Snowpack, Lightning Ignitions, and Fire Severity in Yosemite National Park

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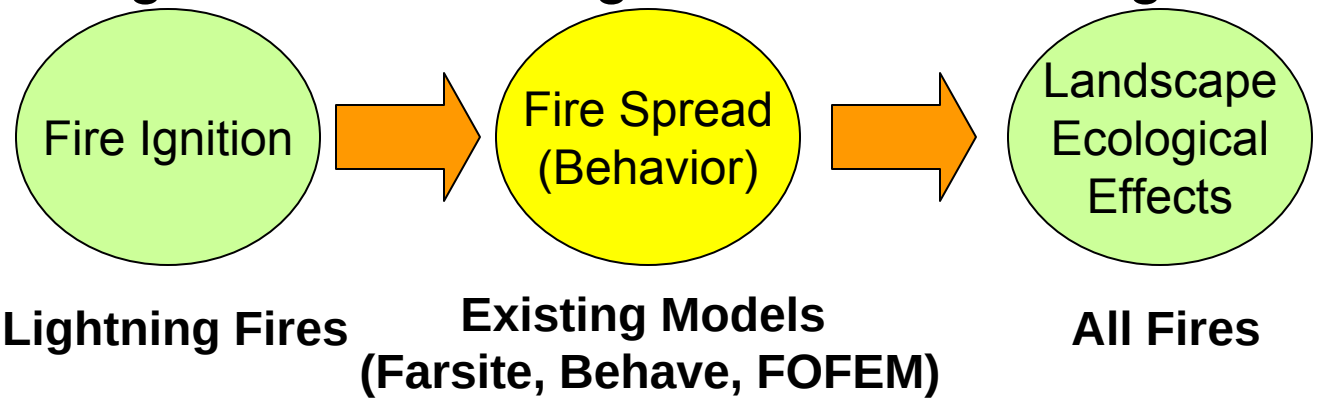
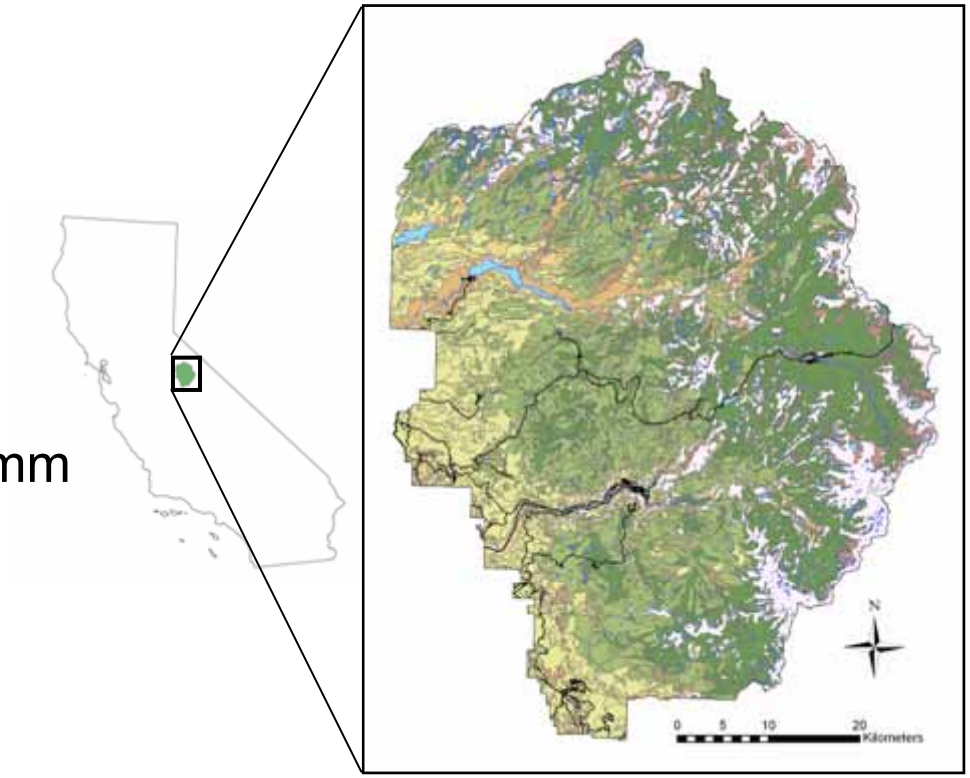
Research Scope and Rationale

- How predictable is the annual fire regime?
  - Most studies are of area burned or fire spread
  - Lightning-ignited fires
  - Burn severities
- Number of fires in a fire season
  - Natural ignitions
- Ecological effects of a fire season
  - What burn severities can be expected?
- How might climate change affect the fire regime?



Yosemite National Park

- Physical features
  - Area: 3,027 km^2
  - ~84% vegetated
  - Elevation: 657 – 3,997 m
  - Precipitation: 800 – 1,720 mm



Landscape Flammability

- Fuel moisture
- Precipitation seasonality
  - Western North America
  - Sierra Nevada
- Spring snowpack
  - Snow course data
  - April 1st Snow Water Equivalent
- $$Flammability = \frac{Lightning\ ignitions}{Lightning\ strikes}$$

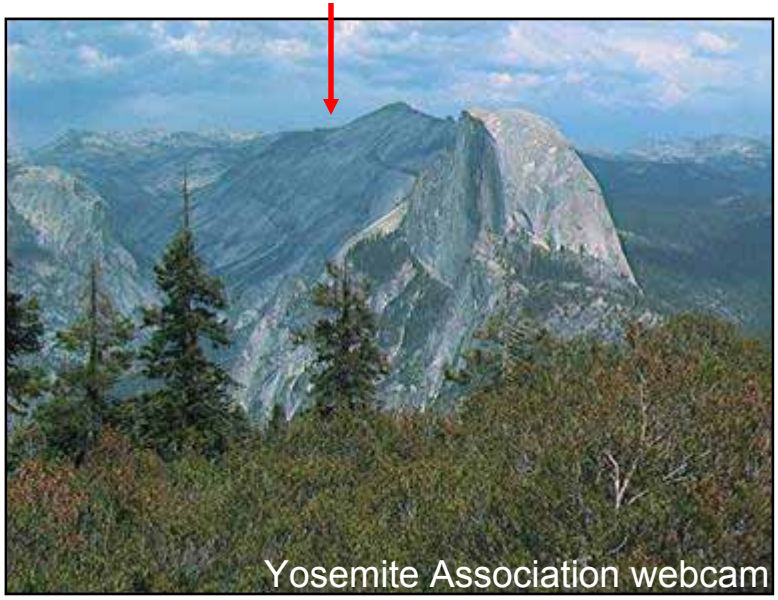
Church 1933, 1935; Waring and Franklin 1979, van Wagtendonk and Cayan 2008, CA Dept. Water Resources

Landscape Flammability

- Higher air and ground temperature
- Lower fuel moisture (drier or drier longer)

Towards Tuolumne Meadows snow course station

1983: June 1st photo
April 1st SWE: 114 cm
Last snow: July 2nd

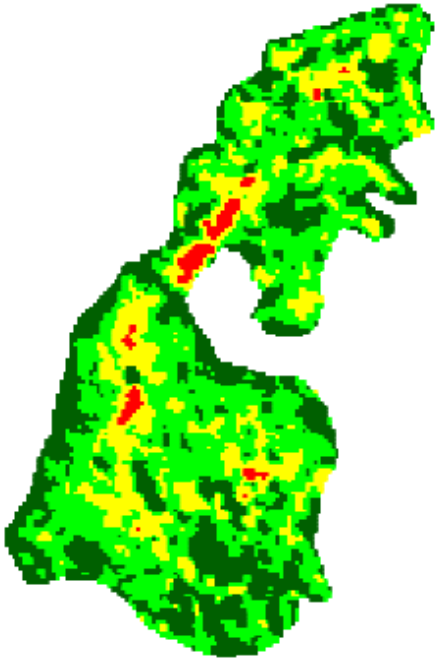


2007: June 1st photo
April 1st SWE: 21 cm
Last snow: April 10th

Methods
Burn Severity

- Landsat TM-derived measure of burn severity
  - Pre-fire
  - Post-fire
- Relative differenced Normalized Burn Ratio (RdNBR)
  - Near infrared (Landsat TM band 4)
  - Mid-infrared (Landsat TM band 7)
  - Landsat TM: began in 1984; 30-m pixel size
- Use RdNBR classifications for fires > 40 ha
  - Four severity classifications
  - Clipped to park boundary
- Park records
  - Area burned (< 40 ha)
  - Ignitions

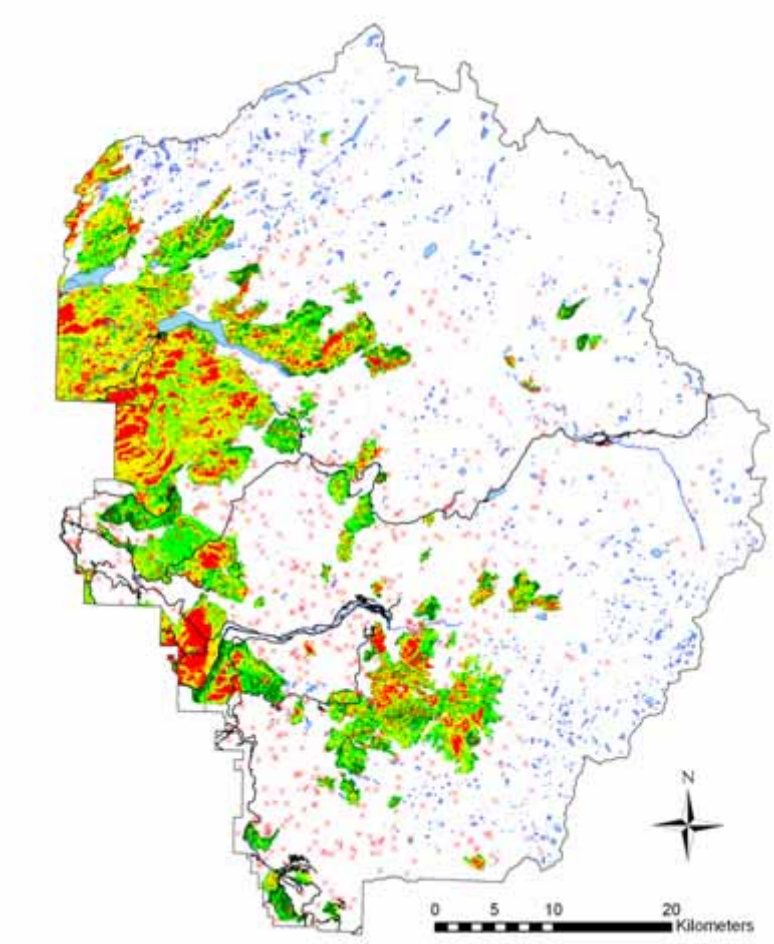
Lost Bear Fire, 1999



Frohn 1998, Key and Benson 1999, 2002, van Wagtendonk *et al.* 2004, Key 2006, Miller and Thode 2007

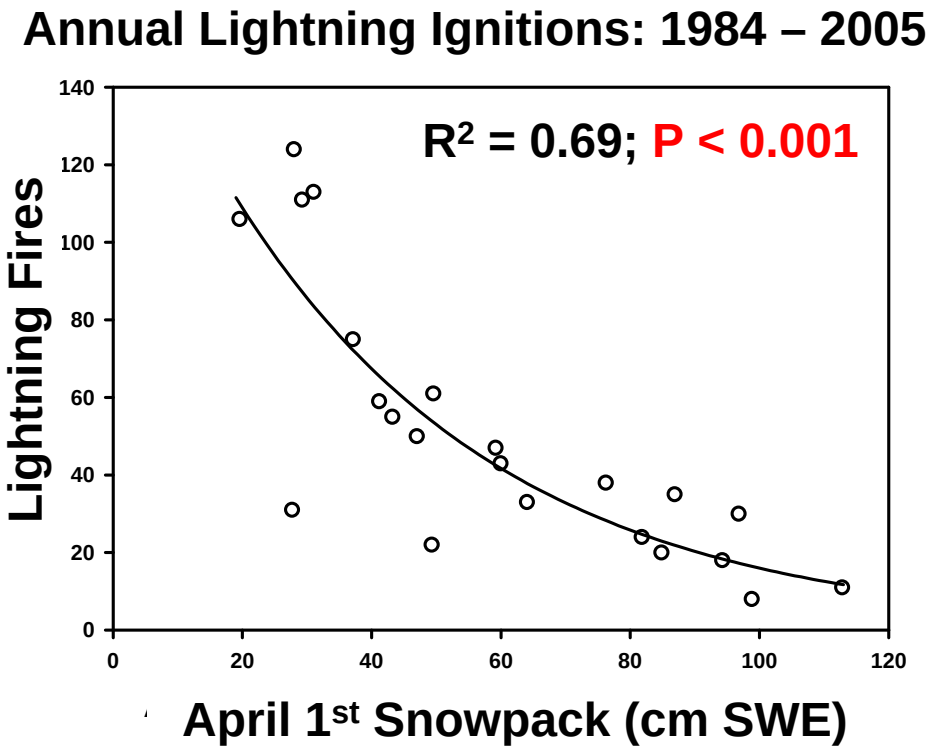
Results
Fire Summary: 1984 - 2005

- All causes
  - 1,870 fires; 77,718 ha
  - 103 > 40 ha; 73,264 ha; 94%
- Lightning
  - 1,113 fires; 63,358 ha; 82%
  - 73 > 40 ha; 61,524 ha
- Satellite analysis of most burn area



Results
Fire – Climate Relationships

- Snowpack ignition envelope
  - High snowpack → few
  - Low snowpack → usually more



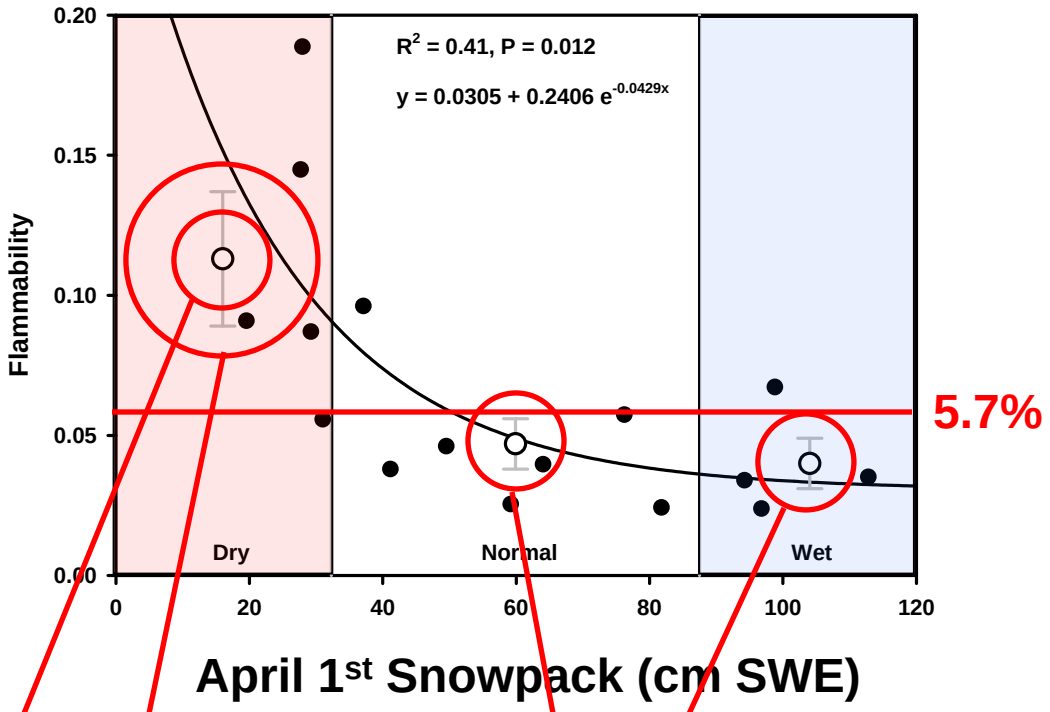
- Marginally significant (P = 0.06) relationship with annual area burned

Results
Landscape Flammability

- $\frac{\textit{Lightning ignitions}}{\textit{Lightning strikes}}$

- Dry years: <1σ
- Wet years: >1σ
- Normal years: ±1σ

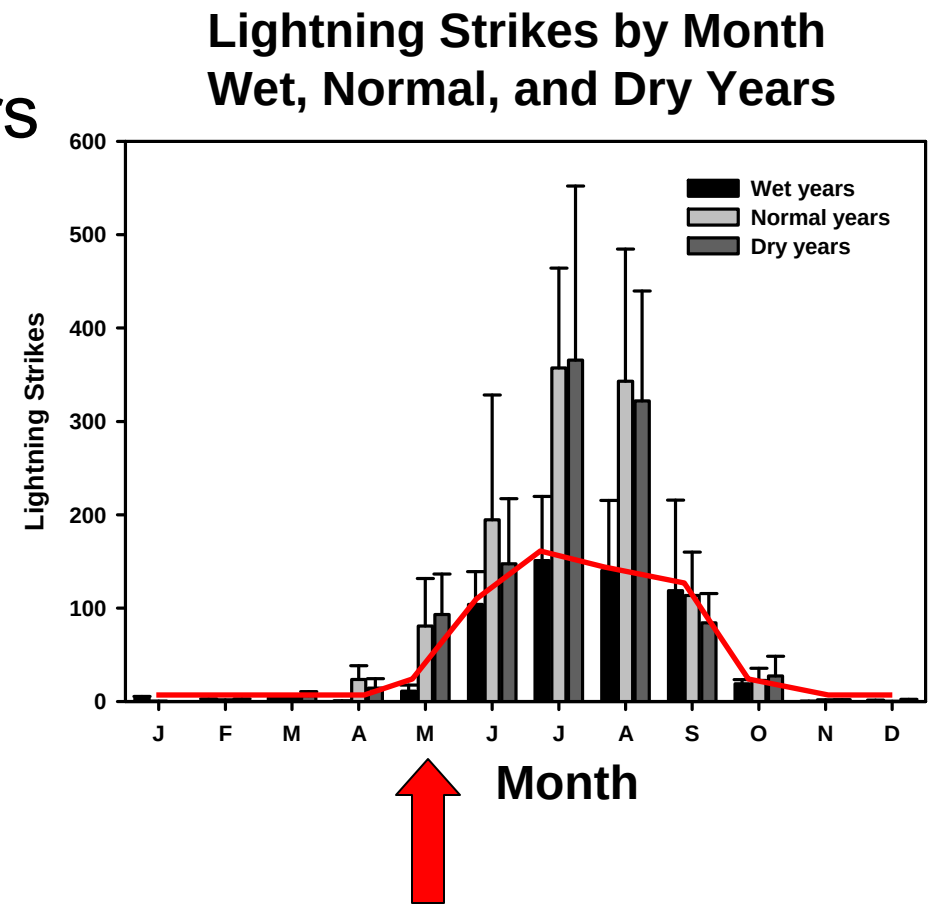
Annual Flammability: 1985 – 2000



Flammability higher in Dry years
Variation higher in Dry years
Flammability in Normal and Wet years not different

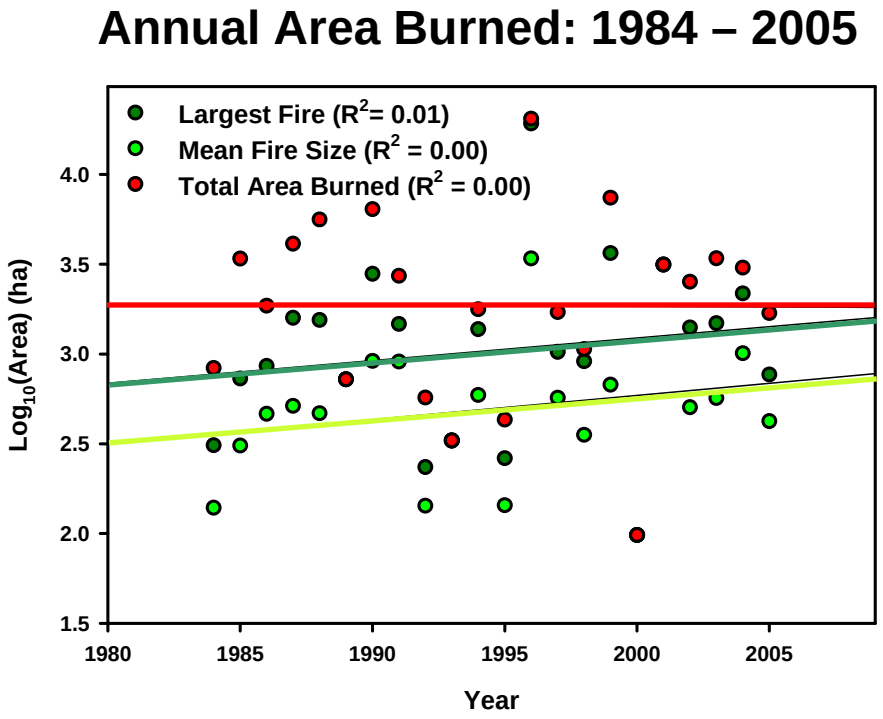
Results
Lightning – Snowpack Relationships

- Fewer strikes in wet years
  - Delayed onset
  - Reduced number
- Regional climate pattern
  - increases snowpack and
  - decreases strikes?



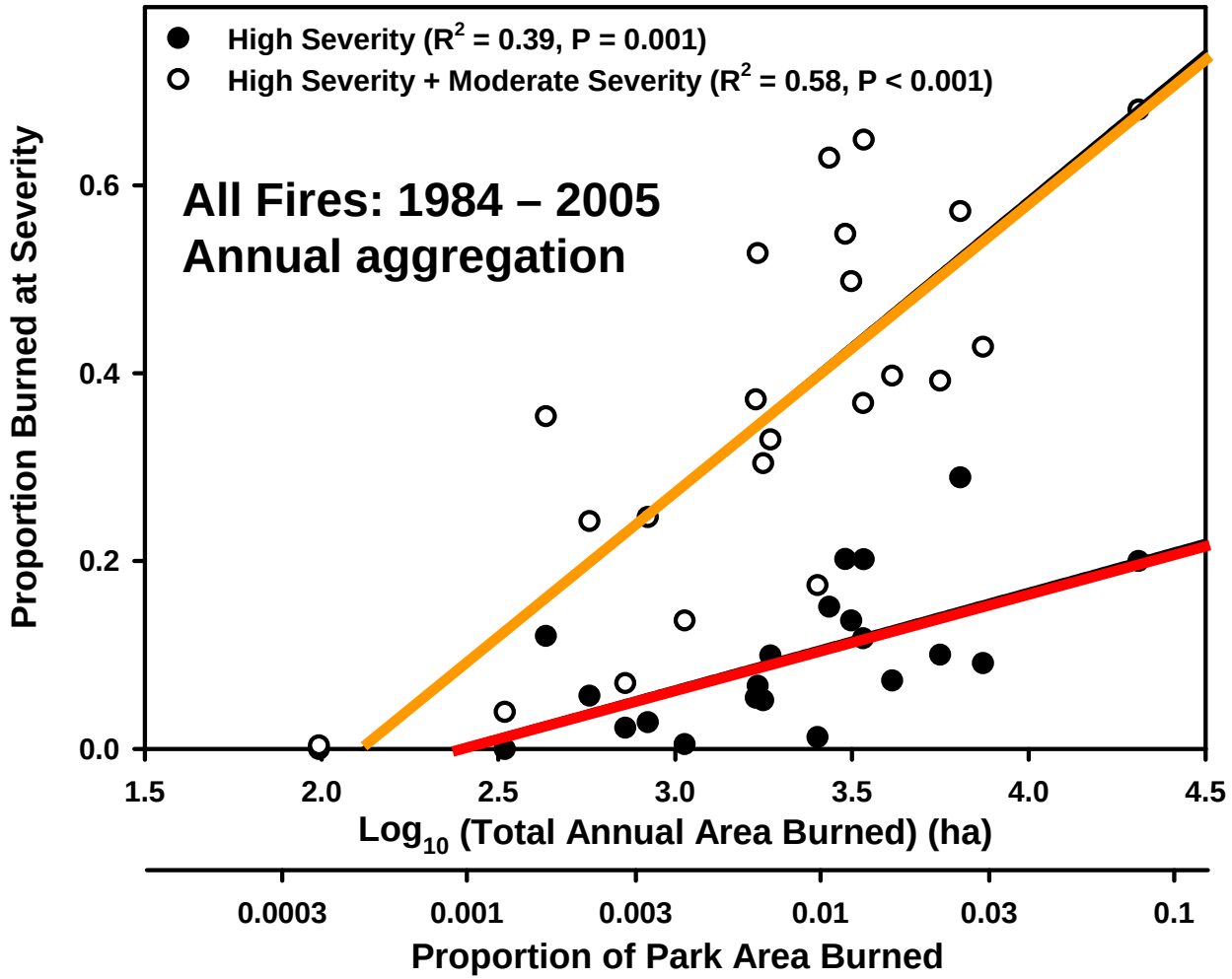
Results
Temporal Trends in Fire

- No trend 1984 – 2005
- 1984 – 2005: 3,330 ha yr^{-1}
- 1962 – 1983: 850 ha yr^{-1}
  - Prescribed burning 1970
  - Wildland fire use 1972
  - Mid-1980s regime switch (P = 0.02)
- **Other sources of variability important at 3,000 km^2 scale**
  - **Variation in snowpack**



Running 2006, Westerling *et al.* 2006, van Wagtendonk and Lutz 2007, Miller *et al.* 2008

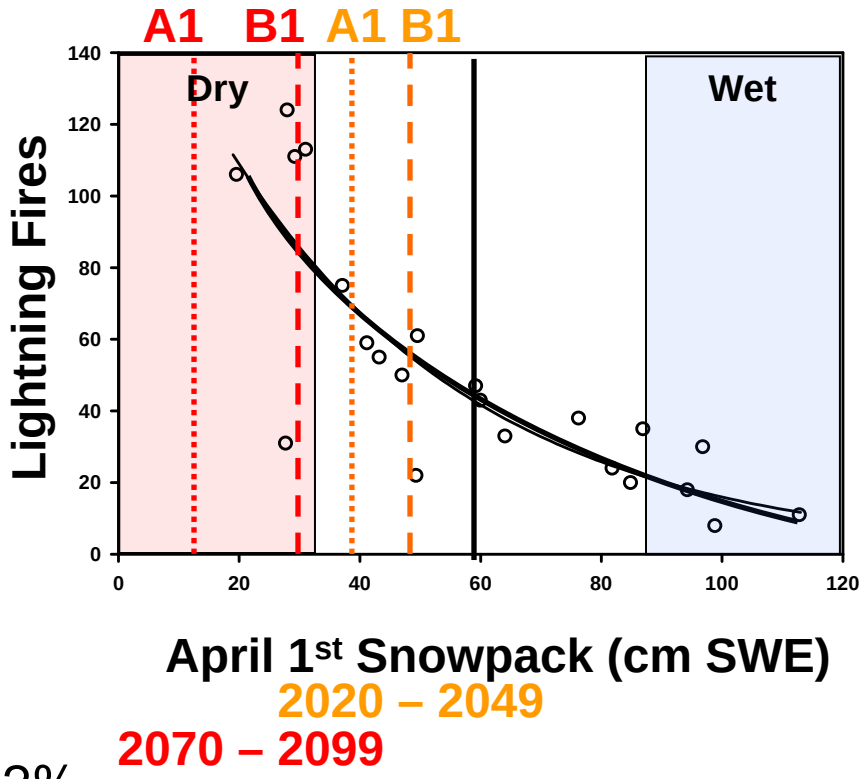
Results
Fire Severity and Area Burned



- Not just more fire

The Future of Fire in Yosemite

- Decrease in California snowpack (one factor)
- IPCC emissions scenarios
  - B1
  - A1fi
- IPCC B1, 2020 – 2049
  - Strikes up 10%
  - Ignitions up 19%
  - Area burned at high severity up 22%



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Gordon *et al.* 2000, Pope *et al.* 2000, Nakićenović *et al.* 2000, Washington *et al.* 2000, Hayhoe *et al.* 2004, Mote *et al.* 2005, Knowles *et al.* 2006, Meehl *et al.* 2007, Miller *et al.* 2008

Conclusions

- Predicting fire in Yosemite National Park
  - Snowpack → ignitions **P < 0.001**
  - Snowpack → area burned **P = 0.06**
  - More area burned → higher severities **P < 0.001**
- If climate change decreases snowpack
  - More ignitions
- If climate change increases annual area burned
  - Increasing burn severity

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