



# LES of jets with embedded vortices impinging on a flat surface

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## Numerical simulations of embedded vortices in boundary layers and wall jets

STATUS QUO

### Wall jets and impinging jets

- Display complex interactions between the outer region and wall turbulence.

### Coherent vortices

Generated by instabilities or forced by other causes (rotor tip)

- Are advected towards the wall and modify the inner/outer layer interaction.
- Can induce particle lift-up (helicopter brownout).

### Open modeling issues

- Wake models are based on inviscid vortex dynamics (Viscous and turbulent diffusion are neglected).
- Accurate description of vortex decay is critical for brownout mitigation.

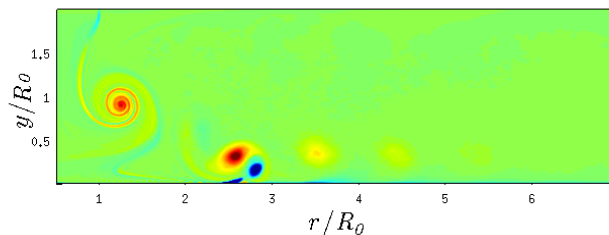
NEW INSIGHTS

### Methodology: Hierarchical model validation

- Exact solutions (DNS) used to validate high-level models (LES).
- LES used to validate lower-level models (Hybrid, RANS, inviscid models).

### MAIN ACHIEVEMENTS:

- Development of method to generate vortices with a specified velocity distribution.
- Validation of the numerical model.
- Simulations of the interaction of vortex rings with the wall (matching experimental studies).



### Array of vortex rings impinging on a wall

Averaged vorticity contours. The array of vortex rings is formed by pulsing periodically a jet (top left), impinges on the wall and moves radially. When it comes near the wall, it generates opposite-sign vorticity, which is lifted up, and interacts with the main vortex. As they move radially, the vortices weaken and eventually dissipate.

### LIMITATIONS:

- Grid must be fine near the generated vortex to avoid numerical errors that can corrupt the solution.
- Development of algorithms that are robust on marginal grids is under way.

### Current Impact

- The numerical method developed allows the study of model cases with high accuracy.
  - A detailed analysis of the turbulent transport mechanisms helps understand the vortex breakdown dynamics.

### Planned Impact

- Continue to develop the model for progressively more complex and realistic configurations.
- Connect high-level-model results to lower-level models normally used to predict particle lift-up in wake-ground-interaction models.

### Research Goals

- Understand the mechanisms that cause vortex breakdown in this geometry.
- Quantify the effects of the vortices on the turbulent flow near the wall.
- Develop models that can predict the flow field and the particle lift up in real time.

QUANTITATIVE IMPACT

END-OF-PHASE GOAL



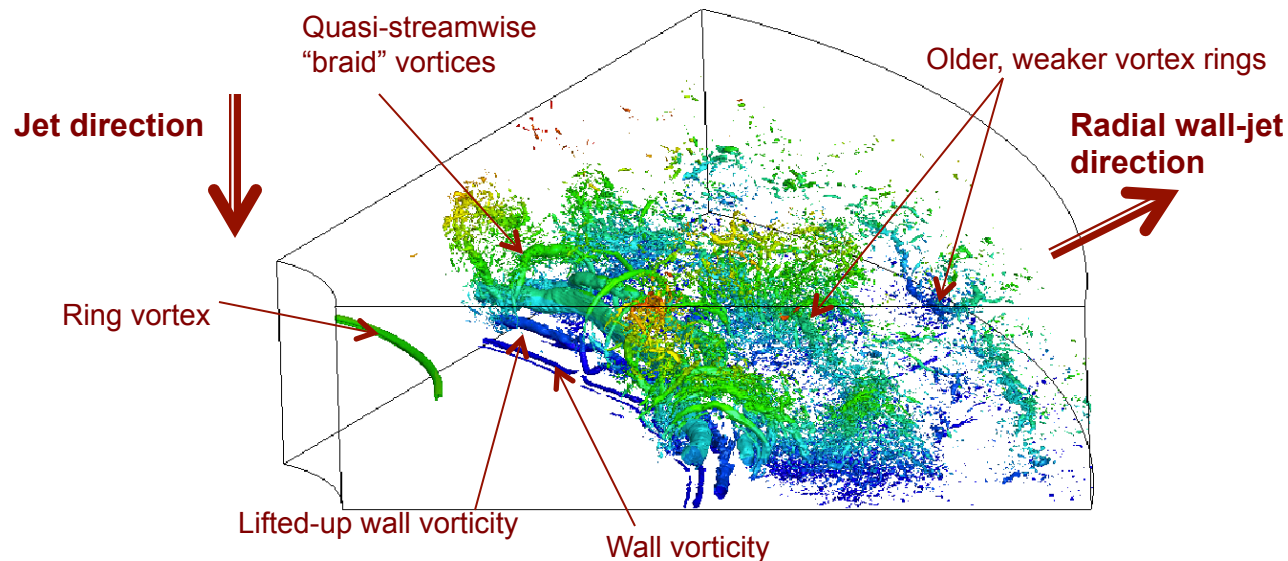
## Highlight Slide Template



### Numerical simulations help understand helicopter brownout



- We are developing a model that simulates accurately the interaction of vortices embedded in an impinging jet and the wall for applications in turbo-machinery or helicopter wakes
- Present state-of-the-art:
  - *Inviscid models, low-level turbulence models*
- Current work:
  - *Unsteady simulations that capture the details of the vortex development.*
  - *More accurate prediction of vortex decay and interaction.*



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