Chapter Four
A Case for A Stressor Other than Fungi

Forest Watch data for 2011 needles lead us to hypothesize that something in the air has stressed white pines. Yes, fungi definitely are causing heavy damage. But why are our white pines suddenly susceptible to fungi with which the pines have lived for thousands of years? Why are the pines unable to protect themselves from fungi which in the past record have only damaged 0.1% of needles, one tenth of one percent?

The U.S. Forest Service reasons that 2009 was unusually wet, with many cloudy days, giving fungi reason to breed. That year another fungi, late blight, *Phytophthora infestans*, spread across New England, devastating the tomato crop. But our look at records indicates that 2009 was only the fourth wettest summer New England has had since 1993. September 2009 was the driest year in the group, as Figure 4.1 shows. April and May, 2010, when the needle cast fungi may have fruited and released spores, and June, 2010, when needles first began dropping, were also very dry, making conditions less than ideal for infecting 2010's new needles.

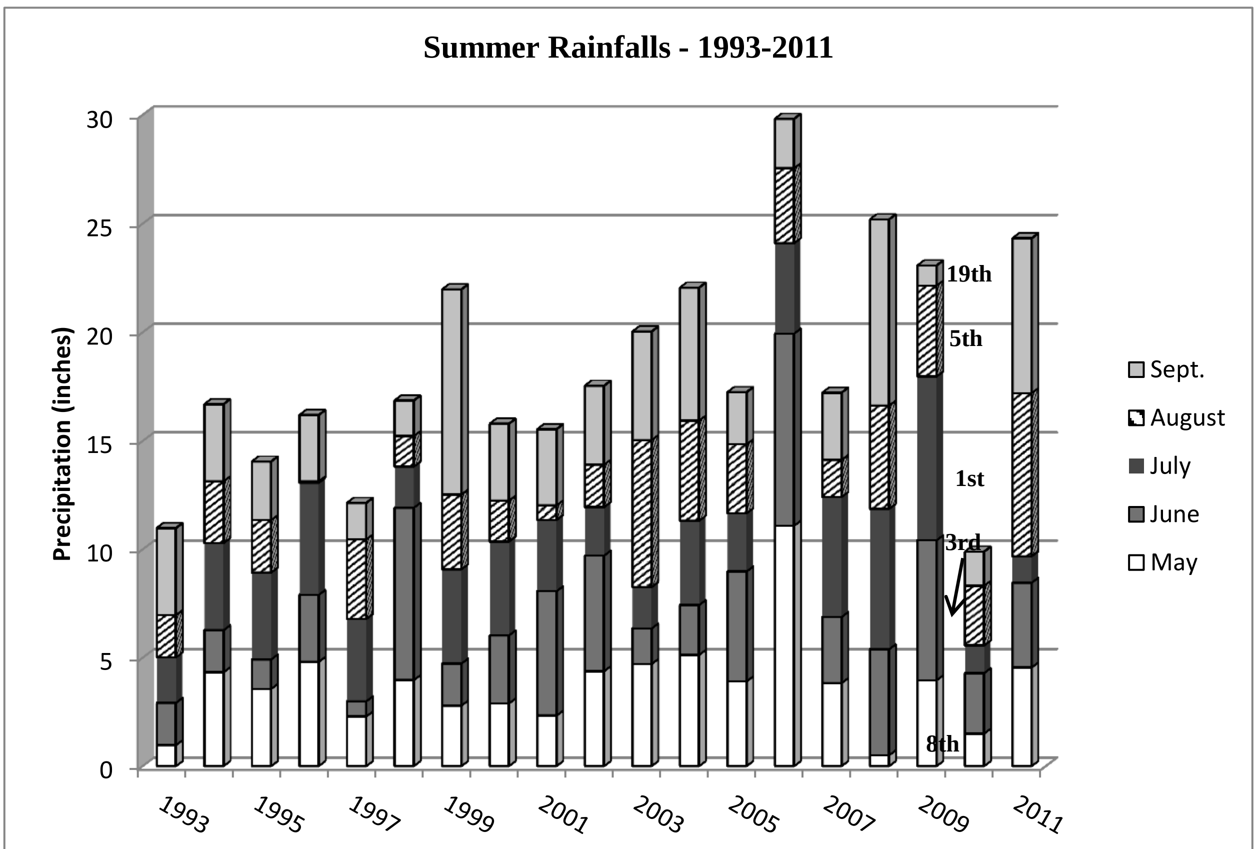

Figure 4.1: Rainfall May-September 1993-2011. In 2009, May was the 8th wettest month, June, the 3rd, July the 1st, August the 5th and September the 19th wettest month. Spring of 2010 was one of the driest years. (National Climatic Data Center, Annual Climatological summaries, www.ncdc.noaa.gov/cdo-web/quickdata, accessed 1-3-13).

We suspect that something else has occurred during the 2010 spring or summer and perhaps repeatedly since then to stress the pines and give the fungi an opportunity to have a population explosion and to continue reinfecting the pines since then.

Until very recently, tracing plant stress to atmospheric chemicals has been a limited science. Air pollution monitors provide point measures and these, as Forest Watch partners know, are mapped by the Environmental Protection Agency's AIRNOW. As we learned from Dr. Robert Talbot two years ago, air is also mapped by highly sensitive monitors on occasional aircraft flights by NASA. A variety of satellites collect information which could lead to information about atmospheric chemistry but interpreting the data has been spotty and disparate.

Now, just recently, air quality reports are being gathered from every available source by U.S. Air Quality, a daily diary and analysis provided by the University of Maryland, Baltimore County Atmospheric Lidar Group. USAQ obtains permission to use the many different satellite, weather and ground-based maps and models it presents. And new satellites provide better data about small particulates in the troposphere. We present a Forest Watch selection of recent USAQ images and statements and attribute the following chronology in large part to U.S. Air Quality Smog Blog (http://alg.umbc.edu/usaq). We intersperse The Smog Blog information with our own observations and findings with white pine needles, in italic.

Forest Watch encourages students and teachers to check The Smog Blog regularly. The images are stunning. The text is informative and quite easy to understand.

This chronology and selection of images offers some support for our hypothesis that atmospheric contaminants are indeed stressing the white pines. Ozone may be one of the culprits. Other pollutants, particularly sulfate, also may be stressors. Air pollution caused by smoke from widespread wild fires may be an issue.

We know from Dr. Rock's past research that a cloud of sulfates or nitrates can produce sulfuric or nitric acids. As cloud vapor, these acids can cause extreme damage to vegetation, particularly at high elevations. In building the chronology, Forest Watch has contacted scientists who produce many of the maps. We've asked them if they think the sulfates they

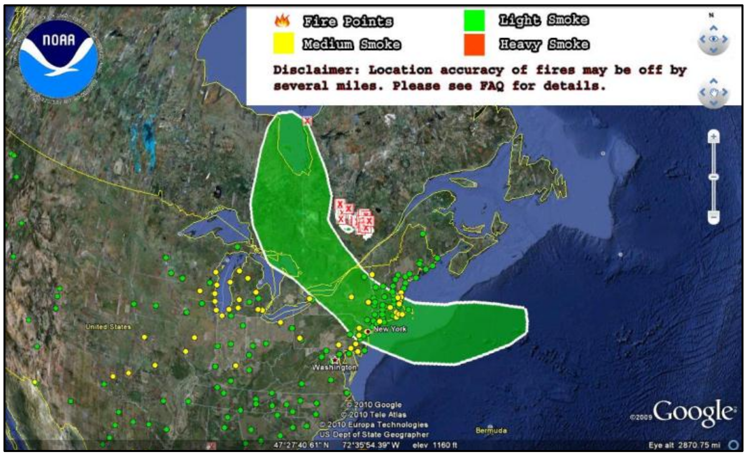

Figure 4.2: Aerosol cloud over Canada and New England, May 26, 2010. Smog Blog.

map are long-lasting enough and of high enough concentration to cause acid rain damage and other stress to white pines. Is anyone using The Smog Blog's maps to raise such a question? As atmospheric chemists, they may need help from Forest Watch to construct a full answer to this question.

We've also shown this chronology to Dr. Isabel Munck, whose article is presented in Chapter 3. Fungi are still her main concern. We include Dr. Munck's time line for fungal activities throughout the chronology. Our hypothesis might be incorrect. Whatever the answer, Forest Watch students and teachers might be the best people to help find it. We hope the chronology will offer clues as to how we should design our next investigative protocols.

Chronology

April and May 2010: Fungi which infected 2009 needles produce long fruiting bodies, producing spores.

May 26, 2010: *White pines in Londonderry release pollen. An atmospheric pollution event on Bald Mountain defoliates sugar maples. We link the defoliation to fires in Quebec with Hysplit (Figure 4.3) and identify peroxyacetyl nitrate (PAN) as the probable oxidant.*

The Smog Blog publishes a model produced by Hazard Mapping Fire and Smoke Product, National Oceanic and Atmospheric Administration, NOAA, showing a large mass of aerosol covering a large region from James Bay to the Great Lakes and across New England Using Hysplit and lidar measurements from their lab at the University of Maryland Baltimore County (UMBC), The Smog Blog team found smoke produced on May 24 sweeping south as far as New York and Baltimore.

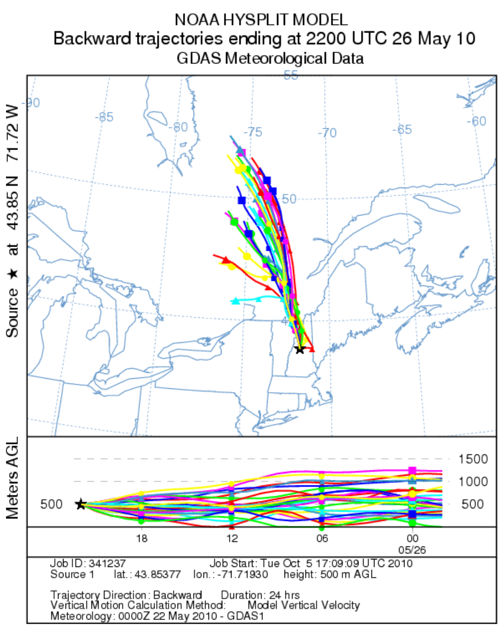

Figure 4.3: HYSPLIT of winds on May 26, 2010, show direct path from Quebec to Bald Mountain, West Campton, NH.

May 30, 2010: *White pines all over New Hampshire cast so many needles, the SandwichBoard, a Yahoo.com chat room for Sandwich, NH, is flooded with queries. So is UNH Extension.*

May 31, 2010: Canada fires continue to produce "unhealthy air quality."

Early June 2010: *White pines open 2010 needles. Spores on any remaining 2009 needles may infect new needles.*

June 26, 2010: Smog Blog releases an animation of carbon monoxide blowing south as far as Maryland from fires in Quebec. (Figure 4.4). They announce a program called BORTAS (Quantifying the impact of Boreal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites).

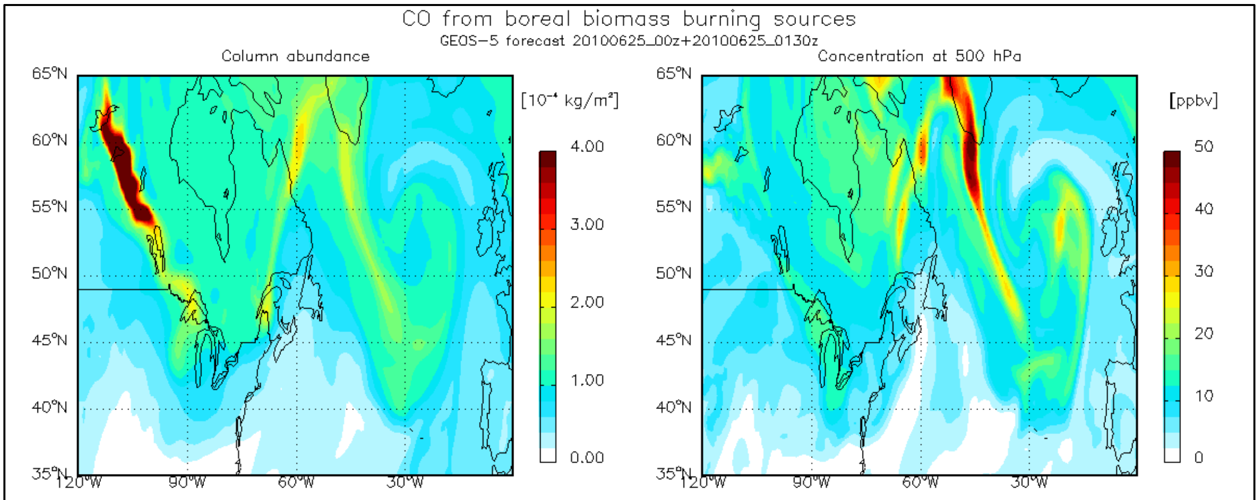

Figure 4.4: Maps of carbon monoxide, CO, released from Canadian forest fires, June 26, 2010. Smog Blog.

July 4, 2010: White pines cast needles infected by fungi.

July 10, 2010: Air quality improves, Smog Blog reports. The first BORTAS flights show a "Casper the Friendly Ghost" cloud of smoke over Canada moving southeast. The cloud of smoke is 1-3 kilometers high and "will not be expected to affect surface air quality until it mixes down further enroute."

August 3, 2010: Smoke comes not only from Canadian wild fires but from peat fires in Russia. Smog Blog mentions the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite, CALIPSO, a satellite which samples the contents of the troposphere and found on July 29, 2010 that smoke can circle the globe.

August and September 2010: Fung, if present, form blister- like damage on 2010 needles.

September 1 &2, 2010: Temperatures in the 90s, clear skies, cause moderate (code yellow) and unhealthy for sensitive groups (code orange) ozone in New Hampshire and throughout

New England. No large fires are reported but aerosols of "unknown origin and composition" are circulating in the region, Smog Blog reports.

Second flush maple leaves on Bald Mountain develop classic ozone chlorosis, Figure 4.5.

Using satellite images from two satellites, CALIPSO and the Moderate Resolution Imaging Spectroradiometer (MODIS), The Smog Blog reports that Michael Fromm of the U.S. Naval Research Laboratory (NRL) in Monterey, CA, can track smoke moving 12 kilometers high, the first evidence that smoke from wild fires can move into the stratosphere. : "Few things have the power to send aerosol particles that high into the atmosphere. Until a decade ago, most scientists thought that only a volcano could do so." Smog Blog says.

Figure 4.5: Sugar maple leaf with chlorosis between veins, following ozone event in September 2010. Photo by Carlson.

The NRL models and CALIPSO profiles of atmospheric aerosols opened new avenues for research by many scientists, including Emily Fischer, an atmospheric chemist who studied at UNH and is now at Harvard. Fischer is using these technologies to build global models of PAN. Wild fires produce large amounts of PAN and, as NRL proved, the fires can send it into the stratosphere where cold temperatures preserve it for long distance transport, Fisher told us on December 7, 2012.

September 24, 2010: A code yellow ozone day, Smog Blog reports.

October 11, 2010: Code yellow ozone.

November 21, 2010: Smog Blog delivers an outstanding lesson on the cause of wintertime ozone events. Although temperatures are cold and photochemistry is reduced by the lower angle of the sun, the troposphere is compressed in winter. Stagnant air is concentrated and can travel horizontally from sources such as Midwest electric generating plants.

November 23, 2010: Code yellow ozone, Smog Blog reports.

The first indication of trouble among the Forest Watch pines might have been from Lyme NH when students sent in samples of 2010 needles on November 23, 2010. We scanned some second year needles from Tree 1369, a hearty tree that stands in an open field.

Notice that the REIPs of the second year needles are very low, 719.3 on the North side and 711.6 on the South side, in Figure 4.6. Needles on both sides are experiencing water stress, particularly on the North side, as the TM5/4 ratios show: 0.764 and 0.625. The NIR 3/1 is alarming. Needles on the North side have an index of 1.023, a reading that indicates the needles are dead. Needles on the South side show beginning senescence with NIR3/1 ratios of 0.933.

Lyme	1369N1	1369N2	1369S1	1369S2
REIP	723.9	719.3	723.9	711.6
NDVI	0.829	0.818	0.831	0.798
TM54	0.497	0.764	0.483	0.625
NIR31	0.842	1.023	0.832	0.933

Figure 4.6: Indices of VIRIS scans of Lyme School trees, November 23, 2010.

Lyme's first year needles appear to be fine but needles that opened in 2009 and grew through the 2009-2010 school year, the summer of 2010 and into fall 2010 had experienced some kind of severe stress. White pines normally retain second, third and even a few fourth year needles. Older needles should be robust with high REIPs, no water stress and no signs of premature senescence.

December 10, 2010: High levels of NO_2 over New England, The Smog Blog reports.

December 12, 2010: High levels of sulfate over New England, The Smog Blog reports.

December 17 & 18: High levels of sulfate, The Smog Blog reports.

December 30 & 31, 2010: Code orange ozone over New England. The EPA, Region 1, reports that in 2010 New England experienced 24 days in which ozone levels exceeded the 75 parts per billion (ppb) limit.

January 20, 2011: Moderate code yellow levels of particulate matter 2.5 are reported (Figure 4.7). Smog Blog explains that nitrogen dioxide reacts with the hydroxyl free radical ($OH^{\cdot}$) to form nitric acid (HNO_3). Nitric acid may form nitrate, return to nitrogen dioxide or, as it frequently does in winter, react with ammonia to form ammonium nitrate (NH_4NO_3). "Cold temperatures and higher humidity strongly favors the formation of fine NH_4NO_3 aerosol particles ….," Smog Blog explained.

Early February 2011: High levels of NO_2 recorded on numerous days over New England.

March 2011: High NO_2 over northeast.

April and May 2011: Fungi, if present, produce fruiting bodies on 2010 needles.

May 26, 2011: Smog Blog reports "bad air" due to smoke from wild fires in Canada, Mexico and Central America.

May 31, 2011: Code orange ozone in Northeast; wild fires in Canada.

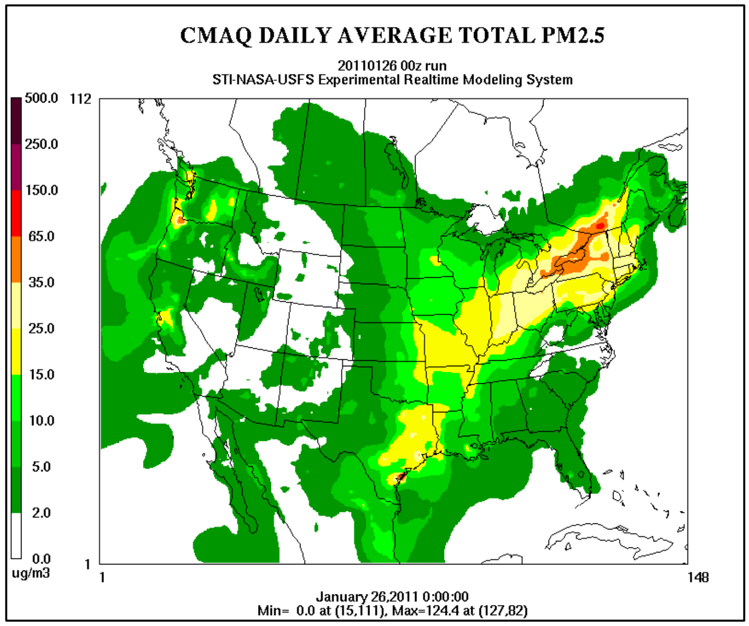

Figure 4.7: Particulate matter over the eastern seaboard, January 26, 2011.

Early June 2011: *White pines release pollen and open 2011 needles. These are the new "first-year needles" discussed in this report. The 2010 needles are now "second-year needles." Remaining 2009 needles are "third-year needles". Fungal spores infect emerging 2011 needles.*

June 1, 2011: Smog Blog reports haze, smoke and ozone over New England.

June 8, 2011: Air "unhealthy" with code orange NO_2 and code red ozone over New England. Wild fires burn over 200,000 acres in Arizona.

June 9, 2011: High ozone over East coast.

June 30, 2011: Wild fires in Canada, high PM 2.5 levels and high ozone over New England.

July 1&2, 2011: Rising ozone levels. *Infected 2009 and 2010 needles are cast.*

July 7, 2011: Ozone builds to a code orange 124 ppb in the afternoon over Baltimore as seen in Figure 4.8, a bar graph familiar to Forest Watch students.

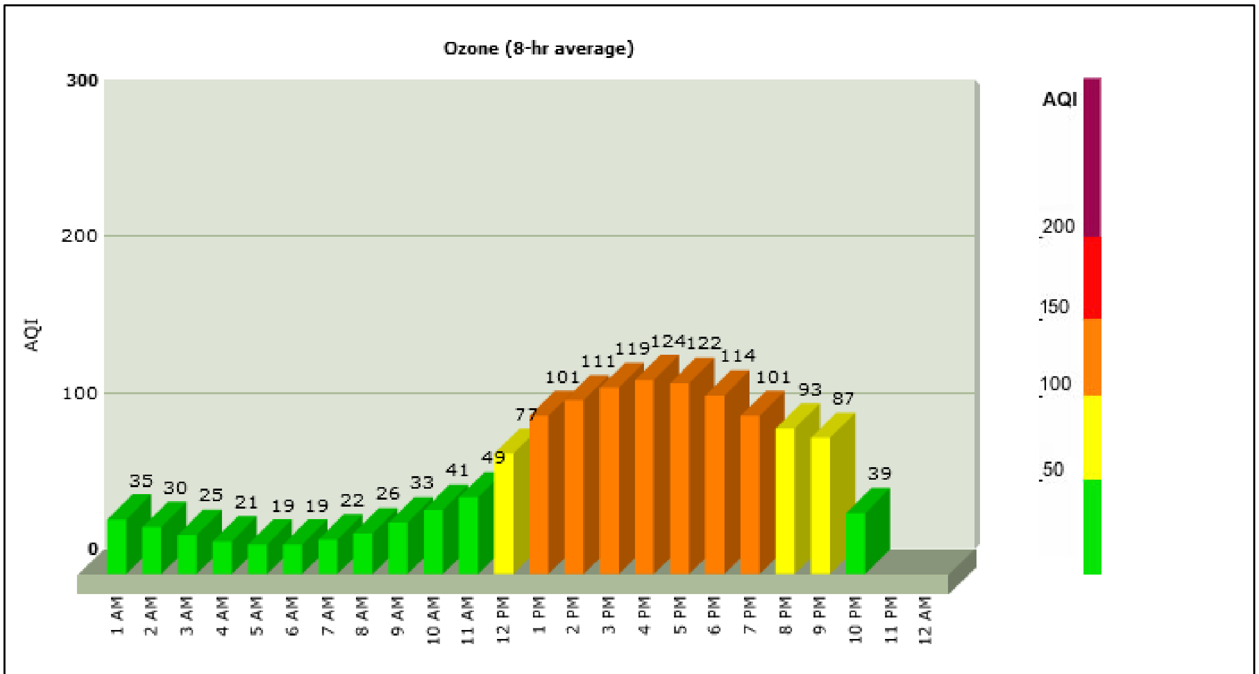

Figure 4.8: Ozone builds to code orange levels on a hot sunny day in Baltimore, July 7, 2011 (Smog Blog).

July 19, 20, 21, 2011: High ozone and smoke are profiled in a lidar image of the troposphere, Figure 4.9.

July 29, 2011: Code orange ozone.

August 1 & 2, 2011: Code yellow ozone, due to fires in Canada.

August 20, 2011: Smoke from the Great Dismal Swamp, North Carolina, causes unhealthy ozone in northeast.

August 28, 2011: Hurricane Irene floods New Hampshire and Vermont with 5 inches of rain and high winds.

September 8, 2011: Smog Blog

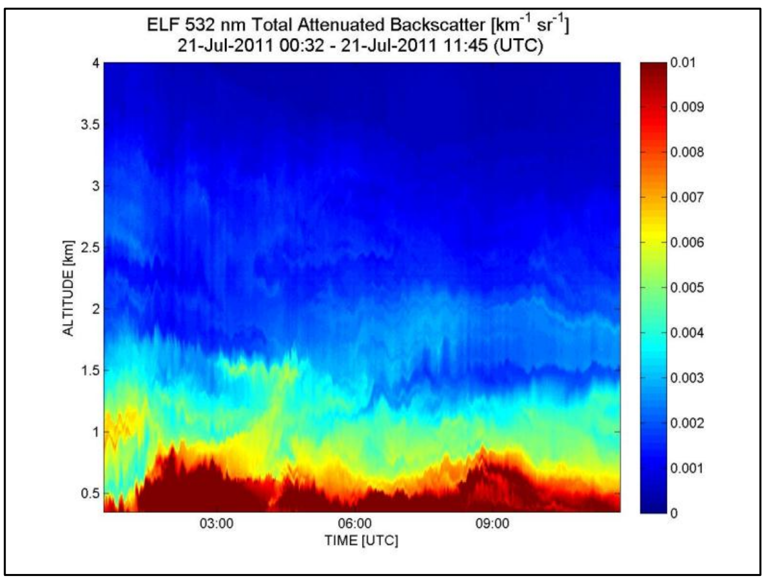

Figure 4.9: A lidar image of the troposphere at UMBC shows high levels of smog and particulates trapped close to the ground, July 21, 2011, Smog Blog.

publishes a photograph of Texas as seen by astronauts aboard the International Space Station. The photograph clearly shows a smoke plume rising from a fire in Bear Creek, Texas. Such images now allow researchers to track smoke plumes visually.

October 29, 2011: Snowstorm over New England.

October 31, 2011: Code orange PM2.5 and ozone in New Hampshire and Massachusetts is caused by a temperature inversion, warm polluted air compressed by upper level cold air onto very cold snowy ground, Figure 4.10.

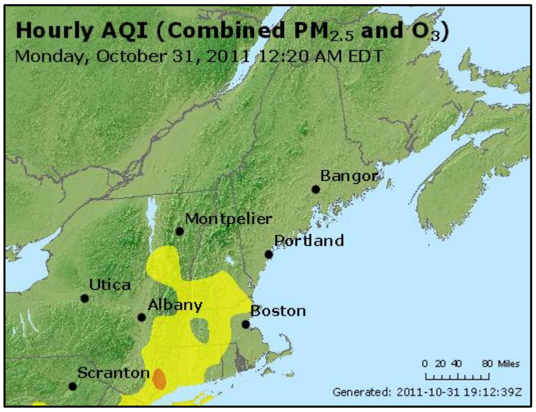

Figure 4.10: AIRNOW image of PM2.5 and O3, October 31, 2011 (Smog Blog).

November 3 & 4, 2011: Poor air quality continues in the Northeast. Smog Blog's Daniel Orozco quotes from a paper by Anabela Carvalho *et al*, 2010. The paper discusses the increase in forest wild fires and its impacts on air quality, human health and plant health. The paper notes that such pollution and the incidence of wild fires are projected to increase with climate change. Carvalho estimates that her region in Portugal will see a 500% increase in wildfires by 2050.

November 7 & 8, 2011: Sulfates cause a code orange and yellow air quality rating over the northeast, Figure 4.11. While ozone and smoke are minimal, sulfate levels are high across the region.

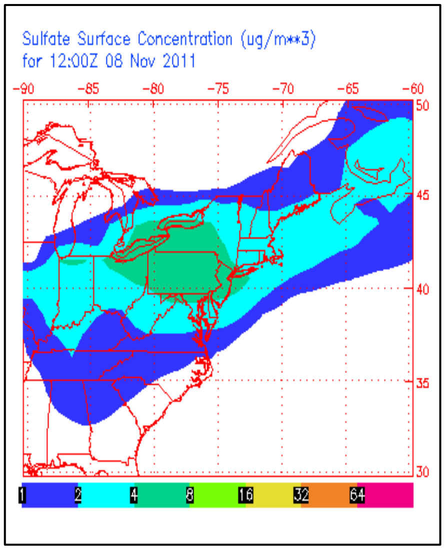

Figure 4.11: Sulfate cloud over New England and east coast, November 8, 2011.

November 9, 2011. Elevated NO_2 and PM2.5 are measured over the northeast. Particulates identified as sulfates cause poor air quality in New England, particularly in Burlington, VT.

December 1, 2011: Smog Blog announces a report by Vitali Fioletov of Environment Canada which used the Ozone Monitoring Instrument (OMI) aboard NASA's Aura satellite. The study finds that sulfur dioxide levels over the Appalachians, near coal-fired power plants, have dropped significantly between 2005 and 2010. The 2005 Clean Air Interstate Rule is credited with prompting many utilities to install desulfurization devices and other sulfur controls.

December 2, 2011: Code yellow ozone.

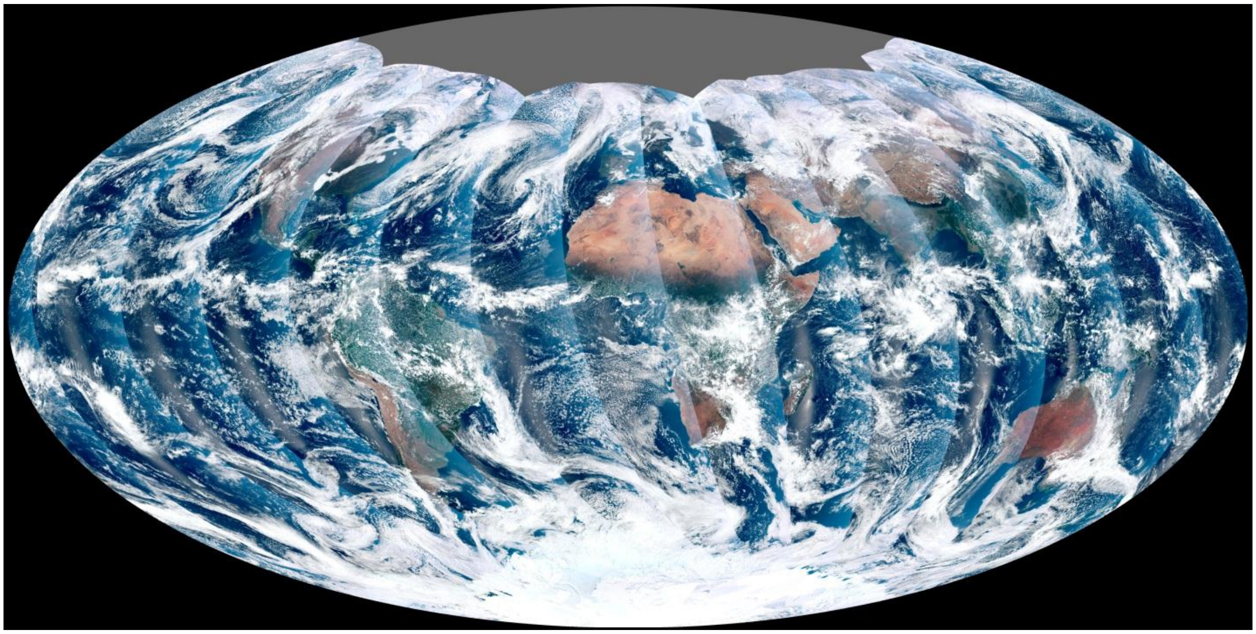

Figure 4.12: VIIRS first portrait of Earth. From Earth Observatory as published by Smog Blog, December 15, 2011.

December 12 & 13, 2011: Ozone and high PM2.5 event over New England and the mid-Atlantic

December 15, 2011: Smog Blog publishes the first complete view of the globe as seen at 824 km (512 miles) produced by the Visible Infrared Imager Radiometer Suite (VIIRS) on the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project, Figure 4.12. High sulfate levels are measured over the northeast, Smog Blog also reports

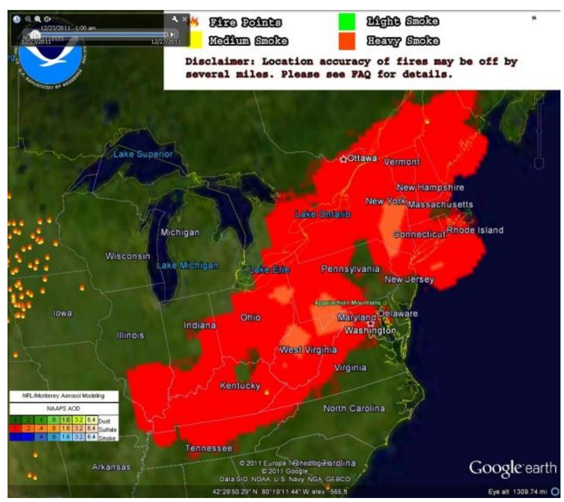

Figure 4.13: High sulfates over the Appalachian Mountains and New England, December 19, 2011. Smog Blog.

December 19, 2011: Weather maps produced by Plymouth State University are published by Smog Blog to help explain code yellow PM2.5 levels over the mid-Atlantic and Northeast. Poor air conditions continue through the rest of the month, including a high sulfate day on December 19, Figure 4.13.

December 30, 2011. As of this date, wildfires have burned 8.7 million acres of land with extensive burning in Texas. Unusual spring *wildfires burned 3.2 million acres of land in March, April and May, the NCDC reports. Large fires in New Mexico and Arizona burned for weeks in June and July. The year ranks third in wildfires in the last 12 years (NCDC 2011).*

The EPA Region 1 reports 16 days in New England when ozone levels exceeded 75 ppb for 8 hours or more.

January 2, 2012: Smog Blog reports that air over the East is clear at last.

Notice this period—October 31, 2011, to January 2, 2012, has day after day of ozone, NO_2 and/or SO_4. In the 1980s, numerous studies reported that co-occurrences of these pollutants were rare in nature. Experiments with deliberate exposure of plants found that white pines showed water stress and chlorotic lesions when exposed to low levels of all three pollutants for 4 hours a day for 35 consecutive days (Yang et al., 1983as reviewed by Kotchmar et al., 1993). Low levels were defined as 0.05 to 0.1 ppm of each of the pollutants. These measurements are at or below current EPA air quality standards—0.075 ppm for ozone, 0.075 ppm for SO_2, and 0.001 ppm for NO_2. Damage to plants depends on time, concentration and mix, the 1980s researchers found (Kotchmar et al., 1993). According to these Smog Blog reports, white pines may have been exposed to a mix of O_3, NO_2 and SO_4 simultaneously over some 60 days. Each of the notifications of poor air quality signaled a day when a particular pollutant exceeded current standards, all higher than the damage level described for co-occurrence damage. The EPA reports in its 2011 Annual Report that an air quality monitor in Pembroke, NH, recorded SO2 levels at 0.263 ppm for one hour.

January 7, 2012: Ozone event, probably caused by smoke from fires in Southeast and Midwest, Smog Blog reports.

January 11, 2012: High PM2.5 with winter formation of ammonium nitrate.

January 31, 2012: High sulfates in northeast, attributed to fires in the Southeast.

February 10 & 11, 2012: Code orange and high NO_2 over Northeast.

February 16, 2012: High sulfates over mid-Atlantic and Northeast.

February 27 & 29, 2012: High ozone and PM2.5 over Northeast.

March 6, 2012: Smoke from Southeast and Great Lakes fires spreads into Northeast.

March 12, 2012: Unusual warming, high PM2.5 levels.

March 18, 2012: St. Johnsbury School sends Forest Watch a second batch of samples. The first set of needles, sent in mid-February, showed REIPs averaging 715, an alarmingly low index of chlorophyll for first year needles. Concerned that something in shipment or our handling of the needles may have damaged them, we asked for a second sampling. Otto Wurzburg and his students sent a second set from the same trees. The VIRIS scans were worse: the mean REIP was 713.9. Four of the 10 samples showed initial or full water stress and initial senescence. The same trees, in 2010, had a mean REIP of 725.74, as shown in Figure 4.14.

	2010	2011A	2011B
REIP	725.74	715.43	713.19
NDVI	0.819	0.829	0.8169
TM54	0.5437	0.5673	0.5459
NIR31	0.8732	0.8554	0.8715

Figure 4.14: Means of VIRIS indices from St. Johnsbury School, St. Johnsbury, VT compare spring 2010 needles with 2011A, taken in February 2012 of 2011 needles, and 2011B taken in March 2012.

March 19, 2012: Temperatures reach 93^{o} F in Orford, NH. Maple sap stops running. Ozone code yellow in New England.

March 28, 2012: Smoke from fires in Midwest and Southeast bring dust and particulates, high sulfates to New England and mid-Atlantic.

March 30, 2012: UMBC's lidar shows very high PM2.5 pressed close to the surface as winds bring smoke from Midwest fires into the mid-Atlantic.

April1 15, 2012: Moderate ozone and PM2.5 with sulfates

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April 16-20, 2012: Record heat, red flag fire warnings, code yellow ozone and PM2.5.

Forest Watch visits Gilmanton School, Gilmanton, NH, and teacher Mary Fougere and her students in 7th grade science. We sample trees from a new site and visit large older trees in the old site. First year needles appear vibrant. These needles have been growing for 10 months, since they opened in June 2011.

Second year needles were much different.

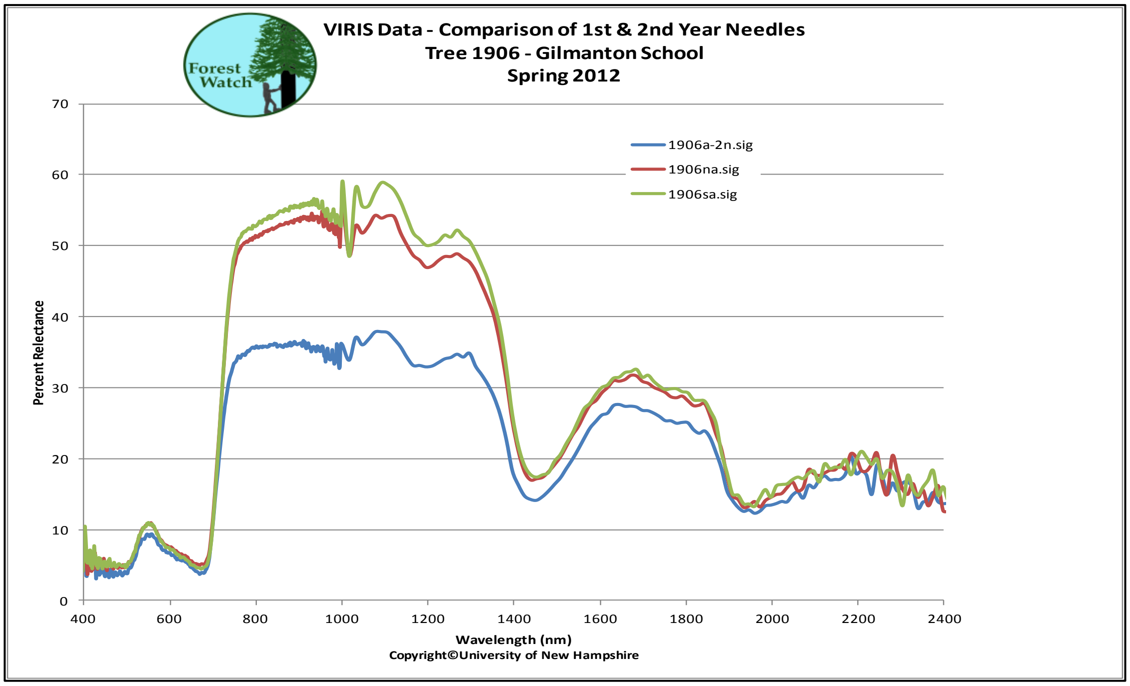

Figure 4.15: VIRIS scan of 1st year needles, North and South, and 2nd year needles from one Gilmanton School white pine, Tree 1906, April 2012.

Gilmanton 2010 needles, Sampled in 2nd year, April 16, 2012.							
	1906-2Yr	1907-2Yr	1908-2Yr	1909-2Yr.	1910-2Yr	Oldsite-2	Mean
REIP	705.4	719.3	720.8	719.3	714.6	719.3	716.45
NDVI	0.774	0.815	0.838	0.836	0.827	0.8	0.815
TM54	0.726	0.633	0.625	0.547	0.558	0.692	0.63
NIR31	0.941	0.94	0.955	0.888	0.907	0.941	0.929

Figure 4.16: Two-year-old needles on both young new trees and one older tree sampled show low REIPs, water stress in the TM5/4 index and oncoming senescence in high NIR 3/1 ratios.

The scan shown here in Figure 4.15 illustrates the extreme difference in reflectance exhibited by first and second year needles. Second-year needles from Gilmanton's Tree 1906 have much lower reflectance in the Near Infrared and the three peaks of the NIR plateau are flat, an indication of aging cells. Four of six trees show water stress in the TM5/4 ratio and early senescence in the NIR3/1. These needles had a mean REIP of 716.45, Figure 4.16.

April and May 2012: Fungi, if present, produce fruiting bodies.

April 21, 2012: Smog Blog publishes a model of Asian dust crossing the Pacific into the American Midwest, Figure 4.17. The model is produced by the Navy Aerosol Analysis Prediction System (NAAPS) which has also produced the many modeled maps of sulfates shown in this report.

May 3, 2012: Sulfates over New England.

May 9, 2012: Sulfates over New England
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May 13, 2012: Code yellow and orange ozone.

May 14, 2012: A wildfire breaks out in Hewlett Gulch, CO. Dr. Anthony Prenni, Colorado State University, Fort Collins, and Bret Schechtel, National Park Service, Fort Collins, use lidar to measure components of smoke. Ammonia, NH_3, increases 20-30% over normal levels and is a major ingredient in the smoke. Carbon monoxide, CO, usually at 30-200 parts per billion (ppb) jumps to 3000-4000 ppb. NO_x compounds, normally 5 ppb, increase to 25-30 ppb (Prenni, personal communication, AGU, San Francisco, 2012).

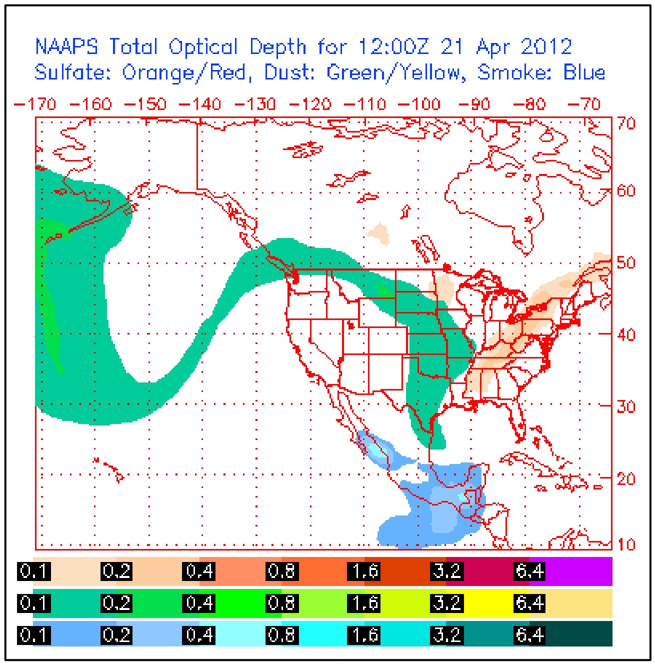

Figure 4.17: NAAPS model of dust from Asia shows dust and particulates arriving in Midwest and spreading northeast, April 21, 2012 (Smog Blog).

May 28, 2012: Smoke from the Baldy-Whitewater fire in New Mexico, burning 82,000 acres of forest, is tracked to the eastern seaboard. Other fires burn along the Mississippi in dry agricultural lands. Poor air quality is measured from New Mexico to Maine, Figure 4.18.

Early June 2012: The 2012 needles open. The 2011 needles are now second-year needles.

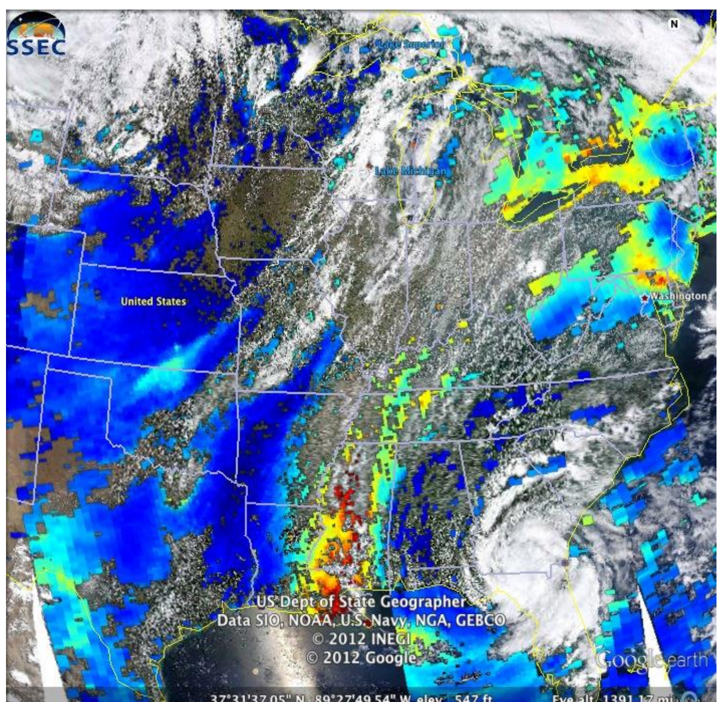

Figure 4.18: Smoke across most of the lower 48 on May 28, 2012 is mapped by the Department of State Geographer using data from numerous satellite sources. (Smog Blog).

July 4th: Dr. Munck finds this the typical date for needle cast if fungi are present.

Fall 2012: Needle cast continues to alarm white pine growers and observers. Dr. Rock's Monitoring Forest Health students examine pines in Vermont and New Hampshire.

- *Nathan Fallon, UNH undergraduate, finds low REIPs and other evidence of stress in white pines in the Green Mountain Forest. Pines at 2000 feet elevation show greater damage than pines at 1500 and 1000 feet. High elevation needles were coated in a black sooty substance.*
- *Wesley Niebling, UNH undergraduate, compares pines infected with Caliciopsis pinea Peck, a fungus which causes cankers on the bark and cambium of the tree. VIRIS scans showed slight differences but both infected trees and uninfected trees had high REIPs, no water stress and no senescence.*

Wildfires continue. By October, more than 9 million acres in Colorado, the Northwest and the Mississippi Valley have burned making the year the second worst fire year since 1990 (NCDC 2012).

November 30, 2012: Sarah Thorne and her students at Prospect Mountain High School, Barnstead, NH, send in 20 samples from 10 trees. Of the first year needles, 5 REIPs showed a moderate lack of chlorophyll. Eleven of 20 showed initial water stress in the TM5/4 and 5 showed full water stress. Two samples of first year needles showed advanced senescence.

We scanned 10 samples of second year needles. Six of the 10 showed initial loss of chlorophyll with REIPs under 720. Nine of the ten showed severe water stress and senescence, Figure 4.19, below.

	21927n	21928n	21929n	21929s	21930s	21931s	21933s	21934n	21935n	21935s		Averages
REIP	716.2	716.2	727	722.4	722.4	716.2	716.2	719.3	716.2	728.5		720.06
NDVI	0.809	0.8	0.812	0.813	0.815	0.785	0.802	0.771	0.775	0.827		0.8009
TM54	0.782	0.695	0.724	0.761	0.713	0.832	0.756	0.718	0.862	0.599		0.7442
NIR31	1.063	0.975	0.993	0.989	0.981	0.996	1.013	0.989	1.046	0.944		0.9989

Figure 4.19: Fall Mountain High School spectral indices of second year needles.

Photographed at 15-40x magnification, Prospect Mountain second year needles presented a variety of damage. A few needles as in Figure 4.20-A, show classic ozone damage with pale yellow chlorosis. A few needles showed fungal damage as described by Munck, 4.20B. Many needles showed a deep orange discoloration that looked like blistering of the needle cuticle, 4.20C and 4.20D. Such damage could be caused by acid.

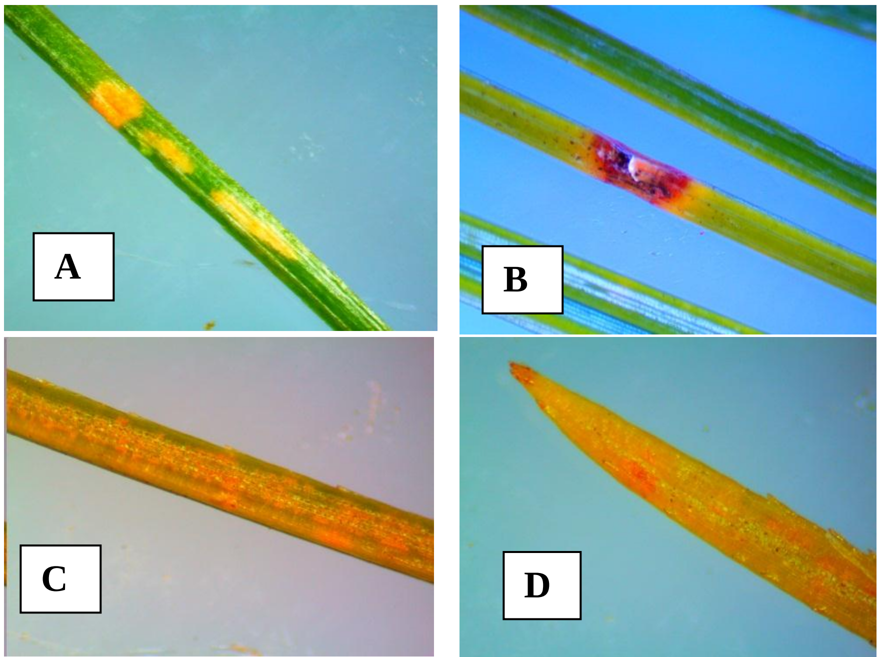

Figure 4.20. Chlorotic mottle in A is typical of ozone damage. Fungal wound in B. Orange blistering in C and D was widespread on these second year needles from Prospect Mountain.

We measured 10 needles selected from second year stems for length and percent of damage by length. Needles were tallied for the presence of tip necrosis, chlorosis and fungi. In Table 4.21, below, all sets had both tip necrosis and chlorotic mottling or blistering. Not all sets showed fungal infection.

Assessment of 10 needles, second years, Prospect Mountain High School, November 2012										
	1927N	1928N	1929N	1929S	1930S	1931S	1933S	1934N	1935N	1935S
Avg. Lengt	89	85	73	73	73	79	83	70	95	80
% Damage	12.5	15.3	15.8	19.8	3.7	51.8	17.5	65.1	43	9.9
# with										
TipNec.	6	7	9	6	10	6	8	10	10	10
Chlorosis	7	5	6	4	5	10	4	10	10	6
Fungi	3	1	0	2	0	6	3	0	1	1

December 31, 2012. The EPA, Region 1, reports that during 2012, ozone levels exceeded the 75 ppb 8-hour limit on 29 occasions.

January 2013. The NCDC reported that in 2012, January through October, wildfires burned more than 9 million acres, 1.5 times the 10 year average. A wildfire report for the entire year was not yet complete for this essay. The year will rank first or second for number of wildfires in the decade.

Conclusion

Forest Watch white pines appear to be stressed by atmospheric pollutants carried into the Northeast from wildfires. These pollutants might include nitric or sulfuric acid fogs and oxidants including ozone and PAN.

Water stress might be associated with leakage of cells caused by oxidants or acid clouds. Early senescence might be caused by cell damage. If the pines are repeatedly stressed by air pollutants which disrupt photosynthesis, the pines may be producing less sugar. Less sugar may reduce the production of protective phenolic compounds which the pine needs to ward off fungal infection.

Forest Watch schools are ideally situated to help research this possibility.

Schools could sample white pines early in the school year, gathering enough needles to monitor both first and second year needles. Using The Smog Blog, Forest Watch and its school partners could learn when poor air quality days are projected and when they occur. Following the event, students could sample needles again, documenting whether significant damage occurred and what type of damage is found. See suggested protocols in Chapter 8.

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