Probabilistic model of realistic pesticide concentrations in surface waters in the Netherlands due to spray drift

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Overview

- Introduction
- Methods
- Results
- Conclusion

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Introduction

- In the Netherlands about 300,000 km of watercourses is present. Preserving these from contamination with hazardous chemicals remains a major challenge.
- Monitoring studies occasionally indicate pesticide concentrations that exceed predefined acceptable levels.
- A new procedure to authorize plant protection products is being developed: '**Dutch interim scenario**'; it focuses on modelling and assessing the processes involved with the spreading and fate of pesticides in edge-of-field watercourses.
- **Spray drift** is an important entry route of pesticides. From spray drift deposits onto surface waters **PEC** levels can be computed. Given a spray application technique, three major factors affect PEC levels:
  - geometry of the watercourse
  - average wind velocity
  - average wind direction

Aims of this study

- To gain insight into the variation in PEC values occurring in watercourses in the Netherlands due to spray drift.
- To develop a model that predicts probabilities of these PEC levels, taking into account the natural variation in
  - geometry of the watercourse
  - average wind velocity
  - average wind direction
- What are the major causes of such variation?
  - spatial: variation in watercourses
  - temporal: probabilistic variation in wind velocity and direction
- Can specific water body types be selected as references? (e.g. in monitoring studies)

Boundary conditions

- Watercourses:
  - Surface width <6 m
  - 66 standard profiles
- Wind:
  - Average velocity <5 m/s
  - Direction: only downwind field edges
- Drift is considered only entry route:
  - Assuming a conventional spray application in a potato crop
    (NL: nozzle DG 11004 @ 3 bar; crop free buffer zone 1.5 m)

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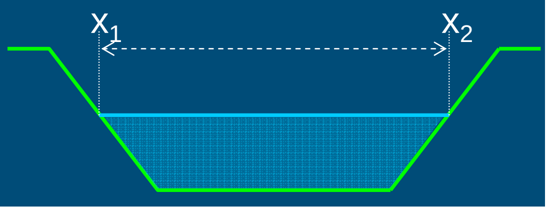
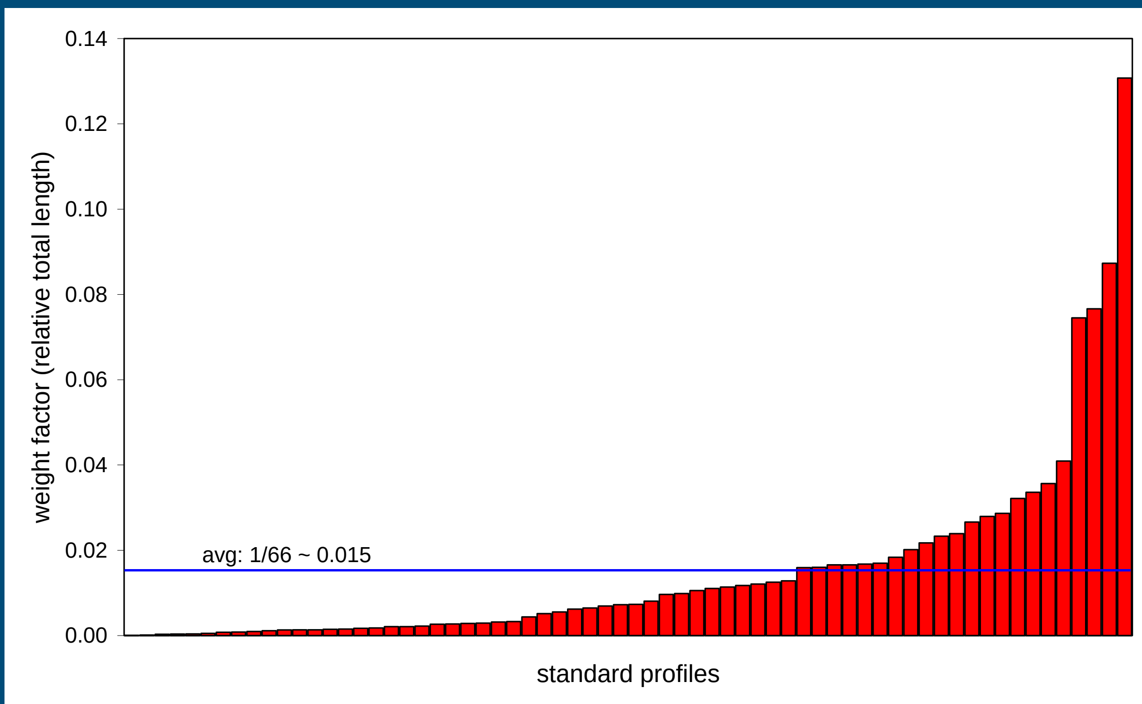
Water body standard profiles

- 66 standard profiles are distinguished in the Netherlands
- 3 water body classes (22 profiles each):
  - Ditches
  - Water bodies <3m width
  - Water bodies 3-6m width
- 6 hydrological regions:
  sandy soil areas (33), marine clay areas (15), fluvial clay areas (6), peat areas (6), dune areas (3), stream valley areas (3)
- Each standard profile has its own geometry
  - Water surface boundary positions (x_1, x_2) are determined for each profile
  - Slopes, depth, volume
- Weighting factor:
  - Relative occurrence of a profile:

$$\frac{\text{total occurrence (length) of one profile}}{\text{total occurrence (length) of all profiles summed}}$$



Weight factors of standard profiles



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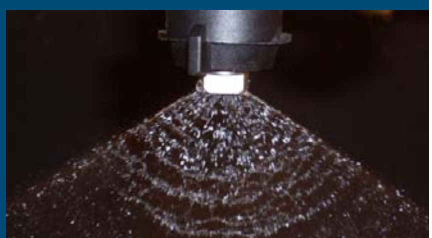
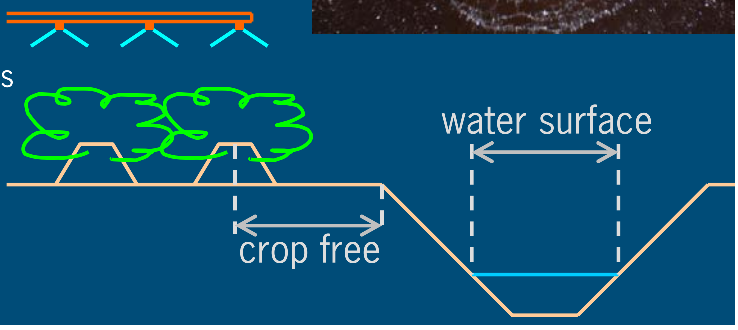
Determining drift onto surface waters

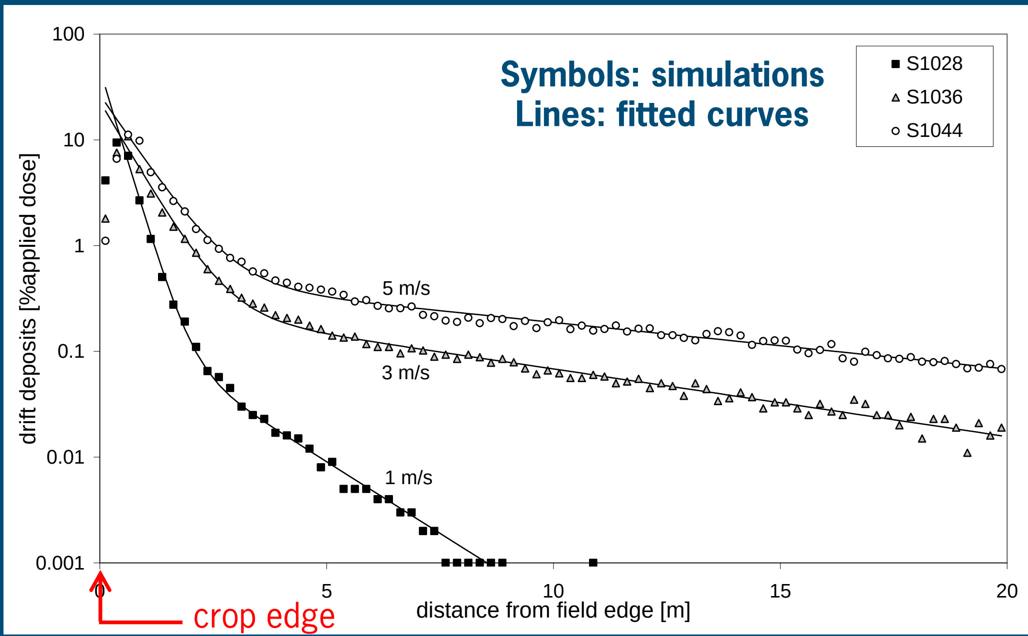
- Spray drift as entry route to surface waters:
  estimated from simulations using the IDEFICS model (v3.4):
  - Wind direction perpendicular to field edge
  - Crop: potato, height 0.50 m, crop free buffer zone: 1.50 m
  - Pesticide dose: 1kg/ha
  - Nozzle type: DG 11004, liquid pressure 300 kPa
  - Sprayer boom height above the crop: 0.50 m
  - Weather conditions:
    - temperature 15°C,
    - relative humidity 60%
    - neutral atmospheric conditions
  - Avg wind velocity range:
    0.25, 0.50, .., 5.00 m/s
    → 20 simulations





Examples of drift deposits curves

IDEFICS, various wind velocities, wind direction perpendicular to crop edge

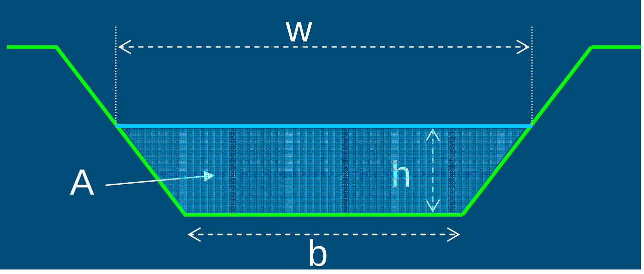


Computation of PEC from drift

- Drift simulations are fitted using an empirical function (sum of 2 exponential functions → 4 parameters)
- These parameters are implicit functions of wind velocity only: they were fitted empirically (polynomials of wind velocity)
- This yields a simple empirical model of drift deposits: a function of wind velocity (0–5 m/s) and downwind distance
- Calculation of PEC from drift deposits at water surface:

PEC = drift*w/A

mg/m^3 (PEC) mg/m^2 (drift) m/m^2 (w/A)



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Wind velocity variations

- Required: frequency distribution of probabilistic variation of wind velocities in the Netherlands

- Current approximation:
  - Local weather station near Wageningen
  - Hourly averaged weather data: e.g. wind velocity at 2 m height
  - Calculate averages over last 10 years (1998–2007)

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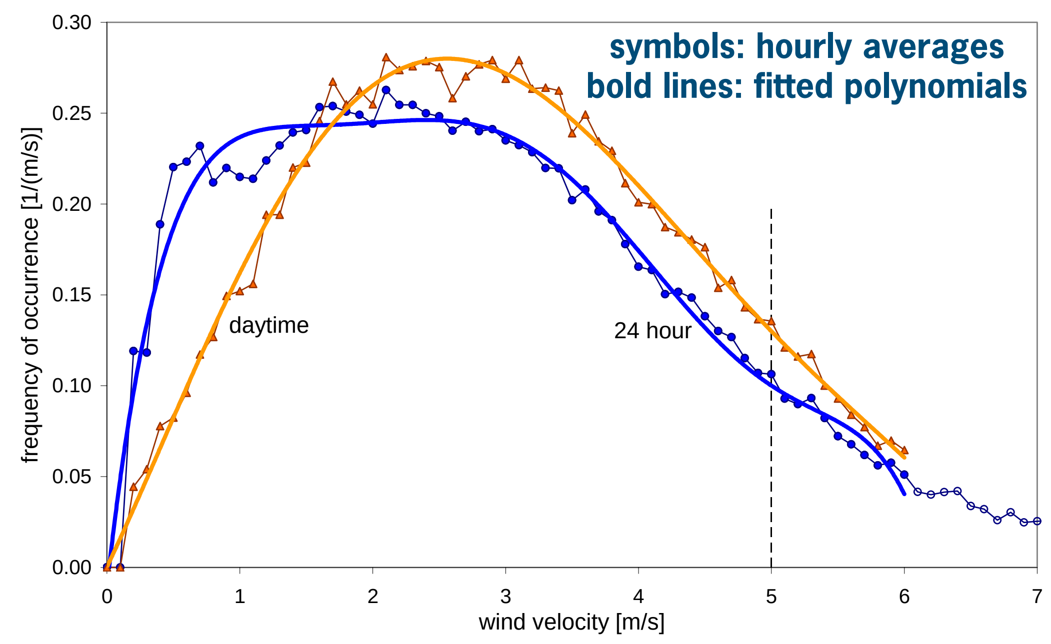
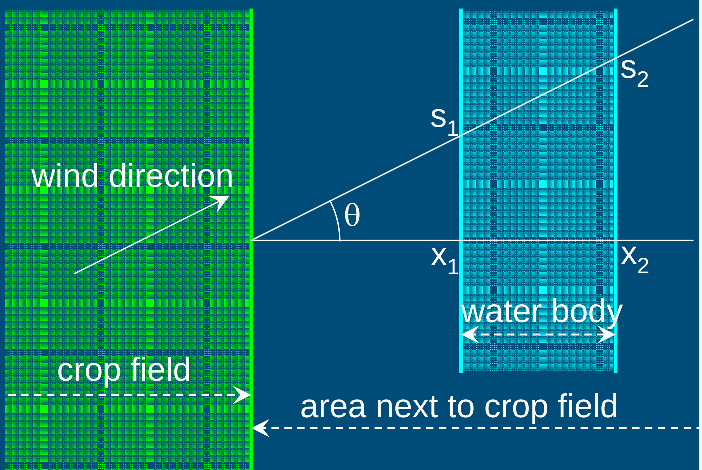
Wind velocity: avg frequency distribution

Hourly averaged wind velocities, Wageningen, 1998-2007



Wind direction

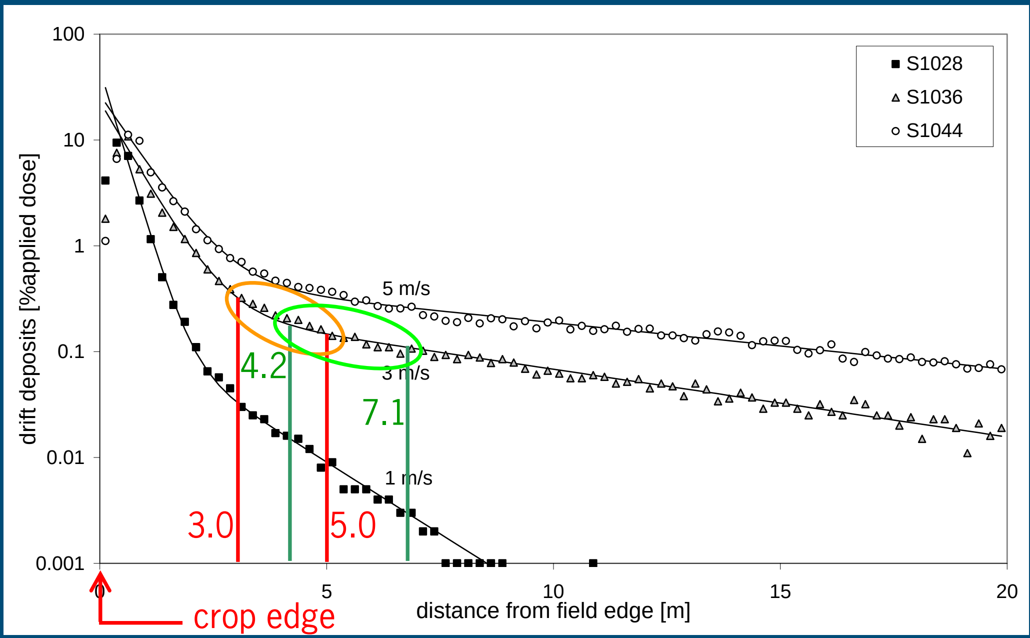
- All wind directions are equally likely
- Assumption: drift deposits for non-perpendicular wind directions can be derived from the perpendicular case:
  - Compute boundary points (s_1, s_2) for actual wind direction
  - Compute average drift on that range, using drift curve for perpendicular wind direction



$$s_1 = x_1 / \cos\theta$$
$$s_2 = x_2 / \cos\theta$$

Effect of wind direction on spray drift deposits

Example: wind direction of 45 degrees



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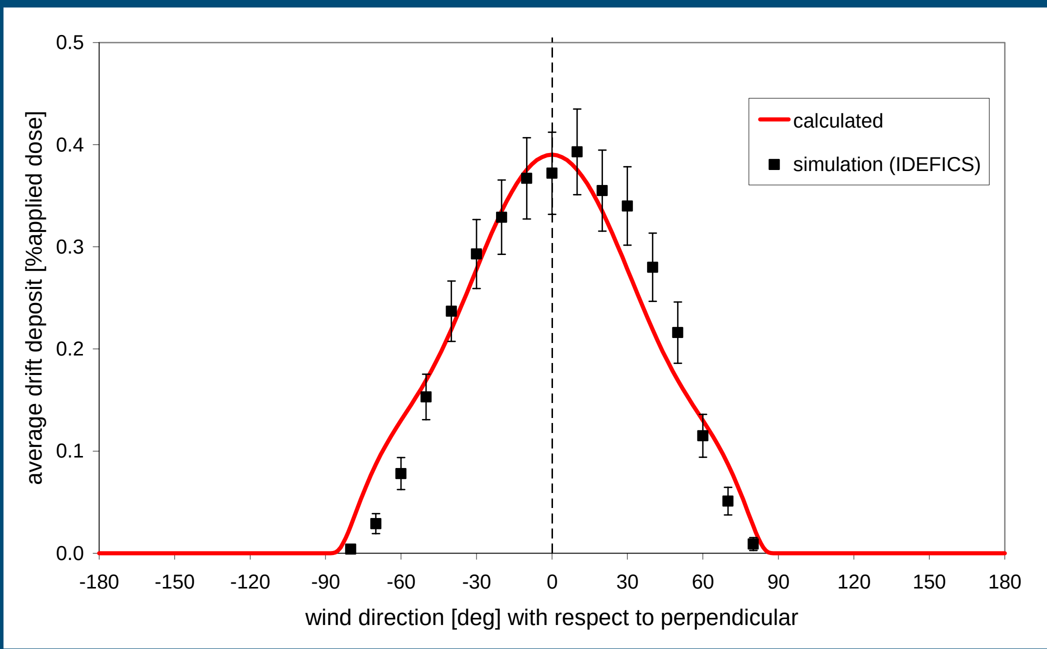
Wind direction and drift deposits

Fixed spraying conditions, fixed water body



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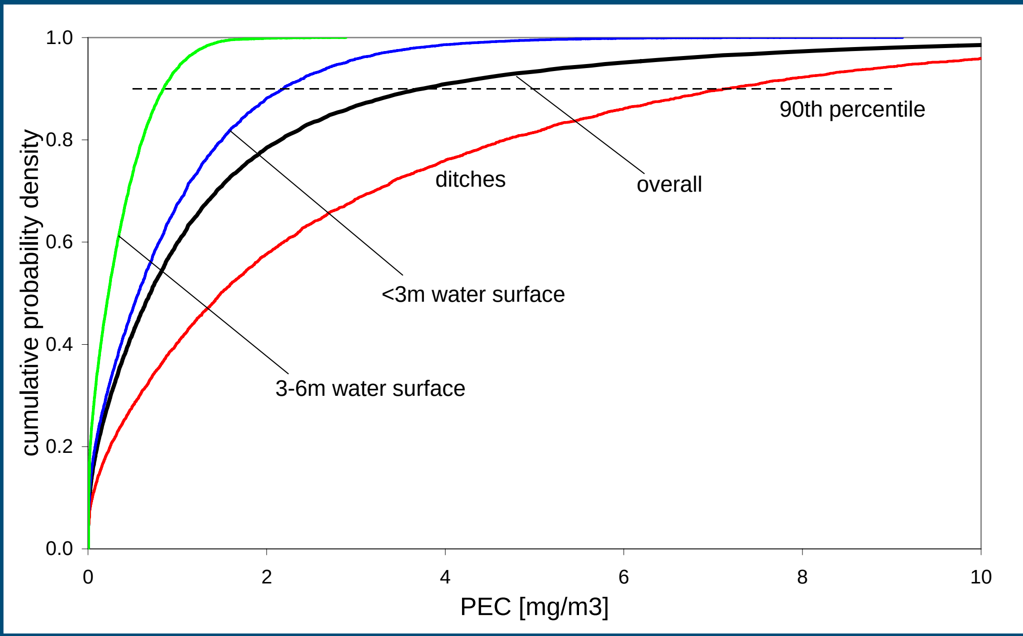
Summary of situations and weighting factors

- 66 standard profiles:
  - Weighting factor: relative total length per profile
- 20 wind velocities:
  - 0.25, 0.50, .., 5.00 m/s
  - Weighting factor derived from frequency distribution
- 35 wind directions:
  - -85, -80, .., +80, +85 degrees (downwind directions only)
  - Weighting factor 1/35 (all directions equally likely)
- This totals up to 46200 situations:
  - Each having its own PEC value and (overall) weighting factor
  - All situations are sorted with respect to increasing PEC

Cumulative probability density functions

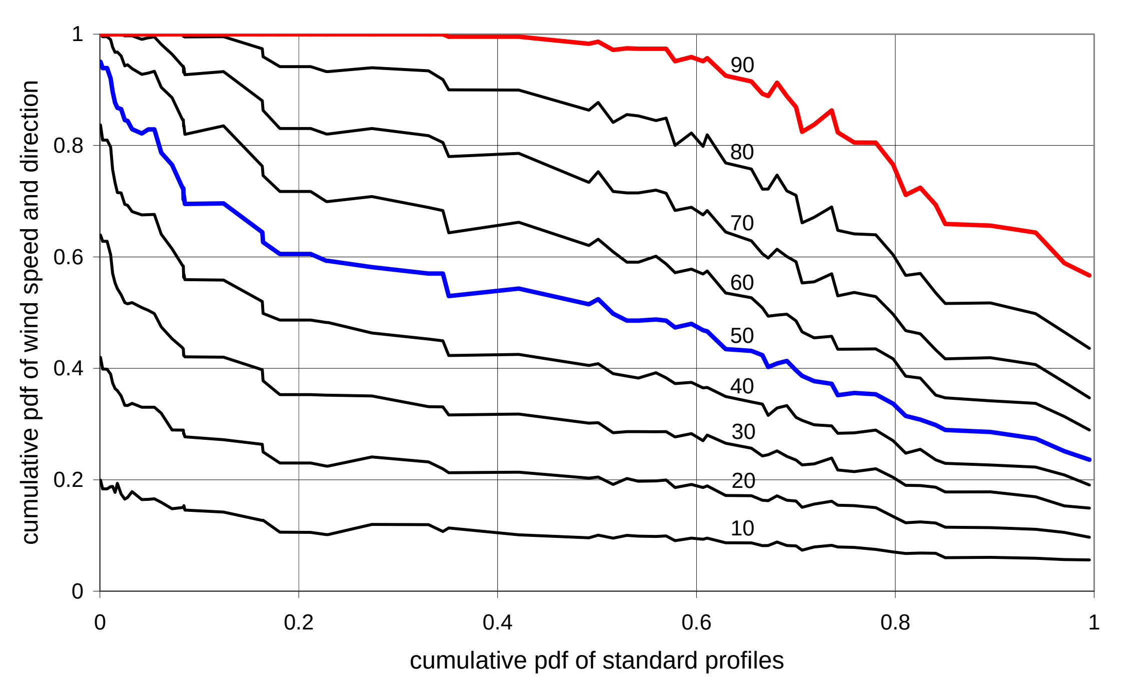
Overall and per water body class



Effects due to wind vectors and watercourses

- Which is the more important factor causing PEC variations:
  - natural variation in occurring wind velocity and direction?
  - variation in geometry of standard profiles?
- For each standard profile (N=66):
  - Calculate pdf by varying wind velocity and direction only (N=700)
  - Compute median (PEC50) from this pdf
  - Sort standard profiles according to increasing PEC50
  - Plot **overall** PEC percentiles as function of cumulative probability functions of standard profiles and wind vectors
  - Draw percentile lines

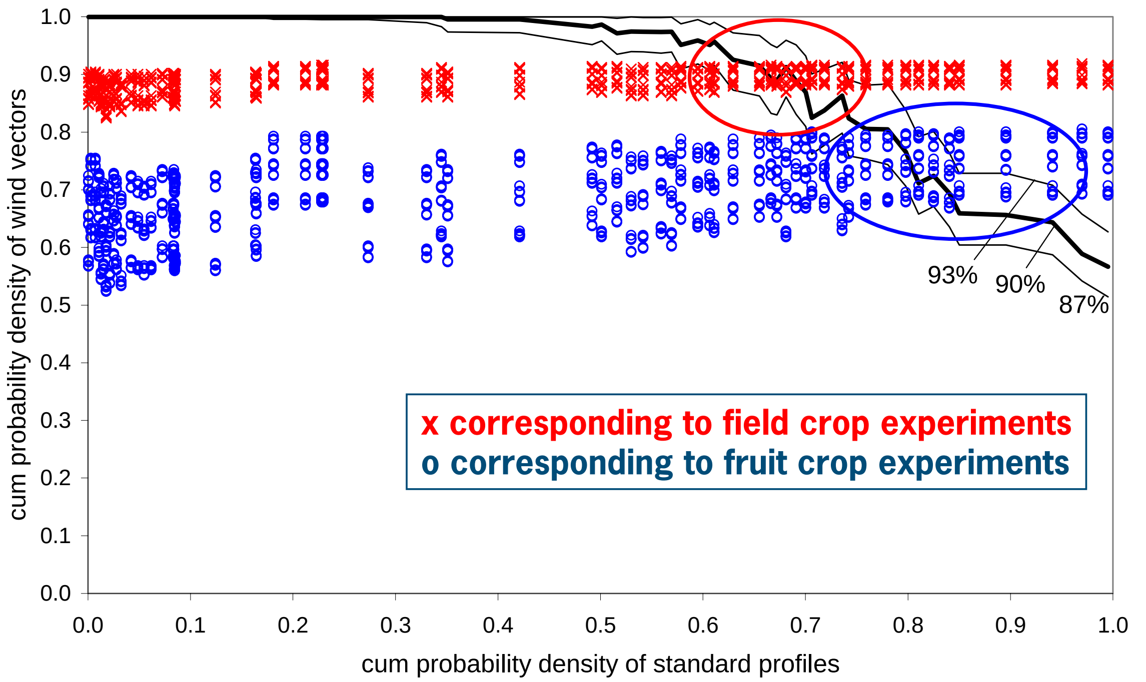
'PEC plot': probability contour plot



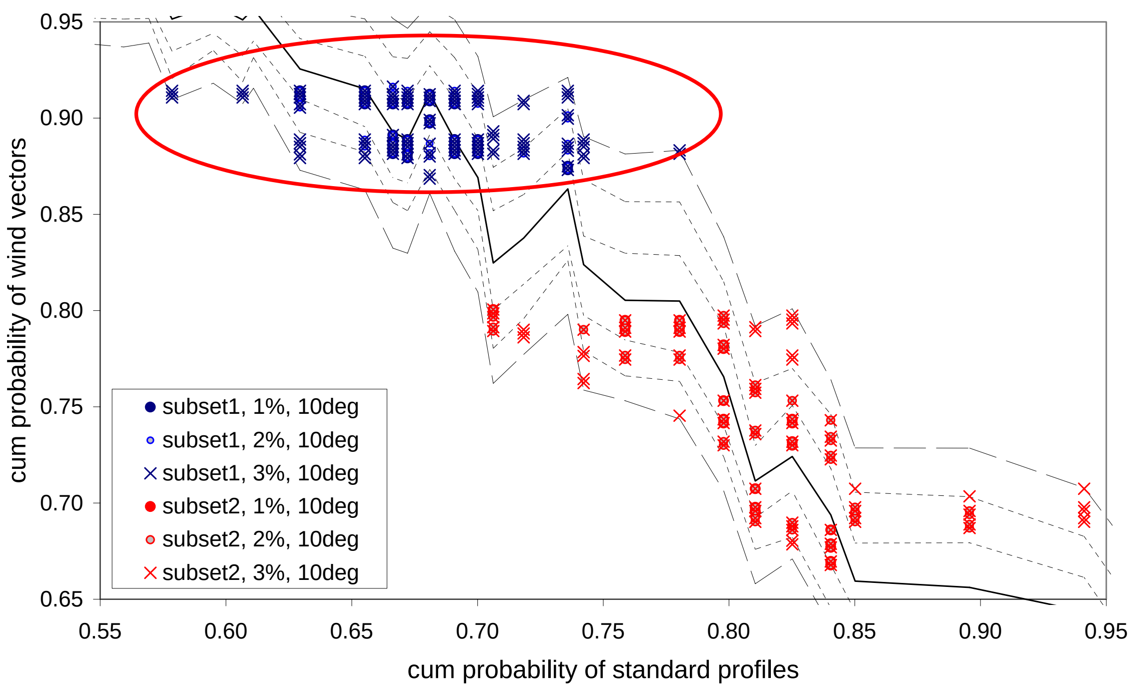
Situations with PEC near 90th percentile

- In which situations do the PEC values approach the 90th percentile?
- Limit these cases to those corresponding to drift measurements for
  - Field crops: wind velo 3.25-3.5 m/s; direction -10..+10 deg
    → 10 wind vector cases
  - Fruit crops: wind velo 2.0-2.5 m/s; direction -10..+10 deg
    → 15 wind vector cases
  - Approaching the 90th percentile within 1, 2 or 3%
- Find the standard profiles within the above limitations

Situations with PEC near 90th percentile



Situations with PEC near 90th percentile



Field crop situations near 90th percentile

WB-code	Water body class	Hydrological region	Hydrotype	#cases within 3% boundaries	Weight factor of profile	Cum w.factor of profile
601006	< 3m width	sandy soil	keileemprofiel	3	0.01674	0.579
601015	< 3m width	sandy soil	Tegelen/Kedichem profiel	3	0.00733	0.607
601003	< 3m width	sandy soil	dekzand profiel	10	0.03567	0.629
601009	< 3m width	sandy soil	Nuenengroep profiel	10	0.01591	0.655
600002	ditch	fluvial clay	Betuwe-stroomruggronden	10	0.00647	0.666
601011	< 3m width	sandy soil	open profiel	10	0.00513	0.672
600019	ditch	marine clay	Westland_DH-profiel	10	0.01253	0.681
601004	< 3m width	dune area	duinstrook	10	0.00723	0.691
601005	< 3m width	sandy soil	Eem en/of keileemprofiel	10	0.01141	0.700
600008	ditch	sandy soil	loss profiel	5	0.00079	0.706
600013	ditch	stream valley	Singraven-beekdalen	7	0.02333	0.718
600012	ditch	sandy soil	Peelo profiel	10	0.01174	0.736
601008	< 3m width	sandy soil	loss profiel	5	0.00085	0.742
600001	ditch	fluvial clay	Betuwe-komgronden	2	0.01106	0.780

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- PEC values vary considerably under naturally occurring conditions and circumstances.
- Wind velocity, wind direction and type of watercourse are major causes of PEC variation.
- High PEC levels mainly occur in ditches, low PEC levels mainly occur in wide watercourses.
- Quite different combinations of wind velocity, wind direction and standard profile may give rise to similar PEC levels.
- Next step: look at situations for drained parcels only. First results show similar graphs, but a different set of standard profiles in the selection procedure.

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Thank you for your attention

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