

Intercomparison Study of Cloud Feature Extraction and Tracking Algorithms

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Motivation

Tracking in General

- long history in research (especially video processing)
- requires object **extraction** and **tracking** step
 - related topics: registration, mapping, (similarity) matching

Cloud Tracking Challenges

- clouds: complex morphology and dynamics,
- no standard extraction procedure
- variety of generating effects
 - (e.g., convection, land interaction, waves...)
- rich source of target modalities
 - (e.g., satellite, radar, simulation)
- various application scenarios
 - different focus aspects and evaluation

Contents

Tracking Comparison – Target Contributions

1. **Collection of cloud object tracking algorithms**
2. **Benchmark data sets**
3. **Standardized output definitions**
4. **Joint statistical evaluation of output**
5. **Web-based access to data sets, evaluation & results**

Cloud Tracking Comparison

1. Collection of Cloud Tracking Algorithms

- Provide overview of approaches → *Appendix*
example: comparison study for storm tracks IMILAST [Neu2013]
- Designed for different modalities and scenarios,
→ fundamental differences in methodology

Current Study Participants:

1. Dixon et al. [Dixon1993, Han2009] → TITAN tracker
2. Skok et al. [Skok2009, Skok2010] → Object-based evaluation (MODE)
3. Trömel and Simmer [Troemel2012] → Mean-shift algorithm (Meanie3D)
4. Heus and Seifert [Heus2013] → Space-time region growing
5. Moseley et al. [Moseley2013] → Iterative Cell Tracking (IRT)
6. Kuhn et al. [Kuhn2014] → Topology-based contour tracking

Cloud Tracking Comparison

1. Cloud Tracking Algorithms - Comparison

- no direct qualitative evaluation
- fundamentally different characteristics
 - (e.g. object extraction & correspondence analysis, split & merge events)
- often algorithms are developed in specific context
 - (e.g. for specific data sources, dimensions)

Comparison Study Goals

- provide *relative* comparison
 - monitor variability of algorithms
- identify *classes* of algorithms
- discuss strengths & weaknesses
 - (e.g. performance, statistical variance, robustness, parameter setup)
- provide basis for future developments
 - (e.g. extensions, improvements, parameter setups)

Cloud Tracking Comparison

2. Benchmark Data Sets

- selection of prototypic data sets
- capture prominent application scenarios
(i.e. temporal / spatial resolution, cloud types, modalities)

Current Data Sets

1. 2D UCLA -LES simulation [Heus2013]

- RICO setup, averaged from 3D simulation
- domain: 25km x 25km at 25m, 40 hours at 60s
- target field: liquid water path (LWP)
→ detailed evolution of cloud life cycle

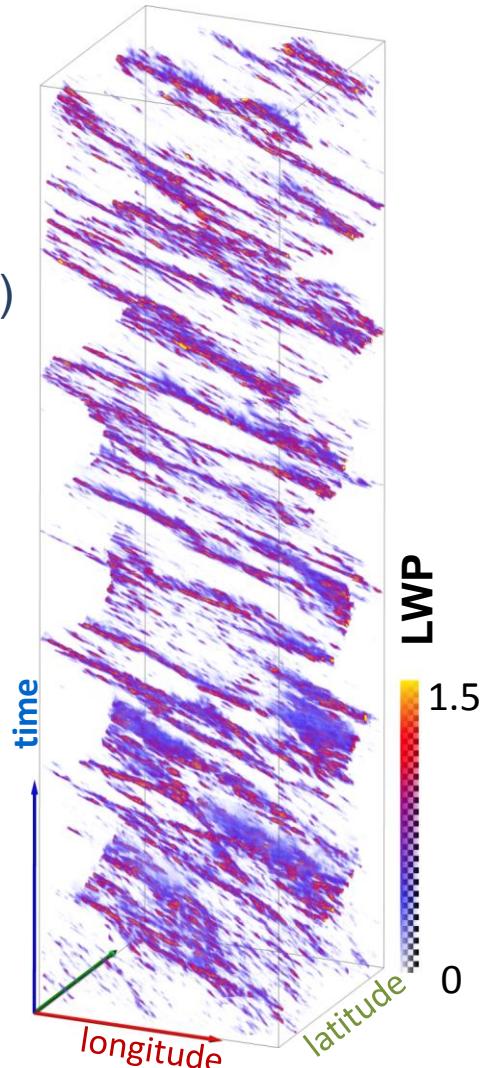


Fig.1: Dataset 1 in space-time

Cloud Tracking Comparison

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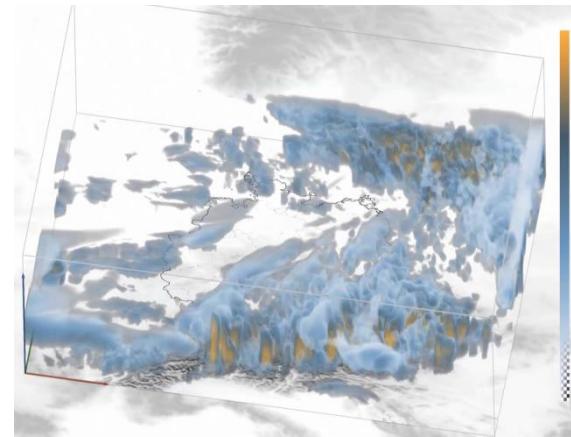


Fig.2: 3D Rendering Dataset 2

2. 3D Pseudo-Reflectivities [Simon2013]

- Forward operator output for 22.06.2011 (based on COSMO-DE)
- domain: ~900km x 900km (Germany) at 1km, 24 hours at 5min
→ limited region with specific features (e.g. rain front)

Cloud Tracking Comparison

2. Benchmark Data Sets – 3D Radar Forward-Operator

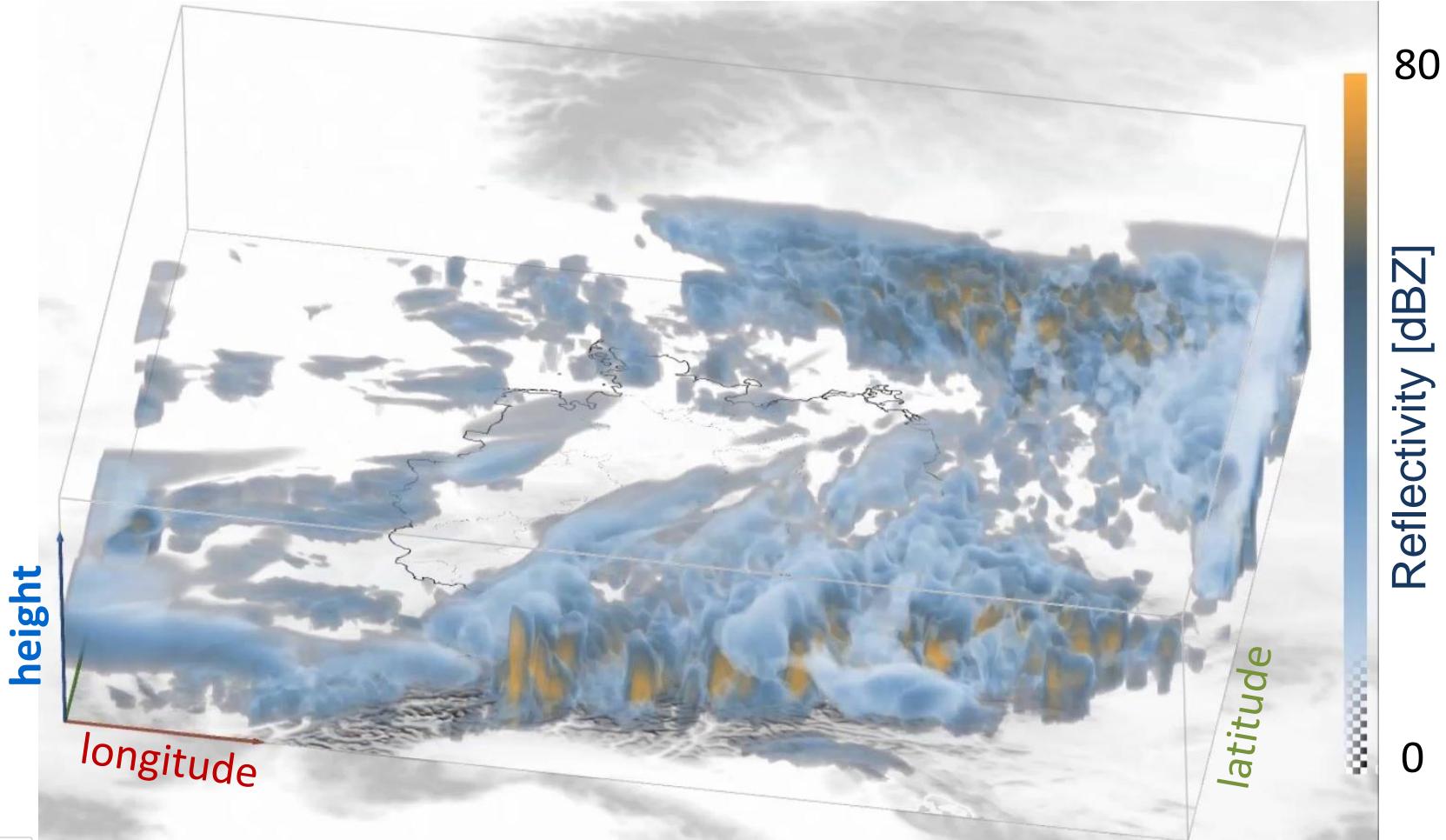


Figure 2: 3D rendering of radar reflectivity around 16:00

Cloud Tracking Comparison

3. Standardized Output

- goal: minimal set of tracking data
- provided as ASCII tables
- stored in two separate tables

1. Object Table → per time-step data

- object ID
- bounding box (2D, 3D)
- target value characteristics
(i.e., min, max, mean)

2. Linking Table → tracking information

- object ID1, object ID2
→ connectivity of tracked objects
- represent split and merge events

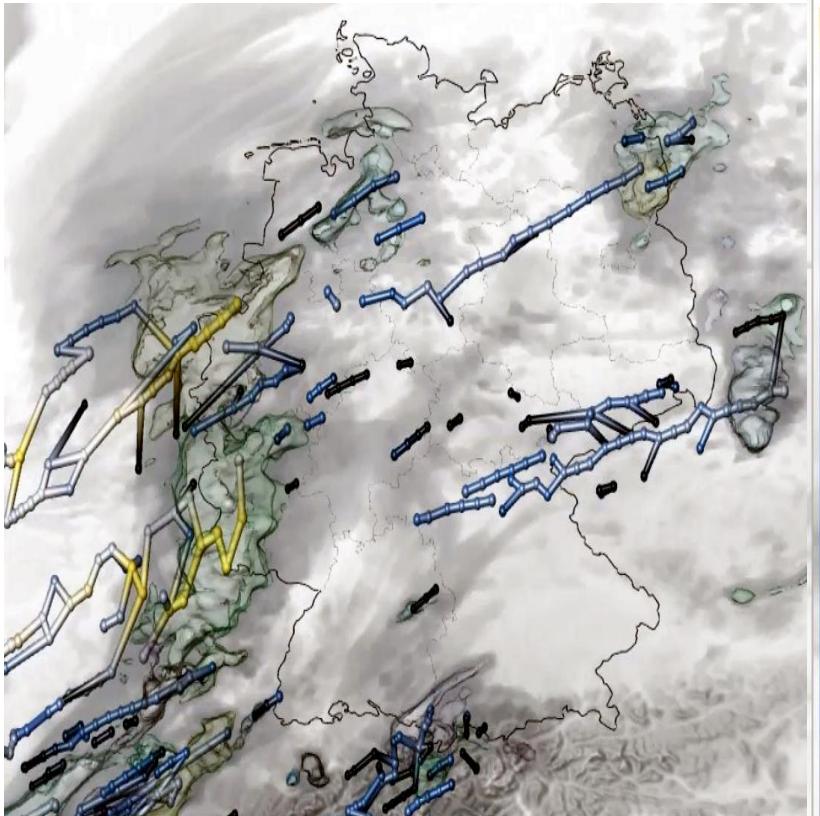


Fig.3: 3D track graph of dataset 2
(22.06.2011, 10:00 MEZ)

Cloud Tracking Comparison

4. Joint Statistical Evaluation

- evaluation based on output tables
- set of *standardized* statistics & plots → assess algorithm characteristics
- scripted evaluation workflow → server-side evaluation

Applications

- algorithm comparison
 - algorithm classification
 - performance evaluation (relative)
 - compare parameter setups
 - ...
- quantify variance between algorithms or setups
→ evaluate robustness, plausibility, number of detections

Cloud Tracking Comparison

4. Joint Statistical Evaluation – Preliminary Examples

- Table 1: Object Statistics, Contour Tracking , 2D LES Dataset [Heus2013]

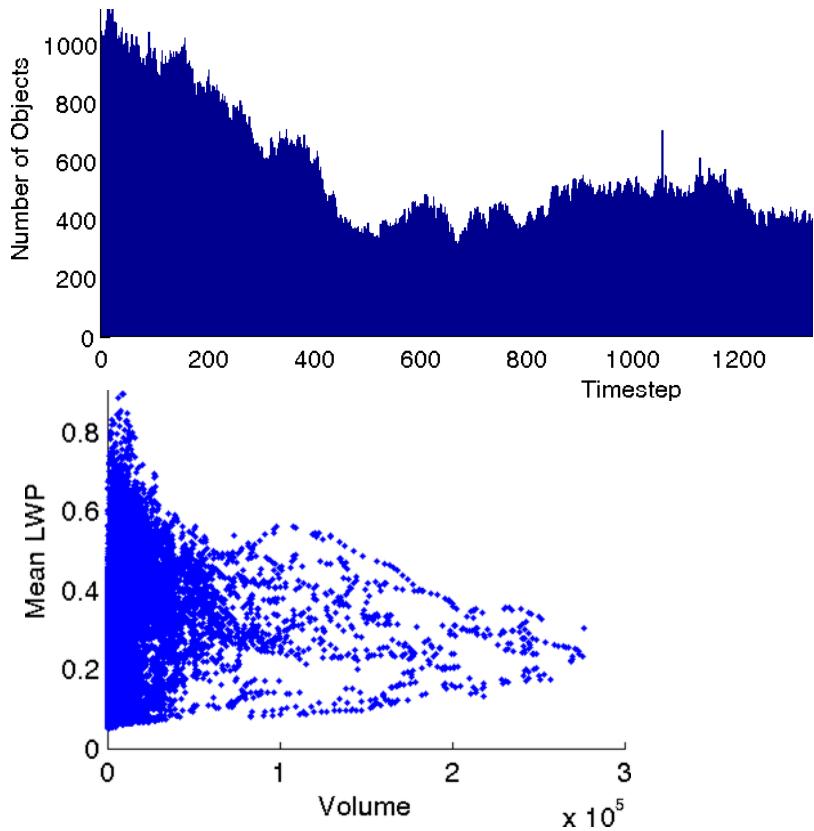


 Fig.4 a): Track object number & LWP distribution

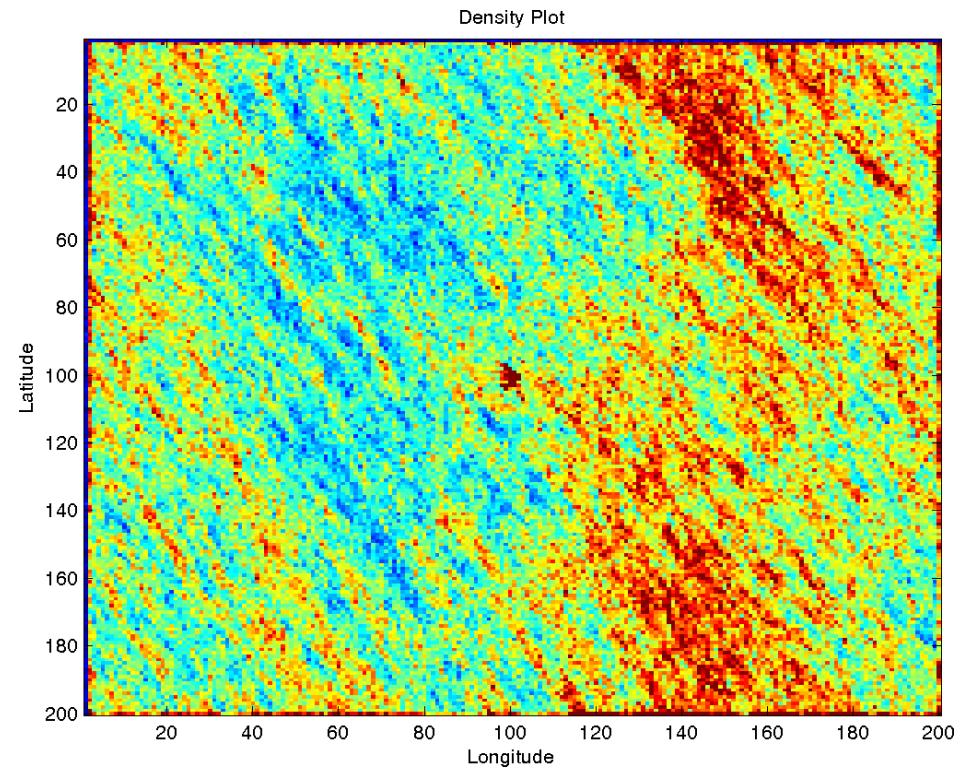


Fig.4 b): Track object density plot

Cloud Tracking Comparison

4. Joint Statistical Evaluation – Preliminary Examples

- Table 2: Tracking Statistics for IRT [Moeseley2013], 2D LES Dataset [Heus2013]

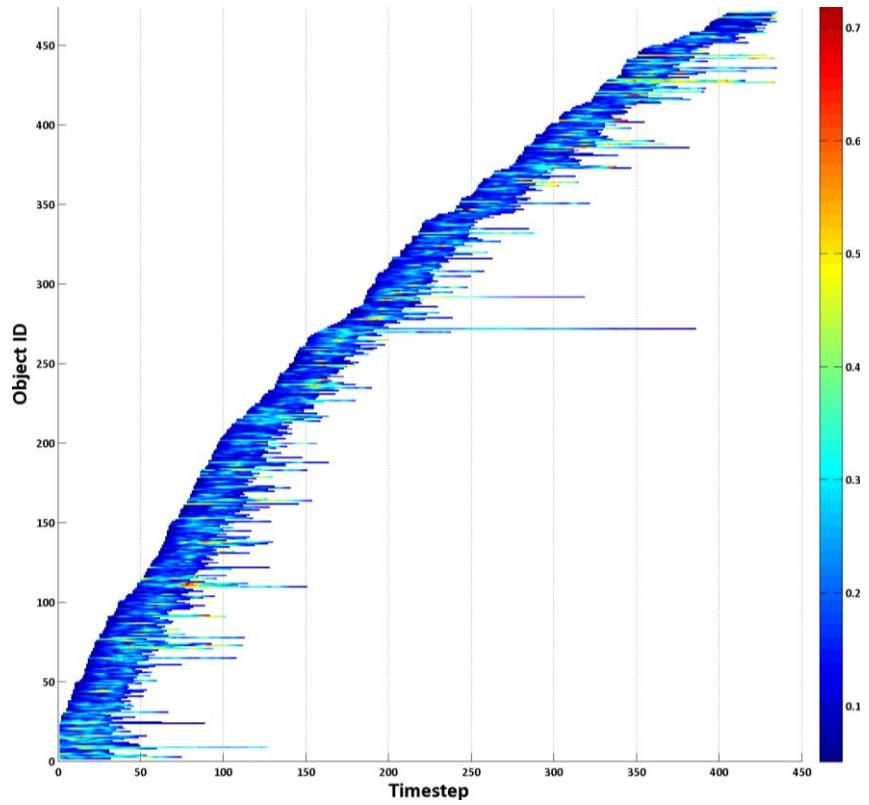
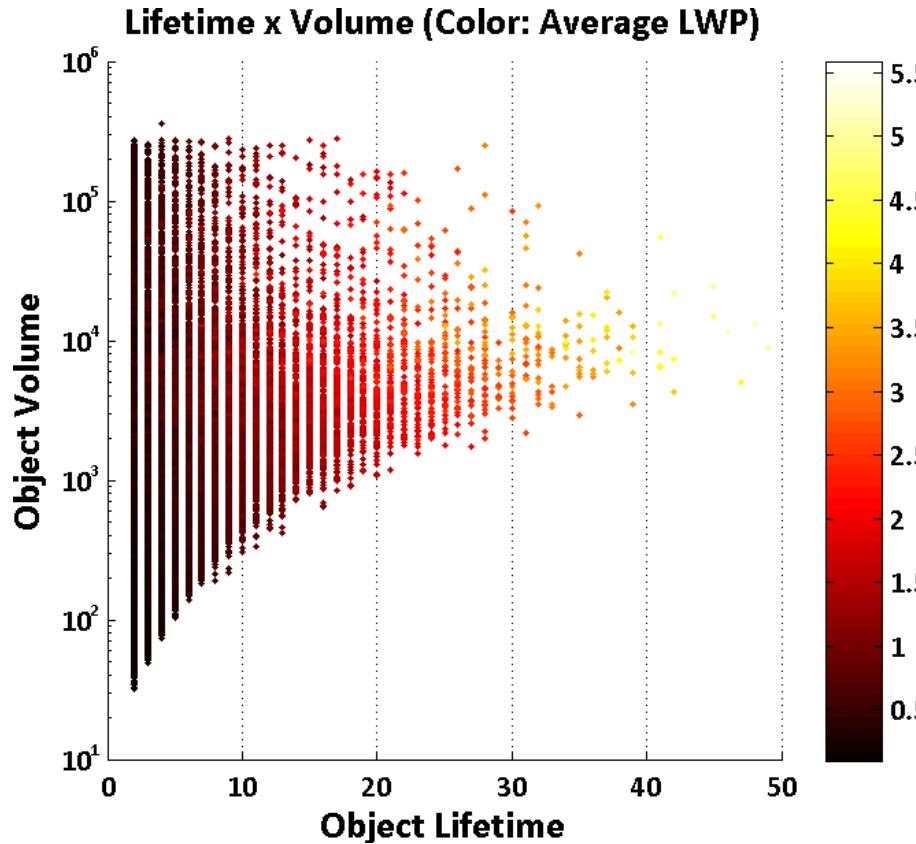
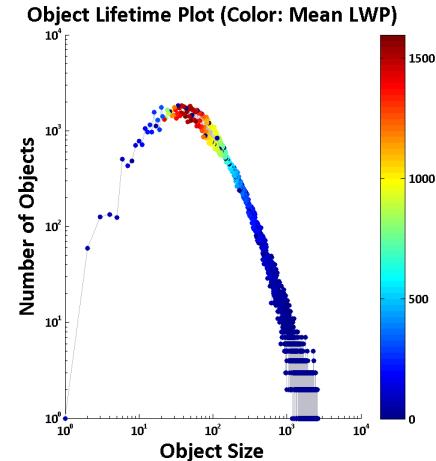
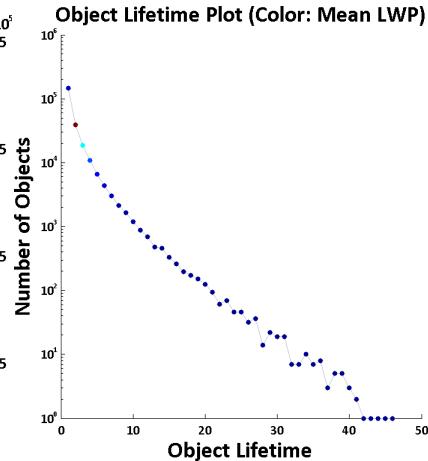
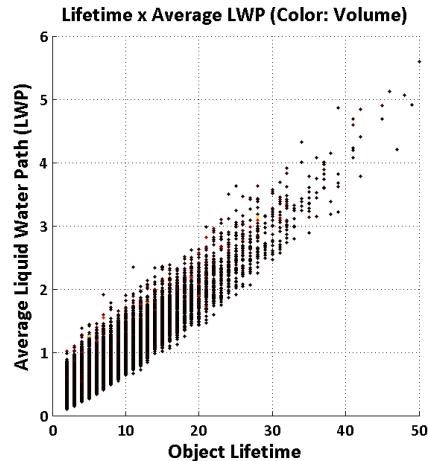
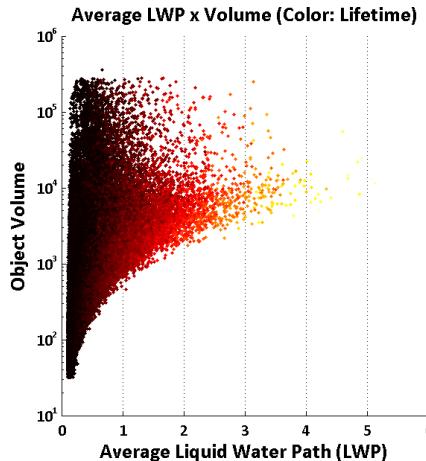


 Fig.5 a): Track volume, lifetime distribution

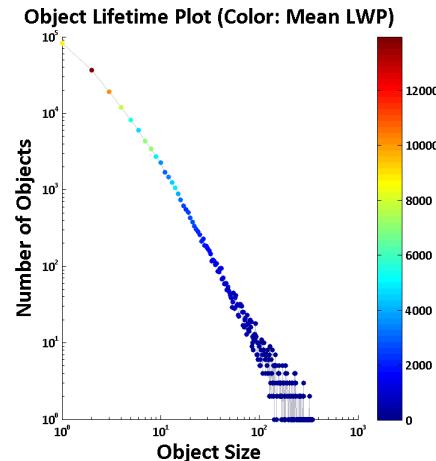
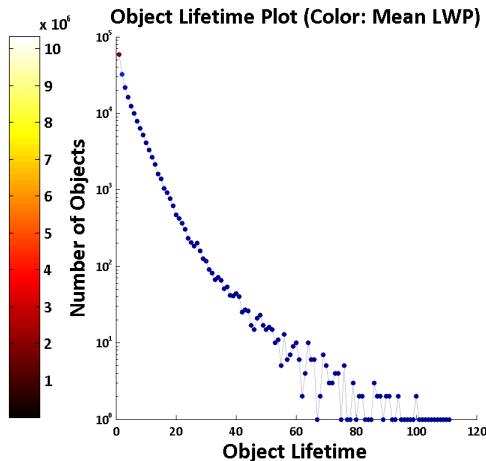
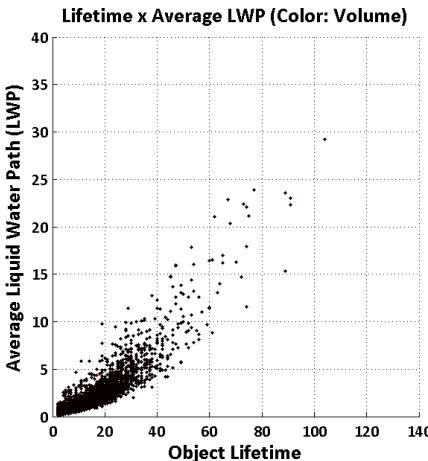
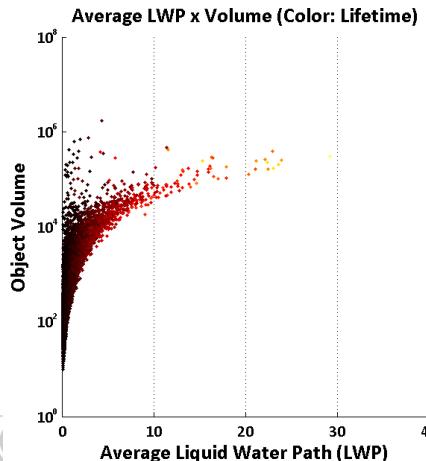
Fig.5 b): Object over time distribution

Cloud Tracking Comparison

Example: Tracking Comparison 2D LES Simulation [Heus2013]
TITAN Tracking Method [Dixon1993]



Iterative Cell Tracking (IRT) [Moseley2013]



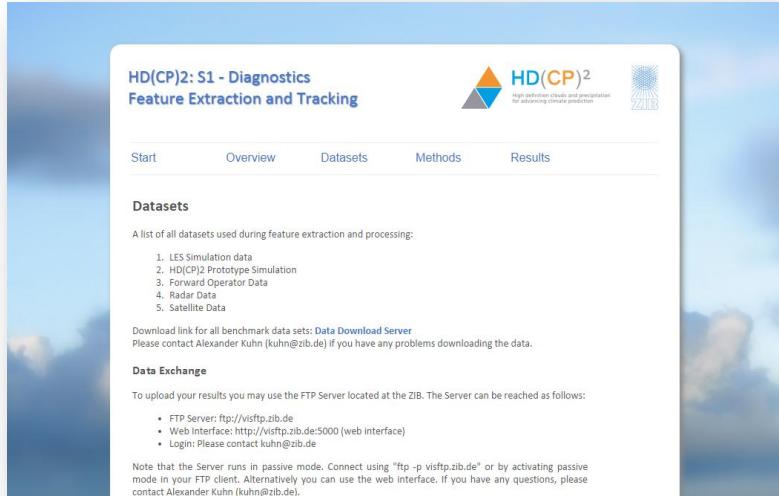
Feature Tracking

5. Web-based Access

- access to study, data sets, and results
- server-side data management
- currently in test phase
(release planned for mid of 2015)

Current Workflow

1. Download benchmark data & information (local)
2. Run tracking algorithm (local)
3. Upload result tables to server (local)
4. Script-based evaluation, plotting of results (server-side)
Publication on website



The screenshot shows a web page titled "HD(CP)2: S1 - Diagnostics Feature Extraction and Tracking". The header includes the ZIB logo and the text "HD(CP)2 High-resolution clouds and precipitation for advancing climate prediction". Below the header is a navigation bar with links: Start, Overview, Datasets, Methods, and Results. The main content area is titled "Datasets" and contains a list of datasets used during feature extraction and processing, numbered 1 to 5. It also includes a download link for benchmark data sets and instructions for uploading results via an FTP server.

Figure 6: Project website

Conclusion

Summary

- tracking study to assess *state-of-the-art cloud tracking* procedures
- *collection* of cloud tracking approaches
- *benchmark data* sets (2D simulation, 3D radar-operator)
- *comparison and evaluation* of state-of-the art tracking procedures
- *joint evaluation* with web-based access to results

Future Work

- open access to tracking study
- include (quantitative) quality measures? [Wernli2008]
- further data sets & parameter studies

Intercomparison Study of Cloud Feature Extraction and Tracking Algorithms

Thank you for your Attention!
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