A global assessment of precipitation chemistry and deposition

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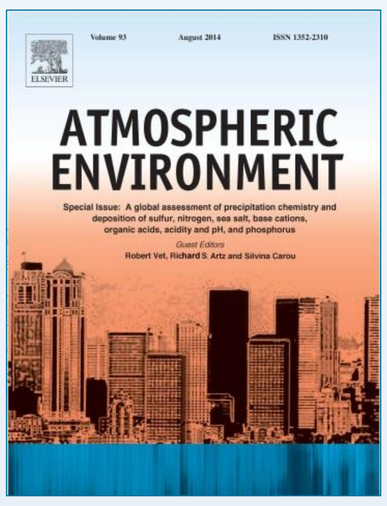
A new assessment, written by the Scientific Advisory Group for Precipitation Chemistry, presents the best information available globally on precipitation chemistry and deposition of key compounds. The assessment, published as a Special Issue of Atmospheric Environment, addresses the following questions:

(1) *what do measurements and model estimates of precipitation chemistry and wet, dry and total deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity, and phosphorus show globally and regionally?*

(2) *has the wet deposition of major ions changed since 2000 (and, where information and data are available, since 1990)?*

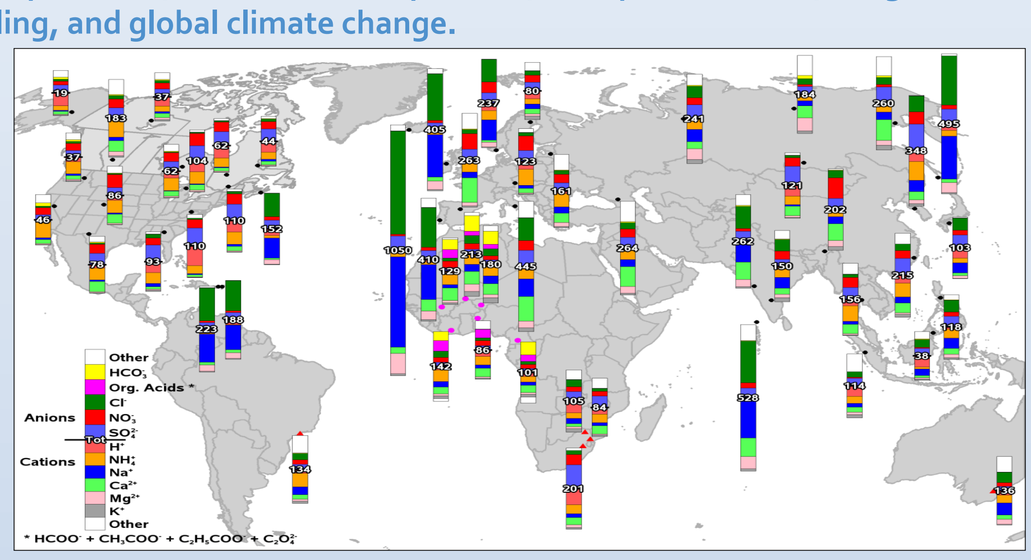
(3) *what are the major gaps and uncertainties in our knowledge?*



Regionally-representative measurements were compiled worldwide for two 3-year-averaging periods, 2000-2002 and 2005-2007. Data from the 2000-2002 averaging period were combined with 2001 ensemble-mean modeling results from 21 global chemical transport models produced by the Task Force on Hemispheric Transport of Air Pollution (TF HTAP). Data were integrated and used to generate global and regional maps of concentrations in precipitation and deposition. Other data on organic acids and phosphorus were also collected, mapped and analyzed. The compiled database of quality assured ion concentration and wet deposition data gathered from regional and national monitoring networks is available on the World Data Centre for Precipitation Chemistry (http://wdcpc.org/).

Precipitation chemistry is a global concern

The chemical composition of precipitation is a major environmental concern in several parts of the world as it contributes to acid deposition, eutrophication, trace metal deposition, ecosystem health, biogeochemical cycling, and global climate change.

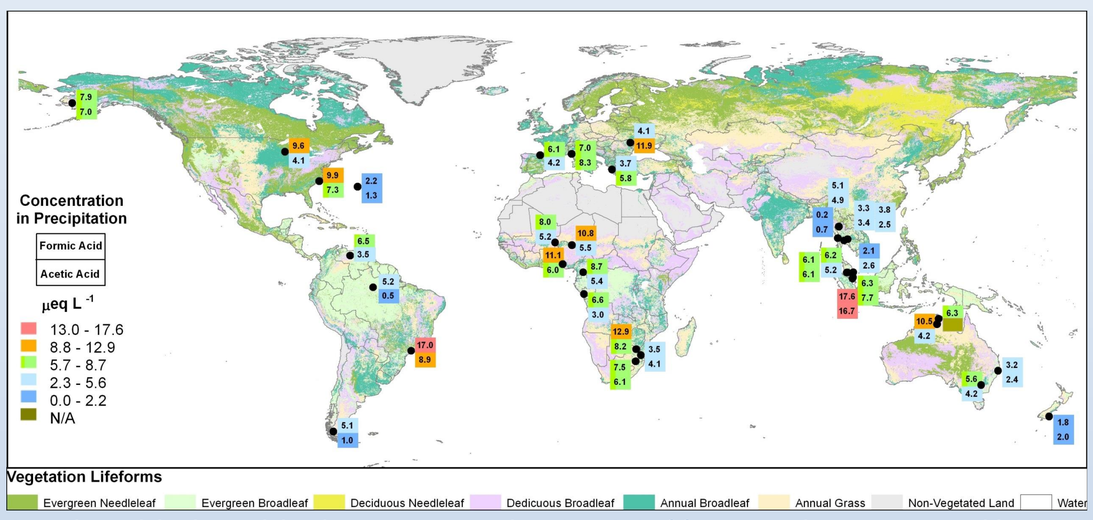


Contribution of individual ions in precipitation to total ion composition (the number at the center of each bar in μeq/L) at selected regionally-representative sites (from Vet et al., 2014).

Acidity and pH are dominated by strong mineral acids (sulfuric and nitric) in locations near and downwind of major industrial regions of the world. In regions where H^+ concentrations in precipitation < 5 μeq L^{-1}, weak acids (carbonates and organics) contribute a great deal of the acidity and H^+ cannot be measured or modeled well without them.

Organic acids

Organic acids play an important role in controlling atmospheric acidity in many regions of the world and dissolved carbon-containing acids in deposition play an important role in ecosystems.

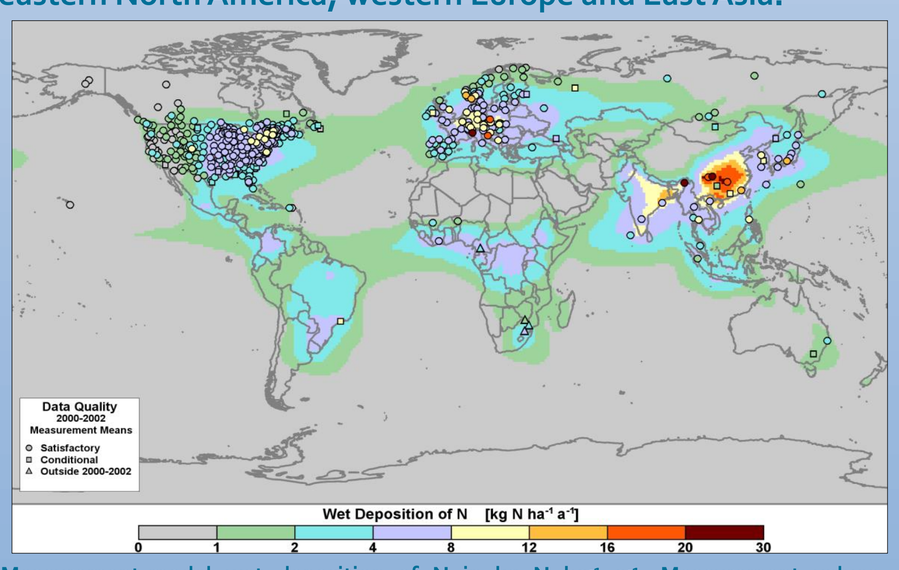


Annual precipitation-weighted mean concentrations (μeq L^{-1}) of formate and acetate reported in non-urban precipitation (see Table 6.1 in Vet et al. (2014) for representative time periods). Global Land Cover Characterization data courtesy of the U.S. Geological Survey.

The highest concentrations of formate and acetate in precipitation are generally observed in forested tropical areas near the equator, with a gradual decrease toward the poles. Total carbon wet deposition from formate and acetate routinely measured at sites in Africa exceeds wet sulfur deposition and is comparable to wet nitrogen deposition.

Sulfur and Nitrogen

Combined measurements and ensemble-mean modeling results showed highest levels of non-sea-salt sulphate wet deposition (> 10 kg S ha^{-1} a^{-1}) in the major established and emerging industrial areas of the world, principally eastern North America, western Europe and East Asia.



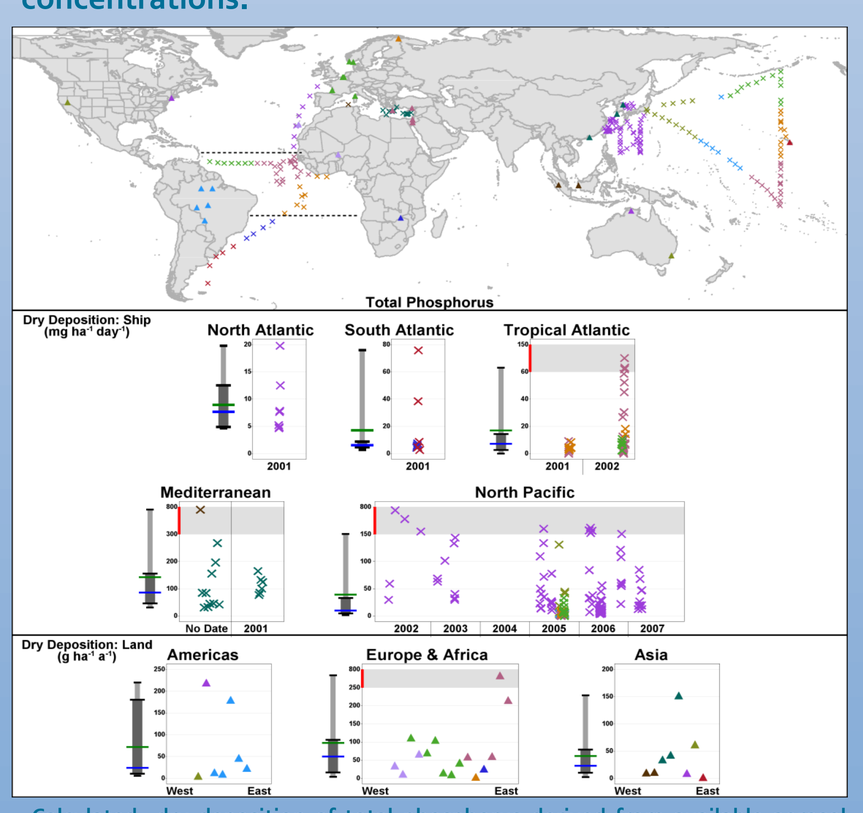
Measurement-model wet deposition of N in kg N ha^{-1} a^{-1}. Measurement values represent the 3-year averages for 2000-2002; model results represent the 2001 model year (from Vet et al., 2014).

The highest levels of nitrogen (N) wet deposition (> 8 kg N ha^{-1} a^{-1}) occurred in eastern North America, southern Europe, and southeast Asia.

Between 2000 and 2007, non-sea-salt sulphate and nitrogen wet deposition decreased significantly in North America and Europe and increased in Asia and Africa, coinciding with changes in precursor emissions in these regions over the same time period.

Phosphorus

Globally, orthophosphate is the only form of phosphorus that is routinely monitored in wet deposition (in the eastern U.S.). Dry deposition is not monitored routinely but has been estimated from atmospheric particle concentrations.



Calculated dry deposition of total phosphorus derived from available aerosol total phosphorus concentrations from studies aboard ships (mg P ha^{-1} day^{-1}) and from long-term measurements at land sites (g P ha^{-1} a^{-1}) (from Vet et al., 2014).

Based on limited data, measured wet deposition and estimated dry deposition both appear to make significant contributions to the global atmospheric phosphorus flux, but their relative contributions vary regionally depending on precipitation rates and proximity to sources.

Base cations and sea salt

Model-based estimates of total deposition of sea salt show that it can be transported and deposited on ecosystems more than 500 km inland.

Three -year average wet deposition of the sum of base cations (keq ha^{-1} a^{-1}) for 2005-2007.

Measurement-based maps of wet-deposited base cations ($Na^+ + Mg^{2+} + Ca^{2+} + K^+$) showed that most of the high deposition sites (i.e., >1 keq ha^{-1} a^{-1}) are located in arid areas, coastal zones or islands.

Overall conclusions

- Many regions of the world, including South America, large areas of North America, much of Asia, Africa, Oceania, the polar regions, and the oceans remain very poorly sampled for all major ions found in precipitation.
- Even in regions where measurement density is higher, little is known about phosphorus, organic acids, and organic forms of nitrogen.
- Regional measurement-based estimates of dry and total deposition are only available at selected sites in North America, Europe, Africa, Japan and Australia, and these only address sulfur, some nitrogen species, and major cation species.
- There is a pressing global need for measuring total (wet+dry) deposition of all of these compounds in order to further our scientific understanding of biogeochemical cycles and assess ecosystem effects.

Source: Vet, R., R.S. Artz, S. Carou, M. Shaw, C.-U. Ro, W. Aas, A. Baker, V.C. Bowersox, F.Dentener, C. Galy-Lacaux, A. Hou, J.J. Pienaar, R. Gillett, M.C. Forti, S. Gromov, H. Hara, T. Khodzher, N.M. Mahowald, S. Nickovic, P.S.P. Rao, N.W. Reid, 2014. A global assessment of precipitation chemistry and deposition of sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. Atmospheric Environment 93: 3-100.