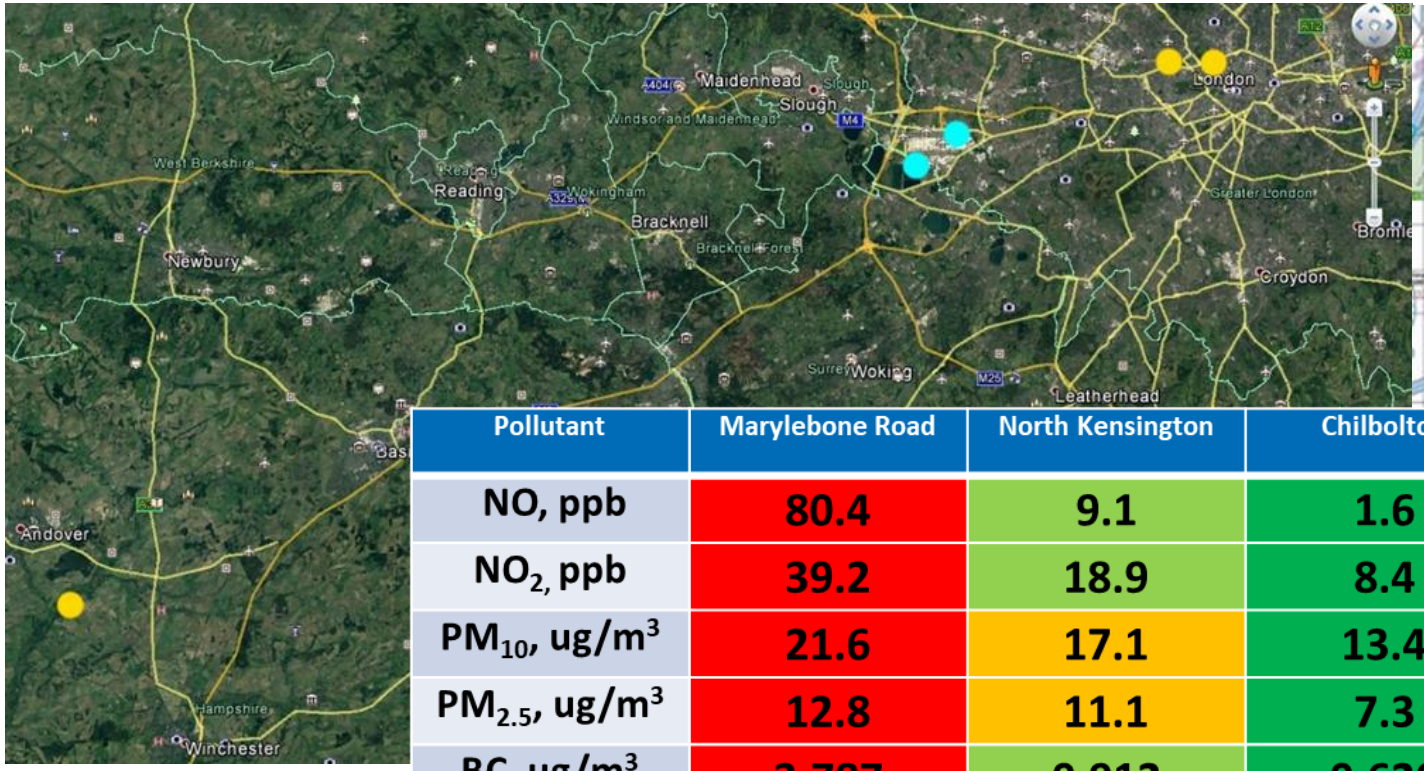
UFP monitoring campaigns at London Heathrow Airport

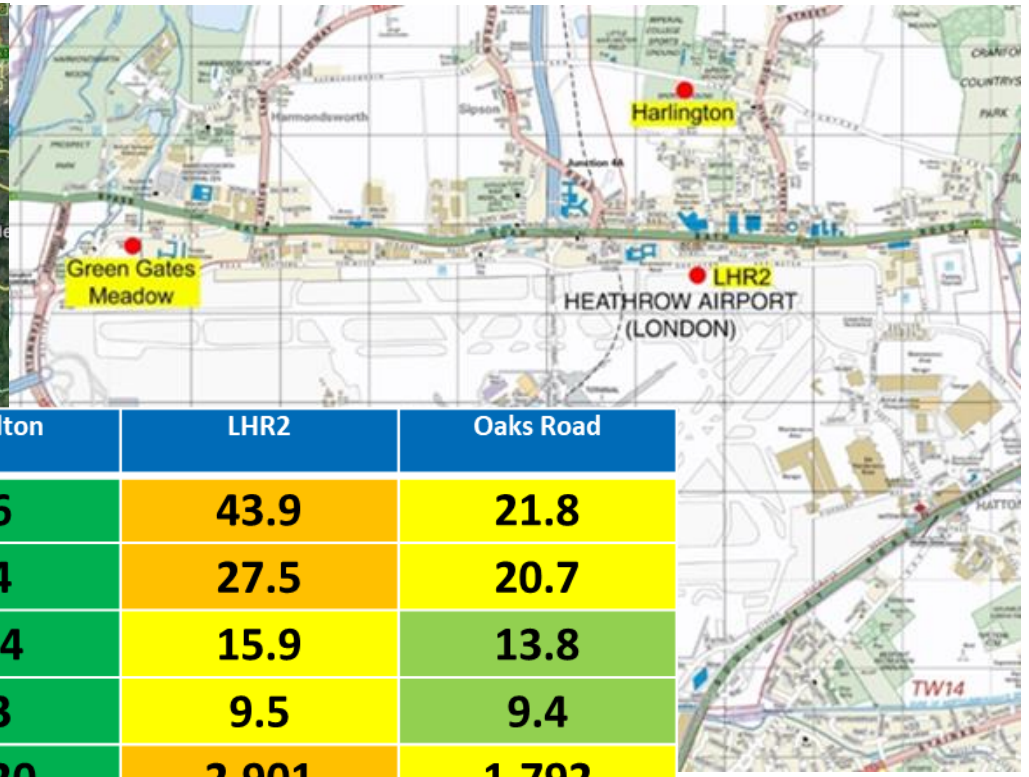
EFCA International Symposium, Brussels 5/6 July 2022

PRESENTATION CONTENTS

- Airport UFP in context
- Effect of flight operating modes
- Fast measurements and emissions
- WHO

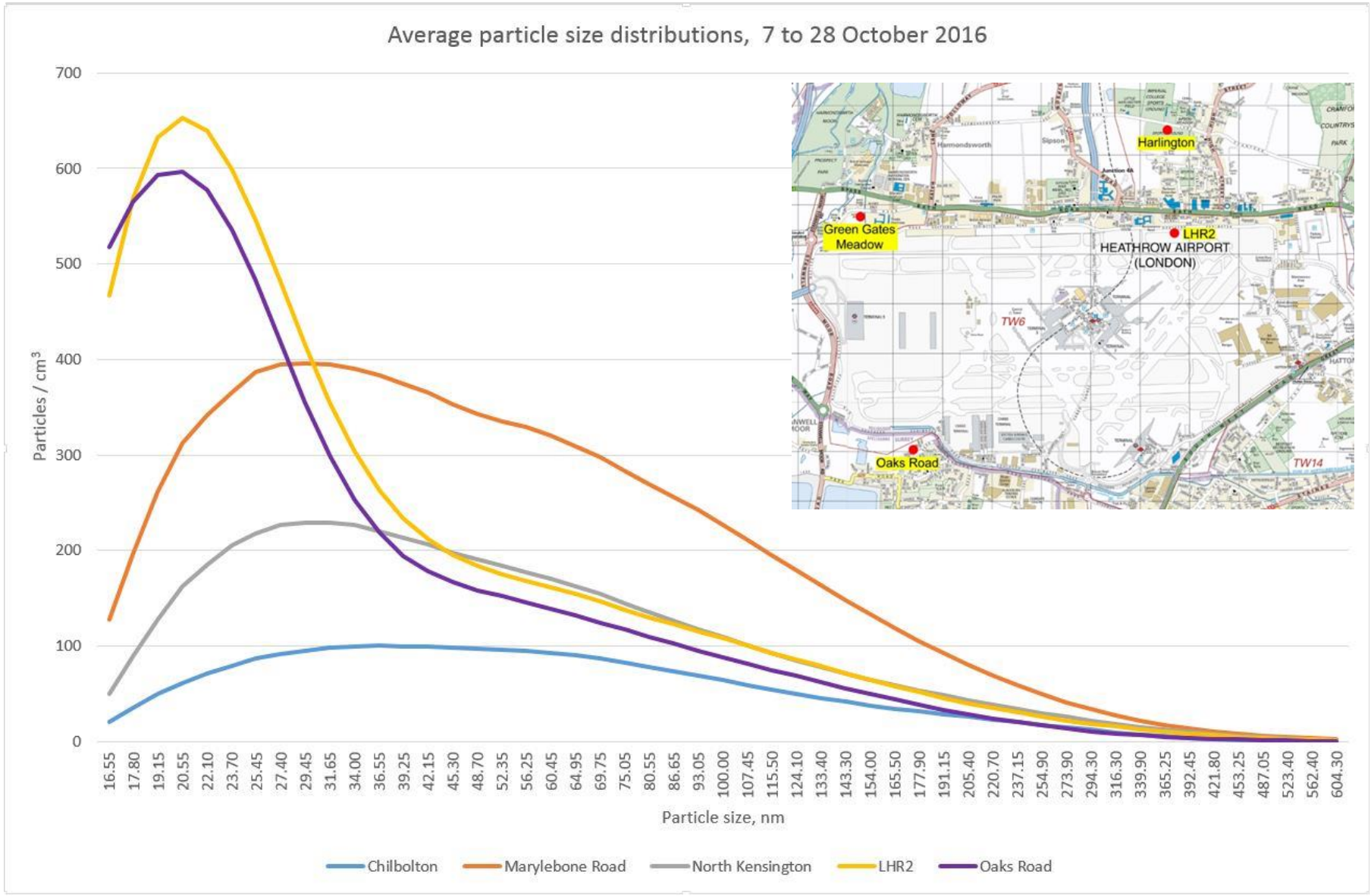
AIRPORT UFP IN CONTEXT - 2016

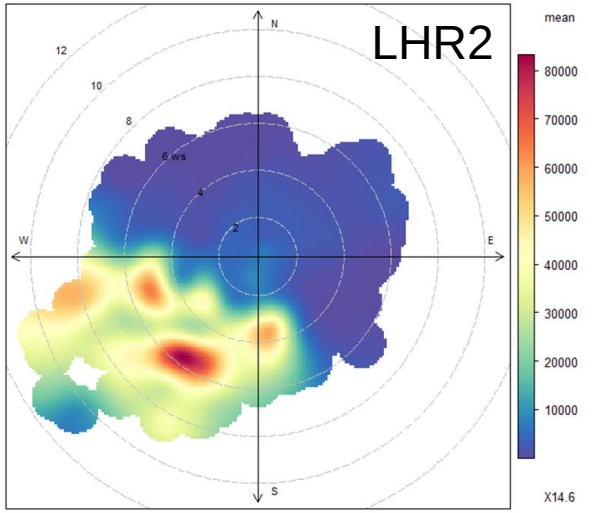


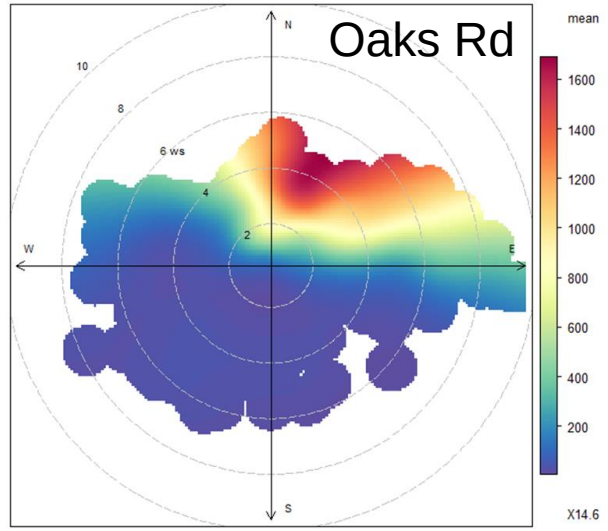


Pollutant	Marylebone Road	North Kensington	Chilbolton	LHR2	Oaks Road
NO, ppb	80.4	9.1	1.6	43.9	21.8
NO_2, ppb	39.2	18.9	8.4	27.5	20.7
PM_{10}, ug/m^3	21.6	17.1	13.4	15.9	13.8
$PM_{2.5}$, ug/m^3	12.8	11.1	7.3	9.5	9.4
BC, ug/m^3	3.787	0.912	0.620	2.901	1.792
UVPM, ug/m^3	0.305	0.198	0.277	0.615	0.537
Total PN, particles/cm^3	10046	5384	2637	9053	7964

CONTEXT - PARTICLE SIZE DISTRIBUTION

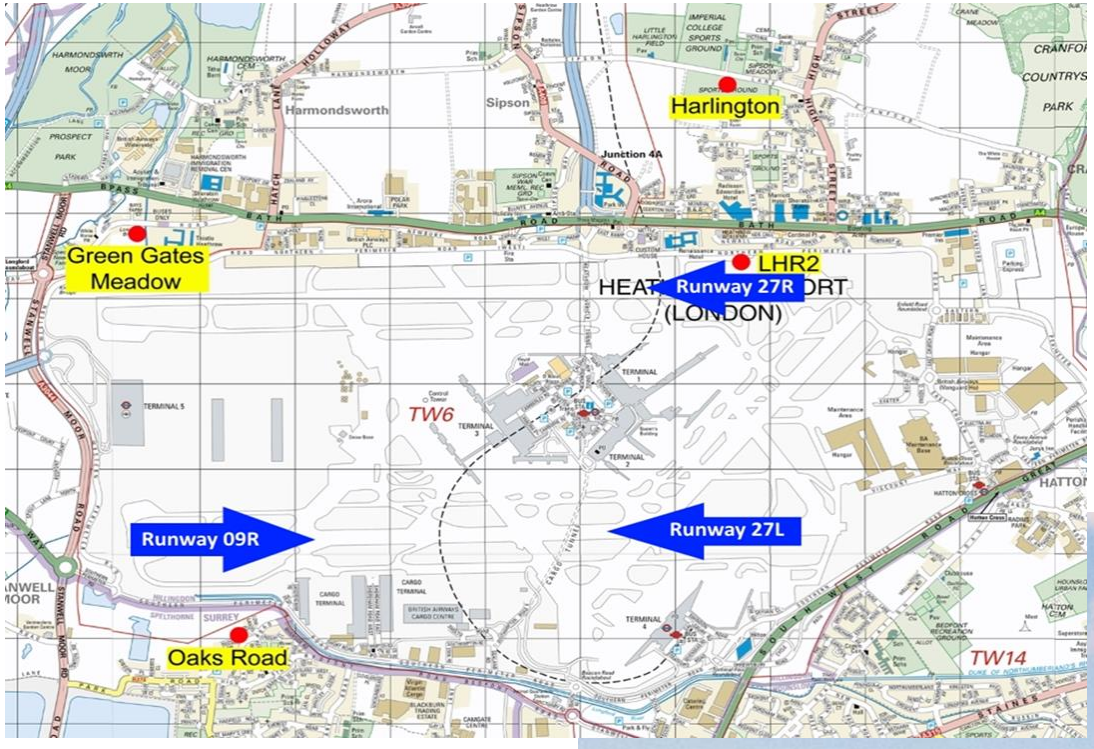


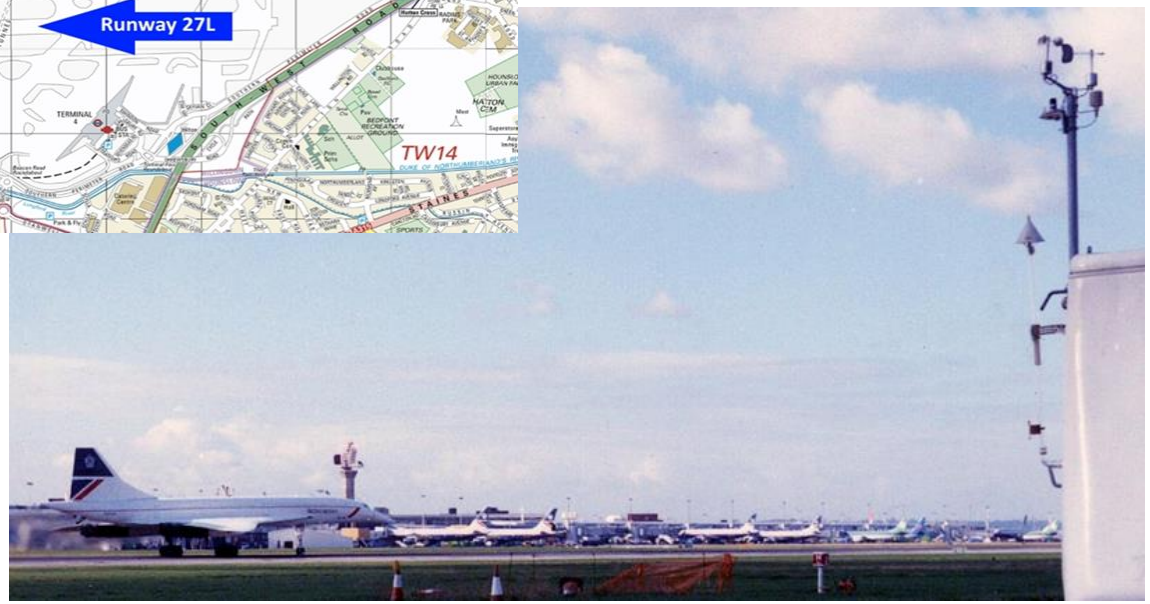




AIRPORT UFP FAST MEASUREMENTS - 2017

- Just airside monitoring station, October / November 2017
- 1 minute UFP scans, basic aircraft movement data and meteorology
- Analysis of measurements from departures and arrivals





AIRPORT UFP FAST MEASUREMENTS - 2017

- Snapshot averages
- Departures UFP, BC and NOx higher than Arrivals.
- 09R data influenced by winds from London

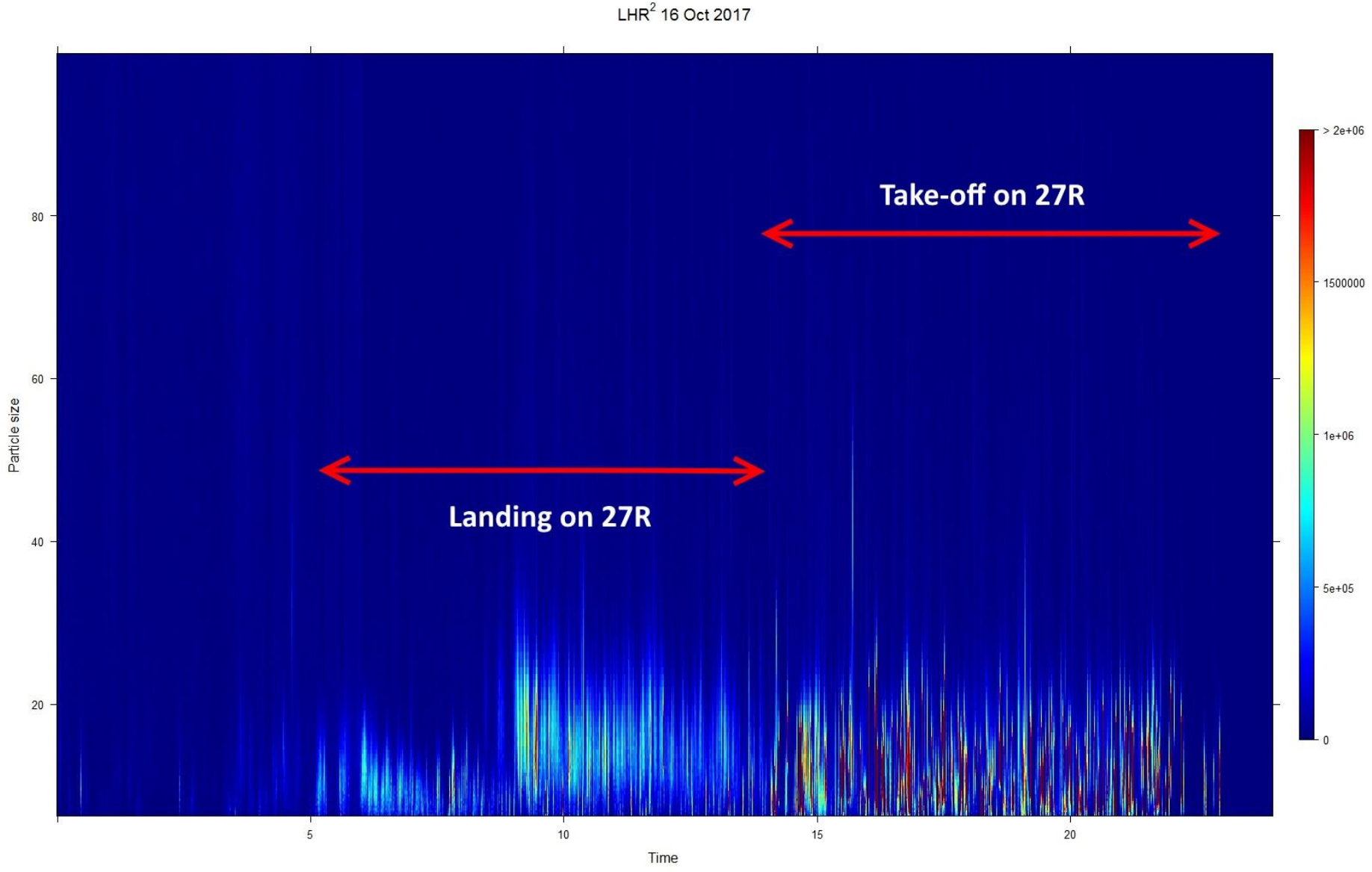
	Average	Depart 27R	Arrive 27R	Depart 09R	Overnight
PN #/cm^3 (5-100nm)	15135	29565	11393	4118	1665
BC µg/m^3	3.22	3.61	2.34	4.47	3.61
UVPM µg/m^3	0.71	0.85	0.49	0.58	0.83
$PM_{2.5}$ µg/m^3	10.0	9.7	8.9	18.6	10.2
NOx ppb	52.9	76.5	39.2	71.5	33.4

AIRPORT UFP FAST MEASUREMENTS - 2017

- Clear differences between overnight, landing and departing modes

BUT:

- 1 minute scan, 1 minute departure and arrival data and 15 minute meteorology not enough to identify individual aircraft

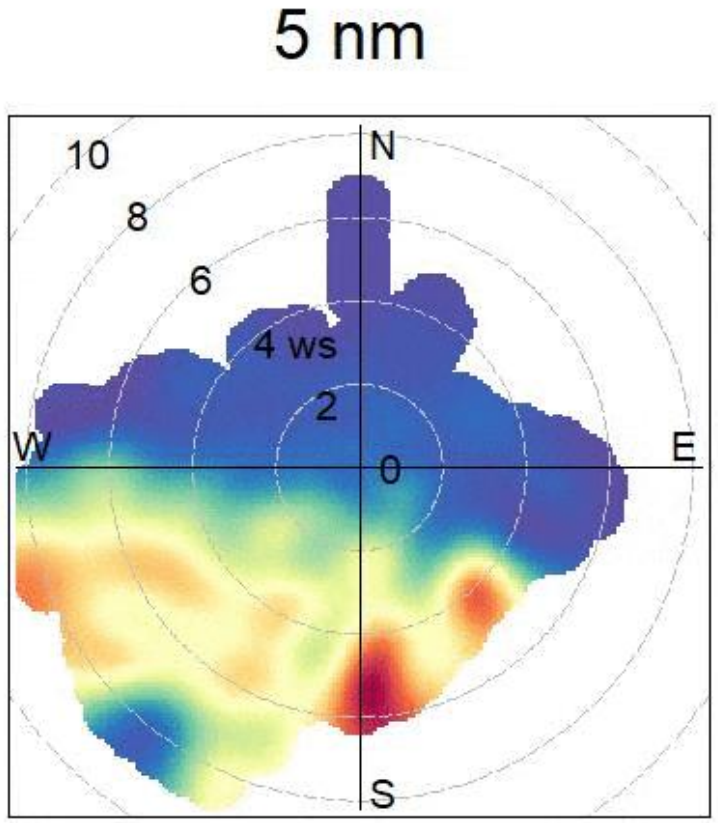


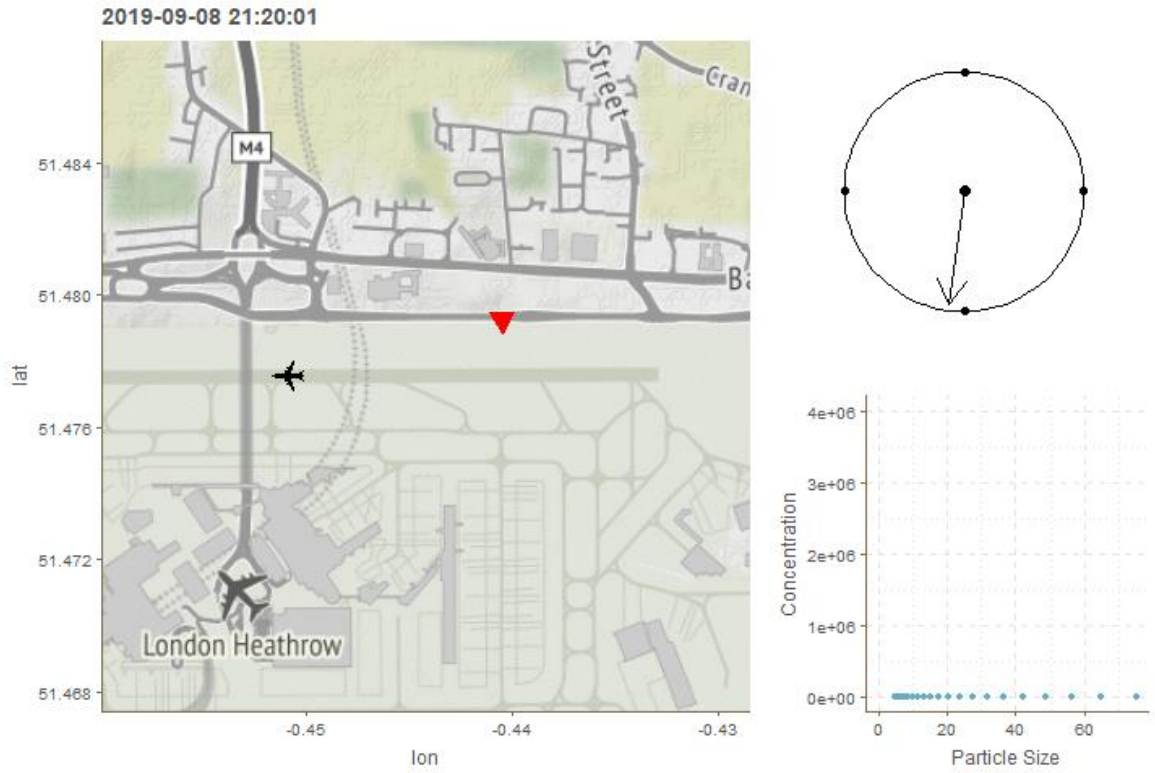
AIRPORT UFP VERY FAST MEASUREMENTS – 2019

- 2019 study (September to November) captured very high resolution data:
- 1 second full scan UFP (5-1000nm)
- 1 second aircraft position and speed
- 10 second NOx data
- 1 minute PM, BC and Met.
- Weekly cascade impactor samples

- Over 25GB raw data!

AIRPORT UFP VERY FAST MEASUREMENTS – 2019





- Very fast data, aircraft position and meteorology allows measurements from individual aircraft to be recorded and emissions contributions to be estimated
- Used NOx measurements and documented NOx emission factors to produce a scaling factor to apply to UFP measurements and calculate a series of UFP emissions rates for aircraft types

AIRPORT UFP VERY FAST MEASUREMENTS – 2019

- Departures (arrivals follow similar, but lower trend)
- Large differences between CAEP and calculated is condensable particles (CAEP @ 300°C)
- Larger and older aircraft (usually) have highest emission rates

	CAEP (x10^15 #/sec)	Measured (x10^15 #/sec)
A319	1.41	94
A32x	3.12	29.8
A330	2.32	117
A340	no data	111
A350	2.04	182
A380	4.84	171
737	2.64	28.2
747	no data	171
757	no data	30.9
767	3.5	128
777	no data	263
787	0.68	164

UFP AT AIRPORT – CLUES?

- Sulphur in aviation fuel is a likely factor in PN formation and PSD at airports

- PSD shape changed when UK migrated to ULS road fuels. PSD in 2007 (prior to the change) remarkably similar to airport profile today
- Current permitted sulphur in road fuel is 20ppm
- Current permitted sulphur in Jet-A1 is 900ppm
- Lots of work exploring alternatives

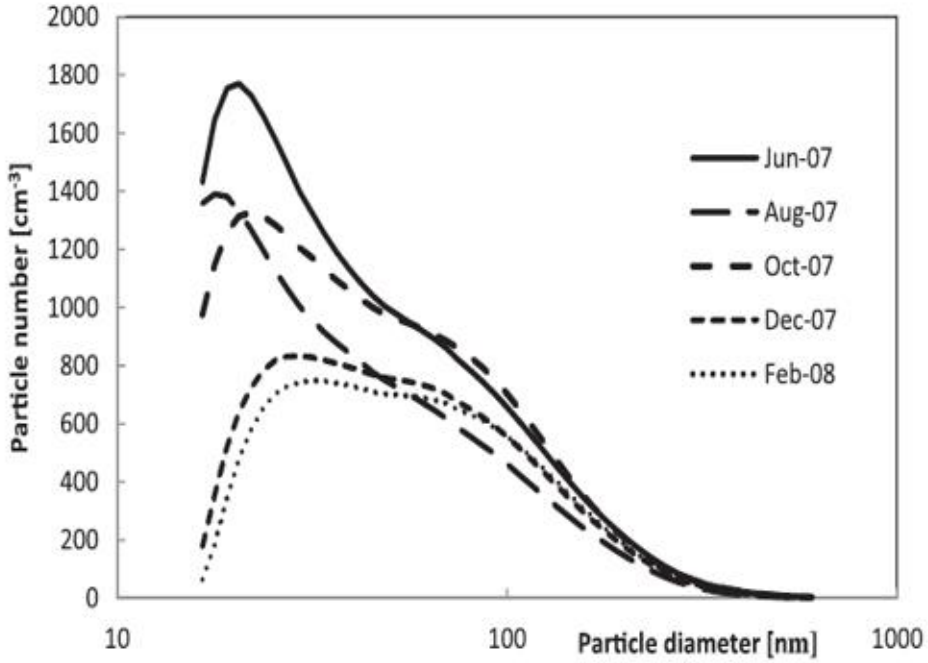


Fig. 7. Marylebone Road - monthly mean particle number size spectra.

Source: Jones et al, Atmospheric Environment 50 (2012), 129-138

UFP AND WHO

- WHO published “best practice” guidance in 2021:
  - High concentrations hour >20,000 #/cm^3
  - High concentrations day >10,000 #/cm^3

- BUT! Analysers are not the same.

  Dylos ≠ Nano Tracer ≠ DMS500 ≠ CPC/SMPS #1 ≠ CPC/SMPS #2 ≠ CPC

- Compliance with guidance will be challenging!

2016 survey	LHR2	MRD
Total measurements	1370h / 57d	1370h/57d
# of hours >20,000 #/cm^3	274 (20%)	233 (17%)
# of days >10,000 #/cm^3	33 (58%)	33

UFP AT HEATHROW AIRPORT – THESIS CONCLUSIONS

- UFP near airports is higher than typical urban areas
- Aircraft are the source of these particles
- UFP from departing aircraft is higher than arriving aircraft
- Larger, older aircraft are (normally) associated with high UFP
- Aircraft UFP emissions are higher than literature values
- UFP measurements near airports exceed 2021 WHO guidance

- We need to harmonise methodologies!

ANY QUESTIONS?

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