Flow Analysis for Scientific Discovery

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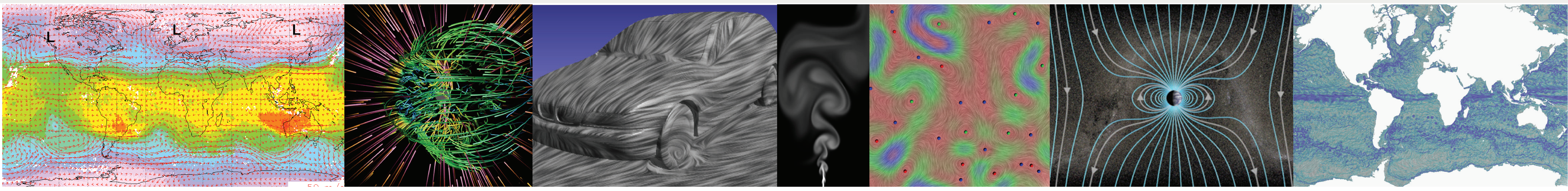

Analysis of flow is indispensable for many applications in science and engineering

- However, applying the theory of smooth flow in real world to sampled data on computer hardware is challenging
- Traditional approaches rely on numerical computations affected by approximations, which are unstable and often produce unphysical result
- As a result, the analysis may be inconsistent, inaccurate, and unstable
- This research focuses on developing novel flow representations that enable consistent, robust, and more accurate extraction of important features of flow
- Thus, establishing new paradigms of analysis of large-scale complex flows in a consistent manner

Shifting the realm towards a consistent, robust, and more accurate analysis

- New flow representations, which are free from numerical approximations, avoid potential inaccuracies and inconsistencies
- Edge Maps [1,2,3] can describe the flow consistently, and within a guaranteed error enabling visualization of spatial and temporal errors (Figs. 1, 2, 3)
- Quantized flow [4] can extract, for the first time, highly unstable structures like vortices consistently and robustly (Figs. 4,5,6)

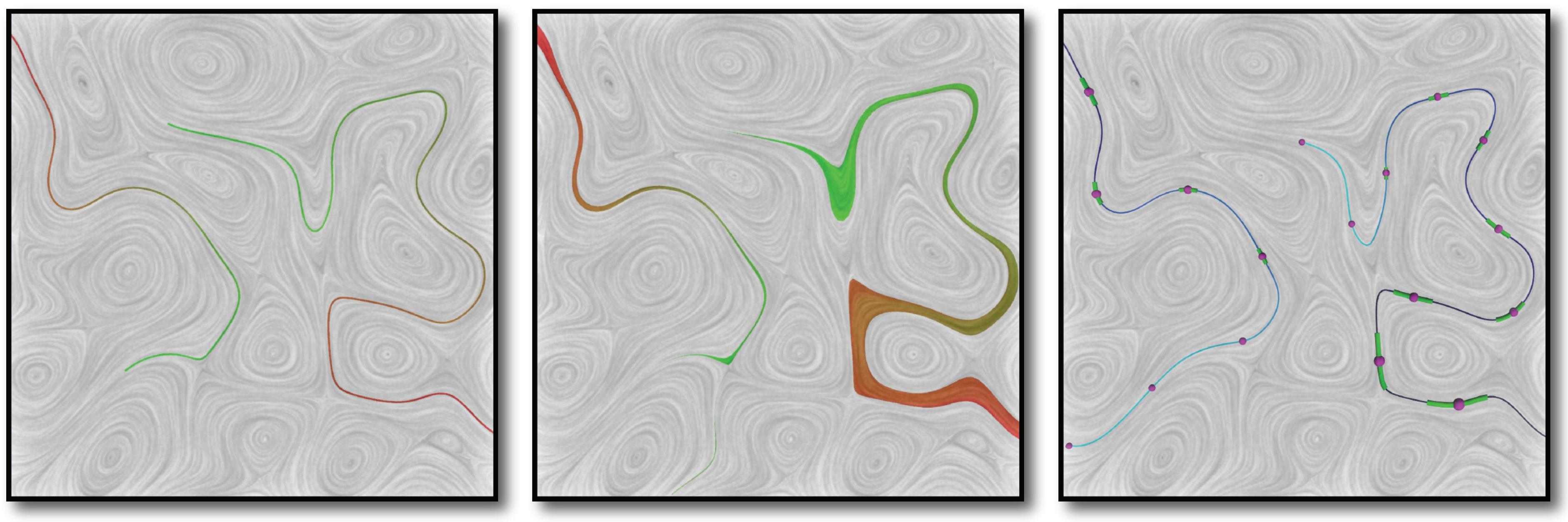

Fig. 1

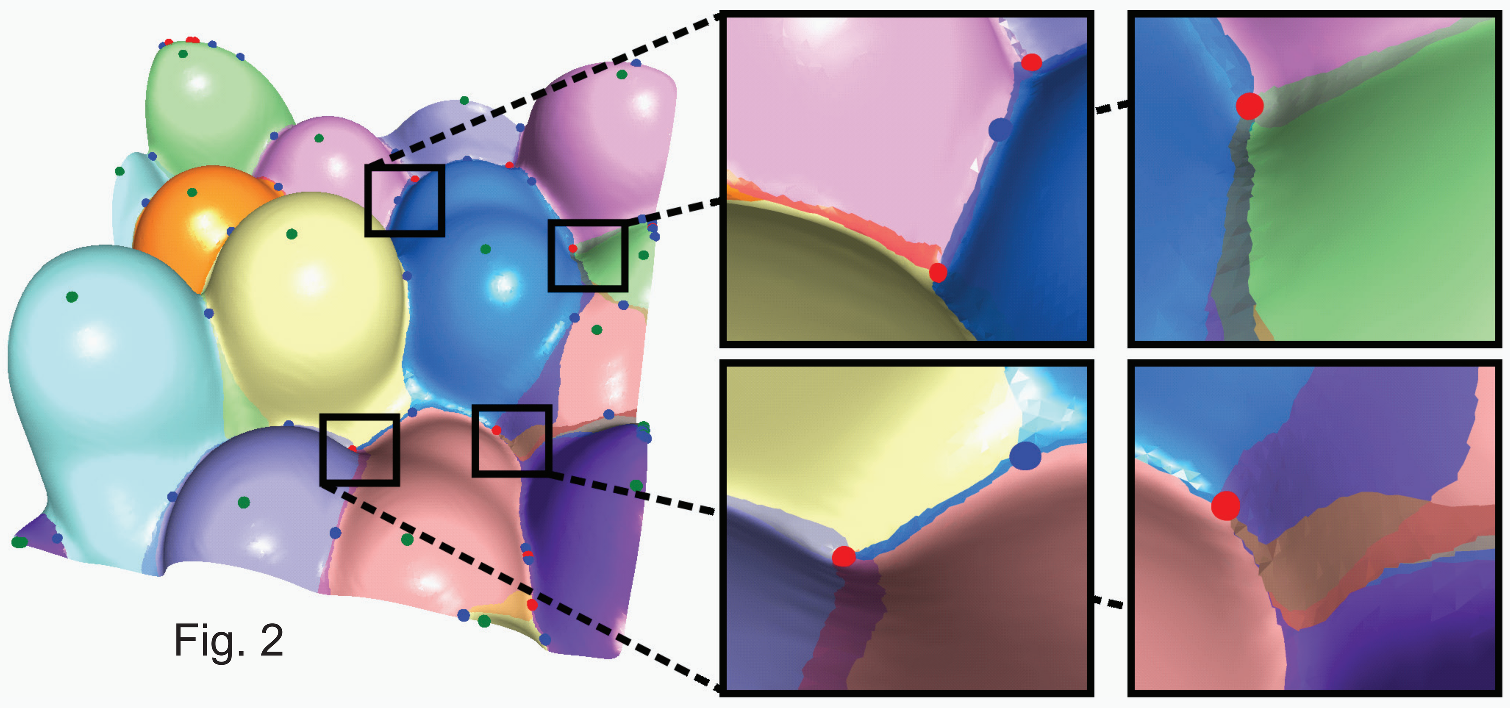

Fig. 2

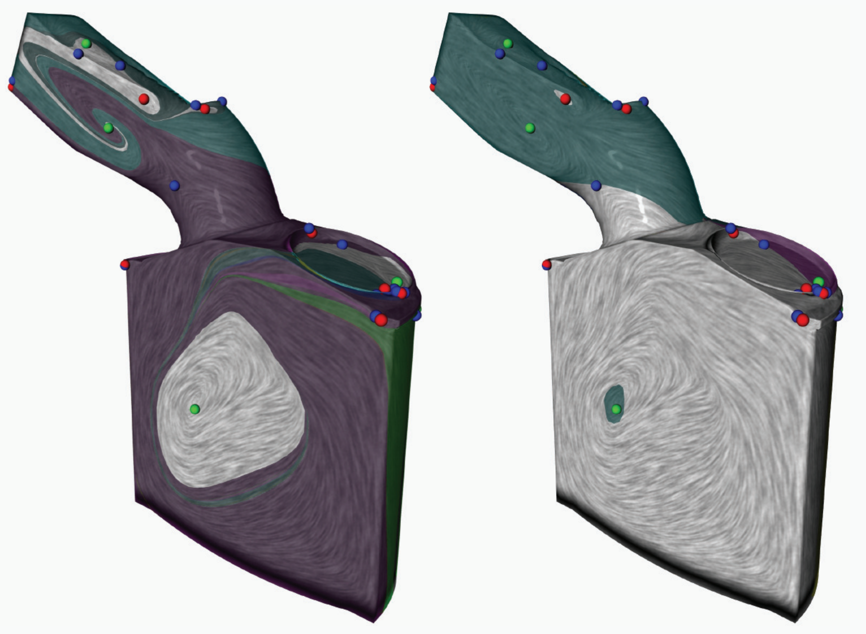

Fig. 3

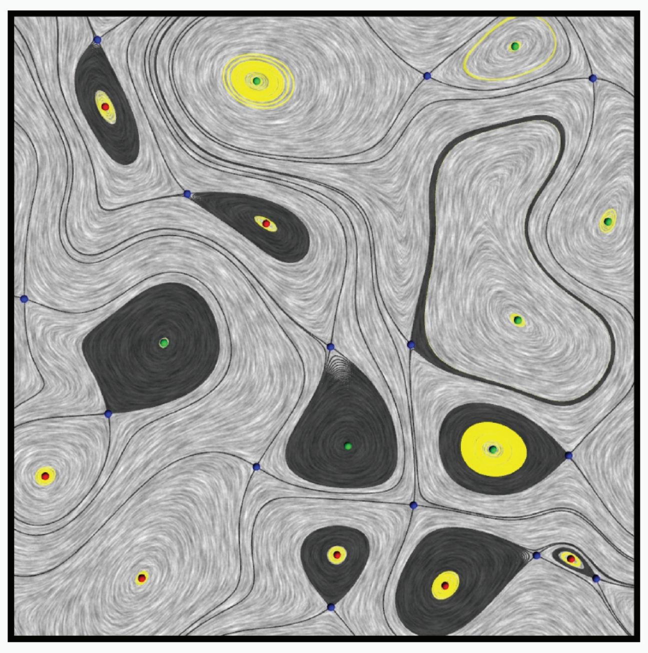

Fig. 4

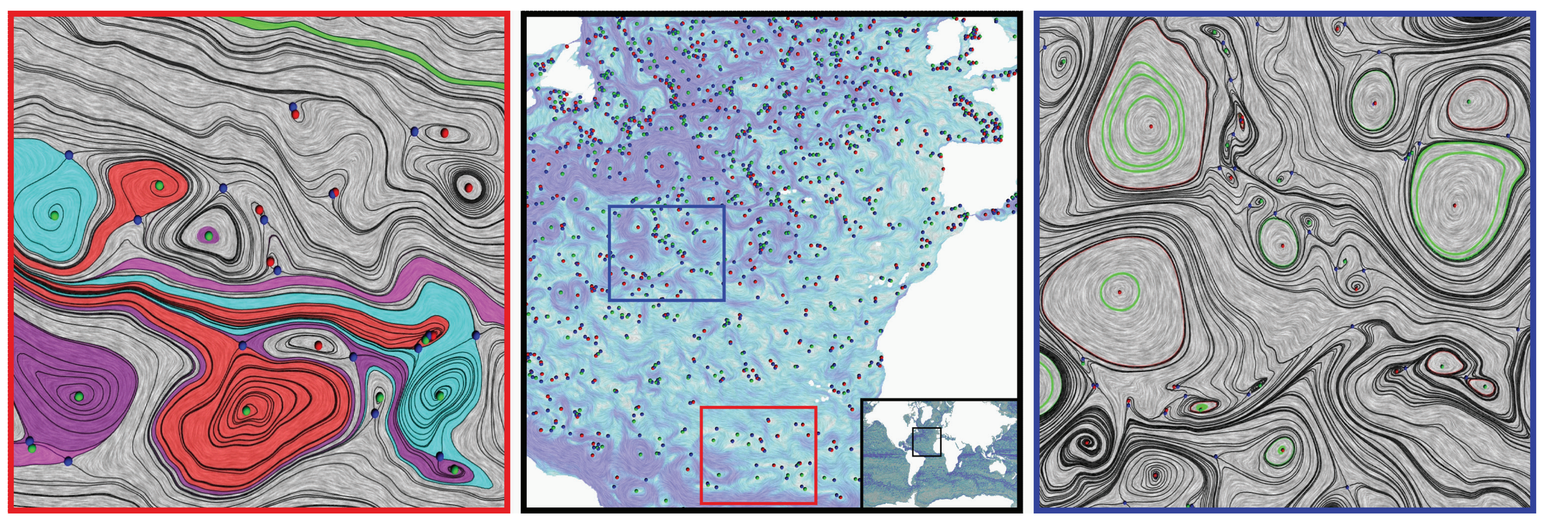

Fig. 5

Enabling scientific discovery

- Understanding the manifestations of spatial and temporal errors in analysis is the first step towards a consistent, robust and accurate scientific discovery (Fig. 1)
- Understanding the structure and fuzziness in simulations of turbulent mixing, which occurs in a broad spectrum of phenomena ranging from boiling water to astrophysics and nuclear fusion (Fig. 2)
- Investigating and evaluating the flow patterns in automotive components in order to improve automotive design and performance (Fig. 3)
- Identifying vortices in modern HCCI (Homogeneous Charge Compression Ignition) engines provides efficiency gains and lowering of emission levels leading to a cleaner energy (Fig. 4)
- Identifying vortices in simulations of global oceanic currents (Fig. 5) and augmenting the analysis by identifying regions of unidirectional flow (Fig. 6) helps understanding global environmental factors and their impact on climatic changes

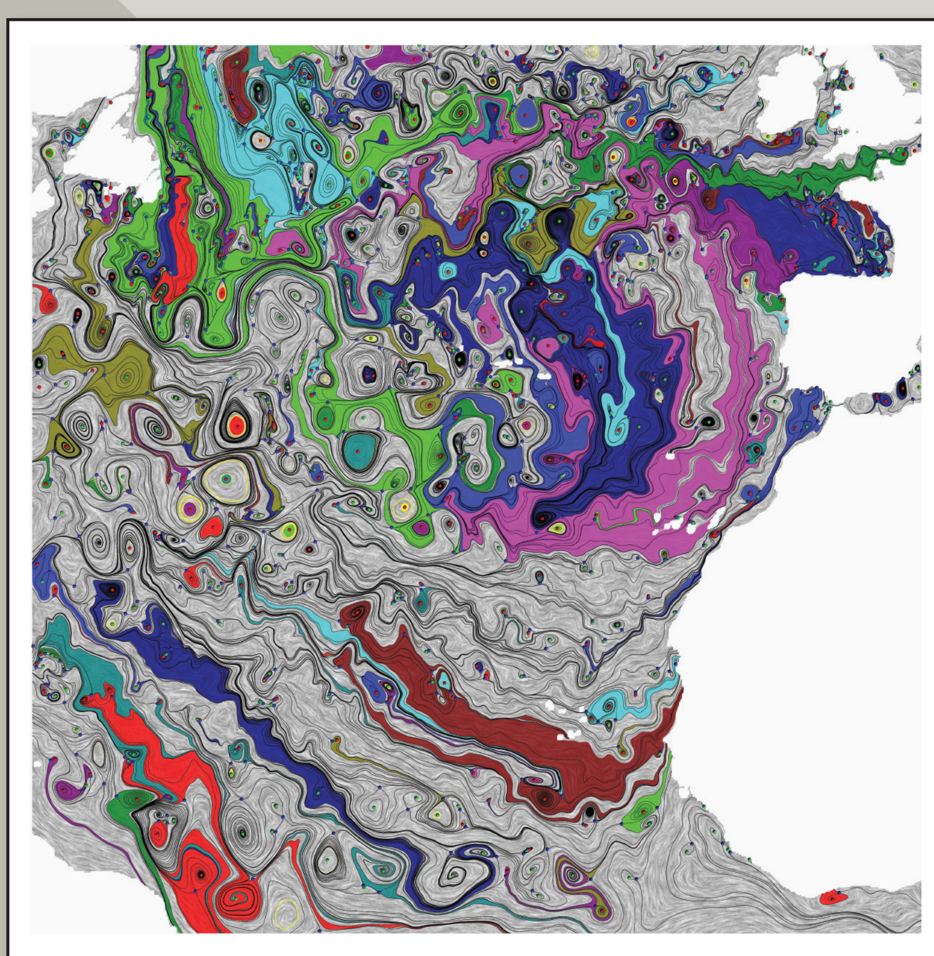

Fig. 6

References

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[3] S. Jadhav, H. Bhatia, P.-T. Bremer, J. A. Levine, L. G. Nonato, and V. Pascucci. Consistent approximation of local flow behavior for 2D vector fields using edge maps. In Topological Methods in Data Analysis and Visualization II – Theory Algorithms, and Applications. Springer 2012. To appear.
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