17th biennial conference on the biology of marine mammals - Capetown, South Africa 29th Nov. -3rd Dec.

CFD simulations of the flow around a humpback whale's pectoral fin

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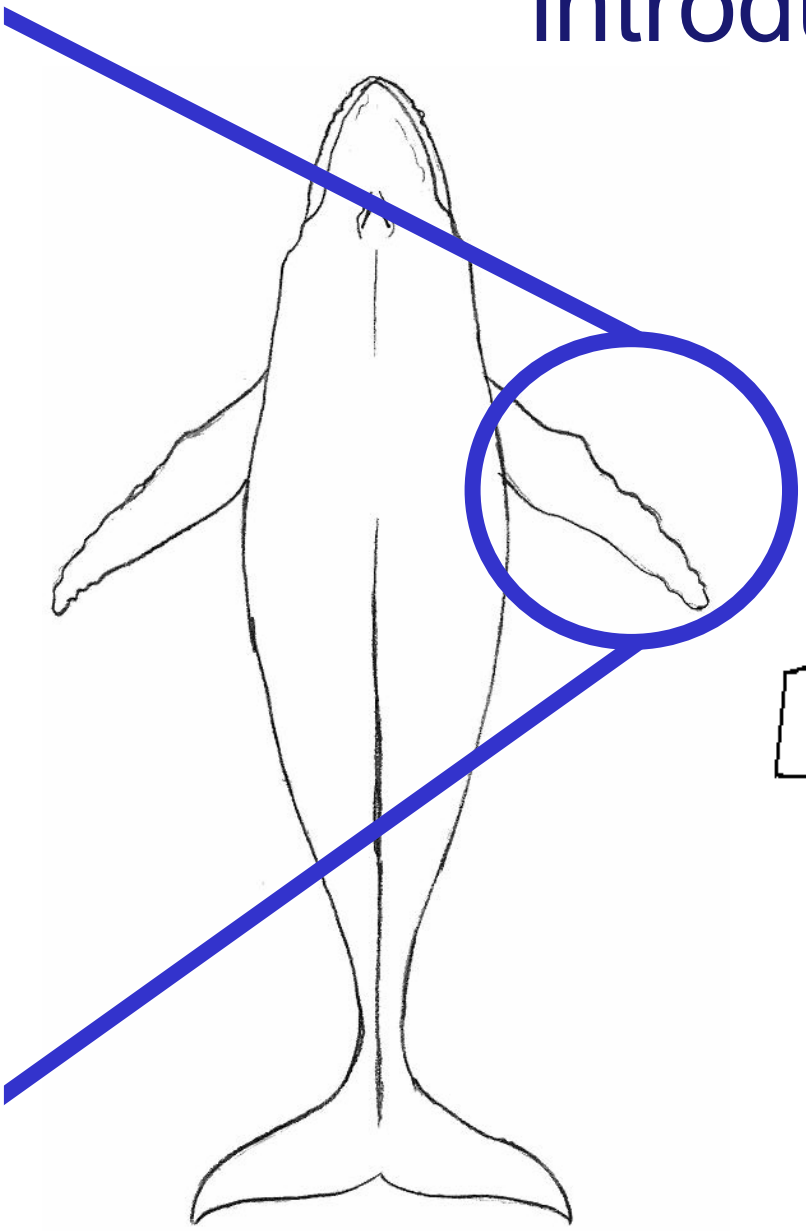
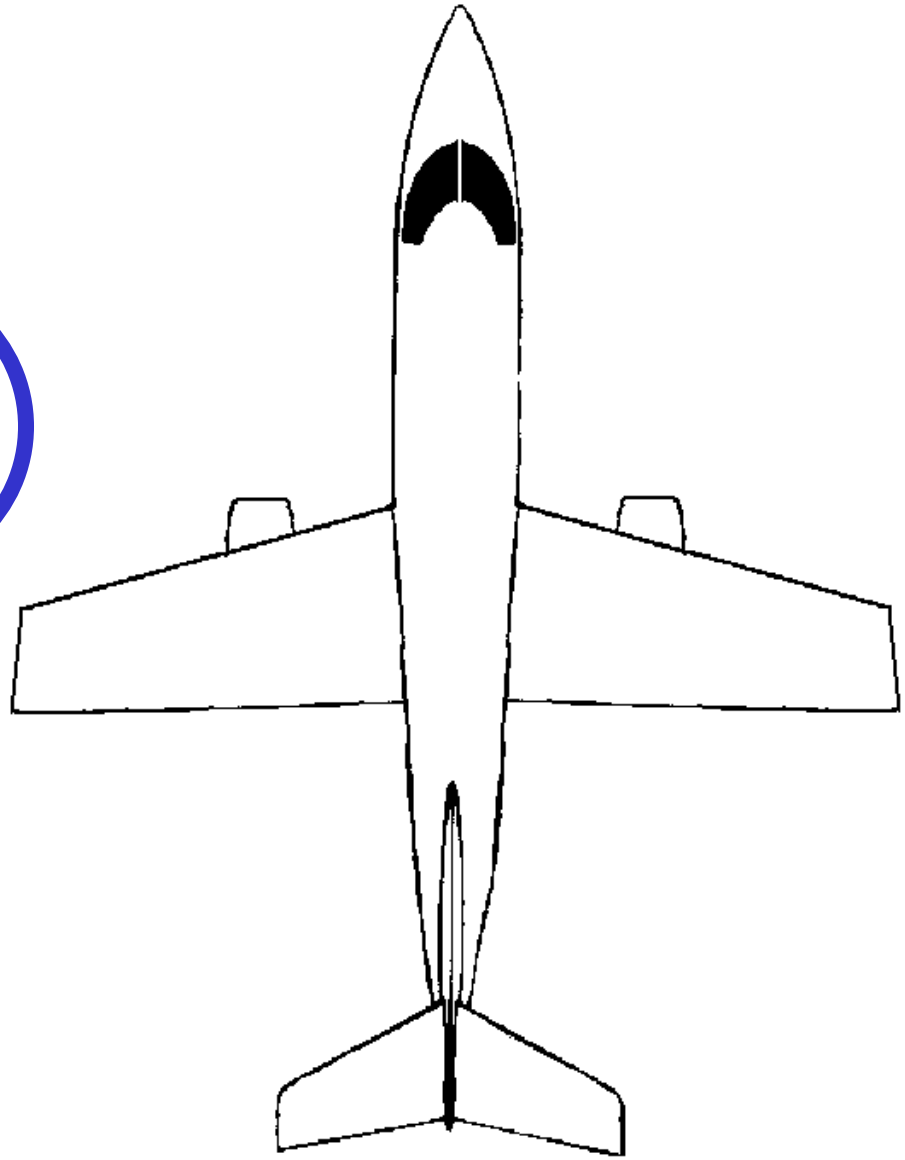
introduction





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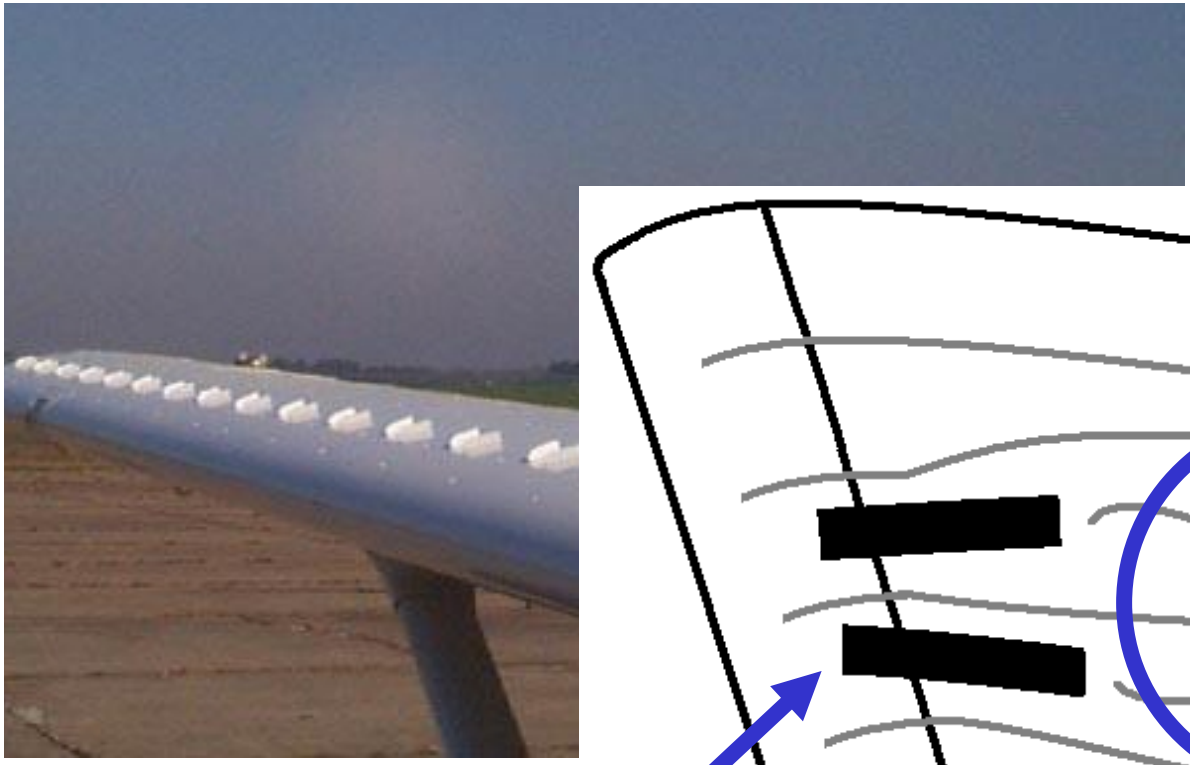
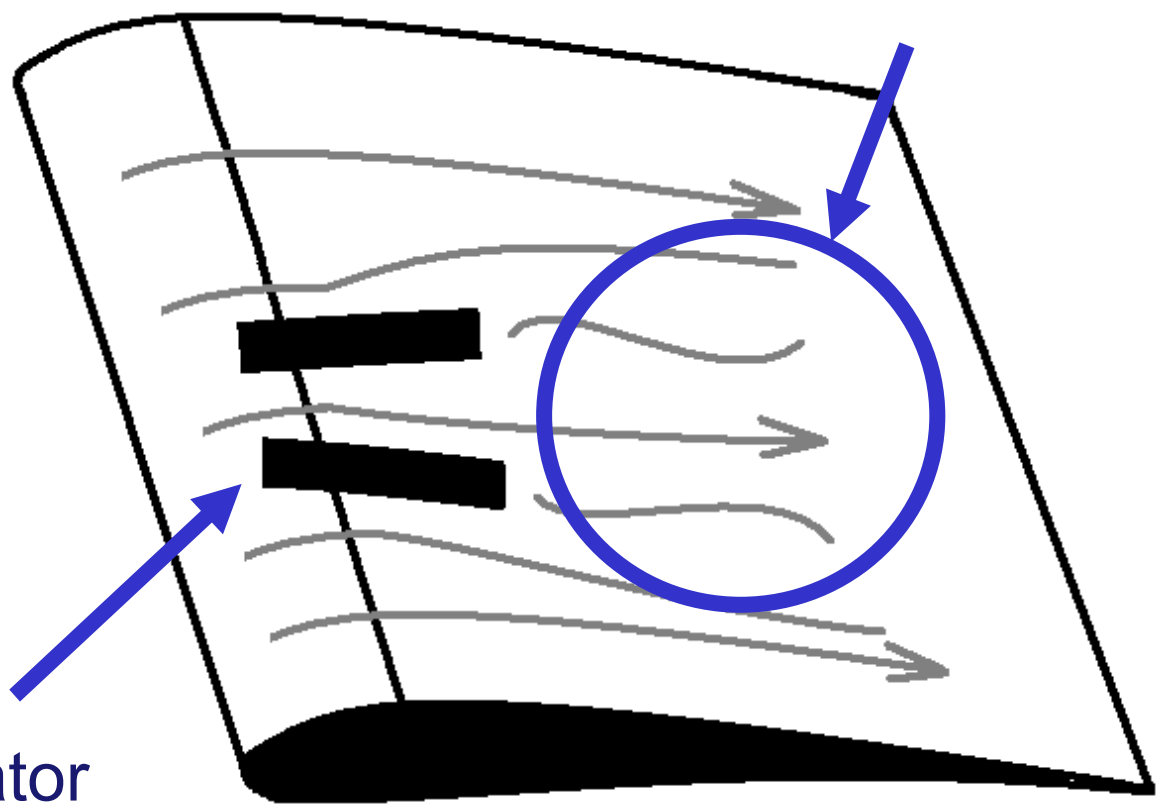
passive flow control



vortices
→ energy loss



vortex
generator

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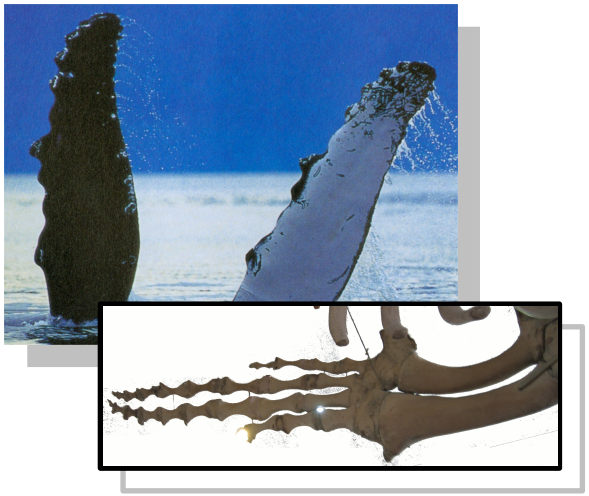
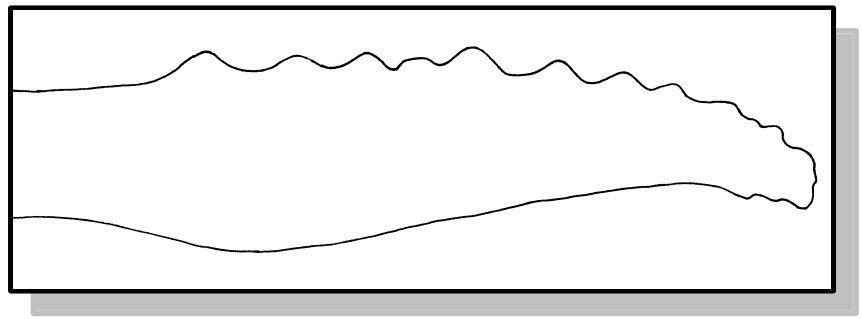
whale fin modelling



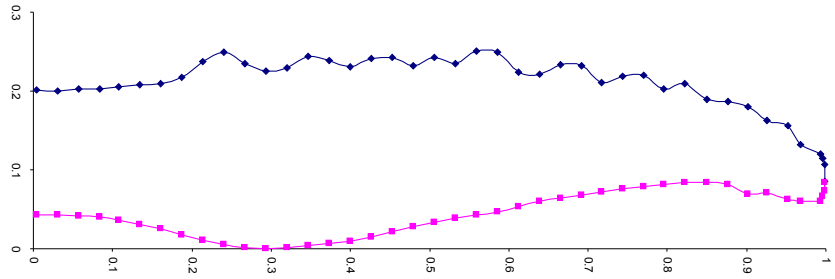
problem: how to come by a realistic HBW pectoral fin geometry?

step 1 → photo & physiognomy study

step 2 → 2D hand sketches (with and without tubercles)



step 3 → transforming hand sketches into coordinates



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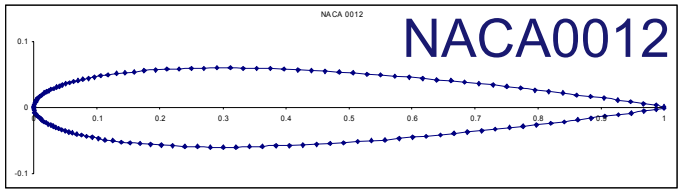
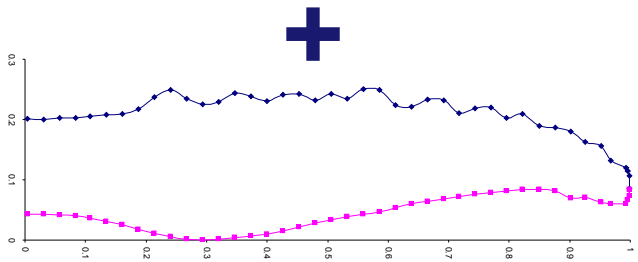
3D pectoral fin model

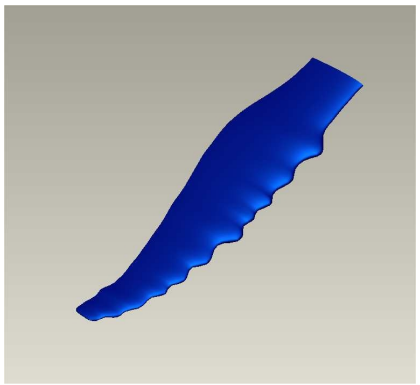


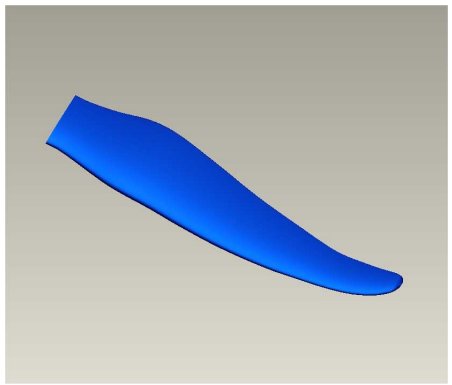


step 4 → choosing an appropriate NACA airfoil profile

step 5 → combining hand sketch coordinates & NACA airfoil profile

3D pectoral fin models:





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numerical simulations

grid-generation: ICEM CFD
CFD-Code: Ansys CFX 10.0
Reynolds-Number: *Re = 1.019.600*
backward-sweep: *0°*
Fin-length: *3,00 m (water)*
1,38 m (air)

List of simulations

Fluid	fin-shape	angle of attack	speed of flow
Water	tubercles	*0°, 10°, 20°*	*2,6 m/s*
	smooth	*0°, 10°, 20°*	
Air	tubercles	*0°, 10°, 20°*	*Ma = 0,2 → 69,2 m/s*

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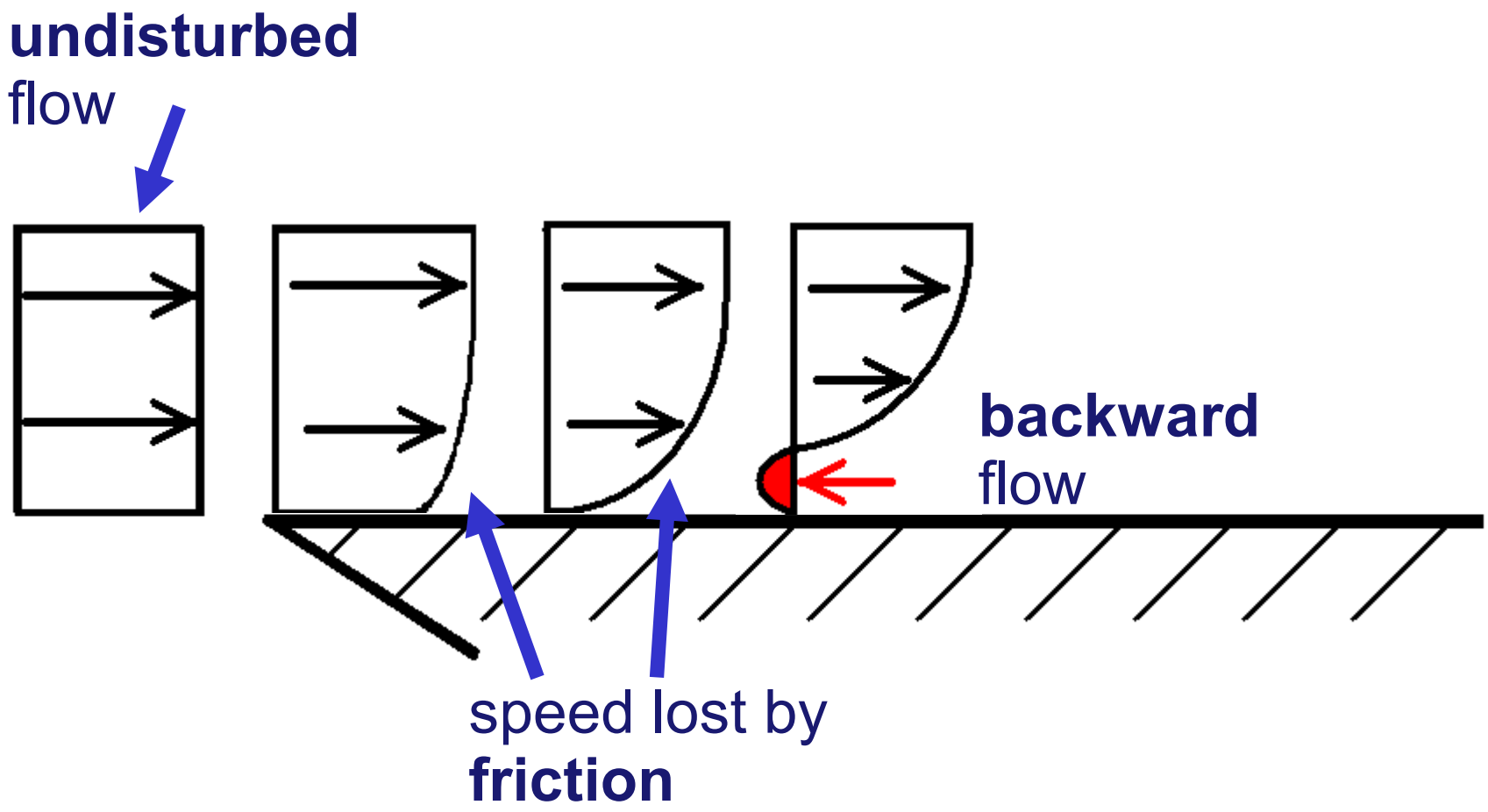
flow physics – friction



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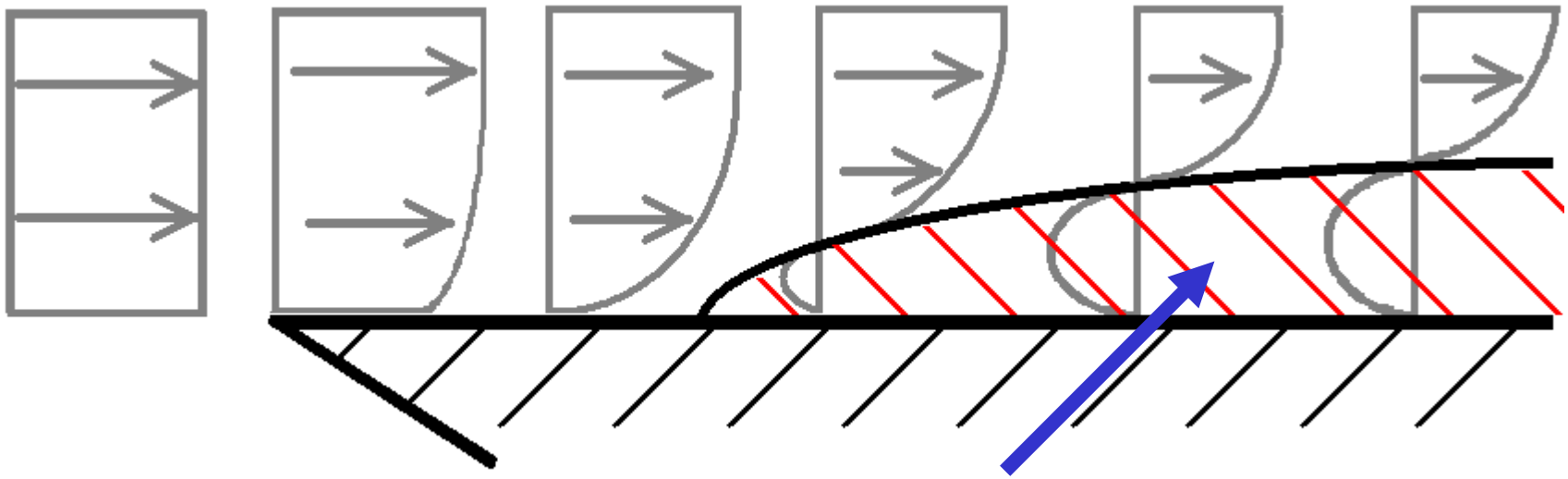
flow physics – separation



area of
separated
flow

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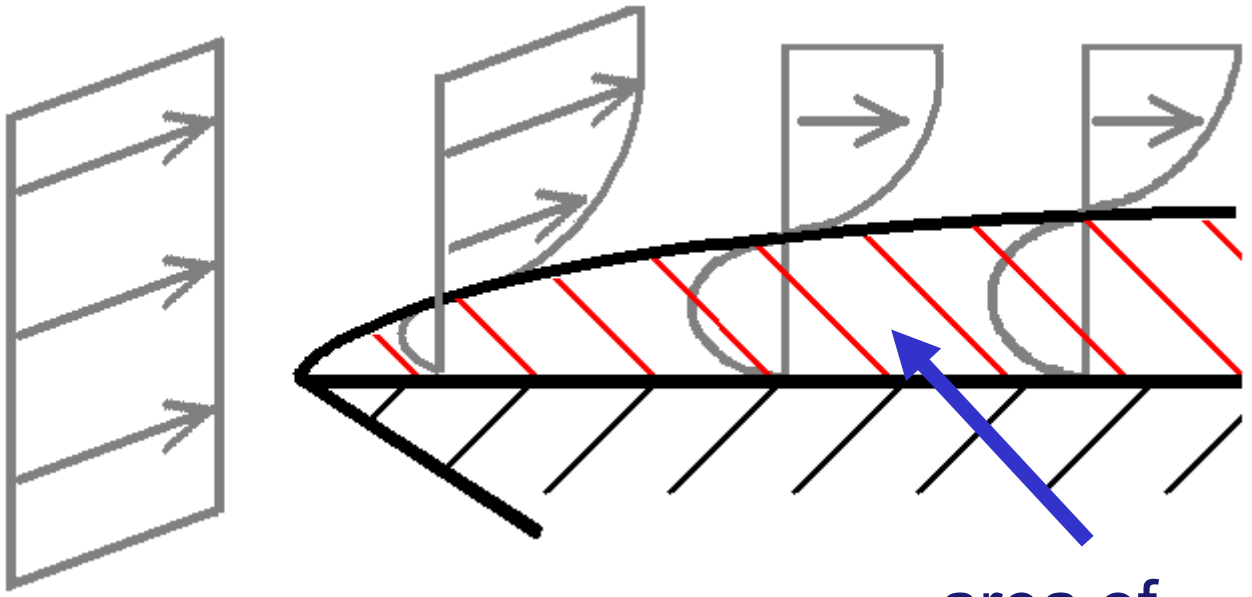
flow physics – incidence



area of **separated** flow

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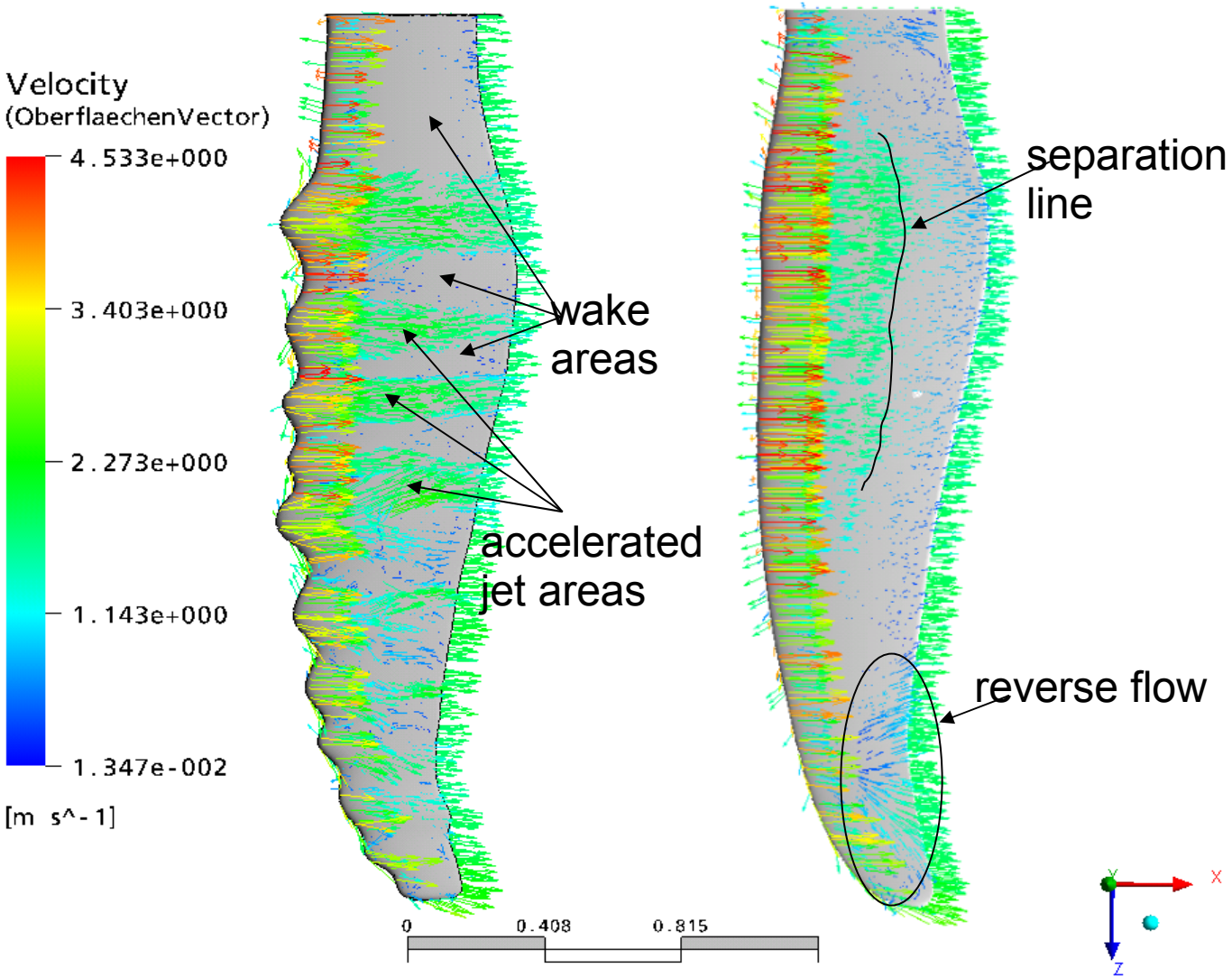
CFD results – surface flow

CFX

10° incidence, water



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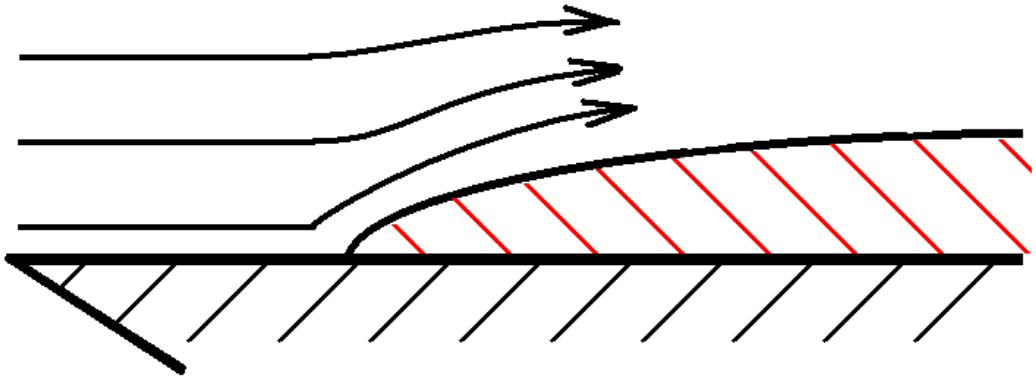
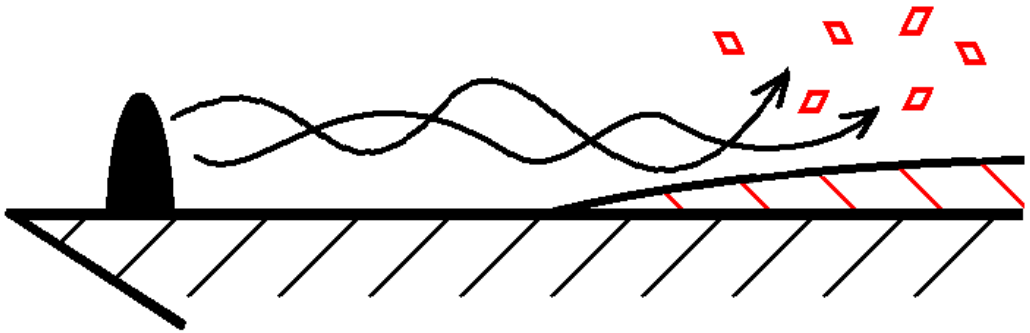
vortex-generators schematic



separation
on airfoil.
→ aerodynamic failure



vortices reduce
separation
→ airfoil functional

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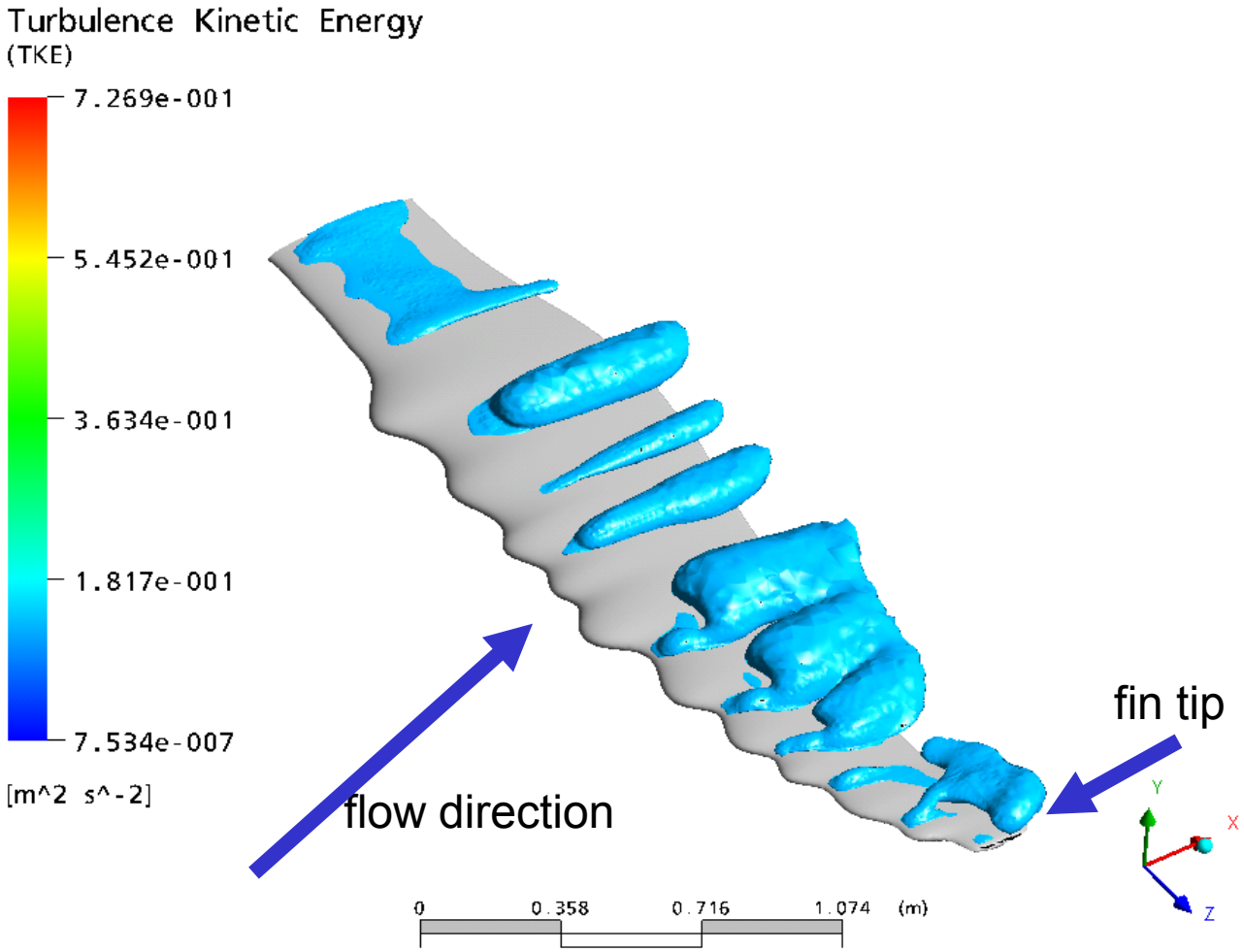
CFD results – TKE

CFX

10° incidence, water



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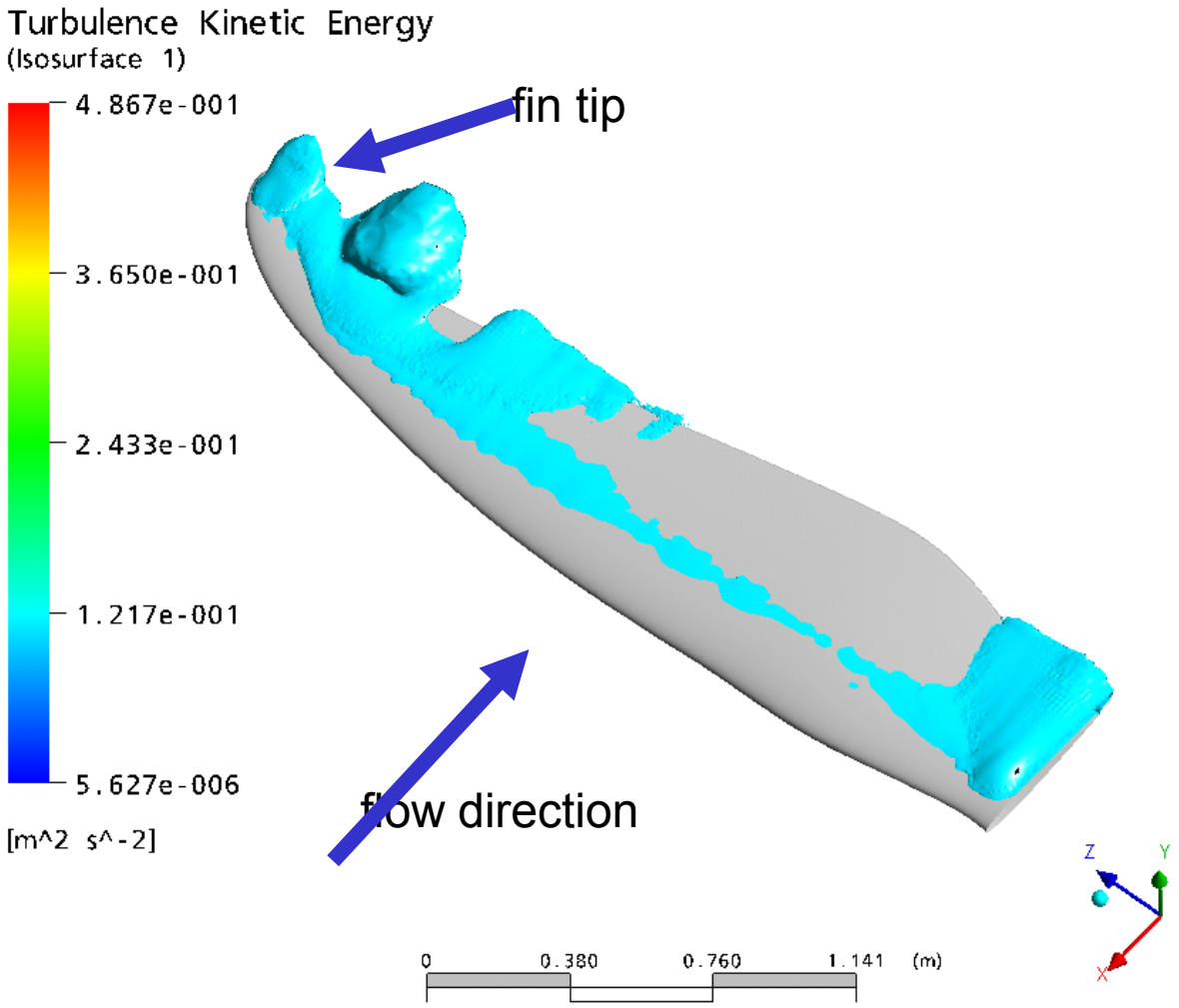
CFD results – TKE

10° incidence, water

CFX



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CFD results - conclusion

- tubercles can stabilise flow by generating vortices (passive flow-control device)
- pectoral fin stays hydrodynamically functional under extreme flow conditions (e.g. HBW swimming a sharp turn)
- drag increases slightly (approx. 6.5%) in less challenging flow conditions

→ capacity for tighter turns takes priority over hydrodynamic efficiency

Outlook / Todo-List

Next tasks

- establish contact with humpback-researchers
- find a more realistic flipper geometry
- record and simulate a typical foraging movement pattern

Open Questions

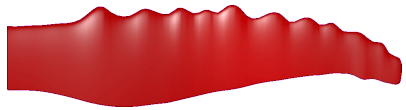
- Are *barnacles* beneficial for vortex-generation?
- Can humpbacks adjust flipper shape?
- Can humpbacks feel flow-conditions (e.g. separation)?

Thank you for your attention

for further information please visit the project's website:

http://www.buckelwalflosse.de

(currently only available in German, but we're working on an English version!)



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