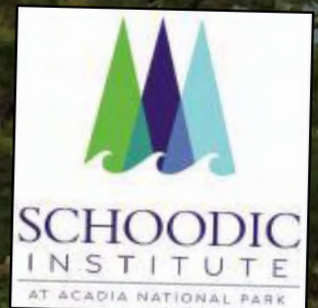


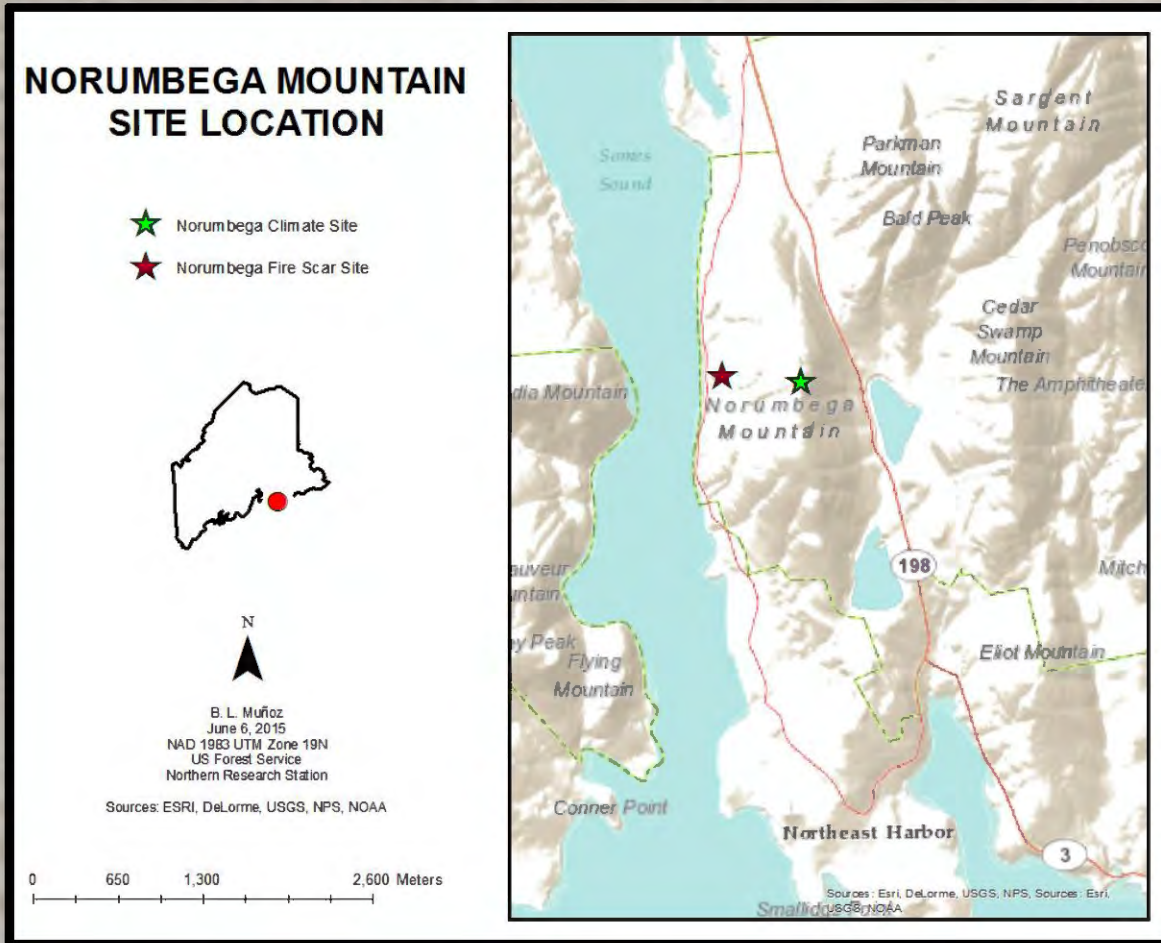
Growth and Climate Responses of Four *Pinus Spp.* on Norumbega Mountain, Acadia National Park

Meghan Foard, Heather Haines, Bethany Muñoz, Molly Rooney,
Stephanie Stotts, and Lara vanAkker

With Guidance From: Peter Brown
and Henri Grissino-Mayer



Study Site: Norumbega Mountain



Pinus spp. of Acadia



Jack Pine (*P. banksiana*)



Pitch Pine (*P. rigida*)



Red Pine (*P. resinosa*)

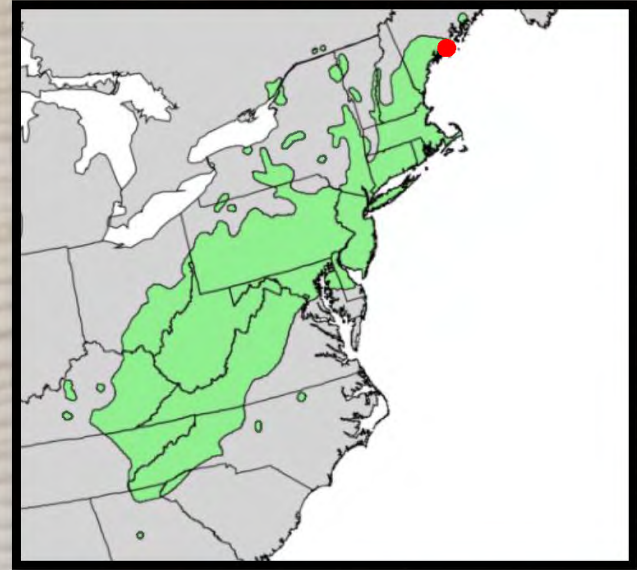


White Pine (*P. strobus*)

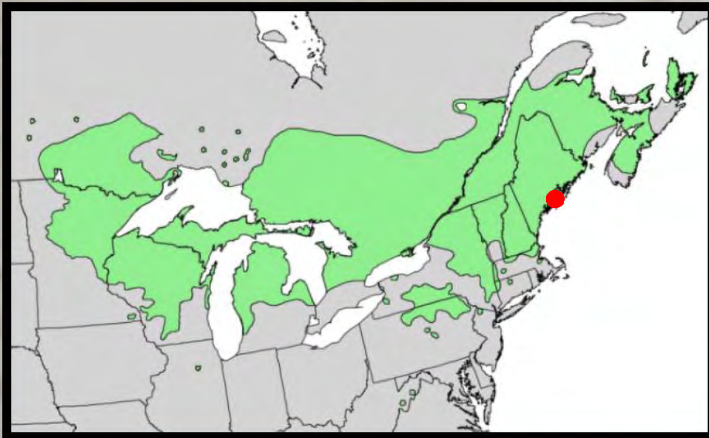
Range of *Pinus spp.*



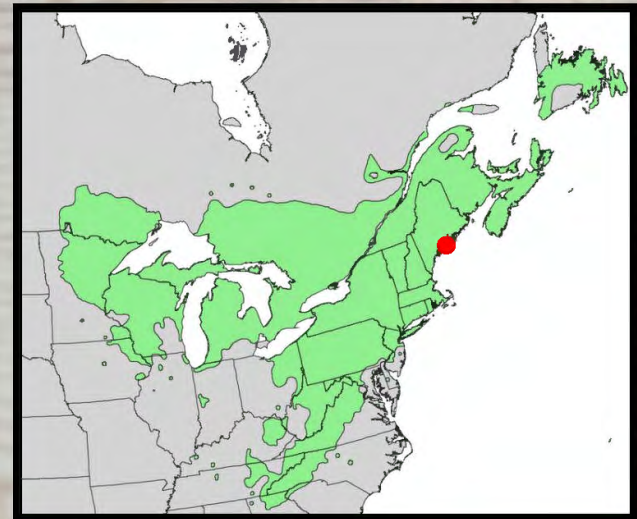
Jack Pine (*P. banksiana*)



Pitch Pine (*P. rigida*)



Red Pine (*P. resinosa*)

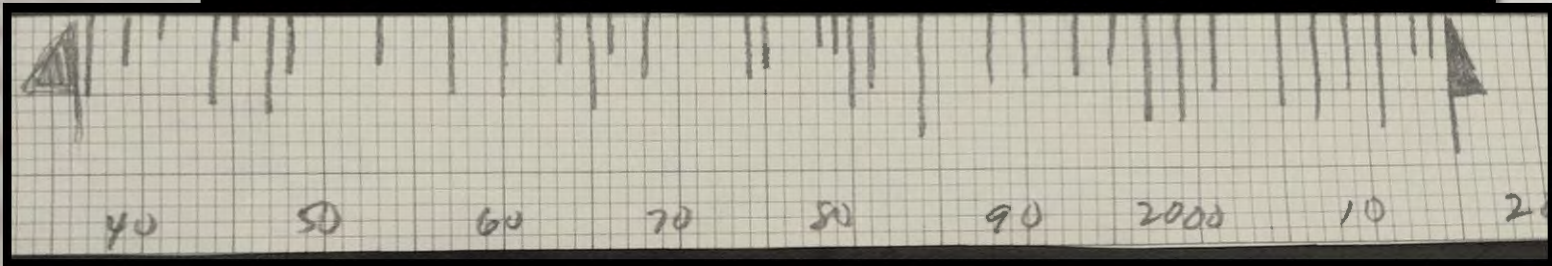


White Pine (*P. strobus*)

Questions

1. What are the species-specific growth patterns among jack, pitch, red, and white pine on Norumbega Mountain?
2. To which climate variables are these species responding?
3. How do climate-growth relationships vary over time?
4. What larger scale climatic drivers will affect spatial-field correlation?

Crossdating



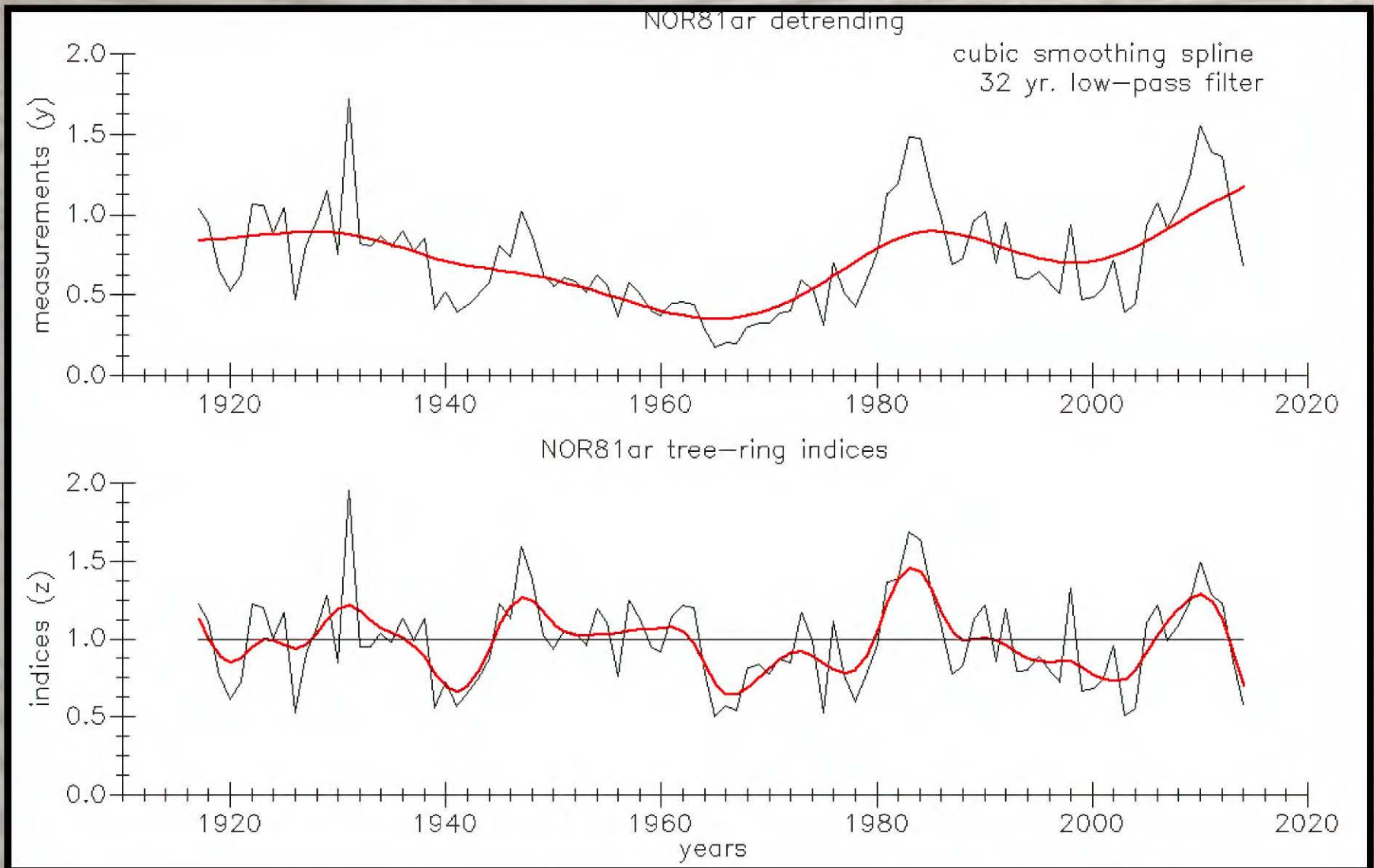
Quality control

```
*****
*C* Number of dated series          32 *C*
*O* Master series 1934 2014      81 yrs *O*
*F* Total rings in all series    1554 *F*
*E* Total dated rings checked    1554 *E*
*C* Series intercorrelation       .526 *C*
*H* Average mean sensitivity      .337 *H*
*A* Segments, possible problems   0 *A*
*** Mean length of series        48.6 ***
*****
```

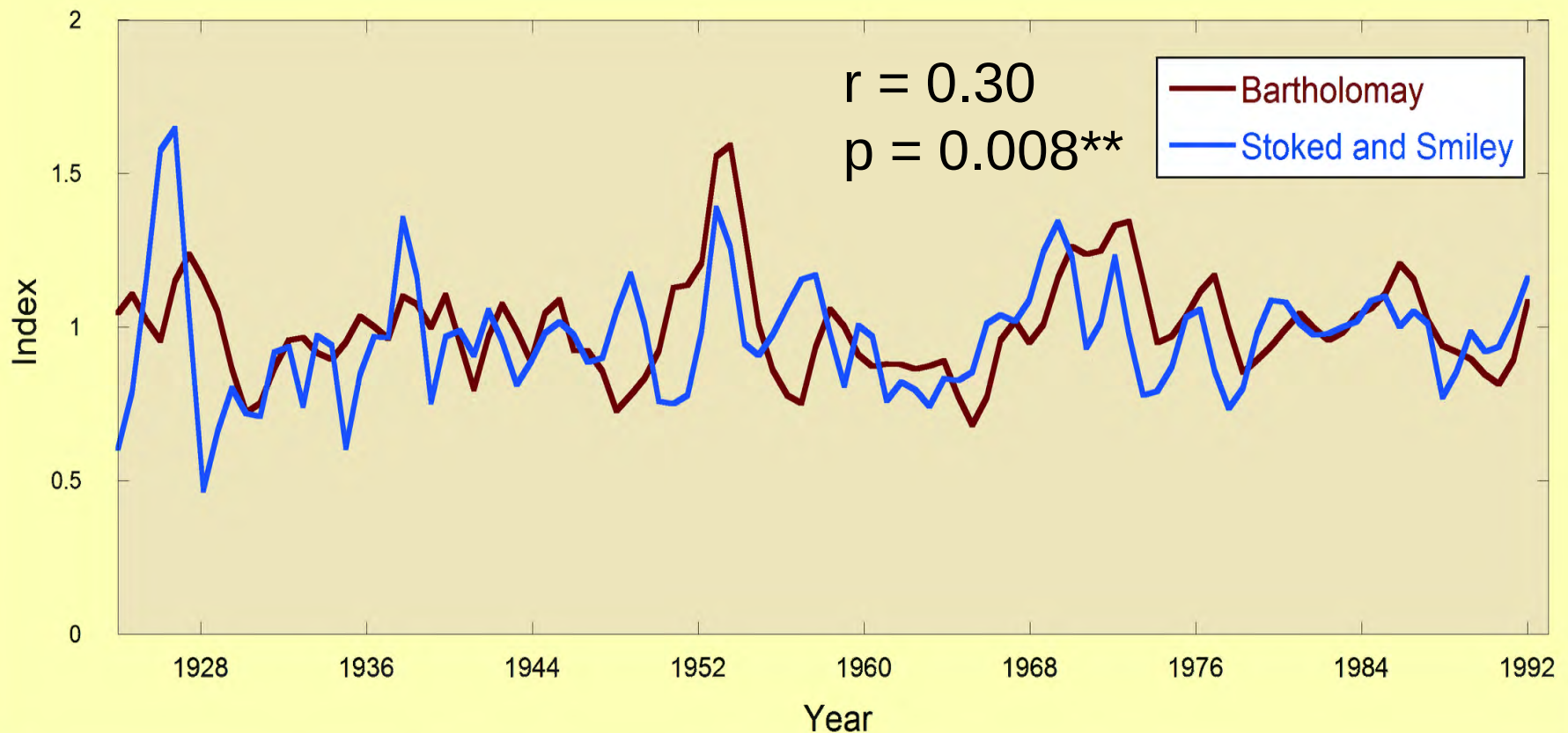
Quality control

Species	Interseries Correlation	Mean sensitivity	Number of dated series
Jack Pine (<i>P. banksiana</i>)	0.526	0.337	32
Pitch Pine (<i>P. rigida</i>)	0.579	0.297	61
Red Pine (<i>P. resinosa</i>)	0.432	0.252	15
White Pine (<i>P. strobus</i>)	0.553	0.251	18

Detrending

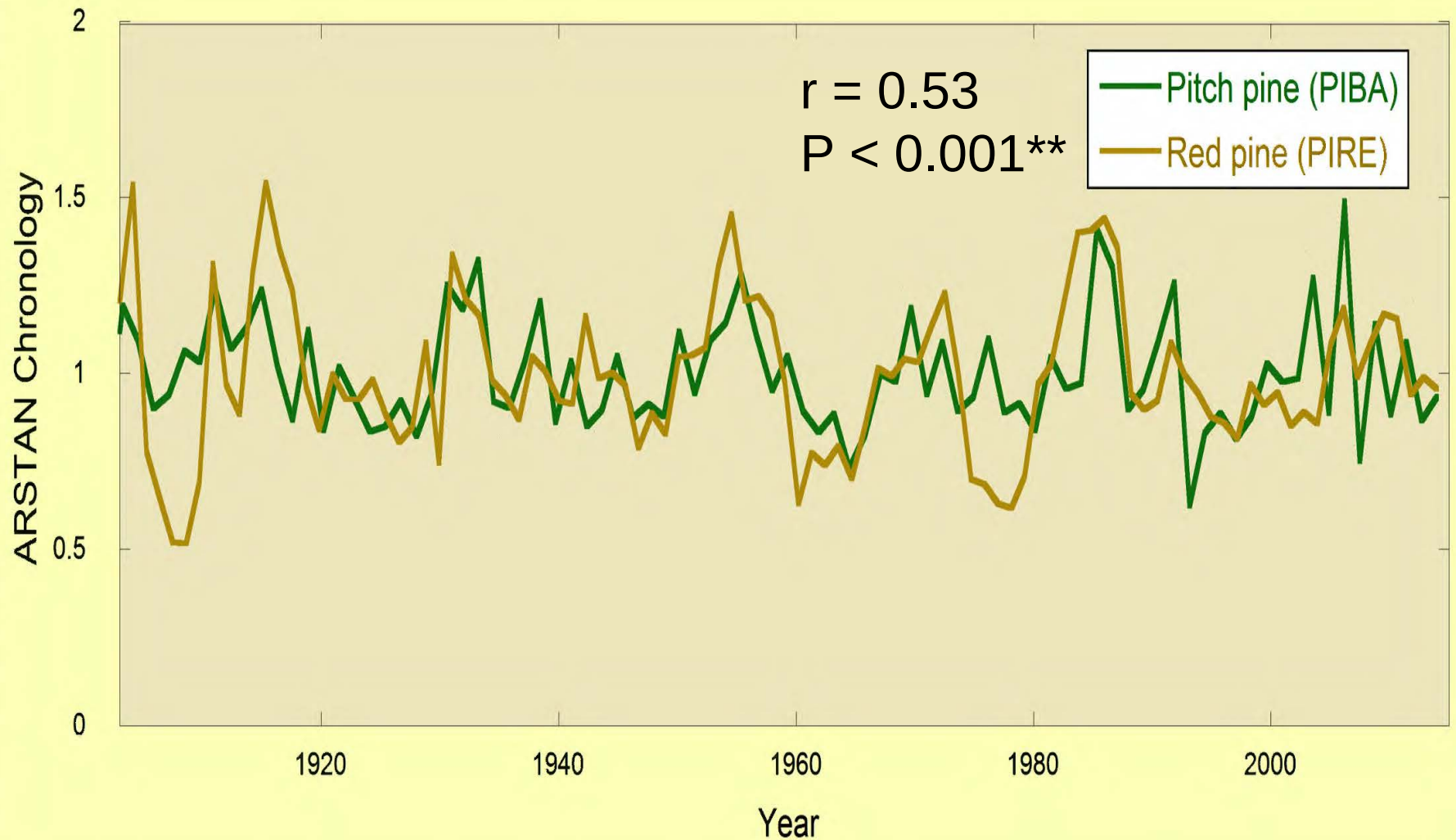


Correlation of White Pine from Bartholomay et al. (1997) and Stoked & Smiley

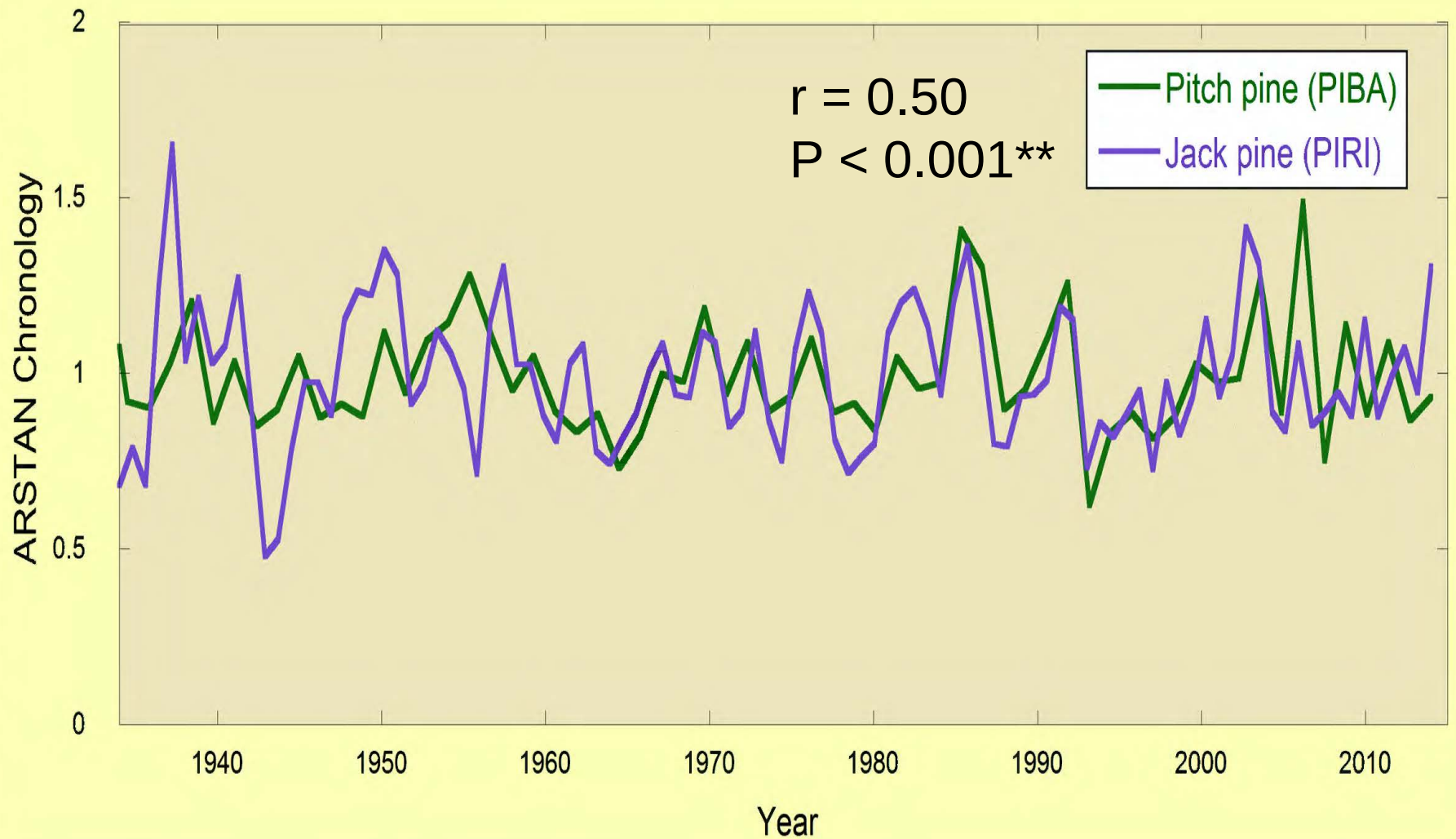


Bartholomay, G. A., Eckert, R. T., & Smith, K. T. (1997). Reductions in tree-ring widths of white pine following ozone exposure at Acadia National Park, Maine, USA. *Canadian Journal of Forest Research*, 27(3), 361-368.

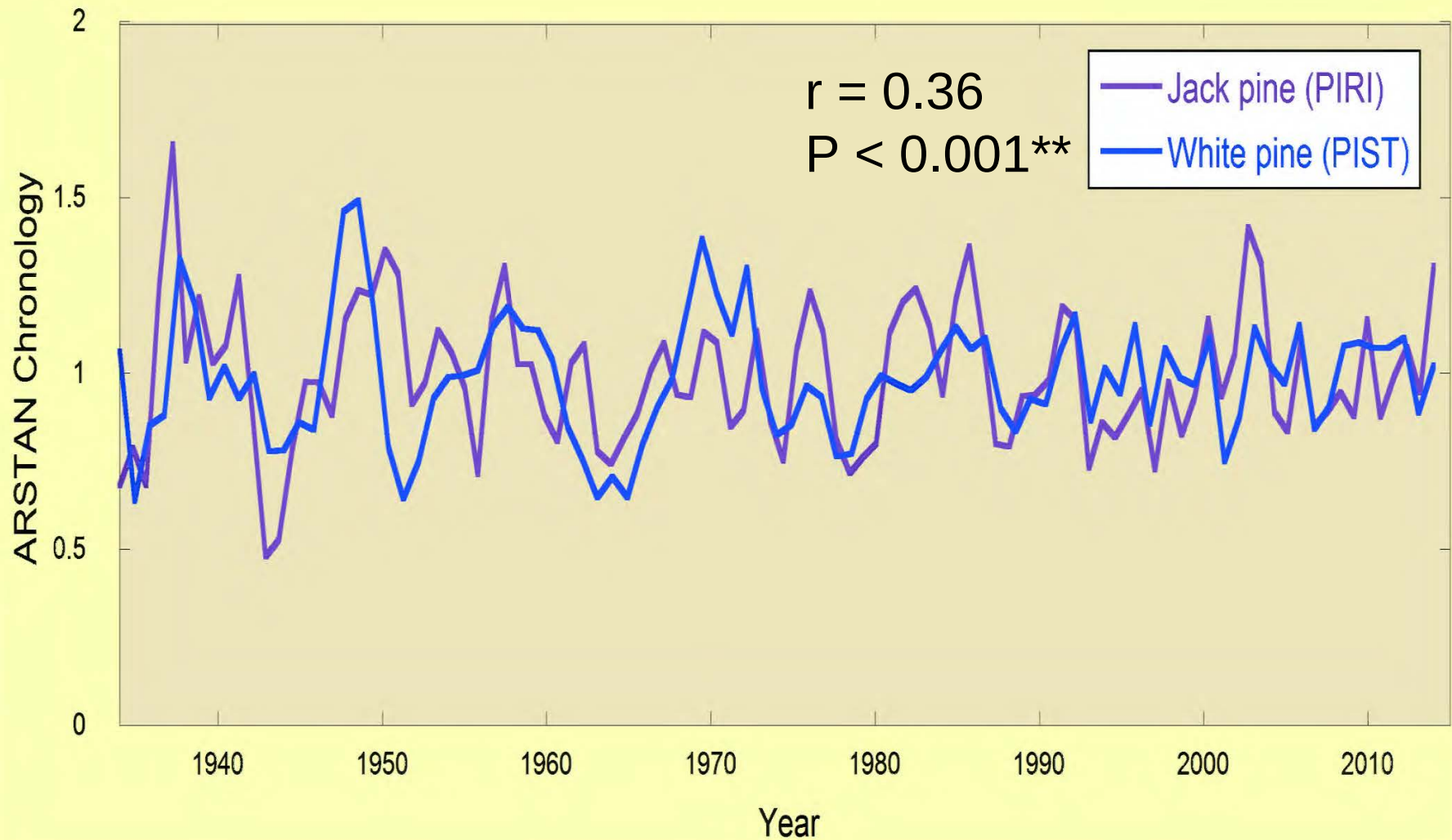
Correlation of Pitch Pine vs. Red Pine



Correlation of Pitch Pine vs. Jack Pine



Correlation of Jack Pine vs. White Pine



Species-specific growth pattern comparisons

32 Spline/ARS	Temporal Range	<i>n</i>	Correlation coefficient (<i>r</i>)	P (2-tail)
Pitch vs. Jack	1934–2014	81	0.50	<0.001**
Pitch vs. Red	1903–2014	112	0.53	<0.001**
Pitch vs. White	1924–2014	91	0.21	0.048*
Jack vs. Red	1934–2014	81	0.22	0.046*
Jack vs. White	1934–2014	91	0.36	<0.001**
Red vs. White	1924–2014	81	0.13	0.24
Bartholomay vs. White	1924–1994	71	0.30	0.008**

Basal Area Increment (cm²)

- Basal area increment (cm²) calculated using Biondi (1999)

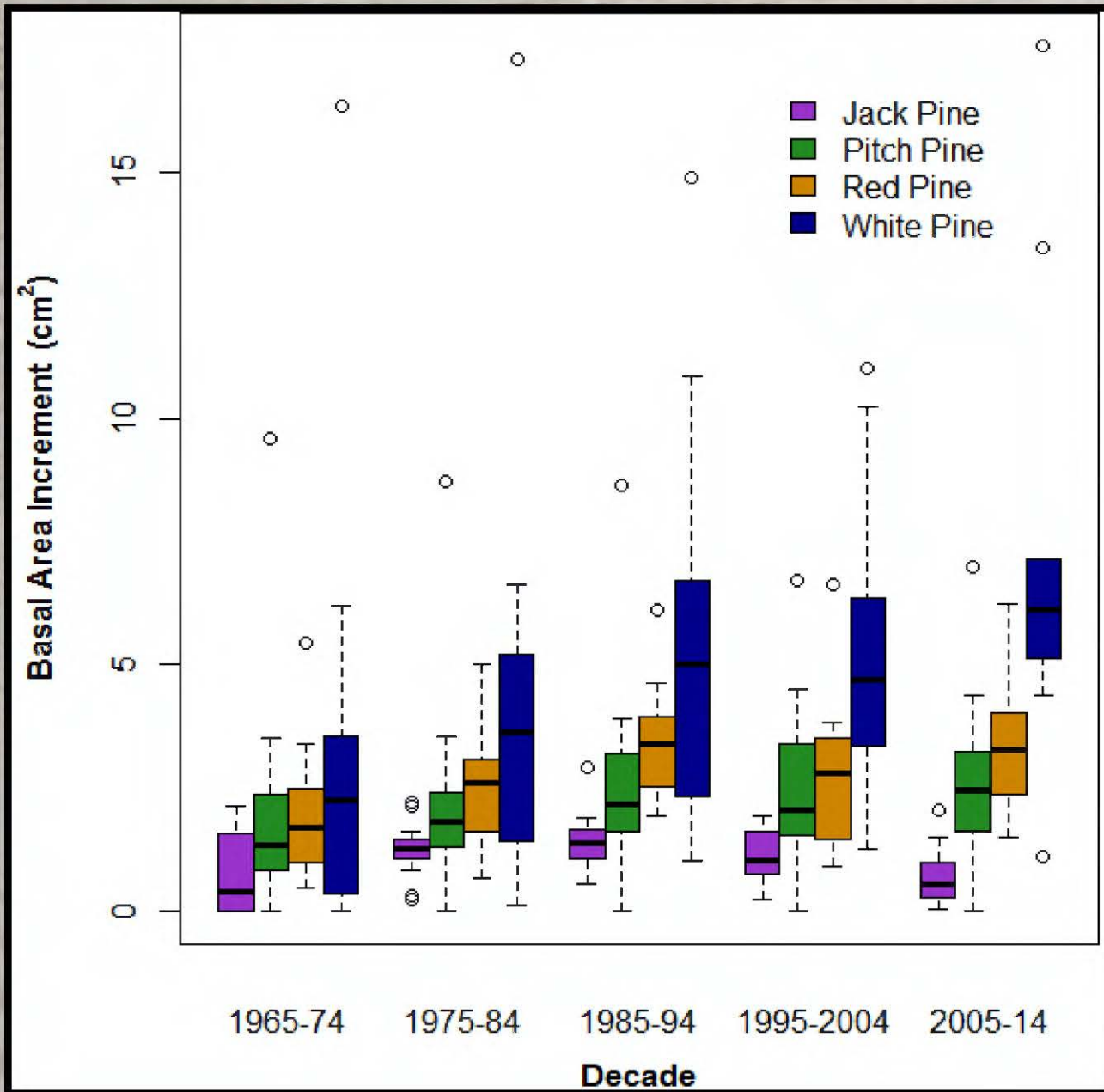
$$a_i = \frac{\pi}{100} w_i \left(w_{i+2} \sum_{j=i}^{i+1} w_j \right)$$

- Used linear model for stand-level comparisons
 - Applied Tukey's Adjustment for multiple comparisons
- Least square means and standard errors are presented in figures

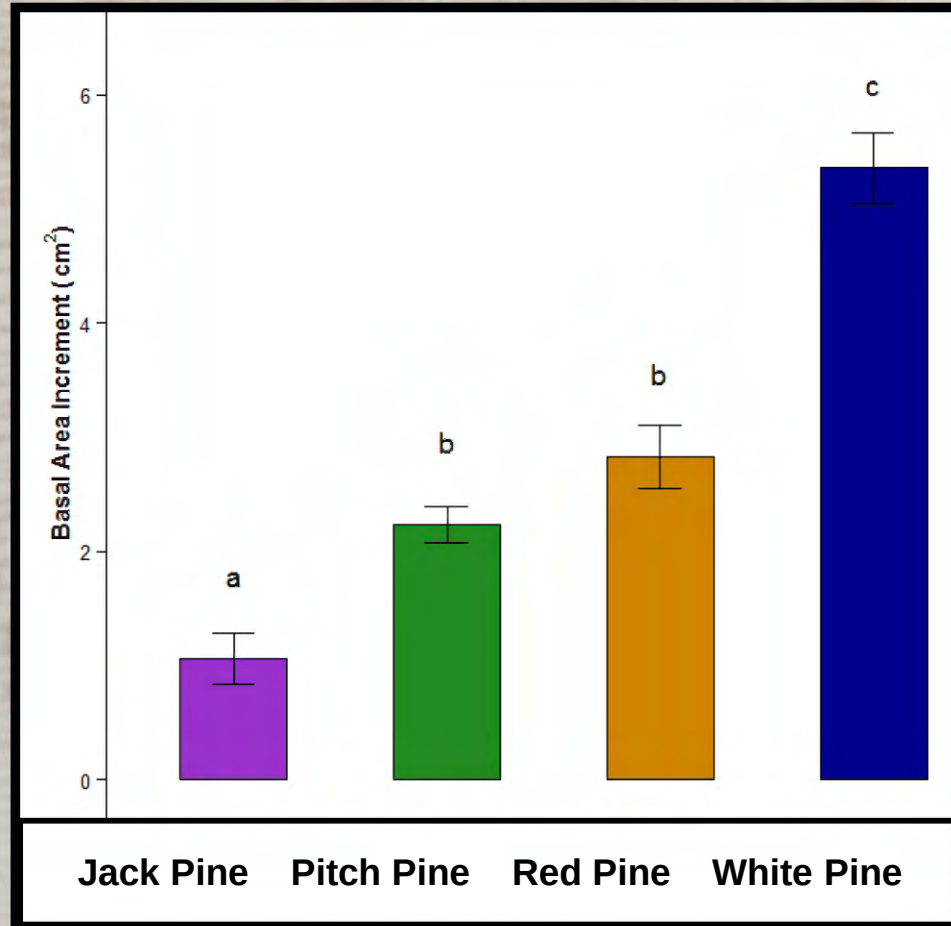
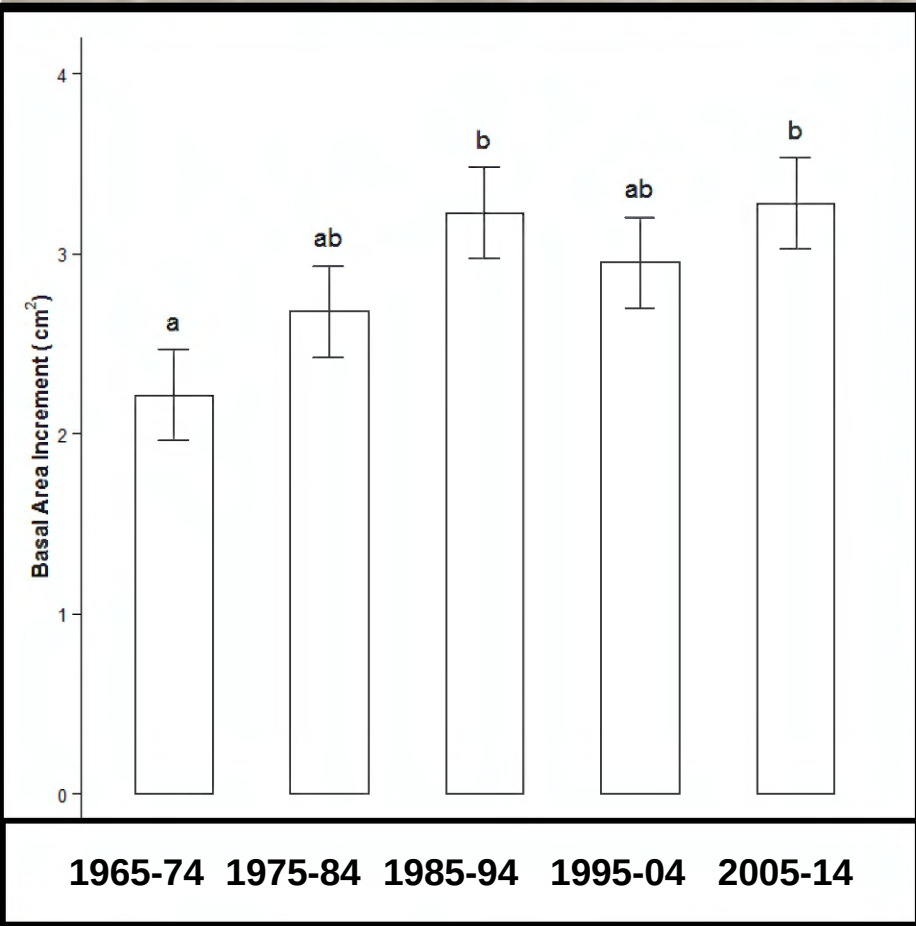
Dependent Variables	Explanatory Variables
Basal Area Increment (cm ²)	1. Species (Jack Pine, Pitch Pine, Red Pine, White Pine) 2. Decade (1965–1974, 1975–1984, 1985–1994, 1995–2004, 2005–2014)

Biondi, F. 1999. Comparing tree-ring chronologies and repeated timber inventories as forest monitoring tools. *Ecol. Appl.* 9:216–227.

BAI (cm²) Results



BAI (cm²) Results



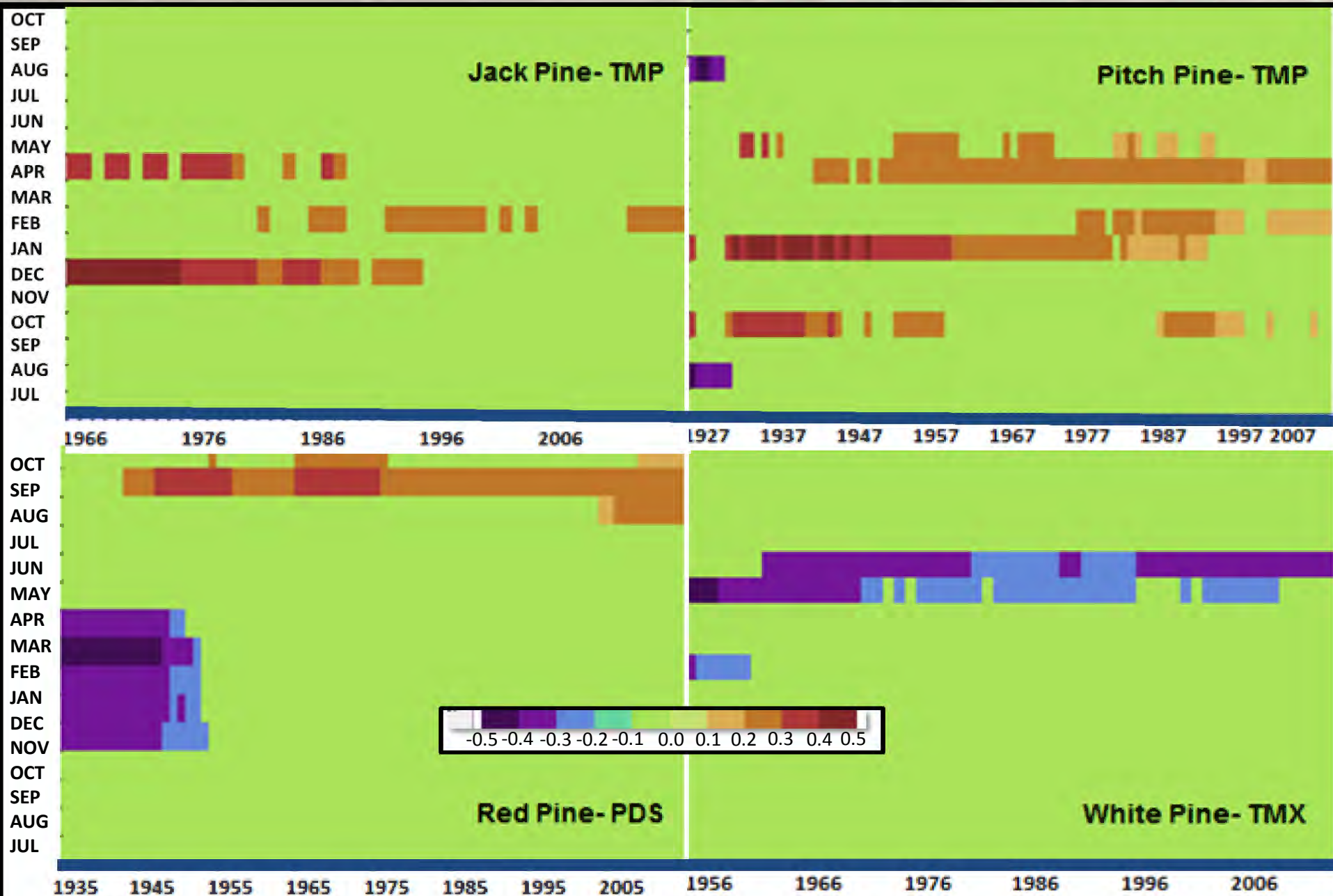
Response Function Analysis

Species	Var.	July	August	September	October	November	December	January	February	March	April	May	June	July	August	September	October
White	TMX	maximum temp															
	TMP	mean temp															
	TMN	minimum temp															
	PCP	precipitation															
	PHD	Palmer hydrological drought index															
	PDS	Palmer drought severity index															
Jack	TMX																
	TMP																
	TMN																
	PCP																
	PHD																
	PDS																
Red	TMX																
	TMP																
	TMN																
	PCP																
	PHD																
	PDS																
Pitch	TMX																
	TMP																
	TMN																
	PCP																
	PHD																
	PDS																

 negative correlation
 positive correlation

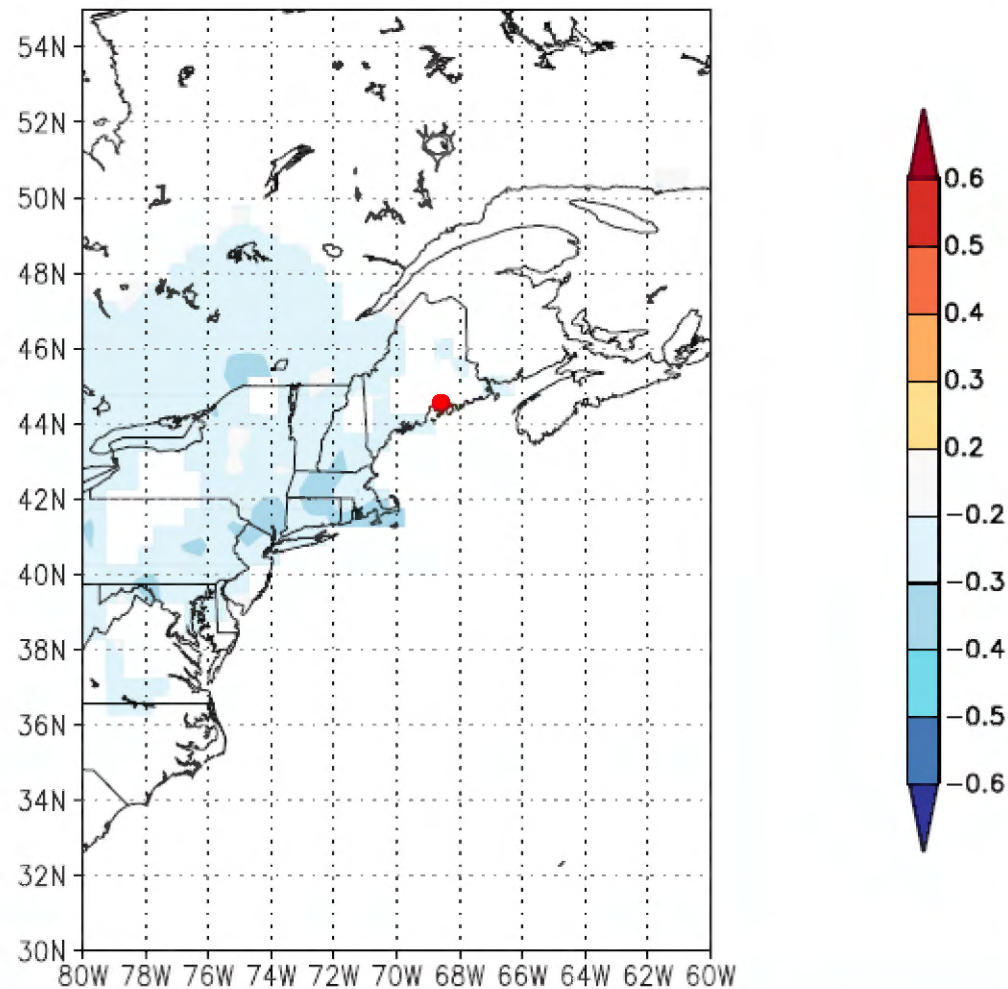
Correlations are significant
at the 95% confidence level

Temporal Stability Analysis



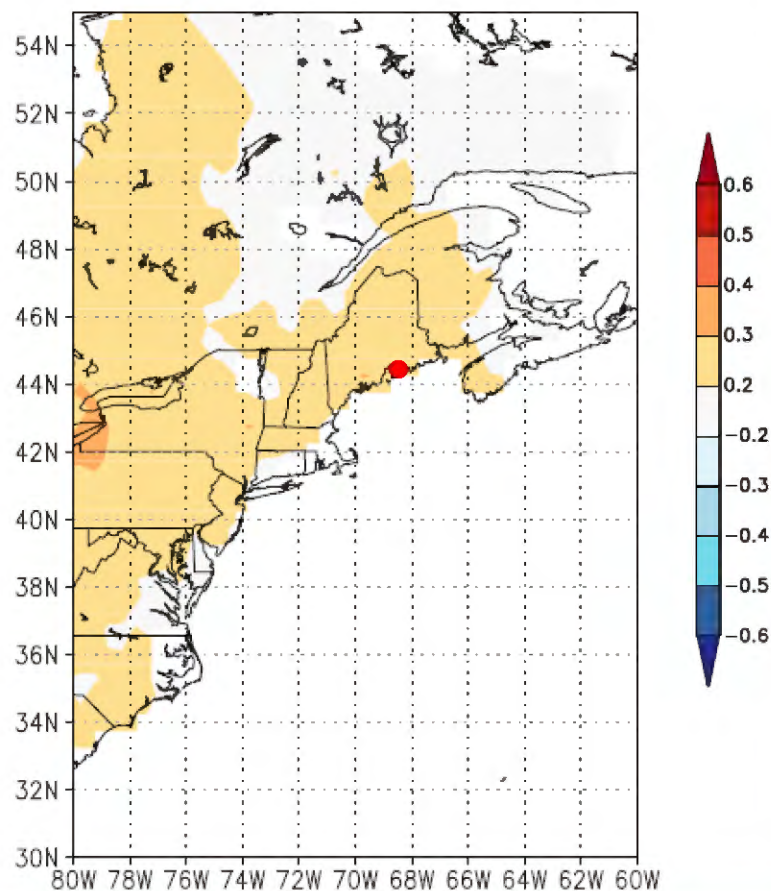
Spatial Analysis: White Pine Climate Relationships

White Pine Index vs June Tmax

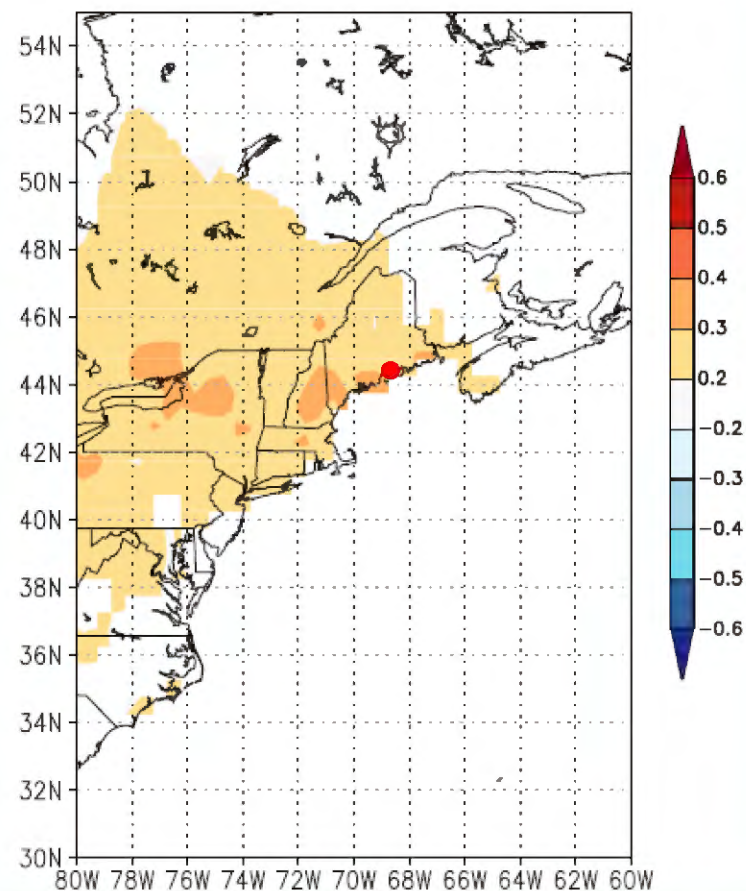


Spatial Analysis: Pitch and Jack Pine Climate Relationships

Pitch Pine Index vs. Feb-Apr Tmax

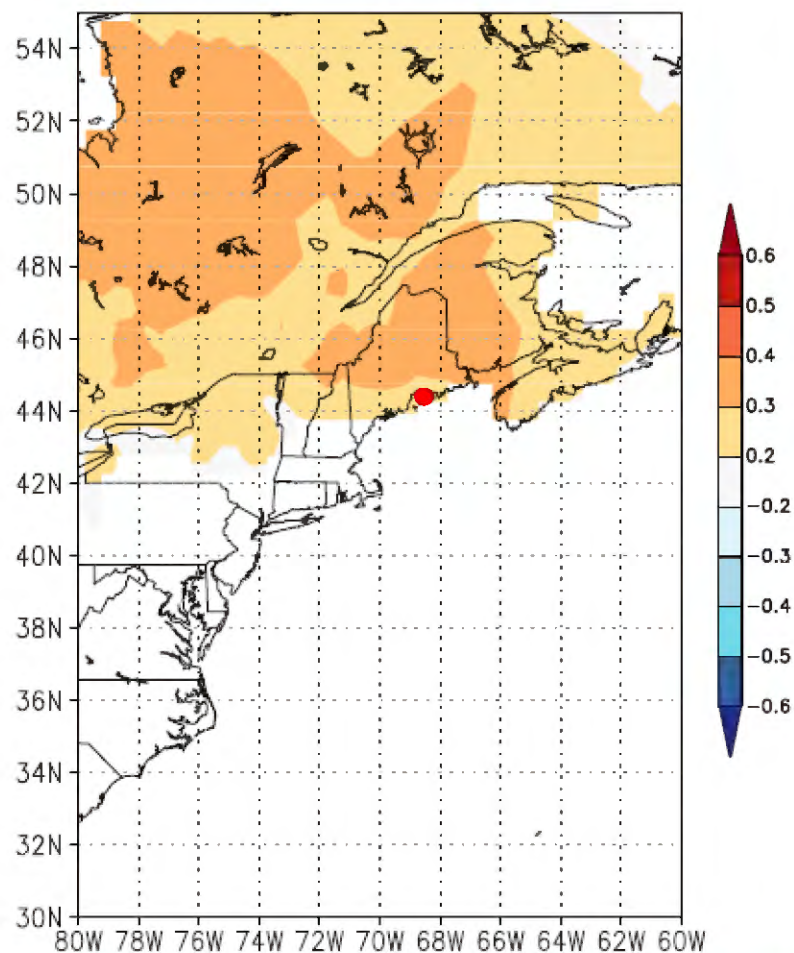


Jack Pine Index vs. Feb-Apr Tmax

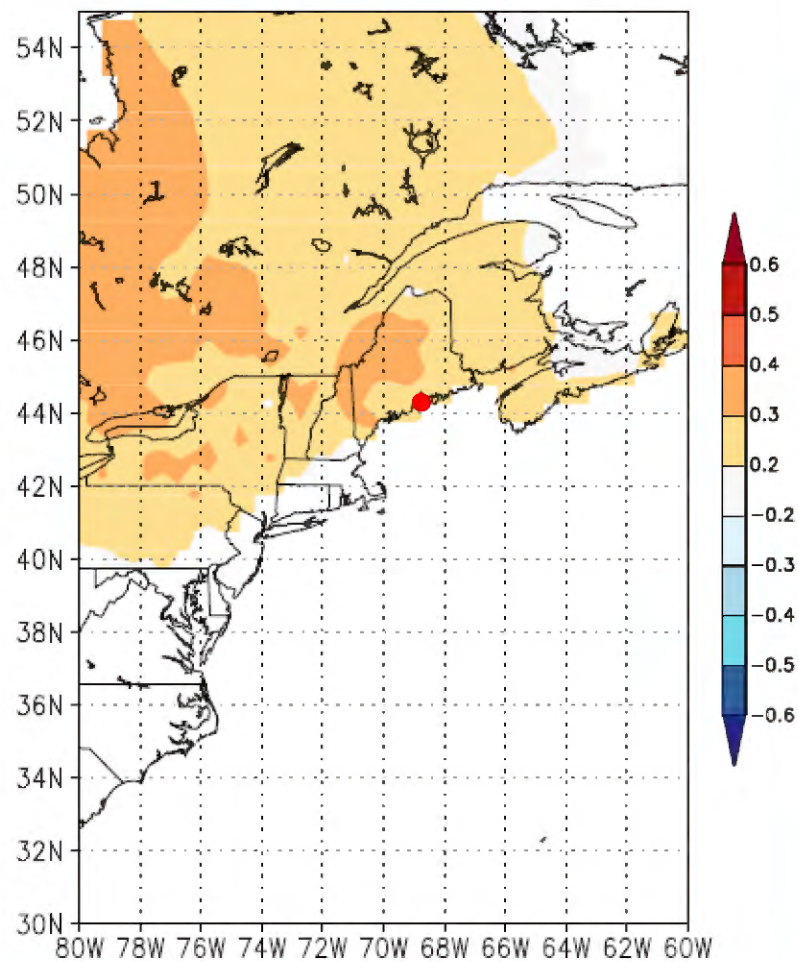


Spatial Analysis: Red Pine Climate Relationships

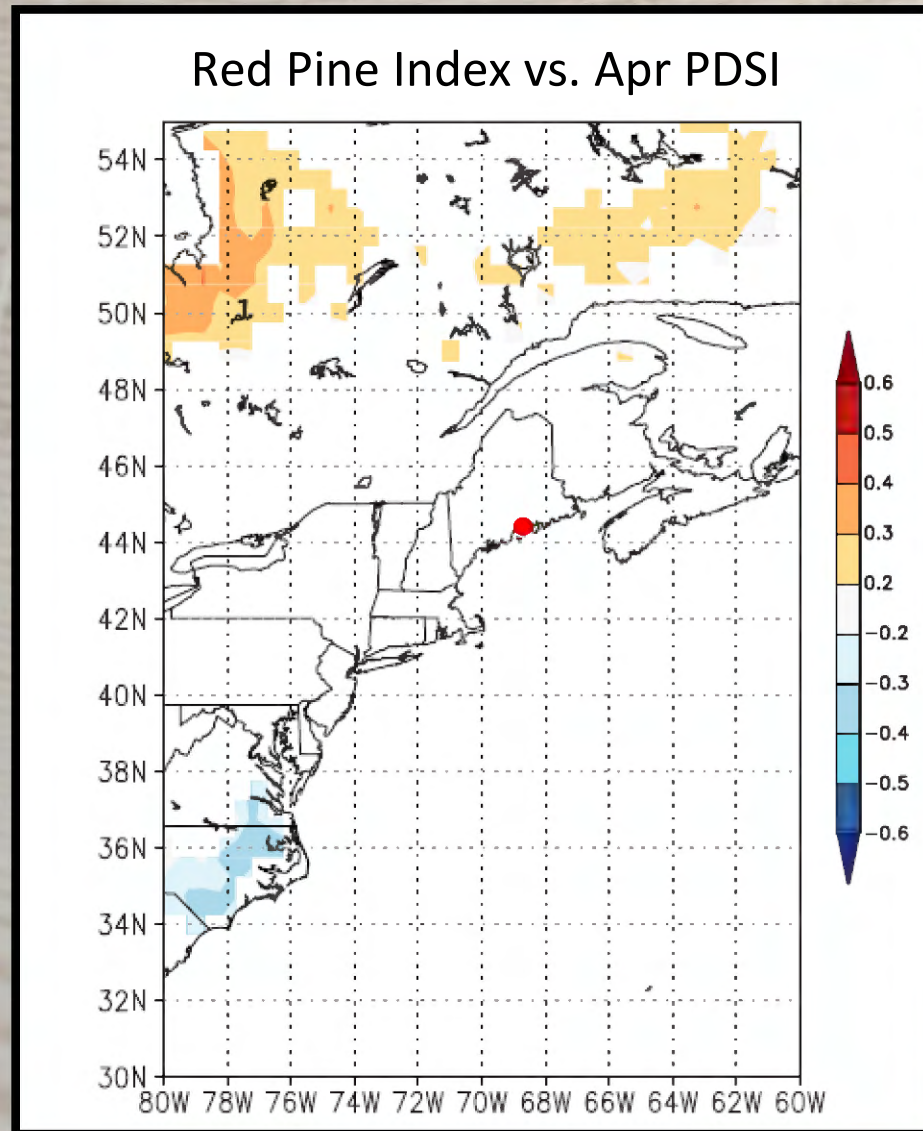
Red Pine Index vs. Apr Tmax



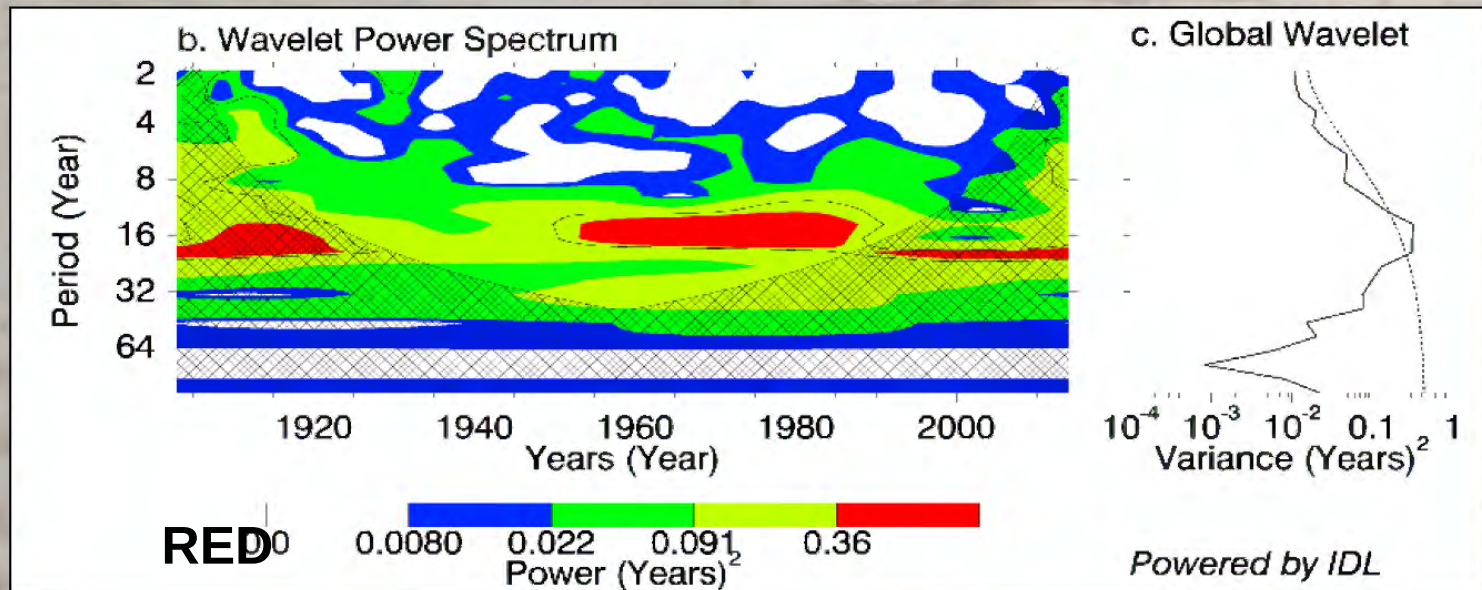
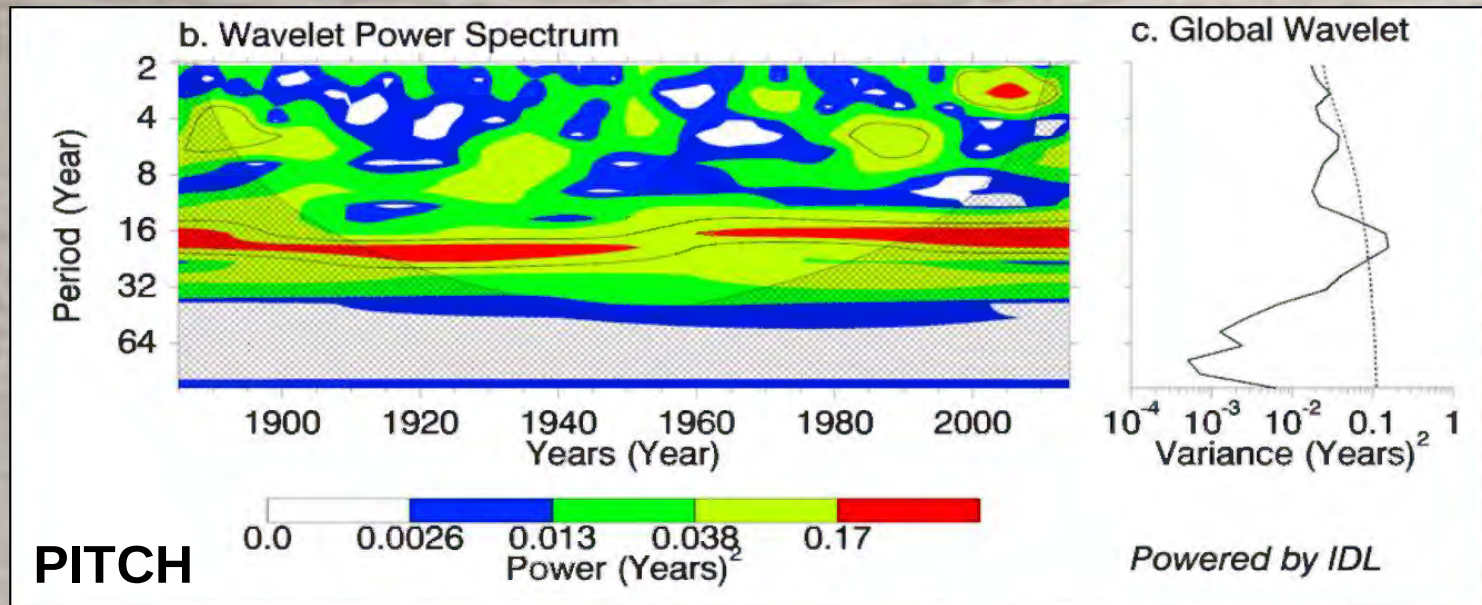
Red Pine Index vs. Apr Tmin



Spatial Analysis: Red Pine Climate Relationships



Wavelet Analysis



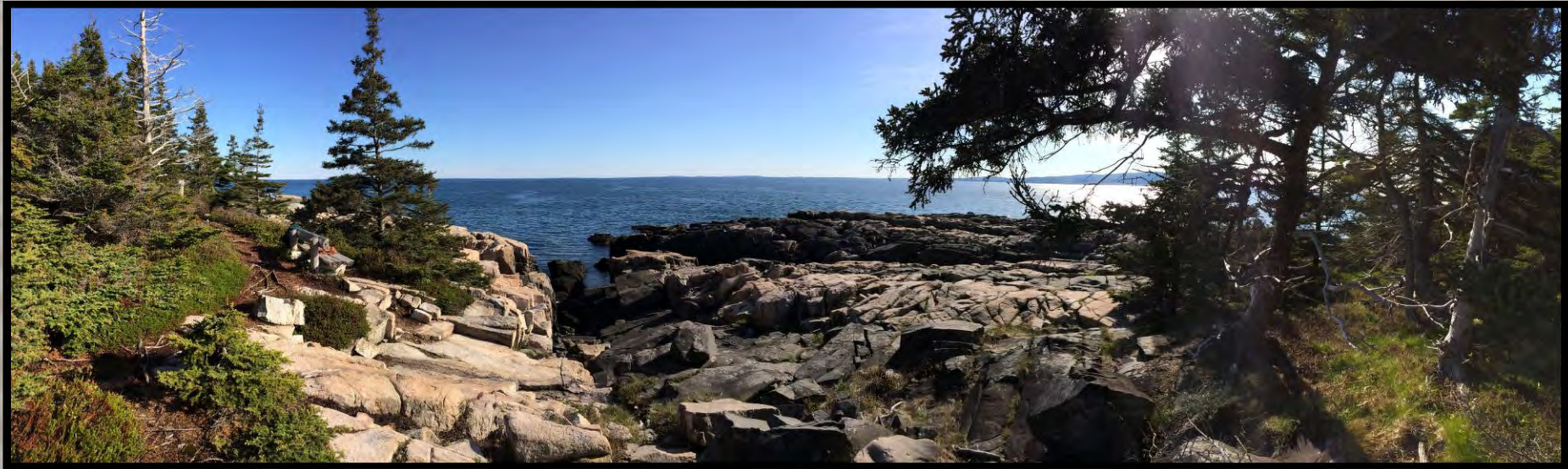
What are the species-specific growth patterns among jack, pitch, red, and white pine on Norumbega Mountain?

- Radial growth is similar among all species except between white and red pine.
- White pine is likely to take over and jack pine will likely disappear from the southernmost margin.
- Jack pine is infected with Eastern Gall Rust, indicating disturbance which might be causing declining growth rate in jack pine.



To which climate variables are pine species on Norumbega Mountain responding?

- **Temperature:** As early growing season temperatures increase pitch, jack, and red pines will be favored.
- **Drought:** Growth of red and pitch pines is negatively affected by drought during the growing season.
- **Climate Change ?** If the temperature regime remains, white pine will dominate, but if summer temperatures increase as predicted by global climate models, the growth of white pine may be dampened.



How do climate-growth relationships vary over time?

- Temporal relationships fairly consistent for white, pitch, & jack pines
- Red pines show a temporal shift in their relationship to PDSI
- A 16-22 year periodicity exists that varies in amplitude over a 20-30 year period



What larger scale climatic drivers are identified in the spatial field correlations?

- Results of spatial analysis confirm the results of our climatic response function analysis
- We found consistent signals between the climate-growth relationships across the Eastern seaboard
- Temperature is the major driver of growth of all four pine species on Norumbega Mountain



Questions?



Fire History

