Summary of the evaluation of COSMO and ICON models at the ESSL Testbed 2017

ESSL report 2017-01

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1 Introduction

1.1 This report

This concise report summarizes the main findings of the evaluation COSMO models at the ESSL Testbed 2017, the results of an attempt to condense the feedback collected from discussions at the Testbed and that collected by questionnaires.

Additionally, a briefing on the evaluation of DWD products will be given by Pieter Groenemeijer at the DWD in Offenbach on 7 December 2017. The raw, unedited feedback of Testbed participants is included as an annex to this report.

1.2 The Testbed 2017 and its participants

The ESSL Testbed 2017 took place during the weeks of 5 – 9 June, 19 – 23 June, 26 – 30 June, and 3 – 7 July 2017 at the ESSL Research and Training Centre in Wiener Neustadt. During these four weeks, 48 external participants took part in the Testbed in addition to 4 ESSL staff.

From DWD, three R&D employees took part (Thomas Heppelmann, Kathrin Wapler and Martin Rempel), who all contributed to the Testbed with an oral presentation. In addition, Thomas Hengstebeck and Paul James provided a presentation remotely from DWD. ESSL would like to thank them for these contributions. In addition, eight DWD forecasters (Robert Hausen, Axel Barleben, Martin Jonas, Matthias Gäßl and Lars Kirchhübel) participated.

Other participants to the Testbed in 2016 included delegates of AEMET (Spain), ZAMG (Austria), OMSZ (Hungary), FMI (Finland), CroControl (Croatia), MétéoFrance, SHMI (Slovakia), DHMZ (Croatia), HNMS (Greece), CHMI (Czechia), LVGMC (Latvia), MeteoSwiss (Switzerland), IPMA (Portugal), NMA (Romania), MeteoGroup, MilMet (Austria), NSSL (U.S.A.), North Carolina State University (USA), University of Central Michigan (U.S.A.). ESSL expresses its thanks to all participants for their contributions.

1.3 Testbed Resources

The following online resources contain further information about the Testbed 2016:

The Testbed Data Interface showing all products and all data, is available online after the end of the Testbed at:
http://weather.essl.org/testbed/nowcast2016.php

Username: testbed
Password: 2016neustadt

A Blog describing the daily activities at the Testbed can be found at:
http://www.essl.org/testbed/blog

Background information and all presentations given at the Testbed can be accessed at:
http://www.essl.org/testbed/info
password: 2016neustadt

1.4 Feedback

Feedback on the products was collected throughout the Testbed, partly **i) in direct discussions with the on-site R&D participants**, and in part **ii) through the documentation of answers to questionnaires** that were filled out jointly by participants, who typically worked in groups of 2-4 persons in dedicated sessions during the afternoons. The feedback from participants has been attached to this report.

1.5 Evaluations

DWD has instructed to evaluate a number of aspects and output of the COSMO and ICON-EPS modelling system at the Testbed. This work consisted of the following activities.

- The definition of questions to be presented to participants.
- The development of visualization of products and implementation of the products in the Testbed Interface.
- Arrangements of presence of R&D experts, the collection of training material and scheduling of training sessions.
- The inclusion of updated information in the Testbed Operations Plan
- Carrying out forecasting and nowcasting activities by Testbed participants, followed by a verification of those forecasts
- An evaluation of the products' characteristics, involving a collection of suggestions for further improvements, both plenary and in groups, that include discussions and collection of feedback through questionnaires
- Publishing cases that illustrate product behaviour on the testbed weblog

1.6 Evaluation of COSMO-DE-EPS

DWD has a new model system set-up in terms of data assimilation and perturbations, which is expected to affect its handling of convective situations. A general evaluation of predictability of deep convection, similar to that which has been carried out in previous editions of the Testbed was carried out.

This time, particular focus was placed on:

- The quality of simulations of weakly vs. strongly-forced convective episodes
- The consistency of subsequent runs of the ensemble system

In addition, new COSMO-DE-EPS products have been evaluated, which had been developed for the assessment of simulated moist convection. Their usability in the context of convective hazard predictions was studied. These products are:

- updraft helicity track
- rotation track
- total condensate track
- maximum updraft track

1.7 Evaluation of selected probabilistic ICON-EPS products

The ICON model is now running pre-operationally in EPS mode twice a day (00 and 12 UTC). It has been investigated how selected probabilistic products, i.e. similar to those delivered for COSMO-EPS can help to identify hazardous convective situation up to 48 hours ahead, both in weakly and strongly forced situations.

2 Summary of results

2.1 General Assessment of COSMO-DE-EPS model performance regarding convective systems

These are our main conclusions regarding COSMO-DE-EPS:

- In the previous Testbeds ever since 2012, we have found that COSMO-DE(-EPS) was too reluctant in producing convection in absence of mountains or well-defined forcing weather systems. At the 2017 Testbed we have not encountered any clear-cut cases of underforecasting. In other words, **the performance of COSMO-DE-EPS in weakly-forced situations that were problematic in the past seems to have been improved greatly**.
- In some cases (19 June, 22 June and 1 August; see Chapter 3), **COSMO-DE(-EPS) produced too much convection in areas where prior convection had already modified the environment**. The model created convection in environments that were likely not as unstable as the model simulated. In particular, on 1 August, a sequence of COSMO-DE-EPS runs predicted many very intense supercells to occur across Northern and Central Germany. The COSMO system, along with many coarser models overestimated the convective potential because of an underestimation of the intensity of elevated convection and the resulting stabilization.
- In one case, June 22, the propagation of an MCS coming from the North Sea across Northern Germany was underestimated until rather late, i.e. probably until it was assimilated by radar. This suggests that the **advection of convective systems into the model domain is still a problem** (as it was in the notorious 9 June 2014 case).

2.2 Specific comments regarding the use of new COSMO-DE-EPS products

- **The updraft-helicity track product appears to be a very suitable tool to pinpoint supercell activity**, much more so than the vorticity track product which shows too many signals, or the non-track products such as the SDI which are more difficult to interpret.
- **The "simulated VIL and VII-track products" appear useful to pinpoint areas of high and correlate well with observed VIL and VII-track products**.

2.3 Comments regarding ICON-EPS

We evaluated these variables of the ICON-EPS:

- 10 m wind gust (thresholds 18 and 25 m/s)
- 6-hourly accumulated precipitation (thresholds 30 and 60 mm)
- 12-hourly accumulated precipitation (thresholds 40 and 70 mm)
- 24-hourly accumulated precipitation (thresholds 50 and 80 mm)
- CAPE (thresholds 500 and 1500 J/kg)

All of the parameters were plotted on four different maps. The exceedance of two thresholds was displayed as well as the median and maximum value of all ensemble members.

- **The model seemed to have realistic predictions of precipitation accumulations and of CAPE.** The model consensus was often comparable to the deterministic ICON-EPS, which did not have a systematic bias compared to the ECMWF model. Due to the lack of wind cases, not much can be concluded about wind gusts. ICON-EPS, like any model with such a resolution is not good at predicting convective wind gusts. This was clear on 11 August 2017, when a strong bow echo produced widespread extreme wind damage across central and northern Poland. One cannot expect a model with that resolution to accurately predict the life cycle of an individual convective storm or even a small mesoscale convective system.

- **The display of ensemble data in terms of exceedance probabilities was liked by the participants.** However, the thresholds chosen by ESSL, similar to DWD's warning thresholds, should be lowered. In convective events, thresholds are not often exceeded by 20 x 20 km grid cell average values. Probably the probability of any precipitation is additionally very informative in cases where convective initiation is uncertain.

2.4 Selected cases in Chapter 3

In the next Chapter, a number of cases that occurred during the Testbed or in the weeks after the Testbed are described. They are:

<u>Testbed cases:</u>

- 19 June: Linear N-S oriented MCS across North Germany and scattered storms
- 22 June: MCS moving into North Germany, more storms forming elsewhere
- 29 June: Flooding in the Berlin area
- 7 July: Some storms south of the Alps and across South Germany

<u>Post-Testbed cases:</u>

- 10 July: Tornado near Schwechat Airport, Vienna
- 1 August: DWD forecast of severe storms and possible tornadoes that did mostly not verify.

2.5 Suggestions for the 2018 Testbed

We have noted a number of imperfections and potential improvements on the side of ESSL. Some of the imperfections have to do with the late provision of new data products that left little time to pre-test before the Testbed.

- ESSL should introduce additional, and lower threshold levels for ICON-EPS products. The current levels are very extreme, especially since they related to grid-cell averages for cells of 20 x 20 km. Furthermore, the display of how many ICON members produce *any* precipitation is an interesting point of information that was not available at the current Testbed.

- ESSL should merge hourly COSMO-DE-EPS tracks to 3-hour tracks to better resemble the products observed by radar.
- ESSL should improve the color scales of some of the track products. Some of the colorscales were not optimally chosen and could not be changed any more.
- ESSL should introduce anticyclonic updraft helicity tracks. This was requested by Ulrich Blahak, contact person for the helicity track products, and is certainly useful in order to detect left-moving storms. Some adaptations need to be made to the plotting script.
- The Supercell Detection Index. It seems that track-based products give more information than instantaneous values.
- DWD is asked to provide more lower-tropospheric pressure level data to enhance the resolution of the low-level hodograph.
- DWD is asked to update the color scales of radar products in coordination with ESSL, if possible.

3 Selection of cases with notes

3.1 19 June 2017

Cooler air approached from the west to replace a warm, unstable air-mass over Germany. Some scattered storms approached NW Germany during the morning and early afternoon. After 12 UTC, more intense convection developed across western Germany, which gradually evolved into a large mesoscale convective system.

In the figure on the next pages (Fig. 3.1.1 and Fig. 3.1.2), radar images and COSMO-DE-EPS forecasts are presented alongside each other. The +3 and +9 hour EPS forecasts of the exceedance of 40 dBZ reflectivity within the area of reference are presented on page one, and the respective +24 hour and +33 to +45 hour forecast from the 03 UTC run on the next page.

+3 and +9 hour forecasts

From the data at 12, 15 and 18 UTC (Fig. 3.1.2.), it can be seen that the COSMO-DE-EPS forecasted the initial convection that moved to Germany quite well: the location of the highest probabilities coincides more or less with the radar image. Later on, some differences between the ensemble consensus and the radar become apparent. At 21, 00 and 03 UTC the +9 and especially the +3 hour forecasts have very high probabilities of storms across some areas behind (i.e. to the west) the first area of convection, over the BeNeLux countries and northwest Germany. In reality, only a very few storms develop at 21 and 00 UTC. Moreover, although some more storms have developed at 03 UTC, the coverage is much smaller than one would expect seeing a band of near 100% probability of storms stretching from the Southern North Sea toward Luxembourg in the +3 hour forecasts valid at 03 UTC.

+24 and forecasts from the 03h ensemble of 18 July

These longer-term forecasts generally give quite clear and correct signals about the locations of actual convection at 12, 15 and 18 UTC. There is hardly any difference in quality between the +24 h runs and the prediction of the ensemble of 3h on 18 June. It is clear, however, that the development of a large cold-pool driven system is supported by a modest fraction of the ensemble members.

Like the shorter-term forecasts, convective activity in the wake of the first system, in particular over the southern North Sea, Netherlands and far northwest Germany is overestimated. A comparison of the observed and forecast vertical profiles at 00 UTC at Norderney (Fig. 3.1.3) reveals that the deterministic COSMO-DE run predicted a more humid and cooler profile in the lowest 2 km. It is thinkable that subsidence by the first leading system whose activity was underestimated, was in part responsible for the difference, but there may also be other reasons.

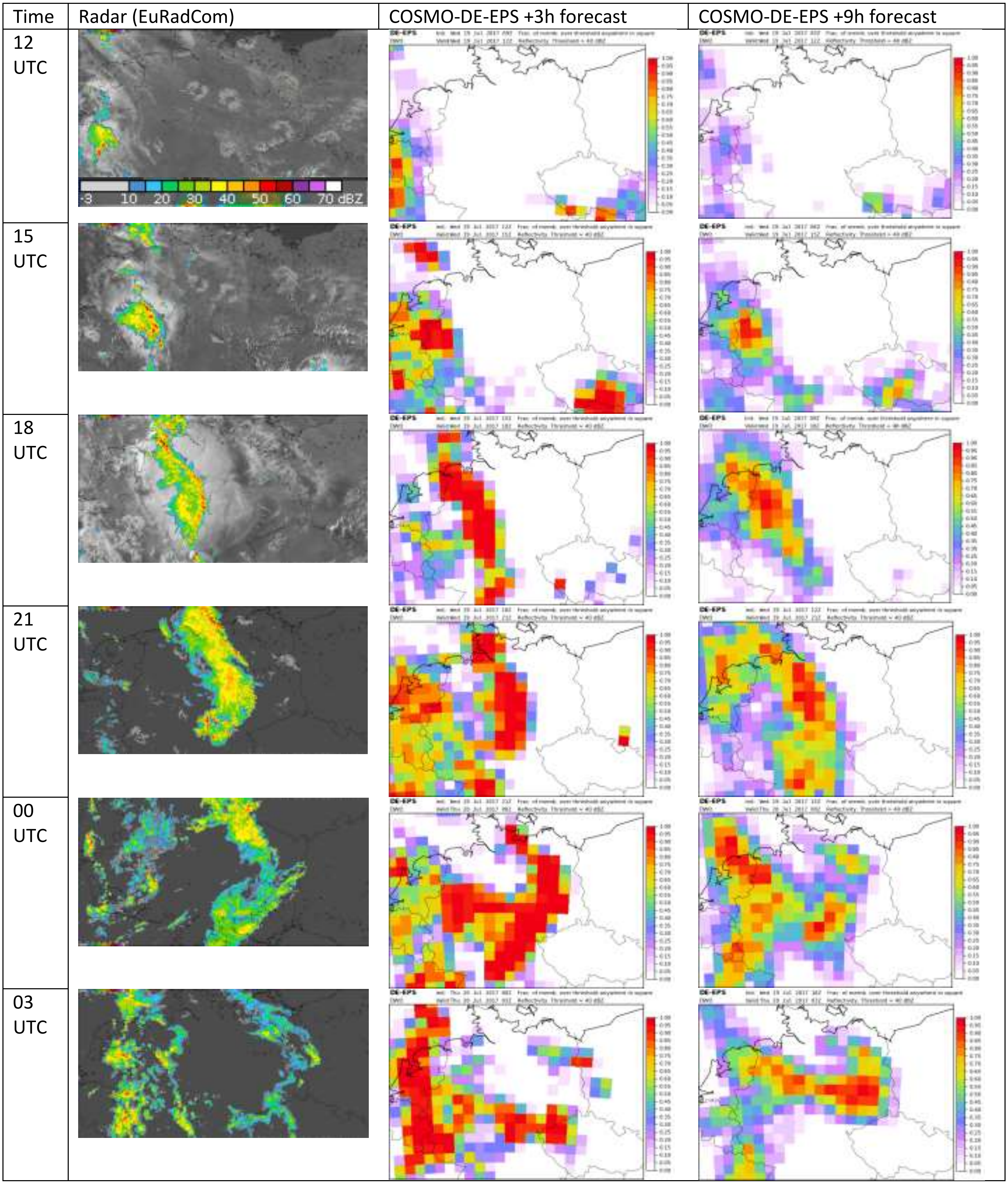


Fig. 3.1.1 Radar composite, and +3 and +9 hour COSMO-DE-EPS forecasts of probability of exceedance of 40 dBZ somewhere within each square.

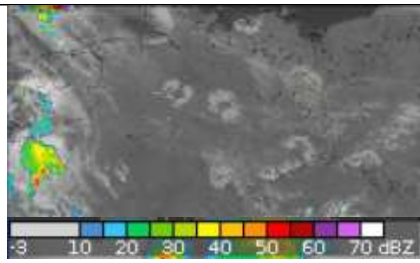
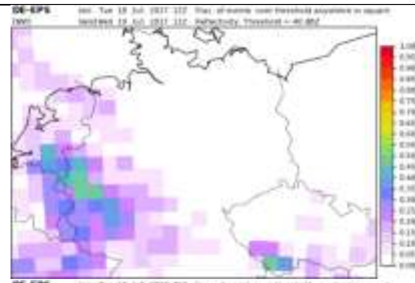
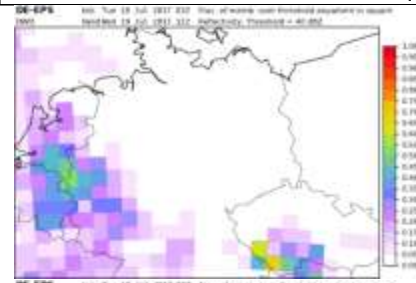
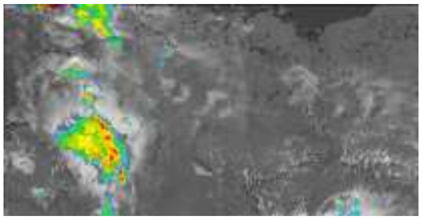
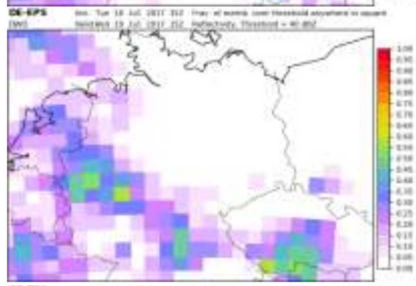
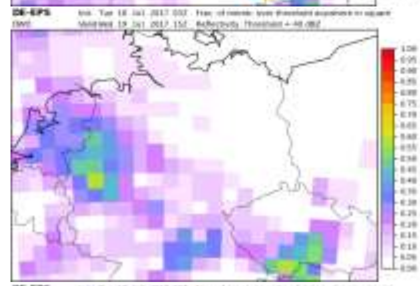
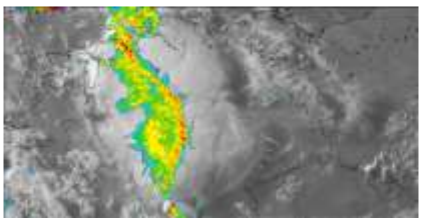
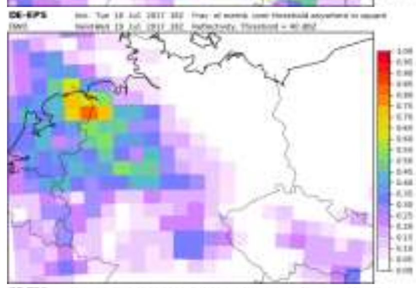
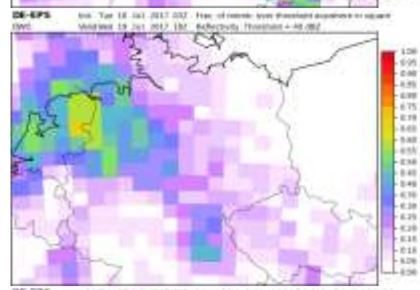
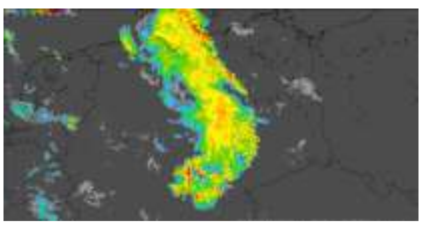
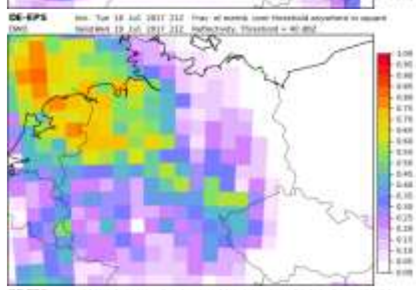
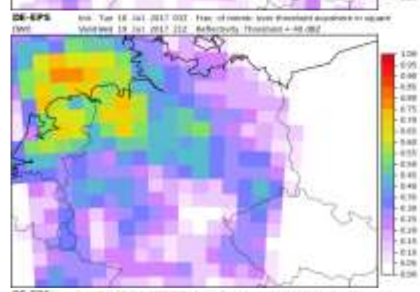
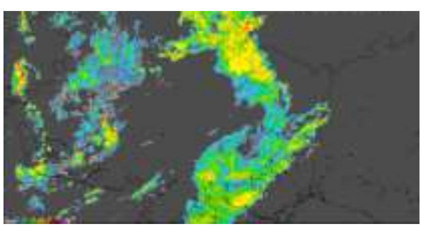
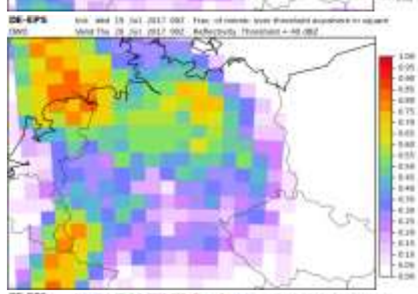
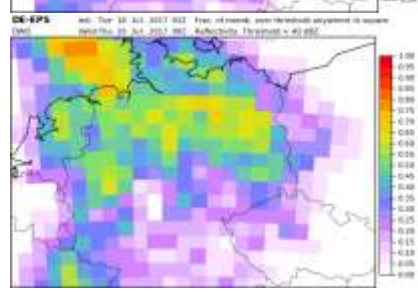
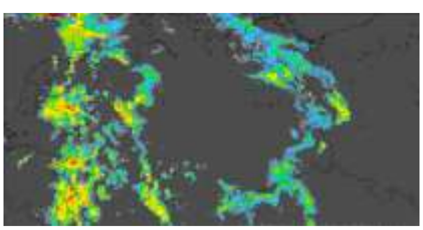
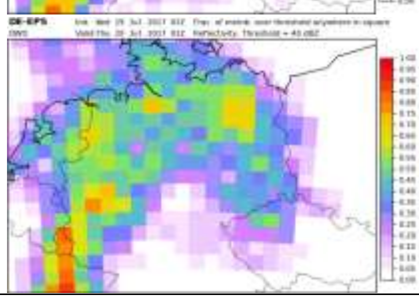
Time	Radar (EuRadCom)	COSMO-DE-EPS +24h forecast	COSMO-DE-EPS 03 UTC run i.e. +33, +36, +39, +42, +45 h, resp.
12 UTC			
15 UTC			
18 UTC			
21 UTC			
00 UTC			
03 UTC			n/a

Fig. 3.1.2. Radar composite and +24 COSMO-DE-EPS forecasts and forecast of the 18/03UTC run, of probability of exceedance of 40 dBZ somewhere within each square.

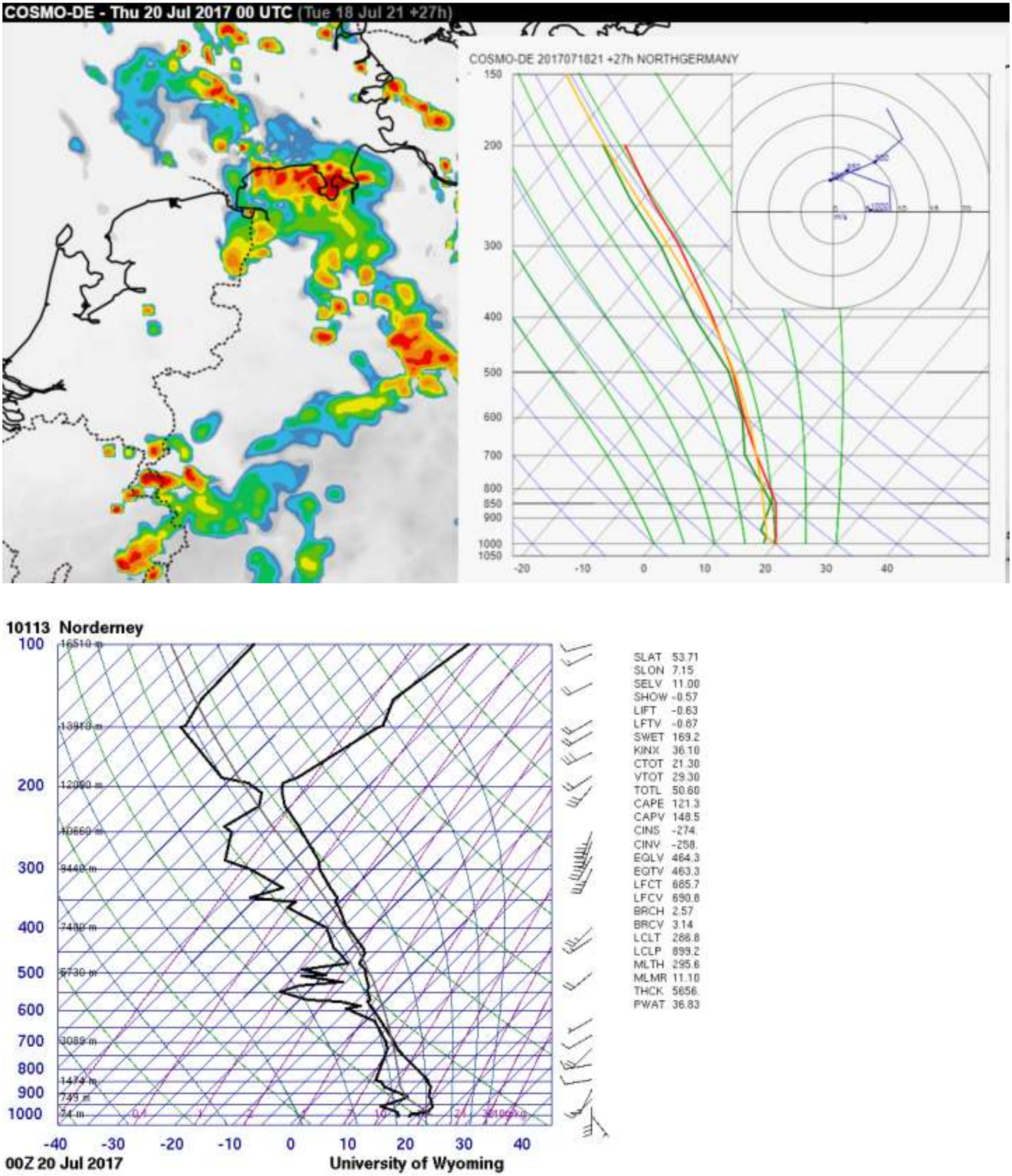


Fig. 3.1.3. Top: Model prediction of reflectivity and model sounding at Norderney at 00 UTC 20 July 2017. Bottom: Observed sounding.

3.2 22 June 2017

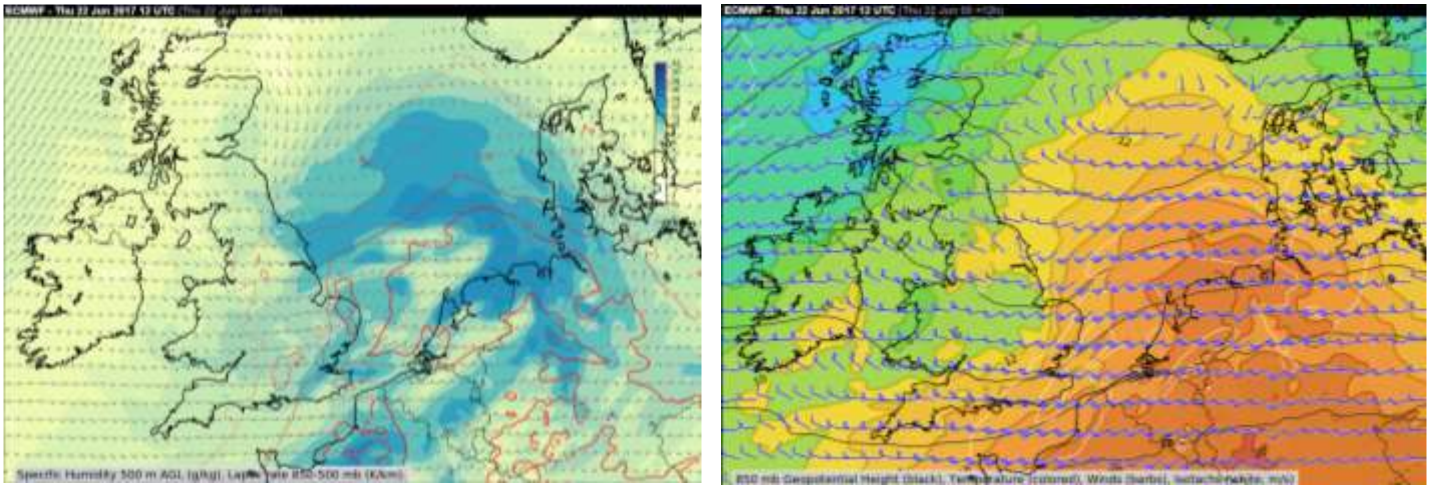


Fig. 3.2.1. Left: Specific humidity at 500 m AGL and lapse rate 850-500 hPa in the ECMWF IFS. Right: 850 hPa Temperature, wind barbs, and geopotential height.

A warm, humid air-mass was advected into northern Germany from the West (Fig. 3.2.1). In the warm advection zone, an elevated MCS that had initiated over the North Sea during the previous night moved south-eastward into North Germany during the morning.

+3 and +9 hour forecasts

None of the COSMO-DE-EPS forecasts valid at 09 UTC and 12 UTC confidently forecast the correct location of the system, with exception of the 06 UTC forecast (and of 09 UTC, not shown), that had probably already assimilated radar information containing the MCS (Fig. 3.2.2).

Comparing the 15 UTC and 18 UTC radar image with forecasts valid at those times shows that +3 hour forecast is very confident (near 100% probability) about the location of some convective areas, and yet is sometimes not correct. For instance, the +3 hour forecast very confidently develops storms over western Poland and far NW Netherlands at 15 UTC, that, respectively, do not develop, and are not located correctly and overestimated.

+24 and forecasts from the 03h ensemble of 20 June

The 24 hour forecasts and those by the 03 UTC run of the previous day show that, in contrast to the 20 July case, the forecast quality 24 hours ahead of time was somewhat better than that of 30 - 42 hours ahead of time. Besides giving few signals for the morning MCS, the 03 UTC run gives only modest hints for the intense storms that develop over western Germany during the afternoon (i.e. at 15 UTC), which the +24 hour forecast is much more confident of.

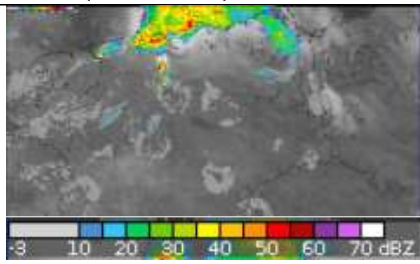
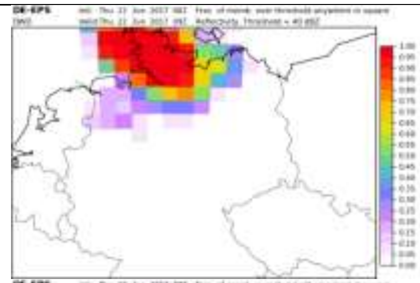
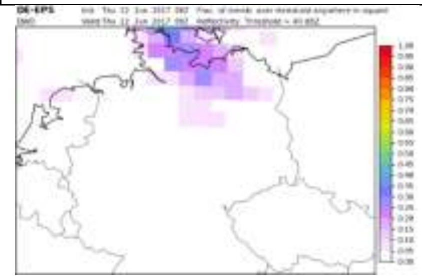
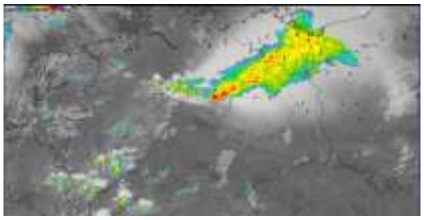
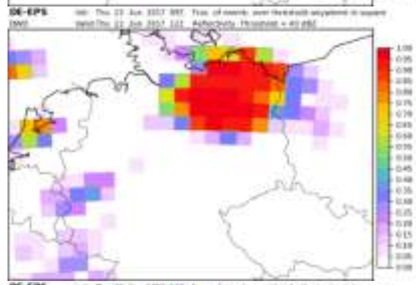
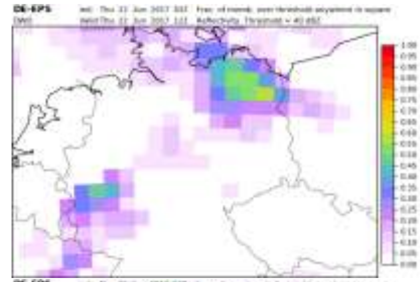
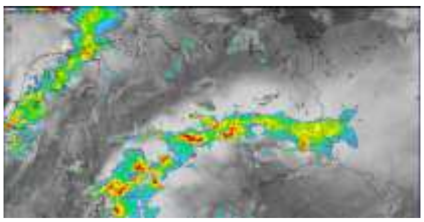
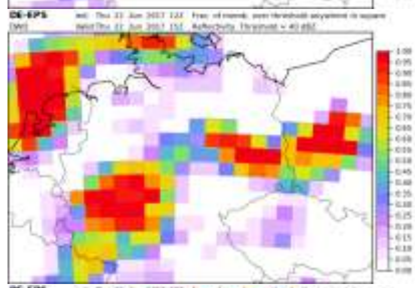
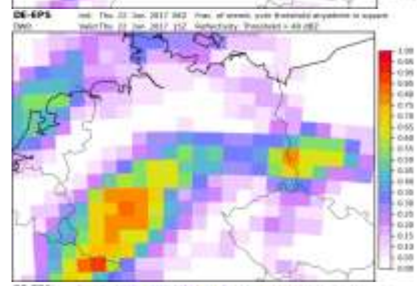
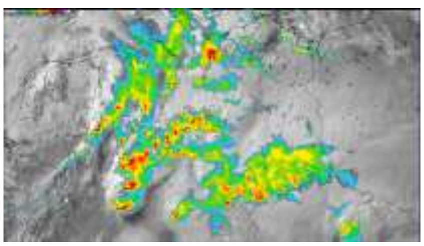
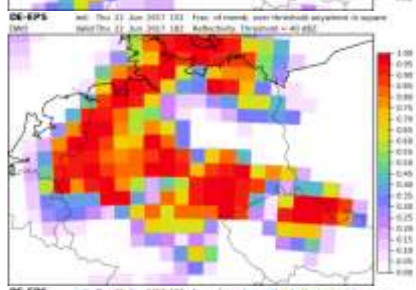
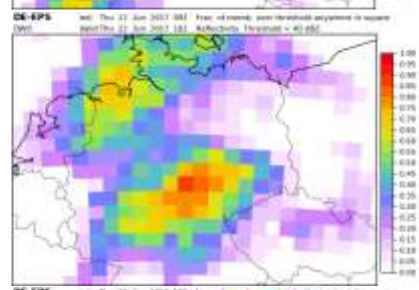
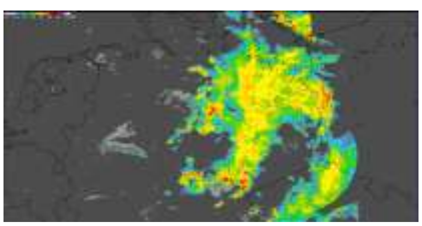
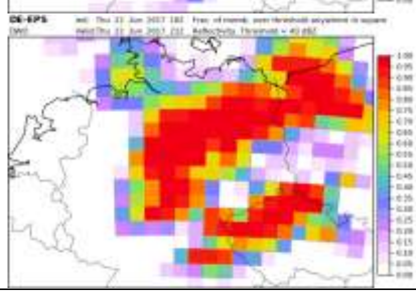
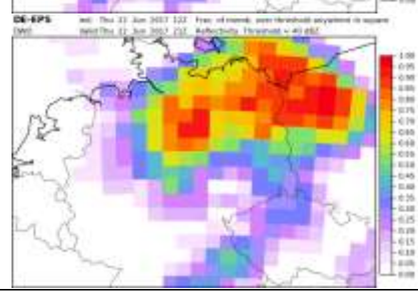
Time	Radar (EuRadCom)	COSMO-DE-EPS +3h forecast	COSMO-DE-EPS +9h forecast
09 UTC			
12 UTC			
15 UTC			
18 UTC			
21 UTC			

Fig. 3.2.2. Radar composite and +24 COSMO-DE-EPS forecasts and forecast of the 18/03UTC run, of probability of exceedance of 40 dBZ somewhere within each square.

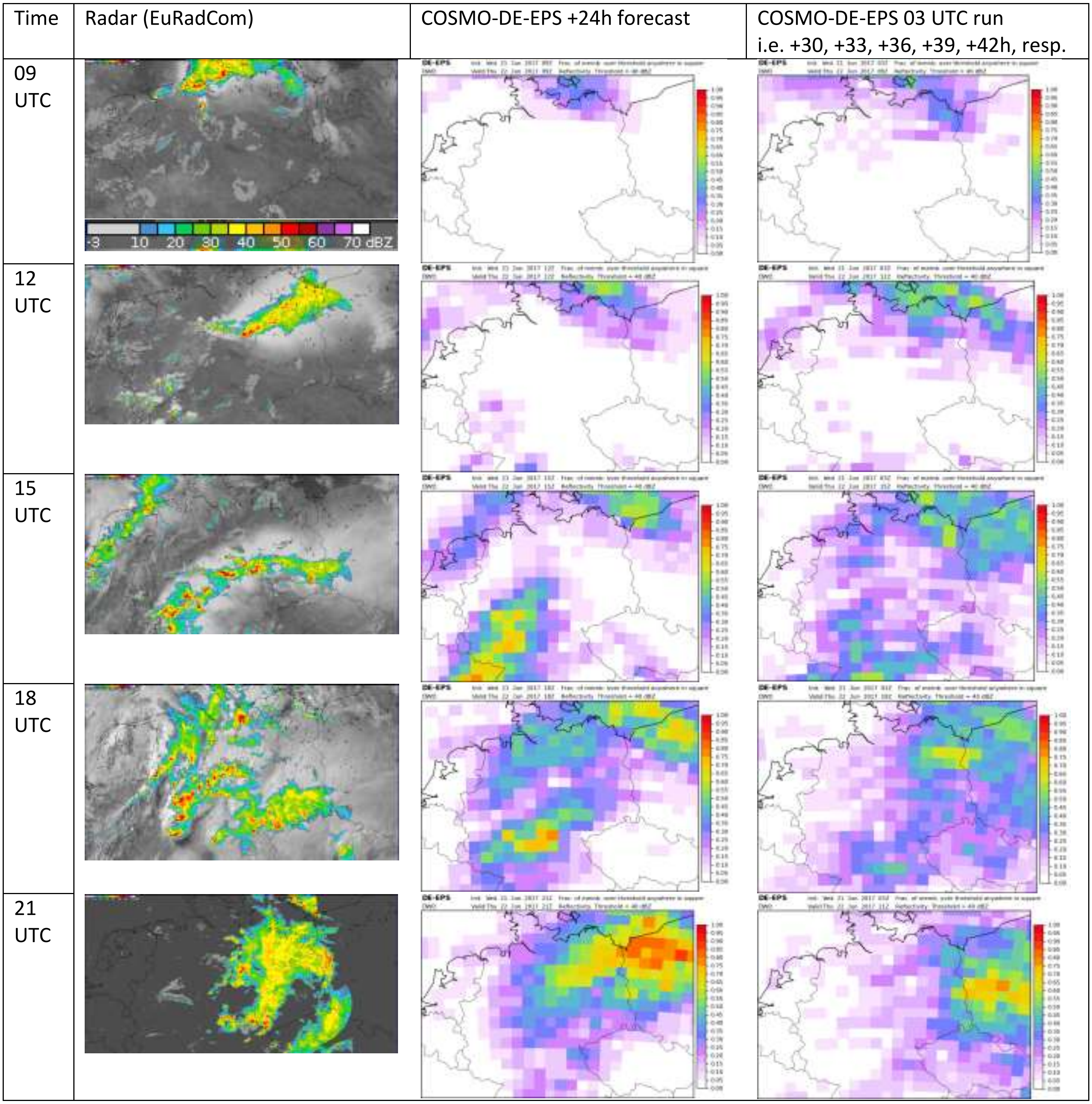


Fig. 3.2.3. Radar composite and +24 COSMO-DE-EPS forecasts and forecast of the 18/03UTC run, of probability of exceedance of 40 dBZ somewhere within each square.

Simulated VII-Track, Rotation-Track, Updraft Helicity-Track and Vorticity-Track products

A comparison between the observed 3-hour-duration VII Track product and the ensemble forecast of the 1-hourly condensate<-10-Tracks at 17 UTC (Fig. 3.2.5) shows that the most important and longest VII-Tracks indeed occured where the 06 UTC COSMO-DE-EPS predicted the highest probabilities, i.e. in a zone stretching from the Rhineland to Saxony. The model performed well in that sense. The contrast in the COSMO-DE-EPS colorscale at values of above 20 kg/m^2 needs to be enhanced.

The most intense condensate<-10-track occurred over Saxony. It was associated with hail of up to 4 cm in diameter as well as widespread wind damage (Fig. 3.2.4). In this area, the Updraft Helicity (UH) Track forecast hinted at a (small) possibility of quite intensely rotating storms (Fig. 3.2.6). Indeed, a few members predicted a right-moving supercell storm, and with UH between 300 and 500 m^2s^2.

The vorticity track product (Fig. 3.2.7) looks very similar to the UH-Track product, except that the tracks of supercell storms stand out less. The Updraft-Track product again shows a similar images, but the area of storms with strongest rotation over Central to Eastern Germany does not stand out as strongly. Instead, the more poorly-organized storms over Western Germany are simulated to have the highest updraft speeds. The colorscales of both quantities can be improved.

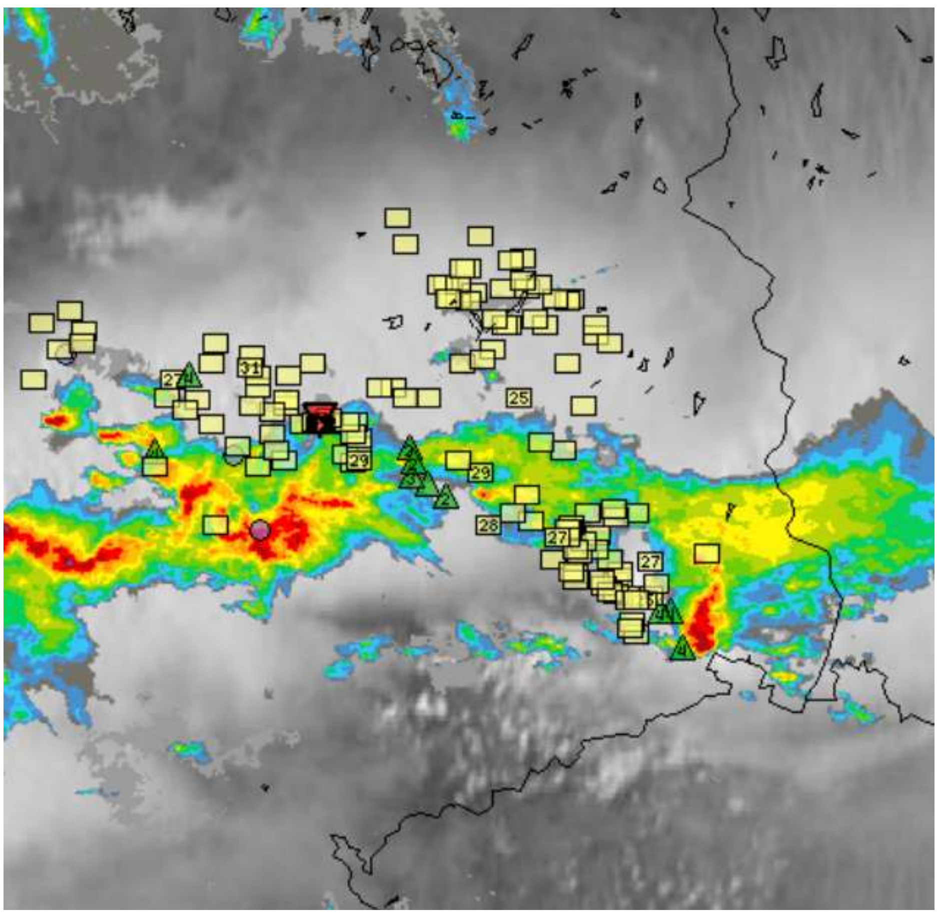


Fig. 3.2.4. Observations of wind damage (yellow rectanglesl; with wind speed in m/s, where measured), large hail (green triangles; with stone diameter in cm, where measured) and tornadoes (red triangle) at 1515 UTC on 22 June 2017.

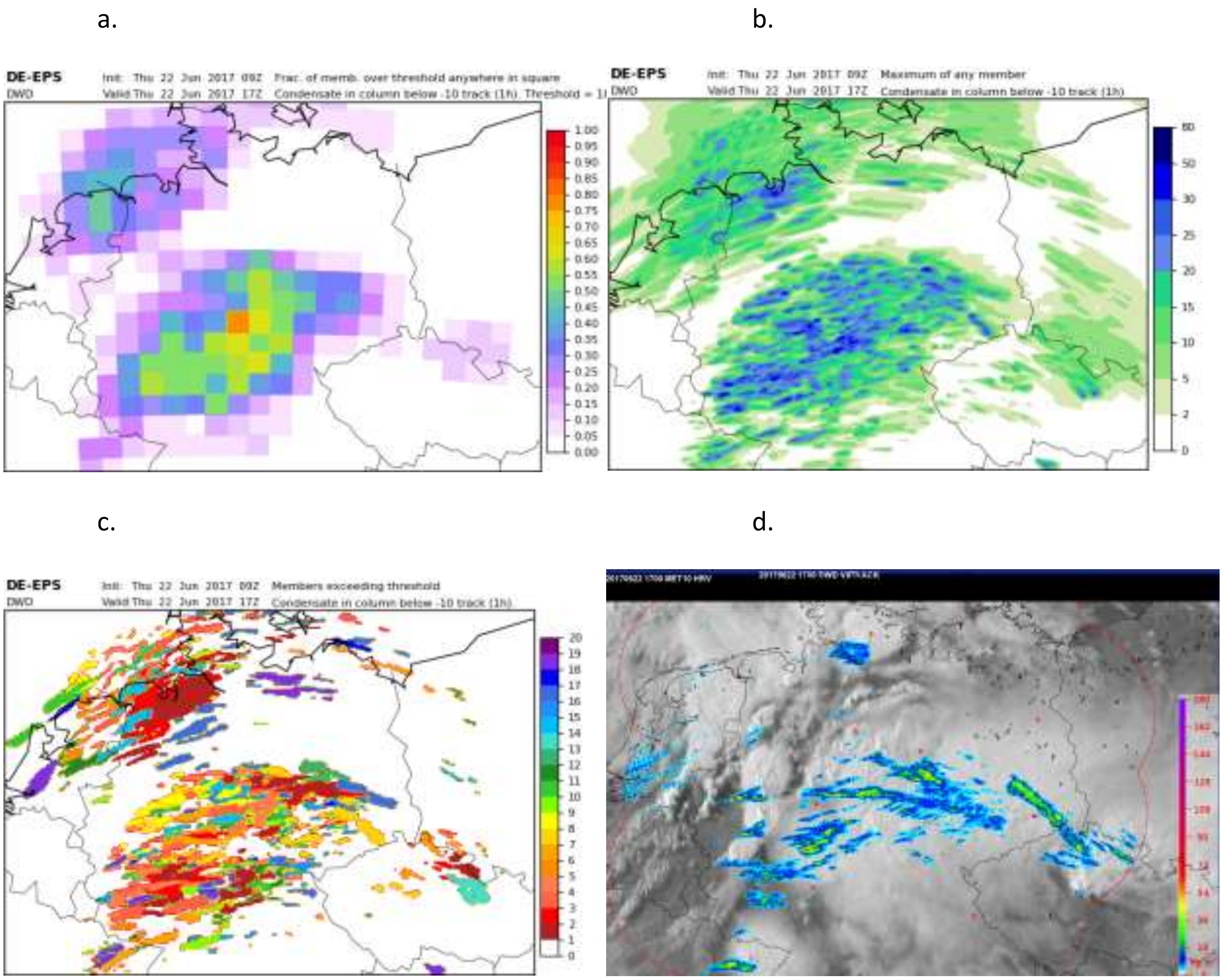
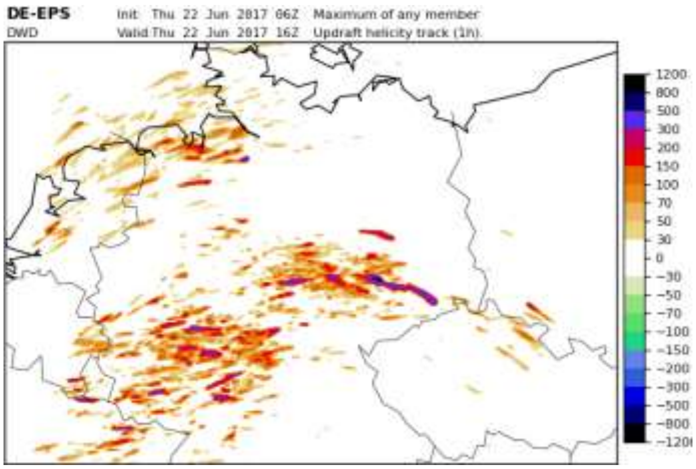


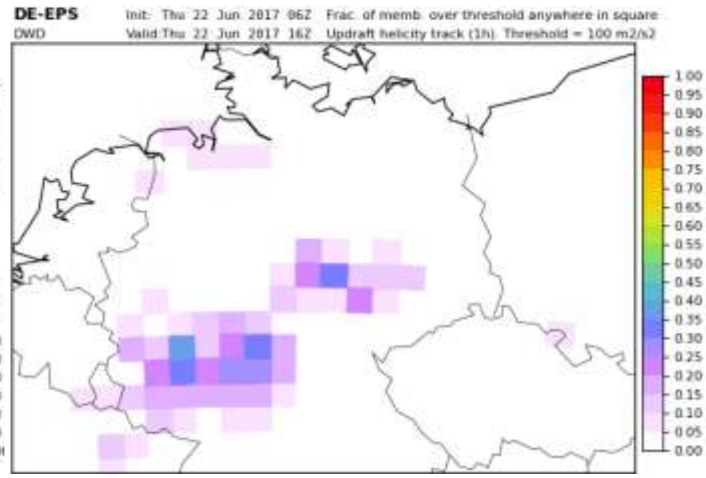
Fig. 3.2.5. COSMO-DE-EPS forecast of the “VII-Track”/column condensate track product in three different visualizations (a., b., c.), and observed VII values from radar composite (d.). Please note that the forecast tracks have a 1 hour duration and the radar product has a 3 hour duration.

Updraft Helicity Track vs. observations

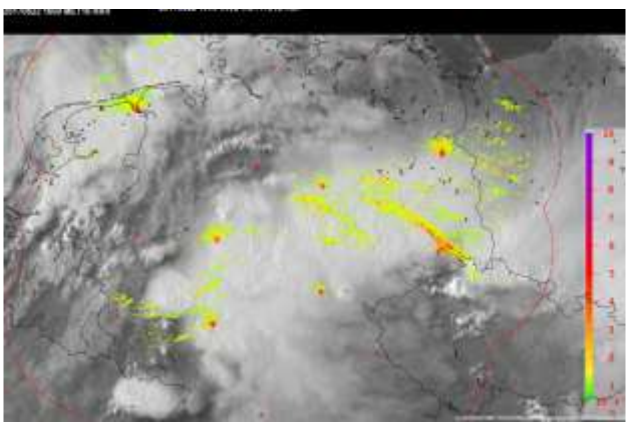
a.



b.



c.



d.

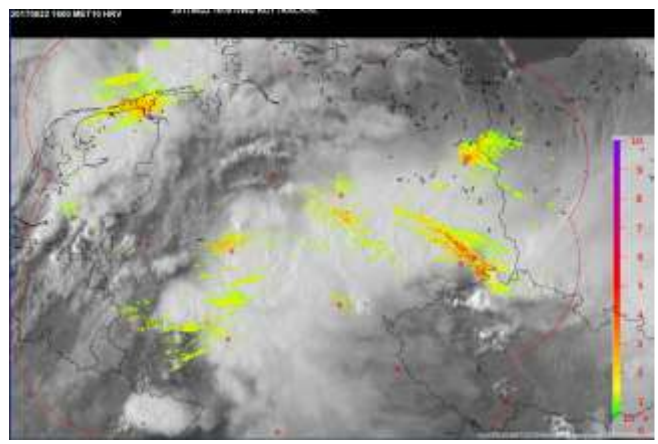
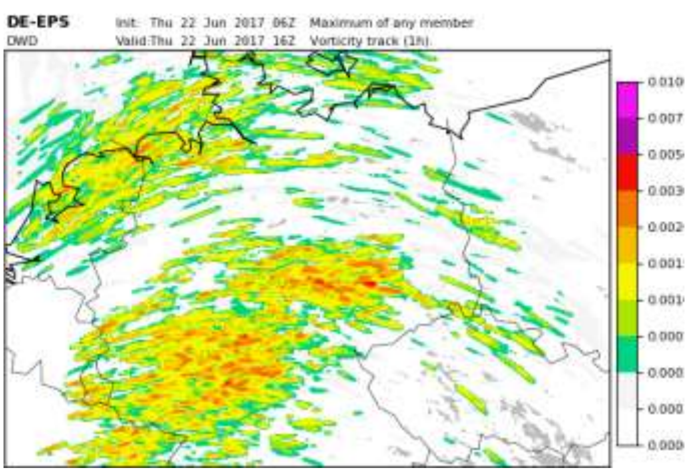


Fig. 3.2.6. +10 h COSMO-DE-EPS forecasts of 1-hour updraft helicity tracks (a., b.) and (c. 0-3 km, d. 3-6 km) shear ("Rotation-Track") radar product.



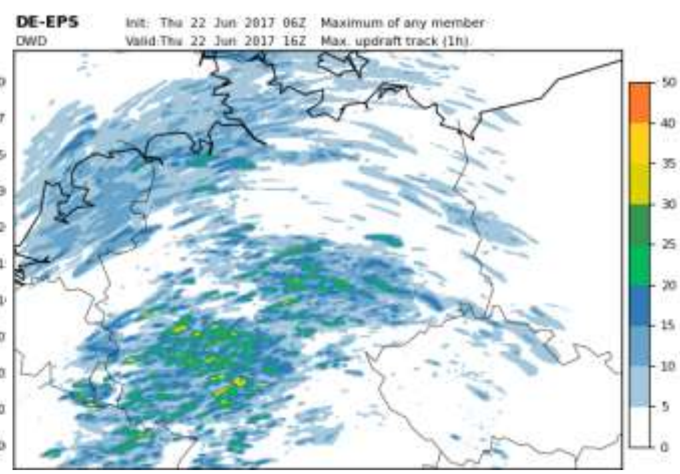


Fig. 3.2.7. Vorticity-Track (a. in s^{-1}) and Updraft-Track (b. in m/s) products from the same forecast and for the same time as in Fig.3.2.6.

3.3 7 July 2017

On 7 July, a moderate westerly flow was present across much of Central Europe. There was little large-scale forcing. A number of storms developed across southern Germany, and southern Austria. Figs. 3.3.1 and 3.3.2. show the performance of COSMO-DE-EPS. The +3 hour forecasts are dominated by the initialization and show up to 100% probability of storms in some areas. The +9 hour forecasts generally indicate the correct locations of where convective storms are going to develop. The +24 hour forecasts and the forecast from 03 UTC of the previous day are clearly less skilfull. Very few and weak rotation tracks are predicted (Fig. 3.3.3), which the radar rotation-tracks confirm to be a good prediction.

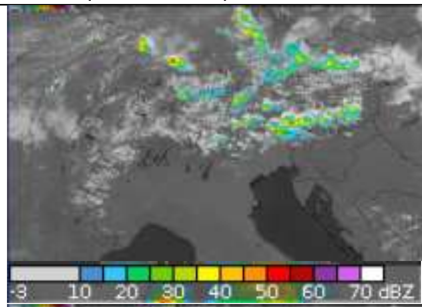
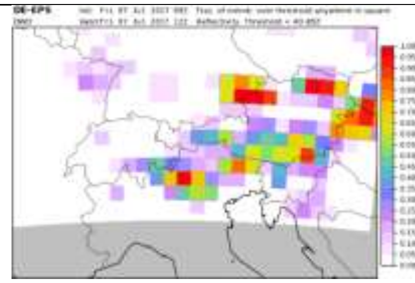
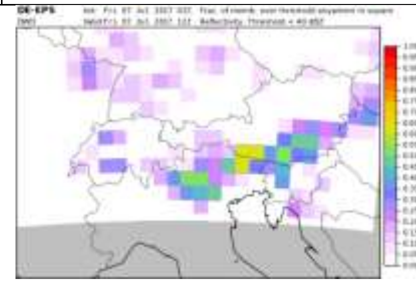
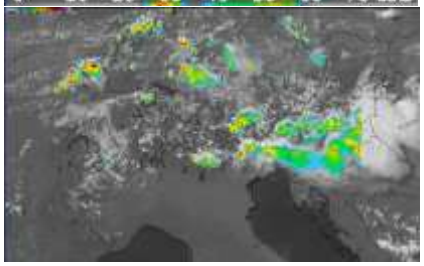
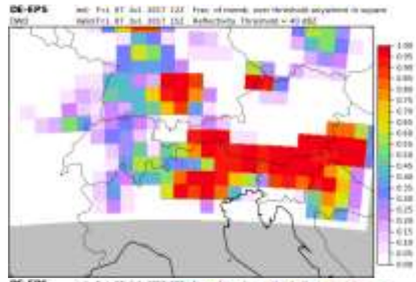
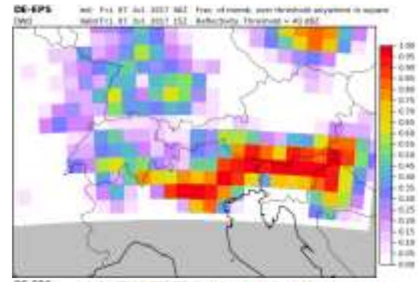
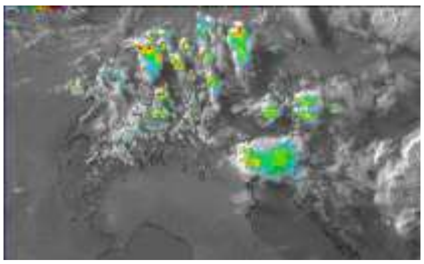
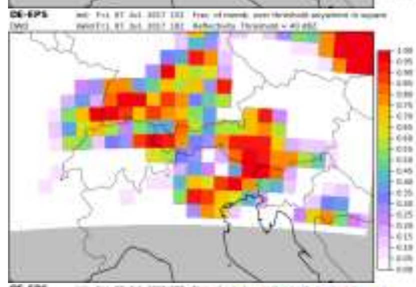
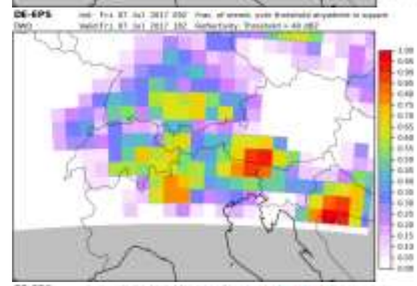
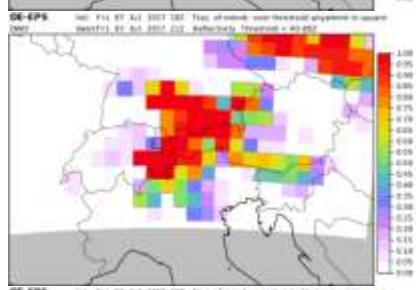
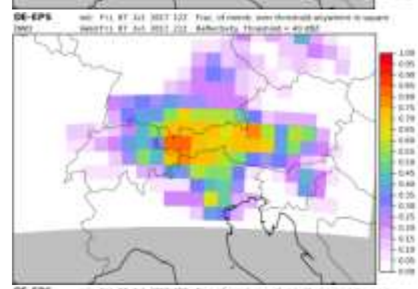
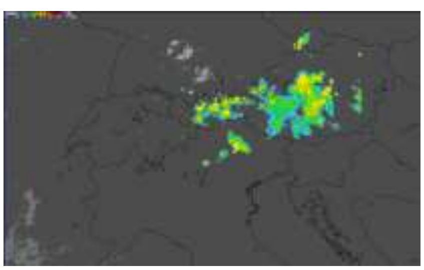
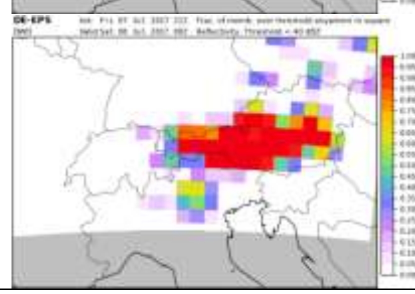
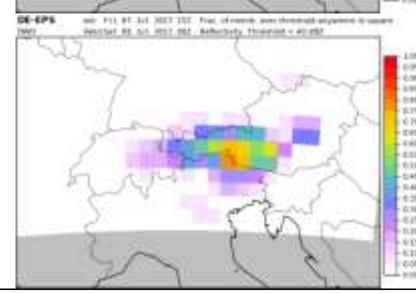
Time	Radar (EuRadCom)	COSMO-DE-EPS +3h forecast	COSMO-DE-EPS +9h forecast
12 UTC			
15 UTC			
18 UTC			
21 UTC			
00 UTC			

Fig. 3.3.1. Radar composite and +3 and +9 hour COSMO-DE-EPS forecasts of probability of exceedance of 40 dBZ somewhere within each square.

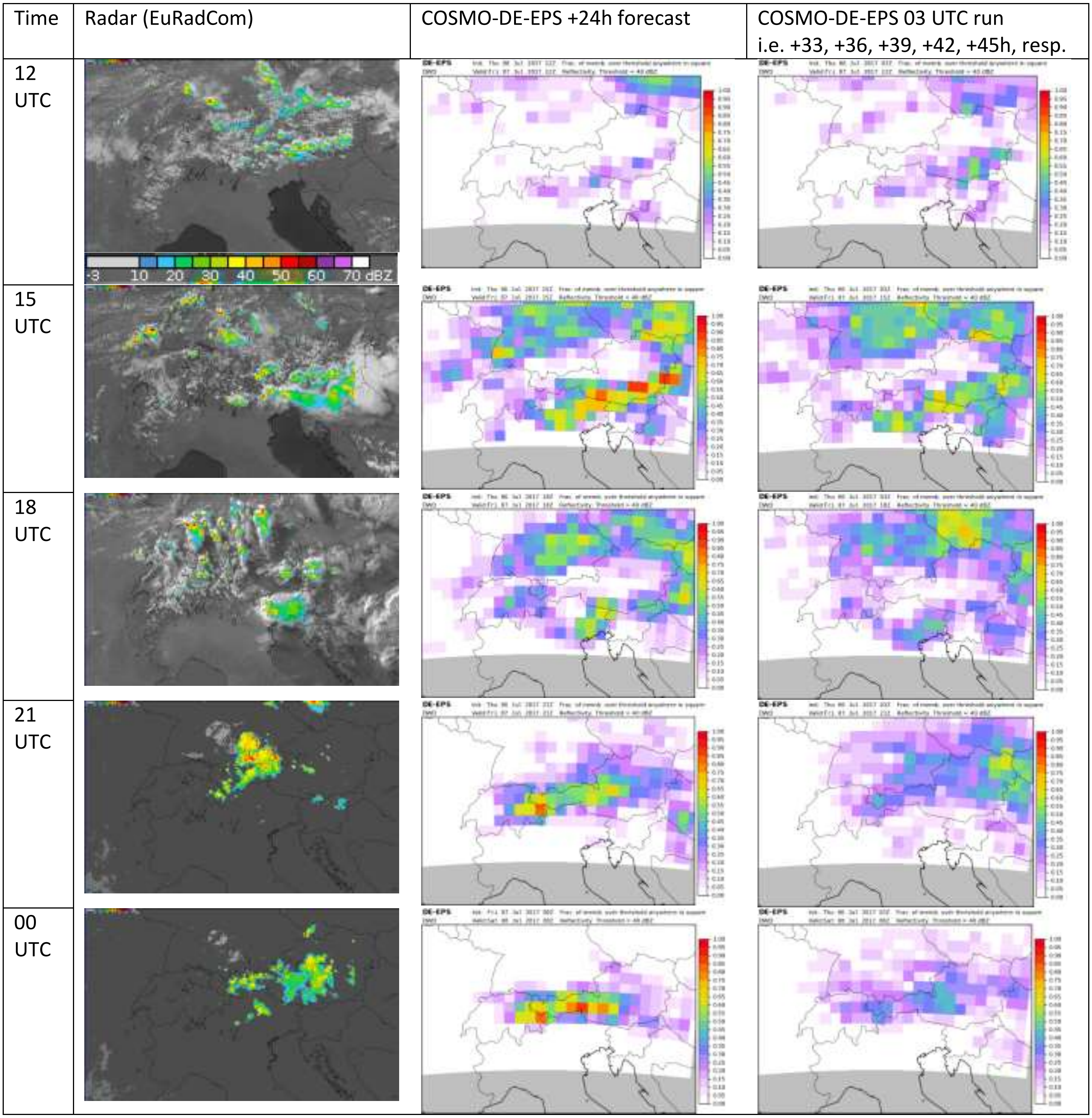


Fig. 3.3.2. Radar composite and +24 COSMO-DE-EPS forecasts and forecast of the 06/03UTC run, of probability of exceedance of 40 dBZ somewhere within each square.

Updraft Helicity Track vs. observations

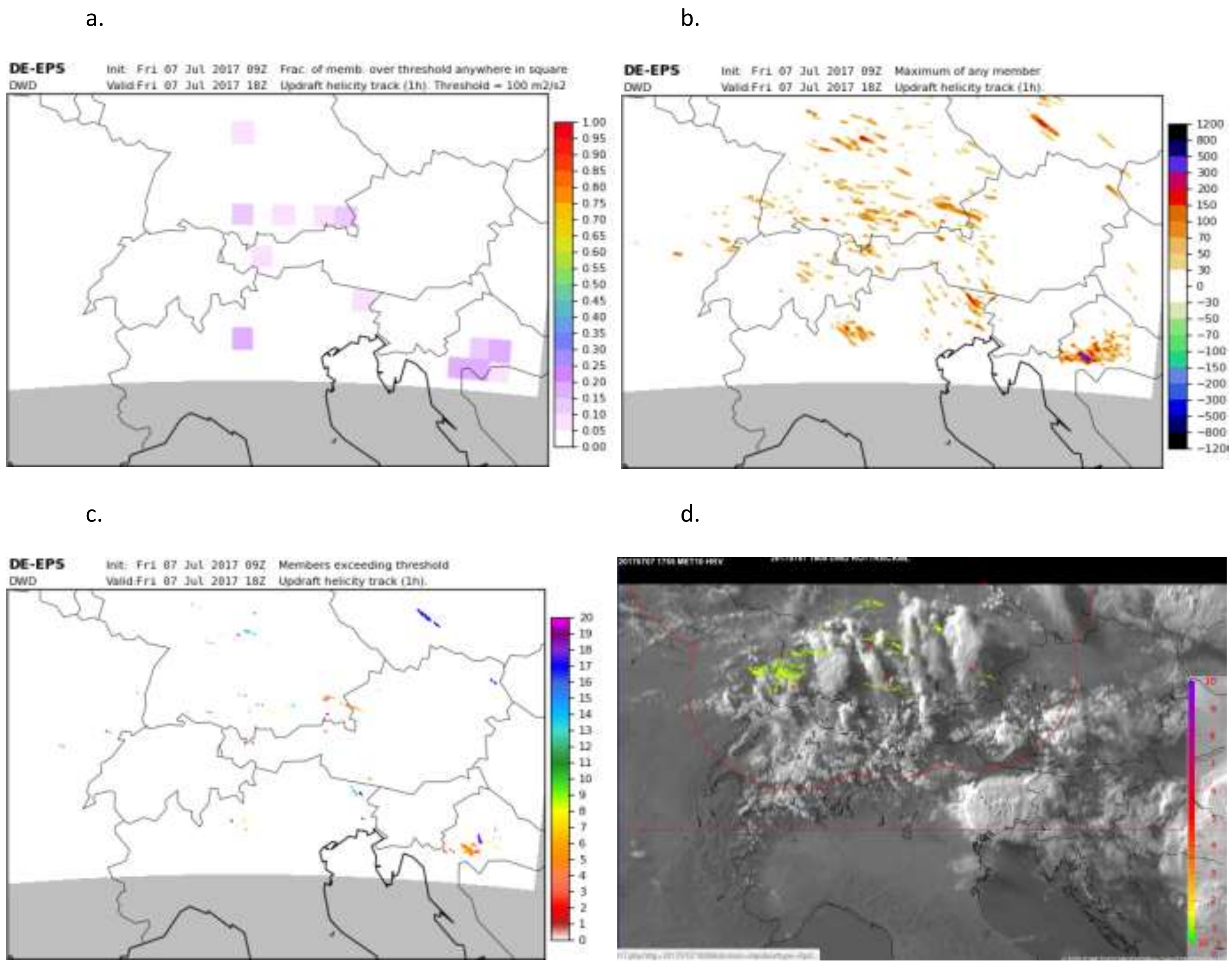


Fig. 3.3.3. +9 h COSMO-DE-EPS forecasts of 1-hour updraft helicity tracks (a., b., c.) and mid-level (3-6 km) shear (“Rotation-Track”) radar product.

3.4 10 July 2017

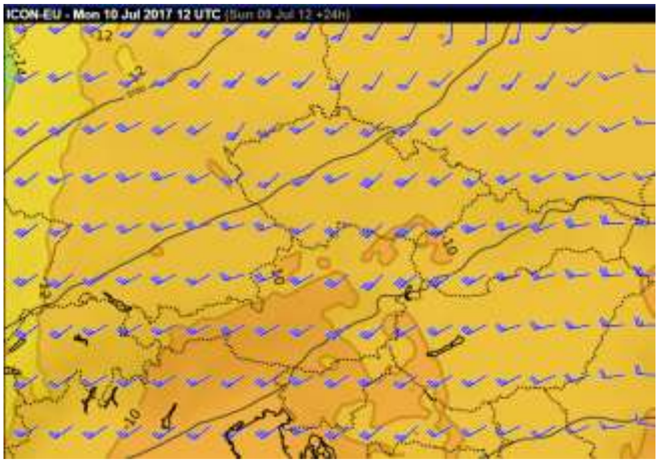


Fig. 3.4.1. a) 500 hPa Temperature (shaded), Wind (barbs) and Geopotential (lines).

On 10 July 2017, a west- to southwesterly flow existed across the Alps. At 850 hPa, a southerly flow existed to the east of the Alps (Fig. 3.4.1.). A supercell storm developed across the easternmost parts of the Alps, the Wienerwald, just to the southwest of Vienna. It produced large hail of up to 8 cm diameter and a tornado near Vienna airport in Schwechat (Fig. 3.4.2.; Fig. 3.4.3.).

The COSMO-DE-EPS helicity track product gave outstanding guidance in showing the potential that such a strongly rotating storm cell would develop (Fig. 3.4.5.). Because neither instability nor the shear was extremely high, at least on the scales represented by models such as the ECMWF IFS or ICON-EU, COSMO-DE-EPS was very valuable in indicating the development of such a cell. Even in the 03 UTC forecast of the previous day, a number of ensemble members already produced rotating storms.

Model soundings at Schwechat at 14 UTC of two ICON-EU and COSMO-DE forecast (Fig. 3.4.4) show that COSMO-DE has developed a more strongly curved low-level hodograph than ICON-EU, which favors low-level flow.

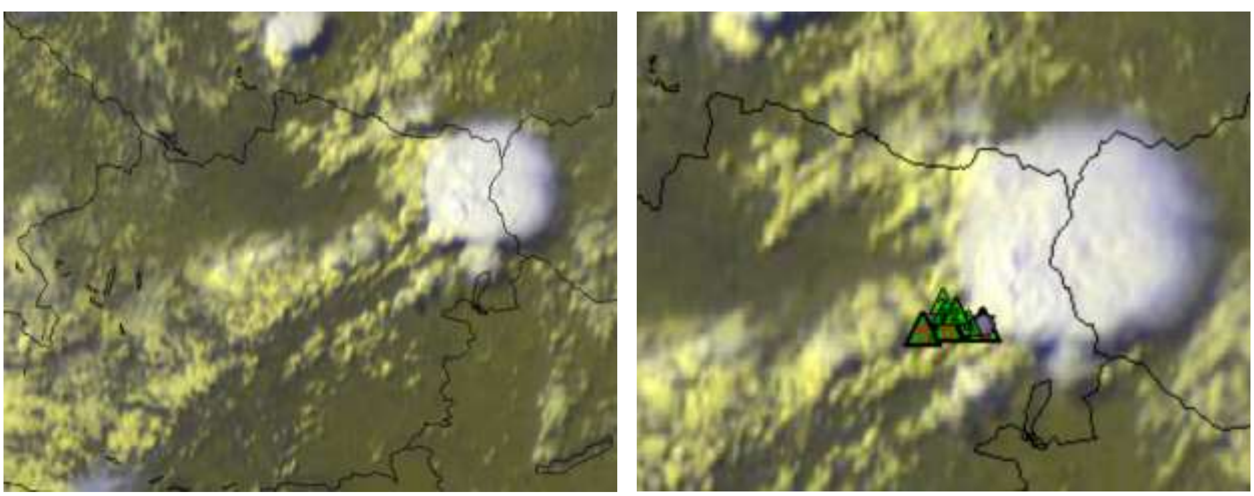


Fig. 3.4.2. Visible satellite image (E-View) at 1415 UTC (left) and 1430 (right) 10 July 2017. The right images additionally shows severe weather reports of hail (green triangles, up to 8 cm in diameter), heavy rainfall (blue circle), and the tornado near Schwechat (red triangle, somewhat hidden behind the rain report).

Fig. 3.4.3. Tornado viewed from an approaching aircraft (photo left: Olga Bystrina) and from the ground (photo: Kleine Zeitung).

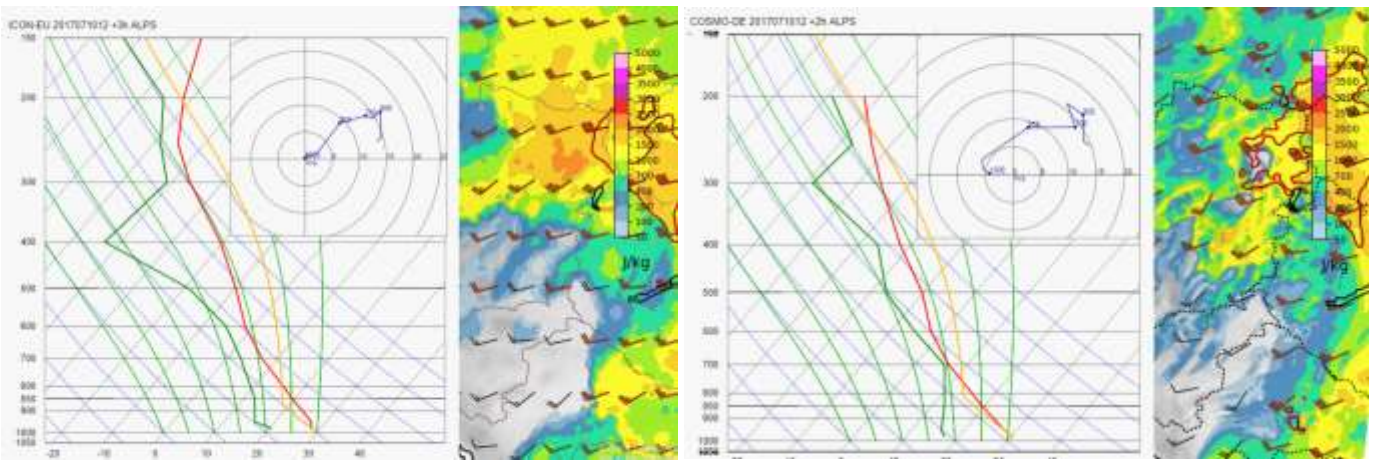


Fig. 3.4.4. Short-term forecasts of CAPE and 0-6 km shear by ICON-EU and COSMO-DE and soundings at Schwechat on 10 July 2017 at 1500/10400 UTC.

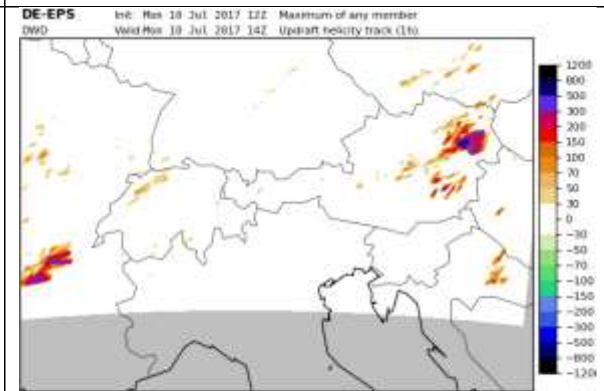
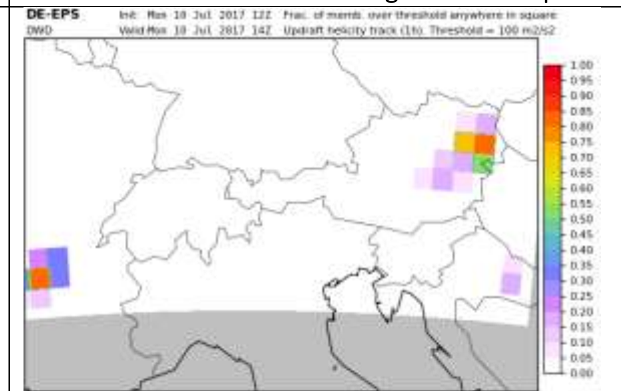
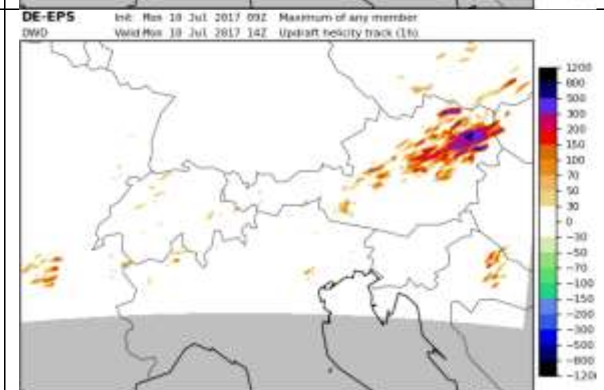
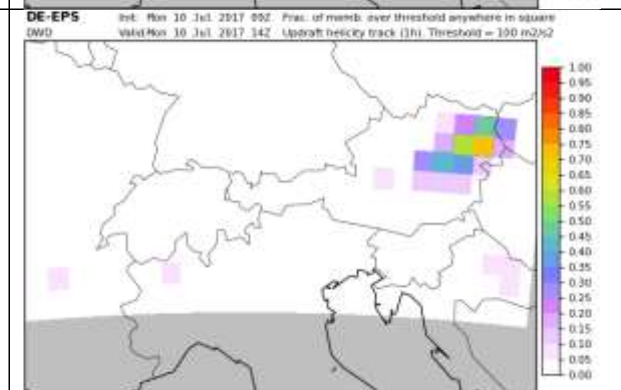
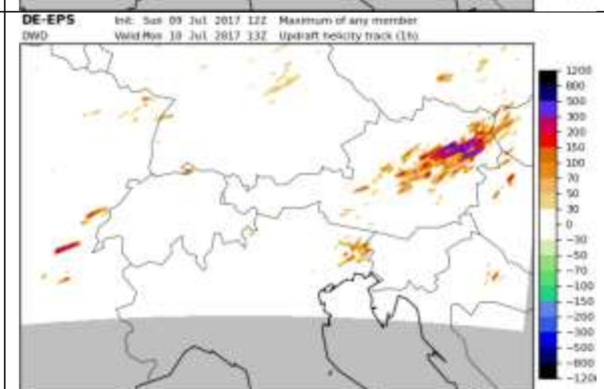
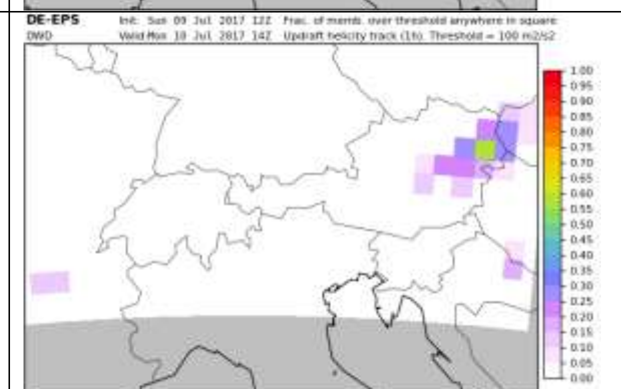
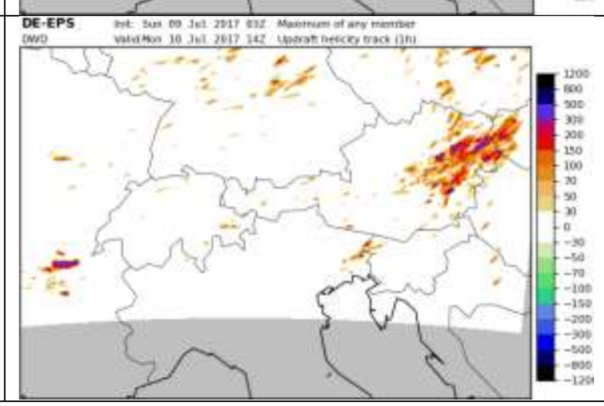
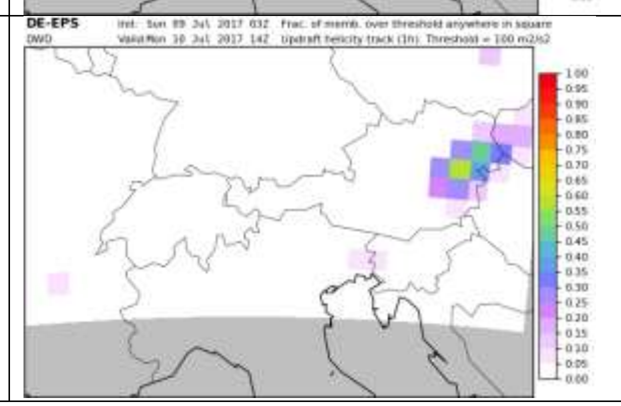
	Maximum of all members	Fraction of members exceeding 40 dBZ in square
10 July 12 UTC + 2 hours		
10 July 09 UTC + 5 hours		
9 July 12 UTC + 25 hours		
9 July 03 UTC + 35 hours		

Fig. 3.4.5. Forecasts of Updraft Helicity-tracks by COSMO-DE-EPS at different lead times.

3.5 1 August 2017

On 1 August, a diffuse cold frontal zone was approaching Germany from the west. Ahead of the front ample deep-layer wind shear and instability were forecast (Fig. 3.5.1). COSMO-DE-EPS predicted a high number of very strong updraft helicity tracks. The location and intensity of the tracks changed from run to run. Particularly large areas of strongly rotating storms were forecast in the 31/21, 01/00 and 01/03 UTC runs across Northeast Germany. In later runs, the risk of rotating storms strongly decreased, and ultimately, in reality almost no strongly rotating storms developed before 1 August 18 UTC (Fig. 3.5.2).

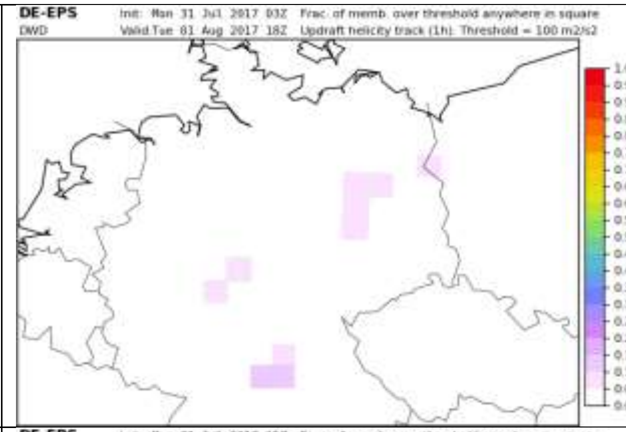
The extreme COSMO-DE-EPS simulations were probably one of the reasons that DWD forecasters issued pre-warnings for severe thunderstorms including a risk of tornadoes for 1 August. Additionally, coarser models like ICON-EU and ECMWF also showed overlapping large CAPE and strong deep-layer shear.

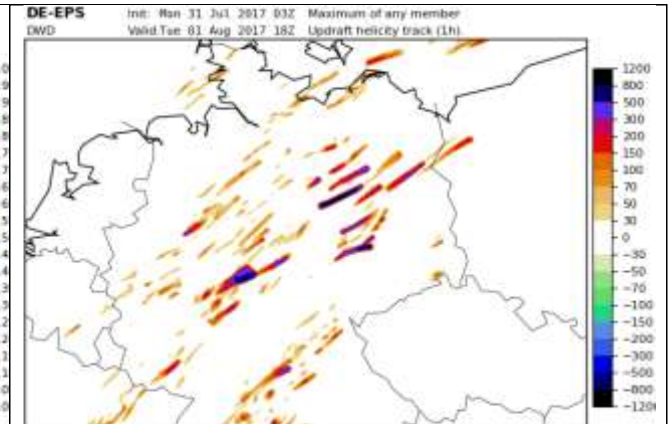
An important question is what caused the reduction in severe risk compared to the model forecasts. Observed soundings give a strong impression that the amount of convective inhibition was underestimated. Fig. 3.5.3 shows the sounding in Idar-Oberstein at 12 UTC as well as the forecast by COSMO-DE initialized at 03 UTC. The observed sounding shows warmer mid-level (500 hPa) temperatures, reducing the lapse rates compared to the modelled sounding. The observed sounding resembles that of a post-convective environment in which subsidence has taken place. Indeed, the sounding was taken amidst areas of elevated convection and rain that were underestimated by the COSMO-model.

Further east at Meiningen, the sounding also differed strongly from that forecast by both ICON-EU and COSMO-DE. There was less CAPE in reality and higher CIN. This was caused by lower humidity in boundary layer, possibly caused by advection of drier air by a westerly flow that was not forecast. Moreover, the low-level temperature profile shows a strong warm drier layer around 800 to 700 hPa that was not forecast by COSMO-DE. The ICON-EPS (Fig. 3.5.5) has an ensemble mean CAPE of between 2000 and 2500 J/kg, whereas the observed CAPE was only slightly more than 500 J/kg.

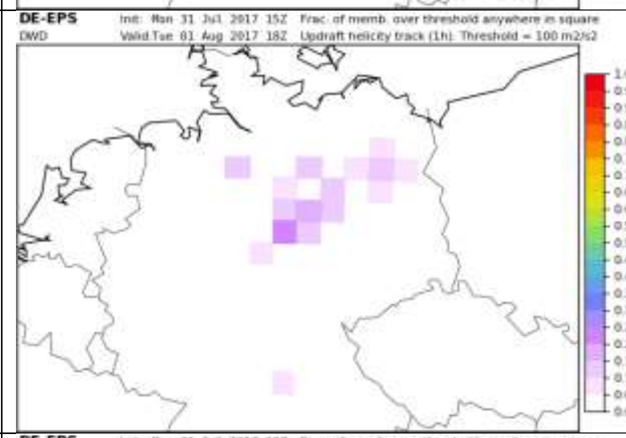
Overall, the intensity of cold air produced by the elevated convection over West Germany was underestimated by the models, so that the wind turned westerly and advected cool air more rapidly eastward than anticipated. Furthermore, subsidence compensating the upward motion in the elevated convective areas may have played a role as well.

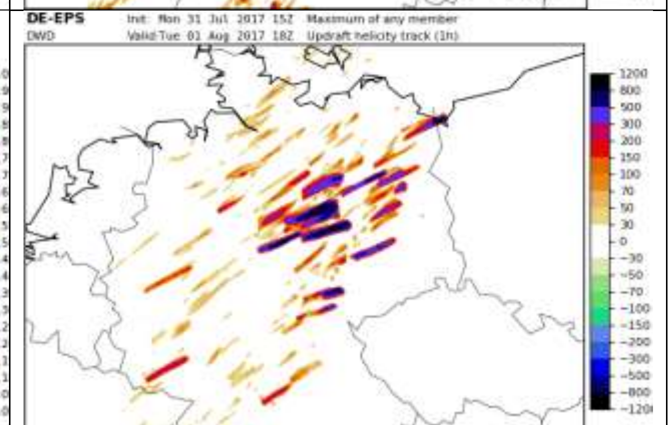
31 03 UTC
+39h
forecast



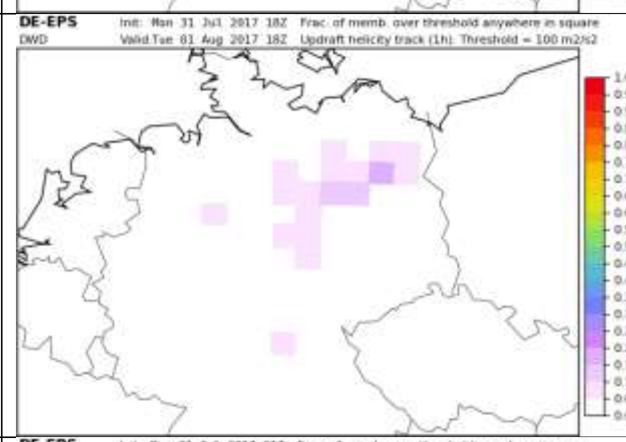


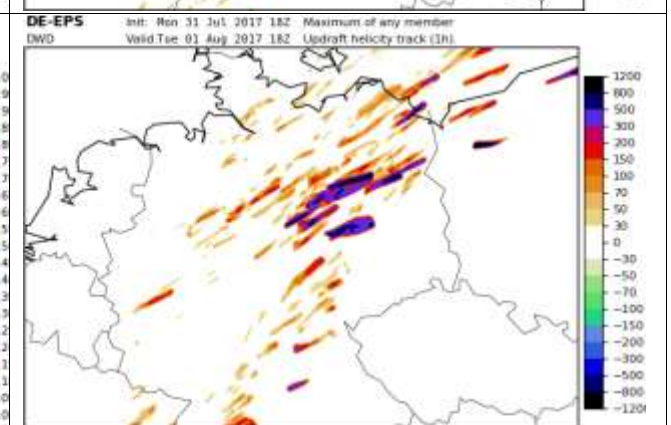
31 15 UTC
+27h
forecast



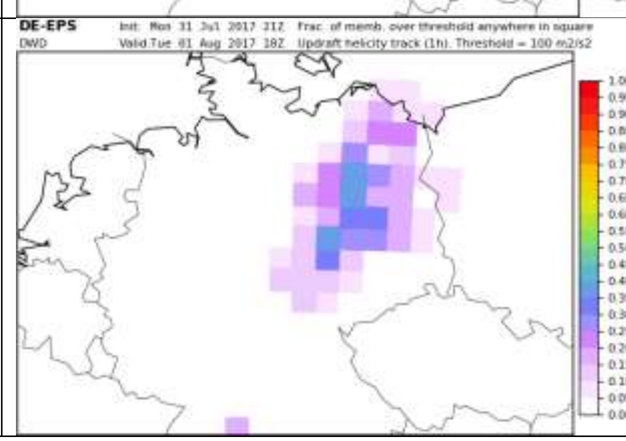


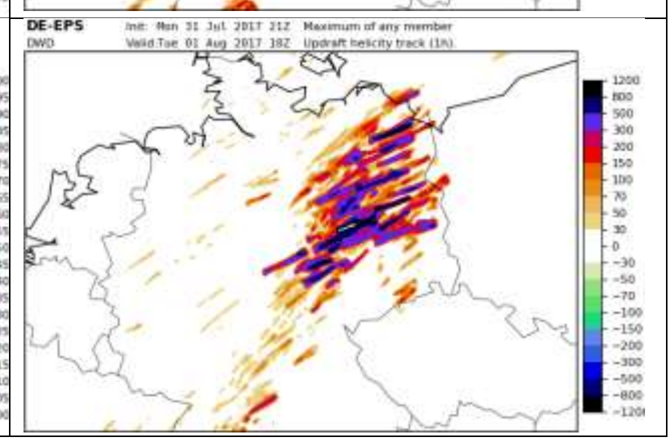
31 18 UTC
+24h
Forecast



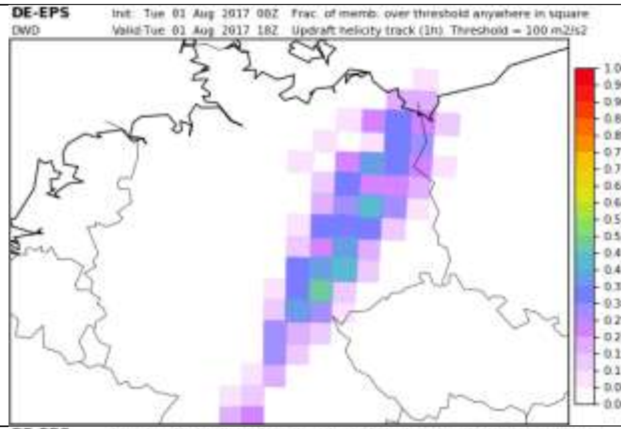


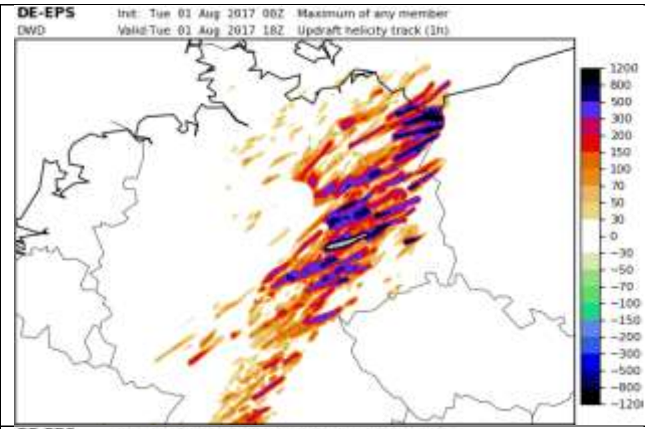
31 21 UTC
+21h
forecast



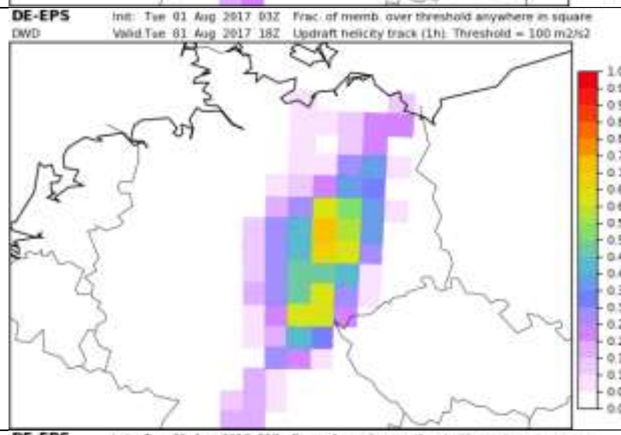


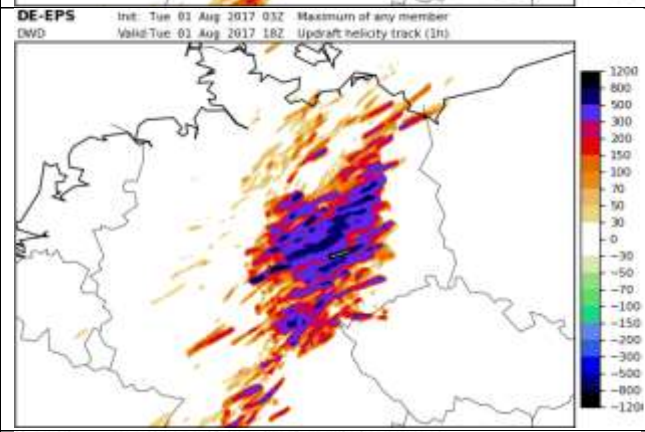
00 UTC forecast +18h



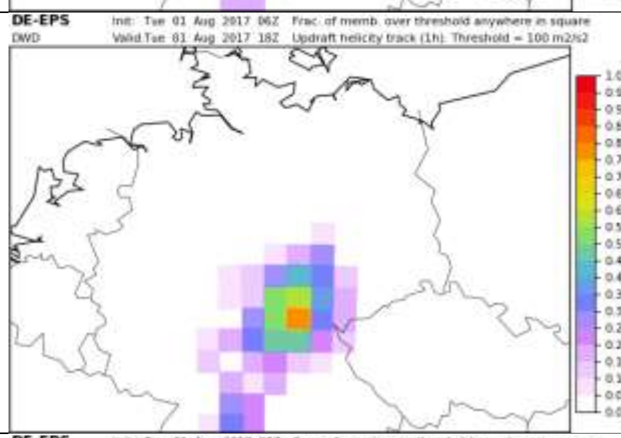


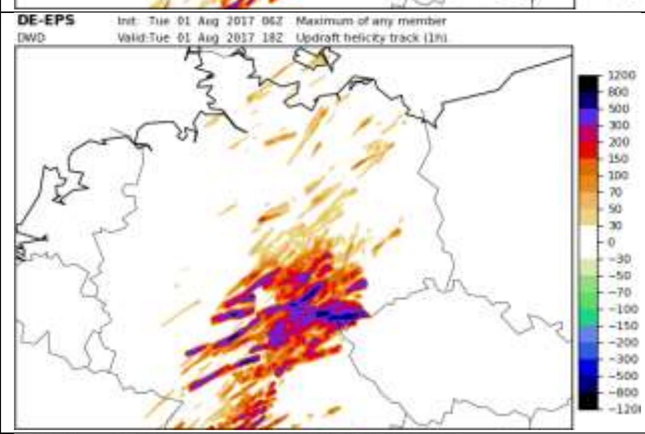
03 UTC forecast +15h



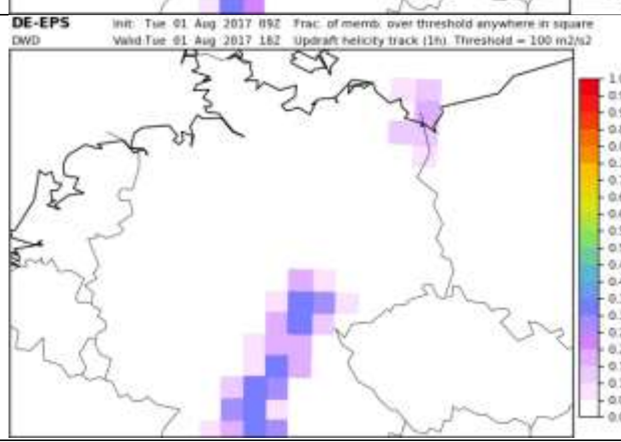


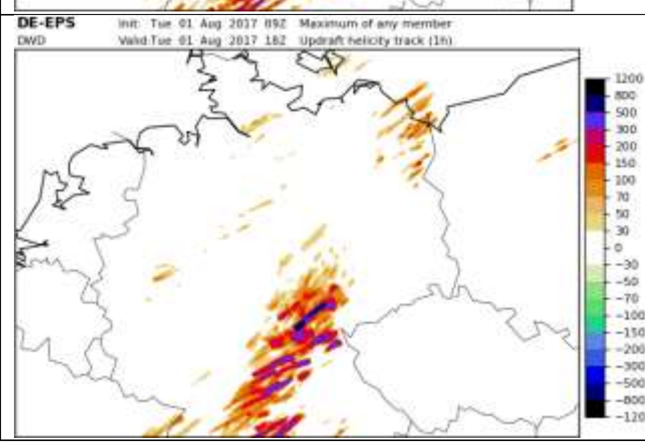
06 UTC forecast +12h





09 UTC forecast +9h





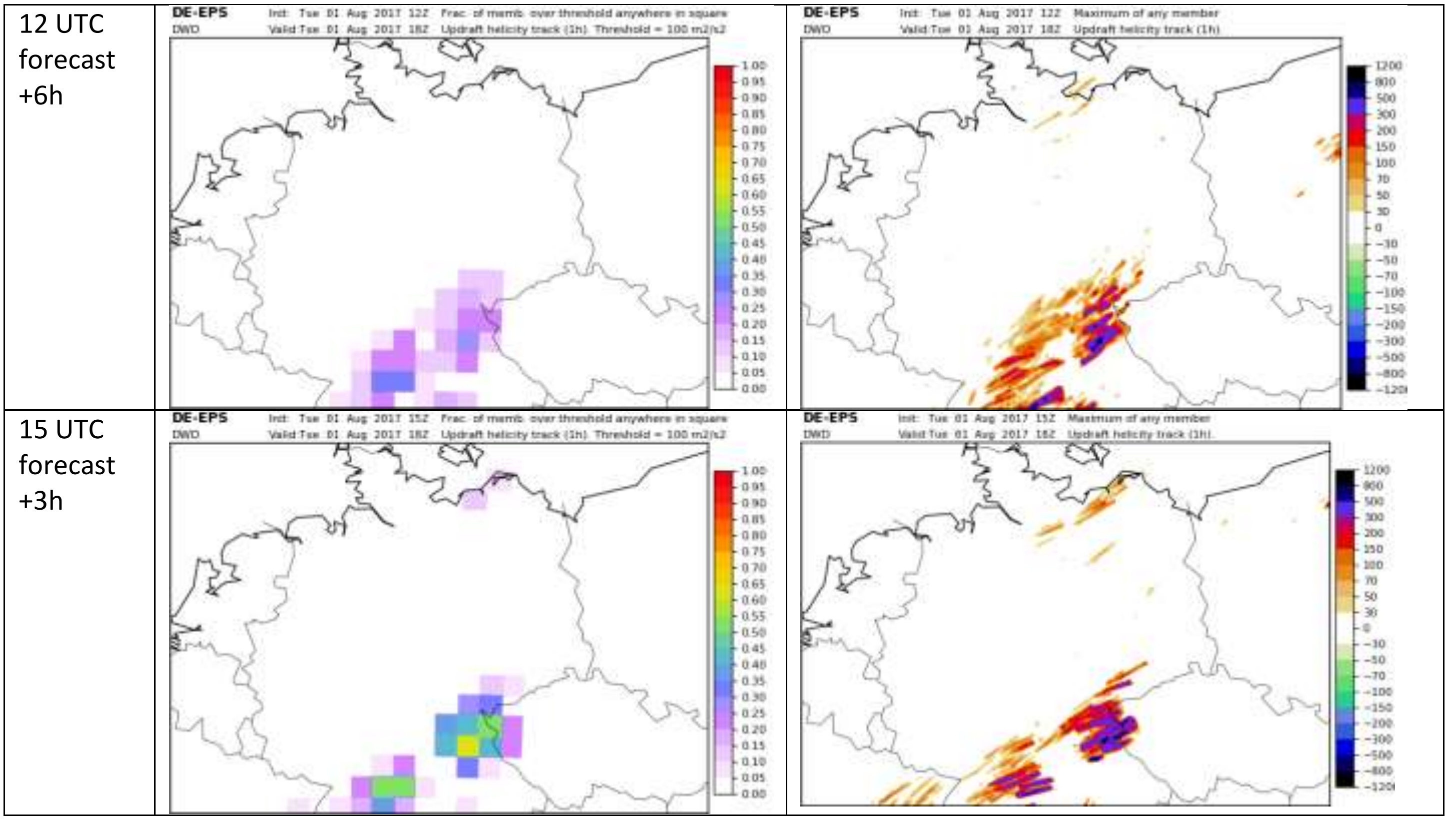


Fig. 3.5.1. 1-hour updraft helicity tracks of COSMO-DE-EPS forecasts valid on 1 August at 18 UTC.

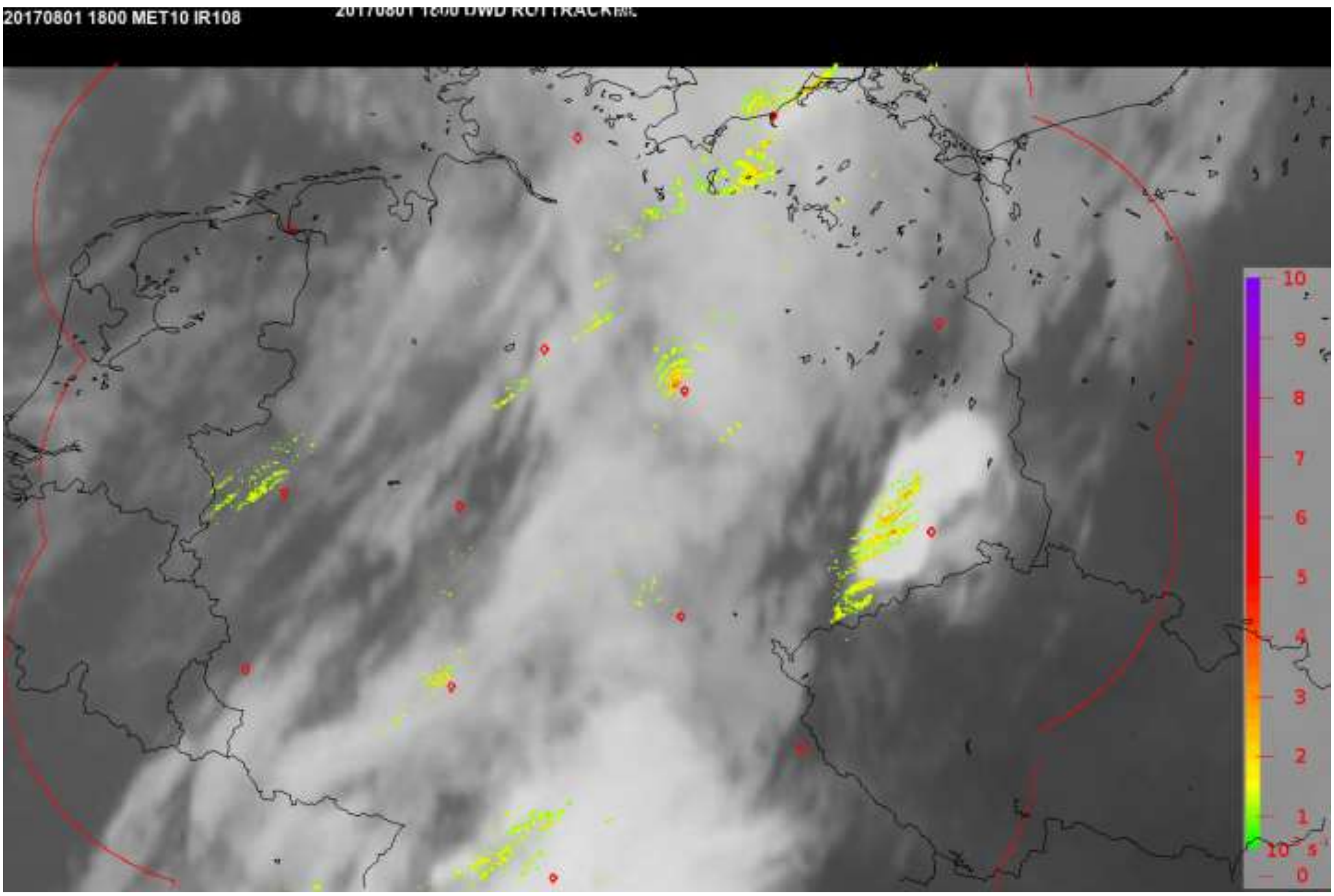


Fig. 3.5.2. Mid-level rotation tracks at 18 UTC (i.e. showing rotation between 15 and 18 UTC) and IR satellite image.

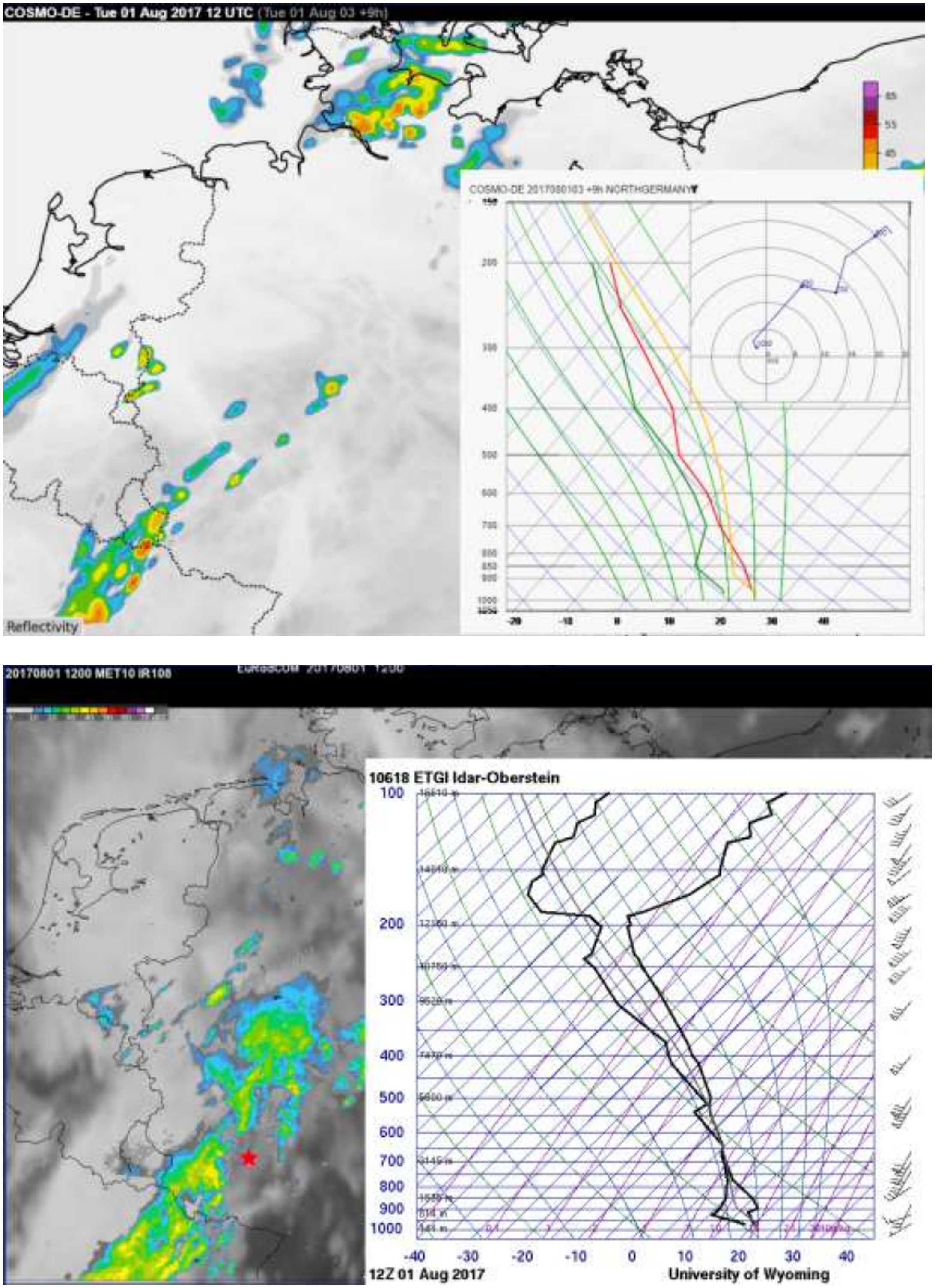


Fig. 3.5.3. Modelled (COSMO-DE at 1 August 03 UTC) and observed reflectivity and sounding at Idar-Oberstein at 12 UTC.

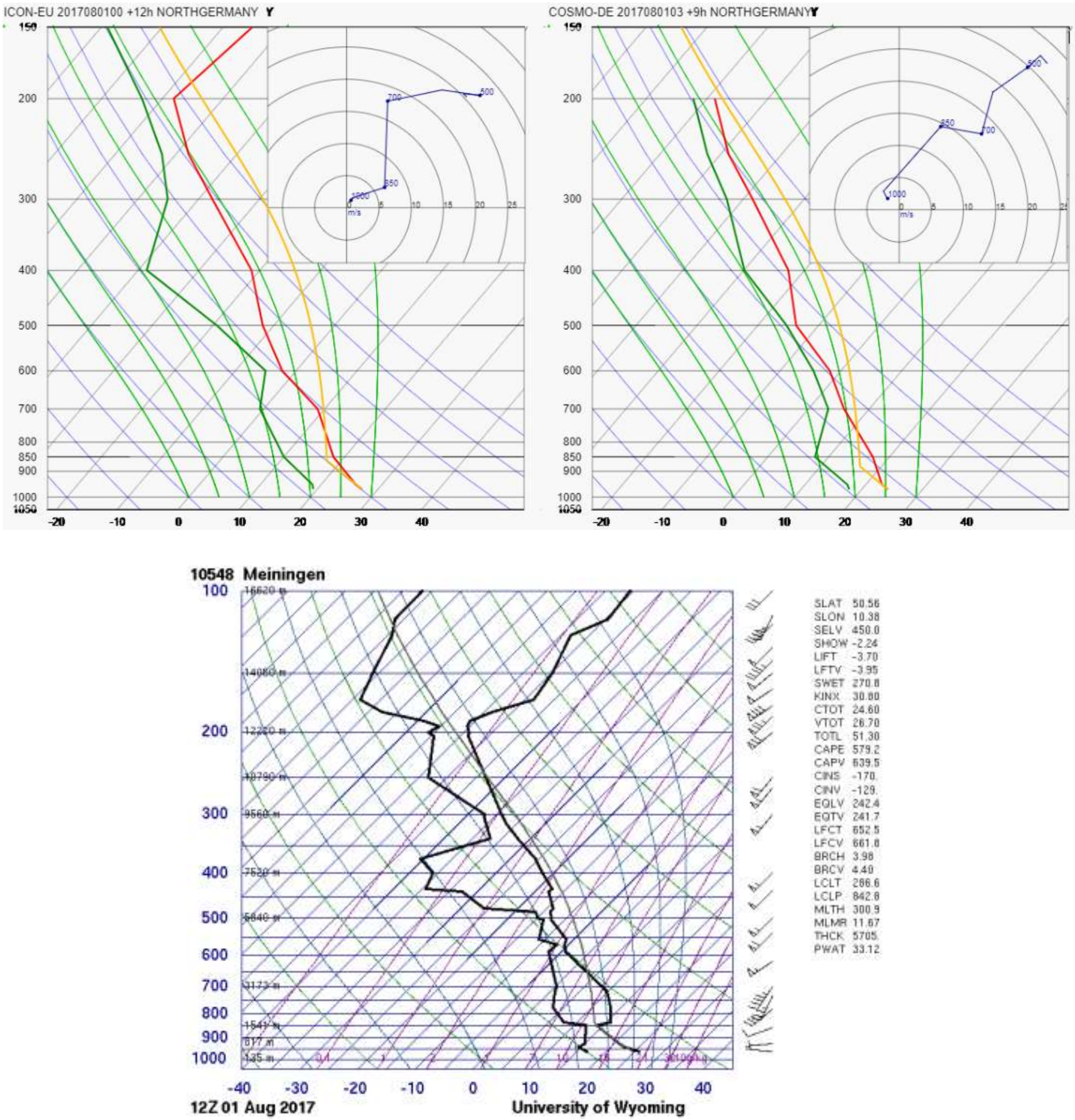


Fig 3.5.4. Modelled (by 03 UTC COSMO-DE) and observed sounding in Meiningen at 12 UTC.

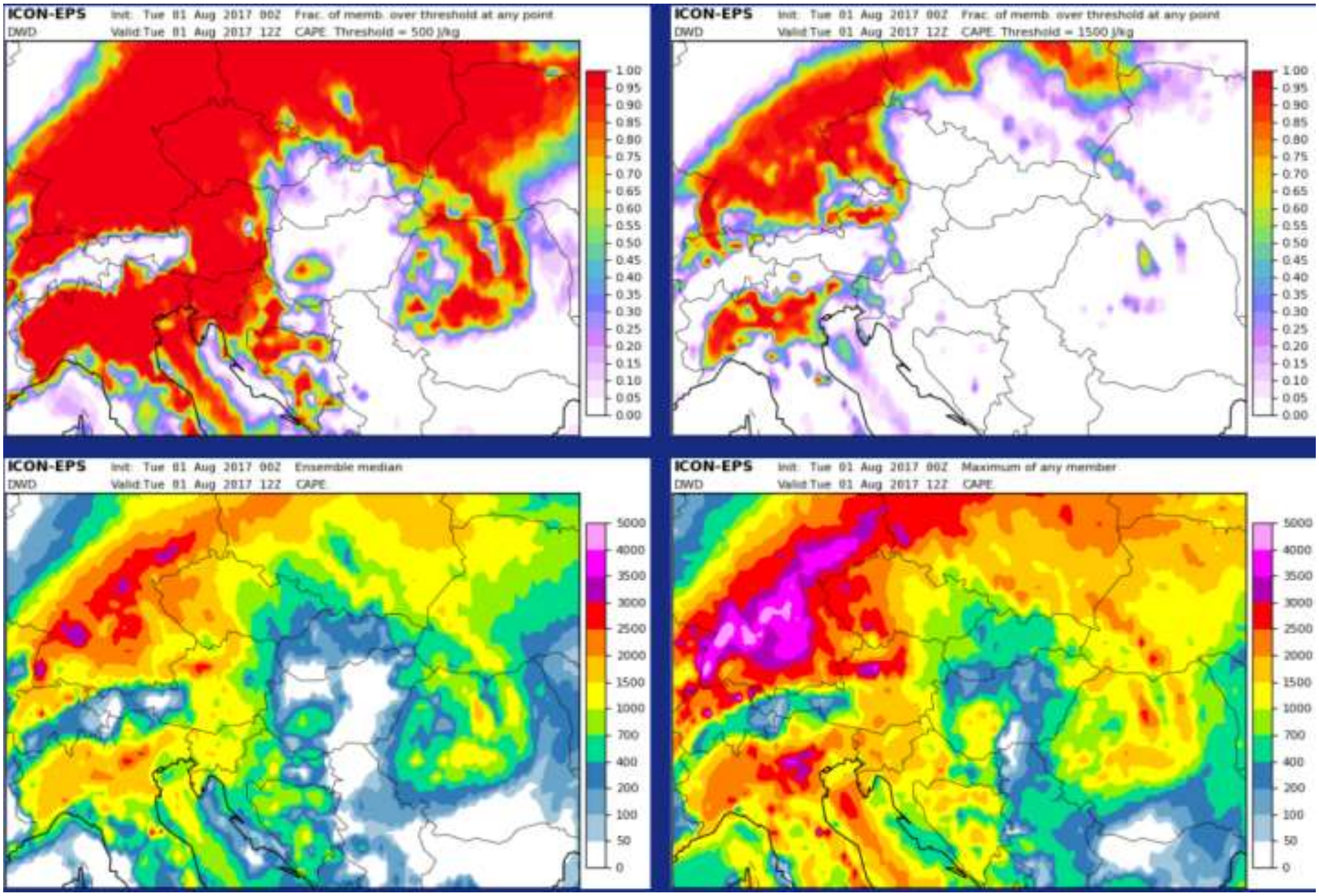


Fig 3.5.5. +12 hours prediction of ICON-EPS.

3.6 29 June 2017

On 29 June, a zone of heavy rainfall occurred over Brandenburg, Berlin and Saxony in a typical “trough with warm air aloft” / occlusion situation in concert with a “Vb”-cyclone (Fig. 3.6.1). The observed precipitation amounts were locally well over 100 mm near Berlin. Figs. 3.6.2-5 show the predictions at various lead times of the rainfall between 06 and 18 UTC on 29 June by both ICON-EPS and COSMO-DE-EPS. One can see that only very few members exceed the 70 mm threshold and even the fraction exceeding 40 mm is rather low. COSMO-DE-EPS is much more aggressive. It is important to note that the criteria are slightly different as ICON predicts the average precipitation over a grid cell of 20 x 20 km, whereas COSMO-DE-EPS predicts the probability of exceeding a thredholds anywhere within a 40 x 40 km area of reference. It seems reasonable to display lower thresholds in the future.

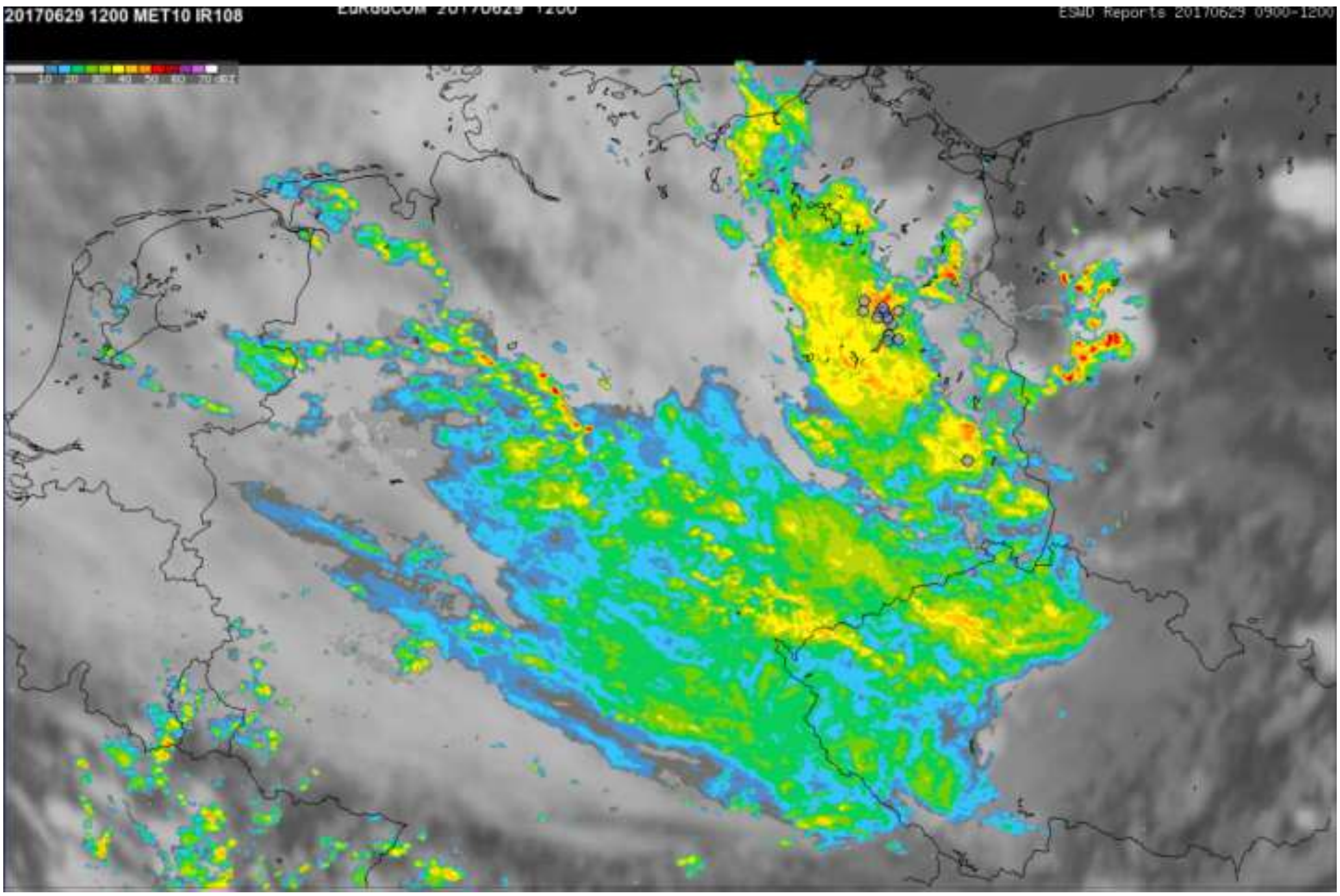


Fig. 3.6.1. Radar composite and IR image and location of flooding events reported at 20170629 12 UTC.

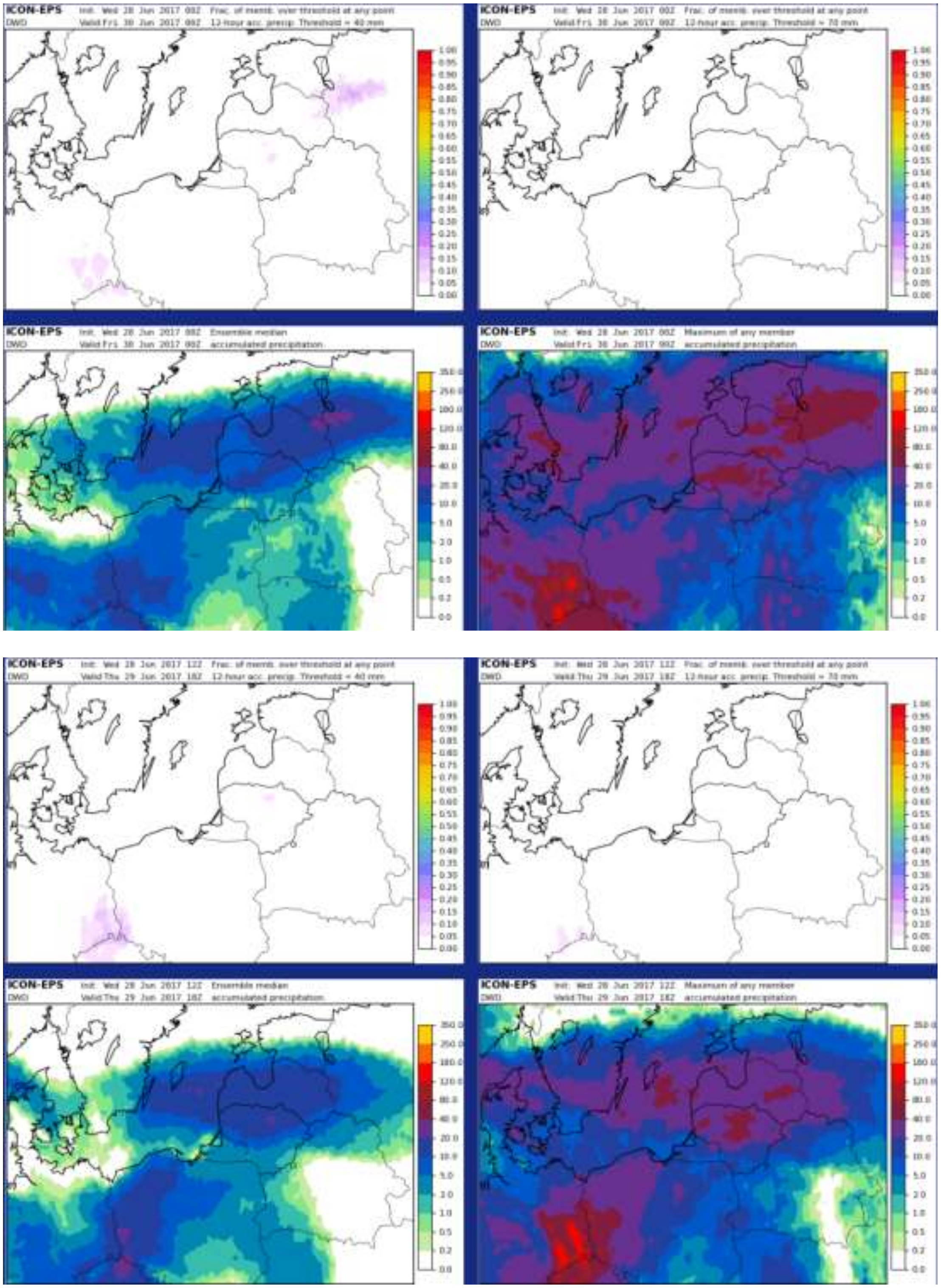


Fig. 3.6.2. ICON predictions of 28/00 UTC and 28/12 UTC for rainfall between 06 and 18 UTC on 29 June 2017.

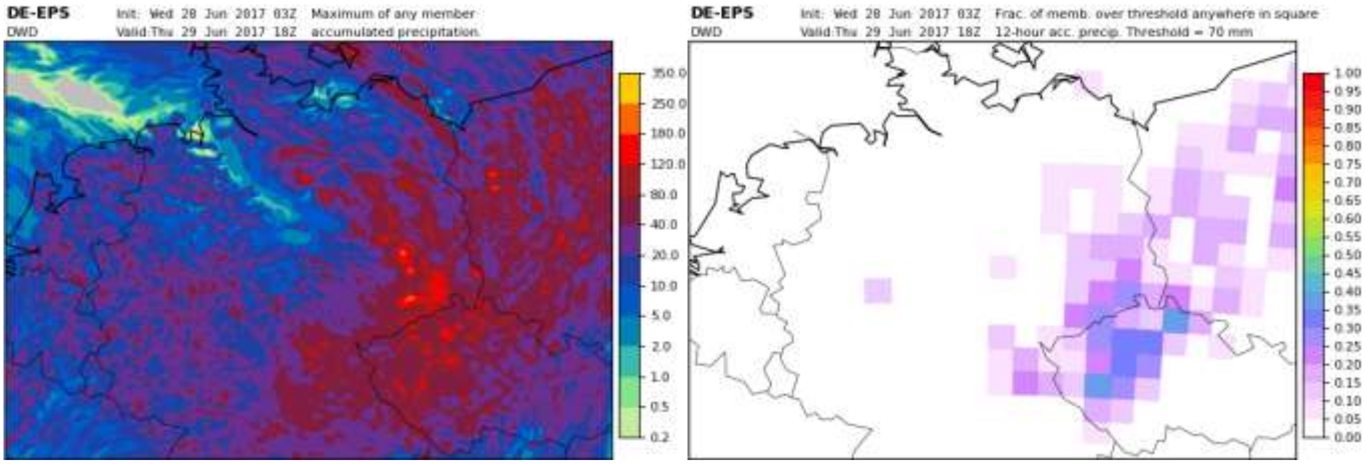


Fig. 3.6.3. COSMO-DE-EPS predictions of 28/03 UTC for rainfall between 06 and 18 UTC on 29 June 2017.

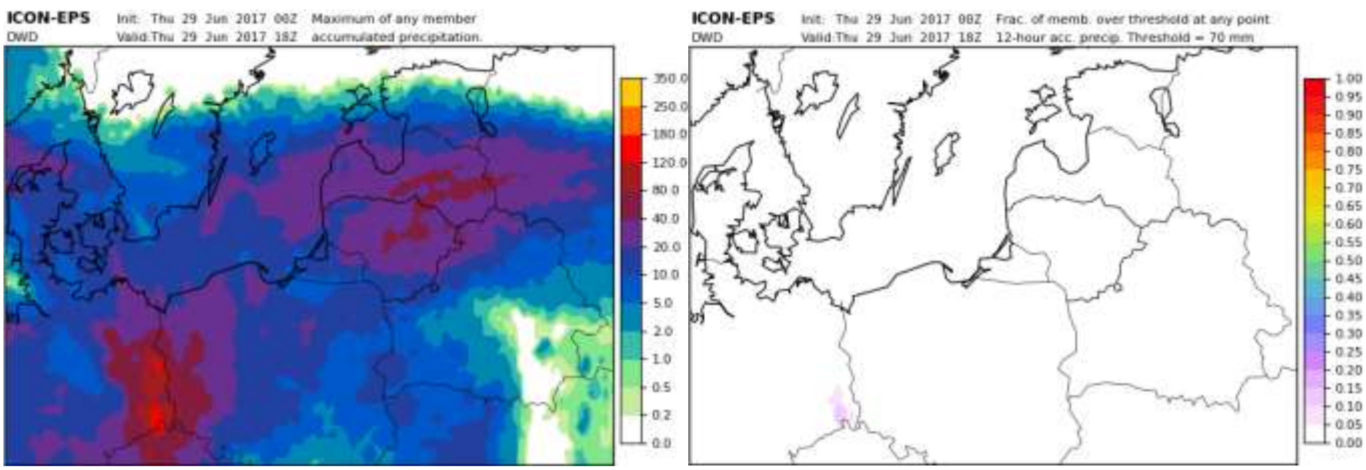


Fig. 3.6.4. ICON-EPS predictions of 29/00 UTC for rainfall between 06 and 18 UTC on 29 June 2017.

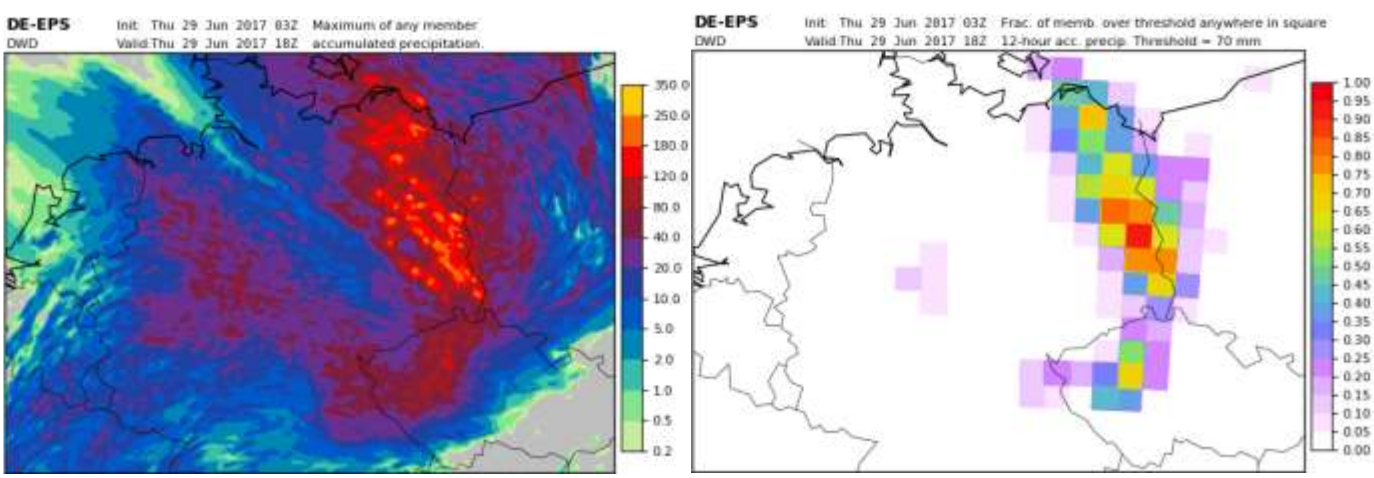


Fig. 3.6.5. COSMO-DE-EPS predictions of 29/02 UTC for rainfall between 06 and 18 UTC on 29 June 2017.