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A novel model for glaze ice accretion

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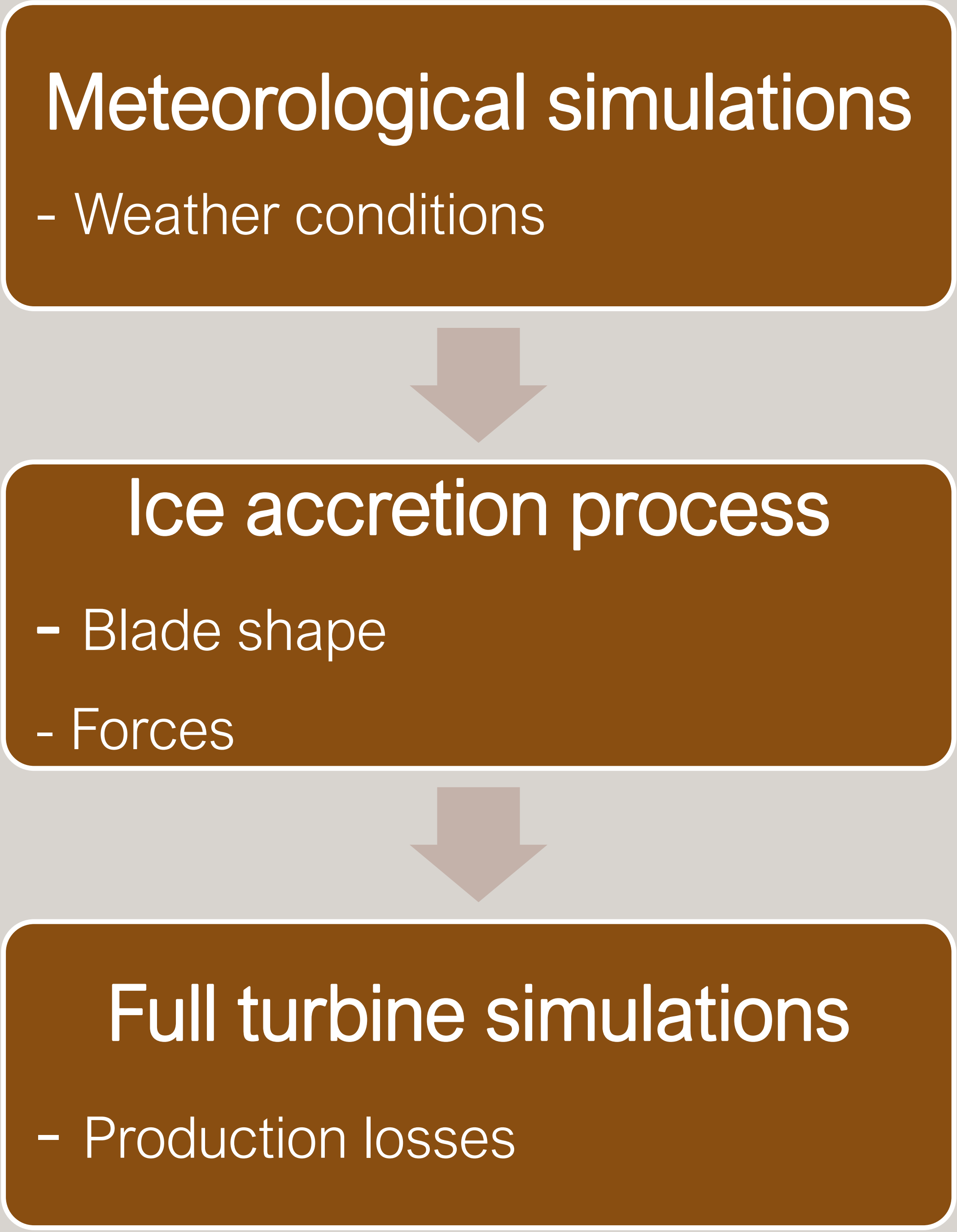
Winterwind INTERNATIONAL WIND ENERGY CONFERENCE

Photo: Lund, 2022.04.05

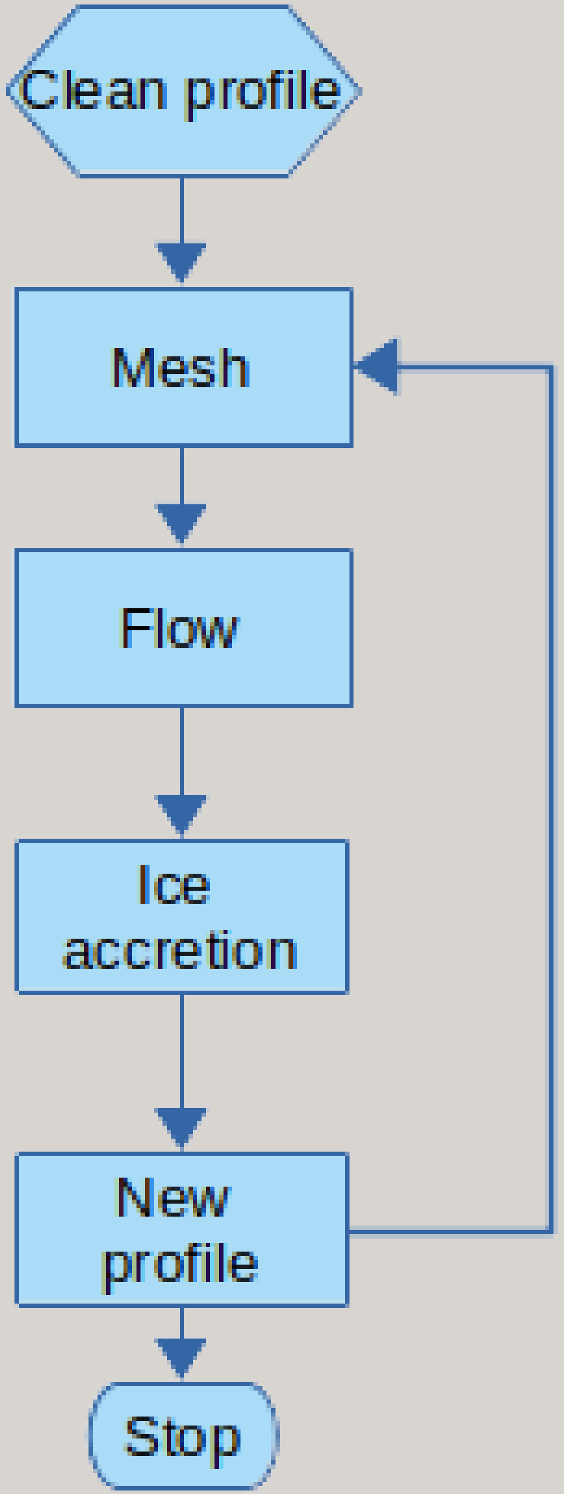
Background

- Developing a model chain to predict production losses
  - Swedish Energy Agency, Proj.Nr. 47053-1
  - SMHI, Lund University, Uppsala University
- Lund University
  - Ice accretion process
  - Large number of simulations for different weather conditions, angles of attack, relative velocity…
  - Fast models needed



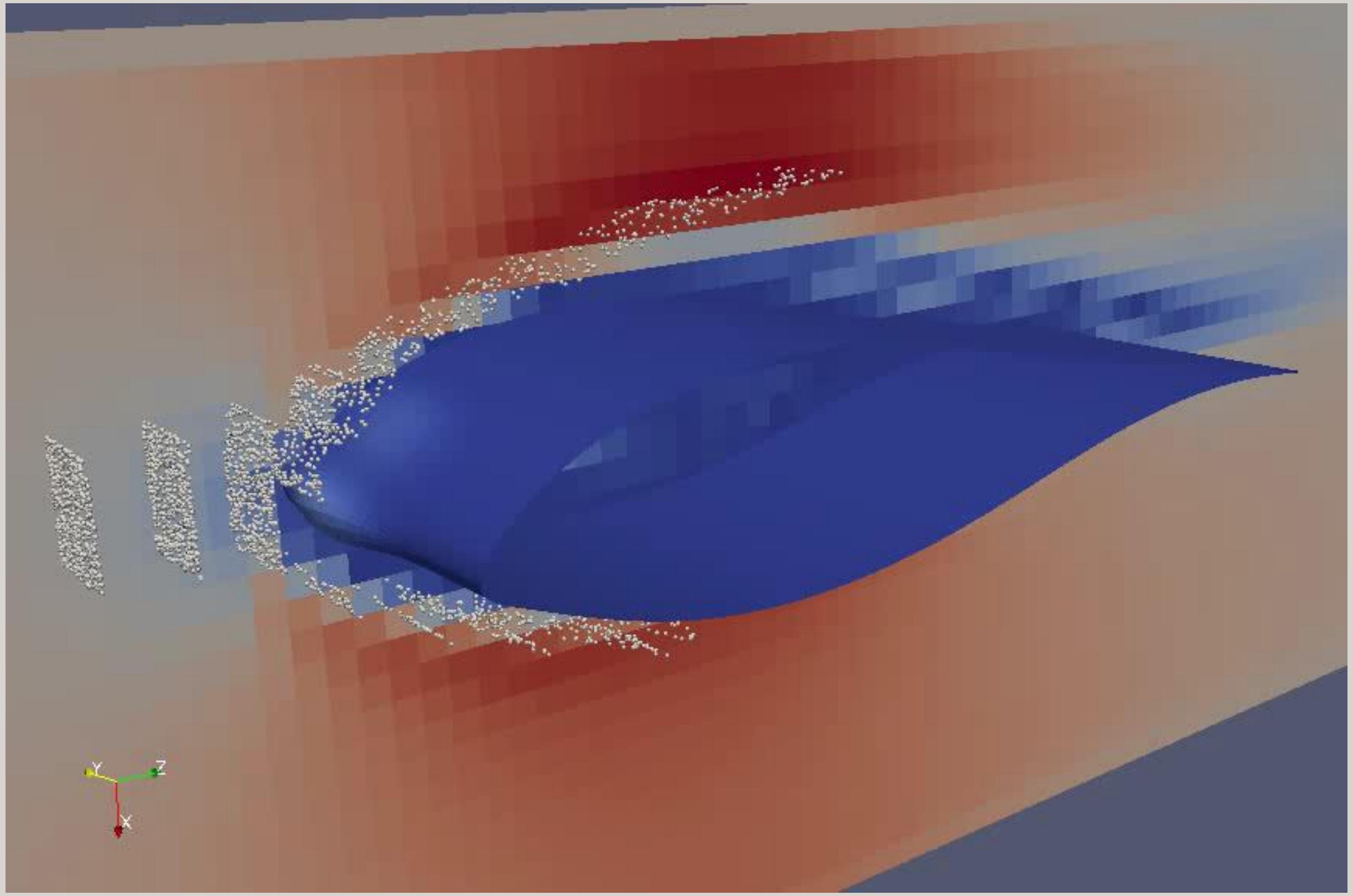
Ice accretion modeling

- Ice accretion and flow time scales significantly different -> possibility to spead up computations:
- Ice accretion process divided in sub-intervals
- Assuming constant shape in each sub-interval
- Flow and ice accretion computed separately
- Extrapolating the amount of ice accreted in a sub-interval in time



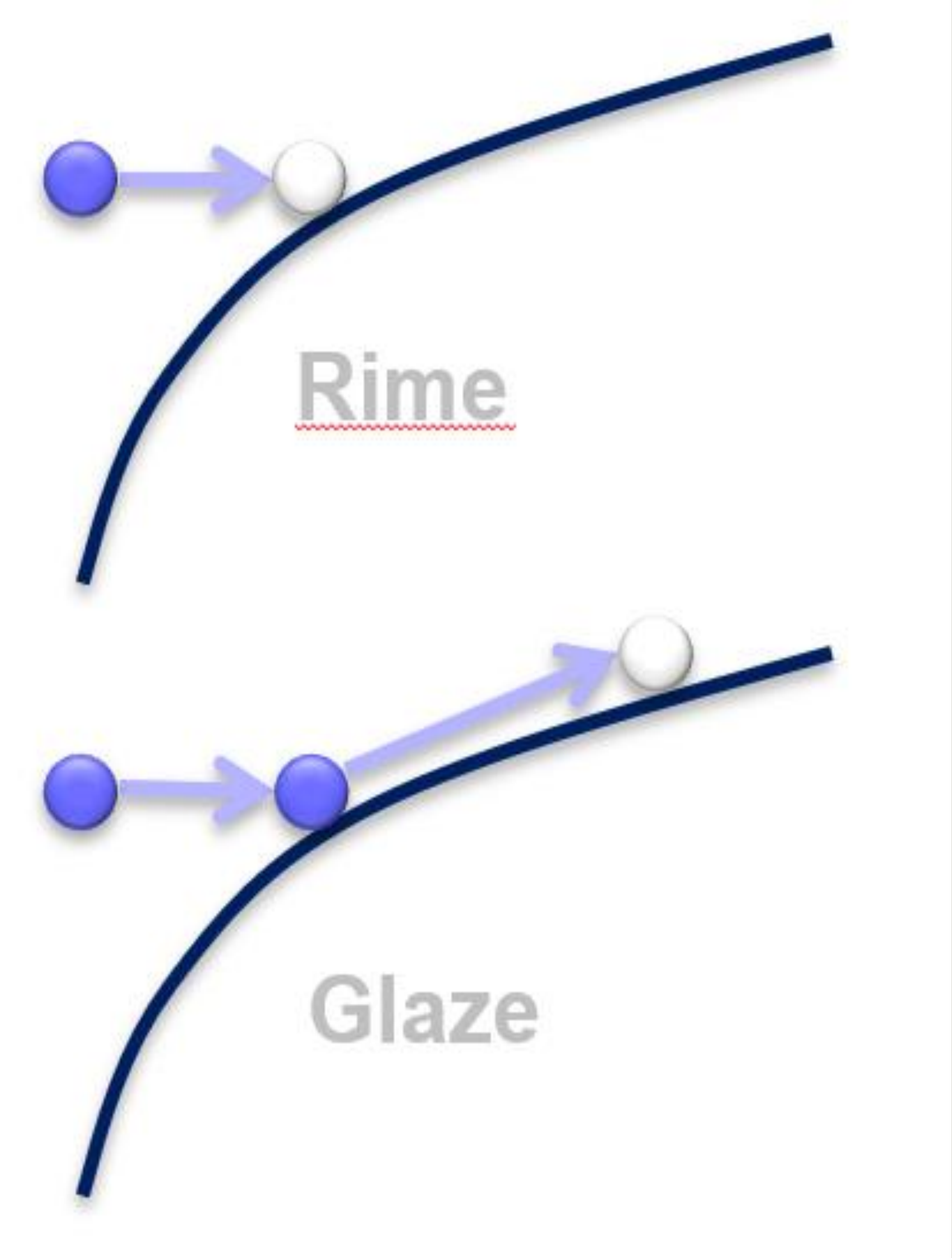
Ice accretion modeling

- Flow: incompressible Navier-Stokes equations
- Droplets: Lagrangian Particle Tracking (LPT)
- Ice accretion
  - Rime: Freeze instantaneously
  - Glaze: water displaced along surface
- **Goal**:
  - Extend existing rime ice model for glaze ice conditions



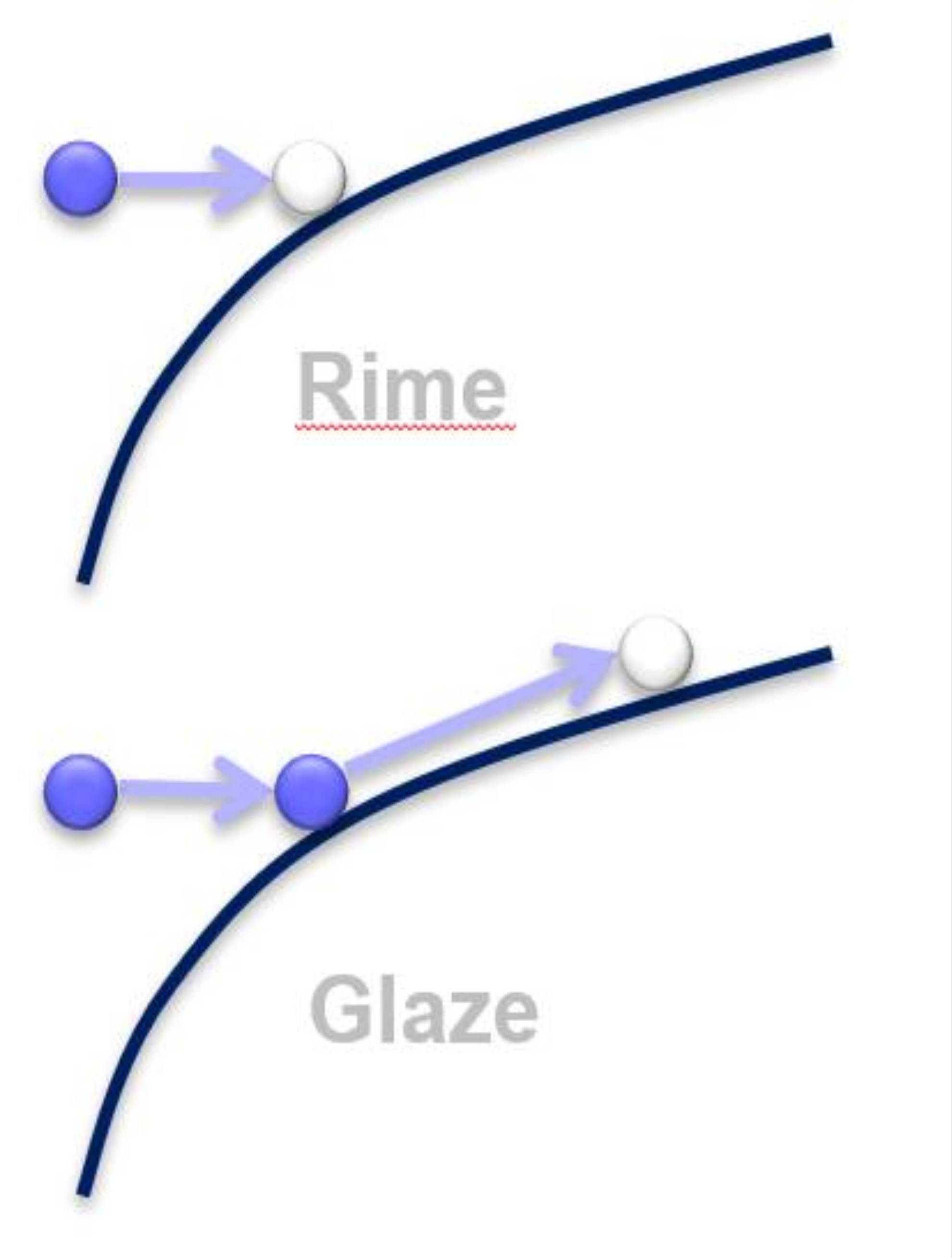
Glaze ice conditions

- Complex physics
  - Heat transfer
  - Wall film
  - …
- Goal
  - Mimic glaze conditions qualitatively
  - Advantages:
    - Faster & more robust model
    - Fewer parameters
  - Disadvantages:
    - Not universal
    - Validation needed



Idea

- Allow LPT droplet to move along the surface, for a certain time, t_f
  - Rime ice conditions become special case with $t_f=0$
  - Freezing time can be specified
    - Constant
    - First order approximation, f(d,T)
  - Additional model constant, e
    - Mimic surface tension effects, $u_N=e\ u_T$



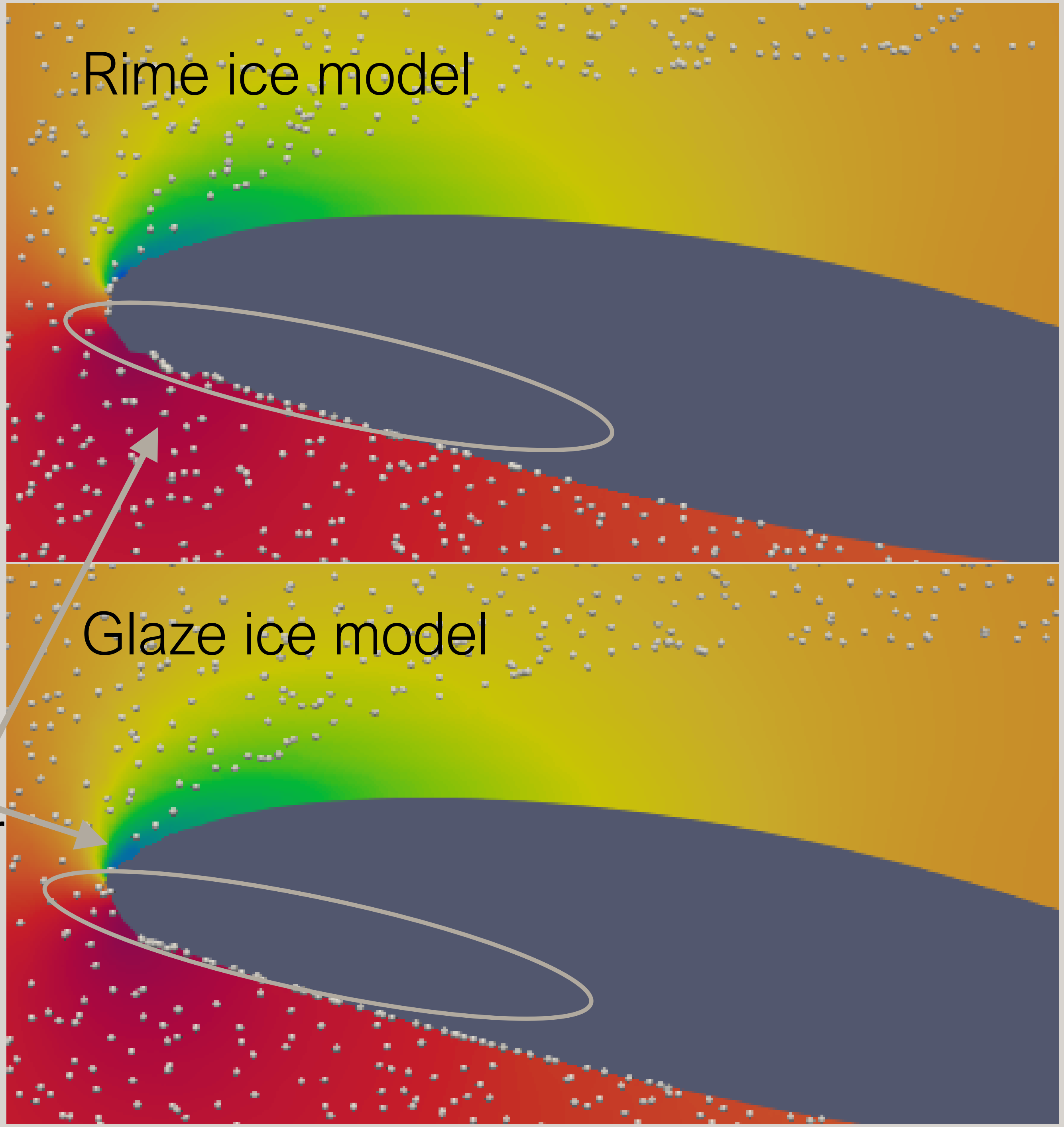
Validation case 1

- Mild glaze ice conditions [1]
- Qualitatively good
- Quantitatively overpredicts ca. 24%

LWC	0.37 g/m^3
MVD	27.6 µm
T	-1.4 ^{o}C
u_{rel}	19.9 m/s
t_{ice}	14.8 min
AoA	6 deg
m_{ice}	48 g
$m_{computed}$	59.4 g

1. Hochart et al. Wind Energ. Vol. 11 (4) pp. 319-333

- Smoother ice surface
- Droplets freeze further downstream



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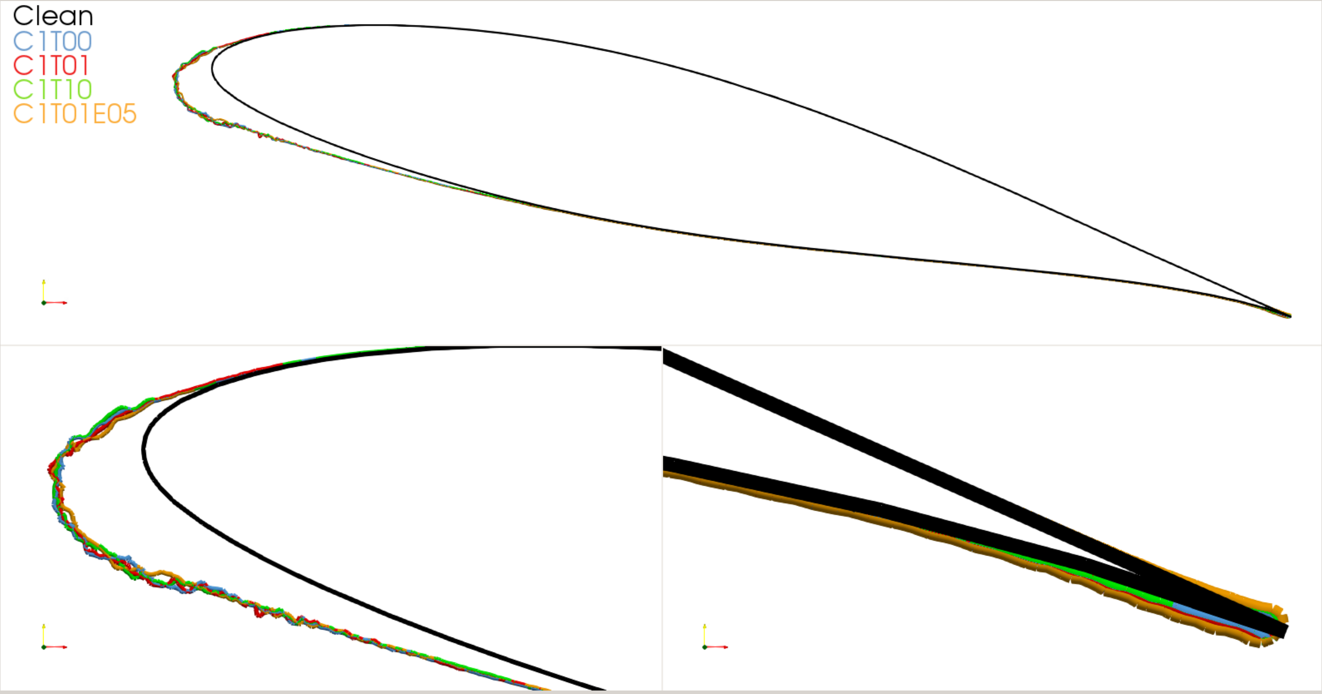


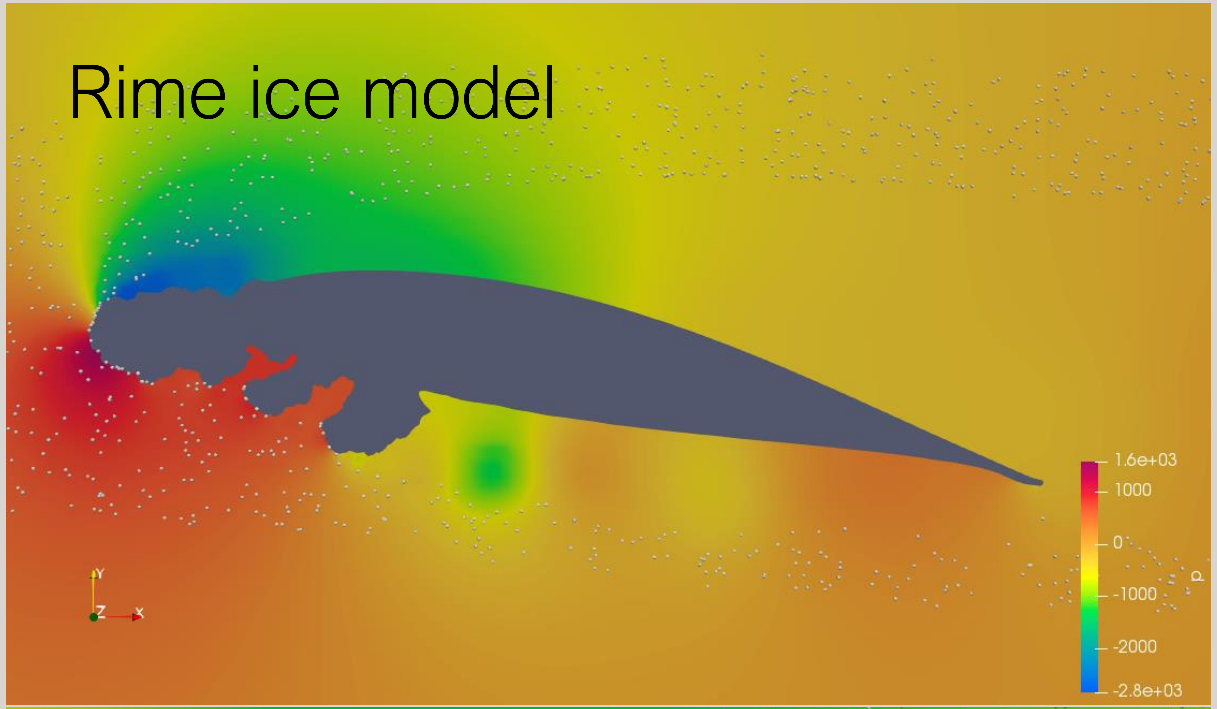
Validation case 2

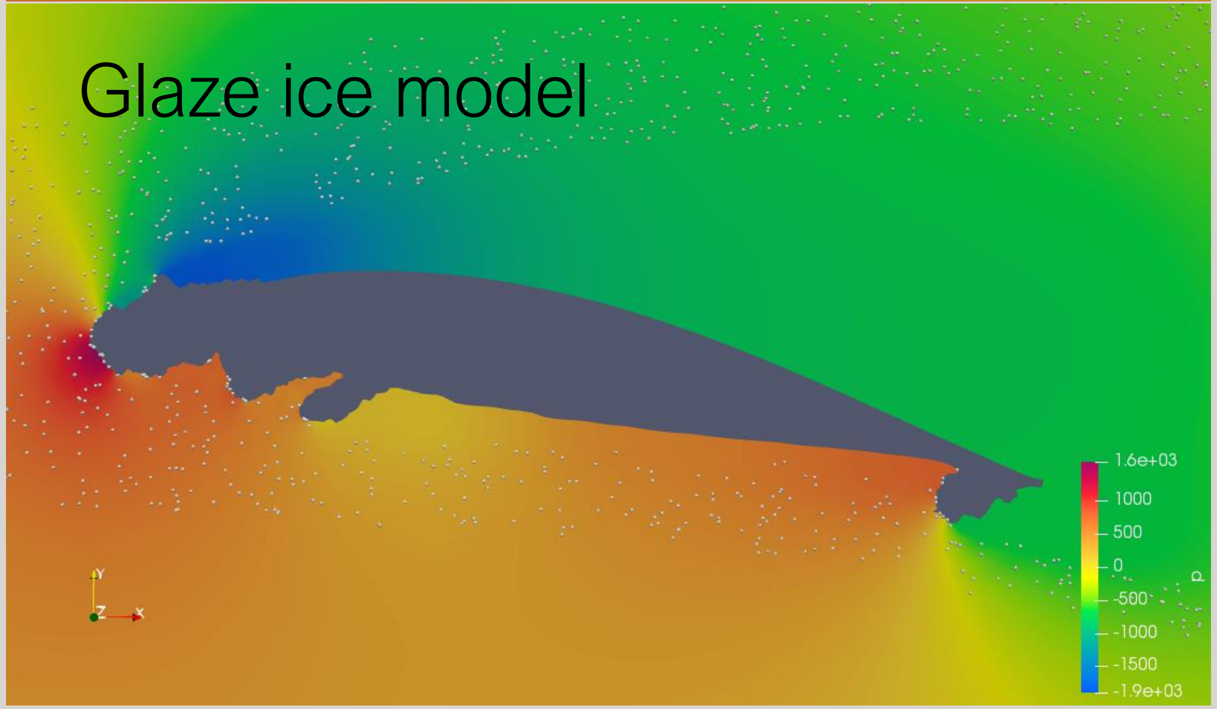
- Severe glaze ice conditions [1]
- Better than rime ice model, but improvements needed
- Significant overprediction, ca. 59%

LWC	0.48 g/m^3
MVD	27.6 µm
T	-1.4 °C
u_{rel}	56 m/s
t_{ice}	24.8 min
AoA	6 deg
m_{ice}	354 g
$m_{computed}$	563 g

1. Hochart et al. Wind Energ. Vol. 11 (4) pp. 319-333

- Lack of ice loss model?





Conclusions

- A simplified glaze ice model is implemented
- Two model parameters
- Qualitatively good for mild conditions, for severe conditions unrealistic ice structures
- Quantitatively overpredicting the amount of ice
- Improvements needed
  - Ice loss model planned

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- Swedish Energy Agency, Proj.Nr. 47053-1
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