

Buds, Leaves and Global Warming

John O'Keefe

Harvard Forest

jokeefe@fas.harvard.edu

- www.harvardforest.harvard.edu/schoolyard-lter-program
- www.harvardforest.harvard.edu/buds-leaves-global-warming
- www.harvardforest.harvard.edu/autumn-foliage-color

What is **phenology**?

The science of the relations between climate and periodic biological phenomena (i.e. leaf emergence, flowering, leaf senescence/drop, animal migration, hibernation etc.)

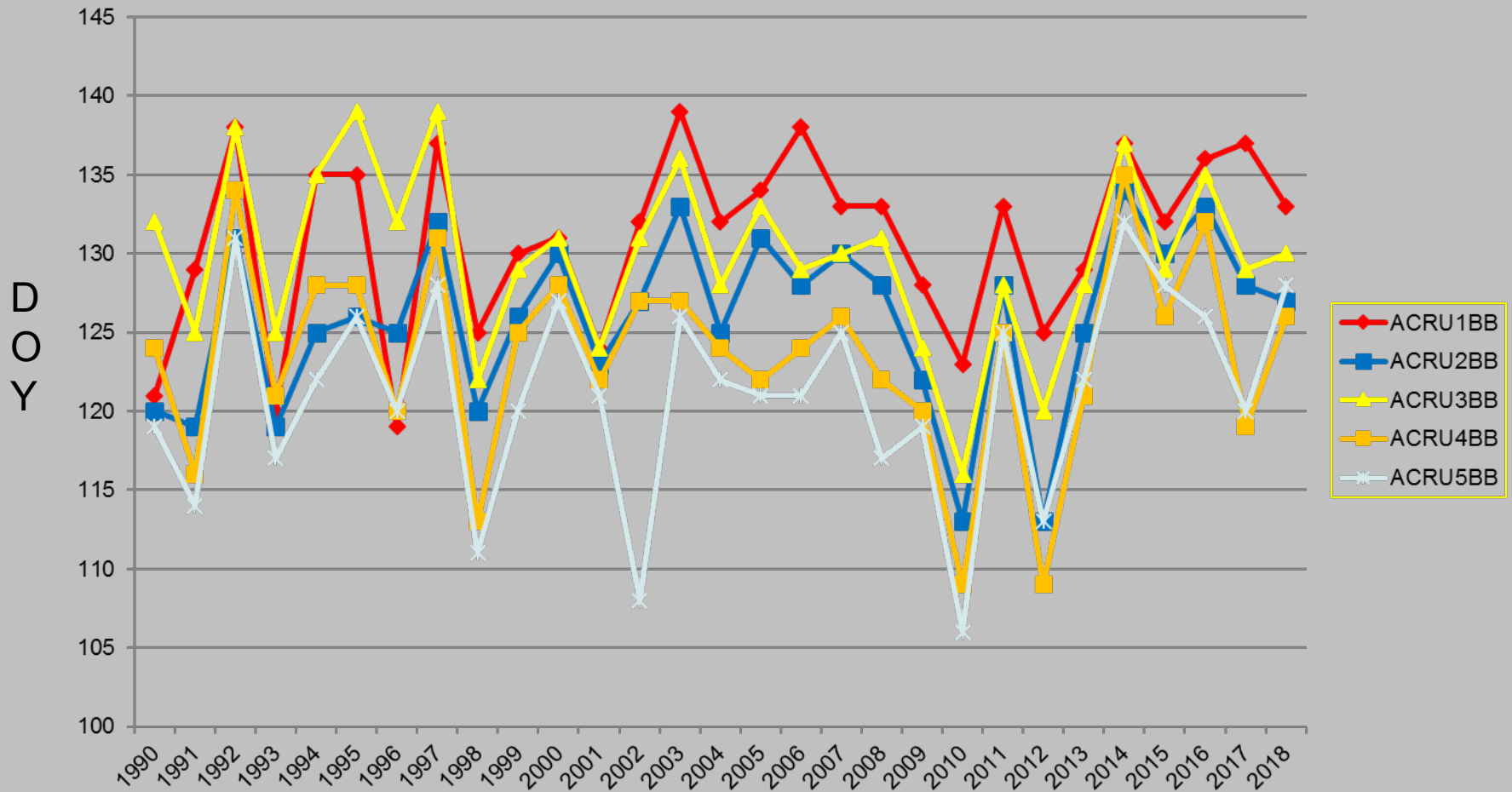
What are the main factors affecting the timing of woody species leaf phenology?

- **Spring leafout**
 - Cold treatment
 - Cumulative heat sum (growing degree days)
 - Day length
- **Fall leaf drop**
 - Temperature and frosts
 - Day length
 - Drought
 - Wind

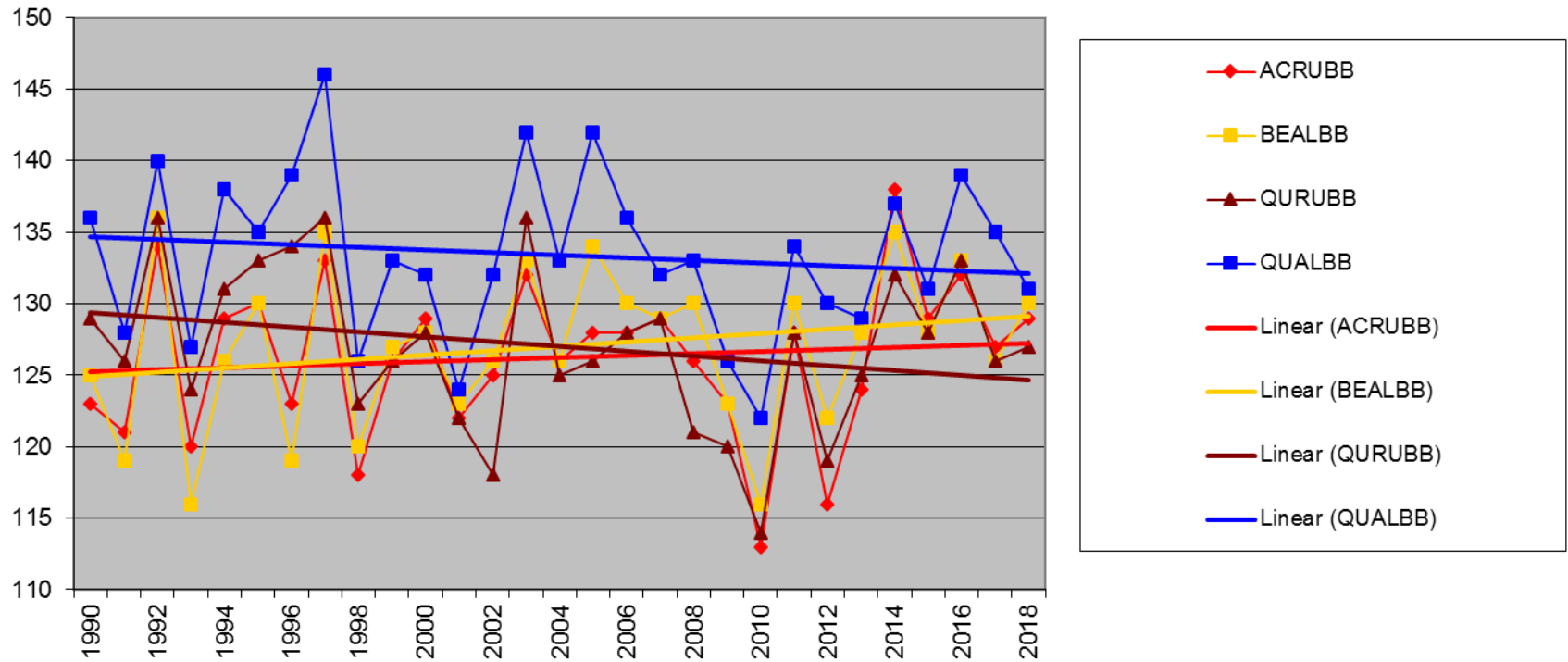
Harvard Forest Study

- Started in 1990 (spring) and 1991 (fall, but fall 1992 not done).
- Originally 33 species of trees and shrubs (3-5 individuals per species), but in 2002 decreased to 15 species in fall and 9 species in spring to reduce the time needed for the study.
- I observe about weekly, but more often in late April-early May and early October when events are progressing most rapidly.
- I observe and estimate % values (leaf emergence, leaf development, leaf color, leaf drop) over the entire tree (rather than a set number of tagged leaves/buds), which is in fact easier than labeling and counting individual leaves, but doesn't work with younger students.

50% budbreak data for 5 red maples 1990-2018

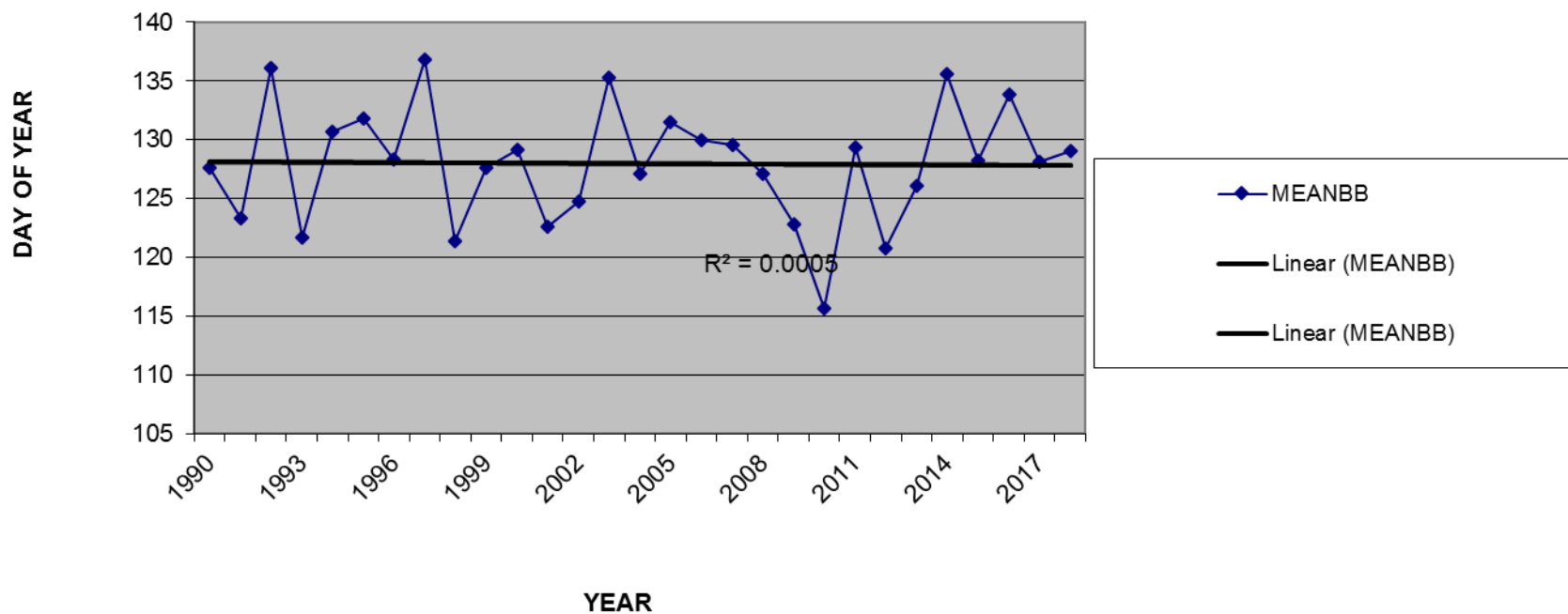


Mean 50% budbreak dates for four species 1990-2018



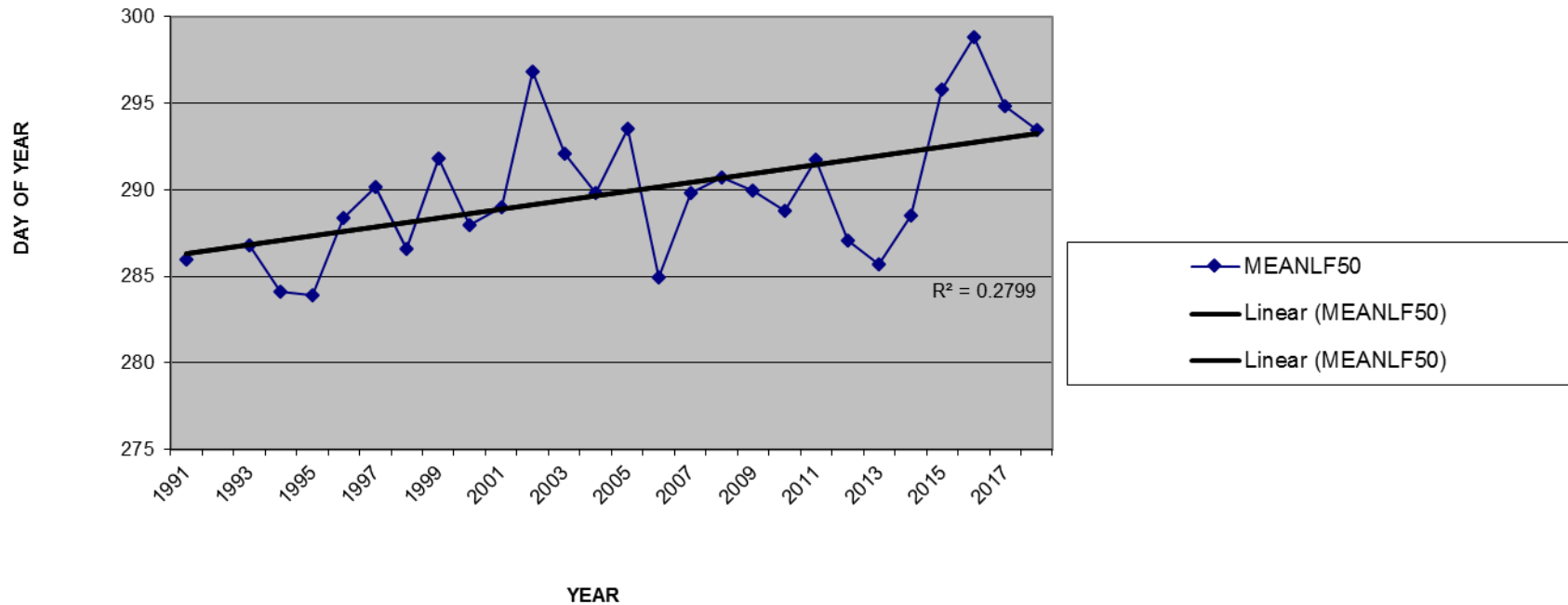
Mean Bud-Burst in 4 Species, 1990-2019

MEAN BB50 (4 SPP, N=15)



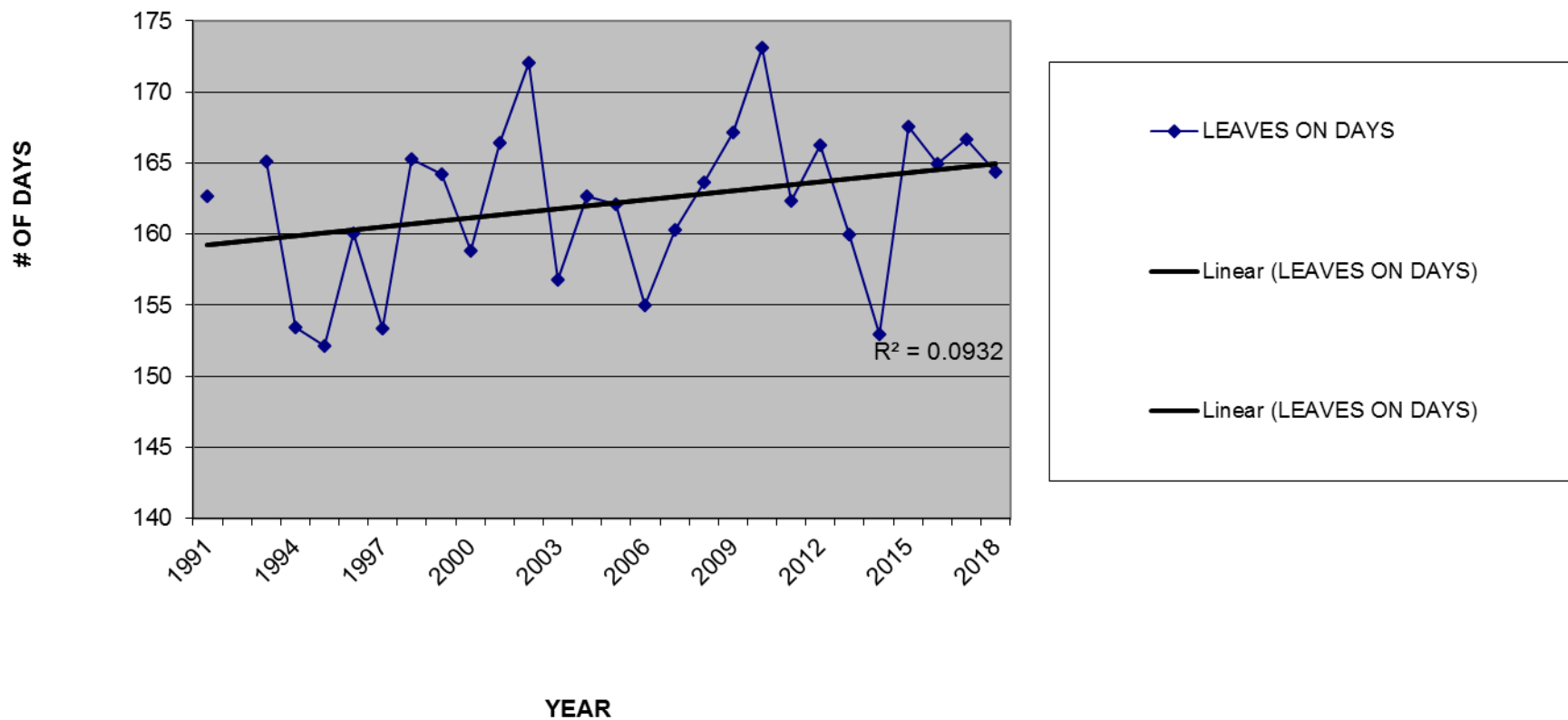
Mean Leaf-Drop in 4 Species, 1991-2019

MEAN LF50 (4 SPP, N=15)

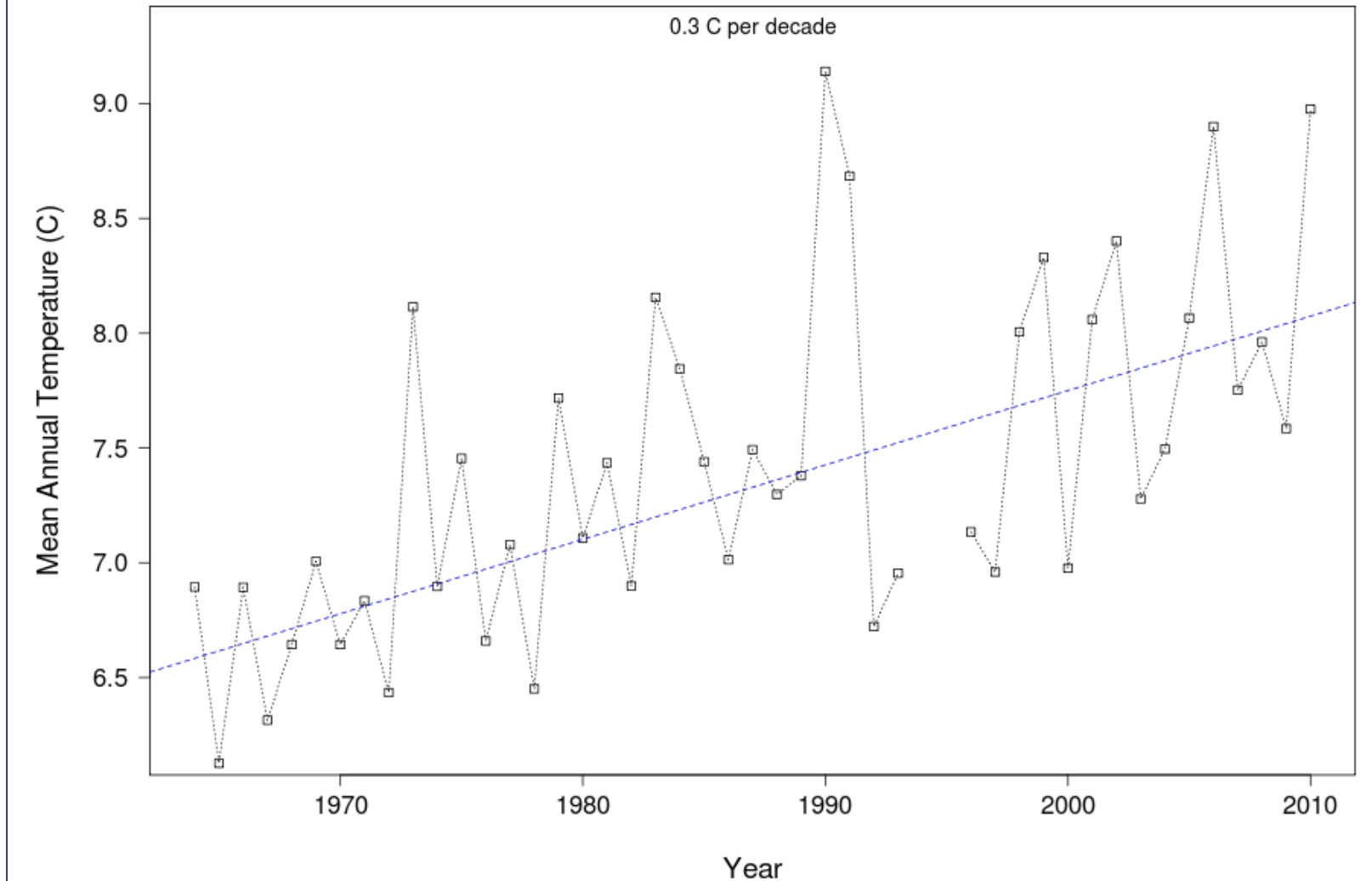


Mean Growing Season Length in 4 Species, 1991-2019

LEAVES ON DAYS (4 SPP, N=15)



Mean Annual Temperature at Harvard Forest Meteorological Station



Mean annual temperature has increased **0.3C** per decade, though with large interannual variability, and seasons independently of annual mean

Tree ID tips

- The first thing to look at is the arrangement of leaves, buds and branches. Are they opposite each other or staggered alternately along the branch or stem.
- Only a few native trees (maples, ashes, dogwoods – **MAD**) have opposite leaves/branches. The rest are alternate.
- Are the leaves simple (each leaf has a bud at the base of its stem or petiole) or compound (the leaf stem that is attached to the woody twig next to the bud has many leaflets along it)? The ashes, hickories, walnut, butternut and sumacs are the main compound leaf species in this region.
- Then look at leaf shape, edges and vein pattern, bud shape and check for twig smell and bark characteristics.

Spring Data Collection

- Typically start data collection in late March, but this may vary depending on March weather. I strongly recommend bringing shoots of study species inside in mid-March to force.
- Try to collect data once a week.
- Each student team will observe the 6 live buds closest to the branch tip (skipping the terminal bud if there is one) that have been previously labeled.
- On the first visit it is a good idea to have them sketch the branch and study buds and bring the sketch on later visits to help identify the study buds.
- They will record how many buds have recognizable leaves, not just leaf tips, emerged from them.
- Once leaves have emerged, record the length (not including stem) of the largest leaf.
- The teacher will combine all data for each tree and submit to Harvard Forest.

Field Notes/Observations

- These notes are optional and not submitted, but represent the type of observations scientists make when they are collecting their data.
- Typical observations might include temperature, cloud cover, precipitation, wildlife observations, any unusual conditions or recent events/changes such as a strong windstorm or frost/freeze.

Red Oak

Moderately
Puffy Buds



Moderately Puffy



White Ash

Slightly puffy buds



Very puffy

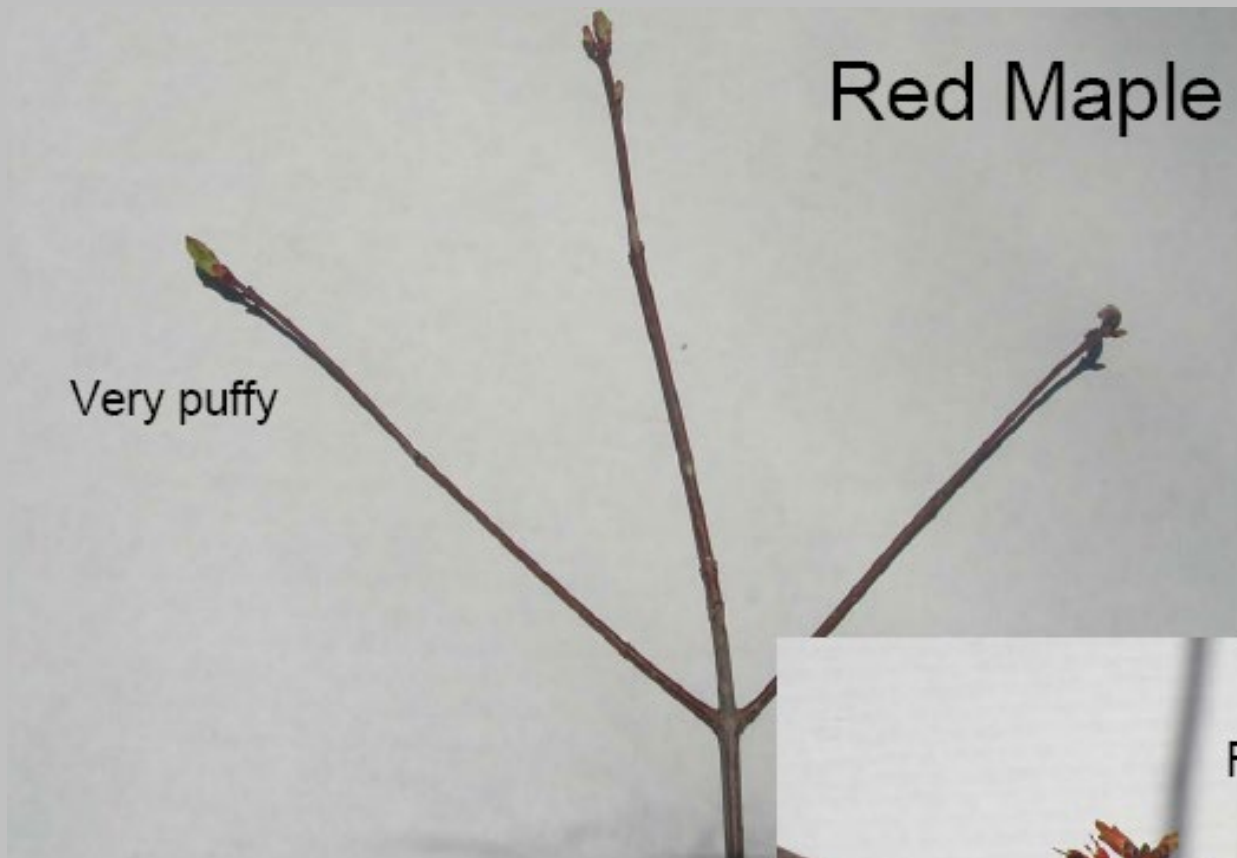




Yellow Birch-Mixed-some open and some puffy

Red Maple

Very puffy

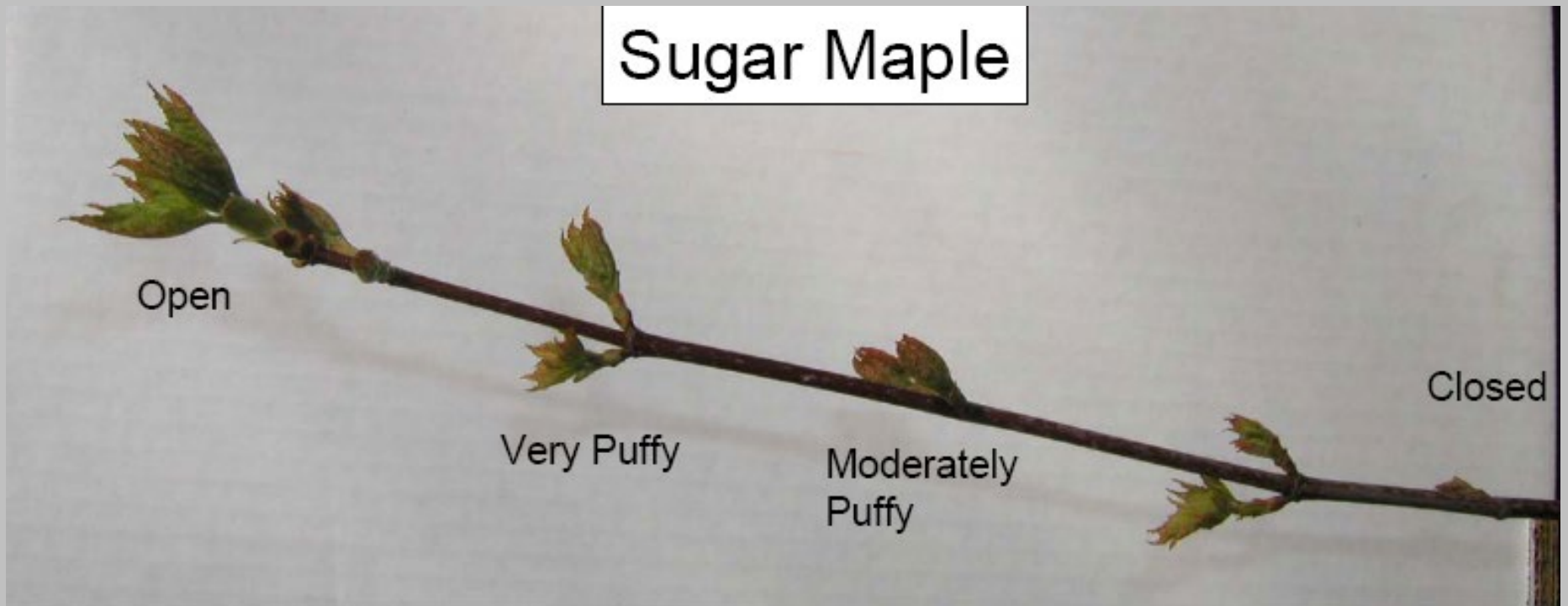


Flowers

Very puffy



Sugar Maple





American Beech-Slightly-moderately puffy buds



Beech-Some buds are open,
Others very puffy

Backyard Buds Study During School Closure

- **Whole Tree Monitoring-** Similar to in the “Whole Tree Color” estimate in on regular fall phenology field sheet, have the students estimate what proportion of the buds have leaves fully emerged.
- **50% Budburst Calculations:** This would still allow calculation of 50% leaf emergence dates that could be compared with other years, but eliminate the hardest part of the setup.
- **Tree ID with Photos:** We recommend students who can do so, take pictures of the trees/branches/buds/developing leaves and we could help with ID over time.





**Harvard Forest LTER Schoolyard Program
Buds, Leaves and Global Warming**

BACKYARD Student Data Sheet – Spring 2020 AT HOME

This field sheet will be available through email via Pamela and will be Posted on a special webpage with resources to use during school closure.

Email Pamela for more information.

Name: _____
 School: _____ Date: _____
 Tree Species: _____
 Tree ID (number): _____ if you are using more than 1 tree at your site, please number each tree and complete separate field sheets for each tree.

1. Try to identify your tree to complete the Tree Species above.
2. Take a photo of each of your Neighborhood study trees for this project. Send them to your teacher by email or Google Classroom, etc. Include the tree species you think each tree is and the tree number in your email to your teacher.
3. Look at all the Buds on your tree. Estimate how many buds have opened all the way. Remember that open means you can see the entire new tiny leaf, including the leaf stem.

Budburst Code	Fraction of buds that have opened
1	0 – 25%
2	26-50%
3	51-75%
4	76-100%

Whole Tree Budburst: Look at the entire tree and estimate what fraction of all the buds on the tree have opened. Use the code from the box on the left to report in the box below.

Whole Tree Budburst Code

4. If you can reach any branches, look for the open bud with the largest leaf.

Measure the leaf length in centimeters: _____

5. **Field notes:**
 Temperature (Degrees Celsius): _____
 Humidity(%): _____ Circle one: Sunny Cloudy Rainy
 Other observations and Notes: _____

Remote Buds Protocol During School Closure

Photos and Notes by Elisa Margarita,
Brooklyn Technical School



- *This week I brought the paper, the rope, dressed warm,.. However, the photos were scrambled and out of order... Now I know next time label the background paper when I take the image.*
- *There are some buds or branches that I am having a hard time figuring out how to record. The Elm is hard to tell if these are leaves in a bundle of flowers. The cherry tree has so many flowers, but they also seem to be bunches of leaves. How do I count those? Leaf out? And Green Ash has a turf at the terminal end- what is that calculated?*

Buds, Leaves and Global Warming

John O'Keefe

Harvard Forest

jokeefe@fas.harvard.edu

- www.harvardforest.harvard.edu/schoolyard-lter-program
- www.harvardforest.harvard.edu/buds-leaves-global-warming
- www.harvardforest.harvard.edu/autumn-foliage-color

Discussion Slides

Extra slides to help with
discussion as needed



Ash

Field maple

Birch

Alder

Elder

Hazel

Beech

Horse chestnut

Rowan



Oak

Lime

Lilac

Hawthorn

Blackthorn

Larch

Sycamore

Dog rose

Elm

Buds related links from teachers and HF staff

Phenocam Education:

<https://phenocam.sr.unh.edu/webcam/education/>

Bennett. 2012. [Phenology and student scientists \(5th grade\)](#).

Bennett. 2012. Using Phenocam images with Schoolyard phenology protocol: [part I](#) and [part II](#). Are some of the activities that Kate Bennett has developed and used with her students that make use of online Phenocam data and images.

Phenology Elementary Podcast [–Phenology Intro.mp4-](#)

Developed by Marjorie Porter at Ct. Audubon to be used as part of our plant life cycle outreach unit for at-home learners.

- [Westwood 2020 Yard Challenge](#) page by Michael McCarthy has students participating in a biodiversity study in their neighborhoods. He has students using online tree/shrub keys for identification by 7th graders. including the [GoBotany Simple Key](#), the [Arbor Day Foundation's What Tree Is That? Online](#), and the [Trees of Massachusetts](#) by [iNaturalist](#).

More Buds Related Resources

- xi. **Forcing Branches//Garden Answers Video** at:
 - <https://www.youtube.com/watch?v=8ALOrDBMpQs>
- shared by Laura Schofield. Pamela S. recommends using Budburst Preview lesson by GLOBE to complement this. Link at: [Budburst Preview Lesson-GLOBE](#)
 - Jane Lucia assigns her students to use the Harvard Forest online graphing tool to create graphs of the growing season for their study trees. Link to the online graphing tool for all schoolyard projects at: https://harvardforest2.fas.harvard.edu/asp/hf/php/k12/k12_graph.php
- To create that specific kind of graph at that **site**, students used **this part of the graphing tool**:
- [graph fall_phenologytype=single&school_code=WNM&site_code=WNM](#)
 - Kindergarten activity to modify for elementary grades:
<https://budburst.org/sites/default/files/pdf-files/Budburst%20Buddies%20Storybook%20and%20Journal%20R>

More Buds Related Resources

Forcing Branches//Garden Answers Video at:

<https://www.youtube.com/watch?v=8ALOrDBMpQs>

shared by Laura Schofield. Pamela S. recommends using Budburst Preview lesson by GLOBE to complement this. Link at: [Budburst Preview Lesson-GLOBE](#)

Growing Season Graph assignment: Jane Lucia assigns her students to use the Harvard Forest online graphing tool to create graphs of the growing season for their study trees. Link to the online graphing tool for all schoolyard projects at:

https://harvardforest2.fas.harvard.edu/asp/hf/php/k12/k12_graph.php

To create that specific kind of graph at that site, students used this part of the graphing tool:

- [graph](#)
[fall_phenologytype=single&school_code=WNM&site_code=WNM](#)

Buds Resources Page 3

- Kindergarten activity to modify for elementary grades:

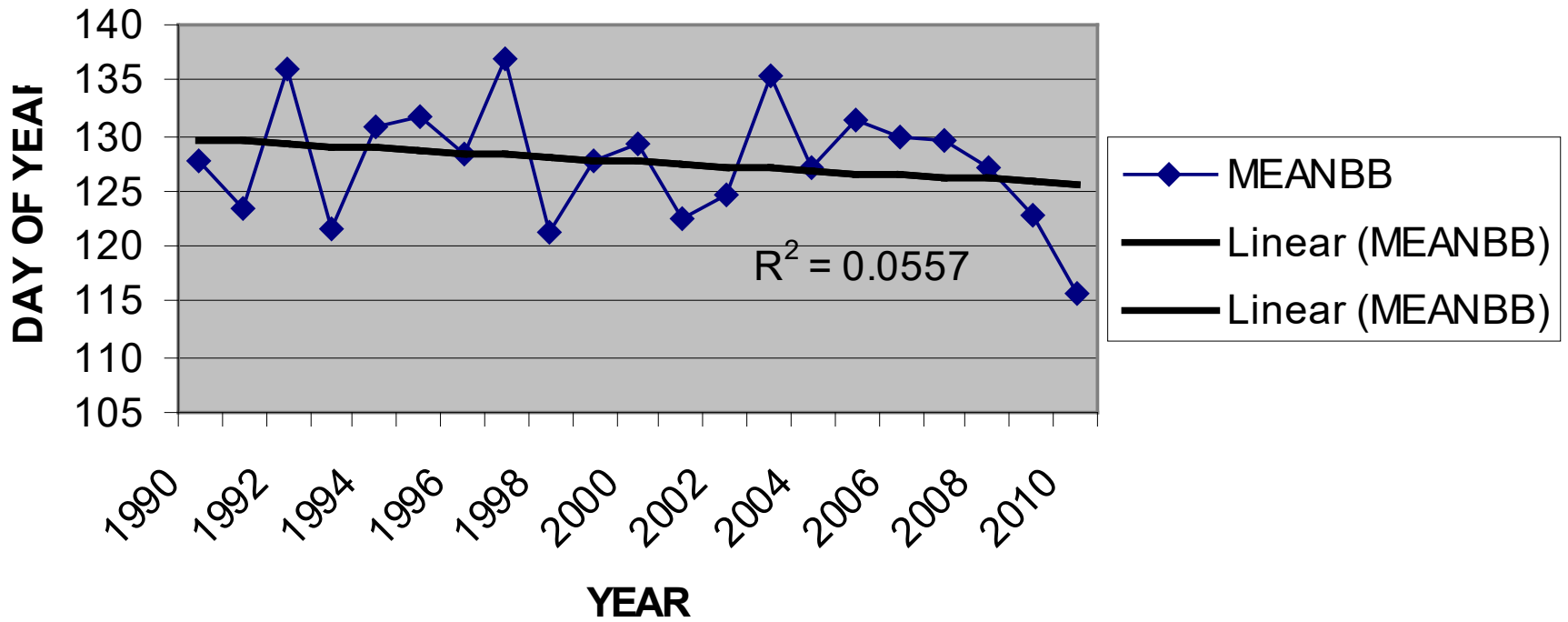
<https://budburst.org/sites/default/files/pdf-files/BudburstBuddiesStorybookandJournal.pdf>

- JANE LUCIA's remote assignment- Share screen and have her tell of her work

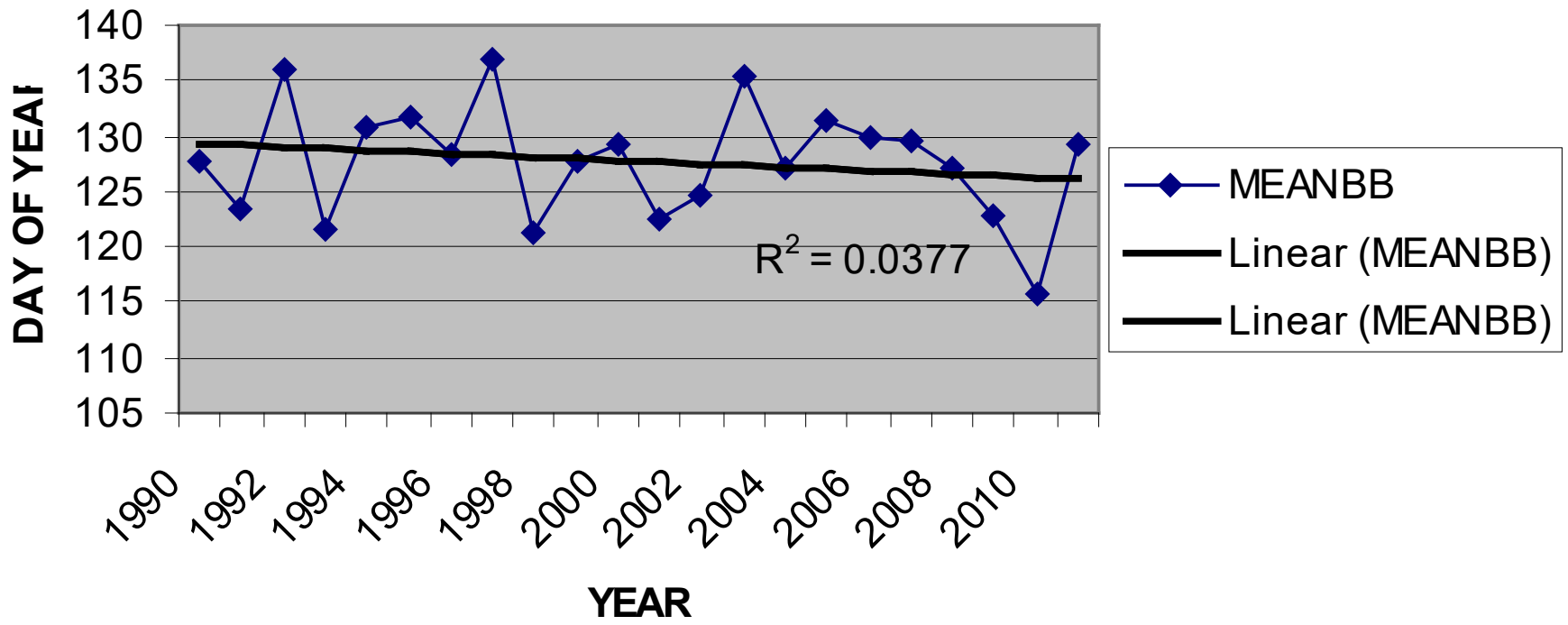
Buds Discussion Points

- **DOCTOR** Maria Blewitt- Austin
Preparatory School Teacher/ Buds,
Leaves and Global Warming teacher
leader has successfully defended her
dissertation which encompassed Citizen
Science in the classroom. She will be
leading a Schoolyard Eco Zoom Session
in May. Stay tuned for more!

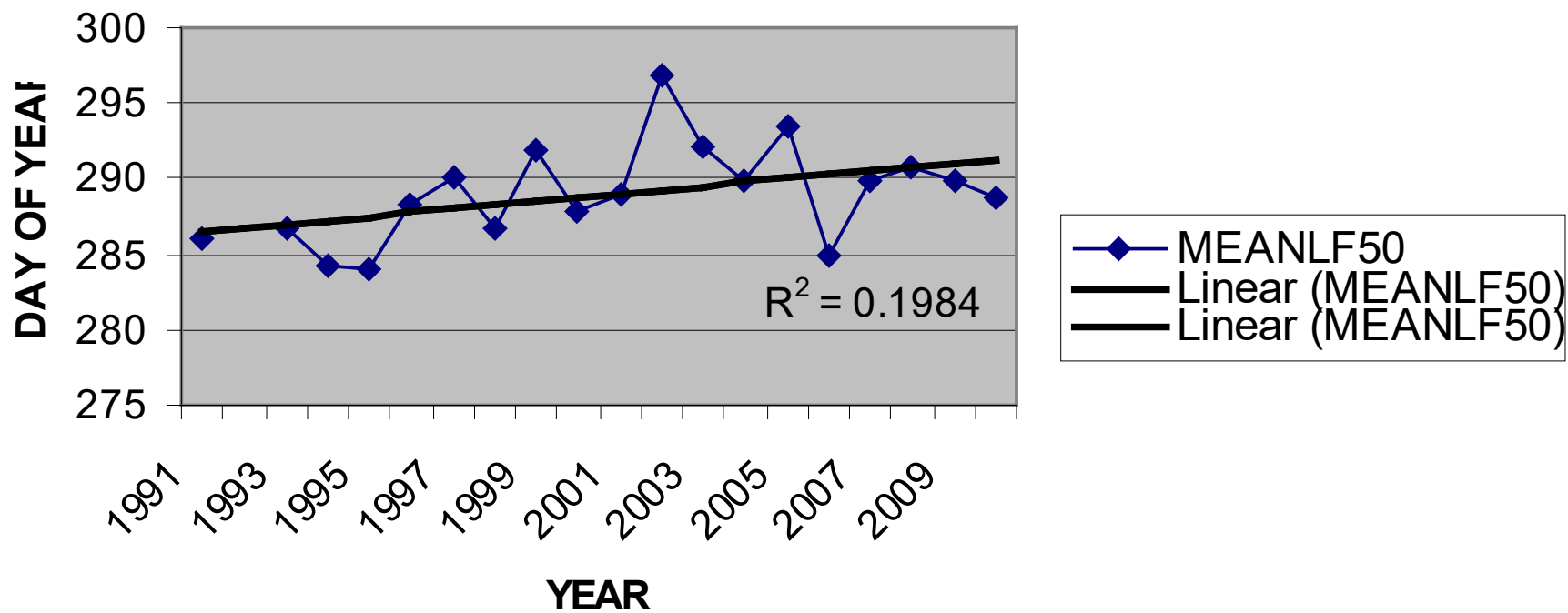
MEAN BB50 (4 SPP, N=15)



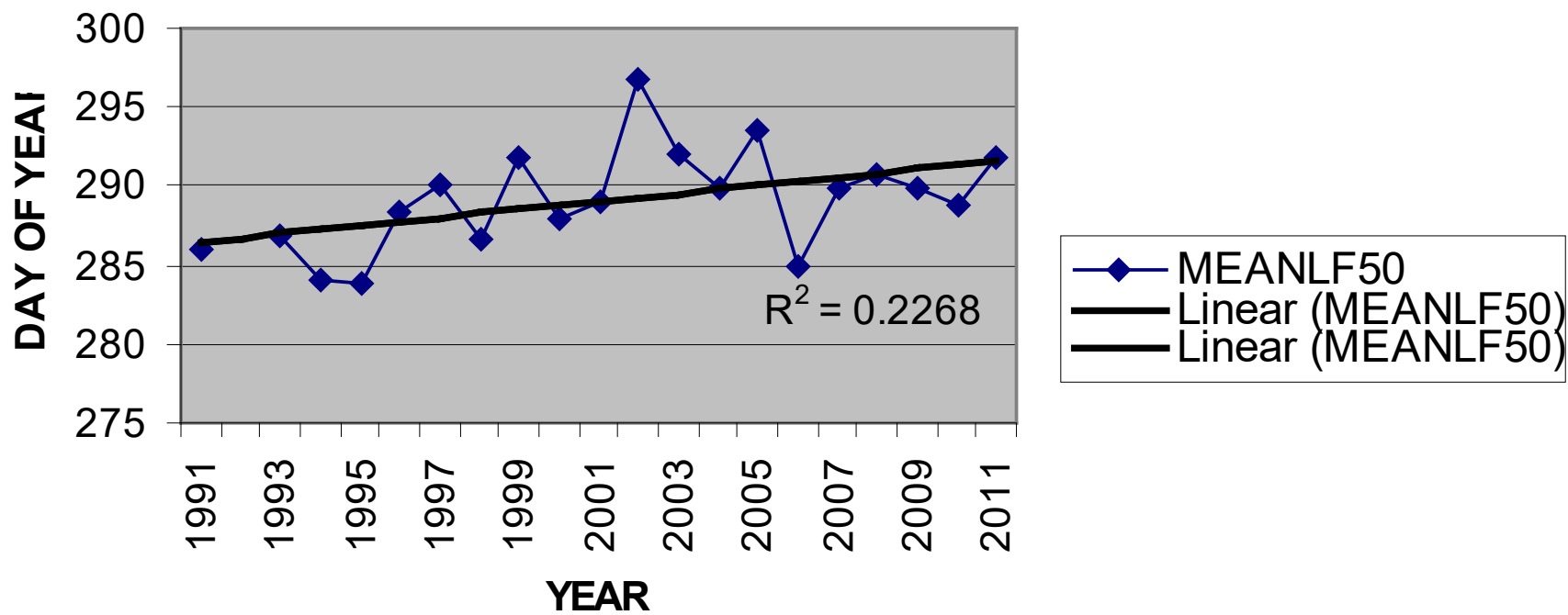
MEAN BB50 (4 SPP, N=15)



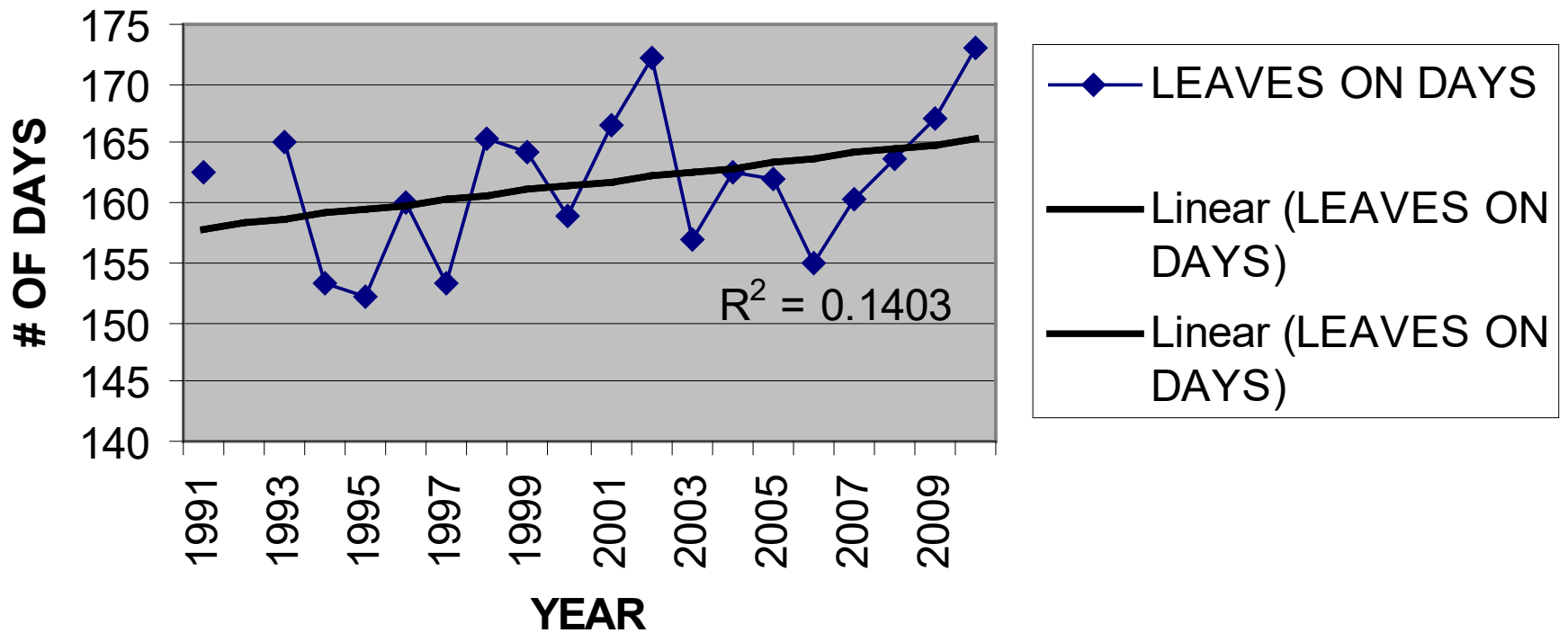
MEAN LF50 (4 SPP, N=15)



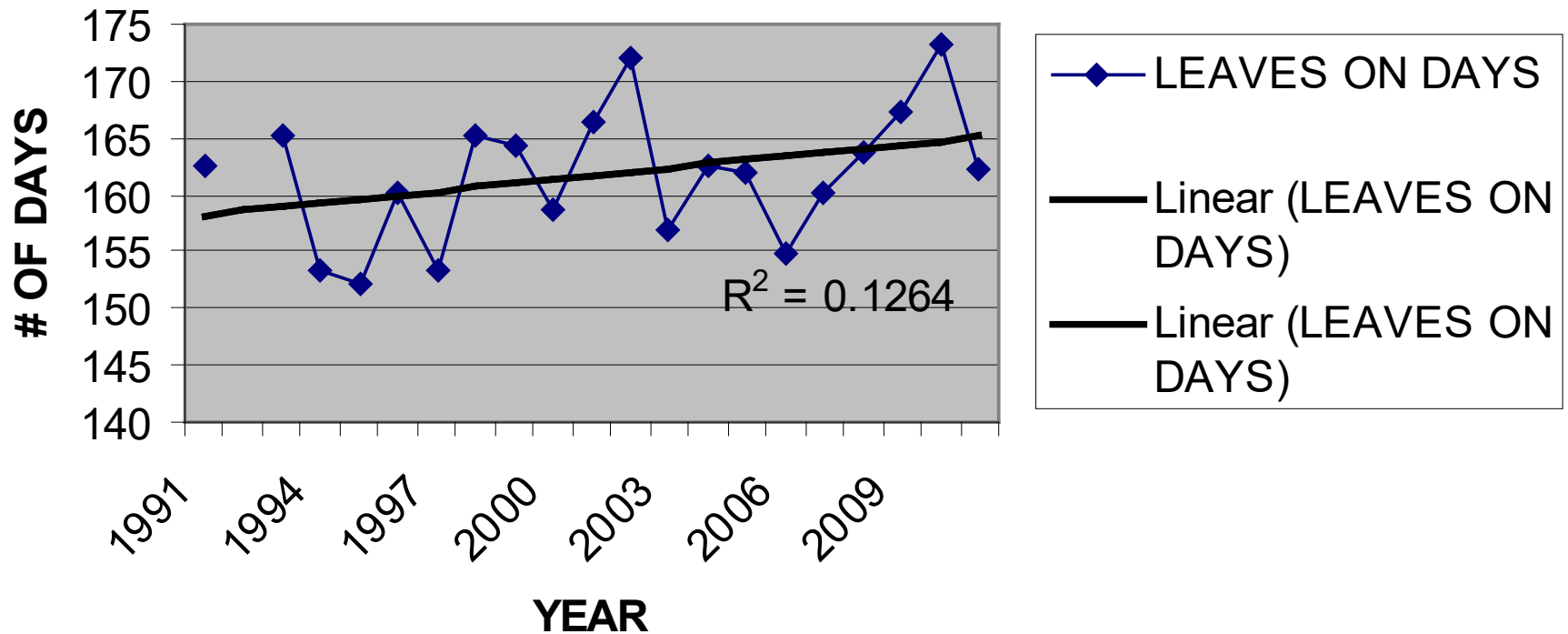
MEAN LF50 (4 SPP, N=15)



LEAVES ON DAYS (4 SPP, N=15)



LEAVES ON DAYS (4 SPP, N=15)



Spring Site Check

- Go to the site and check the condition of the branches you observed in the fall.
- Do the 6 buds you marked and observed leaves fall from look healthy (not obviously dead)?
- If so, leave your tag where it is and observe these buds in the spring.
- If any of these buds are obviously dead, adjust your tag to indicate 6 healthy buds on that branch tip to observe for leaf emergence.
- Have the students sketch the branch and buds so they will have a reference to check the buds they are observing.
- If any buds still fail to develop, reduce the number of buds observed on that branch to reflect the number of buds that actually produced leaves.

Labeling leaves/buds

- This is probably the hardest part of this study, but it is necessary to ensure consistency in data collection. The teacher should choose and label trees and branches (6 leaves/buds per branch) before bringing students to the site.
- Branches are labeled by tying a piece of flagging (with the tree and branch number/letter) just behind the 6 study leaves/buds on the branch.
- When choosing and labeling leaves/buds do not use the terminal/tip leaf/bud, but start counting at the next leaf from the tip as #1, then the next as #2, etc. On opposite leaved trees #1 and #2 will be paired across from each other. If there is a side branch on your main branch before you reach #6, use the tip bud on the side branch as the next # and continue using buds down the side branch until you reach #6 or, if necessary, return to leaves on the main branch. Note, you do use the tip bud on side branches, just not on the main branch.



Harvard Forest Schoolyard Ecology Buds, Leaves, and Global Warming

Spring Protocol: Budburst

Revised July 2012-J.O. and P.S.

Objective: Students will record the progression of bud swelling and budburst to monitor the start of the local growing season. The end of the growing season is monitored in the fall for this project. This means if you do this annually, one class will pass on data to be used by next year's class.

What is Budburst exactly? We are defining budburst as the point where the bud scales have opened AND leaves are fully visible. Leaves may be tiny but the entire leaf can be seen. Budburst indicates when the growing season begins and leaves begin making food for the tree.

Data Collection:

- **Begin and end dates:** Spring data collection should begin in early to mid April (before the buds have become very swollen), and continue until all or most buds have burst, and leaves are fully emerged. Ideally, continue until June 1st or as close to the end of the school-year as is feasible for your schedule. Dr. O'Keefe completes his study when all trees in his field site have 75% leaf development (leaves are 75% of their expected final size estimated from measurements taken the previous fall). This is generally in mid to late June.
- **How often to collect data:** Collect data at least once a week during study time. We recommend going out twice a week if possible when the buds are very swollen and budburst appears imminent, as that would pin point budburst more accurately.
- **Observe the specific branch(s) and buds assigned and labeled.** These will be the six buds nearest the branch tip, not counting the terminal (tip) bud. See Section VIII (Site Preparation) in the Study Overview.

"Student Data Sheet-Spring"

Observe and record whether each bud is completely closed (not puffy), or almost ready (puffy or opening with a green leaf tip visible but not unfolded yet), or open (budburst - the emerging leaf is unfolded/whole leaf is visible) by putting a check in the proper category on the data sheet.

1. Number of buds open: Record on the data sheet how many of the labeled and observed buds (0-6) are closed, puffy, and open. Please refer to photos of buds enclosed in teacher notebook and posted online at:

<http://harvardforest.fas.harvard.edu/museum/data/sy001/budburst-chart.pdf>

to clarify the differences between "puffy", "open" and "closed".

2. "Bud fallen off"-Please note if the bud is no longer on the branch. Place a check mark in appropriate box. If no buds remain on a branch, replace the branch with another branch with live buds. Data from earlier branch should be reported to HF as "NA" (missing).

3. Leaf measurement: If the leaves are fully open, select the largest leaf and record its length. Measure the blade of the leaf only, not including the stem (also called the petiole). Note: If there is more than one leaf growing from each bud, measure the largest leaf only. If the leaf is compound (multiple leaflets are attached to a main leaf stem/petiole), measure from the tip of the entire leaf down to the base of the lowest leaflets where they meet the leaf stem for the leaf length. For width, measure the widest part of the whole leaf-as in the widest pair of leaflets.

4. Field Notes/Observations: This part of data collection is **optional**. Scientists usually take field notes when collecting data. If you choose to include it, record any notes about field conditions – climate (temperature, cloud cover, precipitation), wildlife, what is happening with other plants, moisture, snow, or human activity - that you notice while collecting data. As time allows you may discuss these optional data with students.

5. Teacher Note: In order to prepare data for submission to Harvard Forest, you must combine data from all branches on the same tree to create tree-level data to enter into Excel and email to Harvard Forest.

5. **Number of buds open:** Record on the data sheet how many of the labeled and observed buds (0-6) are closed, puffy, and open.
6. **Leaf measurement:** If the leaves are fully open, select the largest leaf and record its length. Measure the blade of the leaf only, not including the stem (also called the petiole). Note: If there is more than one leaf growing from each bud, measure the largest leaf only.
7. **Field Notes/Observations:** This part of data collection is **optional**. Scientists usually take field notes when collecting data. If you choose to include it, record any notes about field conditions – climate (temperature, cloud cover, precipitation), wildlife, what is happening with other plants, moisture, snow, or human activity - that you notice while collecting data. As time allows you may discuss these optional data with students.
8. **Teacher Note:** In order to prepare data for submission to Harvard Forest, you must combine data from all branches on the same tree to create tree-level data to enter into Excel and email to Harvard Forest.

**Contact Pamela Snow, Schoolyard Coordinator,
at psnow@fas.harvard.edu or (978) 724-3302 x246
to begin your schoolyard research project.**



Harvard Forest LTER Schoolyard Program
Buds, Leaves and Global Warming

Student Data Sheet – Spring

Revised March 2010 by JOK and PS

Regular
School-based
Field Sheet

Names: _____

School: _____ Date: _____

Tree Species: _____

Tree ID (number): _____ Branch ID (letter): _____

1. Put a check mark in the correct column below to show the stage of each bud.

	Bud 1	Bud 2	Bud 3	Bud 4	Bud 5	Bud 6
Closed: Bud is closed and not puffy						
Puffy: Bud is swollen or opening with no unfolded leaf						
Open: Bud has opened and whole leaf is visible (budburst)						
Bud Fallen Off						

2. How many buds were observed in all? _____
Of these, how many were Closed? _____ Puffy? _____ Open? _____

3. Look for the open bud with the largest leaf.
Measure the leaf length in centimeters: _____

4. **Field notes:**

Temperature (degrees Celsius): _____

Humidity(%): _____

Circle one: Sunny Cloudy Rainy

Other observations and Notes: _____

Teacher Note: Please combine data from all branches on the same tree to create tree-level data for submission to Harvard Forest.