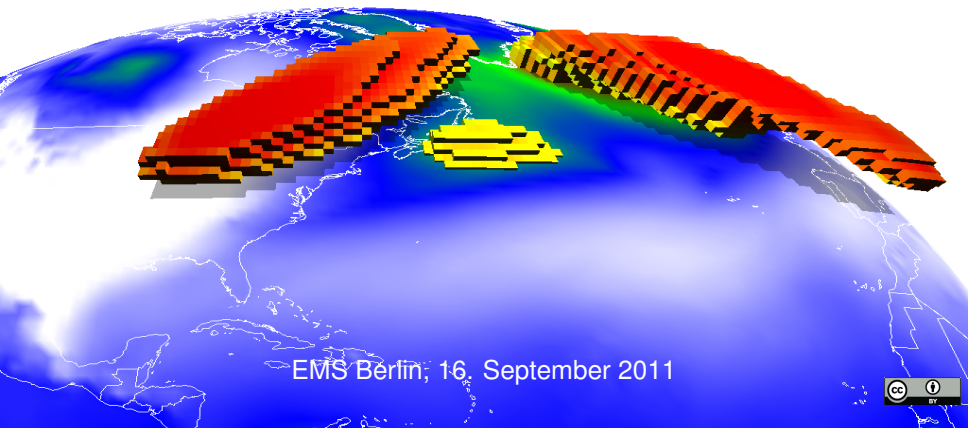# Four-dimensional identification and tracking of cyclones and upper-tropospheric jet-streams

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Overview

Algorithm

- full four-dimensional segmentation based on region-growing
- event localization on grid-point level
- efficient implementation

Applications

- two-years climatology of upper-tropospheric jet-streams and their events
- detection and analysis of three-dimensional cyclone structures (case study including "Kyrill")

Overview (2)

Feature detection

Overview (2)

Feature detection

$\Downarrow$

Feature tracking

Overview (2)

Feature detection
⇓
Feature tracking
⇓
Event localization (mergings, splittings, genesis, lysis)
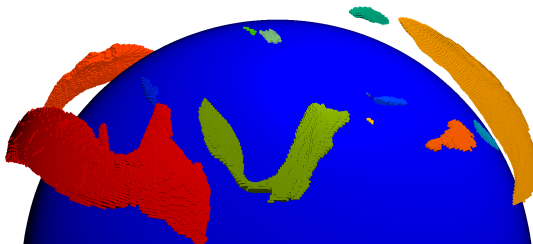
Feature detection

Criteria for features

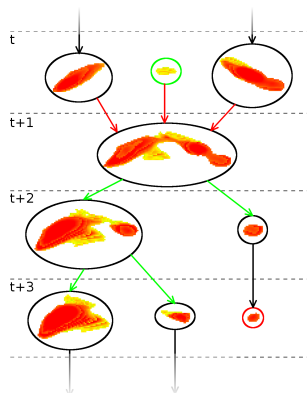- Jet-streams:
  1. wind speed $> 40 \frac{m}{s}$
- Cyclones:
  1. compute 10-days running mean of Z (geopotential height)
  2. compute a vertical profile of the mean negative Z anomaly
  3. mark grid points where Z differs significantly from this vertical profile

Feature tracking

Tracking

- 3D → 4D: feature tracking based on spatial overlaps
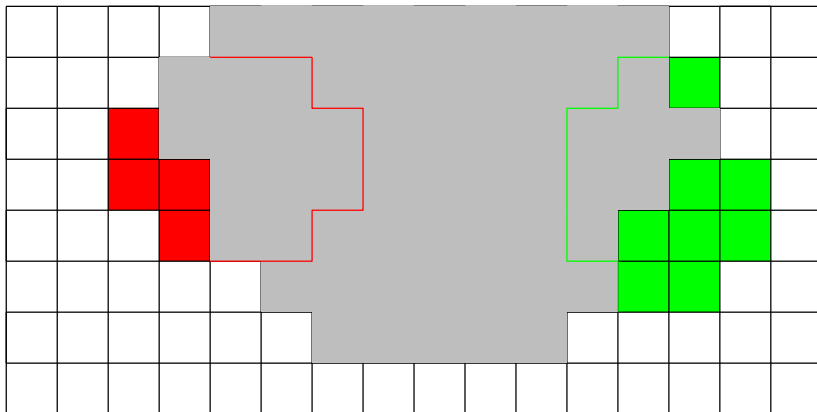- we obtain 4D segments consisting of 3D features

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.
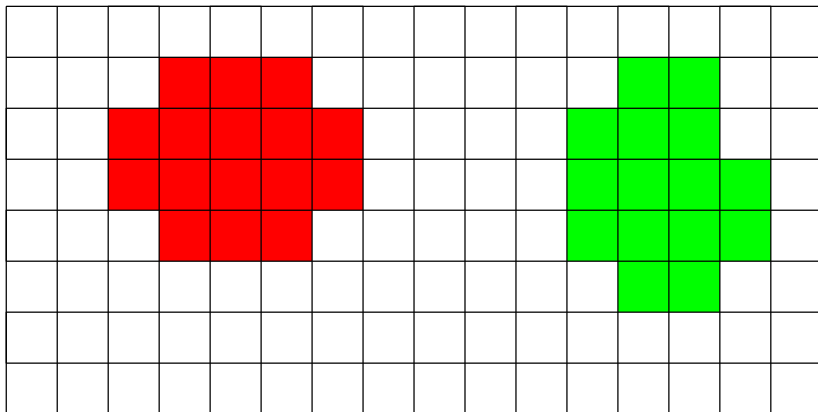
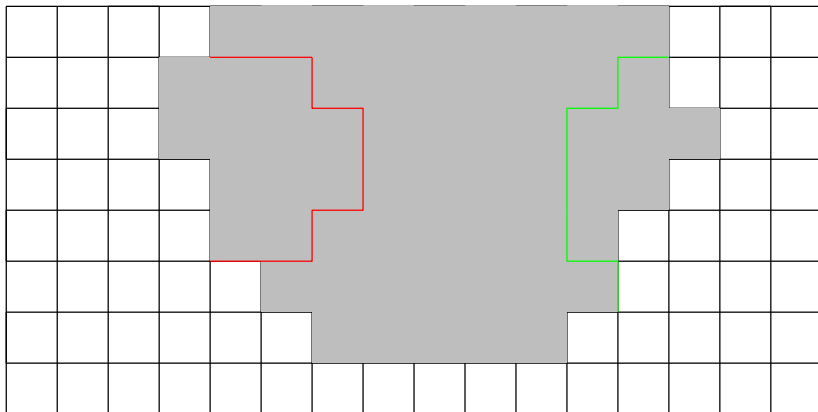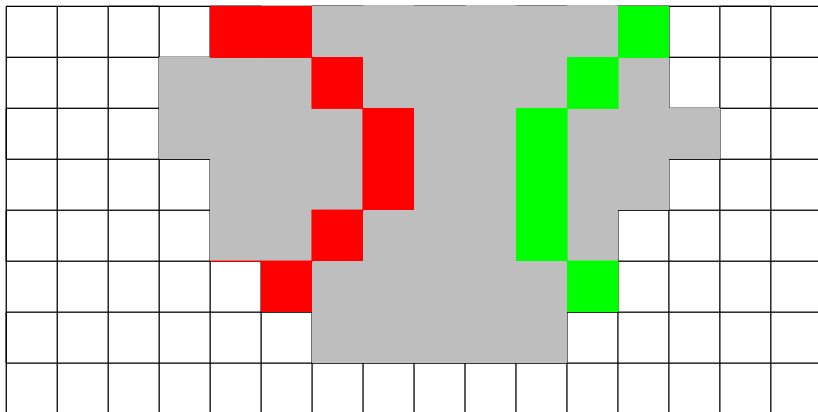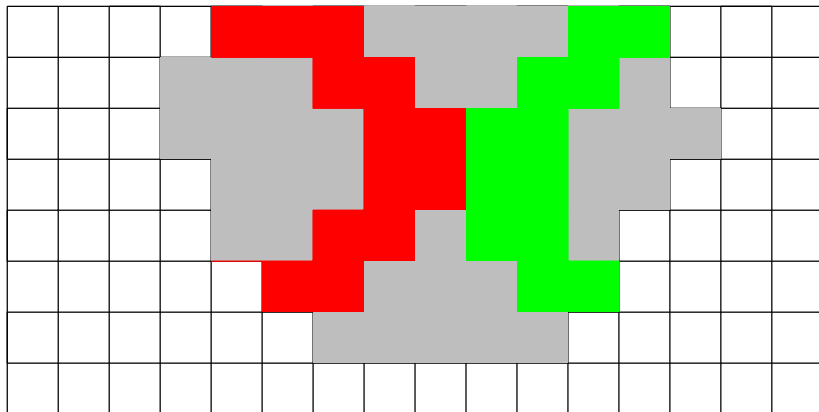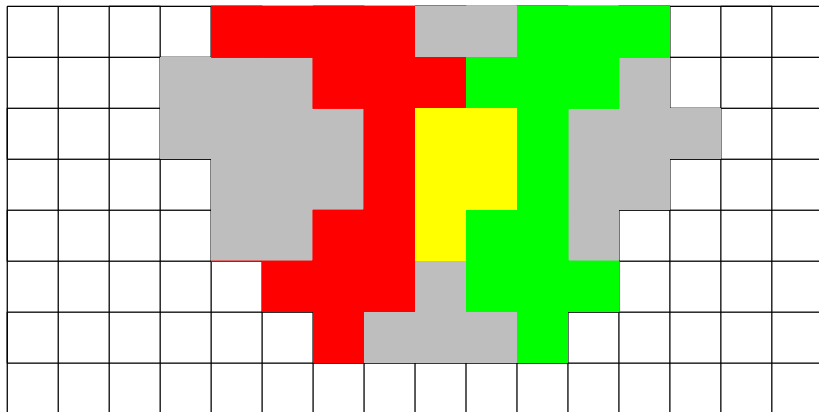timestep n: two separate 3D-features of the same 4D-segment

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

timestep n+1: merging of the two features into the gray feature

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

overlapping grid points are start points for first region growing phase

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

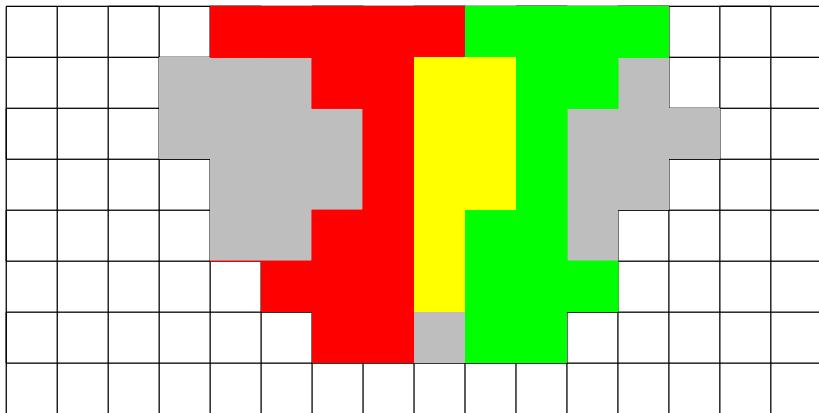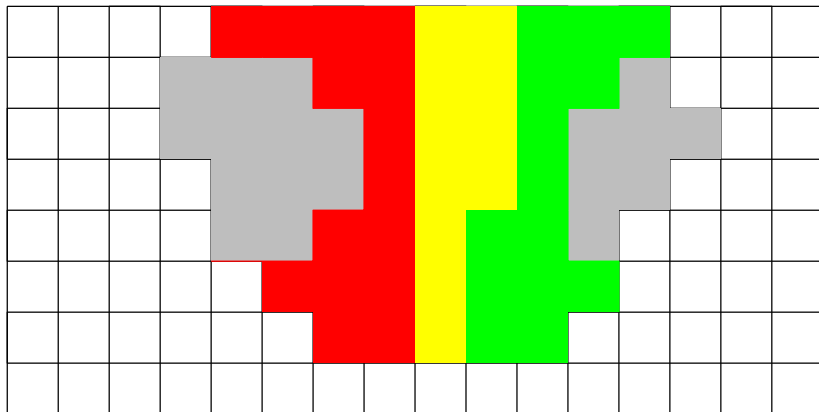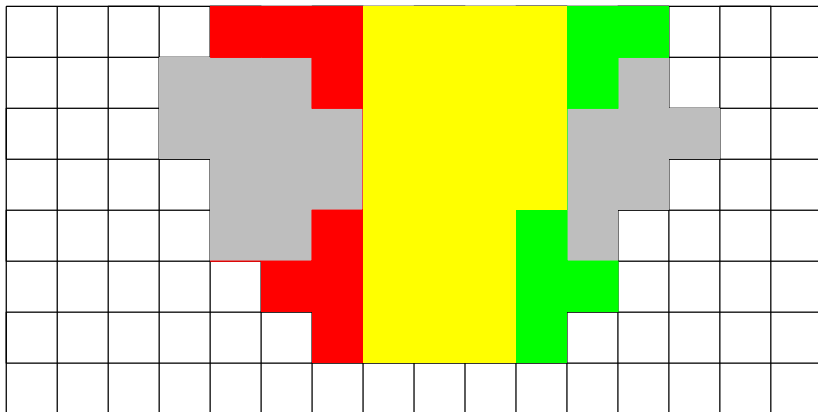region growing inside the gray feature

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

region growing inside the gray feature

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

already visited grid points are marked as event location

## Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

already visited grid points are marked as event location

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

already visited grid points are marked as event location

Localization of events

We perform two additional region-growing phases in order to determine the exact position of the mergings and splittings.

final region growing step to increase size of event location

Examples of segmentation and mergings
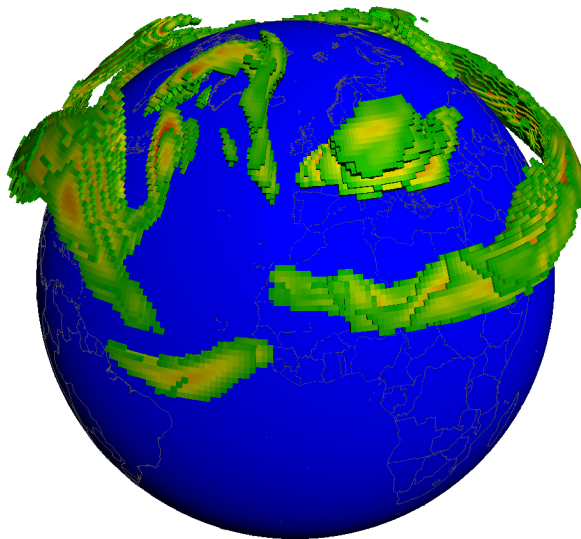
Examples of segmentation and mergings
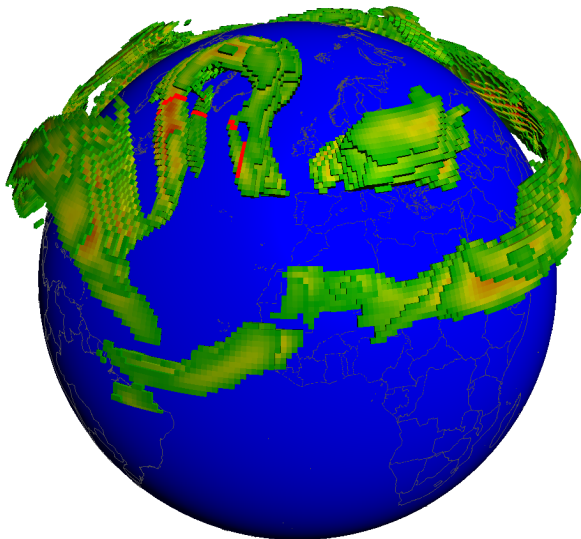
Examples of segmentation and mergings
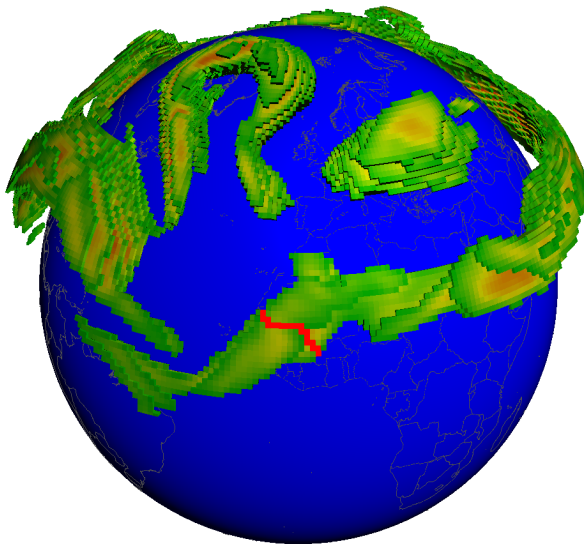
Jet climatologies
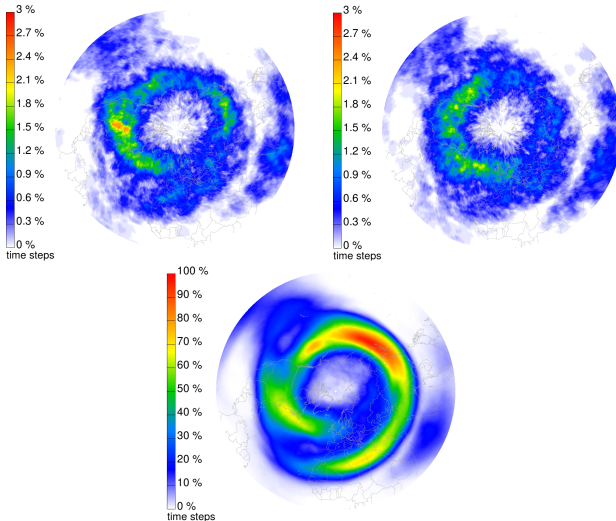
Top left: Mergings. Top right: Splittings. Bottom: Overall jet ratio.
Vertically unified per time step.

Perspective projection
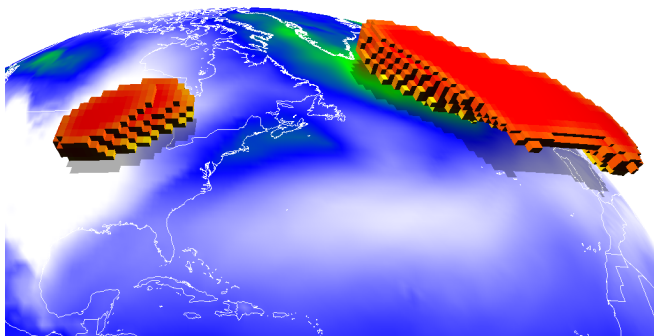
Perspective projection
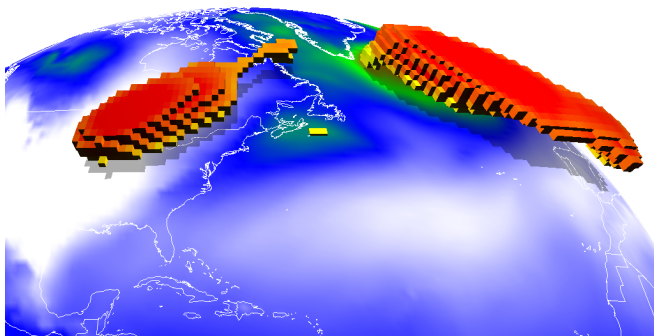
Perspective projection
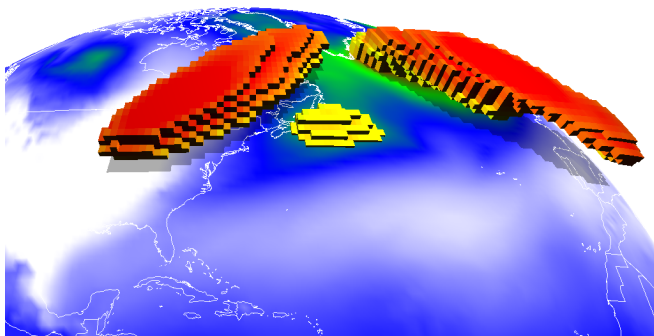
Perspective projection
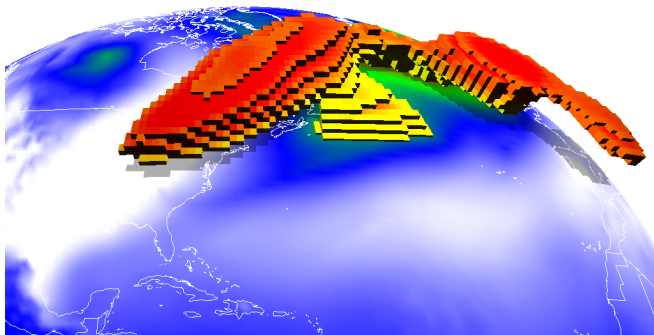
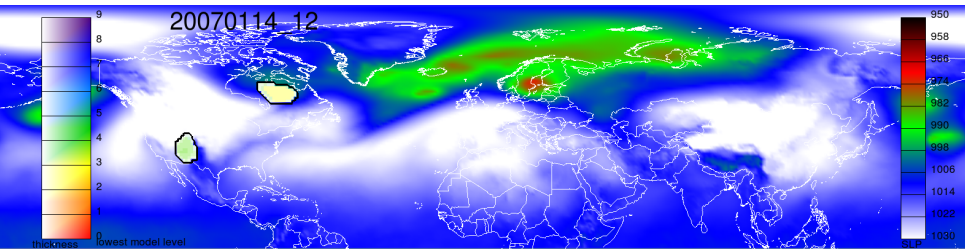# 2D visualization
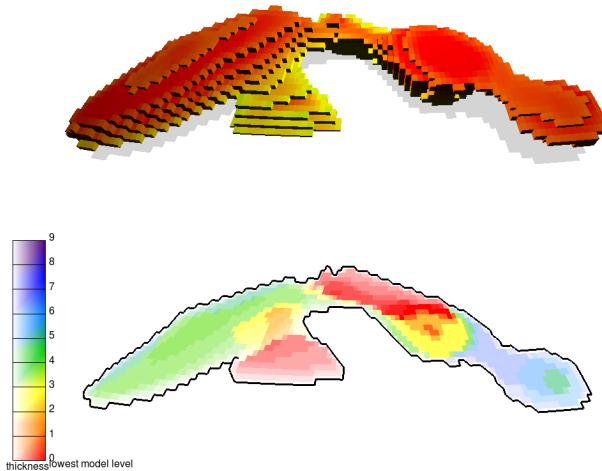
Cyclone segmentation (single segment)
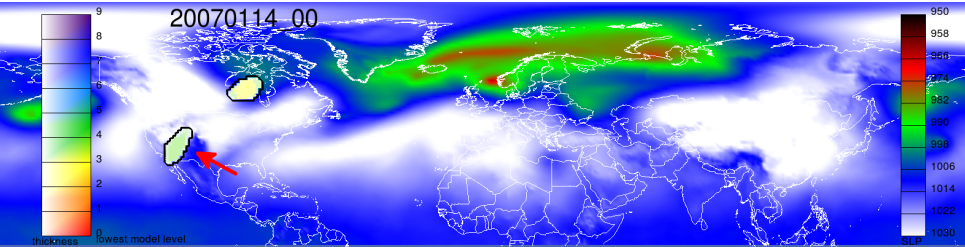
Formation of an upper-level trough over the southwestern US.

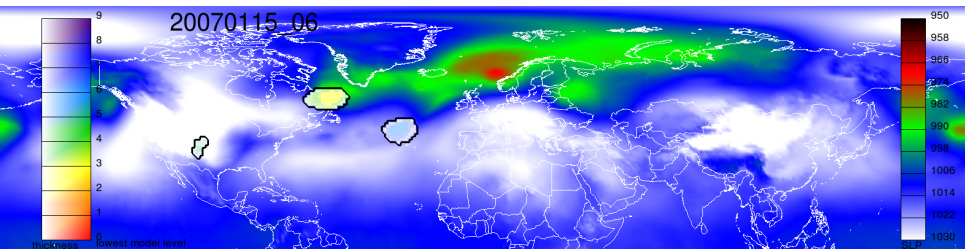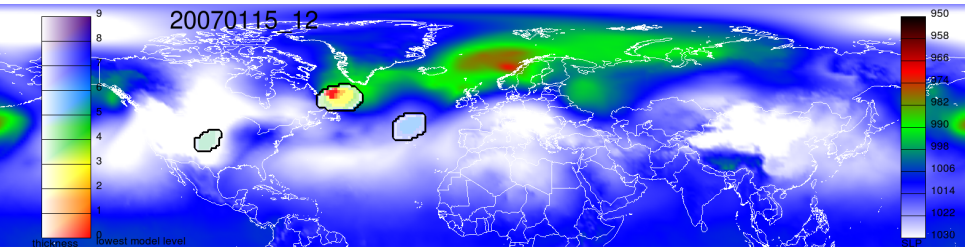# Cyclone segmentation (single segment)
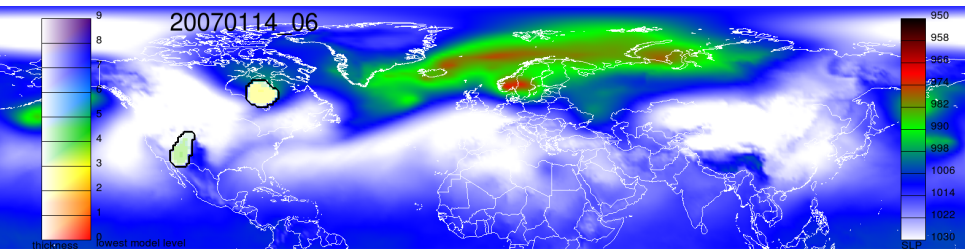
20070114_06

Trough propagates eastwards.

Cyclone segmentation (single segment)

20070114_12

Trough propagates eastwards.

Cyclone segmentation (single segment)

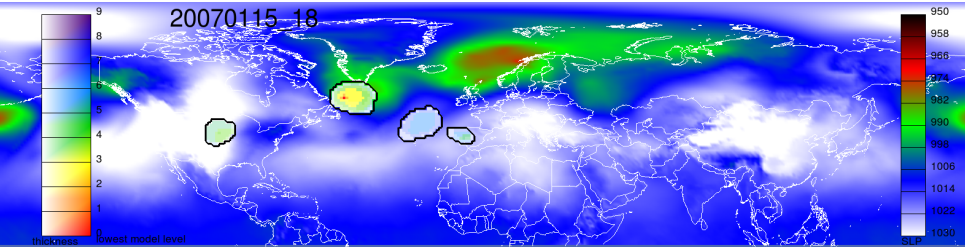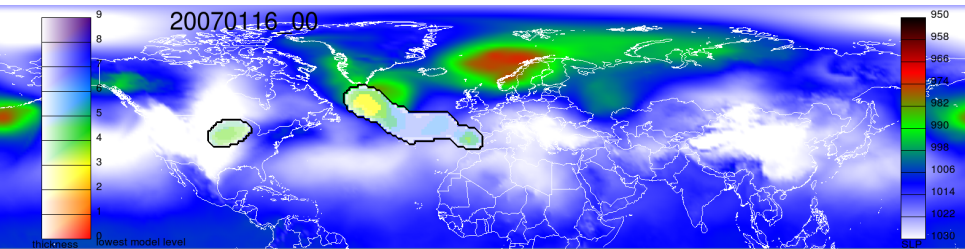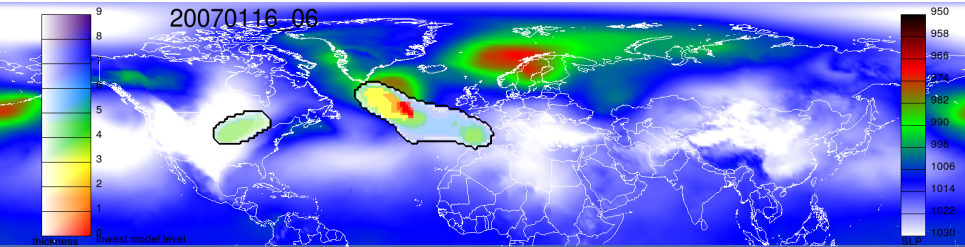Trough propagates eastwards.

Cyclone segmentation (single segment)

20070115_00

Trough propagates eastwards.

Cyclone segmentation (single segment)

20070115_06

Trough propagates eastwards.

Cyclone segmentation (single segment)

20070115_12

Trough propagates eastwards.

Cyclone segmentation (single segment)
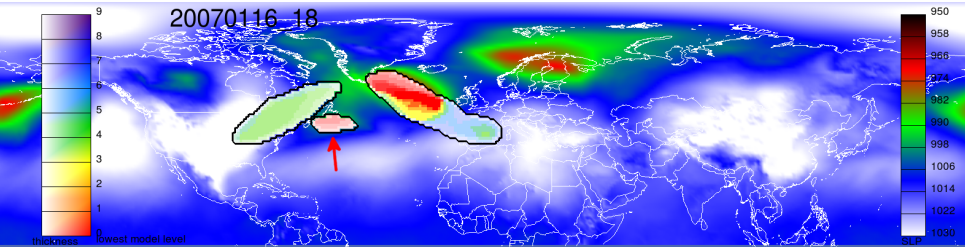

Trough propagates eastwards.

Cyclone segmentation (single segment)

20070116_00

Trough propagates eastwards.

Cyclone segmentation (single segment)

20070116_06

Cyclone segmentation (single segment)
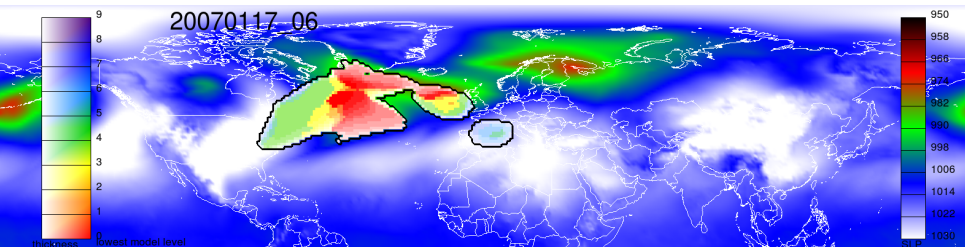
Cyclone segmentation (single segment)

20070116_18
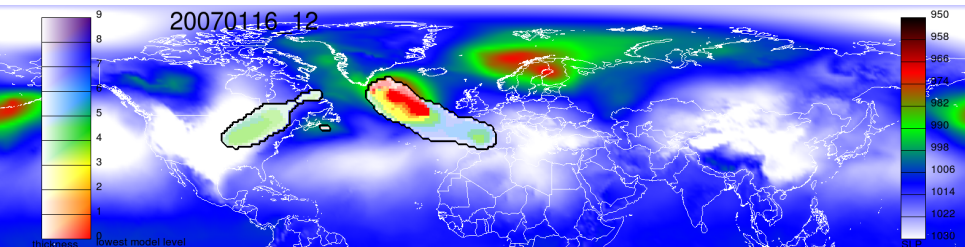
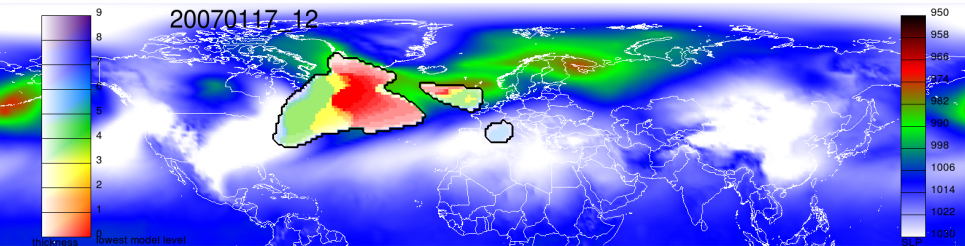Formation of low-level cyclone "Kyrill".

Cyclone segmentation (single segment)
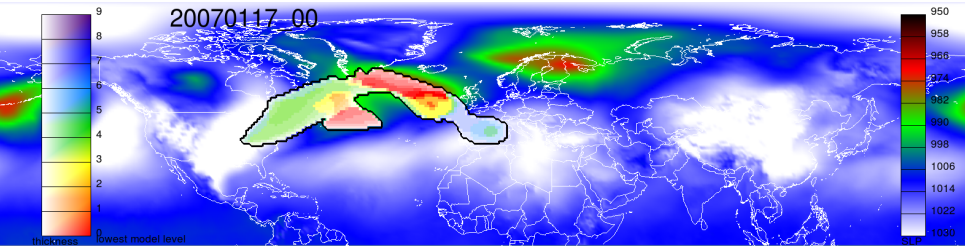
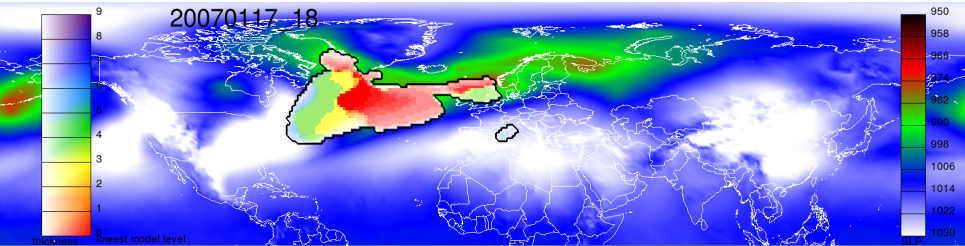Trough merges with "Kyrill" and pre-existing Icelandic low.
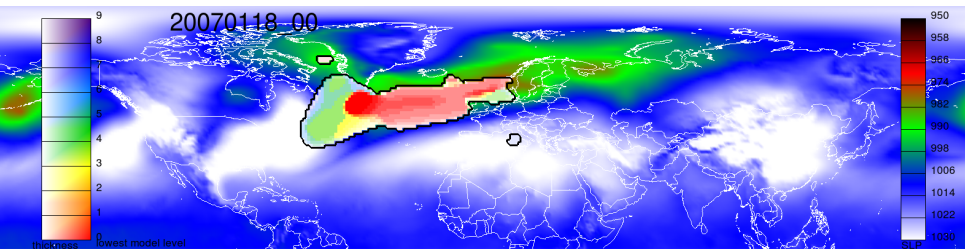
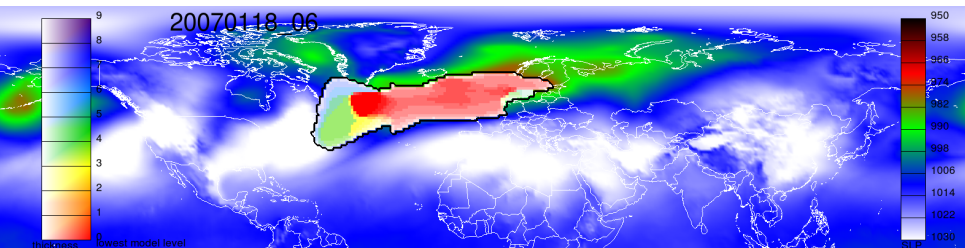# Cyclone segmentation (single segment)
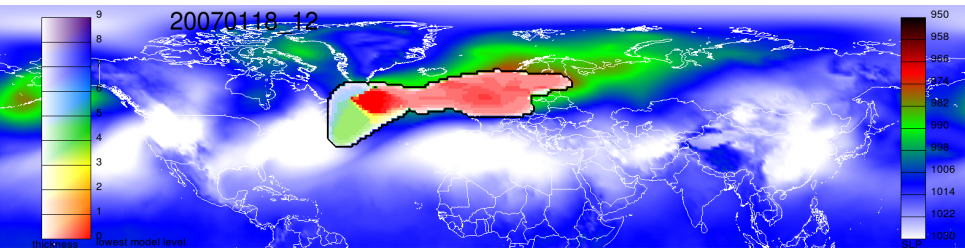

20070117 06

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

20070117_18

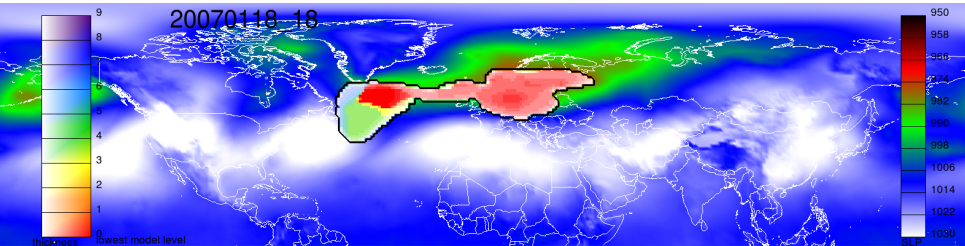# Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

20070118_06

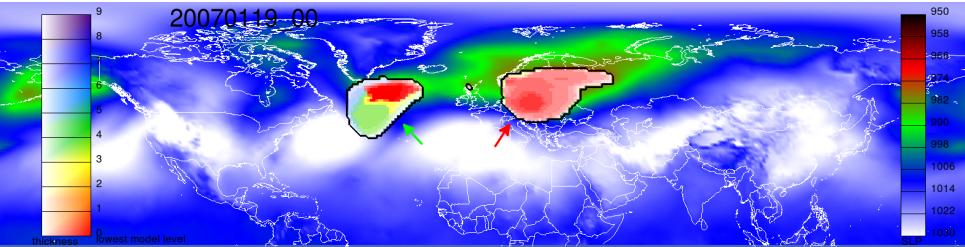# Cyclone segmentation (single segment)

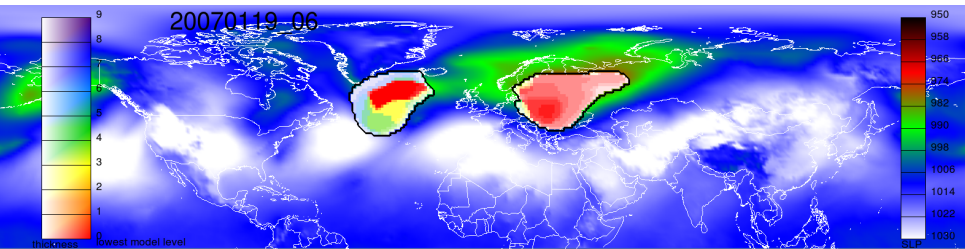# Cyclone segmentation (single segment)

Peak impact on Germany.

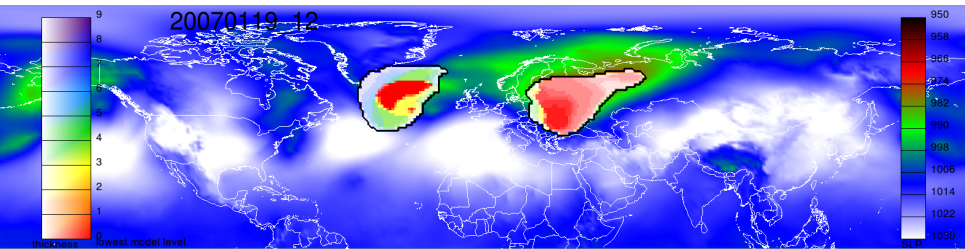# Cyclone segmentation (single segment)

Large cyclone splits into "Kyrill" moving eastwards (red arrow)
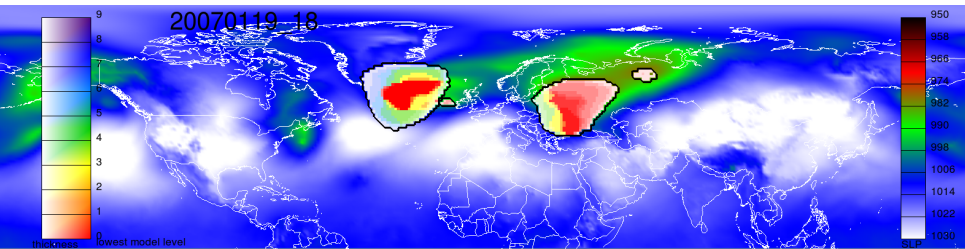and another North-Atlantic cyclone (green arrow).
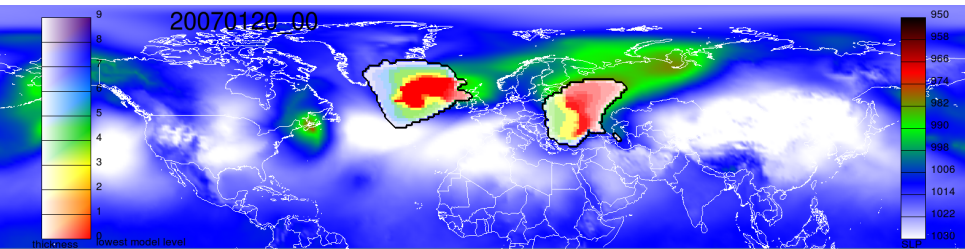
Cyclone segmentation (single segment)
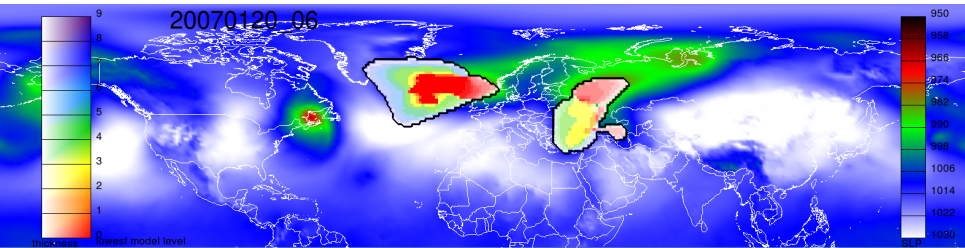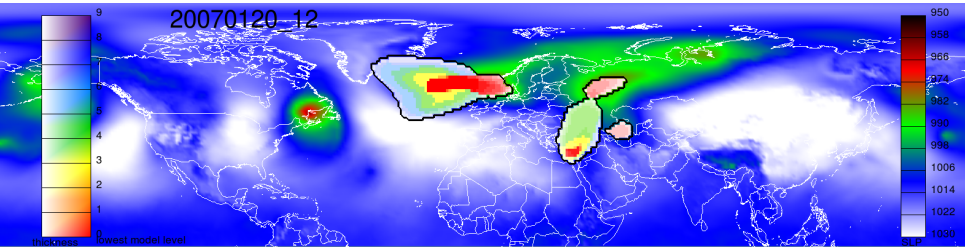

20070119_06

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)
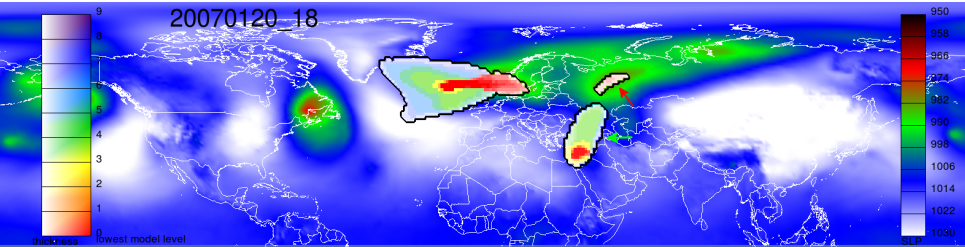
Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

20070120_18

Another split into a weak low-level cyclone (red arrow)
and a still intense cyclone over the Eastern Mediterranean.

Cyclone segmentation (single segment)

20070121_00

Cyclone segmentation (single segment)

20070121_06

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

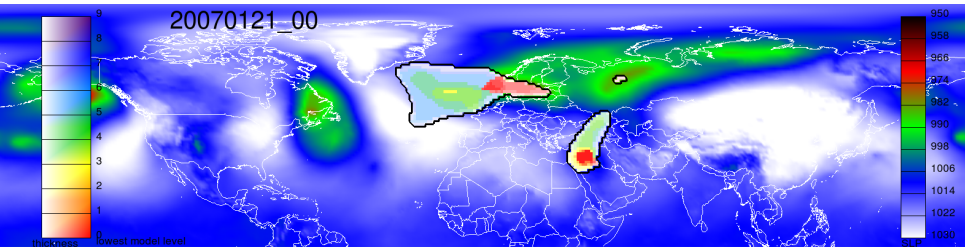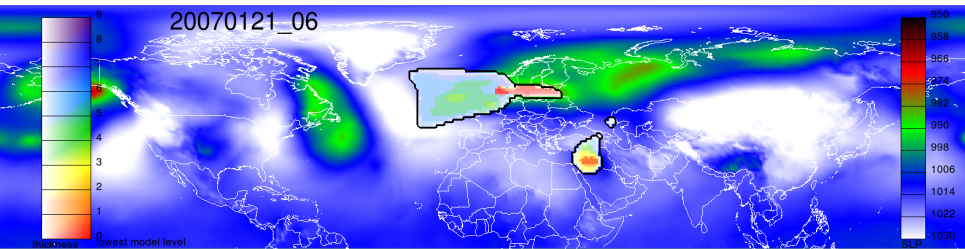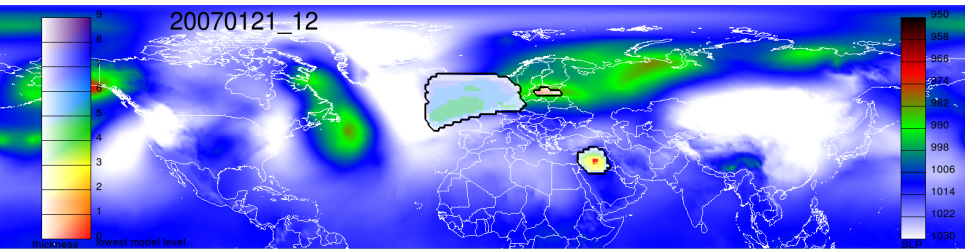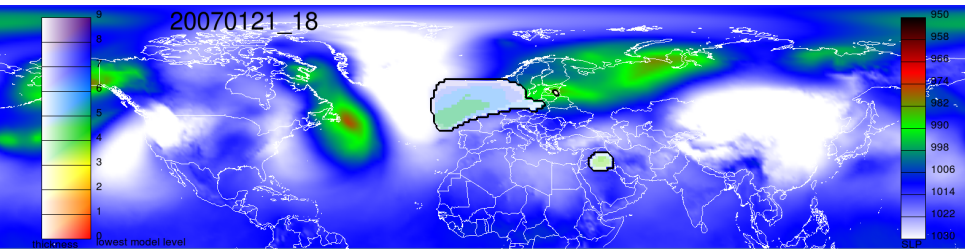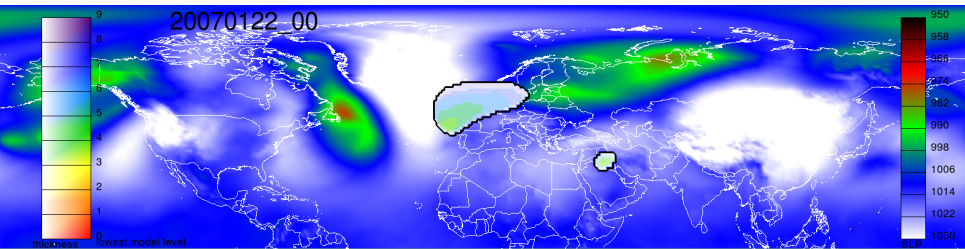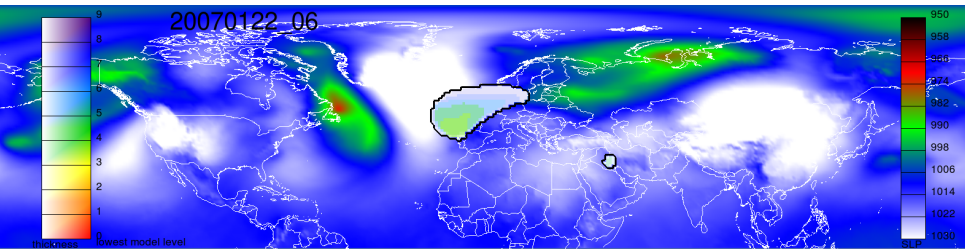# Cyclone segmentation (single segment)

20070122_06

Cyclone segmentation (single segment)

20070122_12

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Formation of another intense cyclone is triggered
by the still prominent upper-level trough.

Cyclone segmentation (single segment)

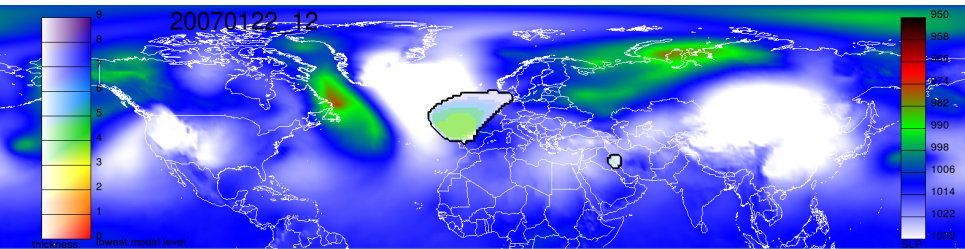# Cyclone segmentation (single segment)
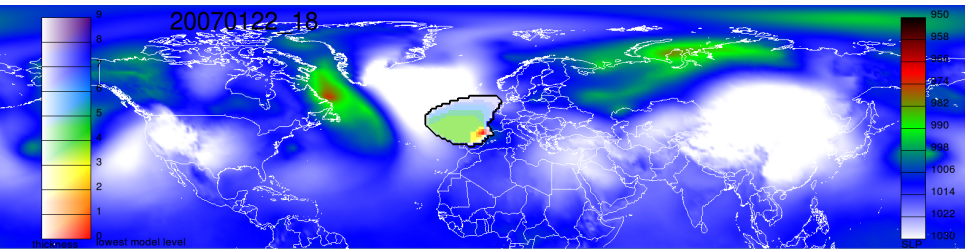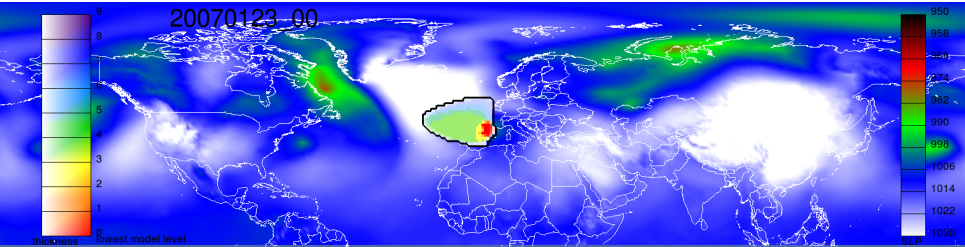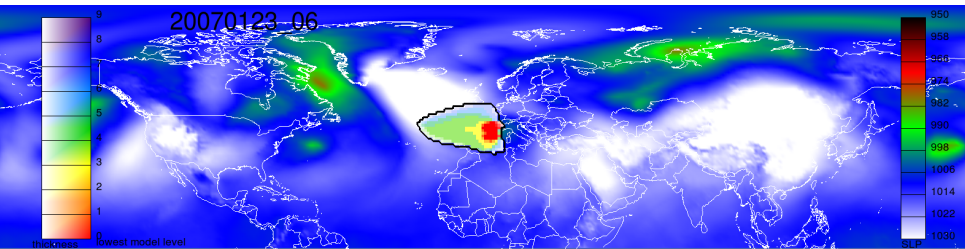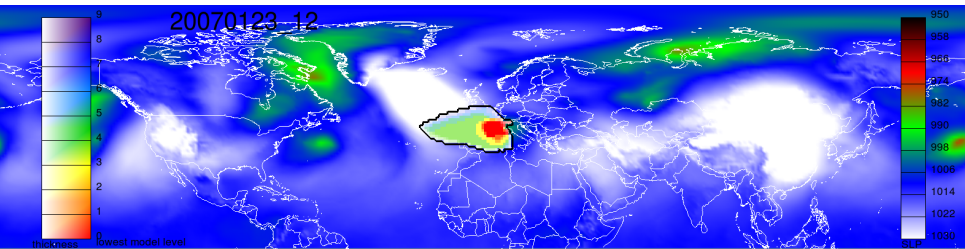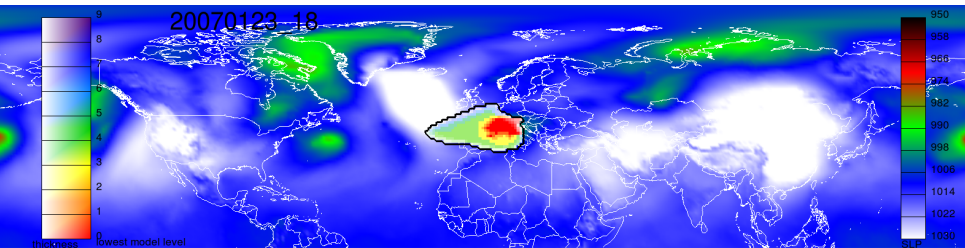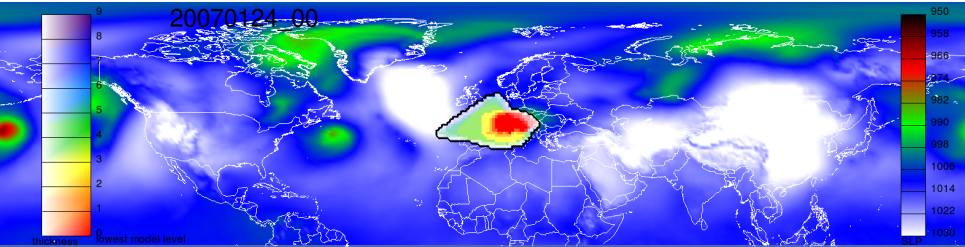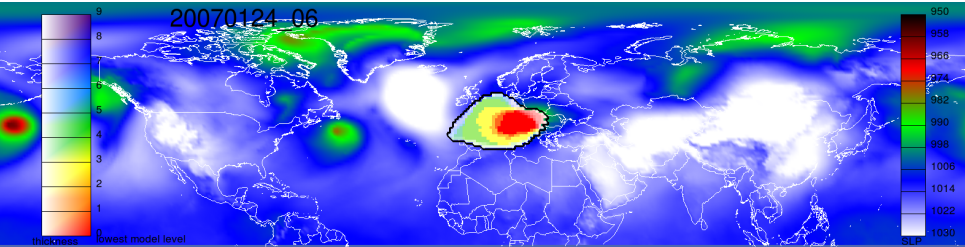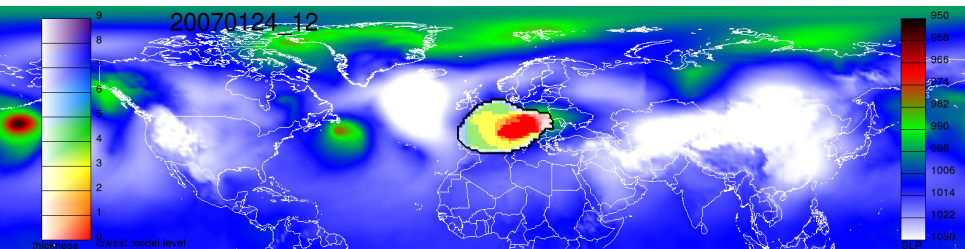

20070123_12

Cyclone segmentation (single segment)
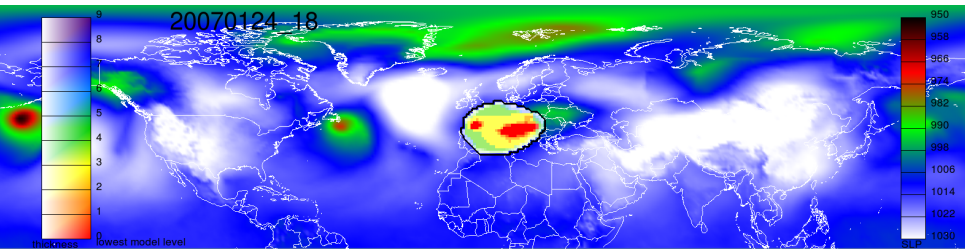
Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

Cyclone segmentation (single segment)

20070124_18

Conclusion - method

Conclusion

- extended 4D region growing segmentation algorithm
- grid-point based event localization
- works on different types of atmospheric structures
- we already applied our method to ozone holes, jet streams and cyclones

Outlook

- we plan to improve the feature tracking and to adapt the localization of the merge and split events
- apply the method to further atmospheric structures

Conclusion - cyclone tracking

Conclusion

- we developed an applicable, three-dimensional tracking criterion
- we verified it on data of the Kyrill episode
- we gathered new insights, for example on the dynamical linkage between upper-level troughs and surface cyclones

Implementation

INSIGHT project:
`http://insight.zdv.uni-mainz.de/trac`