Linkages and Feedbacks Between Climate Change and Plant Invasions: Implications for Management

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4-County CWMA Pull Together

February 24, 2016

Oregon Zoo, Portland, Oregon

Climate Change

- **Climate change is everywhere!**
- **President Obama: No challenge poses a greater threat to future generations than climate change (2015 State of the Union speech).**
- **Widespread SCIENTIFIC consensus that human activities are causing climate change….**

USA TODAY

NEWS SPORTS LIFE MONEY TECH TRAVEL OPINION 61° CROSSWORDS ELECTIONS 2016

2016 kicks off with warmest January

Doyle Rice, USA TODAY 9:38 a.m. EST February 18, 2016

931

Erik Wemple

For the record: A student asked the best question on climate change in all the presidential debates

52 Save for Later Reading List

Why Science Teachers Are Struggling With Climate Change

Updated February 19, 2016 · 7:48 PM ET
Published February 19, 2016 · 9:51 AM ET

CORY TURNER

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All Things Considered 3:33
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Pentagon Signals Security Risks of Climate Change

By CORAL DAVENPORT OCT. 13, 2014

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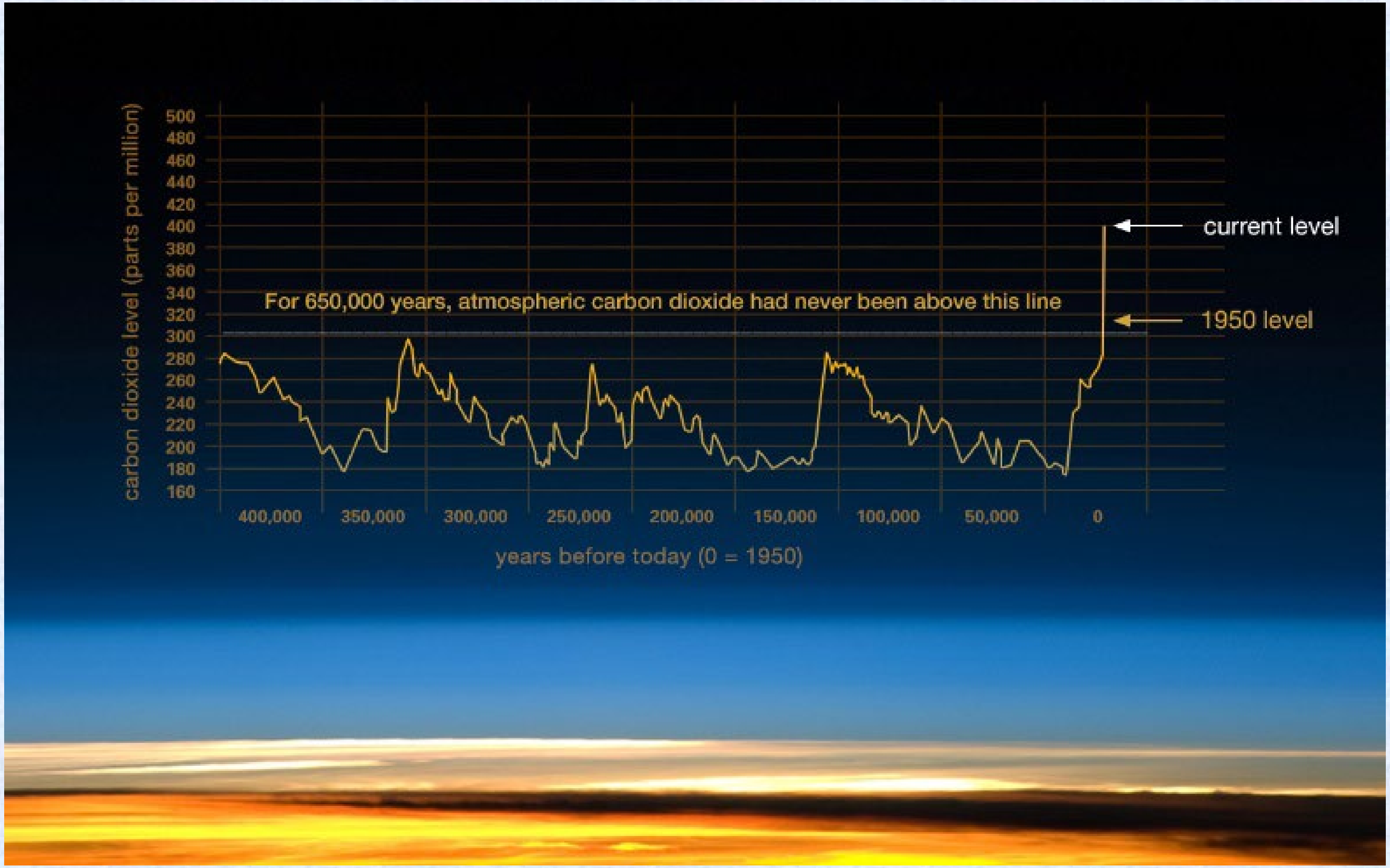
WASHINGTON — The Pentagon on Monday released a report asserting decisively that climate change poses an immediate threat to national security, with increased risks from terrorism, infectious disease, global poverty and food shortages. It also predicted rising demand for military disaster responses as extreme weather creates more global humanitarian crises.

The report lays out a road map to show how the military will adapt to rising sea levels, more violent storms and widespread droughts. The Defense Department will begin by integrating plans for climate change risks across all of its operations, from war games and strategic military planning situations to a rethinking of the movement of supplies.

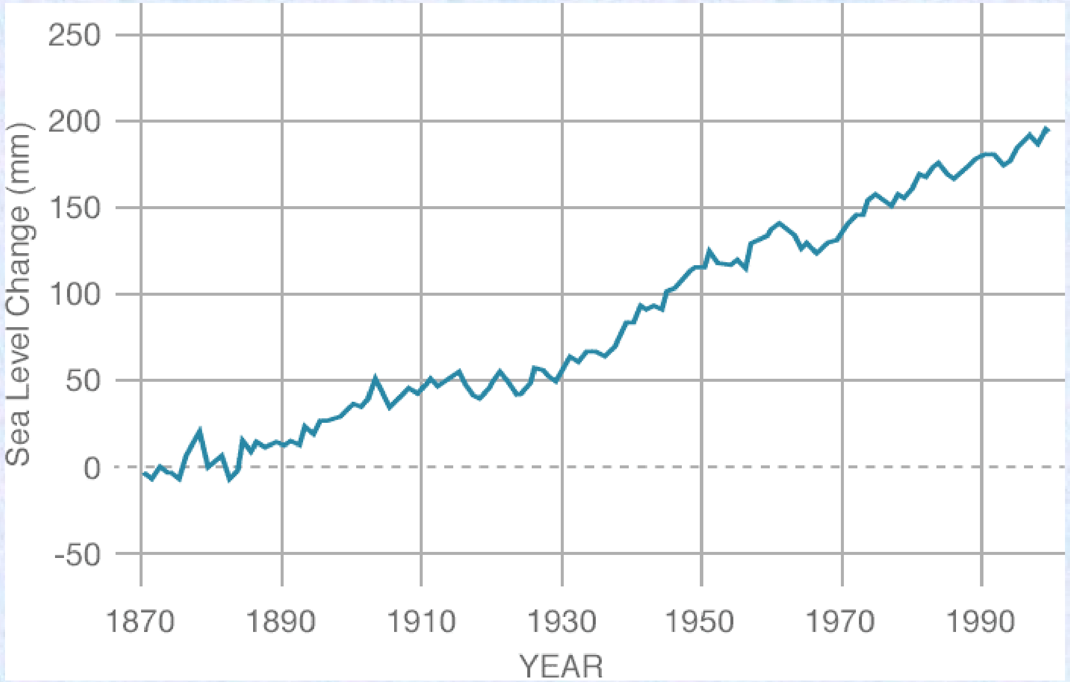
Climate Change - Causes



http://climate.nasa.gov/evidence/

Climate Change – Observed Trends

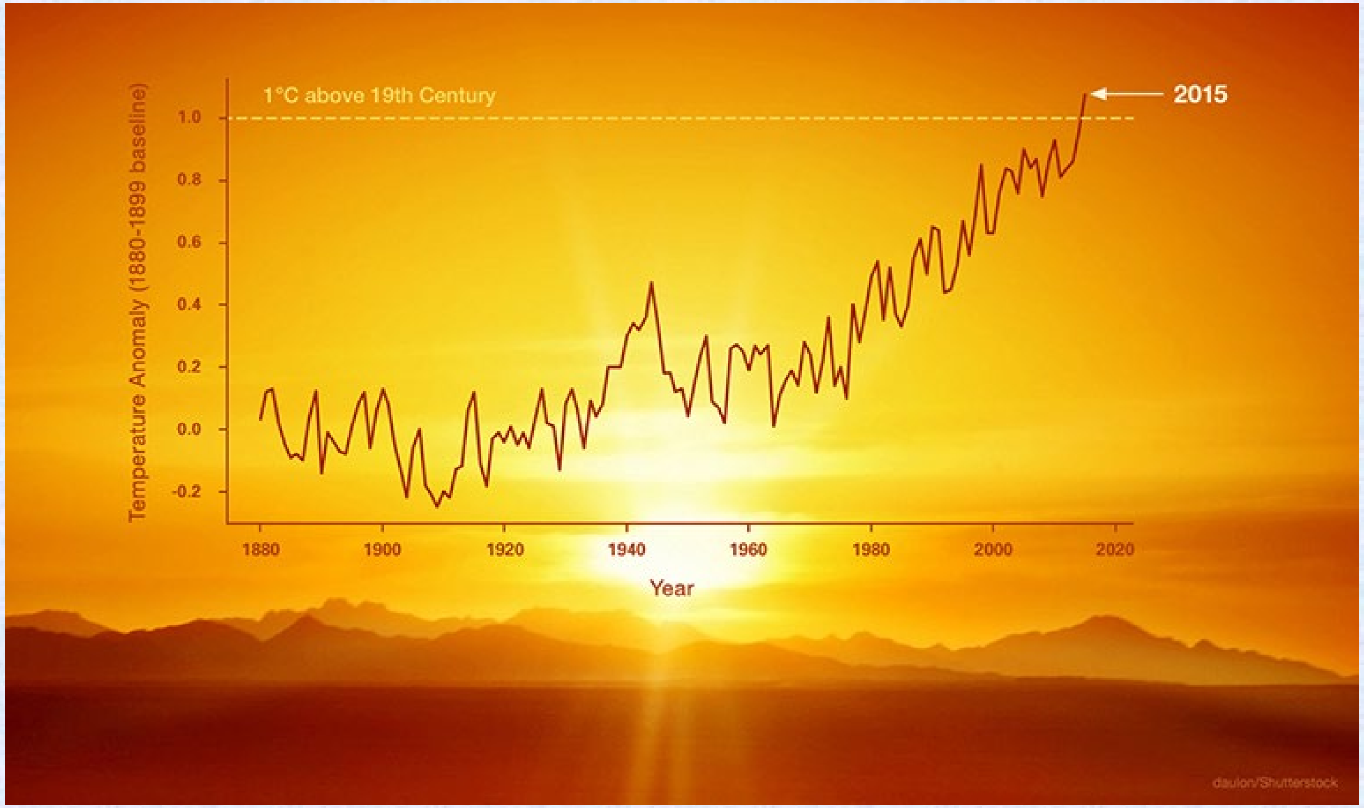
- Evidence for climate change:
  - ➢ Sea level rise
  - ➢ Warming oceans
  - ➢ Shrinking ice sheets
  - ➢ Declining arctic sea ice
  - ➢ Earlier spring
  - ➢ Earlier snowmelt
  - ➢ Reduced snowpack
  - ➢ Changes in fire regimes
  - ➢ Global temperature rise



http://climate.nasa.gov/vital-signs/sea-level/

Climate Change – Global Temperature Rise

- **Lots of annual, decadal variability; general trend of warming**
- **2015 warmest year on record (surface air temp)**
- **January 2016 warmest January on record**
- **The planet's average surface temperature has risen about 1.8 degrees Fahrenheit since the late-19th century**
- **Most of the warming occurred in the past 35 years, with 15 of the 16 warmest years on record occurring since 2001.**



http://climate.nasa.gov/news/2391/

Climate Change – Observed Changes for Vegetation

- **Many studies document expected movement of species up in elevation or northward**
  - **Wolf et al. (2016) showed more introduced species shifted upslope.**
- **Phenological changes- earlier green-up, earlier flowering, decoupling of biotic interactions**
- **Tree growth rates, plant productivity**
  - **Warming can increase productivity in cold ecosystems not limited by water.**
  - **Decrease productivity in warm ecosystems that are water limited**

A Journal of Macroecology

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2016)

RESEARCH PAPER

Altitudinal shifts of the native and introduced flora of California in the context of 20th-century warming

Adam Wolf[1]*, Naupaka B. Zimmerman[2], William R. L. Anderegg[1], Posy E. Busby[3] and Jon Christensen[4]

[1]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544, USA, [2]School of Plant Sciences, University of Arizona, Tucson, AZ 85721, USA, [3]Department of Biology, University of Washington, Seattle, WA 98115, USA, [4]Institute of the Environment and Sustainability, University of California, Los Angeles, CA 90095, USA

ABSTRACT

Aim The differential responses of plant species to climate change are of great interest and grave concern for scientists and conservationists. One underexploited resource for better understanding these changes are the records held by herbaria. Using these records to assess the responses of different groups of species across the entire flora of California, we sought to quantify the magnitude of species elevational shifts, to measure differences in shifts among functional groups and between native and introduced species, and to evaluate whether these shifts were related to the conservation of thermal niches.

Climate Change – The Future…

- To understand potential temperature increase, we use global climate models (GCMs) and emission scenarios (RCPs or Representative Concentration Pathways) as part of CMIP5 and the Intergovernmental Panel on Climate Chante (IPCC).
- Global climate is projected to continue to change over this century and beyond.
- The magnitude of change beyond the next few decades depends primarily greenhouse gas emissions, and Earth's sensitivity to those emissions
- About a 0.5°F increase would be expected over the next few decades even if all emissions from human activities suddenly stopped

Climate Change – The Future…

- Uncertainty is considerable!
  - Uncertainty about emissions, and our knowledge of climate, atmospheric, ocean feedbacks, etc.
- Projection vs. prediction or forecast
- Some things are more certain than others

"…because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know…"

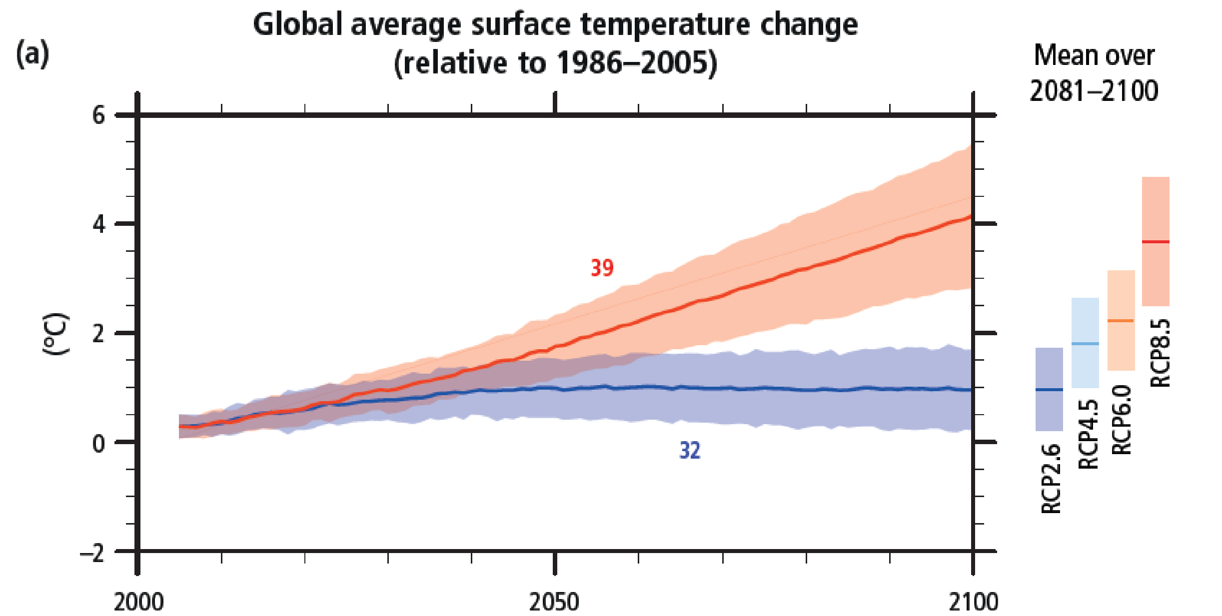
-Donald Rumsfeld, 2002 (stolen from D.H. Lawrence's poem, "New Heaven and New Earth")

- IPCC 2014: The combination of persistent uncertainty in key mechanisms plus the prospect of complex interactions motivates a focus on risk. Because risk involves both probability and consequence, it is important to consider the full range of possible outcomes, including low-probability, high-consequence impacts that are difficult to simulate."

Climate Change – The Future

SPM 2.2 Projected changes in the climate system

Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is *very likely* that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. *{2.2}*



https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

IPCCs Climate Change 2014 Synthesis Report Summary for Policymakers

Climate Change – The Future…

Table 2.1 | Projected change in global mean surface temperature and global mean sea level rise for the mid- and late 21st century, relative to the 1986–2005 period. *{WGI Table SPM.2, 12.4.1, 13.5.1, Table 12.2, Table 13.5}*

		2046–2065		2081–2100	
	Scenario	**Mean**	***Likely* range** [c]	**Mean**	***Likely* range** [c]
Global Mean Surface Temperature Change (°C) [a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	**Mean**	***Likely* range** [d]	**Mean**	***Likely* range** [d]
Global Mean Sea Level Rise (m) [b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

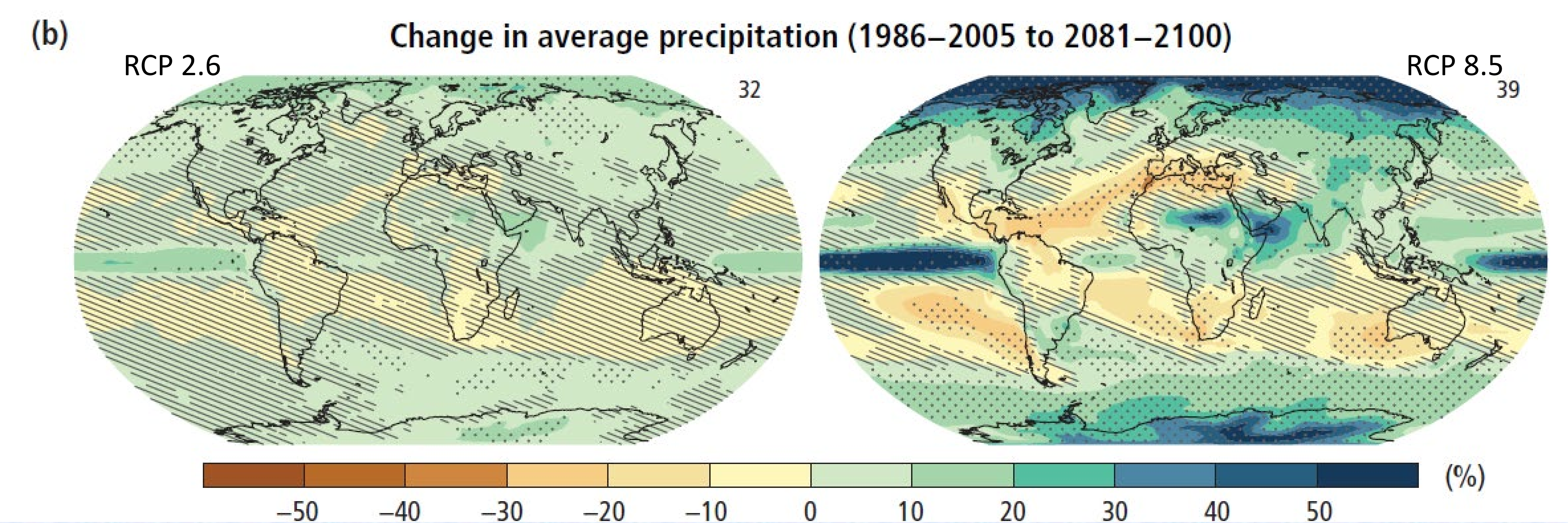
Notes:

[a] Based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble; changes calculated with respect to the 1986–2005 period. Using Hadley Centre Climatic

https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

IPCCs Climate Change 2014 Synthesis Report Summary for Policymakers

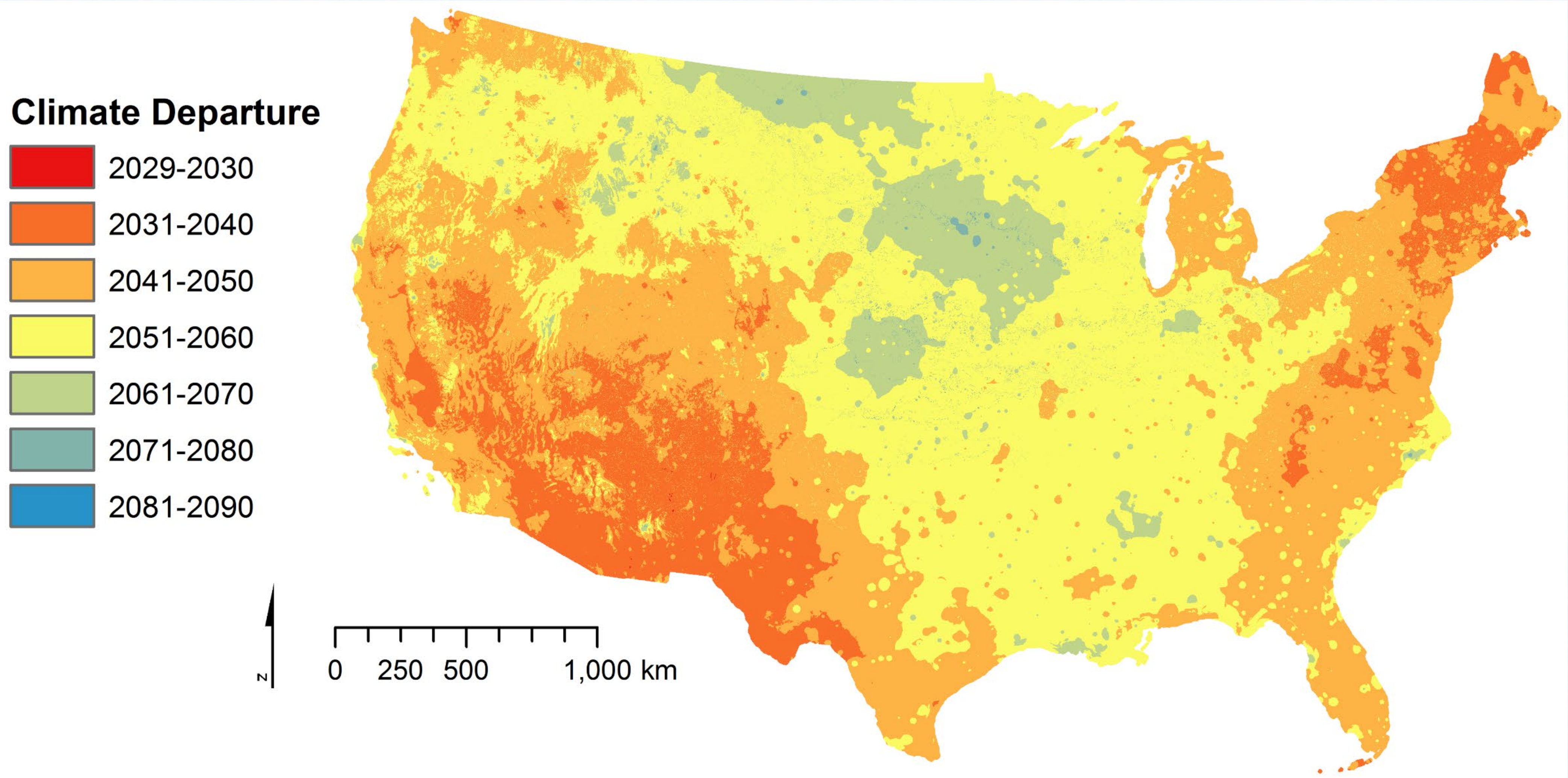
Climate Change – The future…



https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf

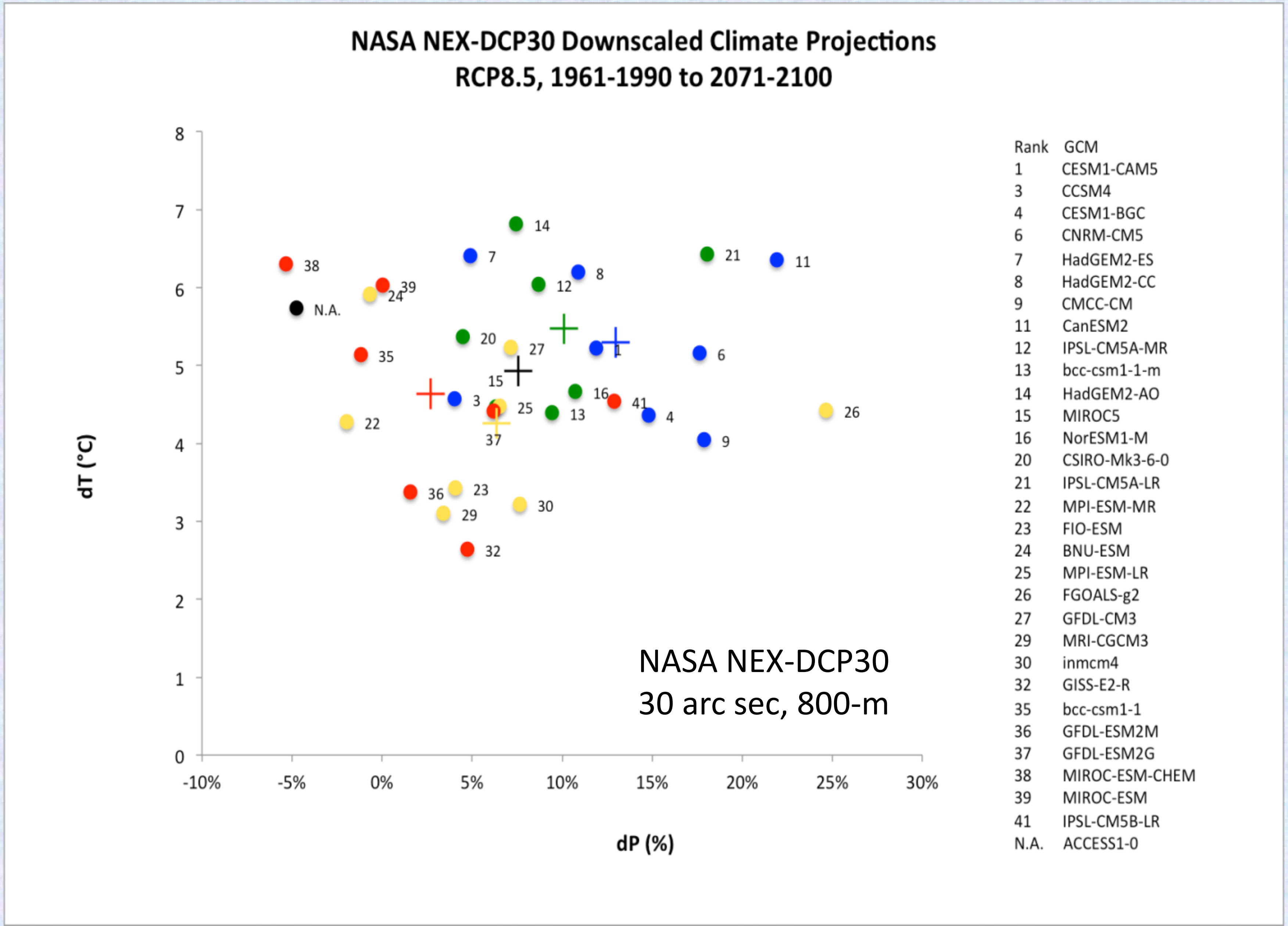
IPCCs Climate Change 2014 Synthesis Report Summary for Policymakers

Climate Change – The Future…

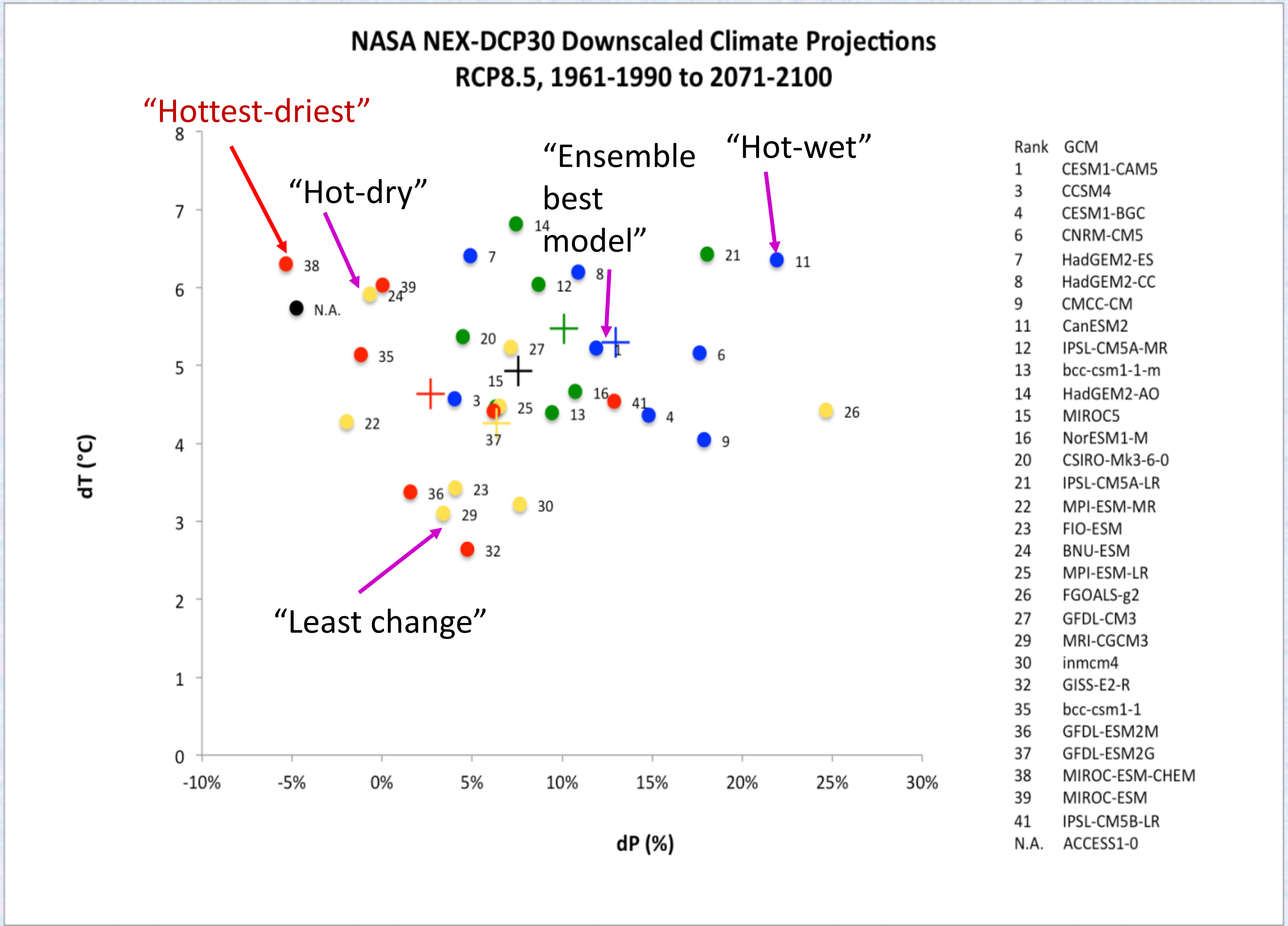


Kerns et al. In Press. US exposure to multiple landscape stressors and climate change. Regional Environmental Change.

Climate Change – The Future for OR/WA?



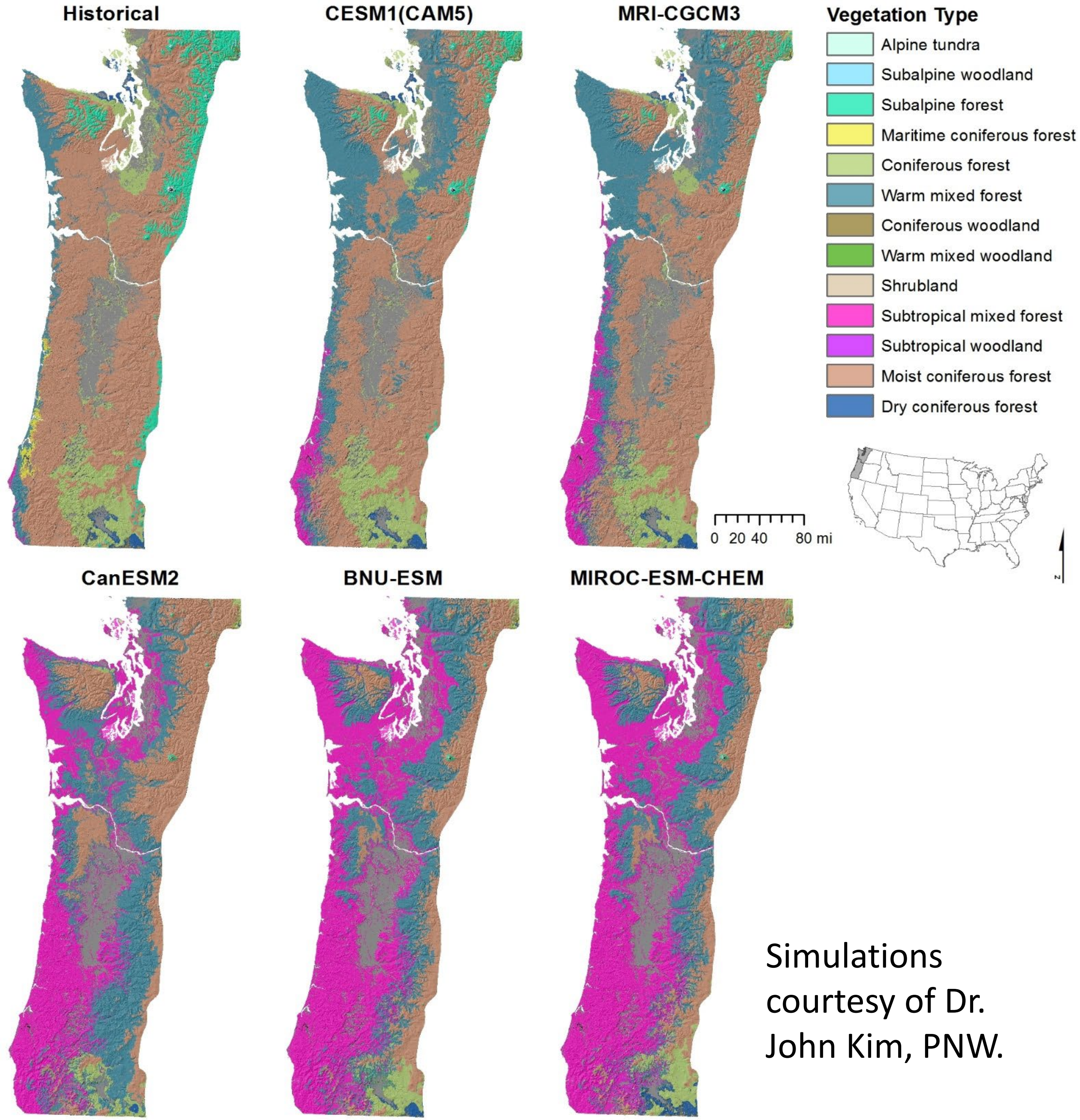
Climate Change – The Future for OR/WA?



Climate Change – The Future…for OR and WA?

- Western OR and WA climate

			Mean Annual Temp (°C)	Mean Annual Precip	GSP (May-Sep)
Rank		GCM	2070-2099		
1	Ensemble best	CESM1-CAM5	4.5	5%	0%
11	Hot-wet	CanESM2	5.7	8%	-10%
24	Hot-dry	BNU-ESM	5.5	-2%	-2%
29	Least chg	MRI-CGCM3	2.7	3%	-11%
38	Turkey hot dry	MIROC-ESM-CHEM	5.6	-3%	-12%



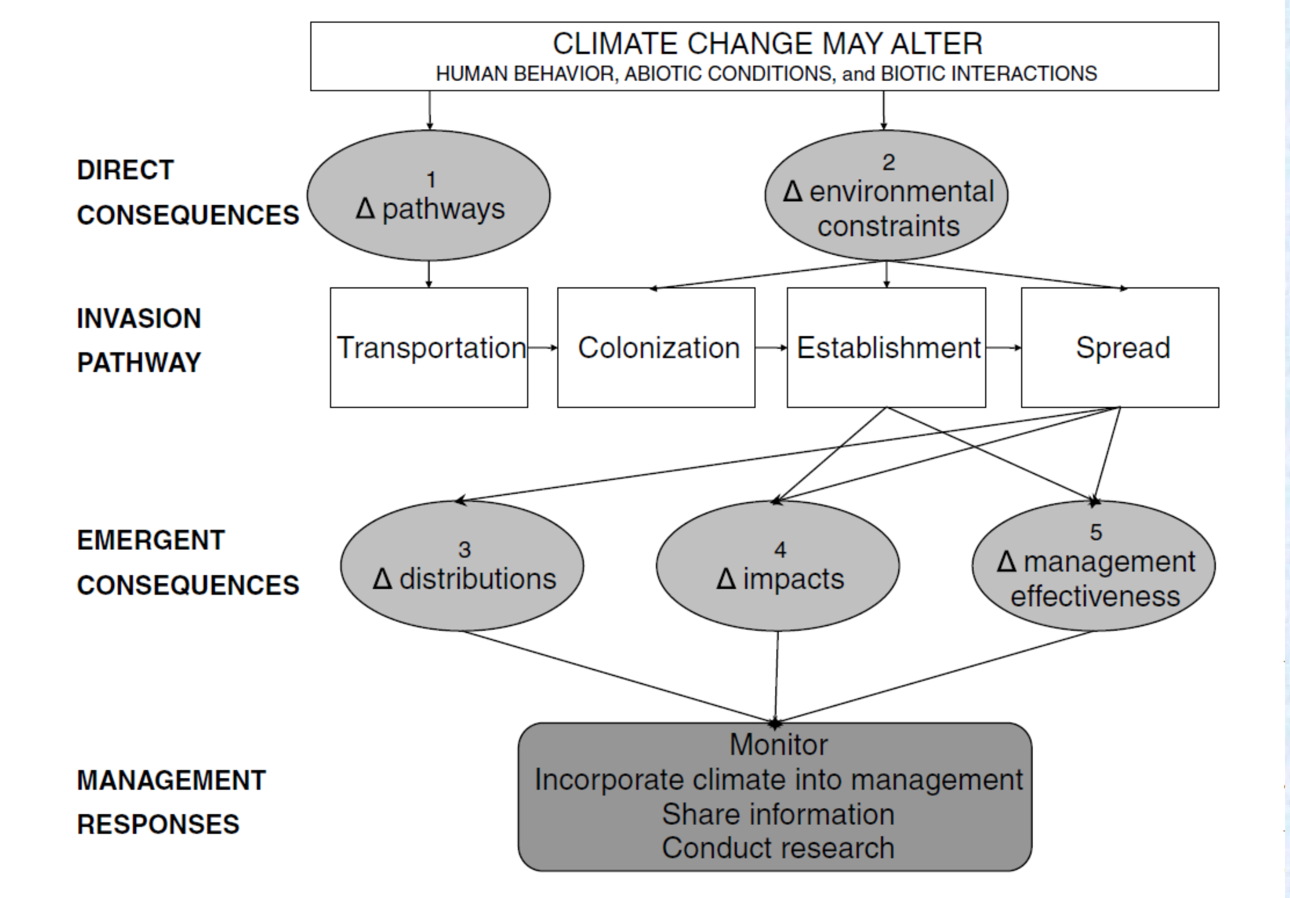
Simulations courtesy of Dr. John Kim, PNW.

Vegetation Projections

- Ensemble best,CESM1-CAM5
  - Warmer, mixed (conifer + deciduous) and subtropical mixed forest increases, subalpine forests decrease
- Least chg, MRI-CGCM3
  - Similar to above, more subtropical forest
- Hotter models show bigger changes with major shifts to warmer, mixed forests, subtropical forests more widespread
  - Hot-wet, CanESM2
  - Hot-dry, BNU-ESM
  - Turkey hot dry, MIROC-ESM-CHEM
- Note that there is really no forest “loss” projected, rather forests change to mixed and subtropical types
  - More hardwoods, species typical in southern Oregon and California

Climate Change and Invasive Plants

- **Climate change will alter biotic and abiotic conditions as well as human behavior**
- **Useful framework Hellmann et al. 2008**
  - **Climate change will influence the environmental constraints related to the colonization, establishment and spread of invasive species, as well as the human-mediated pathways of introduction**
  - **These in turn will cause changes in species distributions, impacts and the effectiveness of management actions**



Climate Change and Invasive Plants

- **Successful invasion of a natural or intact community depends on:**
  - **Environment: temperature, precipitation, and CO_2**
  - **Disturbance and resource availability**
  - **Biotic factors: biotic resistance, competition, “enemies”**
    - **Propagule pressure**

on Biogeography

Diversity and Distributions, (Diversity Distrib.) (2015) **21**, 848–852

BIODIVERSITY VIEWPOINT

Will there be a shift to alien-dominated vegetation assemblages under climate change?

Michelle R. Leishman* and Rachael V. Gallagher

Changes in Temperature and Precipitation

- **Some evidence that exotic invasive species generally have broader environmental tolerance – may be able to cope with rapid change**
  - **Seedling establishment enhanced under higher temps**
- **Increased water availability even in the short term, can facilitate the long-term establishment of alien plant species (Blumenthal and others 2009, Milchunas and Lauenroth 1995).**
- **Some evidence invasive exotics better able to phenologically adapt to climate change**
  - **Evolution of early flowering**

Original Paper
Biological Invasions
October 2014, Volume 16, Issue 10, pp 2049-2061

First online: 31 January 2014

Effects of extreme temperature on seedling establishment of nonnative invasive plants

Qian-Qian Hou, Bao-Ming Chen, Shao-Lin Peng, Lei-Yi Chen

10.1007/s10530-014-0647-8

Effects of experimental climate warming and associated soil drought on the competition between three highly invasive West European alien plant species and native counterparts

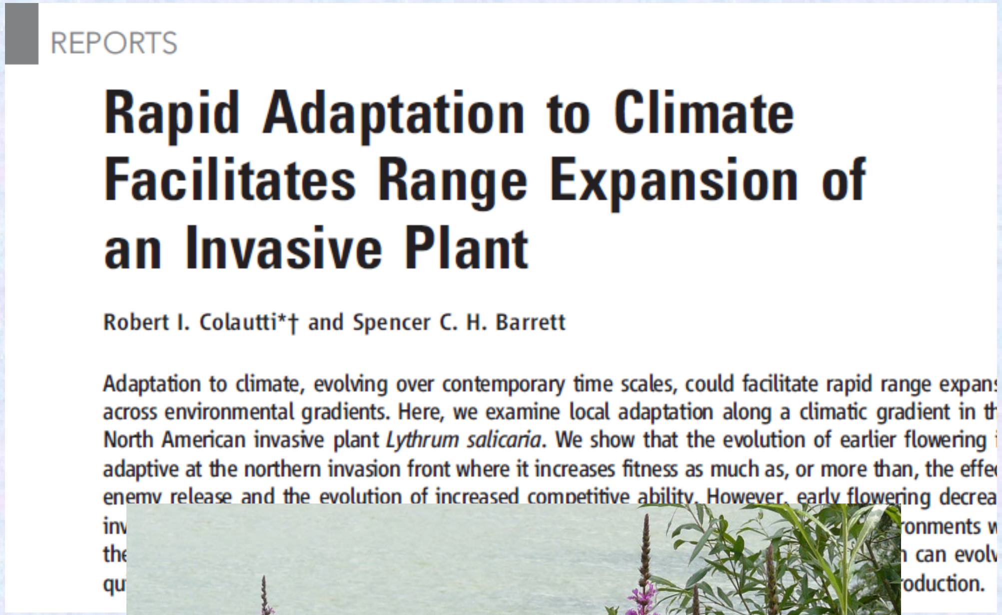
M. Verlinden · A. Van Kerkhove · I. Nijs

Increased snow facilitates plant invasion in mixedgrass prairie

D. Blumenthal[1], R. A. Chimner[2], J. M. Welker[2,3] and J. A. Morgan[1]
[1]USDA ARS Rangeland Resources Research Unit, 1701 Center Avenue, Fort Collins, CO 80526, USA; [2]Natural Resource Ecology Laboratory, Colorado, State University, Fort Collins, CO 80523, USA; [3]Environment and Natural Resources Institute and Biology Department, University of Alaska Anchorage, Anchorage, AK, USA

Evolution of Early Flowering

- **Barrett and Colautti (2013) - purple loosestrife adapted to different climates through changes in size and flowering times**
  - **Comes at a cost of reduced vegetation growth**
- **Adaptation to climate, evolving over contemporary time scales, could facilitate rapid range expansion across environmental gradients**
- **Local adaptation can evolve rapidly in outbreeding invaders like purple loosestrife if multiple introductions from diverse native sources contribute substantial standing genetic variation.**


REPORTS

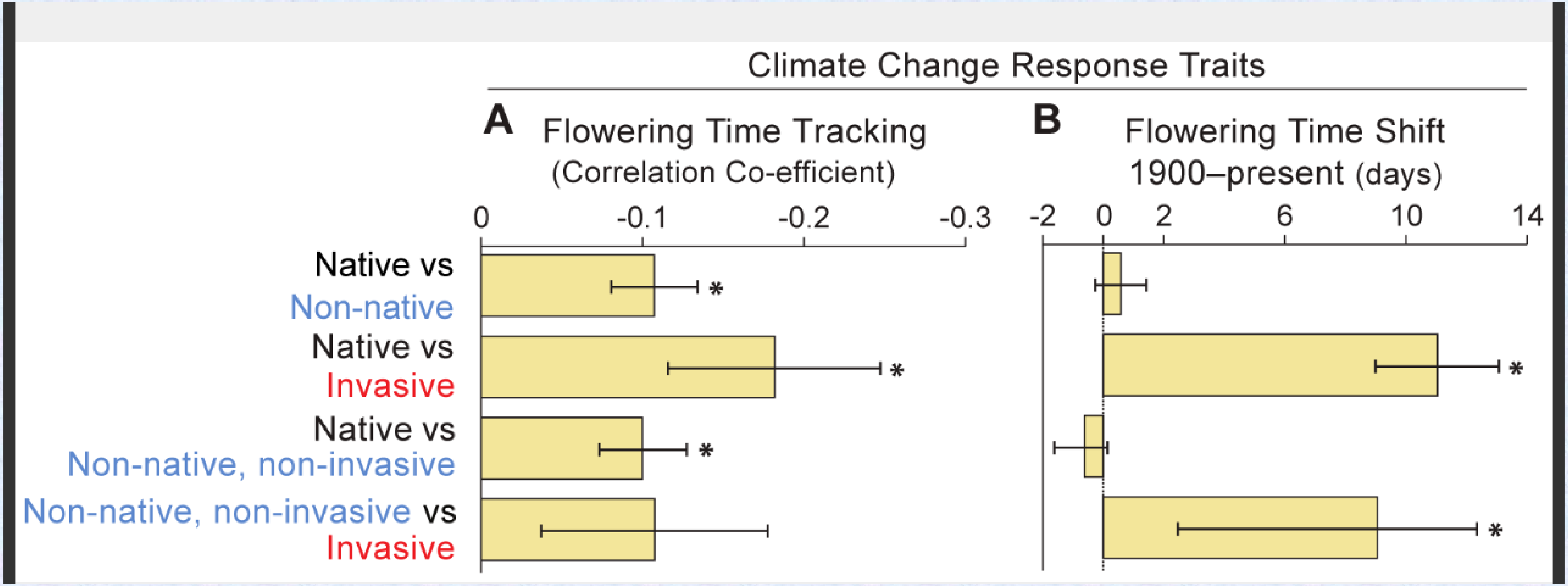
Rapid Adaptation to Climate Facilitates Range Expansion of an Invasive Plant

Robert I. Colautti*† and Spencer C. H. Barrett

Adaptation to climate, evolving over contemporary time scales, could facilitate rapid range expans
across environmental gradients. Here, we examine local adaptation along a climatic gradient in th
North American invasive plant *Lythrum salicaria*. We show that the evolution of earlier flowering i
adaptive at the northern invasion front where it increases fitness as much as, or more than, the effe
enemy release and the evolution of increased competitive ability. However, early flowering decrea
inv ronments w
the n can evolv
qu oduction.

Evolution of Early Flowering

- **Willis et al. 2010 (Concord, Massachusetts, Thoreau Woods)**
  - **Nonnatives, and invasive species in particular, have been far better able to respond to recent climate change by adjusting their flowering time**



Changes in Temperature and Precipitation

- **Information regarding species environmental tolerances can be used to gain insight into potential responses**
  - **For the PNW and especially westside –warming and increased precipitation, longer growing seasons**
  - **MC2 output – warm forest species, subtropical species (examples from mixed southern OO forests, California)**
  - **Exotic species currently limited by cold temperatures may be able to move into new areas**
  - **BUT extreme conditions more common (drought)**

Nassella / Stipa tenuissima (Mexican Feather Grass) Invading hillside in New Zealand - NZGovt


Blue gum Eucalyptus
Image 1 of 5

Changes in Temperature and Precipitation

- **Crimmins et al. (2011) noted in California, a downhill shift in plant species…tracking regional changes in climatic water balance, rather than temperature**
  - **This paper was controversial as most have noted uphill and northward movement of species**
- **Recent meta-analysis (Sorte et al. 2014) indicated no clear benefit to changes in temperature and precipitation for natives vs. nonnative plants**
  - **Winners and losers**
  - **Very context dependent**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REPORT
Rapid Range Shifts of Species Associated with High Levels of Climate Warming
I-Ching Chen[1,2], Jane K. Hill[1], Ralf Ohlemüller[3], David B. Roy[4], Chris D. Thomas[1,*]
+ Author Affiliations
*To whom correspondence should be addressed. E-mail: chris.thomas@york.ac.uk
Science
Vol 333, Issue 6045
19 August 2011
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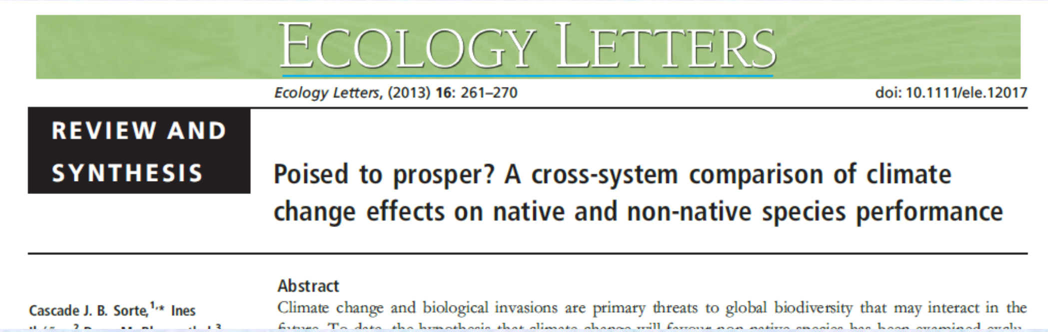
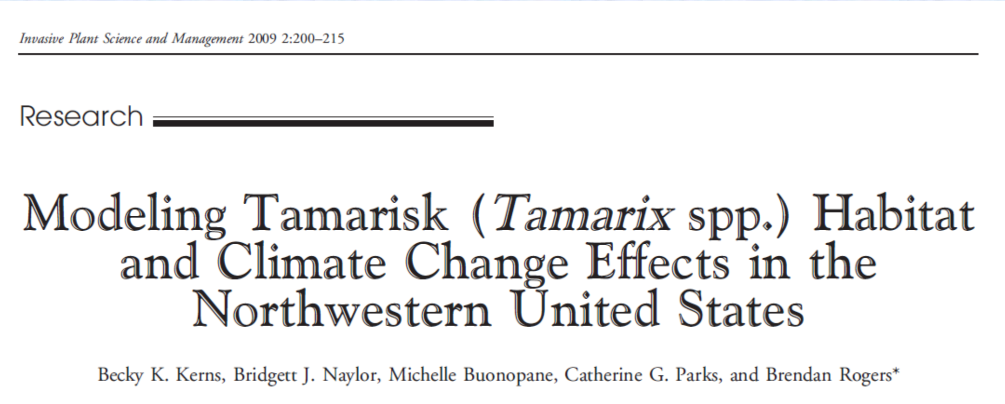
Masthead (PDF)


ECOLOGY LETTERS
Ecology Letters, (2013) 16: 261–270 doi: 10.1111/ele.12017
REVIEW AND SYNTHESIS
Poised to prosper? A cross-system comparison of climate change effects on native and non-native species performance
Cascade J. B. Sorte,[1,*] Ines
Abstract
Climate change and biological invasions are primary threats to global biodiversity that may interact in the

Changes in Temperature and Precipitation

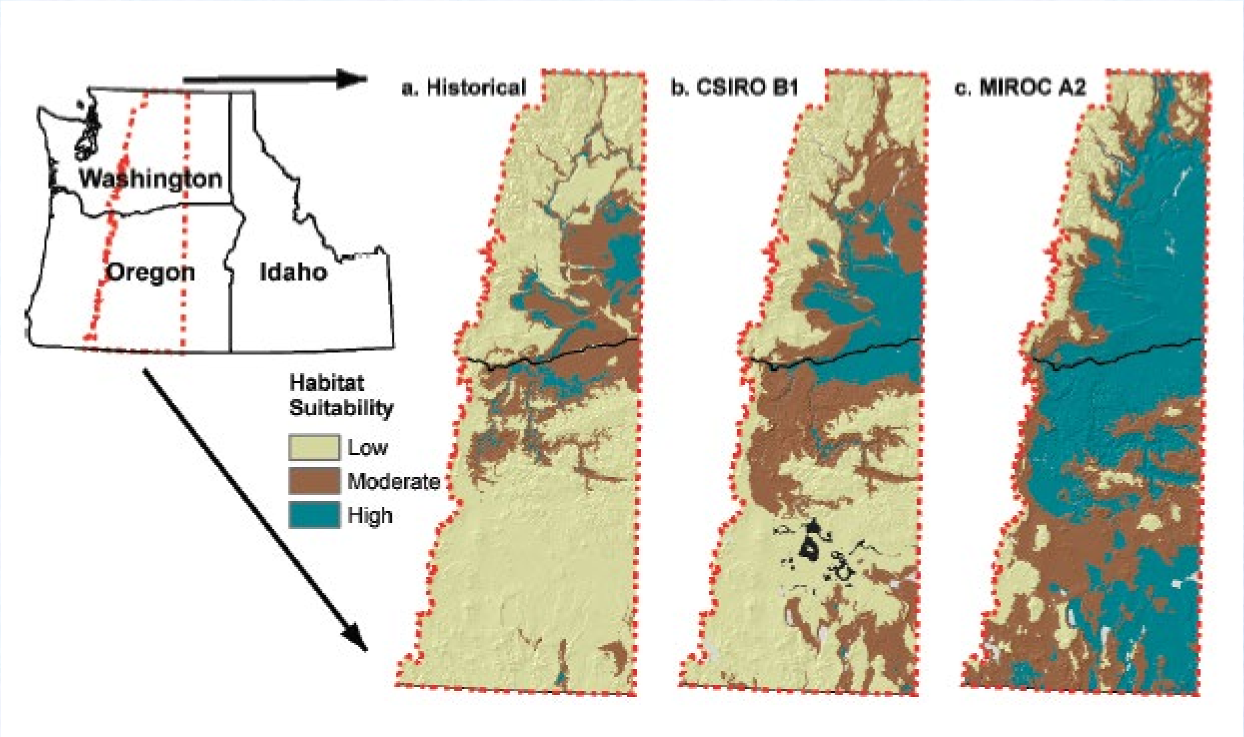
- **Interpret Model Output Cautiously!**
  - **Look under the hood – good model performance for present conditions does not ensure future projections are "correct"**
  - **Species distribution models or bioclimatic envelope models – use cautiously, be aware of caveats**


Invasive Plant Science and Management 2009 2:200–215

Research

Modeling Tamarisk (*Tamarix* spp.) Habitat and Climate Change Effects in the Northwestern United States

Becky K. Kerns, Bridgett J. Naylor, Michelle Buonopane, Catherine G. Parks, and Brendan Rogers*



Elevated CO_2

- **Increased productivity in response to elevated CO_2 documented for many plants under controlled conditions, including many invasives (cheatgrass, Canada thistle, spotted knapweed, yellow star-thistle, kudzu)**
  - **The CO_2 fertilization effect is real…in the greenhouse**
  - **Responses in the field less predictable due to other limiting factors**
- **Increased water use efficiency (drier environments)**
- **Will exotic invasive plants benefit more than natives??**
  - **Rapid growth strategy of many alien invasive species may enable them benefit more from elevated CO_2 (Blumenthal et al., 2013).**
  - **A recent meta-analysis (Sorte et al., 2013) found minor and equivocal evidence that non-native species outperform natives under future CO_2**
- **There is some evidence the effectiveness of herbicides will be reduced in elevated CO_2 environments**

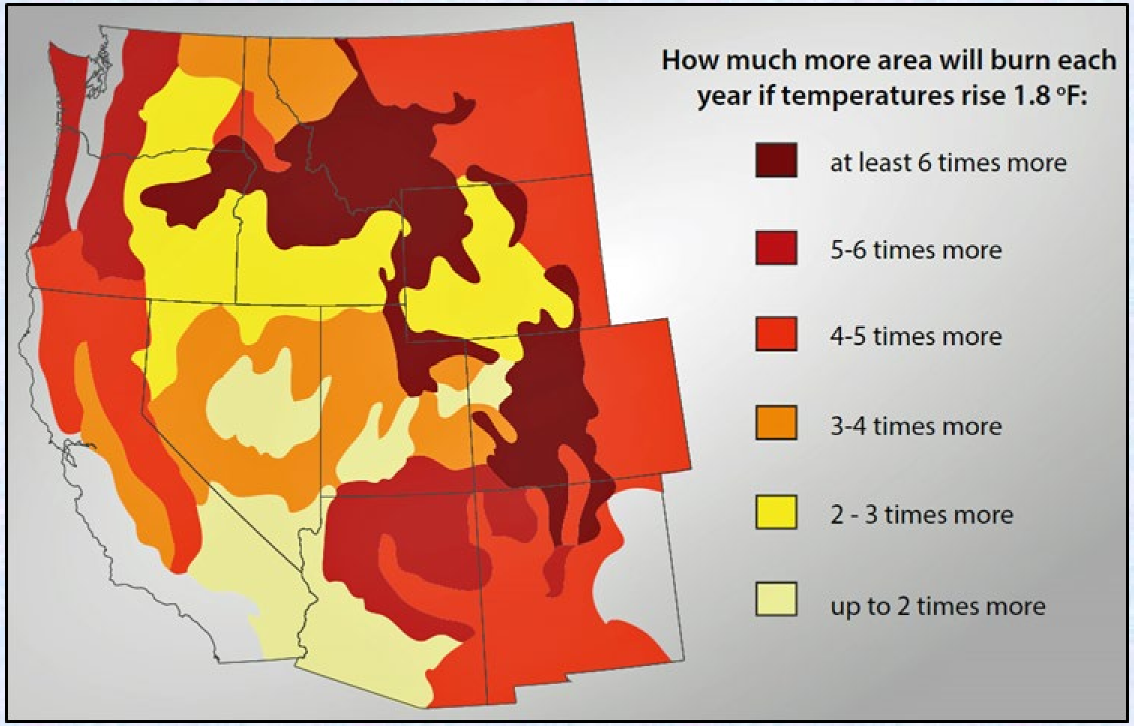
Disturbance and Resource Availability

- **Disturbances such as fire, landslides, volcanic activity, insect and disease outbreaks, logging, road building (other infrastructure), provide more colonization opportunities for invasive exotic plants (open canopies, substrate, water and nutrient availability)**
- **Climate change will increase some disturbances**
- **Exotic invasive plants likely to have advantages due to their superior capacity for**
  - **long-distance dispersal**
  - **rapid growth allowing them to pre-empt space**
- **Increased nutrient availability even in the short term, has experimentally been shown to facilitate the long-term establishment of exotics**
- **Must have propagule supply!**

Wildfire and Climate Change

- **Climate (and weather at a shorter time scales) influences the timing, frequency, and magnitude of fire in any particular location**
- **A warmer climate will cause an increase in the frequency and extent of wildfire in many ecosystems**

Projected increase in area burned by wildfire as associated with a mean annual temperature increase of 1 °C, shown as the percentage change relative to the median annual area burned during 1950-2003 (Littell [n.d.] cited in Ojima et al. [2014]).



Fire and the Invasive Annual Grass Cycle

- **E.g. Cheatgrass-Shrub Steppe, Juniper Woodlands, North Africa grass (*Ventenata dubia*) in Blue Mountains of Oregon**
- **Annual grass invasion increases in fuel abundance**
- **Areas once fuel limited burn more often leading to increases in fire frequency and intensity**
- **This increases native grass, shrub and tree mortality and reduces vigor, facilitating further increases in exotic abundance**
- **Increases in fire projected to occur with climate change**

Invasives and Fire in Western OR/WA

- **Invasion of exotic species can alter fire behavior and fire regimes IF they introduce a novel fuel, or more fuel into the system**
- **Scot's broom, gorse, reported to increase fire intensity and frequency in invaded Oregon white oak communities (Tvetan, 1996).**
- **Other flammable invasive species include Himalayan blackberry, clematis, and reed canary grass.**
- **In many of these areas, blackberry, clematis, and other weeds form "fuel ladders" which facilitate the ability of a fire to travel into the tree canopy of conifers.**

Biotic Factors

- **Biotic resistance**
  - **Climate change may decrease resident vegetation resilience!!**
  - **Winners, losers**
- **Communities with low species diversity and low biomass, probably have lower biotic resistance (Pauchard and others 2009)**
- **Changed interactions between plant species and enemies or mutualists under climate change; some pathogens may be more or less effective (biocontrol)**
- **Elevated CO2 may increase seed production and propagule pressure**

Concluding Thoughts

- **Climate change may increase the success of invasive plants, but not always (winners, loosers)**
- **Critical to understand the response of the most detrimental plants to individual climatic factors, interactions between these factors, and interactions among diverse biotic and other abiotic factors**

Concluding Thoughts and Implications

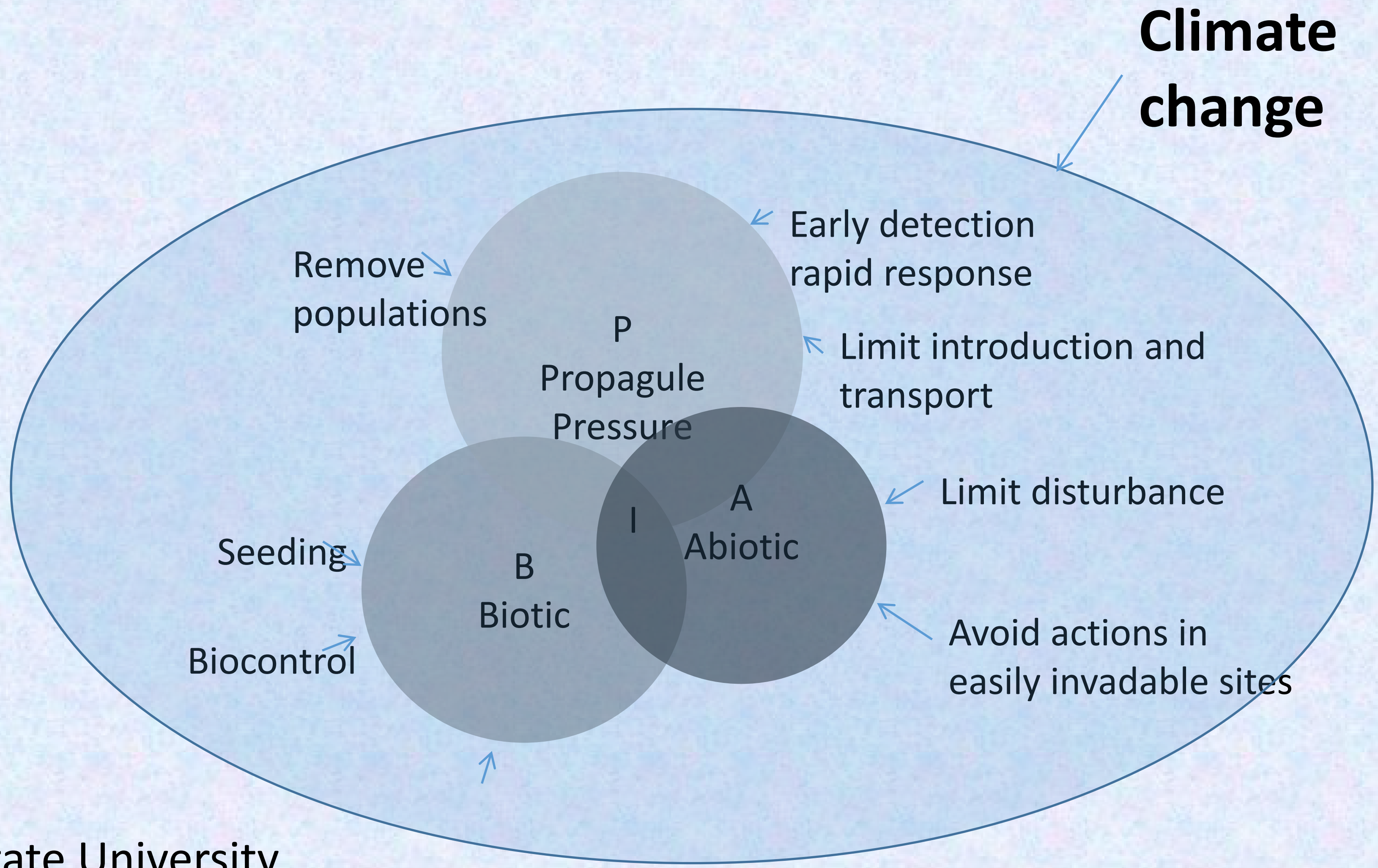
- **The greatest chance for action is in the early phase of invasion**
  - **Consider climate change “tweaking” of early detection and rapid response systems**
  - **Assessment work could be done over broader geographic areas than traditionally has been performed in the past**
  - **Look at simulation model output (multiple models!) to think about relevant “what-ifs” for newly discovered invasive species, new introductions**
  - **Monitor and early eradication efforts in response to disturbance event such as fire, storms and floods, etc.**

Concluding Thoughts and Implications

- **Leishman et al 2015 stress that the strongest drivers for a shift to alien-dominated vegetation are likely:**
  - **a reduction in the resilience of resident vegetation assemblages**
  - **the consequent emergence of new colonization opportunities created by losses of marginal populations at the edges of range boundaries of both native and alien species**
- **These drivers in combination with typical invader traits of good dispersal ability and capacity for fast growth are likely to result in increased success of exotic invaders**
- **What can we do??**
  - **Increase intact and native vegetation resilience**
  - **Replace invasives with species that can compete with typical invaders (functional analogs)**

Thank you!

Q&A?



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  - Contact: Becky Kerns, bkerns@fs.fed.us