Vancouver Island University

Why Bigger, Better, Faster is a Recipe for Disaster in Climate Changing World

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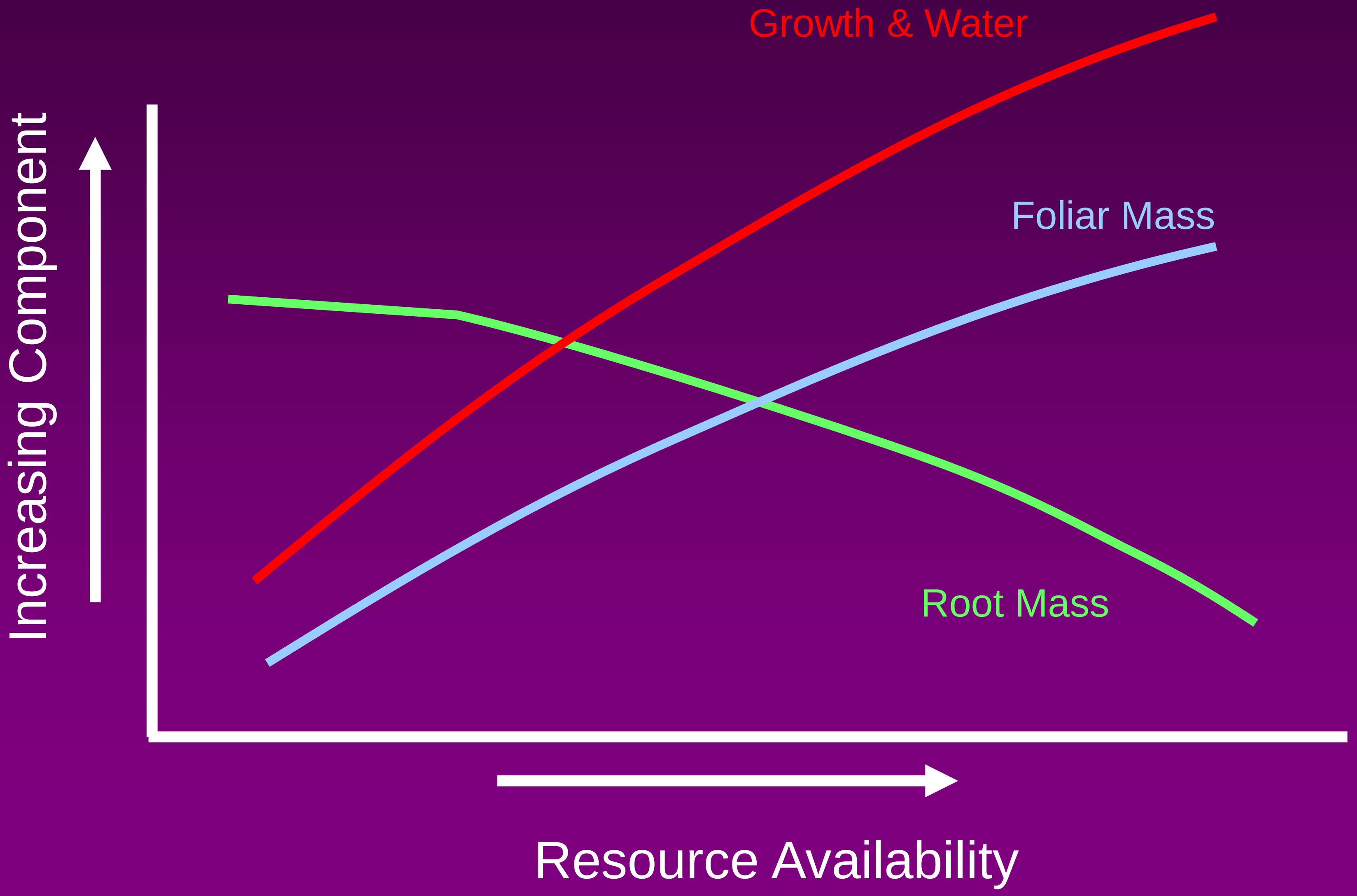
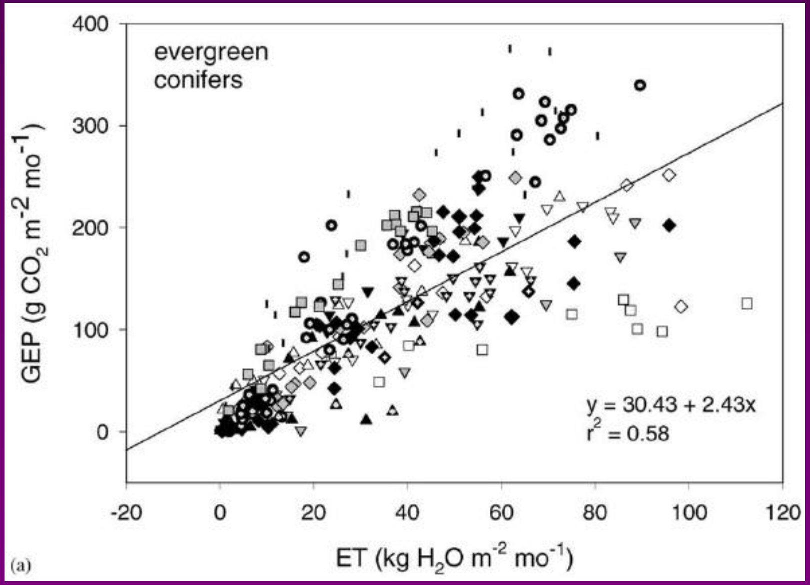
Traditional thought on resource availability and allocation

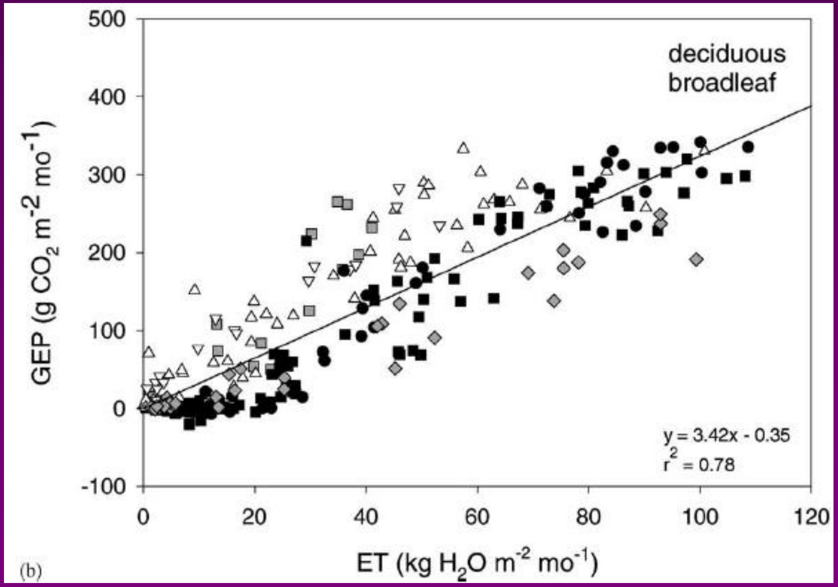


Carbon & Water Relationships

Evergreen Conifers



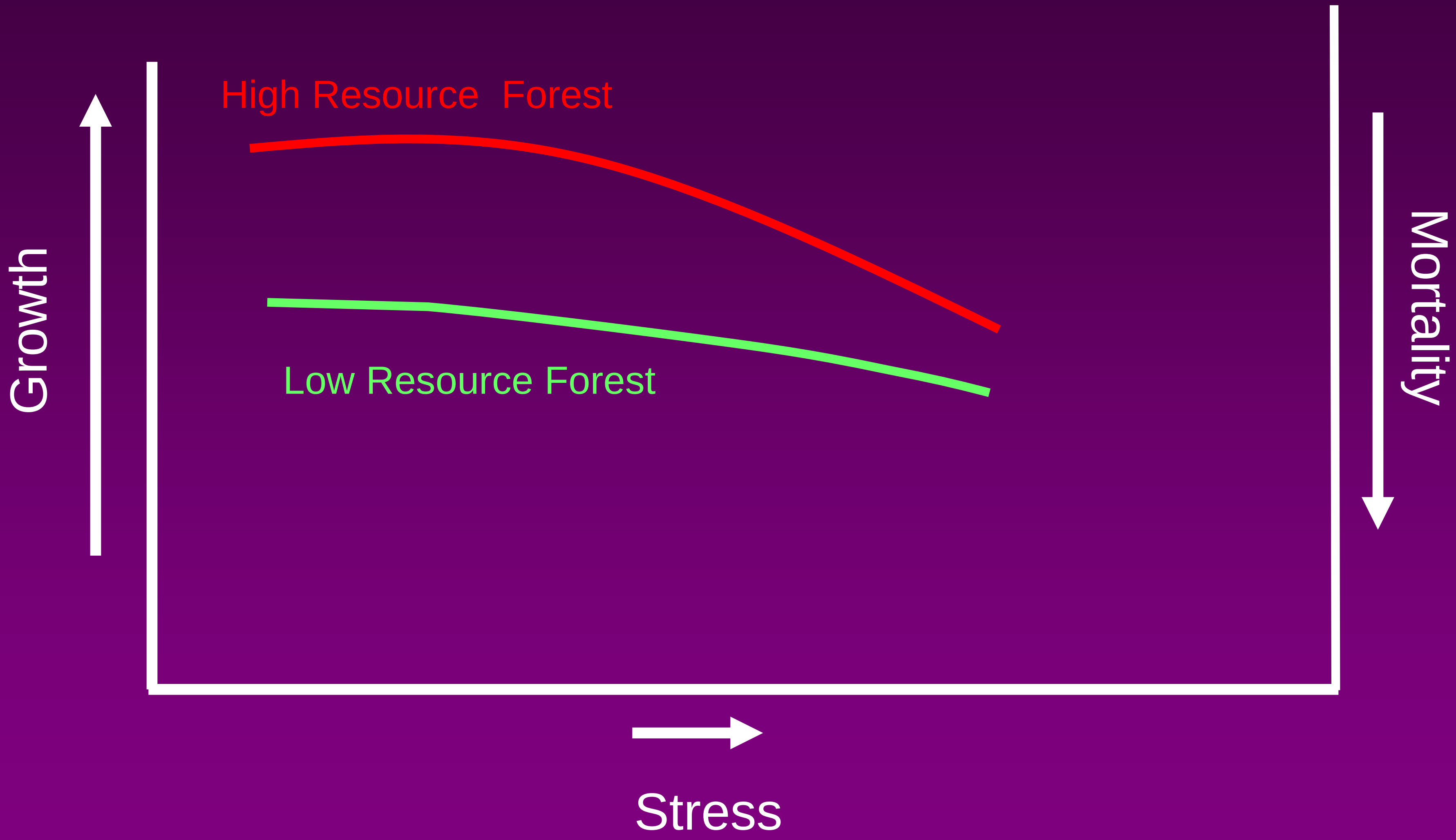
Deciduous Broadleaf

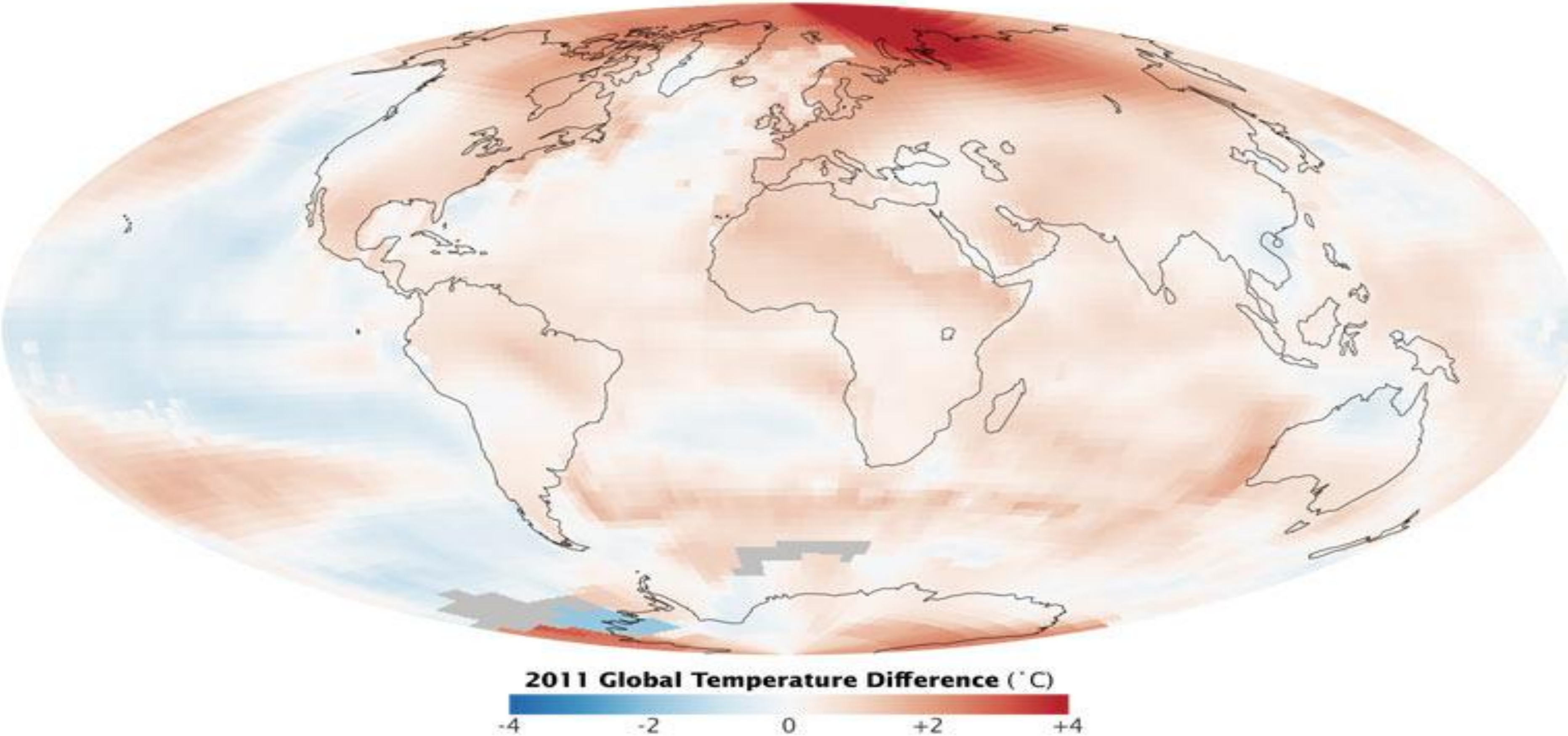


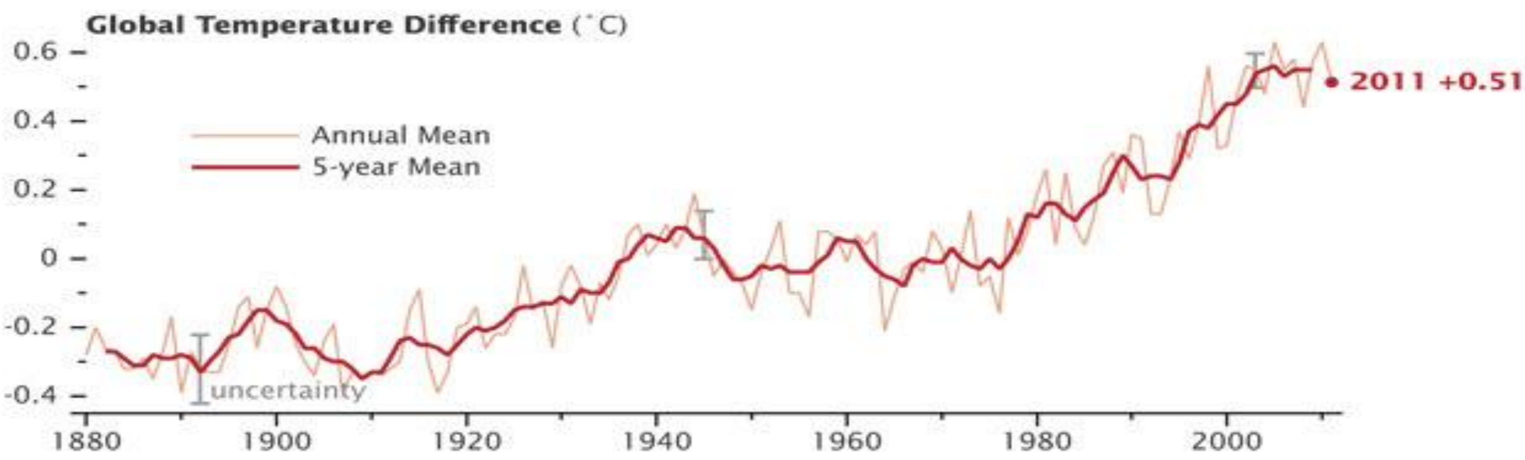
(Law et al., 2002)

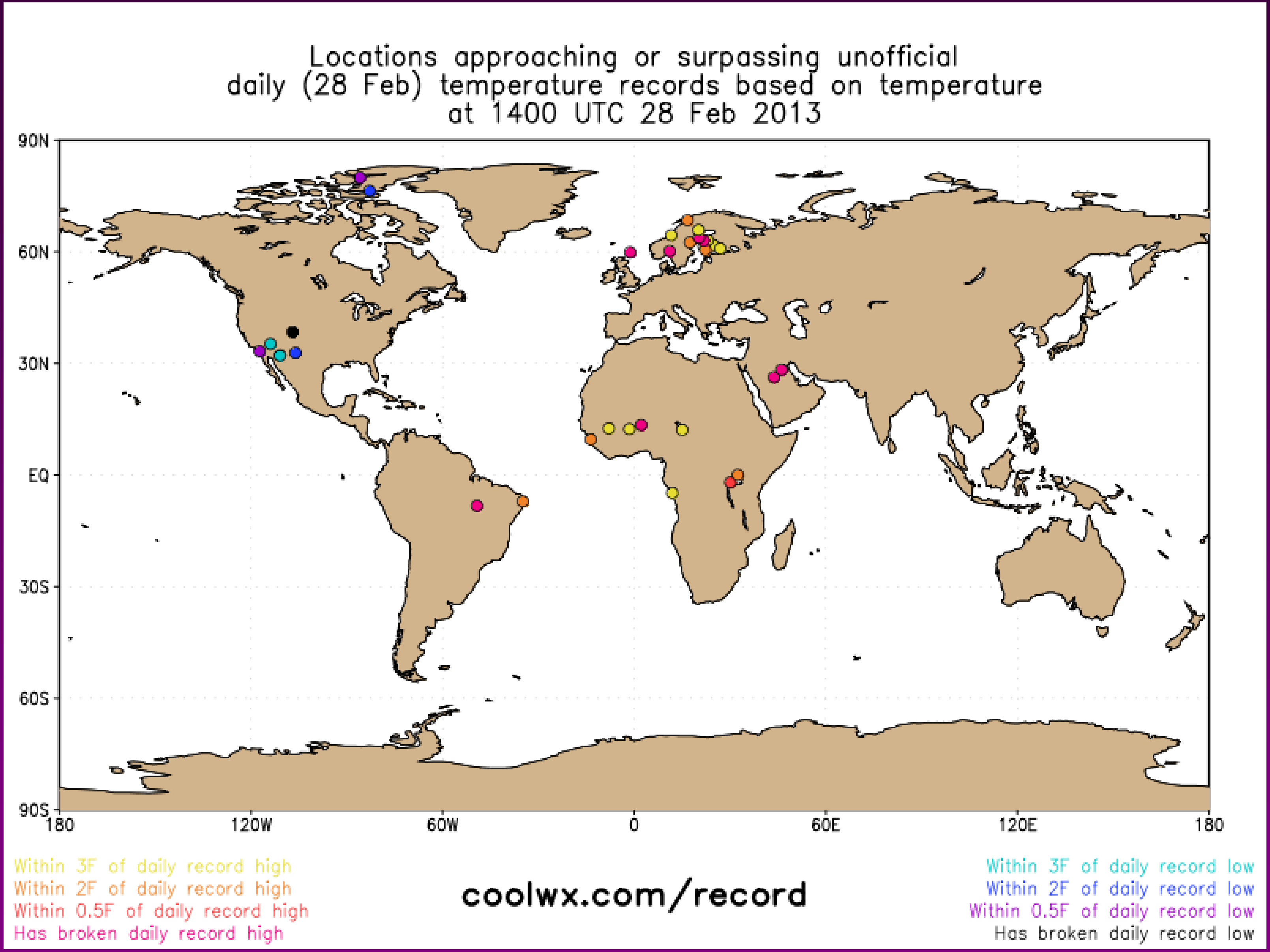
But What about Stress?

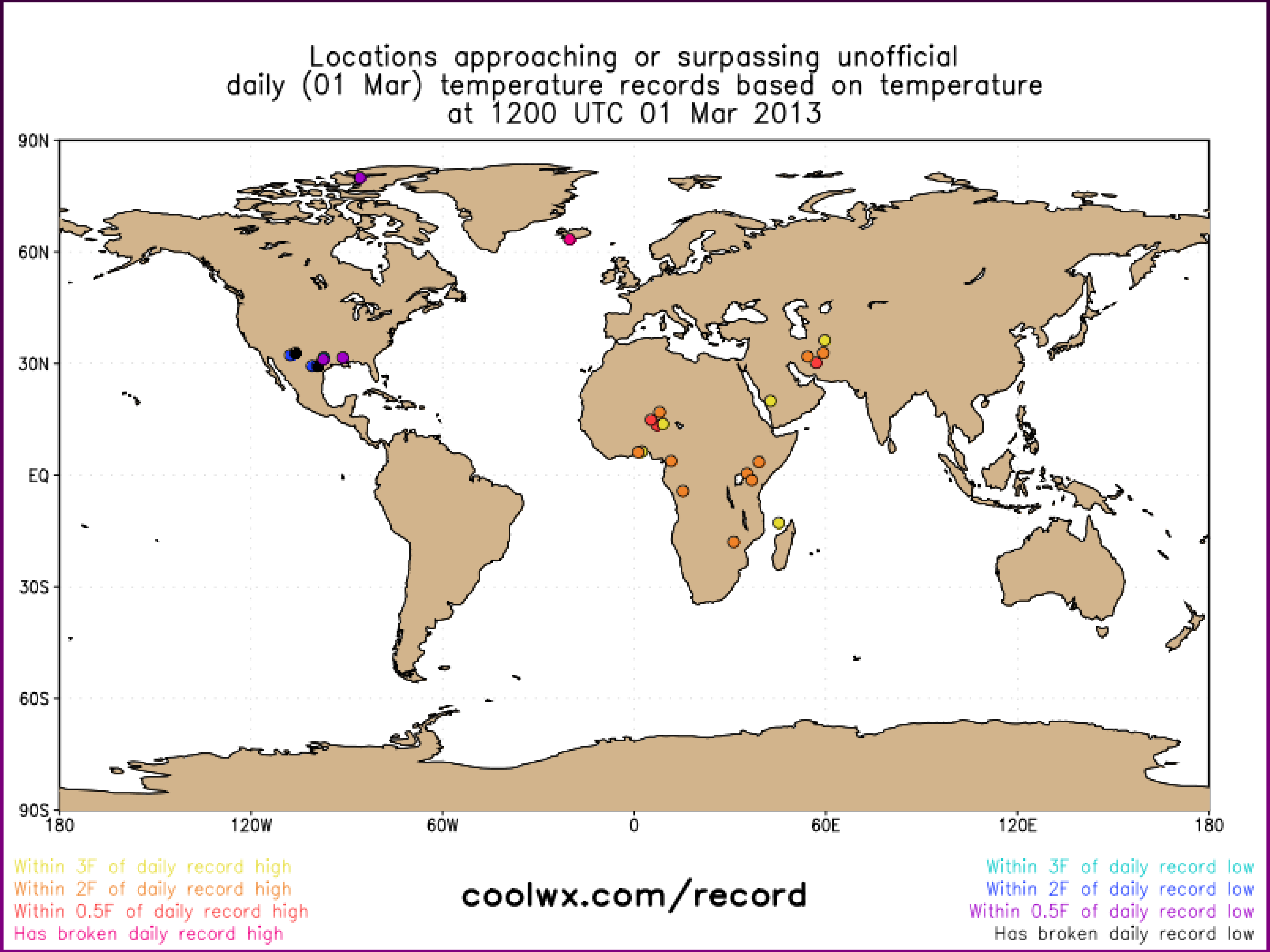
How negative resource availability (i.e. stress) impacts Growth/Mortality




2011 Global Temperature Difference (˚C)
-4
-2
0
+2
+4


Global Temperature Difference (˚C)
0.6
0.4
0.2
0
-0.2
-0.4
Annual Mean
5-year Mean
uncertainty
2011 +0.51
1880
1900
1920
1940
1960
1980
2000


Locations approaching or surpassing unofficial
daily (28 Feb) temperature records based on temperature
at 1400 UTC 28 Feb 2013
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
Within 3F of daily record high
Within 2F of daily record high
Within 0.5F of daily record high
Has broken daily record high
coolwx.com/record
Within 3F of daily record low
Within 2F of daily record low
Within 0.5F of daily record low
Has broken daily record low



Locations approaching or surpassing unofficial
daily (01 Mar) temperature records based on temperature
at 1200 UTC 01 Mar 2013
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
Within 3F of daily record high
Within 2F of daily record high
Within 0.5F of daily record high
Has broken daily record high
coolwx.com/record
Within 3F of daily record low
Within 2F of daily record low
Within 0.5F of daily record low
Has broken daily record low

Daily Record High and Low Global Air Temperatures

	February 28	March 1
High Broken	8	1
High Tied	1	3
High Close to Record	16	15
Low Close to Record	4	3
Low Tied	2	2
Low Broken	2	2

US Recorded Records for past 365 Days

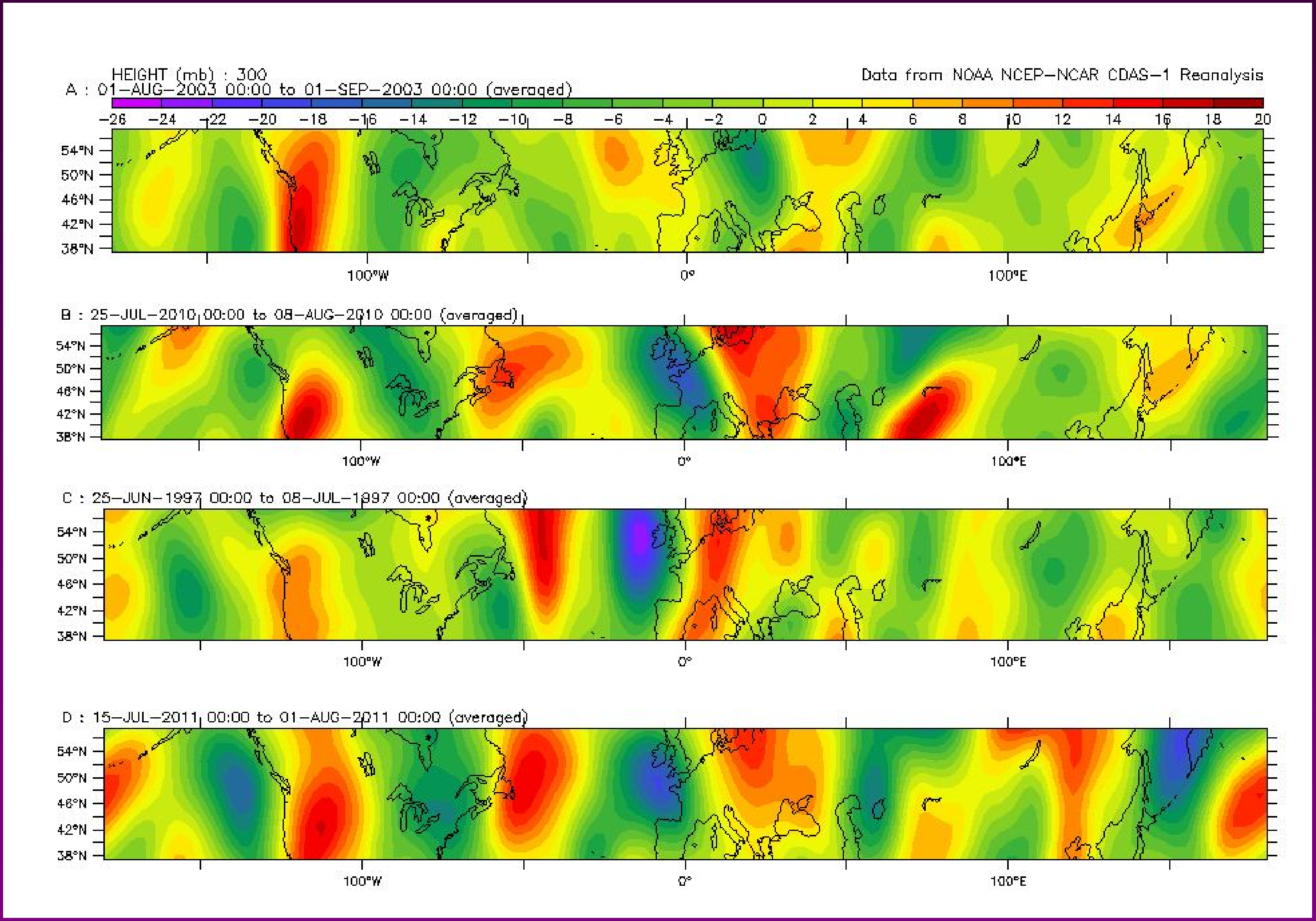
(as of March 1, 2013)

All time record Highs 356

All time record Lows 4

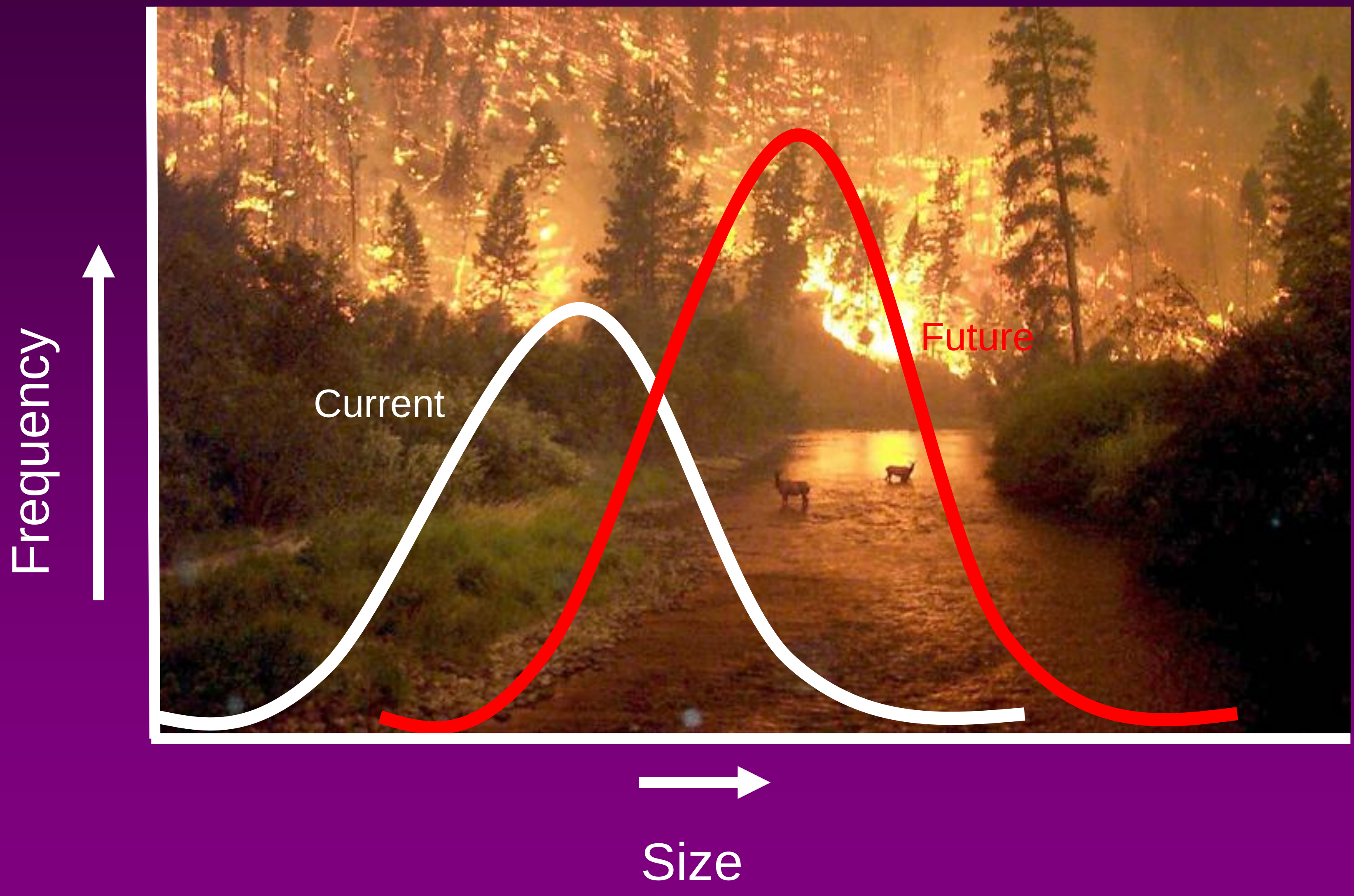
http:///www.ncdc.noaa.gov/extremes/records

Stagnating Air Masses lead to more extreme climate



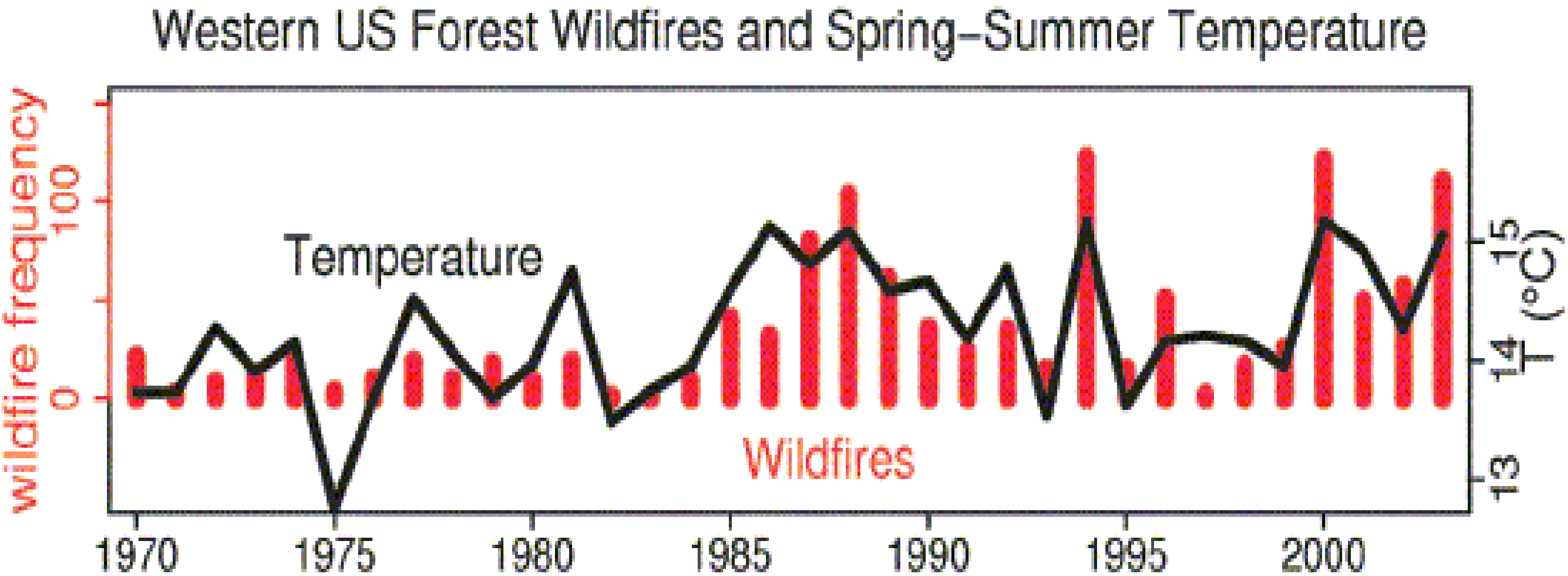
Petoukhov, V., Rahmstorf, S., Petri, S., Schellnhuber, H. J. (2013): Quasi-resonant amplification of planetary waves and recent Northern Hemisphere weather extremes. Proceedings of the National Academy of Sciences (Early Edition)

Wildfire Shifts

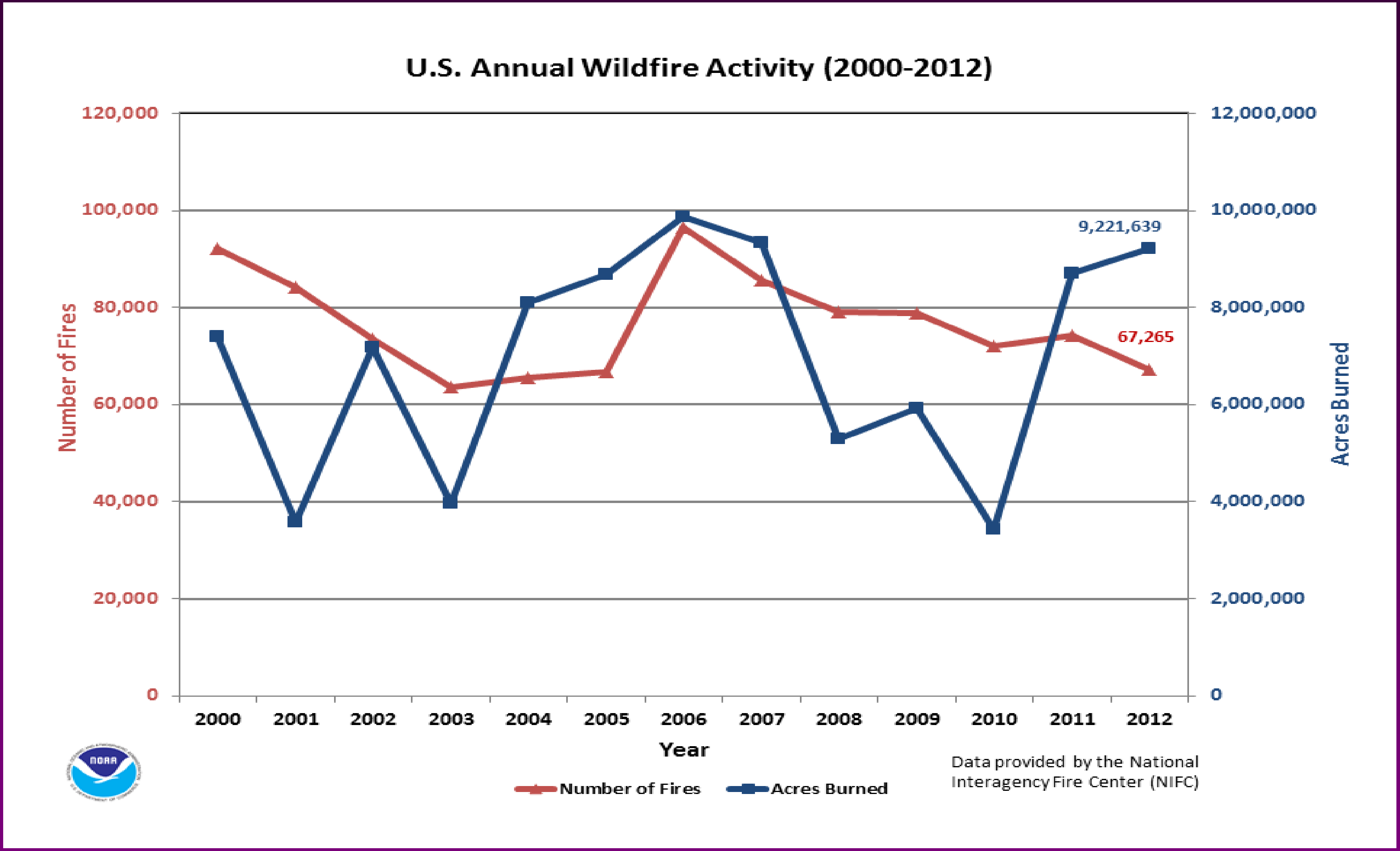



48

Large scale (> 400 ac) Wildfires and Air Temperature

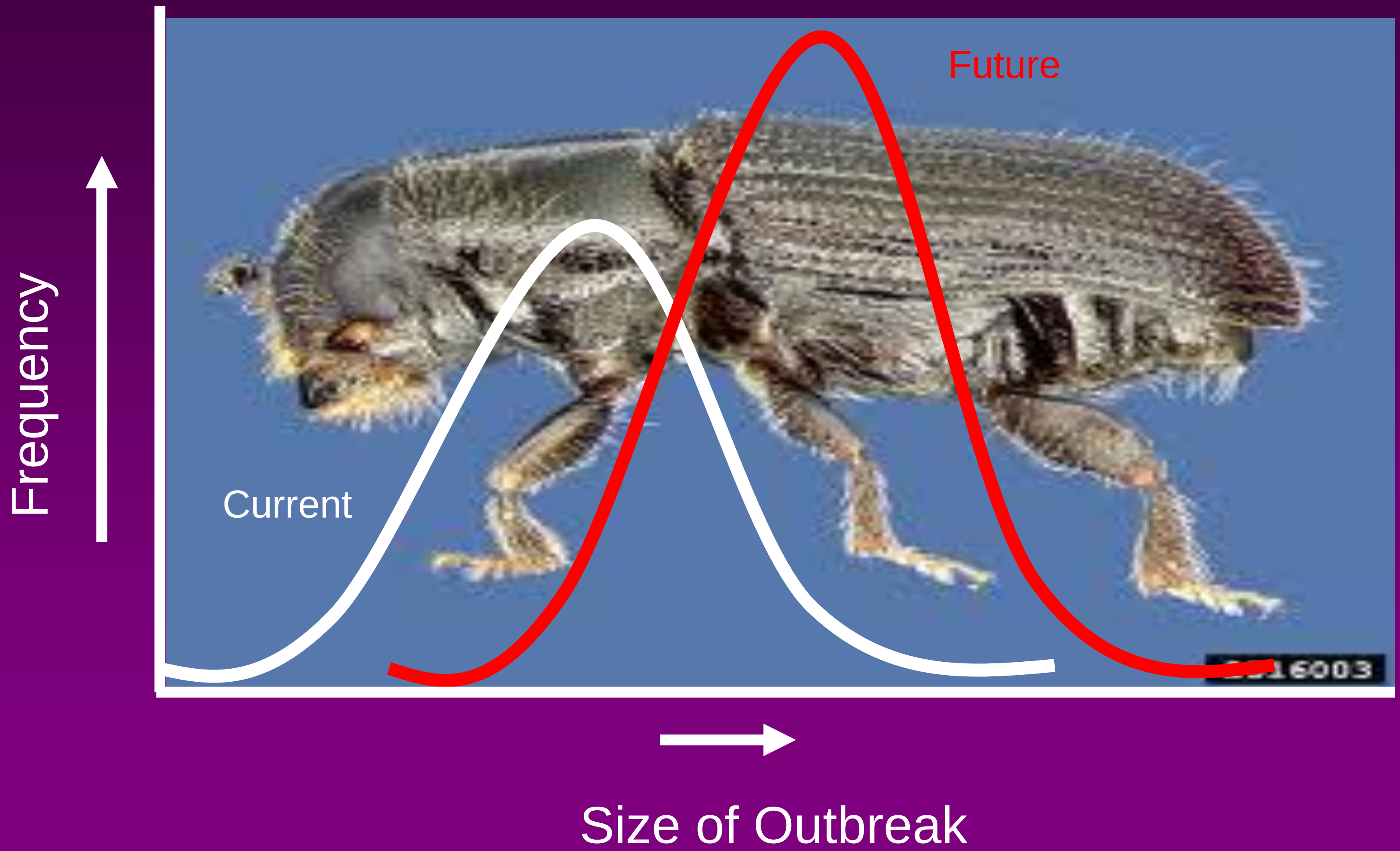


From Westerling et al. 2005

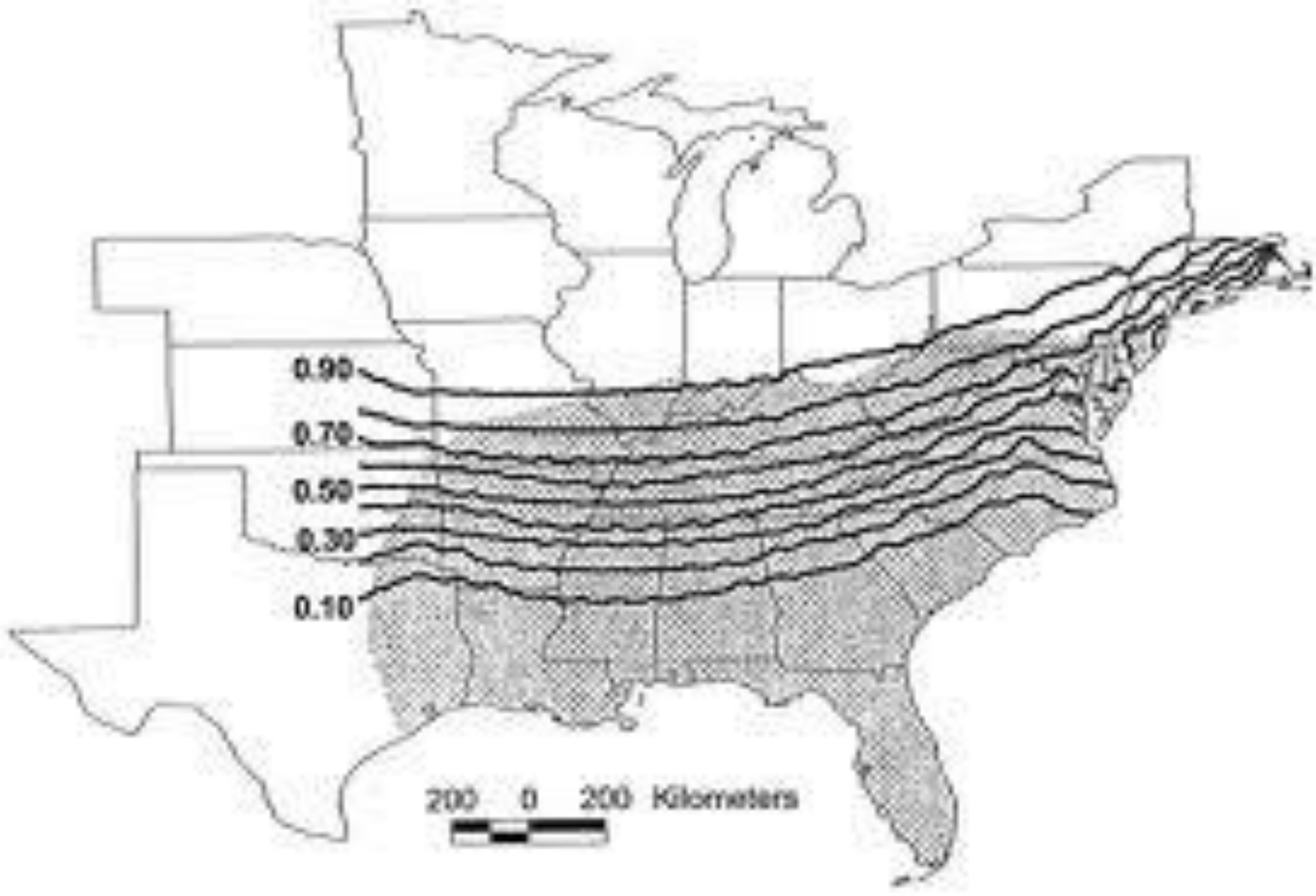


Area burned per fire highest in 2012 over the 13 year recording period

Insect Outbreak Shifts

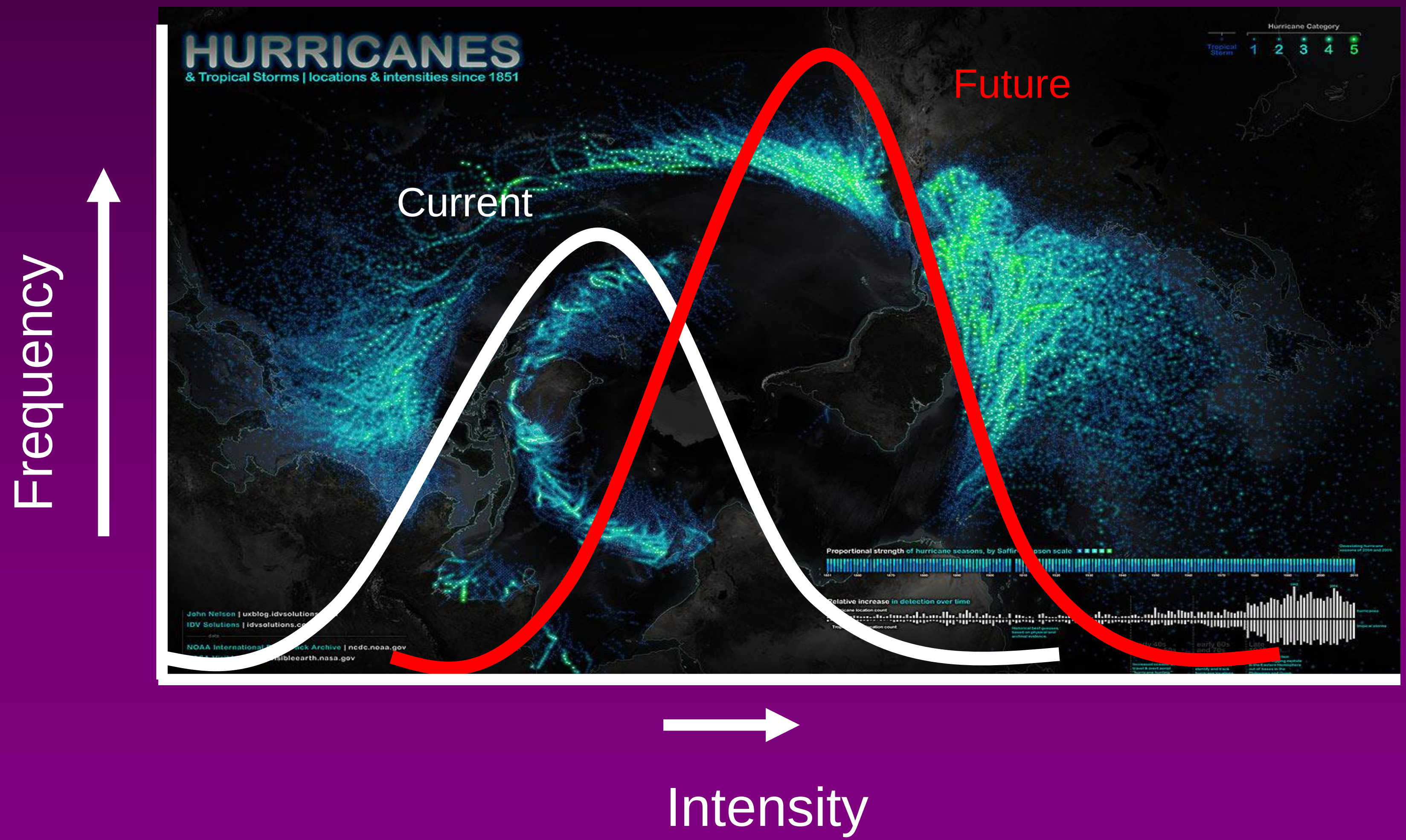


Southern Pine Beetle Range Shift



Ayres and Lombardero 2000

Hurricane Shifts



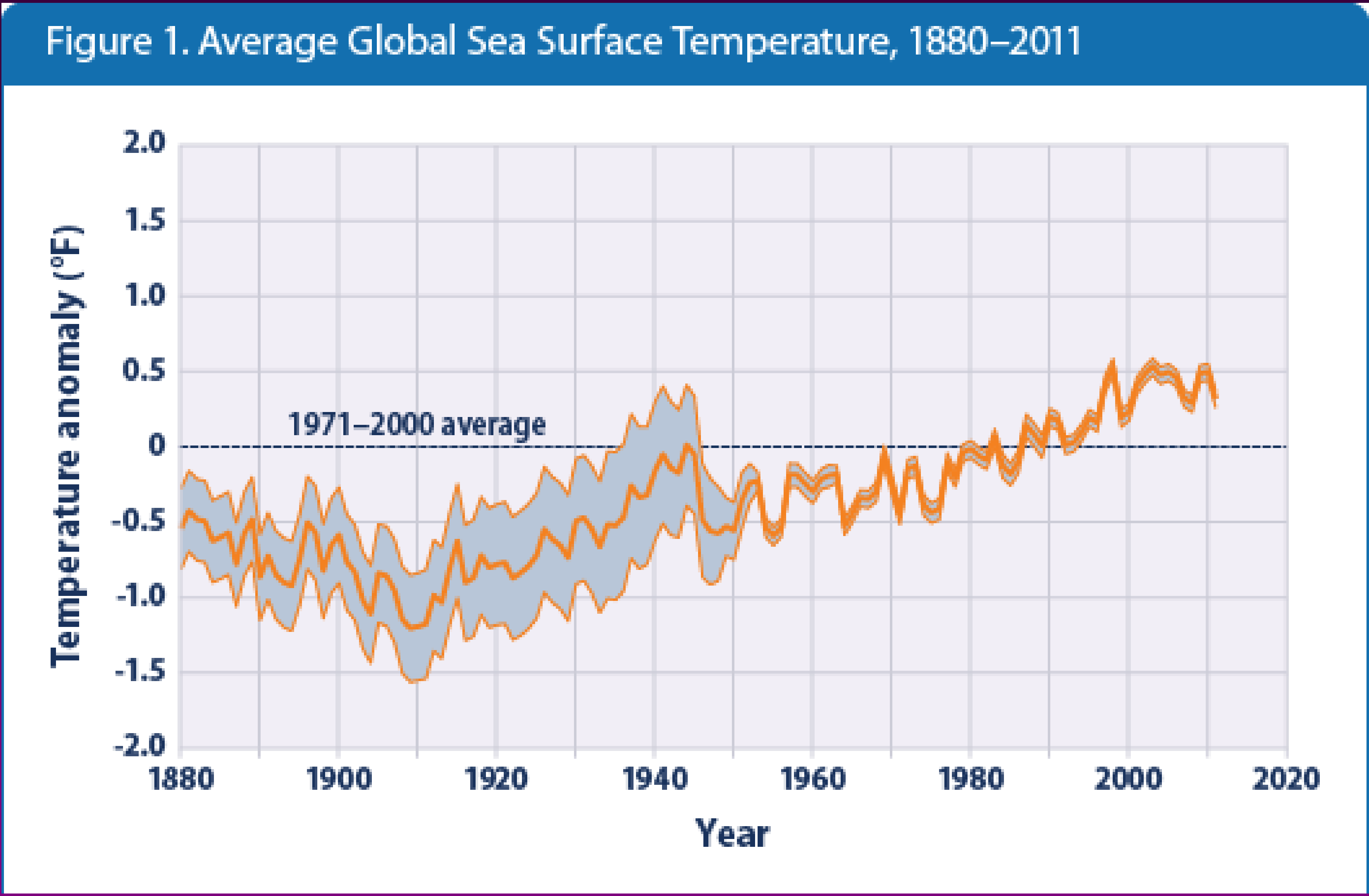


Figure 1. Average Global Sea Surface Temperature, 1880–2011
Temperature anomaly (°F)
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
1971–2000 average
1880
1900
1920
1940
1960
1980
2000
2020
Year

EPA. Gov

Eos, Vol. 87, No. 24, 13 June 2006

EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 87 NUMBER 24

13 JUNE 2006

PAGES 233–244

Atlantic Hurricane Trends Linked to Climate Change

PAGES 233, 238, 241

Increases in key measures of Atlantic hurricane activity over recent decades are believed to reflect, in large part, contemporaneous increases in tropical Atlantic warmth [e.g., *Emanuel*, 2005]. Some recent studies [e.g., *Goldenberg et al.*, 2001] have attributed these increases to a natural climate cycle termed the Atlantic Multidecadal Oscillation (AMO), while other studies suggest that climate change may instead be playing the dominant role [*Emanuel*, 2005; *Webster et al.*, 2005].

Using a formal statistical analysis to separate the estimated influences of anthropogenic climate change from possible natural cyclical influences, this article presents results indicating that anthropogenic factors are likely responsible for long-term trends in tropical Atlantic warmth and tropical cyclone activity. In addition, this analysis indicates that late twentieth century tropospheric aerosol cooling has offset a substantial fraction of anthropogenic warming in the region and has thus likely suppressed even greater potential increases in tropical cyclone activity.

By M. E. Mann and K. A. Emanuel

AMO Revealed

The multidecadal oscillatory pattern in Atlantic sea surface temperature (SST), referred to as the AMO, was first isolated by *Folland et al.* [1986], and was confirmed by subsequent analyses of observational [e.g., *Mann and Park*, 1994; *Schlesinger and Ramankutty*, 1994] and longer-term proxy climate data [e.g., *Delworth and Mann*, 2000]. Modeling studies [e.g., *Delworth et al.*, 1993;

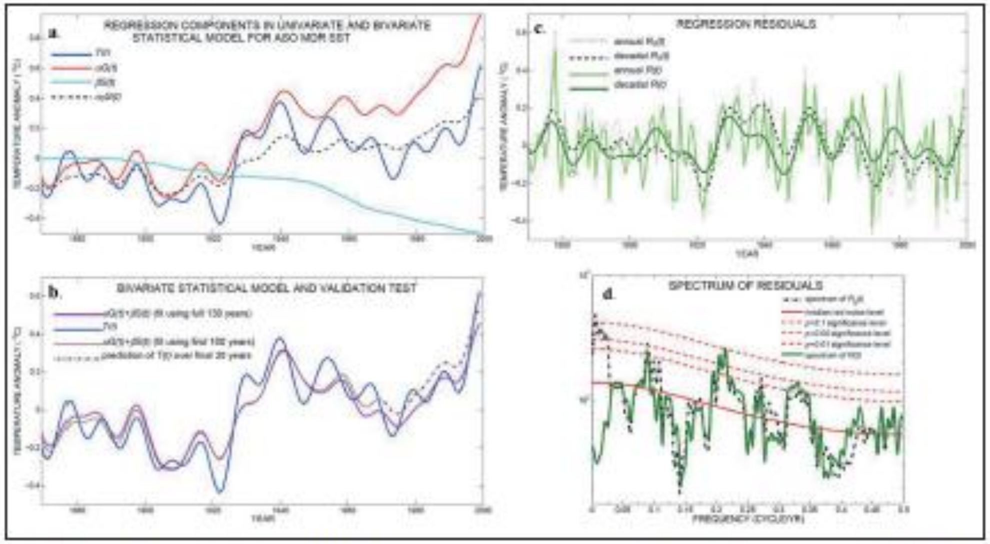
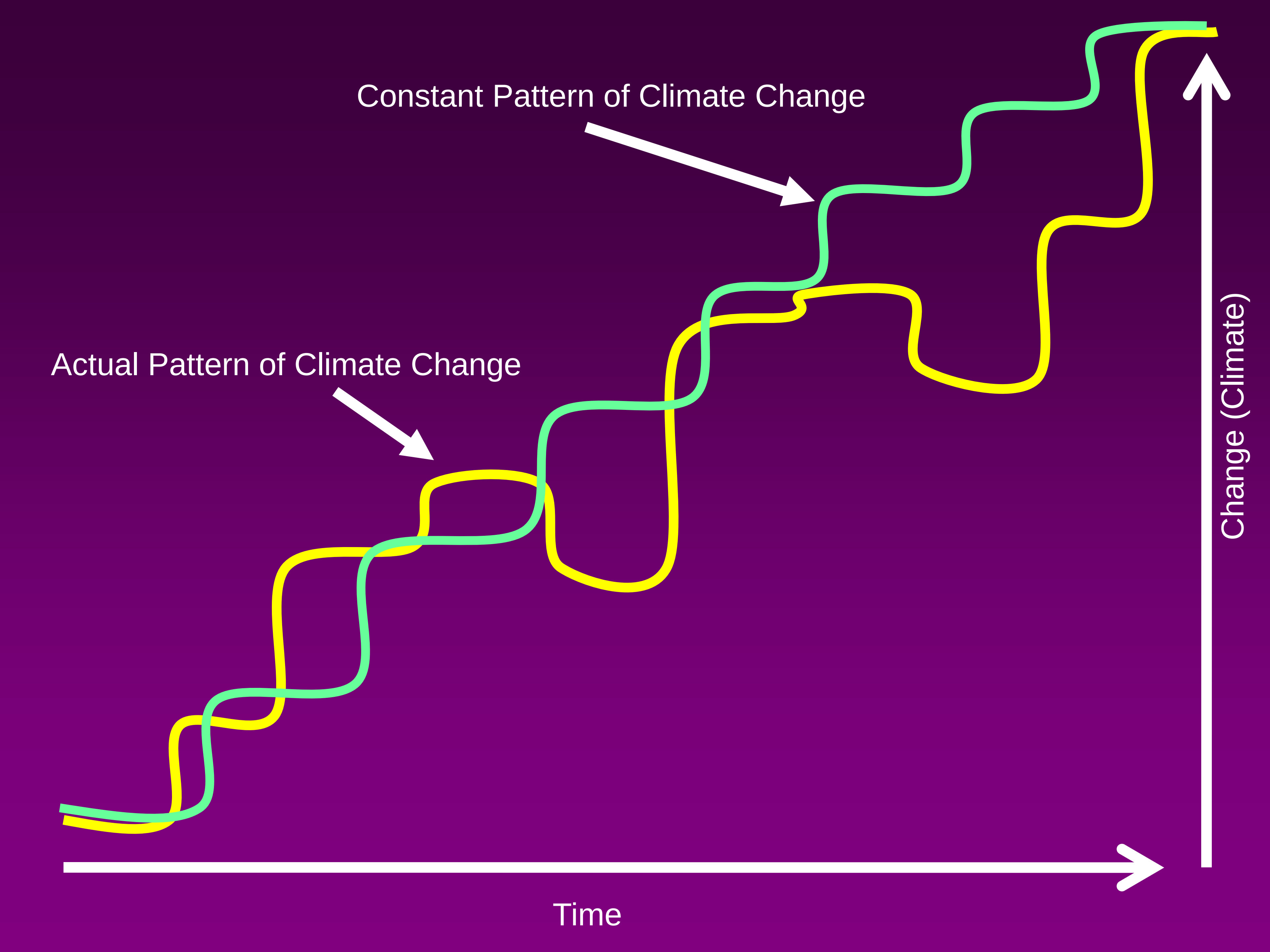
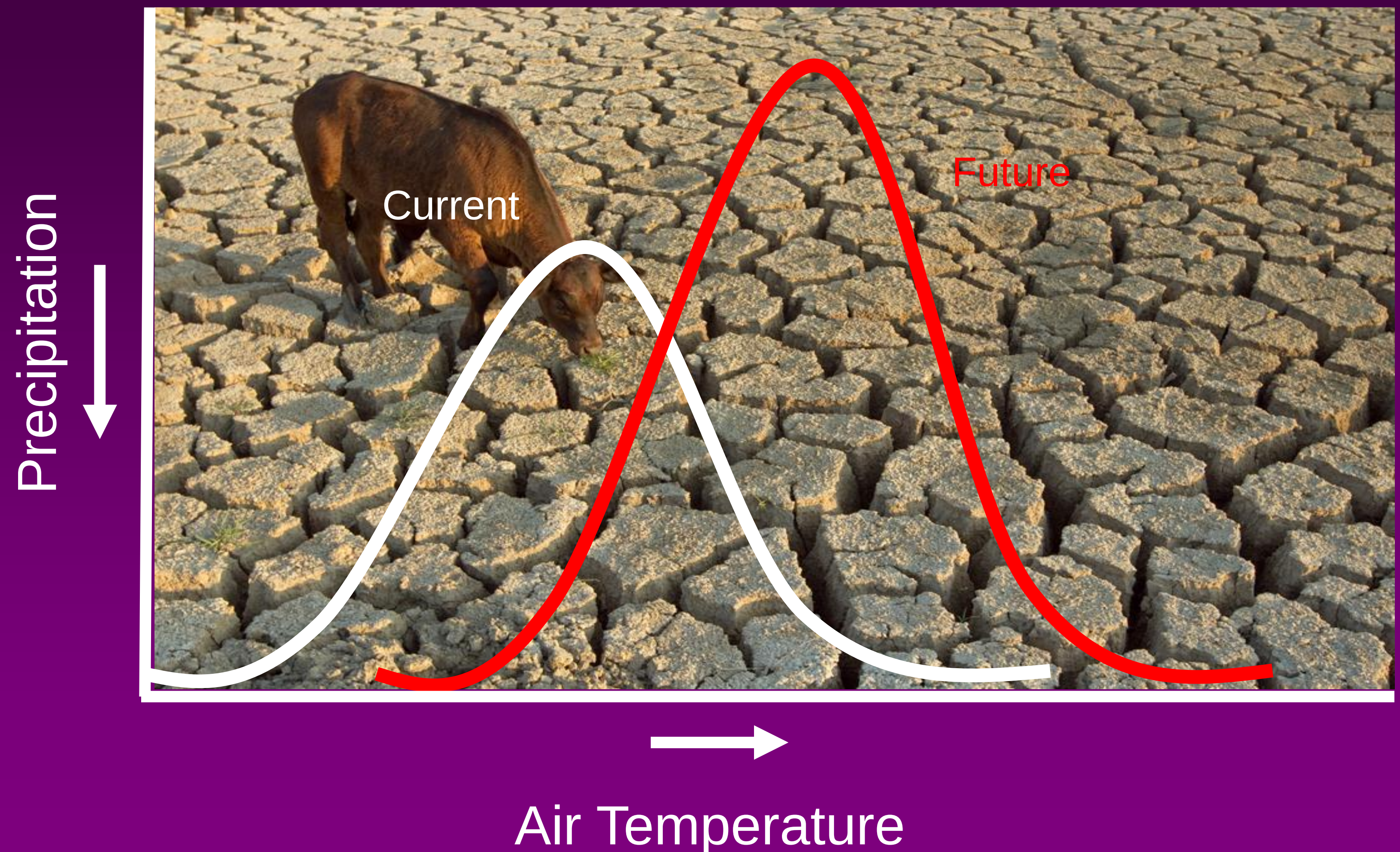
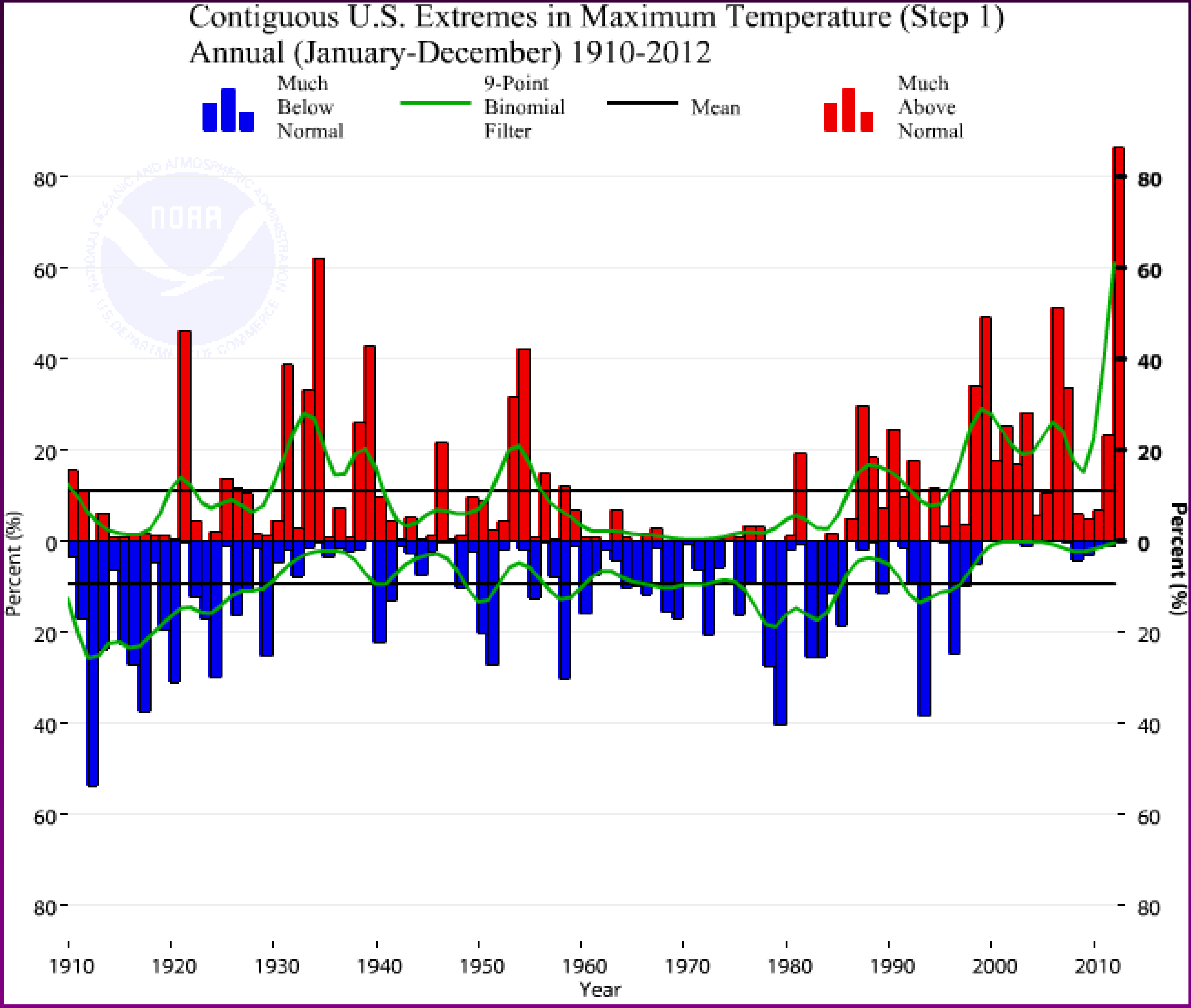


Fig. 1. Analyses of sea surface temperature (SST) series. (a) Decadally smoothed August-September-October (ASO) main development region (MDR) SST series T(t) and estimated components for both (1) univariate regression [equation (1)] using ASO global mean SST [αG(t)] and (2) bivariate regression [equation (2)] including the components associated with ASO global mean SST [αG(t)] and the regional enhancement of anthropogenic tropospheric aerosol cooling [βS(t)]. (b) Bivariate statistical model [equation (2)] for T(t) based on the sum of both regression components shown in Figure 1a. Shown also is the fit of the regression model based on the restricted interval 1870–1969 and the prediction of T(t) over the subsequent 30 years (1970–1999) based on that regression model. (c) Annual and decadally smoothed univariate [R_u(t)] and bivariate [R(t)] regression residuals. (d) Power spectrum of univariate [R_u(t)] regression residuals, with estimated red noise level and associated p = 0.1, 0.05, and 0.01 significance levels. Shown for comparison is the spectrum for the bivariate regression residual [R(t)]. See additional material for further details.

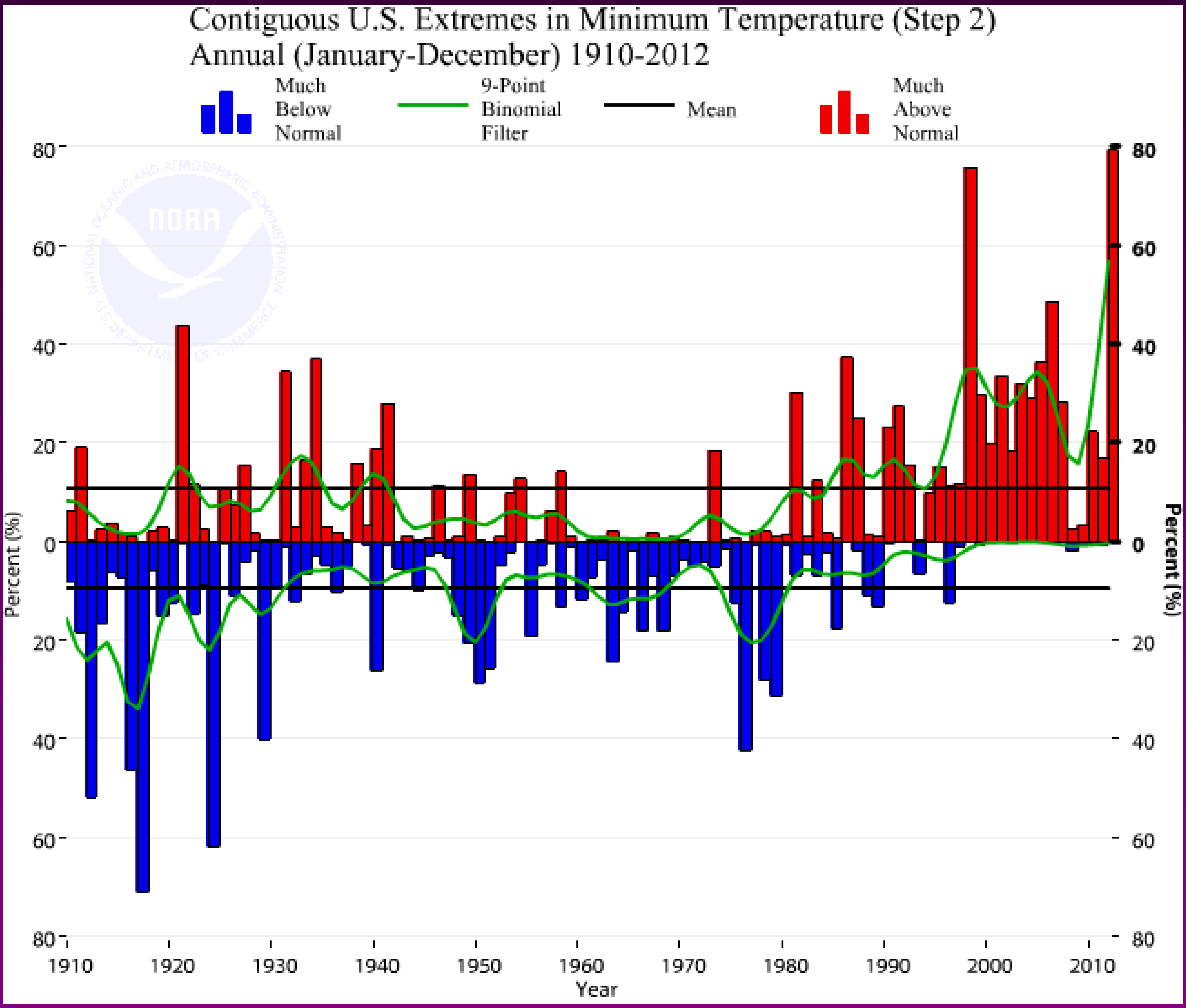

Constant Pattern of Climate Change
Actual Pattern of Climate Change
Change (Climate)
Time

Drought

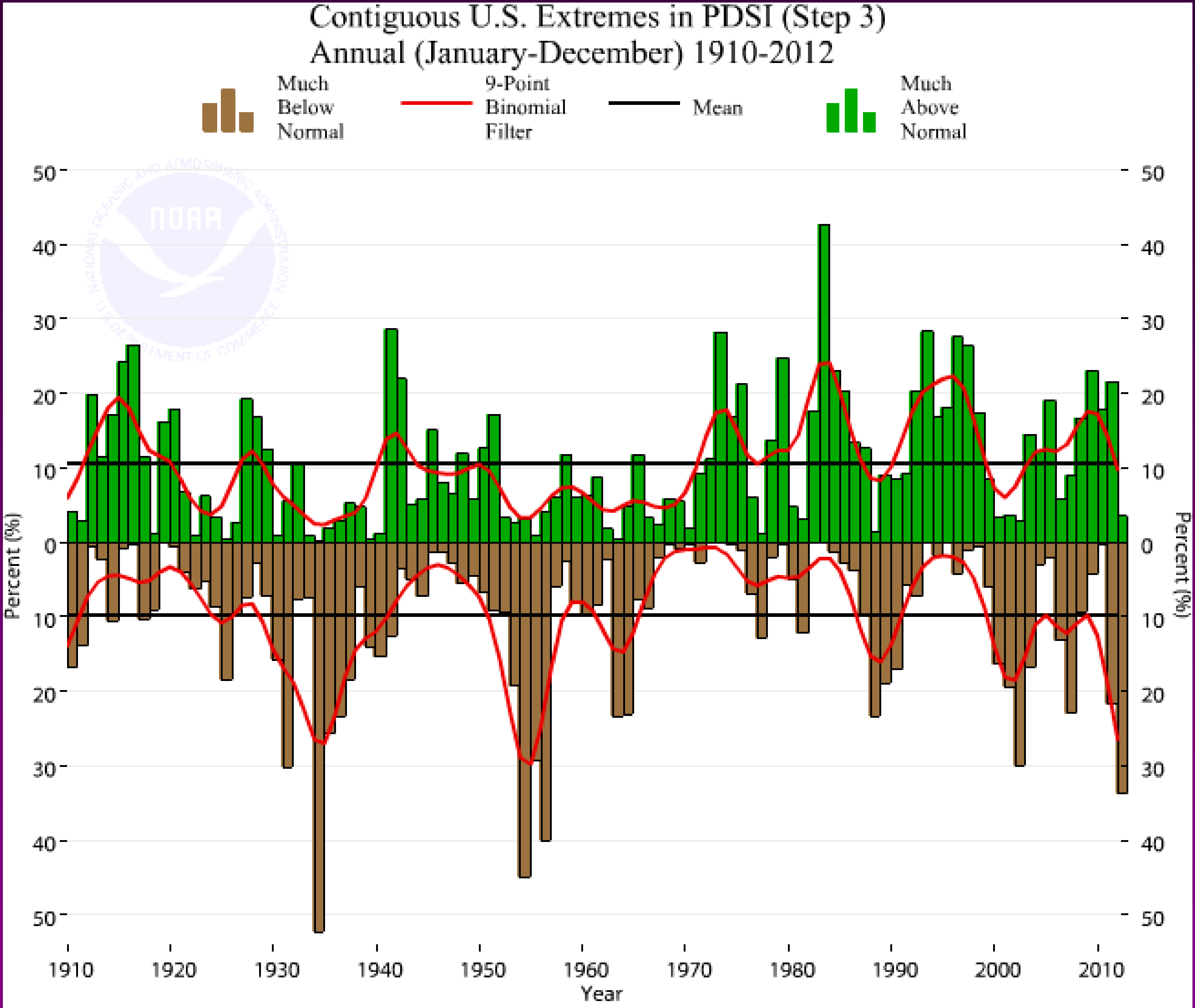


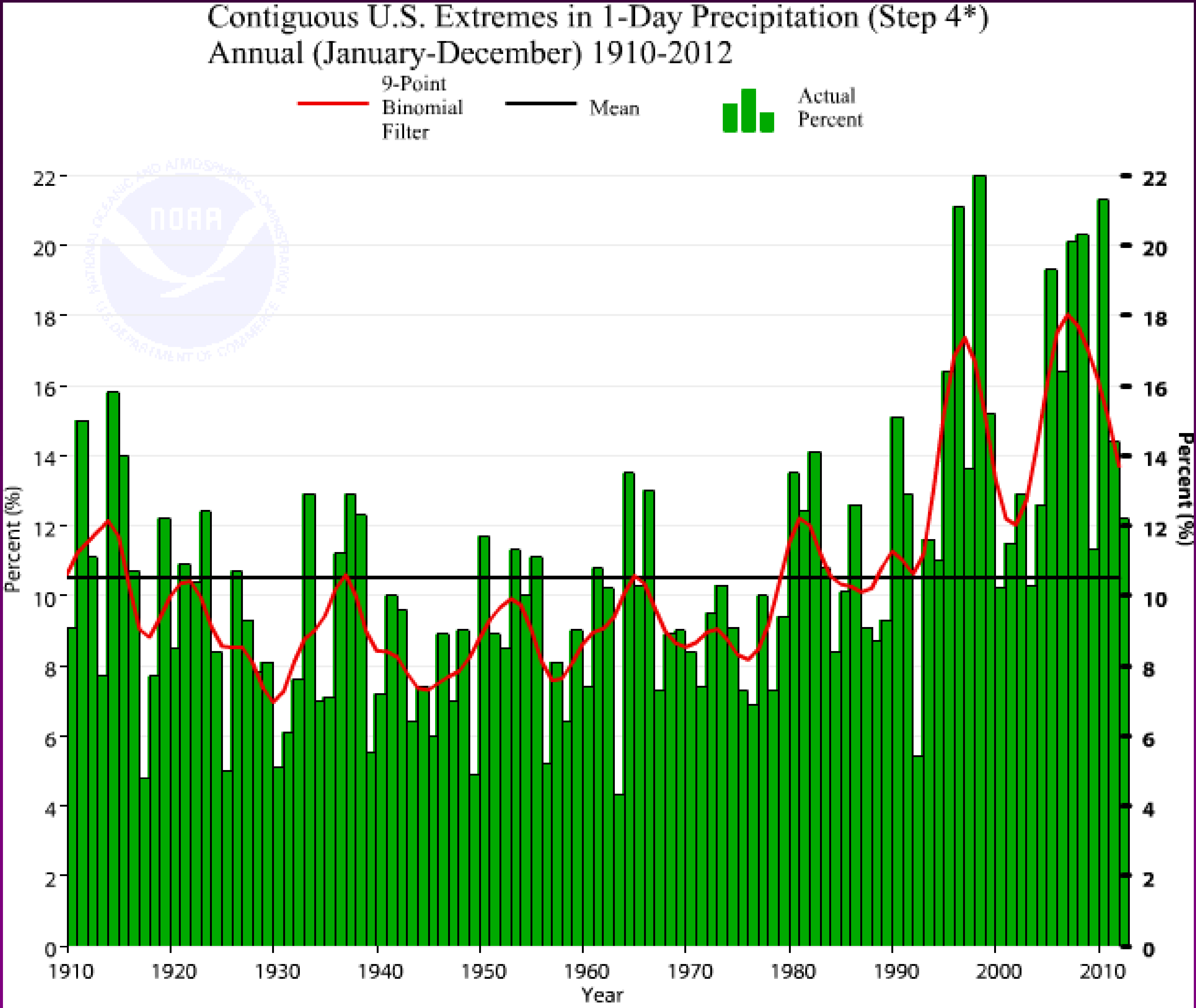


Contiguous U.S. Extremes in Maximum Temperature (Step 1)
Annual (January-December) 1910-2012
Much Below Normal
9-Point Binomial Filter
Mean
Much Above Normal
Percent (%)
Year
80
60
40
20
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

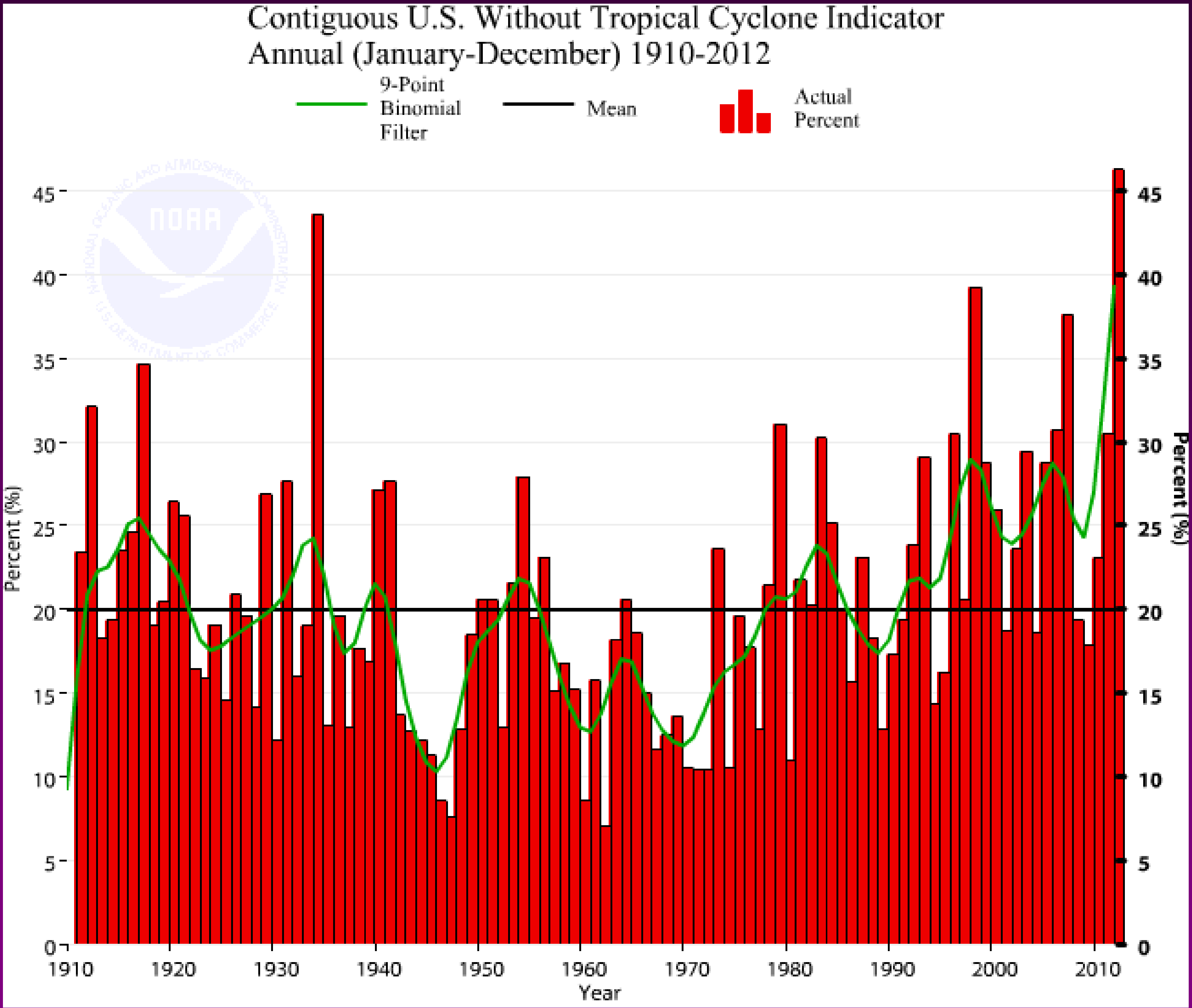


Contiguous U.S. Extremes in Minimum Temperature (Step 2)
Annual (January-December) 1910-2012
Much Below Normal
9-Point Binomial Filter
Mean
Much Above Normal
80
60
40
20
0
20
40
60
80
Percent (%)
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year


Contiguous U.S. Extremes in PDSI (Step 3)
Annual (January-December) 1910-2012
Much Below Normal
9-Point Binomial Filter
Mean
Much Above Normal
Percent (%)
Year
50
40
30
20
10
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

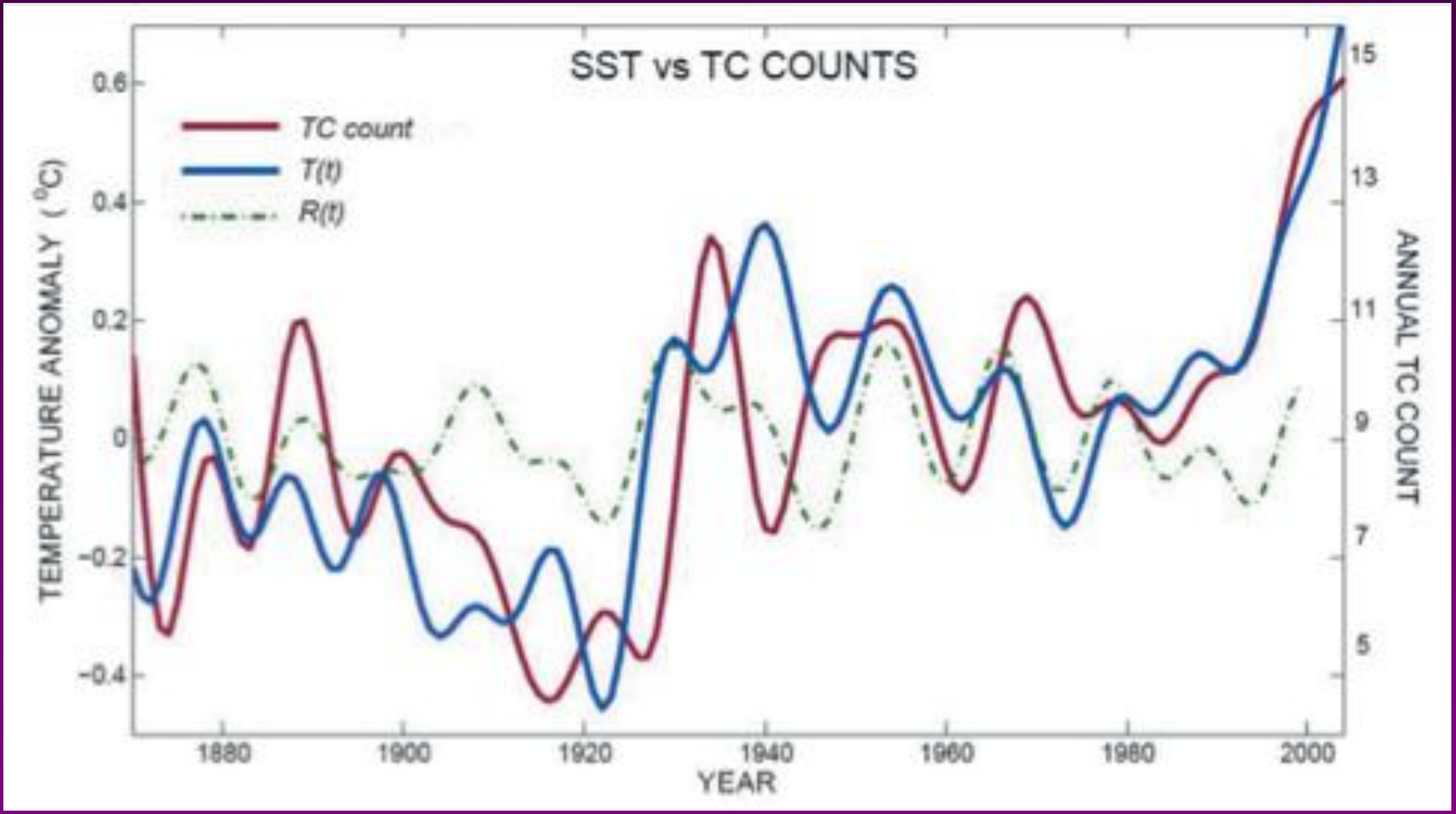


Contiguous U.S. Extremes in 1-Day Precipitation (Step 4*)
Annual (January-December) 1910-2012
9-Point Binomial Filter
Mean
Actual Percent
Percent (%)
Year
0
2
4
6
8
10
12
14
16
18
20
22
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

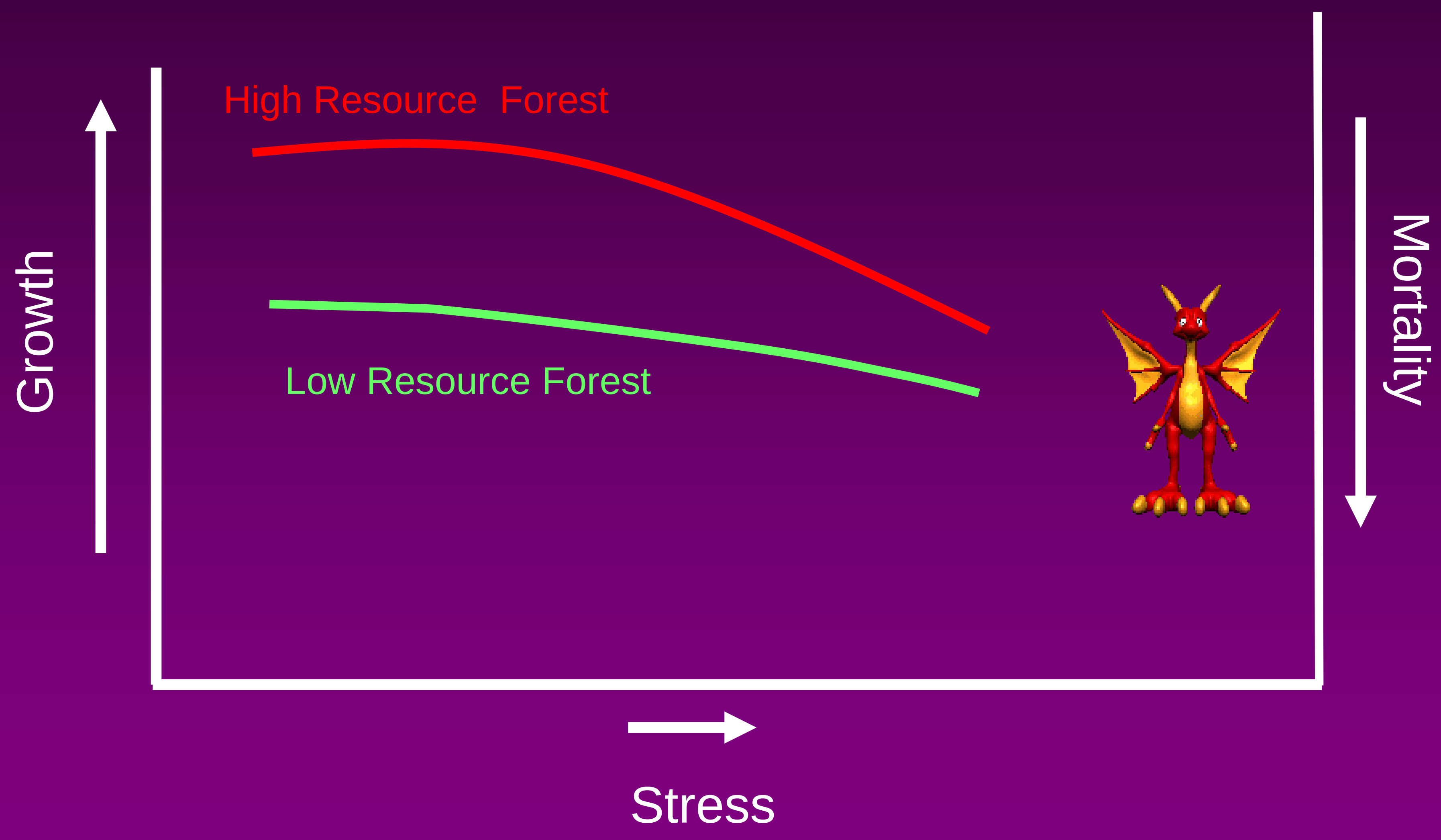


Contiguous U.S. Without Tropical Cyclone Indicator
Annual (January-December) 1910-2012
9-Point Binomial Filter
Mean
Actual Percent
Percent (%)
Year
0
5
10
15
20
25
30
35
40
45
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

Sea Surface Temp. vs. Storms

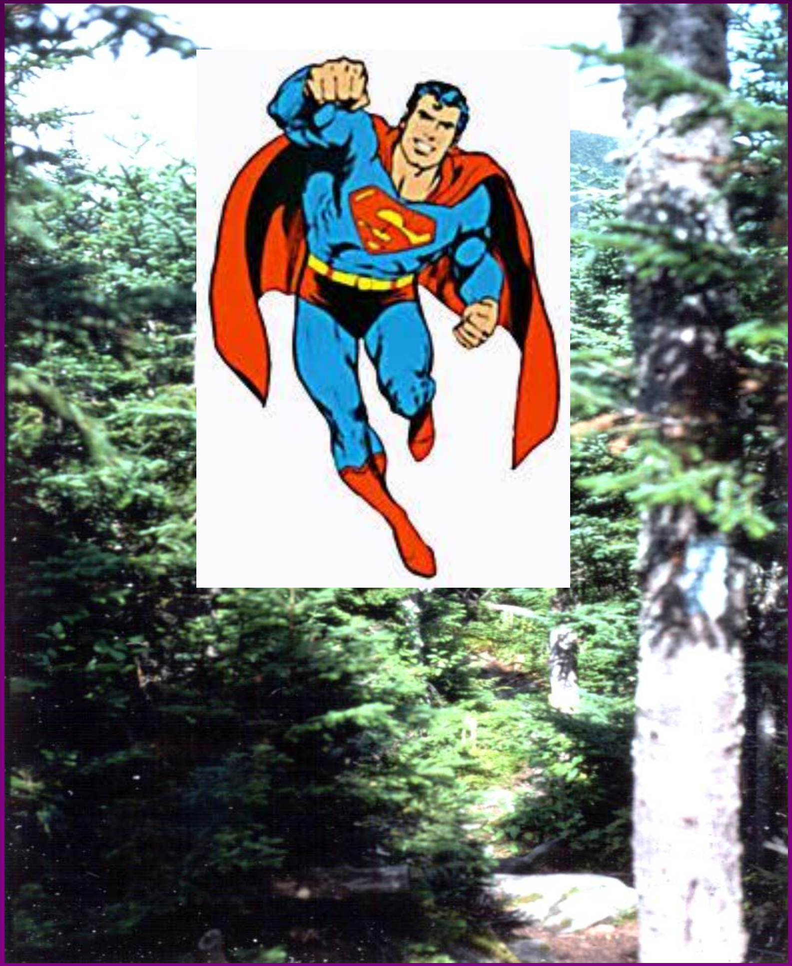


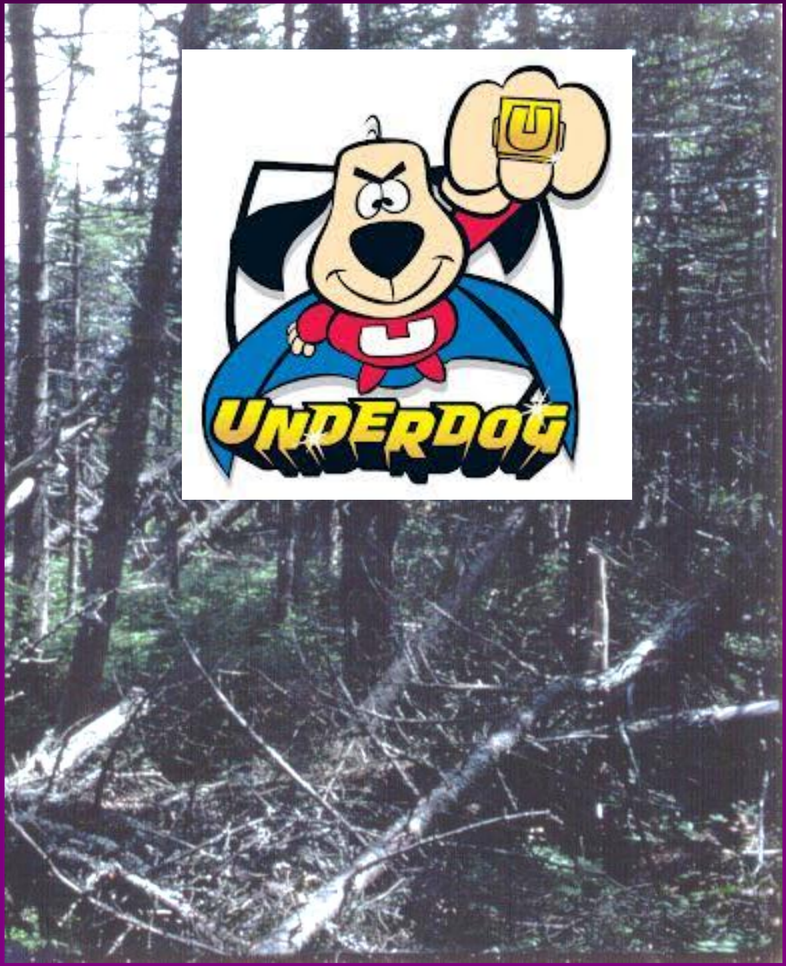
How negative resource availability (i.e. stress) impacts Growth/Mortality



What happens when you take stress beyond previously observe range:

"The Curious case of the 'Underdog' spruce"



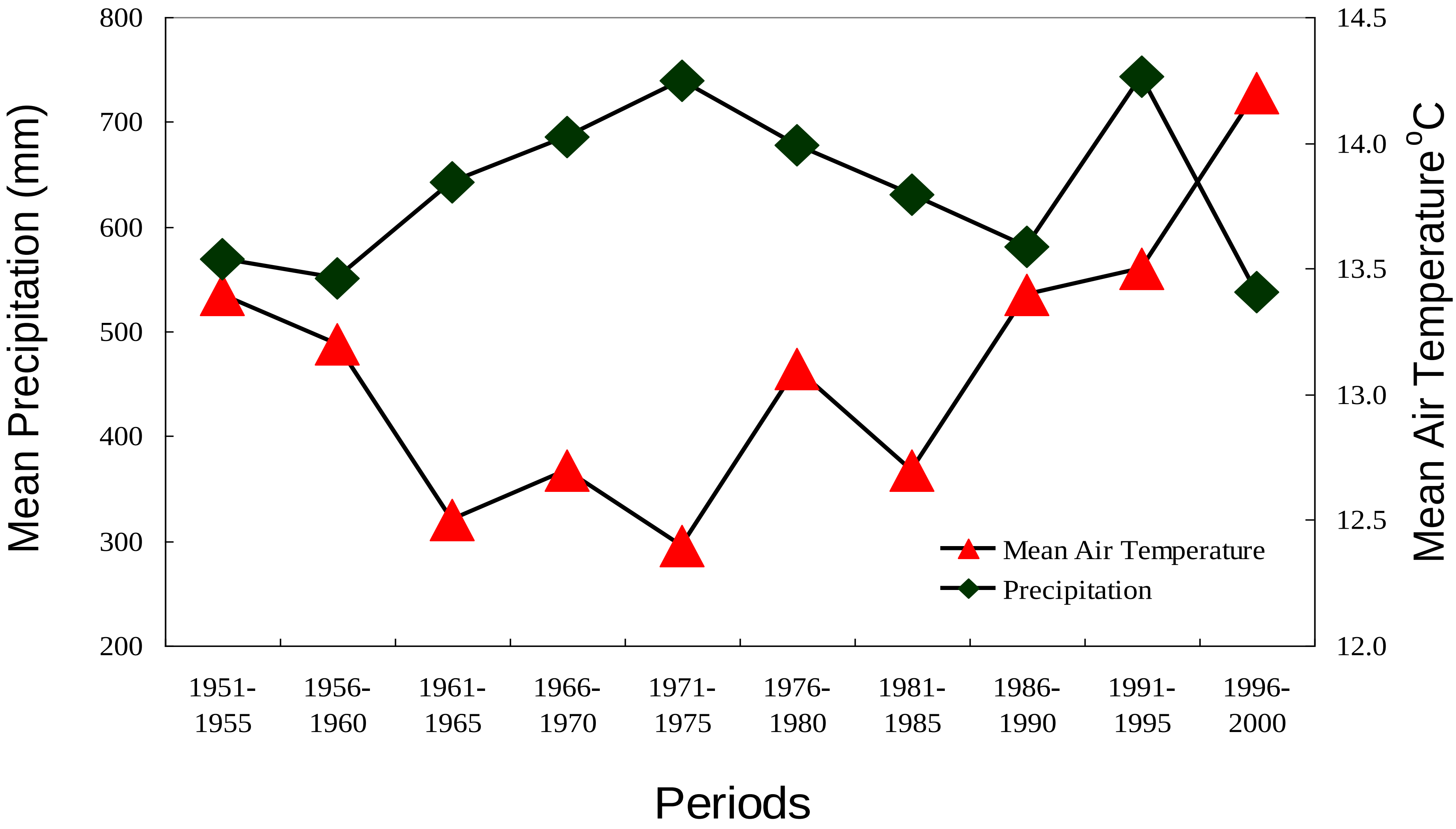


Background

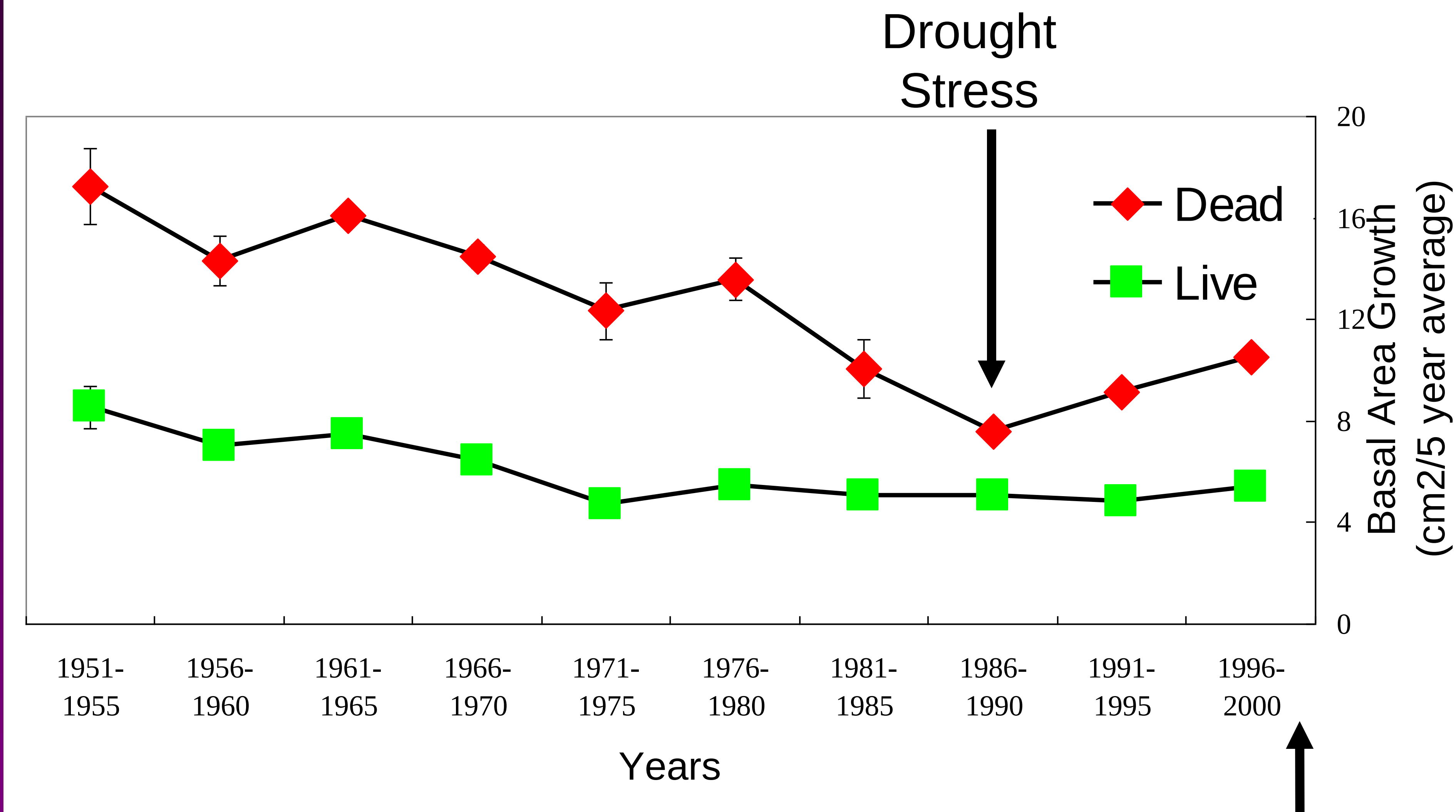
Western NC experienced a moderate three year drought from 1999-2002. In 2001, red spruce (*Picea rubens*) trees began to die in large numbers in and around Mt. Mitchell NC, USA. The initial evidence suggested that the affected trees were killed by the southern pine beetle (SPB). This insect species is not normally successful at colonizing these tree species. Subsequent investigations revealed an interesting pattern where trees died or survived the SPB attack.

Picea rubens (red spruce)
mortality near Asheville, NC

Five Year Averaged Climate (1951 – 2001), Mt. Mitchell, NC, USA

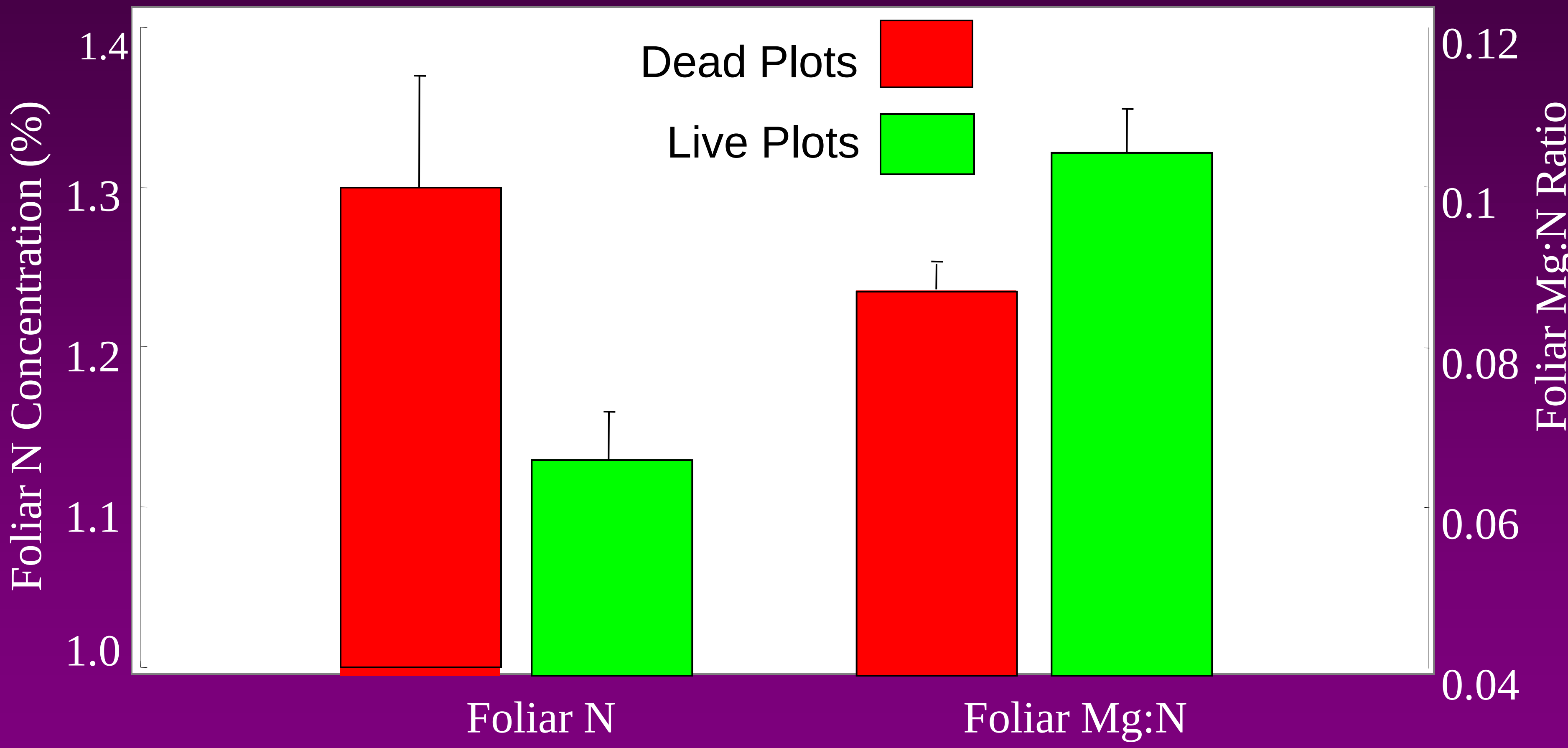


Sampling damaged Southern Appalachian red spruce stand

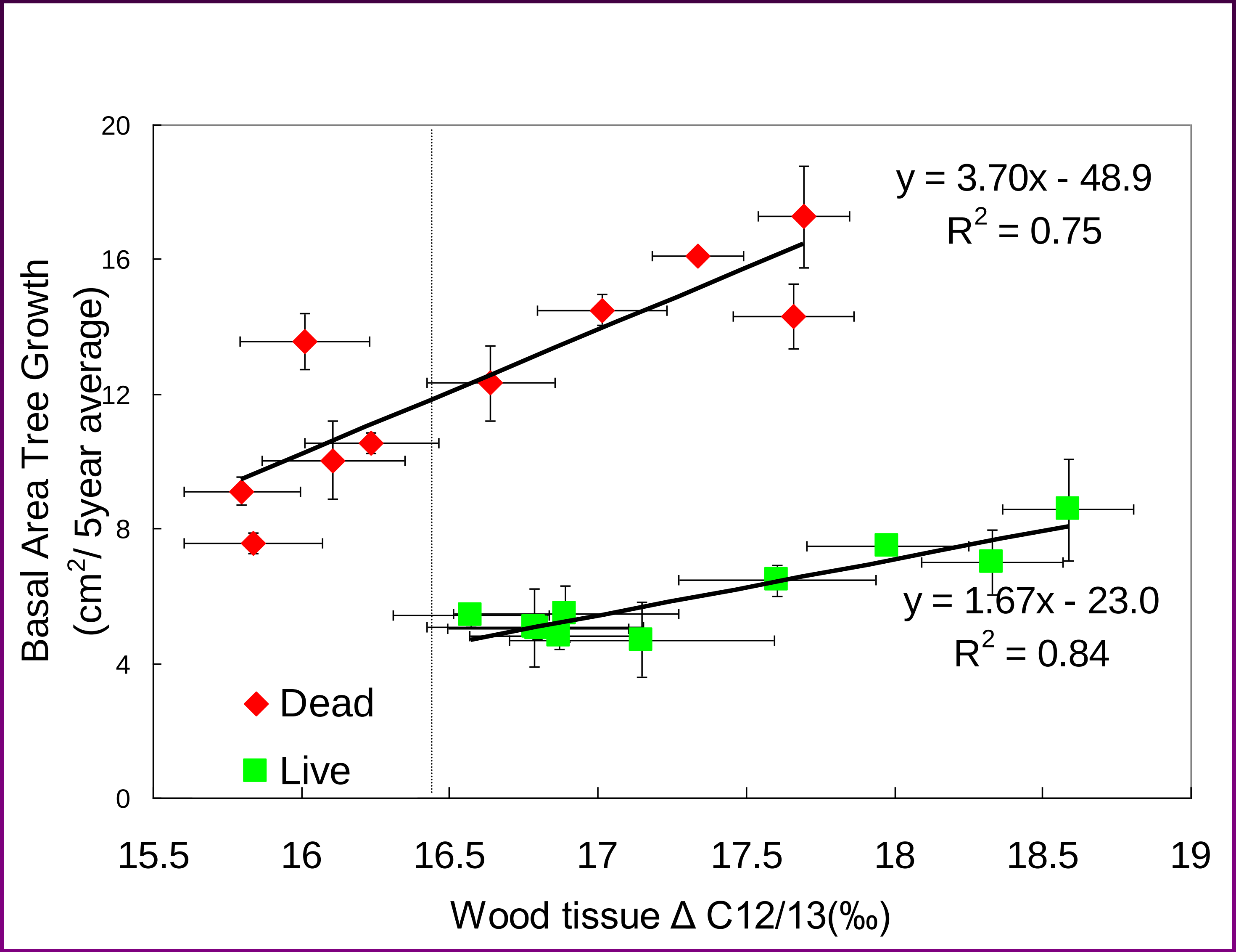


Drought, Temperature, Insect, & N deposition Stresses

Residual Tree Foliar Chemistry



Basal Area Growth as a Tree Water Stress



Question

Why were the stands that would be considered most healthy prior to the drought die while the slower growing, less healthy looking sites survive the stress period?

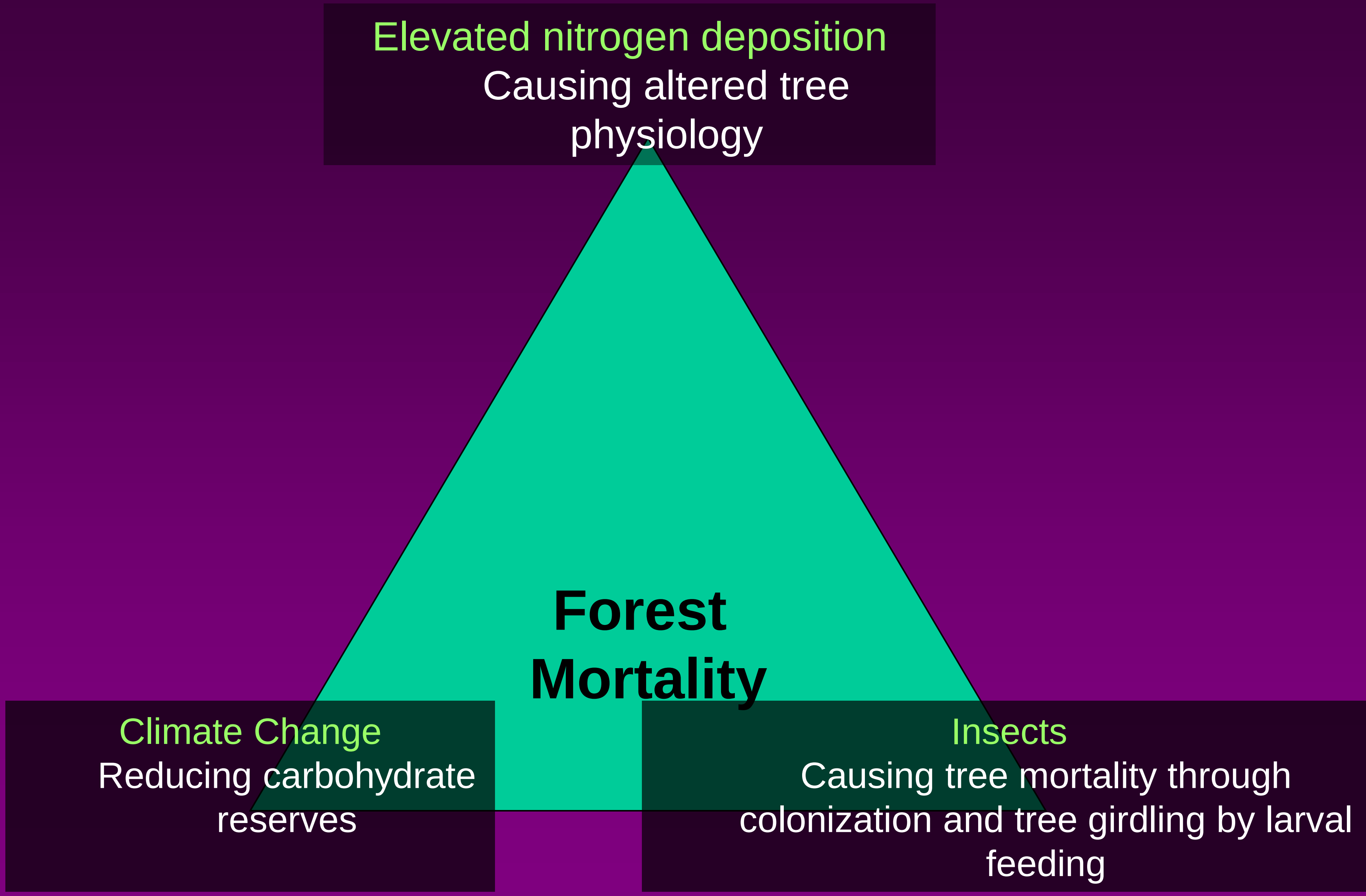
Hypothesis for mortality

- The area in and around Asheville received elevated nitrogen deposition, but these levels are below that considered critical acid load
- The ratio between above ground growth (i.e., stem wood, branches and foliage) and below ground growth (i.e. coarse and fine roots) increased
- The increased level of nitrogen inputs likely had a fertilization impact

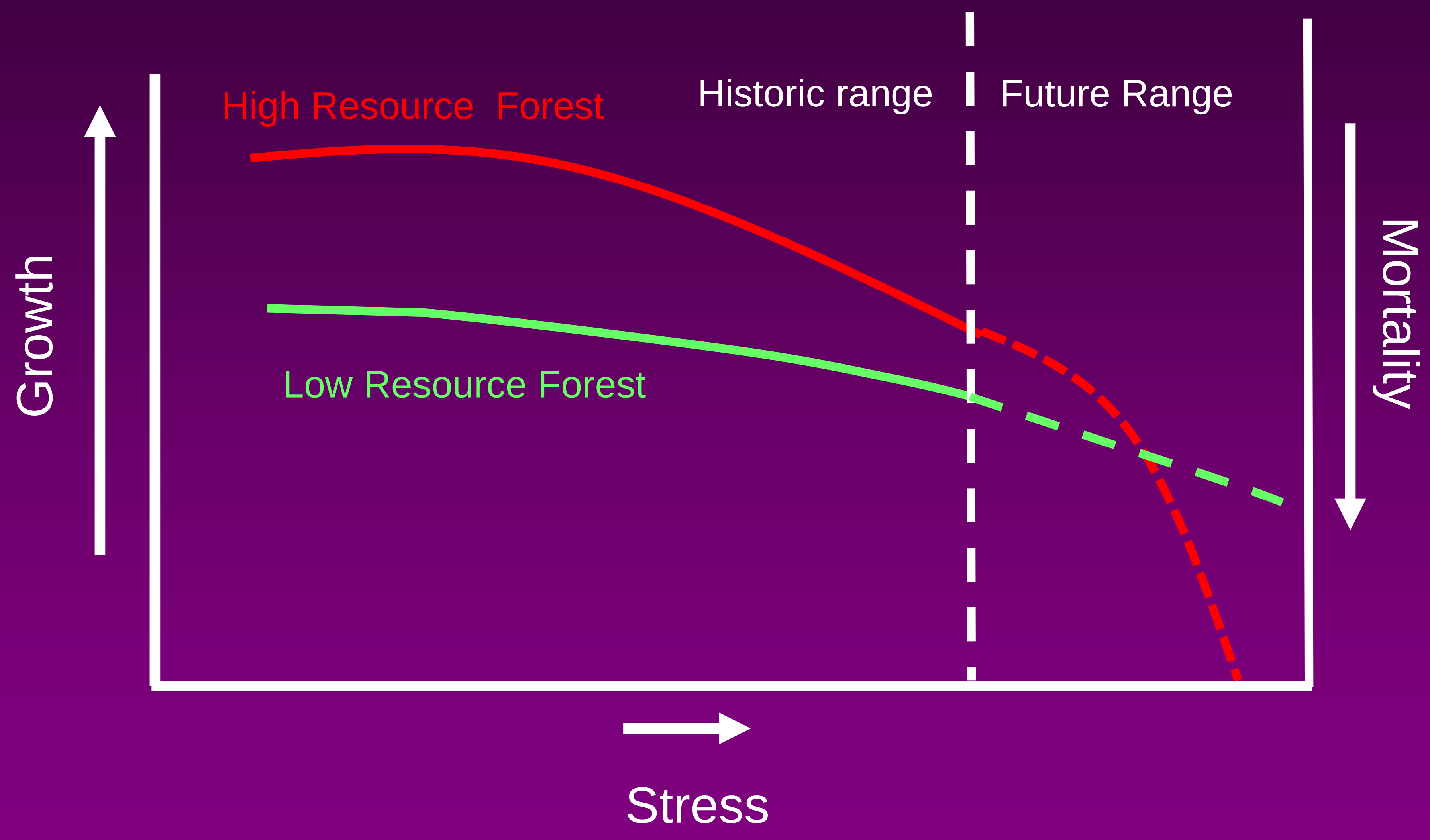
Hypothesis for mortality (cont.)

- The larger more vigorously growing trees had a higher AG/BG ratio than the small trees
- The drought conditions reduced available water, carbohydrate reserves for the production of secondary carbon compounds such as oleoresin.
- The lack of oleoresin (especially in large trees) allowed for the colonization of and large scale forest mortality witnessed during that time.

Stress interactions



Stress Impacts on Growth/Mortality



Two potential implications

1. Natural and engineered forests will be exposed to environmental conditions not seen in modern history
   - By expanding the range of impacts, unexpected consequences are possible

2. Until potential impacts of climate change are better understood in natural ecosystems, genetic manipulation of forest growth may be conter-productive.

Unintended Consequences….

Intended Objective	Potential Unintended Impact
- Increased water Use efficiency	Reduced root mass/water uptake pot. Increased leaf mass/water demand
- Increased nutrient use efficiency	Reduced root mass/water uptake pot. Increased leaf mass/water demand
- increased AG/BG growth allocation	Reduce root mass/water uptake pot. Increased leaf mass/water demand
- Increased wood specific density	Increased hurricane resistance
- Increased drought resistance	?

Conclusions

The climate is changing in ways that not been previously observed, and these changes are triggering unexpected disturbance combinations in natural forests

Attempts to increase forest productivity may exacerbate or accelerate these new type of disturbance impacts

Genetic manipulation of growth stocks need to account for changing climate impacts including extreme event interactions

A better understanding of baseline impacts are needed to reduce the risk of unintended genetic disturbance risk

I wanted a perfect ending. Now I've learned, the hard way, that some poems don't rhyme, and some stories don't have a clear beginning, middle, and end. Life is about not knowing, having to change, taking the moment and making the best of it, without knowing what's going to happen next.

(The late, great) Gilda Radner