# Comparing performance of low-cost dendrometers to traditional dendrometers in tracking tree growth in a changing climate

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## Introduction

- The northeastern United States is experiencing some of the greatest shifts in climate in the US, with warming winters, increased frequency of extreme precipitation events, and severe droughts [1-3].
- Tree productivity is impacted by multiple global change factors, but their impacts may be variable across space [4].
- We are lacking adequate information to connect tree growth and productivity trends across the Northern Appalachian region, which is critical to understand adaptation under future climate scenarios [5-6].
- Broad-scale study of tree growth is limited in feasibility due in part to the high cost of dendrometer instruments - devices that measure the radial growth of tree stems - required to reliably measure these characteristics. However, some cheaper options are starting to come onto the market [7].

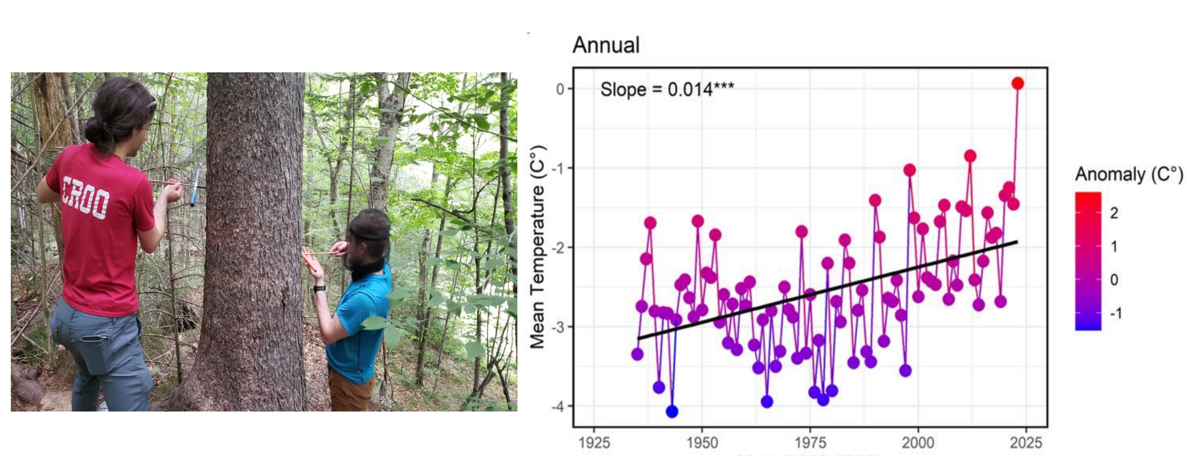



Figure 1: (Left) Traditional methods, such as dendrochronology, to study tree growth across space and time is limited by effort and logistics. (Right) Mean annual temperatures on Mt. Washington, NH, have significantly increased over the last eight decades [1].

## The problem

- A large obstacle for consistent measurement of tree growth rates at meaningful scales is the need to use cost-restrictive dendrometers. Low-cost alternative instruments exist, but there is currently not adequate information on the reliability of these devices to support their use in gathering scientific-grade data.

## Key questions

- Can we adequately capture and compare intra- annual tree growth patterns with both traditional and low-cost dendrometers?
- Can we feasibly implement a low-cost dendrometer network to measure tree radial growth rates across climate/edaphic gradients and between different age classes of trees and tree species both during summer growing periods and colder seasons.

## Methodological approach

### Field design:

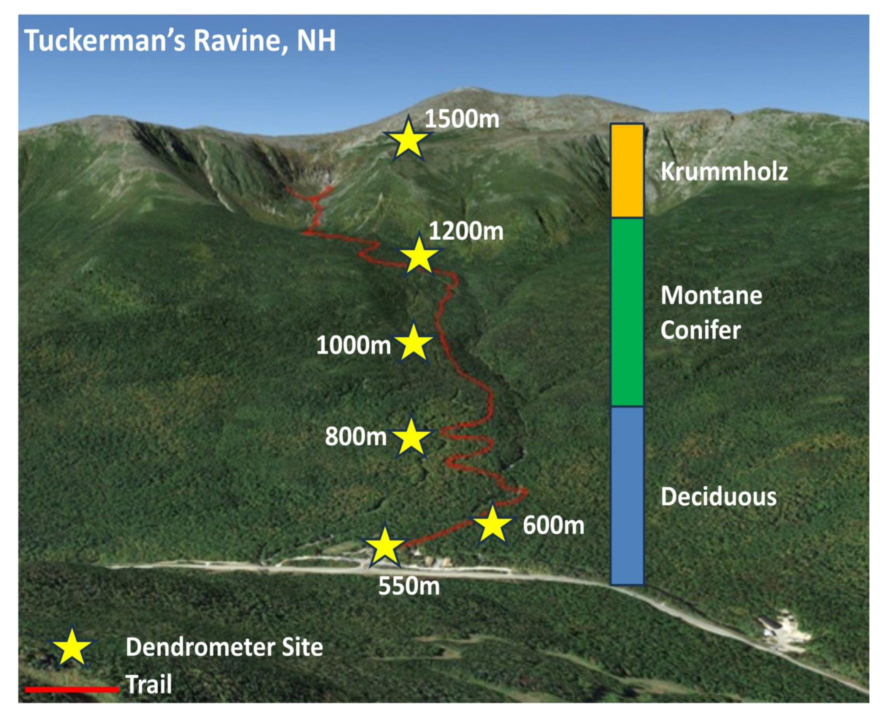



Figure 2 (left):

Dendrometer site placement along the Tuckman Ravine elevation transect.

Figure 3 (right):

Comparison of the traditional expensive Ecomatik (left) dendrometer and the cheaper TOMST (right) point dendrometer on the same trees across an elevation gradient.

### Important contrasts:

- Ecomatik vs. TOMST dendrometer measurements
- Large diameter vs. small diameter tree growth
- High elevation vs. low elevation tree growth
- Deciduous vs. conifer vs. krummholz tree growth

### Analyses:

Generalized linear mixed models:

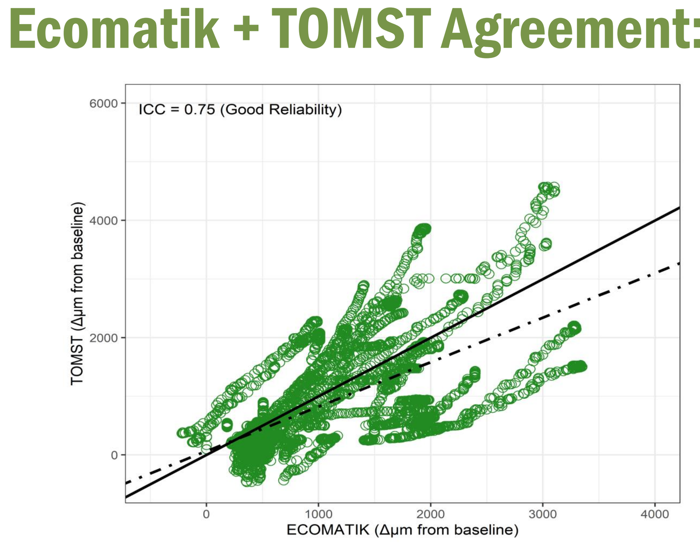
Global: glmer(diff ~ sensor_type + temp + size_class + elevation + (1|tree) + (1|species), family = gaussian

Exploratory comparisons

- T-test + correlations
- Histograms and summary statistics
- Scatterplots

## Direct sensor comparisons

### Ecomatik + TOMST Agreement:




Reduced Model Results (Generalized linear mixed model):

Fixed effects:

| | Estimate | SE | t-value |
|---|---|---|---|
| Intercept | 832.44 | 64.93 | 12.82 |
| **TOMST** | **-151.71** | **10.03** | **-15.13** |

- TOMST underestimates relative to Ecomatik
- ICC indicates good agreement

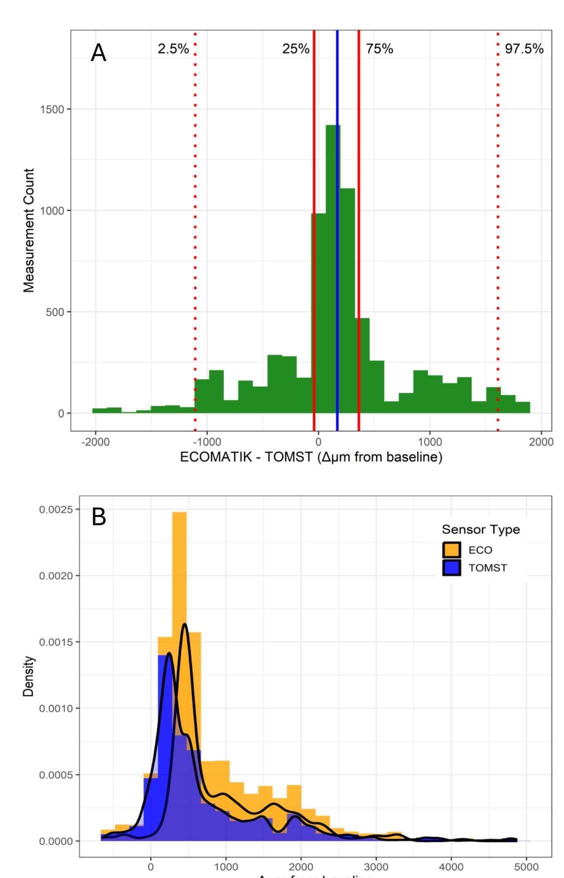
Figure 4 (left):

Comparison of mean daily growth measurements between Ecomatik (x-axis) and TOMST (y-axis) dendrometers. Interclass correlation coefficient (ICC) of 0.75 between the two sensors indicates good agreement. The solid line indicates 1:1 line and dotted line indicates best linear fit.

Figure 5 (right):

(A) Distribution of daily sensor differences between Ecomatik and TOMST units (with 50% and 95% quantiles). (B) Growth measurement histogram for both dendrometer types. Line indicates measurement density distributions.

### Ecomatik + TOMST Reliability:




Summary Statistics:

N: 7102
Min: -1947 μm
Q2.5: -1107 μm
Q25: -40 μm
Mean (±sd): 168 (±639) μm
Q75: 361 μm
Q97.5: 1610 μm
Max: 1846 μm
Range 95%: 2717 μm

- Most TOMST + Ecomatik growth measurements fall within ± 1.4 mm; 50% within ± 0.2 mm

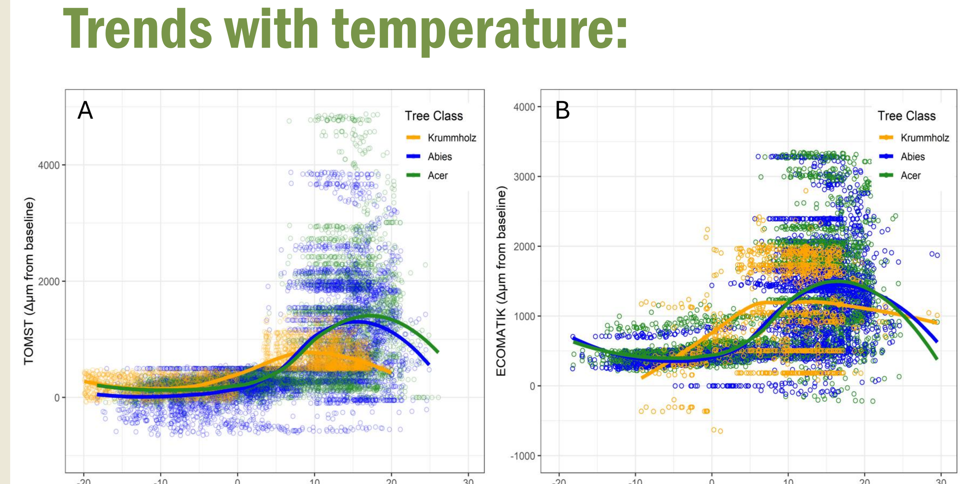
T-Test:

t = -26.588, p-value < 0.001
95% CI: -278 μm to -240 μm
TOMST Mean = 650 μm
Ecomatik Mean = 909 μm

- Ecomatik consistently overestimates tree growth relative to TOMST, magnitude is small

## Relationships with covariates

### Trends with temperature:




Reduced Model Results (Generalized linear mixed model):

Fixed effects:

| | Estimate | SE | t-value |
|---|---|---|---|
| Intercept | 703.88 | 99.47 | 7.07 |
| TOMST | -162.72 | 8.90 | -18.28 |
| **Temperature** | **41.14** | **0.42** | **95.74** |
| **Elevation** | **-16.44** | **9.11** | **-2.86** |

- Temperature (strong positive) and elevation (weak negative) have effects on growth
- Krummholz initiation of growth at lower temperatures than lower elevation trees

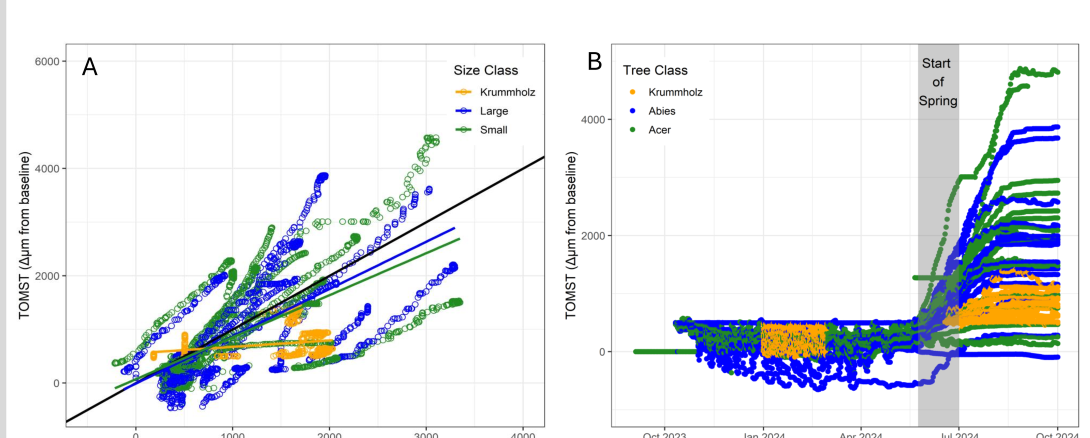
Figure 6 (left):

(A) TOMST tree growth measurements across a range of temperatures partitioned by tree type (krummholz indicates stunted *Abies* at treeline). Colored solid lines indicate loess fits. (B) Ecomatik tree growth measurements across a range of temperatures partitioned by tree type.

Figure 7 (right):

(A) Comparison of TOMST and Ecomatik growth measurements partitioned by tree size class. Solid line indicates 1:1 line. Colored solid lines indicate best linear fits by tree size class. (B) Time series (between October 2023 and October 2024) of TOMST tree growth trends partitioned by tree type (krummholz indicates stunted *Abies* at treeline). Shaded area displays initiation of seasonal tree growth (5/21 – 6/30).

### Trends between diameter and tree classes:




Reduced Model Results (Generalized linear mixed model):

Fixed effects:

| | Estimate | SE | t-value |
|---|---|---|---|
| Intercept | 570.08 | 78.09 | 7.30 |
| TOMST | -162.67 | 8.90 | -18.27 |
| Temperature | 41.14 | 0.43 | 95.74 |
| **Large Size** | **56.54** | **107.98** | **0.52** |
| **Small Size** | **110.38** | **107.98** | **1.02** |

- No significant differences in growth between tree size class
- Initiation of tree growth in spring may be good phenological indicator

## Conclusions

- Expensive Ecomatik dendrometers tended to significantly overestimate radial growth relative to the cheaper TOMST units, but the magnitude of these differences were small and there was generally good agreement between the two.
- The same overall trends as above were also attributed to different tree species, size classes and sites.
- As expected, radial growth patterns were closely tied to temperature, with threshold responses of the onset of seasonal growth detected with both devices.
- Elevation, was only weakly tied to patterns of seasonal radial growth. Krummholz trees displayed reduced growth compared to all other trees monitored, but experienced growth onset at lower temperatures. There were no detectable differences in growth patterns between large and small diameter trees.

### Next steps:

- Examine growth trends across more seasons and include other relevant climate variables, such as accumulated growing degree days (AGDD) and chilling degree days (CDD).
- Test the feasibility of other dendrometer models, particularly those with remote data signaling capability.
- Explore and design methods to establish a dendrometer network across the FEMC monitoring region.

## References

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