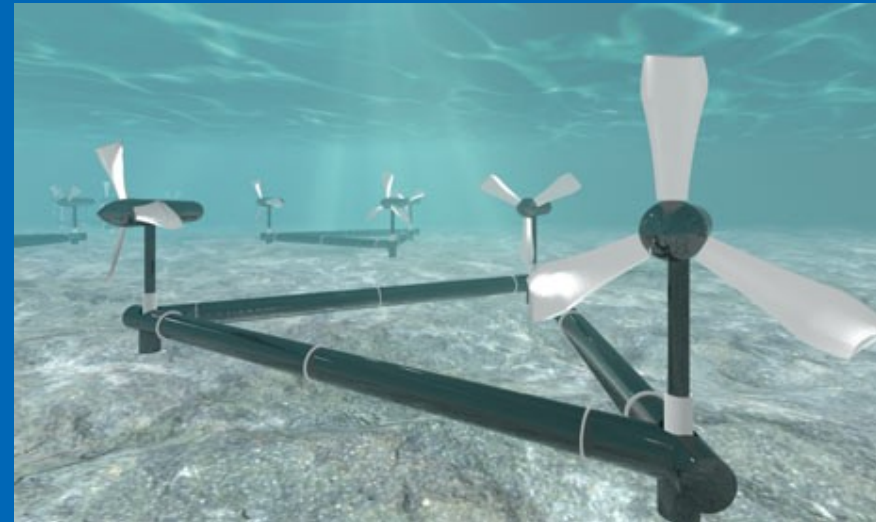


Visualization of Flow Past a Marine Turbine: A Multi-field Challenge

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Overview

- Motivation for marine turbine research
- Basic questions posed by engineers
- Description of multi-field simulation data
- Some experiments & attempts visualizing multi-field data

Multiple-Coordinated Views:

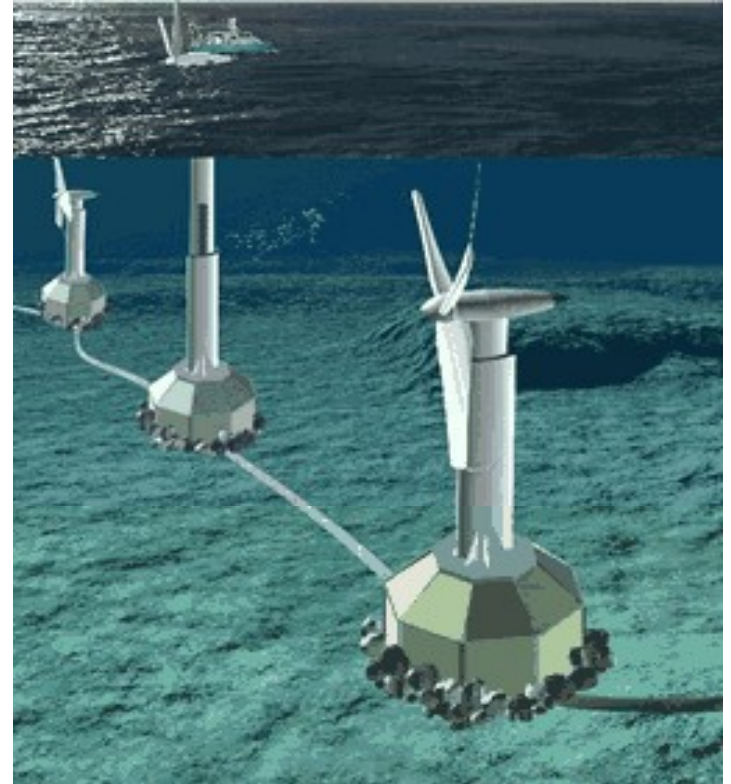
Histogram table, Velocity histogram,
Parallel coordinates, Streamline
graph, Distortion

- Some Observations
- Open questions



Marine Turbines: Motivation

- Renewable, green, and sustainable energy
- Converts kinetic energy from tidal water
- More predictable than wind
- Less environmental impact
 - Deep
 - Slow
- Higher Installation and Maintenance Costs



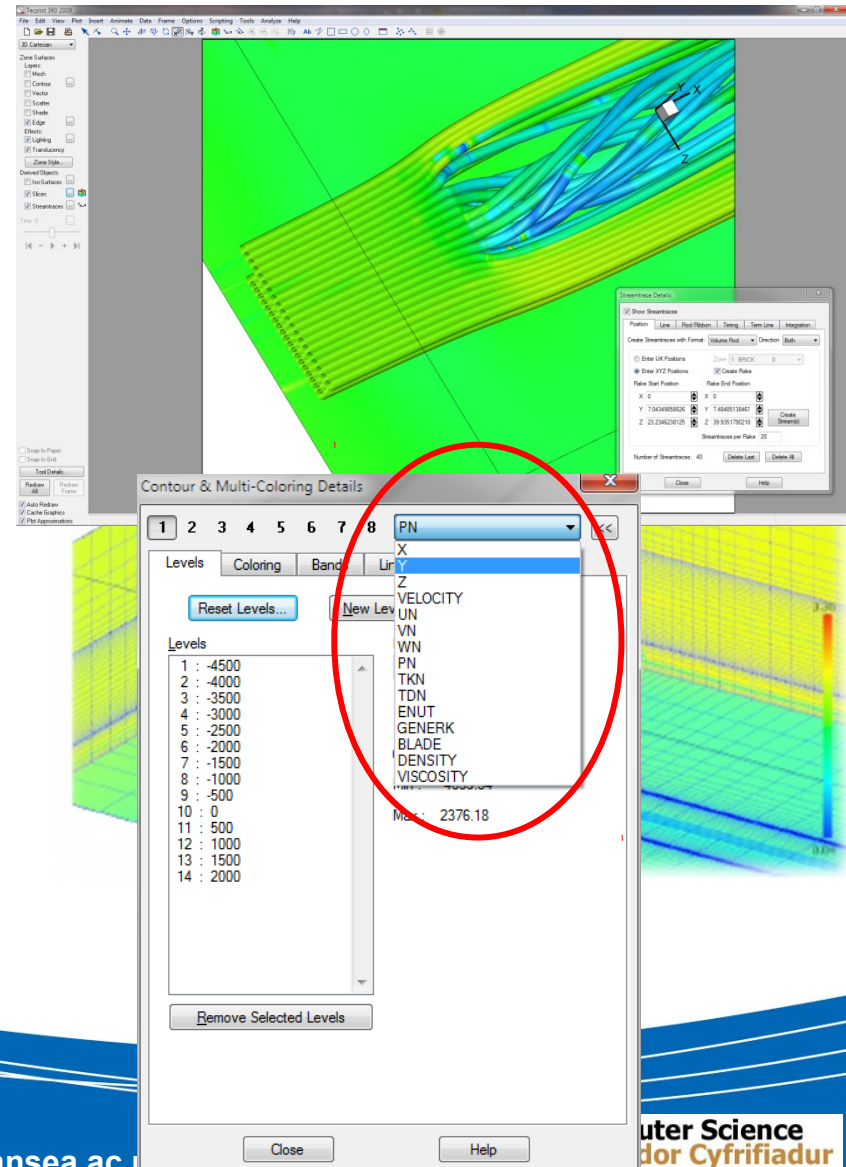
Marine Turbine Simulation: Questions

- What is the optimal Pylon (turbine support) and blade design?
- Goal: maximize energy drawn + minimize impact on flow
- How does the flow past a marine turbine behave?
- To what spatial extent does a marine turbine affect passing flow?
- How closely can turbines be packed in a given region?



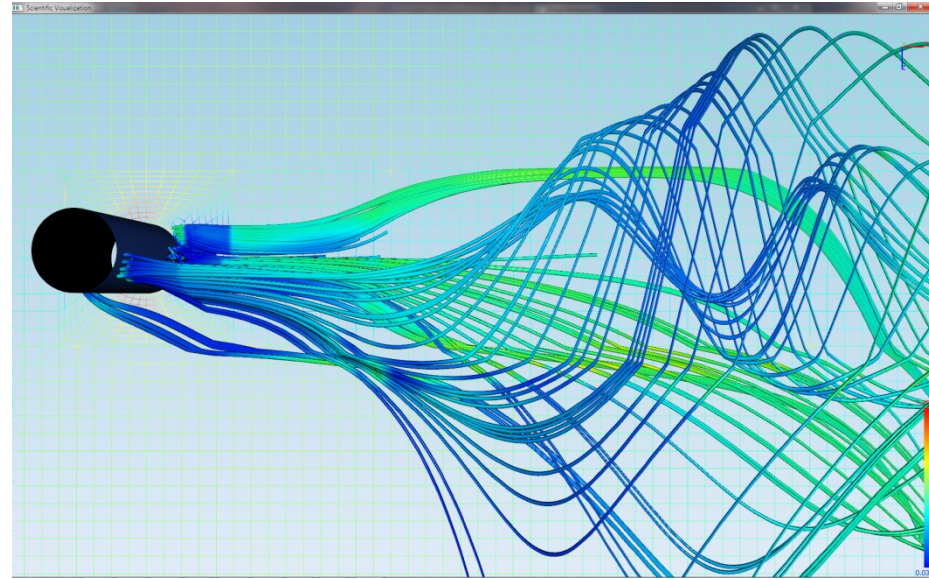
Marine Turbine Visualization Challenges

- Adaptive resolution, unstructured mesh
- High dimensionality of CFD data:
 - Flow Velocity $v(x,y,z)$
 - Relative Pressure (to boundary)
 - Density (can vary due to pollutants)
 - Turbulent Kinetic Energy (energy associated with rotational flow)
 - Turbulent Dissipation Rate (rate kinetic energy is converted into heat)
 - Turbulent Viscosity (diffusive mixing of flow turbulence)
 - Derived Attributes
- Commercial off-the-shelf tools may not provide enough insight

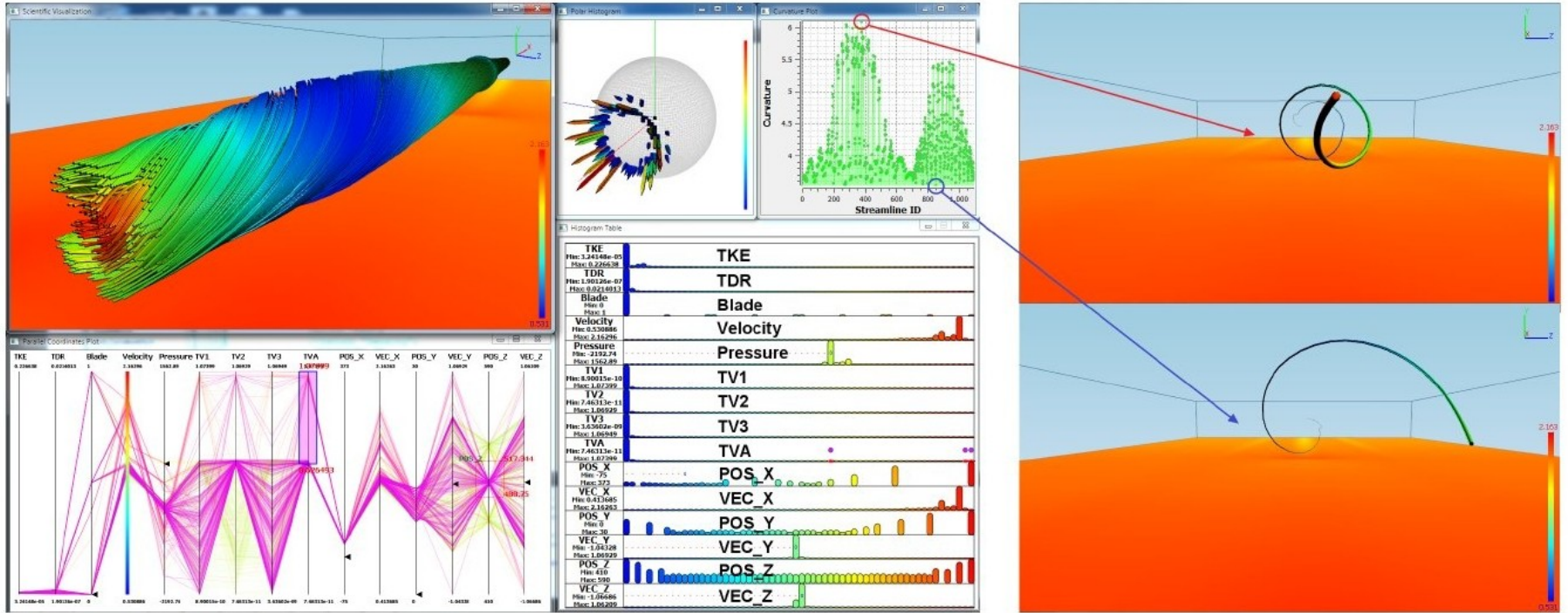


Visualization Application: Features

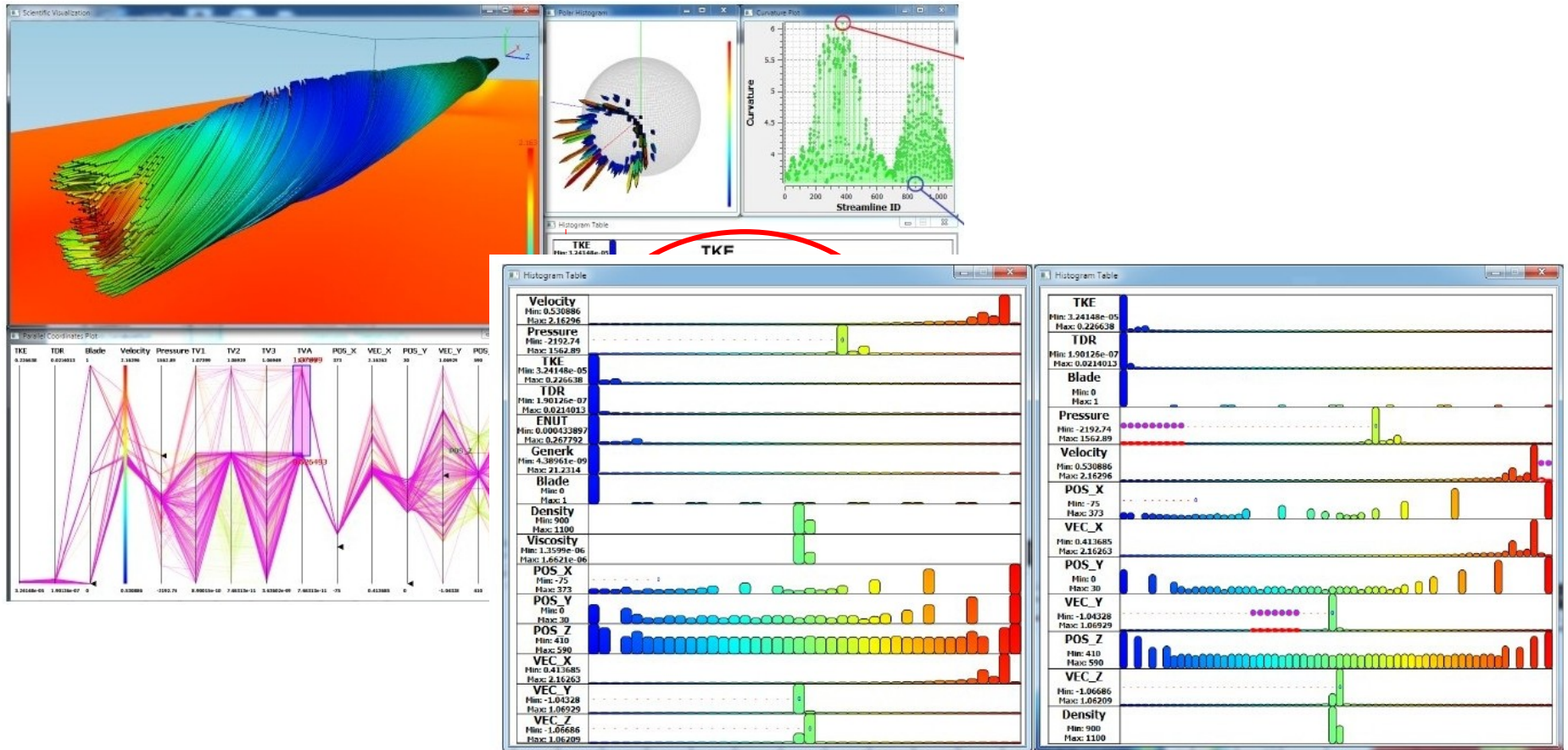
- Multiple-coordinated views for interactive visualization
- Information-Assisted Multi-field Histogram Views
- Interactively multi-select or brush any attributes deemed interesting
- Information and knowledge-assisted streamline seeding
- Knowledge-assisted distortion
- Multi-threading



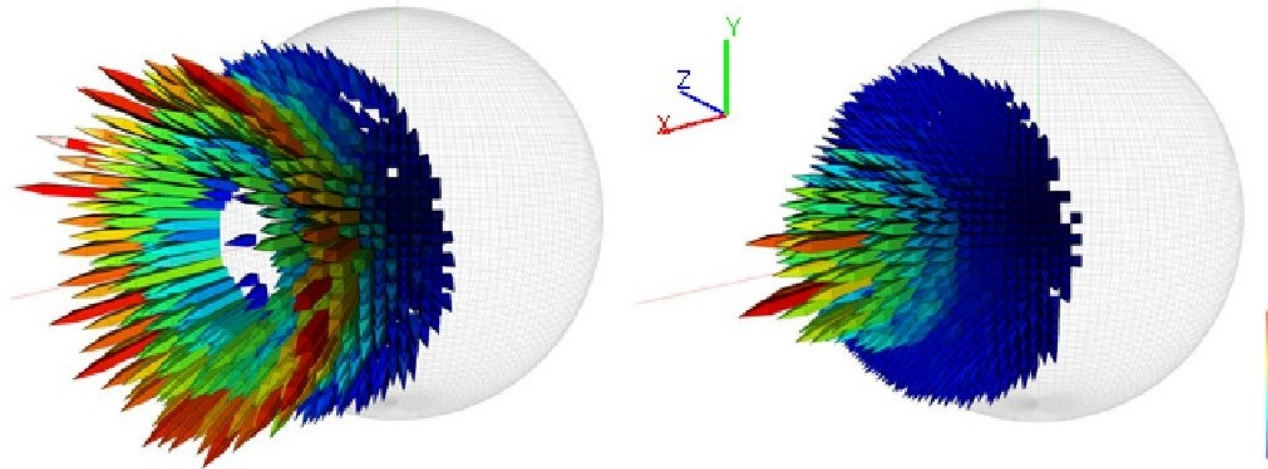
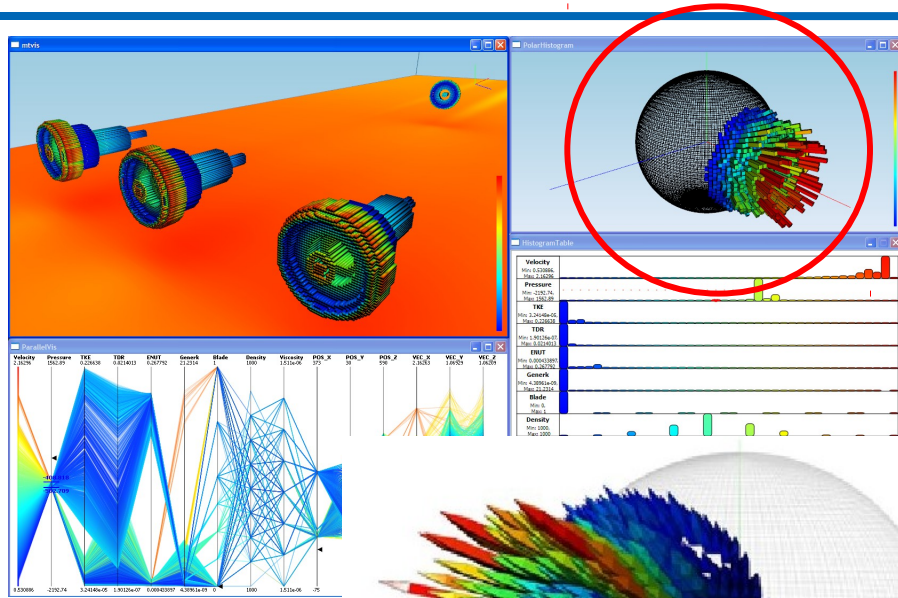
Visualization Application: Overview



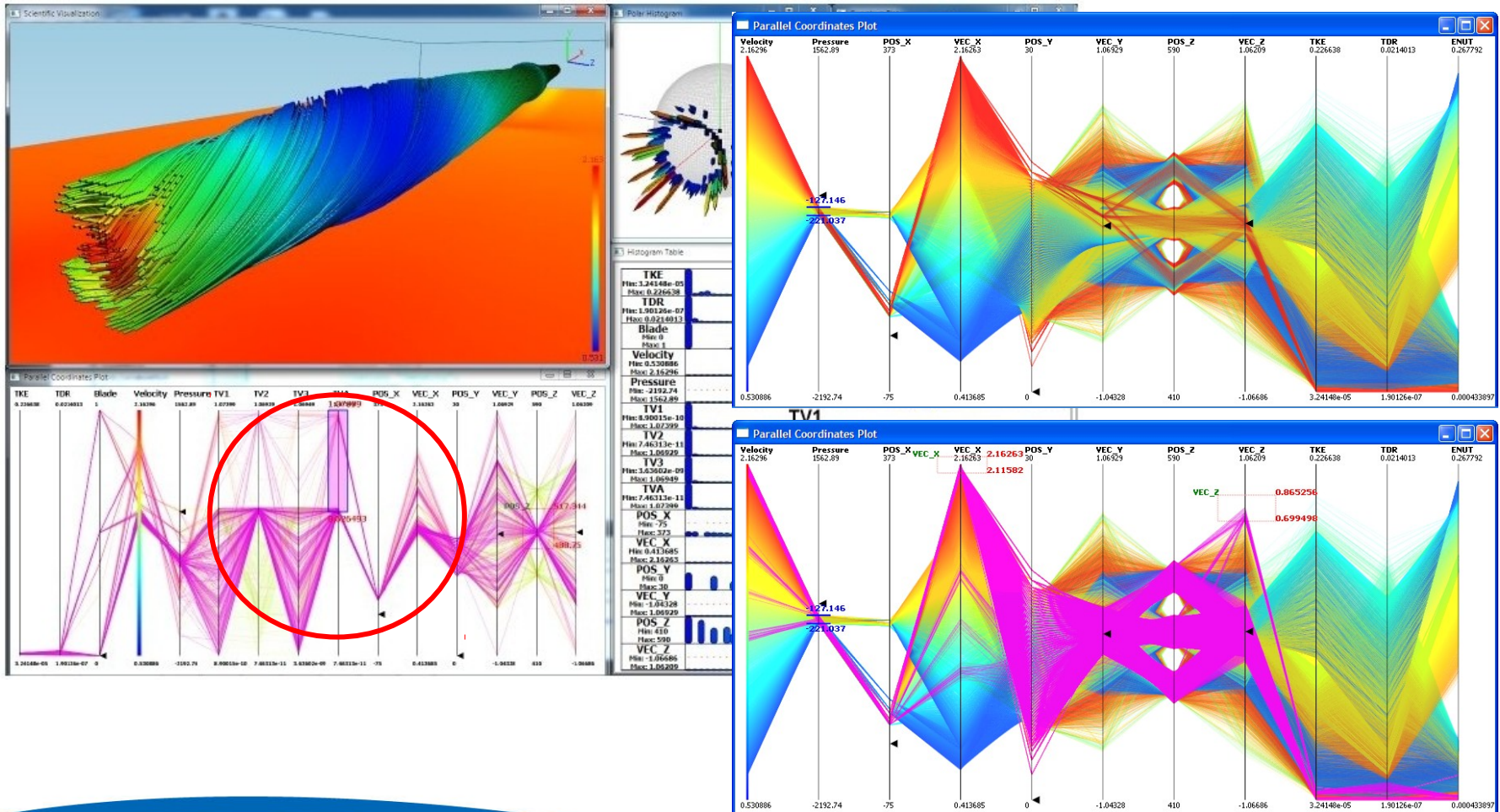
Visualization View: Histogram Table



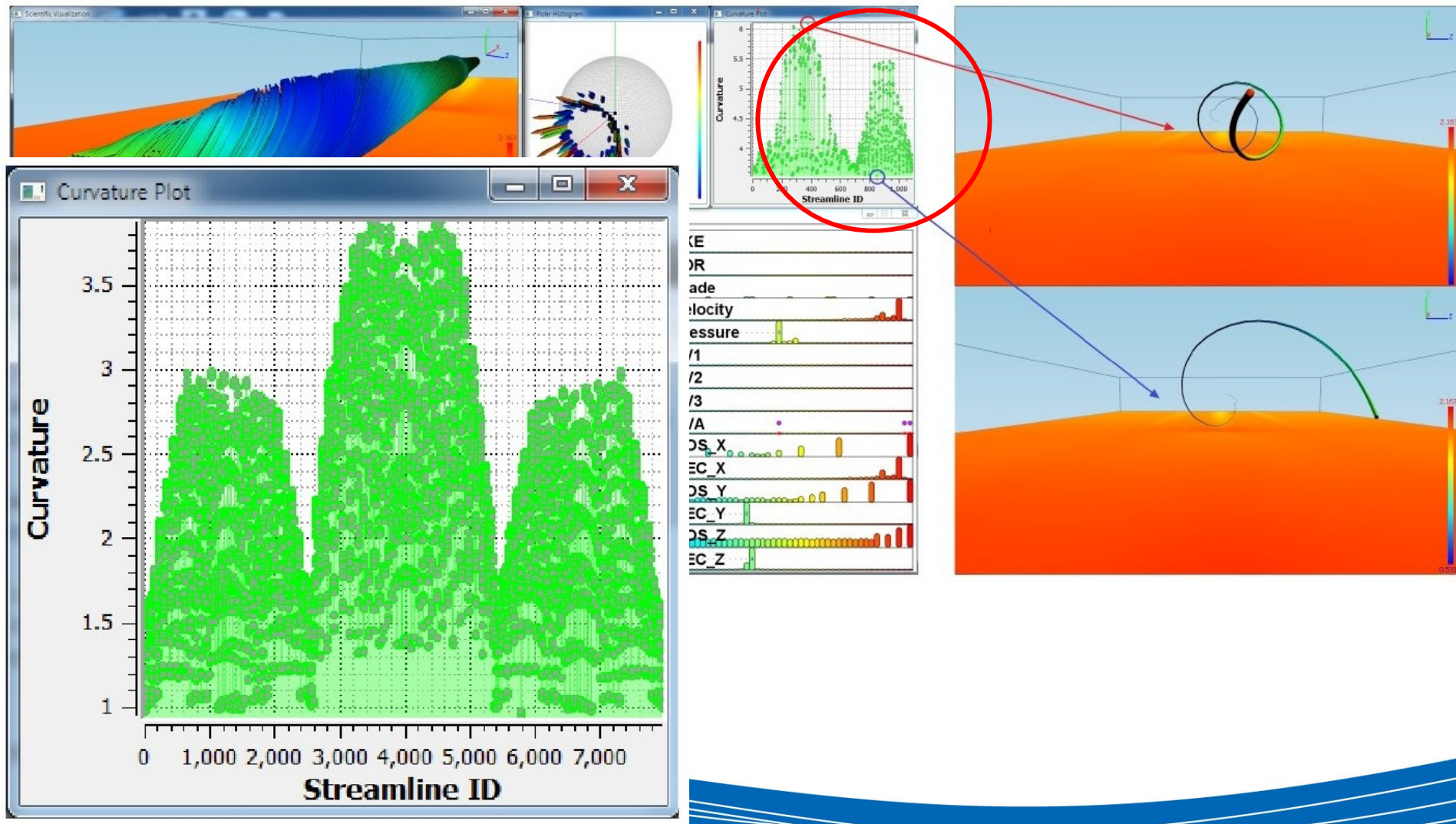
Visualization View: Polar Histogram



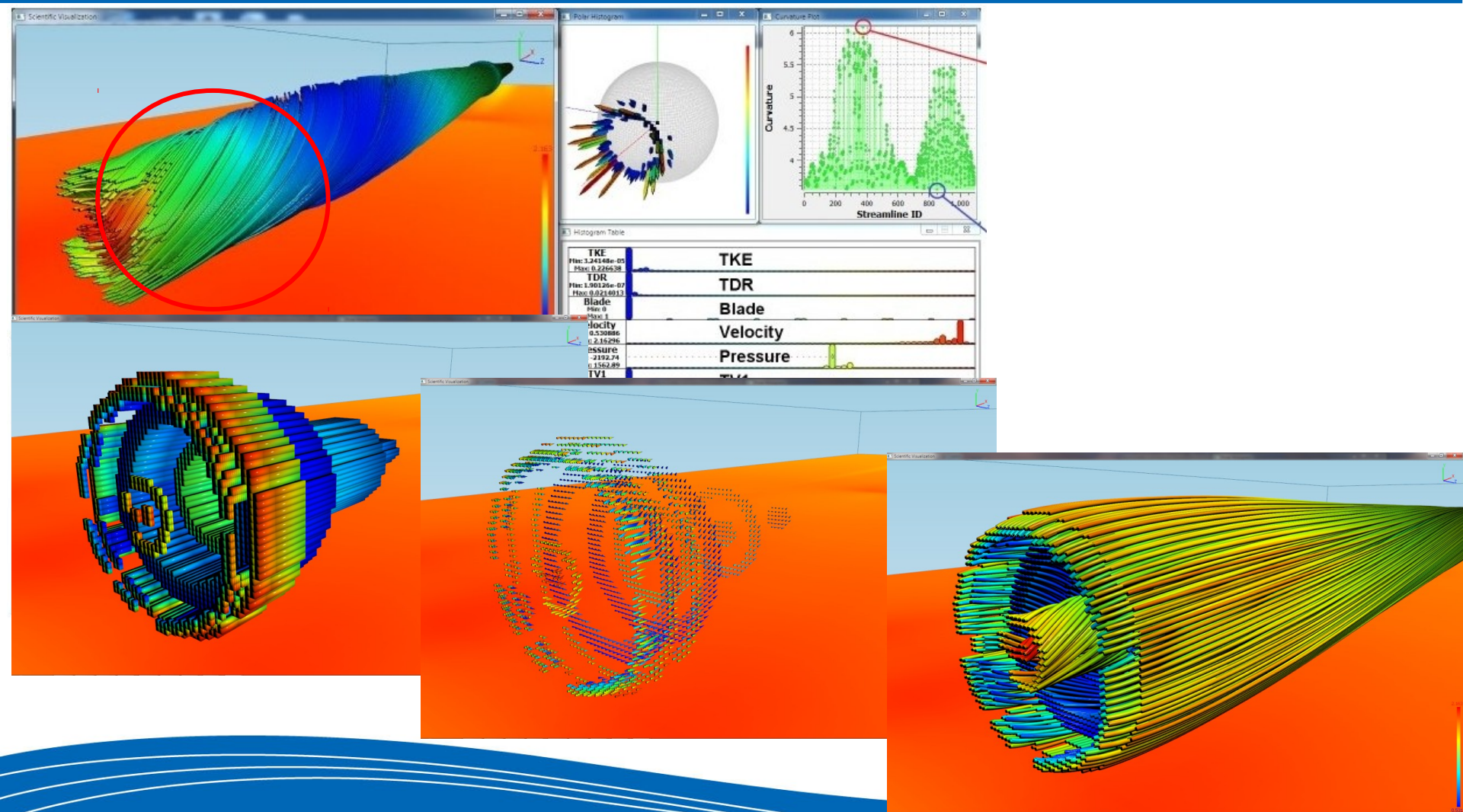
Visualization View: Parallel Coordinates



Visualization View: Streamline Graph



Visualization View: Scientific



Visualization Application: Experiments

Observations, Discussion

- Engineers responded favorably to multiple-views, including parallel coordinates and distortion
- Visualizations highlighted a problem in simulation
- Streamline graph obviates periodicity of swirl flow
- Engineers surprised by asymmetry of tangential velocity
- Engineers want more than just visualization

Question Remaining

- What improvements can be made to histogram table to provide a better overview of multi-field data?
- What alternative scientific or informations visualizations can be used to provide overview of multi-field CFD data?
- Are there any simple techniques to order parallel coordinate axes?
- Can detailed, multi-field views be coupled more closely with the spatial domain?

Acknowledgments

Thank you for your attention!
Any Questions?

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