Visualization Strategies for Optimal 3D Time-Energy Trajectory Planning for AUVs using Ocean General Circulation Models

Thomas Theußl [1], Sultan Albarakati[2], Ricardo Lima[2], Ibrahim Hoteit[3], and Omar Knio[2]

[1] Visualization Core Lab, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

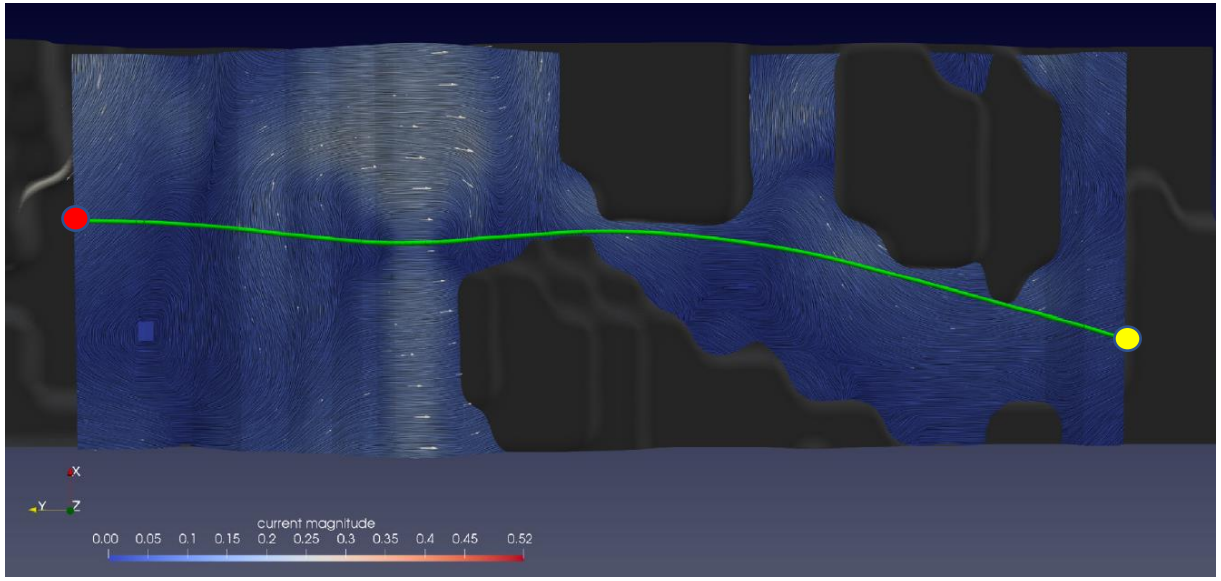
[2] Computer, Electrical, and Mathematical Sciences and Engineering Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

[3] Physical Science and Engineering Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

CORE LABS

KAUST CORE LABS & MAJOR FACILITIES

Motivation

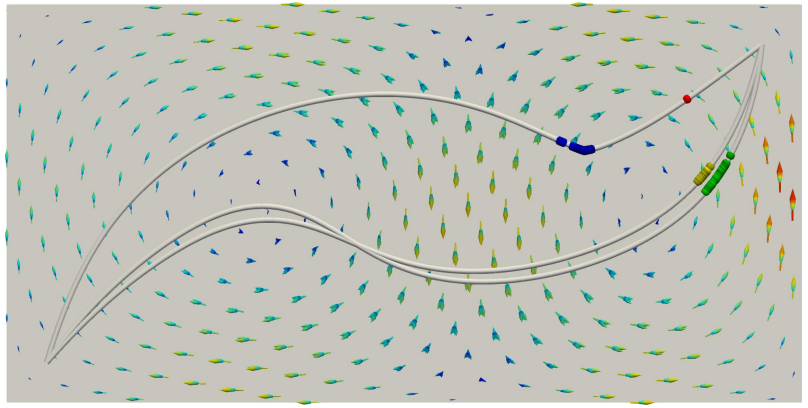


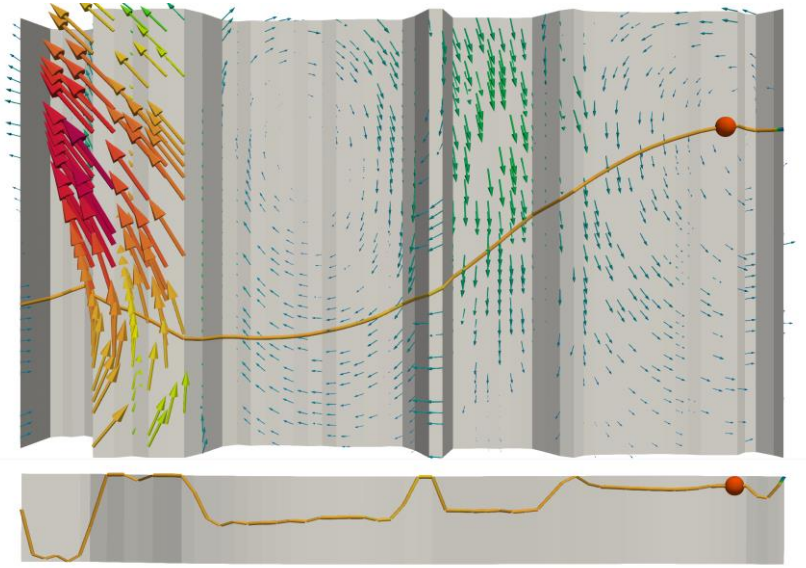
- Autonomous Underwater Vecicles (AUVs)
  - used for collecting information on coastal ecosystems or underwater installations, search and rescue operations, inspection of intake and discharge of thermal plants, …
- Motion / path / trajectory planning to guarantee the efficiency and safety of vehicles
- Optimize different objectives, such as total travel time, energy consumption, and quantity and quality of data collected

Why Visualization and How

Visualization for

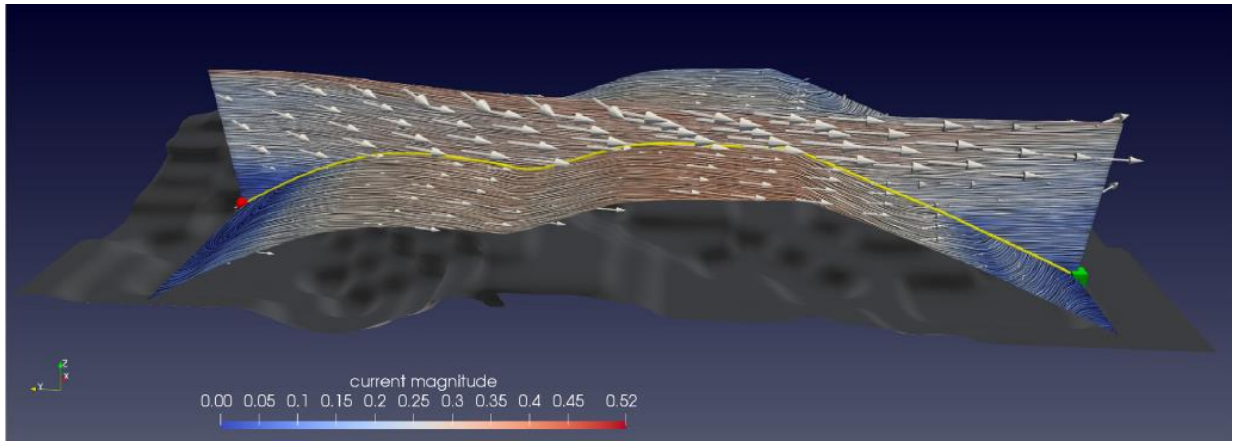
- Exploration
- Explanation
- Illustration





Visualization techniques:

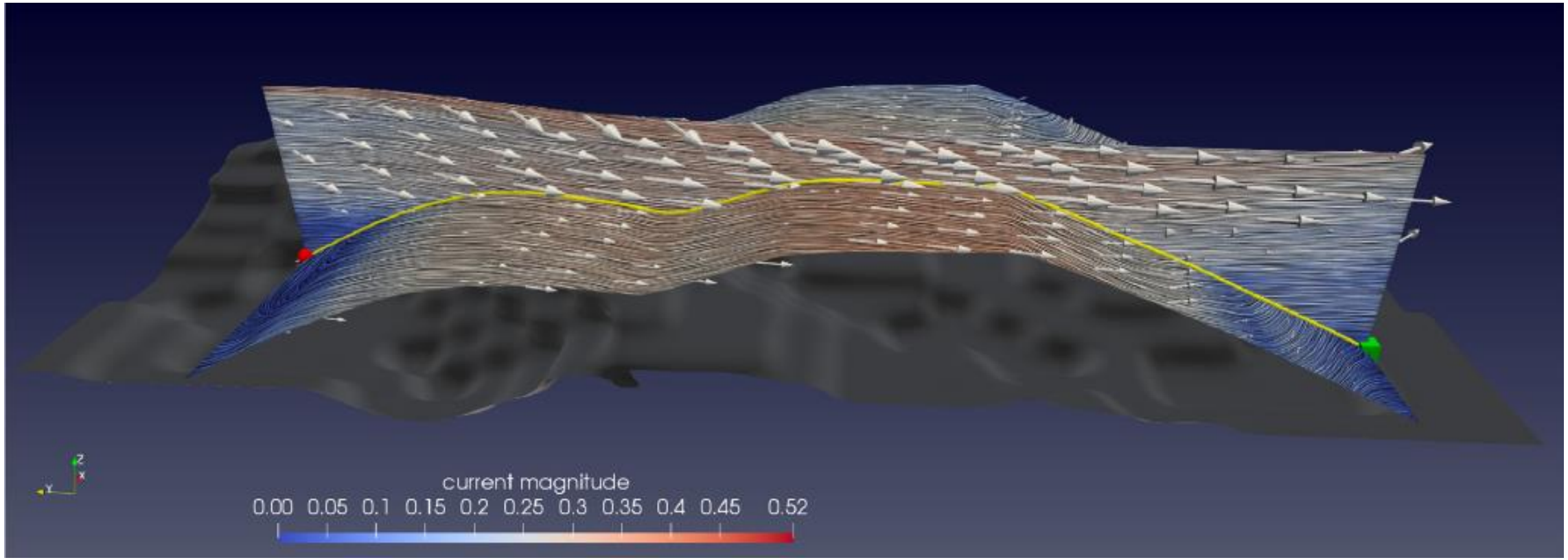
- Arrows, glyphs
- Stream/Pathlines, LIC
- Particle animations
- All renderings produced with ParaView



Spoiler: Simple techniques (arrow plots) worked best

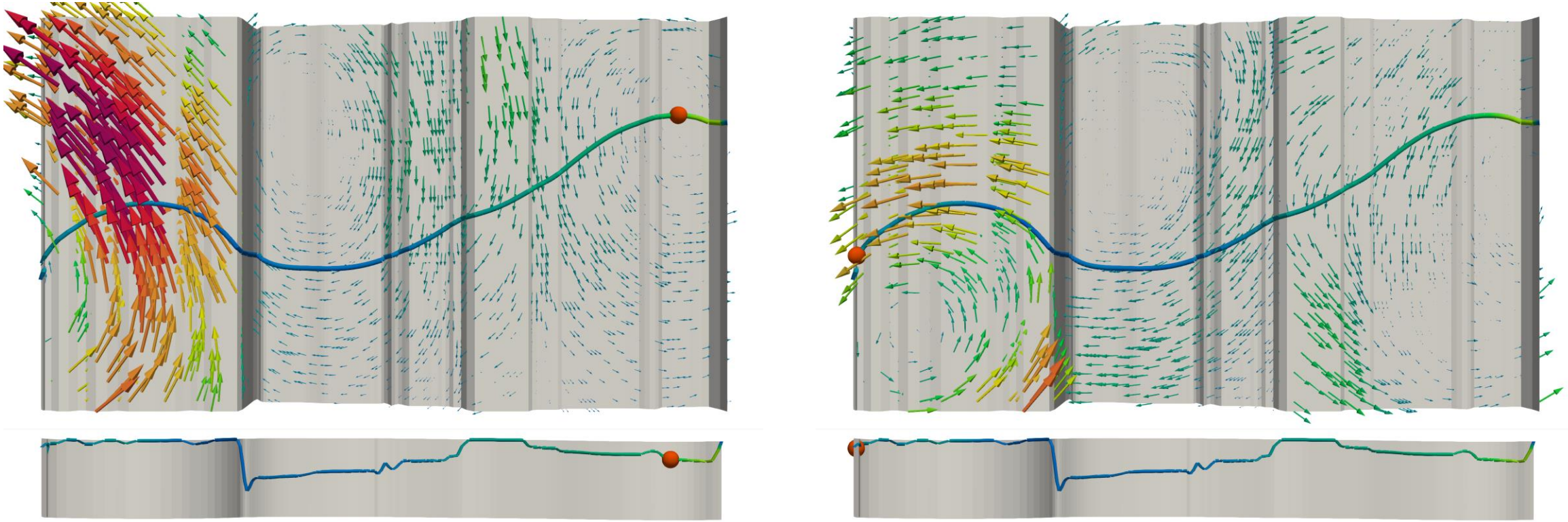
Stage 1: Steady 2D and 3D Flow

- Not using streamlines at all, LIC only as eye candy
- 3D perception difficult, showing horizontal and vertical slices following the path



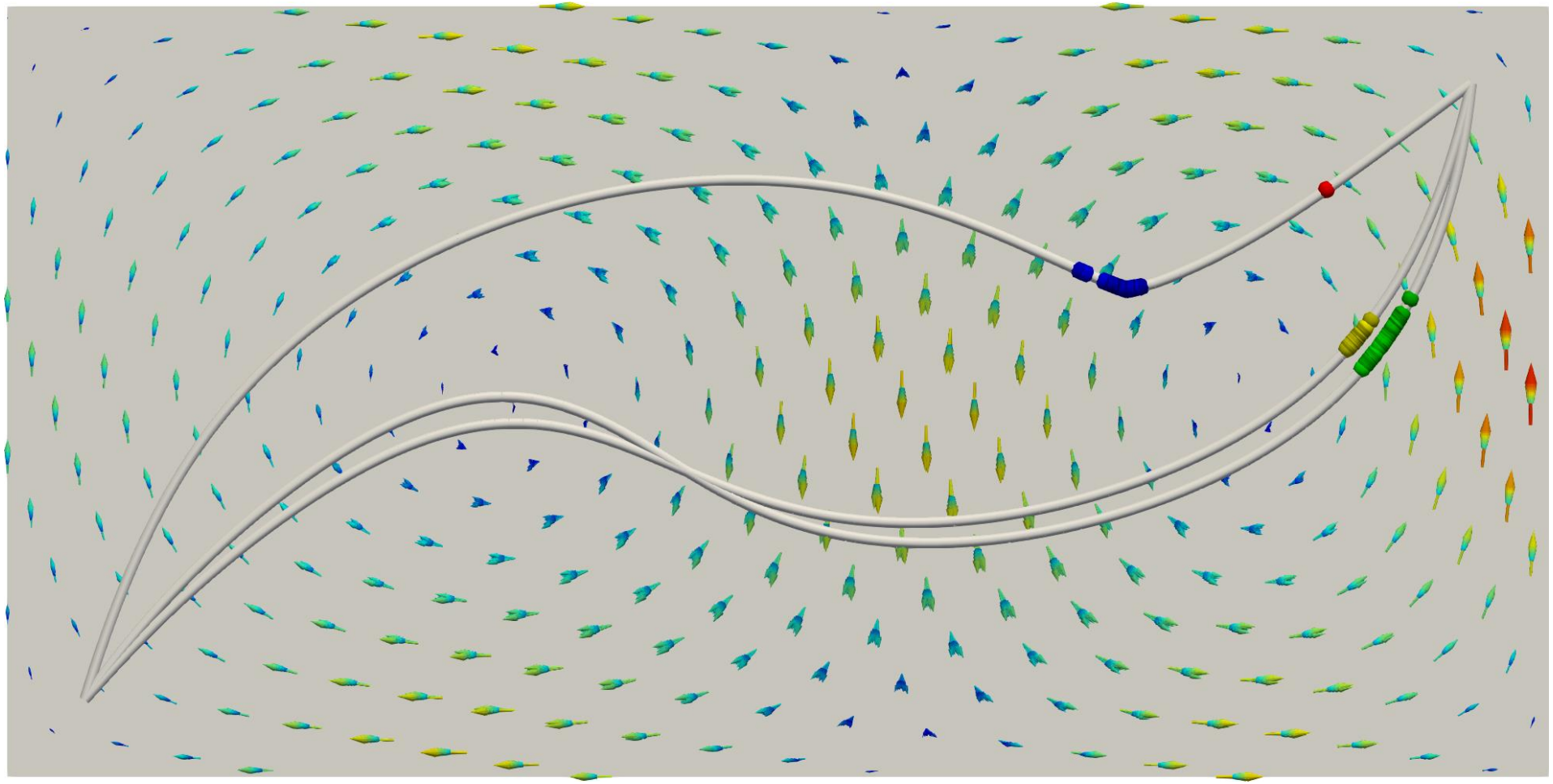
Stage 2: Time-dependent 2D and 3D Flow

- Separated horizontal and vertical slices
- Animation (frames) for time-dependence
- Removed LIC

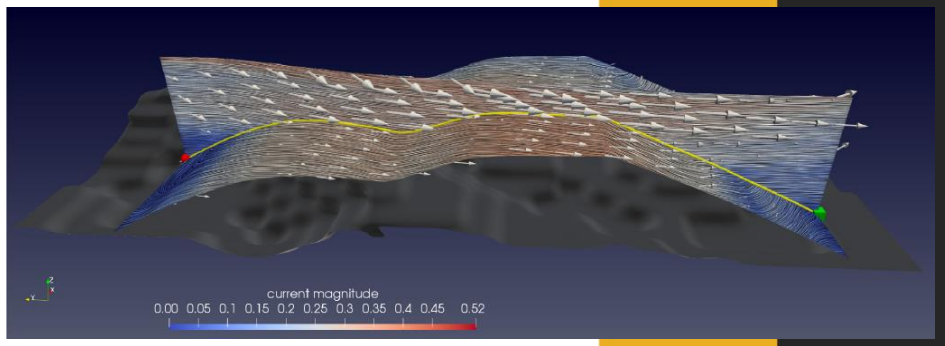


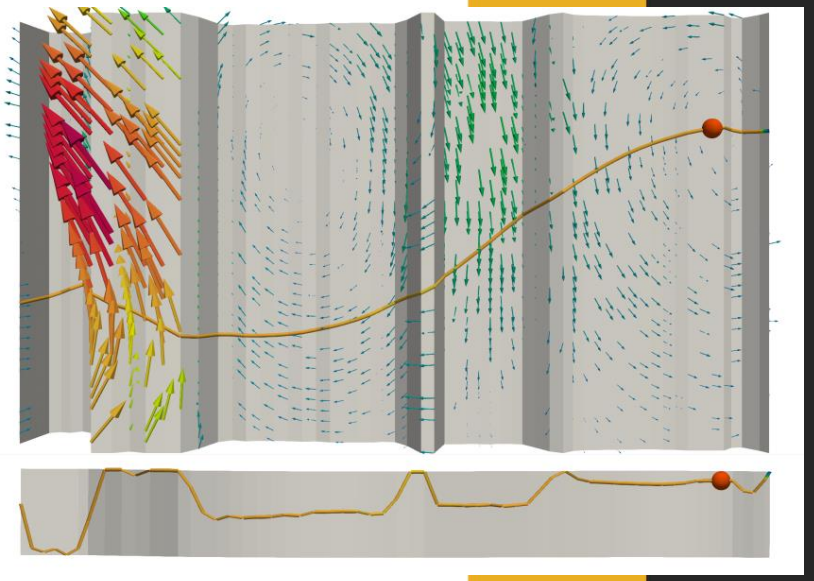
Stage 3: Uncertainty in 2D

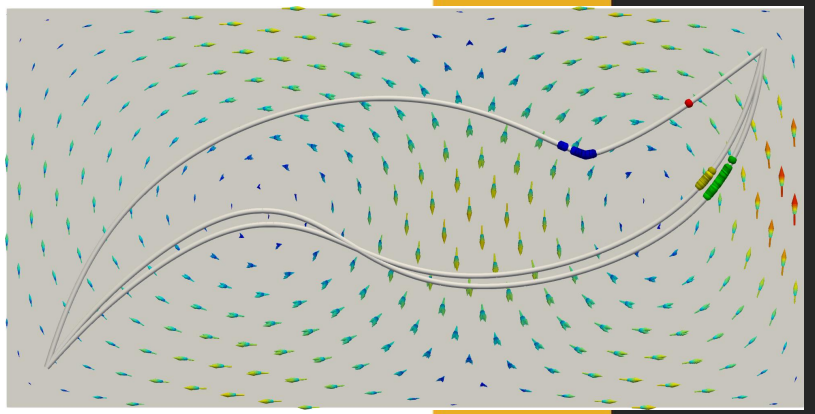
- Simply plotting all arrows at sample points
- Certainly more sophisticated glyph possible



References







Sultan Albarakati, Ricardo M. Lima, Loïc Giraldi, Ibrahim Hoteit, and Omar Knio. “Optimal 3D Trajectory Planning for AUVs Using Ocean General Circulation Models.” *Ocean Engineering* 188 (September 15, 2019): 106266.

Sultan Albarakati, Ricardo M. Lima, Thomas Theußl, Ibrahim Hoteit, and Omar Knio. “Optimal 3D Time-Energy Trajectory Planning for AUVs using Ocean General Circulation Models.” *Ocean Engineering, submitted*.

Sultan Albarakati, Ricardo M. Lima, Thomas Theußl, Ibrahim Hoteit, and Omar Knio. “Multi-Objective Risk-aware Path Planning in Uncertain Transient Currents: an Ensemble-Based Stochastic Optimization Approach.” *Ocean Modelling, submitted*.

Sultan Albarakati, “Trajectory Planning for Autonomous Underwater Vehicles: A Stochastic Optimization Approach”, PhD Thesis, KAUST 2020. In preparation.

Conclusions

1. I consider 3D flow visualization (especially time-dependent and/ or uncertain) an unsolved problem
2. 3D flow visualization will have to include a reduction to 2D
3. LIC / pathlines often (usually?) inadequate


Questions?