

# A closer look at the invisible - unprecedented levels of ultrafine particles (UFP) and the hydrological cycle

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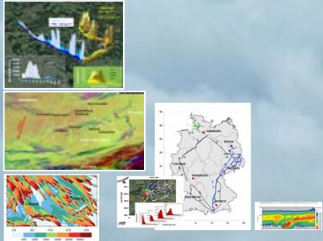


**OBSERVATION:**  
**HIGH (LOCAL) VALUES**  
**REMOTE COUNTRYSIDE**

Where do they come from, primary - secondary, how many and why are they relevant for hydrology?

**CCN**

Day / Night  
Transport



**EXPERIMENTAL**

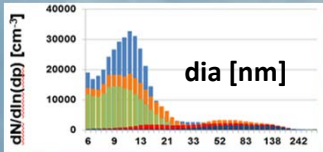
Small Environmental Research Aircraft

**LONG DISTANCE > SOURCE APPORTIONMENT**  
**REGIONAL LAGRANGE > SOURCE STRENGTH**

MONGOLIA-STEPPE, AUSTRALIAN-OUTBACK, -GBR,  
FINLAND-BOREAL FOREST, RURAL GERMANY,  
GREAT BRITAIN, SOUTHERN FRANCE,  
MEXICO, MEDITERRANEAN ISLANDS, BALTIC SEA



**CONTINENTAL**



**DOMINANT SOURCES**

**CONC. 10 km DOWNWIND OF SINGLE EMITTERS**  
**60000 - 180000 cm<sup>-3</sup>, globally > 10<sup>4</sup> units**

size correction

	TG/a	Mode-R [µm]	Global # Particles / a	Y2015
Anthropogenic	42.0	0.040	9.0E+28	
Wildfire	11.0	0.040	2.3E+28	
Biofuel Dom	9.6	0.015	3.9E+29	NUMBERS CALCULATED FROM SIZE MASS DENSITY
Fossil Fuel surface	6.4	0.015	2.5E+29	
Roads / off roads	3.5	0.015	1.4E+29	
Ships	7.8	0.500	1.6E+29	> 5.6E+29 (r~1)
Industry (300m)	39.2	0.500	4.3E+29	
Power-PI (300m)	48.2	0.500	5.1E+29	> 1.3E+30
ANTHROPOGENIC			8.9 E+29	
natural * 10			Y 2015 ~ 2.7E+30 (r ~ 10 nm)	

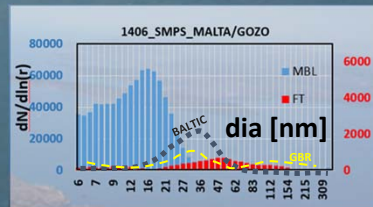
**Fossil power, refineries ... & SHIPS**

= PRIMARY UFP EMITTERS ( ~ 2.5 \* 10<sup>15</sup> MW<sup>-1</sup>s<sup>-1</sup> )

GLOBAL ESTIMATE EXP. ~8\*10<sup>29</sup> / ~5\*10<sup>29</sup> a<sup>-1</sup>

**+ ~ 2 \* Y2K # EMISSION**

**SHIPS (up to 150000 cm<sup>-3</sup>)**



**MALTA, BALTIC HYBRID FERRY**  
**AUSTRALIA-GBR**



**Hydrological cycle, climate relevance**

**MORE CCN**

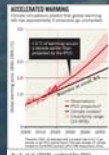
Delay of rain formation, cloud lifetime + -

(drought or flood) Rosenfeld, 2000, 2008, Science

Increased (H<sub>2</sub>O) / latent energy in mid elevations (above PBL)

(torrential rains) Allen & Soden, 2009, Science

(H<sub>2</sub>O column density) Guerreiro, 2018, Nature



Agreement with obs. PW > CC

**CLIMATE MODELS (RCP'S)?**

**DROUGHT**

**INNER MONGOLIA GRASLAND**

**TORRENTIAL RAIN**

Emission (Australia)  
Cloud modification