Further Afield Transport of Spray Drift Using a Coupling Approach

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Background

- **Spray Drift**
  - Material such as Pesticides or Herbicides left airborne following a spraying event targeting a specific area
    - Aerial or Ground spraying
- **Use of Aerial spraying in different types of Applications**
  - To protect crops against pests or invaded plants
  - Mosquito control spraying (25-40 µm droplets)
  - Insecticides spraying in forested areas (80-125 µm droplets)
- **Aerial spraying in control conditions**
  - rare events with material deposited off target

(Tsai et al. 2005)

Background

- **Observations of potential long-range Transport**
  - Traces of pesticides measured in lakes in Canada and Eastern US (Muir et al, 2004)
  - Traces of current-use and historic-use pesticides in snow at National Park in Western US (Hagemann et al, 2006)
  - Experiment measuring spraying above a forest area show in certain conditions small droplets in atmospheric boundary layer (Stoughton et al, 1997 and Miller and Stoughton, 2000)

Background

- **Possible Sources of Pesticides for Long-Range Transport**
  - During spraying applications
  - Material deposited on sand / dust – re-entered the boundary layer with strong wind conditions and available transported further afield
  - Re-evaporation of material deposited on vegetation
  - In lake, from ground-water (crop run-off, seepage, leaching)
- **Focus of this Study**
  - **Spraying Applications from Aircraft**
  - Testing Modelling for potential long-range transport using two models: AGDISP and CALPUFF – Sensitivity study

AGDISP model – Spray Dispersion model

- **Developed mostly by USDA Forest Service**
  - Regular use for estimating spray deposition and drift in agricultural spray dispersion in the vicinity of spraying area
- **Near-wake model based on a Lagrangian Approach**
  - Include effects of aircraft wake
  - aircraft-generated and ambient turbulence
- **Droplets evaporation model**
  - Active fraction of droplets changes as droplets evaporate (single evaporation constant)
- **Evaluated against field observations (Bird et al, 2002)**
  - Deposition validated in region where aircraft wake has influence over the behaviour of release material (wind loading, vortex decay, water-like evaporation)

CALMET/CALPUFF modelling system

- **CALPUFF (Scire, 2000) - non-steady-state Dispersion Model**
  - Calm wind conditions, Stagnation, Recirculation
  - Causality effects, Multiple hours accumulation, Sub-hourly
  - Can be used from 10 m to hundreds km from source
  - Puff sampling routine and elongated-puff (slug) for rapidly varying conditions in the near-field
  - Puff-splitting algorithm for wind shear representation
- **Deposition**
  - Dry deposition: full resistance model for gas and particulates (function of geophysical, met. Conditions)
  - Wet deposition – empirical scavenging coefficients
- **CALMET – diagnostic meteorological model**
  - Provides INPUT meteorological data for AGDISP

Coupling AGDISP/ CALPUFF

- **Previous studies:**
  - Thistle et al. (2005) – How AGDISP outputs can be used as a source for CALPUFF?
  - Bond et al. (2011) – How to implement AGDISP/CALPUFF for adult mosquito control in Florida?

- **In this study we are focusing on the sensitivity of the coupling to critical steps in passing information from AGDISP to CALPUFF**

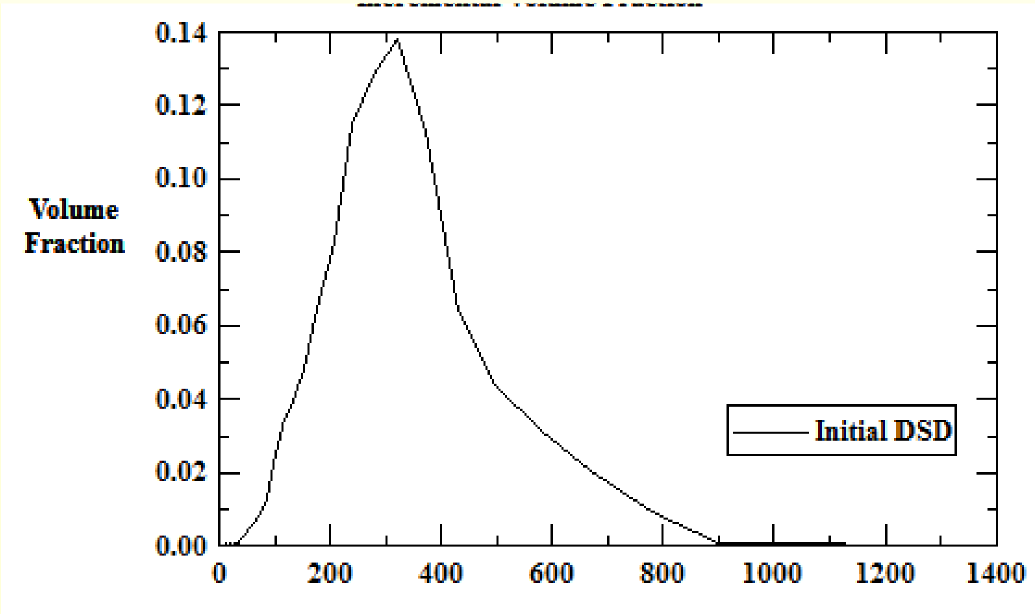
Coupling AGDISP/CALPUFF

- **Handoff Distance**
  - Distance at which near-wake effect and evaporation effect have no more influence on the behaviour of the droplets
    - At a Handoff distance, AGDISP produces a discrete distribution of droplet sizes and airborne drift fraction
- **Drop Size Distribution information for CALPUFF**
  - Single particle size – 1 size = median of distribution
  - Detail particle sizes – discrete number of “species” – each with a different size range of 10 microns (0-10; 10-20; ...)
  - Important for dry and wet deposition
- **Other important parameters:**
  - Source choice in CALPUFF: area sources (shape ratio 1:1, 1:2)
  - Release Height (not a modeller choice)

AGDISP data

- From AGDISP Library:
- AT-802 (Air Tractor AT-802F)
- Initial Droplet Size Distribution:
  - ASAE Fine to medium
  - VMD=254.74μm
  - relative span=1.3
  - Range 0-1000 microns
- 49 Nozzles
- No Canopy

Initial Droplet Size Distribution

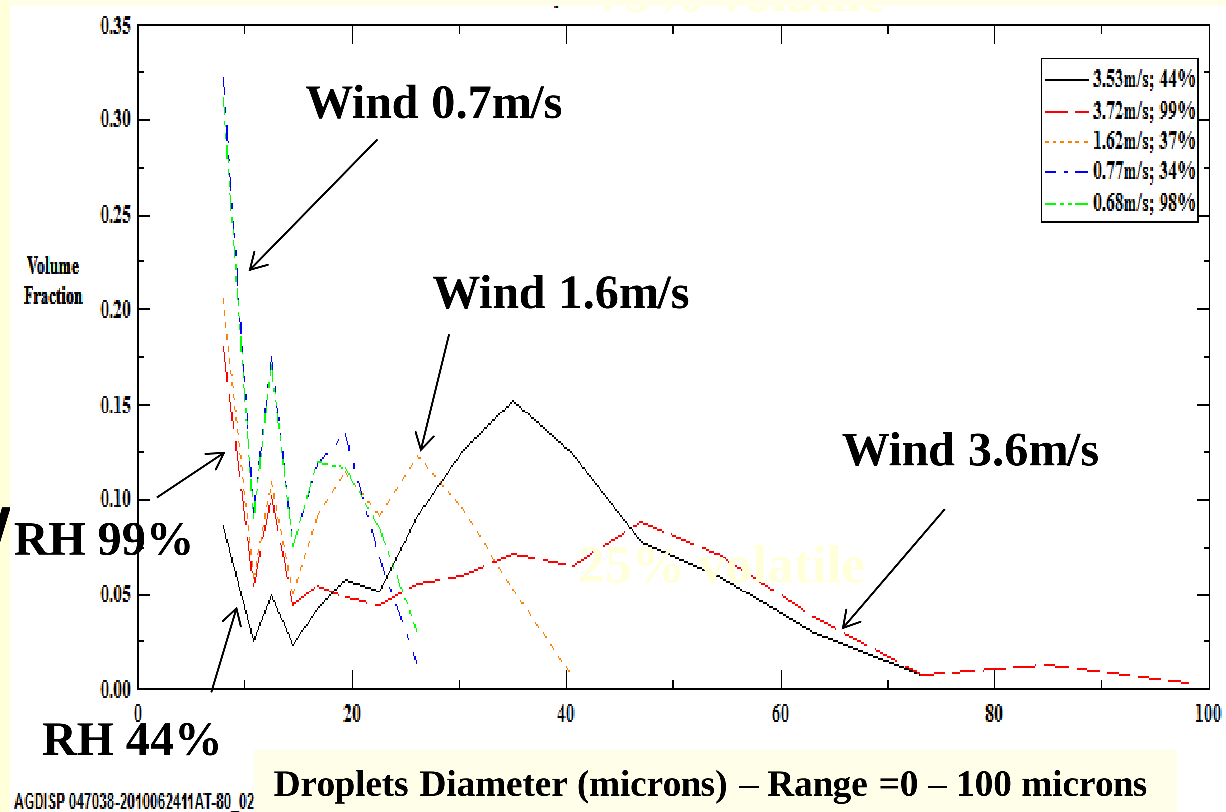


Droplets Diameter (microns) – Range =0 – 900 microns

Handoff Distance of 300m Droplet Size Distribution (DSD)

- **Wind Speed impact on large droplets:**
  - Larger droplets with stronger wind
- **RH impact on smaller droplets when material highly volatile**

Examples of DSD at 300m for 75% Volatile Material



Sensitivity Matrix

Material	Species in CALPUFF defined as different size particles	Handoff Distance in AGDISP for a Release Height of 22ft			Handoff Distance in AGDISP for a Release Height of 8ft
		200m	300m	400m	300m
75% volatile	Detail sizes	X	**X**	X	X
50% volatile	Detail sizes		X		
25% volatile	Detail sizes	X	X	X	
75% volatile	Single size		X		

Base Reference: 75% volatile material; Release height = 22 feet (6.71m); Handoff distance in AGDISP = 300m; 1 area source ratio 1:2; Detailed species distribution in CALPUFF

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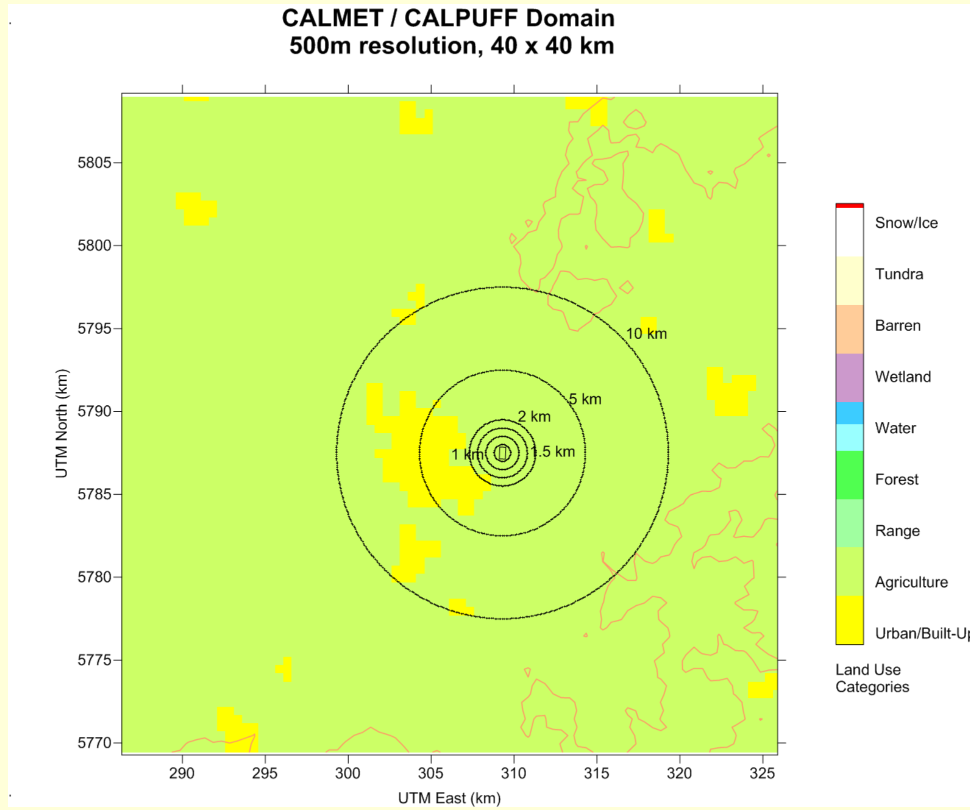
Design an Area of Study

- Fictive domain and source in a relatively flat area
- Source is modelled in CALPUFF as area sources
- Receptors located at 500m, 1 km, 1.5 km, 2 km, 5 km and 10 km
- 47 events with different meteorological conditions are tested
    - Wind (0.25m/s – 5m/s)
    - RH (29% - 100%)
    - Temperature (277.1 K – 297.5 K)
    - Stability (1 - 6)

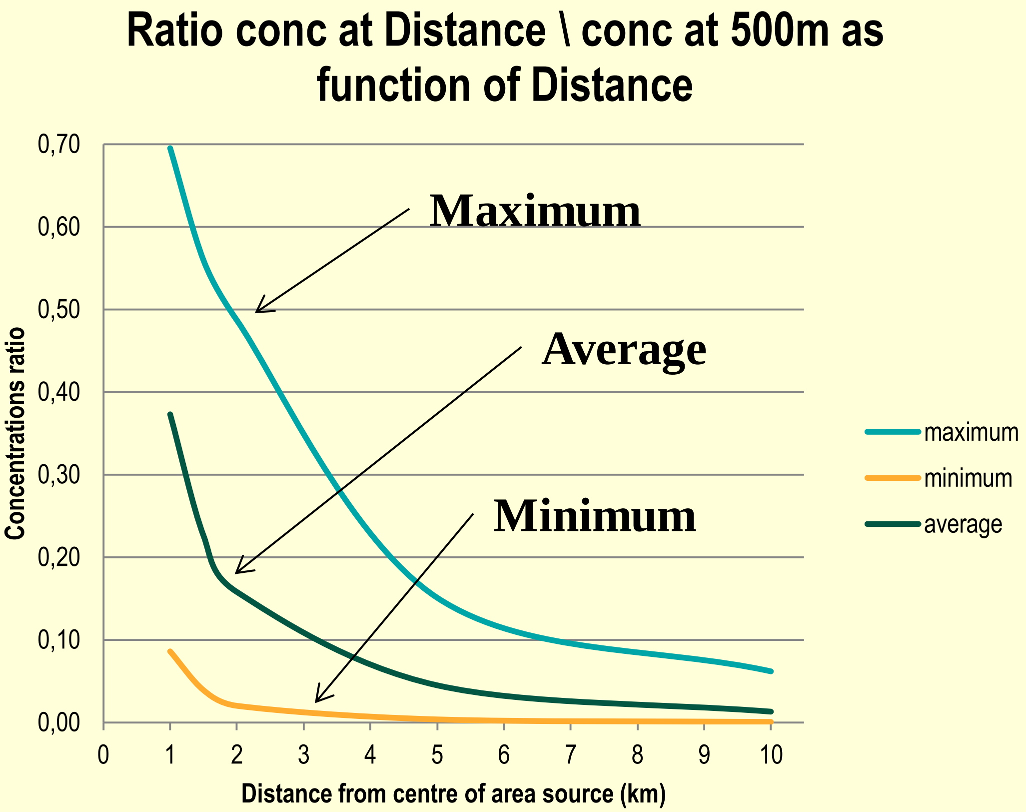


Concentrations ratio for Simulation at Distances of 1km to 10km
(Normalized by concentration Simulated at 500m)

-Sharp decrease of concentrations as distance increase as expected

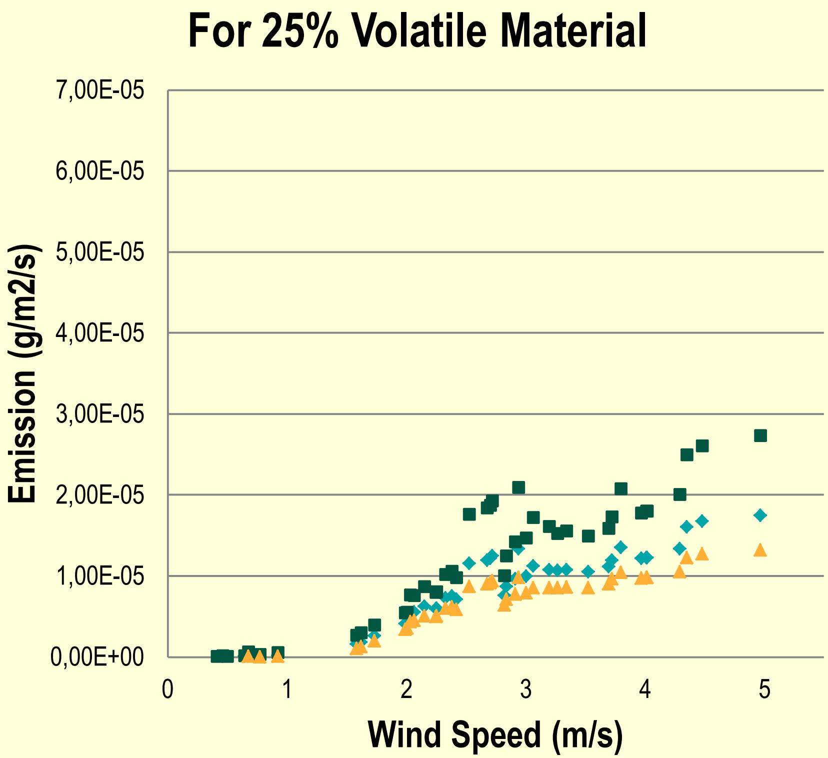
- In the set of example used, maximum at a distance of 10km from the source is 6% of the concentration at 500m
- Depending on met. conditions concentration at 10k varies from 0 to 6% of conc. at 500m

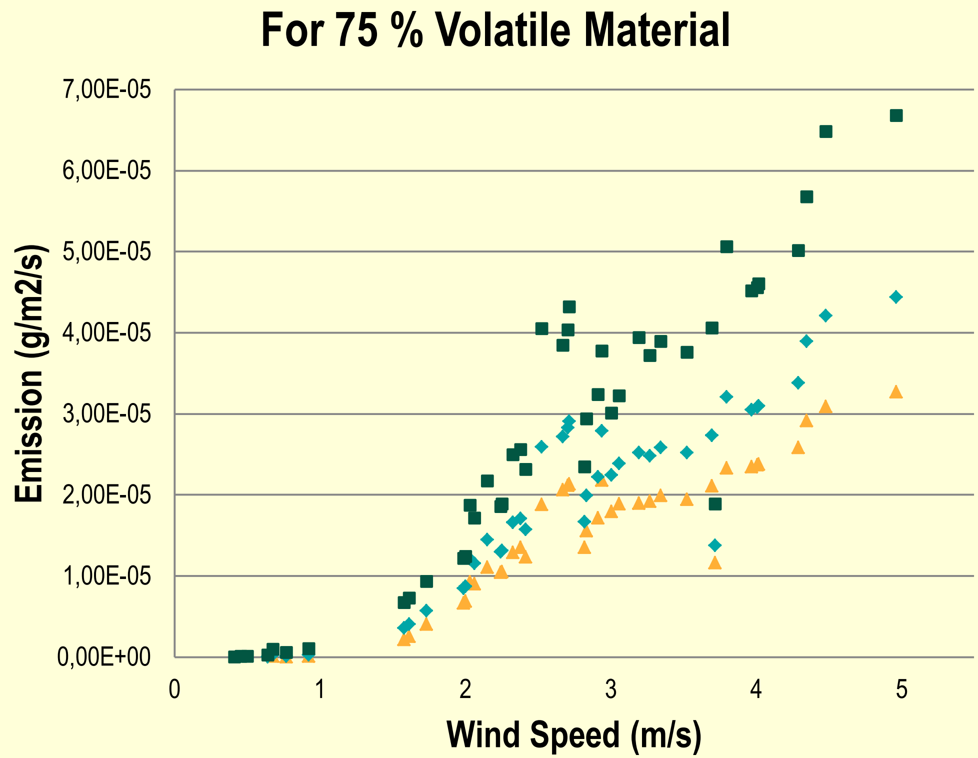
Plot for Base Reference run for 47 events



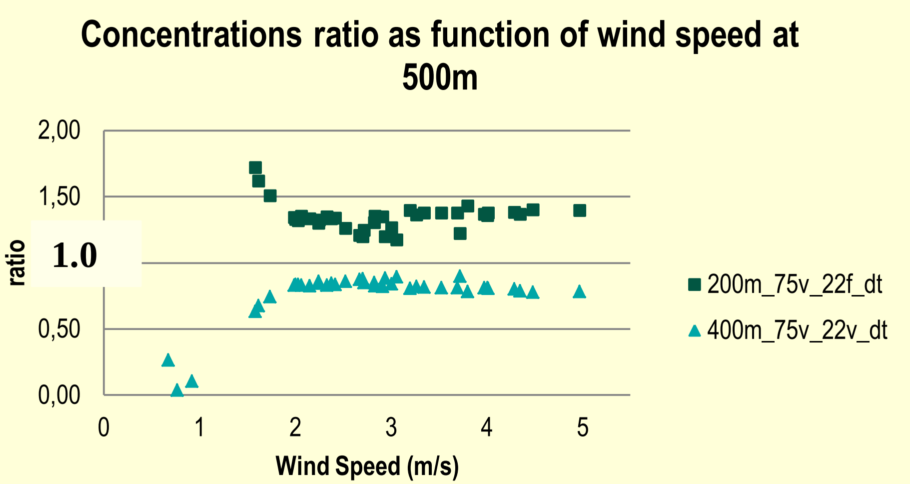
Emission for CALPUFF as Function of Wind Speed for Handoff Distance of 400m ( ), 300m ( ), 200m ( )

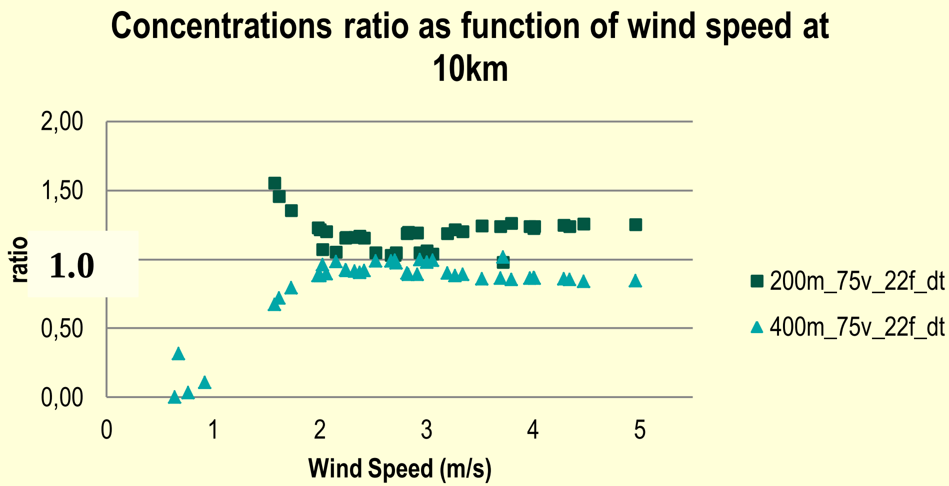
- Emission for area sources is directly proportional to the fraction aloft at the Handoff distance - Emission = (R * D /T) * fractionaloft
- R (rate in gallons/acres); D (density in lbs/gallons); T (period of spraying in seconds); Emission in (lbs/acres/s put in $g/m^2/s$)

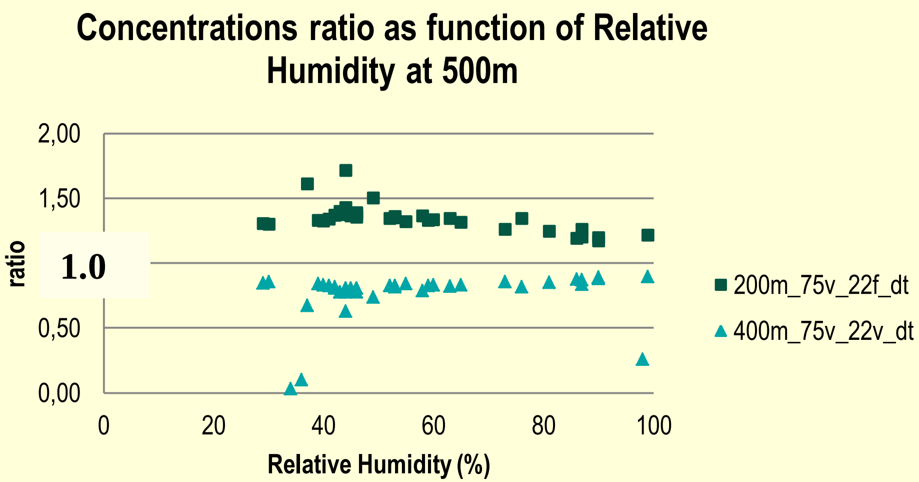


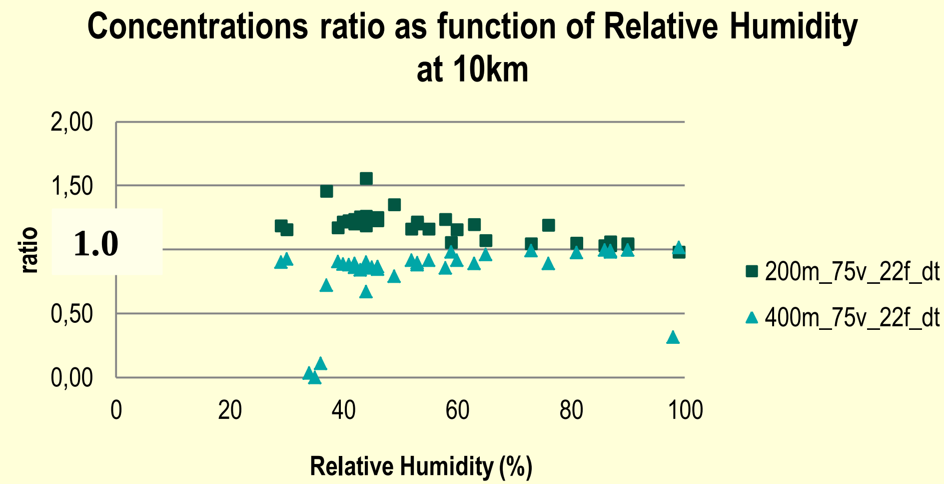


Concentration Ratio : for Handoff Distance 200m (■), 400m (■) divided for Handoff Distance 300m



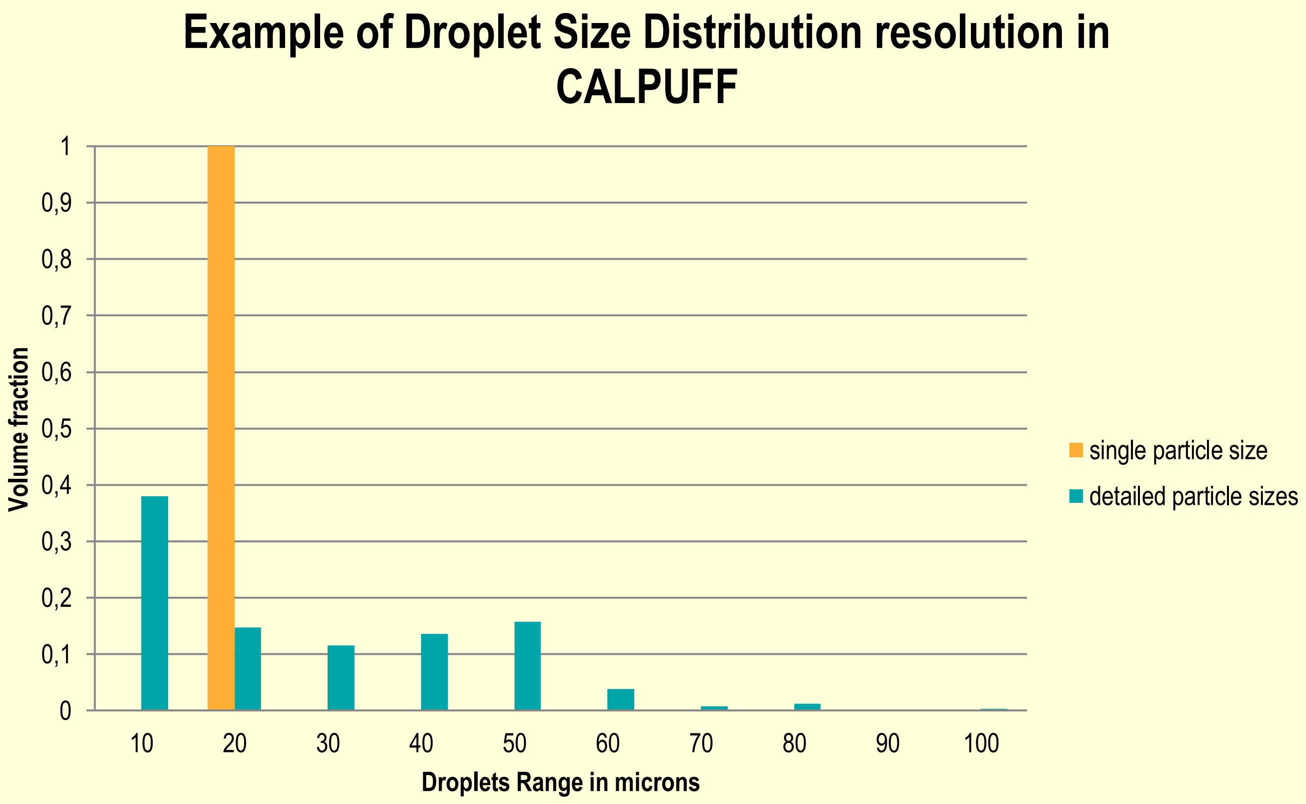






Concentrations for a Hoff distance of 200m are larger (1.35, 1.19) than for a Hoff distance of 300m or 400m (0.82, 0.90).
The concentration difference is larger for 500m simulation than for 10km simulation
Difference becomes smaller at 10km, even more for larger RH - similar plots for 75% volatile or 25% volatile

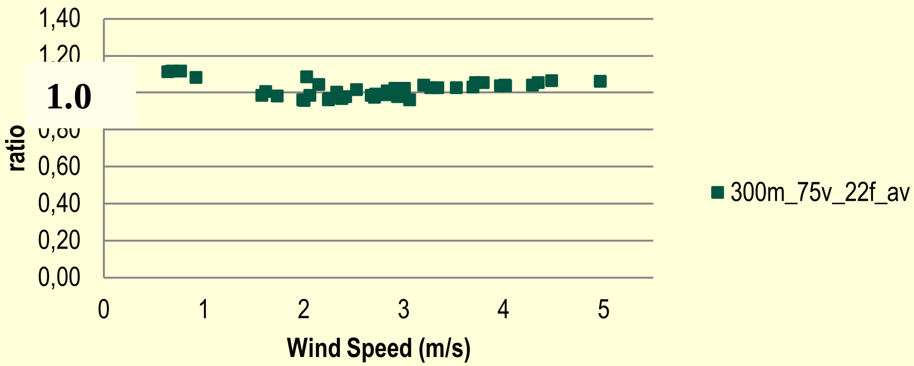
Droplet Size Distributions from AGDISP to be passed to CALPUFF – two methods



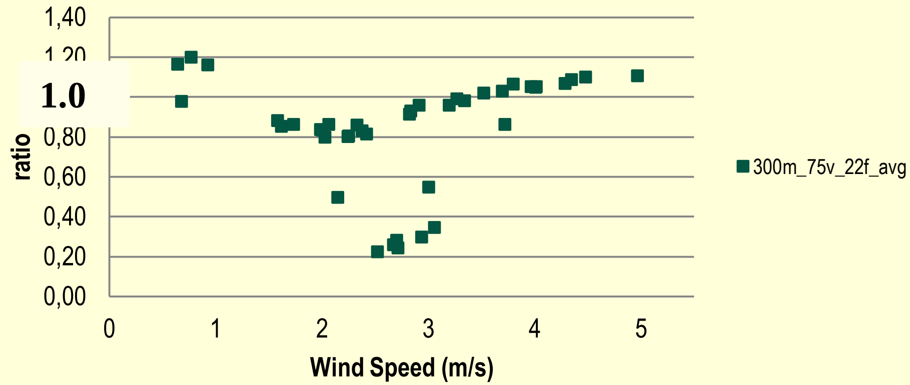
wind speed =3.72m/s; RH=99%
Material 75% volatile

Concentrations Ratio: Single Species (Median Diameter) / Discrete Species (10 um Range)

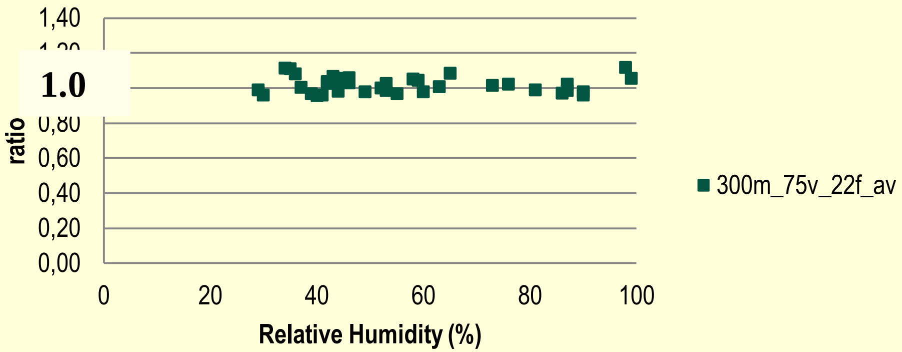
Concentrations ratio as function of wind speed at 500m



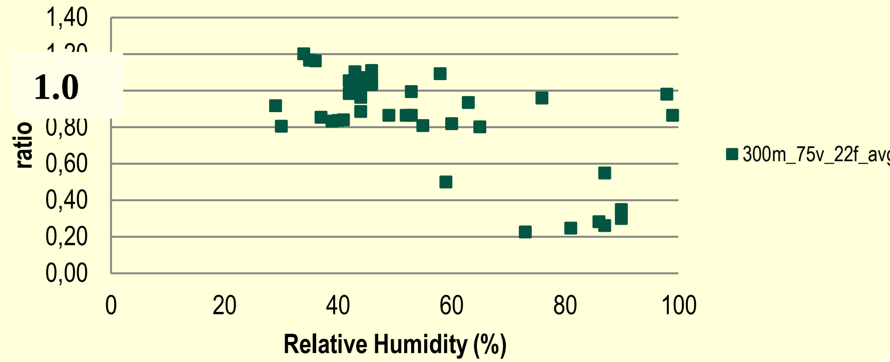
Concentrations ratio as function of wind speed at 10km



Concentrations ratio as function of Relative Humidity at 500m



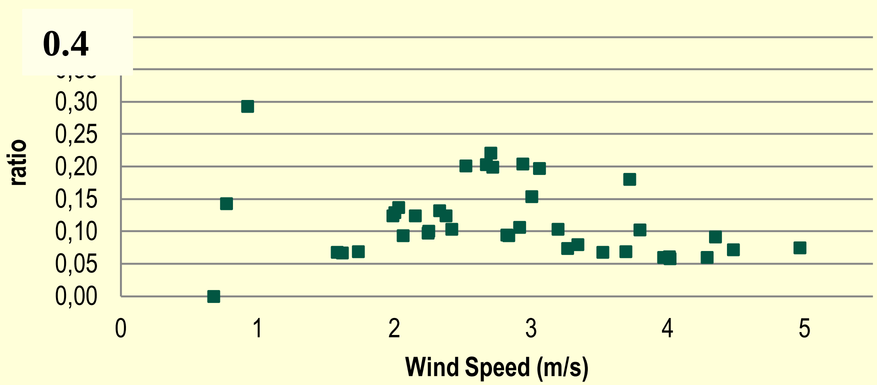
Concentrations ratio as function of Relative Humidity at 10km



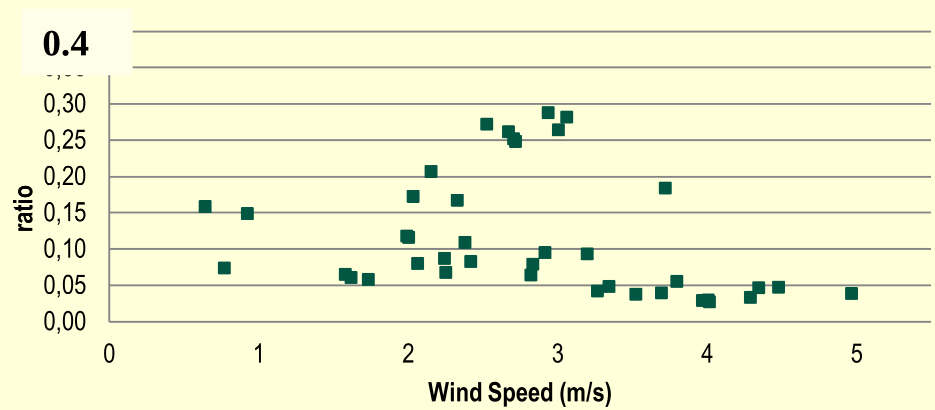
- For concentrations at 500m, not much differences
- For concentrations at 10k, single species run concentrations up to 80% smaller for high RH and up to 20% larger for low RH, low wind speed

Concentrations Ratio for Release Height 8ft (2.44m)/ Release Height 22ft (6.71m)

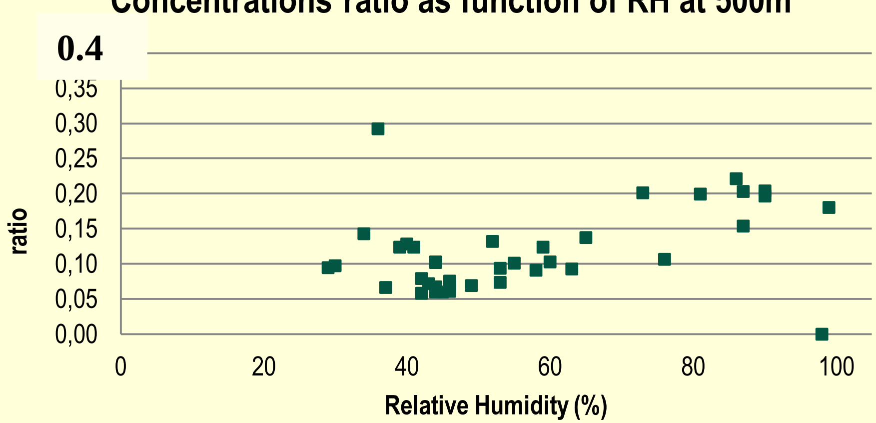
Concentrations ratio as function of wind speed at 500m



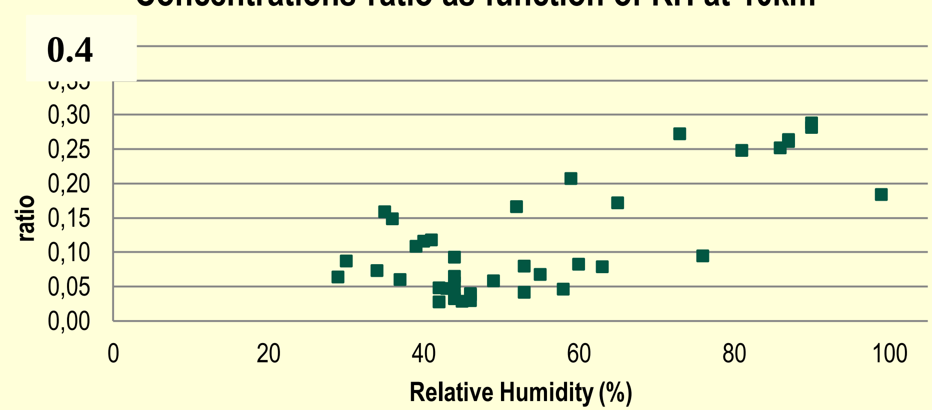
Concentrations ratio as function of wind speed at 10km



Concentrations ratio as function of RH at 500m



Concentrations ratio as function of RH at 10km



Between 80% and 90% lower concentrations for release height of 8ft compare to release height of 22ft
Not too much differences for concentrations simulated at 500m or 10 km

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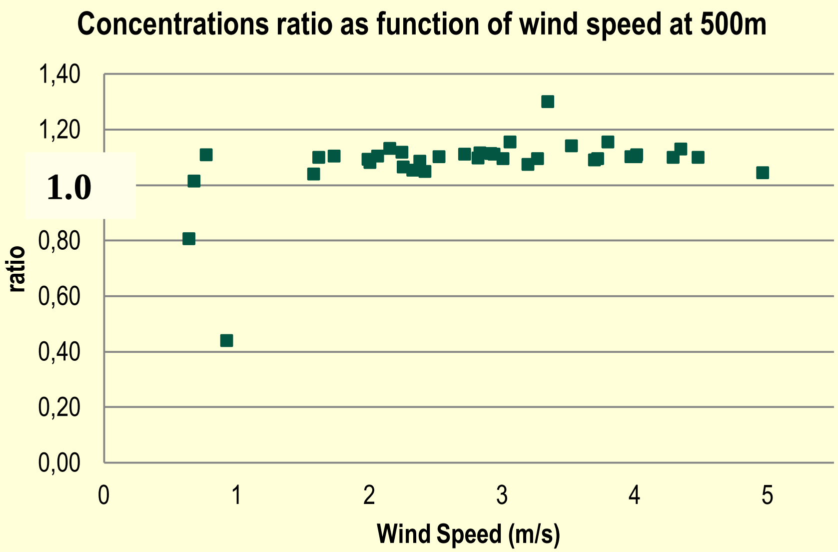
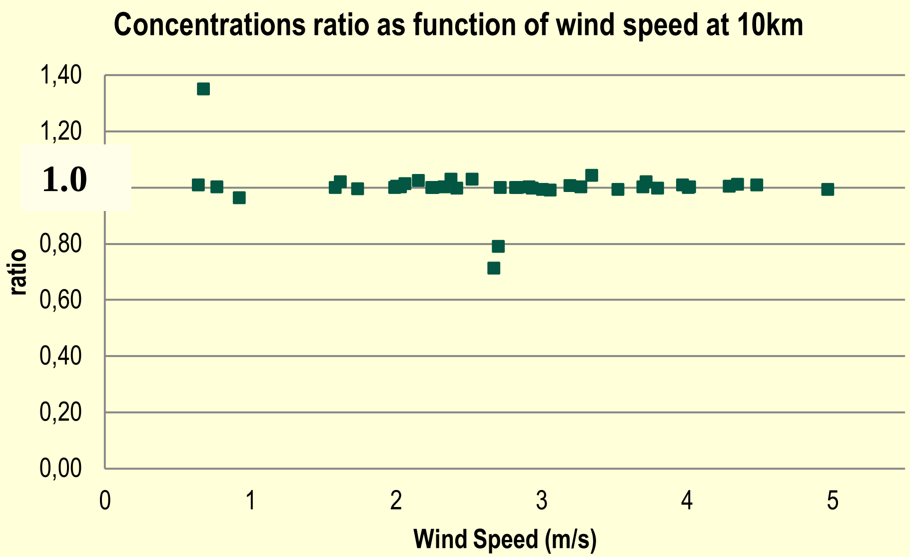
Concentrations ratio for Area source 1:1 / area source 1:2





Note: domain grid resolution = 500m
area source 1:2 = one 700m x 350m
area source 1:1 = two 350m x 350m (recommended option for near-field)

Concentrations at 500m are slightly larger for sources defined as two 1:1 area sources
Concentrations at 10 km – approximately same concentrations using one or the other source definition

Conclusion

- **Importance to use a model such as AGDISP to define source for CALPUFF**
  - Can treat droplets evaporation
  - Take into account aircraft wake
- **Recommendation to use detail droplet size distribution as a discrete number of size particles in CALPUFF**
  - Significant differences from using an average single size particle
- **Sensitivity to all handoff distance tested for volatile material**
  - previous studies recommend 300m (validity of AGDISP within influence of aircraft wake)

Conclusion – potential applications

- **At a distance of 10k, concentrations simulated very small within our range of experiences**
  - the maximum simulated 6% of the concentration at 500m
- **Combination of AGDISP/CALPUFF possible applications:**
  - evaluation of potential exposure and/or risk assessment in the vicinity of the spraying area and further afield
  - In forecast mode, help spraying user to
    - determine weather conditions adapted to the type of spraying needed
    - limit to a minimum the off target impact
    - provide a buffer zone around the spraying area

Further studies

- Evaluating the tool against observations
- Testing tool (AGDISP/CALPUFF) for ground spraying applications (types of spraying within European regulation)
- Introducing Droplet Evaporation in CALPUFF
- Defining more detail DSD in the smaller range of droplets
- Low wind conditions, look at sensitivity with sub-hourly time step meteorological data and CALPUFF runs

Thank you for your attention

Any Questions?

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