The curse of knowledge and sins of omissions: modeling global change

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Conservation Biology Institute and
Oregon State University

My experience as a modeler

* I started modeling in 1979 as a graduate student. (Bill Parton, creator of the biogeochemistry model Century was on my graduate committee)

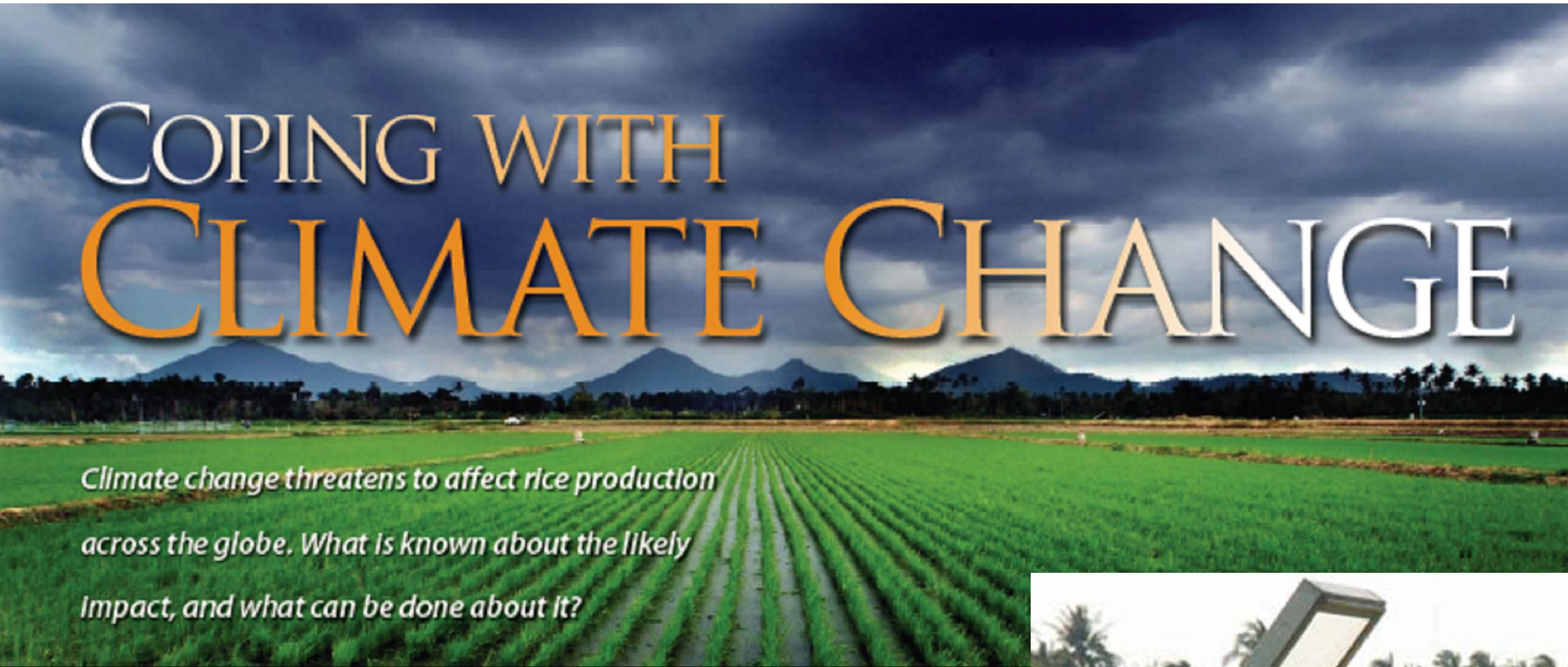
* I started working on climate change in 1988. Participated to IPCC 1995 (ag.), 2000 (Neilson et al.), 2008 (reviewer)

* I worked in Academia (CSU, UCR, NMSU, OSU), as contractor in government agencies (EPA and USFS), in NGOs (Nature Conservancy, Conservation Biology Institute)

Research Projects

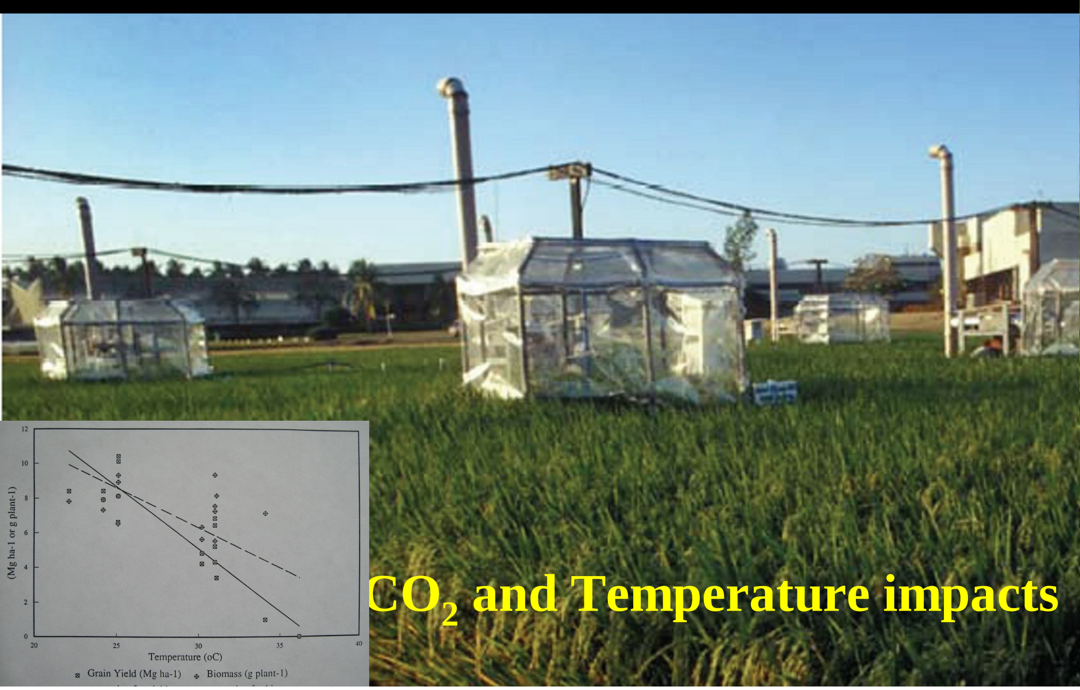
- Climate, plants and animals
  - plant water content and African grasshoppers
  - bisons, grasshoppers, nematodes and shortgrass prairie
  - climate change, rice, pathogens, herbivores, humans
- Dynamic vegetation model development
- Dynamic fire module development
- Packaging results for conservation
  - database development
  - learning networks
  - local projects

Will Burgess / Reuters



80% of rainfed rice in S & SE Asia

soil and irrigation impacts



CO_2 and Temperature impacts

EPA, IRRI, D, NL

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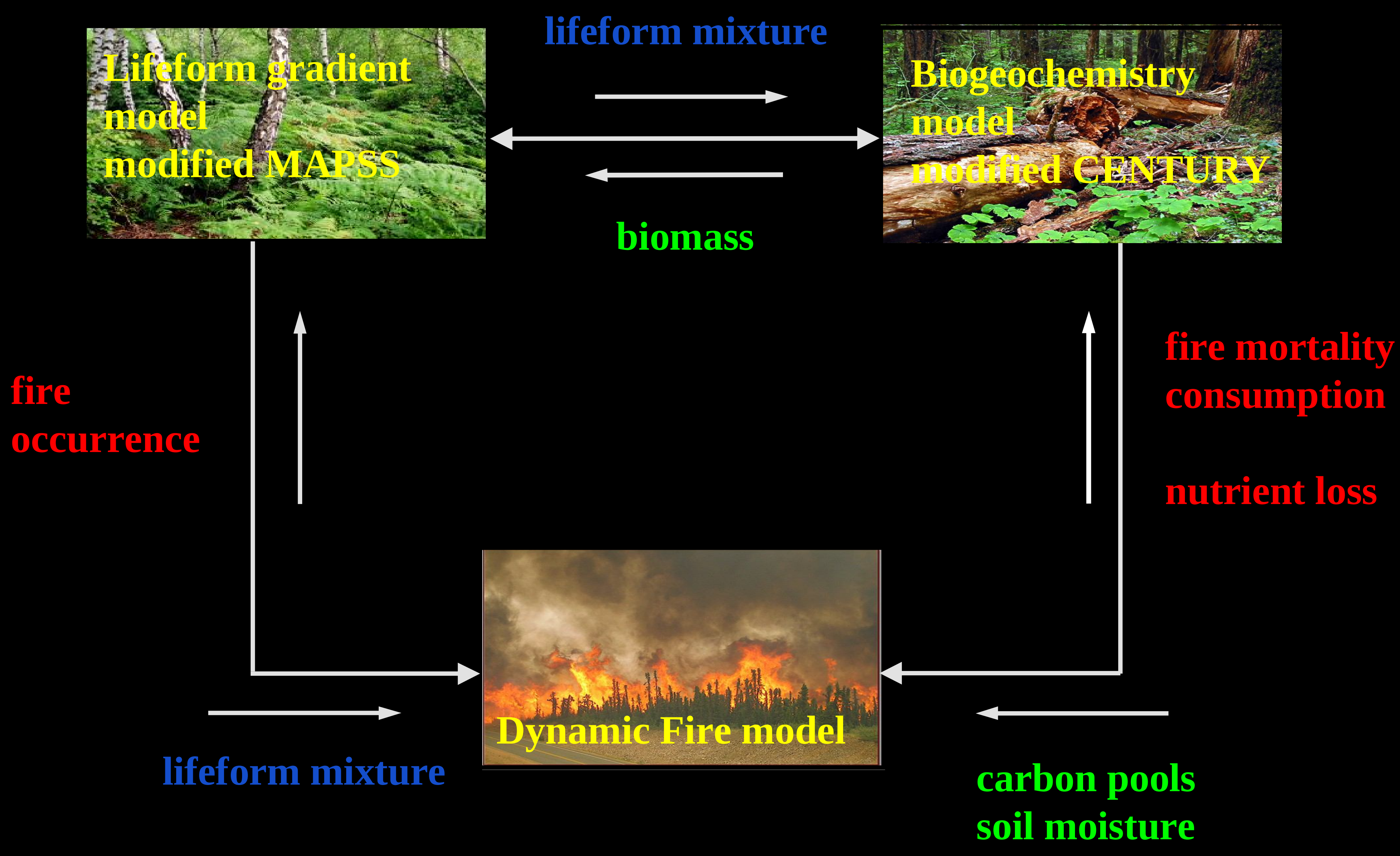
MC1 Dynamic Vegetation Model



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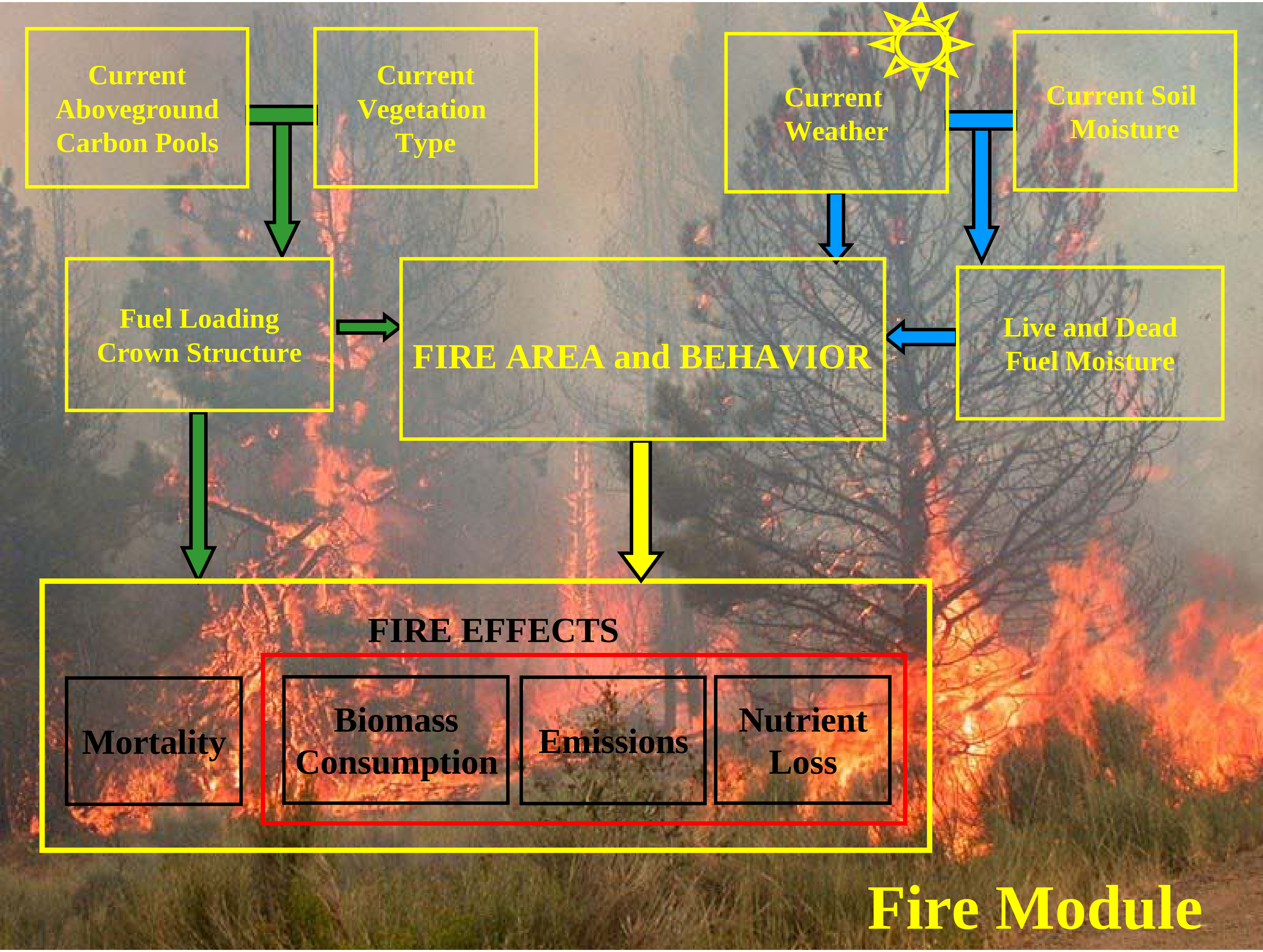
Current Aboveground Carbon Pools
Current Vegetation Type
Current Weather
Current Soil Moisture
Fuel Loading Crown Structure
FIRE AREA and BEHAVIOR
Live and Dead Fuel Moisture
FIRE EFFECTS
Mortality
Biomass Consumption
Emissions
Nutrient Loss
Fire Module

Research Projects

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CBI Data Basin

Climate Adaptation Knowledge Environment

TNC Climate Wizard

OUTLINE

- Definitions
- Climate models
  - **scale**
  - **natural climate variability**
  - **extremes** and surprises
  - **human** impacts
- Impacts models
  - **Transient** versus **static**
  - **Blackbox**es: belowground, CO_2, N
  - **Human** inferences with natural process
- Meeting the audience needs

Simulation model

- simplified representation of a system - at some point in time or space (flat earth)
- iterative process: development; simulation runs; learning; revisions "until an adequate level of understanding is developed”

Modeling is like vintage wine; it matures with time.
http://www.decisioncraft.com/

- trade-off as to what level of detail is included in the model: more complicated less understandable results
- often computerized to study interactions of various system parts

http://www.systems-thinking.org/modsim/modsim.htm

The role of modeling

- Synthesize existing knowledge (across disciplines - common language = math)
- Examine the fundamental behavior of a system (SA, disturbance)
- Identify gaps in current knowledge and guide future research
- Generate hypotheses (as opposed to predictions)
- Forecast future conditions

Global Change

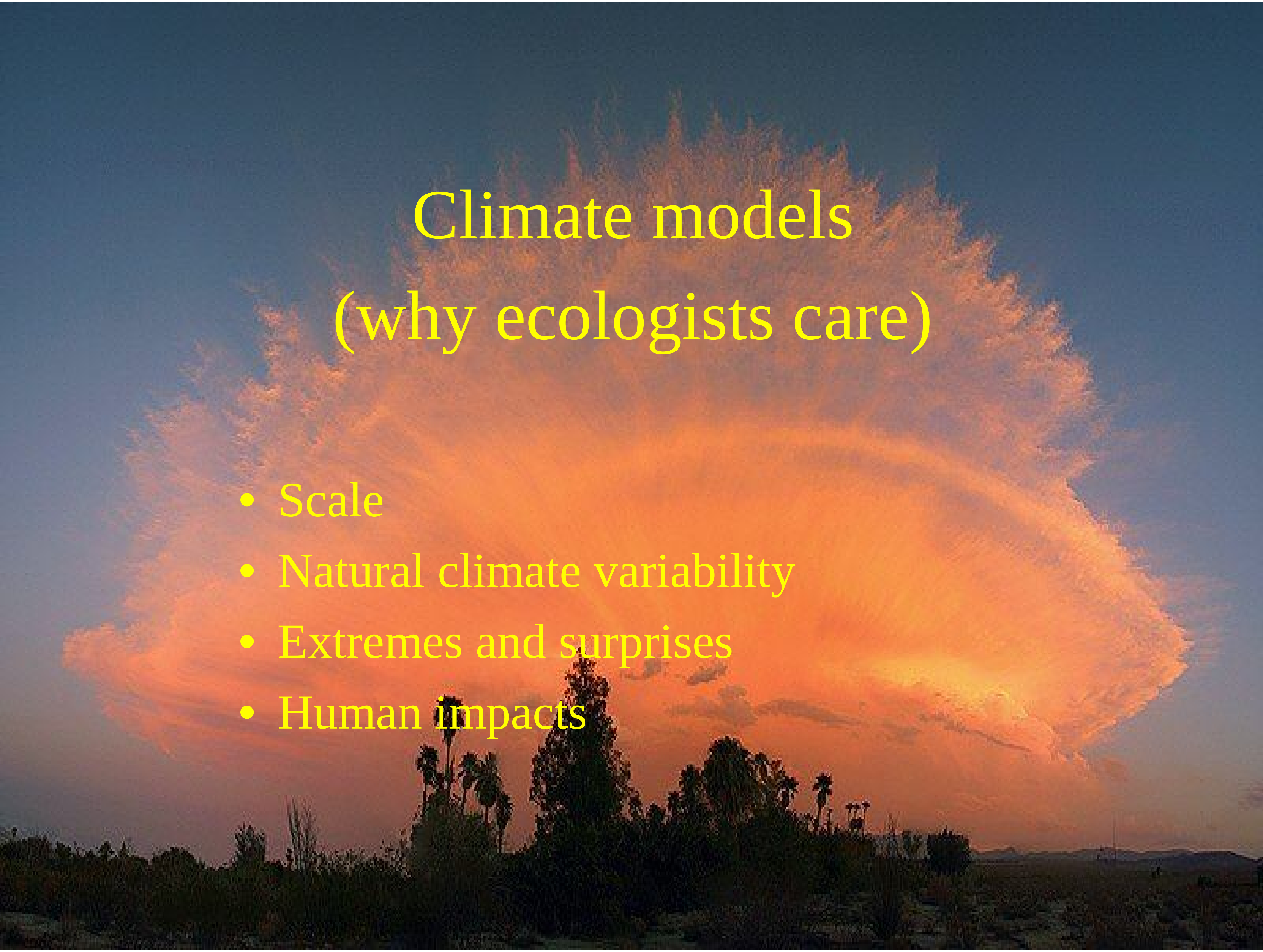
- Climate and indirect effects
  - temperature and precipitation
  - sea level rise
  - ocean acidification among others

- Global population levels and demand
  - pollution: air, water
  - LULC and natural resources: water shortages, soil (salinization, dust), sources of energy
  - fire ignition/suppression/prescription


Humans have footprints in all ecosystems
There are no “pristine” environments
Difficult to tease out climate signal alone

Climate models
(why ecologists care)

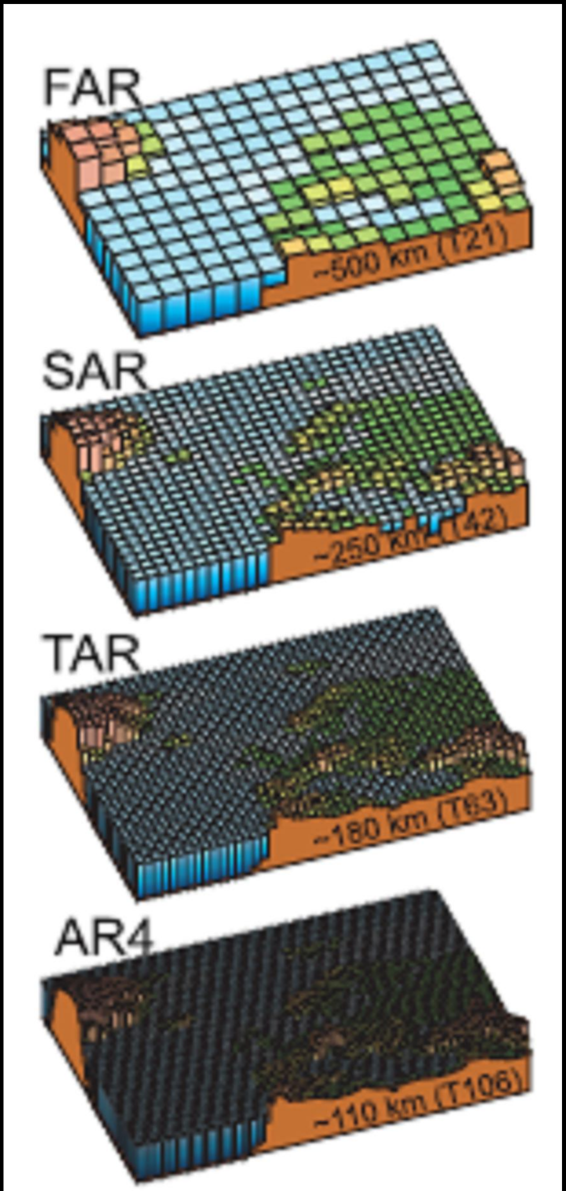
- Scale
- Natural climate variability
- Extremes and surprises
- Human impacts



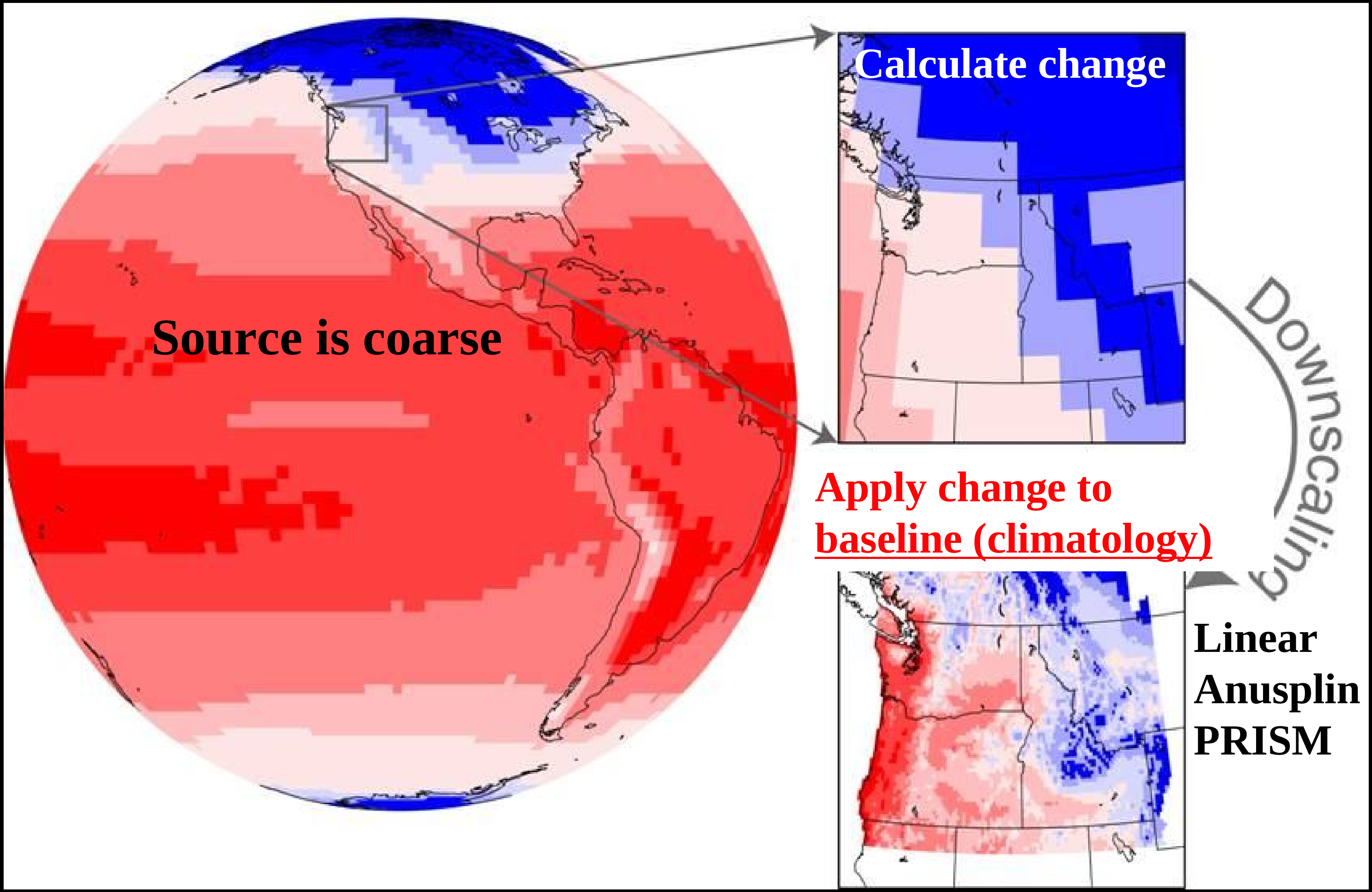
Climate Models: Scale

- General circulation models (GCMs) designed to simulate the globe thus coarse scale: users' responsibility to use output properly

- as computing power (and storage) increases, GCM scale decreases

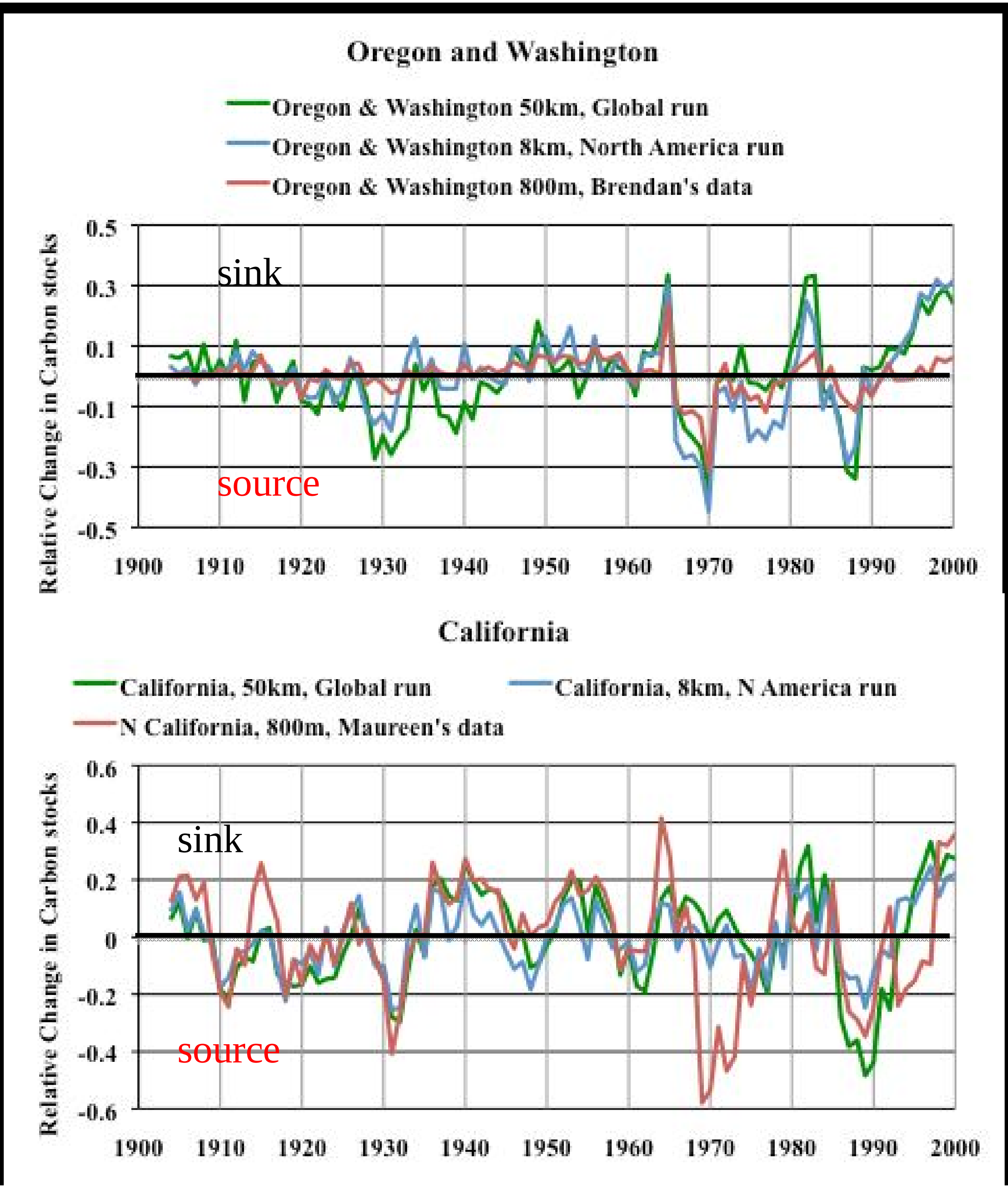


Until better … ecologists downscale



source: CIG Seattle

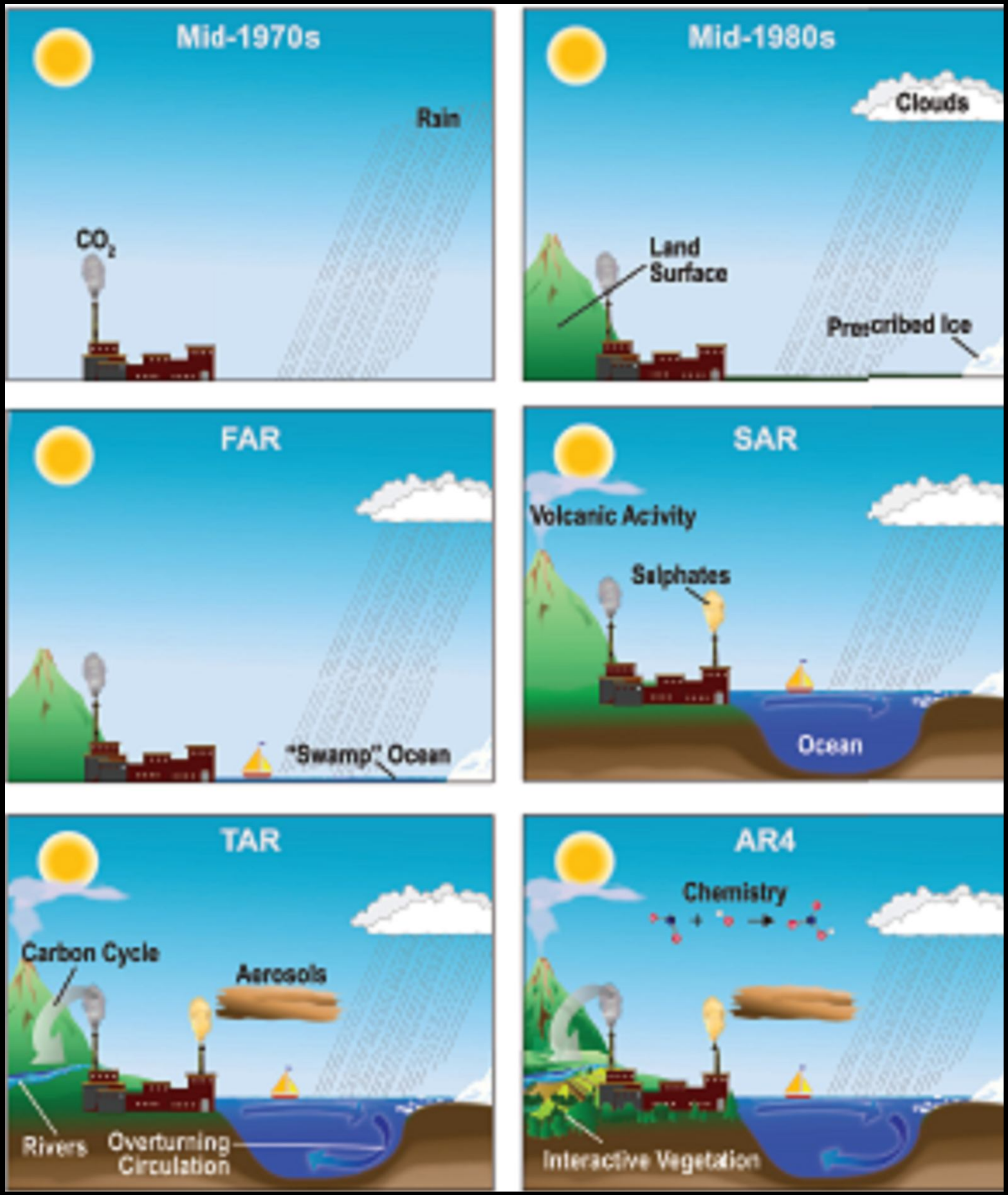
Results and
their interpretation
differ at different
scales:
regionally and
temporally



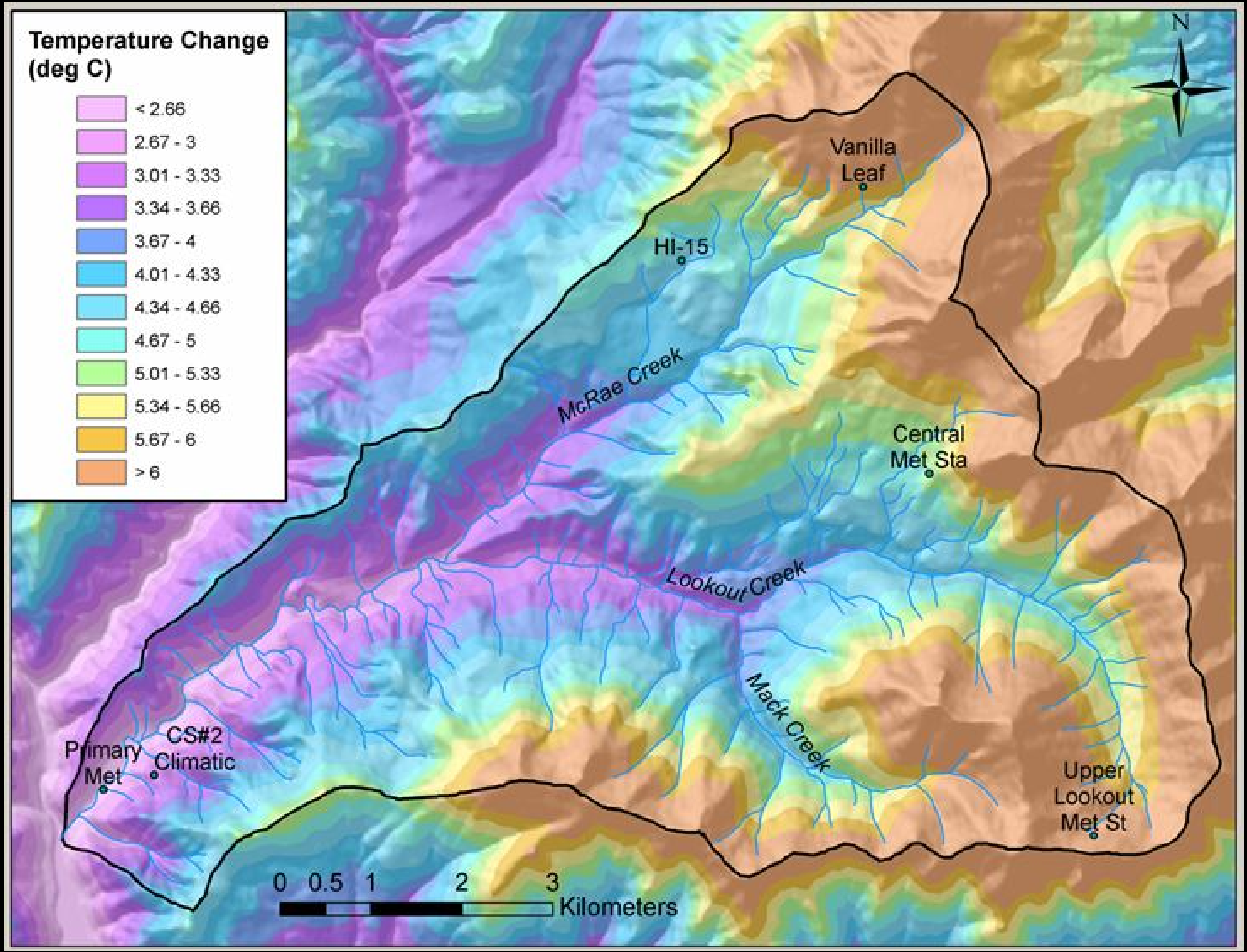
strong El Nino years:
1972-73, 1982-83, 1991-92, 1997-98
La Nina years:
1955-56, 1973-74, 1975-76, 1988-89

Climate Models: Scale

- as computer power increases, level of detail increases (should increase with grain)
- RCMs and nested climate models - details Phil Duffy and Eric Salathe



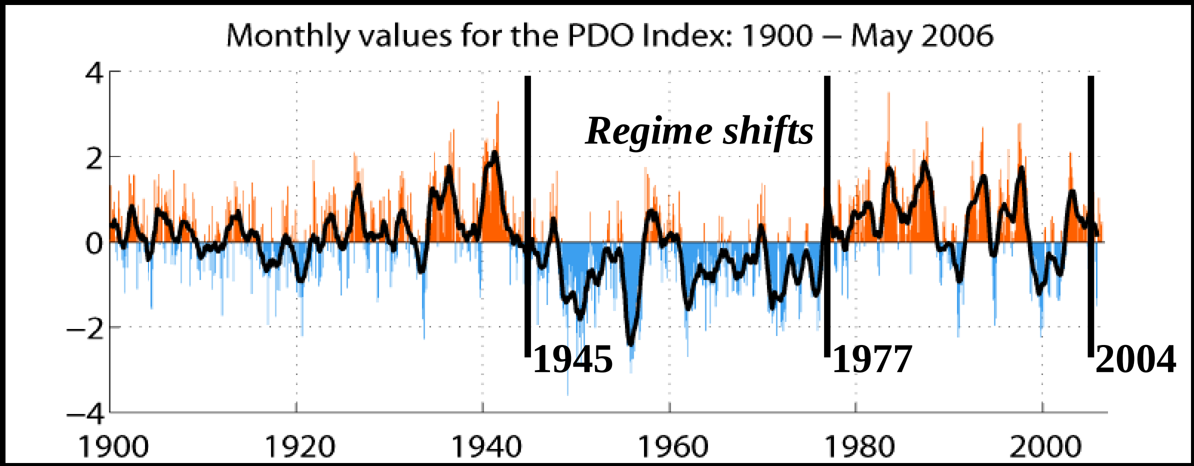
Complex topography can invalidate regional projections

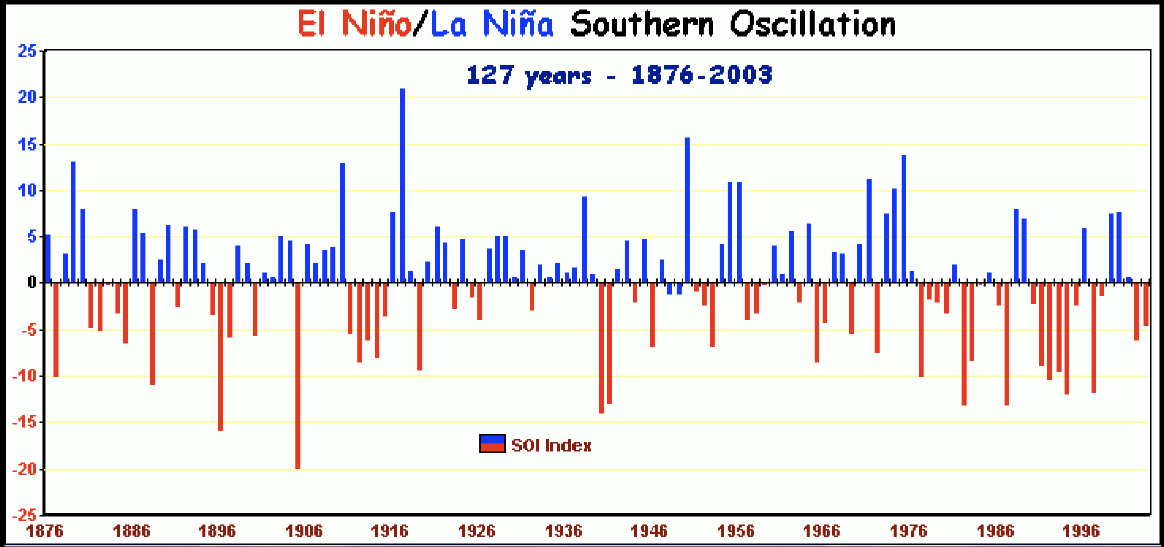


HJ Andrews January Tmax (+2.5C Regional Change and +10 Anticyclone-Cyclone)

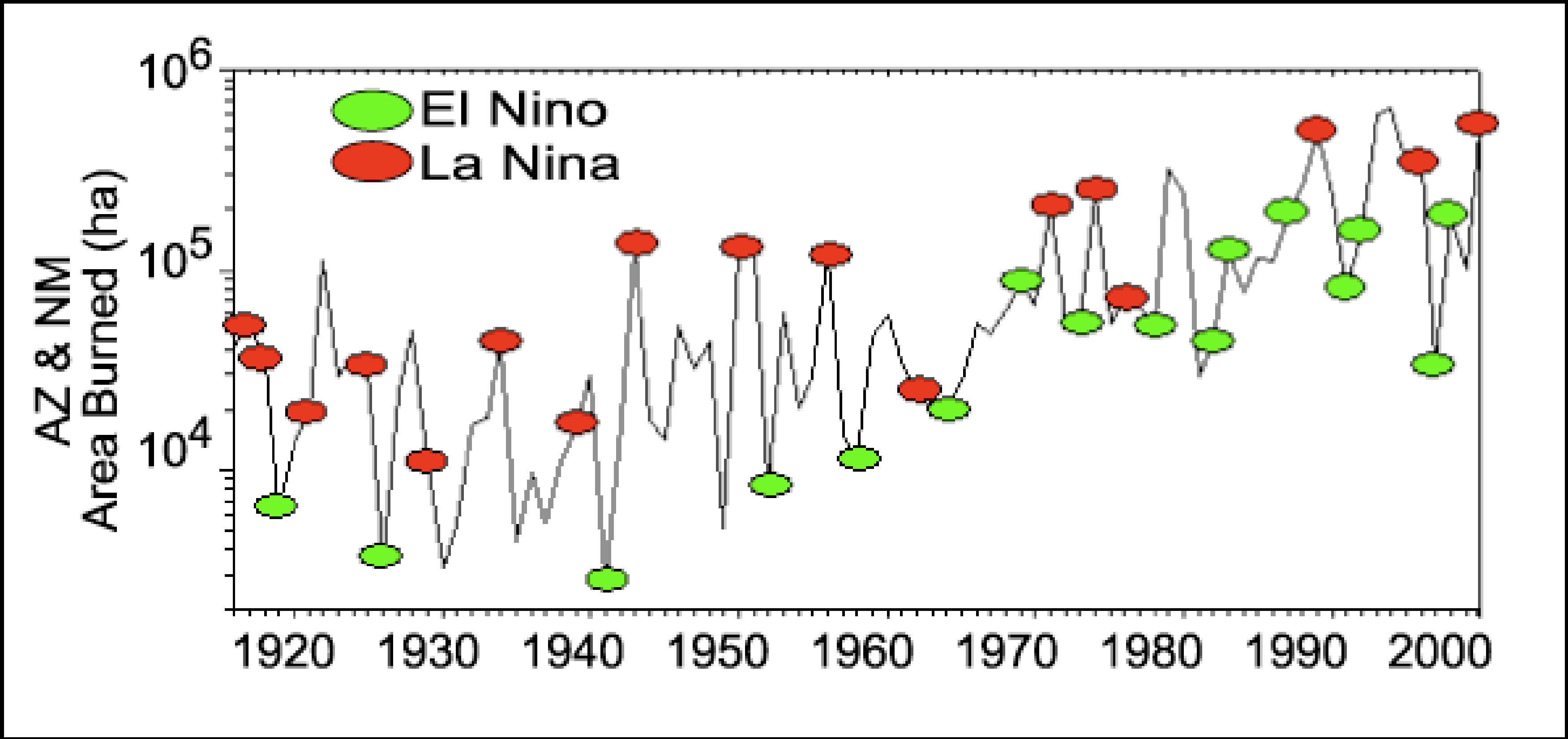
Source: C. Daly, AGU 2007

Climate Models
Natural climate variability





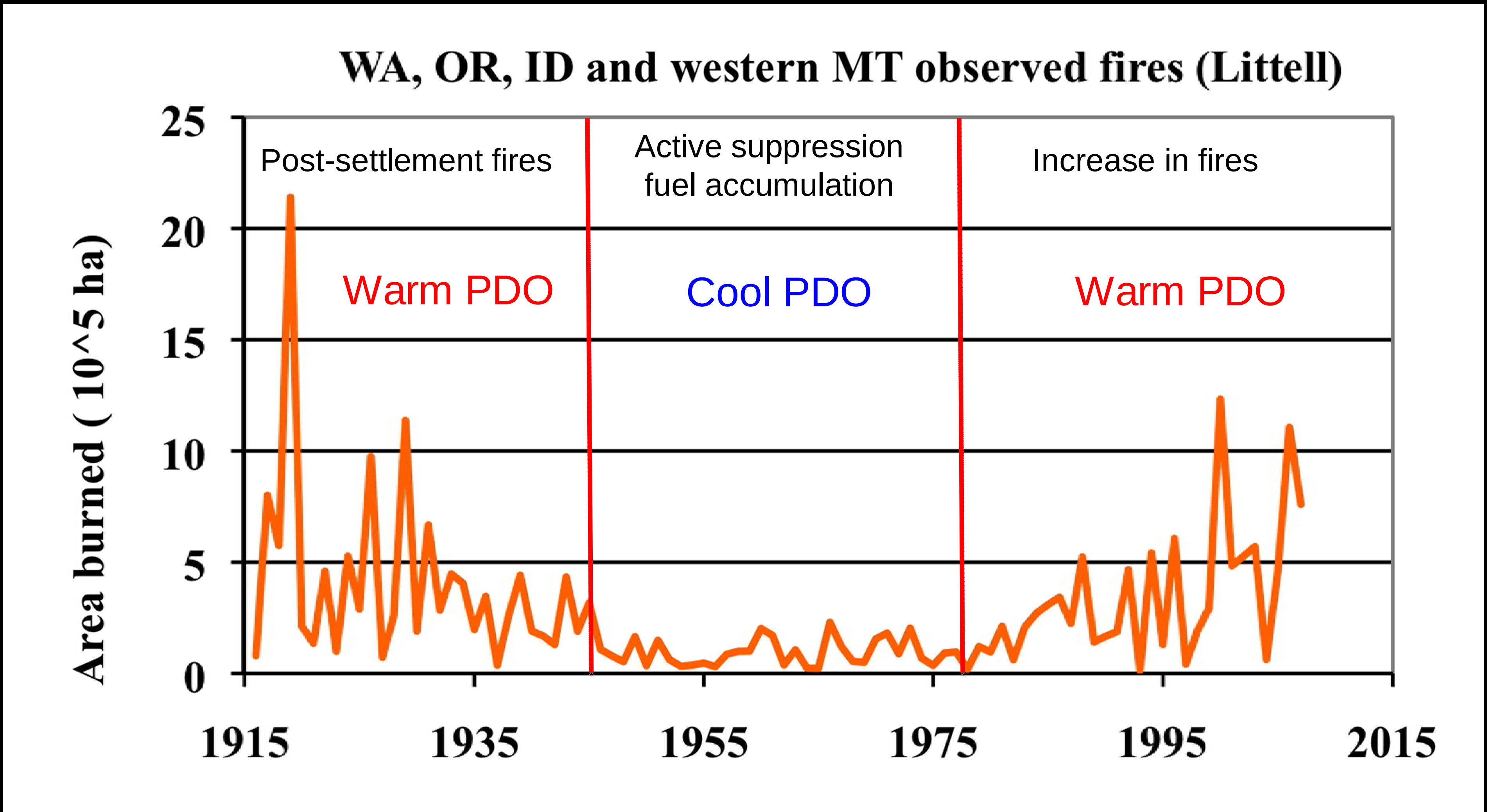
In the Southwestern US, ENSO drives fires



Updated from Swetnam, T.W., and J.L. Betancourt, 1990: Fire-Southern Oscillation relations in the southwestern United States. Science 249:1017-1020.

Pacific Decadal Oscillation (Mantua et al. 1997) affects fires

North Pacific monthly sea surface temperature variability



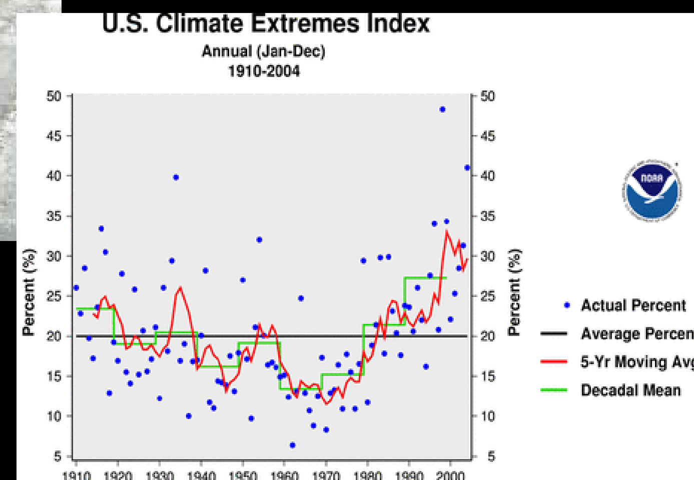
Source: Jeremy Littell et al. 2009. Climate and wildfire area burned in western US ecoprovinces, 1916-2003. Ecological Applications.

Climate Models: Extremes

- difficult to predict
- notion of threshold, tipping points (monitor)
- huge biological impacts

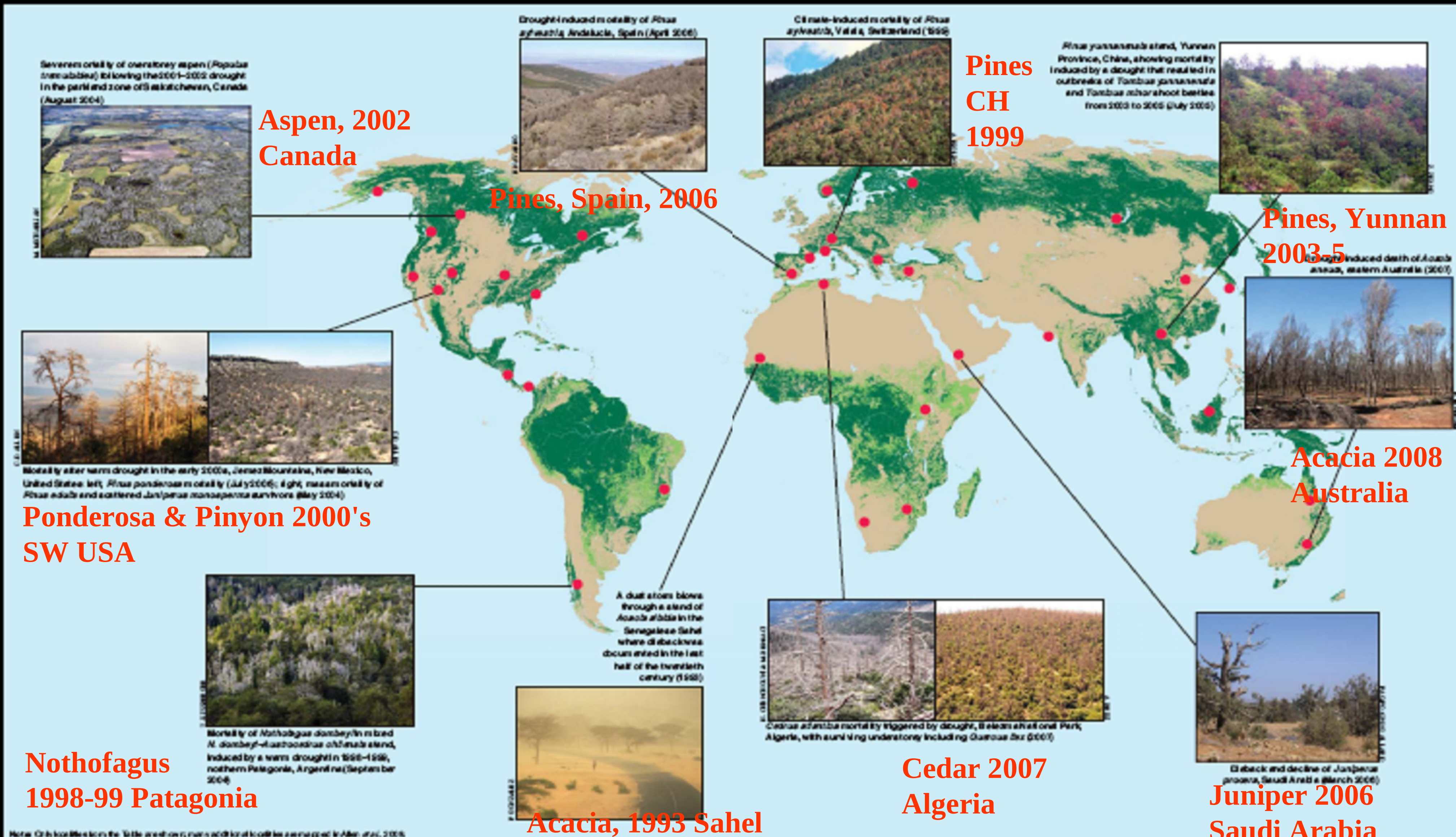
warm ocean

soil erosion



Forest dieback is becoming a global phenomenon: Climate signal?

droughts, heat damage, insect outbreaks

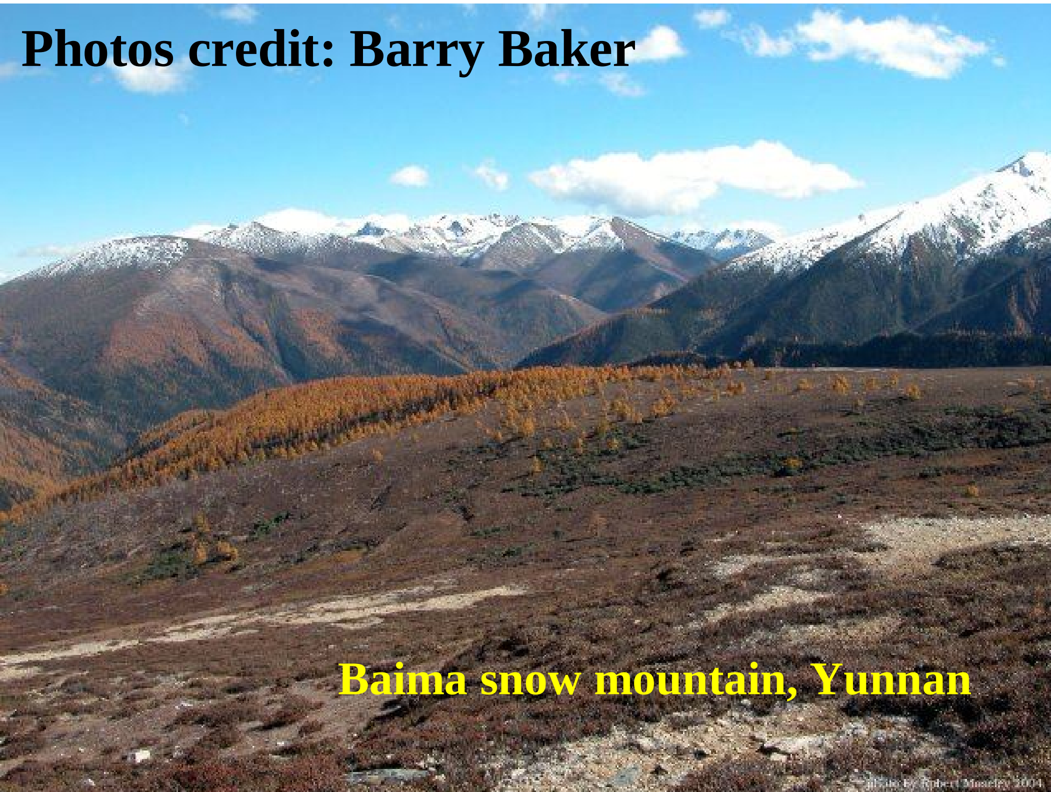


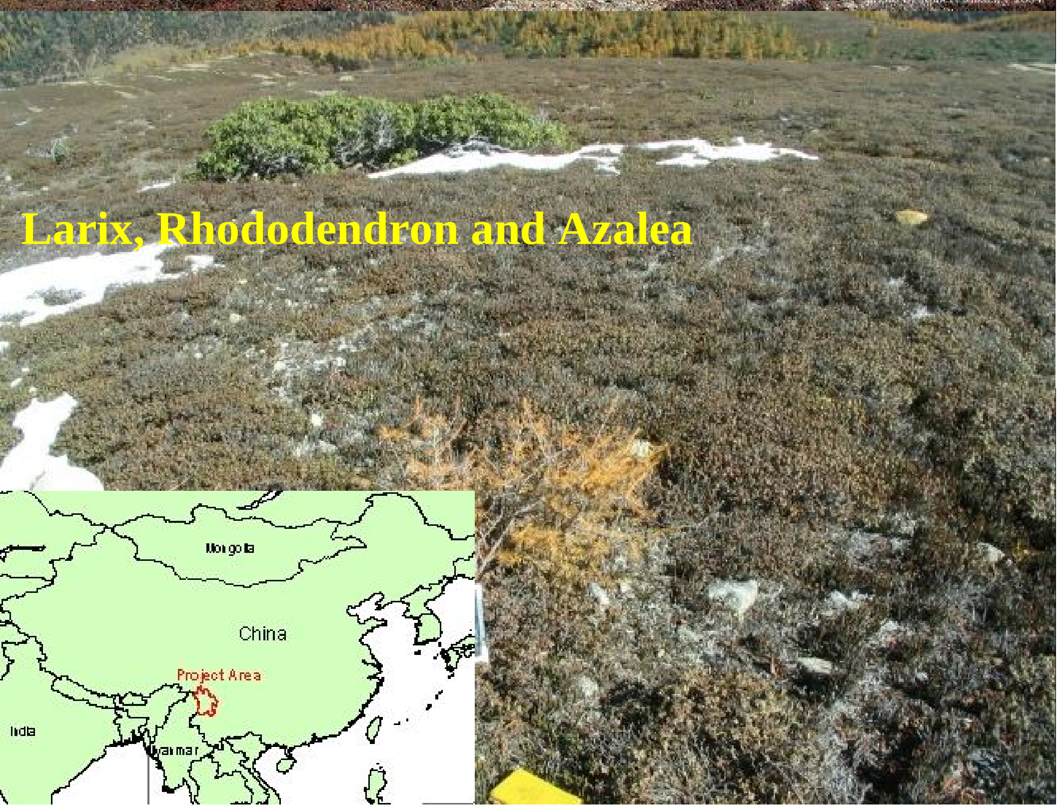
source: Allen 2009

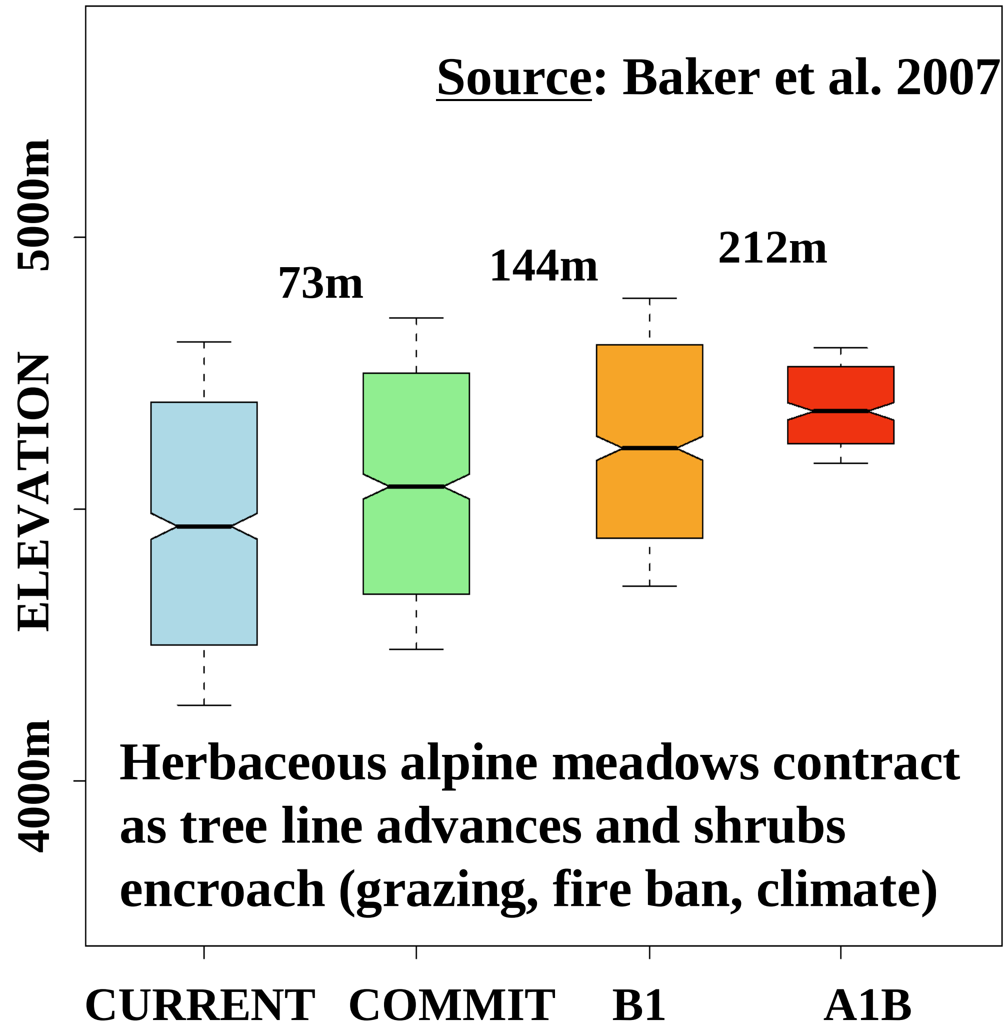
Climate Models: human impacts

- urbanization - urban heat island
- agriculture - effect on water cycle (cloud formation, albedo)
- industrialization - aerosols, particulates (CCN)
- transport - emissions

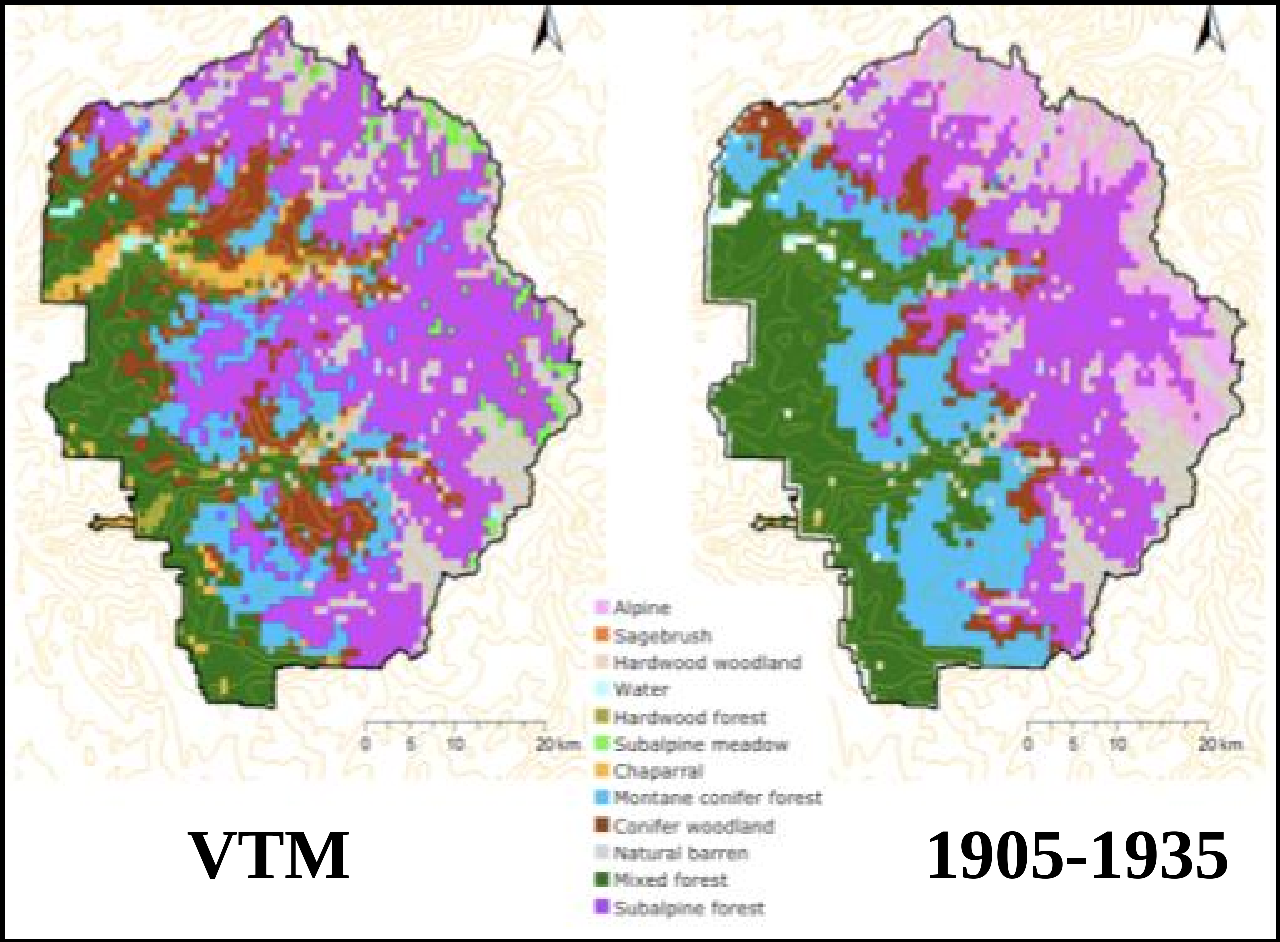
Multiple causes to change in alpine systems







Observations versus Simulations at Yosemite National Park



source: Conklin 2009

Causes of discrepancy between observations and simulations

1. Errors in observations:
    * change in methods between 1930s and 1990s
    * mis-registration of maps
    * uncertainty in cross-walk tables

2. Errors in input data to the model:
    * downscaled climate (complex topography)
    * downscaled/aggregated soils (imprecise map)

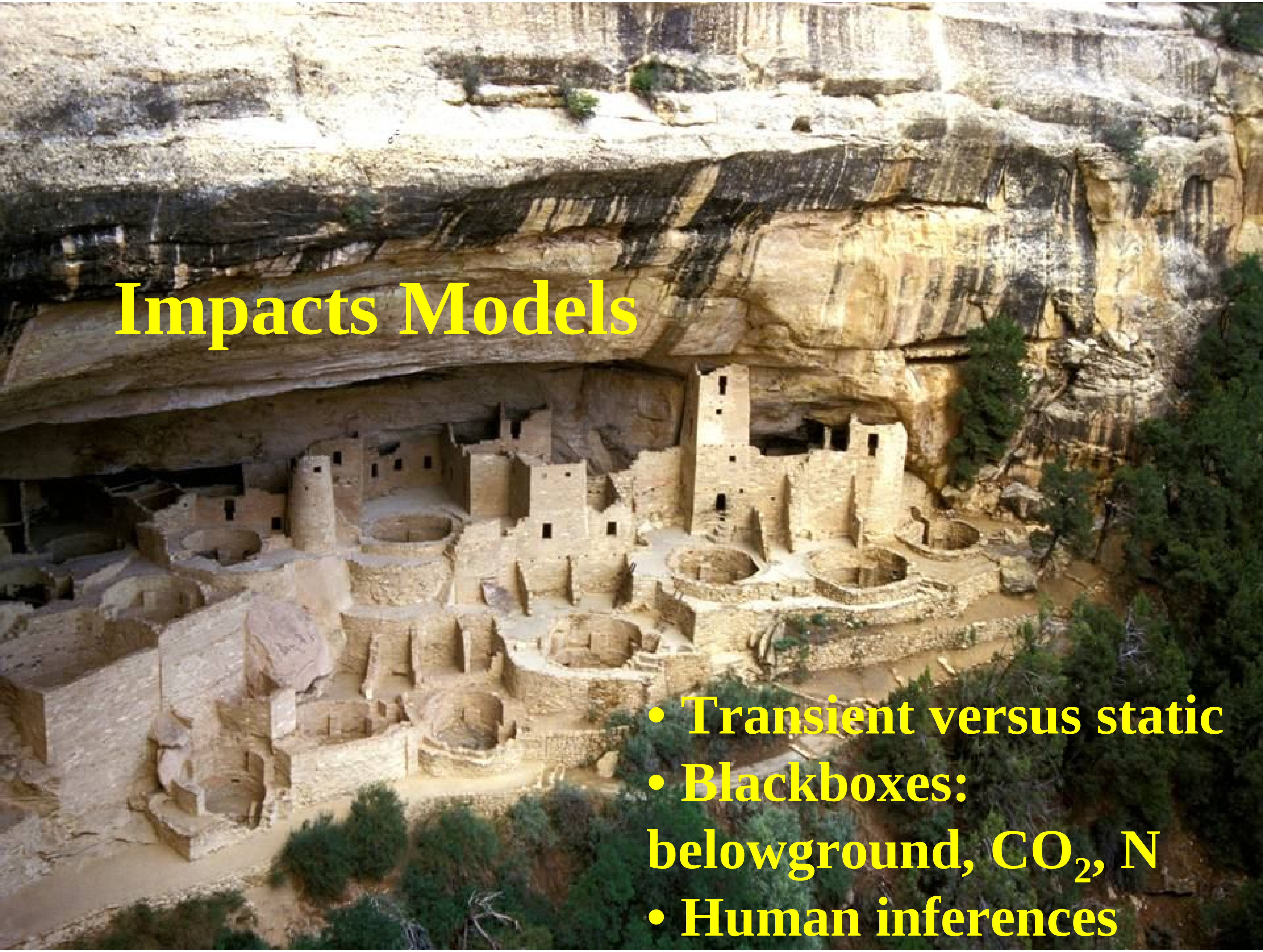
3. Lack of important processes in the model:
    * fire suppression
    * grazing/browsing
    * legacy of landuse: Indians and fire, logging, mining

Conclusions …

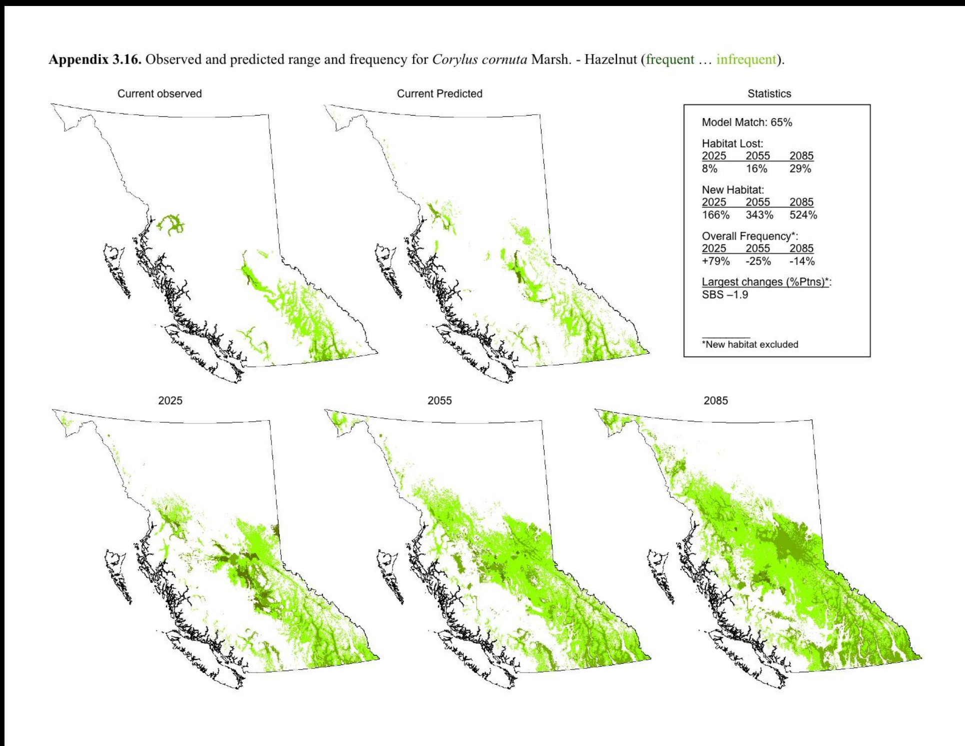
Models are no crystal balls
Models will never be perfect

Toss our models out?

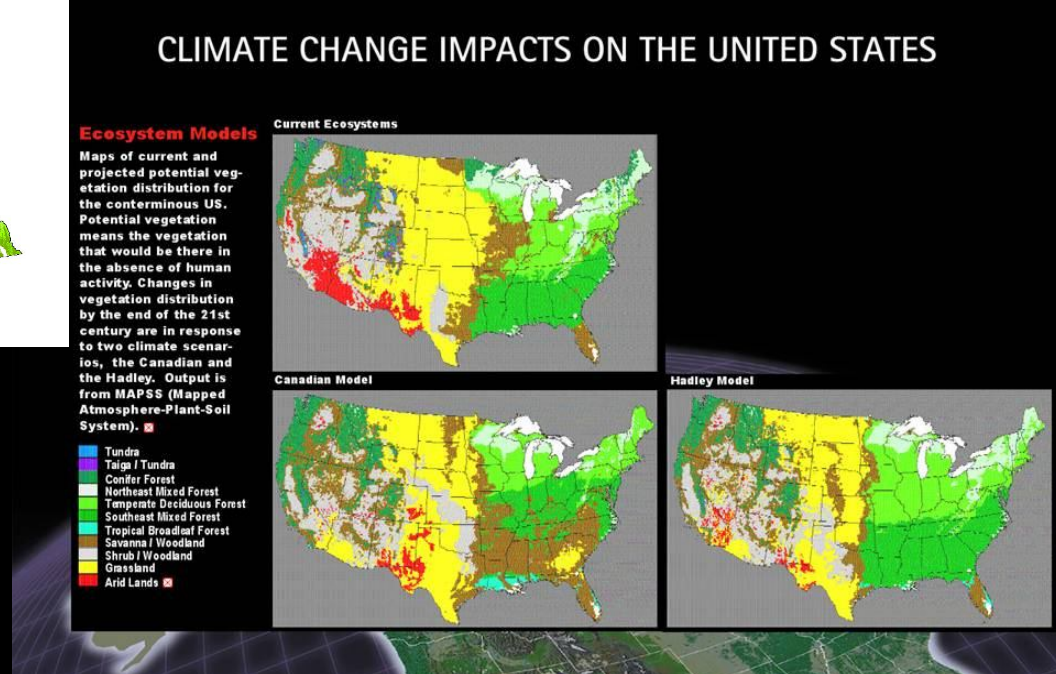
. They remain good synthesis tools
. They allow cheap experiments to test hypotheses
. Now looking at decadal trends using current conditions


Impacts Models
• Transient versus static
• Blackboxes:
belowground, CO_2, N
• Human inferences

Impacts models - Transient vs Static

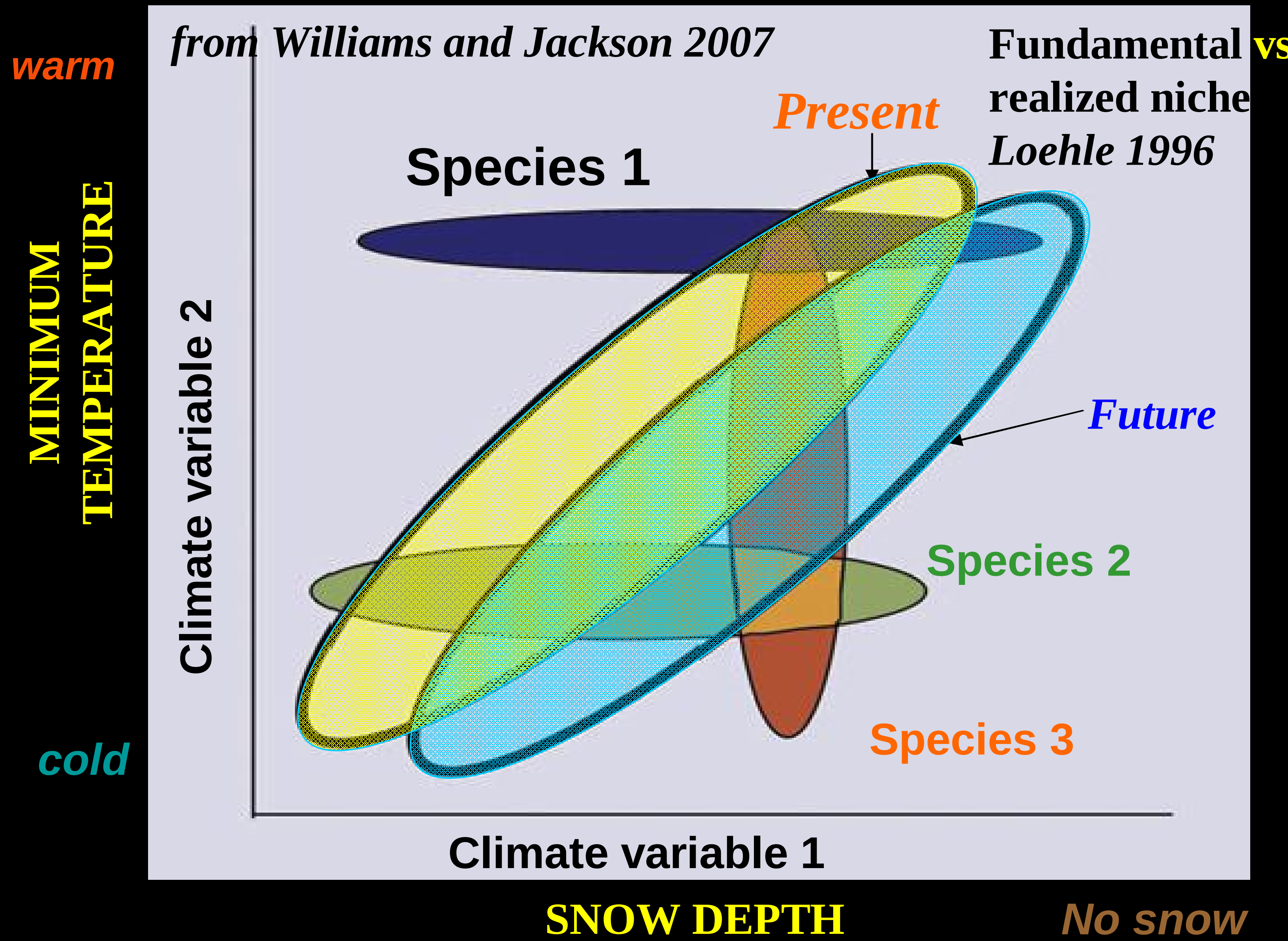


Source: Andreas Hamann



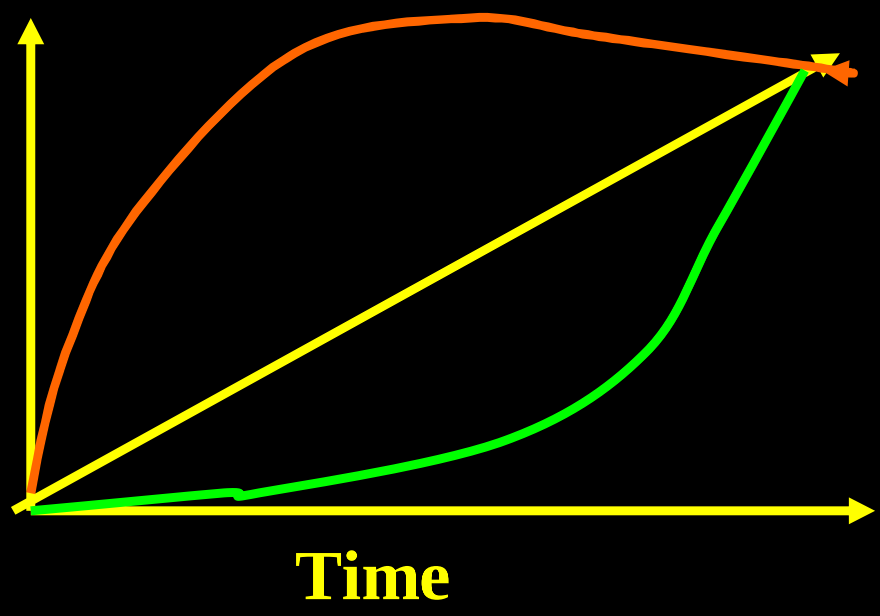
2000 USGCRP
Nat. Ass. Report

Novel climates represent uncharted portions of climate space, where we have no observational data to parameterize and validate ecological forecasts

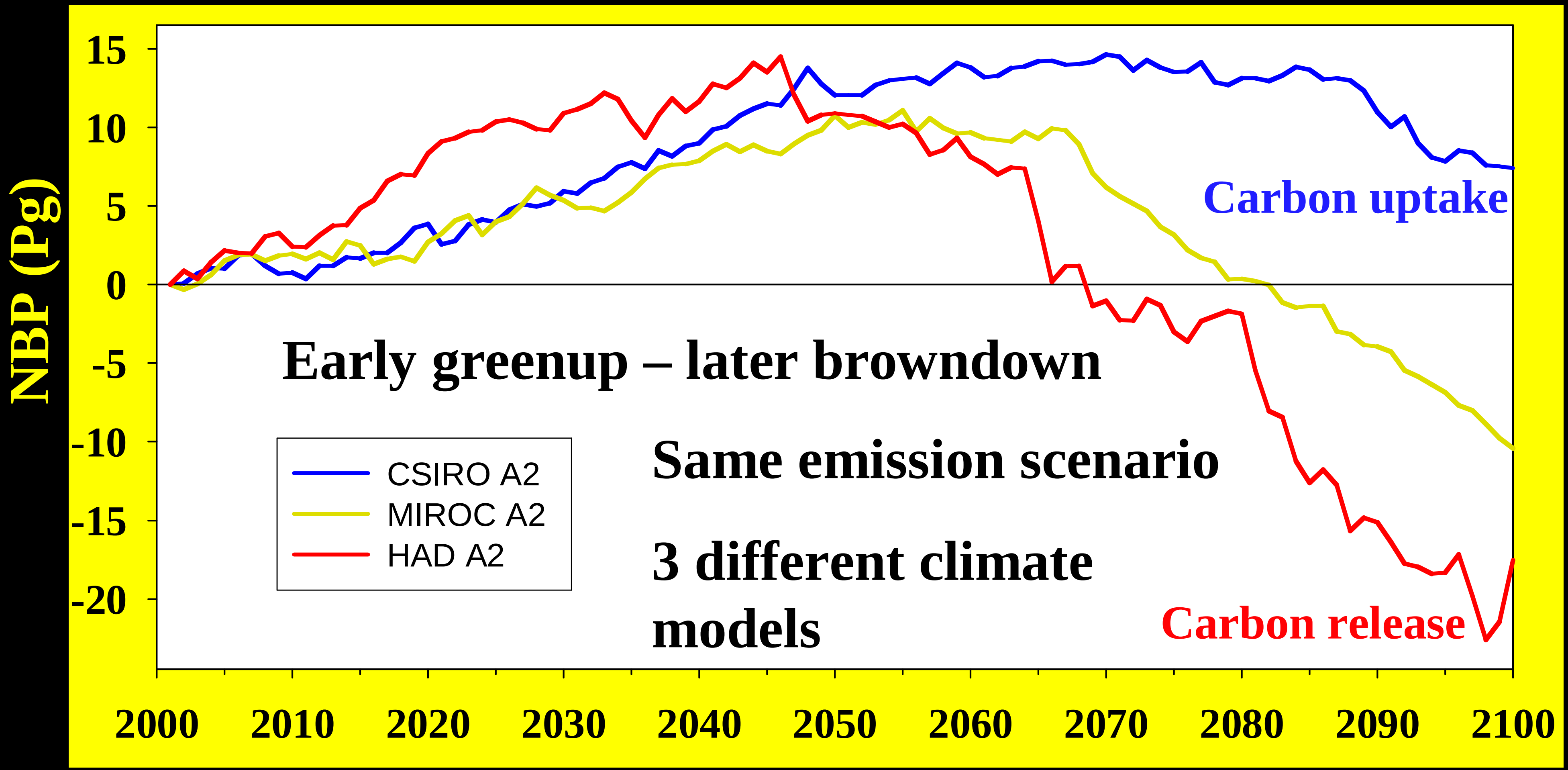


DYNAMIC CHANGE

ex. what will happen between today and 2100?



Testing the impacts of climate inputs on carbon sequestration potential



Bachelet et al. unpub.

Impacts models - level of understanding

- Belowground
- CO_2 fertilization effect
- Nitrogen limitation, saturation

Disturbance driven changes

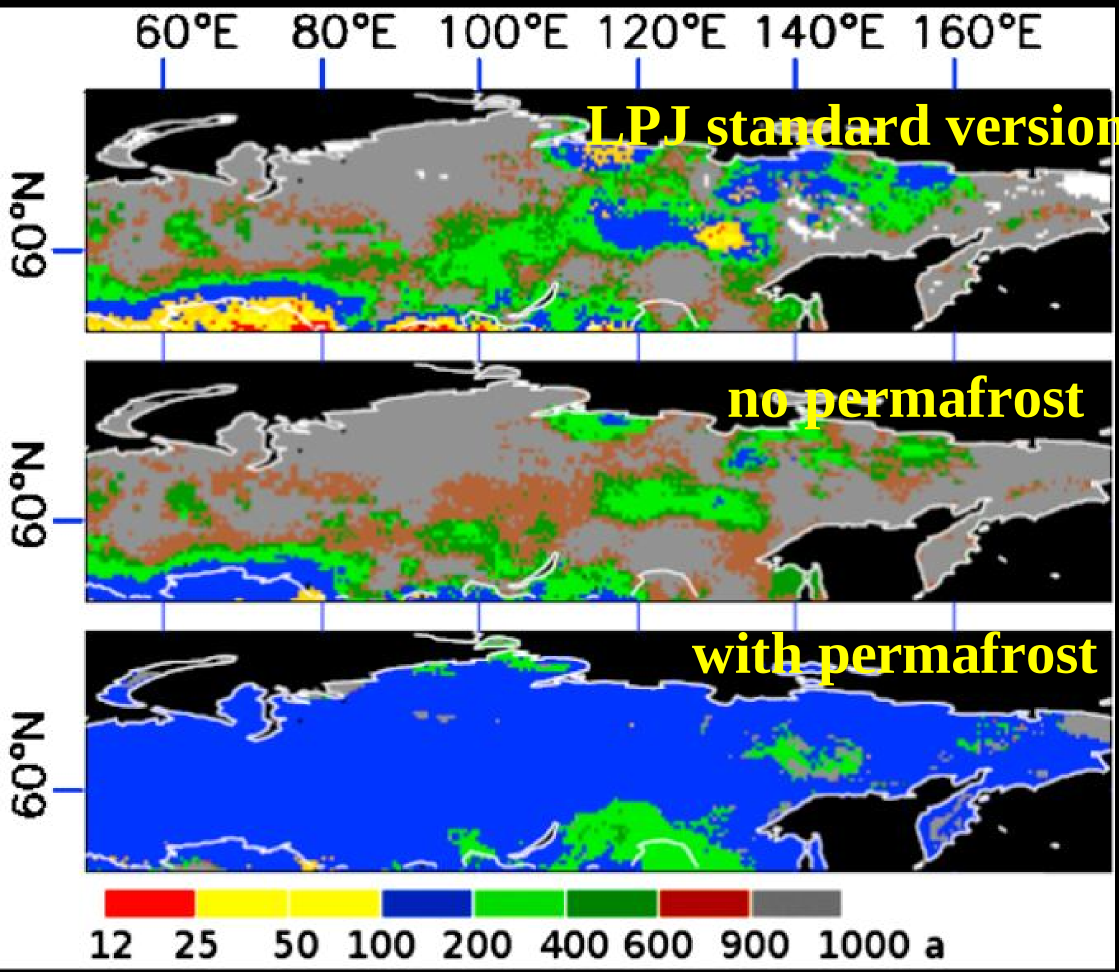
Large uncertainty due to frozen soils

Effects of soil freezing and thawing on vegetation carbon density in Siberia: A modeling analysis with the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ-DGVM)

C. Beer,[1,2] W. Lucht,[3] D. Gerten,[3] K. Thonicke,[4] and C. Schmullius[1]

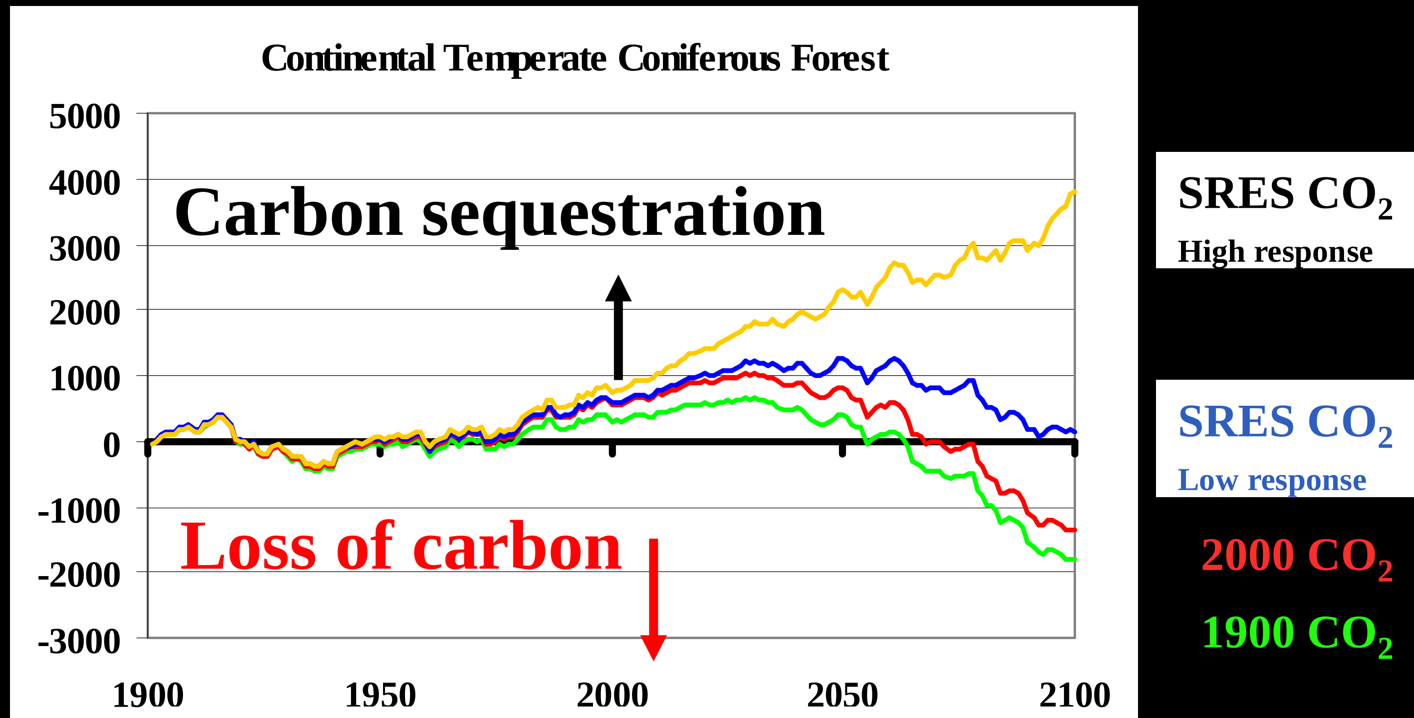
GBC 2007

Mean Fire return interval in N Eurasia 1993-2003



"Without the consideration of freeze-thaw processes, vegetation carbon density would be overestimated by a factor of 2 in southern taiga and a factor of 5 in northern forest tundra, mainly because available soil water would be overestimated with many effects on fire occurrence and NPP."

Testing the impacts of increased atmospheric CO_2 on carbon sequestration potential



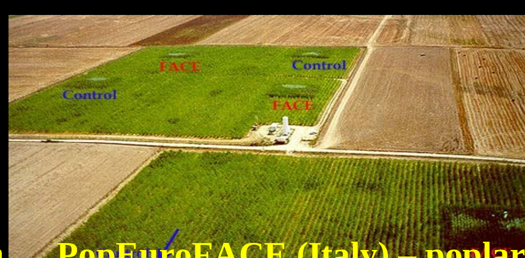
Closed-canopy

DukeFACE (NC) – loblolly pine

ORNL-FACE (TN) – sweetgum

Developing stands

AspenFACE (WI) – aspen/birch



PopEuroFACE (Italy) – poplars

Four experiments: 550ppm exposure for 3-8 years
(*Source: Norby et al. 2005 PNAS 102:1805*)

Revising the impacts of increased atmospheric CO_2 on carbon sequestration potential

Acclimation (23% increase in NPP at peak impacts but dropping)

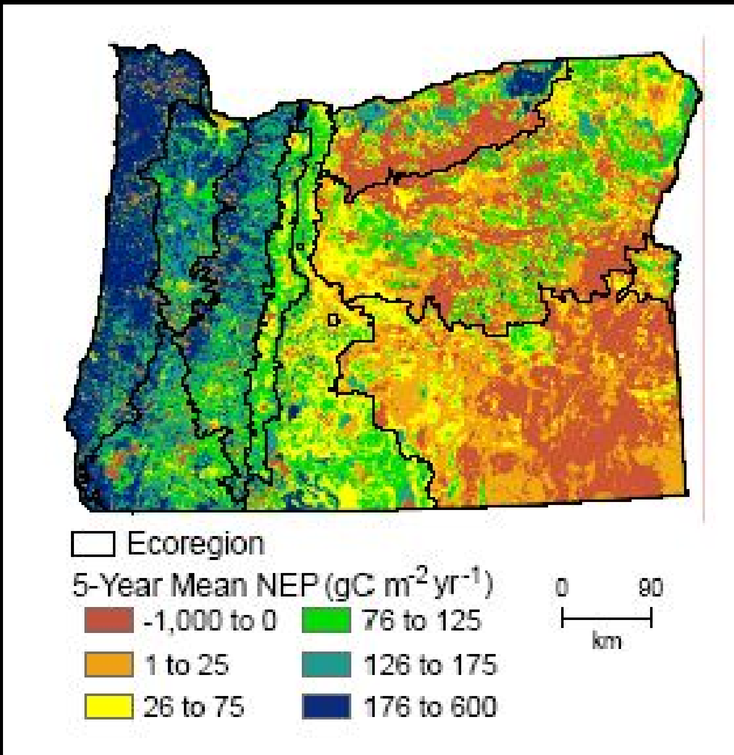
Productivity (turnover) increases belowground: nutrient limitation

Impact on water use efficiency only?

Impacts models – Human impacts

- Economics: price of rice
- Land use: management legacy
- Invasives, gardens, assisted migration

The legacy of the land will affect its response to climate change



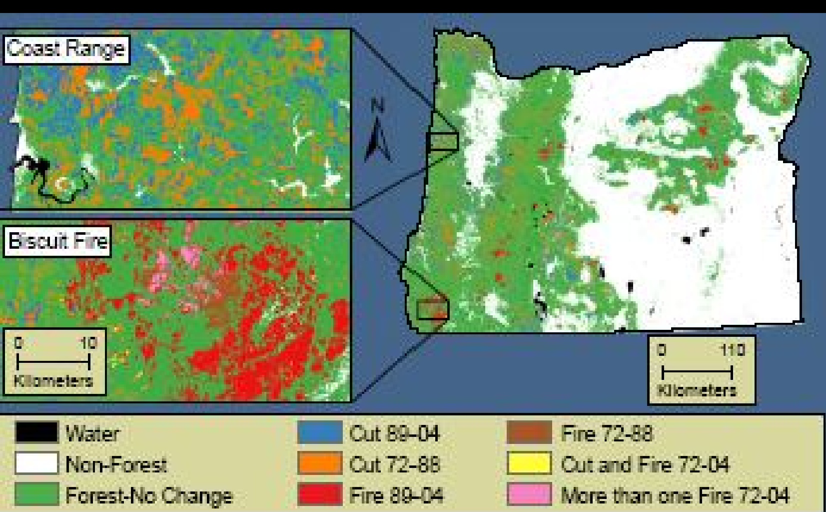
Scaling net ecosystem production and net biome production over a heterogeneous region in the western United States

D. P. Turner[1], W. D. Ritts[1], B. E. Law[1], W. B. Cohen[2], Z. Yang[1], T. Hudiburg[1], J. L. Campbell[1], and M. Duane[1]

[1]Forest Science Department, Oregon State University, Corvallis OR 97331, USA
[2]USDA Forest Service, PNW Station, Corvallis OR 97331, USA

BGC 2007

Carbon sink NEP 1996-2000 = 67 (±42) g C m^{-2} y^{-1} with 63% lost to harvest removal, crop removals, and fires



Prognostic models (spin-up and hist. clim.)
NEP 30 g C m^{-2} y^{-1} in 1990s (*Woodward 2001*)

Diagnostic models (climate obs and NDVI)
C source (< 0) for 1982-1997 (*Potter et al. 2006*)

Cheatgrass causes decline in sagebrush:
fuel continuity, fuel load, cause frequent fires in systems unused to fire

Buffelgrass and Saguaros:
Julio Betancourt's cause

Biofeedbacks to atmosphere

Gaseous fire emissions (GHG, reflection)
Particulate emissions (CCN)
Reduced CO_2 exchange (reduced PAR)
Albedo changes (dust deposition)
Hydrological changes (soil)
Nutrient release and transport (deposition, invasives)

Impacts Models

The purpose of models is not to fit the data but to sharpen the questions.
Samuel Karlin (1924-2007)

. Changes are dynamic, disturbances are key drivers
. Revisions always needed as our knowledge increases (monitoring)
. Human impacts are difficult to predict but always significant

Meeting the Audience Needs

- Scientists - Colleagues:
  - competition for funding
  - collaboration
- Managers, land stewards:
  - extremes
  - field relevance
- Policy makers:
  - now
  - precise

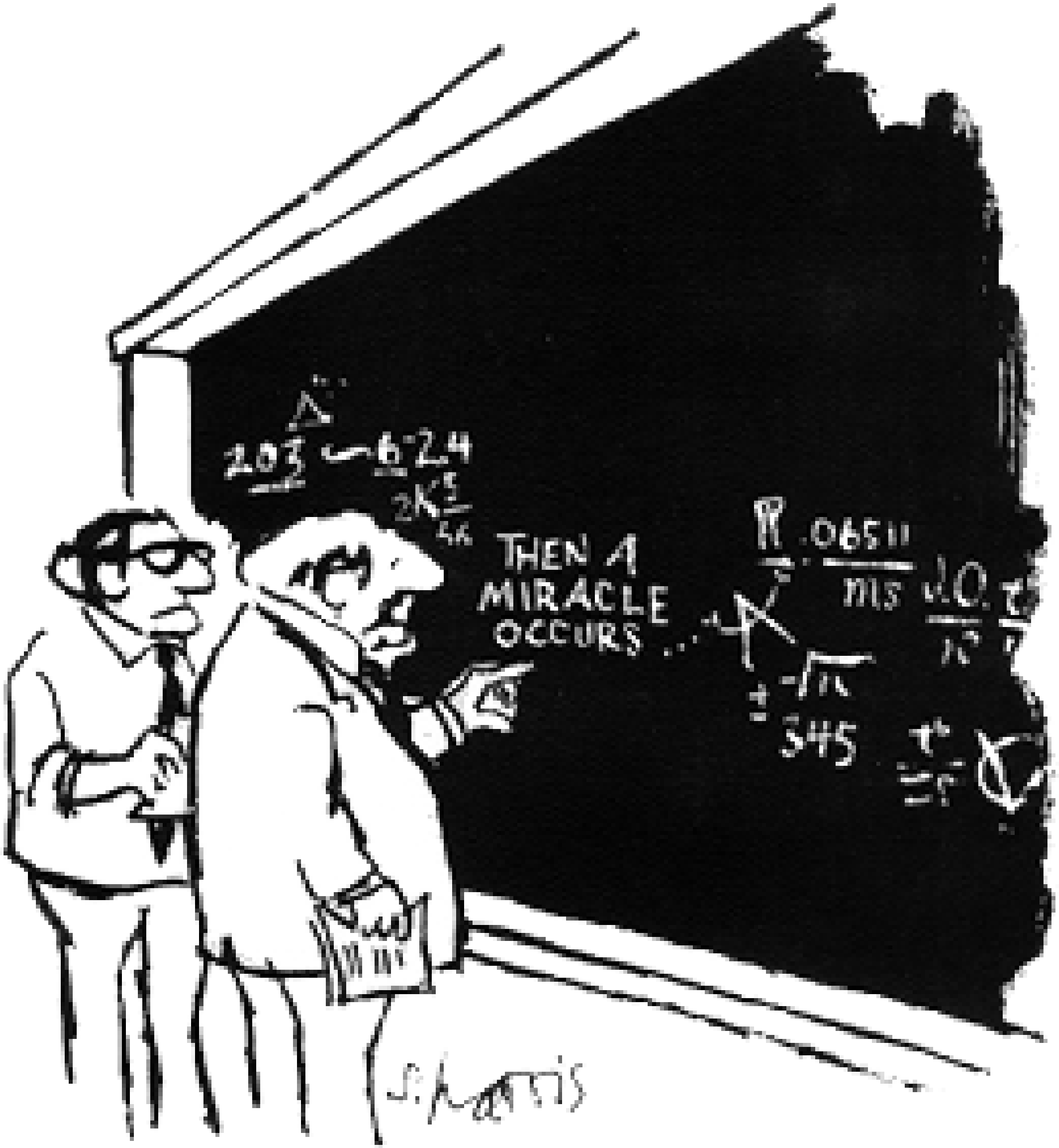
Meaningful and relevant modeling is a product of close and continuous interaction between the decision maker and the modeling experts.

http://www.decisioncraft.com/dmdirect/whymodel.htm

"A theory has only the alternative of being right or wrong. A model has a third possibility: it may be right, but irrelevant."

Manfred Eigen (1927 - ; Nobel in Chemistry in 1967), The Physicist's Conception of Nature, 1973.

The problem

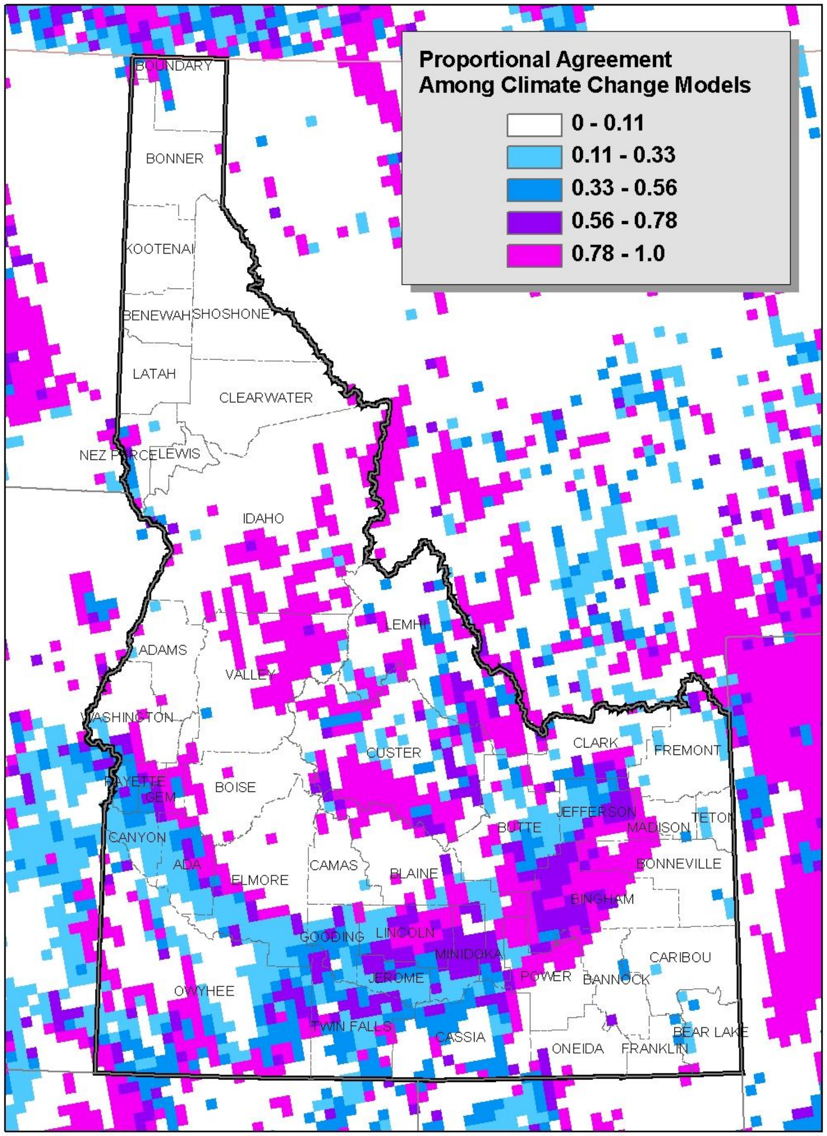


"I think you should be more explicit here in step two."

How can a modeler be effective at transmitting knowledge?

- Package uncertainty: climate, impacts
- Public tolerance of change: education
- Frame of mind rather than knowledge: dynamic, unknowns, past understanding
- Modulate reliance on models for decision
- Scale of concern vs scale of knowledge
- Humans are the wild card
- Data availability and visualization tools

Figure 2. The likelihood that climate change will cause a shift in biome in Idaho for the period 2071-2100 (Gonzalez et al. 2007).



Example with TNC

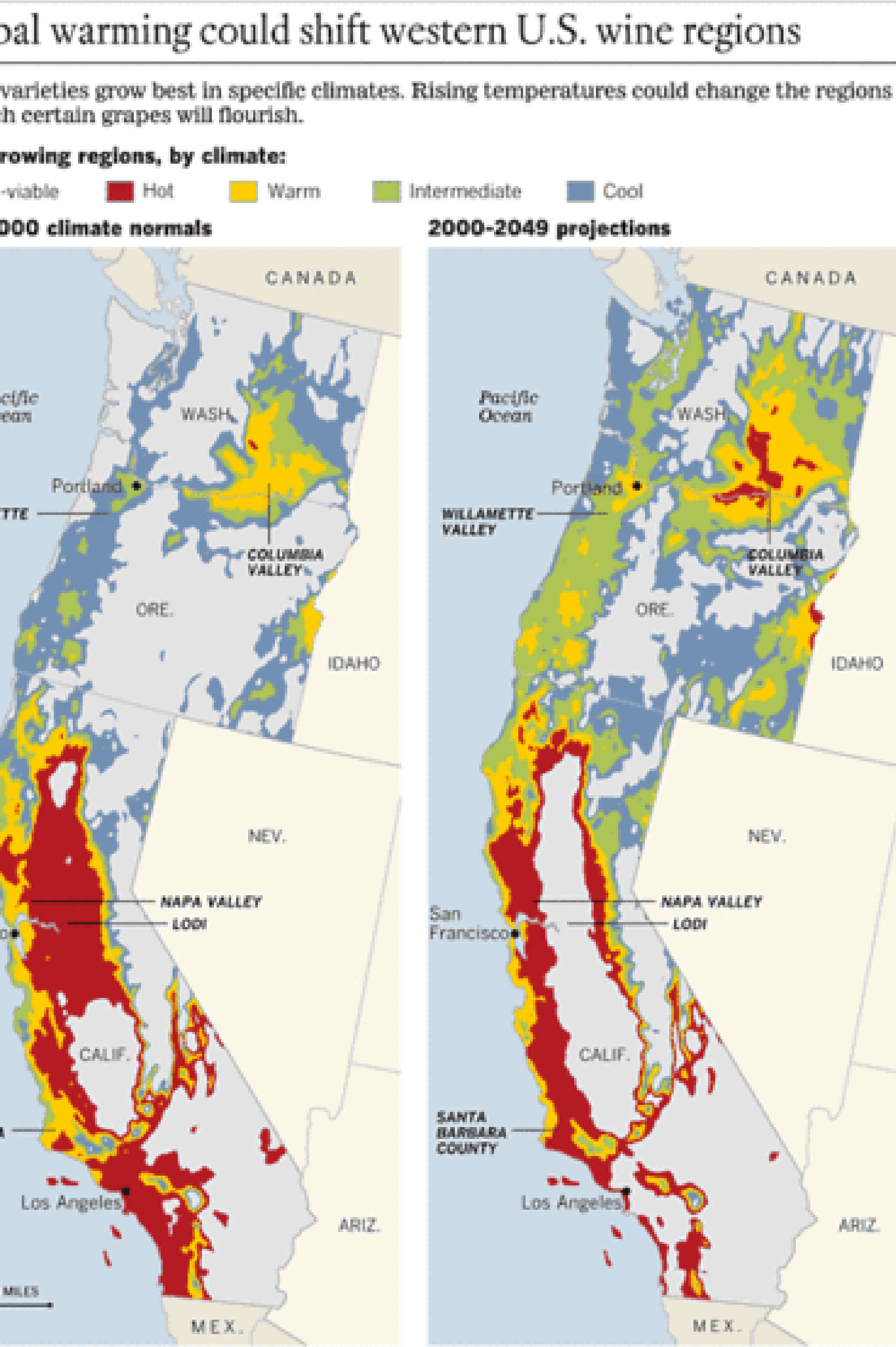
Choices for future conservation areas

3 GCMs (Had, CSIRO, MIROC)

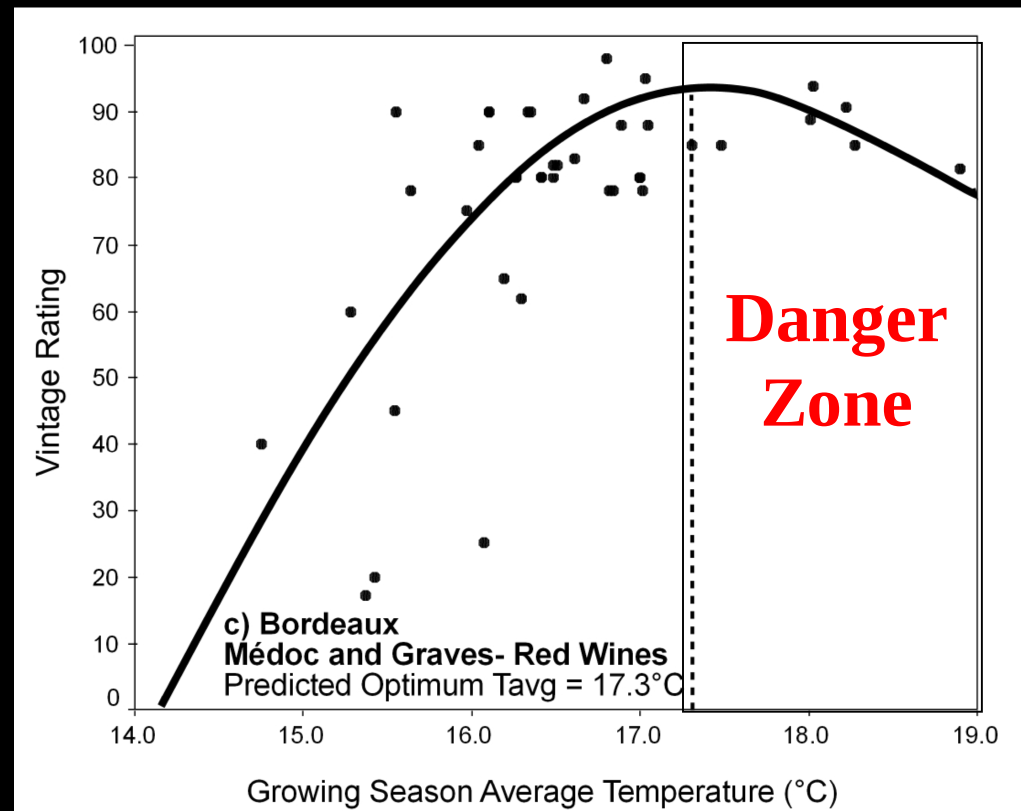
3 emission scenarios (A2, B1, B2)

Agreement among models

Results to be acted upon?

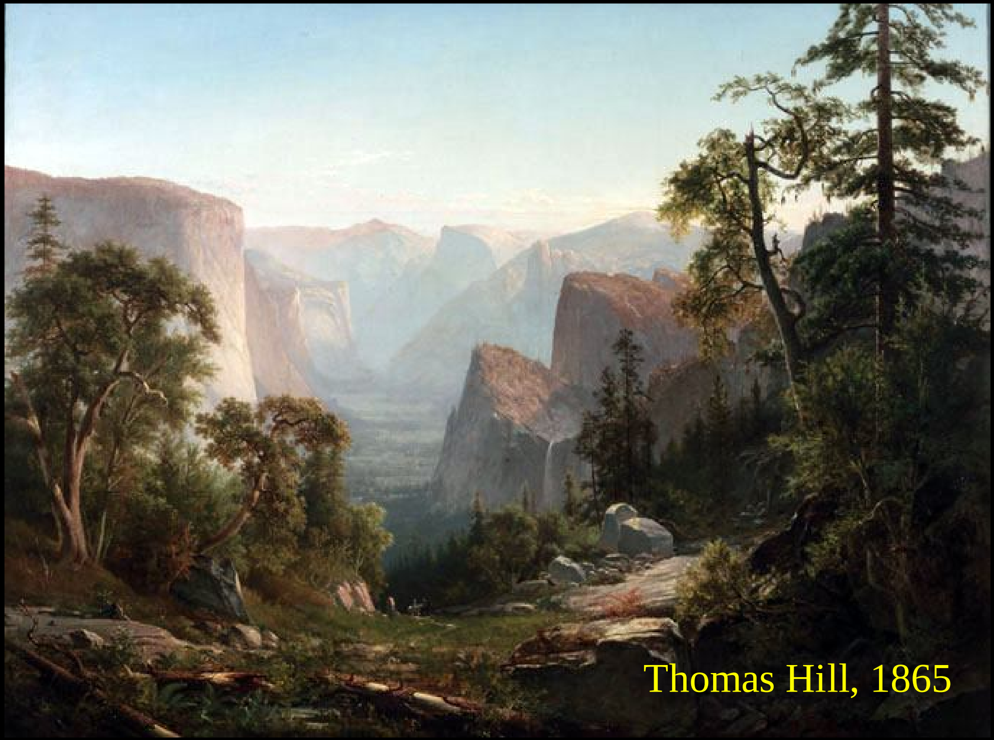


Choosing an interesting subject with simple message



Source: Jones et al. 2005, Climatic Change

Impacts models
Visuals

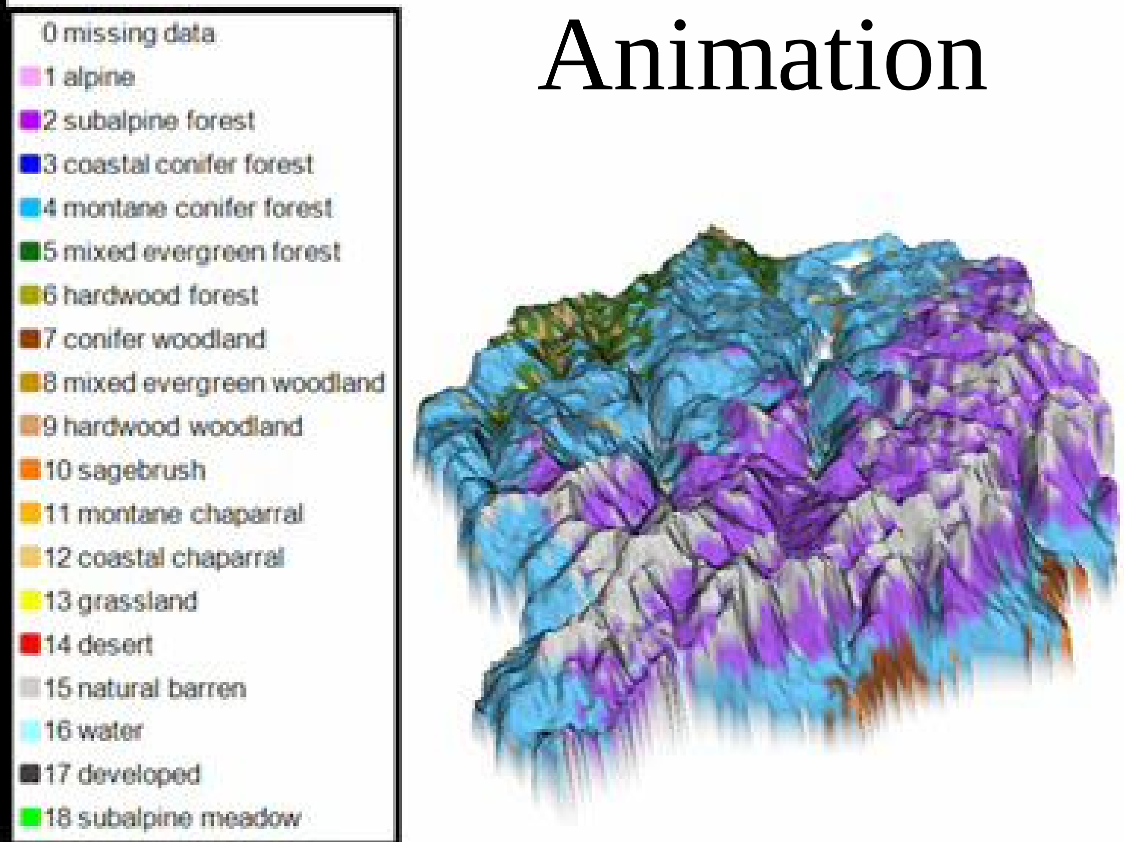


Historical Change

Impacts models
Dramatic Visuals

2007

Impacts models Animation

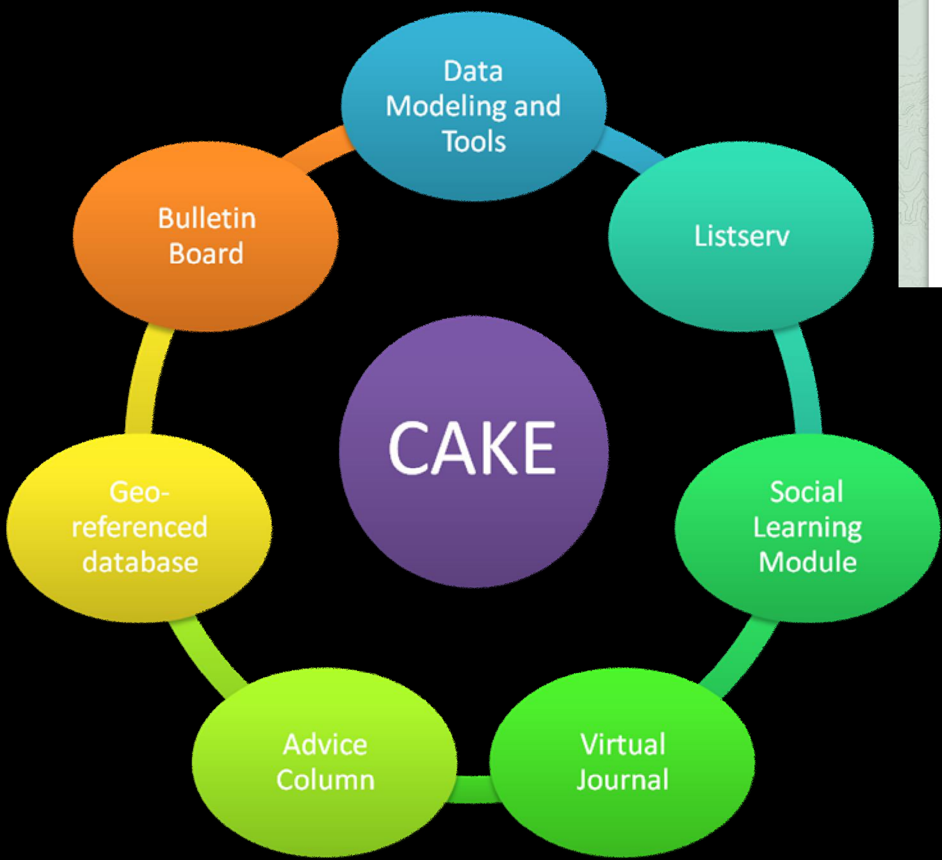


Yosemite- CSIRO model

source: Lee Zeman, Evergreen College, unpub.

CBI Data Basin

Climate Adaptation Knowledge Environment



TNC Climate Wizard

Meeting the Audience needs

. Providing the information (database)
. Providing tools to analyze the data
. Providing network of experts (groups)
. Providing examples (projects)


Thank you for your attention!