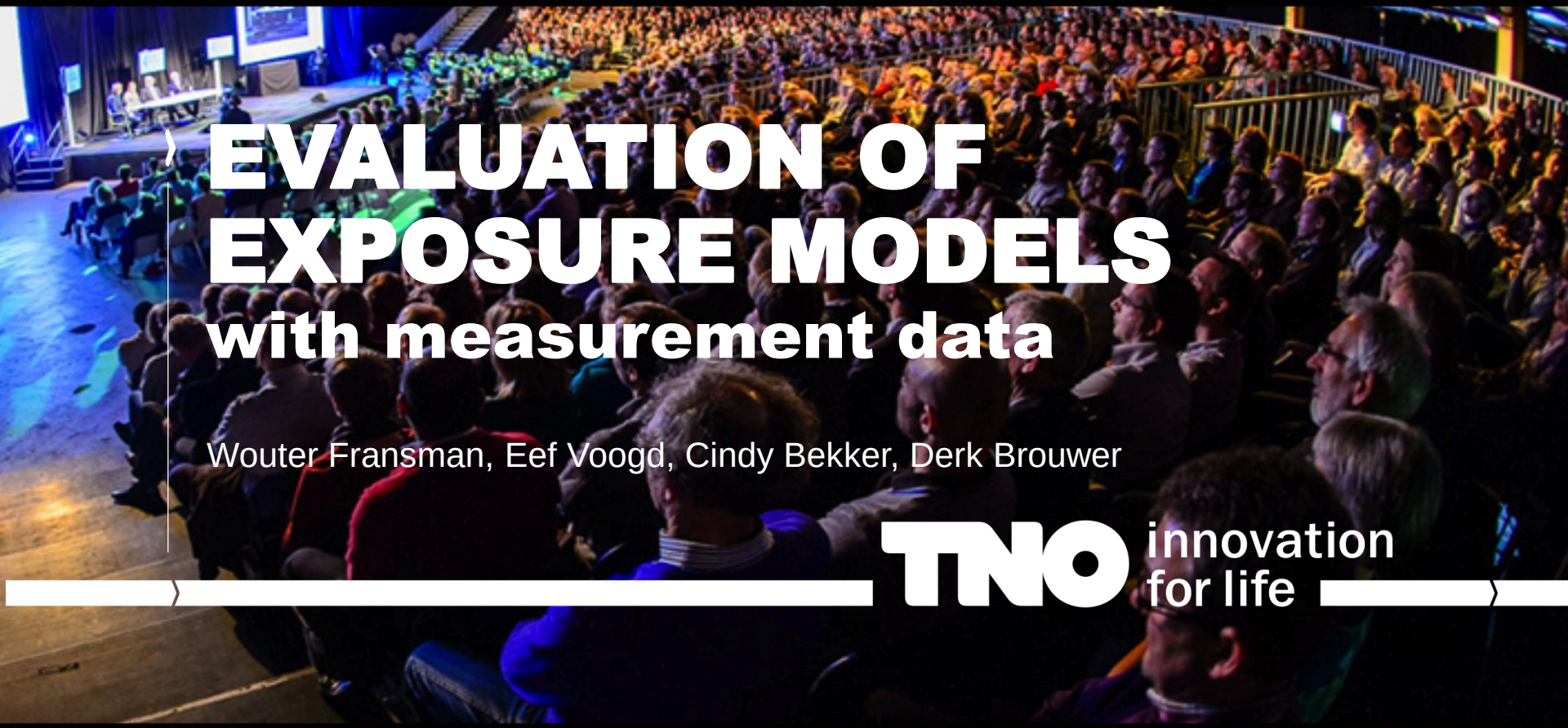

EVALUATION OF EXPOSURE MODELS
with measurement data

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INTRODUCTION

- Currently no quantitative model available to assess exposure to NOAA
- Models available for assessing exposure to powders (in mg/m^3)
- Metric conversion tools can convert particle number concentration to mass concentration.

- Objective: to evaluate the performance of the ART model and the Stoffenmanager Nano 1.0 exposure model by using nano exposure measurement data


DATA SELECTION

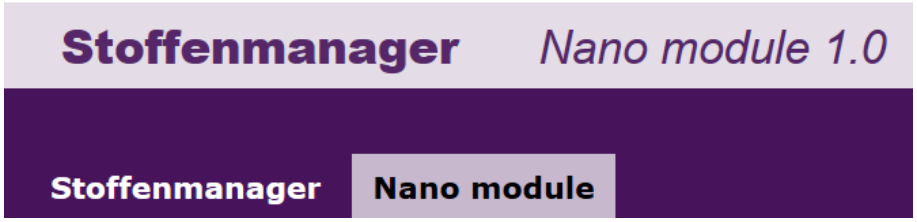
- Data availability vs. data quality
- Contextual information for model input
- Defined activities in the applicability domain of the model
- Raw data available
- Similar measurement strategy / Controlled environment
- SMPS and APS measurement results available

- Dumping powder (n=44)
  - Drop height
  - Moisture content
  - Three substances

	Al_2O_3 (gamma)	SiO_2 (amorphous)	TiO_2 (anatase)
CAS number	1344-28-1	7631-86-9	1317-70-0
Average size diameter	20 nm	15 – 20 nm	10 – 25 nm
Purity	99.9 %	99.5 %	99.5 %
Bulk density	3.5– 3.9 g/cm^3	2.4 g/cm^3	3.9 g/cm^3
Moisture content	2.34 %	9.15 %	0.66 %

PERFORMANCE CHECK ART AND STM-N

- Source receptor models
  - Mechanistic approach
- ART model
  - www.advancedreachtool.com
  - Mass concentration estimate (mg/m^3)
  - Developed for bulk materials
- Stoffenmanager Nano 1.0
  - www.stoffenmanager.nl
  - Exposure banding
  - Relative scoring




METRIC CONVERSION

- Density assumed: bulk or 1 g/cm^3
- Assumed median size of bin range as particle diameter
- Summation of SMPS and APS (background correction)
- Assumed spherical particles

$$C_{mDp} = 10^{-12} \cdot \rho_p \cdot C_{Dp} \cdot {}^{\pi}/_{6} \cdot d^3_{m/a}$$

Where

C_{mDp} = Mass concentration in mg/m^3

ρ_p = particle density in g/cm^3

C_{Dp} = Number concentration #/cm^3

$d^3_{m/a}$ = particle diameter in nm

(Hinds, 1999)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METRIC CONVERSION RESULTS

Density=1	N	GM (mg/m^3)	GSD	Min (mg/m^3)	Max (mg/m^3)
Al_2O_3	16	0.20	2.08	0.07	0.62
SiO_2	12	2.69	2.85	0.35	13.39
TiO_2	16	0.20	2.60	0.06	0.92

Bulk density	N	GM (mg/m^3)	GSD	Min (mg/m^3)	Max (mg/m^3)
Al_2O_3	16	0.76	2.08	0.26	2.29
SiO_2	12	6.50	2.85	0.84	32.40
TiO_2	16	0.77	2.60	0.23	3.57


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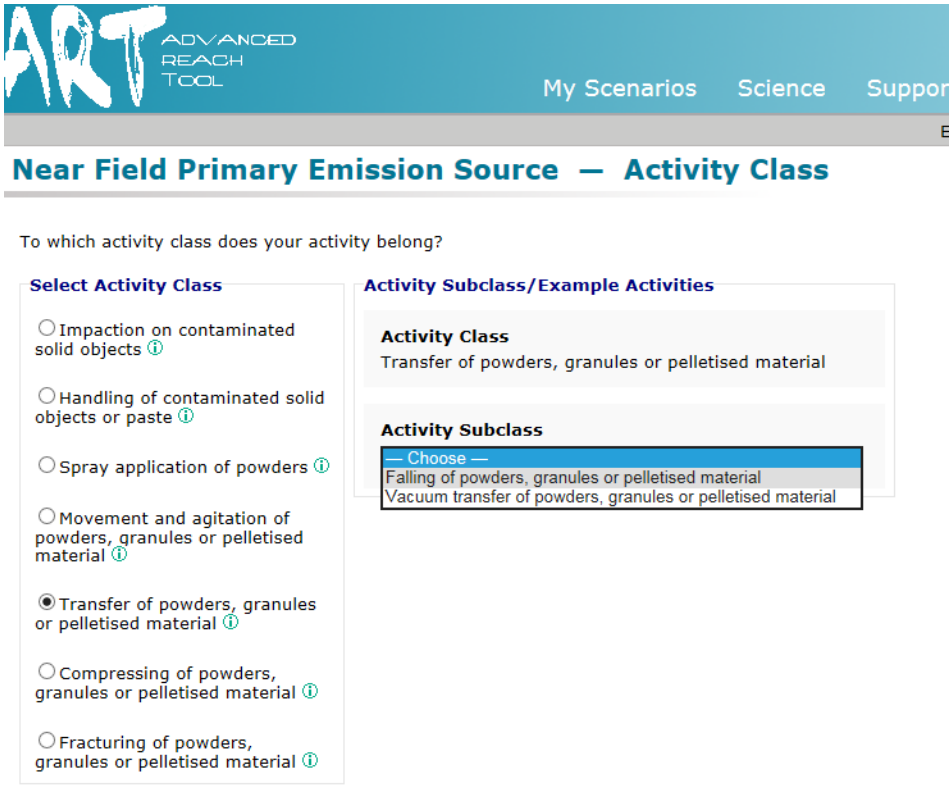
ANALYSIS

- Analysis
  - Plot measured concentration vs. model estimate
  - Correlation (Spearman)
  - (Relative) Bias
  - Deviation from ART uncertainty factors
- Sensitivity analysis
  - Densities: Bulk density vs density = 1 g/cm^3

ART ESTIMATES

- Substance emission potential:
  - Moisture content
- Activity emission potential:
  - Drop height

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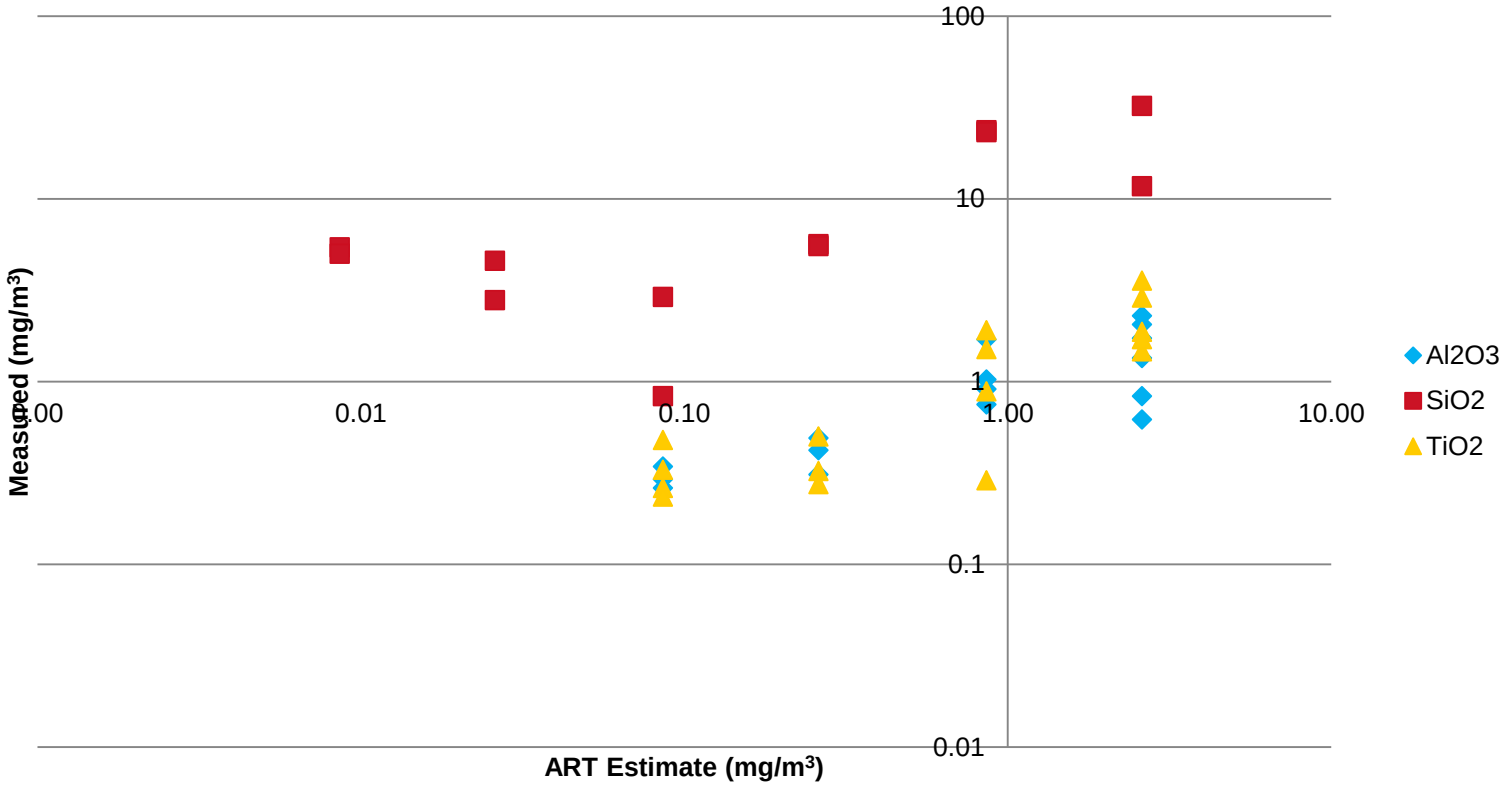
APS+SMPS Bulk density (ART)



Substance	Spearman	p-value	N
Al2O3	0.83	<0.0001	16
SiO2	0.75	0.005	12
TiO2	0.81	0.0002	16
All	*0.28*	*0.0663*	*44*
Al2O3+ TiO2	*0.83*	*<0.0001*	*32*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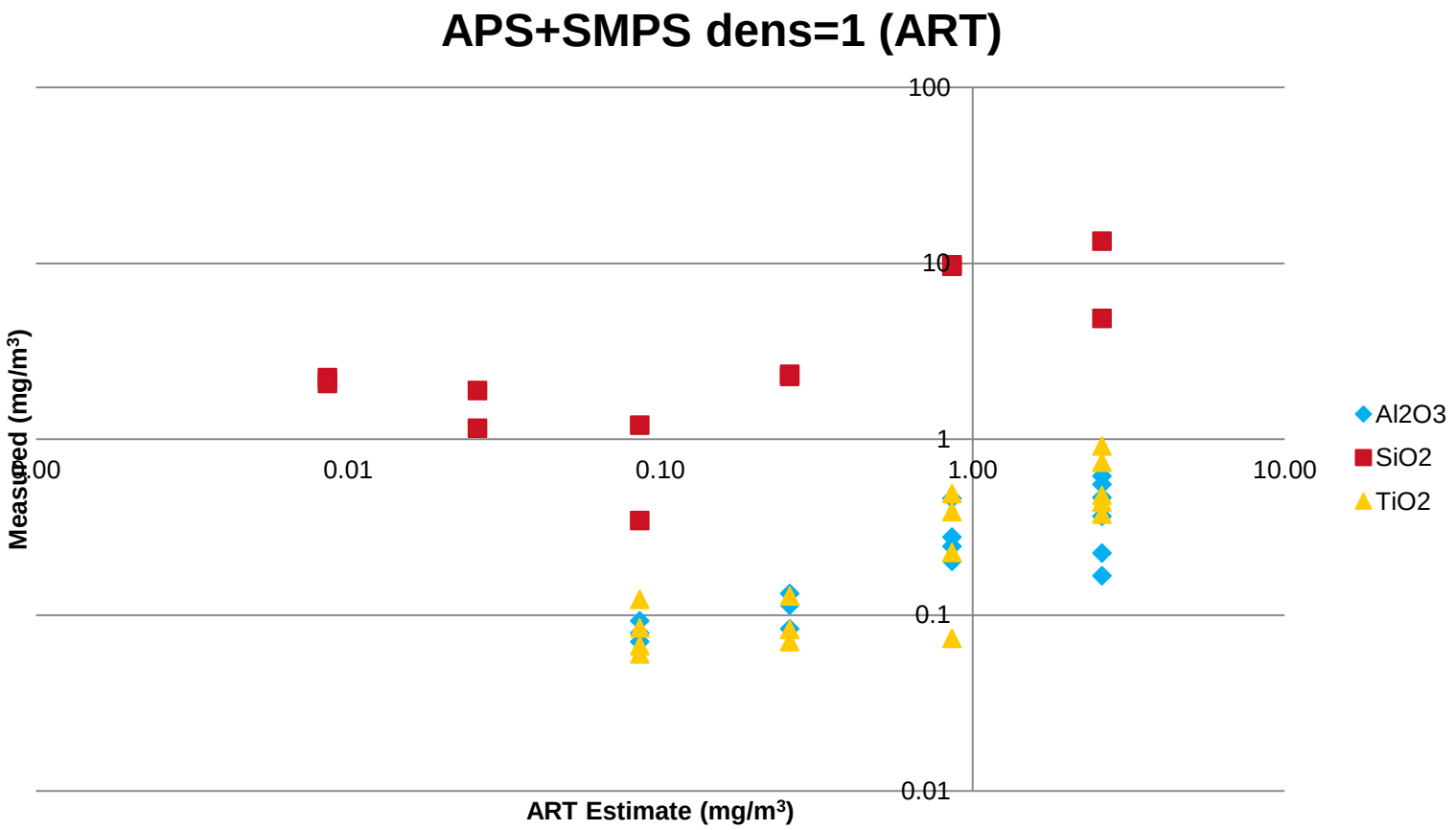



ART EVALUATION

Bulk density

Substance	Relative Bias (%) (bias/GM*100%)	(Total) Bias	GM measured (mg/m^3)
Al2O3	-10.7	-0.08	0.76
SiO2	-97.7	-6.35	6.50
TiO2	-29.2	-0.23	0.77

Substance	# in UF	%	Total
Al2O3	16	100	16
SiO2	4	33.3	12
TiO2	15	93.8	16
All	35	79.6	44
Al2O3+ TiO2	31	96.9	32

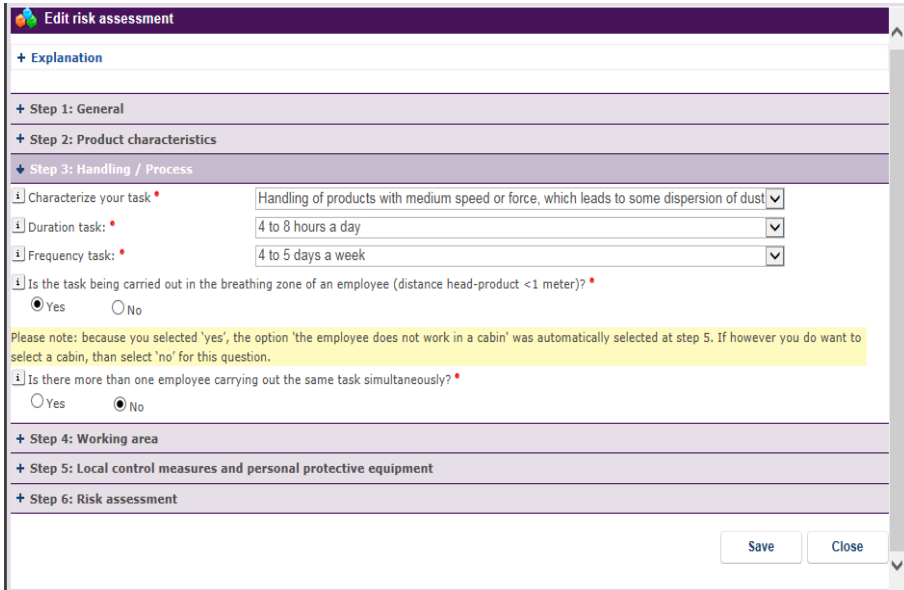
Density = 1

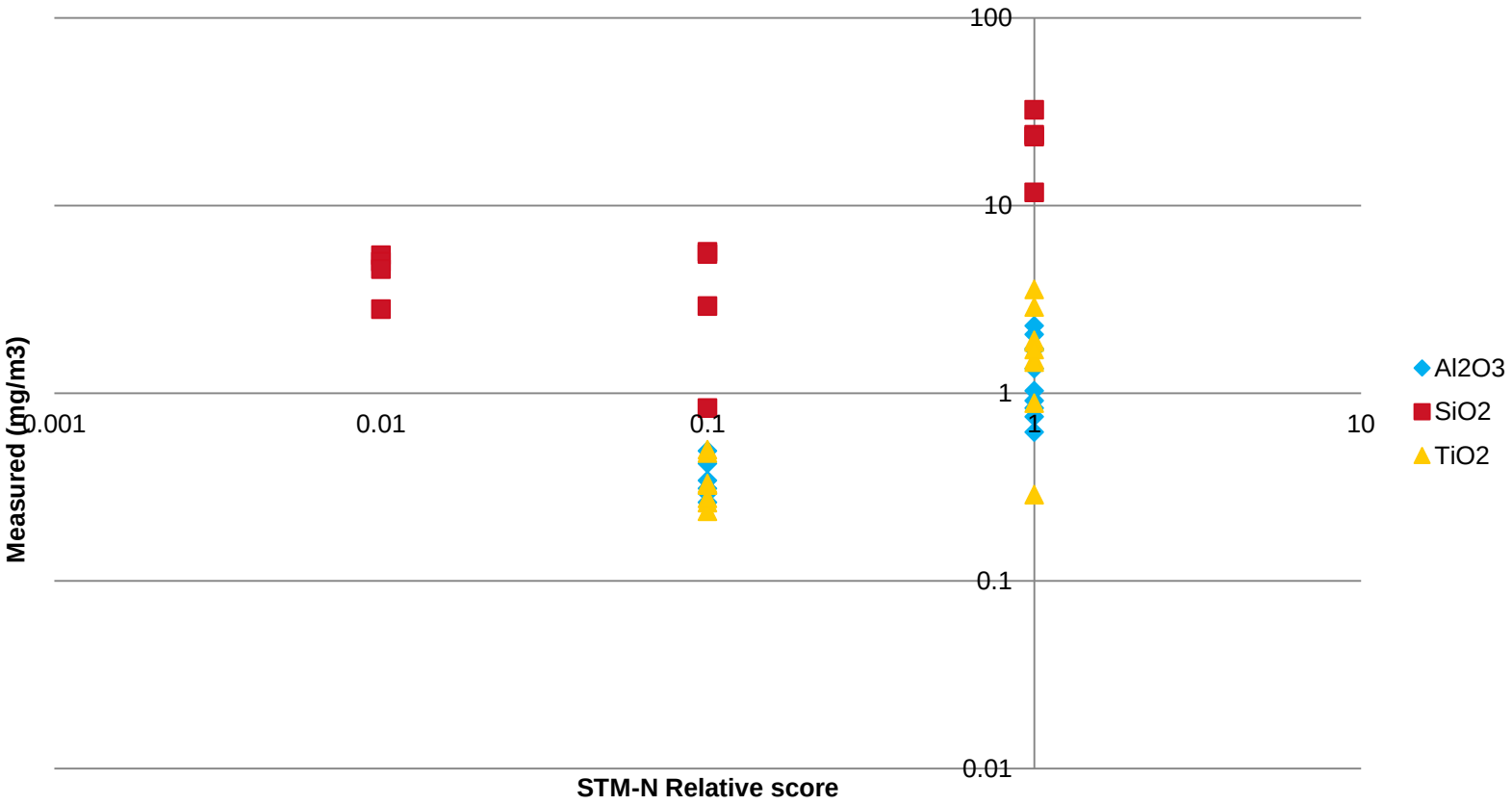
Substance	Relative Bias (%) (bias/GM*100%)	(Total) Bias	GM measured (mg/m^3)
Al2O3	230.2	0.47	0.20
SiO2	-94.4	-2.54	2.69
TiO2	176.1	0.35	0.20

Substance	# in UF	%	Total
Al2O3	11	68.8	16
SiO2	6	50.0	12
TiO2	12	75.0	16
All	29	65.9	44
Al2O3+ TiO2	23	71.9	32

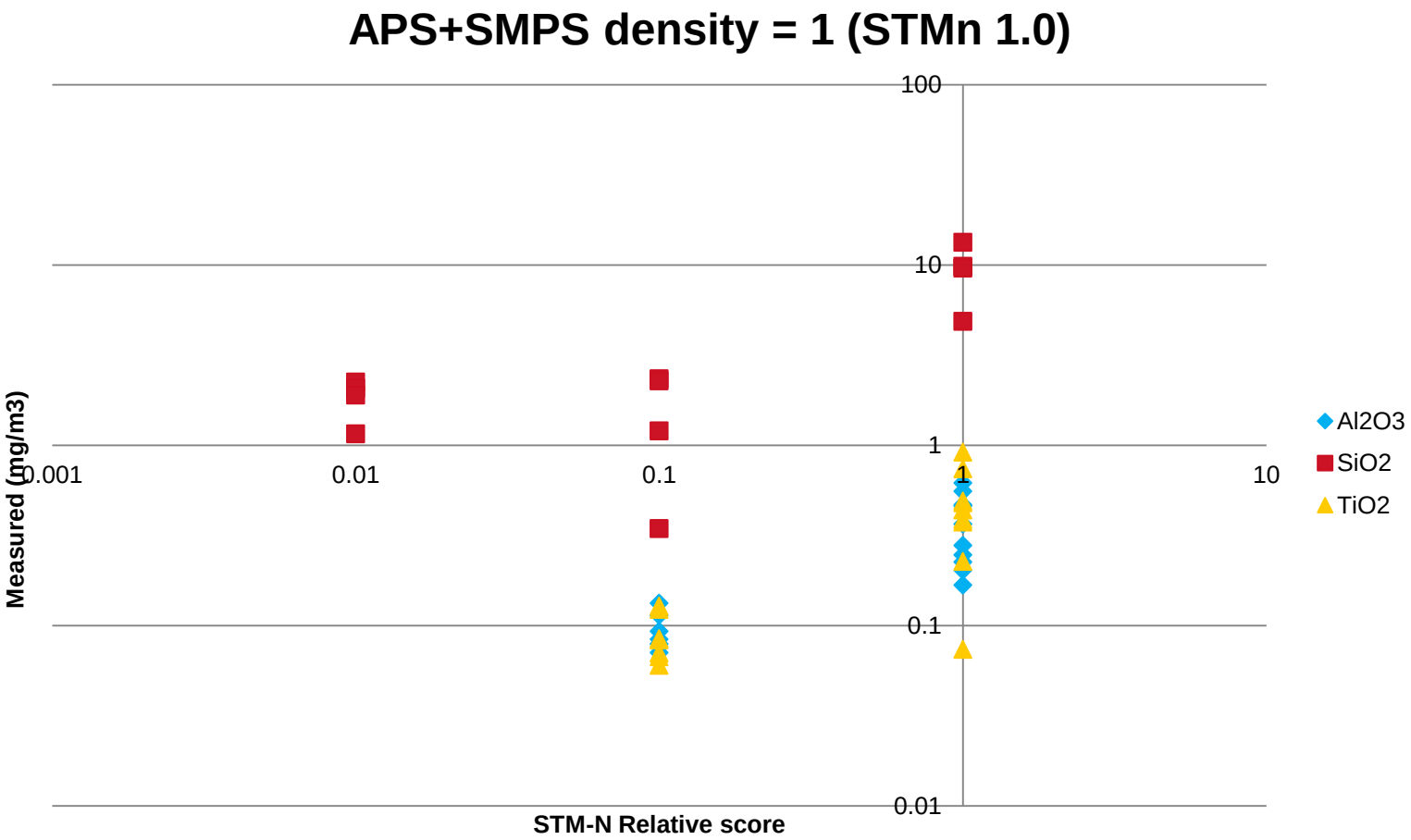
STM-N ESTIMATES

- Only one variable of variation
  - Moisture content
- Relative STM-N Multiplier used
  - No quantitative estimate
  - Only rank correlation
  - No bias calculation possible





Substance	Spearman	p-value	N
Al2O3	0.84	<0.0001	16
SiO2	0.74	0.006	12
TiO2	0.75	0.0008	16
All	0.23	0.14	44
Al2O3+ TiO2	0.80	<0.0001	32



APS+SMPS density = 1 (STMn 1.0)
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
Measured (mg/m3)
STM-N Relative score
Al2O3
SiO2
TiO2


CONCLUSIONS

- Mass-based model assessments correlate reasonably well with converted nano particle number concentration data (for 2 out of 3 nanomaterials)
- Correlation different for different nanomaterials
- Metric conversion from particle number to mass seems to result in reliable estimates
- Similar pattern for bulk density and density = 1, but different bias
- More variation in exposure scenarios needed


DISCUSSION

- Limited number of exposure scenarios
  - Limited to powder dumping scenario
- Only controlled environment
  - More workplace data needed for more variation
- Metric conversion introduces uncertainty
  - Particle shape and diameter assumption

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