Global Nitrogen and Sulfur Budgets Using a Measurement-Model Fusion Approach

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Introduction

Atmospheric nitrogen and sulfur deposition from human activities related to the use of fossil fuels can lead to:

- eutrophication
- changes in carbon sequestration
- loss of biodiversity
- acidification

The United Nations Economic Commission for Europe's Task Force on Hemispheric Transport of Air Pollution (HTAP) is an international effort to improve the understanding of air pollution transport science with emissions models. The second phase of HTAP was launched in 2012. Tan et al. (Tan et al., 2018) used the multi-model mean (MMM) of 11 HTAP II chemistry transport models to estimate the sulfur and nitrogen deposition budgets for 2010. Significant uncertainty remained due to a lack of station measurements, especially in East Asia, a large contributor to the overall budget.

Combining measurements and model estimates in a **"measurement-model fusion" (MMF)** approach has the advantage of:

- retaining the broad spatial coverage of models
- accurately matching observations.

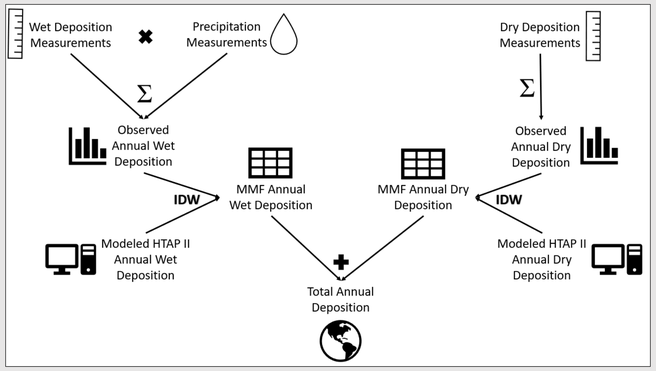
MMF takes model estimates for a region and modifies them based on in-situ point measurements of the phenomenon to "nudge" the model towards the observed values (Labrador et al., 2020). This study updates Tan et al.'s (Tan et al., 2018) global S and N deposition budgets using a variation of the TDep methodology (Schwede and Lear, 2014) to merge NH_x, NO_y, and SO_x gridded surfaces from modeled results with observations of NO_3^-, NH_4^+, and SO_4^{2-} in precipitation and as an aerosol.

This approach is an essential step towards the WMO's goal of reliable deposition products to aid decision-making. We update the 2010 deposition budgets using MMF to combine the broad spatial coverage of a model with accurate in-situ measurements.

Data Availability

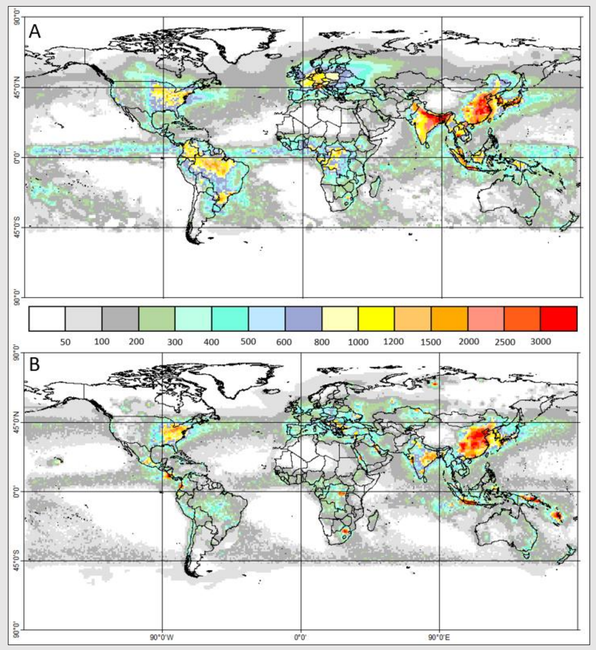
- Wet deposition from the US's National Trends Network (NTN) and Atmospheric Integrated Research Monitoring Network (AIRMoN).
- Dry deposition from the Clean Air Status and Trends Network (CASTNET (Clean Air Status and Trends Network (CASTNET), 2021))
- Canadian Air and Precipitation Monitoring Network (CAPMoN (Canadian Air and Precipitation Monitoring Network, 2021)).
- The European Monitoring and Evaluation Programme (EMEP (European Monitoring and Evaluation Programme (EMEP), 2021; Tørseth et al., 2012), http://ebas-data.nilu.no/).
- A multi-year nationwide field study was compiled by Li et al. (Li et al., 2019) in East Asia
- Acid Deposition Monitoring Network in East Asia EANET (Asia Center for Air Pollution Research, 2021, https://www.eanet.asia/).

Methods

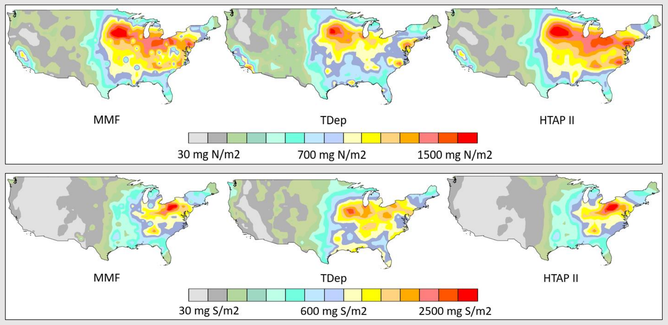


Results

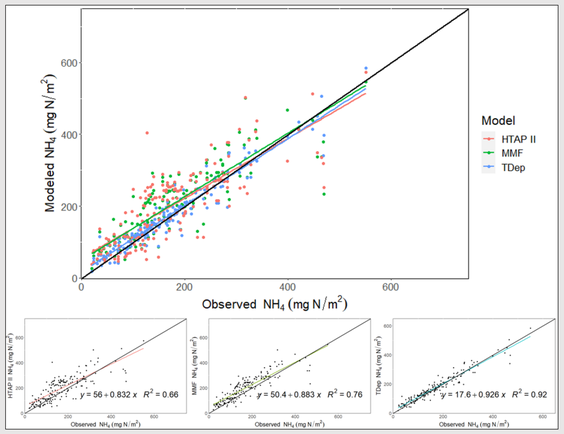
The total nitrogen deposition budget is recalculated to 130 Tg-N and the sulfur budget is 80 Tg-N, representing about a 10% increase and no change, respectively, from the modeled values.



Total N and S deposition in 2010 using the MMF approach. A) Total N deposition (mg N/m^2), the sum of wet and dry NO_3^- and NH_4^+ after applying the MMF approach, as well as HTAP II gridded surfaces of wet and dry NH_3, HNO_3, and NO_2 with no MMF approach due to the lack of measurements. **B)** Total S deposition (mg S /m^2), the sum of wet and dry MMF SO_4^{2-} and wet and dry HTAP II SO_2.



2010 Total N deposition in the US. A) Total N is modeled with 1) MMF (this work), 2) TDep annual map available from the NADP and 3) Tan et al.'s 2018 MMM. **B)** 2010 SO_x wet deposition in the US as modeled with 1) MMF (this work), 2) TDep annual map available from the NADP, and 3) Tan et al.'s 2018 multi-model mean HTAP II output.



Observed and modeled wet NH_4 deposition in the US in 2010. Each NADP/NTN wet deposition measurement and the associated HTAP II, TDep, or MMF NH_x wet deposition value. The black line is the 1:1 line.

Conclusions

We demonstrate the viability of a straightforward but globally applicable MMF approach while remaining consistent with previous work. The models are adequately simulating deposition (in terms of total deposition budgets) but regional discrepancies between models and measurements can be large; and MMF ameliorates this without changing the model parameters and processes that capture the overall deposition reasonably well. Future work to improve MMF should investigate other methods of interpolation to avoid the limitations associated with IDW such as surface artifacts and high error in regions with sparse measurements. It should also incorporate satellite imagery to improve model estimates where in-situ measurements are not available.