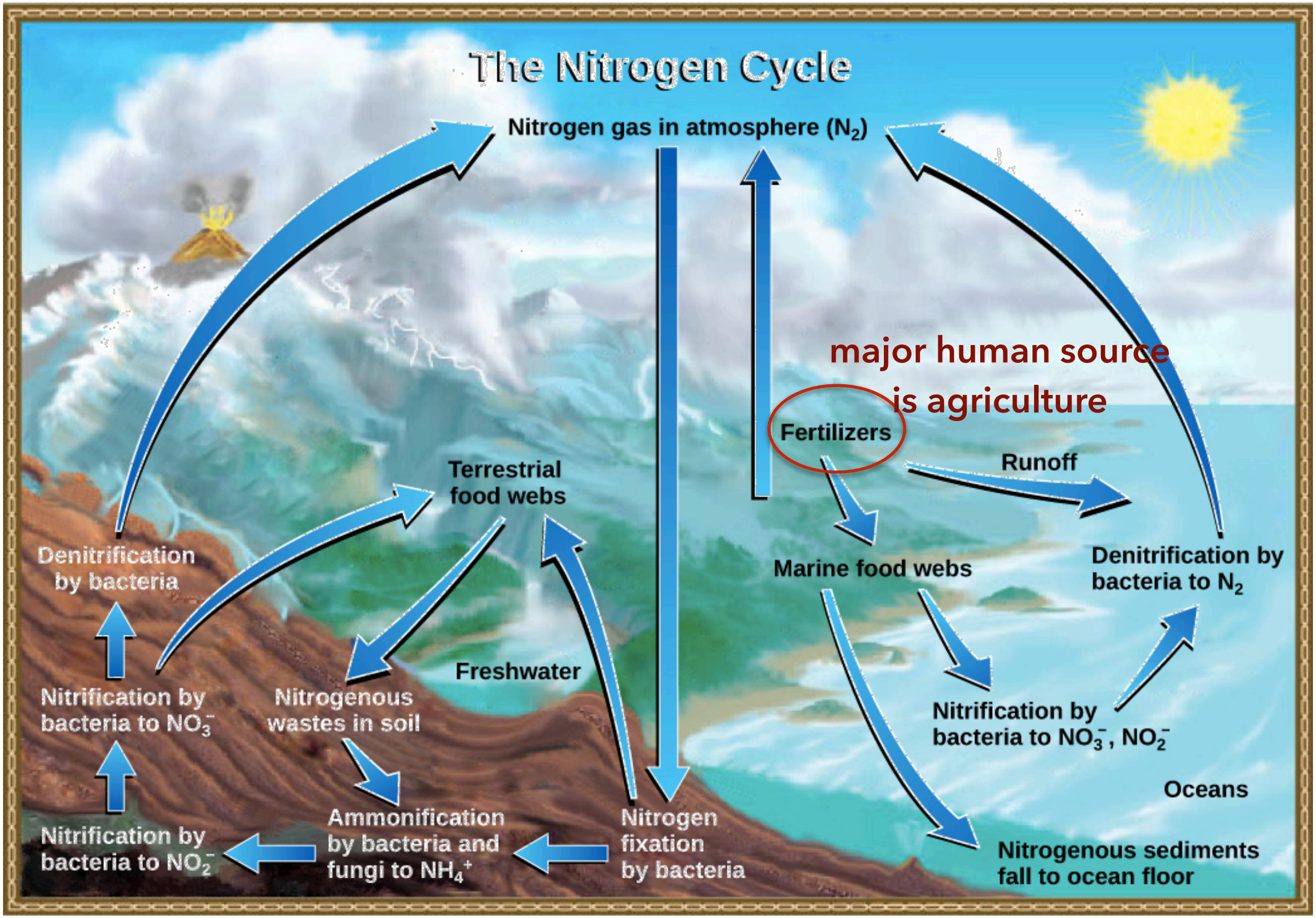
Introduction to the Biosphere-Atmosphere system

Lecture Autumn 2024

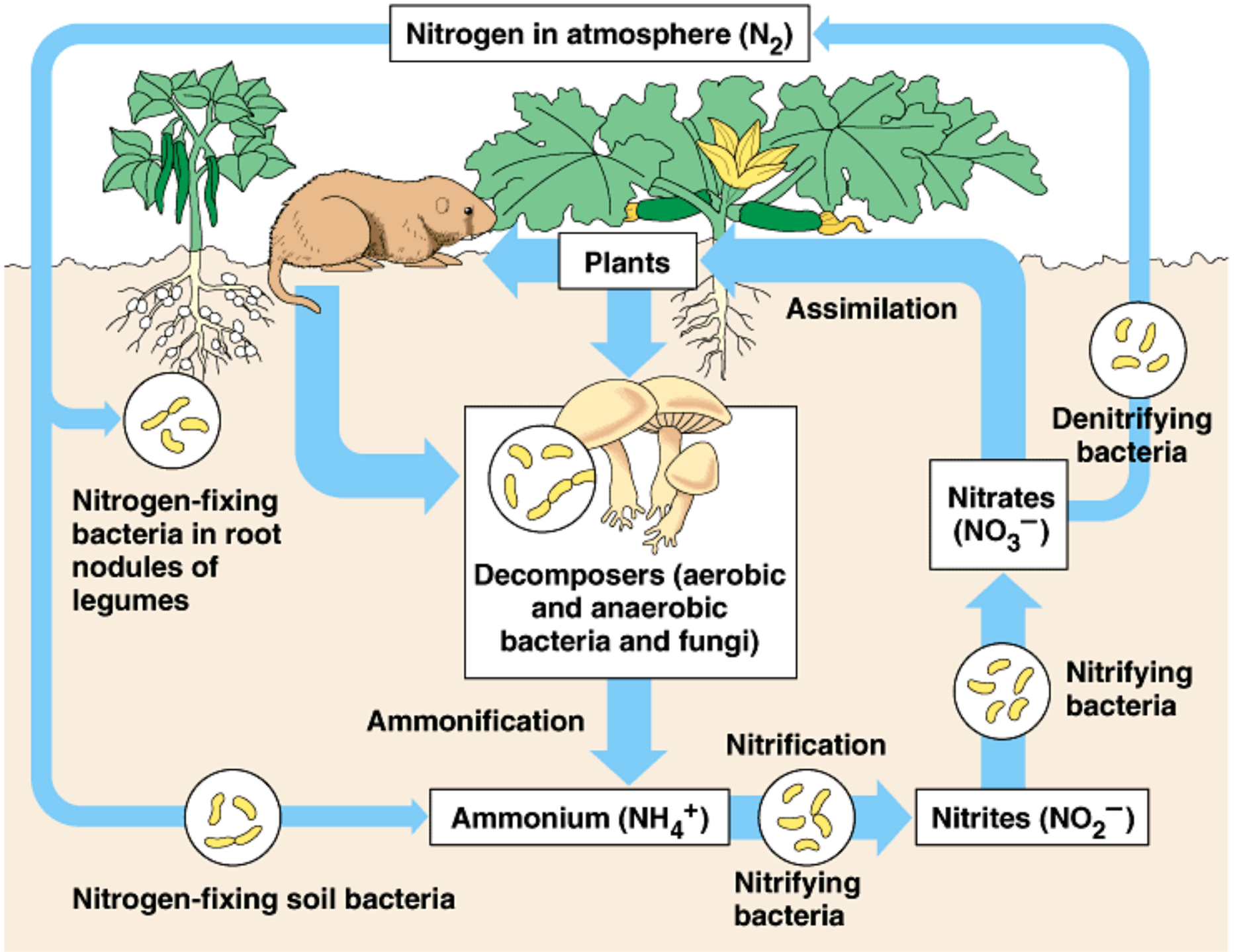
Part V

Steffen M. Noe

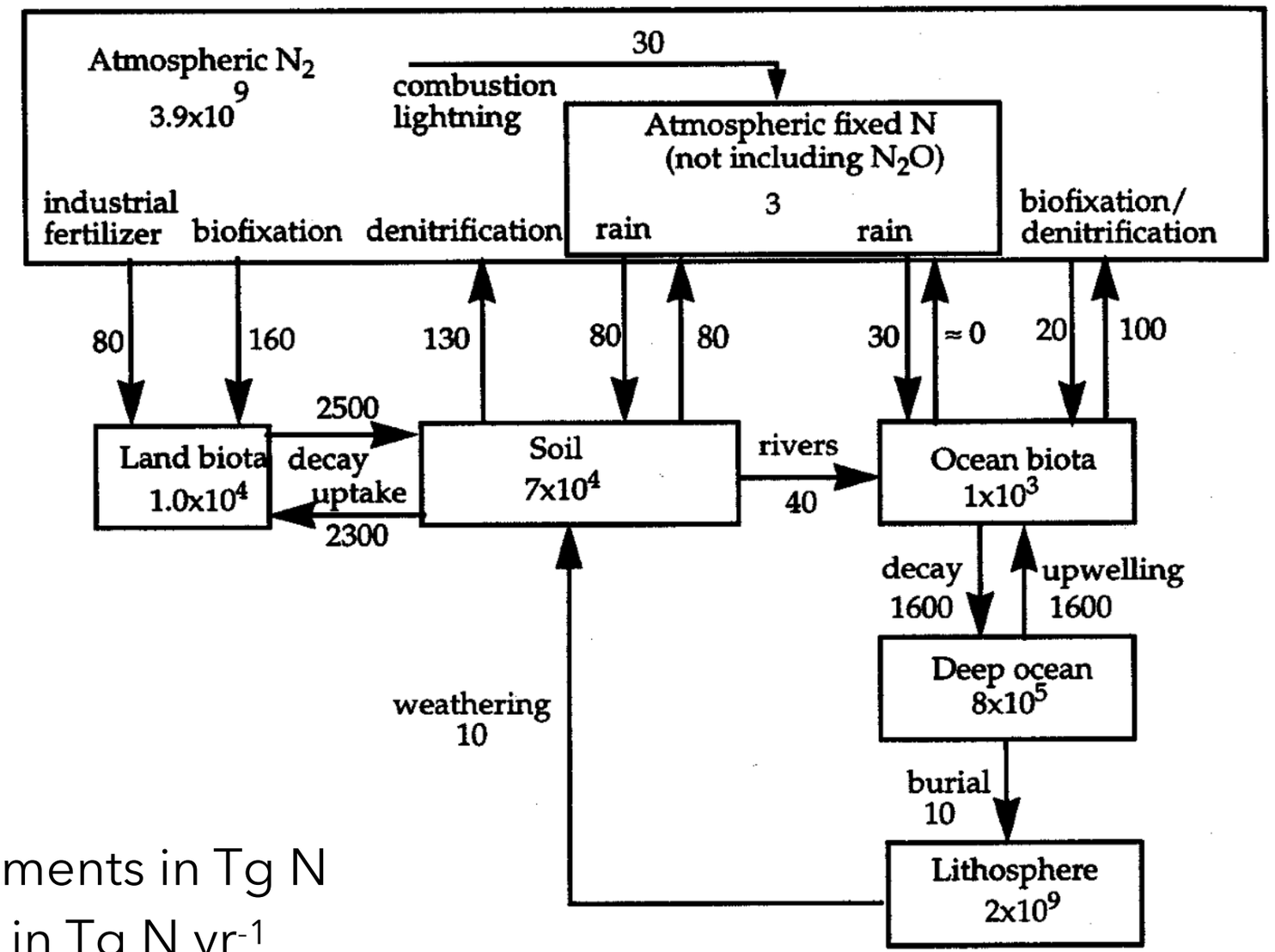
Nitrogen cycle



The terrestrial case



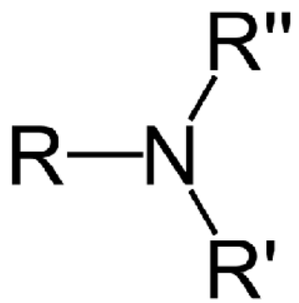
Box model of the nitrogen cycle



compartments in Tg N

Flows in Tg N yr^{-1}

Amines participate in atmospheric reactions leading to feedbacks



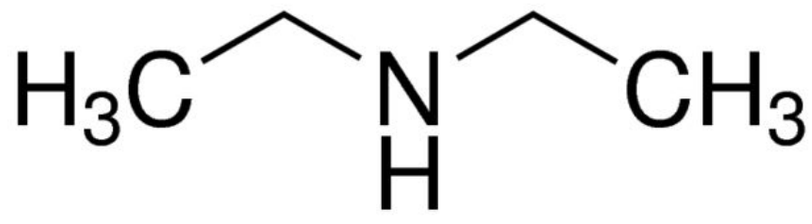
Photooxidation of amines leads to formation and growth of aerosol particles and cloud condensation nuclei.

Amines lead to acid neutralisation and speed up SOA growth.

Because of the neutralisation reactions they are hard to detect in free atmosphere.

Amine (abbrev)	Formula	Estimated Global Emissions, Gg N y^{-1} (Schade and Crutzen, 1995)
Ammonia	NH_3	23 300
Methylamine (MA)	CH_3NH_2	24±15
Trimethylamine (TMA)	$(CH_3)_3N$	108±30
Diethylamine (DEA)	$(CH_3CH_2)_2NH$	–
Triethylamine (TEA)	$(CH_3CH_2)_3N$	–
Ethanolamine (MEA)	$(CH_2OH)CH_2NH_2$	–

Diethylamine



Amines are a hot topic in atmospheric nucleation reactions

Dimethylamine - sulphuric acid clusters found to speed up secondary aerosol growth rates by a factor of 1000 compared to ammonia.

The CLOUD experiment at CERN is one flagship initiative to put forward this research.

Amines are a good candidate to explain the aerosol formation rates in the atmosphere.

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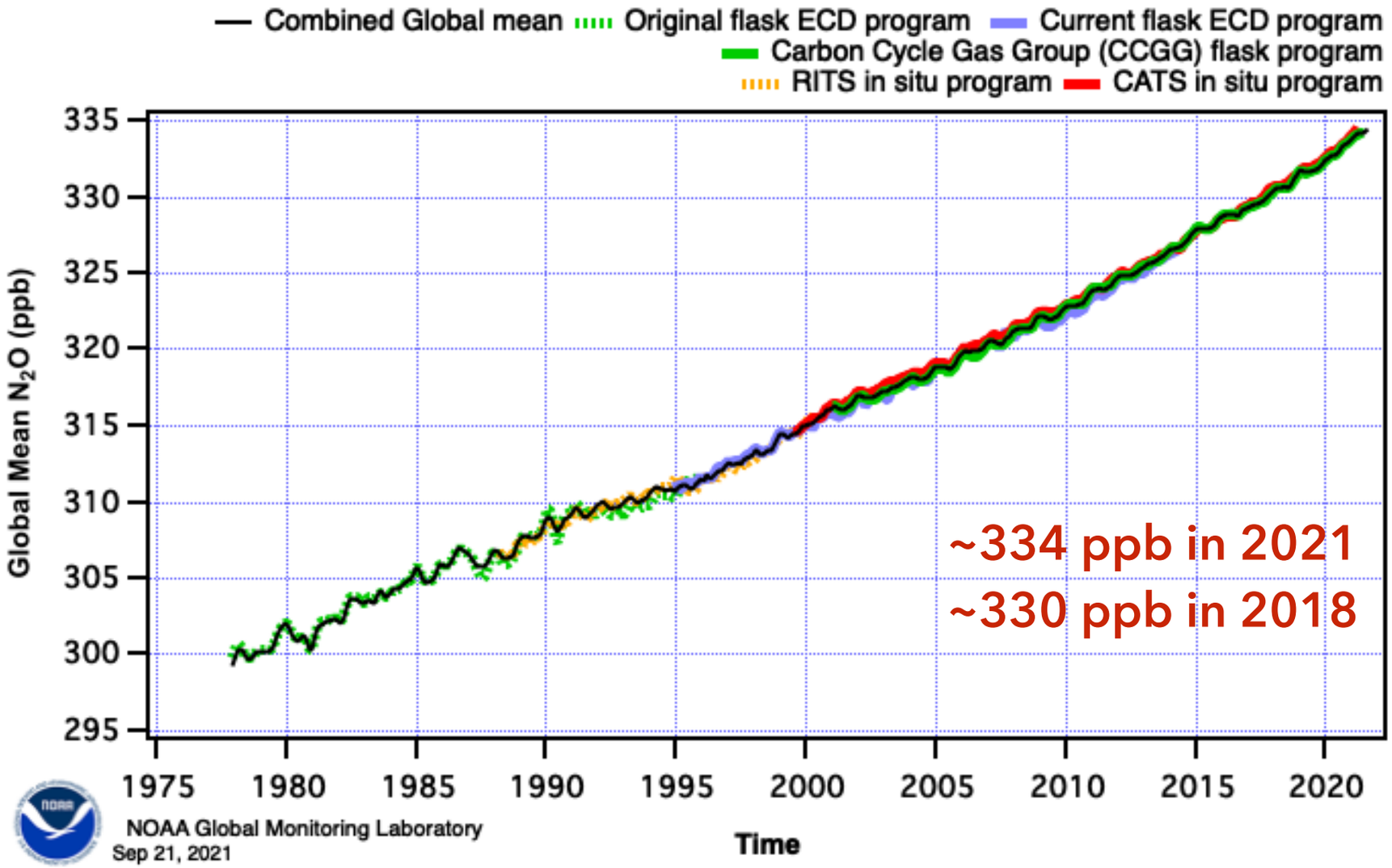
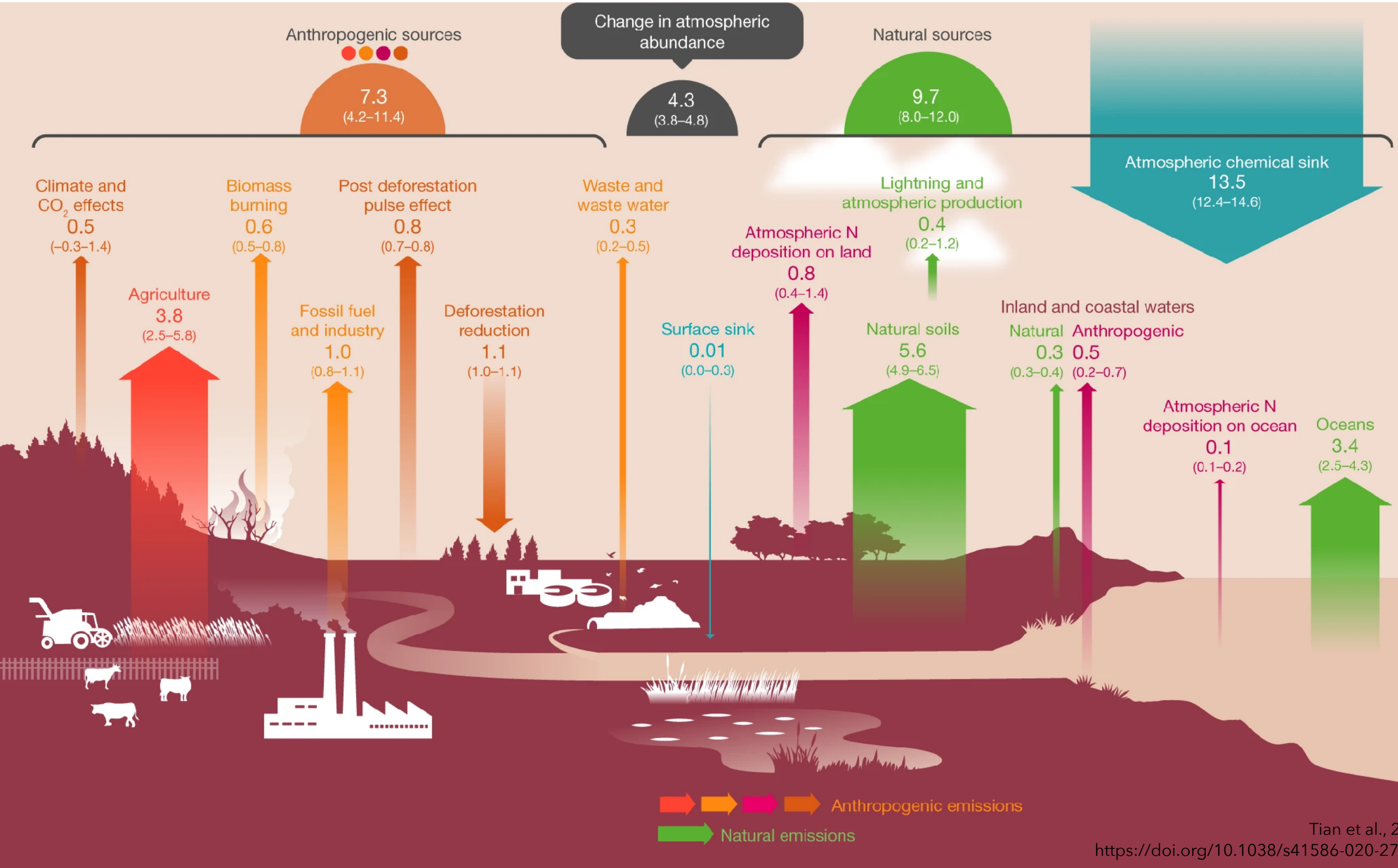
Laughing gas N_2O

low yield product of the bacterial nitrification and denitrification!



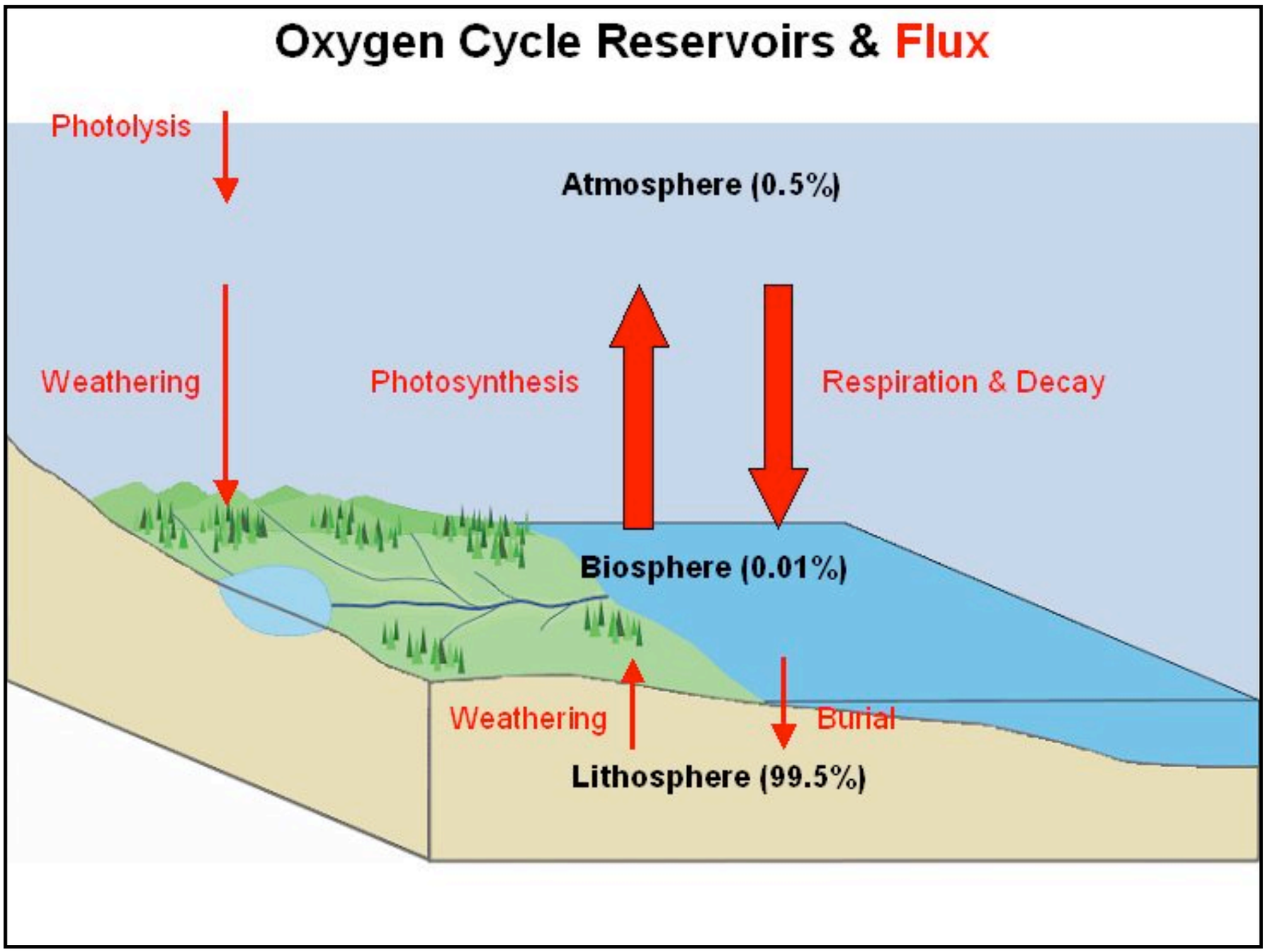
Important as source of NOx radicals in stratosphere
and a greenhouse gas in the troposphere

N_2O sources and sinks

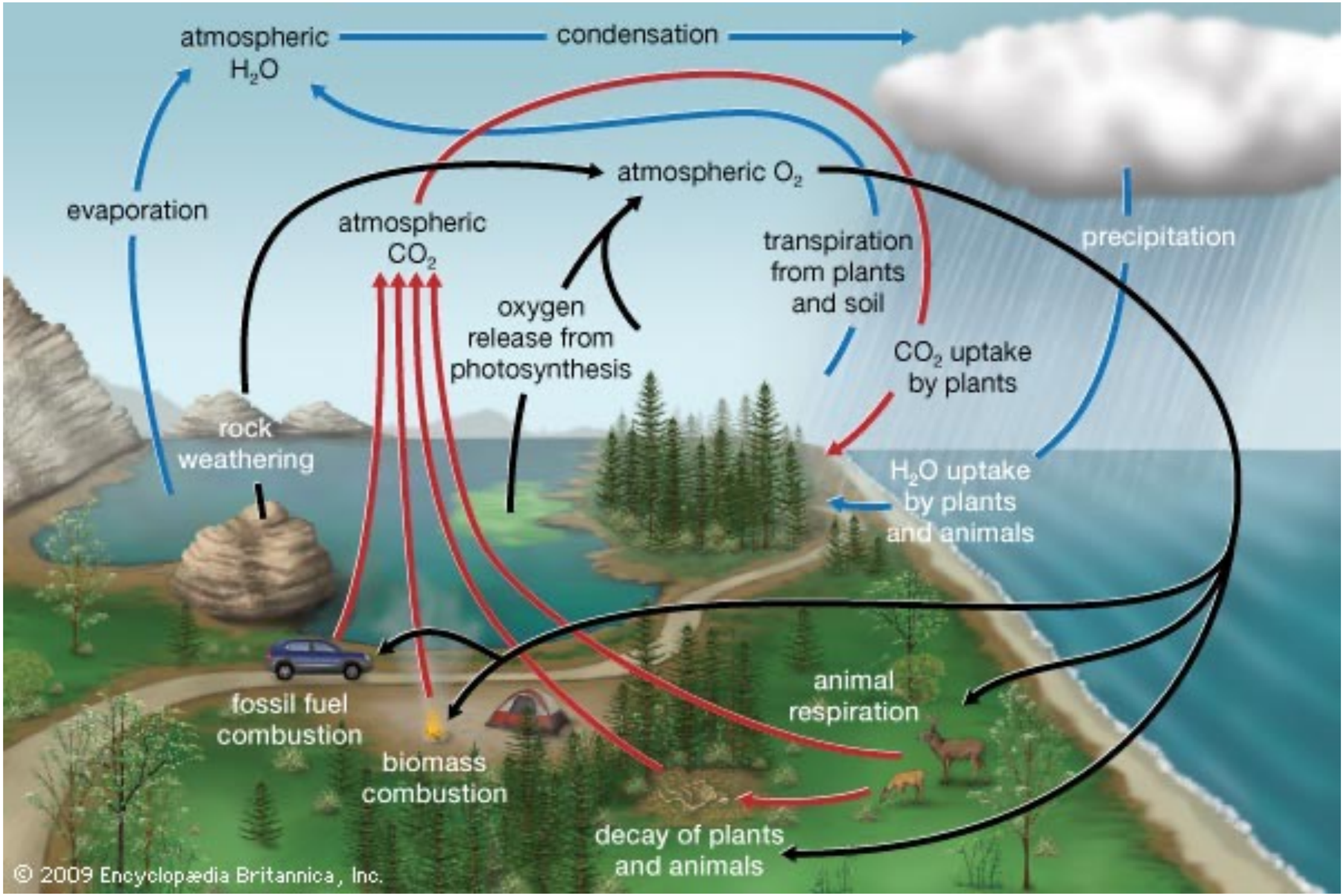


Tian et al., 2020,
https://doi.org/10.1038/s41586-020-2780-0

Oxygen cycle



CO_2, H_2O and O_2 cycles



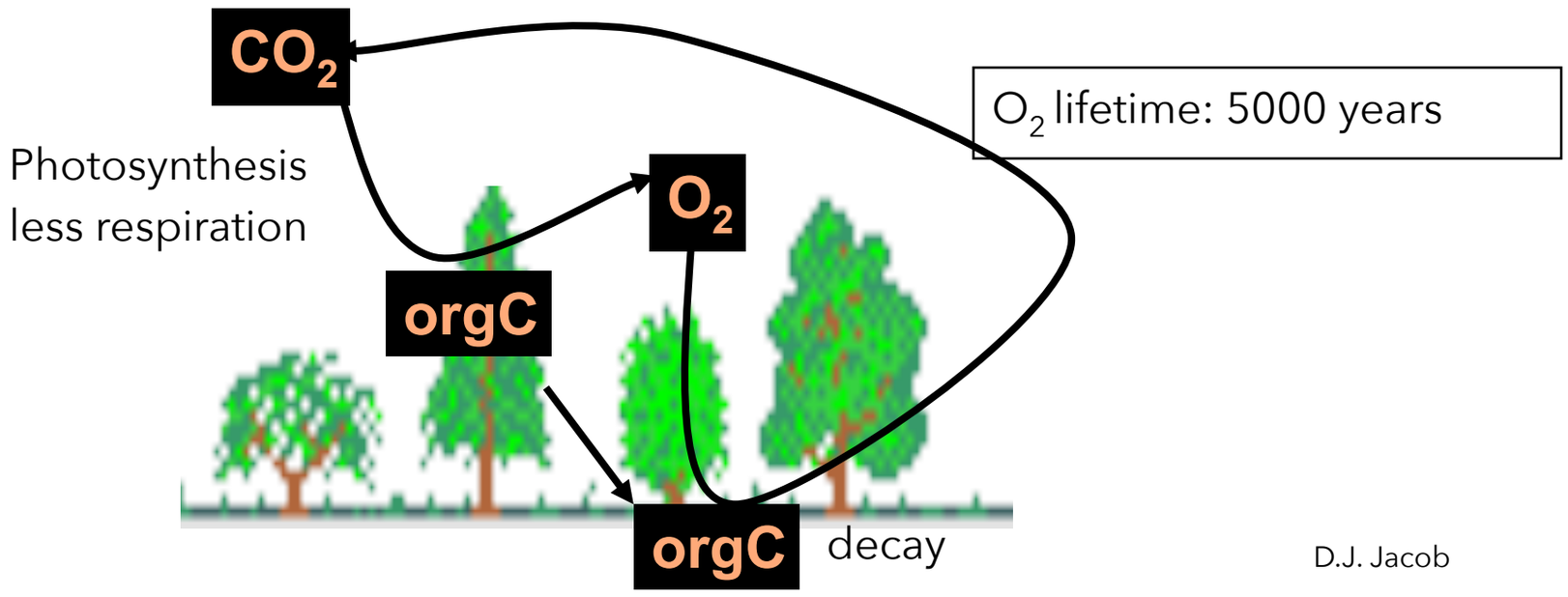
Fast cycling: atmosphere–biosphere

- Source of O_2: photosynthesis

$$nCO_2 + nH_2O \rightarrow (CH_2O)_n + nO_2$$

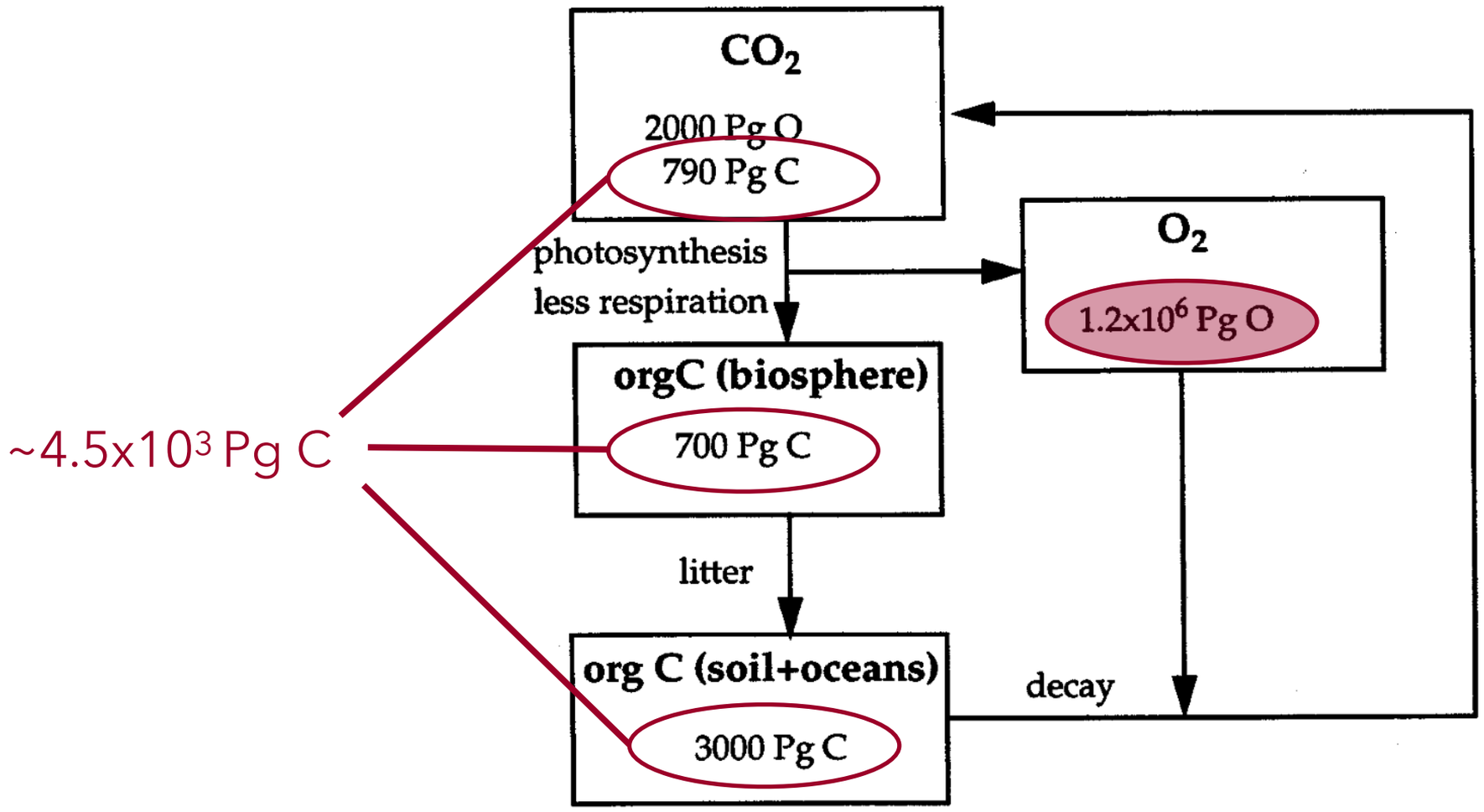
- Sink: respiration/decay

$$(CH_2O)_n + nO_2 \rightarrow nCO_2 + nH_2O$$



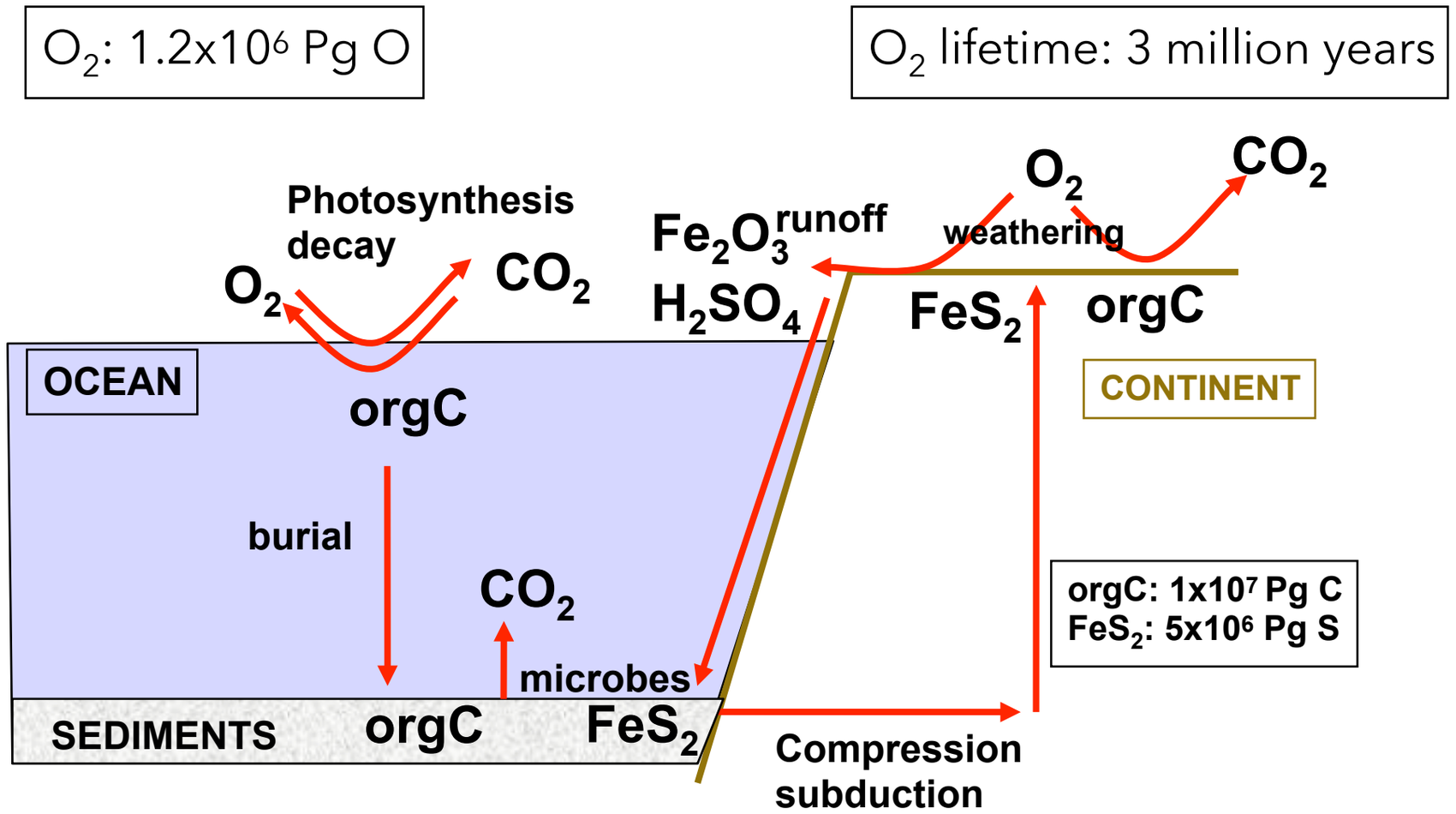
D.J. Jacob

Oxygen cycle box model



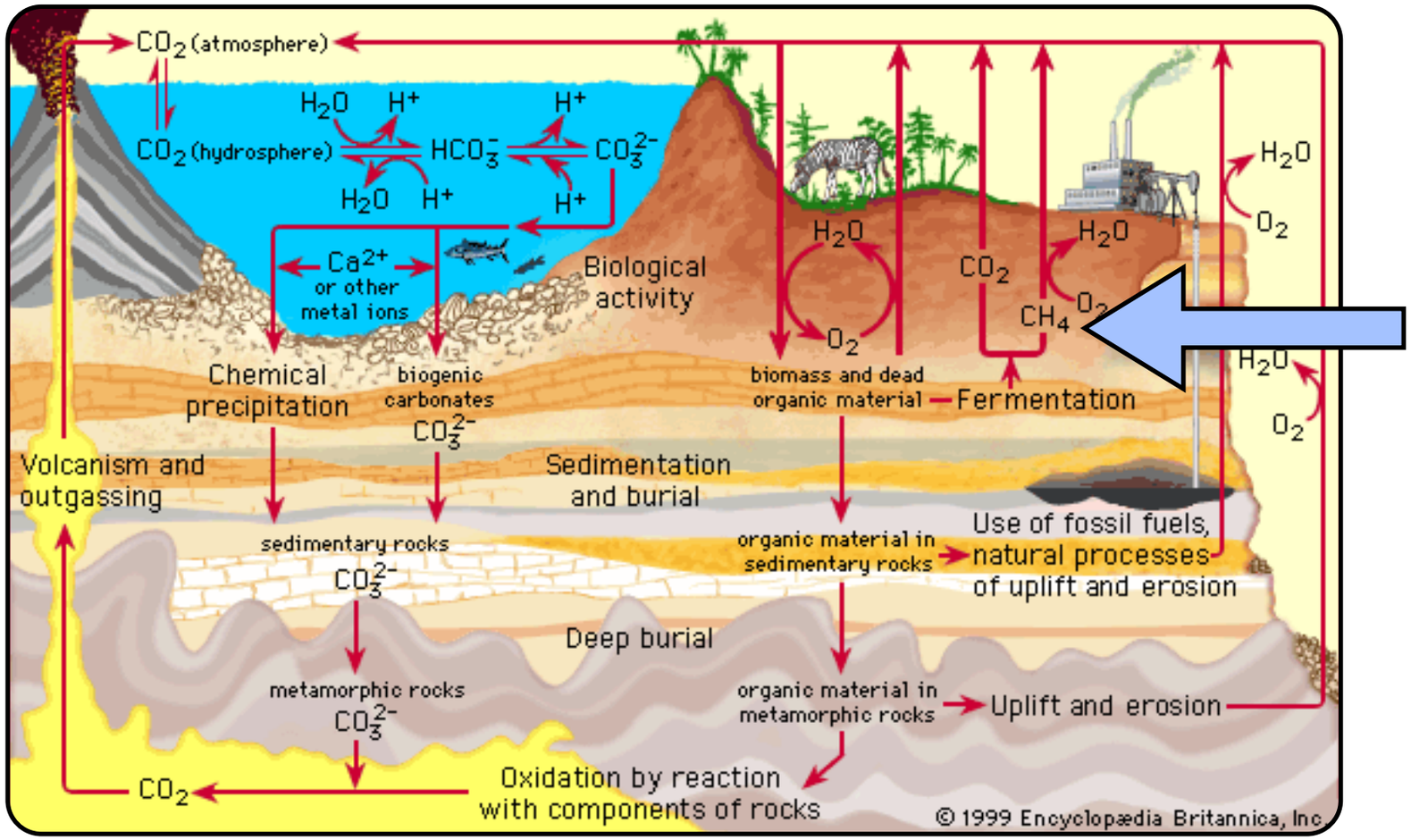
however, the amount of **organic carbon** is too small to control the atmospheric oxygen levels!

Slow cycling: atmosphere–lithosphere



D.J. Jacob

Methane is a part of the carbon cycle



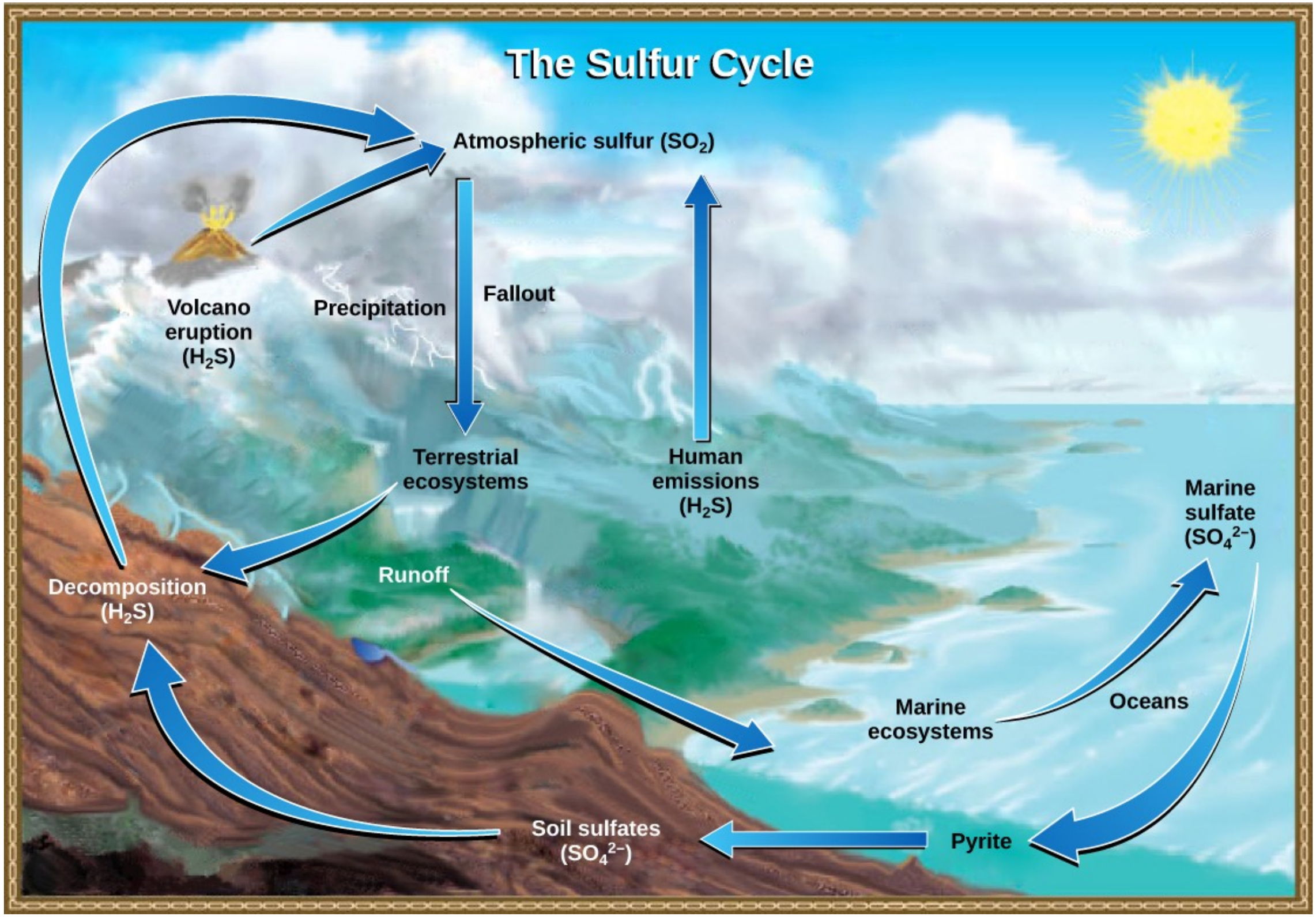
Permafrost

Methane sources and sinks

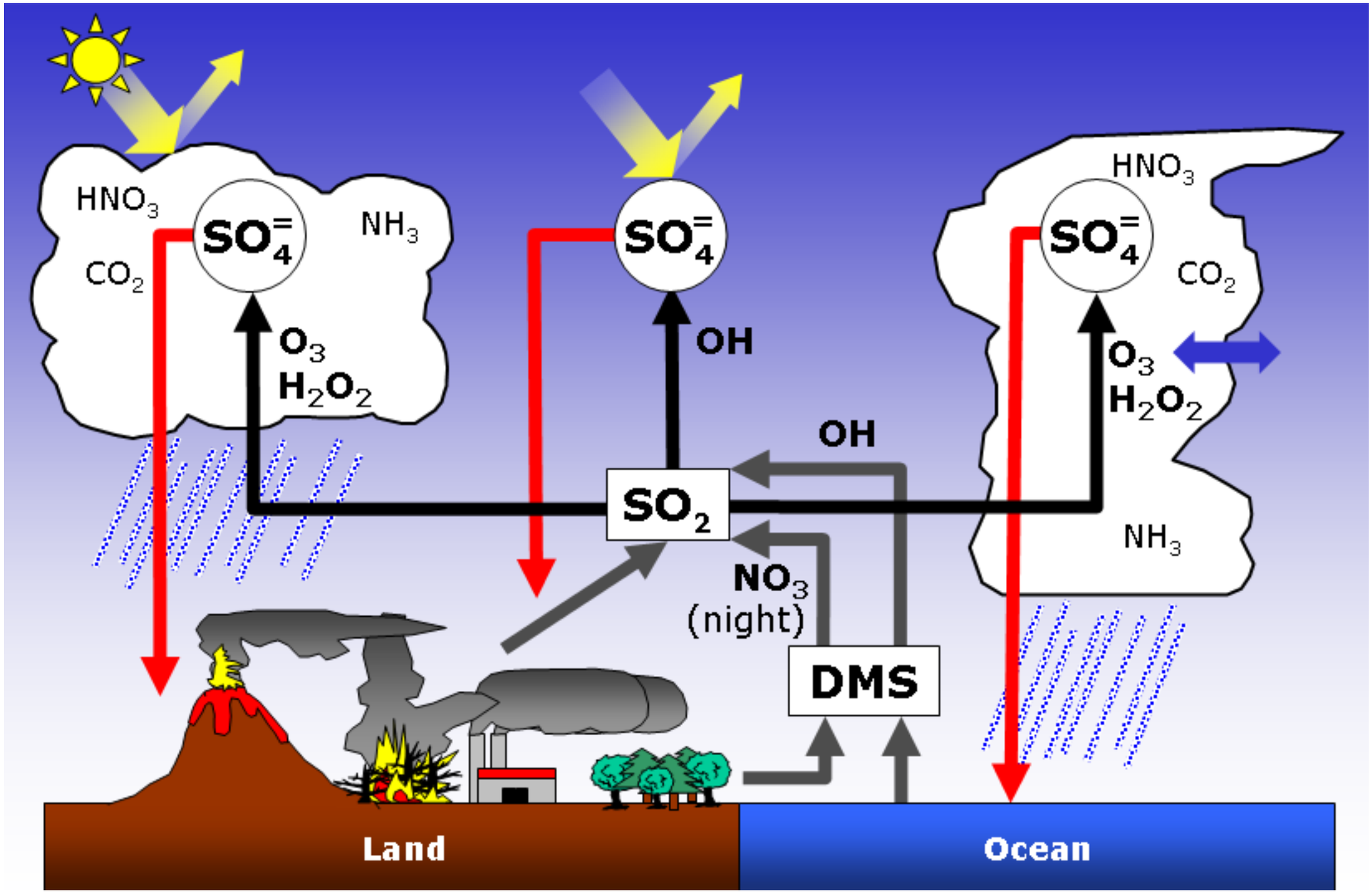
Source: IPCC (2001)

Sources	Amount [Tg yr^{-1}]	
Wetlands	225*	Natural: 182*
Termites	20	
Ocean	15	
Hydrates	10	
Energy	110	Anthropogenic: 418*
Landfills	40	
Ruminants	115	
Waste treatment	25	
Rice agriculture	88*	
Biomass burning	40	
Sinks		
Soil	30	580
Tropospheric OH	510	
Stratospheric loss	40	
Balance	+20 Tg yr^{-1}	

Sulphur cycle

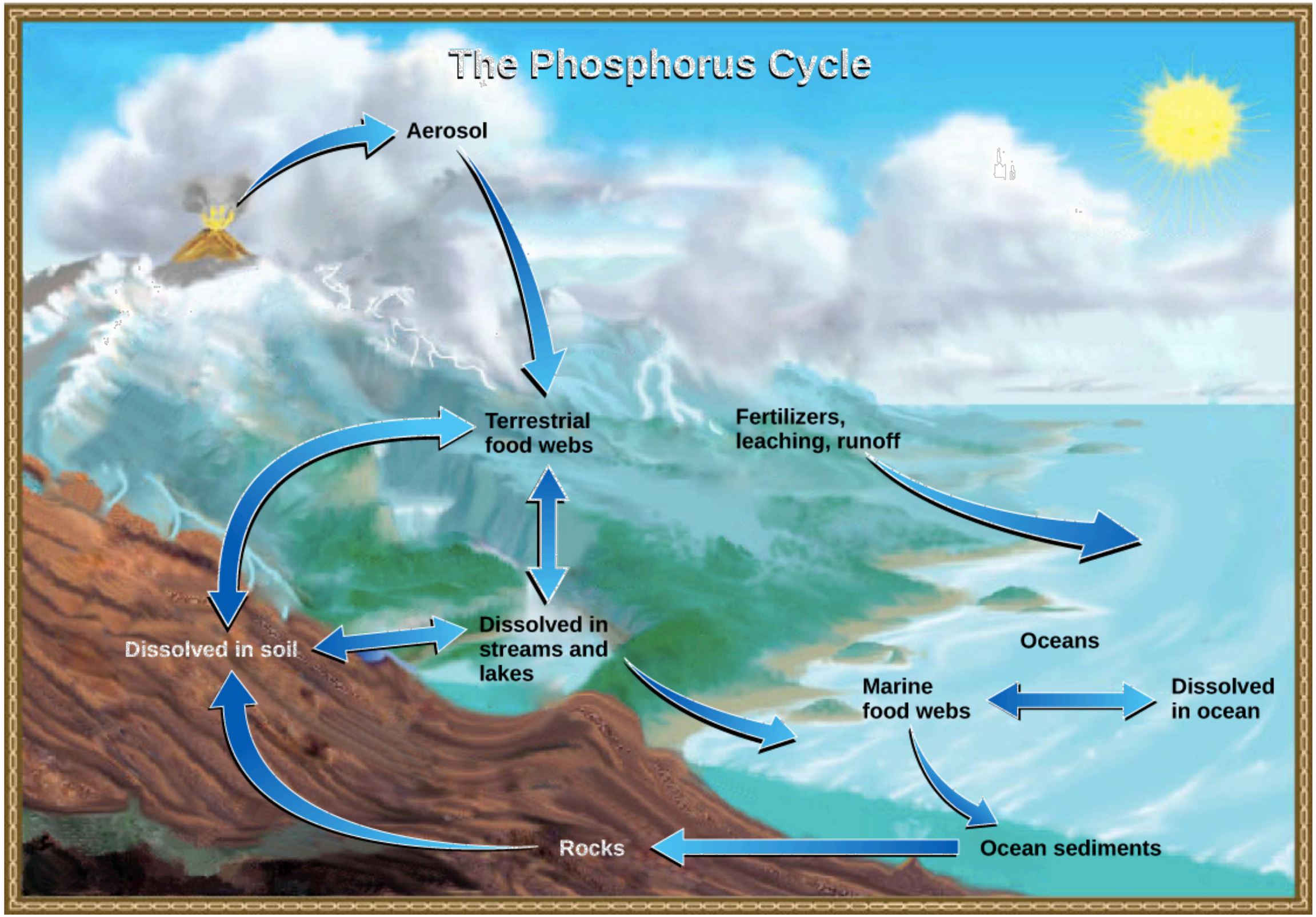


Sulphur sources and sinks



Fossil fuel burning is the largest source beside volcanic outgassing and sea spray.

Phosphorous cycle



Phosphorous cycle sources and sinks