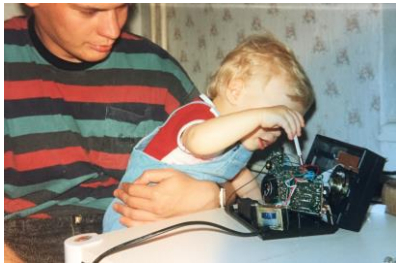
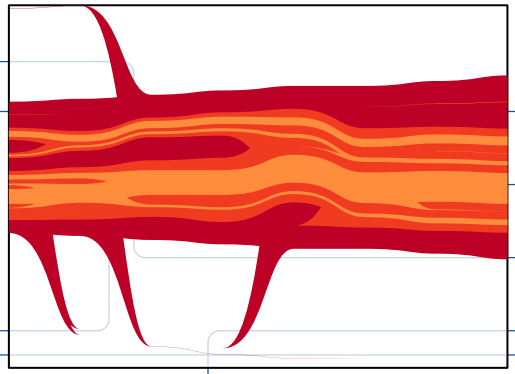
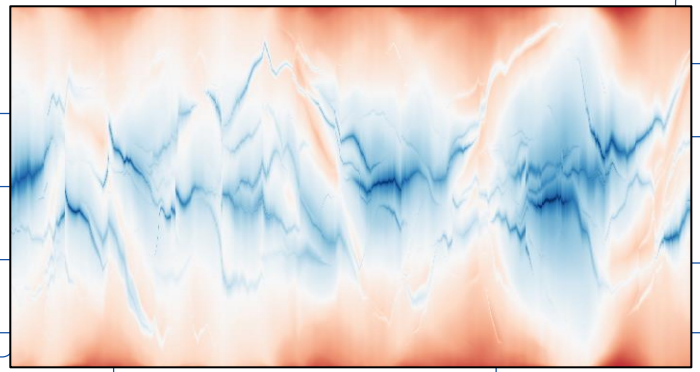
Visualizing Topology-Based Summaries of Flow Simulation Data

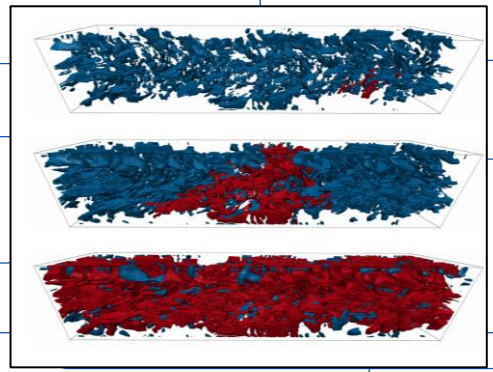


Wiebke Köpp

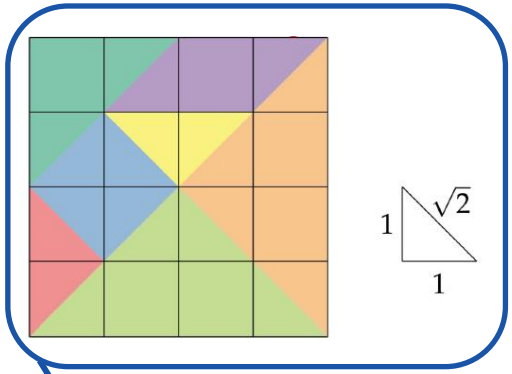
Advanced Light Source Interview, May 2022

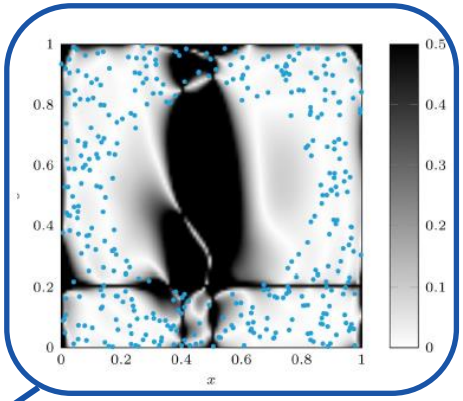






Background





BSc TU Munich

MSc TUM

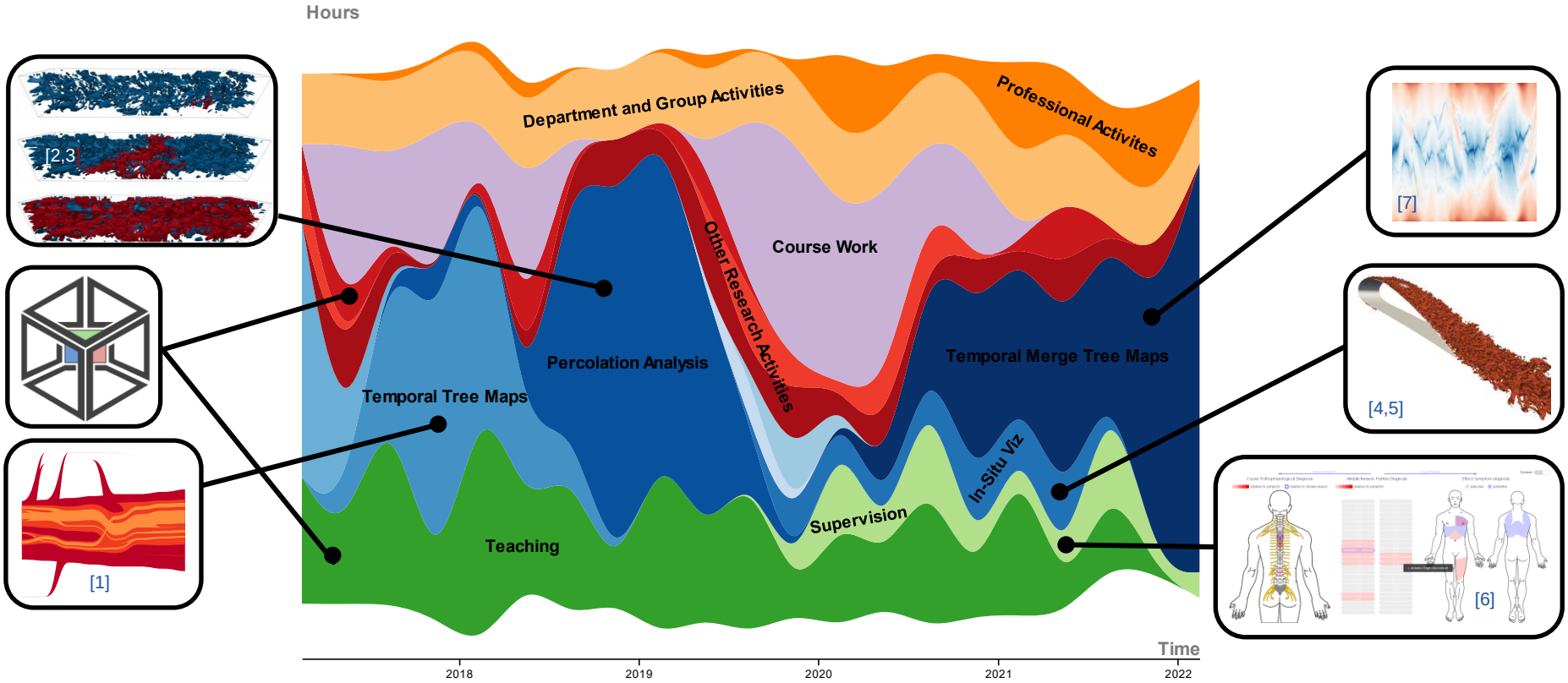
MSc KTH

PhD KTH Stockholm

Biomimetic Robotics and Machine Learning

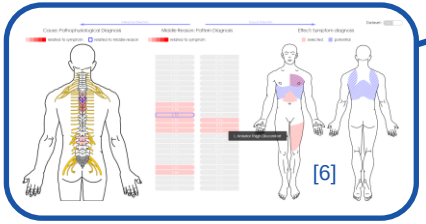
2009 2012 2015 2018 2021

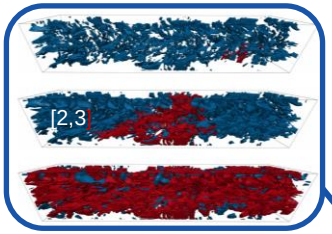
Background / Hats in the past five years



Causality

Hedvig Kjellström
Ruibo Tu
Yuwen Hu





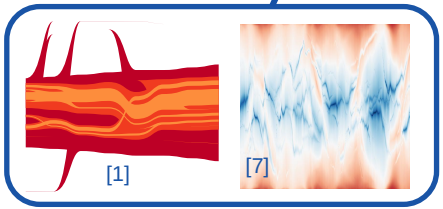
Fluid Mechanics Simulations

Philipp Schlatter
Ricardo Vinuesa
Adam Peplinski
Marco Atzori
Fermin Mallor Franco
Daniele Massaro

Wiebke Köpp

Climate Simulations

Gunilla Svensson
Rodrigo Caballero
Jakob Beran
Hamish Struthers



Visualization

Tino Weinkauf
Ingrid Hotz
Anke Friederici
Michael Ankele
Jiahui Liu
Peter Steneteg
Martin Falk
Daniel Jönsson

Inviwo

High-Performance Computing

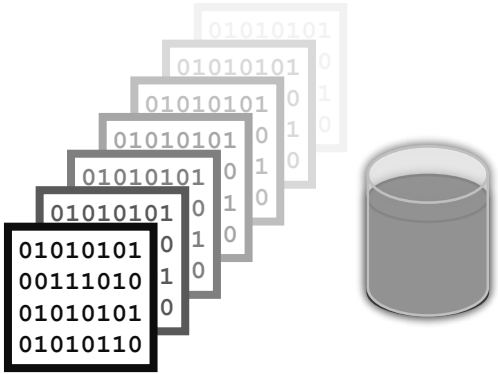
Erwin Laure
Stefano Markidis
Niclas Jansson
Mohamad Rezaei
Steven Wei der Chien

Flow and Climate Simulations

current barriers to progress

Data Size

overwhelms storage systems



Data Complexity

overwhelms analysis tools

Simulation

data too large to save in full resolution

Feature Extraction

in-situ

versatile framework for defining features

notion of feature strength

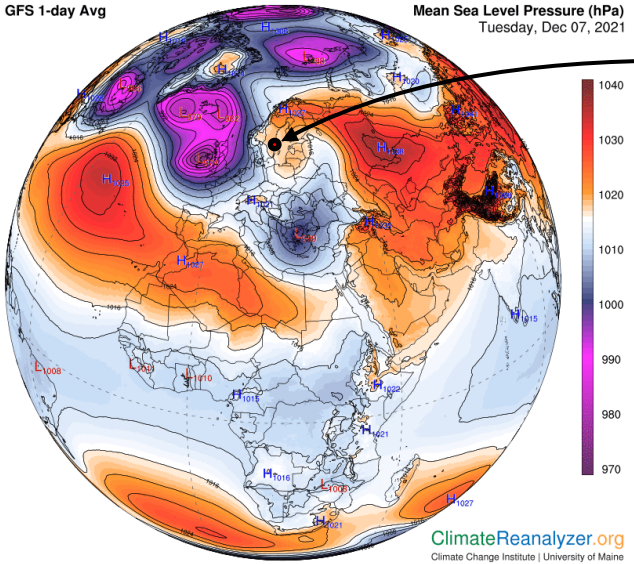
track over time

Interactive Visualization

filter
comparison
hypothesis generation & testing
presentation

Workflow to Insight

Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



I am currently here

Workflow to Insight

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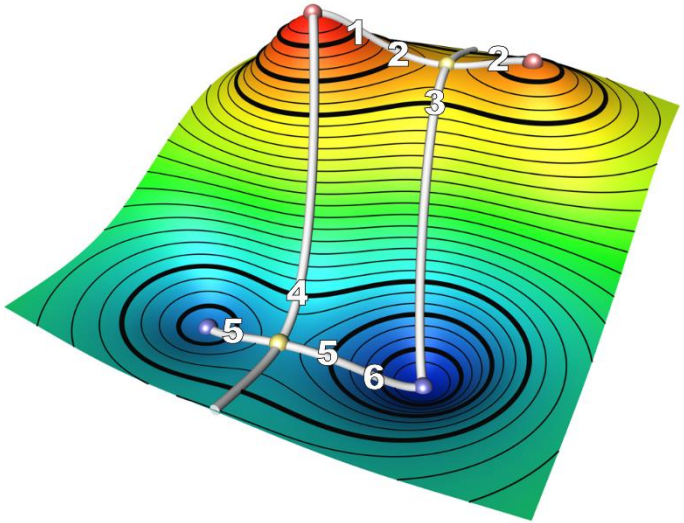
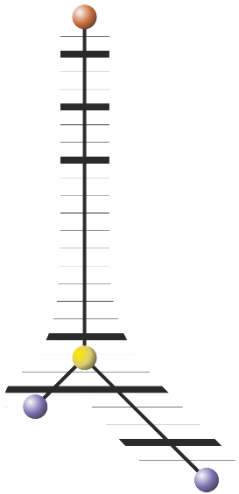
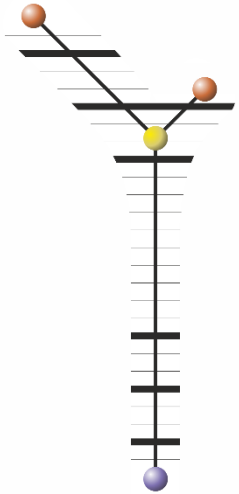


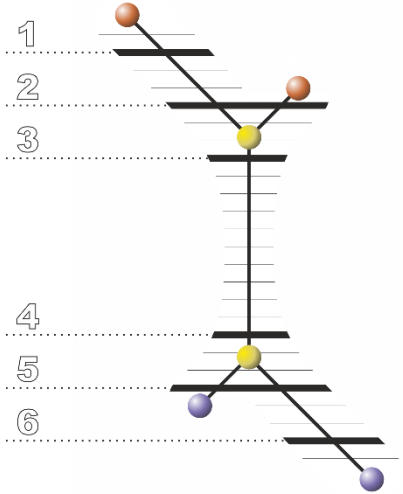
2D scalar field shown as terrain with isolines
Morse-Smale Complex



Split Tree
sub-level sets



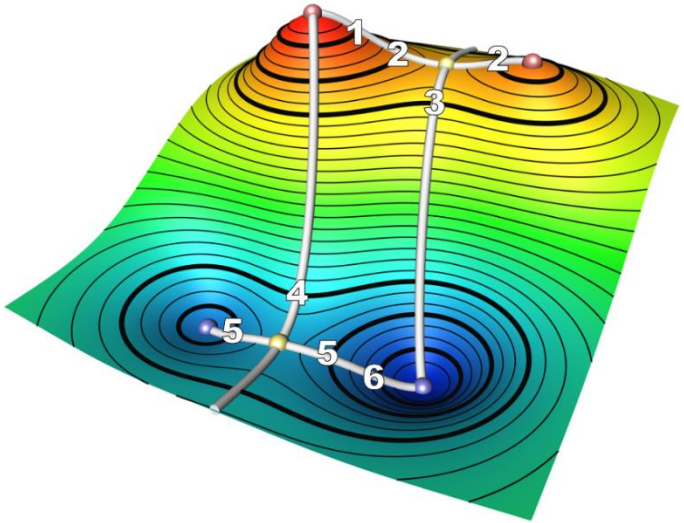
Join Tree
super-level sets



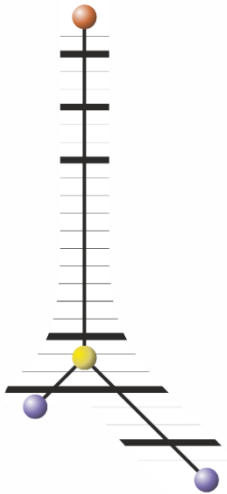
Contour Tree
encodes behavior of isocontours

Topological Summaries

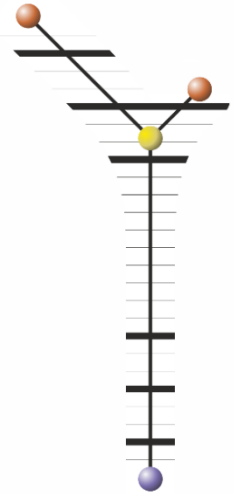
Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



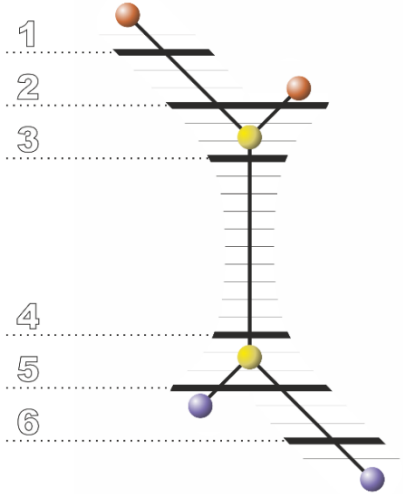
2D scalar field shown as terrain with isolines
Morse-Smale Complex



Split Tree
sub-level sets



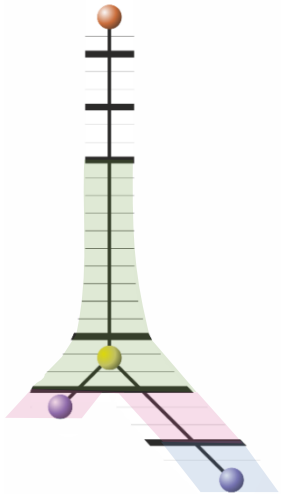
Join Tree
super-level sets



Contour Tree
encodes behavior of isocontours

Topological Summaries

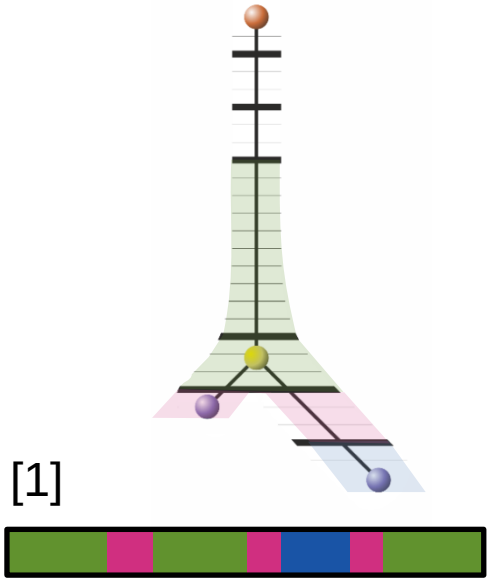
Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



[1]

Topological Summaries

Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



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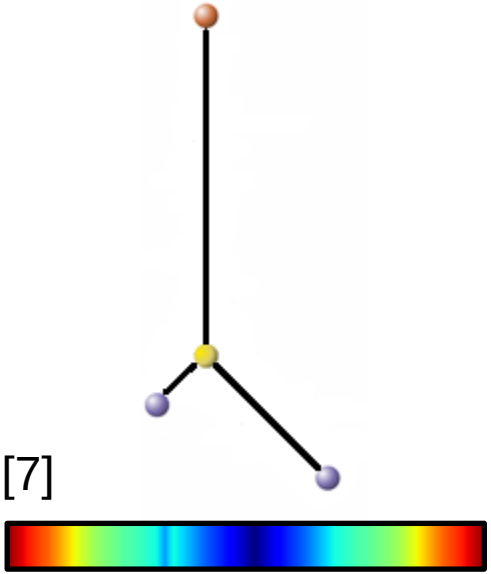

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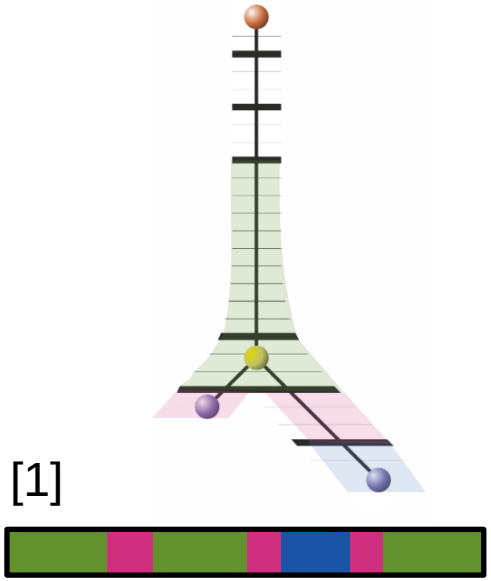
Topological Summaries

Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



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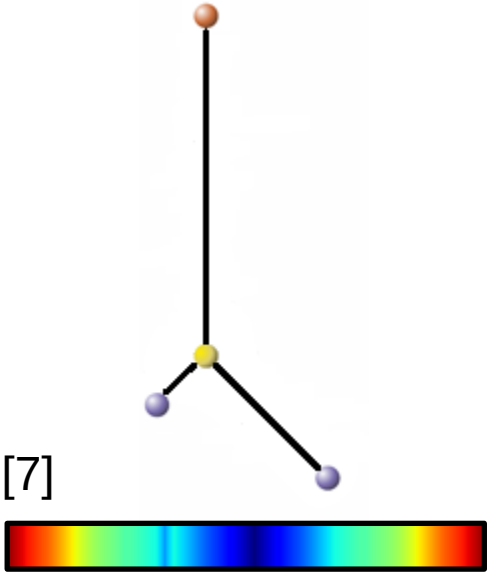

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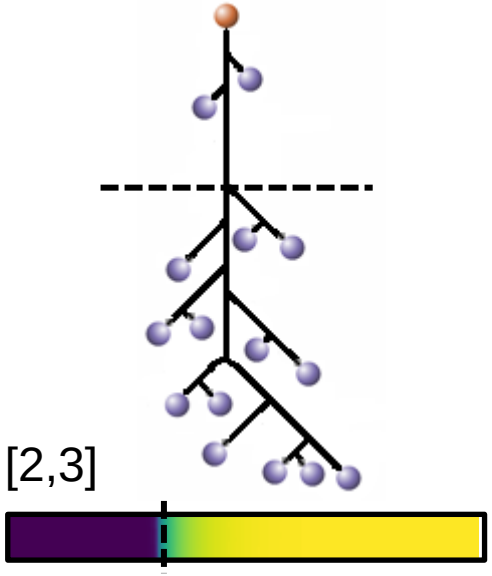
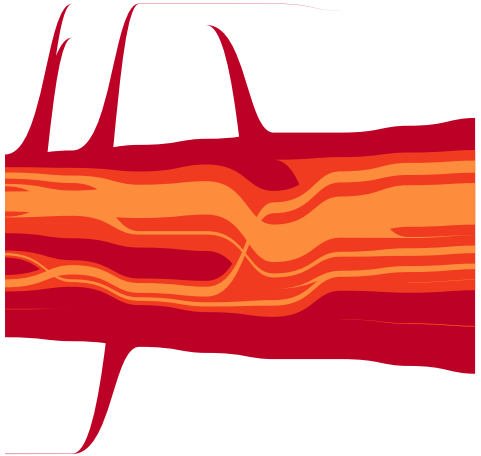


[2,3]

Topological Summaries

Feature Definition → Feature Extraction → Feature Correspondence → Visualization & Analysis



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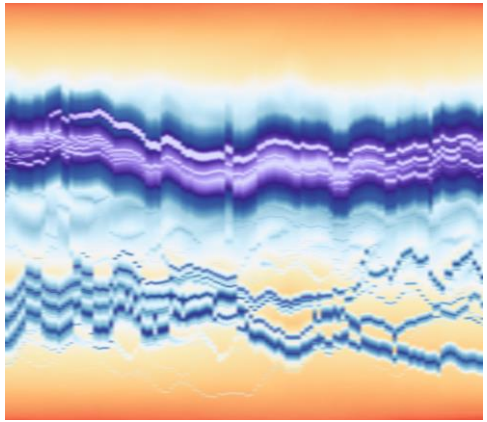

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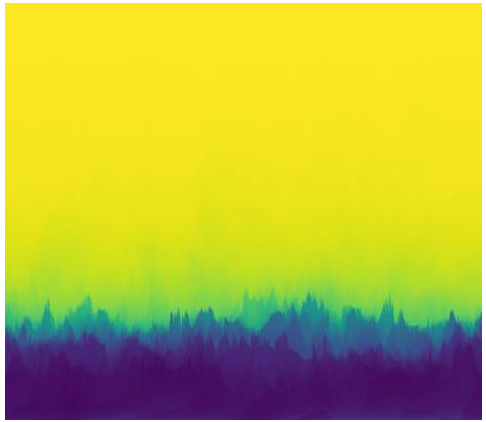
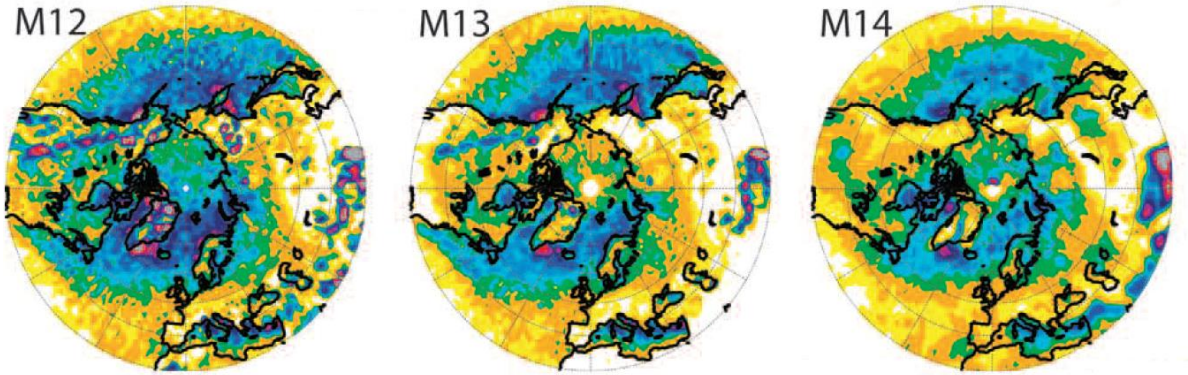
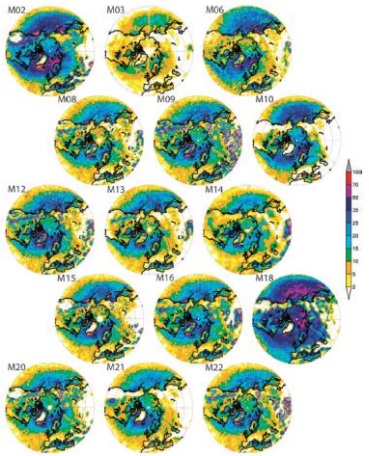


[2,3]

Motivation for Temporal Merge Tree Maps

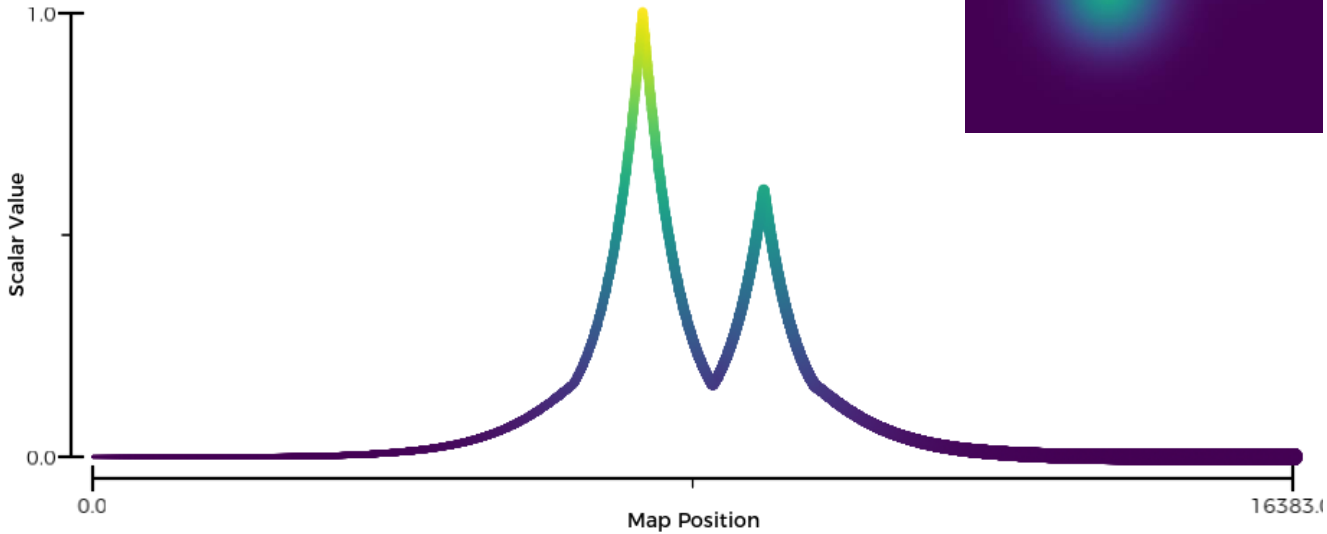
Feature Definition → Feature Extraction → <u>Feature Correspondence</u> → Visualization & Analysis

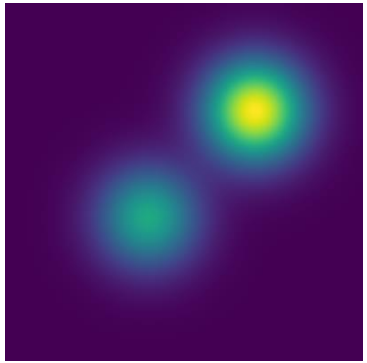




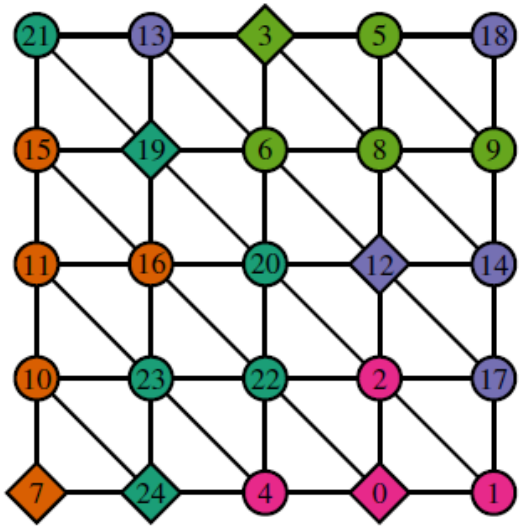
[Neu, Urs, et al. "IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms.“ B*ulletin of the American Meteorological Society* 94.4 (2013)]

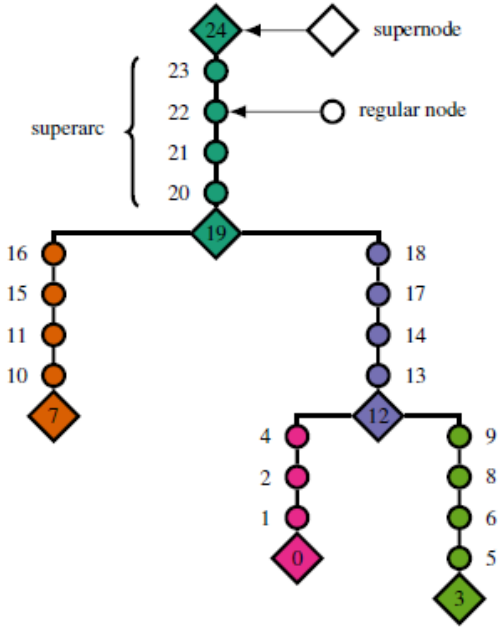
Temporal Merge Tree Maps



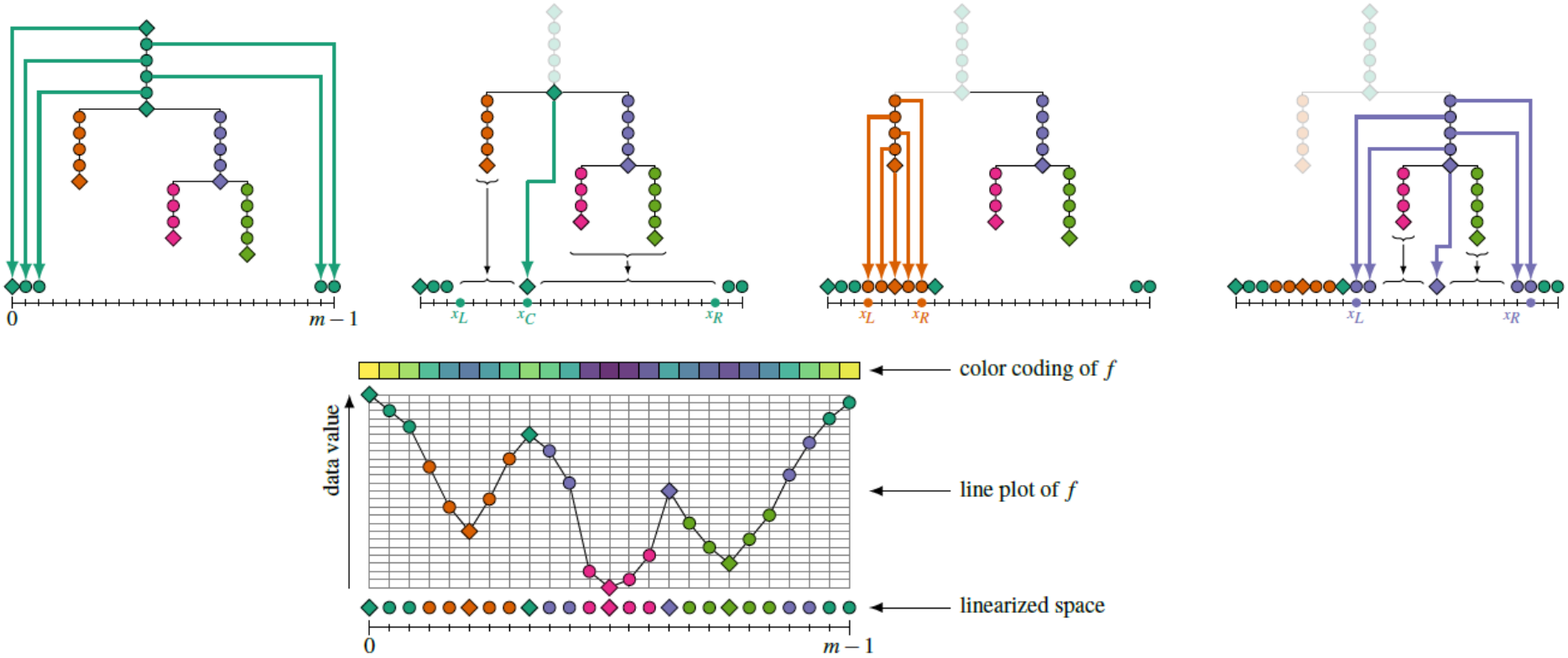


Temporal Merge Tree Maps: Method

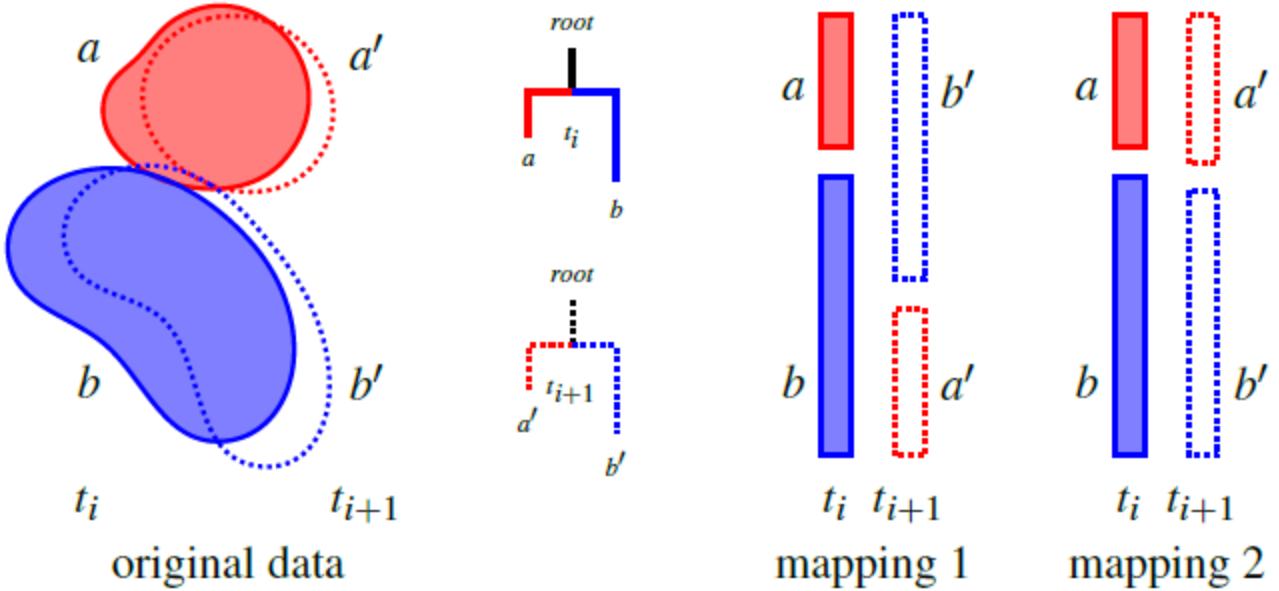




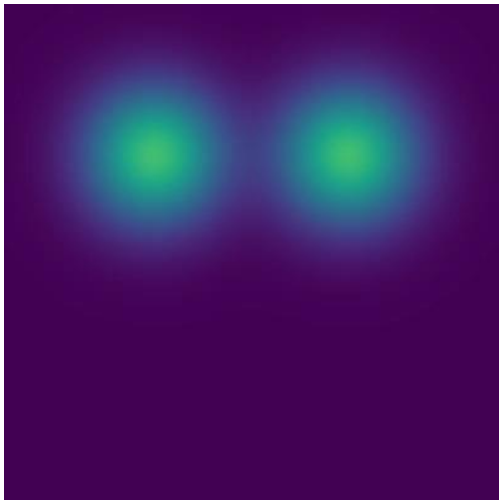
Temporal Merge Tree Maps: Method

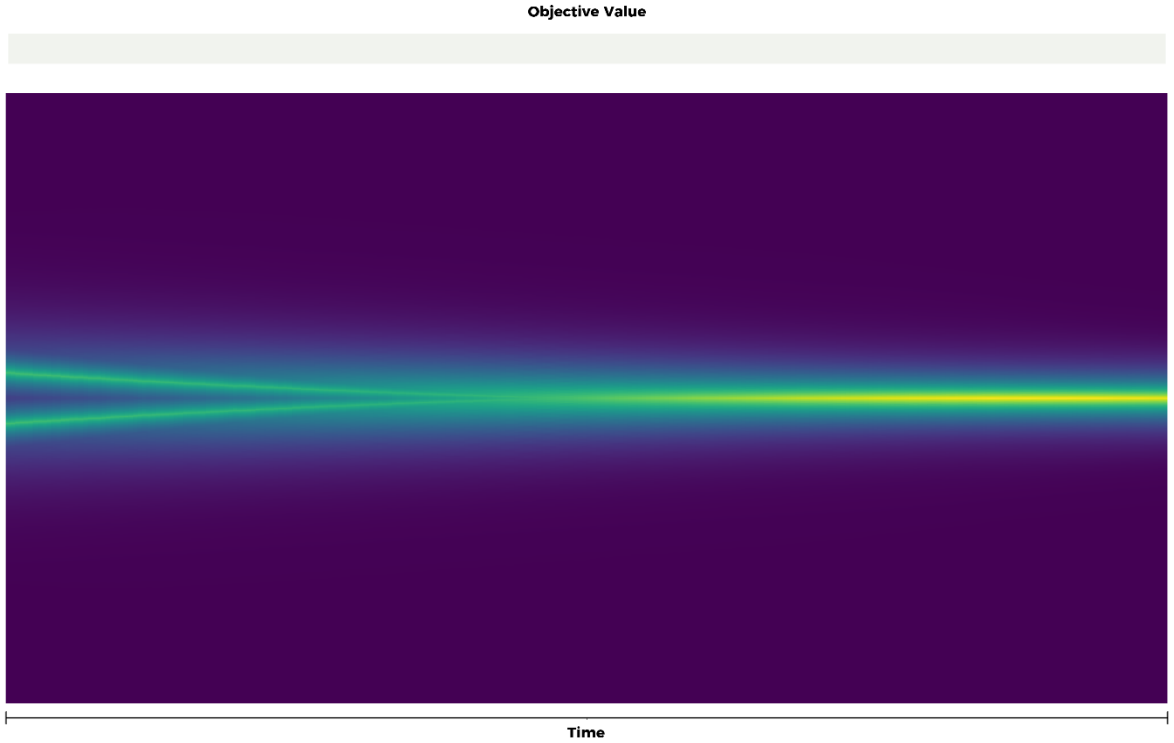


Temporal Merge Tree Maps: Method

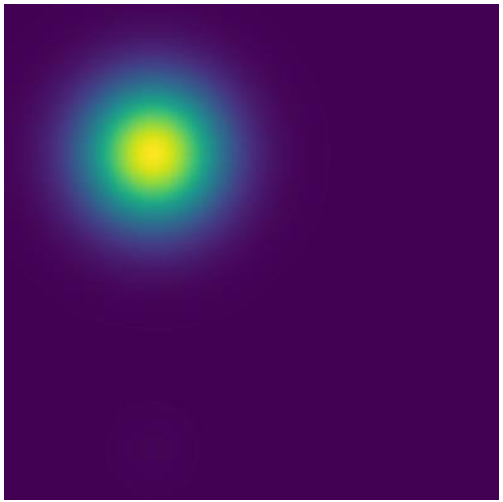


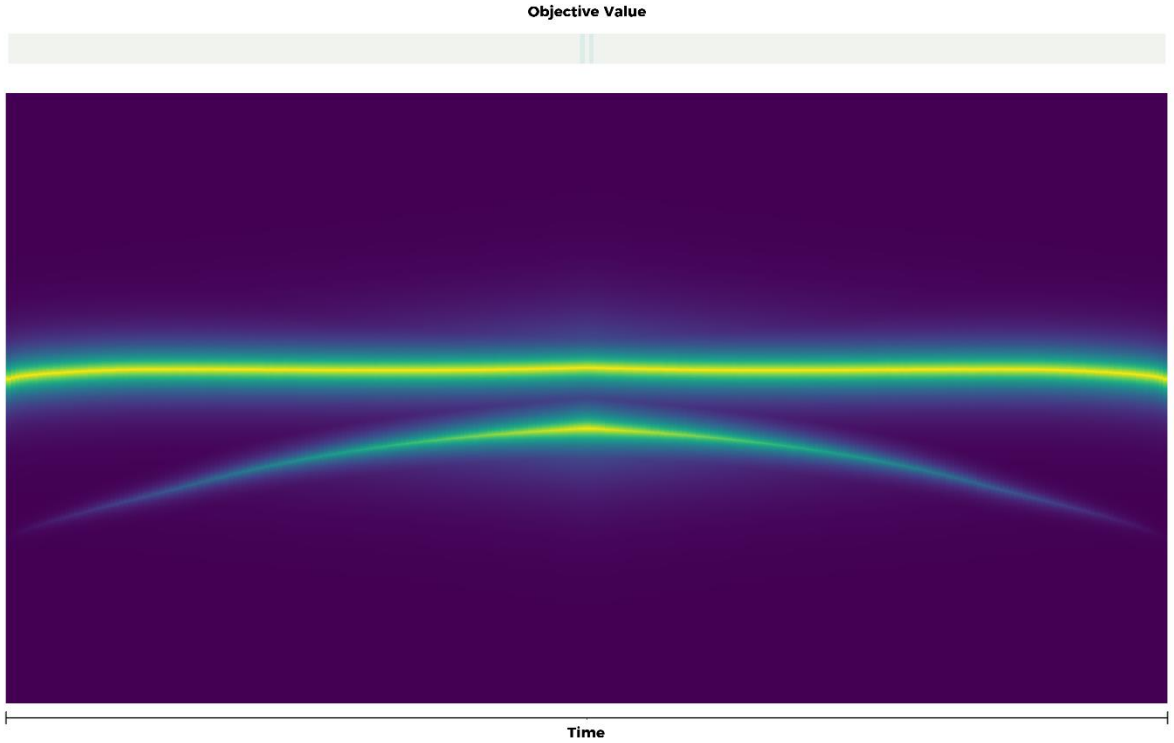
Example: Merge





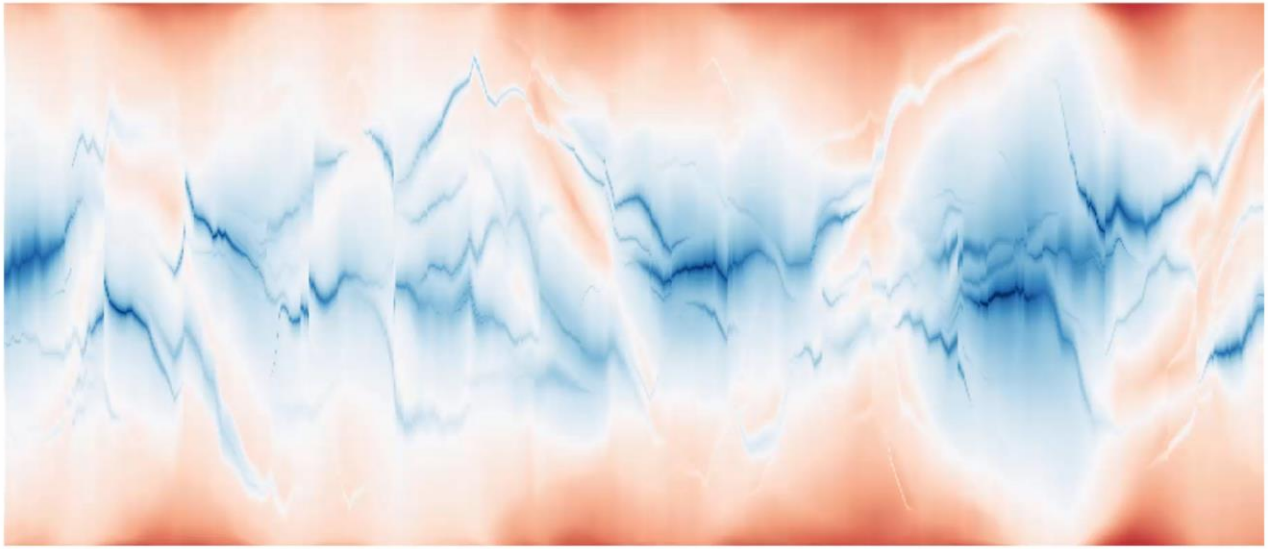
Example: Appear & Disappear



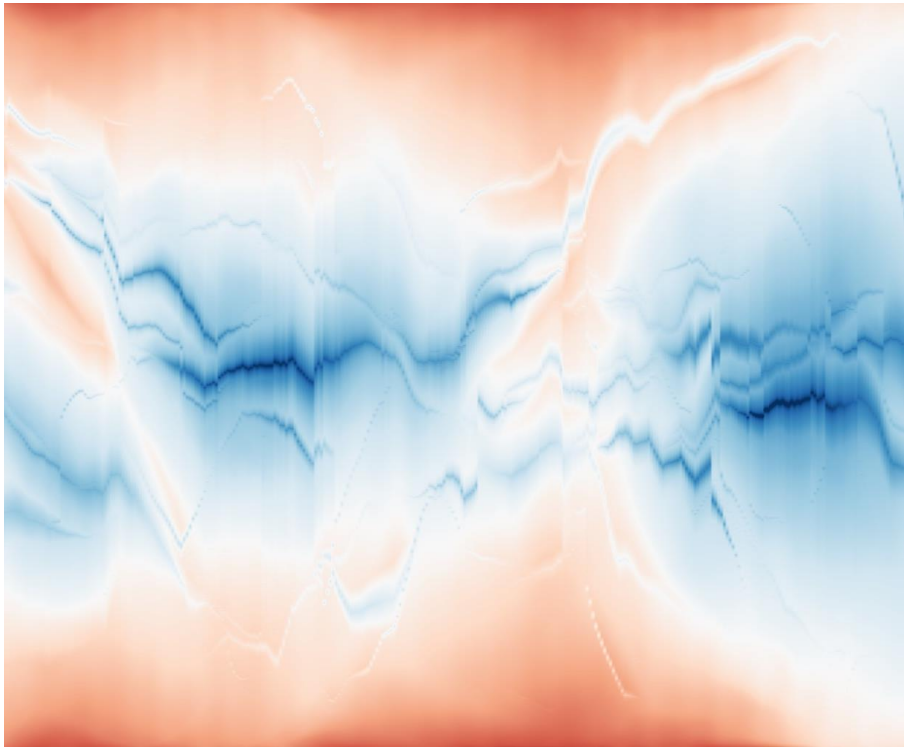


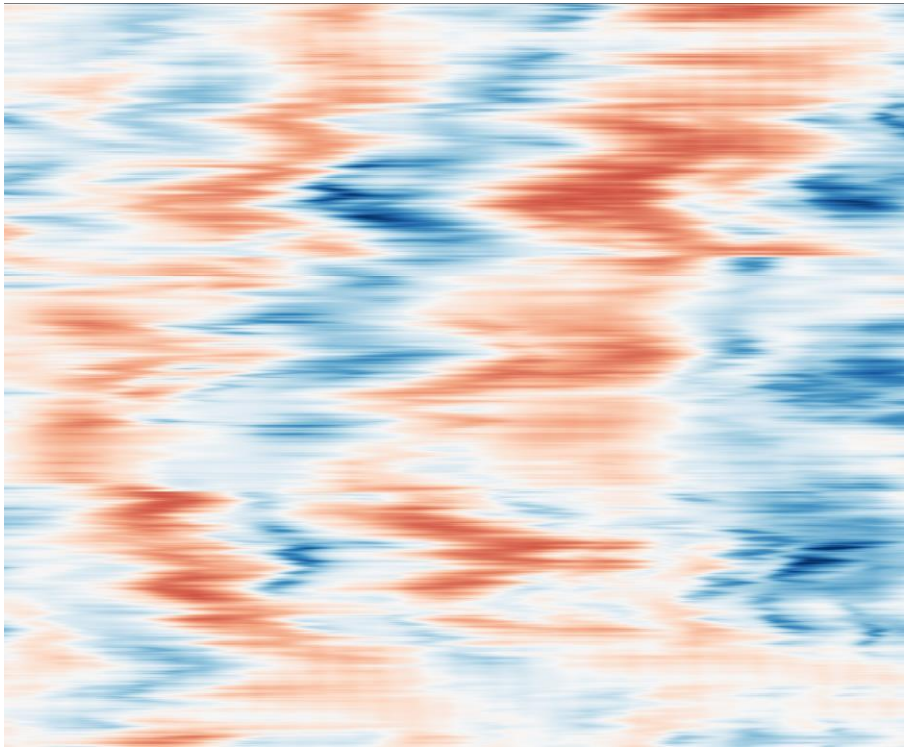
Example: Mean Sea Level Pressure Anomaly

Storms data set

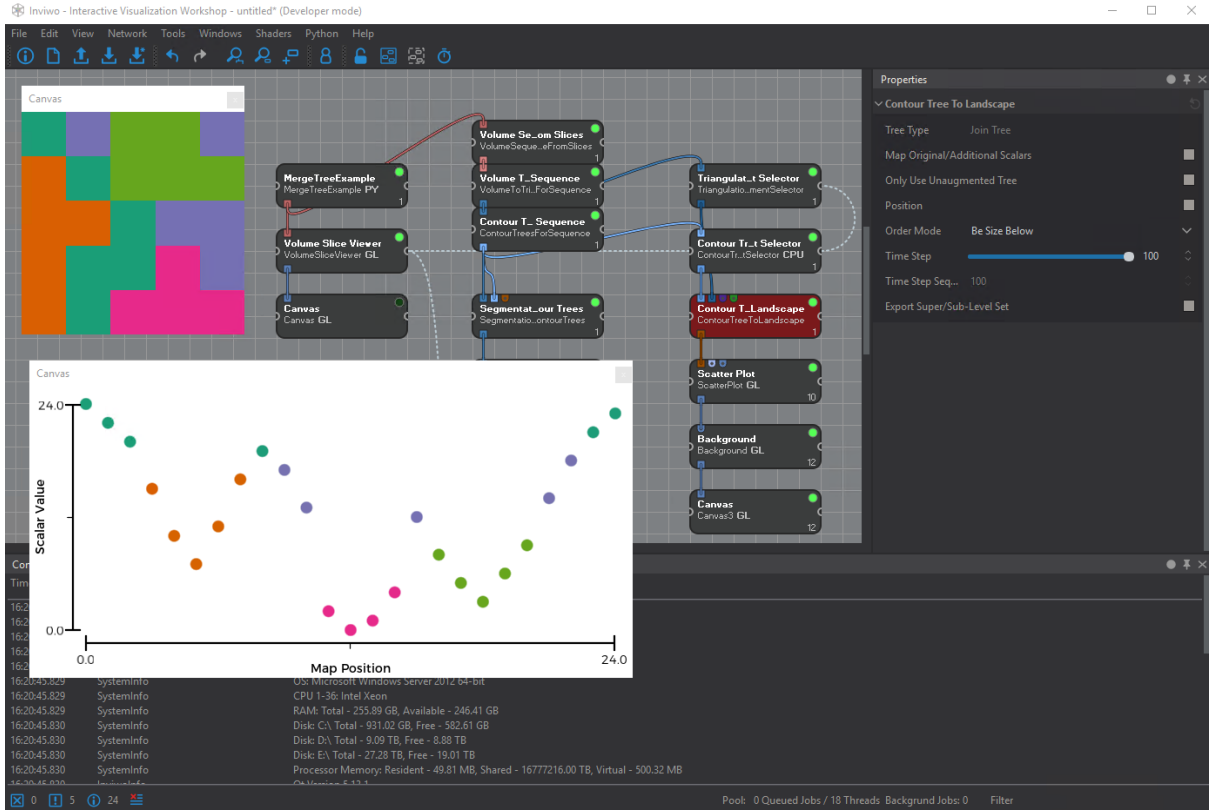


Comparison to other Linearization (Hilbert)



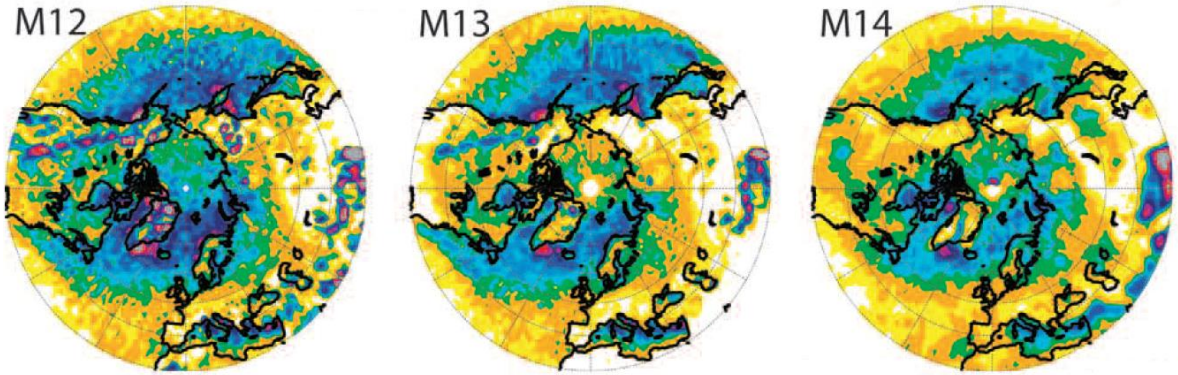


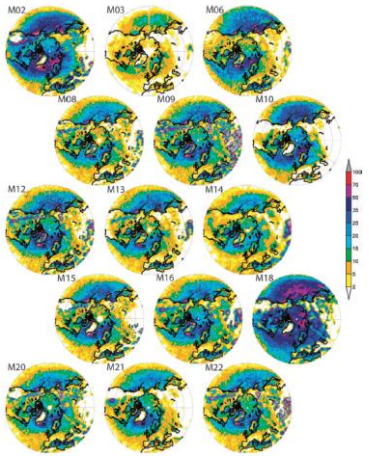
Software: Inviwo



Next step: Integrate Feature Tracking

Feature Definition → Feature Extraction → <u>Feature Correspondence</u> → Visualization & Analysis





[Neu, Urs, et al. "IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms.“ B*ulletin of the American Meteorological Society* 94.4 (2013)]

Visualizing Topology-Based Summaries of Flow Simulation Data

Wiebke Köpp

Advanced Light Source Interview, May 2022

[1] **W. Köpp**, T. Weinkauf. Temporal Treemaps: Static Visualization of Evolving Trees. IEEE Transactions on Visualization and Computer Graphics (Proc. IEEE VIS) 25(1), January 2019

[2] A. Friederici*, **W. Köpp***, M. Atzori, R. Vinuesa, P. Schlatter, and T. Weinkauf. Distributed Percolation Analysis for Turbulent Flows. 9th IEEE Symposium on Large Data Analysis and Visualization (LDAV), 2019. *Received a Best Paper Honorable Mention.*

[3] **W. Köpp***, A. Friederici*, M. Atzori, R. Vinuesa, P. Schlatter, and T. Weinkauf. Notes on Percolation Analysis of Sampled Scalar Fields. In Topology-Based Methods in Visualization (TopoInVis), 2019.

[4] **W. Köpp**, M. Atzori, M. Rezaei, N.Jansson, R. Vinuesa, E. Laure, P. Schlatter, and T. Weinkauf. Effects of Blowing and Suction on the Turbulent Flow around an Airfoil. 73rd Annual Meeting of the APS Division of Fluid Dynamics. Gallery of Fluid Motion 2020. DOI: 0.1103/APS.DFD.2020.GFM.V0058 *Received the Best Visualization Showcase @ PEARC 2021*

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