A novel identification and tracking method of weather-relevant 3D Potential vorticity streamers

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Project overview

• In low predictability regimes, NWPs can be amended by **statistical analyses**
• Here: Identify and parametrize PV streamers in **3D**
• Shape and structure of PV streamers could be a useful **predictor** for high impact weather events
• Three-dimensional descriptions and visualizations could give us **more insight** into the evolution of PV anomalies

In the following slides,
• we outline the novel PV streamer detection algorithm for 2D datasets,
• then expand it to its 3D functionality,
• and finally we evaluate how this information can be used.

From Maier-Gerber et al. (2019). Upper-level PV (colors) and MSLP (contours) in the context of the tropical transition of Hurricane Chris (2012). The evolution of the PV streamer played an important role in this case study.
PV Streamer Identification

• Most existing techniques regarding PV streamer identification
  • can only be applied to individual 2D isentropic levels,
  • do not fully look at the 3D shape of PV disturbances, missing out on specific features, and
  • require different parametrizations for different seasons.
• We want to introduce a novel technique which can be applied to both 2D and 3D datasets.
• A search along the 2 PVU contour (see existing techniques) is not feasible in the 3D case.

From Wernli and Sprenger (2007). Their widely used PV streamer identification strategy is based on thresholds for maximum width of a streamer and minimum length along the 2 PVU contour.

From Papin et al. (2020). Their new PV streamer identification strategy is based on finding points of poleward gradient reversal along the 2 PVU contour as entry starting point of a streamer.
Novel 2D PV Streamer Identification (1)

Input:
- Isentropic field of PV data
- Parameter $w$ (maximum width of streamers)

Step 1:
- Transform data into stereographic projection (separately for each hemisphere)
- Here only shown for the northern hemisphere
- Compute stratospheric air mass based on the **2 PVU threshold**
  \[
  1\text{PVU} \equiv 10^{-6} K \text{kg}^{-1} \text{m}^2 \text{s}^{-1}
  \]
Novel 2D PV Streamer Identification (2)

Step 2:

- Remove $\frac{w}{2}$ km along the edge of the stratospheric air mass (2 PVU boundary),
  - using **signed distance functions**, based on precomputations of pixel-wise distances in this projection
  - taking distortions into account

- Previous techniques walking along contours do not look at the complete boundary
- This forms the „inner PV reservoir“ (red area)
Novel 2D PV Streamer Identification (3)

Step 3:

• Add $\frac{w}{2}$ km along the edge of the inner PV reservoir:
  • This operation mostly represents the inverse to Step 2, but does not reconstruct all areas

• This forms the reconstructed “smoothed“ reservoir

• Areas thinner than $w$ are detected as disturbances in the field and are **not reconstructed** (gray areas)
Novel 2D PV Streamer Identification (4)

Step 4:
- Extract areas not being reconstructed in Step 3
- Label these by cohesiveness
- By design, these areas have a maximum width of $w$ (input parameter)

Finally…
- Postprocessing, filtering based on use case (latitude based, height based…)
- Transformation into projection suitable for data storage and data analysis
Novel 3D PV Streamer Identification

The basic idea of the algorithm (especially the image processing operations in Step 2 and Step 3) is not exclusive to 2D datasets.

→ Algorithm can be expanded to work on 3D datasets as well with some adjustments.

• Use isentropic levels in vertical dimension
• Vertical „stretch factor“ based on scale analysis to achieve better results

Novel 3D PV Streamer Identification

Advantages compared to previous work:

- **New perspective** and insight into the evolution and life-cycle of PV disturbances
- Visual interpretation
- Detects more “interesting“ features since it uses more information about vertical cohesiveness
- Independent on **seasonal cycle**
- Due to preprocessing and fast operations computationally quite effective

Detected PV streamer, takes in this case the form of a „stalagmite“

Reconstructed reservoir, c.f. Step 3 in 2D case
Feature Descriptions

• Compute a set of parameters (feature vector) for each detected streamer
• This includes information about intensity, position, track, age and so on

Planned next:
• Use feature vectors as base…
  • for explorative analysis (What features are interesting?)
  • to create climatologies
  • to explore correlations with extreme weather events, e.g. Tropical Cyclones, heavy rainfall…

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  ...
}
Sources


