METEOROLOGI Nr 166

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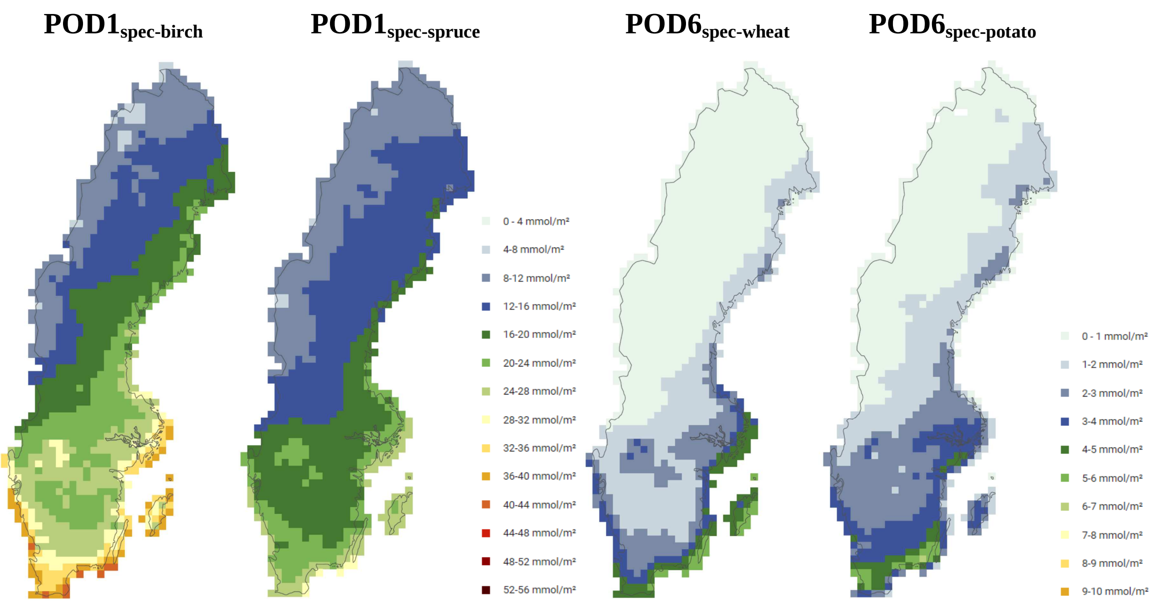

Cover illustration.
The Figure shows from left to right $POD1_{spec\text{-}birch}$, $POD1_{spec\text{-}spruce}$, $POD6_{spec\text{-}wheat}$ and $POD6_{spec\text{-}potato}$ for year 2016 as calculated by the MATCH-Sweden system.

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2019-06-26

Sammanfattning

Vi har lagt till beräkningar av PODY för björk, gran vete och potatis i MATCH Sverigesystemet. Rapporten går igenom de förändringar och uppdateringar som har införts i beräkningarna sedan den ursprungliga implementeringen 2016.

Resultat för receptorerna *generic crops* ($POD3_{gen\text{-}CR}$), *generic deciduous trees* ($POD1_{gen\text{-}DT}$), *birch* ($POD1_{spec\text{-}birch}$), *spruce* ($POD1_{spec\text{-}spruce}$), *wheat* ($POD6_{spec\text{-}whet}$), *potato* ($POD6_{spec\text{-}potato}$), presenteras för åren 2013-2017.

En jämförelse med resultat från EMEP-modellen för *generic crops* och för *generic deciduous trees* ger en bättre överensstämmelse än tidigare. Givet att ett fel i beräkningen av solstrålningen har identifierats i EMEP-modellen så framstår resultaten från MATCH-Sverige och EMEP nu som mer konsistenta.

Variationen från år till år i PODY för björk och gran är av samma storleksordning som den som beräknas för *generic deciduous trees,* men numeriska värden för PODY skiljer sig, framför allt för björk beroende på skillnader i de parametrar som ingår i beräkningen och på användning av längre vegetationsperioder baserade på svenska och skandinaviska data. Kritiska nivåer motsvarande 4 % reduktion i tillväxten av björk och gran överskrids i stort sett i hela landet för alla år som har studerats.

Variationen från år till år i PODY för vete och potatis är större än för *generic crops* på grund av att ett högre tröskelvärde används i beräkningen av PODY för de specifika grödorna. Kritiska nivåer motsvarande skördeförluster på 5 % uppnås i södra delen av Sverige för fyra av de fem studerade åren för vete och för två av åren för potatis.

Det uppdaterade programpaketet för PODY-beräkningar skulle kunna användas för beräkningar av PODY för olika typer av vegetation för perioden 1990-2013 baserat på återanalyserade ozonkoncentrationer. Programpaketet kan också utvecklas för beräkningar av PODY för hela Europa baserat på olika typer av utsläpps- och klimatsscenarier.

PODY presenteras tillsammans med övriga ozonmått på SMHI:s miljöövervakningssida (www.smhi.se/klimatdata/miljo/atmosfarskemi) med start från miljöövervakningsåret 2013.

Summary

We have added calculations of PODY for birch, spruce, wheat and potato to the MATCH-Sweden system. Several important updates compared to the previous implementation for generic crops and generic deciduous trees have been made including improved calculations of canopy level ozone concentrations, updated calculations of quasi-laminar and surface resistance and inclusion of soil moisture dependence for specific vegetation species.

A comparison to results from the EMEP model for generic crops and generic deciduous trees shows a better agreement than previously. Considering also that an error in the EMEP calculations has been identified, affecting primarily the PODY calculations for generic deciduous trees, MATCH-Sweden and EMEP model results now appear to be more consistent.

Year to year variability of PODY for birch and spruce are similar to that for generic deciduous trees while numerical values are different, especially for birch, due to different parameters in the PODY calculation and longer vegetation periods. Critical levels corresponding to a 4 % growth reduction are exceeded for both birch and spruce in major parts of Sweden for all years in the period 2013-2017.

Year to year variability of PODY for wheat and potato are larger than for generic crops due to the higher threshold for PODY used in the calculations. Critical levels

corresponding to a 5 % reduction in crop yield are reached in four of five years in southern Sweden for wheat and for two in five years for potato.

The updated program package for PODY calculations could be used to calculate consistent time series of PODY for different types of vegetation for the period 1990-2013 based on reanalyzed ozone concentrations. The program package could also be developed to calculate PODY for the whole of Europe for different emission- or climate scenarios.

The results presented in this report are also available in digital form at the SMHI home page for environmental monitoring of air quality (www.smhi.se/klimatdata/miljo/atmosfarskemi).

Contents

1 Introduction

Mapping of surface ozone using MATCH-Sweden was introduced as part of Swedish environmental monitoring in 2013 (Alpfjord and Andersson, 2015). The data is used for studies where spatial information about surface ozone is needed as well as for national and international reporting e.g. for the EU NEC directive. Initially 10 different indicators of ozone were included (Fig. 1). Two of these indicators linked to effects on vegetation: AOT40 (Accumulated Ozone dose above threshold 40 ppb(v)) for the period May-July (effects on crops) and for the period April-September (effects on forests).

In 2016 indicators for Phytotoxic Ozone Dose above a flux threshold of Y, PODY, were introduced in MATCH-Sweden and in the Swedish environmental monitoring (Engardt et al., 2016). PODY is used in CLRTAP (*Convention on Long-range Transboundary Air Pollution*) to identify where ozone induced damage on vegetation can occur (CLRTAP, 2017). PODY is determined not only by the surface ozone concentration but also by physical and meteorological parameters such as growing season, solar radiation, temperature, and humidity. In contrast to AOT40 PODY is an indicator based on the uptake of ozone by the vegetation rather than an indicator based on just the ozone concentration. PODY has been shown to be better correlated to ozone induced damages on vegetation (Mills et al., 2011). In 2016 mapping of PODY to *generic crops* and *generic deciduous forest* were first introduced in the annual assessment using the MATCH-Sweden system including the year 2013 and onwards.

With support from the Swedish Environmental Protection Agency (agreement 211-18-001, errand no NV-03411-18) SMHI has extended the MATCH-Sweden system with mapping of ozone fluxes to four additional types of vegetation of specific relevance to Swedish conditions: *birch*, *spruce*, *wheat* and *potato*. This report describes the implementation for the new species and reports results for the years 2013-2017. This means that results also for these four new indicators are available from the year when mapping of ozone indicators were introduced in the MATCH-Sweden system in 2013.

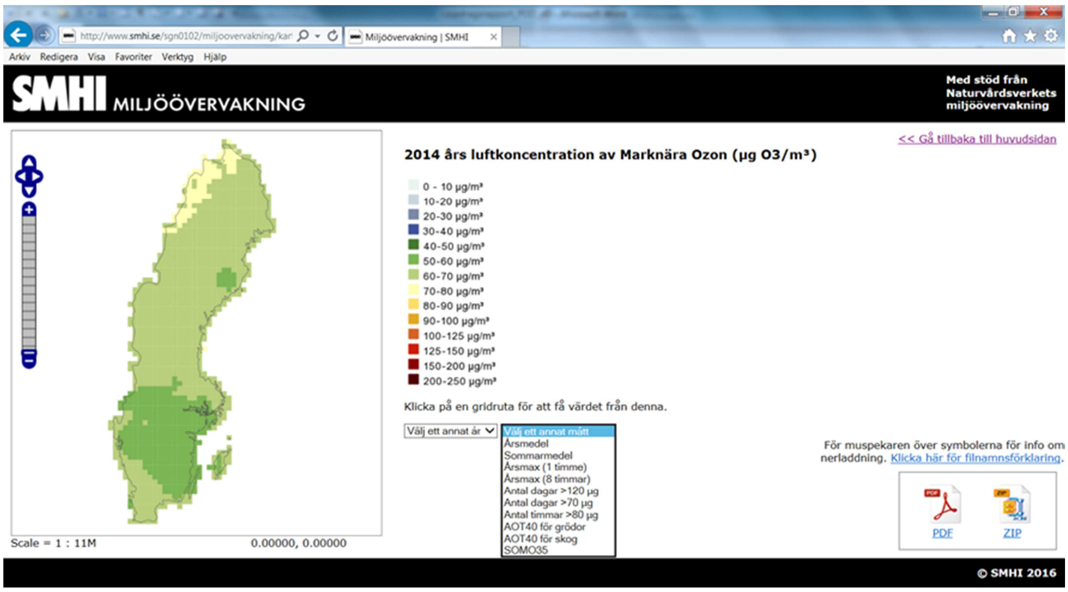

Figure 1. Screen shot showing the original suite of indicators available in the environmental monitoring using the MATCH-Sweden system. (www.smhi.se/klimatdata/miljo/atmosfarskemi, ”ozonmått”).

2 Objectives

This report describes the implementation of PODY for birch, spruce, wheat and potato in the MATCH-Sweden system. The implementation is an extension of the work reported by Engardt et al. (2016) and follows the algorithms and recommendations given in the ”*Mapping Manual*” (CLRTAP, 2017). The *Mapping Manual* is regularly updated and we have therefore created a program package that can be easily modified as updated versions of the manual become official.

We report results for the years 2013-2017 and focus on important updates to the implementation reported by Engardt et al. (2016). The results have been produced using the MATCH-Sweden system but the updated program package is general and can be modified to be used in applications with the MATCH model also outside the MATCH-Sweden system.

3 Methods

Mapping of PODY using MATCH-Sweden for generic crops and generic deciduous trees were first implemented in 2016 and documented by Engardt et al. (2016). Here we focus on the modifications and updates that were needed in order to include PODY for birch, spruce, wheat and potato as well as updates following the most recent version of the *Mapping Manual* (CLRTAP, 2017).

Ozone concentrations used in the PODY calculations in this report are hourly, spatially analyzed concentrations provided by the MATCH-Sweden system. These are based on a two-dimensional variational analysis of surface ozone concentrations using hourly surface ozone observations from Swedish and Norwegian background monitoring stations combined with a European scale simulation of ozone concentrations using the MATCH chemistry transport model (Andersson et al., 2015; Alpfjord Wylde et al., 2019). The meteorological data needed for the PODY calculations are taken from the operational numerical weather prediction model HIRLAM at SMHI and from the IFS model at the European Centre for Medium Range Weather Forecasts, ECMWF. Solar radiation data are taken from the solar radiation mapping model STRÅNG at SMHI (http://strang.smhi.se). All data is interpolated to a 0.2 by 0.2 degree rotated latitude-longitude grid before use in the PODY calculations in MATCH-Sweden.

PODY values are reported as annual values (accumulated dose over one year) without regard to the area covered by different receptors. For quantification of actual effects this information need to be combined with actual vegetation cover of different receptors.

3.1 Ozone flux to stomata, F_{st}

The general equation defining the ozone flux to stomata, F_{st}, is given by [brackets indicating equation number in *Mapping Manual* (CLRTAP, 2017)]:

$$F_{st} = g_{st}\mu_{st}\frac{r_c}{r_b + r_c} \qquad \textbf{[MM2017 III.12b]}$$

Where μ_{st} is the ozone concentration at canopy height in nmol m^{-3}, g_{st} is the stomata conductance in m s^{-1}, r_c is the leaf surface resistance (s m^{-1}), and r_b is the quasi-laminar resistance (s m^{-1}). Calculation of r_c follows the formulation in the *Mapping manual* while for r_b we use the following standard formula:

$$r_b = \frac{2}{ku_*}\left(\frac{Sc}{Pr}\right)^{2/3} \qquad (1)$$

Where k is von Karmans constant, u_* the friction velocity, Sc the Schmidt number for ozone and Pr the Prandtl number. u_* is calculated individually for the different vegetation types using different roughness lengths.

The complete definition of g_{st} follows the multiplicative algorithm suggested by Emberson et al. (2000a,b):

$$g_{st} = g_{max} \times \min(f_{phen}, f_{O_3}) \times f_{light} \times \max(f_{min}, (f_{temp} \times f_{VPD} \times f_{SW})).$$

[**MM2017 III.1**]

The different *f*-functions are governed by physical and meteorological conditions and can have values between 0 and 1. Therefore g_{st} can reach the maximum value g_{max}, but will always become zero if at least one of the functions f_{phen} (growing season), f_{O3} (accumulated ozone stress) or f_{light} (day/night) is zero. The multiplicative algorithm allows for extensions and as an example in studies of future ozone uptake a function f_{CO2} simulating the effect of ”CO_2-fertilization” can be considered (e.g. Klingberg et al., 2011).

The max operator in the equation means there will still be a flux to the stomata defined by f_{min} even if the temperature function, f_{temp}, the vapor pressure deficit function, f_{VPD}, or the soil water function, f_{SW}, should be zero.

The PODY value is given by time integration of the flux F_{st} above a threshold Y representing the susceptibility of the receptor to ozone:

$$\text{PODY} = \sum \max(0, F_{st} - \text{Y}) \times \Delta t \quad (2)$$

Where F_{st} is calculated on an hourly basis following [**MM2017 III.12b**] and Δt is 3600 s. Summation is done for all hours in a year and the unit for PODY is mmol m^{-2}. The numerical values of canopy height, h , g_{max},, f_{min}, and Y for the different types of vegetation considered in this report are given in Table 1.

Table 1. Numerical values of canopy height, h, g_{max},, f_{min}, and Y for the different types of vegetation considered in this report (data from Mapping Manual Tables III.9 and III.11).

Receptor	***h*** [meter]	**g_{max}** [mmol O_3 m^{-2} s^{-1}]	**f_{min}** [0-1]	**Y** [nmol m^{-2} s^{-1}]
Generic crops	**1**	**500**	**0.01**	**3**
Potato	**1**	**750**	**0.01**	**6**
Wheat	**1**	**500**	**0.01**	**6**
Generic deciduous tree	**20**	**150**	**0.1**	**1**
Norway spruce	**20**	**125**	**0.1**	**1**
Silver birch	**20**	**240**	**0.1**	**1**

3.2 Ozone concentrations at canopy level, μ_{st}

As mentioned above hourly analyzed fields of surface ozone concentrations representative for three meters height is provided by the MATCH-Sweden system. The analysis is derived by combining model simulated surface ozone concentrations (geographically and temporally complete data) with observed hourly ozone concentrations at discrete locations (point measurements with high precision) in order to arrive at a best estimate of surface ozone concentrations with optimal spatial and temporal coverage. Measurements and model simulations are combined using a two-dimensional variational data assimilation, or data fusion technique, to produce spatial fields of high quality (Robertson and Kahnert, 2007).

The analyzed fields of ozone concentrations are assumed to be valid at three meters height (the same height as the surface ozone observations). According to the *Mapping Manual* PODY should be calculated based on ozone concentrations at canopy level, *h*. We therefore need to adjust the analyzed ozone concentrations to the correct canopy level. This adjustment is done assuming a constant ozone flux through the atmospheric surface layer and neutral stability:

$$\mu_{st} = \mu_{3m} / \left(1 + \frac{k\, v_d}{u_*}\right) ln(3/h) \tag{3}$$

Where u_{3m} is the analyzed ozone concentration at three meters, *h* is the height of the canopy and, v_d, the deposition velocity for ozone is given by the following formula:

$$v_d = 1/(r_c + r_b) \tag{4}$$

Values for the canopy height, *h*, are given in Table 1. This procedure is more elaborate than that used by Engardt et al. (2016) who used fixed scaling factors to convert ozone concentrations at three meter to values at canopy level.

3.3 Growing season, f_{phen}

Growing seasons differ for different crop and tree species. Equations describing the phenology function f_{phen} are detailed for a number of crop and tree species in the *Mapping Manual*. For crops the timing of the flowering, mid anthesis, is the critical parameter, while for trees the start and end of the growing season is the basic information needed. For the PODY calculations presented here the estimation of vegetation periods are based on local Swedish and Scandinavian data as described by Karlsson et al. (2018). They provide estimates of mid anthesis for wheat and potato in different regions of Sweden based on agricultural statistics as well as formulas for the starts and ends of growing seasons for birch and spruce in terms of daily temperature sums based on phenological data for birch and on data for net primary productivity for spruce. We use the same dates for mid anthesis for wheat and potato in Sweden for all years, but regional variation. For areas outside of Sweden we use the equations for mid anthesis, start and end of growing season as given in the *Mapping Manual.*

As an example Fig. 2 shows plots of mid anthesis for wheat and potato and start of growing seasons for birch and spruce as used in the PODY calculations for 2016. Timing of mid anthesis is given as degree days using a daily mean base temperature of 0˚C. The growing season is then defined as a temperature sum before and after mid anthesis as specified in the *Mapping Manual* while for birch and spruce the start of the growing season is given as day of year (Karlsson et al., 2018).

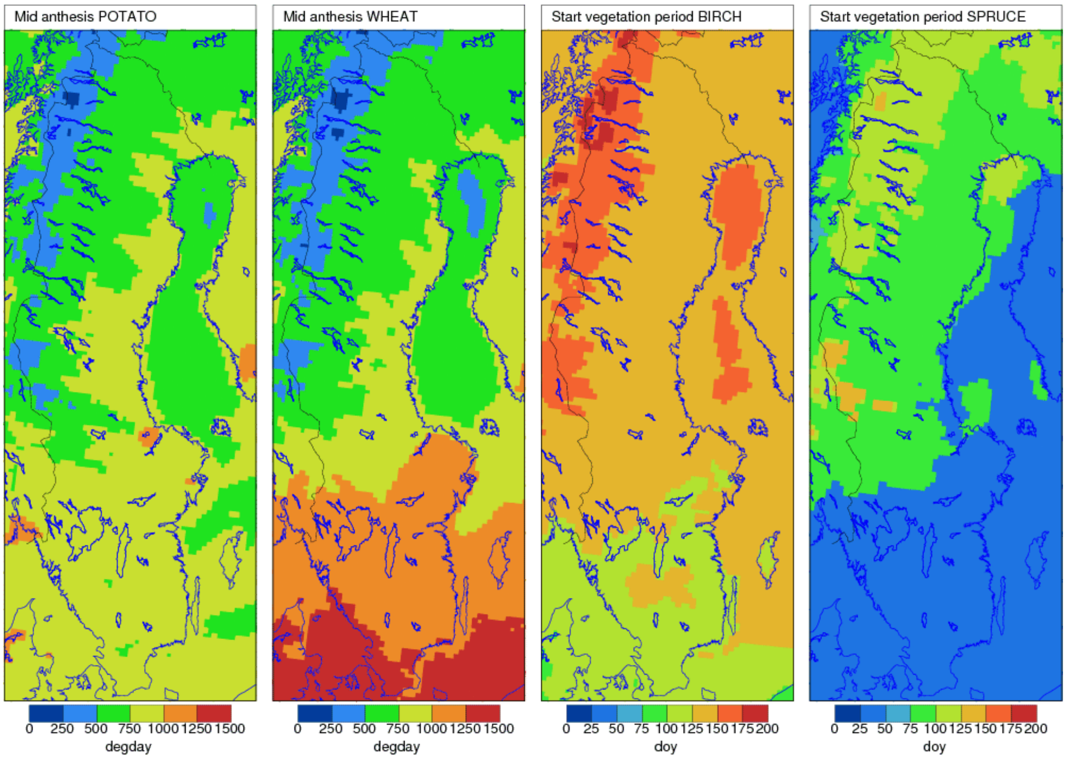

Figure 2. Timing of mid anthesis for potato and wheat and start of growing season for birch and spruce. Units: degree days and day of year (doy) respectively.

3.4 Soil moisture, f_{SW}

The effect of soil moisture is included by f_{SW} in equation [MM2017 III.1] for g_{st}. Following Simpson et al. (2012) we use the soil moisture index, S_{MI}, to calculate f_{SW}:

$$f_{SW} = 1 \quad ,\text{for } S_{MI} \geq 0.5 \qquad (5)$$

$$f_{SW} = 2\, S_{MI} \quad ,\text{for } S_{MI} < 0.5$$

We use S_{MI} values calculated using soil water from the ECMWF IFS model. This is an extension compared Engardt et al. (2016) who did not have to include effects of soil moisture since their PODY calculations were for generic crops and deciduous trees where this effect is not considered.

4 Results

4.1 PODY for generic crops, POD3$_{gen-CR}$

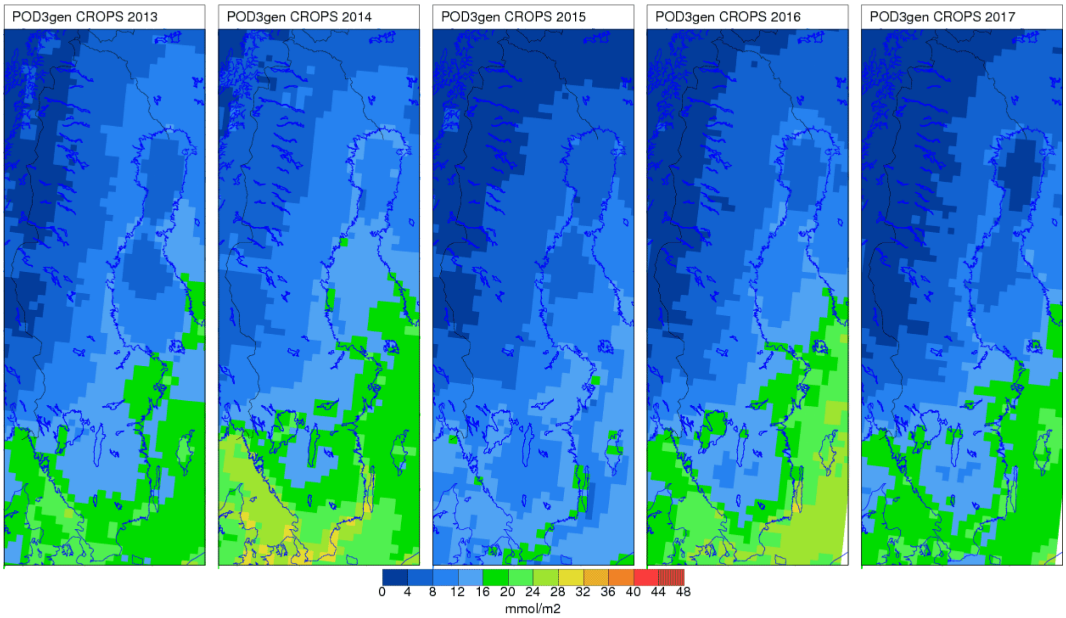

Figure 3. POD3$_{gen-CR}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 3 shows PODY for generic crops, POD3$_{gen-CR}$, calculated using the MATCH-Sweden system for the years 2013-2017. For all years there is a strong gradient from higher values in the southern part of the country towards 5 – 10 times lower values in the mountain areas in the north west. A substantial year to year variability is evident with particularly lower levels for 2015. The spatial average value over Sweden for POD3$_{gen-CR}$ is twice as high in 2014 compared to 2015 (Table 2). Similar inter annual and spatial variations are also seen in the maps of ozone concentrations and AOT40 available on the SMHI environmental monitoring home page (www.smhi.se/klimatdata/miljo/atmosfarskemi).

These new calculations show substantially lower values than presented by Engardt et al. (2016) due to updated formulations of the flux calculations and improved calculations of canopy level ozone concentrations. Comparisons to results from the EMEP model show a better agreement (see Section 4.7).

4.2 PODY for generic deciduous trees, $POD1_{gen\text{-}DT}$

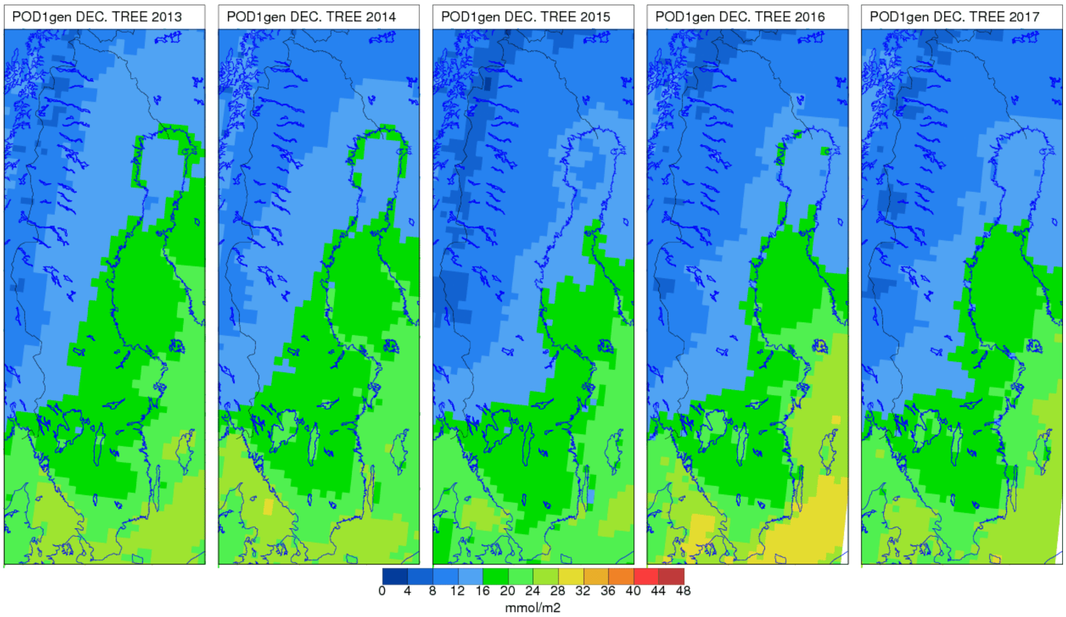

Figure 4. $POD1_{gen\text{-}DT}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 4 shows PODY for generic deciduous trees, $POD1_{gen\text{-}DT}$, calculated with the MATCH-Sweden system for the years 2013 – 2017. As for $POD3_{gen\text{-}CR}$ there is a strong gradient from the mountain range in the north-west towards the southern part of the country. For both $POD1_{gen\text{-}DT}$ and for $POD3_{gen\text{-}CR}$ this gradient is mainly related to a gradient in the stomata conductance (g_{sto}) rather than to gradients in the surface ozone concentrations. Ozone concentrations are in general lower in the northern part of Sweden averaged over April-September, but the relative difference is smaller than for PODY. Also there is not a minimum in ozone concentrations in the mountain range while $POD3_{gen\text{-}CR}$ and $POD1_{gen\text{-}DT}$ show the lowest values there due to unfavorable conditions for vegetation due to low temperatures.

As for $POD3_{gen\text{-}CR}$ values of $POD1_{gen\text{-}DT}$ are lower in 2015 compared to other years, but the differences are smaller than for $POD3_{gen\text{-}CR}$. $POD1_{gen\text{-}DT}$ has a lower threshold value than $POD3_{gen\text{-}CR}$, (Y=1 nmol m^{-2} s^{-1} compared to Y=3 nmol m^{-2} s^{-1}). This leads to a lower variability in $POD1_{gen\text{-}DT}$. Statistics based on a higher threshold show a higher variability from year to year since the number of episodes with high ozone and the corresponding levels of surface ozone are highly variable from year to year.

These new calculations show marginally lower values than presented by Engardt et al. (2016). The effects of updated formulations of the flux calculations and improved calculations of canopy level ozone concentrations are less important for trees.

4.3 PODY for birch, $POD1_{spec\text{-}birch}$

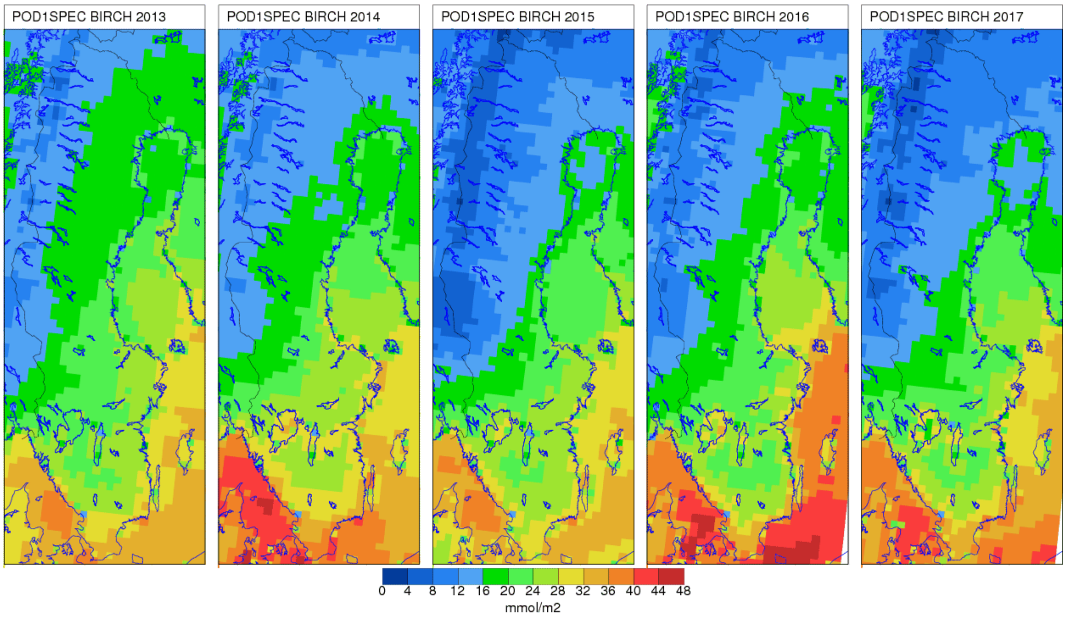

Figure 5. $POD1_{spec\text{-}birch}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 5 shows PODY for birch, $POD1_{spec\text{-}birch}$, calculated with the MATCH-Sweden system for the years 2013 – 2017. The spatial pattern and year to year variability is rather similar to $POD1_{gen\text{-}DT}$ but the numerical values are higher due to a longer vegetation period and a higher value of g_{max} (Table 1) used in the calculation for birch. The vegetation period for Sweden has been specifically described using local data as reported by Karlsson et al. (2018) and the periods are significantly longer than the periods assumed for generic deciduous trees.

According to the *Mapping Manual* critical levels for a 4 % reduction in whole tree biomass production of birch is 5.2 mmol m^{-2}. The results from MATCH-Sweden suggest that this level is exceeded in almost all of Sweden for all years in the period 2013 – 2017.

4.4 PODY for spruce, $POD1_{spec\text{-}spruce}$

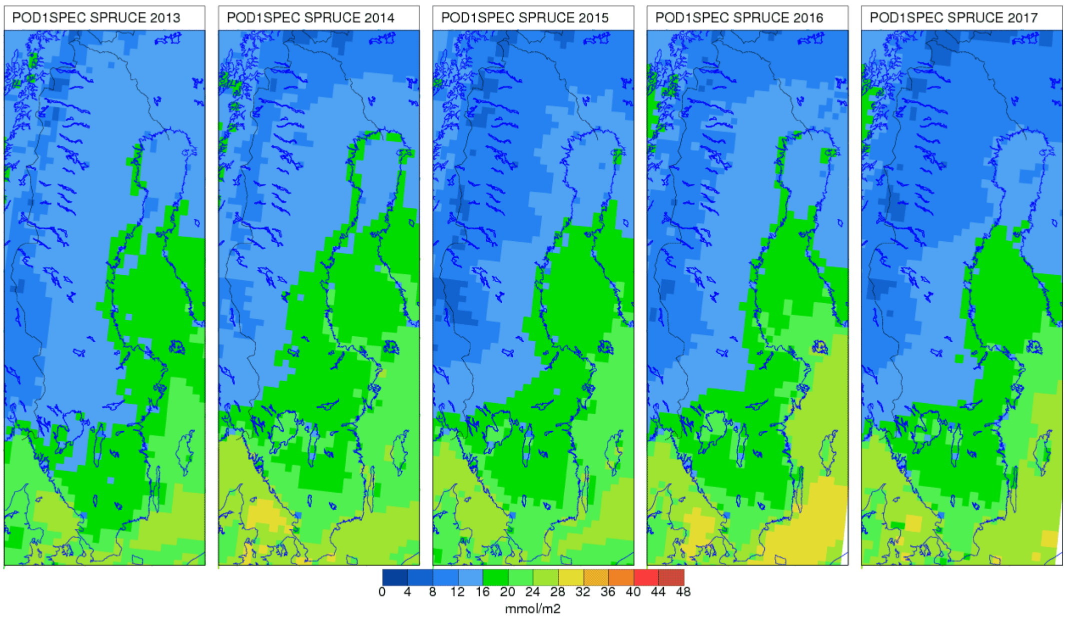

Figure 6. $POD1_{spec\text{-}spruce}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 6 shows PODY for spruce, $POD1_{spec\text{-}spruce}$, calculated with the MATCH-Sweden system for the years 2013 – 2017. The spatial pattern and year to year variability is very similar to $POD1_{gen\text{-}DT}$ and numerical values are also very similar. The vegetation period for Sweden has been specifically described using local data as reported by Karlsson et al. (2018) and vegetation periods are significantly longer than the periods assumed for generic deciduous trees. On the other hand the value of g_{max} (Table 1) used in the calculation for spruce is lower than for generic deciduous trees. For spruce we account for effects of soil moisture as we also do for birch, potato and wheat. In combination these differences compensates for the longer vegetation period.

According to the *Mapping Manual* critical levels for a 4 % reduction in whole tree biomass production of spruce is 9.2 mmol m^{-2}. The results from MATCH-Sweden suggest that this level is exceeded in large parts of Sweden except for the northern most part and in the Scandinavian mountain range for all years in the period 2013 – 2017.

4.5 PODY for wheat, $POD6_{spec\text{-}wheat}$

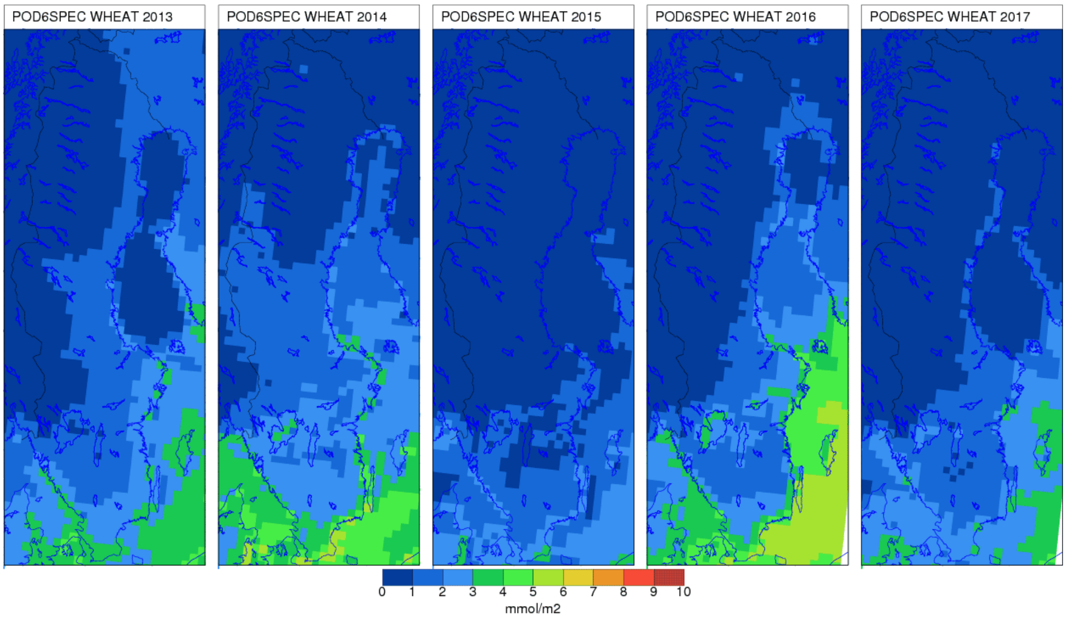

Figure 7. $POD6_{spec\text{-}wheat}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 7 shows PODY for wheat, $POD6_{spec\text{-}wheat}$, calculated with the MATCH-Sweden system for the years 2013 – 2017. The spatial pattern is rather similar to $POD3_{gen\text{-}CR}$ but the numerical values are lower due to the higher threshold value (Y=6 nmol m^{-2} s^{-1} compared to Y=3 nmol m^{-2} s^{-1}). The variability from year to year is also higher for $POD6_{spec\text{-}wheat}$ due to the higher threshold.

According to the *Mapping Manual* critical levels for a 5 % reduction in grain yield, 1000-grain weight and protein yield are 1.3, 1.5 and 2.0 mmol m^{-2} respectively. The results from MATCH-Sweden suggest that these levels are exceeded in the southern part of Sweden for four in five years in the period 2013 – 2017.

4.6 PODY for potato, $POD6_{spec\text{-}potato}$

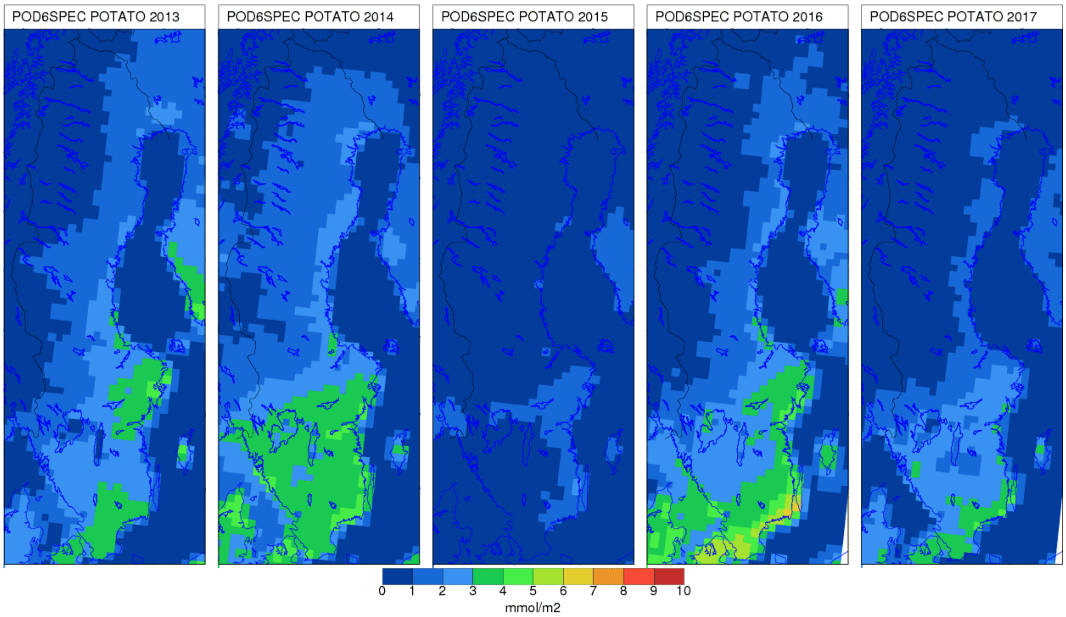

Figure 8. $POD6_{spec\text{-}potato}$ for the years 2013 (left) to 2017 (right). Units: mmol m^{-2}.

Figure 8 shows PODY for potato, $POD6_{spec\text{-}potato}$, calculated with the MATCH-Sweden system for the years 2013 – 2017. The spatial pattern and year to year variability is rather similar to $POD6_{spec\text{-}wheat}$ but the numerical values are lower mainly due to differences in the phenology function.

According to the *Mapping Manual* critical levels for a 5 % reduction in tuber yield is 3.8 mmol m^{-2}. The results from MATCH-Sweden suggest that this level is exceeded in the southern part of Sweden for two in five years in the period 2013 – 2017.

4.7 Comparisons to PODY from the EMEP model

Engardt et al. (2016) compared their PODY calculations for generic crops and generic deciduous trees to corresponding calculations using the EMEP model. Here we repeat these comparisons since we have made updates in the MATCH-Sweden calculations as discussed above. It should be noted here that a perfect agreement between the two calculations cannot be expected primarily due to two factors; firstly the meteorological and solar radiation data that is used are different and secondly, that the ozone concentrations are different. Ozone concentrations from the EMEP model are from a pure model simulation while the ozone concentrations from the MATCH-Sweden system are from a model data fusion using a variational technique as discussed in section 3. We believe that the ozone fields from the model data fusion used in the MATCH-Sweden system provides a better estimate of the real surface ozone concentrations and therefore more reliable estimates of PODY.

Table 2. POD3$_{gen-CR}$ and POD1$_{gen-DT}$ averaged over Sweden from different studies.

	POD3$_{gen-CR}$ [mmol m^{-2}]			**POD1$_{gen-DT}$** [mmol m^{-2}]		
	2013	**2014**	**2015**	**2013**	**2014**	**2015**
Engardt et al. 2016	**14**	**20**	**10**	**17**	**17**	**14**
This work	**10**	**12**	**7**	**16**	**16**	**13**
EMEP model	**7**	**9**	**4**	**20**	**19**	**17**

Table 2 shows PODY results for the area of Sweden from three different calculations, Engardt et al. (2016), the present work and from the EMEP model. The EMEP data are taken from Gauss et al. (2015). Results for generic crops from the MATCH-Sweden system using the updated version of the PODY calculations presented here are much closer to the values calculated by the EMEP model for the years 2013-2015 than the results presented by Engardt et al. (2016). This is due to a combination of factors including the more detailed calculation of canopy level concentrations and updates of the calculations of quasi-laminar and surface resistances. For generic deciduous trees these changes have a smaller impact and the new MATCH-Sweden system results are just marginally lower than those presented by Engardt et al. (2016). It should be noted here that an error was discovered in the radiation calculations in the EMEP model affecting primarily the PODY calculations for generic deciduous trees (Fagerli et al., 2018). Results given for EMEP in Table 2 includes this error. Correction of the error results in about 30 % lower values of POD1$_{gen-DT}$ in the EMEP model which means that MATCH-Sweden now probably gives higher values than EMEP for both POD1$_{gen-DT}$ and for POD3$_{gen-CR}$ for the area of Sweden. This remaining difference in results can most likely mainly be attributed to differences in the surface ozone concentrations used in the different calculations.

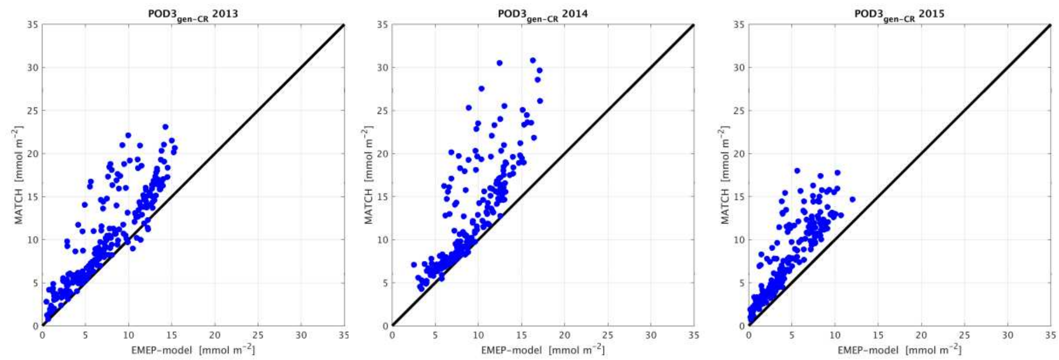

Figure 9. Comparison between POD3$_{gen-CR}$ calculated using MATCH-Sweden and the EMEP-model for 2013, 2014 and 2015. EMEP results are before correction of radiation calculations.

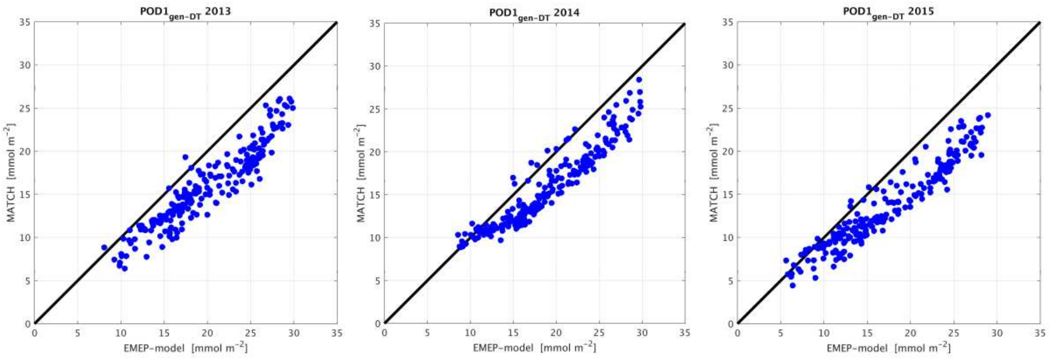

Figure 10. Comparison between $POD1_{gen-DT}$ calculated using the MATCH-Sweden system and the EMEP-model for 2013, 2014 and 2015. EMEP results are before correction of radiation calculations.

Figure 9 and 10 show a more detailed comparison grid point by grid point between the MATCH-Sweden system and EMEP-model results for $POD3_{gen-CR}$ and $POD1_{gen-DT}$. Data for the EMEP model is taken from the EMEP home page (www.emep.int/mscw/mscw_ydata.html#NCdata; collected 2016-09-26) and represent the values at the center of the 50 km × 50 km grid squares of EMEP model. For $POD3_{gen-CR}$ we can see that MATCH-Sweden gives higher values primarily in the higher end of the frequency distribution while for $POD1_{gen-DT}$ the difference is more uniform between high and low values. This could be due to that peak concentrations are better captured in the model data fusion approach used in the MATCH-Sweden system. MATCH-Sweden also uses a higher horizontal resolution. Given that the threshold Y is higher for crops in the PODY calculation the high ozone concentrations are more important for $POD3_{gen-CR}$ than for $POD1_{gen-DT}$.

4.8 County average data for Sweden

County and Sweden average data for 2016 are given in Table 3. These numbers can be used together with statistics on vegetation cover and production to do a monetary evaluation of production losses. Tabulated data for all years are given in Appendix I.

Table 3. PODY values averaged over counties and for the whole of Sweden for year 2016. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	18.7	21.0	3.5	3.1	20.7	27.7
Uppsala	15.0	18.3	2.7	2.2	18.3	24.3
Södermanland	16.6	19.4	3.2	2.4	19.2	25.4
Östergötland	14.5	18.6	2.8	1.9	18.7	24.2
Jönköping	13.0	18.4	2.7	1.7	18.8	23.8
Kronoberg	15.8	20.0	3.5	2.2	20.0	26.2
Kalmar	19.5	21.2	4.3	2.9	21.2	28.0

Gotland	22.8	24.8	2.9	4.3	24.7	32.5
Blekinge	20.9	23.0	4.9	3.5	22.8	31.1
Skåne	20.7	24.1	4.4	3.4	23.3	33.2
Halland	16.9	22.0	3.1	2.4	21.1	29.8
Västra Götaland	13.9	18.6	2.5	1.9	18.8	25.3
Värmland	10.3	15.8	1.5	1.2	16.1	21.0
Örebro	12.8	16.6	2.5	1.7	16.7	21.9
Västmanland	13.1	16.6	2.4	1.7	16.8	22.0
Dalarna	7.8	13.6	1.2	0.9	13.6	17.8
Gävleborg	9.7	15.1	1.7	1.1	15.4	20.1
Västernorrland	7.3	13.2	1.2	0.8	13.7	17.8
Jämtland	4.4	10.7	0.6	0.4	11.4	13.3
Västerbotten	5.4	11.5	0.8	0.6	12.5	14.4
Norrbotten	5.0	10.5	0.8	0.6	11.5	12.4
Sweden	9.2	14.4	1.6	1.2	14.8	18.5

5 Conclusions

We have added calculations of PODY for wheat, potato, spruce and birch to the MATCH-Sweden system. Several important updates compared to the previous implementation for generic crops and generic deciduous trees by Engardt et al. (2016) have been made including improved calculations of canopy level ozone concentrations, updated calculations of quasi-laminar and surface resistance and inclusion of soil moisture dependence for specific vegetation species. These updates affects all PODY calculations and results for generic crops and generic deciduous trees are therefore different compared to those reported by Engardt et al. (2016).

Comparisons to results from the EMEP model for generic crops and generic deciduous trees shows a better agreement compared to Engardt et al. (2016). Considering also that an error in the radiation EMEP calculations affecting primarily the PODY calculations for generic deciduous trees has been identified, MATCH-Sweden and EMEP model results now appear to be more consistent. We believe that the ozone fields from the model data fusion used in the MATCH-Sweden system provides a better estimate of the real surface ozone concentrations and therefore more reliable estimates of PODY

Year to year variability of PODY for birch and spruce are similar to that for generic deciduous trees while numerical values are different, especially for birch, due to different parameters in the PODY calculation and longer vegetation periods. Critical levels corresponding to a 4 % growth reduction are exceeded for both birch and spruce in major parts of Sweden for all years in the period 2013-2017.

Year to year variability of PODY for wheat and potato are larger than for generic crops due to the higher threshold for PODY used in the calculations. Critical levels corresponding to a 5 % reduction in crop yield are reached in four of five years in southern Sweden for wheat and for two in five years for potato.

The updated program package for PODY calculations could be used to calculate consistent time series of PODY for different types of vegetation for the period 1990-2013 based on reanalyzed ozone concentrations presented by Andersson et al. (2015). The program package could also be developed to calculate PODY for the whole of Europe for different emission- or climate scenarios.

The results presented in this report are also available in digital form at the SMHI home page for environmental monitoring of air quality and will be extended on an annual basis (www.smhi.se/klimatdata/miljo/atmosfarskemi).

6 References

Alpfjord Wylde, H., Andersson, C. och Leung, W., 2019. *Nationell miljöövervakning med MATCH Sverige-systemet – utvärdering och resultat för åren 2015-2017.* **RAPPORT 2019/12** (in Swedish).

Alpfjord, H. and Andersson, C. 2015. *Nationell miljöövervakning med MATCH Sverige-systemet - ny metodik, utvärdering och resultat för åren 2012-2013.* **RAPPORT 2015-7**, 45 pp, (in Swedish).

Andersson, C., Engardt, M. and Alpfjord, H. 2015. *Återanalys av marknära ozon i Sverige för perioden 1990-2013*. **RAPPORT NR 2015-80**, 44 pp, (in Swedish).

CLRTAP 2017. *Mapping critical levels for vegetation, Chapter III of Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends.* UNECE Convention on Long-range Transboundary Air Pollution; accessed on 9 February 2019 on web at www.icpmapping.org

Emberson, L.D., Ashmore, M.R., Cambridge, H.M., Simpson, D. and Tuovinen, J.-P. 2000a. Modelling stomatal ozone flux across Europe. *Environmental Pollution* **109**, 403-413.

Emberson, L., Simpson, D., Tuovinen, J.P., Ashmore, M. and Cambridge, H.M. 2000b. *Towards a model of ozone deposition and stomatal uptake over Europe*. **EMEP MSC-W Note 6/2000**.

Engardt, M., Alpfjord, H. and Andersson, C., 2016. *PODY-beräkningar med MATCH Sverigesystemet*. **METEOROLOGI 160**, 44 pp, (in Swedish).

Fagerli, H. et al. 2018. Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components, EMEP Status Report 1/2018, Norwegian Meteorological Institute.

Gauss, M., Semeena, V.S., Benedictow, A. and Klein, H. 2015. *Transboundary air pollution by main pollutants (S, N, O_3) and PM in 2013. Sweden*. **MSC-W Data Note 1/2015**.

Klingberg, J., Engardt, M., Uddling, J., Karlsson, P.E. and Pleijel, H. 2011. Ozone risk for vegetation in the future climate of Europe based on stomatal ozone uptake calculations. *Tellus* **63A**, 174-187. DOI: 10.1111/j.1600-0870.2010.00465.x

Mills, G., Hayes, F., Simpson, D., Emberson, L., Norris, D., Harmens, H. and Büker, P. 2011. Evidence of widespread effects of ozone on crops and (semi-)natural vegetation in Europe (1990-2006) in relation to AOT40- and flux-based risk maps. *Global Change Biology* **17**, 592-613.

Robertson, L. and Kahnert, M. 2007. *2D variational data assimilation of near-surface chemical species,* in: C. Borrego and E. Renner (Eds.), Air Pollution Modeling and Its Application XVIII, Elsevier, Amsterdam.

Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Flechard, C. R., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J.-P., Valdebenito, Á., and Wind, P. 2012. The EMEP MSC-W chemical transport model – technical description, Atmos. Chem. Phys., 12, 7825-7865, https://doi.org/10.5194/acp-12-7825-2012.

7 Appendix I

Tabulated county and Sweden average data for the years 2013 – 2017.

Table A1. Data for 2013. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	18.0	20.5	3.8	2.5	17.6	26.6
Uppsala	15.4	19.2	2.9	1.8	16.5	24.8
Södermanland	16.1	18.8	3.3	1.9	15.7	24.0
Östergötland	14.8	19.5	2.6	1.8	16.8	25.0
Jönköping	14.2	19.0	2.6	1.7	16.5	24.2
Kronoberg	16.7	20.6	3.1	2.3	17.7	26.6
Kalmar	17.2	21.9	2.5	2.5	19.0	28.4
Gotland	20.3	24.1	2.5	3.6	21.3	31.0
Blekinge	19.4	22.6	3.4	2.8	19.7	29.5
Skåne	20.0	23.9	3.1	3.0	21.2	31.8
Halland	18.4	22.8	2.6	2.5	19.4	28.0
Västra Götaland	14.5	18.8	2.1	1.6	16.3	24.3
Värmland	10.5	16.1	1.4	0.9	13.9	20.4
Örebro	13.5	17.4	2.3	1.3	15.0	22.3
Västmanland	14.5	18.2	2.8	1.4	15.6	23.4
Dalarna	9.0	15.3	1.5	1.0	13.8	19.4
Gävleborg	10.8	16.7	2.2	1.5	15.3	21.2
Västernorrland	8.5	15.2	1.6	1.2	14.7	18.7
Jämtland	5.1	12.5	0.9	0.7	12.7	15.4
Västerbotten	6.2	13.2	0.9	0.7	13.4	16.8
Norrbotten	6.0	12.1	0.9	0.7	12.8	15.3
Sweden	9.9	15.6	1.6	1.2	14.6	19.8

Table A2. Data for 2014. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	17.7	19.8	3.3	2.3	19.8	28.3
Uppsala	15.0	18.6	2.3	1.9	19.1	26.5
Södermanland	15.8	18.5	3.4	2.0	18.6	26.7
Östergötland	16.4	19.3	3.6	2.1	19.6	27.6
Jönköping	16.4	19.2	3.3	2.3	19.7	27.3
Kronoberg	19.6	20.5	3.6	2.6	21.1	29.5
Kalmar	21.2	21.7	3.8	3.0	22.1	30.8
Gotland	19.1	22.5	2.3	2.5	23.0	31.5
Blekinge	24.3	23.2	4.4	3.6	23.7	33.7
Skåne	24.6	23.6	3.4	3.5	24.2	35.1
Halland	21.0	22.8	3.5	2.8	22.6	32.3
Västra Götaland	17.2	19.9	3.4	2.3	20.2	28.5
Värmland	12.9	16.9	2.5	1.5	16.9	23.0
Örebro	14.6	17.8	3.1	2.1	17.8	25.1
Västmanland	13.8	17.5	2.6	1.7	17.7	25.1
Dalarna	10.2	15.4	1.5	1.5	15.3	19.6
Gävleborg	11.8	16.9	2.0	1.7	17.8	21.8
Västernorrland	9.9	14.9	1.9	1.0	15.6	18.1
Jämtland	7.9	13.1	1.3	1.2	13.6	15.7
Västerbotten	8.3	12.6	1.5	0.7	13.3	15.4
Norrbotten	7.8	11.4	1.1	0.7	12.1	13.6
Sweden	11.8	15.5	2.1	1.4	15.9	20.3

Table A3. Data for 2015. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	14.1	18.3	1.5	1.2	18.8	26.9
Uppsala	11.5	16.8	0.8	0.8	17.5	24.0
Södermanland	12.8	17.4	1.5	1.0	17.7	25.1
Östergötland	11.6	17.8	1.0	1.0	18.3	25.0
Jönköping	10.8	17.5	0.7	1.1	18.3	24.1
Kronoberg	12.4	19.2	1.0	1.5	20.1	26.7
Kalmar	14.6	20.6	1.5	1.6	21.2	28.2
Gotland	15.1	22.2	0.8	2.0	23.3	31.0
Blekinge	15.1	21.2	1.4	2.1	22.2	29.6
Skåne	14.7	21.1	0.6	2.0	22.0	29.3
Halland	13.0	21.1	0.6	1.6	21.4	28.8
Västra Götaland	11.7	18.1	0.5	1.1	19.0	25.7
Värmland	9.4	14.6	0.6	0.6	15.3	19.6
Örebro	10.5	15.6	0.8	0.6	16.6	21.9
Västmanland	10.5	15.4	0.8	0.6	16.2	22.0
Dalarna	6.8	12.3	0.2	0.3	12.9	14.8
Gävleborg	7.6	13.7	0.6	0.4	15.2	17.2
Västernorrland	6.1	12.0	0.5	0.3	13.2	14.2
Jämtland	4.0	9.4	0.2	0.2	10.5	9.9
Västerbotten	4.7	10.5	0.3	0.2	11.5	11.6
Norrbotten	3.5	9.5	0.1	0.1	10.5	10.0
Sweden	7.3	13.2	0.5	0.5	14.1	16.5

Table A4. Data for 2016. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	18.7	21.0	3.5	3.1	20.7	27.7
Uppsala	15.0	18.3	2.7	2.2	18.3	24.3
Södermanland	16.6	19.4	3.2	2.4	19.2	25.4
Östergötland	14.5	18.6	2.8	1.9	18.7	24.2
Jönköping	13.0	18.4	2.7	1.7	18.8	23.8
Kronoberg	15.8	20.0	3.5	2.2	20.0	26.2
Kalmar	19.5	21.2	4.3	2.9	21.2	28.0
Gotland	22.8	24.8	2.9	4.3	24.7	32.5
Blekinge	20.9	23.0	4.9	3.5	22.8	31.1
Skåne	20.7	24.1	4.4	3.4	23.3	33.2
Halland	16.9	22.0	3.1	2.4	21.1	29.8
Västra Götaland	13.9	18.6	2.5	1.9	18.8	25.3
Värmland	10.3	15.8	1.5	1.2	16.1	21.0
Örebro	12.8	16.6	2.5	1.7	16.7	21.9
Västmanland	13.1	16.6	2.4	1.7	16.8	22.0
Dalarna	7.8	13.6	1.2	0.9	13.6	17.8
Gävleborg	9.7	15.1	1.7	1.1	15.4	20.1
Västernorrland	7.3	13.2	1.2	0.8	13.7	17.8
Jämtland	4.4	10.7	0.6	0.4	11.4	13.3
Västerbotten	5.4	11.5	0.8	0.6	12.5	14.4
Norrbotten	5.0	10.5	0.8	0.6	11.5	12.4
Sweden	9.2	14.4	1.6	1.2	14.8	18.5

Table A5. Data for 2017. Units: mmol m^{-2}.

County	$POD3_{gen-CR}$	$POD1_{gen-DT}$	$POD6_{spec-potato}$	$POD6_{spec-wheat}$	$POD1_{spec-spruce}$	$POD1_{spec-birch}$
Stockholm	16.7	19.9	2.3	1.7	18.9	26.9
Uppsala	13.4	17.8	1.8	1.3	16.9	23.5
Södermanland	15.8	18.0	2.4	1.5	17.0	24.4
Östergötland	14.6	17.8	2.2	1.4	17.6	24.8
Jönköping	13.0	17.8	2.2	1.2	17.8	24.0
Kronoberg	15.4	19.5	2.8	1.6	20.0	27.3
Kalmar	17.9	20.3	2.9	1.9	20.6	29.3
Gotland	19.9	23.0	1.7	2.7	23.1	29.4
Blekinge	18.7	21.8	3.6	2.2	22.2	32.0
Skåne	18.2	22.1	3.0	2.3	22.5	32.8
Halland	16.8	21.1	2.4	1.9	20.8	28.8
Västra Götaland	15.1	18.6	2.2	1.6	18.5	25.4
Värmland	9.6	15.9	1.2	0.8	15.2	20.9
Örebro	11.7	16.1	1.8	1.1	15.3	21.2
Västmanland	12.1	16.0	1.6	1.1	15.3	21.4
Dalarna	6.8	13.8	0.7	0.5	13.3	16.8
Gävleborg	8.1	15.1	0.9	0.8	15.0	18.4
Västernorrland	6.5	13.2	0.8	0.6	13.0	15.8
Jämtland	3.3	10.4	0.3	0.2	10.8	11.9
Västerbotten	4.6	11.1	0.6	0.4	10.4	12.2
Norrbotten	3.6	10.1	0.4	0.3	9.5	9.9
Sweden	8.2	14.0	1.1	0.8	13.6	17.2

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Spridningsberäkningar för Uddevallas fjärrvärmecentral i Hovhult

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Spridningsberäkningar rörande gasutsläpp från ett antal källor inom SSAB Luleå-verken

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En klimatstudie för Arlanda stad

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Extrem arealnederbörd i Sverige

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Spridningsberäkningar för lösningsmedel i Tibro

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Vindmätningar i höga master - kvartalsrapport 1/1986

22 Kvick, T. (1986)
Beräkning av vindenergitillgången på några platser i Halland och Bohuslän

23 Krieg, R., Andersson, C. (1986)
Vindmätningar i höga master - kvartalsrapport 2/1986

24 Persson, Ch. (SMHI), Rodhe, H. (MISU), De Geer, L.-E. (FOA) (1986)
Tjernobylolyckan - En meteorologisk analys av hur radioaktivitet spreds till Sverige

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Spridningsberäkningar för Spendrups bryggeri, Grängesberg

26 Krieg, R. (1986)
Beräkningar av vindenergitillgången på några platser i Skåne

27 Wern, L., Ring, S. (1986)
Spridningsberäkningar, SSAB

28 Wern, L., Ring, S. (1986)
Spridningsberäkningar för ny ugn, SSAB II

29 Wern, L. (1986)
Spridningsberäkningar för Volvo Hallsbergverken

30 Fredriksson, U. (1986)
SO_2-halter från Hammarbyverket kring ny arena vid Johanneshov

31 Persson, Ch., Robertson, L., Häggkvist, K. (1986)
Spridningsberäkningar, SSAB - Luleåverken

32 Kindell, S., Ring, S. (1986)
Spridningsberäkningar för SAABs planerade bilfabrik i Malmö

33 Wern, L. (1986)
Spridningsberäkningar för svavelsyrafabrik i Falun

34 Wern, L., Ring, S. (1986)
Spridningsberäkningar för Västhamnsverket HKV1 i Helsingborg

35 Persson, Ch., Wern, L. (1986)
Beräkningar av svaveldepositionen i Stockholmsområdet

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USAs månadsprognoser

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Utemiljön vid Kvarnberget, Lysekil

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Spridningsberäkningar av freon 22 från Ropstens värmepumpverk

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Vindklassificering av en plats på Hemsön

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Utvärdering av sommarens (1986) använda konvektionsprognoshjälpmedel

42 Krieg, R., Kvick, T. (1986)
Vindmätningar i höga master

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Vindarna över Sverige

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Spridningsberäkningar rörande gasutsläpp vid ScanDust i Landskrona - bestämning av cyanvätehalter

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Vindförhållandena i Sveriges kust- och havsband, rapport nr 2

46 Fredriksson, U. (1986)
Spridningsberäkningar för en planerad panncentral vid Lindsdal utanför Kalmar

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Spridningsberäkningar för Volvo BMs fabrik i Landskrona

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Spridningsberäkningar för ELMO-CALFs fabrik i Svenljunga

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Spridningsberäkningar rörande gasutsläpp från syrgas- och bensenupplag inom SSAB Luleåverken

50 Wern, L., Fredriksson, U., Ring, S. (1986)
Spridningsberäkningar för lösningsmedel i Tidaholm

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Spridningsberäkningar för Volvo BM ABs anläggning i Braås

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Meteorological measurements performed May 15, 1984, to June, 1984, by the SMHI

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Spridningsberäkning för Kockums Plåtteknik, Ronneby

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Frekvensanalys av timvisa temperaturobservationer

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Luktberäkningar för AB ELMO i Flen

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Spridningsberäkningar rörande utsläpp av NO_x inom Fagersta kommun

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Luften i Nässjö

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Spridningsberäkningar rörande gasutsläpp vid ScanDust i Landskrona - bestämning av cyanväte

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Receptorbaserad partikelmodell för gatumiljömodell för en gata i Nyköping

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Spridningsberäkningar för Varbergs kommun. Bestämning av halter av SO_2, CO, NO_x samt några kolväten

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Spridningsberäkningar för Kockums Plåtteknik, Ronneby. 2

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Klimatkorrigering för energiförbrukningen i ett eluppvärmt villaområde

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Spridningsberäkningar för AB Åetå-Trycks planerade anläggning vid Kungens Kurva

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En överskalig klimatstudie för Tornby, Linköping

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En numerisk modell för beräkning av vertikal momentumtransport i områden med stora råhetselement. Tillämpning på ett energiskogsområde

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Extrem arealnederbörd i Sverige 1881 – 1988

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Satellitmeteorologi

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Background report on air pollution situation in the Baltic States - a prefeasibility study
IVL Publikation B 1038

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Utnyttjande av persistens i temperatur och nederbörd för vårflödesprognoser

83 Moberg, A. (1992)
Lufttemperaturen i Stockholm
1756 - 1990. Historik, inhomogeniteter och urbaniseringseffekt
Naturgeografiska Institutionen, Stockholms Universitet

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Normalvärden för perioden 1961-90 av globalstrålning och solskenstid i Sverige

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Några huvuddrag i det svenska nederbördsklimatet 1961-1990

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Växthuseffekten och klimatet i Norden - en översikt

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Persson, C. Roos, E., Bergström, R. (SMHI) (1998)
Nationell miljöövervakning av luft- och nederbördskemi 1996

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Jämförelse mellan observationer och fält med griddad klimatologisk information

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Nationell emissionsdatabas för utsläpp till luft - Förstudie

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Model for Simulation of Air and Ground Contamination Associated with Nuclear Weapons. An Emergency Preparedness Model

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Nationell miljöövervakning av luft- och nederbördskemi 1997, 1998 och 1999

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Validation of AVHRR cloud products

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Beräkningar av moln- och dimdeposition i Sverigemodellen - Resultat för 1997 och 1998

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Temperaturen och nederbörden i Sverige 1961-1990. Referensnormaler - utgåva 2

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Nowcasting SAF - Retrieving Cloud Top Temperature and Height in Semi-transparent and Fractional Cloudiness using AVHRR

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Temperatur och nederbörd i Sverige 1860 - 2001

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Kvaliteten hos nederbördskemiska mätdata som utnyttjas för dataassimilation i MATCH-Sverige modellen.

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CM-SAF cloud products feasibility study in the inner Arctic region
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Kvaliteten i uppmätta nederbördsmängder inom svenska nederbörskemiska stationsnät

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Vedeldning i småhusområden

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Korrektion av nederbörd enligt enkel klimatologisk metodik

112 Joro, S., Dybbroe, A.(2004)
Nowcasting SAF – IOP
Validating the AVHRR Cloud Top Temperature and Height product using weather radar data
Visiting Scientist report

113 Persson, Ch., Ressner, E., Klein, T. (2004)
Nationell miljöövervakning – MATCH-Sverige modellen
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CM-SAF Validating the Cloud Top Height product using LIDAR data

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Utvärdering av PM_{10} - mätningar i några olika nordiska trafikmiljöer

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Vindstatistik för Sverige 1961-2004

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The land-surface scheme of the Rossby Centre regional atmospheric climate model (RCA3)

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VEDAIR – ett internetverktyg för beräkning av luftkvalitet vid småskalig biobränsleeldning
Modellbeskrivning och slutrapport mars 2007

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Beräknade temperaturförhållanden för tre platser i Sverige – perioderna 1961-1990 och 2011-2040

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Total ozone from zenith radiance measurements. An empirical model approach

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Utvärdering för svenska tätorter och trafikmiljöer avseende är 2004 och 2005

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Sveriges vindklimat 1901 – 2008
Analys av förändring i geostrofisk vind

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Korttidsnederbörd i Sverige, 1995 – 2008

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Dagens och framtidens luftkvalitet i Sverige. Haltberäkningar av NO_2, PM10 och PM2.5 i svenska trafikmiljöer för framtidsscenarier med minskade europeiska emissioner

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Åska i Sverige 2002 – 2009

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Extrem nederbörd i Sverige
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Modellering av Marknära Ozon
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Utvärdering av SIMAIR mot mätningar av PM10 och NO2 i Göteborg, Stockholm och Umeå för åren 2006-2009. Undersökning av en ny emissionsmodell för vägtrafikens slitagepartiklar.

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