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Modeling fire occurrence as a function of landscape

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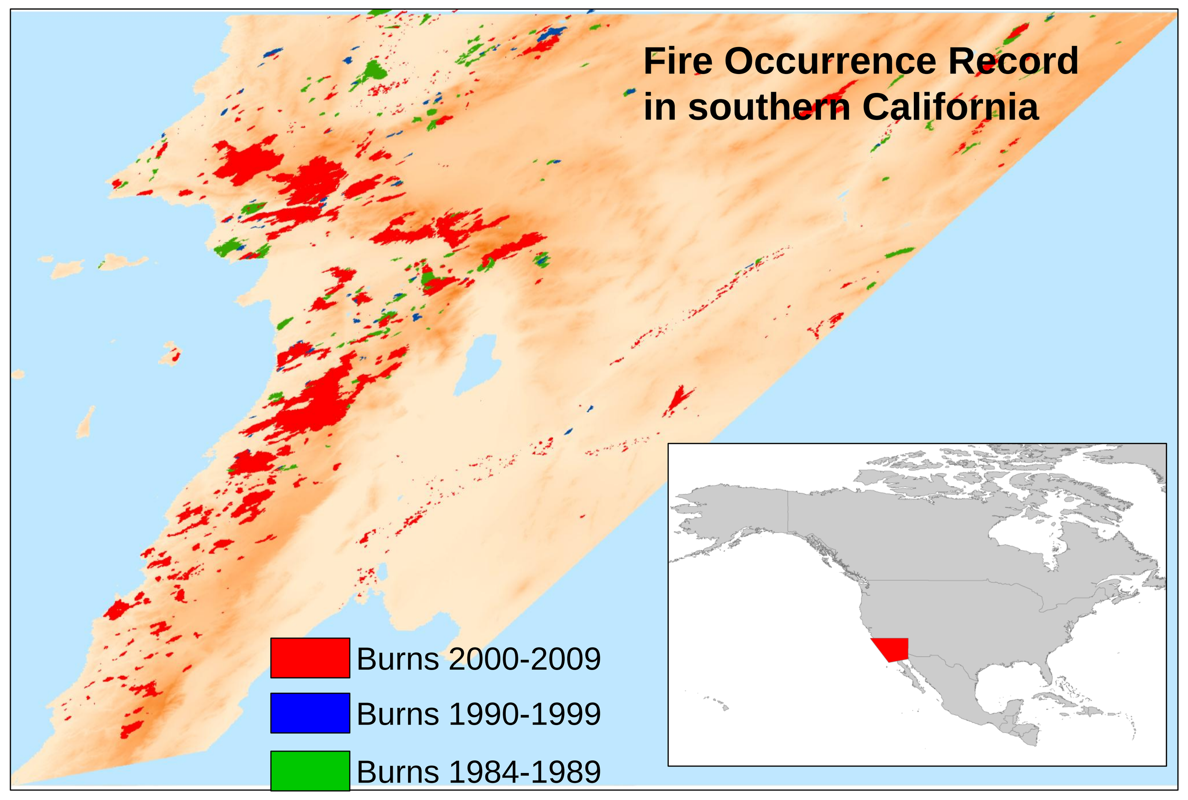


Introduction and Background

Wildland fire is a prominent component of ecosystem functioning worldwide. Nearly all ecosystems experience the impact of naturally occurring or anthropogenically driven fire. Here, we present a spatially explicit and regionally parameterized Fire Occurrence Model (FOM) aimed at developing fire occurrence estimates at landscape and regional scales. The model provides spatially explicit scenarios of fire occurrence based on the available records from fire management agencies, satellite observations, and auxiliary geospatial data sets. Fire occurrence is modeled as a function of the risk of ignition, potential fire behavior, and fire weather using internal regression tree-driven algorithms and empirically established, regionally derived relationships between fire occurrence, fire behavior, and fire weather. The FOM presents a flexible modeling structure with a set of internal, globally available default geospatial independent and dependent variables. However, the flexible modeling environment adapts to ingest a variable number, resolution, and content of inputs provided by the user to supplement or replace the default parameters to improve the model's predictive capability. A Southern California FOM instance (SC FOM) was developed using satellite assessments of fire activity from a suite of Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data, Monitoring Trends in Burn Severity fire perimeters, and auxiliary geospatial information including land use and ownership, utilities, transportation routes, and the Remote Automated Weather Station data records.

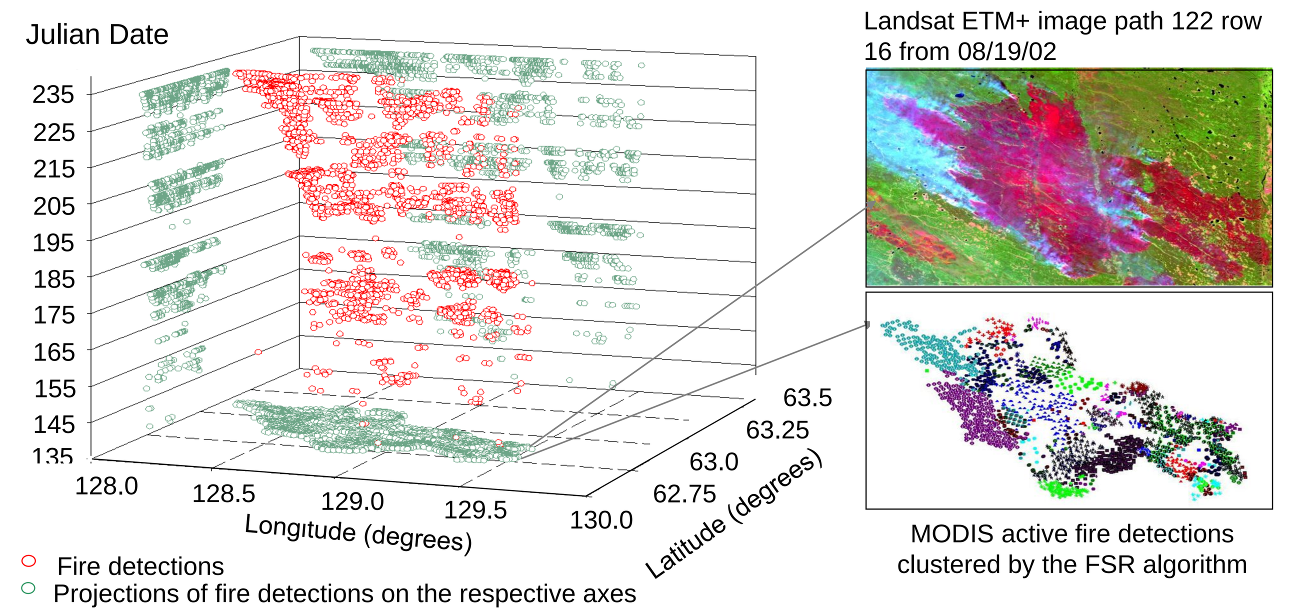
Below: Station Fire in La Crescenta, California (AP Photo/Jae C. Hong)

Above: A pyrocumulus cloud over Downtown Los Angeles (photo - Michael Castillo)

Southern California Instance of the Fire Occurrence model (SC FOM)

Risk of Ignition (ROI)

MODIS)active fire detections [1] were processed through Fire Spread Reconstruction Algorithm [2], illustrated below. This algorithm clusters individual fire ignitions in space-time to identify contiguous fire events and proxy ignition points. In this study we used MODIS fire detections acquired between 2001 and 2009 to train the FOM.



MODIS active fire detections clustered by the FSR algorithm

Monthly fire ignition points were used to assign monthly ignition weights to annual probability of burning, developed within the PB module, by 0.01 intervals:

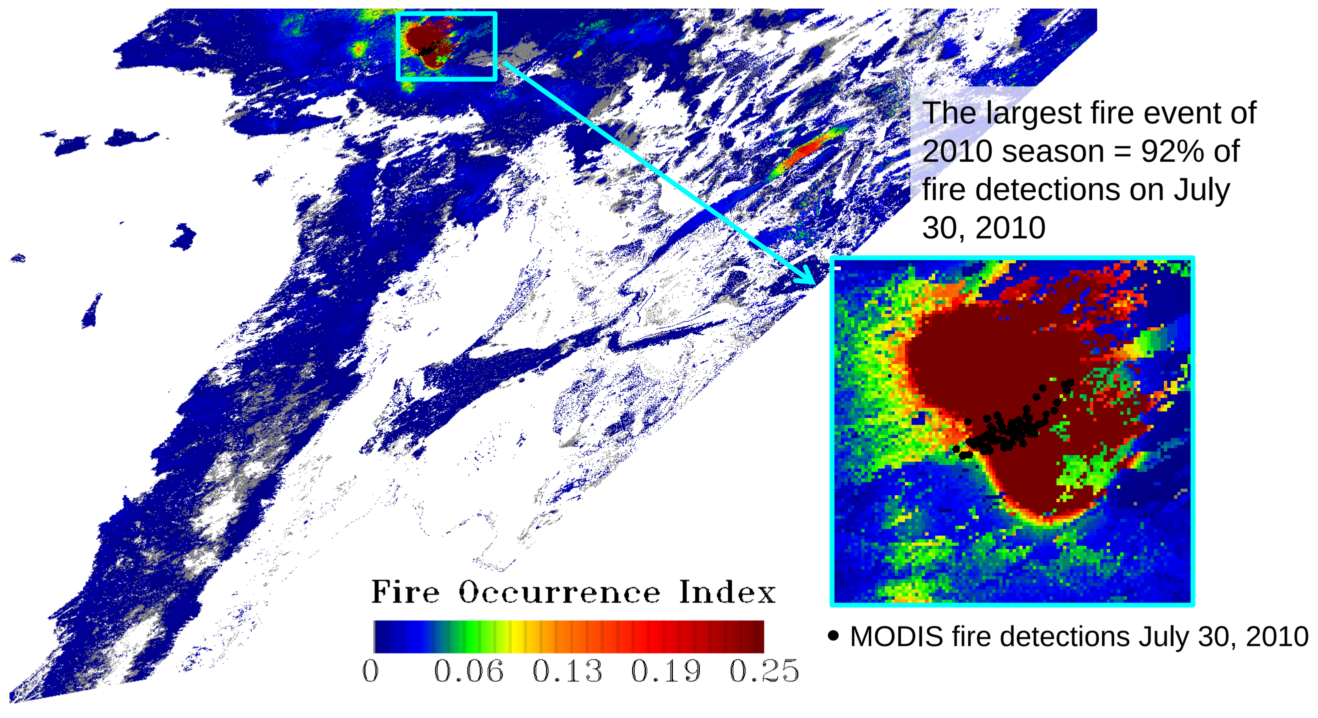
$$ROIweight = \frac{monthly\ ignitions\ within\ PB\ zone}{total\ ignitions}$$

Fire Occurrence Index

Fire Occurrence Index (FOI) is calculated daily :

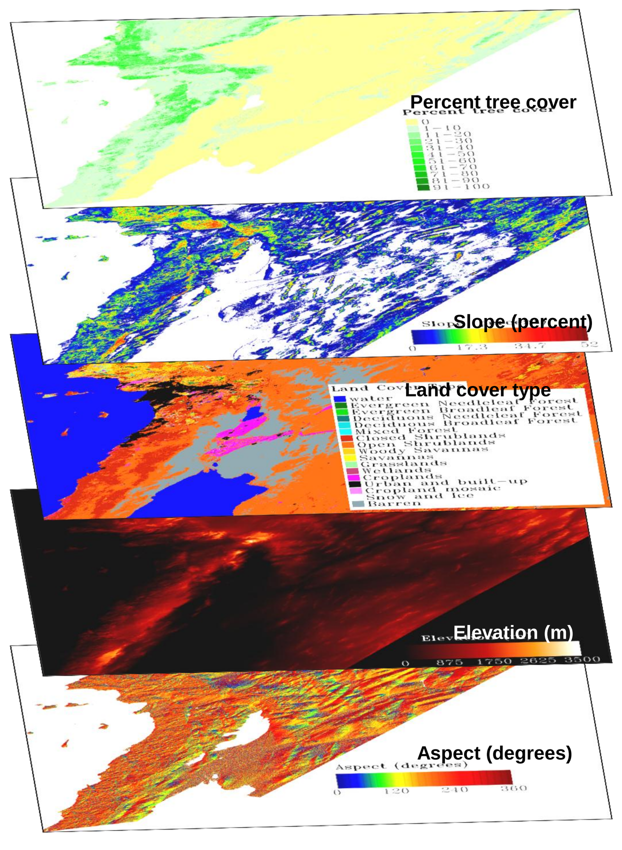
$$FOI = PFB(annual) * ROIweight(monthly) * FWIweight(daily)$$

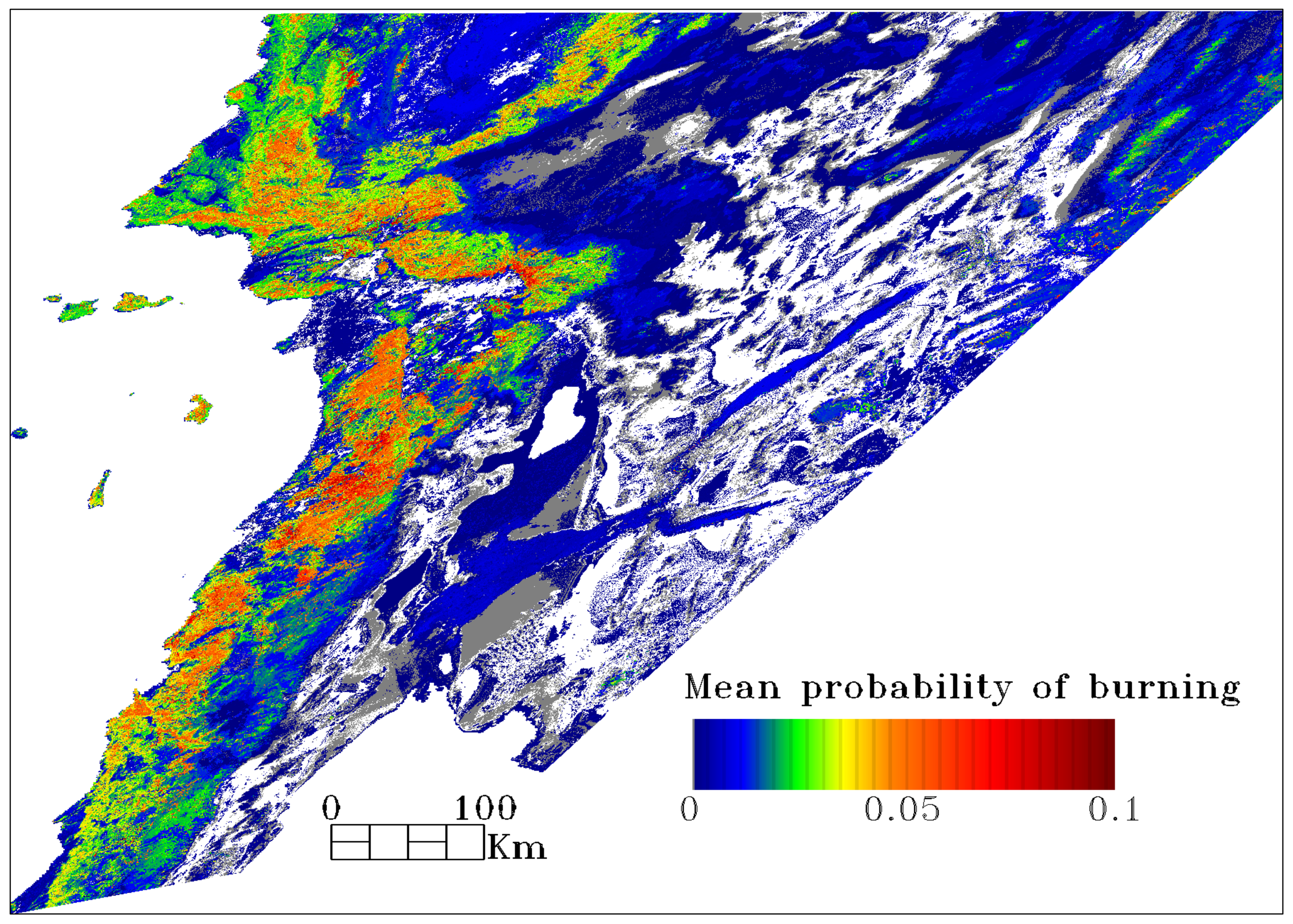
Fire Occurrence Index (FOI) on July 30, 2010



Potential Burning (PB)

Monitoring Trends in Burn Severity (MTBS) burn perimeters from 1984 – 2000 and combined MTBS and MODIS burned area products from 2001 - 2009 were used to model Potential Burning (PB) as a function of land cover (MODIS land cover product [3]), percent tree cover (MODIS Vegetation Continuous Fields [4]), and topography including slope, aspect and elevation obtained from the Shuttle Radar Topography Missions Digital Elevation Model and aggregated to the MODIS nominal 500 m resolution (below left).

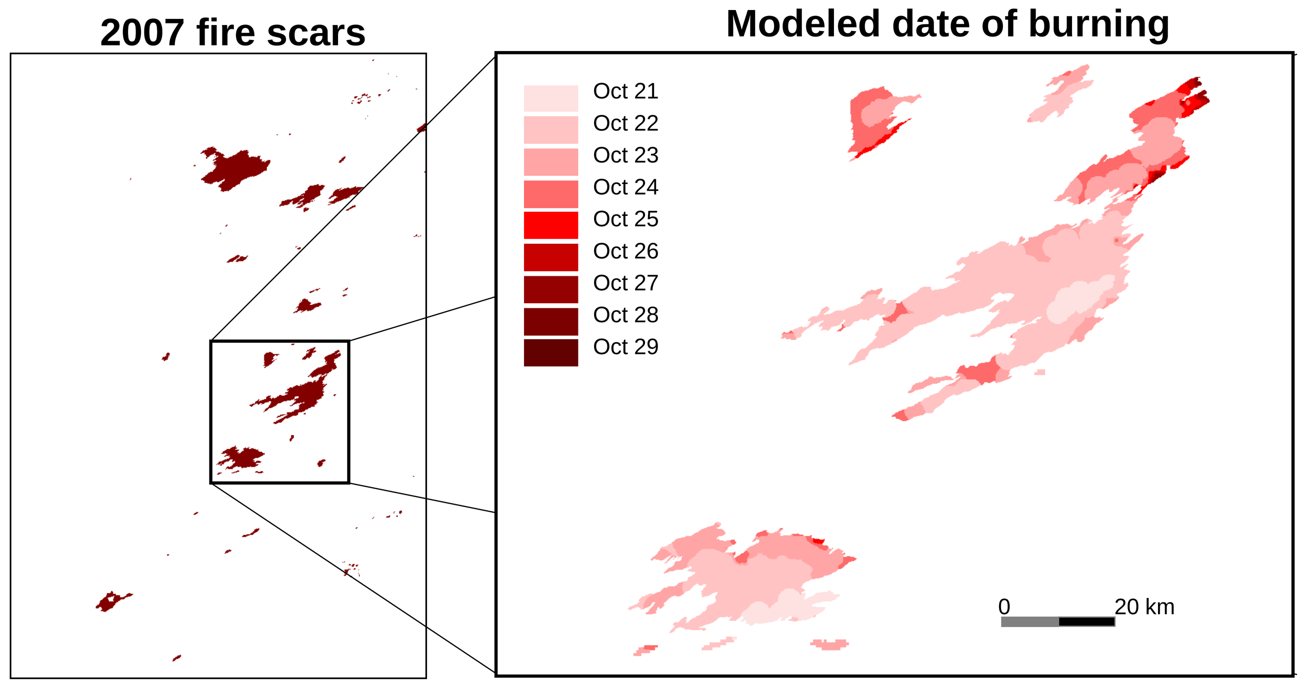




- Regression tree classifications were developed from annual distribution of burned areas between 1984 and 2009. These classifications partitioned the spectral space by the likelihood of burning driven by the burned (all burned pixels from a given year) and unburned (randomly selected within study area 3 times the number of burned pixels) training samples.
- Probabilities of burning were calculated per each class generated by the decision tree for each year.
- PB = mean annual probabilities 1984-2009 (above right).

Fire Weather

The combined MTBS and MODIS burned area record 2001-2009 was enhanced through additional processing using the MODIS active fire detection to model daily fire progression. MODIS active fire detections were clustered using the Fire Spread Reconstruction algorithm and used to build daily fire progression surfaces, illustrated below.



The Remote Automated Weather Station (RAWS) data 2001-2010 were interpolated across the study area following the protocol developed for the Canadian Fire Weather Index (CFWI) calculations [5, 6] to develop a 10-year record of CWFI at the daily time step. Weather weights were calculated following:

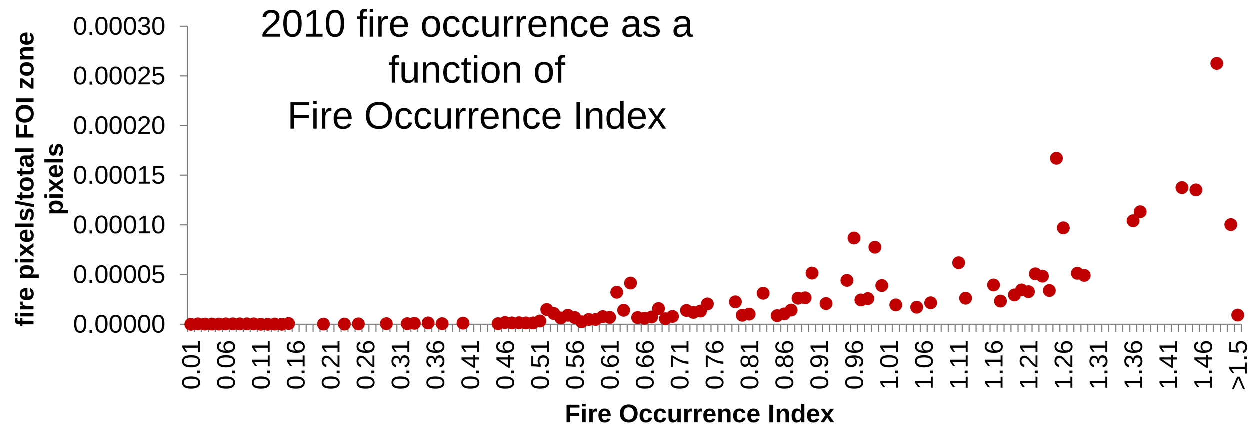
$$FWloading = \frac{fraction\ area\ burned\ within\ a\ CFWI\ zone\ from\ all\ burned}{fraction\ of\ CFWI\ zone\ from\ the\ total\ area}$$

Subsequently, 2 regression equations were fitted:

CFWI < 80: weight = 0.041*exp(0.0557*CFWI) (R^2 = 0.94)

CFWI ≥ 80: weight = 0.000008*exp(0.1616*CFWI) (R^2 = 0.98)

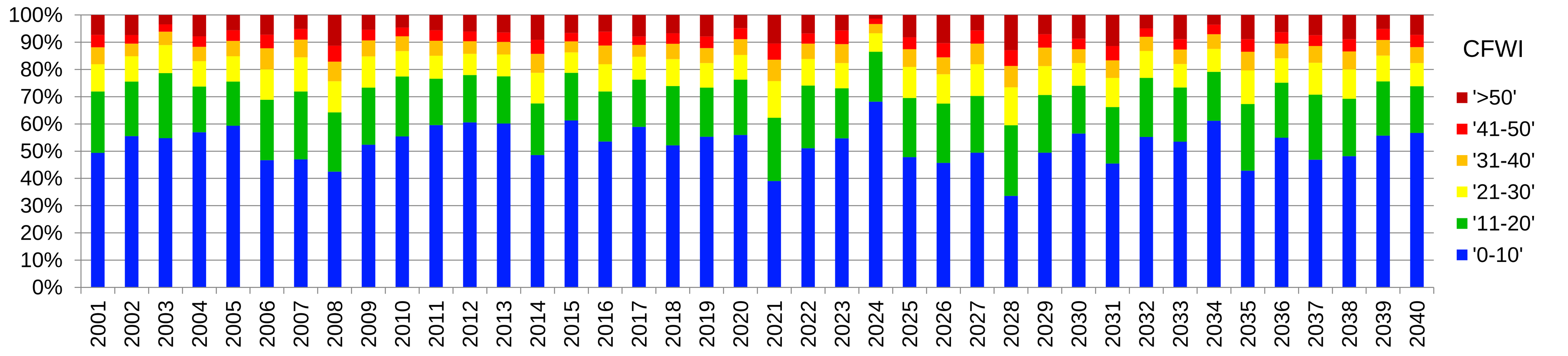
FOM validation for 2010 fire season



Weather variables from the RAWS dataset were ingested into the FOM to produce FOI projections for 2010 fire season. Results (above) show that higher FOI are directly linked to higher probability of fire occurrence.

Future Climate–induced Changes in Fire Occurrence

Future weather conditions, modeled at 25 km resolution using the Regional Climate Model (RegCM Version 4.1) [7], do not project a noticeable change in frequency of high fire weather conditions (expressed through CFWI), compared to the 2001-2010 period (below). It is likely that the San Diego county will experience approximately 2 extreme fire seasons each decade by 2040 (see graph below).



References and Acknowledgements: This work has been supported by the **NIH-NIEHS Climate Change Grant #1RC1ES018612-01**. [1] Giglio L, Descloitres J, Justice CO & Kaufman YJ, 2003. An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment*, 87 (2-3), 273-282. [2] Loboda T, Csiszar I, 2007. Reconstruction of Fire Spread within Wildland Fire Events in Northern Eurasia from the MODIS Active Fire Product. *Global and Planetary Change,* 56 (3-4): 258-273. [3] Friedl MA, McIver DK, Hodges JCF, et al. (2002). Global land cover mapping from MODIS: algorithms and early results. *Remote Sensing of Environment*, 83, 287-302. [4] Hansen MC, DeFries RS, Townshend JRG et al., 2003. Global percent tree cover at a spatial resolution of 500 m: first results of the MODIS vegetation continuous fields algorithm. *Earth Interactions*, 7 (10), 1–15. [5] Turner JA, Lawson BD, 1978. Weather in the Canadian Forest Fire Danger Rating System. A user guide to national standards and practices. Environment Canada, Pacific Forest Research Centre, Victoria, BC. BC-X-177; [6] Van Wagner CE; Pickett TL, 1985. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System. Canadian Forest Service, Ottawa, ON. Forestry Technical Report 33. [7] Pal, J. S., et al. (2009), The ICTP RegCM3 and RegCNET: Regional Climate Modeling for the Developing World, Bull. Amer. Meteo. Soc., 88, 1395.