Why do drought indices overestimate the drought-related impacts of global warming - in models and in reality?

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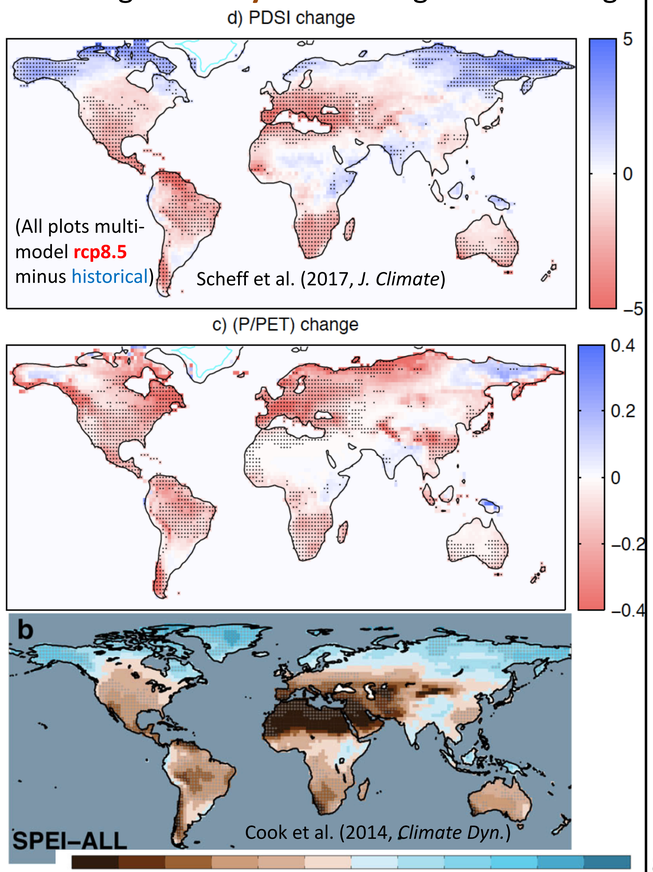
Abstract

In global climate models, CO2-driven warming causes strong and very widespread mean drying trends in climatic wetness indices like the Palmer Drought Severity Index, Aridity Index and Standardized Precipitation-Evapotranspiration Index. Yet, these same simulations also predict that runoff will not decline over most of Earth's surface, that root-zone soil moisture and evaporative fraction will decline only regionally, and that vegetation will become broadly greener. Thus, actual drought impacts of warming in these models are far less broad and severe than implied by the drought indices. Here, I probe why this "index-impact gap" occurs, and whether it is a feature of reality as well as models. In particular, I show that the discrepancies are not just limited to simulations which assume a substantial direct CO2 effect on vegetation, but are also large in greenhouse-only simulations, implying that they occur for fundamental climatic reasons rather than via CO2-physiological pathways. I also review key observational evidence that the index-impact gap has also been large over the historical era and was very evident for the last glacial-to-interglacial warming, lending much additional credence to the model output.

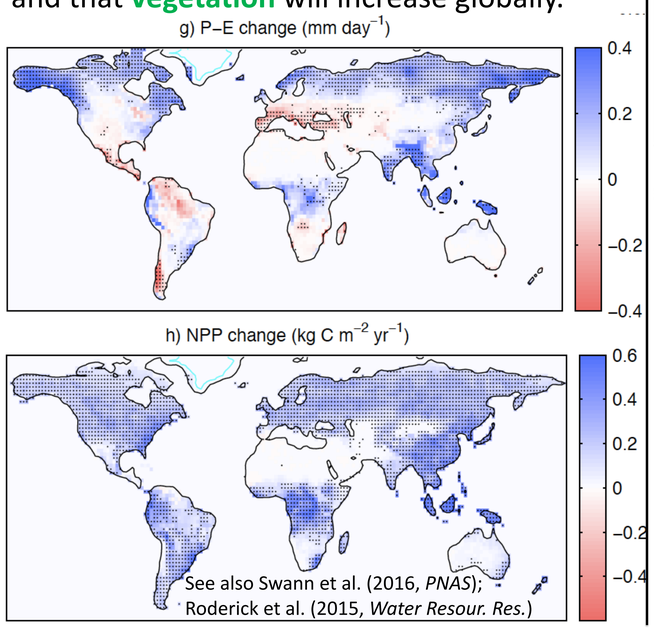
Drought *indices* overpredict the drought *impacts* of warming – in models and in reality

Jacob Scheff, Geography & Earth Sciences, University of North Carolina Charlotte (*Curr. Climate Change Rep.*, 2018)

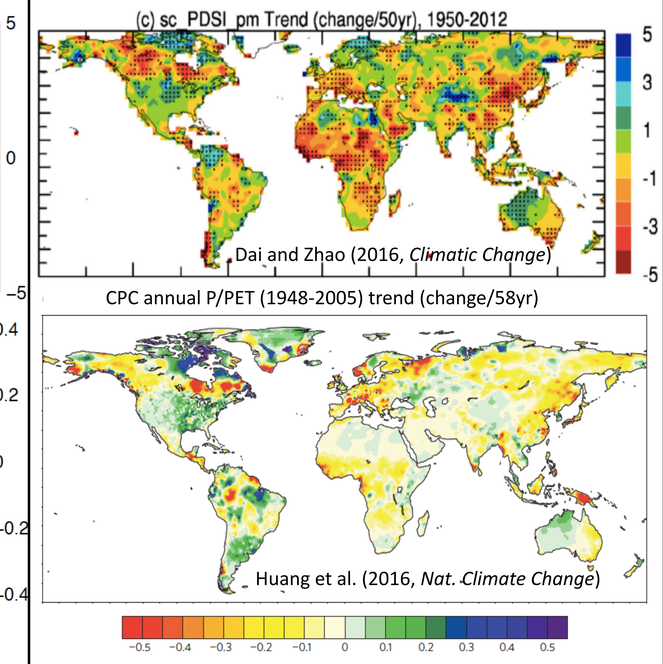
Earth System Models project that PDSI, SPEI, and Aridity Index (P/PET) will all trend strongly toward global **"dryness"** with global warming.



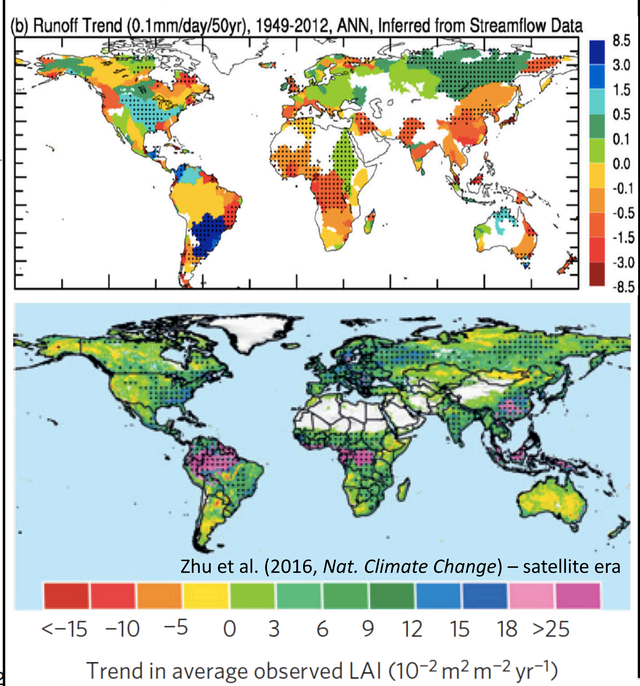
Yet the exact same models also project that **runoff** will variously increase and decrease – and that **vegetation** will increase globally.



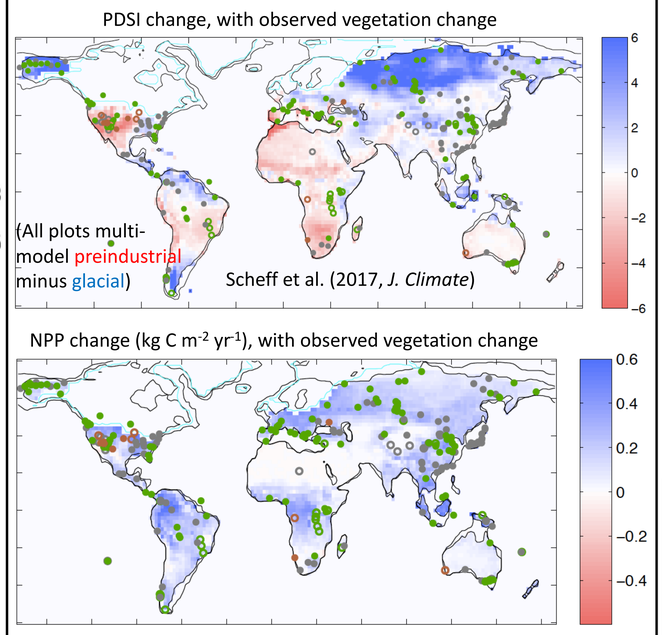
Is this **believable?** **Yes** – in fact it **already seems to be happening**: PDSI and P/PET are trending toward **"dryness"** globally…



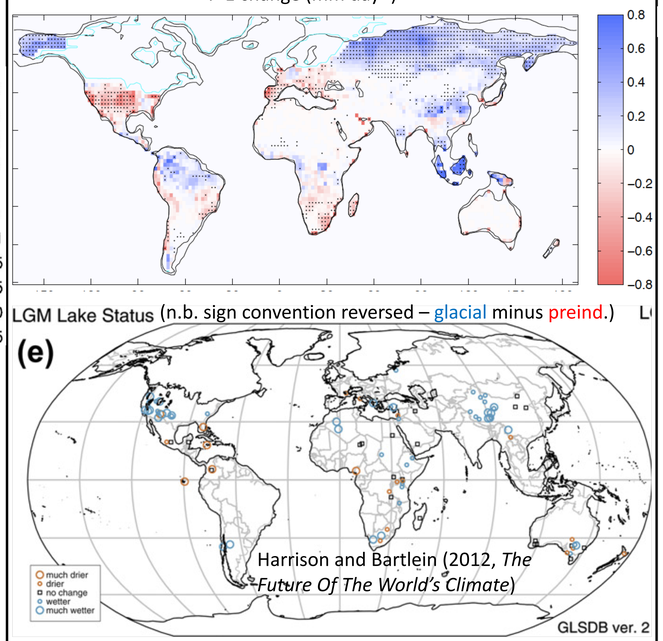
…while **runoff** is variously increasing and decreasing with no preferred polarity, and **vegetation** is increasing over many areas but decreasing almost nowhere.



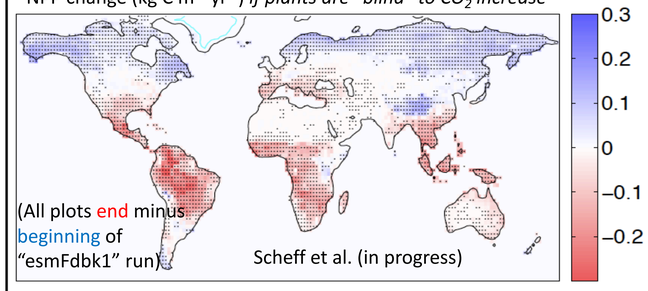
And it **happened** going out of the last glacial: Earth warmed with CO_2; **vegetation density** (dots - from pollen) followed model **NPP** (increasing) rather than **PDSI** (declining)…



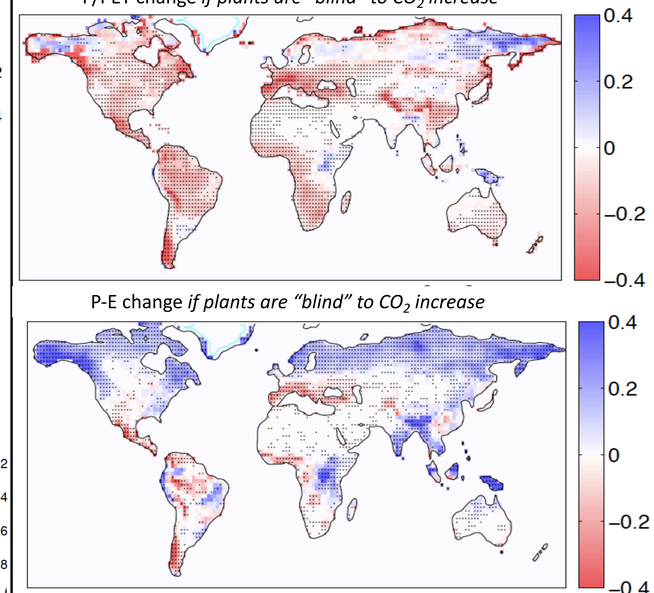
and **runoff** (from paleolake data) followed model P-E projections, validating them:



Why is this? Direct CO_2 effects on vegetation are often cited (e.g. Roderick et al. 2015 *WRR*, Swann et al. 2016 *PNAS*, Milly and Dunne 2016 *Nat. Climate Change*.) Indeed, CO_2 totally explains the **NPP/veg increase**:



But, CO_2 **fails** to explain why the dryness indices don't predict the **runoff** response.



So the mismatch between index-based drying and lack of actual runoff drying must be due to **something other than CO_2-plant effects**! Candidates include:

-increased VPD closing leaf stomata (Novick et al. 2016 *Nat. Climate Change*)
-increased precipitation intensity (e.g. Dai et al 2018 *Curr. Climate Change Rep.*) and/or seasonality (Chou et al. 2013 *Nat. Geosci.*)
-Penman PET formulation itself flawed (Milly and Dunne 2016 *Nat. Climate Change*)
… ???

So, CO_2 warming **does** indeed seem to be characterized by **index-based drying** with **greening vegetation** and **varied runoff response**. **Drought indices ≠ drought impacts.**