Extra, Extra, Read All About It:
New NADP Publication
(or better yet, pick up a copy of the booklet)

Nitrogen from the Atmosphere

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NADP released *Nitrogen in the Nation's Rain* in the year 2000 as a non-technical summary of our understanding of nitrogen (N) deposition, it's consequences and NADP's efforts to measure it. This booklet was designed as an informative source for policy makers, students and others interested in N deposition and it's impacts on people and the environment. Since it's publication over 15 years ago, our understanding of the role of nitrogen has grown and a new, more comprehensive booklet titled *Nitrogen from the Atmosphere* is now available. We summarize here some of the new information included in this booklet. ***Please help yourself to a booklet if you or your colleagues will find it useful.***

SOME HIGHLIGHTS (An Overall Summary):

Nitrogen is a fundamental constituent of life and the most abundant gas (N_2) in the atmosphere. However N_2 gas is generally non reactive (N_{n-r}). It is only when it is converted to a reactive (N_r) form of nitrogen that it becomes available to most organisms. Organisms such as nitrogen fixing bacteria convert N_2 to N_r and in the early 1900's humans learned to convert N_2 to N_r, in the form of NH_3 (the Haber-Bosch process). Thus N-fertilizer (and N based explosives!) became readily available.

N_r causes a cascade of effects as it moves through ecosystems and forms different N containing compounds in the process.

NADP measures N_r in rain in reduced (ammonium (NH_4^+)) and oxidized (NO_3^- (nitrate)) form. These are the most abundant forms of N_r in precipitaton but not the only forms (e.g. organic nitrogen). NADP, since 2007, also measures ammonia gas, NH_3, which is both deposited and emitted in the landscape.

On a global basis we have doubled the N_r circulating in the biosphere and this has both positive and negative consequences. Therefore it is important to measure and monitor trends in N_r derived from the atmosphere. This is an important contribution that NADP participates in.

The Nitrogen Cascade

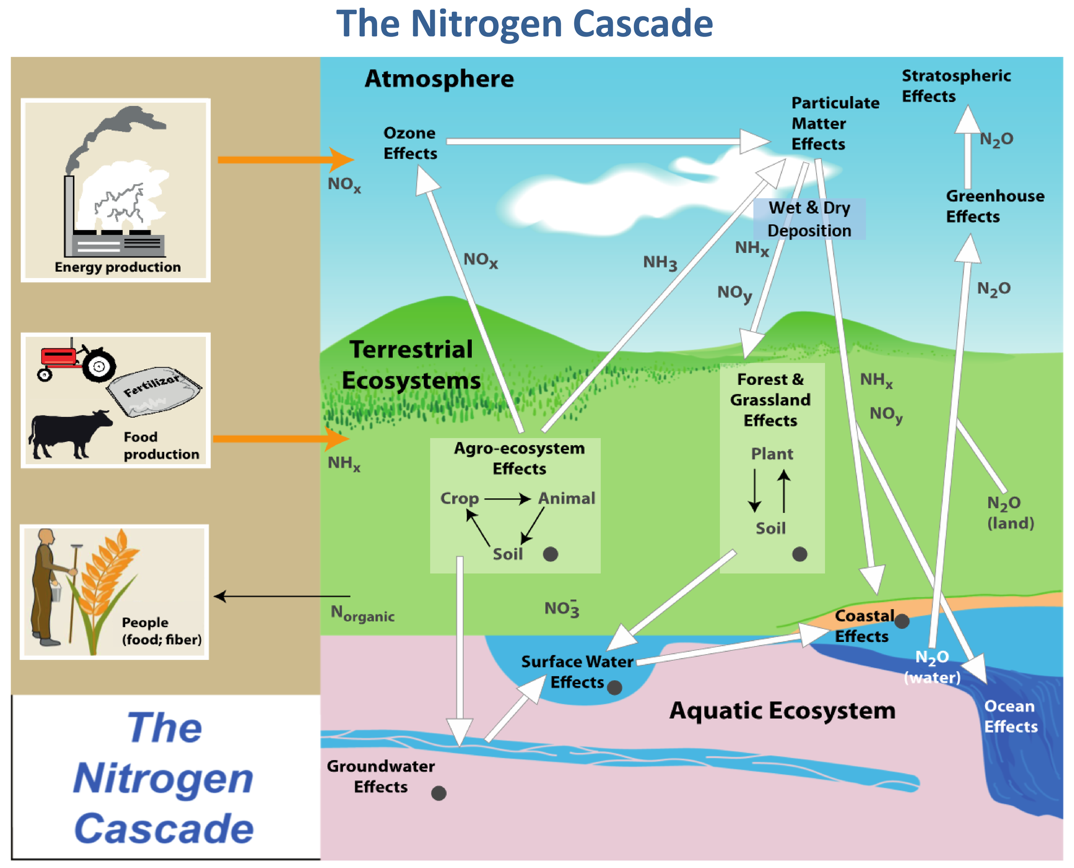
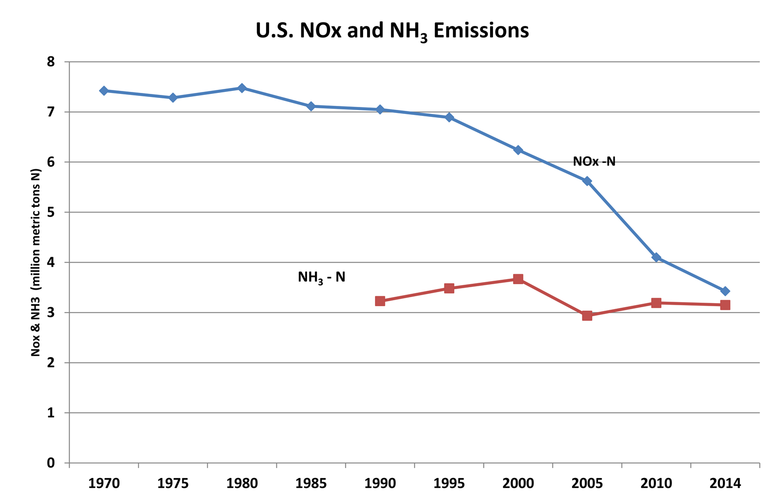


Illustration of the nitrogen cascade showing the sequential effects that a single atom of nitrogen in its various molecular forms can have in various reservoirs after it has been converted from nonreactive N_2 to a reactive form by energy and food production (orange arrows). Once created, the reactive nitrogen has the potential to continue to contribute to impacts until it is converted back to N_2. The small black circle indicates that there is the potential for denitrification to occur within that reservoir. Source: adapted from Ciais et al, 2013 with permission from the GEO Yearbook 2003.

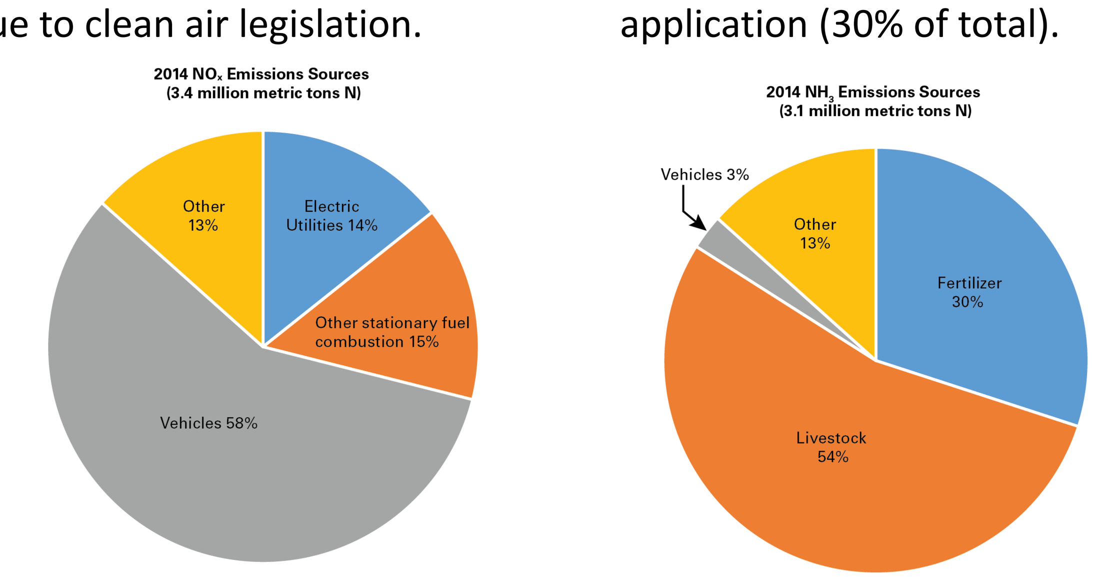
WHICH HUMAN ACTIVITIES CONTRIBUTE NITROGEN?

Reactive N in the atmosphere is derived from NO_x emissions and NH_3 emissions, both from largely different sources. In the past most N_r emissions in the USA were from NO_x, but now nearly equivalent amounts of N_r are derived from NH_3 emissions. In most of the USA

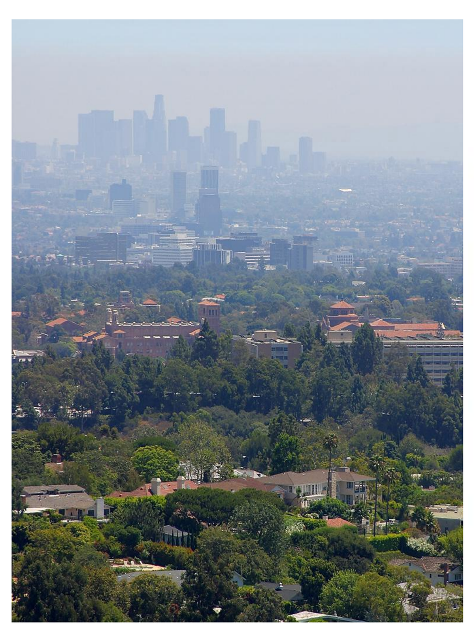


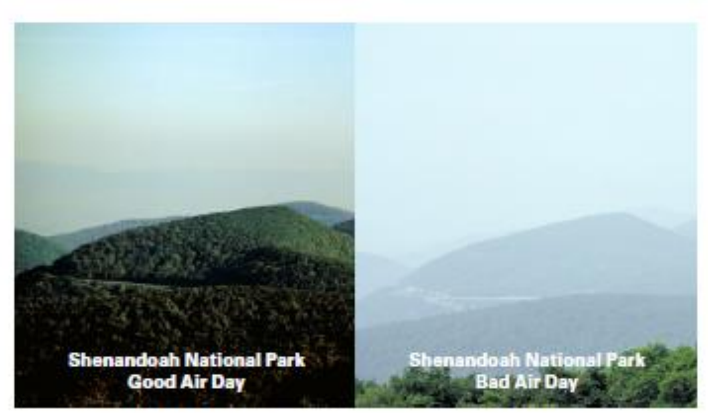
NO_x is derived mainly from fossil fuel combustion. Vehicle emissions are the main contributor (58% of the total). Electric utilities have become relatively less important due to clean air legislation.

Over 80% of NH_3 emissions are from the agricultural sector. Livestock production is the largest source (54%) followed by fertilizer application (30% of total).



USA 2014 NO_x and NH_3 emissions by source from National Emissions Inventory (NEI).

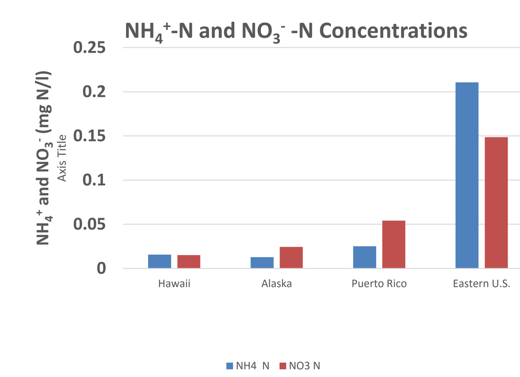




NO_x emissions (and volatile organic carbon (VOC) emissions) interacting with sunlight, are a major contributor to smog seen here in the Los Angeles Basin (west), and Shenandoah National Park (east).

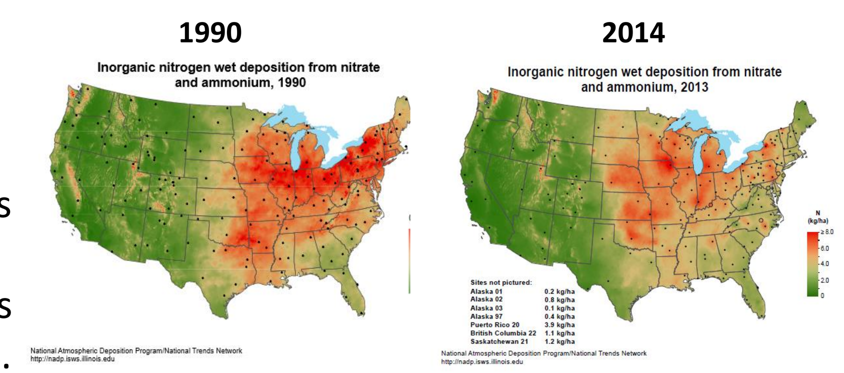
NADP measurements in precipitation: NO_3^- and NH_4^+

Remote vs populated areas

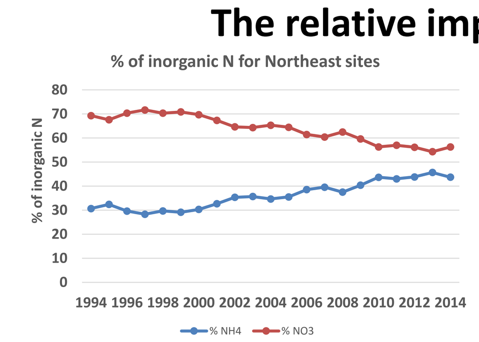


Comparison of NH_4^+ and NO_3^- content (as N) of precipitation in remote (Hawaii, Alaska, Puerto Rico) and more highly populated (eastern USA) areas of the USA. Based on NADP 2012 to 2014 annual volume-weighted mean concentrations (except Hawaii, which is based on 2002 to 2004; site closed in 2005).

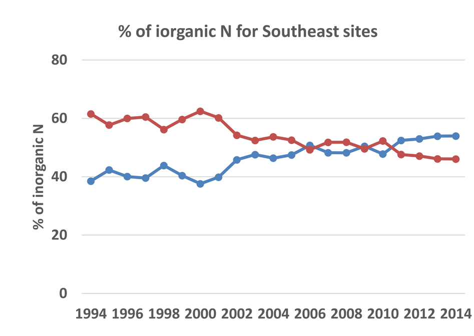
Temporal Trends
Inorganic N (NO_3^- -N + NH_4^+ -N) in precipitation is declining in most areas of the USA as illustrated in these deposition maps comparing 1990 to 2014.

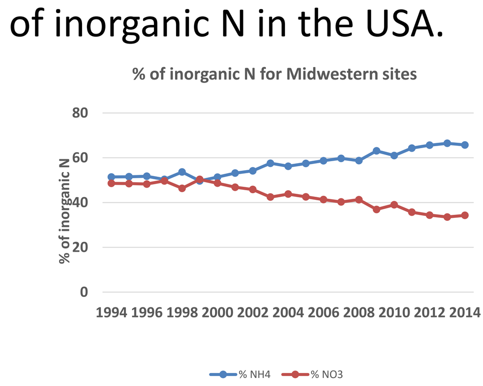


The relative importance of NO_3^- vs NH_4^+ is changing.



In the past NO_3^- was often the major form of inorganic N deposition in precipitation. However with significantly reduced emissions of NO_x and very little change in NH_3 emissions over time, NH_4^+ is becoming relatively more important and in many cases the dominant form of inorganic N in the USA.

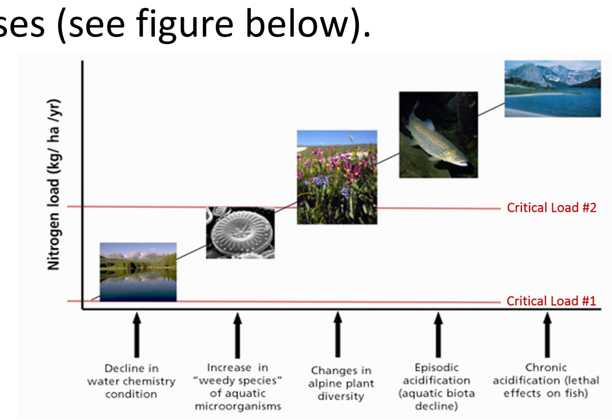




Note: NADP also measures air concentrations of NH3 at 94 sites as part of an effort to understand deposition of NH3

CRITICAL LOADS: HOW MUCH N DEPOSITION IS TOO MUCH?

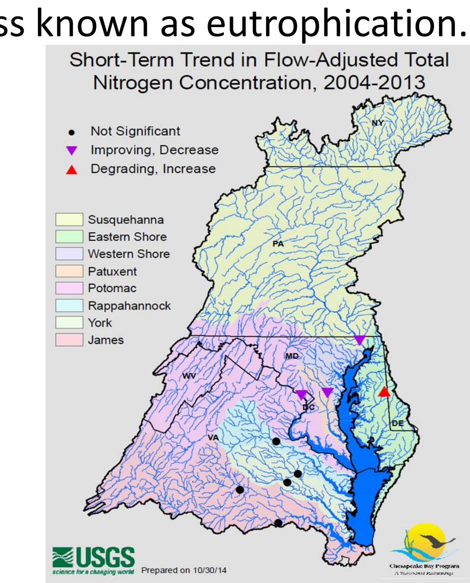
The term critical load is used to describe the threshold of atmospheric deposition that causes harm to sensitive resources in an ecosystem, typically expressed in terms of kilograms per hectare per year (kg/ha/yr) of wet or total (wet + dry) deposition. Critical loads can be developed for a variety of ecosystem responses (see figure below).

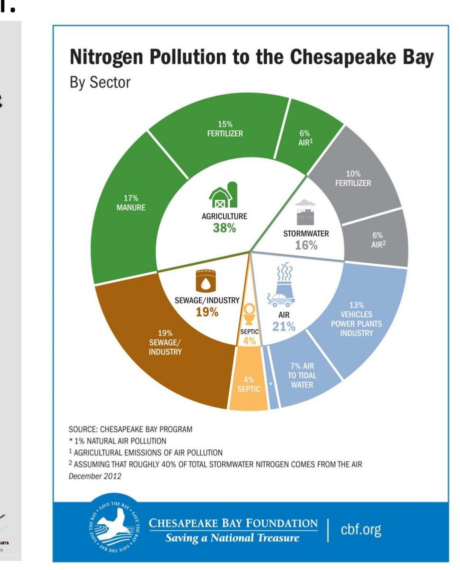


When critical loads are exceeded, the environmental effects can extend over great distances. For example, excess nitrogen can change soil and surface water chemistry, which in turn can cause eutrophication of downstream estuaries. The long-term, spatially extensive wet deposition data provided by NADP are instrumental in developing critical loads in the USA, thereby helping to quantify the impacts of air pollution on ecosystems. NADP also provides a format for critical loads development through the **CLAD (Critical Loads and Atmospheric Deposition) Science Committee** (http://nadp.isws.illinois.edu/committees/clad/).

THE CHESAPEAKE BAY: A CASE STUDY

The Chesapeake Bay is the largest of 130 estuaries in the nation and is located in coastal Maryland and Virginia. The population within the Chesapeake Bay watershed is approximately 17 million and growing.
One of the largest problems facing the environmental health of the Bay is an overabundance of nutrients, especially N. This often leads to increased algal production and organic matter, a process known as eutrophication.





Nitrogen is introduced into the Chesapeake Bay as runoff or wastewater from agricultural operations, storm water drainage, sewage and industry, and 1/3 is from deposition from the air.

The Chesapeake Bay Program seeks ways to reduce N entering the Bay, which include programs to promote farming conservation practices to curb drainage and runoff of fertilizers and animal waste. Researchers are using NADP data to compute the amount of N deposited by precipitation in the Bay and its watershed.

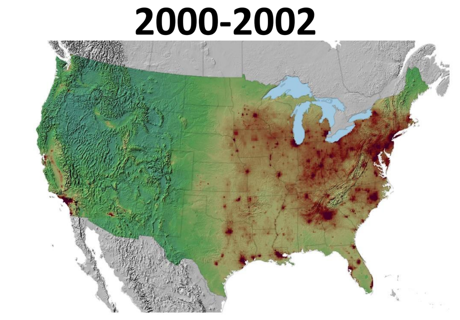
Aerial view of algal blooms in the Elizabeth, Lafayette, and James Rivers, VA. N in the water is causing the explosive growth of algae, which later die, depleting the water of oxygen and leading to hypoxic zones. Source: Chesapeake Bay Foundation.

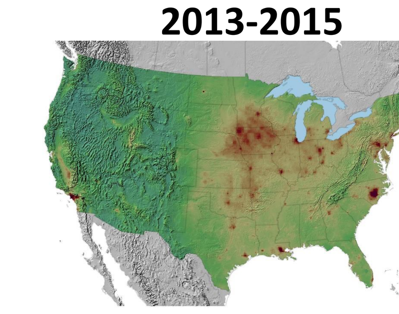
MEASURING TOTAL DEPOSITION (wet + dry)

NADP has also attempted to better understand total wet and dry nitrogen deposition through the **Total Deposition (TDEP) Science Committee.** Using a "hybrid" approach of combining measured data (e.g., precipitation NO_3^- and NH_4^+, dry deposition of particulate NH_4^+ and NO_3^-, and gaseous NH_3)* with modeled deposition data of other known, but not measured, nitrogen species (e.g., wet and dry organic N, HONO, NO_2, etc.), estimates of total N deposition are obtained.

Mean annual total N deposition

2000-2002 **2013-2015**





Such work aids another NADP science committee, the Critical Loads and Atmospheric Deposition (CLAD) Committee in evaluating whether sensitive areas are experiencing too much N deposition.

* The Clean Air Status and Trends Network (**CASTNET**) measures dry species of N (particulate NH_4^+ & NO_3^-, as well as HNO_3) and calculates N deposition of these species at 95 sites.