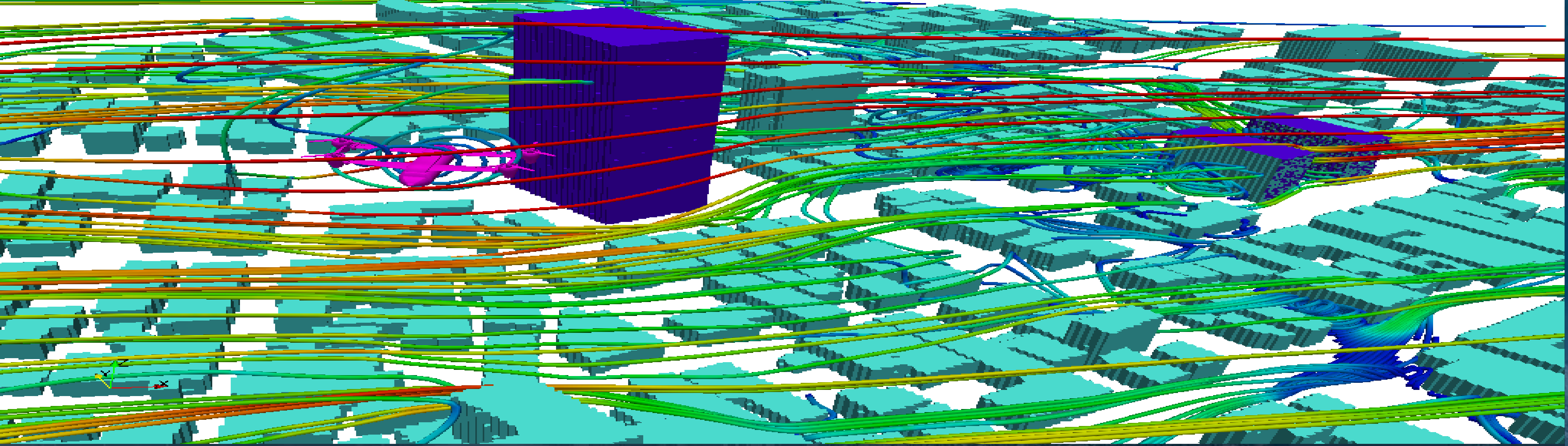


The concept of hybrid analytics methods to decide on drone landing and take-off platforms in urban areas.

Drones within the health care sector, June 19, Hamar.

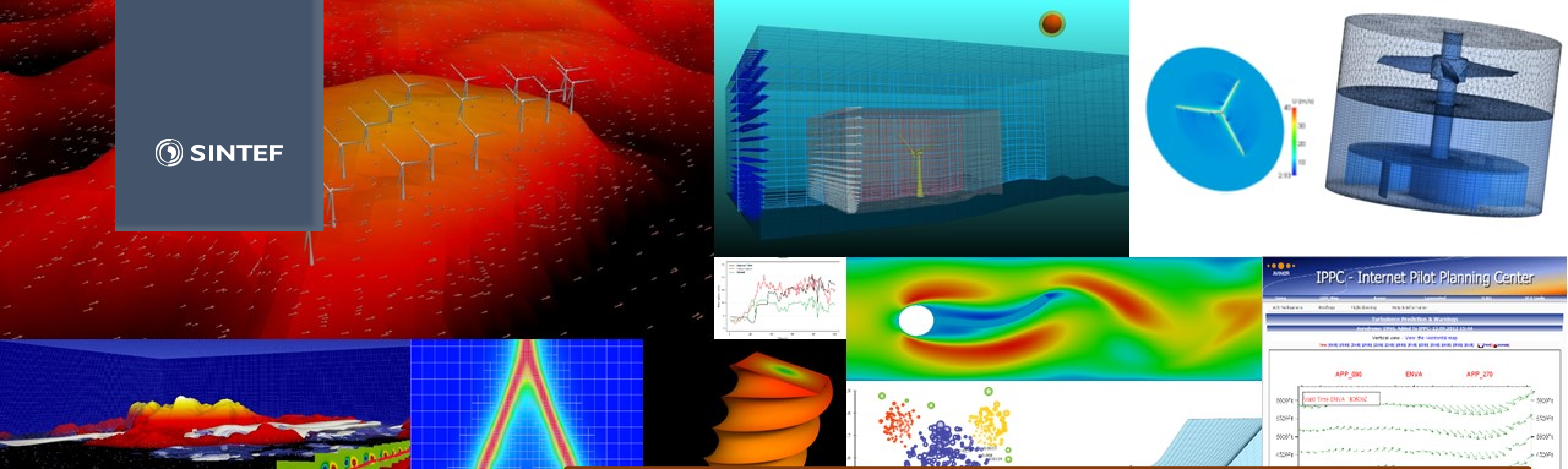
Mandar Tabib and Adil Rasheed , SINTEF Digital

CONTENT

- BACKGROUND
  - PUT THE WORK IN PERSPECTIVE :
    - SAFE AVIATION : FROM CIVIL AIRCRAFT SAFETY TO DRONE SAFETY
      - Building induced Turbulence
      - Terrain induced turbulence
  - SPECIFIC CHALLENGES WITH DRONES
- HYBRID ANALYTICS – the future way forward.
  - What is it?
  - A part of the solution.
- CONCLUSION

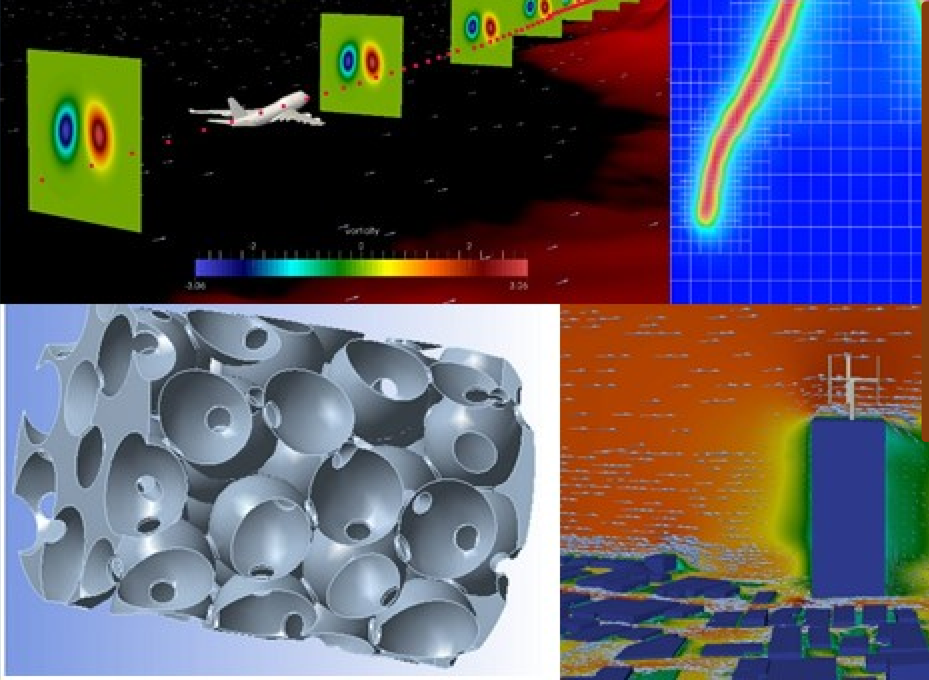
Background

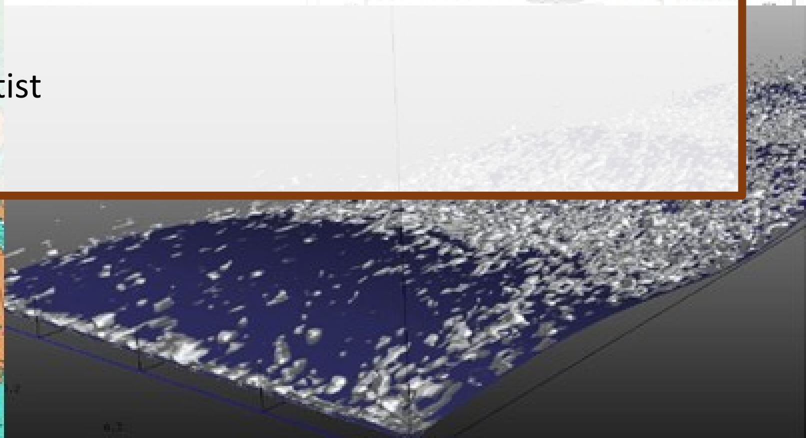
SINTEF's Journey in contributing to safety in Civil Aviation

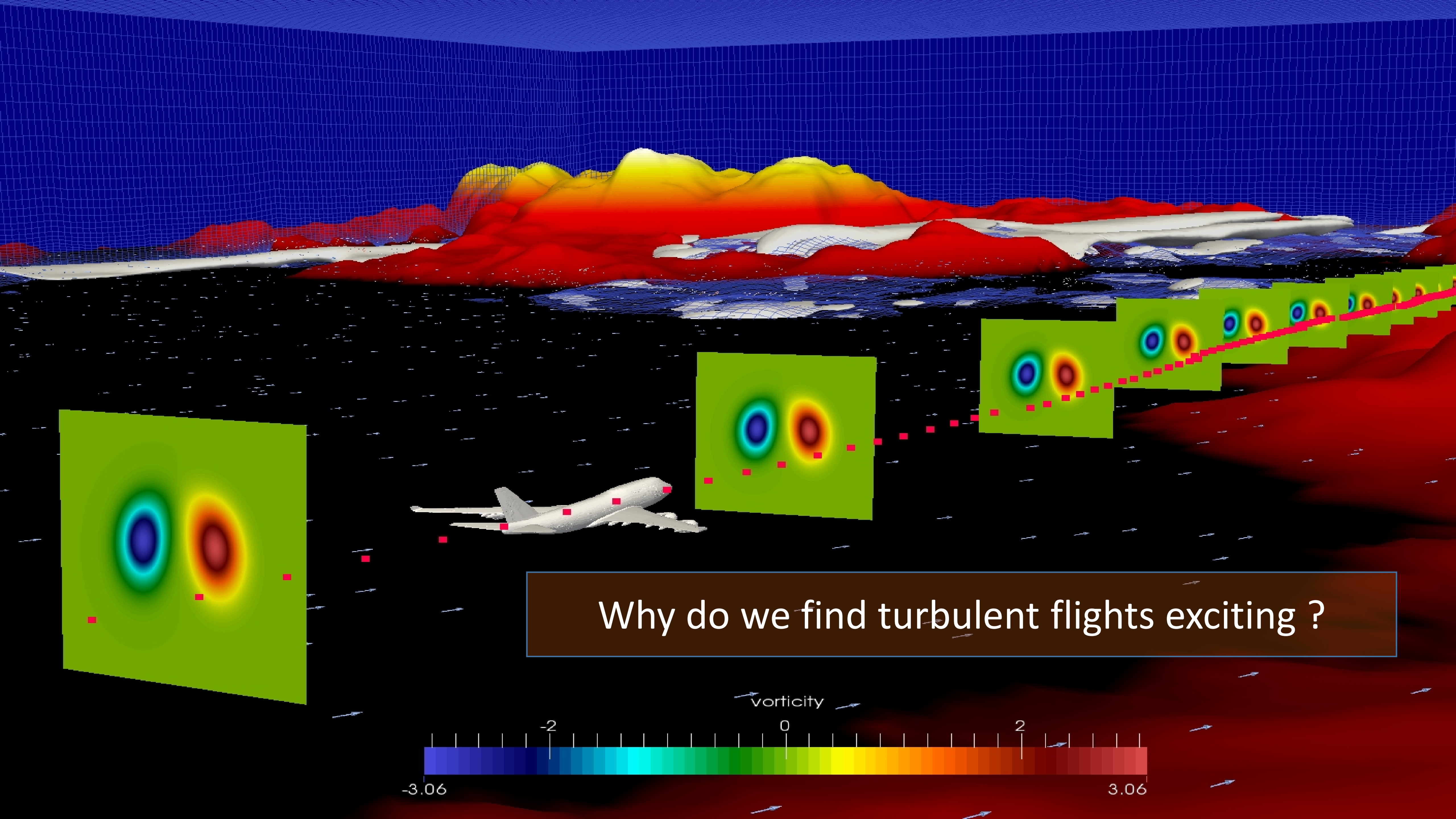


WE = COMPUTATIONAL SCIENCES AND ENGINEERING GROUP

Mandar Tabib, Research Scientist
and
Adil Rasheed, Research Manager & Senior Scientist
Mathematics and Cybernetics
SINTEF Digital, www.sintef.no/cse

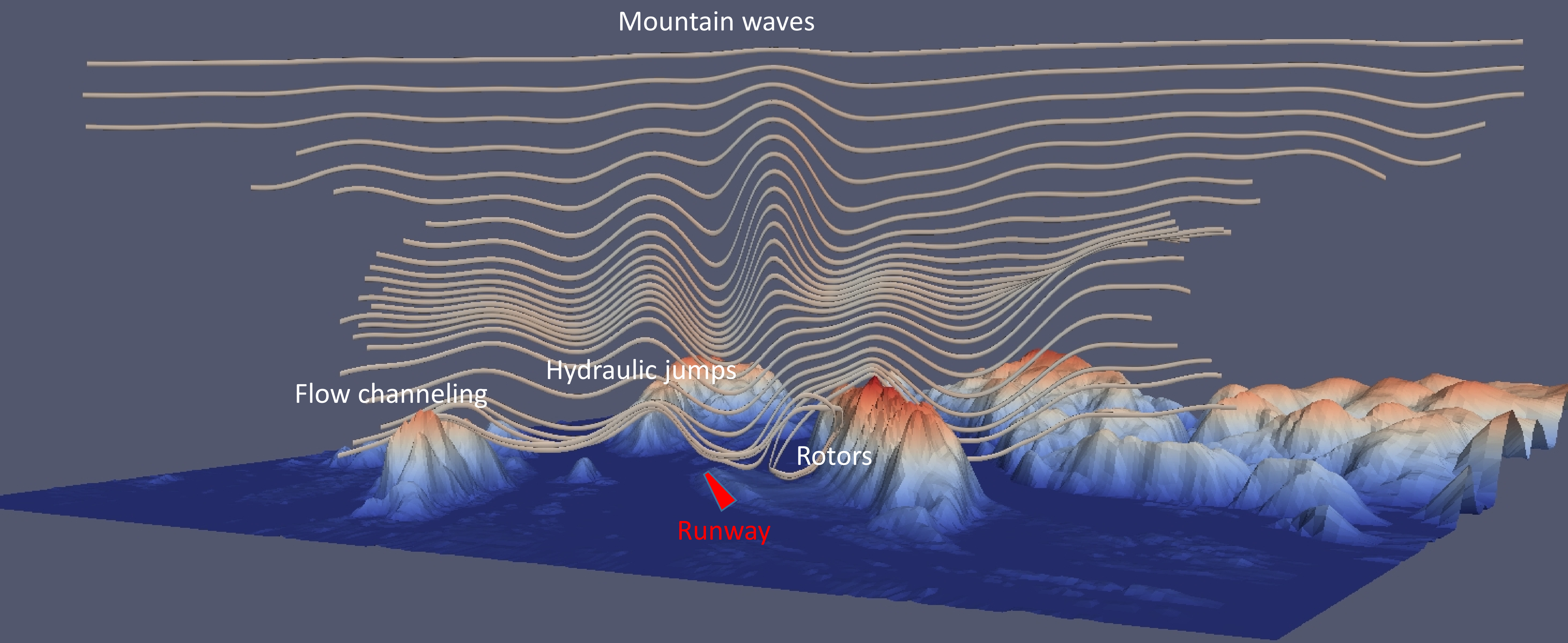





Why do we find turbulent flights exciting ?
vorticity
-2
0
2
-3.06
3.06


Amsterdam

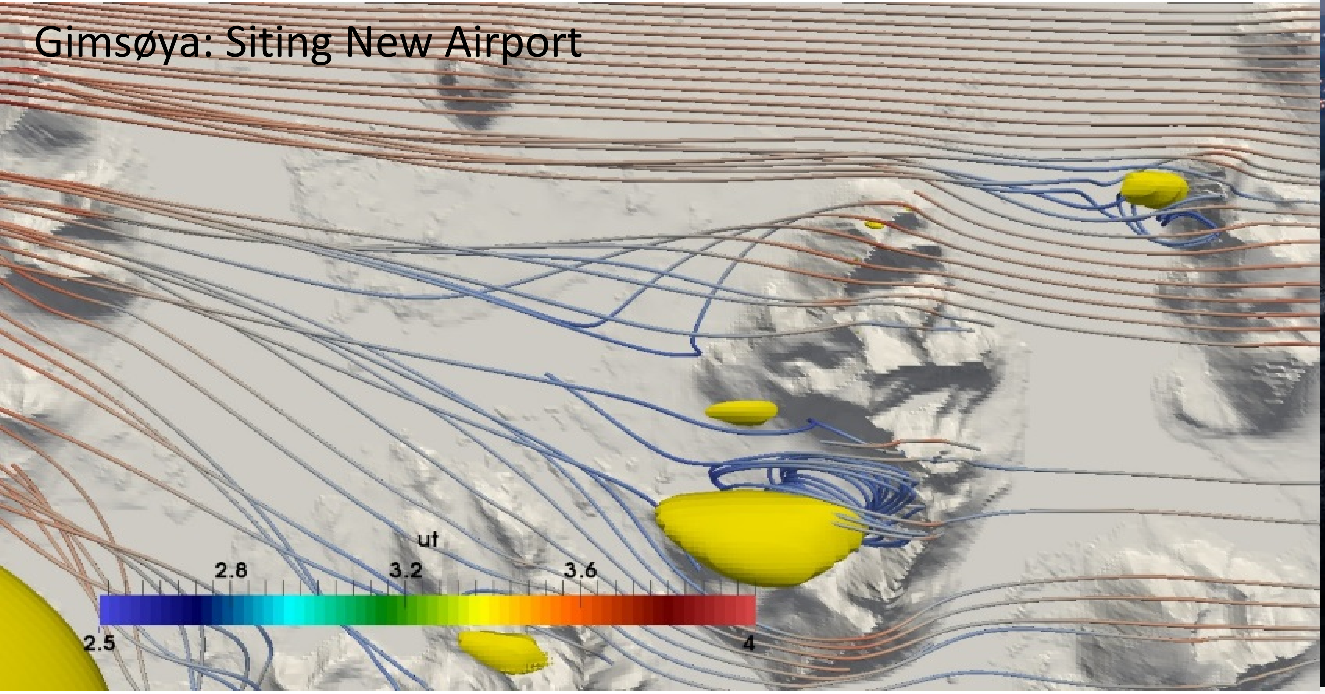

Sandnessjøen Airport



Mountain waves
Hydraulic jumps
Flow channeling
Rotors
Runway

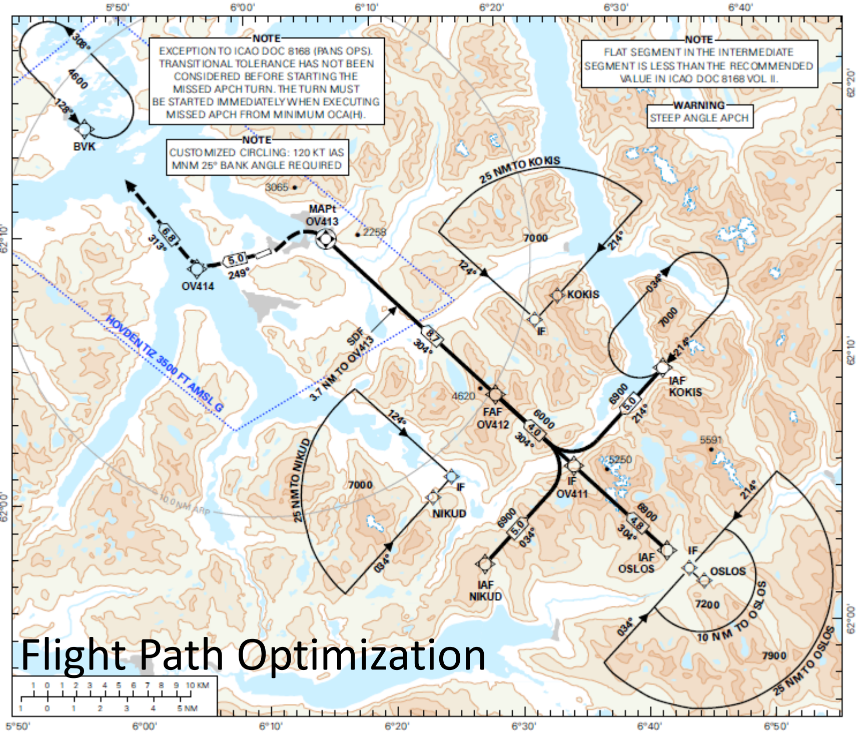
Hammerfest Airport

Wideroe DH8A on May 1st 2005
The Aviation Herald



Gimsøya: Siting New Airport

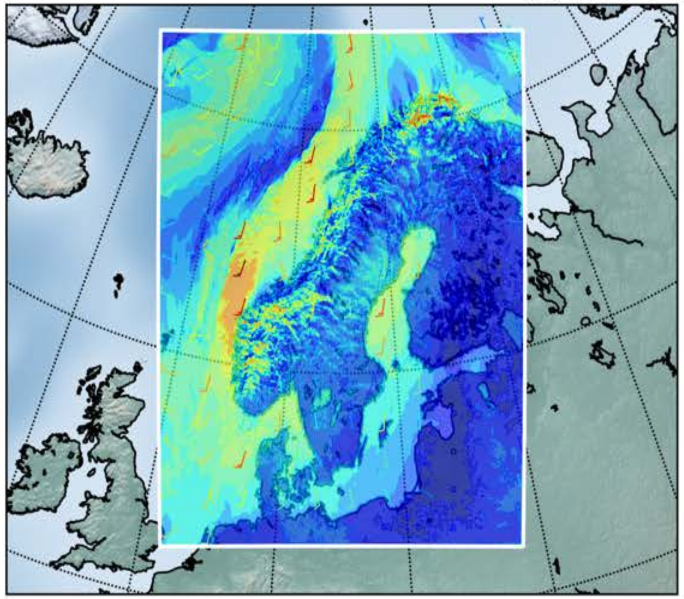
Sola Airport: New buildings

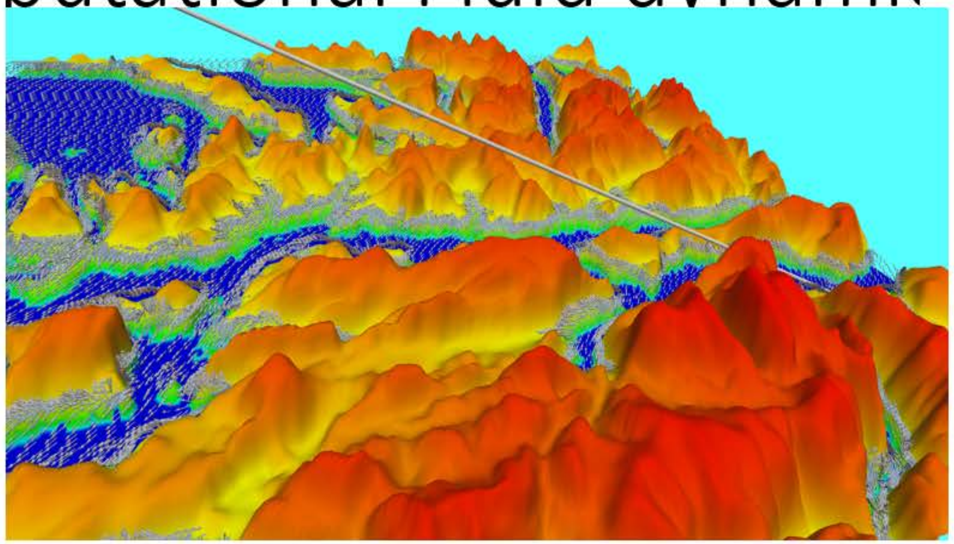


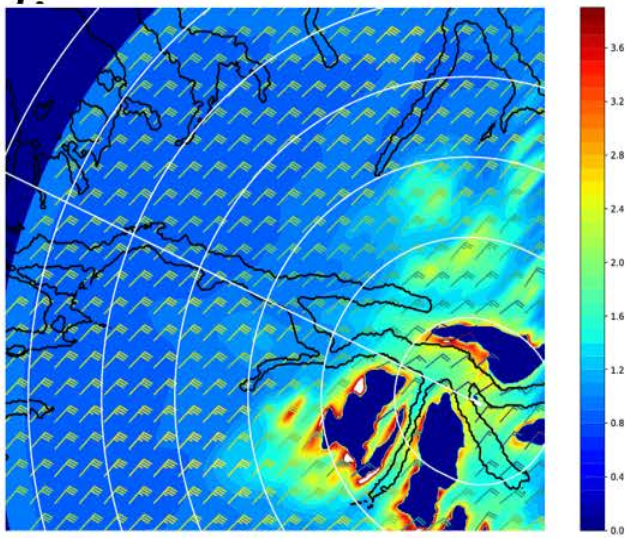
Flight Path Optimization

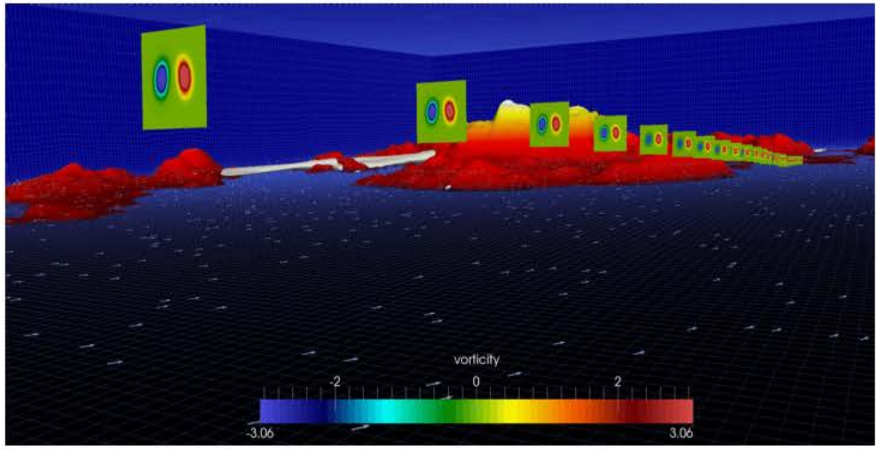
Making aviation safer

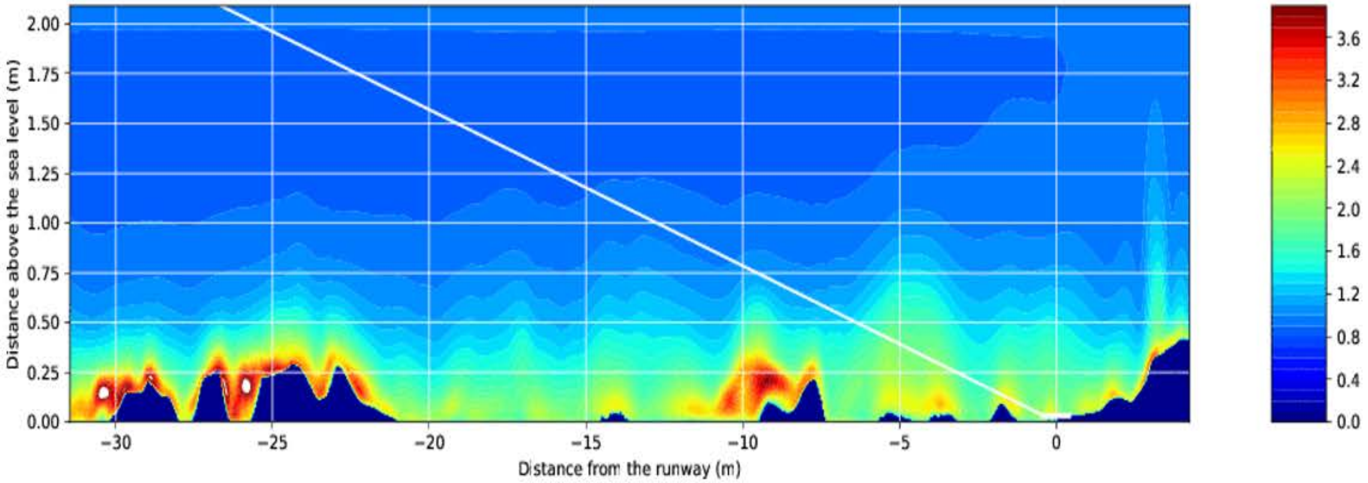
Real-time turbulence alert system based on Computational Fluid dynamics.





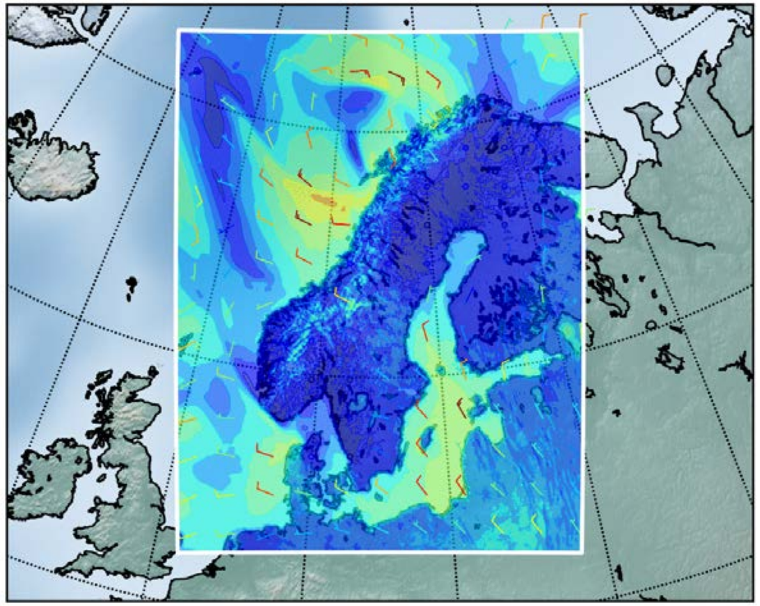


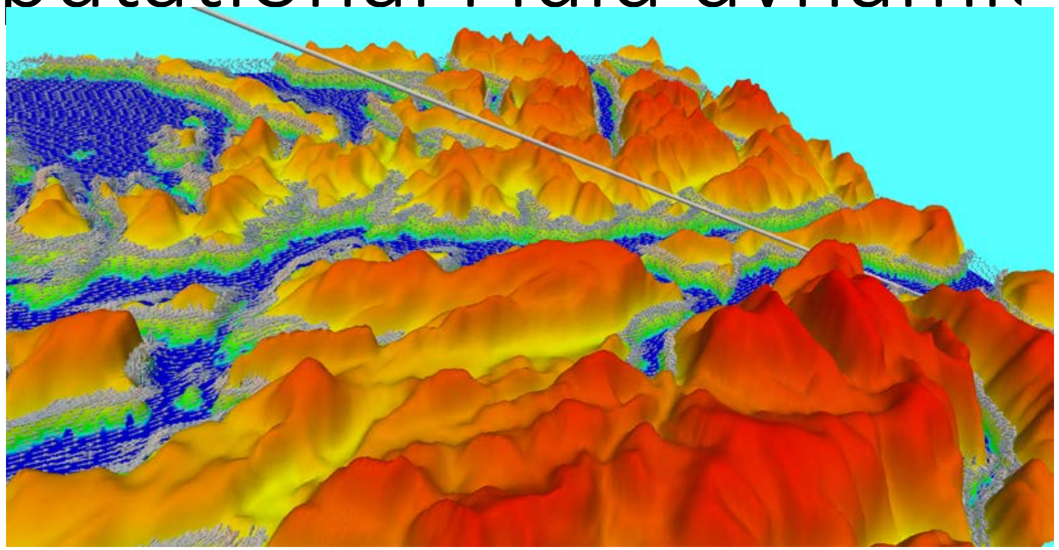


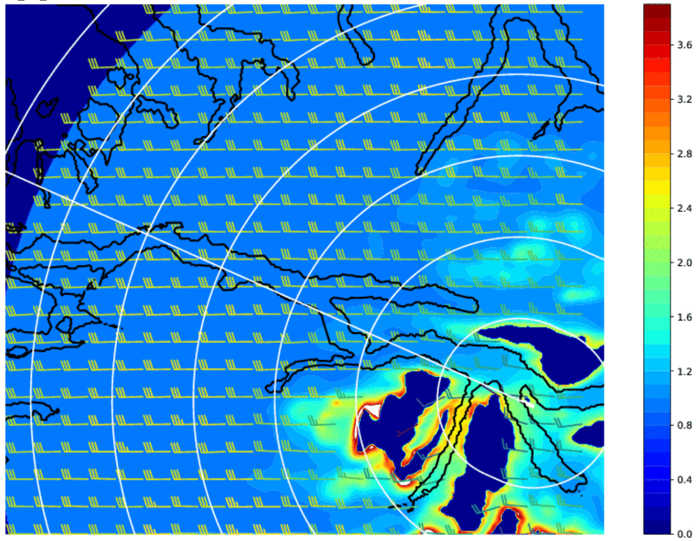


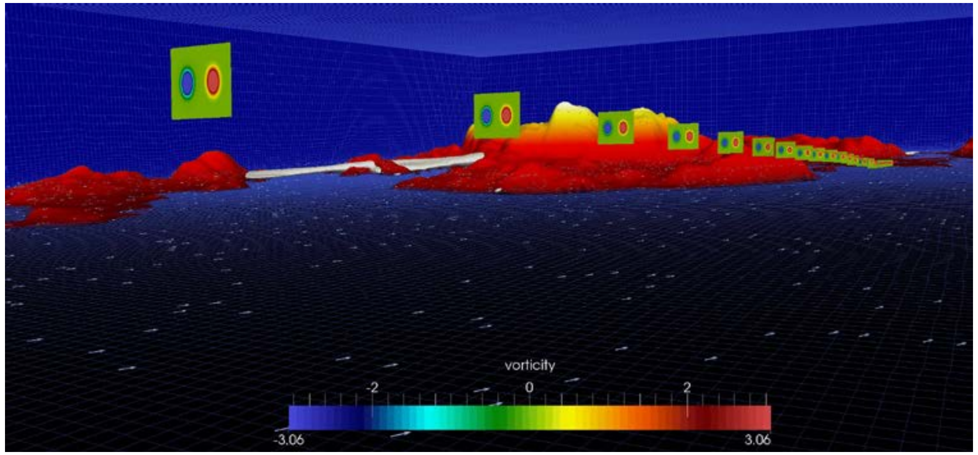
World's FIRST and ONLY operational microscale turbulence alert system operating at **20 Norwegian airports**

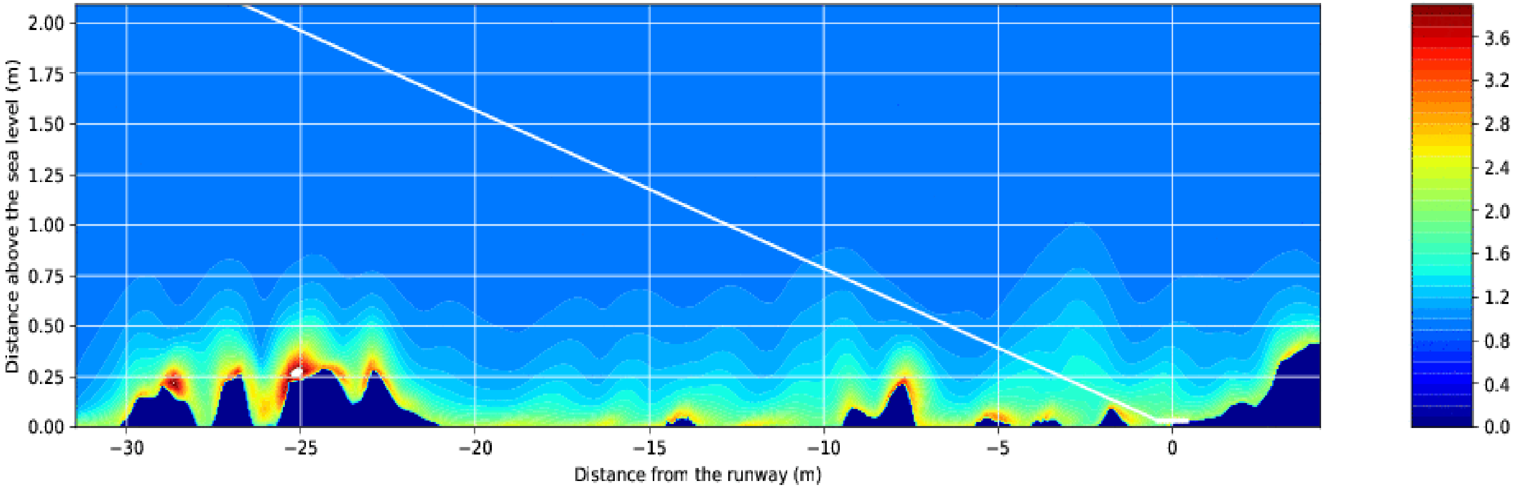
Real-time turbulence alert system based on Computational Fluid dynamics









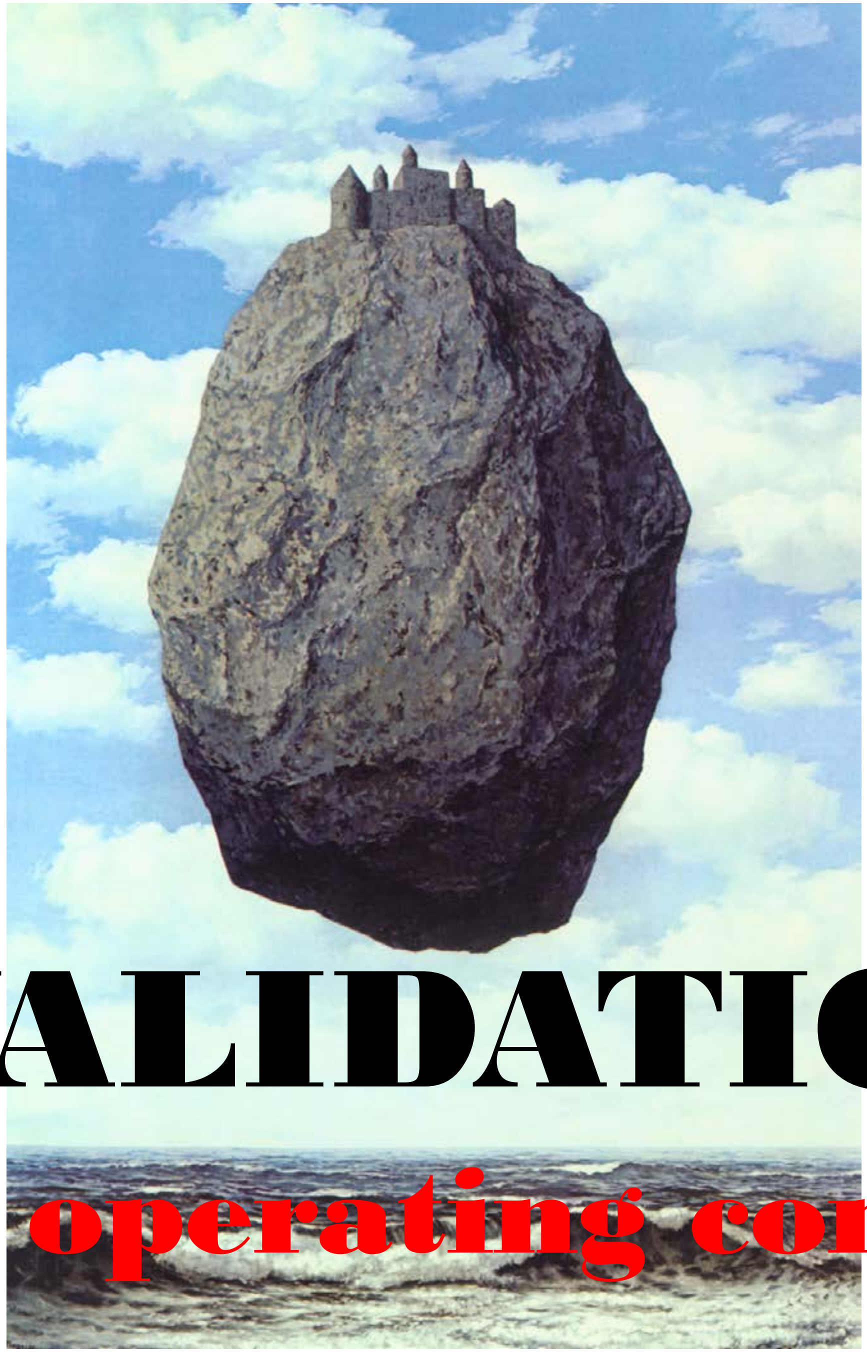


World's FIRST and ONLY operational microscale turbulence alert system operating at **20 Norwegian airports**

There is a little bit of SINTEF in everybody's life

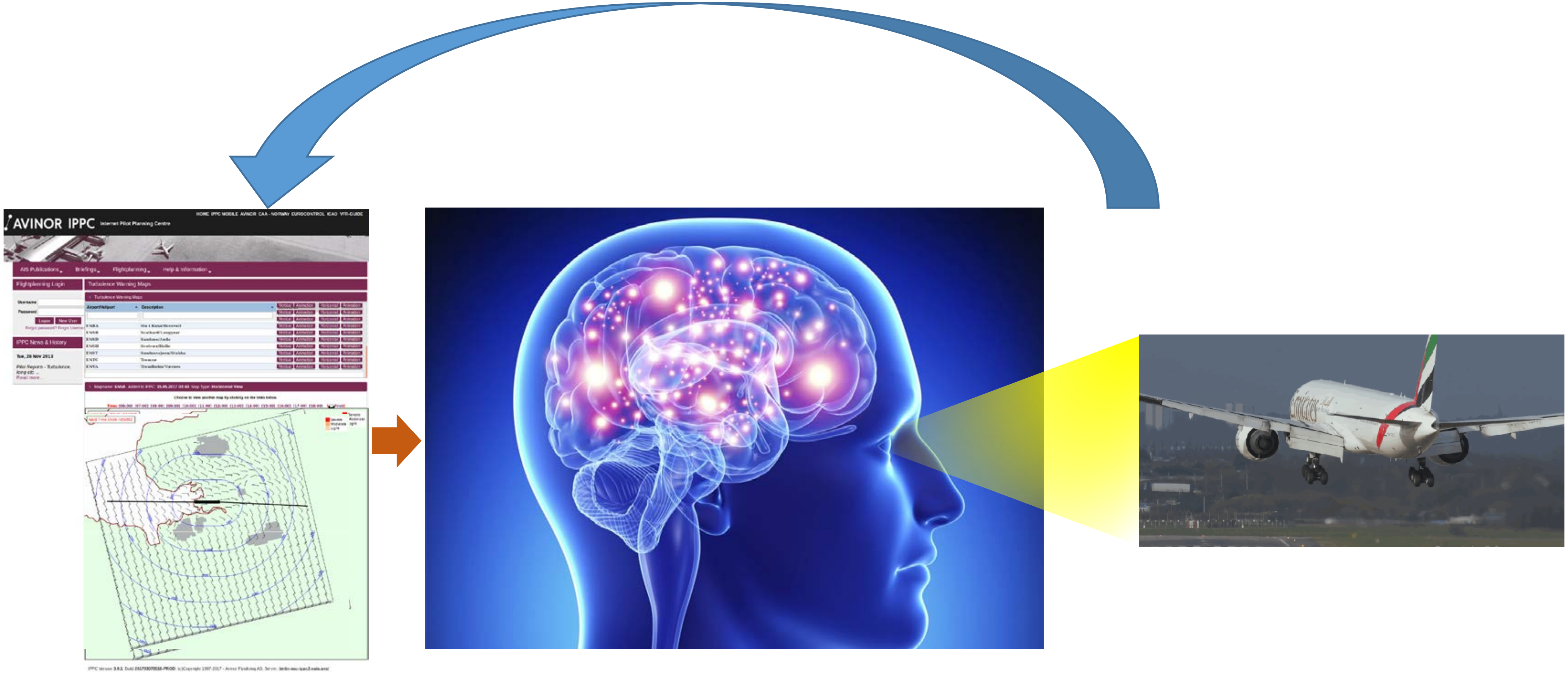
-Erling Bergersen, Avinor

a SOLID piece of research ?

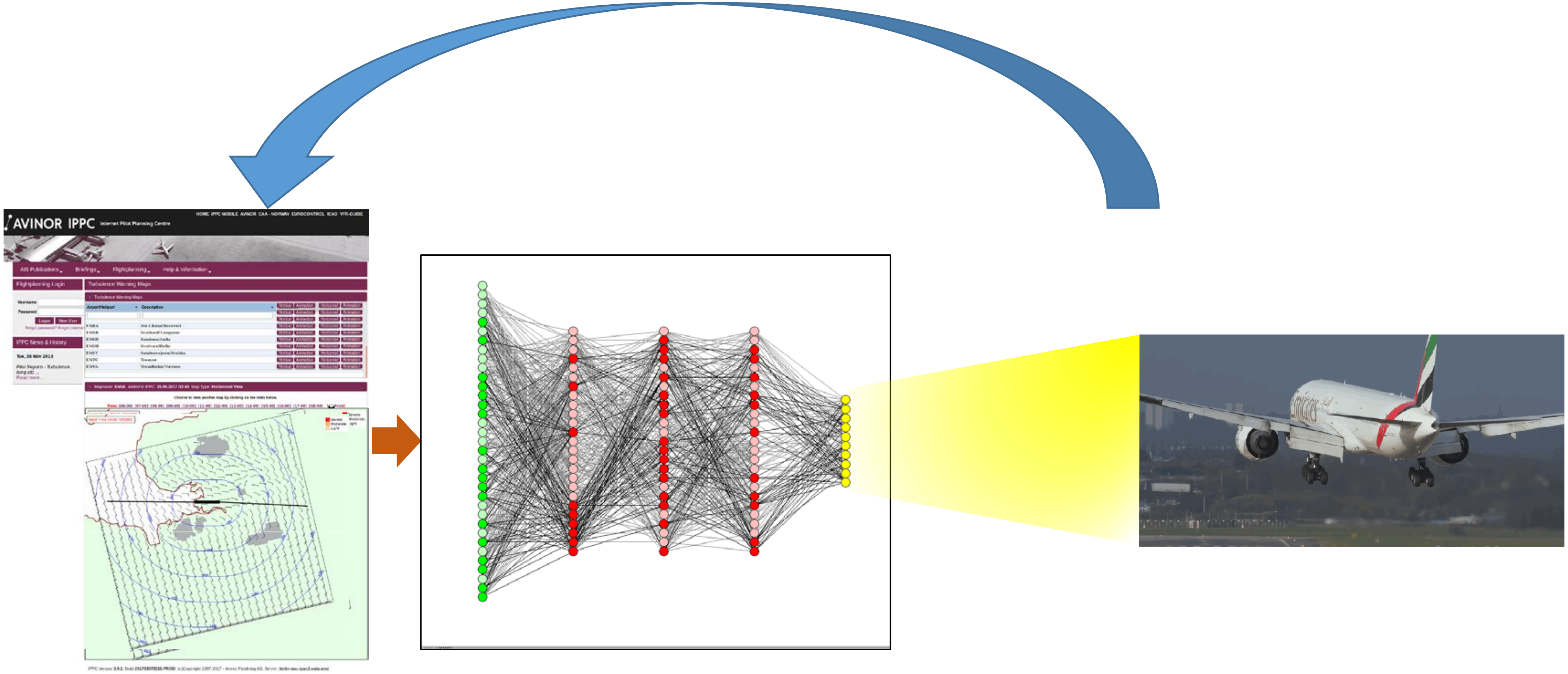


VALIDATION

under operating conditions



Currently, Our CFD model is validated and good and is performing well on 20 airports in Norway.
but we continue to make it better as part of continuous validations
Currently: Learning through experience



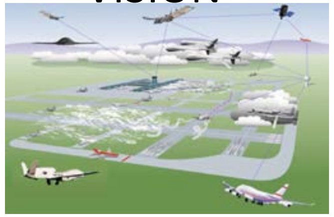
Future: combine Machine learning with CFD using Hybrid Analytics.

Challenges with Drone :

Background and Challenges with Drone :

CURRENT

VISION



- Current status :
- Drones are mostly operating within Line of sight and in Remote area.
  - Current status : Rely on operational segregation of drones for safety.
  - Vision : Co-Sharing of air-space

- Regulations: Still being developed. No regulations in place for urban area operations and out-of-sight

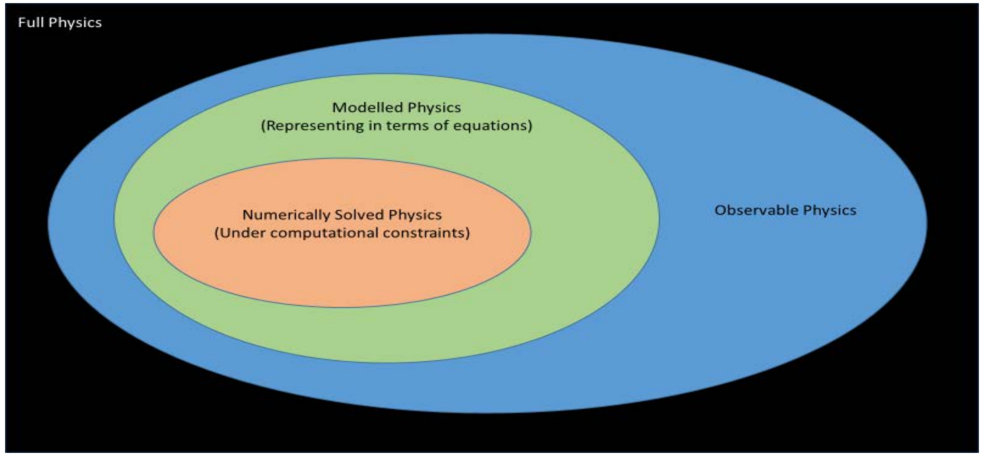
- Drone characteristics: No idea how drones behave in a real environment

- Real-time : No real time simulation tools for predicting wind, turbulence and visibility in real time

- **Use our past experience in aviation safety and the current ATB project :**
  - Develop this area of regulations and real-time drone safety service for urban usage.

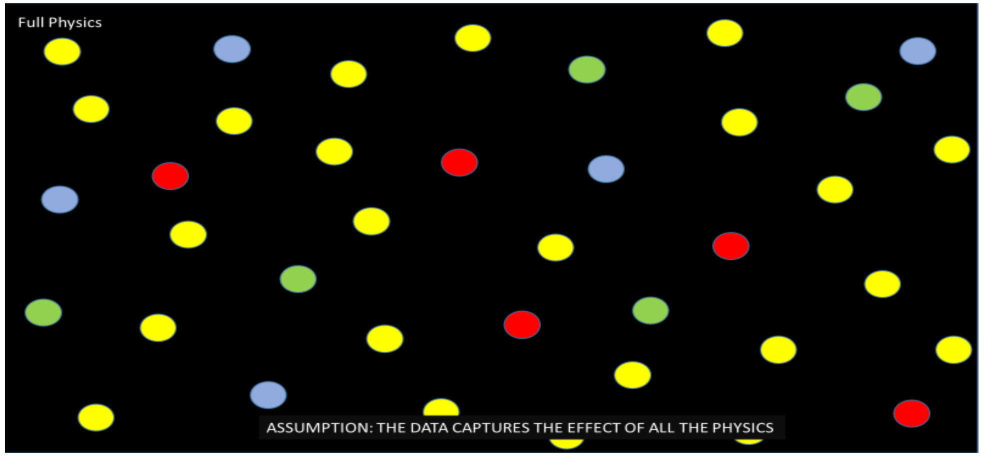
HYBRID ANALYTICS: Why ?
Towards Intrepretability and Causality.

Physics based model



So far, the world has been driven mostly by a **physics based modelling** approach. The approach consists of observing physical phenomena, developing an understanding, putting it in the form of mathematical equations and ultimately solving them. We can never claim to understand all the physics (shown in black) governing a particular process. Actually, we observe only part of the physics (blue) and model even smaller part of it (shown in green). To make the numerical solution of the modeled equations computationally tractable, more assumptions are made leading to further loss of physics (thus only the orange part is accounted for).

Data-driven model



On the other hand, we have purely **data driven modeling** approach which thrives on the availability of data. It is expected that data is a manifestation of all the physics driving a particular process and hence even without any knowledge of the governing physics one can model their effects. This approach which was frowned upon until recently is now gaining traction due primarily to four reasons: *Access to huge amount of data, Access to opensource libraries, Access to computational Learning resources.*

It is expected that just by increasing the number of data points we can capture more and more physics. Although it can be possible that a limited amount of data captures all the required physics.

Example of unintended pattern learning by ML: Classification: Wolf or a husky (dog)

Predicted: Wolf
True: Wolf

Predicted: Wolf
True: Wolf

Predicted: husky
True: husky

Predicted: husky
True: husky

Predicted: Wolf
True: Wolf

Predicted: Wolf
True: Husky

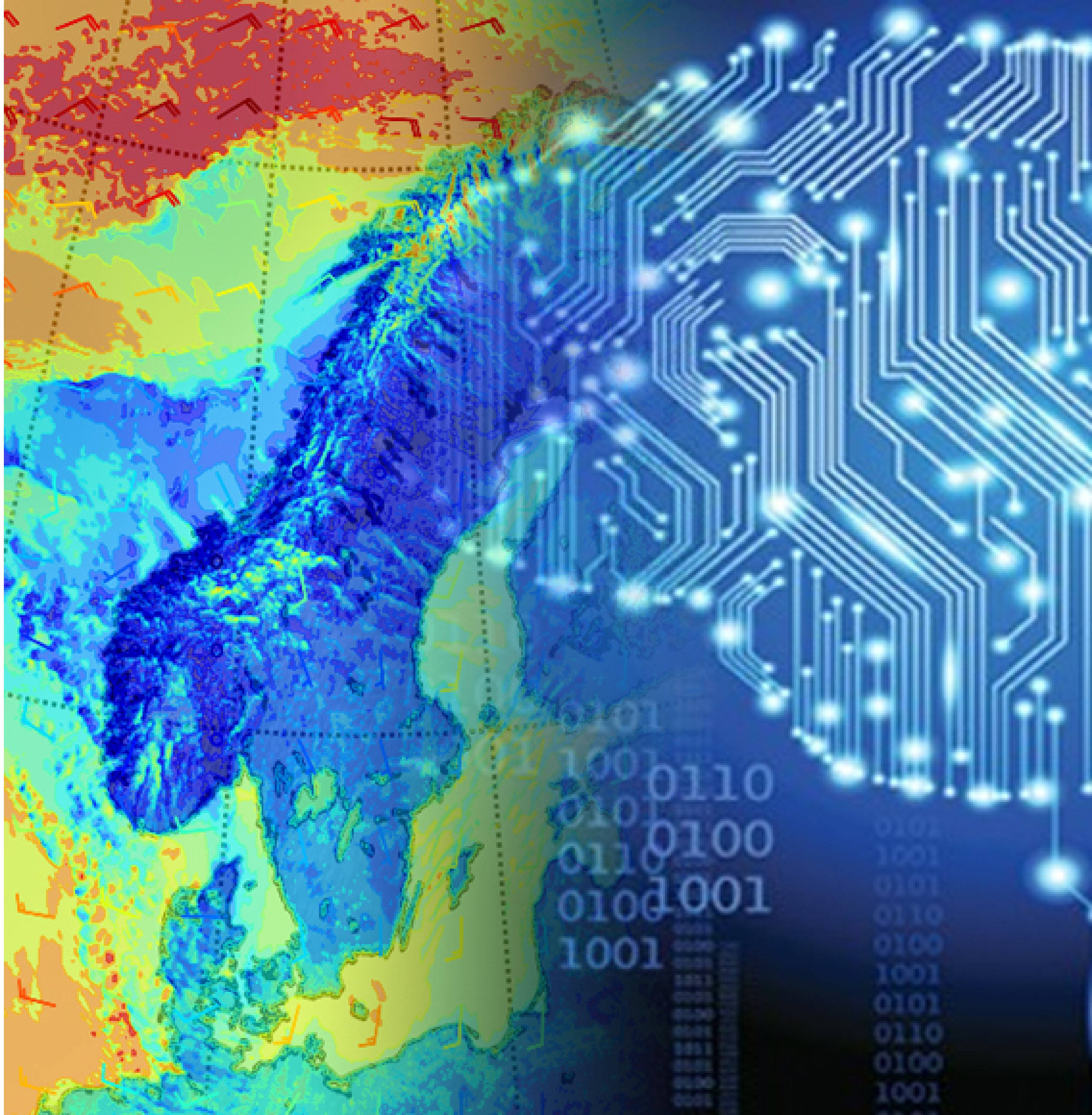
Only one wrong prediction

The classifier actually learnt to classify based on the background

BIAS

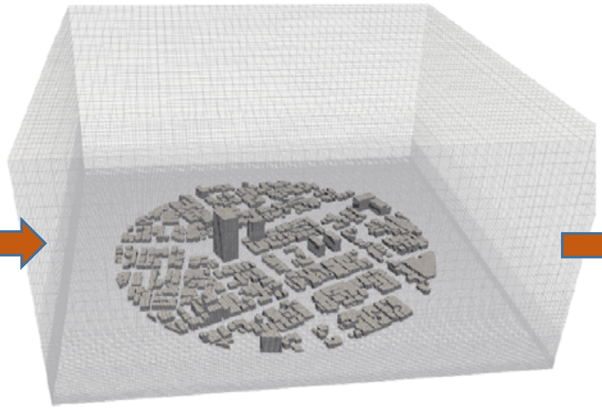
Hybrid Analytics as solution

*Hybrid Analytics is a modeling approach that combines the interpretability, robust foundation and understanding of a **physics-based approach** with the accuracy, efficiency, and automatic pattern-identification capabilities of advanced **data-driven** machine learning and artificial intelligence algorithms.*

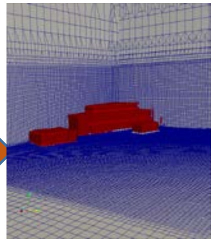


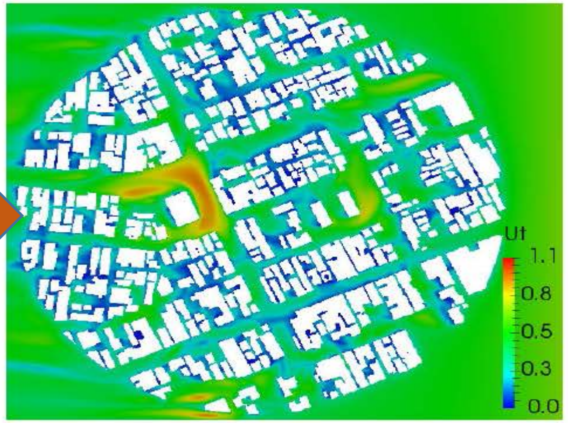
Current workflow for landing and take-off based on turbulence analysis (cfd)

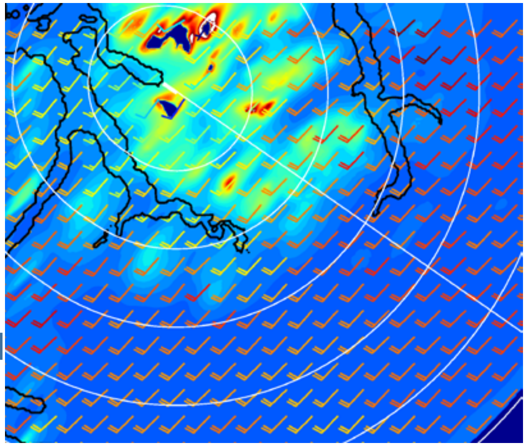
(b) Measurement point locations

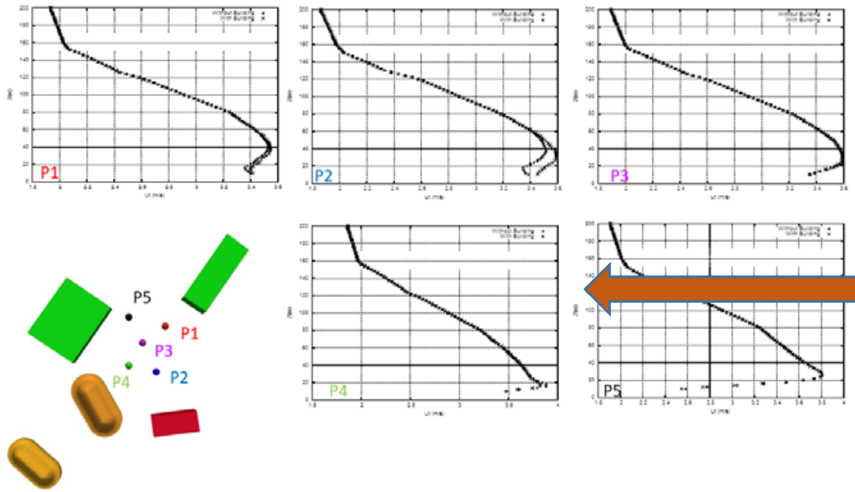


(a) Geometry and Mesh

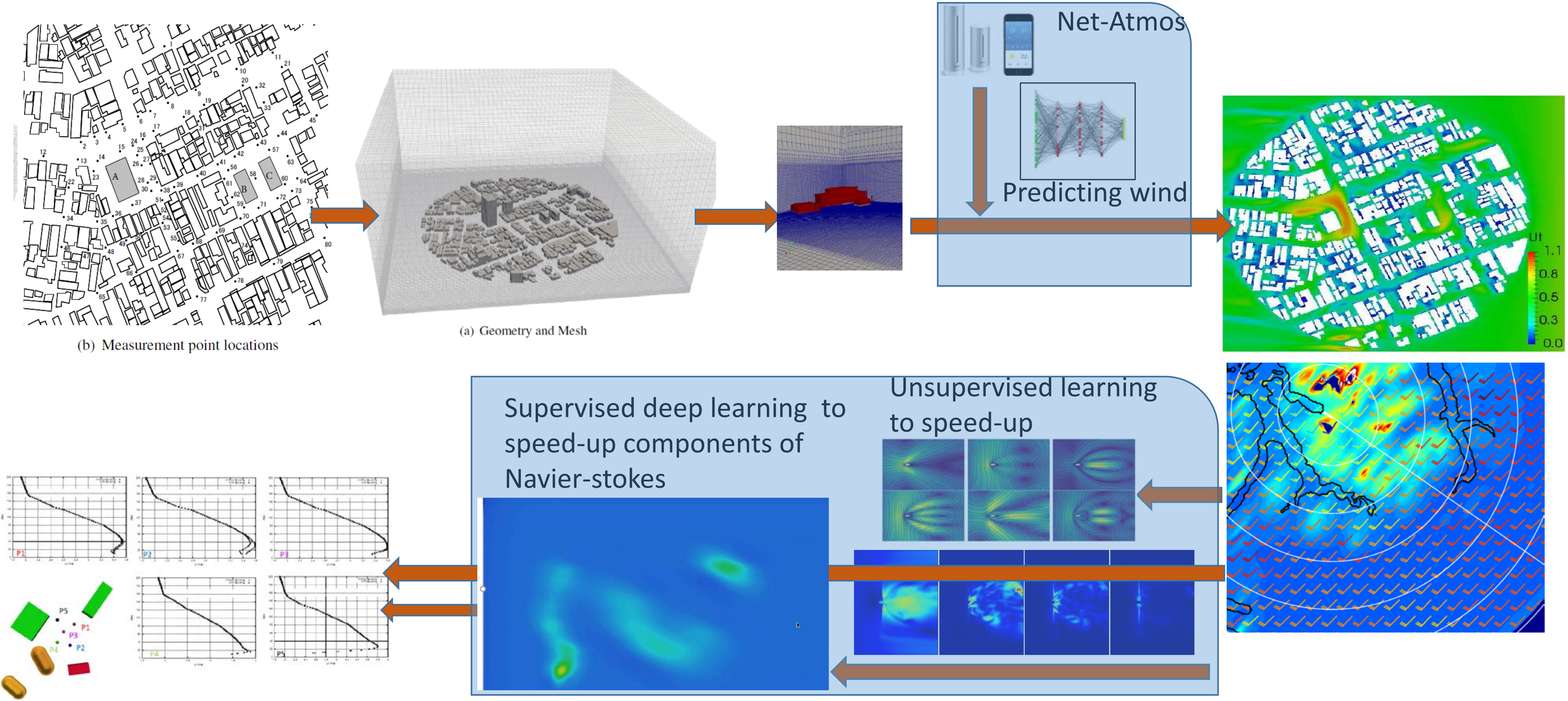








Future workflow for landing and take-off based on hybrid analytics for speedier operations (CFD + ML)

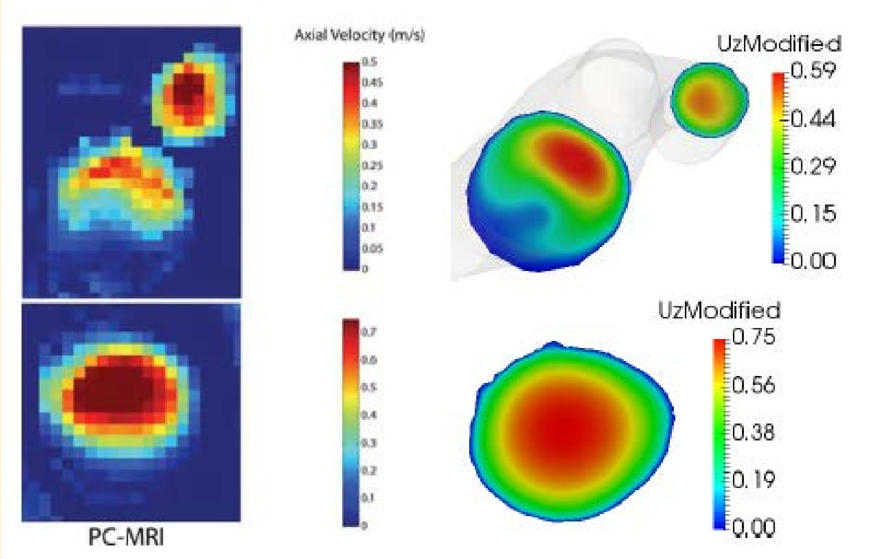


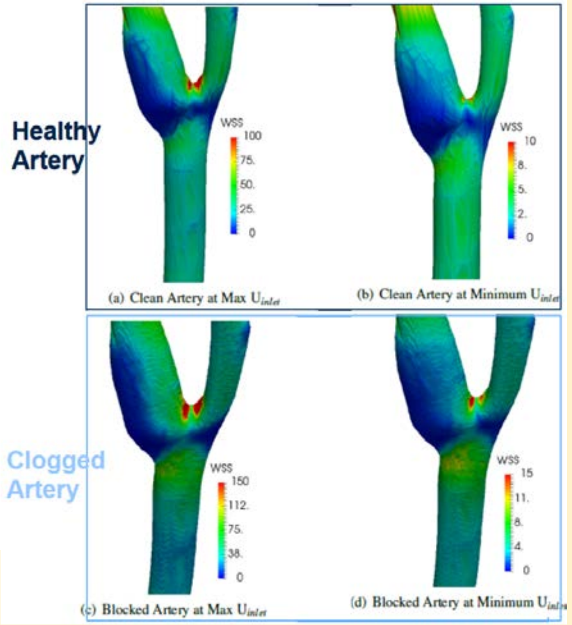
Hybrid analytics in health – Carotid Artery Disease Progression.

SINTEF Digital. Journal Reference : A computational framework involving CFD and data mining tools for analyzing disease in carotid artery bifurcation. M. V. Tabib, A. Rasheed, E. Fonn. Progress in Applied CFD – CFD2017, (ISBN 978-82-536-1544-8 and ISSN 2387-4295). SINTEF Proceedings (2), Page 125-132.

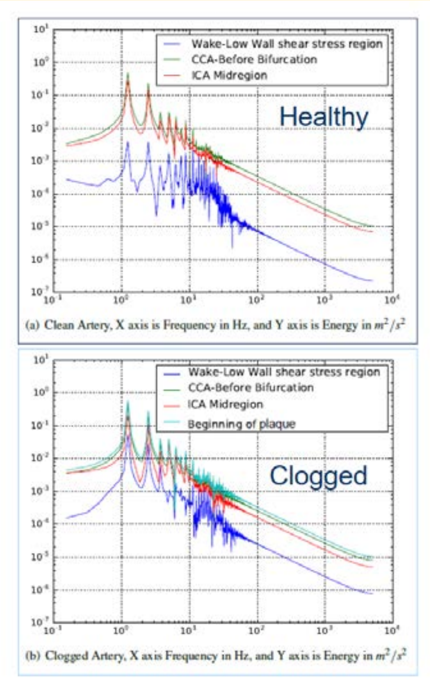
SOMETHING SIMILAR WITH DRONE BASED OPERATIONS.

CFD



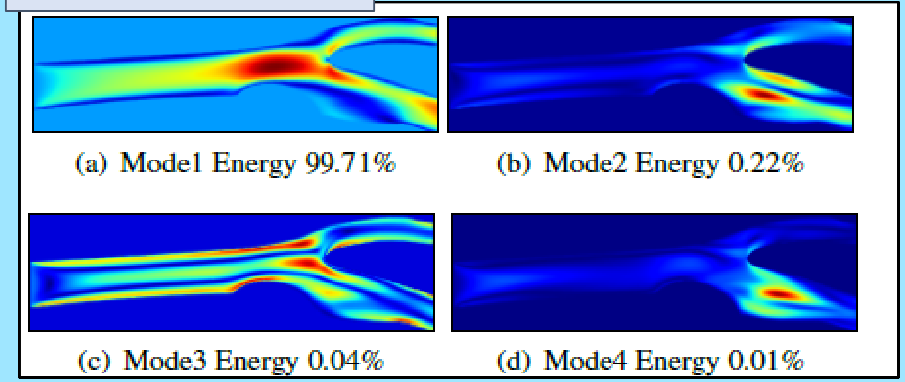


Data Analysis

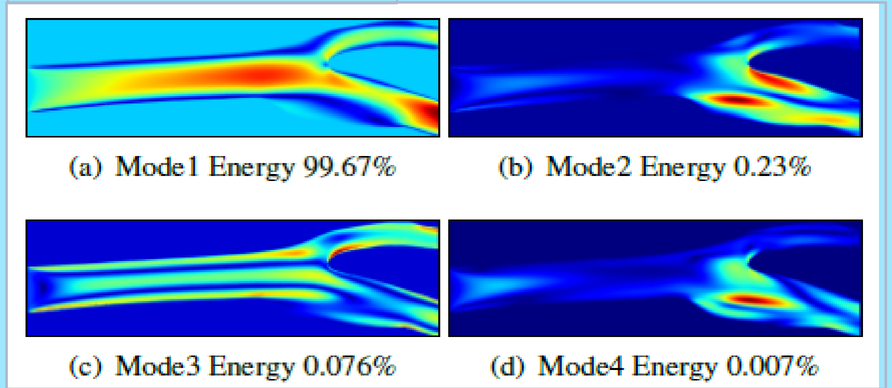


Unsupervised Learning : Reduced Order Model.

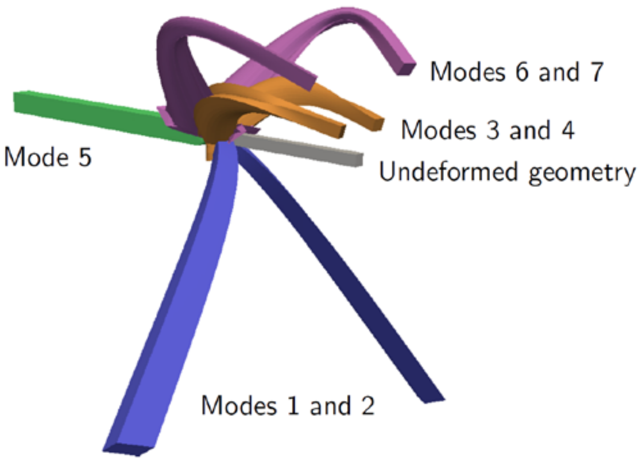
Clogged Artery

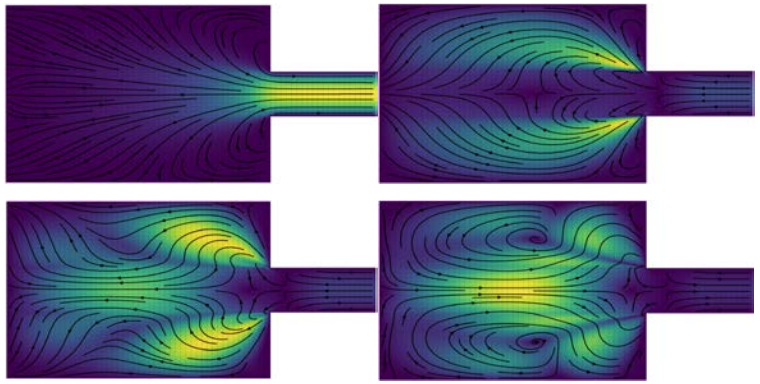


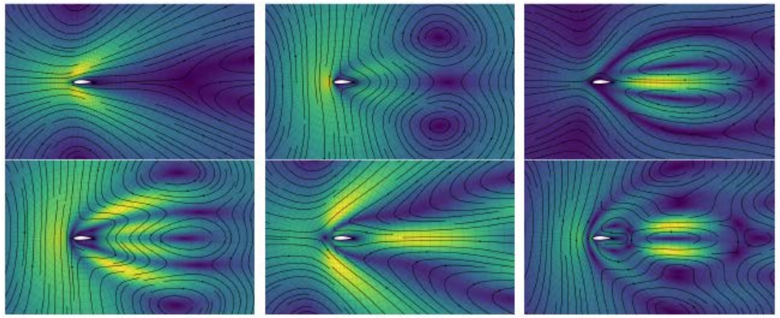
Healthy Artery

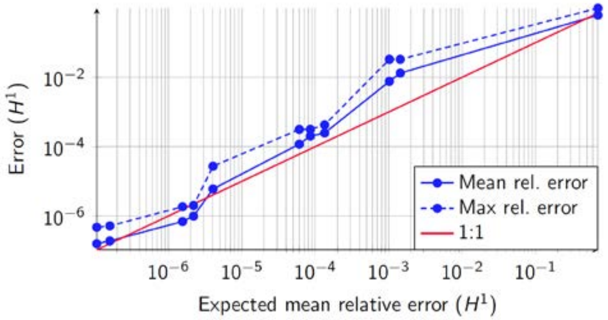


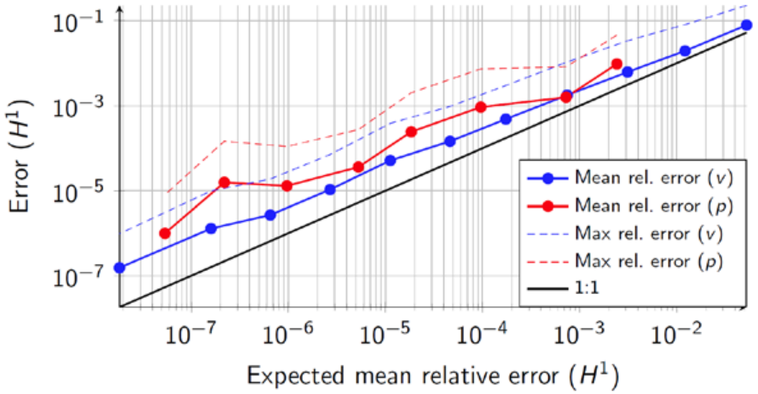
1. Reduced Order Modeling

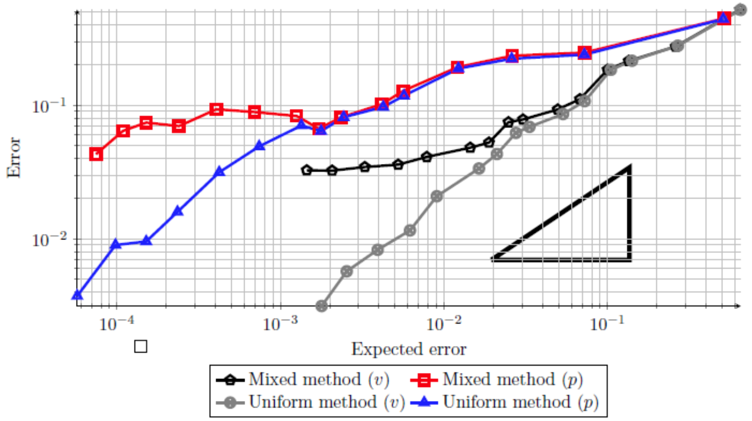












The high-fidelity method ($150 \times 10 \times 10$ elements) took about 5 seconds on average to solve each problem instance.

Each reduced method completed the solution in 200 microseconds on average. (The systems are too small to see a noticeable dependence on M.)

Speedup factor: 25000

The high-fidelity method (18847 DoFs) took about **25 seconds** on average to solve each problem instance.

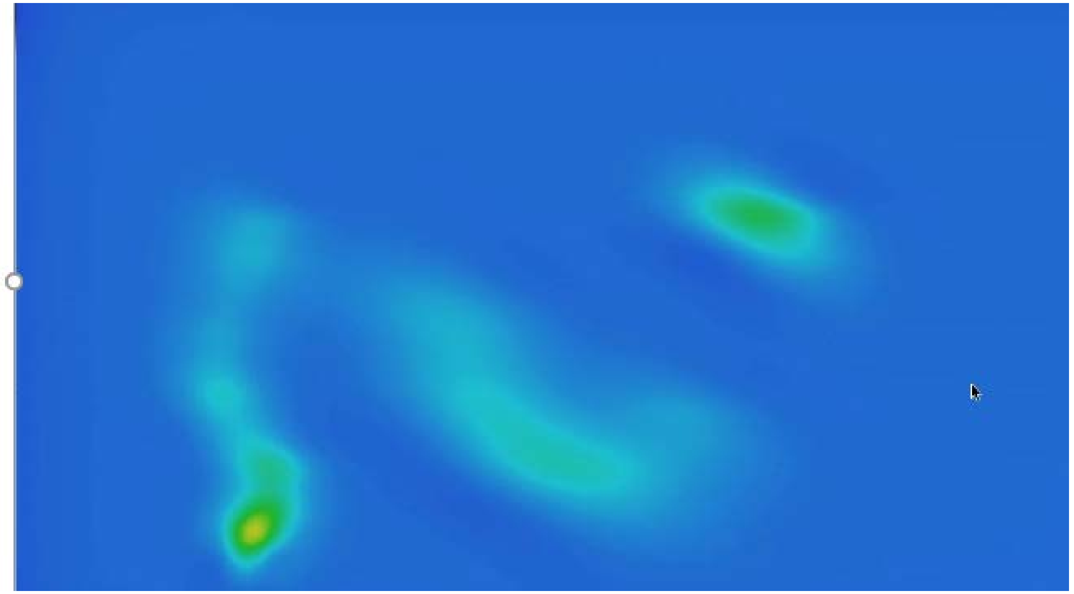
Each reduced method completed the solution in **1 millisecond** or less on average.

Speedup factor: 25000

	♯ DoFs	Speedup	Relative error (velocity)	Relative error (pressure)
High fidelity	110	1	0	0
Uniform method	5	15370	1.07×10^{-1}	3.07×10^{0}
	10	4122	3.02×10^{-2}	9.06×10^{-1}
	15	1972	1.01×10^{-3}	3.3×10^{-1}
	20	1011	3.03×10^{-3}	3.01×10^{-1}
Mixed method	5	25981	1.10×10^{-1}	3.12×10^{0}
	10	6902	4.75×10^{-2}	1.98×10^{0}
	15	2936	3.51×10^{-2}	5.0×10^{-1}
	20	1764	3.01×10^{-2}	5.3×10^{-1}

2. Speeding up numerical solvers using Deep Learning

Machine learning predicted heat diffusion



- The Convolutional Neural Network learned the physics governed by the heat equation
- The animation above was in real time
- Can be generalized to solve problems from other domains

- Solves heat equation:

$$\frac{\partial u}{\partial t} - \nabla(\alpha \nabla u) + f = 0$$

- Cubic basis functions, 5000 DOFs
- Solution time FEM: 20,000 ms
- Solution time CNN: 8 ms

- **Speedup: 2,500x**

CONCLUSION

- Operation of drones in urban areas have their own challenges, pertaining to :
  - A. Safety regulations.
  - B. Non-availability of real-time operational systems.
  - C. Knowledge about drone flight dynamics in urban conditions.

- Currently , a validated physics based CFD model is operating at 20 norwegian airports and provides insights on turbulence.
- SINTEF can collaborate with others and help with above three drone challenges.
- The new hybrid analytic concept introduced here is under development aims to combine the available domain knowledge, with physics-based and machine learning models to develop an operational real-time drone safety predictor.