AIRCOAT

How can nature help reduce greenhouse gas emissions in the shipping industry?

May 19 | 03.00 pm CET | Webinar

European Commission

#EUGreenWeek
2021 PARTNER EVENT

AIRCOAT

INTRODUCING AIRCOAT

Jonathan Weisheit
Research Associate
Fraunhofer CML

Fraunhofer CML

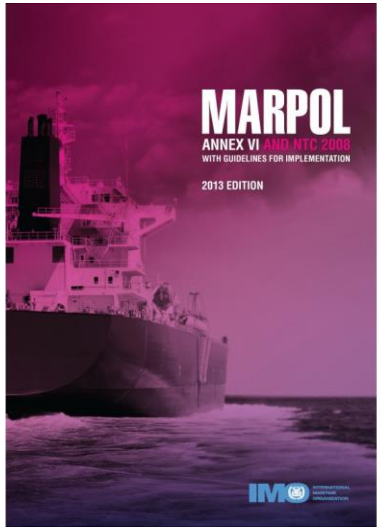
The AIRCOAT project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 764553.

SHIPPING

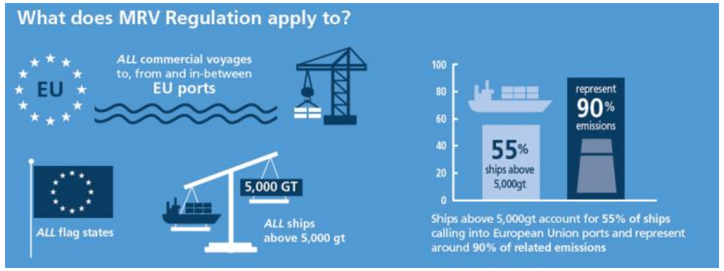
- **Transports 80% of global goods[1]**
- **Consumes 276 MT fuel annually [2]**
- **Emits 940 MT CO_2 and contributes to 2.5% of global GHG annually [3]**

[1]ESCA, Shipping and Global Trade. 2017. [2]Johansson, L., J.-P. Jalkanen, and J. Kukkonen, *Global assessment of shipping emissions in 2015 on a high spatial and temporal resolution.* Atmospheric Environment, 2017. 167: p. 403-415. [3]IMO, Third IMO Greenhouse Gas Study, in International Maritime Organization. 2014.

REGULATIONS



- Since 2005 regional SECA/NECA (MARPOL Annex VI)
- Since 2017 European monitoring (EU MRV)
- From 2020 global sulphur Cap (0.5 % m/m)
- Until 2050 IMO Decarbonisation target (cut CO_2 by 50%)



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PROJECT PROFILE

PARTNERS

10 partners from **6** countries

AquaBioTech Group · Avery Dennison · B-I-C Hochschule Bremen Bionik-Innovations-Centrum · danaos · Ilmatieteen Laitos / Meteorologiska Institutet / Finnish Meteorological Institute · Fraunhofer CML · HSVA · KIT Karlsruher Institut für Technologie · PPG Industries · REVOLVE

DURATION

36 months **+ 12** months
(1. May 2018 – 30. April 2022)

CALL

MG-2.1-2017 – *Innovations for energy efficiency and emission control in waterborne transport.*

GRANTED FUNDING

5.3 million Euros

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SALVINIA EFFECT

Complex micro - and nanostructures with **hydrophobic** surfaces create a **permanent layer of air**. Inspired by this phenomenon, AIRCOAT intends to implement this effect on a **self-adhesive foil system**.

MAGNIFICATION

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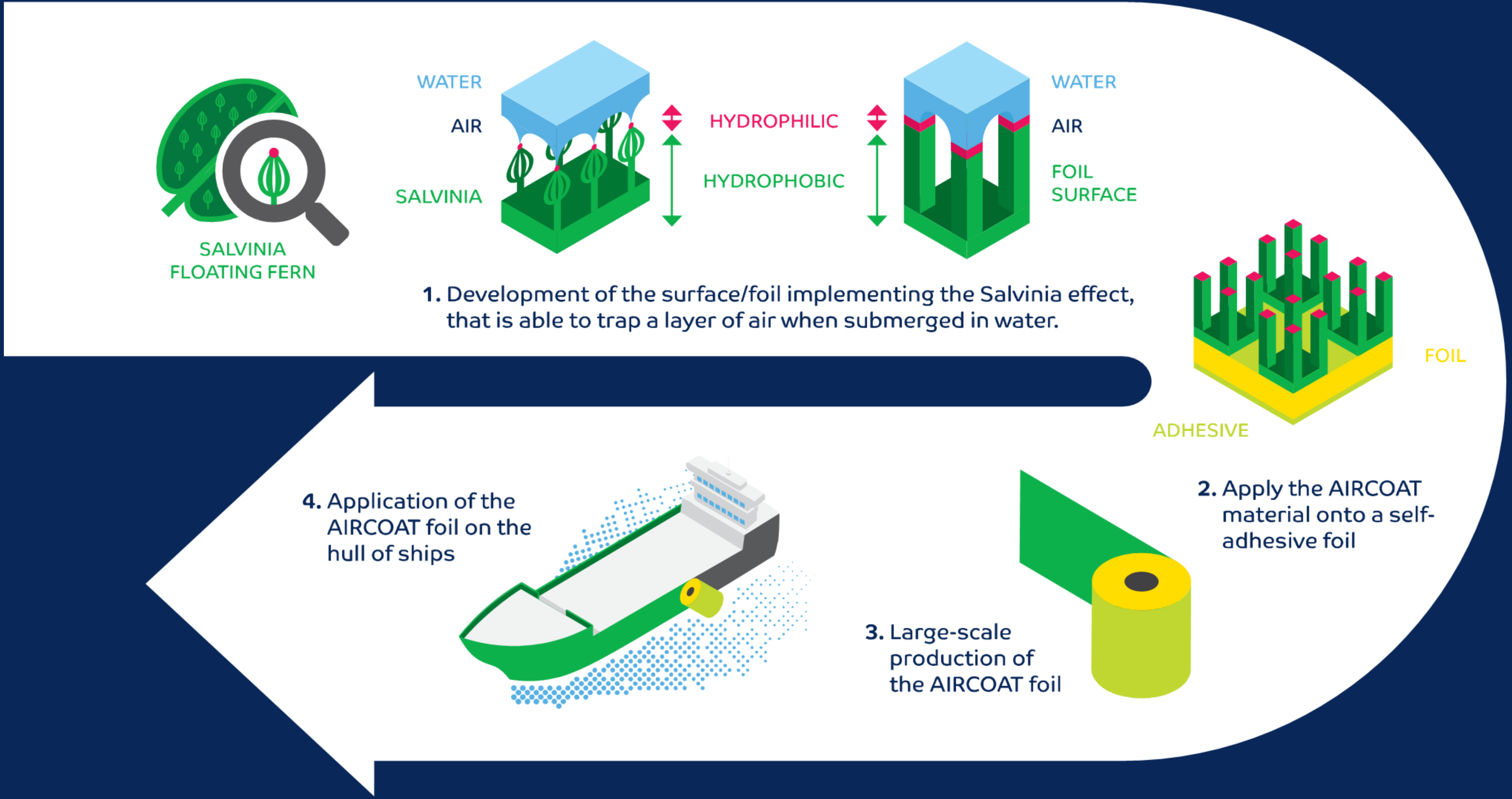

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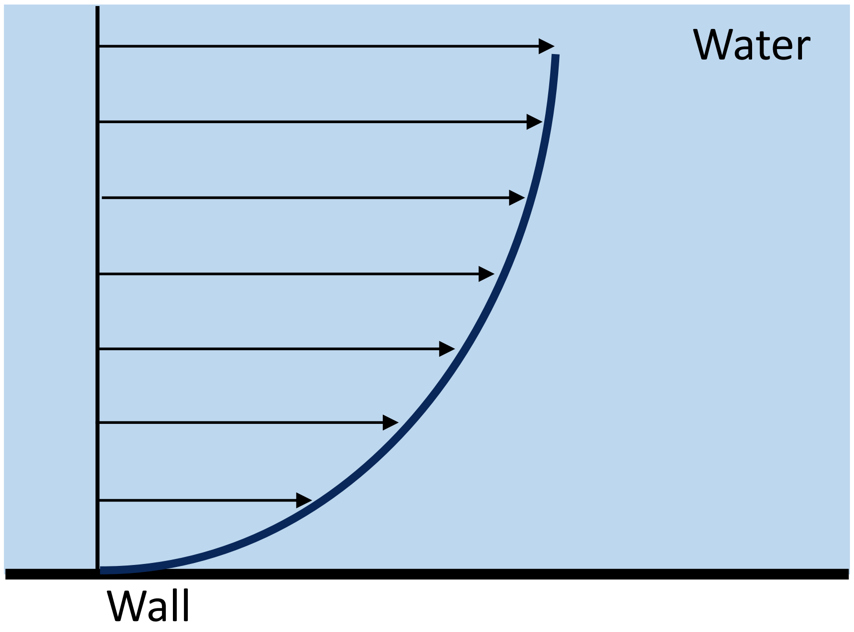
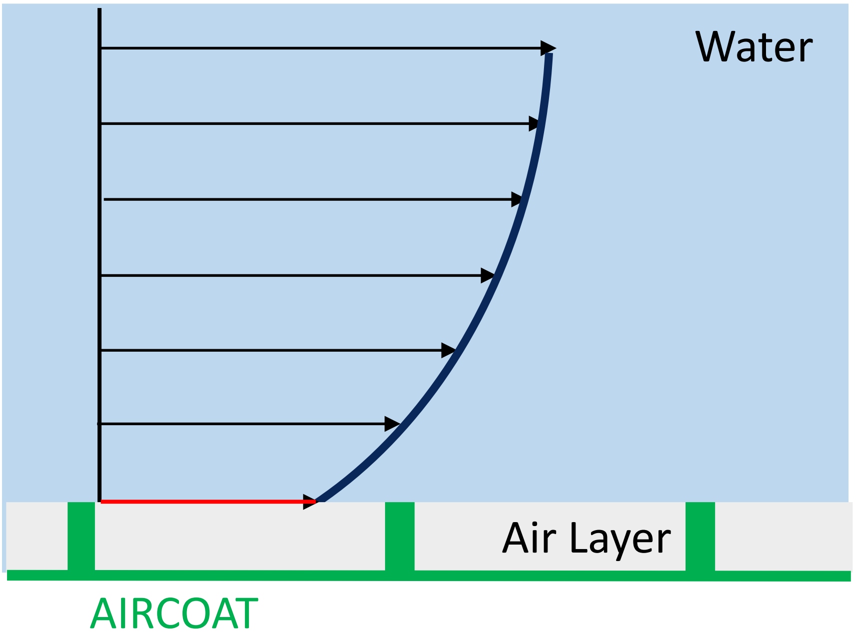
DRAG REDUCTION OF AIR LUBRICATION





VELOCITY = 0
↓
HIGH GRADIENT
↓
HIGH SHEAR STRESS

VELOCITY > 0
↓
LOWER GRADIENT ➡ **REDUCED (SKIN) FRICTION**
↓
LOWER SHEAR STRESS

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AIRCOAT BENEFITS

Primary Friction Reduction

Passive Air Lubrication

- ↓ Friction
- ↓ Energy use
- ↓ Costs

↓ Emissions

Physical Barrier

Secondary Friction Reduction

- ↓ Biofouling
- ↓ Corrosion
- ↓ Biocides
- ↓ Noise

↑ Fuel Efficiency **↑ Sustainability** **→ Refit Technology** **→ No application limit**

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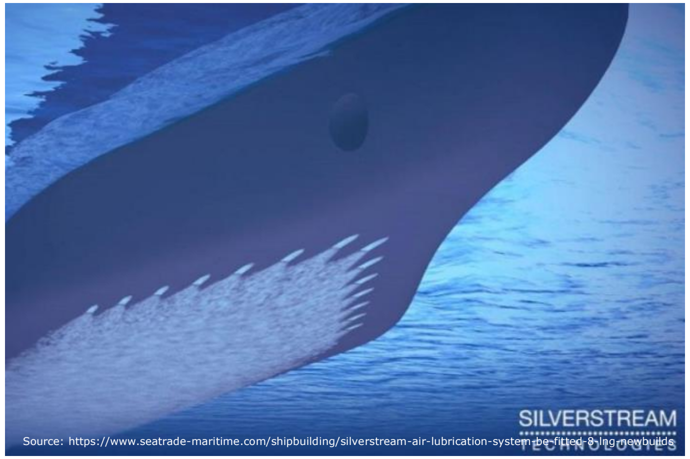
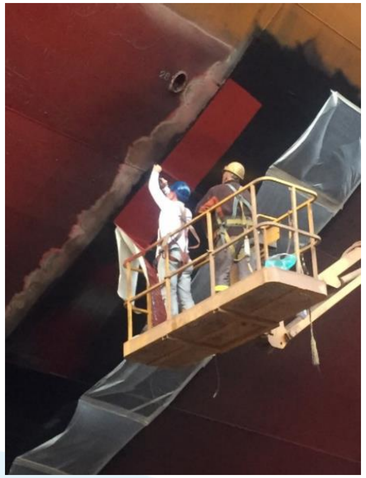
REPLACING PAINTS WITH AIR LUBRICATING FILMS

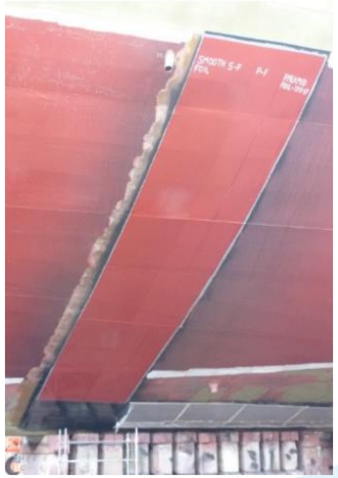
Source: https://safety4sea.com/hull-coatings-technologies

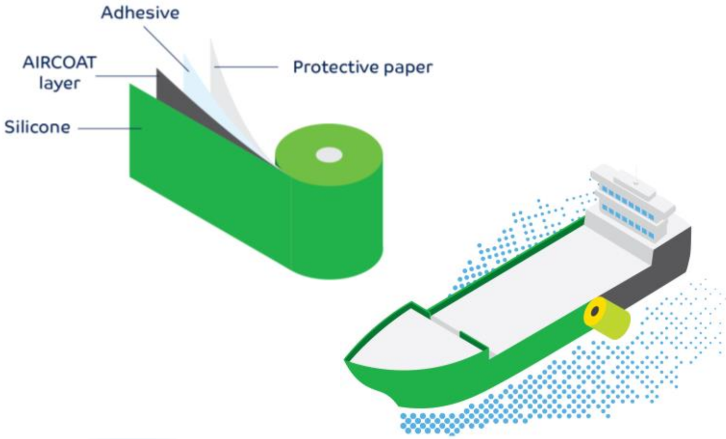
Source: https://www.motorship.com/news101/ships-and-shipyards/airmax-prototype-demonstrator-gets-airborne



Source: https://www.seatrade-maritime.com/shipbuilding/silverstream-air-lubrication-system-be-fitted-8-lng-newbuilds







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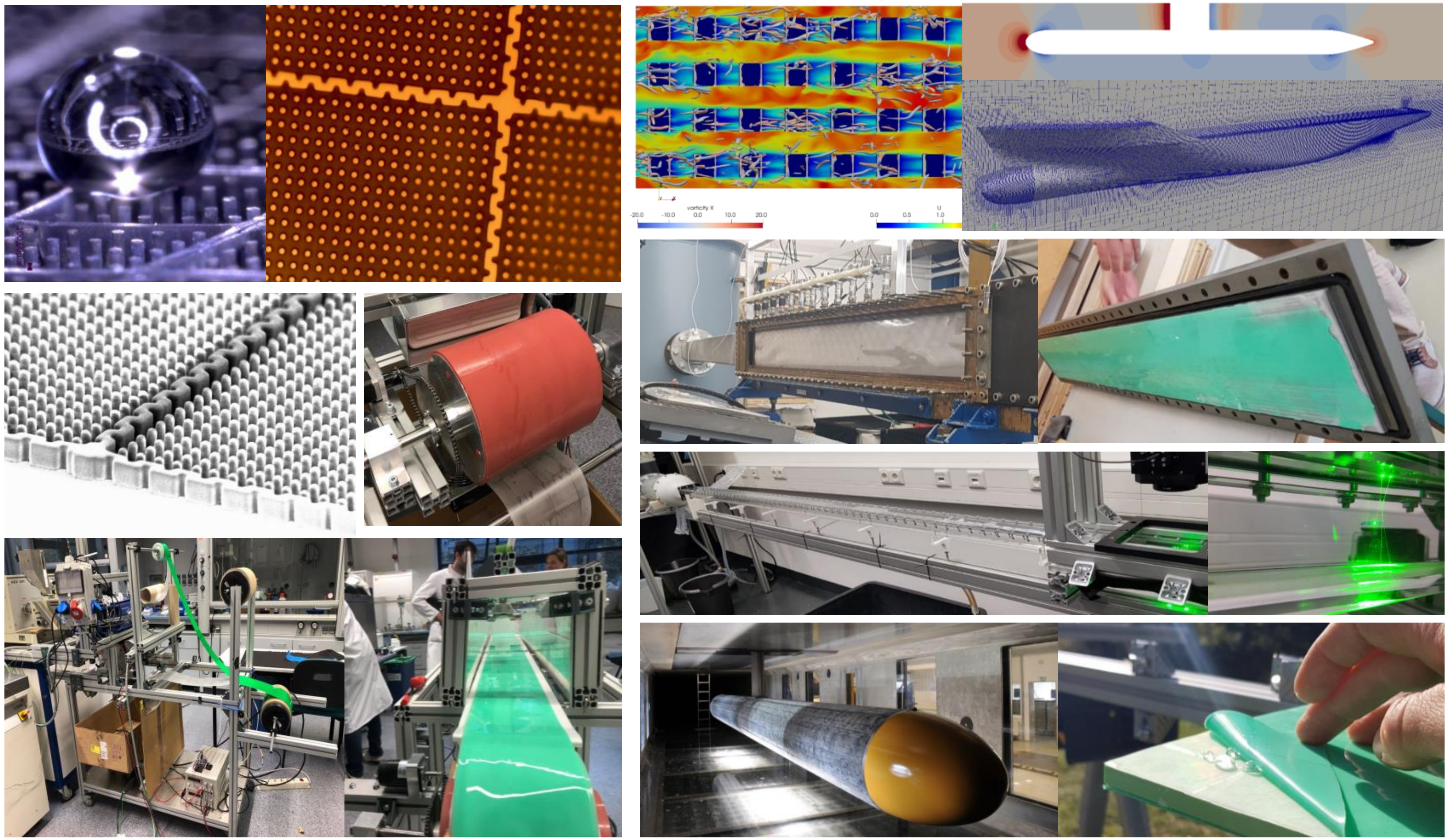
slido

Have you ever worked with an adhesive coating to protect a ship hull?

ⓘ Start presenting to display the poll results on this slide.

PRODUCTION, EXPERIMENTS, NUMERICS



- Project results show highly complex dependencies of
  - ✓ Air Layer Stability
  - ✓ Application Depth
  - ✓ Fouling Behaviour
  - ✓ Drag Reduction
  - ✓ Production Feasibility
  - ✓ Material

- The larger the depths the higher the cost for production and innovation

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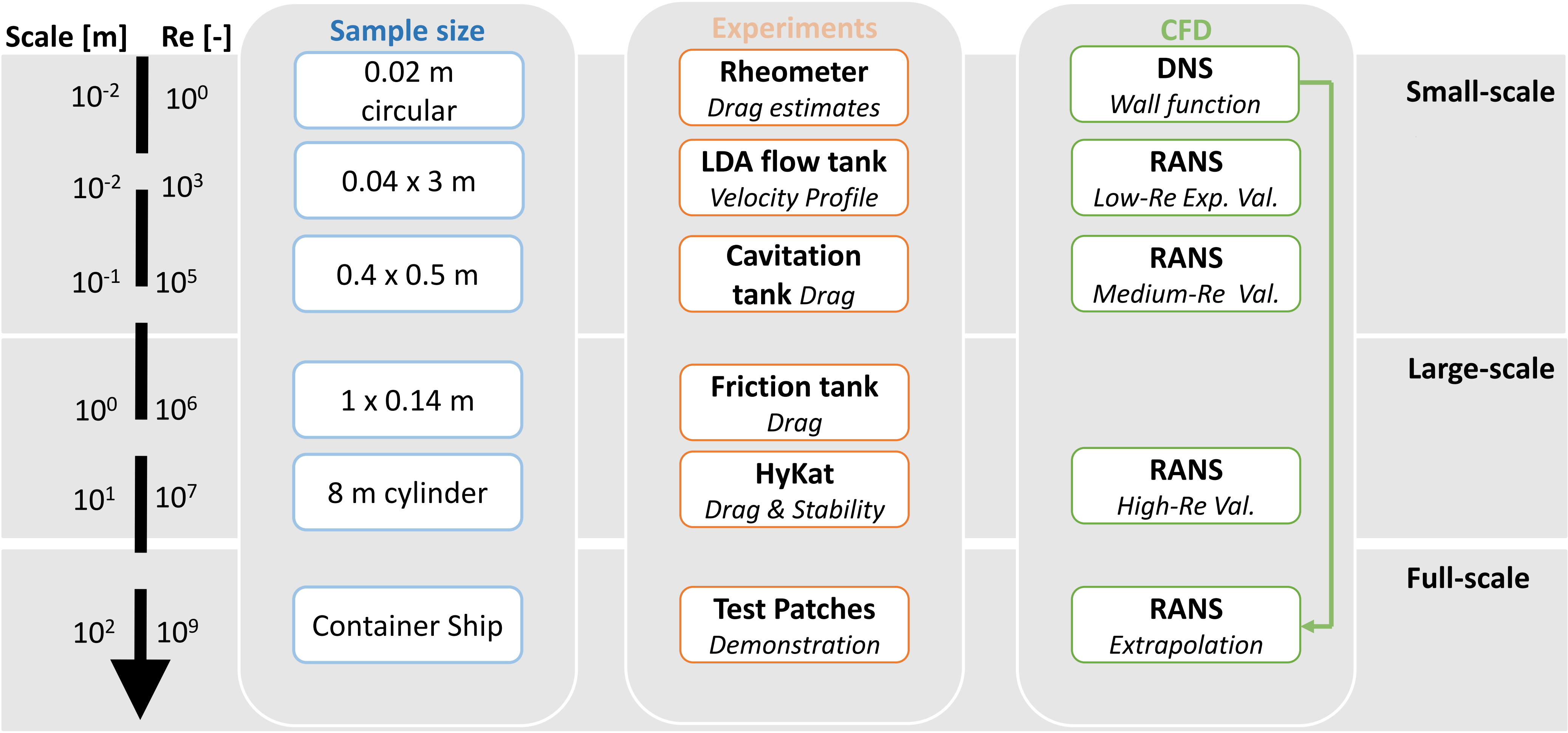
AIRCOAT SCALING



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| TODAY’S SESSIONS

AIRCOAT

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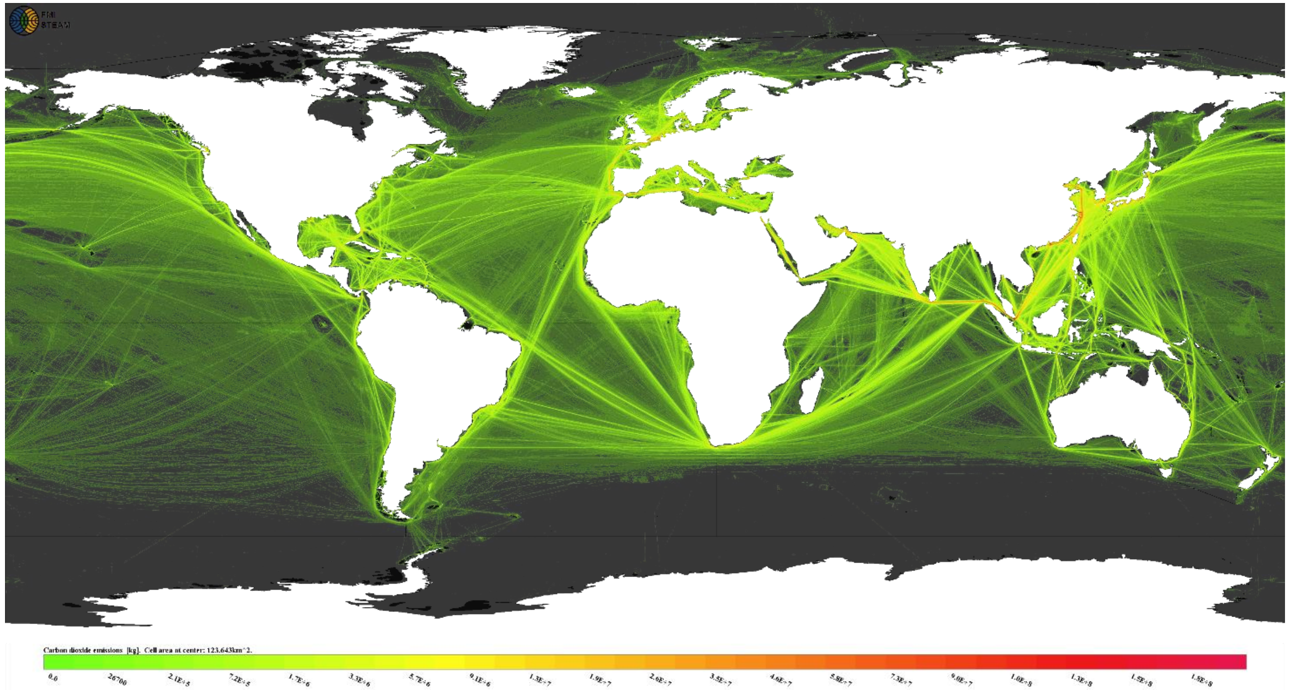
TODAY'S SESSION 1

Large scale: Friction Reduction for the global fleet.

What is the main problem?



Presented by

Dr Jukka-Pekka Jalkanen
Senior Researcher
Finnish Meteorological Institute - FMI

FINNISH METEOROLOGICAL INSTITUTE

Team:

Jukka-Pekka Jalkanen, Lasse Johansson, Elisa Majamäki

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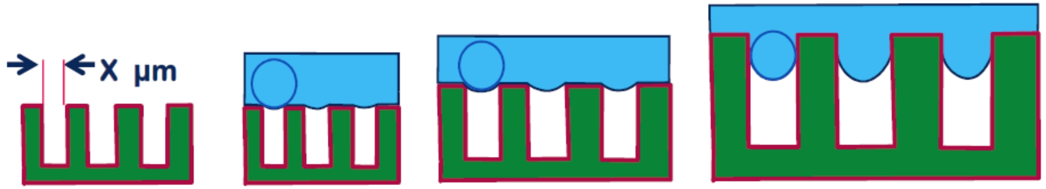
TODAY'S SESSION 2

Salvinia Effect and Air Spring Effect.
Focus on the structure of AIRCOAT, the production phase, why the size of the pillars matters.



Presented by

Dr Stefan Walheim
Senior Researcher
Karlsruher Institut Für Technologie - KIT

KIT Karlsruher Institut für Technologie

Team:

Matthias Barczewski, Roland Gröger, Robert Droll, Lutz Speichermann-Jägel, Susanna Dullenkopf-Beck, Stefan Walheim

Prof. Thomas Schimmel Group

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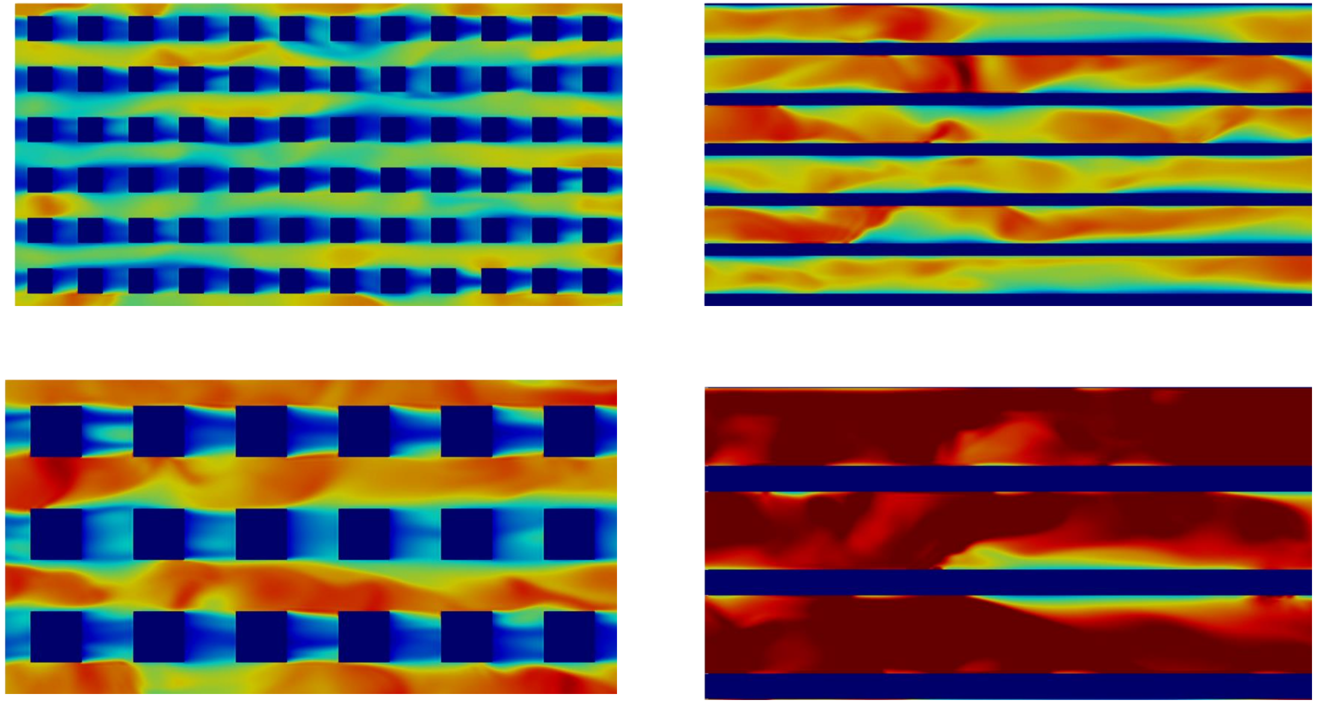
TODAY'S SESSION 3

Small scale drag reduction.
How to simulate AIRCOAT numerically?



Presented by

Christoph Wilms
Researcher
B-I-C of City University Of Applied Sciences Bremen

Dr Albert Baars
Group Leader Computational Fluid Dynamics | B-I-C of City University Of Applied Sciences Bremen

Team:
Christoph Wilms, Daniel Matz, Antonia Kesel, Albert Baars

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AIRCOAT

GLOBAL IMPACTS

AIR INDUCED FRICTION REDUCING SHIP COATING

Jukka-Pekka Jalkanen

Finnish Meteorological Institute

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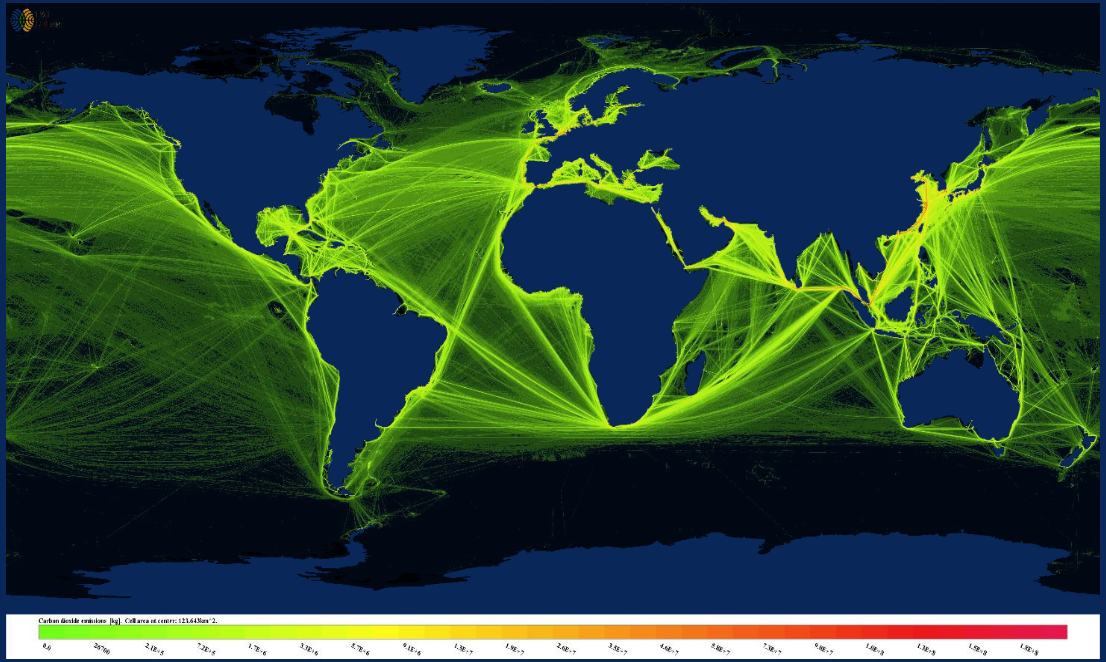
SHIPPING CONTRIBUTION TO GHG EMISSIONS

The 4th IMO GHG study: 1056 Mton CO_2 (2018)

- 2.9% from global total

Decarbonisation efforts

- Operational changes
- Energy efficiency improvements
- New fuels
- New designs, engines, abatement



CO_2 emissions from ships in 2018 (FMI)

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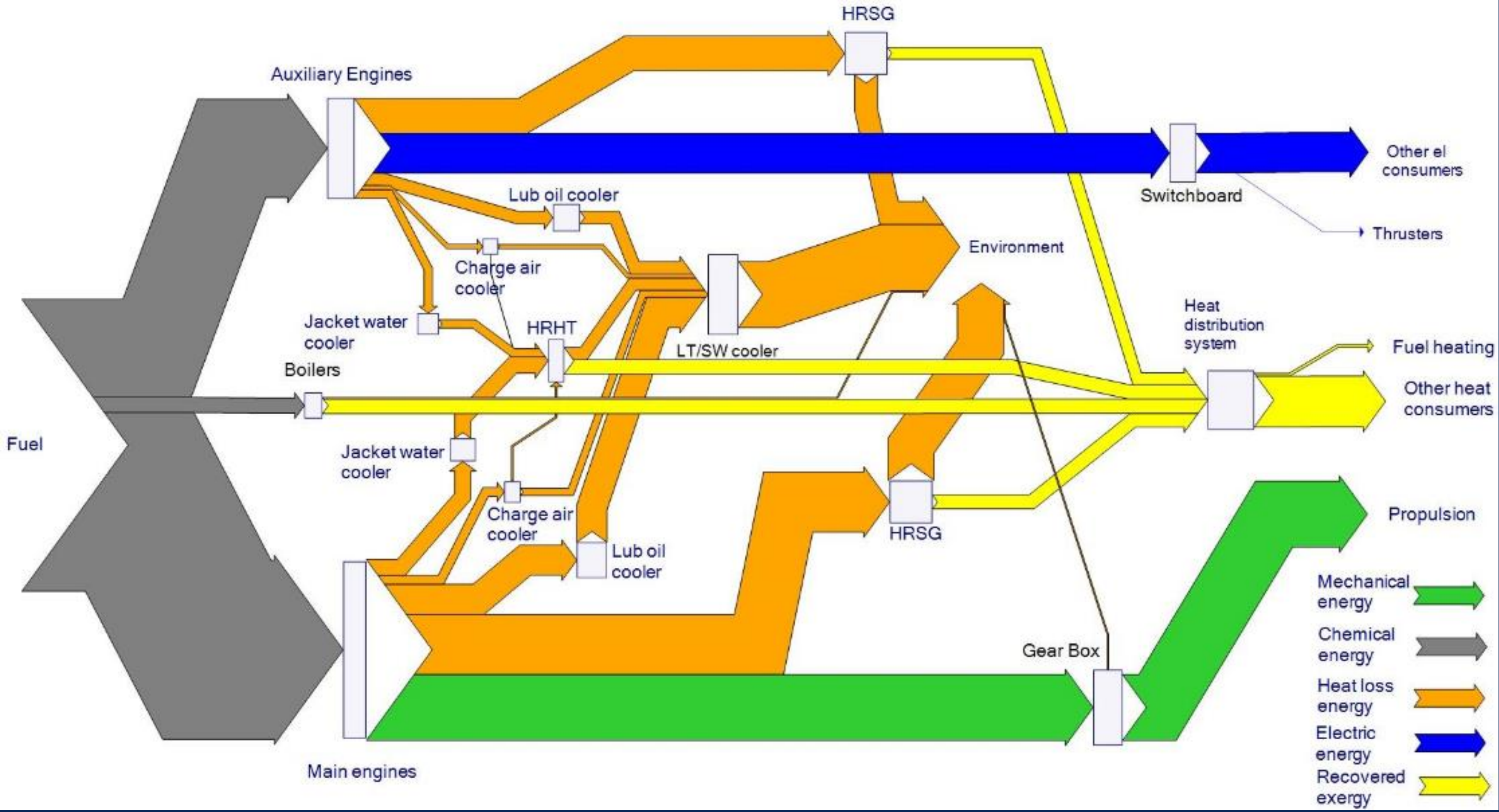
ONBOARD ENERGY FLOWS

- **Sankey diagram**
- **Fuel is used for**
  - ✓ Propulsion engines ~70-75%
  - ✓ Boilers
  - ✓ Auxiliary engines
- **Power transmission**
  - ✓ Mechanical
  - ✓ Electrical
  - ✓ Shaft generation



Baldi, F., Ahlgren, F., Nguyen, T., Gabrielii, C., Andersson, K. (2015): Energy and exergy analysis of a cruise ship. In: Proceedings of ECOS 2015

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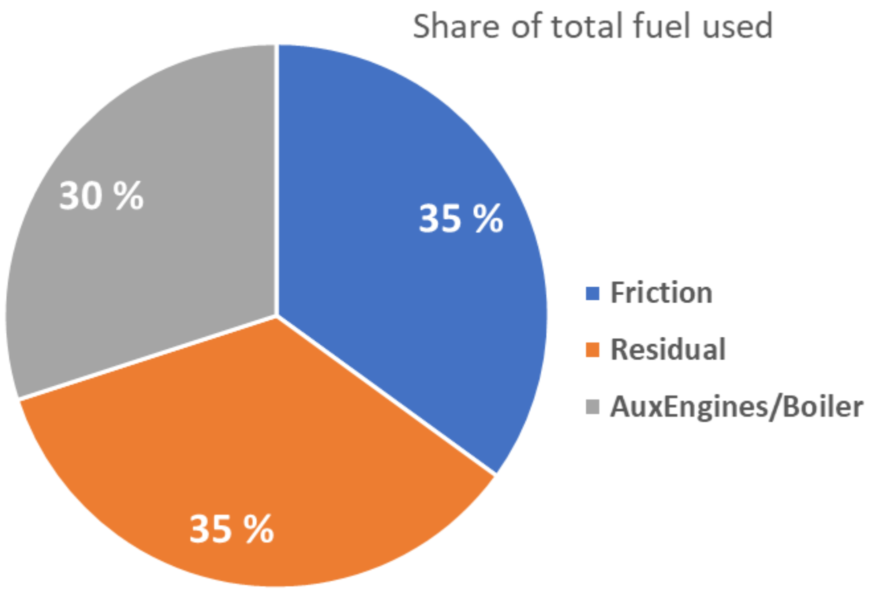
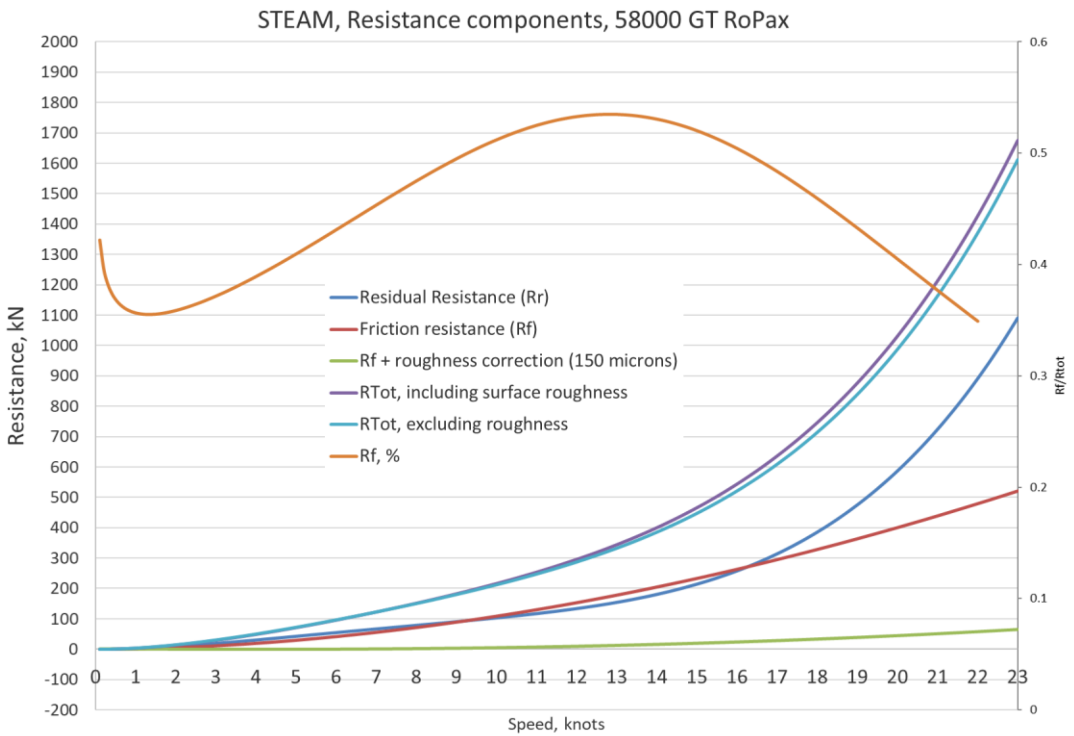
PROPULSION FUEL USE?

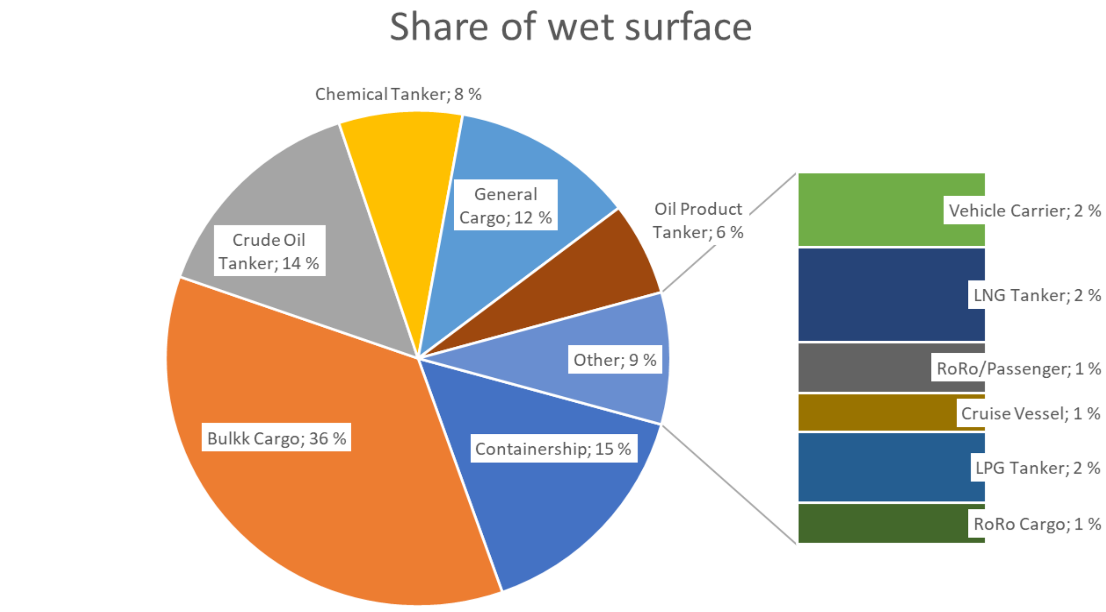
- ~70% of fuel used for propulsion
  - ✓ Friction, residual resistance
  - ✓ Speed dependent
  - ✓ Shiptype differences
- Identification of friction contribution
- Hull roughness vs friction
  - ✓ Biofouling
- Magnitude of friction in global fleet?
  - ✓ Slow & fast vessels

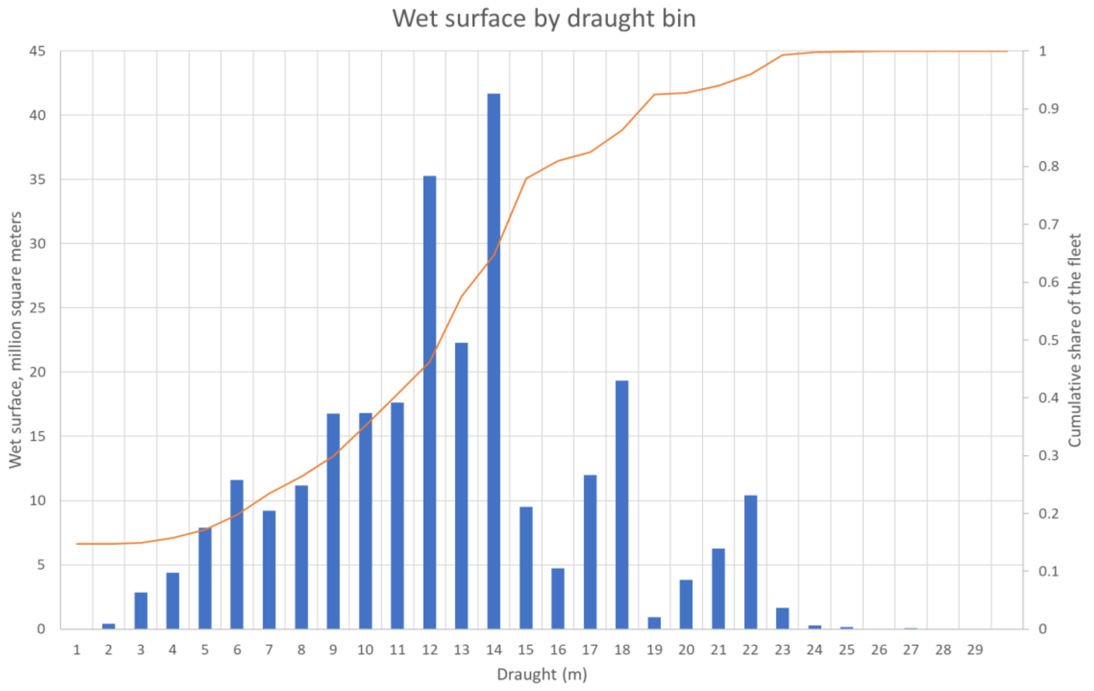




GLOBAL FLEET STATISTICS

- Global fleet draught histogram
- Ship specific wet surface area
- Ballast vs loaded
- How much of this can be covered with AIRCOAT?





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FRICTION REDUCTION?

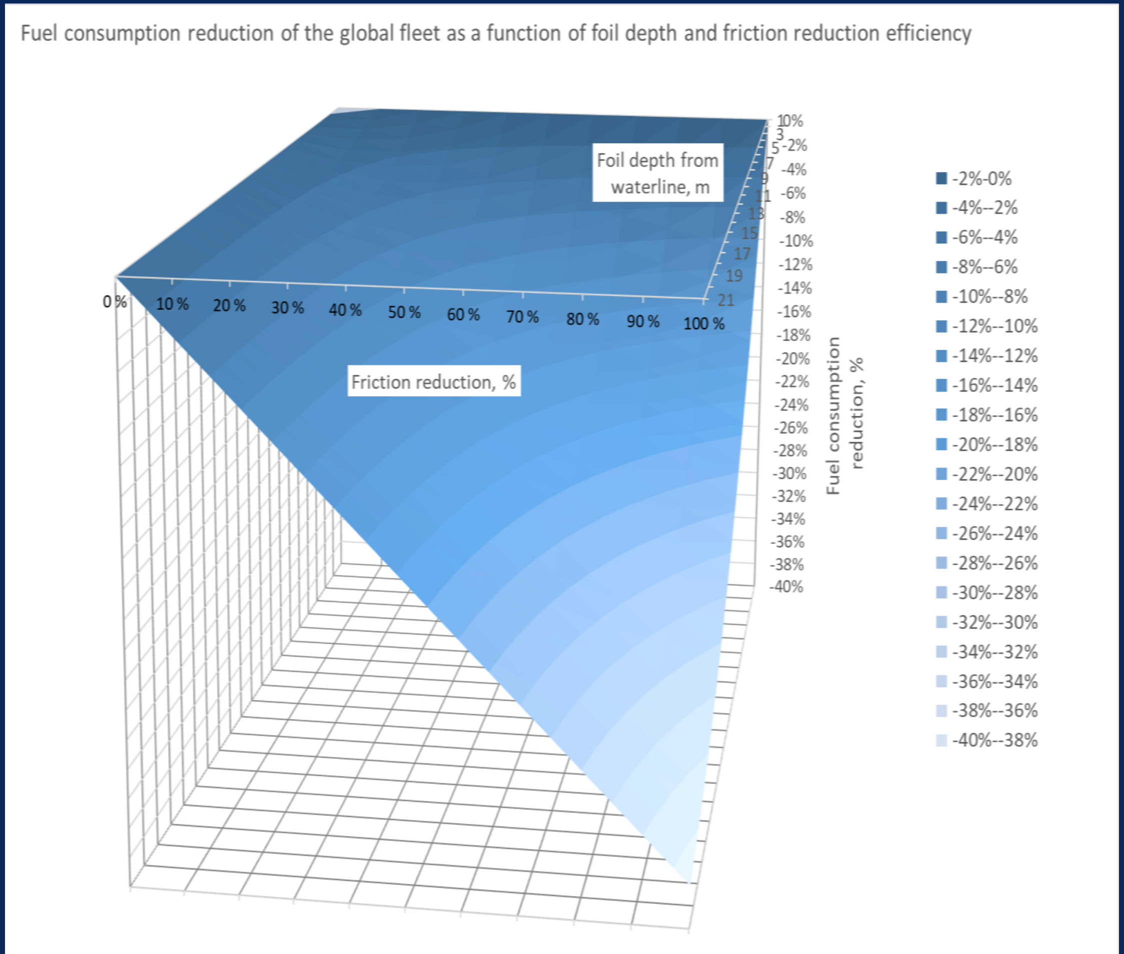
Proven methods

- Air bubbles
- Modification of surface coating

If successful, then the question becomes: Do ships…

a) Maintain the speed and benefit from lower fuel consumption, or

b) Use the friction reduction to increase speed?



STEAM prediction of fuel consumption with AIRCOAT application

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GHG REDUCTION POTENTIAL?

- Friction reduction of AIRCOAT?

Elimination of friction means 30/40% less fuel used.

- IMO GHG4 2050 estimate for CO_2 abatement with 100% air lubrication is low

Table 78 - (b) Calculated results for 2050

4th IMO GHG report

Code	Technology group	Scenario 1		Scenario 2	
		MAC (USD/tonne -CO_2)	CO_2 abatement potential (%)	MAC (USD/tonne -CO_2)	CO_2 abatement potential (%)
Group 10	Optimization water flow hull openings	-119	3.00%	-119	0.90%
Group 3	Steam plant improvements	-111	2.13%	-111	0.64%
Group 6	Propeller maintenance	-102	3.95%	-102	1.22%
Group 9	Hull maintenance	-91	3.90%	-91	1.24%
Group 12	Reduced auxiliary power usage	-59	0.71%	-59	0.21%
Group 8	Hull coating	-50	2.55%	-50	0.83%
Group 2	Auxiliary systems	-39	1.59%	-39	0.48%
Group 1	Main engine improvements	-34	0.45%	-34	0.14%
Group 13	Wind power	2	1.66%	2	0.50%
Group 16	Speed reduction	10	7.54%	10	8.18%
Group 5	Propeller improvements	18	2.40%	18	0.80%
Group 11	Super light ship	54	0.39%	54	0.12%
Group 4	Waste heat recovery	54	3.09%	54	0.93%
Group 7	Air lubrication	93	2.26%	93	0.77%
Group 15A	Use of alternative fuel with carbons	-	-	249	2.03%
Group 15B	Use of alternative fuel without carbons	416	64.08%	416	20.00%
Group 14	Solar panels	1,048	0.30%	1,048	0.09%

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OTHER BENEFITS?

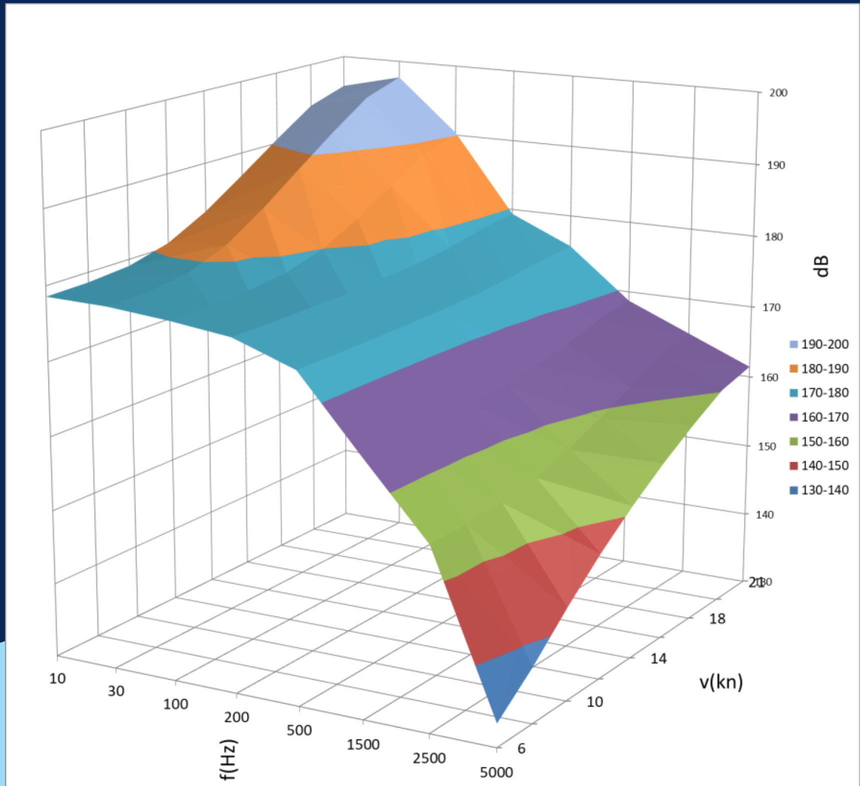
Reduction of antifouling paint use

- Tri-Butyl Tin (TBT) ban, antifouling convention
- Baltic Sea: 370 tonnes of Cu, 71 tonnes of Zn in 2019
- → Environmental impact?
- Fouling tests in AIRCOAT project

Noise reduction

- Noise vs AIRCOAT coating, performance vs layer thickness
- Impact on machinery noise, not the main source
- The main noise source, propeller, unaffected

(C) IIMS, https://www.iims.org.uk/time-to-rethink-the-challenge-of-global-biofouling/



Noise source level (FMI)

CONCLUSION

Over 2/3 of fuel is used to propel the vessel

- Half of that is used to overcome friction

Reduced friction can mean many things

- Increased ship speed with same amount of fuel, or
- Reduced fuel consumption at normal speed

Potential benefits of AIRCOAT

- Less fuel used: Reduction of emissions
- Avoidance of toxic hull paints
- Dampening of vessel noise, esp. machinery noise

LESS FRICTION

LESS FUEL USE

LESS EMISSIONS

Nature has solved some of these problems already → Biomimetics

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SALVINIA EFFECT AND THE BIOMIMETIC STRUCTURE OF AIRCOAT

Stefan Walheim
KIT Karlsruhe Institute of Technology

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THE SALVINIA EFFECT

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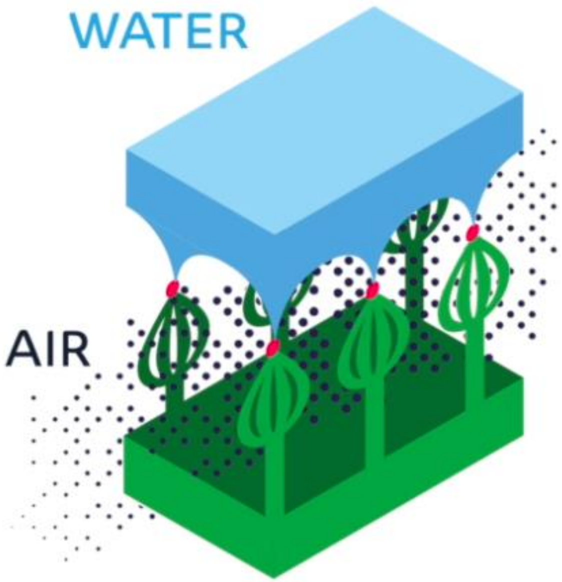
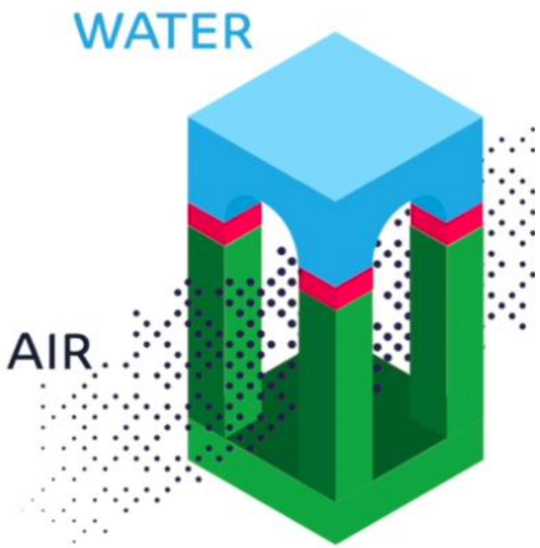


SALVINIA PLANT



AIRCOAT FOIL

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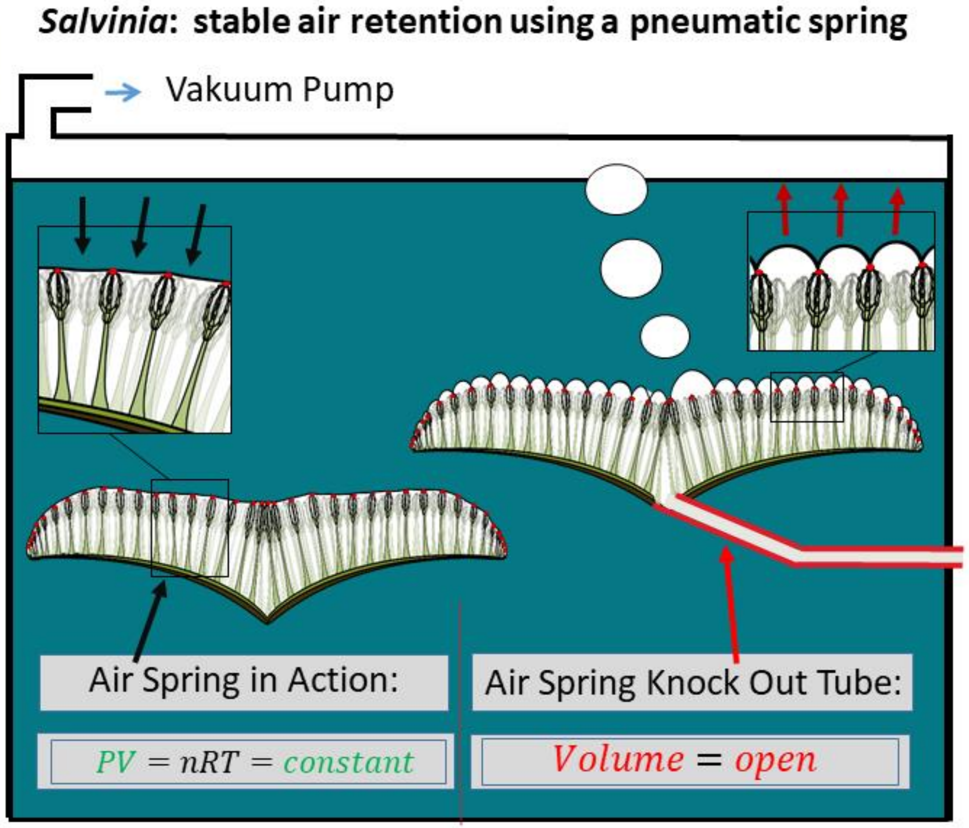
THE AIRSPRING EFFECT: UNRAVELLING THE SECRET OF THE MISSING 99%

PINNING FORCE VS. AIR SPRING EFFECT



Air Retention under Water by the Floating Fern Salvinia: The Crucial Role of a Trapped Air Layer as a Pneumatic Spring

Daniel Gandyra[1], Stefan Walheim[1], Stanislav Gorb[2], Petra Ditsche[3], Wilhelm Barthlott[3], and Thomas Schimmel*[1,4]*

Small ***2020****, 2003425,* ***DOI: 10.1002/smll.202003425***

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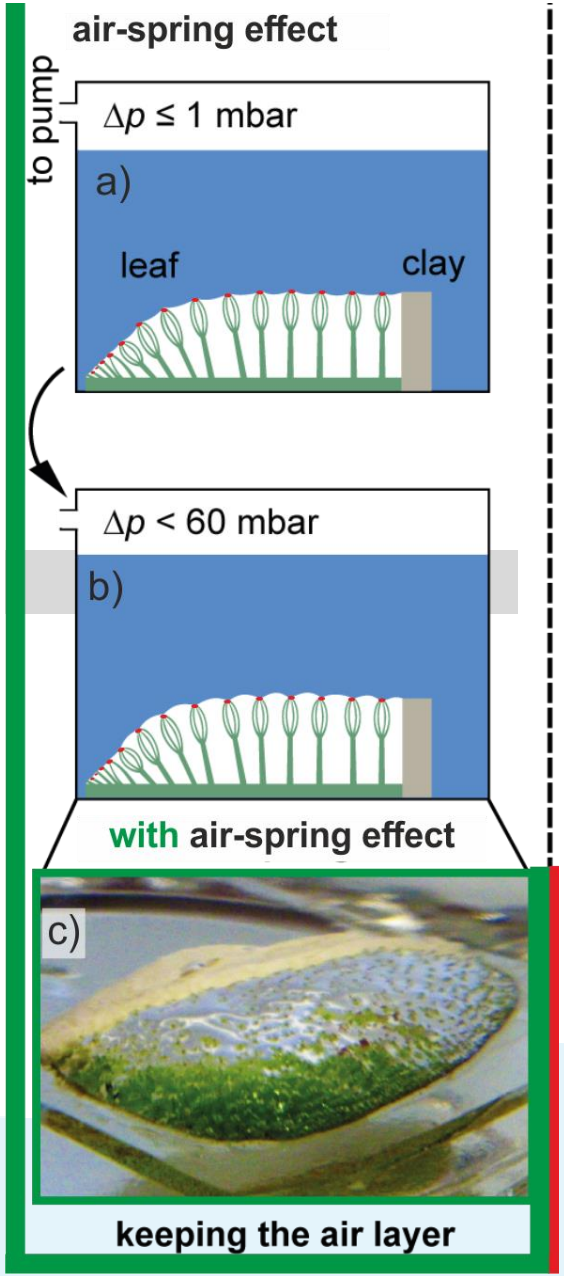

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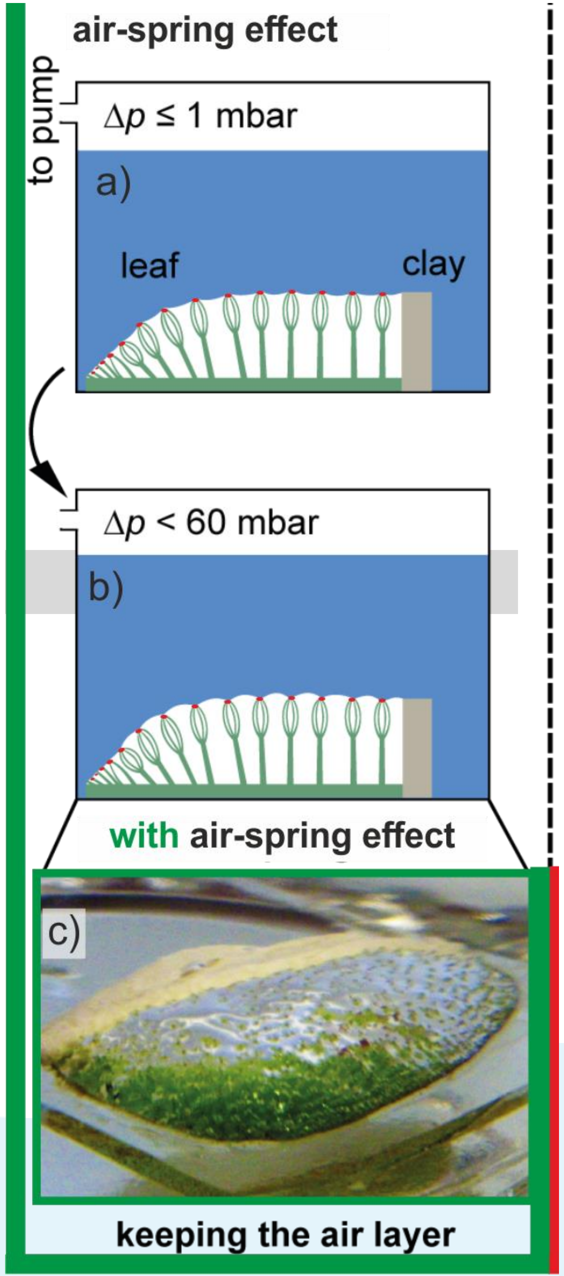

The entrapped air volume acts as a pneumatic spring

when the entrapped air volume is compressed or expanded, it produces a restoring force according to:

$$pV = nRT = const.$$

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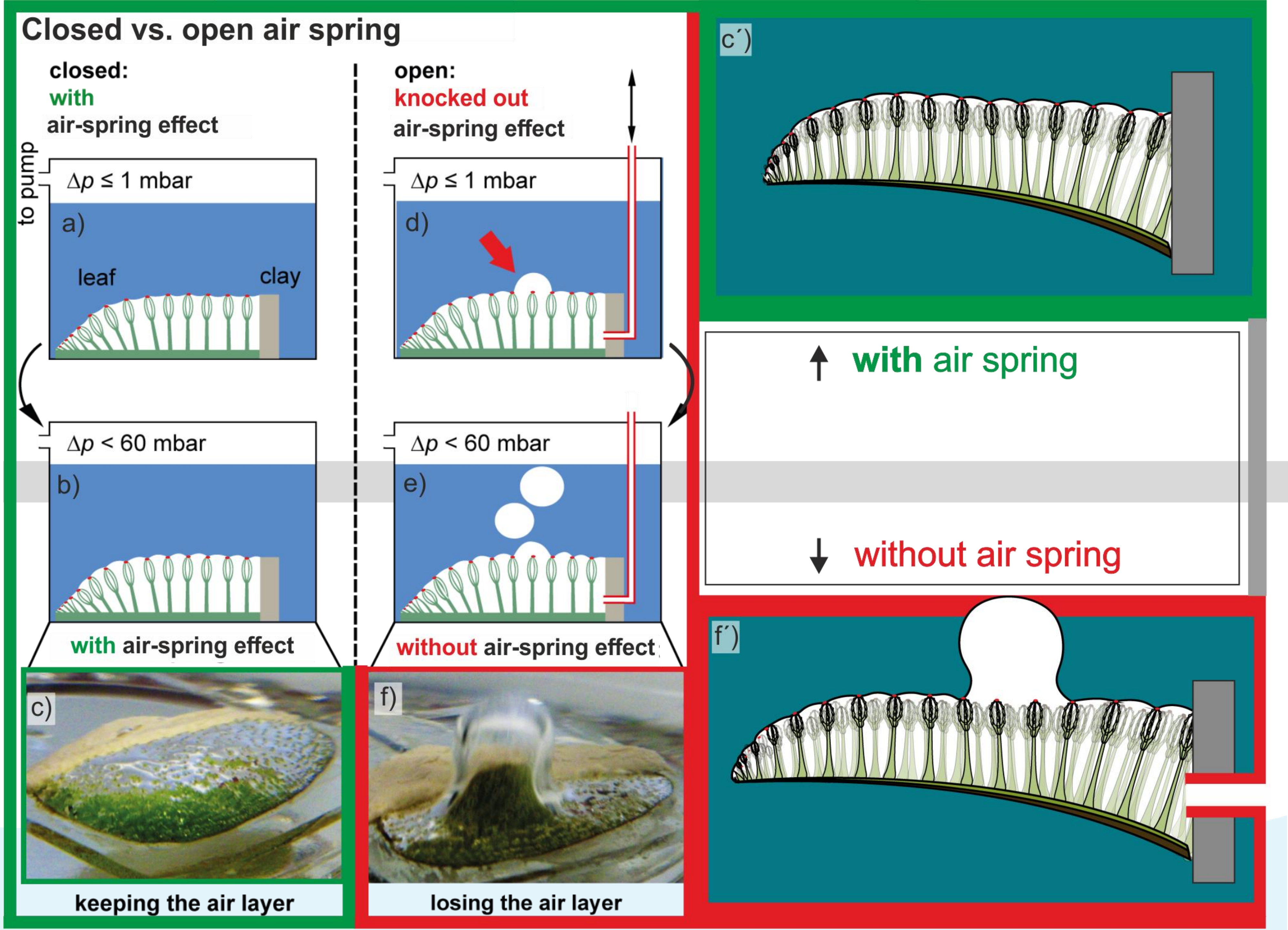
THE AIRSPRING EFFECT:

UNRAVELLING THE SECRET OF THE MISSING 99%



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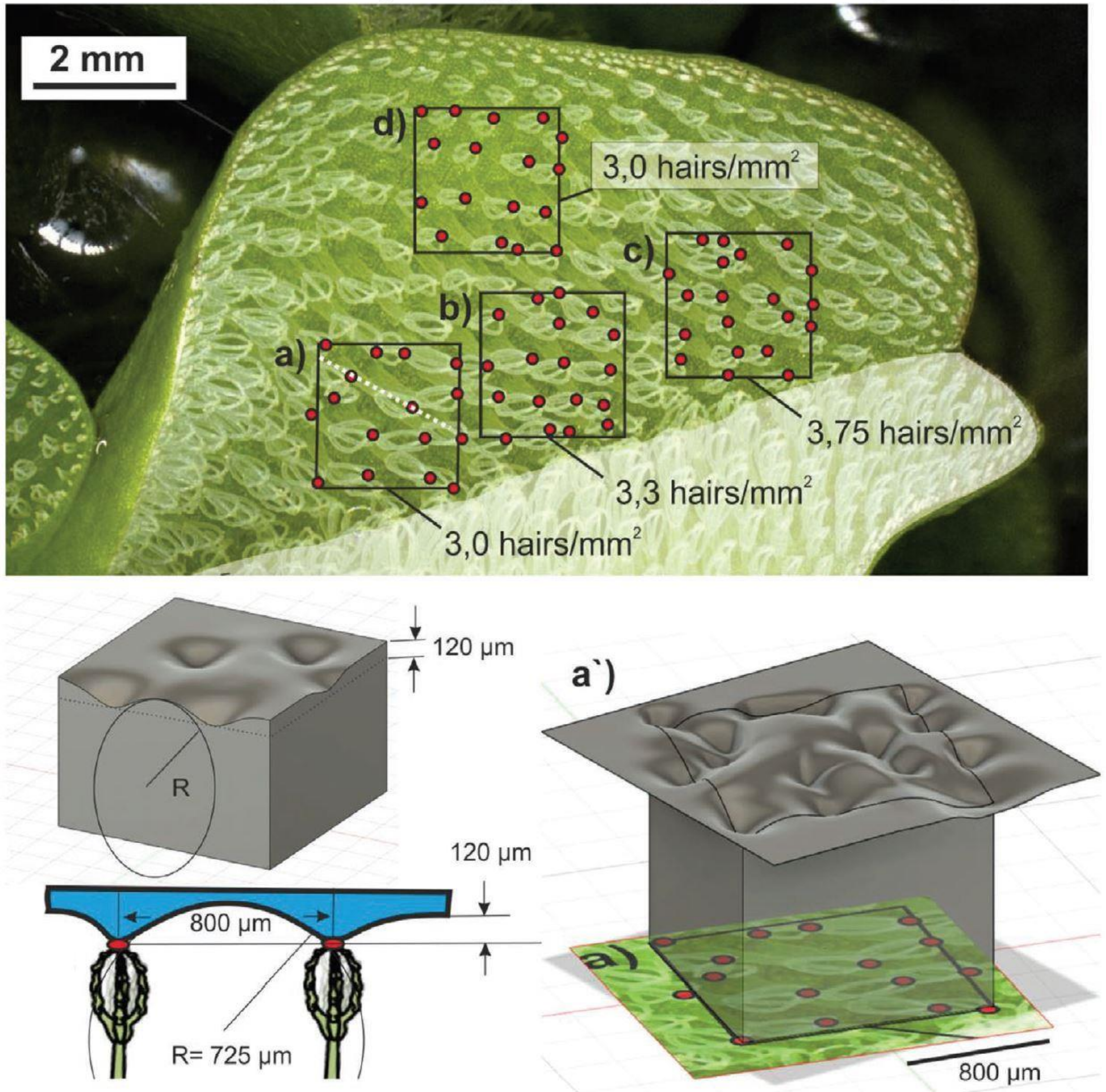
Quantative analysis of pinning point density and air spring function



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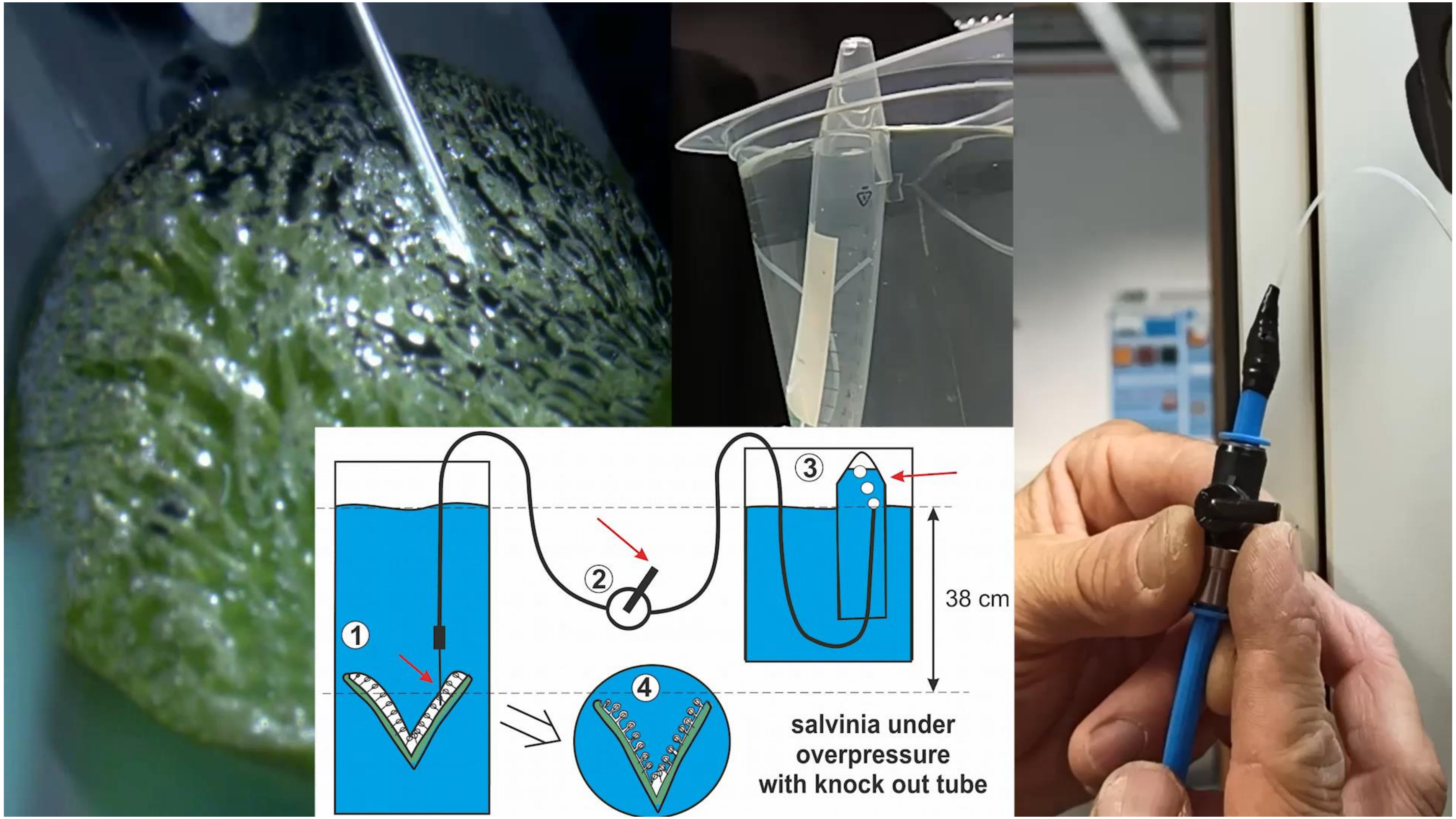

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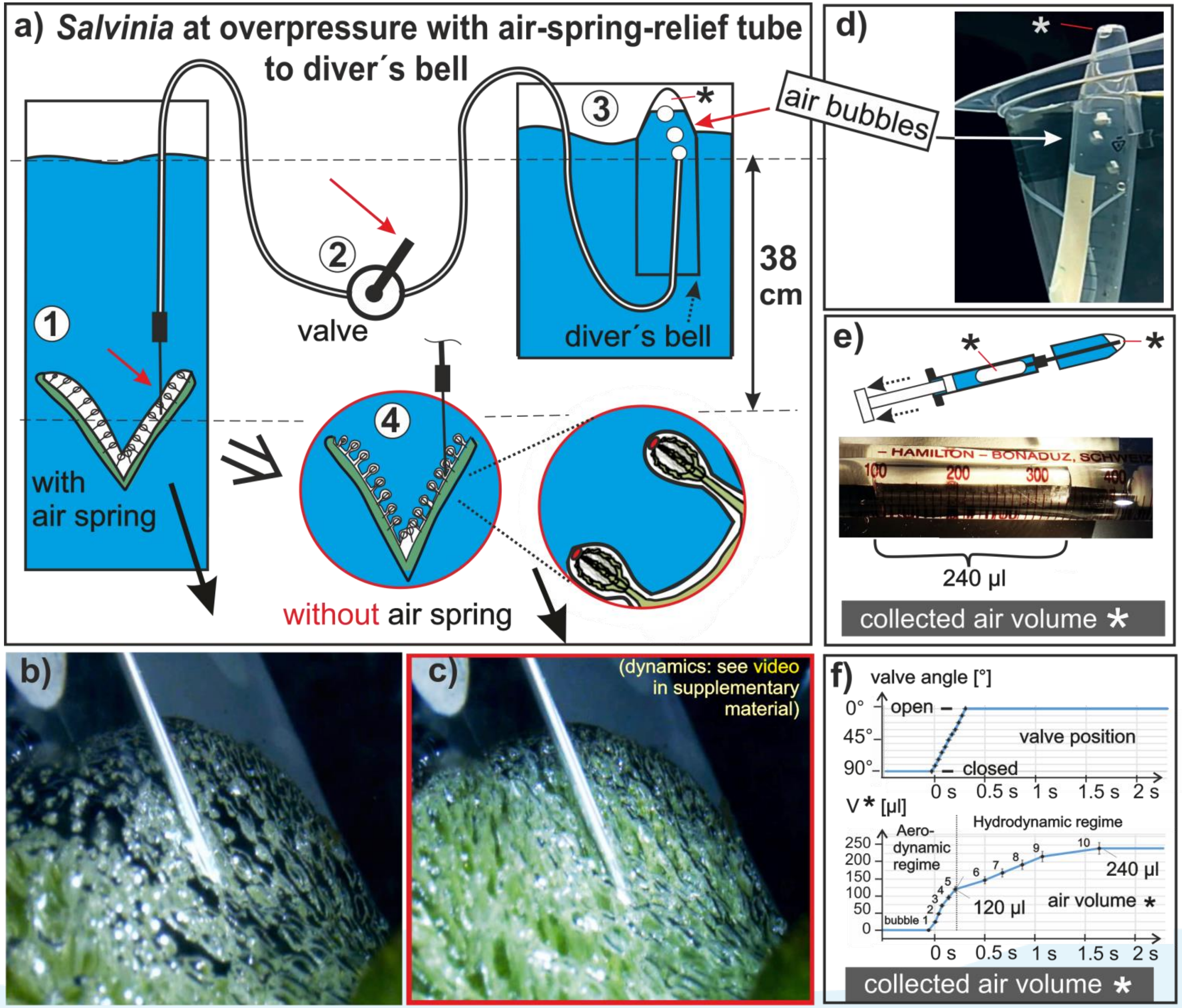

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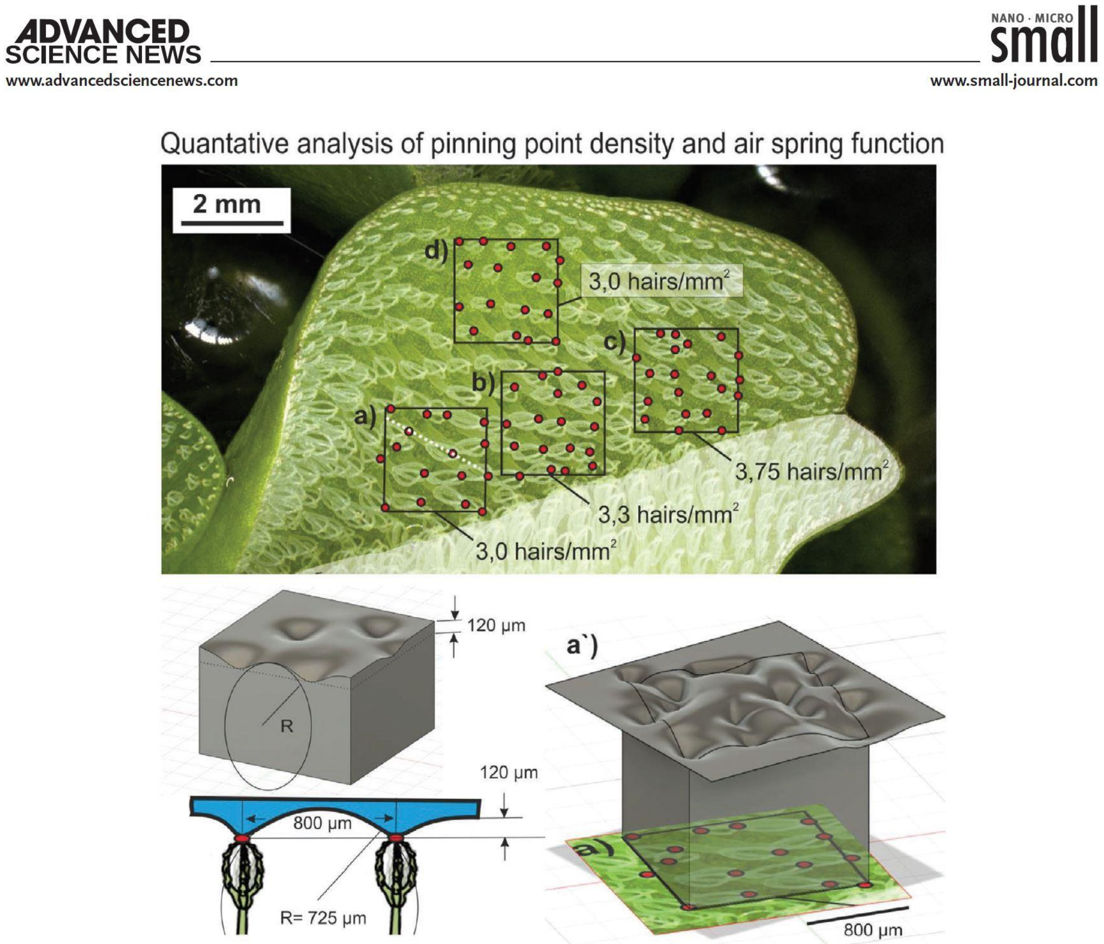
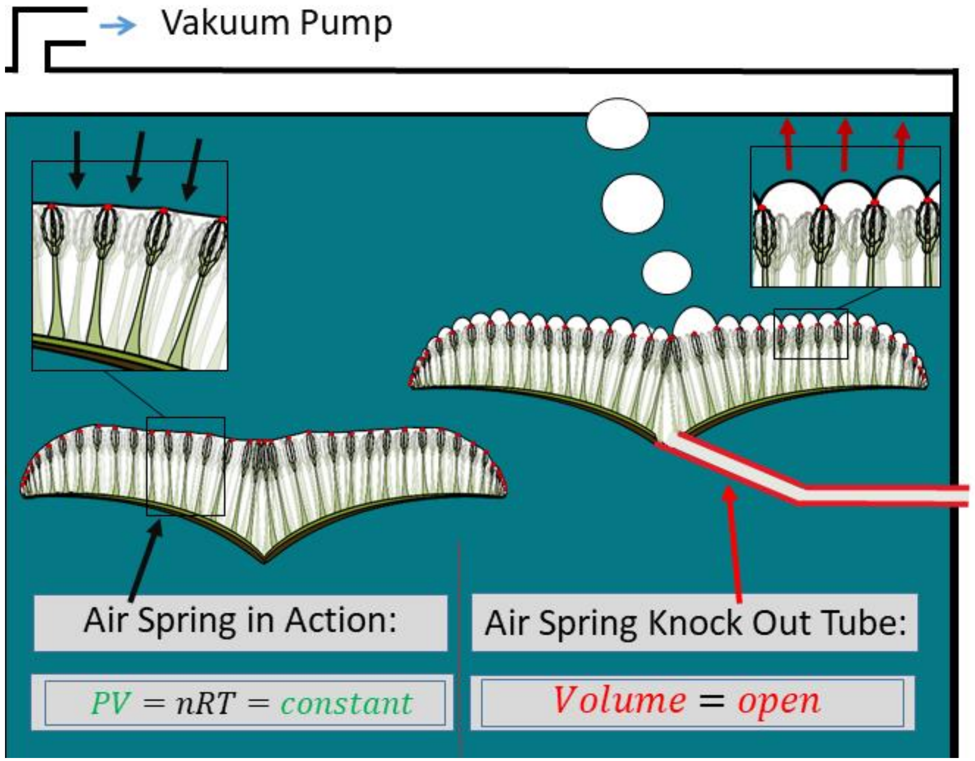
THE AIR SPRING EFFECT-EFFECT EFFECTIVELY STABILISES THE AIR LAYER





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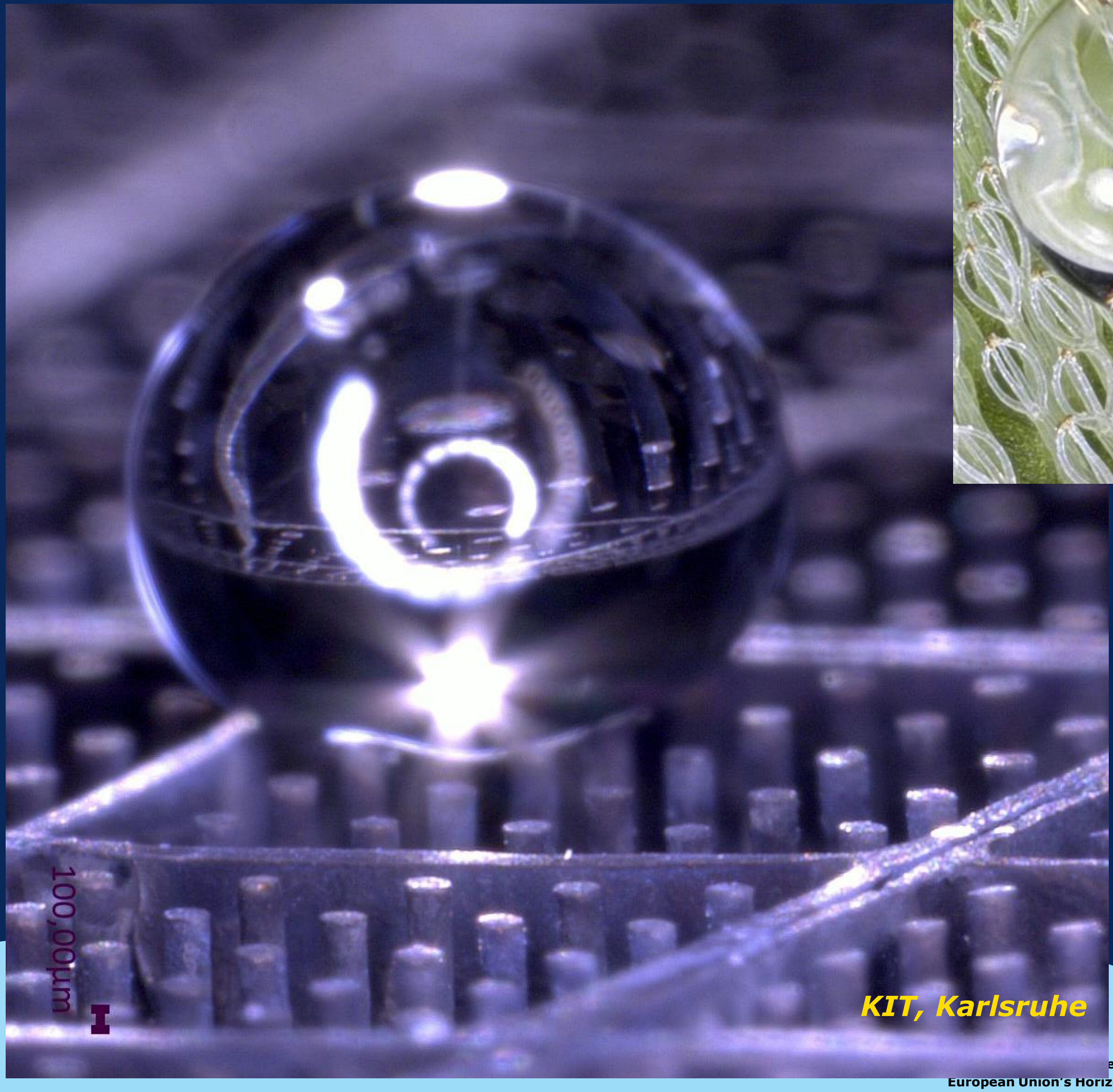
A WATER DROPLET CARRIED BY THE PILLARS OF AN ARTIFICIAL BIOINSPIRED STRUCTURE



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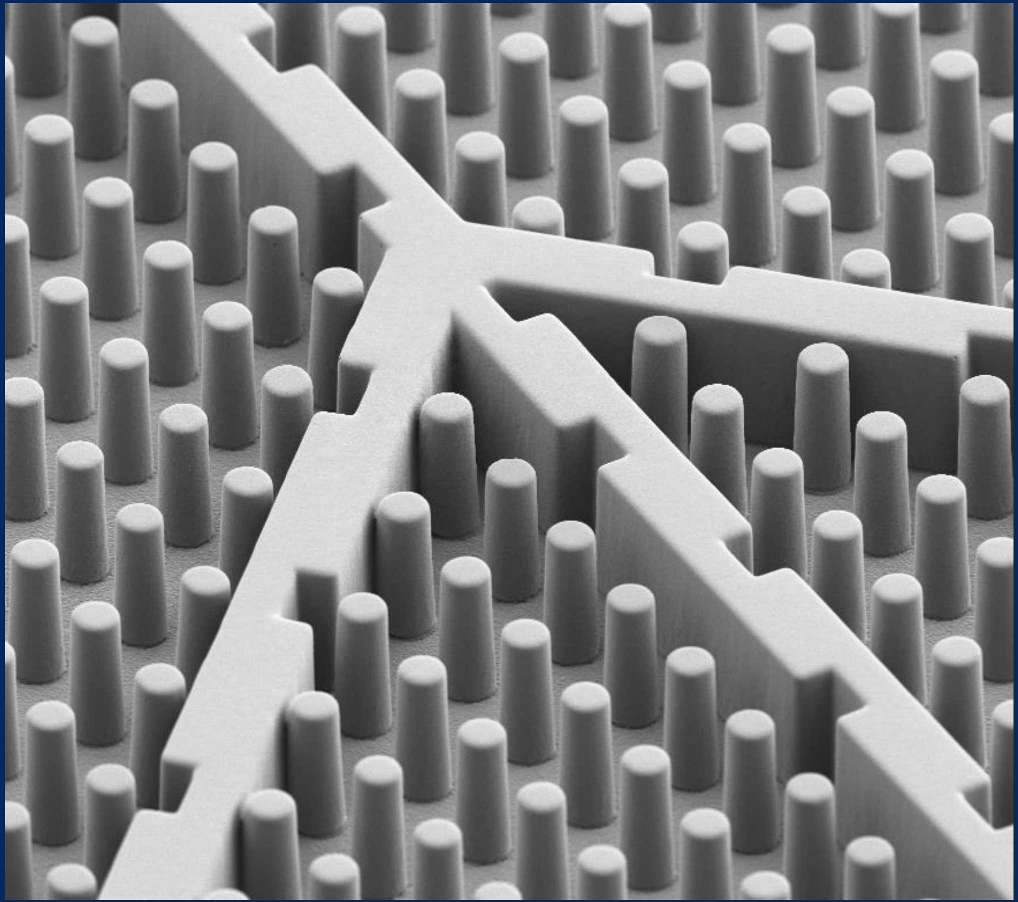
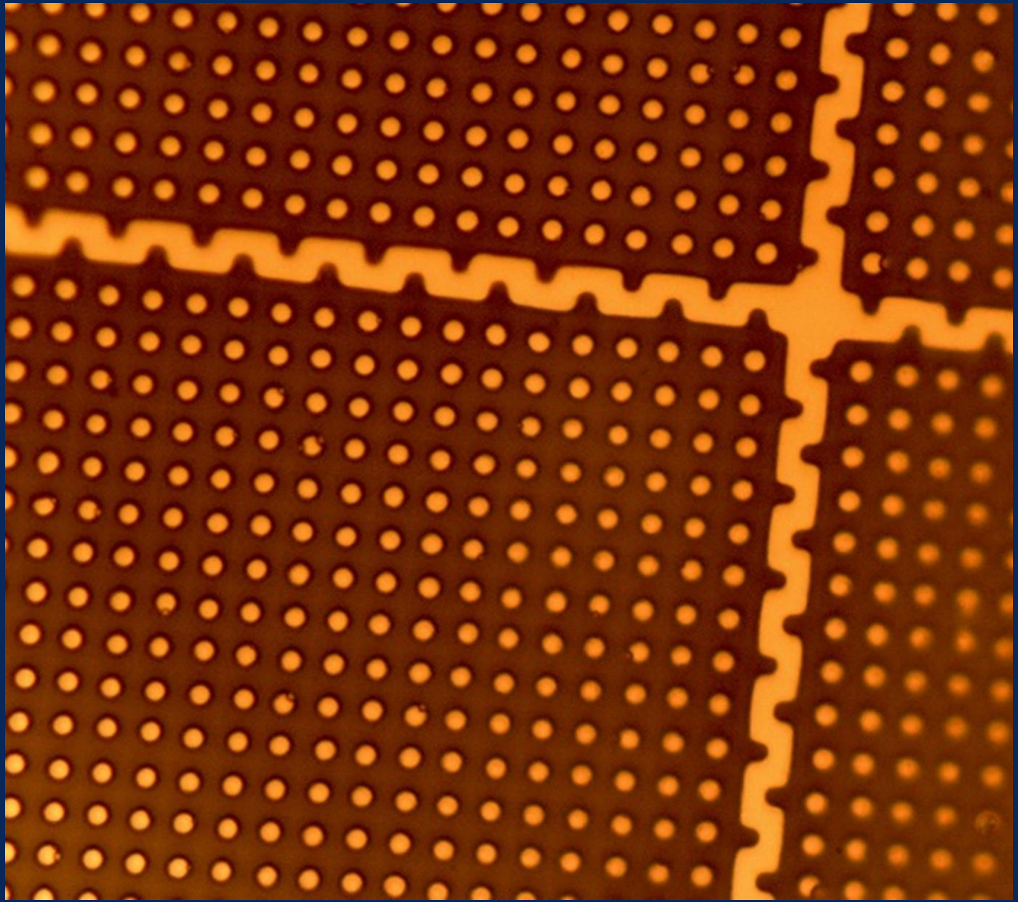
Getting Much Smaller: Ultrasmall Patterning

Progress towards technological air-retaining surfaces: ultrasmall structure development for higher pressures





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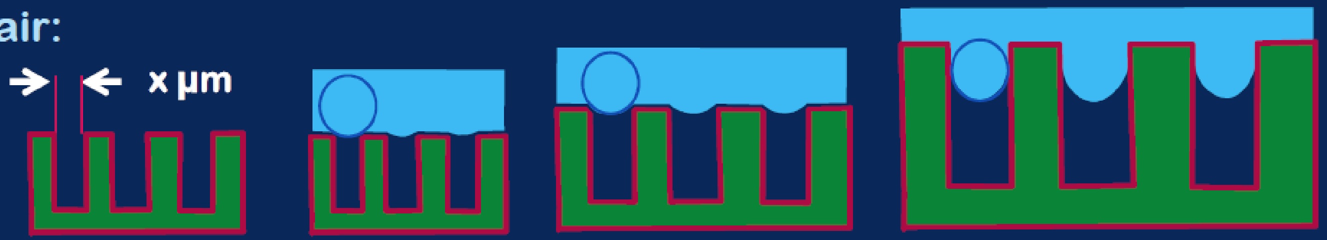
PRODUCING SMALL SAMPLES AND SCALE UP

Structures for permanent air retention under hydrostatic pressure:

1. **Structure size has to be small!**
   The smaller, the deeper the structure can retain air:

   100 µm → 0.1 m Draught
   10 µm → 1 m Draught
   1 µm → 10 m Daught



Theoretical values for 120° water contact angle

2. **Material has to be hydrophobic**
   Water Contact Angle (WCA) has to be > 100°
   (advancing and receding) → chemical functionalization

3. **Structures have to be producable (in large scale) → mechanical stability and mouldability**

4. **For efficient drag reduction:**
   - The depth of the structure has to be high
   - The contact area has to be as small as possible

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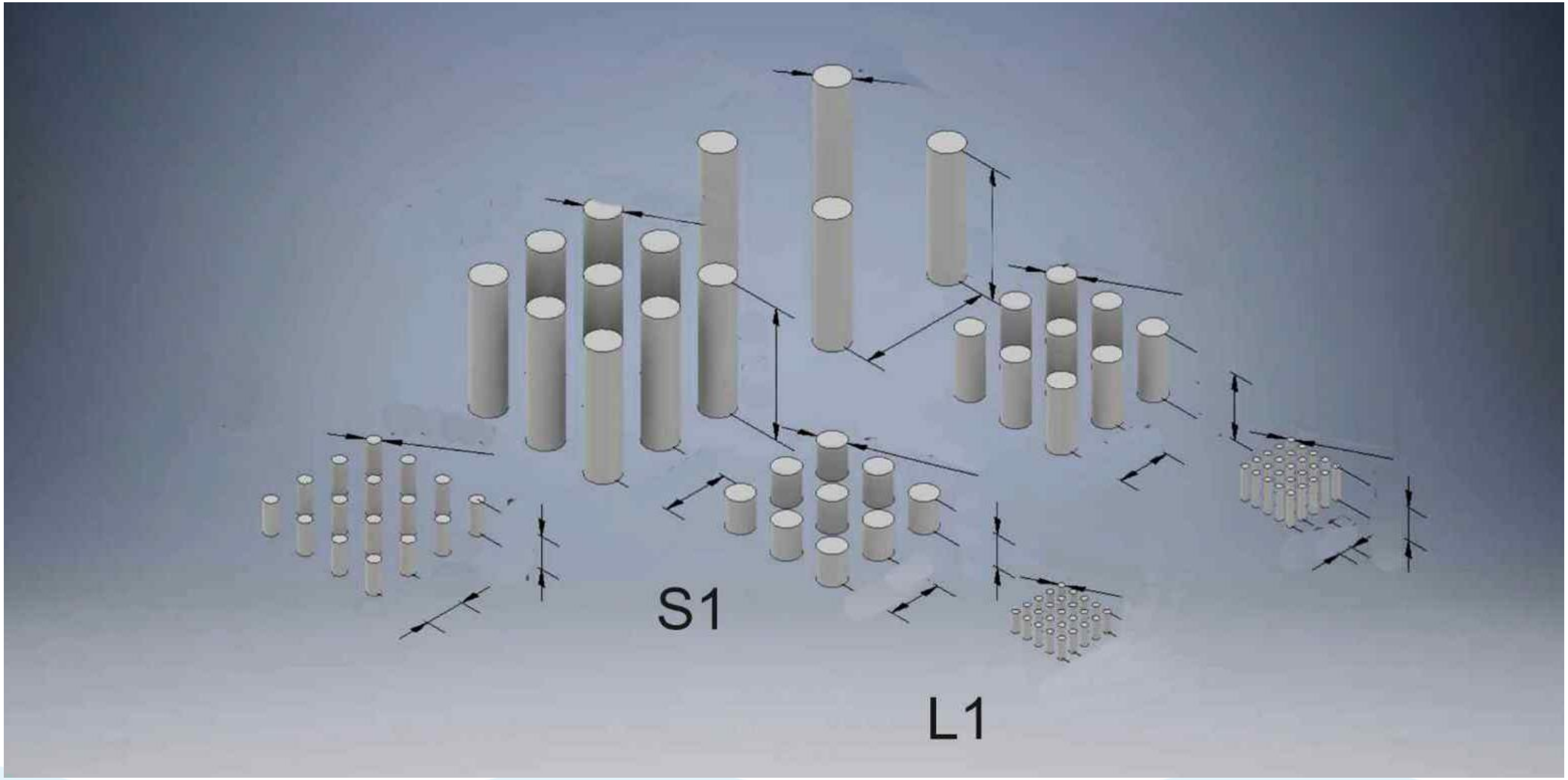
AIRCOAT SURFACE STRUCTURE EVOLUTION



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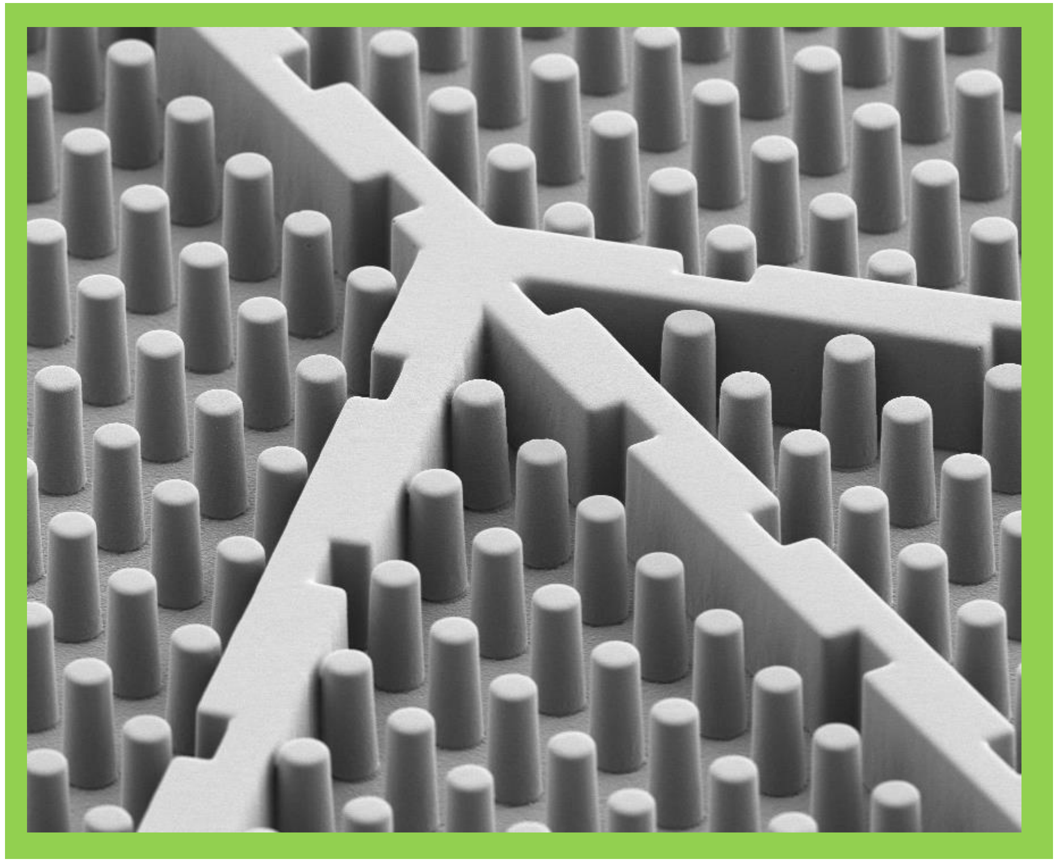
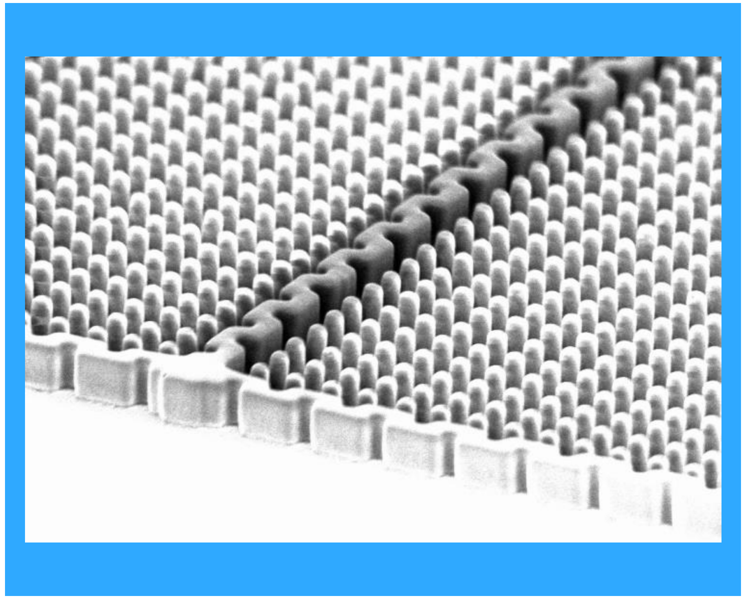
AIRCOAT SURFACE STRUCTURE EVOLUTION

GRACILIFICATION: NOTE THE DIFFERENCE BETWEEN S1 AND L1





SAME SCALE

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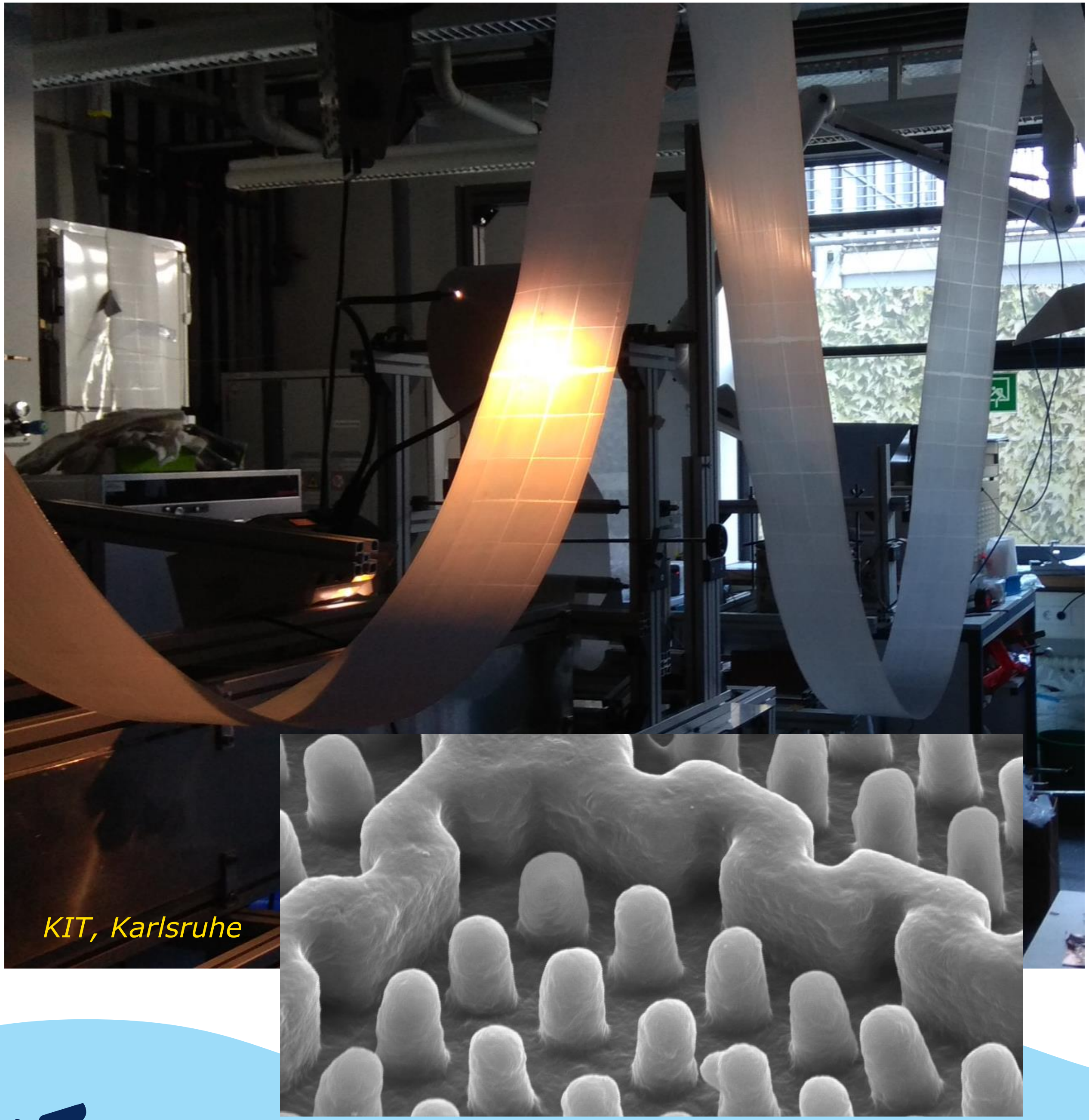
AIRCOATing – Progress and Perspectives

Progress towards technological air-retaining surfaces: large-area roll-to-roll fabrication at KIT



THE ROLL-TO-ROLL PRODUCTION LINE AT KIT: IMPRESSIVE NUMBERS

- In this way, > **1000 meters** of micropatterned surface were produced material based on the specific roll-to-roll process developed at KIT.
- The width oft the patterned samples was 17 cm, corresponding to a total area of micropatterned surface of 170 square meters.
- This corresponds to about 7 x 10^{12} micropillars produced in this way, i.e. ***7 000 billion microstructures*** (!).

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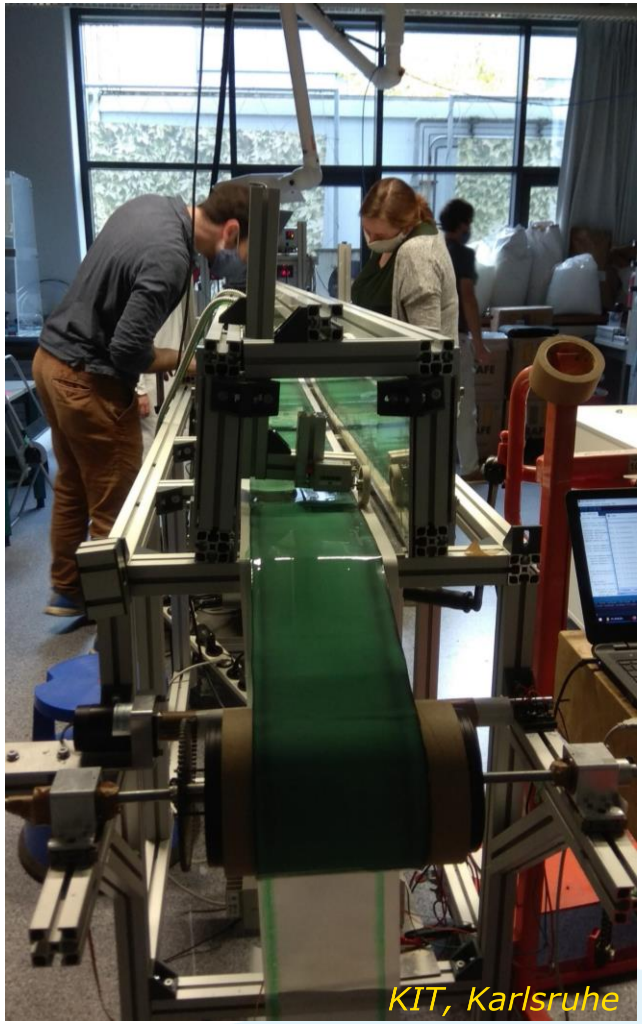
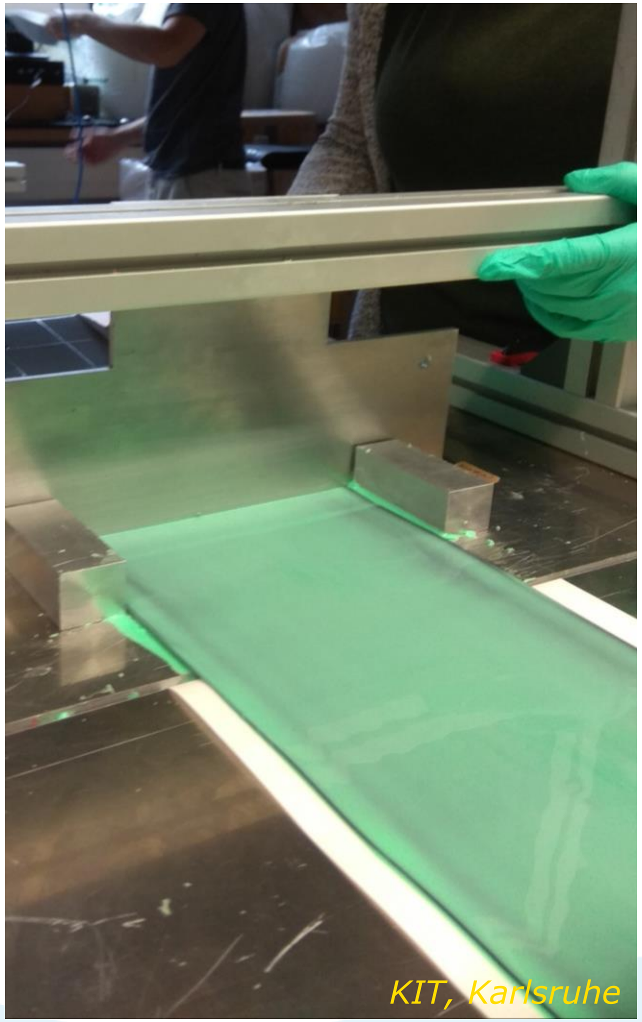
AIRCOAT FOIL PRODUCTION





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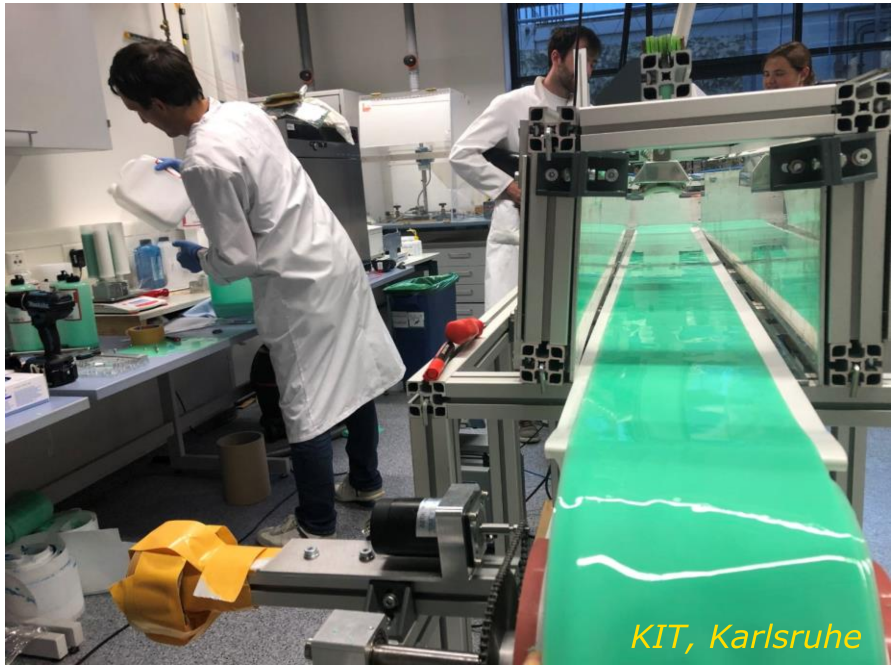
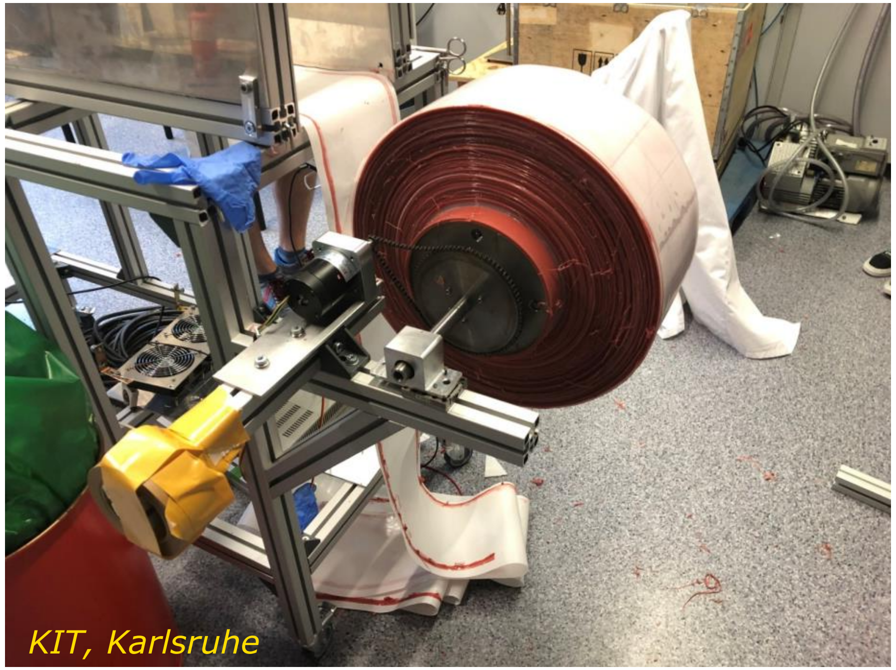
AIRCOAT FOIL PRODUCTION



After optimizing the **thermoplastic film production**, a coating system was successfully installed downstream in the production direction to apply a **protective top layer**.



The layer protects the film for the subsequent cutting and coating process. It is **removed after** the self-adhesive film has been applied to the vessel.

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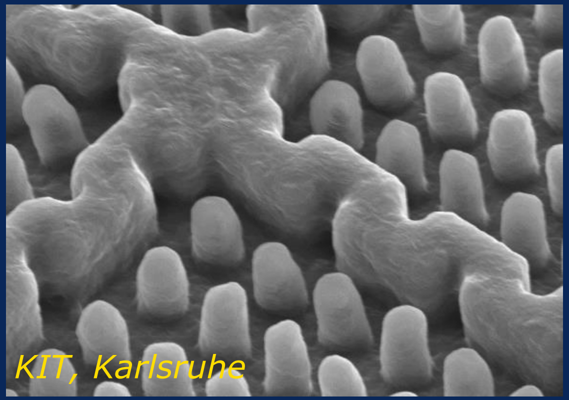
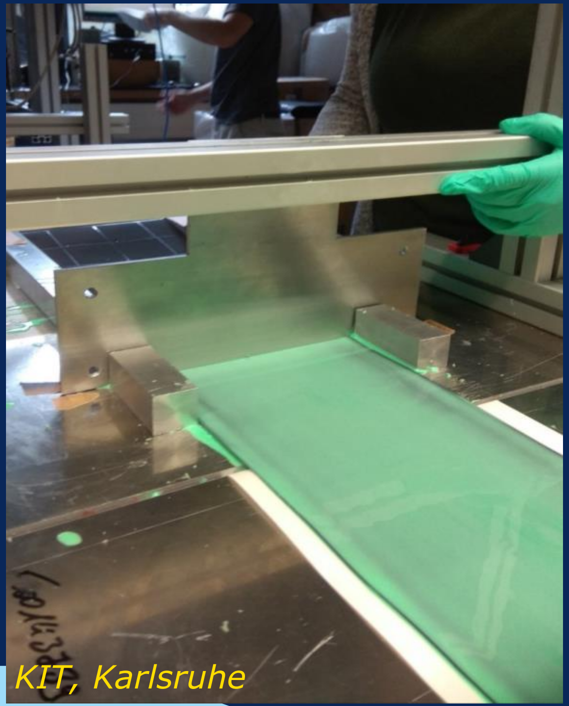


- No visible degradation after 1000 meters of production!



- Cover layer allows for rubbing and squeezing the product during cutting and application

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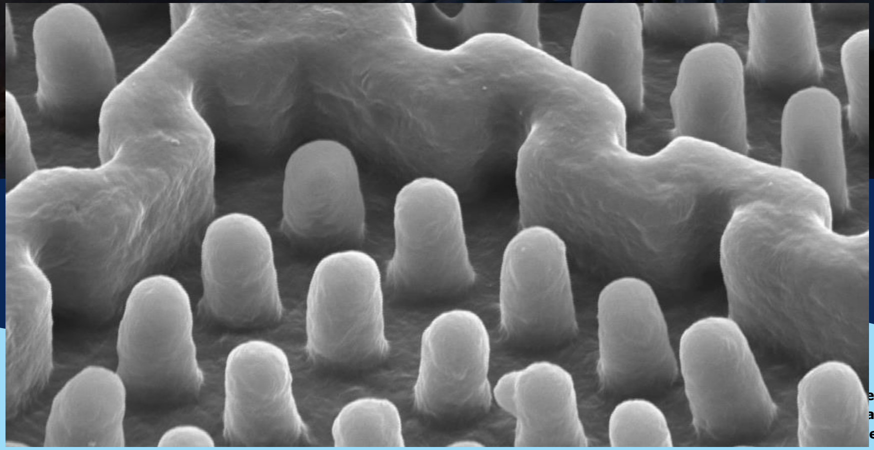
CONCLUSION

AIRCOAT:

- THE AIR SPRING EFFECT EFFECTIVELY STABILISES THE AIR LAYER
- LARGE AREA BIOMIMETIC MICRO STRUCTURE:

  1000 METERS PRODUCED @ KIT



KIT, Karlsruhe

ed funding from the
arch and innovation
eement N° 764553.

NUMERICAL SIMULATION IN SMALL SCALE

Albert Baars & Christoph Wilms
B-I-C of City University of Applied Sciences Bremen

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METHOD

Model equations and normalisation

$\frac{\partial u_i}{\partial x_i} = 0$; $\frac{\partial u_i}{\partial t} + \frac{\partial u_i u_j}{\partial u_j} = -\frac{\partial p}{\partial x_i} + \frac{1}{Re}\frac{\partial^2 u_i}{\partial x_j^2} + f_i$; $x_i = \frac{x_i^*}{h^*}$; $u_i = \frac{u_i^*}{\bar{u}_0^*}$; $p = \frac{p^*}{\rho^* \bar{u}_0^{*2}}$; $f_i = \frac{f_i^* h^*}{\rho^* \bar{u}_0^{*2}}$; $Re = \frac{\bar{u}_0^* h^*}{\nu^*}$; $Re_\tau = \frac{u_\tau^* h^*}{\nu^*}$; $x^+ = \frac{u_\tau^* x_i^*}{\nu^*}$

Boundary conditions

- Top surface of the structure: no-slip condition
- Air-water interface: slip condition
- Cyclic boundary condition in stream- and spanwise direction

Code

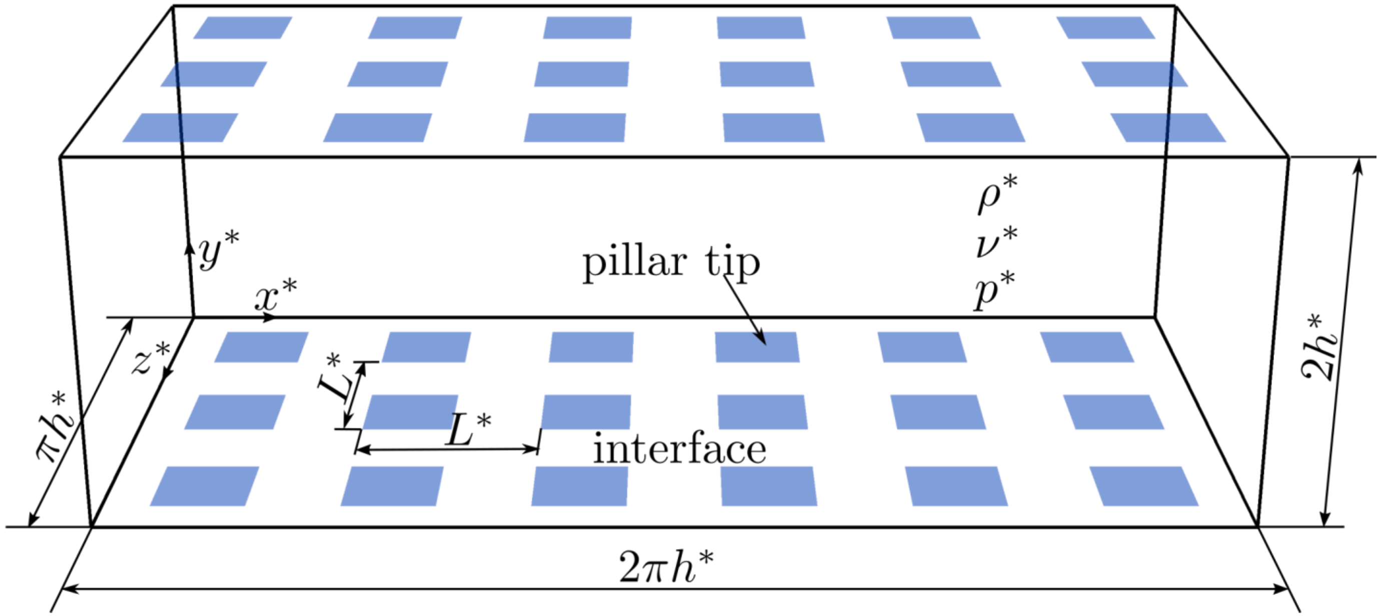
- OpenFOAM (2nd order) and Nek5000 (3rd, 7th / 9th order)

Parameter

- Structure geometry: squared pillars, squared holes, stream- and spanwise grooves
- Structure size: $10 \leq L^+ \leq 236$
- Ratio of interface area (slip) to complete area: $A_S/A = 0.75$
- $Re_\tau \approx 180\,;\,300$

Drag reduction

$$\mathrm{DR} = 1 - \left(\frac{\bar{u}_0^+}{\bar{u}_{SHS}^+}\right)^2$$



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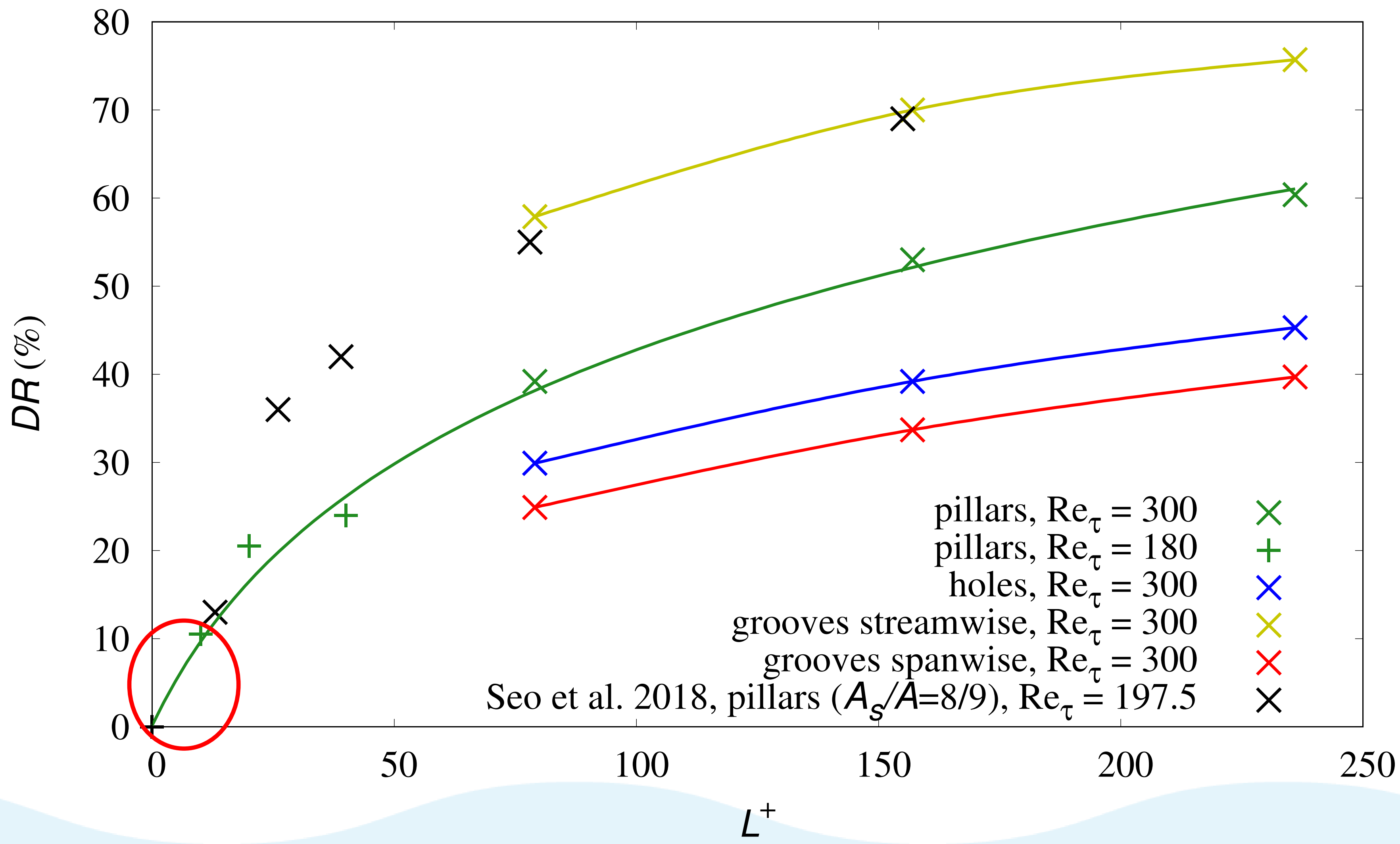
RESULTS - DISCUSSION



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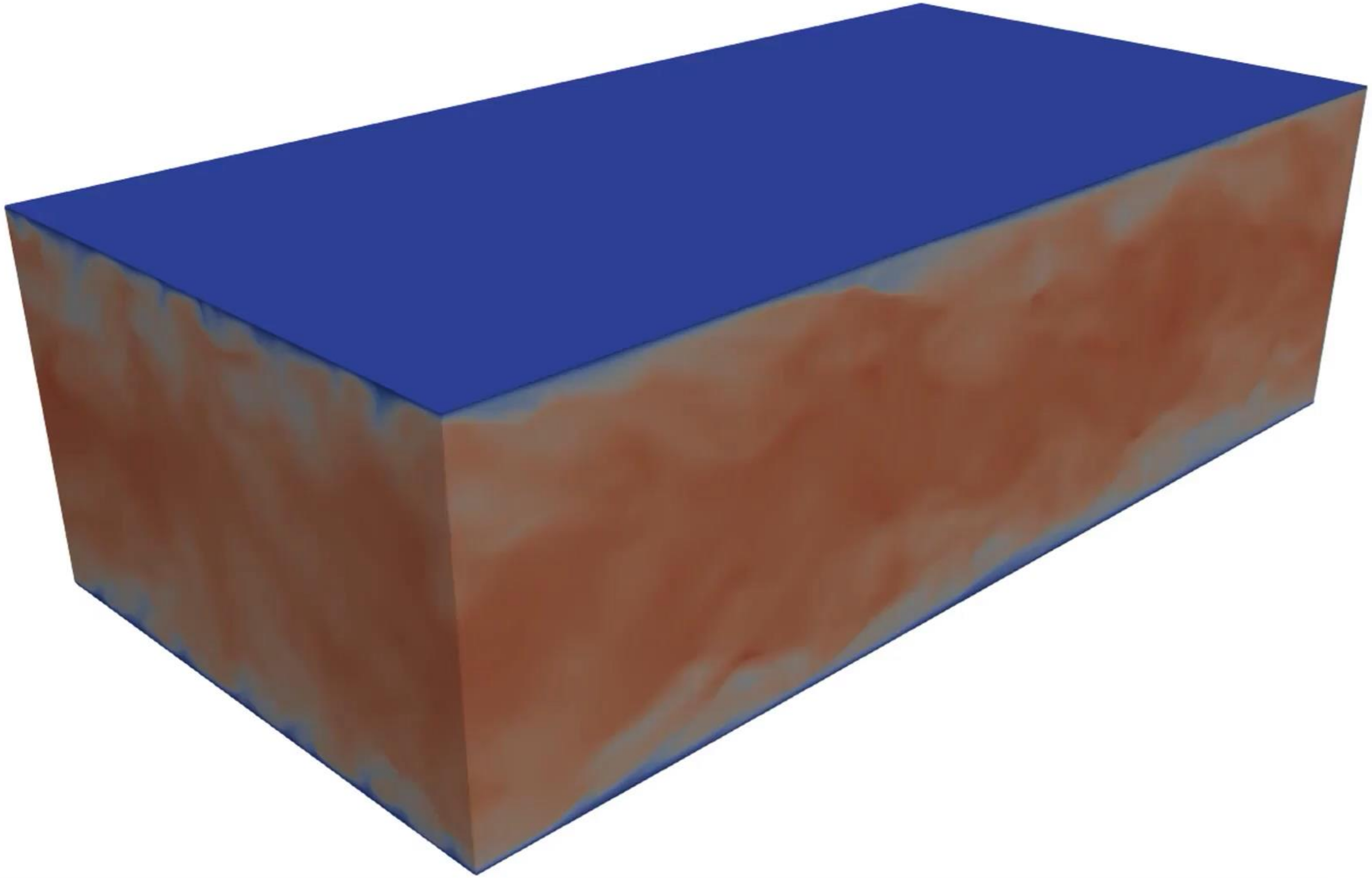
RESULTS - DISCUSSION

$Re_\tau = \mathbf{180}$, wall: no-slip condition and pillars $(L^+ = 80)$



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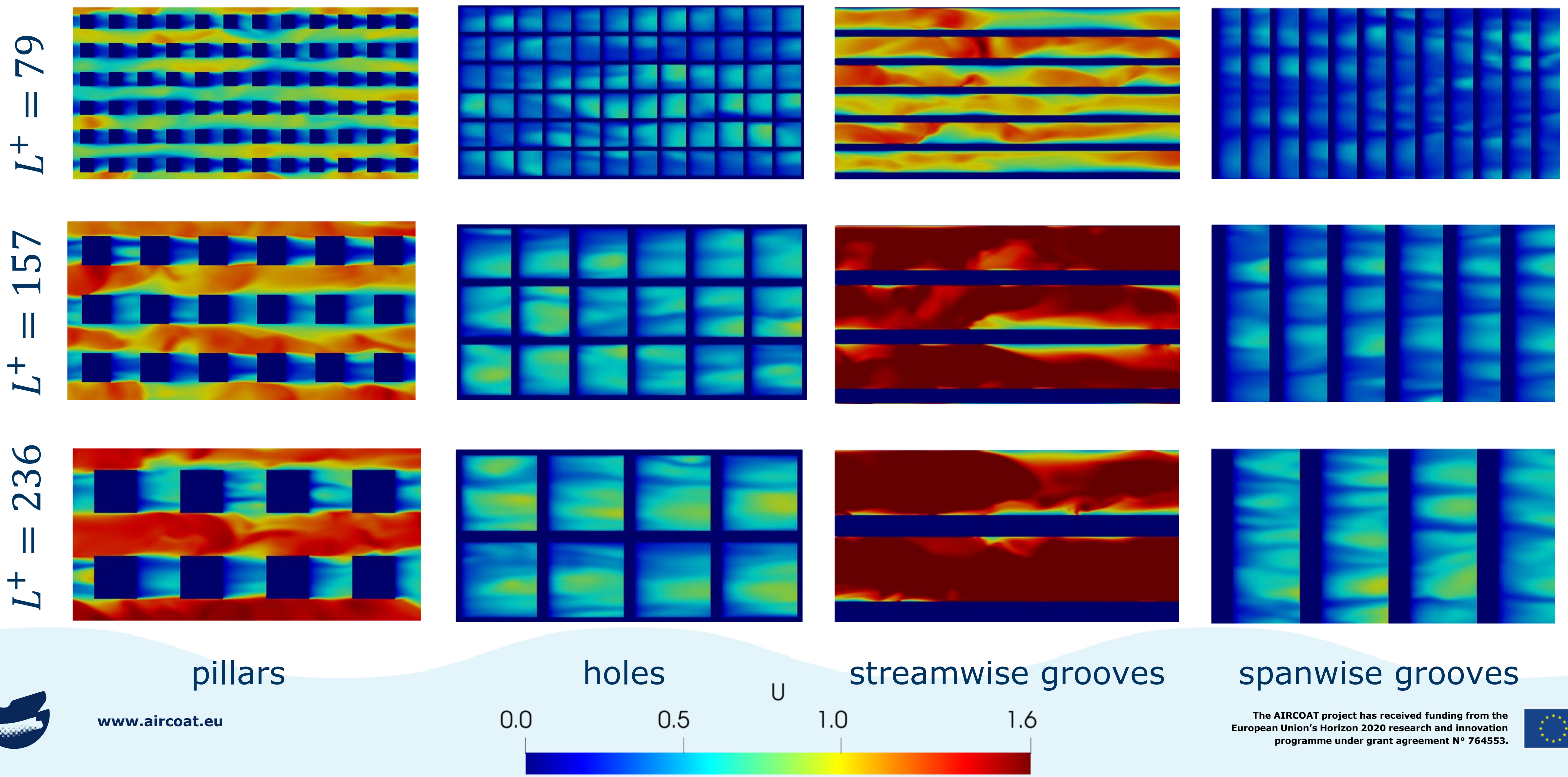
RESULTS - DISCUSSION

$Re_\tau = 300$, velocity field on the wall



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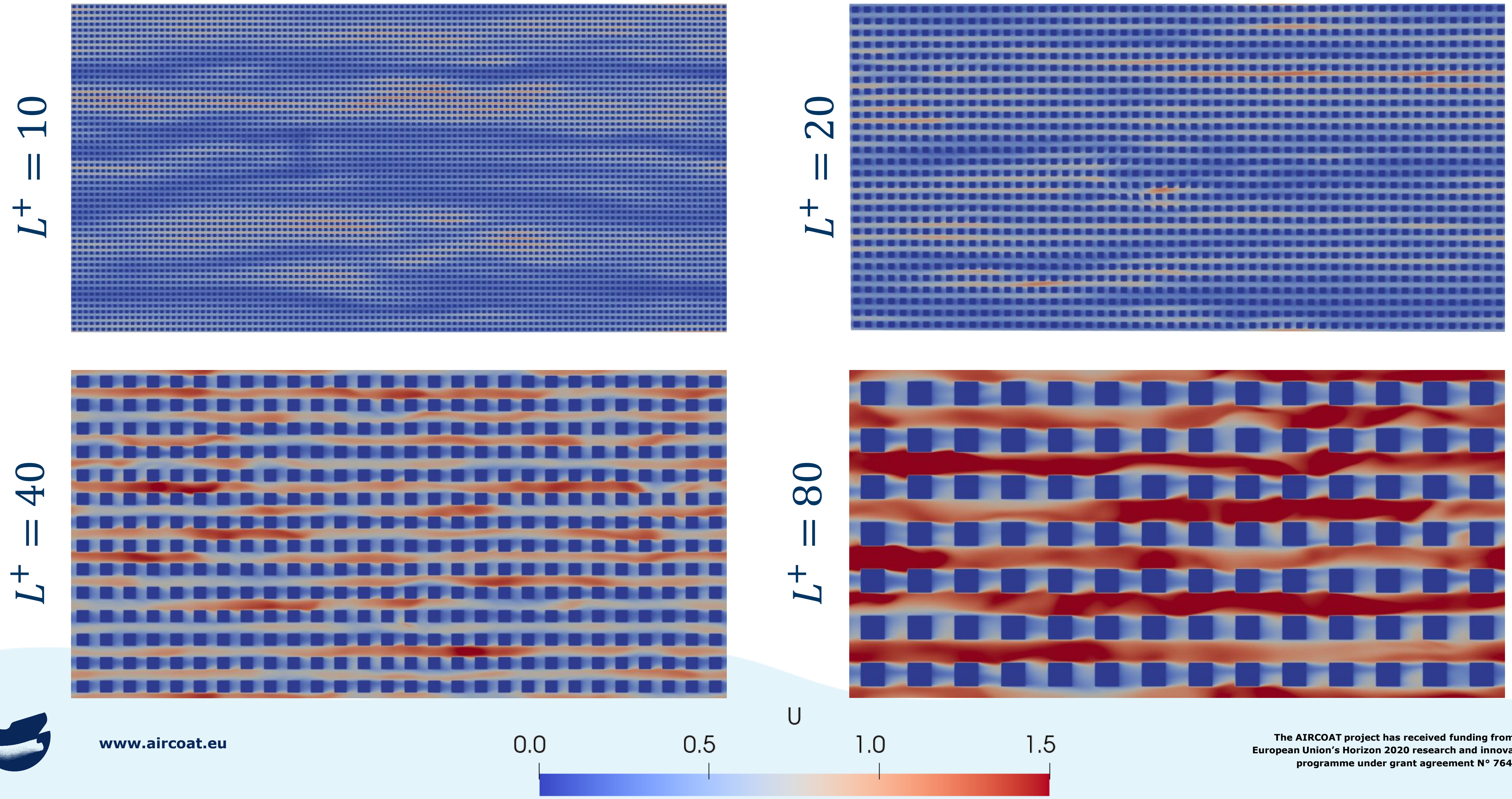
RESULTS - DISCUSSION

$Re_\tau = 180$, velocity field on the wall for pillars



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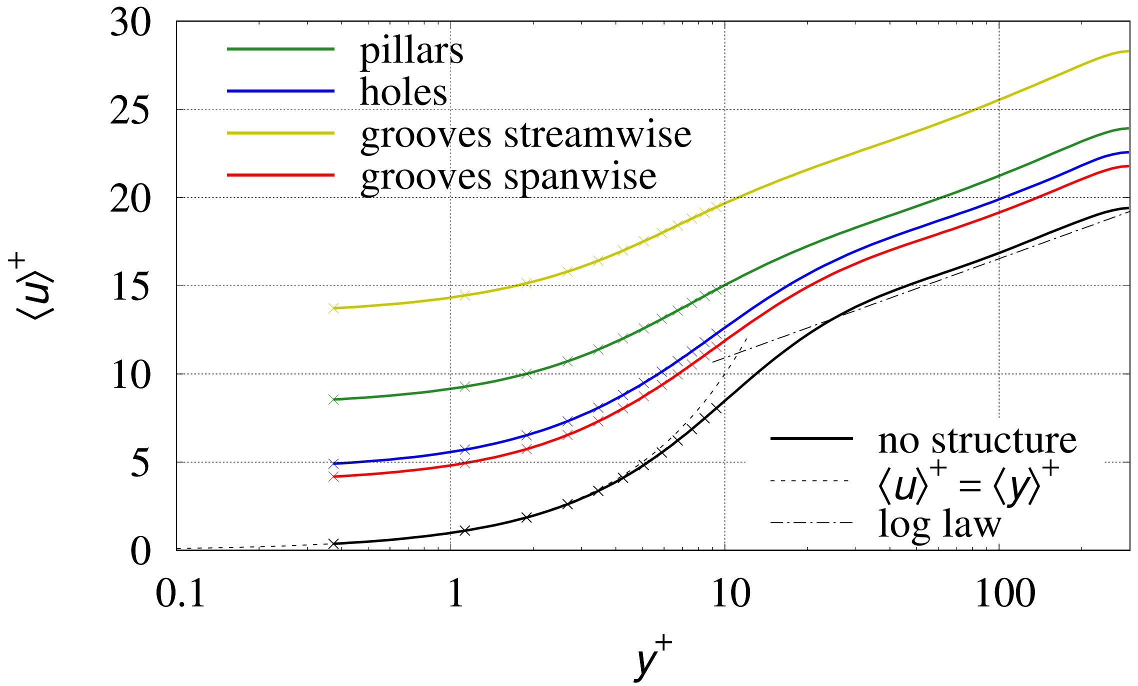
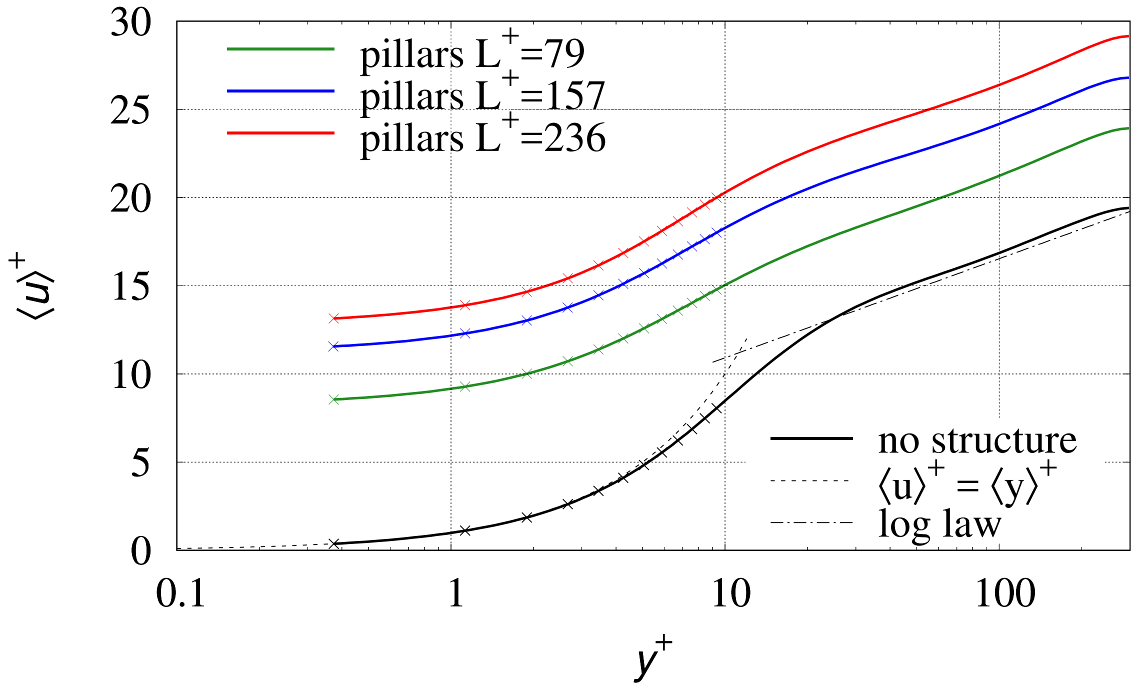
RESULTS - DISCUSSION

Averaged velocity profiles in time and space





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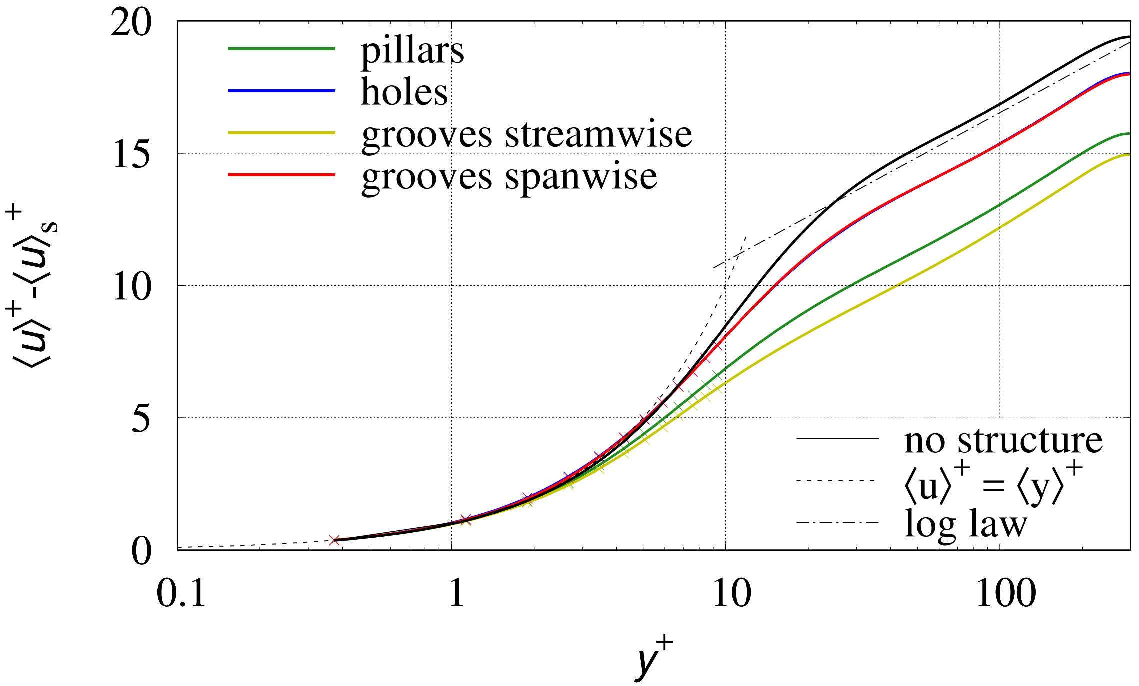
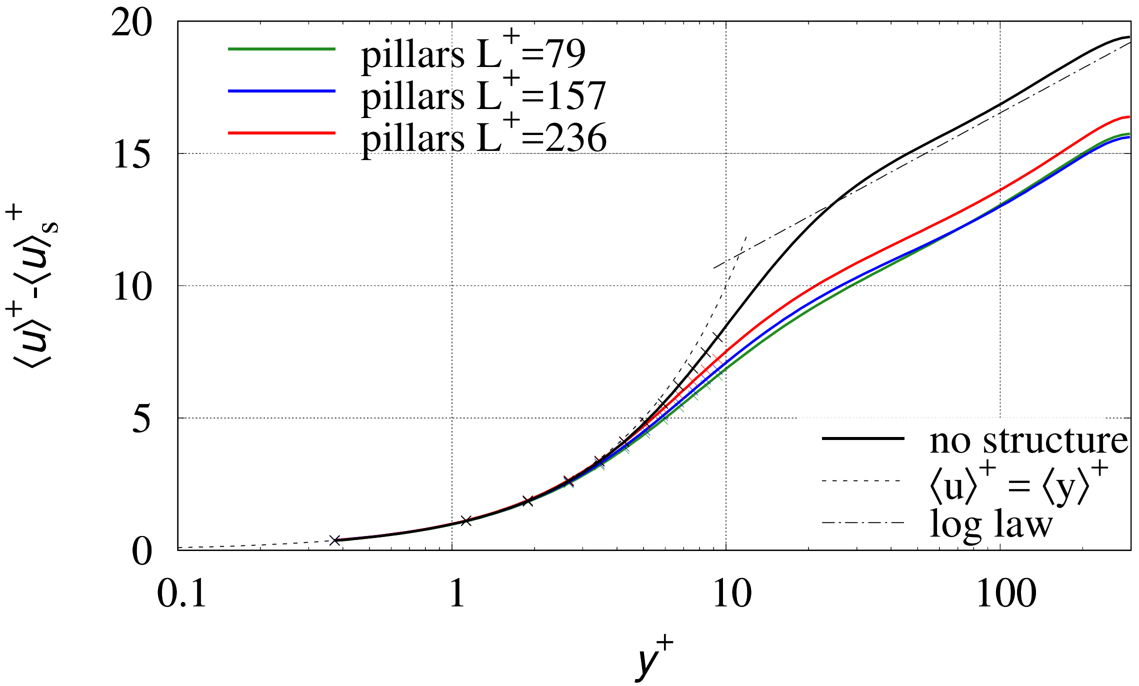
RESULTS - DISCUSSION

Averaged velocity profiles in time and space





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CONCLUSION

Direct numerical simulation of a turbulent channel flow

- $Re_\tau \approx 180\,;300$, different sizes and geometries of retaining structures
- $10 \leq L^+ \leq 236$
- Pillars, holes, grooves in stream- and spanwise direction

Drag reduction rises

- with increasing sturcture size
- from grooves in spanwise direction, over holes, pillars to grooves in streamwise direction

Air retaining surface influence the velocity profile

- Slip velocity on the wall → contributes to drag reduction
- Enlargement of the logarithmic domain towards the wall → contributes to a drag increase
- Effect by slip velocity dominates the effect of enlargement of the logarithmic domain

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CONCLUSION & OUTLOOK

Jonathan Weisheit
Research Associate
Fraunhofer CML

Fraunhofer
CML

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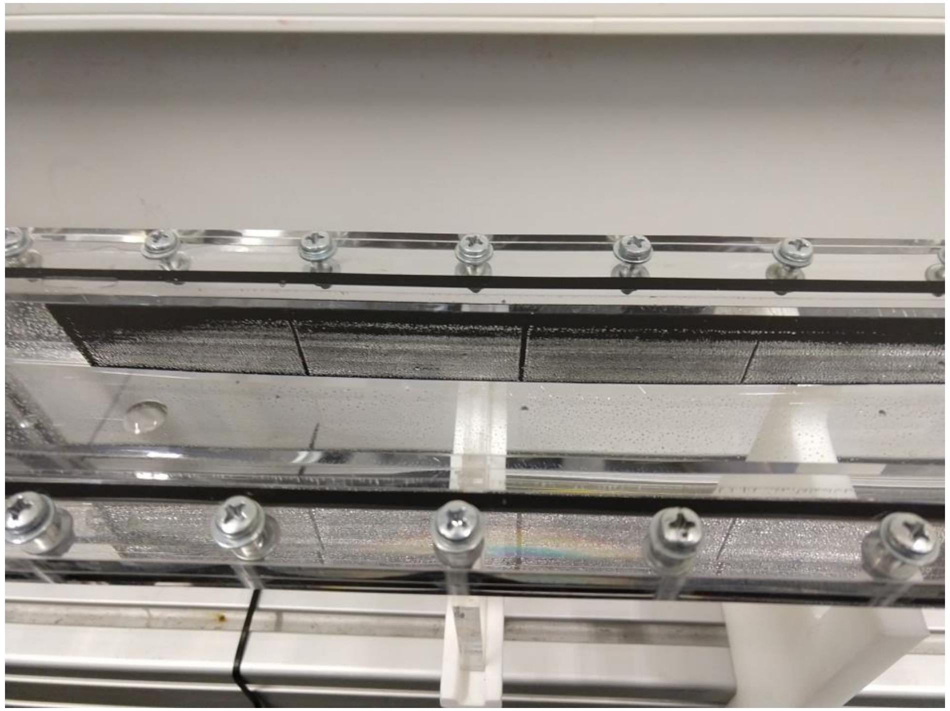
CHALLENGES TO FACE

1. Increase gas saturation during laboratory experiments



- undersaturated water will cause diffusion from air layer into water
- saturation is pressure and temperature dependent

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CHALLENGES TO FACE

2. Coating of a research vessel

Travel restrictions due to the pandamic situation.

MS Provider (ABT)

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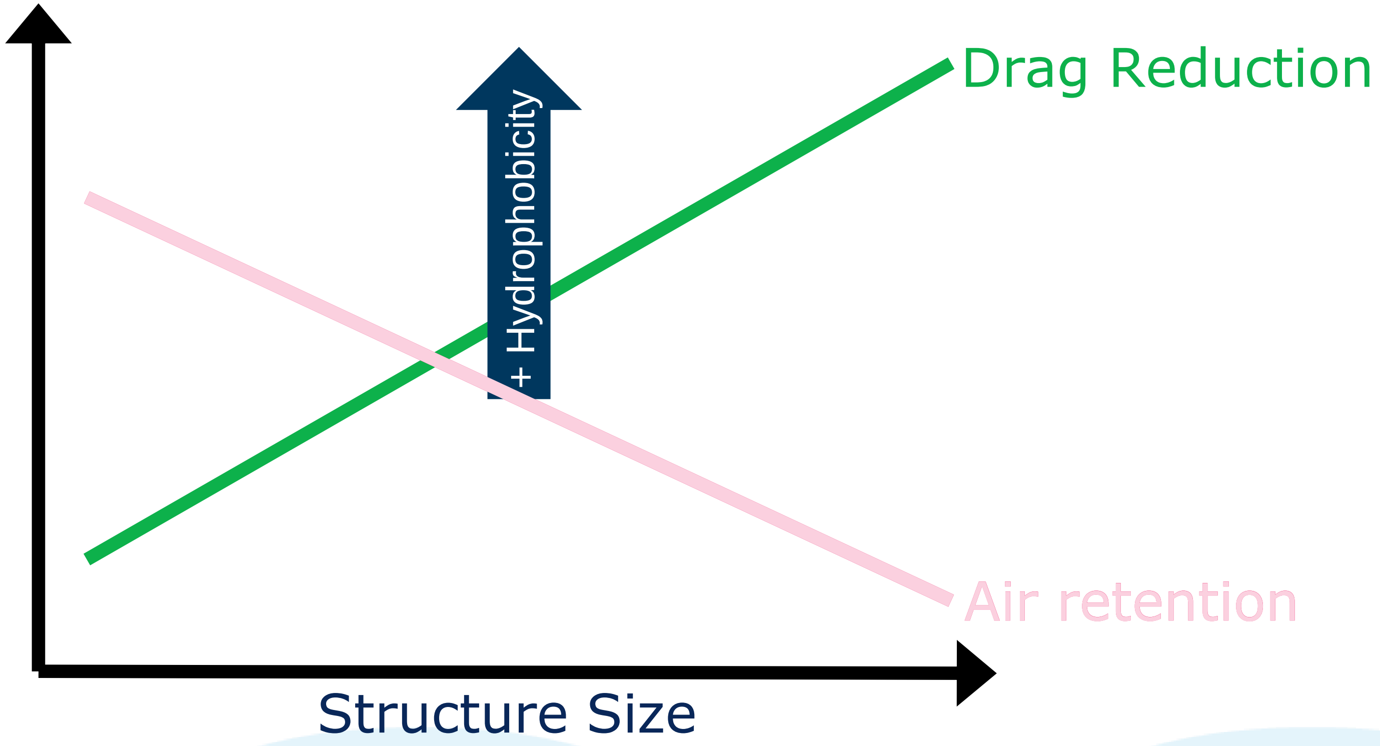
CHALLENGES TO FACE

3. Hydrophobicity of the material



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ACKNOWLEDGEMENT

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THANK YOU FOR YOUR ATTENTION

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