Land surface models systematically overestimate the intensity, duration and magnitude of seasonal-scale evaporative droughts

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Supplementary Information

This supplementary information contains Tables S1-S2 and Figures S1-S3.
Table S1: Land surface models used in this study. Further details on each model can be found in Best et al. (2015).

| Full model name                                                                 | Abbreviated name | Reference                                                                 |
|---------------------------------------------------------------------------------|------------------|----------------------------------------------------------------------------|
| Community Atmosphere Biosphere Land Exchange (CABLE) version 2.0                | CABLE-2.0        | Kowalczyk *et al* (2006); Wang *et al* (2011)                             |
| CABLE SubgridSoil GroundWater                                                   | CABLE-GW         | Decker (2015)                                                              |
| CABLE Soil-Litter-Iso                                                           | CABLE-SLI        | Haverd and Cuntz (2010); Haverd *et al* (2016)                            |
| Tiled ECMWF Scheme for Surface Exchanges over Land (TESSEL), uncoupled version  | CHTESSEL         | Balsamo *et al* (2009); Boussetta *et al* (2013)                         |
| Centre for Ocean-Land-Atmosphere Studies Simplified Simple Biosphere            | COLASSiB         | Dirmeyer and Zeng (1999); Guo and Dirmeyer (2013)                        |
| Interaction Soil-Biosphere-Atmosphere (ISBA) 3-layer soil                      | ISBA-3L          | Boone *et al* (1999); Masson *et al* (2013)                               |
| ISBA multilayer soil                                                            | ISBA-dif         | Decharme *et al* (2011); Masson *et al* (2013)                            |
| Joint UK Land Environment Simulator (JULES) version 3.1                         | JULES-3.1        | Best *et al* (2011)                                                       |
| JULES-altP                                                                      | JULES-altP       | Best *et al* (2011)                                                       |
| Mosaic                                                                          | Mosaic           | Koster and Suarez (1992, 1994)                                            |
| Noah version 2.7.1                                                              | Noah 2.7         | Ek *et al* (2003)                                                         |
| Noah version 3.2                                                                 | Noah 3.2         | www.ral.ucar.edu/research/land/technology/lsm.php                         |
| Noah version 3.3                                                                 | Noah 3.3         | www.ral.ucar.edu/research/land/technology/lsm.php                         |
| ORganizing Carbon and Hydrology In Dynamic EcosystEms                           | ORCHIDEE         | Krinner *et al* (2005)                                                    |
Table S2: Study sites. Observed mean annual precipitation (P; mm yr\(^{-1}\)), mean annual evapotranspiration (E; mm yr\(^{-1}\)) and climatological aridity index (the ratio of mean annual potential evapotranspiration to P) were determined from the available years.

| Site name     | Country | Lat. | Long. | Record length | Mean annual P | Mean annual E | Aridity index |
|---------------|---------|------|-------|---------------|---------------|---------------|---------------|
| Amplero*      | Italy   | 41.90| 13.61 | 2003-2006     | 853           | 599           | 1.2           |
| Blodgett*     | USA     | 38.90| -120.63| 2000-2006   | 1377          | 671           | 0.9           |
| Bugac         | Hungary | 46.69| 19.60 | 2002-2006     | 530           | 458           | 1.6           |
| El Saler      | Spain   | 39.35| -0.32 | 2003-2005     | 559           | 554           | 2.5           |
| Espirra*      | Portugal| 38.64| -8.60 | 2001-2006     | 660           | 602           | 2.1           |
| Fort Peck     | USA     | 48.31| -105.10| 2000-2006  | 395           | 305           | 2.4           |
| Harvard       | USA     | 42.54| -72.17| 1994-2001    | 1080          | 451           | 0.7           |
| Hesse         | France  | 48.67| 7.06  | 1999-2006    | 941           | 288           | 0.9           |
| Howard Springs*| Australia| -12.49| 131.15| 2002-2005   | 1827          | 1077          | 1.1           |
| Howland (main)| USA     | 45.20| -68.74| 1996-2004    | 817           | 362           | 1.0           |
| Hytylää       | Finland | 61.85| 24.29 | 2001-2004    | 461           | 297           | 1.2           |
| Kruger        | South Africa| -25.02| 31.50| 2002-2003 | 264           | 232           | 6.5           |
| Loobos        | Netherlands| 52.17| 5.74  | 1997-2006    | 944           | 482           | 0.8           |
| Merbleue      | Canada  | 45.41| -75.52| 1999-2005   | 841           | 456           | 1.0           |
| Mopane*       | Botswana| -19.92| 23.56| 1999-2001  | 269           | 364           | 7.5           |
| Palang*       | Indonesia| 2.35  | 111.04| 2002-2003 | 2072          | 1234          | 0.8           |
| Tumbarumba    | Australia| -35.66| 148.15| 2002-2005  | 1281          | 683           | 0.9           |
| University of Michigan | USA | 45.56| -84.71| 1999-2003 | 616           | 529           | 1.4           |

* Selected site
**Figure S1:** Simulated and observed (a) Edrought duration (number of drought days per year), (b) Edrought magnitude (cumulative deficit; mm yr$^{-1}$) and (c) Edrought intensity (mm) at the supplementary flux tower sites. Individual model estimates are shown as coloured bars, observations as the dotted line and the mean of all models as the solid line. Hesse and Howland are not shown as there were no simulated or observed Edroughts at these sites. We exclude Sylvania (where precipitation forcing was found to be erroneous) and El Saler 2 (an irrigated site; Haughton *et al* 2016)).
Figure S1 continued.
Figure S2: Location of flux tower sites. The names of sites presented in the main manuscript are indicated. Vegetation types were taken from Best et al (2015).
Figure S3: Simulated and observed sensible heat flux during an example one-year period. The time series show the 14-day running mean from January to December. The grey bars show 7-day precipitation totals.
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