Finite-volume methods

The Computation of Transonic Flow Through Two-Dimensional Gas Turbine Cascades

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Steady transonic flow through two-dimensional gas turbine cascades is efficiently predicted using a time-dependent formulation of the equations of motion. An integral representation of the equations has been used in which subsonic and supersonic regions of the flow field receive identical treatment. Mild shock structures are permitted to develop naturally without prior knowledge of their exact strength or position. Although the solutions yield a complete definition of the flow field, the primary aim is to produce airfoil surface pressure distributions for the design of aerodynamically efficient turbine blade contours. In order to demonstrate the accuracy of this method, computed airfoil pressure distributions have been compared to experimental results.

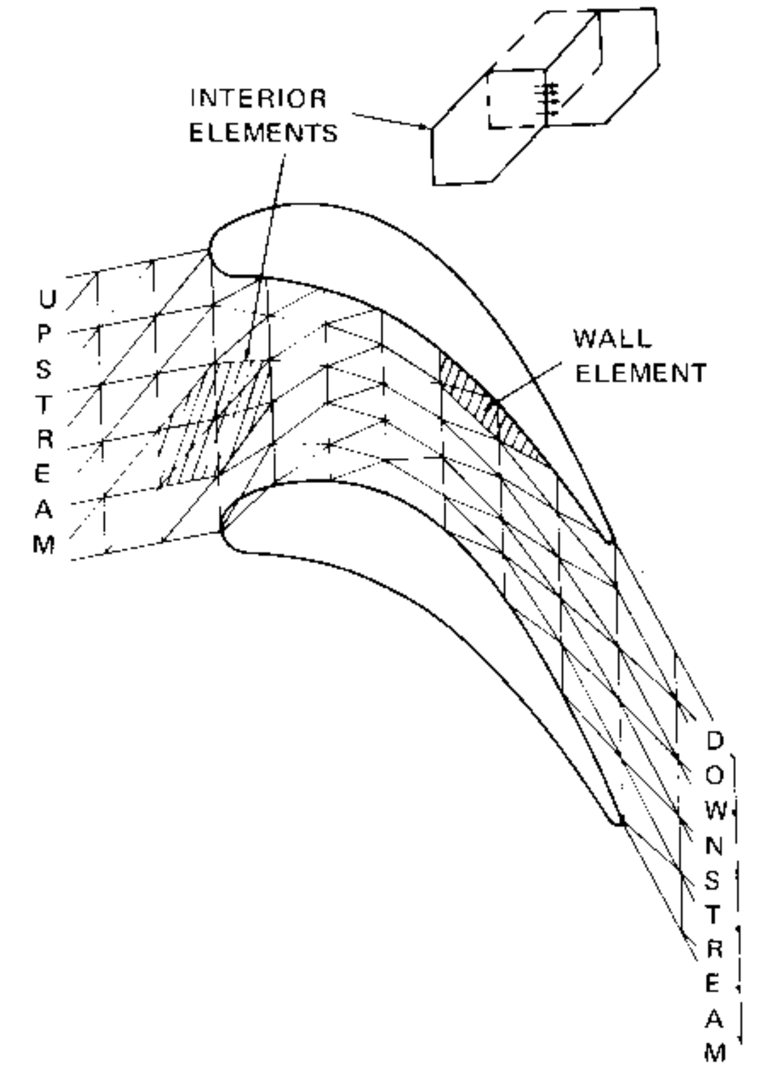

Fig. 1 Cascade system with finite area mesh.

[McDonald, 1971]

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Numerical simulation of elastic wave propagation using a finite volume method

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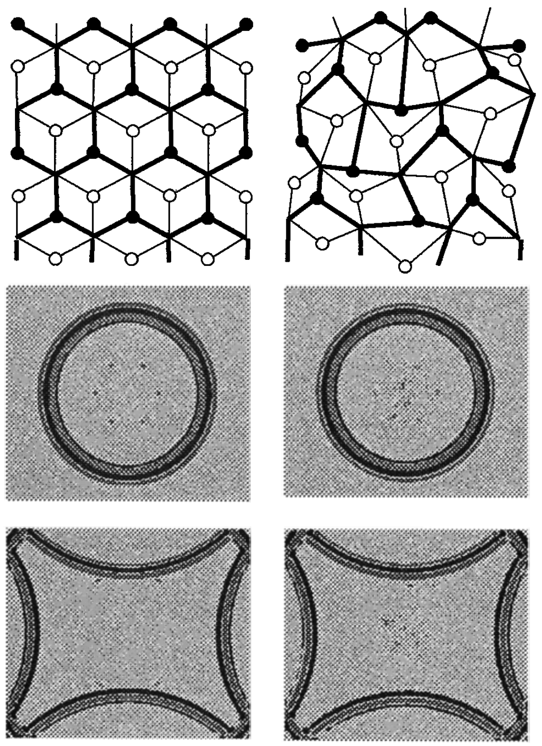
Abstract. Like the finite difference method, the finite volume method gives an approximate value for the derivative of a field at a given point using the values of the field at a few locations neighboring the point. The method uses the divergence theorem, considers a "finite volume" around the point and discretizes the surface bounding the volume. When the finite volumes considered are regular polyhedra, one obtains the expressions corresponding to standard centered finite differences, but the finite volume method is more general than the finite difference method because it may deal directly with irregular grids. It is possible to give a finite volume formulation of the elastodynamic problem, using dual volumes, that correspond, in the regular case, to the staggered grids used in the finite difference method. The scheme thus obtained is more general than the one obtained using finite differences, as the "grids" may be totally unstructured, but at the cost of having, in the general case, only a first-order accuracy. Although the scheme is not consistent, numerical tests suggest that it is stable and convergent. This implementation of a finite volume method does not provide a way for a more general treatment of the boundaries than the conventional finite difference method.



[Dormy & Tarantola, 1995]

Idea

- intended to solve **conservation laws**:
  mass, momentum, ..

- considers and discretizes the **integral form** of the equation(s):

$$\partial_x^2 T + f = 0 \longrightarrow \int_\Omega \partial_x^2 T(x)\, dx + \int_\Omega f(x)\, dx = 0$$

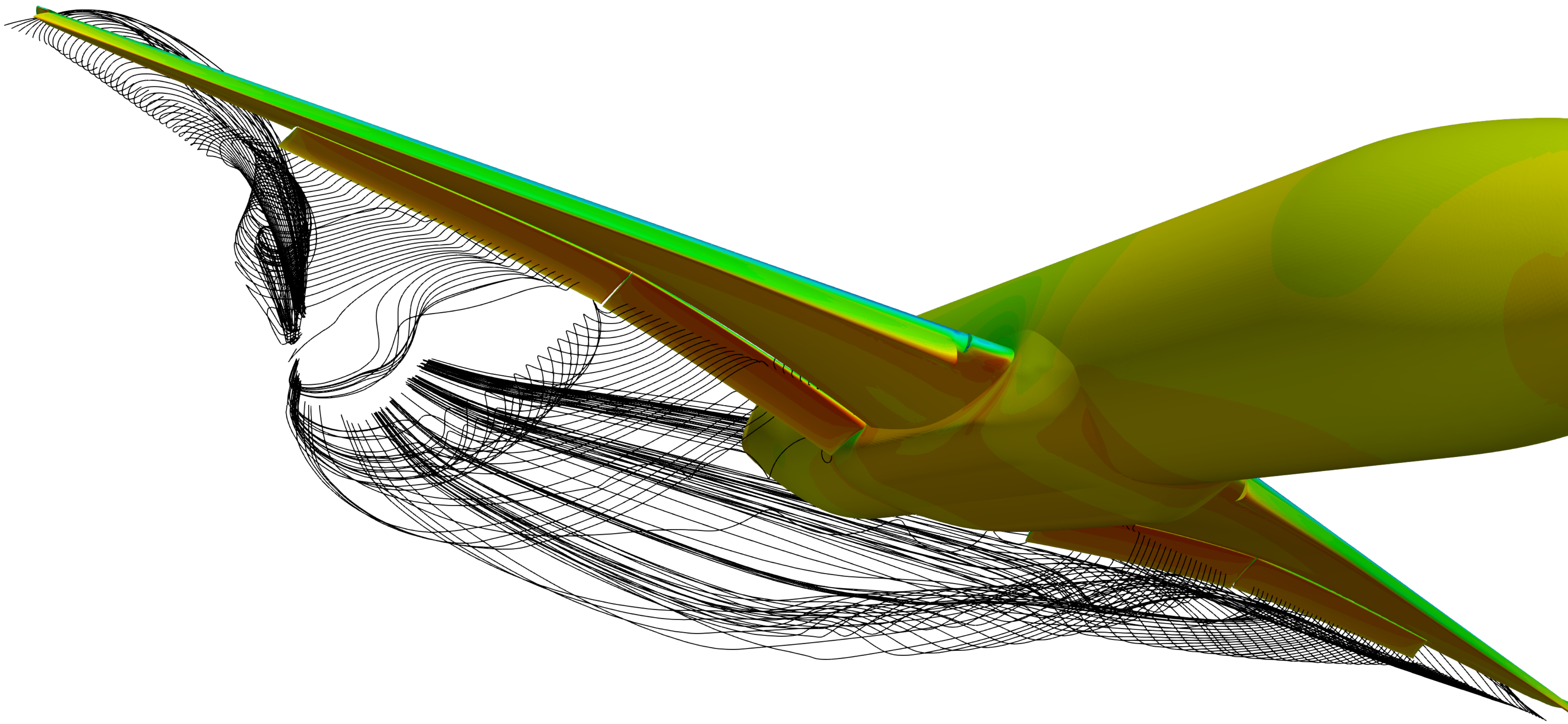
- makes use of **Gauss' theorem** to compute the divergence of a quantity in term of its fluxes across element surfaces

$$\int_V \nabla \cdot \mathbf{q}\, \mathbf{dV} = \int_{\mathbf{S}} \mathbf{q} \cdot \hat{\mathbf{n}}\, \mathbf{dS}$$

divergence $\longrightarrow$ fluxes

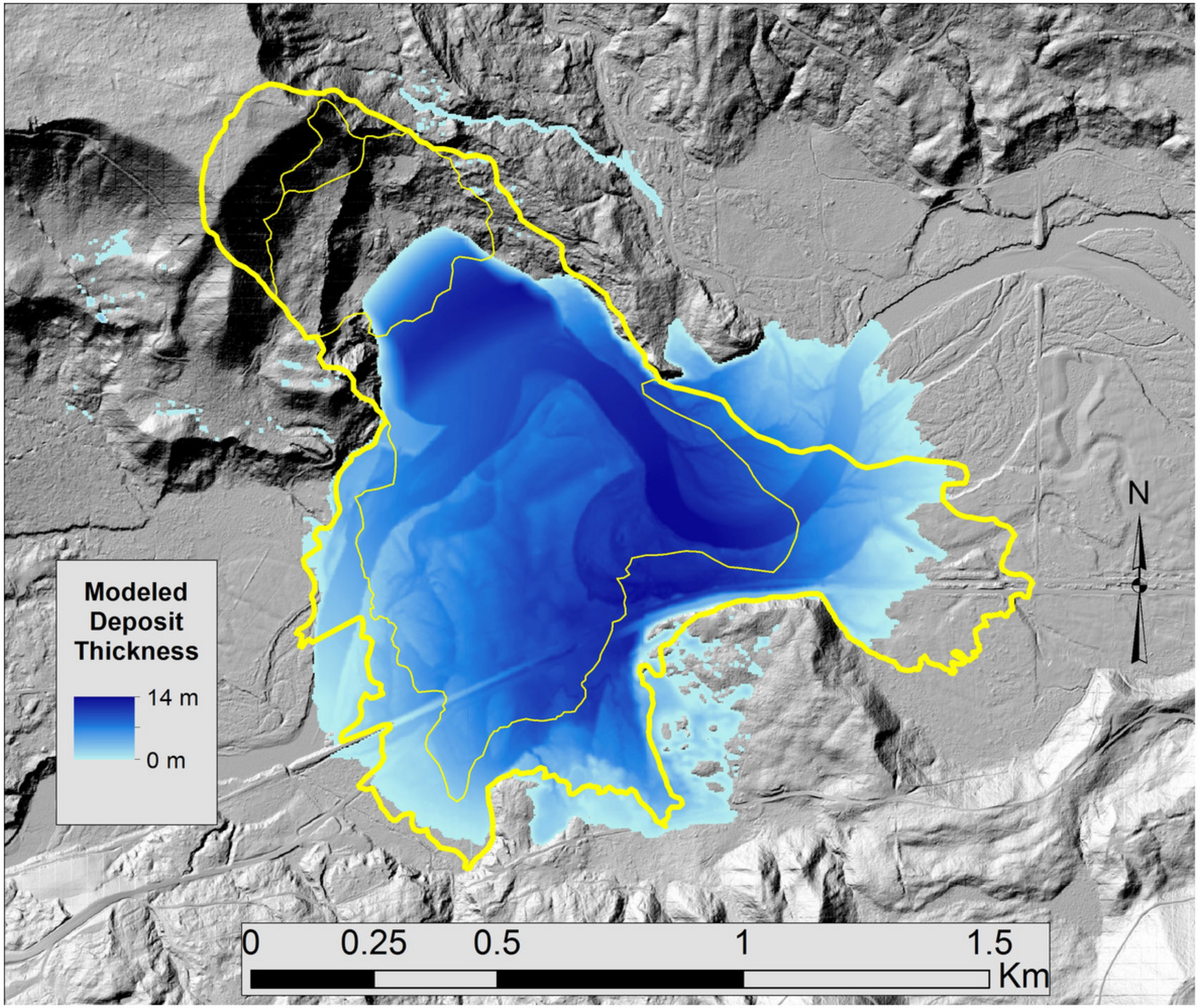
Idea

continuous → **finite-volume**



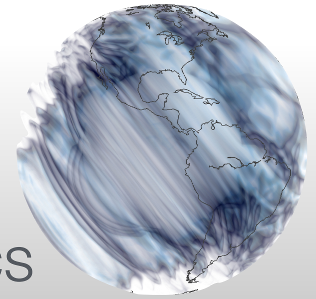
Computational fluid dynamics

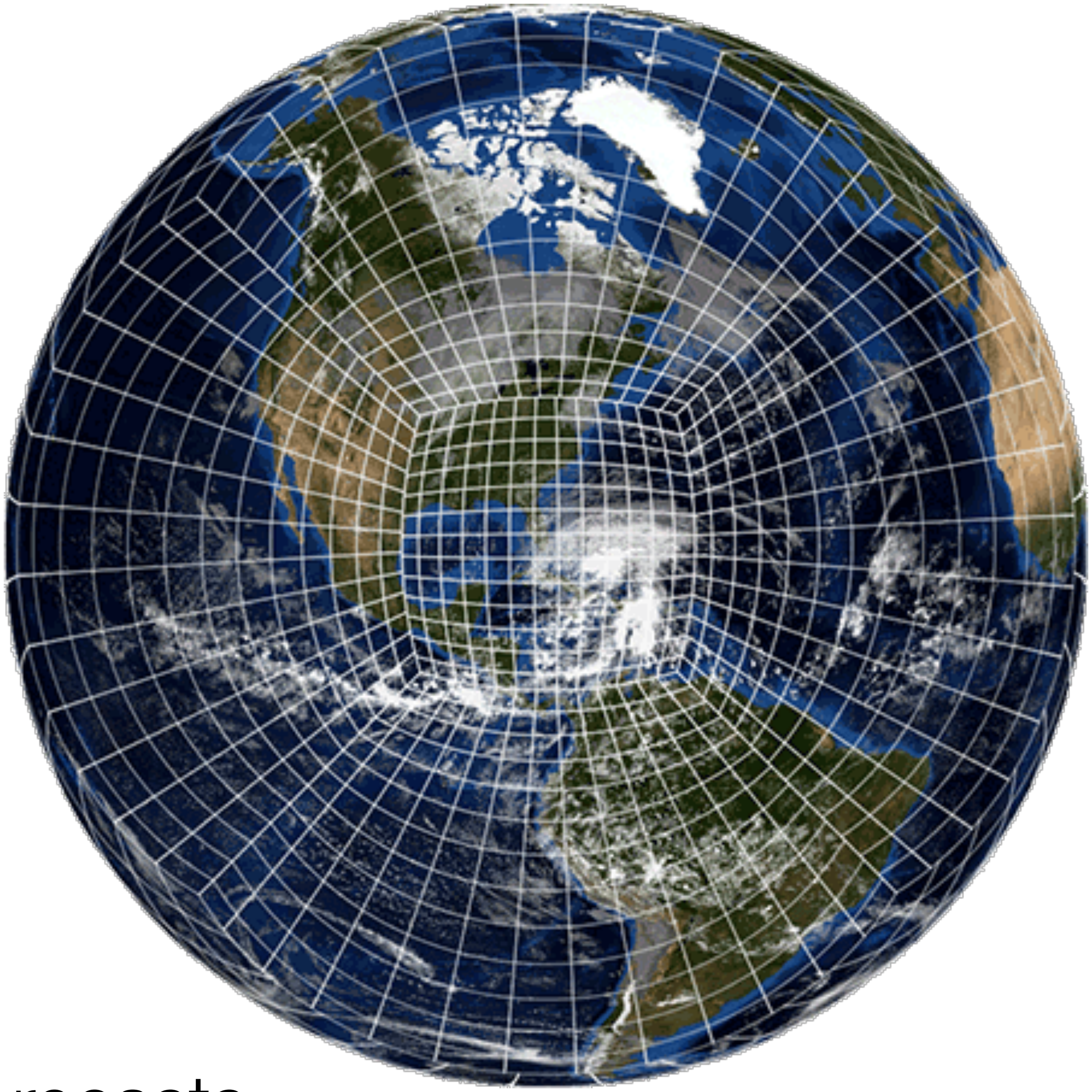
SU2



Landslides, tsunamis, shock waves, heat transport ..

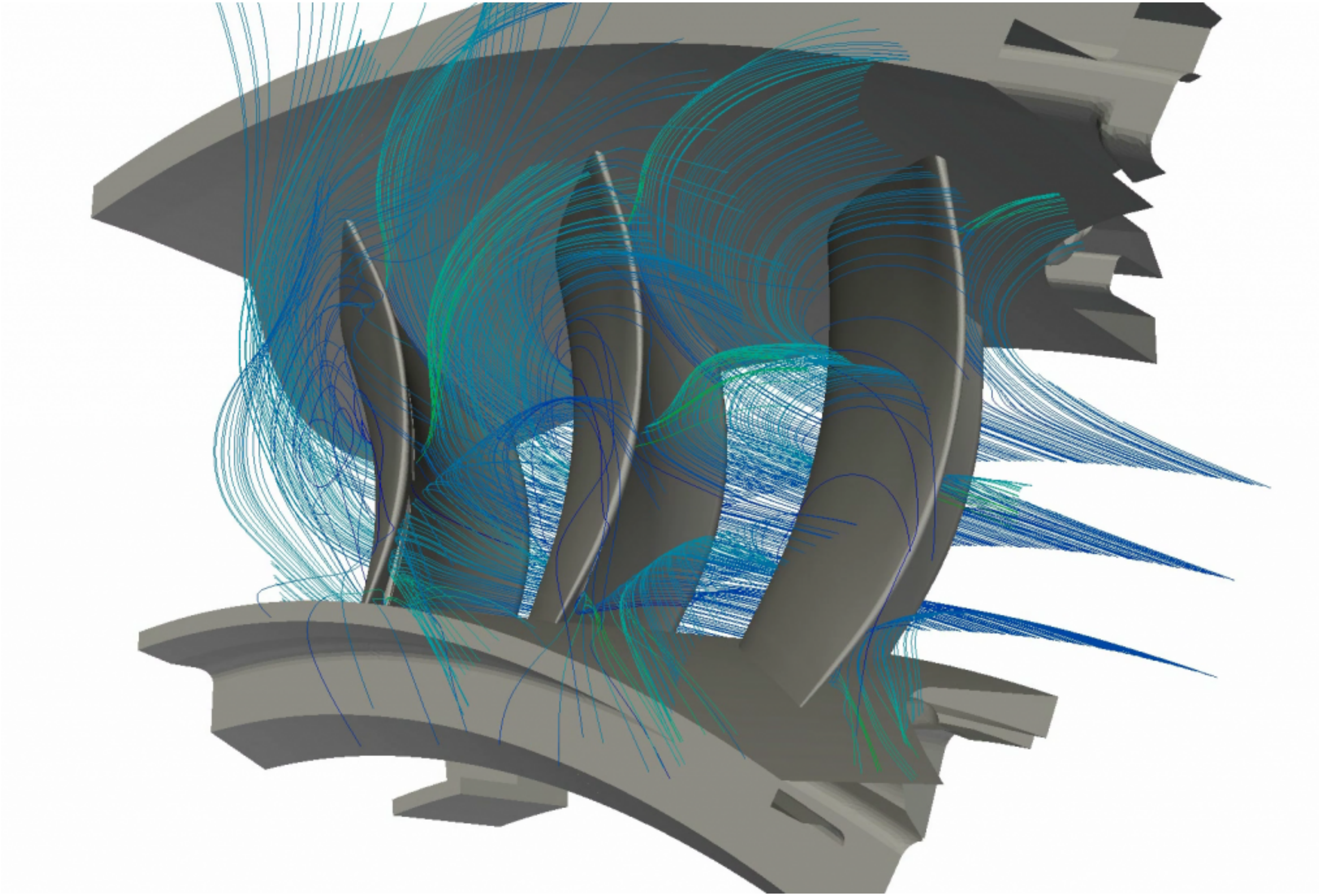
CLAWPACK





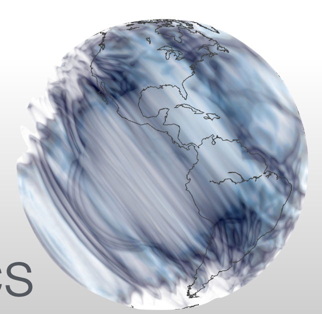
Weather forecasts

NOAA



Fluid mechanics

Commercials, ANSYS Fluent,..



Finite-volume software

commercial

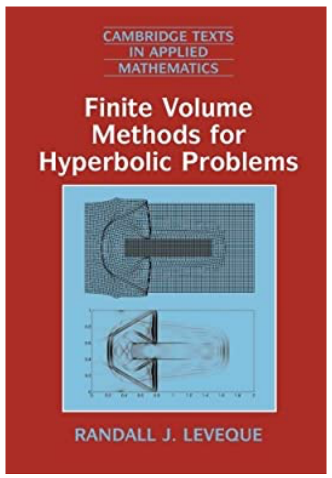
ANSYS Fluent
ANSYS CFX
Siemens Simcenter Star-CCM+
..

open-source

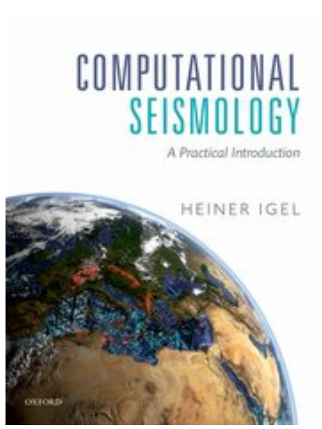
CLAWPACK
OpenFOAM
SU2
FiPy
Code_Saturne
..

Finite-volume literature

books



R. J. LeVeque
Finite Volume Methods for Hyperbolic Problems,
Cambridge University Press, 2004.



H. Igel
Computational Seismology
Oxford Press University, 2016.

online tutorials

https://youtu.be/E9_kyXjtRHc - Aidan Wimshurst, Fluid mechanics 101