Inhalation exposure and dermal deposition of airborne particles during electrostatic spraying of liquid TiO_2-based nanocoating

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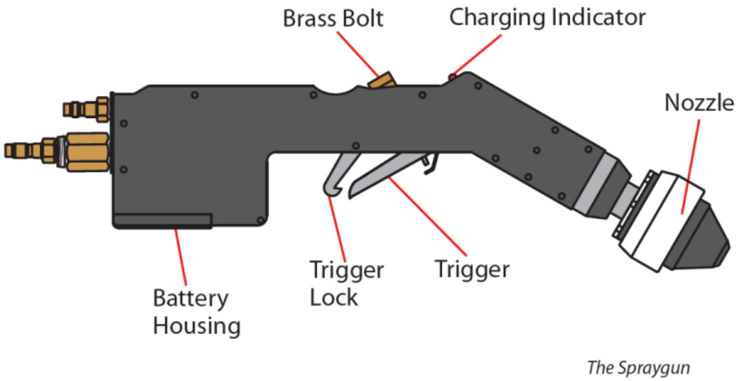
Outline

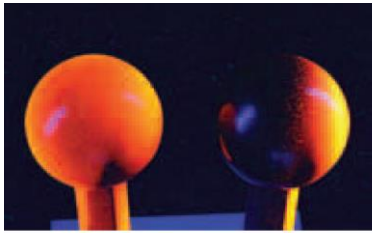
- Electrostatic spray (ESS) system
- Experimental methods
  - Spray application and emission room
  - Indoor aerosol model
- Results
  - Measurements vs. modelings
- Summary and conclusions

Electrostatic spray (ESS)

- Atomizes droplets in the nanometer range
- Charged particles have reduced coagulation and increased deposition efficency.
- Use in industry: e.g. painting, agriculture, micro- and nanothin film deposition
- ESS transfer efficiency is ~8 times higher than in traditional spraying systems (Kabashima *et al*. 1995)

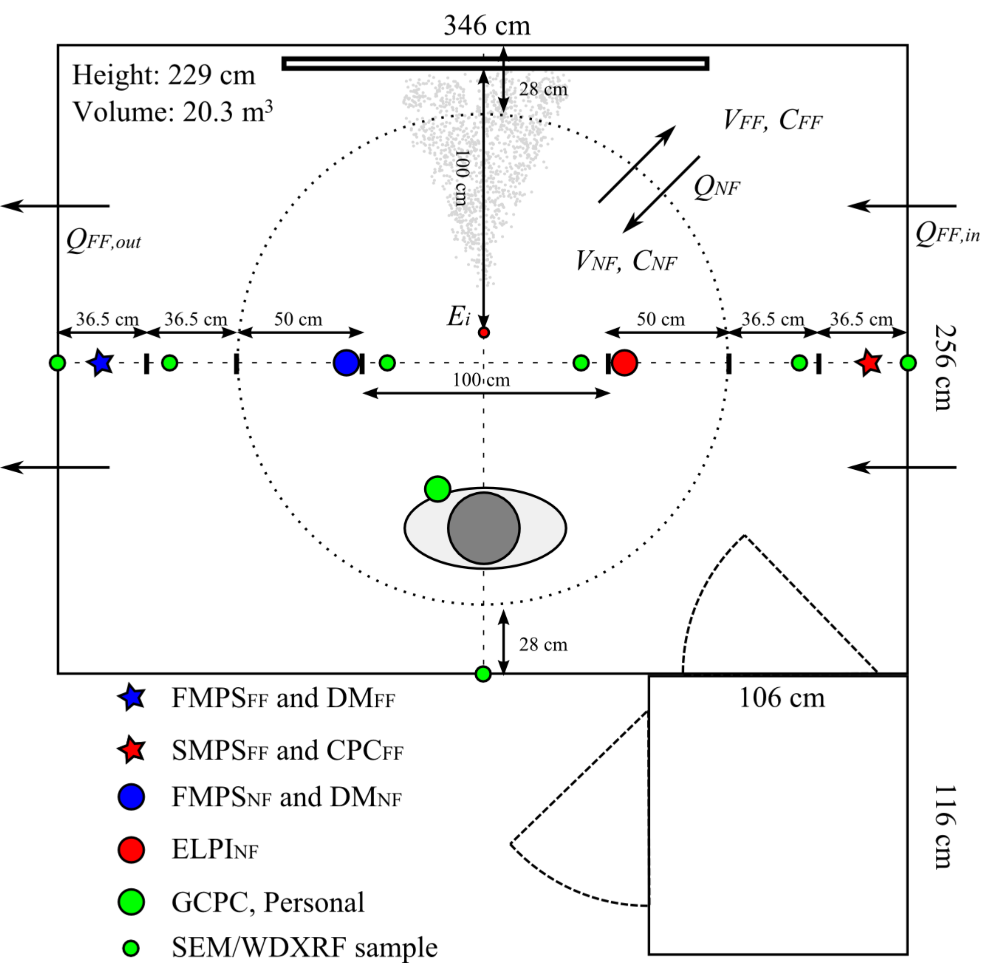


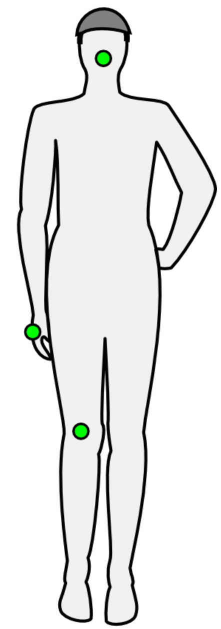
Electrostatic system:
ON OFF



Figures adopted from Electrostatic Spraying Systems, Inc. SC-ET Owner's manual

Experimental





Ventilation rate = 0.50±0.05 h^{-1},
RH = 50±5 %, T = 23±1 ^oC

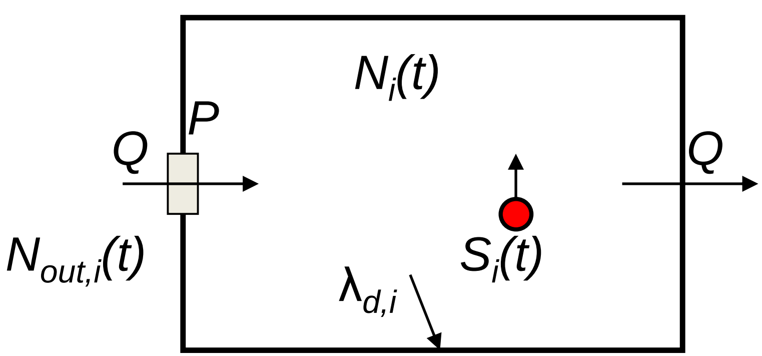
Properties of ESS system:

- $Q_{precursor}$ = 0.9 g s^{-1} (TiO_2 0.5 % vol/vol)
- Q_{air} = 1.9 L min^{-1}
- U_{nozzle} = 1.2 to 1.3 kV


Personal CPC
SC-ET
Near field:
dust monitor and
FMPS
Spray time ~15
and 150 seconds

General dynamic equation of aerosol particles (e.g. Hussein *et al.* 2014)

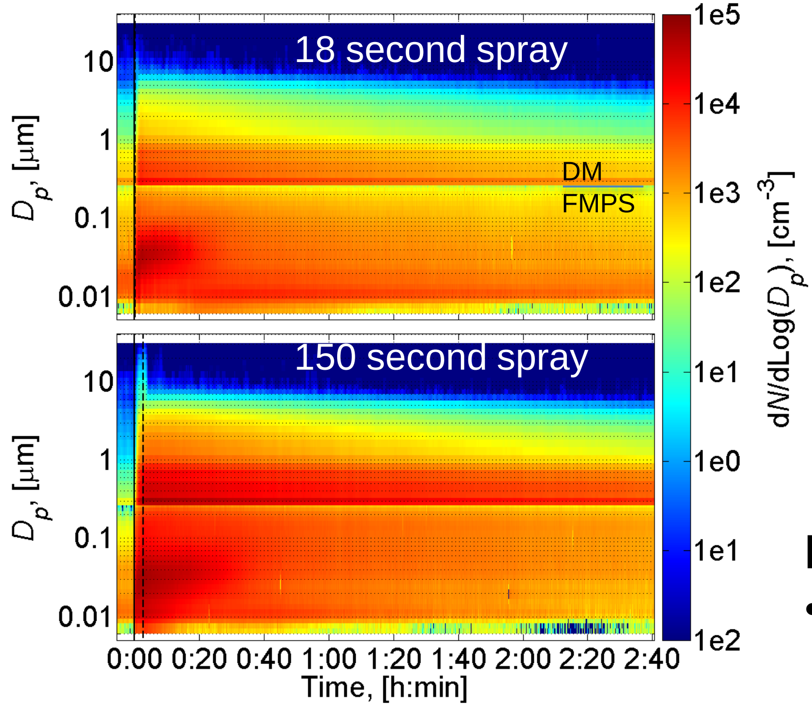
$$\frac{dN_i(t)}{dt} = \underbrace{N_{out,i}\lambda P}_{\text{Background particles from ventilation air}} - \underbrace{(\lambda + \lambda_{d,i})N_i(t)}_{\text{Particle removal by ventilation } (\lambda) \text{ and deposition } (\lambda_{d,i})} + \underbrace{S_i(t)}_{\text{Particle source(s)}} + \left.\frac{dN_i(t)}{dt}\right|_{coagulation}$$

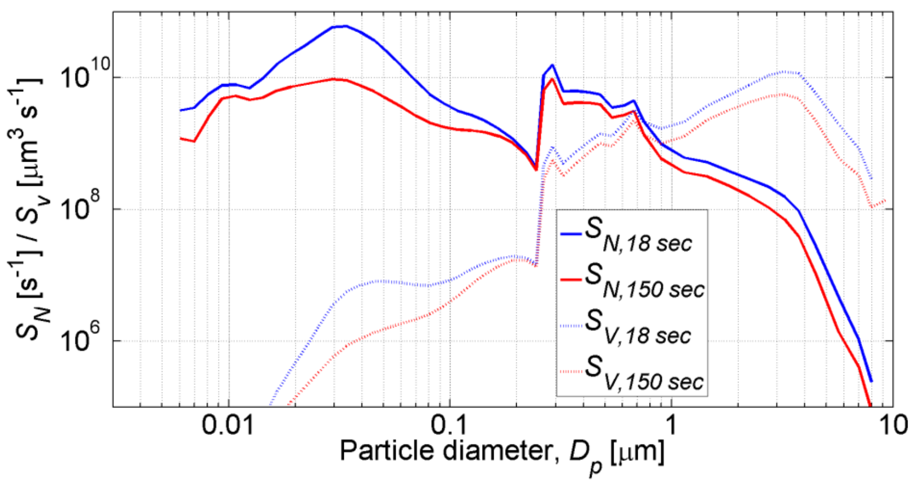


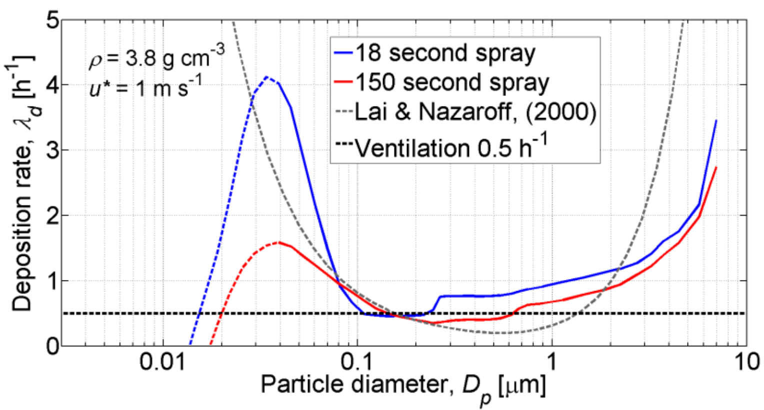
Terms and parameters:

$N_i(t)$	Indoor aerosol concentration, [cm^{-3}]
$N_{out,i}(t)$	Outdoor aerosol concentration, [cm^{-3}]
P	Particle penetration factor
Q	Ventilation flow, [m^3h^{-1}]
$S_i(t)$	Indoor particle source, [$cm^{-3}h^{-1}$]
$\lambda_{d,i}$	Particle deposition rate, [h^{-1}]
λ	Ventilation rate, [h^{-1}]
i	size section

Results



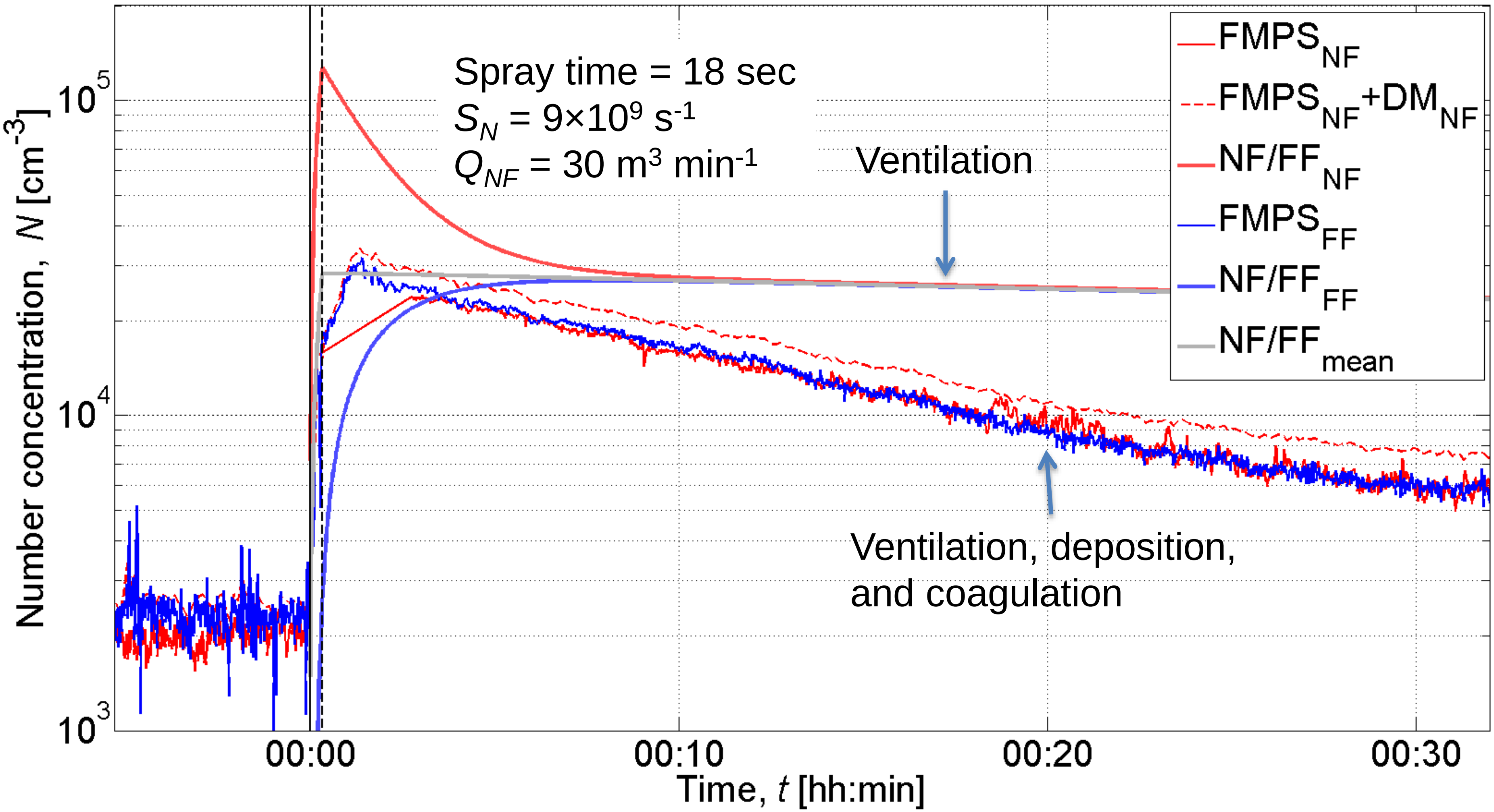




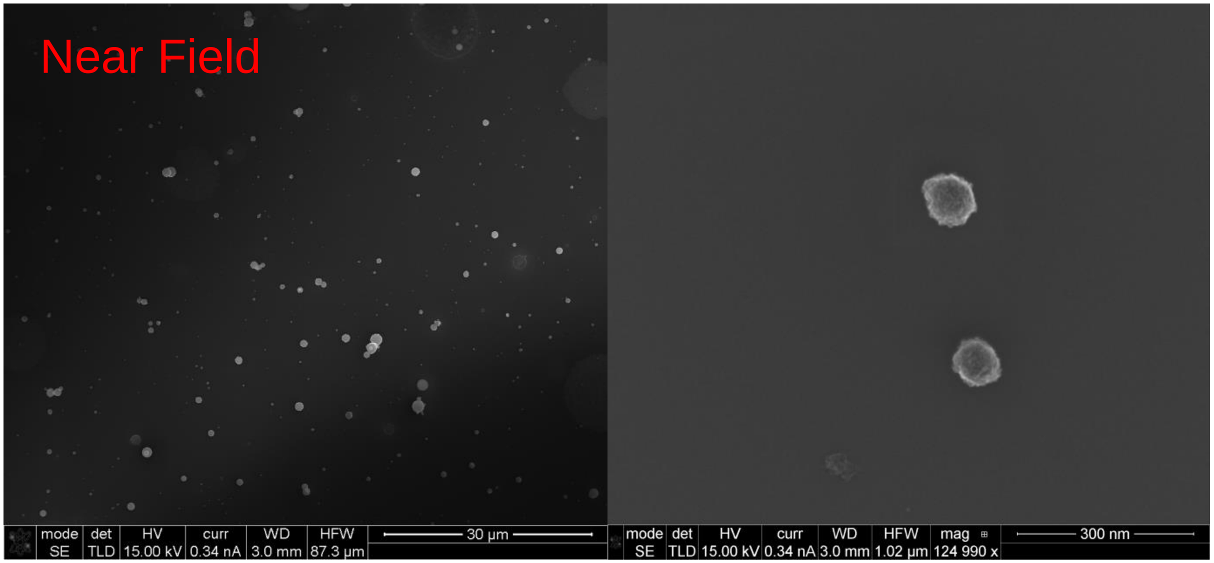
Emission rates from the spray process:

- Particle number S_N:
  - 9×10^9 to 30×10^9 s^{-1}
- Volume S_V (spherical particle, ρ = 4 g cm^{-3}):
  - 0.003 to 0.006 mL s^{-1}
- TiO_2 volumetric feed rate from the ESS:
  - 0.0045 mL s^{-1}

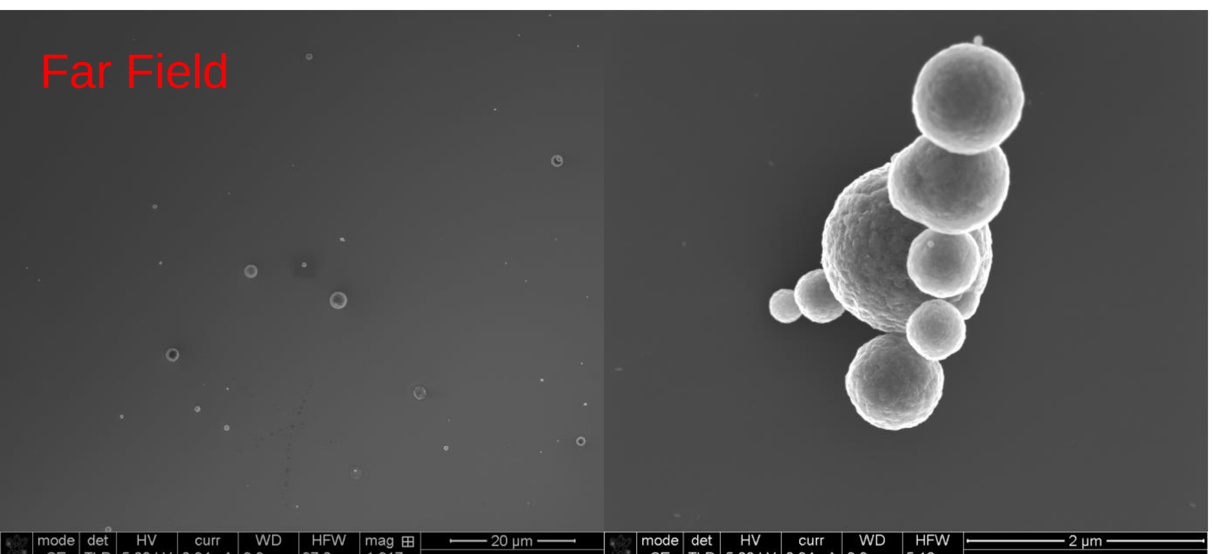
NF/FF modelings

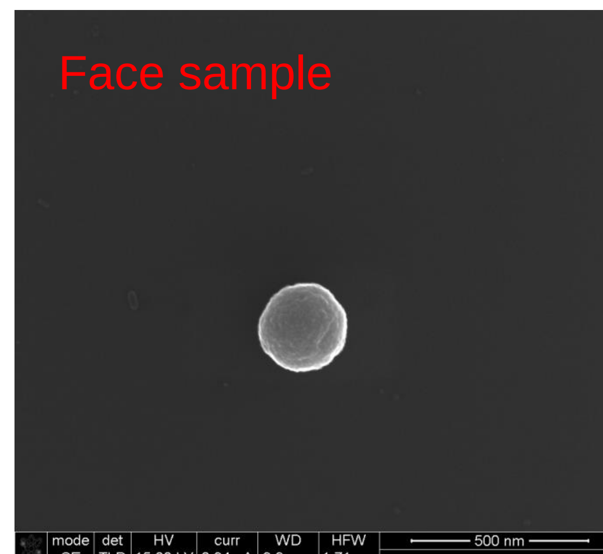


Surface deposition

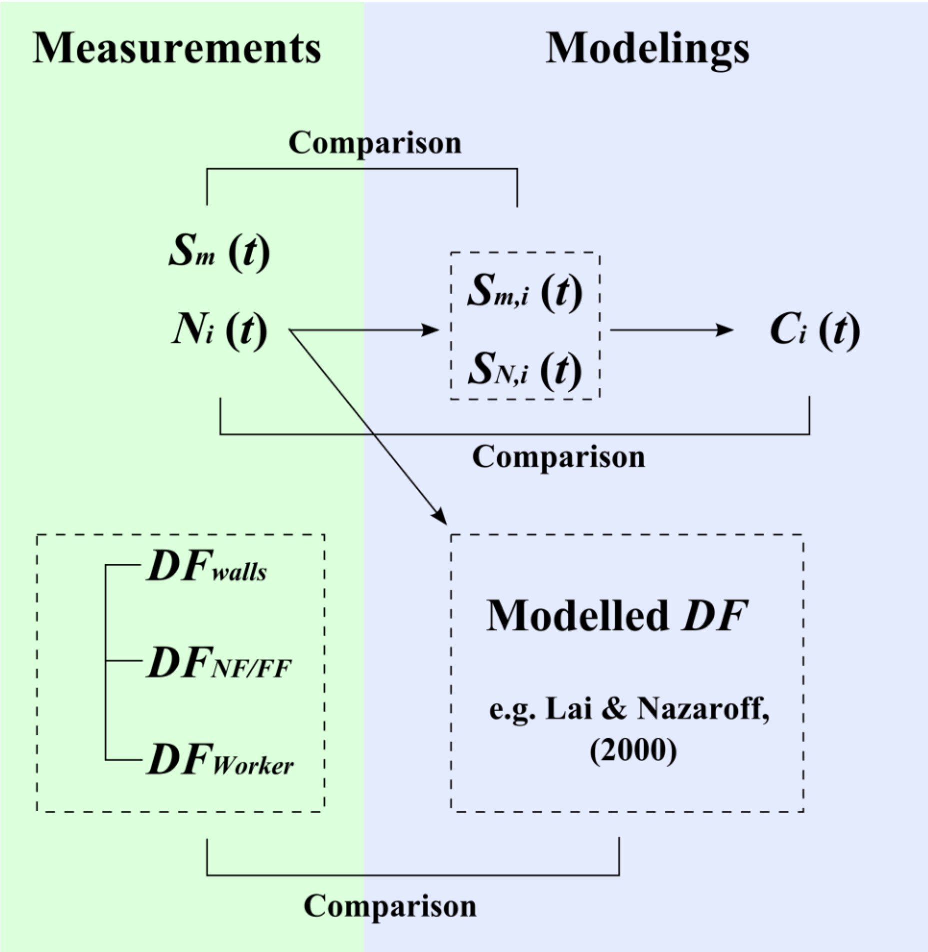


- Near Field < 10 µm
- Far Field < 5 µm
- Face < 500 nm (~3 minutes)





Summary



Measurements:

- Size resolved concentrations (N, V)
- Dispersion (NF/FF, personal)
- Precursor feed rates
- Size resolved surface deposition (NF/FF, personal)
- Particle characterization (density, morphology, composition)

Modelings:

- Emission rates to air (S_N, S_V)
- Deposition rates (walls, floor)
- Concentrations (N, V)

Comparison of measurements with:

- Exposure assessment models/tools

Conclusions

- Electrostatic spray (ESS) is promising technique for NOAA coatings
- Particles were fully mixed → single box
- Indoor aerosol models can esitmate airborne particle emission rates
- Transfer efficiency = $S_V - S_{precursor}$

References

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Thank you!