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Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe

Working Group on Effects

Third joint session
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Item 3 of the provisional agenda
Progress in activities in 2017 and further development of effects-oriented activities

Effects of air pollution on natural vegetation and crops

Report by the Programme Coordinating Centre of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops

Summary

The present report is being submitted for consideration by the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe and the Working Group on Effects at their third joint session in accordance with the request of the Executive Body for the Convention on Long-range Transboundary Air Pollution in the 2016-2017 workplan for the implementation of the Convention (ECE/EB.AIR/133/Add.1, items 1.1.1.7 and 1.1.1.12) and the informal document approved by the Executive Body for the Convention at its thirty-fourth session, “Basic and multi-year activities in the 2016-2017 period” (items 1.1.1, 1.1.6, 1.1.7, 1.2.2 and 1.8.1-3).

The report of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops presents the results of the revision and establishment of new flux-effect relationships and critical levels of ozone (21 in total), the revision of chapter 3 (“Mapping critical levels for vegetation”) of the *Manual on Methodologies and*

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Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends,[1] and progress with the 2015/16 survey on the concentration of heavy metals, nitrogen and persistent organic pollutants in mosses. The report also presents the results of the thirtieth meeting of the Programme Task Force held in Poznan, Poland, from 14 to 17 February 2017.

Contents

[1] Online document, available from http://icpmapping.org/Latest_update_Mapping_Manual.

I. Introduction

1. The present report of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) is being submitted for the consideration of the Steering Body to the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP) and the Working Group on Effects in accordance with the request of the Executive Body for the Convention on Long-range Transboundary Air Pollution in the 2016-2017 workplan for the implementation of the Convention (ECE/EB.AIR/133/Add.1, items 1.1.1.7 and 1.1.1.12) and the informal document approved by the Executive Body for the Convention at its thirty-fourth session, "Basic and multi-year activities in the 2016-2017 period" (items 1.1.1, 1.1.6, 1.1.7, 1.2.2 and 1.8.1-3). The report presents the results of the revision and establishment of new flux-effect relationships and critical levels of ozone (21 in total), the revision of Chapter 3 ("Mapping critical levels for vegetation") of the *Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends* (Modelling and Mapping Manual),[2] and progress on the 2015/16 survey on the concentrations of heavy metals, nitrogen and persistent organic pollutants in mosses. The lead country for ICP Vegetation is the United Kingdom of Great Britain and Northern Ireland, with the Programme Coordination Centre at the Centre for Ecology & Hydrology in Bangor. ICP Vegetation has over 250 participants in some 50 countries, including outreach to countries that are not Parties to the Convention.

II. Workplan items

A. Set up a contact group to compare measured and modelled exposure (item 1.1.1.7)

2. A group was set up between the EMEP Meteorological Synthesizing Centre-West (MSC-West) and ICP Vegetation to improve the application of large scale flux-based ozone risk assessment using the EMEP model, especially for dry (soil moisture limited) regions such as the Mediterranean, Central and Eastern Europe and under future scenarios of climate change. The group developed a workplan for 2017-2019 and has started to analyse spatial and temporal variability of the soil moisture index across Europe and compare soil moisture index estimates using the EMEP model with site-specific soil moisture measurements for different vegetation cover.

B. Conduct the European moss survey 2015/16 (item 1.1.1.12)

3. Data for the 2015/16 moss survey have been submitted to the new moss survey Coordination Centre in the Russian Federation by means of a new, purpose-built data management system. Approximately 35 countries have submitted data on heavy metal concentrations in mosses, including eight countries from South-Eastern Europe and nine countries from Eastern Europe, the Caucasus and Central Asia (i.e., Armenia, Azerbaijan,

[2] A first version of the Modelling and Mapping Manual was published in 1993. It has since been updated three times: in 1996, 2004 and again in 2016. The full text of the 2016 version is available as online, by chapter, from the website of the International Cooperative Programme on Modelling and Mapping of Critical Levels and Loads and Air Pollution Effects, Risks and Trends: http://icpmapping.org/Latest_update_Mapping_Manual. Chapter 3 was updated again in 2017.

Belarus, Georgia, Kazakhstan, Republic of Moldova, Russian Federation, Tajikistan and Ukraine). In addition, data on nitrogen have been submitted by 13 countries and 8 countries have submitted data on selected persistent organic pollutants (POPs) concentrations in mosses.

III. Basic and multi-year activities

Develop further the flux-based approach for setting critical levels of ground-level ozone for vegetation and update the dose-response functions and the Modelling and Mapping Manual (item 1.2.2)

4. At the thirtieth meeting of the ICP Vegetation Task Force (Poznan, Poland, 14-17 February 2017), the Task Force adopted 21 ozone stomatal flux-based critical levels for vegetation. A distinction was made between species (group)-specific phytotoxic ozone dose critical levels (POD_YSPEC) for detailed risk assessment based on flux-effect relationships developed for specific plant species or a group of plant species, and vegetation type-specific (i.e., crops, forest trees, (semi-)natural vegetation) critical levels for indicative risk assessment in large scale modelling, including integrated assessment modelling (POD_YIAM). Sixteen POD_YSPEC- (table 1) and five POD_YIAM-based (table 2) flux-effect relationships and derived critical levels are now available. As the parameterization of the stomatal flux model and the accumulation period for calculating POD_Y is (group of) species (POD_YSPEC)- and vegetation type (POD_YIAM)-specific, critical levels are not directly comparable with each other. Further details are available in the revised chapter 3 ("Mapping critical levels for vegetation") of the Modelling and Mapping Manual. Supplementary information is available in the associated Scientific Background Document A available from the ICP Vegetation website.[3]

5. Minor adjustments were made to existing flux-effect relationships and critical levels for the crop species wheat (yield quantity and quality), potato (yield quantity) and tomato (yield quantity and quality) and for the forest tree species beech/birch (total biomass) and Norway spruce (total biomass). New flux-effect relationships and critical levels were established for Mediterranean deciduous oak species (total biomass and root biomass) and Mediterranean evergreen species (above-ground biomass). For the first time, flux-effect relationships and critical levels were developed for groups of ozone-sensitive (semi-)natural vegetation species, i.e., for temperate perennial grassland (total biomass, above-ground biomass and flower number) and for Mediterranean annual pasture (above-ground biomass and flower/seed biomass).

6. POD_YSPEC-based flux-effect relationships and critical levels can be applied at any geographical scale. For crops they can be used to quantify the potential negative impacts of ozone on the security of food supplies (yield losses) and associated economic losses. For forest trees they were derived from experiments with young trees and they can be used to quantify the potential negative impacts of ozone on the annual growth of the living biomass of trees. They can also be used as a starting point for assessing impacts on carbon sequestration in trees and impacts on tree diversity. For (semi-)natural vegetation they can be used to quantify the risk of potential negative ozone impacts on annual biomass production and reproductive capacity. Furthermore, POD_YSPEC-based flux-effect relationships and critical levels can be used as a starting point for assessing impacts on

[3] The document is expected to be posted shortly on the ICP Vegetation web page dedicated to the Modelling and Mapping Manual: http://icpvegetation.ceh.ac.uk/manuals/mapping_manual.html.

carbon sequestration and plant biodiversity. The critical levels can be used for calculating critical level exceedances, both amount and area.

Table 1
Overview of ozone flux-based critical levels for specific (group of) plant species based on the phytotoxic ozone dose above a threshold value of Y nanomols per square meter (nmol m^{-2}) projected leaf area (PLA) s^{-1} (POD_YSPEC)

(Group of) species	*Effect parameter*	*Biogeographi-cal region*[a]	*Potential effect at critical level (% reduction)*	*Critical level (mmol m^{-2} PLA)*
Crops				
Wheat	Grain yield	A, B, C, M[b] (S, P)	5	1.3
Wheat	1,000-grain weight	A, B, C, M[b] (S, P)	5	1.5
Wheat	Protein yield	A, B, C, M[b] (S, P)	5	2.0
Potato	Tuber yield	A,B,C (M,S,P)	5	3.8
Tomato	Fruit yield	M (A,B,C,S,P)	5	2.0
Tomato	Fruit quality	M (A,B,C,S,P)	5	3.8
Forest trees				
Beech/birch	Total biomass	B,C (A,S,P)	4	5.2
Norway spruce	Total biomass	B,C (A,S,P)	2	9.2
Deciduous oak species	Total biomass	M	4	14.0
	Root biomass	M	4	10.3
Evergreen tree species	Above-ground biomass	M	4	47.3
(Semi)-natural vegetation				
Temperate perennial grasslands	Above-ground biomass	A,B,C (,S,P)	10	10.2
	Total biomass	A,B,C (,S,P)	10	16.2
	Flower number	A,B,C (,S,P)	10	6.6
Mediterranean annual pasture	Above-ground biomass	M	10	16.9
	Flower/seed biomass	M	10	10.8

Notes: Y = 6 nmol m^{-2} PLA s^{-1} for crops (POD_6SPEC) and 1 nmol m^{-2} PLA s^{-1} for forest trees and (semi-)natural vegetation (POD_1SPEC).

[a] Derived for species growing in regions not in brackets, but could also be applied to regions in brackets. Abbreviations in this column are linked to the biogeographical regions followed by the

European Environment Agency: A: Atlantic; B: Boreal; C: Continental, M: Mediterranean, P: Pannonian; S: Steppic (see European Environment Agency, "Biogeographical regions", available from http://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3 (last updated 19 June 2017)).

[b] Different parameterization of flux models applied for Mediterranean and non-Mediterranean regions.

7. POD_YIAM-based ozone flux models have a simpler form than POD_YSPEC-based ones and have been developed specifically for use in large-scale integrated assessment modelling, including for scenario analysis and optimization runs. Separate parameterizations are provided for Mediterranean and non-Mediterranean areas for application in risk assessments for crops, forest trees and (semi-)natural vegetation. The crops parameterization can be used for potential maximum yield loss calculation and indicative economic losses. For forest trees and (semi-)natural vegetation, they are indicative of the potential maximum risk for estimating environmental cost, but not economic losses. The critical levels can be used for calculating critical levels exceedances, both amount and area. For *applications* in a climate change context, the POD_YSPEC method is recommended, as key factors such as phenology and soil moisture are not included in the parameterization of POD_YIAM.

Table 2

Overview of ozone flux-based critical levels for vegetation types based on the phytotoxic ozone dose above a threshold value of Y nmol m^{-2} projected leaf area (PLA) s^{-1}, suitable for application in large scale modelling, including integrated assessment modelling (POD_YIAM)

(Group of) species	*Effect parameter*	*Use to assess risk of reduction in*	*Biogeographical region*[a]	*Potential effect at critical level (% reduction)*	*Critical level (mmol m^{-2} PLA)*
Crops					
	Grain yield	Grain yield	A, B, C, M[b] (S, P)	5	7.9
Forest trees					
	Total biomass	Annual growth of living biomass	A, B, C (S, P)	4	5.7
			M	4	13.7
(Semi-)natural vegetation					
Temperate perennial grasslands	Flower number	Vitality of species-rich grasslands	A, B, C (S, P)	10	6.6
Mediterranean annual pastures	Flower/seed biomass	Vitality of species-rich grasslands	M	10	10.8

Notes: Y = 3 nmol m-2 PLA s-1 for crops (POD3IAM) and 1 nmol m-2 PLA s-1 for forest trees and (semi-)natural vegetation (POD1IAM).

[a] Derived for species growing in regions not in brackets, but could also be applied to regions in brackets. Abbreviations in this column are linked to the biogeographical regions followed by the European Environment Agency: A: Atlantic; B: Boreal; C: Continental, M: Mediterranean, P: Pannonian; S: Steppic (see European Environment Agency, "Biogeographical regions", available from http://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3).

[b] Different parameterization of flux models should be applied for Mediterranean and non-Mediterranean regions.

IV. Expected outcomes and deliverables over the next period and in the longer term

8. Over the next period and in the longer term, ICP Vegetation is expected to work and report on:

(a) Improving and validating the soil moisture index in the EMEP model and the development of ozone flux maps adapted for soil moisture limited areas (in collaboration with MSC-West);

(b) Available evidence of ozone impacts on crops in developing regions (and impacts on global food production in the longer term);

(c) Knowledge transfer of ozone risk assessment methodologies to developing regions;

(d) The outcome of the 2015/16 survey on heavy metals, nitrogen and POPs concentrations in mosses;

(e) The monitoring manual for 2020 survey on heavy metals, nitrogen and POPs concentrations in mosses (and the outcome of the survey in the longer term);

(f) Ozone risk maps for regions and scenarios of the Task Force on Hemispheric Transport of Air Pollution, in collaboration with the Task Force.

V. Policy-relevant issues, findings and recommendations (item 1.8.2)

9. See section III above.

VI. Issues for the attention and advice of other groups, task forces or subsidiary bodies, notably with regard to synergies and possible joint approaches or activities (item 1.8.1)

10. Issues for the attention and advice of other groups, task forces or subsidiary bodies include:

(a) Collation of further field-based evidence for the impacts of ozone on vegetation, including epidemiological studies, and co-location of sites for the collection of mosses to determine their heavy metal and nitrogen concentrations, in collaboration with the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests);

(b) Further development of the ozone risk assessment methodology for and its application to vegetation, in collaboration with ICP Forests and MSC-West. Focus in the coming years will be on:

(i) Improving and validating the soil moisture index used in the EMEP model and developing ozone flux maps adapted for soil moisture limited areas (MSC-West), with data on the soil moisture content in soil moisture-limited forested regions in Europe contributed by ICP Forests;

(ii) The ICP Forests project on PRedicting Ozone Fluxes, Impacts, and critical Levels on European forests (PRO$_3$FILE);

(c) The assessment of temporal trends and spatial patterns in past and predicted future ground-level ozone concentrations in a changing climate, and associated (risk of) impacts on vegetation (including crops) at the European and global scale, in collaboration with MSC-West, the Task Force on Measurements and Modelling, the Task Force on Hemispheric Transport of Air Pollution and ICP Forests. There is a need to apply the ozone flux-based risk assessment methodology globally for a range of vegetation types (including crops) and future air pollution abatement and climate change scenarios;

(d) Assessment of temporal trends and changes in spatial patterns in heavy metal deposition in collaboration with the Meteorological Synthesizing Centre-East, and potential application of the data on heavy metal and nitrogen concentrations in mosses sampled at ICP Forests sites in the assessment of the state of forests at those sites, in collaboration with ICP Forests.

VII. Enhance the involvement of countries in Eastern Europe, the Caucasus and Central Asia (item 1.1.1)

11. To further strengthen implementation and ratification of the protocols to the Convention in the Caucasus, Central Asia and Eastern and South-Eastern Europe, further evidence of air pollution deposition to and impacts on vegetation in countries of those subregions should be sought through increased participation in the work of ICP Vegetation. The latter is promoted by:

(a) The Moss Survey Coordination Centre in the Russian Federation;

(b) Knowledge transfer through meetings or workshops, the publication of reports, the Modelling and Mapping Manual and leaflets in the Russian language;

(c) Encouraging experts from those countries to attend the ICP Vegetation Task Force meeting and, where possible, arrange financial support for their participation;

(d) Encouraging countries of those subregions to identify and support the participation of ozone experts in ICP Vegetation.

VIII. Outreach activities outside the United Nations Economic Commission for Europe region (items 1.1.6 and 1.1.7)

12. ICP Vegetation will continue and further stimulate collaboration with Asian, South-American and African countries regarding: (a) the collation of evidence of impacts of ozone on vegetation, including crops and the implication for food production; and (b) the application of mosses as biomonitors of atmospheric deposition of heavy metals, nitrogen and POPs. The Programme Coordination Centre will host a training workshop on ozone risk assessment methodology in the second half of 2017 for selected experts in developing regions and is testing local varieties of crops species in developing regions for ozone-sensitivity.

13. ICP Vegetation contributed to the “Tropospheric Ozone Assessment Report (TOAR): Global metrics for climate change, human health and crop/ecosystem research” (ongoing), and will continue to contribute to any follow-on assessments or activities. This is an activity of the International Global Atmospheric Chemistry Project.[4] Data collection has

[4] See http://www.igacproject.org.

been completed and the paper on vegetation metrics, to be published in *Elementa*: *Science of the Anthropocene*, an open-access non-profit science journal,[5] was led by the head of the Programme Coordination Centre for ICP Vegetation.

14. A representative of ICP Vegetation attended and gave a presentation at the Climate and Clean Air Coalition expert workshop on metrics for evaluating and reporting methane and black carbon interventions (Ottawa, 16-17 March 2017).

IX. Scientific findings: highlights

15. Highlights of the scientific findings of ICP Vegetation are summarized in the 2017 joint progress report on policy-relevant scientific findings (ECE/EB.AIR/GE.1/2017/3–ECE/EB.AIR/WG.1/2017/3) and in section III above.

X. Meetings

16. The ICP Vegetation Programme Coordination Centre organized the United Nations Economic Commission for Europe Ozone Critical Levels Workshop (Madrid, 7-8 November 2016) in collaboration with the local host, the Centre for Energy, Environmental and Technological Research (CIEMAT). The workshop was attended by 25 experts from eight countries. Further actions and data analyses were agreed in order to finalize ozone flux-effect relationships and associated critical levels for adoption at the thirtieth meeting of the Programme Task Force (see section III for details).

17. The thirtieth meeting of the Programme Task Force was held in Poznan, Poland, from 14 to 17 February 2017. The meeting was hosted by Poznan University of Life Sciences and organized together with the Institute of Biology of the Polish Academy of Sciences in Krakow. The meeting was attended by 88 experts from 23 countries. Minutes of the meeting are available from the ICP Vegetation website.[6]

XI. Publications

18. For a list of ICP Vegetation publications and references for the present report, please visit the ICP Vegetation website.[7]

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[5] See https://www.elementascience.org/.
[6] See http://icpvegetation.ceh.ac.uk/.
[7] See http://icpvegetation.ceh.ac.uk/publications/