Mining the Historical MODIS Hotspots Archive to Characterize Global Fire Regimes

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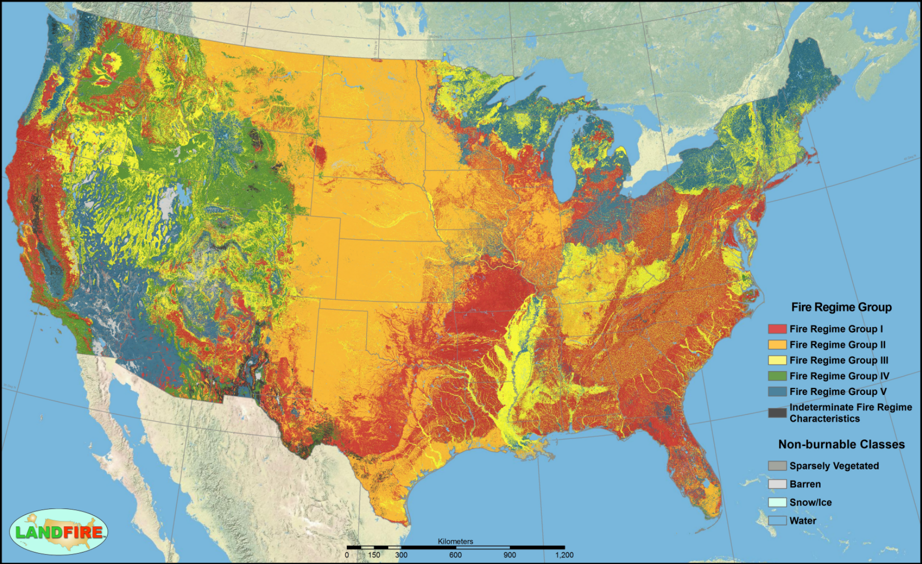
Fire Regimes

- **Fire regimes** represent a combination of characteristics influencing the repeated pattern of fire on the landscape.
- These characteristics are dynamic processes that are sensitive indicators of climate and land use change.
- Understanding fire regimes is important for quantifying fire emissions, planning fire suppression and control, and predicting how fire risk may be altered in response to environmental and land use change.
- Despite that importance, fire regime attributes are often vaguely understood, and systematic tracking of fire regimes at broad scales has proved difficult.

LANDFIRE Fire Regime Groups



Conventional fire regimes are defined by climate, fuels, and ignitions, but typically do not account for changes in stressors, values, and tradeoffs.

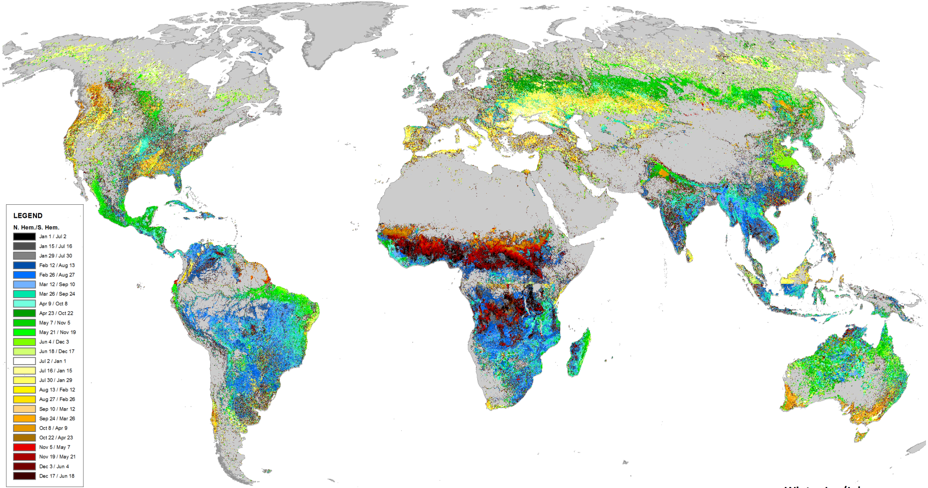
Satellite-based Fire Detection

- Satellite-based high temperature (hotspot) detection has the potential for coarsely estimating a broad suite of ecologically and climatologically relevant fire regime attributes.
- Attributes include year-to-year fire occurrence, within-year seasonal timing, fire intensity, and importance of fire at the landscape scale.
- Landscapes that experience small and large wildfires, prescribed burns, and agricultural clearing and crop residue fires often exhibit different attributes that can be tracked within a scale- and geography-sensitive monitoring framework.
- We used hotspot detections from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Terra and Aqua satellites for the period 2002–2013 (see `http://earthdata.nasa.gov/`).
- MODIS hotspot detections are available at roughly 1 km resolution with global coverage.

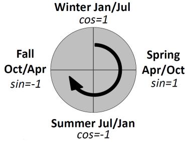
Methods

- 1-km hotspot detections were assigned to 10×10 km grid cells for analysis of fire regime attributes.
- We selected four fire regime attributes believed to be most significant:
  1. **Seasonality** was quantified by grouping the day of year into biweeks and selecting the top six to minimize zero values resulting from an all-year analysis. Cross-year seasonal continuity was retained through use of a sine-cosine transform. To provide cross-hemispheric comparability, Southern Hemisphere fire dates were adjusted with a 6-month lag, which may cause false differences near the equator.
  2. **Inter-year fire occurrence** was captured by a) the total number of years with >2 hotspots, b) the number of continuous years with fire, and c) continuous years without fire.
  3. **Intensity** was captured by calculating the minimum, mean, and maximum hotspot temperature.
  4. **Density** was provided by the total hotspots over the entire period, linked to the general importance of fire within a grid cell.

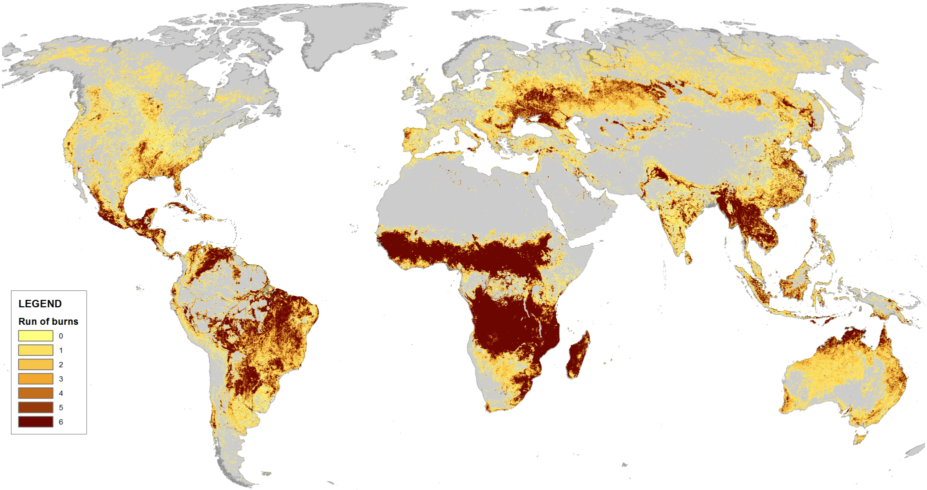
Seasonality (Biweek 1)



Day of year was grouped into biweeks and the top six were selected. Cross-year seasonality continuity was retained through use of a sine-cosine transform (see figure at right). Southern Hemisphere fire dates adjusted with a 6-month lag.

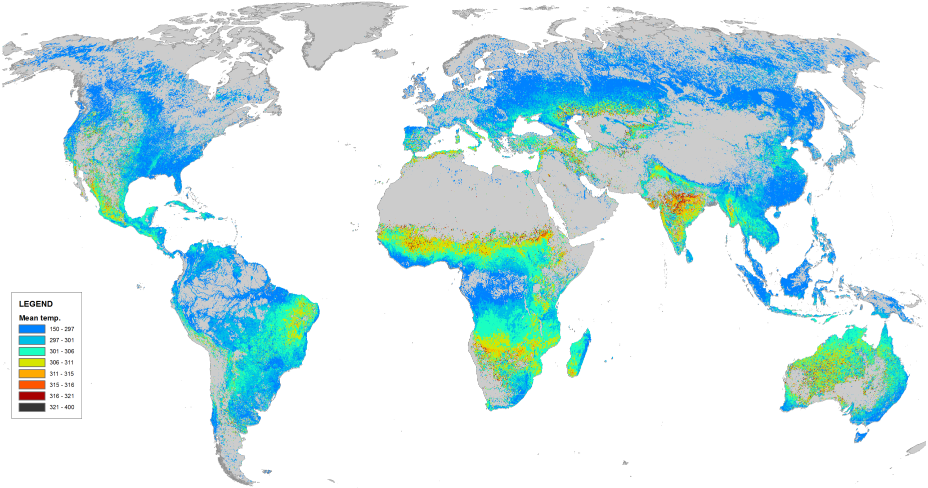


Inter-Year Fire Occurrence (Run of Burn Years)

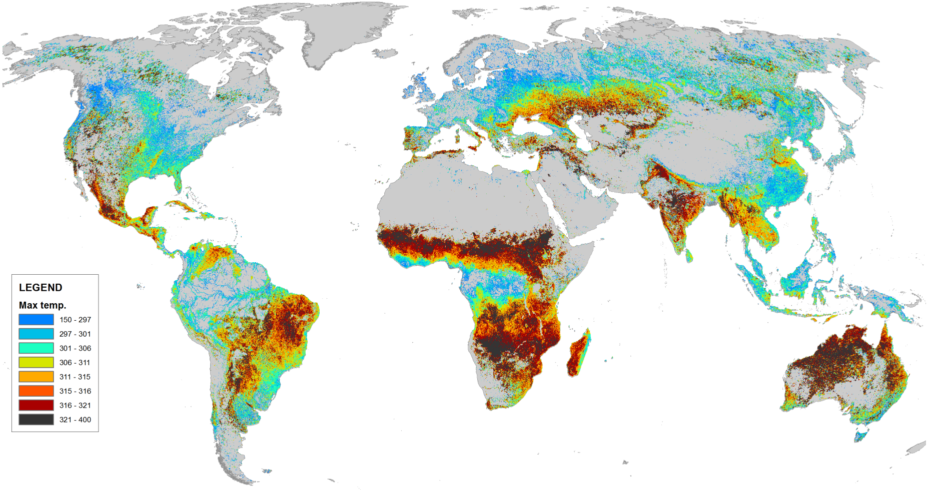


Number of continuous years with fire (runs).

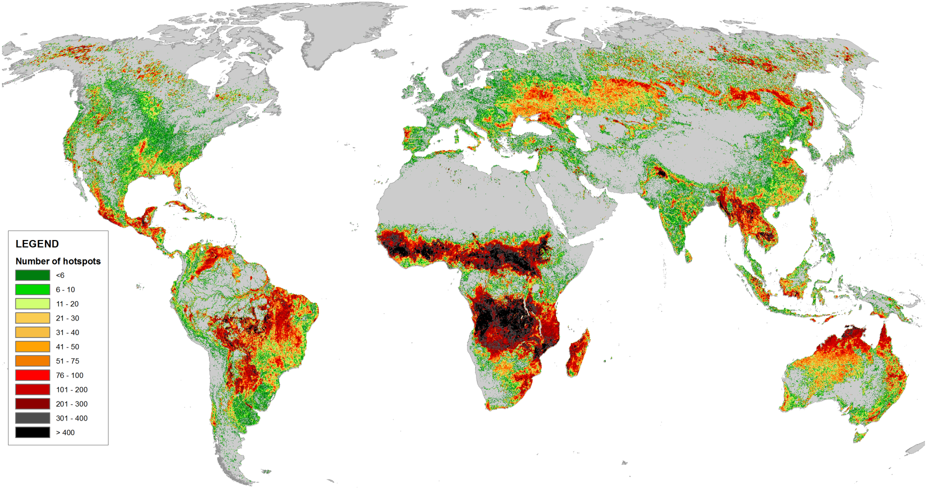
Intensity (Mean Hotspot Temperature, °C)



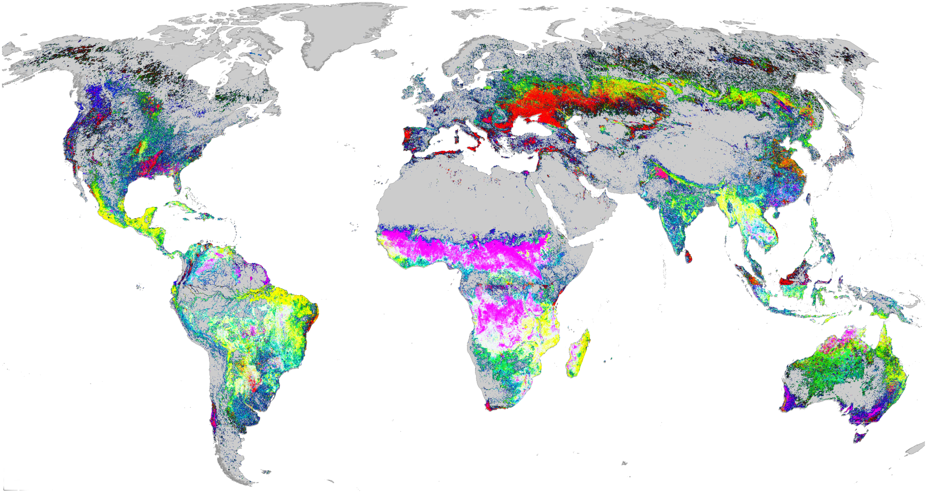
Intensity (Maximum Hotspot Temperature, °C)



Density (Number of Hotspots)



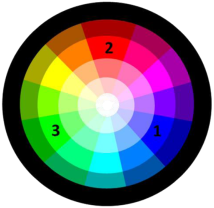
MODIS Hotspots-based Global Fire Regimes



All 19 attributes were clustered to produce the seamless global classification shown in this map, which exhibits regions with similar fire behaviors. Strong latitudinal patterns are evident globally.

Similarity Colors Definitions

	Measure	Factor 1	Factor 2	Factor 3
A	Biweek 1 sin	0.026	0.000	**0.758**
	Biweek 1 cos	**0.826**	0.141	0.095
	Biweek 2 sin	0.022	0.027	**0.750**
	Biweek 2 cos	**0.852**	0.082	0.051
	Biweek 3 sin	0.029	0.038	**0.704**
	Biweek 3 cos	**0.822**	0.067	0.047
	Biweek 4 sin	0.051	0.058	**0.627**
	Biweek 4 cos	**0.771**	0.052	0.039
	Biweek 5 sin	0.067	0.088	**0.521**
	Biweek 5 cos	**0.705**	0.061	0.089
	Biweek 6 sin	0.084	0.131	**0.386**
	Biweek 6 cos	**0.622**	0.044	0.128
B	Years with fire	0.301	**0.882**	0.267
	Run of burns	0.276	**0.883**	0.256
	Run of no burns	-0.306	**-0.873**	-0.274
C	Mean temp.	0.040	-0.002	**0.097**
	Max. temp.	0.001	**0.384**	0.174
	Min. temp.	0.065	**-0.433**	0.141
D	Num. hotspots	-0.059	**0.485**	-0.211



Red indicates high inter-year fire occurrence, intensity, and density. **Green** indicates hemisphere-coordinated late winter to spring seasonality. **Blue** indicates late fall to winter seasonality. White colors are high across all three factors, while black colors are low in all three factors.

Summary of Findings

- Continuous patterns of fire regimes span continents and relate to latitudinal climate that influences vegetation and fuels, wildland fire, and land use.
- Pockets of agricultural fire use are evident in the Punjab region of India, the Flint Hills of Kansas, the lower Mississippi Valley, and eastern China.
- Topographic gradients are visible in mountainous regions such as the Himalayas, the northern Andes, and Mexico.
- Dense forests of Papua New Guinea and the Amazon lack a clear fire regime due to rarity of fire detections during the MODIS period.
- By integrating continuous monitoring and expectations from historical data, the coarse dynamics of diverse types of wildland fire and land use can be recognized and quantified as they change.

Next Steps

- Interpret patterns of hotspot-derived fire regimes to understand influences of climate, land use, and fire practices regionally.
- Continuously analyze new hotspot observations to understand fire behaviors under changing environmental stressors.
- Produce evolving fire regime maps for validating predictive fire models and informing development of fire risk products.
- Develop products to constrain fire emissions and disturbance effects in Earth system models.

Acknowledgments

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