TECHNISCHE UNIVERSITÄT DRESDEN

AirMetro
Research Training Group
2947 at TU Dresden

T7: Microclimatic effects

Weather-robust UAS flight planning and operation

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Motivation

- Wind-sensitive Advanced Air Mobility (AAM) aircraft should also be able to operate under adverse conditions, e.g. wind speeds of up to 14 m/s and high turbulence (EASA VTOL.2105)
- In particular take-offs and landings (T2 and T3) are influenced by microclimatic effects (turbulence)
- Proof of wind stability is to be obtained using microclimatic modeling methods
- Robust and precise weather forecasts in urban areas are a prerequisite

Objective: Identification of the operational risks of AAM aircraft in urban areas by formulating weather-related operational boundaries and limitations

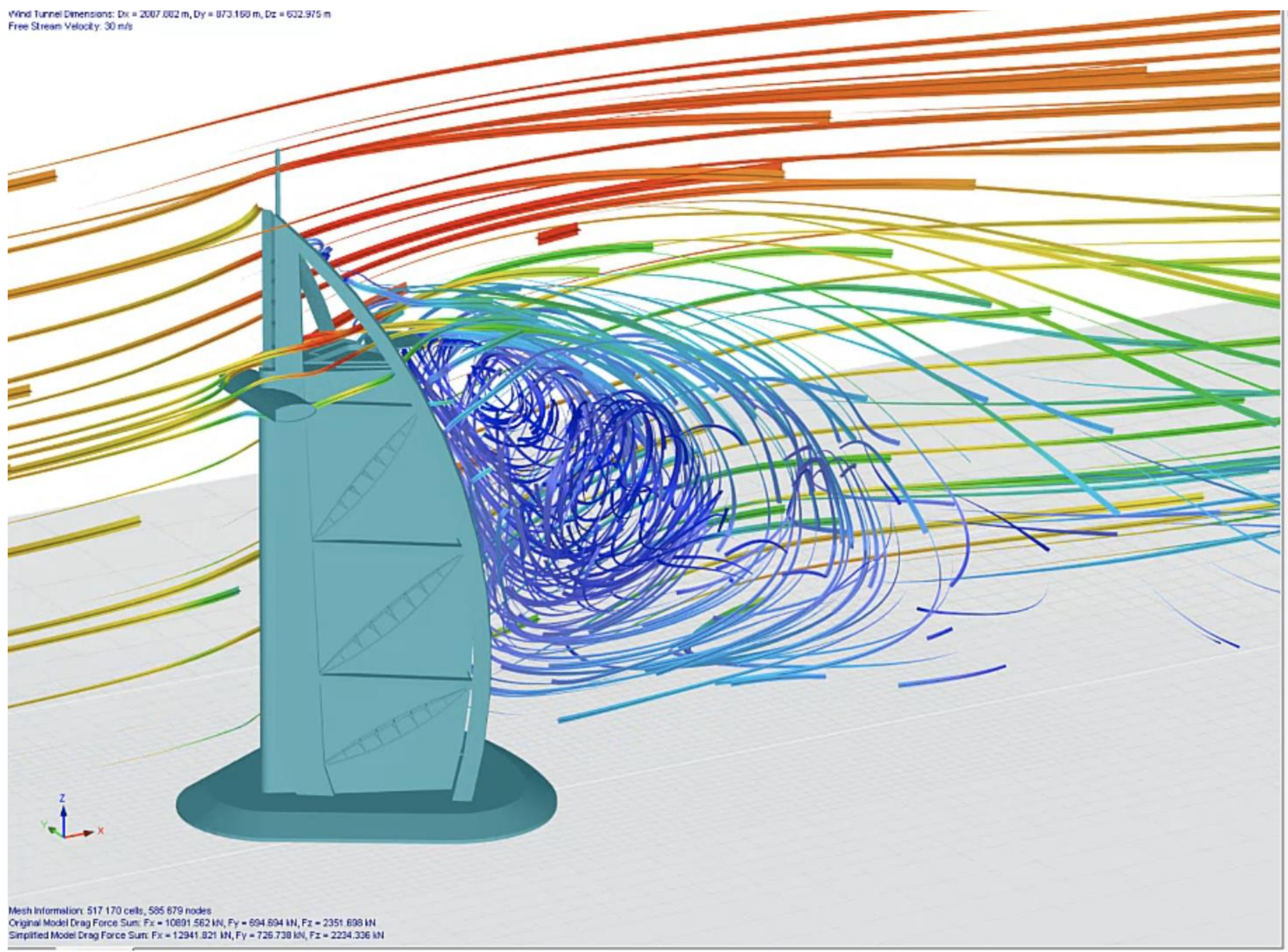

Figure 1: Example of a CFD simulation with RWIND2 [1]

Methods

- Recording critical weather situations in urban areas from high-precision data sets as input data for simulation using Computational Fluid Dynamics (CFD)
- Selection and implementation of a suitable turbulence model, e.g. k-ω-SST model

- Development and application of different approaches to solve the Navier-Stokes equations for compressible flows:

$$\rho \frac{\mathrm{D}v_x}{\mathrm{D}t} = -\frac{\partial p}{\partial x} + \mu \Delta v_x + f_x$$
$$\rho \frac{\mathrm{D}v_y}{\mathrm{D}t} = -\frac{\partial p}{\partial y} + \mu \Delta v_y + f_y$$
$$\rho \frac{\mathrm{D}v_z}{\mathrm{D}t} = -\frac{\partial p}{\partial z} + \mu \Delta v_z + f_z$$
$$\frac{\mathrm{D}}{\mathrm{D}t} = \frac{\partial}{\partial t} + v_x \frac{\partial}{\partial x} + v_y \frac{\partial}{\partial y} + v_z \frac{\partial}{\partial z}$$

- Use of simulation environments (e.g. RWIND2 or Simulink)

- Calibration of lift/drag polars for flight performance modeling [2] of AAM
- Calculation of aerodynamic gust loads on the AAM aircraft using the Versatile Aeromechanic Simulation Tool (VAST)

Results

- Numerically simulated **shear forces and gust loads for specific AAM aircraft in a sample city**
- Determining the navigation accuracy of AAM aircraft in the atmospheric boundary layer

- Identification of minimum distances to buildings, detection of critical heights, street canyons and e.g. subway tunnels to ensure safe routing as well as take-off and landing maneuvers

- Weather robust flight routes ready for operational optimization (T6)

- Requirements analysis of suitable take-off/landing sites for different city configurations (T11)

- Input data for determining the operational risks of AAM aircraft in urban areas (T3)

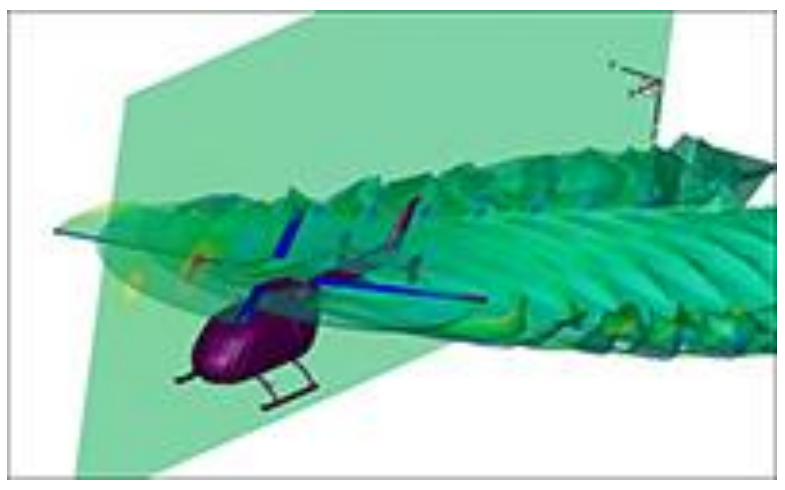

Figure 2: VAST simulation showing the flow in the wake of the main rotor of a helicopter[3]

Networking in the RTG

- The AAM demand network developed in **T11** provides sources and sinks in an exemplary city model
- Both the calibrated **flight performance model**, the risks and uncertainties extracted from the microclimatic modelling and the calculated **gust loads** form the input data for topic T6
- Determined navigation accuracy as input for T5 and T8
- Safe process planning in the near-ground area (T3) depends on the developed limit values and properties.

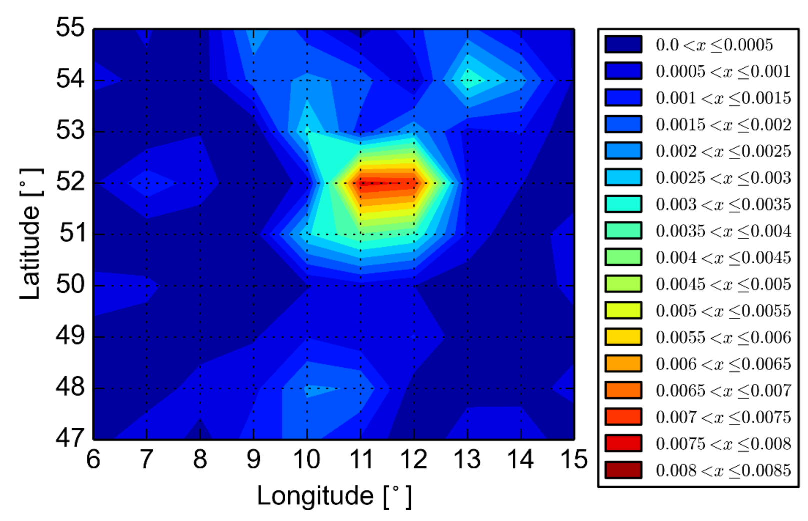

Figure 3: Simulated eddy dissipation rate ε [m^2/s^3] as a measure of turbulence in the atmospheric boundary layer [4]

References:

[1] *https://www.dlubal.com/en/products/stand-alone-structural-analysis-software/rwind-simulation*

[2] *J. Rosenow et al. (2023): Multiple Aircraft in a multi-criteria Trajectory Optimization, Fifteenth USA/Europe Air Traffic Management Research and Development*

[3] *https://www.dlr.de/sc/desktopdefault.aspx/tabid-12766/22301_read-51581/*

[4] *Judith Rosenow, Hartmut Fricke (2019): Individual Condensation Trails in Aircraft Trajectory Optimization, Sustainability, Volume 11, Issue 21, DOI: 10.3390/su11216082*

Network member in:

DRESDEN concept
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