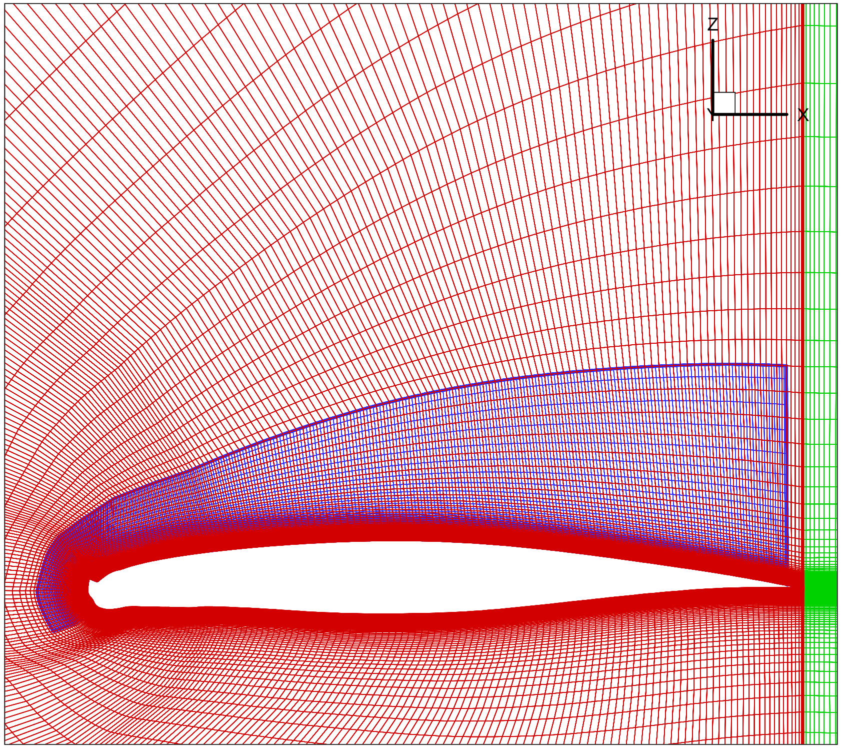
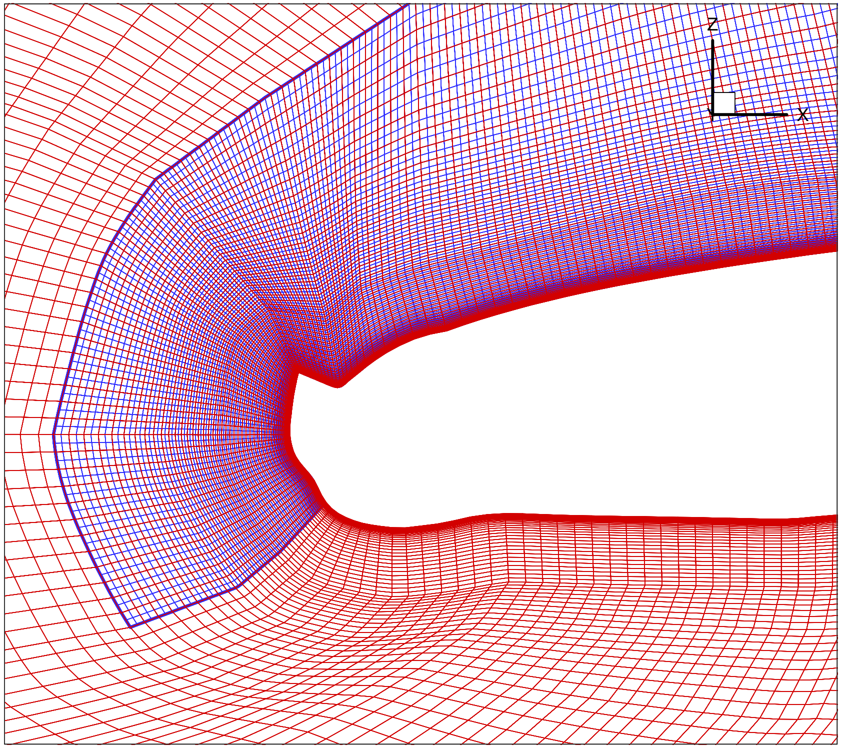
Mesh - HMR grid

- 88 000 nodes

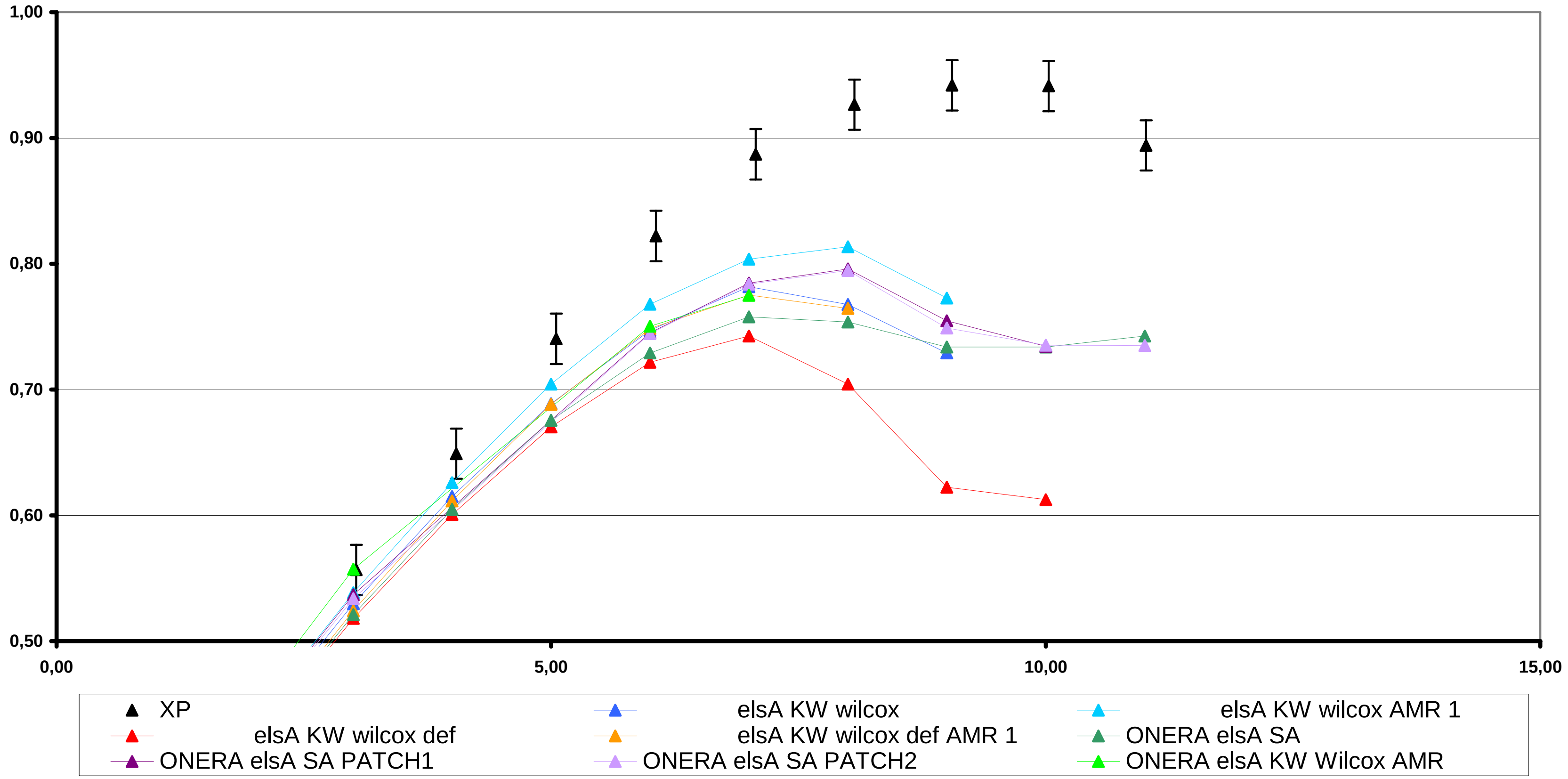


Airfoil



Leading edge detail

Results



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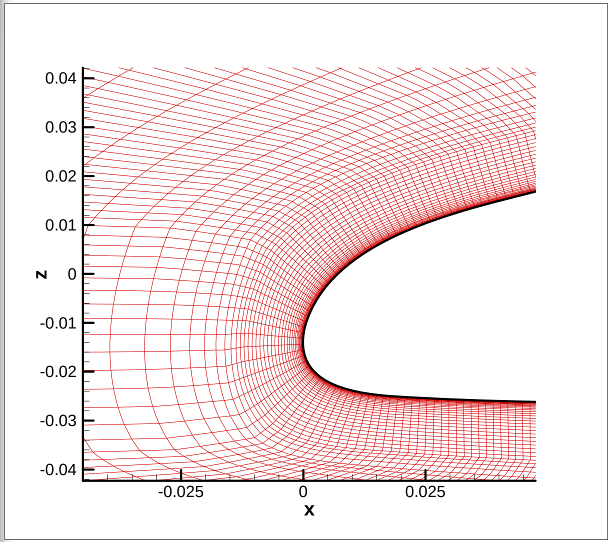
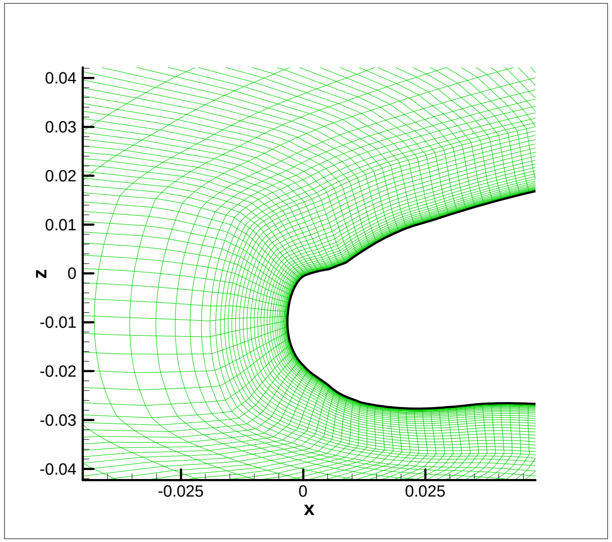
Deforming mesh

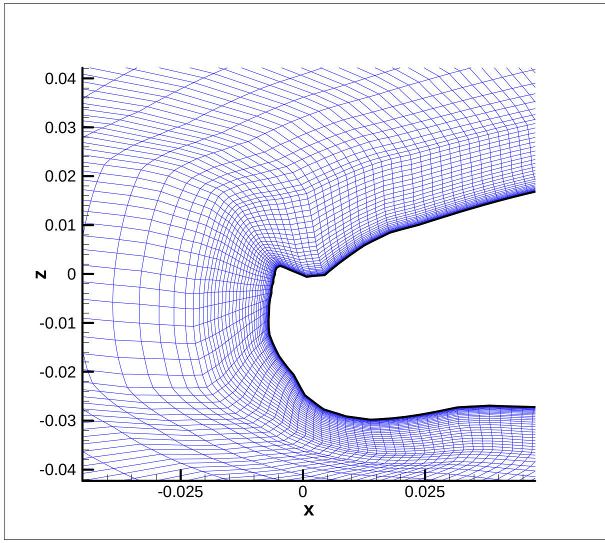
airfoil mesh – 2 steps to achieve final shape



initial mesh



Half displacement



Final mesh

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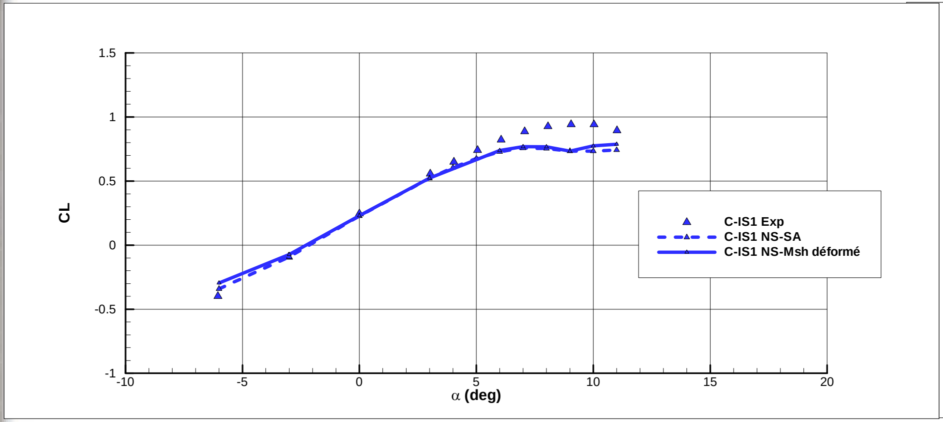
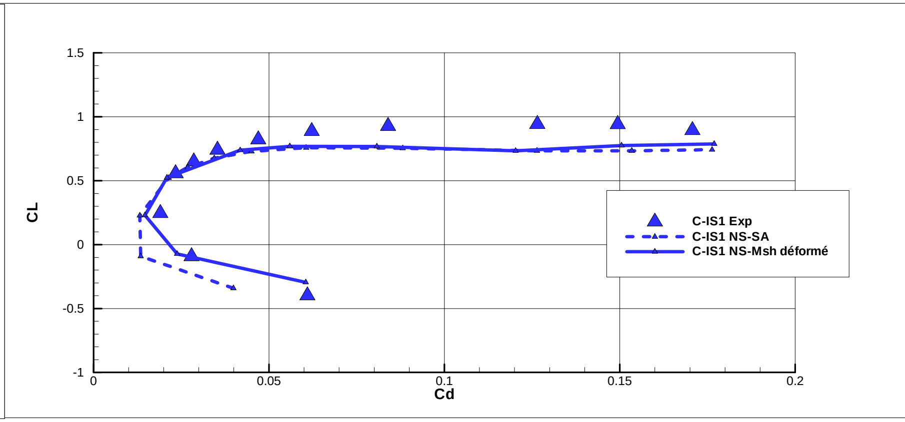
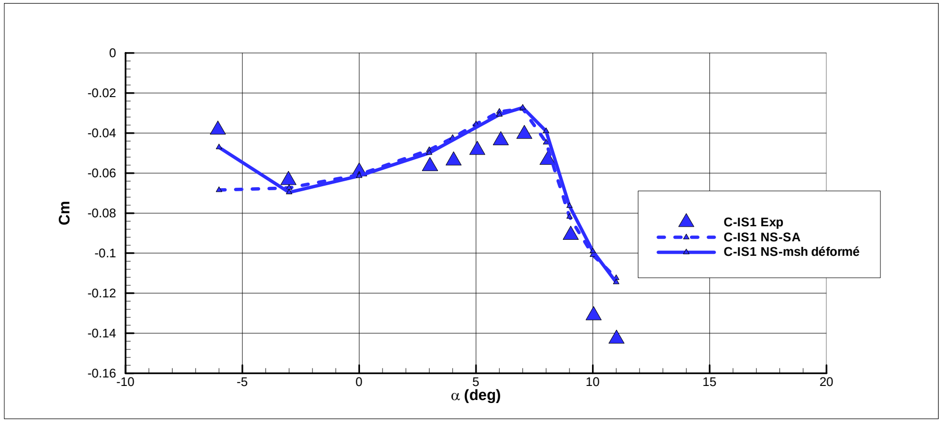
Deforming mesh - results







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Conclusions for CFD 2D

- 2D RANS approach gives good agreement in the linear portion of the CL(α) curve and the relative degradation value

- Massively separated flows are always difficult to compute with 2D RANS approach since the flow is unsteady 3D (see difference between computed and experimental results close to stall area)

- Results obtained with chimera strategy are very close of the classical strategy ;

- Association of chimera strategy and deforming mesh using computed displacements is possible to create a complete chain to predict aerodynamic capabilities.

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PERSPECTIVES

- **RANS/k-ω Menter SST: correction SST is judicious to improve significantly the prediction in the presence of boundary layer separation (unfavourable gradient of pressure). Development are necessary to treat rough walls**

- **URANS: test non stationary phenomena in the presence of massive separations**

- **Test with LES**

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Ice growth modeling suite

The Stakes:

- **Establish the 3D accretion code capabilities**
- **Reduce over conservatism of artificial ice shape**
- **Improve competitiveness of air framers**

State of art:

- **No full 3D accretion suite is used in an industrial phase**

Ice growth modeling suite

The aims:

- **To develop a 3D ONERA icing suite using an unstructured or structured Navier-Stokes solver, an Eulerian trajectory solver and an ice accretion solver**
- **To develop a 3D icing suite that enables users to use their own components (flow and/or trajectory fields)**
- **To ensure interoperability between these components that composed the full 3D icing suite**

Use the CGNS standard to communicate and interface the components

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Ice growth modeling suite

Interoperability ensured by:

- Defining a specific set of mandatory parameters (seen as a restriction to CGNS norm) for the solvers to be able to give the ice growth

⇩

- a data specification for the exchange file

- A certification tool for the compliance with the restriction to the CGNS norm

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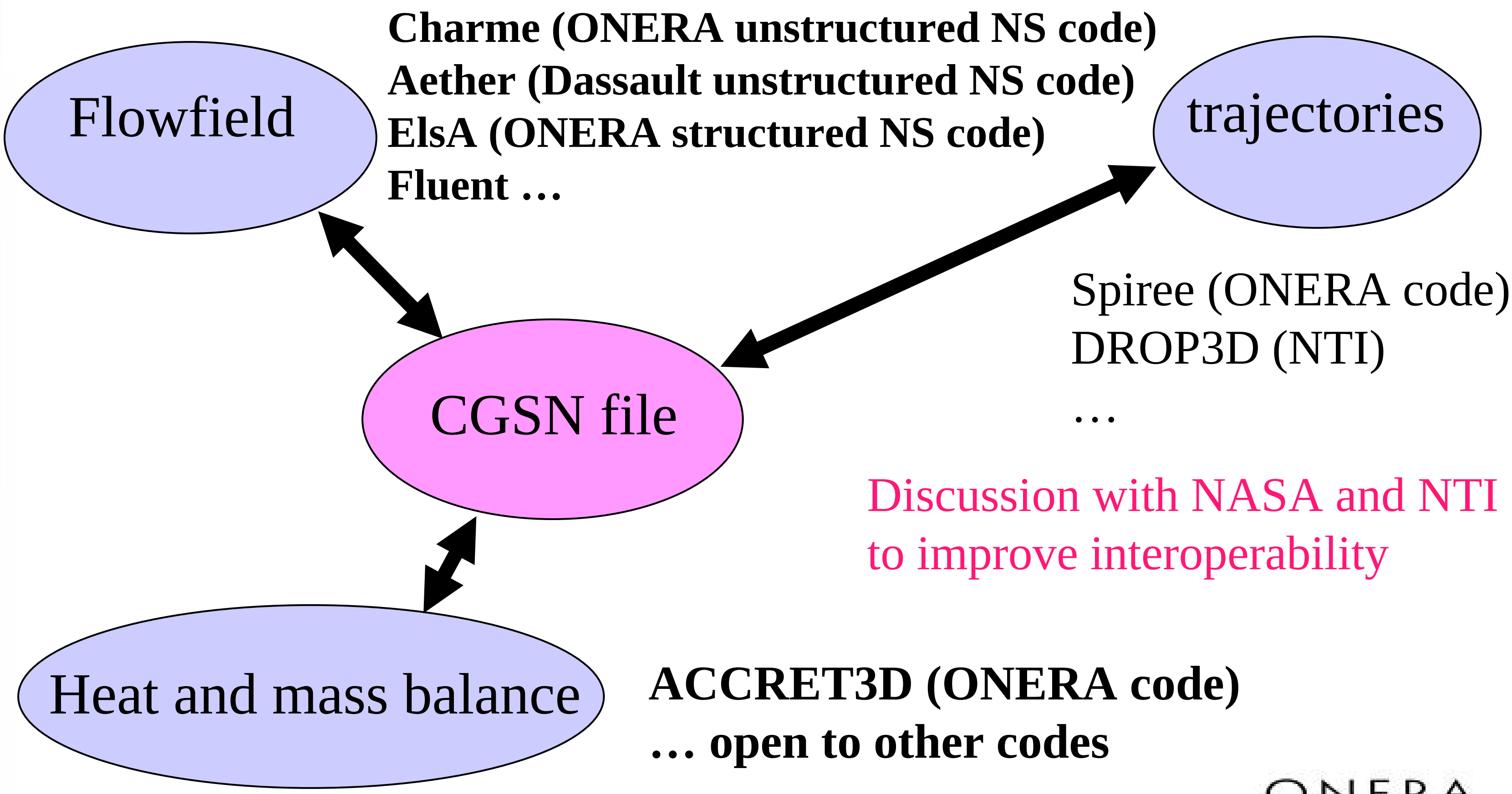
Ice growth modeling suite

3D CODE ICING SUITE STRUCTURE



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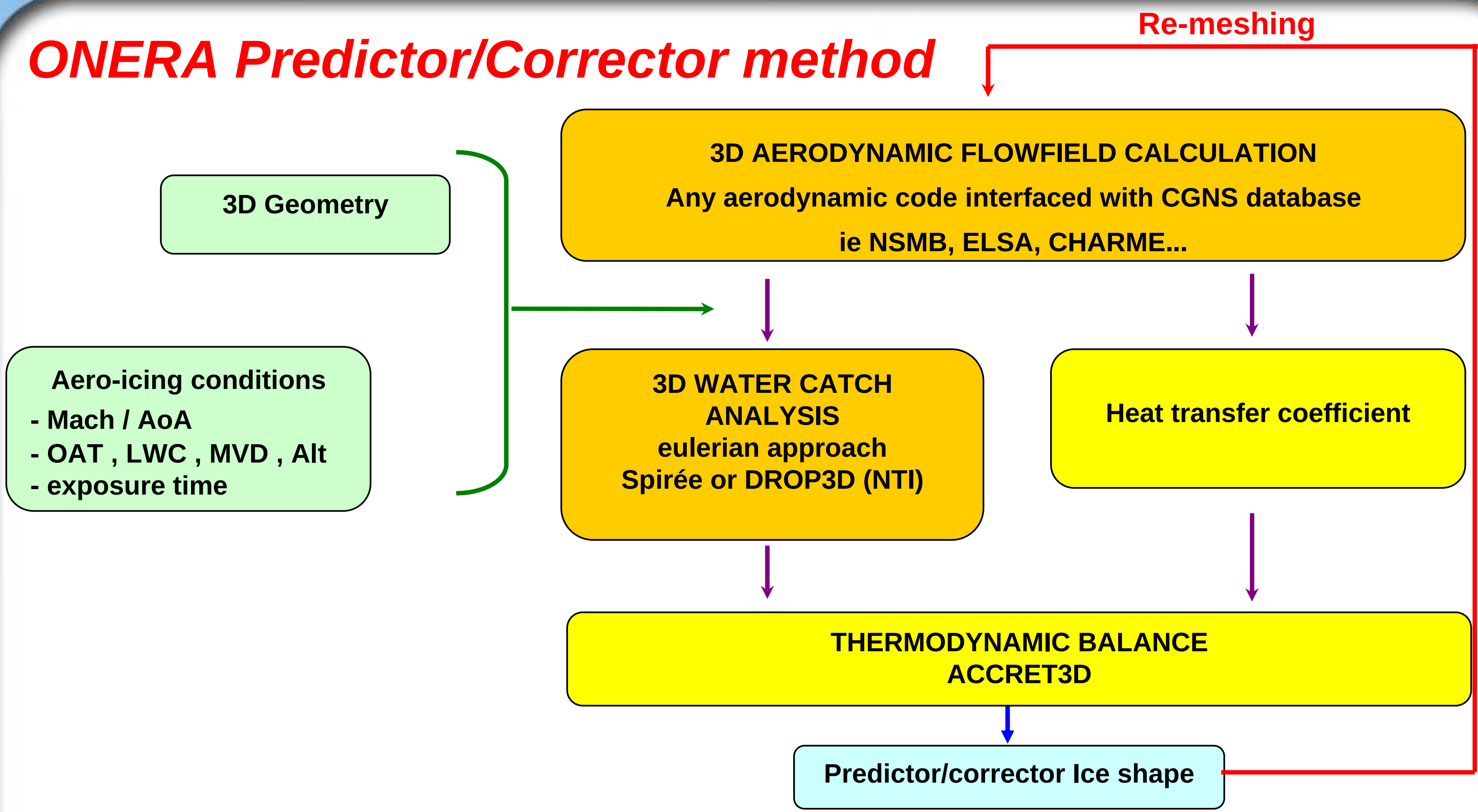
Ice growth modeling suite

ONERA Predictor/Corrector method



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Ice growth modeling suite

CFD codes used:

- **ONERA:**
  - **ElsA : a compressible NS solver based on structured finite volume approach**
  - **Charme : a compressible NS solver based on unstructured finite volume approach**
  - **Spiree : a multi-class eulerian trajectory solver based on unstructured finite volume approach**
  - **Accret3D : ice accretion solver based on unstructured volume control approach**
- **DA:**
  - **Aether : a compressible NS solver based on finite element approach**
- **ECF:**
  - **Fluent**
  - **DROP3D (NTI)**

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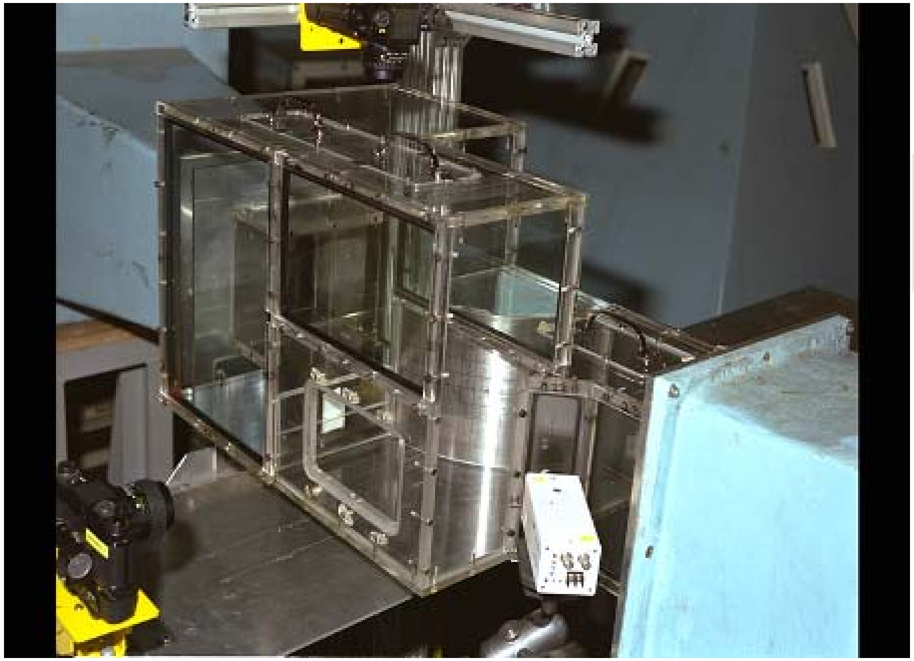
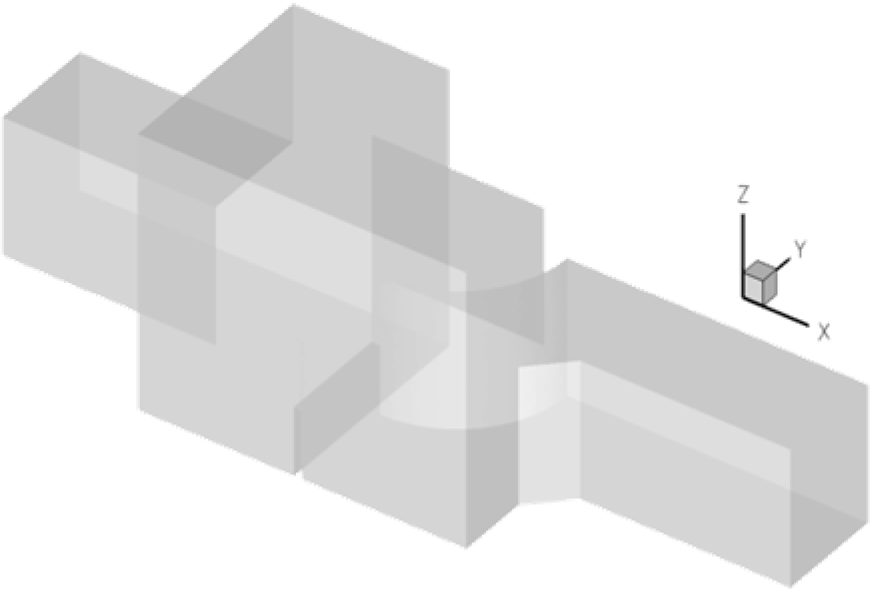
Ice growth modeling suite

First test : Ice prediction on a complex 3D internal flow

down-stream





up-stream

TEST PERFORMED IN THE CEPr WINDTUNNEL

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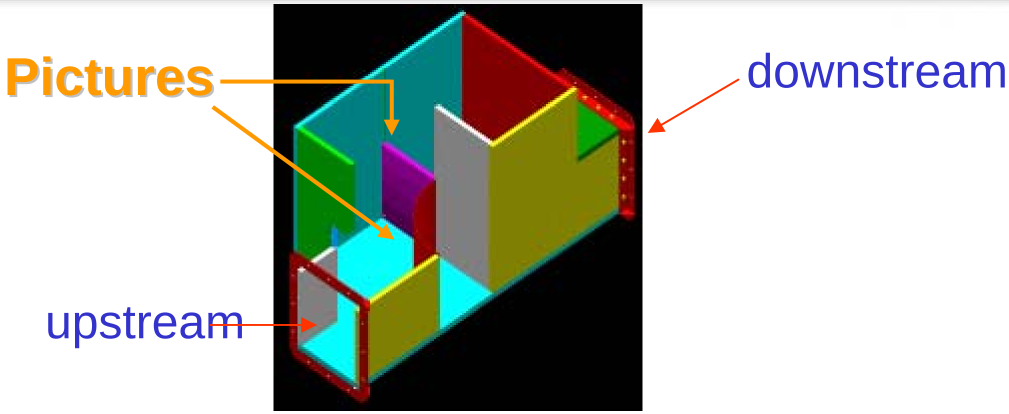
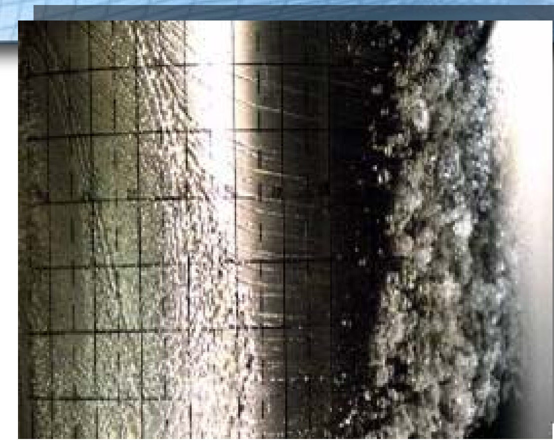
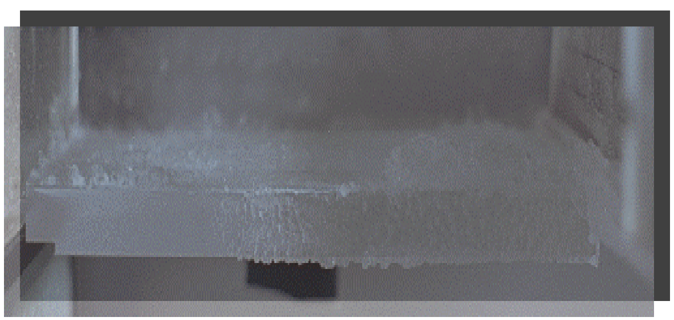
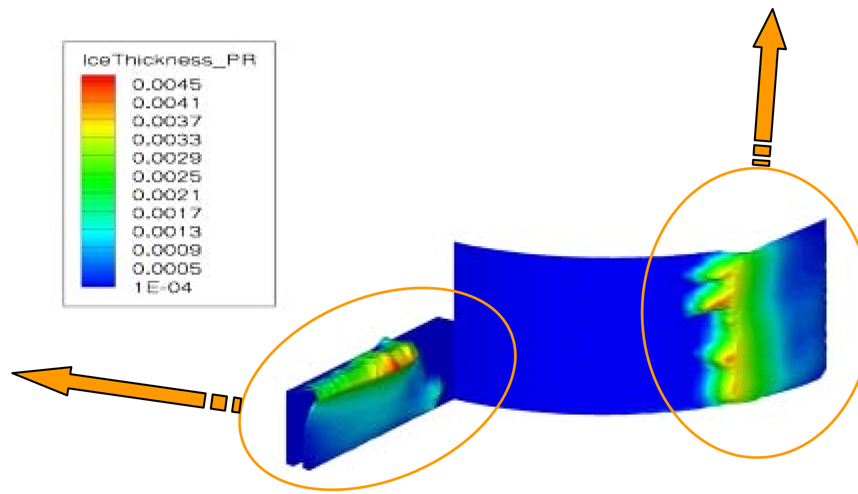
Ice growth in an air intake duct test case comparison calculation/tests



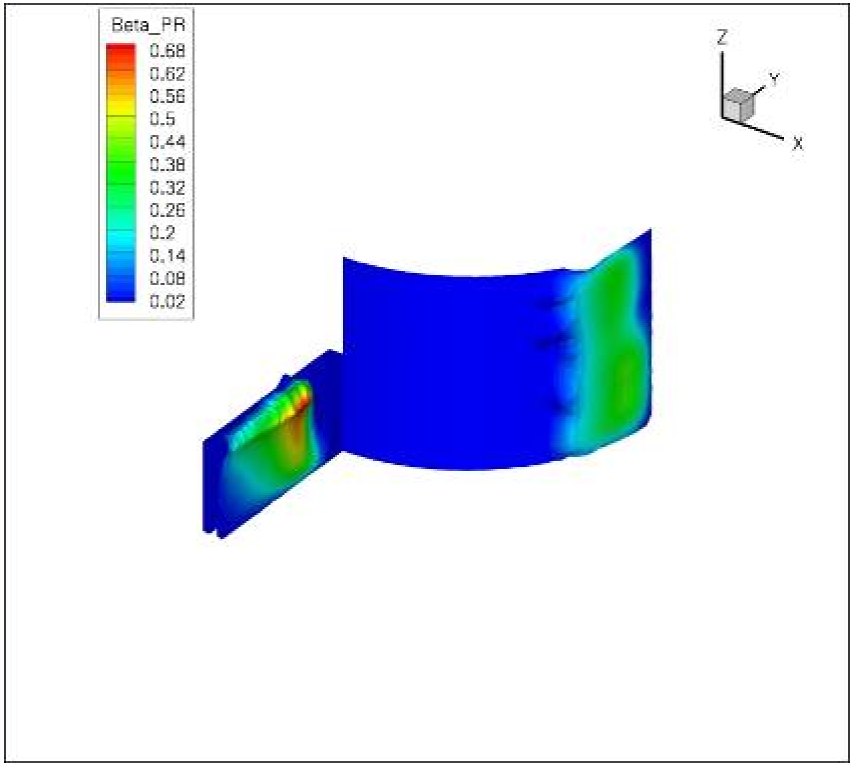




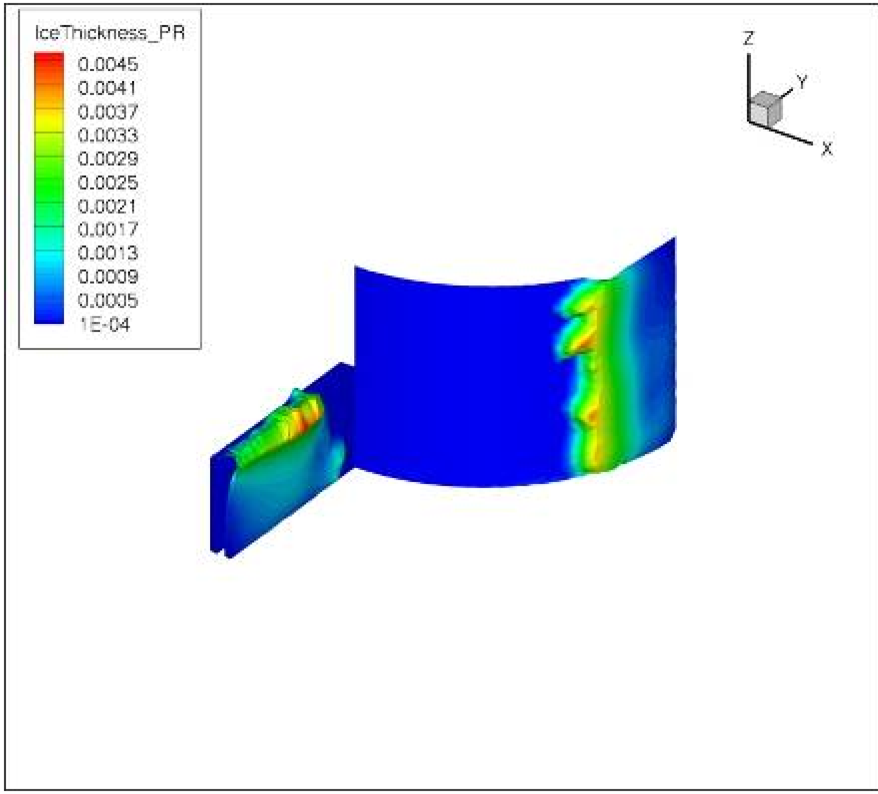


Ice thickness with runback calculation (warm case) (-3°C)

Ice growth in an air intake duct test case comparison calculation/tests



CATCH EFFICIENCY



ICE SHAPE

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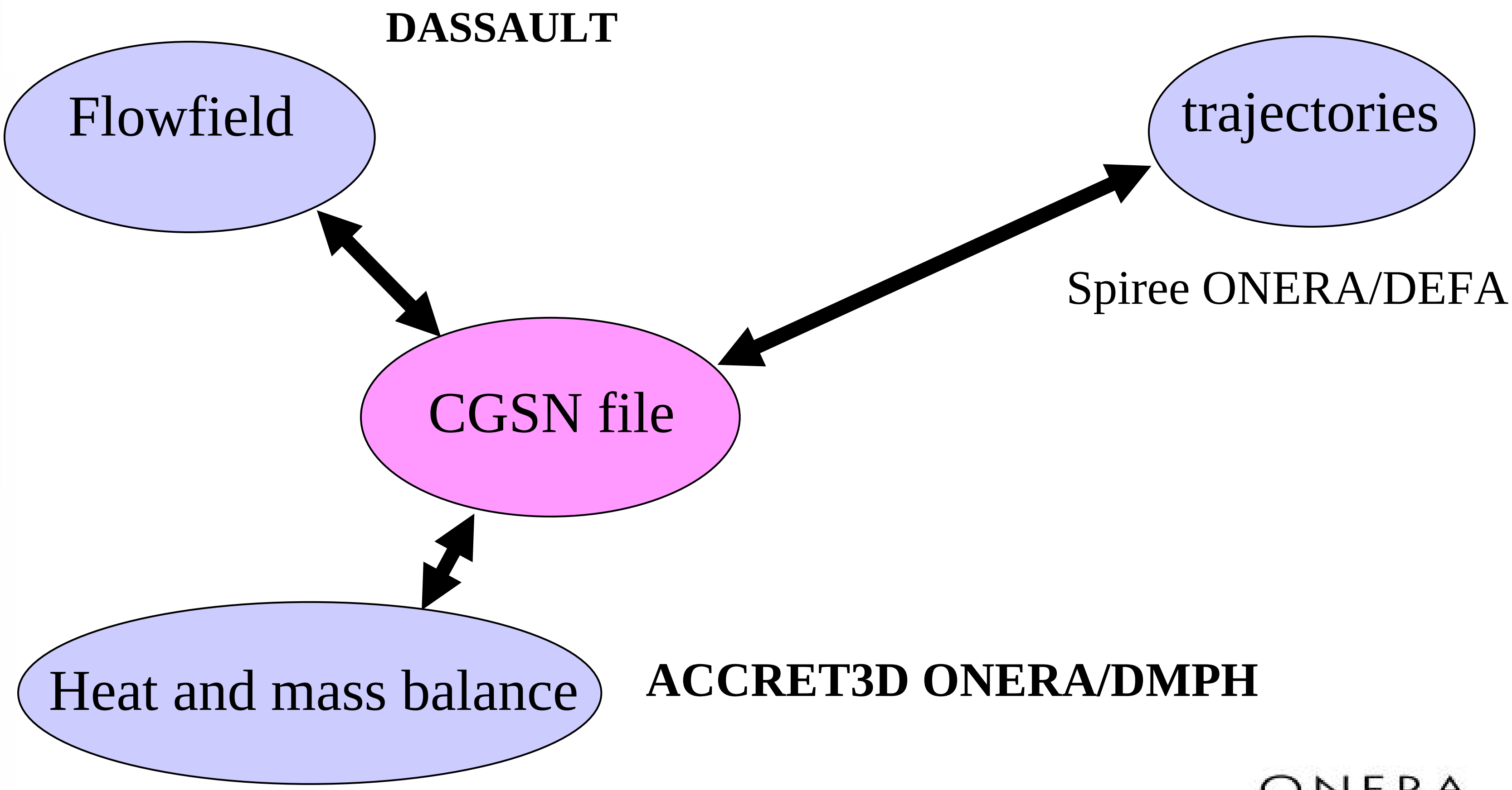
Ice growth modeling suite

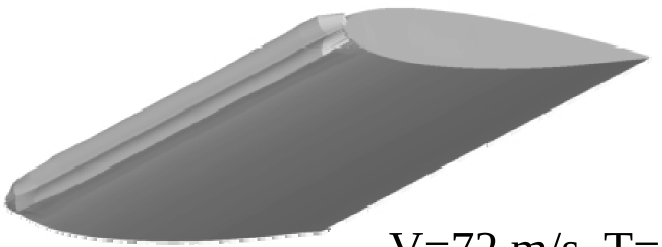
INTEROPERABILITY TEST VALIDATION

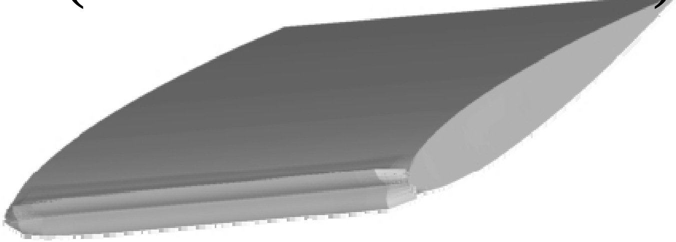


Ice growth modeling suite

Ice shape on a swept wing (NACA12 profile)

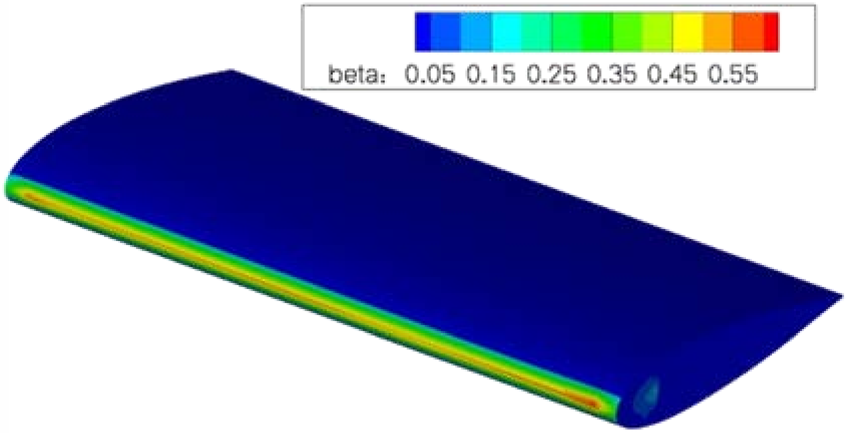
AIAA 92-004 Jan 1992 by Reehorst A.L (Lobster tails accretion)

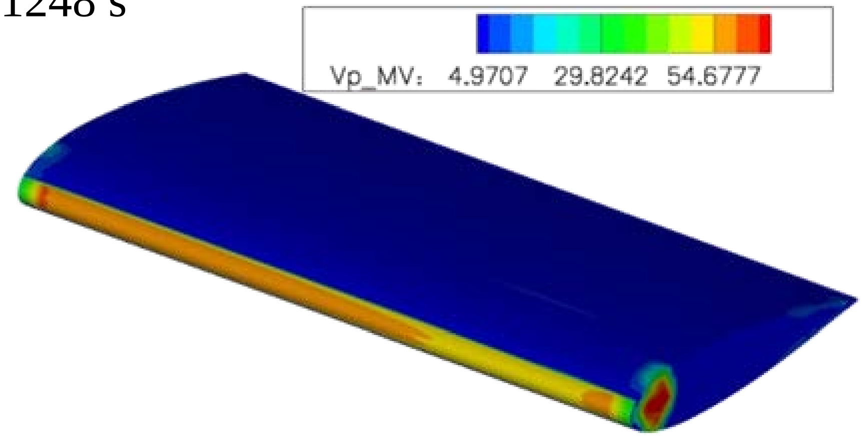




V=72 m/s, T=270K, LWC=0.22 g/m^3

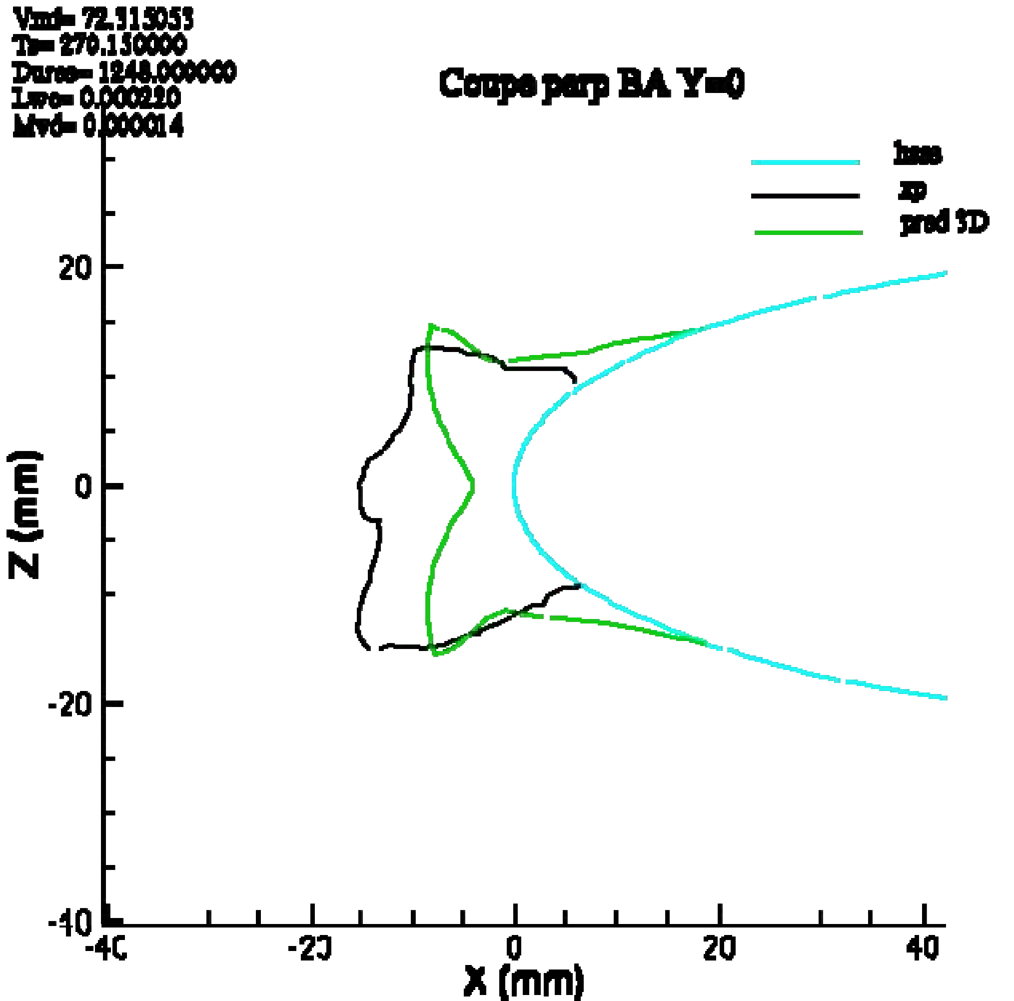
MVD = 14 µm, Duration = 1248 s





Ice growth modeling suite

Ice shape on a swept wing (NACA12 profile)



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Conclusion for 3D Ice accretion

Conclusion for the 3D modeling:

- **Good interoperability through CGNS specification**
- **Usable for very complex 3D configurations**

Perspectives:

- **SLD in 3D configurations**
- **Improvement of the eulerian module**
- **Improvement of the re-meshing**
- **More extensive validation (need to have a 3D data base)**

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