

MEETING SUMMARY

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The Air Quality subcommittee explored metrics of air pollution exposure that are (a) grounded in well-established science, (b) appropriate for examining the influence of air quality on ecosystems, and (c) relate to ecological response metrics proposed by the project's Ecological Change subcommittee. The subcommittee also evaluated the possibility of identifying specific ecosystem types likely to be more responsive to changes in air quality.

Key Discussion Points

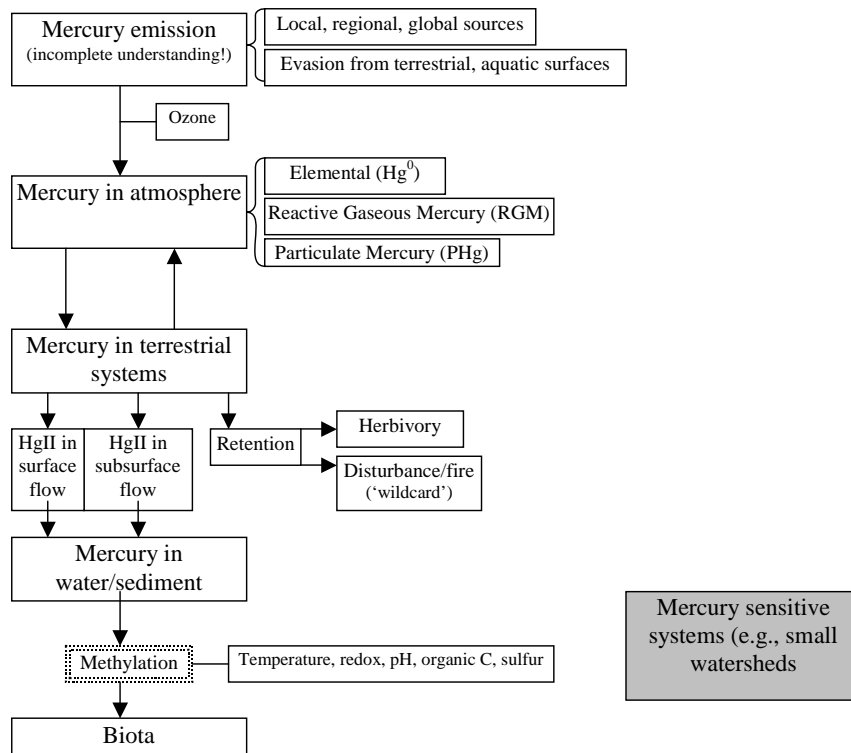
Mercury

Atmospheric speciation of mercury is complex and information is "poor at best." In the atmosphere, we find predominantly elemental mercury with small amounts of gaseous ionic mercury and particulate mercury. Atmospheric transport properties are highly variable at multiple scales – for example, 'local' mercury distribution can range from 20 to 200 miles depending on wind conditions. Work has been done to compare different mercury transport models.¹

Rapid chemical transformations are known to occur in the context of other atmospheric constituents (e.g., halogens, ozone). The coastal zone and urbanized settings were identified as areas of complex and poorly understood transformations. Caution was encouraged in referring to "background" mercury levels because of the complexity of mercury geochemistry (i.e., deposited mercury can be reemitted to the atmosphere from terrestrial, freshwater and marine systems).

The Mercury Deposition Network measures wet deposition with reasonable coverage for half or more of the U.S. There has been a recent shift in this network to focus on impacted ecosystems rather than regionally representative sites. Many formerly regional sites have been affected by urbanization, posing a challenge in constructing national scale information. Technical challenges prevent direct measurement of dry deposition which is modeled, requiring use of model output only at appropriate scales. (Note that dry deposition may be an important component of exposure to local mercury sources.) Robust measurements of mercury and other relevant compounds are required to validate models. In forested ecosystems, measurement of *throughfall* may serve as a potential integrator for total wet and dry deposition.

¹ See Ryaboshapko et al. (2003) Intercomparison study of numerical models for long-range atmospheric transport of mercury - Stage II. Comparison of modeling results with observations obtained during short-term measuring campaigns. MSC-East Technical Report 1/2003 (available at <http://www.msceast.org/publications.html>).



In terrestrial systems, there is emerging evidence for an invertivore pathway for mercury biomagnification in terrestrial-dwelling birds. Also, particulate mercury may be taken up directly by vegetation. Terrestrial disturbance events (e.g., forest fires) can inject substantial quantities of mercury into the atmosphere. It can take 10-20 years for atmospherically deposited mercury to move through a watershed (depending in part on the depth of the hydrologic flow path) and it can be difficult to determine when mercury in freshwaters was originally deposited. Mercury movement in association with organic material may be an important transport mechanism.

Processes in aquatic systems are central to mercury methylation (which occurs via sulfur-reducing bacteria) and are therefore key to biomagnification. Methylmercury concentration measures are relevant to characterizing bioavailability and efficiency of the conversion process. Work from the Ontario METAALICUS² project has provided direct evidence of ecosystem response to mercury loading, in particular direct deposition to freshwater surfaces. Studies from Chesapeake Bay have shown that methylation is occurring efficiently on the ocean shelf (i.e., the fraction of methylated mercury is higher in shelf sediments than it is in the middle of the bay).

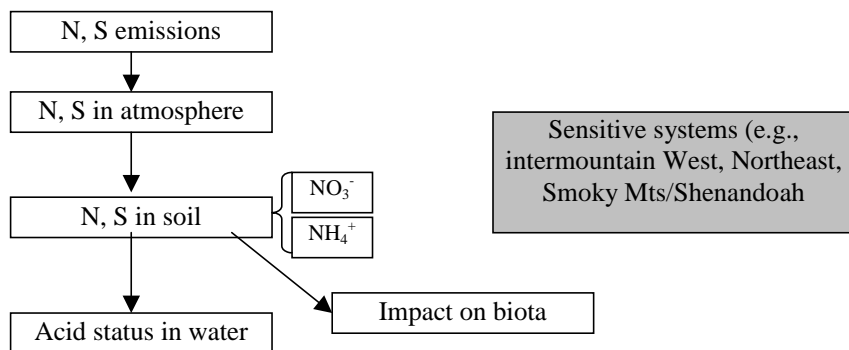
² Mercury Experiment To Assess Atmospheric Loading In Canada and the United States (<http://www.umanitoba.ca/institutes/fisheries/METAALICUS.html>)

The subcommittee endorsed the concept of focusing on geographic regions or locations that receive high deposition and have high capacity for methylation and biological uptake.³ Increasingly, scientists understand the factors that contribute to methylation capacity (e.g., organic matter, sulfate). A spatial correlation approach was suggested to compare GIS layers for atmospheric deposition⁴, sediment concentration, mercury methylation and fish tissue concentration. Suggestions for case studies included: (a) the Everglades as a shallow ecosystem with a small watershed, (b) documented changes in mercury in Minnesota lakes and fish (note that some mixed results have been observed).

Nitrogen enrichment/Acidification

With regard to atmospheric deposition of nitrogen and sulfur, the subcommittee identified several issues and resources for further consideration:

- *Speciation.* There is potential for different ecological responses to oxidized, reduced and organic⁵ species of nitrogen (e.g., stimulating particular types of algae). Work by Hans Paerl and Chris Lehmann are recommended resources.
- *Monitoring/modeling.* There are substantial challenges in implementing monitors for direct deposition to coastal waters. Robin Dennis (EPA) has modeled deposition impacts to Chesapeake Bay and constructed 'zone of influence' maps in 8-9 major estuaries on the east coast (i.e., area from which ~70% of atmospheric sources are emitted). Other relevant work has been done by Richard Valigura (AGU monograph), Paul Stacey (Long Island Sound studies), Hutchinson (Colorado feedlots), Robin Dennis (CMAQ nitrogen modeling for Tampa Bay), Charlie Driscoll (modeling forest deposition and acidity), and Bern Sweeney (Chesapeake Bay). Models have also been constructed for the effects of ammonia reductions in California's Central Valley.



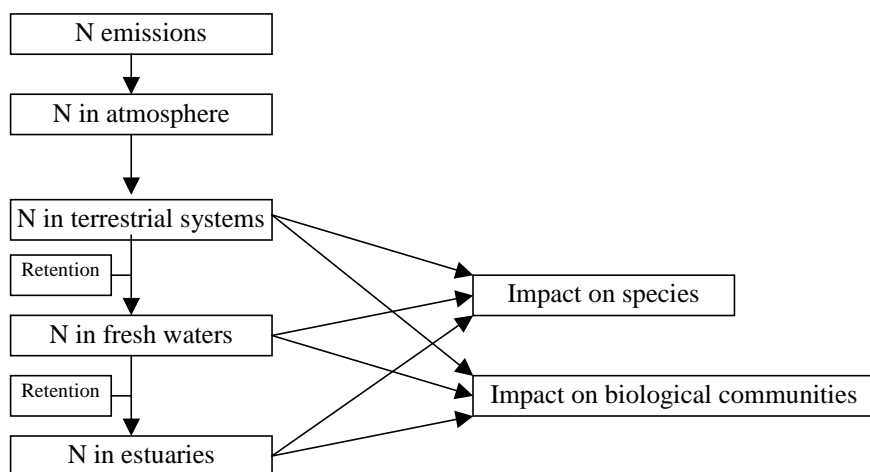
Note: There are also direct atmospheric effects of N, S on plants through acid precipitation and rime ice.

³ Not that 'hotspots' was characterized as a non-scientific term.

⁴ Mercury deposition maps have resolution to approximately 12 km.

⁵ Note that measurement techniques for organic nitrogen are still evolving.

- *Atmospheric nitrogen dominated systems.* In order to develop indicators that are sensitive to changes in pollutant exposure, the subcommittee recommended focusing on smaller ecosystems and watersheds. To identify smaller, ‘reference’ estuaries that are not substantially influenced by other factors, one approach would be to screen all U.S. nutrient sensitive waters for those with major agricultural and point sources. Another approach would be to draw upon the states’ 305b reports to estimate the proportion of Total Maximum Daily Load (TMDL) attributed to atmospheric nitrogen. A suggested case study is Tampa Bay (documented reduced atmospheric input).
- *Linking to ecological endpoints.* The subcommittee recommended drawing more explicit linkages among exposure, chemical changes (e.g., N saturation) and community-level changes (e.g., change in community structure). A number of points were raised with regard to the Ecological Change subcommittee’s selected endpoints: Chlorophyll *a* was acknowledged as useful endpoint. Nitrate in freshwater was recognized as a well-established outcome of nitrogen saturation, but not fully understood in terms of geographic distribution. Concerns were raised about the utility of an N to P ratio. It was noted that concentration is not always a good measure of flux (i.e., when there is efficient turnover it is difficult to observe the total loading). Consideration was encouraged for abrupt changes in species/cover type (e.g., Inability of water plants to recover following hurricane attributed to chronic N loading).
- *Nitrogen cycling.* Nitrogen addition was linked to shifts in the balance of N-fixing and non-N-fixing microbes as well as triggering nutrient limited conditions (e.g., boron in the Southeast) with substantial addition of N. It was noted that release of nitrous oxide into the atmosphere via denitrification is not very well characterized.⁶



Note: Atmospheric N is also deposited directly to water bodies, including estuaries.

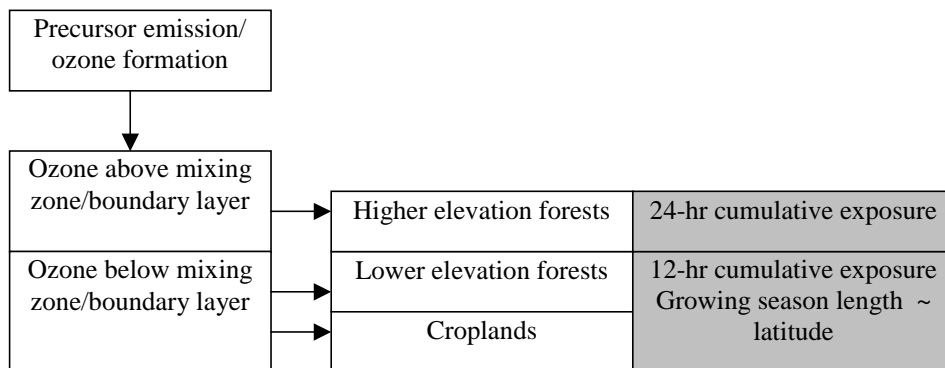
Ozone

A key ozone discussion topic was accounting for variation in diurnal ozone concentrations with respect to elevation. At higher elevation, diurnal variability is much less due to boundary layer

⁶ Some research has documented freshwater streams with high nitrate levels as important sources of nitrous oxide emissions.

effects and the absence of NO_x scavenging (e.g., in Essex County, NY ~1900 feet ASL was identified as a key threshold). In general, commercial forestry and crop production occur at lower elevation. Analogous NO_x scavenging patterns may be observed along rural-urban gradients and it was noted that highest ozone concentrations are not always in the urban centers. It was recognized that ozone concentration measurements are largely concentrated in urbanized settings with the exception of the Clean Air Status and Trends Network (CASTNet).

Metrics of cumulative exposure were endorsed by the subcommittee with recognition that ideally all hours of exposure to elevated ozone would be included because not all plants operate with stomata closed at night.⁷ For example, since length of growing season corresponds generally to latitude, cumulative exposure indices should be parameterized accordingly.



When plants need to allocate energy to ozone detoxification, more energy is used to protect above ground portions resulting in less root growth than shoot growth.⁸ Ozone and other air pollutants have been shown to stress (southern) pine trees and increase susceptibility to bark beetles and also to root rot (California). It was noted that the ability of plants to recover from ozone is reduced by multiple sequential high ozone years. The subcommittee expressed interest in linkages among foliar injury, changing physiology, changes in yield and economic value.

The National Crop Loss Assessment Network (NCLAN) was identified as the current state of the art for ozone impacts on croplands. Some work has been done on the effects of ozone in grasslands in Oklahoma, Kansas and eastern Montana.

General

A general approach proposed by the subcommittee was to make use of maps as a central tool in identifying relevant ecological indicators. Some of the map surfaces suggested include: boundary layer/mixing zone/low wind speed; ozone exposure; deposition of oxidized and reduced species of nitrogen; biomes; EPA regions; court systems.

⁷ See Musselman, R.C., Minnick, T., 2000. Nocturnal stomatal conductances and ambient air quality standards for ozone. Atmospheric Environment 34, 719-733.

⁸ See work by Sandy McLaughlin on above- and below-ground influence on forest plants.