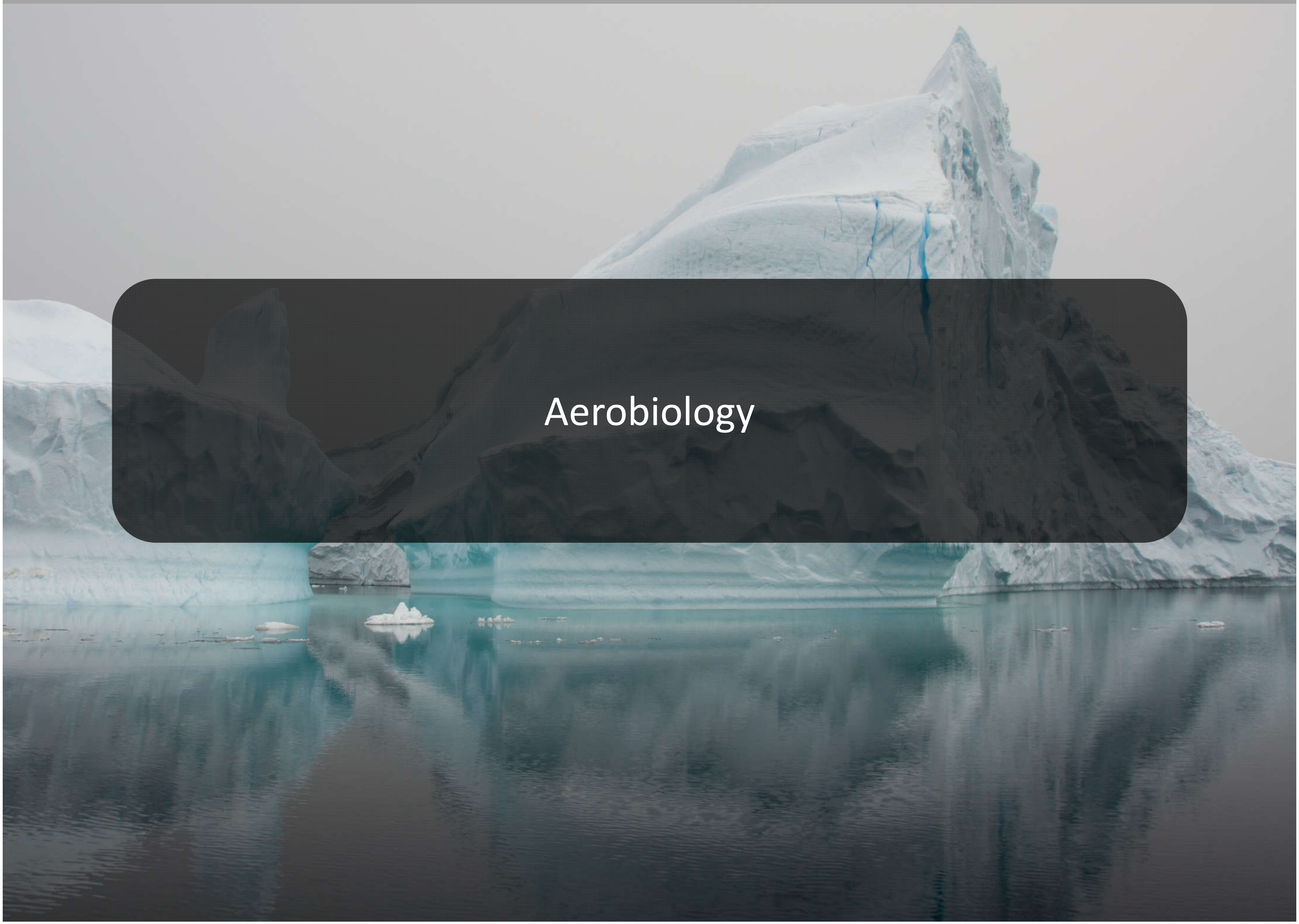


Aerobiology

Announcements

- Jeff gone Friday-Friday, guest lectures, will be on email

1. Rank the following from highest to lowest expected productivity: englacial, supraglacial, subglacial.

   Supraglacial, subglacial, englacial

2. List two major primary consumers in cryoconite holes.

   Tardigrades, rotifers, ice worms

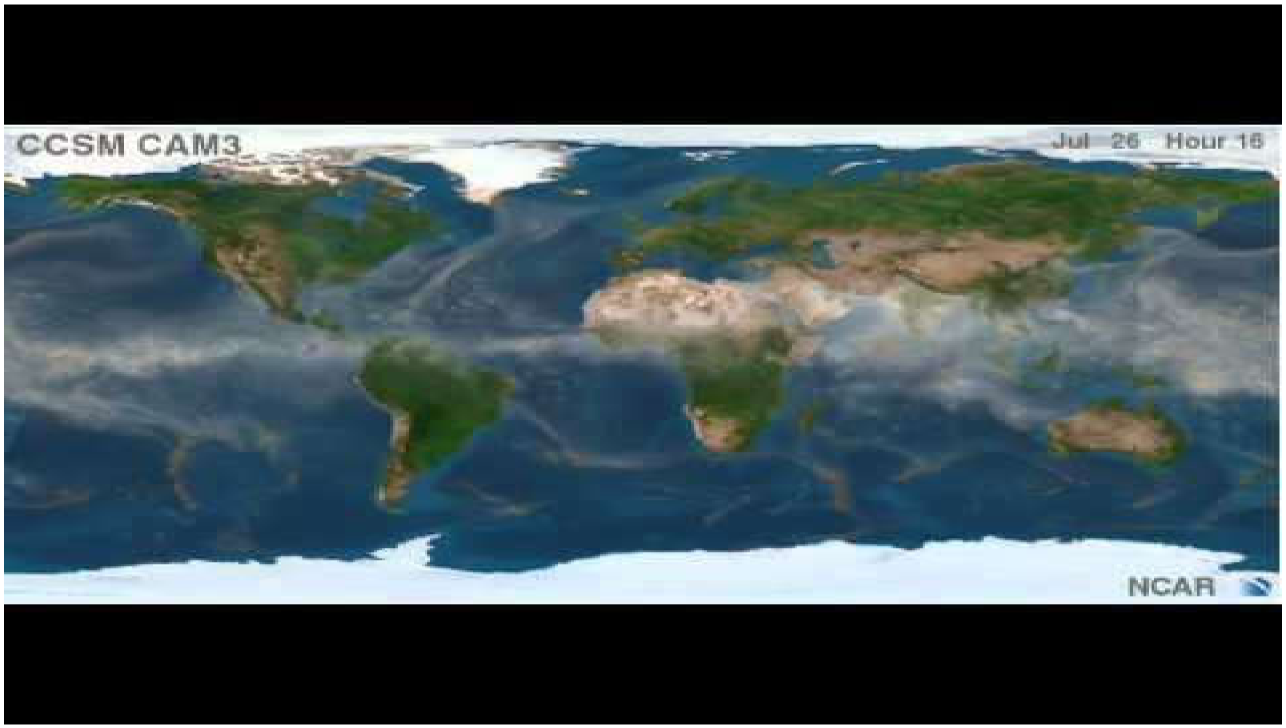
3. For a metabolism involving Fe(III) and organic sulfur, which is the terminal electron acceptor?

   Fe(III)

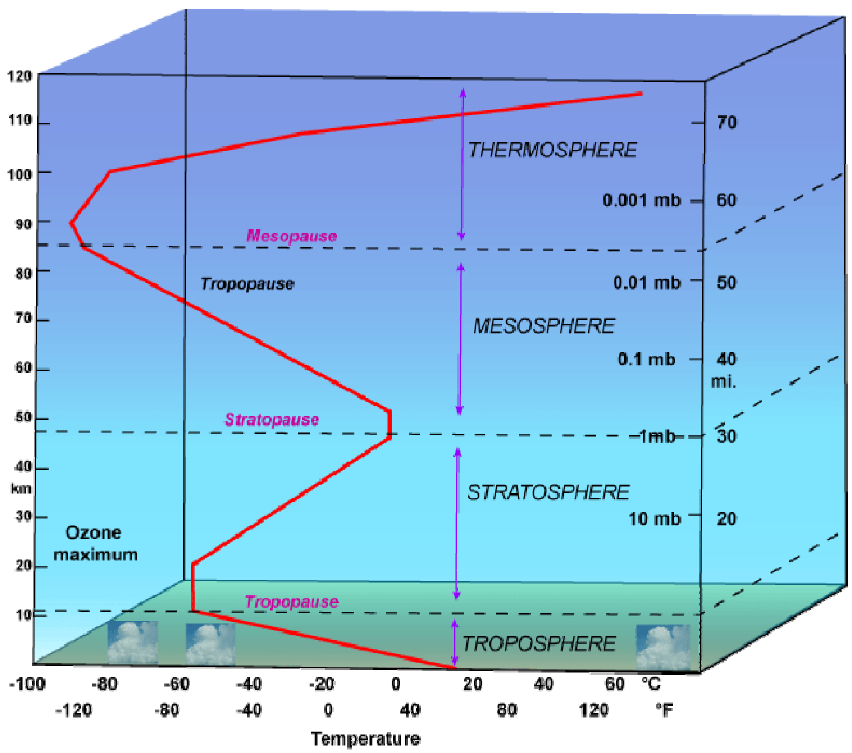
1. List two <u>moons</u> in our solar system for which there is strong evidence of liquid water.
2. What are the three basic requirements for life that define our search for extraterrestrial life?
3. What gas was produced during the Viking Lander life detection experiments?

https://www.nytimes.com/2018/05/05/science/nasa-mars-insight-launch.html?emc=edit_ca_20180507&nl=california-today&nlid=5695446020180507&te=1

- Aerobiology: The study of organisms in the atmosphere
- The atmosphere is plausibly one component of the cryosphere, but it also serves to connect other frozen environments



- Aerobiology: The study of organisms in the atmosphere
- The atmosphere is plausibly one component of the cryosphere, but it also serves to connect other frozen environments
- Only the lowest reaches of the atmosphere can serve as a microbial habitat
  - Troposphere, boundary layer



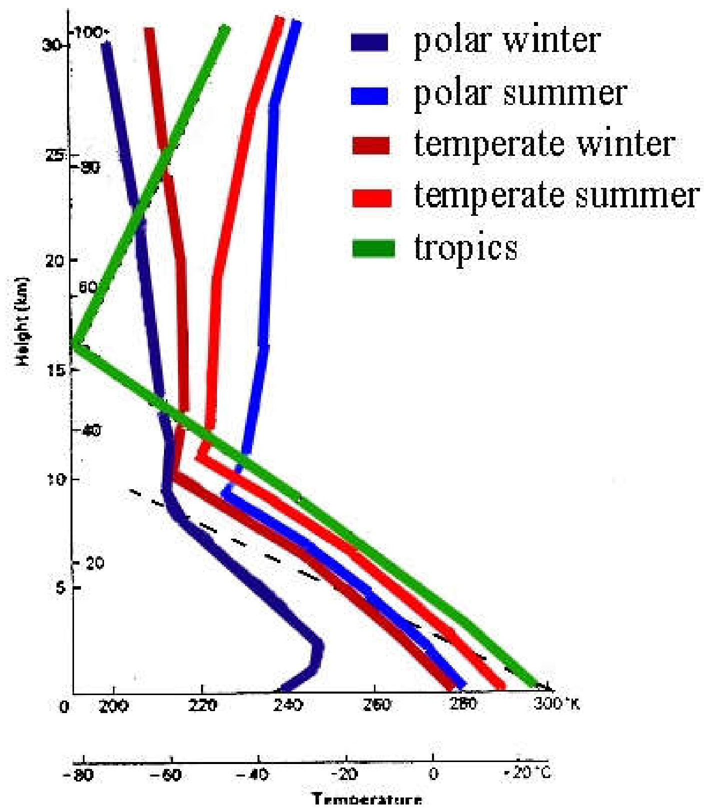


Table 1. Initial bio-physico-chemical characteristics for the three cloud events, sampled at the puy de Dôme station

Characteristic	Cloud 1	Cloud 2	Cloud 3
Air-mass origin	Northwestern	Southwestern	Northeastern
Air-mass type	Marine	Continental	Urban
Date of sampling	6/1/10 8:20 PM	6/8/10 12:05 PM	6/18/10 11:15 AM
Duration of sampling	6:30	11:20	19:45
Temperature	10 °C	13.5 °C	10 °C
pH	6.1	5.2	3.9
Conductivity ($\mu S \cdot cm^{-1}$)	3.5	37.6	78.6
TOC (DOC) ($mg \cdot L^{-1}$)	1.1 (1.1)	6.8 (6.7)	6.9 (6.8)
Compound	Concentration (μM)		
Acetate	4.5	25.4	23.2
Formate	4.9	42.7	33.2
Succinate	—	3.1	3.8
Oxalate	1.0	9.7	9.3
Malonate	—	3.1	3.5
Cl^-	3.0	7.7	11.3
NO_3^-	4.5	70.6	228.7
SO_4^{2-}	1.8	46.1	64.0
Na^+	2.2	10.1	8.8
NH_4^+	8.5	100.3	122.3
K^+	—	1.5	2.2
Mg^{2+}	1.0	2.1	2.7
Ca^{2+}	1.7	3.8	3.8
Fe (total)	0.9	1.1	1.3
Fe (II)	0.3	0.5	0.5
Formaldehyde	1.5	2.7	6.1
H_2O_2	3.6	33.4	57.7
ATP ($pmol \cdot mL^{-1}$)	0.8	2.3	2.1
ADP ($pmol \cdot mL^{-1}$)	1.1	0.7	1.1
ADP/ATP ratio	1.4	0.3	0.5
Total fungal spores and yeasts ($cells/mL^{-1}$)	9×10^3	3×10^3	3×10^3
Total bacteria ($cells/mL^{-1}$)	3×10^4	8×10^4	9×10^4

DOC, dissolved organic carbon; TOC, total organic carbon.

"Typical" warm cloud physicochemical environment (Vaïtilingom et al., 2012)

Ecosystem	Best estimate[a]	Low estimate[a]	High estimate
coastal[b]	7.6×10^4	2.3×10^4	1.3×10^5
crops[b]	1.1×10^5	4.1×10^4	1.7×10^5
deserts[c]		1.6×10^2	3.8×10^4
forests[d]	5.6×10^4	3.3×10^4	8.8×10^4
grasslands[b,e]	1.1×10^5	2.5×10^4	8.4×10^5
land ice[f]			1×10^4
seas[b,f,g]	1×10^4	1×10^1	8×10^4
shrubs[e,f]	3.5×10^5	1.2×10^4	8.4×10^5
tundra[d,f]	1.2×10^4		5.6×10^4
wetlands[h]	9×10^4	2×10^4	8×10^5
urban (curbside)[d]	6.5×10^5	4.4×10^5	9.2×10^5
urban park[b]	1.2×10^5	4.8×10^4	1.9×10^5

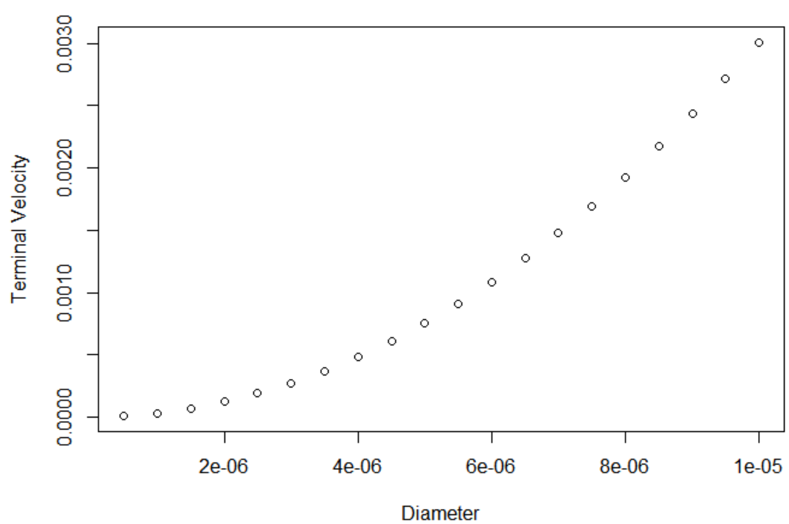
Typical abundances per m^{-3} (much higher in clouds and dust)
Bacteria at sea surface are ~10^{11} m^{-3}, or 6-7 orders of magnitude higher!
Bacteria in dust/clouds roughly 4-5 orders of magnitude higher

Burrows et al., 2012

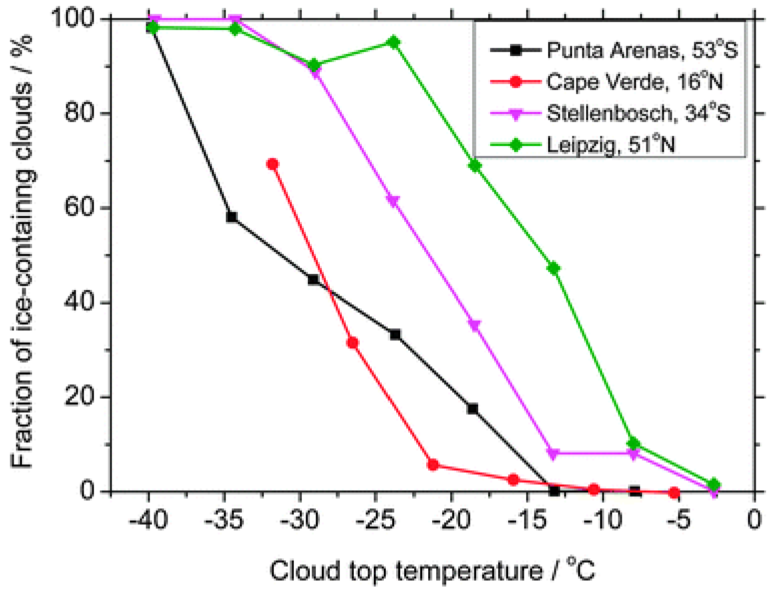
- There is, however, no evidence for a specialized atmospheric microbial community
- Q: Why aren't clouds green?
- A: Many reasons, but fundamentally large actively growing cells have no way to stay in clouds.
- Terminal velocity for particles of given size and density can be calculated from Stoke's Law:

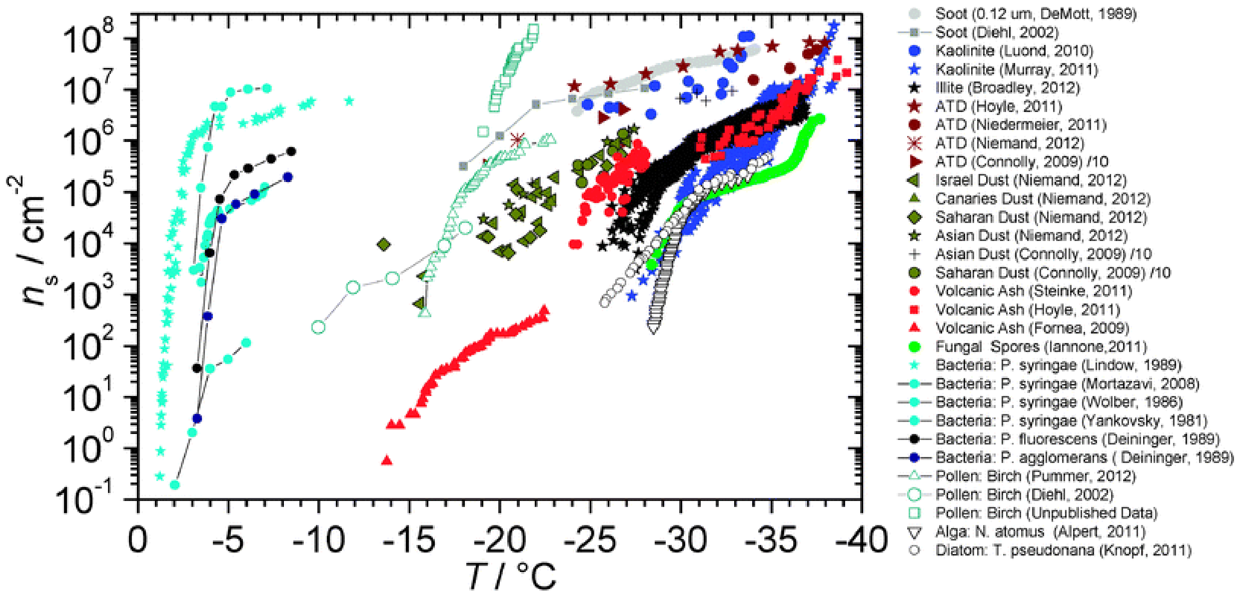
$$v_t = \frac{r_p {d_p}^2 g}{18u}$$

v_t = terminal velocity
r_p = density of particle
d_p = diameter of particle
$g = 9.807\ m\ s^{-2}$



- Larger particles are also much more efficient nucleators of water droplets and ice, thus they are prone to precipitating out

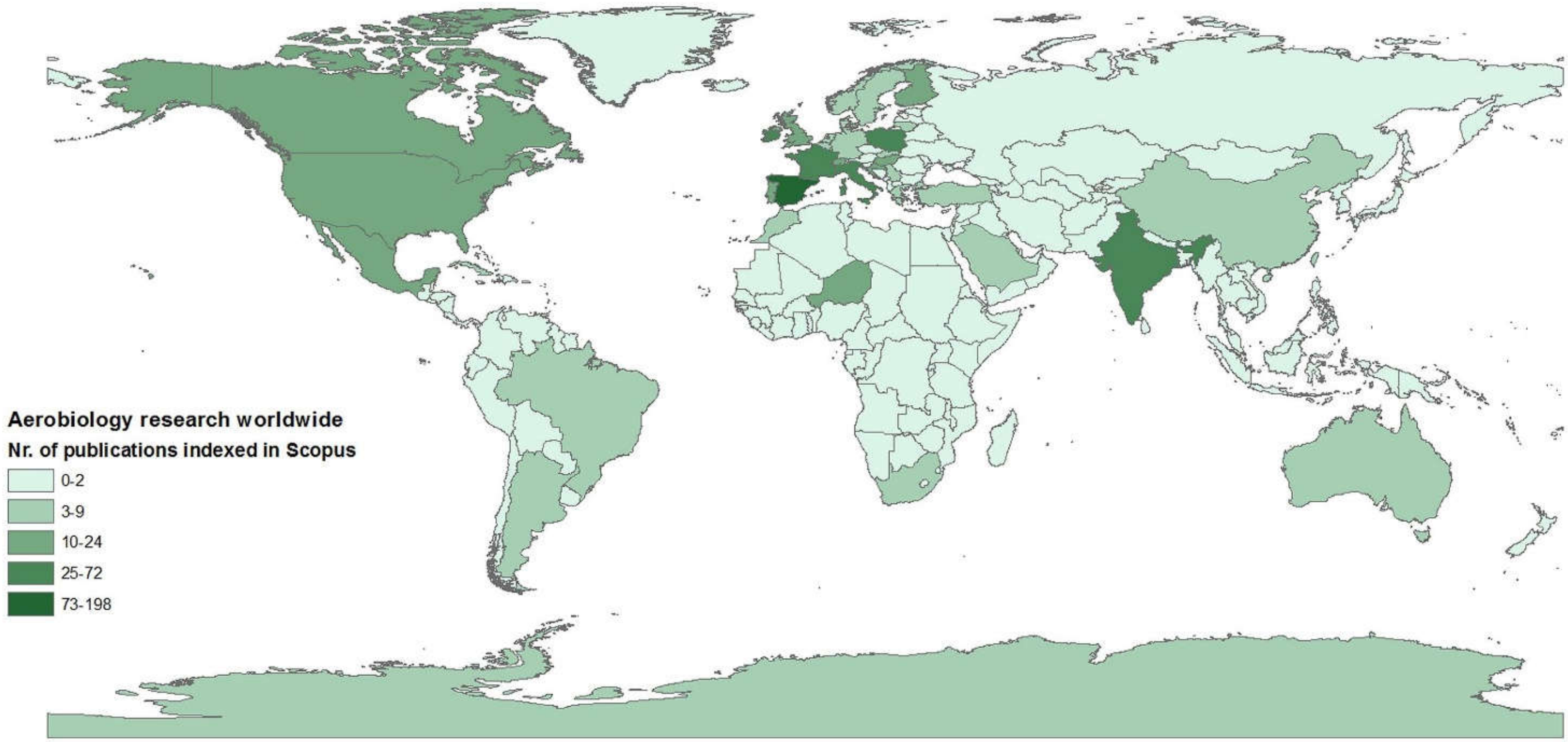




Murray et al., 2012

- Very few studies of organisms in the atmosphere, and most have focused on urban air
- Most of these papers are not very good! Basically, we know very little about microbial dynamics in the atmosphere

Pierce et al., 2016



- We don't recognize an active microbial "ecosystem" within the atmosphere, we are most concerned with the atmosphere as:
  - A transport mechanism between different components of the cryosphere
  - A case study for low temperature activity

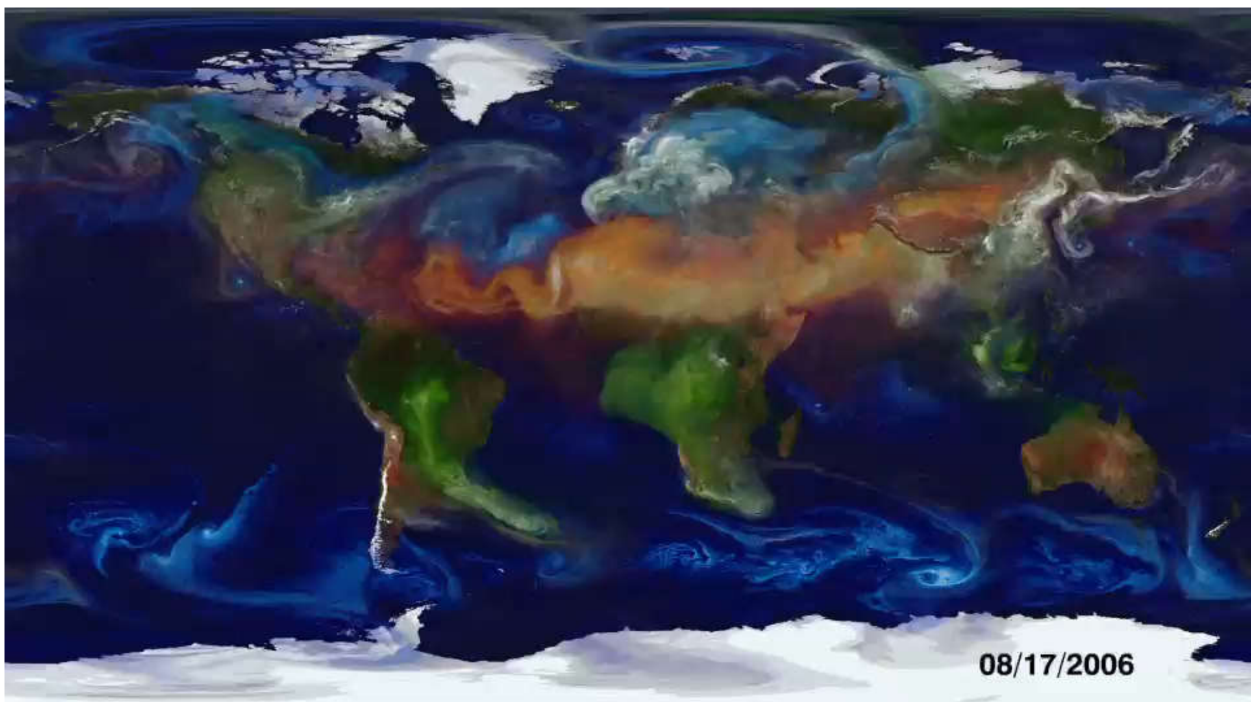
AEM
Journals.ASM.org

Intercontinental Dispersal of Bacteria and Archaea by Transpacific Winds

David J. Smith,[a] Hilkka J. Timonen,[b] Daniel A. Jaffe,[b,c] Dale W. Griffin,[d] Michele N. Birmele,[e] Kevin D. Perry,[f] Peter D. Ward,[a] Michael S. Roberts[e]

University of Washington, Department of Biology, Seattle, Washington, USA[a]; University of Washington, Science and Technology Program, Bothell, Washington, USA[b]; University of Washington, Department of Atmospheric Sciences, Seattle, Washington, USA[c]; U.S. Geological Survey, Tallahassee, Florida, USA[d]; NASA Kennedy Space Center, ESC Team QNA, Kennedy Space Center, Florida, USA[e]; University of Utah, Department of Atmospheric Sciences, Salt Lake City, Utah, USA[f]

Red: dust
Salt: blue
Sulfate: white
Black and organic carbon: green

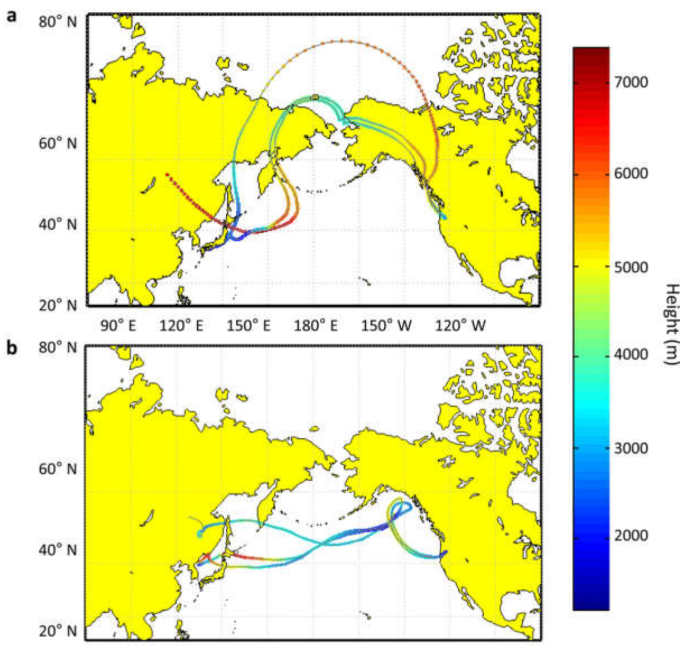


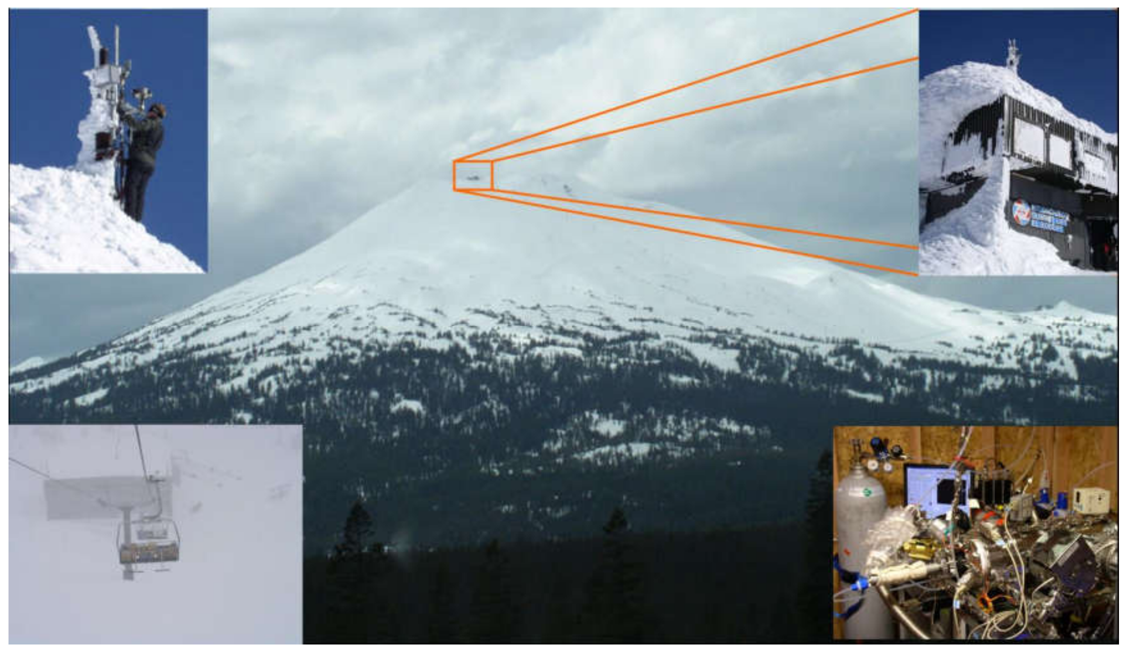
AEM
Journals.ASM.org

Intercontinental Dispersal of Bacteria and Archaea by Transpacific Winds

David J. Smith,[a] Hilkka J. Timonen,[b] Daniel A. Jaffe,[b,c] Dale W. Griffin,[d] Michele N. Birmele,[e] Kevin D. Perry,[f] Peter D. Ward,[a] Michael S. Roberts[e]

University of Washington, Department of Biology, Seattle, Washington, USA[a]; University of Washington, Science and Technology Program, Bothell, Washington, USA[b]; University of Washington, Department of Atmospheric Sciences, Seattle, Washington, USA[c]; U.S. Geological Survey, Tallahassee, Florida, USA[d]; NASA Kennedy Space Center, ESC Team QNA, Kennedy Space Center, Florida, USA[e]; University of Utah, Department of Atmospheric Sciences, Salt Lake City, Utah, USA[f]





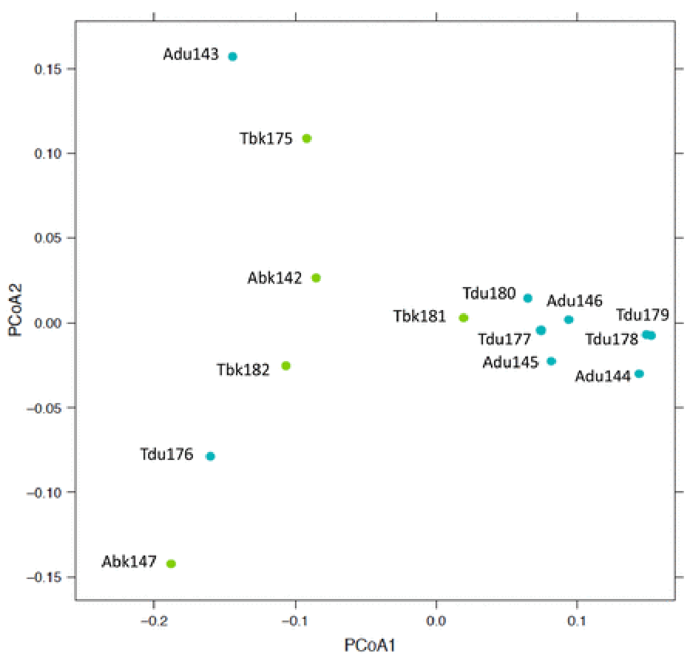
Mt. Bachelor Observatory, 2.8 km above sea level

- Atmospheric dust plumes are distinct from background air

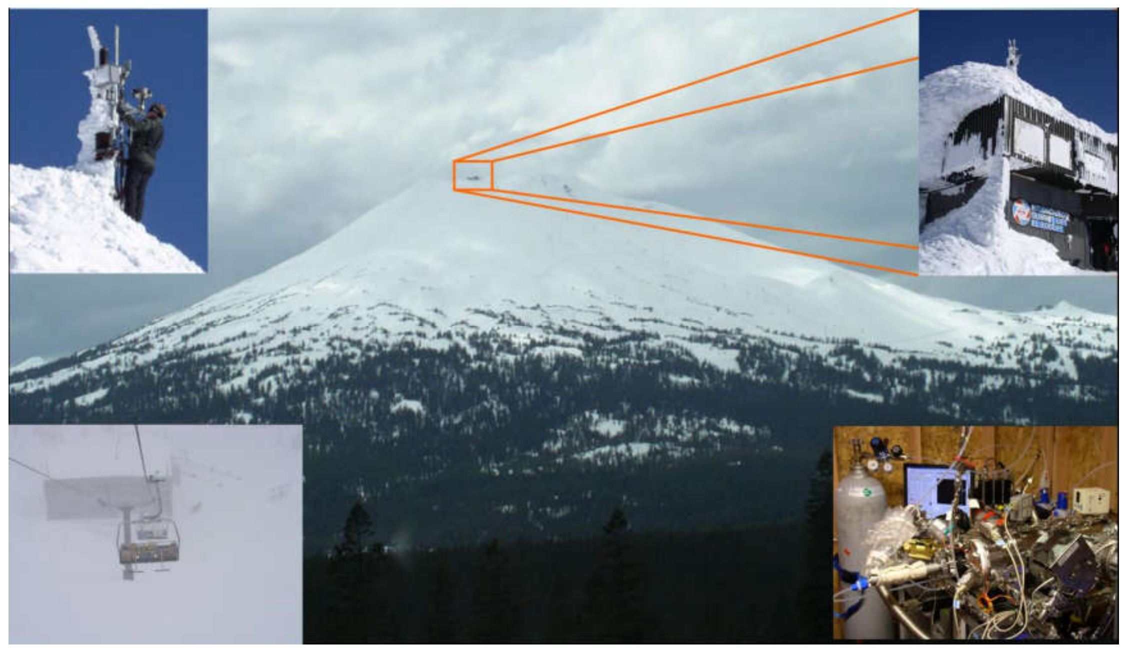
AEM
Journals.ASM.org

Intercontinental Dispersal of Bacteria and Archaea by Transpacific Winds

David J. Smith,[a] Hilkka J. Timonen,[b] Daniel A. Jaffe,[b,c] Dale W. Griffin,[d] Michele N. Birmele,[e] Kevin D. Perry,[f] Peter D. Ward,[a] Michael S. Roberts[e]
University of Washington, Department of Biology, Seattle, Washington, USA[a]; University of Washington, Science and Technology Program, Bothell, Washington, USA[b]; University of Washington, Department of Atmospheric Sciences, Seattle, Washington, USA[c]; U.S. Geological Survey, Tallahassee, Florida, USA[d]; NASA Kennedy Space Center, ESC Team QNA, Kennedy Space Center, Florida, USA[e]; University of Utah, Department of Atmospheric Sciences, Salt Lake City, Utah, USA[f]

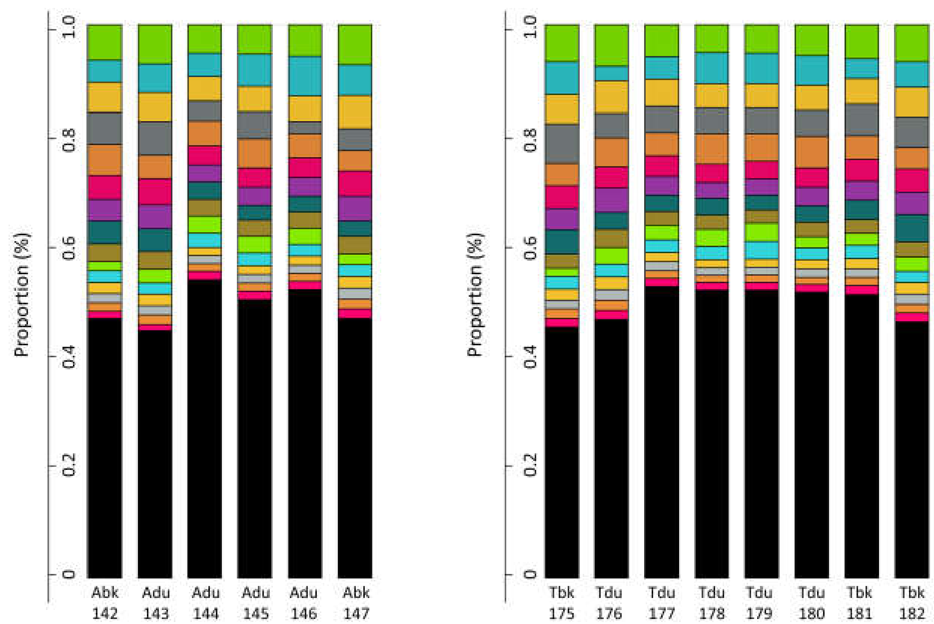


Plume: blue
Background: green



Mt. Bachelor Observatory, 2.8 km above sea level

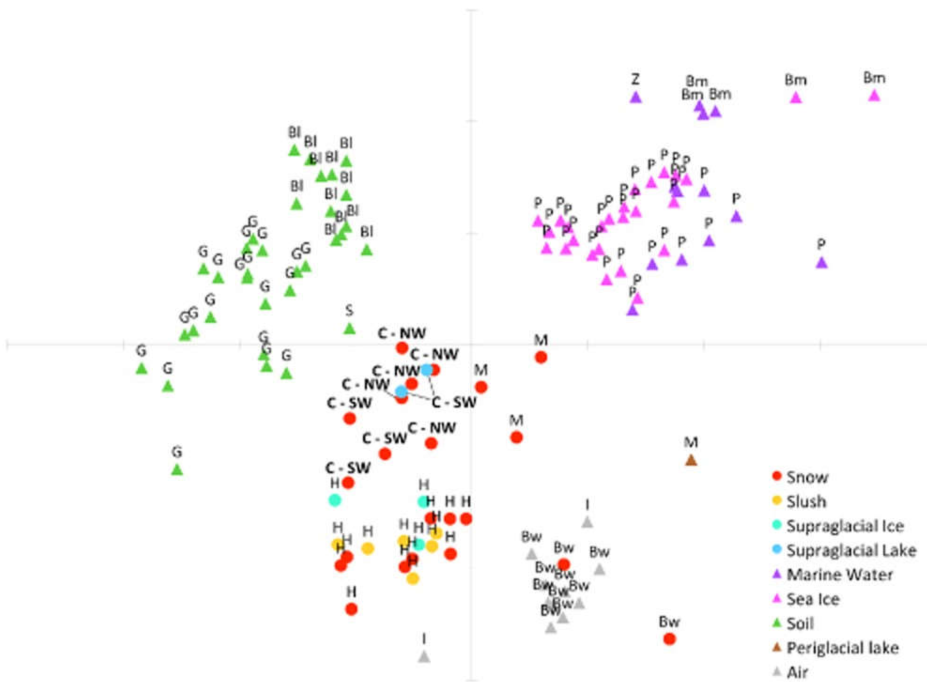
- Atmospheric dust plumes are distinct from background air
- Dust plume microbial communities look (not surprisingly) like soil microbial communities



Color	Domain	Phylum	Class	Order	Family
	Bacteria	Proteobacteria	Betaproteobacteria	Burkholderiales	Comamonadaceae
	Bacteria	Firmicutes	Bacilli	Bacillales	Bacillaceae
	Bacteria	Proteobacteria	Gammaproteobacteria	Pseudomonadales	Pseudomonadaceae
	Bacteria	Proteobacteria	Gammaproteobacteria	Enterobacteriales	Enterobacteriaceae
	Bacteria	Firmicutes	Clostridia	Clostridiales	Lachnospiraceae
	Bacteria	Actinobacteria	Actinobacteria	Actinomycetales	Corynebacteriaceae
	Bacteria	Firmicutes	Bacilli	Bacillales	Staphylococcaceae
	Bacteria	Firmicutes	Bacilli	Lactobacillales	Streptococcaceae
	Bacteria	Bacteroidetes	Flavobacteria	Flavobacteriales	Flavobacteriaceae
	Bacteria	Actinobacteria	Actinobacteria	Actinomycetales	Streptomycetaceae
	Bacteria	Firmicutes	Clostridia	Clostridiales	Ruminococcaceae
	Bacteria	Proteobacteria	Betaproteobacteria	Burkholderiales	Aquabacteriaceae
	Bacteria	Actinobacteria	Actinobacteria	Actinomycetales	Micrococcaceae
	Bacteria	Proteobacteria	Gammaproteobacteria	Pseudomonadales	Moraxellaceae
	Bacteria	Proteobacteria	Alphaproteobacteria	Sphingomonadales	Sphingomonadaceae
	Other				

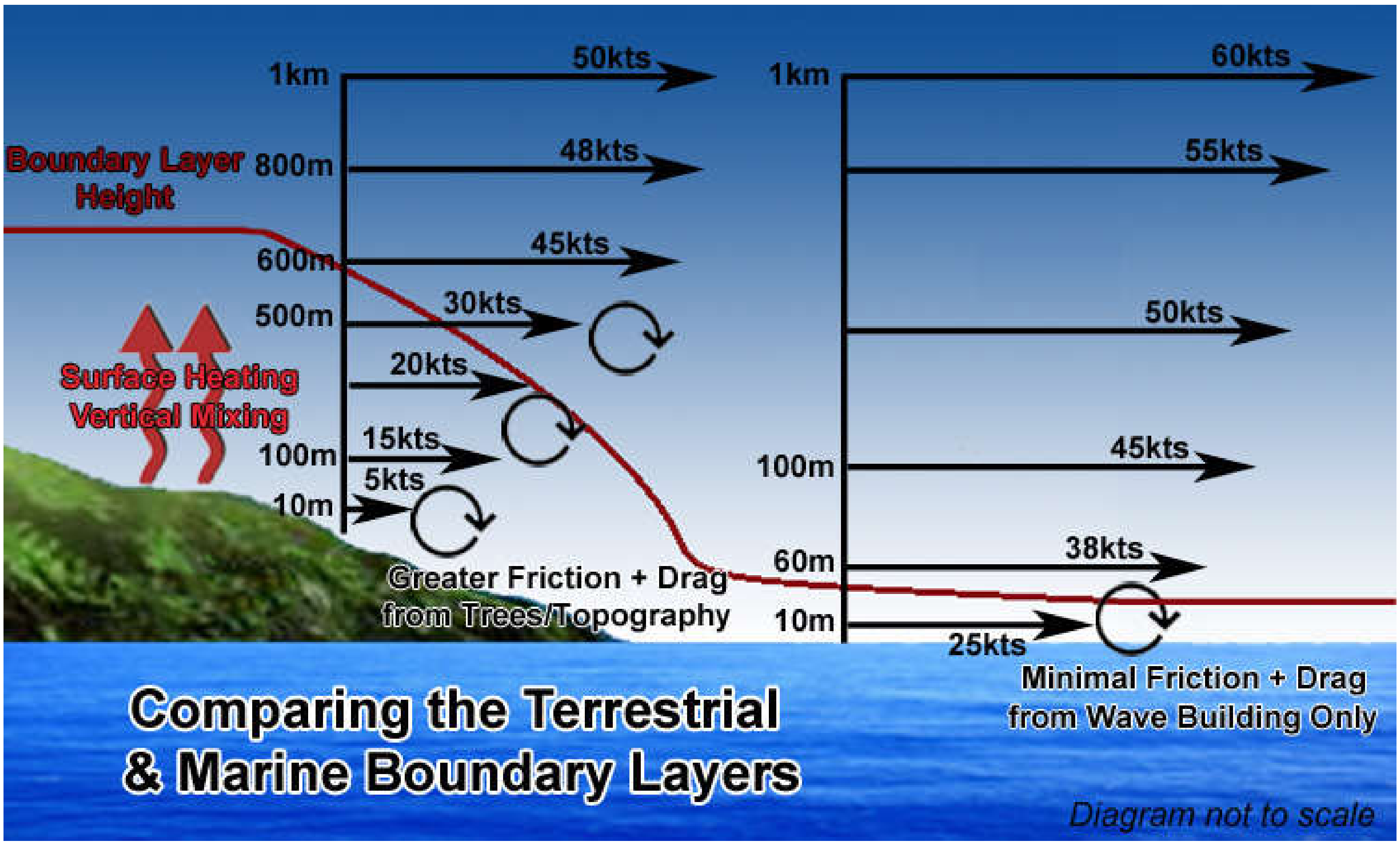
FIG 3 Relative abundance of 15 common bacterial families across the April plume (left) and May plume (right). The size of each color block (assigned to families in the table below) represents the number of OTUs detected in the family relative to the total number of OTUs detected in that sample. For example, *Bacillaceae* OTUs accounted for 6.5% of the total OTUs detected in the first April sample (Abk142). Generally, family proportions remained constant across both episodes.

- Atmospheric dust plumes are distinct from background air
- Dust plume microbial communities look (not surprisingly) like soil microbial communities
- This has implications for those components of the cryosphere where dust accumulates

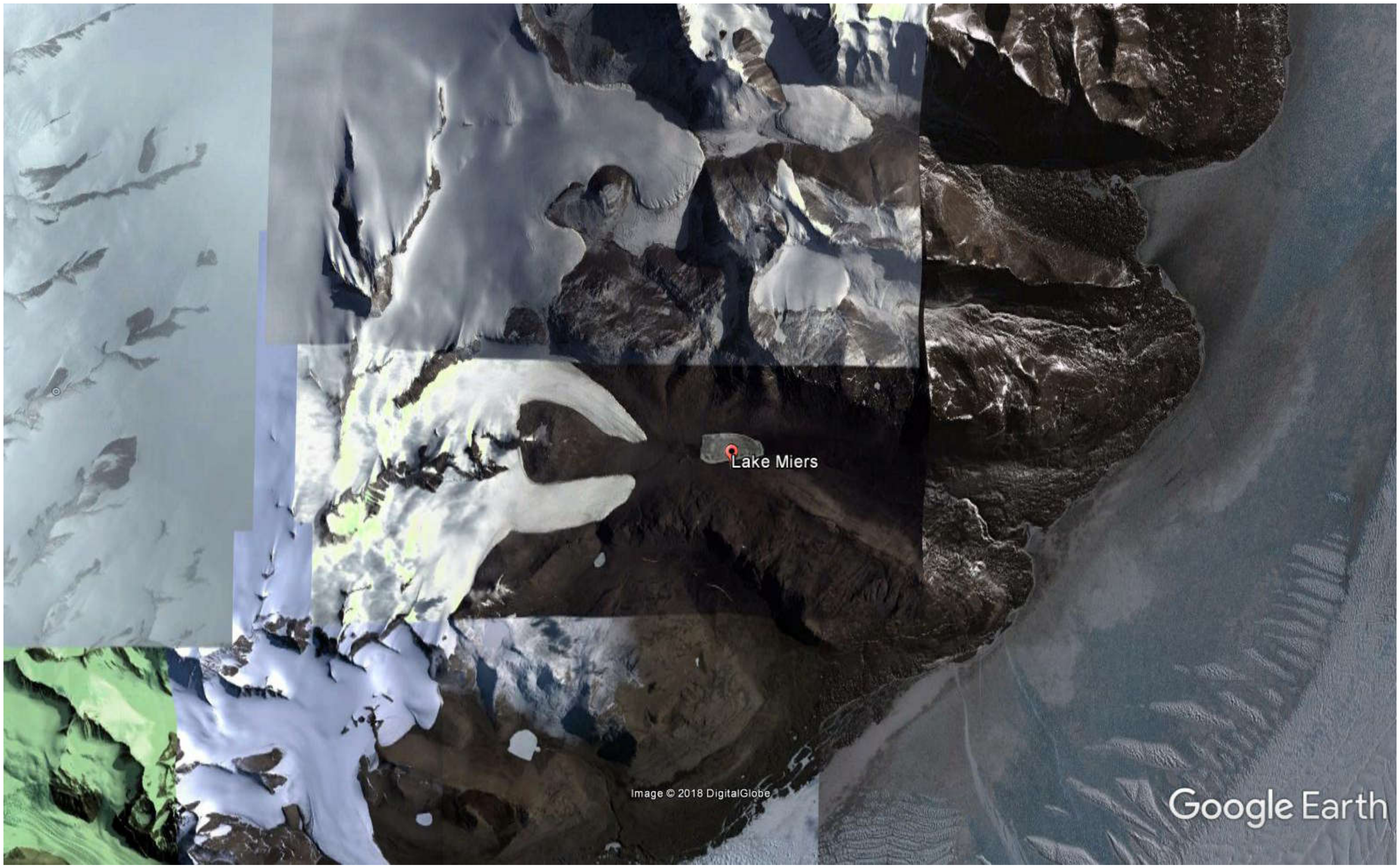


Cameron et al., 2014

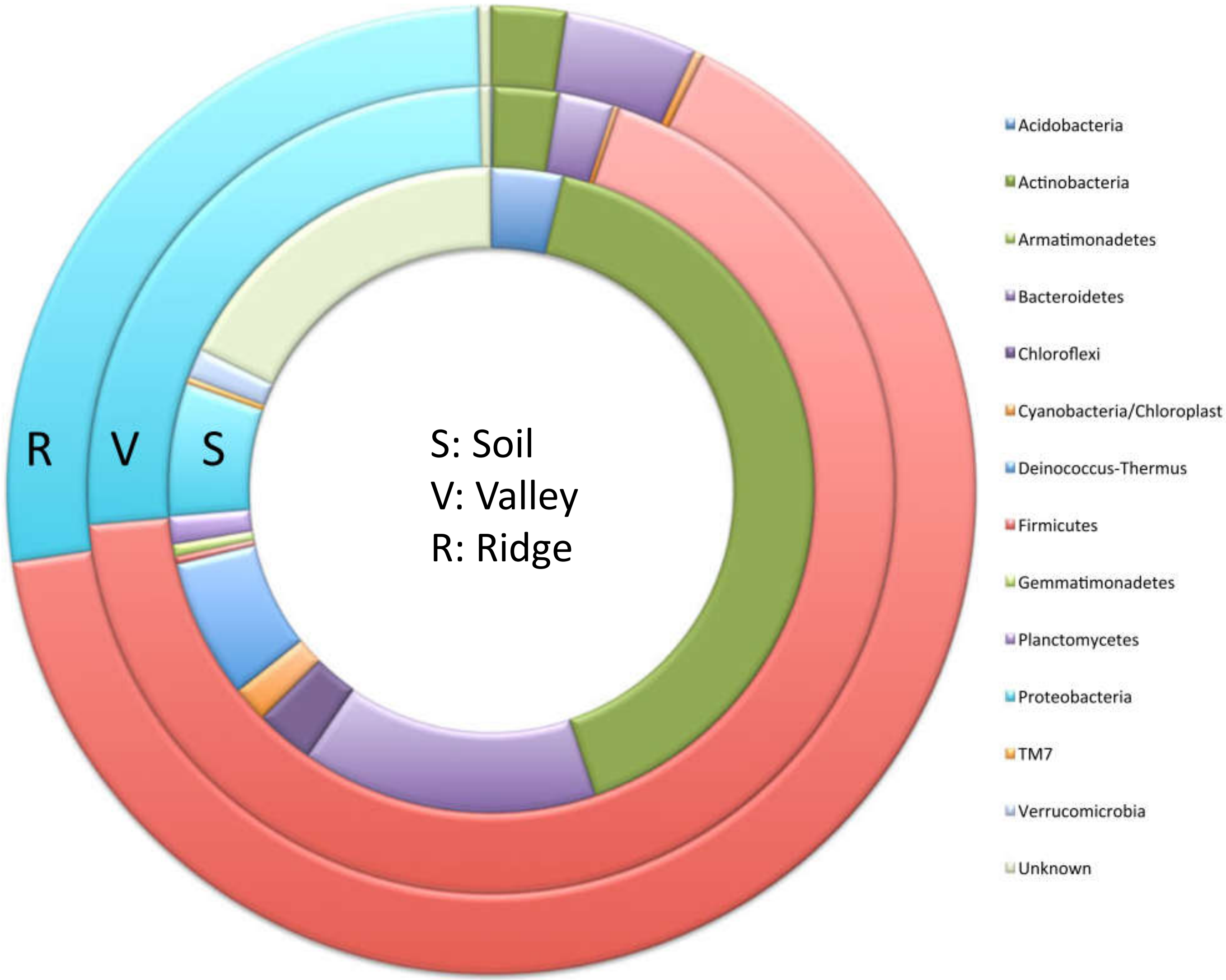
- Why aren't marine microbes common in the atmosphere? Isn't there an analogous process for the marine system?
  - Limited opportunities for marine microbes to make it into the atmosphere
  - Microbial abundance at the sea surface is much less than for soil
  - Marine microbes are less resilient in the atmosphere



- But atmospheric microbes don't always look like *local* soil microbes



- But atmospheric microbes don't always look like *local* soil microbes



Bottos et al., 2014

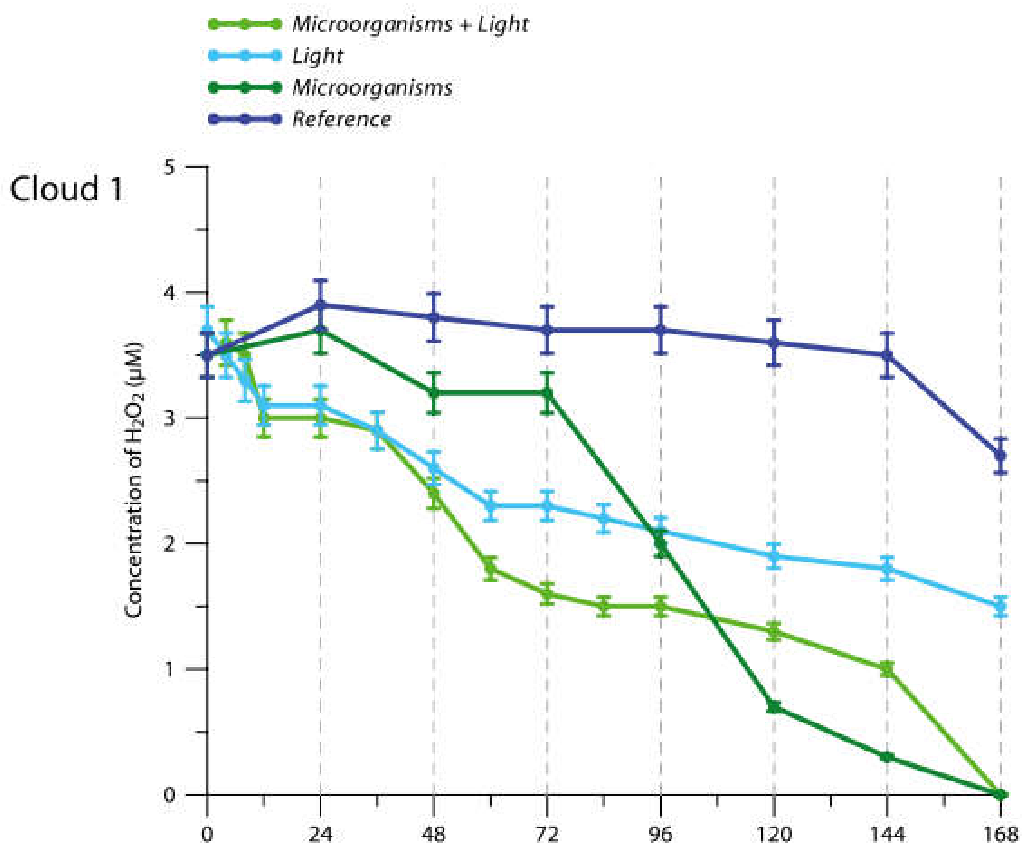
- But atmospheric microbes don't always look like *local* soil microbes
  - Selective transport
  - Selective survival
  - Diversity decreases with altitude, with only a handful of UV and desiccation resistant organisms found in the stratosphere

Scoma and Vorholt, 2018

- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.

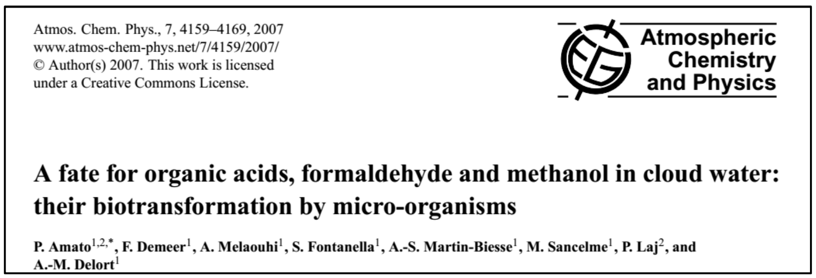
Potential impact of microbial activity on the oxidant capacity and organic carbon budget in clouds

Mickael Vaïtilingom[a,b,c,d], Laurent Deguillaume[c,d], Virginie Vinatier[a,b], Martine Sancelme[a,b], Pierre Amato[a,b], Nadine Chaumerliac[c,d], and Anne-Marie Delort[a,b,1]



Experiments at 17°C

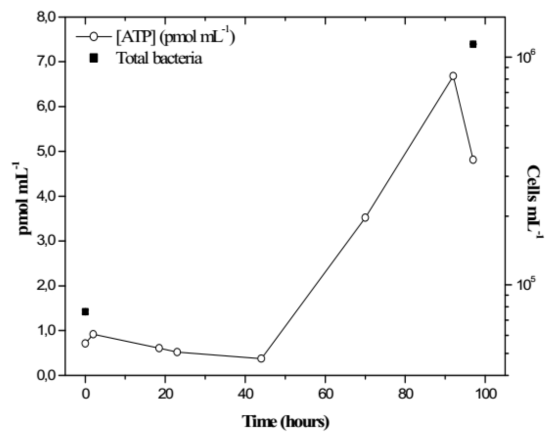
- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.
- We know bacteria and fungi isolated from clouds can degrade organics commonly found in the atmosphere

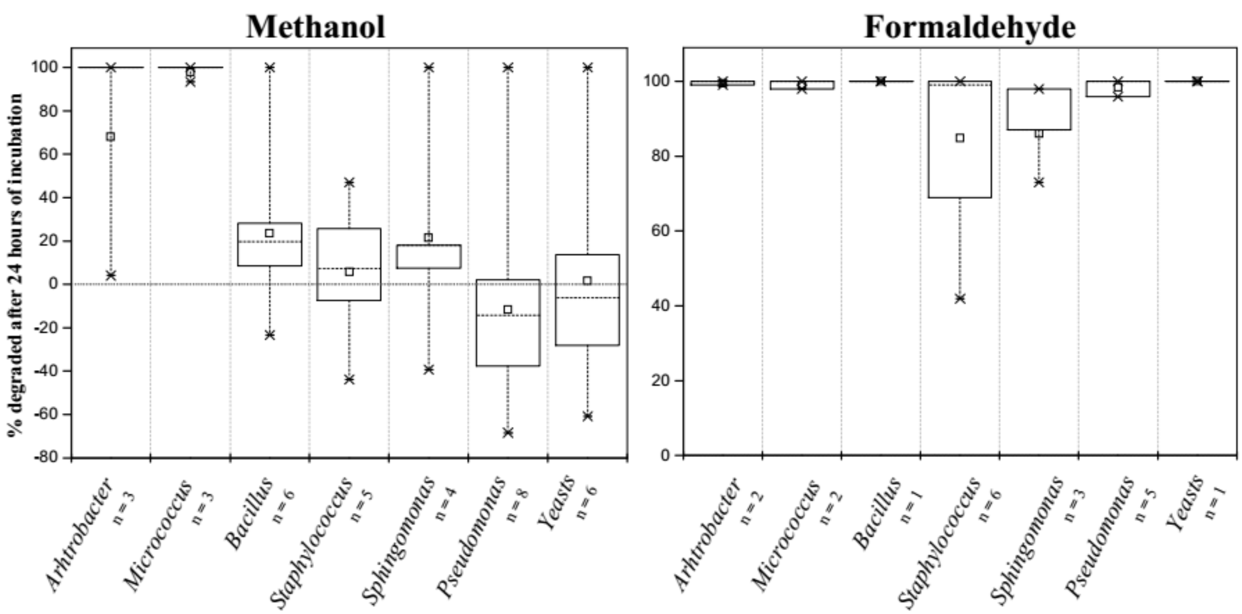

Atmos. Chem. Phys., 7, 4159–4169, 2007
www.atmos-chem-phys.net/7/4159/2007/
© Author(s) 2007. This work is licensed
under a Creative Commons License.

Atmospheric Chemistry and Physics

A fate for organic acids, formaldehyde and methanol in cloud water: their biotransformation by micro-organisms

P. Amato[1,2,*], F. Demeer[1], A. Melaouhi[1], S. Fontanella[1], A.-S. Martin-Biesse[1], M. Sancelme[1], P. Laj[2], and A.-M. Delort[1]

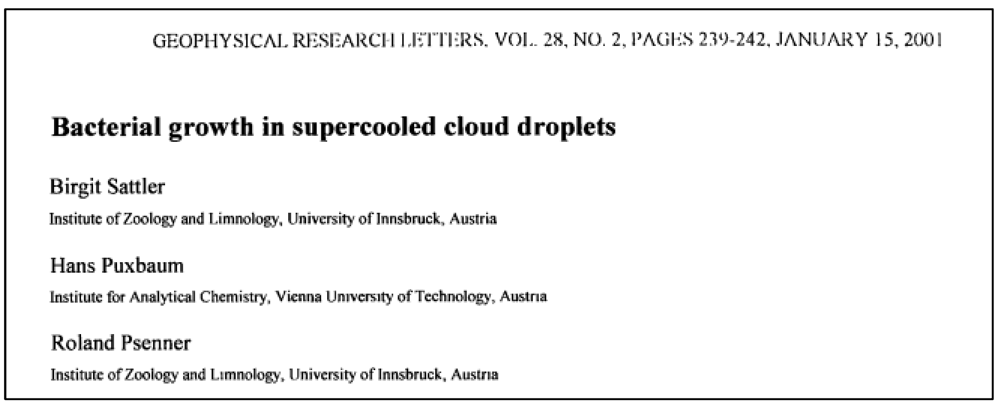




Experiments at 18°C

SIO 121, Lecture 11: Aerobiology: Activity

- Limited studies have directly assessed biological activity in clouds, usually at relatively warm temperatures.
- We know bacteria and fungi isolated from clouds can degrade organics commonly found in the atmosphere
- Some (weak) evidence for activity in super-cooled water droplets

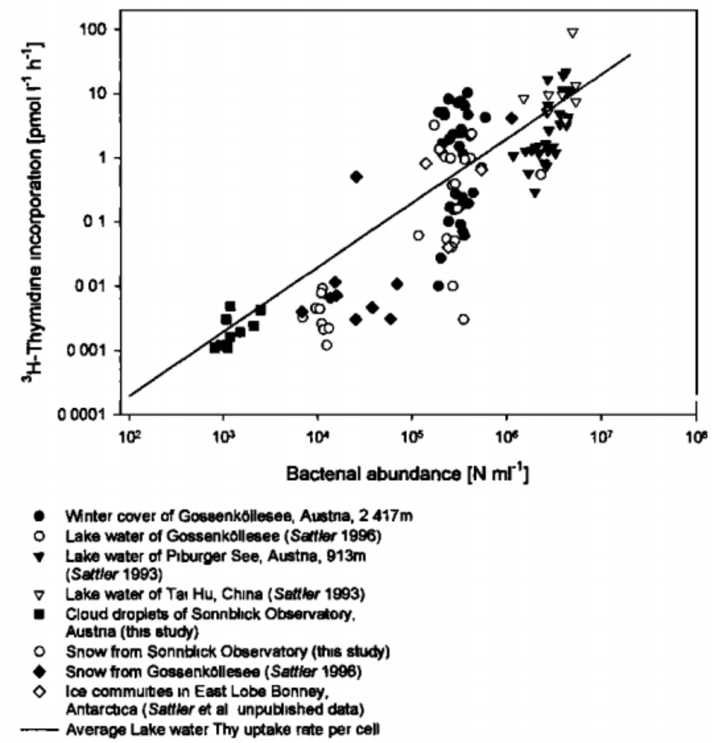

GEOPHYSICAL RESEARCH LETTERS, VOL. 28, NO. 2, PAGES 239-242, JANUARY 15, 2001

Bacterial growth in supercooled cloud droplets

Birgit Sattler
Institute of Zoology and Limnology, University of Innsbruck, Austria

Hans Puxbaum
Institute for Analytical Chemistry, Vienna University of Technology, Austria

Roland Psenner
Institute of Zoology and Limnology, University of Innsbruck, Austria



Experiments at 0°C