Mixed diversity of shifting IOD and El Niño dominates the location of Maritime Continent autumn drought

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The Maritime Continent is a huge heat source region over the Indo-Pacific warm pool and it plays a key role in global weather/climate variations. The locations of Maritime Continent autumn droughts, linked to frequent rampant forest wildfires, are closely related to the mixed diversity of El Niño and Indian Ocean Dipole events.

Considering that the MC land precipitation possesses large dry–wet annual cycle and significant local features/variances due to the unique geographic location [1], here we apply a rotated empirical orthogonal function (REOF; see Supplementary Data and Methods for more details) to capture the interannual leading modes of the normalized-and-detrended NOAA (i.e. the National Oceanic and Atmospheric Administration) land-precipitation anomalies in the MC region (95°E–145°E, 11°S–9°N), which (i.e. the REOF1 and REOF2 shown in Fig. 1a and b, and see Supplementary Fig. 1 for details) highlight the rainfall deficit over the western MC (WMC) and the eastern MC (EMC), respectively. The corresponding principal components (i.e. RPC1 and RPC2) of MC land precipitation, with clear interannual variations, are plotted in Fig. 1a and b (black lines), which explain 34.3% and 27.9% of the total normalized variances (see Supplementary Note 1 and Supplementary Fig. 1 for details). It is worth noting that similar results can be reproduced with another three new sets of central Pacific (CP) El Niño and subtropical IOD (SIOD, hereafter CP-SIOD; Supplementary Fig. 5b), whereas EMC droughts are mainly jointly induced by a new set of central Pacific (CP) El Niño and tropical IOD (hereafter EP-IOD; Supplementary Fig. 5a), whereas WMC droughts show strong linkages to the traditional combination of eastern Pacific (EP) El Niño and tropical IOD (hereafter EP-IOD; Supplementary Fig. 5a), whereas EMC droughts are mainly jointly induced by a new set of central Pacific (CP) El Niño and subtropical IOD (SIOD, hereafter CP-SIOD; Supplementary Fig. 5b). Then, the EP-IOD and CP-SIOD indices are accordingly defined in the following Definition Description and are shown in Fig. 1a and b (red lines), respectively.

Definition description: The CP El Niño index (CPI) is calculated by [SST]C − 0.5∗[SST]E–0.5∗[SST]W, where [SST]C, [SST]E and [SST]W represent the seasonal area-mean of monthly grid-normalized SST anomalies over the three regions: (165°E–145°W, 10°S–20°N), (120°W–70°W, 10°S–5°N), (125°E–145°E, 0°–25°N), respectively. The EP El Niño index (EPI) is defined as the seasonal area-mean of monthly grid-normalized SST anomalies over (140°W–80°W, 12°S–5°N). Likewise, the IOD index [6] is defined as [SST]55°E–70°E, 10°S–10°N) − [SST](90°E–110°E, 10°S–0°), whereas the SIOD index is defined as [SST](55°E–70°E, 25°S–15°N) − [SST]
Figure 1. Modulations of different ENSO-IOD combinations on the MC precipitations in SON. Shown in (a) and (b) is the normalized time series (black) of RPC1 and RPC2 of NOAA land-precipitation anomalies over the MC (95°E–145°E, 11°S–9°N) and their REOF correlation modes during boreal autumn (SON) for 1979–2016 (see Supplementary Fig. 1 for details of REOF-correlation modes). Also shown in (a) and (b) are the normalized EP-IOD and CP-SIOD indices (red lines), respectively. Correlation (RPC1, EP-IOD) = 0.71 and correlation (RPC2, CP-SIOD) = 0.68. Shown in (c) and (d) are the SST-anomaly modes (including correlation in shadings and regression in contours with an interval of 0.1 K) associated with (c) EP-IOD index (after removing RPC2 & CP-SIOD) and (d) CP-SIOD index (after removing RPC1 & EP-IOD), respectively. Shown in (e) and (f) are the regressions of H200 (shadings, P < 0.01 outlined by black lines) and UV200 (only the vectors with P < 0.01) anomalies on the EP-IOD (after removing RPC2 & CP-SIOD) and CP-SIOD (after removing RPC1 & EP-IOD), respectively. Note that here the RPC2 & CP-SIOD or RPC1 & EP-IOD have been linearly removed from all variables before producing (c)–(f) due to the weak but significant correlations among them (see Supplementary Fig. 6). To obtain the large-scale land–ocean precipitation anomaly modes and to further cross-validate the reliability of the REOF results shown in (a) and (b), the anomaly patterns of GPCP v2.3 precipitation (correlation in shadings, red lines indicate the robust correlations > 0.60) and water-vapor flux (WVF, regressions, only show the vectors with P < 0.01) linked to RPC1 and RPC2 are also shown in (g) and (h), respectively. The green and black boxes in (c) and (d) outline the regions that define the EP-IOD and CP-SIOD indices (see the text for details), respectively. The orange circles in (e)–(h) highlight the relative MC position as a reference system.
Finally, the EP-IOD and CP-SIOD indices are straightforwardly calculated from the normalized (EPI+IOD)/2 and (CP1+SIOD)/2, respectively (Supplementary Note 2). Relevant SST regions are outlined in Fig. 1c and d. Their correlations are shown in Supplementary Fig. 6.

As expected, their time series are strongly in phase, with high correlations (Fig. 1a and b) up to 0.71 (0.68) between RPC1 and EP-IOD (between RPC2 and CP-SIOD), statistically exceeding the 99.9% confidence level. Relevant SST modes are shown in Fig. 1c and d, which perfectly mirror the SST patterns (Supplementary Fig. 5) associated with RPC1 and RPC2, respectively. Two such types of combined Indo-Pacific SST modes would lead to different changes in (i) the large-scale Rossby waves (Fig. 1e and f) via upper-level divergence perturbed by tropical convective activities [7,8] and (ii) the low-level winds and convergence via forcing different surface-pressure gradients [9] (Supplementary Fig. 7a and b), which together result in distinct Walker-circulation anomalies with different ascending and sinking motions over the Indo-Pacific Ocean and the WMC/EMC (Supplementary Fig. 8), respectively.

In comparison with Fig. 1e and Supplementary Fig. 7a for EP-IOD events, Fig. 1f and Supplementary Fig. 7b reveal that the resultant upper-level convergent winds and low-level divergent winds are shifted from WMC to EMC during CP-SIOD events (referring to the orange circles shown in Fig. 1e–h), corresponding to the location changes in the sinking motions of the Walker circulation (see the red boxes shown in Supplementary Fig. 8a and b). Then, the resultant water-vapor-flux responses (see the orange circles shown in Fig. 1g and h and Supplementary Fig. 7c and d) contribute to the location shift of MC drought (Fig. 1g and h and Supplementary Fig. 7c and d). Such phenomena indicate the geographical adaptability of MC precipitation/drought to ENSO–IOD diversity (Supplementary Fig. 5). Of note is that Fig. 1c–f and Supplementary Figs 7 and 8 are obtained independently from the REOF analysis, except for the SST-box choices used for defining the EP-IOD and CP-SIOD indices, suggesting that the above results are reliable and robust.

In summary, the nature of ENSO–IOD combinations and the changes in their performances, including the modulation of tropical waves, convections and Walker-cell patterns, make good sense to understand MC-rainfall and forest-fire activities. Additionally, a higher prevalence of extreme El Niño and IOD events is anticipated in future climate scenarios [10,11] and that the spurious IOD as well as the Modoki El Niño are mysteriously changing under greenhouse warming [3,8,12], indicating that climate change and variability may exert more severe impacts on the MC autumn drought than previously thought. More importantly, our results highlight that, once the precursor signals of variant ENSO–IOD combinations were monitored or predicted, it would provide early warning to relevant policymakers to plan and act effectively to minimize forest-fire losses (including homes and crops destroyed, fisheries ruined, etc.) and shelter air quality and life safety during the dry-season months for MC countries.

**SUPPLEMENTARY DATA**

Supplementary data are available at NSR online.

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Why does caloric restriction increase life and healthspan? The ‘clean cupboards’ hypothesis

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The disposable soma hypothesis explanation of the effects of caloric restriction (CR) on lifespan fails to explain why CR generates negative impacts alongside the positive effects and does not work in all species. I propose here a novel idea called the clean cupboards hypothesis which overcomes these problems.

BACKGROUND

The effects of caloric restriction (CR) on longevity were discovered 100 years ago [1]. Since then the effect has been replicated in a wide variety of animals (reviewed in [2]). More recent work in non-human primates provides a complex picture but also indicates that there are some beneficial impacts on both healthspan and lifespan [3–6]. Impacts on human lifespan will likely never be systematically studied, but a short-term randomised controlled trial produced indicative changes in important biomarkers of ageing [7,8]. There are also suggestions that naturally restricted human populations show increased longevity [9].

The disposability soma hypothesis (DSH) [12–14] is a classical trade-off model that posits energy resources are limited and hence animals must make an evolutionary decision about how to use them. There are two main uses: somatic maintenance and reproduction. If an animal invests in somatic maintenance it improves survival probability, but it does so at the cost of reproduction. Alternatively, investing heavily in reproduction can only occur at the costs of somatic maintenance and hence survival. The DSH therefore explains the phylogenetic inverse correlation between reproductive output and lifespan [15]. This theory also provides a potential evolutionary explanation of what is happening during CR. It is presumed that wild animals would only experience CR as a temporary phenomenon. Since attempts to reproduce under such limited energy supply would likely fail, animals are better served by switching off reproductive investment completely and diverting all their resources into somatic maintenance. This would maximise their chances of surviving the period of restricted energy supply. This resource allocation model is illustrated in Fig. 1. In the laboratory the lean period never ends, and the animals keep the somatic maintenance activities switched on indefinitely, leading to the lifespan increase [14]. This idea is consistent with direct observations that exposure to CR reduces reproductive investment [16], and potentially explains why CR may be less effective in males, which expend less energy on reproduction ([17] but see review [11] suggesting no sex difference in the response).

This DSH interpretation of the evolutionary background to the function of CR leads to the prediction that because the costs of reproduction in small animals are substantially higher (relative to baseline non-reproductive costs) than the reproductive costs in larger animals, the savings that can be made by switching off reproduction and diverting energy to somatic maintenance are considerably larger in smaller animals. Hence it is argued we observe a large effect of CR in small mammals like mice [18], rats [19] and very small primates [6], but in larger animals the impact is attenuated