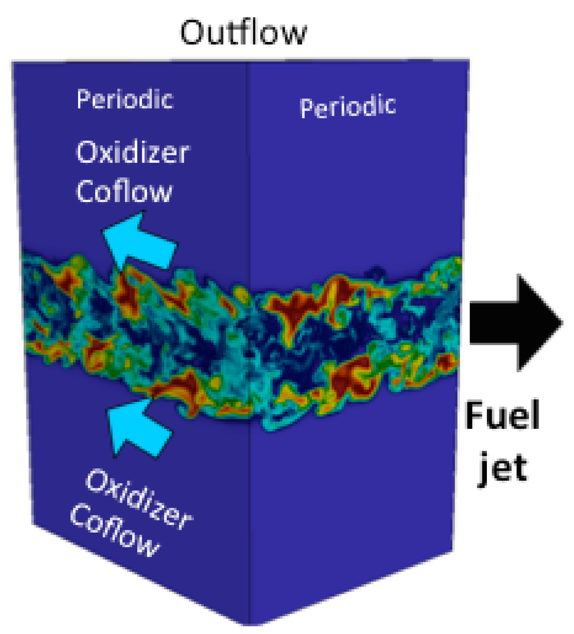
Analyzing and Tracking Features in Large-Scale Turbulent Combustion at Scale

P.-T. Bremer[1,2], W. Widanagamaachchi[2], A. Landge[2], P. Klacansky[2], J. Chen[3], A. Bhagatwala[3], H. Kolla[3], V. Pascucci[2,4]
[1]Lawrence Livermore National Laboratory, [2]University of Utah, [3]Sandia National Laboratory, [4]Pacific Northwestern National Laboratory

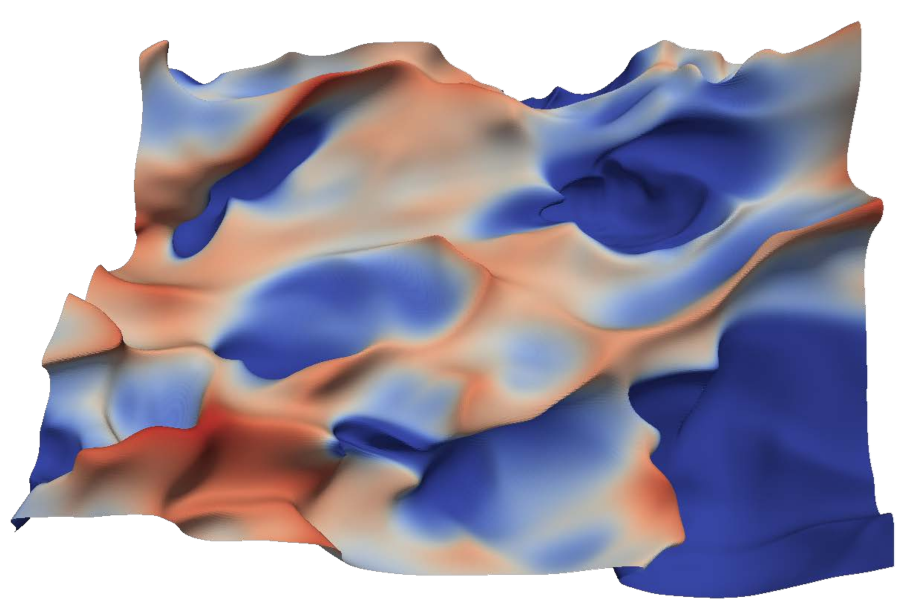
Understanding Flame Stability in Turbulent Non-Premixed Combustion

Non-premixed combustion is of interest for anything from diesel engines, to gas turbines and aviation. In the high Reynold number regimes of most interest the flame can become unstable and undergo significant extinction and re-ignition decreasing efficiency and increasing emissions.

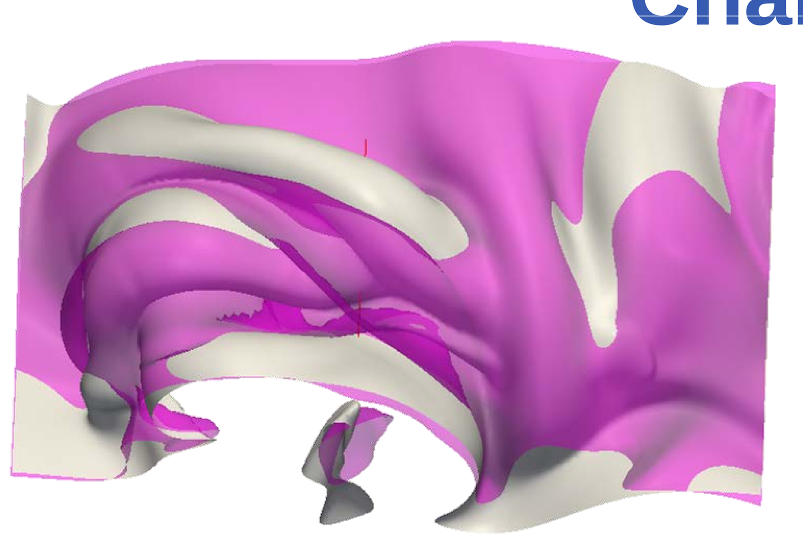


Use Case: DNS of a turbulent jet flame performed using the S3D framework. The experiment uses a di-methyl ether fuel stream in an oxidizer co-flow with parameters chosen specifically to promote local extinction and re-ignition.

Problem: Define the flame as mixture fraction isosurface and analyze how the actively burning portions of the flame (red) develop extinction *holes* (dark blue). The goal is to track holes over time to understand how they form, grow and ultimately heal.



Challenges

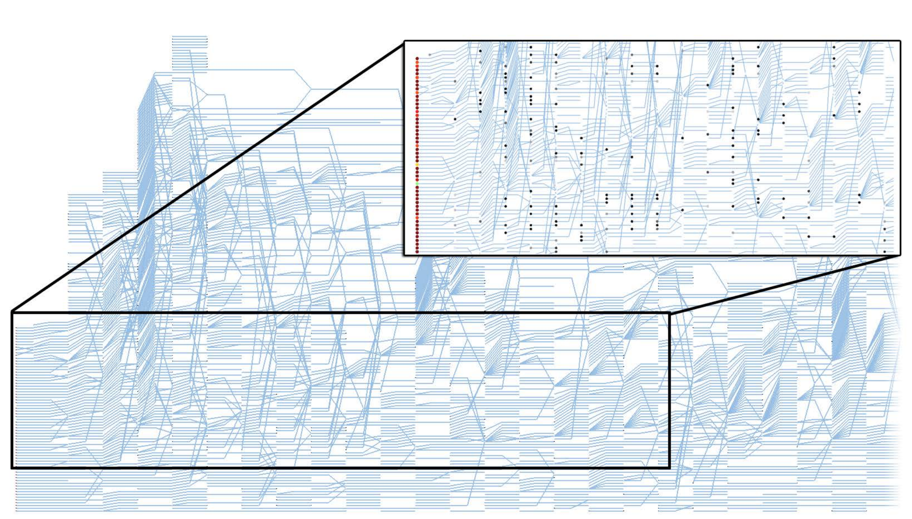


The flame evolves discontinuously (grey to pink) due to low temporal resolution

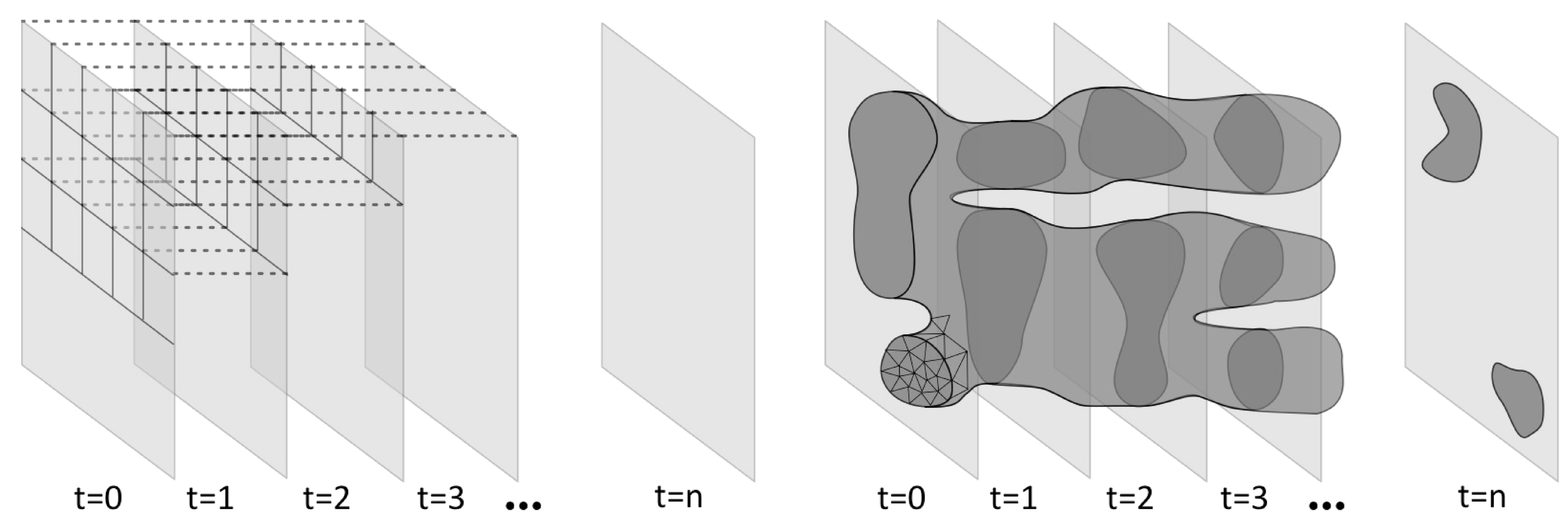
- No common domain for tracking
- Complex fast moving geometry
- Temporal interpolation artifacts

Extinction threshold is uncertain and unstable

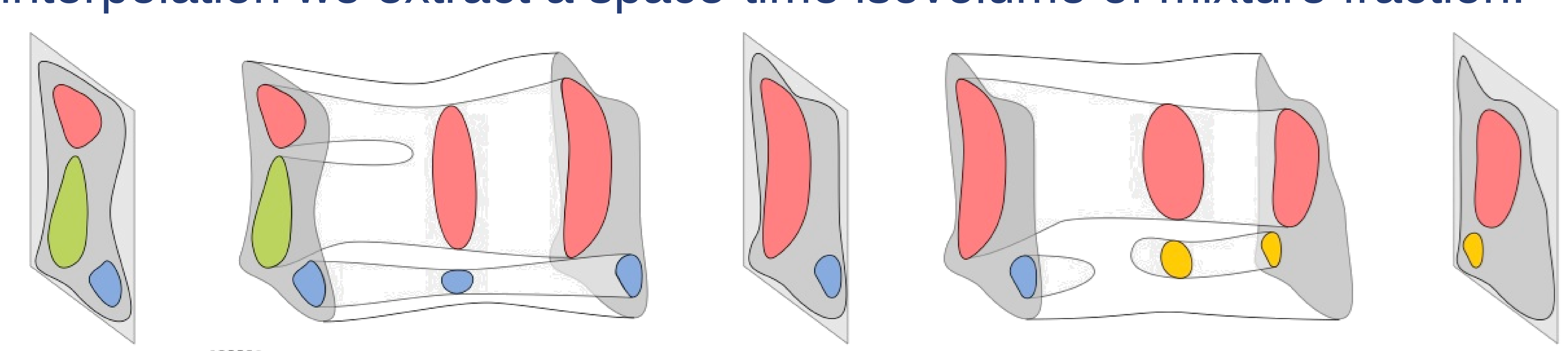
- Parameter-independent techniques are mandatory
- Instabilities in the tracking
- Complex and convoluted tracking graphs

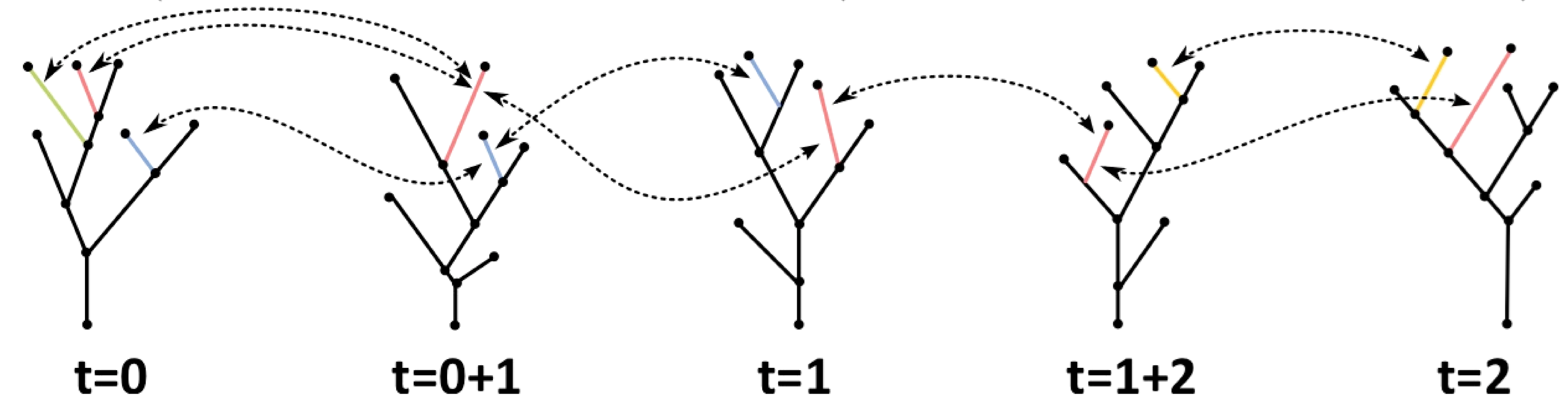


Parameter-Independent Tracking of Embedded Features



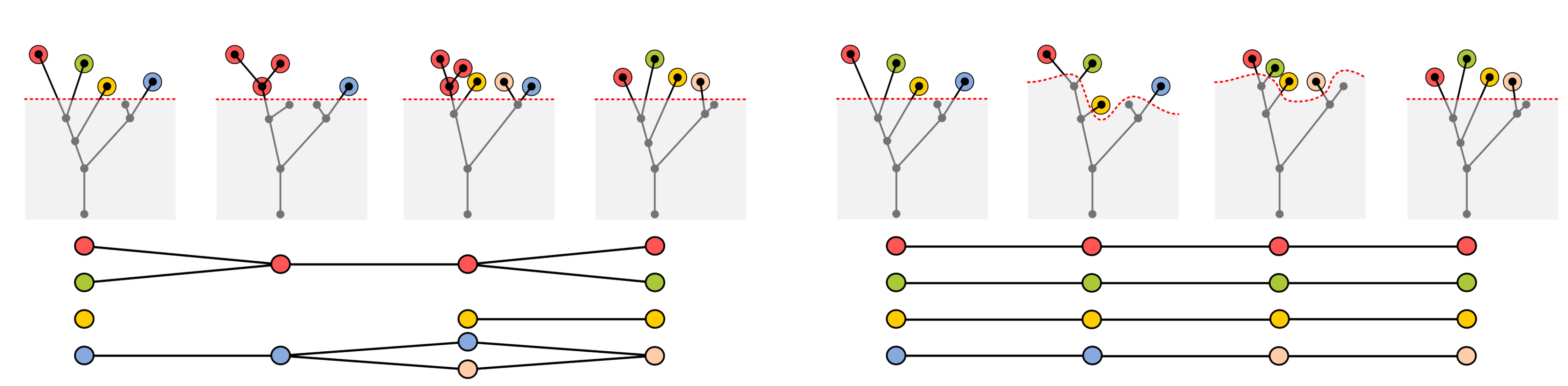
Connect consecutive grids to form space-time mesh. Assuming linear interpolation we extract a space-time isovolume of mixture fraction.





Computing merge trees within each time step provides parameter-independent feature detection. Merge trees of the combined space-time mesh of consecutive time steps enable simple overlap tracking.

Local Thresholds

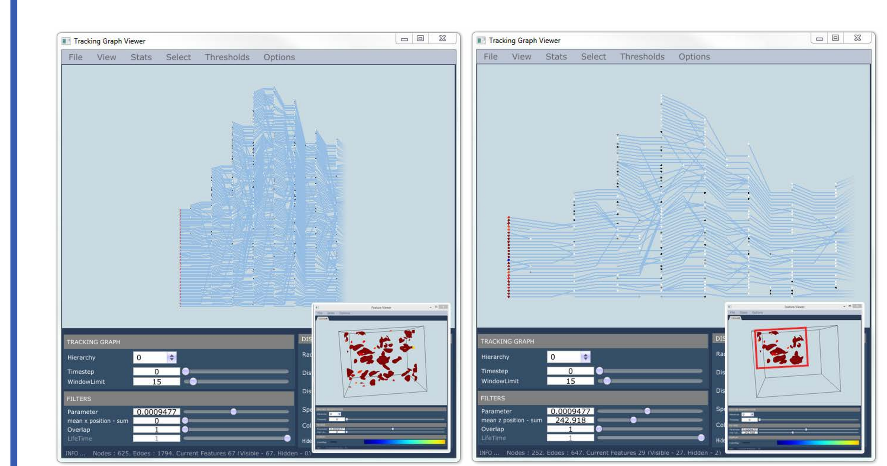


Using fixed thresholds creates spurious events in the tracking graph (left) due to instabilities in the threshold and artifacts of the linear interpolation in time. Given a small error tolerance in the threshold allows to locally adapt the feature definition to create a cleaner, more intuitive tracking graph.

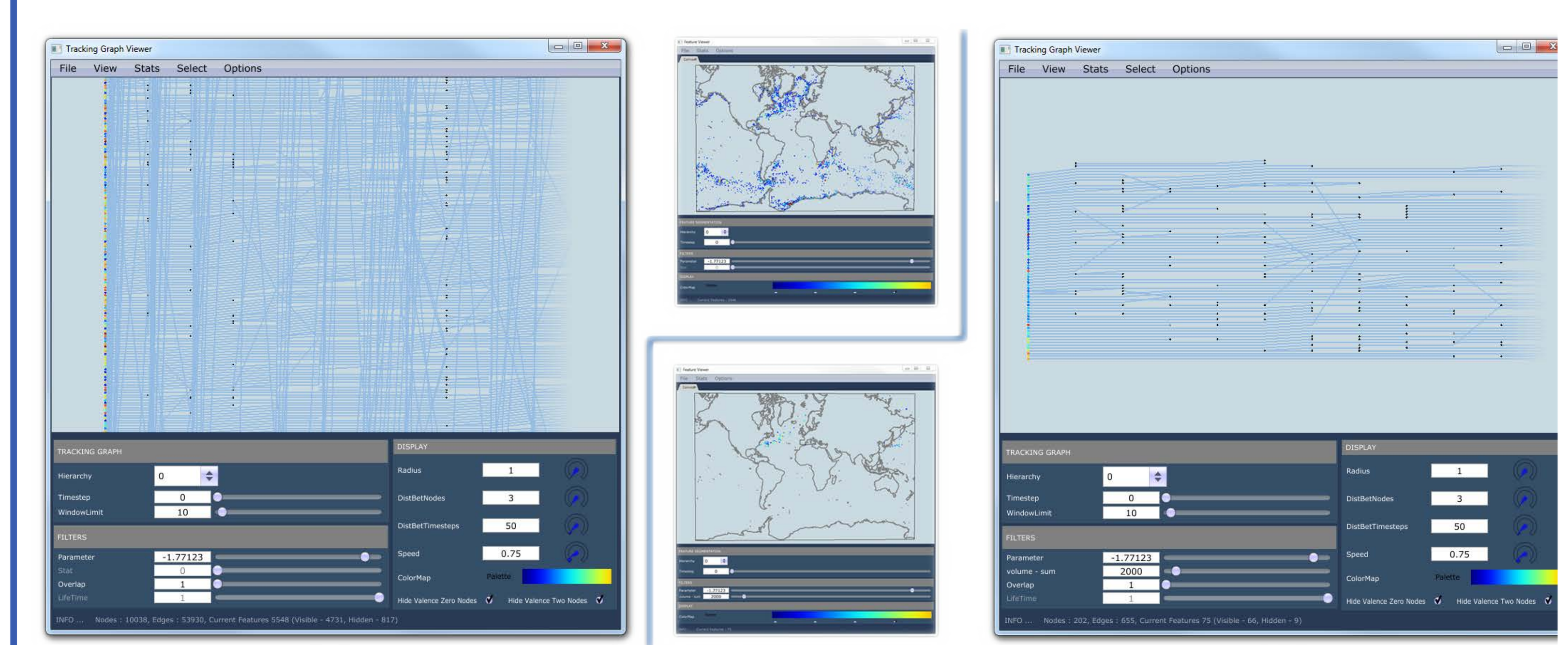
Exploring the Evolution of Extinction Regions in Turbulent Flames

Tracking graph of the first time steps of the extinction regions in a di-methyl ether flame. (Left) Original graph; (Middle) Sub-selection by feature size. (Right) Modified graph using adaptive threshold to produce cleaner tracks, easier to understand and analyze.

Interactive Exploration, Tracking and Analysis of Features in TALASS



Integrating the new capabilities into the TALASS environment developed by the SDAV center provides unprecedented freedom in interactively exploring, tracking and analyzing temporally evolving features. TALASS enables an interactive threshold selection computes and adjusts the tracking graph on-the-fly and provides the ability to select features based on size or spatial location.



TALASS provides a generic infrastructure that is easily extended and adapted to additional use cases. For example, one can provide custom renderings like this display of ocean eddies from a high resolution POP simulation performed at ORNL. Other examples are tracking of topics in twitter feeds and numerous combustion studies.