



***An Approach to Define Adverse Wx Zones Based
on the Flight Management Performed by Pilots in
Convective Weather Events***

Ulrike Gelhardt, Jürgen Lang





Agenda

1. Motivation and Objective
2. Data Basis
3. Method
4. Results



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Objective

WX4CATO

In ATM and ATC often weather radar data are used to determine areas with adverse convective weather (Adverse Wx Zones) events like thunderstorms.

37dBZ radar reflectivity is the threshold value used in Germany then aircraft avoid such weather events.

But: no one ever had verified this threshold.

Overview

Meteorological Data (DWD):

1. convective warning level product
(categorical data)
2. weather radar data
(metric data, dBZ-Values)

Flight data (DFS)

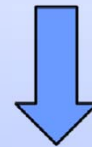
Objective

WX4CATO

In the frame of a SESAR project DFS Deutsche Flugsicherung GmbH (German Air Navigation Service, DFS) commissioned a study by MeteoSolutions.

The German National Weather Service (Deutscher Wetterdienst, DWD) was involved too.

**„Characteristics of
severe weather zones
which are avoided by aircrafts“**



**Achieve an improved definition of
„Adverse Wx Zones“**



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1. Weather radar product RX:

- radar reflectivity in dBZ
- low elevation scan (heights mostly between 100 m and 2 km)



In Germany often 37dBZ is used as a threshold to define convective areas.

2. Warning Levels of the NowCastMIX-Aviation Product



Input:

- weather radar products
- observations (stations)
- lightning data
- output of NWP models

Category	Project-specific Name	Attributes
heavy rain	WS0	<ul style="list-style-type: none"> • > 37 dBZ, without lightning
warning level 1 (light)	WS1	<ul style="list-style-type: none"> • thunderstorm with wind gusts up to 40 kt
warning level 2 (moderate)	WS2	<ul style="list-style-type: none"> • thunderstorm with wind gusts up to 55 kt and/or heavy rain (15-25 mm/h)
warning level 3 (heavy)	WS3	<ul style="list-style-type: none"> • thunderstorm with wind gusts more than 56 kt, optionally heavy rain • thunderstorm with hail • thunderstorm with heavy rain (25-40 mm/h)
warning level 4 (extreme)	WS4	<ul style="list-style-type: none"> • thunderstorm with wind gusts more than 56 kt and heavy rain, optionally hail • thunderstorm with extrem heavy rain (more than 40 mm/h), optionally hail



Warning- and Radar product:

1. 2D grid in polar stereographic projection
2. horizontal resolution: 1 km x 1km
3. temporal resolution: 5 minutes

Flight data:

- origin airport
- destination airport
- aircraft type
- engine type
- wake turbulence category
- payload (Pax / Cargo)



Flight trajectory (temporal resolution 4 sec.)

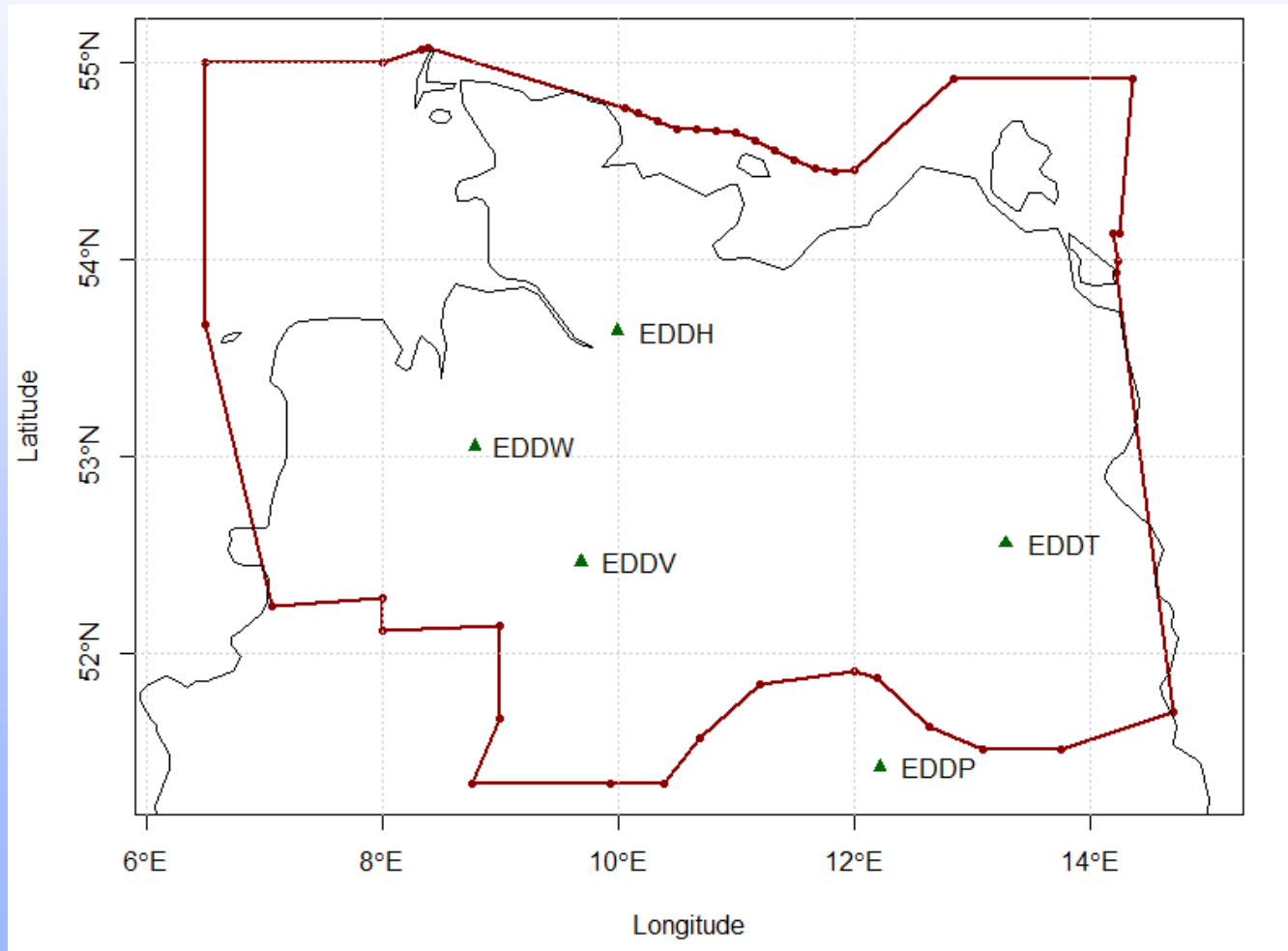
- geogr. coordinates, speed, height etc.

Flight trajectory (resolution: 4 sec):



- time offset
- UTM coordinates
- heights above the base height level (NHN)
- ground speed
- along track distance
- flight phase

Area of interest: Airspace Bremen ACC





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Method

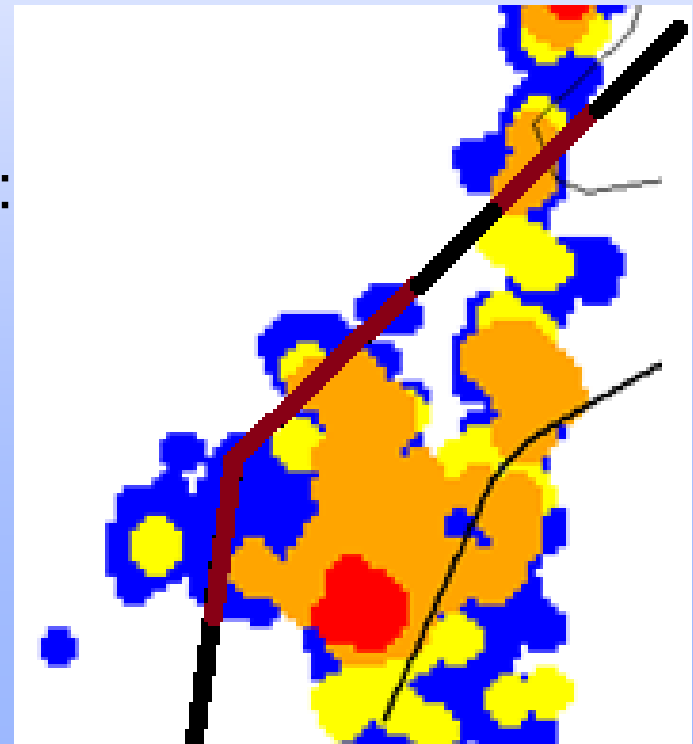
WX4CATO

Data Merging \longrightarrow Warning levels and reflectivity values along flight trajectories
(time synchronization
+ spatial mapping)

Conflict with convective area (“Event“):

Warning level along the trajectory
 \geq warning level 0 (WS0)

Events are separated by a time
distance criteria of **min. 5 minutes.**

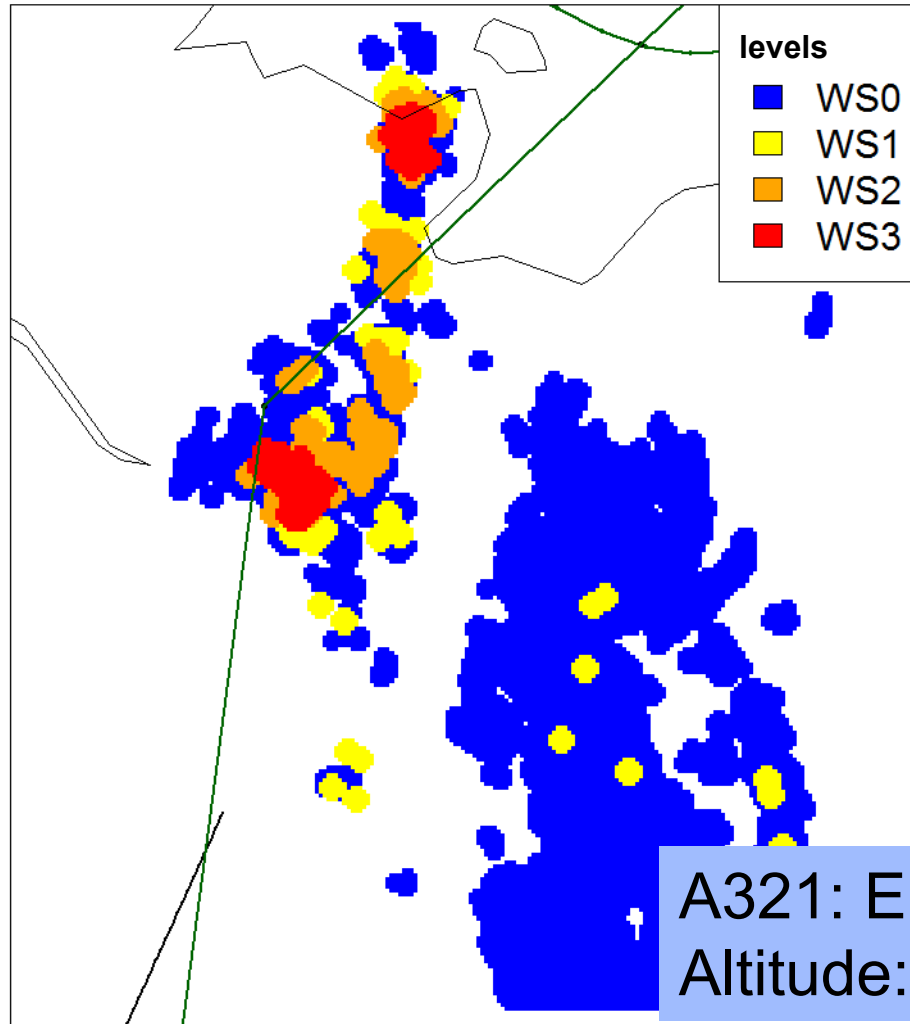


Example: Data Merging

WX4CATO

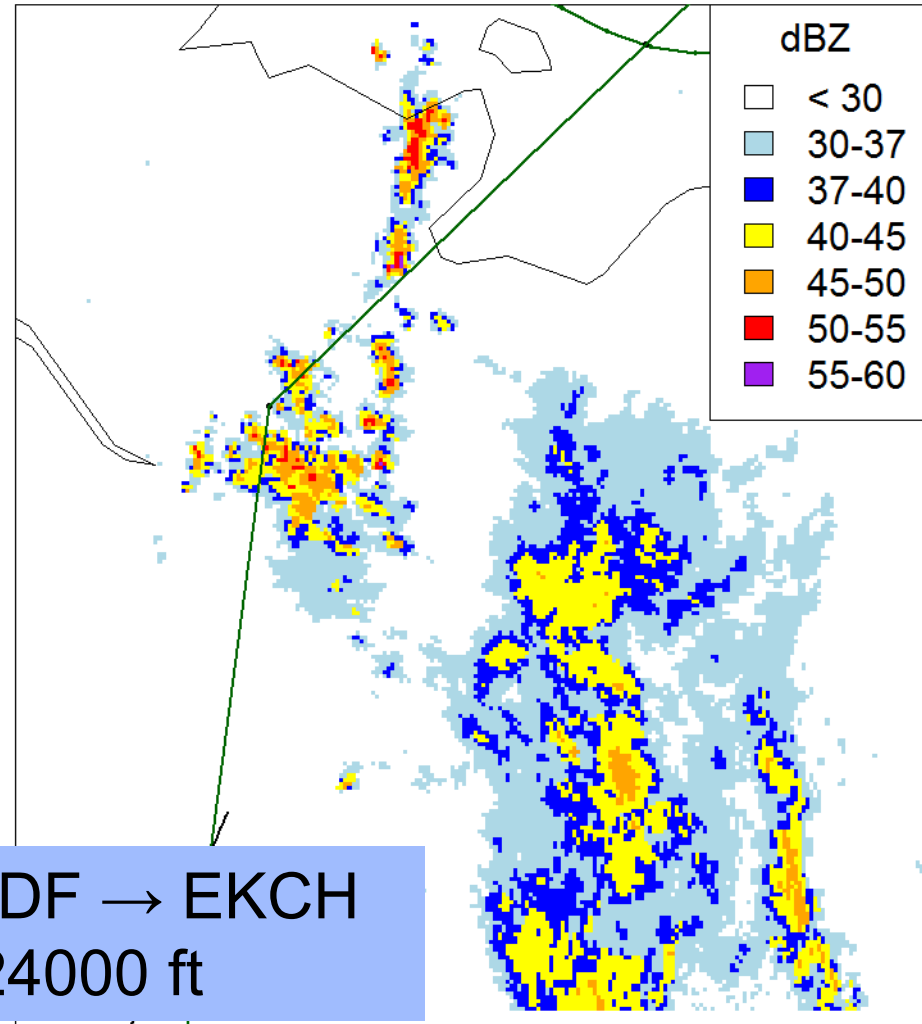
Warning Levels

20:35



Reflectivity

20:35



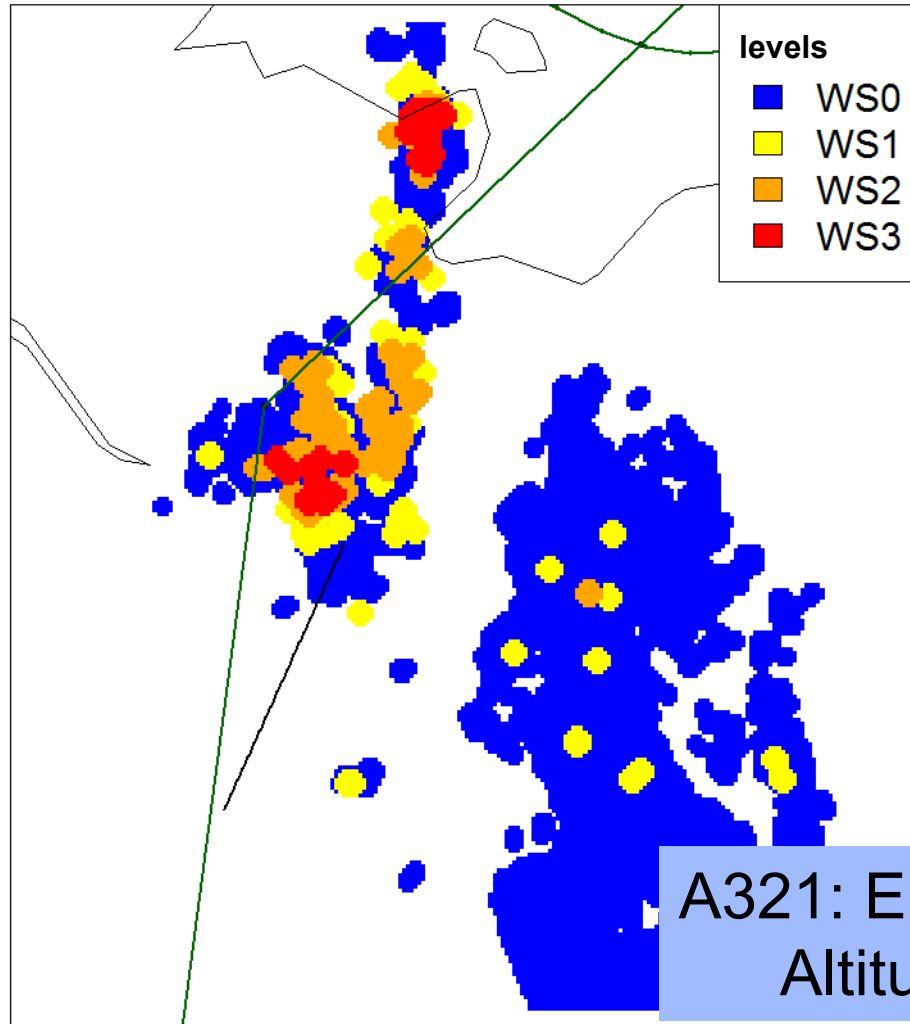
A321: EDDF → EKCH
Altitude: 24000 ft

Example: Data Merging

WX4CATO

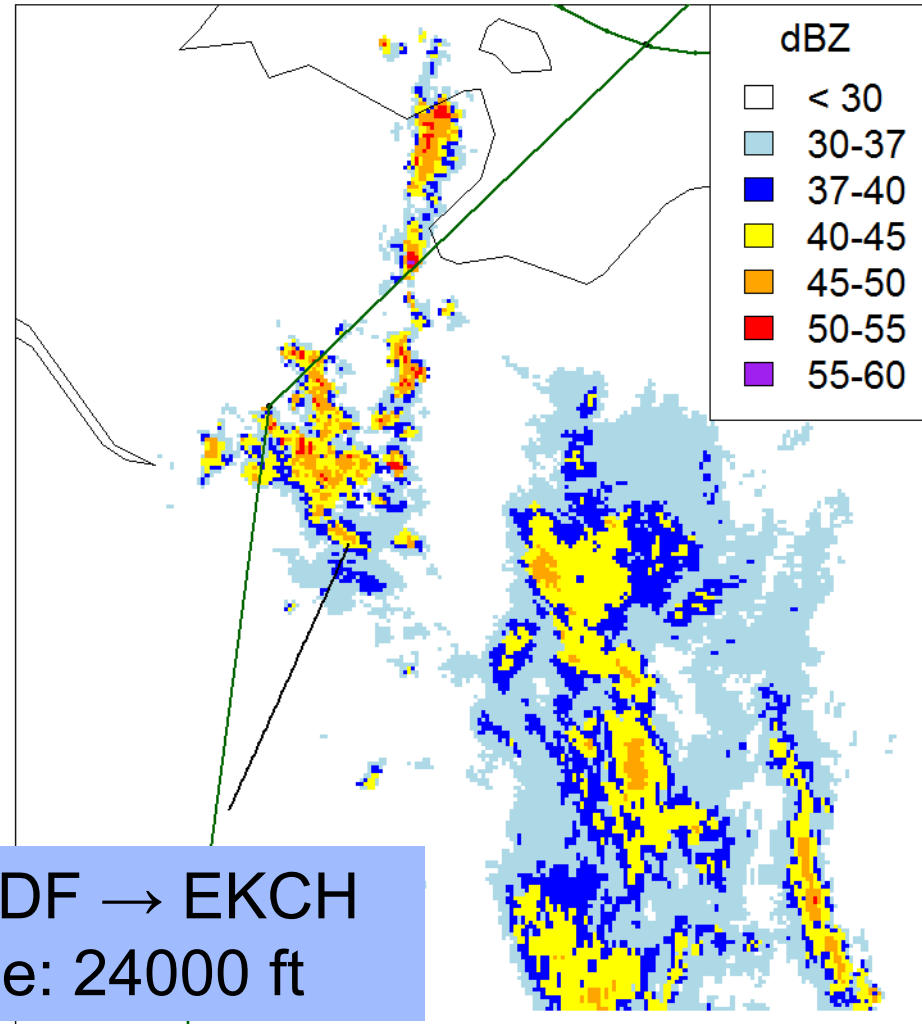
Warning Levels

20:40



Reflectivity

20:40



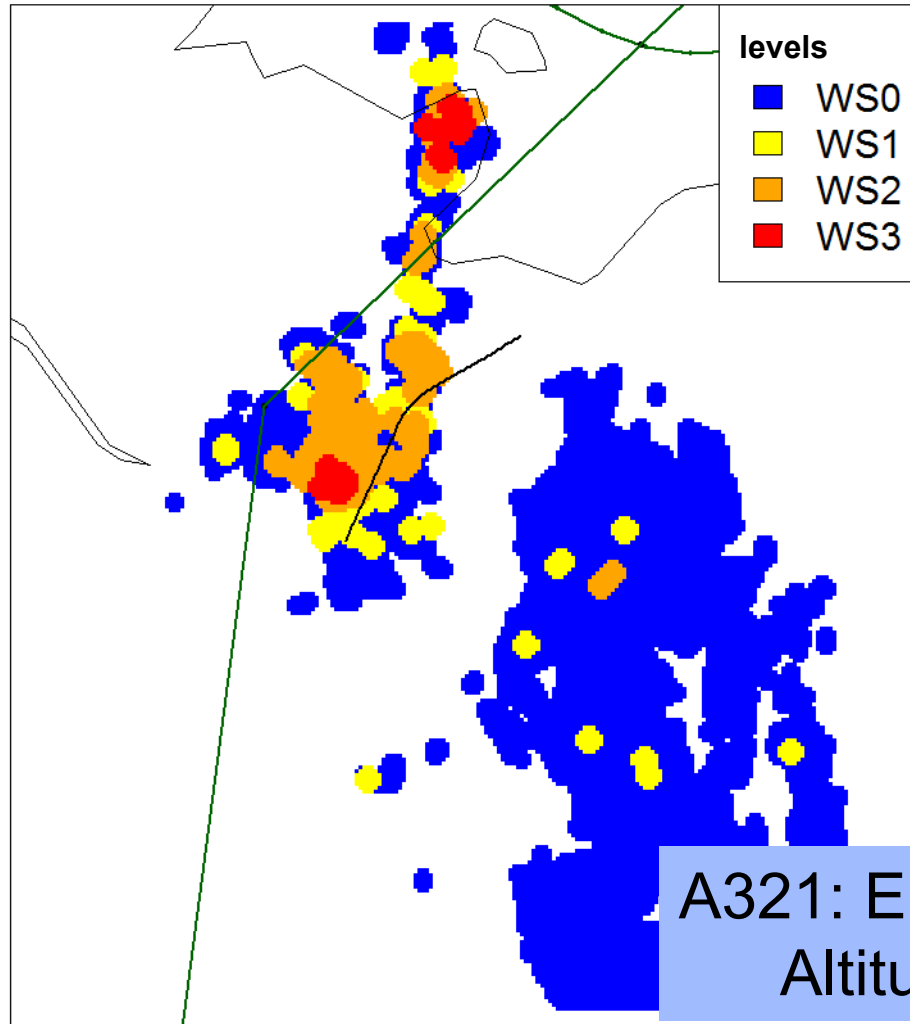
A321: EDDF → EKCH
Altitude: 24000 ft

Example: Data Merging

WX4CATO

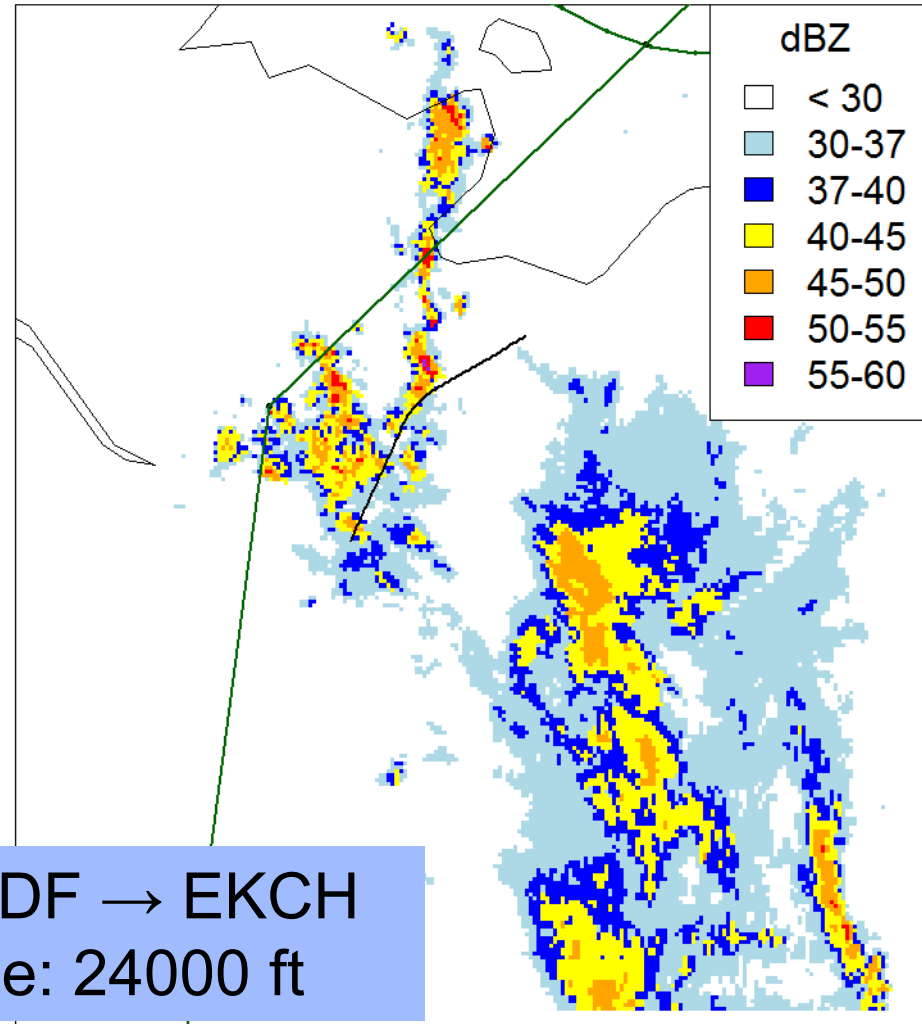
Warning Levels

20:45



Reflectivity

20:45



A321: EDDF → EKCH
Altitude: 24000 ft

Example: Data Merging

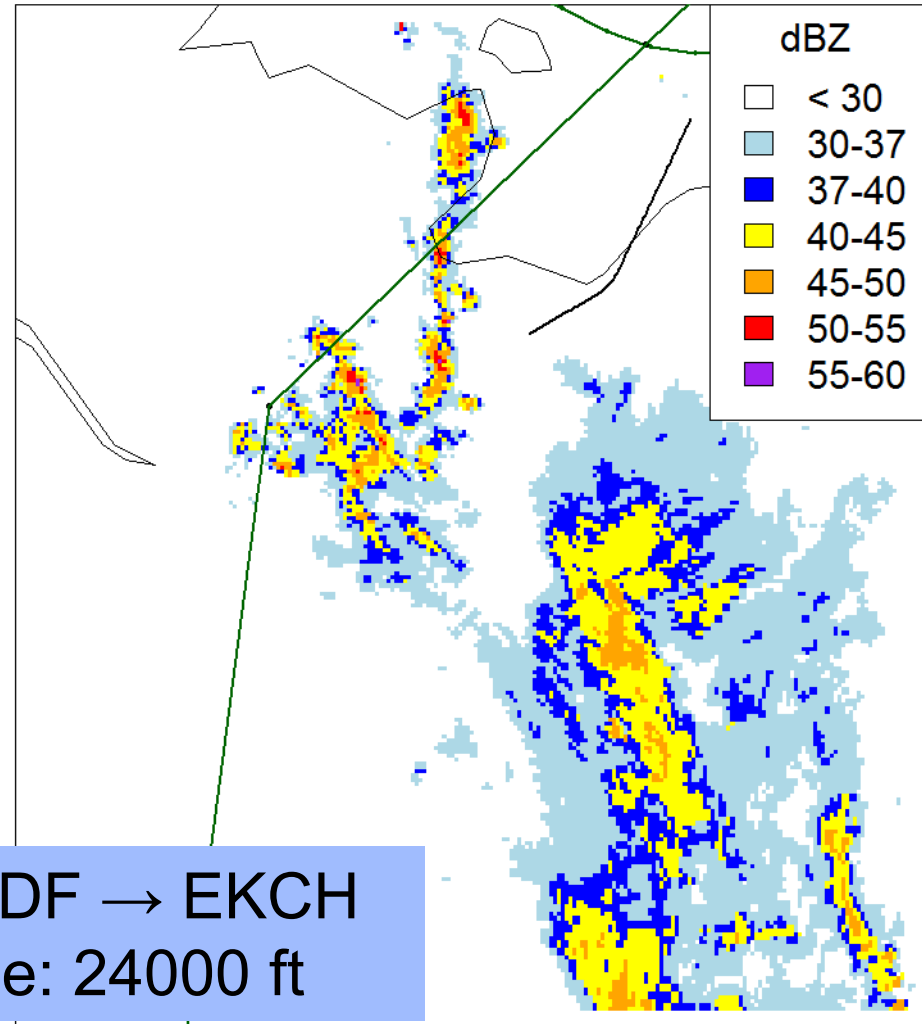
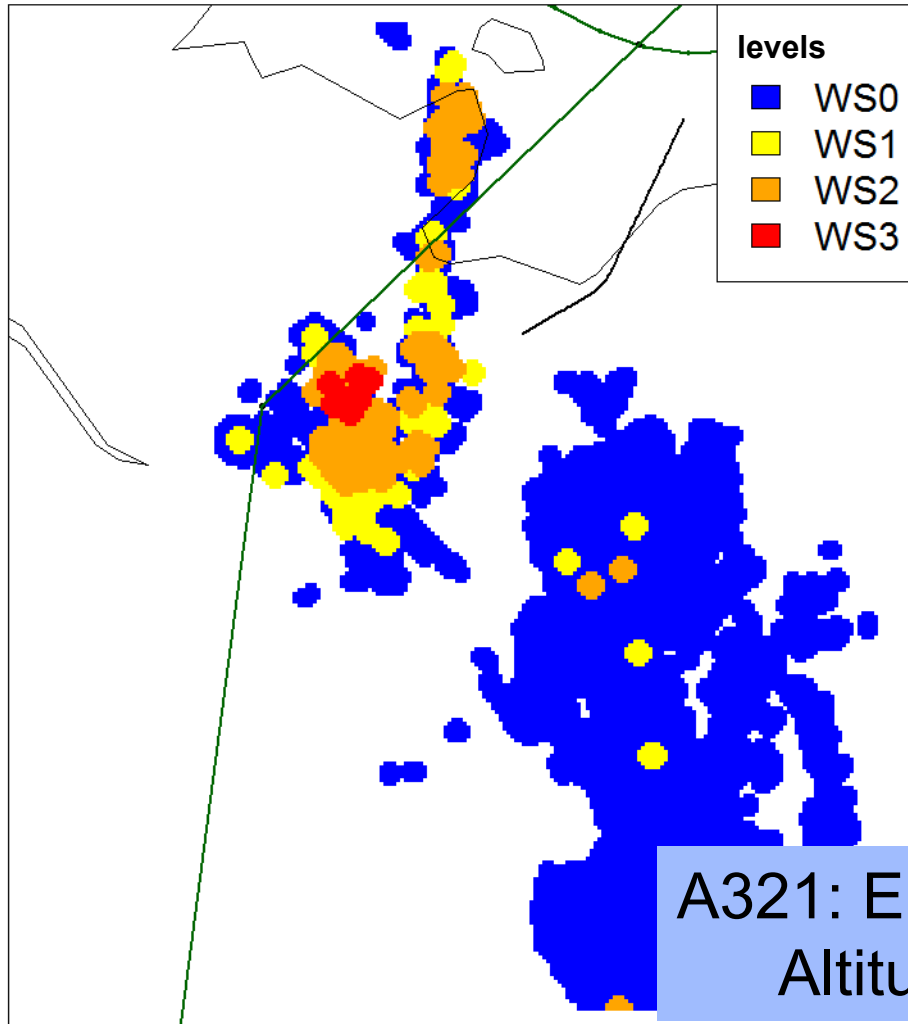
WX4CATO

Warning Levels

20:50

Reflectivity

20:50



A321: EDDF → EKCH
Altitude: 24000 ft

Information for each event:

- Max. radar reflectivity
- Flight duration and distance, time of entry
- Number of trajectory points with WS0, WS1, WS2, WS3 und WS4



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Used data for the analysis:

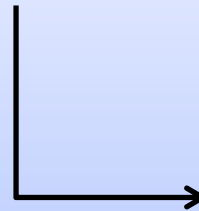
- DWD used objective criteria for the selection
- 20 thunderstorm situations in June 2017 in ACC Bremen
- nearly 14.000 minutes
- 4.414 events

Results

WX4CATO

Criteria for adverse weather (DWD)

Parameter	Criterion
Intensity	Threshold reflectivity = 30 dBZ
Duration	10x5 min in a row: reflectivity > 30 dBZ
Horizontal Resolution	0.5 % of the area of interest (Bremen FIR)



Vielleicht nur Text

Adverse Weather in in June 2017 (DWD)	Duration [min]	Duration Night [min]
03.06. 03:55 – 03.06. 15:15	680	5
03.06. 17:10 – 04.06. 12:30	1160	480
05.06. 18:05 – 05.06. 19:50	105	0
06.06. 10:20 – 07.06. 01:40	920	340
07.06. 06:45 – 07.06. 22:30	945	150
08.06. 13:10 – 08.06. 15:15	125	0
09.06. 01:55 – 09.06. 02:45	50	50
09.06. 03:15 – 09.06. 06:25	190	45
09.06. 07:40 – 10.06. 00:35	1015	275
11.06. 14:25 – 12.06. 02:30	725	390
15.06. 14:55 – 16.06. 04:45	830	480
16.06. 05:10 – 16.06. 06:10	60	0
16.06. 08:55 – 16.06. 18:55	600	0
22.06. 04:50 – 22.06. 14:15	565	0
22.06. 14:25 – 23.06. 04:15	830	480
25.06. 00:40 – 25.06. 01:50	70	70
25.06. 01:55 – 25.06. 14:00	725	125
26.06. 02:45 – 26.06. 04:00	75	75
27.06. 18:35 – 29.06. 00:35	1800	275
29.06. 07:30 – 30.06. 21:05	2255	480
Σ	13725	3720 (=27%)

Results

WX4CATO

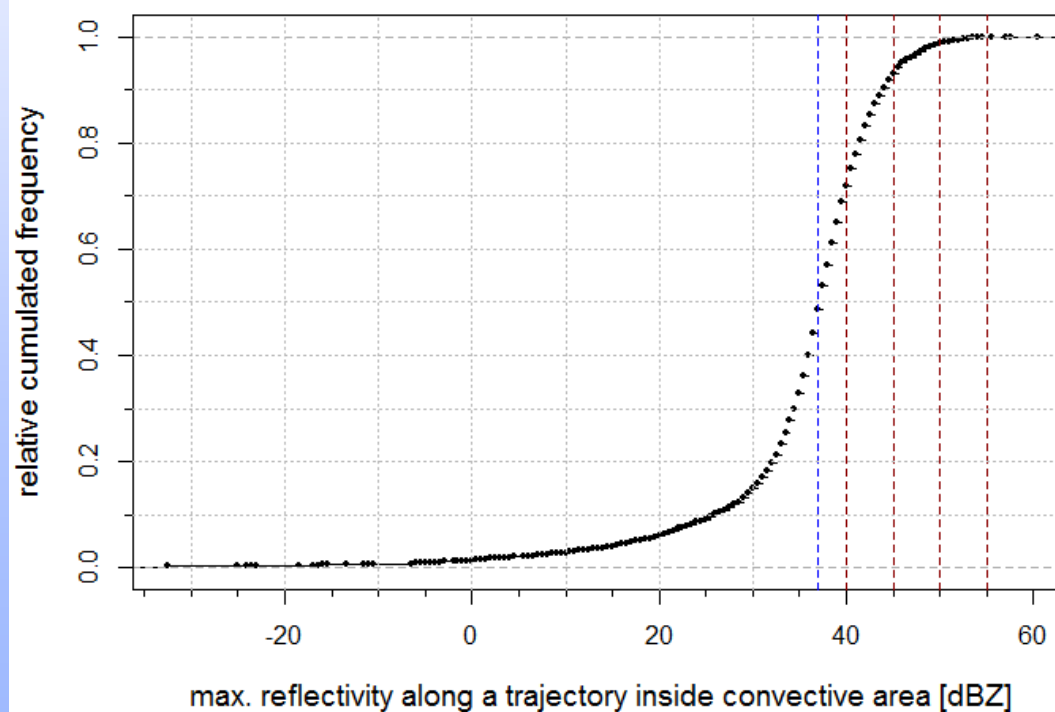
Severe Weather Conditions in June 2017	Number of Events		Σ Events
	Mean Altitude < 8km	Mean Altitude ≥ 8km	
03.06. 03:55 – 03.06.15:15	188	167	355
03.06. 17:10 – 04.06.12:30	186	110	296
05.06. 18:05 – 05.06.19:50	15	3	18
06.06. 10:20 – 07.06. 01:40	215	187	402
07.06. 06:45 – 07.06. 22:30	292	234	526
08.06. 13:10 – 08.06. 15:15	0	0	0
09.06. 01:55 – 09.06. 02:45	0	0	0
09.06. 03:15 – 09.06. 06:25	0	1	1
09.06. 07:40 - 10.06. 00:35	290	181	471
11.06. 14:25 – 12.06. 02:30	186	138	324
15.06. 14:55 – 16.06. 04:45	141	107	248
16.06. 05:10 – 16.06. 06:10	11	6	17
16.06. 08:55 – 16.06. 18:55	306	151	457
22.06. 04:50 – 22.06. 14:15	99	49	148
22.06. 14:25 – 23.06. 04:15	268	157	425
25.06. 00:40 – 25.06. 01:50	0	0	0
25.06. 01:55 – 25.06.14:00	195	116	311
26.06. 02:45 – 26.06. 04:00	1	0	1
27.06. 18:35 – 29.06. 00:35	367	348	715
29.06. 07:30 – 30.06. 21:05	1654	769	2423
Σ Ereignisse	4414	2724	7138

Results

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Empirical Distribution Function

50% of all events flight trajectories crossing areas > 37dBZ



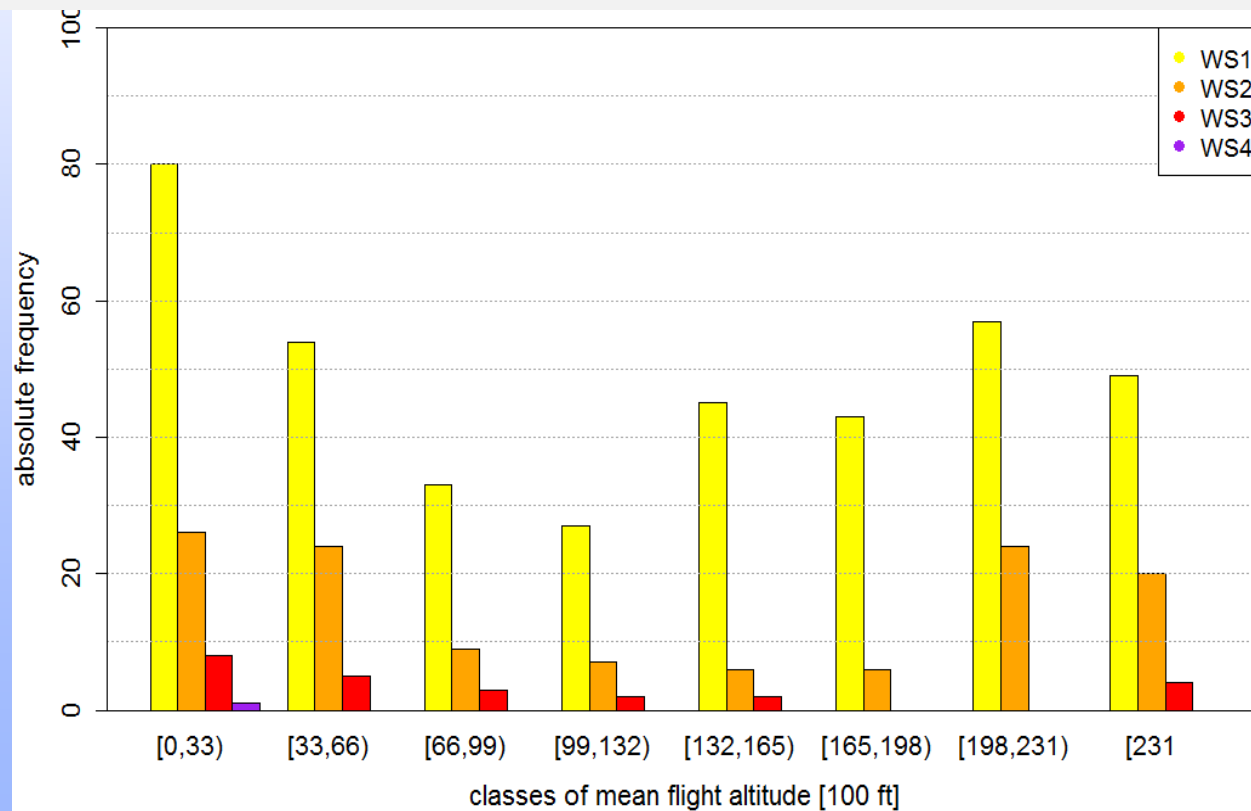
WS >= WS0

Results

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Dependency with height

10% of all events flight trajectories crossing WS 1



Results

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Relationship between warning levels and max. reflectivities along a trajectory

$W \geq WS_0$	Classes of max. reflectivity [dBZ]						Σ Events
	37)	[37,40)	[40,45)	[45,50)	[50,55)	[55	
$W_{\max}=0$	1775	1007	876	196	21	4	3879
$W_{\max}=1$	133	58	106	65	25	1	388
$W_{\max}=2$	33	17	33	26	13	0	122
$W_{\max}=3$	9	2	5	4	3	1	24
$W_{\max}=4$	1	0	0	0	0	0	1
Σ Events	1951 44%	1084 25%	1020 23%	291 7%	62 1,4%	6 <1%	4414 100%

Summary

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Problem	Effect
Warning levels: polygons enlarged by technical reason	Larger pass-through rate
Reflectivity: large spatial variability	Error in data merging caused by spatial / temporal synchronization
Radar data from precipitation scan / onboard radar probably shows different structures	Unknown cell structure in upper atmospheric levels / inconsistencies caused by data merging
2D-data (no altitude information)	No differences between pass-through and fly-over

Adverse WX Zones: Proposal

WX4CATO

- Combination of the 2 meteorological products: warning levels and reflectivity
- Request: only 2 levels of adverse conditions

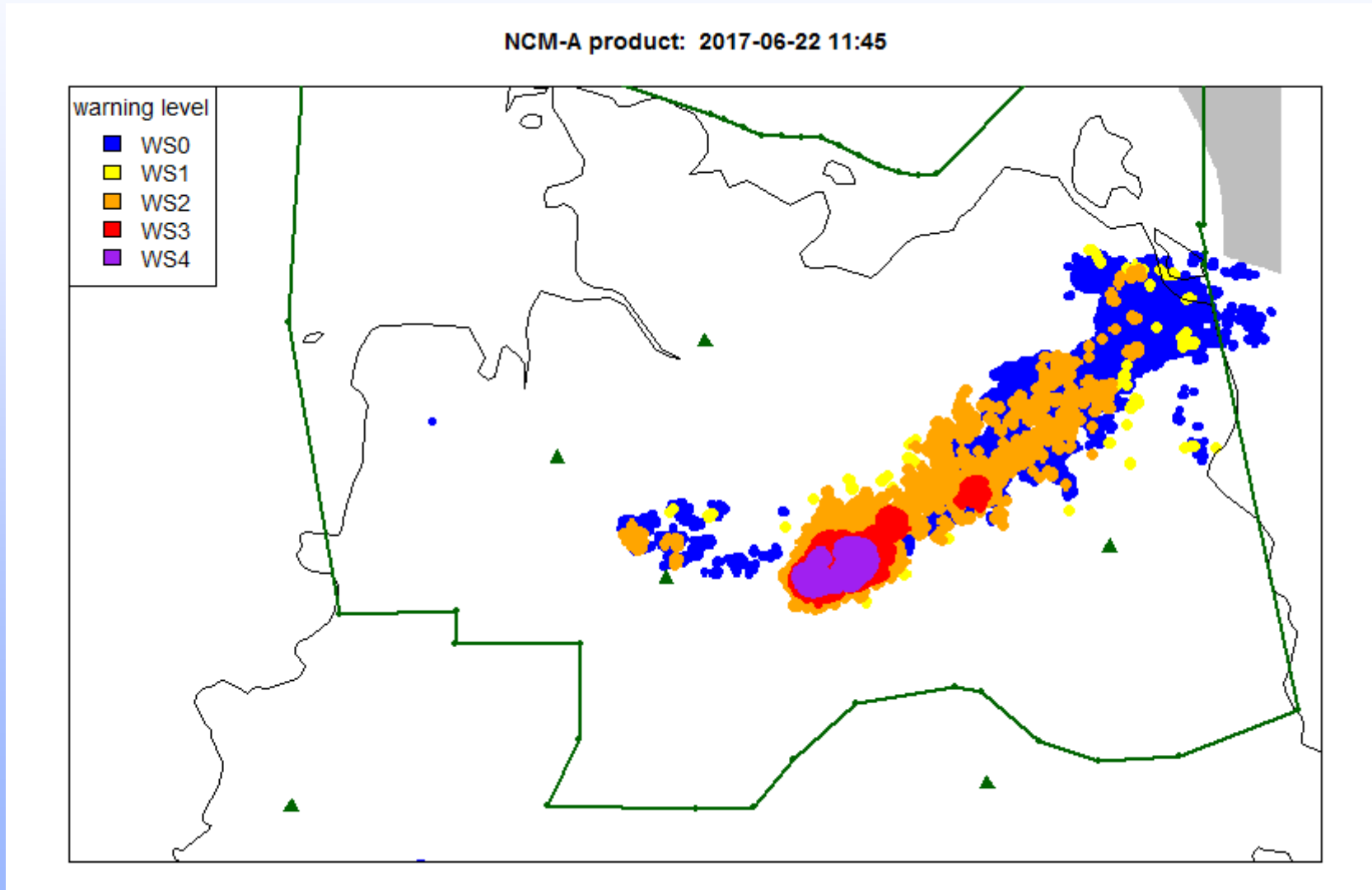


Original Nowcast-Mix Aviation	Adverse Wx Zones (Version1)	Adverse Wx Zones (Version 2)
WS0	WS0 & $R > R_{\text{threshold}}$	WS1 & $R > R_{\text{threshold}}$
WS1	WS1 & $R > R_{\text{threshold}}$	
WS2	WS2	WS2
WS3	WS3	WS3
WS4	WS4	WS4

e.g. $R_{\text{threshold}} = 37 \text{ dBZ}$

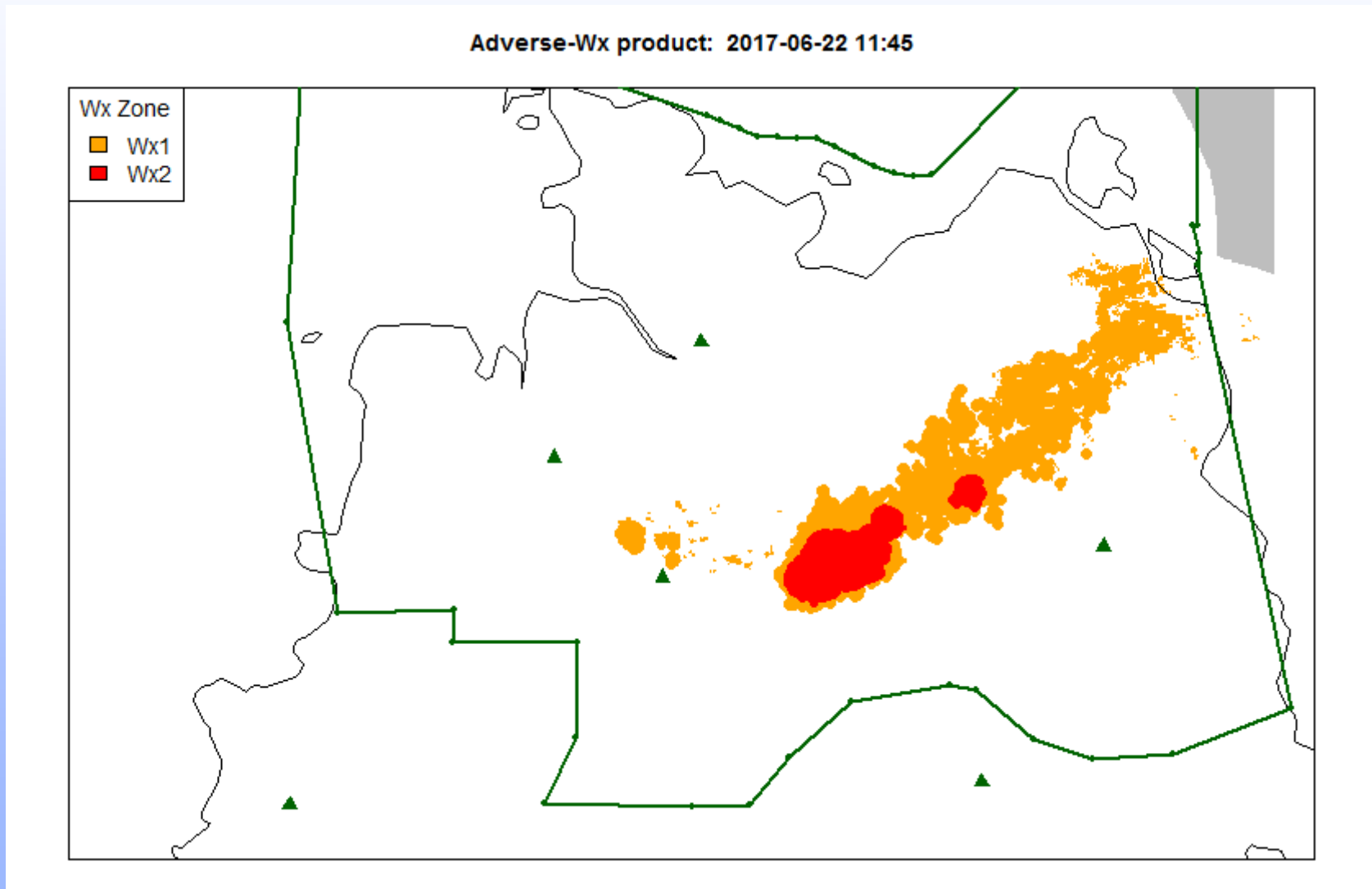
Example: Adverse Wx Zones (Original)

WX4CATO



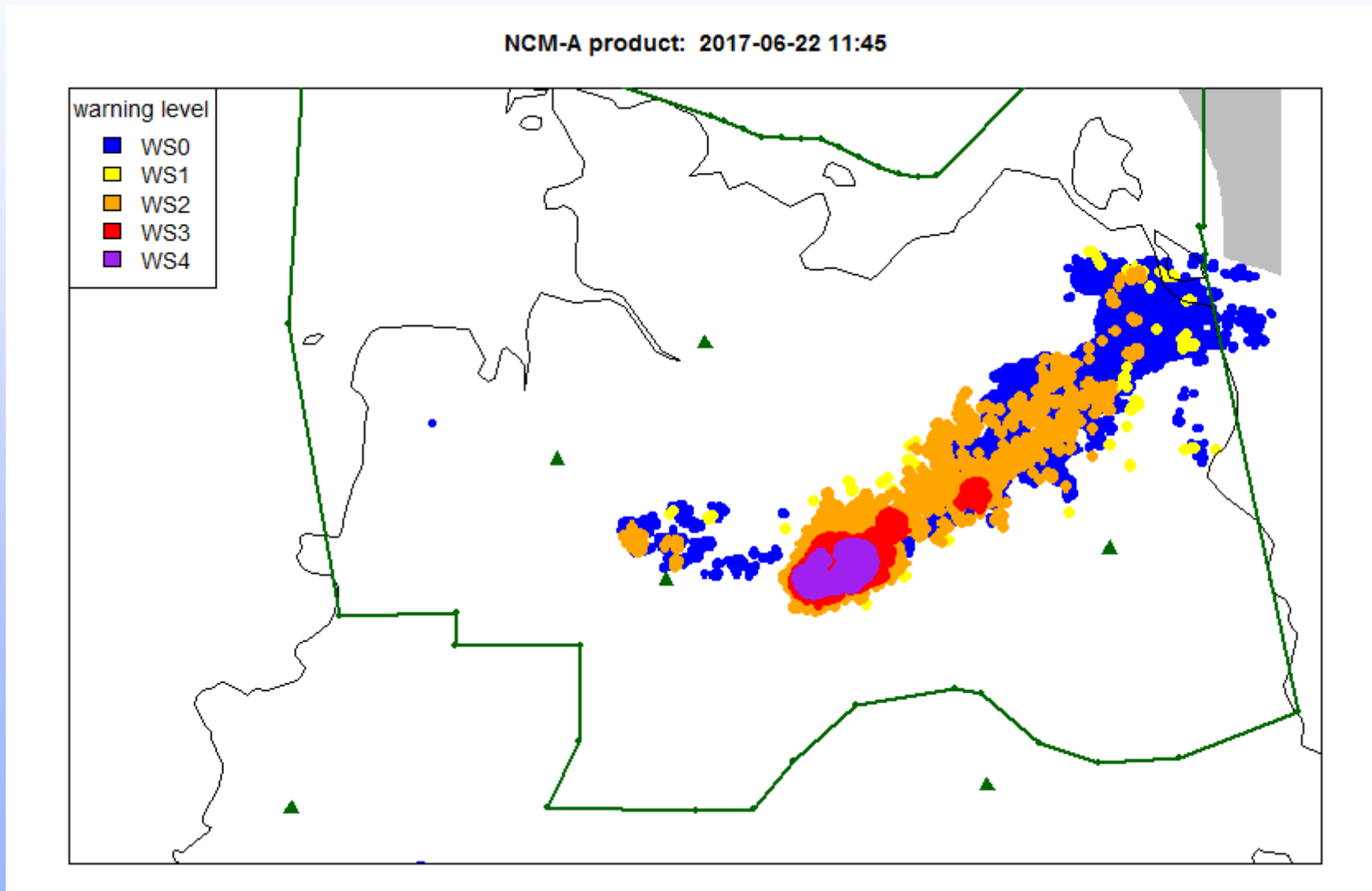
Example: Adverse Wx Zones (Version 1)

WX4CATO



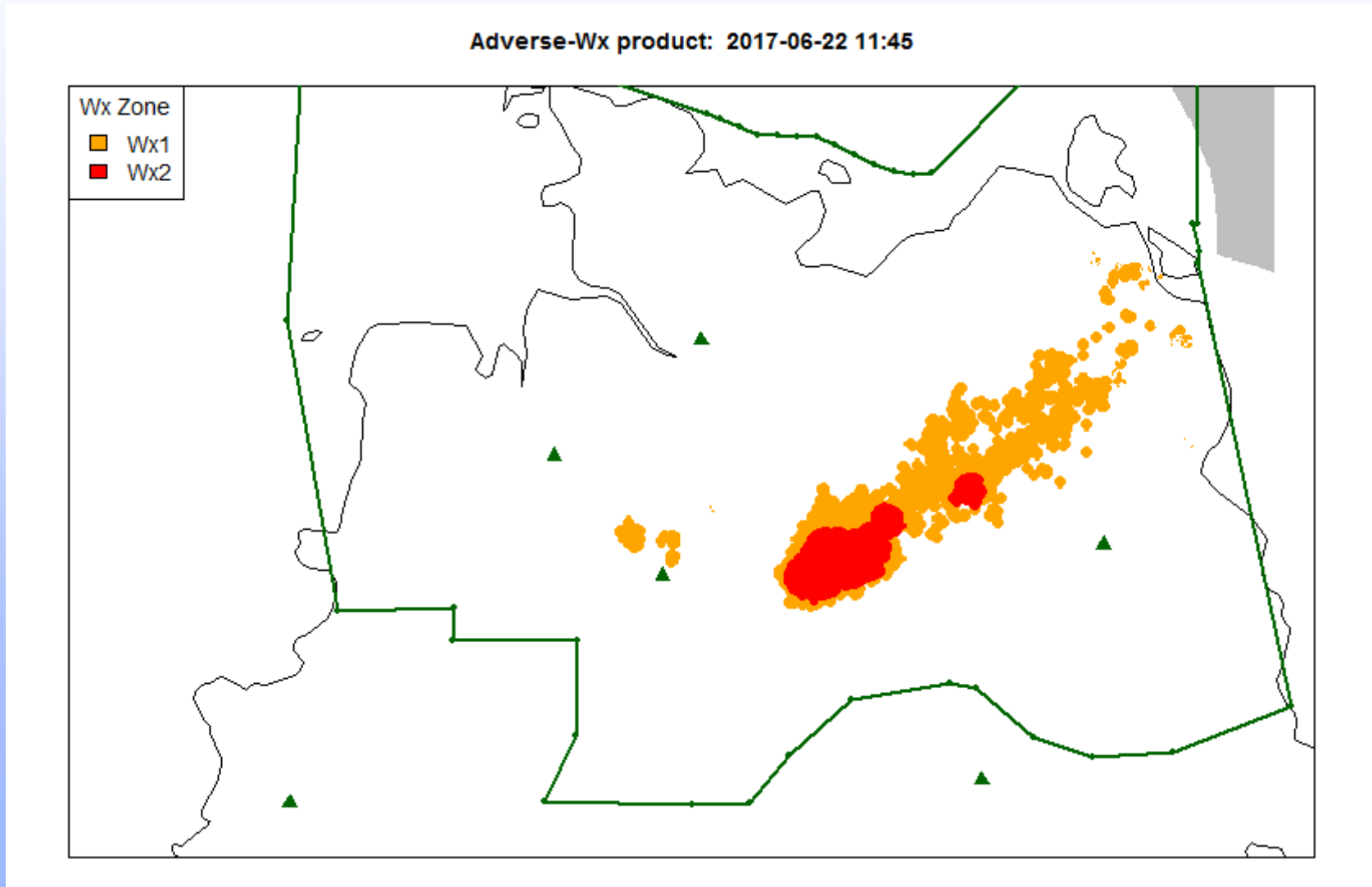
Example: Adverse Wx Zones (Original)

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Example: Adverse Wx Zones (Version 2)

WX4CATO



Project will be continued.

Questions?

MeteoSolutions GmbH

Wilhelminenstraße 2

64283 Darmstadt

Fon: +49 6151 / 59 90 340

Fax: +49 6151 / 59 90 339

E-Mail: info@meteosolutions.de

www.meteosolutions.de