6th European Conference on Severe Storms (ECSS 2011)
3 - 7 October 2011, Palma de Mallorca, Balearic Islands, Spain

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

The Mesocyclone Detection Algorithm of DWD

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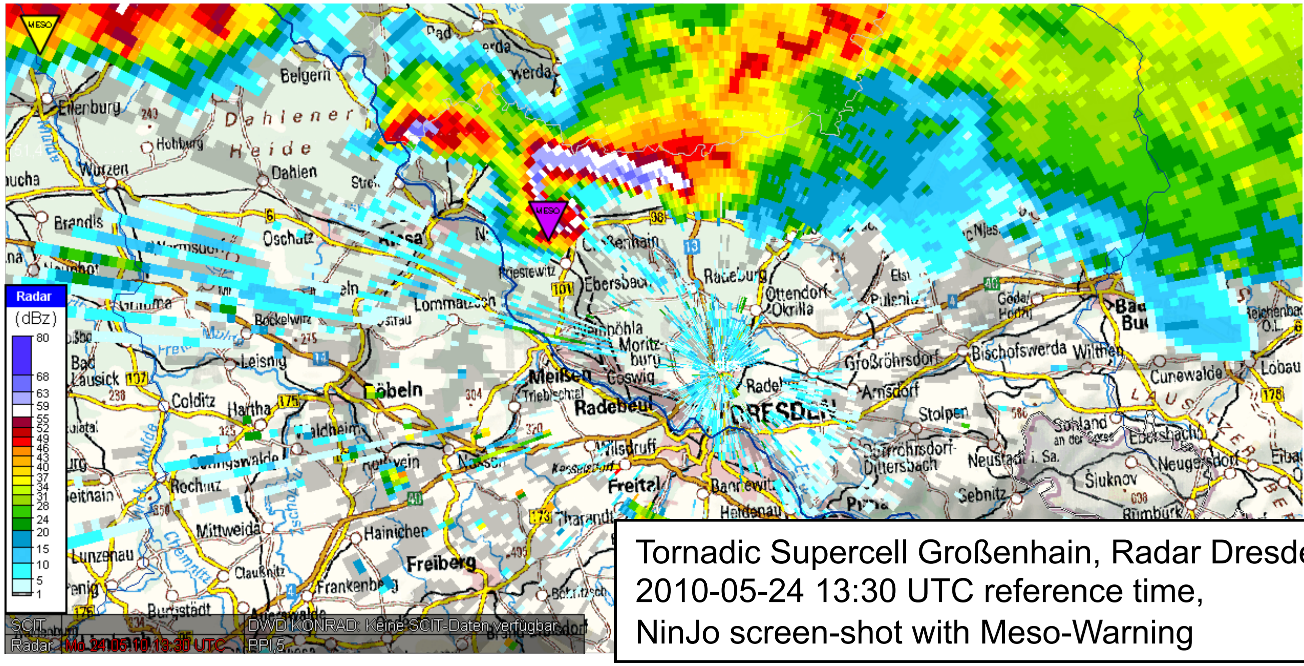
[3]*Environment Canada, Toronto, Ontario, Canada, paul.joe@ec.gc.ca*
[4]*Deutscher Wetterdienst (DWD), Hohenpeissenberg, Germany, peter.lang@dwd.de*



Tornadic Supercell Großenhain, Radar Dresden,
2010-05-24 13:30 UTC reference time,
NinJo screen-shot with Meso-Warning

Dr. Thomas Hengstebeck, Deutscher Wetterdienst, FEZE-C

Contents

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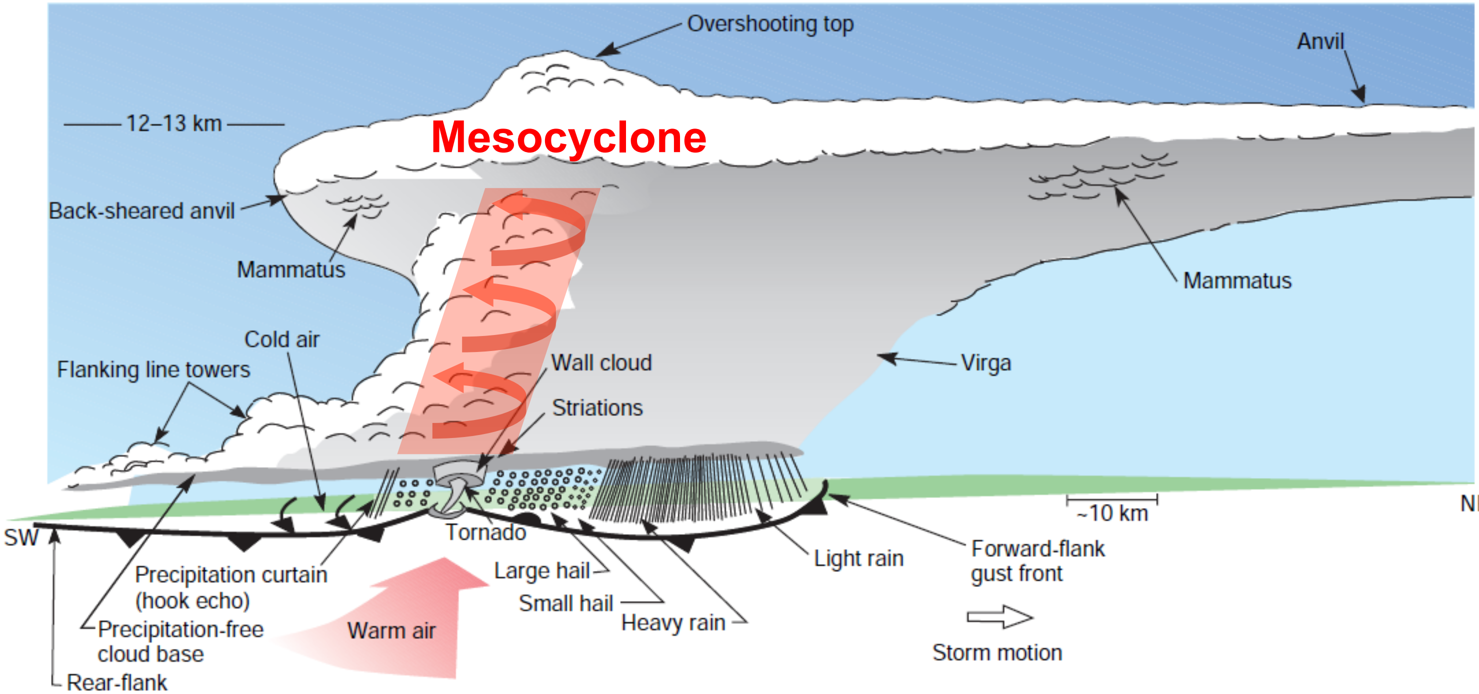
MDA – Motivation
Supercell storm

Definition Mesocyclone:*
A cyclonically rotating vortex, around 2-10 km in diameter, in a convective storm. Mesocyclones are frequently found in conjunction with updrafts in supercells.

*see AMS Glossary of Meteorology

Mesocyclones often occur in connection with severe weather events:

- ➔ Heavy rain
- ➔ Hail
- ➔ Strong winds
- ➔ *Tornados*



Structure of a typical supercell storm (adapted from Wallace, Hobbs, *Atmospheric Science*, 2006)

Automated Meso-Warnings can give valuable hints to meteorologists in the warning service (who usually cannot analyze all available data in real time).

MDA – Principle
Rankine Combined Vortex

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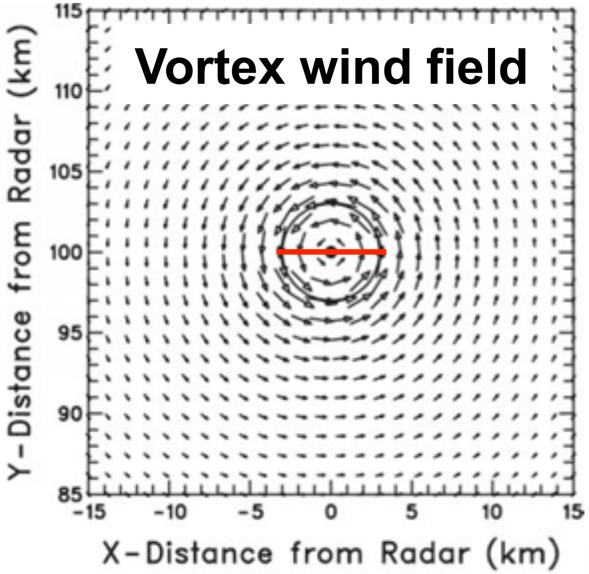
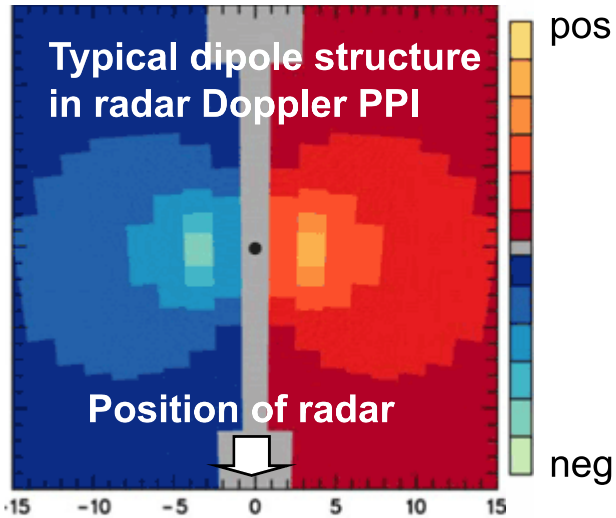
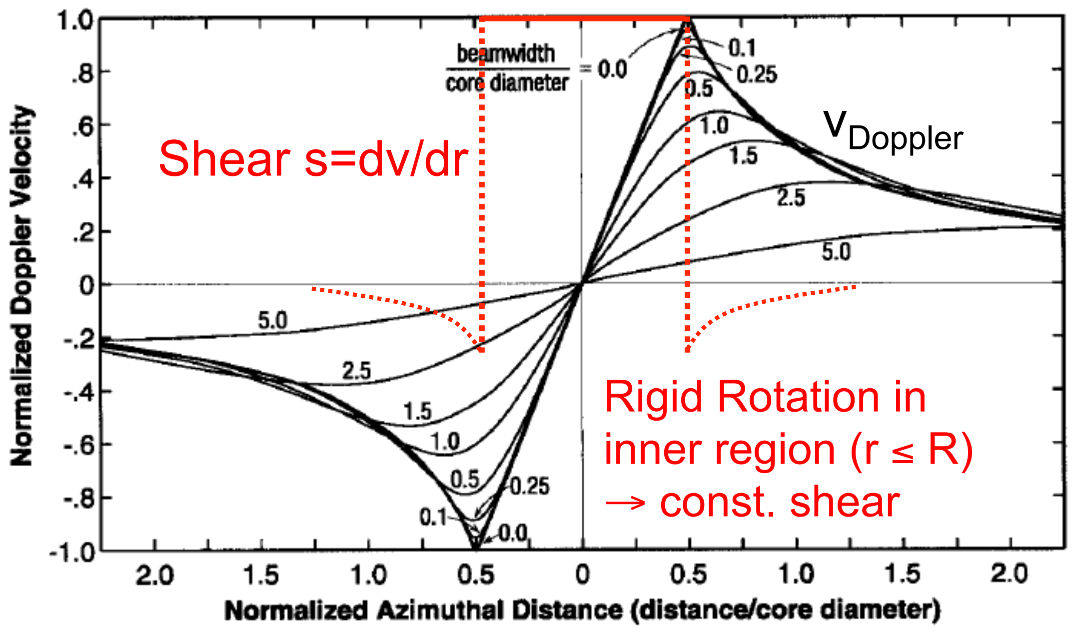




Adapted from http://www.nssl.noaa.gov/papers/dopplerguide/chapter4.html



Mathematical Model

$$v_{doppler} = v_0 \cdot \begin{cases} r/R, & r \le R \\ R/r, & r > R \end{cases}$$

Figure adapted from S. V. Vasiloff: *Improving Tornado Warnings with the Federal Aviation Administration's Terminal Doppler Weather Radar*
Bull. Amer. Meteor. Soc., 82, 861–874, 2001

MDA – Principle
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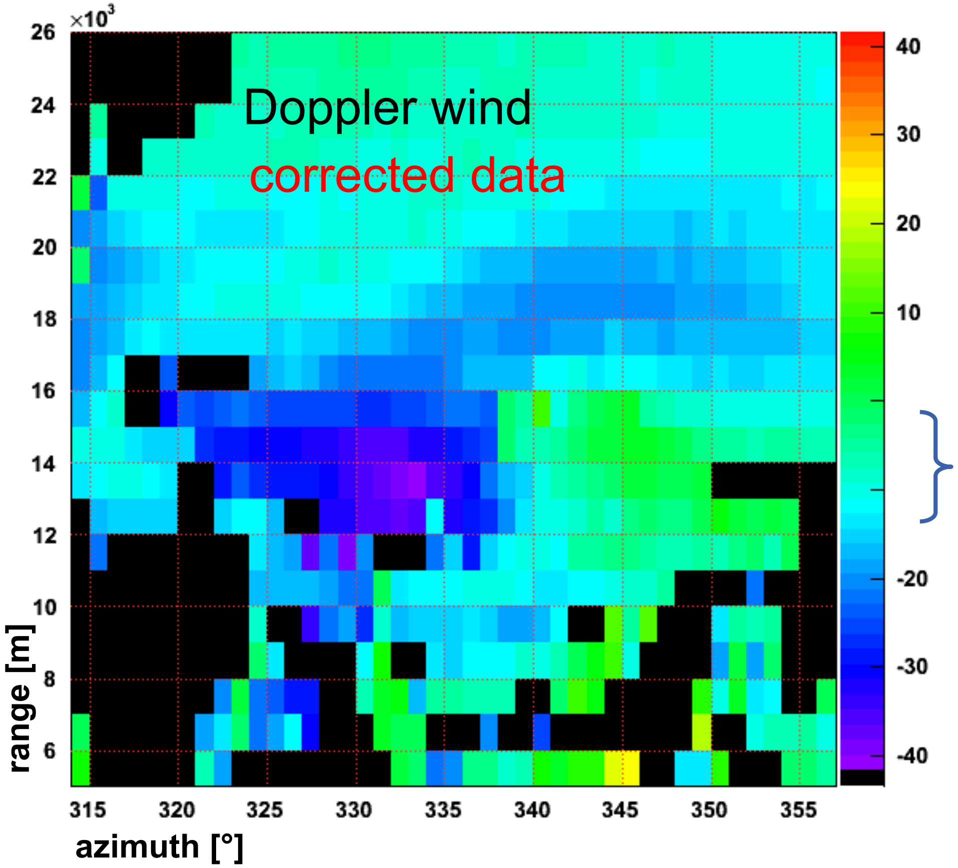
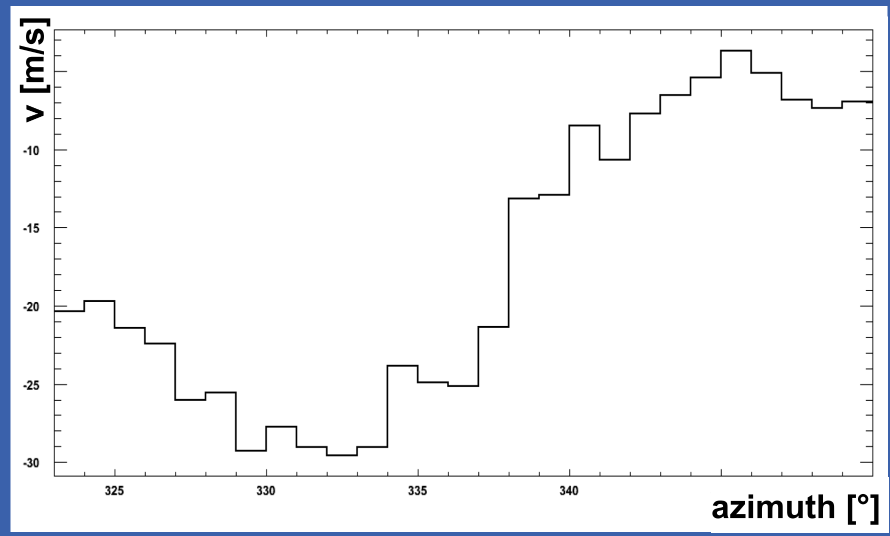
Appearance in radar (example) Tornadic Supercell Großenhain, May 24, 2010 13:45 UTC reference time, Tornado rated F3



Azimuthal profile



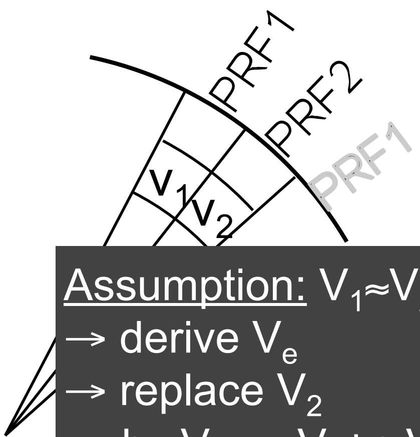
RC – vortex signature clearly visible

Doppler Data Preprocessing

- ➔ Correction of Doppler wind for DualPRF unfolding errors (Laplacian operator*)
- ➔ Calculation of azimuthal shear *correcting aliasing*

DualPRF unfolding

Combine long range and large measurement inter-vall of Doppler velocities by means of DualPRF mode



For DWD Doppler scan (1200/800Hz):

$V_{ext. Nyquist}$ = 32 m/s

$Range_{max}$ = 124 km

Assumption: $V_1 \approx V_2$

→ derive V_e

→ replace V_2 by $V_{2,e} = V_2 + n\, V_{2n}$

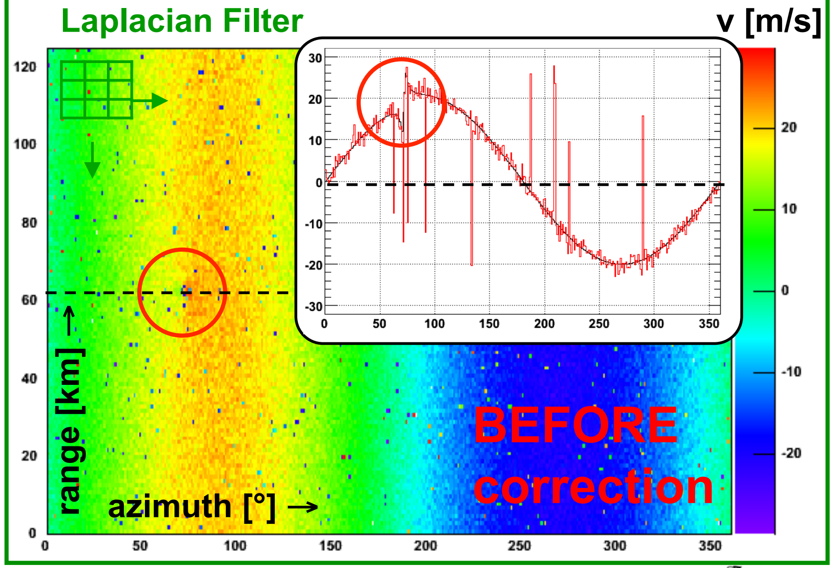
ERROR if $v_1 \neq v_2$ (tolerance of 5.3 m/s exceeded)

*P. Joe, P. T. May: *Correction of Dual PRF Velocity Errors for Operational Doppler Weather Radars* J. Atmos. Oceanic Technol., 20, 429–442, 2003.

Correction*

Simulated Data:

Meso Vortex superimposed on uni-directional wind field, Gaussian noise added, DualPRF 1200/800Hz



MDA – Processing

Doppler Data Preproc. and Program Flow

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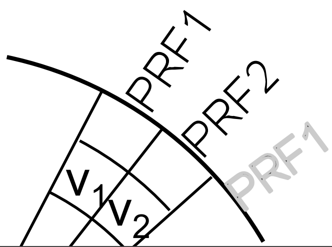

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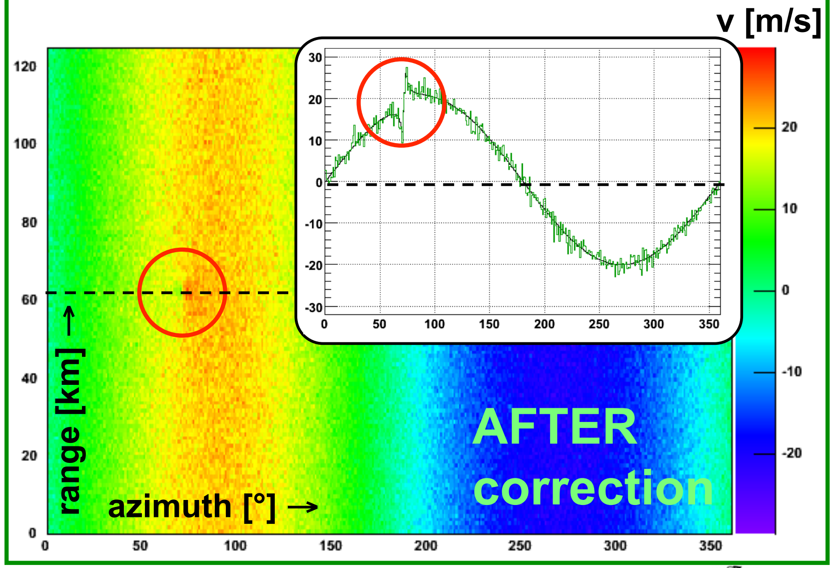


MDA – Processing
Doppler Data Preproc. and Program Flow

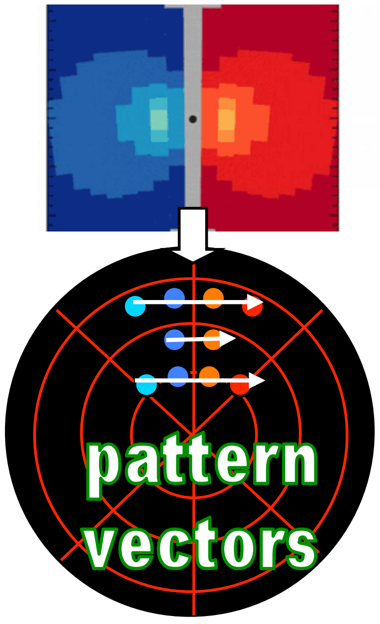
Doppler Data Preprocessing

- Correction of Doppler wind for DualPRF unfolding errors (Laplacian operator)
- Calculation of azimuthal shear *correcting aliasing*

MDA*

Pattern vectors

- Search for pattern vectors, i.e.sequences of significant, positive azimuthal shear
- Filter pattern vectors (momentum and shear thresholds)



Single sweep, 2D-plot

*basic algorithm described in:

D.S. Zrnic, D.W. Burgess and L.D. Hennington
Automatic Detection of Mesocyclonic Shear with Doppler Radar
J. Atmos. Oceanic Technol., 2, 425–438, 1985.

MDA – Processing
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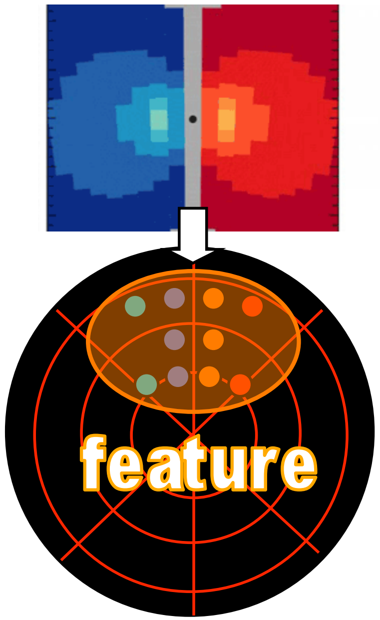
Features

- Group pattern vectors to features
- Filter features (no. of pattern vectors, symmetry criteria)



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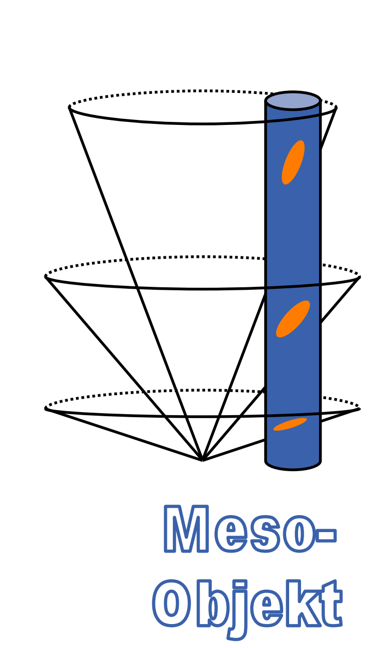
Features

- ➔ Group pattern vectors to features
- ➔ Filter features (no. of pattern vectors, symmetry criteria)

Meso-Objects

- ➔ Group features to meso-objects
- ➔ Estimate Severity of meso-objects

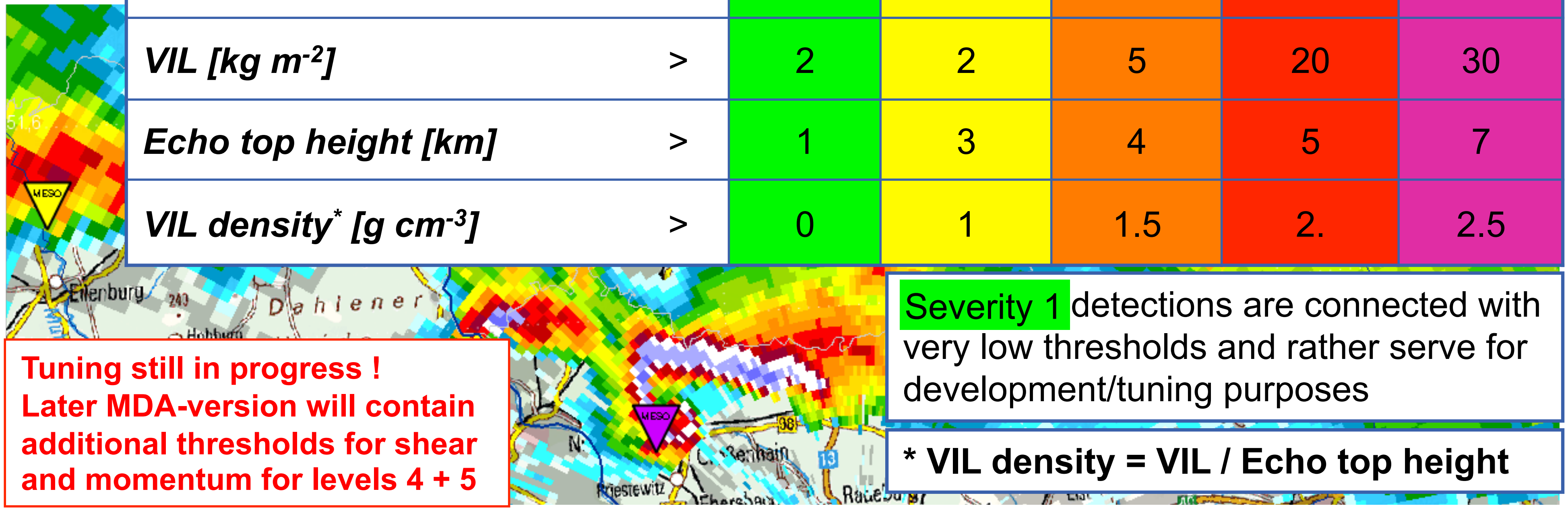


Group of sweeps, 3D-plot

MDA – Processing
Severity Calculation

Severity-Level		1	2	3	4	5
Max. reflectivity [dBZ]	≥	10	30	40	50	55
Avg. Reflectivity [dBZ]	≥	10	20	25	35	40
Height above ground [km]	≤	5	3	2.5	2	1.5
Meso-Height [km]	>	0	0	2	4	6
VIL [kg m^{-2}]	>	2	2	5	20	30
Echo top height [km]	>	1	3	4	5	7
VIL density [g cm^{-3}]*	>	0	1	1.5	2.	2.5

Quality of Detection / severity level



Severity 1 detections are connected with very low thresholds and rather serve for development/tuning purposes

Tuning still in progress !
Later MDA-version will contain additional thresholds for shear and momentum for levels 4 + 5

*** VIL density = VIL / Echo top height**

Contents

All Doppler wind plots in this section show data with applied dualPRF unfolding error correction

Supercell Großenhain
Tornado rated F3, May 24, 2010

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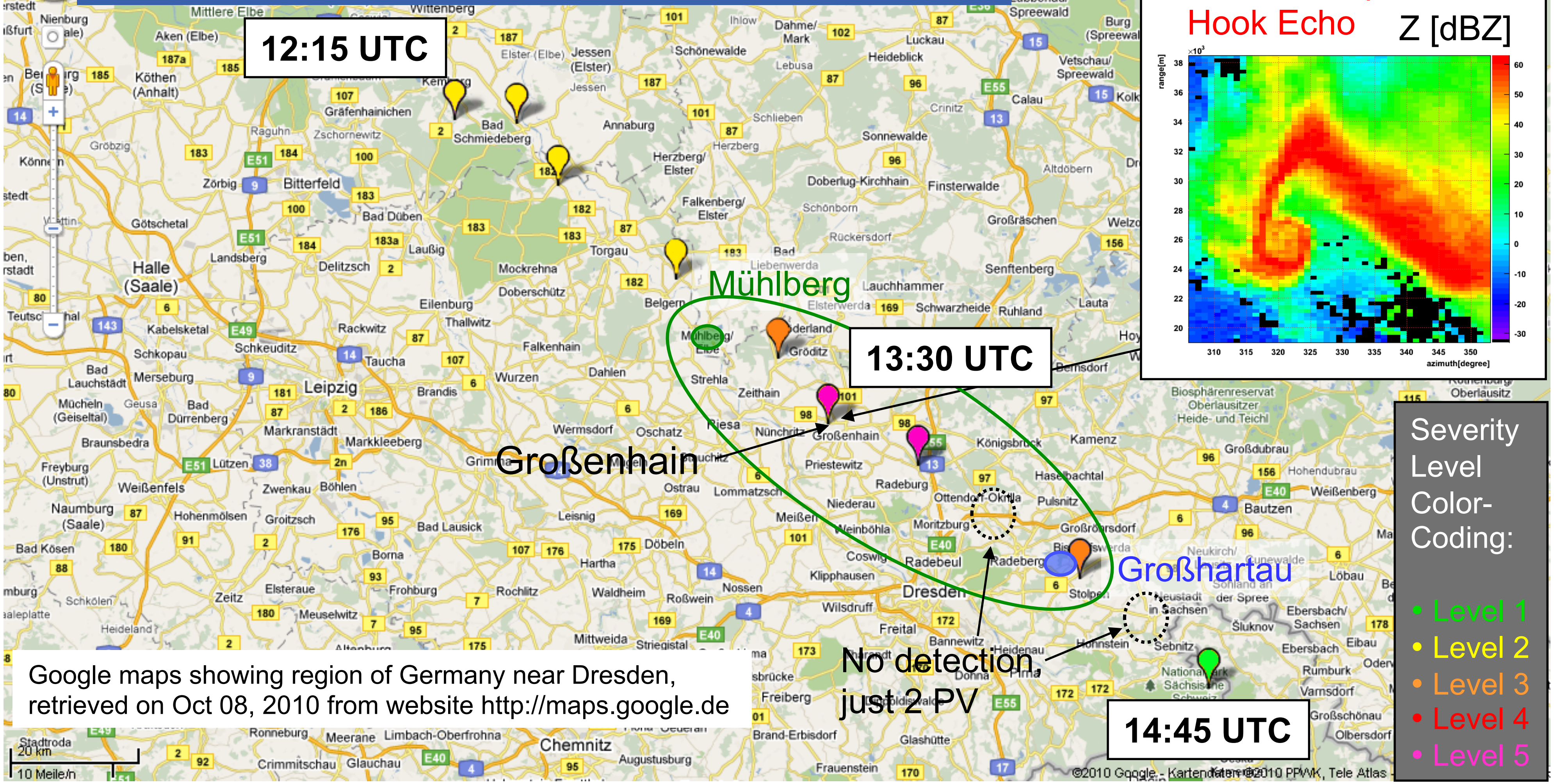
80-100 km long track of damage mainly between Mühlberg in Brandenburg and Großhartau in Saxony

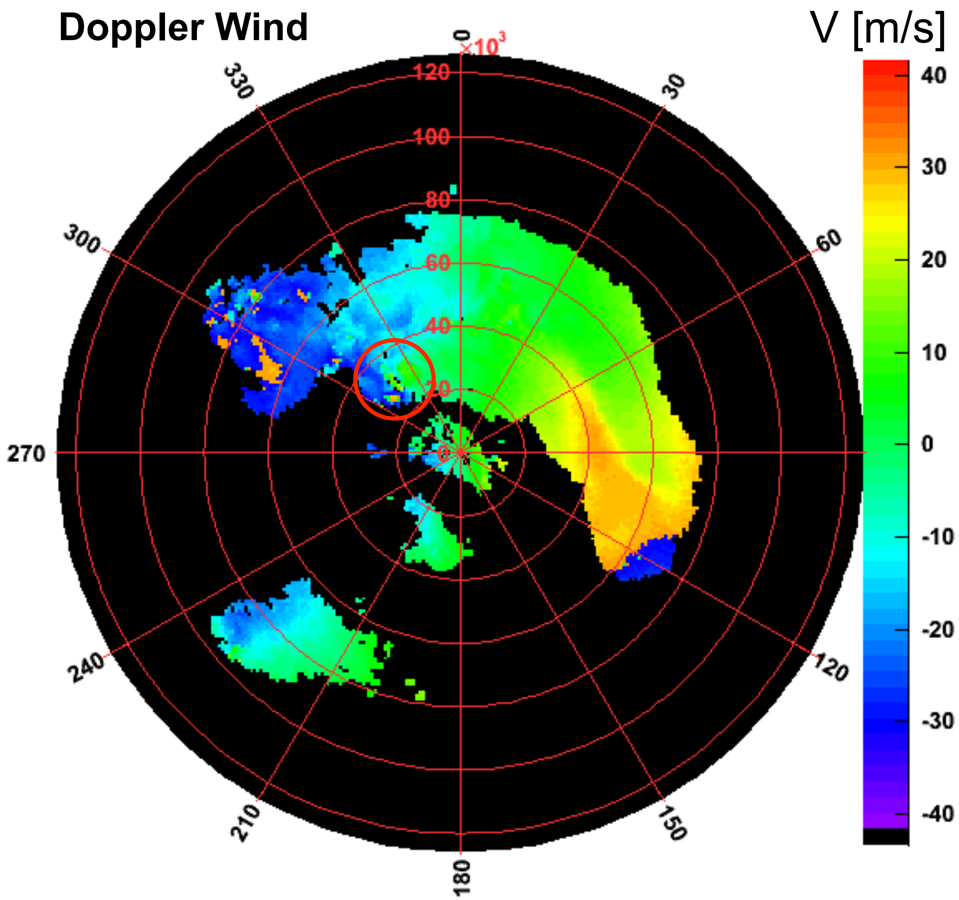


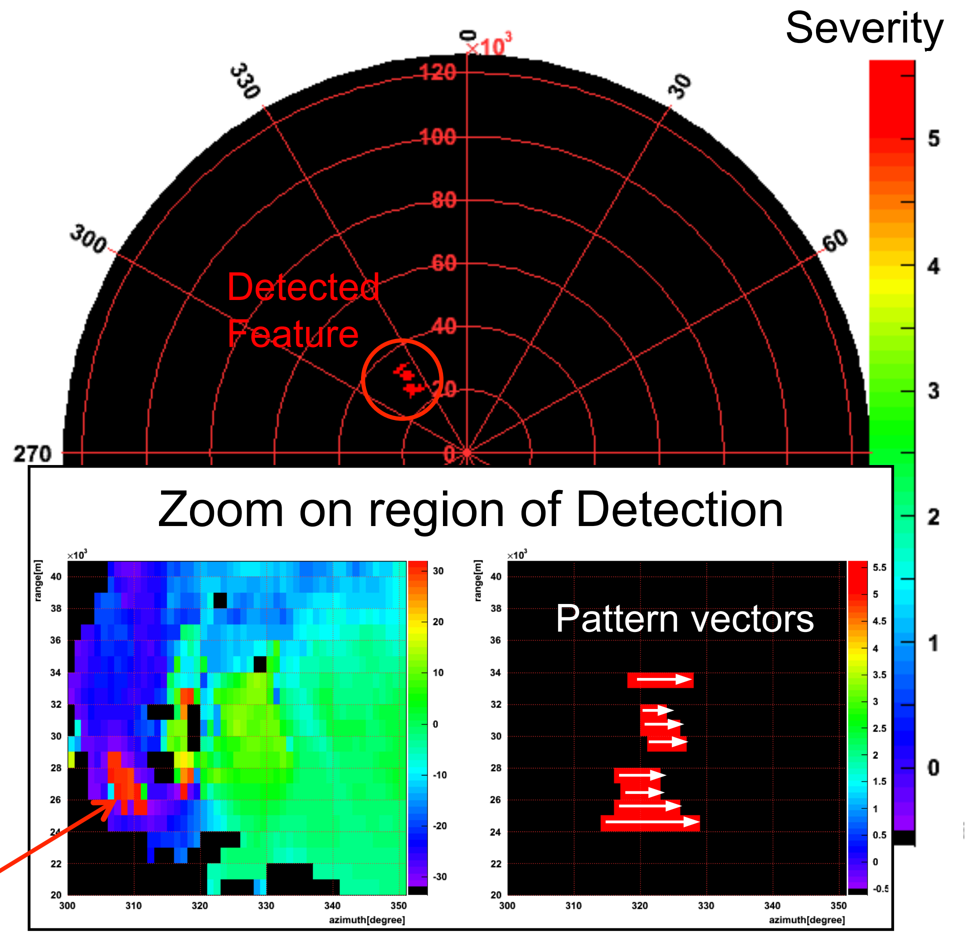
Google maps showing region of Germany near Dresden, retrieved on Oct 08, 2010 from website http://maps.google.de

Supercell Großenhain
Tornado rated F3, May 24, 2010

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Radar Dresden, 2010-05-24 13:30 UTC, Elevation 6.5°
Mesocyclonic signatures detected in 12 sweeps (Elevations 1.5°, 2.5°, 4.5-11°,15-19°)





Aliasing corrected during azim. shear calc.

Supercell Großenhain
Tornado rated F3, May 24, 2010

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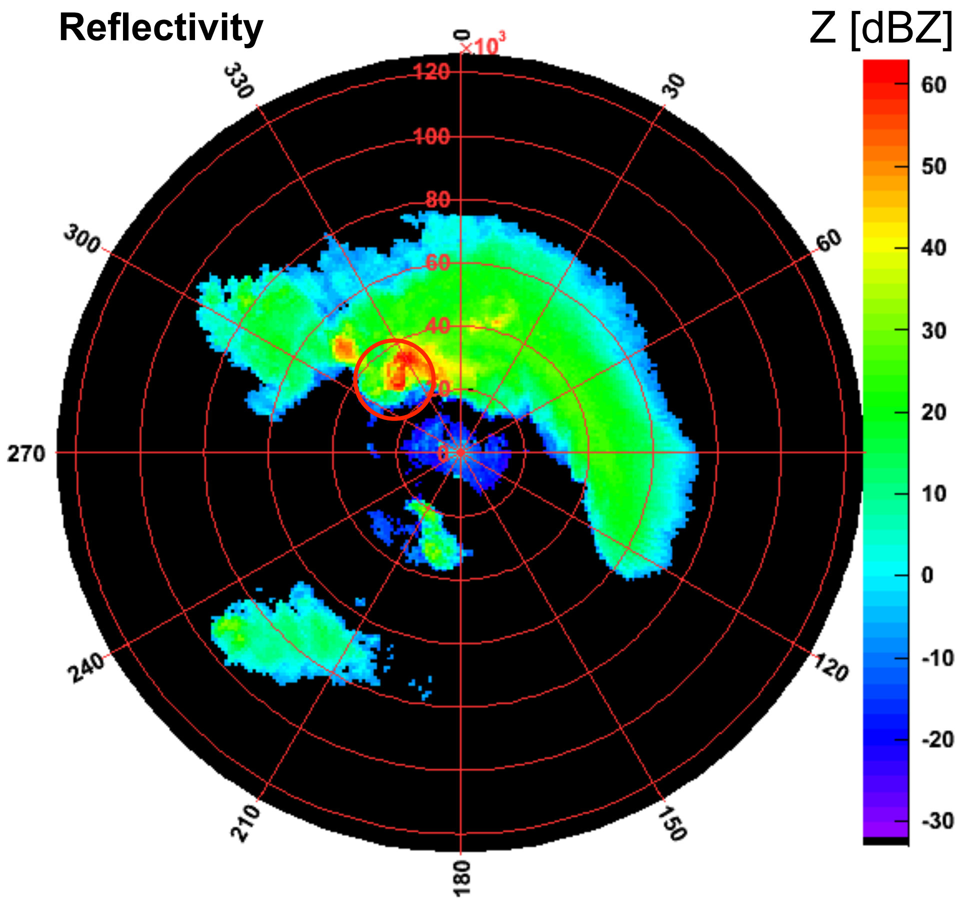
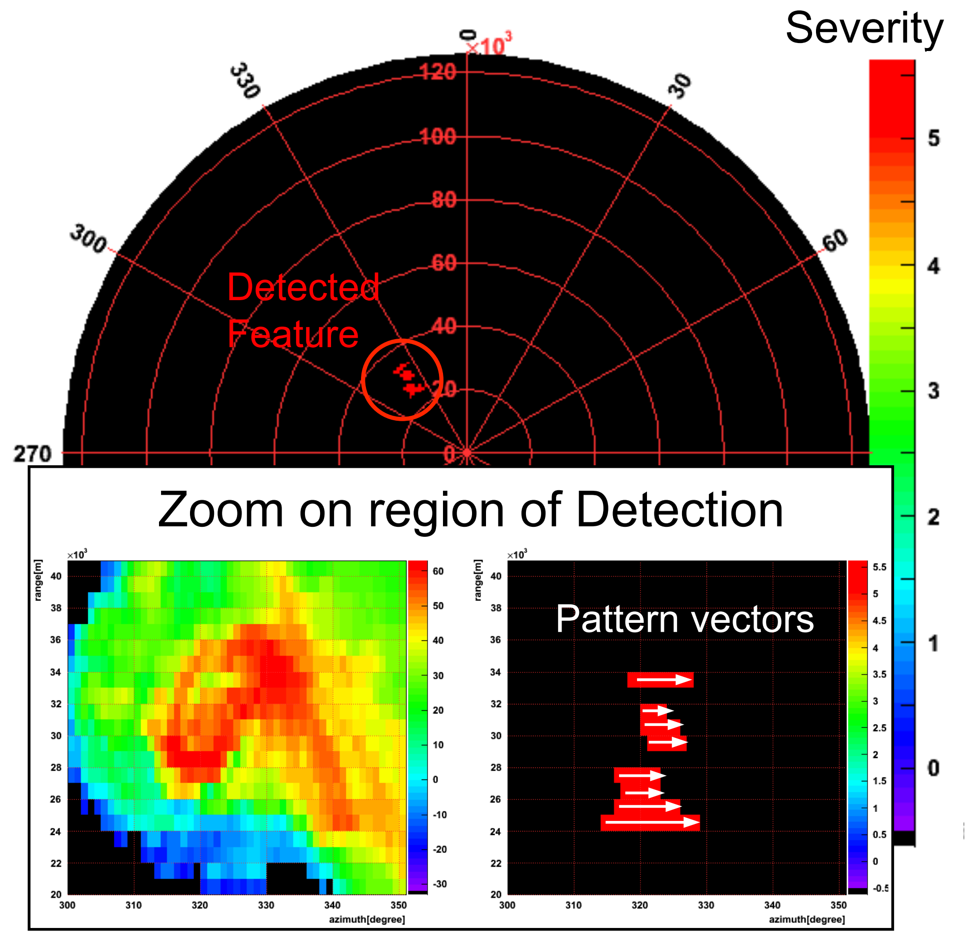
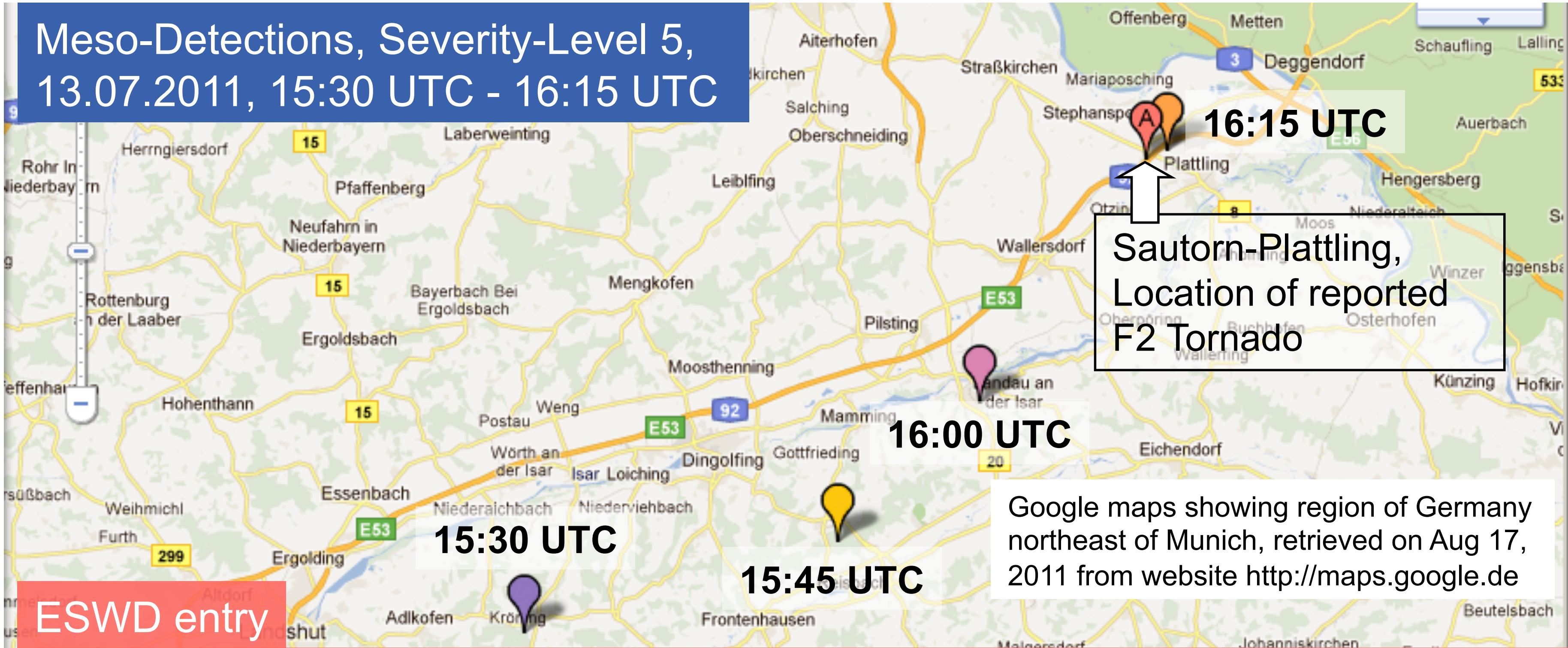




Supercell Sautorn, Bavaria
Tornado rated F2, July 13, 2011

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Meso-Detections, Severity-Level 5, 13.07.2011, 15:30 UTC - 16:15 UTC



Google maps showing region of Germany northeast of Munich, retrieved on Aug 17, 2011 from website http://maps.google.de

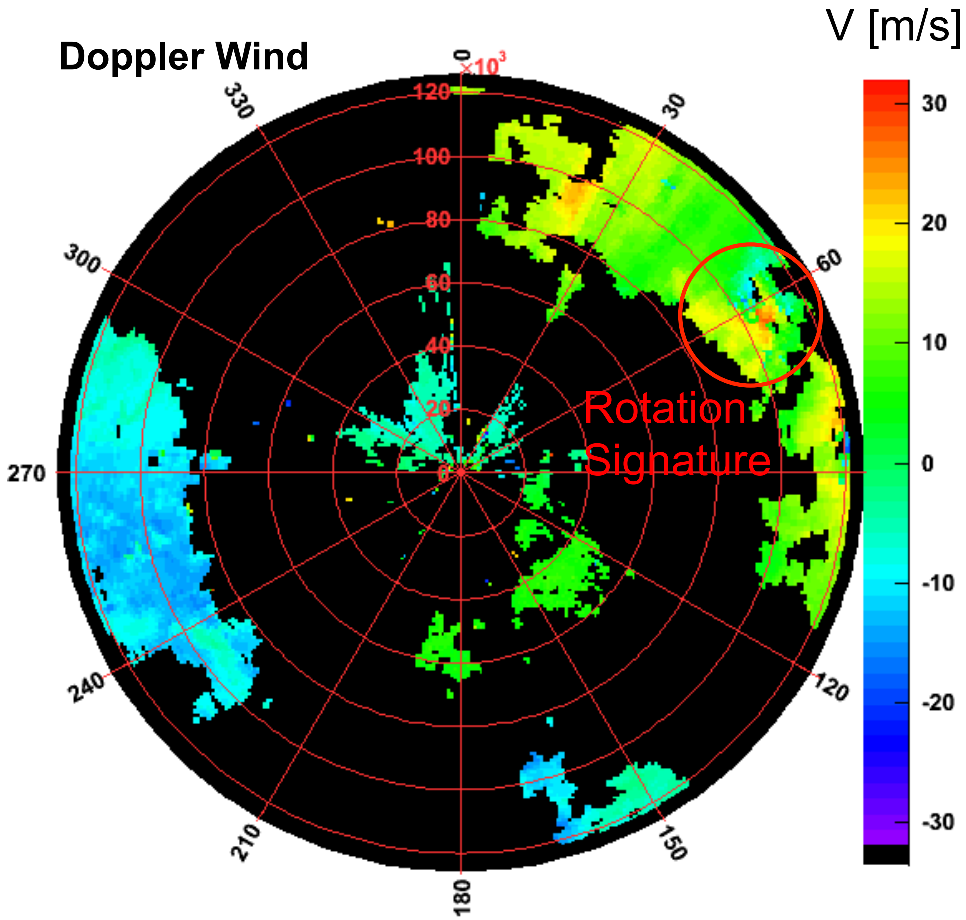
ESWD entry

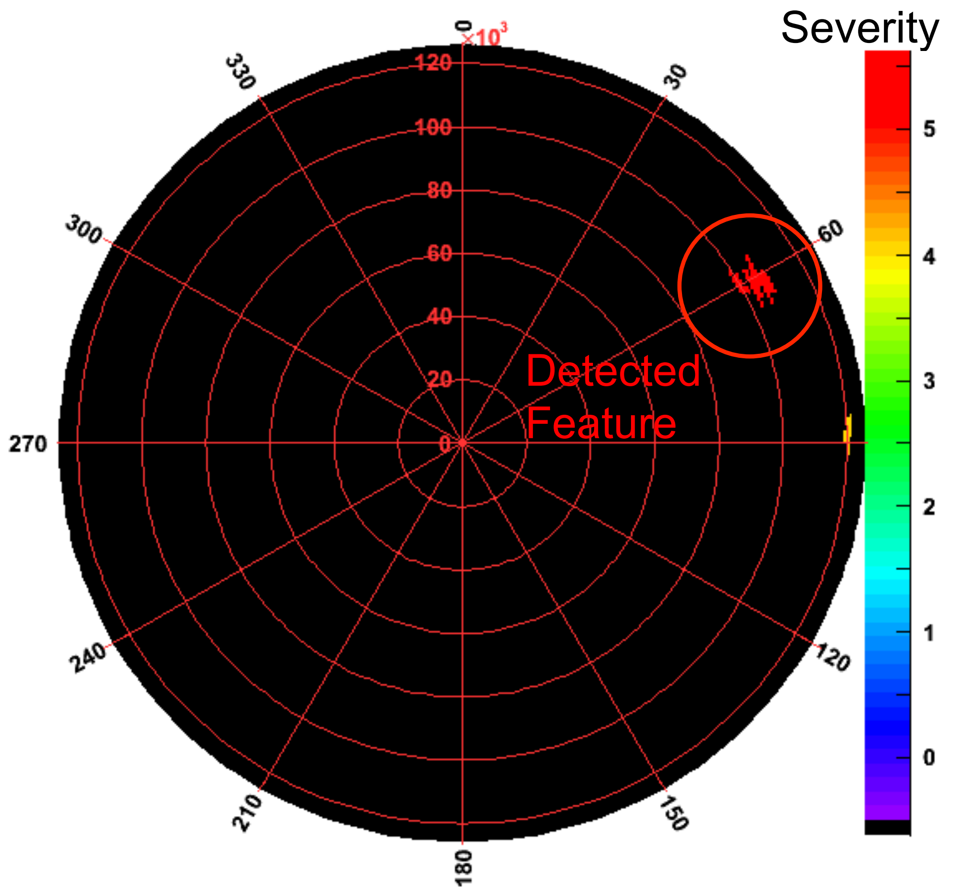
tornado	**Sautorn** Bayern **Germany** (48.78 N, 12.82 E) **13-07-2011** (Wednesday) **16:00** UTC (+/- 1 hrs.)	based on: information from an eye-witness report, photograph(s) and/or video footage of the inflicted damage, a report on a website, a damage survey by a severe weather expert, an eyewitness report of the damage occurring over: land land use where event was first observed: land intensity: **F2 T4** the intensity rating was based on a damage survey by a severe weather expert, photograph(s) and/or video footage of the inflicted damage, an eyewitness report of the damage. path length: 1 km *tornado caused damages in Sautorn village; brick-barn downed / destroyed; roofs blown away; lorry blown off; source: TORNADLISTE; http://www.tornadoliste.de/110713sautorn.htm* report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]

Supercell Sautorn, Bavaria
Tornado rated F2, July 13, 2011

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Radar Munich, 2011-07-13 16:15 UTC, Elevation 0.5°





Supercell Sautorn, Bavaria
Tornado rated F2, July 13, 2011

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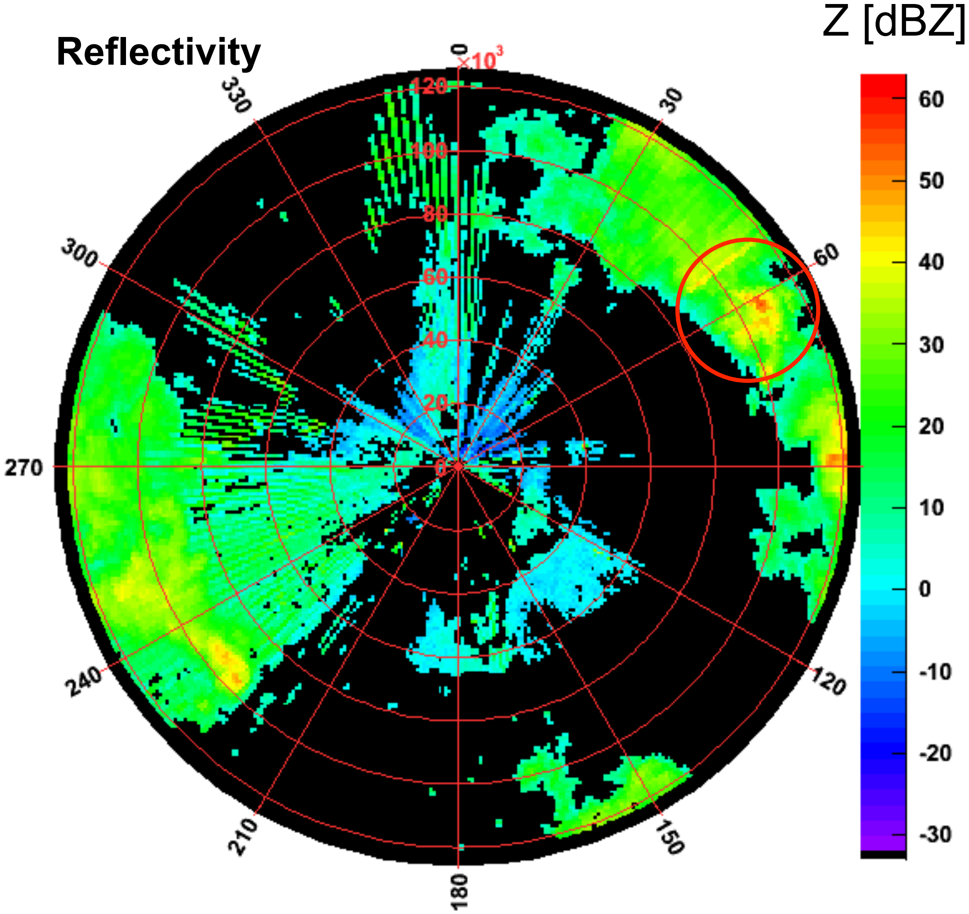
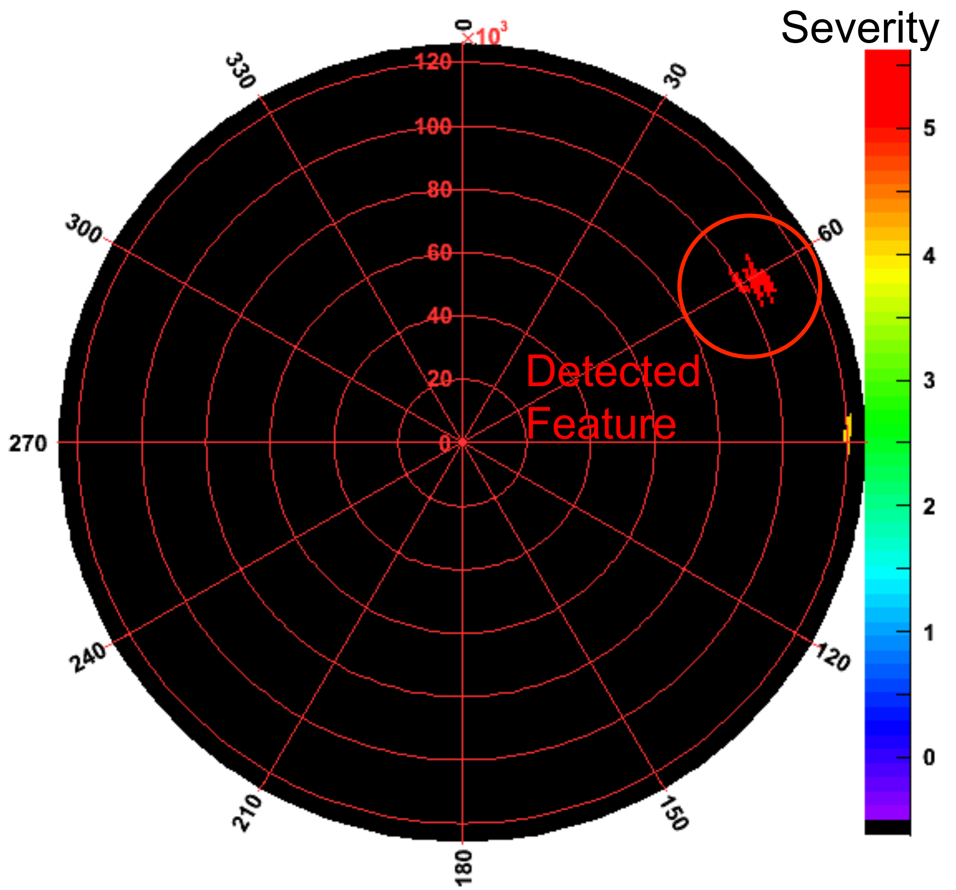
Radar Munich, 2011-07-13 16:15 UTC, Elevation 0.5°





MDA – verified detections 2011

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

#	date	Region	Comment
1	2011-05-31	Brandenburg	Supercell mesocyclone
2	2011-06-06	Allgäu, Nordeifel	Supercell mesocyclone
3	2011-06-16	Central Franconia, Passau	Supercell mesocyclone
4	2011-06-22	Alps (Rosenheim)	Supercell mesocyclone
5	2011-07-12	Baden-Württemberg	Supercell mesocyclone
6	2011-07-13	East from Munich to Bavarian Forest	Supercell mesocyclone, F2 tornado at Sautorn
7	2011-07-19	Munich	Supercell mesocyclone
8	2011-08-14	Bavaria, Danube	Supercell mesocyclone
9	2011-08-18	North Rhine-Westphalia	Mesocyclone at southern end of squall line
10	2011-08-24	Central Hesse, Berlin	Supercell in Hesse (hail ∅ 4cm), splitting supercell close to Berlin
11	2011-09-02	South of Stuttgart	Supercell mesocyclone
12	2011-09-04	Ravensburg	HP-supercell (hail ∅ 4 cm, 100 mm precipitation)
13	2011-09-11	Harz Mountains (Elsnigk, Bernburg), Würzburg, Kassel, Eberswalde	Several supercells, F2 tornado at Bernburg

Outlook

RADSYS-E (exchange of DWD radar network 2010-14: modern dual-polarized C-band Doppler radars, 17 operational systems)

- ➔ Better quality of Doppler data from new radar systems expected (less noise)
- ➔ Usage of new products for better severity estimation (e.g. hydrometeor classification → identification of hail core)

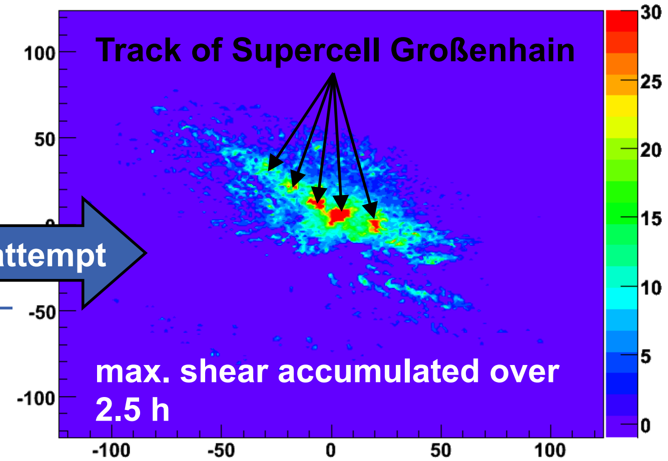
Change of scan-strategy

- ➔ Higher temporal and range resolution (→ better tracking)
- ➔ Use *unfiltered* data and supply threshold parameters (e.g. SQI) for special application based settings instead of using filtered data (→ avoid „filter holes“)

Further development

- ➔ Extension of KONRAD (SCIT) to KONRAD3D, linking of MDA to cell detection
- ➔ Consideration of near Storm environment (shear, CAPE from model)
- ➔ Calculation of Rotation tracks (see NSSL*) as further to judge plausability of mesocyclone detections

first attempt



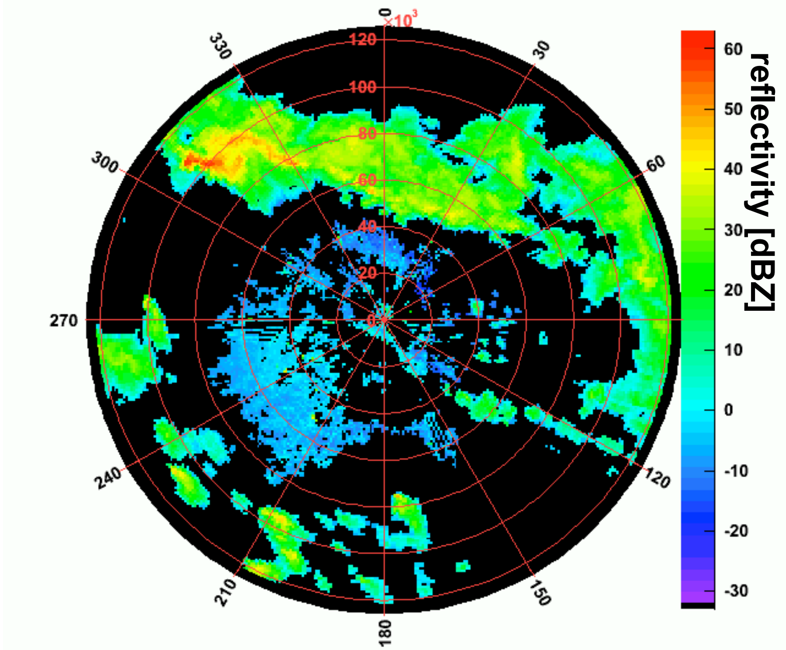
* T. M. Smith, K. L. Elmore: *The Use of Radial Velocity Derivatives to Diagnose Rotation and Divergence,* 11th Conference on Aviation, Range, and Aerospace Meteorology

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Outlook

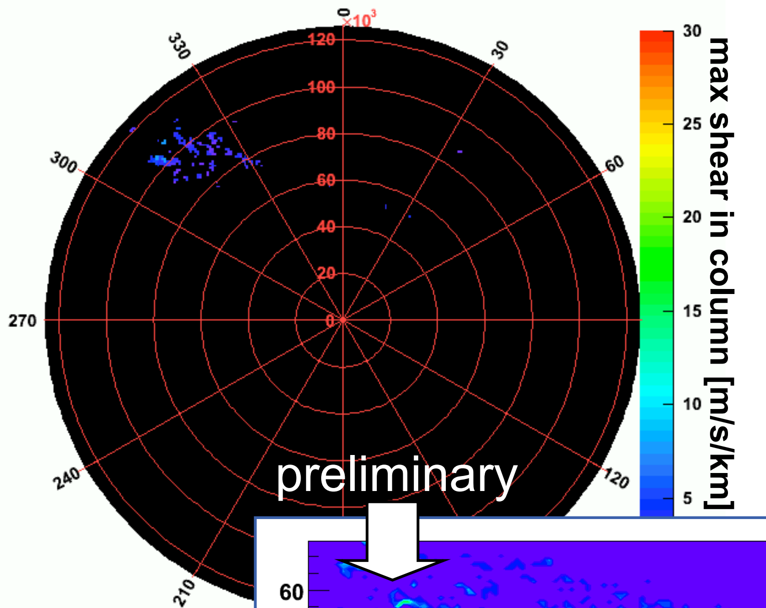
Supercell Großenhain, Radar Dresden, 24 May, 2010, 12:15 UTC – 14:45 UTC

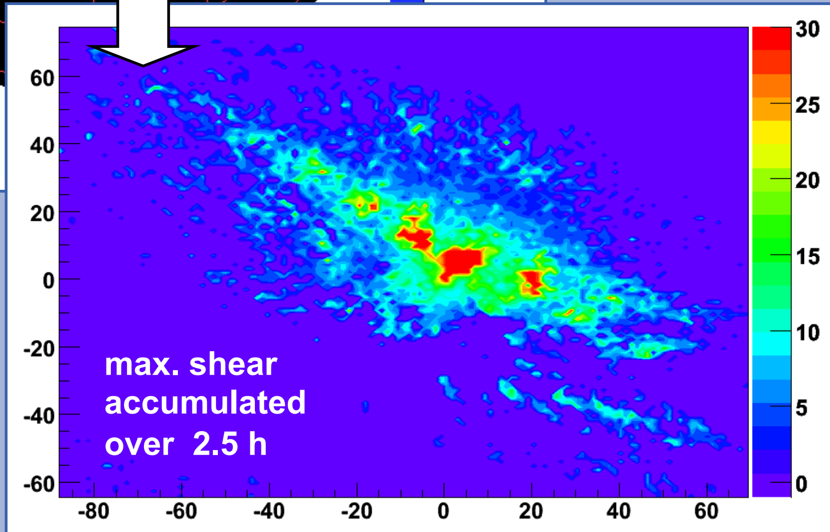
ID / Time: VOL_10488_17_20100524_1215



Reflectivity [dBZ], elevation 0.5°

Maximum shear in column





Thank you for your attention!