Drought, Climate Change and Humans, Oh My!
25 Years of Tree-Ring Research in Hudson Valley Forests

25 years of boring trees and people too!
1975 2000
TREE RING LAB
Lamont-Doherty Earth Observatory

Long-term Hudson Valley Drought

Ed Cook & Gordon Jacoby. 1977. Tree-ring-Drought Relationships in the Hudson Valley, NY. Science 198: 399-401.

Ed Cook & Gordon Jacoby. 1979. Evidence for Quasi-periodic July Drought in the Hudson Valley, New York. Nature 282: 390-392.

These two landmark studies accomplished 3 important goals:
1st) They put the severe drought of the 1960s in a long-term perspective
2nd) Established the fact that dendroclimatology is achievable in the humid eastern US, as opposed to only the semi-arid western US
3rd) Established a strong foundation upon which to grow the Tree-Ring Lab of the Lamont-Doherty Earth Observatory.

Biodiversity Aiding Dendroclimatology:

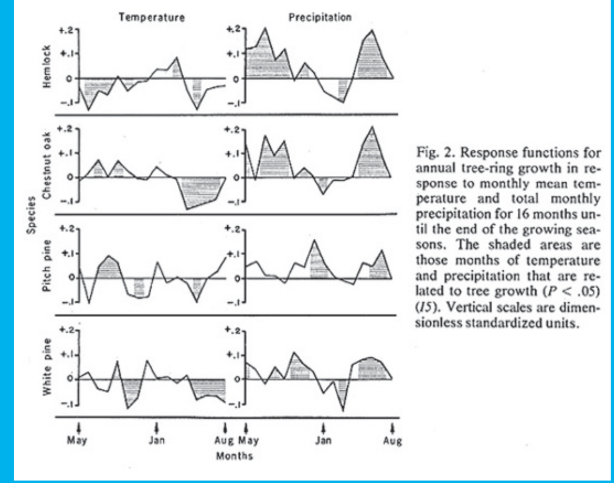


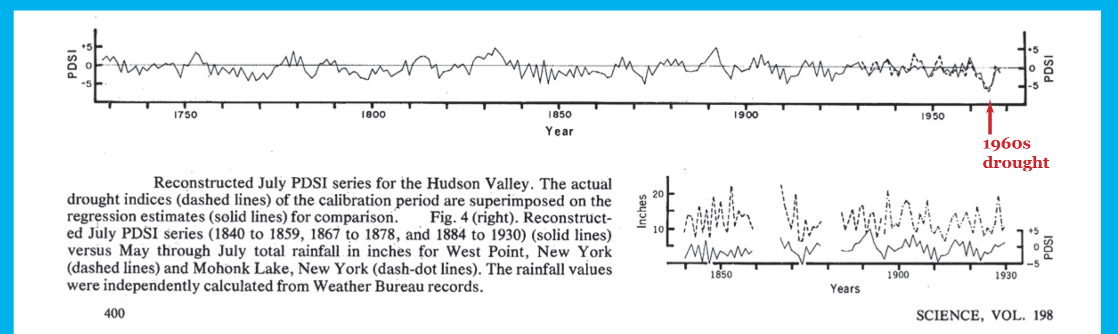
Fig. 2. Response functions for annual tree-ring growth in response to monthly mean temperature and total monthly precipitation for 16 months until the end of the growing seasons. The shaded areas are those months of temperature and precipitation that are related to tree growth ($P < .05$) (15). Vertical scales are dimensionless standardized units.

Ring-width chronologies of 4 tree species were used to reconstruct drought history: eastern hemlock, chestnut oak, pitch pine, & e. white pine.

Growth of each species was primarily limited by July drought (fig. left).

Each chronology was developed from drought sensitive sites - i.e. stands typically growing on rocky, shallow soils.

Each growth chronology was combined in a step-wise regression to reconstruct drought back to 1728.



Reconstructed July PDSI series for the Hudson Valley. The actual drought indices (dashed lines) of the calibration period are superimposed on the regression estimates (solid lines) for comparison. Fig. 4 (right). Reconstructed July PDSI series (1840 to 1859, 1867 to 1878, and 1884 to 1930) (solid lines) versus May through July total rainfall in inches for West Point, New York (dashed lines) and Mohonk Lake, New York (dash-dot lines). The rainfall values were independently calculated from Weather Bureau records.

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Reconstructed July Palmer Drought Severity Index for the Hudson Valley (top fig). The drought indices are superimposed with the reconstruction for comparison. It can be seen that the 1960s drought was one of the most severe in the last 260 yrs.

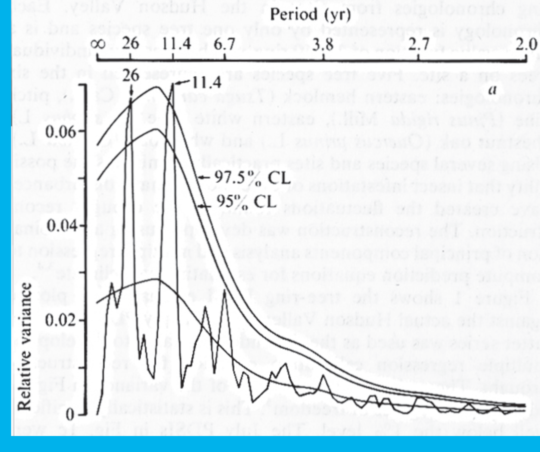
The lower right figure compares independent May-July rainfall (dashed lines) with the July PDSI reconstruction further showing that the trees were tracking drought.

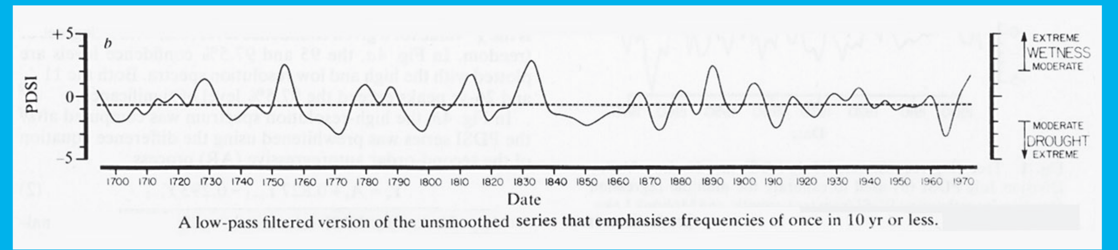
The 1979 *Nature* paper presented a longer drought reconstruction back to 1694.

Time-series analysis showed that drought frequency occurred roughly every 11 & 26 years (figure right).

The new series (below) was smoothed to emphasize decadal-scale drought.

The new series shows the 1960s drought to be the most intense. However, droughts of longer duration occurred mid-19th & late-18th centuries.





A low-pass filtered version of the unsmoothed series that emphasises frequencies of once in 10 yr or less.

Together, these two series showed that, while the 1960s drought was quite severe, longer, severe droughts have occurred in the Hudson Valley over the last 300 yrs. Thus, severe droughts in the Hudson Valley can be expected to recur with some regularity in the future given continuation of historical natural climate variations.

Historical Preservation

Tree-Ring analysis can be used to date the construction of historical buildings using a technique called cross-dating.

Cross-dating is the fundamental process of tree-ring analysis. Using various methods such as pattern matching and statistical tests, researchers can study rings to establish the actual calendar date for each annual growth ring.

Therefore, by cross-dating historical samples to living trees with known calendar dates, tree-ring scientists can date to the year with no error [+/- 0] the date of construction or tree cutting for the samples of interest.

Dendrochronology Solves Palisades Big House Age Mystery

A great deal of what has been written about the Big House in Palisades is based on the idea that it was built by Dr. Lockhart (first patent holder) around 1685. However, there were no roads at the time and if he had built a house, it would have been nearer to the Hudson River.

Tree-ring dating performed by the Tree-Ring Lab's Gordon Jacoby has definitively established the true construction date of the Big House. Examination of the 15 cores clearly showed that the last, partial, ring in several of the central basement supporting beams & beams from under the kitchen dated to 1738. This would mean that the house was built in 1738 or shortly afterward by Henry Ludlow.

Palisades Big House sometime in the late 19th-century.

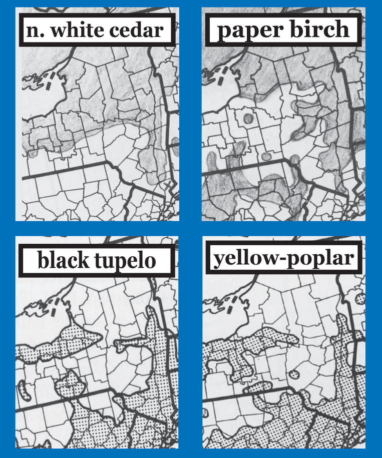
Palisades Big House as it may have appeared after being built.

Ecotones, Ecosystems & the Hudson Valley Migration Corridor

The Hudson Valley (HV) lies at an important biome transition zone between the oak-hickory, northern hardwood and boreal forest types. It has nearly 10 boreal and more than 20 southern temperate tree species living near or at a range limit. Its position at a large-scale ecotone makes it rich in biodiversity. The biodiversity plus unique geographic & ecological qualities make it a natural laboratory for studying the effects of climate change on forested ecosystems.

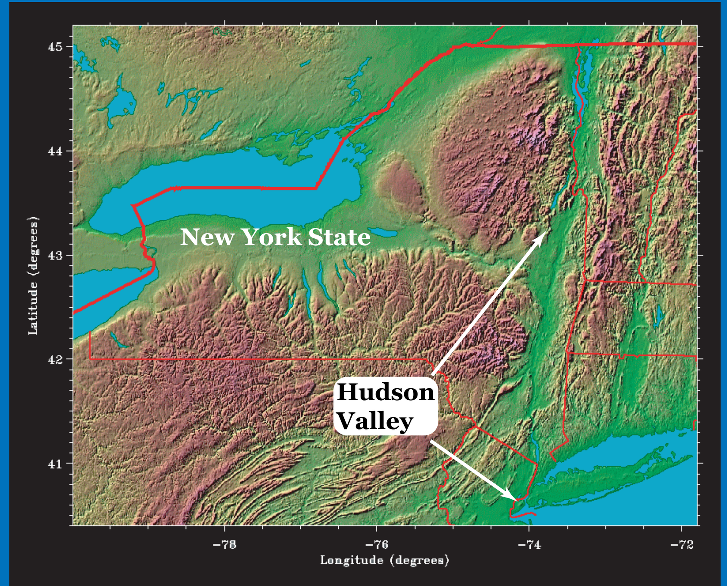
Extreme Hudson Valley Ecosystems

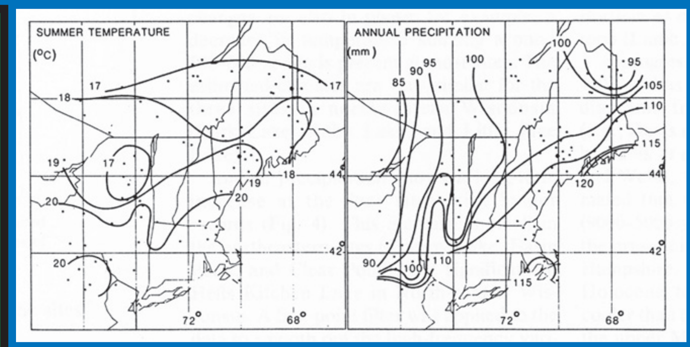
The HV has several ecosystems that are typical of dramatically different climate regions (see more @ the Tree-Ring Lab). The white spruce forest above is more common in Canada. The Atlantic white-cedar forest below is more common in North Carolina.



Distribution maps of trees with range margins in the Hudson Valley:

Northern white cedar and Paper birch are more northern species while black tupelo and yellow-poplar are southern temperate





The climate of the HV (right; from Gajewski, 1988) seems to reflect its geographic structure.

The climate of the N HV is an important climatic transition from the maritime climate of the eastern seaboard to a cooler, more continental climate. A wetter climate, like the HV, is thought to reduce heat stress of boreal tree species.

It is believed that the Hudson Valley served as a species migration corridor during periods of hemispheric warming. Its location between the Catskill, Taconic, Green and Adirondack Mtns. (figure above) makes it a natural corridor for more southern species. Indeed, since the late 1800s, southern bird species like black and turkey vultures and blue grosbeak, among others, were observed to extend their range into the Hudson Valley.

Thus, in the context of future climate change predictions, the Hudson Valley could be seen as a source of biodiversity for northern New York and New England. However, it is just as likely that even minor changes in climate will negatively impact northern species and ecosystems.

1915 vegetation map of New York State by William L. Bray. Bray completed several transects throughout NY to describe vegetation patterns.

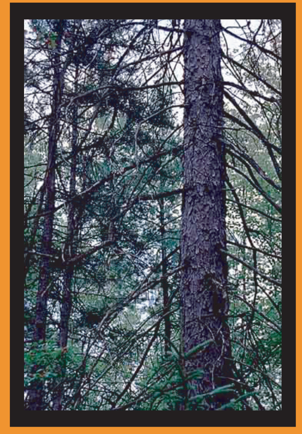
Comparing the Hudson Valley's geographic structure (figure left) and climatic distribution (figure above right) to Bray's vegetation map (figure right), it is clear that geography and climate interact to play an important role in the distribution of vegetation in eastern NY state.

The HV can be essentially outlined by the distribution of the oak-hickory-chestnut forest type (light orange). Likewise, the Adirondack and Catskill Mtns. can be seen by the distribution of northern hardwood (yellow) and boreal forests (light green).

True southern tree species can be found at the very bottom of the HV in Staten Island, NYC & southern Long Island (dark orange).

Climate Change & Range Limits: How Will the Trees Migrate?

Climate modellers have predicted, with a 90% probability, that global climate over the next 100 yrs will warm 1.7-4.9 degrees Celsius. A primary question is, *"How will trees and forests respond to such a rapid climate change?"* There is surprisingly little information of the climatic factors that are important for trees growing at low elevation, mid-latitude forests. Tree-Ring Lab researchers are trying to fill in these data gaps for the Hudson Valley (more @ the Tree-Ring Lab).



A red spruce bog in the N Hudson Valley

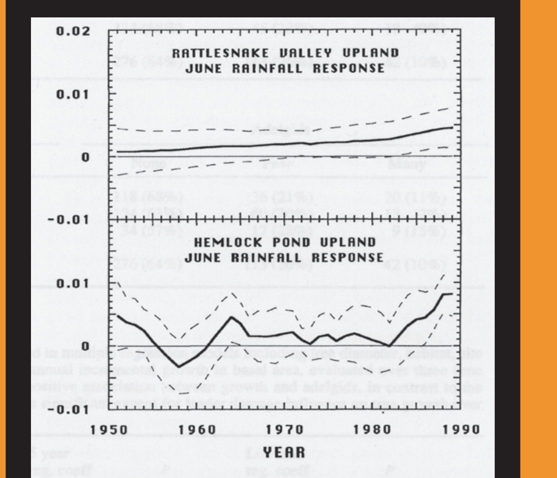


FIG. 8. Time-dependent relationships between June rainfall and the RVU and HPU chronologies. Heavy solid lines show the regression parameter as it changes with time; dashed lines are 2-standard error limits. Where these confidence intervals do not intersect zero, the parameter is significant at the 95% confidence level.

Webb, S.L., Glenn, M.G., Cook, E.R., Wagner, W.S. and Thetford, R.D. 1993. Range edge red spruce in New Jersey, U.S.A.: bog versus upland population structure and climate responses. Journal of Biogeography 20: 63-78.

This study was conducted in the early 1990s on red spruce growing near a southern range limit in northern New Jersey.

Climate response analysis showed that most of the upland sites sampled grew better with increased precipitation during March and June. The bog red spruce showed no such response.

The upland populations also became more drought stressed over the last 50 years. It was concluded that local pollution may be the cause for the change in the climate/growth relationship. Plant ecophysiologists believe that trees growing near their southern range limit avoid heat stress by growing on wet sites or in regions with greater precipitation. Thus, it could also be that warming in the NE US over the last 50 yrs has outstripped the water requirements of red spruce, increasing their heat stress and sensitivity to drought.

Kalman filter analysis shows red spruce (figure above) & its changing relationship w/rain.

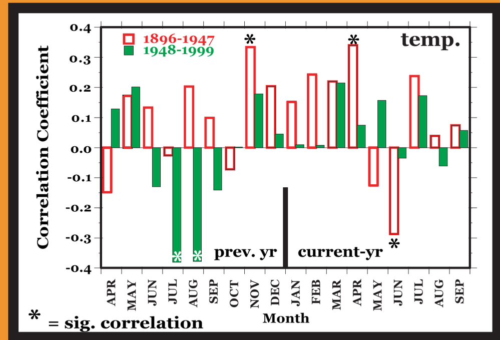
Climate/Growth Relationships of Range Margin Southern Temperate & Boreal Tree Species in the Hudson Valley

Neil Pederson (grad student) under the guidance of
Gordon Jacoby, Ed Cook, Dorothy Peteet & Kevin Griffin

A recent vegetation modeling study predicted significant changes in eastern US forests including tree species migration of 100 to 250 km under greenhouse gas warming scenarios within 100 years. However, the type of tree growth factors used & lack of long-term climate-tree growth information limits the realistic modelling for future climate change scenarios.

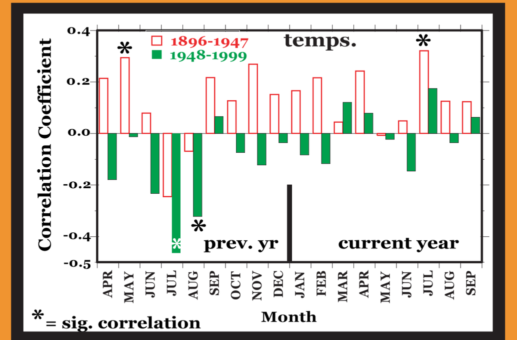
Tree-ring analysis has long been used to directly determine a tree species' monthly or seasonal climate response. It can also reveal how a species' relationship to climate changes as the result of a changing climate. By using the biodiversity of the Hudson Valley, tree-ring analysis can determine a robust, long-term estimate of climate/growth relationship for many important eastern US tree species.

Shushan Outlier White Spruce
Split Period Climate Analysis



- growth *is* limited by high temperatures, esp. from 1948-99 and this population is becoming *more sensitive* to current-yr August drought

Lincoln St. Forest Black Tupelo
Split Period Climate Analysis



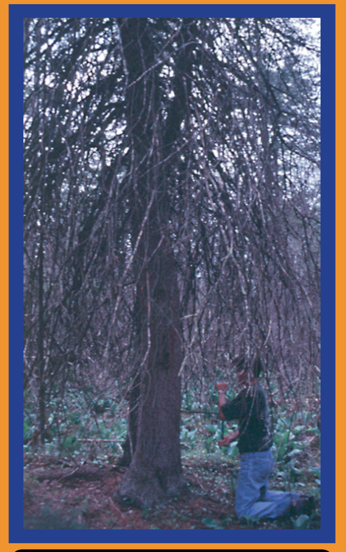
- temps 1896-1947: warm p. May, curr. July
- temps 1948-1999: Cool prev. Jul & Aug

The first step in this new study was to compare the climate response of two contrasting tree species, white spruce and black tupelo.

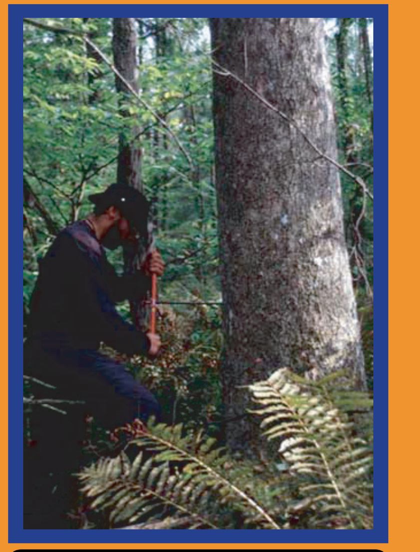
White spruce is the dominant tree species at the North American hemispheric northern treeline while black tupelo is more common throughout the SE US.

Results show that in the last 50 years, white spruce @ its southern range limit is becoming more sensitive to warm summer temperatures and August drought despite growing in a swamp. This result supports climate model predictions of future tree migration.

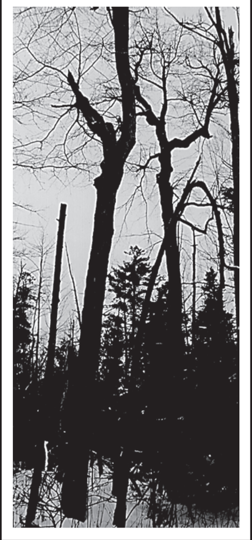
The negative temperature response of black tupelo over the last 50 years was unexpected. Factors that could contribute to this unusual result are age, canopy structure, an inherently high respiration rate for black tupelo or the influence of pollution.



Shushan White Spruce Outlier - southernmost known NYS population



Lincoln Mountain State Forest Black Tupelo - oldest known trees in New York State



Centuries of storm damage to black tupelo crowns (above) may play a role in the negative response to high summer temperatures.

Future Directions:

A network including a minimum of 30 tree species will be developed to provide a characterization of the species-climate relationship in the Hudson Valley.

Thus, this study will have direct application to how climate change may effect biodiversity and ecosystem processes under future global change scenarios.

The potential movement of the biome ecotone in the Hudson Valley region will be more easily anticipated as a result of this study.

Comprehending climate change impacts on forest ecology will be important for regional economics.

Such knowledge will also aid development of ecosystem management plans for public and private landowners.

Furthermore, this study should be a ton of fun!