Atmospheric fluxes of organic N & P to the global ocean

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Coupling of biogeochemical cycles

Motivation

- C/N/P cycles are coupled, mainly through photosynthetic fixation of these elements by biological activity.
- Biological productivity relies on the availability nutrients
- There is increasing evidence that significant fractions of N and P deposition occur as organic nitrogen (ON) and organic phosphorus (OP).
- *Human activities have modified the atmospheric content and deposition fluxes of OC, ON and OP*
- Critical biogeochemical feedbacks might exist between chemistry/climate/terrestrial and marine biosphere that involve the coupling of the C/N/P cycles.

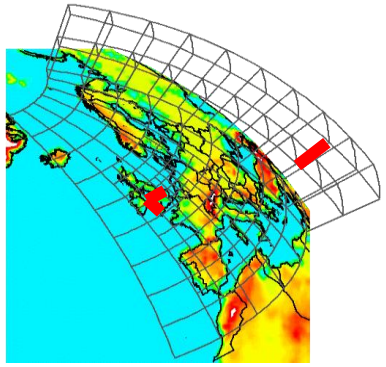
3-d global modeling of atmospheric deposition & data compilation

Methodology

- Use the global 3-d Chemistry Transport Model TM4-ECPL

  VOC /NOx/oxidants chemistry & all major aerosol components including primary & secondary OC , coupled with ISORROPIA II.

  Myriokefalitakis et al., Atmos. Chem. Phys., 2008, Advances in Meteorology 2010, Atmos. Chem. Phys., 2011



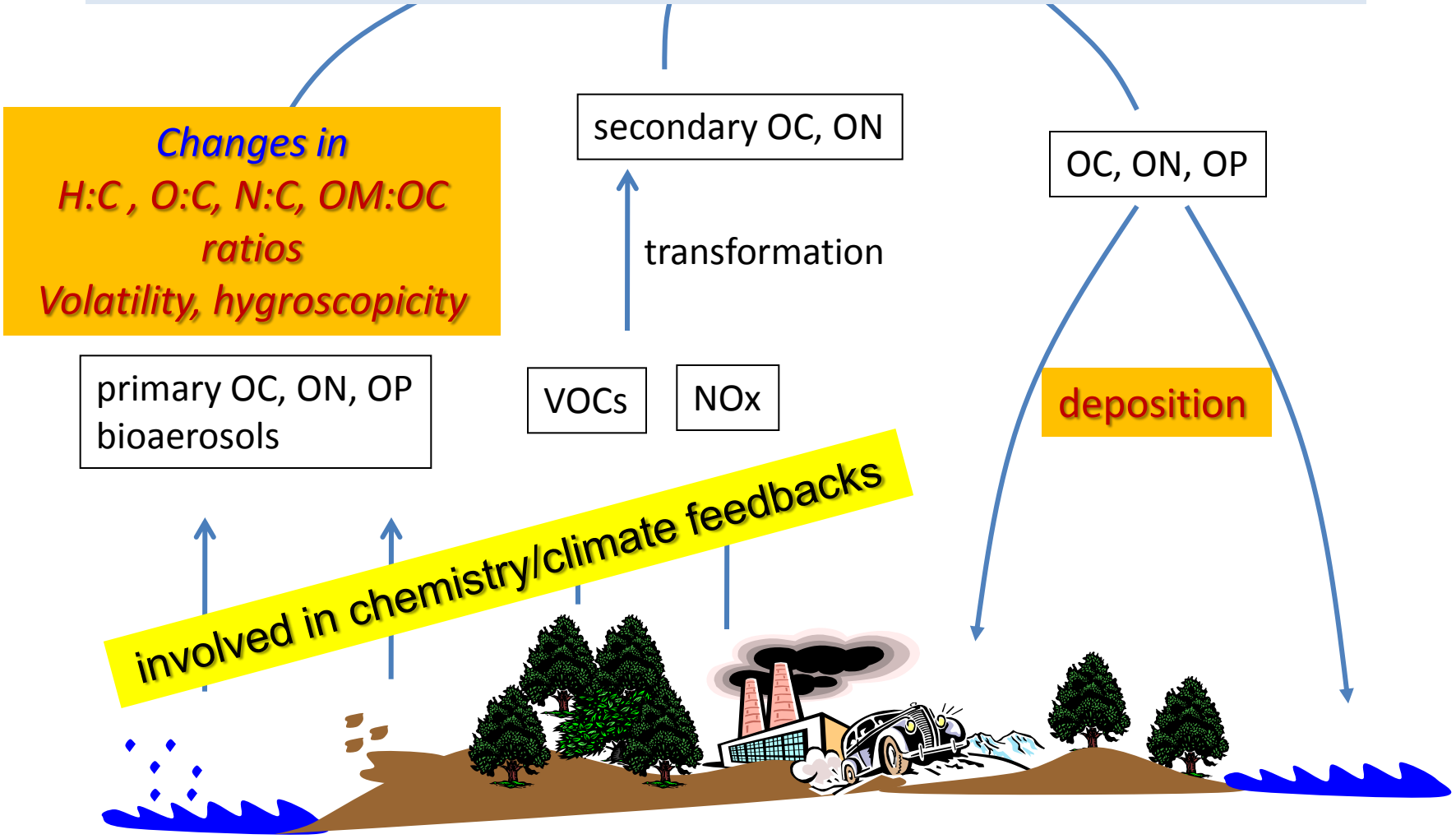
- Explicitly calculate IN gases and particles and ON in the gas phase

- **Use observed ON/OC and OP/OC ratios in aerosols to calculate ON and OP in the particulate phase**

- Present day simulations as in

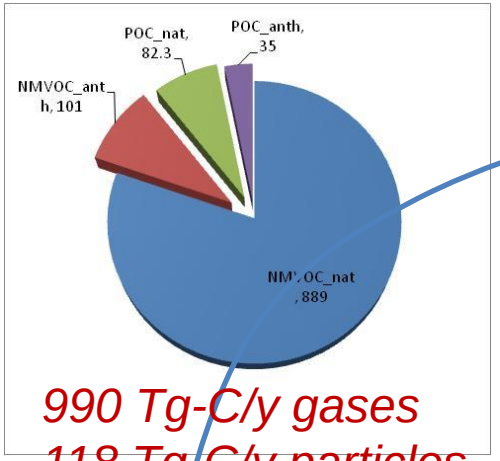
  Kanakidou, et al. Global Biogeochemical Cycles, 2011GB004277, 2012
  (anthropogenic CIRCE, biomass burning gfedv2, biogenic emissions POET)

Aim: Provide an updated picture of the role of organics in transporting nutrients particularly N and P to the oceans.



Kanakidou et al., GBC 2012

Organic Carbon in the global atmosphere



990 Tg-C/y gases
118 Tg-C/y particles

Tg-C/yr

transformation

transport

secondary OC, ON

OC, ON, OP

transformation

primary OC, ON, OP
bioaerosols

VOCs

NOx

NH_3

deposition

NH_3

30 p
72 g

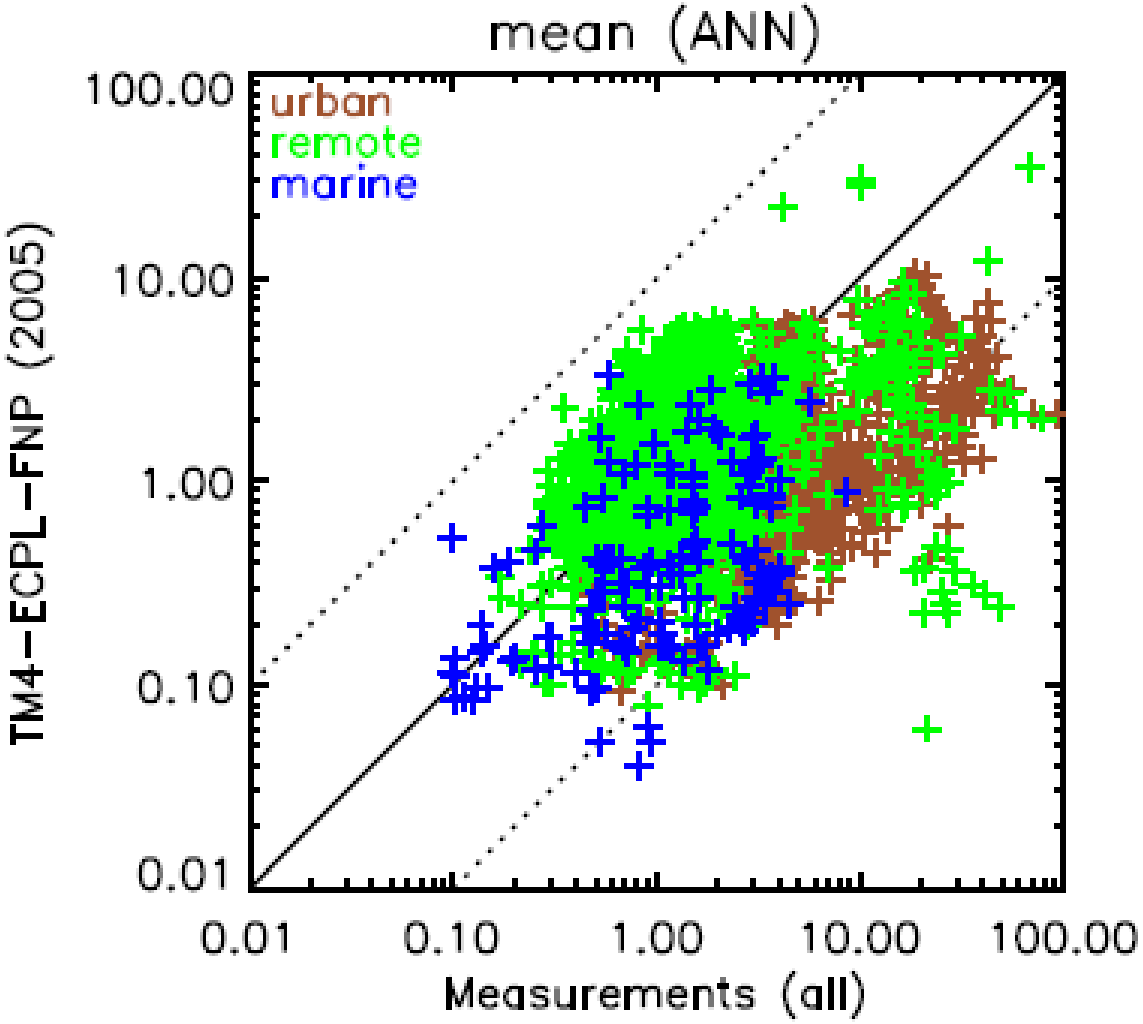
2.3 p

50 p
817 g

35 p
101 g

Kanakidou et al., GBC, 2012

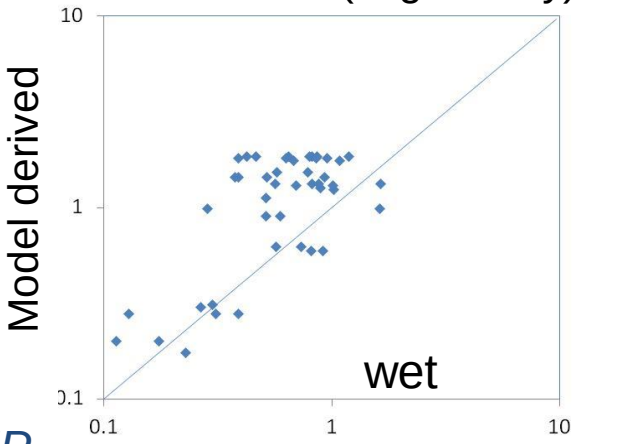
Aerosol - Organic Carbon simulations versus observations ($PM_{2.5}$)



Evaluation as part of the AEROCOM –OA intercomparison – Tsigaridis et al in preparation

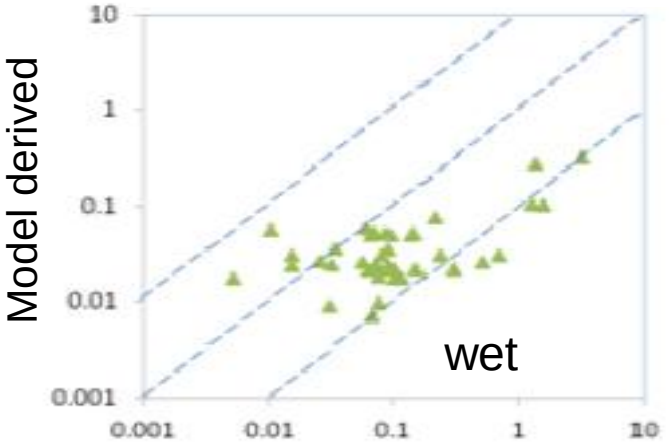
Deposition of soluble IN,ON and OP comparison to observationally derived fluxes

Soluble IN (in g-N/m^2/y)



EMEP dataset

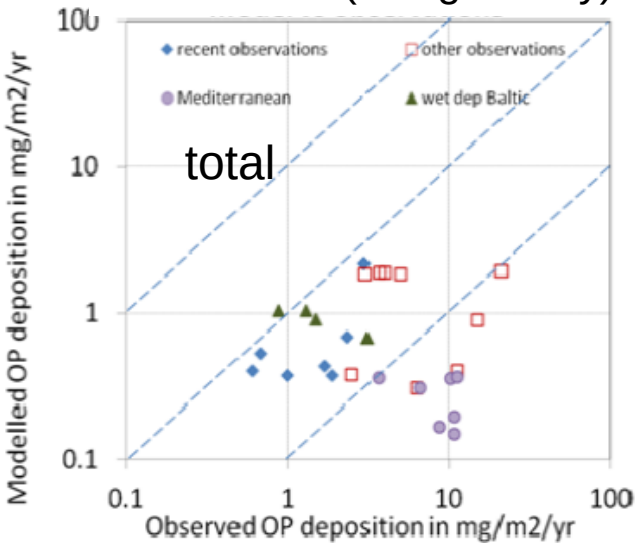
soluble ON (in g-N/m^2/y)



Kanakidou et al., GBC 2012

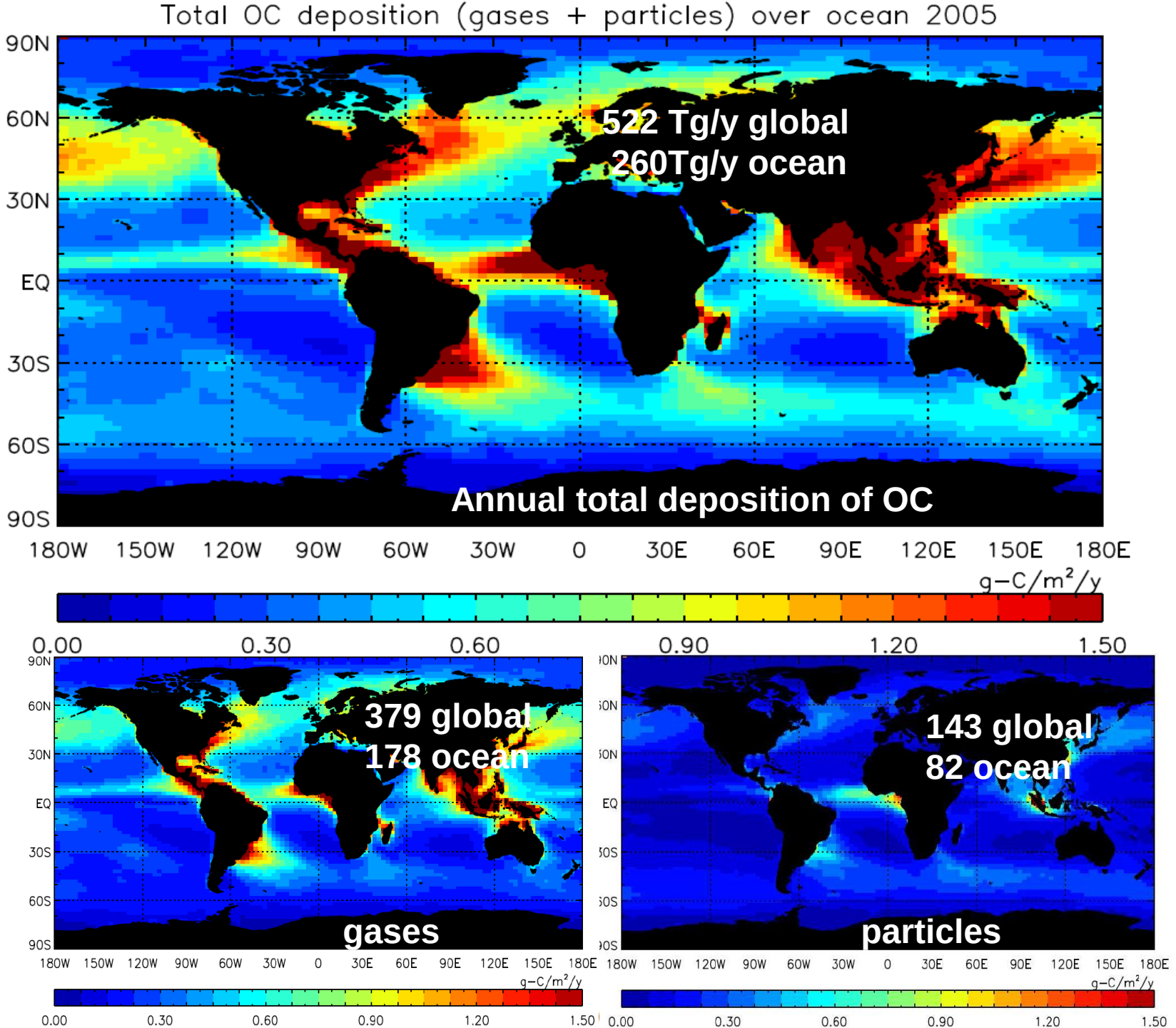
Depending on location, the observed water soluble ON fraction ranges from ~3% to 90% (median of ~35%) of total soluble N in rainwater;
Soluble OP fraction ranges from ~20-83% (median of ~35%) of total soluble P.

soluble OP (in mg-P/m^2/y)



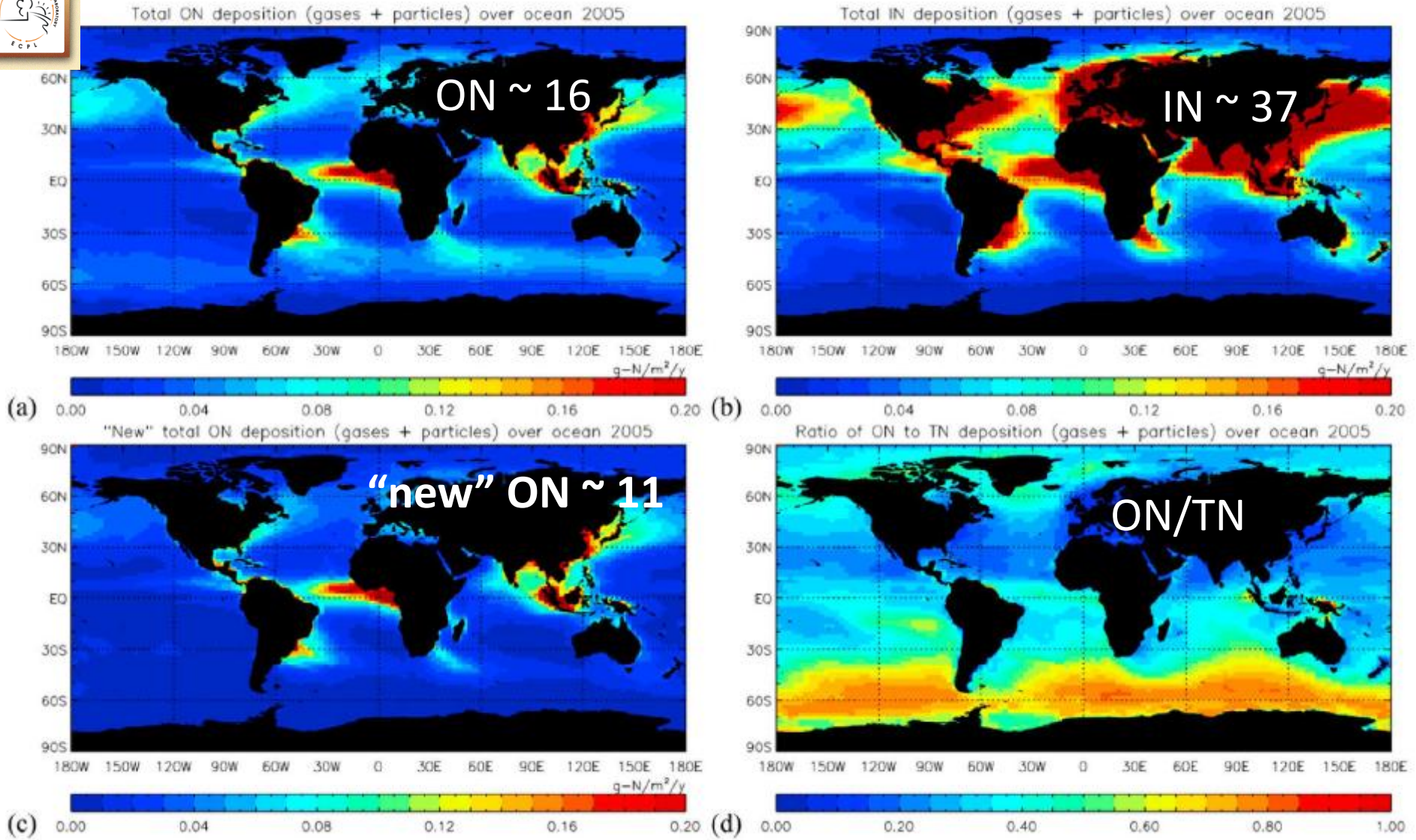
OC atmospheric deposition

Kanakidou, *et al. GBC, 2011GB004277, 2012*



Soluble Nitrogen deposition over the ocean

Tg-N/yr



Kanakidou, *et al. GBC, 2011GB004277, 2012*

Organic Phosphorus Deposition

Deposition over sea
0.35Tg/y

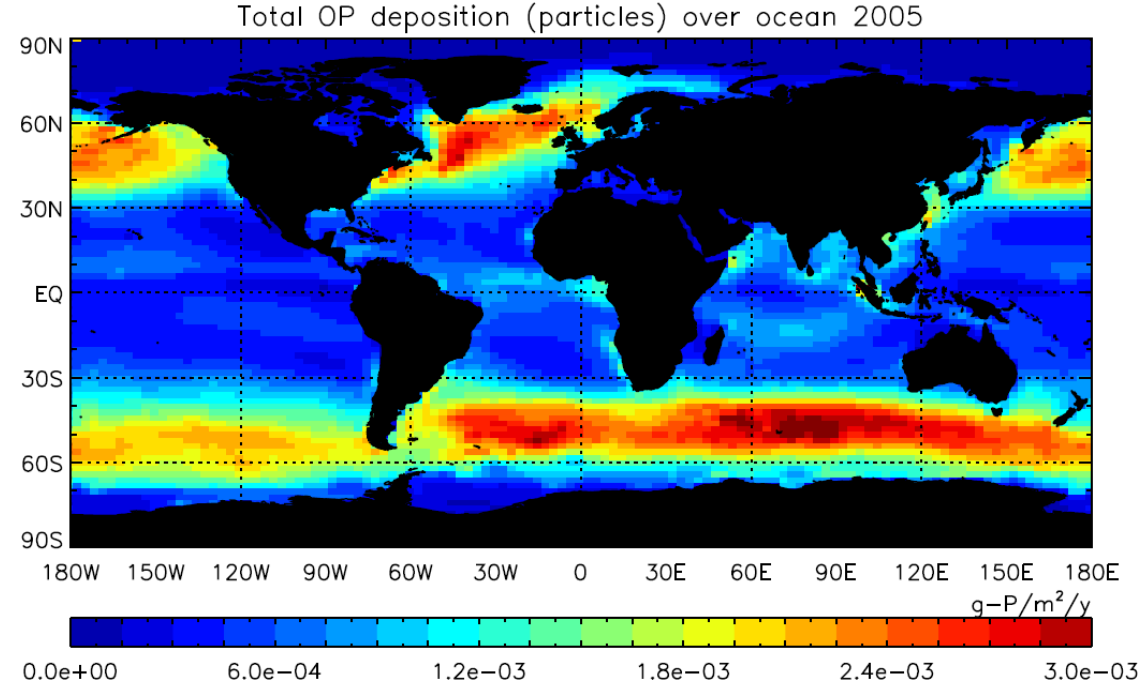
6% anthropogenic
4% terrestrial natural
90% ocean recycling

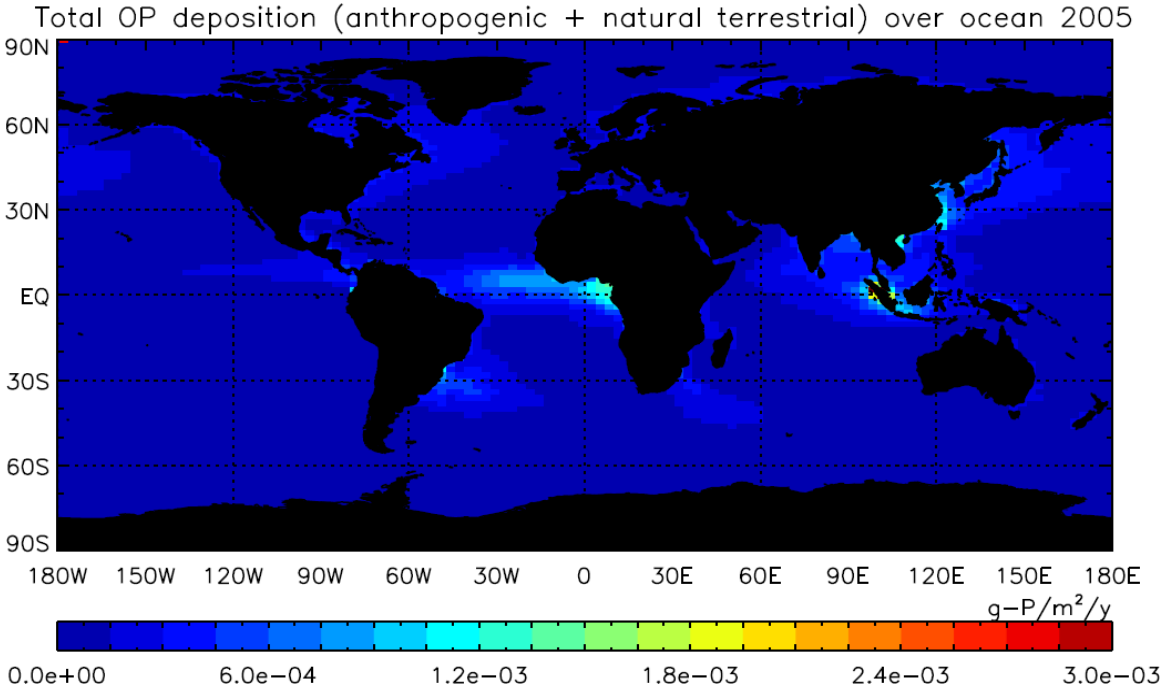
Turn overtime 3.8 days

'New' Organic Phosphorus Deposition

Deposition over sea
0.04Tg/y

Uncertainty at least an order of magnitude

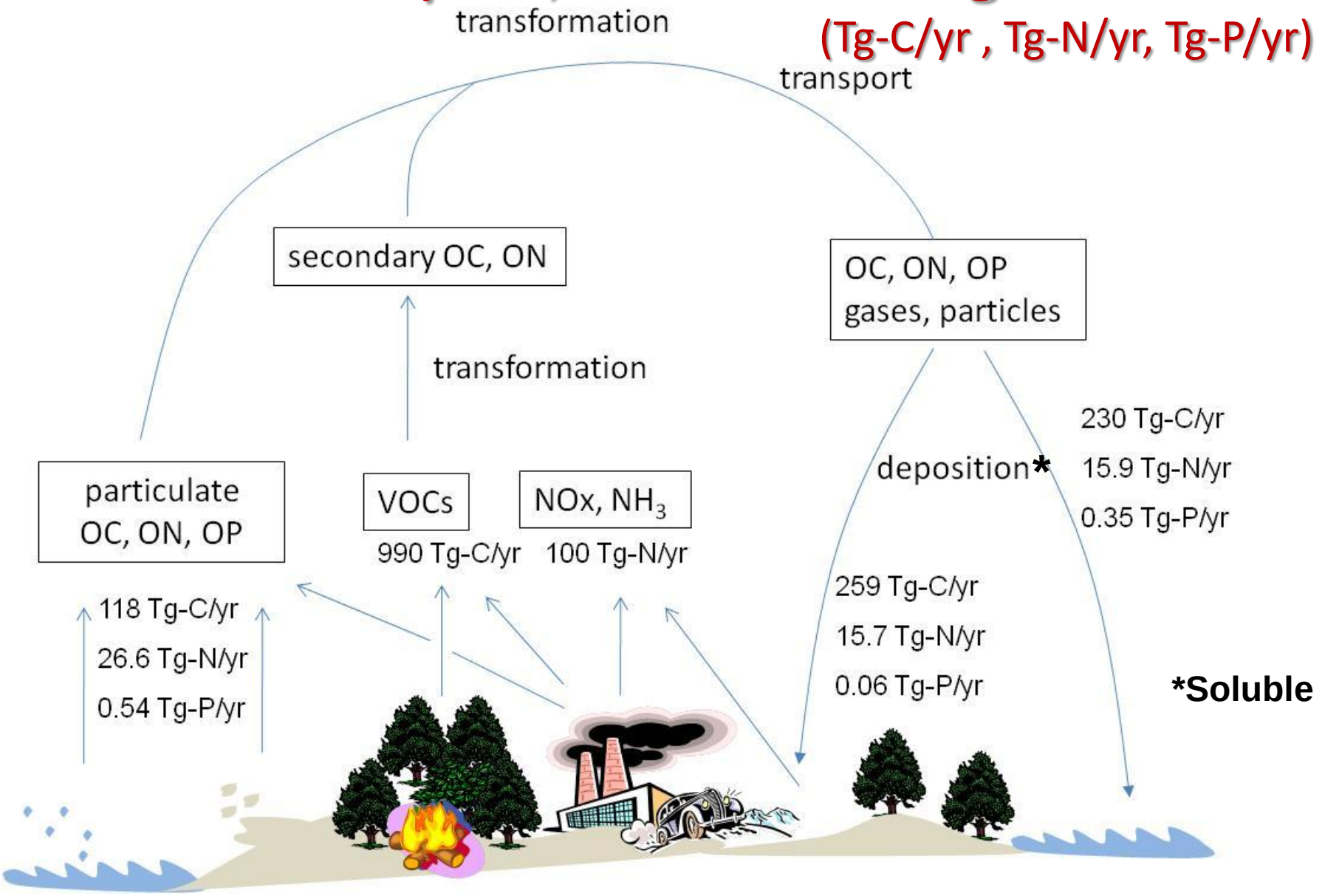




Kanakidou, *et al. GBC, 2011GB004277, 2012*

Present day OC, ON & OP budgets

(Tg-C/yr , Tg-N/yr, Tg-P/yr)



Kanakidou et al., GBC, 2012, doi 10.10.1029/2011GB004277

Conclusions

- Present day global ON deposition is ~32 Tg-N/yr (~ 1/4 of TN)
- ~40% of the ON deposition and ~45% of the total ON atmospheric source are associated with anthropogenic activities.
- ~6% of the OP deposition and ~10% of the total OP atmospheric source are associated with anthropogenic activities.
- The model-derived present-day soluble ON and OP deposition to the global ocean is estimated to be ~16 Tg-N/yr and ~0.35 Tg-P/yr respectively with an order of magnitude uncertainty. Of these amounts 33% (ON) and 90% (OP) are recycled oceanic materials.
- Anthropogenic emissions might modify the N:P composition of atmospheric deposition of nutrients.

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Recommendations

- The exact deposited amounts of the ON and OP to the global ocean and their assimilation by marine organisms are still an open question.
- ON & OP should be taken into account in impact studies.
- Need for : More ON, OP observations & standardized
- Targeted observational experiments to parameterize the bounding of N & P on OC under clean and polluted atmospheres.

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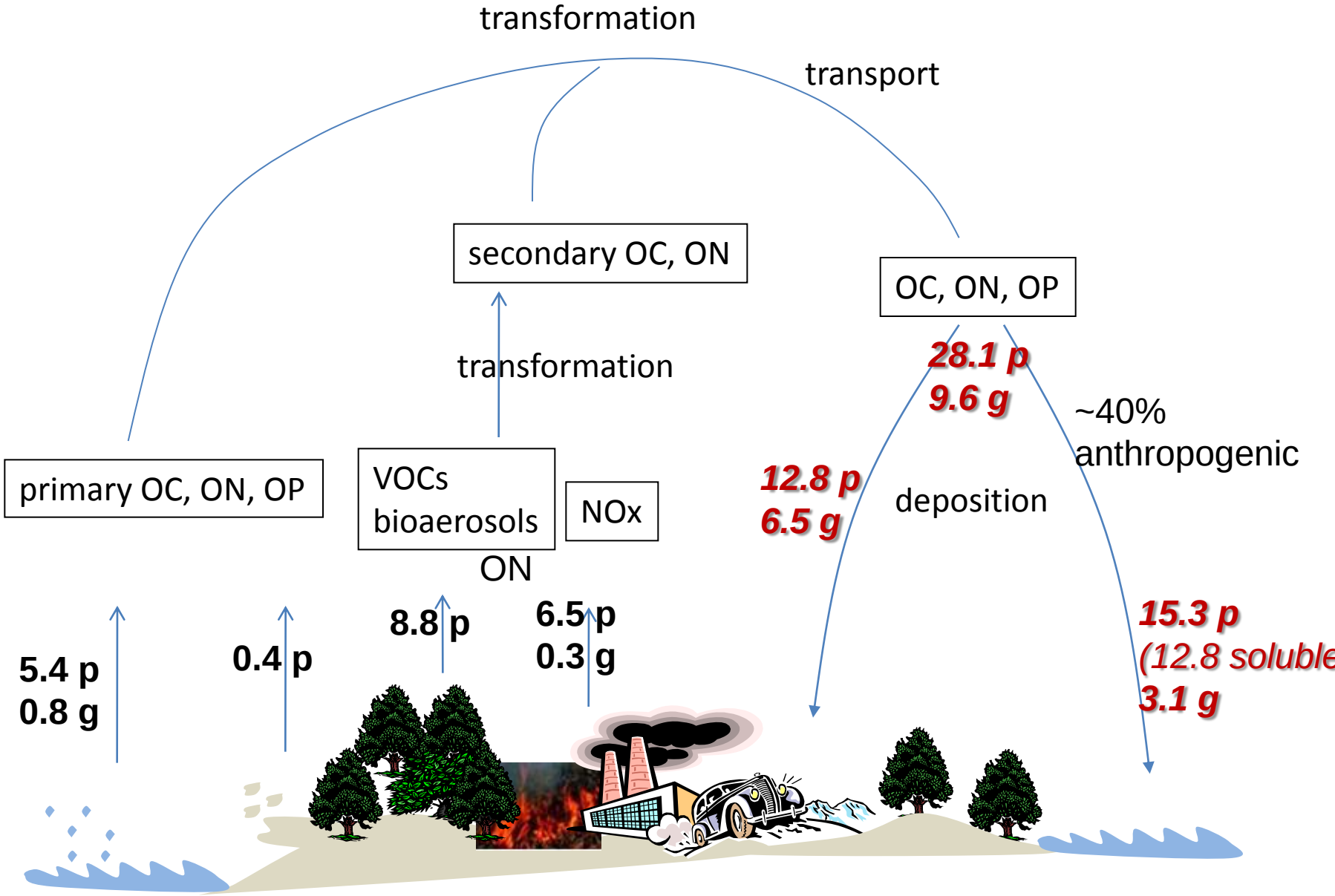
PERSEUS –EU – FP7 project

CITYZEN – EU- FP6 project
PEGASOS –EU-FP7 project
ECLIPSE – EU- FP7 project

Thank you!

ON budget Tg/y



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Particulate Organic Phosphorus (OP) budget Tg-P/yr

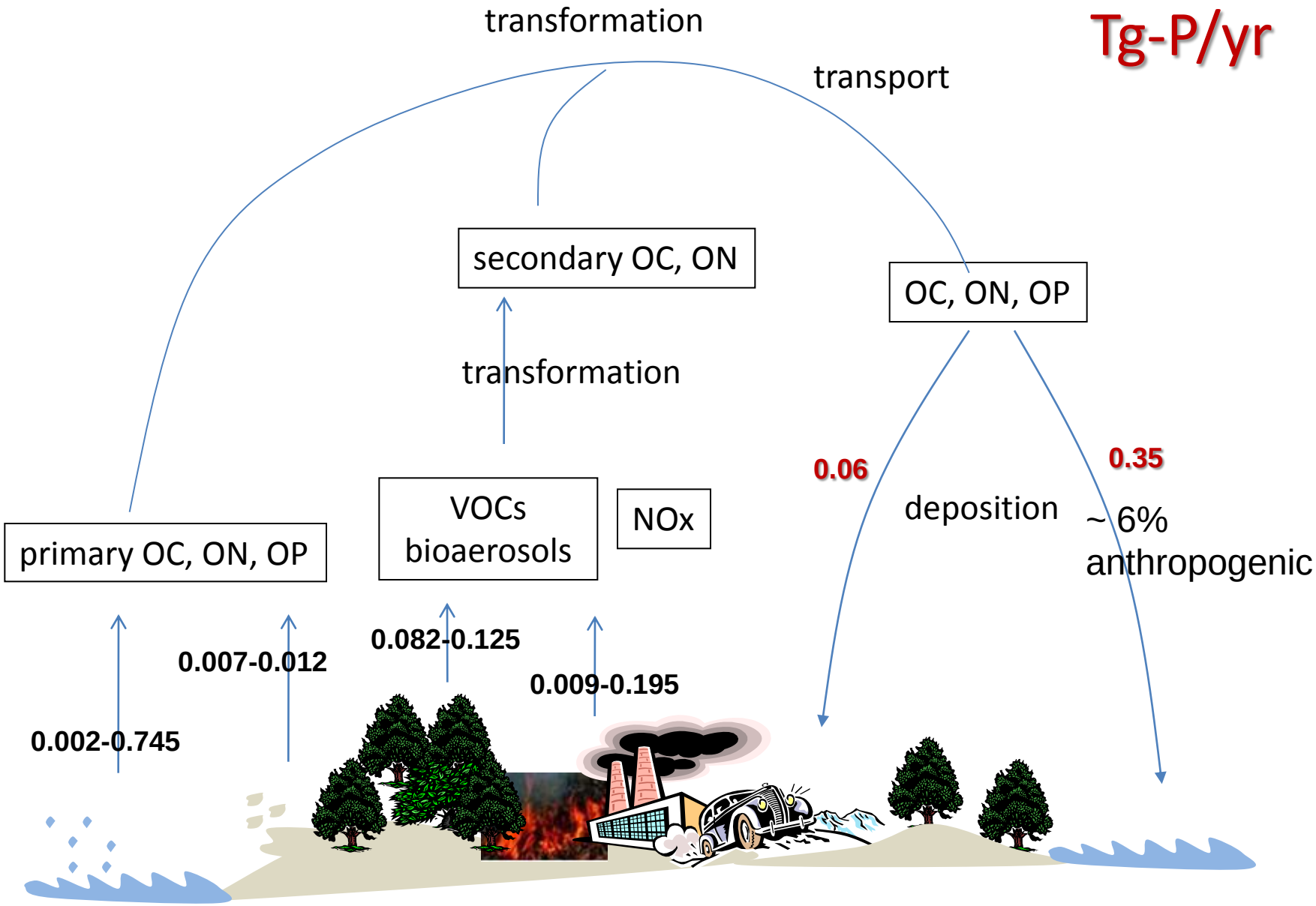

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Table 1. NMOC Emissions

a) Global Anthropogenic, Biomass Burning and Natural Annual NMVOC Emissions – used in global models

Emissions Tg/yr	Stevenson et al. 2006 IPCC TAR		Fiore et al. 2009	This work
	Tg/yr	*Tg/yr*	*Tg-C/yr*	Tg-C/yr
biomass burning	31	42		37[&]
vegetation isoprene	580 *	249		442
terrestrial terpenes &other reactive VOC	295 *	144		375[##]
oceans biosphere- DMS	20 (Tg S/yr)	24		72[$&]
Anthropogenic Emissions	116 -176	161		64[&]
Total NMVOC	*1042-1102*		*630 ± 221*	*995*

b) Global Anthropogenic, Biomass Burning and Natural Annual POC Emissions – used in TM4-ECPL and comparison with literature estimates, in Tg-C/yr except if differently indicated.

Emissions	Range in literature	This work
Biomass burning, biofuel, fossil fuel,	17 - 77[a]	35
Primary biogenic particles (PBP)	7.5 – 82.5[b]	50[&]
soil organic matter on dust	1.3- 34.5[c]	2.3[&]
ocean	2-75	30.6[&]
Total POC Tg-C/yr	*27.8 – 269*[d]	*118*

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Gaseous Organic Nitrogen

VOC → → RONO2 , PAN –like, SOA_N

Particulate Organic Nitrogen emissions Tg-N/yr

Emissions	best estimate	estimated range[$]
Biomass burning, biofuel, fossil fuel,	6.5	0.3-14.4
Primary biogenic particles (PBP)	8.8[&]	0.1-16.4
soil organic matter on dust	0.4[&]	0.01-6.04
ocean PON	5.4[&]	0.3-13.2
Total PON Tg-N/yr	*21.1*	*0.71-50.4*
Ocean amines Tg N/yr	*0.8*	
CH_3CN (not accounted here)	*0.28*[&]	

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Particulate Organic Phosphorus (OP) emissions

Sources	Range Tg-P/y	Best estimate	Estimated from TSP[#]
Biomass burning, biofuel, fossil fuel,	0.008-0.719	0.195	0.009
Primary biogenic particles (PBP)	0.001-0.825	0.125	0.082
soil organic matter on dust	0.003-0.138	0.007	0.0115
ocean	0.048-1.826	0.745[&]	0.0015
	0.8-3.2*	(1.6*)	
Total POP Tg-P/yr	*0.060-4.882*	*1.072*	*0.072*
Anthropogenic fraction[$]		*18%*	*12%*

* Based on Na content in the seawater, see text; [&] based on OC emissions and assuming a Redfield ratio; [$] including biomass burning; [#] based on PO_4^{3-} estimate by *Mahowland et al [2008]* and Table 8 observational data on OP/TSP.

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Comparison with literature

Soluble Nitrogen deposition Tg-N/y

	Global		Ocean	
	this work	*Neff et al 2002*	this work	*Duce et al 2008 & Dentener et al 2005*
ON	~32 (48% *) ~10 (g) 22(p)	9 -50	~16 (38%*) ~ 3 (g) ~ 13 (p)	20 (10-30)
IN	~ 91 ~ 62 (g) ~ 29 (p)	~ 84	~ 37 ~ 26 (g) 11 (p)	47 (28-66)
TN	~ 122	~ 93	~ 53	67 (38-96)
ON/TN	0.26	0.10	0.30	0.30

* Anthropogenic contribution

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Comparison with literature

Organic Carbon – Emissions and Deposition

Emissions Tg-C/yr	This work TM4-ECPL model	Goldstein& Galbally 2007	Hallquist et al 2009	
OC gases	990	1300	1334	
OC particles	118		16	
OC gas+ particles	1108			
Deposition Tg-C/yr Global (ocean)	This work TM4-ECPL model	Goldstein& Galbally 2007	Hallquist et al 2009	Jurado et al. (2008) (soluble)
OC gases	381 (166)	130-270	800	(187)
OC particles	147 (109)	175-375	150	(58)
OC gas+ particles	528 (489)			(245)

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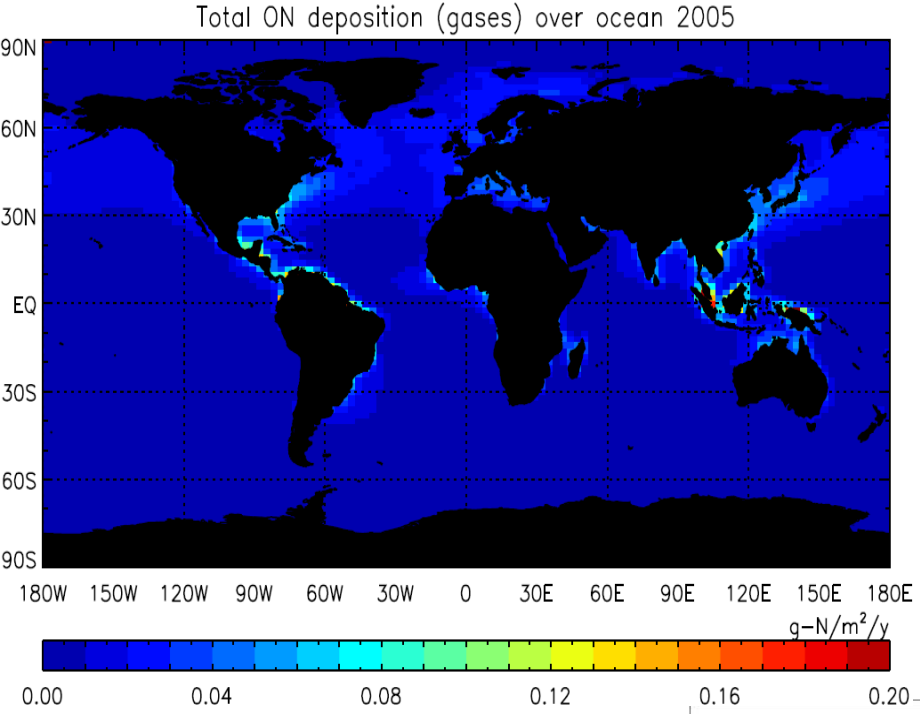

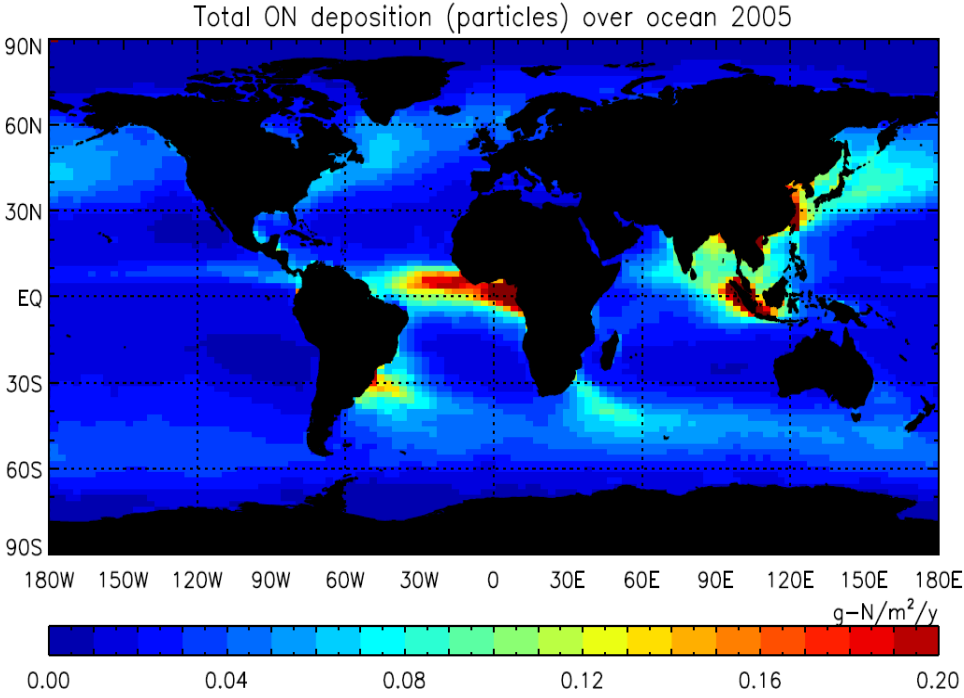

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Vegetation driven sources

Human driven sources