General information

author(s)	Adriaenssens S
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taxa	*Betula pendula*, *Fagus sylvatica*, *Picea abies*, *Pinus sylvestris*, *Quercus robur*
project	PhD Adriaenssens_2012
supervisor	Verheyen K, Boeckx P, Samson R
institution	Forest & Nature Lab, Laboratory of Applied Physical Chemistry, University of Antwerp
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data	

Materials & Methods

study area	5n (measuring tower)
time period	2009–2011
goal	Get more insight into canopy exchange and the influence of tree canopies on dry deposition.
set-up	see papers below
data collection	see papers below
remarks	C5: Throughfall deposition and canopy exchange processes along a vertical gradient within the canopy of beech and Norway spruce (Adriaenssens_etal_2012_ScTotalEnv) C6: Dry deposition along a vertical gradient within a beech canopy: comparison of methods and dependence on canopy structure (submitted) C7: Atmospheric deposition to forests based on throughfall measurements: effect of canopy budget model approaches on stand deposition, forest type effect and time trend analysis (in press: Adriaenssens_etal_Biogeochemistry)

Abstract

Increased deposition of atmospheric nitrogen (N) and sulphur (S) on forest ecosystems has caused changes in biogeochemical processes, which may have adverse effects on forest structure and functioning. Therefore, an accurate quantification of total atmospheric deposition is required to establish cause-effect relationships and evaluate abatement measures and mitigation strategies. However, measurements of dry deposition, which is a major fraction of total deposition on forests, are still subject to several problems and are complicated by canopy exchange processes in tree canopies. This study aimed to address existing knowledge gaps on dry deposition and canopy exchange, in particular of N, and to gain a better understanding of the influence the forest canopy exerts on these processes. Next to this, we aimed to evaluate the often-used canopy budget model to calculate total atmospheric deposition from throughfall measurements. Dry deposition and canopy exchange processes were examined at different spatio-temporal scales for five temperate tree species widespread in Western Europe, a region with a high N

deposition load. The effect of forest canopy characteristics, i.e. leaf characteristics and canopy structure, on the measured response variable was examined.
Retention of inorganic N from wet (ammonium (NH_4^+), nitrate (NO_3^-)) and dry (ammonia (NH_3)) deposition by foliage and twigs was quantified for saplings of European beech (*Fagus sylvatica* L.), pedunculate oak (*Quercus robur* L.), silver birch (*Betula pendula* Roth) and Scots pine (*Pinus sylvestris* L.) by means of stable N isotope (^{15}N) tracing. Retention patterns for dissolved inorganic N were mainly determined by foliar uptake, except for Scots pine. In general, retention rates were 3-10 times higher for $^{15}NH_4^+$ than for $^{15}NO_3^-$, 2-3 times higher for deciduous species than for Scots pine and lower for developing leaves, although this was tree species dependent. The observed effects of tree species and phenological stage in foliar retention could be related to differences in leaf wettability, and not to water storage capacity. The small $^{15}NH_4^+$ retention by twigs was mainly due to physicochemical adsorption to the woody plant surface. Retention of $^{15}NH_4^+$ calculated from throughfall water was, on average, 20 times higher than retention by the plant material, indicating that a large part of the applied $^{15}NH_4^+$ could not be accounted for. The $^{15}NH_3$ retention by leaves and twigs was affected by tree species, treatment date, applied NH_3 concentration and the interaction between these factors. Maximum $^{15}NH_3$ retention occurred at 5, 20 or 50 ppb, depending on the treatment date, but never at the highest NH_3 concentration level. Birch, beech and oak leaves showed the highest $^{15}NH_3$ retention in August, while for pine needles this was in June, and was generally higher for the deciduous species than for pine. Both leaf characteristics as well as measured $^{13}CO_2$ retention did not provide a strong explanation for the observed differences in $^{15}NH_3$ retention.

Throughfall deposition, dry deposition and canopy exchange of major ions calculated by the canopy budget model were studied along a vertical gradient within a beech and two Norway spruce (*Picea abies* Karst.) canopies, located in forests in Belgium and Denmark, respectively. Throughfall and net throughfall deposition of all ions other than H^+ increased significantly with canopy depth in the middle and lower canopy of the beech tree and in the whole canopy of the spruce trees. Dry deposition of all ions and canopy uptake of inorganic N and H^+ occurred mainly in the upper canopy, while canopy leaching of K^+, Ca^{2+} and Mg^{2+} was observed at all canopy levels. Canopy exchange was always higher during the growing season compared to the dormant season. This observational study illustrated that biogeochemical deposition models would benefit from a multilayer approach for shade-tolerant tree species such as beech and spruce. For the beech canopy, a comparison of dry deposition calculated by the canopy budget model was made with dry deposition calculated from air concentration measurements and dry deposition onto multi- and single-layered artificial foliage. The multi-layered artificial foliage showed a good agreement with the canopy budget model for coarse aerosol deposition. For NH_x, the canopy budget model and the air concentration measurements yielded similar results, however, for SO_x the canopy budget model yielded higher dry deposition than estimated from air concentration measurements and for NO_y the model resulted in lower estimates. Combining throughfall measurements with multi-layered artificial foliage could aid to quantify dry deposition of NO_y. Net throughfall and dry deposition of all variables except throughfall volume, H^+ and NO_3^-, were significantly correlated with the volume of canopy elements above the throughfall collectors, which was measured by terrestrial laser scanning.

To determine the effect of different canopy budget model approaches on atmospheric deposition estimates, we calculated the range of atmospheric deposition obtained by combining canopy budget model approaches for three typical case studies: (i) total N and potentially acidifying deposition onto a forest canopy, (ii) the ratio of these deposition variables between a coniferous and a deciduous stand and (iii) the parameters of a deposition time trend analysis. The effect of each step in the canopy budget model on the obtained range was assessed. The time step, type of precipitation data and tracer ion used in the model had a significant effect on the derived deposition in the three case studies. In addition, including or excluding canopy leaching of weak acids and canopy uptake of NH_4^+ and NO_3^- during the leafless season largely affected the results, while including or excluding canopy uptake of NO_3^- generally showed no effect. Our results provided more insight into the role of the forest canopy on dry deposition and canopy exchange of major ions. Furthermore, canopy retention of N was accurately quantified and methodological recommendations with regard to the quantification of dry deposition and canopy exchange for N compounds from the canopy budget model could be formulated.

RESULTS

Canopy retention was 3-10 times higher for $^{15}NH_4^+$ than for $^{15}NO_3^-$, 2-3 times higher for European beech, pedunculate oak and silver birch than for Scots pine and lower for developing leaves, although this was tree species dependent. Leaf wettability was correlated with foliar retention; twig retention was mainly due to adsorption.

Canopy retention of $^{15}NH_3$ was affected by tree species, treatment date, applied NH_3 concentration and the interaction between these factors.

Throughfall and net throughfall deposition of all ions other than H^+ increased significantly with canopy depth. Dry deposition of all ions and canopy uptake of inorganic N and H^+ occurred mainly in the upper canopy; canopy leaching of K^+, Ca^{2+} and Mg^{2+} was observed at all canopy levels. Canopy exchange was always higher during the growing season compared to the dormant season. Net throughfall and dry deposition of all variables except throughfall volume, H^+ and NO_3^-, were significantly correlated with the volume of canopy elements above the throughfall collectors.

The time step, type of precipitation data and tracer ion used in the canopy budget model had a significant effect on the calculated deposition. In addition, including or excluding canopy leaching of weak acids and canopy uptake of NH_4^+ and NO_3^- during the leafless season largely affected the results; including or excluding canopy uptake of NO_3^- generally showed no effect.