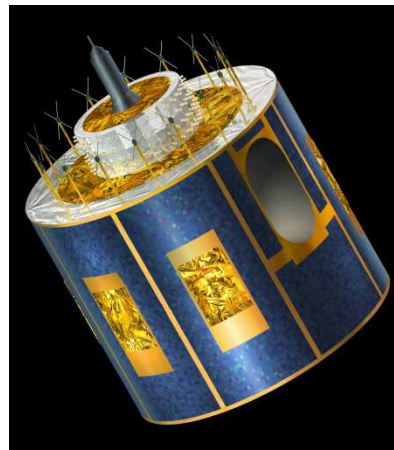


Synergetic use of multi-sensor data



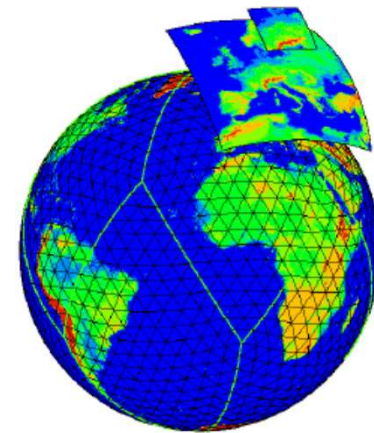
Polarimetric X-Band Radar Bonn



MSG



Lightning detection NETwork



Numerical Weather Prediction

Kathrin Wapler

Hans-Ertel-Zentrum für Wetterforschung, Deutscher Wetterdienst

Objectives

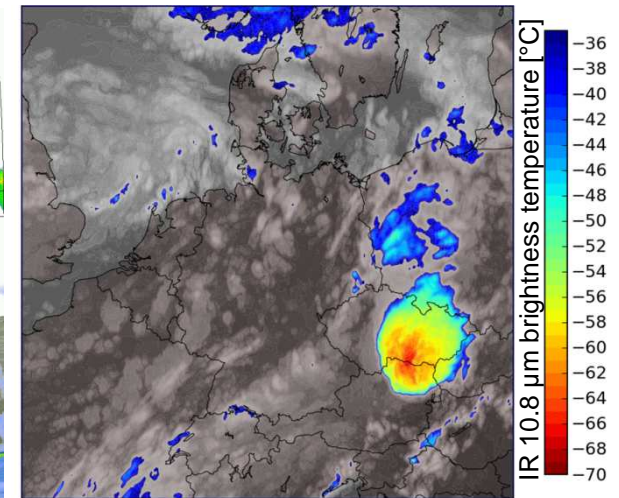
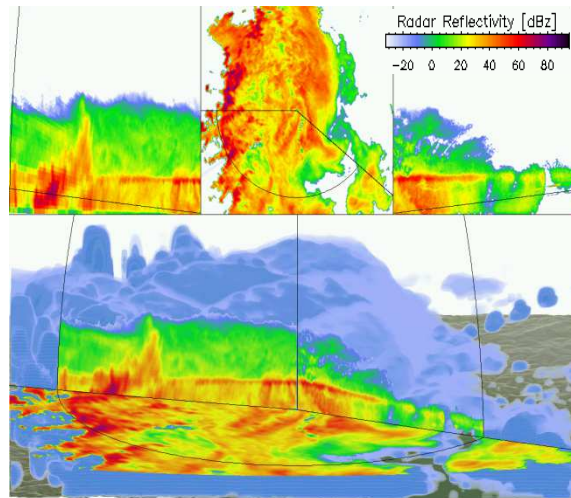
- What are the goals of the project “Object-based Analysis and SEamless prediction”?
- Where do thunderstorms occur in Germany and when?
- What are typical life cycles of convective events?
- How good are convective systems represented in high-resolution NWP?

Object-based Analysis and Seamless prediction

Kathrin Wapler, Silke Trömel, Theresa Bick, Malte Diederich, Ákos Horváth,
Fabian Senf, Jürgen Simon, *Felix Dietzsch, Christopher Frank, Sebastian
Kiefer, Benedikt Nonnen, Martin Rempel, Michael Ziegert*



Picture taken from: www.spc.noaa.gov

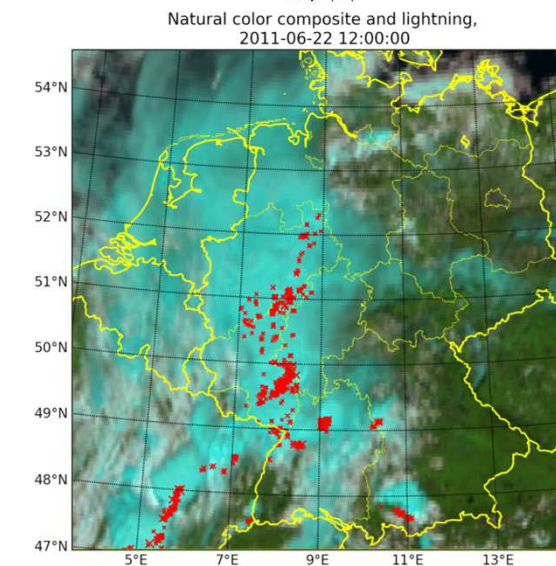
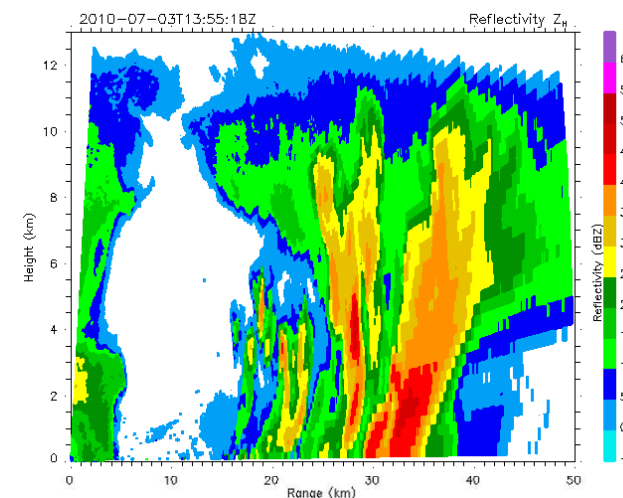


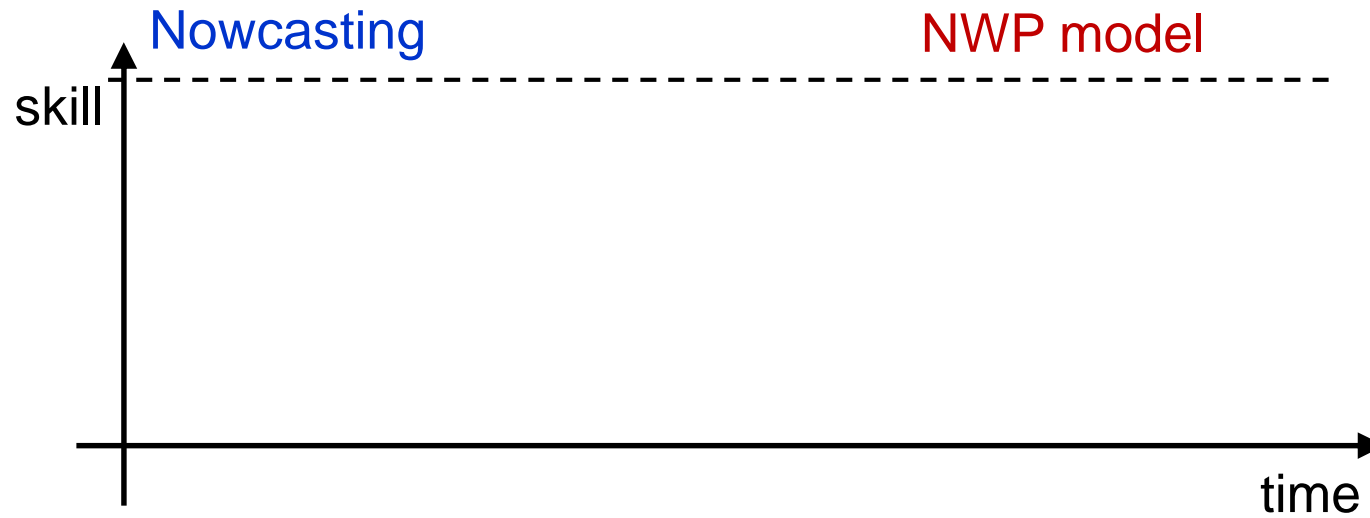
Project objectives

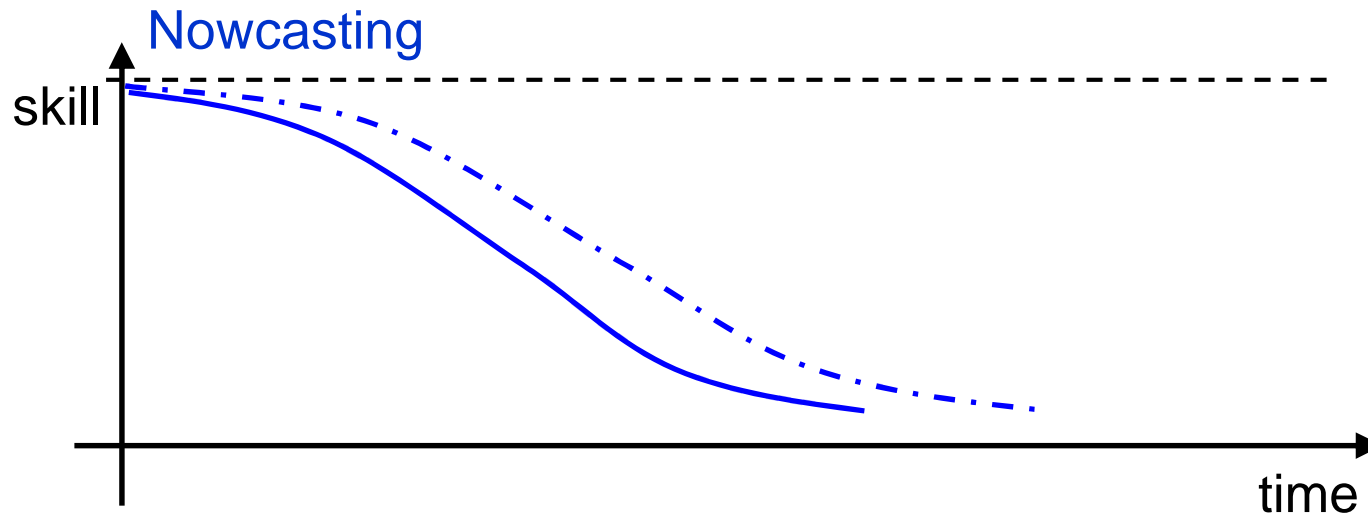
- ⇒ Better understanding, characterization and quantification of process structure and life cycles of severe weather events
- ⇒ First steps towards seamless prediction of convective events

Project components

- High-resolution 3D radar/satellite composite
- Object-based weather analysis
- 3D tracking algorithm
- High-resolution model-based ensemble generation and prediction
- Analysis of extreme weather events

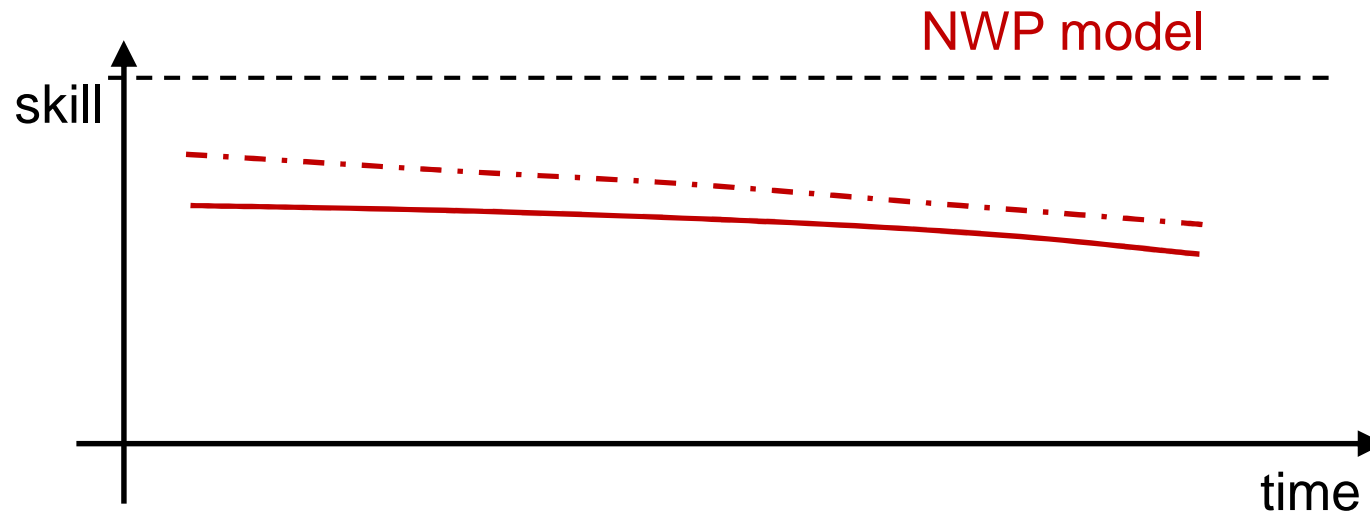






Improved probabilistic nowcasting based on:

- comprehensive multi-sensor data set
- included life-cycle effects in addition to advection-based nowcasting
- novel tracking algorithm



Improved NWP based on:

- comprehensive multi-sensor data set
- LETKF with very rapid update cycle
- improved understanding of model errors through object-based evaluation

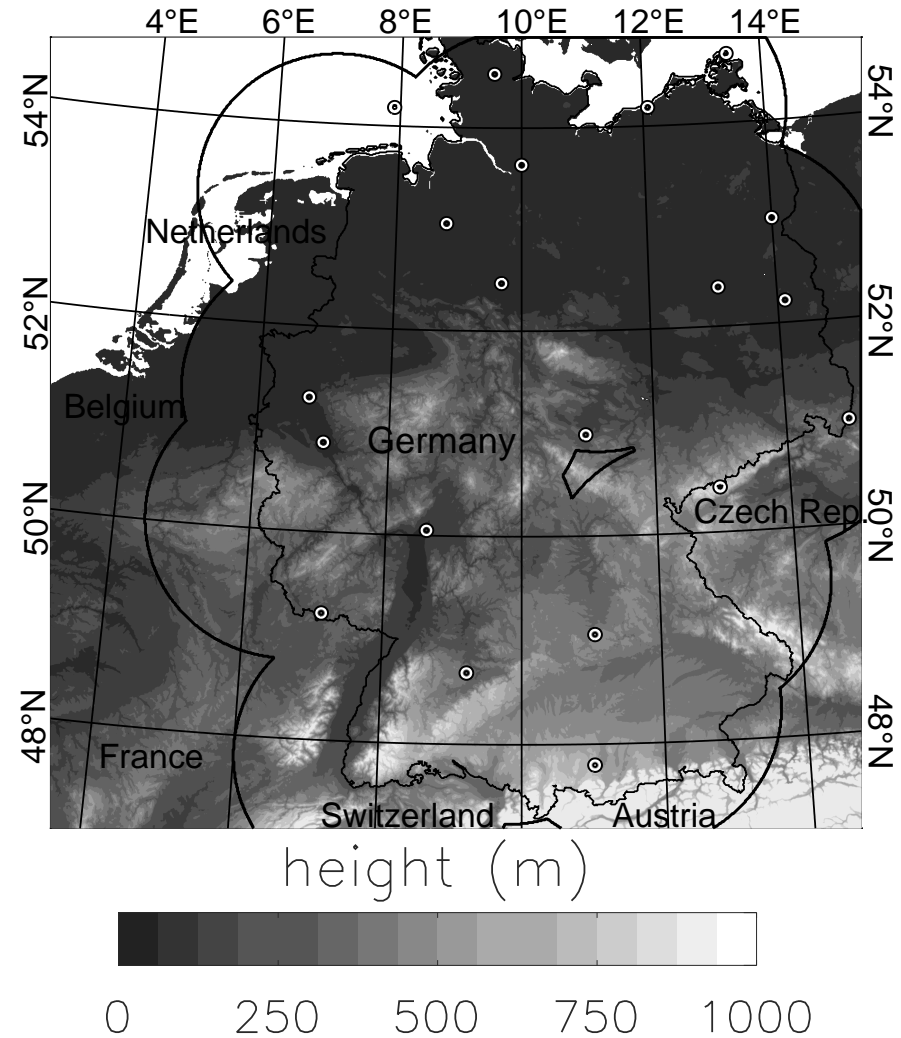
Objectives

- What are the project goals of HErZ Branch 1?
- **Where do thunderstorms occur in Germany and when?**
 - How often is a certain area affected by thunderstorms?
 - Under which synoptical conditions do thunderstorms occur?
 - How do thunderstorm characteristics differ?
- What are typical life cycles of convective events?
- How good are convective systems represented in high-resolution NWP?



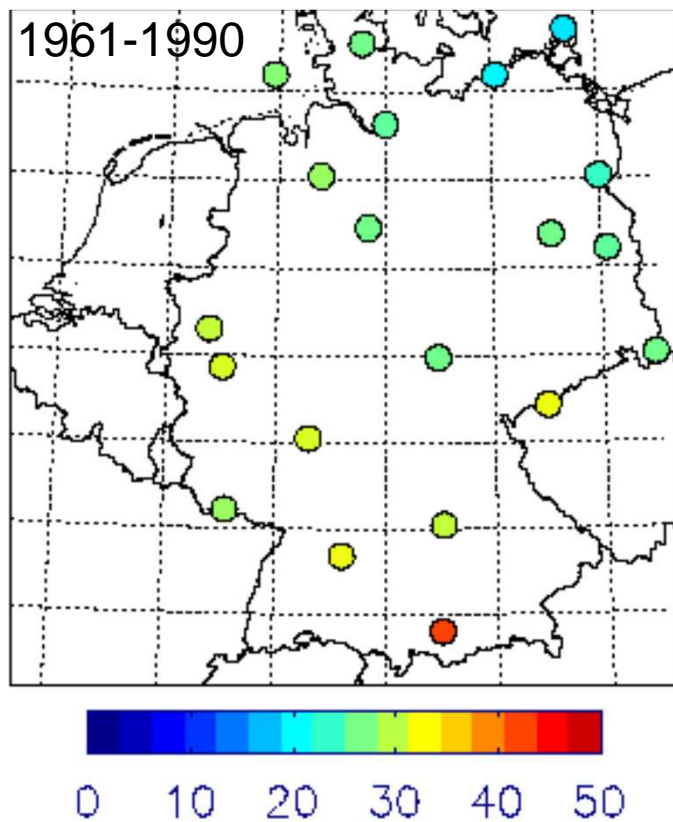
Data

- Lightning detection network LINET:
 - 2007 – 2012
 - 36 million strokes
 - Mapped on a 1 km * 1km grid
- Human thunderstorm observations:
 - 20 weather stations
 - 1961-2012

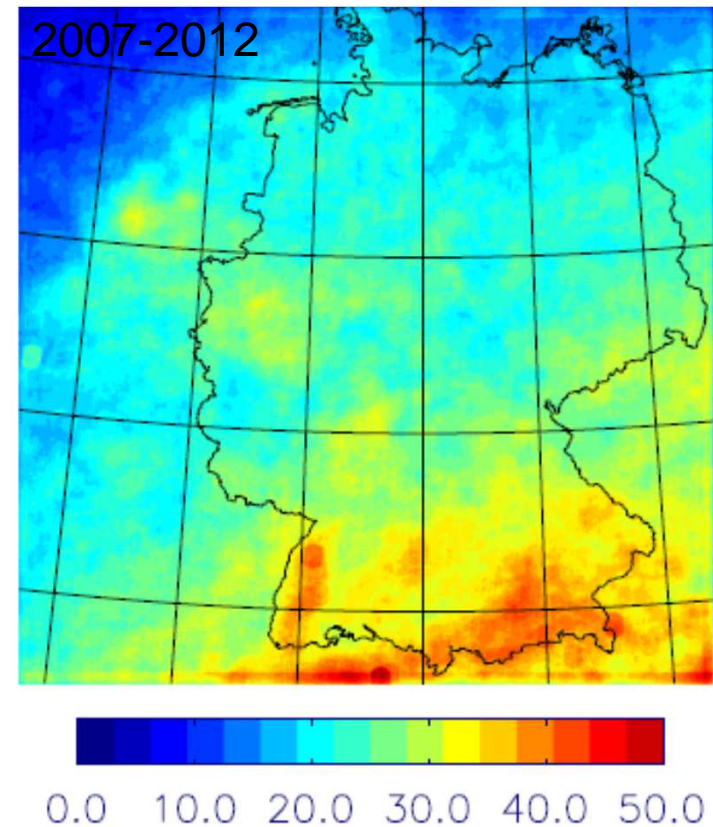


Spatial distribution

Mean annual number of
days with thunderstorm



Mean annual number of
days with >2 strokes <15km



Data

- Lightning detection network LINET
- Human thunderstorm observations
- Classification of synoptic weather regimes:
 - extended from James 2007 (based on widely used Grosswetterlagen (GWL) series of Hess and Brezowsky 1952)
 - readily identifiable large-scale circulation patterns over Europe
 - using mean-sea-level pressure, 500hPa geopotential height, 500-1000hPa rel. thickness, total water column
 - calculated daily based on NWP analysis
 - 29 classes

Synoptical classification

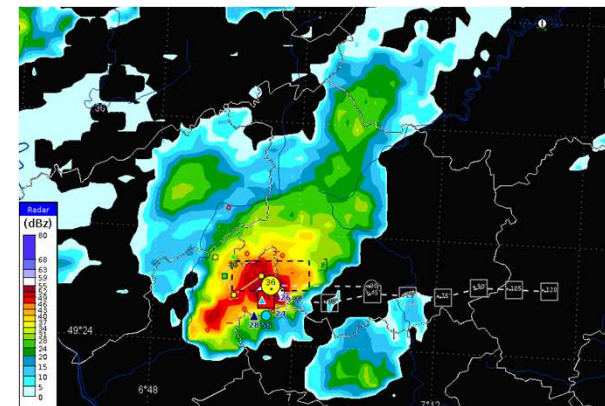
31	Wa	Anticyclonic Westerly
77	Wz	Cyclonic Westerly
46	Ws	South-Shifted Cyclonic Westerly
56	Ww	Maritime Westerly (Block E.Europe)
35	SWa	Anticyclonic South-Westerly
85	SWz	Cyclonic South-Westerly
44	NWa	Anticyclonic North-Westerly
56	NWz	Cyclonic North-Westerly
21	HM	High over Central Europe
40	BM	Zonal Ridge across Central Europe
49	TM	Low over Central Europe
21	Na	Anticyclonic Northerly
8	Nz	Cyclonic Northerly
21	HNa	High Norwegian Sea, Ridge C.Europe
44	HNz	High Norwegian Sea, Trough C.Europe

27	HB	High over the British Isles
62	TrM	Trough over Central Europe
26	NEa	Anticyclonic North-Easterly
38	NEz	Cyclonic North-Easterly
25	HFa	Scandinavian High, Ridge C.Europe
23	HFz	Scandinavian High, Trough C.Europe
22	HNFa	High Norw. Sea to Finland, Ridge C.Eur.
28	HNFz	High Norw. Sea to Finland, Trough C.Eur.
49	SEa	Anticyclonic South-Easterly
7	SEz	Cyclonic South-Easterly
28	Sa	Anticyclonic Southerly
31	Sz	Cyclonic Southerly
39	TB	Low over the British Isles
59	TrW	Trough over Western Europe

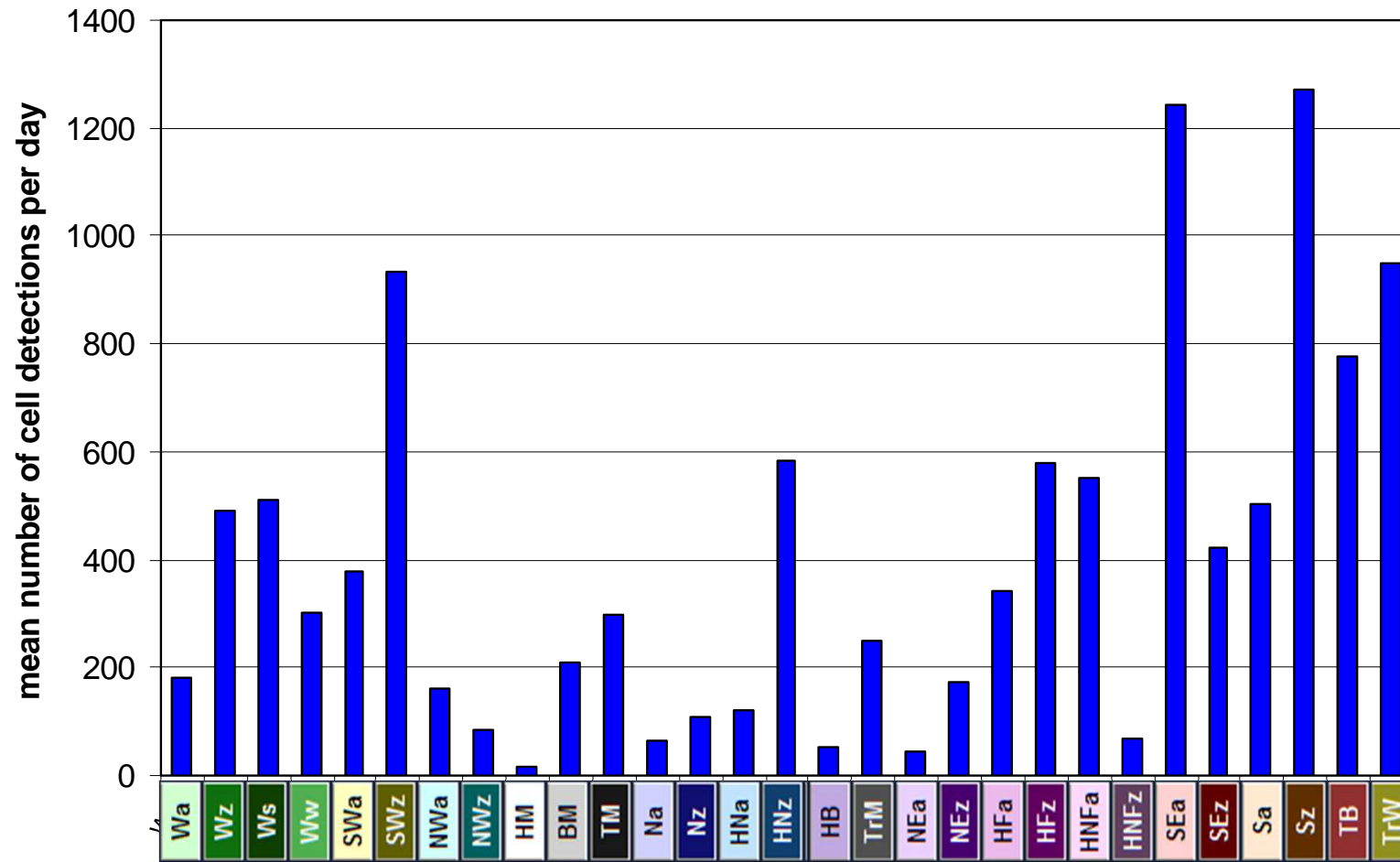


Data

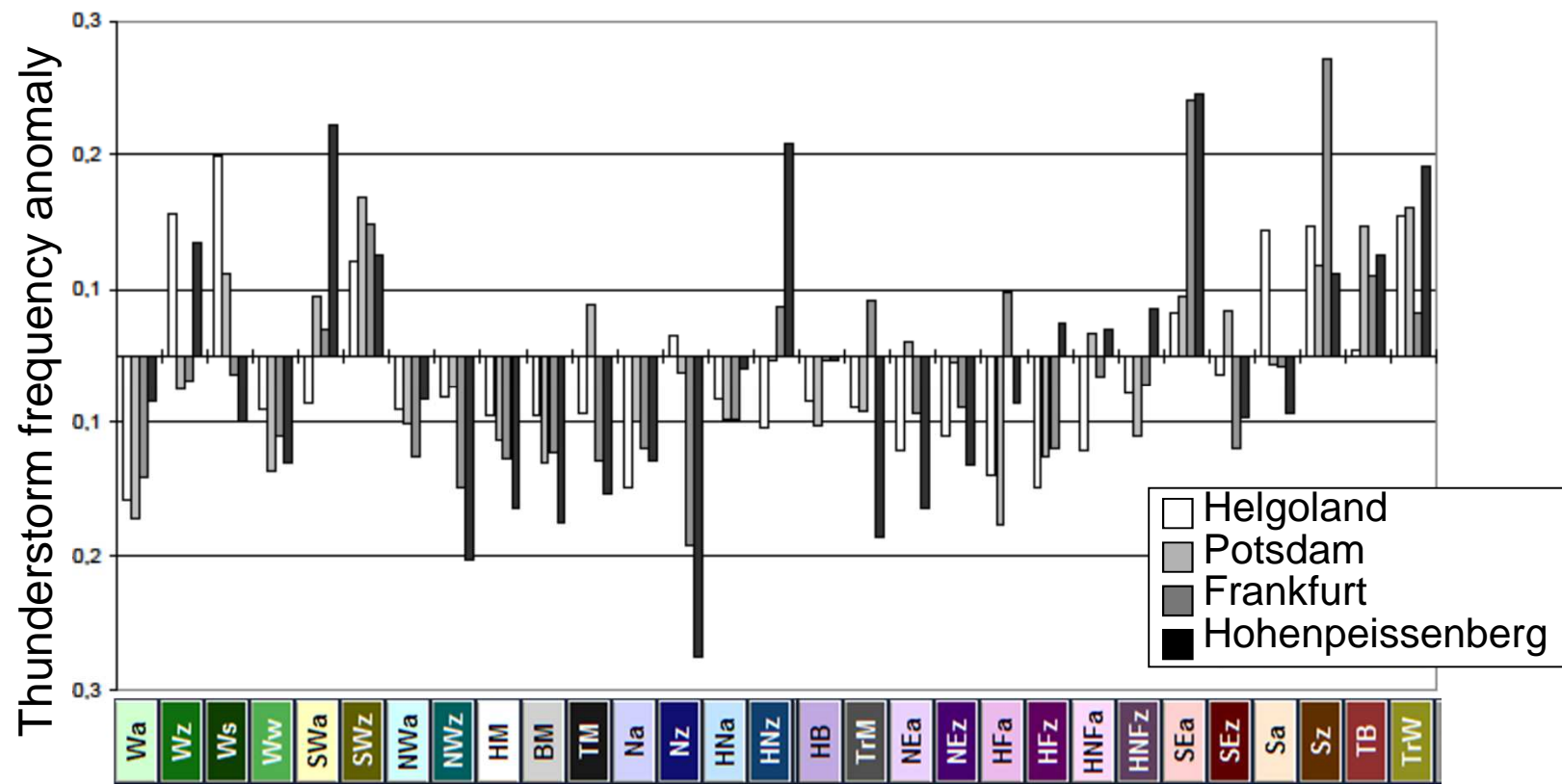
- Lightning detection network LINET
- Human thunderstorm observations
- Classification of synoptic weather regimes
- Cell detection KONRAD:
 - $15 \text{ km}^2 \geq 46 \text{ dBZ}$ in 2D radar reflectivity
 - Analysis interval 5-min



Thunderstorm activity vs synoptic pattern



Thunderstorm activity vs synoptic pattern



Summary – thunderstorm occurrence

- **While mesoscale processes are associated with the impact itself, it is the synoptical situation that creates the environment for such events.**
 - **Analysis reveals conditions favourable for thunderstorm development and highlights regions affected under different flow regimes.**
 - **Differing thunderstorm characteristics under different flow regimes.**
- ➔ **may support a better understanding of thunderstorm formation as well as improve forecaster's situational awareness.**

WAPLER, K., 2013: High-resolution climatology of lightning characteristics within central Europe. *MAP*, 122: 175-184.
WAPLER, K. and P. JAMES, 2013: Thunderstorm occurrence and characteristics in Central Europe under different synoptical conditions. *Atmos. Res.*, *submitted*.

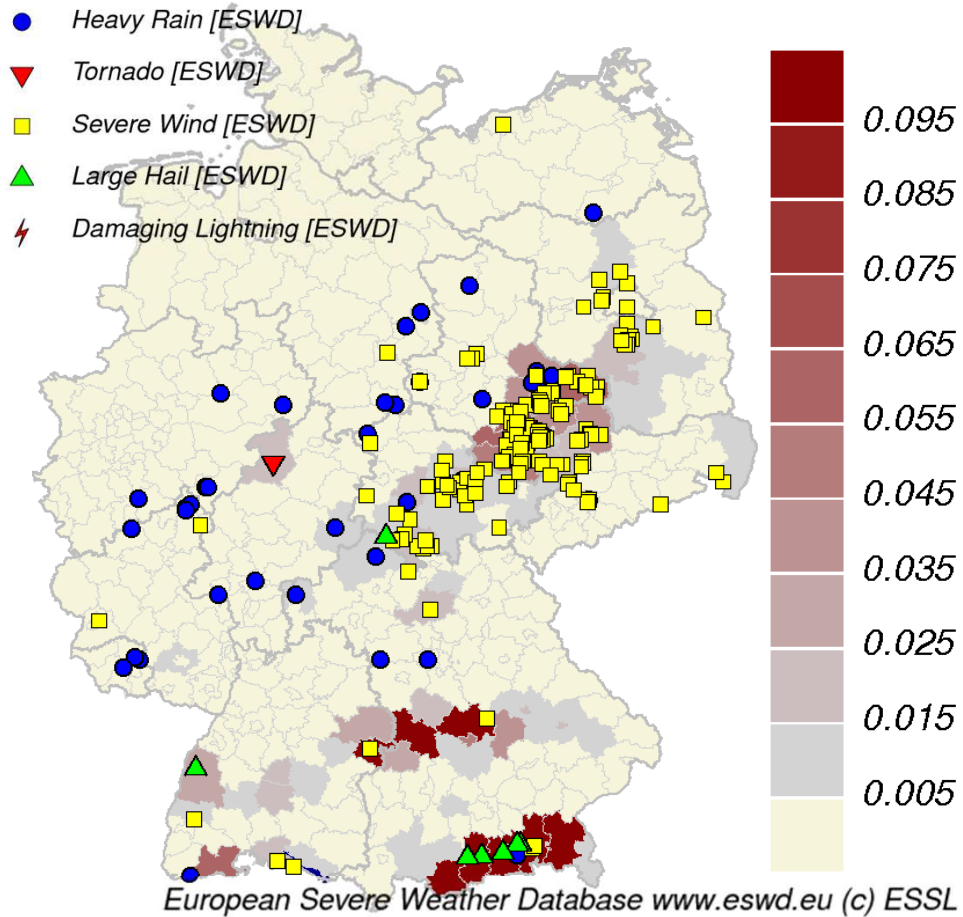


Objectives

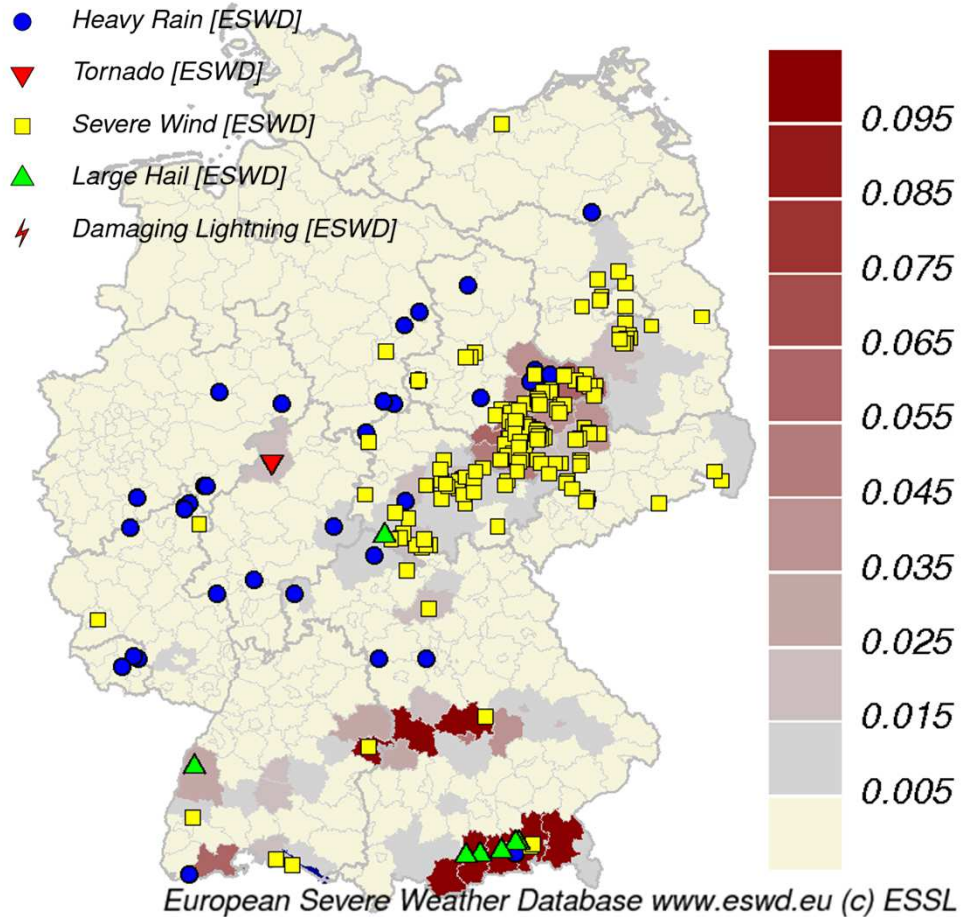
- What are the project goals of HErZ Branch 1?
- Where do thunderstorms occur in Germany and when?
- **What are typical life cycles of convective events?**
 - What are parameters that have predictive skill for nowcasting?
 - What can we learn from a multi-sensor approach?
- How good are convective systems represented in high-resolution NWP?



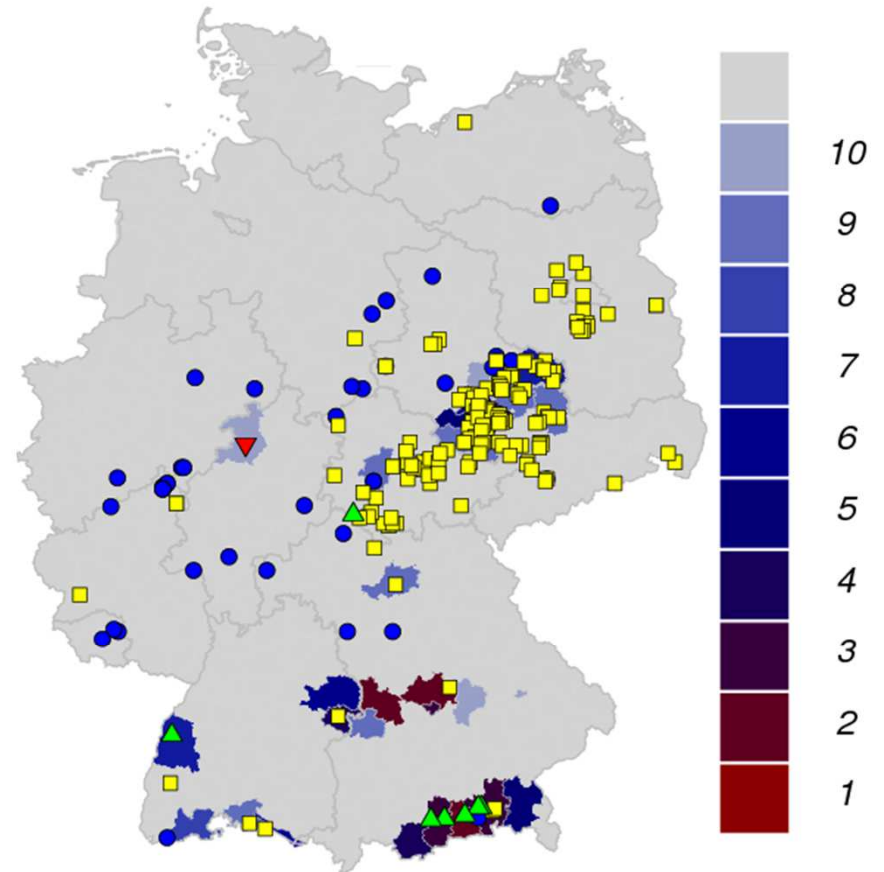
22 June 2011 ESWD and occurred losses [%]



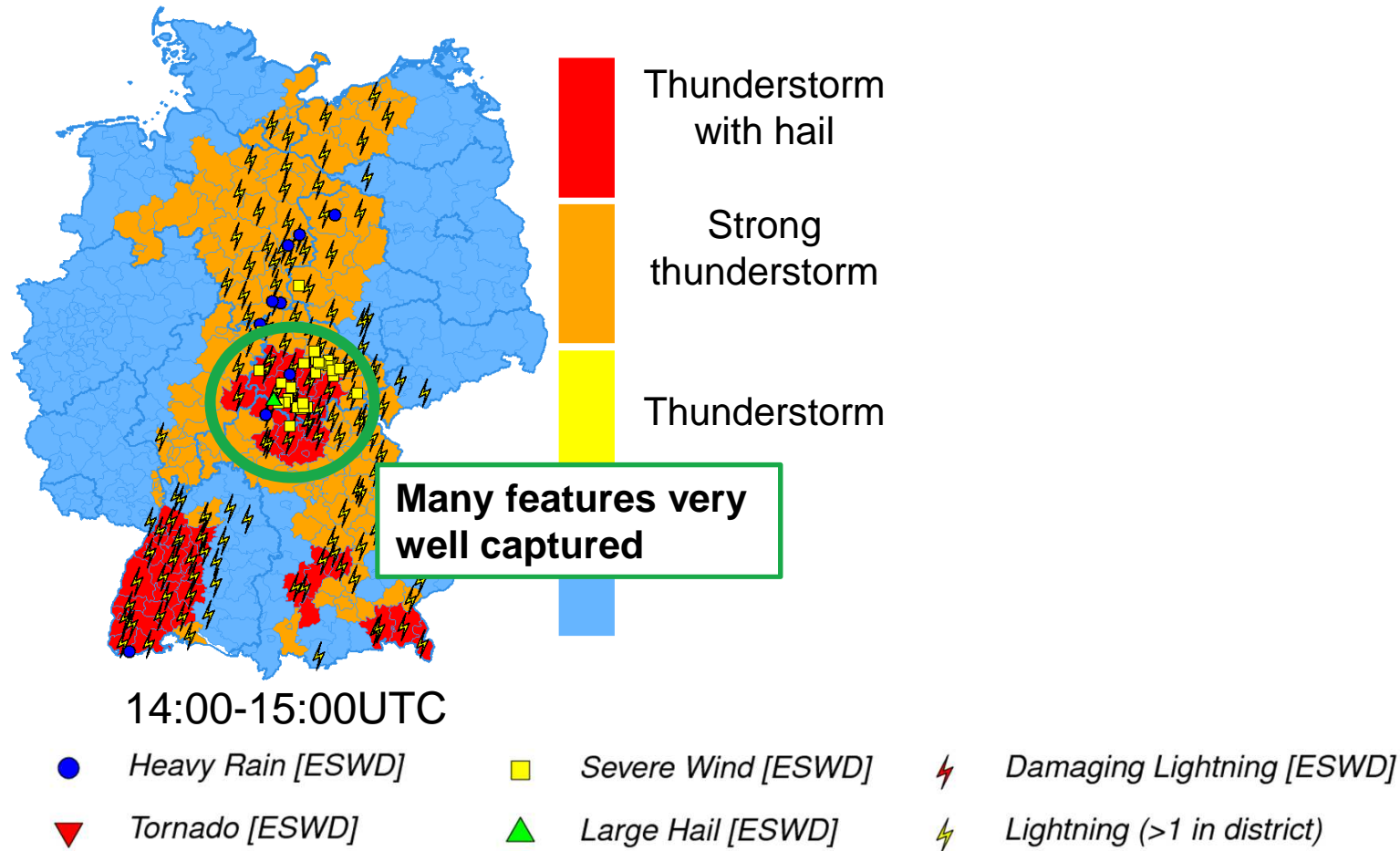
22 June 2011 ESWD and occurred losses [%]



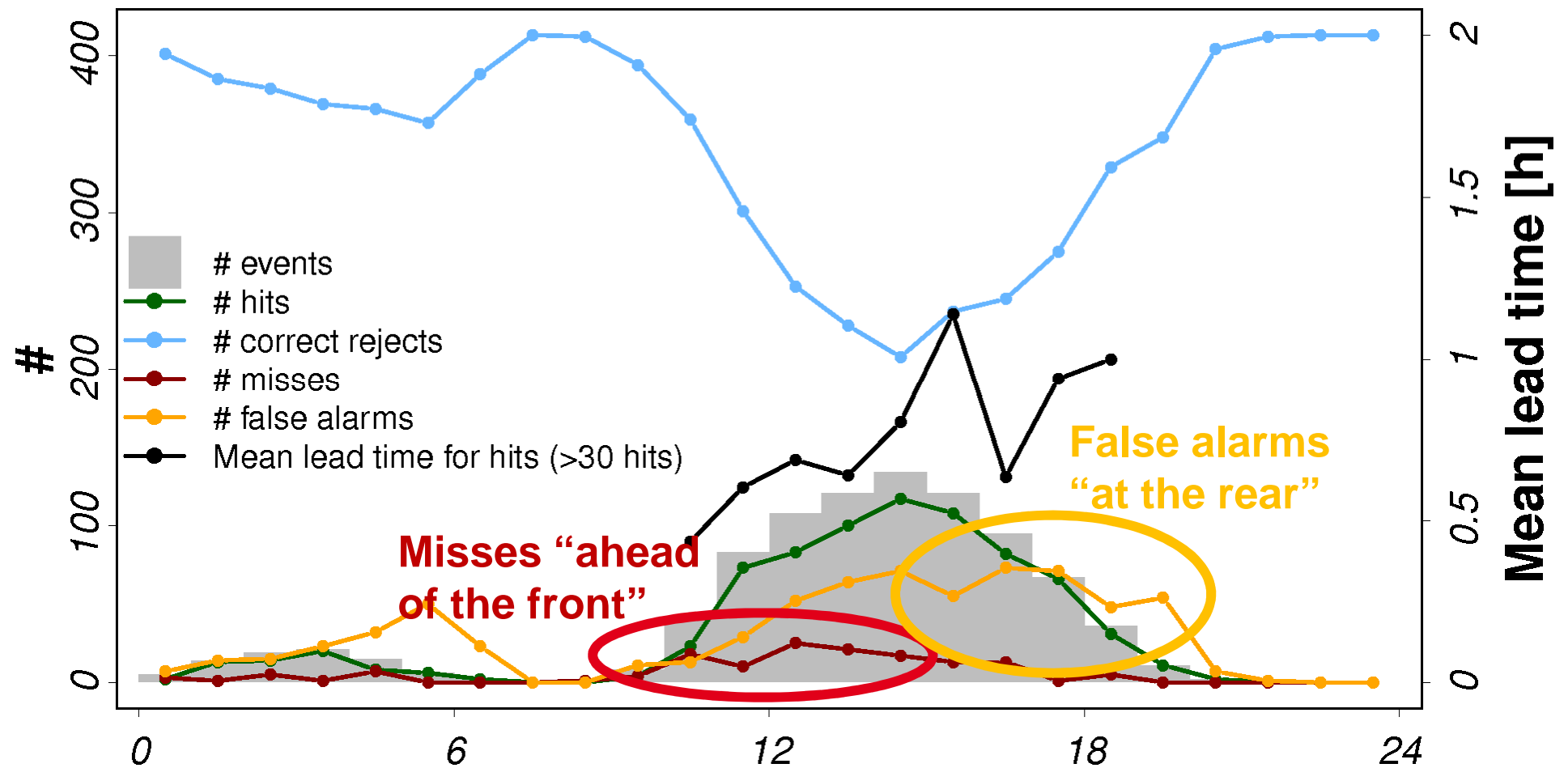
rank relative to all days



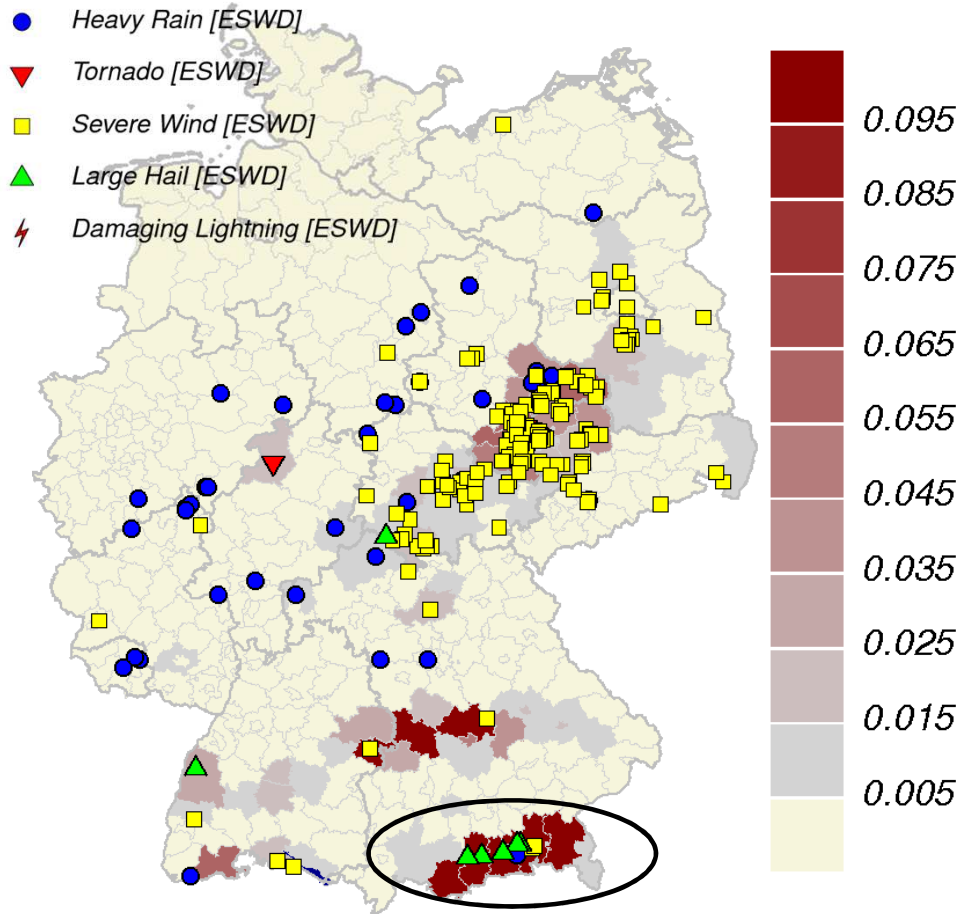
Operational warnings



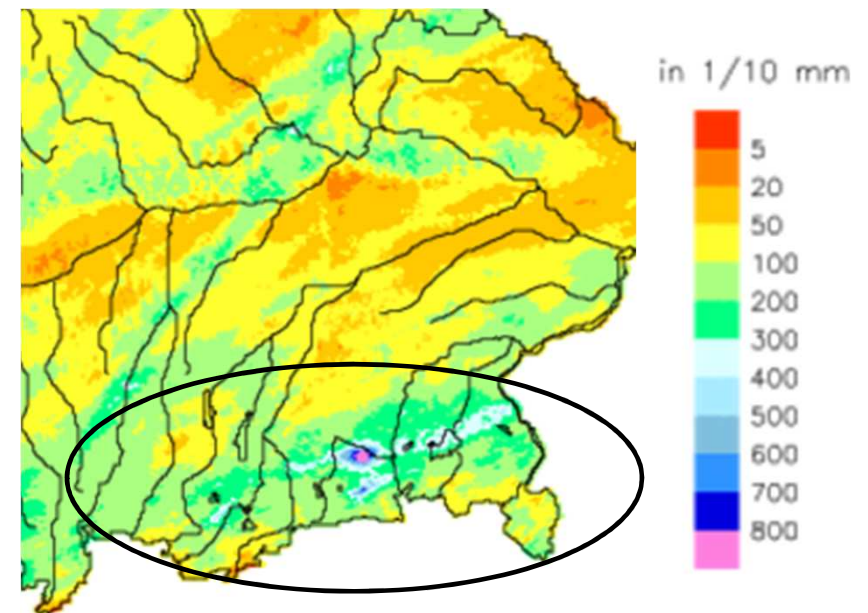
Operational warnings



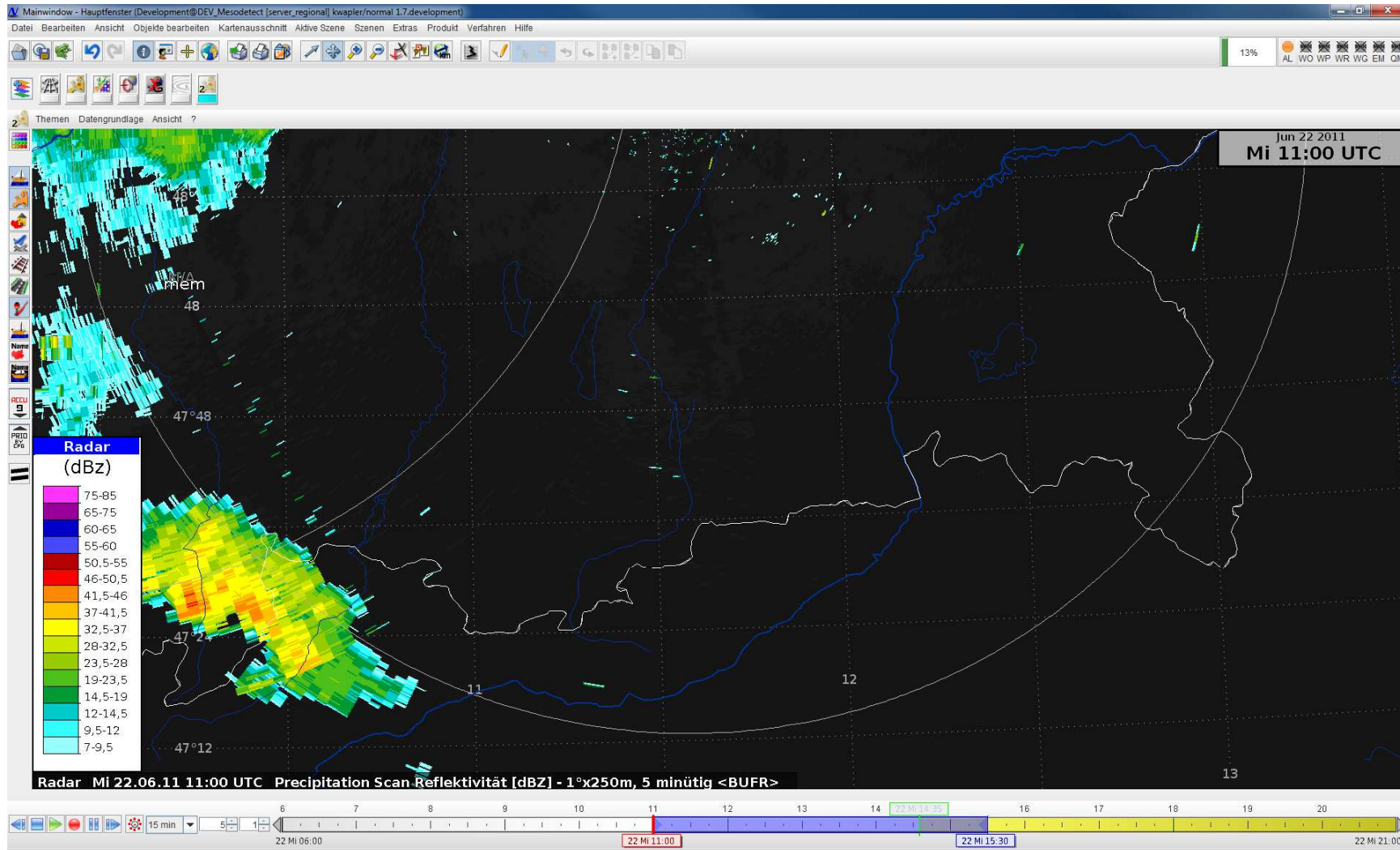
22 June 2011 ESWD and occurred losses [%]



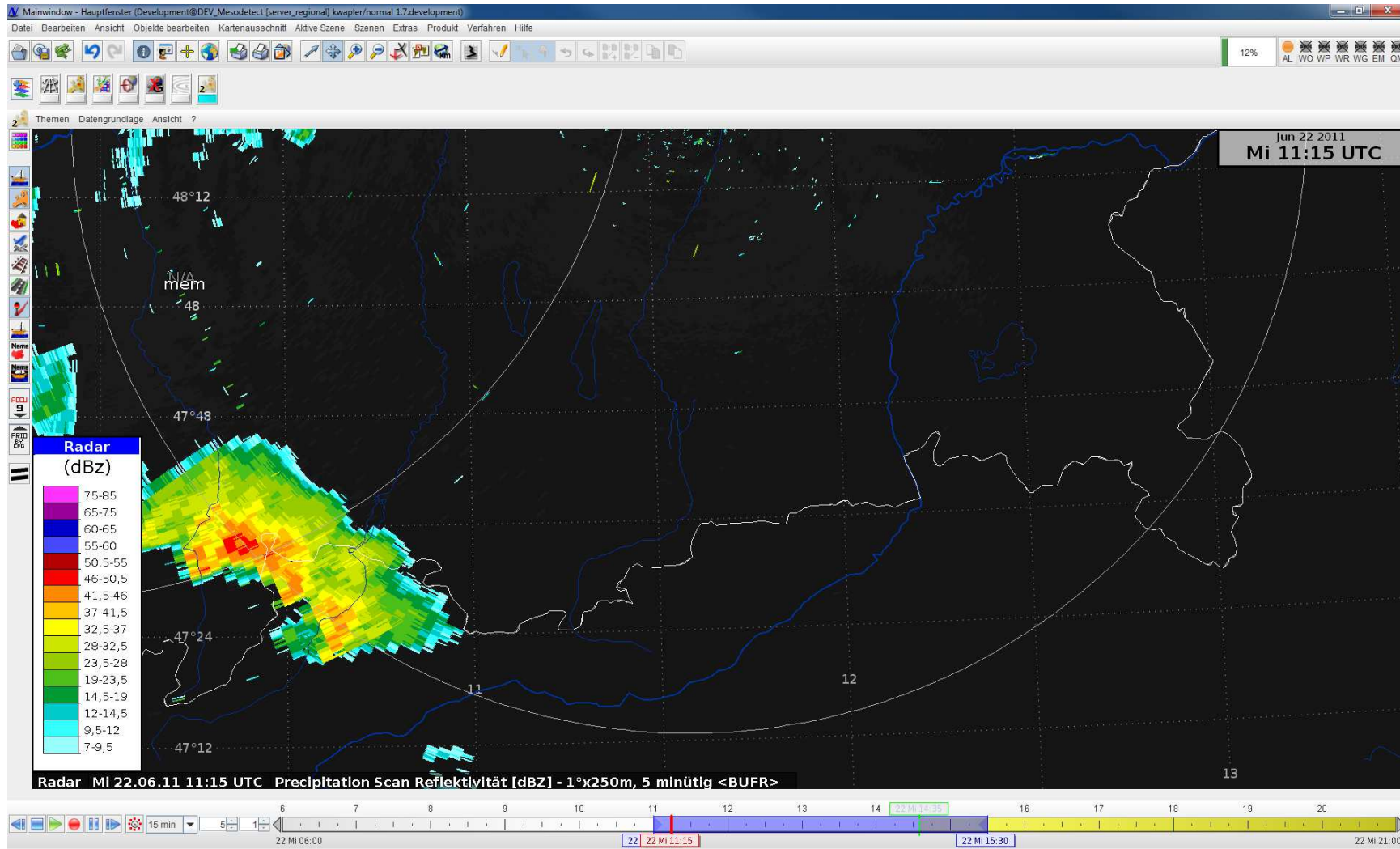
22 June 6:00 – 23 June 2011 6:00 UTC Precipitation (RW)



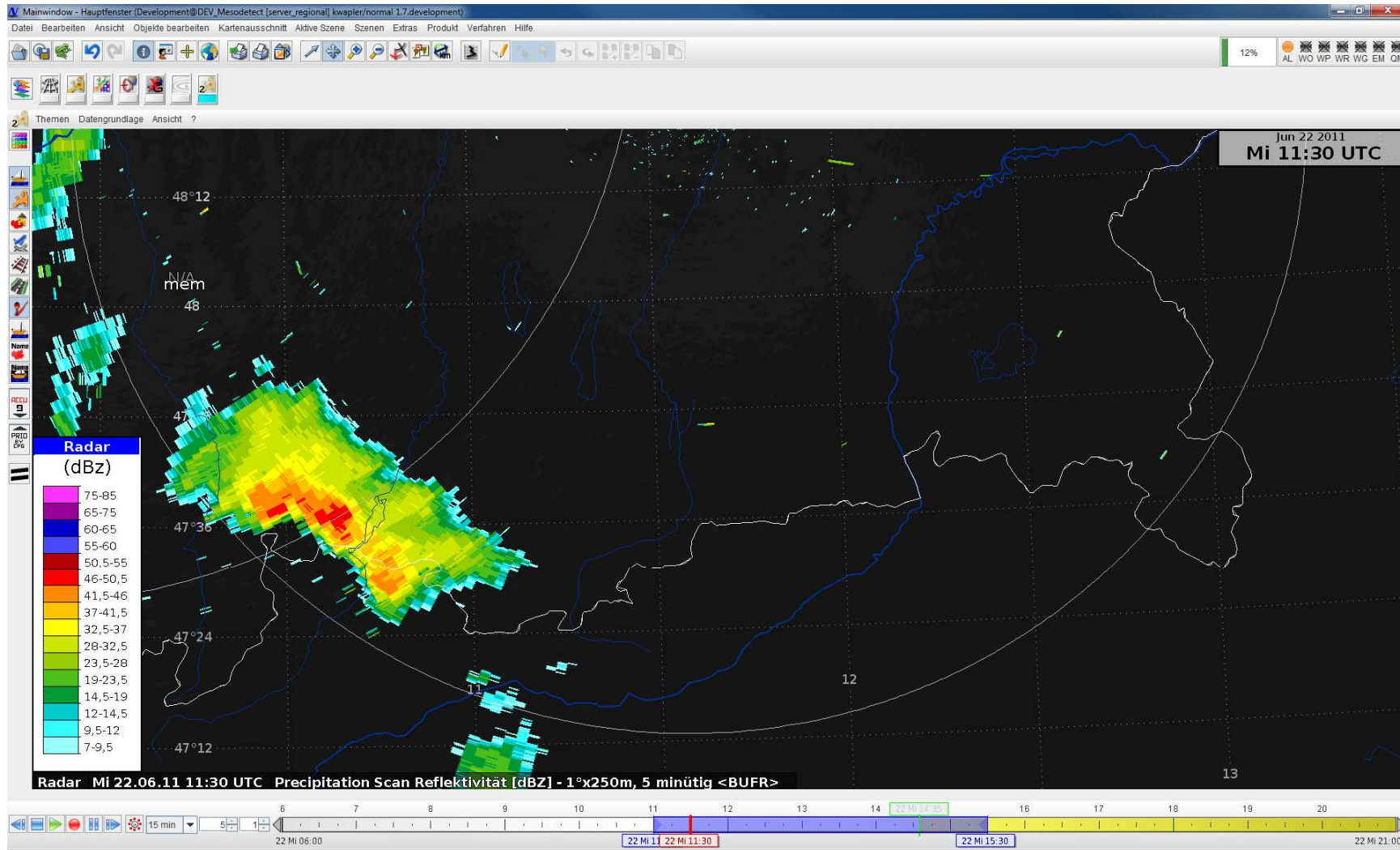
Lightning jump example: severe convective cell in southern Bavaria



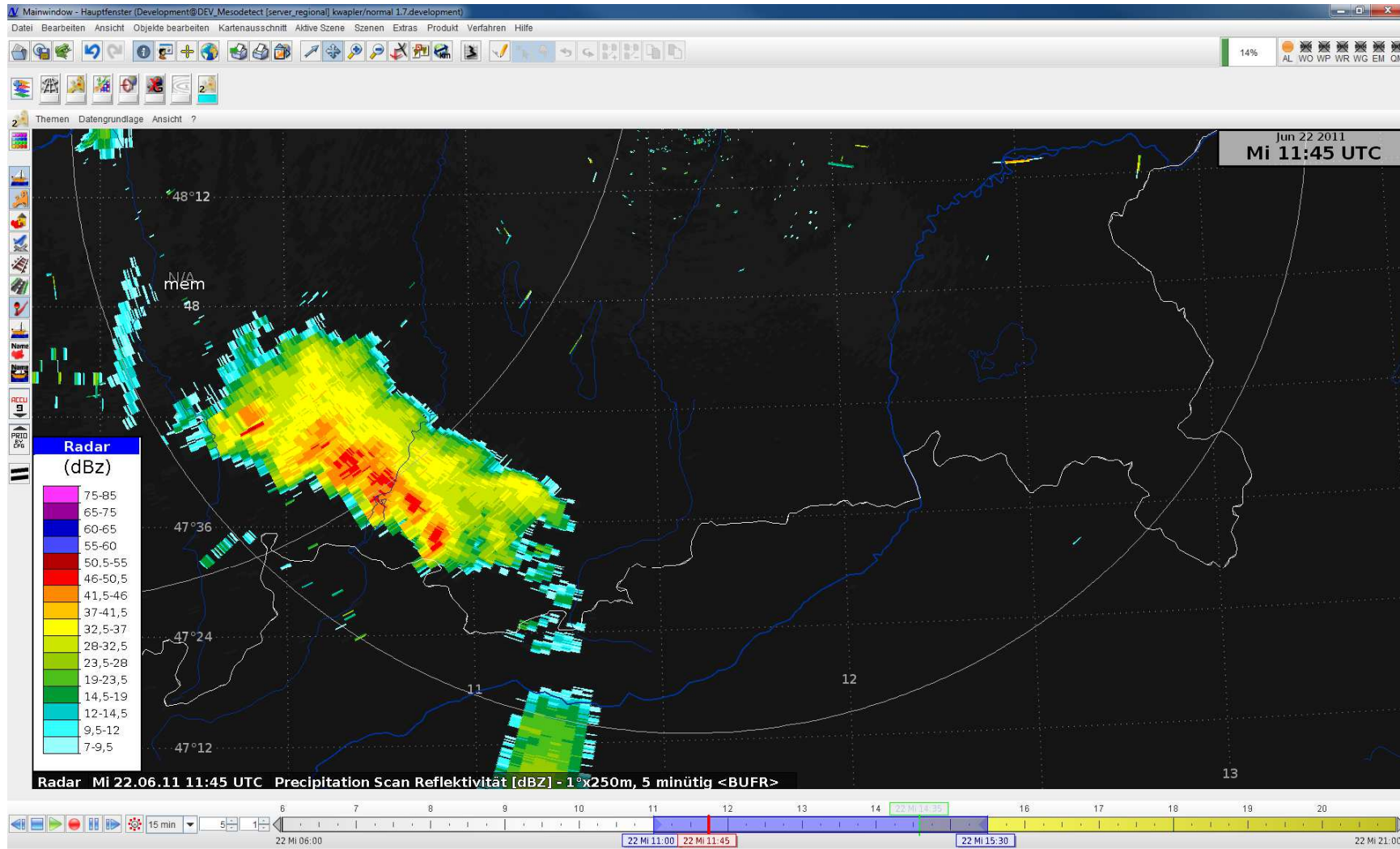
Lightning jump example: severe convective cell in southern Bavaria



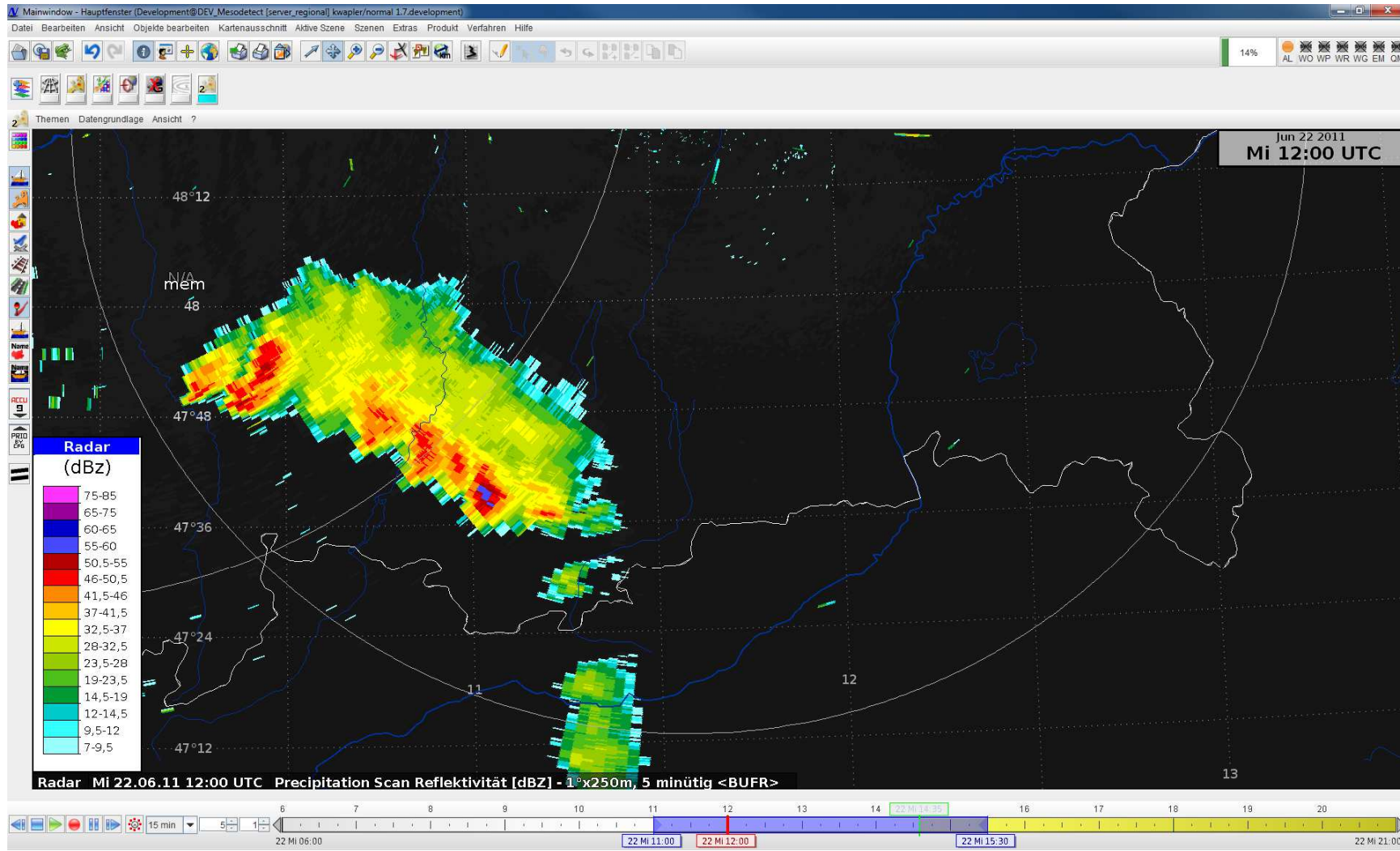
Lightning jump example: severe convective cell in southern Bavaria



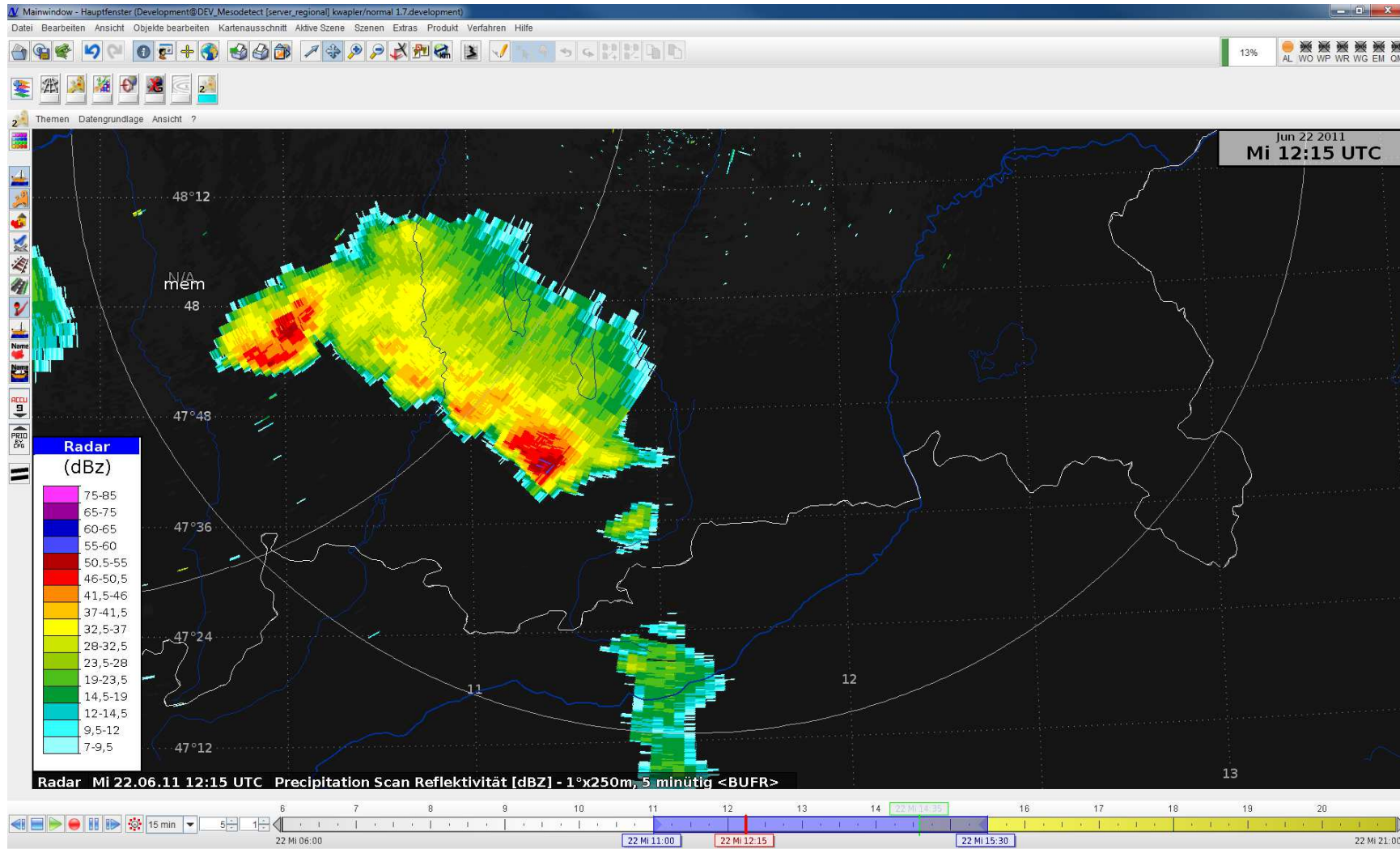
Lightning jump example: severe convective cell in southern Bavaria



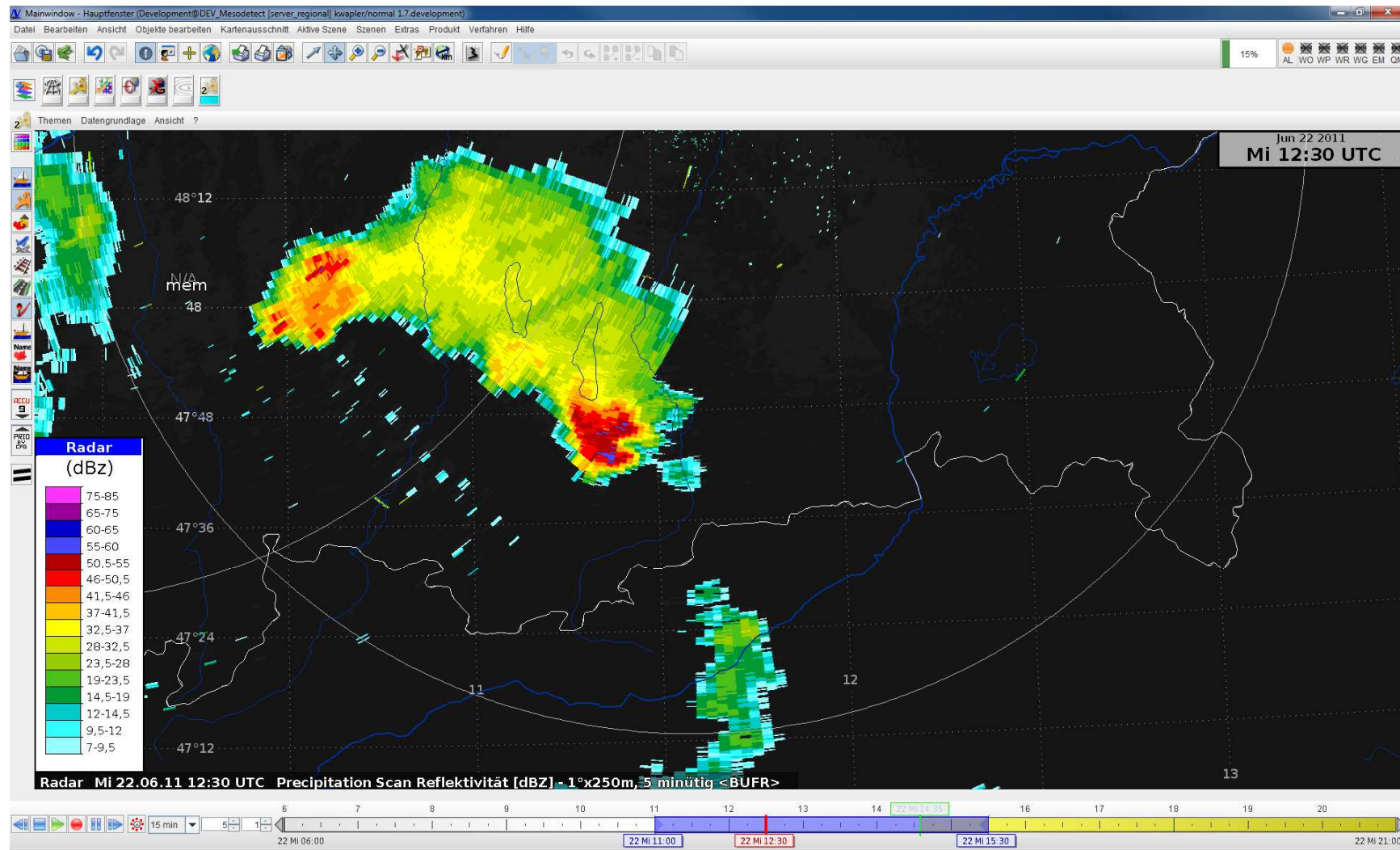
Lightning jump example: severe convective cell in southern Bavaria



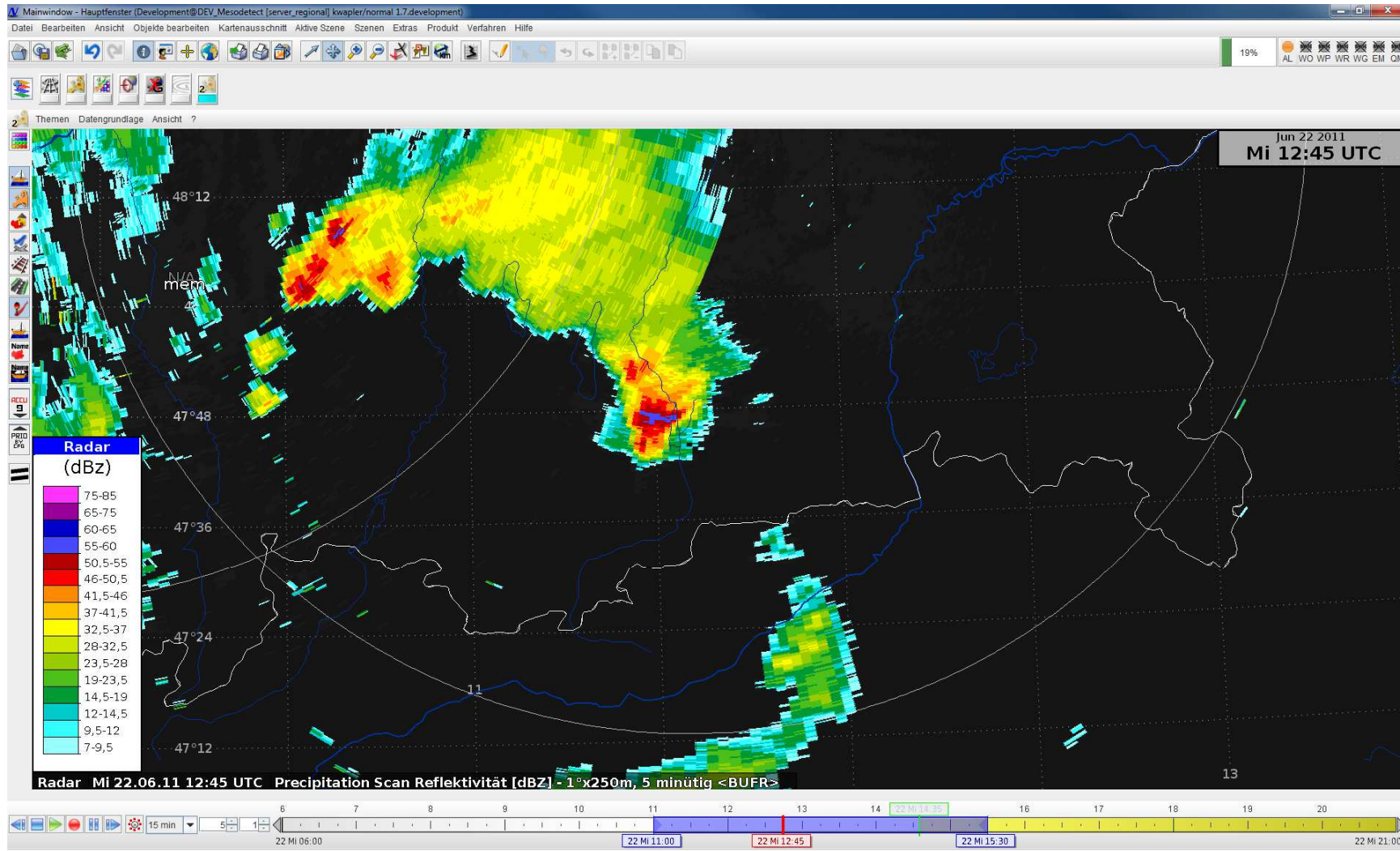
Lightning jump example: severe convective cell in southern Bavaria



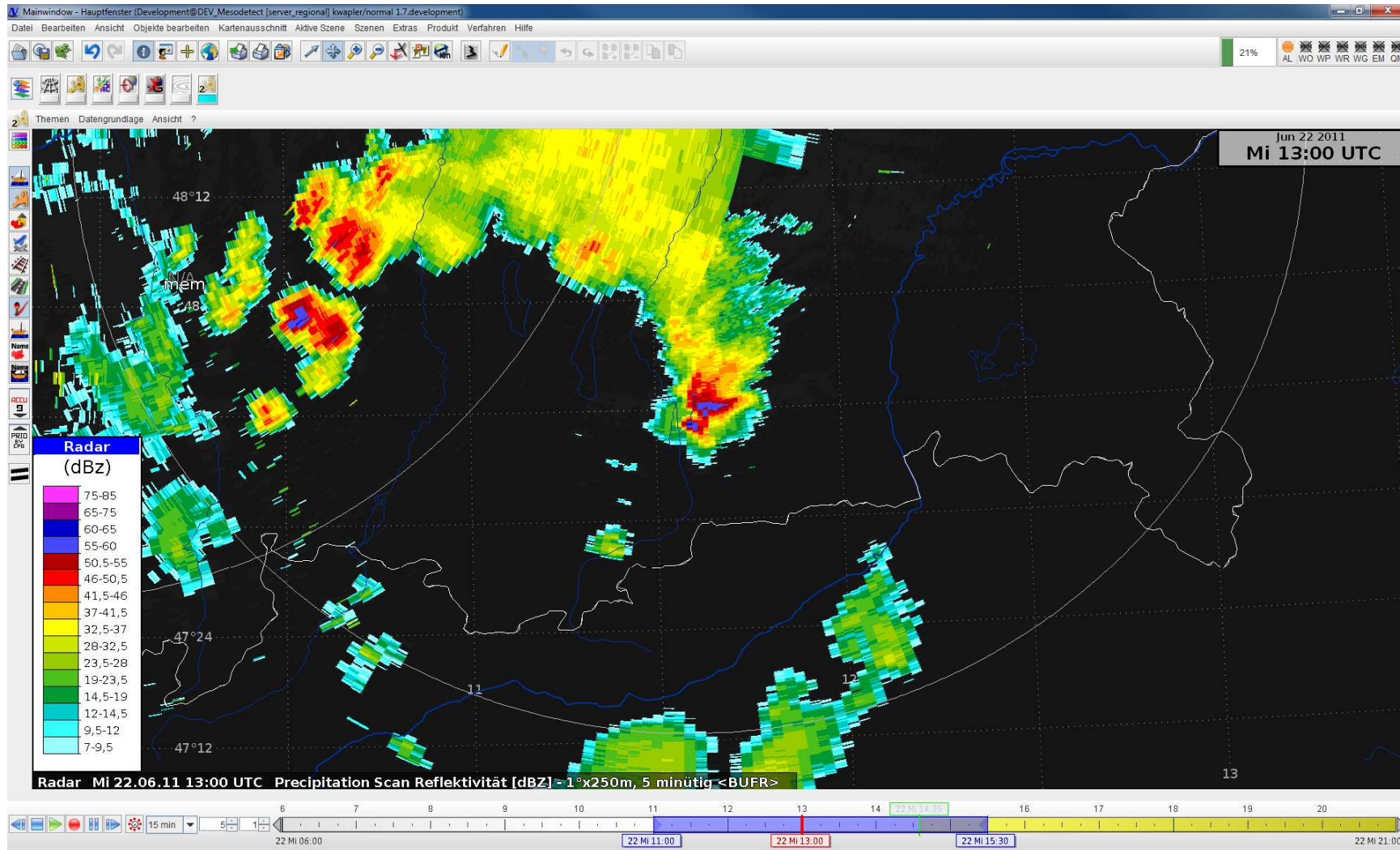
Lightning jump example: severe convective cell in southern Bavaria



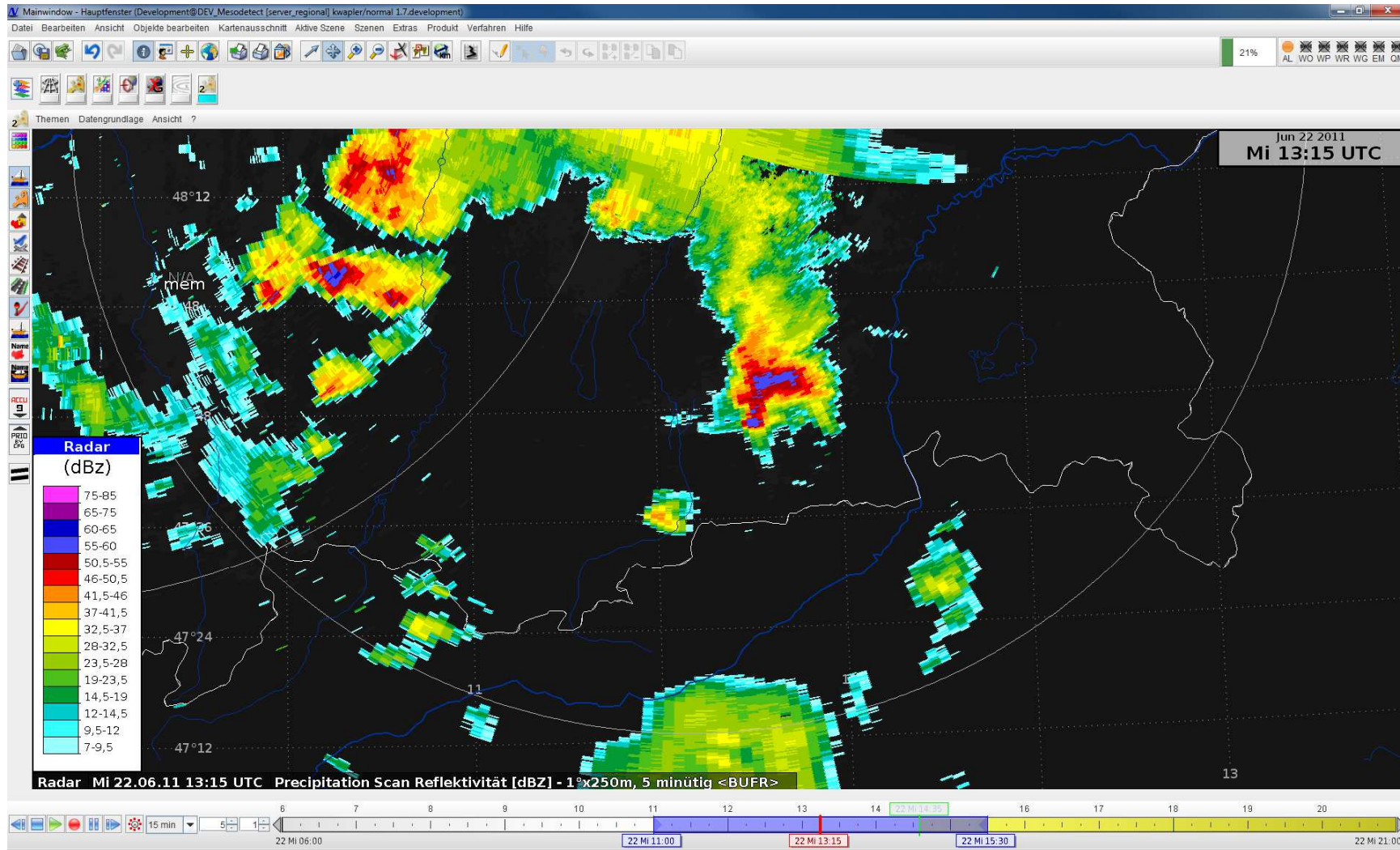
Lightning jump example: severe convective cell in southern Bavaria



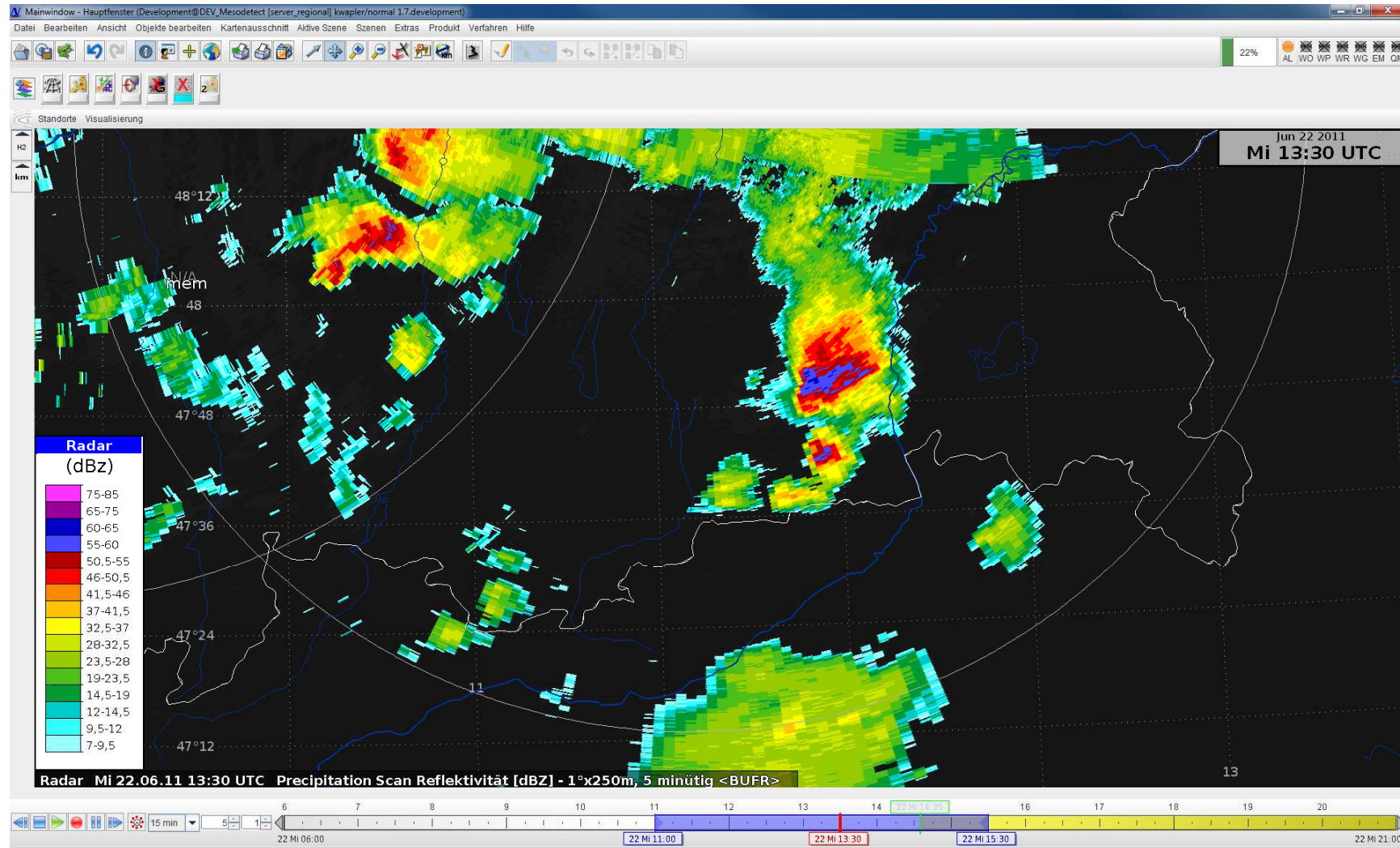
Lightning jump example: severe convective cell in southern Bavaria



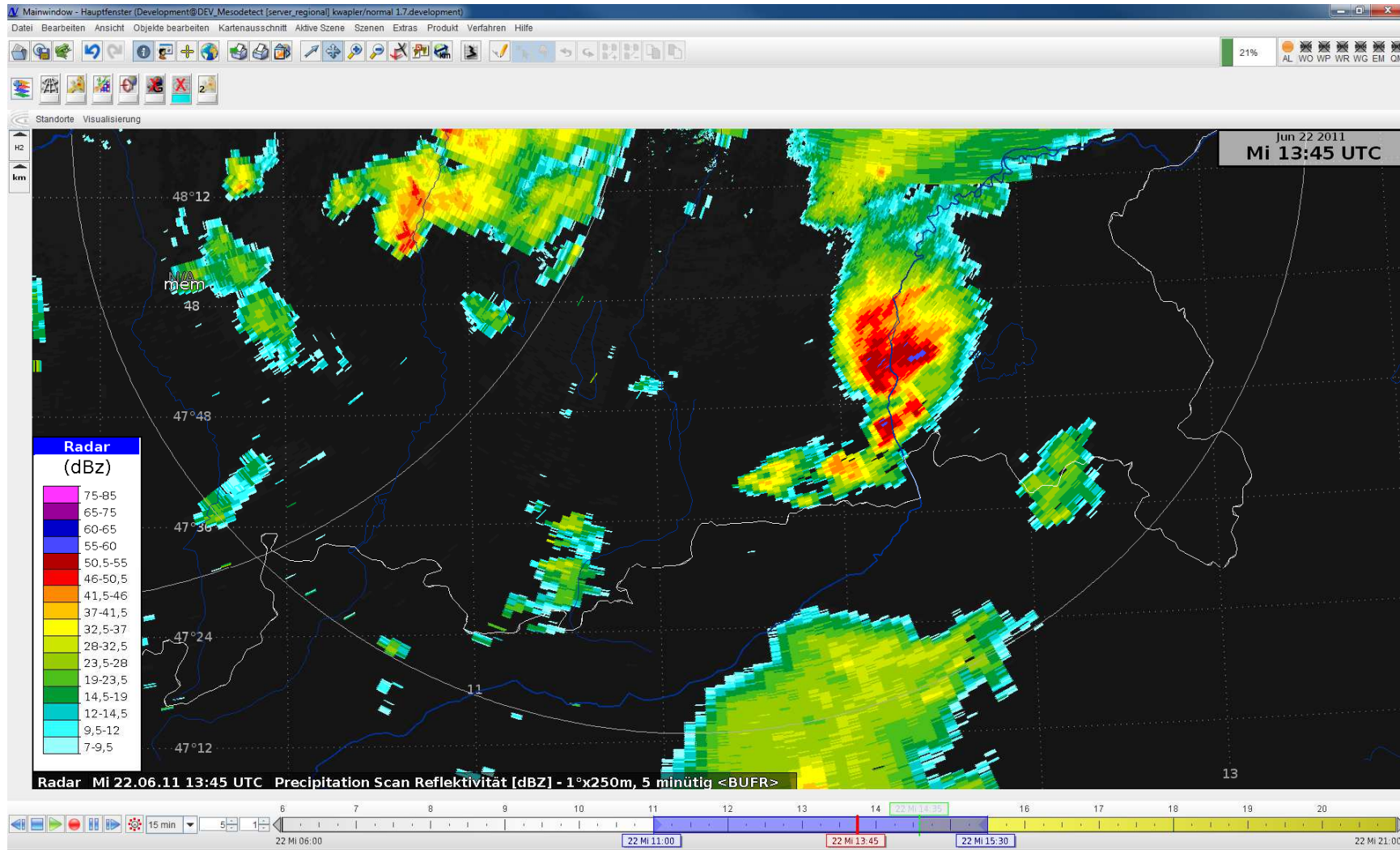
Lightning jump example: severe convective cell in southern Bavaria



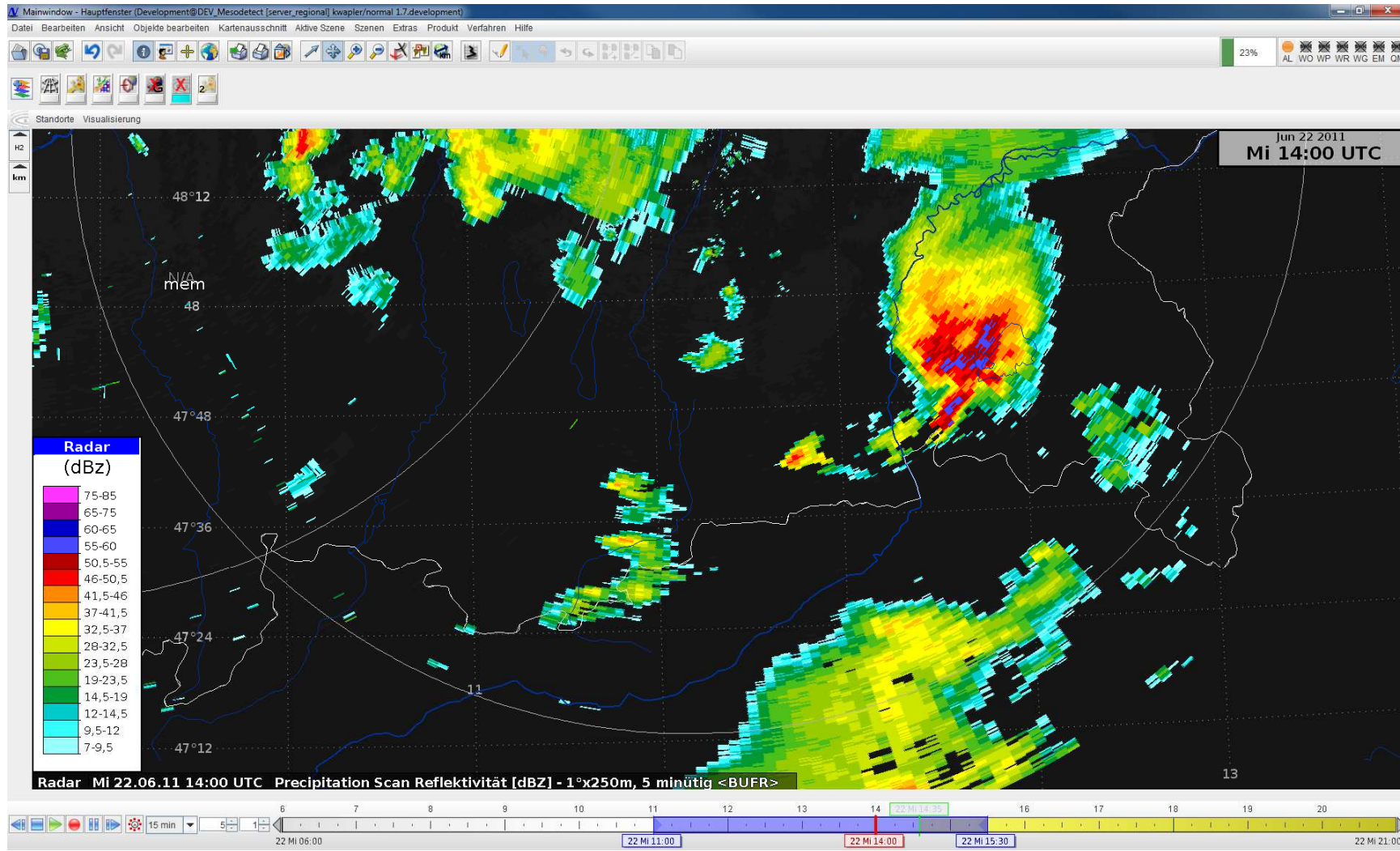
Lightning jump example: severe convective cell in southern Bavaria



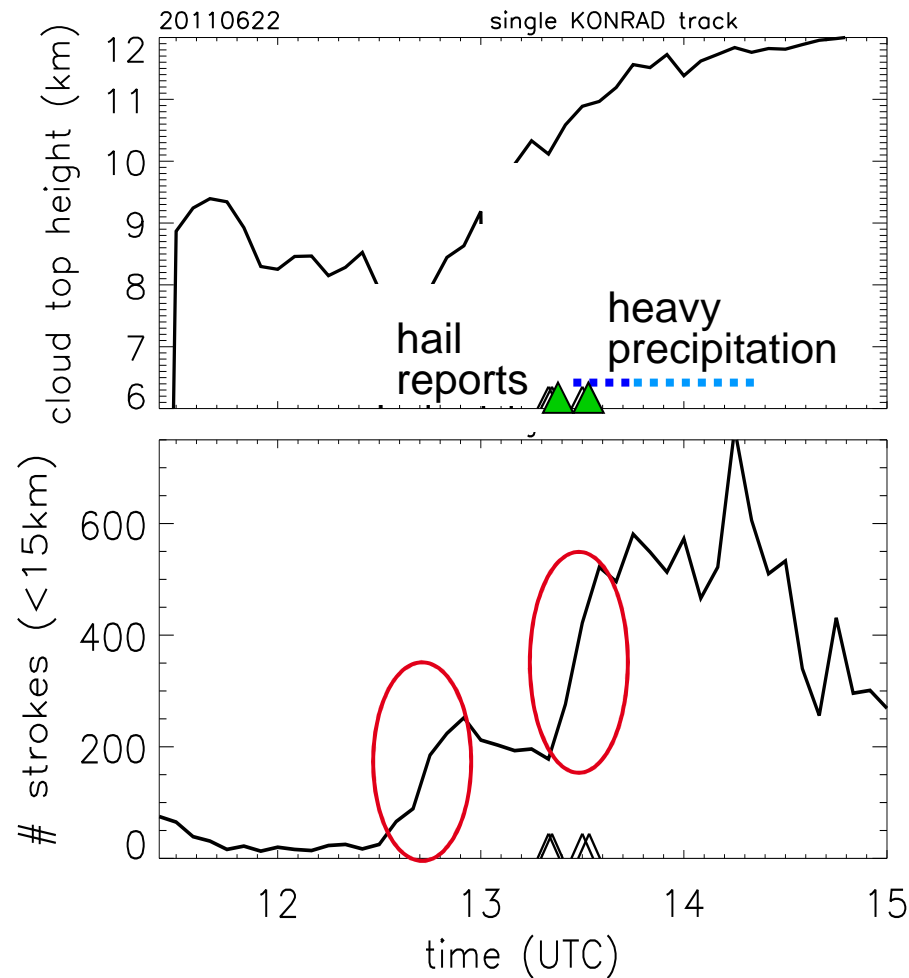
Lightning jump example: severe convective cell in southern Bavaria



Lightning jump example: severe convective cell in southern Bavaria

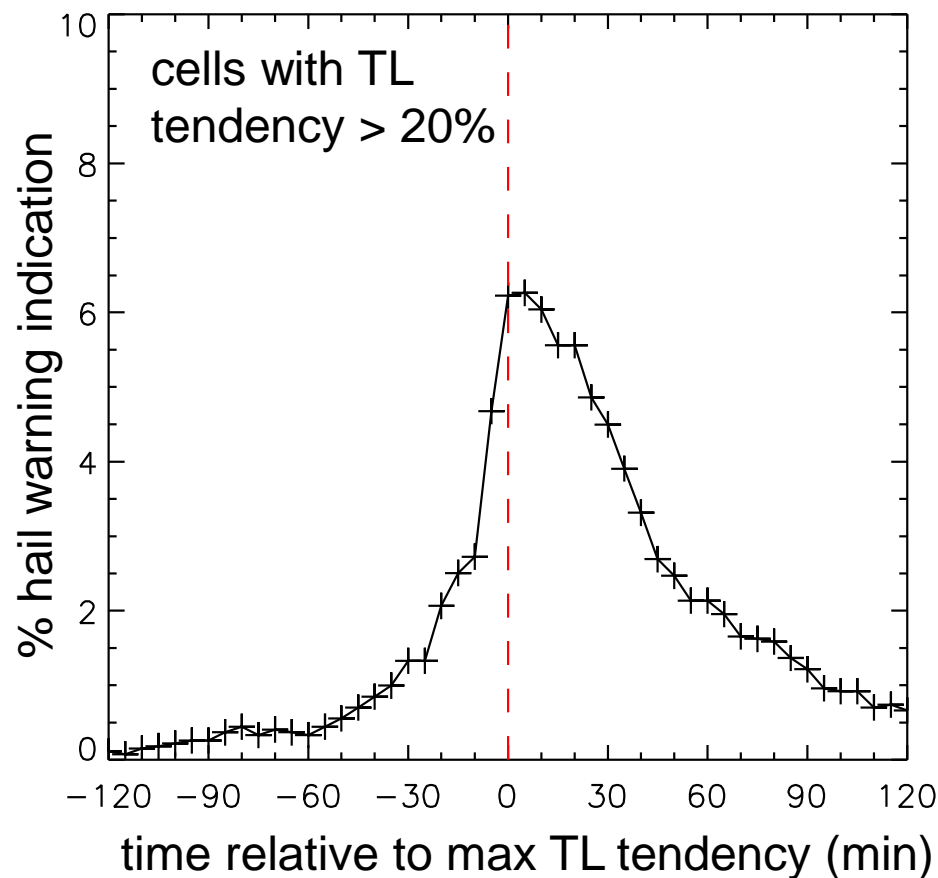


Lightning jump example: severe convective cell in southern Bavaria



- Two lightning jumps occurred
 - First lightning jump ~30min prior to, and second lightning jump at time of severe weather (hail) and onset of heaviest precipitation
- use of lightning jumps may provide lead time for warning of severe weather

Intense reflectivity relative to max lightning tendency



- 1700 cells in summer 2011
- two hail warning categories:
 - > 1 km² >55 dBZ
 - > 13 km² >55 dBZ or > 1 km² >60 dBZ
- more frequent hail warnings after max 5min-tendency of lightning rate
- High lightning rate tendencies know as “lightning jumps”





Another example

- Combination of lightning and polarimetric radar data

Polarimetric radar signatures

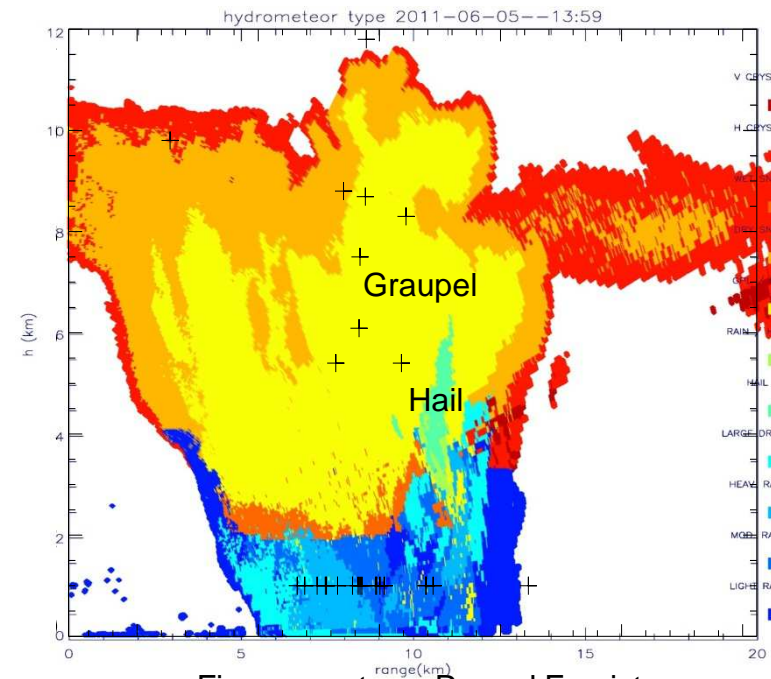
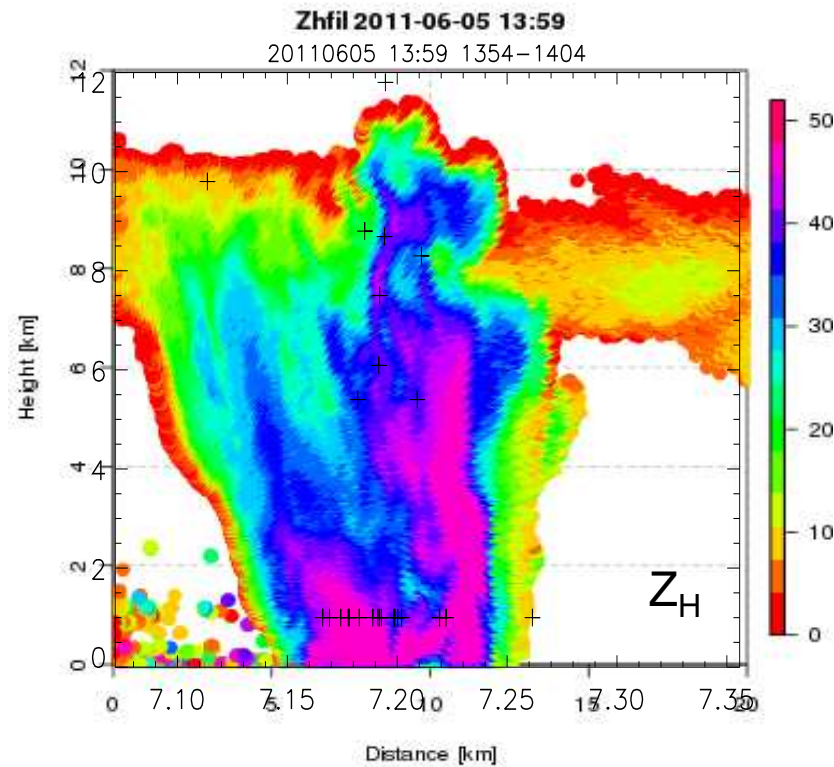
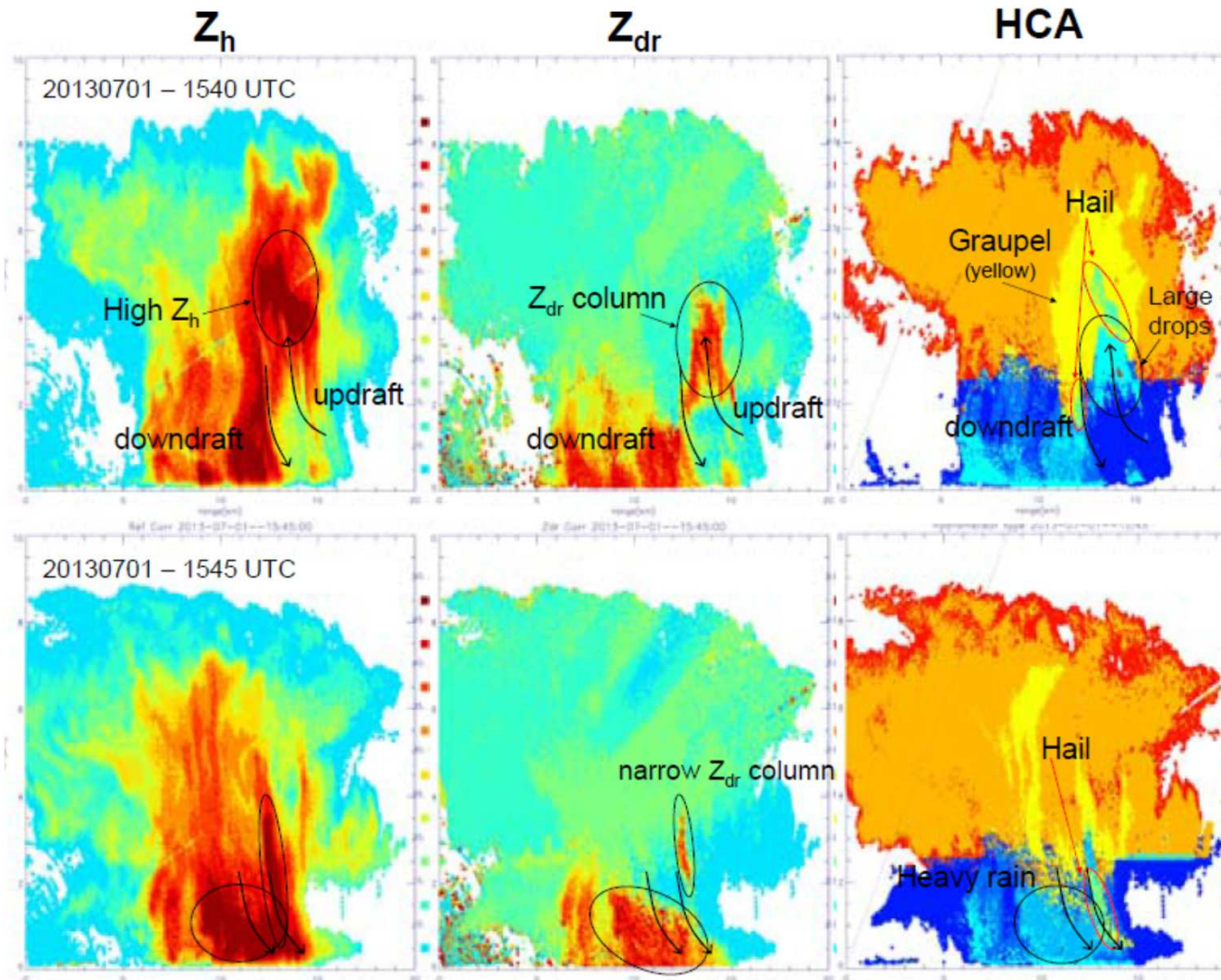


Figure courtesy: Raquel Evaristo

+ LINET strokes





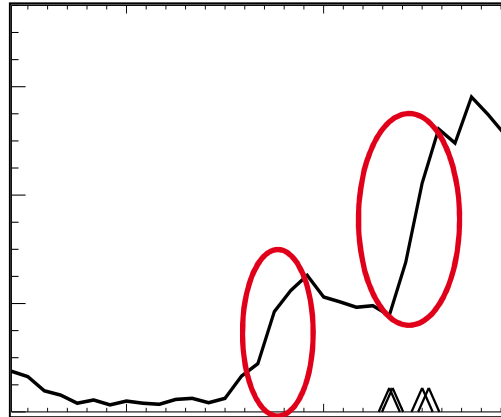
Polarimetric radar signatures

- Some features of a mature convective cell:
 - updraft & downdraft
 - hail shaft
 - Z_{DR} column → precursor of heavy precipitation
- Hydrometeor classification identifies:
 - lots of graupel
 - hail shaft
 - large drops in the updraft
 - heavy rain in the downdraft

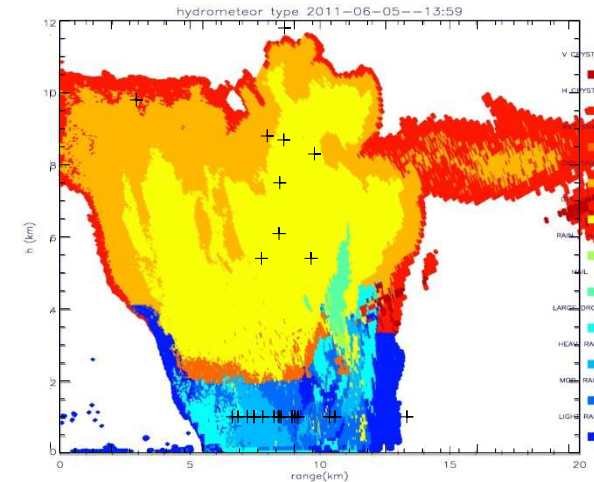
Figure taken from Evaristo et al. (2013), 36 th AMS conference on radar meteorology



Summary – life cycle



See Fabians talk



Lightning jumps: precursor
of intensifying reflectivity

??: precursor of intensifying
thunderstorm and lightning
activity

Supported by polarimetric
radar descriptors

- ➔ better understanding of life cycle of deep convection
- ➔ support for nowcasting of such events

HORVÁTH, Á., K. WAPLER, F. SENF, H. DENEKE, 2012: Lagrangian analysis of precipitation cells using satellite, radar, and lightning observations. Ext. Abstracts, 2012 EUMETSAT Meteorological Satellite Conference, Sopot, Poland.



Summary

- What are the goals of the OASE project?
→ Better understanding and characterization of process structure, life cycles and predictability of severe weather events
- Where do thunderstorms occur in Germany and when?
→ Differing thunderstorm characteristics under different flow regimes
- What are typical life cycles of convective events?
→ new predictors from various sensors may support nowcasting
- How good are convective systems represented in high-resolution NWP?
→ new evaluation approaches using synthetic satellite and radar data support characterisation of model errors



Note

Summer school on “**Remote Sensing of Clouds and Precipitation**” 2013

Lectures have been recorded and are available at UniBonnTV

<http://www.youtube.com/user/UniBonnTV>

Radar

- *The Capability of Cloud Radars*
- *From Doppler velocities to 3D-wind vectors*
- *Polarimetric radar fingerprints of various microphysical processes*
- *Microphysical retrievals using polarimetric radars*

Satellite

- *Clouds as seen by passive VIS/IR imagers*
- *Convective initiation and Cloud development*
- *Overshooting tops and Mature convection*
- *Cloudsat/ Calipso Cloud radiative effects and aerosol/cloud interactions*

Synergetic use of various instruments

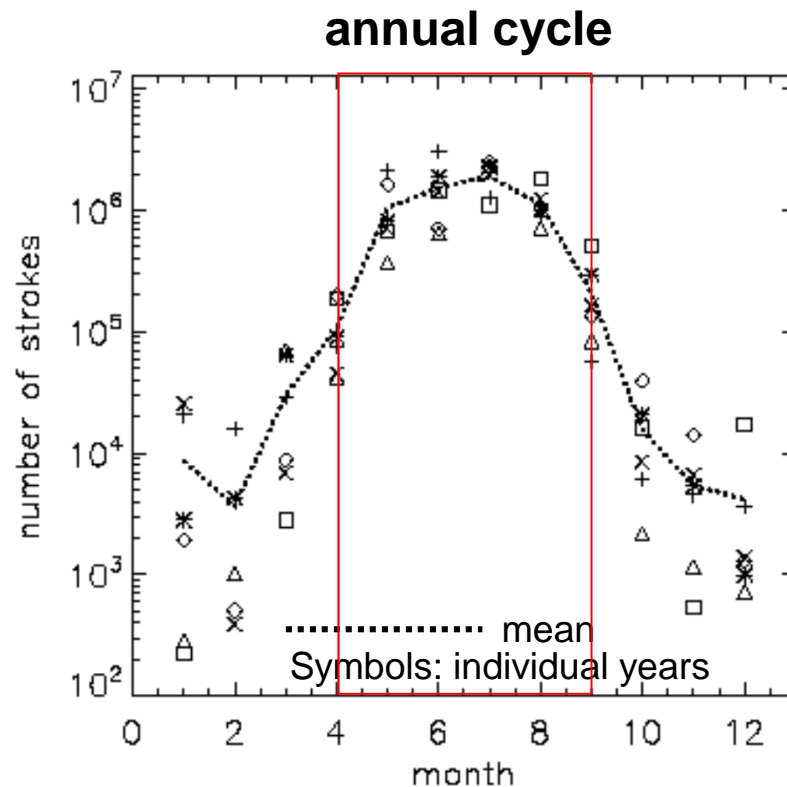
- *The Jülich ObservatorY for Cloud Evolution (JOYCE)*
- *Use of remote sensing of clouds and precipitation for improved weather forecasting / warning*





Appendix

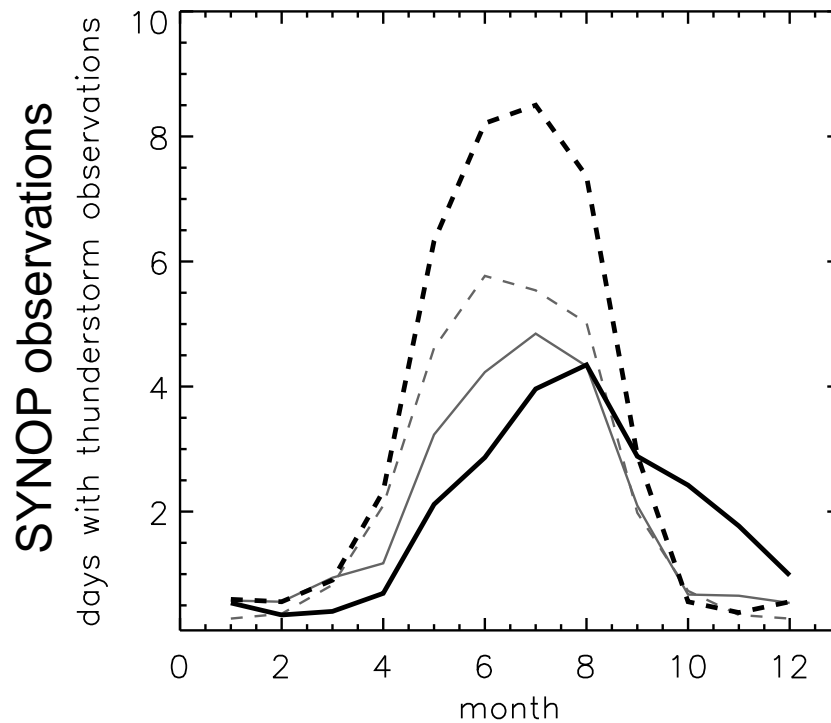
Temporal distribution



- Annual cycle
- High year-to-year variability
- Maximum lightning frequency from April to September

Temporal distribution

annual cycle



Hohenpeissenberg, Frankfurt,

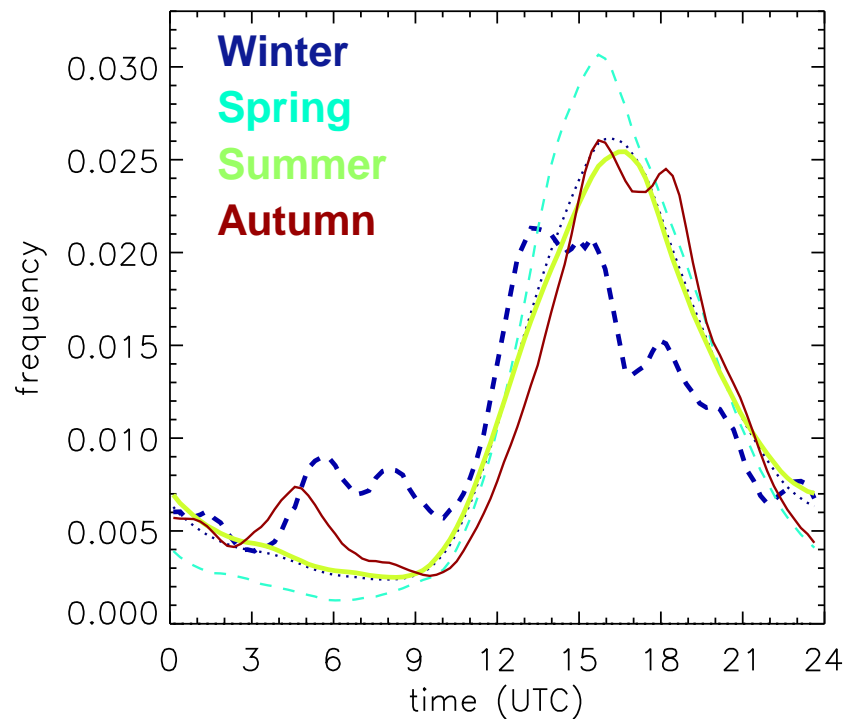
Helgoland, Hamburg,

- Annual cycle
- High year-to-year variability
- Maximum lightning frequency from April to September
- Amplitude and timing of annual cycle varies geographically



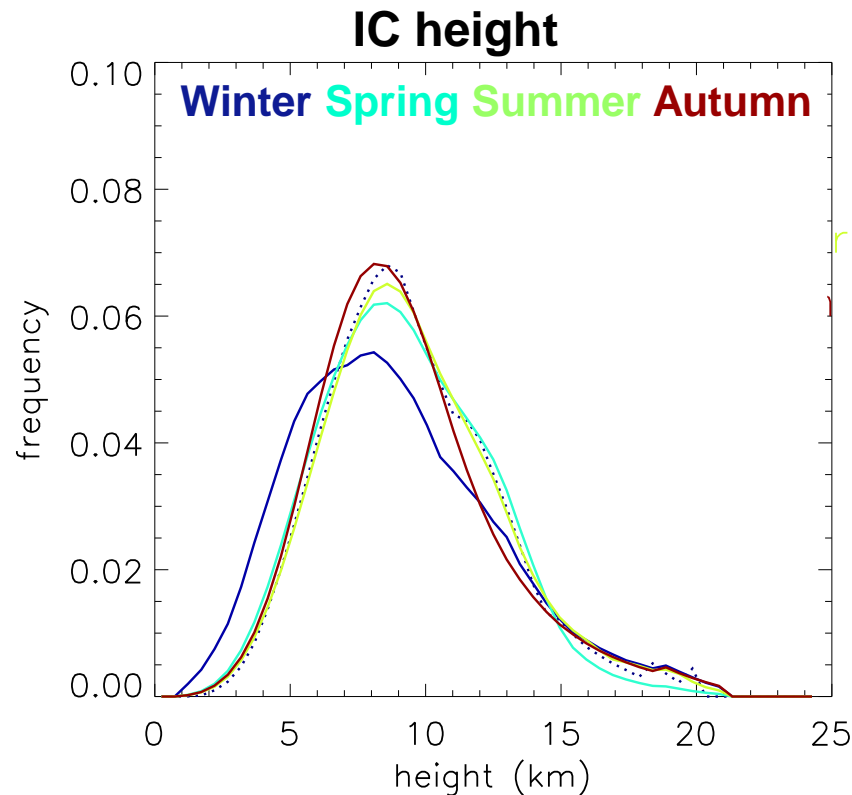
Temporal distribution

diurnal cycle



- Diurnal cycle
- Maximum lightning frequency from 12 to 21 UTC
- Diurnal cycle has an annual cycle

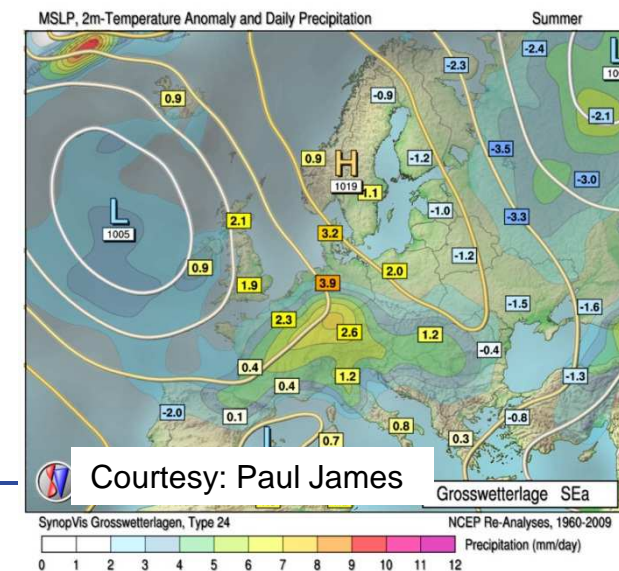
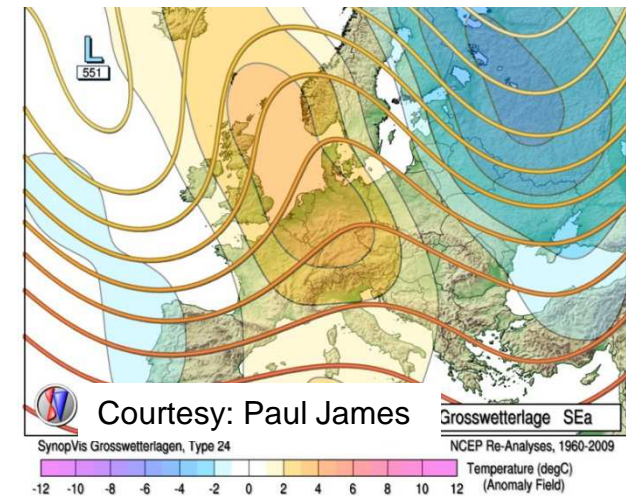
Lightning characteristics



- Mean IC height at 8.5 km
- Half of all IC between 7 and 11 km
- Annual cycle of IC heights: lower strokes in winter, higher strokes in spring and summer

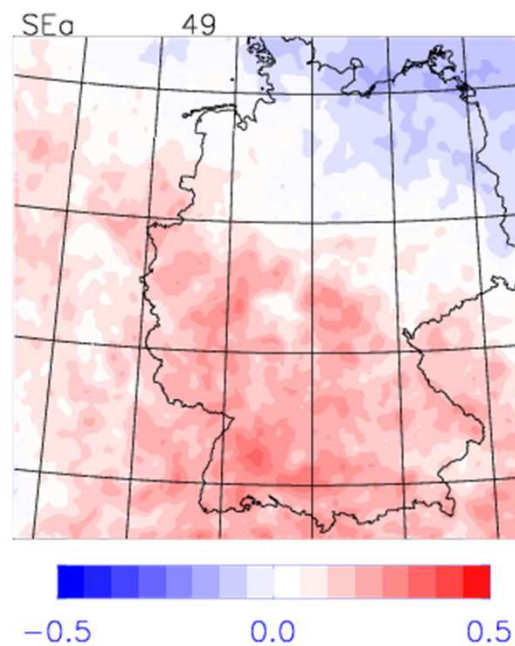
Thunderstorm activity vs Synoptic pattern

Anticyclonic South-Easterly

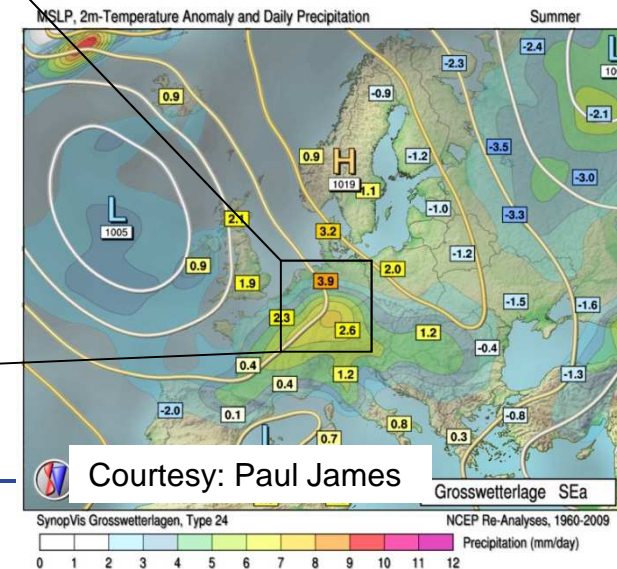
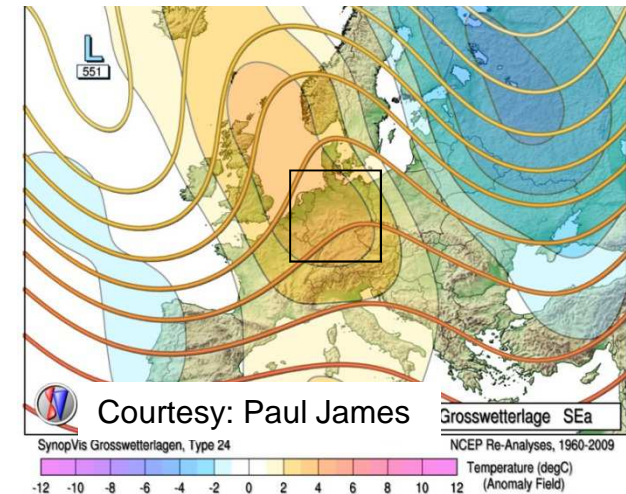


Thunderstorm activity vs Synoptic pattern

- More thunderstorm days in the S and W
- Less thunderstorm days in the NE

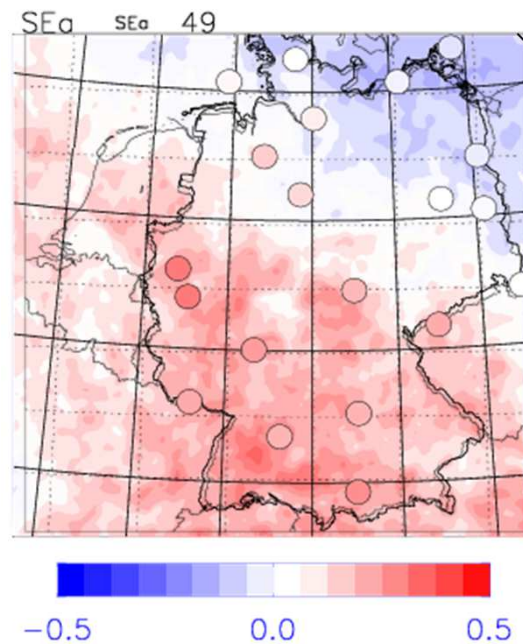


Anticyclonic South-Easterly

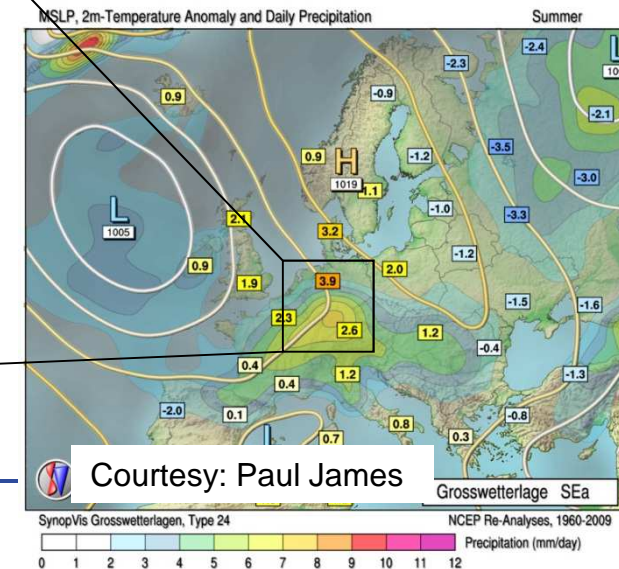
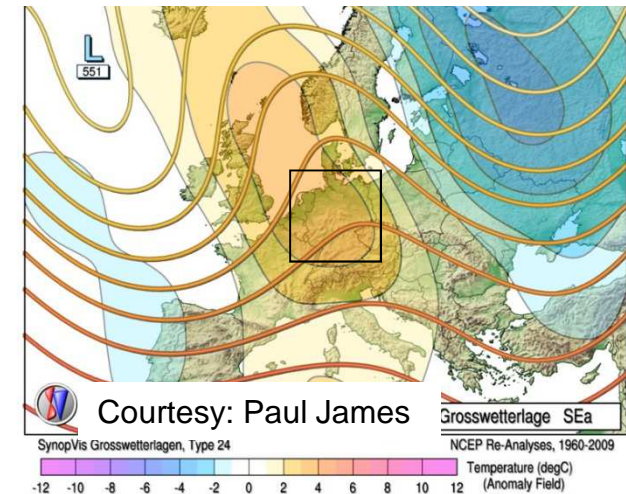


Thunderstorm activity vs Synoptic pattern

- More thunderstorm days in the S and W
- Less thunderstorm days in the NE



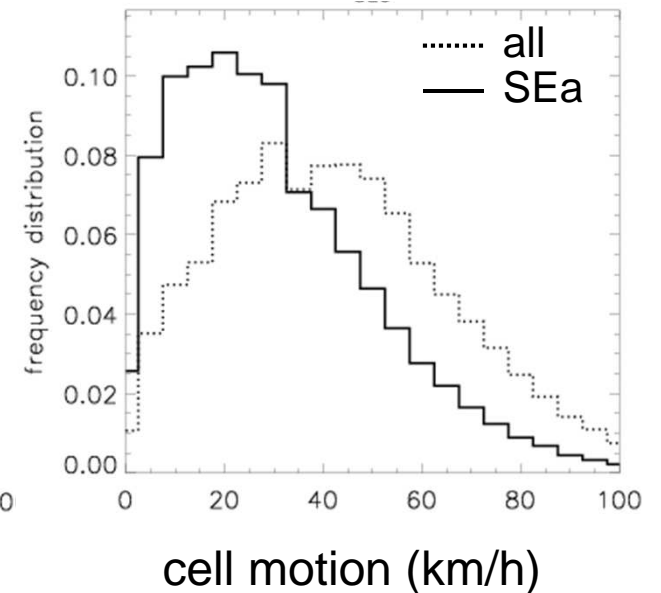
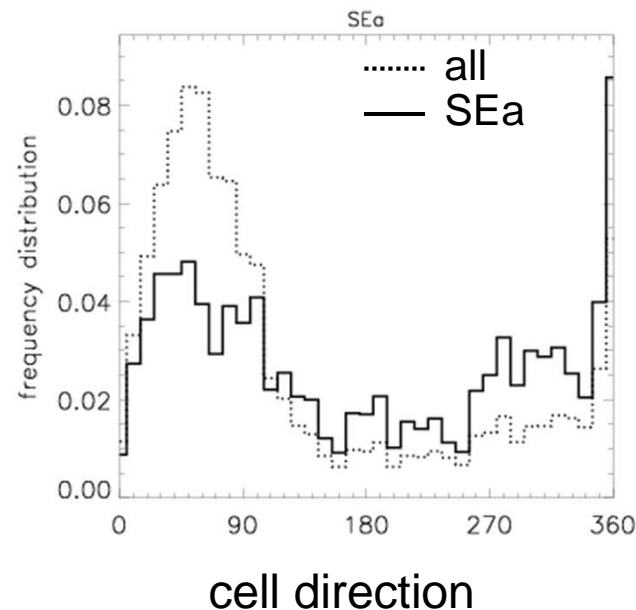
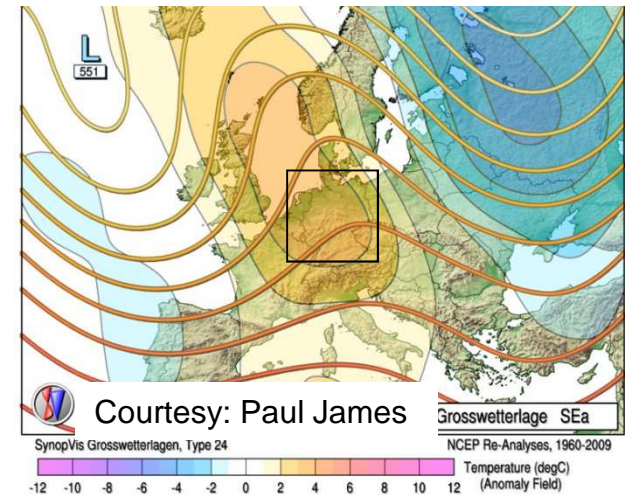
Anticyclonic South-Easterly



Thunderstorm characteristics vs Synoptic pattern

- More thunderstorm days in the S and W
- Less thunderstorm days in the NE
- Slow moving cells
- Various cell directions, mainly to the N(E)

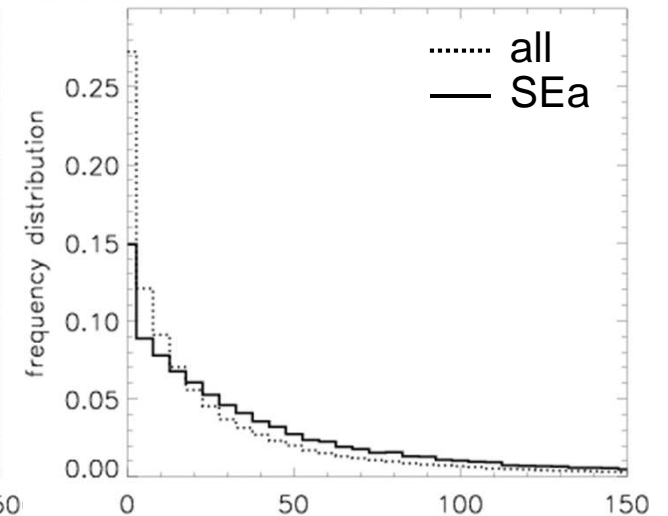
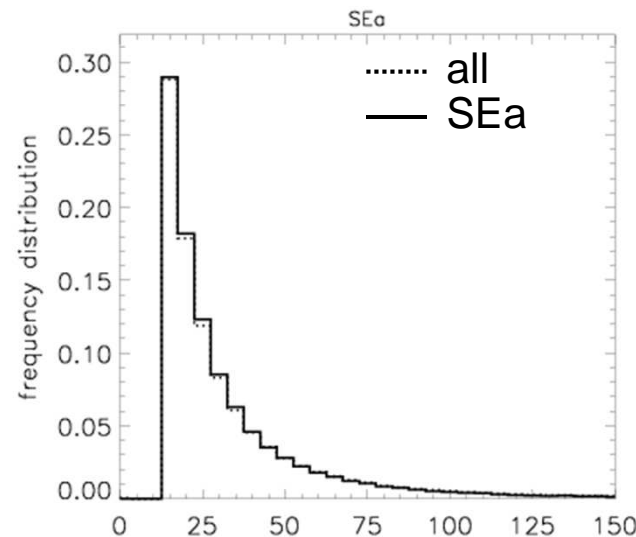
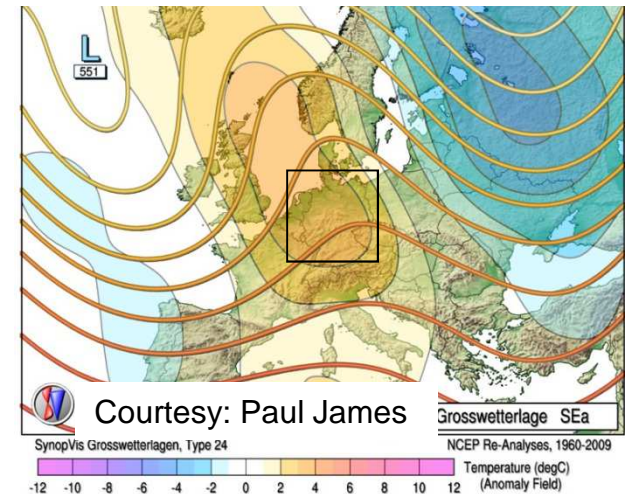
Anticyclonic South-Easterly



Thunderstorm characteristics vs Synoptic pattern

- More thunderstorm days in the S and W
- Less thunderstorm days in the NE
- Slow moving cells
- Various cell directions, mainly to the N(E)
- Average cell sizes
- More lightning strokes per cell

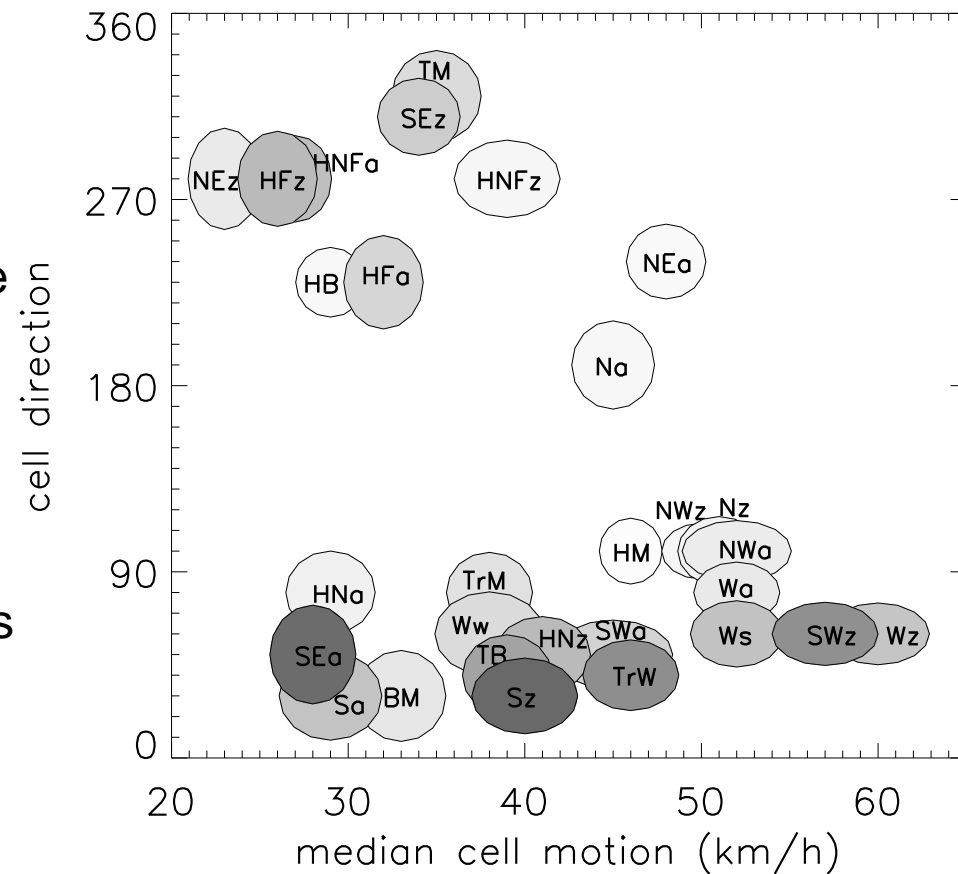
Anticyclonic South-Easterly

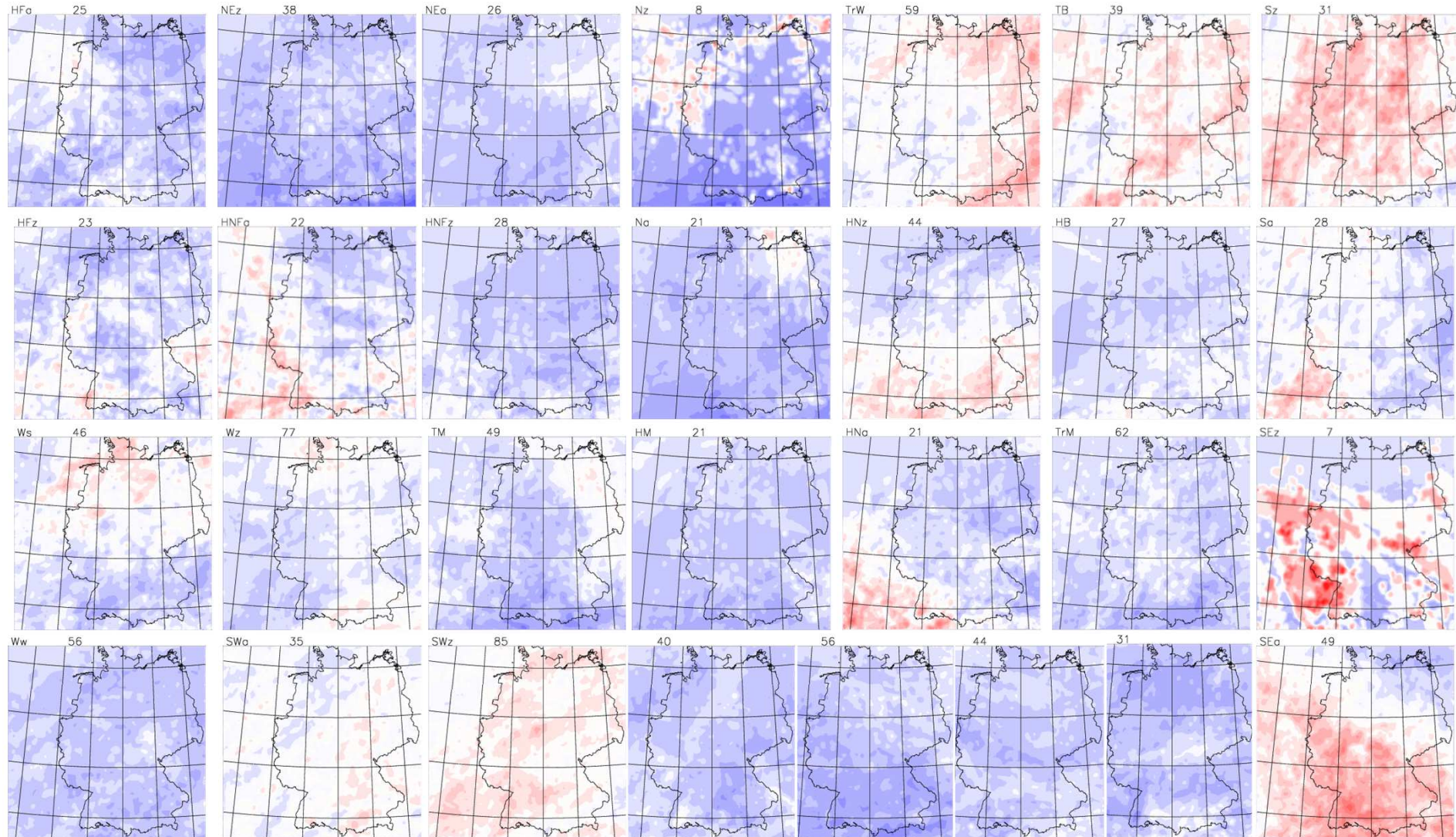


Thunderstorm characteristics vs Synoptic pattern

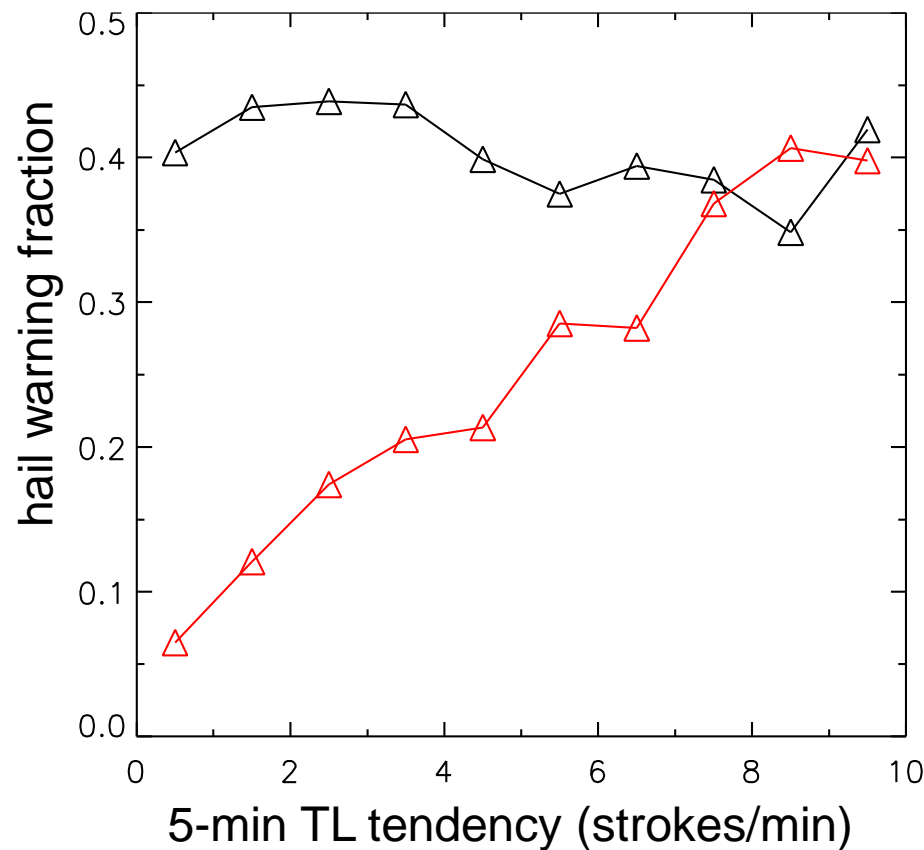
- Most cells move from SW to NE, some move in NW directions
- GWLs with westerly surface flow have narrow distribution of cell directions
- GWLs with less sharply defined synoptical patterns (e.g. HFz) have widest spread of cell directions
- Cell motion highest for westerly GWLs (due to relatively strong wind speeds at mid-levels)

Ue



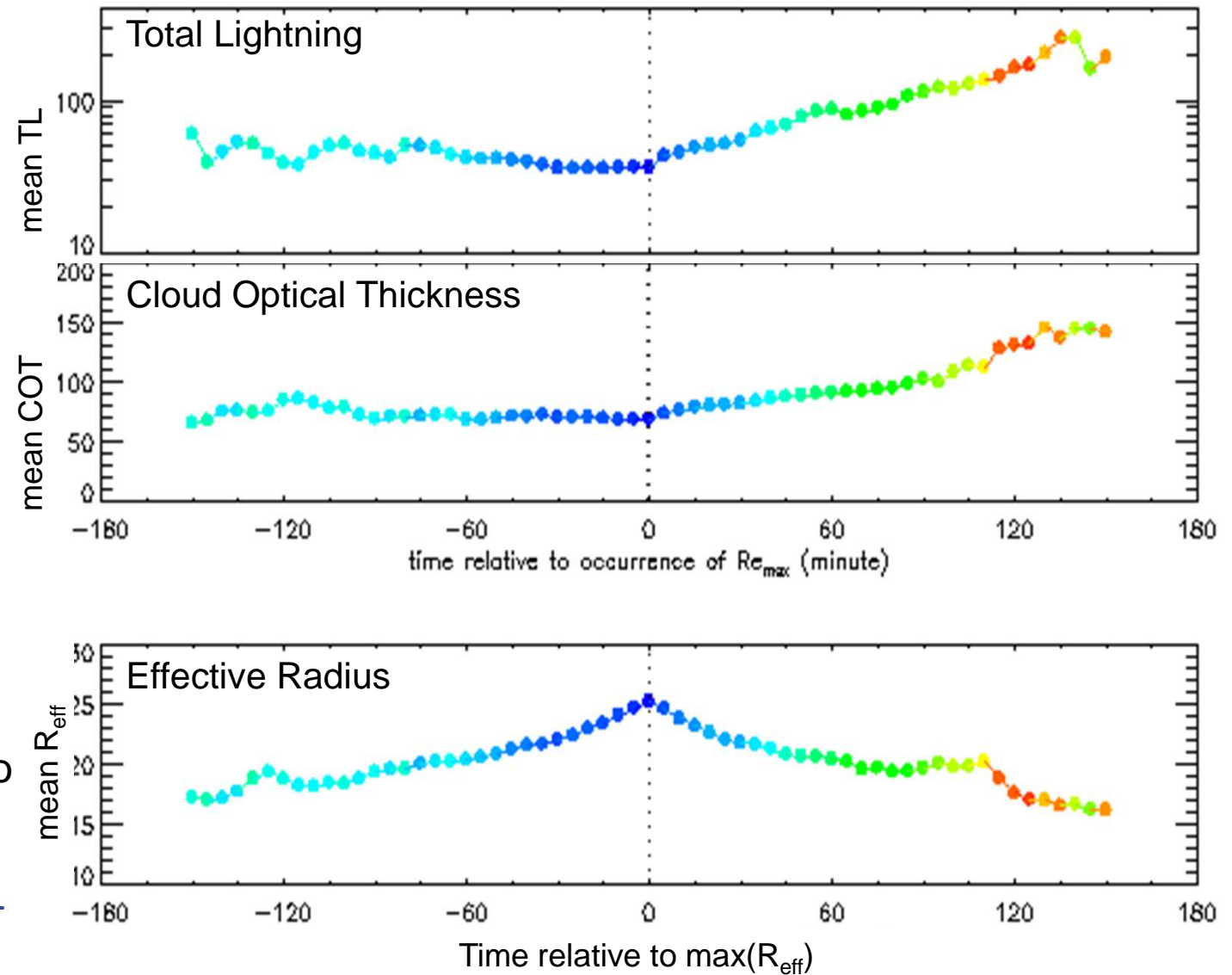


Lightning tendency vs intense reflectivity



- two hail warning categories:
 - > 1 km² >55 dBZ
 - > 13 km² >55 dBZ or > 1 km² >60 dBZ
- more frequent hail warnings level 2 with increasing lightning tendency

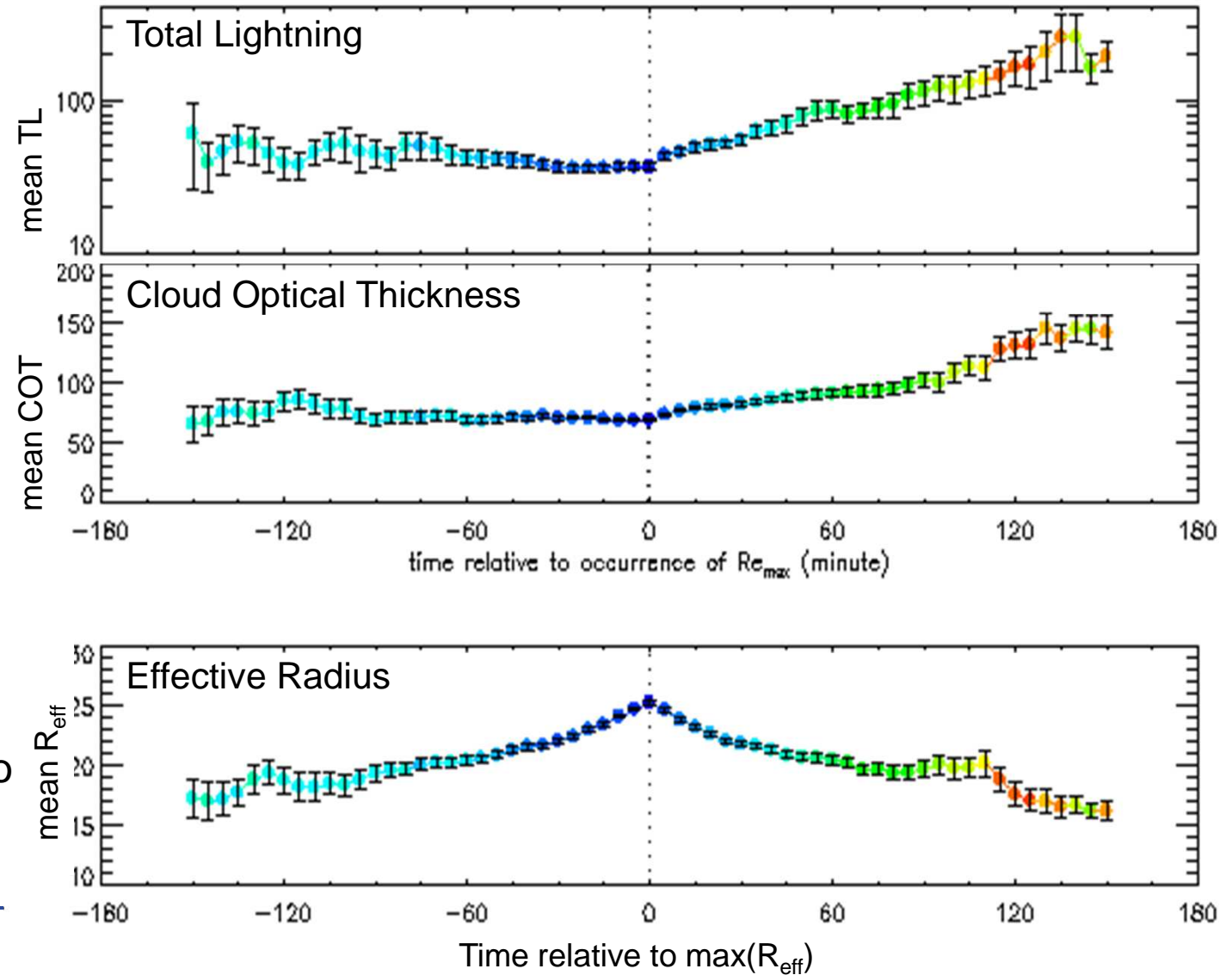
Life cycle



Tracks synchronized
in time with respect to
maximum R_{eff}



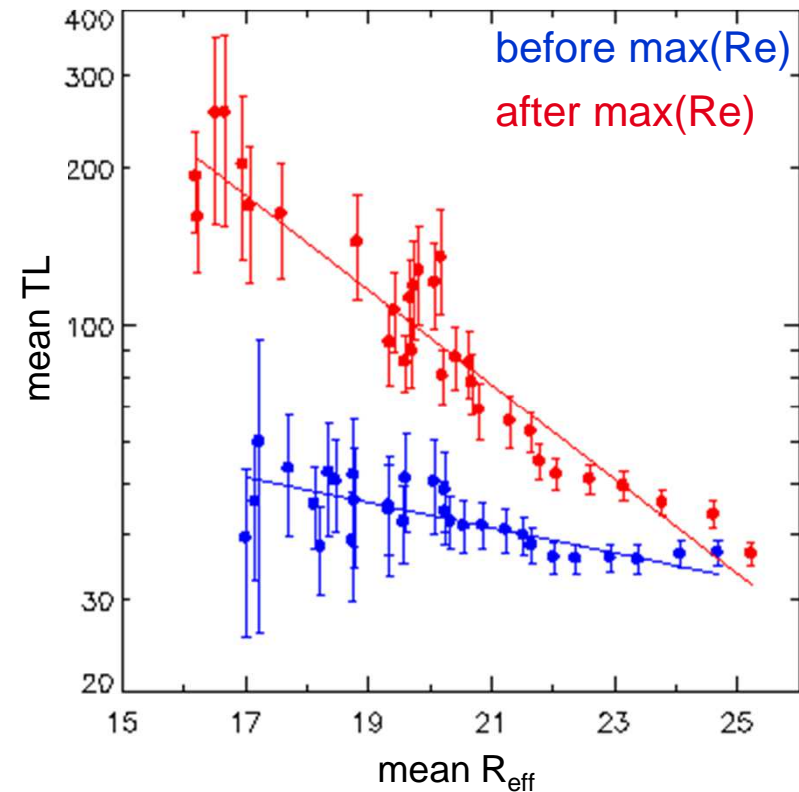
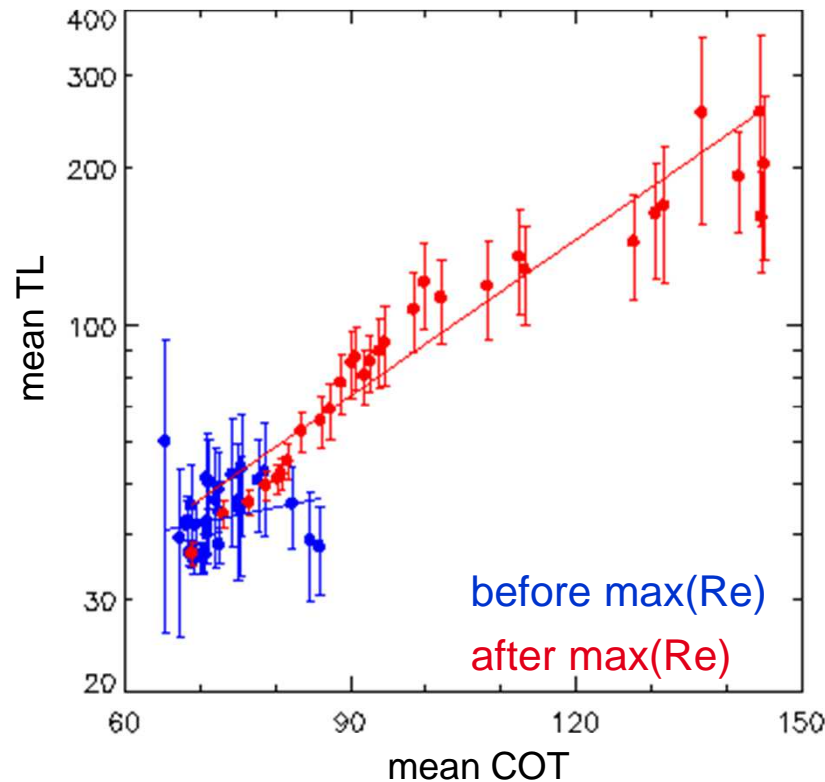
Life cycle



Tracks synchronized
in time with respect to
maximum R_{eff}



Lightning vs COT and Reff



- total lightning positively correlated with COT both before and after max(Re)
- correlation between total lightning and R_e strongly negative after max(R_e)!
- descent of large particles induces electrification

