ICP VEGETATION

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POSTERS

Working Group on Effects
of the
Convention on Long-range Transboundary Air Pollution

MOSS SURVEY

Author(s)	Title
Koroleva Yulia et al.	Features of the trace element composition of bryophytes in coastal landscapes (southern Curonian Spit, Russia).
Borovská Jana et al.	Atmospheric deposition of Heavy metals in Slovakia.
Ilić M. et al.	Can *Hypnum cupressiforme* be easily found within urban areas? – a case study in Serbia.
Saxena D.K. & Saxena A.	Atmospheric Metal Load By Mosses During Pre-Lockdown And Lockdown Pandemic Period.

OZONE

Author(s)	Title
Felix Leung et al.	Evidence of Ozone-Induced Visible Foliar Injury in Hong Kong using Phaseolus vulgaris as a Bioindicator.
Li Li et al.	Response of gas exchange, biomass and nonstructural carbohydrates (NSC) allocation in Indocalamus decorus to experimental atmospheric O_3 enrichment in a suburb of Beijing, China.
Falk S. et al.	Characterizing subarctic biomes for land surface modeling of pollution and climate risk.

MOSS SURVEY POSTERS

FEATURES OF THE TRACE ELEMENT COMPOSITION OF BRYOPHYTES IN COASTAL LANDSCAPES (SOUTHERN CURONIAN SPIT, RUSSIA)

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Immanuel Kant Baltic Federal University, Russia, Kaliningrad

INTRODUCTION. Mosses' high sensitivity to environmental changes makes them good bioindicators of pollution. Both the species diversity of bryophytes and pollutant concentrations in plants are used as environmental condition indicators. Continental mosses are known to have higher capacity to retain elements than similar coastal-marine species. This is related to the fact that coastal-marine natural systems in the land-sea contact area have a high degree of transformation. Natural systems of sand bars (spits) are characterised by highly dynamic natural processes subjected to considerable seasonal and annual fluctuations. One of the key coastal-marine objects for studying the accumulation of elements in mosses is the Curonian spit, a sand depositional active landform in the south-eastern part of the Baltic Sea. Its natural systems feature high biological and landscape diversity with mosses dominating and forming the environment of a number of its ecosystems.

MATERIAL AND METHODS. The Curonian Spit is a curved sand bar separating the Curonian Lagoon from the Baltic Sea. The Spit is a UNESCO World Heritage Site located in the territory of two states, the Republic of Lithuania and the Russian Federation. The total length of the Spit within the Russian Federation is 46 km with forests covering 72% of its territory.

The combination of variuos landscapes, including sand dune complexes, different types of forests, coastal water ecosystems, moraines, and raised bogs, creates great biological diversity that provides insight into important long-term environmental processes of the development of terrestrial, wetland and marine ecosystems as well as plant and animals communities.

To investigate the accumulation of trace and other elements in mosses two sampling sites were selected on the territory of the Curonian Spit (Fig. 1). Each of the sites has three identified biotopes. At the proximal end of the Spit, they include green-moss and pine forests, alder carr and Svinoe raised bog. In the sampling site in the centre of the Spit, there is green-moss and pine forests, alder woodland and an artificial sand dune. Moss samples were collected from various substrates: soil, tree trunks, sand, decaying wood, and peat.

X-ray fluorescent spectrometry was carried out using Spectroscan Max G (Spectron, St. Petersburg, Russia) to determine their elemental composition. This allowed determining at a voltage the concentration of 8 elements (Fe, Mn, Zn, Ni, Br, Sr, Rb, Ca). Due to the limit of detection of the spectrometer this technique allows for determining only these elements with the margin of error. The results of the analysis were monitored using certified reference materials.

The descriptive statistics method (table 1) and principle component analysis were applied to the elemental concentration data set to explain variations in the data and their origin.

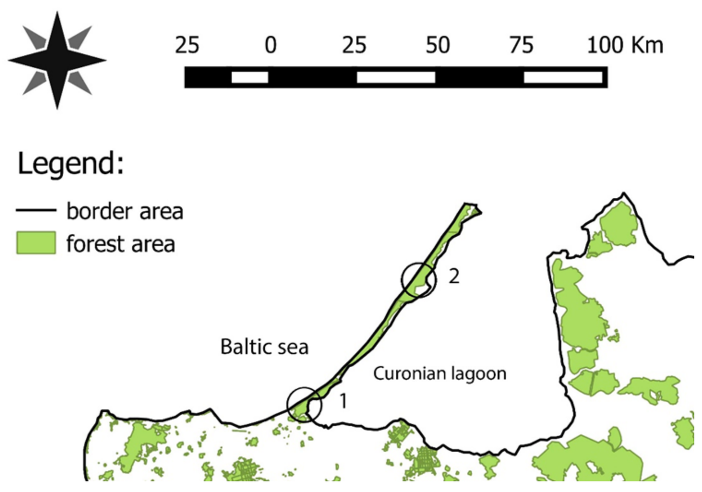


Figure 1. The explored area in Curonian spit.

The species composition of mosses at the plot 1: *Hypnum sp., Brachythecium sp., Mnium hornum, Plagiomnium undulatum, Pleurozium schreberi, Dicranum polysetum, Leucobryum glaucum, Sphagnum magellanicum, Sphagnum rubellum, Pleurozium schreberi, Sphagnum cuspidatum, Sphagnum sp*. (green).

The species composition of mosses at the plot 2 *Hylocomium splendens, Pleurozium schreberi, Dicranum polysetum, Pseudoscleropodium purum, Rhytidiadelphus triquetrus, Plagiomnium affine, Hypnum cupressiforme, Polytrichum formosum, Syntrichia ruralis, Ceratodon purpureus, Bryum argenteum* (mixed), *Brachythecium albicans.*

Table 1. Descriptive statistics of the concentration data (mg/kg, DW) in moss samples of two plots in Curonian spit.

El.	Mn	Ni	Zn	Br	Sr	Rb	Fe	Ca
Plot 1. Number of samples – 12. Saturation - 11/**Plot 2.** Number of samples – 16. Saturation - 12								
min	15,4/21,8	0,414/0,811	18,8/19,9	1,63/0,888	<1,88/0,454	0,579/0,996	136/162	1614/2482
max	271/276	4,05/52,2	54,6/69,8	15,6/14,7	21,8/26,1	481/30,7	656/2530	1017/10738
mediana	73,4/79,2	1,48/2,98	29,8/28,1	3,35/2,67	5,62/10,7	10,8/5,46	257/328	3482/5928
mean	97,4/117	1,73/7,53	33,3/32,8	4,65/3,91	8,60/12,7	49,5/7,39	323/480	4689/6299
SE	22,3/20,9	0,310/3,16	3,27/3,37	1,11/0,865	2,13/2,29	39,3/1,74	47,4/143	819/702
SD	77,2/83,7	1,08/12,6	11,3/13,5	3,83/3,46	7,40/9,16	136/6,95	164/573	2837/2809
CV, %	79/71	62/168	34/41	82/88	86/72	275/94	51/119	61/45

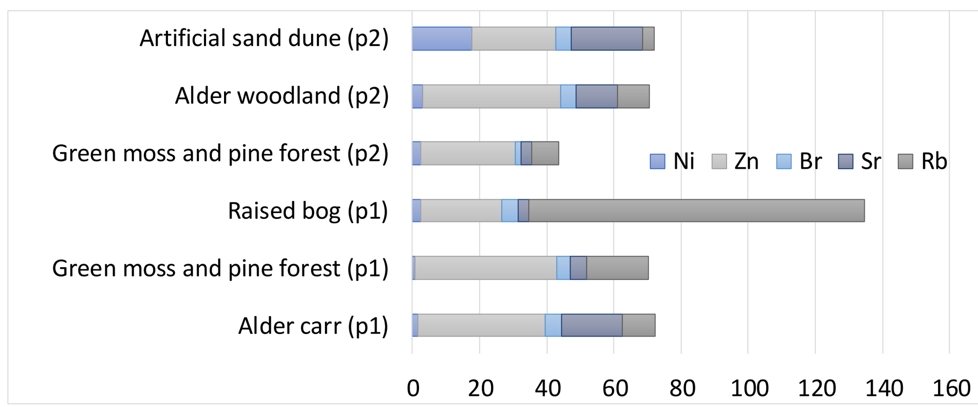
Table 2. Contamination factor of mosses in biotops of Curonian Spit and classification

elements	CF/Classification					
	Plot 1			Plot 2		
	Alder carr	Green moss pine forest	Raised bog	Alder woodland	Green moss pine forest	Artificial sand dune
Mn	2,0/C3	3,2/C3	2,9/C3	3,0/C3	6,1/C4	1,2/C2
Ni	2,9/C3	1,4/C2	4,2/C4	5,5/C4	4,3/C4	31/C6
Zn	1,9/C2	2,2/C3	1,2/C2	2,1/C3	1,4/C2	1,3/C2
Br	3,2/C3	2,6/C3	3,1/C3	3,0/C3	1,2/C2	2,9C3
Sr	4,3/C4	1,1/C2	0,8/C1	2,9/C3	0,7/C1	5,0/C4
Rb	2,2/C3	4,2/C4	23/C5	2,2/C3	1,8/C2	0,8/C1
Fe	2,3/C3	1,2/C2	1,1/C2	1,4/C2	0,9/C1	4,3/C4
Ca	4,6/C4	2,1/C3	1,4/C2	3,5/C4	1,7/C2	5,1/C4
average	2,4/C3	2,2/C3	4,7/C4	3,0/C3	2,3/C3	7,9/C4

To estimate the degree of contamination (table 2) in the Kaliningrad region, the contamination factor was calculated according to the following formula:

$$CF = \frac{C_i}{C_b}$$

For interpreting the results, six categories corresponding to CF values were introduced. CF 1 means no contamination (category C1), 1–2 suspected contamination (C2), 2–3.5 slight contamination (C3), 3.5–8 moderate contamination (C4), 8–27 severe contamination (C5), and 27 extreme contamination levels (C6).



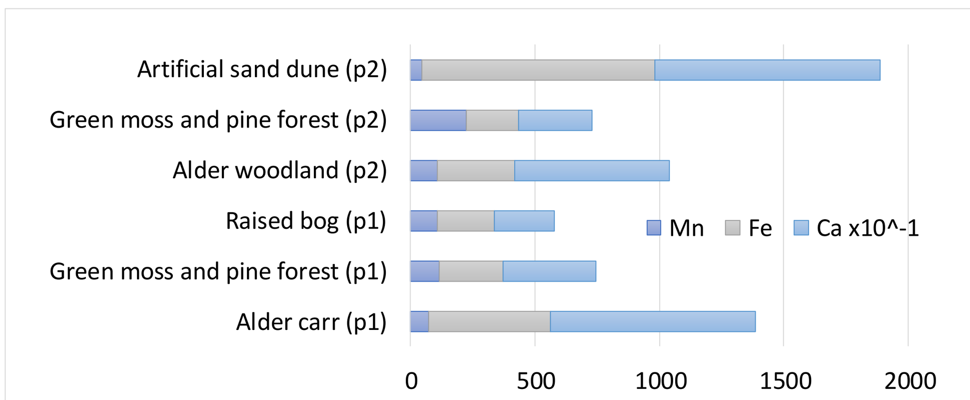


Fig 2. Accumulation of microelements by different biotops mosses (average, µg/g DW) in Curonian spit

To identify the relationships (linear dependence) between the elements in bryophyte samples, a correlation matrix was calculated. It shows slight correlations <0.3-0.4; high correlations – 0.5-0.75, and significant correlations >0.75. A negative value means that introduction of one element leads to decrease in another. It is essential to take into consideration only significant correlations: at p = 0.01 and at p = 0.05. A significant positive correlation (r^2> 0.75, p = 0.01) was found between Fe and Ni, Sr, and Ca.

High positive correlation (r^2> 0.5) at p = 0.01 was discovered between Br-Fe and Sr-Fe. A moderate positive correlation (r^2<0.5) was established between Br-Sr, Ni-Sr, Fe-Ca (p = 0.05) and a negative correlation was observed between Mn-Br, Mn-Sr (p = 0.05). This may be indicative of a common source of contamination. The correlations are presumably associated with wind transport, atmospheric deposition, marine aerosol, and leaching from plant residues.

To aid interpretation of the findings, PCA was carried out, whose results allowed us to derive three main factors to be further interpreted as source categories contributing to element concentrations at the sampling site. Examining the factor profiles, i.e., the loading of elements and other variables after varimax rotation, identified the source categories. **The first factor** accounting for 38.6% of all variables is characterized by input of nickel and iron that may be caused by ***wind transport and atmospheric deposition*** explaining its presence in the artificial sand dune. **The second factor** (22.9%) is associated with accumulation of zinc, strontium and calcium, which may indicate ***the plant origin*** of these components, that is leaching from leaf litter. The second factor is characteristic of alder carr. **The third** factor (18.1%) influences the accumulation of bromine and rubidium and manganese decrease, which is probably due to the influence of ***marine aerosol***, high values of this factor appear in all biotopes.

CONCLUSION

1. The study established spatial differences in the accumulation of elements by mosses of similar biotopes at the proximal end and in the central part of the Spit. The concentration of the elements is higher in mosses of the proximal end of the Curonian Spit.
2. Mosses of different biotopes are prone to accumulate certain elements more intensely than others. For example, manganese accumulation is typical for pine forests; nickel, strontium and iron for sand dunes; rubidium – for raised bogs.
The study established the high affinity of *Brachythecium sp.* to zinc, of *Sphagnum sp.* to bromine and rubidium, of *Brachythecium sp.* and *Cerotodon purpureus* to calcium, of *Pseudoscleropodium purum to* manganese*,* of *Syntrichia ruralis* to nickel, strontium, iron.
3. Most of the territory of the Curonian Spit is the low pollution area. The level of trace element and calcium contamination in the Curonian spit is estimated on average as C3 (slight contamination).
4. A positive correlation was established between the accumulation of Fe and Ni, Sr, and Ca; Br-Fe and Sr-Fe, Br-Sr, Ni-Sr, Fe-Ca in mosses. It indicates the same origin of the elements. The correlations are tentatively associated with wind transport, atmospheric deposition, marine aerosol, and leaching from plant residues.
5. The principal component analysis also shows three factors possibly affecting the accumulation of the elements studied. The first factor is characterized by accumulation of nickel and iron. It can be associated with wind transport and atmospheric deposition which can explain its presence in the artificial sand dune. The second factor is associated with accumulation of zinc, strontium and calcium, which may indicate the plant origin of these components, that is leaching from leaf litter. The second factor is characteristic of alder woodland. The third factor influences the accumulation of bromine and rubidium and manganese decrease. It is probably connected with marine aerosol. This factor shows high values in all biotopes.

34th ICP Vegetation Task Force Meeting,
22nd-25th February 2021

ATMOSPHERIC DEPOSITION OF HEAVY METALS IN SLOVAKIA

Author(s): Borovská J.[1], Matej Florek[2], Katarína Gerhátová[1], Tomáš Rusňák[1]

The representative moss samples for the last completed Survey 2015/16 were collected on 68 sampling plots. The network of moss monitoring plots has been developed since 1990 in a design to cover the whole SK territory in a grid of 16×16 km. In the current Survey 2020/21 were collected mosses on 58 sampling plots so far. The collection will be continued.

Mosses collected in the last Survey were analysed in Joint Institute for Nuclear Research in Dubna, Russia by INAA method and in National Forest Centre in Zvolen, Slovakia were analysed N by EA method, Cu, Cd, Pb by ETA AS method.

In the last Survey was detected high mean value of nitrogen deposition (20,7 g/kg) in the territory of SK ranging from 8,52 to 39,6 g/kg. Increased depositions of mainly reactive nitrogen compounds cause ecosystem eutrophication and may cause loss of sensitive species and disrupt ecological stability.

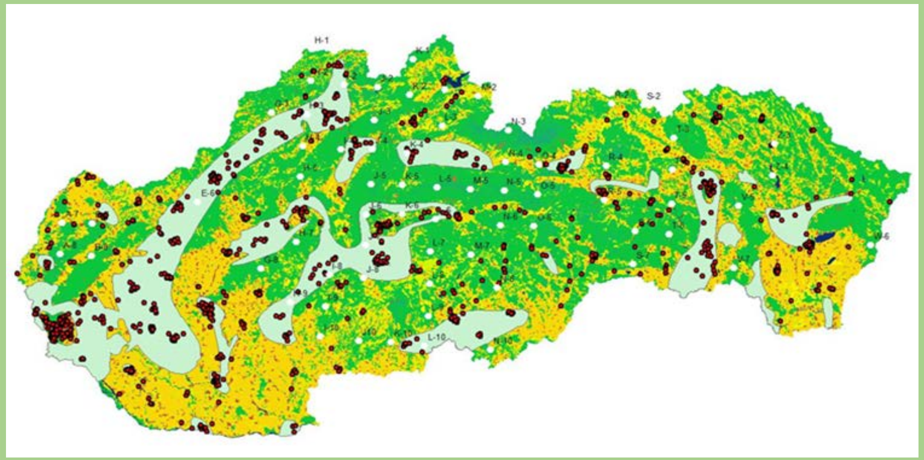


Fig. 1: Map with sources of pollution (red), areas with high pollution (blue) and sampling points (white).

In Slovakia many pollution sources are overlapping (fig.1). Among the most significant anthropogenic sources belong power stations located in the Upper Nitra and Vojany. Metallurgy, nonferrous ores processing and cement factories located in Central Spiš, Central Pohronie, in the area of Rožňava, and Lower Orava. Dumps of stone chips, manufacture of basic metals and fabricated metal product, chemical and military products located in Snina, Strážske, Stropkov, Volovské Mts., Kremnické Mts. and Štiavnické Mts. Aluminium factories located in the area of Žiar nad Hronom.

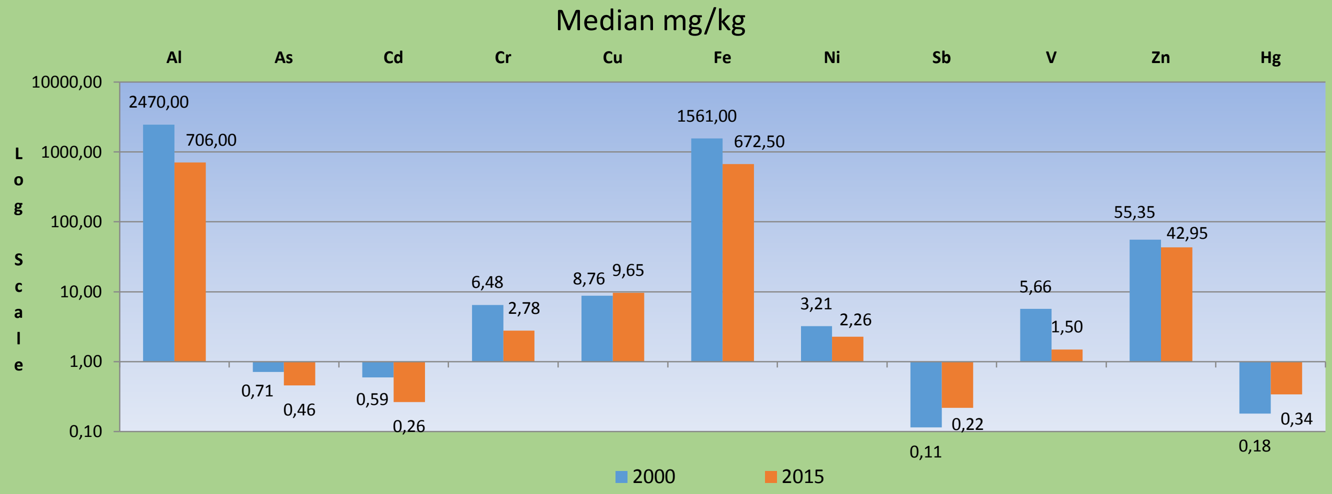


Fig. 2: Compared median concentrations of selected heavy metals in mosses in 2000 and 2015.

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CAN *Hypnum cupressiforme* BE EASILY FOUND WITHIN URBAN AREAS? – A CASE STUDY IN SERBIA

ICP VEGETATION
34th Task Force Meeting

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Why?

Passive biomonitoring of air quality using pleurocarpous bryophytes is well established in Europe, and implemented in heavy metal surveys within ICP Vegetation Programme. According to the monitoring manual, the sampling sites are representatives of non-urban areas. But, what about urban areas? Large cities in Serbia have developed good air pollution monitoring, but it is hard to establish an instrumental monitoring network with high resolution. The major problem of passive biomonitoring in urban areas is lack of recommended bryophyte species due to their vanishing from these sites. On the contrary, urbanization creates preconditions for the existence of specific microhabitats, which can be inhabited by bryophytes. Bryophytes can be abundant in urban areas due to the absence of competitively superior vascular plants.

Aim

In this research we wanted to answer to the following question: Whether recommended bryophyte species can be easily found in urban areas (towns and villages)?

How?

The following species were object of our interest: *Hypnum cupressiforme, Hylocomium splendens, Pleurozium schreberi, Pseudoscleropodium purum, Abietinella abietina, Homalothecium lutescens, Homalothecium sericem* within 34 urban sites (towns and villages) of Fruška gora Mountain (Northern Serbia).

Results

- ✓ *Hylocomium splendens* and *Pleurozium schreberi* were not recorded at any of the investigated sites. This is not surprising since these species prefers coniferous forests or very humid, swampy habitats.
- ✓ **The most common species was *H. cupressiforme* and it was present at 18 sites.** The fact that this species can be frequently found in investigated sites is a good starting point for its usage in passive biomonitoring of air pollution within urban areas. The absence of this species from remaining sites was probably influenced by various human activities and urbanization.
- ✓ *Pseudoscleropodium purum, Abietinella abietina* and *Homalothecium sericeum* were found on 2, while *Homalothecium lutescens* on 3 sites.

Hypnum cupressiforme can be found in majority of urban sites, therefore it can serve as biomonitor of air pollution within these areas.

How the lacking of this species can be overcome? "Moss bag" technique can serve as a good alternative for such obstacles.

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Atmospheric Metal Load By Mosses During Pre-Lockdown and Lockdown Pandemic Period

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[1]Department of Botany, Bareilly College, India; [2]University of Waterloo, Canada

BACKGROUND

Bryophytes (mosses) respond quickly to environmental changes. Their small size, ability to survive under varying weather conditions and unwaxed surface makes them suitable to be used for biomonitoring of atmospheric metals[1]. Based on these characteristics, the authors demonstrate a possible relationship between metals accumulated in mosses and their presence in the environment. The biological monitor was used which does not require expansive instruments, manpower and power supply[2].

A nationwide lockdown was announced by the Government of India in March when industrial functioning and vehicular movement came to a standstill. In view of the lockdown, it was the intention to investigate how much effective the mosses are for assessing the pattern of atmospheric pollution specially metals.

METHODS

The study is based on an average metal load measured from moss samples. *Brachythecium kamounense* and *Isopterigum elegans* were harvested from study areas during two different time periods. The routine moss samples were transplanted for monitoring of atmospheric metals in the first and last week of March 2020, when the lockdown also commenced. The exposed moss transplants were harvested in August 2020 and were transported to the lab for metal analysis from two cities, Nainital and Almora. The metal data obtained from the analysis of these moss samples belonged to lockdown duration which were compared with moss transplants already analyzed from pre-lockdown periods of March 2019 to August 2019.

ACRONYMS AND REFERENCES

I.e.- Isopterigum elegans, *B.k.*-Brachythecium kamounense

1. Zechmeister H. G. Dirnbock T. Hulber, K. & Mirtl M.2007. Assessing airborne pollution effects on bryophytes— lessons learned through long-term integrated monitoring in Austria. Environmental Pollution, 147: 696–705.
2. Vuković G. Aničić Uroševic M. Razumenić, I. Goryainova Z. Frontasyeva M. Tomašević M. Popović, A.,2013. Active moss biomonitoring of small-scale spatial distribution of airborne major and trace elements in the Belgrade urban area. Environmental Science and Pollution Research. 20: 5461-5470.
3. Bryophytes of N-India 2010 - M. Lüth, February 17, 2021, http://www.milueth.de/Moose/Aktuell/India/03,15%20c%20Brachythecium%20buchananii.html.

ACKNOWLEDGEMENT

1. Ministry of Environment, Forestry and Climate Change, India.

AIM

The present study aims to measure the changes in atmospheric metal load using moss analysis during the two phases of the COVID-19 pandemic (pre-lockdown and lockdown period) and to establish their relationship to the environment.

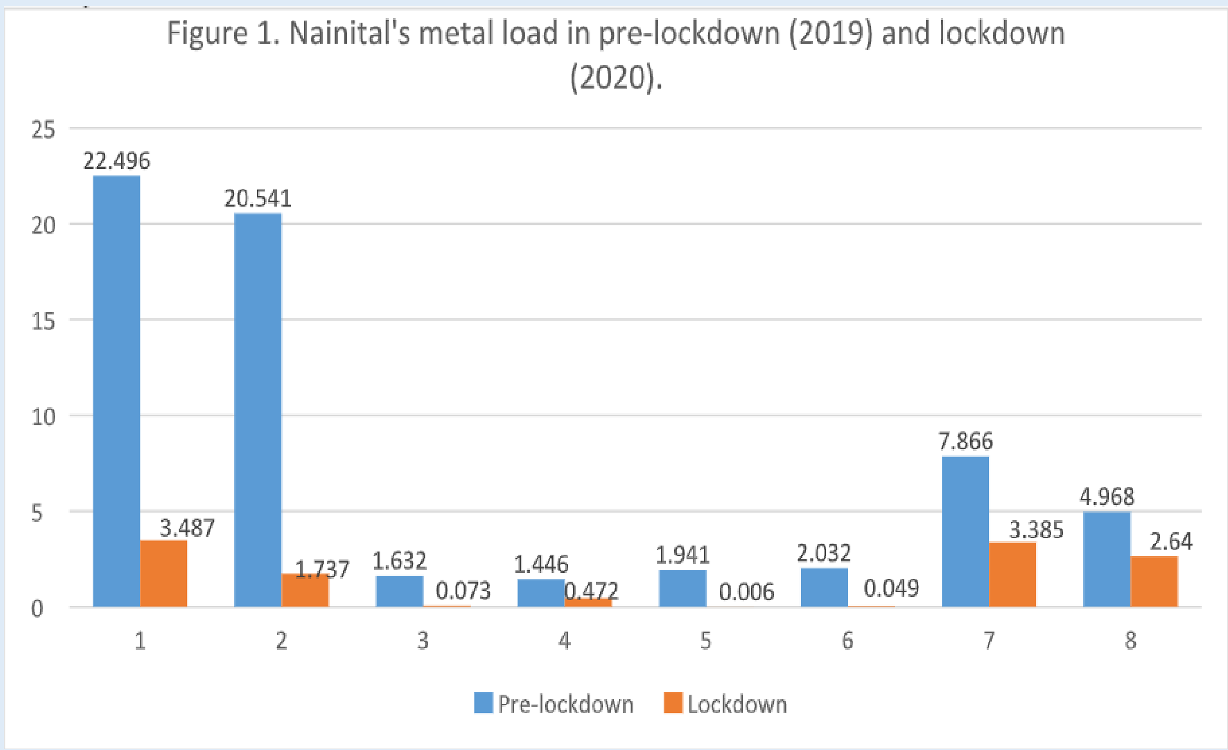


Figure 1. Nainital's metal load in pre-lockdown (2019) and lockdown (2020).

1,2: Pb (*I.e., B.k.* respectively); 3,4: Cu (I.*e., B.k.* respectively); 5,6: Zn (*I.e., B.k.* respectively); 7,8: Mn (*I.e., B.k.* respectively).

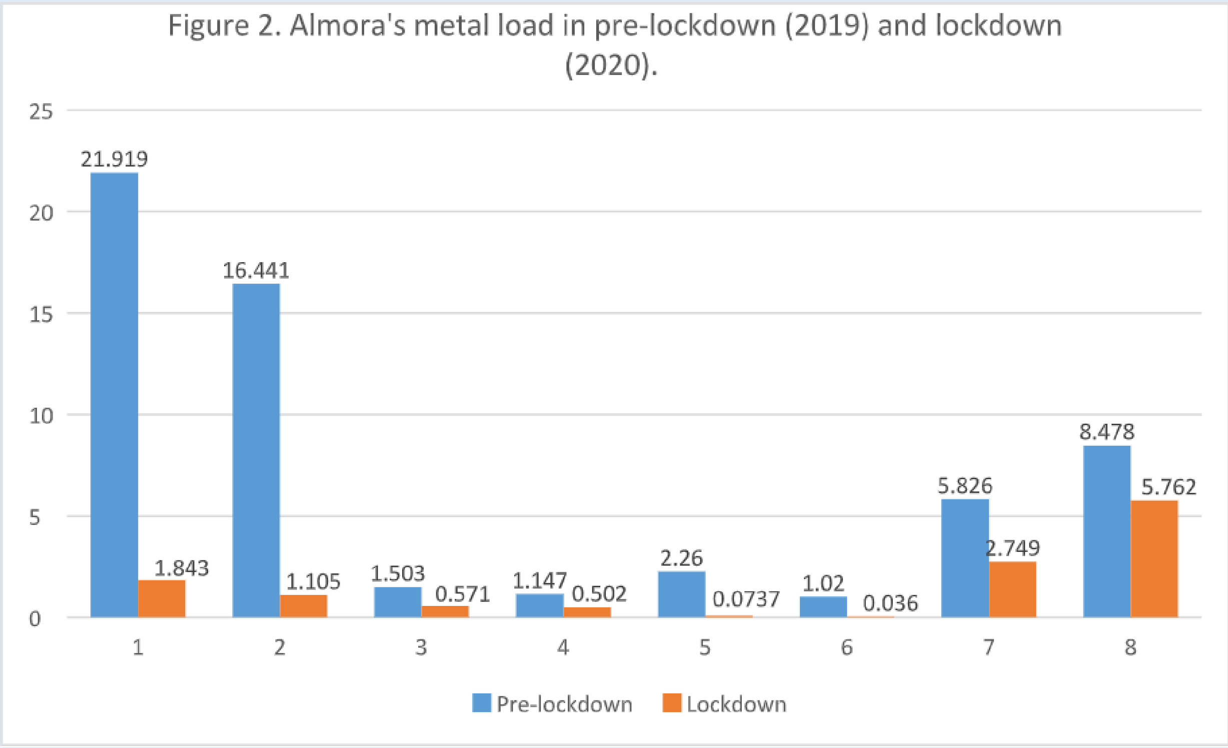


Figure 2. Almora's metal load in pre-lockdown (2019) and lockdown (2020).

1,2: Pb (*I.e., B.k.* respectively); 3,4: Cu (I.*e., B.k.* respectively); 5,6: Zn (*I.e., B.k.* respectively); 7,8: Mn (I.*e., B.k.* respectively).

DISCUSSION

A drastic fall in metal accumulation in moss samples measured during the complete lockdown period could be due to a very minimal or no vehicular movement, halted operations of the factories and construction sites which led to a shutdown of the major polluting sources. Due to quick response to atmospheric metal load, mosses can be considered as the best inexpensive method for monitoring of atmospheric methods.

FINDINGS

The study revealed that the metal level dropped sharply immediately after the lockdown and the concentration of pollutants touched the saturation level within a few days, beyond which probably further decline was not possible. The study confirms the application of mosses for the monitoring. The results further strengthens the study proving that mosses as a biological monitor of atmospheric metals appears to be an adequate method for monitoring of atmospheric metals.

Image 1. *Brachythecium* moss[3]

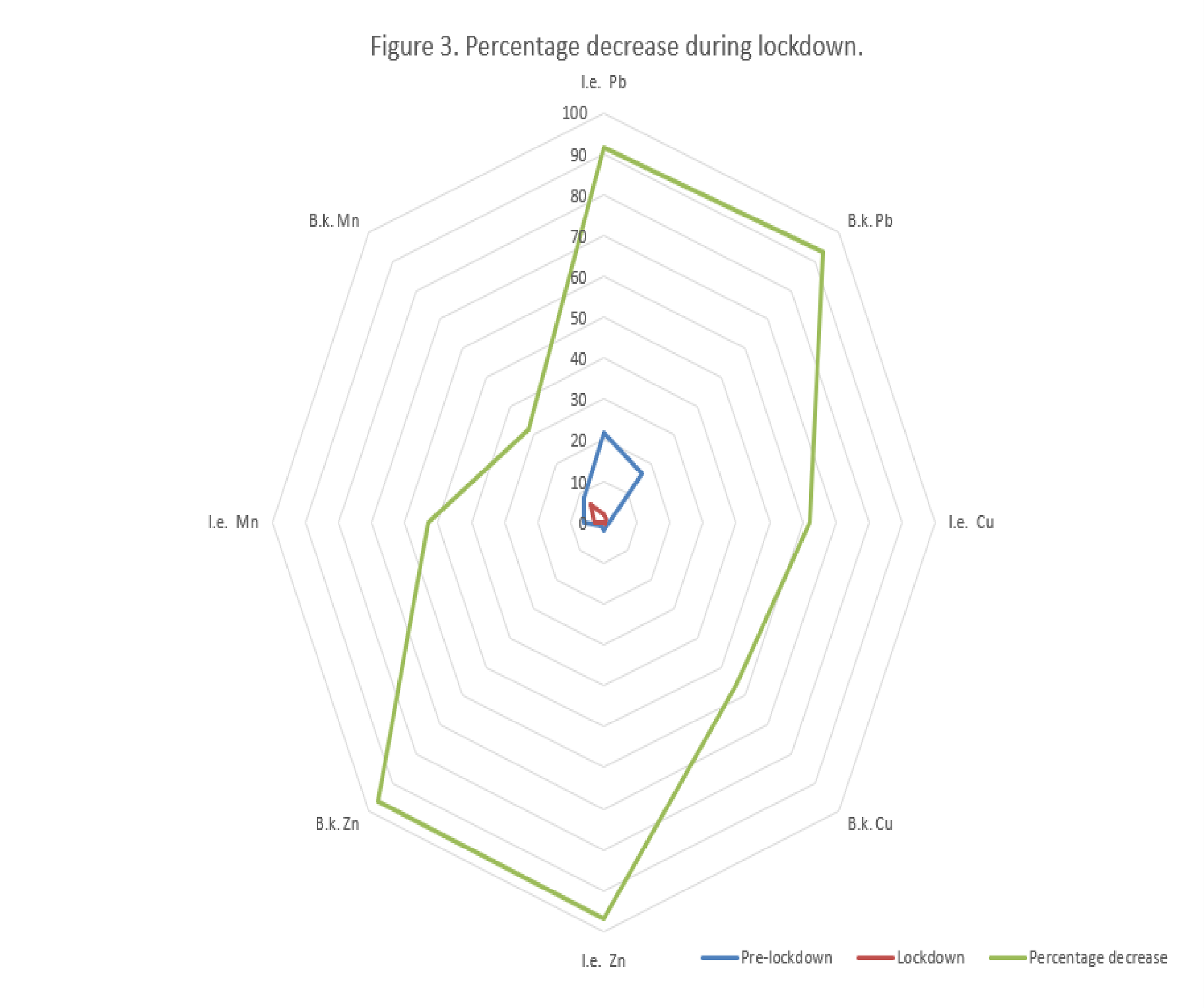


Figure 3. Percentage decrease during lockdown.

OZONE POSTERS

Evidence of ozone-induced visible foliar injury in Hong Kong using *Phaseolus vulgaris* as a bioindicator

香港中文大學 The Chinese University of Hong Kong

香港中文大學環境、能源及可持續發展研究所 IEES Institute of Environment, Energy and Sustainability, CUHK

Felix Leung, Amos P. K. Tai, Jacky Pang, Timothy Lam, Donald Tao, Katrina Sharp

UK Centre for Ecology & Hydrology

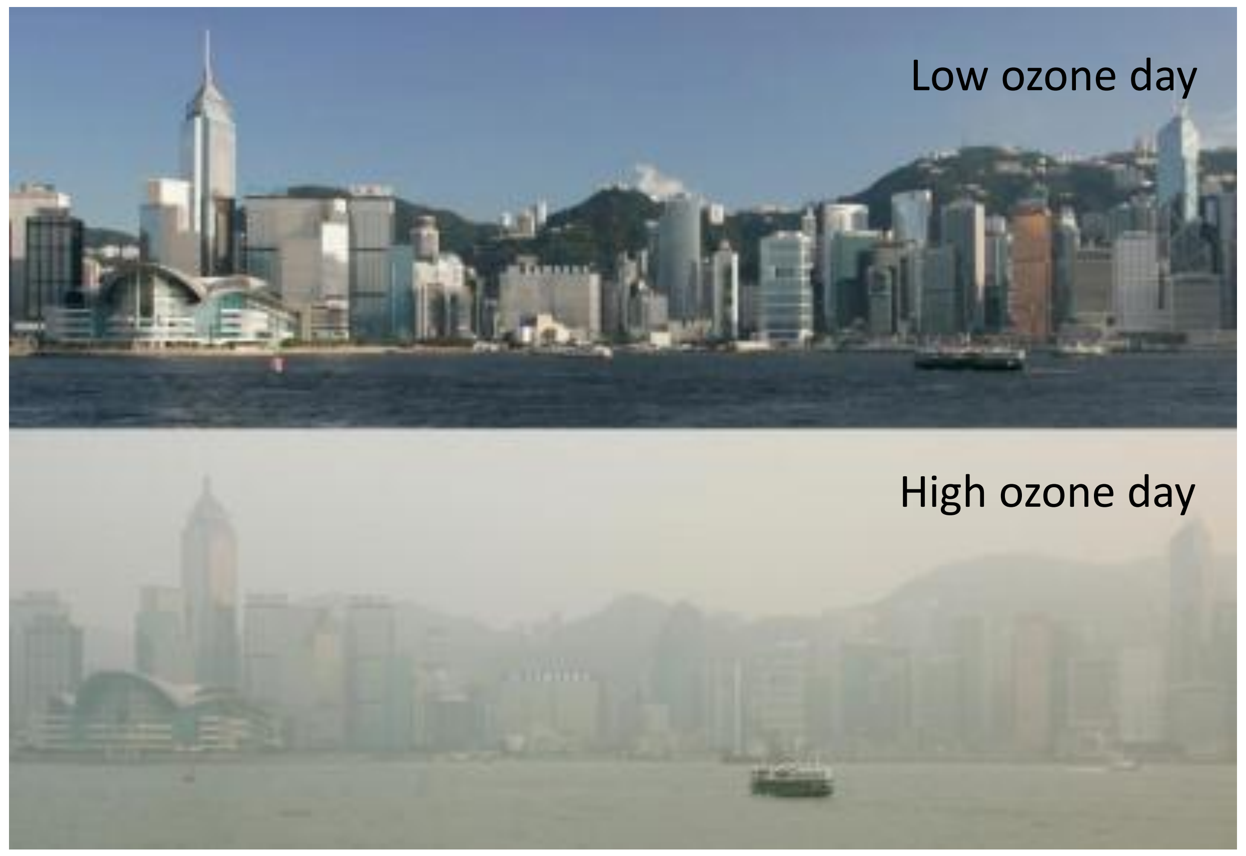
Abstract

Hong Kong is one of the most densely populated cities in the world, with millions of people exposed to severe air pollution. Surface ozone (O_3), mostly produced photochemically from anthropogenic precursor gases, is harmful to both humans and vegetation. The phytotoxicity of ozone has been shown to damage plant photosynthesis, induce early leaf death, and retard growth. We use genotypes of bush bean ***Phaseolus vulgaris*** with various degrees of sensitivity to ozone to investigate the impacts of ambient ozone on the morphology and development of the beans. We use **ozone-induced foliar injury index** and measure the flowering and fruit production to quantify the ozone stress on the plants. We expected that the ozone-sensitive genotype would suffer from a reduction of yield. Results, however, show that the ozone-sensitive genotype suffers higher ozone-induced foliar damage as expected but produces more pods and beans and heavier beans than the ozone-resistant genotype. It is postulated that the high ozone sensitivity of the sensitive genotype causes stress-induced flowering, and therefore results in higher bean yield. A higher than ambient concentration of ozone is needed to negatively impact the yield production of the ozone-sensitive genotype. Meanwhile, ozone-induced foliar damage shows a graduated scale of damage pattern that can be useful for indicating ozone levels. This study demonstrates the usefulness of bioindicators to monitor the phytotoxic effects of ozone pollution in a subtropical city such as Hong Kong.

Introduction

Air pollution in Hong Kong

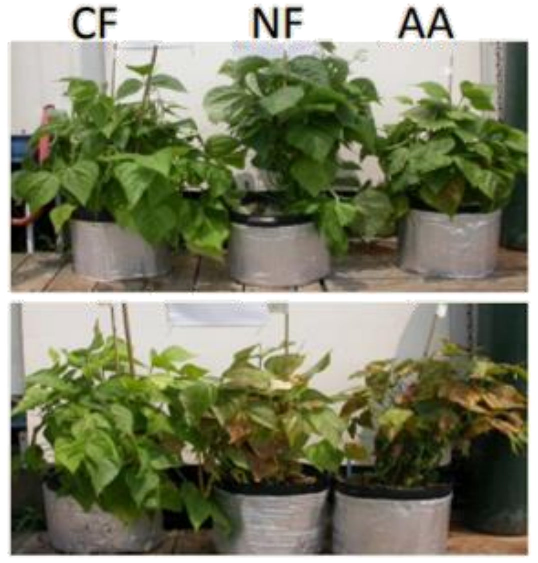
- Main source of ozone precursors are from vehicles, shipping and pollutants from southern China
- Poor visibility affect tourism and investment
- Air pollution causes 1600 premature death every year
- Loss of productivity and business costs HK $11 billion every year
- Ozone concentration is highest in Autumn when it is dry and with lots of sunny day



Methods

Genotype development of *Phaseolus vulgaris* from Burkey et al., (2012). selected from the United States Department of Agriculture, Agricultural Research Service.

- Ozone resistant R123 and Ozone sensitive S156



Original genetic cross
Oregon-91G (S) x Wade Bush (T)

↓

F_1 and F_2 generations evaluated for injury
Reinert and Eason (2000) J Amer. Hort. Sci. 125:222-227

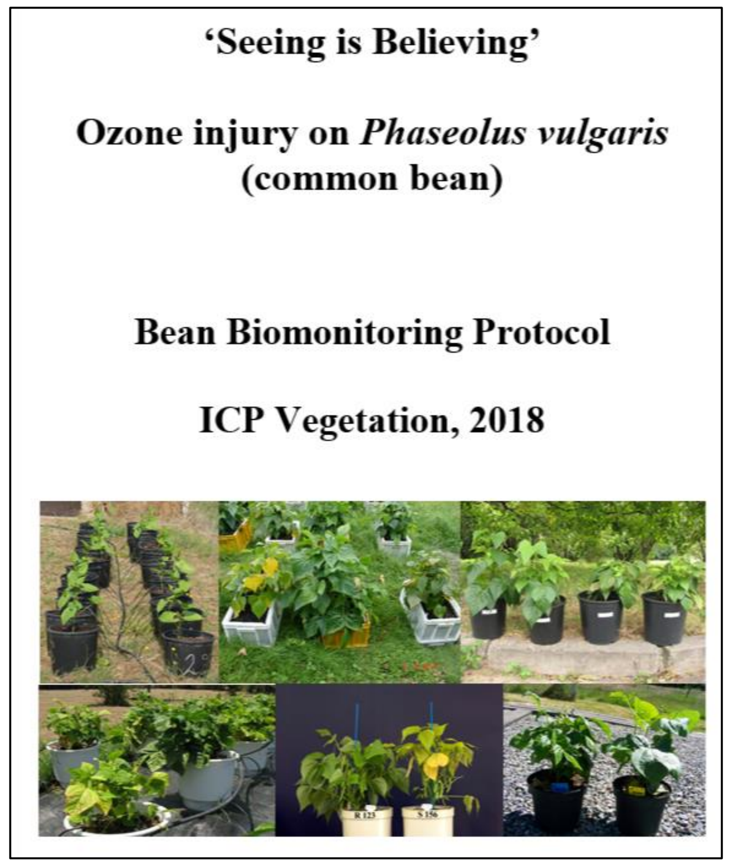
↓

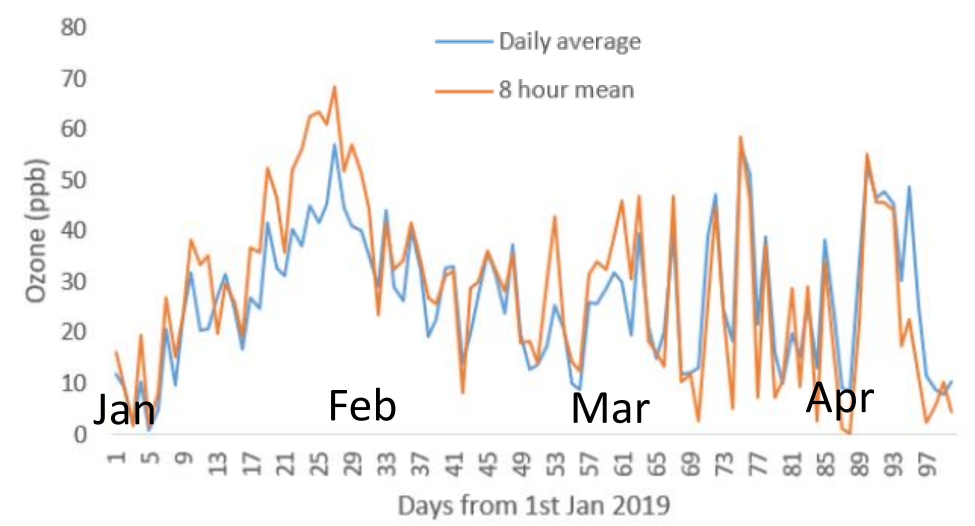
Random inbred lines advanced to F_6 selecting material for growth similar to Oregon-91G parent.

↓

Lines selected for differences in ozone response.

R and S "pairs" established based on similar mature pod/seed yields under CF conditions and differential response to ozone.



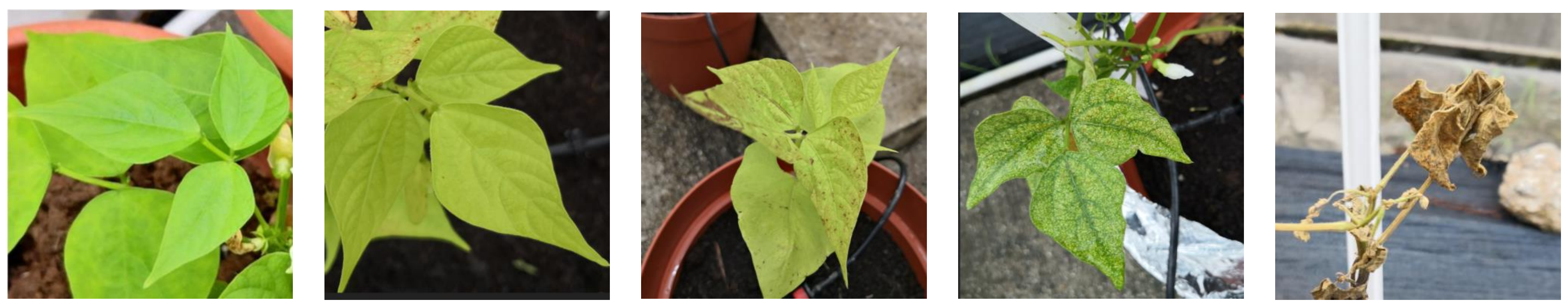


Quantify Ozone damage

We compared the differences between O_3 sensitive and O_3 resistant beans by quantifying the O_3 injuries on leaves. We measured the number of flowers and pods developed. We harvested the beans when 50% of the pods had turned brown.

We followed the statistical analysis performed by Hayes et al. (2019), who tested if the proportion of leaves per injury category varied with the genotype of the bean. We used the "multinom" function in the "nnet" package in R to perform a multinomial logistic regression models on the relationship between leaf injury and genotype.

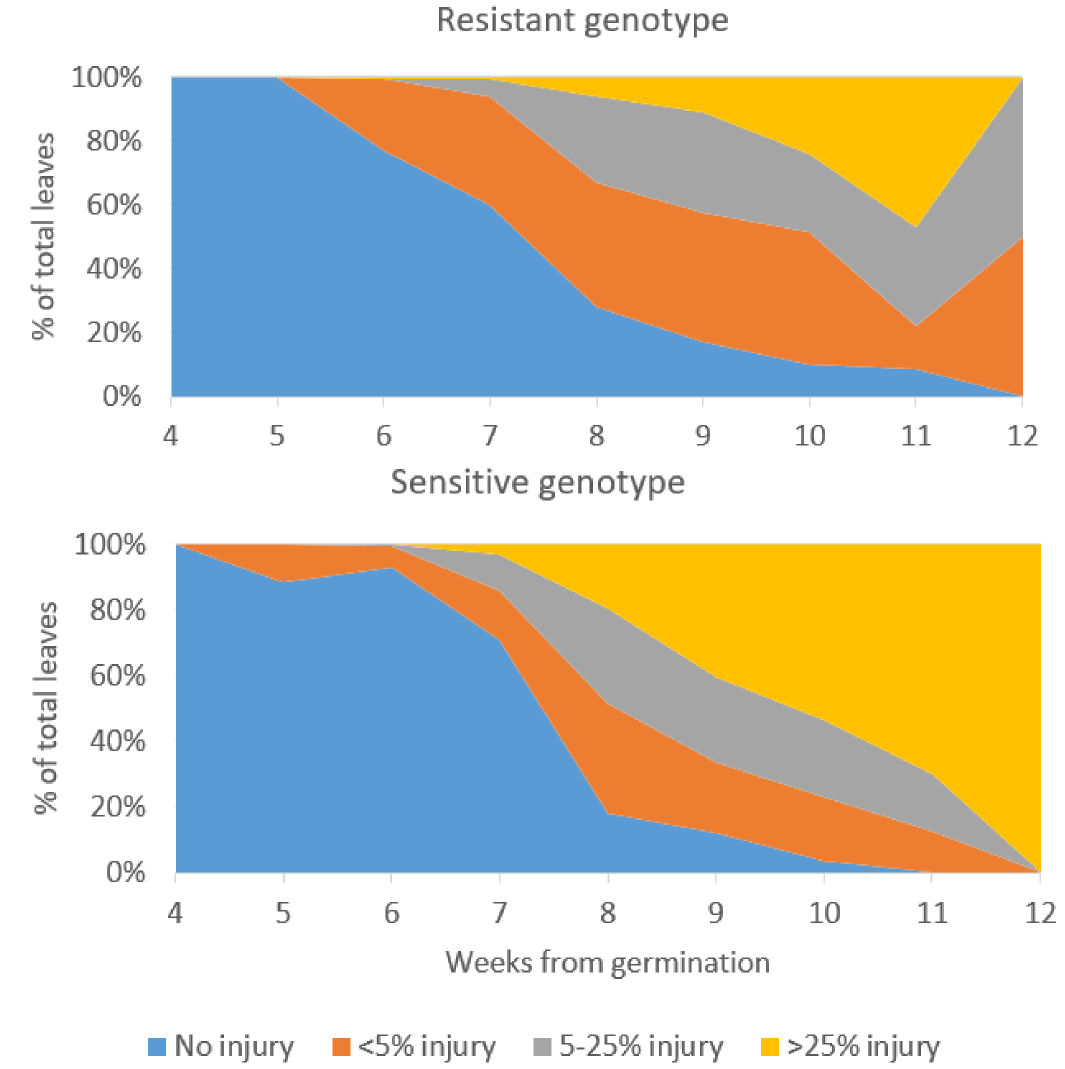
0% injury (none) | <5% injury (mild) | 5-25% injury (moderate) | >25% injury (severe) | Senescence/dead



Results

	Count for resistant genotype	Count for sensitive genotype	χ^2	p-value
Successful and (unsucessful) fruit development	58 (32)	74 (81)	6.39	**<0.05**

	Mean for resistant genotype ±1 σ SD	*Number of replicates for resistant*	*Mean for sensitive genotype ±1 σ SD*	*Number of replicates for sensitive*	*t-value*	*p-value*
Bean dry weight (g)	0.21± 0.06	128	0.24± 0.05	136	-4.47	**<0.001**
Total bean weight per plant (g)	2.09± 1.55	12	2.69± 1.85	12	-0.84	0.412
Maximum number of flowers	8.01± 2	12	12.7± 6	12	-2.55	**<0.001**



Discussions and Conclusions

The overall results show a higher average yield for the O_3-sensitive beans than the resistant ones, however, the difference was not statistically significant, possibly due to the small sample size of plants.

This overall result is consistent with the study by Elagöz & Manning (2005), in which the sensitive genotype produced heavier beans with a higher variation in bean weight and number of beans per pod.

The O_3 concentration in Hong Kong is high enough to induce foliar injury and the stress-induced flowering and fruiting for sensitive genotypes, but not high enough to create significant yield losses.

Response of gas exchange, biomass and nonstructural carbohydrates (NSC) allocation in *Indocalamus decorus* to experimental atmospheric O_3 enrichment in a suburb of Beijing, China

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Introduction

- The summer **O_3 maximum concentration in Beijing** frequently exceed 120 ppb, O_3 foliar injury have been found widespread in and around Beijing
- Quantifying the contribution of NSC storage to trees carbon balance is the key to understand tree survival and growth, which may reflect the status of carbon supply in whole plant, the growth and survival capability, the buffer ability to conquer environmental disturb.
- There were still few research on bamboo not to mention the response to elevated O_3 Concentrations.
- *Indocalamus decorus*, a member of the subfamily Bambusoideae (family Poaceae), has sympodial rhizomes and large green leaves. The species is very adaptable across a wide range of environmental

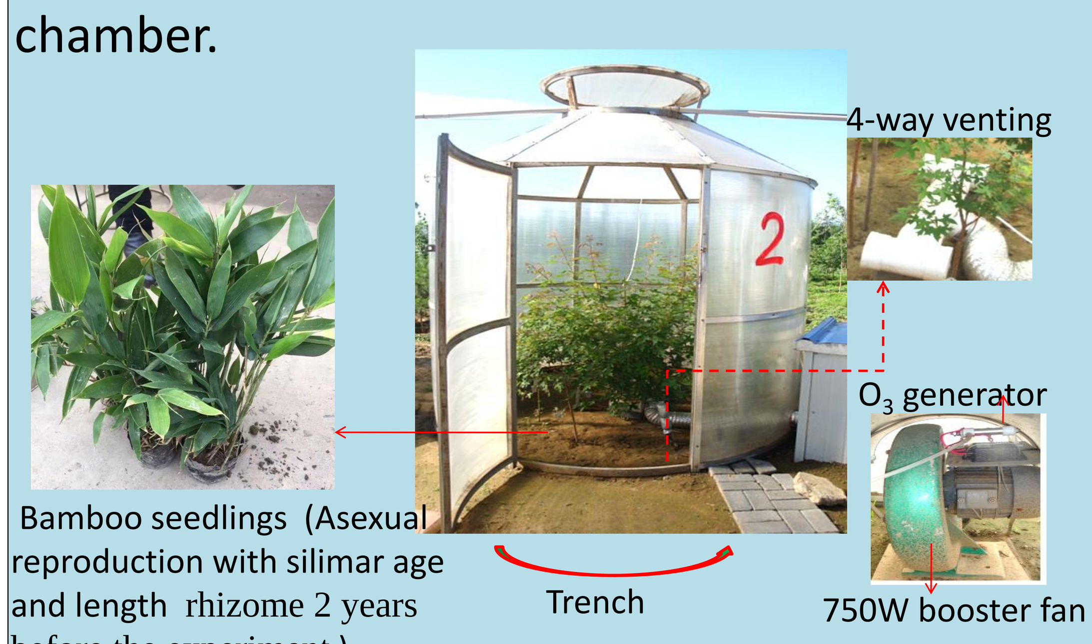
The O_3 injure on plants in and around Beijing (Wan et al., 2014)

Hypothesis

- **Elevated O_3 would affect growth and biomass of Indocalamus decorus**
- **NSC allocated among organs would response different under O_3 exposure.**

Materials and methods

- **Experimental site:** Chang Ping district, a suburb of Beijing, China.
- **Plant material:** 3-yr old ***Indocalamus decorus*** seedlings.
- **Open-top chambers (OTCs):** 2.5 m(H)×2 m (D) , a rain cap above the frustum and a trench covered with impermeable plastic sheeting around the chamber to prevent rain from intruding into the chamber.

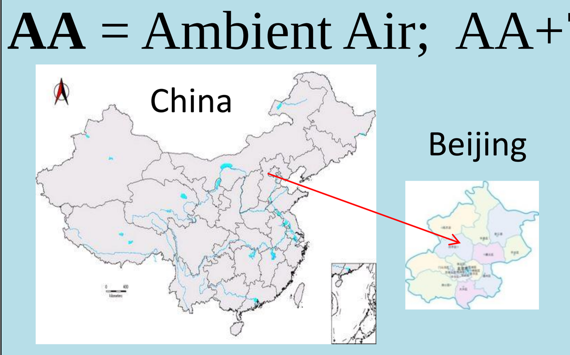


Open-top Chamber

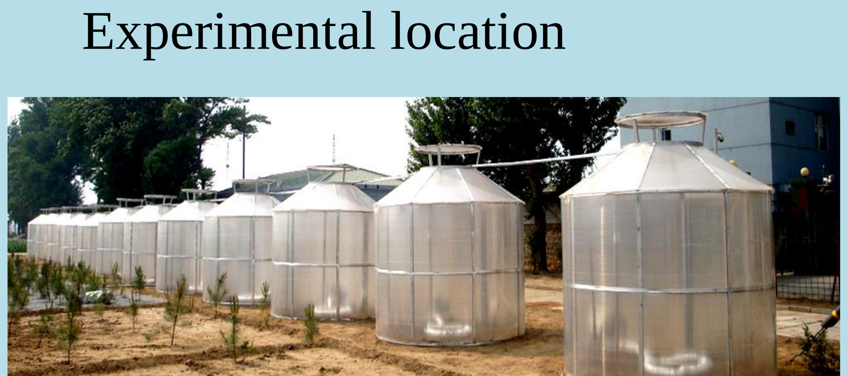
Experimental design

Three treatments were administered with three replicates among 9 chambers

AA = Ambient Air; AA+70; AA+140.



Experimental location



The appearance of the OTCs

Results

O_3 control

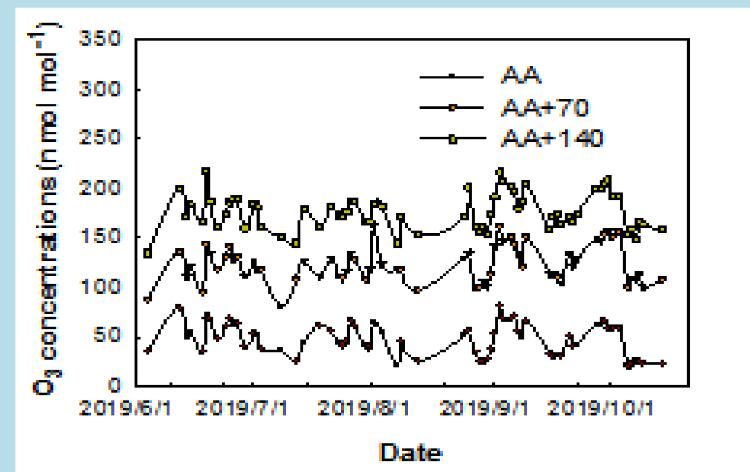


Figure 1. O_3 concentrations of three treatments

The average ambient [O_3] was 47.68 nmol mol^{-1}. The average of AA+70 and AA+140 were 123.51 and 217.42 nmol mol^{-1}, which meant the O_3 control can meet the target (Figure1). The O_3 fumigation was operated from 8:30-17:30, 9 hours every day, the total days of O_3 fumigation were lasted for 87 days (Figure 1).

Foliar injury

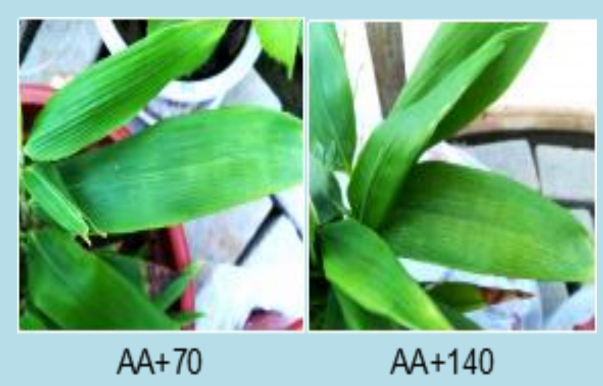


Figure 2 O_3 injury symptoms of *I. decorus* leaves under different O_3 concentrations

The foliar O_3 injury symptom first appeared on upper surface of the 1-yr old leaves of AA+140 on Jul. 24th, in the 22th day from the fumigation began, when the AOT40 value was 26.62 mmol.h^{-1}. And then the foliar O_3 injury symptom appeared on AA+70 on Sep.6th on the 1-yr old leaves as well, when the AOT40 value was 33.20 mmol.h^{-1}. The O_3 injury symptoms were typically with yellow, dotted, chlorotic stippling, reddening, and premature leaf senescence on the interveinal areas of upper leaf surfaces (Figure 2).

Gas exchange

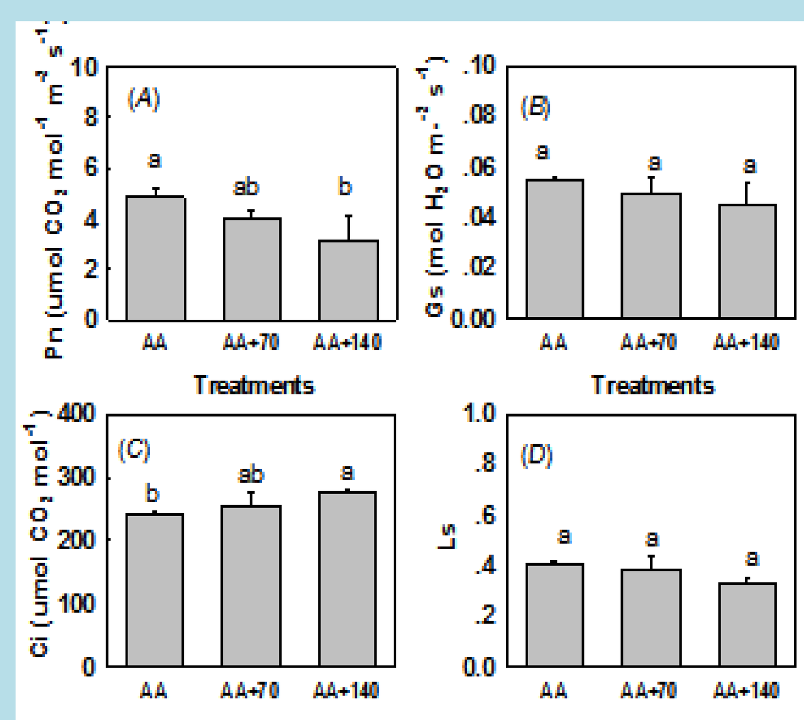


Figure 3 Effects of elevated O_3 on net photosynthesis rate (Pn, *A*), stomatal conductance (Gs, *B*), intercellular CO_2 concentration (Ci, *C*) and stomatal limitation (Ls, D) of *Indocalamus decorus*. Lowercase letters above bars in the graph mean multiple comparisons results among the treatments when O_3 effects were significant at 0.05 level.

After almost 5 months fumigation, Pn decreased 17.3% and 34.5% in AA+70 and AA+140, respectively (Figure 3). However, unlike Pn, Ci increased significantly with O_3 fumigation, which increased 4.9% and 13.9% in AA+70 and AA+140, respectively. Gs and Ls showed decline trends but not significant at 0.05 level.

Biomass allocation

Figure 4 The appearance of *Indocalamus decorus* under three O_3 treatments at the end of experiment (A-AA; B-AA+70; C-AA+140).

We separate the total biomass into new rhizome, stem, root, buds and leaf.

Table 1. Biomass (g) allocation of *Indocalamus decorus*. under three O_3 treatments.

Treatments	NR	Stem	RR	RB	Leaf	AGB	TB
AA	14.4±0.8a	15.8±5.5a	8.3±1.8a	1.5±0.8a	34.2±6.7a	50.1±13.0a	74.2±12.3a
AA+70	7.6±1.8b	11.2±1.8a	5.3±1.3b	0.7±0.1a	20.5±4.9b	33.5±8.8a	45.2±9.4b
AA+140	5.6±2.6b	10.3±1.2a	4.3±0.7b	0.7±0.4a	18.7±5.5b	29.5±6.9a	39.6±10.1b

NR-New rhizome, RR-Rhizome root, RB-Rhizome buds, AGB-Above ground biomass, TB-total biomass, R/S-root to shoot ratio

- The results showed that the total biomass was reduced by 39.0% and 46.6% in AA+70 and AA+140 , which was mainly induced by the significantly reduction of new rhizome, rhizome root and leaf, respectively.
- Comparing with root and leaf reductions induces by elevated O3, new rhizome performed the most serious reduction by 47.57% in AA+70 and 61.09% in AA+140.
- AA+70 and AA+140 had no significant differences. Root/ shoot ratio had no significant change among three treatments.

Nonstructural Carbohydrates (NSC) allocation

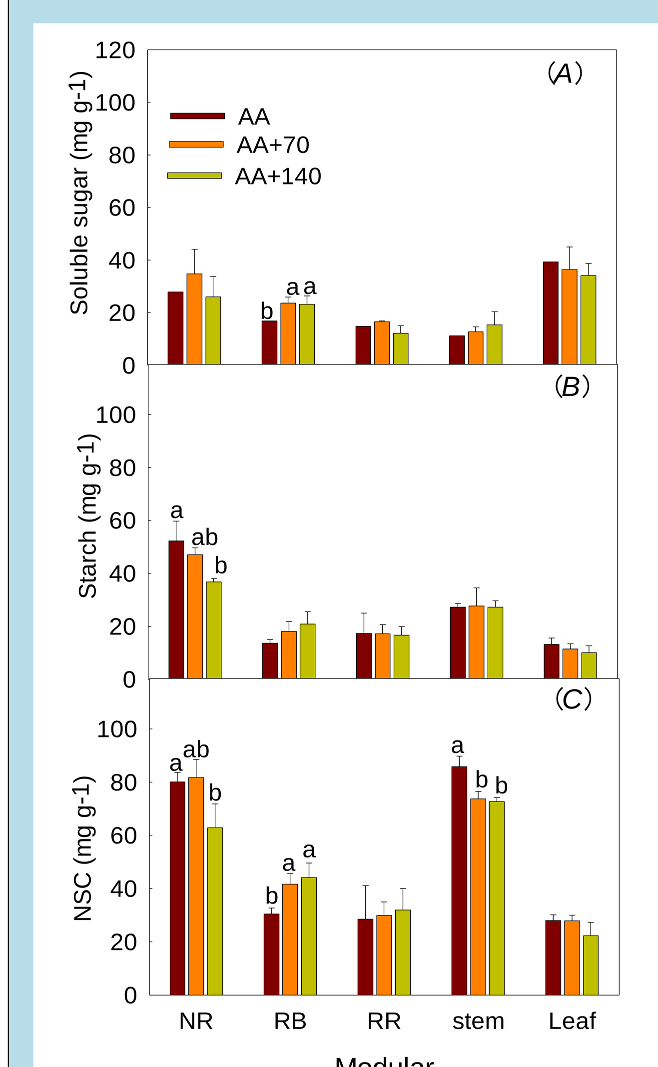


Figure 4 Effects of elevated O_3 on the contents of soluble sugar (A), starch (B) and nonstructural carbohydrates (NSC, C) of all modular of Indocalamus decorus. Llower letters above bars in the graph mean multiple comparisons results of the same plant part among the three O3 treatments when O3 effects were significant at 0.05 level.

Contrary to rhizome and leaf, the soluble sugar and NSC contents of rhizome buds were increased 36.84% and 44.99% in AA+70 and AA+140 while starch in rhizome contents declined significantly

Underground structure

Treatments	RN	TRL(cm)	Length (cm)	CBN	RBN	TBN
AA	15.1±1.8a	112.6±13.1a	7.5±0.3b	14.4±1.4a	19.9±2.4a	34.3±3.2a
AA+70	8.6 ±1.1b	88.8±18.5ab	11.2±1.4a	8.9±2.8b	13.7±4.7a	22.6±5.8b
AA+140	6.1±2.6b	66.1±17.5b	13.9±2.8a	7.8±3.2b	12.3±3.5a	20.1±1.6b

Rhizome number-RN; Total rhizome length-TRL; Culm basebuds number-CBBN; Rhizome buds number-RBN; Total buds number-TBN

RN, TRL, CBBN and TBN all showed significantly decrease under O_3 treatments. The decline percent in AA+140 from high to low were 59.93% in TN, 45.96%in CBBN, 41.50% in TBN, 41.4 in TRL and 38.27 in RBN while in AA+70 were 43.42 in RN, 38.38% in CBBN, 34.13 in TBN. The MRL was lengthened by elevated O_3, the MRL was increased 49.36% and 86.45% in AA+70 and AA+140, respectively. Elevated O_3 had no effects on RBN.

Conclusions

Although photosynthesis, growth and total biomass were restrained when growing under elevated O_3, *Indocalamus decorus* might allocated more NSC from new rhizome to new buds for ensuring the regeneration growth as high priority.

Acknowledgments

The research was supported by the National Natural Science Foundation of China (No. 31700439) .

- **Li Li is looking for a post-doctoral position with scholarship.** 
- **Li Li also has experiences working on the effects of CO_2 enrichment on tree phenology and physiology in UMass, Amherst.**
- **Welcome to email lili7381741@yeah.net for my CV.**

UiO : Department of Geosciences
University of Oslo

ICP VEGETATION

LRTAP Long-range Transboundary Air Pollution

Falk S., Vollsnes A.V., Emberson L., O'Neill C., Eriksen A.E.B., Stordal F., Berntsen T.

Characterizing subarctic biomes for land surface modeling of pollution and climate risk

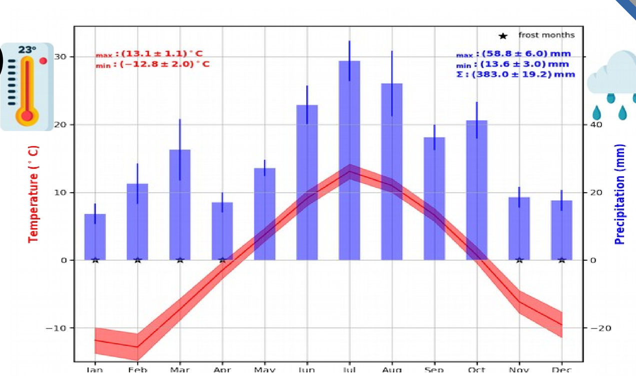
Abstract. We assess the importance of key meteorological variables and air pollution profiles on modeled susceptibility of sub-arctic vegetation to ozone. We investigate differences in uptake of ozone using the DO3SE model, for typical vegetation types. We find that bespoke parameterization is essential for an accurate estimation of Phytotoxic Ozone Dose (POD) and assessment of damage risk. The use of a subarctic parameterization suggested an improvement in risk assessment as POD values are increased in 2018; corroborated by evidence of visible injury in the NIBIO Environment Centre Svanhovd ozone garden [1].

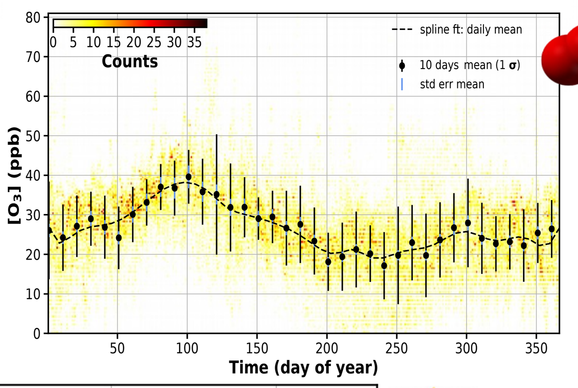
2 Classification of subarctic climate and ozone profile

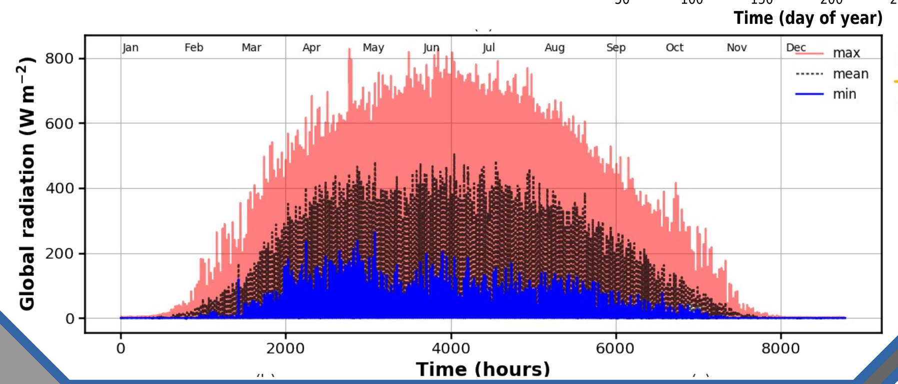
- *NIBIO Environment Centre Svanhovd, Pasvik river valley*
- *Atmospheric monitoring (e.g. temperature, precipitation, global irradiance, wind)*
- *Ozone monitoring (2018/19)*

→ Regular subarctic climate (Dfc)

- **Temperature**
  - 5 consecutive month below freezing
  - 2 month above 10°C (July, August)
  - T_{min} = –42.2°C, T_{max} = 29.4°C
- **Precipitation**
  - Relatively dry (383 mm annual mean)
  - 3 month above 40 mm (Jun–Aug)
- **Global irradiance**
  - Max 800 Wm^{-2} (Jun/Jul)
  - Midnight sun (Mid May–Mid Jul)
- **Ozone**
  - Spring peak (40 ppb in early Apr)
  - Summer minimum (20 ppb in Aug)
  - Annual mean (28 ppb)





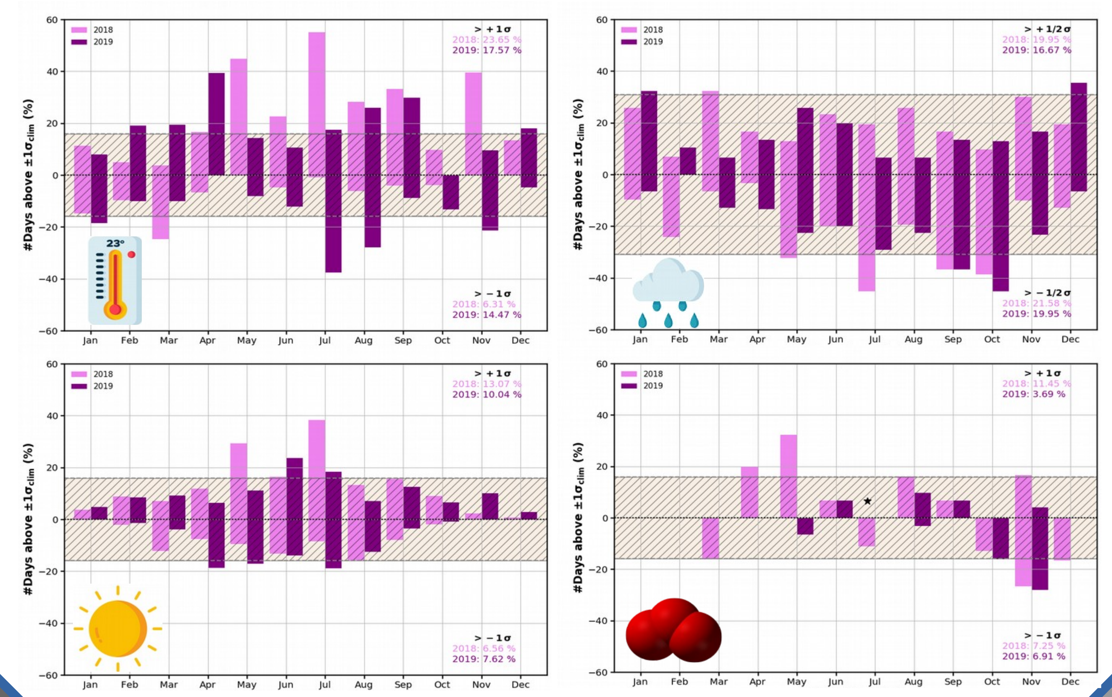


Ozone observation sites in northern Fennoscandia

3 Significance of climate anomalies in 2018/19 growing season

- *Blocking pressure system (2018) over Scandinavia [2]*
- *Most extensive fires in central Sweden in younger history [3]*

- **Temperature**
  - 2018 warmer than ave. (May–Sep)
  - 2019 warmer than ave. (May,Aug/Sep)
  - 2019 colder than ave. (Jul/Aug)
- **Global irradiance**
  - 2018 higher than ave. (May, Jul)
- **Precipitation**
  - 2018 below ave. (May, Jul)
  - 2019 below ave. (Sep, Oct)
- **Ozone**
  - 2018 higher than ave. (Apr/May)
  - 2019 average

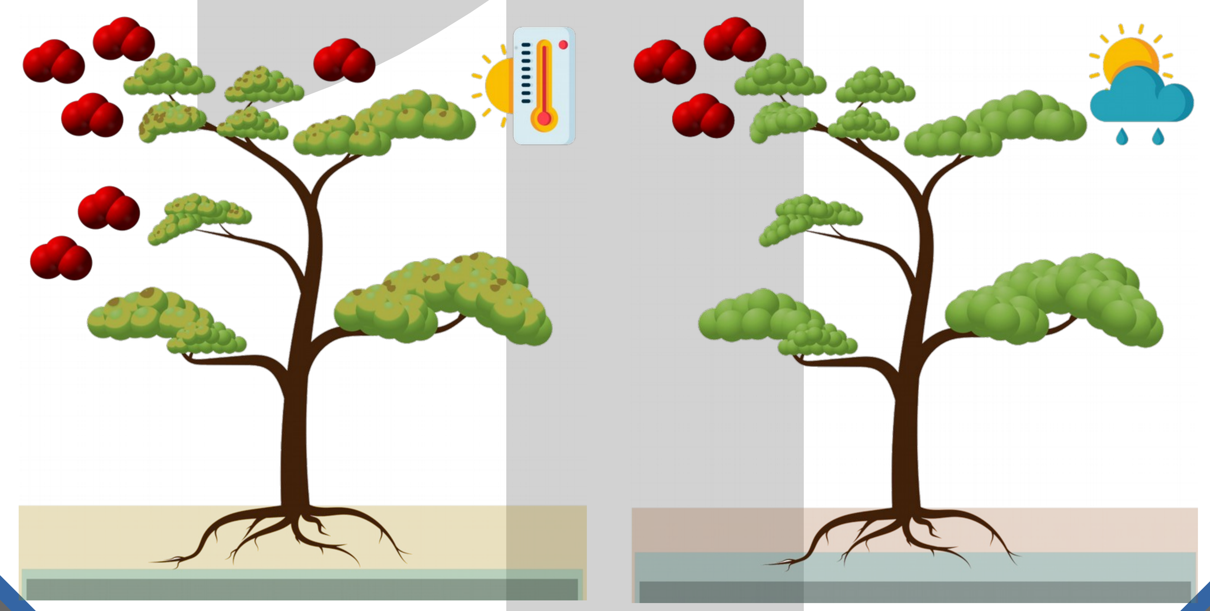


Subarctic vegetation climate adaptation → ozone susceptibility?

- Short growing season → optimization of CO_2 uptake
- Midnight sun conditions → suppression of night time repair[5]
- Temperature acclimation → cold tolerant, sensible to heat
- Cold soils → low nutrition (e.g. nitrogen, phosphor)

Climate change [9]
→ Higher (night time) temperatures
→ Earlier and longer growing season
→ More frequent heat waves
→ Increase in nutrient availability

Other factors
- Wildfires
- Photochemical conditions for O_3 formation
- Anthropogenic activity



NIBIO Environment Centre Svanhovd

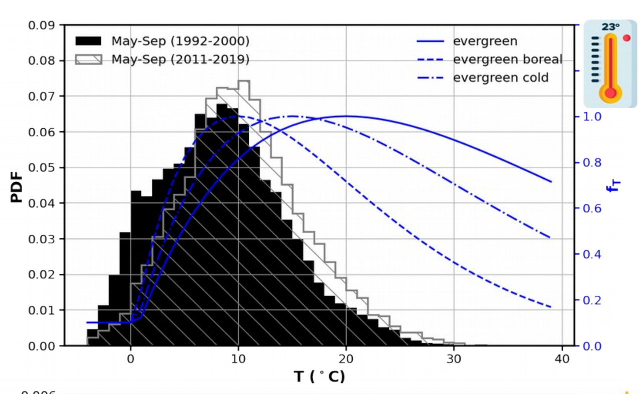
Clover in Svanhovd ozone garden

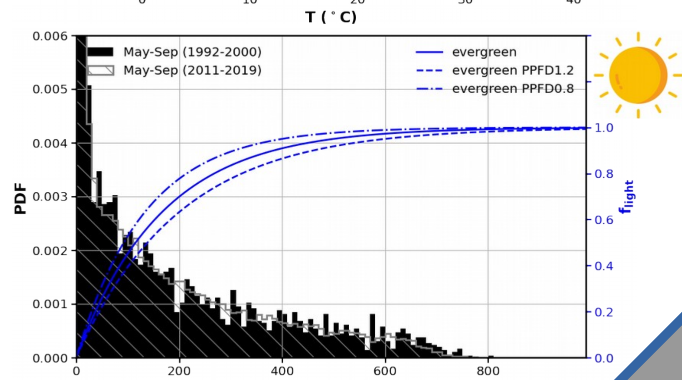
4 Bespoke/hypothetical PFT Norway Spruce

Assumptions

- *Connection between Probability Density Function (PDF) of climate variables and stomata response functions*
- *Larger enclosed area → optimized response*
- *Plants optimize carbon sequestration*
- $g_{sto} \propto A_n$

- Start with mapping manual (*MM*) parameters [4]
- Bespoke response functions
  - **Temperature** inspired by [6]
    - cold tolerance → *Cold*
    - cold tolerance + heat intolerance → *Boreal*
  - **Light** intensity threshold
    - 20% lower → PPFD0.8
    - 20% higher → PPFD1.2
  - **Growing season** (2018/19)
    - MODIS photosynth. data (1x1 km)
    - SeNorge.no snow melt data
- PDF from climate data for growing season (May–Sep) for 1992–2000 and 2011–2019, respectively





Ongoing climate change
- **Temperature** PDF shifted towards **higher** temperatures
- **Light** PDF shifted to **lower** max. intensities
- **Vapor pressure deficit** has already become a **limiting factor**

Conclusions & Outlook

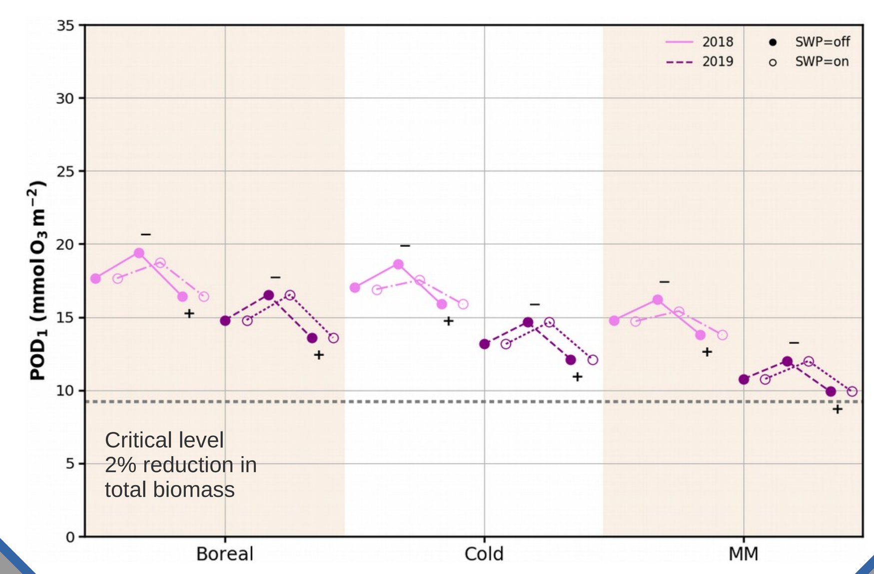
- **Elevated POD_1** in 2018 compared to 2019 (4 mmol m^{-2} PLA)
- **Critical level** for Norway spruce were **breached** in both 2018 and 2019
- **Default parameterizations**[4] may **not sufficiently describe** vegetation adapted to **cold and boreal environments (c.c.** [8])
- Large **systematic uncertainties** (31–53)%
- **Response functions** impact on POD_1
  - Temperature (15–37%)
  - Light (–8–11%)
  - Soil water potential (weak)

- Coordinated **experimental validation** of bespoke/hypothetical boreal PFTs
- Automation of acclimation (machine learning?)
- Influence of midnight sun conditions?

5 Phytotoxic Ozone Dose & critical level Norway Spruce

- *Model stomatal ozone uptake (DO3SE model [7]) → POD_1*
- *MM parameterizations vs bespoke response functions*
- *Investigate 2018/19 growing season*
- *Critical level for 2% reduction in total biomass [4]*
- *Deduce maximum systematic uncertainty*

POD1 (mmol m^{-2} PLA)	Type	2018	2019
Temperature	Boreal	+19%	+37%
	Cold	+15%	+22%
Light	PPFD0.8 ('–')	+9%	+11%
	PPDF1.2 ('+')	–7%	–8%
Soil water potential	on	Weak response	No response
Max. sys. uncert.	**Boreal+PPFD0.8**	**+31%**	**+53%**



Resources

[1] FALK ET AL. - BioGeoScience (2021), in preparation.
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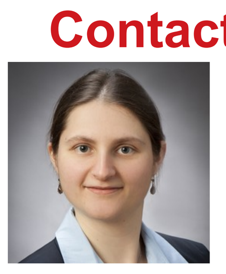
Contact



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