Living with fire (and smoke) in California's warming climate

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Outline

Science

- Climate
- Fire and fire severity

Science

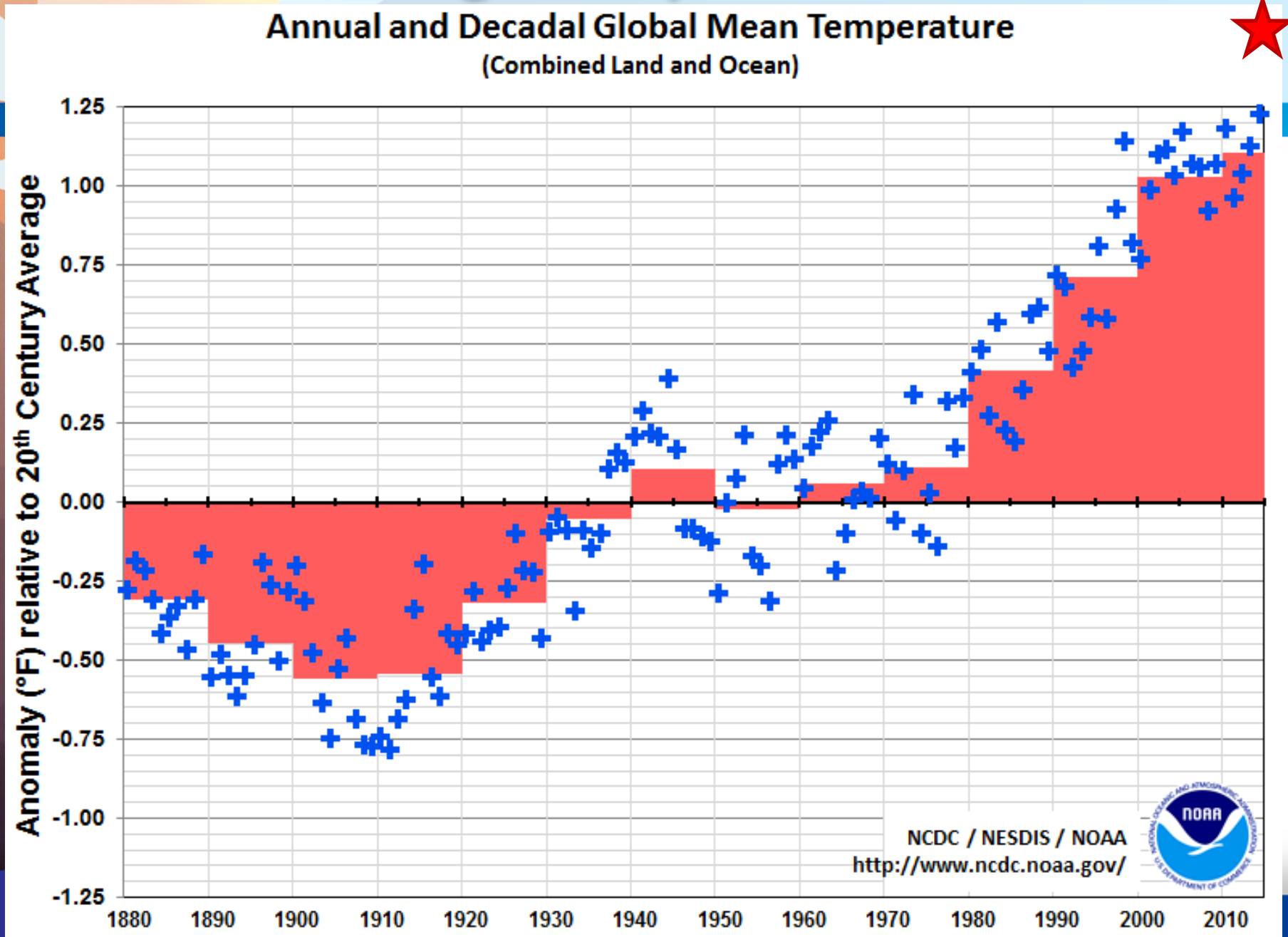
- Strategies for land managers
- Strategies for messaging and public health

Science

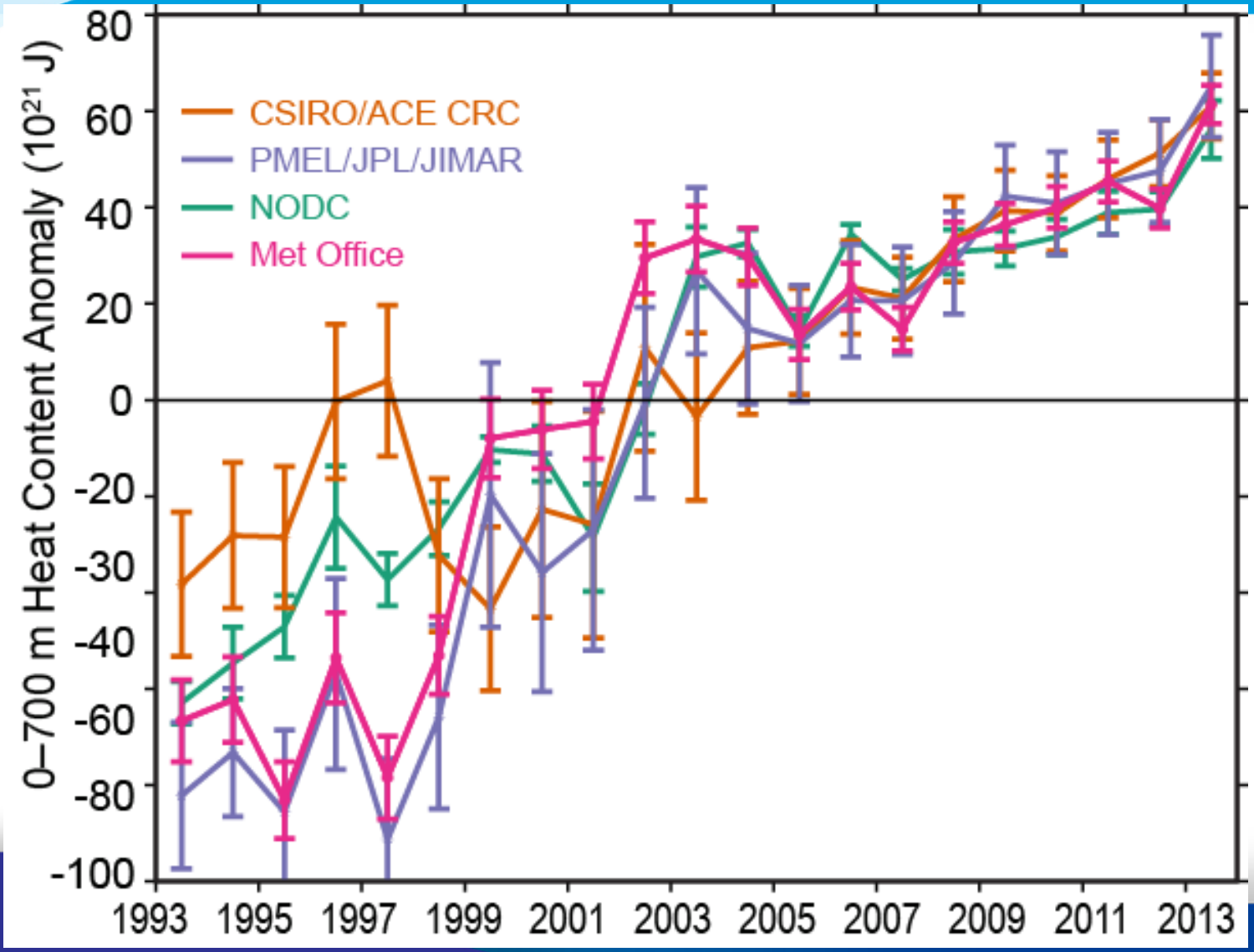
Relationship between weather & climate

Literature Review: Stallone et al. (1976)

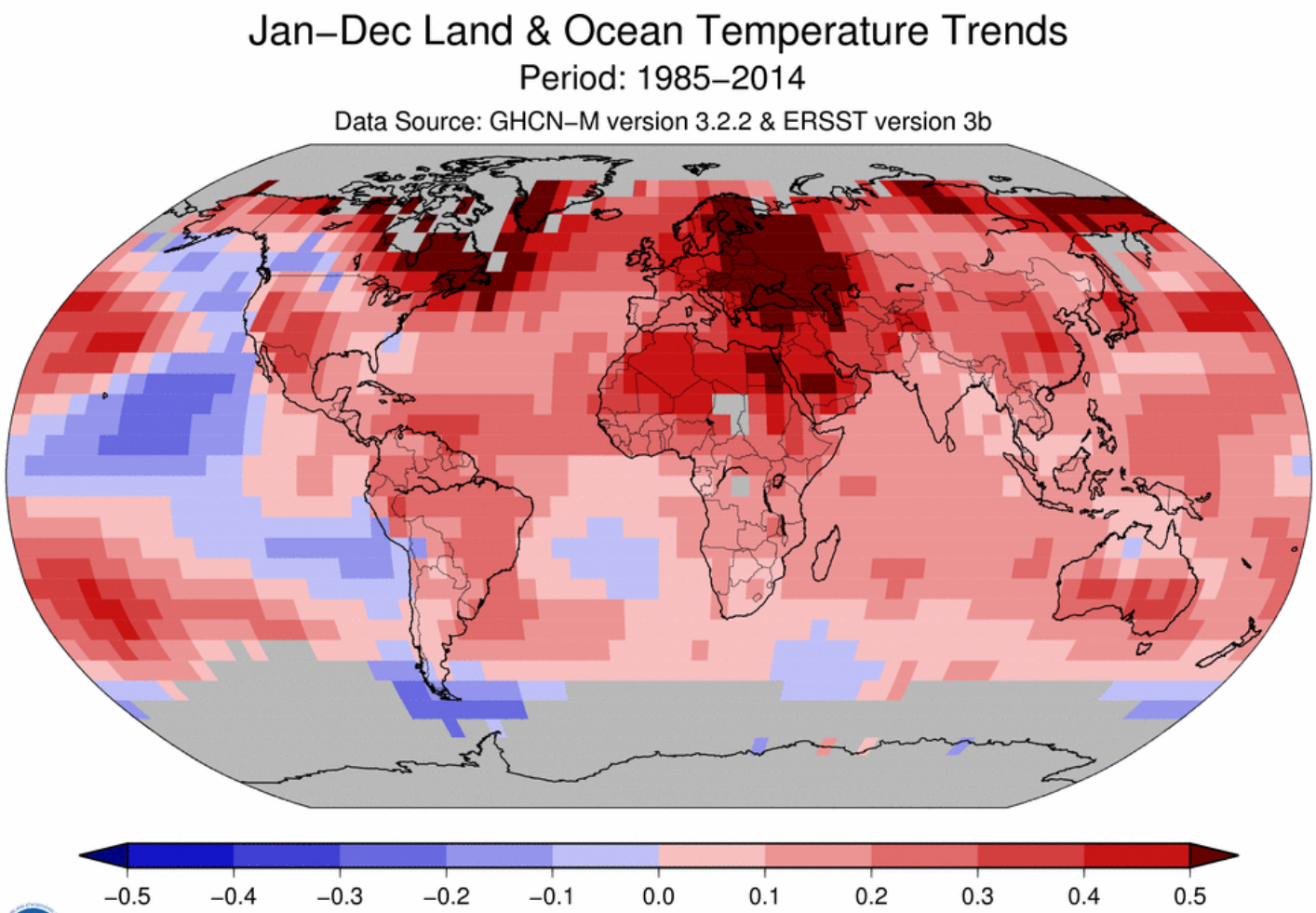
Global-Average Temperature since 1880



Upper Ocean Heat Content: 2013

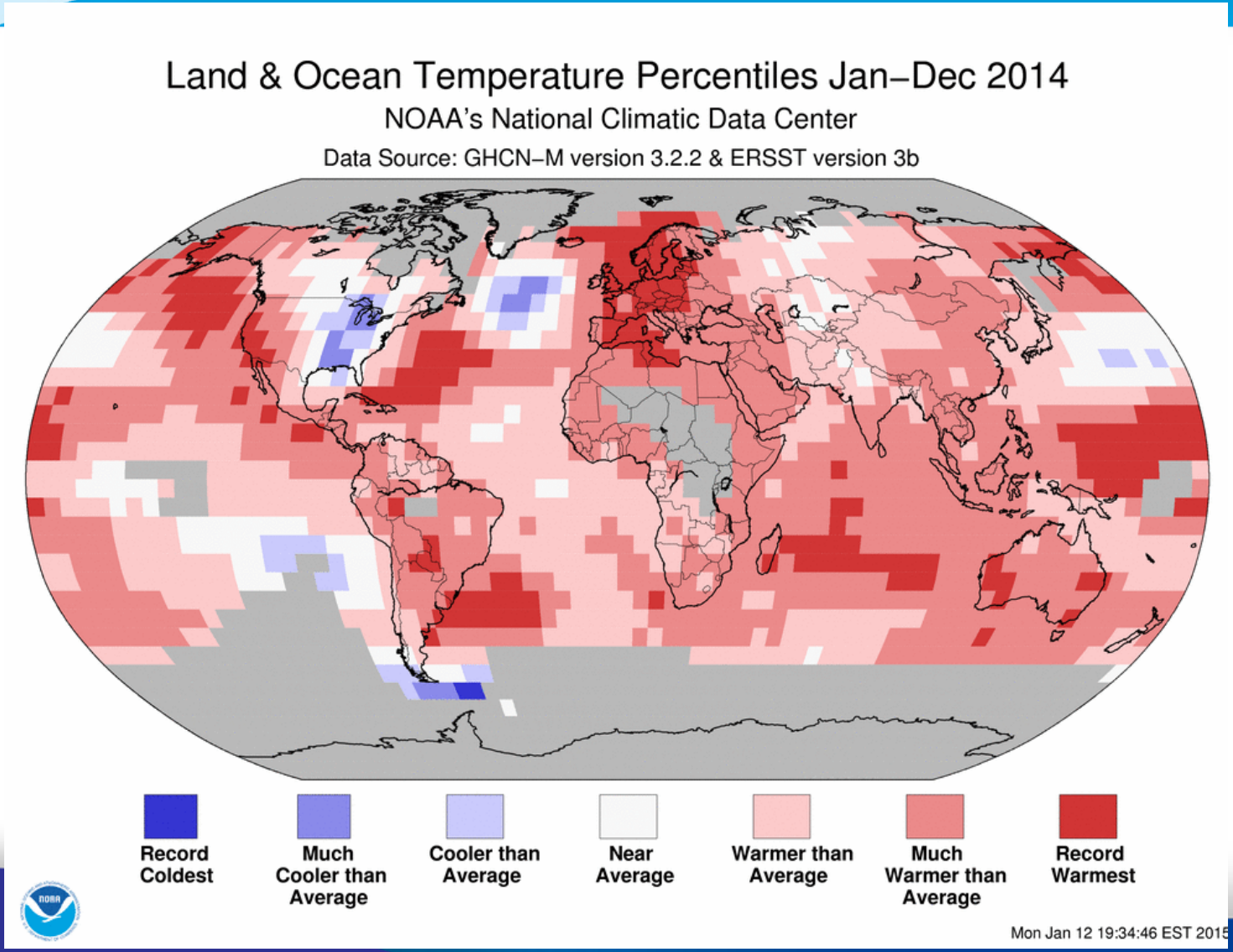


Trends since 1985



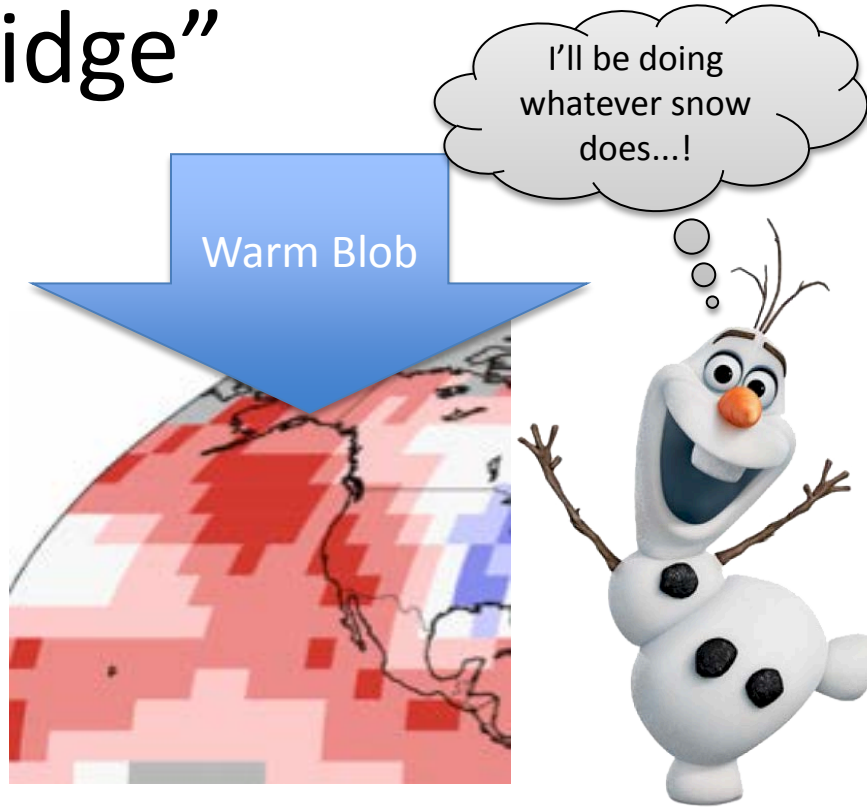
Land & Ocean Temperature Percentiles

Annual 2014 (grid points with at least 80 yrs on record)



The “warm blob” and the “ridiculously resilient ridge”

- Warm blob is proximately related to longer term ocean circulation cycles, or “intrinsic variability” (e.g., Pacific Decadal Oscillation)
- Models indicate there may be a component ultimately attributable to sea ice loss, but the empirical evidence for this is masked by aforementioned “intrinsic variability”



- Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua (2015), Causes and impacts of the 2014 warm anomaly in the NE Pacific, Geophys. Res. Lett., 42, doi:10.1002/2015GL063306.
- Screen, J. A., I. Simmonds, C. Deser, and R. Tomas. 2013. The Atmospheric Response to Three Decades of Observed Arctic Sea Ice Loss. Journal of Climate **26**:1230-1248.
- Sewall, J. O., and L. C. Sloan (2004), Disappearing Arctic sea ice reduces available water in the American west,Geophys. Res. Lett., 31, L06209, doi:10.1029/2003GL019133.
- Sewall, J. O. 2005. Precipitation shifts over western North America as a result of declining Arctic sea ice cover: The coupled system response. Earth Interactions **9**.

Megafires

of damage

- Land-use changes, as well as moderate to severe drought, often precede mega-fires
- Intact fire regimes (those minimally affected by fire exclusion for several decades) can restrict the size and severity of some mega-fires
- Changing governance structures can quickly alter land-use pattterns and subsequent fire regimes

Figure 2. *Major factors governing mega-fires (the "mega-fire triangle"). The blue triangle identifies the main factors that define contemporary fire regimes, the green triangle indicates key processes or conditions that govern fire regimes, and the red triangle identifies those causes, nested under the factors, that influence and predispose landscapes to mega-fires. PDO = Pacific Decadal Oscillation; AMO = Atlantic Multi-decadal Oscillation; ENSO = El Niño–Southern Oscillation; WUI = wildland–urban interface.*

Front Ecol Environ 2014; 12(2): 115–122, doi:10.1890/120332 (published online 15 Jan 2014)

Climate and Fire in California

Fire Ecology Volume 8, Issue 3, 2012
doi: 10.4996/fireecology.0803041

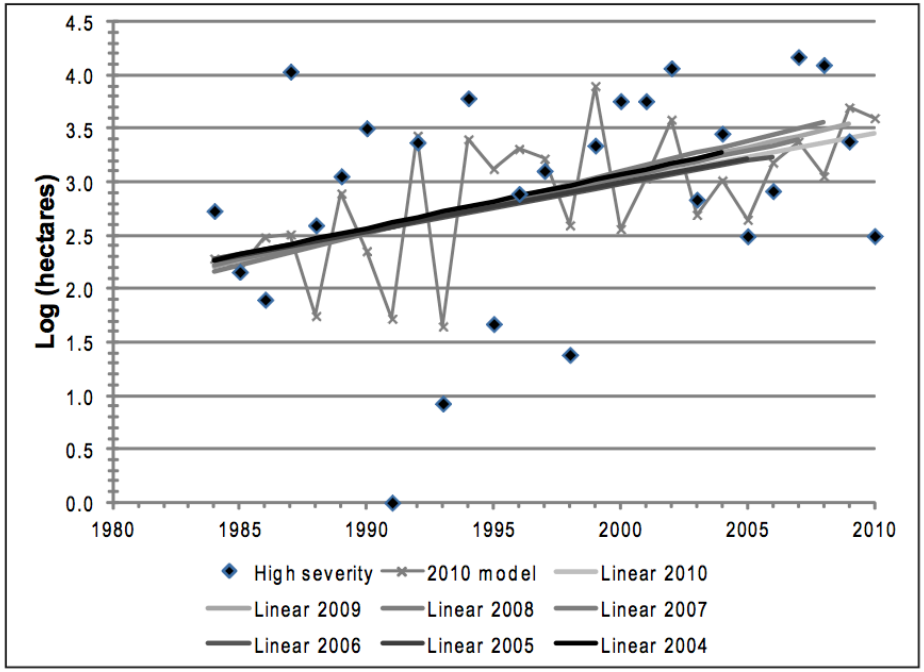


Figure 3. Temporal trends in area of high-severity fire for yellow pine-mixed-conifer (YPMC) forest types in fires ≥80 ha in the study area between 1984 and 2010. Data shown are yearly percentages of high severity, ARIMA model for the 1984 to 2010 time series, and linear trend lines for seven time series ending in years 2004 to 2010. Linear trends for the three shorter time series ending in 2004, 2005, and 2006 are not significant ($P > 0.05$), but they are consistent with the significant trend lines for time series ending in the last four years.

Fire Ecology Volume 8, Issue 3, 2012
doi: 10.4996/fireecology.0803041

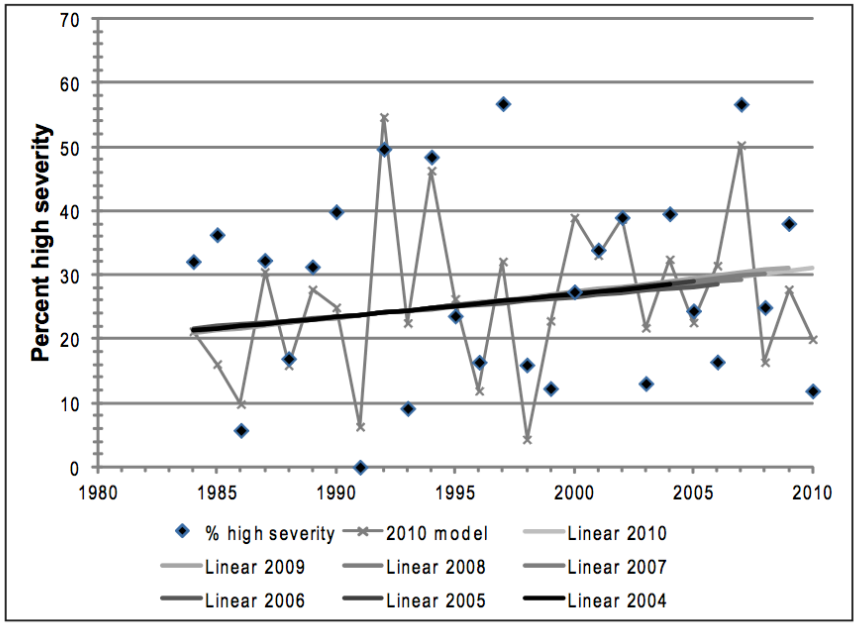


Figure 1. Temporal trends in percentage of high-severity fire for yellow pine-mixed conifer (YPMC) forest types in fires ≥80 ha in the study area between 1984 and 2010. Data shown are yearly percentages of high severity, ARIMA model for the 1984 to 2010 time series, and linear trend lines for seven time series ending in years 2004 to 2010.

Total PM could increase by 50-100% over the next 50-100 years

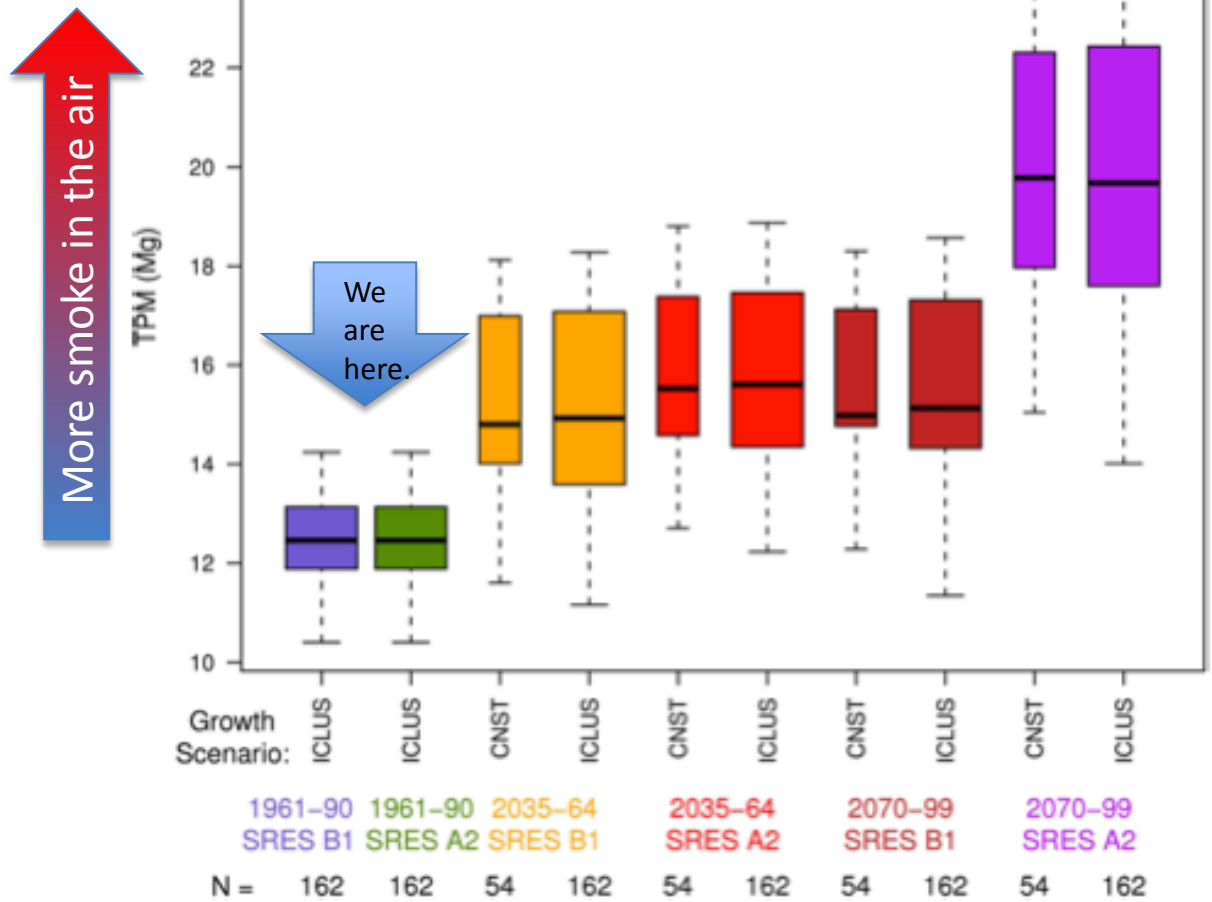


Figure 1. Projected total particulate matter (TPM) aggregated over the state of California, averaged for historical (1961–1990), mid-century (2035–2064), and late-century (2070–2099) time periods for both projected population growth (ICLUS) and population held constant at year 2000 levels (CNST) and SRES B1 and A2 emission scenarios.

Hurteau et al., 2014

Moderating severity has a chance at halving smoke (and GHG) emissions

- Miller and Safford, 2012: "Based upon the evidence from Yosemite, a shift in FS fire management policy similar to Yosemite's may have some effect on lowering the proportion of high severity on FS lands."

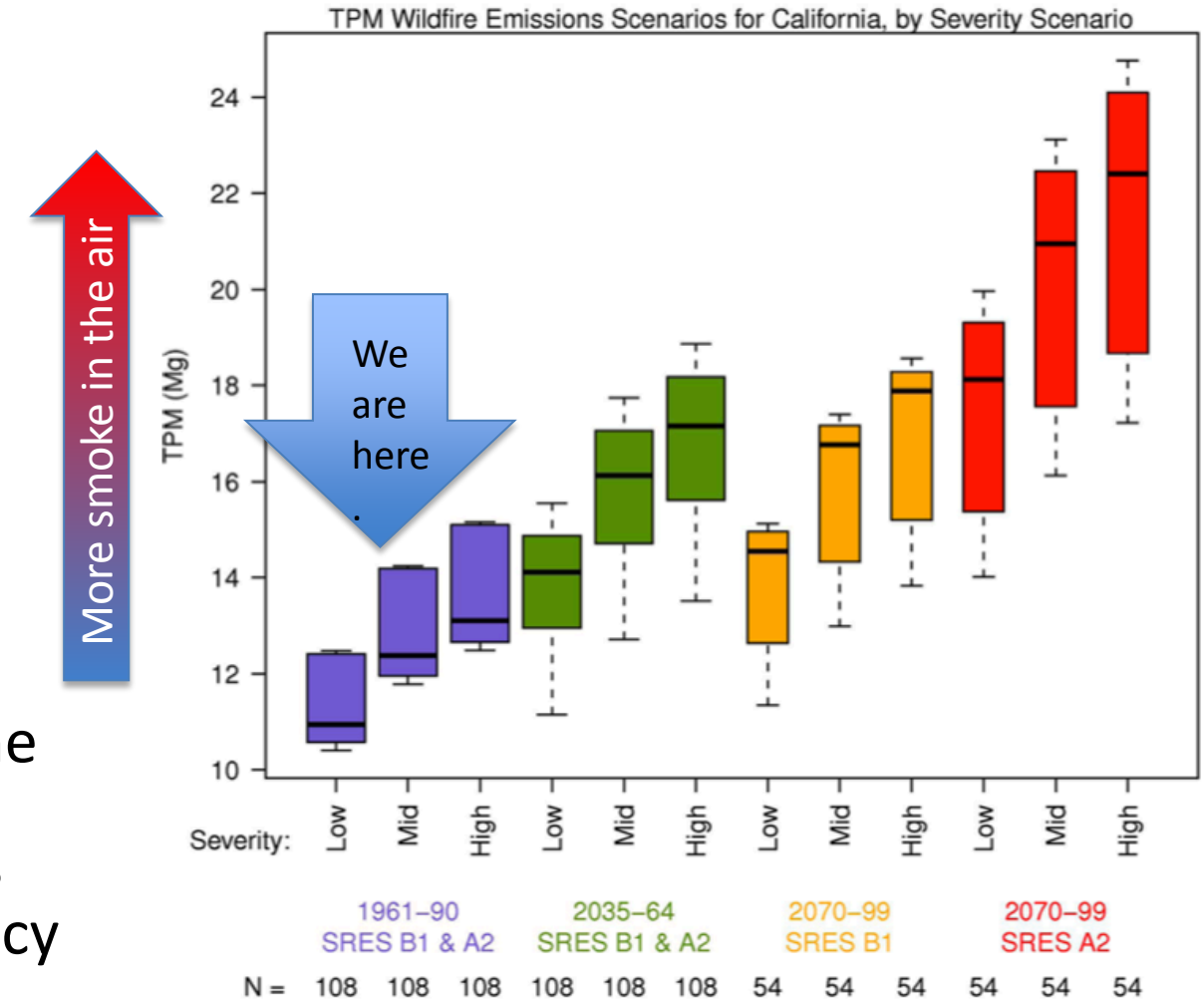


Figure 2. Projected total particulate matter emissions over the historical (1961–1990), mid-century (2035–2064), and late-century (2070–2099) time periods by burn severity. Low severity equals wildfire activity being aggregated in low biomass portions of each grid cell. Mid severity distributes wildfire activity across biomass types within each grid cell and assumes mixed severity fire. High severity aggregates wildfire activity in the highest biomass portions of each grid cell and assumes high severity fire.

Hurteau et al., 2014

The Forest Next Time: Resistance to Control

Risk Tolerance

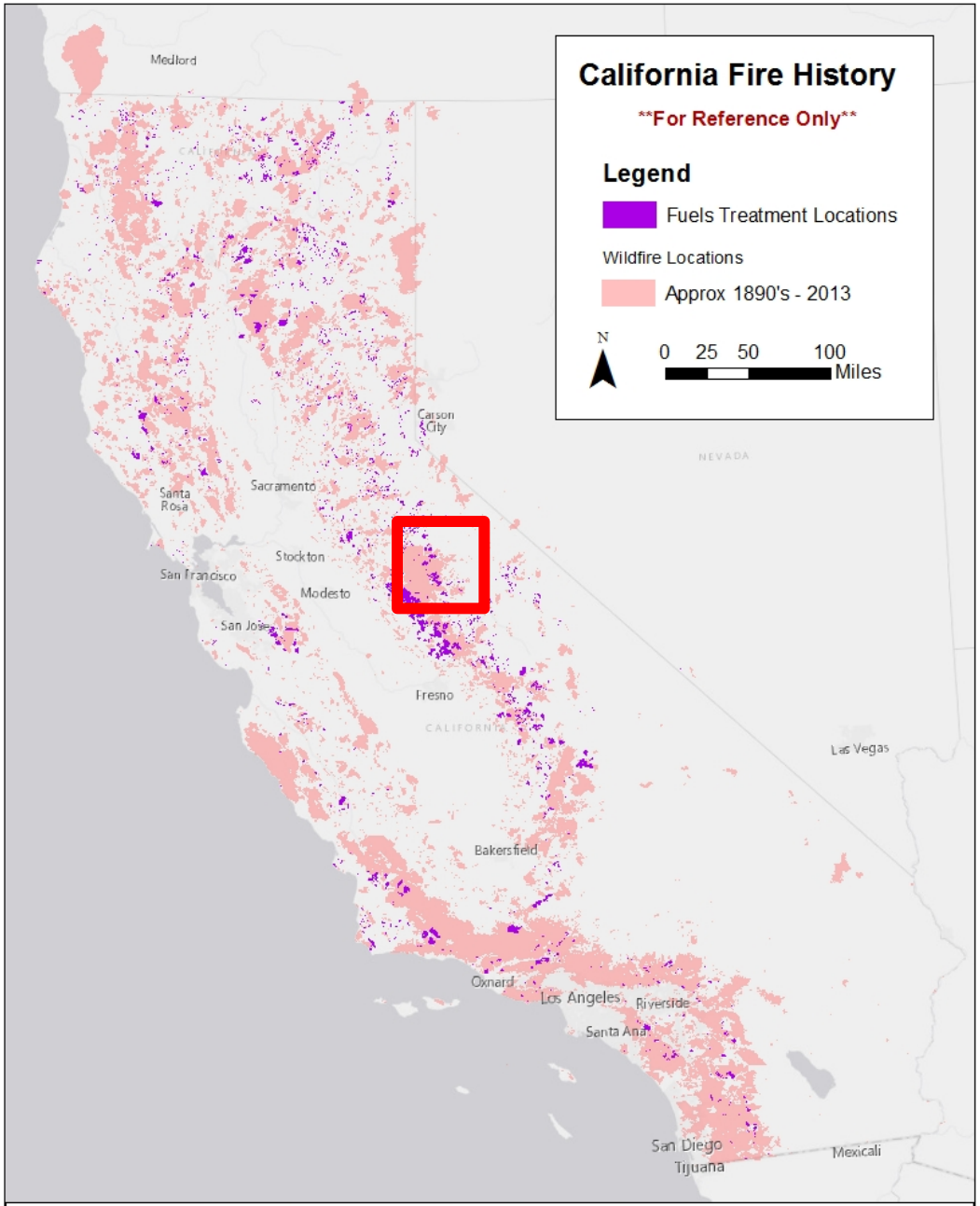
People, and Agencies, are asking why fire (and smoke) is different from a hurricane or other disturbance, where we prep the landscape and then get out of the way?

Matthew Carroll

ferent!

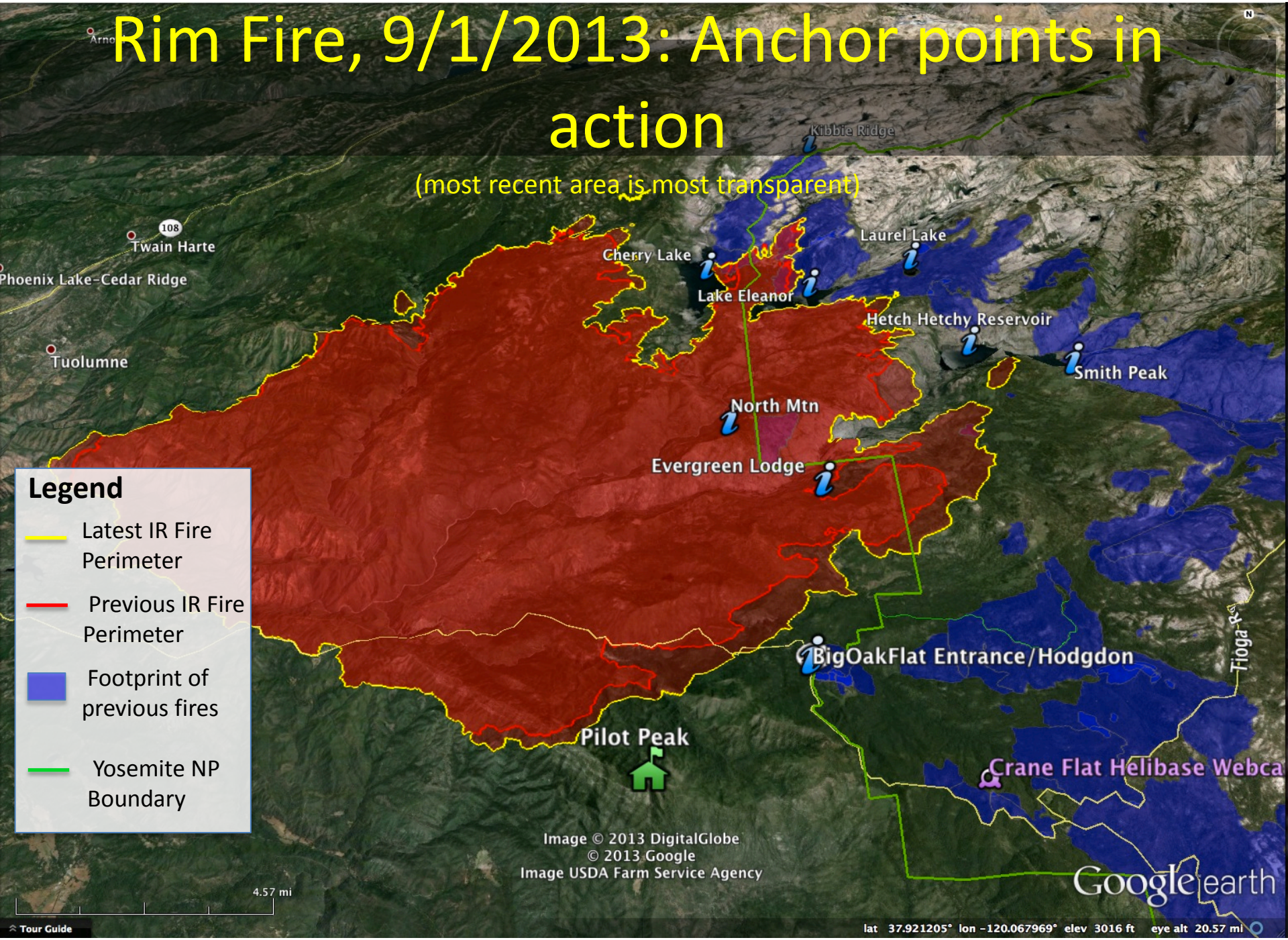
Where? Triage and Priorities

- Let's face it, this situation took 100+ years to create; It'll take decades to fix, so we have to prioritize
- Where?

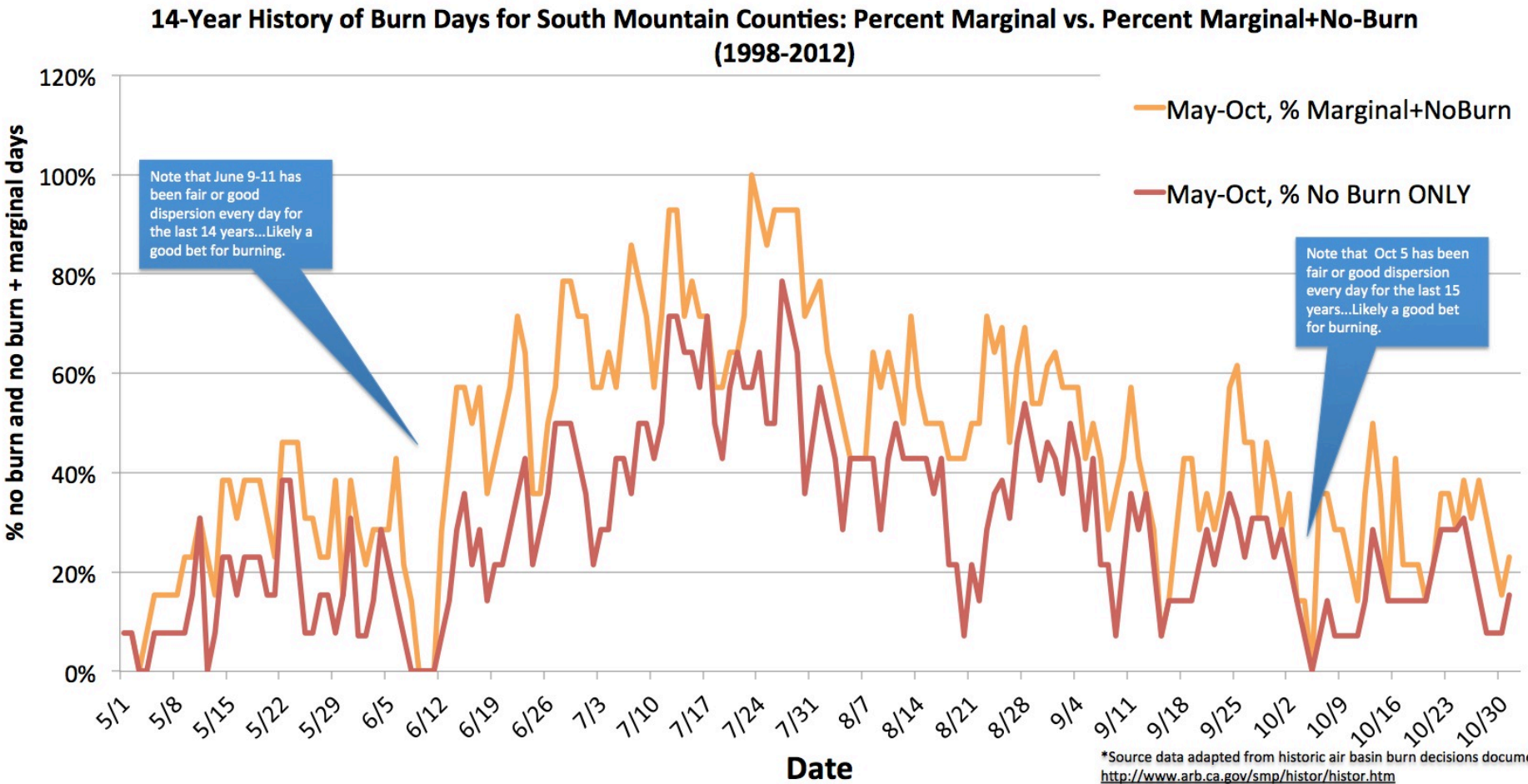


Rim Fire, 9/1/2013: Anchor points in action

(most recent area is most transparent)



Not if, but when….So when?



*Source data adapted from historic air basin burn decisions documented at: http://www.arb.ca.gov/smp/histor/histor.htm

HMS combined with Monitoring:

Lion Fire Case Study

- Localized impacts
- No impact on central valley
- No exceedances of NAAQS (98th) design values at monitored sites

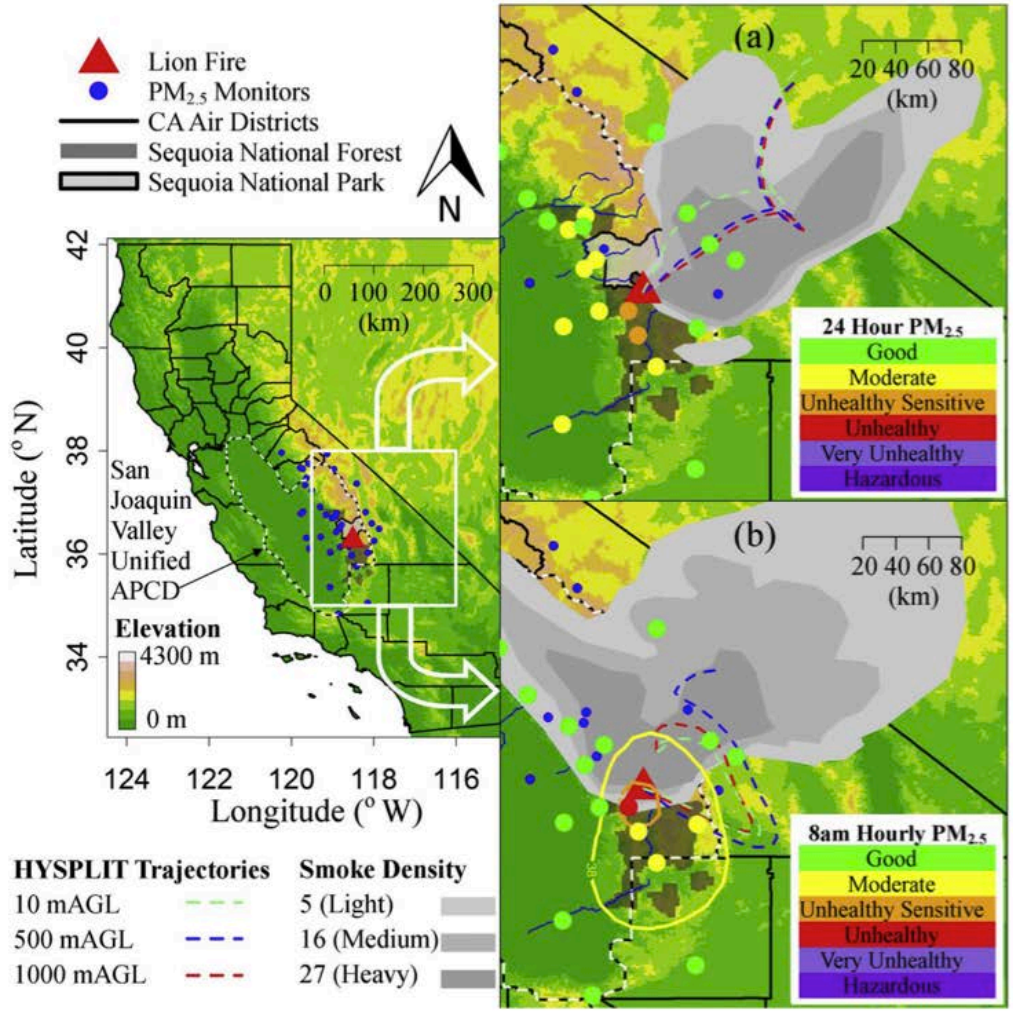
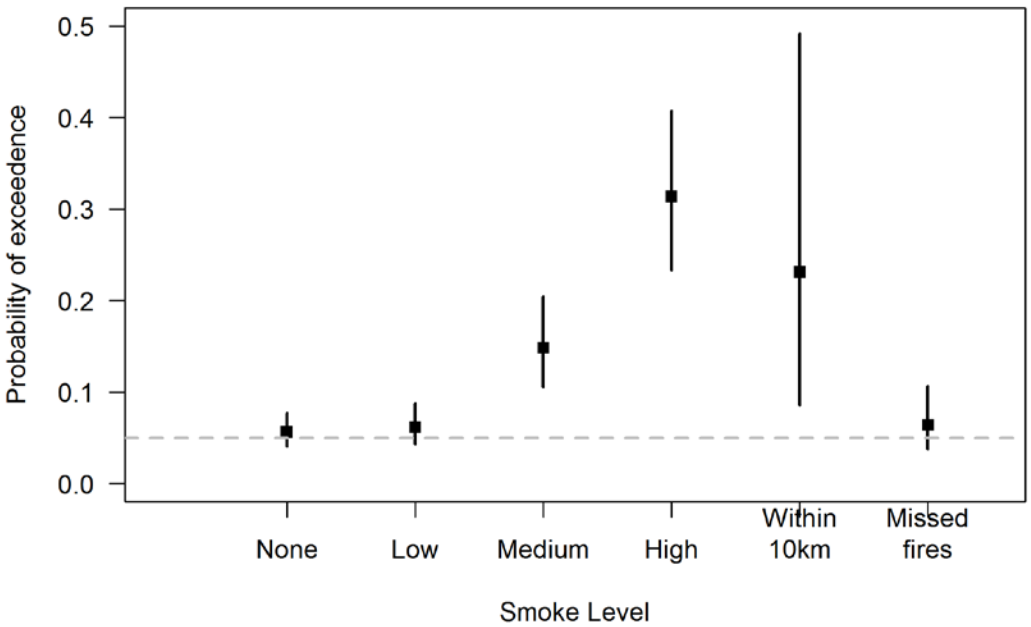


Fig. 2. Smoke dispersal patterns using monitoring site data, Hazard Mapping System (HMS) data, fitted trend surface using hourly ground based data, and HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) forward trajectories for (a) afternoon 7/18/2011 1600 with daily Air Quality Index (AQI) for each site (fitted trend surface modeled using the hourly data was good for entire area) and (b) morning (7/26/2011 0800) with 1-h AQI for each site.

Schweizer, D., and R. Cisneros. 2014. Wildland fire management and air quality in the southern Sierra Nevada: Using the Lion Fire as a case study with a multi-year perspective on PM2.5 impacts and fire policy. Journal of Environmental Management **144**:265-278.

HMS as a way to define smoke influence (not necessarily impact)

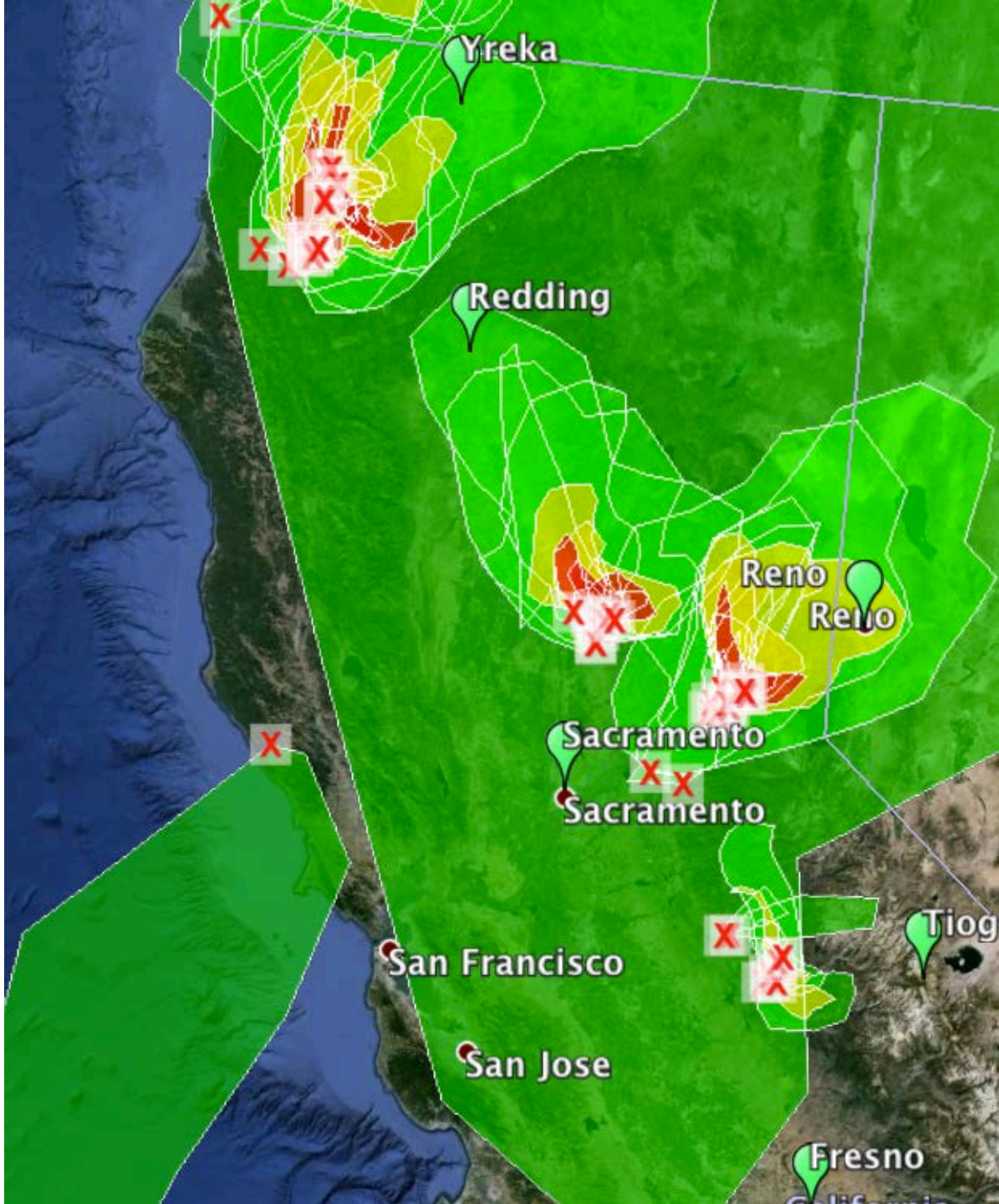
- At the surface, low HMS (green) levels are not significantly different from background (i.e., none)
  - Basically defines extent of significant haze
- At the surface, moderate and high HMS levels correspond to a surface influence 30% of the time
  - Good metric for area of influence
  - Needs surface measurements to corroborate surface impacts
  - Using both HMS + monitoring data and statistical "normal" can yield confidence toward causality and the "but for" issue with Exceptional Events.



Preisler et al., in press

HMS as a more objective way to compare fire impacts?

- Km2/day
- Spatial extent and magnitude, by day

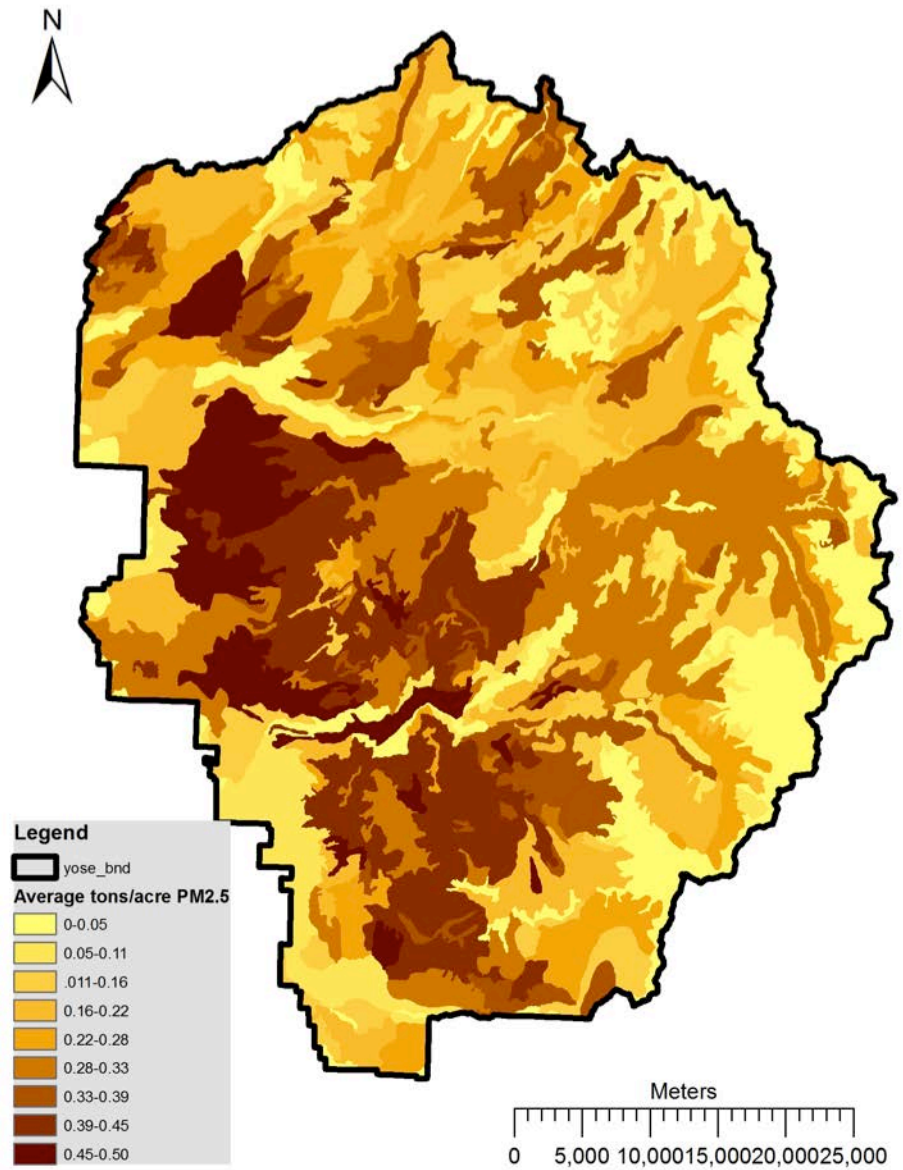


The evolution of smoke impact metrics

- Acres
- Emissions
- Concentrations
- Exposure
- Public Health impact

Acres vs. Emissions

- Emissions can (and do) vary by an order of magnitude on a per acre basis



Other ways to lower public smoke exposure (dose)

"Dose makes the Poison"

SMOKE IMPACT (Dose) = concentration * ventilation rate * time exposed

- **CONCENTRATION**: Lower emissions and hope that translates to lesser smoke impacts on public health
- **VR+TIME:** Public messaging to reduce exposure time and ventilation rate.
  - Activity reduction advise based on smoke levels
- **VR+TIME:** Interventions to reduce exposure time and ventilation rate
  - (i.e., cancel activities, close schools, evacuate)

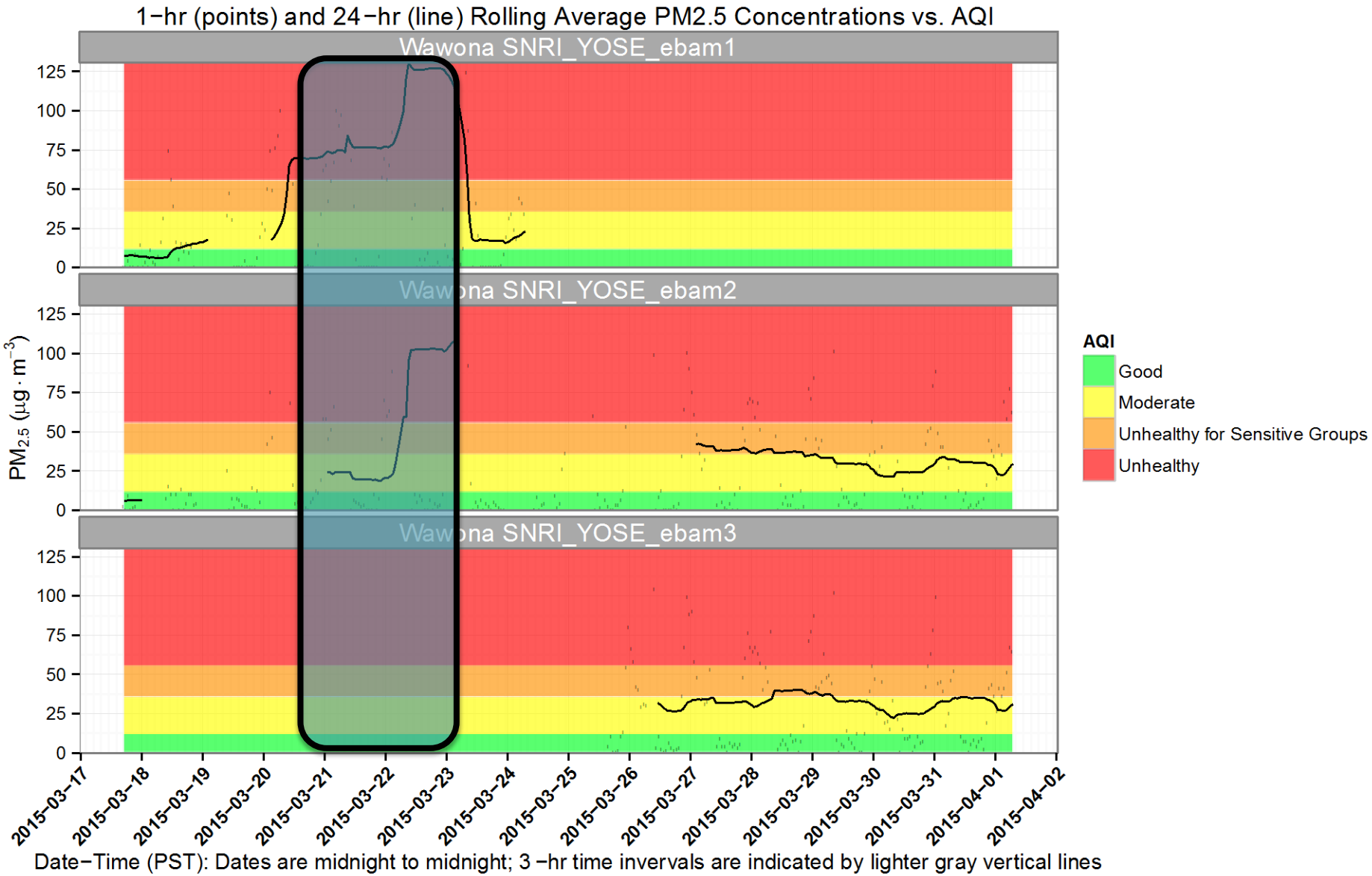
There's now some science showing that messaging can reduce smoke related public health impacts

Rappold et al., 2014—Main points:

- Wildfire episodes have impact on the communities and their health.
- The cost of excess asthma and congestive heart failure fire-attributable ED visit exceeded $1M, while the cost of general health outcomes exceeded $48M with 87% of the total burden accounted for by increased mortality.
- used forecasts of $PM_{2.5}$ from NOAA to show that forecasts can predict health outcomes and that by using forecasts to define interventions we can reduce impacts on communities.
- Found a trade off between the threshold used to trigger interventions and precision: interventions implemented at low smoke levels had higher false positive rate, but the highest positive predictive value (precision).
- **Implementing interventions at too high of a level was not effective at any level of compliance. Health outcomes were not driven by the highest exposures**.

Rappold, A. G., N. L. Fann, J. Crooks, J. Huang, W. E. Cascio, R. B. Devlin, and D. Diaz-Sanchez. 2014. Forecast-Based Interventions Can Reduce the Health and Economic Burden of Wildfires. Environmental Science & Technology **48**:10571-10579.

Overall Air Quality (24 hr rolling average with AQI)



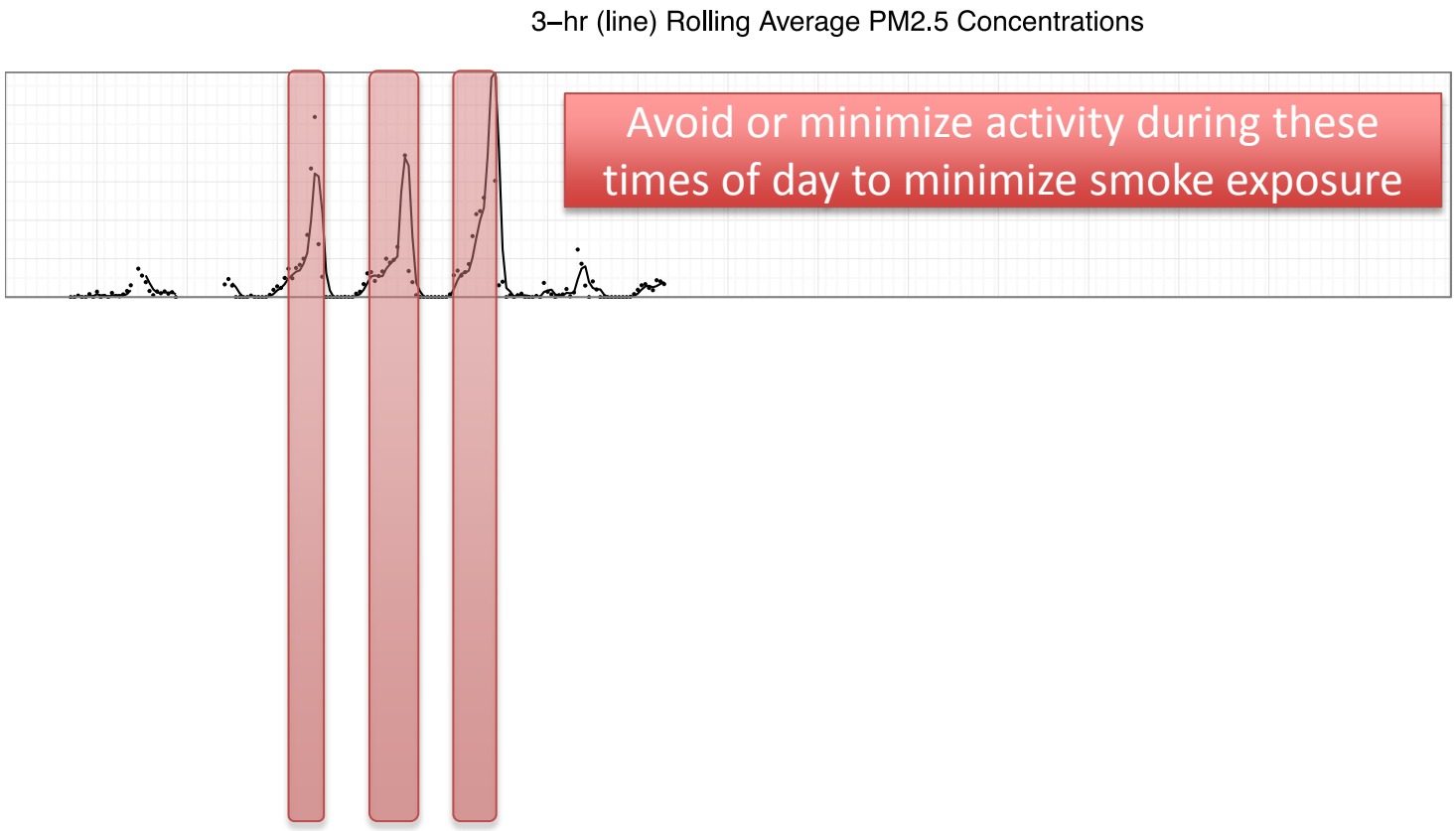
But the air is not "unhealthy" the whole time:

(Time-lapse snapshots from that same period)

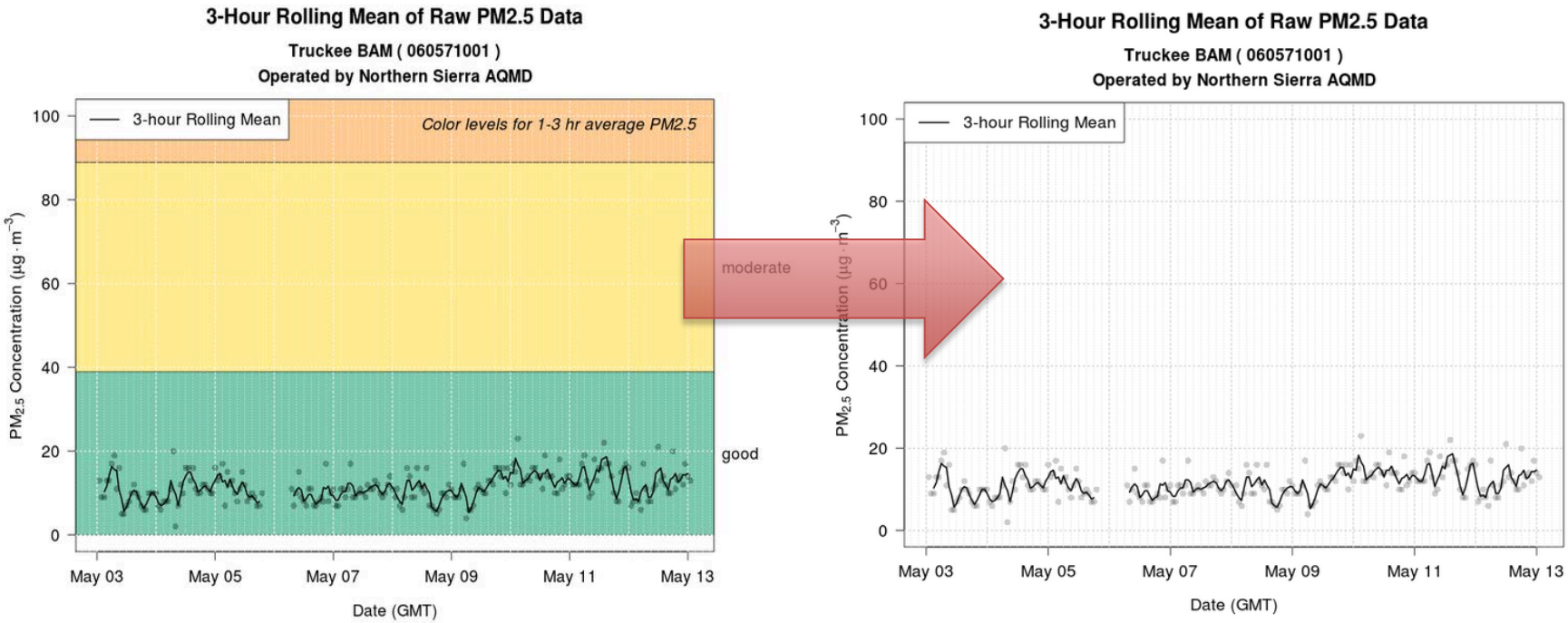
0730 0830 0930 1030

1130 1330 1530 1730

Here's the same dataset, but with 3 hr rolling average



Decoupling AQI from short term (e.g., 3-hr) smoke concentrations



- AQI is based on 24 hr and longer exposures
- 24 hr averages are not useful for telling people about current conditions and managing exposures
- We know very little about health impacts at temporal scales under 24 hrs.

Simplifying wildfire smoke messaging

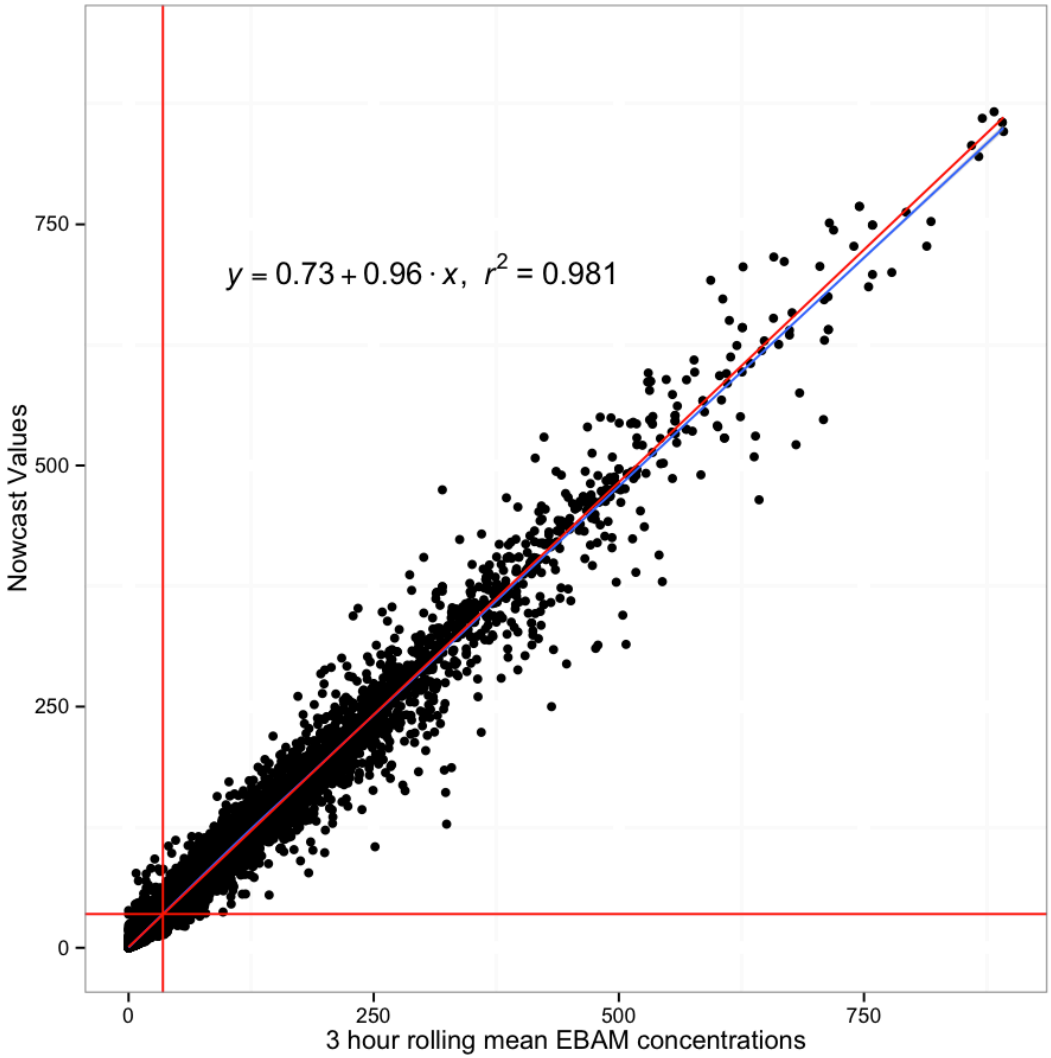
- An example of a simpler, 3-level smoke messaging scheme
- Visibility-based measurements can be very subjective,
  - there is potential to use this same type of scheme with more objective sources like our EBAM smoke monitors
  - And in combination with smoke modeling to forecast and message

https://nmtracking.org/en/environ_exposure/fire-and-smoke/

https://nmtracking.org/media/cms_page_media/179/ER%20Wildfire%20Smoke%20091514.pdf

…And by the way, NOWCAST = 3 hr averages for EBAMS

Insert AQI graphs here with nowcast and 3hr on same graph…



- Need to check this out for BAM 1020 data too…

Exceptional Events

- Smoke from managed fires has little effect on design values at most Southern Sierra sites
  - Cisneros and Schweizer, 2011
- HMS, combined with stats, can ID exceptional events, with skill:
  - Preisler et al., in press
- More EPA guidance is coming…
  - Kurpius presentation

A Method for Determining Impact of Wildland Fires on Particulate Matter ($PM_{2.5}$) in Central California aided by Satellite Imagery of Smoke

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[d]

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Abstract

As the climate in California warms and wildfires become larger and more severe, satellite-based observational tools for documenting and attributing air quality impacts to those wildfires are becoming widely used. However little objective work has been done to quantify the skill these satellite observations of smoke plumes have to predict impacts to PM2.5 concentrations at surface monitors, especially those monitors used to determine attainment values for air quality under the Clean Air Act. Using PM2.5 monitoring data from a suite of monitors throughout the Central California area, we found a significant, but weak relationship between satellite-observed smoke plumes and PM2.5 concentrations measured at the surface. However, when combined with an autoregressive statistical model that uses weather and seasonal factors to identify thresholds for flagging unusual events at these sites, we found that the presence of smoke plumes could reliably identify periods of wildfire influence with less than 2% error.

Questions and challenges

- How do we increase pace and scale to reduce forest emissions in the long term, but still protect regulatory design values and public health in the short term?
  - Need to get better at public messaging for Rx and WFRB
- Can we mitigate public health impacts with messaging?
  - Do we need public health metrics and tracking?
  - What about dedicated crews, or even Type 1 and 2 incident management teams for large scale projects?
- Can we mitigate any regulatory and design value impacts that do occur despite best efforts with exceptional events (isn’t that what it’s for)?

Conclusions

- There will be more smoke, but if we can work together, there's a way to live with it and reduce emissions in the long run.
- The pieces are in place for doing this:
- Land managers:
  - Key metrics for tradeoffs with wildfire are emissions/day, HMS area of influence
  - Decadal scale investment, beginning with large projects at strategic anchor points on the landscape
  - Substantially increased pace and scale, focused on priority landscapes, is a must for success
- Air Districts and Regulators**:**
  - Timely messaging, especially about smoke diurnal patterns, is as important as smoke monitoring, if not more, for protecting public health
  - Colored AQI-equivalent backgrounds on 3-hr average graphs are going away, replace with activity-based messaging (See demo)
  - New BlueSky playground tools are available to perform scenario analysis in preparation for larger scale burns (see demo)
  - New Interagency monitoring tools for graphing and comparing smoke concentrations across all agency monitoring platforms.
  - New tools for documenting exceptional events (see EPA talk)

Spacer slide

2013-2014 Smoke Monitoring Review

Metadata (i.e., we need to learn from every incident)

meta

2014_USFS_1027_meta.csv

2014_USFS_1027_meta.c

Search in Sheet

Home | Layout | Tables | Charts

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B2 | Baseline

	A	B	C	D
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  [5] "Cool_ARB_oer13"                       "Crowley Lake_ARB_oer13"
  [7] "DevilsPostpileNM_USFS_1016"           "DevilsPostpileNM_USFS_1027"
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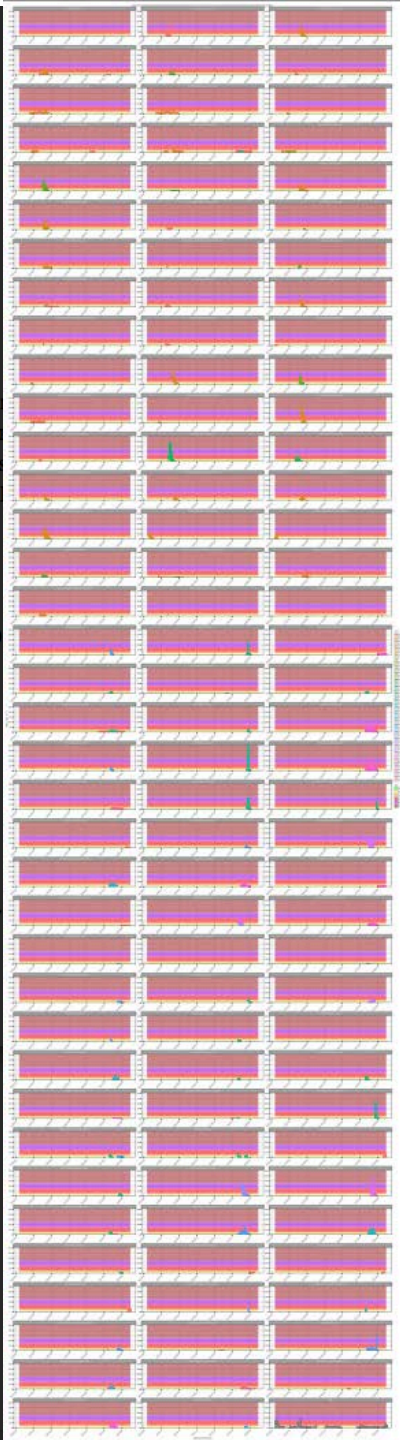
 [23] "Mariposa_ARB_oer14"                   "Markleeville_ARB_1011"
 [25] "Mather Hodgdon Entrance_YOSE_ebam1"   "Oakhurst FS_ARB_oer15"
 [27] "Oakhurst FS_YOSE_ebam1"               "Oakhurst_ARB_oer14"
 [29] "Pinecrest Lake_YOSE_ebam1"            "PollockPines_ARB_oer3"
 [31] "Ponderosa Basin FS_APCD_mrpsa"        "RidgeAboveBassLake_ARB_oer16"
 [33] "Rim Fire ICP_USFS_1020"               "Round Valley_ARB_oer2"
 [35] "SawyersBar_USFS_1044"                 "Somes Bar_USFS_1029"
 [37] "South Lake Tahoe_ARB_1012"            "Tuolumne Meadows CG_ARB_oer15"
 [39] "Tuolumne Meadows CG_YOSE_ebam2"       "TuolumneCityFS_ARB_1005"
 [41] "Wawona Hotel_YOSE_ebam3"              "Wawona, Robin Lane_YOSE_ebam3"
 [43] "Wentworth_ARB_oer2"                   "Woodland Elementary School_ARB_oer13"
 [45] "Yosemite Valley CGs_2013_ARB_oer17"   "Yosemite Valley CGs_YOSE_ebam3"
 [47] "Yreka, S. end_USFS_1029"              "Ash Mountain_SEKI_ebam4"
 [49] "Burney_ARB_oer23"                     "Camino_ARB_oer17"
 [51] "Camp Nelson_USFS_1016"                "Columbia_ARB_oer13"
 [53] "Coulterville_ARB_oer13"               "Coulterville_ARB_oer20"
 [55] "Devils Postpile_USFS_1027"            "Doyle_ARB_oer20"
 [57] "Etna_APCD_sisk1002"                   "Fall River Mills_ARB_oer22"
 [59] "Foresthill_ARB_oer25"                 "Fort Jones_APCD_sisk1001"
 [61] "Garberville_APCD_ncu1001"             "Garden Valley_ARB_oer3"
 [63] "GrassValley (S. Nev. Cnty)_ARB_oer24" "Hammond_SEKI_ebam5"
 [65] "Happy Camp_ARB_oer21"                 "Happy Camp_ARB_oer28"
 [67] "Hodgdon Housing_YOSE_ebam1"           "Hoopa _USFS_1045"
 [69] "Johnsondale_USFS_1051"                "Kennedy Meadows_USFS_1013"
 [71] "Klamath_ARB_oer29"                    "KlamathFalls,OR_USFS_1030"
 [73] "La Grange_ARB_oer20"                  "LaGrange_ARB_oer29"
 [75] "Lakeshore_ARB_oer24"                  "Lee Vining_YOSE_ebam2"
 [77] "Loyalton_ARB_oer13"                   "Macdoel_ARB_oer25"
 [79] "Macdoel_ARB_oer28"                    "Midpines_ARB_oer18"
 [81] "Midpines_ARB_oer24"                   "Mt. Shasta_ARB_oer24"
 [83] "North Fork USFS 1026"                 "Oakhurst FS ARB oer3"
```

Every hour, tagged with unique combinations of site and instrument

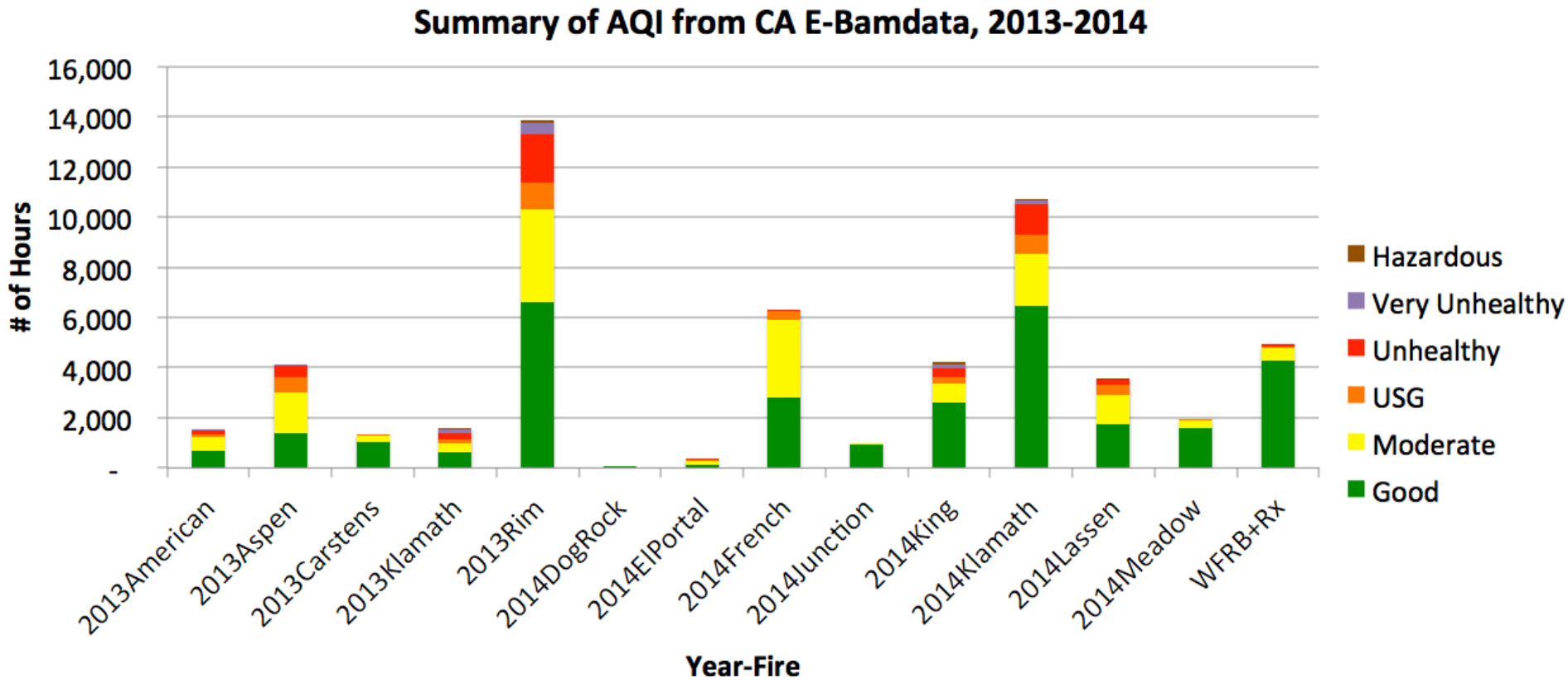
84 unique site_instrument combinations

```
> levels(dat.AAR_2013_14_data$Fire)
  [1] "AspenWF"                  "Baseline"                    "CarstensWF"
  [4] "ForbiddenWF"              "RimWF"                       "Wawona NW Rx_1ignition_phase"
  [7] "Wawona NW Rx_2burndown_phase" ""                        "ForbiddenWF "
 [10] "ForbiddenWF, AspenWF"     "ForbiddenWF, CarstensWF"     "pile-burning"
 [13] "American+RimWF"           "AmericanWF"                  "AmericanWF "
 [16] "Rim Fire"                 "CorralWF"                    "SalmonRiverC"
 [19] "French WF"                "King WF"                     "DarkHole+EP Fire"
 [22] "Drk+EP+Frnch Fire"        "tba"                         "Beaver+Whites"
 [25] "Drk+Frnch Fire"           "MeadowWF"                    "French+EP Fire"
 [28] "Meadow WF"                "Happy Camp Complex"          "Eiler, Bald, + Day"
 [31] "King Fire"                "July and Happy Camp complex" "Dog Rock WF"
 [34] "July Complex"             "Beaver "                     "Happy Camp"
 [37] "Happy Camp and Beaver"    "Mosquito"                    "TBA"
 [40] "Beaver+HappyCamp"         "Junction WF"                 "Dark Hole WF"
 [43] "El Portal WF"             "Beaver_JulyComplex"
[109] "Yreka_APCD_sisk1000"                                    "Yreka_USFS_1029"
>
```

Every hour, tagged with unique combinations of Fire influence (subjective/interpreted)



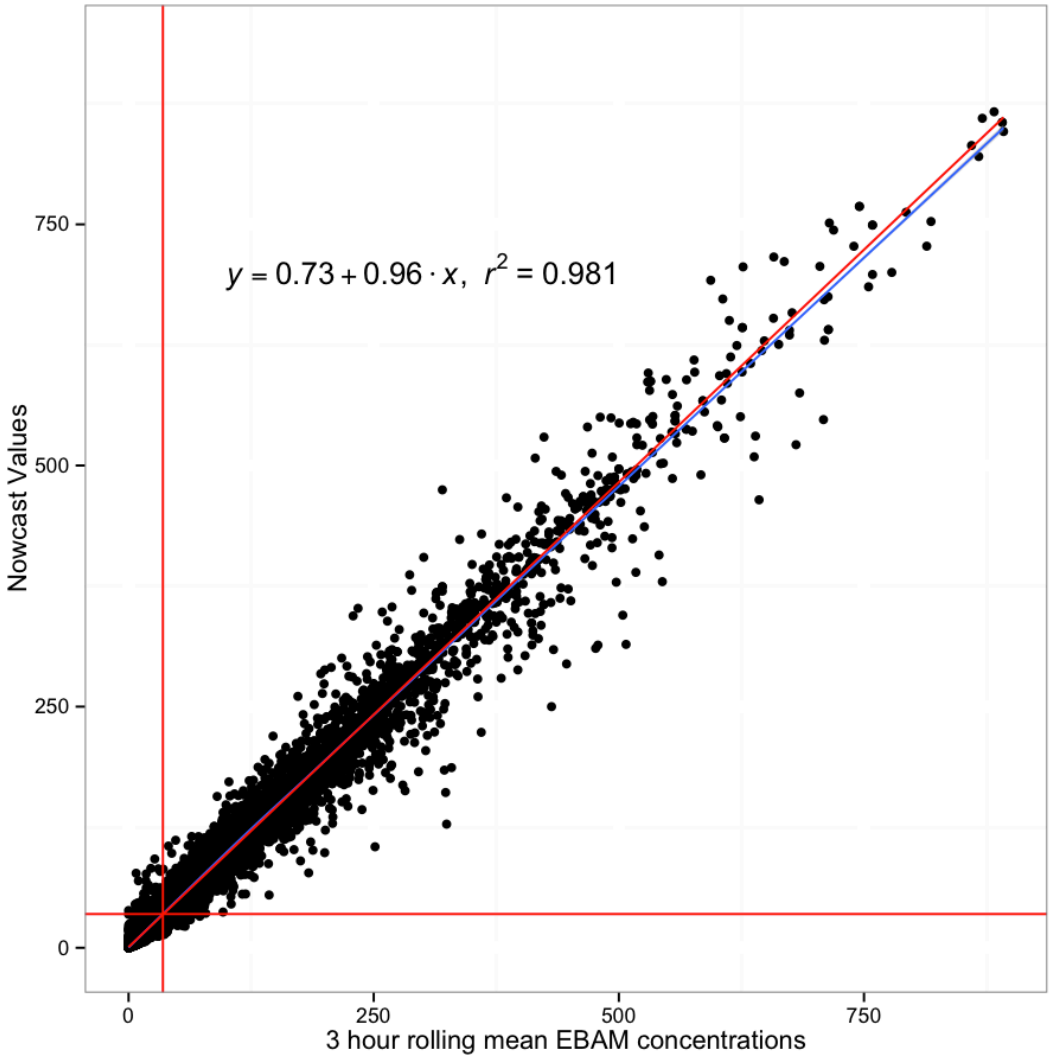
2013-2014 impacts, by fire



Yes…I cheated and used excel to graph this…

…And by the way, NOWCAST = 3 hr averages for EBAMS

Insert AQI graphs here with nowcast and 3hr on same graph…



- Need to check this out for BAM 1020 data too…

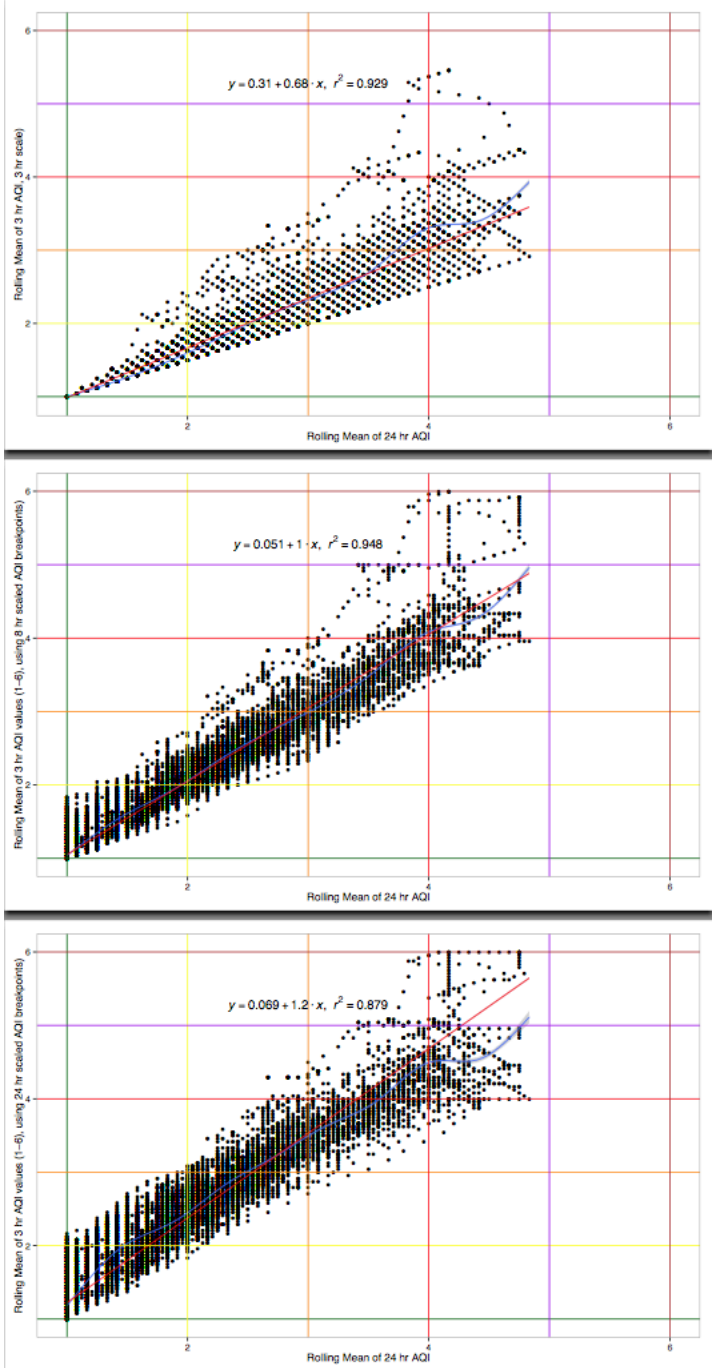
AQI, Table 3, and "breakpoint scaling bias"

Table 3. Recommended Actions for Public Health Officials [2,3]

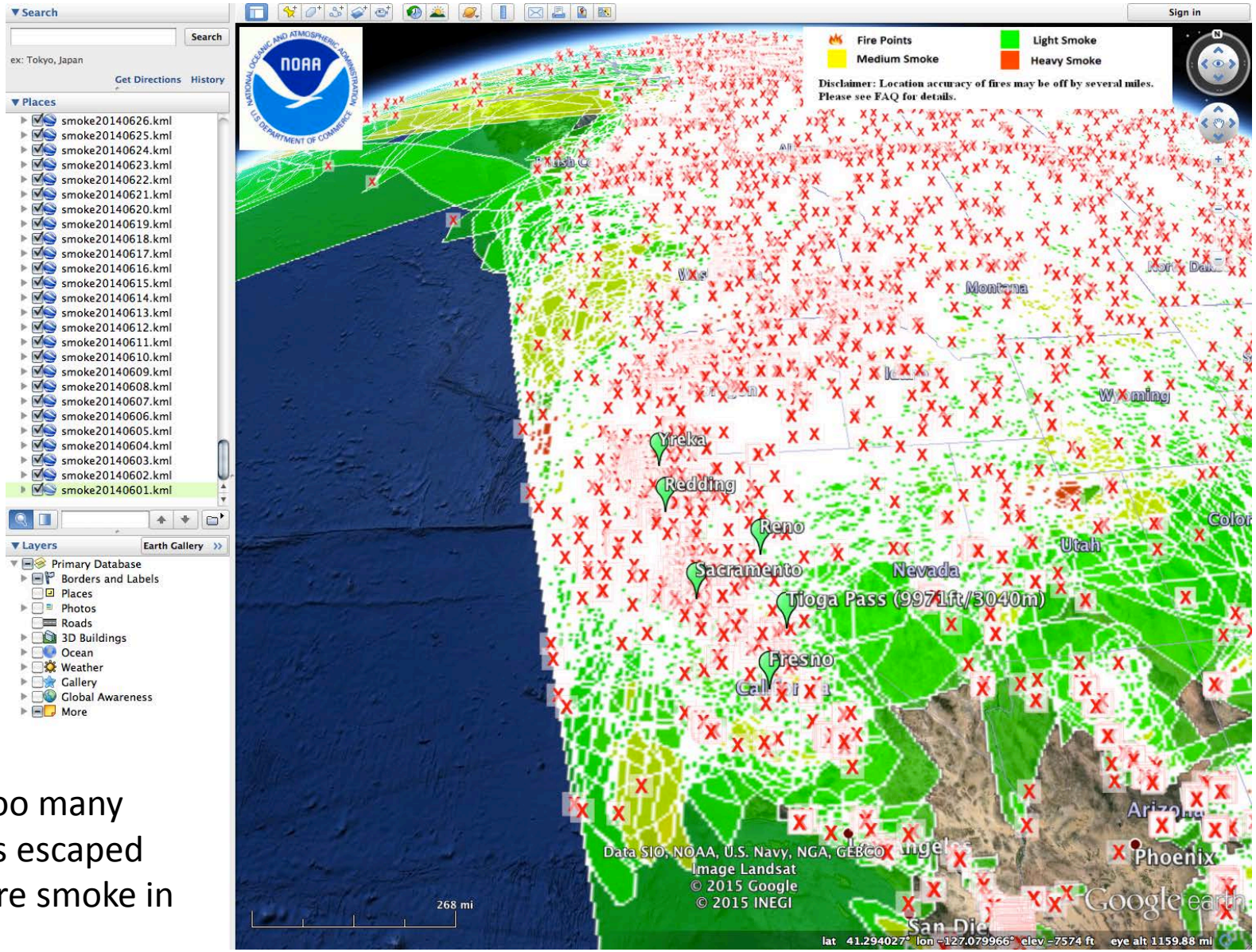
AQI Category (AQI Values)	PM2.5 or PM10 Levels (ug/m^3)			Visibility - Arid Conditions (miles)	Recommended Actions
	1-3hr avg	8 hr avg	24 hr avg[1]		
Good (0 to 50)	0 – 38	0 – 22	0 – 12	≥ 11	• If smoke event forecast, implement communication plan
Moderate (51 to 100)	39 – 88	23 – 50	12.1 – 35.4	6 – 10	• Issue public service announcements (PSAs) advising public about health effects and symptoms and ways to reduce exposure • Distribute information about exposure avoidance
Unhealthy for Sensitive Groups (101 to 150)	89 – 138	51 – 79	35.5– 55.4	3 – 5	• If smoke event projected to be prolonged, evaluate and notify possible sites for cleaner air shelters • If smoke event projected to be prolonged, prepare evacuation plans
Unhealthy (151 to 200)	139 – 351	80 – 200	55.5 – 150.4	1.5 – 2.75	• Consider "Smoke Day" for schools (i.e., no school that day), possibly based on school environment and travel considerations • Consider canceling public events, based on public health and travel considerations
Very Unhealthy (201 to 300)	352 – 526	201 – 300	150.5 – 250.4	1 – 1.25	• Consider closing some or all schools (Newer schools with a central air cleaning filter may be more protective than older, leakier homes. See "Closures", below.) • Cancel outdoor events (e.g., concerts and competitive sports)
Hazardous (> 300)	> 526	> 300	> 250.5-500	< 1	• Close schools • Cancel outdoor events (e.g., concerts and competitive sports) • Consider closing workplaces not essential to public health • If PM level is projected to remain high for a prolonged time, consider evacuation of sensitive populations

[1]Revised 24 hour average breakpoints from the **Revised Air Quality Standards for Particle Pollution and Updates to the Air Quality Index**, US Environmental Protection Agency, December 14, 2012. Available at http://www.epa.gov/airquality/particlepollution/actions.html#dec12.

[2]These 1- and 8-hr PM2.5 levels are estimated using the 24-hr breakpoints of the PM2.5 Air Quality Index included in the February 7, 2007 issue paper (http://www.epa.gov/airnow/aqi_issue_paper_020707.pdf) by dividing the 24-hr concentrations by the following ratios: 8-hr ratio is 0.7, 1-hr ratio is 0.4. Visibility is based on 1-hr values. If only PM10 measurements are

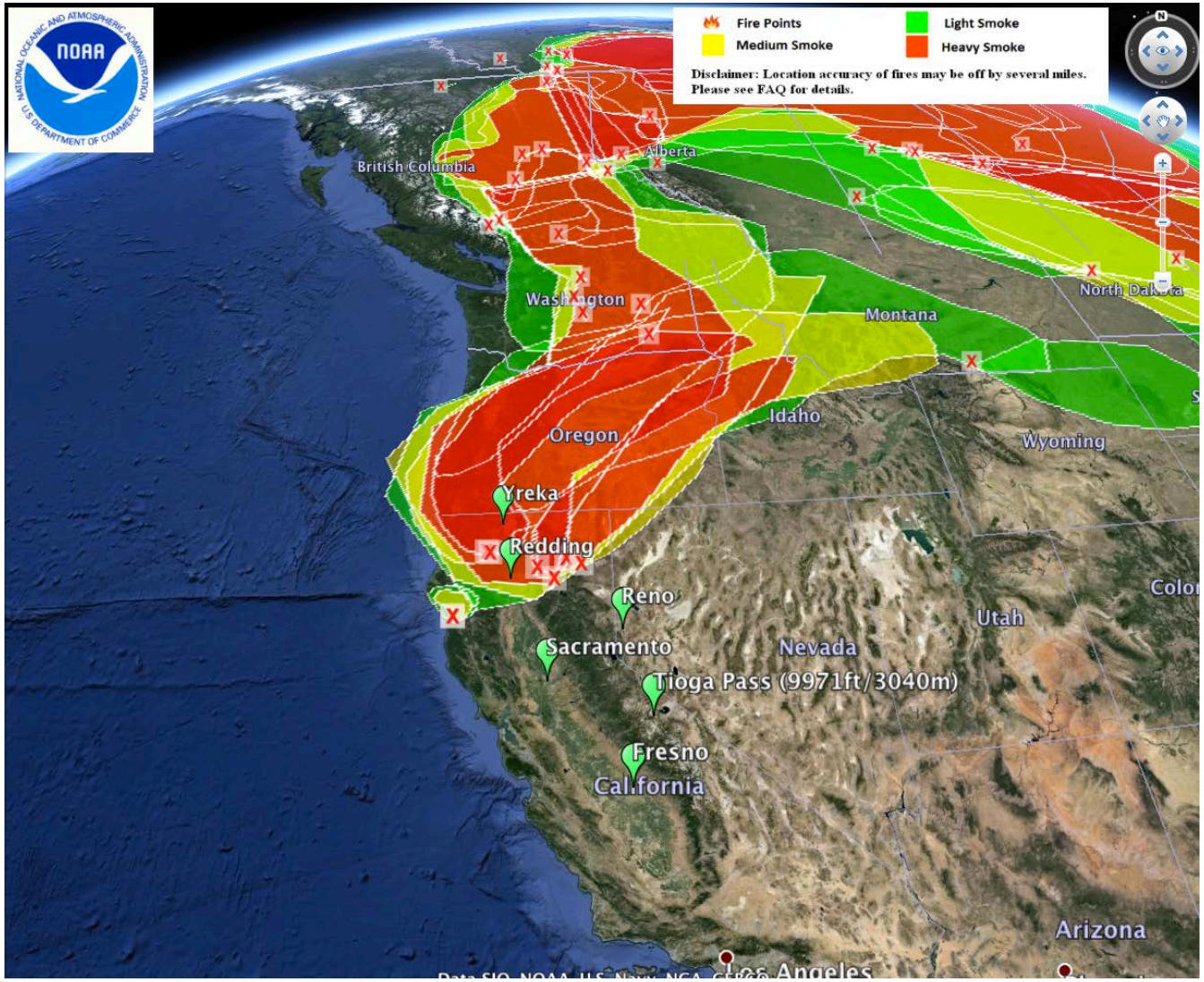


2014 HMS, June-Sept



Not too many places escaped wildfire smoke in 2014

HMS, 8/4/2014


Fire Points
Light Smoke
Medium Smoke
Heavy Smoke
Disclaimer: Location accuracy of fires may be off by several miles.
Please see FAQ for details.
British Columbia
Alberta
Washington
Montana
North Dakota
Idaho
Oregon
Wyoming
Yreka
Redding
Reno
Utah
Sacramento
Nevada
Tioga Pass (9971ft/3040m)
Fresno
California
Arizona
Los Angeles