Ozone concentration, exposure and foliar injury in European forests

a ten-year study on permanent monitoring plots

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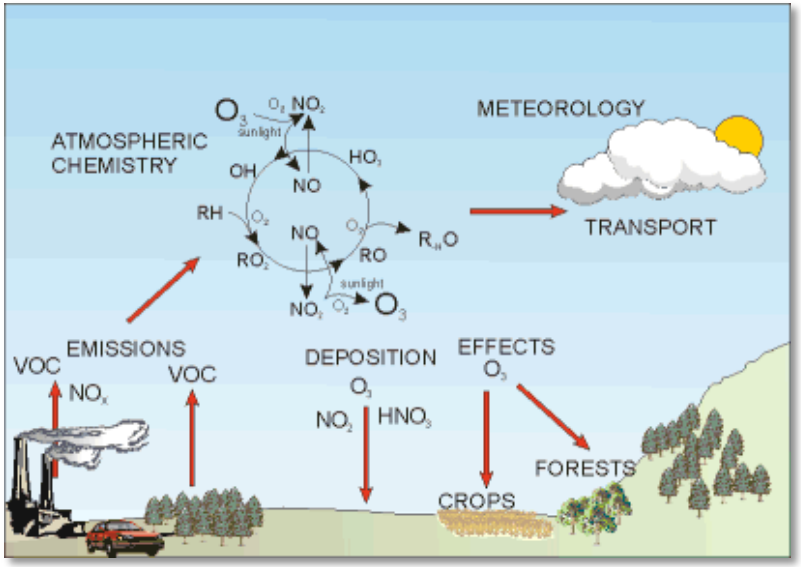
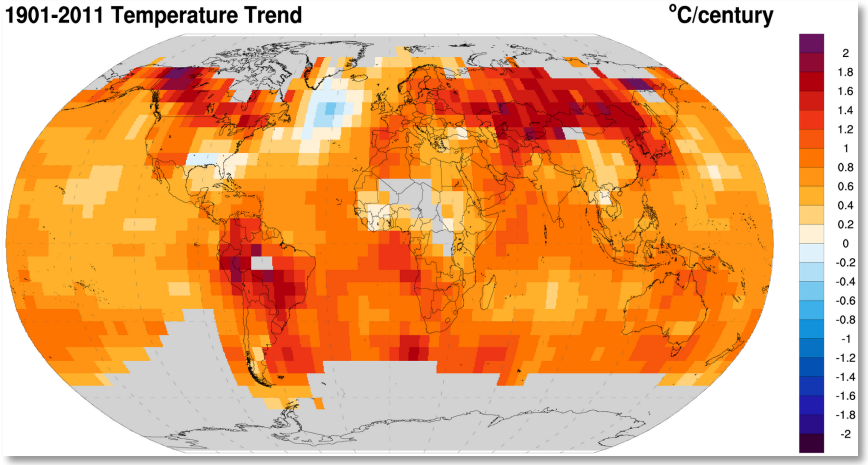
Introduction

- Ozone (O_3) is toxic for humans, animals, plants and materials
- The 1999 Gothenburg Protocol to the LRTAP Convention, amended in 2012 (UNECE, 2012), Objectives
- Thresholds to protect plants: AOT40, Phytotoxic Ozone Dose (PODy)
- ICP Forests WG AAQ data series since 2000 for O_3 concentrations and since 2002 for visible symptoms
- Total of 152 plots from 18 countries (max. in 2009)
- Today (2011), 95 Level II plots from 9 countries



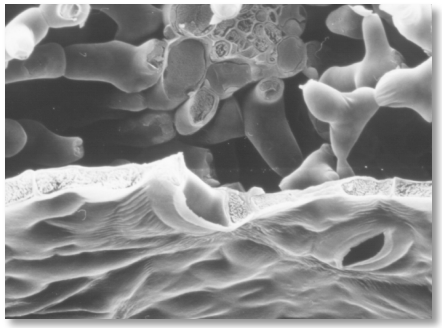
Introduction

- O_3 precursor gas emissions decreased considerably between 2002 and 2011:
  - NO_X emissions -27%
  - non-methane-VOCs -28%
  - CO -32%
  - CH_4 -15%



Source: EEA, 2014 & NOAA-NCDC

- O_3 concentrations in the 2002-2011 period do not strongly reflect the reductions in emissions of O_3 precursors.
- Increase of intercontinental transport of O_3 and its precursors in the northern hemisphere is masking.
- Complex plant effects interactions under climate change and increasing drought



Objectives

1) Spatial trend analysis based on [$O_{3\_passive}$]

2) Temporal [O_3] trend for 2000-2010

3) Comparison of different AOT40 based on different assessment methodologies

4) Comparison between measured concentration/exposures and EMEP estimates

5) Symptom occurrence in relation to O_3 concentration/AOT40 respectively

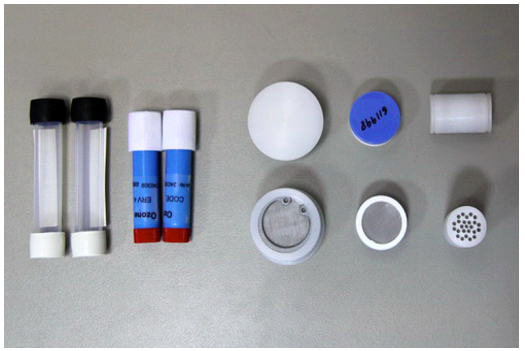
[$O_{3\_passive}$] – ICPF data base

Table 1. Number of Level II plots with $O_{3\_passive}$ samplers

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Austria											6	
Belgium								1	1	4	4	4
Cyprus										2	2	2
Czech Republic								8	8	9	9	9
Estonia										1	1	1
France	24	24	25		25	25	25			10		
Germany			12	17	19	19	33	34	26	42	42	39
Greece [1]										2	3	
Hungary										5	5	
Ireland										2	2	
Italy [2]			26	25	27	30	30	11	24	22	22	21
Latvia										1	1	
Lithuania [3]						2		2	2	2		
Luxembourg	2	2	2	2	2	2	2					
Poland										8	12	
Romania								4	4	4	4	4
Slovak Republic									3	8	8	8
Slovenia									6	10	10	
Spain	12	12	12	13	13		13	13	13	13	13	
Switzerland			15	15	15	8	7	7	7	7	7	7
United Kingdom			15	16								
Total	**38**	**38**	**107**	**88**	**101**	**86**	**110**	**80**	**94**	**152**	**151**	**95**

Source: ICPF data base, March 2014

Methods – DQL [$O_{3\_passive}$]



- Completeness ≥ 80% Apr-Sept (applied)
- Completeness ≥ 80% from reported plots (applied)
- 75% of the data within ± 30% of reference value (applied ringtest, Calatayud & Schaub 2009)
- CV among replicates ≤ 10% (not applied; mean/three values)
- For trend analyses:
  - Spatial trend: 2009 for all countries
  - Temporal trend: 2002-2011 for IT, SP, FR, CH
  - Non-parametric Mann-Kendall test resulting in weighted means
  - minimum of 5 years with valid data required (applied)
- Data from co-located ozone monitors have not been considered yet

Results – spatial O_3 trend

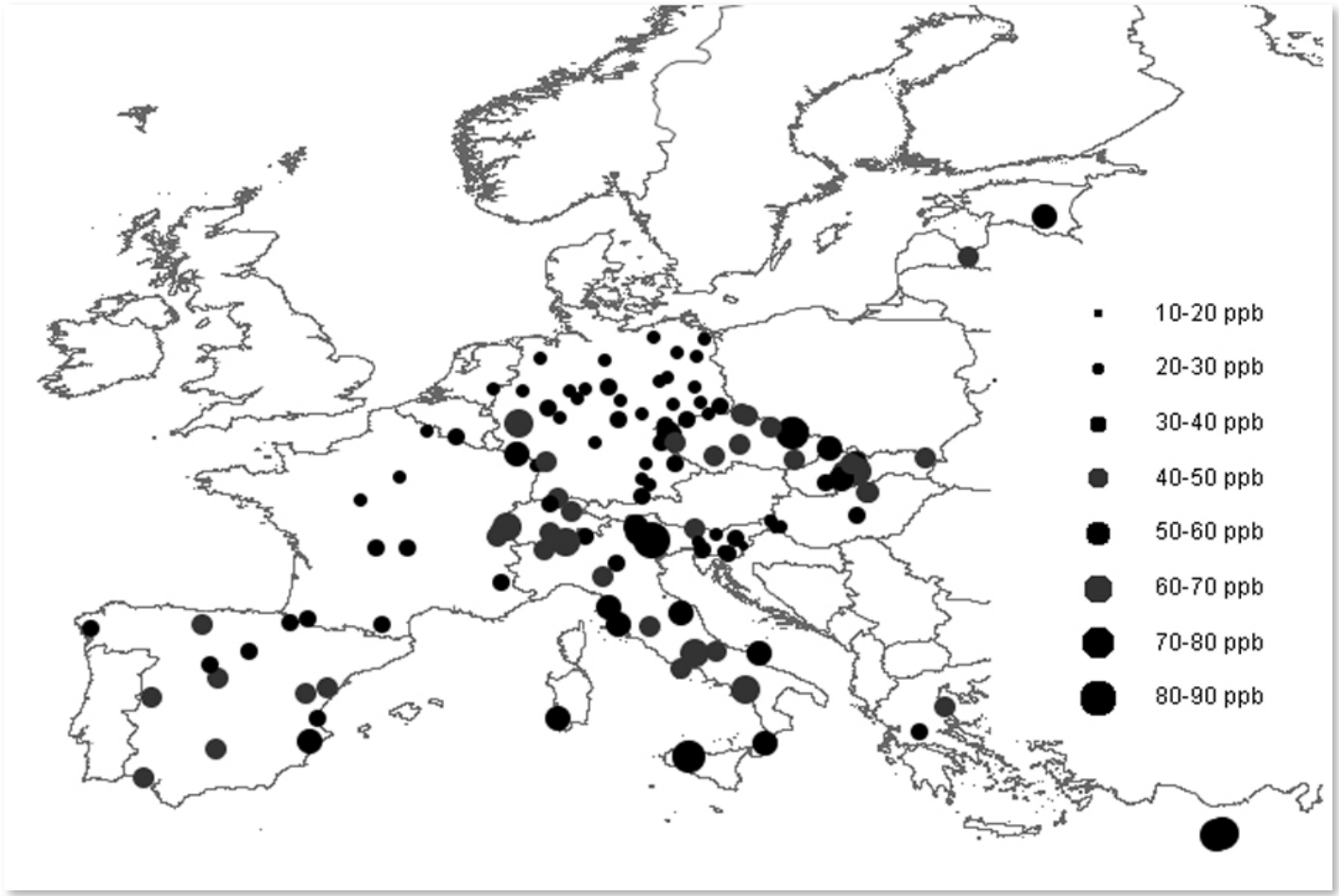


Figure 1. **2009** [$O_{3\_passive}$] weighted means for plots with a coverage ≥80% during April-September for 152 plots, 18 countries.

Results – spatial O_3 trend

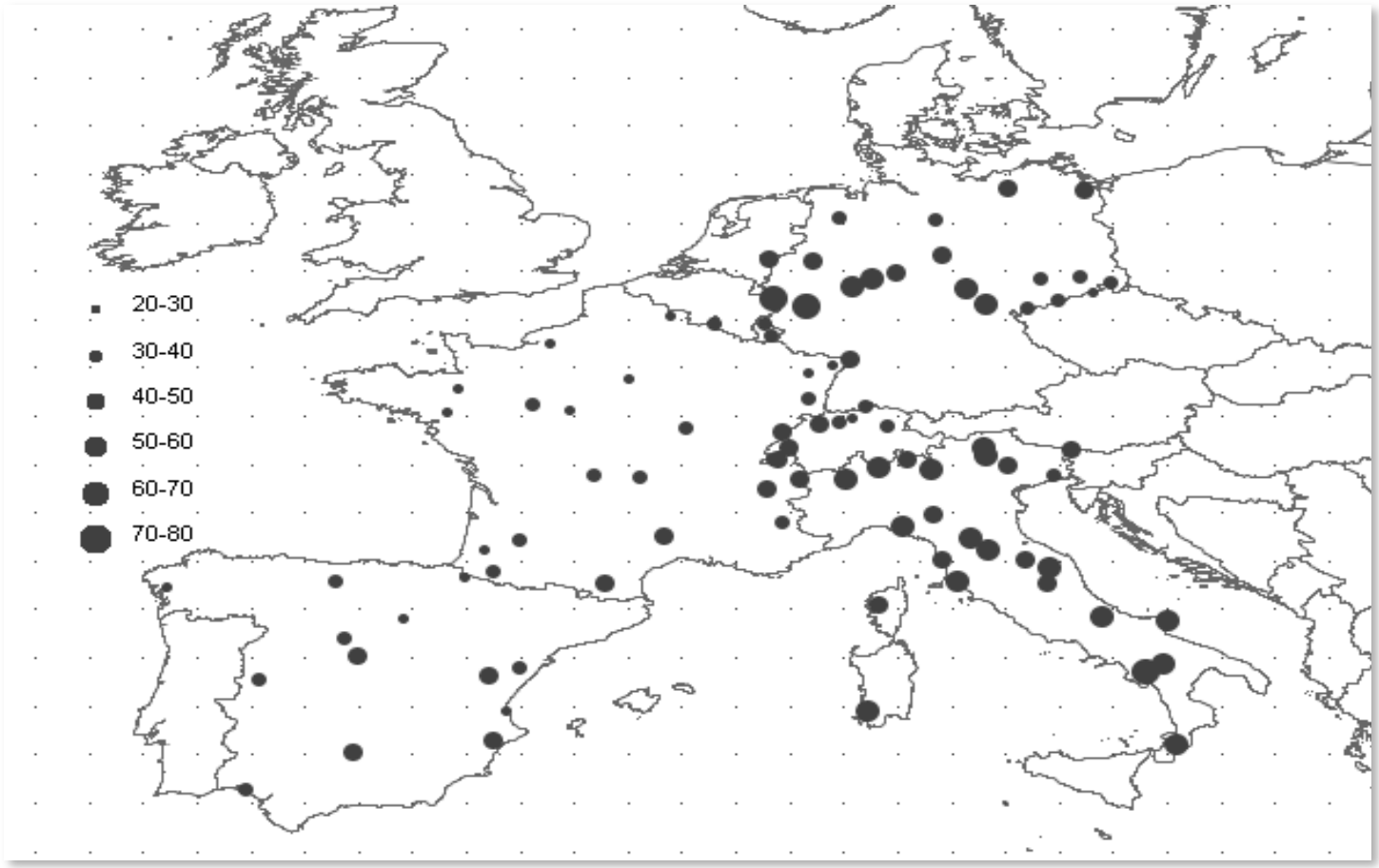
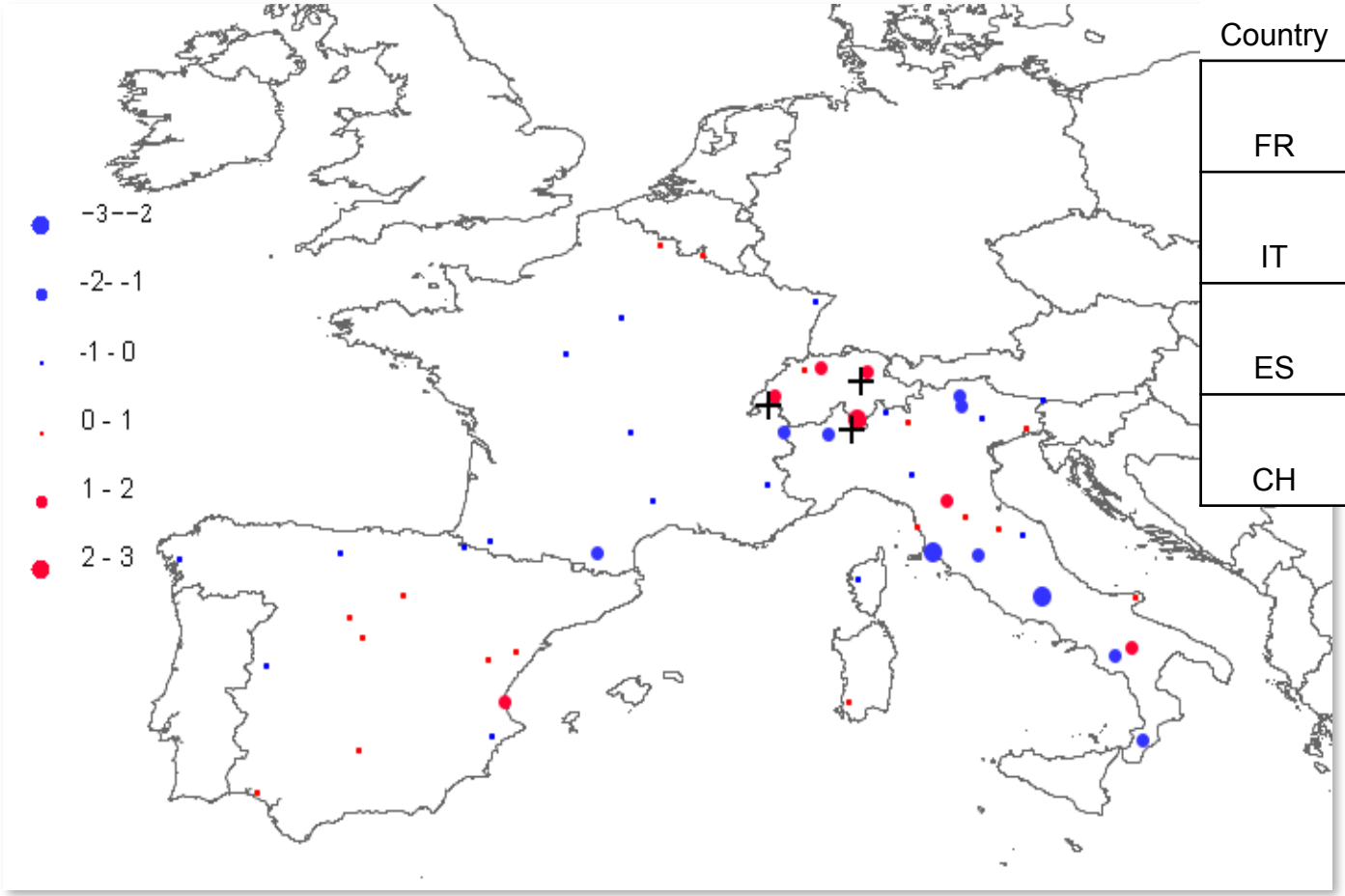


Figure 2. **2000-2010** [$O_{3\_passive}$] weighted means for plots with a coverage ≥80% during April-September and ≥5 years coverage.

Results – temporal O_3 trend

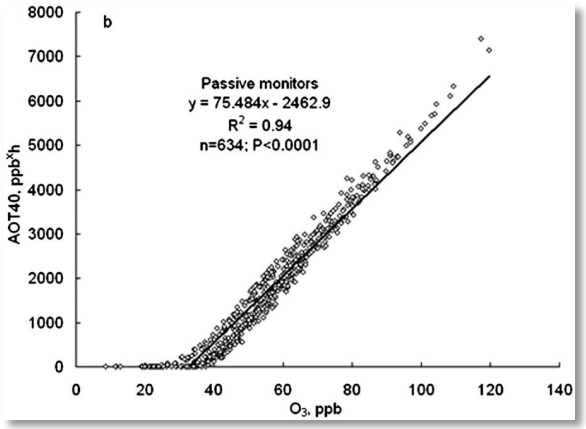


Country	Slope	Sign.	Nr Plots
FR	Decrease	NO	9
	Increase	NO	2
IT	Decrease	NO	14
	Increase	NO	9
ES	Decrease	NO	5
	Increase	NO	8
CH	Increase	NO	3
		YES	3

Figure 3. Increasing (25 plots) and decreasing (28 plots) trends of ozone concentrations during 2002-2010 with three significant ($p<0.05$) plots (+).

Methods – AOT40 estimation

- 2000-2002 data from IT, SP, FR, CH
- Approaches: (i) Gerosa et al. 2007,
  (ii) Ferretti et al. 2012 and (iii) EMEP



Ferretti et al. 2012 approach:

- Rapid, empirical method for estimating weekly AOT40 from [$O_{3\_passive}$]
- **$AOT40_{season}=\Sigma AOT40_{weekly}=\Sigma(75.848 * [O_{3\_passive\_weekly}]- 2462.9)$**
- For [$O_{3\_passive\_weekly}$] < 32.47 ppb -> AOT40 is assumed to be 0
- No assumptions, no complex modeling technique

- Time period June-September
- Gap filling: duplication of data from previous weeks to obtain weekly concentrations for 18 consecutive weeks
- For ES, June-Sept data were estimated from mean Apr-Sept/June-Sept ratio from the other countries based on Gerosa et al. 2007

Results – AOT40

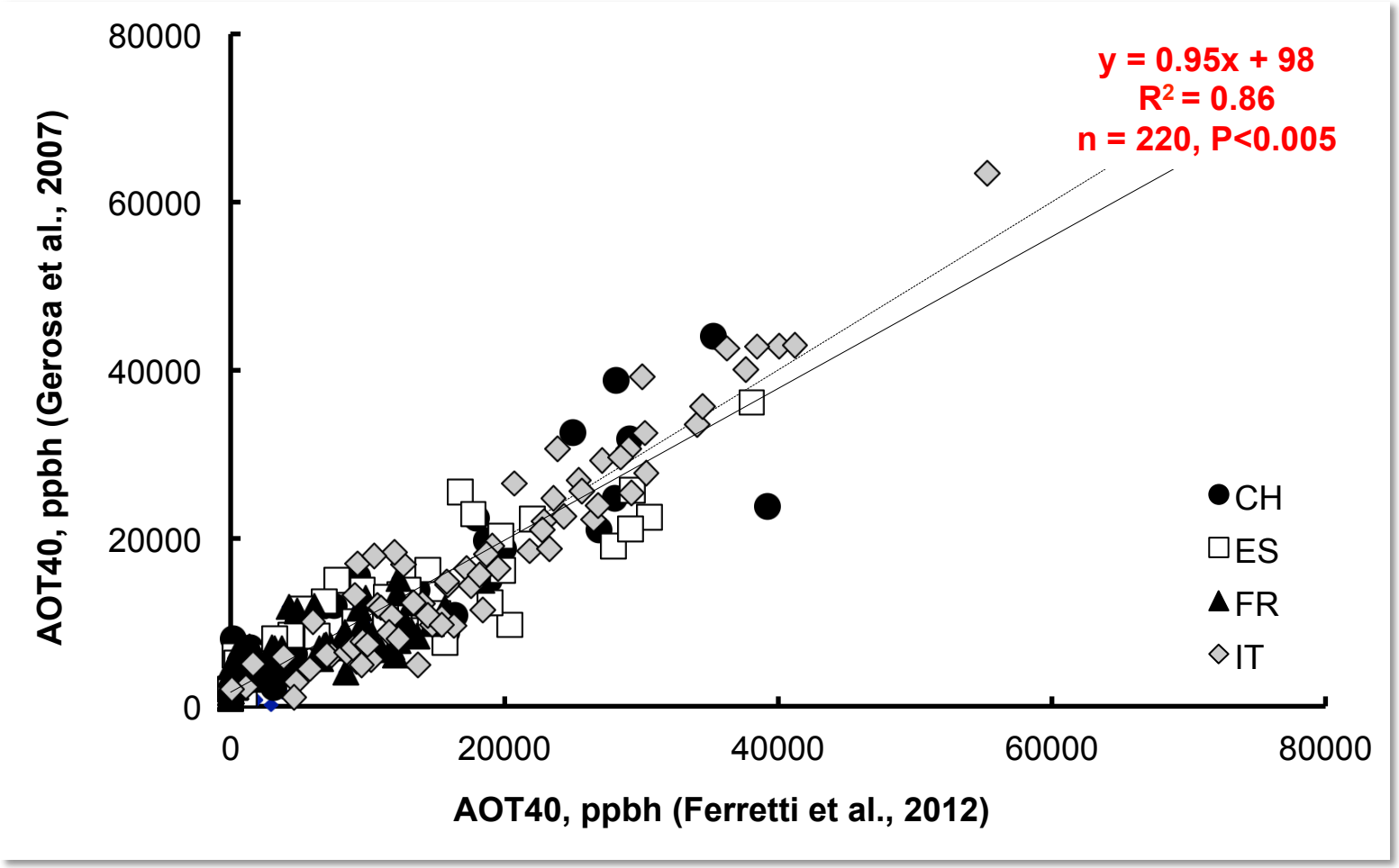


Figure 4. Comparison of AOT40 analyses according to Gerosa et al. 2007 *vs*. Ferretti et al. 2012.

Results – AOT40

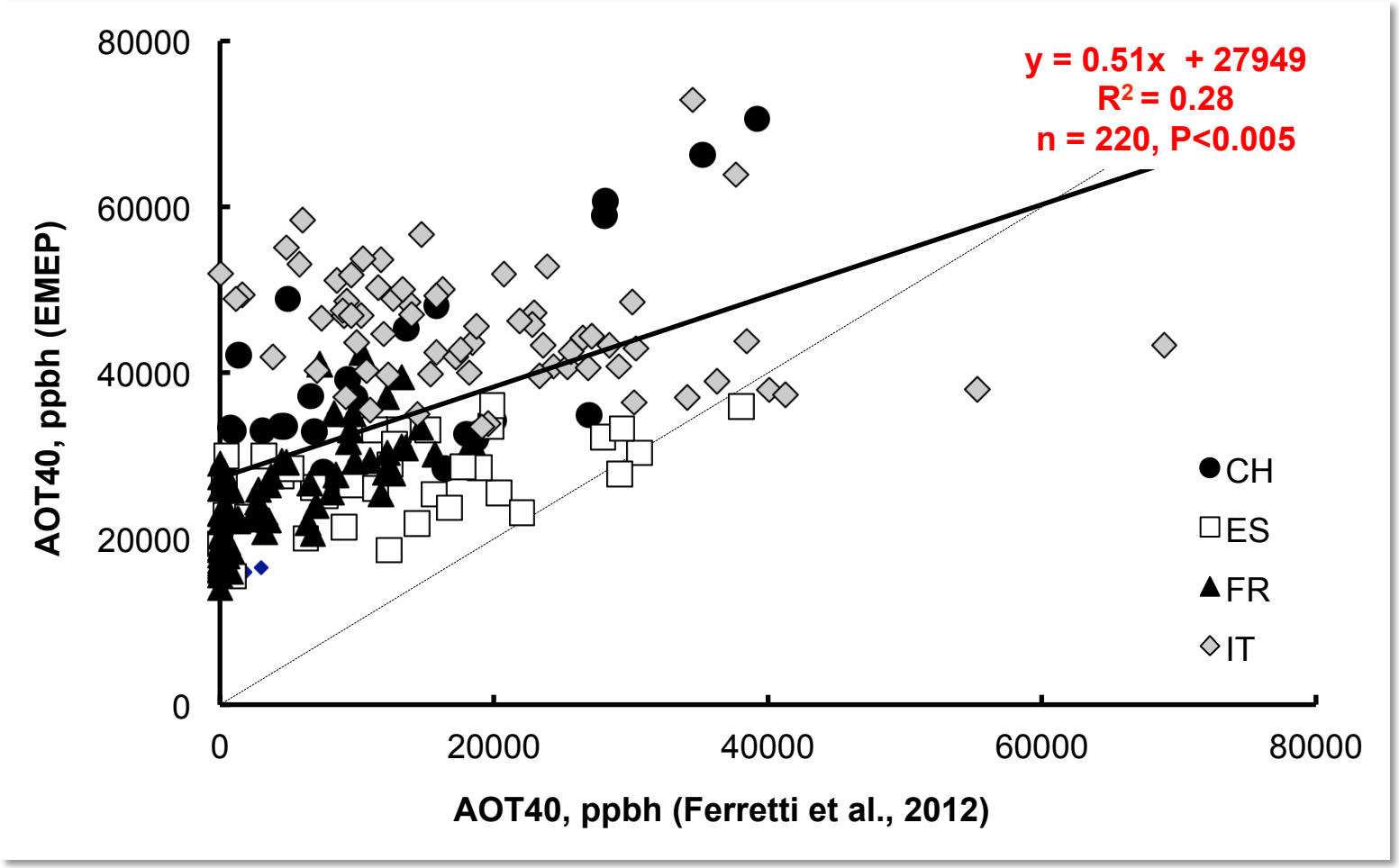


Figure 5. Comparison of AOT40 analyses according to EMEP *vs*. Ferretti et al. 2012.

Results – AOT40

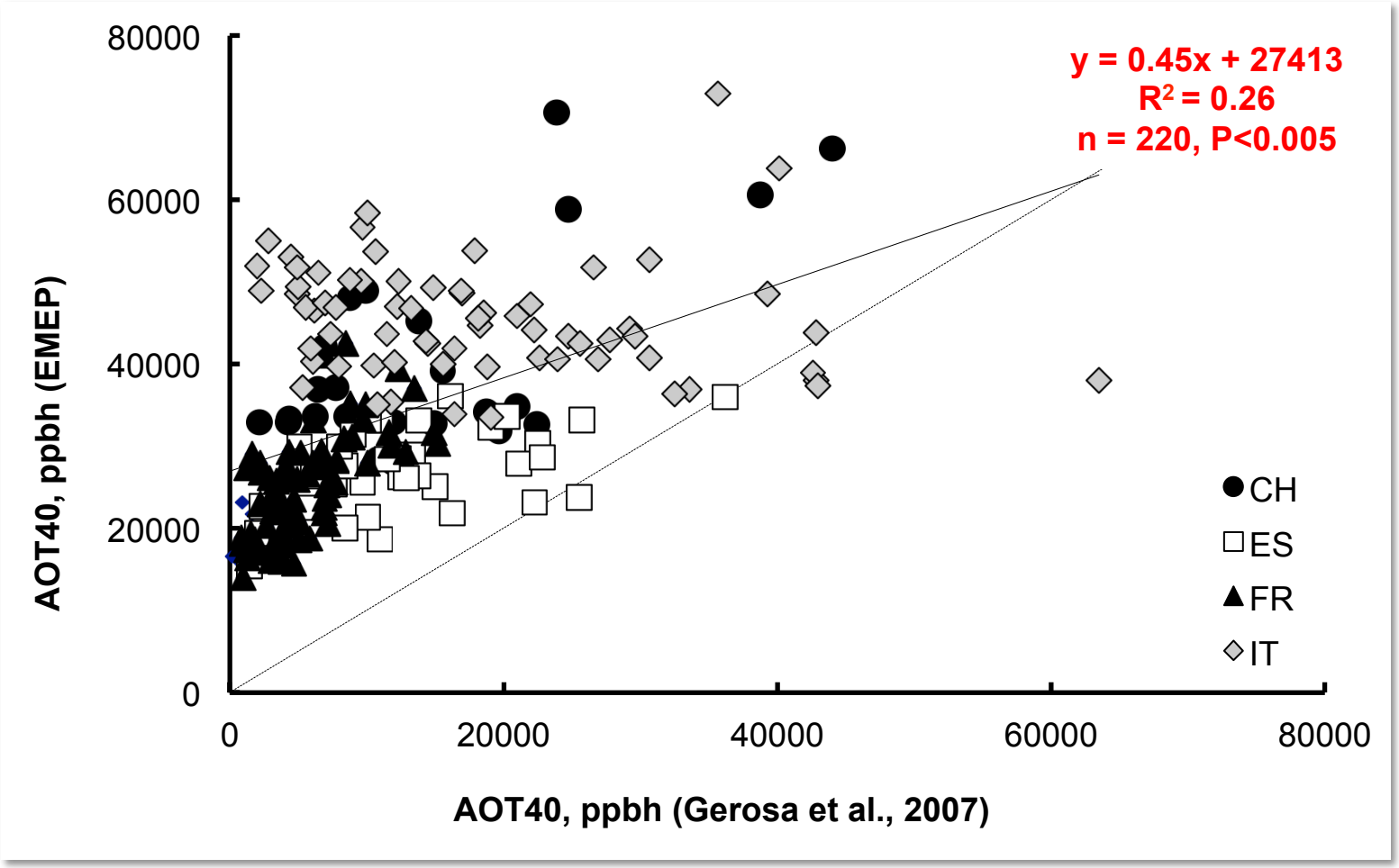


Figure 6. Comparison of AOT40 analyses according to EMEP *vs*. Gerosa et al. 2007.

Results – AOT40

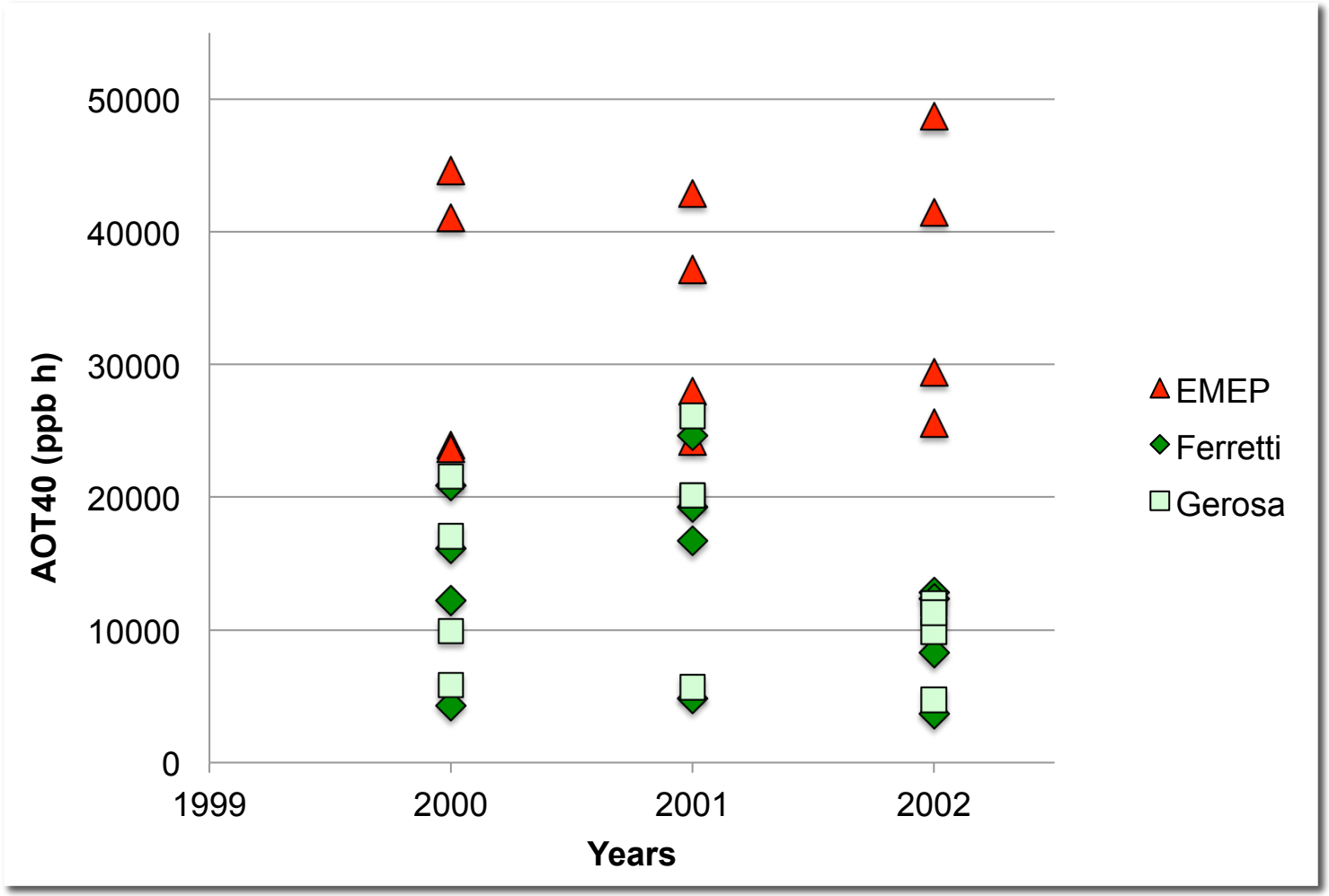


Figure 7. Comparison of AOT40 approaches/values for CH, ES, FR, IT.

Symptoms – ICPF data base

Table 5. No. of Level II plots with ozone symptom assessment at LESS (ICP Forests data base, March 2014).

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Austria								6	6	
Belgium					1	1	1	4	4	
Croatia										1
Cyprus								2	2	
Czech Republic						6	3	4	6	7
France				2						
Germany				3				18	25	11
Greece								2	3	3
Hungary		9	9	9	9			5	5	5
Italy			4	8	4	4	2	22	22	4
Latvia			1							
Lithuania			9			9	9	9	9	9
Romania								4	4	3
Serbia								1	1	1
Slovak Republic						1	3	8	8	8
Slovenia								4		
Spain	11	10	3		13	13	13	13	13	13
Switzerland	16	15	13	8	7	7	7	8		8
UK			7							
Total	**27**	**34**	**46**	**30**	**34**	**41**	**38**	**110**	**108**	**73**

Methods – DQL [symptoms]

- Data based on LESS surveys
- Non-conservative: periennial species ->

  (Conservative: perennial & woody & validated only -> 6 countries, 43 species)
- Completeness ≥ 80% of the expected number of quadrates (not applied)
- *Rubus* sp. omitted (*Rubus* sp., *Rubus fruticosus* group, *Rubus idaeus*, …)
- Species and genus mixed, only one count (*Cornus sanguinea*, *Cornus* sp.)

Results – frequency of symptoms

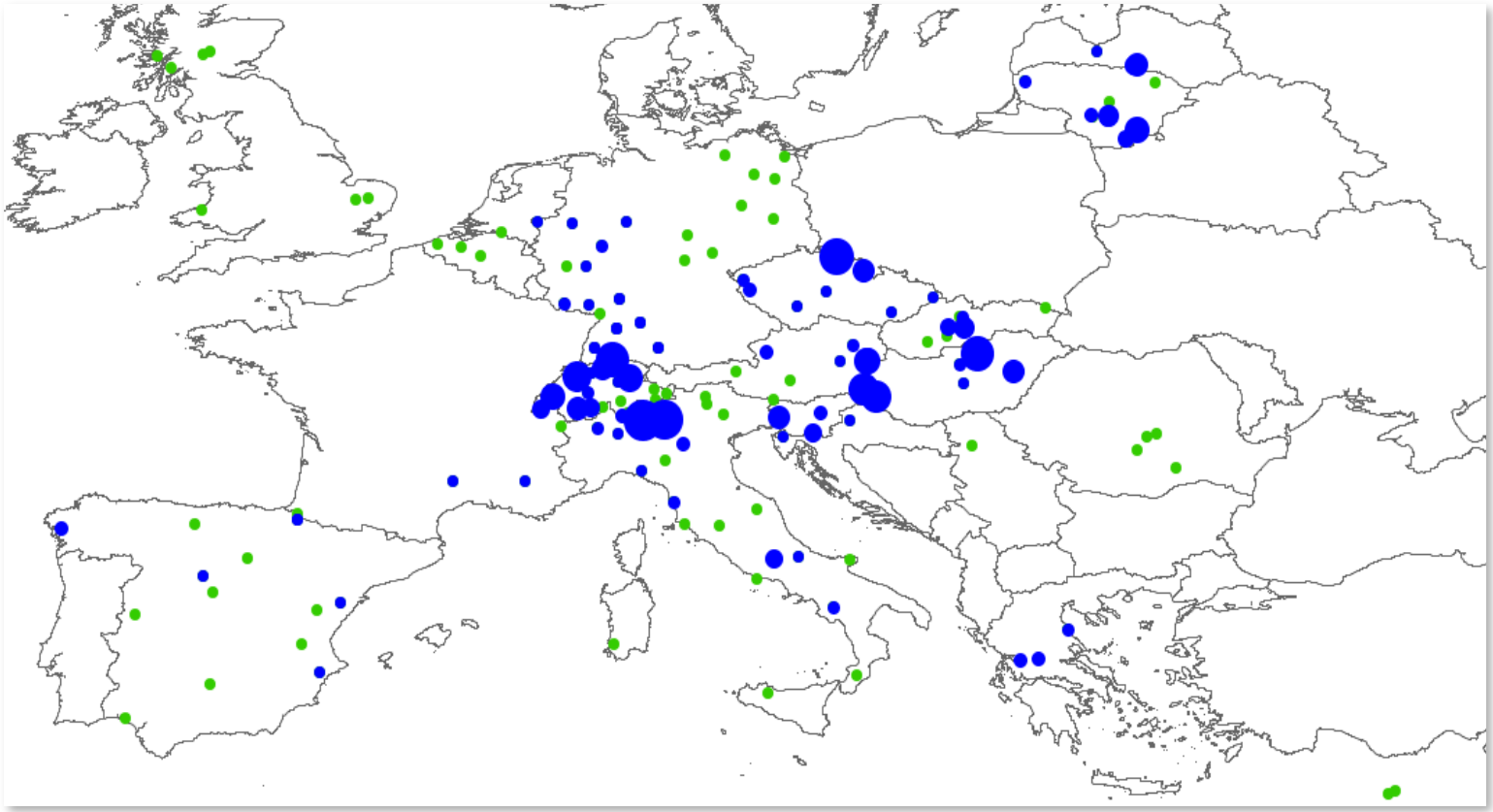


Figure 8. Frequency of number of symtomatic and non-symptomatic species per plot in 2002-2010 based on a total of 206 ICPF Level II plots. Max. sympt. species = 29 per plot.

Results – frequency of symptoms

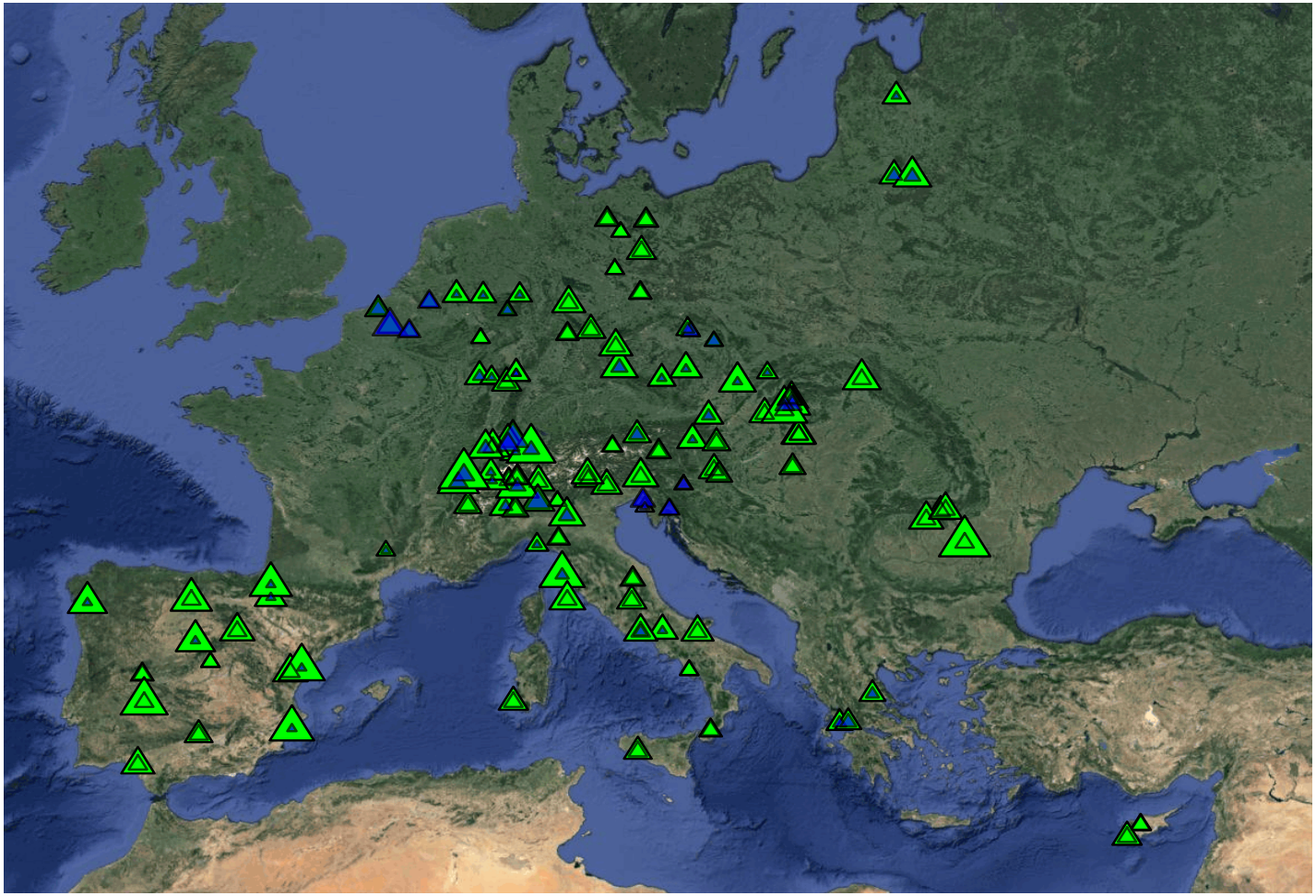


Figure 9. Frequency of symptomatic (▲) and non-symptomatic (△) species in relation to species diversity, i.e. number of assessed species for 2002-2010.

Results – symptoms *vs*. [$O_{3\_passive}$]

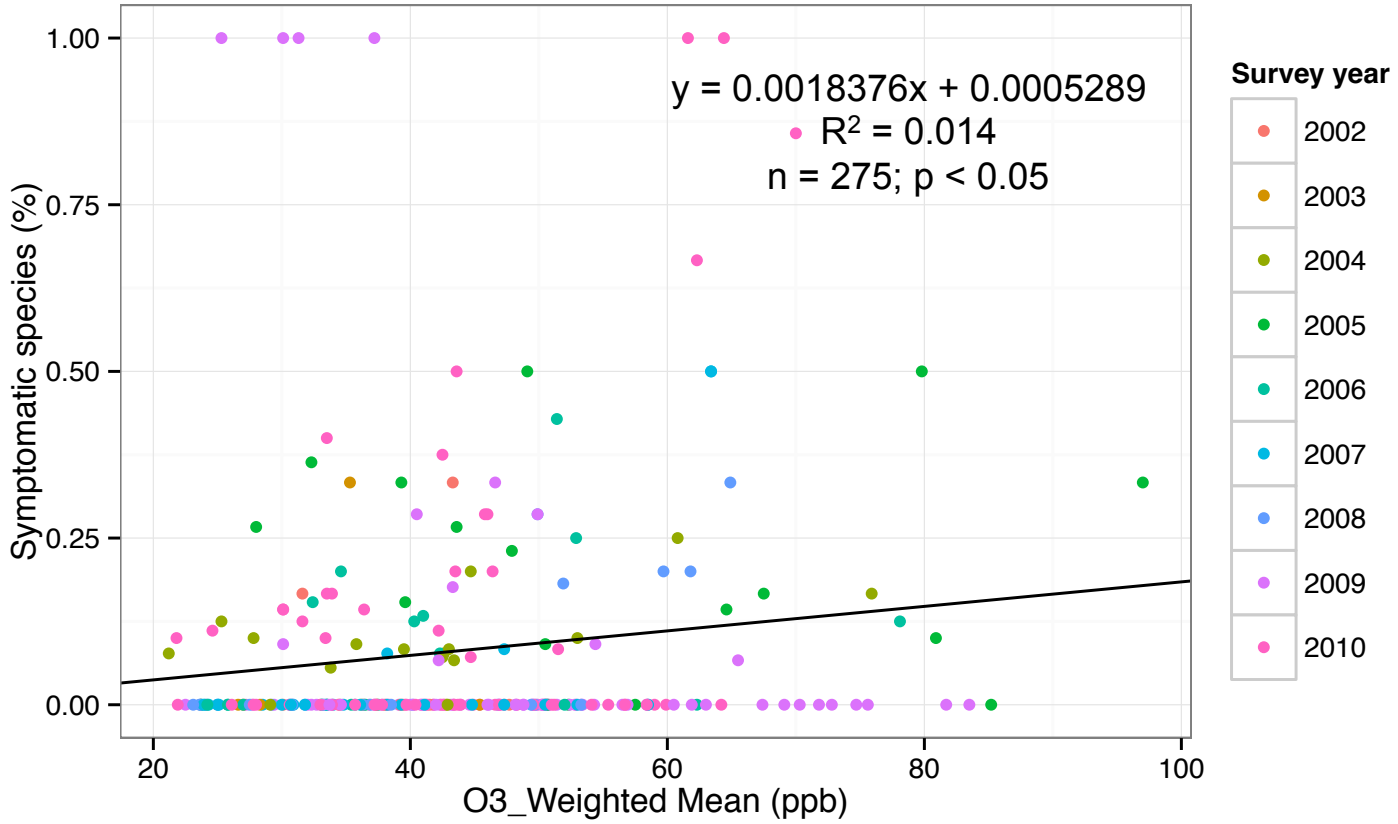


Figure 10. Correlation analyses for 2002-2010: %symptomatic species *vs*. weighted means of [O_3].

Results – symptoms *vs*. [$O_{3\_passive}$]

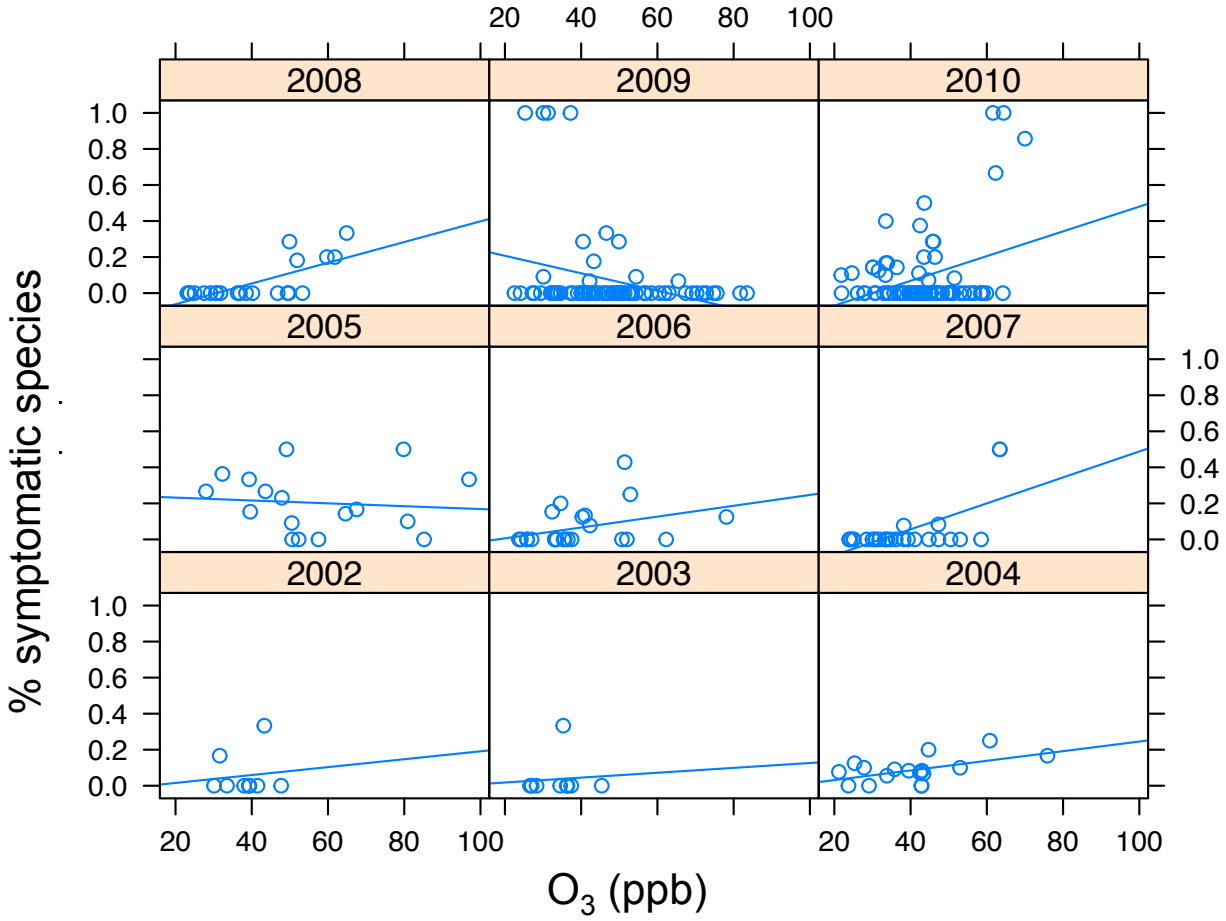


Figure 11. Correlation analyses for 2002-2010: %symptomatic species *vs*. weighted means of [O_3] with a total of 195 symptomatic species.

Conclusions I

1) For **ozone concentrations**, neither a spatial nor a temporal trend could be found across Europe and for 2000-2010.
    - For most plots in FR, IT, ES and CH, there seems to be a decreasing trend for ozone concentrations – but non-significant.
    - The significant increase for three Swiss plots needs further investigation.
2) As demonstrated by the Ferretti 2012 approach, ozone concentration serves as a good proxy for **AOT40**.
    - While the two approaches from Ferretti 2012 & Gerosa 2007 correlate quite well (R^2 = 0.86), the **EMEP model outputs** seem to overestimate AOT40 estimates from field measurements.
3) Frequency of symptom occurrence seems to be highest in central Europe. However, influence of species diversity (numbers of species assessed) needs further investigation.

Conclusions II

4) Across 2002-2011, there is no *significant* correlation between ozone concentration and % of symptomatic species.

5) Possible sources of variation:

   a) passive ozone devices
   b) different people (countries & Bundesländer)
   c) microclimatic conditions (VPD, PAR, SWC)
   d) site specific species diversity
   e) presence/absence of sensitive species

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