# 4.1 Fire regimes

# You understand:

- ✓ Fire fundamentals
- ✓ Fire behavior
- ✓ Fire ecology
- ○ **Fire regimes**
- ○ Fire management
- ○ Fire in a changing world

# What is a "fire regime"?

- Concept built from properties of many individual fires
- Aggregate properties of multiple fires in space and time
- Not just mean conditions, also interested in variation in space and time
- Includes linkages to regulating factors of fire behavior and ecology

Falk et al. 2011

# Properties of individual fires (you know this stuff now!)

| Property | Typical units or metrics |
|---|---|
| ***Type*** | Classified as ground, surface, active or passive crown fires |
| Ignition | Lightning, human (intentional, inadvertent) |
| ***Behavior*** | |
| Rate of spread | m $min^{-1}$ |
| Crowning index | km $hr^{-1}$ |
| ***Biophysical*** | |
| Fireline intensity | kW $m^{-1}$ |
| Energy output per unit time | BTU $m^{-2}$ $hr^{-1}$ or kJ $m^{-2}$ $hr^{-1}$ |
| Flame length | m |
| Peak temperature | °C |
| ***Spatial*** | |
| Extent | Total area covered by event, typically outer fire perimeter (ha or $km^2$). |
| Spatial heterogeneity | Proportion of burn area by intensity or severity class (%); patch size distribution. |
| ***Temporal*** | |
| Duration | Elapsed time (hr, day), residence time at a point (min). |
| Seasonality | Time of year; relationship to plant phenology or annual animal life cycles |
| ***Severity*** | Effects on biotic and abiotic ecosystem elements. |
| Fuel consumption | % consumed or kg $m^{-2}$ by fuel size class |
| Plant mortality | % by size class and species |
| Soil effects | Duff and organic layer consumption (cm, %); hydrophobic conditions (%) |

# So a “fire regime” is:

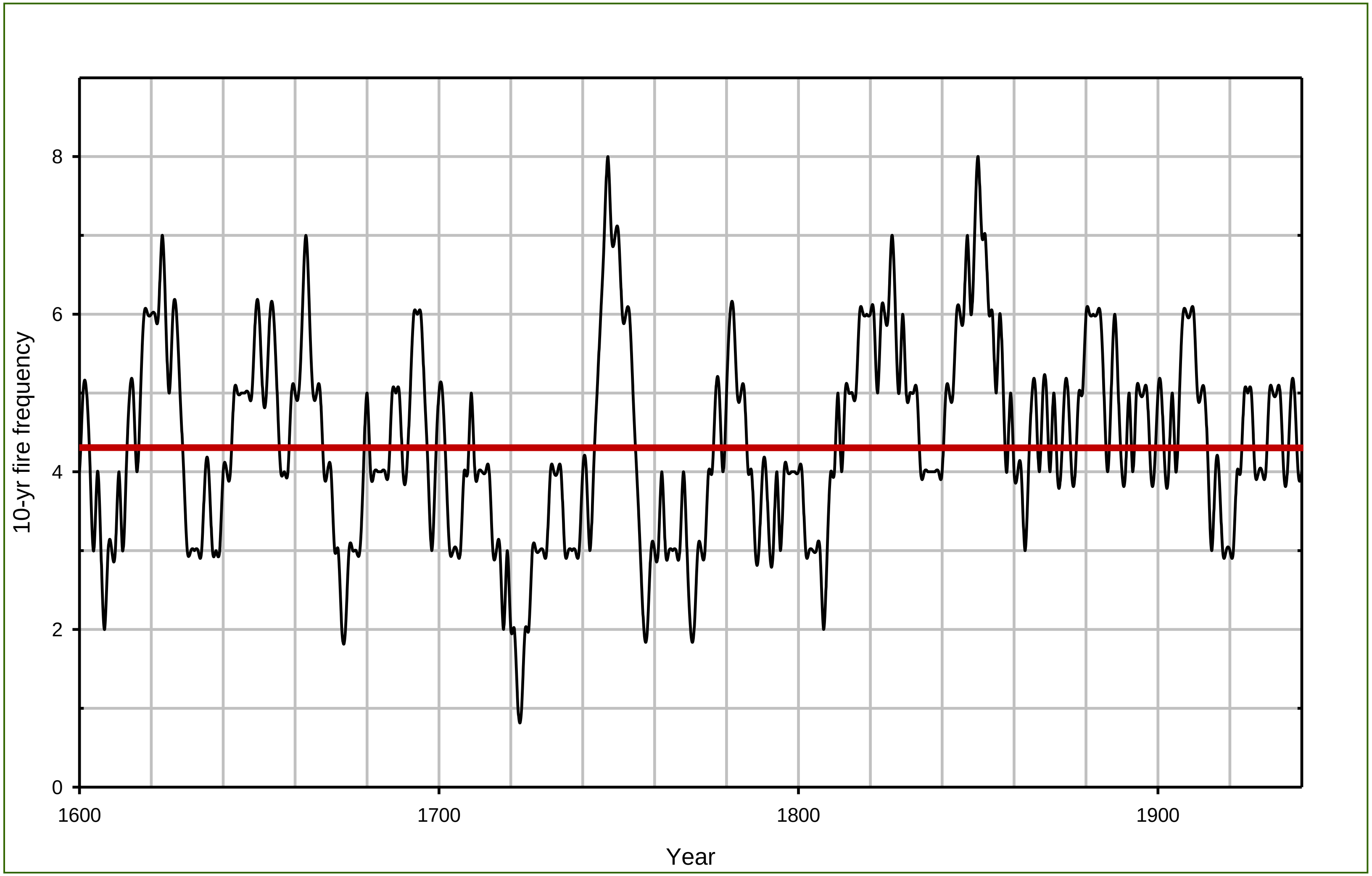
“…the combined properties of multiple fires in space and time.”

# Then how do we characterize fire *regimes*?

| **Dimension** | **Typical metrics and units** |
|---|---|
| | |
| ***Temporal distribution*** | |
| Frequency (*f*) | Number of events (events $t^{-1}$ area$^{-y}$ = 1/*I*). |
| Return interval (*i*) | Time between events (*t* event $^{-1}$ area$^{-y}$ = 1/*f*). |
| Fire rotation or fire cycle | Time to burn defined area (time total area$^{-1}$); modelled mean fire interval (fire cycle). |
| Frequency or interval variability (temporal heterogeneity) | Statistical measures of central tendency (mean, median, mode) and dispersion (variance, skewness, kurtosis). Also reflected in parameter values in mathematical models. |
| Duration | Residence time (*t*) for a defined area. |
| Seasonality | Intra-annual occurrence. |
| | |
| ***Spatial distribution*** | |
| Fuel types | Ground, surface canopy fuels; fuel size distribution. |
| Extent | Total area covered ($km^2$). |
| Spatial heterogeneity | Proportion of total area affected (%); patch size (ha), aggregation and contagion indices. |
| | |
| ***Intensity*** | Physical properties, *e.g.*: flame length (m), flame temperature (°C.), fireline intensity (kW $m^{-1}$), rate of spread (m $hr^{-1}$), energy output (BTU $hr^{-1}$ $m^{-2}$ or kJ $m^2$). |
| | |
| ***Severity*** | Effects on biotic and abiotic elements of the community, *e.g.*: mortality by species (%), litter and duff consumption (%), canopy scorch height (m), crown consumption (%), soil loss. |

# Temporal variability in fire regimes

## 10-year moving fire frequency at Monument Canyon RNA



## Of these, the most important fire regime properties (the ones we'll talk most about) are:

1. Characteristic fuel stratum burned
2. Fire frequency
3. Fire interval (mean and distribution)
4. Fire size (area burned)
5. Seasonality
6. Burn severity, patch sizes
7. Percent mortality (usually of overstory)
8. Soil and hydrological effects
9. Relationship to climate

**Understanding fire regimes is how we can determine whether some areas are becoming converted to historically unprecedented regimes**

# Major types of fires

- Ground fire
- Surface fire
- Crown fire

- These all depend on the location (stratum) and type of fuel that is burning
- Big differences in behavior, intensity, and severity

# Ground Fuels

All combustible materials lying beneath the surface:

- Deep duff
- Tree roots
- Rotten buried logs
- Other organic material

# Ground fuels are important for:

- Fire spread (smoldering, creeping)
- Fire effects (belowground, e.g. effects on roots and soil)
- Fire breaks used in suppression

# Surface Fuels

Combustible materials on or above the soil surface, usually within ~1-3 m

- Fine fuels (grasses, forbs, litter)
- Woody fuels (1-1000 hr)
- Small shrubs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# Canopy Fuels

Combustible materials in the crowns of large shrubs and trees

- Foliage (live and dead)
- Branches
- Epiphtyes


Canopy fire in
sagebrush
ecosystem
Photo: Cal Farris, NPS

## Torching:

- When crown fire occurs in a single tree
- "Torching index": the windspeed needed to carry fire from the surface to canopy
- Low TI means that fire goes up into canopy easily

Rodeo-Chediski Fire; ERI, NAU

Main fuels in crown fires are <u>live foliage</u>

Branches, dead foliage also consumed depending on heat output

Larger branches and trunk often not consumed

# Two basic classes of canopy (or "crown") fires

- ACTIVE crown fires
  - Propagate directly through the forest canopy from tree to tree
  - Generally highest temperatures and most extreme behavior
- PASSIVE crown fires
  - Canopy burning is "supported" from below by intense surface fire
  - Can have significant effects because flames are continuous ground to canopy

# Fire behavior by fuel strata:

| | GROUND | SURFACE | CANOPY |
|---|---|---|---|
| **Rate of spread** | Slow | Fast | Fast |
| **Residence time** | Long (hours-weeks) | Short (seconds-minutes) | Short (minutes) |
| **Maximum temperature** | Low (300-500$^{o}$ C) | Moderate (500-800$^{o}$ C) | High (> 800$^{o}$ C) |
| | | | |

# Fire and grasslands: A 5-million year long love affair

# Forest surface fire regimes

- Widely distributed in North America
- Generally high-frequency, short intervals
- Associated with generally open stand structures, high crown lift
- Size-dependent mortality (lowest in large adult trees, highest in seedlings and saplings)

# Woodland and savanna fire regimes

Grasslands and savannahs

Piñon-Juniper woodlands

P-J photos: Northern Arizona University; US Forest Service (C. Squire)

# Canopy/stand replacing fire regimes

Canadian Forest Service

# Chaparral fire regimes

Photos: California Depts. of Forestry and Fish & Game

# Mixed severity fire regimes

Fire regimes are not always constant over time and space

Many forests may have “mixed severity” fire regimes:

- Spatially heterogeneous at one moment in time (*e.g.* burn severity maps)
- Temporally heterogeneous for any place over time (change over time)
- Reconstruction difficult because evidence may be obscured by high-severity events

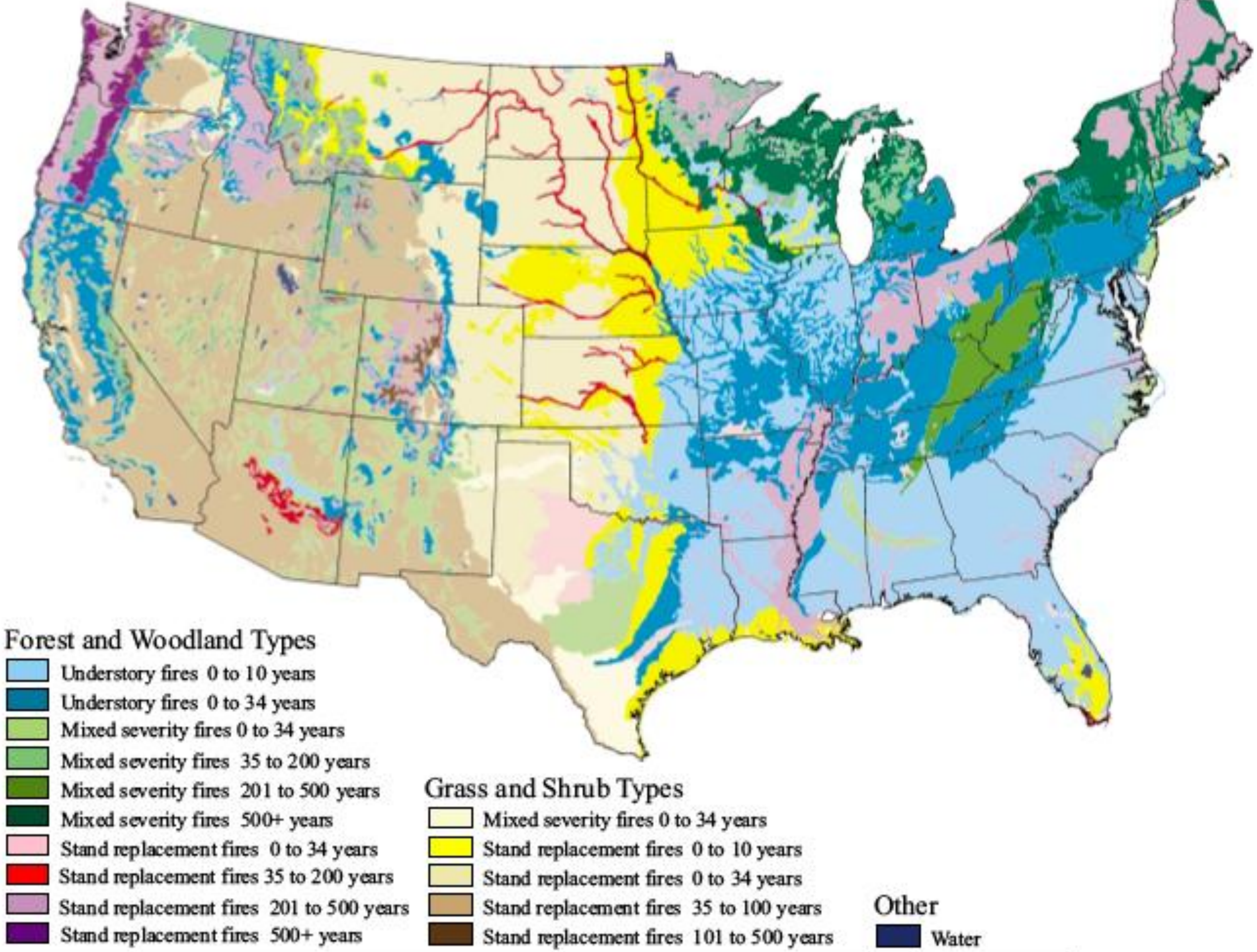



**Figure 1-2**—Fire regime types based on Kuchler's Potential Natural Vegetation types (prepared by Jim Menakis).

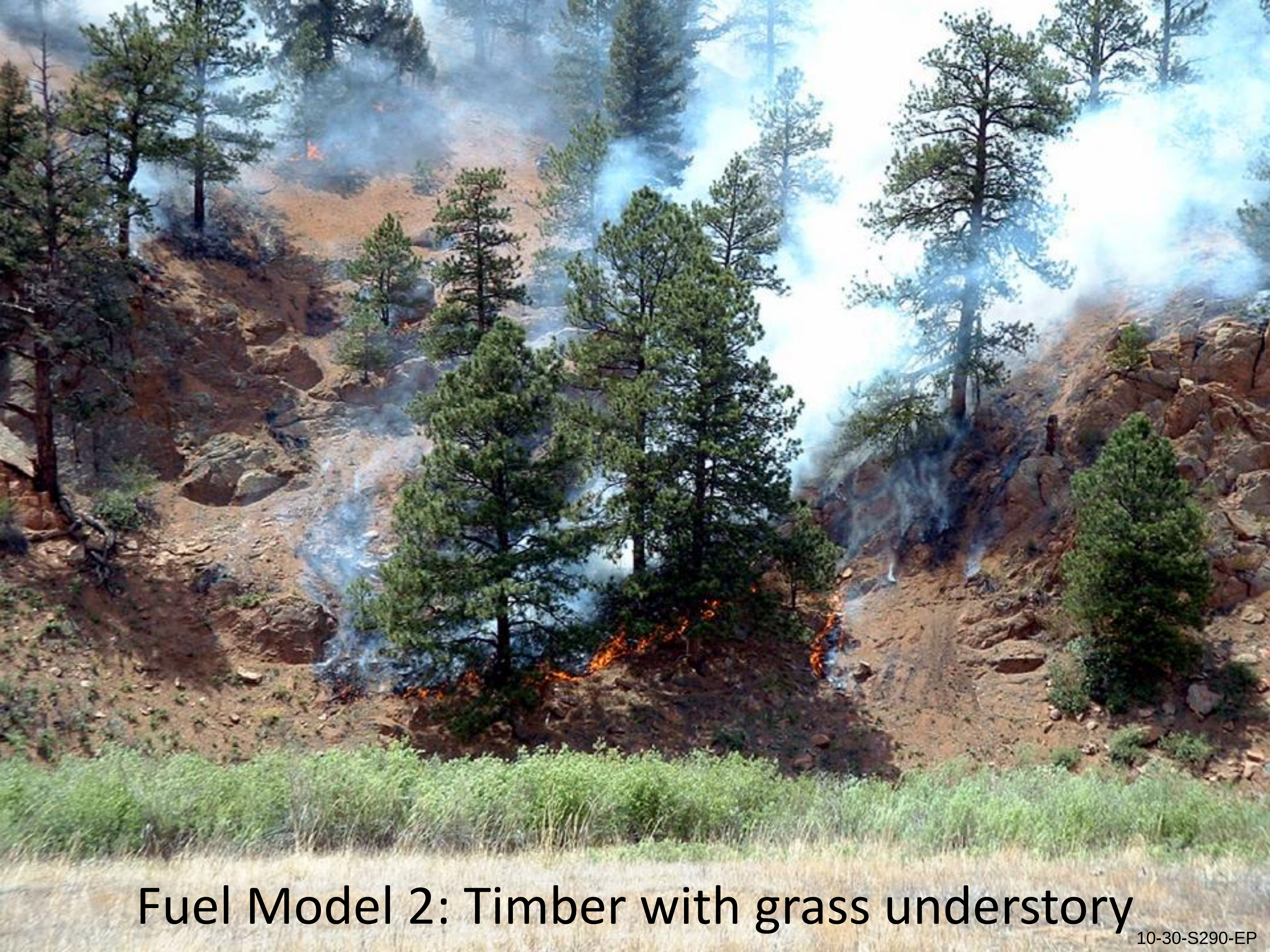




**From Brown (2000)**

# Fuel models relate to the fire regime – recall that:

- Fuel models are is a way of characterizing the typical vegetation of a location
- Simplify some of the complexity among ecosystems
- Provide a range of <u>fuel mass</u> values (kg/ha) in different fuel sizes – this related to the plant community and thus indicative of fire regime



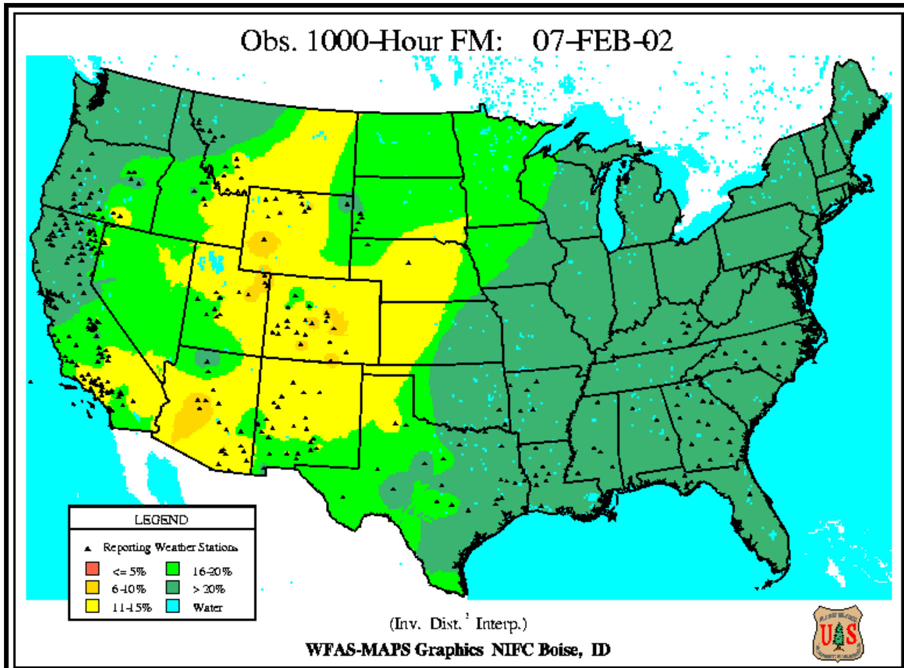
Fuel Model 2: Timber with grass understory

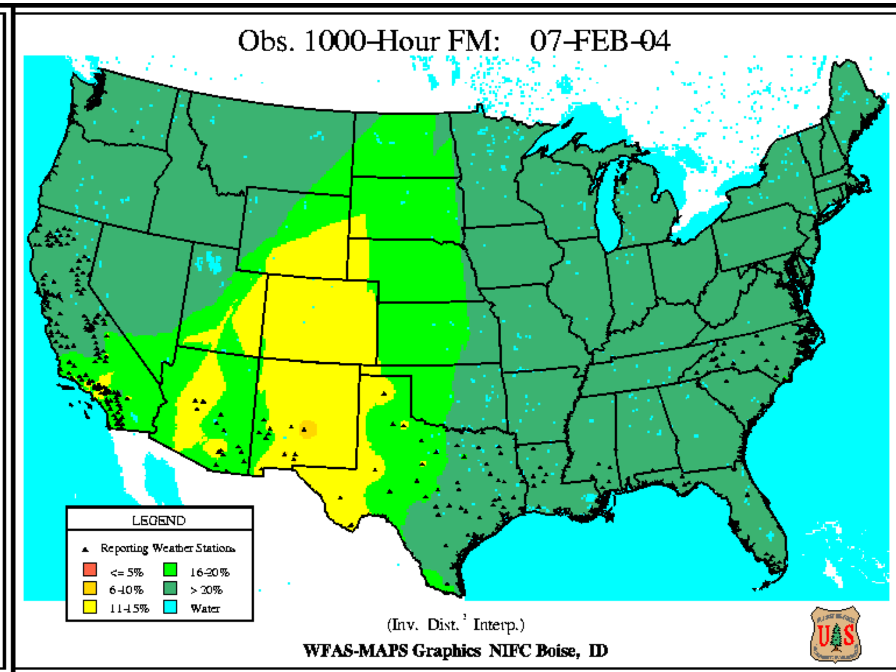
# So:

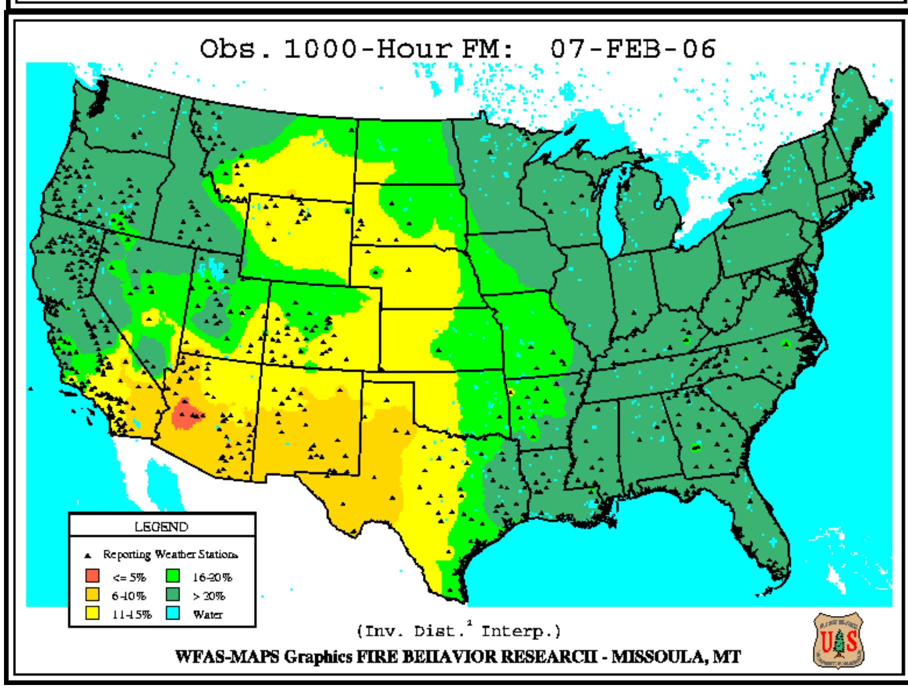
1. Certain fuel models are characteristic of any ecosystem
2. Thus, properties of the ecosystem tend to group into certain kinds of fire behavior
3. This is the basis for geographically consistent fire regimes

# What drives temporal variation in fire regimes?

- “temporal” : over time
- Topography: pretty constant over time scales of decades to millennia
- Vegetation: change at century to longer scales can be abrupt
- **Climate: main time-varying factor**



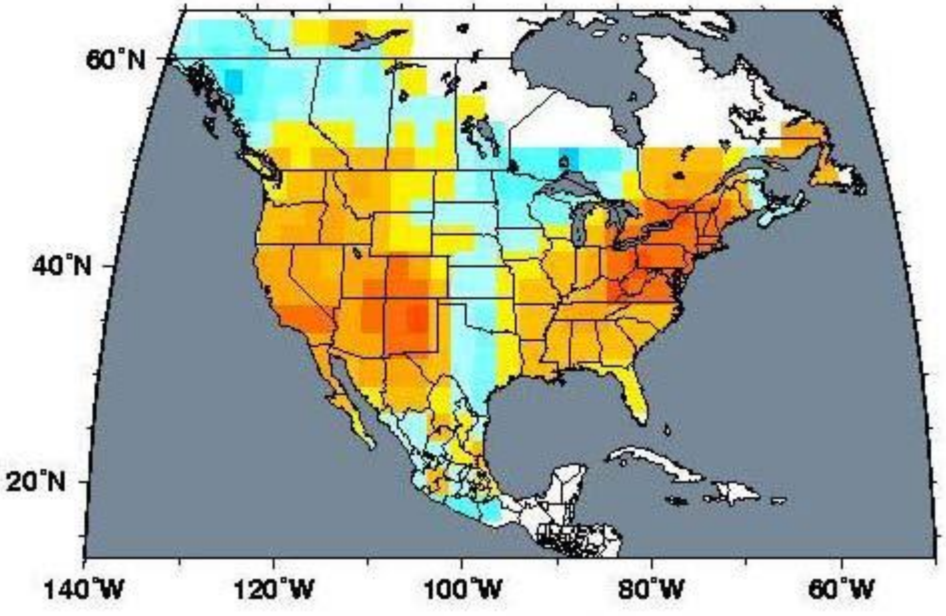

**1000-hour fuel moistures for 7 February in:**

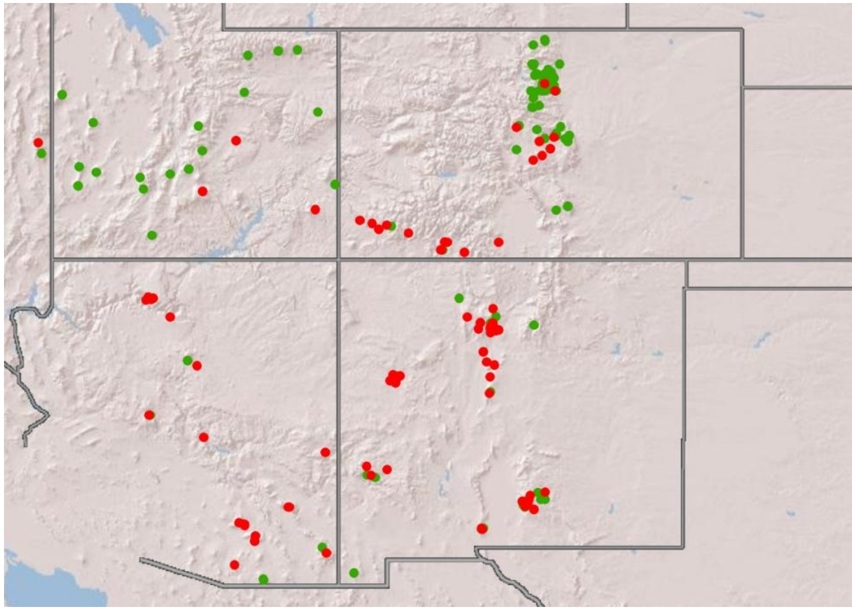
**2002 top left**

**2004 top right**

**2006 bottom left**

# Widespread fire years are almost always associated with regional drought conditions



Left: Reconstructed Palmer drought index for 1748

Right: Reconstructed fire occurrence for 1748

Next: fire regimes in grasslands and prairies

Work on your fire project selections and Fire Ecology exercise