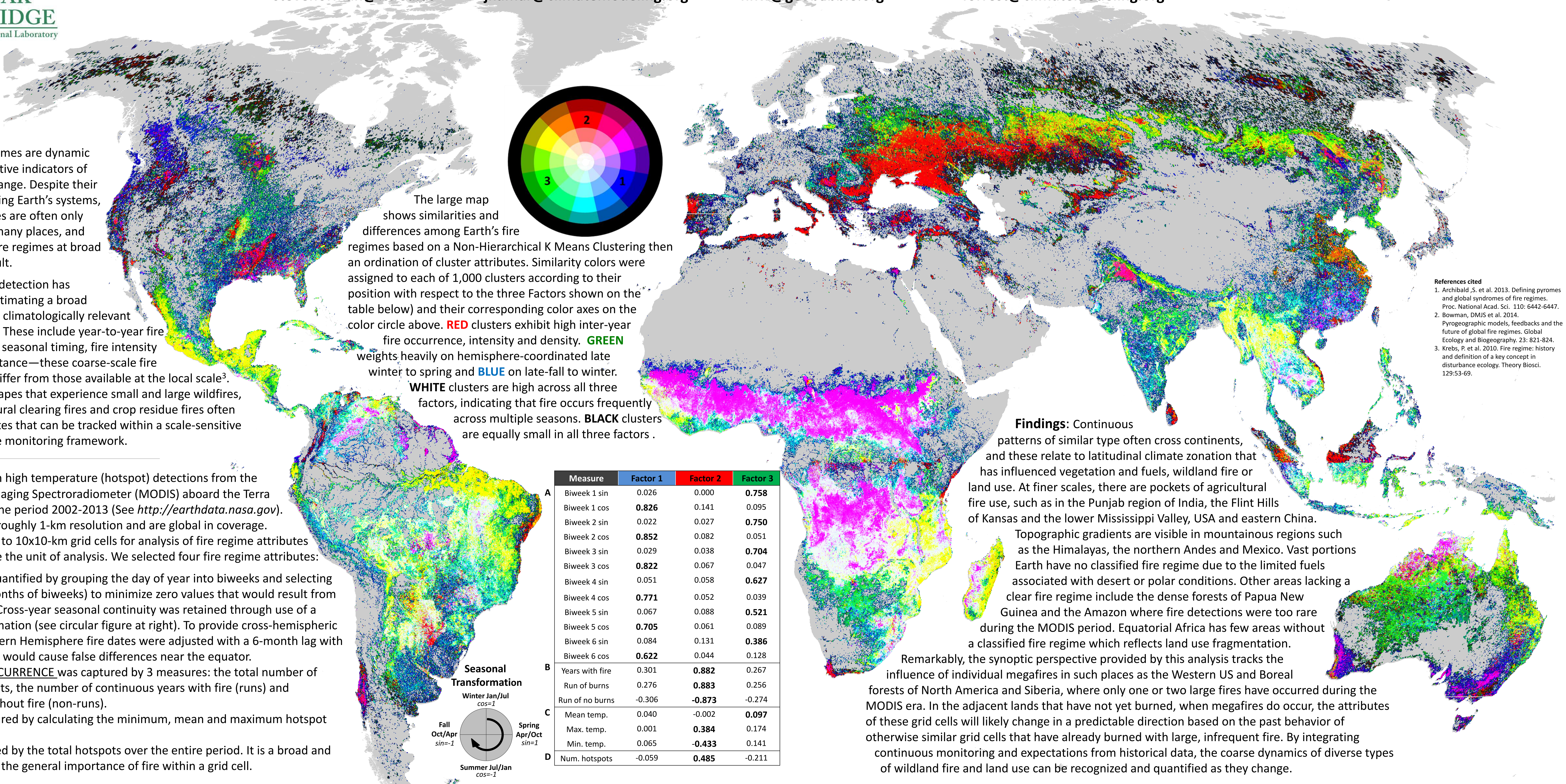
A Global Classification of Contemporary Fire Regimes

Steven P. Norman[1] Jitendra Kumar[2] William W. Hargrove[1] Forrest M. Hoffman[2]

stevenorman@fs.fed.us jkumar@climatemodeling.org hnw@geobabble.org forrest@climatemodeling.org

1. USDA Forest Service, Southern Research Station, Asheville, NC

2. Oak Ridge National Laboratory, Oak Ridge, TN



Introduction: Fire regimes are dynamic processes that are sensitive indicators of climate and land use change. Despite their importance for monitoring Earth's systems, key fire regime attributes are often only vaguely understood in many places, and systematic tracking of fire regimes at broad scales has proved difficult.

Satellite-based hotspot detection has potential for coarsely estimating a broad suite of ecologically and climatologically relevant fire regime attributes[1,2]. These include year-to-year fire occurrence, within-year seasonal timing, fire intensity and fire's general importance—these coarse-scale fire regime measures may differ from those available at the local scale[3]. The attributes of landscapes that experience small and large wildfires, prescribed fire, agricultural clearing fires and crop residue fires often exhibit different attributes that can be tracked within a scale-sensitive and geography-sensitive monitoring framework.

Methods: We relied on high temperature (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*). Hotspot detections are roughly 1-km resolution and are global in coverage. Hotspots were assigned to 10x10-km grid cells for analysis of fire regime attributes and the grid cell became the unit of analysis. We selected four fire regime attributes:

(A) SEASONALITY was quantified by grouping the day of year into biweeks and selecting the top six (*i.e.,* 3 months of biweeks) to minimize zero values that would result from an all-year analysis. Cross-year seasonal continuity was retained through use of a sine-cosine transformation (see circular figure at right). To provide cross-hemispheric comparability, Southern Hemisphere fire dates were adjusted with a 6-month lag with anticipation that this would cause false differences near the equator.

(B) INTER-YEAR FIRE OCCURRENCE was captured by 3 measures: the total number of years with >2 hotspots, the number of continuous years with fire (runs) and continuous years without fire (non-runs).

(C) INTENSITY was captured by calculating the minimum, mean and maximum hotspot temperature.

(D) DENSITY was provided by the total hotspots over the entire period. It is a broad and inclusive measure of the general importance of fire within a grid cell.

The large map shows similarities and differences among Earth's fire regimes based on a Non-Hierarchical K Means Clustering then an ordination of cluster attributes. Similarity colors were assigned to each of 1,000 clusters according to their position with respect to the three Factors shown on the table below) and their corresponding color axes on the color circle above. **RED** clusters exhibit high inter-year fire occurrence, intensity and density. **GREEN** weights heavily on hemisphere-coordinated late winter to spring and **BLUE** on late-fall to winter. **WHITE** clusters are high across all three factors, indicating that fire occurs frequently across multiple seasons. **BLACK** clusters are equally small in all three factors .

	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

Seasonal Transformation

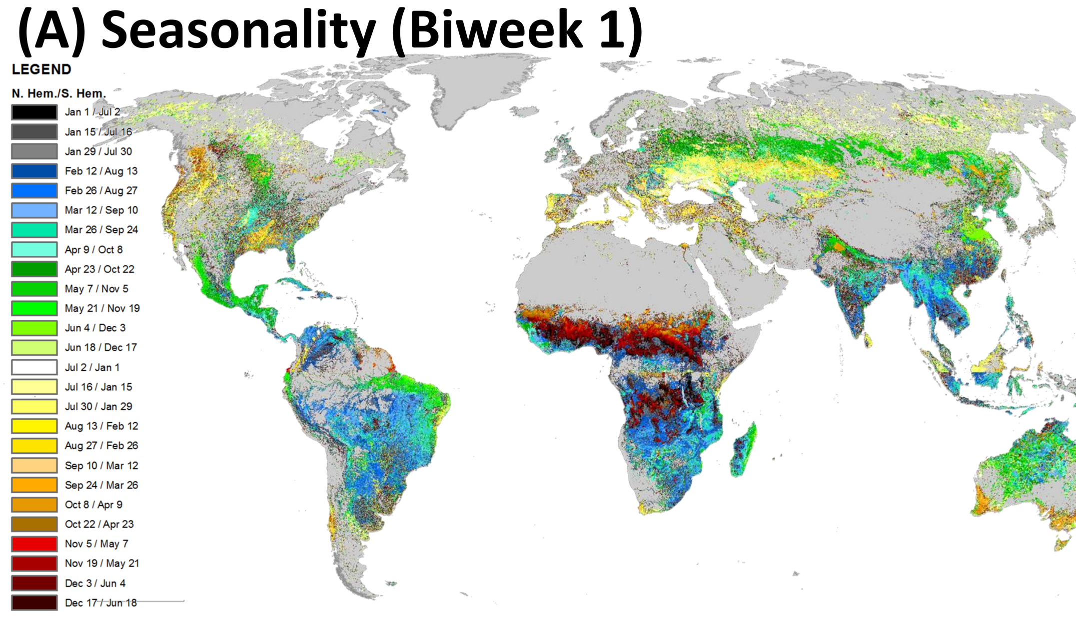
Winter Jan/Jul *cos=1*
Fall Oct/Apr *sin=-1*
Spring Apr/Oct *sin=1*
Summer Jul/Jan *cos=-1*

Findings: Continuous patterns of similar type often cross continents, and these relate to latitudinal climate zonation that has influenced vegetation and fuels, wildland fire or land use. At finer scales, there are pockets of agricultural fire use, such as in the Punjab region of India, the Flint Hills of Kansas and the lower Mississippi Valley, USA and eastern China. Topographic gradients are visible in mountainous regions such as the Himalayas, the northern Andes and Mexico. Vast portions Earth have no classified fire regime due to the limited fuels associated with desert or polar conditions. Other areas lacking a clear fire regime include the dense forests of Papua New Guinea and the Amazon where fire detections were too rare during the MODIS period. Equatorial Africa has few areas without a classified fire regime which reflects land use fragmentation. Remarkably, the synoptic perspective provided by this analysis tracks the influence of individual megafires in such places as the Western US and Boreal forests of North America and Siberia, where only one or two large fires have occurred during the MODIS era. In the adjacent lands that have not yet burned, when megafires do occur, the attributes of these grid cells will likely change in a predictable direction based on the past behavior of otherwise similar grid cells that have already burned with large, infrequent fire. 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.

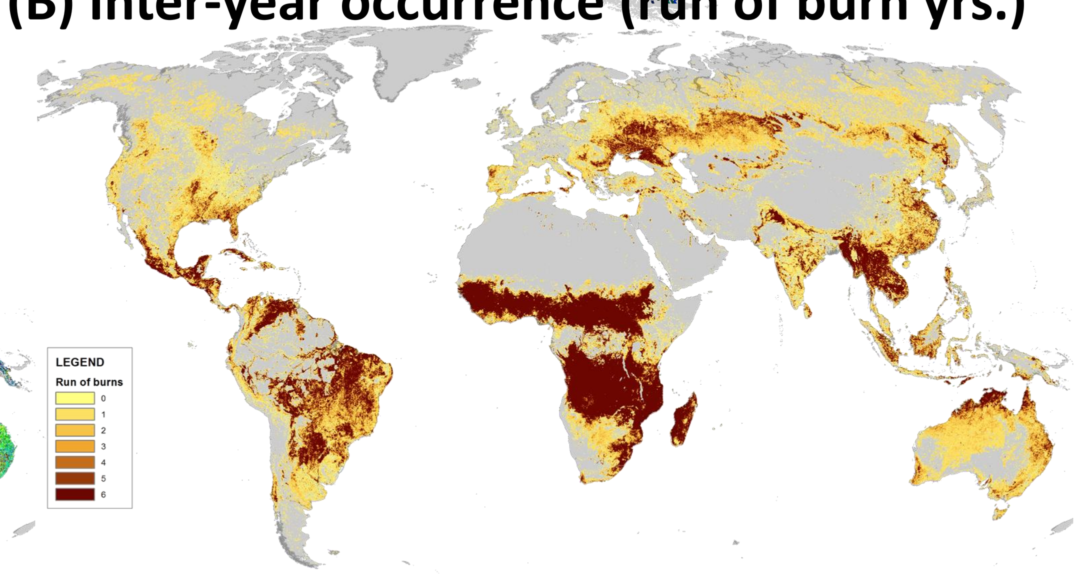
References cited

1. Archibald ,S. et al. 2013. Defining pyromes and global syndromes of fire regimes. Proc. National Acad. Sci. 110: 6442-6447.
2. Bowman, DMJS et al. 2014. Pyrogeographic models, feedbacks and the future of global fire regimes. Global Ecology and Biogeography. 23: 821-824.
3. Krebs, P. et al. 2010. Fire regime: history and definition of a key concept in disturbance ecology. Theory Biosci. 129:53-69.

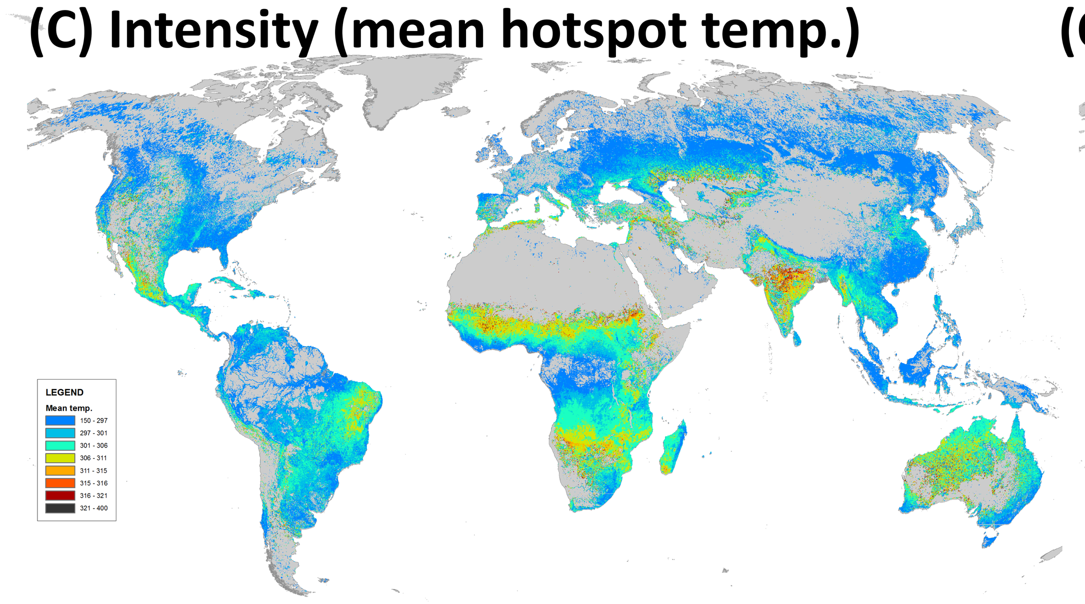
(A) Seasonality (Biweek 1)



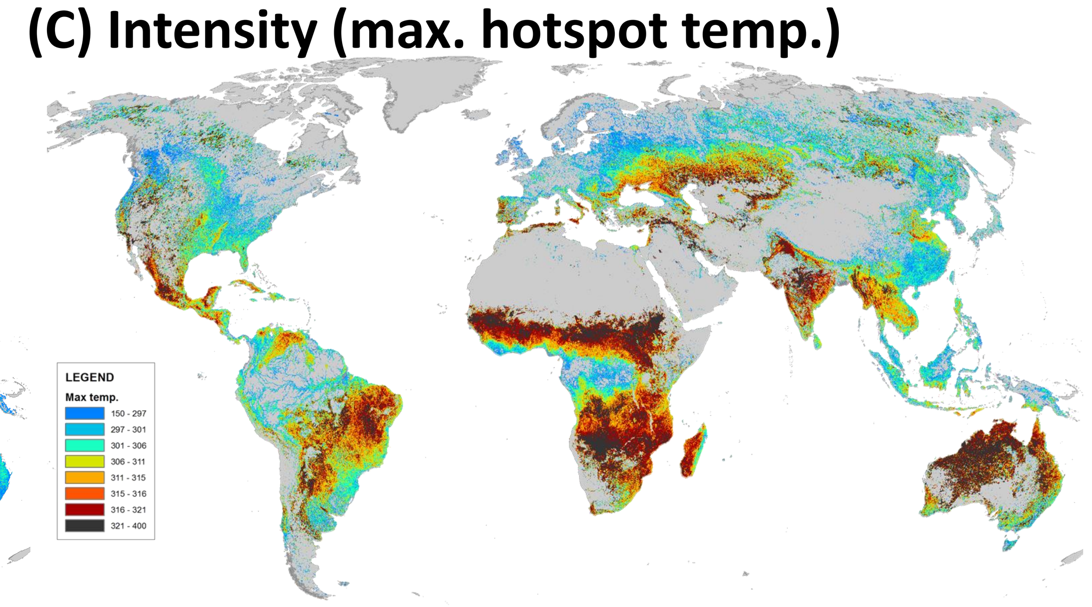
(B) Inter-year occurrence (run of burn yrs.)



(C) Intensity (mean hotspot temp.)



(C) Intensity (max. hotspot temp.)



(D) Density (number of hotspots)