Climate Change: Eastern U.S. Forests

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MAPSS Team

(Mapped Atmosphere-Plant-Soil System)

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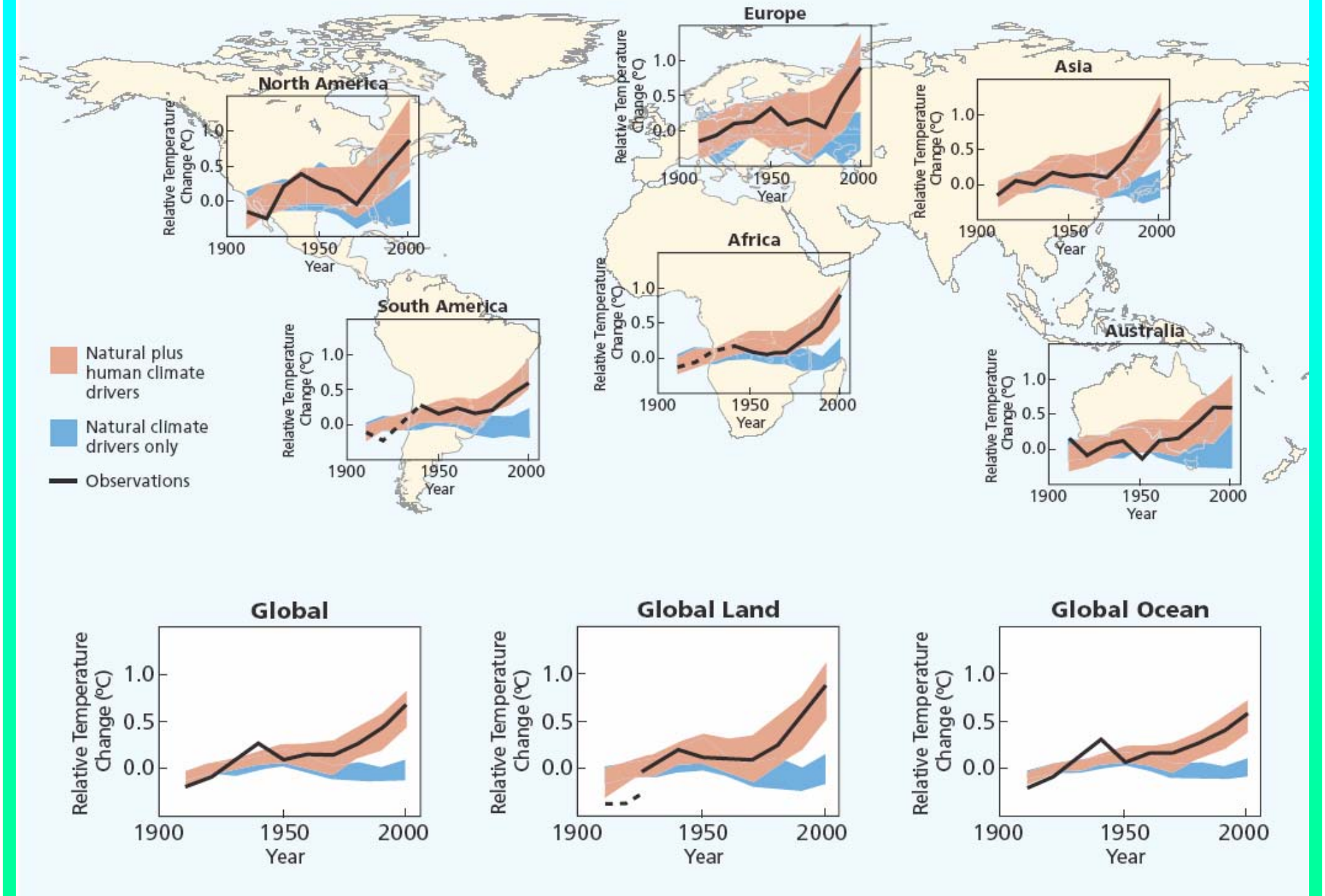
Dave Conklin, OSU
John Wells, OSU

Introduction

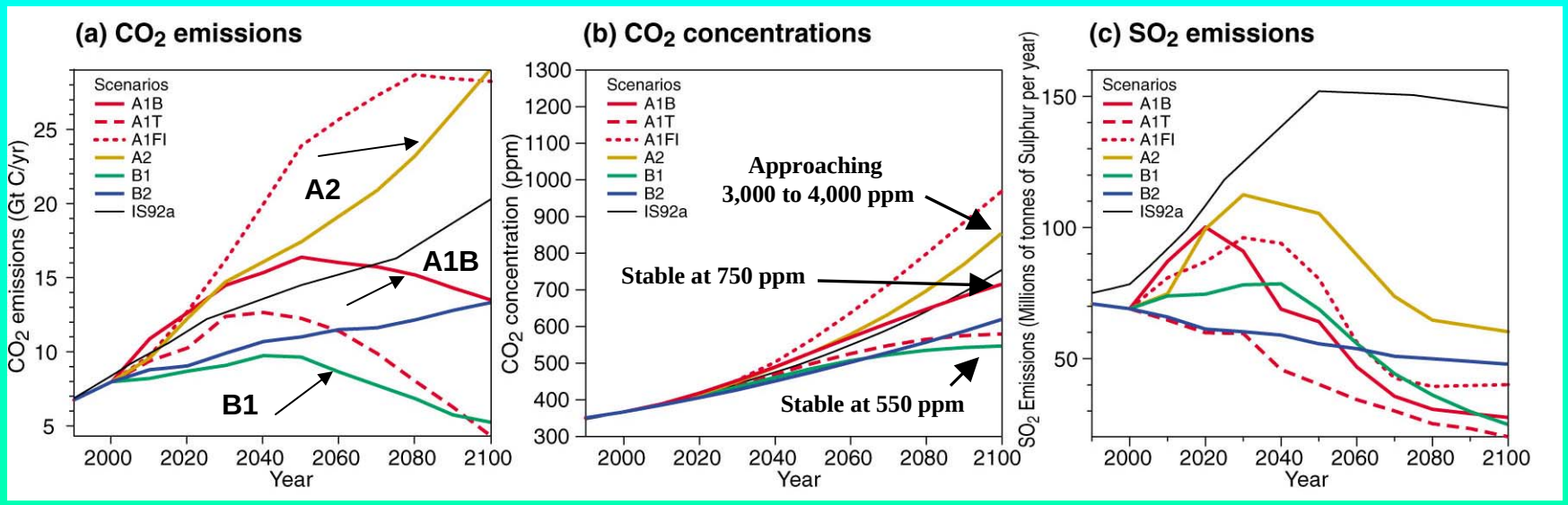
- **Some Basic Climatology:**
  - **Past,**
  - **Future,**
  - **Variability**



IPCC *Climate Change 2007: The Physical Science Basis*—Summary for Policymakers.

Assessments of Future Climate Change Begin with Uncertainty

CO_2 and SO_2 in the 21st Century



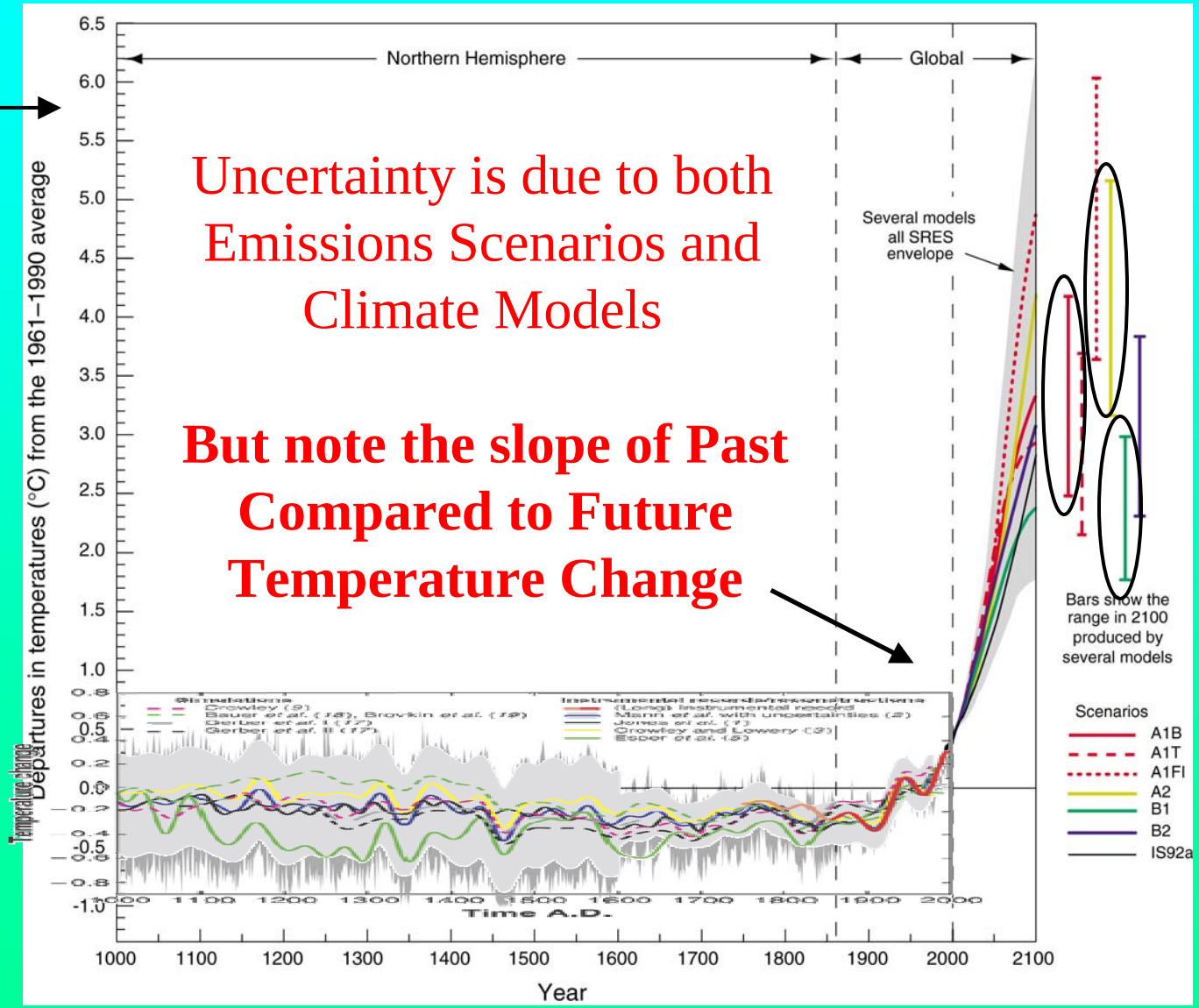
Future Scenarios are Based on Socio-Economic 'Storylines'

This Presents a Paradigm for All Future Management Considerations

Source: IPCC TAR 2001

Variations of the Earth's Surface Temperature: 1000 to 2100

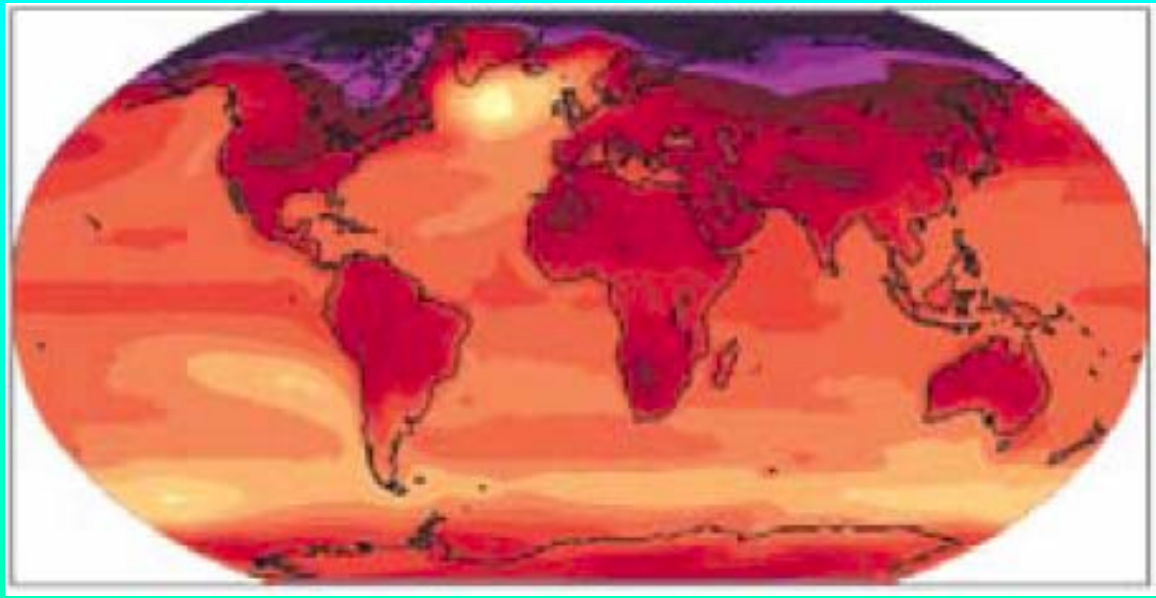
Similar to Glacial – Interglacial Temperature Change



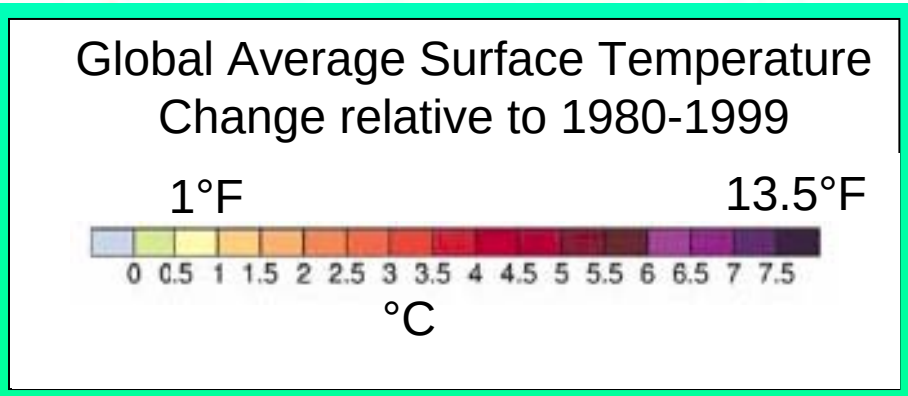
- **1000 to 1861, N. Hemisphere, proxy data;**
- **1861 to 2000 Global, Instrumental;**
- **2000 to 2100, SRES projections**

The NorthWest is at risk for large consequences from a higher emissions scenario.

Future Risks



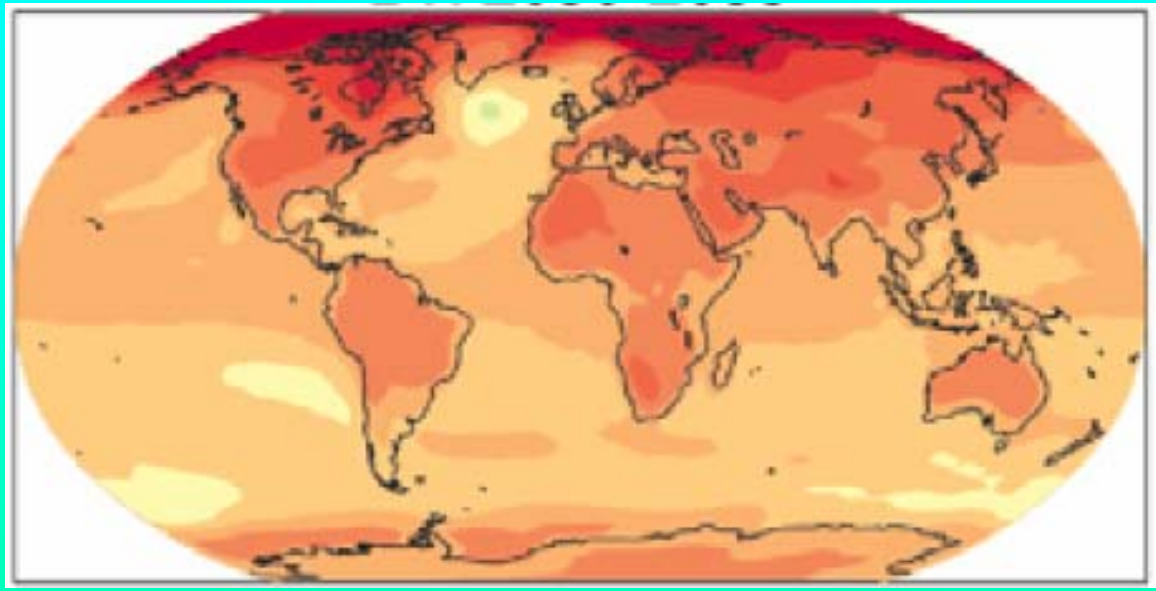
A2 IPCC scenario averaged over 2090–2099



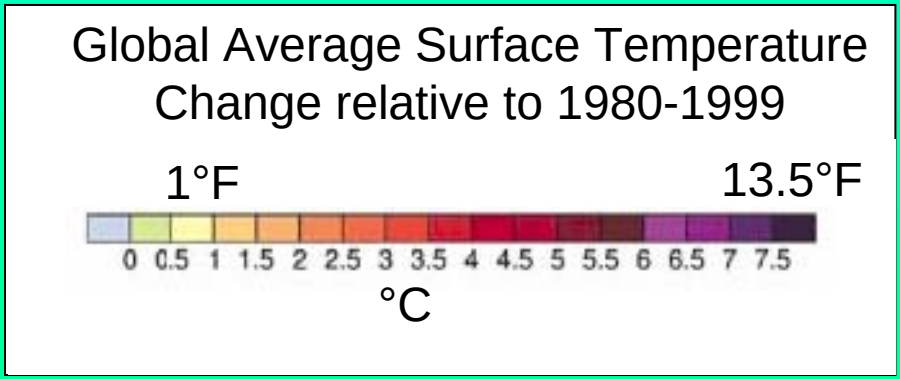
Source: IPCC *Climate Change 2007: The Physical Science Basis*—Summary for Policymakers.

The NorthWest can avoid experiencing even the lowest emissions scenario projections of the IPCC if the world follows deep reductions targets.

Future Risks

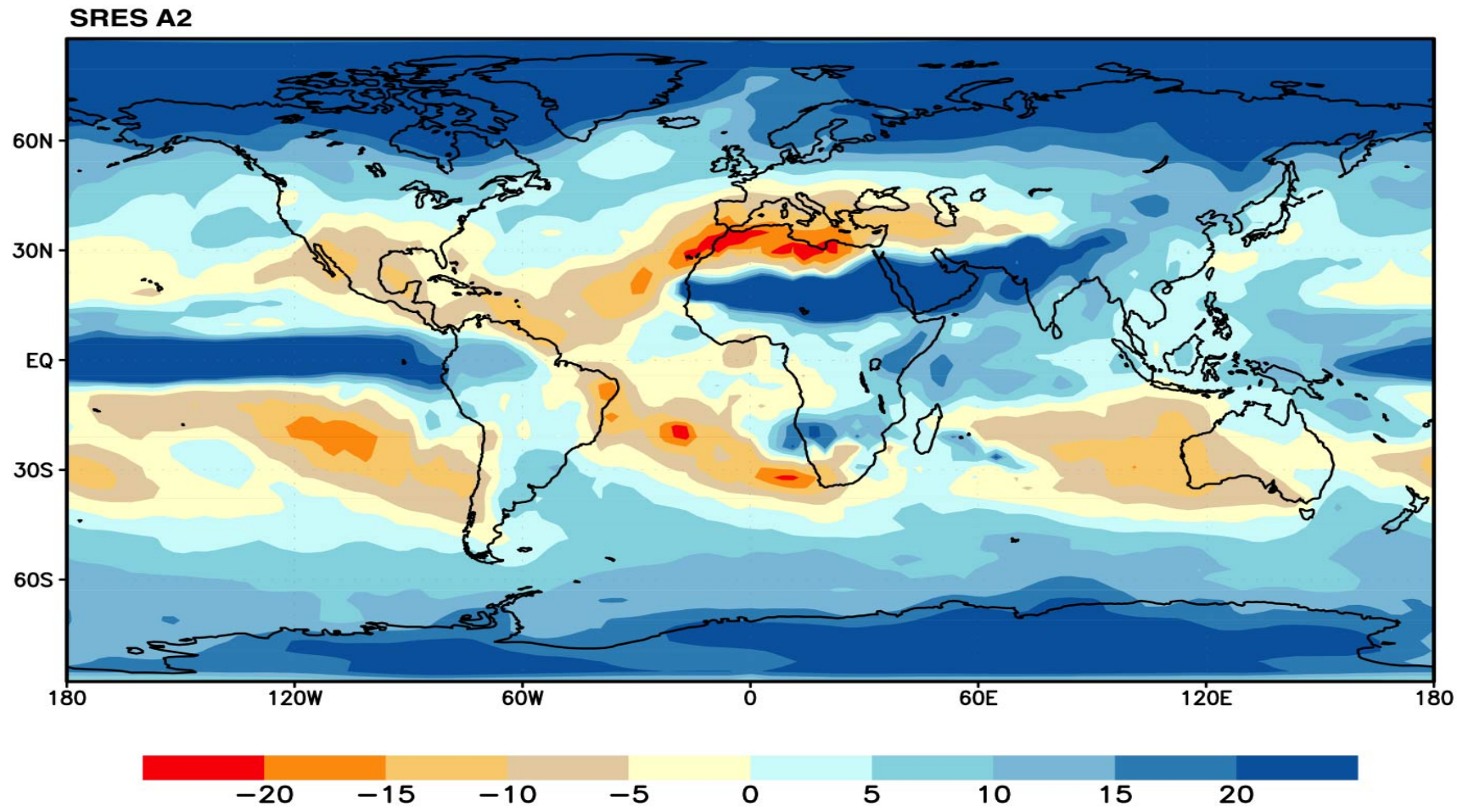


B1 IPCC scenario averaged over 2090–2099



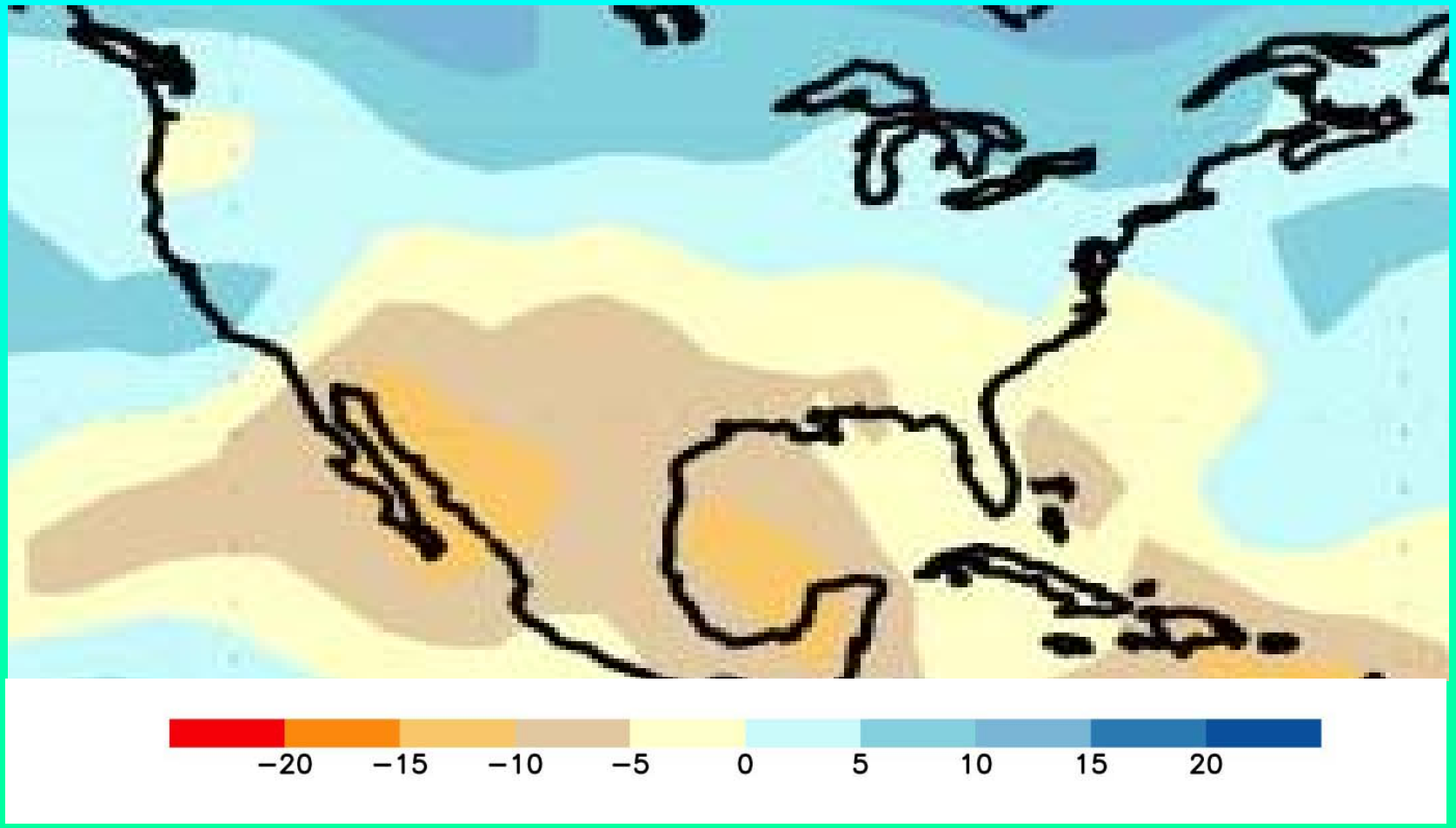
Source: IPCC *Climate Change 2007: The Physical Science Basis*—Summary for Policymakers.

Some areas are projected to become wetter, others drier with an overall increase projected



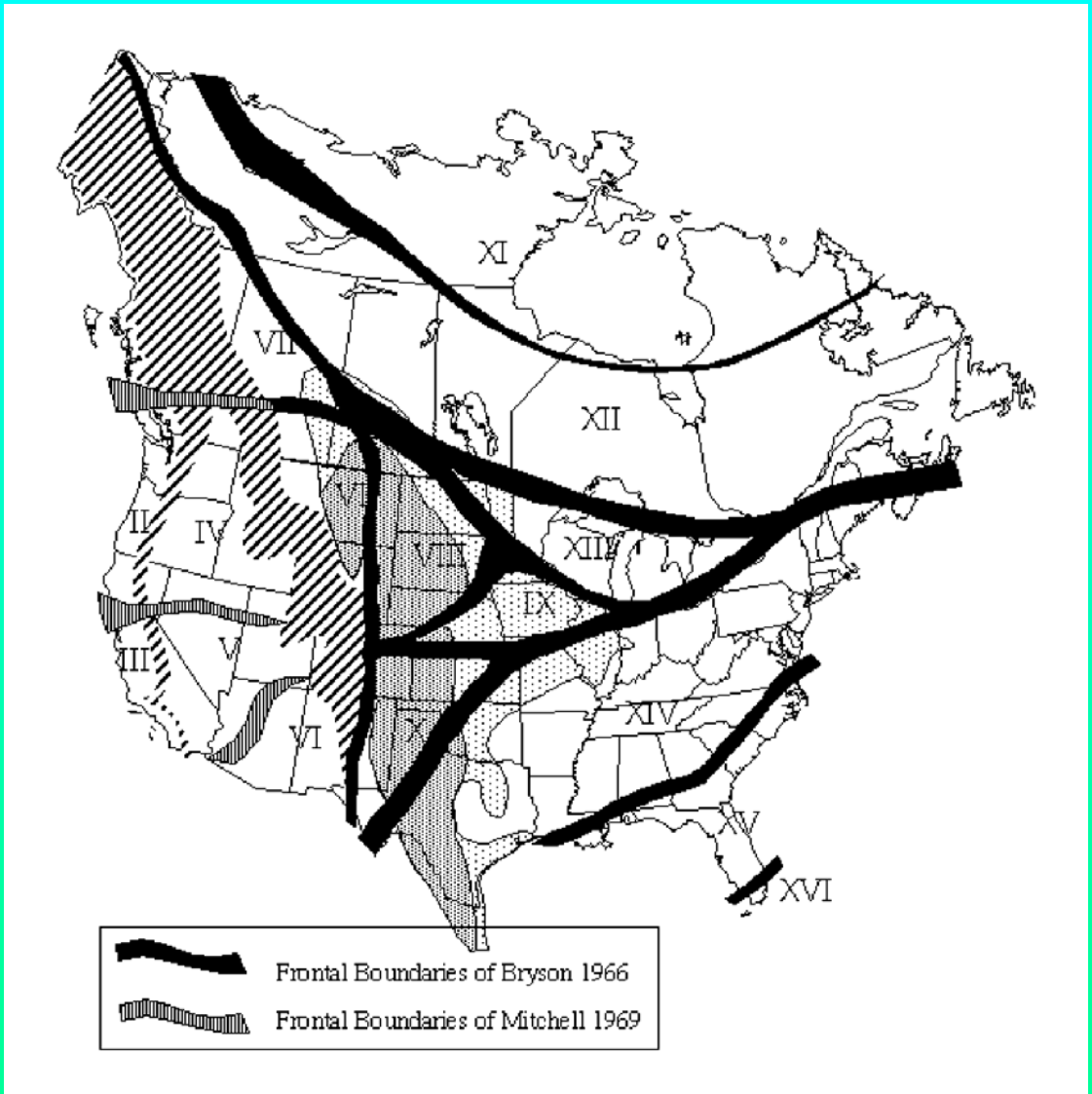
Annual mean precipitation change: 2071 to 2100 Relative to 1990

Some areas are projected to become wetter, others drier with an overall increase projected

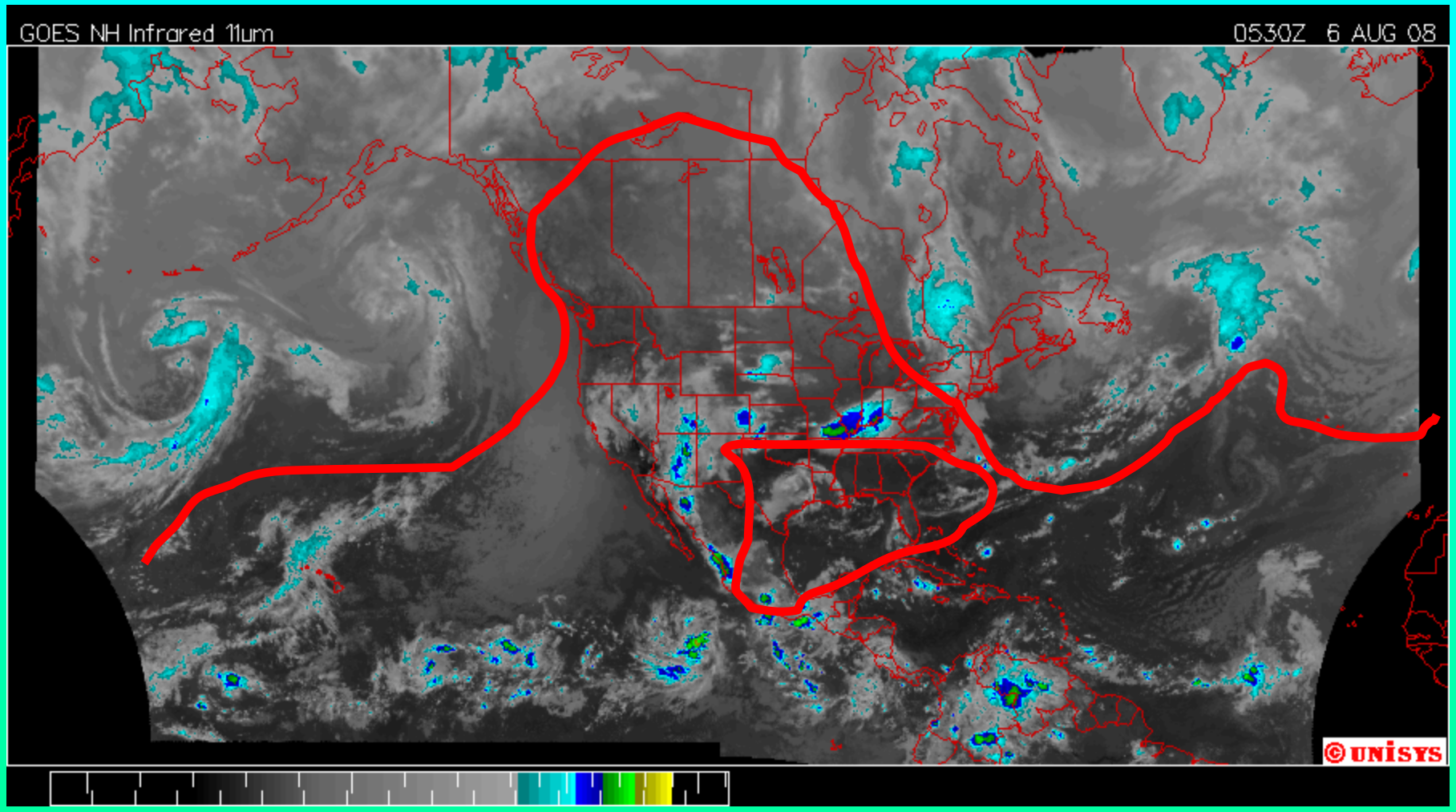


Annual mean precipitation change: 2071 to 2100 Relative to 1990

Airmass Regions of North America
Vegetation Dynamics – Temporal Patterns
And Climate Variability

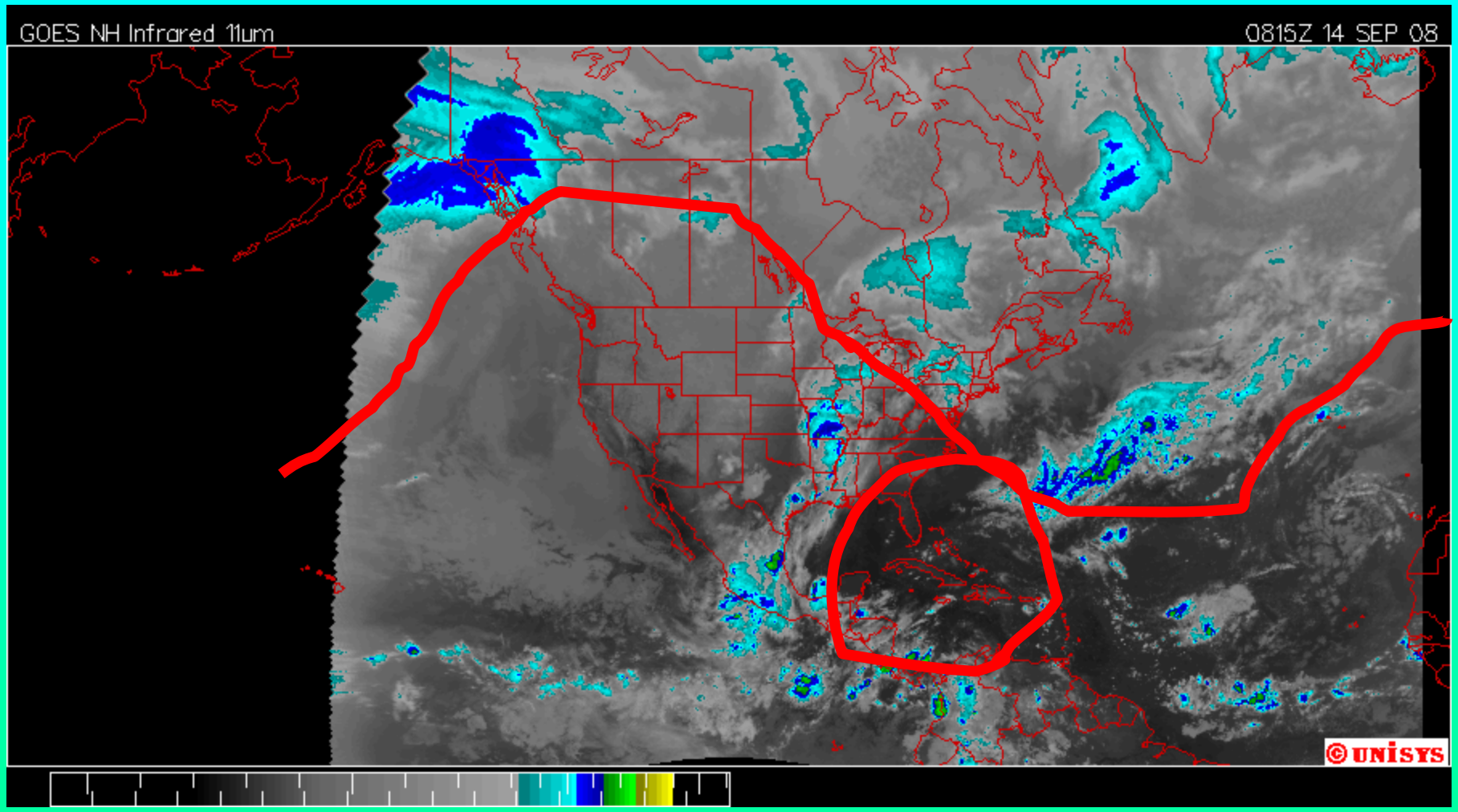


September 14, 2008



The Water Cycle moves most of the energy from the Tropics to the Poles!

August 6, 2008

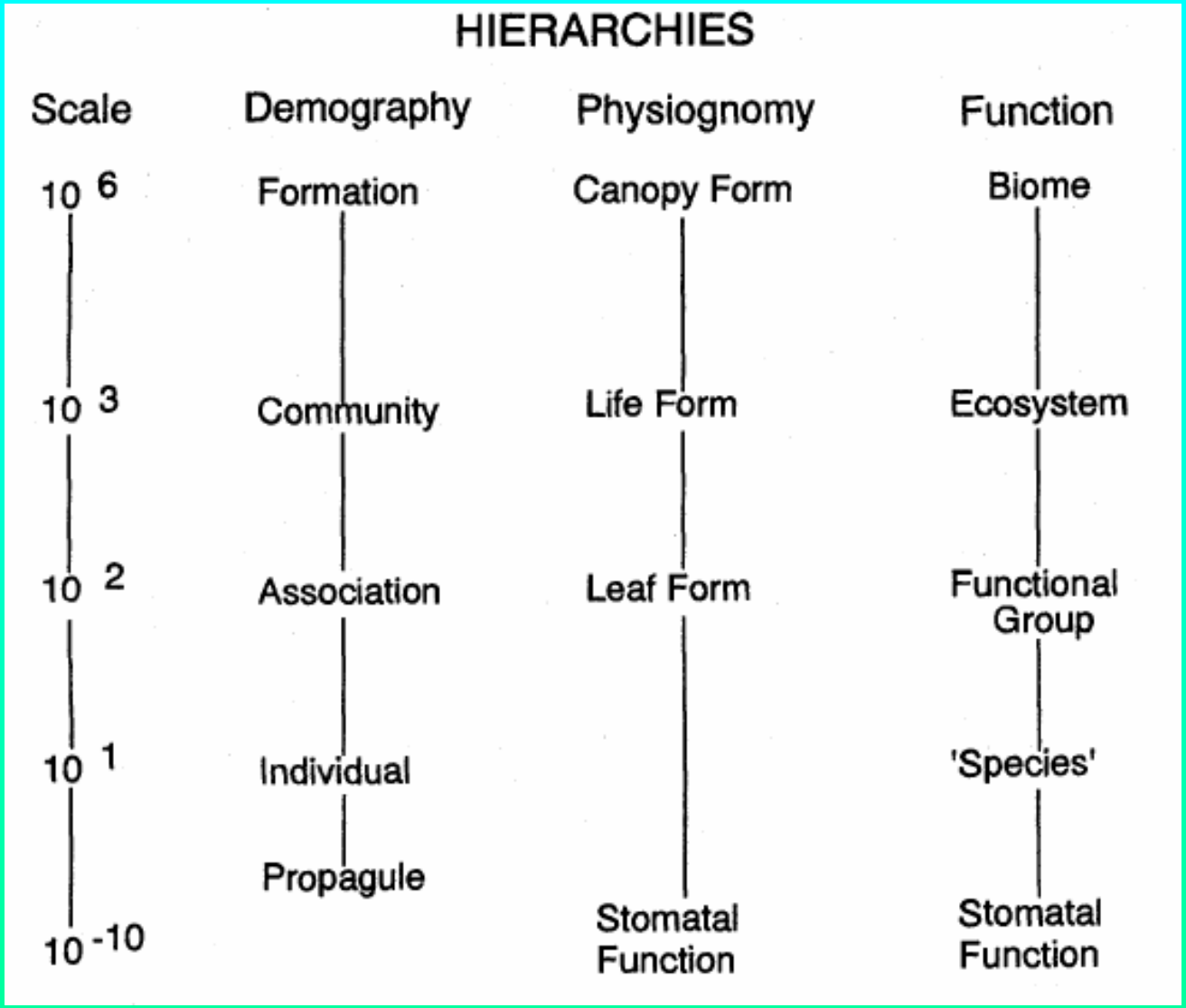


The Water Cycle moves most of the energy from the Tropics to the Poles!

Vegetation Patterns

- Hierarchical Structure
  - Classification
  - Pattern
  - Process

Some Necessary Terminology



Neilson,R.P. 1993. Transient ecotone response to climatic change: Some conceptual and modelling approaches. Ecological Applications 3:385-395.

Some Necessary Terminology

Standardized National Vegetation Classification System
November 1994

Prepared For:
United States Department of Interior
National Biological Service and
National Park Service

Prepared By:
The Nature Conservancy

TERRESTRIAL VEGETATION
of the UNITED STATES
VOLUME I
The National Vegetation Classification System:
Development, Status, and Applications
D. H. Grossman, D. Faber-Langendoen, A. S. Weakley, M. Anderson,
P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson,
M. Pyne, M. Reid, and L. Sneddon

Some Necessary Terminology

A. PHYSIOGNOMY

System: Terrestrial/Aquatic - (hydrological regime)

Class - Woodland - (spacing & height of dominant form)

Subclass - Evergreen Woodland - (morphological & Phenological similarity)

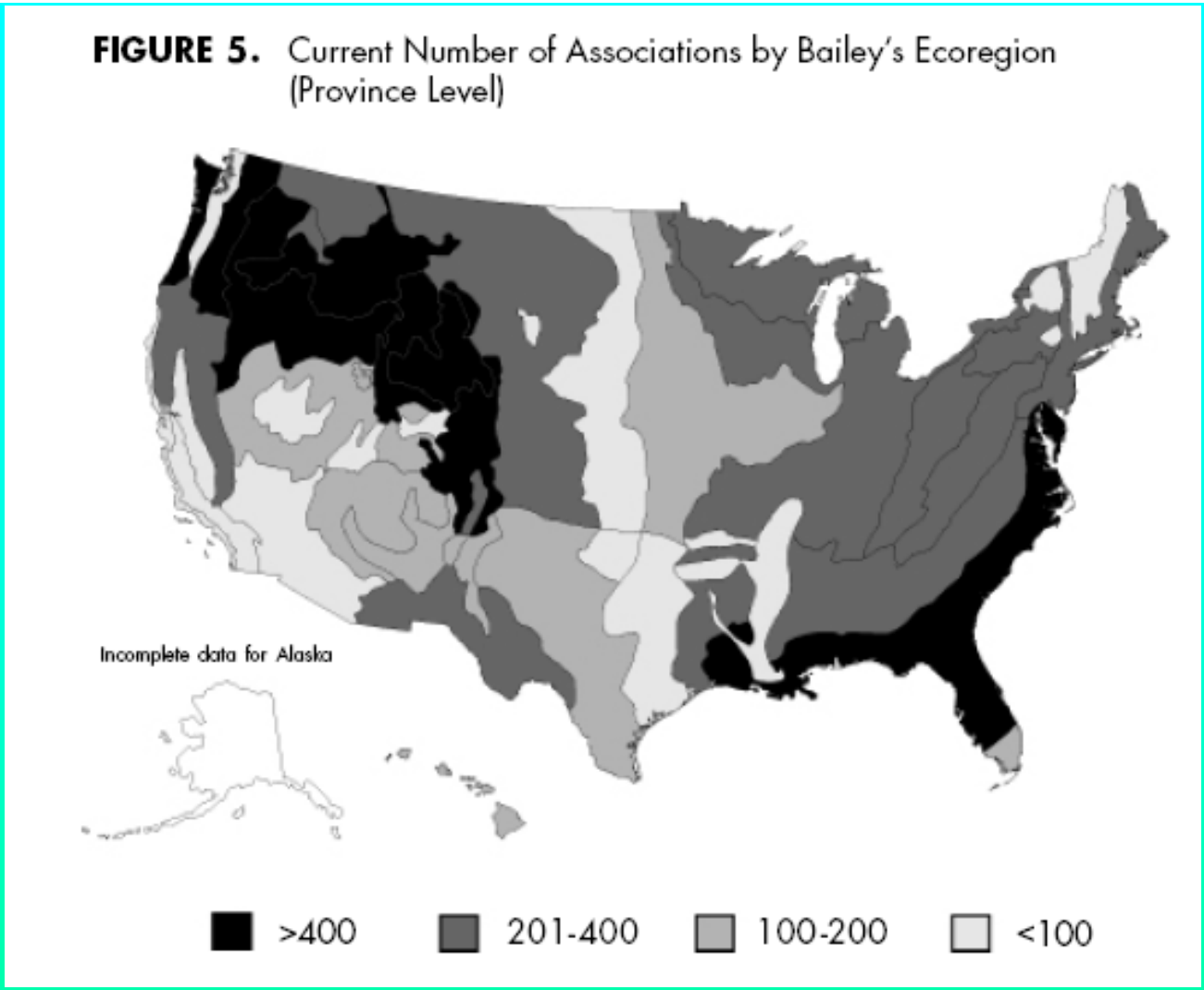
Group - Temperate Evergreen Needle-leaved - (climate latitude, growth form, leaf form)

Formation - Evergreen needle-leaved forest with conical crowns - (mappable units)

B. FLORISTICS

Alliance (or cover type) - Abies lasiocarpa Forest (dominant species)

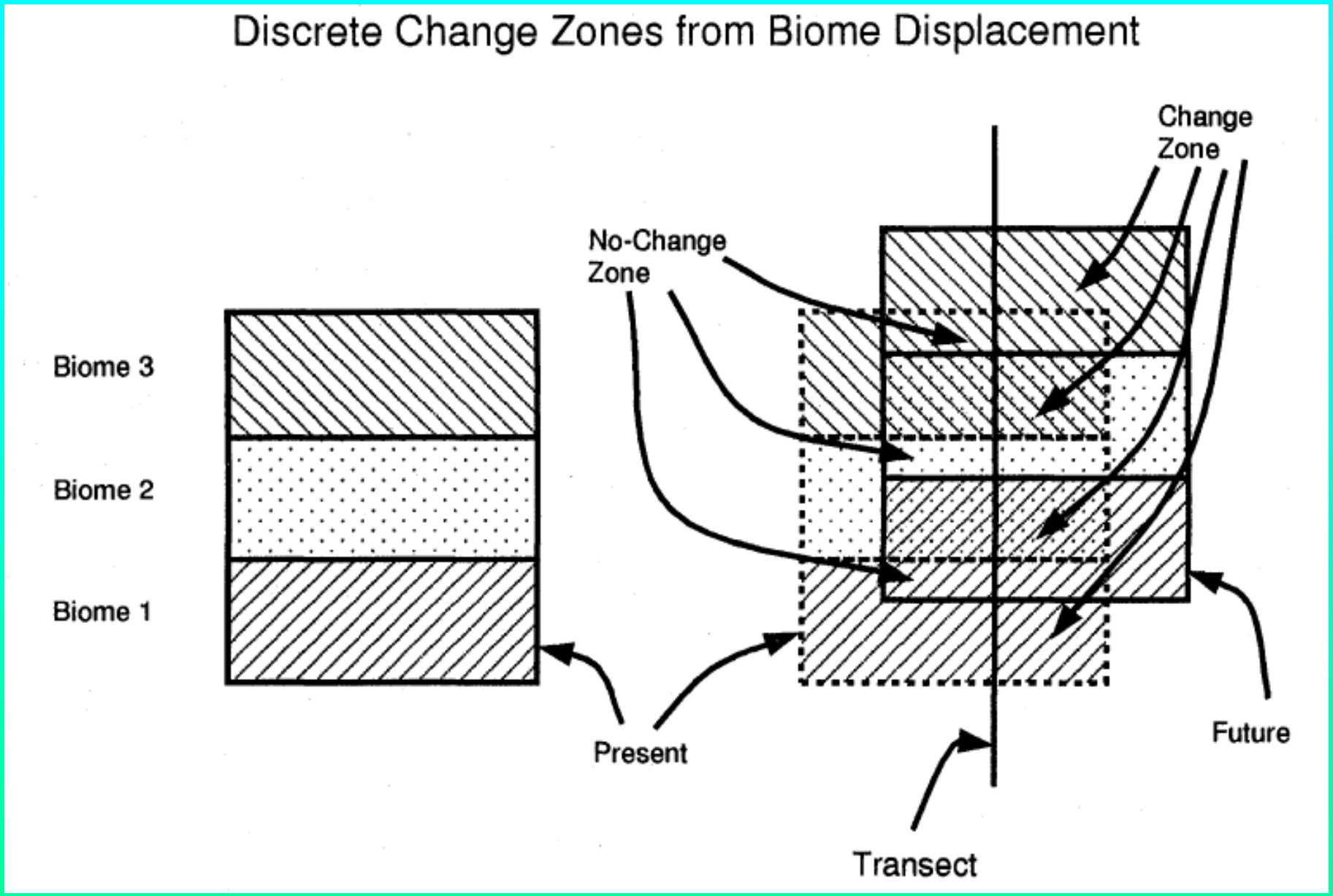
Association (or community) - Abies lasiocarpa/Vaccinium scoparium [Subalpine fir/Grouseberry] (subdominant or associated species with similar ecological processes)



Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. ***International classification of ecological communities: terrestrial vegetation of the United States. Volume I. The National Vegetation Classification System: development, status, and applications.*** The Nature Conservancy, Arlington, Virginia, USA.

Theories of Change

- Hierarchical Level of Change
  - Classification
  - Pattern
  - Process



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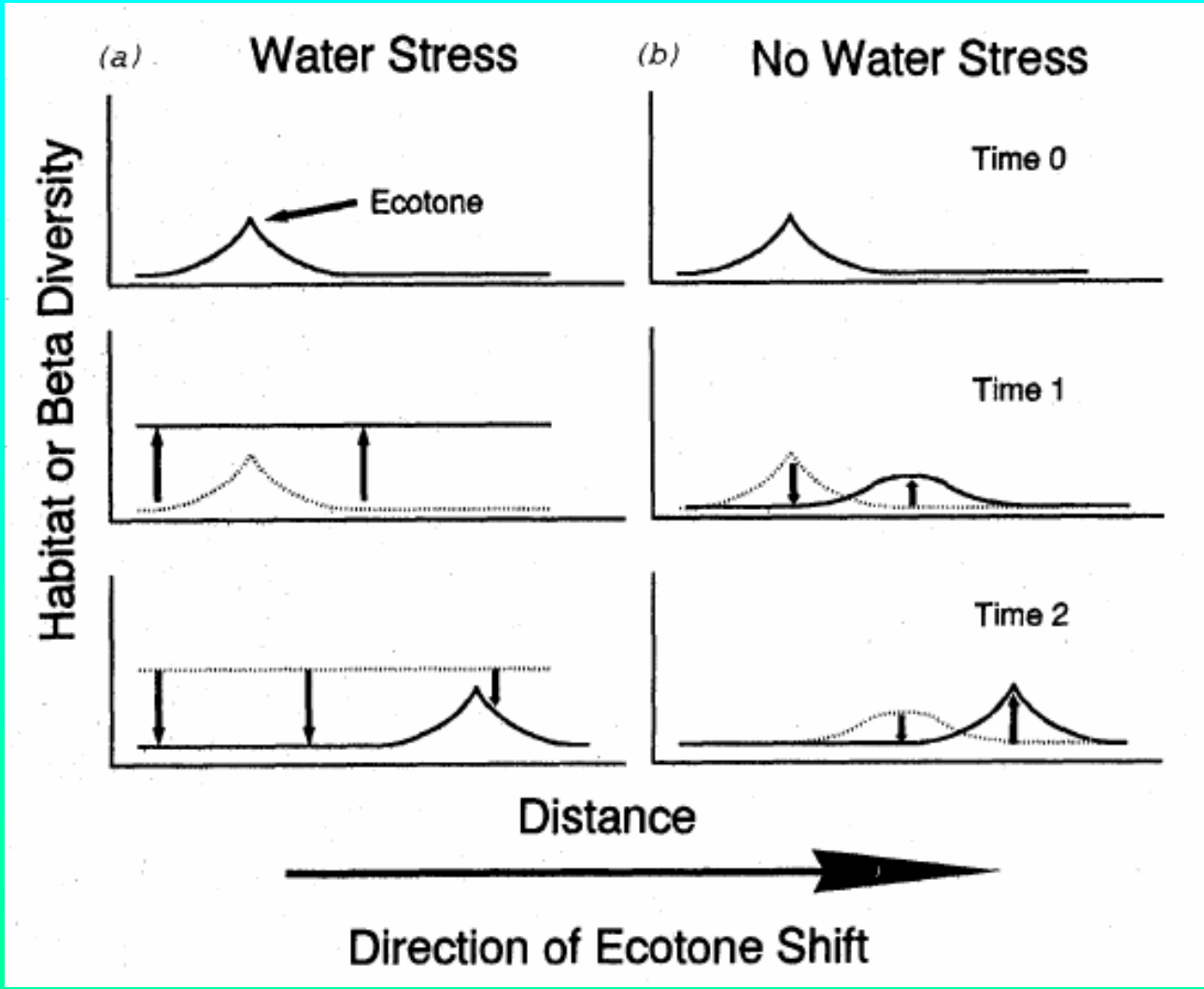
How Should Vegetation Change Occur on the Ground?



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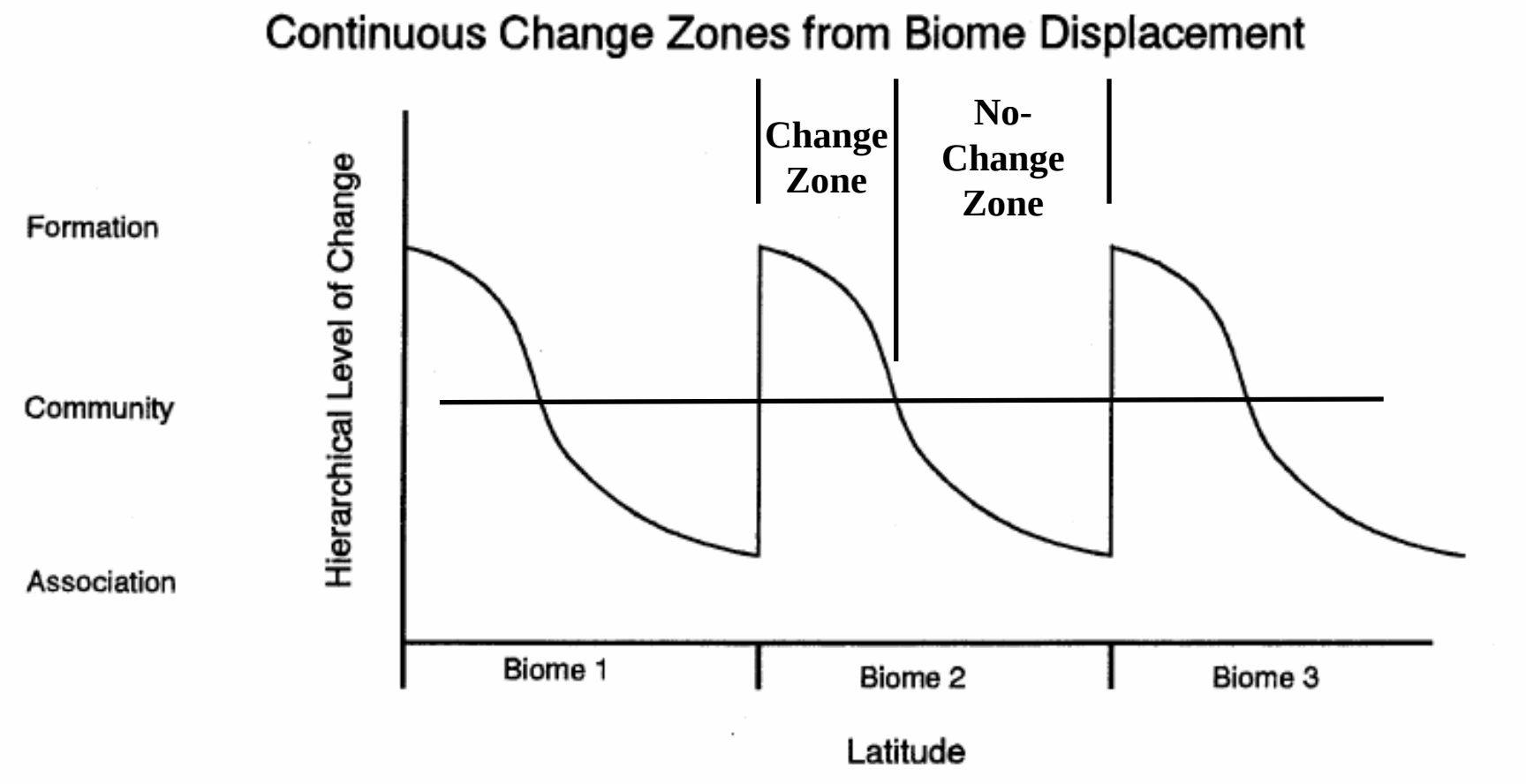

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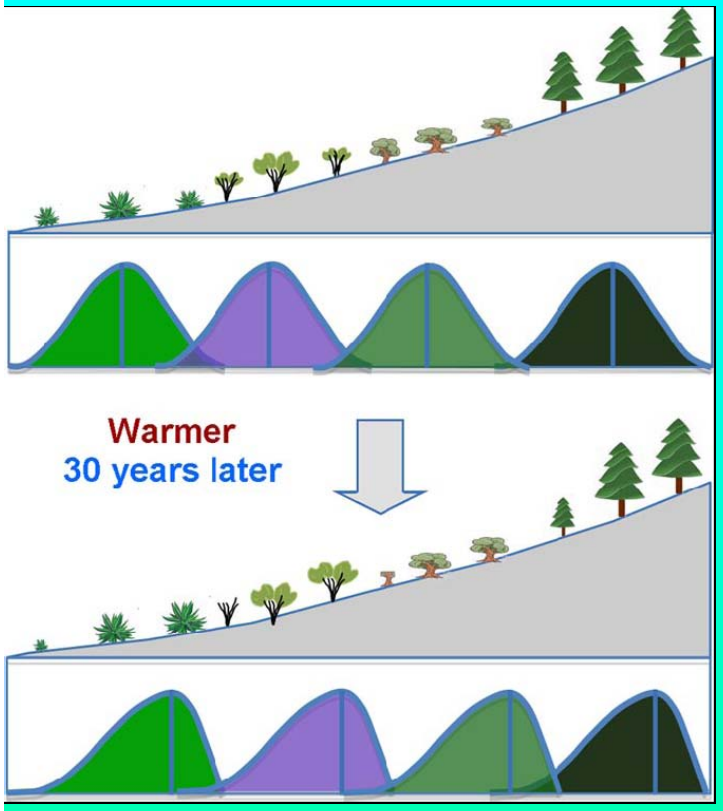


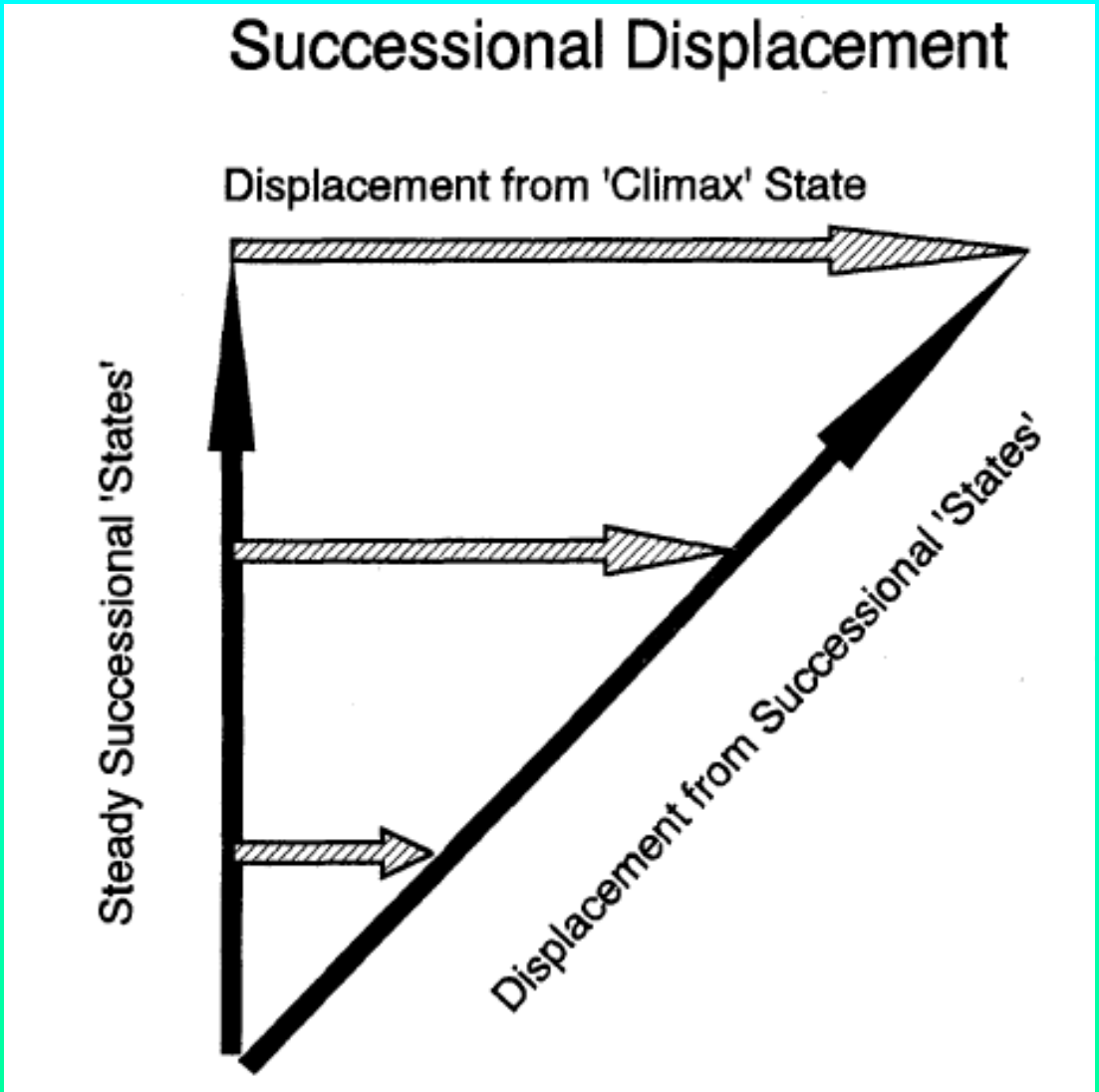
Individual Species' Responses Shifting Dominance

In Southern California's Santa Rosa Mountains the average elevation of the dominant plant species rose by 65 m (1977 – 2007).

Breshears,D.D., T.E.Huxman, H.D.Adams, C.B.Zou, and J.E.Davison. 2008. Vegetation synchronously leans upslope as climate warms. Proceedings of the National Academy of Sciences 105:11591-11592.

Kelly A, Goulden M (2008) **Rapid shifts in plant distribution with recent climate change.** *Proc Natl Acad Sci USA* 105:11823–11826.

How Should Vegetation Change Occur on the Ground?



Neilson,R.P. 1993. Transient ecotone response to climatic change: Some conceptual and modelling approaches. Ecological Applications 3:385-395.

How do plants move around?
and
Once there, how do they stay there?

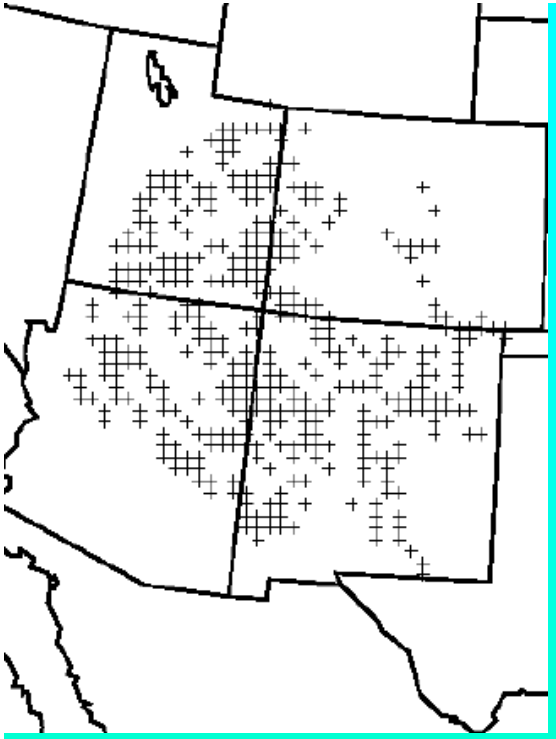
Spread – Complete the Sexual Cycle

1) Produce propagules
    1) Usually seeds, but can be vegetative parts
2) Disperse propagules
    1) Wind, Animals Water, etc.
3) *Establish* propagules in new location
    1) Usually a very critical bottleneck
4) Grow to age of reproduction and produce new propagules

Survival – Sexual or Asexual Cycle

1) Repeat Sexual reproductive steps, above
2) Asexual Reproduction
    1) Vegetative parts
    2) Layering
    3) Stump sprouting
    4) Rhizomatous mats

Relictual Oak Populations

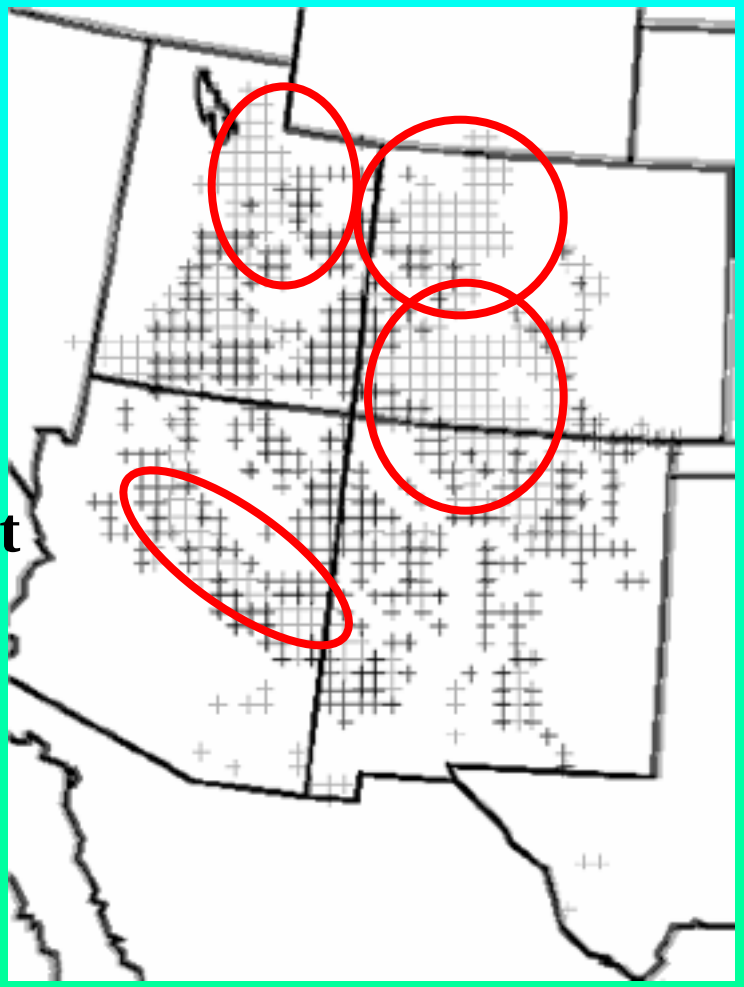


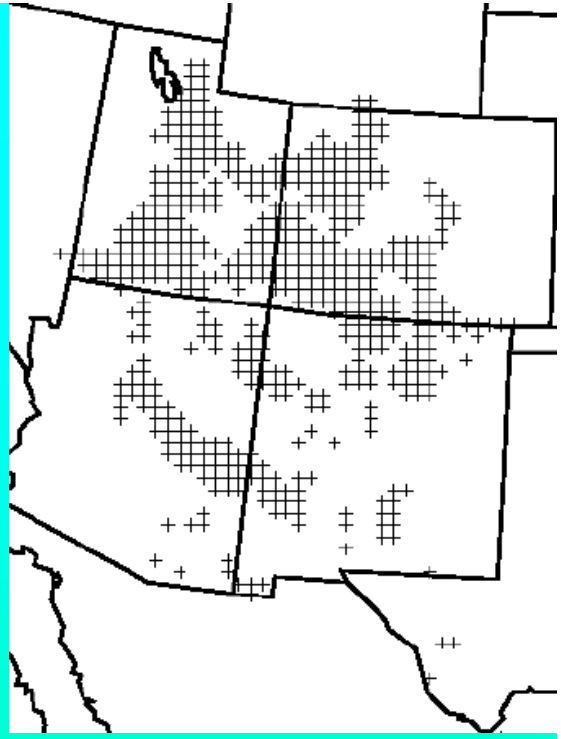
Pinus edulis

Share establishment Niche

Pine – Sexual only

Oak – Asexual and Sexual

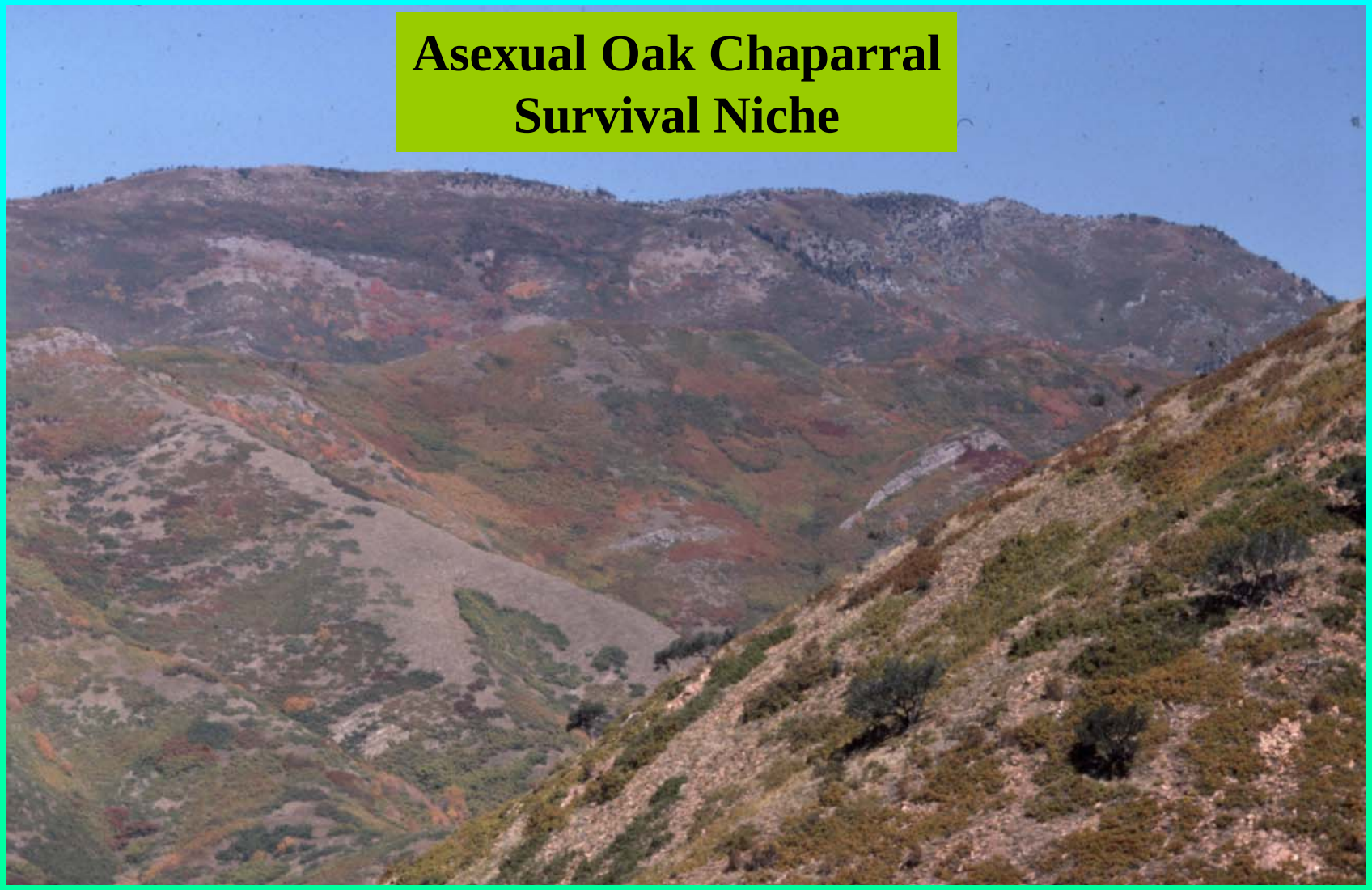




Quercus gambelii

Holocene, climates left relicts behind over large landscapes (red).

Gambel Oak, Northern Distribution – Physiognomy → Chaparral

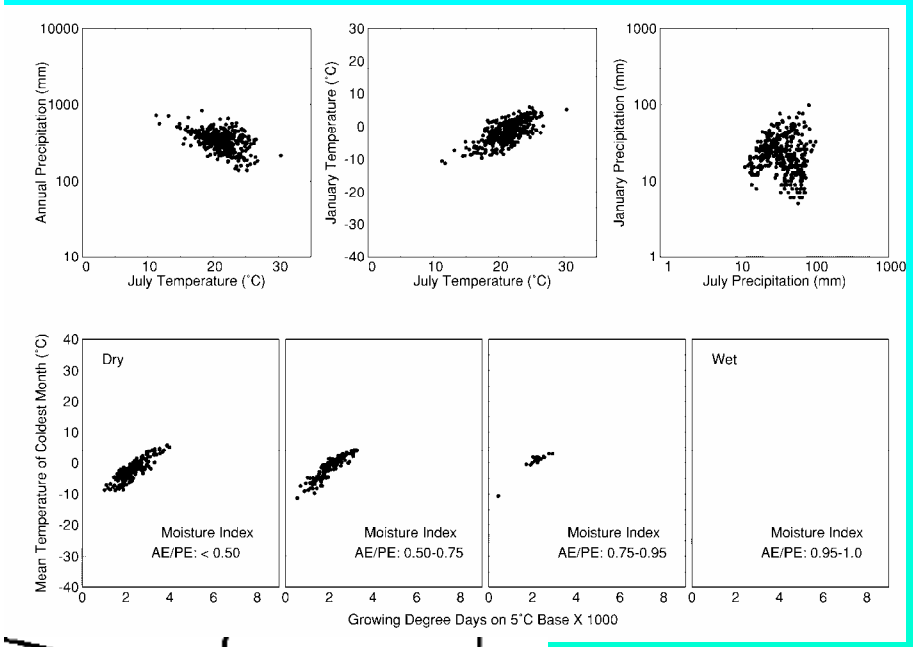


Gambel Oak, Southern Distribution – Physiognomy → Woodland / Forest

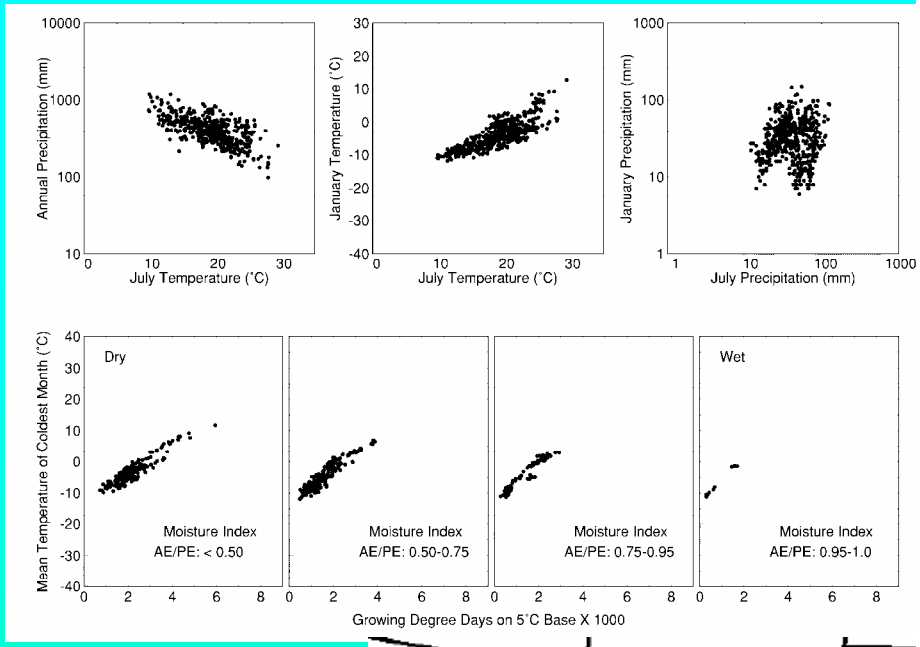
Simulating Vegetation Change

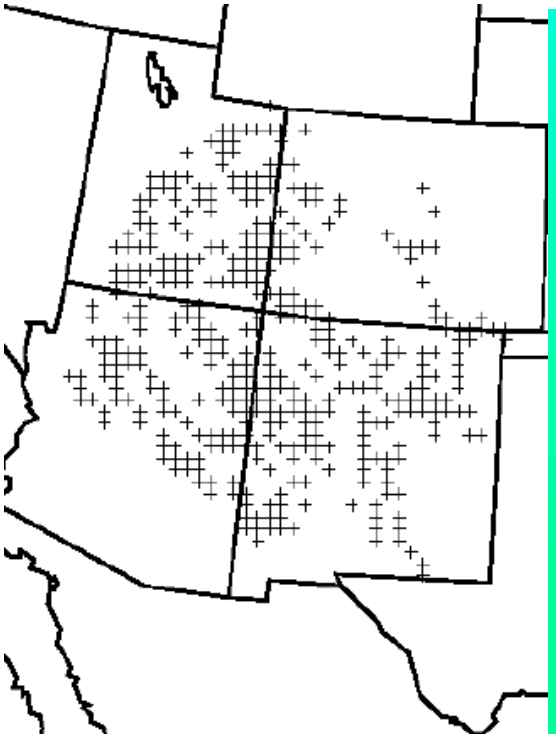
- **Species Models**
  - Survival Niche (Current and Relictual Populations)
  - Statistical Species, Community Distribution
  - Some Mechanistic Migration
  - Lack Physiology, Physiognomy
- **Mechanistic Models**
  - Survival Niche (Physiognomic Constraints)
  - Mechanistic Biome (Formation) Distribution
  - Lack Migration Niche (Some emerging technology)

Pinus edulis



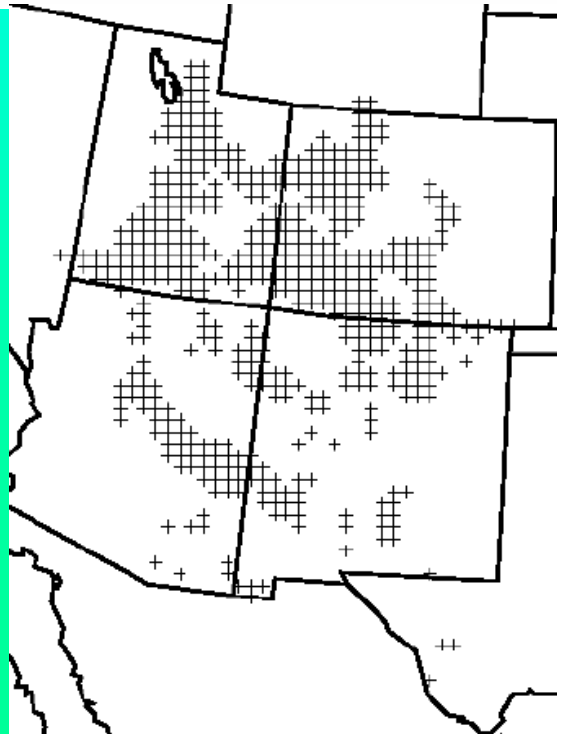
Quercus gambelii





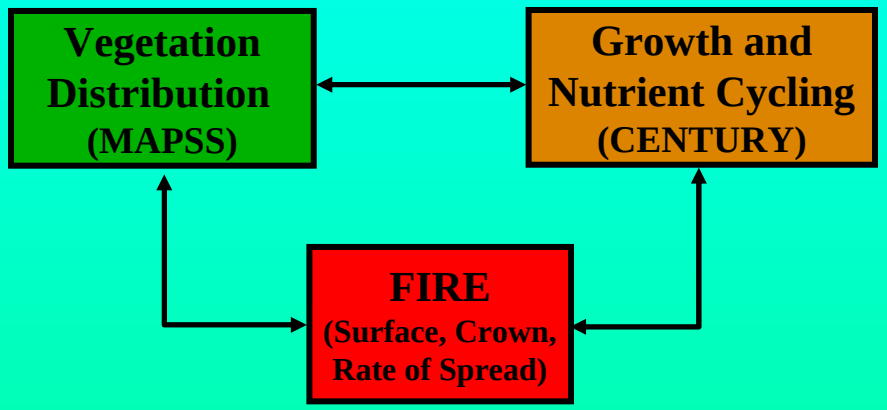
Niche-based Statistical Modeling

Energy, moisture limitations

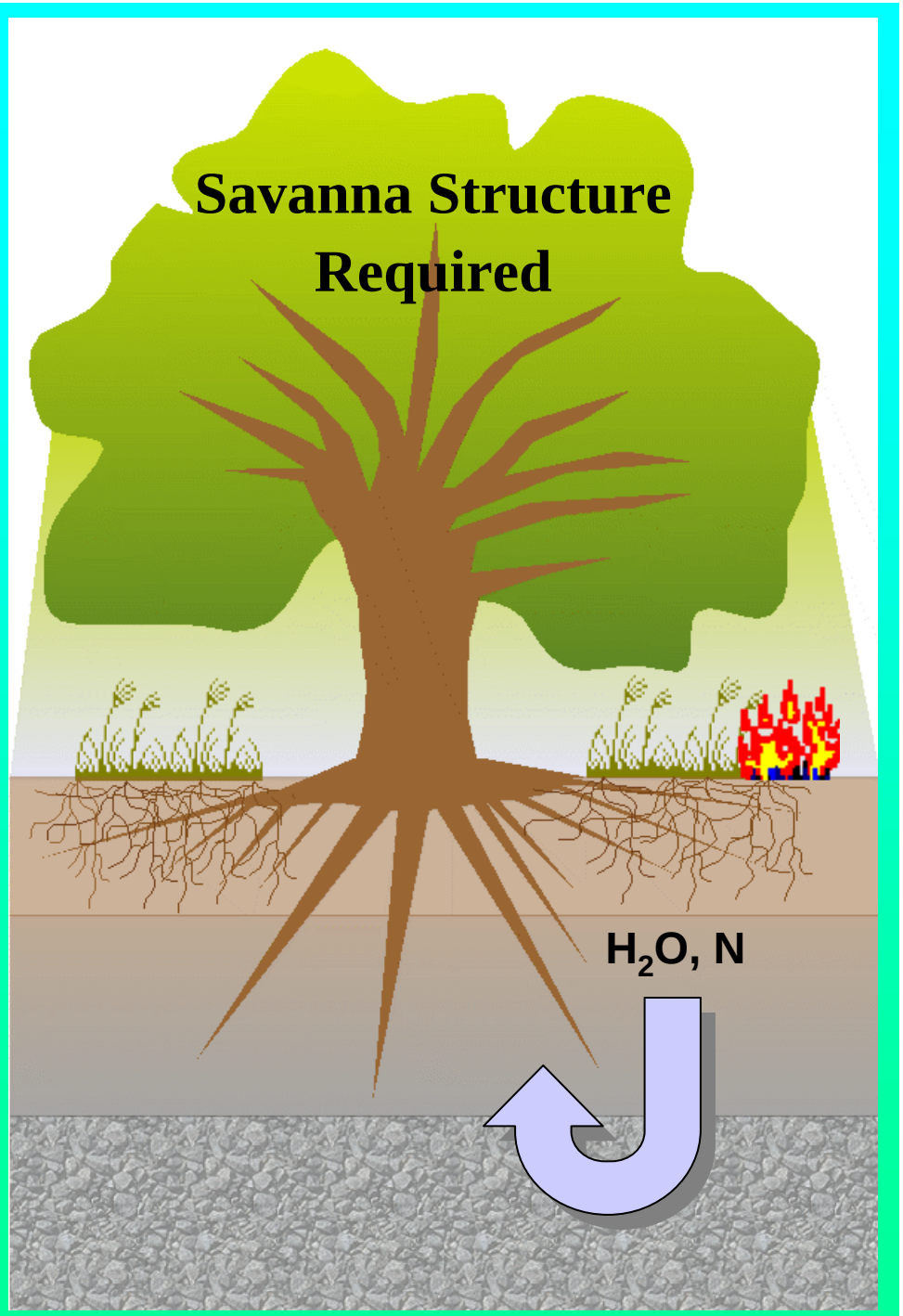


Mechanistic Modeling

Vegetation and
Fire Dynamics
(MC1 Model)



Drought Responses
Fire Risks
Carbon Sequestration



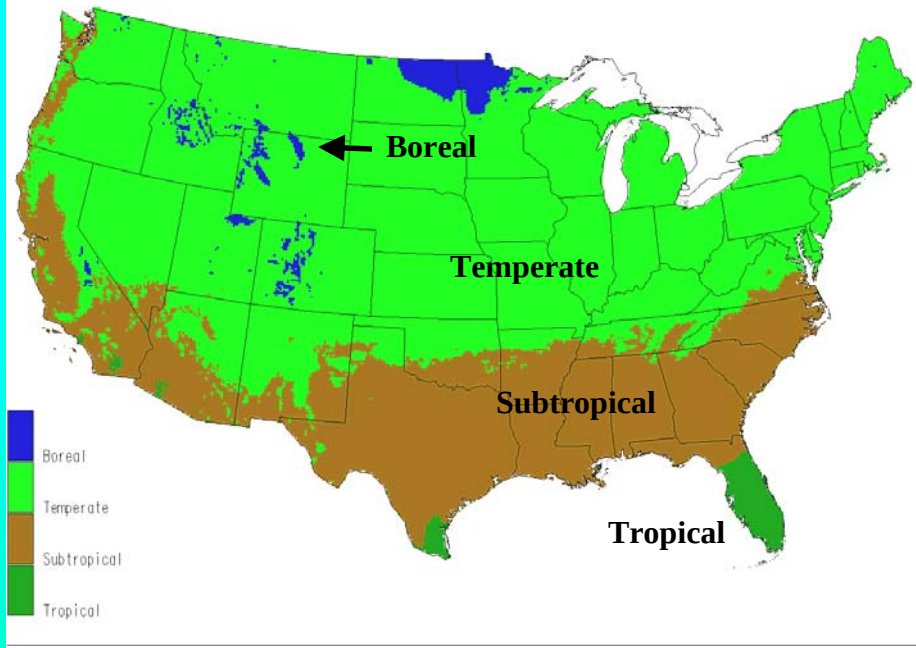
Thermal Zones

MAPSS Simulations

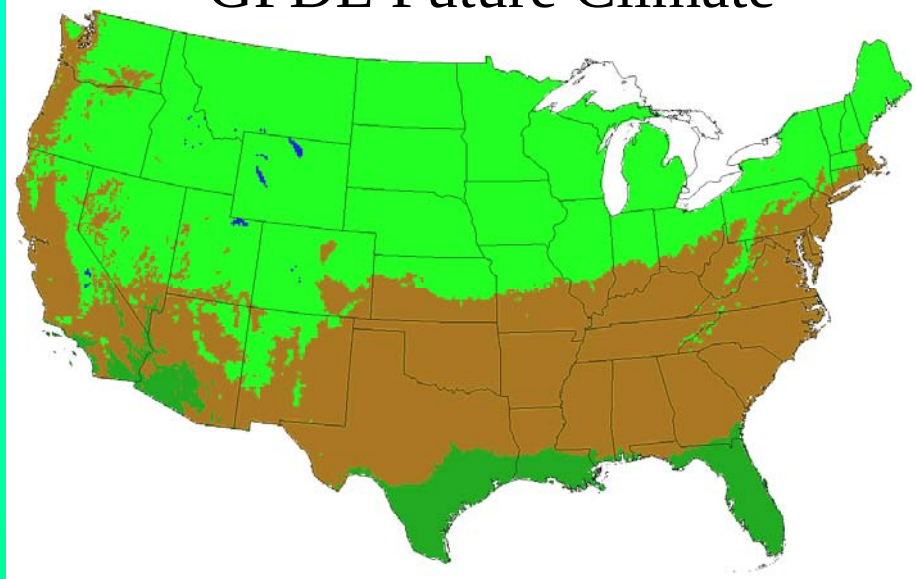
Future Thermal Impacts

- **Longer Growing Season**
- **Natives Invade Natives**
- **Release of Frost Limitations**
- **Loss of Most Alpine**
- **Larger, Drier Subtropics**
  - **Great Basin Thresholds**
- **Expansion of Tropics**

Current Climate

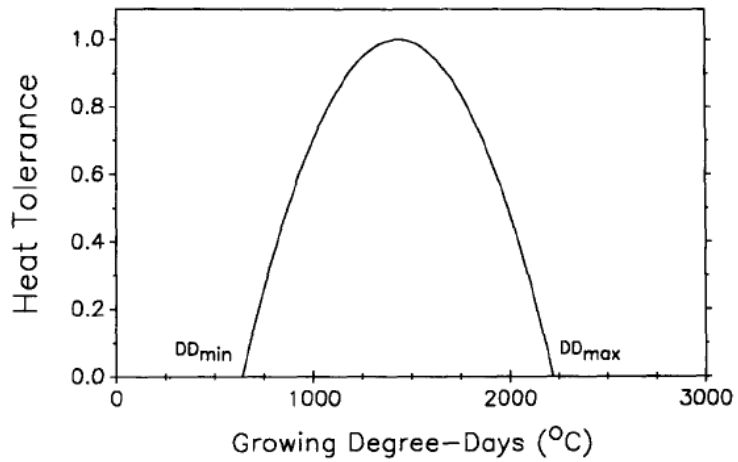


GFDL Future Climate

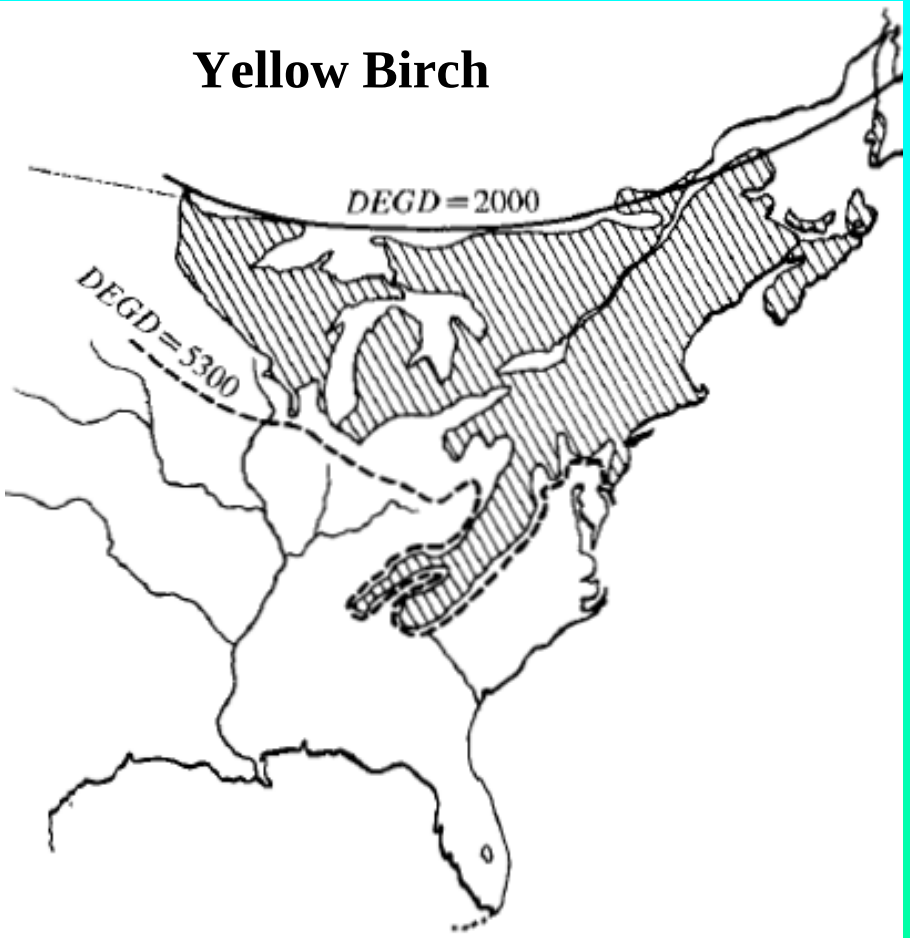


First Forest Succession Model (JABOWA)
Combines Mechanism (Succession) and 'Climate-Envelope'

Temperature controls northern and southern boundaries of species



Yellow Birch

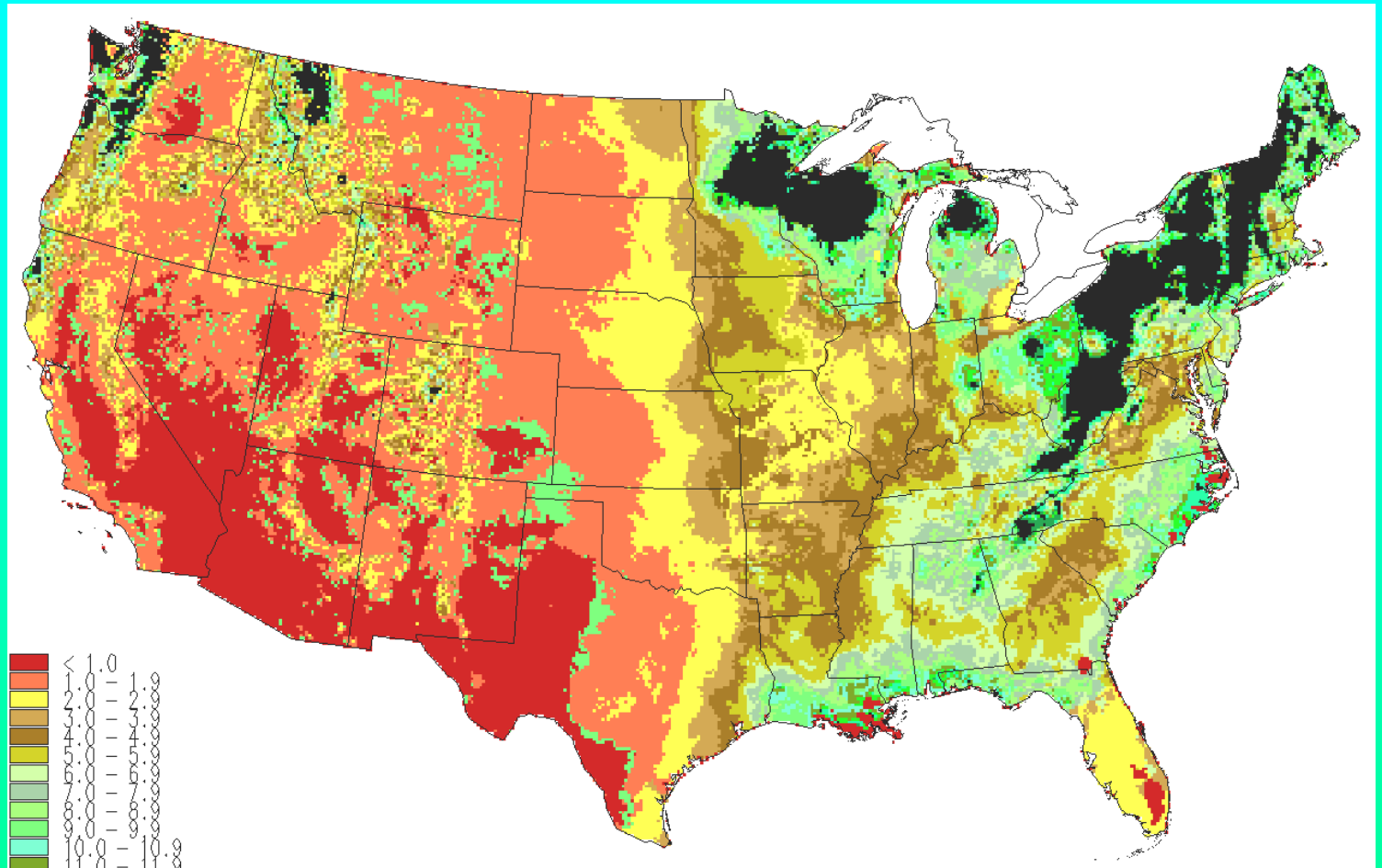


Climate Envelope

Rationale, limitations, and assumptions of a northeastern forest growth simulator
DB **Botkin**, JF **Janak**, JR **Wallis** - IBM Journal of Research and Development, 1972

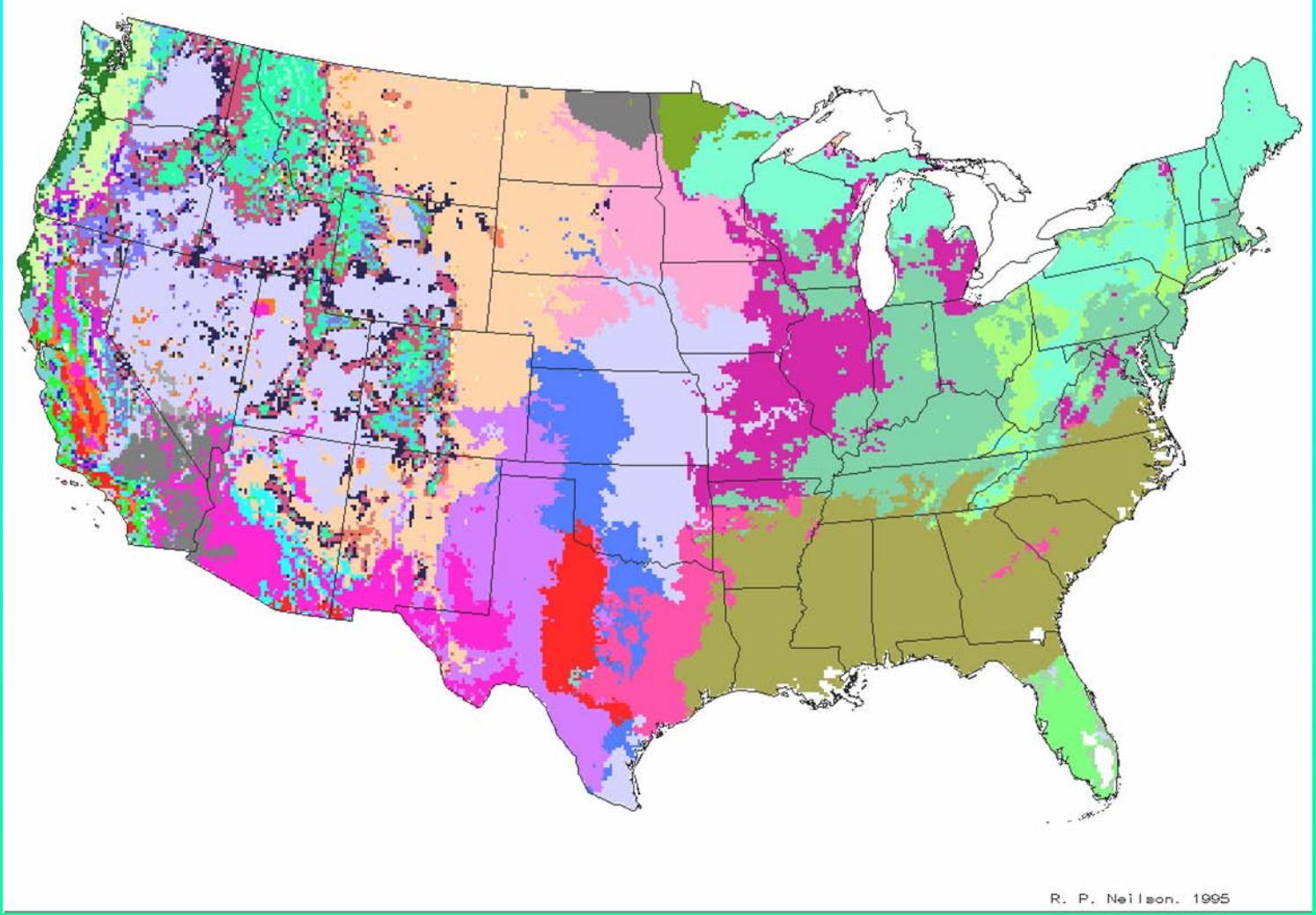
Kirtland's warbler habitats: a possible early indicator of climatic warming **Botkin**, **Woodby**, **Nisbet** - Biological conservation, 1991

MAPSS Simulated Leaf Area Index
Mechanistic Simulation of
Water-limited Leaf Area Carrying Capacity

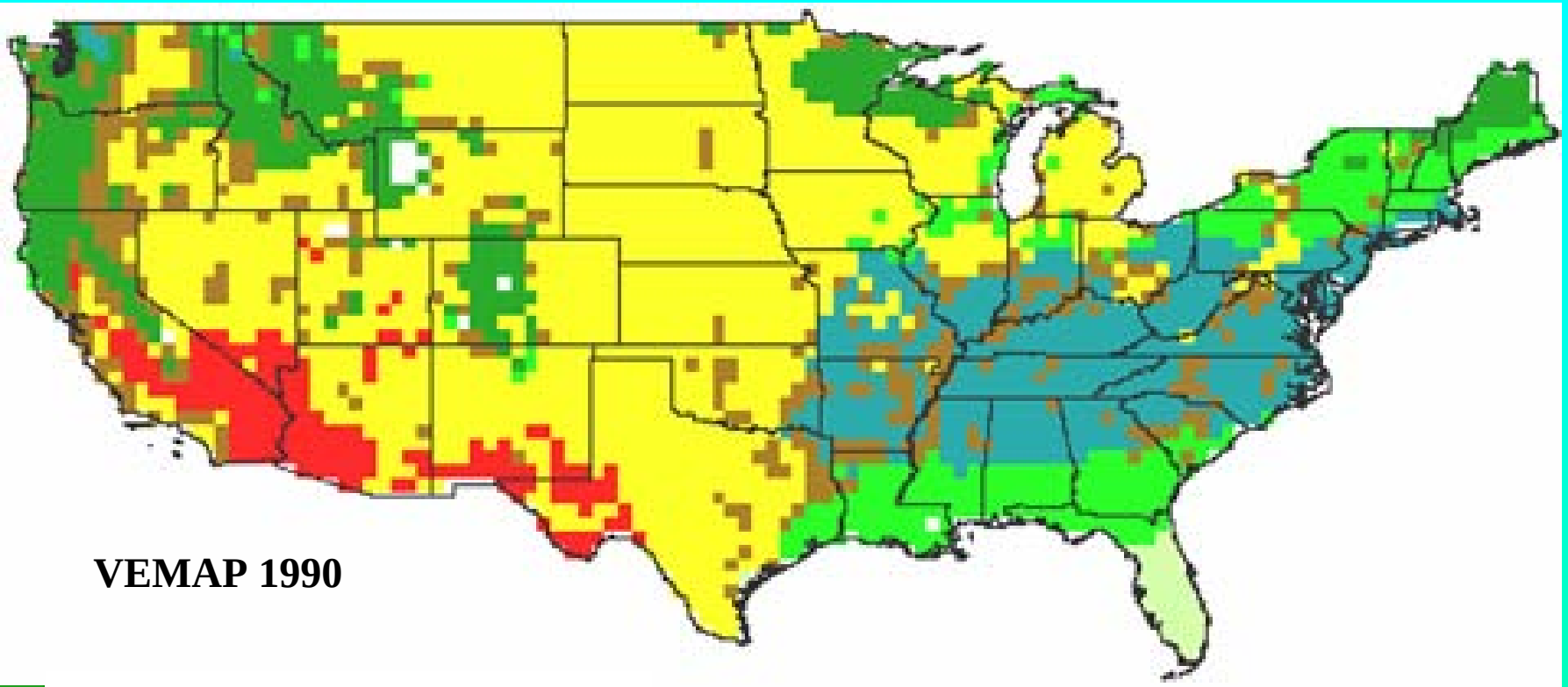


Competes Woody Overstory with ephemeral Understory
Calibrated Monthly Runoff

MAPSS Simulated Vegetation Distribution
Current Climate



HISTORICAL CONDITIONS



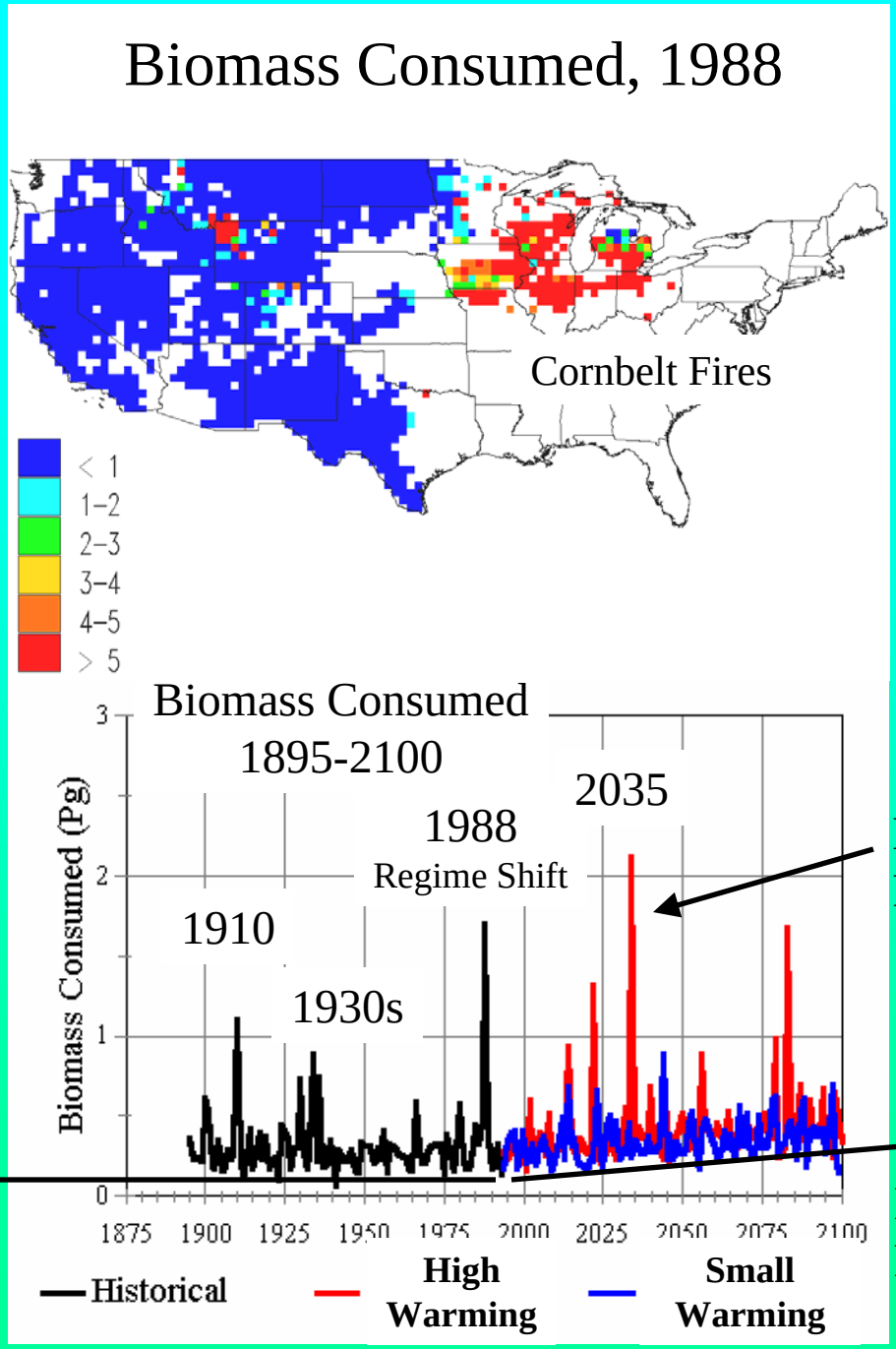
- Coniferous forests
- Winter deciduous forests
- Mixed forests
- Broadl. & everg. drought decid. forests
- Savannas and woodlands
- Grasslands and shrublands
- Deserts

Mechanistic Disturbance (Drought, Fire) + Biogeography – Biogeochemistry =

‘Prairie Peninsula’

Bachelet,D., R.P.Neilson, J.M.Lenihan, and R.J.Drapek. 2001. Climate change effects on vegetation distribution and carbon budget in the U.S. Ecosystems 4:164-185.

Yellowstone Fire



Disturbance Mediates Ecosystem Change

MC-FIRE Simulation

Large, 'Catastrophic' Fires

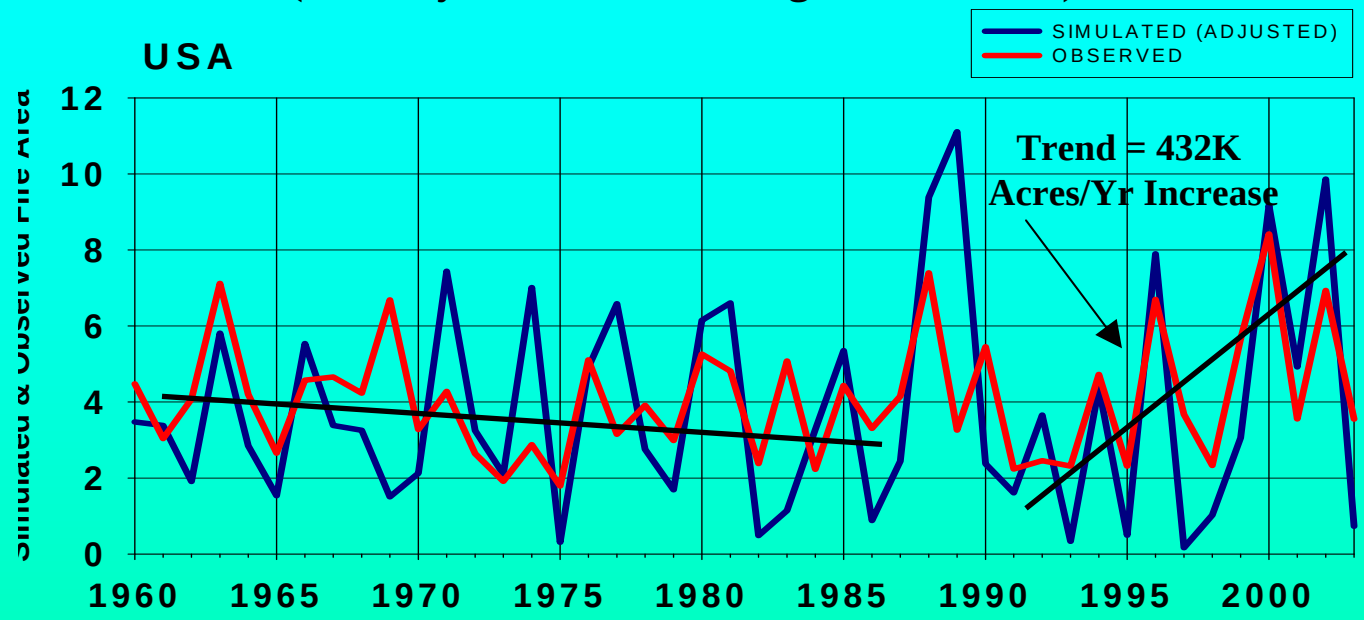
Historic Trend

Future Trend

Increase in 'Background Fire Severity

Observed and Simulated Fire Area for the Conterminous U.S. (Millions of Acres)

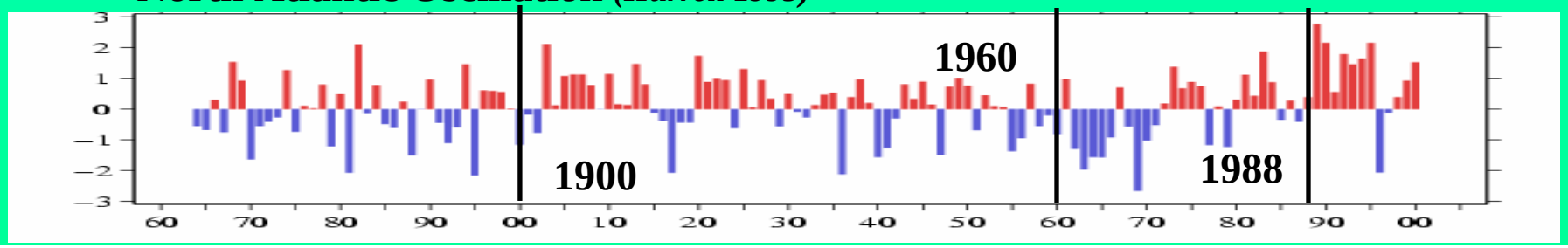
(MC1 Dynamic General Vegetation Model)



Simulated Fire Suppression
Suppression Factor = .125

"…large wildfire activity increased suddenly and dramatically in the mid-1980s….
(Westerling et al. 2006. Science)

North Atlantic Oscillation ***(Hurrell 1995)***



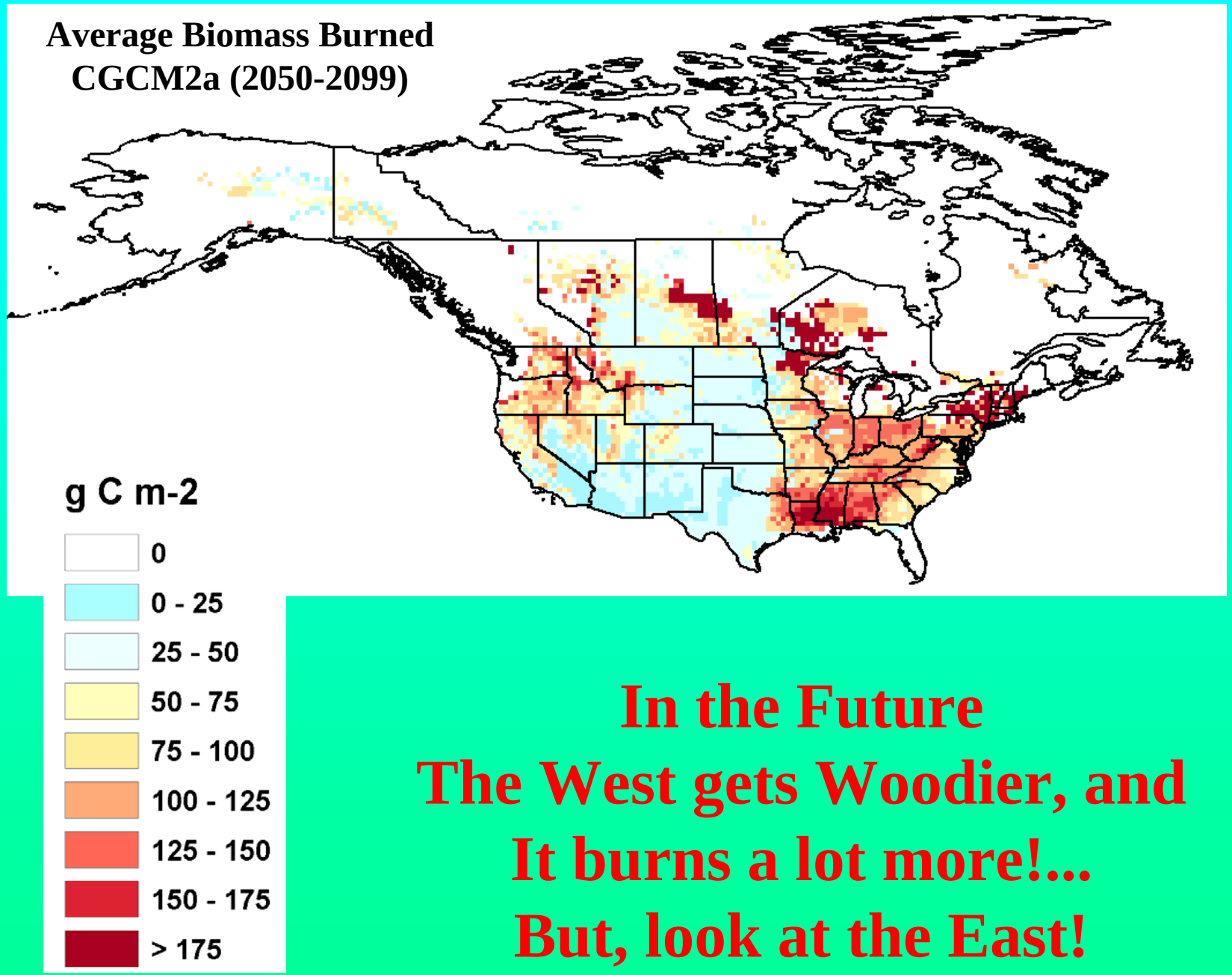
Future Climate
Managing for *Change* with *Uncertainty*

Current Assessments

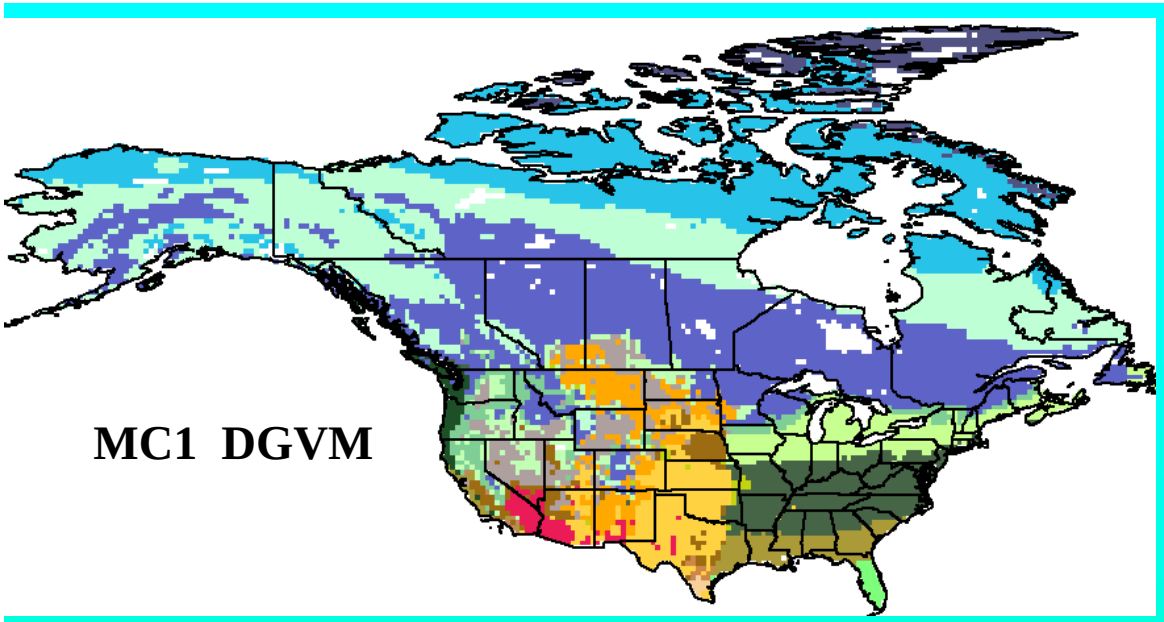
Bachelet, D., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2001. *Climate change effects on vegetation distribution and carbon budget in the U.S.* Ecosystems 4:164-185.

Bachelet, D., J. Lenihan, R. Drapek, and R. Neilson, 2008: *VEMAP vs VINCERA: A DGVM's sensitivity to differences in climate scenarios*. Global and Planetary Change.

Lenihan, J.M., D. Bachelet, R.P. Neilson, and R. Drapek, 2008: *Simulated response of conterminous United States ecosystems to climate change at different levels of fire suppression, CO_2, and growth response to CO_2*. Global and Planetary Change.



In the Future
The West gets Woodier, and
It burns a lot more!...
But, look at the East!

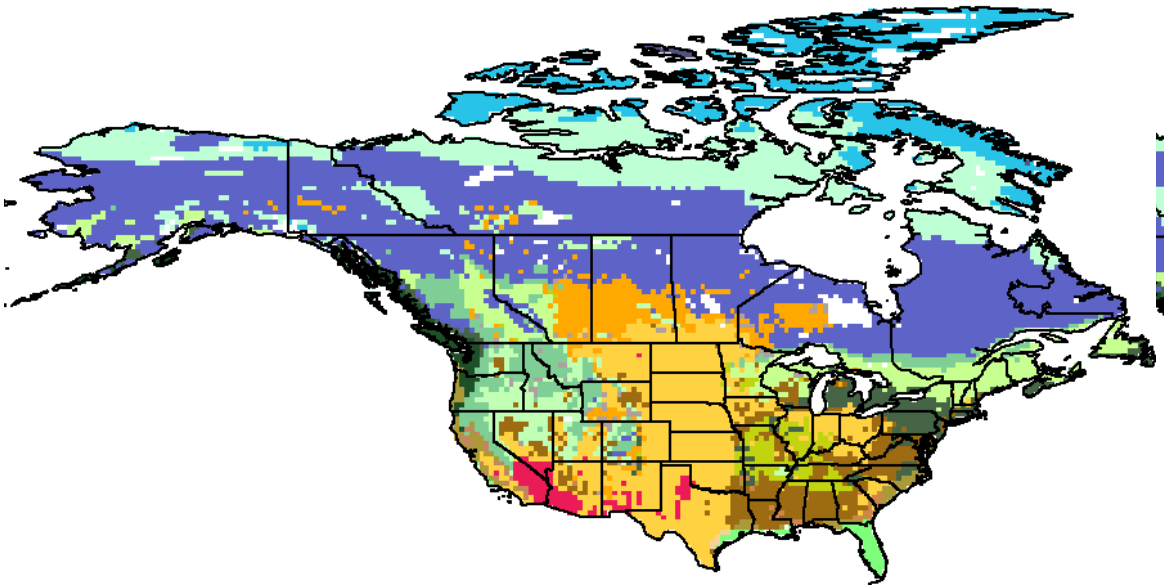


Current Vegetation (1961-1990)
Suppressed Fire

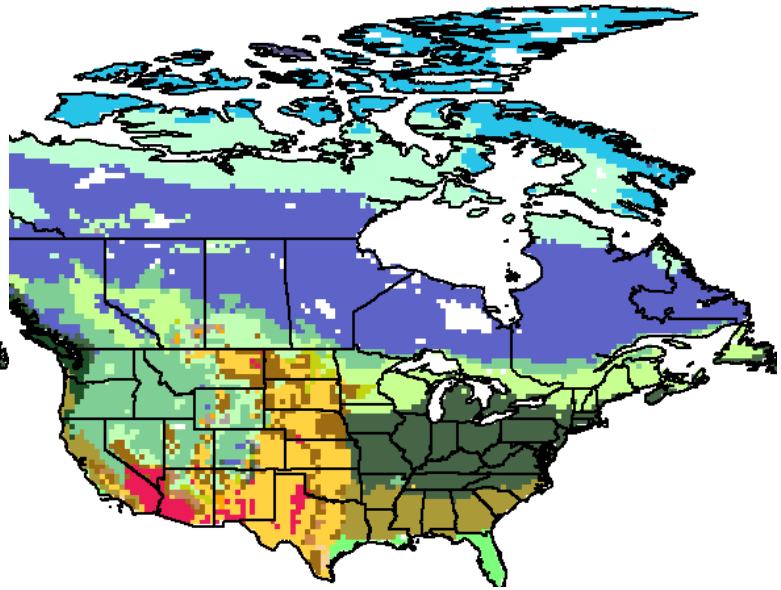
MAPSS Team. 2008.
Global and Planetary Change.

CGCM2-A2 Scenario

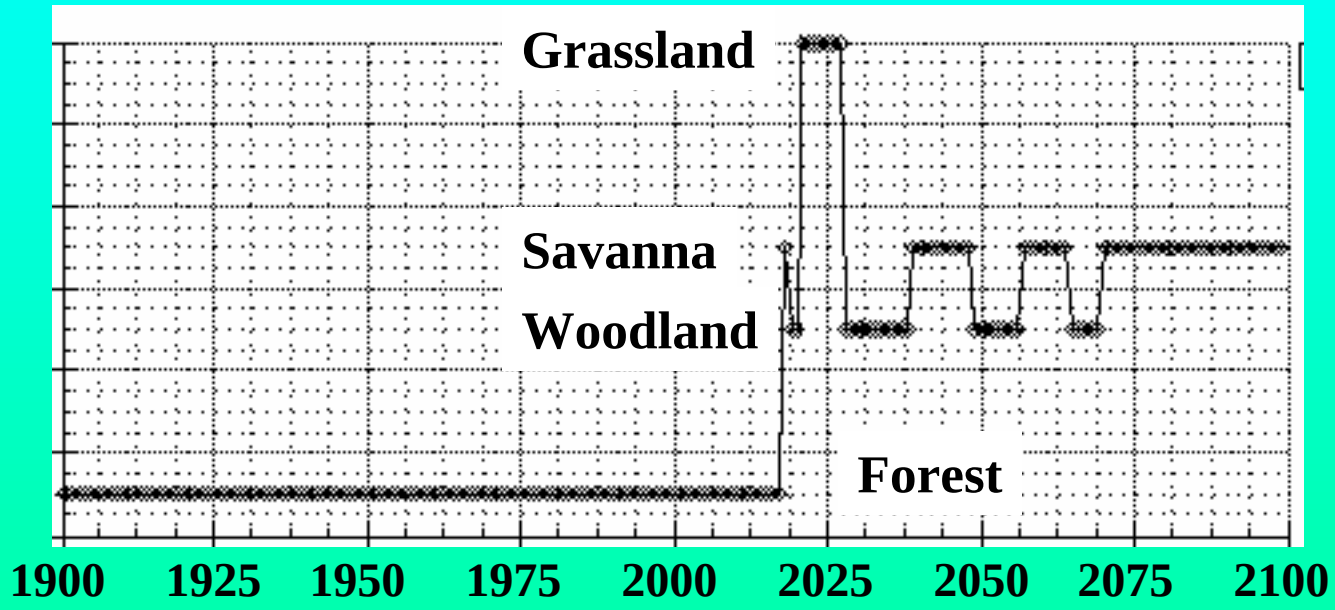
With Fire

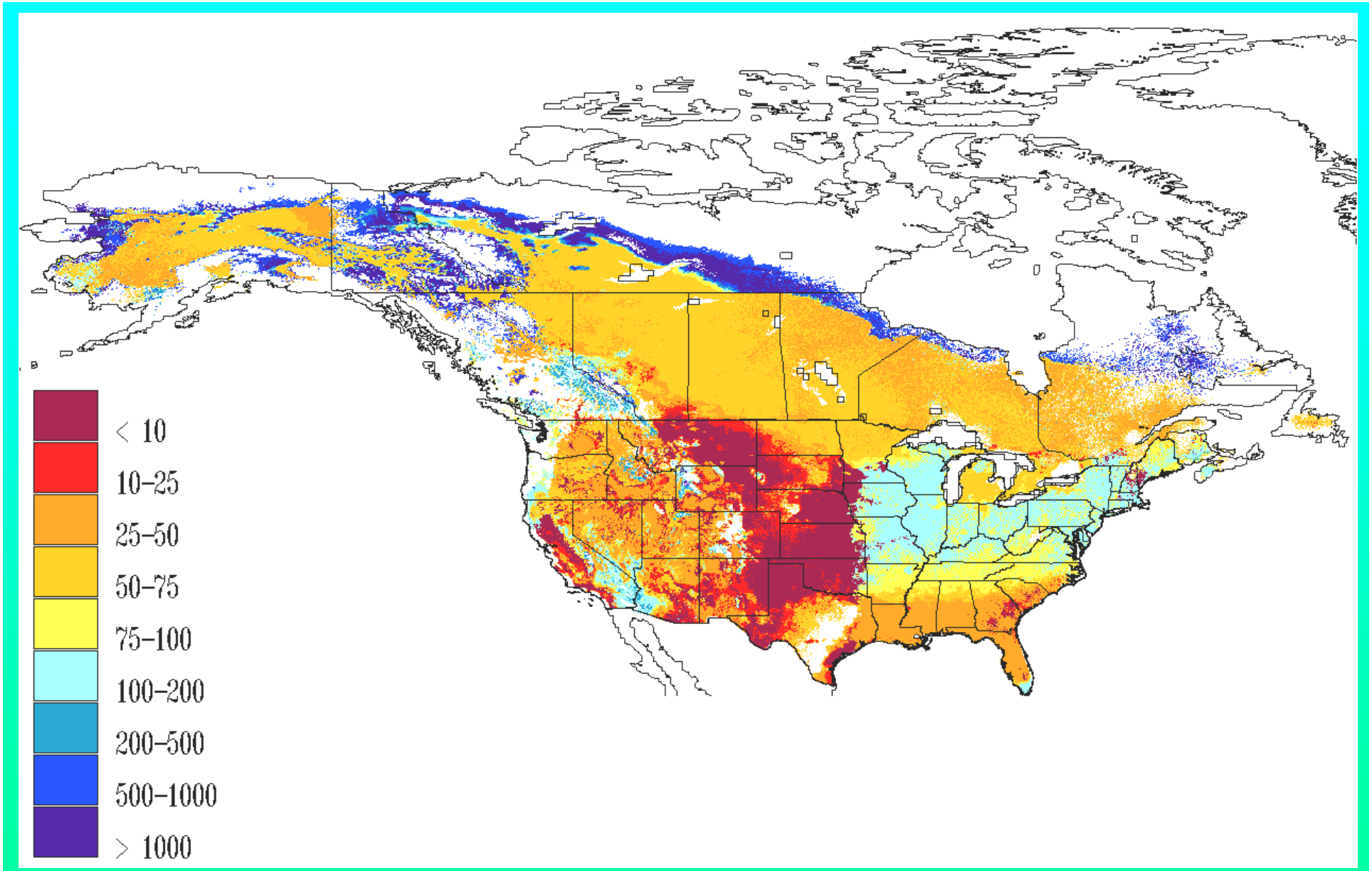


Suppressed Fire

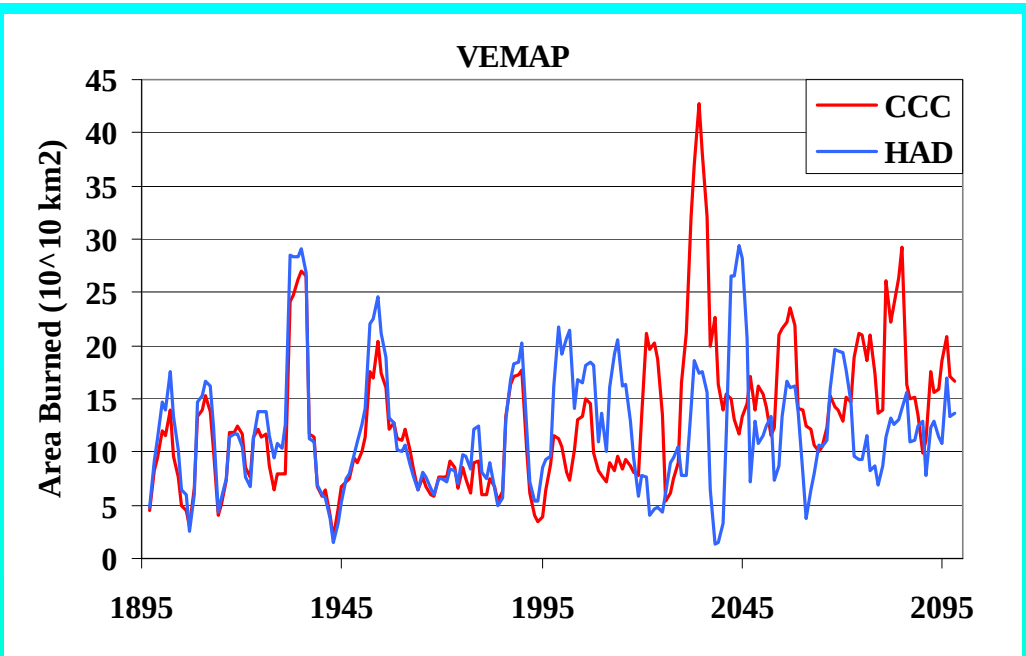


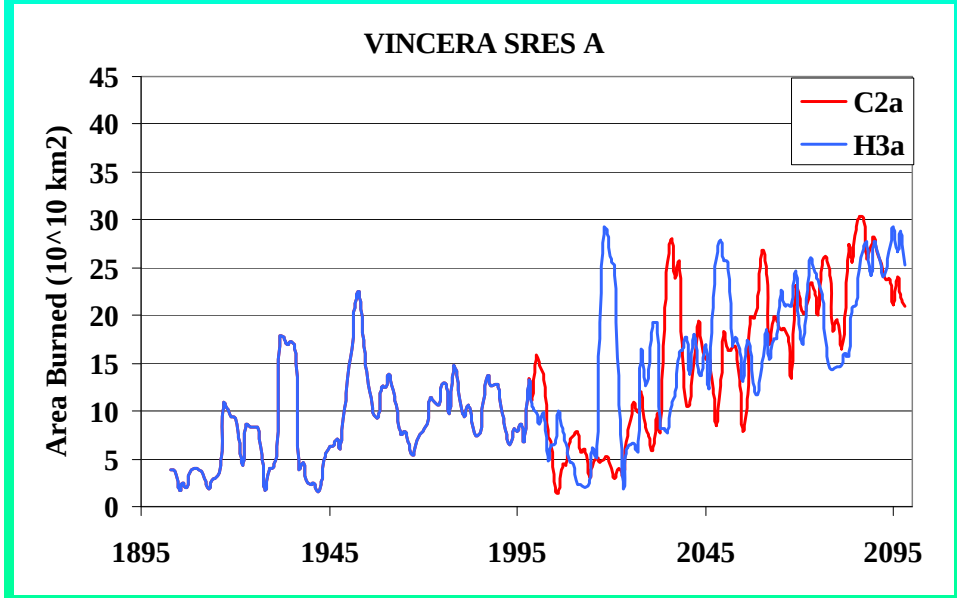
VINCERA HADCM3-A2
Eastern Deciduous Forest Region

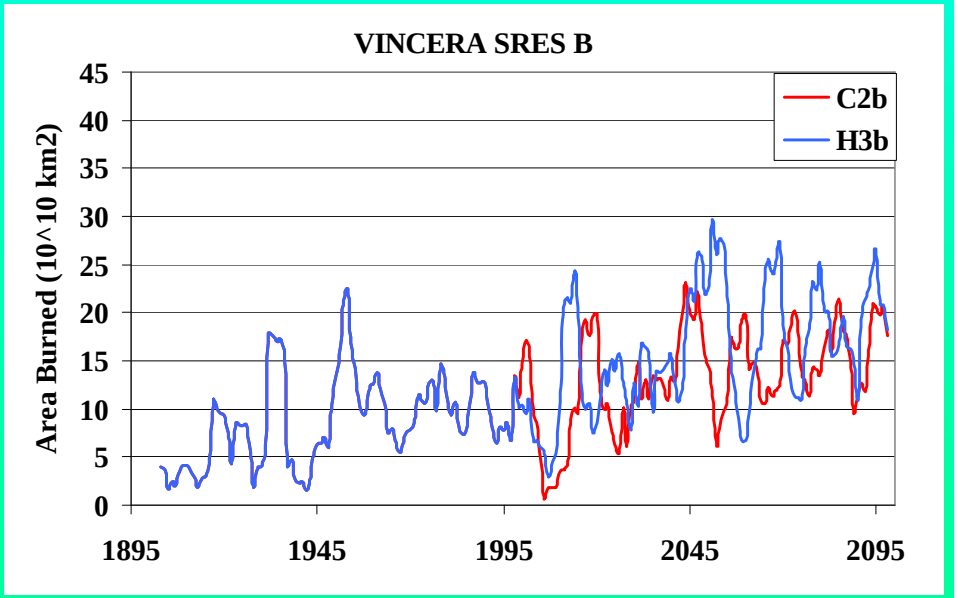




Simulated Fire Rotation Period (years)
1950-2000 Historical Period


VEMAP
Area Burned (10^10 km2)
45
40
35
30
25
20
15
10
5
0
1895
1945
1995
2045
2095
CCC
HAD

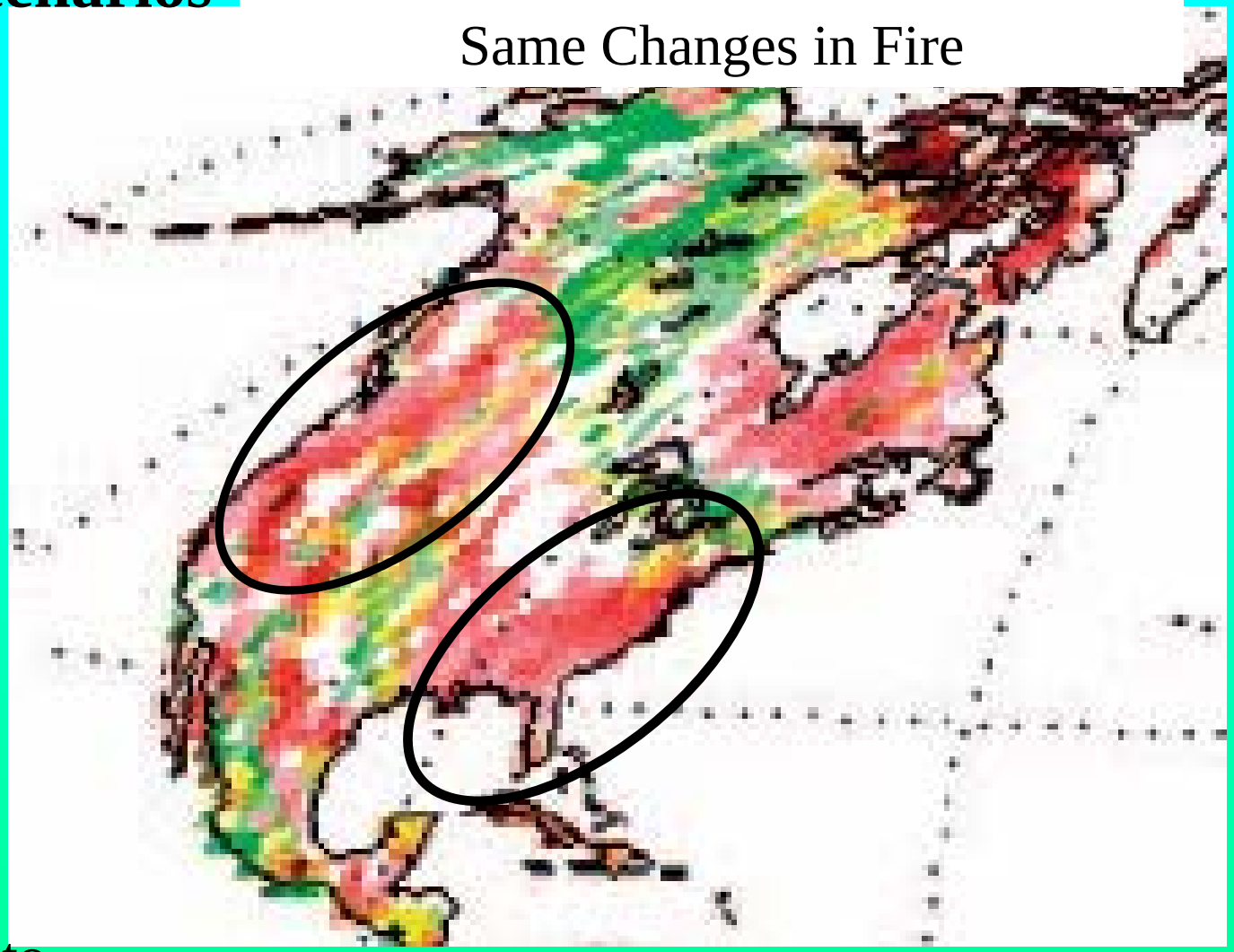

VINCERA SRES A
Area Burned (10^10 km2)
45
40
35
30
25
20
15
10
5
0
1895
1945
1995
2045
2095
C2a
H3a


VINCERA SRES B
Area Burned (10^10 km2)
45
40
35
30
25
20
15
10
5
0
1895
1945
1995
2045
2095
C2b
H3b

LPJ DGVM
16 Climate Scenarios

Different Ecological Model
Different Climate Scenarios
Same Changes in Fire

Red = + Fire
Green = - Fire



Changes relative to
Base Period 1961 – 1990

Scholze et al. 2006.
Proc. Natl. Acad. Sci.

Some Observations

1. Biomes are Physiognomic
   1. Definable boundaries
2. Associations are Floristic
   1. Changing Composition
3. Northern boundaries are often temperature-controlled
4. Southern boundaries are very complex
   1. Water balance vs. temperature constraints
   2. CO_2 physiology, Water-use-efficiency
   3. Possible shift to Asexual Reproduction with large spatial and temporal lags
5. Competition!!!
   1. Sexual vs. Asexual reproduction
6. Disturbance – Drought, Fire!!!???

Management Implications

(personal musings)

- **Management Goals** face an ***uncertain*** Future
  - The Future will NOT echo the Past
- Instead,… **Manage *Change***, *per se*
  - Desired *function* may supercede 'Desired future *condition*'
- Near-term strategies – Manage the ***Status Quo***
  - Forestall effects – ***increasing*** **management to maintain**
- Long-term strategies – **Improve resilience**
  - Density Management – water-limited carrying capacity
  - Enhanced diversity increases flexibility
- Fire, carbon and other **policies at cross-purposes** demanding creative management of change