Monitoring and Climate Change

Dave Cleland

Presentation Outline

National perspective on status and needs of climate change monitoring

Brief review of emerging monitoring programs

Short term approach to monitoring climate change-ecosystem-species interactions

Example of cross-scale interactions and need for multi-scaled analysis and monitoring

February 18, 2010

MEMORANDUM FOR HEADS OF FEDERAL DEPARTMENTS AND AGENCIES

FROM: NANCY H. SUTLEY, Chair, Council on Environmental Quality

SUBJECT: DRAFT NEPA GUIDANCE ON CONSIDERATION OF THE EFFECTS OF CLIMATE CHANGE AND GREENHOUSE GAS EMISSIONS

I. INTRODUCTION

The Council on Environmental Quality (CEQ) provides this draft guidance memorandum for public consideration and comment on the ways in which Federal agencies can improve their consideration of the effects of greenhouse gas (GHG) emissions[1] and climate change in their evaluation of proposals for Federal actions under the National Environmental Policy Act (NEPA), 42 U.S.C. §§ 4321 et seq. This draft guidance is intended to help explain how agencies of the Federal government should analyze the environmental effects of GHG emissions and climate change when they describe the environmental effects of a proposed agency action in accordance with Section 102 of NEPA and the CEQ Regulations for Implementing the Procedural Provisions of NEPA, 40 C.F.R. parts 1500-1508. This draft guidance

“For sources of the best scientific information available on the reasonably foreseeable climate change impacts, Federal agencies may summarize and incorporate by reference the Synthesis and Assessment Products of the U.S. Global Change Research Program “

http://www.globalchange.gov/publications/reports/scientific-assessments/saps),

The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

U.S. Climate Change Science Program
Synthesis and Assessment Product 4.3

May 2008

SAP 4.3 The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

"The report documents that

(1) numerous, substantial impacts of climate change on U.S. natural resources are already occurring,

(2) that these are likely to become exacerbated as warming progresses, and

(3) that existing monitoring systems are insufficient to address this issue."

SAP 4.3 The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

"Existing monitoring systems, while useful for many purposes, are not optimized for detecting the impacts of climate change on ecosystems.

The authors of this report also have very limited confidence in the ability of current observation and monitoring systems to provide the information needed to evaluate the effectiveness of actions that are taken to mitigate or adapt to climate change impacts."

SAP 4.3 The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

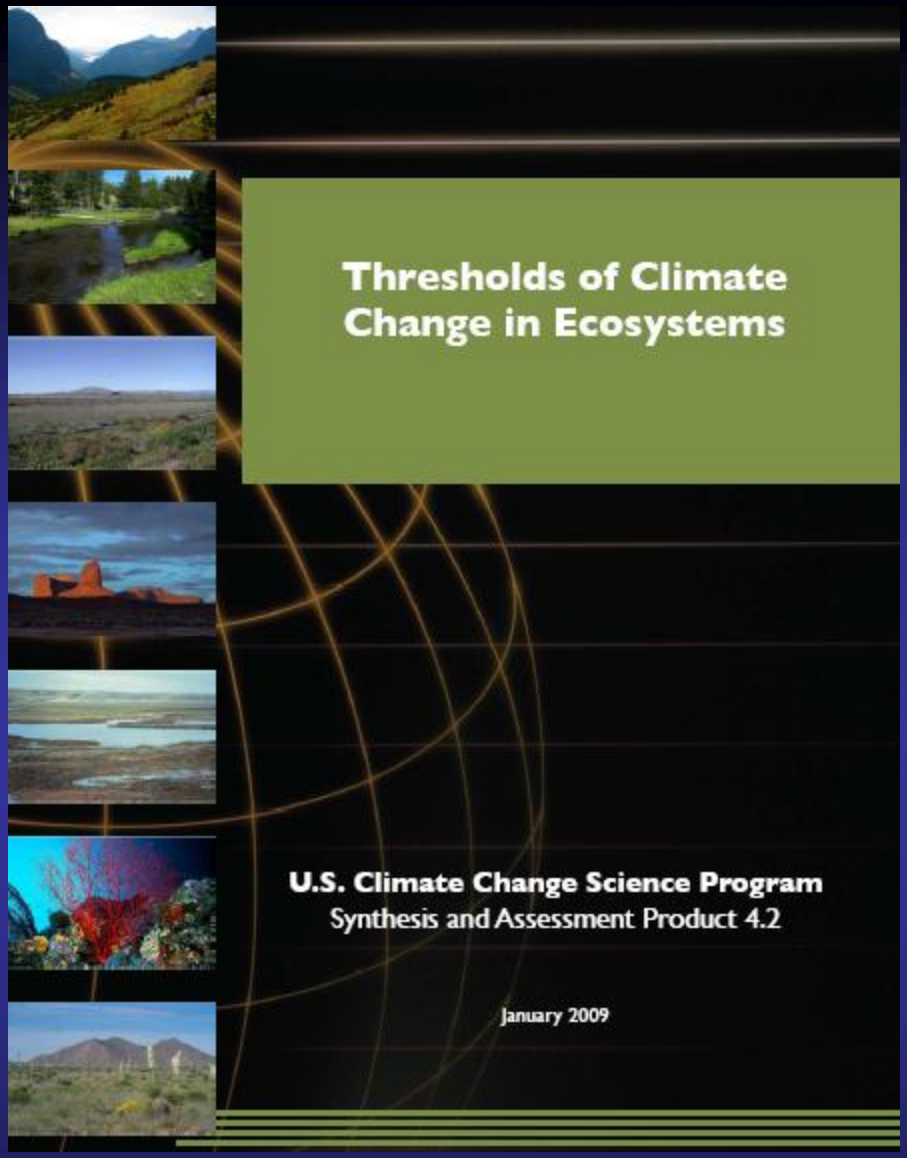
"There is no coordinated national network for monitoring changes in land resources associated with climate change, most disturbances, such as storms, insects, and diseases, and changes in land cover/land use.

No aspect of the current hydrologic observing system was designed specifically to detect climate change or its effects on water resources."

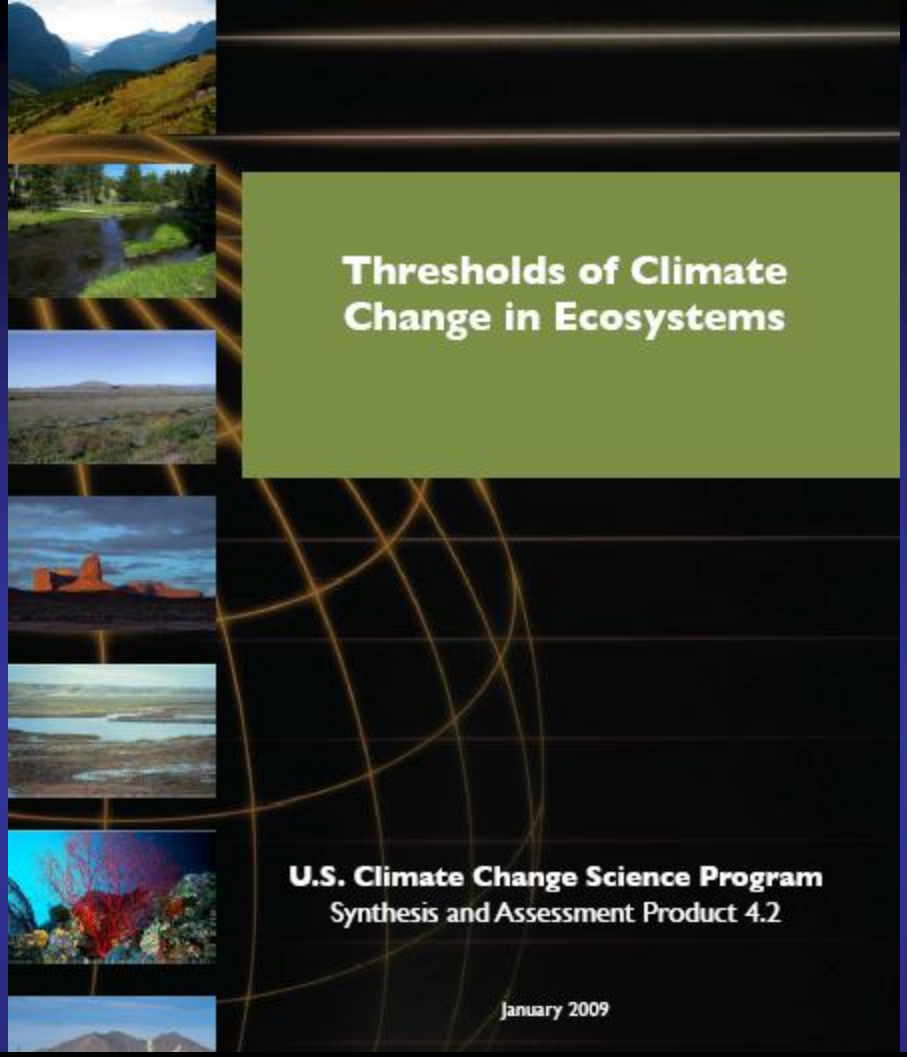
SAP 4.3 The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

"The monitoring systems that have been used to evaluate the relationship between changes in the physical climate system and biological diversity were likewise not designed with climate variability or change in mind.

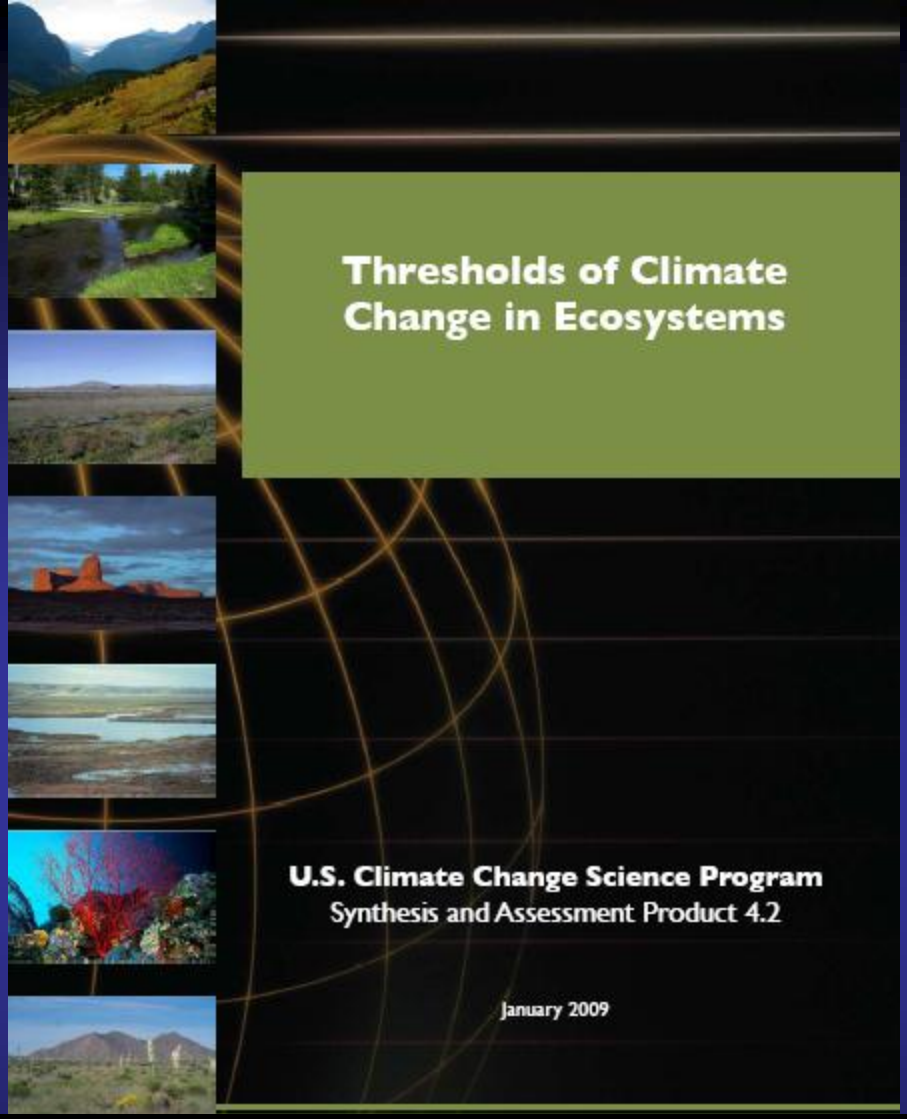
As a result, it is likely that only the largest and most visible consequences of climate change are being detected."



5.2.1 Role of Monitoring: “Because climate change effects are likely to interact with patterns and processes across spatial and temporal scales, it is clear the monitoring strategies must be integrated across scales.”



“First and foremost, the earth’s surface must be hierarchically stratified (for example, using the MLRA’s and Ecological Site Description System of the U.S.D.A. National Resources Conservation Service and U.S. Forest Service ecoregions), and conceptual or simulation models of possible impacts and feedbacks must be specified for each stratum (Herrick et al., 2006).



Second, simultaneous multiple-scale monitoring should be implemented at up to three spatial scales based on these scenarios and the recognition of pattern-and-process coupling developed in the models, which may feature cross-scale interactions.”

SAP 4.2 Thresholds of Climate Change in Ecosystems

Remote-sensing platforms can be used to monitor some **broad-scale** spatial patterns, including

- significant shifts in plant community composition;
- vegetation production;
- changes in plant mortality;
- bare-ground, soil, and water-surface temperatures;
- water clarity.

These platforms may also be used to detect rates of change in some contagious processes, such as the spread of readily observable invasive species.

SAP 4.2 Thresholds of Climate Change in Ecosystems

Mesoscale monitoring often requires widely distributed observations across a landscape (or ocean) acquired with rapid methodologies including sensor networks.

Such widely distributed monitoring is necessary in some situations because incipient changes may materialize in locations that are difficult to predict in.

SAP 4.2 Thresholds of Climate Change in Ecosystems

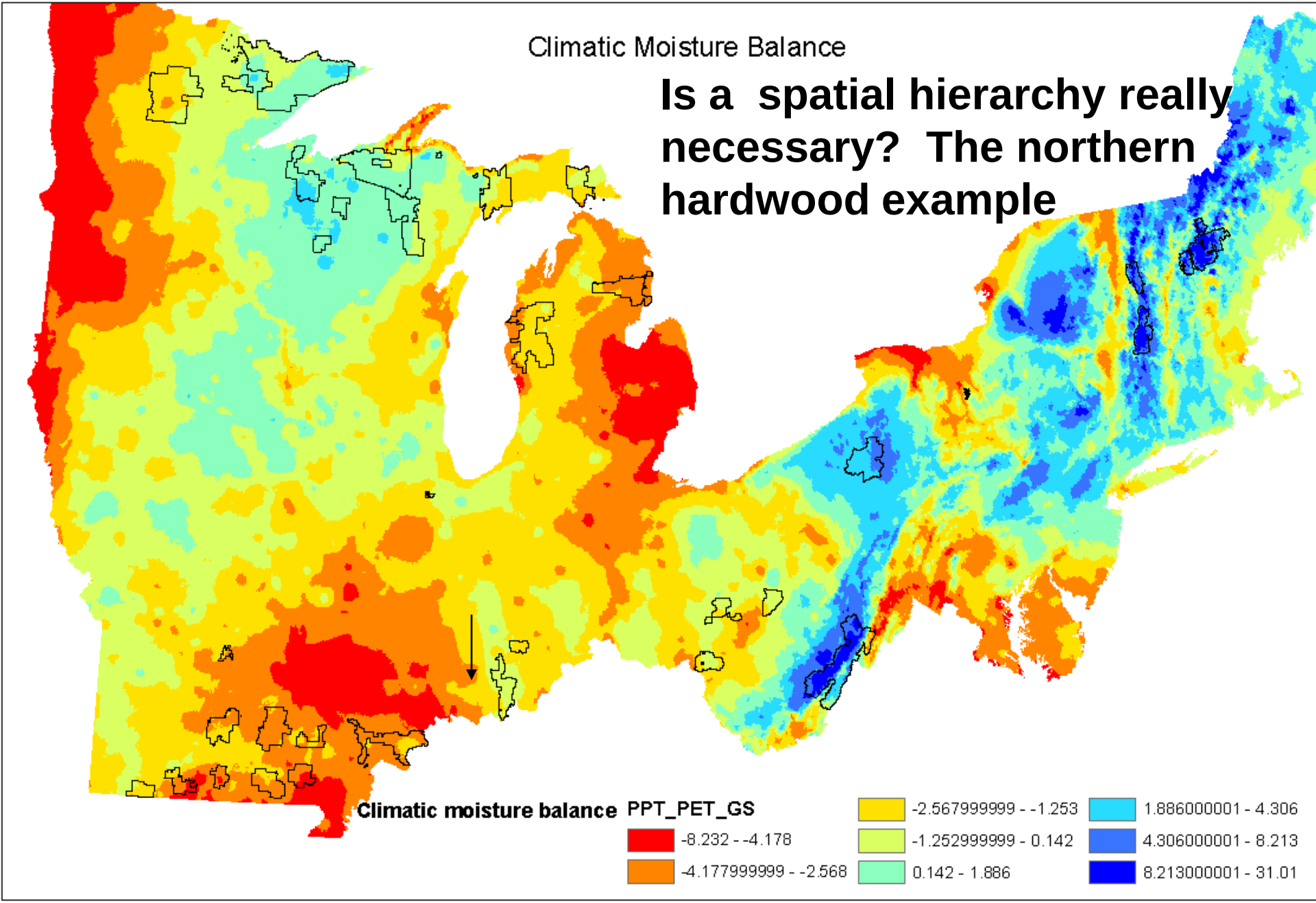
In other cases, however, more **targeted** monitoring is necessary to detect mesoscale discontinuities in smaller areas that are likely to first register broad-scale change, such as at ecotone boundaries (Neilson, 1993).

Finally, **patch-scale** monitoring can feature methodologies that focus on pattern-and-process linkages that scale up to produce systemwide threshold changes, such as when vegetation patches degrade and bare patches coalesce to result in desertification

SAP 4.2 Thresholds of Climate Change in Ecosystems

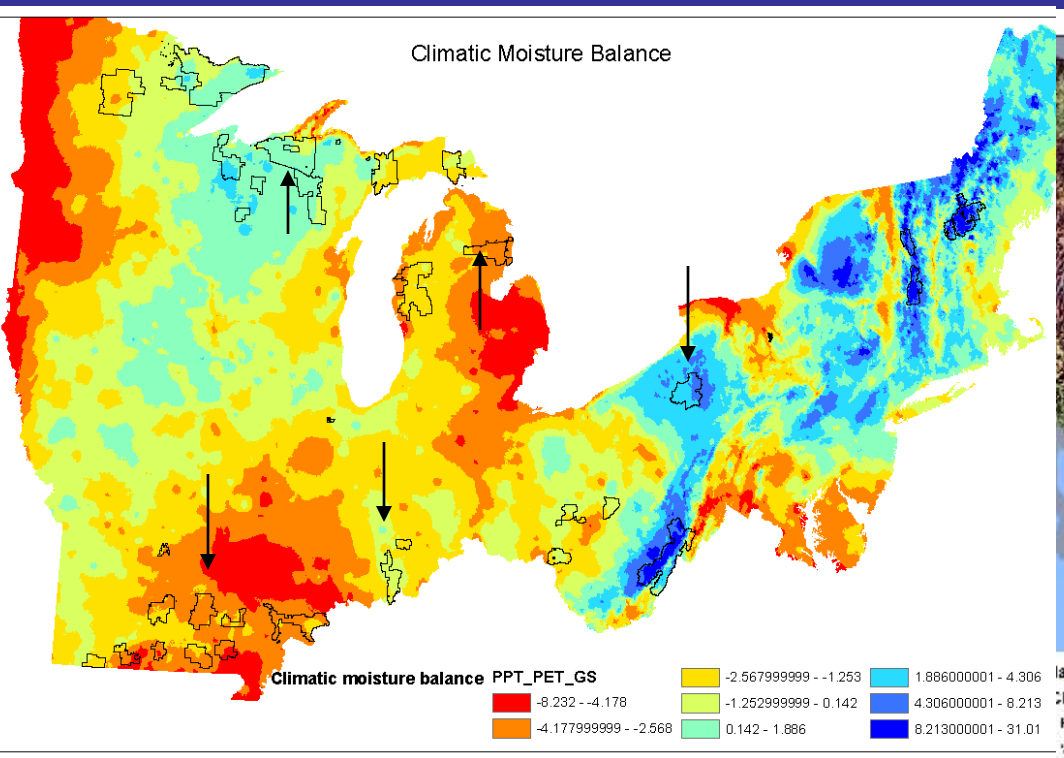
Cross-scale interaction, where change in a large-scale variable, such as climate, alters a local-scale driver of threshold change, such as fire, is a great challenge in assessing and preventing threshold change.

. . . the science of understanding and predicting ecological thresholds is still in its infancy, and our existing understanding of many aspects and potential impacts of these thresholds is qualitative at best.

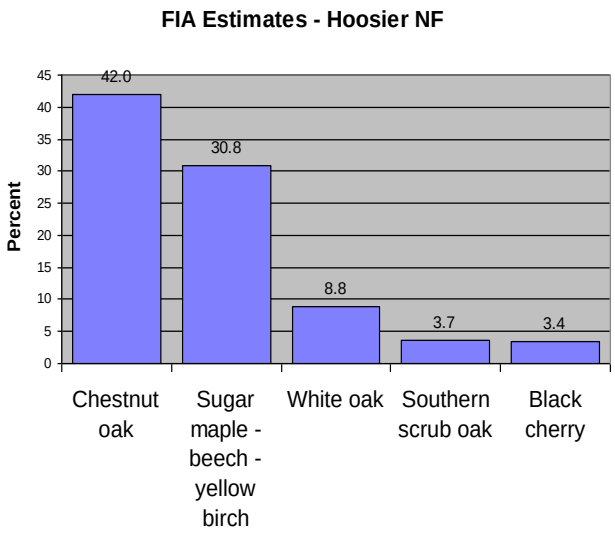


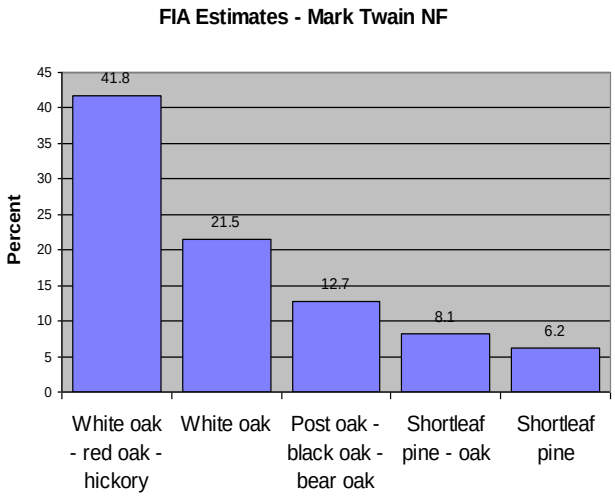
major criteria for an ecological hierarchy.

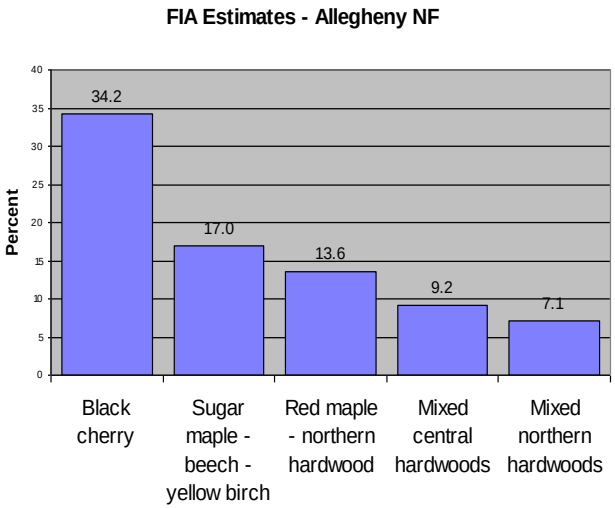
Moisture and nutrient demanding hardwoods occur in different climatic regimes, and on glaciated (young) and non-glaciated (350 million year old) surfaces.

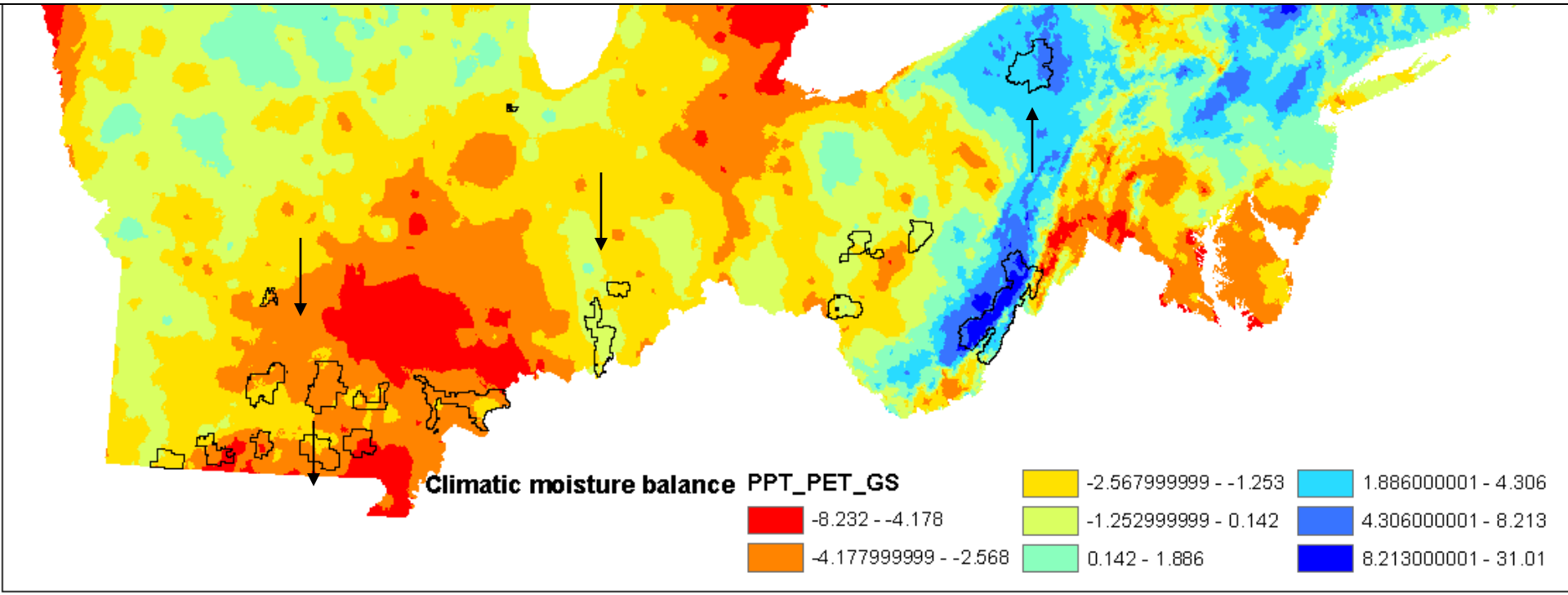


Glaciated vs. non-glaciated ecoregions, a major criteria for an ecological hierarchy.



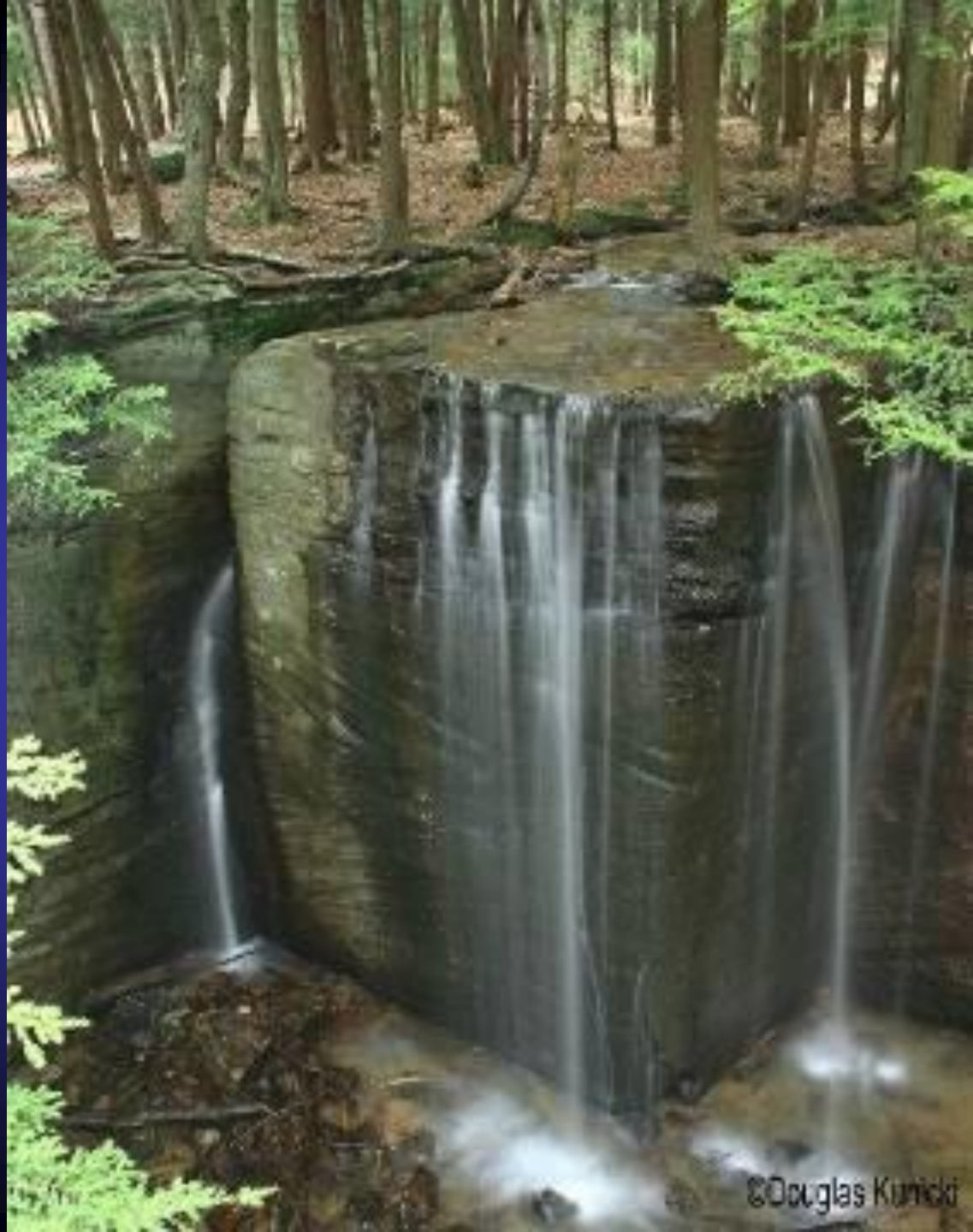




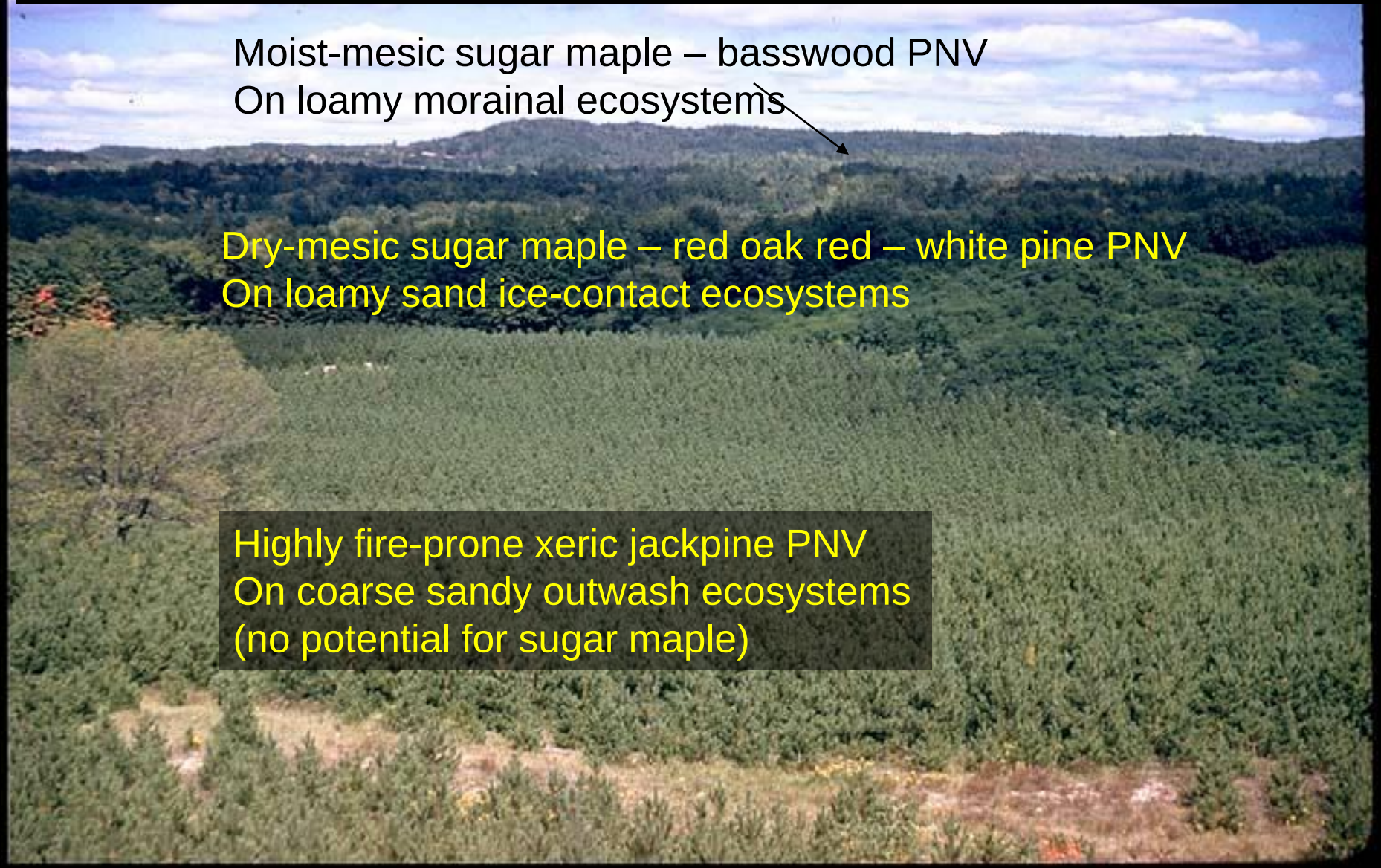


major criteria for an ecological hierarchy.

Hydroponics from the sky



Within a macroclimatic and physiographic zone, northern hardwoods may occur within landforms composed of sandy to loamy soils, with a 3-fold range in soil moisture holding capacities. Effects of changing climatic regimes will likely vary across these local ecosystems supporting the same forest type.



NRCS-BLM-FS Ecological Site Description Handbook Ecological Mapping Systems

Hierarchical Planning and Analysis Levels	National Hierarchical Framework of Ecological Units[1]	NRCS Soil Geography Hierarchy[3]
Continental and Region (Ecoregion)	Domain, Division, and Province (1:5,000,000-1:30,000,000)	Land Resource Region (LRR) (1:7,500,000), Climate zones
Subregion	Section (1:3,500,000) and Subsection (1:250,000)	Major Land Resource Area (MLRA) (1:3,500,000) Land Resource Unit (LRU)/Common Resource Area (CRA) (1:1,000,000) General Soil Map (1:250,000)
Landscape (watershed—5th unit of Hydrologic Unit Code)	Landtype Association (1:60,000)	Soil-geomorphic systems
Land Unit (subwatershed—6th unit of Hydrologic Unit Code), grazing allotment, farm/ranch)	Landtype (1:24,000)	Detailed Soil Map (1:24,000)
	Landtype Phase (1:12,000)	Soil Series (1:12,000)
Individual Sites	Sampling plot	Soil Pedon

From: **Draft Interagency Ecological Site Handbook**

SAP 4.2 Thresholds of Climate Change in Ecosystems

"Institutional changes that promote greater interdisciplinary and interagency scientific and information exchange are likely to increase adaptive capacity in general.

Such institutional changes would be especially helpful when implementing comprehensive monitoring to detect and document responses to thresholds in ecosystems.

Brief review of emerging monitoring programs

As part of the Five-Year Strategy the USGS has proposed the following priority science activities:

- **Use and create high-resolution climate modeling information and derivative products for forecasting ecological and population response at national, regional, and local levels**

- **Develop standardized approaches to modeling and monitoring techniques, to facilitate the linkage of monitoring efforts to climate and ecological/biological response models**

Brief review of emerging monitoring programs

Some of the products and services that LCCs produce include:

Integrated data for seamless spatial modeling of species and habitats, within and across geographic area boundaries;

Monitoring and assessments to predict the ability of the landscape to support and sustain priority fish and wildlife populations;

Development of a Methodology for National Assessment of Ecological Carbon Stocks, Carbon Sequestration, and Greenhouse Gas Fluxes

Edited by Zhiliang Zhu

Authors: Anne Wein, Benjamin Sleeter, Bradley Reed, Brian Bergamaschi, David Clow, Dennis Dye, Jinxun Liu, Matt Reeves, Matt Rollins, Richard Bernknopf, Rob Striegl, Robert Gleason, Sarah Stackpoole, Shuguang Liu, Stephen Faulkner, Stephen Prisley, Stephen Stehman, Terry Sohl, Todd Hawbaker, William Forney, and Zhiliang Zhu

Open-File Report 2010–XXXX

U.S. Department of the Interior
U.S. Geological Survey

Figure 3.1. Level II ecoregions by the U.S. Environmental Protection Agency. This ecoregional framework will be used to define ecosystems as required by EISA legislation, and will be used as assessment units for purposes of planning, prioritization, and reporting.

The use of EPA Level II ecoregions is an appropriate scale for assessment because results will be analyzed (including validation and uncertainty analysis) and reported for the ecoregion as a whole.

LandCarbon

General category	Product name	Data type	Unit	Temporal	Spatial
Carbon stock, flux, and sequestration rate by ecosystems and scenarios	Net primary productivity (NPP)	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Net ecosystem productivity (NEP)	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Net biome productivity (NBP)	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Net ecosystem carbon balance (NECB)	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Soil carbon stock	Map series and statistics	tC/ha, kgC/m^2	Annual for 2001–2050	≥ 250 m
	Fire induced carbon emission	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Tree biomass removal	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Grain yields	Map series and statistics	tC/ha/yr, kgC/m^2/yr	Annual for 2001–2050	≥ 250 m
	Carbon stock/flux trends	Statistics	TgC/yr, TgC	Annual for 2001–2050	Assessment unit
	C accumulation in lake/reservoir sediments	Statistics	tC	Annual for 2001–2050	Assessment unit
	C accumulation in coastal oceans	Statistics	tC	Annual for 2001–2050	Assessment unit

LandCarbon

General category	Product name	Data type	Unit	Temporal	Spatial
GHG flux by ecosystems and scenarios	CH_4 efflux	Map series and statistics	kgC/ha/yr, $gC/m^2/yr$	Annual for 2001–2050	≥ 250 m
	N_2O efflux	Map series and statistics	kgN/ha/yr, $gN/m^2/yr$	Annual for 2001–2050	≥ 250 m
	Methane flux from lakes, reservoirs	Statistics	tCH_4/kM^2	Annual for 2001–2050	Assessment unit
	Delivery of organic carbon by rivers to coastal areas	Statistics	$tDOC/kM^2$	Monthly and annual	Assessment unit
	Delivery of inorganic carbon by rivers to coastal areas	Statistics	$tDOC/kM^2$	Monthly and annual	Assessment unit
	CH_4 and N_2O flux from estuaries and coastal waters	Statistics	tCO_{2e}	Monthly and annual	Assessment unit
Data and information products informing mitigation	Land suitability for REDD by NPP, fire disturbance categories, and scenario storylines	Map series and statistics	Thematic classes	Annualized average	≥ 250 m, and by assessment unit
	Future soil erosion and surface	Map series and	Thematic	Annualized	≥ 250 m, and

LandCarbon

“Downscaling of the GCM datasets for the individual IPCC scenarios is a necessary step to provide the spatial and temporal resolution needed for the national assessment.

The resulting future climate projection data will include mean maximum temperature, mean minimum temperature, and total precipitation with 1 km spatial resolution at monthly time steps (over a 50 year period)

Mechanisms and methods for effectively monitoring climate change are developing and will be used in long-term national strategies.

In the short-term, the Forest Service should cooperate in interagency endeavors while undertaking three forms of monitoring designed to address specific objectives.

These interrelated programs include:

- targeted monitoring,
- enhancements of current systematic monitoring programs, and
- effectiveness monitoring

Targeted monitoring is limited to assessing particular areas based on specific objectives, and uses measurements or indicators related to that objective.

It consists of obtaining quantitative or qualitative data in areas where a given species, ecosystem, or process has been identified as potentially vulnerable and tracking change over time.

Targeted monitoring is essentially about asking the right question in the right place.

One goal is to enable effective early detection of adverse climate change effects and facilitates rapid responses for adaptation or restoration needs.

Examples include monitoring of weather related changes in hydrology in watersheds, or outbreaks of insects and diseases in areas that have been identified as being vulnerable to infestation due to climate change.

Systematic monitoring establishes monitoring locations across large areas, with monitoring stations often located in an established grid of various resolutions.

An example of systematic monitoring is the Forest Inventory and Analysis (FIA) program which utilizes a systematic plot based system that has extensive coverage and utilizes standard measures within forestlands of the United States.

Systematic monitoring

The US Geological Survey (USGS) National Stream Gauging Network, USGS National Atmospheric Deposition Program's National Trends Network, Natural Resources Conservation Service's Natural Resource Inventory, and the Environmental Protection Agency's Ambient Air Quality Monitoring Program are additional examples of systematic monitoring programs.

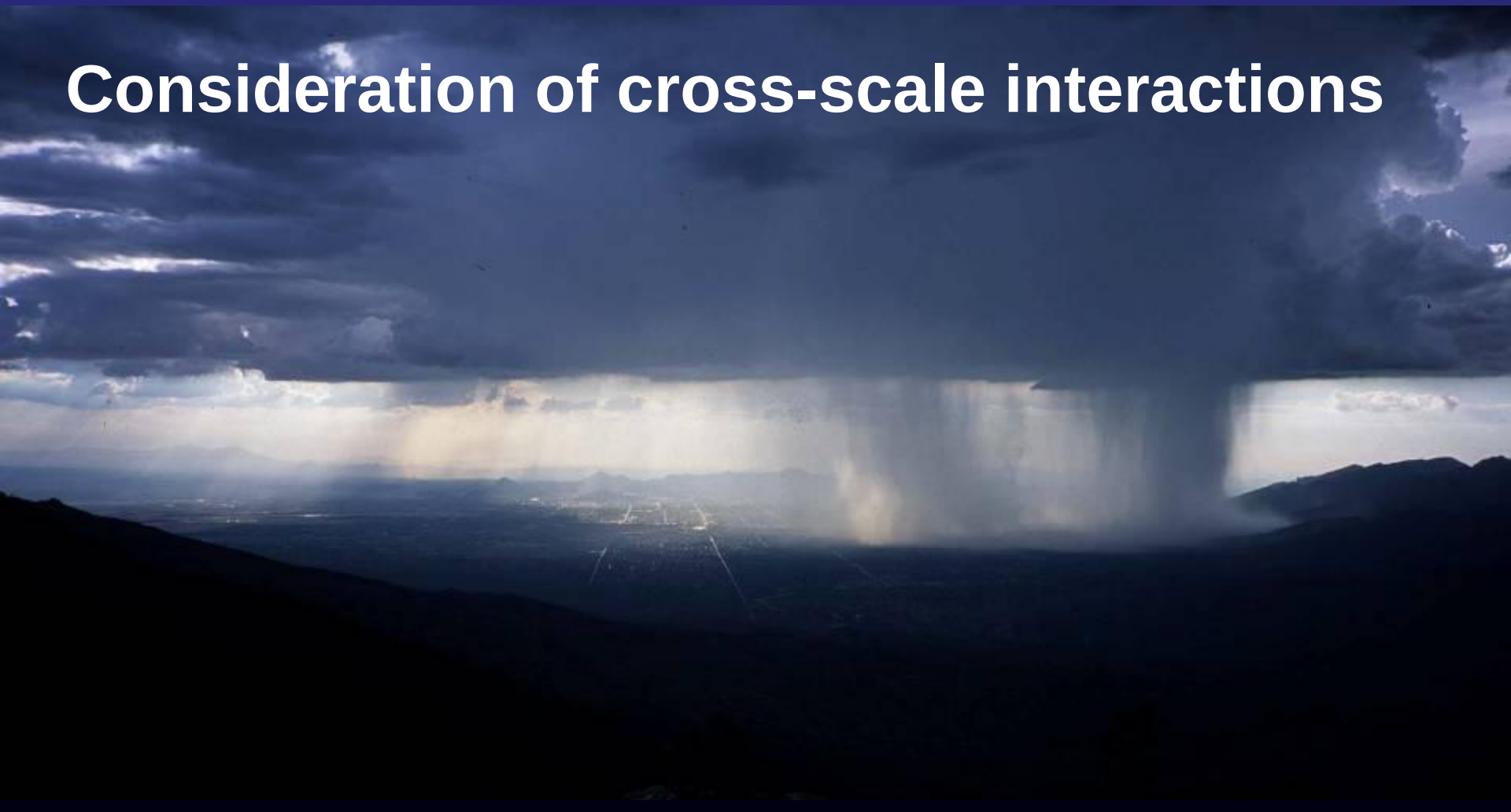
Effectiveness monitoring is focused on evaluating resilience and adaptation outcomes from on-the-ground activities.

The aim is to determine the effectiveness of management actions taken to reduce stressors, enhance resilience, or conserve species.

Example of the need for:

Multi-scaled analysis and monitoring, and

Consideration of cross-scale interactions



SAP 4.3 The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States

Understanding climate impacts requires monitoring both many aspects of climate and a wide range of biological and physical responses.

Putting climate change impacts in the context of multiple stresses and forecasting future services requires an integrated analysis.

Adequately distinguishing climate change influences is aided by the collection of data at certain spatial and temporal resolutions, as well as supporting ground truth measurements

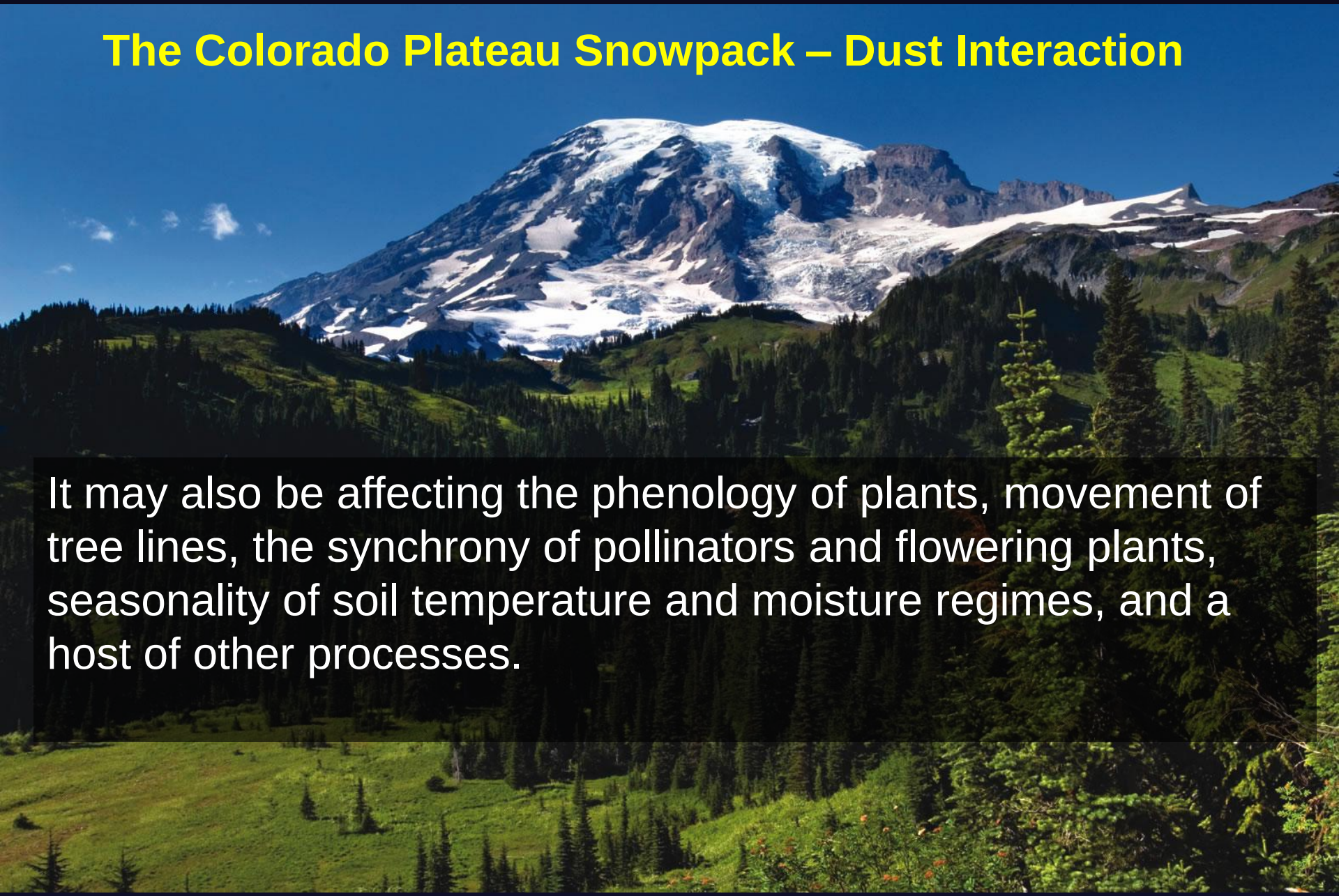
The Colorado Plateau Snowpack – Dust Interaction

Dust originating from larger surrounding shrubland and grassland dominated landscapes is being deposited within alpine zones in Colorado.

This has caused snowpacks to melt 35 – 45 days earlier than normal, affecting hydrologic function, urban water supply, and recreation (skiing).

(IPPC)

The Colorado Plateau Snowpack – Dust Interaction



It may also be affecting the phenology of plants, movement of tree lines, the synchrony of pollinators and flowering plants, seasonality of soil temperature and moisture regimes, and a host of other processes.

(IPPC)

The Colorado Plateau Snowpack – Dust Interaction

This raises several questions related to:

- Causal relationships
- Scale of observation for monitoring and detection
- Interactions which may be occurring across scales

Causal Relationships

Dust is originating from drier, lower lying areas where destablization of soil crusts, loss of vegetative cover, and high winds facilitate higher elevation deposition.

The effect of regional sources of dust vary at a landscape scale, with altered albedo in alpine areas differing from lower elevation forests areas.

Causal Relationships

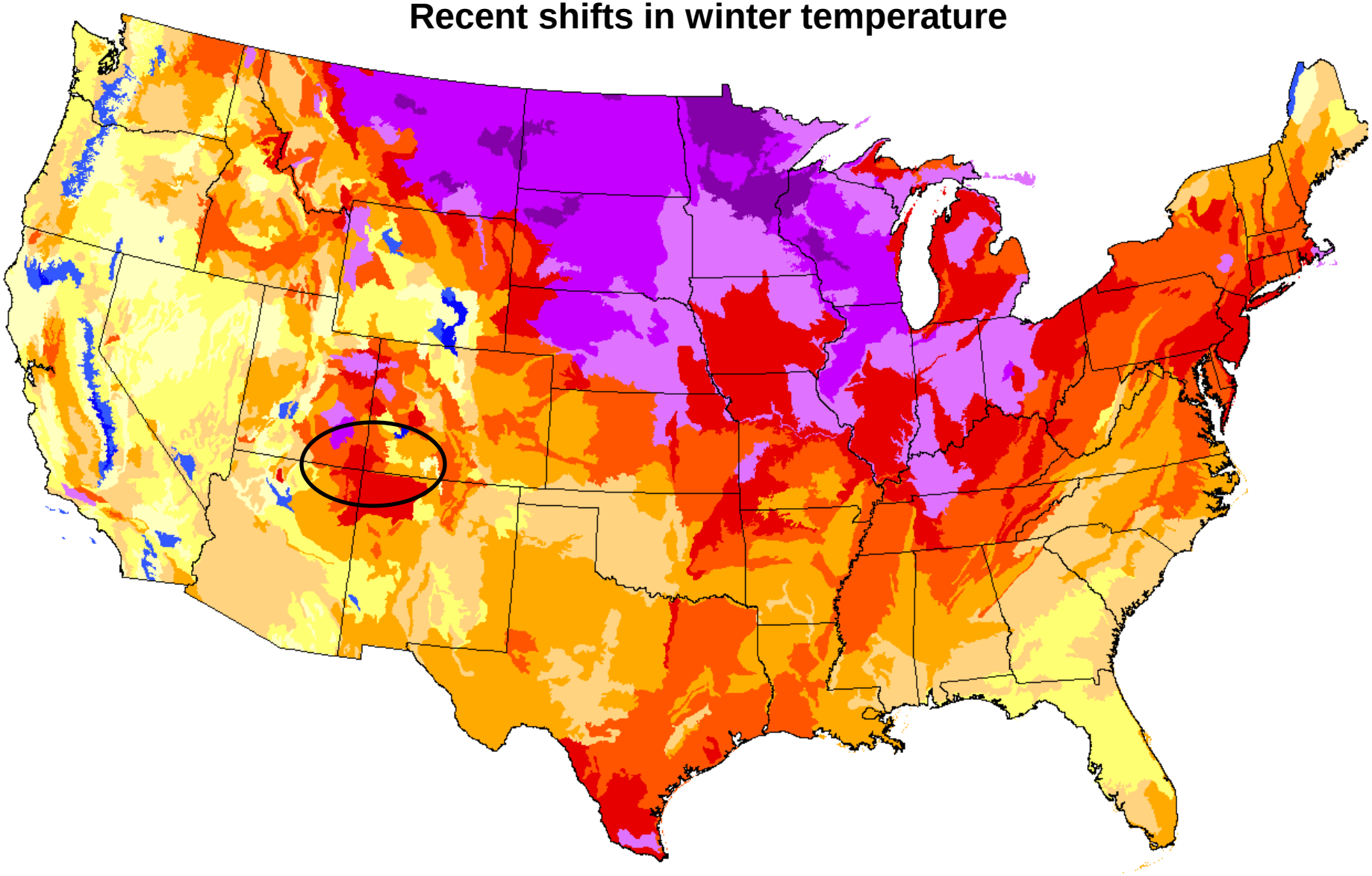
The questions are, is desertification taking place because of:

(i) recent drought or climate change?
(ii) anthropogenic forcing via land-use?
(iii) a natural range of variability phenomenon?
(iv) interactions of the above?

Recent shifts in climatic regimes

Comparison of components of climatic regimes of the 1961-1990 versus 1991-2007 periods

Recent shifts in winter temperature

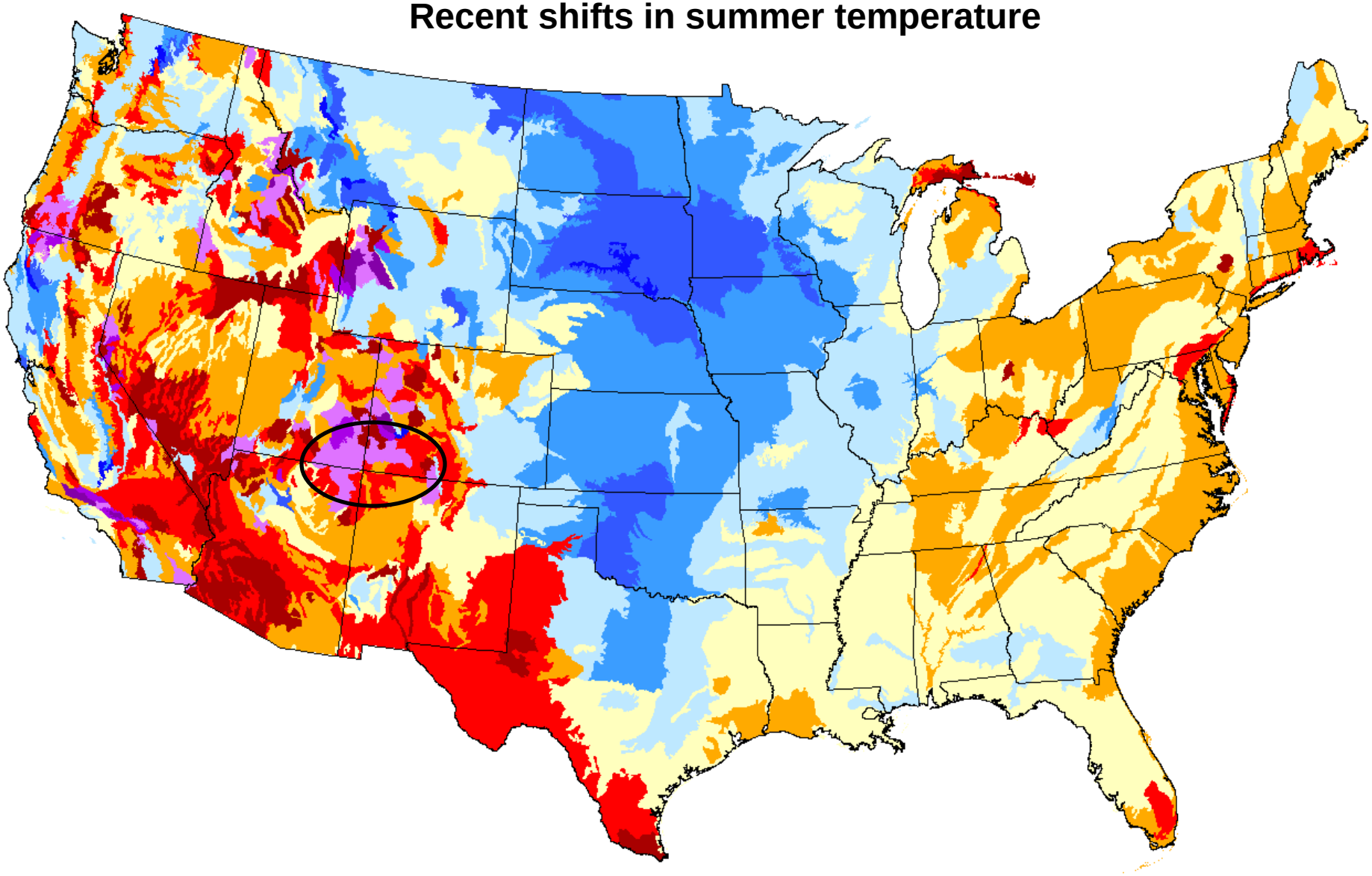


Change_Winter_Temp

Subsections **WN_CNG_T**

	0.2 - 0.5	1.3 - 1.6	2.5 - 2.8
-0.9 - -0.4	0.6 - 0.9	1.7 - 2.0	2.9 - 3.3
-0.3 - 0.1	1.0 - 1.2	2.1 - 2.4	3.4 - 4.2

Recent shifts in summer temperature

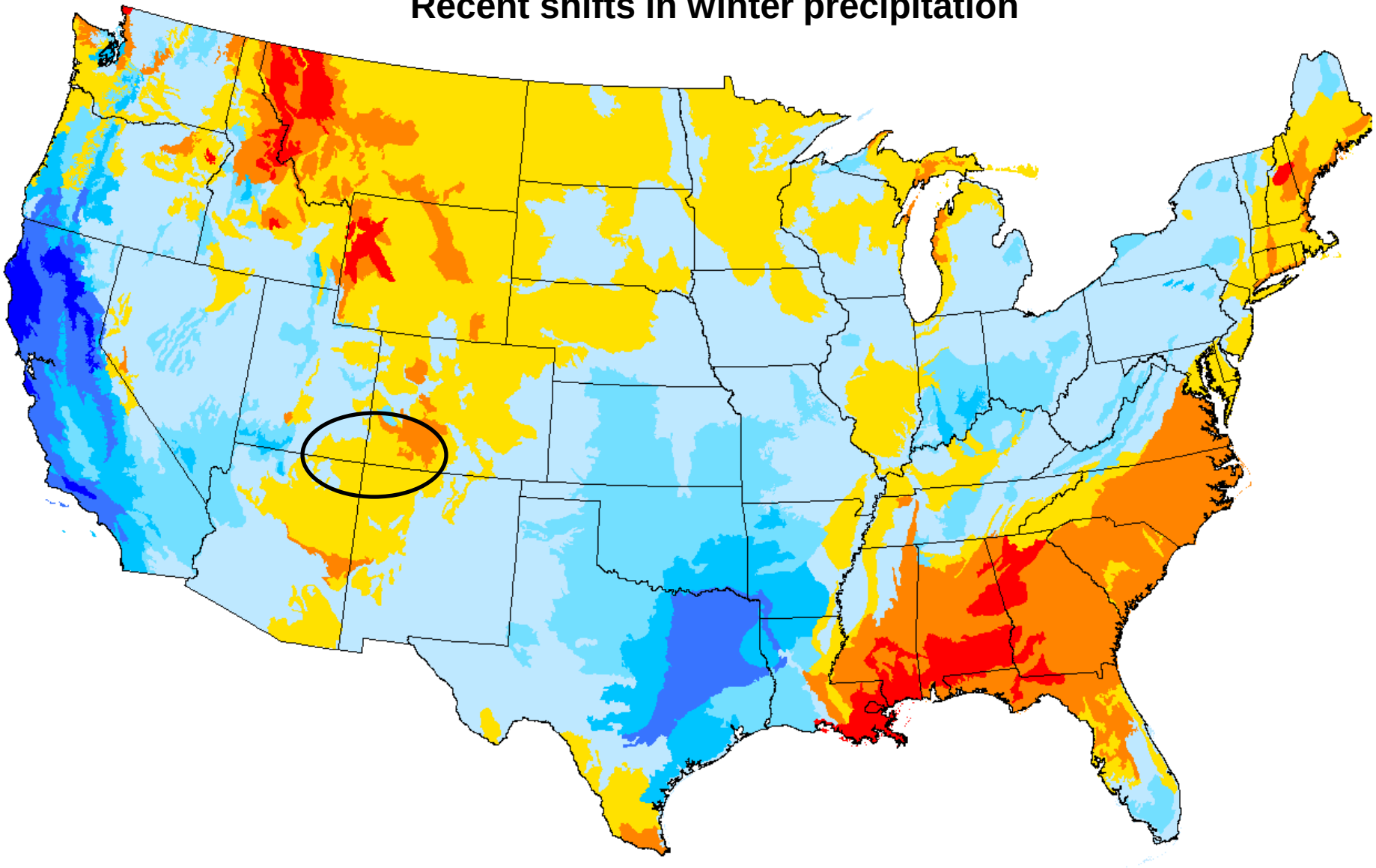


Change_Summer_Temp

Subsections SU_CNG_T

-1.5 - -1.1	-0.5 - -0.2	0.6 - 0.8	1.5 - 1.9
-1.0 - -0.6	-0.1 - 0.2	0.9 - 1.1	2.0 - 2.5
	0.3 - 0.5	1.2 - 1.4	2.6 - 3.3

Recent shifts in winter precipitation

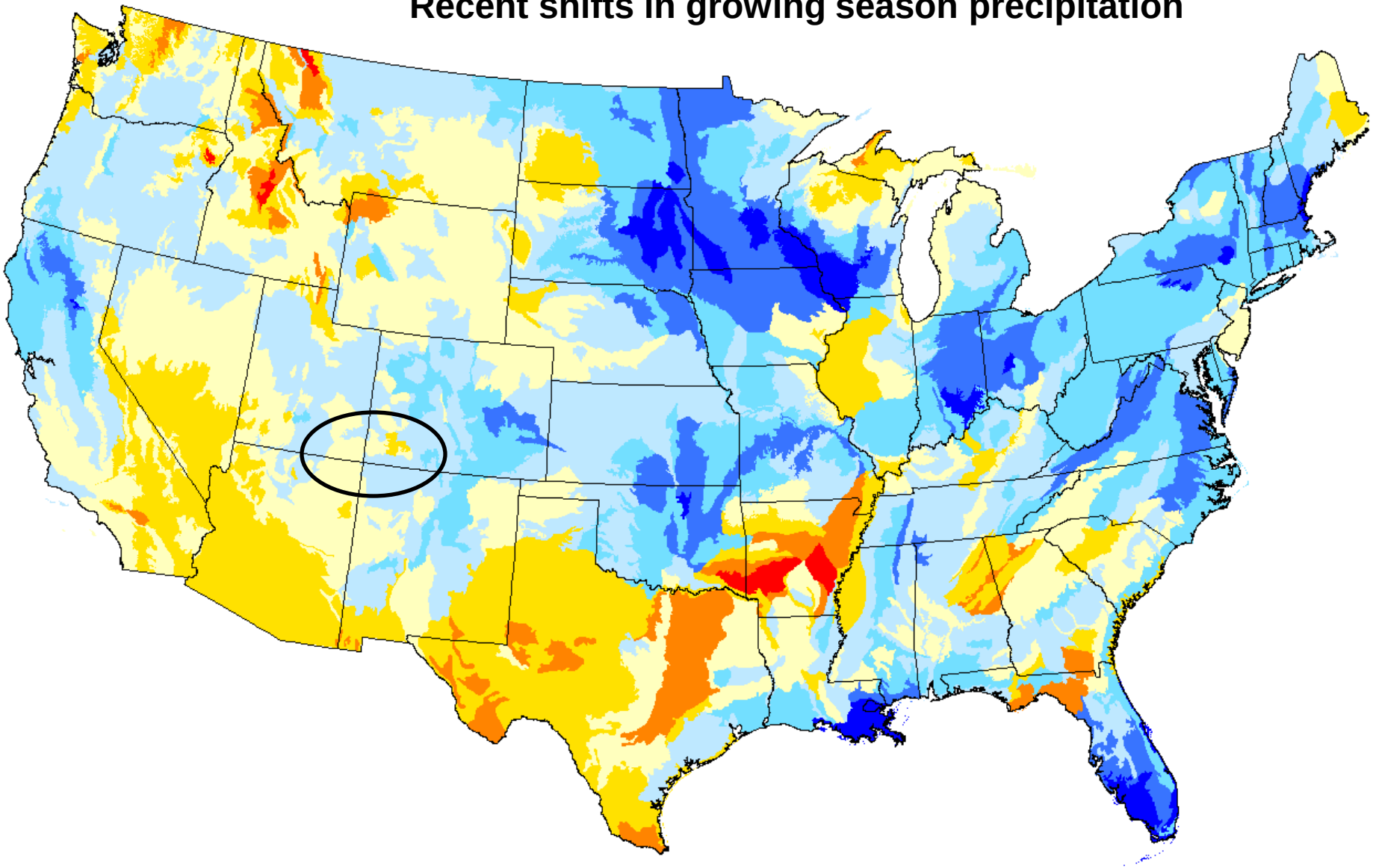


Change winter precipitation

Subsections WN_CNG_P

-1.5 - -0.5	0.1 - 0.5	1.1 - 2.0	5.3 - 7.9	
-4.9 - -1.6	-0.4 - 0.0	0.6 - 1.0	2.1 - 5.2	

Recent shifts in growing season precipitation

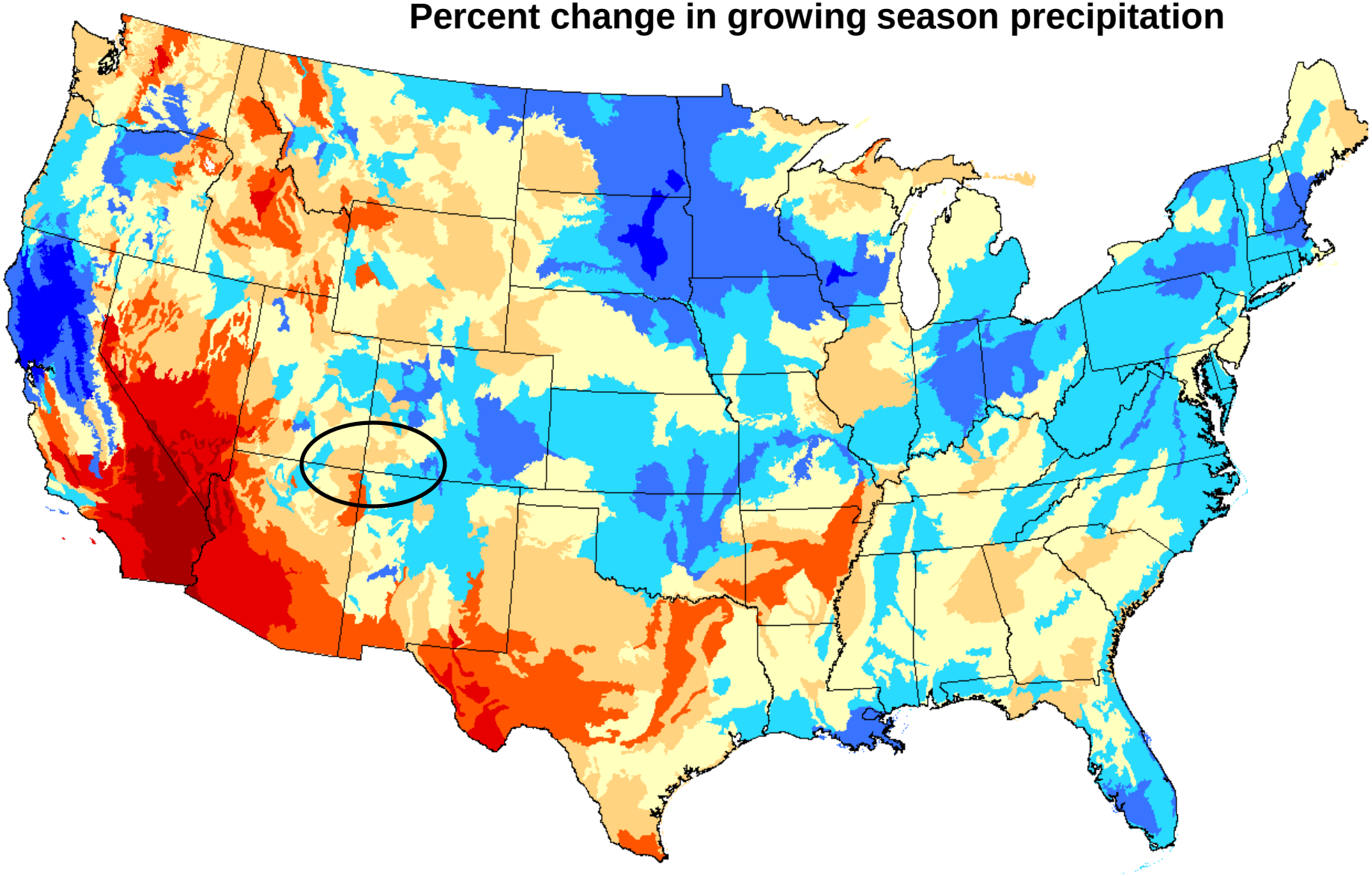


Change growing season precipitation

Subsections GS_CNG_P

-2.7 - -1.3	-0.5 - -0.1	0.6 - 1.2	2.2 - 4.6	
-4.8 - -2.8	-1.2 - -0.6	0.0 - 0.5	1.3 - 2.1	

Percent change in growing season precipitation

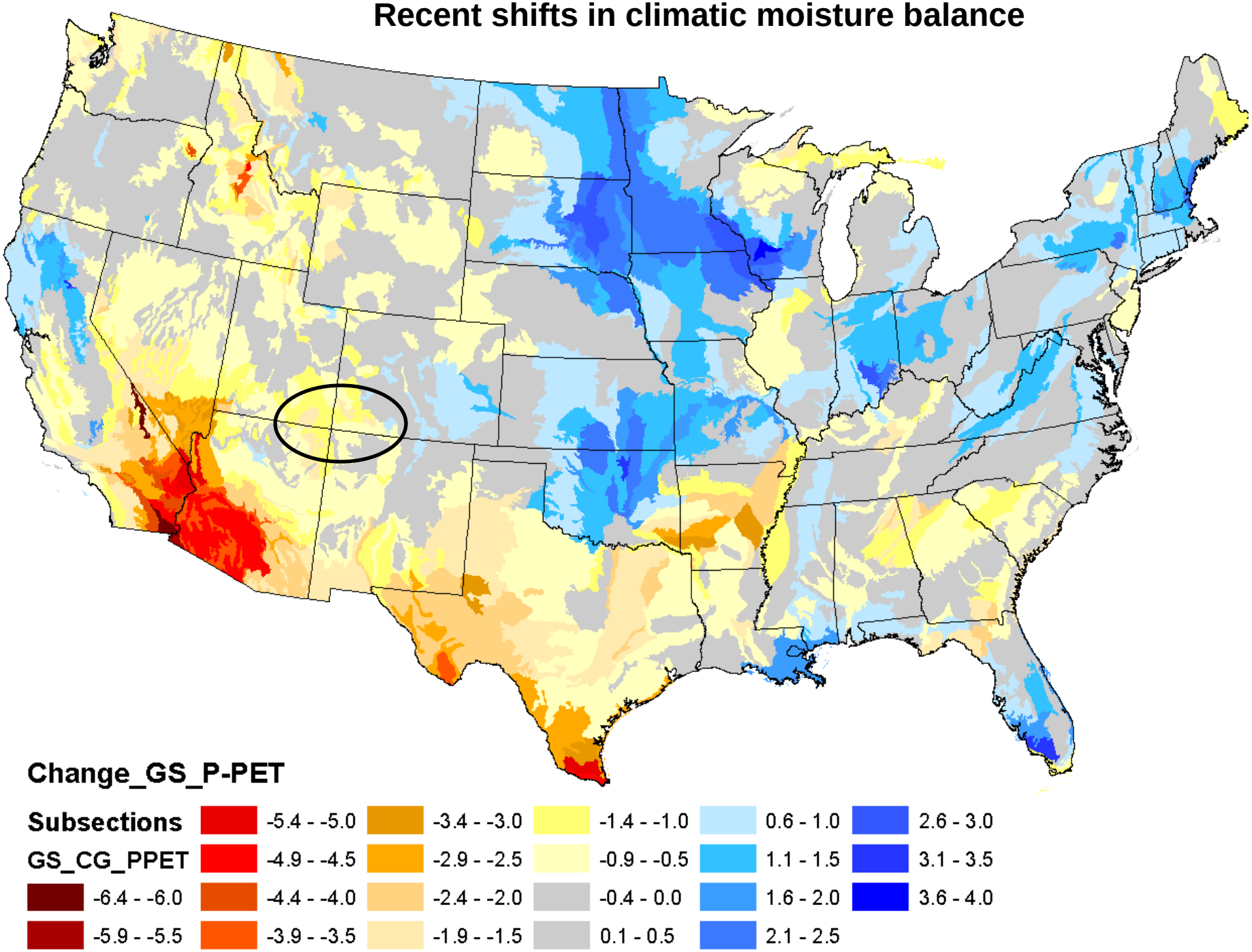


Percent Change Growing Season Precipitation

Subsections GS_CG_P_PT

- -45.8 - -26.4
- -26.3 - -15.0
- -14.9 - -7.0
- -6.9 - -2.1
- -2.0 - 1.8
- 1.9 - 6.4
- 6.5 - 13.8
- 13.9 - 30.2

Recent shifts in climatic moisture balance



Scale of observation for monitoring and detection

Macro-scale – monitoring climate change

Meso-scale – monitoring land use, BMP's

Landscape scale – monitoring snow, dust, vegetation within Alpine zones

Local scale – monitoring response of various species, hydrology, other phenomena of interest

Interactions that may be occurring across scales

It is possible that climate change is the driving force

It is possible that land use is the driving force

It is possible that long-term natural variability in climate is the driving force

Interactions that may be occurring across scales

It is also possible that implementation of best management practices has been effective in reducing effects of grazing, recreation, or other anthropogenic impacts.

And that the rate of desertification due to climate change has been slowed through these practices.

Interactions that may be occurring across scales

However, monitoring meso-scale trends in land use in the absence of macro-scale monitoring might lead to conclusions that BMP's are ineffective, that opportunity costs of limiting resource use are being incurred, and BMP's should be adjusted accordingly.

Interactions that may be occurring across scales

Similarly, assessing landscape level conditions and processes, and implementing adaptation strategies at the landscape scale may not be effective without implementing adaptation strategies at the meso-scale.

Cross-scale interactions

The bottom line is broader scale stressors may override finer-scale conditions and actions that are effective at reducing adverse cumulative effects.

And finer-scale processes (destabilized soil crusts, coalescence of open patches) may propagate upward through the system to alter broader scale patterns (dust production, snowpack melt).

Multi-scaled Monitoring

Designing monitoring programs that employ concepts of hierarchical structures is therefore needed for assessing climate change as well as other stressors.

Developing quantitative methods for understanding and predicting cross-scale interactions is also necessary.