

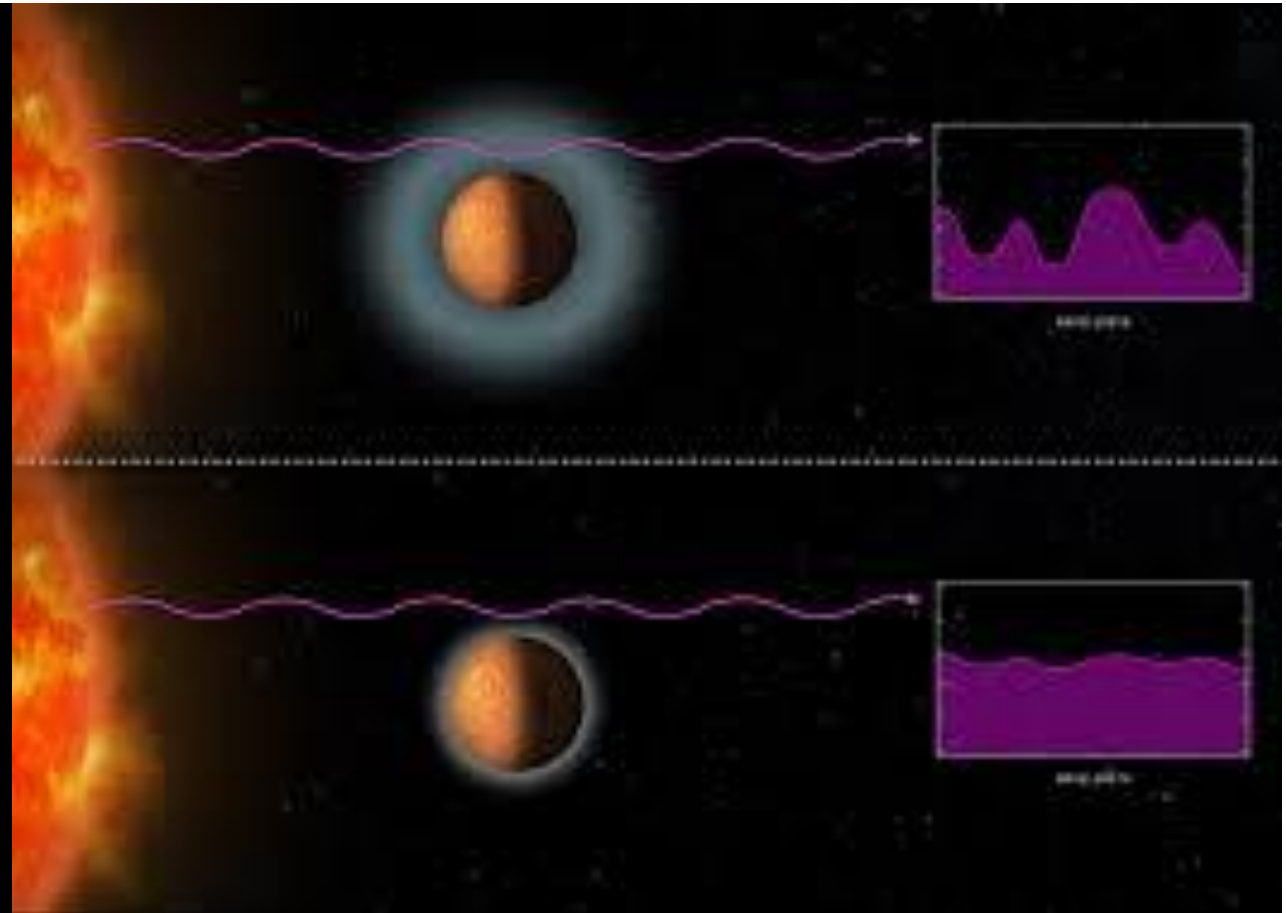
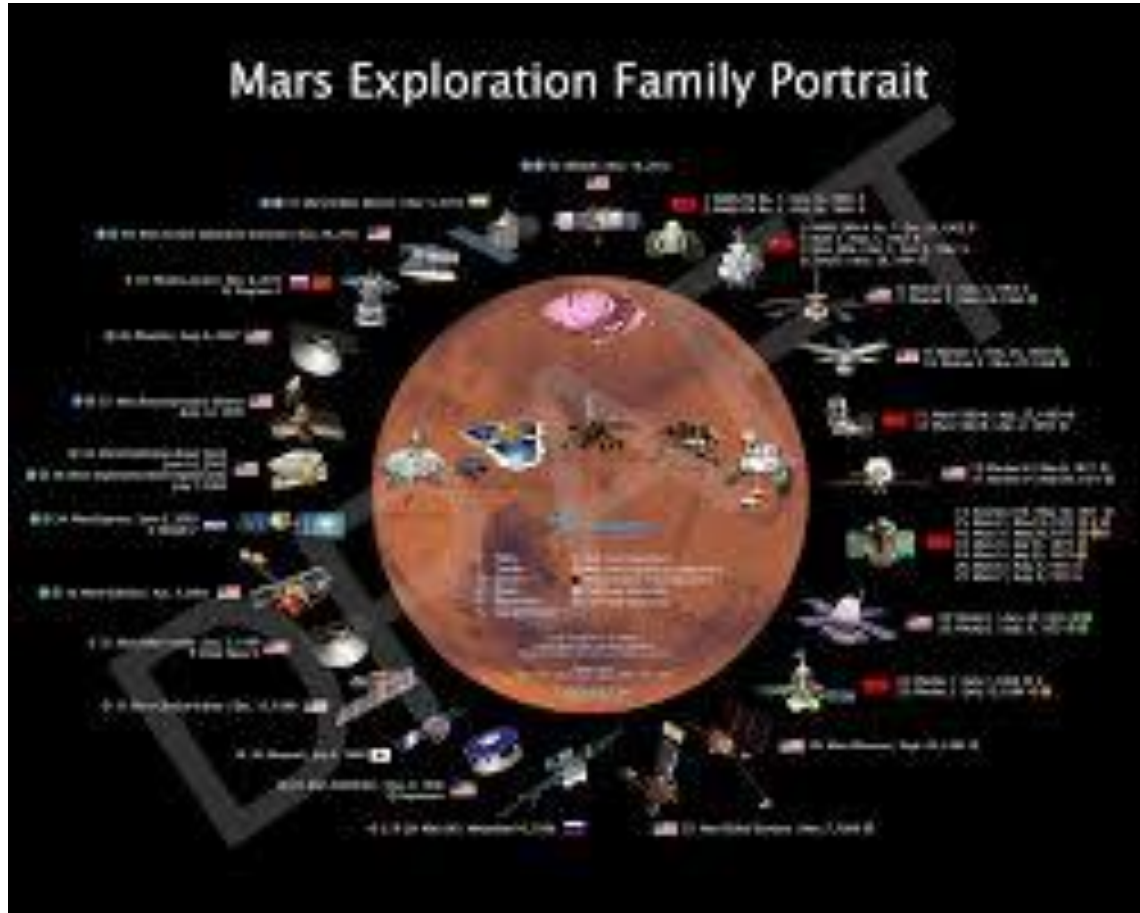
”DRAMA”

Deciphering the *Role* of
Atmospheric Microbial Aerosols

Kai Finster, Tina Santl-Temkiv, Thomas Boesen, Merete Bilde, Tobias Weidner, Claus Melvad (Aarhus University)

Erik Thomson (Gothenburg University), Annika Ekman (Stockholm University), Dagmar Woebken (Vienna University)

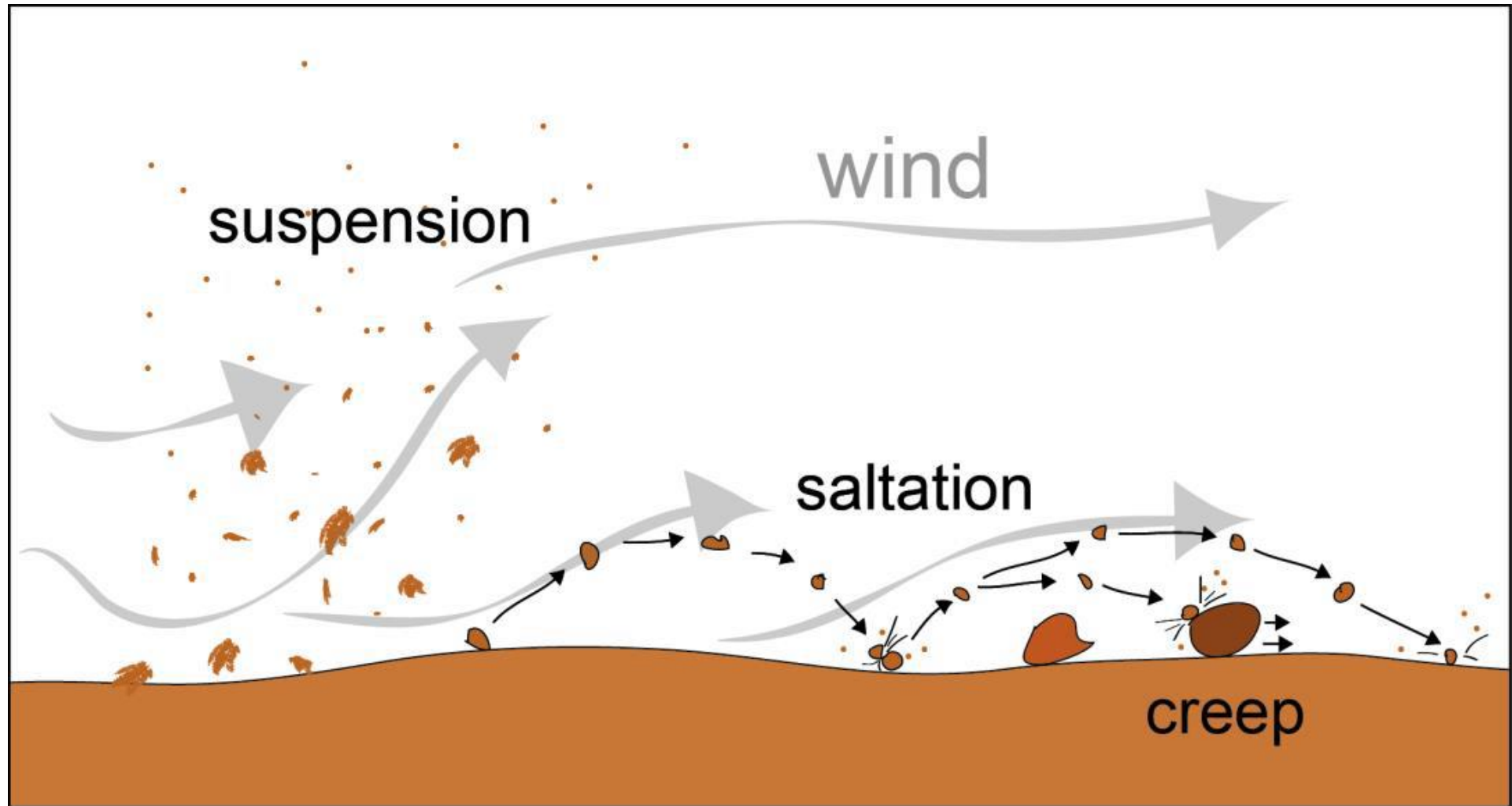
Relation between Aerobiology and Astrobiology

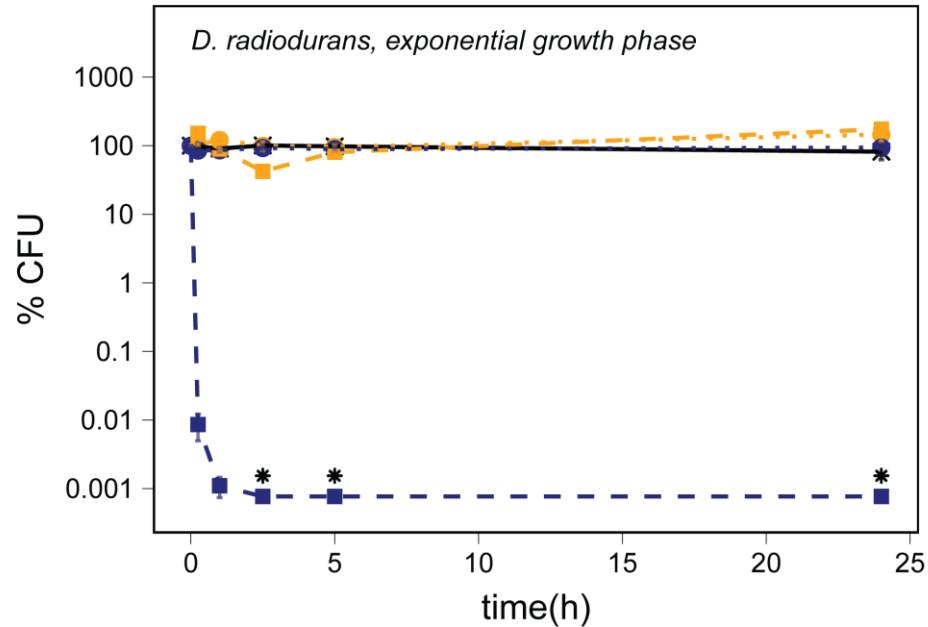


Mars surface processes

Atmospheric biosignatures on Exoplanets

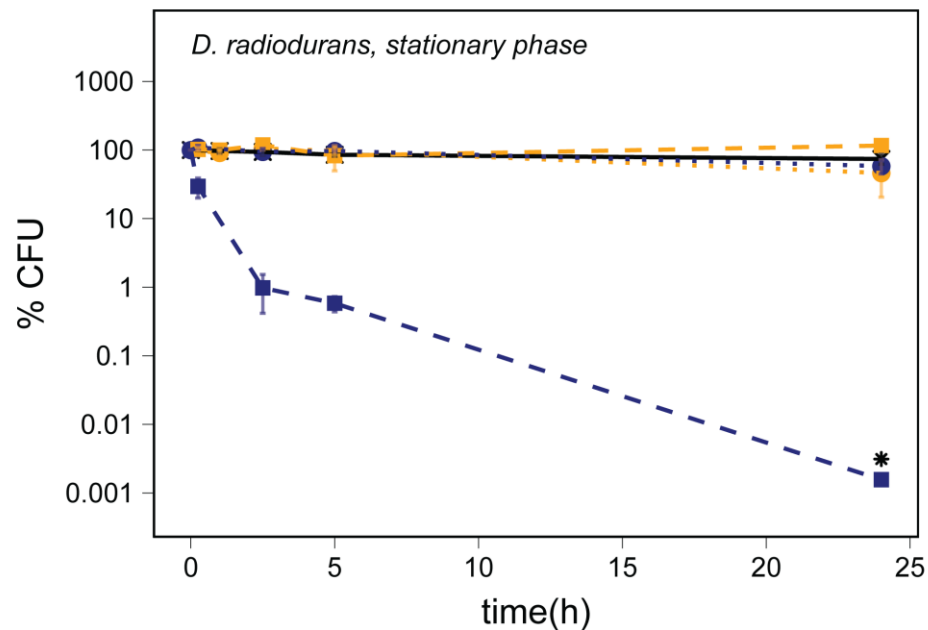
Wind-driven processes on the Martian surface





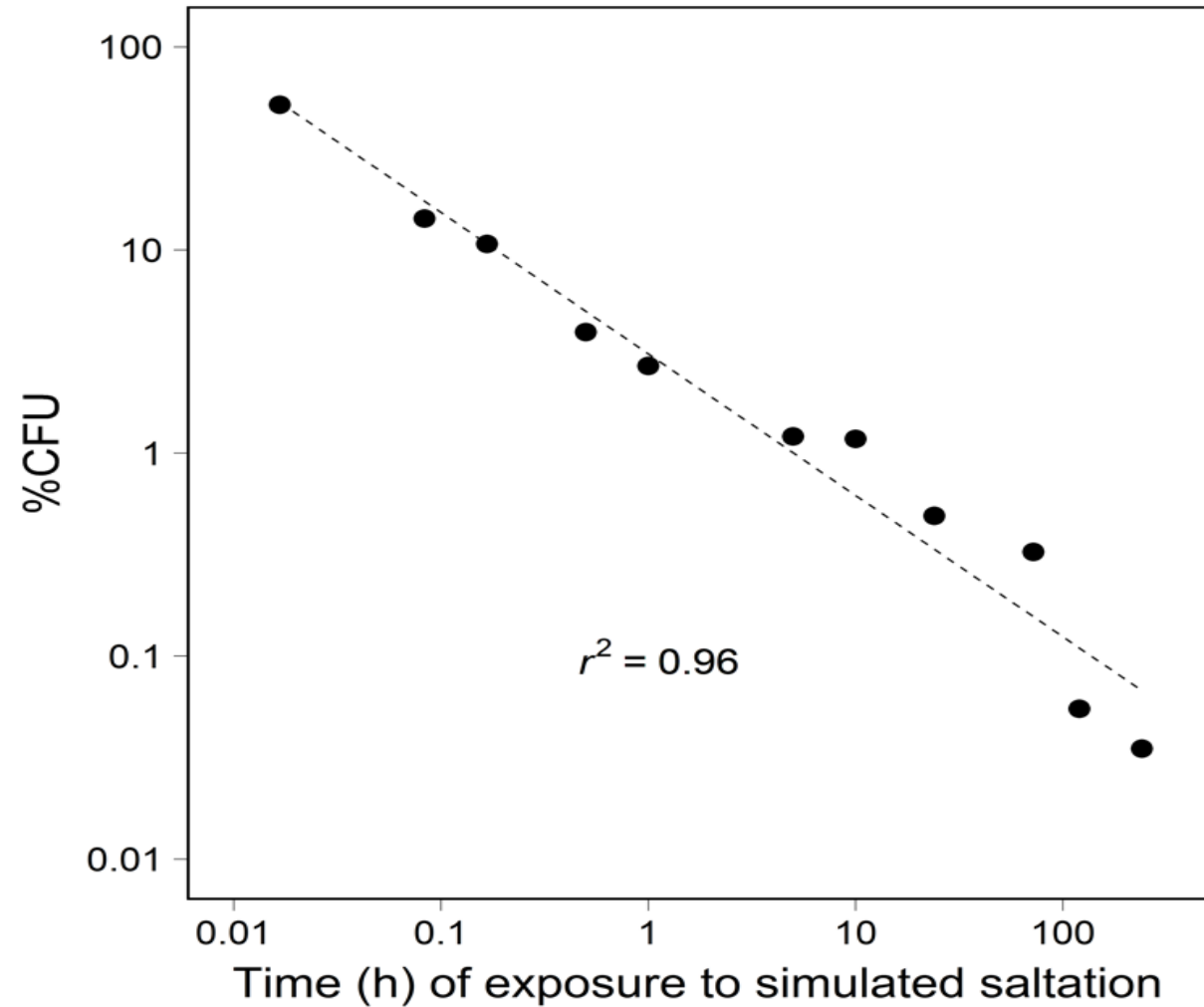
(A)

Survival of *D. radiodurans* harvested in the exponential phase **(A)** and in stationary phase **(B)** in the PBS control (X) and after addition of abraded quartz (●) and basalt (■) relative to the starting concentration of $\sim 10^6$ CFU/ml. The survival of *D. radiodurans* is shown for experiments with inactivated silicates (orange) and abraded silicates kept anoxic (blue). The asterisks indicate that the number of CFU was below the LOD.

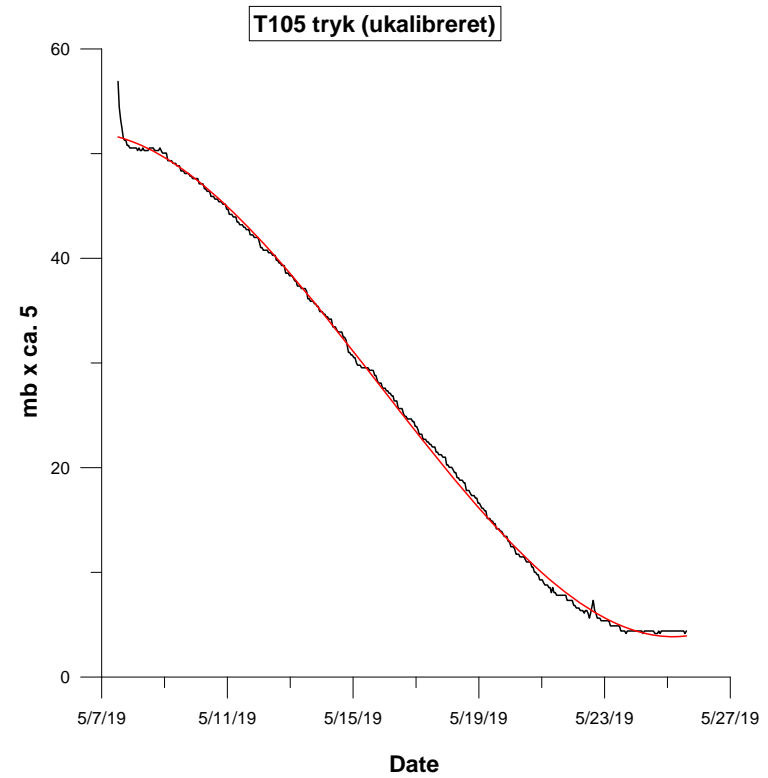


(B)

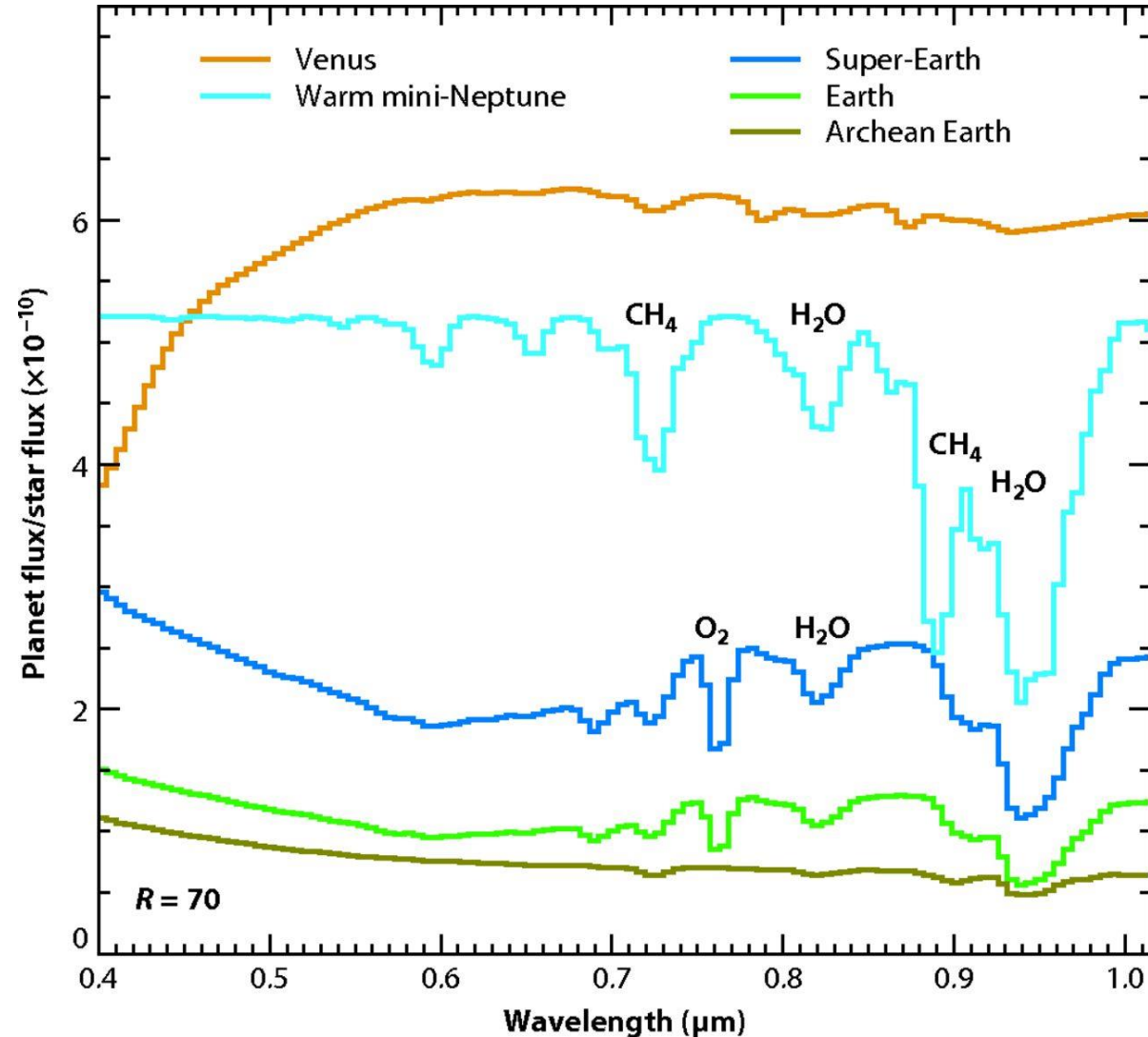
Spore survival as function of erosion



Erosion of silicates as a sink for methane on Mars



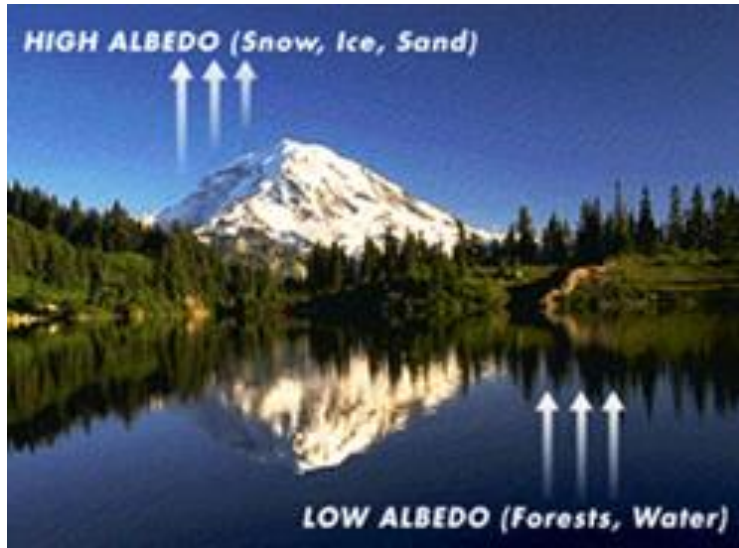
Atmospheric biosignatures of Exoplanets



Atmospheric biosignatures of Exoplanets

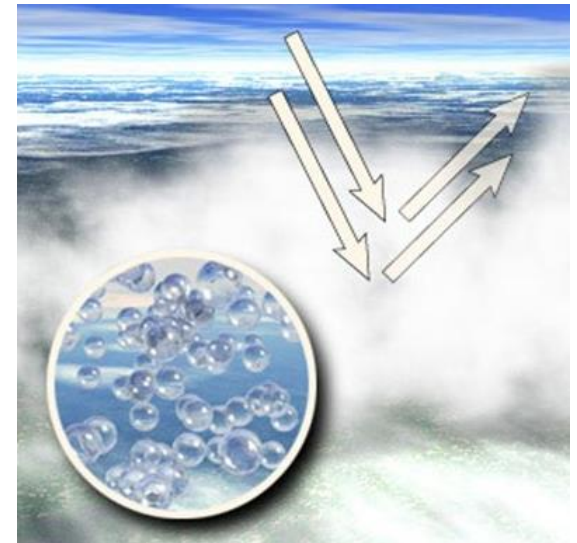
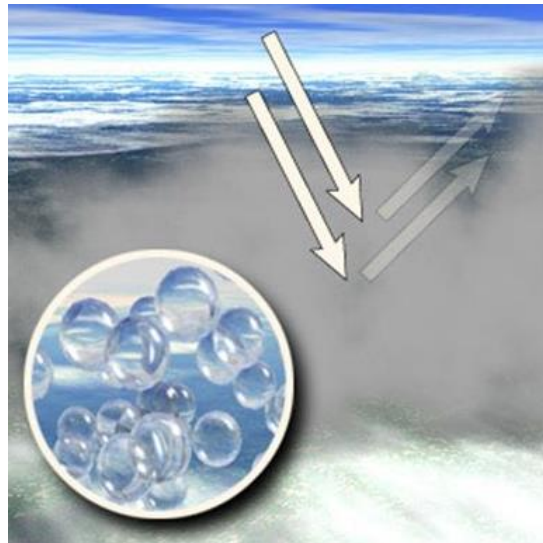


Clouds and Earth's radiation budget



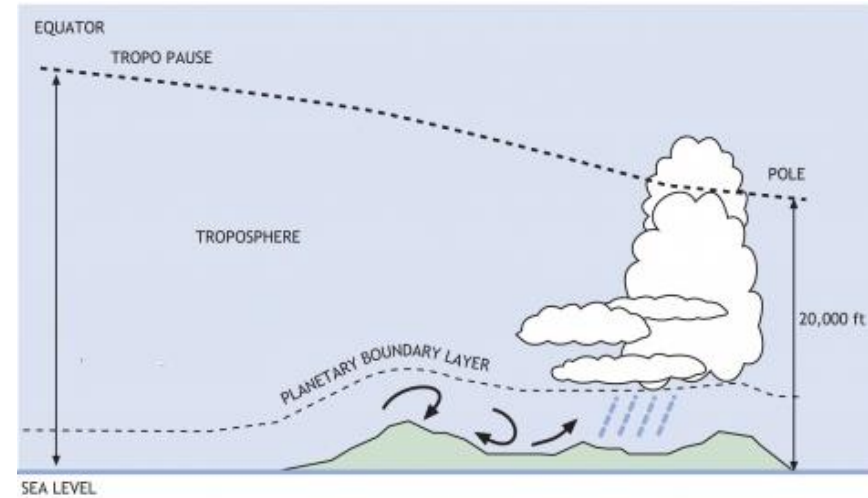
Albedo = solar energy that is reflected back to space (~30%)

Clouds → negative forcing



Bacteria in the atmosphere

Terrestrial and aquatic sources:
emissions from plant surfaces > emissions from soil > emissions from waters
Mean bacterial global emissions: $7.5 \cdot 10^{15}$ – $3.3 \cdot 10^{16}$ CFU/s



Bacteria in the dry atmosphere

- Air over land: 10^4 - 10^5 cells per m^3
- Residence times: days-weeks
- Extreme environment: desiccation, UV light, oxidative environment, low temperature...

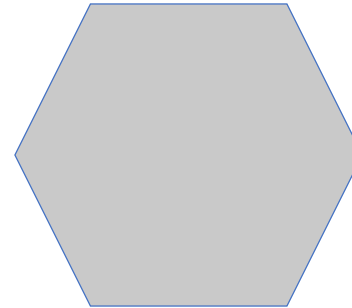
Bacteria in clouds

- **1500 - 430 000 cells per ml**
- 20% of time in cloud droplets
- Favorable compared to dry air
- Extreme environment: low pH, toxic compounds, cycles of drying and wetting or freezing and thawing.

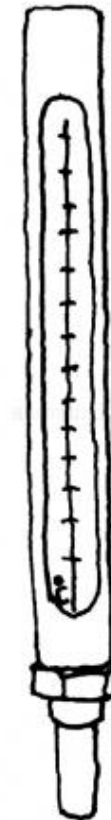
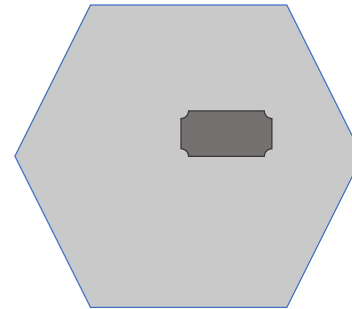
Freezing in the atmosphere



✧ **Homogenous freezing:**
pure water



✧ **Heterogenous freezing:**
presence of ice nucleators



← -38 °C

← -20 °C

The DRAMA team

The Aarhus core group:



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Dept. of Chemistry



Tobias Weidner
Dept of Chemistry



Thomas Boesen
iNANO &
Miol.Biol.



Tina Santl-Temkiv
Dept. Of Biology



Kai Finster
Dept. of Biology

External partners:



Dagmar Wuebken
University of Vienna



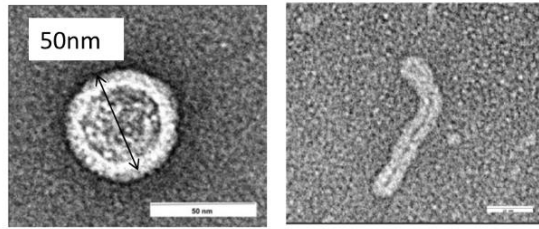
Erik Thomson
Gothenborg University



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Stockholm University

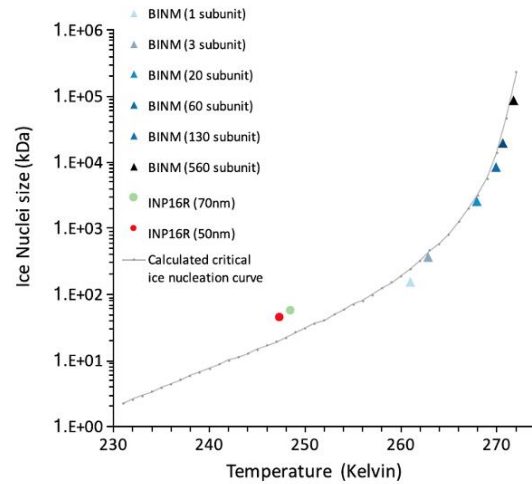
DRAMA Background

A



INP16R

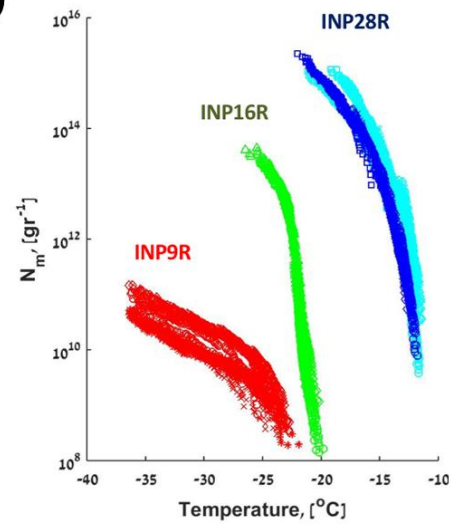
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C



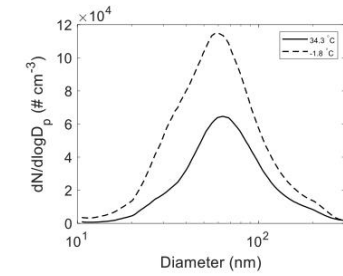
D



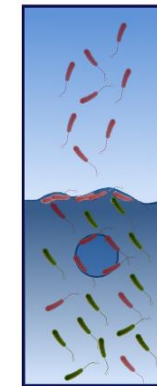
E



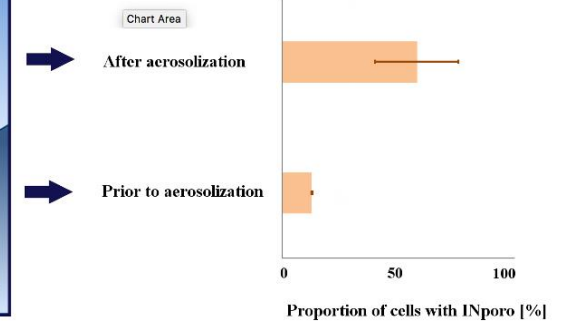
F



G



H



The DRAMA project idea

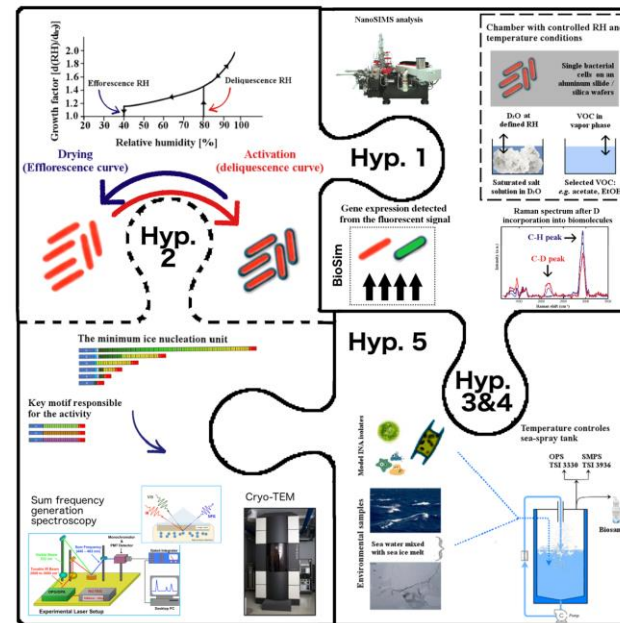


Fig. 1: Conceptual presentation of DRAMA. DRAMA is organized around four workpackages (WP) testing 5 hypotheses. For details consult information provided in WP 2, 3 and 4. In the upper left corner, the effect of the hygroscopicity of bacterial cells as a response to the relative humidity (RH) of the atmosphere is illustrated. Deliquescence RH is the relative humidity at which an initially-dry body (salt or cell) first takes on liquid water during an increase in relative humidity. We will test how this is linked to cell activity. In the upper right corner, a picture of the Nano-Sims is shown. The instrument will be used to determine whether cells that are aerosolized in the BioSIM chamber can take up water (D₂O) and/or carbon. In the lower left corner, different length varieties of an ice nucleating protein are shown. The structure of the proteins will be analyzed by CryoTEM and the interaction with water and ice formation will be studied with sum frequency generation spectroscopy. In the lower right corner, studies addressing the role of aerosolization of partitioning of bacterial and algal cells are sketched. Natural samples will be collected from the marine surface microlayer as well as from bulk water off the coast of Greenland and the effect of aerosolization on the composition of the airborne microbial community will be studied using a bubble tank.

WP1: Instrument development

Central DRAMA Instrument: electro-dynamic levitator

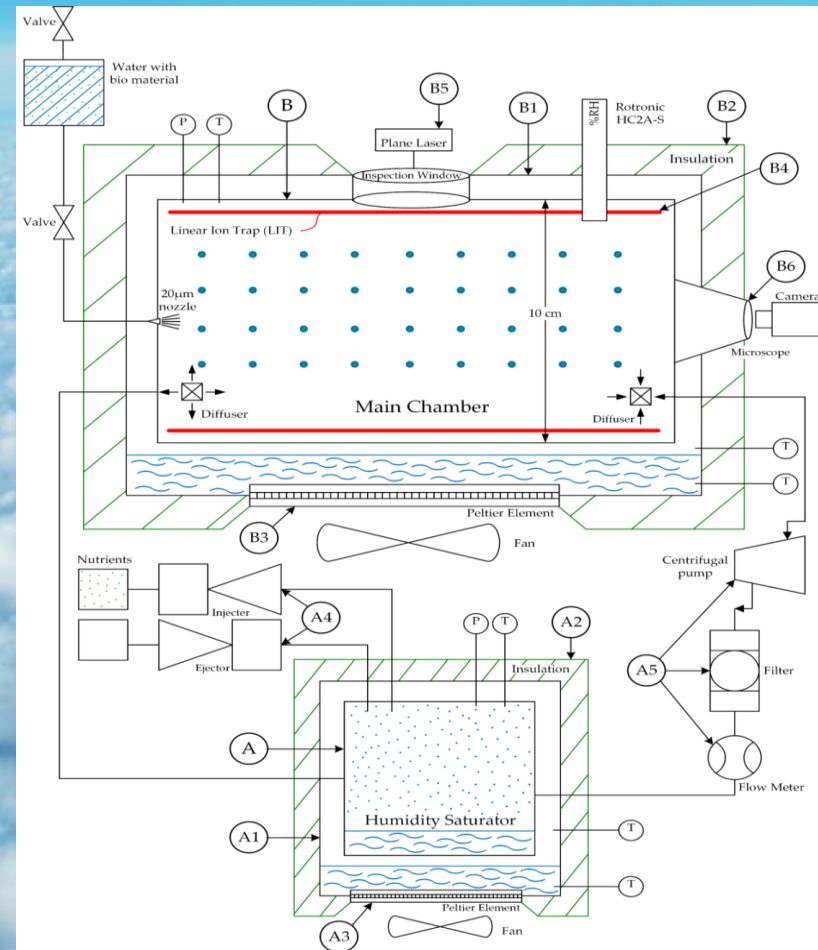


Fig 2.: Technical drawing of the BioSIM chamber. Detailed description is giving in WP1. **A:** Temperature control chamber: A1: Acetone-filled Heat pipe; A2: Isolation-Shell; A3: Peltier elements; A4: injector-ejector system; A5: flow meter; **B:** Experimental chamber: B1: heat pipe; B2: insulation; B3: Peltier elements; B4: Linear Ion trap; B5: laser plane; B6: microscope camera.

WP2: Studies of hygroscopicity of IN proteins
and microbial surfaces and Ice nucleation

Hypothesis to be tested:

- *Hypothesis 1 : Cellular hygrosensitivity is key to cellular activity in the atmosphere*



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Expected outcomes:

- obtaining first hygroscopicity data for bacterial cells, determining at which RH conditions cells can maintain activity in air.



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- establishing a technique for bio-aerosol hygroscopicity measurements and determination of water structure, which is key for activity studies but also for evaluating (a) direct radiation effects and (b) health effects of bio-aerosols.

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- establishing a technique for bio-aerosol hygroscopicity measurements and determination of water structure, which is key for activity studies but also for evaluating (a) direct radiation effects and (b) health effects of bio-aerosols.
- **establishing whether cell surfaces get conditioned by the environmental conditions at the site from where they get aerosolized.**

Hypothesis to be tested:

Hypothesis II: Ice nucleating proteins play a central role in cellular hygroscopicity and their activity is determined by properties of their molecular structure.



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Expected outcomes:

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Hypothesis II: Ice nucleating proteins play a central role in cellular hygroscopicity and their activity is determined by properties of their molecular structure.

Expected outcomes:

- elucidating the relationship between the IN-protein size and structure and IN properties.
- determining the role of bioINP in ice-binding and ice growth control.

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Hypothesis II: Ice nucleating proteins play a central role in cellular hygroscopicity and their activity is determined by properties of their molecular structure.

Expected outcomes:

- elucidating the relationship between the IN-protein size and structure and IN properties.
- determining the role of bioINP in ice-binding and ice growth control.
- **obtaining parametrisation of INP properties including onset of freezing as function of structure, size and level of agglomeration for use in cloud and climate models.**

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- determining the role of bioINP in ice-binding and ice growth control.
- obtaining parametrisation of INP properties including onset of freezing as function of structure, size and level of agglomeration for use in cloud and climate models.
- elucidating the detailed INA cell surface ultrastructure and modification of the ultrastructure upon changing environmental conditions of *P. syringae* R10.79 to high resolution.

WP3:Activity studies and gene expression of
cells in the atmosphere

Hypothesis to be tested:

Hypothesis III: The relative humidity of the atmosphere determines the metabolic activity of airborne microbial cells.



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Expected outcomes:

- determining under which conditions bacterial cells take up water from the vapor phase and use deuterium incorporation as an activity proxy.

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Expected outcomes:

- determining under which conditions bacterial cells take up water from the vapor phase and use deuterium incorporation as an activity proxy.
- determining the threshold RH for bacterial activity in the atmosphere and identifying the VOCs serving as carbon and energy sources that support activity.

Hypothesis to be tested:

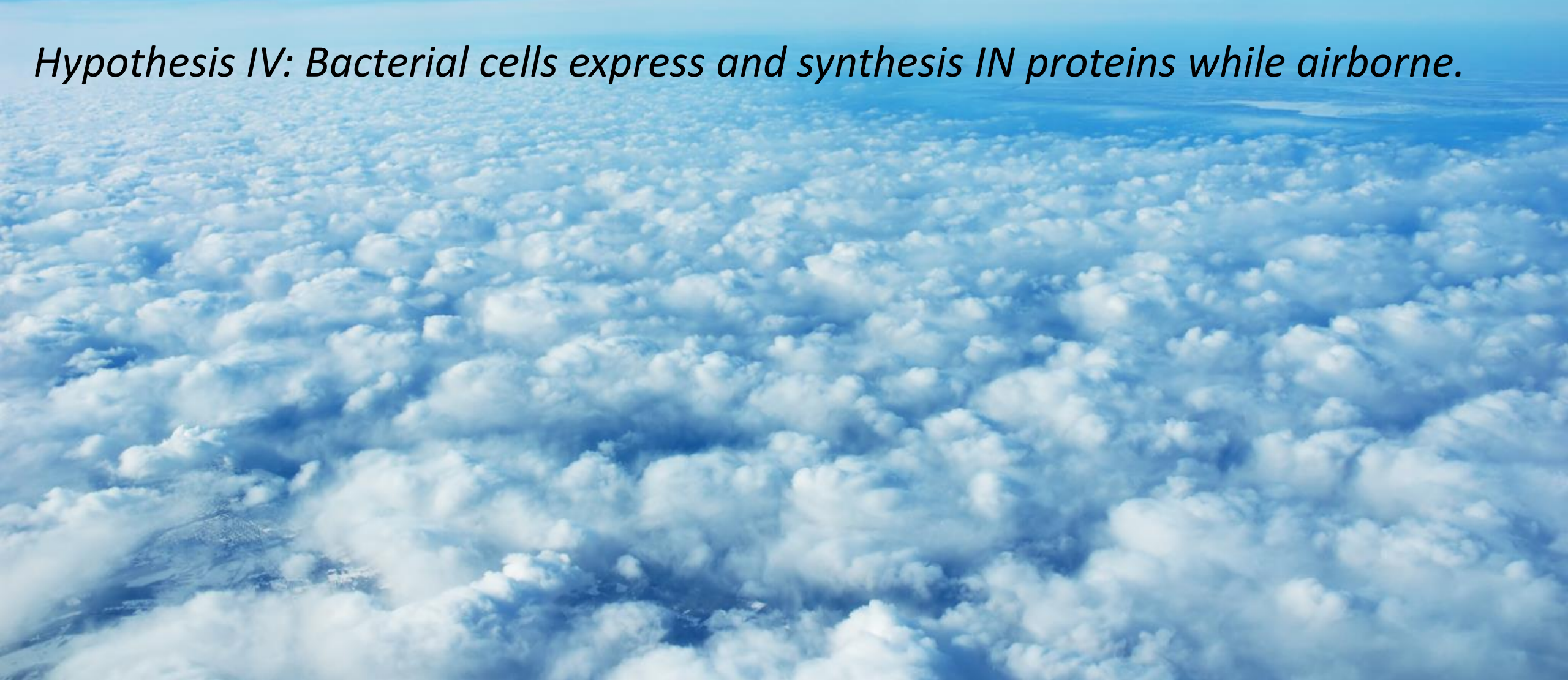
Hypothesis III: The relative humidity of the atmosphere determines the metabolic activity of airborne microbial cells.

Expected outcomes:

- determining under which conditions bacterial cells take up water from the vapor phase and use deuterium incorporation as an activity proxy.
- determining the threshold RH for bacterial activity in the atmosphere and identifying the VOCs serving as carbon and energy sources that support activity.
- establishing a technique for measuring activity supported by compounds in the vapour phase.

Hypothesis to be tested:

Hypothesis IV: Bacterial cells express and synthesis IN proteins while airborne.



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Expected outcomes:

- observing de novo synthesis of bioINP in airborne cells.

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Expected outcomes:

- observing de novo synthesis of bioINP in airborne cells.
- determine the conditions under which bioINP synthesis can take place.

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Hypothesis IV: Bacterial cells express and synthesis IN proteins while airborne.

Expected outcomes:

- observing de novo synthesis of bioINP in airborne cells.
- determine the conditions under which bioINP synthesis can take place.
- using *P. syringae* R10.79 results to pave the way for follow on studies with a wider range of microbes typically encountered in the atmosphere.

WP4: Factors triggering the aerosolization of
bio-aerosols from the arctic sea

Hypothesis to be tested:

Hypothesis V: Marine bioaerosols stem primarily from the sea surface microlayer (SML).



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Expected outcomes:

- obtaining quantitative data on the aerosolization potential of microbial SML and Bulk water community members.



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Expected outcomes:

- obtaining quantitative data on the aerosolization potential of microbial SML and Bulk water community members.
- obtaining first data on the surface properties of aerosolised bacterial cells from natural samples using BioSIM.

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- obtaining quantitative data on the aerosolization potential of microbial SML and Bulk water community members.
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- obtaining first data on the metabolic activity of aerosolised bacterial cells from natural samples using BioSIM.

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- obtaining fractions of aerosolized cells to be incorporated in cloud models.

Hypothesis to be tested:

Hypothesis V: Marine bioaerosols stem primarily from the sea surface microlayer (SML).

Expected outcomes:

- obtaining quantitative data on the aerosolization potential of microbial SML and Bulk water community members.
- obtaining first data on the surface properties of aerosolised bacterial cells from natural samples using BioSIM.
- obtaining first data on the metabolic activity of aerosolised bacterial cells from natural samples using BioSIM.
- obtaining fractions of aerosolized cells to be incorporated in cloud models.
- obtaining the fraction of IN positive microalgae and bacteria after aerosolization to be implemented in cloud models.