Climate, Invasions and Altered Wildfire Regimes in the Southwest

Workshop: Strategic Management of Invasive Species in the Southwest
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I. Decadal-to-Multidecadal (D2M) Variability

- Long intervals when observations remain above/below mean
- Characteristic of instrumental record of past century & tree-ring record of last two millennia
- Synchronized across multiple basins
- Forcing not well understood (oceans); may or may not be predictable
- Unclear how natural D2M will function with climate change; key timescale for adaptation is D2M
- Water and natural resource management has glossed over problems posed by D2M variability
D2M variability is a consistent feature of long-duration climate reconstructions.

- D2M stays after low-order persistence removed.
- Significantly higher D2M power than red noise.

Gray, Graumlich and Betancourt 2007 QR
Significant Ecological Resetting Events

Cook’s Southwest Drought Index

- Wet Early 14th Century
- NM Spanish Colonization & Encomienda
- Colorado River Over-Allocation
- Post-1976 Step Change
- Great Drought
- Casas Grandes/Hohokam Collapse
- 16th Century Mega-drought
- Pueblo Revolt
- 1950s Drought

Year

1200 1300 1400 1500 1600 1700 1800 1900 2000

Reconstructed PDSI
Reconstruction of Colorado River at Lees Ferry, AD 762 - 2002

25-yr running means of reconstructed and observed annual flow of the Colorado River at Lees Ferry, expressed as percentage of 1906-2004 observed mean (Meko et al. 2007, Geophysical Research Letters)
Large-scale impacts of D2M Variability

Western U.S. Percentage Area Wet or Dry
January 1900 - December 2004

1896-1904 1930s 1950s Late 1980s 1999-2004
1905-1918 1940-41 Early 1980s 1990s

Percent Area Dry
Percent Area Wet
Year
National Climatic Data Center / NESDIS / NOAA

*Based on the Palmer Drought Index
- Moderate - Extreme Drought
- Moderate - Extreme Wet
Global SST’s and Drought Variability

Annual SST Anomalies

1932-1938

1951-1956

2000-2002
AMO- 10-yr running mean of detrended SST anomalies averaged over N Atlantic from 0-70ºN

PDO- Standardized leading PC of monthly SST anomalies in N Pacific poleward of 20ºN
Pacific Decadal Oscillation

Monthly Values for the PDO Index, 1900-2000
Thermohaline Circulation and the Atlantic Multidecadal Oscillation

Enfield, Mestas-Nuñez & Trimble (2001)
AMO can persist for decades in one mode, but when it switches mode, it does so in matter of months.
Low-frequency variations in ENSO and the AMO?

Wavelet Analysis - NINO3.4 SSTs

5S-5N; 170W-120W
Blue- low drought frequency

Red- high drought frequency

25% = normal drought frequency

25% = normal drought frequency

II. Climate Change in the West

• 1-2°C warming since 1980’s; longer & hotter growing season, less snowpack, earlier snowmelt & streamflow, more large fires, more extensive bark beetle outbreaks, etc

• ~60% attributed to greenhouse gases (Barnett et al 2008. Science)

• Multiple climate models predict less precip at subtropical latitudes, more at high latitudes

• Probable that regional climate has exited envelope of natural variability & past no longer indicative of future
Warming in the Western U.S. vs. Global

Annual Surface-Air Temperature Anomalies

Temperature, in degrees C

1900 1920 1940 1960 1980 2000

Global
Western States

Courtesy of Mike Dettinger
March-April-May Mean Minimum Temperature

Monthly Mean Minimum Temperature for Wyoming
Monthly Mean Minimum Temperature for Utah
Monthly Mean Minimum Temperature for Nevada
Monthly Mean Minimum Temperature for California
Monthly Mean Minimum Temperature for Colorado
Monthly Mean Minimum Temperature for New Mexico

Monthly Mean Minimum Temperature for Arizona
3 month period ending in May

Temperature

ENDING YEAR OF PERIOD


36 F 38 F 40 F 42 F 44 F
Step (?) Change in timing of spring onset, wheat headings, Center of Mass, and fire frequency and area burned
Early vs. late snowmelt years based on Center of Mass: Date when 50% of annual streamflow has passed gage

Late Snowmelt Years

Early Snowmelt Years

1972 - 2003, NPS, USFS & BIA Fires over 400 hectares
Correlation between # fires >400 ha for each year between 1970-2003 in the West and Center of Mass

Westerling, Betancourt, and Schwartz, in prep
Spring indexes vs. # of large fires in SW: Phenology spring index does better job

Westerling, Betancourt, and Schwartz, in prep

**IPCC AR4 Model Intercomparison**

- 19 models
- A1B emissions scenario: CO2 emissions increase until 2050 & then decrease modestly leading to 720 ppm by 2100
- Subtropics dry, high latitudes get wetter
- For AZ & NW Mexico 1950’s aridity becomes new climatology
Reduced P-E in U.S. SW is associated with both reduced precipitation and increased evaporation.

Red brome collection

Salo (2006)
Red brome collection
Salo (2005)
Red brome collection

Salo (2006)
Red brome collection
Salo (2005)
PDO and Red Brome Invasion in Western North America
(Salo 2005 *Biological Invasions*)

The graph shows the invasion pattern of Red Brome across different decades:
- **Fast 1930-1942** (WET)
- **Slow 1943-1975** (DRY)
- **Fast 1976-1998** (WET)

The equation for the fast invasion is:

\[ Y = 7.39 + 124.11 / (1 + e^{-(X-1936.3)/10.29}) \]

The adjusted R² is 0.979, and the inflection point is 1936.3.

Monthly values for the PDO index from 1900 to July 2000.
Grass invasions in deserts are changing the relationship between climate and fire in the West

Grassland/shrubland fires have different climatologies than forest fires. With increasing frequency, size and intensity of invasives-driven fires, expect desert fires to become forest fires, and fire climatologies to change.

**Graph:**
- Grass/Shrub fires FOLLOW WET years
- Forests burn DURING DRY years

*Courtesy of Tony Westerling, UC-Merced*

*Ignition front, Beatty Fire 2006*
Invader Abundance, Fuel Connectivity & Wildfire Size

Average fire size

Invader Abundance (Time)

Nonlinear due to increasing connectivity
Given a nonstationary climate, how will we manage grass invasions and altered wildfire regimes in the American deserts? What should post-fire treatments such as reseeding aim for?

June 2005  Cave Creek Complex Fire, AZ  248,000 acres
Potential Distribution of Buffelgrass in Arizona under Present Conditions

Courtesy of Aaryn Olsson, U of Arizona
Best Case Climate Change Scenario

Land Area

Climate Variable

Decreased Risk

Total Distribution

Retreat Area?

Invasive Distribution

At Risk

Bradley & Wilcove 2009
Climate Ensemble Modeling

Projected Change in Intermountain West Precipitation by 2100

Bradley & Wilcove 2009
Bradley & Wilcove 2009
Post-Disturbance Treatments, Shifting Seed Transfer Zones & Assisted Migration in a Changing and Uncertain Climate

How do science, land management, and the seed industry mobilize to meet this challenge?
Issues & Opportunities for the Seed Industry

• Climate variability & climate change will affect opportunities for seeding and its success.

• Most successful seed ventures probably will be the ones that best assimilate short and long-lead climatic ecological forecasts and anticipate regional needs.

• Long-term success of post-fire seeding in the American deserts will require novel mixes of species, phenotypes, and genotypes adapted to future, not past, climates.

• "Assisted migration" may target not just endangered species but also common ones, requiring abundant and well accessioned seed sources.

• As large-scale ecological disturbances increase with plant invasions and climate change, there will be an increasing need to manage the products of succession.
Summary

- D2M variability will continue to modulate rates of invasion and opportunities for intervention
- Climate change could produce both contractions and expansions of invasive grasses, depending on species
- C4 summer-flowering grasses such as buffelgrass will expand their range north and upslope
- Earlier spring onsets are increasing fire frequency and size in western forests
- Fires associated with winter annual grasses are changing the relationship between ENSO and fire in both the deserts and forests
- The seed industry needs inspiration and guidance to aid postfire treatments in the context of a changing and uncertain climate and shifting seed transfer zones