

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



Dominique Bachelet, Ph D.
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
 - bison, 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

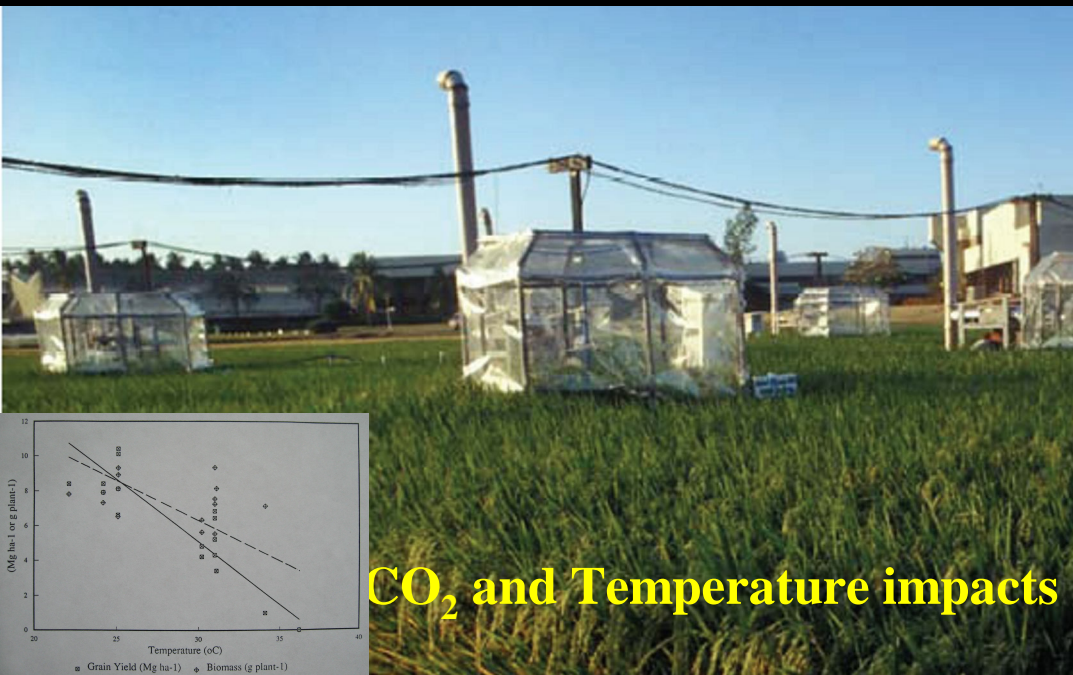


Will Burgess / Reuters

COPING WITH CLIMATE CHANGE

Climate change threatens to affect rice production across the globe. What is known about the likely impact, and what can be done about it?

80% of rainfed rice in S & SE Asia

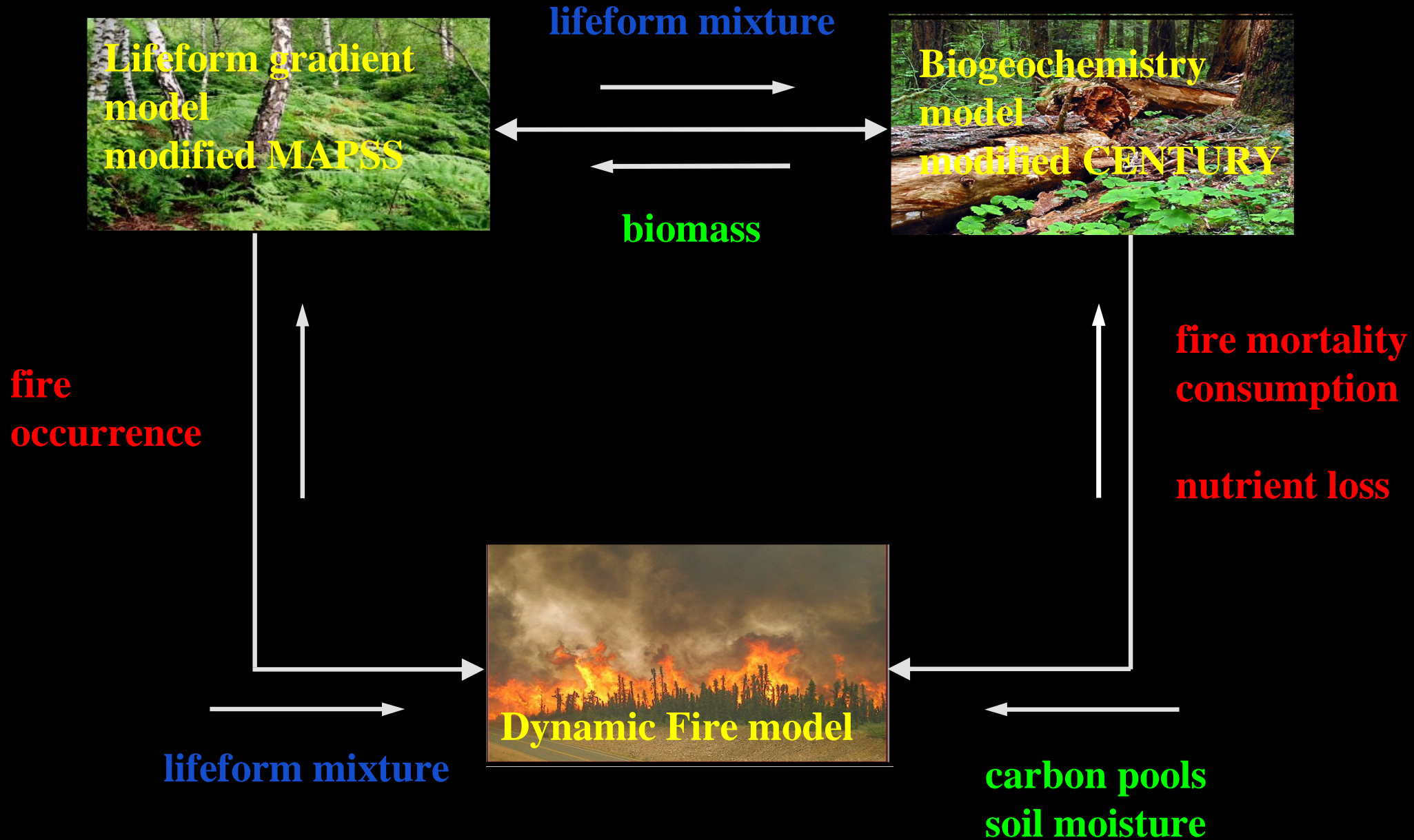


EPA, IRRI, D, NL

Research Projects

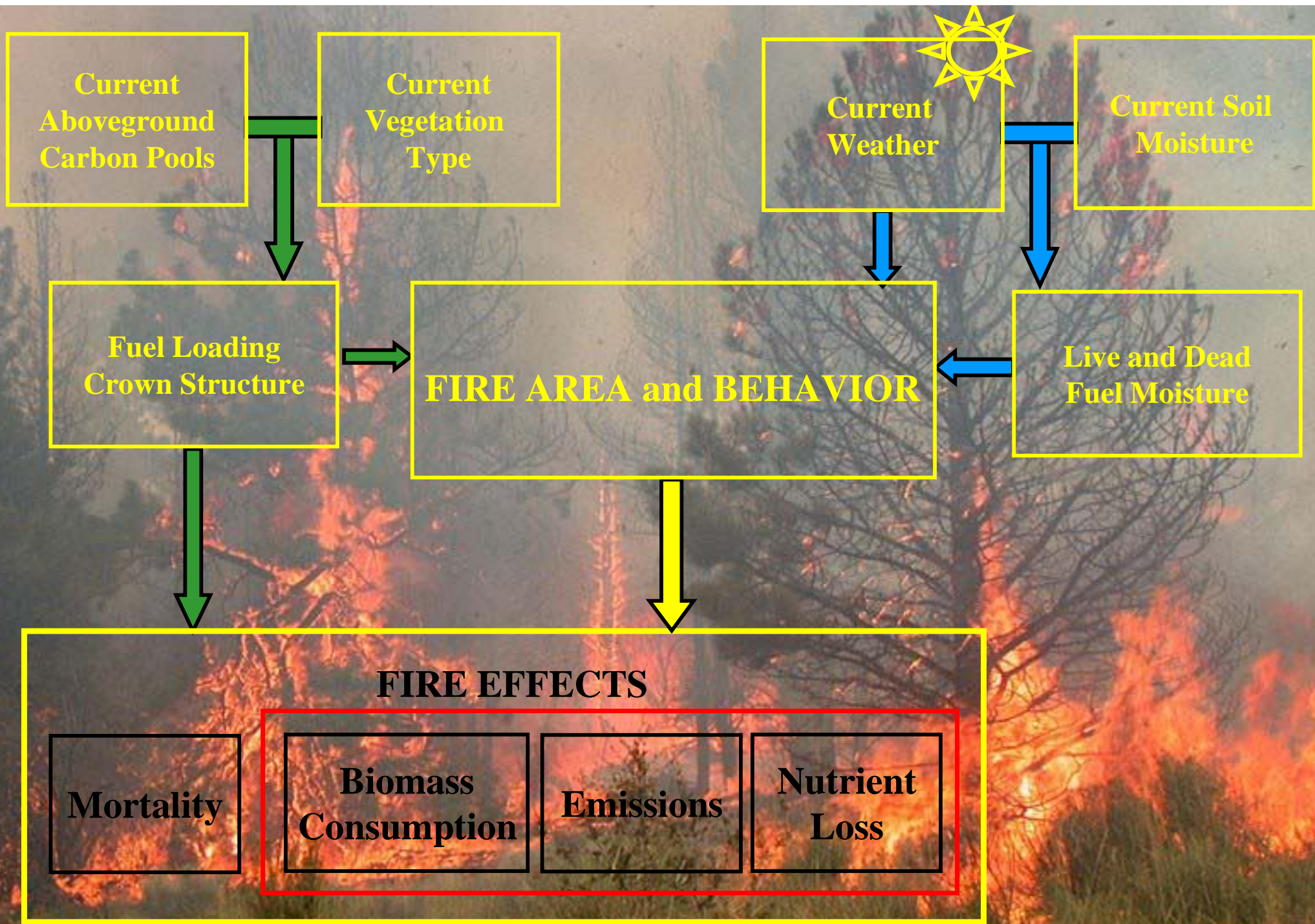
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MC1 Dynamic Vegetation Model



Research Projects

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Fire Module

Research Projects

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Climate Adaptation Knowledge Environment



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- World Terrain Source: ESRI
- World Imagery Source: ESRI
- World Streets Source: ESRI
- World Political Boundaries Source: ESRI
- World Shaded Relief Source: ESRI

The Nature Conservancy | **ClimateWizard** | UNIVERSITY OF WASHINGTON | THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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Analysis Area
 United States Global
 United States

Time Period
 Past 50 Years
 Mid Century (2050)
 End Century (2100)

Map Options
 Map of Average
 Map of Change
 Annual

Measurement
 Average Temperature
 Precipitation

Resources
[Case Studies](#)
[Documentation](#)
[Data \(GIS format\)](#)
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Future Climate Model
 IPCC Fourth Assessment
 Emission Scenario: High A2
 General Circulation Model: Ensemble Average

Change in Annual Temperature by 2100
 Model: Ensemble Average, SRES emission scenario: A2

Map Transparency: 0

Mean Temp (F) Departure: 10.0 F, 7.5, 5.0, 2.5, 0.0, -2.5, -5.0, -7.5, -10.0

Data Source: Base climate projections downloaded by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Map data ©2009 LeadDog Consulting, Tele Atlas, INEGI, EuroGIS Technologies - 12/25

OUTLINE

- Definitions
- Climate models
 - scale
 - **natural climate variability**
 - **extremes** and surprises
 - **human** impacts
- Impacts models
 - **Transient** versus **static**
 - **Blackboxes**: belowground, CO₂, 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

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**

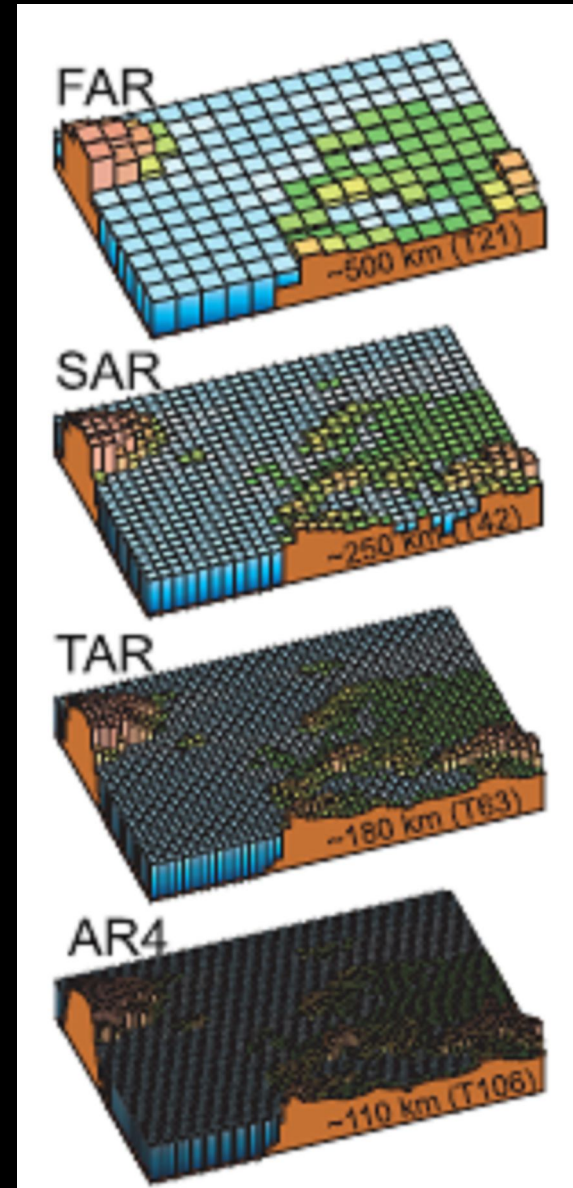


Climate models (why ecologists care)

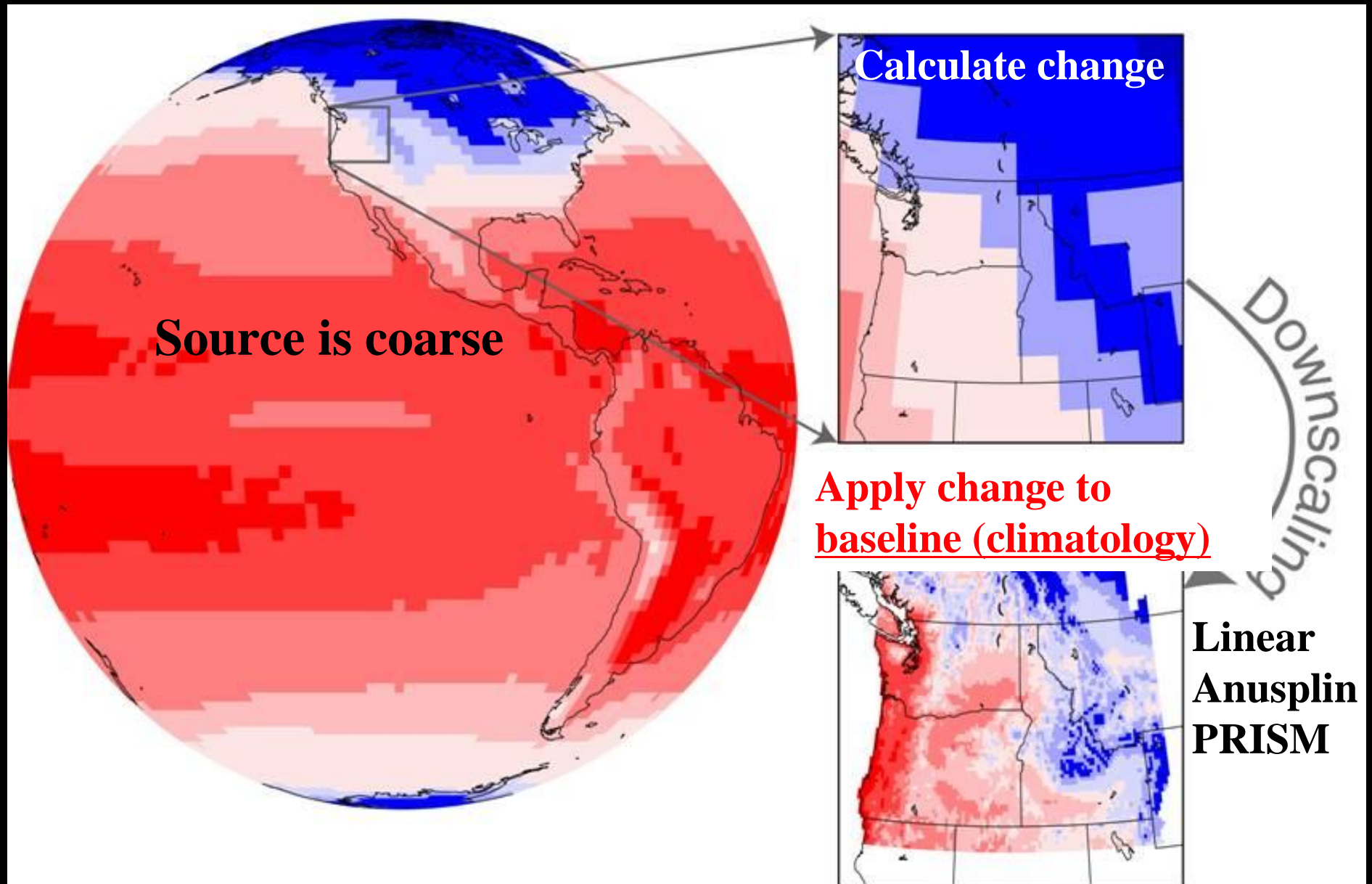
- Scale
- Natural climate variability
- Extremes and surprises
- Human impacts

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



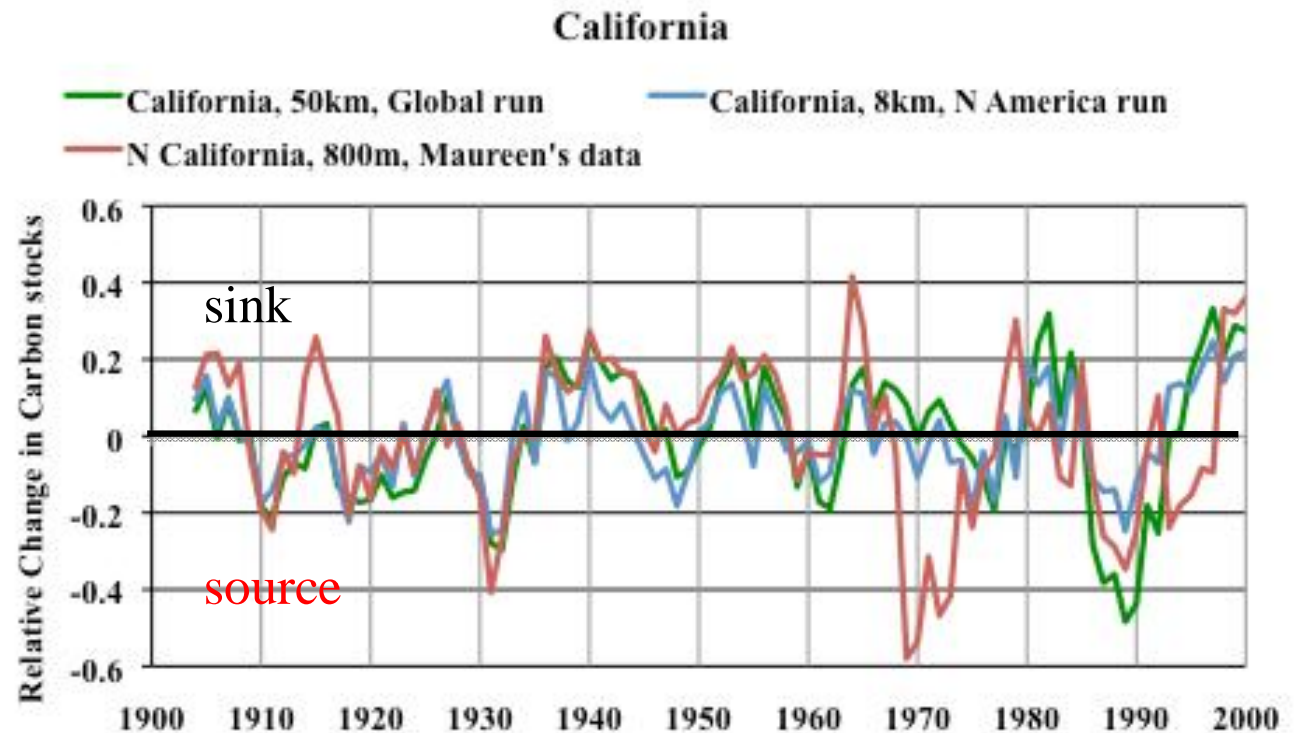
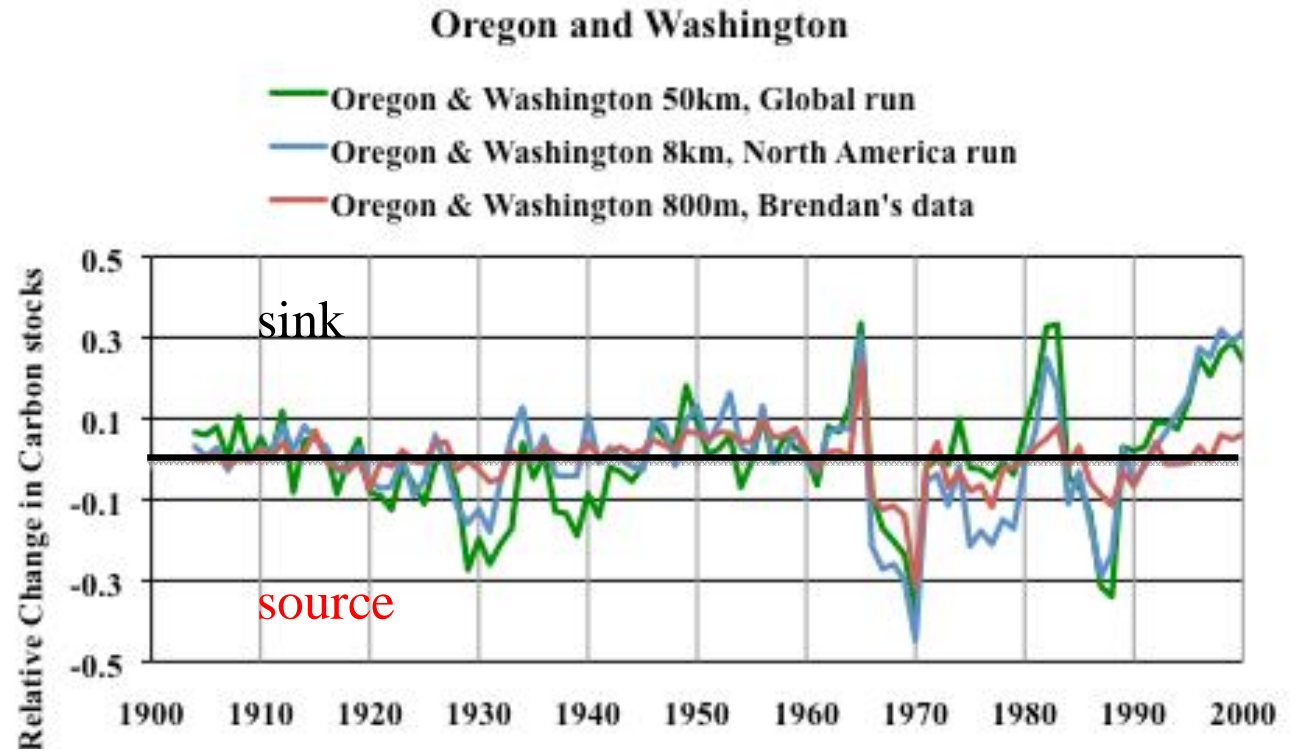
Until better ... ecologists downscale



source: CIG Seattle

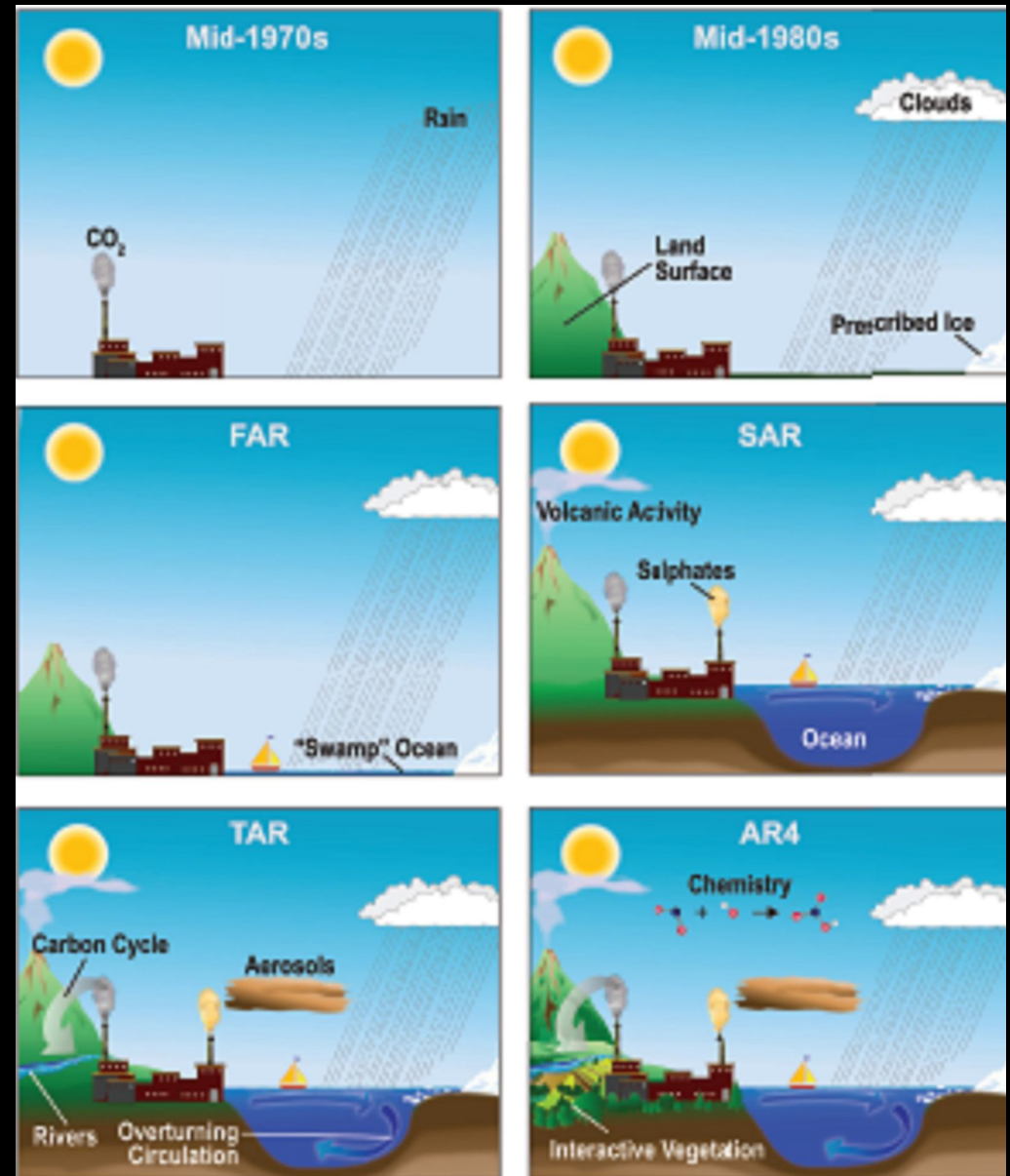
Results and their interpretation differ at different scales: regionally and temporally

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

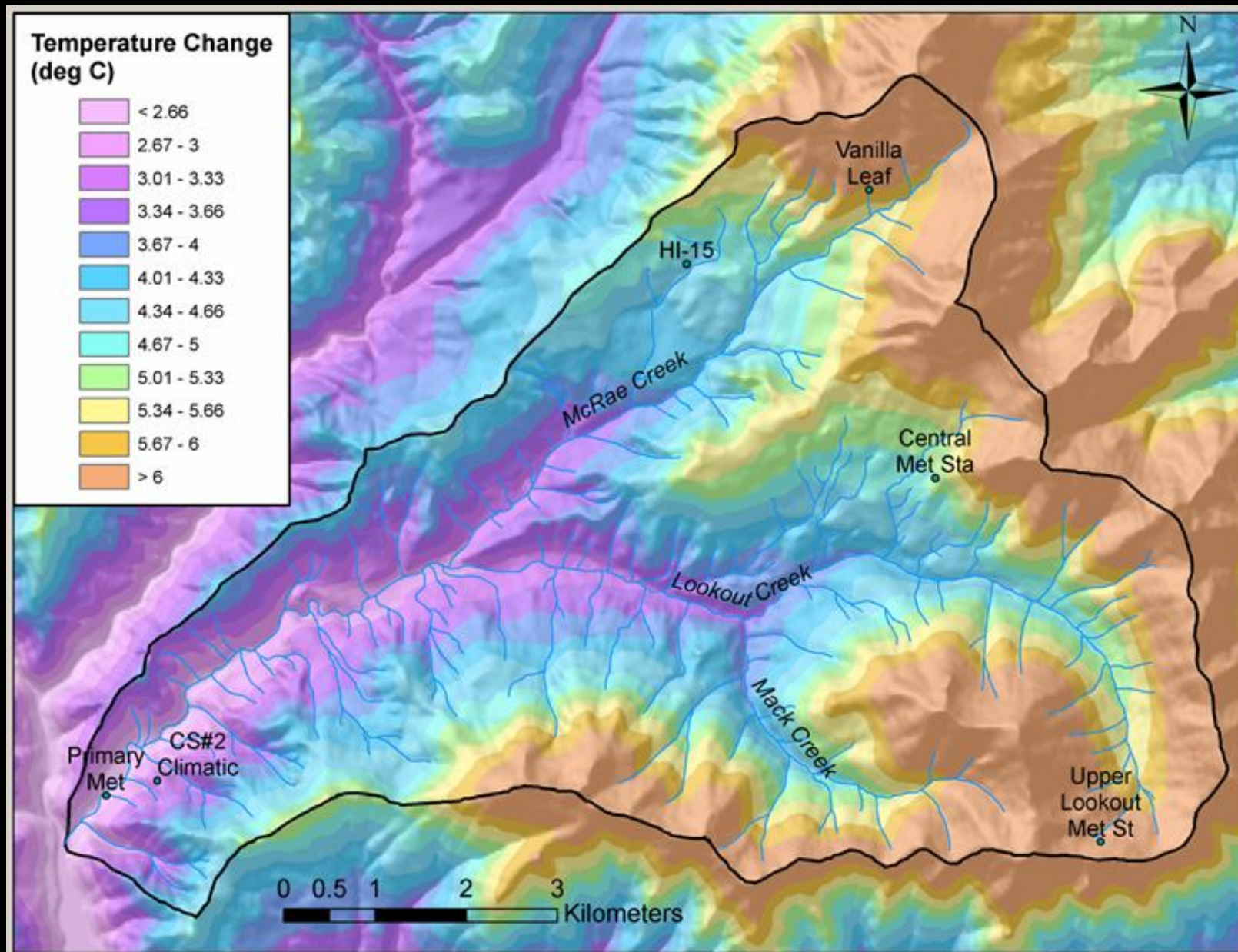


Climate Models: Scale

- 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

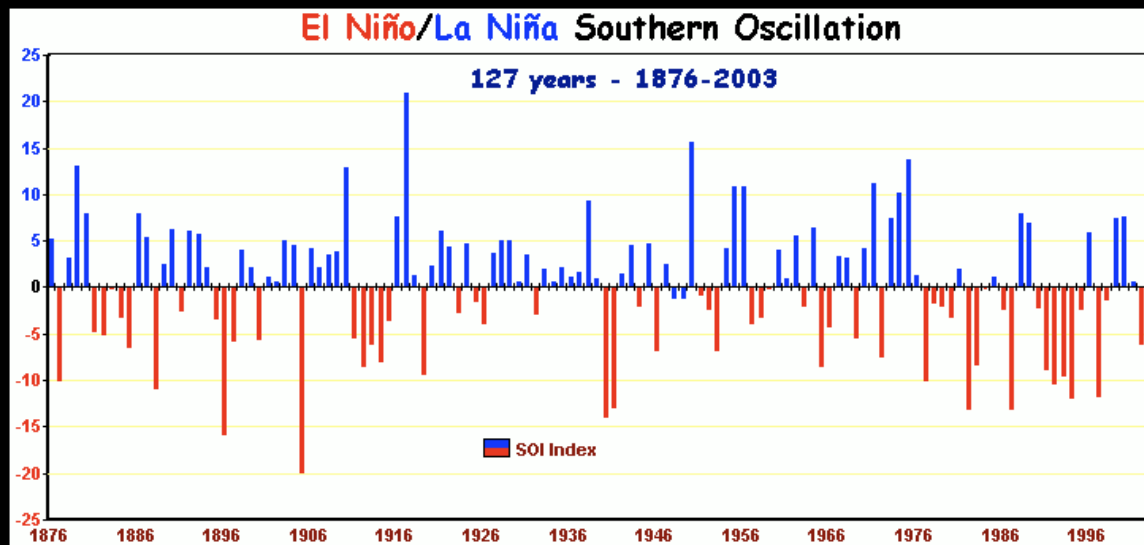
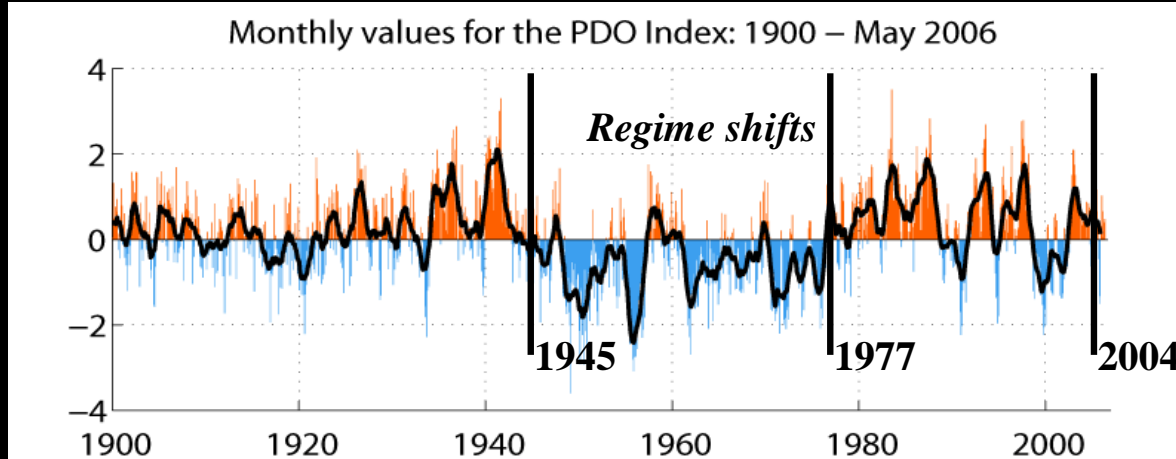


HJ Andrews January Tmax (+2.5C Regional Change and +10 Anticyclone-Cyclone)

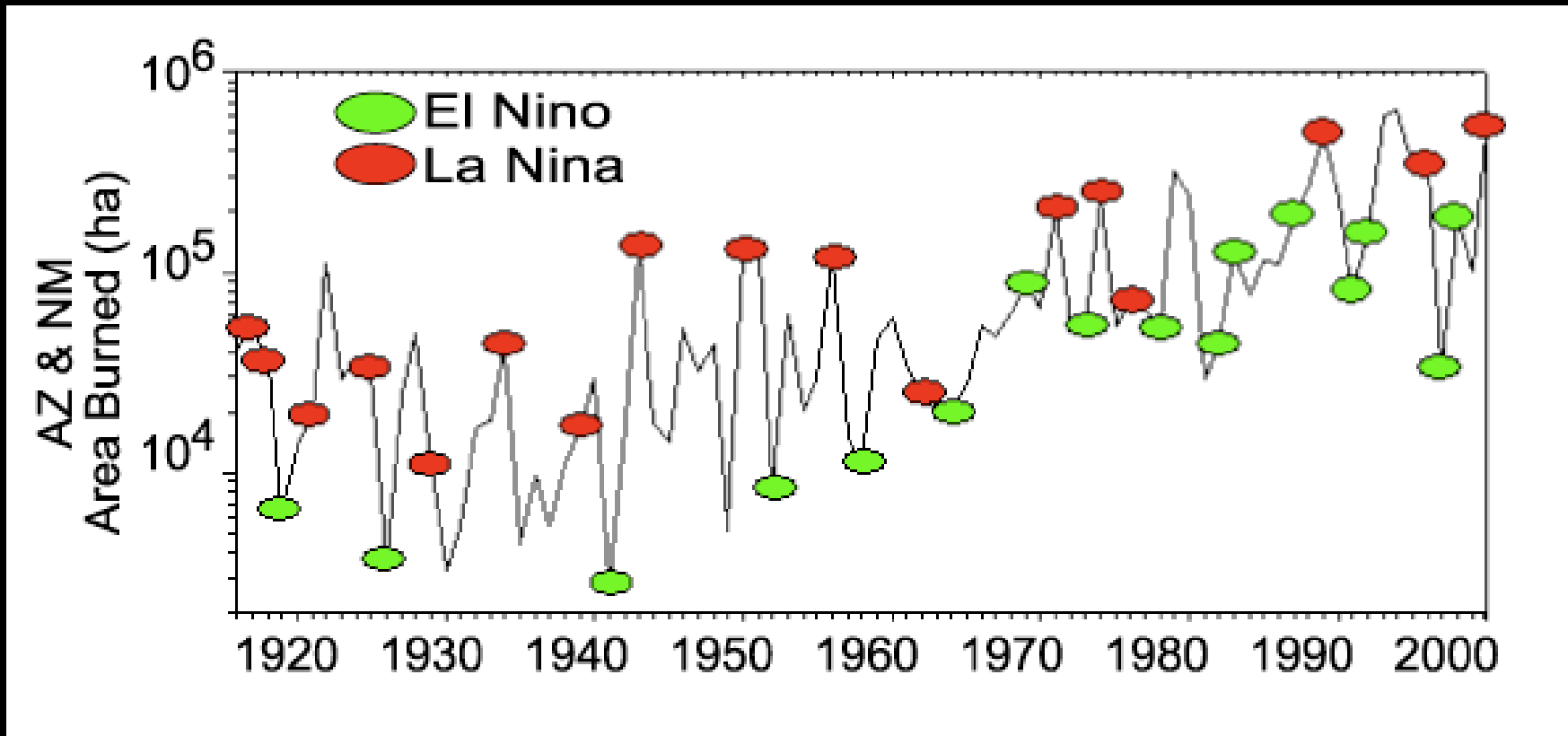
Source: C. Daly, AGU 2007

Climate Models

Natural climate variability



In the Southwestern US, ENSO drives fires

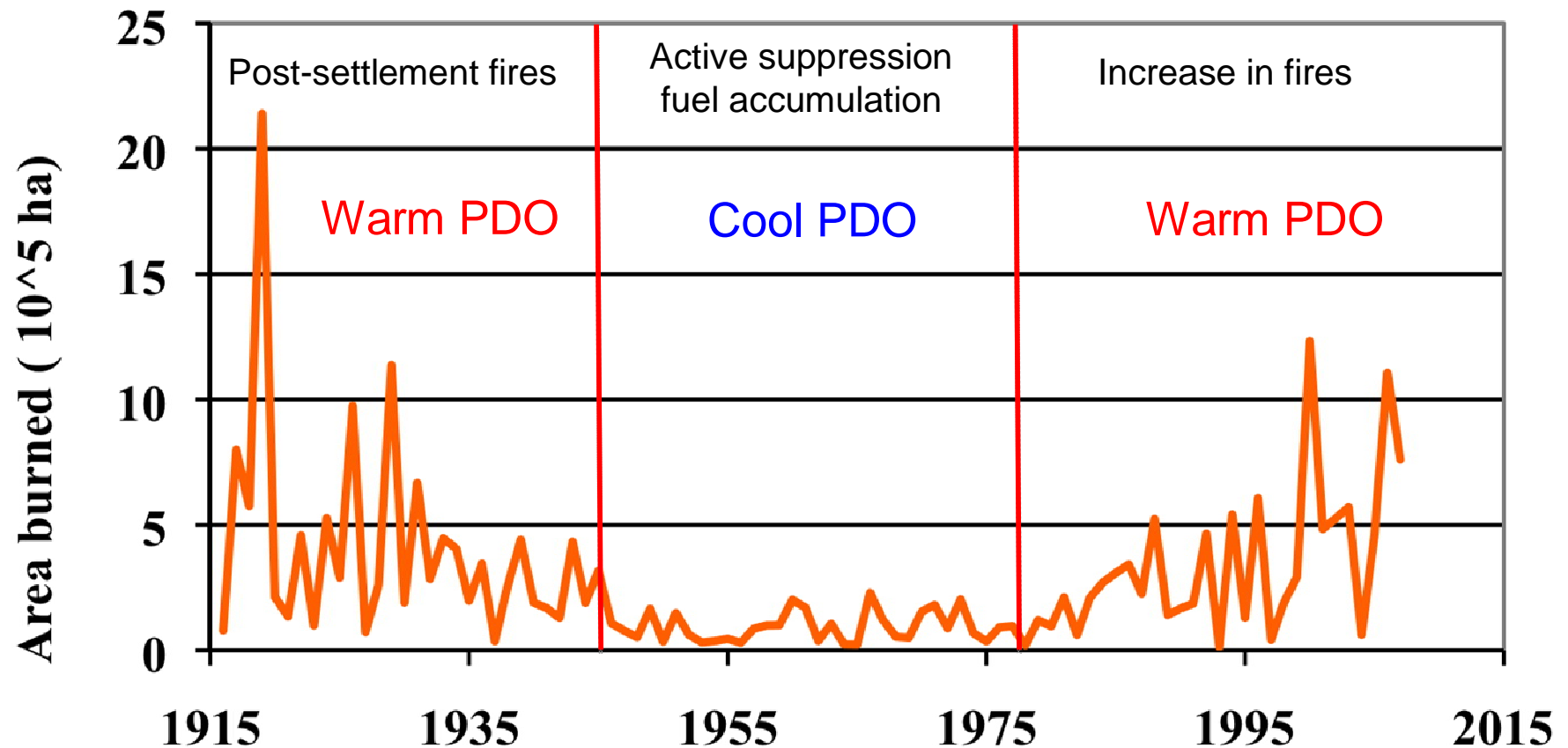


Updated from Swetnam, T.W., and J.L. Betancourt, 1990: Fire-Southern Oscillation relations in the southwestern United States. *Science* 249:1017-1020.

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

North Pacific monthly sea surface temperature variability

WA, OR, ID and western MT observed fires (Littell)



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



Katrina, Alabama

warm ocean

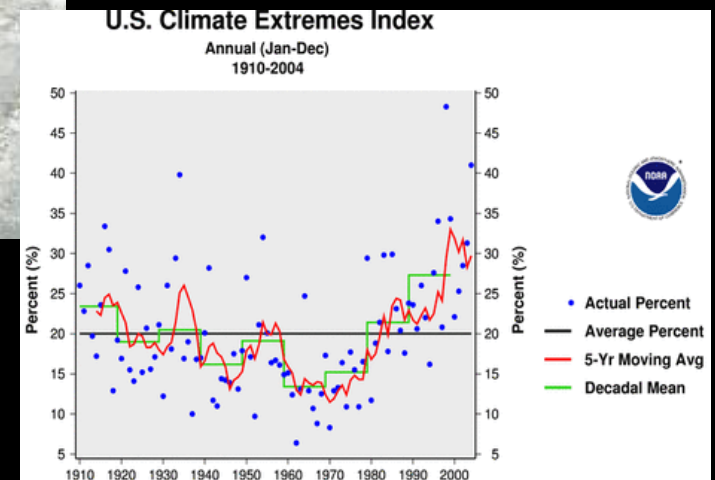


Geneva, 2005

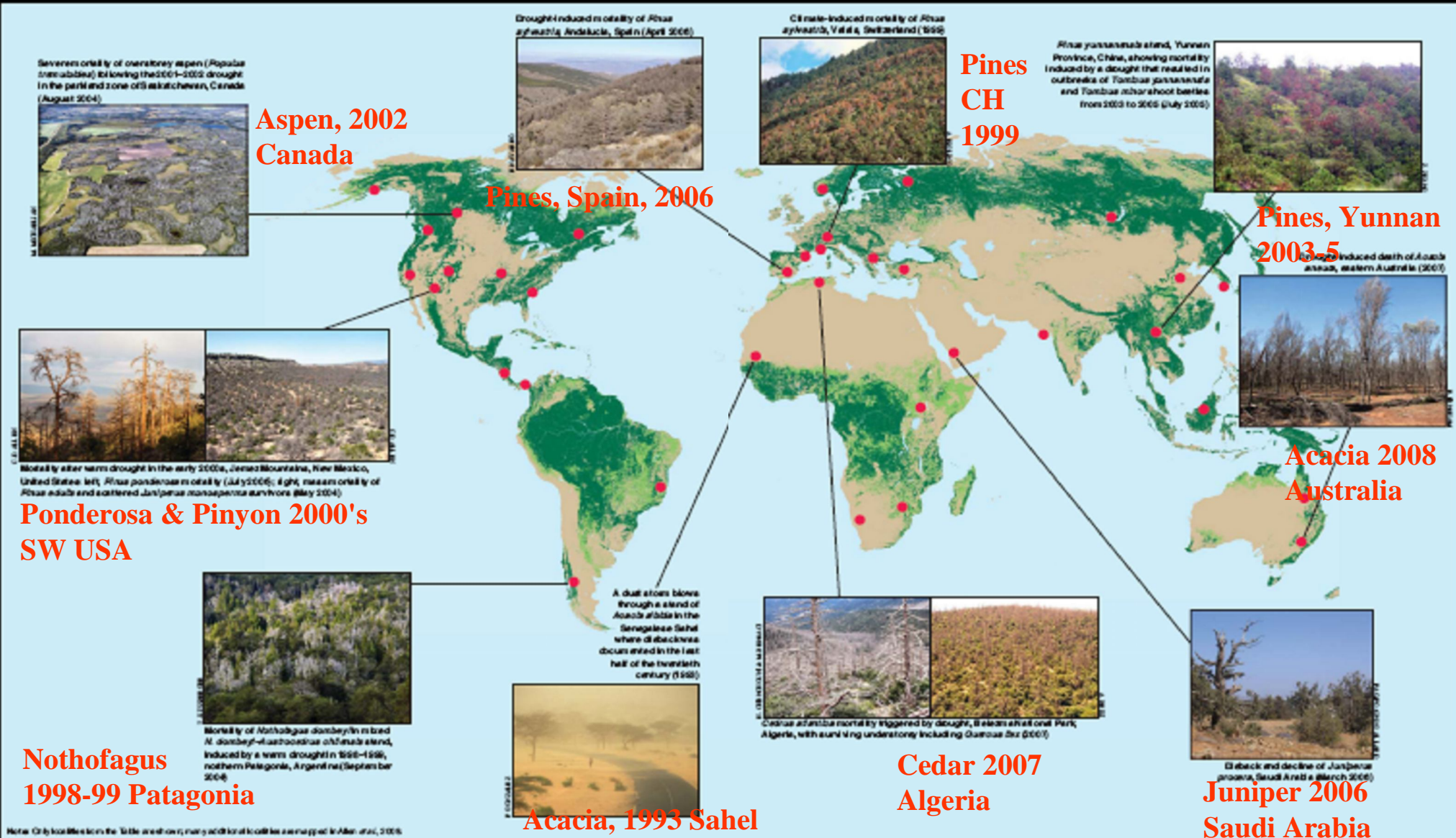


Dust bowl 1930s

soil erosion



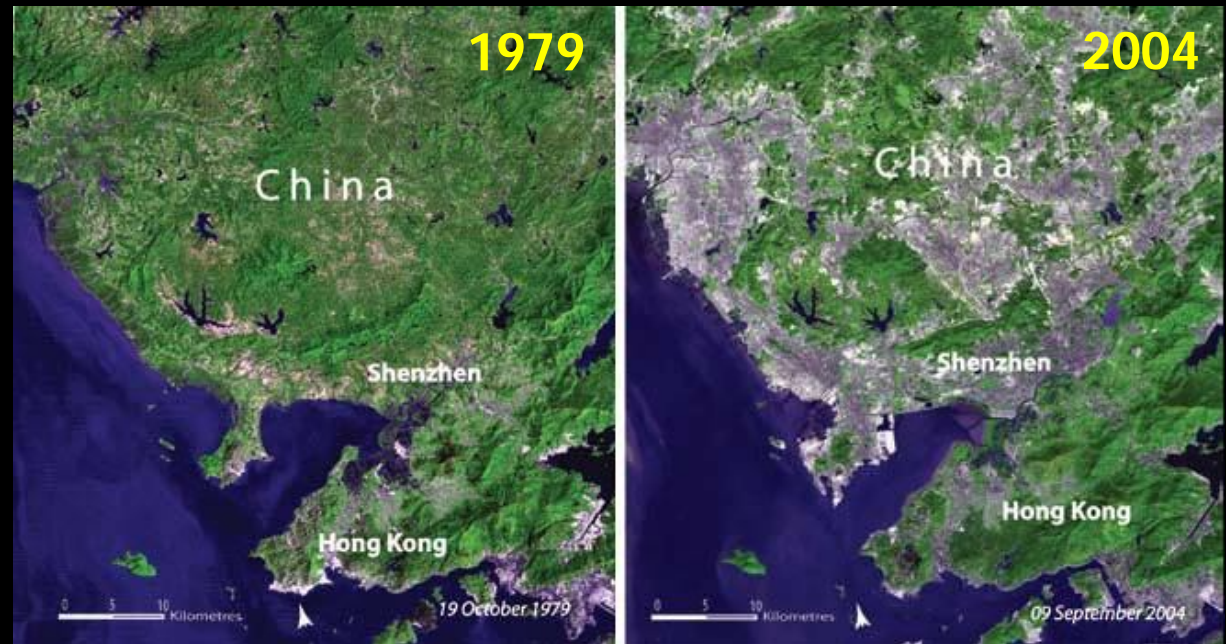
Forest dieback is becoming a global phenomenon: Climate signal? droughts, heat damage, insect outbreaks



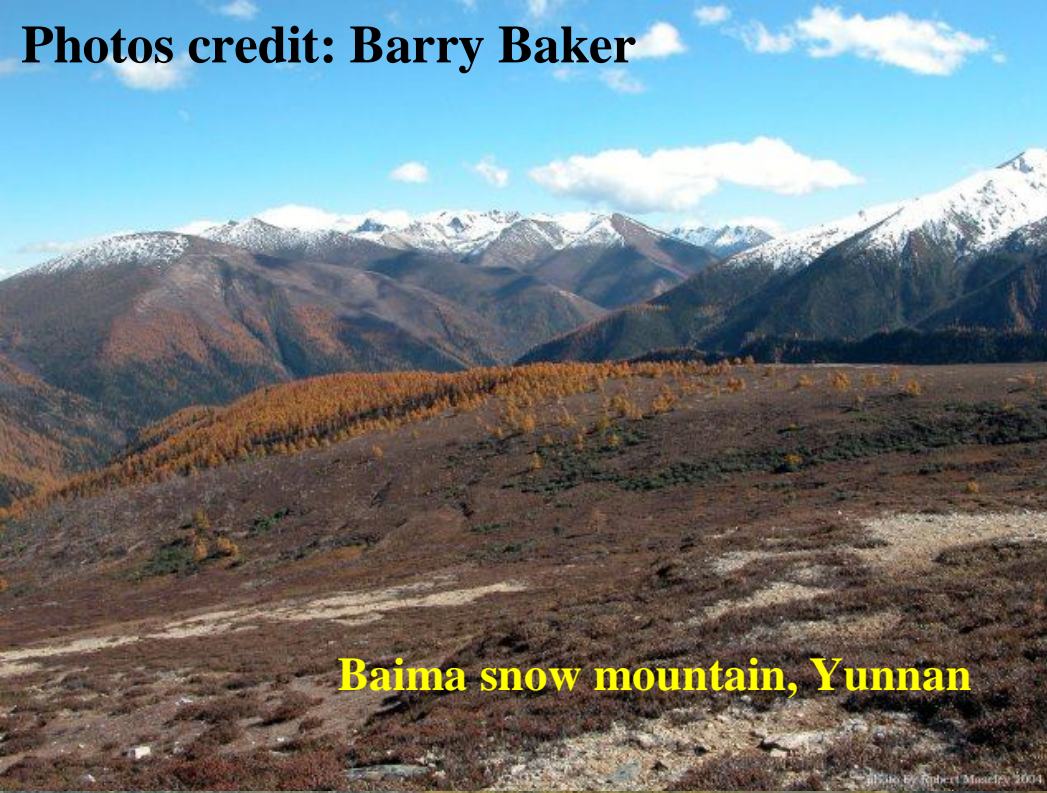
Note: Only locations on the title are shown; many additional locations are mapped in Allen et al., 2009.

Climate Models: human impacts

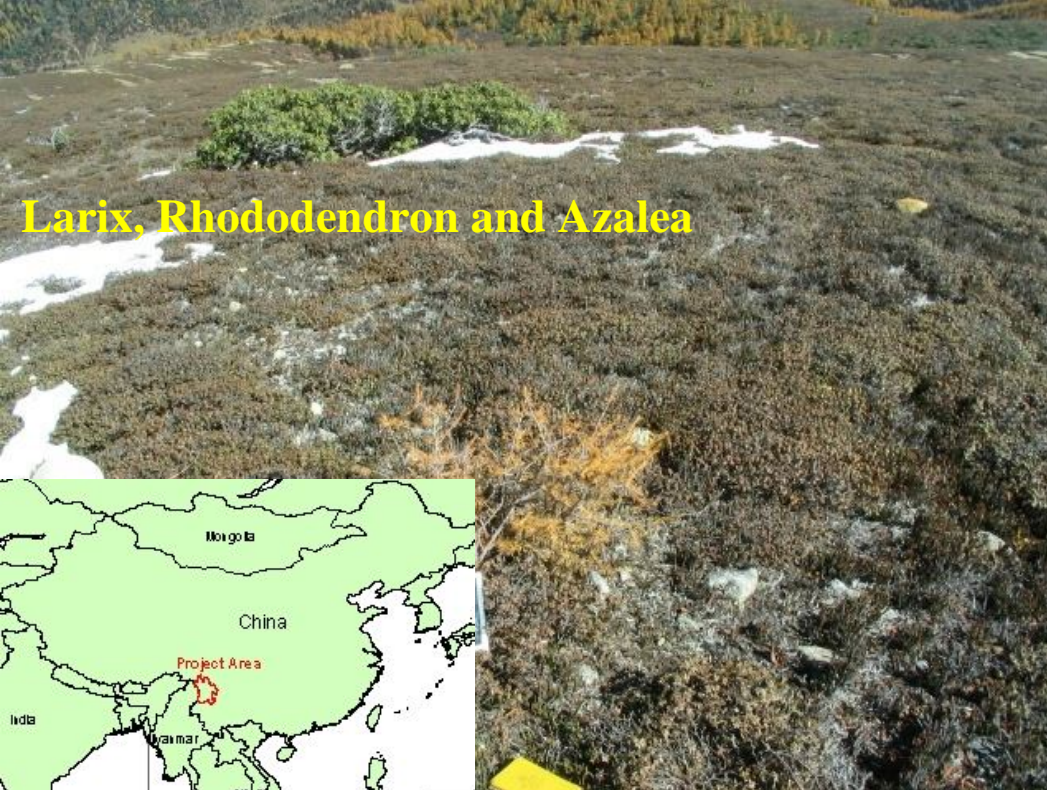
- urbanization - urban heat island
- agriculture - effect on water cycle (cloud formation, albedo)
- industrialization - aerosols, particulates (CCN)
- transport - emissions



Photos credit: Barry Baker

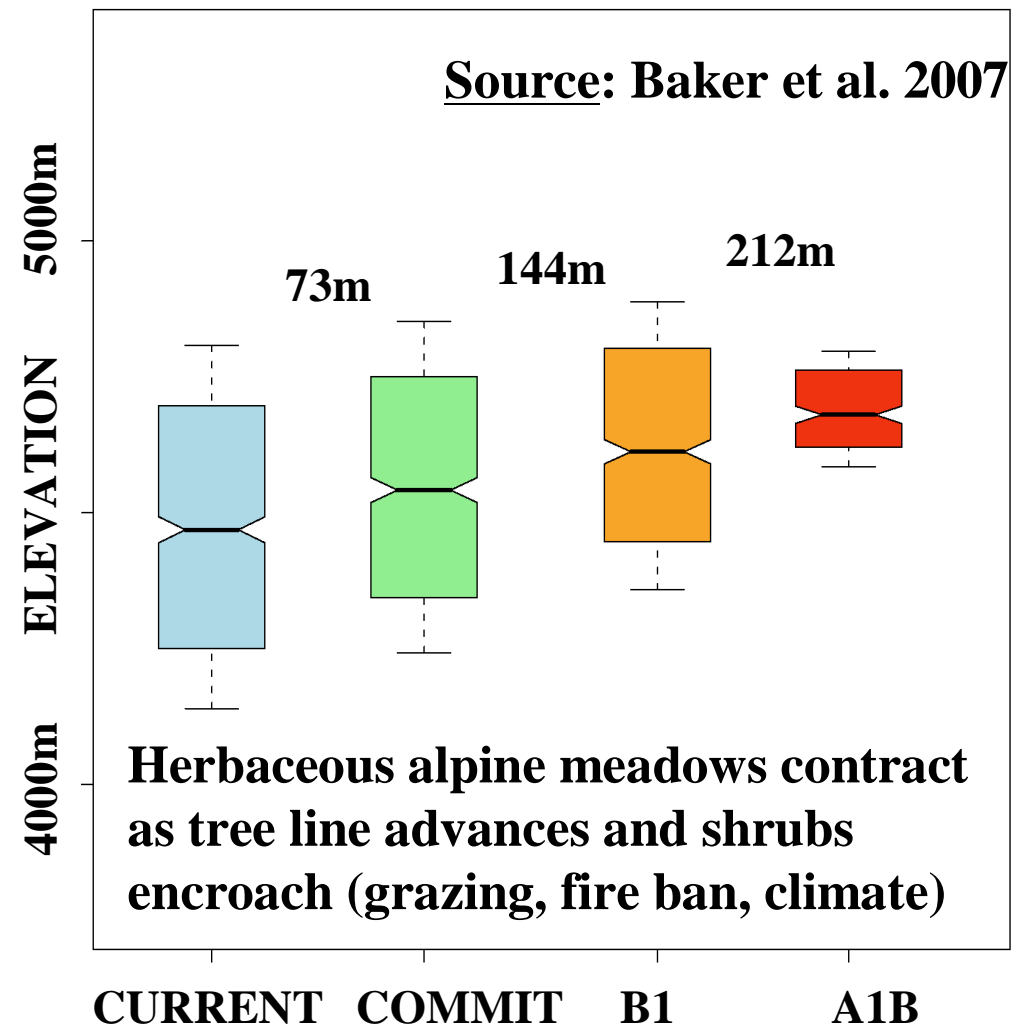


Baima snow mountain, Yunnan

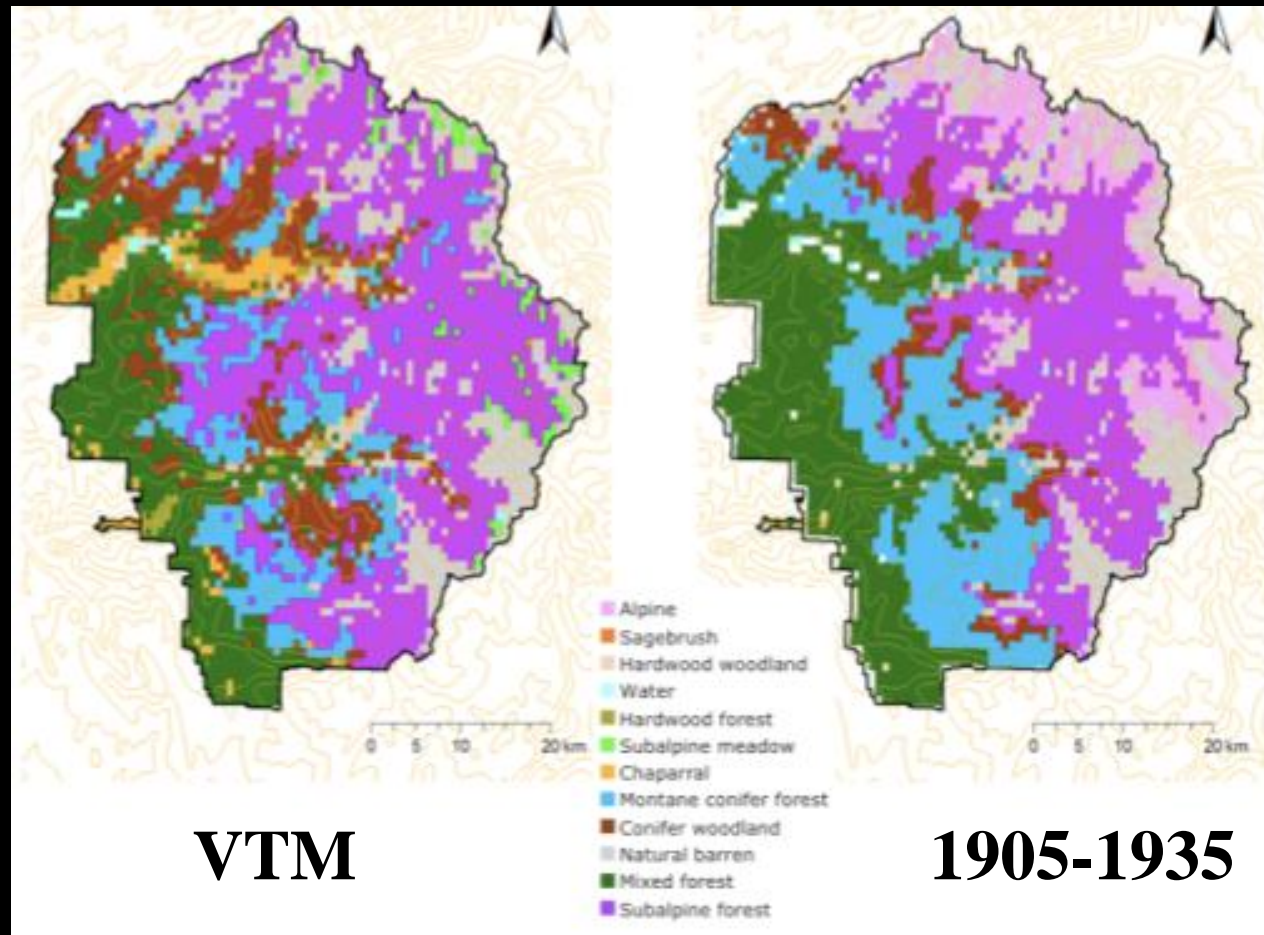


Larix, Rhododendron and Azalea

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**

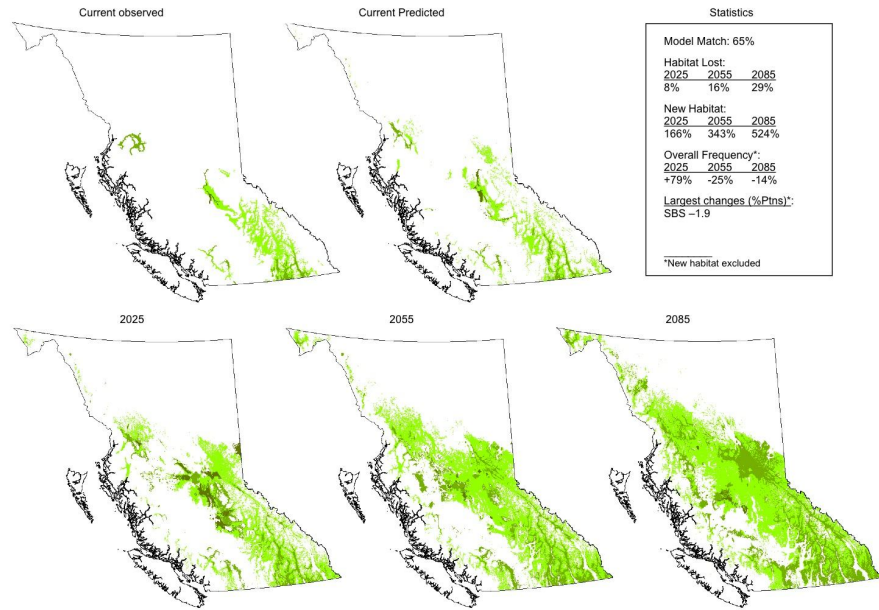


Impacts Models

- **Transient versus static**
- **Blackboxes:**
belowground, CO₂, N
- **Human inferences**

Impacts models - Transient vs Static

Appendix 3.16. Observed and predicted range and frequency for *Corylus cornuta* Marsh. - Hazelnut (frequent ... infrequent).



Source: Andreas Hamann

CLIMATE CHANGE IMPACTS ON THE UNITED STATES

Ecosystem Models

Maps of current and projected potential vegetation distribution for the conterminous US. Potential vegetation means the vegetation that would be there in the absence of human activity. Changes in vegetation distribution by the end of the 21st century are in response to two climate scenarios, the Canadian and the Hadley.

- Tundra
- Taiga / Tundra
- Conifer Forest
- Northeast Mixed Forest
- Temperate Deciduous Forest
- Southeast Mixed Forest
- Tropical Broadleaf Forest
- Savanna / Woodland
- Shrub / Woodland
- Grassland
- Arid Lands

Current Ecosystems



Canadian Model



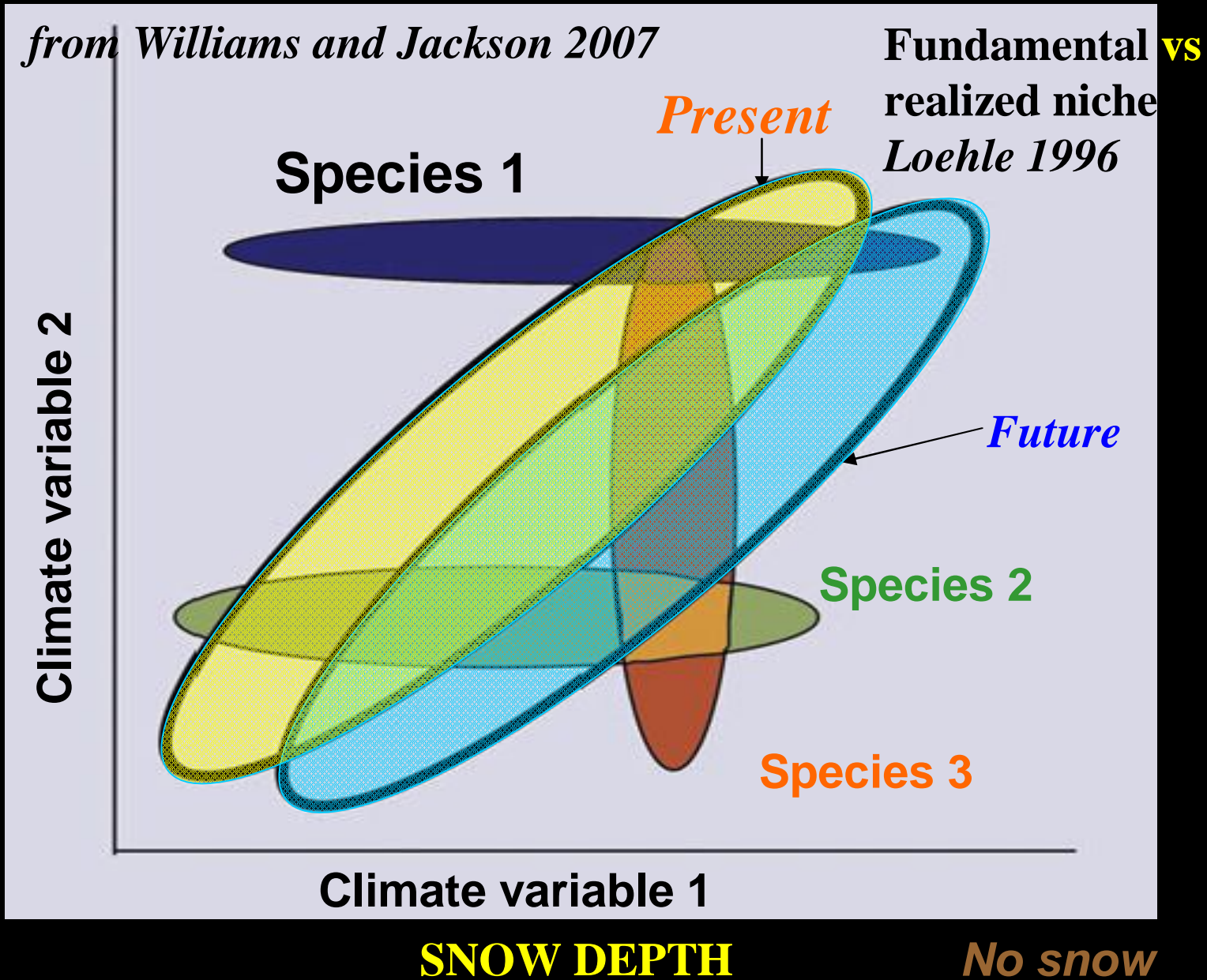
Hadley Model



2000 USGCRP
Nat. Ass. Report

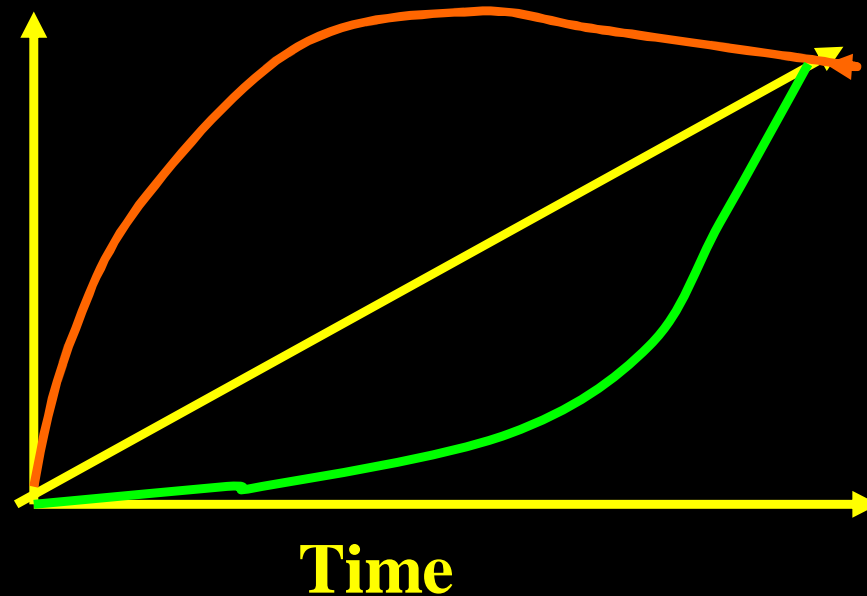
Novel climates represent uncharted portions of climate space, where we have no observational data to parameterize and validate ecological forecasts

warm
MINIMUM TEMPERATURE
cold

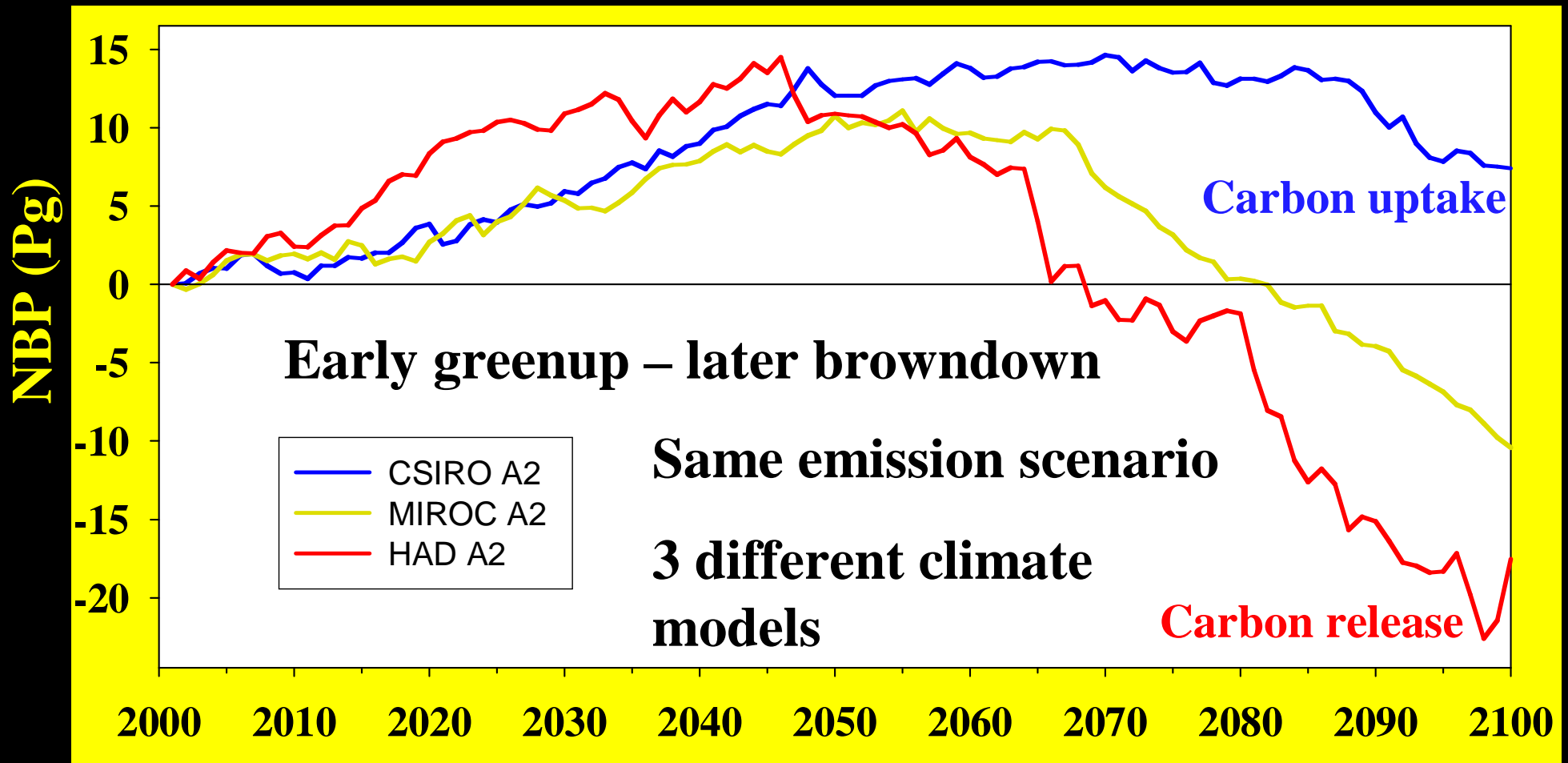


DYNAMIC CHANGE

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
- CO₂ fertilization effect
- Nitrogen limitation, saturation



Disturbance driven changes

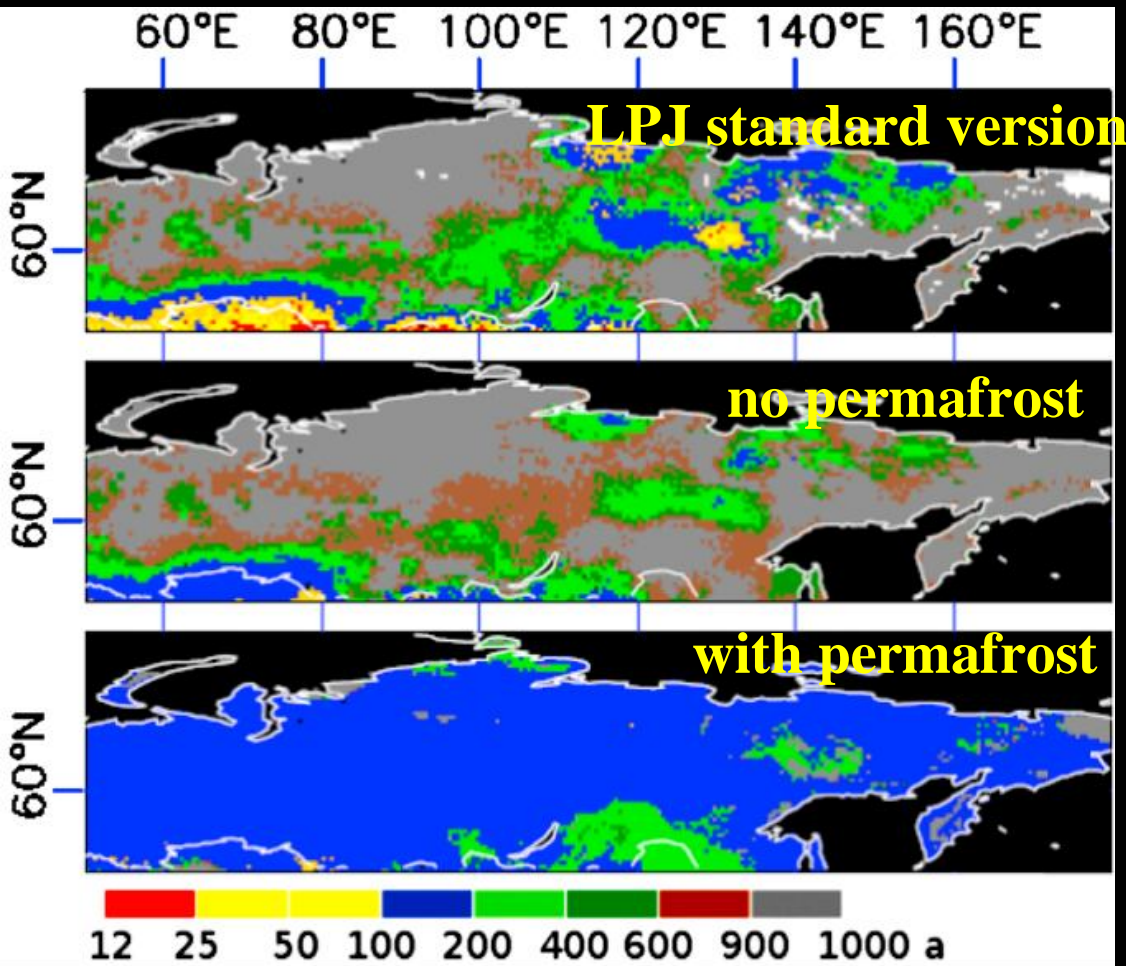
Large uncertainty due to frozen soils

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. Schmullius¹

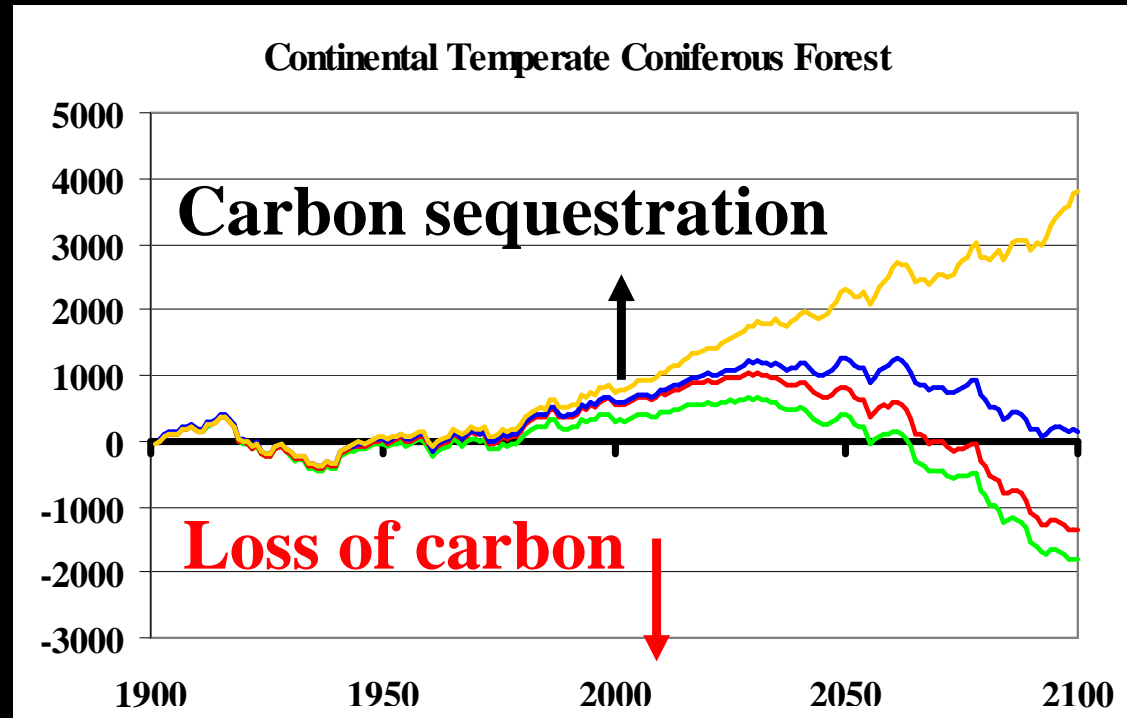
GBC 2007

Mean Fire return interval in N Eurasia 1993-2003

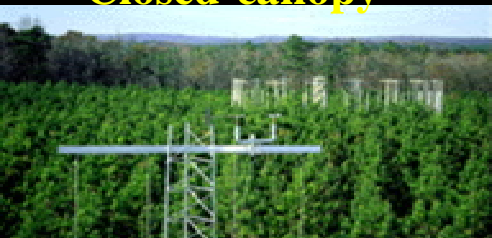


“Without the consideration of freeze-thaw processes, vegetation carbon density would be overestimated by a factor of 2 in southern taiga and a factor of 5 in northern forest tundra, mainly because available soil water would be overestimated with many effects on fire occurrence and NPP.”

Testing the impacts of increased atmospheric CO₂ on carbon sequestration potential



Closed-canopy



DukeFACE (NC) – loblolly pine

Developing stands



AspenFACE (WI) – aspen/birch



ORNL-FACE (TN) – sweetgum



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 CO₂ on carbon sequestration potential

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

Productivity (turnover) increases belowground: nutrient limitation

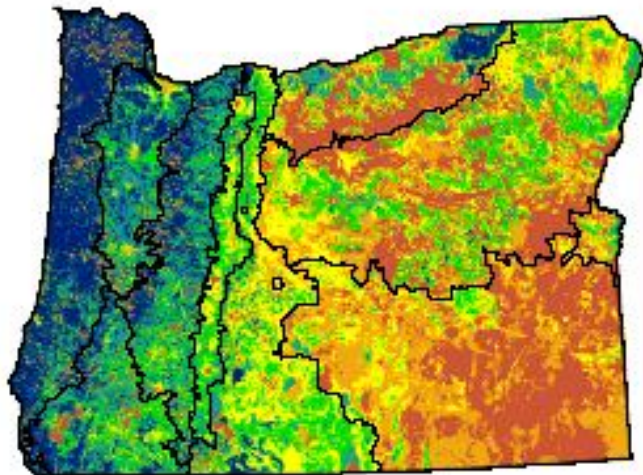
Impact on water use efficiency only?

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. Turner¹, W. D. Ritts¹, B. E. Law¹, W. B. Cohen², Z. Yang¹, T. Hudiburg¹, J. L. Campbell¹, and M. Duane¹

¹Forest Science Department, Oregon State University, Corvallis OR 97331, USA

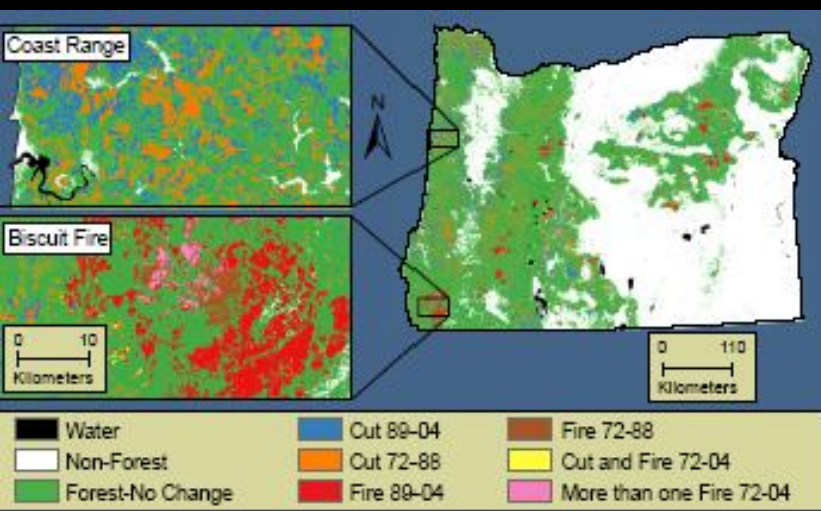
²USDA Forest Service, PNW Station, Corvallis OR 97331, USA

BGC 2007

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

**Prognostic models (spin-up and hist. clim.)
NEP $30 \text{ g C m}^{-2} \text{ y}^{-1}$ 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 CO₂ 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

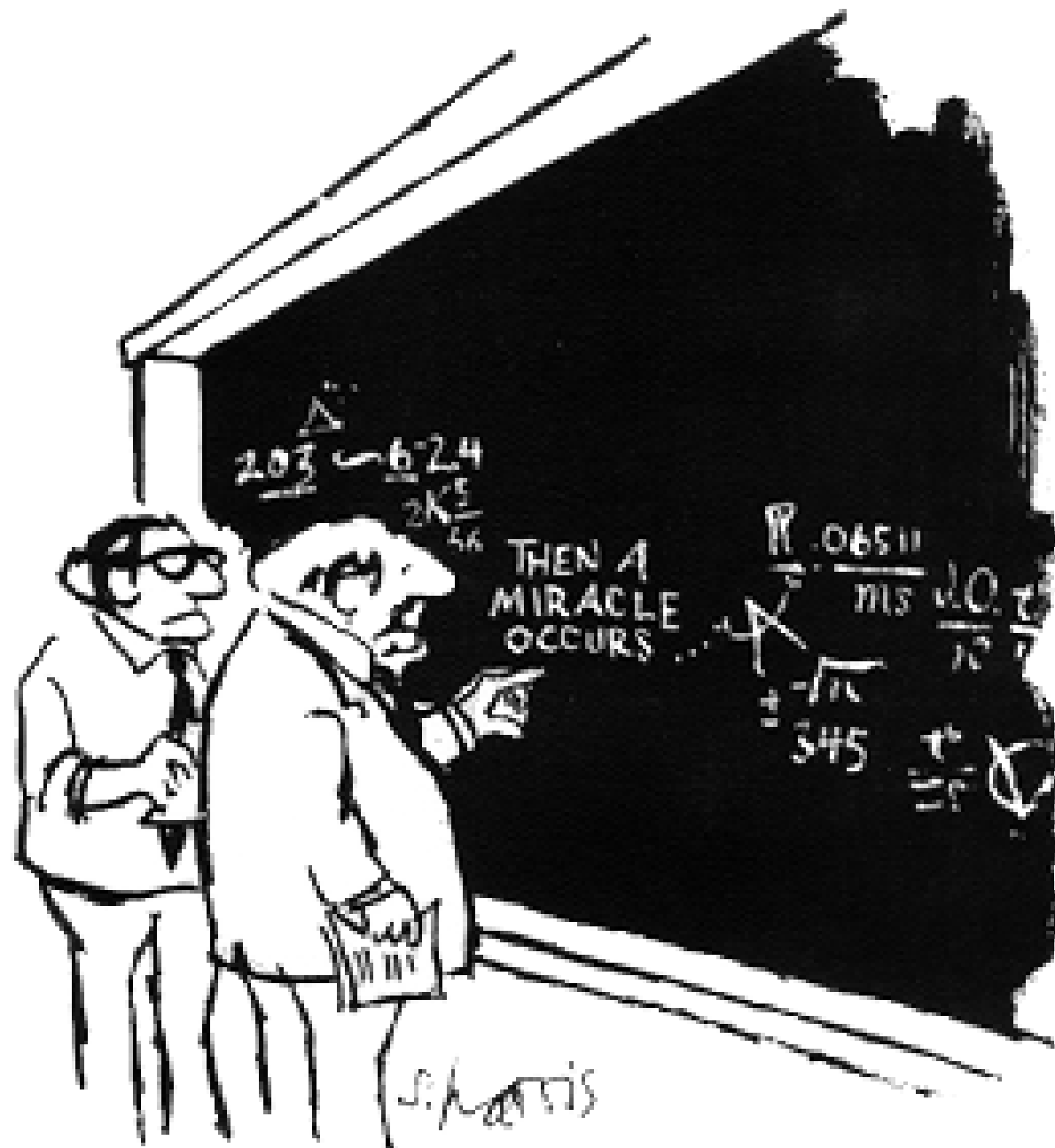
Meaningful and relevant modeling is a product of close and continuous interaction between the decision maker and the modeling experts.

<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

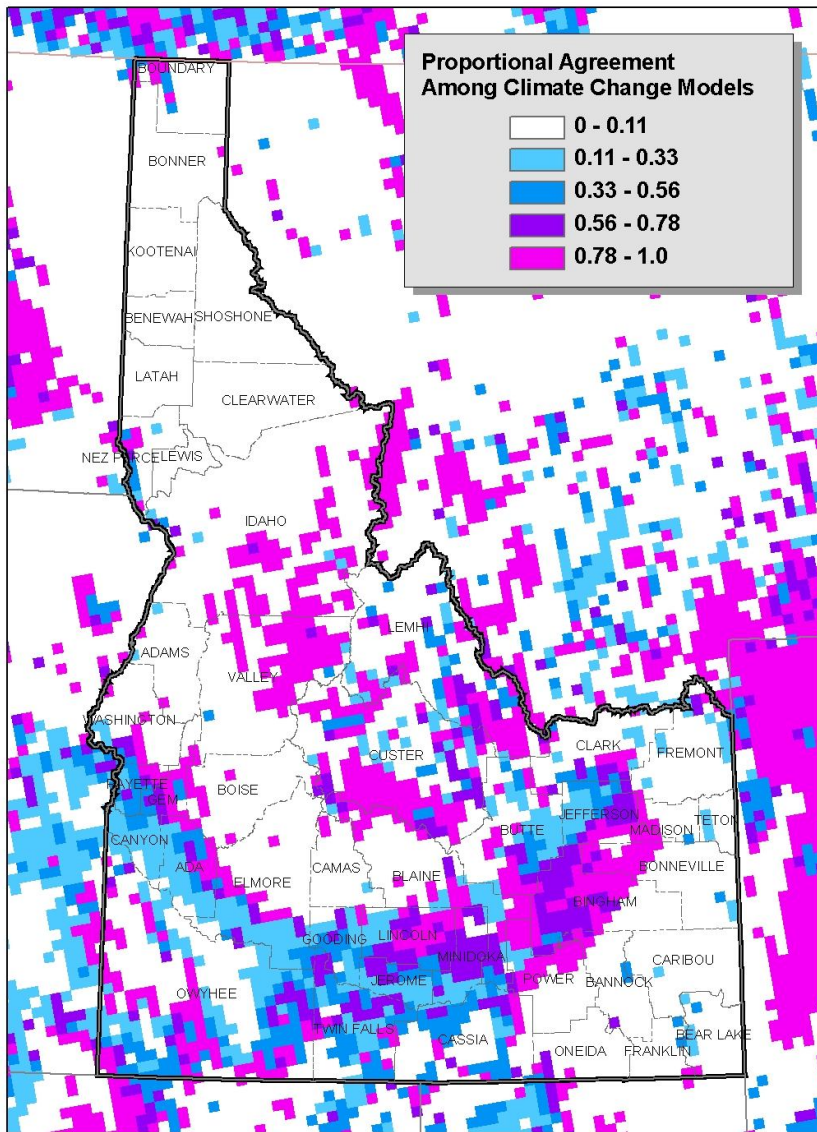


"I think you should be more explicit here in step two."

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?

Global warming could shift western U.S. wine regions

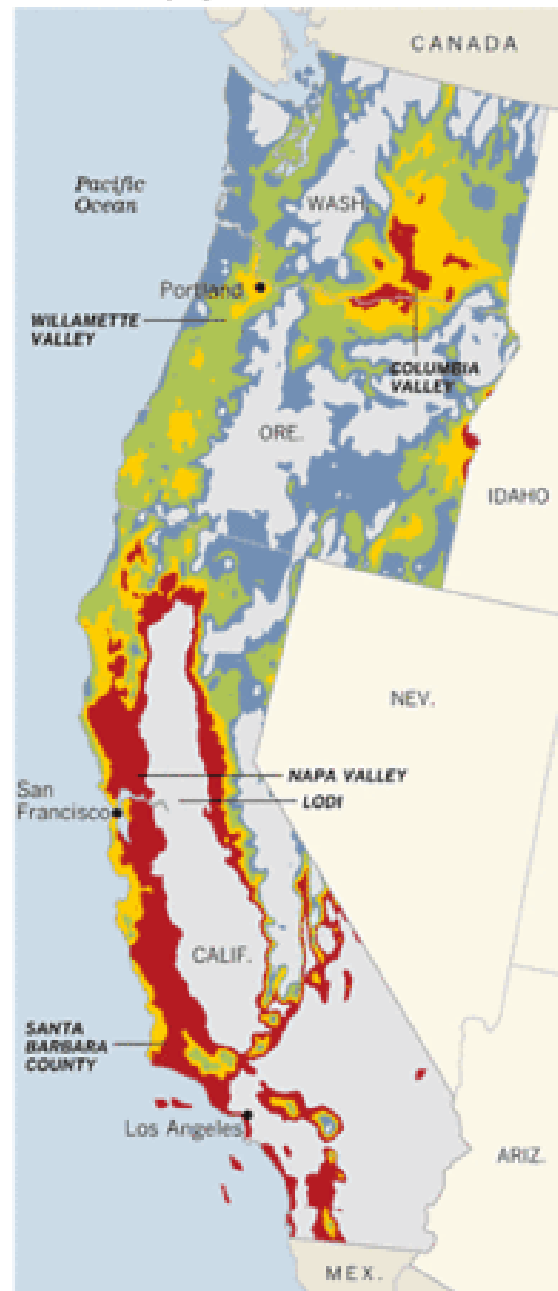
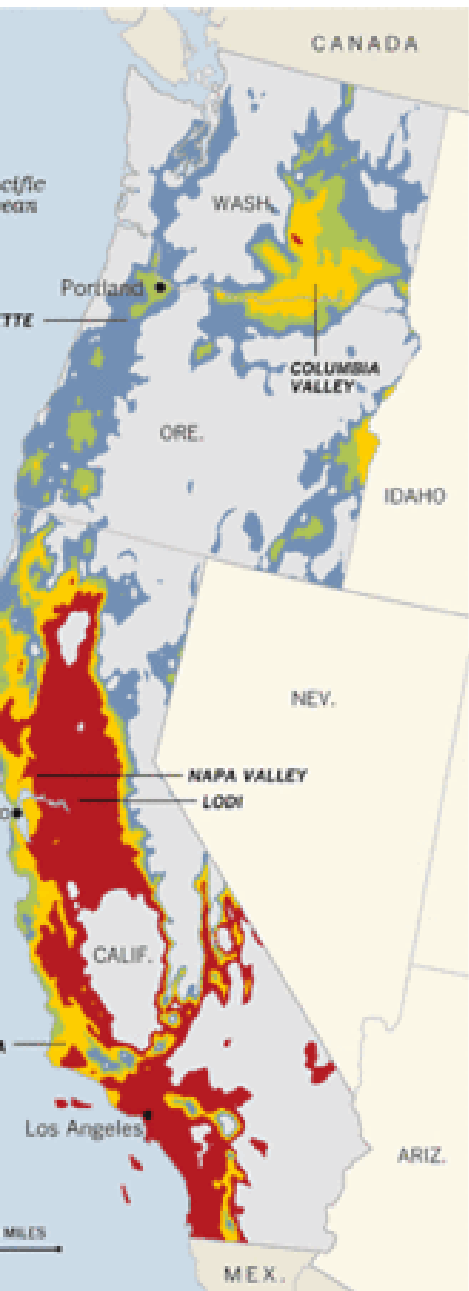
Wine varieties grow best in specific climates. Rising temperatures could change the regions where certain grapes will flourish.

Growing regions, by climate:

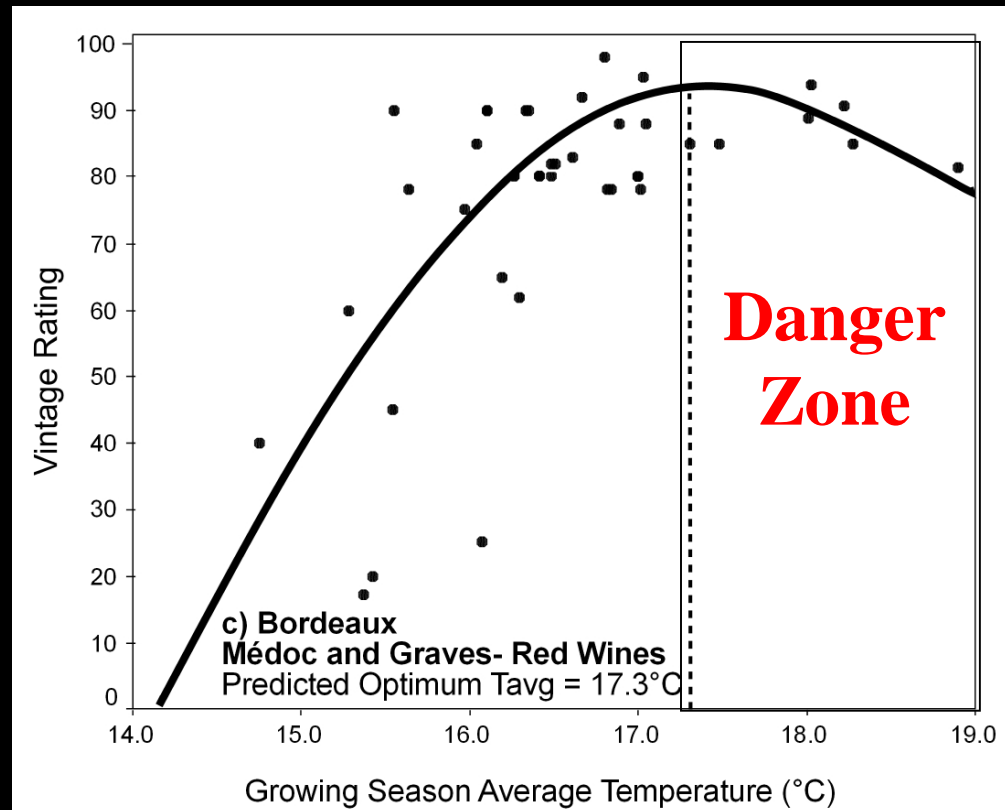
Unsuitable **Hot** **Warm** **Intermediate** **Cool**

2000 climate normals

2000-2049 projections

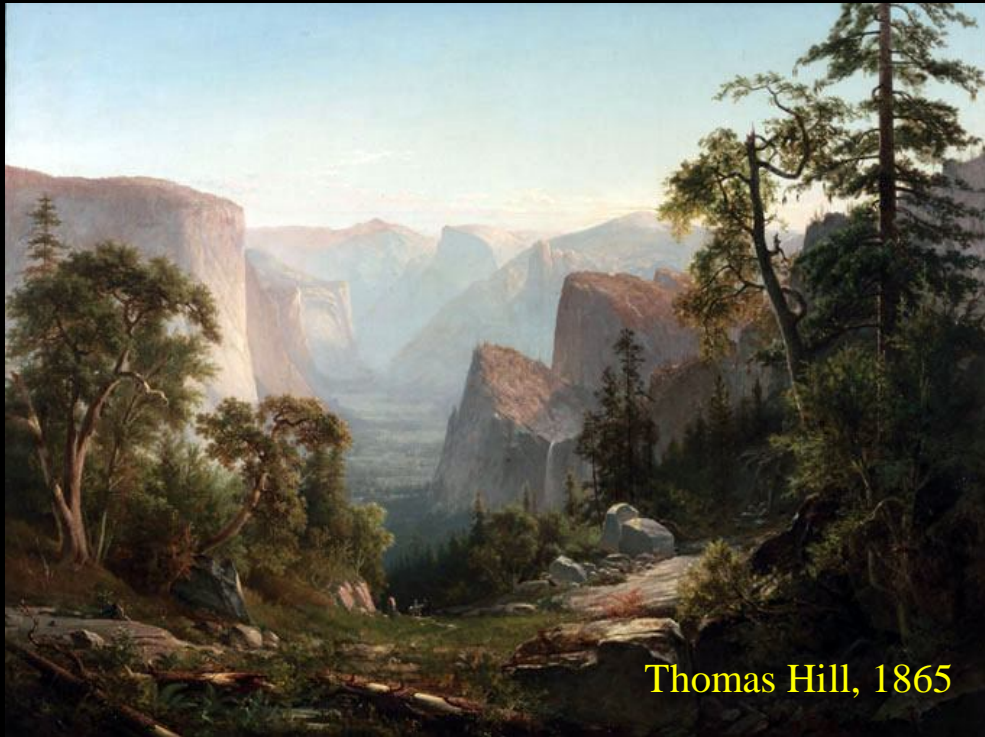


Choosing an interesting subject with simple message



Source: Jones et al. 2005, Climatic Change

Impacts models Visuals



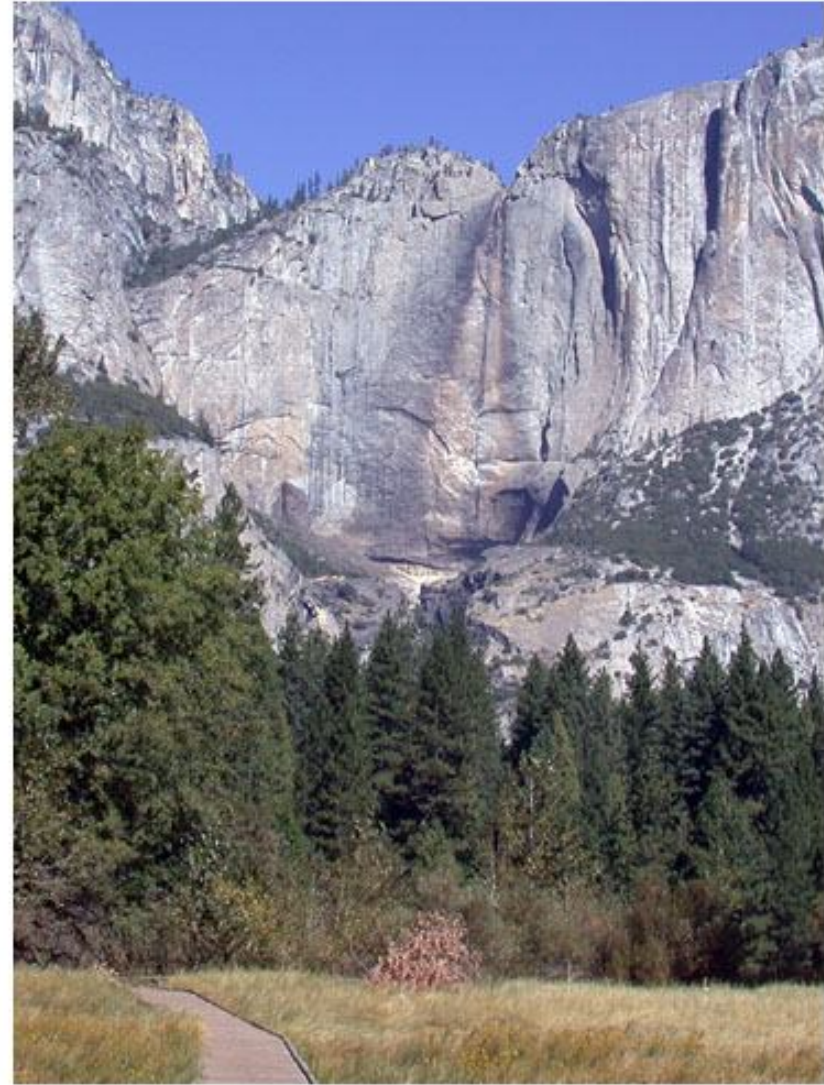
Thomas Hill, 1865



Feb 2009

Historical Change

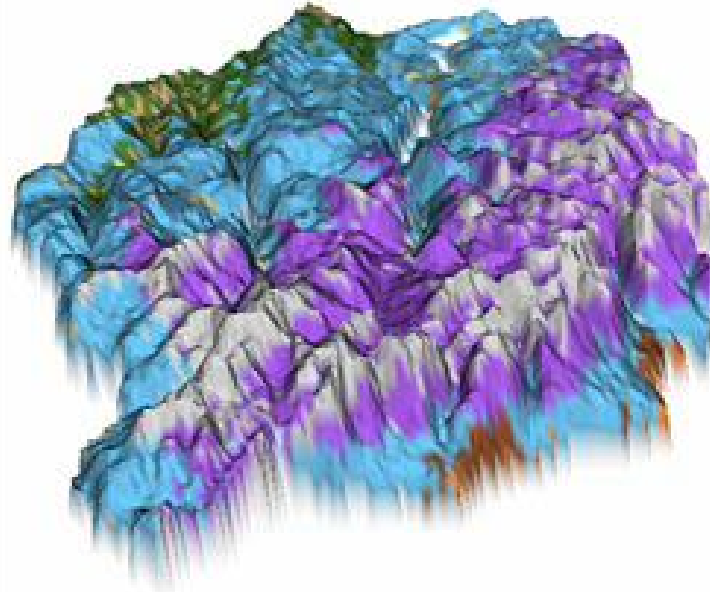
Impacts models Dramatic Visuals



2007

Impacts models Animation

- 0 missing data
- 1 alpine
- 2 subalpine forest
- 3 coastal conifer forest
- 4 montane conifer forest
- 5 mixed evergreen forest
- 6 hardwood forest
- 7 conifer woodland
- 8 mixed evergreen woodland
- 9 hardwood woodland
- 10 sagebrush
- 11 montane chaparral
- 12 coastal chaparral
- 13 grassland
- 14 desert
- 15 natural barren
- 16 water
- 17 developed
- 18 subalpine meadow



Yosemite- CSIRO model

Climate Adaptation Knowledge Environment



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The Nature Conservancy ClimateWizard UNIVERSITY OF WASHINGTON THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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Analysis Area: United States Global
 United States

Time Period: Past 50 Years Mid Century (2050) End Century (2100)

Map Options: Map of Average Map of Change
 Annual

Measurement: Average Temperature Precipitation

Resources: [Case Studies](#) [Documentation](#) [Data \(GIS format\)](#) [Map Image](#) [Printer Friendly Version](#)

Future Climate Model: IPCC Fourth Assessment
 Emission Scenario: High A2
 General Circulation Model: Ensemble Average

Change in Annual Temperature by 2100
 Model: Ensemble Average, SRES emission scenario: A2

Map Transparency: 0

Mean Temp (F) Departure: 100 F, 75, 50, 25, 0.0, -25, -50, -75, -100

Data Source: Base climate projections downloaded by Maurer, et al. (2007) Santa Clara University. For more information see About Us.

Map data ©2009 LeadDog Consulting, Tele Atlas, INEGI, EuroGIS Technologies - 12/25

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!