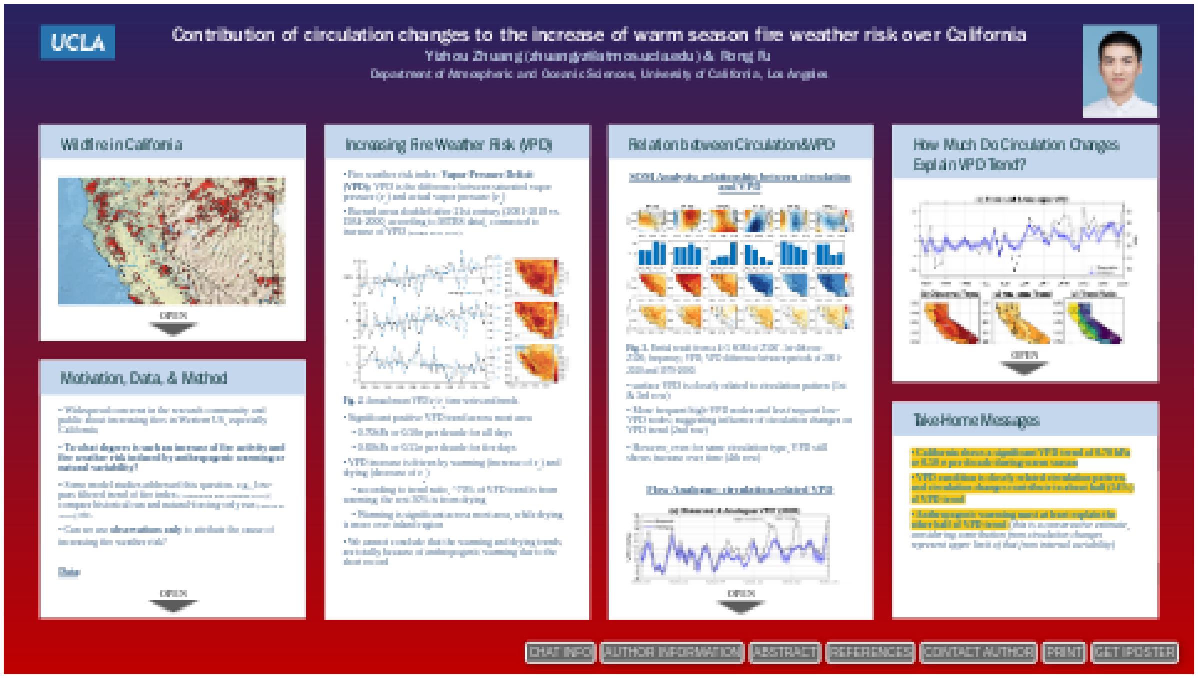
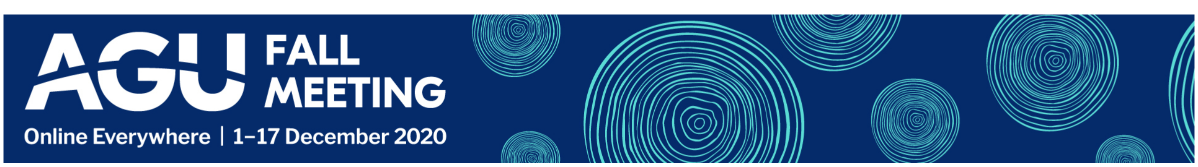
Contribution of circulation changes to the increase of warm season fire weather risk over California



Yizhou Zhuang (zhuangyz@atmos.ucla.edu) & Rong Fu

Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles

PRESENTED AT:



WILDFIRE IN CALIFORNIA

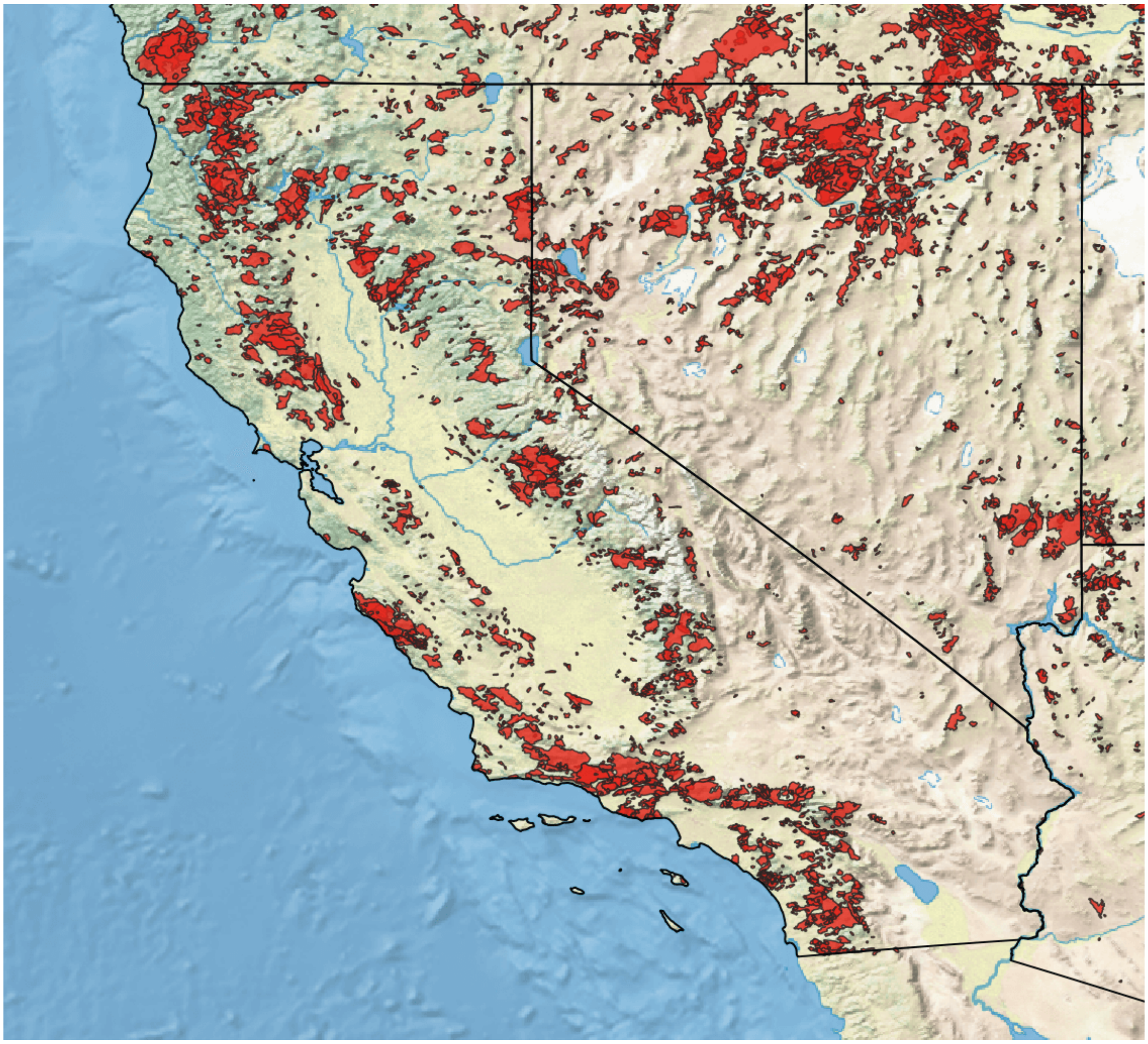


Fig. 1. MTBS burned areas in California (1984-2018)

• **California** is one of the regions most prone to wildfire in US. Most fires occur in coastal side of California and Sierra-Nevada region

• **Warm season (May-Sep)** is one main fire season (over 80% of large fire events and burned areas); the other fire season is Oct-Dec (more related to Santa Ana Wind)

• **2020 is a record-breaking year**

- • Severe thunderstorms (Aug & Sep) ignited numerous wildfires in west coast
- • Burn **over 5 million acres** (NICC)
- • Top 20 largest wildfires: 6 are from 2020, only 3 are before 21st century (Cal Fire)

MOTIVATION, DATA, & METHOD

• Widespread concerns in the research community and public about increasing fires in Western US, especially California

• To what degrees is such an increase of fire activity and fire weather risk induced by anthropogenic warming or natural variability?

• Some model studies addressed this question. e.g., low-pass filtered trend of fire index (Abatzoglou and Williams 2016); compare historical run and natural-forcing-only run (Tett et al. 2018); etc.

• Can we use **observations only** to attribute the cause of increasing fire weather risk?

Data:

• Monitoring Trends in Burn Severity (MTBS) burned areas boundaries

• 4-km daily Gridded Surface Meteorological (gridMET; Abatzoglou 2013) data

• Daily 500-hPa geopotential from reanalyses (ERA5, MERRA2, CFSR, JRA55)

Main method:

• Linear regression for trend analysis

• Self Organizing Maps (SOM) (Kohonen 1990; Zhuang et al. 2020)

• Flow Analogue (Yiou et al. 2007)

• For each day, its analogue days are determined by Z500' pattern similarity; selected from similar calendar range (61-day period centered on this day) but different years

• Medium VPD value of top 10 analogue days is used as analogue VPD for each given day

• We use different spatial ranges and reanalysis datasets (ERA5, MERRA2, CFSR, JRA55) to create 60 analogue schemes; the interquartile range (IQR) is used as uncertainty range

INCREASING FIRE WEATHER RISK (VPD)

• Fire weather risk index: **Vapor Pressure Deficit (VPD);** VPD is the difference between saturated vapor pressure (e_s) and actual vapor pressure (e_a)

• Burned areas doubled after 21st century (2001-2018 vs. 1984-2000, according to MTBS data), connected to increase of VPD (Seager et al. 2015)

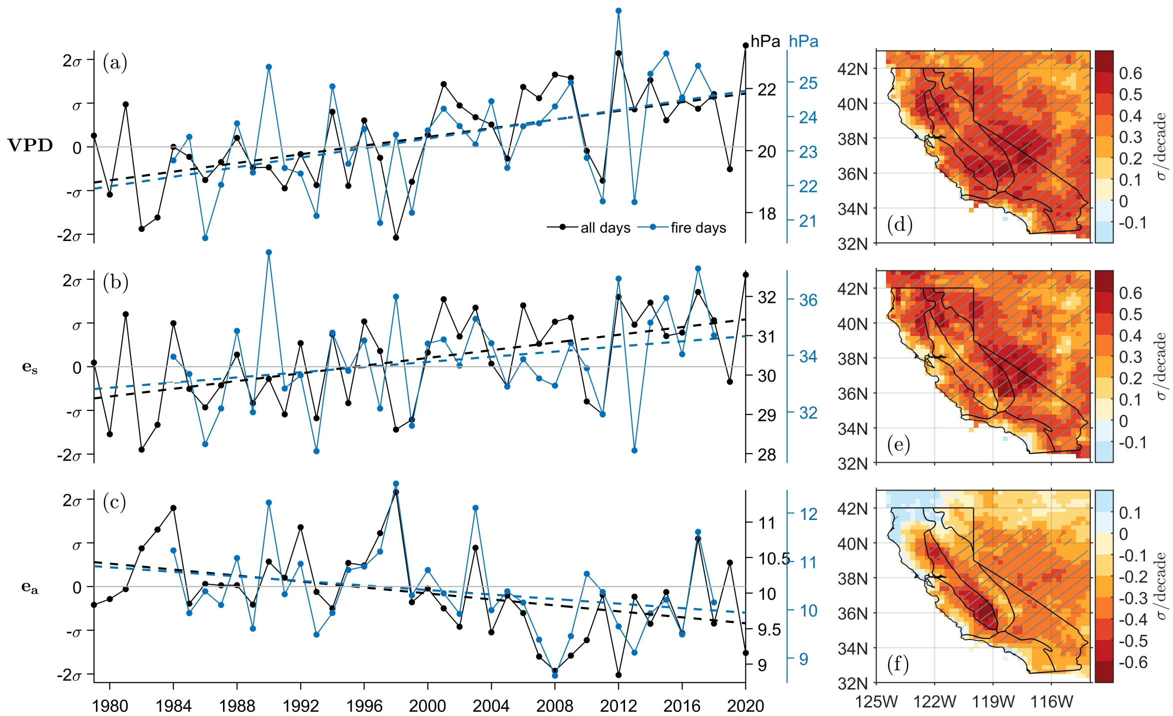


Fig. 2. Annual mean VPD/e_s/e_a time series and trends.

• Significant positive VPD trend across most area

  • 0.70hPa or 0.50σ per decade for all days

  • 0.69hPa or 0.55σ per decade for fire days

• VPD increase is driven by warming (increase of e_s) and drying (decrease of e_a)

  • according to trend ratio, ~70% of VPD trend is from warming; the rest 30% is from drying

  • Warming is significant across most area, while drying is more over inland region

• We cannot conclude that the warming and drying trends are totally because of anthropogenic warming due to the short record

RELATION BETWEEN CIRCULATION&VPD

SOM Analysis: relationship between circulation and VPD

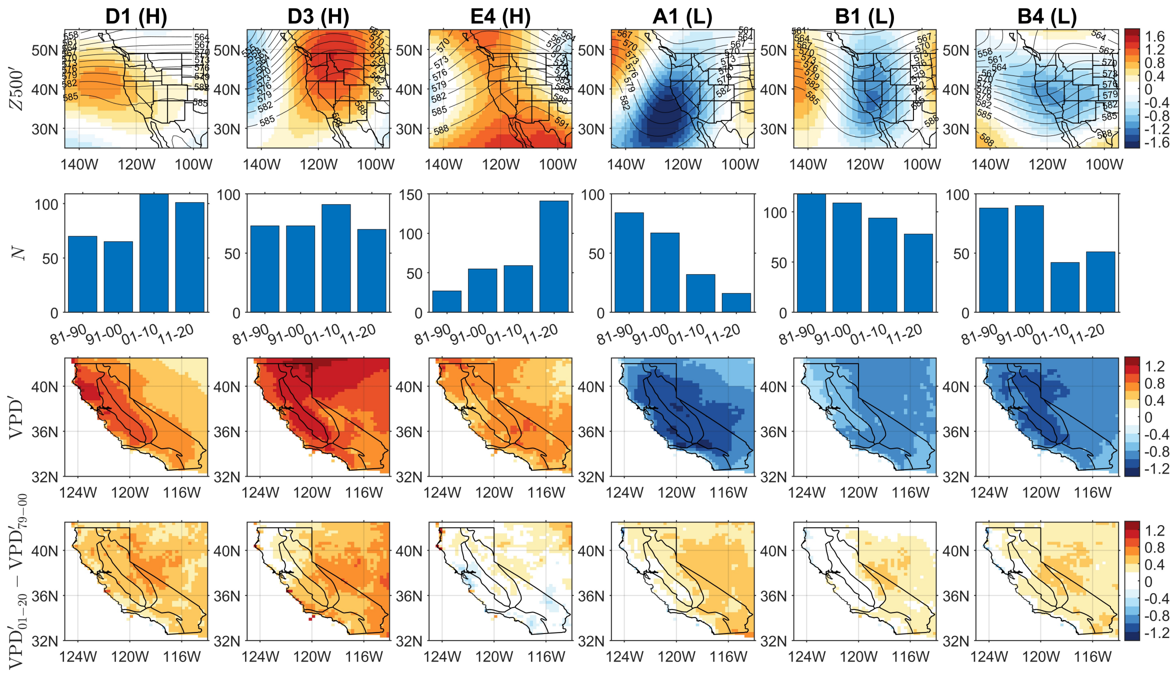


Fig. 3. Partial result from a 4×5 SOM of Z500' .1st-4th row: Z500; frequency; VPD; VPD difference between periods of 2001-2020 and 1979-2000.

• surface VPD is closely related to circulation pattern (1st & 3rd row)

• More frequent high-VPD nodes and less frequent low-VPD nodes; suggesting influence of circulation changes on VPD trend (2nd row)

• However, even for same circulation type, VPD still shows increase over time (4th row)

Flow Analogue: circulation-related VPD

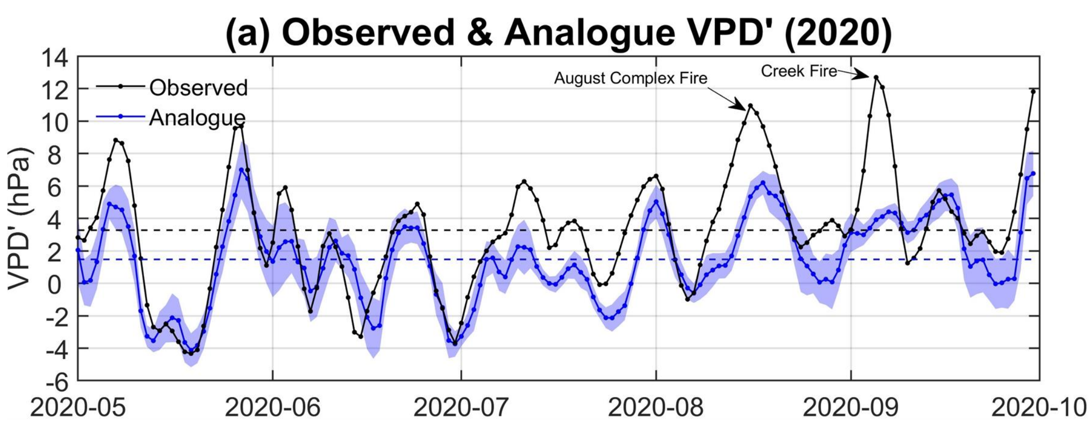


Fig. 4. Analogue & observed VPD during 2020.

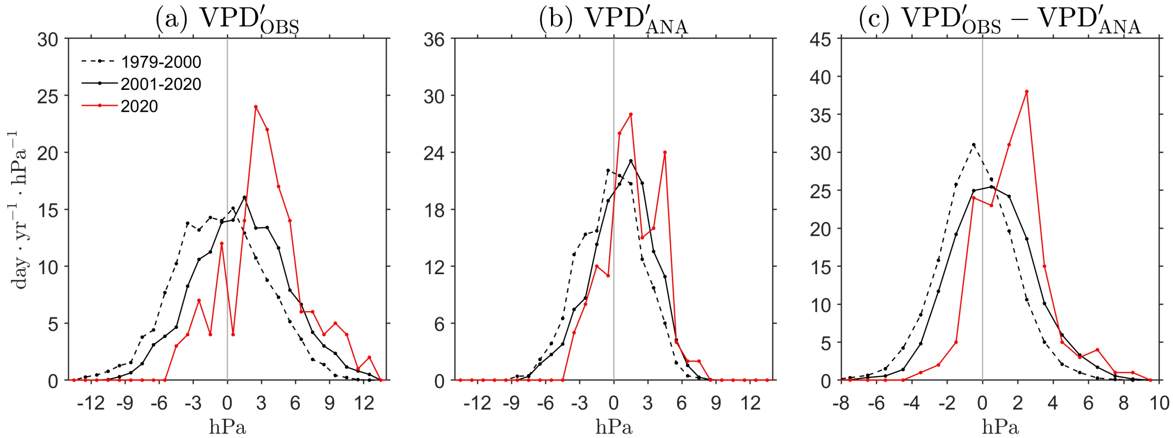


Fig. 5. Probability density function of (a) observed VPD, (b) analogue VPD, and (c) their difference.

• Analogue VPD well matches observed VPD with similar daily and annual variability (r≃0.8)

• It's becoming more likely that flow-analogue VPD underestimates observed VPD.

HOW MUCH DO CIRCULATION CHANGES EXPLAIN VPD TREND?

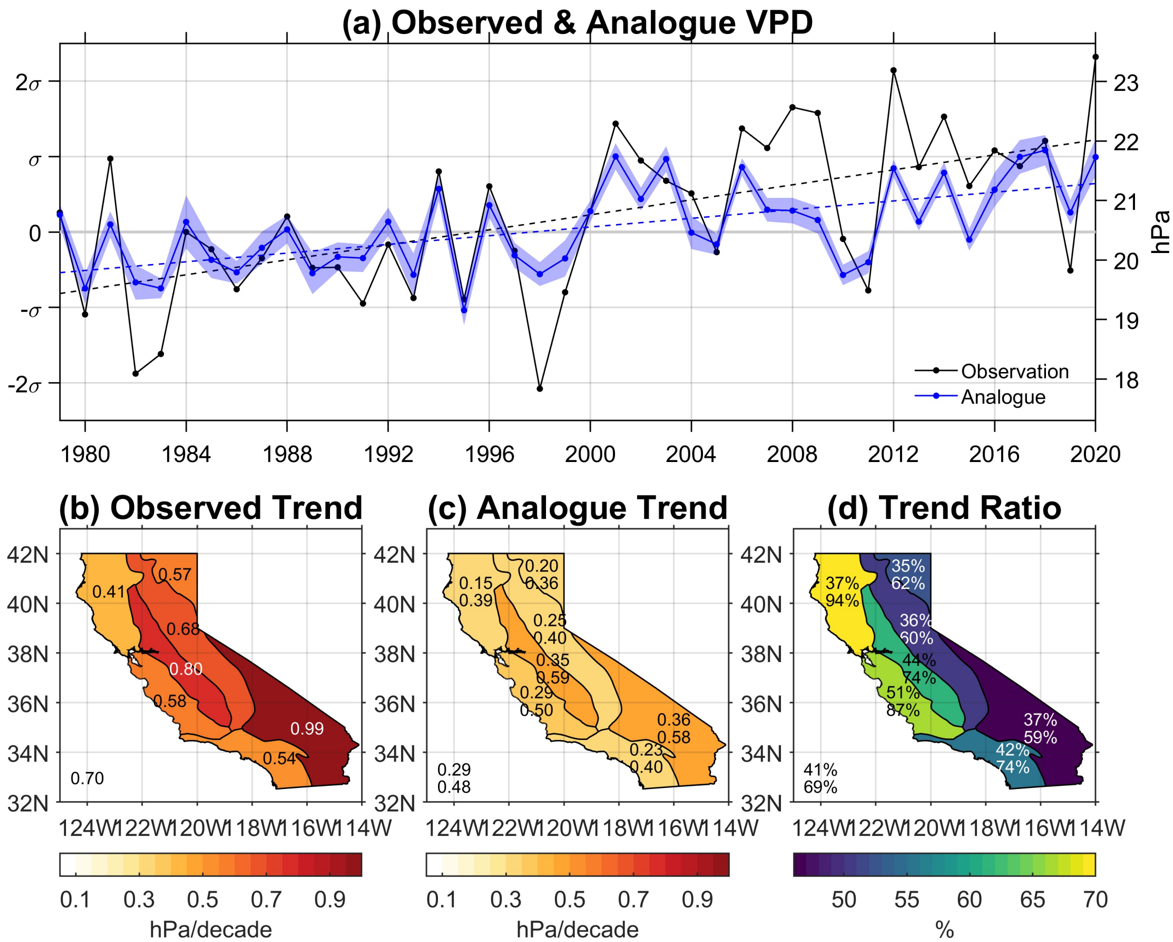


Fig. 6. (a) Annual observed & analogue VPD; (b) observed VPD trend; (c) analogue VPD trend; (d) ratio of analogue to observed trend. Two-number pair in (c) and (d) is interquartile range (IQR).

- Analogue VPD has a trend of 0.38 hPa/decade (IQR: 0.29-0.48), compared to the observed 0.70 hPa/decade; similar statistics for analogue fire-day VPD

- Circulation changes explains half (54%) of the observed trend, and anthropogenic warming at least explains the other half

- Contribution from circulation changes ranges from 47-72% in different regions of California

TAKE-HOME MESSAGES

• California shows a significant VPD trend of 0.70 hPa or 0.50 σ per decade during warm season

• VPD condition is closely related circulation pattern, and circulation changes contribute to about half (54%) of VPD trend

• Anthropogenic warming must at least explain the other half of VPD trend (*this is a conservative estimate, considering contribution from circulation changes represent upper limit of that from internal variability*)

AUTHOR INFORMATION

Yizhou Zhuang, Ph.D.

Postdoctoral Scholar

Department of Atmospheric and Oceanic Sciences

University of California, Los Angeles (UCLA)

Email: zhuangyz@atmos.ucla.edu

ResearchGate: https://www.researchgate.net/profile/Yizhou_Zhuang (https://www.researchgate.net/profile/Yizhou_Zhuang)

ABSTRACT

Recent increasing wildfire activities in California have raised widespread public concerns. This raises a question as to whether the increase of of fire weather this year and in recent decades is mainly due to weather pattern change dominated by natural variability or anthropogenic warming. We observed that vapor pressure deficit (VPD), an important fire weather risk index, in the warm season (May to September) of California, has increased significantly since 1979, with a positive trend of 0.70 hPa or 0.50 σ per decade, and this trend is also significant for VPD in large fire days; trend analysis of saturated and actual vapor pressure suggests that direct warming and drying contributes to about 70% and 30%, respectively, to the positive VPD trend. This increase of VPD and warming for such a short period cannot be simply linked to anthropogenic factors as it can also be affected by circulation changes. Our self-organiazing maps analysis reveals the close relationship between VPD and circulation. Using a flow analogue approach, we estimated circulation changes contribute to about half (54%) of the observed VPD trend. Since circulation changes represent the upper limit of internal variability of the climate system because both the internal climate variability and anthropogenic forcings can contribute to such a change, our results suggest that anthropogenic warming must explain at least the other half of the observed VPD trend.

REFERENCES

Abatzoglou, J. T., 2013: Development of gridded surface meteorological data for ecological applications and modelling. Int J Climatol, 33, 121-131.

Abatzoglou, J. T., and A. P. Williams, 2016: Impact of anthropogenic climate change on wildfire across western US forests. P Natl Acad Sci USA, 113, 11770-11775.

Kohonen, T., 1990: The self-organizing map. Proceedings ofthe IEEE, 78(9), 1464–1480.

Seager, R., A. Hooks, A. P. Williams, B. Cook, J. Nakamura, and N. Henderson, 2015: Climatology, Variability, and Trends in the US Vapor Pressure Deficit, an Important Fire-Related Meteorological Quantity*. J Appl Meteorol Clim, 54, 1121-1141.

Tett, S. F. B., and Coauthors, 2018: Anthropogenic Forcings and Associated Changes in Fire Risk in Western North America and Australia during 2015/16. B Am Meteorol Soc, 99, S60-S64.

Yiou, P., R. Vautard, P. Naveau, and C. Cassou, 2007: Inconsistency between atmospheric dynamics and temperatures during the exceptional 2006/2007 fall/winter and recent warming in Europe. Geophys Res Lett, 34.

Zhuang, Y., R. Fu, and H. Wang, 2020: Large-Scale Atmospheric Circulation Patterns Associated With U.S. Great Plains Warm Season Droughts Revealed by Self-Organizing Maps. Journal of Geophysical Research: Atmospheres, 125(5), 1-18.