Downwind deposits of spray drift: a probabilistic approach

Henk Jan Holterman

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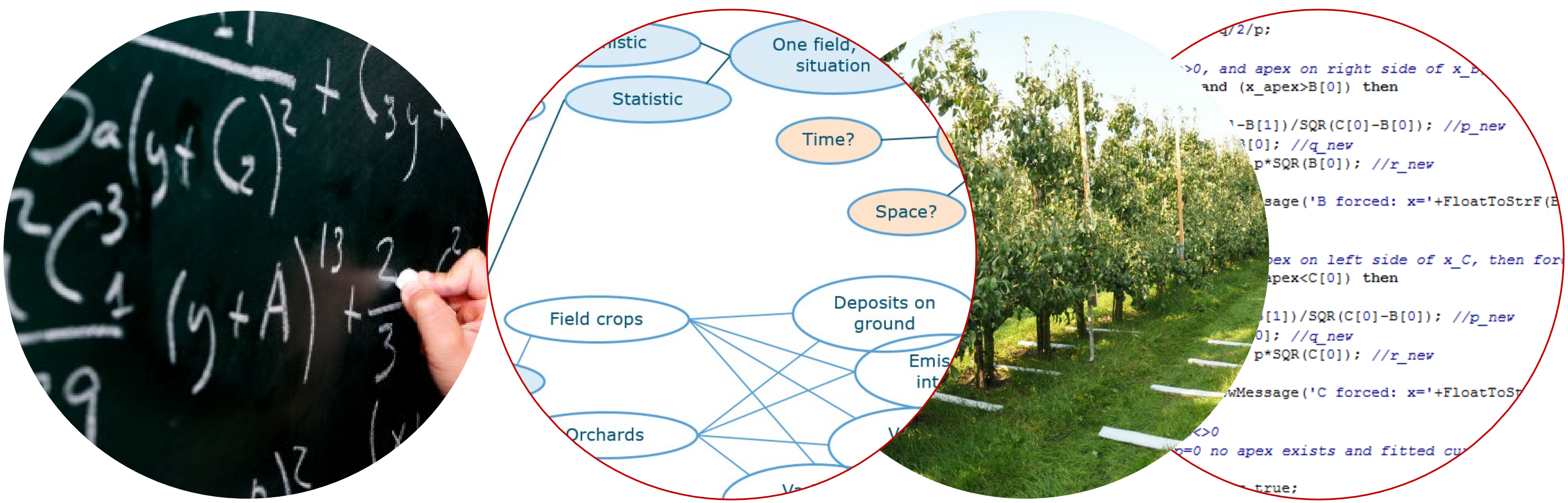

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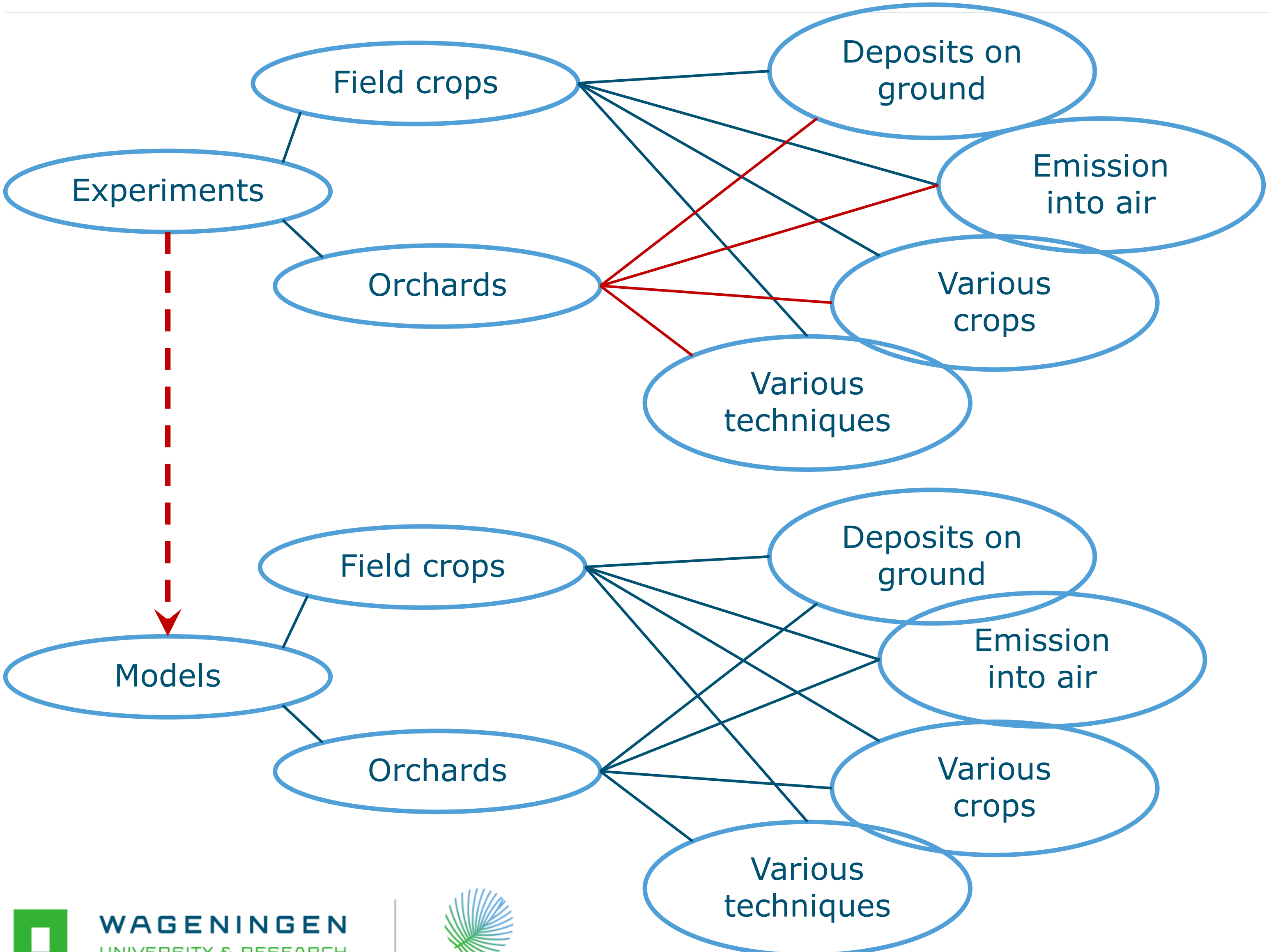
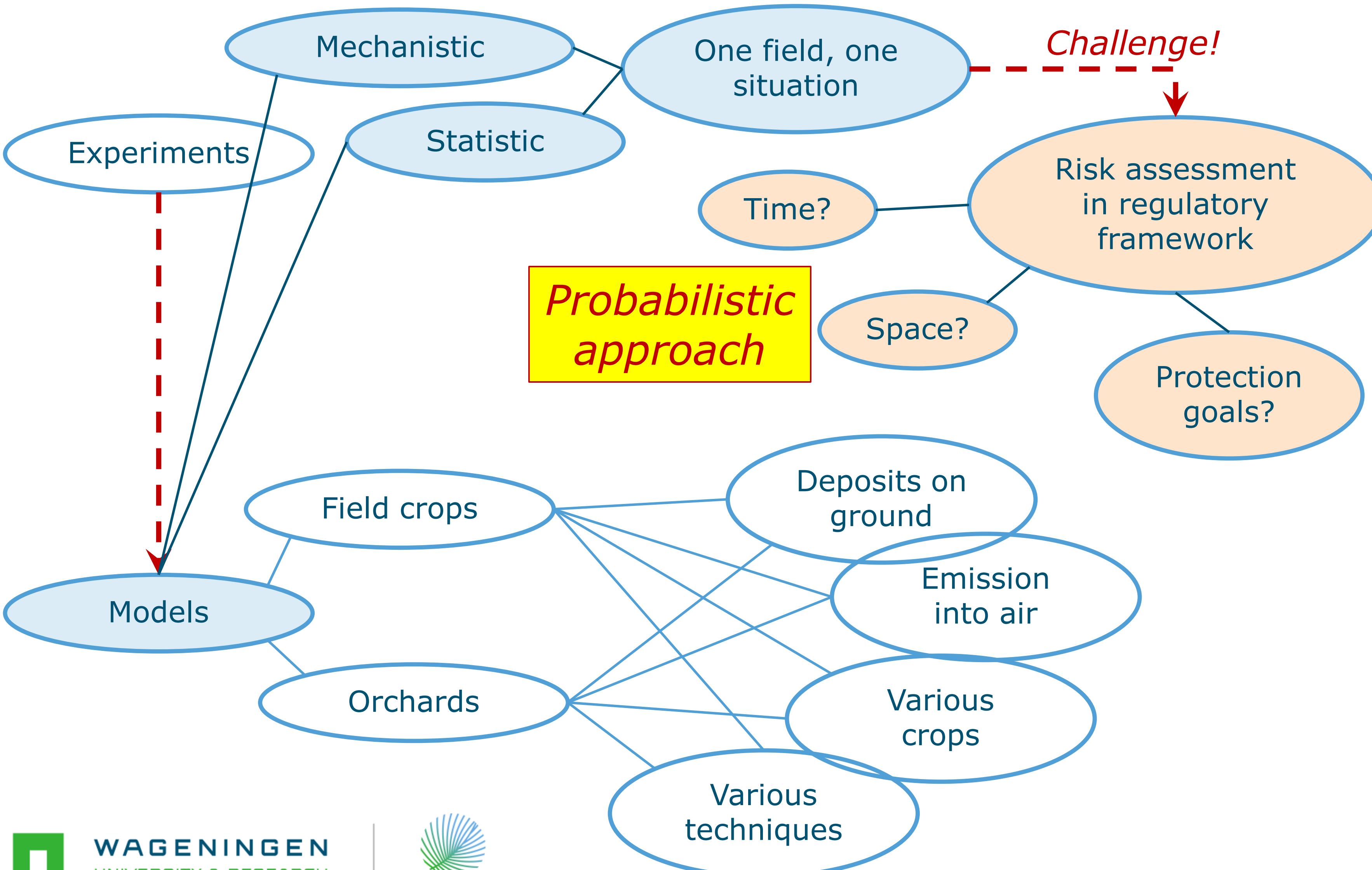
overview

- Introduction
- Probabilistic spray drift modelling in fruit growing
- Probabilistic spray drift modelling, other cases
- Discussion

Spray drift studies



Spray drift studies



overview

- Introduction
- **Probabilistic spray drift modelling in fruit growing**
- Probabilistic spray drift modelling, other cases
- Discussion

Current situation

- Fruit growing in NL: 19,000 ha
  - Pome fruit (apple, pear): 85%
- Current Dutch regulations: drift deposits on *standardized ditch*:
  - *Dormant*: drift deposits 17% of applied dose (<May 1)
  - *In full leaf*: 8.6% of applied dose (≥May 1)

Exposure risk in fruit growing

- Main objective of the project:

  Development of *higher-tier assessment tool* for authorization of pesticides in *fruit* growing regarding the risk of *exposure* of *aquatic organisms* to *pesticides*

- Considerations/limitations:
  - Scale = The Netherlands
  - Edge-of-field watercourses only
  - Spray drift is major entry route
  - As realistic as possible

project set-up: ‘multi-stage rocket’

Launch Apollo 11; 1969
courtesy: NASA

implementation into **DRAINBOW**:
risk assessment model for
exposure of aquatic organisms to ppp
due to drift and drainage
considering hydrology, time development etc.

+TOXSWA

selection of
representative scenarios
corresponding to a 90% risk level

exposure assessment model:
risk analysis for whole NL:
simulation of ppp deposits onto
all watercourses next to *all orchards* in NL

GIS maps

spray drift model:
compute deposits of
plant protection product (ppp)
onto edge-of-field watercourse
next to an orchard

one orchard, one ditch

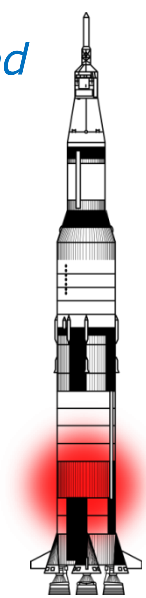
'stage 1': modelling spray drift in fruit growing

Spray drift model SPEXUS:

(**sp**ray drift **ex**posure model for **u**pward and **s**ideways applications)

- empirical, based on 20 years of field trials
- apple tree orchards (most important fruit crop in NL)
- regression analysis reveals most important factors

spray deposits measured next to fruit orchard, 0 – 25 m downwind, in duplicate



Spray drift model basics

$$y = q_1 e^{-q_2 x^c}$$

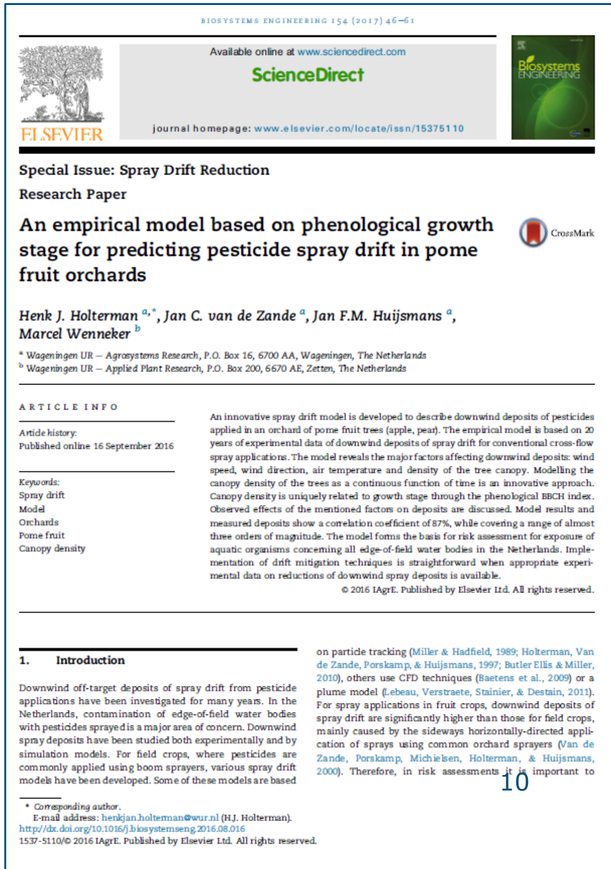
y = spray drift deposits; x = distance downwind

q_1, q_2, c : positive constants, depending on:

- wind speed
- wind direction
- ambient temperature
- canopy density (→ *growth stage; BBCH*)
- orchard size
- sprayer settings

Fitting the model to experimental data yields the optimal relations for q_1, q_2 and c

Details are presented in paper:
Biosystems Eng. 154(2017):46-61
http://dx.doi.org/10.1016/j.biosystemseng.2016.08.016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Special Issue: Spray Drift Reduction
Research Paper

An empirical model based on phenological growth stage for predicting pesticide spray drift in pome fruit orchards

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An innovative spray drift model is developed to describe downwind deposits of pesticides applied in an orchard of pome fruit trees (apple, pear). The empirical model is based on 20 years of experimental data of downwind deposits of spray drift for conventional cross-flow spray applications. The model reveals the major factors affecting downwind deposits: wind speed, wind direction, air temperature and density of the tree canopy. Modelling the canopy density of the trees as a continuous function of time is an innovative approach. Canopy density is uniquely related to growth stage through the phenological BBCH index. Observed effects of the mentioned factors on deposits are discussed. Model results and measured deposits show a correlation coefficient of 87%, while covering a range of almost three orders of magnitude. The model forms the basis for risk assessment for exposure of aquatic organisms concerning all edge-of-field water bodies in the Netherlands. Implementation of drift mitigation techniques is straightforward when appropriate experimental data on reductions of downwind spray deposits is available.

1. Introduction

Downwind off-target deposits of spray drift from pesticide applications have been investigated for many years. In the Netherlands, contamination of edge-of-field water bodies with pesticides sprayed is a major area of concern. Downwind spray deposits have been studied both experimentally and by simulation models. For field crops, where pesticides are commonly applied using boom sprayers, various spray drift models have been developed. Some of these models are based on particle tracking (Miller & Hadfield, 1989; Holterman, Van de Zande, Porskamp, & Huijsmans, 1997; Butler Ellis & Miller, 2010), others use CFD techniques (Baetens et al., 2009) or a plume model (Lebeau, Verstraete, Stainier, & Destain, 2011). For spray applications in fruit crops, downwind deposits of spray drift are significantly higher than those for field crops, mainly caused by the sideways horizontally-directed application of sprays using common orchard sprayers (Van de Zande, Porskamp, Michielsen, Holterman, & Huijsmans, 2000). Therefore, in risk assessments it is important to

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‘stage 2’: scaling up to countrywide approach

- Implementation of the SPEXUS model into countrywide exposure assessment model (whole NL)

  Finding a 90th percentile risk of exposure to ppp
  for all edge-of-field watercourses next to all fruit orchards in NL

- This requires:

  A. *Realistic mapping of orchards and watercourses* → *spatial configuration*

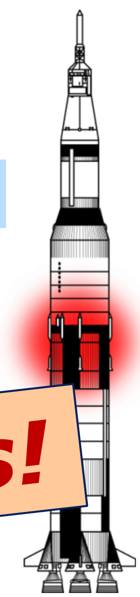
  B. *Realistic weather conditions* → *temporal configuration*

frequency distributions!

probability distributions!

frequency distributions!

probability distributions!



A. Spatial configuration

- Location, orientation and geometry
  of edge-of-field watercourses next to fruit orchards

- Spatial variables:
  - location of orchards (per districts)
  - watercourse types
  - water levels
  - orchard orientations
  - orchard side where watercourse is located

Countrywide risk assessment model

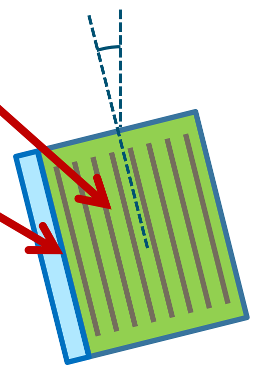
simulation procedure: *spatial* variables

All combinations of:

- district (14)
- water body (44)
- water depth (9)
- orchard orientation (18)
- orchard side where water body is located (4)

14 meteorological districts

description	profile width <3m	profile width 3-6m
Betuwe-komgronden	601001	602001
Betuwe-stroomruggronden	601002	602002
Dekzand profiel	601003	602003
Duinstrook	601004	602004
Eem en/of keileemprofiel	601005	602005
Keileem profiel	601006	602006
Keileem-Peelo profiel	601007	602007
Loss profiel	601008	602008
Nuenengroep profiel	601009	602009
Oost-Nederland profiel	601010	602010
Open profiel	601011	602011
Peelo profiel	601012	602012
Singraven-beekdalen	601013	602013
Stuwwallen	601014	602014
Tegelen/Kedichem profiel	601015	602015
Westland-C-profiel	601016	602016
Westland-D-profiel	601017	602017
Westland-DC-profiel	601018	602018
Westland-DH-profiel	601019	602019
Westland-DHC-profiel	601020	602020
Westland-H-profiel	601021	602021
Westland-HC-profiel	601022	602022



about 74,000 spatial configurations are simulated, weighted according to their probability of occurrence

B. Temporal configuration

- Variables that change over time
  - *crop stage (BBCH → DOY)* — *depends on spray application scheme*
  - wind speed
  - wind direction
  - ambient temperature

use regional division (meteorological districts)

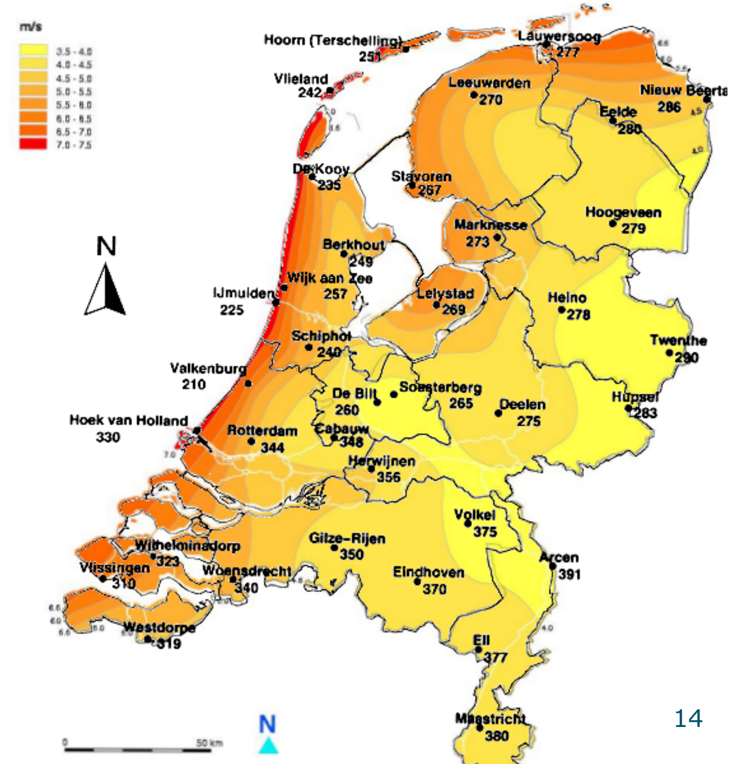
Frequency distributions

F (district, DOY)

using 20 yrs meteorological data, hourly base

(KNMI, Royal Dutch Meteorological Institute)

annually averaged wind speed



modified from: KNMI klimaatatlas

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Countrywide risk assessment model

simulation of meteorological years: *temporal* variables

Choose a spray application scenario
(*number of applications, dates, application techniques, ...*)

- dates determine canopy density (growth stage)
  → amount of spray drift

For each spatial configuration:

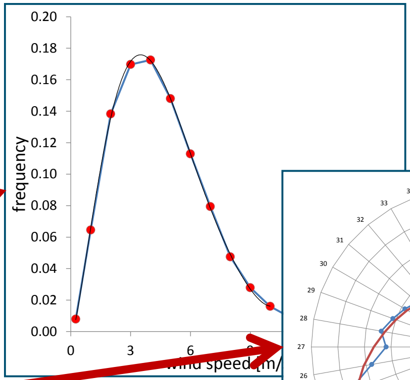
- Choose many years (e.g. 100)

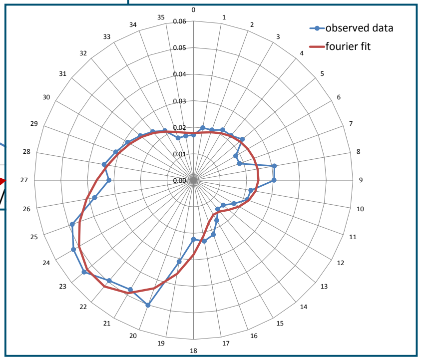
For each year, select:

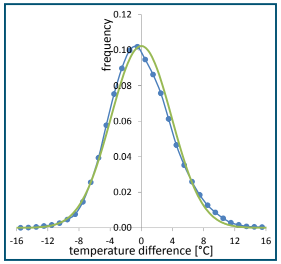
- Wind speed
- Wind direction
- Ambient temperature

randomly drawn from their frequency distributions

F (district, DOY)







‘stage 3’: representative configuration

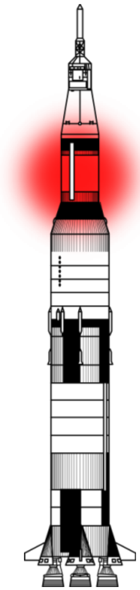
It is impossible to carry out full-scale risk assessment combining exposure and fate for all situations countrywide

Workaround:

- Can we select a *single spatial configuration* as a *representative* of all possible configurations?
- So that studying this *single* configuration allows us to do a *countrywide* risk assessment?

Yes we can!

Selection criteria for single config:
- Overall risk level ~90%
- Important spatial configuration
- Important fruit growing region
- Common water body type
- Common orchard orientation
- Common summer water level



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Countrywide scenarios procedure

- Selection of *limited* set of spray application scenarios
- Countrywide simulations for risk assessment, for these scenarios → compute *overall 90th % PEC*
- Selection of a *single* spatial configuration as a *representative* of all possible configurations
- Simulations for the *single* configuration during *many* stochastic years (e.g. 10,000 y)
- Determination of *temporal percentile* of single configuration corresponding to the overall 90th % PEC

a relatively common watercourse with a common water depth, in a district with lot of fruit growers, next to an orchard with common orientation

PEC = predicted environmental concentration

Typical scheme for spray applications in apple tree orchards

Week number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
dodine												1																																								
pyrimethanil													1																																							
dithianon														1																																						
cyprodinil															1																																					
dithianon																1	2																																			
thiacloprid																	1																																			
indoxacarb																	1																																			
penconazool																		1	2																																	
captan																		1	2				3	4	5	6	7			8	9		10					11				12		13		14						
trifloxystrobin																				1																																
chlorantraniliprole																						1																														
pirimicarb																							1																													
emamectine																											1																									
pyraclostrobine + boscalid																																		1	2																	

Selected basic scenarios

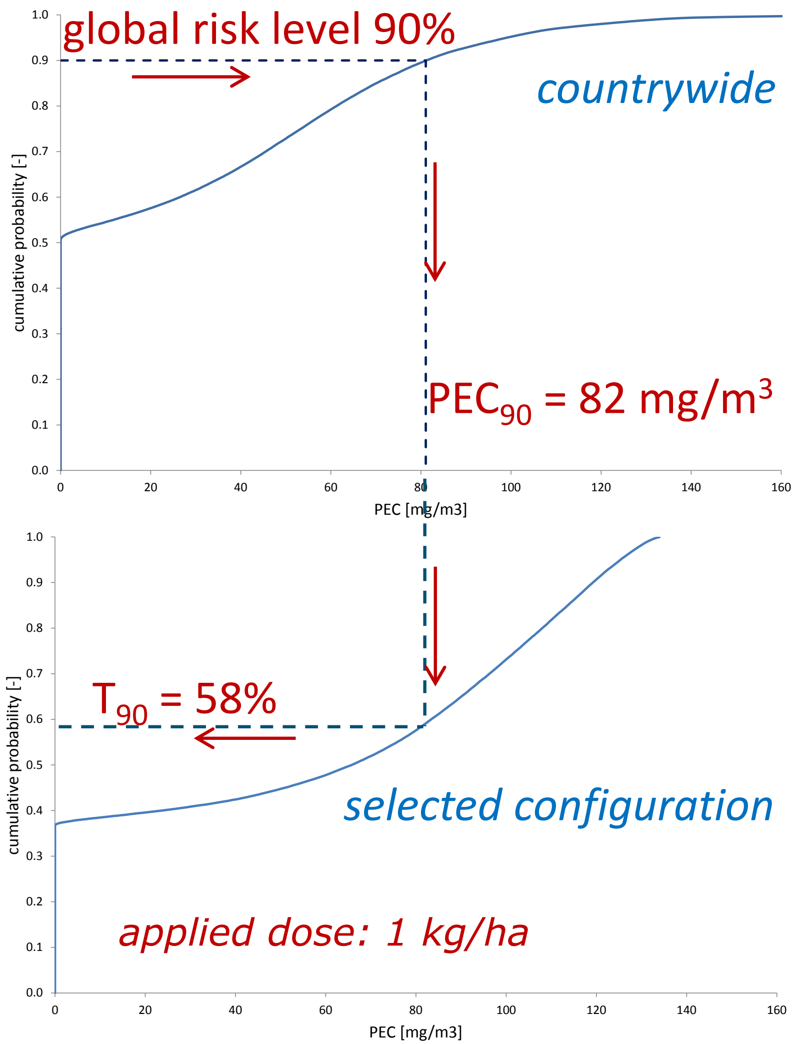
Five scenarios selected to represent most types of spray treatment and fate of pesticides

	scenario				
code	**E1**	L1	E3	L3	S15
application date	***E***arly	*L*ate	*E*arly	*L*ate	*S*eason
# spray applications	**1**		3		15

early = canopy starts developing (May)
late = in full leaf (August)
season = during summer season
multiple applications: 1 week interval;
full dissipation is assumed within one week

How to determine appropriate temporal percentile T_{90}

example: basic scenario E1



- 100 years
- 74,000 spatial configurations

  → *7,400,000 PECs*

to conclude for E1:
in a multi-year study
*for the **single** configuration*
the 58th percentile corresponds to
*the **countrywide** 90th percentile risk*

- 10,000 years
- 1 selected spatial configuration (monitoring)

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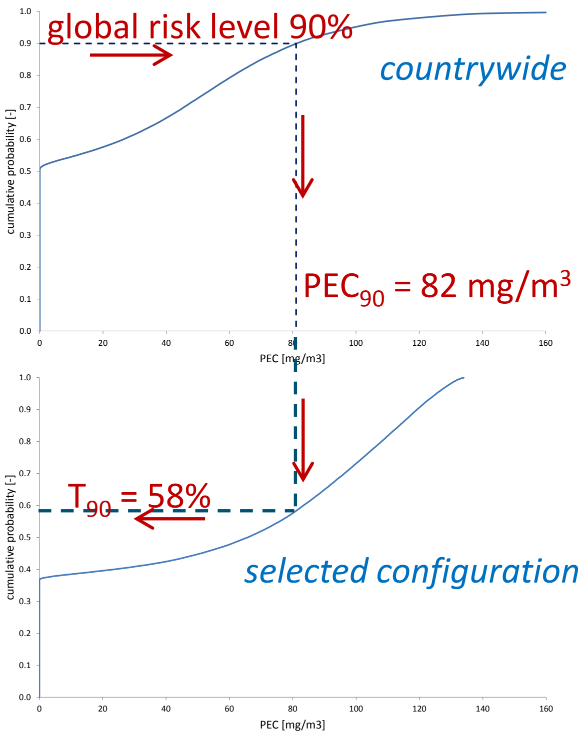
How to determine appropriate temporal percentile T_{90}

example: basic scenario E1



- Determine overall PEC_{90} (countrywide)
- Lookup this value in local cpdf
- Find corresponding temporal percentile T_{90}

Apply this procedure to

- 5 basic scenarios: E1, L1, E3, L3, S15
- 7 pesticide application techniques: conventional + 6 drift reducing techs
- 10 crop-free buffer zones: 0-9m

→ table of 350 T_{90} values !

real situations
(not covered by the basic scenarios)
can be approximated by 'smart interpolation'
using these 350 cases

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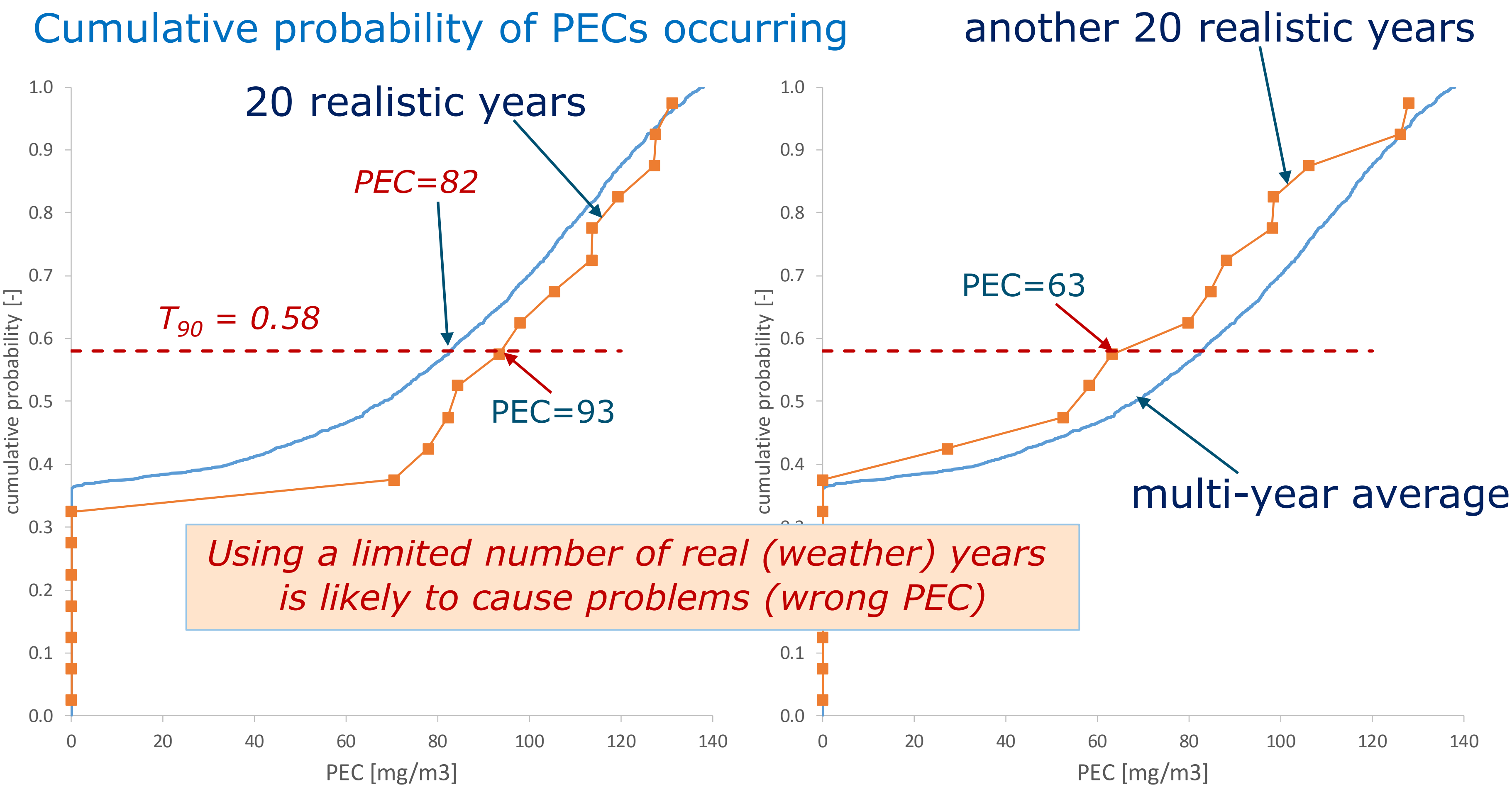
Scenario E1

20 yrs distributions, *selected* spatial config

Cumulative probability of PECs occurring

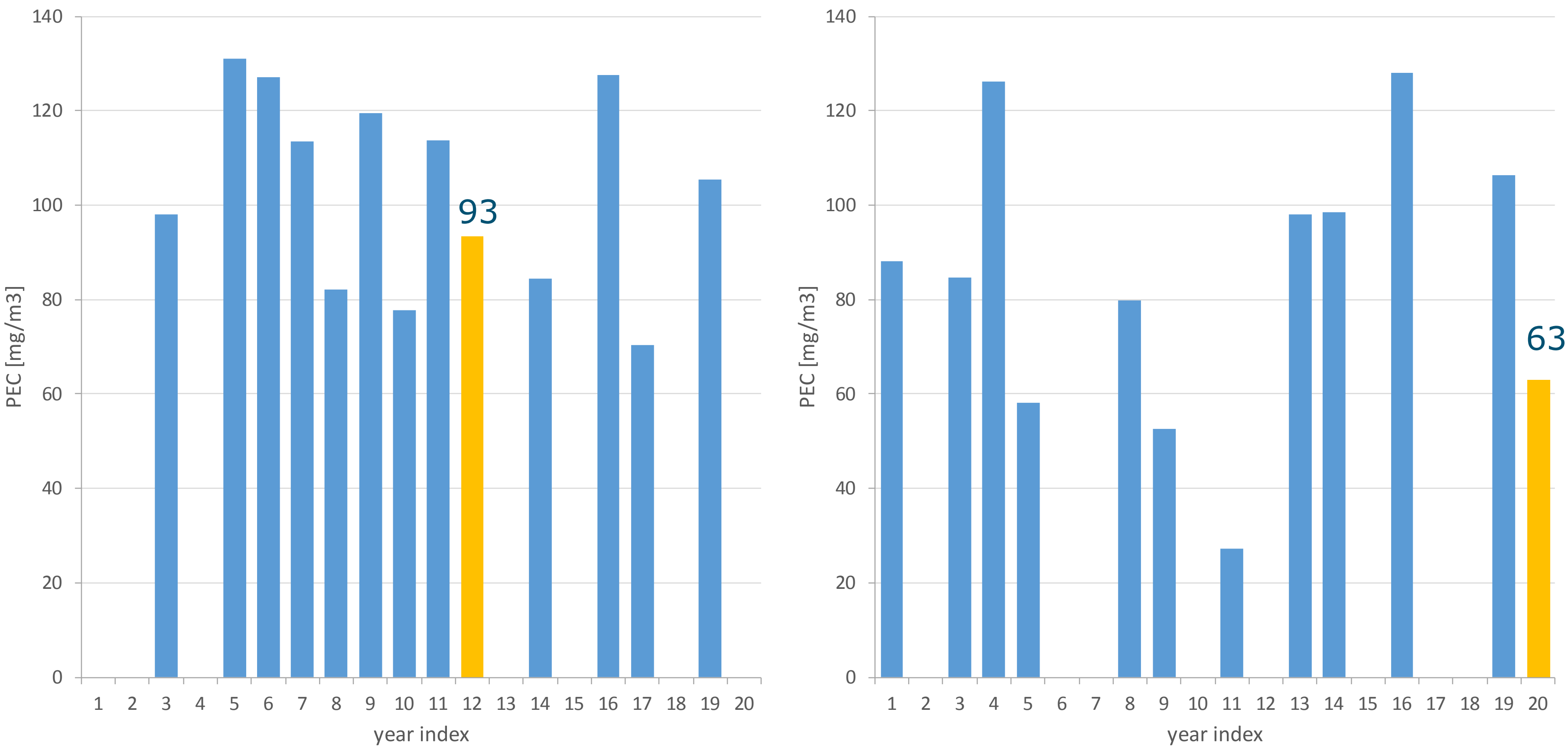


Using a limited number of real (weather) years is likely to cause problems (wrong PEC)

Scenario E1

20 yrs distributions, *selected* spatial config

Selecting the year with PEC close to the given percentile



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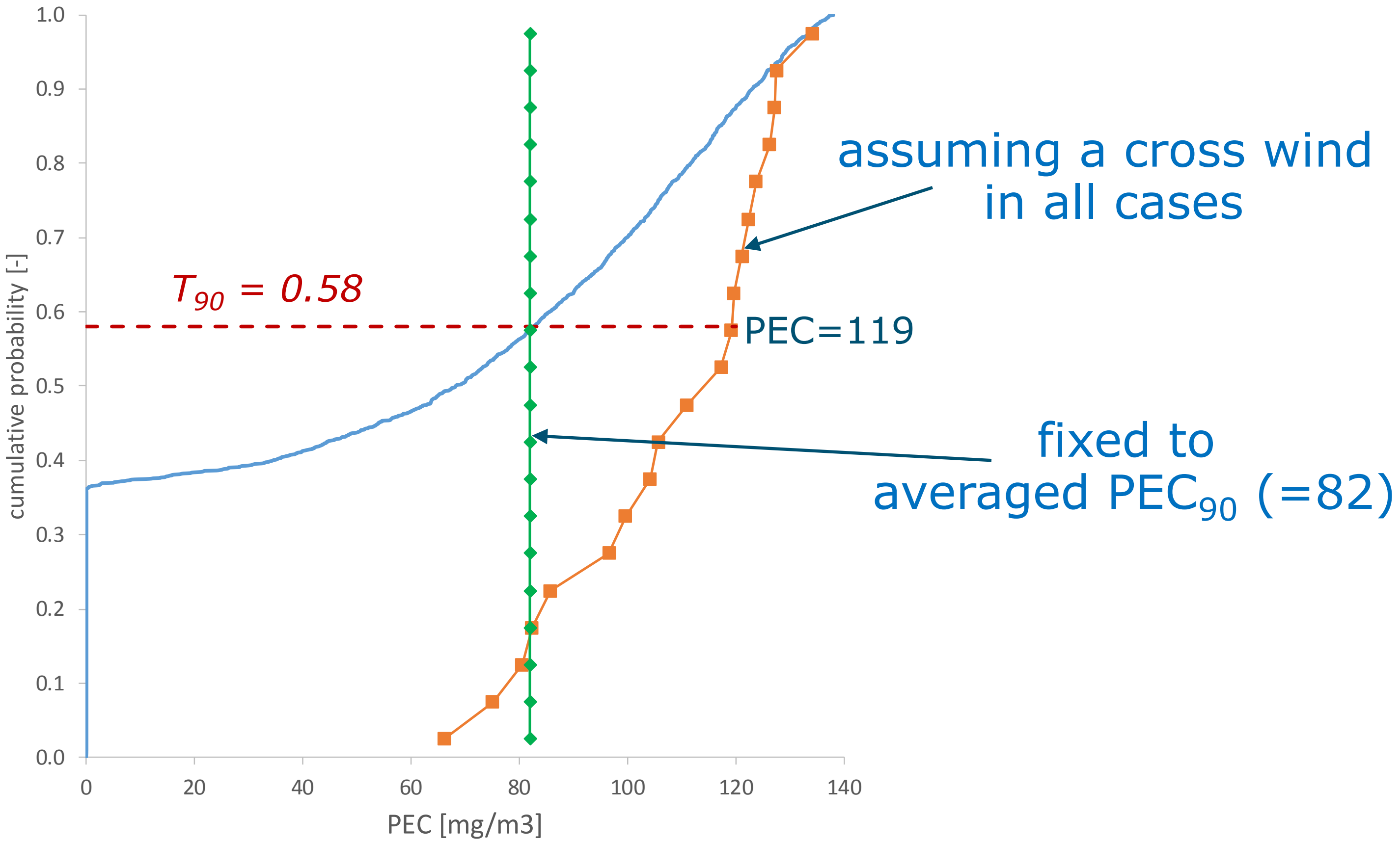
Scenario E1

20 yrs distributions, *selected* spatial config

Using simplified drift data for exposure is unrealistic



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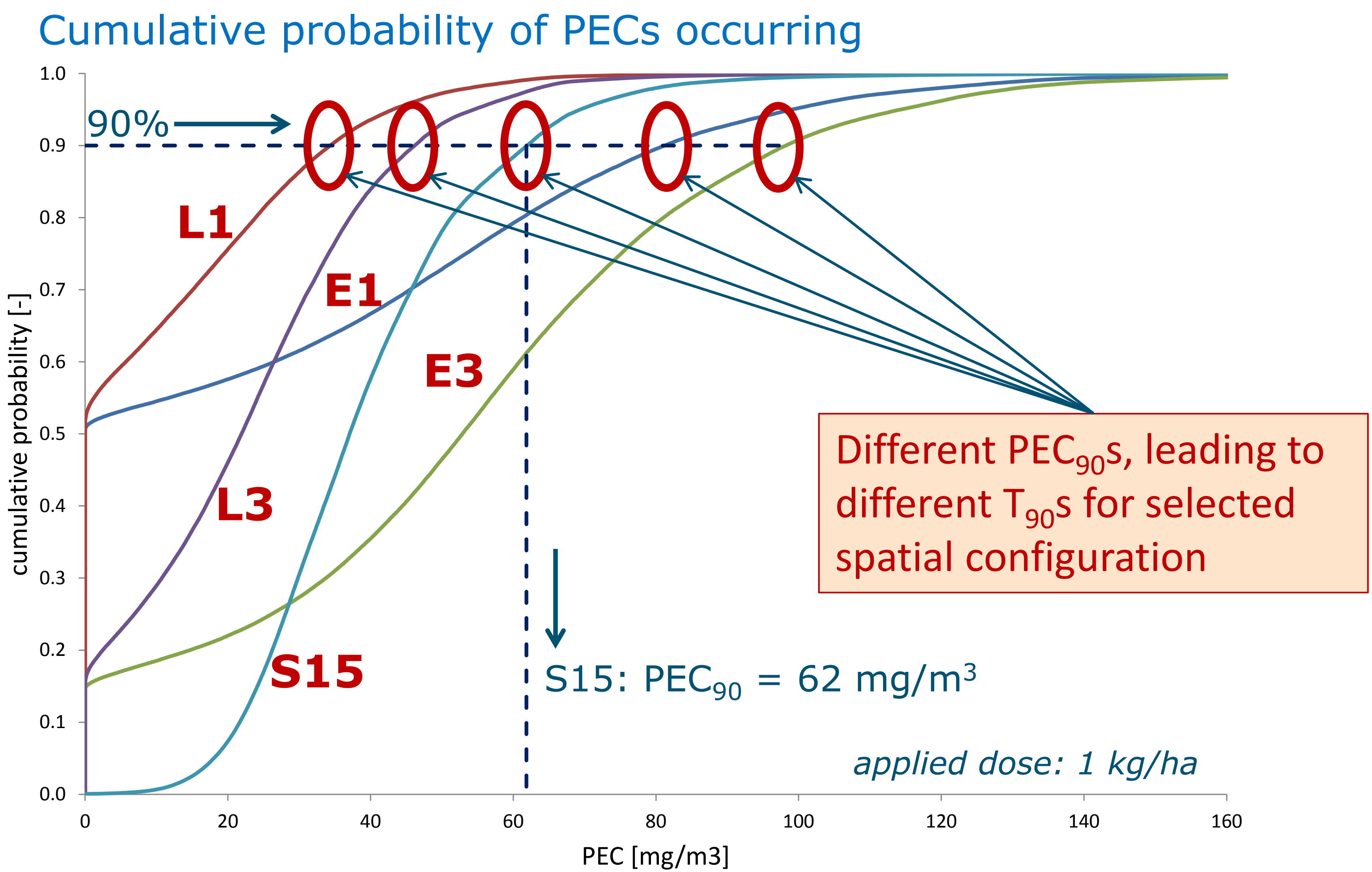
All basic scenarios

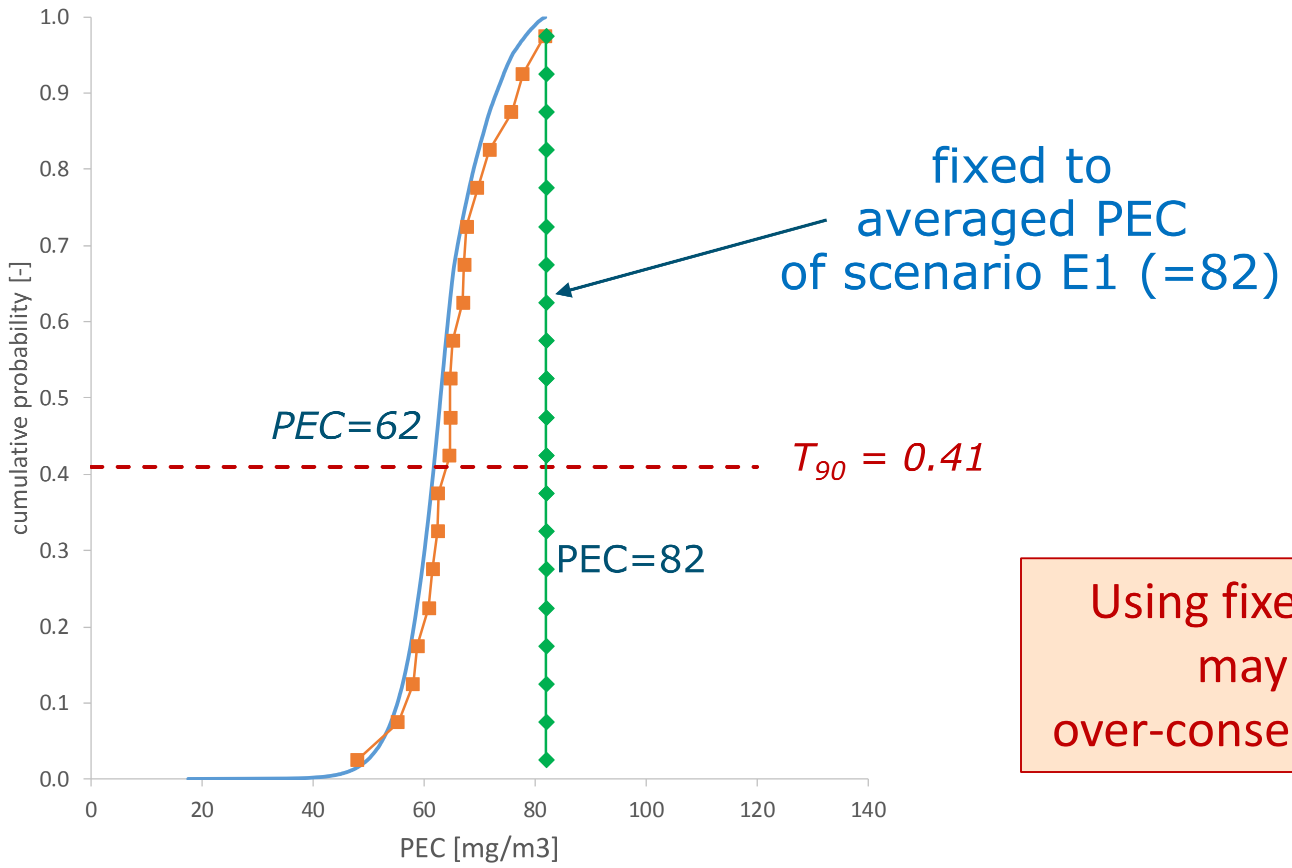
countrywide simulation, N=100yrs



Scenario S15: 15 spray applications

20 yrs distributions, *selected* spatial config

Assumption: risk is governed by *maximum* PEC of 15 applications



Using fixed drift input may lead to over-conservative results

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- **Probabilistic spray drift modelling, other cases**
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Probabilistic modelling, other crops/situations

- Under development...
- Field crops: same set-up seems possible:
  - Spray drift model *IDEFICS*
  - Combining NL maps of crops, edge-of-field watercourses
  - How to implement *crop rotation*? Is it relevant?
- Non-target arthropods & plants
- Exposure risk for workers, bystanders, residents

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- Probabilistic spray drift modelling for field crops
- **Discussion**

Discussion

- Highly drift-reducing techniques: input from *drains* may be significant! How does this affect the present results?
- Using *selected* ditch with *limited* number of basic scenarios is not ‘the real thing’
- Scenarios with *slow dissipation* of pesticides in ditch are not parameterised yet: *challenge!*
- Other countries/climates: same procedure should be possible, provided that all relevant data is available
- Regulatory implementation: combined exposure & fate; higher tiers: might be a ‘long and winding road’ ...


thank
you