An Exploratory Framework for Cyclone Identification and Tracking

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Primary Goals

- Design of topological and geometric methods for cyclone identification and tracking.
- Design interactive query based visualization tools which enable meteorologist to conduct detailed visual analysis of cyclones.

Motivation

- Cyclones are large-scale, nonlinear, coherent structures that exist in planetary atmospheres.
- Cyclone understanding plays an important role in global weather forecasts.
- State of the art methods use domain specific knowledge for cyclone identification and tracking.

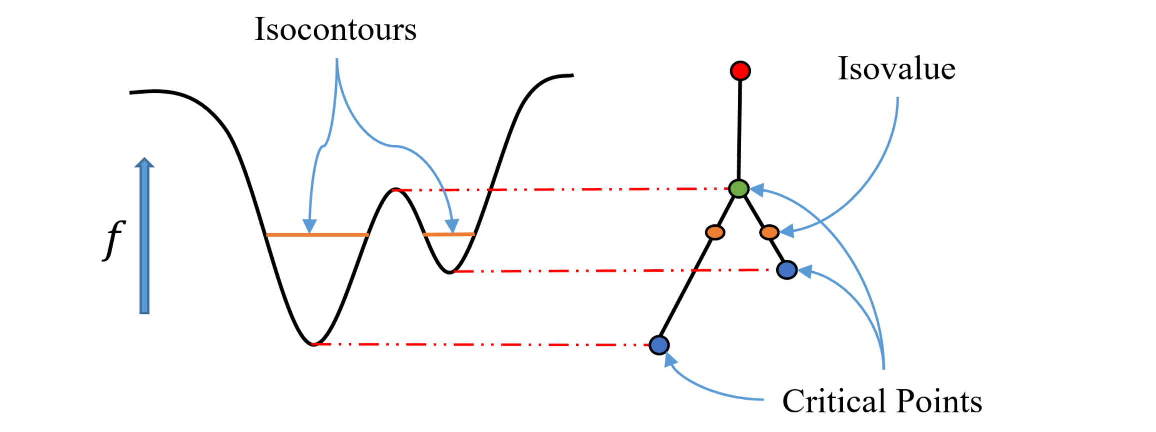
Challenges

- **Uncertainty:** Cyclones can consist of multiple depressions and have their own fuzzy border or structure.
- **Spatial & Temporal noise:** Removal of "not so deep" cyclones and short lived cyclones is important for analysis and visualization.
- **Visualization:** Presence of multiple features may lead to cluttered views.

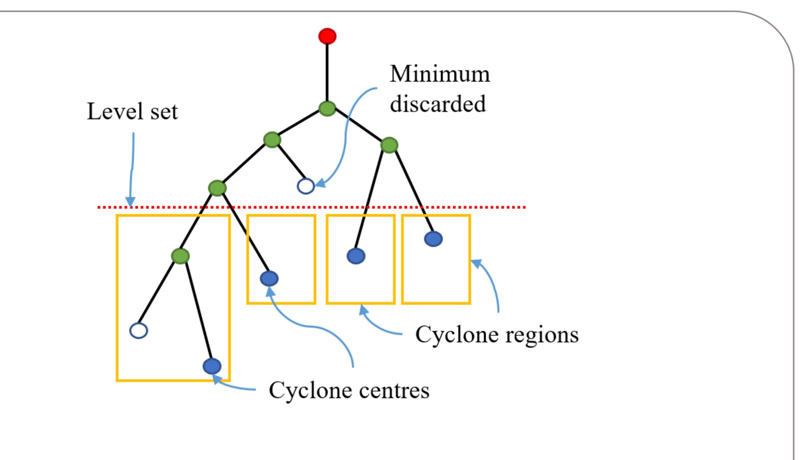
Definitions

- Scalar field: A function that maps a point in the domain to a real value.
- Critical point: A point where the gradient of the scalar field becomes zero.
- Level set: Given a real value c, a level set is the preimage of isovalue c.
- Sub-level set: Pre-image of the interval (-∞, c].
- Join tree: Abstract representation of the connectivity of sub-level sets of a scalar field.

Background



Join tree is an abstract representation of the connectivity of sub-level sets of a scalar field. Height function defined on a 2D domain (left) and the corresponding join tree (right).

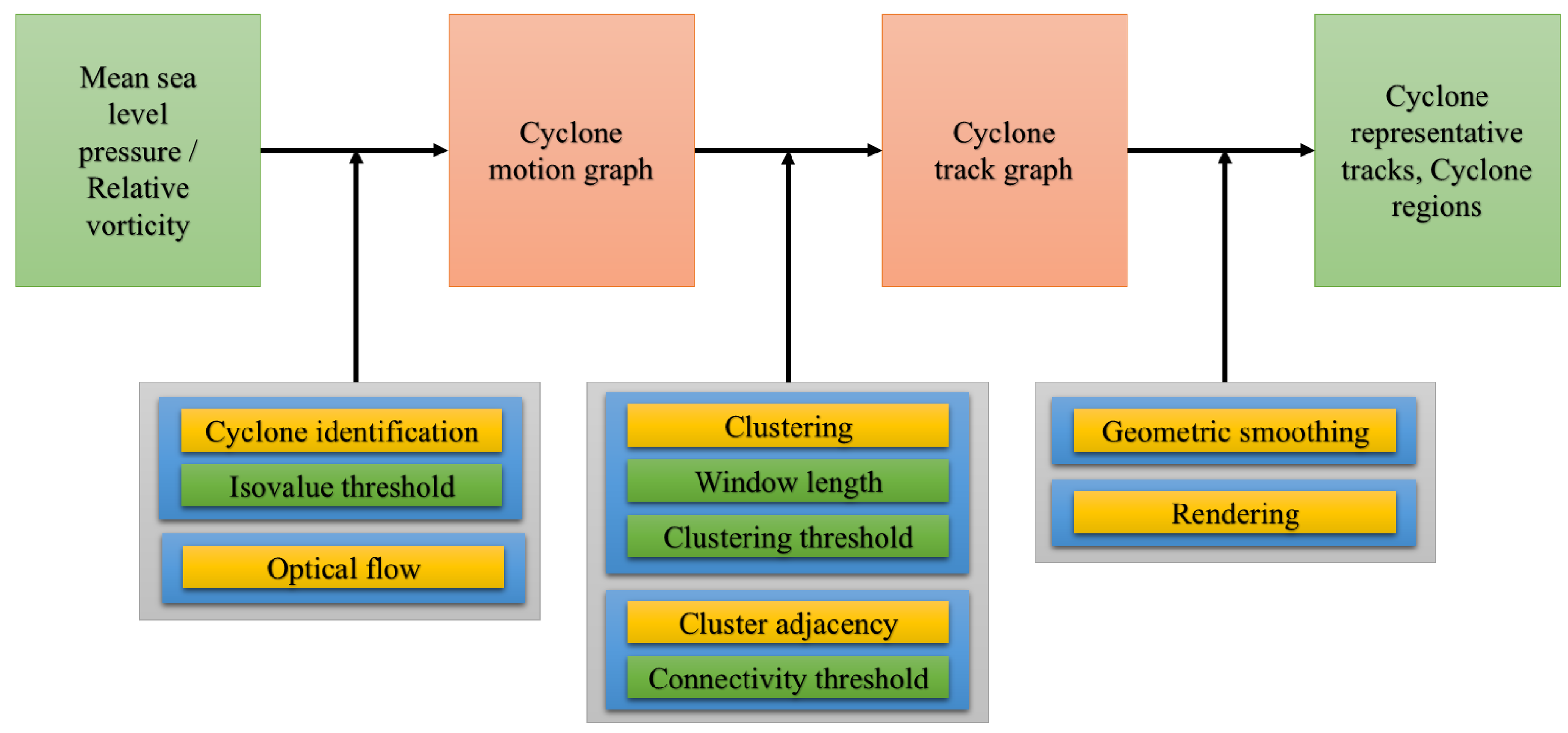


Each subtree below a chosen level set corresponds to a cyclone centre.

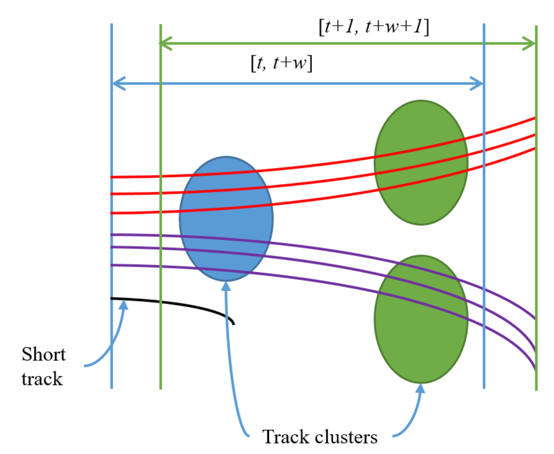
Algorithm

- **Cyclone Centres:**
  - Join/Split tree is computed per time frame.
  - Manually or statistically selected isovalue threshold is used to identify cyclonic regions.
- **Cyclone Motion Graph:**
  - Nodes correspond to cyclonic regions.
  - An edge exists between two nodes if the optical flow connects the corresponding cyclonic regions.
- **Cyclone Track Graph:**
  - Raw tracks are computed from the cyclone motion graph within a fixed time window & clustered together.
  - A Node corresponds to a cluster.
  - Two nodes are connected by an edge if corresponding clusters contain a common track.
- **Representative Tracks:**
  - A path in cyclone track graph is termed as a representative track.
  - Displayed as a Bspline curve. Nodes on the representative track are the control points of the curve.
- **Parameters:**
  - Isovalue Threshold: Analytically or manually given as user input to identify cyclonic regions.
  - Window length: Helps in eliminating temporal noise by ensuring minimum cyclone track size.
  - Clustering Threshold: Analytically determined to cluster the cyclone tracks from same window.

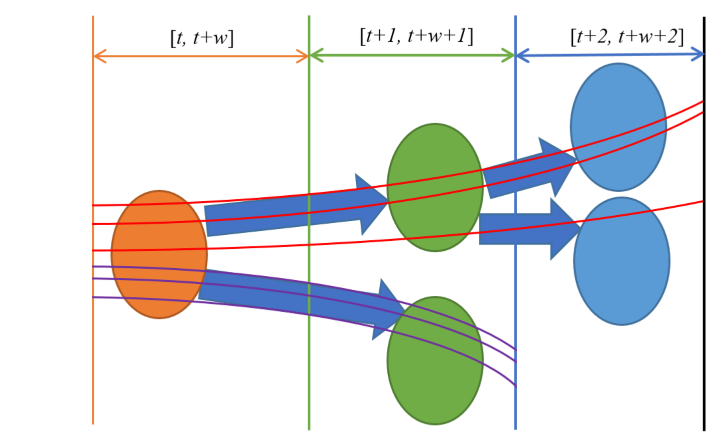
Workflow



Cyclone identification and tracking workflow. Blocks in yellow indicate computations required to construct the intermediate graphs and tracks.



Clustering tracks within a moving time window.

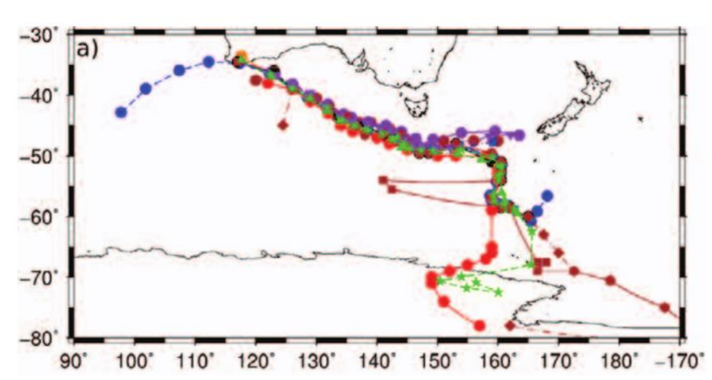


An edges is inserted into the cyclone track graph if at least one raw track pass from one node to another in the next time window.

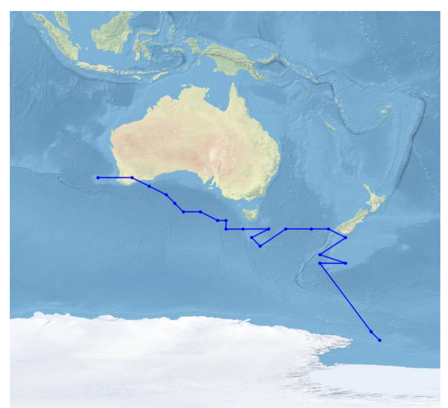
Experimental Results

- **Contributions:**
  - Identification of cyclonic regions using a spatio-temporal approach combining topology, optical flow and clustering. The isovalue threshold is analytically determined and/or taken an user input as part of the exploration framework.
  - Computing representative tracks per cyclone resulting in a clutter free visualization.
  - Supporting query based user interaction based on cyclone motion and cyclone tracking graph.
  - Generic framework for extrema tracking with a small number of intuitive parameters.
- **Evaluation:**
  - Case studies that demonstrate the applicability of the method to well known cyclonic phenomenon.
  - Comparison with IMILAST [U. Neu et al.] case studies.
- **Future work:**
  - Usage of physically motivated filtering methods based on area of cyclones and spherical geometry of domain.
  - Scale to data that spans multiple years.

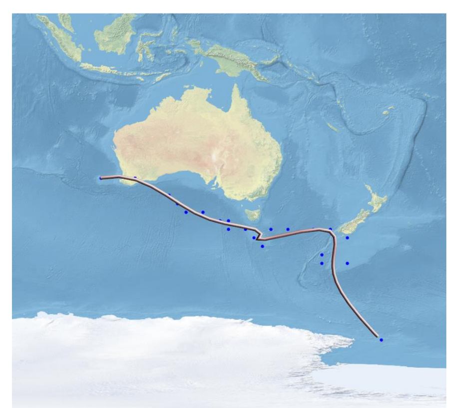
Use Case



Track comparison near Australian Bight due to a southern hemisphere storm (unnamed; 22-29 May 1994).

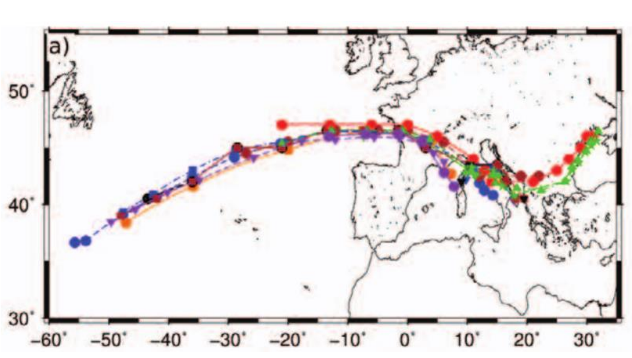


A representative track obtained from our framework



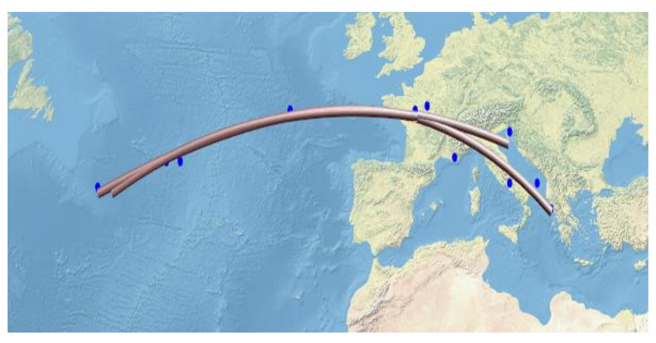
A representative track obtained after geometric smoothing

Use Case



Track comparison in northern hemisphere due to storm Klaus on 22-27 January 2009.

A representative track obtained from our framework



A representative track obtained after geometric smoothing

Acknowledgements

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References

- U. Neu et al., IMILAST Bulletin of the American Meteorological Society, vol. 94, no. 4, pp. 529–547, 2013.
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