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Geography 404
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Laboratory experiments of ↑CO_2

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Effect of ↑CO_2 for plants with different photosynthetic pathways

Biomass enhancement

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Effect of ↑CO2 diminishes when other factors (here, competition) are present

When plants have high relative growth rate (RGR), effects of competition limit effects of CO2 fertilization

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Different field experimental methods

Hannah, 2011

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Different field experimental methods

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Different field experimental methods

http://sciencespace-wang.blogspot.com/2011_06_01_archive.html

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Free air CO_2 enrichment (FACE) experiments

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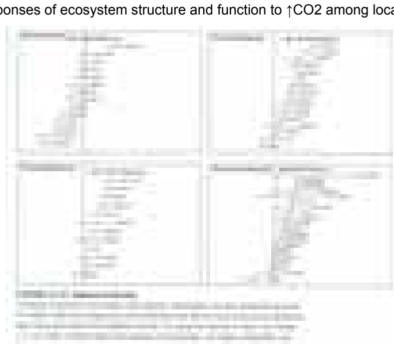
Responses of ecosystem structure and function to $\uparrow CO_2$ among locations



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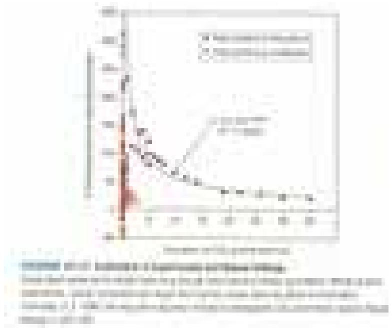
Over time, the growth enhancement of ↑CO2 diminishes



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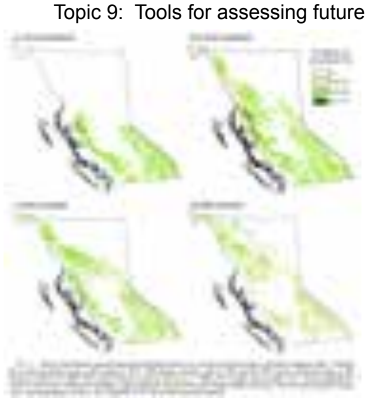

"Whitebark pine (Pinus albicaulis) assisted migration potential: testing establishment north of the species range"

McLane and Aiken, Ecol. Appl., 2012

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Trial locations (black dots)

Seed sources (white squares)

McLane and Aiken, Ecol. Appl., 2012

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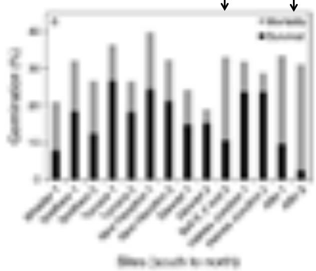
Results of trials

coldest sites



McLane and Aiken, Ecol. Appl., 2012

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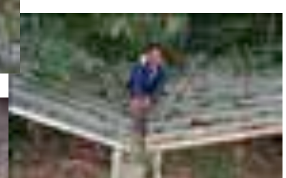
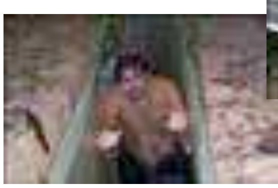
Amazon drought experiment





http://earthobservatory.nasa.gov/Features/AmazonDrought/stealing_rain3.php, photos by D. Nepstad

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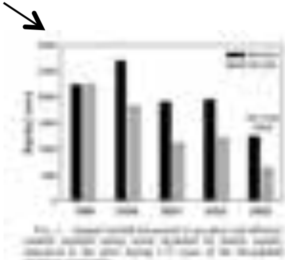
Experiment effectively reduced rainfall



http://earthobservatory.nasa.gov/Features/AmazonDrought/stealing_rain3.php, photos by D. Nepstad; Nepstad et al., Ecology, 2007

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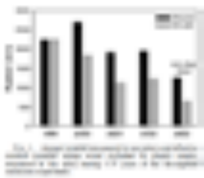
Reduced rainfall led to decreased soil moisture



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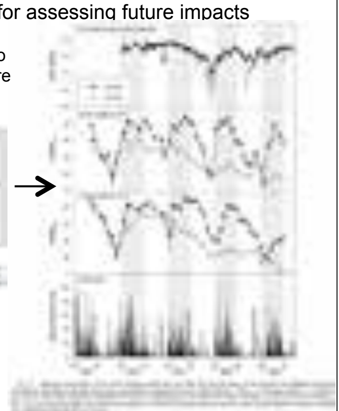

Nepstad et al., Ecology, 2007

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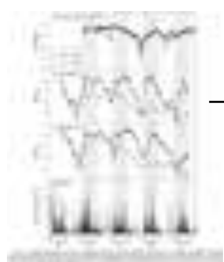
Reduced soil moisture led to plant mortality



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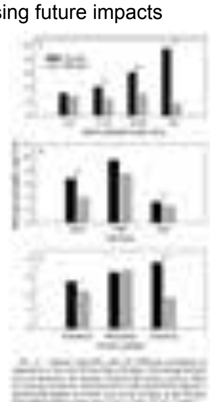

Nepstad et al., Ecology, 2007

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SUMO: Survival Mortality experiment in New Mexico

www.youtube.com/watch?feature=player_embedded&v=6-eyL1AlMoM

Figure courtesy N. McDowell, LANL

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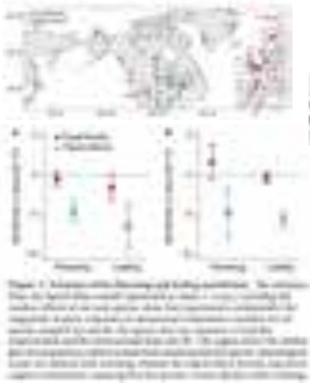

Dangers of misinterpreting experiments

Possible explanations

- experiments focused on T, not on correlated factors that may drive changes in observed phenology (sunshine, snowpack/snowmelt, soil moisture)
- issues with meta-analyses (devil is in the details)
- use of mean annual temperature

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How to develop a species distribution model

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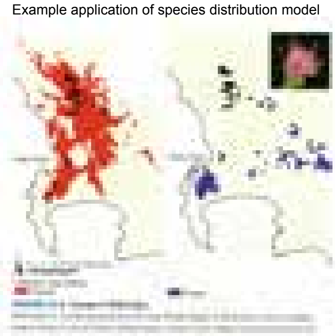
Example application of species distribution model



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Evaluating species distribution models with historical observations

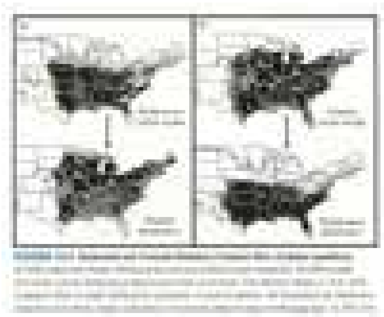

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Figure 1. Observed pika occurrence points (plusses), pika subspecies (dashed lines), and modeled suitable habitat for current climate (gray).

Species distribution model of pika

Trook, Buotte, Hicke, unpublished

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Probability of occurrence as function of climate variables

Trook, Buotte, Hicke, unpublished

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Projections of future potential habitat based on climate change projections

Figure 2. Modeled suitable habitat for American pika for current climate and for climate emission/model projections GFDLCM21/B1, CGCM3/A1B, and GFDLCM21/A2. For the majority of future habitat, more warming leads to a contraction in habitat area upslope (or disappearance). In the small amount of purple area in the northern Rocky Mountains, the GFDLCM21/B1 projection was warmer in the warmest month than the CGCM3/A1B projection.

Trook, Buotte, Hicke, unpublished

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Area of habitat and % of current for climate change projections

Trook, Buotte, Hicke, unpublished

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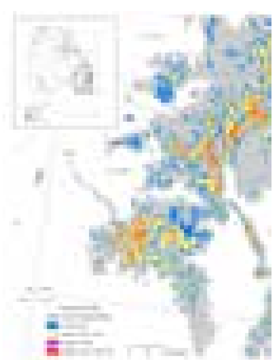

Fine spatial resolution projections allowed visualization of habitat fragmentation

Trook, Buotte, Hicke, unpublished

Figure 3. Same as Figure 2 but for an area in southwestern Colorado illustrating increased fragmentation of pika habitat as a result of warming.

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We couldn't get this work published…why?

- lack of inclusion of necessary habitat
  - talus maps of uncertain quality
- lack of inclusion of important variables
  - presence of subtalus snow or water
- uncertainty about pika's ability to persist in hot, dry places
  - behavioral change
- uncertainty about importance of other factors
  - snow cover as insulation
  - cold-air drainage through talus slopes

Trook, Buotte, Hicke, unpublished

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Example application of gap model

Hannah, 2011

Flow diagram of ecosystem model

Smith et al., Global Ecology & Biogeography, 2001

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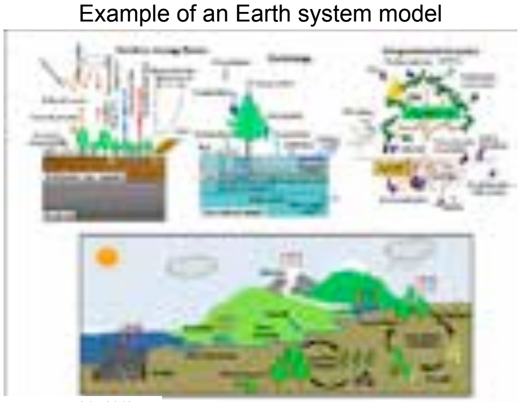
Example application of dynamic global vegetation model

Hannah, 2011

Example of an Earth system model

https://www2.ucar.edu/news/understanding-climate-change-multimedia-gallery

Example of an Earth system model



www.cesm.ucar.edu/models/clm

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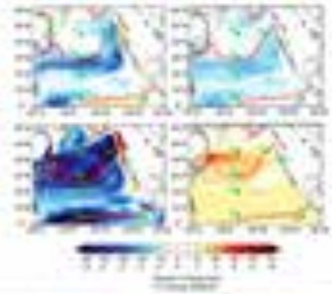
Example application of an Earth system model:
climate change impacts on fish catch



Woodworth-Jefcoats et al., Global Change Biology, 2012

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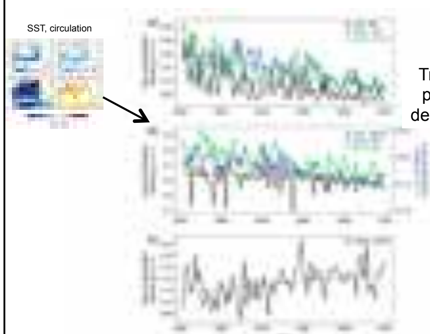
SST, circulation



Trends in large phytoplankton density by region

Woodworth-Jefcoats et al., Global Change Biology, 2012

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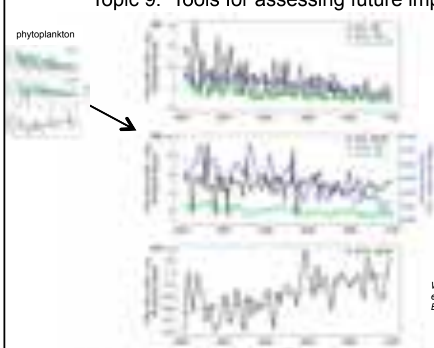
phytoplankton



Trends in fish catch by region

Woodworth-Jefcoats et al., Global Change Biology, 2012

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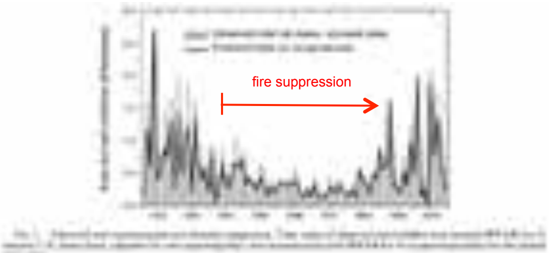
How can modeling support assessments of impacts of climate change?

Example: How has/will climate change influence(d) wildfire in the West?



Littell et al., EA, 2009

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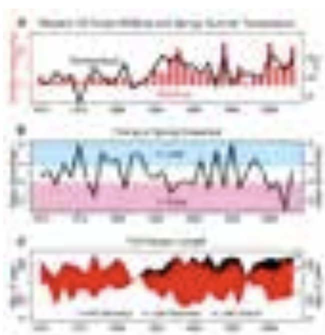

Wildfire: Recent observations

earlier snowmelt =>

more moisture stress on plants =>

longer fire season =>

more fires

Westerling et al., *Science*, 2006

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- statistical analysis assessing which climate factors influence burned area in the last several decades
- different assessments for different ecoprovinces (vegetation types)

Littell et al., EA, 2009

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Important climate variables: PPT, T (depending on ecoprovince)

Climate drivers of historical burned area

mountains: burned area negatively correlated with year-of-fire precip, positively correlated with year-of-fire T
- drying of existing fuels

grass/shrub: burned area positively correlated with antecedent precip
- also fuels production

Littell et al., EA, 2009

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Wildfire: Projections based on future climate change

increase in burned area for 1º C increase in temperature

Littell et al., *Ecological Applications*, 2009; National Academies, *Climate Stabilization Targets*, 2010

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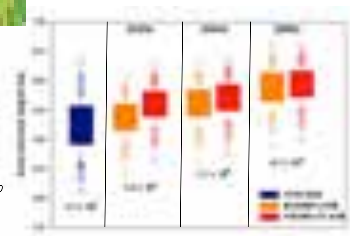
Burned area in Pacific Northwest increases substantially in future



Littell et al., Climatic Change, 2010

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Summary

- multiple factors influenced the observed increase in burned area
  - attribution: difficult
- multiple types of studies guide our understanding of climate influences on wildfire
- although recent climate change has likely (but not definitively) caused increased wildfire in the past, we are more certain that continued climate change will increase wildfire in the future