Climate Change and Southwest Rangelands: Past, Present, and Future

Climate and Rangelands Workshop

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Arizona Drought

Arizona Statewide Percent of Average Precipitation

- Reconstructed Percent of Average Precipitation
- Instrumental Precipitation
- 1896-1988 Average Precipitation
- 10-year Average Precipitation
- 2002 Statewide Average

Data: CLIMAS/University of Arizona Laboratory of Tree-Ring Research
Arizona Wet Periods

Arizona Statewide Percent of Average Precipitation

Data: CLIMAS/University of Arizona Laboratory of Tree-Ring Research
1950s New Mexico Tree Mortality
Resetting the Ecosystem Clock

Courtesy of Tom Swetnam (University of Arizona) and Julio Betancourt (USGS)
Climate Variations
El Niño-Southern Oscillation (ENSO)

- Persistent changes
- Duration 1-3 years
- Occur every 2-7 years

Slide courtesy of Greg McCabe, USGS
El Niño: Winter Effects U.S.

- Increased groundwater, less pumpage

Source: NOAA Climate Prediction Center
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif
La Niña: Winter Effects U.S.

- Drought circulation pattern

Source: NOAA Climate Prediction Center
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif
Decadal Variations
Pacific Decadal Oscillation (PDO)

- Discovered in 1990s
- 20-30 year changes
- Likely Mechanisms:
  - ENSO
  - Kuroshio Current
  - Aleutian Low

Courtesy of N. Mantua – University of Washington
Mantua et al., 1997 *Bulletin of the American Meteorological Society*
Pacific Decadal Oscillation (PDO)

Figure 8. Smoothed (15-month moving window using the Savitzky-Golay procedure) monthly indices of the Pacific Decadal Oscillation (PDO) (upper) and combined seasonal precipitation (standardized anomaly index, SAI) (lower) for the Colorado Plateau.

Hereford and Webb (2002), USGS
Positive AMO Phase

- West: Warm, dry, high pressure
- Associated with 1950s and late-1500s droughts

Slide courtesy of Greg McCabe, USGS
PDO (neg.) AMO (pos.) Combination

Drought Frequency % (25 = expected)

McCabe et al., 2004 Proceedings of the National Academy of Sciences
The Perfect Ocean for Drought

Martin Hoerling\(^1\) and Arun Kumar\(^2\)

Observed Climate Change: Global and Hemispheric to the Southwest
2004 = 4th warmest on record

8 of top 10 warmest years have occurred in the last decade!

NOTE: More change over land

Courtesy of Jonathan Overpeck, UA-ISPE
Climate Warming in the Arctic: Significant and Accelerating

- Warming greatest on planet
- Arctic Sea Ice Pack: thinned by 40% in last 50 years
- Greenland Ice Sheet: ditto, 16% increase in melt area between 1979 and 2002

Arctic Impacts of Arctic Warming, Cambridge Press, 2004
Grinnell Glacier
Glacier National Park, 1938 - 1998

1938 T.J. Hileman
1998 D. Fagre

Courtesy of Andrew Fountain, 2004 MTNCLIM Conference
Observed Changes in Snowpack Depth and Snowmelt Timing (1950 to 2000)

Change in spring snowpack depth

Change in timing of peak spring snowmelt

From: Service, 2004; adapted from Mote, Hamlet and Clark, 2004

Major reductions/retreats in most of Arizona
2. Trends in Nov-Mar Snowfall Fraction

 Shift from Snowfall to Rainfall

 Trends in ratio of winter (Nov-Mar) snowfall water equivalent (SFE) to total winter precipitation (rain plus snow) for the period WY1949-2004. Circles represent significant (p<0.05) trends, squares represent less significant trends.

 Courtesy of Noah Knowles, USGS
Winter (DJF) MIN T Trends
1931-2002

Legend
- Arizona HCN stations
- Arizona counties

Courtesy of Casey Thornbrugh, CLIMAS
Climate Change Projections for the Western U.S.
PCM - 20th Century Experiments
Forcings: Combined Natural-Anthropogenic and Natural Only

Meehl et al. (2004)
Climate Change: Extreme Events

- 2071-2095 vs. 1961-1985 (RF)
- Extremes: top or bottom 5% of RF
  - Heat waves
- Dry days: less than 1 mm/day

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science
More Heat Events

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science
Longer Heat Waves

Diffenbaugh et al., 2005
Proceedings of the National Academy of Science
Fewer Cool Events
Diffenbaugh et al., 2005
Proceedings of the National Academy of Science
More Precipitation in Extremes
Diffenbaugh et al., 2005
Proceedings of the National Academy of Science
Summary
Paleoclimate

Drought

• Past droughts were longer and more severe than 20th century
  • *Higher temperatures, greater aridity*
  • *La Niña*
    • *Warmer world?*
Climate Change

• Observed changes in the Southwest
  – Relatively subtle, but real
  – Ocean regime changes

• Observed climate change and models show
  – Earlier snowmelt
    • More precipitation falling as rain
  – Increased temperatures
  – Increased precipitation
    • Increased hydrological cycle
Climate Change Extremes

- Increased temperatures
  - More high temperature days
  - Longer heat waves
- Increased precipitation
  - Increased precipitation extremes
Implications for Ecosystems

• Regime Changes
  • Affect landscape for long periods of time
  • Complex overlay of disturbance impacts

• Increasing Temperatures
  • Stress
  • Species’ ranges

• More precipitation in high extremes
  • Runoff
  • Erosion
Doom or Opportunity?

- Katrina:
  - We had the science
  - We anticipated the event
Doom or Opportunity?

- Katrina:
  - We had the science
  - We anticipated the event
  - **We did not reduce vulnerability or increase resilience**
Challenge

• How do we integrate climate change knowledge into management decisions…
• Given a lack of information on the spatial scales of management units?
Acknowledgments

- Ben Crawford, Casey Thornbrugh, CLIMAS
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- Noah Diffenbaugh, Purdue University
Thank You For Your Attention

Any Questions?

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References and Materials Cited
Slides 2-3

Slide 4
From analyses by Tom Swetnam (University of Arizona Laboratory of Tree-Ring Research) and Julio Betancourt (USGS Desert Research Laboratory, Tucson, Arizona).
Climate Variations (Slides 6-8)

Slide 6

Slides 7-8
Slides from the NOAA Climate Prediction Center. For more information on El Niño-Southern Oscillation, see: http://www.elnino.noaa.gov/
Decadal Variations (Slides 10-14)

Slide 10

Slide 11

Slide 12

Slide 13

Slide 14
Observed Climate Change
(Slides 16-22)

Slide 16
Courtesy of Jonathan Overpeck, Institute for the Study of Planet Earth, University of Arizona. Data from the National Climatic Data Center.

Slide 17
Courtesy of Jonathan Overpeck. From: Impacts of a Warming Arctic - Arctic Climate Impact Assessment

Slide 18

Slide 19
From a presentation by Martin Hoerling (NOAA Earth Science Research Lab) at the “Improving the Application of Science in Western Drought Management & Planning” conference, Tempe, Arizona, 2004.
http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slide 20
Observed Climate Change (Slides 16-22)

Slide 21
From a presentation, entitled “Trends in Snowfall versus Rainfall for the Western United States” by Noah Knowles (USGS) at the American Geophysical Union annual meeting, December 2005, San Francisco, CA.

Slide 22
Courtesy of Casey Thornbrugh, CLIMAS. Arizona Historical Climatology Network station minimum temperature trends for December-February.
Climate Change Projections for the Western US (Slides 24-30)

Slide 24
From a presentation by Martin Hoerling (NOAA Earth Science Research Lab) at the “Improving the Application of Science in Western Drought Management & Planning” conference, Tempe, Arizona, 2004.
http://www.westgov.org/wga/initiatives/drought/tempe.htm

Slide 25

Slide 26-30