Climate Change Implications for Fire and Invasive Species across American Deserts

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Primary Questions

1) What is currently known about climate drivers of fire and invasive species?
2) What are climate change projections for American Deserts?
3) How will climate change manifest in future fire regimes and spread of invasives?

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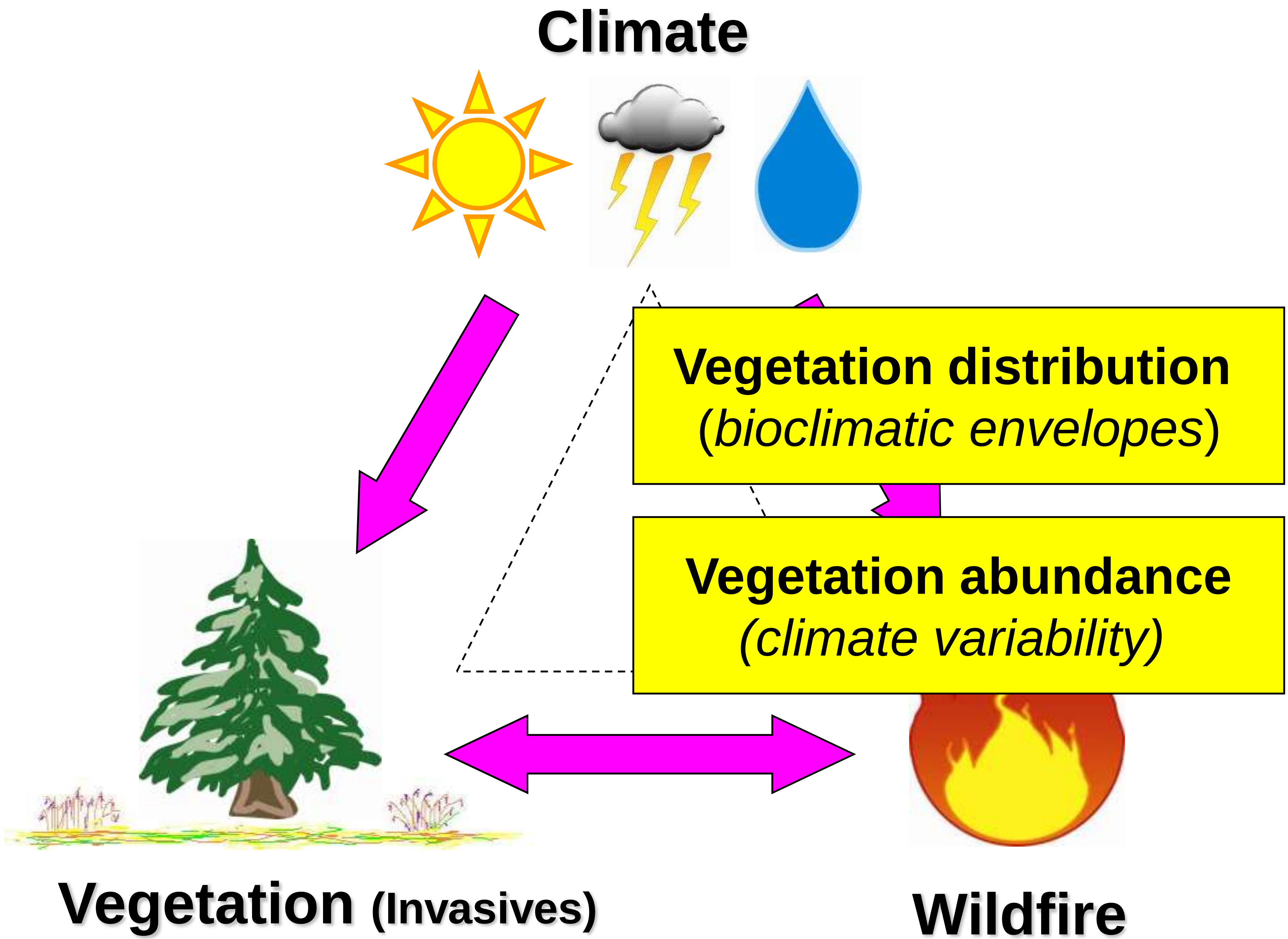
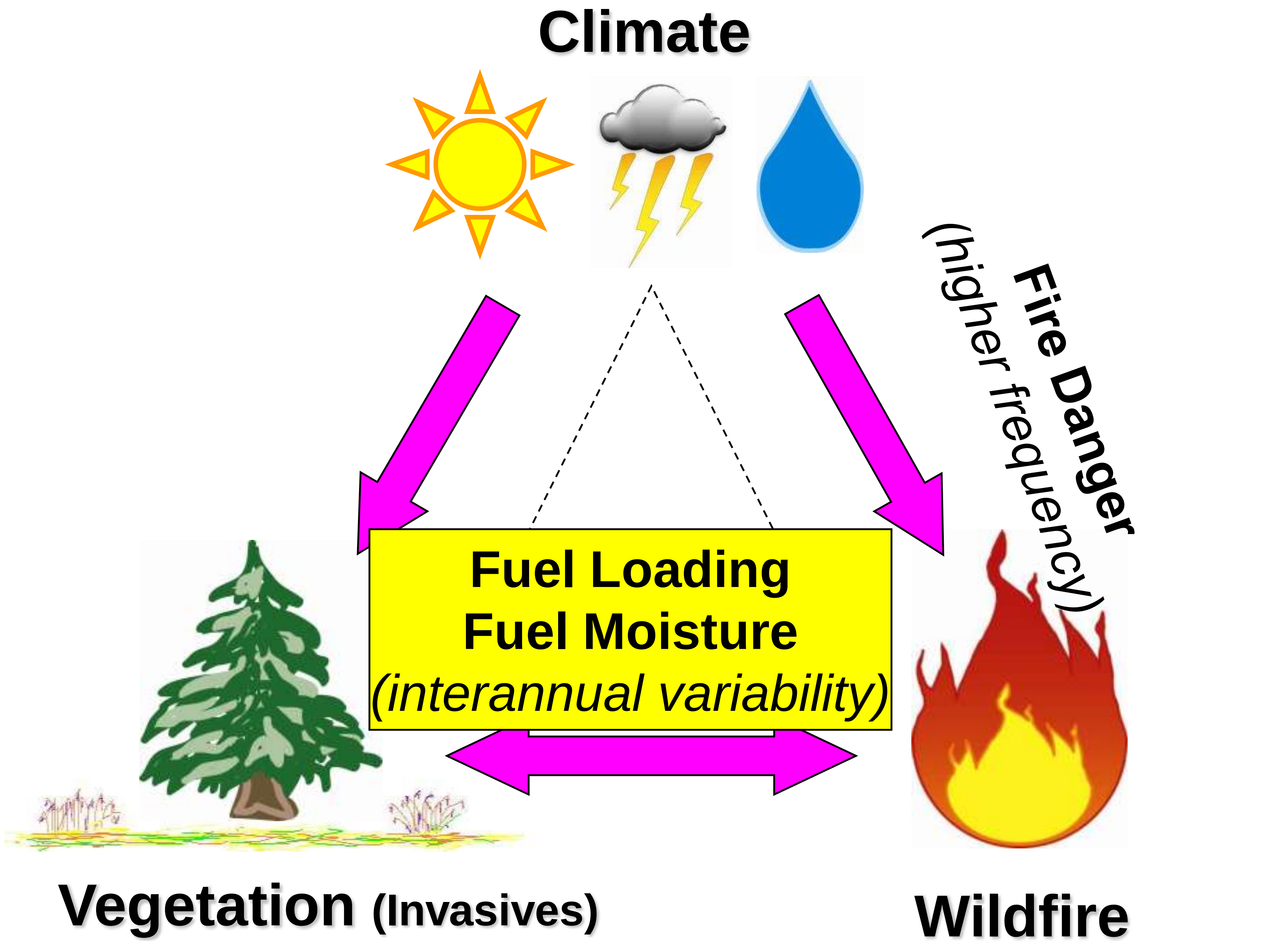


Climate
Vegetation distribution
(bioclimatic envelopes)
Vegetation abundance
(climate variability)
Vegetation (Invasives)
Wildfire



Climate
Fire Danger
(higher frequency)
Fuel Loading
Fuel Moisture
(interannual variability)
Vegetation (Invasives)
Wildfire

State of Knowledge on Fire-Climate Relationships

Two kinds of fire regimes based on fire-climate relationships:

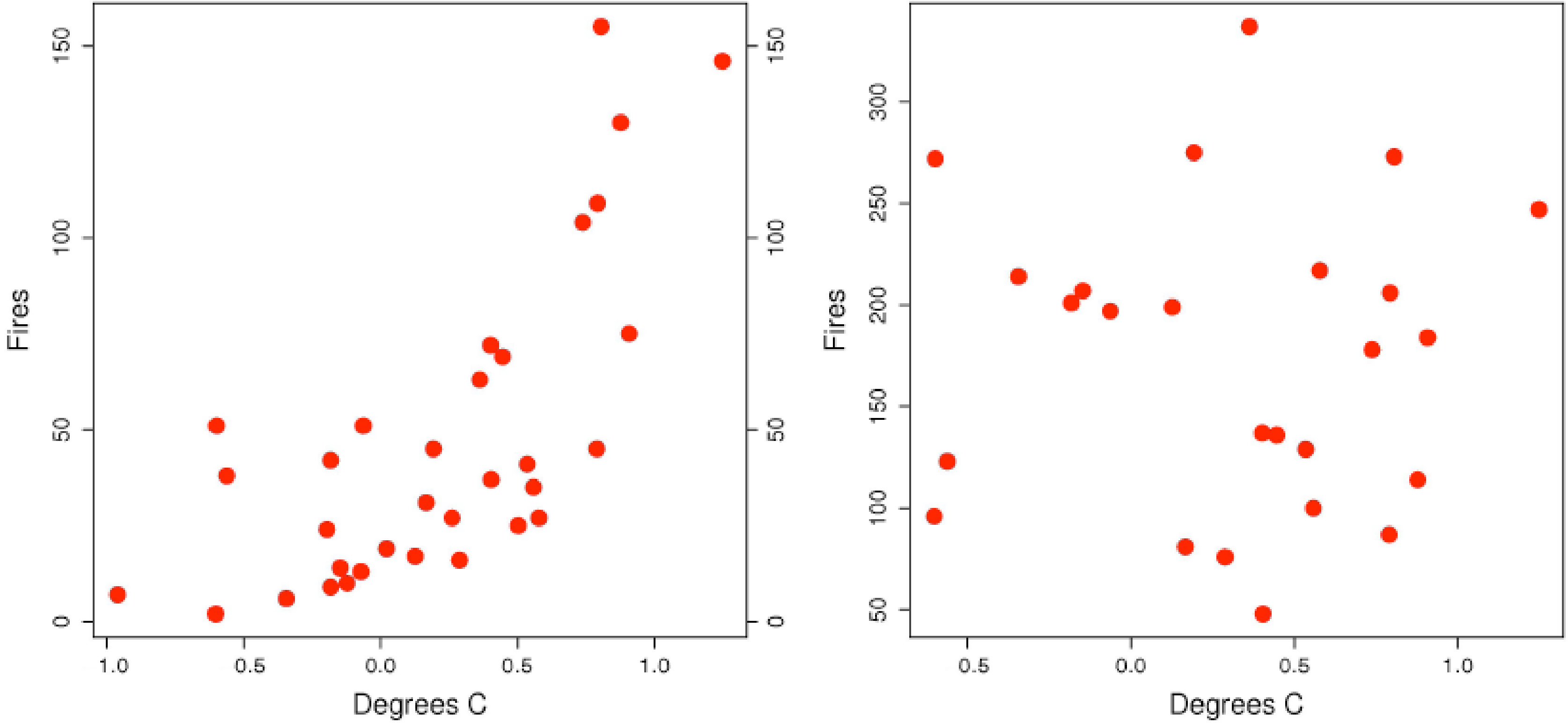
Flammability limited: Mesic environments, continuous fuel bed, not usually dry enough to burn

Fuel limited: Xeric environments, discontinuous fuel bed, always dry enough to burn

State of Knowledge on Fire-Climate Relationships

Ecosystems exhibit differential patterns in climate drivers of fire regimes for the western US

Forest Wildfires **Non-Forest Wildfires**

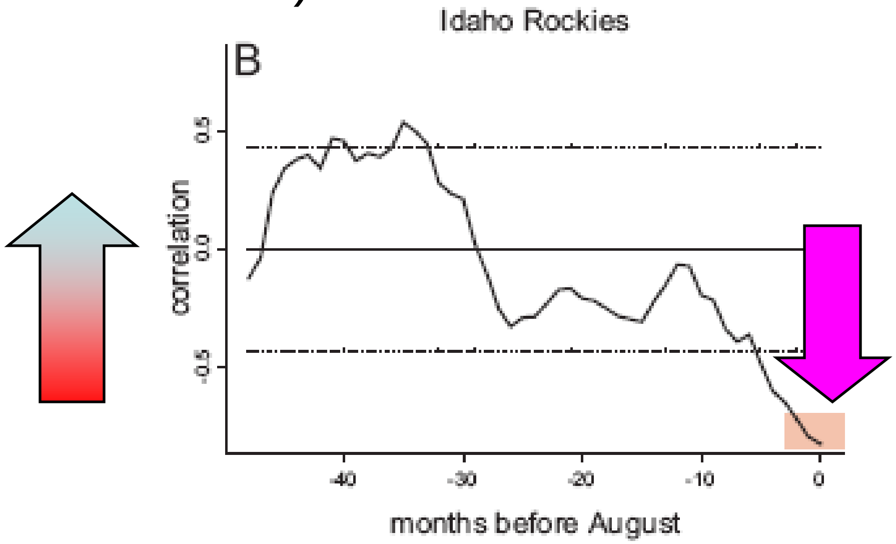


Spring-Summer Temperature Anomaly

(Westerling , 2008)

State of Knowledge on Fire-Climate Relationships

Flammability Limited Systems
(sufficient fuel and moisture)



(Westerling et al, 2003)

Antecedent climate:

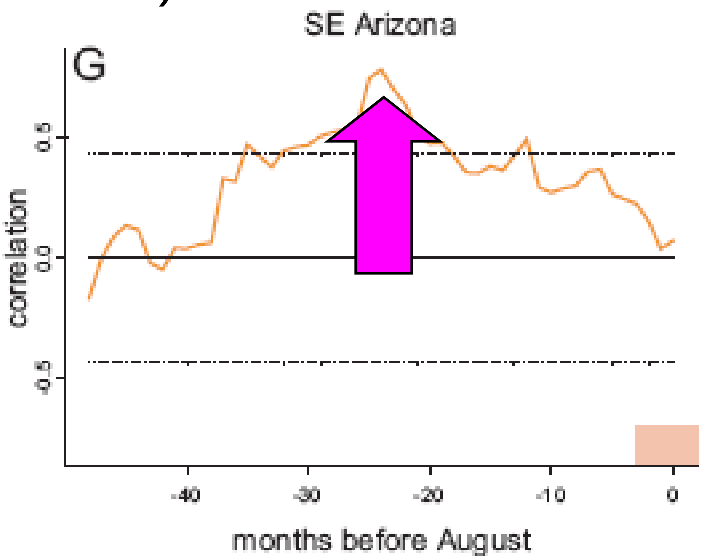
Dry winters + warm springs

Longer fire season "window"

Contemporaneous moisture deficit plays a strong role in increasing fuel flammability

State of Knowledge on Fire-Climate Relationships

Fuel Limited Systems- **American Deserts**
(insufficient fuel and moisture)



(Westerling et al, 2003)

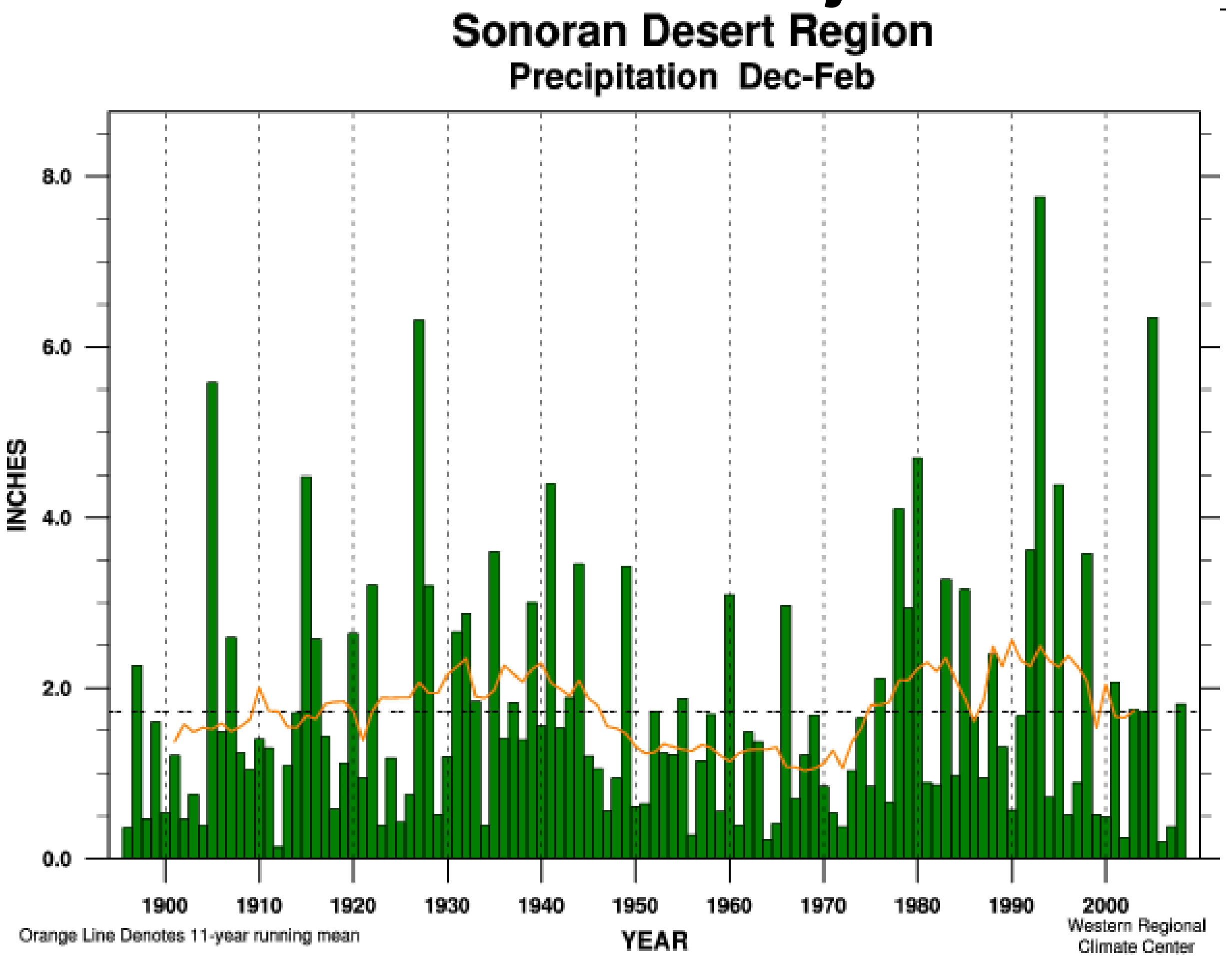
Antecedent climate:

- Moisture abundance drives increased fuel loading
- Perennials accumulate biomass through a moderate response to moisture availability (**1-2 year lag)**

Leading moisture surplus (1-2 years) enhances fuel loading

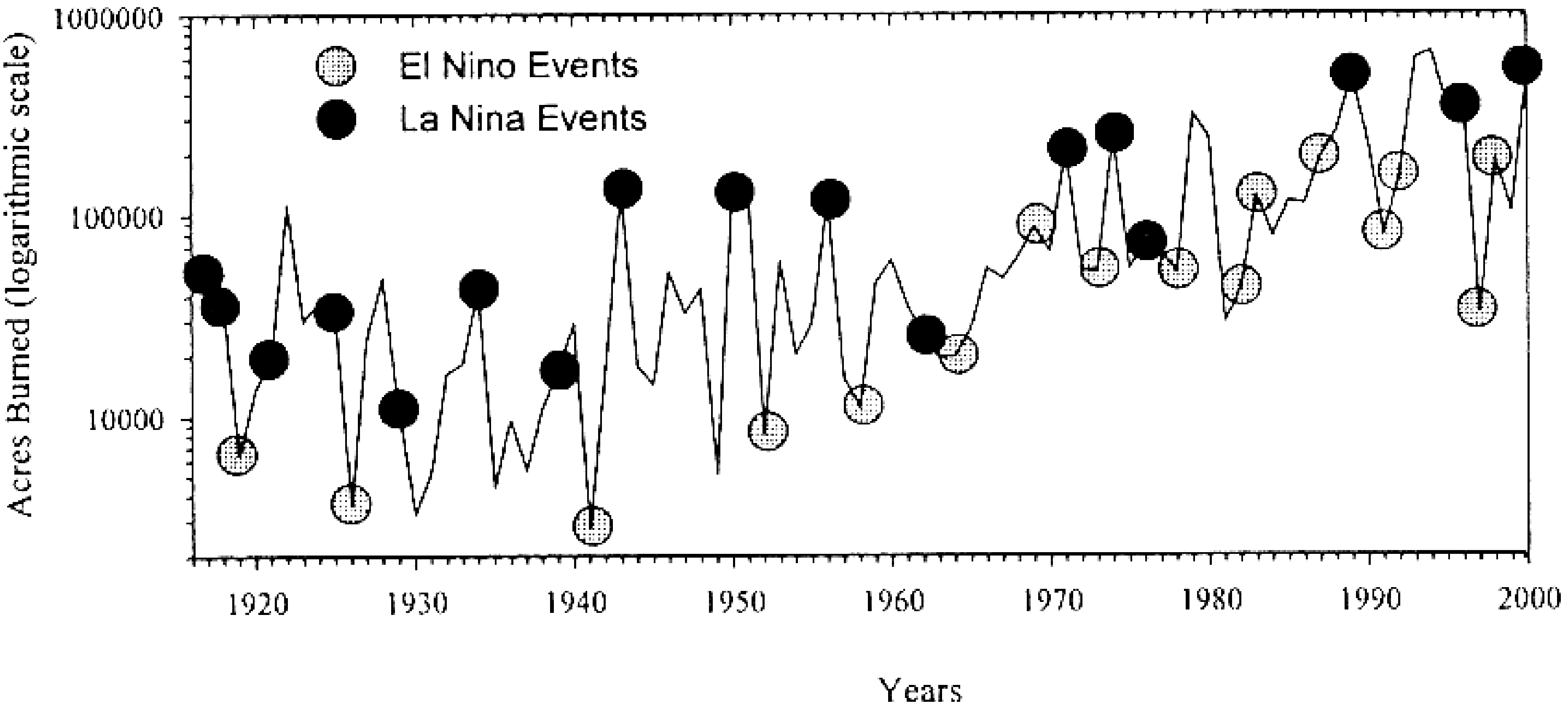
State of Knowledge on Fire-Climate Relationships

CLIMATE includes more than just the means…



State of Knowledge on Fire-Climate Relationships

Fire-ENSO Relationship Across the Southwest



**Swetnam and Baisan, 2003*

State of Knowledge on Fire-Climate Relationships

Fire-ENSO Relationship: **Based on ENSO dipole**

Pacific NW

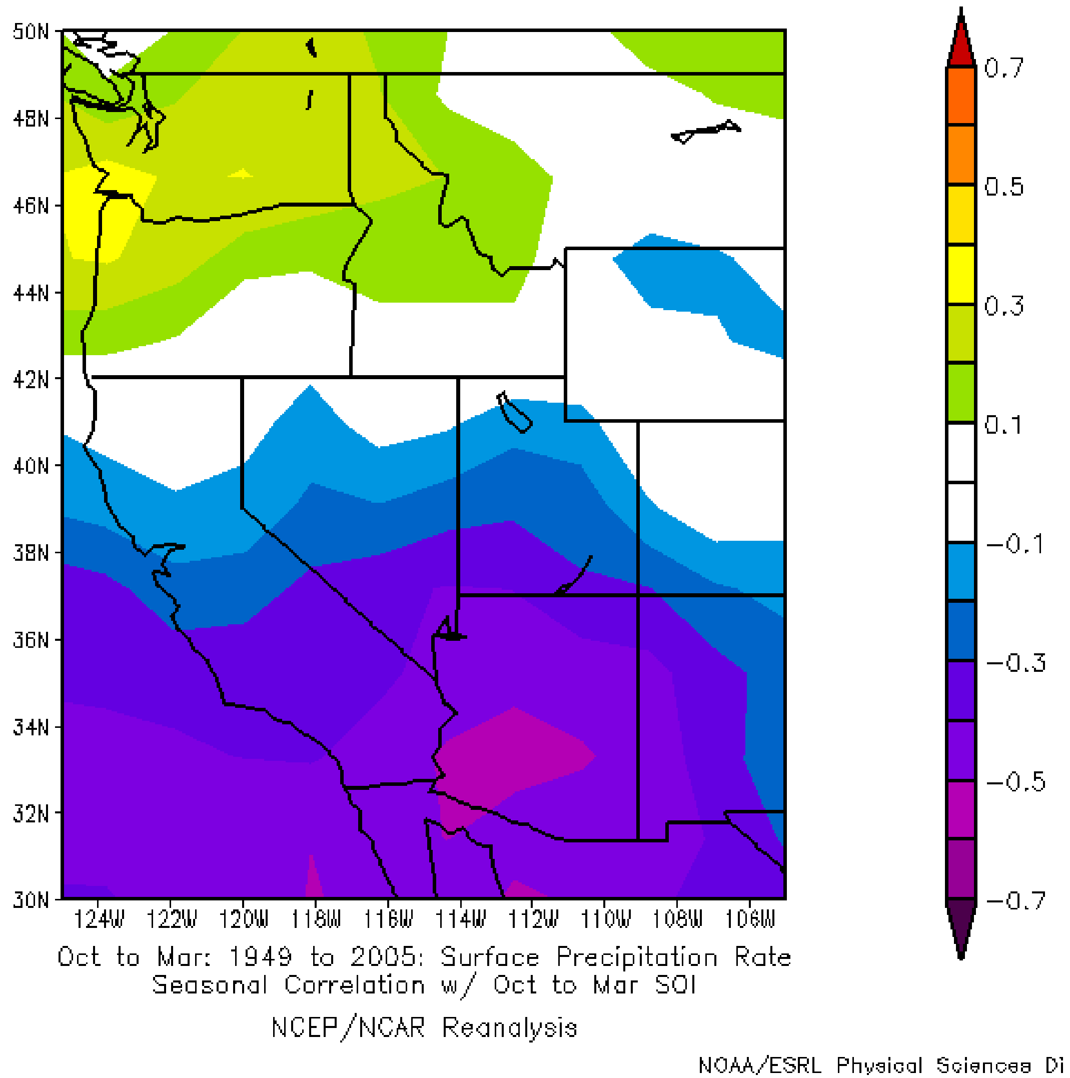
El Nino: dry

La Nina: wet

Southwest

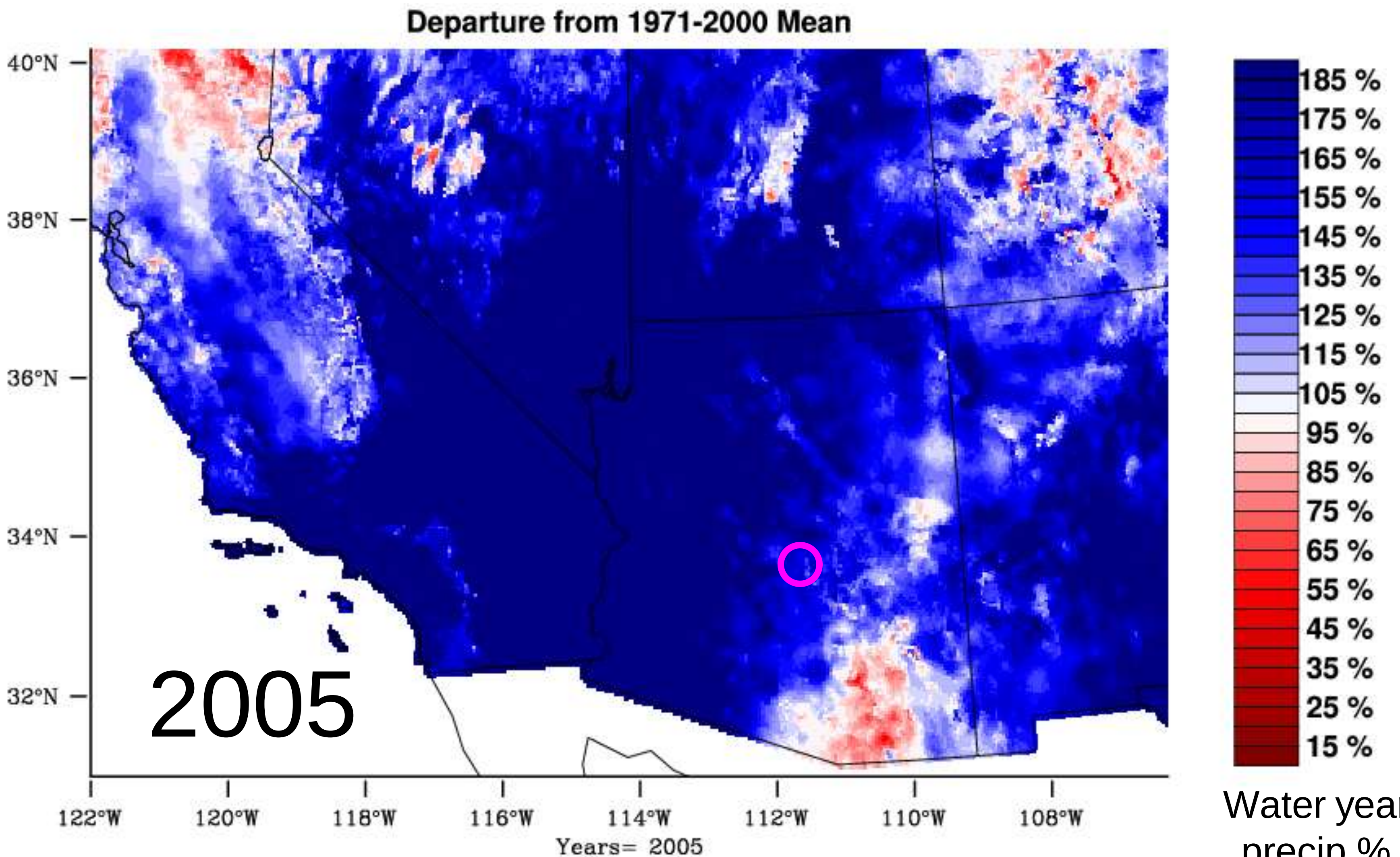
El Nino: wet

La Nina: dry



State of Knowledge on Fire-Climate Relationships

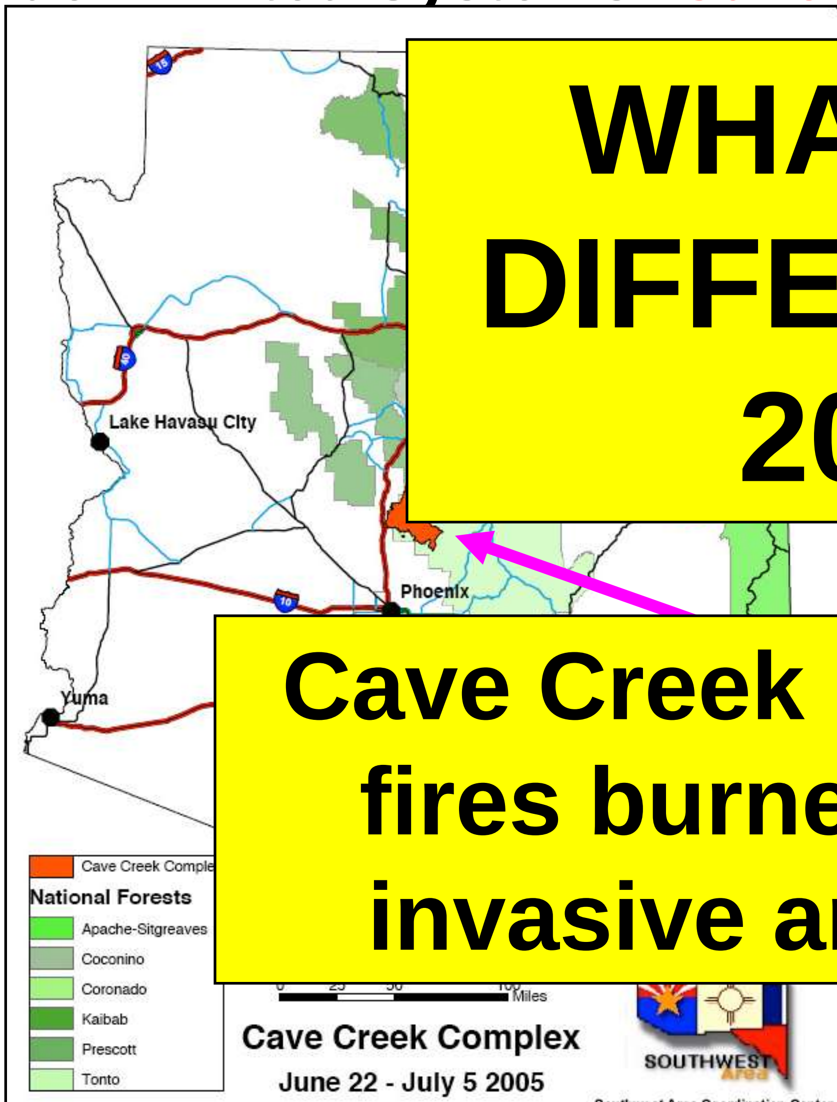
2004-05: Weak to Moderate El Nino

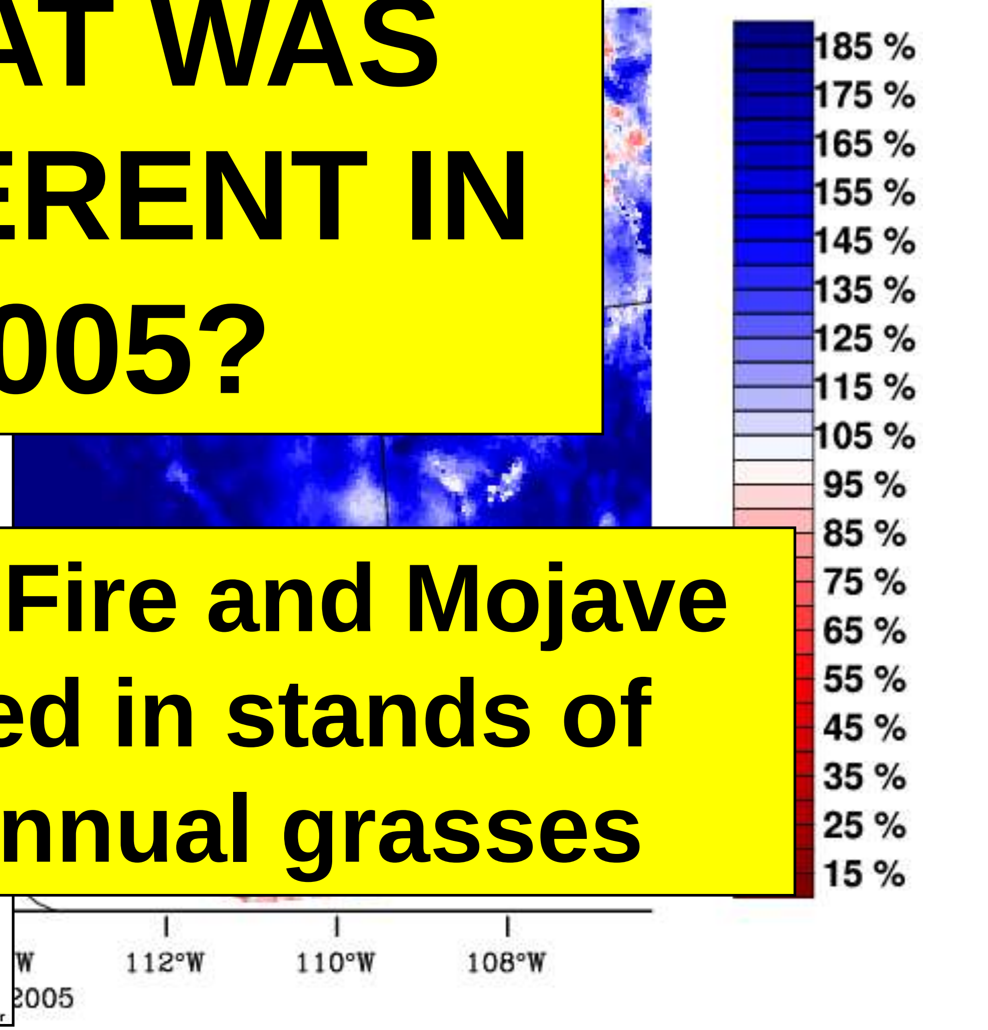


Water year
precip %

State of Knowledge on Fire-Climate Relationships

Fuel Limited Systems- Cave Creek Fire (2005), 100K ha

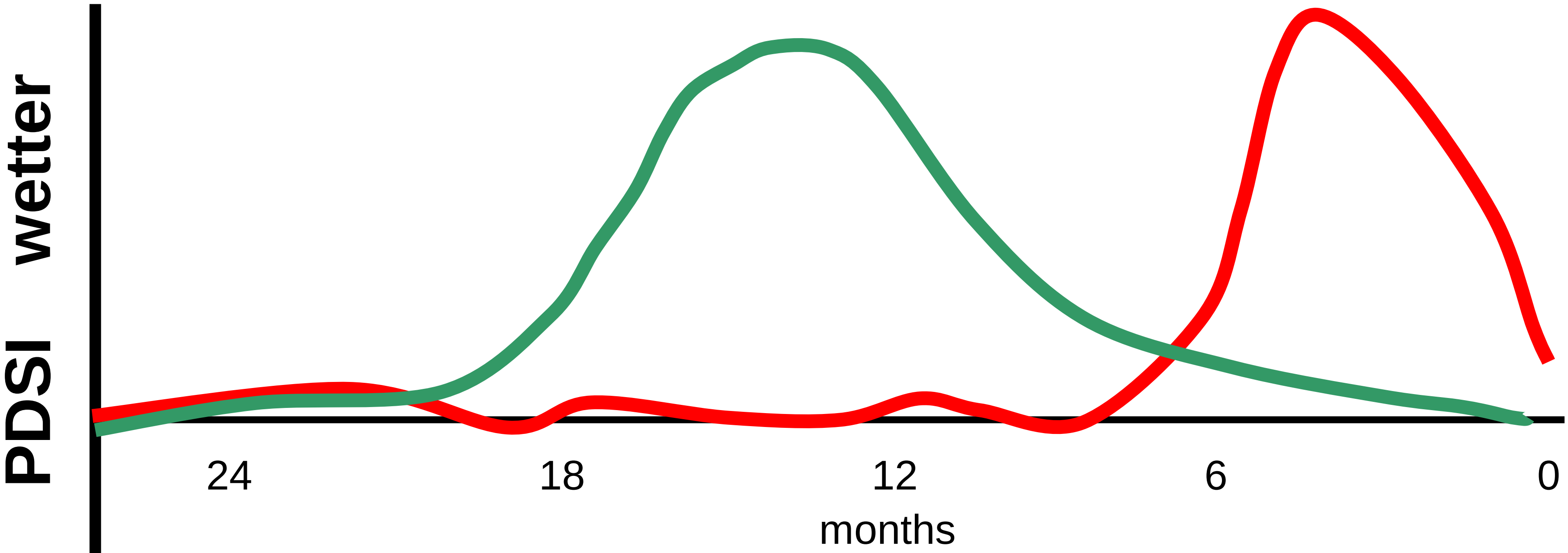




WHAT WAS DIFFERENT IN 2005?

Cave Creek Fire and Mojave fires burned in stands of invasive annual grasses

“New” Fire-Climate relationship in an invaded landscape?



Pre-Invasives: 1-2 year lag in moisture anomaly for fuel loading to peak and wildfire potential to be enhanced

Post-Invasives: < 6 month lag in moisture anomaly to enhanced fuel loadings and wildfire potential

Primary Questions

1) What is currently known about climate drivers of fire and invasive species?
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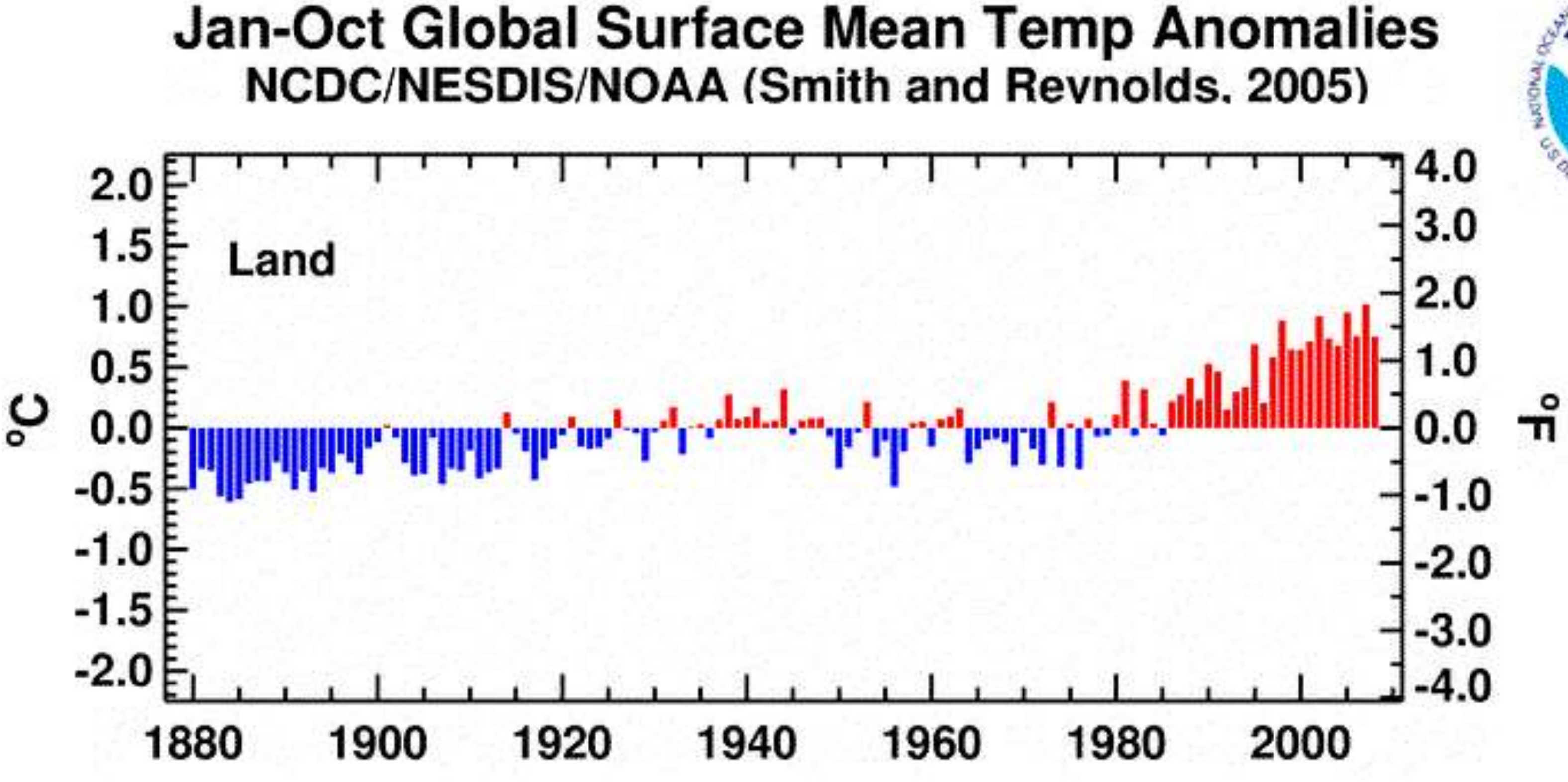
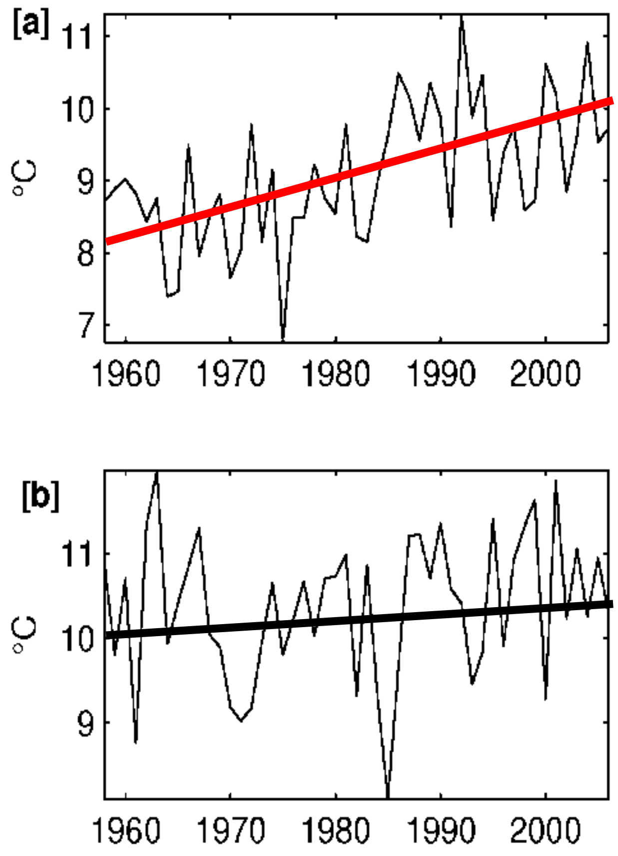
Observations of Change



Oct 2008: Warmest Global Land Surface Temperature
Calendar Year to Date: 6th warmest on record (2007 warmest)

Observations of Change

Beyond just mean annual temperature…



Spring:
+0.28˚C/decade

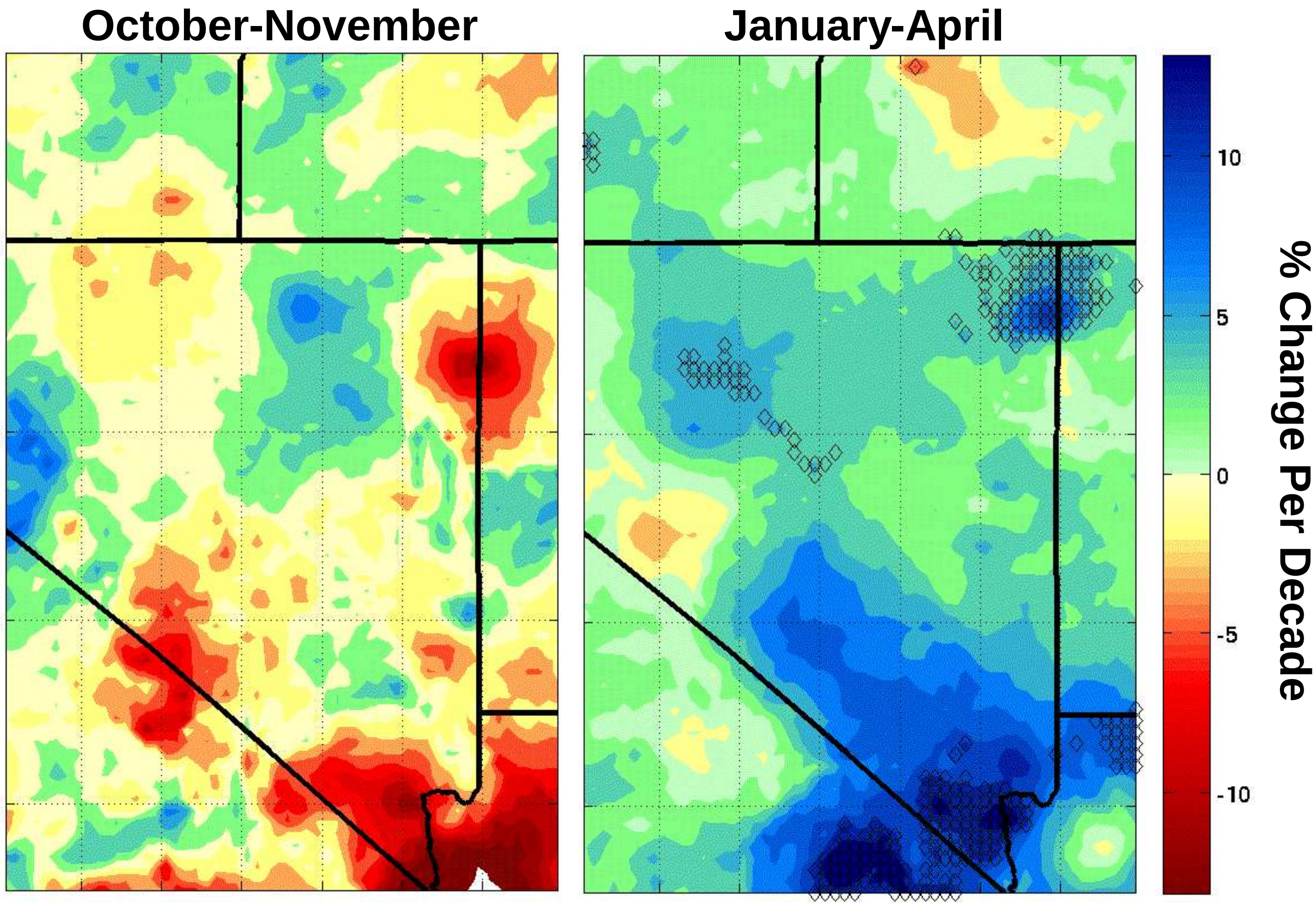
Autumn:
+0.07˚C/decade

Areal Average of 11 Western States

Abatzoglou & Redmond, 2007

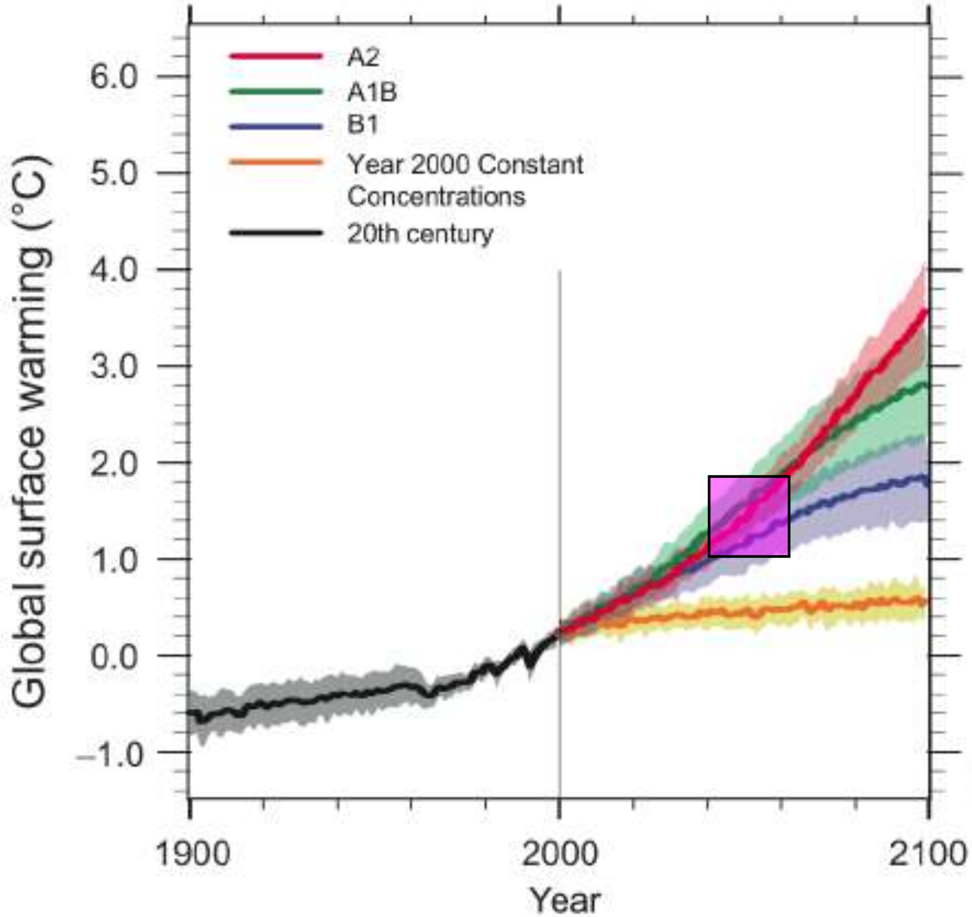
Observations of Change

Asymmetric Trend in Cool Season Precipitation



Linear Trend 1958-2006

Projections also based on Emissions Scenarios



IPCC AR4

Envelopes: Range of Expected Conditions from models

The “unknowns” = many models (GCMs)

SRES-A1B Emission Scenario

↓

Climate Models

IPSL CM4	BCCR BCM2.0	GFDL CM2.0	GFDL CM2.1	CGCM T47	CGCM T63	MIROC hires	MIROC medres

FGOALS	INM	NASA	MRI	CNRM CM3	ECHAM5	CSIRO MK3.5

<u>Projections in 5-Dimensions</u>

Time

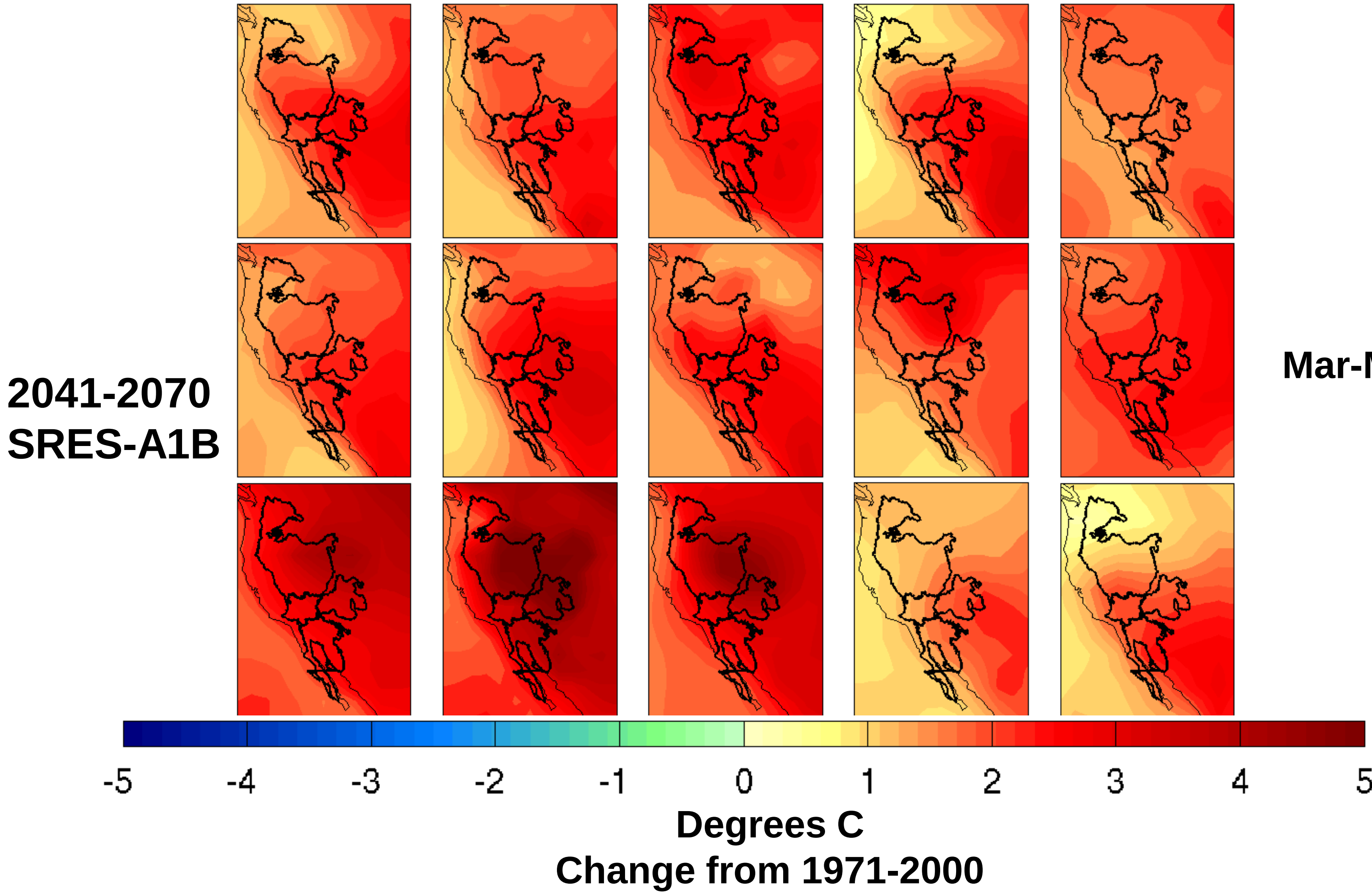
Space (3-D)

Probability

Climate Change ***(2˚x2˚ horizontal resolution)***

ΔTemp, Δ Precipitation, Δ Relative Humidity, Δ Wind Speed

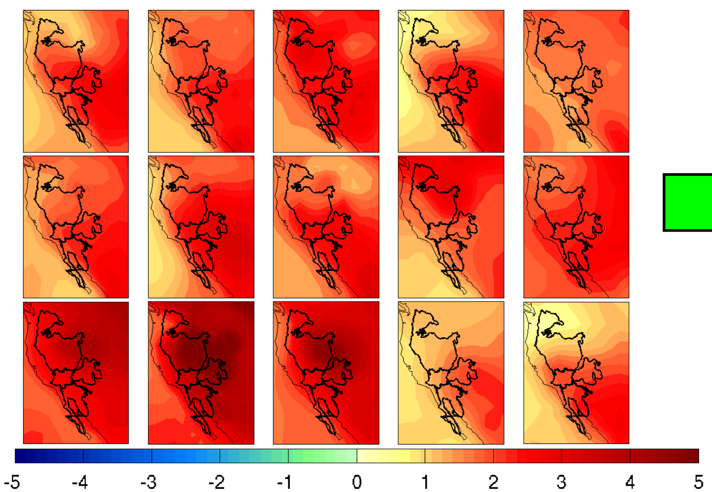
Many models = many projections (some commonality)



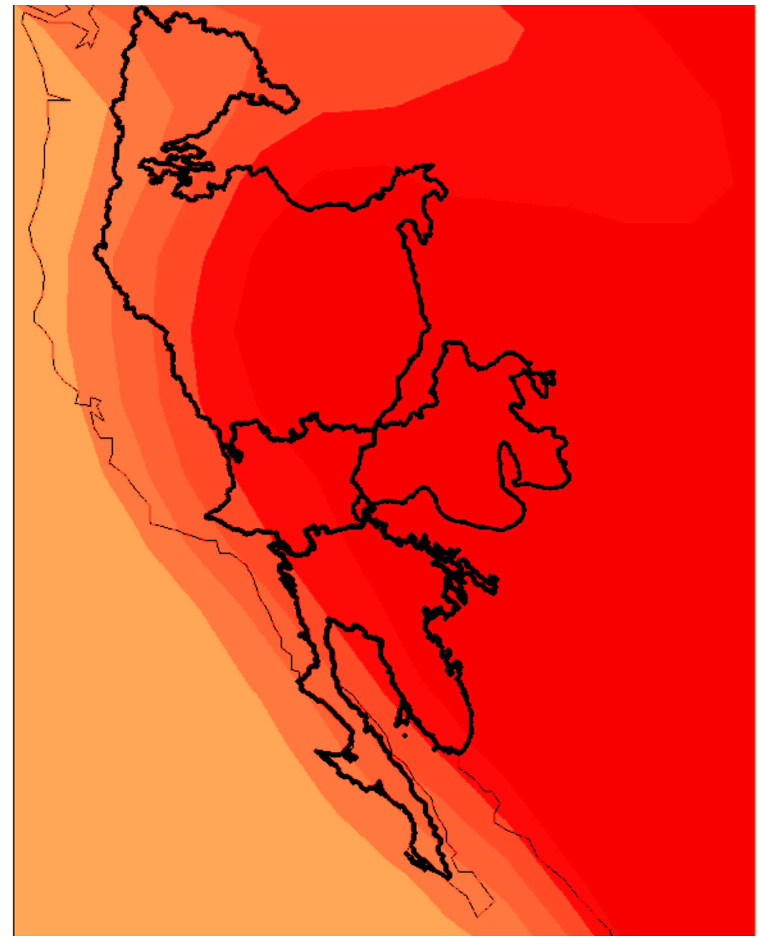
Basic projections: warming in western US

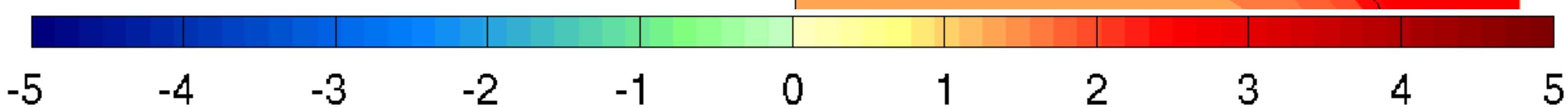
Forming a consensus of Future Climate Change

“High degree of Certainty”



Degrees Celsius Change from 1971-2000





Mar-May

Basic projections: warming in western US

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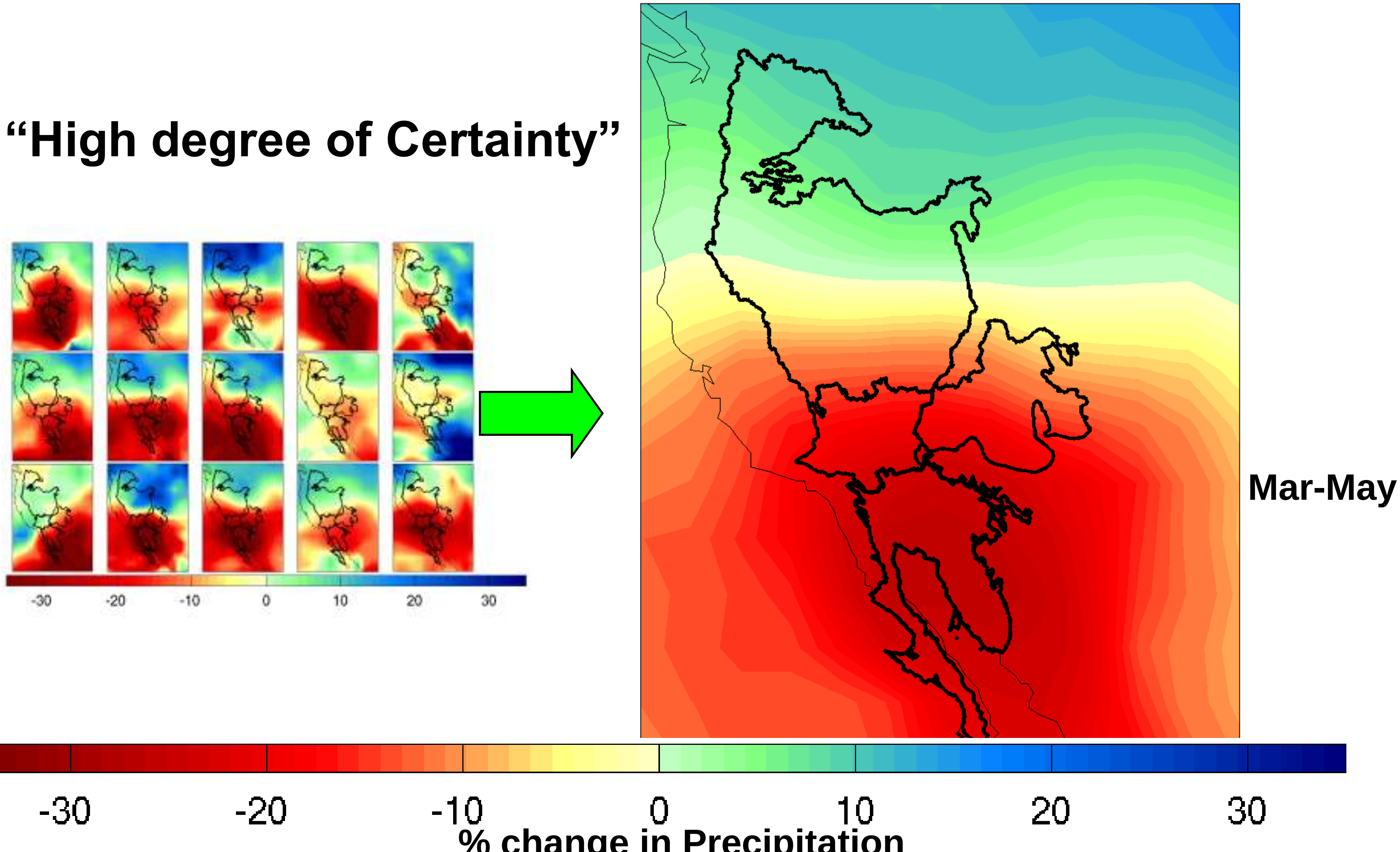
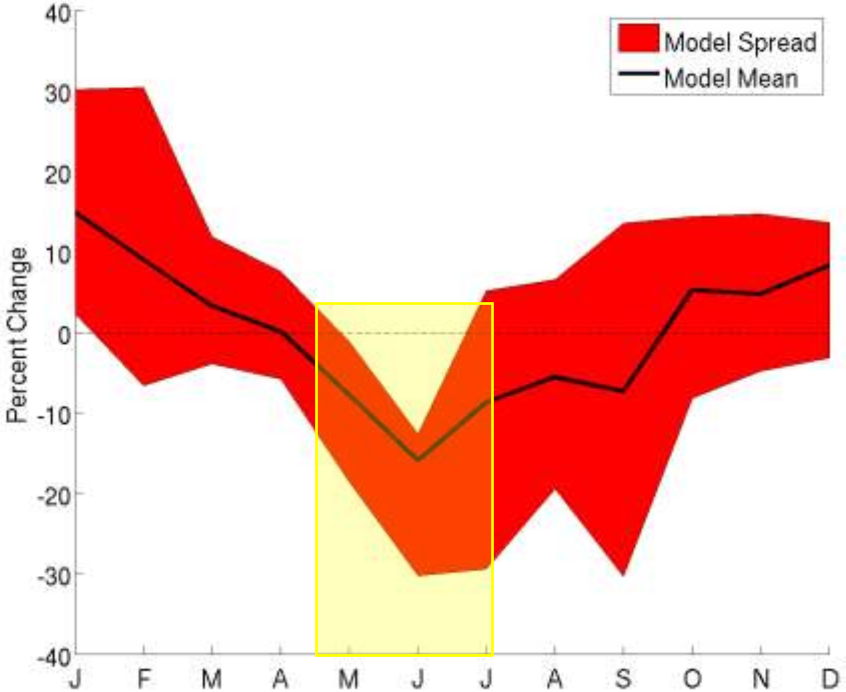


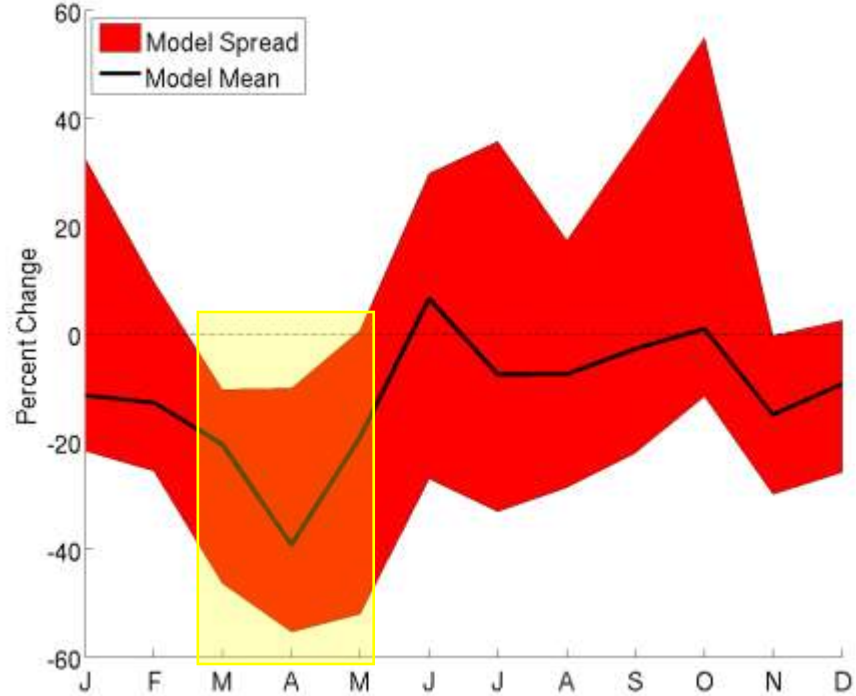
Basic projections: meridional dipole in spring precipitation

Seasonal Differences in Precipitation

Great Basin Desert

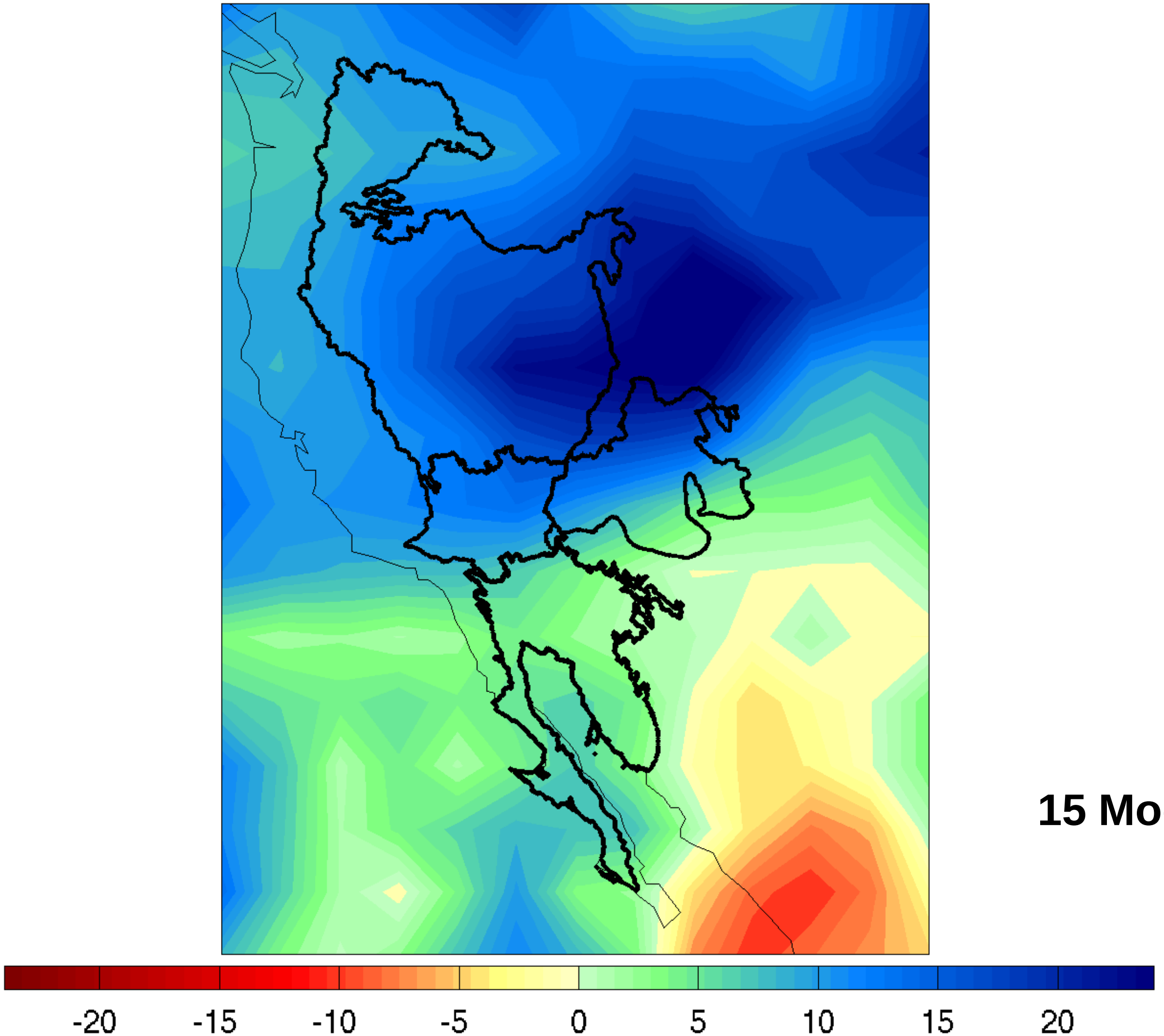


Sonoran Desert



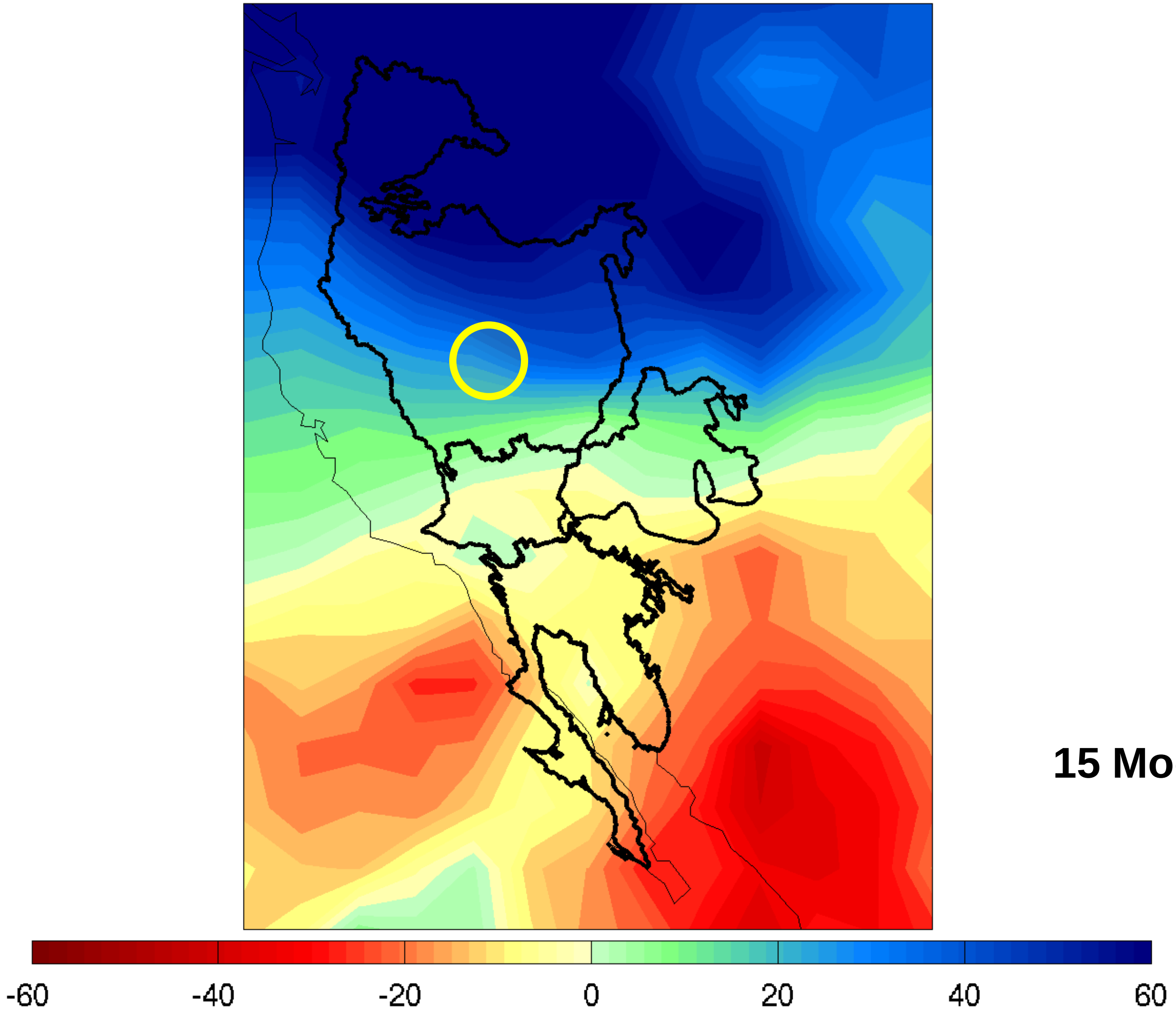
Basic projection: Drier during “Fire Season”

Basic projections: increased variability in winter precipitation



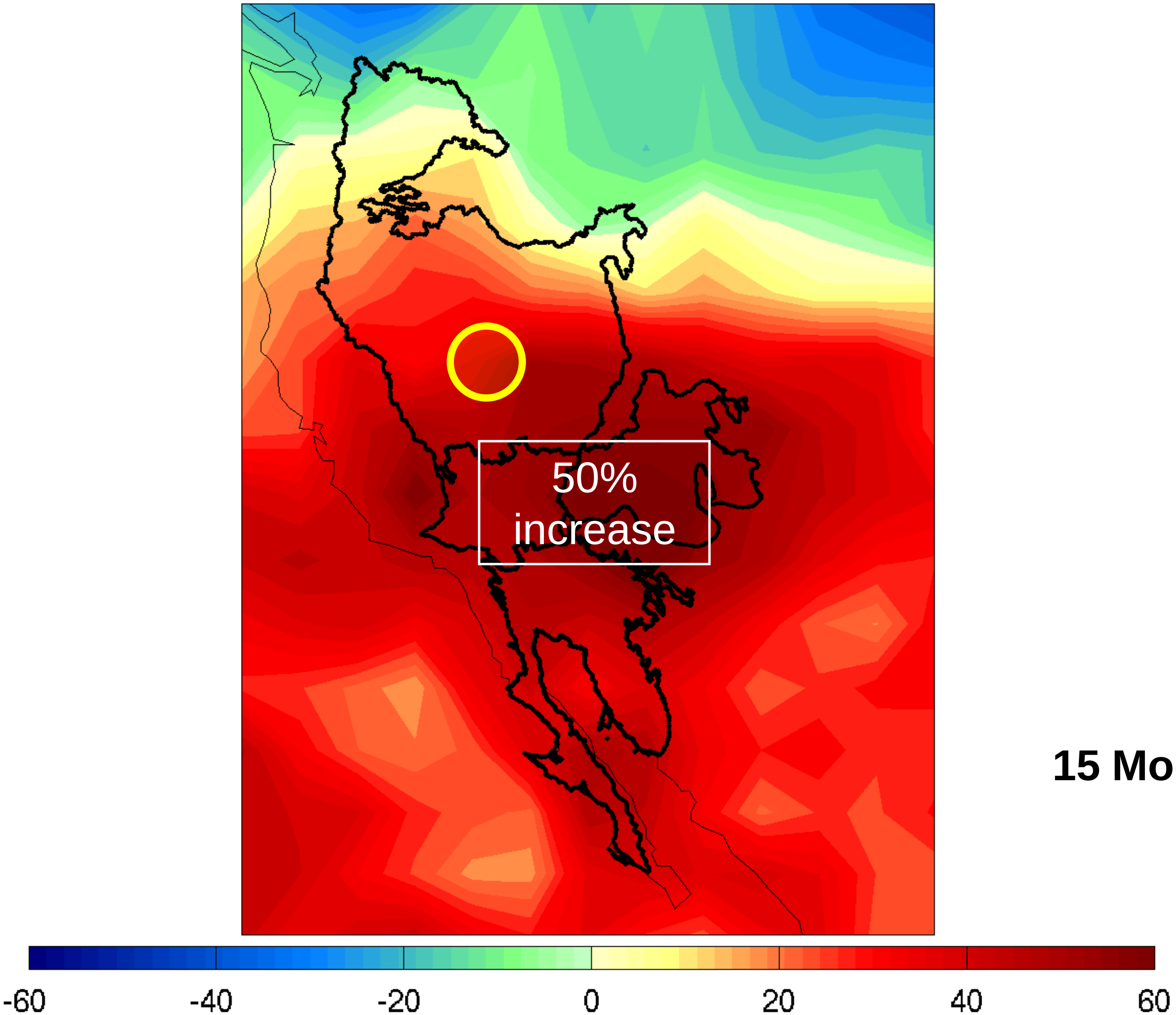
15 Model Median

Projections: potential for a “wet” winter



15 Model Median

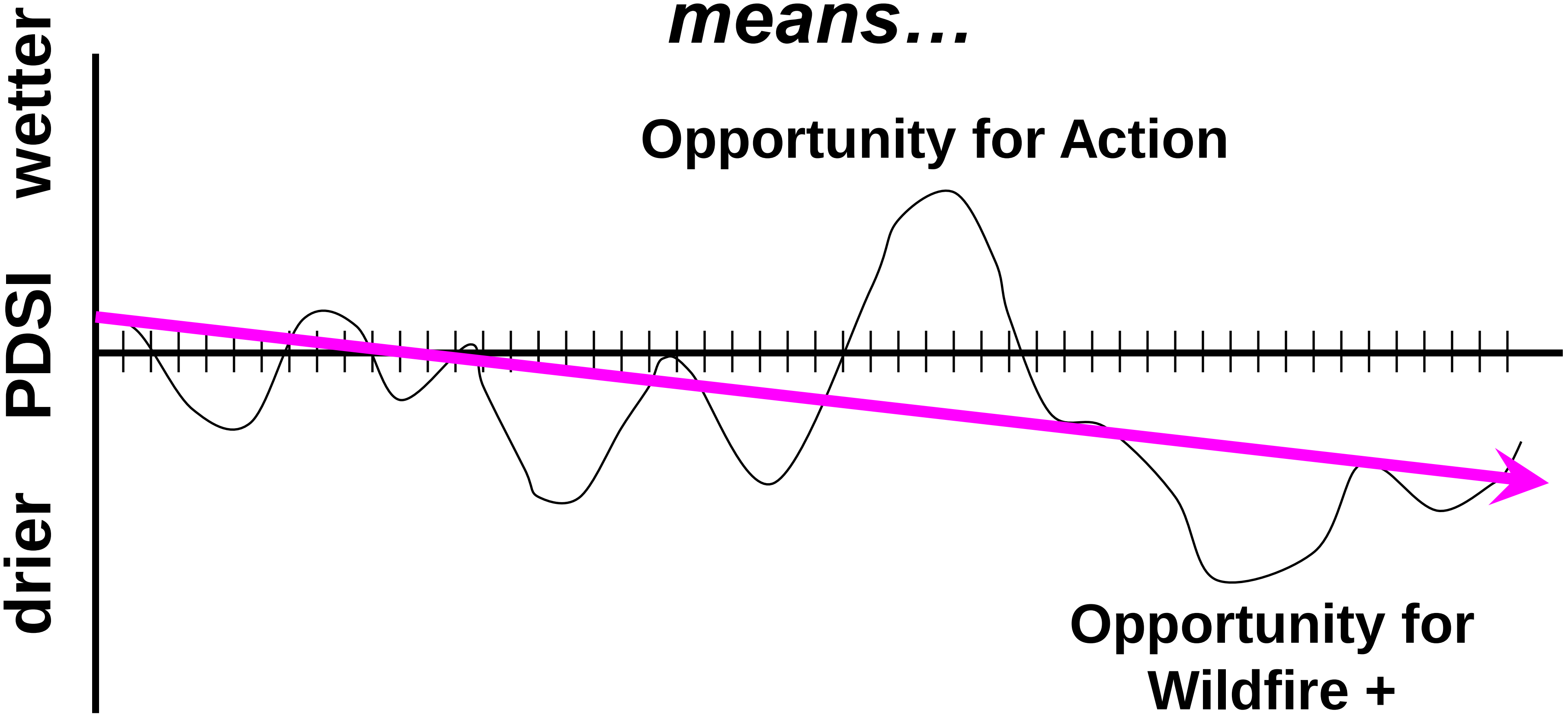
Basic projections: potential for a “dry” spring



15 Model Median

Opportunistic Management

Climate Variability means…



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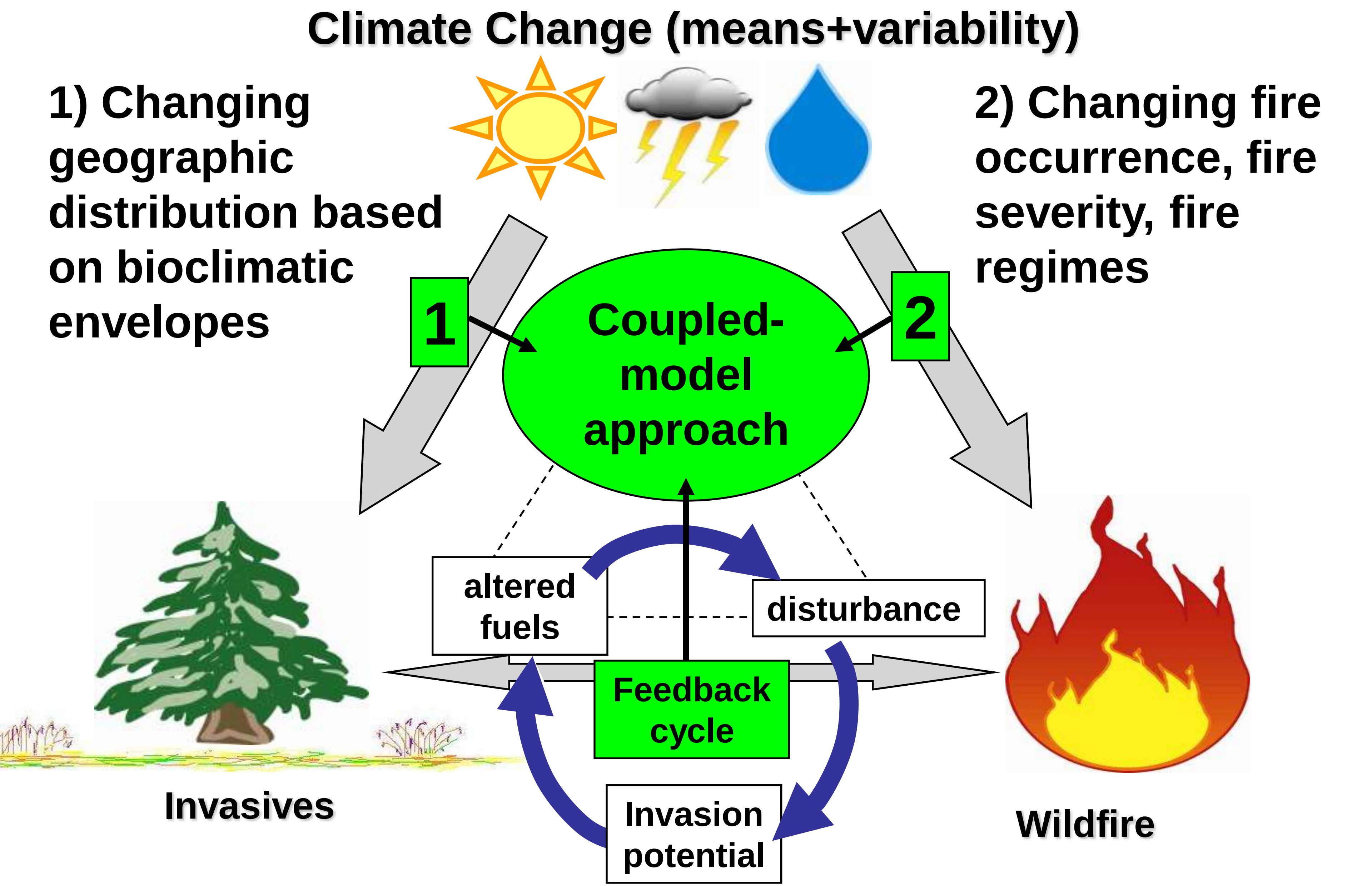
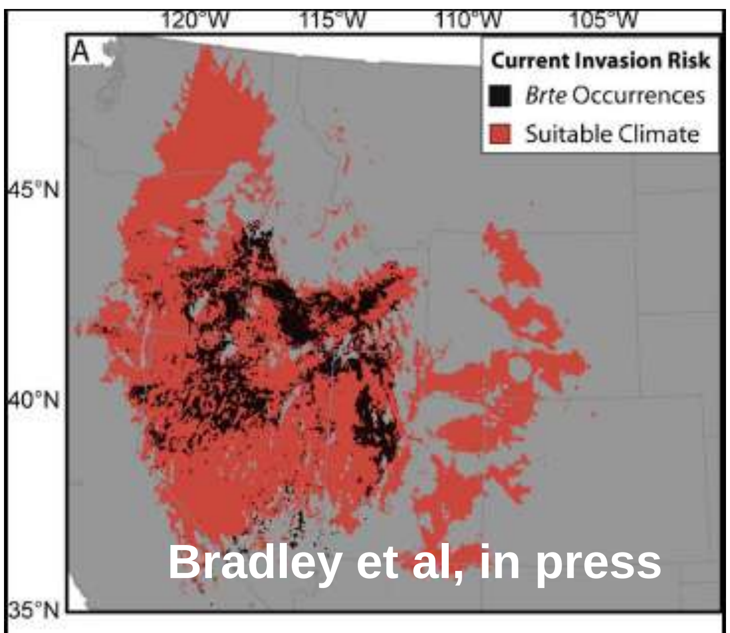
Impacts on fire and invasives

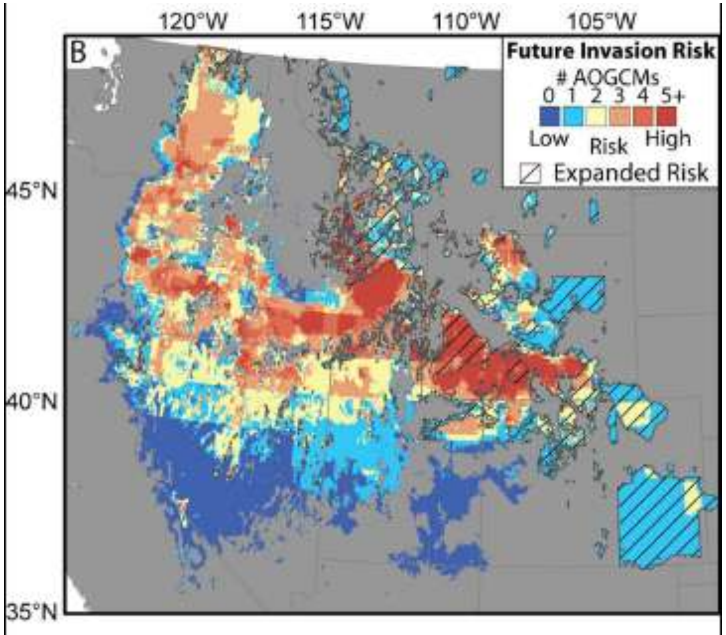


Impacts on fire and invasives

1) Changing geographic distribution based on bioclimatic envelopes

- Requires an understanding of bioclimatic thresholds through predictive vegetation models … assuming stationary vegetation…
- Development of these models requires presence/absence maps and spread maps (not yet done for invasives at landscape scales)
- **Bioclimatic envelope needs to include climate variability**

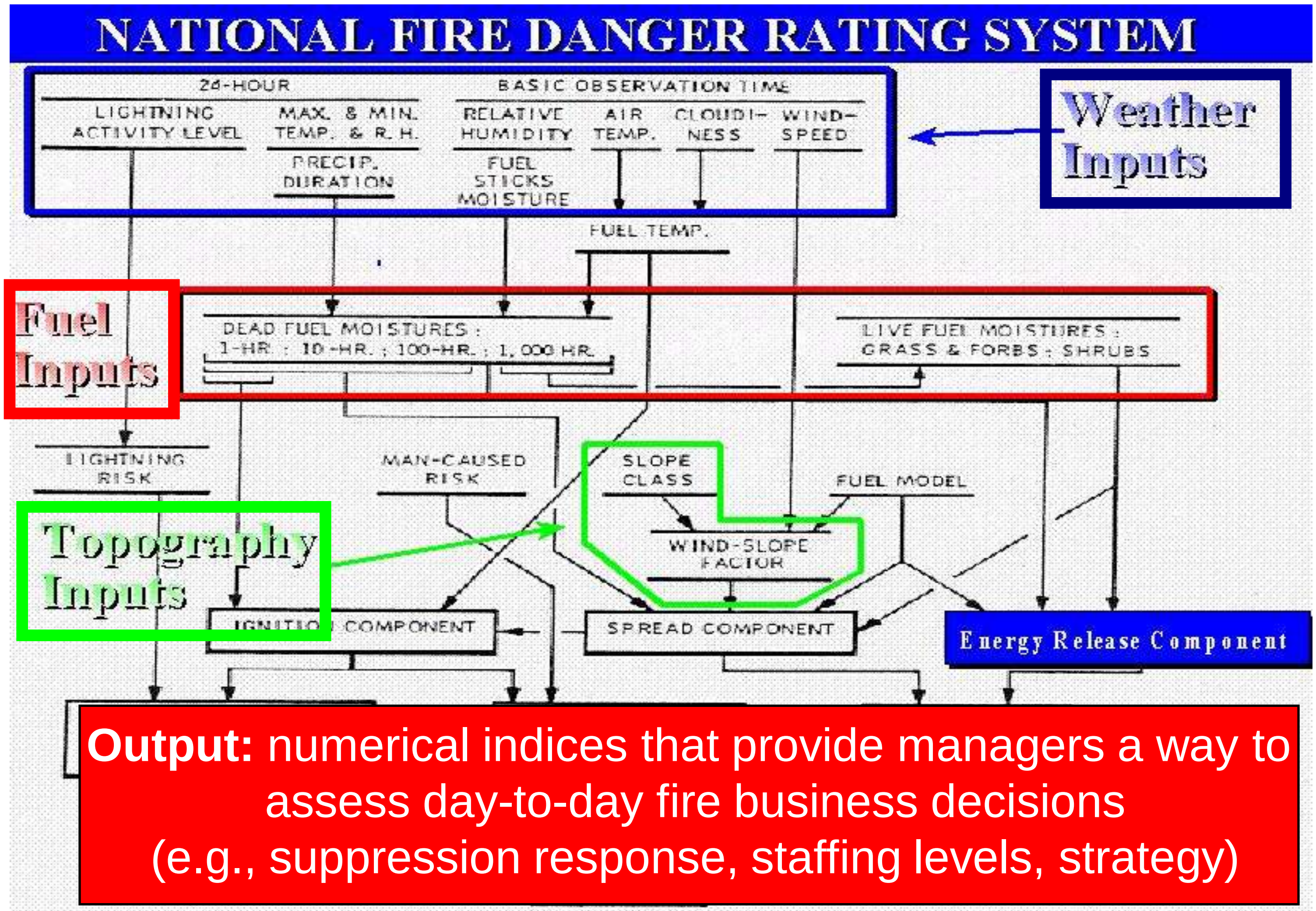




Bradley et al, in press

Impacts on fire and invasives

2) Changing fire danger – based on NFDRS



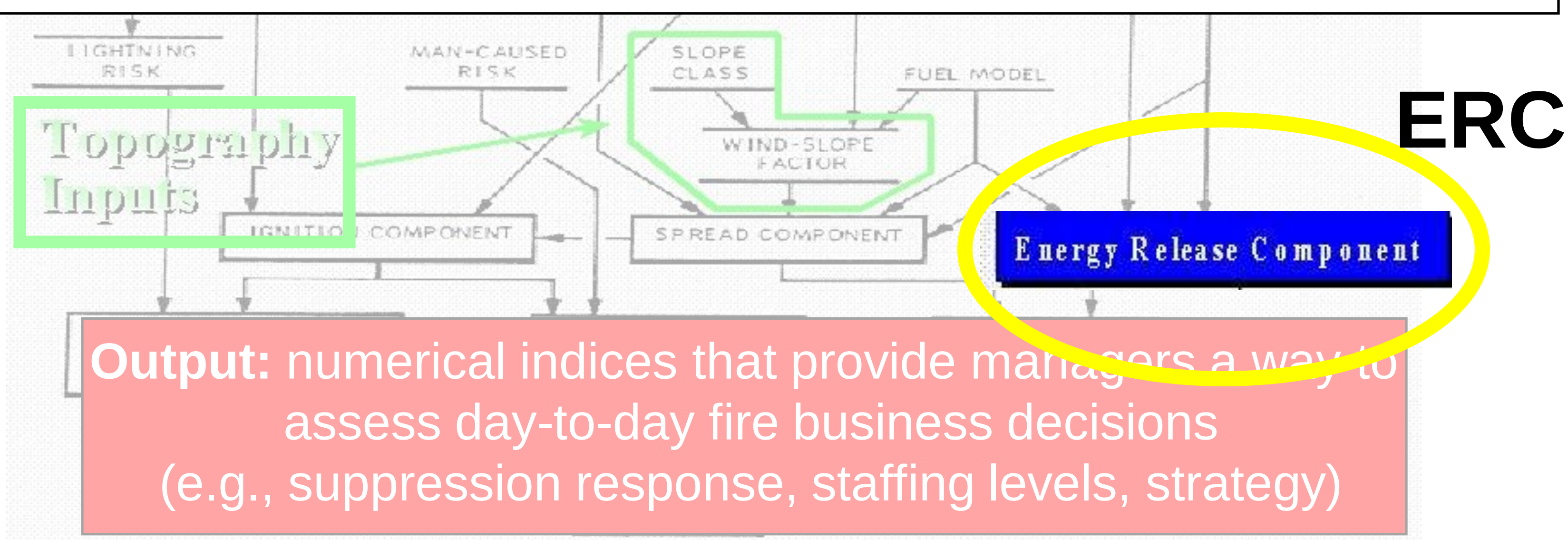
Output: numerical indices that provide managers a way to assess day-to-day fire business decisions (e.g., suppression response, staffing levels, strategy)

Impacts on fire and invasives

1) Changing fire danger – based on NFDRS

Energy Release Component (ERC): potential fire intensity

Extreme Fire Danger: 97th percentile ERC for the historical period (1980-2007)

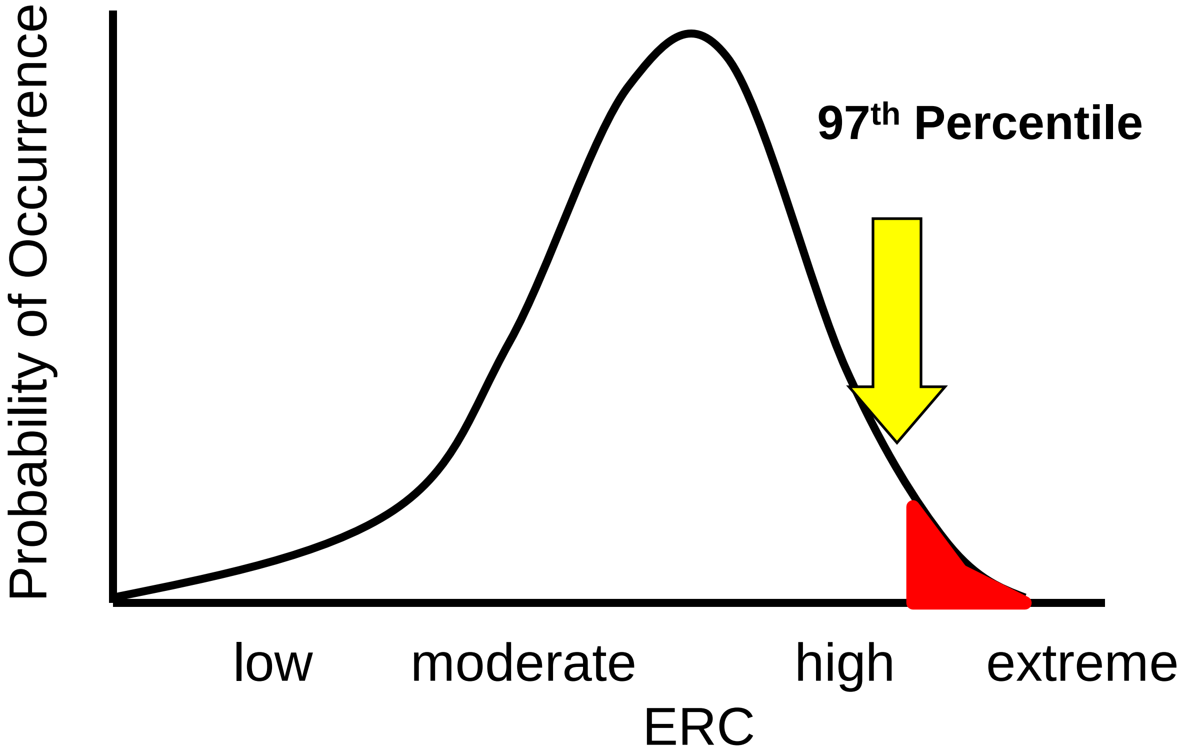


Output: numerical indices that provide managers a way to assess day-to-day fire business decisions (e.g., suppression response, staffing levels, strategy)

Impacts on fire and invasives

1) Changing fire danger – based on NFDRS

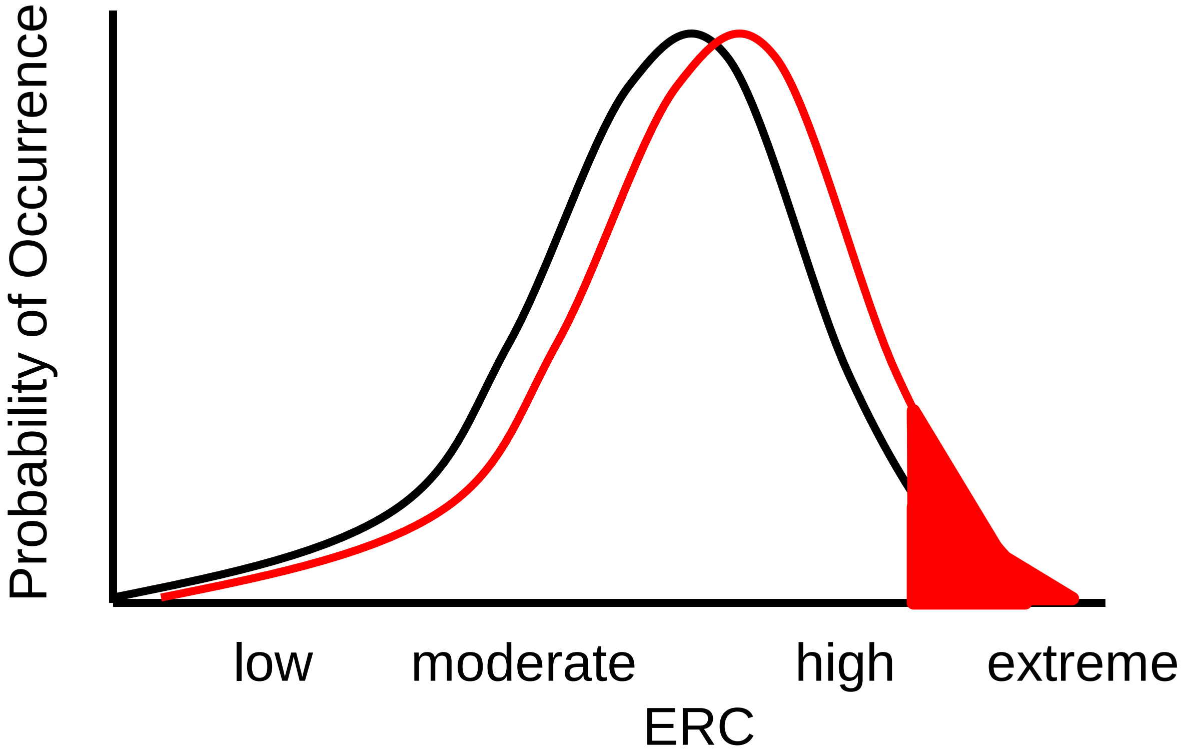
Most important changes are the extremes, not the mean



Wildfire tend to happen during **extreme** events

Impacts on fire and invasives

1) Changing fire danger – based on NFDRS

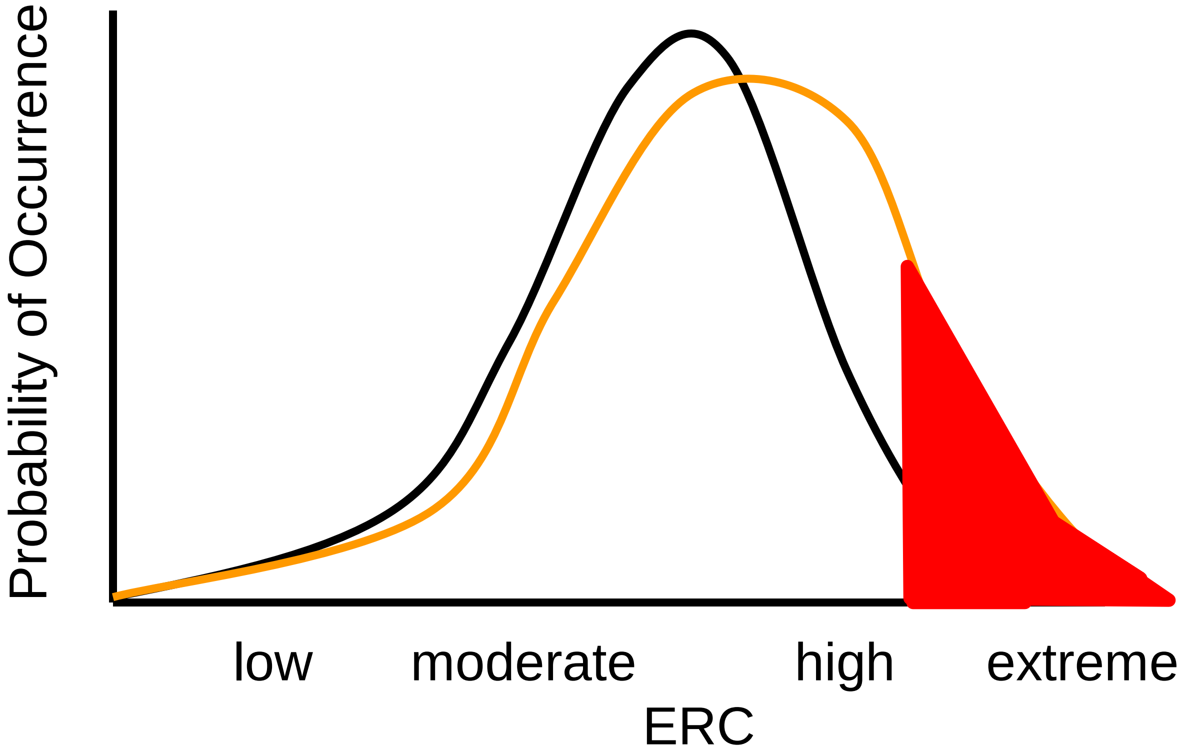


Wildfire tend to happen during **extreme** events

How will climate change alter the frequency of high **fire danger (ERC)**?

Impacts on fire and invasives

1) Changing fire danger – based on NFDRS

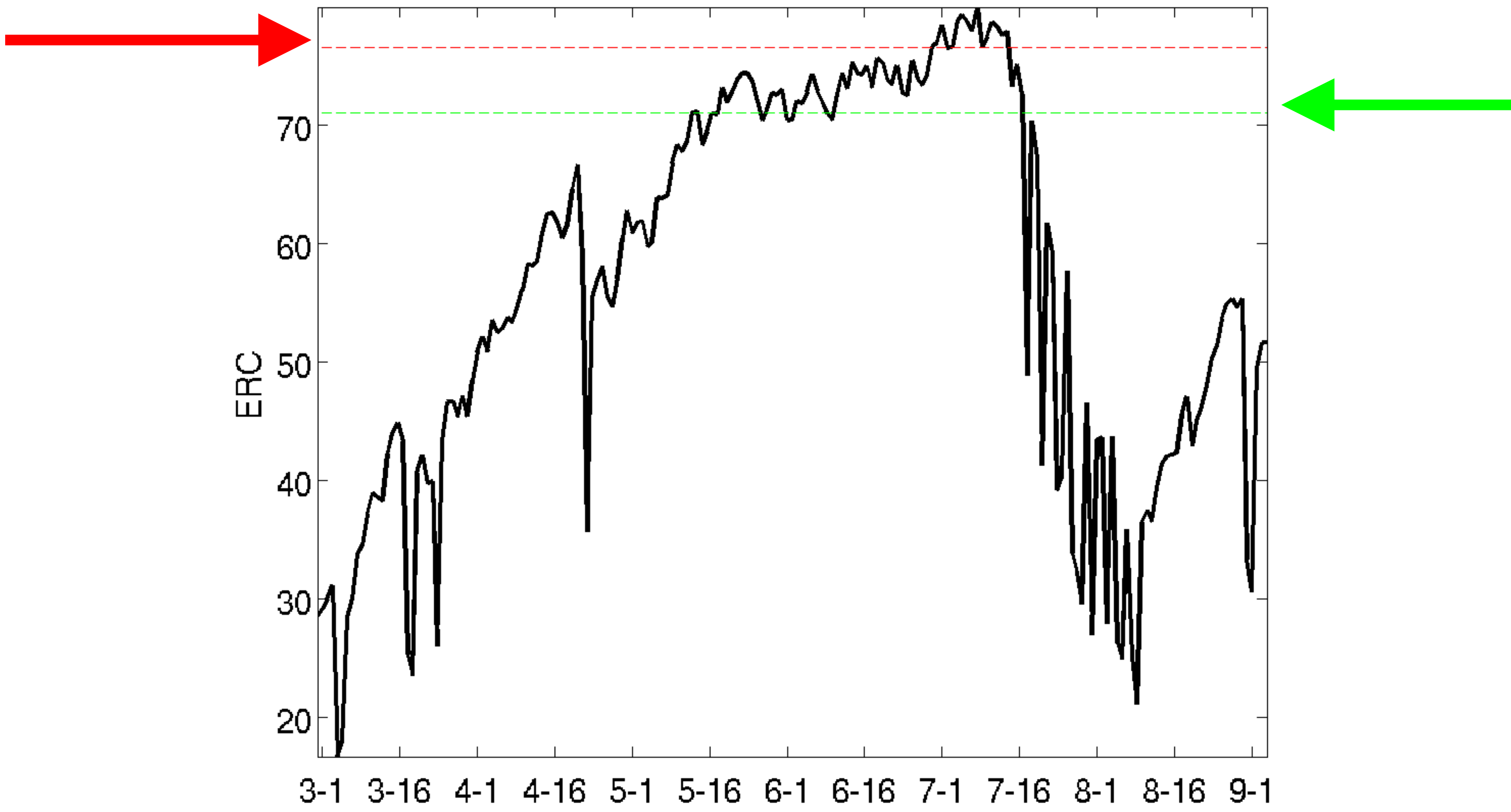


Wildfire tend to happen during **extreme** events

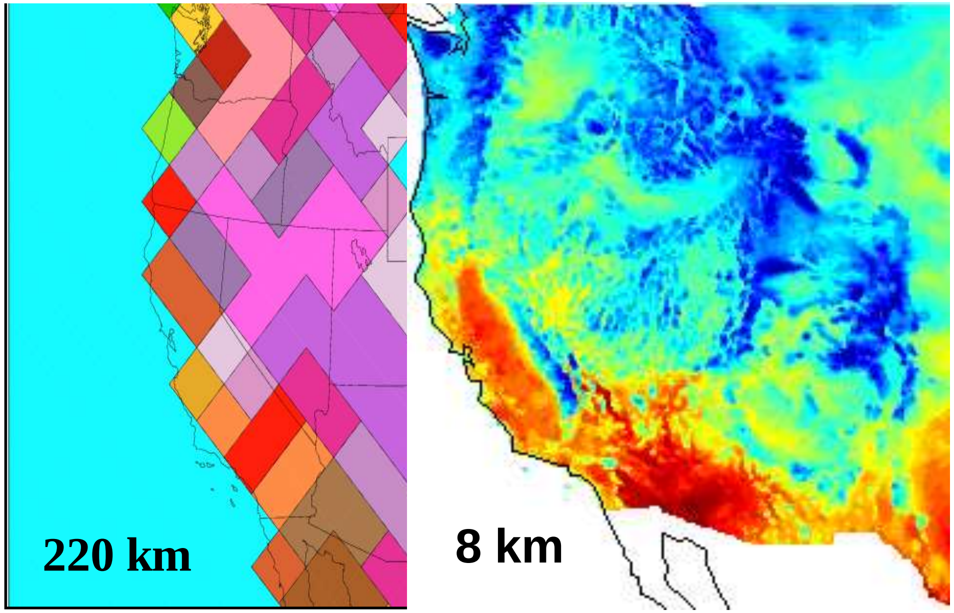
How will climate change subsequently alter the frequency of high **fire danger (ERC)**?

Example of extreme fire danger

97th % (ERC=48) defines EXTREME fire danger for 2005 Cave Creek fire



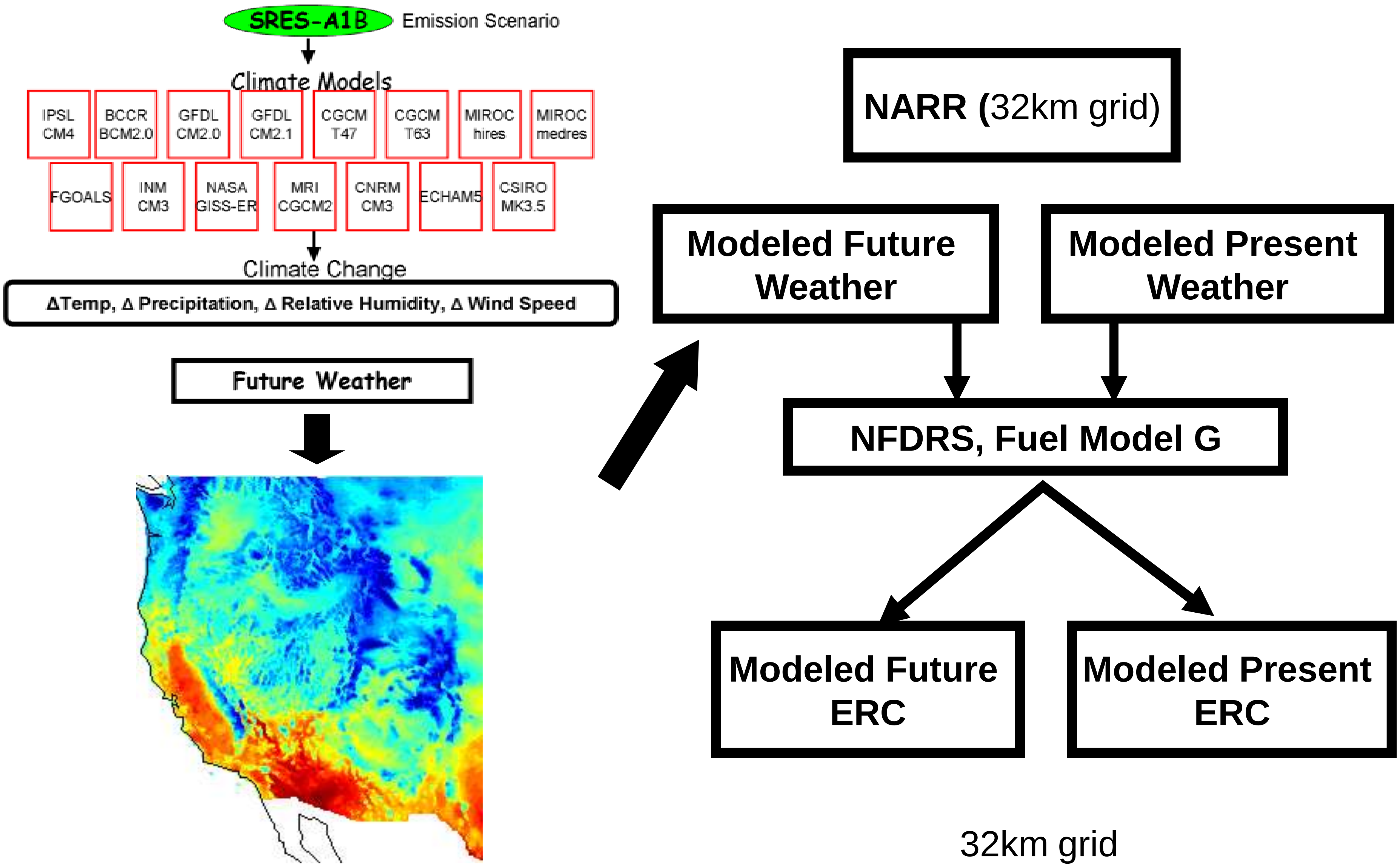
Downscaling for Climate Change Assessment



Problems: (1) GCM resolution is far too coarse required for assessment
(2) Biases in climatology (spatially and temporally)
(3) Regional climate variability (topography, water)

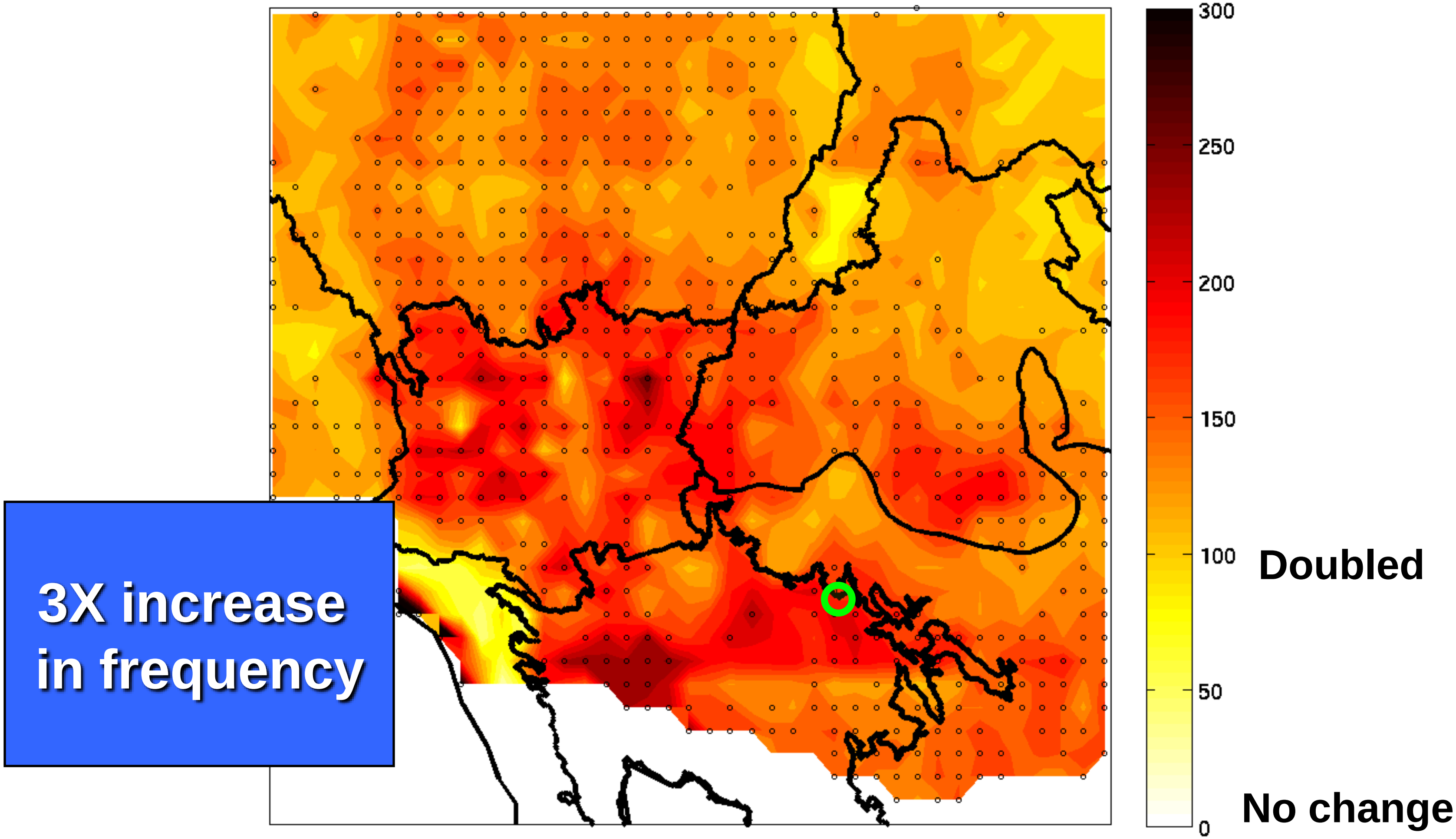
Solution: Downscaling coarse scale predictors (500hPa height, temp, precip, SLP) to fine scale predictants (TMAX, RHMIN,…)

Calculating future extreme fire danger



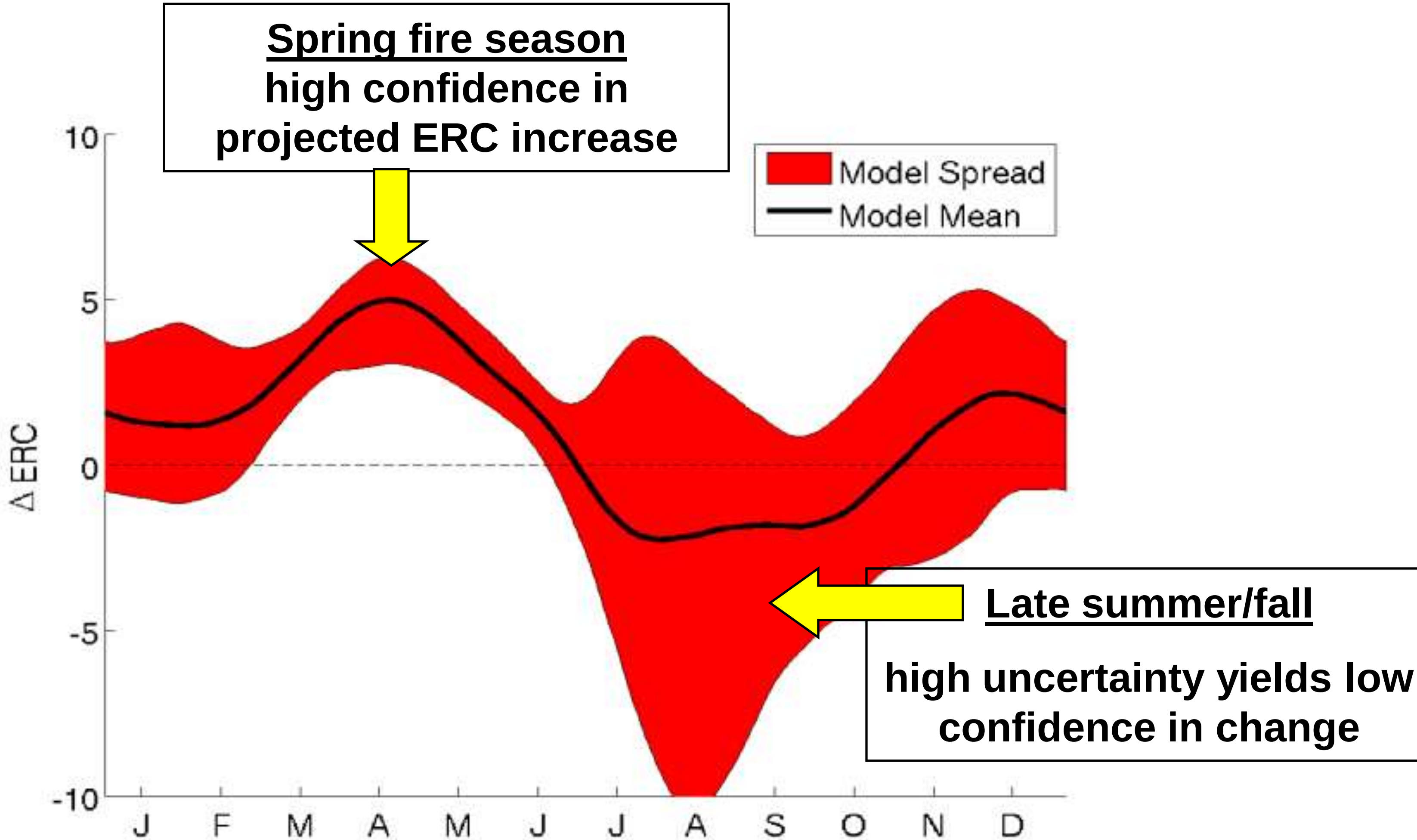
32km grid

Future Fire Danger



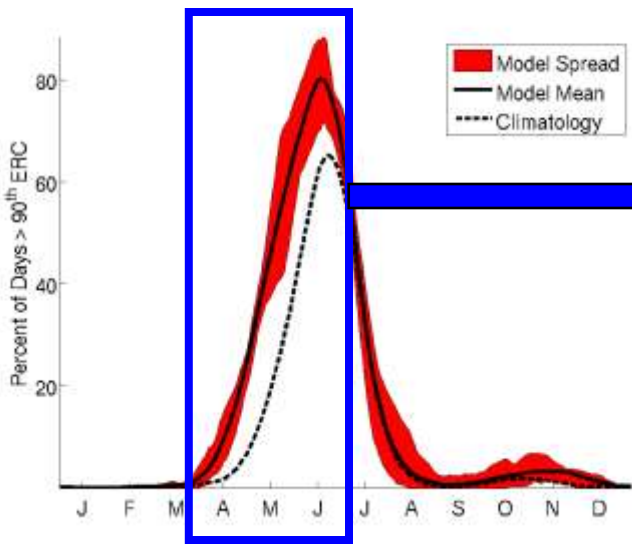
Percent increase in Extreme Fire Danger Frequency by Mid-21st Century

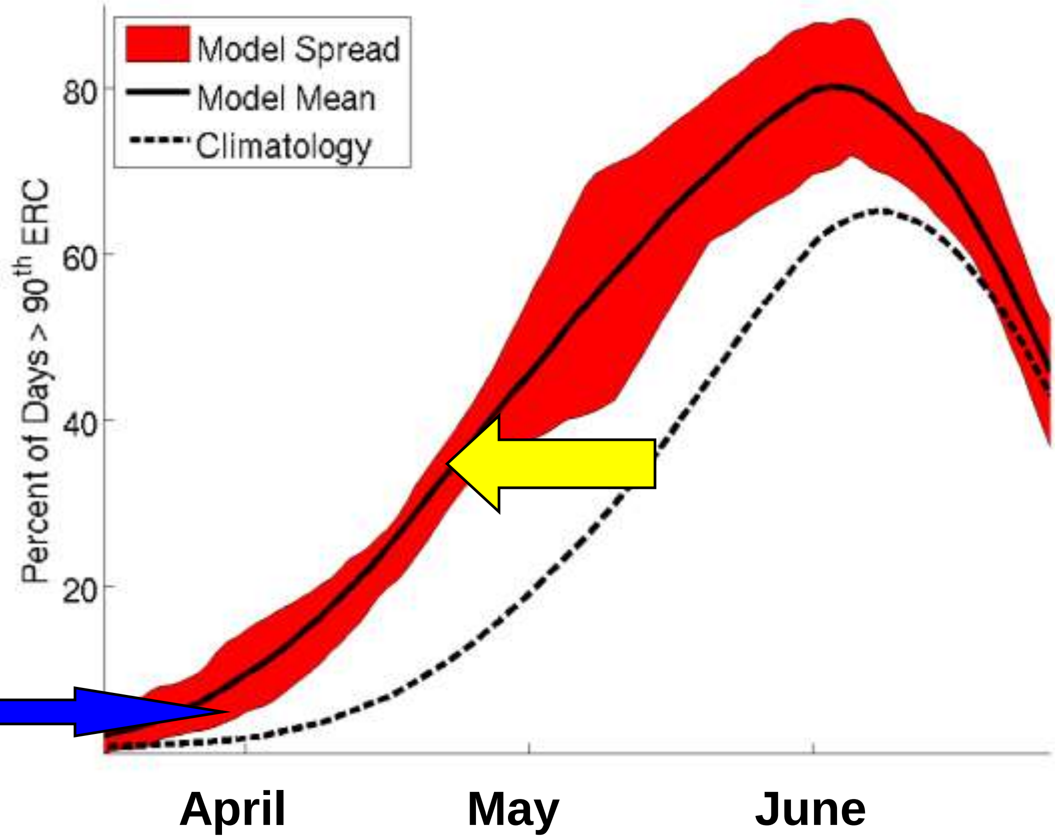
Future Fire Danger: Cave Creek



Future Fire Danger: Cave Creek

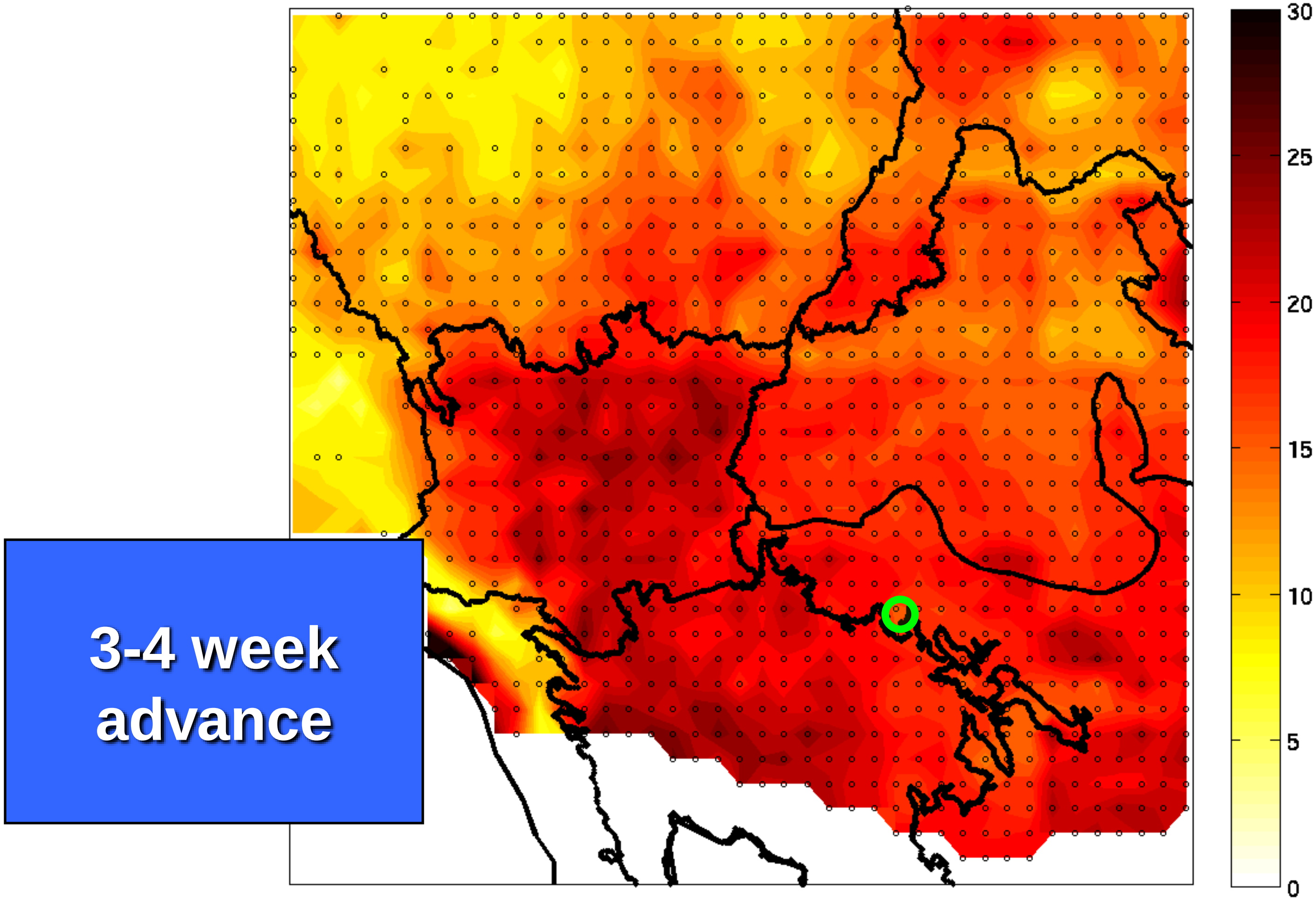
<u>Length of fire season</u>: use 90th percentile ERC as a proxy for start/end of fire season to look at shifts in season length and timing





***Earlier onset of fire season, more intense (higher fire danger at peak)**

Future Fire Danger



Median Advance in First Day of Year Exceeding 90th Percentile ERC

Summary

Climate-Fire-Invasives : Climate Variability

- Revised fire-climate relationships
- Phenological models for non-native successful establishment
- High resolution climate and meteorological datasets (CEFA)

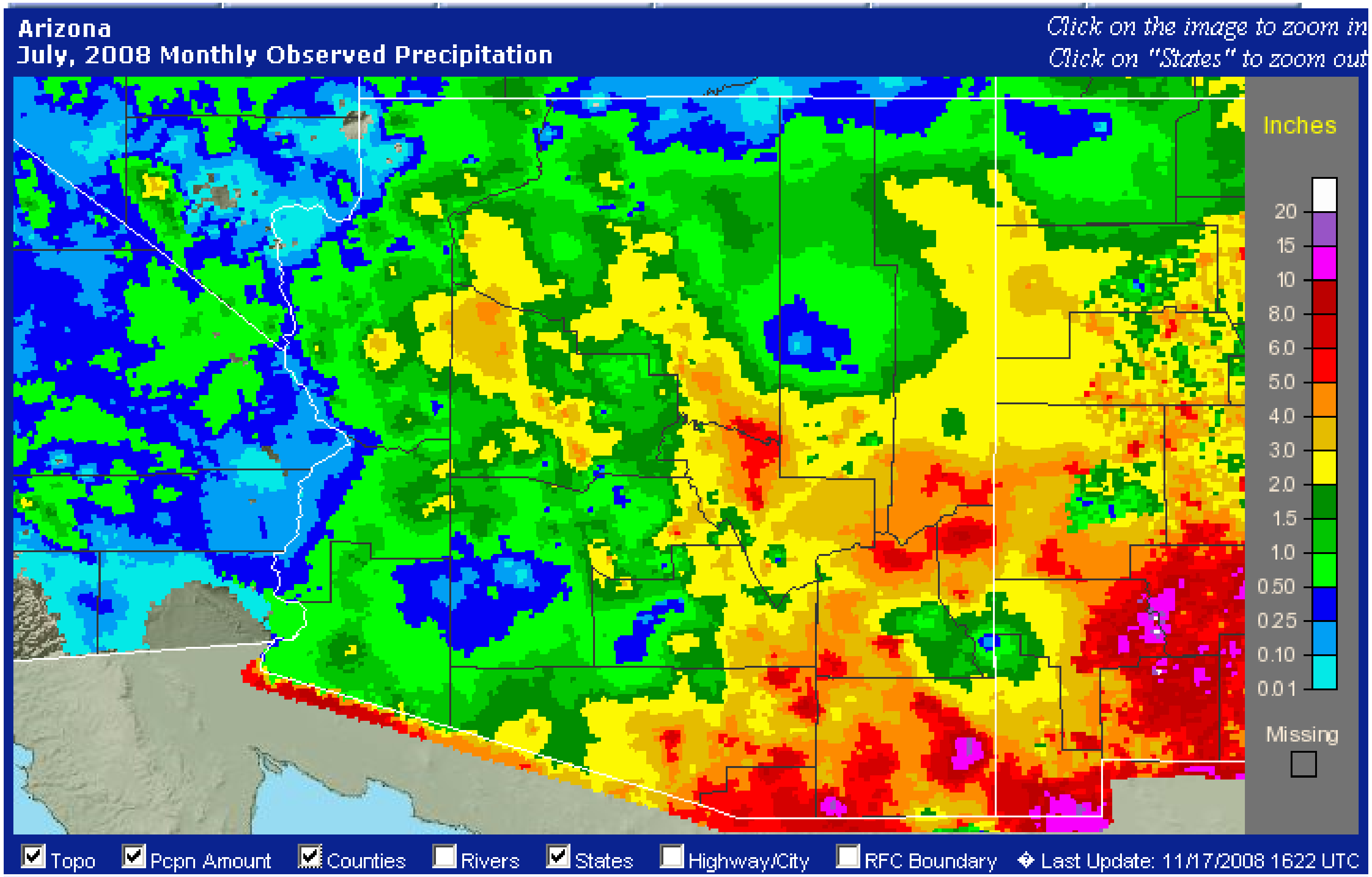
Climate projections for the American Deserts

- High confidence in warming
- Decent confidence in decreases in winter/spring precipitation
- Variability is not dead, opportunities for management

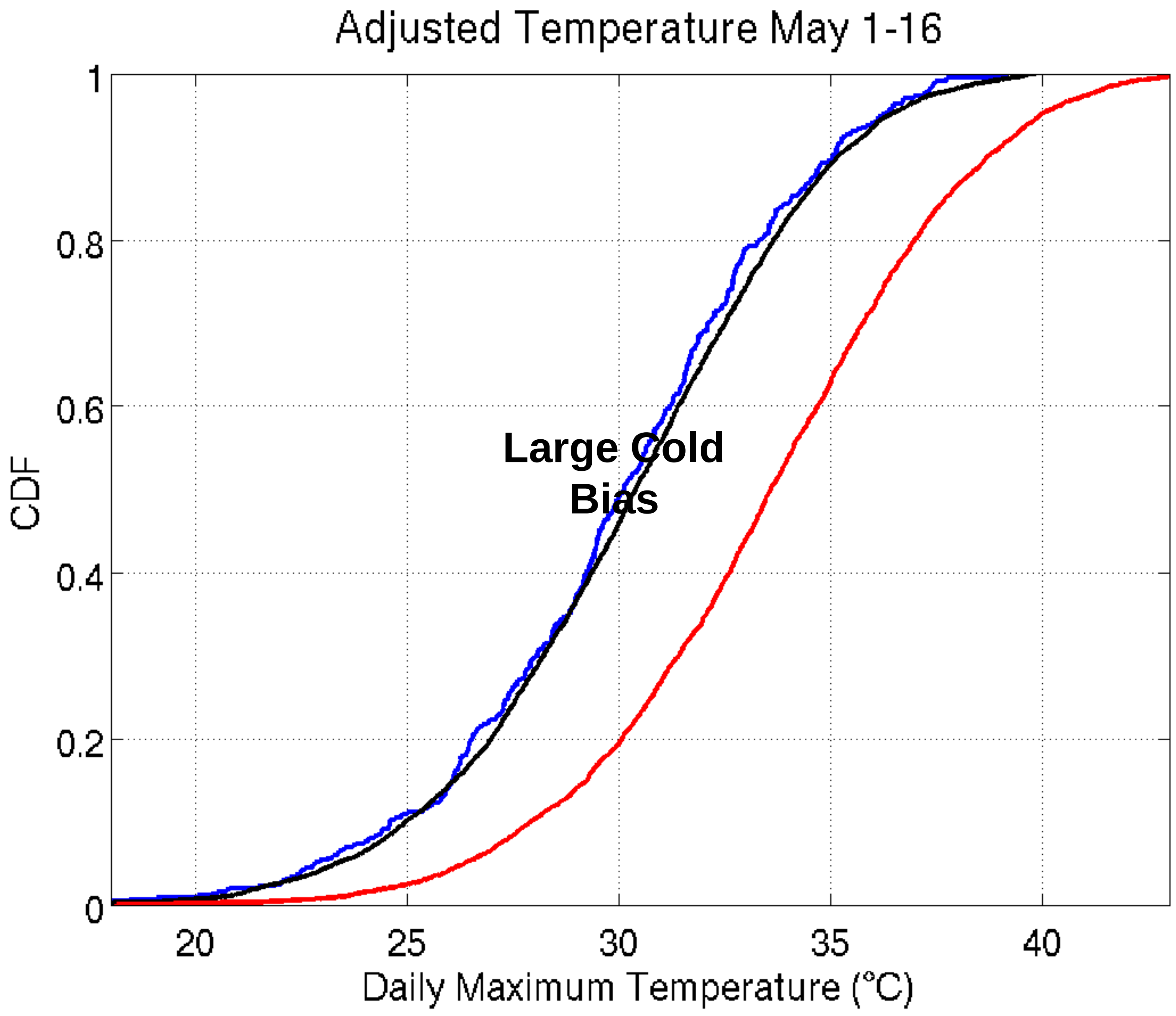
Future fire in the deserts

- Drier springs = early fire danger + increase in extreme fire danger
- Invasives can effectively convert a fuel-limited system to one <u>not</u> limited by fuels or flammability

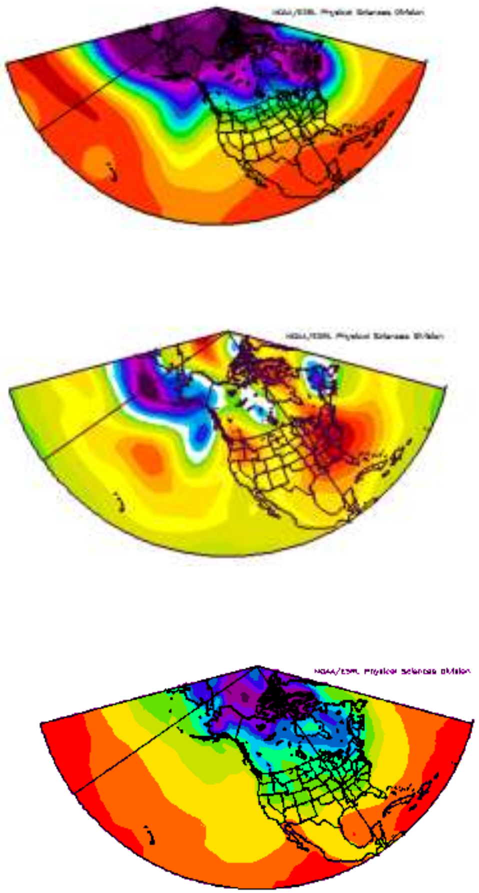
The end

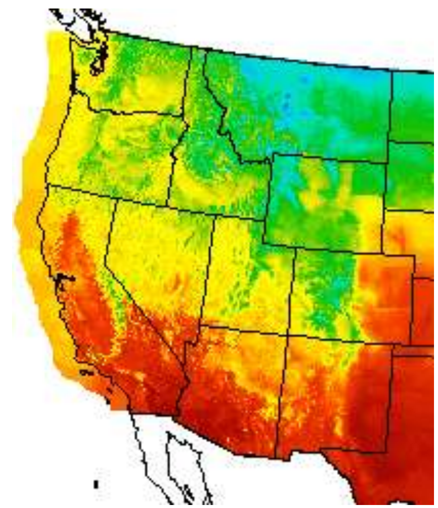

Arizona
July, 2008 Monthly Observed Precipitation
Click on the image to zoom in
Click on "States" to zoom out
Inches
20
15
10
8.0
6.0
5.0
4.0
3.0
2.0
1.5
1.0
0.50
0.25
0.10
0.01
Missing
Topo
Pcpn Amount
Counties
Rivers
States
Highway/City
RFC Boundary
Last Update: 11/17/2008 1622 UTC

Bias Correction



Catalogue of Predictors

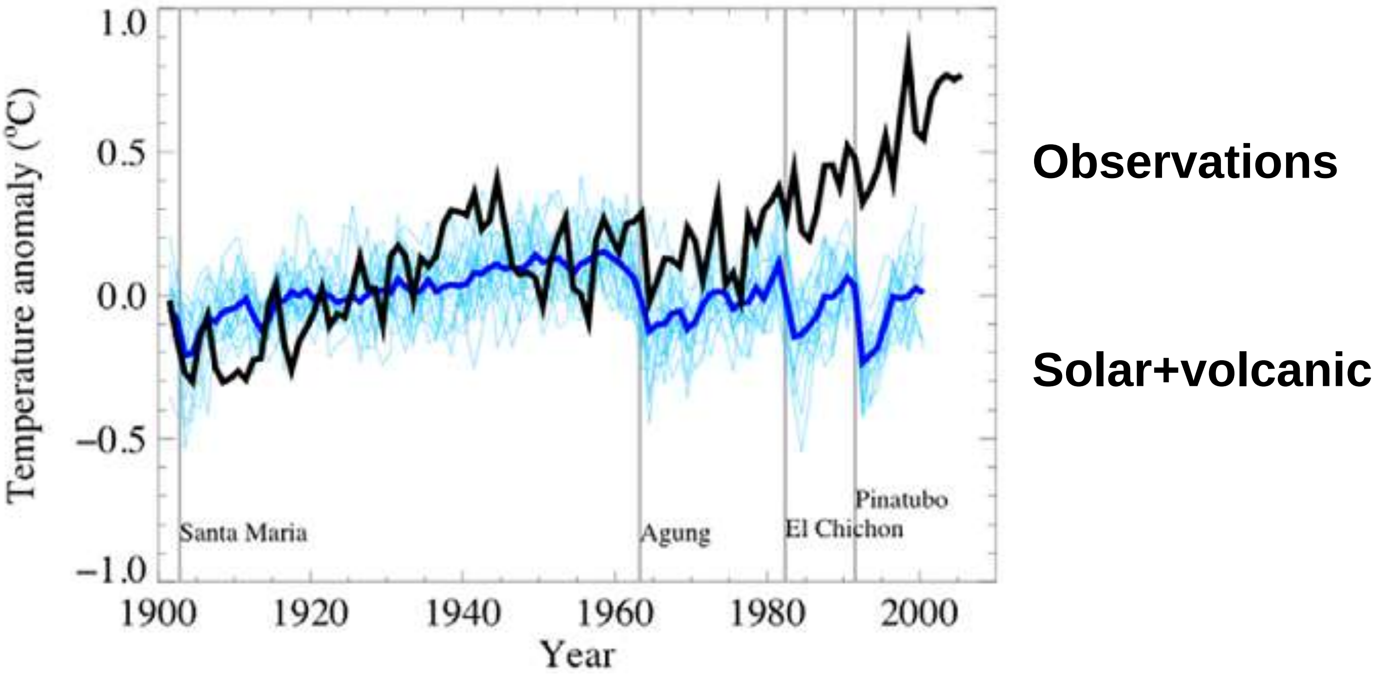




Coarse-Scale Predictors
Reanalsyis/GCMs

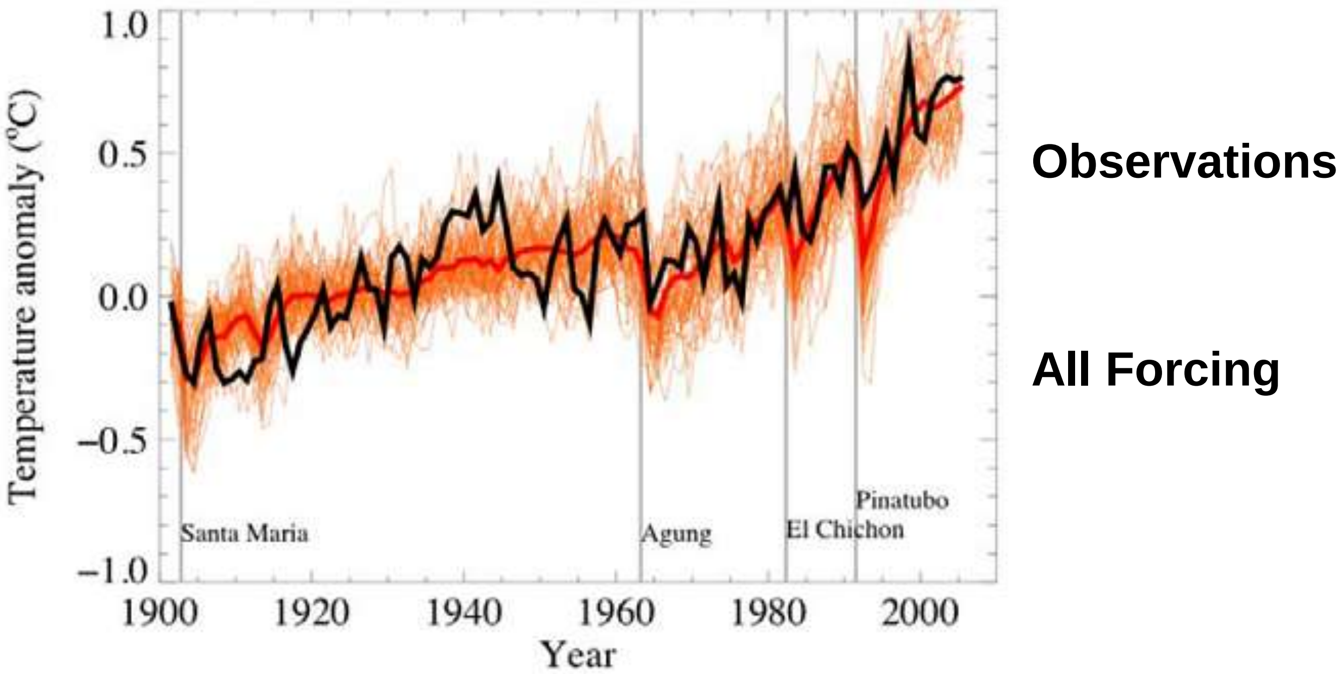
Fine-Scale Predictand
Obs/Future Downscaled

20^{th} Century Climate: Model Simulations



Experiment 1: Only apply natural forcing: solar+volcanic

20th Century Climate: Model Simulations

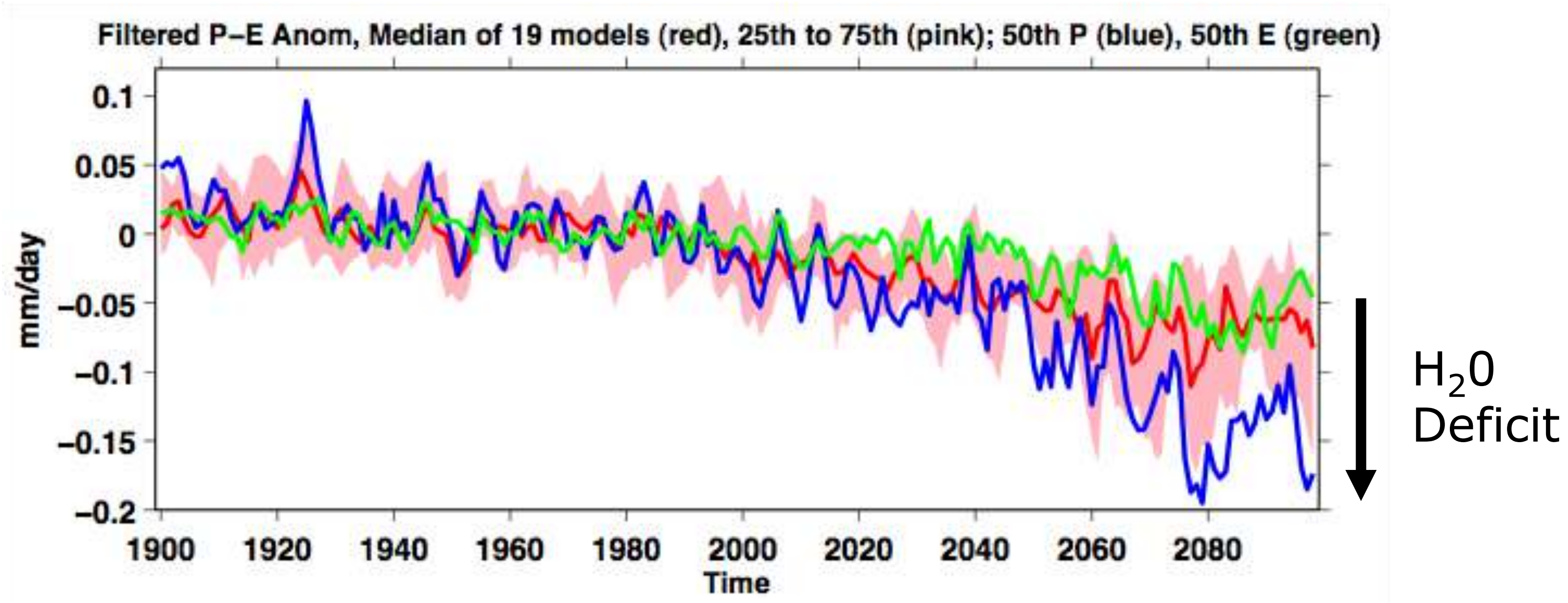


Experiment 2: Now apply anthropogenic forcing + natural

"***Most of observed increase in global average temperatures since the mid -20th century is very likely due to observed increase in anthropogenic greenhouse gas concentrations."***

-IPCC AR4 (2007)

Basic projections: changes in water deficit



- 18/19 GCMs predict decreases in water balance for the SW United States (Arizona, New Mexico)
- Changes in atmospheric circulation and water transport lead to storm track shifting poleward and not bringing winter rains to the SW

State of Knowledge on Fire-Invasives Relationships

Fire is part of a positive feedback cycle with certain invasives (particularly annuals) in desert ecosystems

- Promotes invasion through disturbance
- Invasive species (esp. annuals) are able to outcompete natives in early regeneration
- Once established, fire frequency increases due to more continuous fuel bed, wider range of conditions under which fuels can burn

Effectively converts a fuel-limited system to one <u>not</u> limited by fuels or flammability