Emission, transport et dépôts atmosphériques des microplastiques

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Banyuls sur Mer

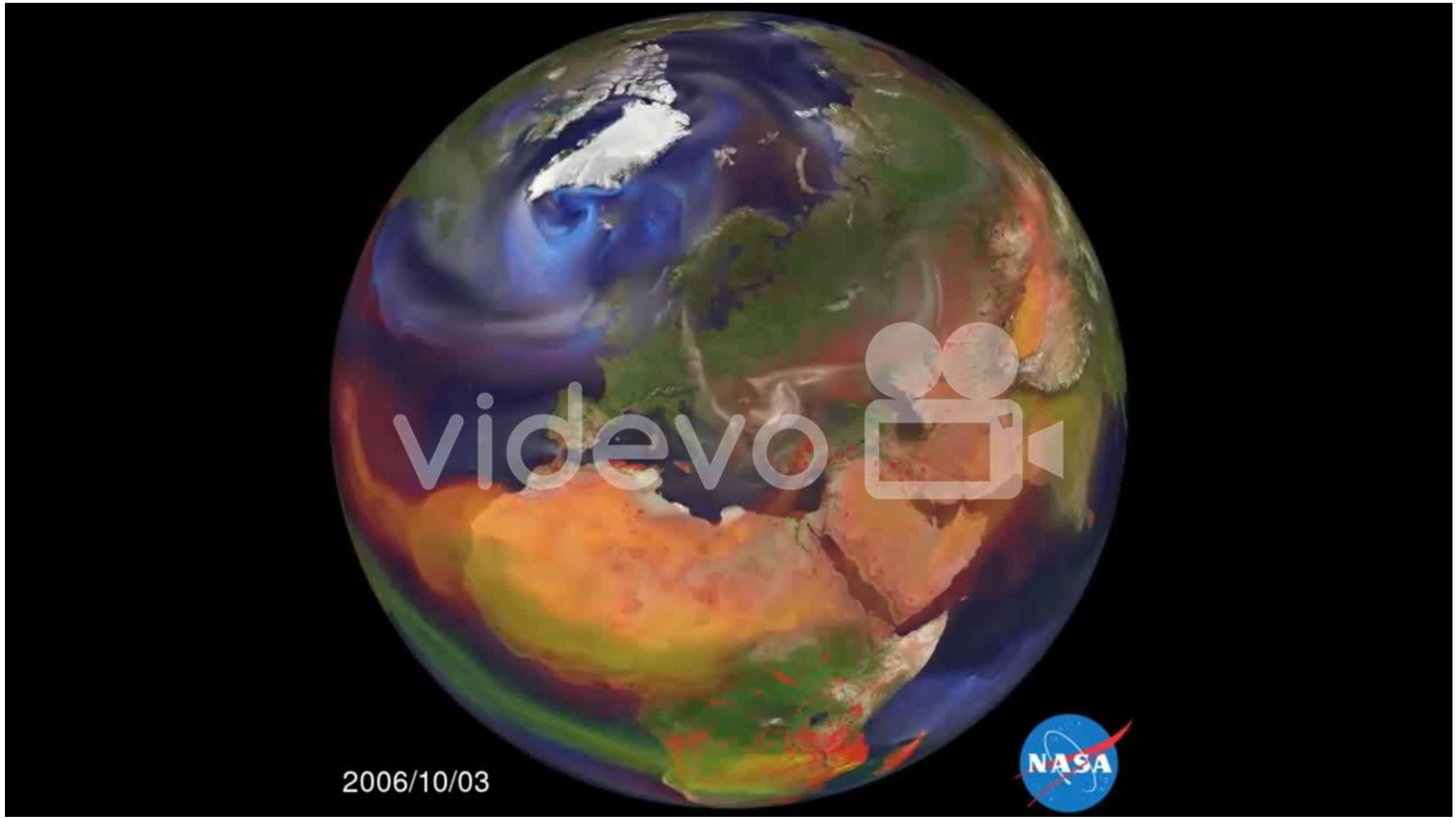
Université de Toulouse

ANR ATMO-PLASTIC

cnrs

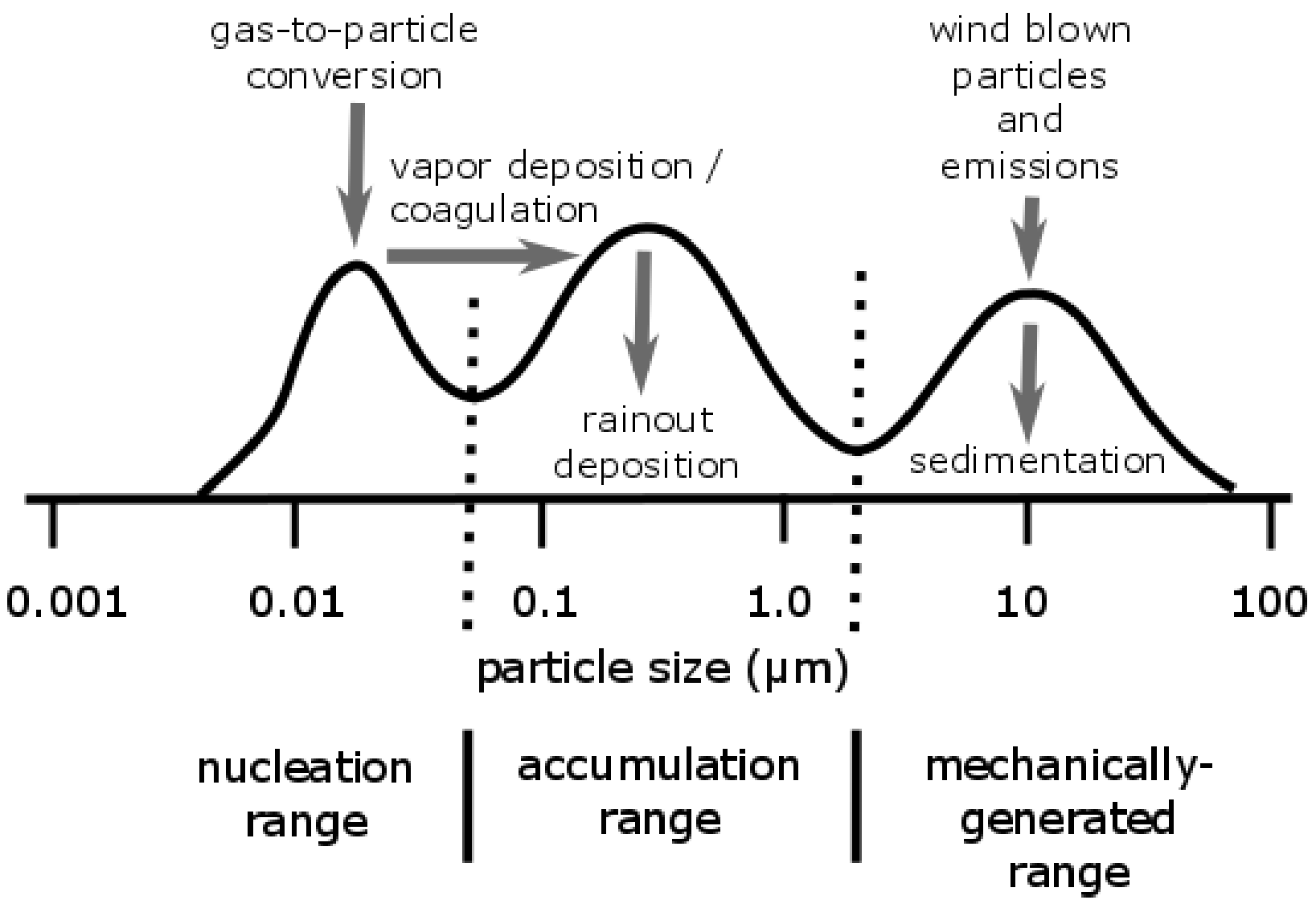
Source: Internet

Global atmospheric microplastic dispersal?



Source: NASA

Atmospheric particle size distribution



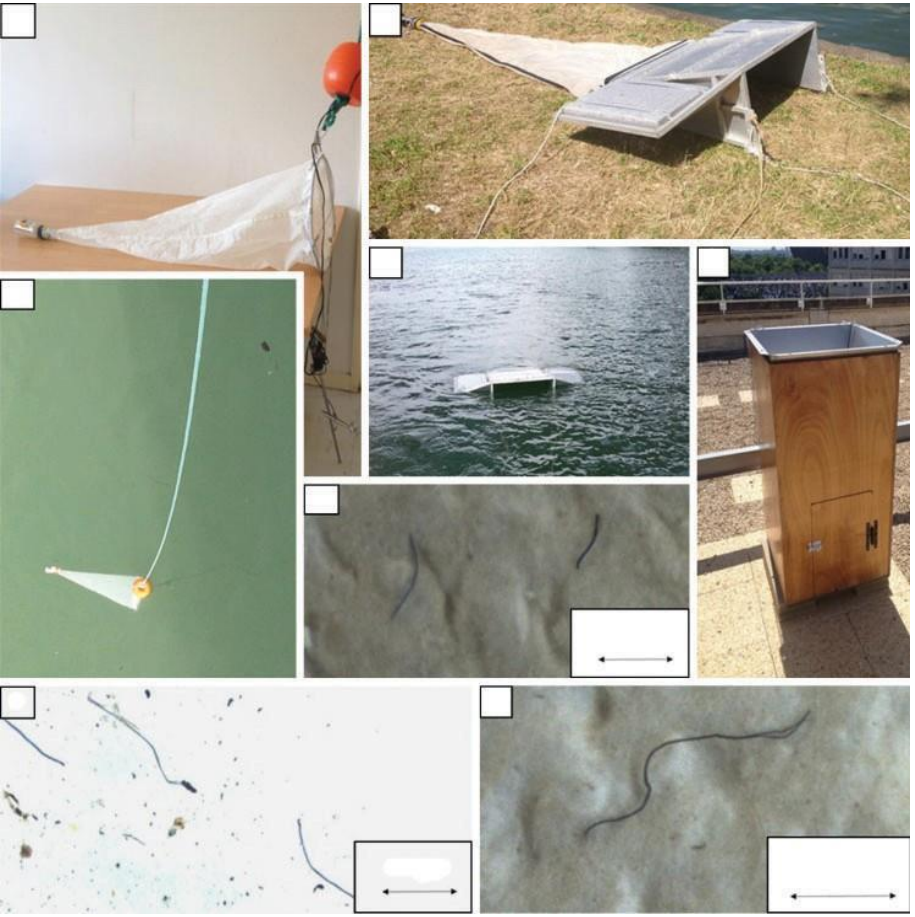
>30µm, FTIR

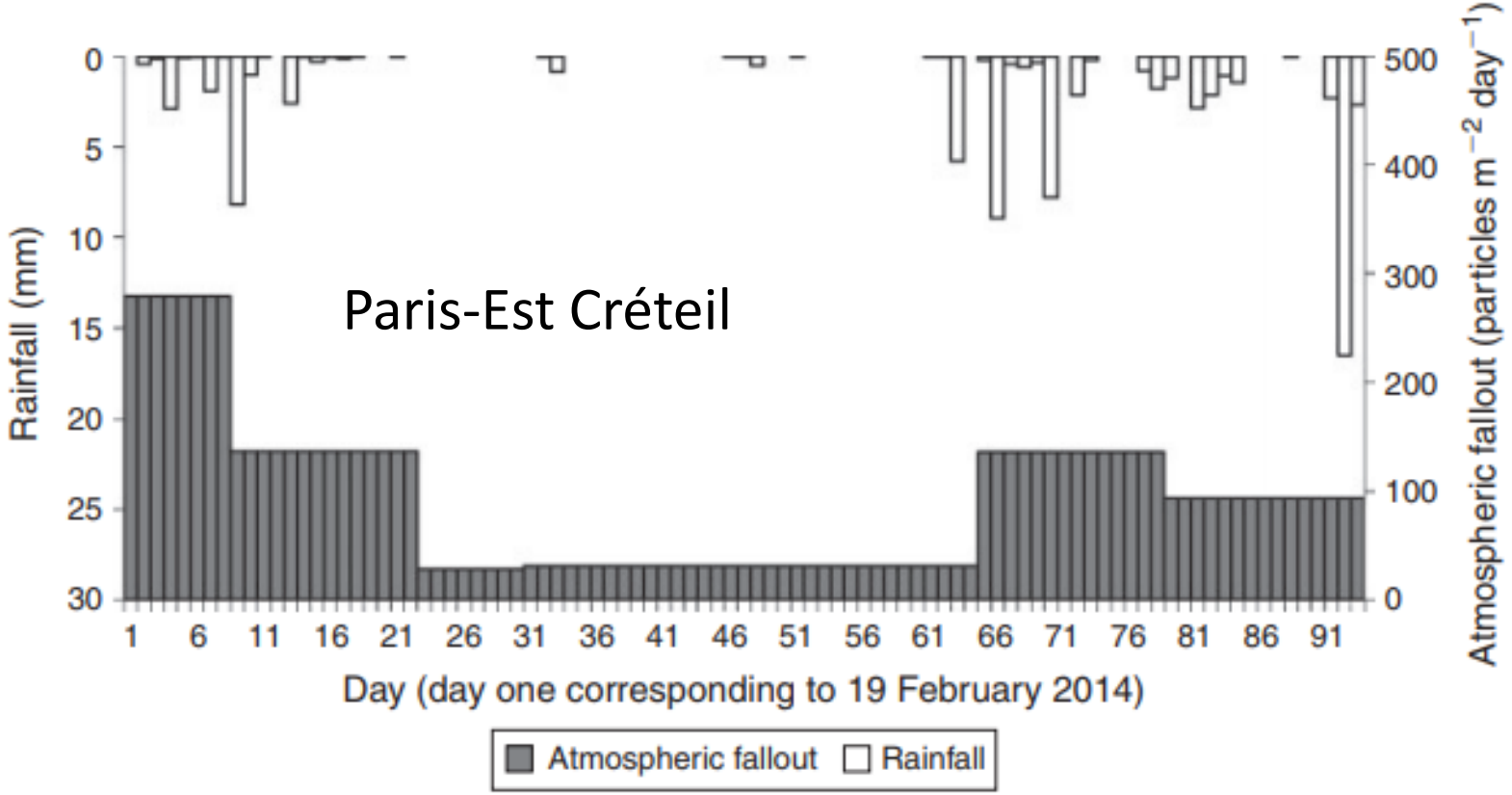
>1µm, Raman

Source: Internet

Microplastic contamination in an urban area: a case study in Greater Paris

Rachid Dris, Johnny Gasperi, Vincent Rocher, Mohammed Saad, Nicolas Renault, Bruno Tassin

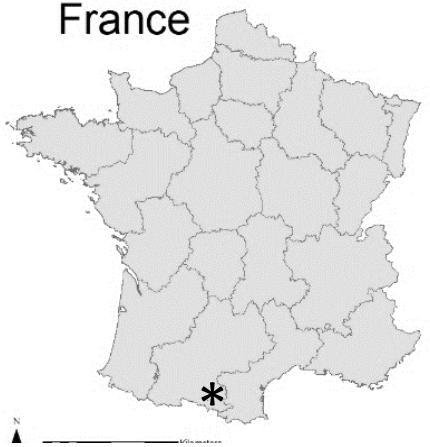


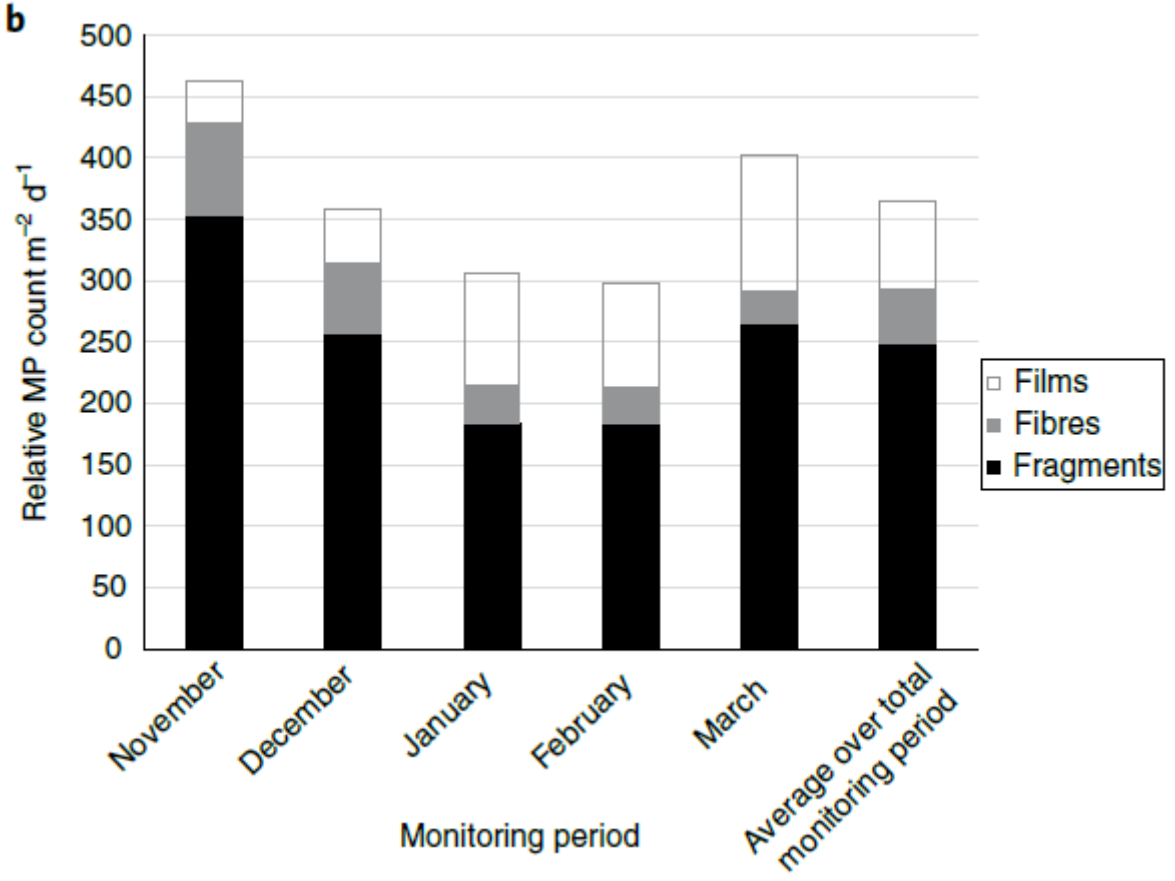


Driss et al., 2015 Env.Chem.

Atmospheric transport and deposition of microplastics in a remote mountain catchment

Steve Allen[1,2,5], Deonie Allen[1,5*], Vernon R. Phoenix[2], Gaël Le Roux[1], Pilar Durántez Jiménez[1], Anaëlle Simonneau[3], Stéphane Binet[1,3] and Didier Galop[4]



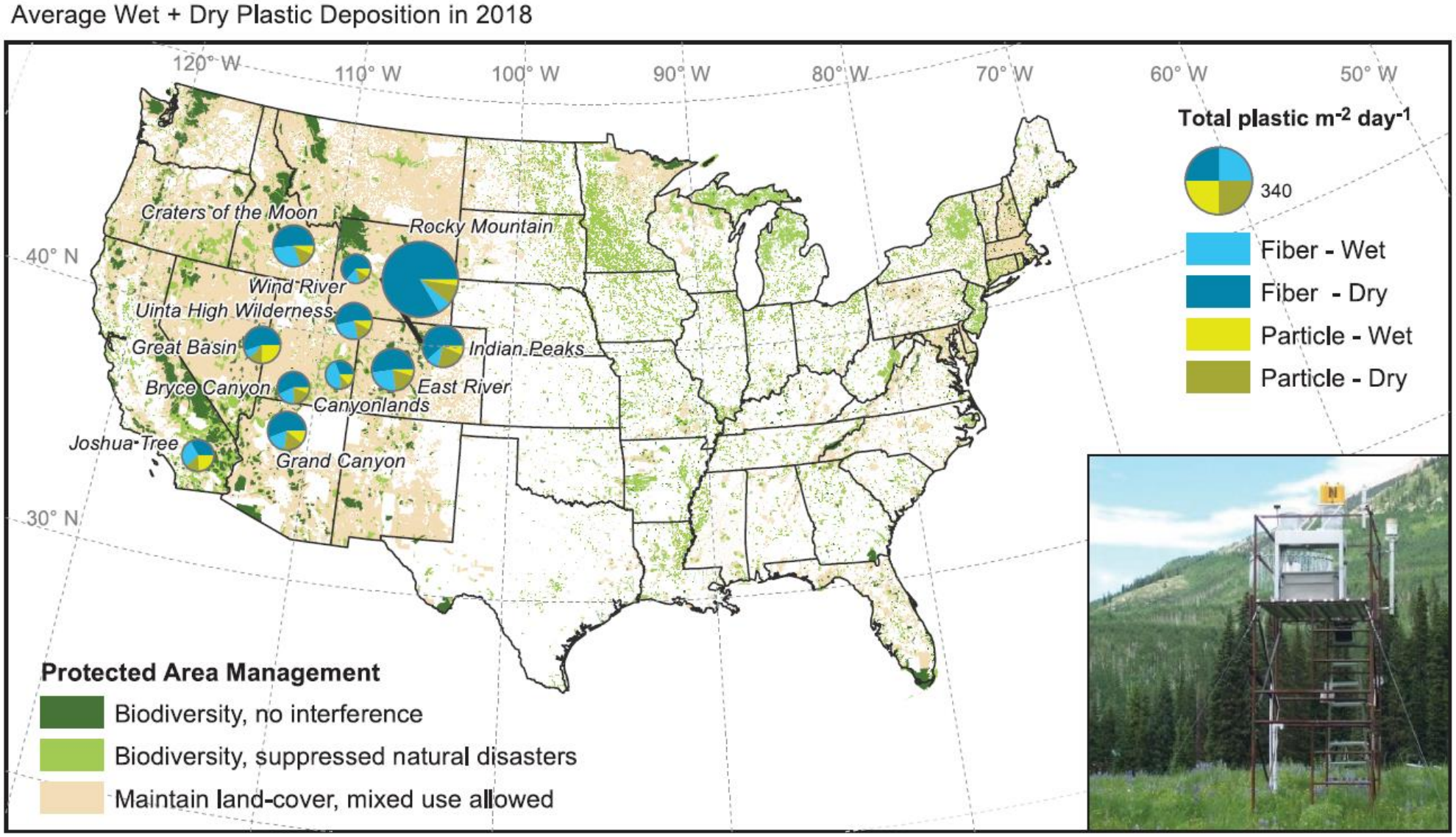


Allen et al., 2019 Nature Geoscience

PLASTIC POLLUTION

Plastic rain in protected areas of the United States

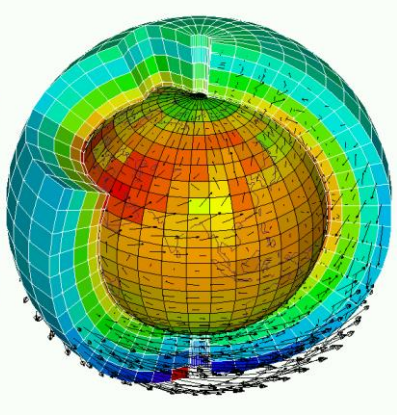
Janice Brahney[1]*, Margaret Hallerud[1], Eric Heim[1], Maura Hahnenberger[2], Suja Sukumaran[3]

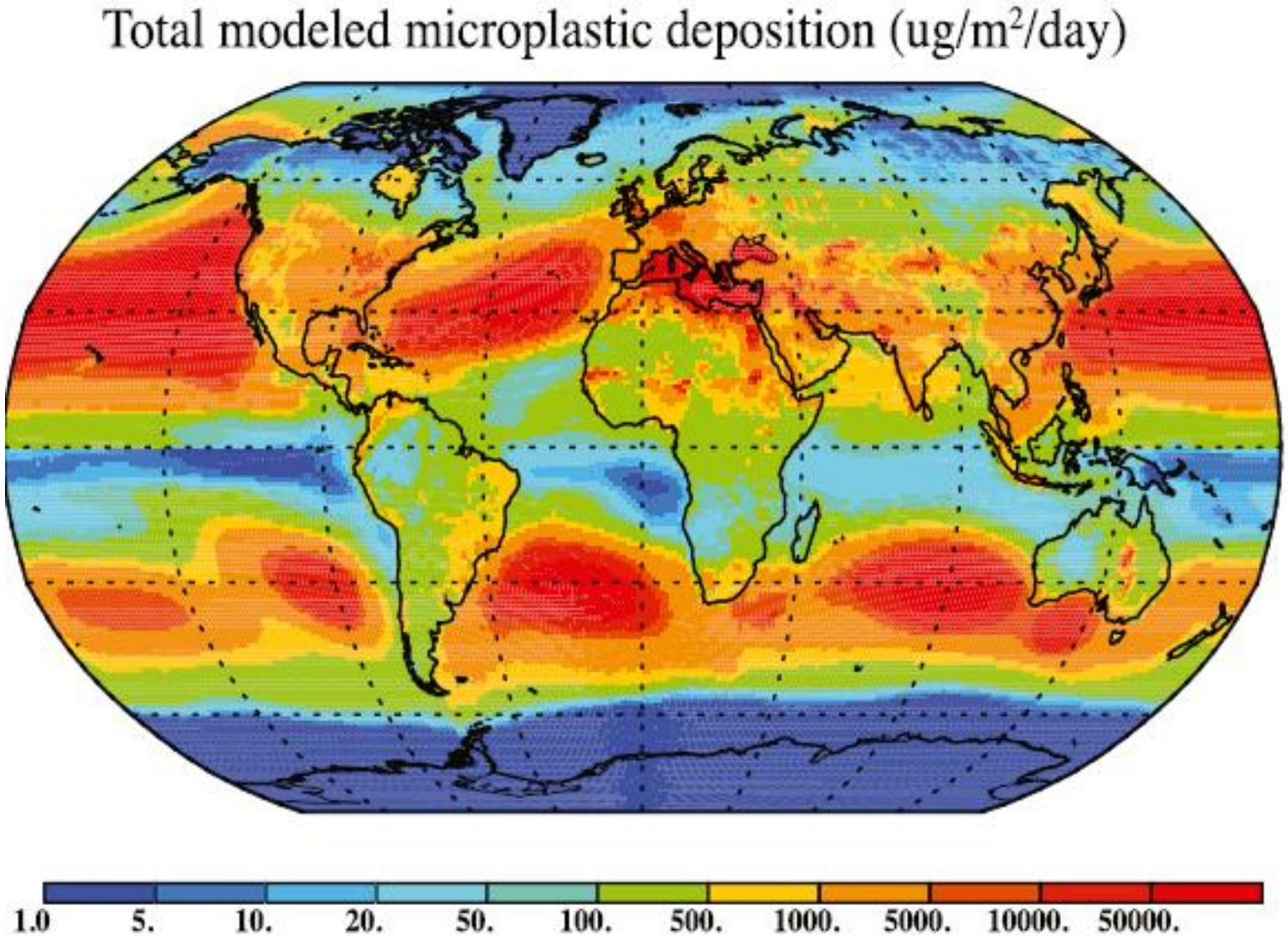


Brahney et al., 2020
Science

Constraining the atmospheric limb of the plastic cycle

Janice Brahney[a,2,1], Natalie Mahowald[b,2,1], Marje Prank[b,c], Gavin Cornwell[d], Zbigniew Klimont[e], Hitoshi Matsui[f], and Kimberly Ann Prather[g,h]





Brahney et al., 2021
PNAS

Constraining the atmospheric limb of the plastic cycle

Janice Brahney[a,2,1], Natalie Mahowald[b,2,1], Marje Prank[b,c], Gavin Cornwell[d], Zbigniew Klimont[e], Hitoshi Matsui[f], and Kimberly Ann Prather[g,h]

Table S3. Source strength of optimal estimation for the base case by bin in Tg/year of microplastics. Aerodynamic size of the microplastics are shown (inside parenthesis)

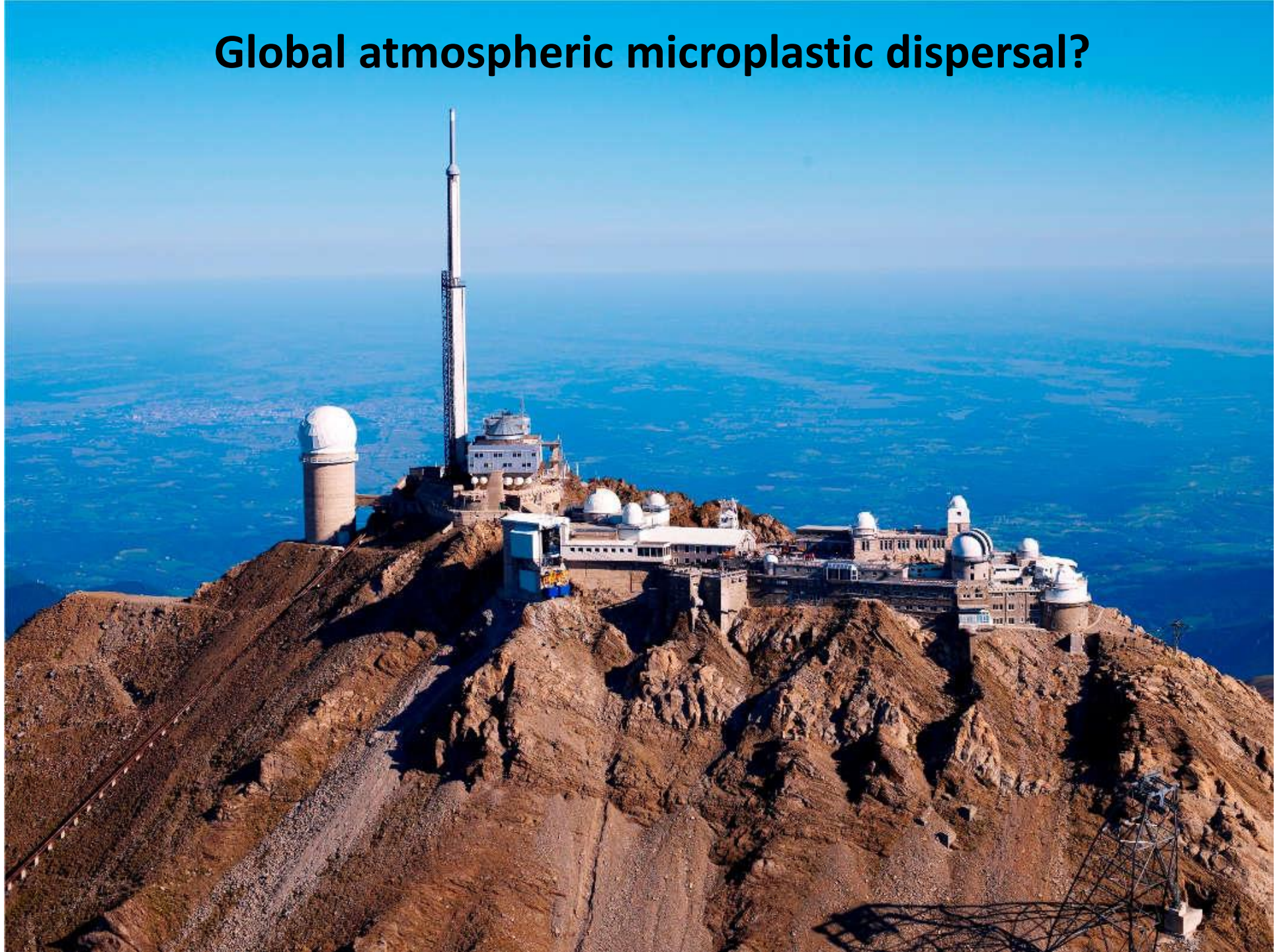
	Roads	Ocean	Ag dust	Pop dust
Bin 1 (0.3μm)	0.00070	0.00033	0.00001	0.000
Bin 2 (2.5μm)	0.0067	0.0035	0.0029	0.001
Bin 3 (7μm)	0.020	0.029	0.011	0.003
Bin 4 (15μm)	0.024	0.098	0.016	0.004
Bin 5 (35μm)	0.023	1.09	0.019	0.005
Bin 6 (70μm	0.022	7.3	0.020	0.006
Total	0.096	8.6	0.069	0.018

Surface Ocean plastics: 0.3 Tg

T_{res} = 0.3/8.6 = 13 days?

Brahney et al., 2021
PNAS

Global atmospheric microplastic dispersal?

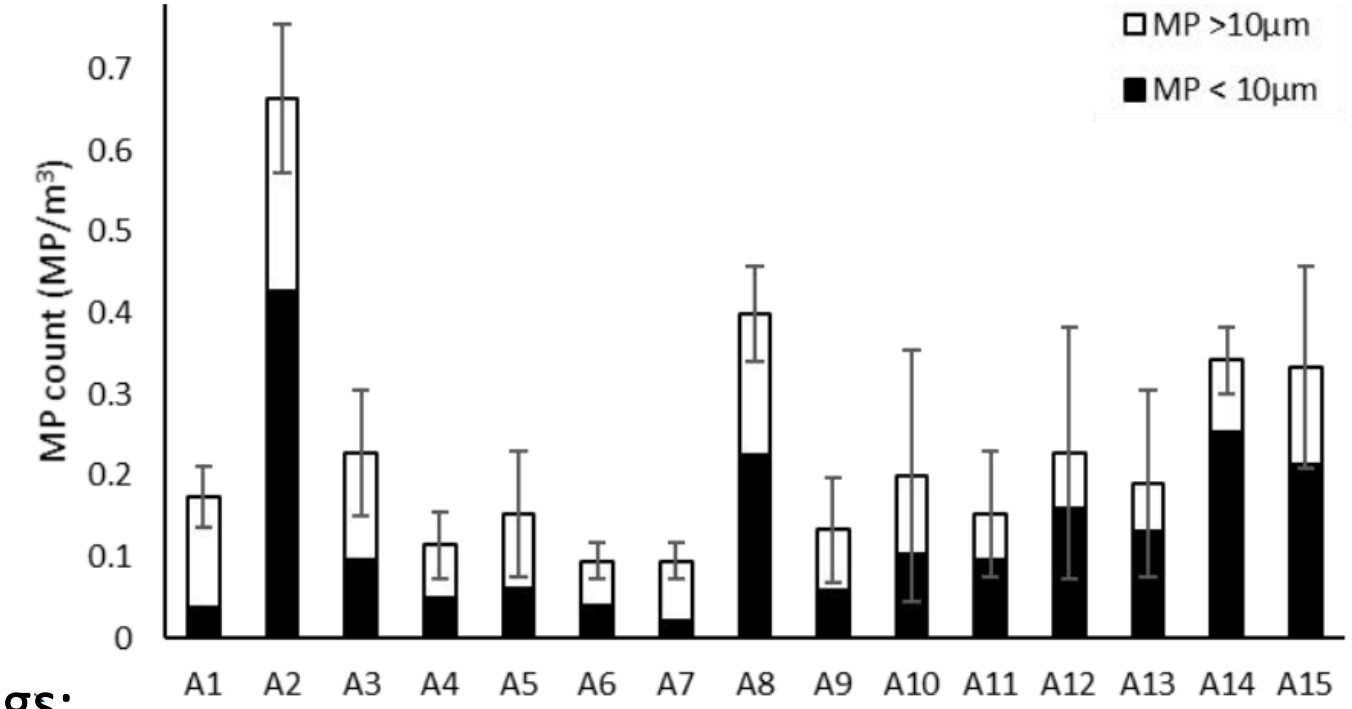



1 m³/min
TISCH

Hautes-Pyrénées : des microparticules de plastique détectées dans l'air au sommet du Pic du Midi

ABONNÉS

At night (20h – 8h), Pic du Midi « samples » the free troposphere



Key findings:

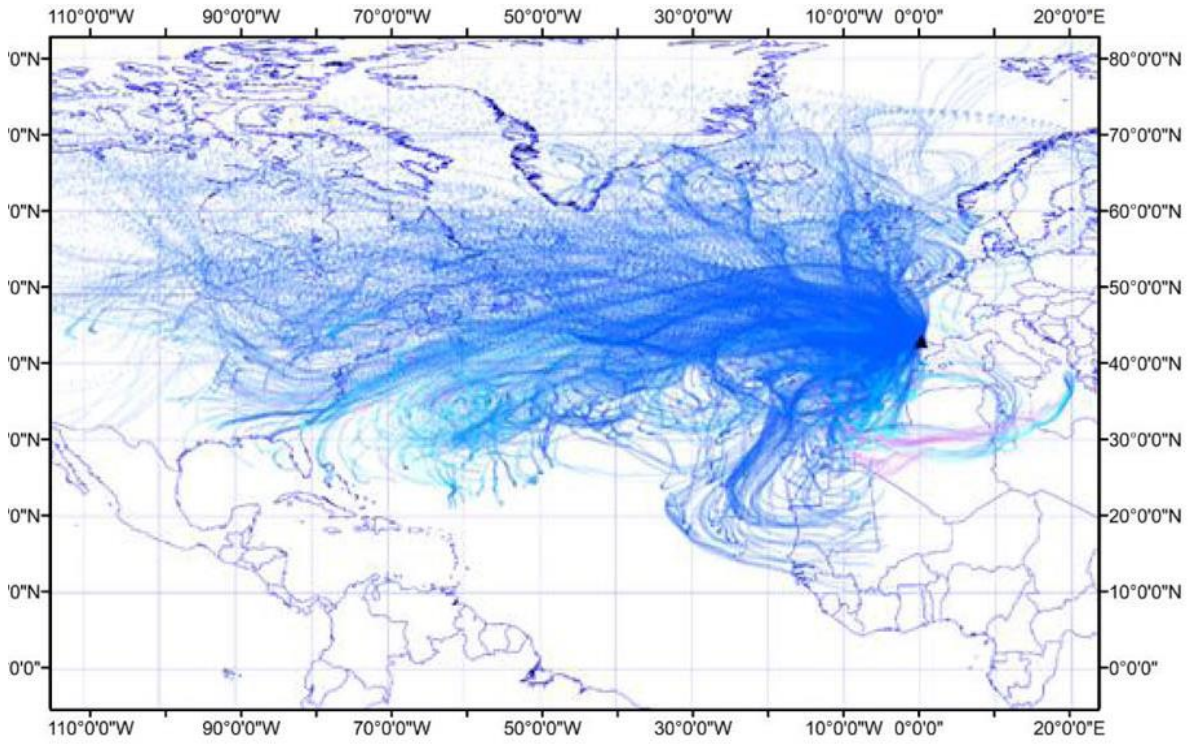
- On average we observed 0.25 microplastics per m^3 = not a lot?
- Multiplied by the volume of the atmosphere from 0-13km altitude: 2000 tons of microplastics
- Public Health? No
- Urban and interior concentrations are 100 to 1000 larger
- But, urban and interiori fin particulate matter (PM10) is 1,000,000 higher

Allen et al., 2021 Nature Comms.

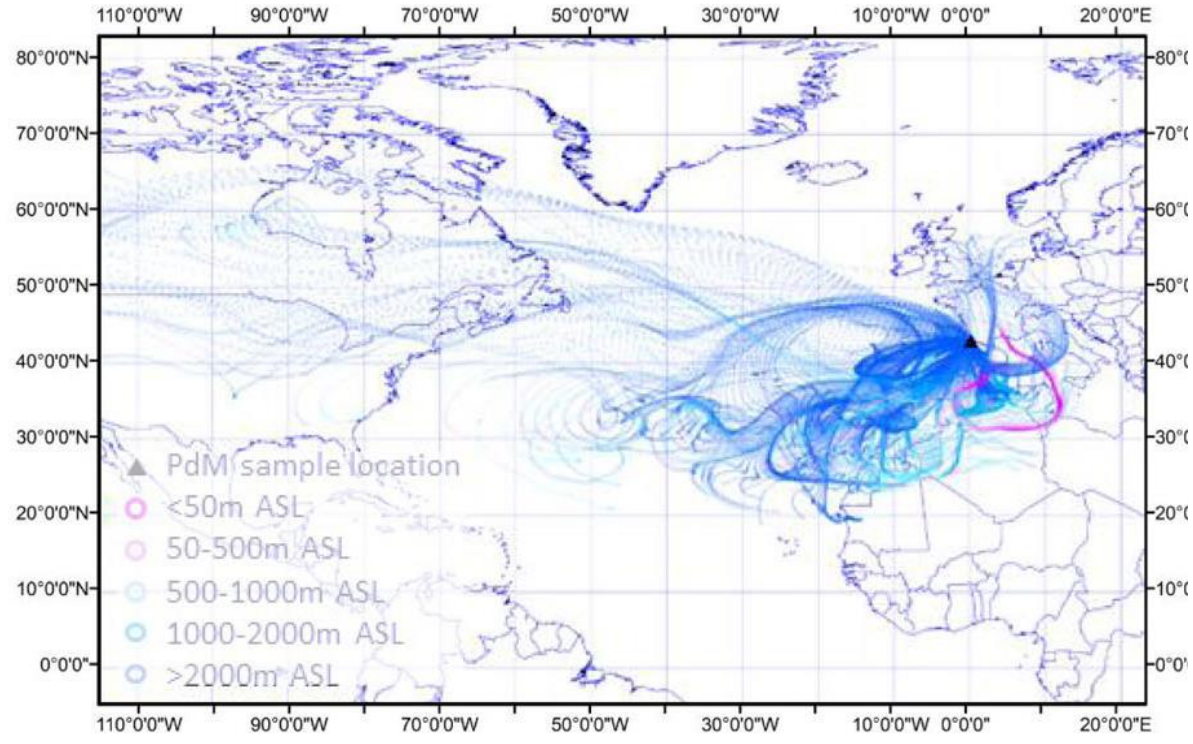
Origin of microplastics at the Pic du Midi?

NOAA Hysplit and Flexpart trajectory models driven by meterology (Jennie Thomas, IGE, Grenoble)

Small MP, 3-30 micromètres; <5% PBL contact



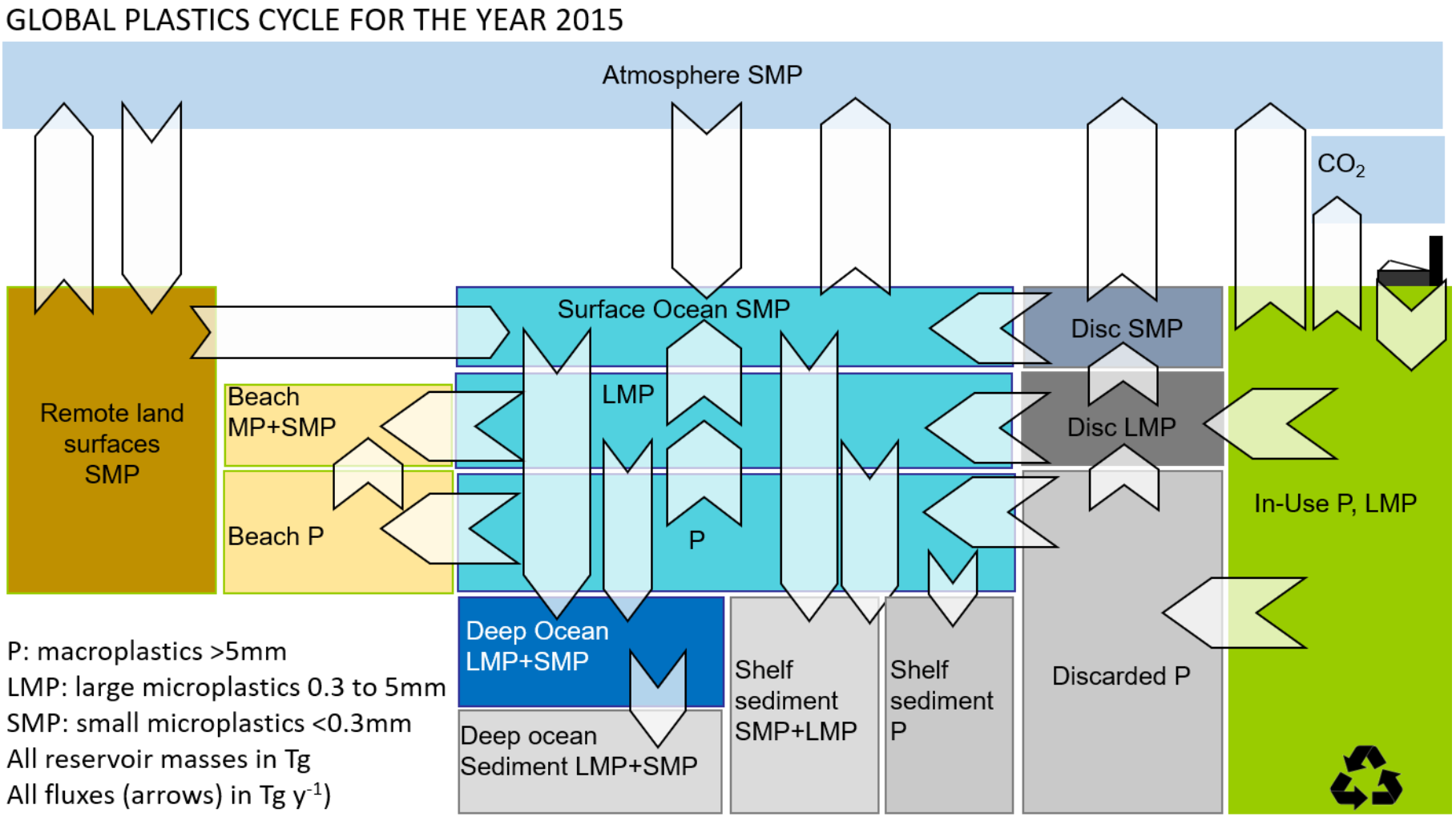
Medium MP, 30-50 micromètres; 20% PBL contact



Evidence for marine emissions and intercontinental atmospheric MP transport

Allen et al., 2021 Nature Comms.

A simplified global plastics budget, cycle and box model

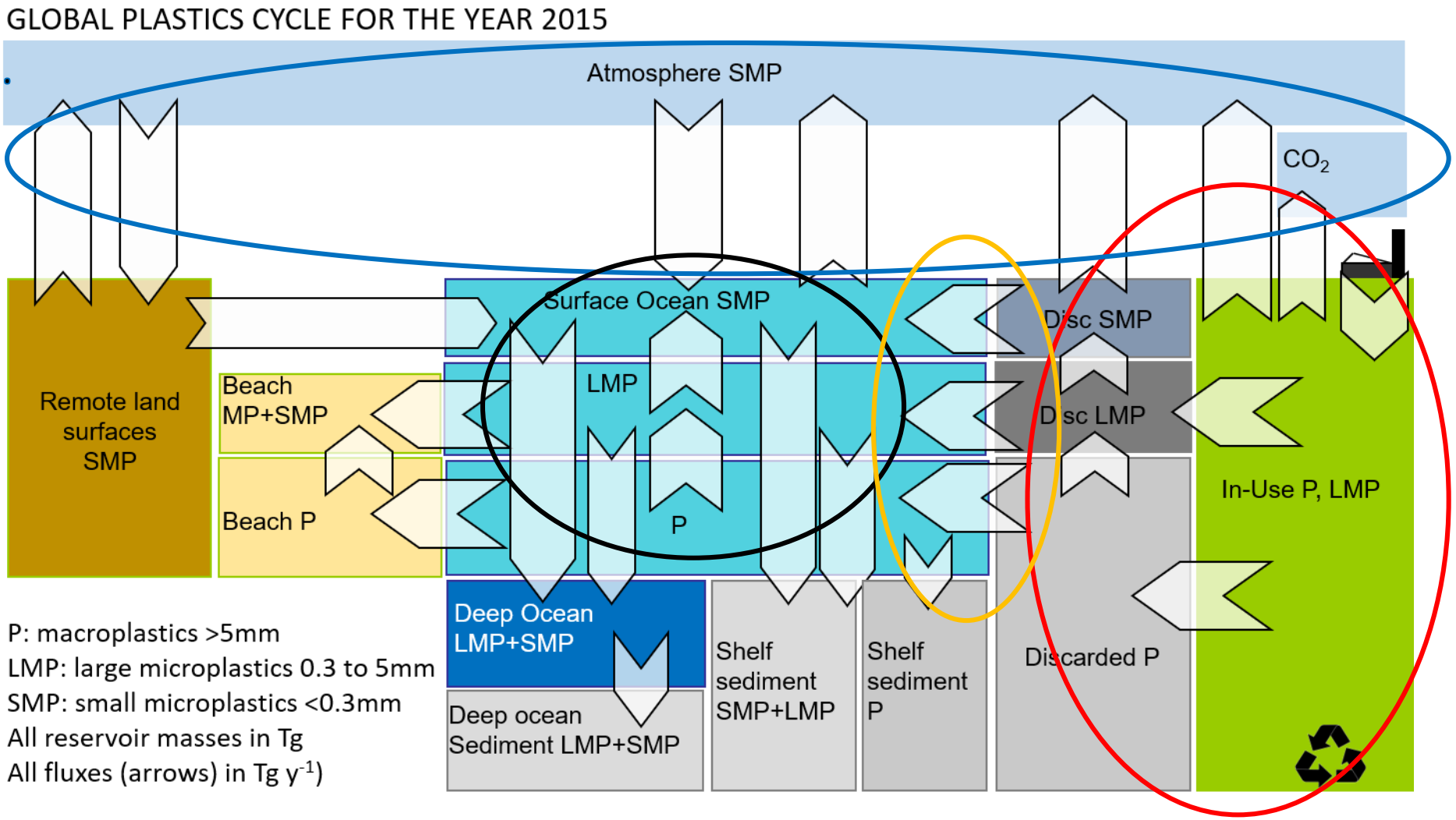


- Three plastics size classes: P, LMP, SMP
- Degradation of P → LMP, and LMP→SMP

Brahney et al., 2021,PNAS
Evangeliou et al. 2020 NCOMMS

Surface Ocean: Eriksen 2014 Plos-One

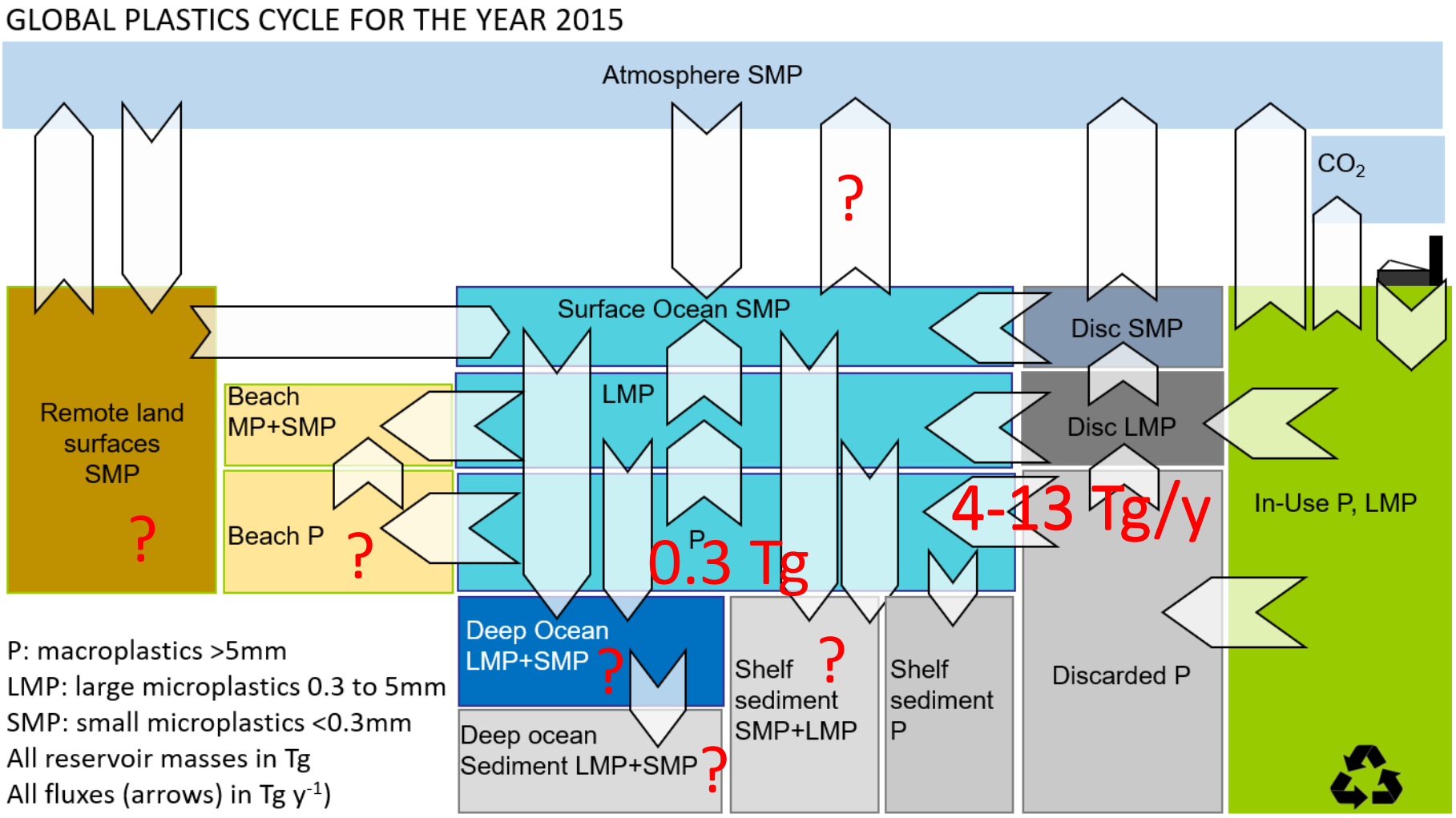
Rivers: Jambeck 2015, Science
Weiss 2021, Science



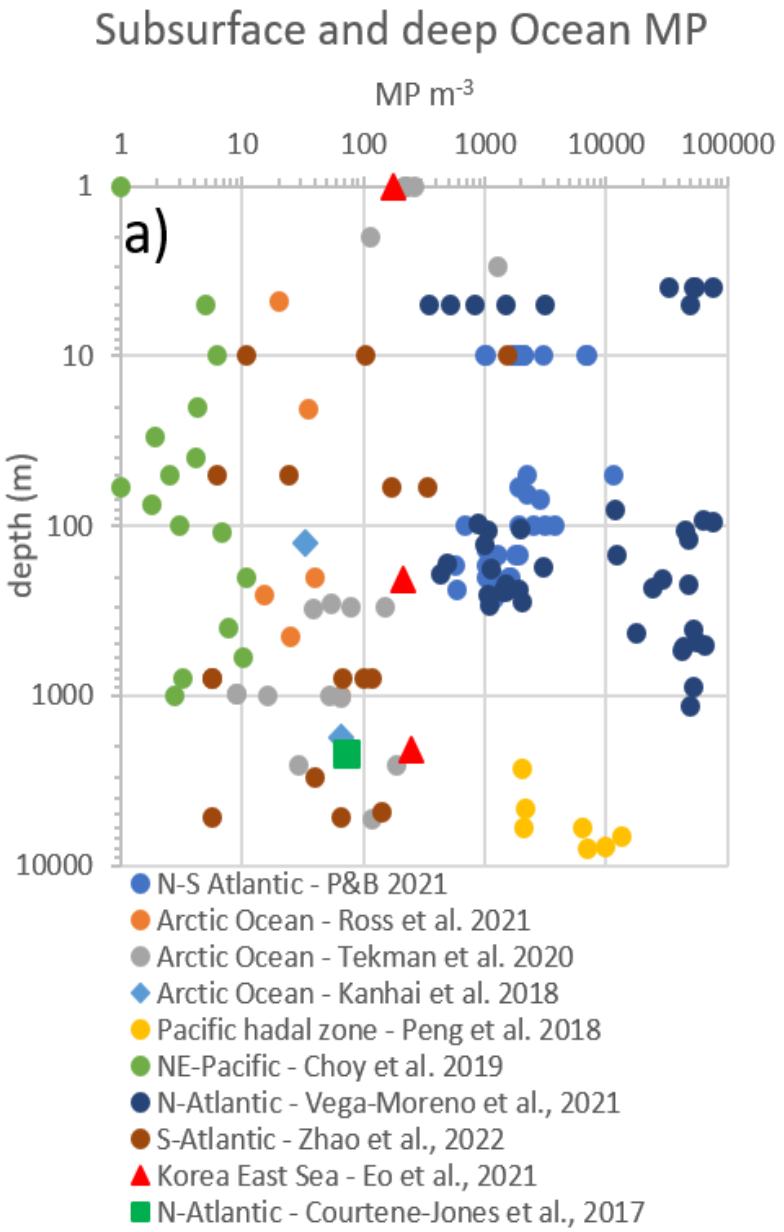
Discarded pool: urban, industrial, agricultural, landfills, impacted rivers+wetlands

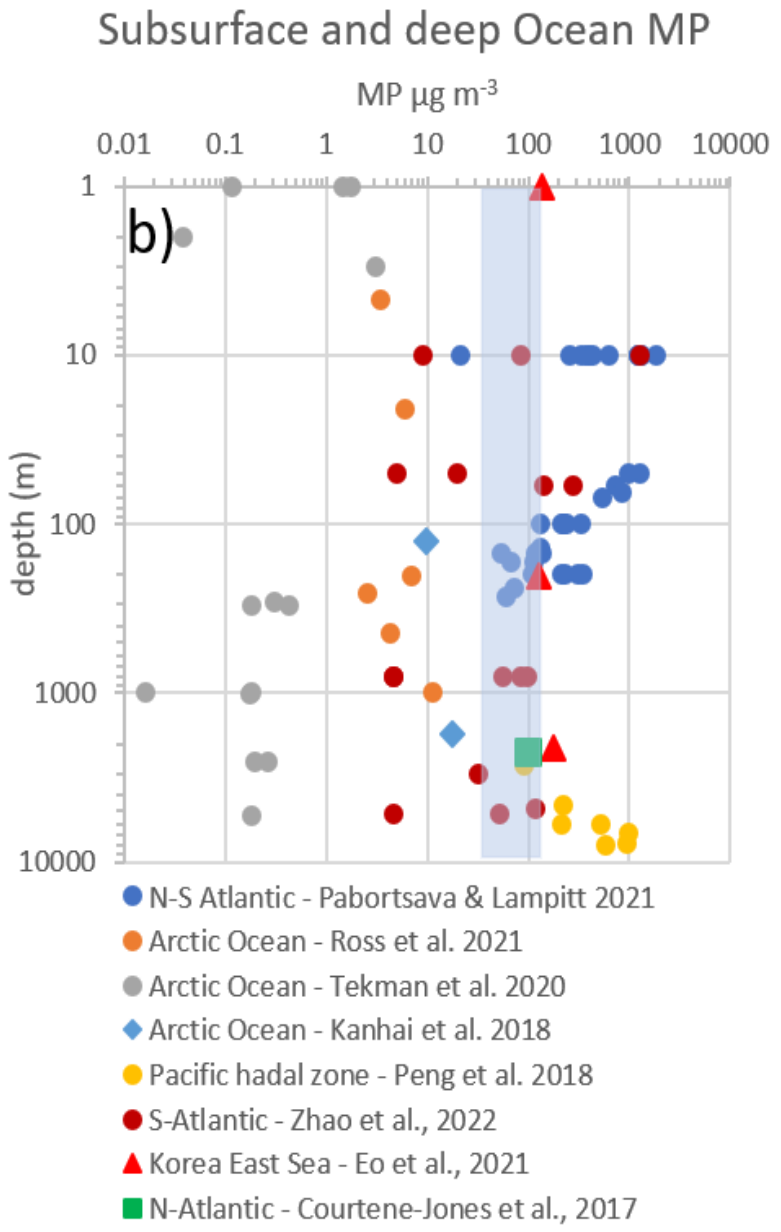
Geyer et al., 2017, Science: Production (8300 Tg), use and fate of all plastics ever made

The ‘missing marine plastics’ paradox



1 teragram (Tg) = 1 million metric tons





MP = LMP + SMP

to mass conversion is extremely critical and uncertain: $V=L^3*0.1$ or $V=4/3pi*r^3$

Need to consider full size and # distribution (including non-observed particles)

Most mass is in the larger, less abundant MP

A subsurface Ocean LMP+SMP budget

Ocean basin	Volume	LMP + SMP	LMP + SMP	1σ
	km^3	$\mu g\ m^{-3}$	Tg	Tg
Arctic Ocean	18750000	24	0.4	0.6
North Atlantic	146000000	**91**	13.0	3.0
South Atlantic	160000000	**91**	14.3	3.3
Indian Ocean	264000000	43	11.0	11.0
North Pacific	331000000	**131**	42.2	14.1
South Pacific	329000000	4	1.2	12.0
Southern Ocean	71800000	4	0.3	3.0
Total			**82**	47

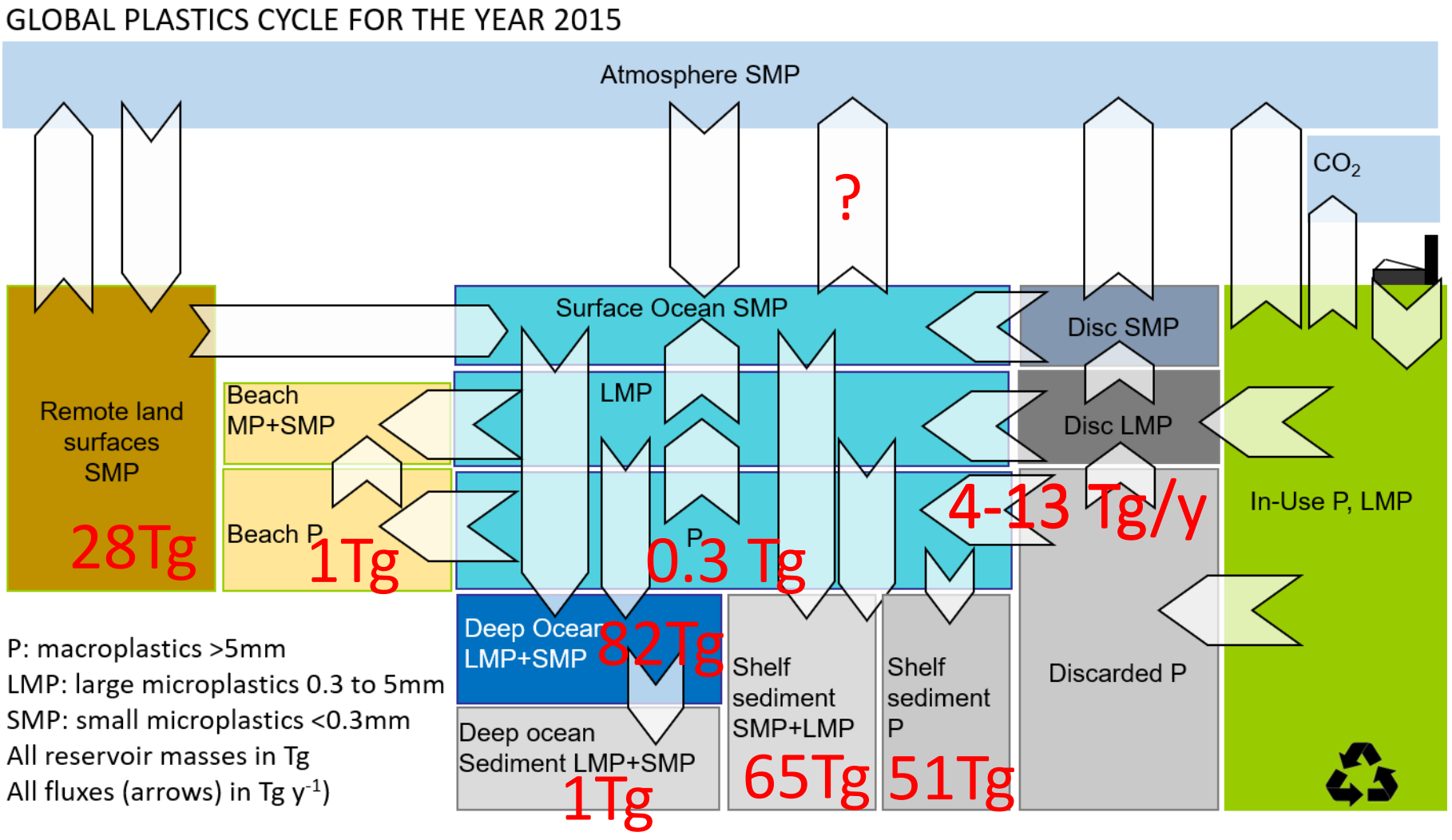
LMP = large MP 300um – 5mm

SMP = small MP 1-300um

MP = LMP + SMP

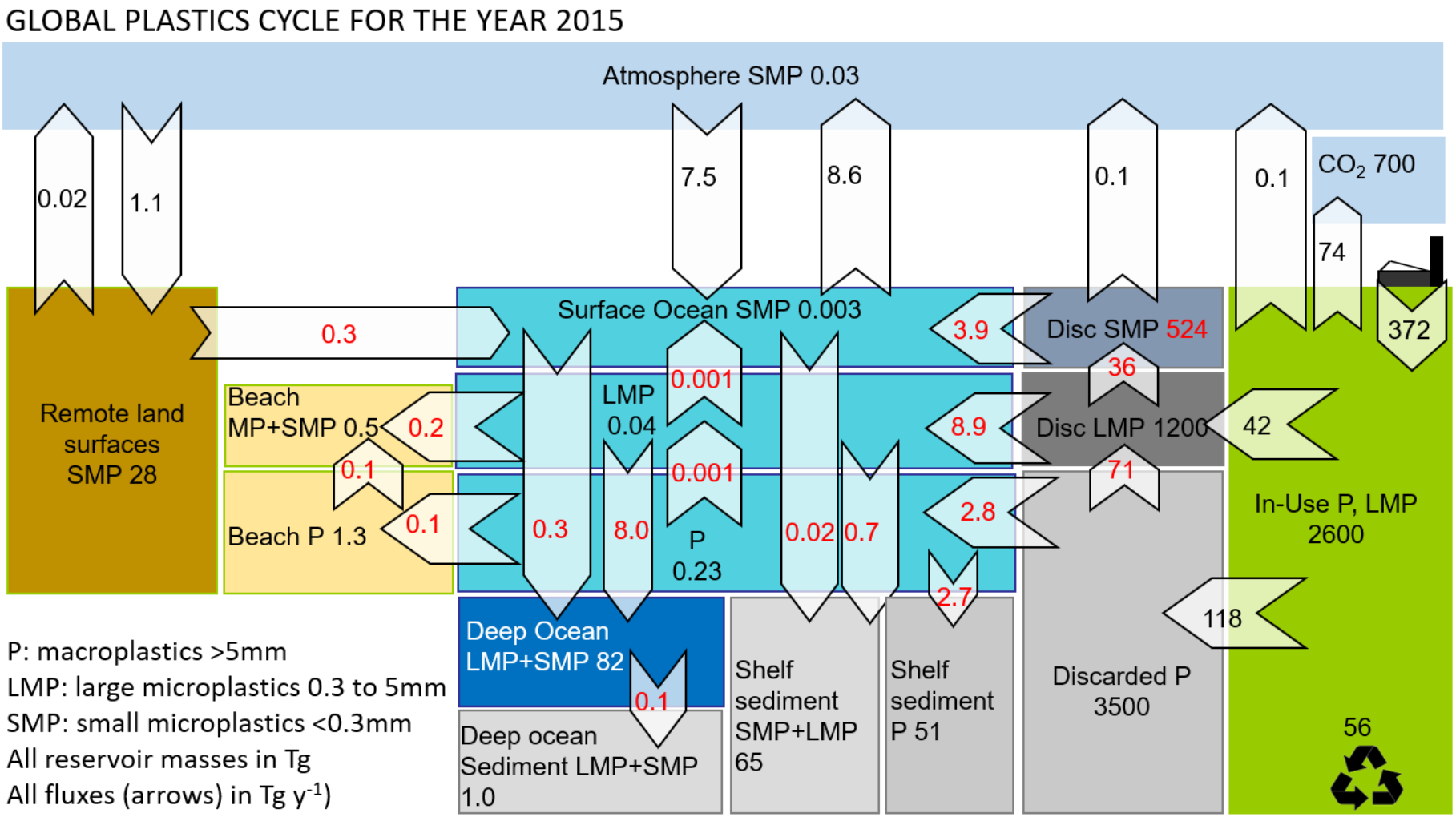
1 teragram (Tg) = 1 million metric tons

The ‘missing marine plastics’ paradox



1 teragram (Tg) = 1 million metric tons

A simplified global plastics budget and cycle 2015



Key findings:

- River flux = 16 Tg/y
- Land emissions = 0.2 Tg/y
- Large marine emissions of 9 Tg/y drive dispersion to remote land
- 200 Tg downstream of land waste = 3% of production
- Large mass of discarded LMP and SMP = 1700 Tg

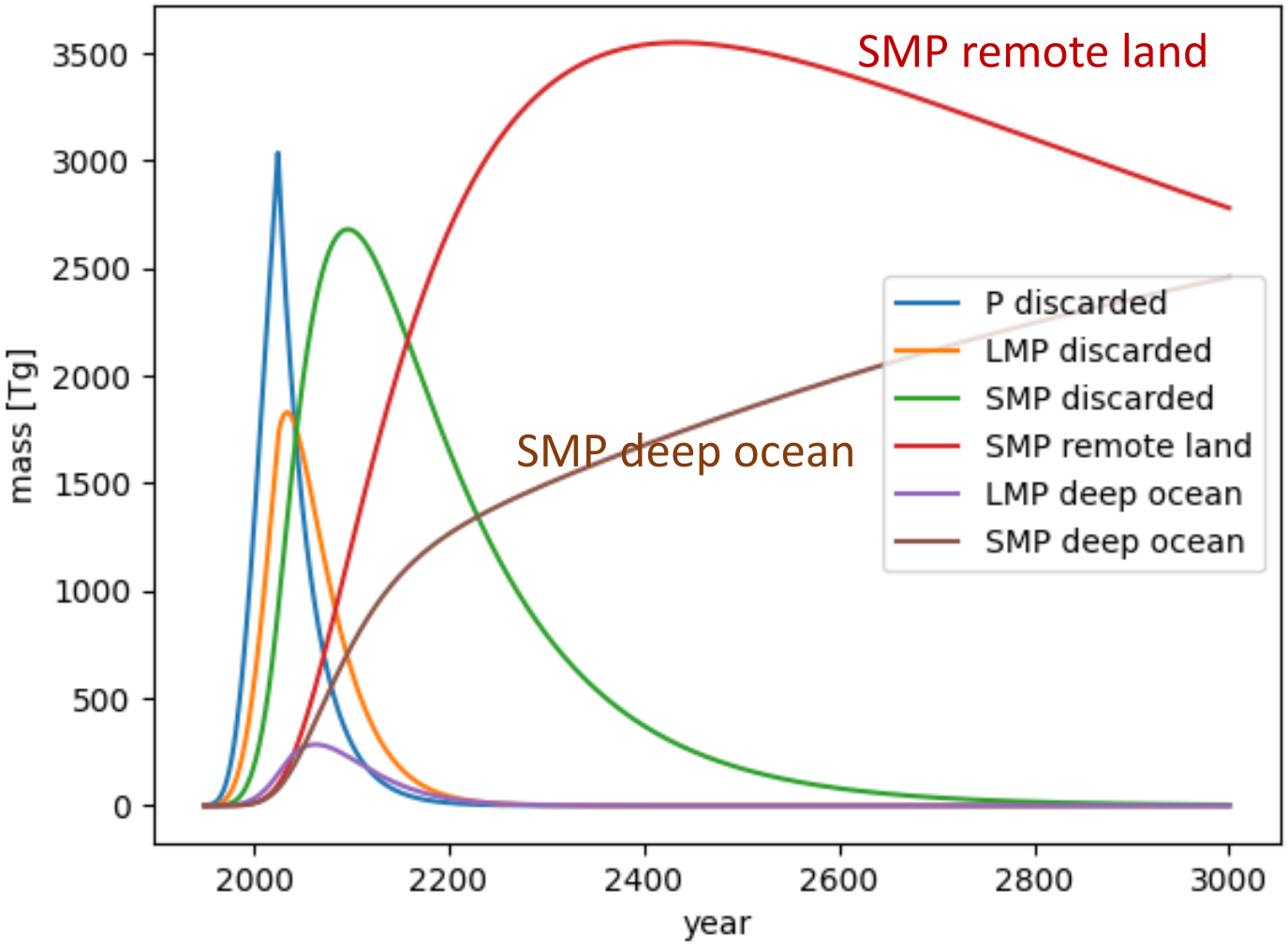
Black: observations and published model data

Red: model estimate (this study)

Sonke et al., 2022 Microplastics & Nanoplastics

Future plastics (P, LMP, SMP) dispersal if we stop polluting in 2025

Drive box model with Geyer et al. (2017) plastic production and waste rates

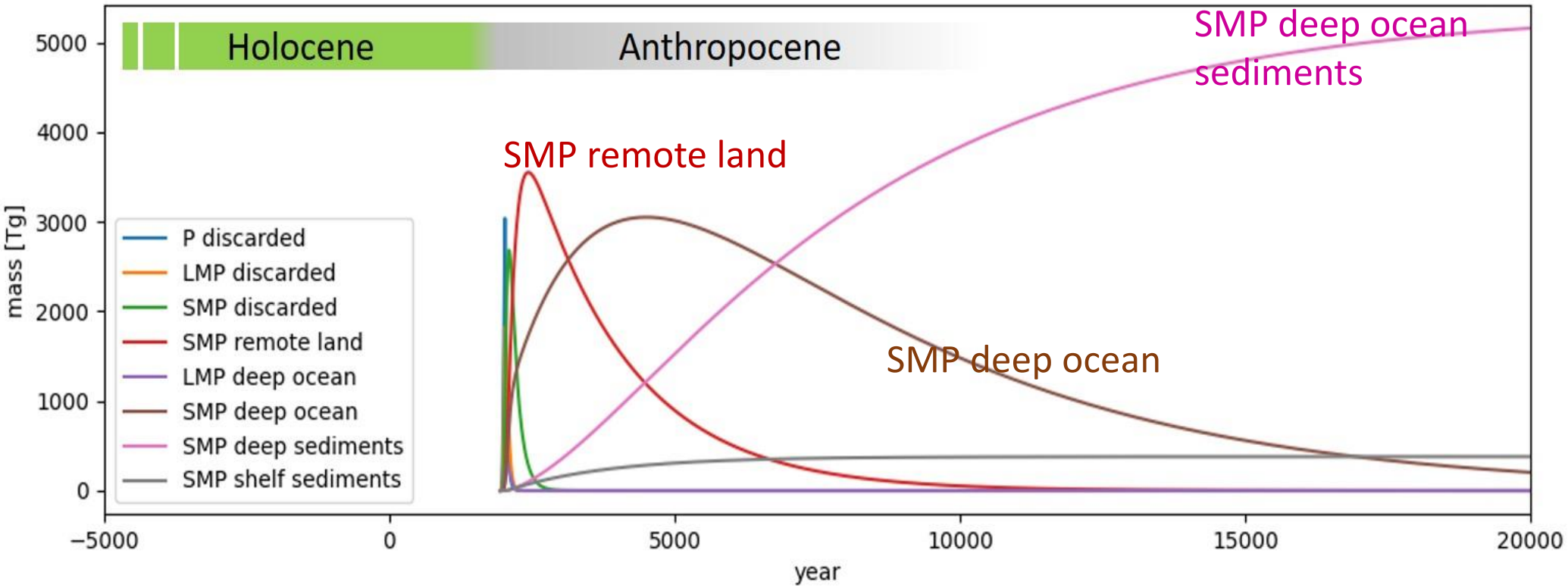


P = macroplastics >5mm
LMP = large microplastics 0.3-5mm
SMP = small microplastics <0.3mm

Discarded pool: urban, industrial, agricultural, landfills, impacted rivers+wetlands

Sonke et al., 2022 Microplastics & Nanoplastics

Future plastics (P, LMP, SMP) dispersal if we stop polluting in 2025

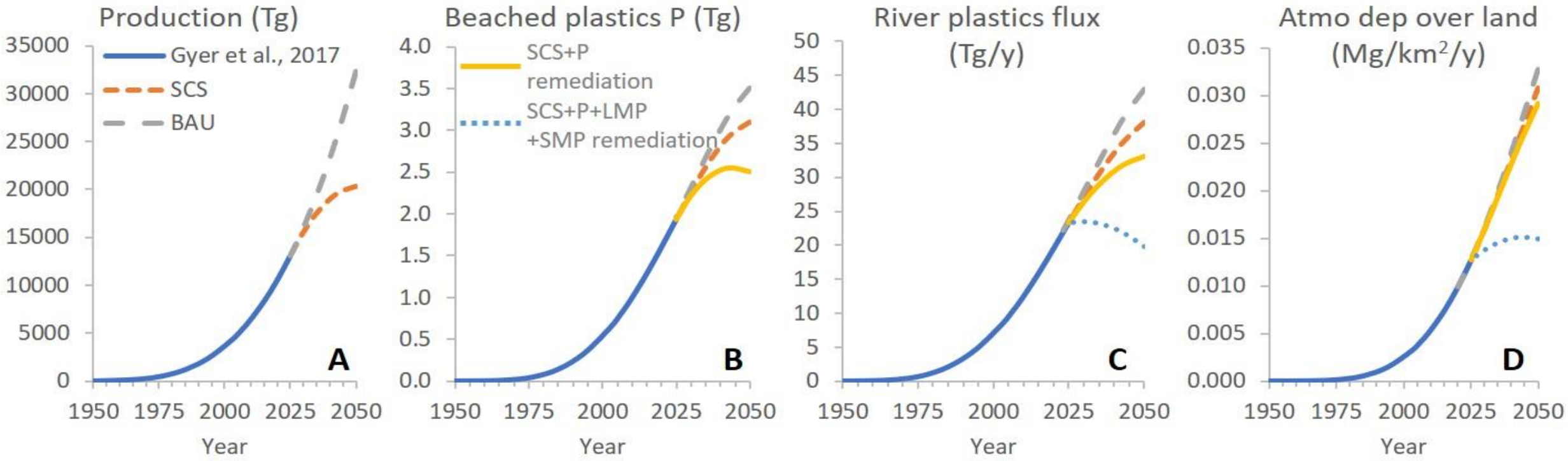


→ Simulate different production, discard, and remediation scenarios

Sonke et al., 2022 Microplastics & Nanoplastics

Simulating 2025-2050 environmental plastics concentrations, fluxes

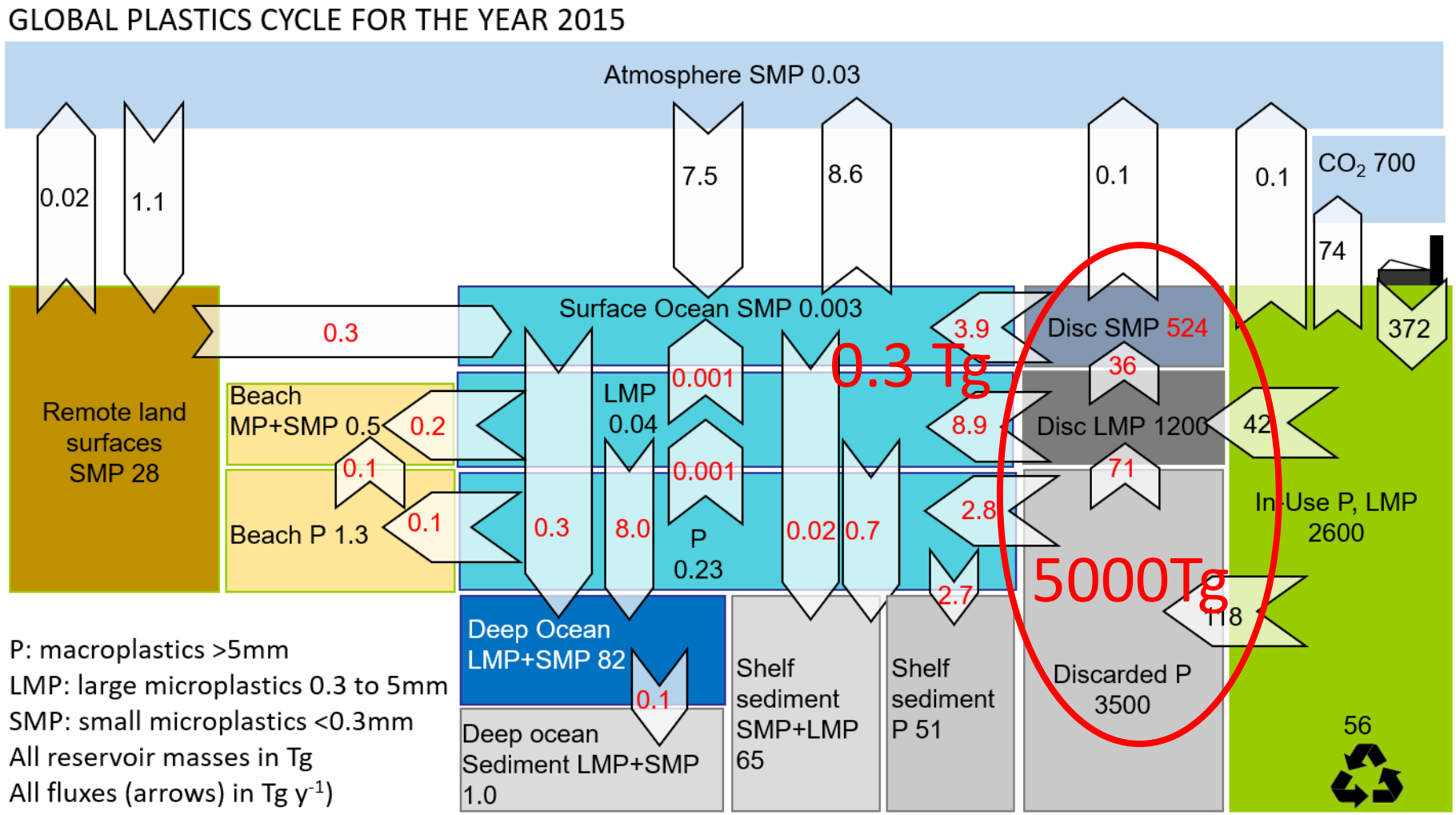
BAU = Business as usual production and discard evolution (Geyer et al., 2017)
SCS = Systems change scenario = feasible plastics policy implementation (Lau Winnie et al., 2020, Science)



Remediation scenarios (terrestrial discarded plastics clean-up + landfill waste management)
SCS + P = 3% per year clean-up effort
SCS + P +LMP + SMP = 3% per year clean-up effort

Sonke et al., 2022 Microplastics & Nanoplastics

Conclusion: Systems change is not enough; remediation of land P, MP pools is necessary to limit long-term dispersal and exposure



Sonke et al., 2022 Microplastics & Nanoplastics

Perspectives

- Cycle des plastiques: manque d'observations → incertitudes importantes (5x = 500%)
- Modèle de dispersion/dégradation:
  - Discerner différents polymères
  - Mieux comprendre et paramétriser leur dégradation (3%/an)
  - Inclure nanoplastiques, et leur dégradation en polymeres (source C, energie)

- Modèle fourni des trajectoires de MP dans l'air, océan, plages etc
  - Utile pour d'autres modèles écotox et tox ou socio-economiques

- En région Occitanie?
  - Etablir un bilan/budget/cycle de vie à l'echelle de la région
  - Stimuler le recyclage, et alternatives
  - Assurer une gestion de déchets durable
  - Explorer l'assainissement des sources de plastiques+MP (anciens décharges etc)

Questions?

GOLDSCHMIDT® LYON 2023 9-14 JULY

Questions?

Session 12d Plastic, PFAS, and other emerging contaminants as ubiquitous pollutants: occurrence, fate, and behavior