensity-Areal extent-Frequency (IAF) curve of drought during Rabi season (November through January) estimated using three LSMs. Dark brown color shade shows uncertainty in models without considering distribution uncertainty while light brown color with considering distribution uncertainty for all-India with return periods (a) 10, (b) 20, (c) 50, (d) 100, (e) 200, and (f) 500 years. Black error-bars indicate uncertainty in the intensity and areal extent for the 2001 Rabi season drought using three LSMs.

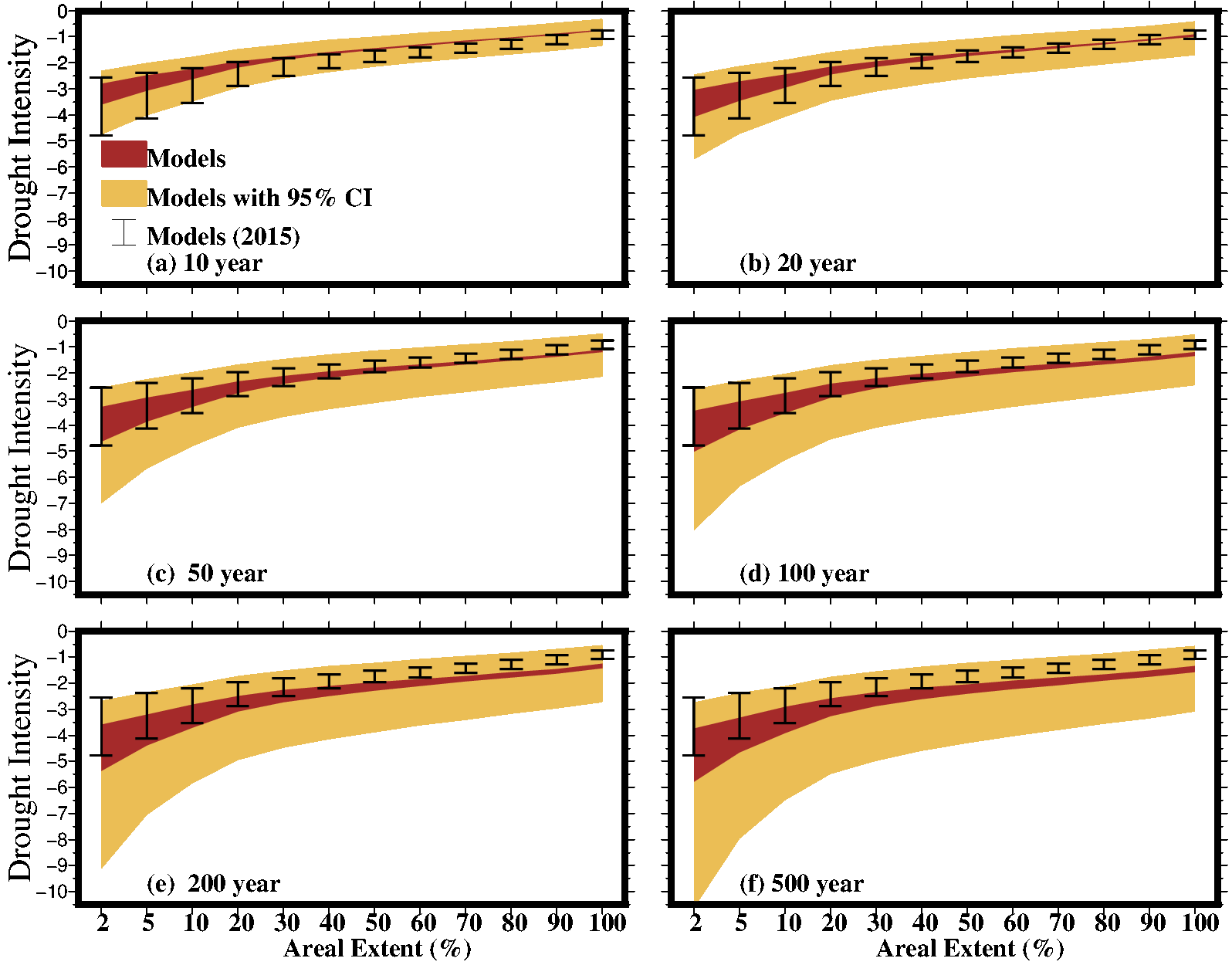


Figure S13: Same as Fig. S12, but for 12-month SSI at the end of December for the Indo-Gangetic plain.

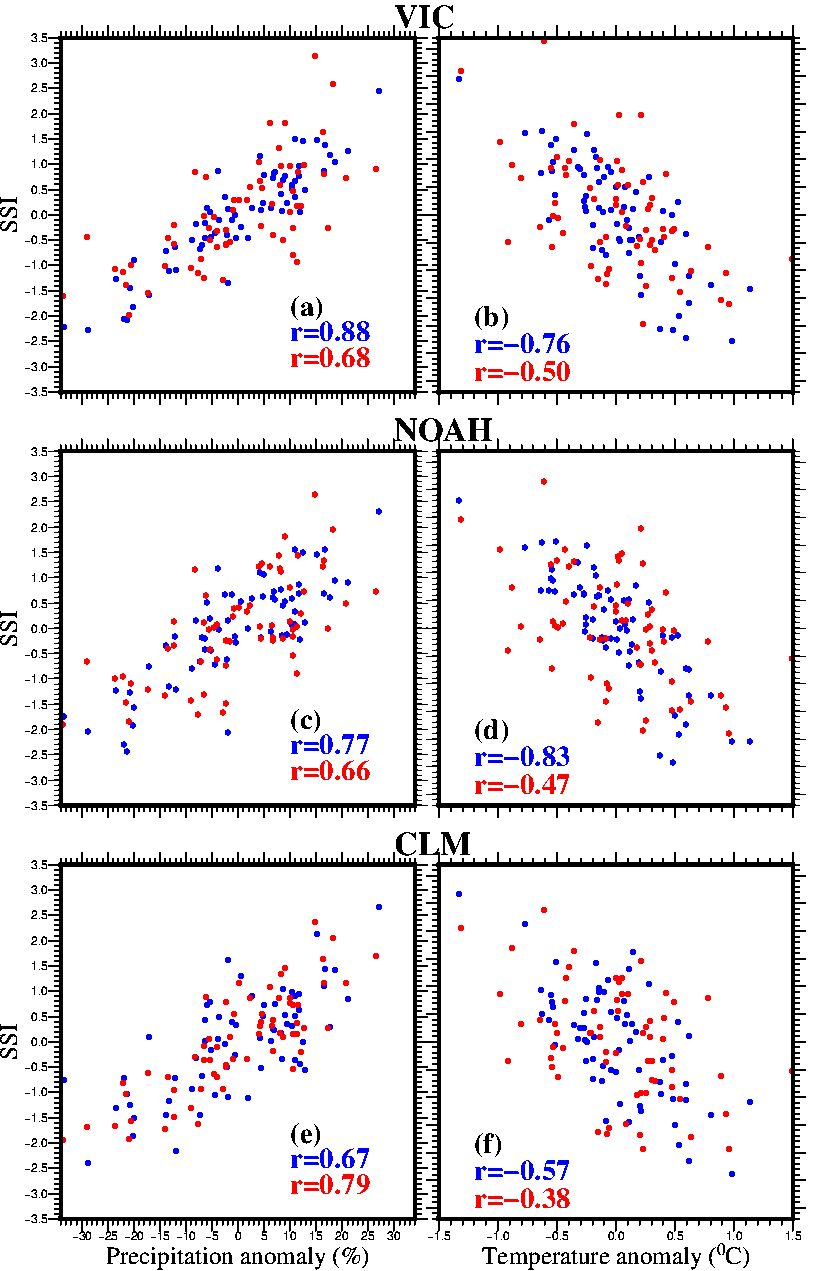


Figure S14. (a,c,e) Relationship between monsoon season precipitation anomaly (%) and 4-month SSI at the end of the Rabi season. (b,d,f) same as (a,c,e) but for the relationship between 4-month SSI and air temperature anomaly of the Rabi season. Correlation coefficients are shown for all-India SSI (blue) and 4-month SSI of the Indo-Gangetic plain (red).

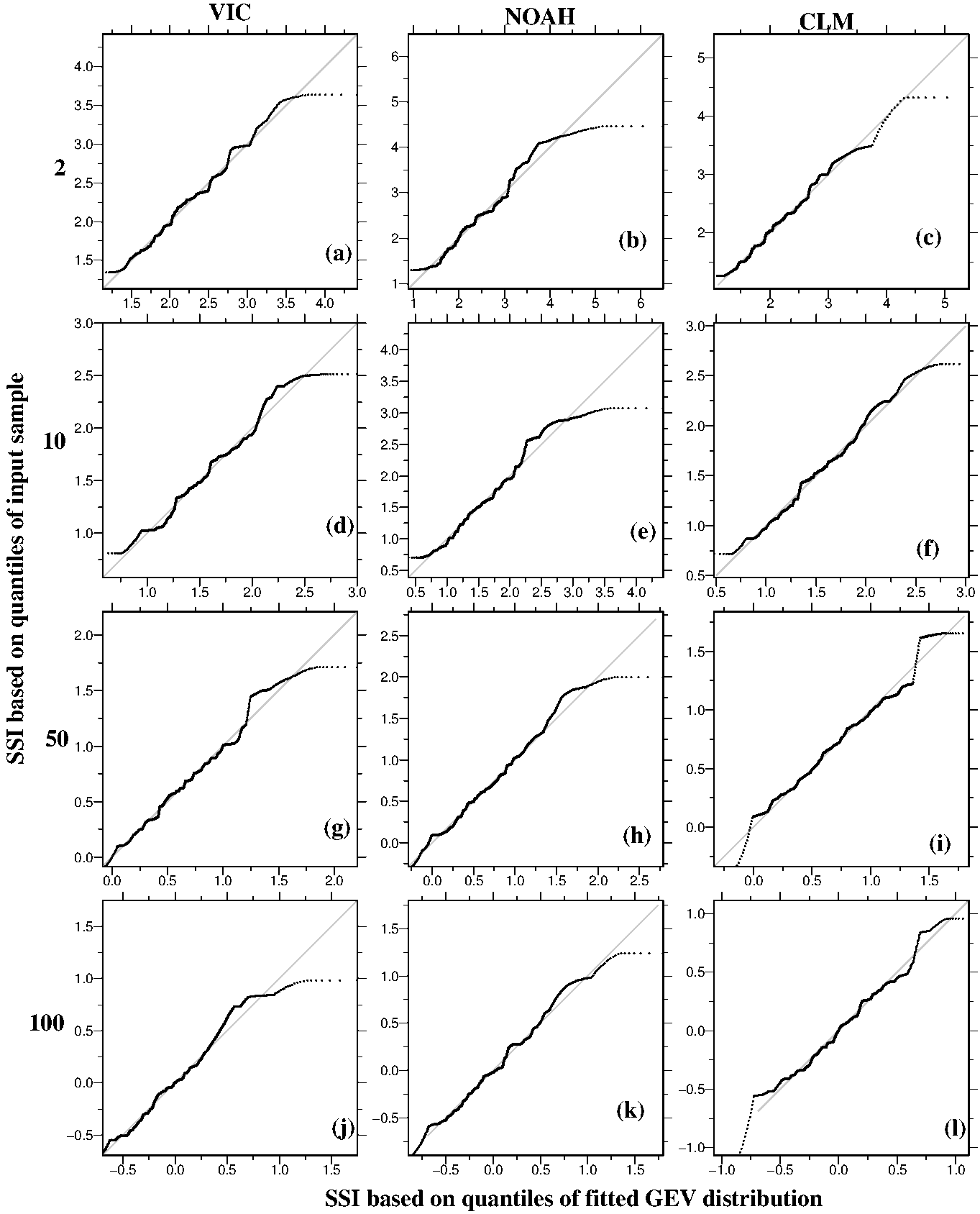


Figure S15: Quantile-quantile plot of the monsoon season SSI for different areal extent (%, written in left as bold) of all India from the VIC (a,d,g,j), NOAH (b,e,h,k), and CLM (c,f,i,l); and the corresponding SSI estimated by fitting a GEV distribution to the monsoon season SSI.

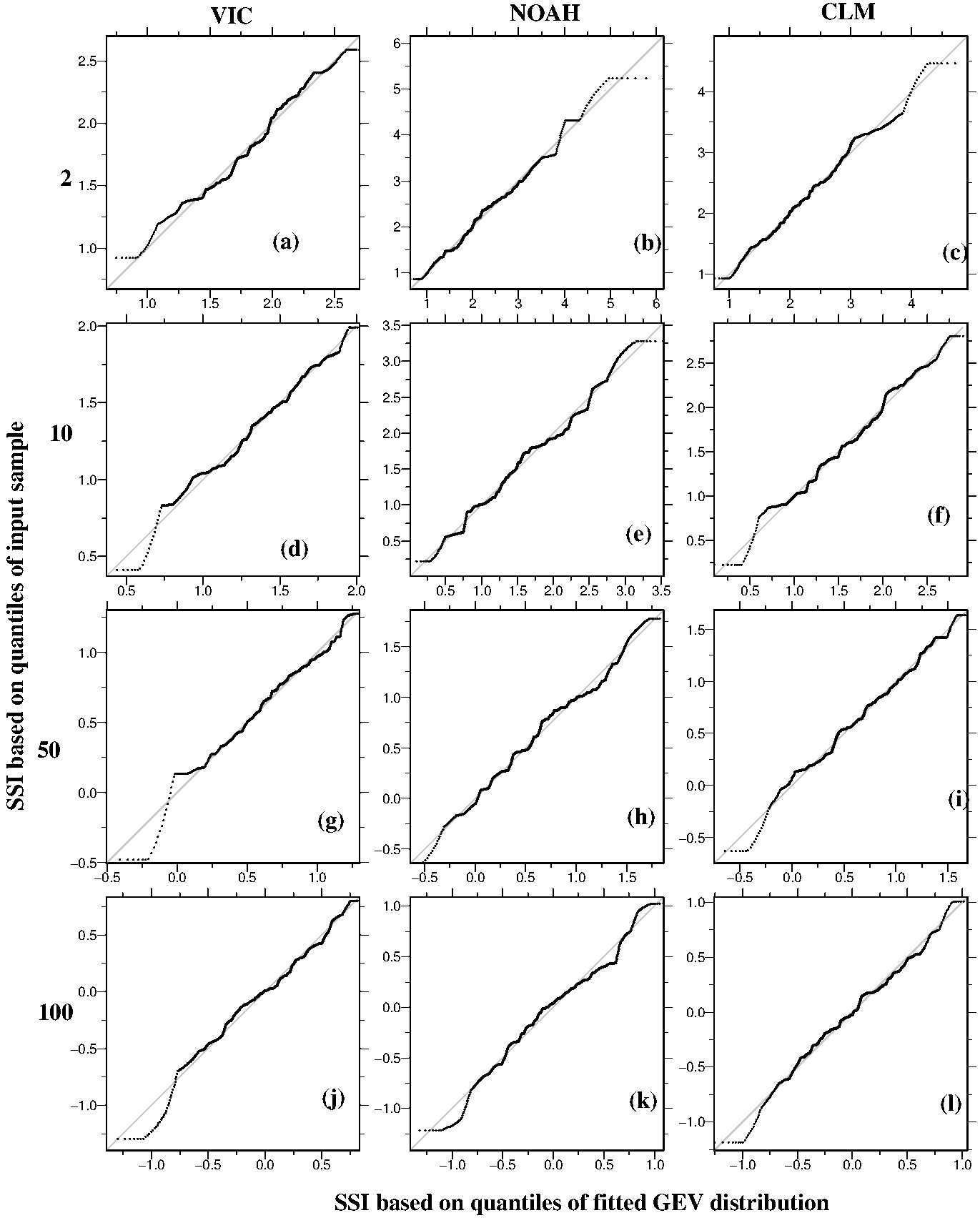


Figure S16: Same as Figure S15 but for the Rabi season.

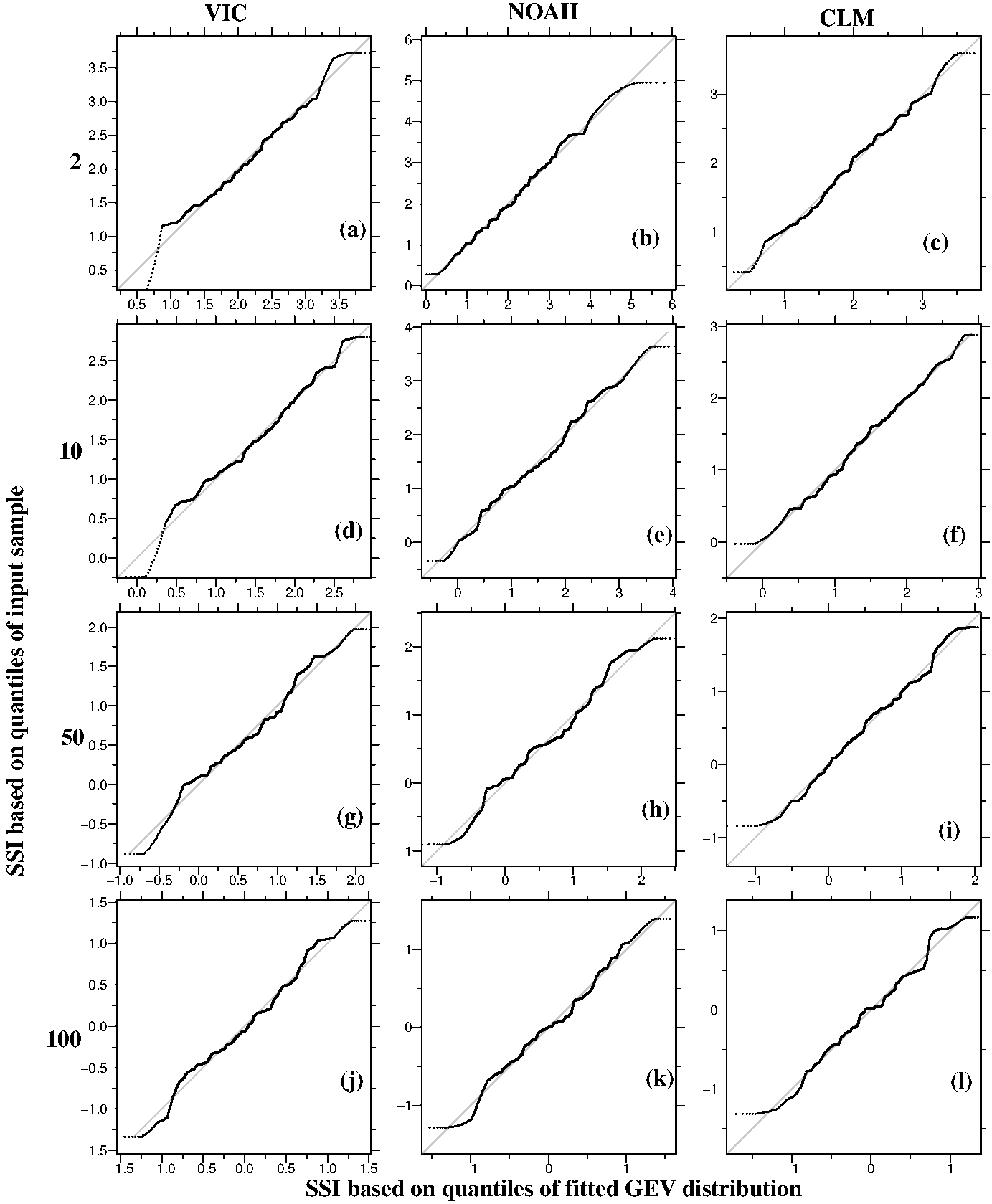


Figure S17: Same as Figure S15 but for annual SSI estimated for areal extent of Indo-Gangetic plain.

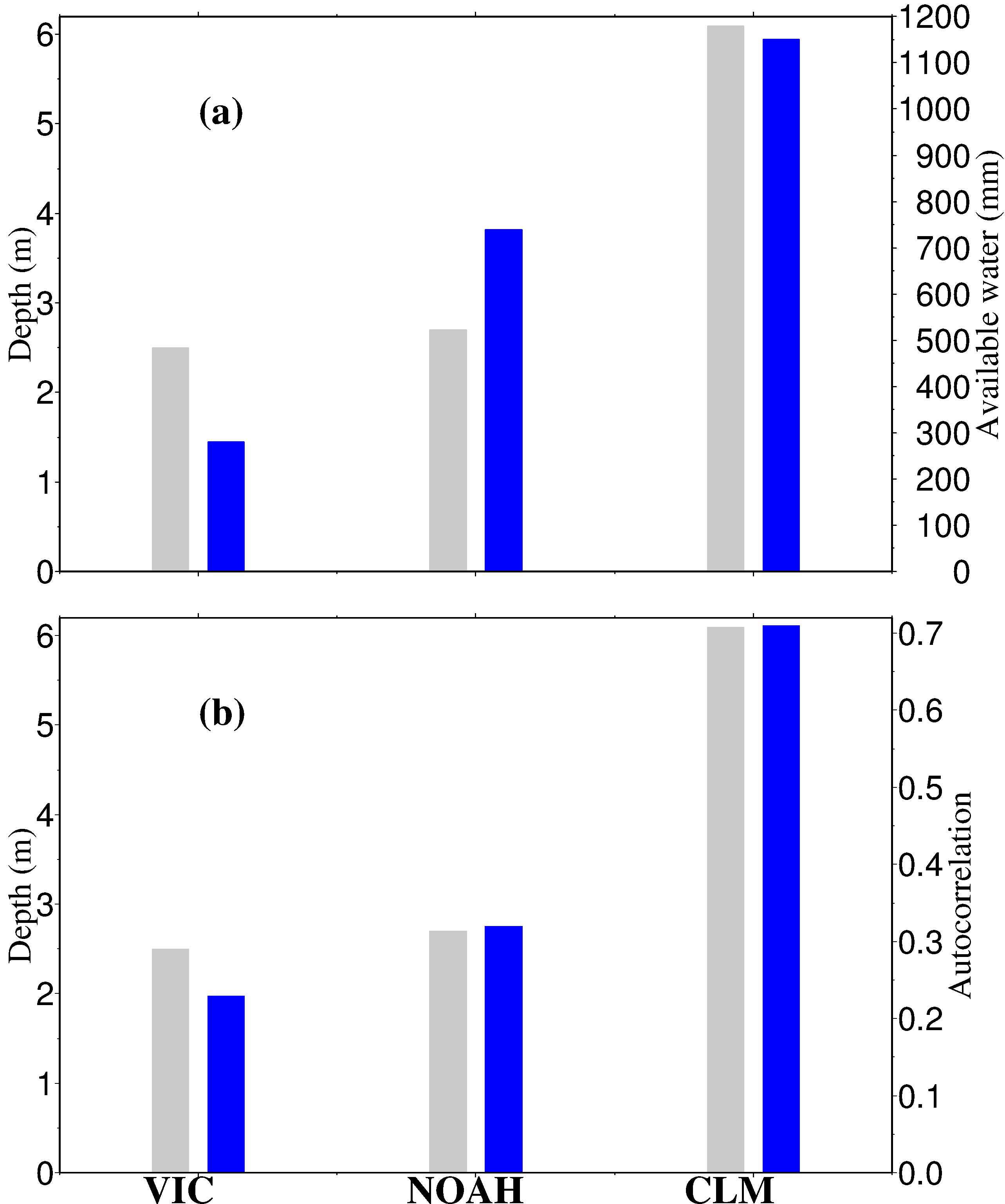


Fig. S18. Relationship between soil depth (gray) and all- India median available water (a), and soil depth (gray) and all- India median soil moisture persistence (b) from the three (VIC, Noah, and CLM) land surface models.

Table S1: Brief description of major hydrological processes, parameters, and forcing variables across the three selected LSMs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **LSM** | **Hydrology** | **Soil Layers** | **Soil/ vegetation parameters** | **Forcing variables** |
| VIC v4.2.1.a | Variable Infiltration Capacity curve for runoff, Arno model for Base flow, drainage driven by gravity, Penman-Monteith equation for evapotranspiration (ET) | Three layers | Vegetation parameter based on 1km Advanced Very High Resolution Radiometer (AVHRR),  Soil parameter from Harmonized world soil database (HWSD) | Four parameters, Precipitation, Maximum and Minimum air temperatures, and Wind speed |
| NOAH v3.1 | Exponential distribution of infiltration capacity for runoff, baseflow proportional to storage, drainage driven by gravity, Penman-Monteith equation for ET estimation, | Four layers | Modified IGBP MODIS 20-category vegetation, vegetation fraction derived based on Normalized Difference Vegetation Index (NDVI) from AVHRR, Soil parameters derived from FAO. | Precipitation, air temperature, wind speed, surface pressure, humidity, surface downward shortwave and longwave radiations. |
| CLM v3.0 | TOPMODEL for surface runoff, groundwater scheme, , Penman-Monteith equation for ET | 10 Layers | Vegetation parameters represented for 17 plant functional types (Bonan et al. 2002), soil parameters based on FAO | Precipitation, air temperature, specific humidity, incident solar radiation, and surface pressure. |

Table S2: Performance of three LSMs (VIC, NOAH, and CLM) in terms of Nash Sutcliffe Efficiency (NS) and correlation coefficient (R) for the monthly streamflow simulations compared against observations across 19 gauging stations across India (see Figure S1 for locations of these basins) for the calibration and validation periods. Additionally the skill of the ensemble mean streamflow (ENS) from the three LSMs is also provided in this Table.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Basins** | **Station** | **Lon**  **(˚)** | **Lat (˚)** | **Drainage Area (km2)** | **Period** | | **VIC** | | **Noah** | | **CLM** | | **ENS** | |
| **R** | **NS** | **R** | **NS** | **R** | **NS** | **R** | **NS** |
| a | Brahmani | Anandpur | 86.12 | 21.21 | 10,000 | Calibration | 1974-1982 | 0.93 | 0.86 | 0.89 | 0.63 | 0.92 | 0.59 | 0.95 | 0.78 |
| Validation | 1985-1990 | 0.95 | 0.74 | 0.90 | 0.48 | 0.94 | 0.64 | 0.96 | 0.74 |
| b | Brahmaputra | Bahadpur | 89.66 | 25.18 | 444,375 | Calibration | 1969-1971 | 0.88 | 0.66 | 0.96 | 0.90 | 0.90 | 0.76 | 0.94 | 0.85 |
| Validation | 1973-1975 | 0.94 | 0.85 | 0.98 | 0.94 | 0.92 | 0.82 | 0.96 | 0.89 |
| c | Cauvery | KMVadi | 76.29 | 12.34 | 3125 | Calibration | 1991-1995 | 0.85 | 0.36 | 0.92 | -6.14 | 0.36 | -0.46 | 0.85 | -4.34 |
| Validation | 1996-2000 | 0.93 | -10.78 | 0.90 | -20.2 | 0.38 | -1.40 | 0.89 | -7.92 |
| d | Ganga | Farakka | 87.92 | 24.83 | 865,000 | Calibration | 1952-1960 | 0.98 | 0.89 | 0.98 | 0.93 | 0.88 | 0.73 | 0.98 | 0.92 |
| Validation | 1965-1973 | 0.98 | 0.78 | 0.98 | 0.91 | 0.87 | 0.66 | 0.98 | 0.88 |
| e | Godavari | Polavaram | 81.78 | 16.92 | 260,000 | Calibration | 1952-1960 | 0.98 | 0.95 | 0.97 | 0.74 | 0.96 | 0.90 | 0.98 | 0.92 |
| Validation | 1965-1973 | 0.95 | 0.81 | 0.94 | 0.72 | 0.93 | 0.85 | 0.97 | 0.88 |
| f | East coast | Tiruk | 79.26 | 12.98 | 10,625 | Calibration | 1976-1977 | 0.79 | 0.30 | 0.85 | -2.20 | 0.69 | -2.31 | 0.80 | -2.24 |
| Validation | 1978-1979 | 0.83 | -1.43 | 0.87 | 0.61 | 0.73 | -0.72 | 0.85 | -0.13 |
| g | North east coast | Purus | 84.87 | 19.51 | 6250 | Calibration | 1997-2000 | 0.87 | 0.75 | 0.81 | 0.17 | 0.81 | -0.09 | 0.86 | 0.36 |
| Validation | 2001-2005 | 0.94 | 0.78 | 0.93 | 0.70 | 0.87 | 0.45 | 0.95 | 0.78 |
| h | South coast | Thump | 76.70 | 9.23 | 1875 | Calibration | 1980-1990 | 0.79 | 0.58 | 0.83 | 0.62 | 0.88 | 0.52 | 0.91 | 0.82 |
| Validation | 1991-1995 | 0.89 | 0.53 | 0.94 | 0.01 | 0.65 | 0.39 | 0.91 | 0.67 |
| i | West coast | Sante | 74.59 | 14.43 | 2500 | Calibration | 1989-1999 | 0.98 | 0.90 | 0.98 | 0.90 | 0.97 | 0.93 | 0.98 | 0.94 |
| Validation | 2000-2005 | 0.87 | 0.55 | 0.89 | 0.50 | 0.88 | 0.59 | 0.88 | 0.57 |
| j | Indus | Baram | 74.33 | 34.22 | 13,125 | Calibration | 1968-1974 | 0.9 | 0.68 | 0.87 | 0.73 | 0.79 | 0.53 | 0.86 | 0.62 |
| Validation | 1976-1979 | 0.90 | 0.80 | 0.84 | 0.68 | 0.88 | 0.71 | 0.84 | 0.69 |
| k | Krishna | Takli | 75.85 | 17.41 | 37,500 | Calibration | 1969-1974 | 0.88 | 0.76 | 0.90 | 0.77 | 0.82 | 0.67 | 0.91 | 0.81 |
| Validation | 1976-1979 | 0.82 | 0.64 | 0.90 | 0.74 | 0.74 | 0.53 | 0.88 | 0.74 |
| l | Mahanadi | Basantpur | 82.79 | 21.72 | 48,750 | Calibration | 1972-1975 | 0.92 | 0.80 | 0.94 | 0.75 | 0.95 | 0.90 | 0.96 | 088 |
| Validation | 1976-1980 | 0.95 | 0.88 | 0.94 | 0.84 | 0.96 | 0.88 | 0.97 | 0.93 |
| m | Mahi | Khanpur | 73.14 | 22.53 | 30,625 | Calibration | 1980-1995 | 0.96 | 0.93 | 0.97 | 0.93 | 0.85 | 0.68 | 0.94 | 0.84 |
| Validation | 1996-2005 | 0.92 | 0.71 | 0.96 | 0.93 | 0.84 | 0.58 | 0.96 | 0.77 |
| n | Narmada | Garudeshwar | 73.65 | 21.89 | 76,250 | Calibration | 1973-1987 | 0.97 | 0.93 | 0.97 | 0.93 | 0.97 | 0.93 | 0.98 | 0.97 |
| Validation | 1996-2005 | 0.95 | 0.66 | 0.96 | 0.79 | 0.92 | 0.64 | 0.96 | 0.77 |
| o | Pennar | Alladupalli | 78.67 | 14.72 | 9375 | Calibration | 1988-1989 | 0.93 | 0.85 | 0.85 | 0.72 | 0.92 | 0.84 | 0.93 | 0.87 |
| Validation | 1990-1991 | 0.89 | 0.70 | 0.83 | 0.65 | 0.84 | 0.62 | 0.91 | 0.83 |
| p | Sabarmati | Ahmedabad | 72.63 | 23.08 | 10,000 | Calibration | 1968-1969 | 0.90 | 0.69 | 0.96 | 0.93 | 0.95 | 0.43 | 0.95 | 0.87 |
| Validation | 1970-1972 | 0.89 | 0.22 | 0.89 | 0.75 | 0.95 | 0.57 | 0.94 | 0.69 |
| q | Tapi | Sarangpur | 74.53 | 21.43 | 46,250 | Calibration | 1980-1986 | 0.97 | 0.93 | 0.97 | 0.92 | 0.92 | 0.84 | 0.97 | 0.93 |
| Validation | 1990-2005 | 0.93 | 0.81 | 0.91 | 0.83 | 0.88 | 0.76 | 0.93 | 0.85 |
| r | Subarnarekha | Govindpur | 86.92 | 21.55 | 4375 | Calibration | 1994-2000 | 0.88 | 0.76 | 0.86 | 0.70 | 0.87 | 0.47 | 0.92 | 0.79 |
| Validation | 2001-2005 | 0.94 | 0.83 | 0.92 | 0.84 | 0.81 | 0.35 | 0.92 | 0.81 |

Table S3: Uncertainty in extent of drought area (%) under severe to exceptional drought based on models simulated SSI during JJAS (shown in Fig. 2a) and based on lagged 4-month SSI (shown in Fig. 4) during the major JJAS droughts based on SPI.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Major JJAS drought (based on SPI)** | **JJAS SSI (Figure 1)** | | | | **Lagged 4-month SSI (Figure 4)** | | | |
|  | **VIC** | **NOAH** | **CLM** | **Ensemble** | **JASO VIC** | **JASO NOAH** | **ASON CLM** | **Ensemble** |
| 1987 | 37.74 | 39.16 | 33.05 | 36.73 | 35.70 | 38.93 | 32.45 | 35.92 |
| 2002 | 34.11 | 38.73 | 37.65 | 35.95 | 38.98 | 48.54 | 37.97 | 41.42 |
| 1979 | 26.61 | 26.25 | 13.19 | 19.87 | 30.31 | 27.28 | 21.15 | 25.49 |
| 1972 | 32.54 | 47.44 | 19.21 | 29.81 | 32.71 | 39.03 | 24.43 | 30.27 |
| 2009 | 29.05 | 34.20 | 33.56 | 31.46 | 22.45 | 27.70 | 29.03 | 26.13 |
| 2015 | 14.01 | 21.21 | 18.13 | 16.51 | 24.33 | 32.82 | 29.07 | 27.51 |

Table S4: Uncertainty in extent of drought area (%) under severe to exceptional drought based on models simulated SSI during Rabi season (NDJF; shown in Fig. S9) during major Rabi season drought based on ensemble mean SSI.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Major Rabi season drought (based on Ensemble SSI)** | **Rabi season SSI (Figure S9)** | | | |
|  | **VIC** | **NOAH** | **CLM** | **Ensemble** |
| 1966 | 16.93 | 25.21 | 25.79 | 21.90 |
| 1973 | 12.40 | 30.11 | 19.61 | 20.68 |
| 2001 | 17.25 | 40.75 | 24.75 | 26.17 |
| 2003 | 19.02 | 36.27 | 34.85 | 28.84 |

Table S5: Shows the monsoon season (JJAS) drought intensity for SSI with different areal-extent (% of India) and return period (in years) based on three LSMs. The GEV distribution is fitted to the JJAS SSI for different areal-extent for the period 1951-2015.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Return period** | **10** | | | **20** | | | **50** | | | **100** | | | **200** | | | **500** | | |
| **Areal Extent** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | |
| **2** | -2.89 | -3.52 | -3.00 | -3.16 | -3.98 | -3.36 | -3.48 | -4.57 | -3.83 | -3.72 | -5.02 | -4.19 | -3.94 | -5.46 | -4.55 | -4.22 | -6.05 | -5.04 | |
| **5** | -2.46 | -2.93 | -2.51 | -2.66 | -3.31 | -2.77 | -2.89 | -3.79 | -3.09 | -3.04 | -4.15 | -3.31 | -3.18 | -4.50 | -3.52 | -3.34 | -4.96 | -3.79 | |
| **10** | -2.15 | -2.47 | -2.14 | -2.32 | -2.79 | -2.32 | -2.53 | -3.20 | -2.54 | -2.66 | -3.50 | -2.67 | -2.78 | -3.78 | -2.80 | -2.91 | -4.15 | -2.94 | |
| **20** | -1.81 | -2.01 | -1.78 | -1.98 | -2.29 | -1.93 | -2.18 | -2.64 | -2.09 | -2.31 | -2.90 | -2.20 | -2.43 | -3.14 | -2.29 | -2.57 | -3.44 | -2.38 | |
| **30** | -1.58 | -1.73 | -1.55 | -1.76 | -2.00 | -1.70 | -1.97 | -2.33 | -1.85 | -2.10 | -2.56 | -1.95 | -2.22 | -2.78 | -2.03 | -2.37 | -3.06 | -2.12 | |
| **40** | -1.41 | -1.52 | -1.38 | -1.59 | -1.78 | -1.53 | -1.80 | -2.10 | -1.68 | -1.94 | -2.32 | -1.77 | -2.07 | -2.54 | -1.85 | -2.22 | -2.80 | -1.94 | |
| **50** | -1.25 | -1.35 | -1.23 | -1.44 | -1.60 | -1.38 | -1.66 | -1.91 | -1.53 | -1.80 | -2.13 | -1.62 | -1.94 | -2.34 | -1.70 | -2.10 | -2.60 | -1.78 | |
| **60** | -1.11 | -1.19 | -1.10 | -1.30 | -1.44 | -1.24 | -1.53 | -1.75 | -1.39 | -1.68 | -1.96 | -1.49 | -1.82 | -2.16 | -1.57 | -1.99 | -2.42 | -1.65 | |
| **70** | -0.98 | -1.05 | -0.97 | -1.17 | -1.30 | -1.11 | -1.40 | -1.59 | -1.27 | -1.56 | -1.80 | -1.36 | -1.72 | -2.00 | -1.44 | -1.90 | -2.25 | -1.53 | |
| **80** | -0.84 | -0.91 | -0.83 | -1.04 | -1.15 | -0.98 | -1.28 | -1.44 | -1.13 | -1.45 | -1.64 | -1.23 | -1.61 | -1.83 | -1.31 | -1.81 | -2.07 | -1.40 | |
| **90** | -0.70 | -0.77 | -0.69 | -0.90 | -1.00 | -0.84 | -1.15 | -1.28 | -0.99 | -1.33 | -1.47 | -1.08 | -1.50 | -1.65 | -1.16 | -1.71 | -1.88 | -1.25 | |
| **100** | -0.52 | -0.60 | -0.51 | -0.73 | -0.82 | -0.65 | -0.99 | -1.08 | -0.80 | -1.18 | -1.27 | -0.90 | -1.35 | -1.44 | -0.97 | -1.58 | -1.65 | -1.06 | |

Table S6: Parameters and confidence interval for the GEV distribution fitted to monsoon season (JJAS) SSI for three LSMs with different areal extent (% of India).

| **areal extent** | **parameter** | **VIC** | | | **NOAH** | | | **CLM** | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **value** | **Lowe r CI** | **Higher CI** | **value** | **Lower CI** | **Higher CI** | **value** | **Lower CI** | **Higher CI** |
| 2 | shape | -0.06 | -0.25 | 0.14 | 0.00 | -0.22 | 0.22 | 0.02 | -0.18 | 0.23 |
| scale | 0.42 | 0.35 | 0.52 | 0.63 | 0.51 | 0.78 | 0.47 | 0.38 | 0.58 |
| location | 2.00 | 1.88 | 2.12 | 2.10 | 1.92 | 2.28 | 1.92 | 1.79 | 2.05 |
| 5 | shape | -0.14 | -0.35 | 0.06 | -0.02 | -0.25 | 0.21 | -0.06 | -0.26 | 0.13 |
| scale | 0.40 | 0.32 | 0.49 | 0.55 | 0.45 | 0.68 | 0.42 | 0.35 | 0.52 |
| location | 1.70 | 1.58 | 1.81 | 1.71 | 1.55 | 1.87 | 1.63 | 1.51 | 1.74 |
| 10 | shape | -0.16 | -0.36 | 0.04 | -0.04 | -0.26 | 0.19 | -0.17 | -0.36 | 0.03 |
| scale | 0.38 | 0.31 | 0.46 | 0.50 | 0.40 | 0.62 | 0.40 | 0.33 | 0.49 |
| location | 1.43 | 1.33 | 1.54 | 1.39 | 1.25 | 1.53 | 1.39 | 1.28 | 1.50 |
| 20 | shape | -0.15 | -0.34 | 0.03 | -0.06 | -0.27 | 0.15 | -0.22 | -0.38 | -0.07 |
| scale | 0.36 | 0.30 | 0.44 | 0.46 | 0.37 | 0.56 | 0.38 | 0.31 | 0.46 |
| location | 1.12 | 1.02 | 1.22 | 1.04 | 0.91 | 1.16 | 1.10 | 1.00 | 1.21 |
| 30 | shape | -0.14 | -0.32 | 0.04 | -0.07 | -0.26 | 0.13 | -0.24 | -0.38 | -0.10 |
| scale | 0.36 | 0.29 | 0.43 | 0.44 | 0.36 | 0.54 | 0.38 | 0.31 | 0.45 |
| location | 0.90 | 0.80 | 0.99 | 0.80 | 0.68 | 0.93 | 0.90 | 0.80 | 1.00 |
| 40 | shape | -0.13 | -0.31 | 0.04 | -0.07 | -0.26 | 0.12 | -0.24 | -0.38 | -0.11 |
| scale | 0.36 | 0.29 | 0.43 | 0.43 | 0.35 | 0.53 | 0.38 | 0.31 | 0.45 |
| location | 0.72 | 0.62 | 0.81 | 0.62 | 0.50 | 0.74 | 0.73 | 0.63 | 0.83 |
| 50 | shape | -0.12 | -0.30 | 0.06 | -0.07 | -0.26 | 0.12 | -0.24 | -0.38 | -0.11 |
| scale | 0.35 | 0.29 | 0.43 | 0.42 | 0.35 | 0.52 | 0.38 | 0.31 | 0.45 |
| location | 0.56 | 0.46 | 0.65 | 0.47 | 0.35 | 0.58 | 0.58 | 0.48 | 0.68 |
| 60 | shape | -0.11 | -0.30 | 0.08 | -0.07 | -0.26 | 0.11 | -0.24 | -0.37 | -0.11 |
| scale | 0.35 | 0.29 | 0.43 | 0.42 | 0.34 | 0.51 | 0.38 | 0.31 | 0.45 |
| location | 0.41 | 0.32 | 0.51 | 0.33 | 0.21 | 0.44 | 0.44 | 0.34 | 0.54 |
| 70 | shape | -0.09 | -0.29 | 0.10 | -0.07 | -0.26 | 0.11 | -0.24 | -0.37 | -0.11 |
| scale | 0.35 | 0.28 | 0.42 | 0.41 | 0.34 | 0.50 | 0.38 | 0.31 | 0.45 |
| location | 0.27 | 0.18 | 0.37 | 0.20 | 0.09 | 0.32 | 0.31 | 0.21 | 0.41 |
| 80 | shape | -0.08 | -0.28 | 0.12 | -0.08 | -0.26 | 0.11 | -0.24 | -0.37 | -0.10 |
| scale | 0.34 | 0.28 | 0.42 | 0.40 | 0.33 | 0.49 | 0.38 | 0.31 | 0.45 |
| location | 0.14 | 0.04 | 0.23 | 0.08 | -0.03 | 0.19 | 0.18 | 0.08 | 0.28 |
| 90 | shape | -0.06 | -0.27 | 0.14 | -0.08 | -0.27 | 0.10 | -0.24 | -0.38 | -0.11 |
| scale | 0.33 | 0.27 | 0.41 | 0.40 | 0.33 | 0.48 | 0.38 | 0.31 | 0.45 |
| location | 0.00 | -0.10 | 0.09 | -0.04 | -0.15 | 0.07 | 0.04 | -0.06 | 0.14 |
| 100 | shape | -0.05 | -0.26 | 0.17 | -0.09 | -0.28 | 0.10 | -0.24 | -0.38 | -0.11 |
| scale | 0.33 | 0.27 | 0.40 | 0.39 | 0.32 | 0.48 | 0.37 | 0.31 | 0.45 |
| location | -0.18 | -0.27 | -0.08 | -0.19 | -0.30 | -0.09 | -0.14 | -0.24 | -0.04 |

Table S7: Shows the Rabi season (NDJF) drought intensity (SSI) corresponding to different areal-extent (% of India) and return period (in years) for three LSMs. The GEV distribution is fitted to NDJF SSI for different areal extent and for the period 1951-2015.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Return period** | **10** | | | **20** | | | **50** | | | **100** | | | **200** | | | **500** | | |
| **Areal extent** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** |
| 2 | -2.31 | -3.42 | -3.21 | -2.42 | -3.87 | -3.53 | -2.52 | -4.43 | -3.92 | -2.58 | -4.85 | -4.18 | -2.63 | -5.25 | -4.42 | -2.68 | -5.78 | -4.71 |
| 5 | -1.99 | -2.90 | -2.71 | -2.08 | -3.26 | -2.96 | -2.17 | -3.71 | -3.25 | -2.23 | -4.02 | -3.44 | -2.27 | -4.31 | -3.60 | -2.31 | -4.68 | -3.80 |
| 10 | -1.74 | -2.42 | -2.28 | -1.82 | -2.66 | -2.45 | -1.90 | -2.94 | -2.63 | -1.94 | -3.11 | -2.73 | -1.97 | -3.26 | -2.81 | -2.00 | -3.43 | -2.90 |
| 20 | -1.48 | -1.94 | -1.85 | -1.55 | -2.11 | -1.97 | -1.62 | -2.28 | -2.07 | -1.65 | -2.37 | -2.13 | -1.68 | -2.45 | -2.17 | -1.70 | -2.52 | -2.22 |
| 30 | -1.33 | -1.68 | -1.61 | -1.40 | -1.84 | -1.72 | -1.45 | -1.99 | -1.83 | -1.48 | -2.07 | -1.88 | -1.51 | -2.14 | -1.93 | -1.53 | -2.20 | -1.97 |
| 40 | -1.21 | -1.49 | -1.42 | -1.27 | -1.64 | -1.54 | -1.33 | -1.78 | -1.65 | -1.36 | -1.87 | -1.71 | -1.38 | -1.93 | -1.76 | -1.40 | -1.99 | -1.80 |
| 50 | -1.10 | -1.33 | -1.27 | -1.17 | -1.48 | -1.39 | -1.23 | -1.62 | -1.50 | -1.26 | -1.70 | -1.57 | -1.28 | -1.76 | -1.61 | -1.29 | -1.83 | -1.66 |
| 60 | -1.01 | -1.18 | -1.13 | -1.08 | -1.33 | -1.25 | -1.14 | -1.47 | -1.37 | -1.17 | -1.55 | -1.44 | -1.19 | -1.62 | -1.49 | -1.21 | -1.68 | -1.54 |
| 70 | -0.90 | -1.04 | -0.99 | -0.98 | -1.18 | -1.12 | -1.05 | -1.33 | -1.25 | -1.09 | -1.41 | -1.32 | -1.12 | -1.47 | -1.37 | -1.14 | -1.54 | -1.42 |
| 80 | -0.80 | -0.90 | -0.86 | -0.88 | -1.04 | -0.99 | -0.96 | -1.18 | -1.12 | -1.00 | -1.27 | -1.19 | -1.03 | -1.33 | -1.25 | -1.06 | -1.39 | -1.31 |
| 90 | -0.67 | -0.75 | -0.72 | -0.77 | -0.90 | -0.85 | -0.86 | -1.04 | -0.98 | -0.90 | -1.12 | -1.06 | -0.93 | -1.18 | -1.12 | -0.97 | -1.24 | -1.18 |
| 100 | -0.51 | -0.59 | -0.54 | -0.61 | -0.72 | -0.68 | -0.70 | -0.86 | -0.81 | -0.75 | -0.94 | -0.89 | -0.78 | -1.00 | -0.95 | -0.82 | -1.06 | -1.01 |

Table S8: Parameters and confidence interval for the GEV distribution fitted to the Rabi season (NDJF) SSI estimated for different areal-extent (% of India) for three LSMs.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Areal extent** |  | **VIC** | | | **NOAH** | | | **CLM** | | |
| **Parameter** | **Value** | **Lower CI** | **Higher CI** | **Value** | **Lower CI** | **Higher CI** | **Value** | **Lower CI** | **Higher CI** |
| 2 | Shape | -0.35 | -0.55 | -0.15 | -0.03 | -0.20 | 0.15 | -0.11 | -0.27 | 0.06 |
| Scale | 0.38 | 0.31 | 0.47 | 0.67 | 0.55 | 0.81 | 0.59 | 0.49 | 0.72 |
| Location | 1.72 | 1.62 | 1.82 | 1.96 | 1.78 | 2.15 | 2.03 | 1.86 | 2.19 |
| 5 | Shape | -0.36 | -0.51 | -0.21 | -0.08 | -0.22 | 0.07 | -0.17 | -0.32 | -0.02 |
| Scale | 0.34 | 0.28 | 0.41 | 0.62 | 0.51 | 0.74 | 0.54 | 0.45 | 0.66 |
| Location | 1.47 | 1.38 | 1.56 | 1.63 | 1.46 | 1.79 | 1.69 | 1.54 | 1.84 |
| 10 | Shape | -0.39 | -0.52 | -0.26 | -0.20 | -0.34 | -0.06 | -0.29 | -0.45 | -0.14 |
| Scale | 0.31 | 0.26 | 0.38 | 0.58 | 0.48 | 0.69 | 0.51 | 0.43 | 0.62 |
| Location | 1.27 | 1.19 | 1.35 | 1.37 | 1.21 | 1.53 | 1.43 | 1.29 | 1.57 |
| 20 | Shape | -0.43 | -0.55 | -0.31 | -0.33 | -0.47 | -0.18 | -0.42 | -0.61 | -0.23 |
| Scale | 0.30 | 0.25 | 0.37 | 0.54 | 0.45 | 0.66 | 0.49 | 0.40 | 0.60 |
| Location | 1.05 | 0.97 | 1.13 | 1.08 | 0.93 | 1.22 | 1.13 | 1.00 | 1.27 |
| 30 | Shape | -0.47 | -0.59 | -0.35 | -0.35 | -0.48 | -0.21 | -0.42 | -0.57 | -0.26 |
| Scale | 0.31 | 0.26 | 0.38 | 0.53 | 0.44 | 0.63 | 0.47 | 0.39 | 0.58 |
| Location | 0.89 | 0.81 | 0.98 | 0.86 | 0.72 | 1.00 | 0.91 | 0.79 | 1.04 |
| 40 | Shape | -0.50 | -0.63 | -0.37 | -0.35 | -0.48 | -0.21 | -0.40 | -0.55 | -0.26 |
| Scale | 0.33 | 0.27 | 0.40 | 0.51 | 0.43 | 0.62 | 0.47 | 0.39 | 0.57 |
| Location | 0.76 | 0.68 | 0.85 | 0.69 | 0.55 | 0.83 | 0.73 | 0.61 | 0.86 |
| 50 | Shape | -0.51 | -0.65 | -0.37 | -0.35 | -0.48 | -0.21 | -0.39 | -0.52 | -0.25 |
| Scale | 0.35 | 0.29 | 0.42 | 0.50 | 0.42 | 0.61 | 0.46 | 0.38 | 0.56 |
| Location | 0.64 | 0.54 | 0.73 | 0.54 | 0.41 | 0.67 | 0.58 | 0.46 | 0.70 |
| 60 | Shape | -0.49 | -0.63 | -0.36 | -0.34 | -0.47 | -0.21 | -0.37 | -0.50 | -0.24 |
| Scale | 0.37 | 0.30 | 0.44 | 0.49 | 0.41 | 0.59 | 0.45 | 0.38 | 0.55 |
| Location | 0.51 | 0.41 | 0.61 | 0.40 | 0.27 | 0.53 | 0.44 | 0.32 | 0.56 |
| 70 | Shape | -0.47 | -0.61 | -0.34 | -0.33 | -0.46 | -0.21 | -0.35 | -0.48 | -0.23 |
| Scale | 0.38 | 0.31 | 0.46 | 0.48 | 0.40 | 0.58 | 0.45 | 0.37 | 0.54 |
| Location | 0.38 | 0.28 | 0.48 | 0.27 | 0.14 | 0.40 | 0.30 | 0.18 | 0.42 |
| 80 | Shape | -0.45 | -0.58 | -0.32 | -0.33 | -0.46 | -0.21 | -0.34 | -0.46 | -0.22 |
| Scale | 0.40 | 0.33 | 0.48 | 0.48 | 0.40 | 0.57 | 0.44 | 0.37 | 0.53 |
| Location | 0.24 | 0.13 | 0.34 | 0.14 | 0.02 | 0.27 | 0.17 | 0.05 | 0.28 |
| 90 | Shape | -0.44 | -0.56 | -0.31 | -0.33 | -0.46 | -0.21 | -0.33 | -0.44 | -0.21 |
| Scale | 0.41 | 0.34 | 0.50 | 0.47 | 0.39 | 0.56 | 0.43 | 0.36 | 0.52 |
| Location | 0.09 | -0.02 | 0.19 | 0.01 | -0.11 | 0.14 | 0.03 | -0.08 | 0.15 |
| 100 | Shape | -0.43 | -0.55 | -0.30 | -0.34 | -0.46 | -0.22 | -0.31 | -0.43 | -0.20 |
| Scale | 0.43 | 0.35 | 0.51 | 0.46 | 0.39 | 0.56 | 0.42 | 0.35 | 0.50 |
| Location | -0.11 | -0.22 | 0.00 | -0.14 | -0.27 | -0.02 | -0.14 | -0.25 | -0.03 |

Table S9: Shows the 12-month drought intensity based on SSI at the end of December corresponding to different areal-extent (% of Indo-Gangetic plain) and return period (in years) for three LSMs. The GEV distribution is fitted to 12-month SSI at the end of December for different areal extent and for the period 1951-2015.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Return period** | **10** | | | **20** | | | **50** | | | **100** | | | **200** | | | **500** | | |
| **Areal extent** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** | **VIC** | **NOAH** | **CLM** |
| 2 | -2.96 | -3.60 | -2.79 | -3.20 | -4.07 | -3.04 | -3.45 | -4.64 | -3.30 | -3.61 | -5.02 | -3.46 | -3.74 | -5.37 | -3.60 | -3.88 | -5.80 | -3.75 |
| 5 | -2.59 | -3.06 | -2.48 | -2.80 | -3.44 | -2.71 | -3.01 | -3.87 | -2.95 | -3.13 | -4.15 | -3.10 | -3.23 | -4.39 | -3.22 | -3.34 | -4.68 | -3.35 |
| 10 | -2.28 | -2.63 | -2.24 | -2.46 | -2.95 | -2.44 | -2.65 | -3.31 | -2.65 | -2.75 | -3.53 | -2.77 | -2.83 | -3.71 | -2.87 | -2.92 | -3.92 | -2.97 |
| 20 | -1.96 | -2.17 | -1.95 | -2.14 | -2.45 | -2.14 | -2.32 | -2.75 | -2.32 | -2.43 | -2.93 | -2.42 | -2.51 | -3.09 | -2.50 | -2.59 | -3.26 | -2.57 |
| 30 | -1.75 | -1.88 | -1.75 | -1.94 | -2.15 | -1.93 | -2.13 | -2.42 | -2.10 | -2.24 | -2.59 | -2.20 | -2.32 | -2.74 | -2.27 | -2.42 | -2.89 | -2.34 |
| 40 | -1.58 | -1.67 | -1.59 | -1.77 | -1.92 | -1.77 | -1.97 | -2.19 | -1.94 | -2.08 | -2.35 | -2.04 | -2.17 | -2.48 | -2.11 | -2.27 | -2.63 | -2.18 |
| 50 | -1.42 | -1.49 | -1.45 | -1.62 | -1.74 | -1.63 | -1.82 | -1.99 | -1.80 | -1.94 | -2.15 | -1.90 | -2.03 | -2.28 | -1.97 | -2.13 | -2.42 | -2.04 |
| 60 | -1.28 | -1.34 | -1.32 | -1.48 | -1.57 | -1.50 | -1.68 | -1.82 | -1.67 | -1.80 | -1.97 | -1.77 | -1.90 | -2.10 | -1.84 | -2.00 | -2.24 | -1.92 |
| 70 | -1.15 | -1.19 | -1.19 | -1.34 | -1.42 | -1.37 | -1.55 | -1.67 | -1.54 | -1.67 | -1.82 | -1.64 | -1.77 | -1.94 | -1.72 | -1.88 | -2.08 | -1.80 |
| 80 | -1.01 | -1.06 | -1.06 | -1.21 | -1.28 | -1.24 | -1.42 | -1.52 | -1.42 | -1.54 | -1.66 | -1.52 | -1.64 | -1.78 | -1.59 | -1.75 | -1.92 | -1.67 |
| 90 | -0.88 | -0.92 | -0.92 | -1.07 | -1.14 | -1.10 | -1.28 | -1.37 | -1.28 | -1.40 | -1.51 | -1.38 | -1.51 | -1.63 | -1.45 | -1.62 | -1.75 | -1.53 |
| 100 | -0.72 | -0.76 | -0.75 | -0.91 | -0.98 | -0.92 | -1.12 | -1.20 | -1.10 | -1.24 | -1.33 | -1.19 | -1.35 | -1.45 | -1.27 | -1.46 | -1.57 | -1.34 |

Table S10: Parameters and confidence interval for the GEV distribution fitted to 12-month SSI at the end of December for different areal-extent (% of Indo-Gangetic plain) for the period 1951-2015 for the three LSMs.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Areal extent** |  | **VIC** | | | **NOAH** | | | **CLM** | | |
| **Parameter** | **Value** | **Lower CI** | **Higher CI** | **Value** | **Lower CI** | **Higher CI** | **Value** | **Lower CI** | **Higher CI** |
| 2 | shape | -0.24 | -0.37 | -0.11 | -0.11 | -0.30 | 0.07 | -0.23 | -0.39 | -0.07 |
| scale | 0.63 | 0.53 | 0.76 | 0.89 | 0.73 | 1.09 | 0.63 | 0.52 | 0.76 |
| location | 1.86 | 1.69 | 2.03 | 1.83 | 1.58 | 2.07 | 1.69 | 1.52 | 1.86 |
| 5 | shape | -0.29 | -0.42 | -0.16 | -0.17 | -0.35 | 0.00 | -0.26 | -0.42 | -0.10 |
| scale | 0.61 | 0.51 | 0.73 | 0.84 | 0.69 | 1.01 | 0.62 | 0.52 | 0.76 |
| location | 1.59 | 1.43 | 1.75 | 1.51 | 1.28 | 1.74 | 1.42 | 1.25 | 1.59 |
| 10 | shape | -0.32 | -0.47 | -0.18 | -0.22 | -0.38 | -0.05 | -0.31 | -0.46 | -0.15 |
| scale | 0.59 | 0.49 | 0.71 | 0.79 | 0.65 | 0.95 | 0.64 | 0.53 | 0.78 |
| location | 1.33 | 1.17 | 1.49 | 1.23 | 1.01 | 1.44 | 1.19 | 1.02 | 1.37 |
| 20 | shape | -0.32 | -0.48 | -0.17 | -0.24 | -0.41 | -0.08 | -0.36 | -0.52 | -0.20 |
| scale | 0.59 | 0.49 | 0.71 | 0.73 | 0.60 | 0.88 | 0.66 | 0.54 | 0.80 |
| location | 1.02 | 0.86 | 1.18 | 0.90 | 0.71 | 1.10 | 0.93 | 0.75 | 1.11 |
| 30 | shape | -0.31 | -0.47 | -0.15 | -0.25 | -0.41 | -0.08 | -0.37 | -0.54 | -0.21 |
| scale | 0.59 | 0.49 | 0.71 | 0.69 | 0.57 | 0.84 | 0.66 | 0.55 | 0.81 |
| location | 0.79 | 0.64 | 0.95 | 0.69 | 0.50 | 0.88 | 0.74 | 0.56 | 0.92 |
| 40 | shape | -0.30 | -0.46 | -0.14 | -0.25 | -0.41 | -0.08 | -0.37 | -0.54 | -0.21 |
| scale | 0.59 | 0.48 | 0.71 | 0.67 | 0.55 | 0.81 | 0.66 | 0.54 | 0.80 |
| location | 0.62 | 0.46 | 0.77 | 0.52 | 0.34 | 0.70 | 0.59 | 0.41 | 0.77 |
| 50 | shape | -0.29 | -0.45 | -0.13 | -0.25 | -0.41 | -0.09 | -0.37 | -0.54 | -0.20 |
| scale | 0.58 | 0.48 | 0.70 | 0.65 | 0.54 | 0.78 | 0.65 | 0.54 | 0.79 |
| location | 0.46 | 0.31 | 0.62 | 0.38 | 0.20 | 0.55 | 0.45 | 0.27 | 0.63 |
| 60 | shape | -0.28 | -0.44 | -0.12 | -0.25 | -0.41 | -0.09 | -0.36 | -0.53 | -0.19 |
| scale | 0.57 | 0.47 | 0.69 | 0.63 | 0.52 | 0.76 | 0.64 | 0.53 | 0.78 |
| location | 0.33 | 0.17 | 0.48 | 0.25 | 0.08 | 0.42 | 0.32 | 0.15 | 0.50 |
| 70 | shape | -0.28 | -0.44 | -0.12 | -0.25 | -0.41 | -0.09 | -0.35 | -0.52 | -0.18 |
| scale | 0.57 | 0.47 | 0.68 | 0.61 | 0.51 | 0.74 | 0.63 | 0.52 | 0.77 |
| location | 0.20 | 0.04 | 0.35 | 0.14 | -0.03 | 0.30 | 0.20 | 0.03 | 0.37 |
| 80 | shape | -0.27 | -0.43 | -0.11 | -0.25 | -0.40 | -0.09 | -0.35 | -0.52 | -0.18 |
| scale | 0.56 | 0.46 | 0.67 | 0.60 | 0.49 | 0.72 | 0.62 | 0.51 | 0.76 |
| location | 0.07 | -0.08 | 0.22 | 0.03 | -0.13 | 0.19 | 0.08 | -0.09 | 0.25 |
| 90 | shape | -0.26 | -0.42 | -0.11 | -0.25 | -0.40 | -0.10 | -0.34 | -0.52 | -0.17 |
| scale | 0.55 | 0.45 | 0.66 | 0.58 | 0.48 | 0.70 | 0.61 | 0.50 | 0.74 |
| location | -0.05 | -0.20 | 0.10 | -0.08 | -0.24 | 0.08 | -0.04 | -0.21 | 0.13 |
| 100 | shape | -0.26 | -0.42 | -0.10 | -0.25 | -0.41 | -0.10 | -0.34 | -0.52 | -0.17 |
| scale | 0.54 | 0.44 | 0.65 | 0.57 | 0.47 | 0.69 | 0.60 | 0.49 | 0.73 |
| location | -0.20 | -0.34 | -0.05 | -0.21 | -0.36 | -0.06 | -0.19 | -0.35 | -0.03 |

Table S11: P-value (at 5% significance level) and h value for goodness of fit-test (chi-square test) performed to test fit of the GEV distribution fitted to monsoon season SSI for the selected areal extents (%) of drought over India. The P-value more than 0.05 and h equal to 0 indicate that the fit-test do not reject the null hypothesis that the GEV distribution fits the monsoon season SSI.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Areal Extents (%) | VIC | | NOAH | | CLM | |
| p | h | p | h | p | h |
| 2 | 0.4561 | 0 | 0.1224 | 0 | 0.2017 | 0 |
| 5 | 0.5614 | 0 | 0.0193 | 1 | 0.1253 | 0 |
| 10 | 0.0039 | 1 | 0.1075 | 0 | 0.2826 | 0 |
| 20 | 0.0895 | 0 | 0.4278 | 0 | 0.5560 | 0 |
| 30 | 0.8090 | 0 | 0.4843 | 0 | 0.7565 | 0 |
| 40 | 0.8653 | 0 | 0.6782 | 0 | 0.4341 | 0 |
| 50 | 0.6169 | 0 | 0.9178 | 0 | 0.2901 | 0 |
| 60 | 0.6535 | 0 | 0.8591 | 0 | 0.1416 | 0 |
| 70 | 0.6797 | 0 | 0.9521 | 0 | 0.4647 | 0 |
| 80 | 0.7765 | 0 | 0.6975 | 0 | 0.5668 | 0 |
| 90 | 0.7715 | 0 | 0.8193 | 0 | 0.7120 | 0 |
| 100 | 0.6236 | 0 | 0.5412 | 0 | 0.3994 | 0 |

Table S12: P-value (at 5% significance level) and h value for goodness of fit-test (chi-square test) performed to test fit of the GEV distribution fitted to Rabi season SSI for the selected areal extents (%) of drought over India. The P-value more than 0.05 and h equal to 0 indicate that the fit-test do not reject the null hypothesis that the GEV distribution fits the Rabi season SSI.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Areal Extents (%) | VIC | | NOAH | | CLM | |
| p | h | p | h | p | h |
| 2 | 0.0734 | 0 | 0.3150 | 0 | 0.5683 | 0 |
| 5 | 0.5521 | 0 | 0.2178 | 0 | 0.2678 | 0 |
| 10 | 0.1061 | 0 | 0.0437 | 1 | 0.8159 | 0 |
| 20 | 0.5601 | 0 | 0.1862 | 0 | 0.0359 | 1 |
| 30 | 0.0650 | 0 | 0.1159 | 0 | 0.4452 | 0 |
| 40 | 0.3063 | 0 | 0.2194 | 0 | 0.2711 | 0 |
| 50 | 0.4567 | 0 | 0.0423 | 1 | 0.2256 | 0 |
| 60 | 0.7388 | 0 | 0.0592 | 0 | 0.2453 | 0 |
| 70 | 0.8595 | 0 | 0.1084 | 0 | 0.7286 | 0 |
| 80 | 0.6454 | 0 | 0.1711 | 0 | 0.6279 | 0 |
| 90 | 0.1219 | 0 | 0.3509 | 0 | 0.5686 | 0 |
| 100 | 0.5028 | 0 | 0.2988 | 0 | 0.4191 | 0 |

Table S13: P-value (at 5% significance level) and h value for goodness of fit-test (chi-square test) performed to test fit of the GEV distribution fitted to annual SSI for the selected areal extents (%) of drought over Indo-Gangetic plain. The P-value more than 0.05 and h equal to 0 indicate that the fit-test do not reject the null hypothesis that the GEV distribution fits the annual SSI.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Areal Extents (%) | VIC | | NOAH | | CLM | |
| p | h | p | h | p | h |
| 2 | 0.4525 | 0 | 0.5415 | 0 | 0.3826 | 0 |
| 5 | 0.7838 | 0 | 0.3348 | 0 | 0.7478 | 0 |
| 10 | 0.0929 | 0 | 0.6391 | 0 | 0.9476 | 0 |
| 20 | 0.1229 | 0 | 0.2932 | 0 | 0.8235 | 0 |
| 30 | 0.1277 | 0 | 0.0367 | 1 | 0.6543 | 0 |
| 40 | 0.0596 | 0 | 0.3943 | 0 | 0.6637 | 0 |
| 50 | 0.0947 | 0 | 0.5460 | 0 | 0.7185 | 0 |
| 60 | 0.0715 | 0 | 0.4994 | 0 | 0.6978 | 0 |
| 70 | 0.2186 | 0 | 0.5070 | 0 | 0.5262 | 0 |
| 80 | 0.1146 | 0 | 0.4389 | 0 | 0.6752 | 0 |
| 90 | 0.0532 | 0 | 0.2795 | 0 | 0.6849 | 0 |
| 100 | 0.1506 | 0 | 0.9097 | 0 | 0.8758 | 0 |