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Key Points:
- Anthropogenic climate change is projected to enhance fire weather across most burnable global land surfaces during the twenty-first century
- Emergence of fire weather conditions from natural variability is modeled to occur in the first half of the twenty-first century in many regions
- Extent of fire-weather emergence is twice as large when global temperature surpasses 3 °C, compared to 2 °C, above preindustrial levels

Supporting Information:
- Supporting Information S1

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Global Emergence of Anthropogenic Climate Change in Fire Weather Indices

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Abstract Changes in global fire activity are influenced by a multitude of factors including land-cover change, policies, and climatic conditions. This study uses 17 climate models to evaluate when changes in fire weather, as realized through the Fire Weather Index, emerge from the expected range of internal variability due to anthropogenic climate change using the time of emergence framework. Anthropogenic increases in extreme Fire Weather Index days emerge for 22% of burnable land area globally by 2019, including much of the Mediterranean and the Amazon. By the midtwenty-first century, emergence among the different Fire Weather Index metrics occurs for 33–62% of burnable lands. Emergence of heightened fire weather becomes more widespread as a function of global temperature change. At 2 °C above preindustrial levels, the area of emergence is half that for 3 °C. These results highlight increases in fire weather conditions with human-caused climate change and incentivize local adaptation efforts to limit detrimental fire impacts.

Plain Language Summary Observed increases in the frequency and severity of fire weather have been observed across portions of the globe over the past half century. We used climate models to identify where and when anthropogenic climate change causes fire weather conditions to exceed that of natural variability. Modeling results show that emergence for some fire weather indices is already under way for a sizable portion of the globe, including much of southern Europe and the Amazon, and with an expansion of this area with continued warming over the twenty-first century. These findings suggest substantial increases in fire potential in regions where vegetation abundance and ignitions are not limiting, highlighting the urgency to adapt to changes in fire disturbances and hazards.

1. Introduction

Fire is both a natural ecological process and tool used by humans that impacts ecosystems, water supplies, carbon budgets, and society (Bowman et al., 2017; Johnston et al., 2012; Randerson et al., 2012; Turetsky et al., 2015). Retrospective estimates of burned area gleaned through proxy records and modeling support a global decline since the industrial revolution due to societal factors such as land use conversion and fire suppression (Andela et al., 2017; Arora & Melton, 2018; Marlon et al., 2012). However, increases in broad-scale burned area are well documented in some portions of the globe over the past half century (Kasischke & Turetsky, 2006; Westerling, 2016), suggestive of the influence of changing climate conditions and increased temperatures on fire activity when other ingredients such as biomass abundance are not limiting. Climate variability imparts distinct relationships on fire activity mediated through its influence on biomass production and fuel aridity (Bradstock, 2010), with fuel aridity exhibiting strong concurrent relationships with burned area in flammability-limited regions, while strong antecedent relationships are observed between pluvial conditions one to two years prior to the fire season and burned area in fuel-limited regions (Abatzoglou et al., 2018; van der van der Werf et al., 2008).

Proxies for fuel aridity, including fire weather indices, indicate positive (drying) trends across much of the globe over the past four decades (Jolly et al., 2015). In western United States forests, approximately half of the observed increase across a suite of fuel aridity proxies from 1979 to 2015 was attributed to anthropogenic warming (Abatzoglou & Williams, 2016), and Gillett et al. (2004) noted a detectable influence of anthropogenic climate change on increased summer temperatures and burned area across Canadian forests. Detection and attribution of global fire activity to anthropogenic climate change is confounded by influences of other anthropogenic activities such as land-cover change, population, and fire suppression as well as temporally limited satellite-based fire records. Studies have examined the relative influences of these factors to observed and projected global fire activity (Knorr et al., 2016; Pechony & Shindell, 2010; Ward et al., 2018), but have not explicitly tried to identify when and where the influences of climate change will become perceivable locally, regionally, or globally. Joint attribution efforts for natural systems are more challenging than attribution of meteorological and climate variables to anthropogenic climate change (Rosenzweig et al., 2008), let alone coupled natural-human processes such as fire. As an alternative, a limited set of attribution studies that focus on atmospheric drivers and enablers of fire have been conducted but have often been limited geographically and methodologically (e.g., Abatzoglou & Williams, 2016; Gillett et al., 2004; Kirchmeier-Young et al., 2017; Tan et al., 2018).

Attribution studies have elucidated the influence of anthropogenic climate change across a host of metrics such as temperature, precipitation, ocean temperatures, and mountain snowpack (e.g., Barnett et al., 2008; Pierce et al., 2008) as well as distinct events (e.g., Risser & Wehner, 2017; Williams et al., 2015). These studies interrogate the relative contribution of causal factors to changes in some measurable element or the magnitude of frequency of a distinct event to a given forcing versus that which arises solely due to internal climate variability (Stott et al., 2015). An alternative approach that complements traditional attribution methods is the framework of the time of emergence (ToE) of anthropogenic climate change. ToE is defined when a signal forced by anthropogenic climate change exceeds some measure of the internal climate variability that occurs in the absence of anthropogenic forcing. Studies have demonstrated the ToE for first-order climate variables like mean temperature (Diffenbaugh & Scherer, 2011; Hawkins & Sutton, 2012), precipitation and temperature extremes (King et al., 2015; Tan et al., 2018), and sea level rise (Lyu et al., 2014). The signal-to-noise framework of ToE can not only highlight potential timelines for adaptation measures but also may be particularly important for ecosystem processes including fire, given that the approach queries whether changes exceed the natural variability upon which many systems are adapted to.

This study uses the ToE framework to address when and where the signal of anthropogenic climate change emerges from internal climate variability through the lens of the Fire Weather Index (FWI). The FWI from the Canadian Forest Fire Weather Index System is considered in this study given its widespread usage globally (Di Giuseppe et al., 2016; Field et al., 2016; Groot et al., 2014); its reflection of potential fire intensity tied to fuel aridity and fire weather irrespective of land cover and biomass; its sensitivities to temperature, precipitation, humidity, and wind speed (e.g., Flannigan et al., 2016); and its established empirical relationships to burned area across broad regions of the globe (e.g., Abatzoglou et al., 2018). While previous studies have shown changes in global fire weather metrics such as the FWI under anthropogenic climate change (e.g., Flannigan et al., 2013), these have been limited to a small number of models, and have not explicitly demonstrated if or when anthropogenic-forced changes emerge from internal variability. We aim to address this knowledge gap in projected changes in fire weather using a large set of models and address differences both geographically and across a set of different measures of FWI.

2. Data and Methods

Simulations from 17 models participating in the Fifth Phase of the Coupled Model Intercomparison Project were used in this analysis (Table S1). Models were selected that archived daily maximum temperature (*tasmax*), accumulated precipitation (*pr*), mean wind speed (*sfcWind*), and daily minimum relative humidity (*rhsmin*) for historical (1861–2005) and future (2006–2099) experiments, with the latter using Representative Concentration Pathway 8.5. Analyses were limited to a single realization (r1i1p1) per model. Ten models lacked archived *rhsmin* prior to 1950 (Table S1). For these models, we extended *rhsmin* back to 1861 using *tasmax* and daily mean 2-m specific humidity and bias correction procedures (Supporting information). All model output was regridded to a common 2.5° grid from 50°S to 70°N. Land areas where more than 80% of current land cover was classified as water, snow and ice, or barren or sparsely vegetated by MODIS land cover type product (Friedl et al., 2010) were considered unburnable and masked out. Results are presented using raw output from global climate models (GCMs). Experiments using univariate and multivariate bias correction procedures showed qualitatively similar conclusions (Cannon, 2018; Li et al., 2010; Pierce et al., 2015; supporting information).

The FWI is an output of the Canadian Forest Fire Danger Rating System (Van Wagner, 1987) that is a widely used numerical indicator of potential fire intensity. The system was originally developed as a numerical proxy for fire behavior in evergreen forests of eastern Canada, but has been shown to be an effective correlate of intraseasonal to interannual fire activity globally across diverse vegetation types, most notably in flammability-limited environments (Abatzoglou et al., 2018). The FWI integrates the effects of fuel availability through a buildup index that combines three different classes of fuel moisture with the potential rate of fire spread. The former is a climate-weather hybrid that entrain information (e.g., precipitation, temperature) on time scales ranging from the previous day to the preceding couple months, whereas the latter is predominantly influenced by daily fluctuations in weather (e.g., wind speed). Calculation of FWI requires daily 24-hr accumulated precipitation as well as temperature, humidity, and wind speed at 1200 local time. Given the barriers in obtaining observed and modeled data at 1200 local time, we use daily maximum temperature (*tasmax*), daily minimum relative humidity (*rhsmin*), daily accumulated precipitation (*pr*), and daily mean wind speed (*sfcWind*) following prior global analyses (e.g., Abatzoglou et al., 2018; Jolly et al., 2015).

We chose four annualized FWI metrics as indicators of fire potential including two frequency-based metrics that examine the number of days per year of extreme fire weather and length of the fire weather season, and two magnitude-based metrics that examine annual maxima and seasonal averages in FWI. These metrics were selected to highlight differences in ToE across different statistical properties of FWI that have established relationships to fire activity. First, we calculated for each pixel the number of days per year of high FWI, quantified as days exceeding the 95th percentile (FWI_{95d}) because fire growth preferentially occurs during high fire danger periods (e.g., Barbero et al., 2014). Second, we calculated the fire weather season length (FWI_{fwsl}) following Jolly et al. (2015), defined as days per year exceeding the midrange point. Third, we calculated the annual maximum FWI (FWI_{max}) which provides a measure of extreme fire risk (Tan, Chen, & Gan, 2018). Finally, we calculated the annual peak 90-day mean FWI (FWI_{fs}) as a measure of seasonal fuel aridity during the primary fire season—as studies have shown that a majority of annual burned area at regional scales occurs within three consecutive months and interannual burned area variability exhibits significant relationships to concurrent FWI (e.g., Abatzoglou et al., 2018). A flexible 90-day window was used to calculate FWI_{fs} as it provided slightly more explained variance to interannual burned area records than fixed dates in prior studies (Higuera et al., 2015), and may account for changes in phenology of the fire season.

A variety of approaches have been used in ToE studies leading to challenges in cross-study comparisons. These include various baseline periods and approaches for estimating internal climate variability, statistical procedures for quantifying emergence, and uses of model ensembles (Diffenbaugh & Scherer, 2011; Hawkins & Sutton, 2012; Lehner et al., 2017). We used a 50-year baseline period from 1861 to 1910 when anthropogenic forcing was closer to a preindustrial state to gauge quasi-natural variability (e.g., King et al., 2015). This 50-year period was also used to define the local 95th percentile threshold value for calculating FWI_{95d} and midpoint range (average of maximum and minimum value of FWI) for calculating FWI_{fwsl}. Emergence was quantified using a signal-to-noise criterion (e.g., Hawkins & Sutton, 2012). This was done using moving 30-year windows starting in the year 1980 on the basis of the signal of change, defined as the difference of means between a given 30-year period and the baseline period, exceeding the noise of natural variability, defined herein as one standard deviation (calculated for the baseline period). We additionally calculated ToE using a right-tailed *t* test ($p < 0.05$). This alternative approach showed more widespread and earlier emergence than the approach we adopted; thus, we consider the signal-to-noise approach used here to be more conservative. To limit pseudo-emergence, ToE was indexed as the first year in a moving 30-year window (e.g., 2011 was the ToE for 30-year period from 2011 to 2040; e.g., King et al., 2015), whereby criteria are met for all subsequent moving 30-year periods. Additionally, we restrict emergence to occurring no later than 2050 to ensure persistence for at least 2 decades after initial detection, following previous methods (Hawkins et al., 2014; King et al., 2015).

Estimates of local ToE were conducted at the 2.5° grid of interpolated GCM output as well as at larger, regional scales. Previous studies have shown that ToE is later at local scales than regional scales (Maraun, 2013), as internal variability is reduced through geographic aggregation. Local emergence of FWI may be ecologically important for fire regimes and trajectories of species distributions. However, regional emergence may be informative for broader adaptation efforts as widespread fuel aridity is associated with synchronous regional fire activity in flammability-limited fire regimes (Abatzoglou & Williams, 2016). Likewise, geographic synchrony in fire weather indices has direct implications for regional fire suppression efforts and broad-scale implications for smoke-related health impacts. We aggregate data to IPCC SREX regions as used in previous efforts (King et al., 2015) for assessing regional emergence of FWI. Aggregation was performed by calculating averages of daily FWI for all pixels within the bounds of each region and summarizing the four metrics as done at the pixel scale.

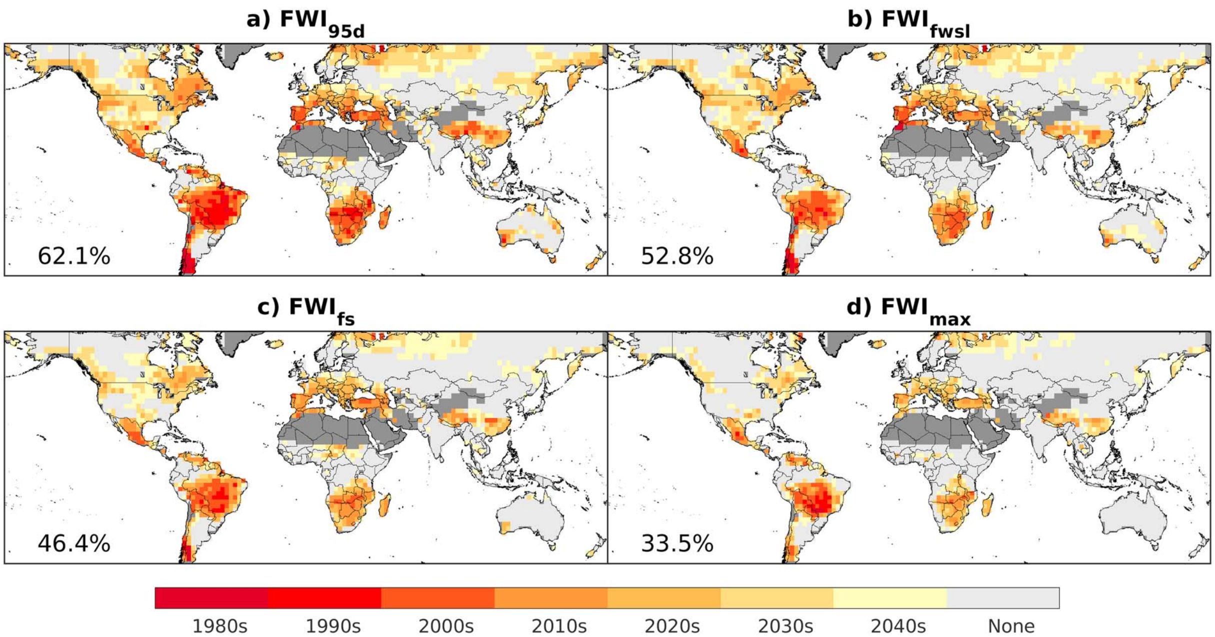

Figure 1. Time of emergence of anthropogenic climate change for (a) the frequency of days exceeding the 95th percentile, (b) the length of the fire weather season, (c) the peak 90-day average FWI, and (d) annual maximum FWI. Mapped is the 17-model median date at which the anthropogenic signal emerges based on the change exceeding the standard deviation of the baseline period. Areas of light gray highlight where the signal does not emerge for at least eight models by 2050. Unburnable lands where >80% of the area is water, snow, and ice or barren or sparsely vegetated are shown in dark gray. The percent of burnable land with emergence by 2050 is denoted in the bottom left corner of each map.

Given the potential challenges with reconciling varied climate sensitivity of individual models and uncertainty regarding emission pathways, we consider an alternative to the ToE concept by replacing time with global mean temperature following Hawkins and Sutton (2012). We refer to this as the Global Temperature of Emergence (GToE), which uses the same framework as ToE, but may be advantageous because it is agnostic with respect to model and emission pathway and is more directly aligned with climate policy targets. The GToE differs from ToE in that GToE is defined by the 30-year average global mean air temperature difference for the period when ToE is first identified relative to baseline conditions for 1861–1910 (i.e., quasi pre-industrial conditions). Identifying GToE for FWI metrics may provide insight into risk avoidance though mitigation efforts without explicitly comparing differences in climate forcing by inferring differences in model-derived transient climate response given the varied equilibrium climate sensitivity of the models used (between 2.1 and 4.7 K; Table S1). However, this approach is conservative given the noted differences between transient and equilibrium climate responses.

Emergence was tallied separately for each model. We focus on multimodel median ToE and GToE in the results section. Emergence is thus stated to not occur where fewer than 9 of the 17 models show emergence. When a majority of the GCMs show emergence, ToE is reported as the year when the ninth model emerges from internal variability. Results of regional emergence for individual models are provided in the supporting information to highlight model uncertainty in ToE.

3. Results

Local emergence of the four FWI metrics by 2050 was found for between 33 and 62% of global burnable land surfaces (Figure 1). Local ToE was earlier and more widespread for frequency-based FWI metrics (FWI_{95d} and FWI_{fwsl}) than for magnitude-based metrics (FWI_{fs} and FWI_{max}). Heightened internal variability for annual maxima of other variables results in generally lower signal-to-noise detection (Diffenbaugh et al., 2017; King et al., 2015), and ambiguity in modeled changes in wind extremes concurrent with low fuel moistures that often result in peak FWI likely limit emergence as defined in this study (e.g., Tan, Chen, & Gan, 2018). Substantial geographic variability in ToE was evident with local emergence across much of the Mediterranean, southern Africa, southern Chile and Argentina, and Amazonia for most FWI metrics by 2030, consistent with the development of geographic hot spots of increasing drought risk imparted by anthropogenic climate change (e.g.,

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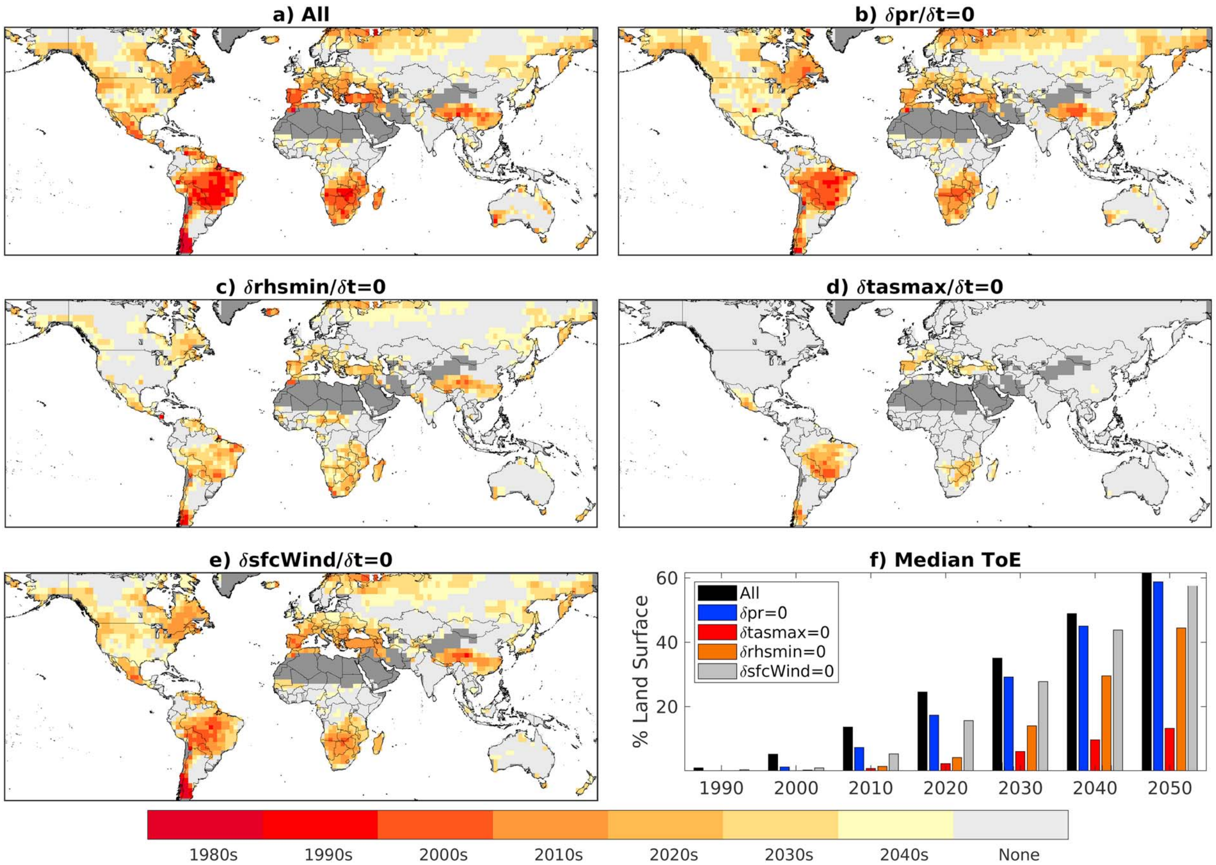

Figure 2. Median ToE for FWI_{95d} using (a) changes in all variables, (b) excluding monthly changes in precipitation totals, (c) excluding monthly changes in minimum relative humidity, (d) excluding monthly changes in maximum temperature, and (e) excluding monthly changes in wind speed. (f) The percent of global burnable land where median ToE occurs by date for the reference case and the four experiments.

Greve & Seneviratne, 2015; Gudmundsson & Seneviratne, 2016). By contrast, emergence was not found by 2050 in a majority of GCMs for much of equatorial Africa, portions of Australia, and sections of boreal systems in eastern Russia and Canada. A comparative analysis using bias-corrected GCM outputs showed similar results (Figures S1 and S2). We additionally visualize the number of GCMs with emergence commencing by 2019 (Figure S3), for which a majority of models depict emergence of FWI_{95d} to be under way for approximately 22% of global burnable land surfaces.

Emergence is a function of the signal of change and persistence subject to internal climate variability as compared to the natural variability of the baseline period. We deconstruct the primary drivers of emergence in FWI metrics using two approaches. First, we present multimodel median changes in the four FWI metrics for the midtwenty-first century (2040–2069) relative to the baseline period (Figure S4). A majority of terrestrial surfaces show statistically significant increases in all metrics (*t* test; $p < 0.05$) for a majority of models by midcentury, including a doubling of FWI_{95d} versus the historical baseline for 31% of burnable global lands. For comparison, the multimodel median standard deviation calculated over the baseline period shows relatively high interannual variability in FWI metrics across portions of Australia which impede emergence based on a signal-to-noise ratio (Figure S5). Modeled changes in FWI metrics are broadly consistent with projected midtwenty-first century changes in the four meteorological variables used to calculate FWI during the core fire season (defined as the 17-model median date of maximum 90-day FWI over the baseline period), with substantial increases in *tasmax* and declines of greater than 2% in *rhsmin* across most land surfaces (Figure S6). Changes in *pr* during the core fire season exhibit more distinct geographic variability with decreases in the Mediterranean, Amazonia, and southern Africa where FWI signals emerge earliest, and increases across much of the high latitudes of North American and Eurasia where emergence is delayed. Tan, Gan, and Horton (2018) showed similar patterns for the ToE of consecutive dry days across the globe, with increases for most land surfaces except

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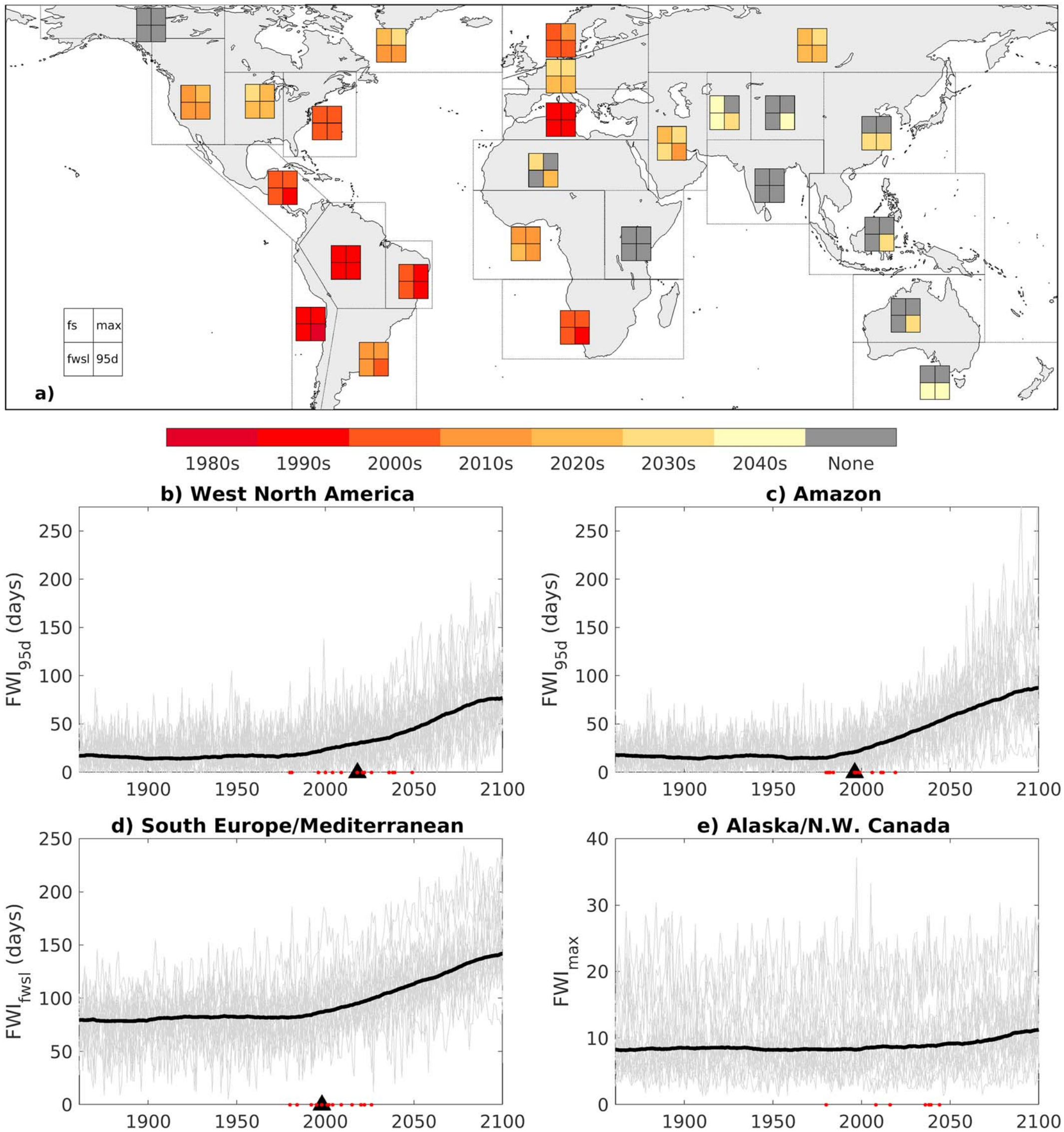

Figure 3. (a) Time of emergence of anthropogenic climate change at subcontinental regions as depicted by the median ToE from 17 models. The four quadrants show the ToE for the frequency of FWI extremes (FWI_{95d}; SE quadrant), length of the fire weather season (FWI_{fwsl}; SW quadrant), peak 90-day FWI (FWI_{fs}; NW quadrant), and annual maximum FWI (FWI_{max}; NE quadrant). Light black lines show the geographic delineation of the regions. The lack of regional emergence before 2050 is denoted by dark gray. Time series of regional FWI metrics from 1861–2100 for 17 different GCMs of (b) FWI_{95d} for the West North America region, (c) FWI_{95d} for the Amazon region, (d) FWI_{fwsl} for South Europe/Mediterranean region, and (e) FWI_{max} for Alaska-Northwest Canada region. The bold black line shows the multimodel median 30-year moving average. ToE for individual models are denoted by red dots along the *x* axis. The 17-model median ToE is denoted by a black triangle for regions where at least nine models show emergence.

declines in tropical Africa and high latitudes. The Canadian Forest Fire Danger Rating system and thus FWI directly incorporate precipitation occurrence and dry spell lengths into measures of fuel moisture.

Second, we performed a sensitivity analysis to decompose the trends for each of the four meteorological variables used to calculate FWI had on ToE for FWI_{95d} (supporting information). Results show that emergence is predominately imparted by *tasmax* increases. Calculations performed in the absence of modeled trends in *tasmax* resulted in 13.2% of the burnable lands with ToE by 2050, compared to 62% when all trends were considered (Figure 2). Regions where emergence occurs in the absence of increased *tasmax* are areas with notable decreases in *pr* and *rhsmin* during the fire season (Figure S6). Increased fire season *pr* across high latitudes

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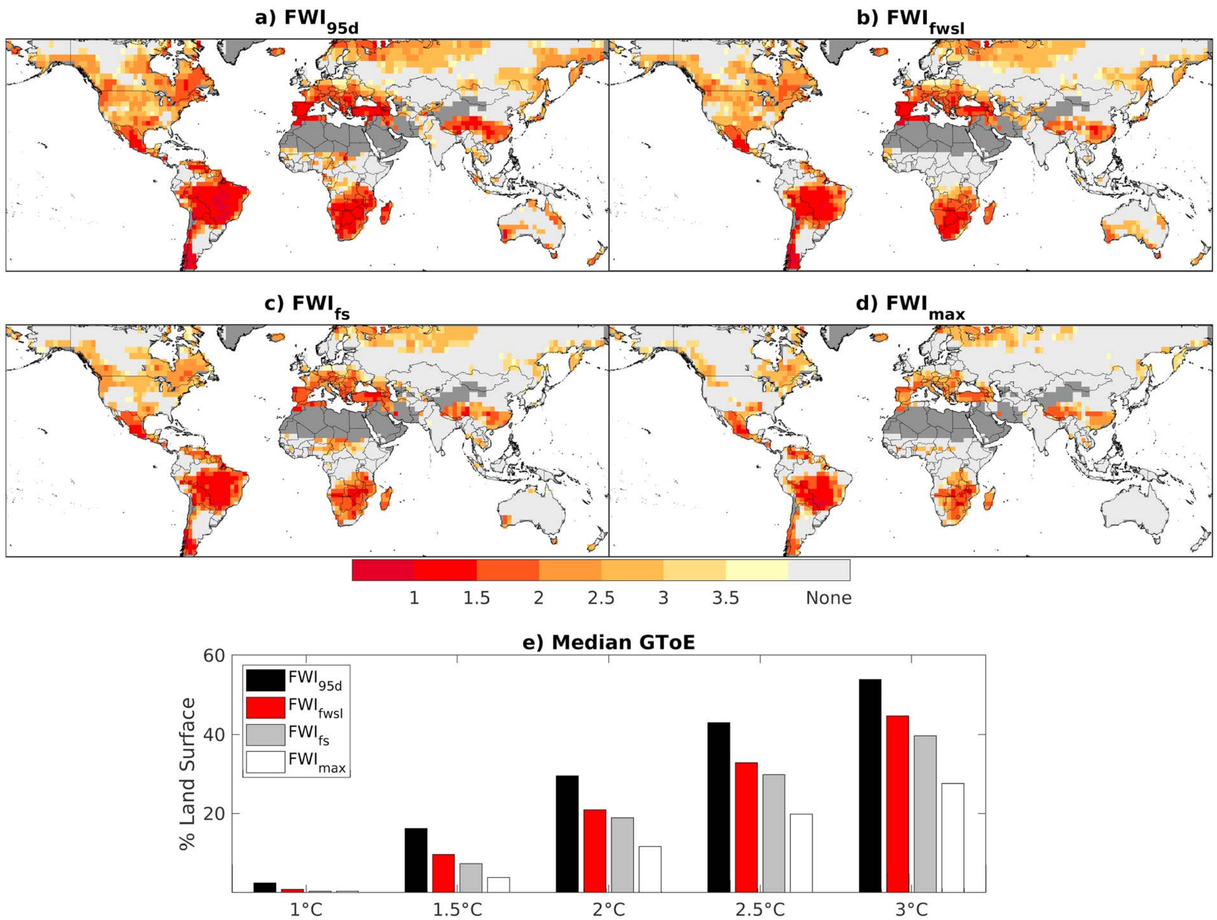

Figure 4. Amount of warming in annual global mean air temperature (1861–1910 baseline) at which anthropogenic signals emerge for (a) the frequency of days exceeding the 95th percentile (FWI_{95d}), (b) the length of the fire weather season (FWI_{fwsl}), (c) the peak 90-day average FWI (FWI_{fs}), and (d) annual maximum FWI (FWI_{max}). Maps show the 17-model median global temperature of emergence (GToE). Areas of light gray highlight where emergence does not occur by 2050. (e) The multimodel median proportion of burnable terrestrial surfaces for which emergence occurs as a function of global temperature increase beyond the preindustrial baseline.

of North America and Eurasia partially offsets the influence of warming trends on FWI per the sensitivity analysis by Flannigan et al. (2016), thus helping explain the delayed emergence of FWI metrics in those locations.

Regional emergence of FWI metrics was approximately 2 decades earlier than for local emergence (Figure 3a). Emergence occurs for FWI metrics in most regions by 2050, and modeled results suggest that a regional signal emerges by 2019 in many areas including the Mediterranean, portions of South America, and North America. The earlier and more robust ToE at regional scales versus local scales is congruent with previous ToE and broader detection and attribution studies pertaining to the reduction of internal variability through geographic aggregation (e.g., King et al., 2015). By contrast, regional emergence for a majority of models was not seen for any of the four metrics in northwestern North America, eastern Africa, and southern Asia.

We provide select examples of annualized time series of FWI metrics to illustrate the ToE framework and magnitude of projected changes in Figure 3. Models project an average of 3 times the baseline FWI_{95d} by the end of the century for the western North America and Amazon regions (Figures 3b and 3c). Median ToE was 2018 and 1997 for these western North America and Amazon regions, respectively, although one model does not show emergence for the Amazon region (Figures S7–S10). Strong intermodel agreement of increased FWI_{fwsl} was found for the Mediterranean region with all models showing emergence under way by 2030 and FWI_{fwsl} being nearly twice that of baseline conditions by the end of the twenty-first century (Figure 3d). By contrast, fewer than half of the models show emergence of FWI_{max} in the Alaska-Northwest Canada region (Figure 3e).

With a 2 °C warming in global mean temperature over baseline, approximately 30 and 21% of global burnable land shows local emergence of FWI_{95d} and FWI_{fwsl}, respectively. Emergence at 2 °C warming is most pronounced in the Mediterranean, southern Africa, and portions of the Americas (Figures 4a–4d). With a 3 °C warming in global mean temperature, the geographic coverage of local emergence of FWI metrics nearly doubles beyond that associated with 2 °C warming (Figure 4e). The geographic extent of emergence for FWI_{fs} and FWI_{max} lags that of FWI_{95d} and FWI_{fwsl} with all metrics increasing commensurate with warming.

4. Discussion and Conclusion

Previous studies have detected increases in fire weather indices regionally and globally over a relatively short observational record (Abatzoglou & Kolden, 2013; Dowdy, 2017; Jolly et al., 2015). This study demonstrates an emergence of FWI-based metrics from "natural" variability for 33–62% of burnable lands globally by the midtwenty-first century due to anthropogenic climate change. Local emergence of the frequency of extreme fire weather days showed the most widespread changes, including modeled evidence of emergence commencing by 2019 for 22% of burnable lands globally. By contrast, emergence of magnitude-based metrics such as annual maxima was less robust and delayed relative to frequency-based metrics, suggesting distinct patterns in the character of fire weather changes resulting from anthropogenic forcing. Emergence for FWI is delayed and exhibits more geographic variability relative to the emergence of temperature-based measures (e.g., King et al., 2015) given the complementary (e.g., Mediterranean) and competing (e.g., boreal) roles of changes in precipitation during the fire season on FWI. The ToE framework does not explicitly exclude natural variability from influencing changes in FWI, but the persistence of time scales used in quantifying emergence, consideration of 17 climate models, and sensitivity to temperature as the predominant driver of projected changes in FWI combine to implicate anthropogenic factors.

Emergence at regional scales occurs earlier than at local scales as noted in previous ToE and attribution studies (Fischer & Knutti, 2014; King et al., 2015). Local emergence of fire weather metrics has pronounced impacts for ecological processes, but the regional emergence of fire weather extremes may be more perceivable from a societal perspective. We note that the spatial scale of our analysis is inadequate for resolving mesoscale processes important for local extreme fire weather conditions such as those that arise in southwestern California (e.g., Hughes & Hall, 2010). Heightened regional-scale fire weather and fuel aridity has been shown to have strong relationships with macroscale burned area (e.g., Williams & Abatzoglou, 2016). Increased regional fire weather contributes to geographic synchronicity in fire activity in flammability-limited regions that compromises regional and national resources available for suppression activities, thereby decreasing suppression efficacy for new ignitions (Flannigan, Stocks, et al., 2009) and require reallocating funds meant for preventative maintenance to fire suppression efforts (North et al., 2015). Likewise, the regional emergence in fire weather metrics is reasoned to have notable impacts on regional to continental air quality and human health (McClure & Jaffe, 2018; Spracklen et al., 2009).

The emergence of fire weather metrics viewed through the lens of changes in global mean temperature provides an alternative policy-based framework for viewing potential risks. We demonstrate that policy targets to limit warming of global mean temperature to no more than 2 °C above preindustrial levels have substantial implications for changes in the local FWI emergence. The geographic extent of emergence of the four FWI metrics doubles between a 2 and 3 °C warming. These results are in qualitative agreement to the findings of Turco et al. (2018), who showed that while modeled estimates of burned area in Mediterranean Europe increased with warming, the magnitude of such increases was substantially reduced when warming was held below 2 °C above preindustrial levels. Whereas observations suggest that changes have already occurred for aspects of fire weather metrics, these results highlight the risk avoidance for heightened fire weather conditions, fire potential, and associated fire hazards through climate mitigation efforts.

Projected changes in global fire activity broadly show increases in flammability-limited systems where fuel abundance in not limiting (Flannigan, Krawchuk, et al., 2009; Moritz et al., 2012). While this study does not explicitly attempt to model fire activity, our results generally support previous efforts given the strong contemporary relationships between FWI in both burned area in many flammability-limited regions globally (Abatzoglou et al., 2018) and the occurrence of extremely energetic fire events, many of which have had notable societal impacts (Bowman et al., 2017). Different fire weather indices each engender varied sensitivities to temperature, precipitation, humidity, and wind (e.g., Flannigan et al., 2016) and are reasoned to show varied response to anthropogenic climate forcing (e.g., Abatzoglou & Williams, 2016). The FWI is not the only climate variable or biophysical property that influences fire activity or fuel dryness, and may not adequately capture the influence of live fuel moisture as it pertains to potential fire behavior (Ruffault et al., 2018). There are many reasons why changes in FWI should not directly translate into emergent changes in realized fire activity such as in fuel-limited fire regimes where FWI exhibits negligible influence on annual burned area (e.g., Abatzoglou et al., 2018), as well as those due to vegetation-fire feedback in a changing climate (e.g., Littell et al., 2018), and due to human activity altering climatic driven trends in fire activity through fire suppression and land use changes (Fréjaville & Curt, 2017; Marlon et al., 2012). Nonetheless, increased fire weather in a changing climate will be one of many ingredients that will continue to shape changes in global fire activity in the Anthropocene and will require local adaptation efforts to curb negative fire impacts.

Acknowledgments
Archive climate model output from CMIP5 can be accessed at https://esgf-node.llnl.gov/projects/cmip5/. J.T.A. was partially supported by the National Science Foundation under award DMS-1520873.

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