

Nitrogen increases in the Eastern portion of the Columbia River Gorge National Scenic Area

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Recent analyses of a variety of air quality monitoring sources along with an understanding of the Columbia Basin winter meteorology come together to paint an interesting and very revealing picture. This information provides the foundation and many building blocks that define the Columbia Basin pollutant source region and the resulting effects on the Columbia River Gorge National Scenic Area, as well as the Basin itself.

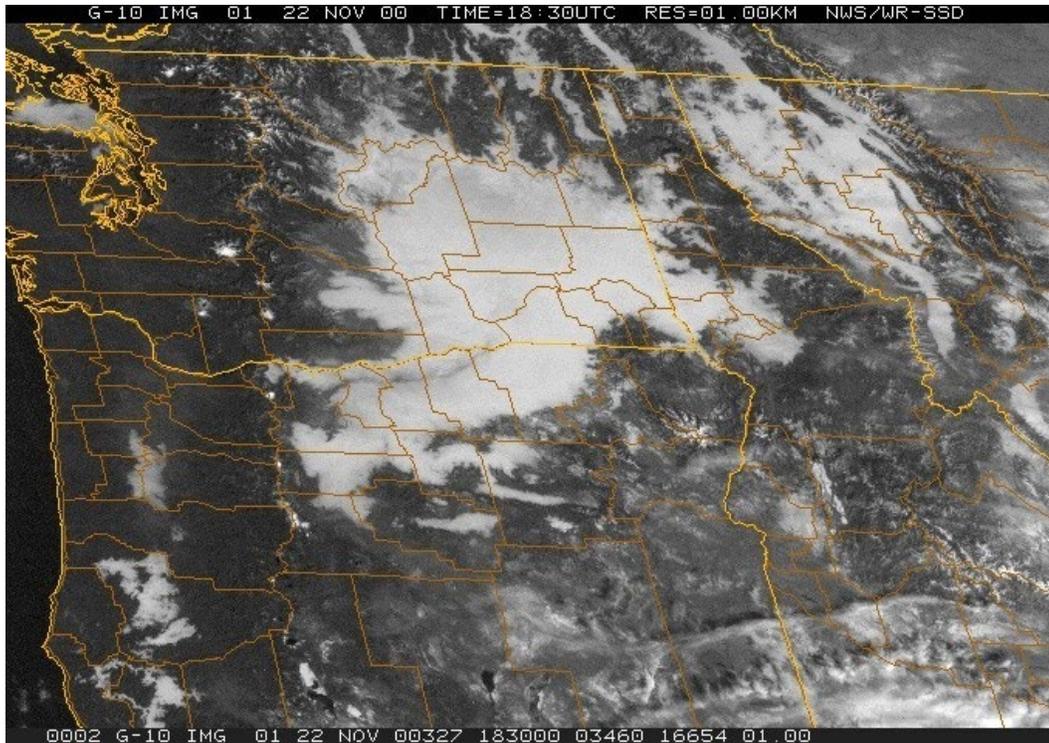
Meteorological indicators

It is often said that a picture is worth a thousand words. The weather satellite picture below along with some basic meteorology is a good first step in fitting this puzzle together. This picture is an excellent example of a winter stagnation and air pollution episode in the Columbia River Basin winter. Note the Snake River drainage is also involved in this episode. This is a visible (what the eye sees from space) picture as opposed to infrared and shows a low cloud layer that has formed under a temperature inversion formed by subsiding air on the east side of an upper atmosphere high pressure system. This type of inversion originates well above the surface and slowly lowers and strengthens over a period of days. In the Basin these inversions often settle below the surrounding rim providing an effective lid over the Basin. The stagnant trapped air under this inversion becomes increasingly moist until the cloud layer forms – this layer has a base generally below 1000 feet with a variable depth. As this pattern persists over a period of days the pollution (hygroscopic forms) emitted below the inversion are entrained into the cloud layer. The surface air movement in these situations is light and variable -- since the air is also cold and dense it settles into the lowest areas, which in this case are the river channels. The polluted air then slowly meanders toward and thru the lowest Basin outlets – the primary outlet in the Basin is the Columbia River Gorge. An understanding of these weather patterns is fundamental to understanding why the Basin source region is so important to the air quality in the Columbia River Gorge winter -- it is the mechanism that delivers high and increasing concentrations of nitrogen – in all its forms discussed below.

Modeling Issues

As a currently relevant aside it is important to note that while simple this Basin weather pattern is very difficult to model using current modeling tools. That applies to both the meteorological (mm5) and the preferred air quality model (CMAQ). The mm5 model currently performs very poorly in this type of Basin stagnation and CMAQ is not capable of modeling cloud or fog water deposition – the primary mechanism depositing pollution

in this pattern. The modeling results are as likely to mislead as inform. It is also important to note that an emission inventory and modeling domain encompassing the area covered by the cloud layer would be necessary – a difficult requirement given the modeling grid resolution needed to resolve the Basin and Gorge topography. To understand the air quality problem in the Basin will require a fairly extensive and sophisticated monitoring network such as was originally envisioned in the early versions of the Scenic Area Monitoring Strategy.



Nitrogen and ammonium trends

The visibility impairment bar chart below shows the frequency of visibility impairment and recent increases in impairment broken down into categories of impairment. This information is based on the IMPROVE visibility monitoring period of record currently available from the two Gorge IMPROVE sites – Mt. Zion in the western Gorge and Wishram in the Eastern Gorge. The visibility impairment increase is supported by several sources of information including ammonia emission inventories in the Columbia Basin and along the Snake River drainage indicating steady growth in ammonia emissions – the Three Mile Canyon Farm near the Boardman Power Plant stands out as a new and extremely large ammonia source. Further agreement comes from the results of the winter 2003-2004 acid deposition study in the Eastern Gorge indicating unusually high nitrogen deposition – approximately half coming from ammonia. And finally a

summary of nitrogen concentrations in lichen tissue in the Columbia River Gorge showing unusually large nitrogen increases over the past ten years in the Eastern Gorge.

Visibility

The bar graph below represents monitoring results thru 2003 (most recent available) from the two IMPROVE air quality (visibility) monitoring sites in the Columbia River Gorge. Wishram monitoring began in 1993 and Mt.Zion in 1996.

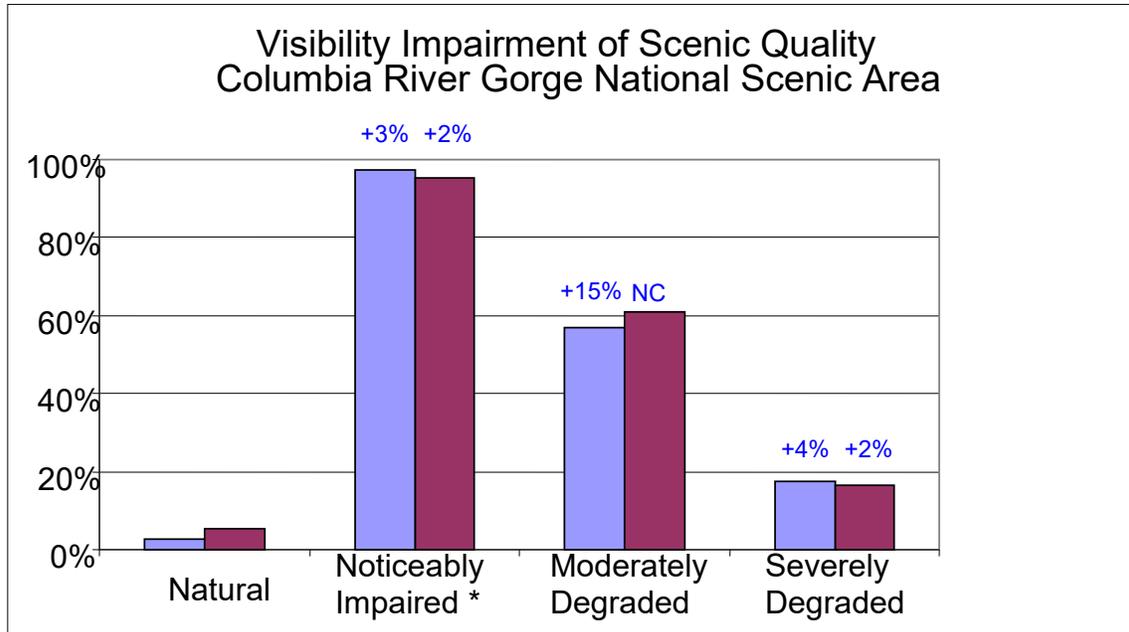
The left margin indicates the percent of the time each site is in the impairment category indicated below each bar. Note the percent of time in the moderately degraded and severely degraded categories are also included in the noticeably impaired category. For example the percent of time Wishram (blue bars) is in the noticeable category with moderate and severe removed is about 23%.

The blue bars represent the Eastern Gorge site near Wishram, Washington, about 12 miles east of The Dalles. Additional information about visibility and this site can be found at <http://www.fsvisimages.com/cori1/cori1.html>

The maroon bar on the right is from Mt. Zion (at highway 14 elevation) -- just across the river and slightly east of the Crown Point lookout.

The bar chart impairment categories are as follows: Natural (<20mm-1) indicates no human caused pollutants are present – as indicated this occurs infrequently. The Noticeable category (>20mm-1 to 41mm-1) in this case these bars include moderate and severe) ranges from the point some people will notice some haze in the view up to the point that the scenes are still relatively clear or clean but features in the scene are starting to lose the details in color and contrast. Almost all viewers will notice impairment at the upper range. Moderate impairment (>41mm-1 to <70mm-1) is the range where details of the color and contrast in the scene are lost with the scene features increasingly degraded at the upper range of this category. In the Severe category (>70mm-1) virtually all features of the scene are lost – for example in the camera view from Wishram (at the URL above) you would not be able to see Mt. Hood at all and most features in the view are gone except those within a few miles of the camera or viewer.

The blue percentages above each bar indicate change from 2000 to 2003. The most notable and surprising is the increase in moderate impairment at Wishram – up 15%. The increases are primarily due to ammonium nitrate. It is also notable and significant that relatively small or no change occurred at Mt. Zion on the West end of the Gorge. Note that, as is true with any short term air quality monitoring information, year to year meteorological variability will affect the results.



Percentages in blue above bars indicate change since 2000
 The blue bar is from Wishram data and the maroon is Mt Zion
 * Noticeably impaired on this chart includes moderate and severe impairment

Further information about IMPROVE regional haze and visibility can be found at <http://vista.cira.colostate.edu/views/>

Lichen Nitrogen concentration trends

Information derived from a summary of the past ten years of lichen data complements the changes (increases) in the visibility information. At the East end of the Scenic Area the concentrations of nitrogen absorbed in lichen tissue has increased 30-35% in the last ten years. Nitrogen increases absorbed in lichen tissue at some level can be seen thru the Eastern two thirds to three quarters of the length of Scenic Area, while there has been no change in the nitrogen concentrations in lichen tissue at the West end. More information on lichen and air quality can be found at: <http://www.fs.fed.us/r6/aq/lichen/> & <http://airlichen.nacse.org/cgi-bin/qml/usair/region6/area6.qml>

Nitrogen Deposition (cloud water) indicator

The high nitrogen and ammonia concentrations in the east end of the Gorge are also supported by nitrogen deposition from ammonium and from ammonium nitrate measured in the winter 2003-2004 acid deposition study. This was a four and a half month winter study which is insufficient for trend information, but nevertheless is very significant because of the very high nitrogen and ammonium deposition rates and the extremely acidic bulk water measurements. The study focused primarily on deposition from cloud and fog water. In the Eastern Gorge, and likely along the length of the Gorge rim and the

elevations above the rim, cloud and fog water deposition is the primary input to total deposition – although measurements to assess the level of cloud water deposition in the west end of the Gorge are very limited. Atmospheric deposition from winter rainfall and dry deposition are generally relatively smaller inputs. During this winter period, as discussed earlier, prevailing winds in the Gorge are from the East. The conclusions from this study indicate that acid deposition is occurring thru the length of the Gorge, however the support for this conclusion in the West end comes from precipitation chemistry with origins west of the Cascades, as opposed to cloud water. This study indicates potentially serious risk to tribal archeological resources in the Gorge, and indicates the potential for nitrogen saturation and soil acidification, particularly in the treed and forested areas of the Eastern Gorge.

The report from this study is available at:

http://www.fs.fed.us/psw/programs/atdep/col_river/crgnsa_final_report.pdf

Summary and conclusions

A logical combination of the trend information from lichen studies, visibility IMPROVE data, emission inventory information, and the 2003-2004 winter deposition study all support the conclusion that a significant contribution to the increase in nitrogen is from ammonia and is from sources in the Columbia Basin.

The cloud water study also indicated episodic acid deposition events (nitric acid) with pH measurements as low as 3.7. This indicator suggests very complex atmospheric chemistry since high ammonium levels would be expected to neutralize acidity in the cloud water. This contradiction could also be explained by the light wind regimes during the Basin stagnation events which over time will vary carrying high nitrogen concentrations from different emission sub-regions within the Basin. This hypothesis has not been tested.

The unusually high short term (approximately ten year) nitrogen increase is seen in the ammonia emission inventory, in IMPROVE data trends, and in results from the ten years of lichen monitoring trend information.

One could also conclude that a small part of the nitrogen increases in the East end occur from summer dry deposition generated by transportation sources of all types within the Gorge under the summer prevailing westerly winds.

Credits

Washington Department of Ecology, the USDA Forest Service and the IMPROVE Program for establishment of the IMPROVE monitoring sites and the concentration and trend information they provide

Scott Copeland, USDA Forest Service and the Cooperative Institute for Research in the Atmosphere, for the visibility analyses, the updated bar chart and the attributing the increases to ammonium nitrate.

Dr. Linda Geiser, USDA Forest Service, for the ongoing Lichen studies in the Gorge and elsewhere.

Dr. Mark Fenn, USDA Forest Service, for the Eastern Gorge Acid Deposition Study.

Dr. Geiser and Dr. Fenn are collaborating on a scientific journal article on the lichen and cloud water deposition work referenced above.