

Impact of cloud microorganisms on atmospheric processes

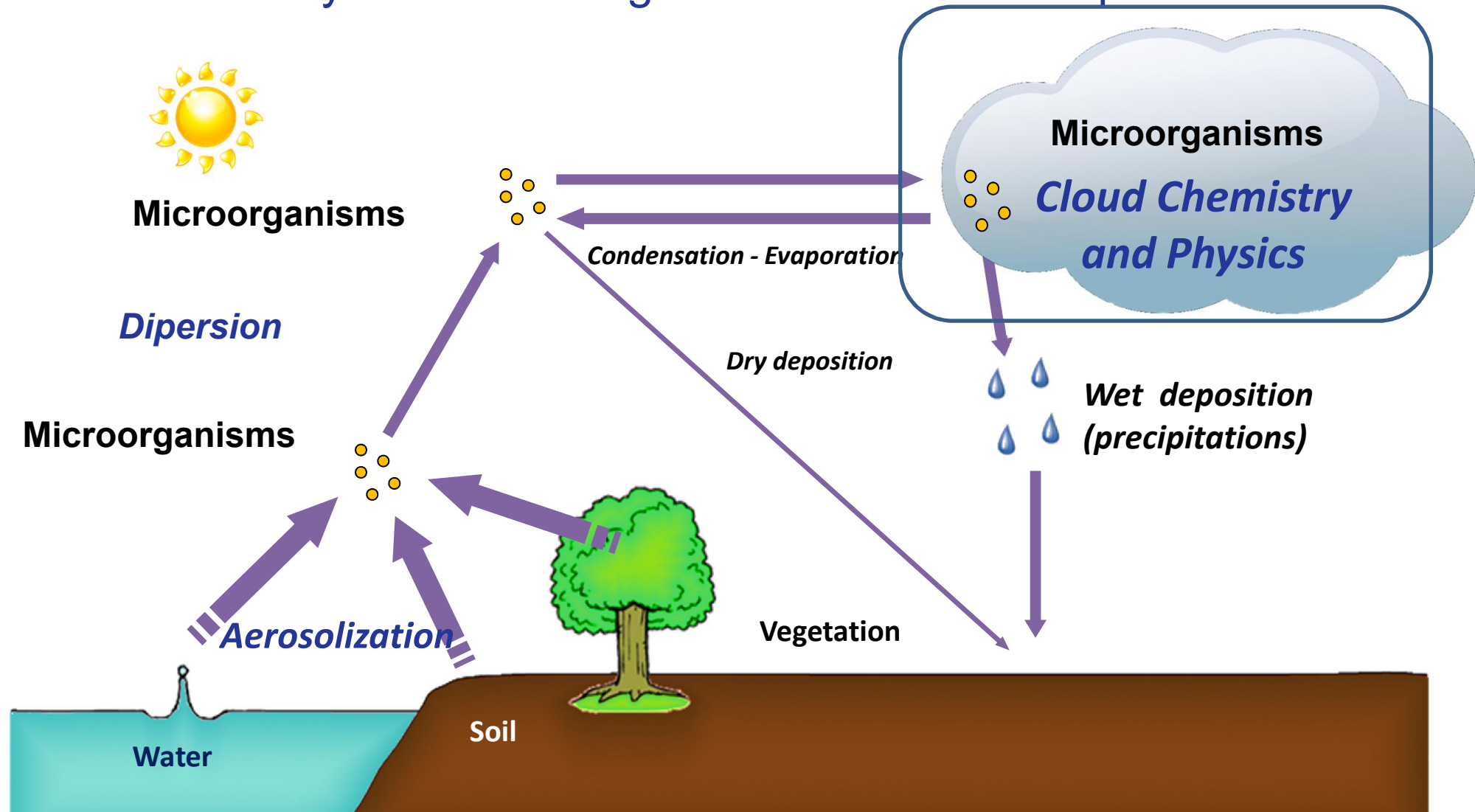
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Microorganisms in clouds

The cycle of microorganisms *via* the atmosphere



Cloud sampling at the puy de Dôme station (1465 m asl)



**GAW (Global Atmospheric Watch)
ACTRIS**



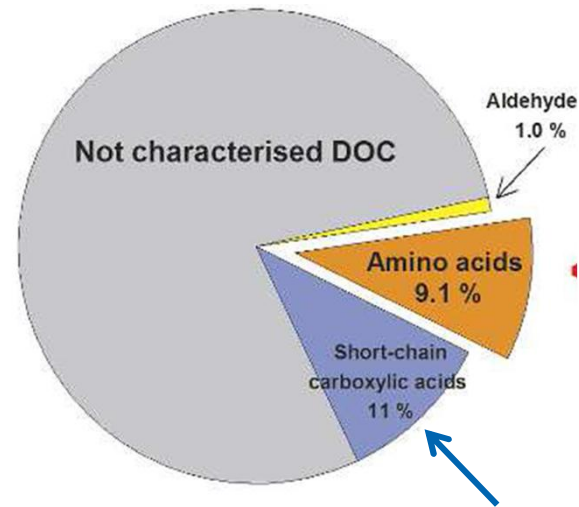
©2009 Google

Altitude 1146.19m





- ☐ Water condensed on aerosols
- ☐ Droplets or ice crystals ($>10\ \mu\text{m}$)
- ☐ Acidic ($\text{pH} = 3 - 7$)
- ☐ Oxidative (H_2O_2 , Fe, OH and NO_3 radicals)
- ☐ Ions (NO_3^- , SO_4^{2-} , Na^+ , NH_4^+ , Cl^- ...)
- ☐ Organic Matter

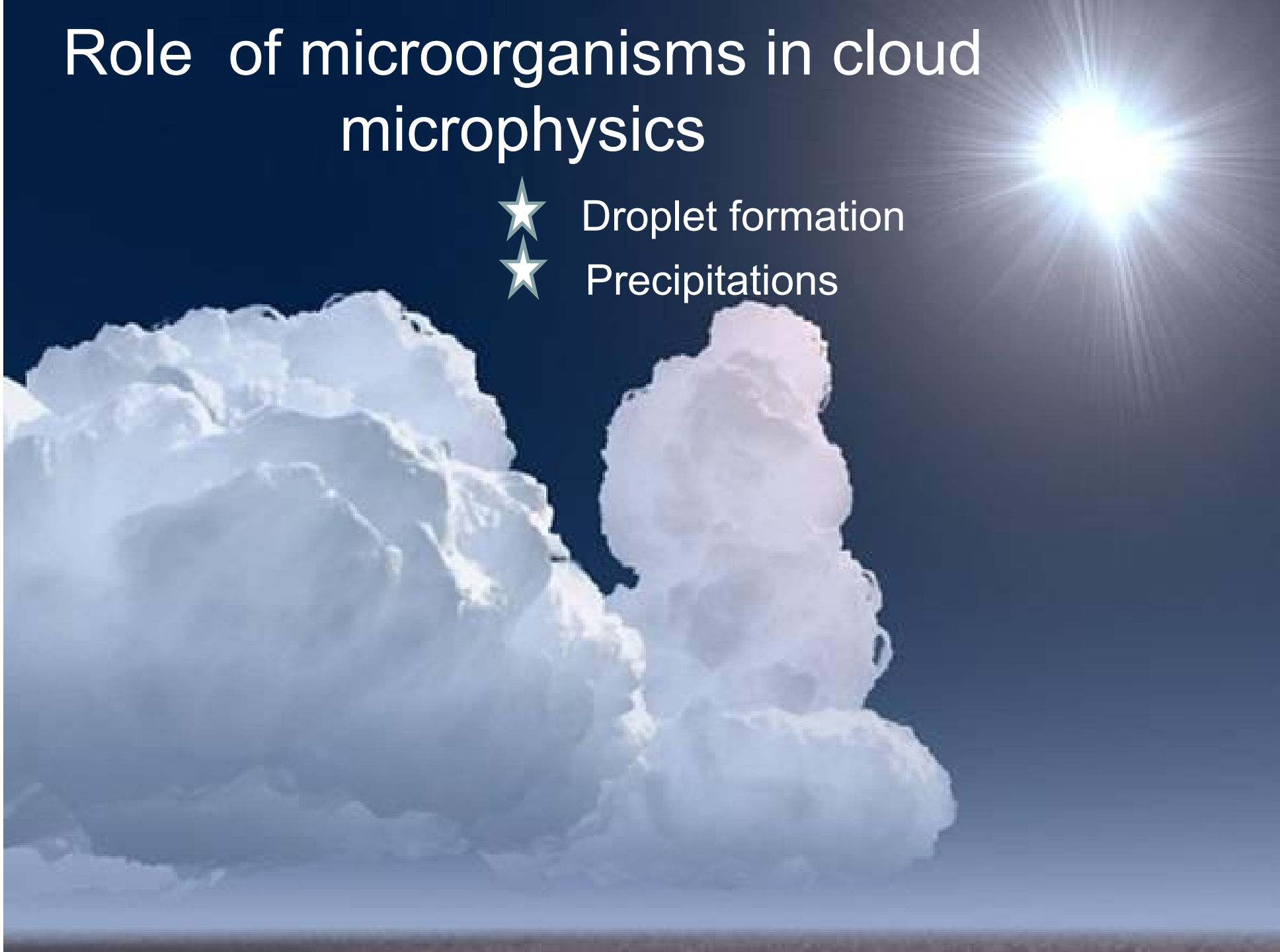


Acetic, Formic, Succinic, Lactic, Oxalic...

- ☐ Presence of active microorganisms
(10^5 cells/ml)

Role of microorganisms in cloud microphysics

- ★ Droplet formation
- ★ Precipitations



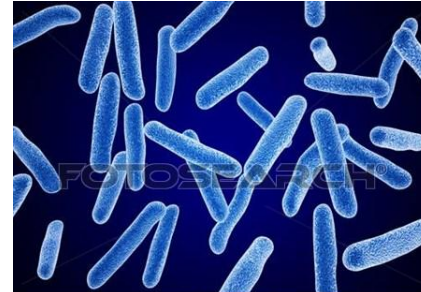
Role in the formation of cloud droplets



- **Microorganisms as Cloud Condensation Nuclei (CCN)**



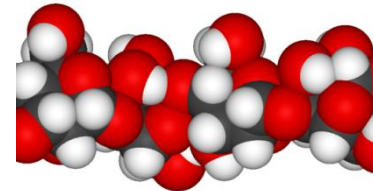
(Particules μM)



- **Microorganisms as sources of bioactive metabolites**

➡ Production of biosurfactants

➡ Production of EPS (Extracellular Polymeric Substances)



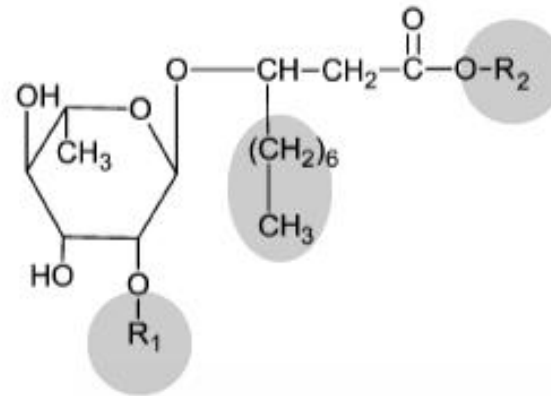
Cloud microorganisms: Role in the formation of cloud droplets



Production of biosurfactants

Glycolipids

ramnolipids,
sophorolipids,
trehalolipids



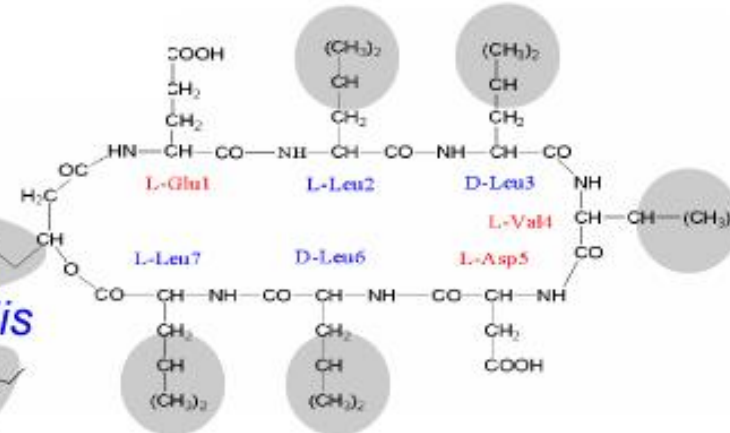
ramnolipid
from *Pseudomonas sp.*

Lipopeptides

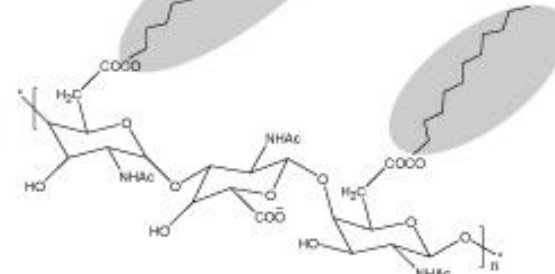
surfactin,
iturin,
fengycin

surfactin

from *Bacillus subtilis*



Polymeric surfactants

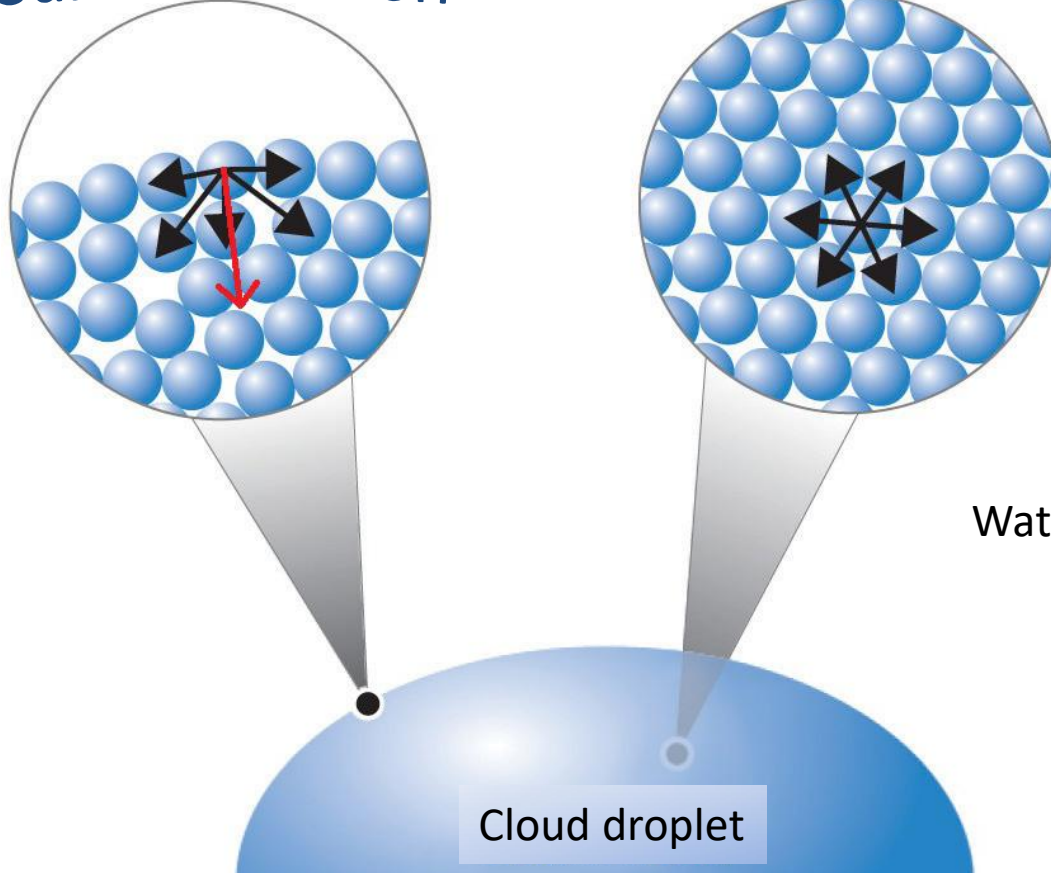


bioemulsan
from *Acinobacter sp.*

Surface tension

The cohesive forces among liquid molecules are responsible for the phenomenon of surface tension.
"Not so easy to form a droplet"

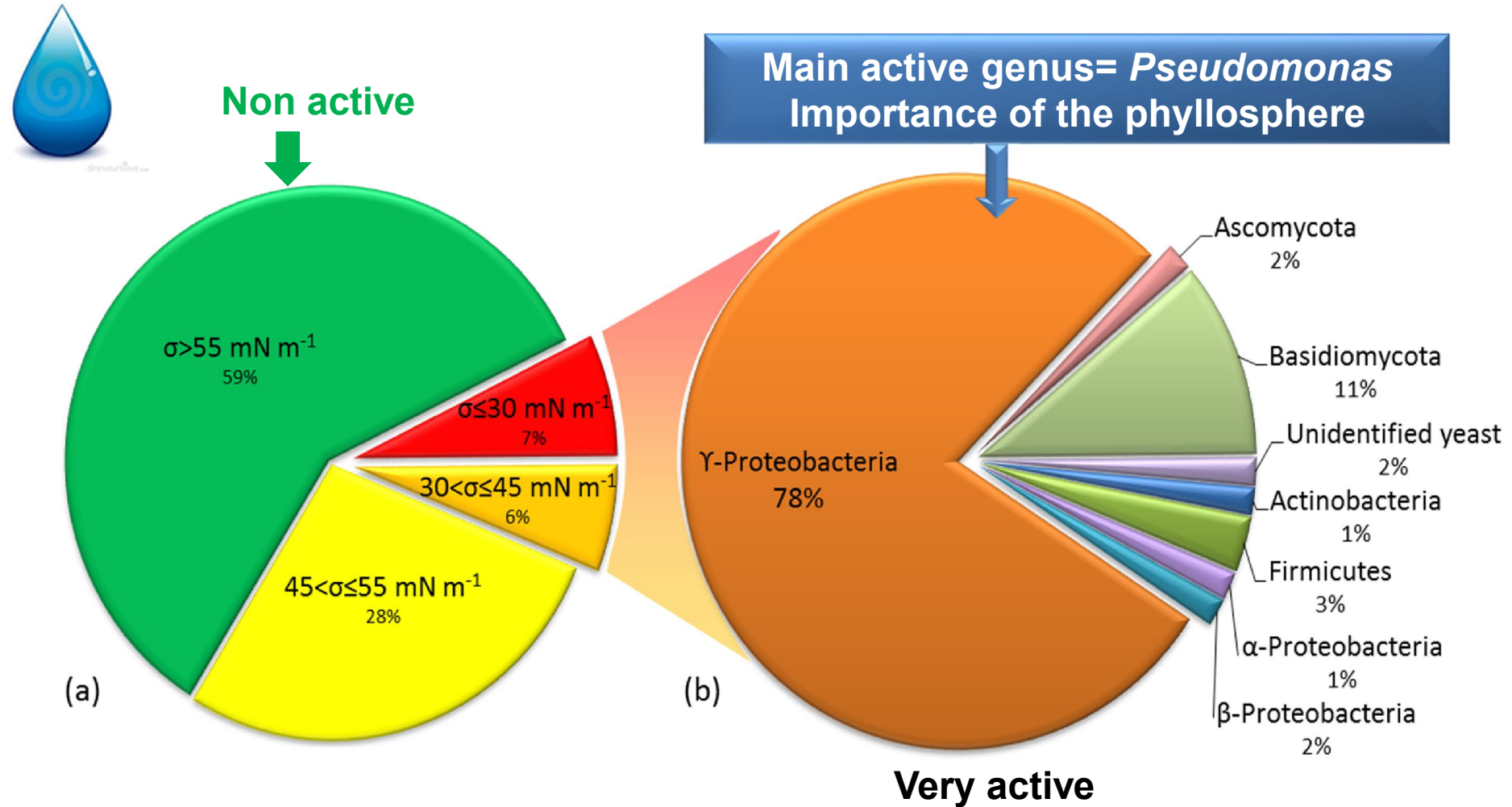
Surface tension



SURFACE TENSION

Water surface tension: 72 mN.m^{-1} at 25°C

Screening of 480 microbial strains isolated from clouds for the production of biosurfactants

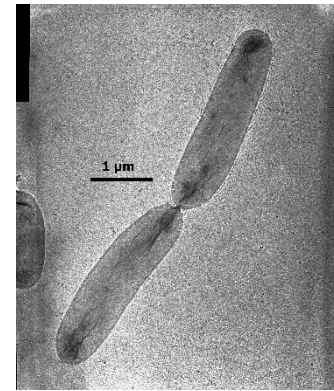


Cloud microorganisms: role in precipitations

Microorganismes as ice nuclei (IN)

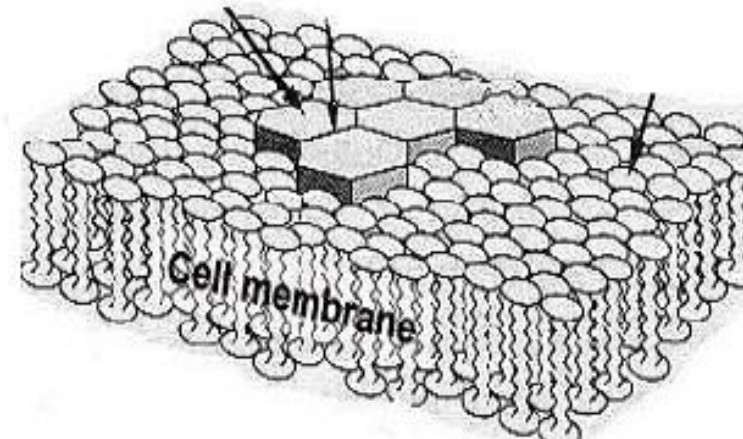
- Bacteria from the phyllosphere induce the formation of ice at $T^{\circ} > -10^{\circ}\text{C}$ (instead of -39°C):

Pseudomonas syringae, *P. fluorescens*, *P. viriflava*, *Pantoeas agglomerans* (*Erwinia herbicola*), *Xanthomonas campestris*,



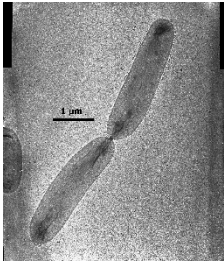
Plant pathogens

- Membrane protein: INP 150 -180 kD
- Snowmax® and other biological molecules



Cloud microorganisms: role in precipitations

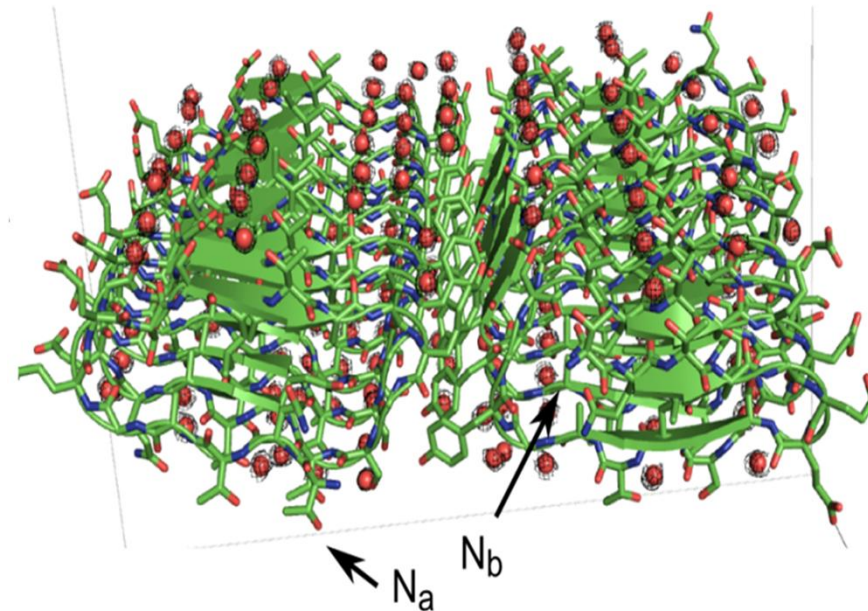
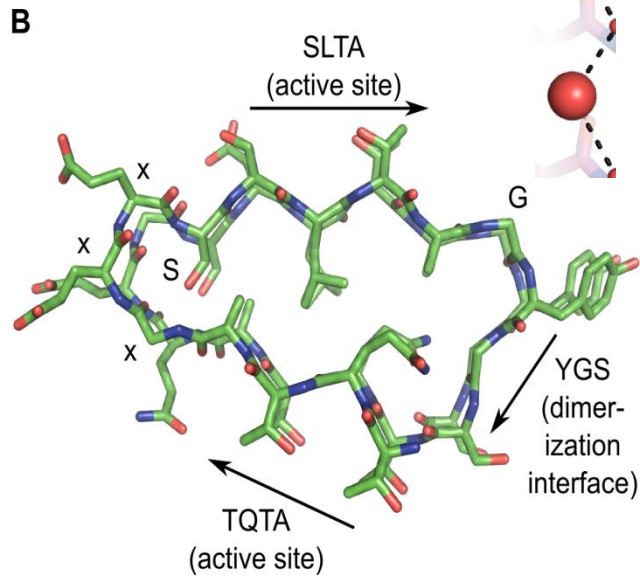
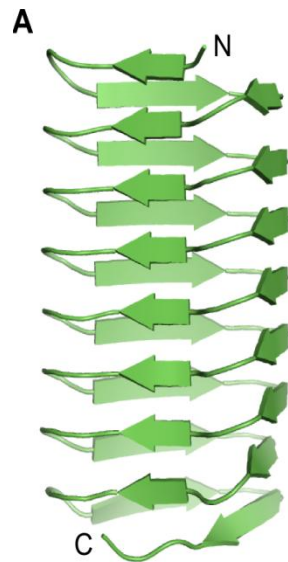
Microorganismes as ice nuclei (IN)



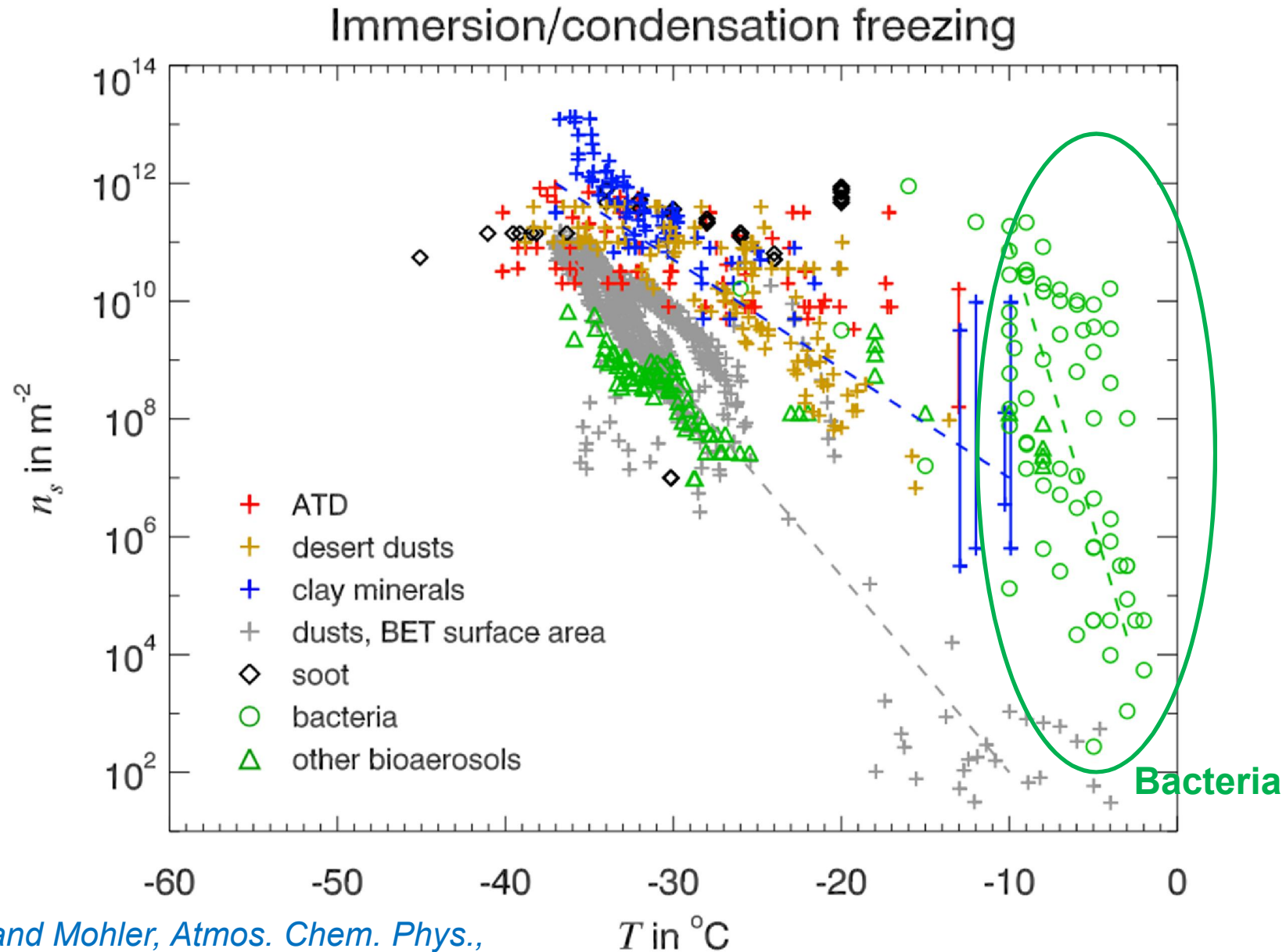
➤ Membrane protein: INP 150 -180 kD



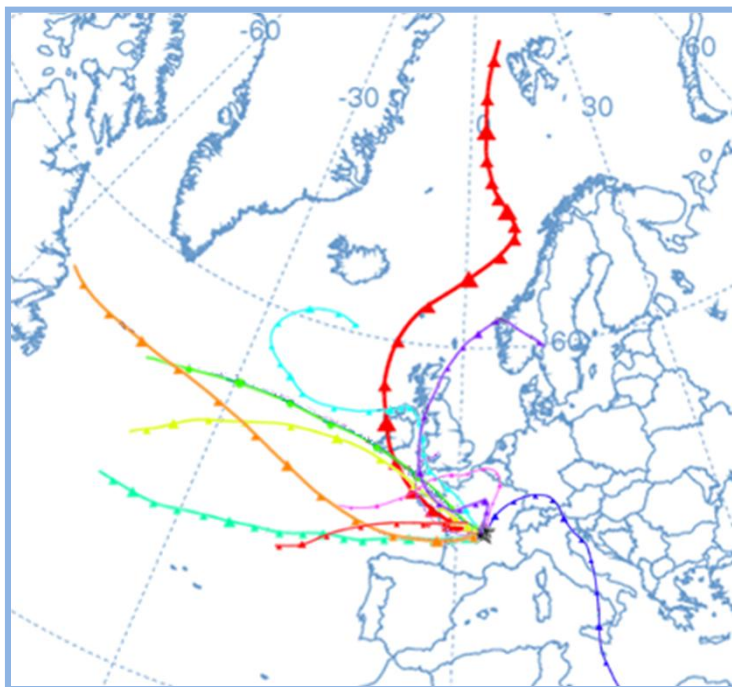
Water molecules



IN activity: biological vs non biological aerosols



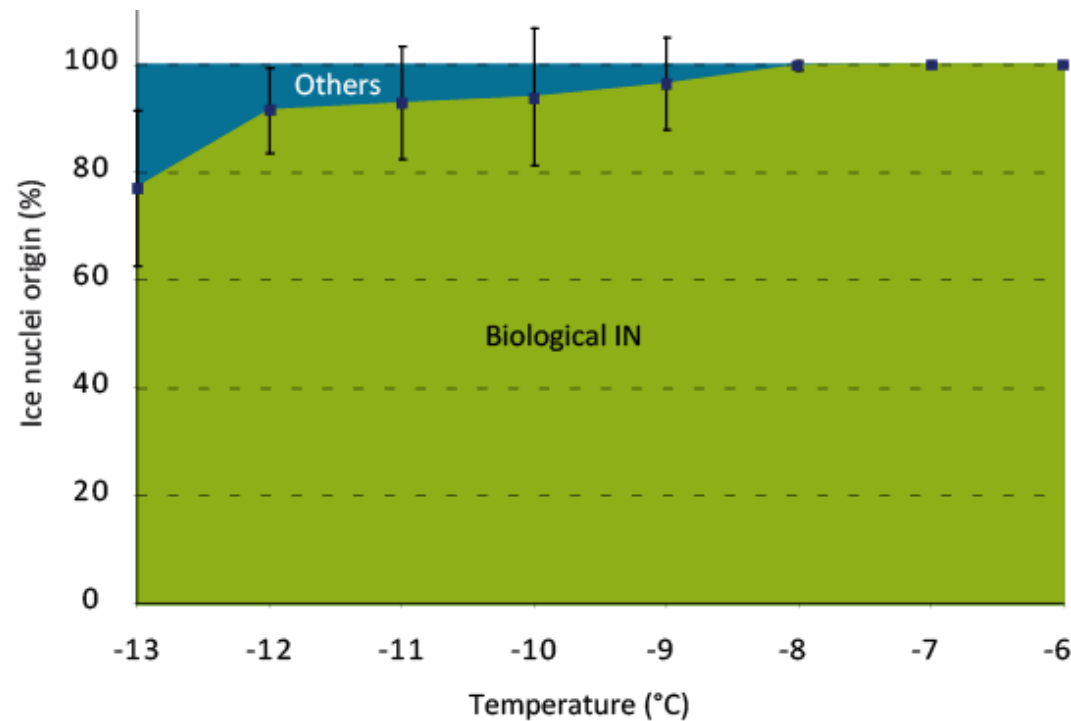
Biological contribution to Ice Nuclei in real clouds?



12 Cloud samples

Warmed at 90°C ➡ Biological IN

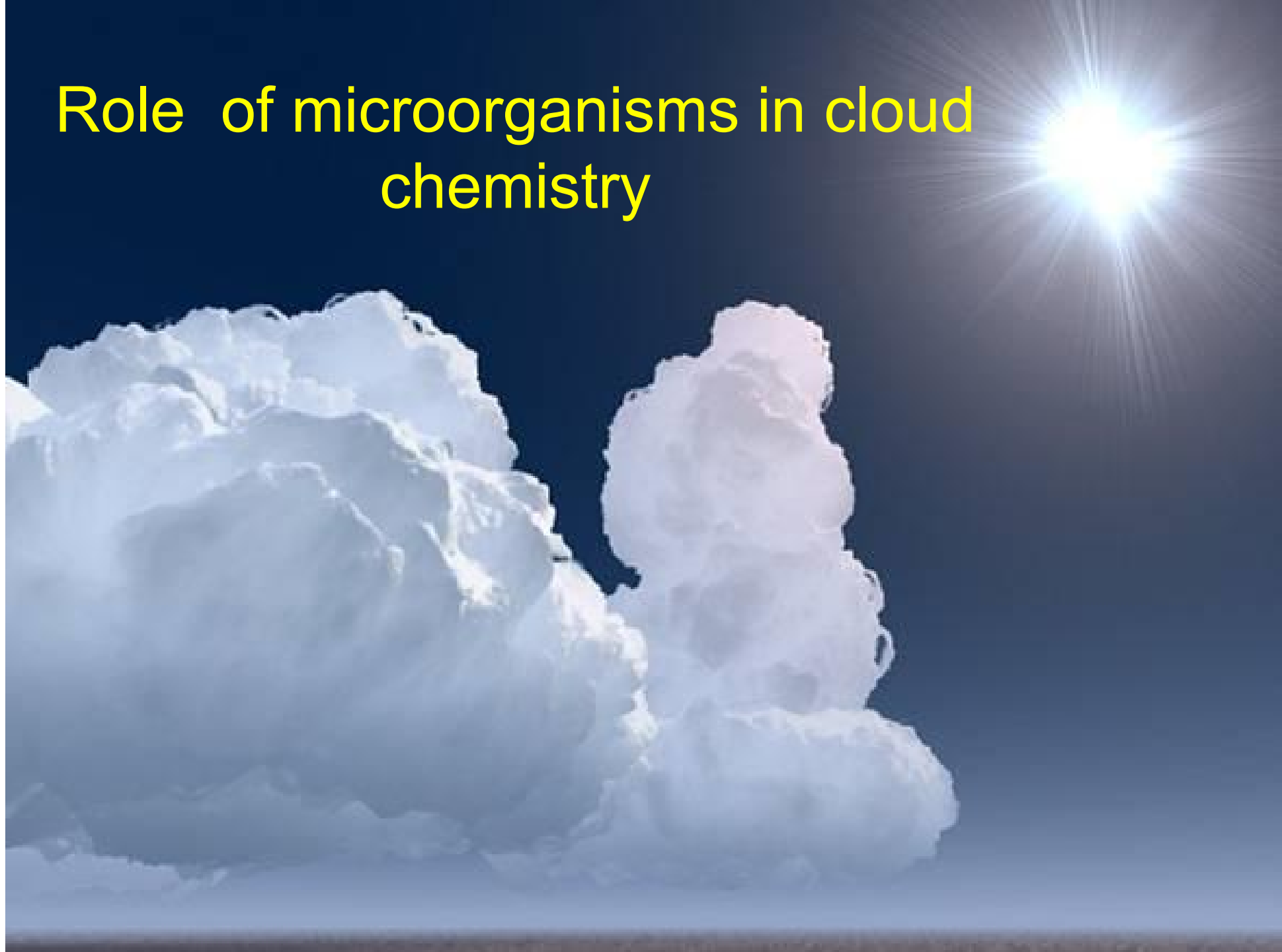
Non warmed ➡ total IN



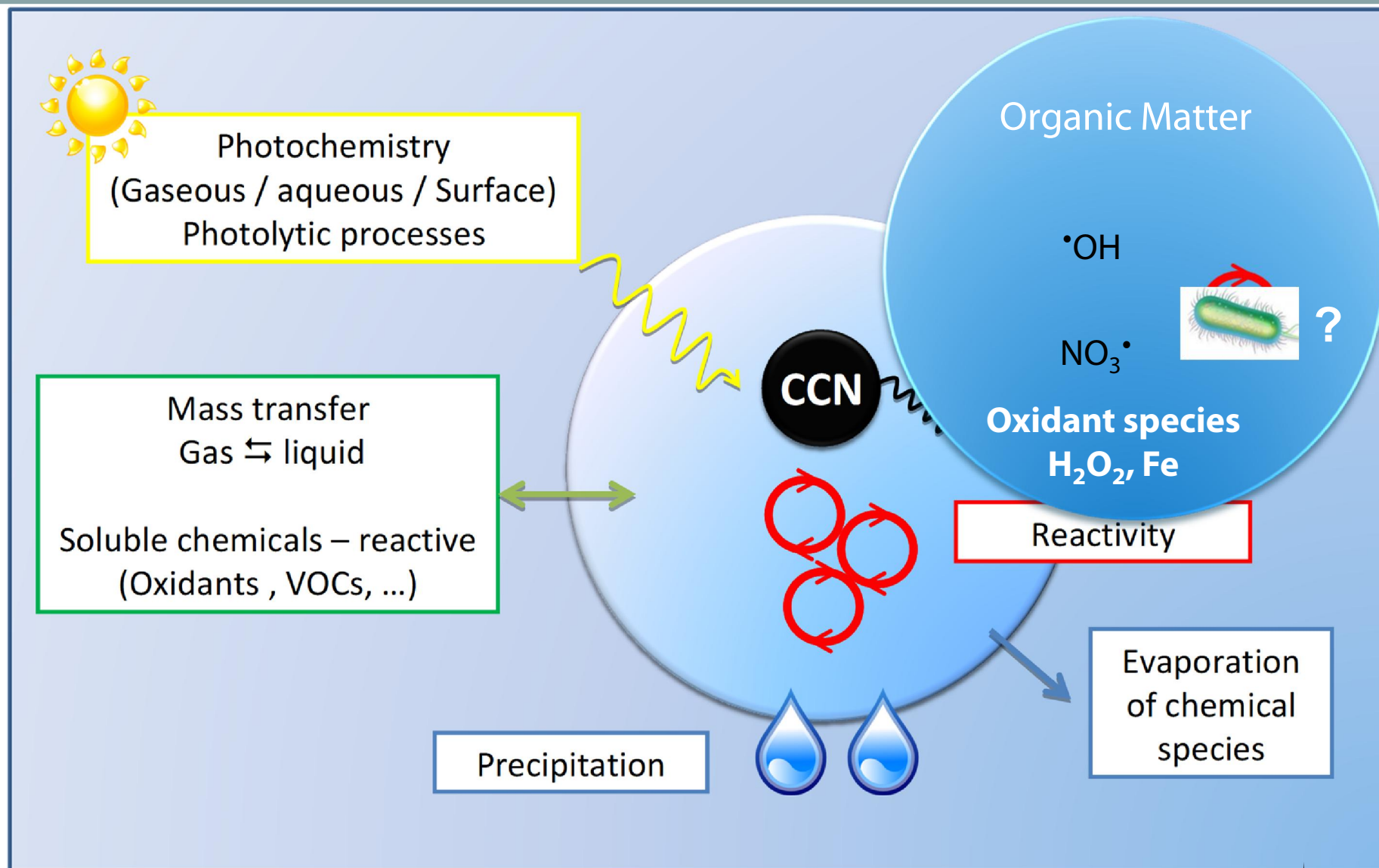
> 90% of IN are biological
($T > -12^{\circ}\text{C}$)

Same result in rain and snow

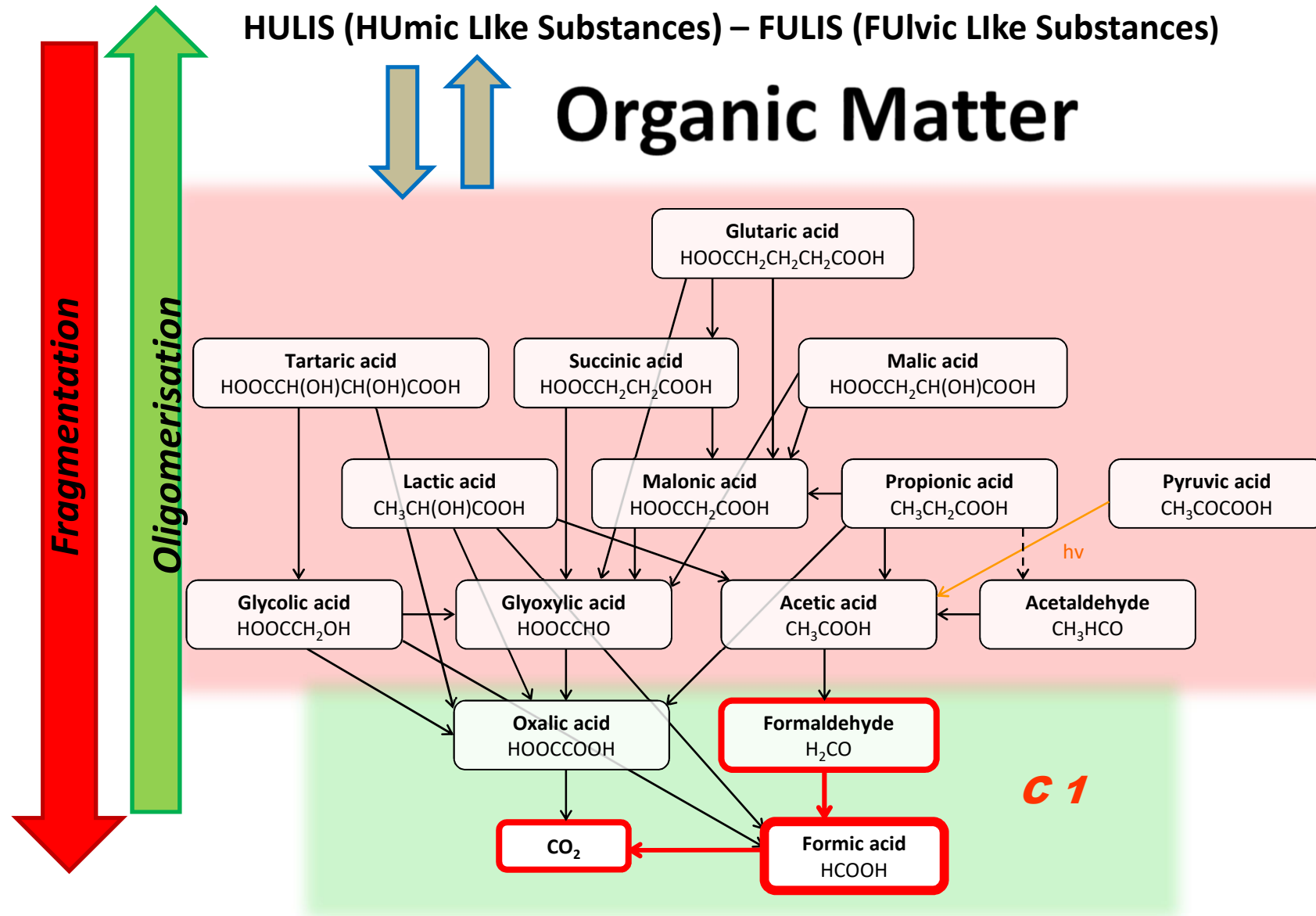
Role of microorganisms in cloud chemistry



Cloud chemistry

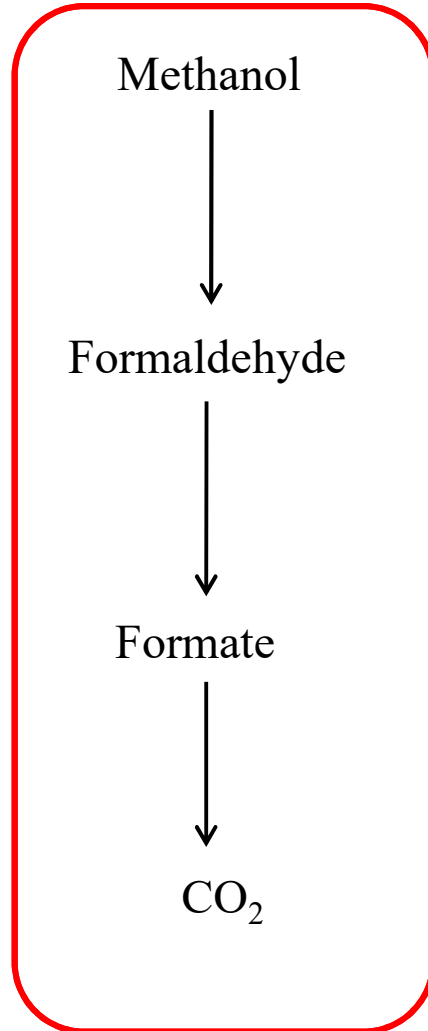


Example of radical chemistry in clouds

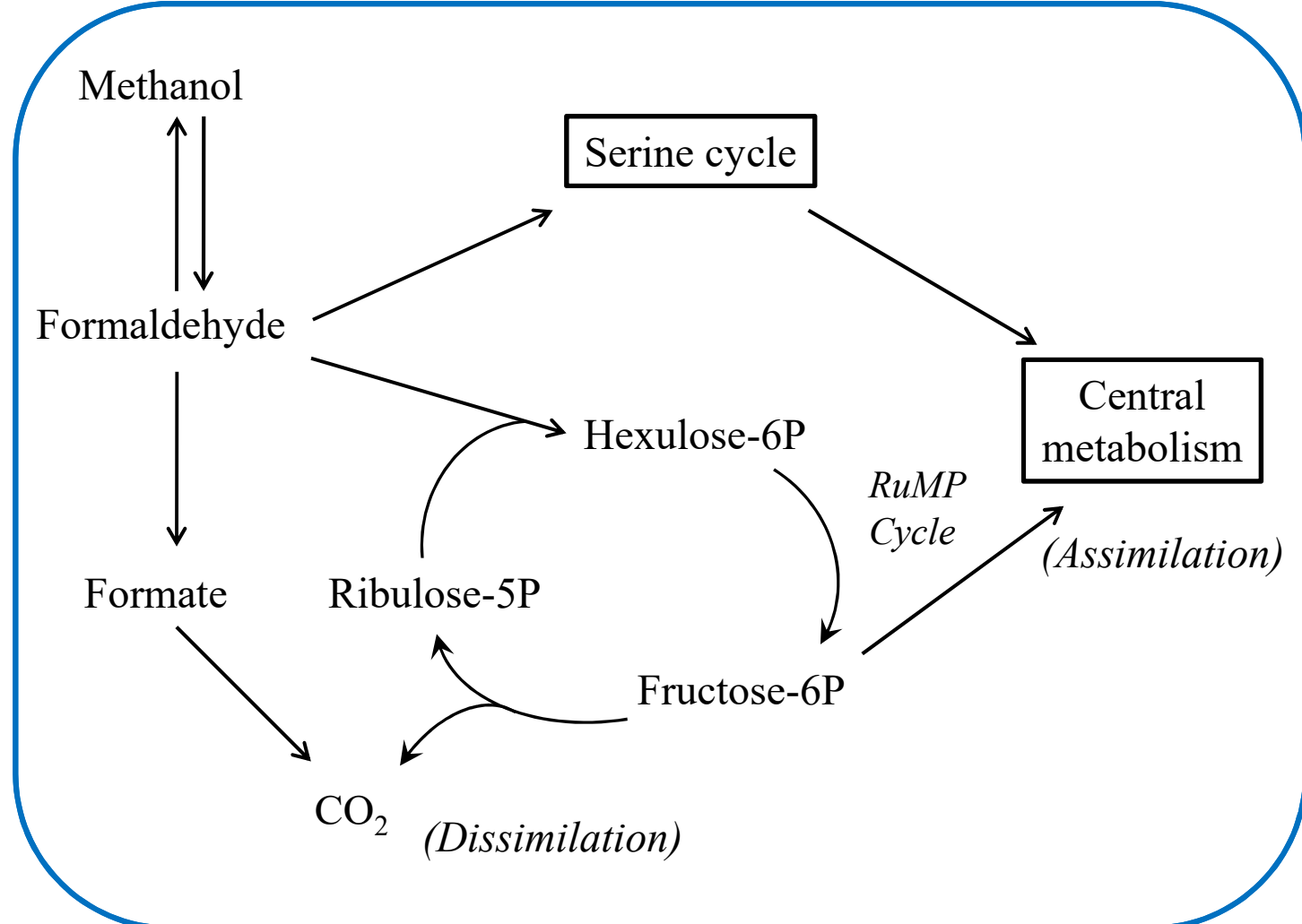


Transformation of C1 compounds in clouds

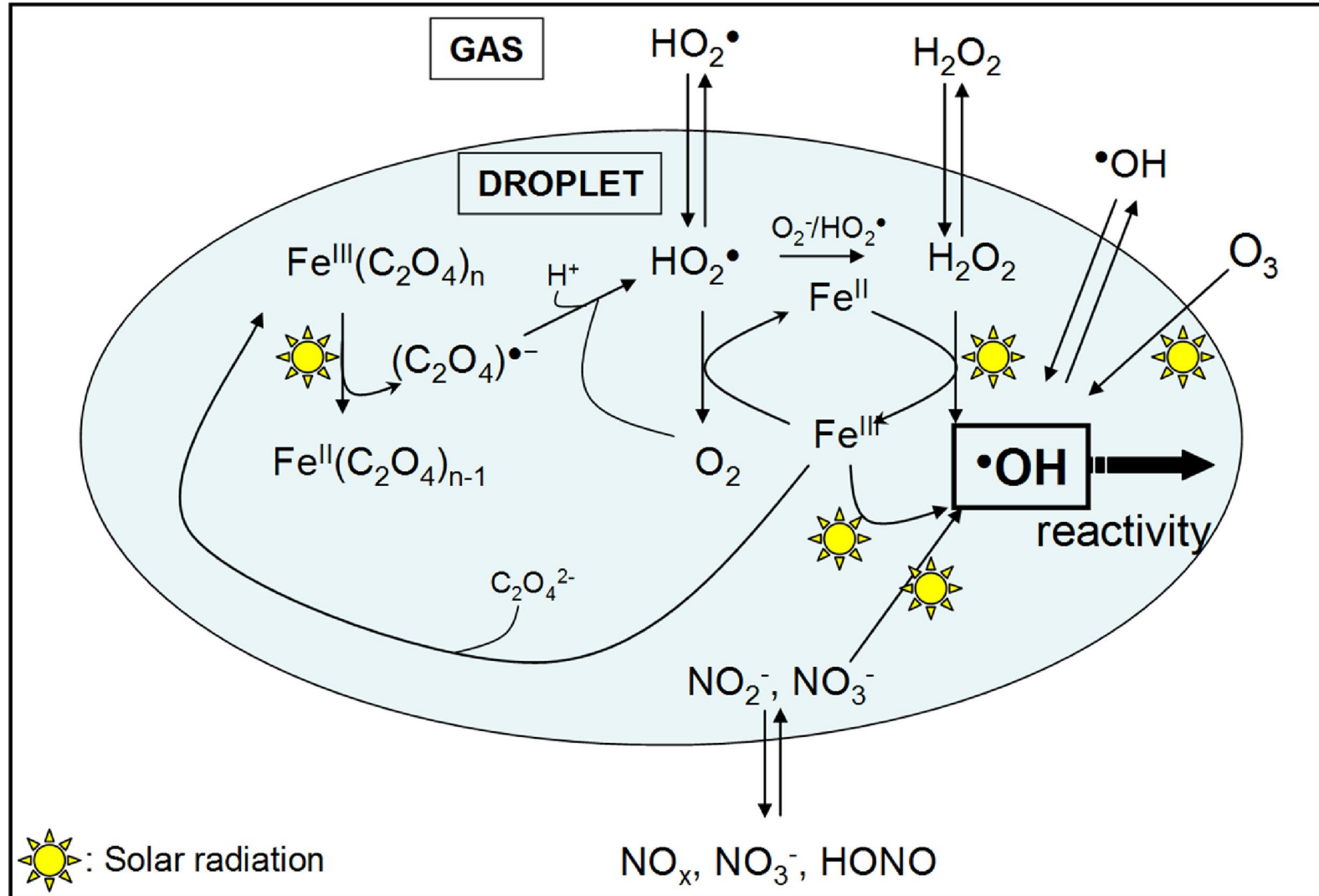
Photochemistry



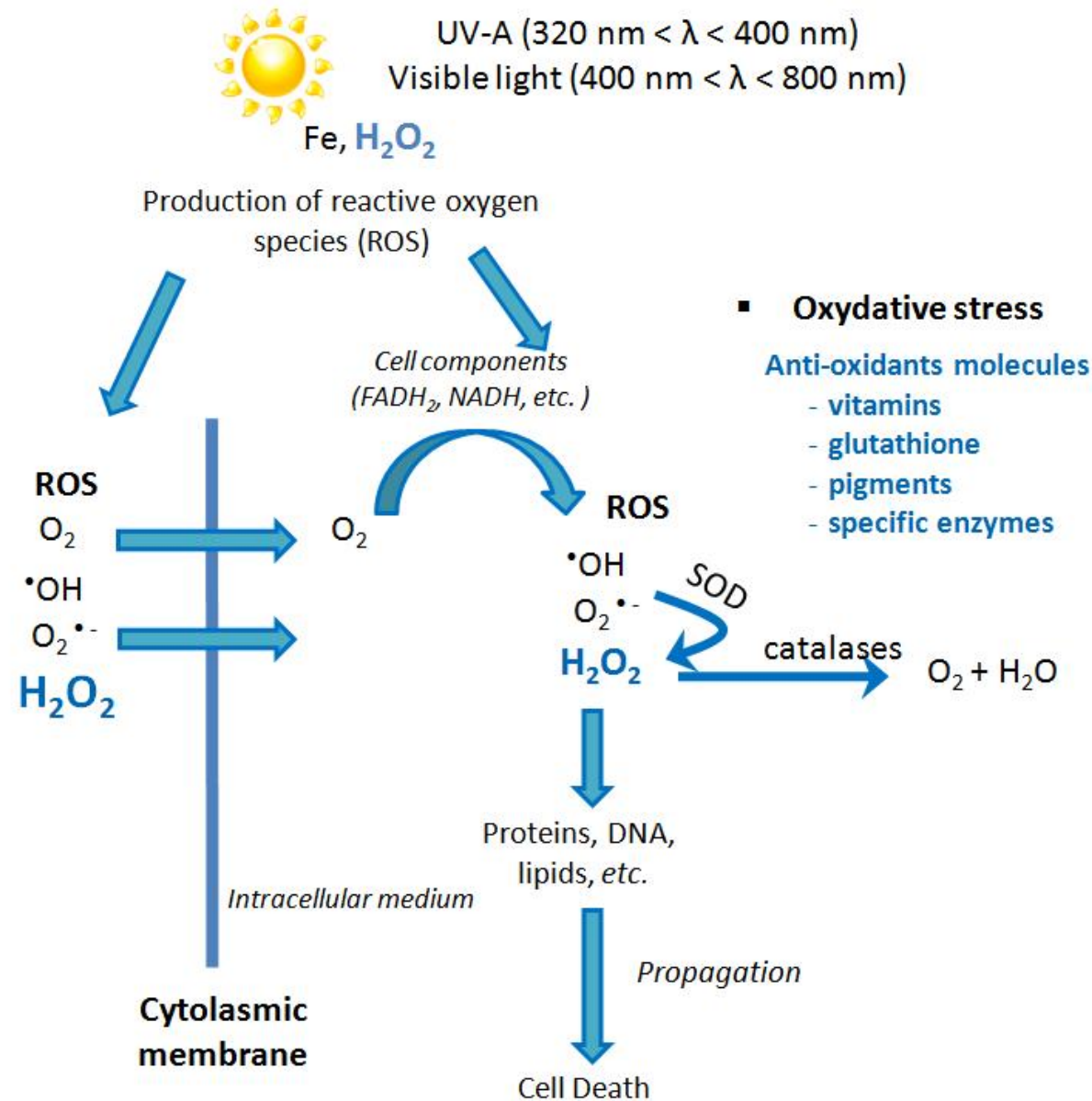
C1-metabolism



Production of $^{\circ}\text{OH}$ radical from H_2O_2 and iron sources

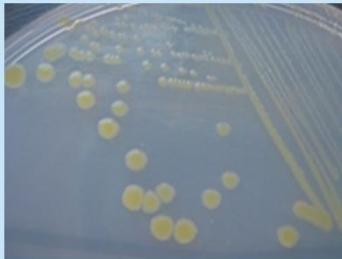


Oxidative stress metabolism



Microbial metabolism *versus* radical chemistry

- **Transformation of the organic matter**
(C1 compounds, organic acids, pollutants)
- **Interaction with the oxidants:**
Transformation of H_2O_2 ; Iron complexation



Cloud isolates
(artificial cloud medium)



Real cloud samples
(complex chemical mixture and biodiversity)

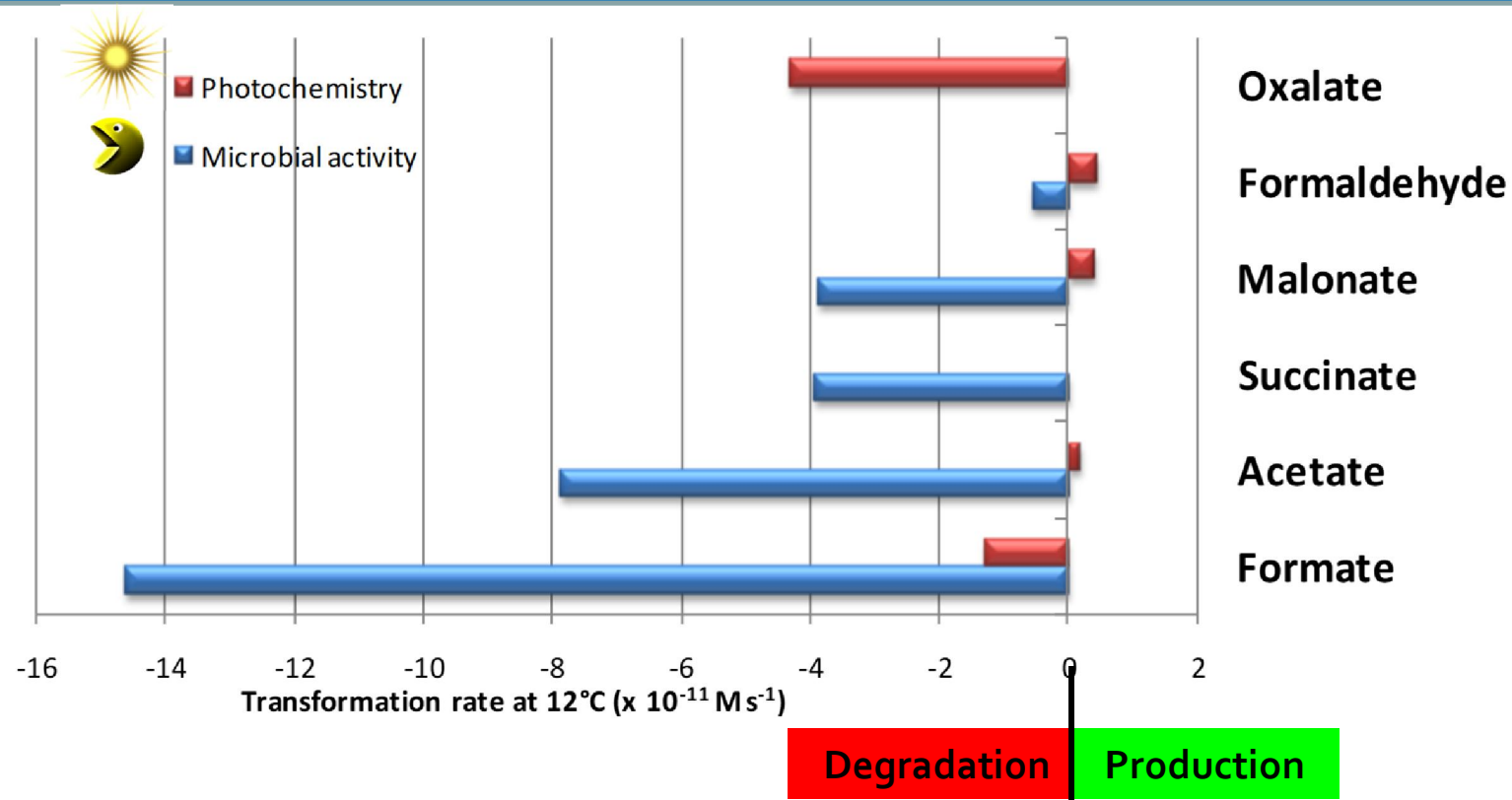


***In lab* experiments** (incubations in microcosms)



***In cloud* measurements** (metatranscriptomics)

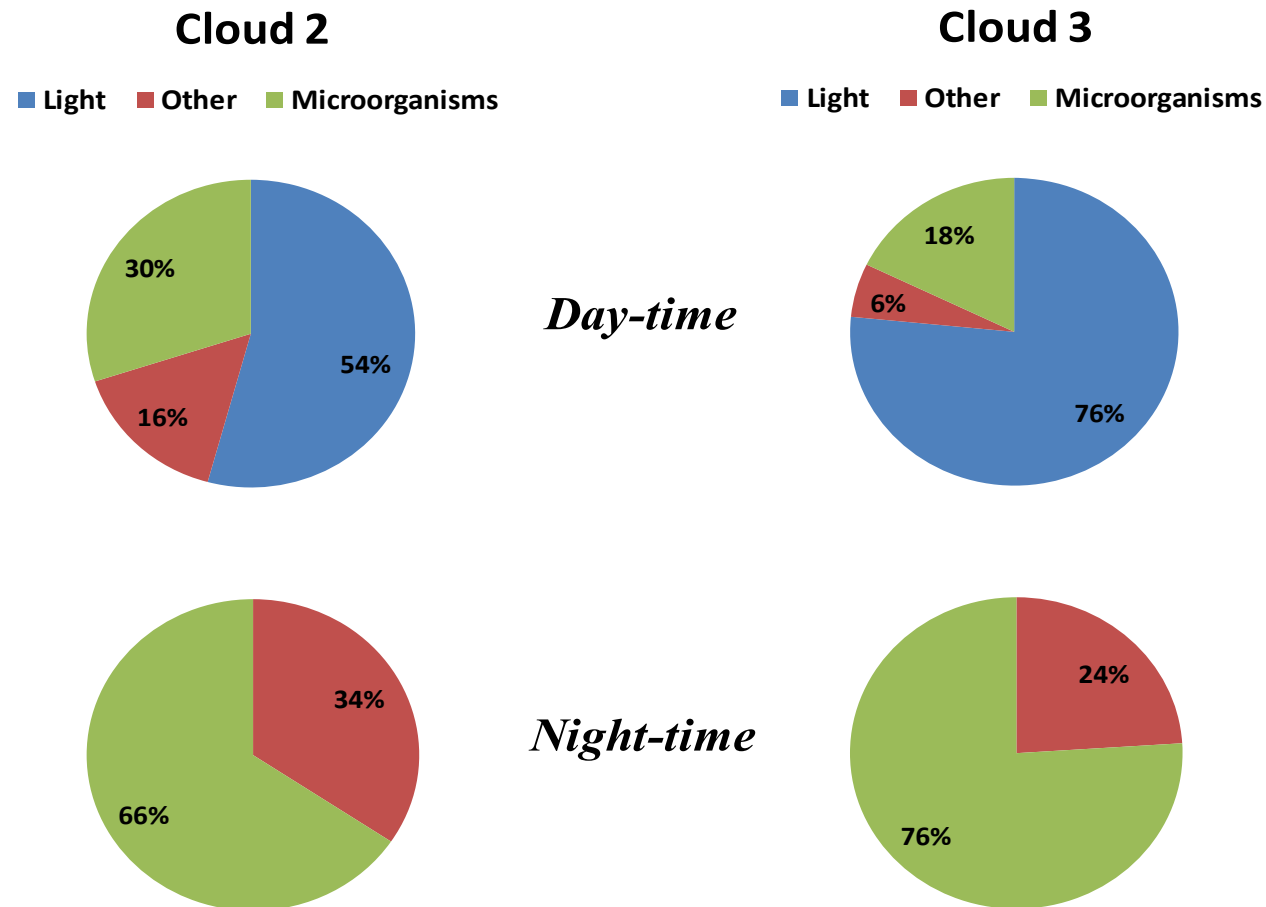
Carboxylic acids and C1 compounds: metabolism vs radical chemistry



Transformation rates are within the same range or order
(in lab experiments)

Vaïtilingom et al., *Proc. Nat. Acad. Sci.*, 2013

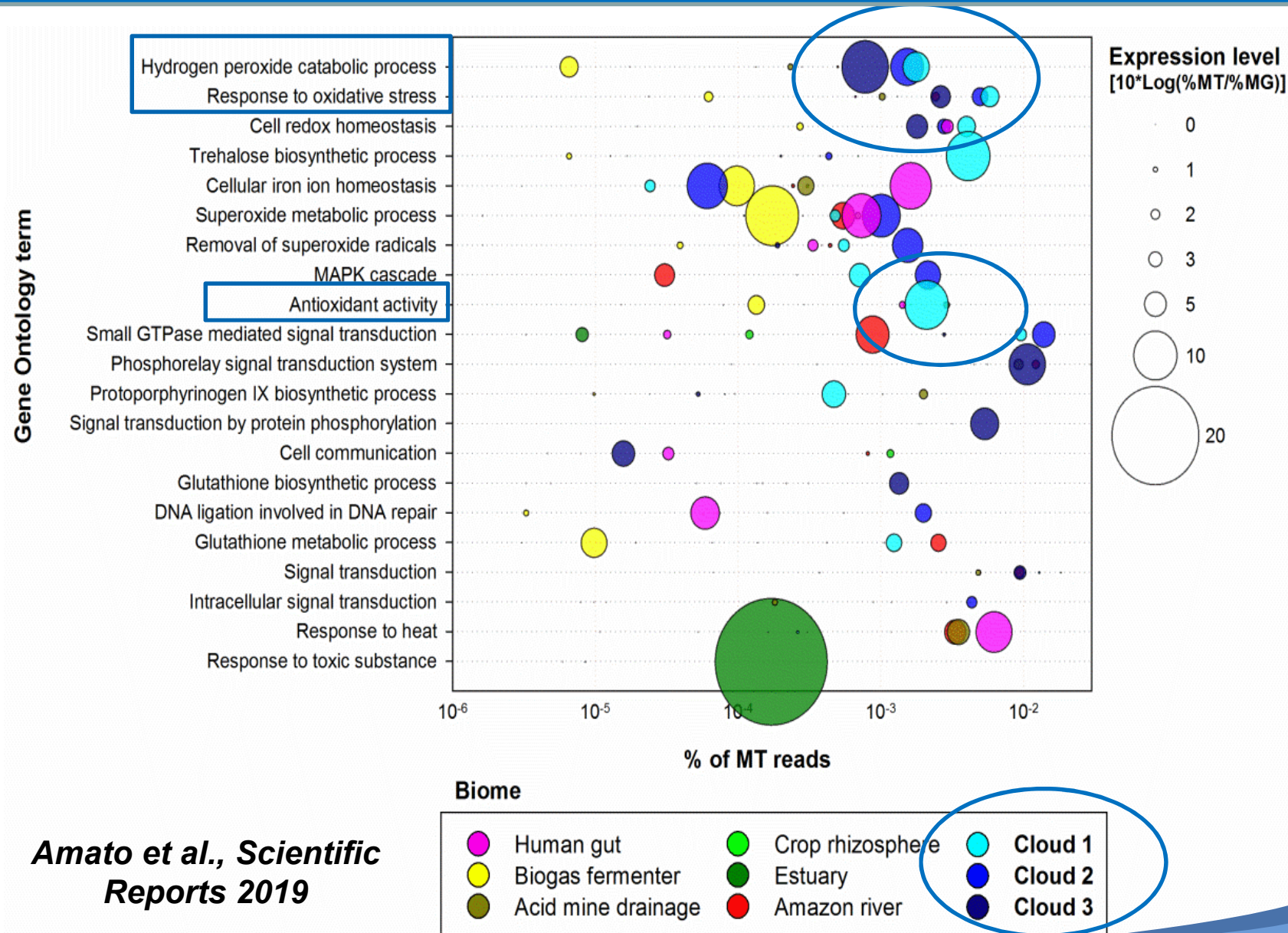
H₂O₂ degradation: metabolism vs radical chemistry



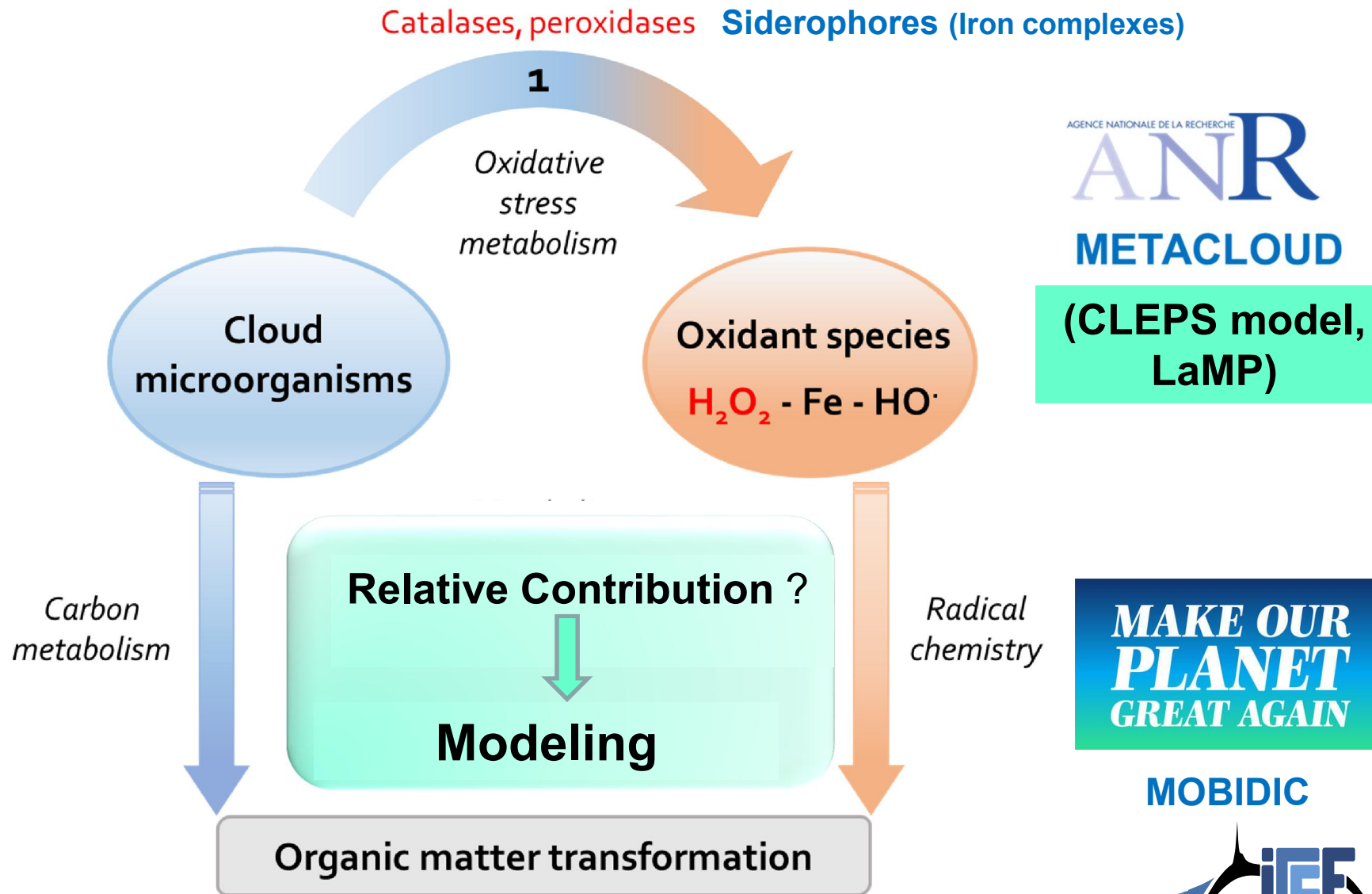
Transformation rates are within the same range of order
(in lab experiments)

Vaïtilingom et al., Proc. Nat. Acad. Sci, 2013

In cloud activity: H₂O₂ and anti-oxydants (Metatranscriptomics)



Consequence for atmospheric chemistry

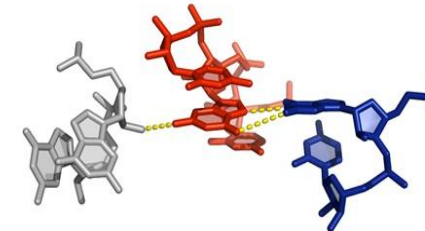


CONCLUSION



How microorganisms play a role in clouds??

- In the formation of cloud droplets
- In the formation of ice crystals (and precipitation)
- In cloud chemistry

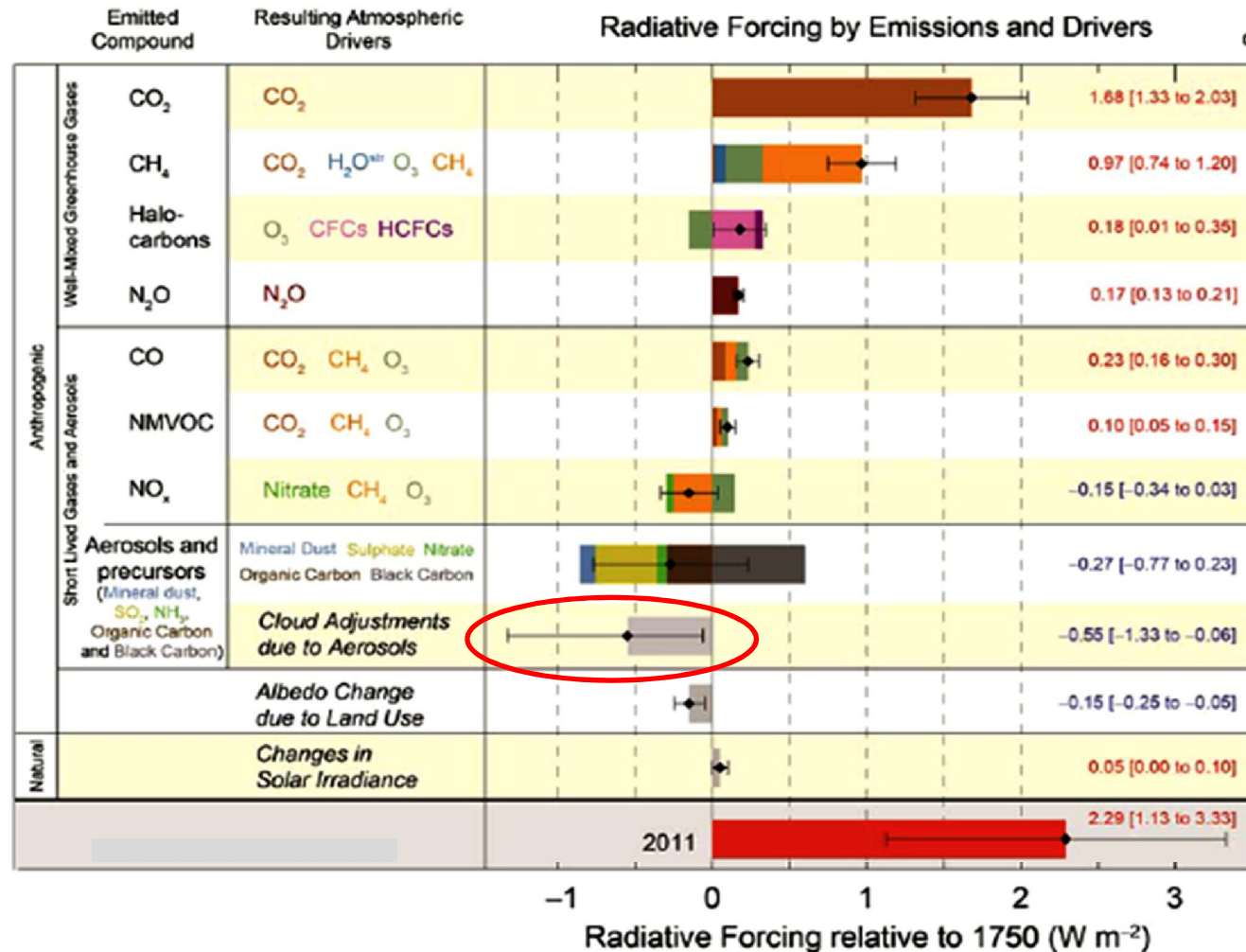


Potential impacts on

- Climate change
- Air pollution

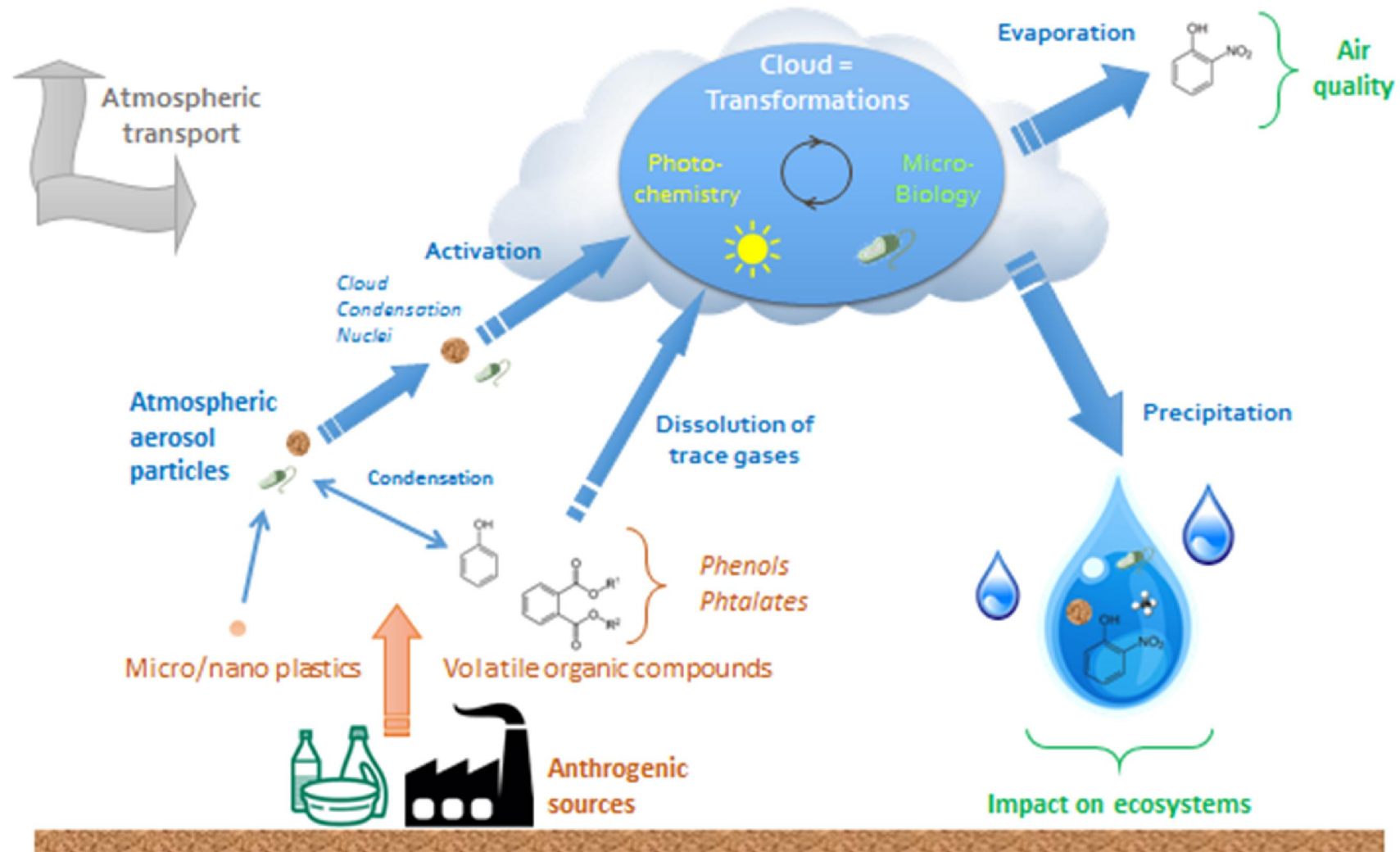
More data,
+Modeling
necessary

Importance of clouds on the Climate



Clouds = major cooling factor in the climate budget
But are the main uncertainty for the prediction of the climate change

Cycle of pollutants in the atmosphere



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MINISTÈRE
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DE L'ENSEIGNEMENT SUPÉRIEUR
ET DE LA RECHERCHE

Thank you for your attention...



I-SITE Clermont
Clermont Auvergne Project



Laboratoire de météorologie physique
LaMP

