Annual Report 2024

ESSL

European Severe Storms Laboratory

Background: Photo of a downburst by David Gruber

About the Laboratory

The *European Severe Storms Laboratory e.V.* (ESSL e.V.) was founded as a private, non-profit research organisation in December 2006. It is a spin-off of German Aerospace Centre DLR in Weßling and relies on the expertise of its international team.

In Europe, severe thunderstorms inflict an estimated annual damage of about € 8 billion and lead to dozens of fatalities and many more injuries. ESSL wants to make Europe more resilient to severe weather by…

- Performing fundamental and applied research on severe convective storms in Europe,
- Operating the European Severe Weather Database, ESWD,
- Organizing the European Conferences on Severe Storms, ECSS.

The *European Severe Storms Laboratory – Science & Training* is a subsidiary located in Wiener Neustadt, Austria, which pursues similar goals. It operates the Research and Training Centre, which is the venue of various courses, workshops, and the ESSL Testbed. In addition to the goals above, it…

- Operates the ESSL Testbed, where it evaluates new forecast-supporting tools,
- Organizes various courses for various target groups, such as weather forecasters, to enhance their understanding of convective storms.

In pursuing these goals ESSL collaborates with its members that include Europe's weather services, and international organisations such as EUMETSAT and ECMWF.

Registration number: VR200584, Amtsgericht München
V.A.T. Number: DE 252519763

Address:
European Severe Storms Laboratory (ESSL)
Kirchstrasse 3
82234 Weßling
GERMANY

E-Mail: inflow@essl.org
Web: https://www.essl.org
Phone: +49 151 5903 1839
Fax: +49 8151 9659 999 11

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Foreword

Dear Reader,

In 2024, a record number of 9 institutional supporting members joined ESSL, probably as an indirect consequence of the exceptional hailstorm damage that occurred in Europe in 2023. The Italian regional environmental protection agency ARPA-Emilia Romagna joined ESSL as a full member. The new memberships provided ESSL with additional financial means to help fulfil its goals of advancing scientific understanding, building human capacity, and fostering cooperation within severe storm science across Europe.

Indeed, several important efforts were started or continued in 2024, most prominently the preparations for the large field campaign Thunderstorm Intensification from Mountains to plains, or TIM, which involved a large amount of coordination and exploratory work with potentially interested parties, and the authoring of a whitepaper to scientifically underpin the motivation for the campaign. In addition, we started developing a new implementation of the European Severe Weather Database, which would become operational in the third quarter of 2025. A third major investment was in the development of a new component of the ESSL Weather Data Displayer that would show Doppler radar data from European radars. At a course in December 2024, it would be used for the first time. Furthermore, a separate legal entity ESSL Services GmbH was founded to carry out services for ESSL members and others, such as developing hazard models or providing access to ESSL's Weather Data Displayer.

Weatherwise, 2024's most impactful events were related to heavy rainfall. The most prominent event by a large margin was the tragedy that unfolded near Valencia in eastern Spain on 29 October, where, sadly, a total number of 219 fatalities occurred as a result of a storm system that remained quasi-stationary over the region for many hours. In addition to this event, severe autumnal floods with more than a dozen fatalities also occurred in Morocco and in Bosnia-Hercegovina. The western Balkans also were the hot spot of large hail occurrence in 2024, although the total impact of hailstorms was considerably lower than in 2023, because hailstones of exceptional size were considerably rarer. The number of requests for ESWD data by non-members stayed at approximately the same, high, level as in 2023. An overview of severe weather is given in Chapter 1.

This Annual Report also gives an update on the various research projects that ESSL scientists were working on, the largest of which were CHECC, PreCAST, and the collaborative projects with ECMWF. These projects resulted in significant advancements in forecasting severe weather in the medium range, where considerable predictability of hailstorms was noted to extend to 10 days in advance. Furthermore, projections of the future hailstorm climate based on the CMIP6-generation of climate models were obtained. More details can be found in Chapter 2.

2024 saw a continuation of work to support nowcasting and forecasting of severe weather and featured a record number of seven weeks of testbeds. Five of them were organized

as part of a continuing collaboration with EUMETSAT on promoting the user uptake of products from the Meteosat Third Generation satellites. This collaboration also involved the organization of four expert workshops in total on the new Lightning Imager and Flexible Combined Imager (FCI) instruments. The remaining ESSL Testbed weeks heavily focused on Numerical Weather Prediction and nowcasting tools, including a range of products from the German Weather Service's SINFONY project, the C-LAEF model used in the PreCAST project, and the statistical AR-CHaMo models applied to ECMWF ensemble forecasts. For more information, see Chapter 3.

In Chapter 4, we report on the thirteen workshops and courses, a record number, that ESSL organized in 2024. Some were part of the collaboration with EUMETSAT, others were from ESSL's existing portfolio of courses on forecasting severe storms, but two were entirely new: a course on Communication of Meteorological Information, which we offered in online form and an on-site course on Radar Meteorology and Microphysics rendered possible by the newly developed Radar Displayer tool.

Chapter 5 describes ESSL's endeavours to organize a large field campaign TIM with partners from across Europe. The campaign seeks to investigate why storms tend to be particularly intense in areas surrounding high mountain ranges, and addresses storm initiation, microphysical processes, and climate change aspects. The challenge at the core of this initiative is the search for funding.

In 2024 ESSL strengthened its global network, interacting with the newly founded Canadian Severe Storms Laboratory and starting a project enabling sharing of storm data and the participation of South American researchers in ESSL events. Besides, ESSL was active in public and social media, and in other outreach activities. Four Newsletters were published and sent to ESSL members. We report on this in Chapter 6.

On the financial side (See Chapter 7), results of 2024 were as planned. For both ESSL e.V. (in Wessling, Germany € -58,333) and ESSL Science and Training (Wiener Neustadt Austria, € -63,620) booked negative results. This was planned in advance and resulted from the decision to make various important investments, such as the new ESWD, the Radar Displayer, and the TIM project preparations. Sufficient financial reserves remained at the end of 2024.

Wrapping up, I am more than happy to present you with this Annual Report 2024, which describes ESSL's achievements in its eighteenth full business year.

18 August 2025,

Dr Pieter Groenemeijer
ESSL Director
Chair of the Executive Board

1 Severe Weather in 2024

A key activity of ESSL is the collection of severe weather data in the European Severe Weather Database in cooperation with its partners. The data forms the starting point of research within and outside of ESSL.

1.1 Evolution of the European Severe Weather Database

Event Types

In 2024, 56 469 new severe weather reports were added to the ESWD (Figure 1-1), which is less than the 64 542 reports of the previous year, 2023 (Table 1-1). The most frequently reported severe weather phenomenon was severe wind gusts (31 975), followed by heavy rain (10 753) and large hail (10 173). Comparing convective hazards to 2023, heavy rain (+26.6%), tornadoes (+20.8%), and damaging lightning strike (+13.4) showed a substantial increase. Large hail reports reached more than 10 000 reports in a year.

Table 1-1. Reports entered in the European Severe Weather Database in 2024.

Report Type	Number of reports	% of total	% change relative to 2023
Severe Wind Gusts	31 975	56.7	-22.7
Heavy Rain	10 753	19.0	+26.6
Large Hail	10 173	18.0	+3.3
Damaging Lightning Strikes	1 722	3.1	+13.4
Tornadoes (incl. waterspouts)	1 080	1.9	+20.8
Heavy Snowfall/Snowstorms	550	1.0	-72.7
Avalanches	138	0.2	+17.9
Ice Accumulation	67	0.1	-58.1
Total	56 469	100.0	-12.5

A general increase of the number of reports for the four convective weather hazards has occurred since 2008 (Figure 1-2). The increase is probably mostly caused by the growth of the number of partners who report severe weather to ESSL, and the increased resources spent on data collection by ESSL. The strong increase from 2022 to 2024 was at least in part due to the discovery of several new online resources that list impacts on the power grid. Both 2023 and 2024 stand out as years with a very large number of both hail and wind reports. As should be clear from the above, it is not possible to infer multi-annual trends of true hazard occurrence directly from these data because they are strongly influenced by effects not related to meteorology.

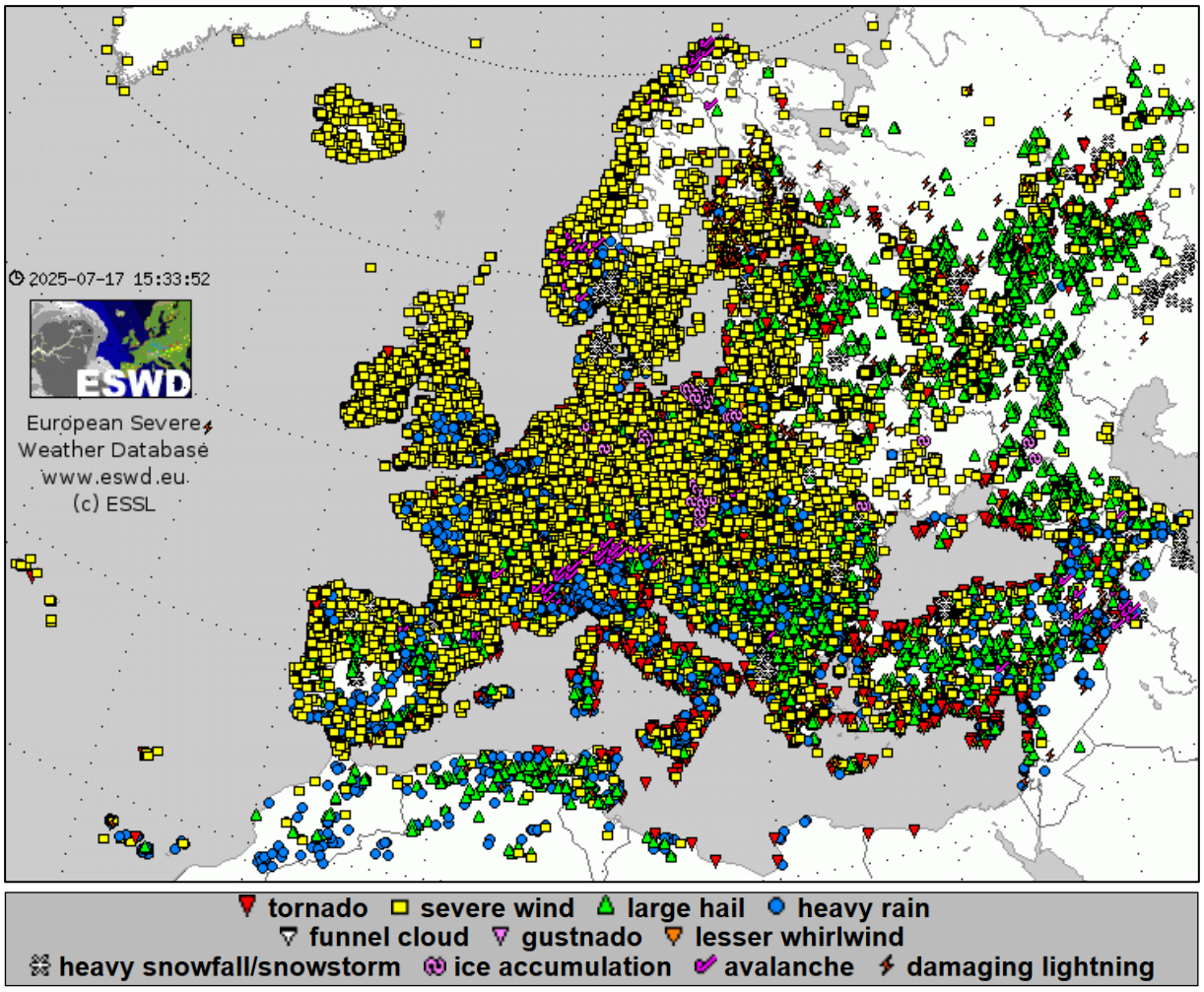

Figure 1-1. The 56 469 ESWD reports of events occurring in 2024.

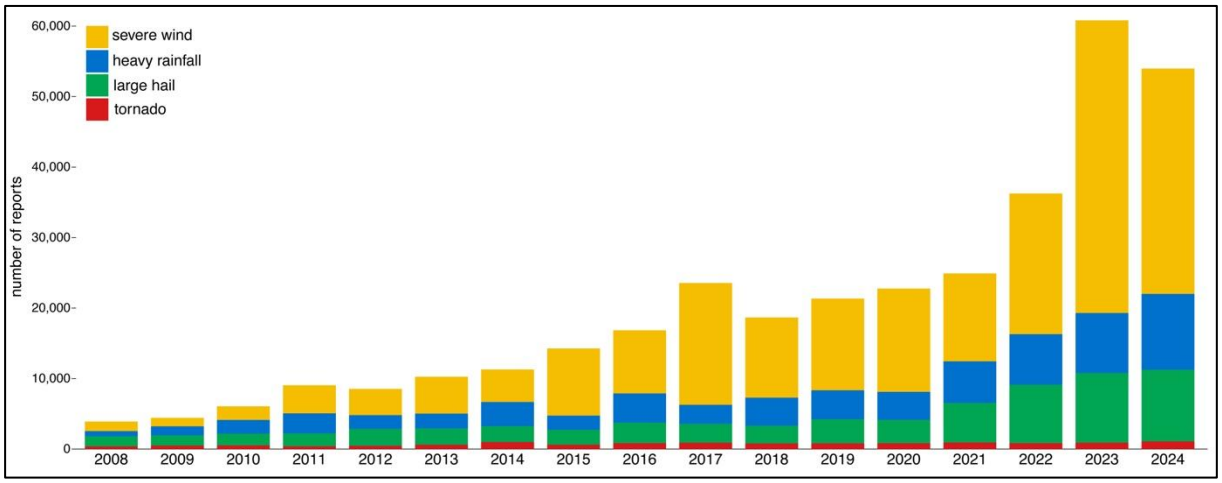

Figure 1-2. Trend of reports of the four convective hazards, severe wind, heavy rainfall, large hail, and tornado in the ESWD.

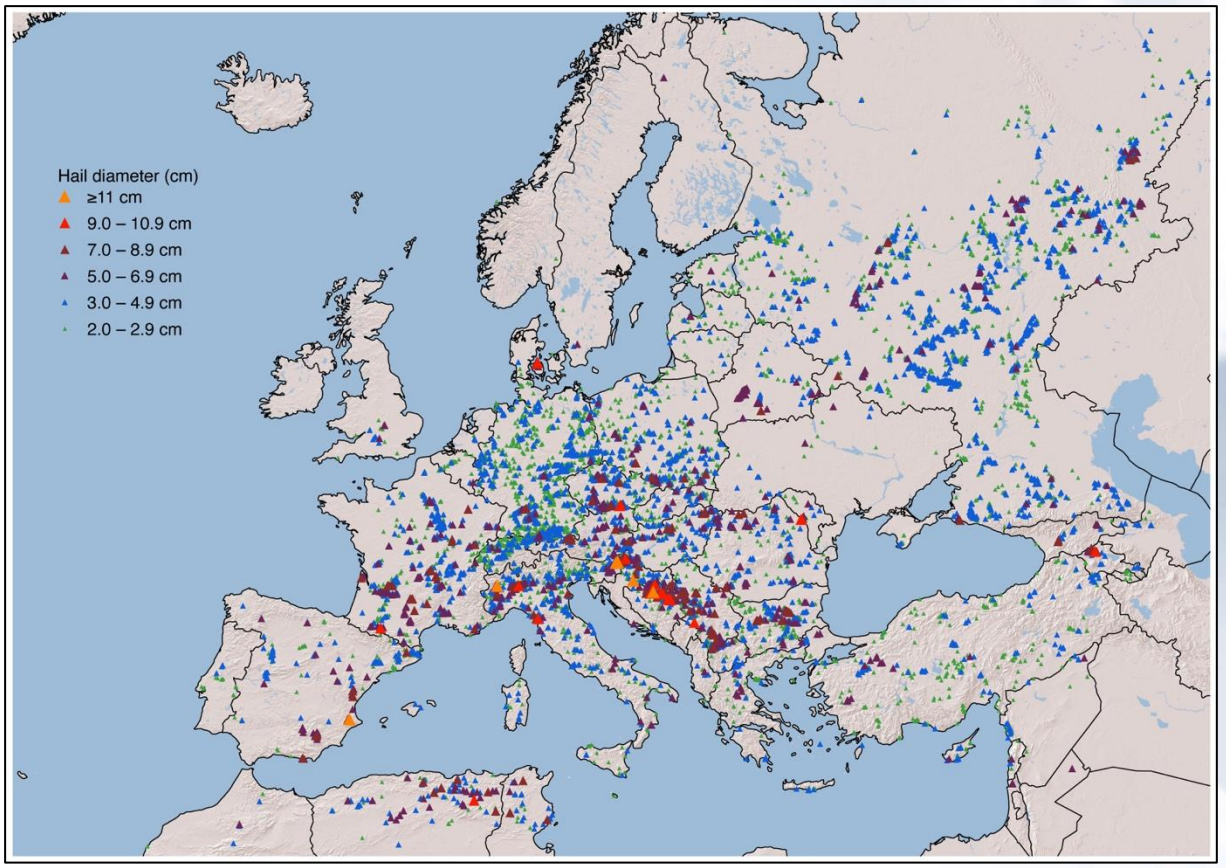

Figure 1-3. ESWD large hail reports of 2024.

A closer inspection of the hail reports for 2024 shows a further increase in events compared to previous years (**Figure 1-3**). The total number counting 8873 hail reports of 2 cm in diameter or larger. Hailstones with a diameter of 12 cm were reported in Italy (29 June) and Slovenia (13 July), which marks the 2024 record for hail sizes in Europe. Giant hail (10 cm in diameter or larger) also affected in Bosnia and Herzegovina, Croatia, Denmark, Italy, Romania, Serbia, Slovenia, Spain, and Romania.

A look at the cumulative number of days on which hail of at least 5 cm is reported in the ESWD illustrates the increase: it also shows that the season in which very large hail is extending more into autumn than in recent years (**Figure 1-4**, Figure 1-5). That being said, the preceding year of 2023 was still more exceptional in terms of damage. Indeed, the number of reports of giant hail with diameters of at least 10 cm was much higher in 2023 compared to 2024 (**Table 1-5**).

A more detailed discussion of the hail events in 2024 is available on the ESSL news blog at https://www.essl.org/cms/hailstorms-of-2024/ .

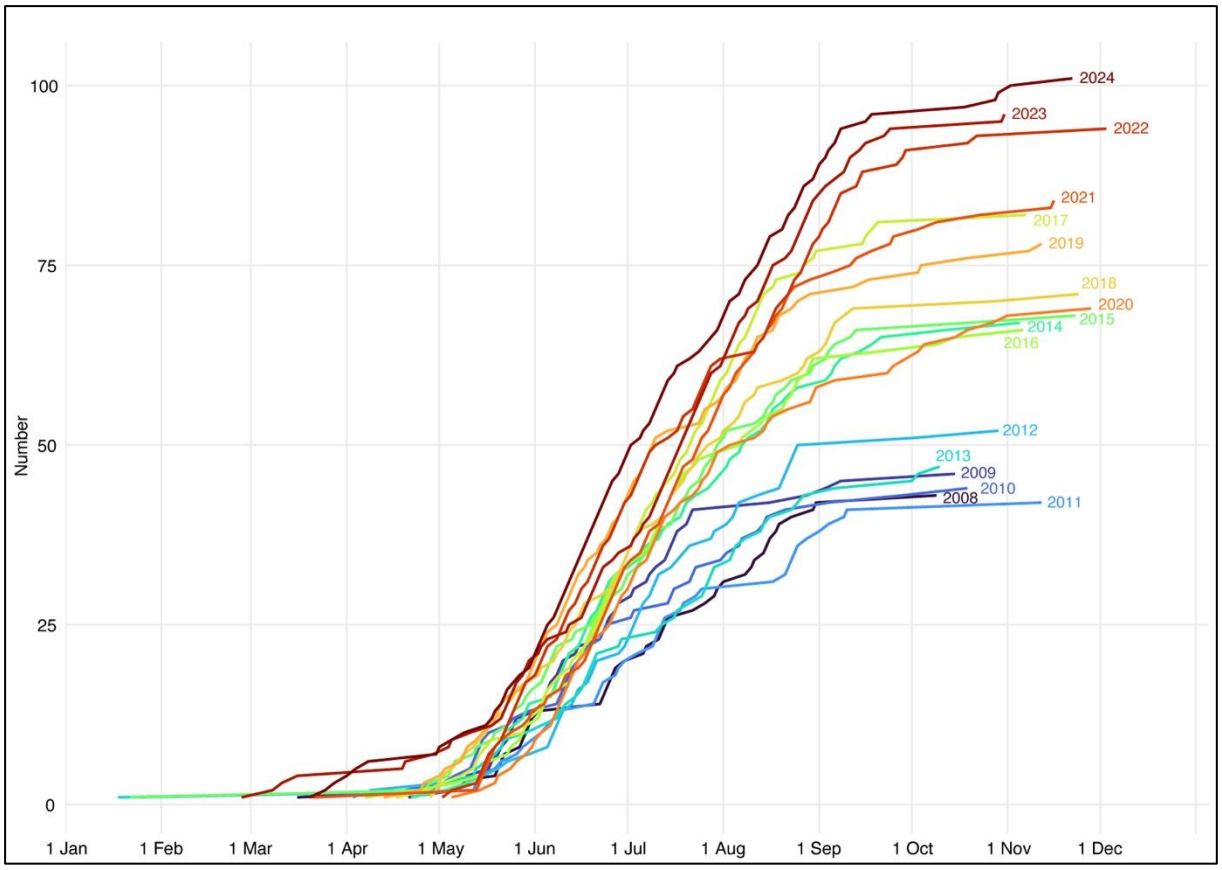

Figure 1-4. Cumulative number of days with hail of at least 5 cm diameter per year since 2008.

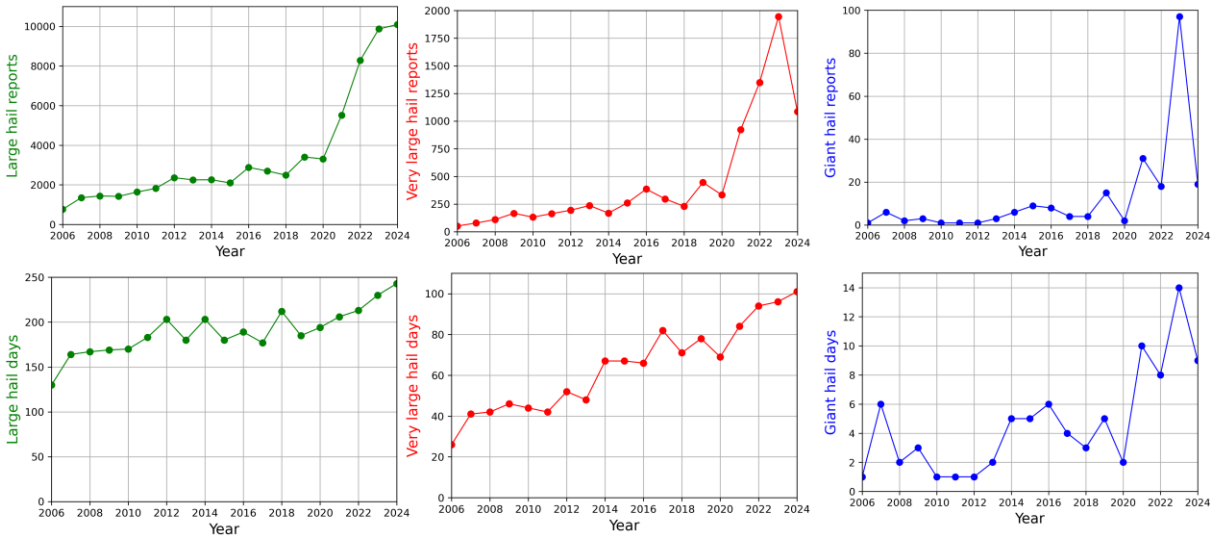

Figure 1-5. Number of reports of large (2.0 – 4.9 cm), very large (5.0 - 9.9 cm) and giant (> 10 cm) hail reports and hail days (i.e. days with at least one report) in recent years.

Quality Control

The ESWD team and partners assess reports for trustworthiness. Reports from untrusted sources start at QC0 (unchecked). After review, they may be upgraded to QC0+ (plausible), QC1 (confirmed by a reliable source), or QC2 (full scientific study). QC levels can be raised if new, reliable information emerges. All reports from 2024 have been upgraded at least to QC0+ (Table 1-2). For 9.0 % of reports, it was not possible to assign a higher rating than QC0+, i.e. “plausibility checked”.

Table 1-2. Quality control levels of ESWD reports from 2024.

Quality Control level	Number of reports	%
QC0: as received	0	0
QC0+: plausibility checked	5 062	9.0
QC1/QC2: report confirmed by reliable source	51 407	91.0

ESWD Partners

ESSL’s partners both collect severe weather reports and check them for correctness. Such partners are individuals, associations, and weather services. ESSL’s most active partners in 2024 are listed in Table 1-3. The current leading contributor of severe weather events is the Association MeteoNetwork/PRETEMP, that feed their data automatically into the ESWD, contributing recent, but also historical severe weather reports. The individual contributing the most severe weather reports was Mr. Nicolas Baluteau, who on his own managed to report 1321 occurrences of severe weather in France.

In many other countries, valuable and significant contributions to the ESWD are made by the individuals and associations listed in the table. On a yearly basis, ESSL individual volunteers are rewarded with ESSL merchandise, free participation in selected ESSL events, or a small financial compensation.

Table 1-3. Most active ESWD partners in 2024

Name	Country	Number of reports
1. Association MeteoNetwork/PRETEMP	Italy	4 192
2. Mr Baluteau	France	1 321
3. Mr Dasevschii	Moldova	806
4. Mr Paul	France	425
5. Mr Van der Ploeg	Netherlands	365
6. Amateur Meteorological Society	Czechia	324
7. Mr Lindberg Jensen	Denmark & Norway	315
8. Mr Kiitsak	Estonia & Finland	273
9. Mr Pfeifhofer	Austria	158
10. Slovak HydroMeteorological Institute	Slovakia	143

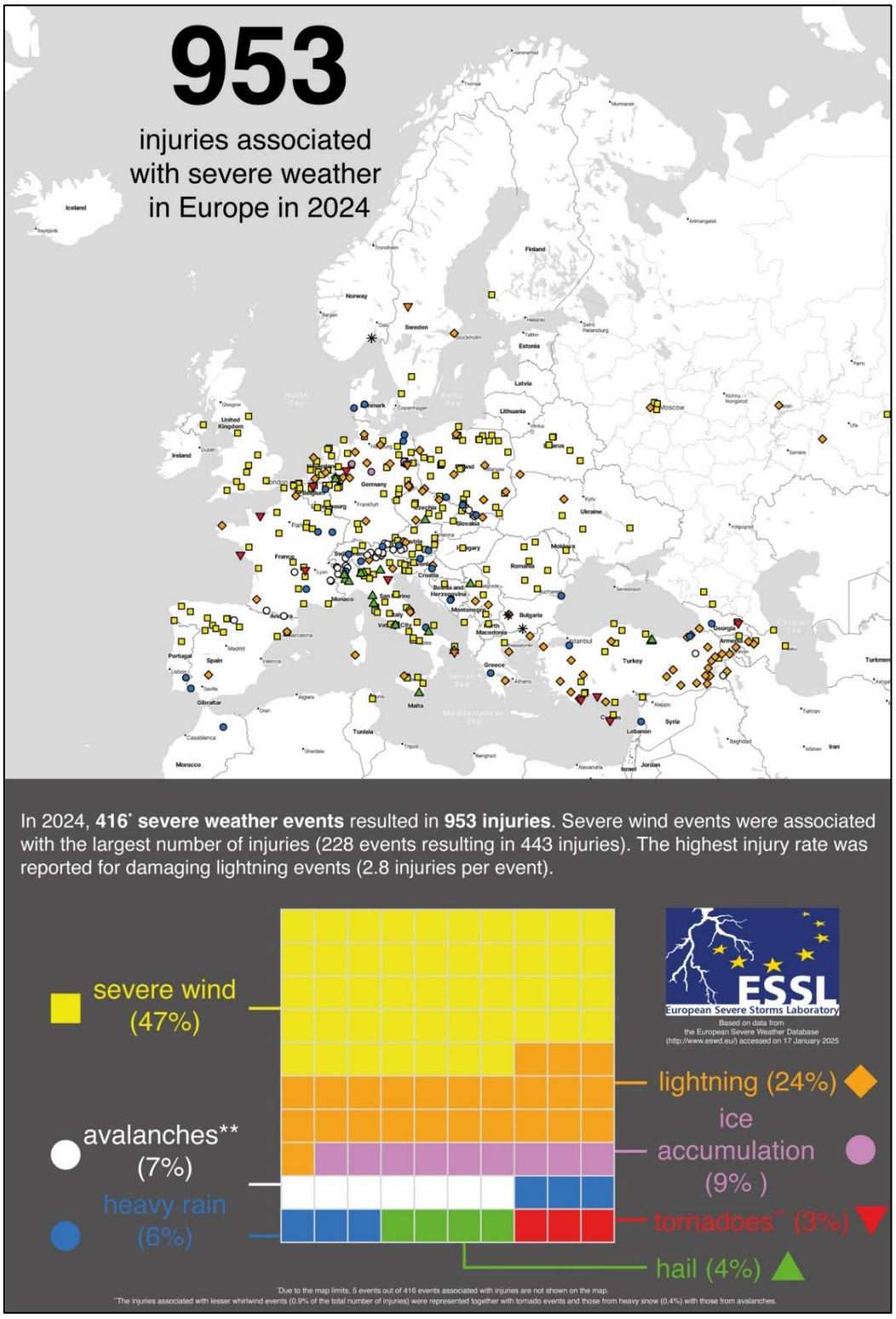

Figure 1-6. The spatial distribution of the ESWD severe weather reports in Europe, associated with injuries in 2024. Below, the percentage of injuries associated with each type of severe weather across the entire ESWD area, i.e., including Mediterranean Africa and Asia, and Central Asia (excluding categories < 1%).

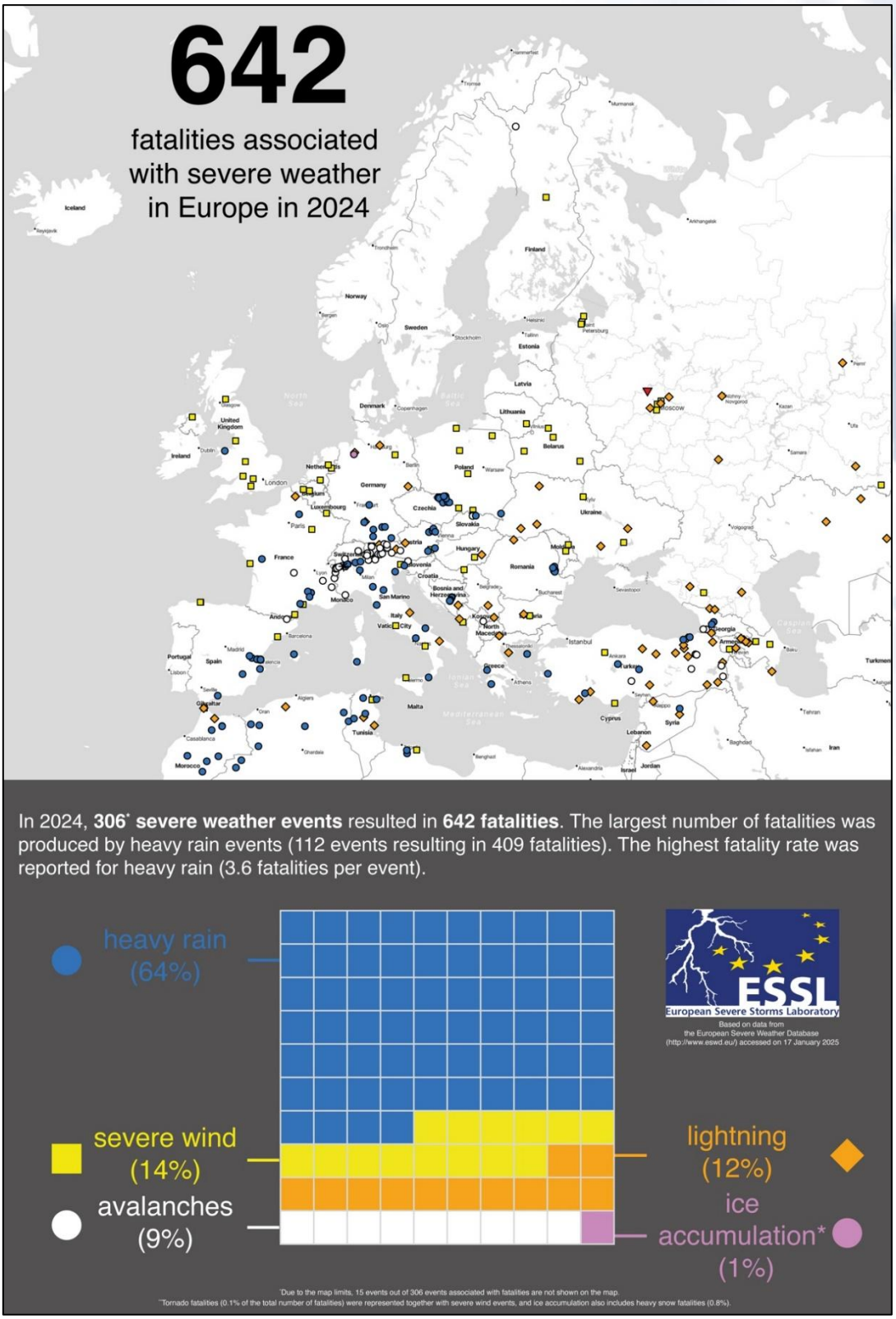

Figure 1-7. The spatial distribution of the ESWD severe weather reports in 2024 associated with fatalities. Below, the percentage of fatalities associated with each type of severe weather across the entire ESWD area, i.e., including Mediterranean Africa and Asia, and Central Asia (excluding categories < 1%).

Fatalities and Injuries

Severe weather in Europe unfortunately led to a considerable number of fatalities in 2024. In total, the events recorded in the ESWD caused 642 fatalities (Figure 1–4) and 953 injuries (Figure 1-3). The number of fatalities was much higher than in 2023, when 524 fatalities were reported.

Table 1-4. Recorded severe weather fatalities in 2024 per event type.

	Hazard(s)	Fatalities
1	Heavy Rain	409
2	Severe Winds	87
3	Lightning Strikes	80
4	Avalanches	59
5	Heavy Snowfall	5
6	Tornadoes	1
	Ice Accumulation	1

1.2 Major severe weather events

Table 1-4 shows the distribution of severe weather-related fatalities based on event types. The events with the most fatalities in 2024 are listed in **Table 1-5**. In contrast to earlier years, 2024 remarks a large number of fatalities caused by heavy rainfall/flooding. The deadliest event occurred over the larger metropolitan area of Valencia City and its periphery on 29 October 2024. In the afternoon and early evening hours, excessive rainfall caused violent flash floods, mainly the streams of Rambla del Poyo and Turia, which washed away dozens of cars, trucks, and busses being caught in evening traffic jams on major streets and motorways. With at least 219 confirmed fatalities and dozens still missing even months after the event, it remarks one of the deadliest flash floods in Spain in the last decades.

Table 1-5. The severe weather events with most fatalities in 2024 recorded in the ESWD.

	Hazard(s)	Date(s)	Location	Fatalities
1	Heavy Rain	29 Oct 2024	Valencia region (Spain)	219
2	Heavy Rain	04 Oct 2024	Neretva River (Bosnia-Hercegovina)	21
3	Heavy Rain	20 Sep 2024	Tata region (Morocco)	14
4	Heavy Rain	07 Sep 2024	Auokerda (Morocco)	10
5	Heavy Rain	06 Feb 2024	Nergeeti (Georgia)	9
6	Severe Wind	19 Aug 2024	Santa Flavia (Italy)	7
7	Heavy Rain	28 Jun 2024	Osh region (Kyrgyzstan)	5
	Heavy Rain	05 Jun 2024	Sidi Bel Abbes region (Algeria)	5
	Snowstorm	09 Mar 2024	Valais Alps region (Switzerland)	5
1	Avalanche	25 Feb 2024	Mont-Dore (France)	4
0	Heavy Rain	29 JUN 2024	Maggia (Switzerland)	4

1.3 ESWD Data Users

ESWD data are used by a wide range of users. ESSL receives a considerable number of requests from potential new users, usually initiated by e-mails sent to the address eswd@essl.org.

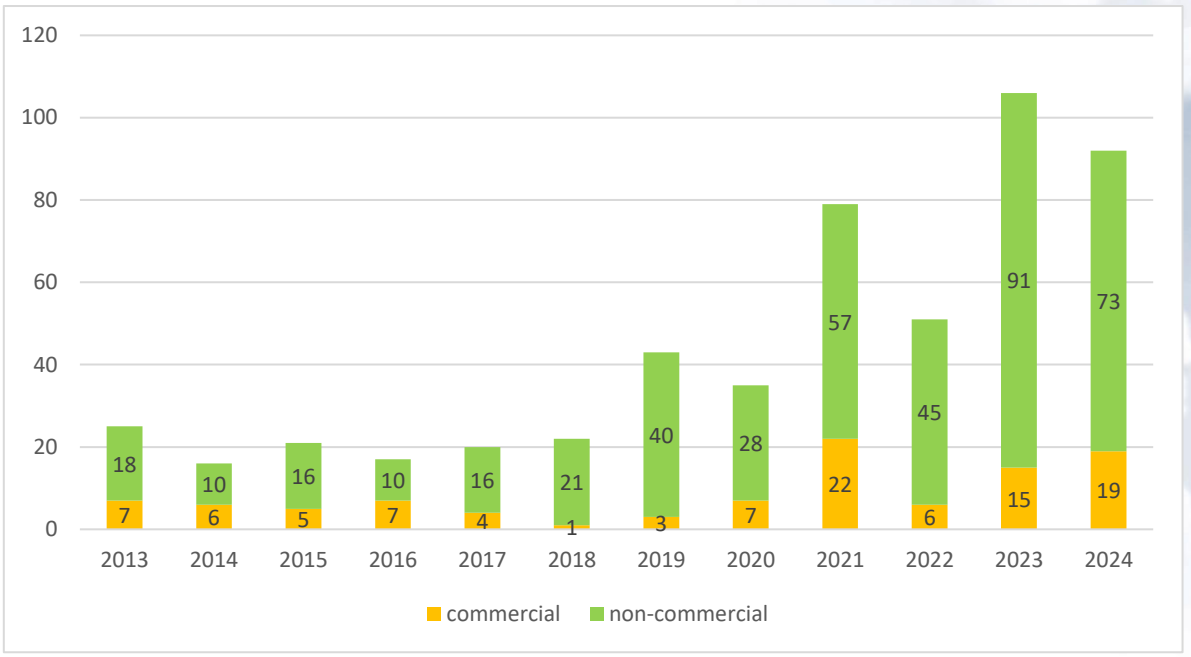

Figure 1-8. Number of requests for ESWD data by non-members.

Interest in ESWD data has strongly increased over the last five years (Figure 2-7). The requests in 2024 were for both commercial (19 requests) and non-commercial (73 requests) purposes. Most requests, come from students or individual researchers who would like to use parts of the database to support their study. If commercial interest does not drive the study and the researcher agrees to the User Agreement, ESSL will deliver the data free of cost. If the study has a dedicated budget, ESSL will request a financial contribution to support the ESWD data collection. When a commercial party would like to access the data, they are invited to join the association as a supporting member, or to purchase data from ESSL.

2 Research

ESSL's research dealt with the changing risk of convective hazards as a result of climate change in the project CHECC-II, while improving severe weather forecasts was the focus of the collaboration with ECMWF and the PreCAST project.

2.1 Convective Hazard Evolution under Climate Change Phase II (CHECC-II)

Federal Ministry of Education and Research

CLIMXTREME Climate Change and Extreme Events

FONA Research for sustainability

Grants:	€ 216 154
Funded by:	German Federal Ministry of Education and Research (BMBF)
Period:	August 2023 – September 2026
Carried out by:	European Severe Storms Laboratory e.V. (ESSL), Weßling
Supported by:	Institute of Meteorology, Freie Universität Berlin; Mateusz Taszarek (University of Poznań)
ESSL employees:	Francesco Battaglioli, Thilo Kühne, Pieter Groenemeijer

2024 saw a continuation of the CHECC projects, which were funded by the German Ministry of Research and Education and are a part of the national ClimXtreme research network, focusing on the analysis of extreme weather and climatological events.

In the predecessor project CHECC-I, ESSL focused on improving the statistical dynamical models (AR-CHaMo) to detect extreme convective events such as hail and tornadoes from reanalysis and climate model data. The AR-CHaMo models use storm reports collected in the European Severe Weather Database and lightning detection data and are based on an Additive Regression. Using these data, changes in severe weather probability during the last decades were mapped across Europe (Battaglioli et al, 2023).

The work in 2024 shifted from mapping past severe weather trends to those in the future, by using climate model projections and as a function of increasing levels of global warming. To do this, the AR-CHaMo models were applied to climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP-6), i.e. CNRM-CM6-1, CNRM-ESM2-1, MPI-ESM1-2-LR, MRI-ESM2 and MIROC6, to estimate the future occurrence of large (≥ 2 cm) and very large (≥ 5 cm) hail across Germany and neighbouring countries. The analysis was conducted by considering the most aggressive scenario called Socio-Economic Pathway SSP5-8.5, and considered the moment each of these models in that scenario would exceed any of three levels of global warming compared to the historical period 1980-2010: 1.5°, 2.0° and 3.0°C.

First, a 24-year period centred around the warming thresholds of 1.5°C, 2.0°C and 3.0°C was identified for each of these models. The subsequent application of the hazard models for large hail ≥ 2 cm (Figure 1) and very large hail ≥ 5 cm (Figure 2) exclusively show increases across Germany and neighbouring regions. The highest hail frequency will affect southern regions of the country, including Bavaria and Baden-Württemberg, with a mean frequency of around 0.40 events for hail ≥ 2 cm and 0.05 for hail ≥ 5 cm across every 25 x 25 km grid.

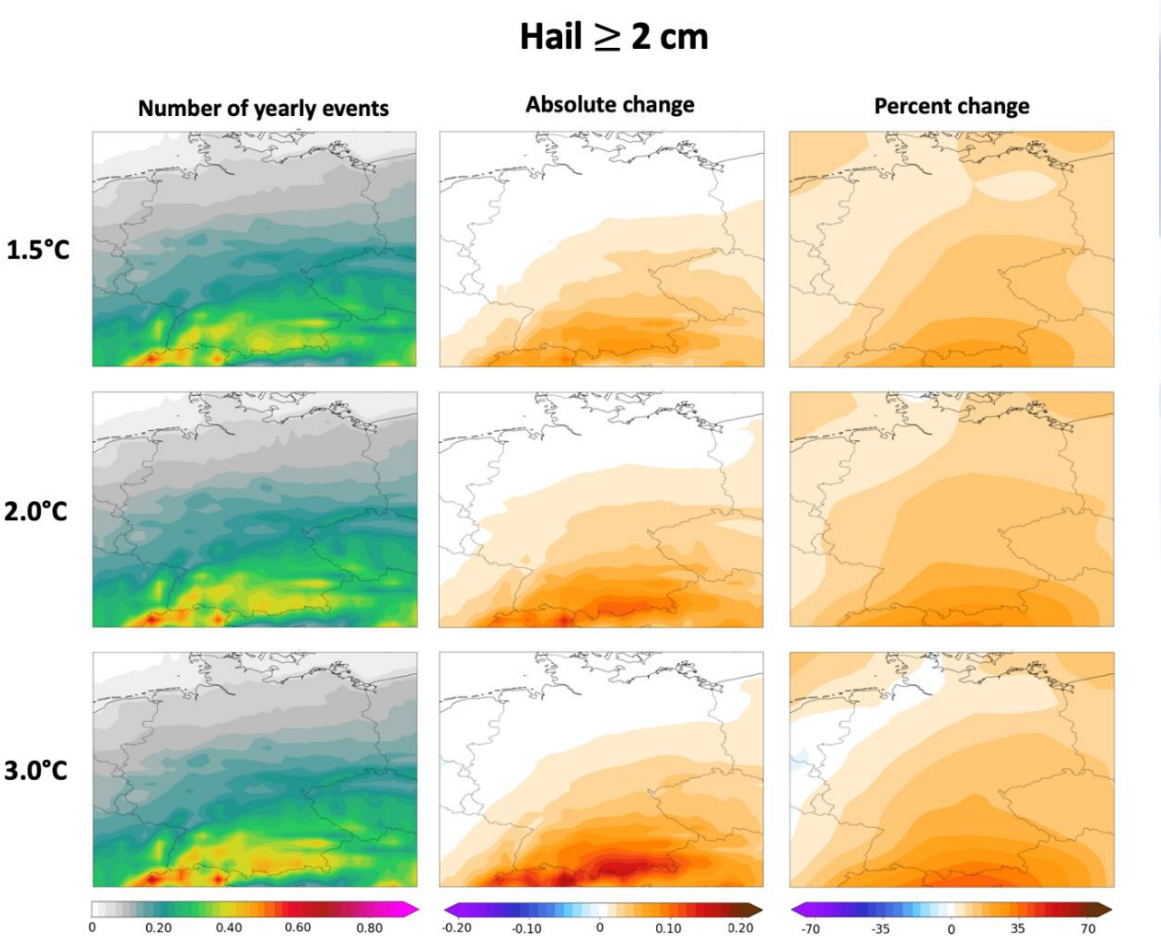

Figure 2-1. AR-CHaMo based number of hourly periods with hail ≥2 cm (first column), change in hourly periods compared to 1980-2010 (second column), and relative percent change (third column) for 1.5°C, 2.0°C and 3.0°C warming compared to the period 1980-2010.

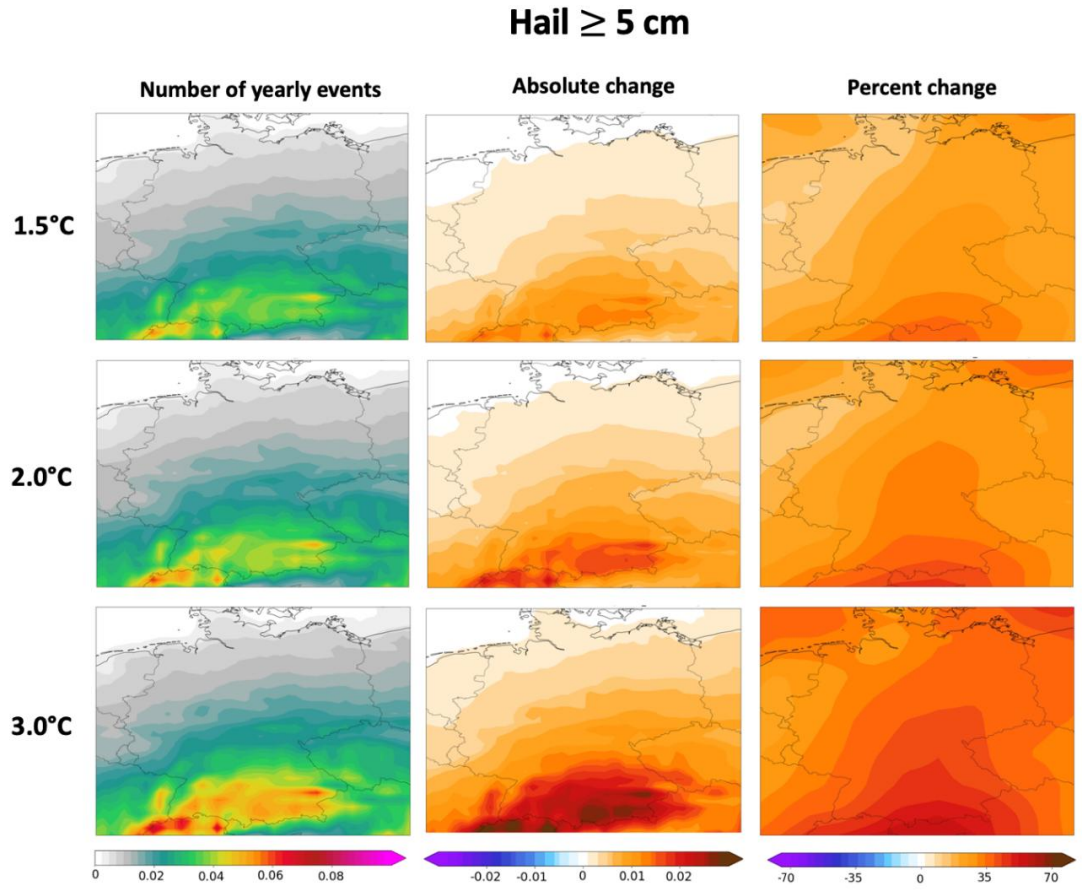

Figure 2-2. As Fig 8, but for very large hail (5 cm).

The increase in hail events depends on the amount of warming, with the upward trend increasing sharply in magnitude for the 3.0°C threshold, especially for very large hail ≥ 5. This upward trend will be the sharpest across southern Germany, both in absolute terms and expressed as a relative change in percentages. The strongest positive trends are projected for very large hail, whose frequency is expected to increase by more than 60% across southern Germany. A strong north-south gradient is projected in the future occurrence of hail across Germany, with trends appearing to be much smaller in the North, especially for hail ≥ 2 cm.

In 2025, the same approach developed for hail will be extended to tornadoes ≥ F1. The predictors for the corresponding AR-CHaMo model are being calculated from CMIP6 model level data: Storm Relative Helicity (SRH) in the lowest 500m Above Ground Level (AGL), the Lapse Rates at the lowest 1km AGL, and the vertical vorticity at 10m AGL.

We are grateful to the Institute of Meteorology of the Free University of Berlin which kindly offered office space to host the CHECC scientists, and to the great collaboration with Dr Mateusz Taszarek (National Severe Storms Laboratory, USA; and University of Poznań, Poland) who supported CHECC by providing convective parameters calculated from reanalysis data.

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2.2 Prediction of Convective hazards Across Spatio-Temporal Scales

FWF Der Wissenschaftsfonds.

Grant:	ESSL: € 293 010, total: € 483 280
Funded by:	FWF Der Wissenschaftsfonds (Austria)
Period:	1 September 2020 – 28 February 2025
Carried out by:	European Severe Storms Laboratory – Science and Training, Wiener Neustadt, and GeoSphere Austria
Supported by:	European Centre for Medium-Range Weather Forecasts (ECMWF)
ESSL employees:	Tomáš Púčik, Pieter Groenemeijer

GeoSphere Austria

The PreCAST project aims to improve the prediction of convective extreme events by blending medium-range models AR-CHaMo probabilistic model for hazard occurrence with convection permitting models for the short range. ESSL works on the development of AR-CHaMo while project partner GeoSphere Austria improves their C-LAEF convection permitting model ensemble.

2024 was the last full year of the project PreCAST with its end foreseen in February 2025. Thus, it was time to start evaluating what we've done so far and write down the results in the scientific publications. The year began with the application of our in-house developed statistical models, AR-CHaMo-s, which predict lightning, hail ≥ 2 cm and ≥ 5 cm, and severe wind gusts to the 51-members of the IFS run by the ECMWF twice a day. Models have been developed using data from three regions: Europe, the United States and Australia. This means the forecasts based on these models were available on the global scale. During the ESSL Testbed 2024, we evaluated these models across Europe. Feedback gained from the forecasters showed that lightning and severe wind gust models still need some refinement and the work on them continues in 2025 as a part of the collaboration with the ECMWF.

During the autumn months, we evaluated all forecasts of hail ≥ 2 cm and ≥ 5 cm both from the quantitative and qualitative perspective starting on 1 May 2024 and ending on 30 September 2024. We learnt that the improved large hail model is skillful at least 7 days in advance, and occasionally longer. The area under the ROC curve (AUC) scores reached 0.850/0.911 on day 7 and 0.781/0.861 on day 9 for hail ≥ 2 cm and ≥ 5 cm, respectively, which is an encouraging result. We have also learnt that it is slightly more difficult to predict hail ≥ 5 cm, and our model typically forecasts higher than observed probability for

this intensity. Qualitative investigation of the main failure models of the forecasts showed that most frequently, severe wind gusts occur instead of large hail or that the storms fail to initiate across the highlighted area. An article on the evaluation of these forecasts has been submitted.

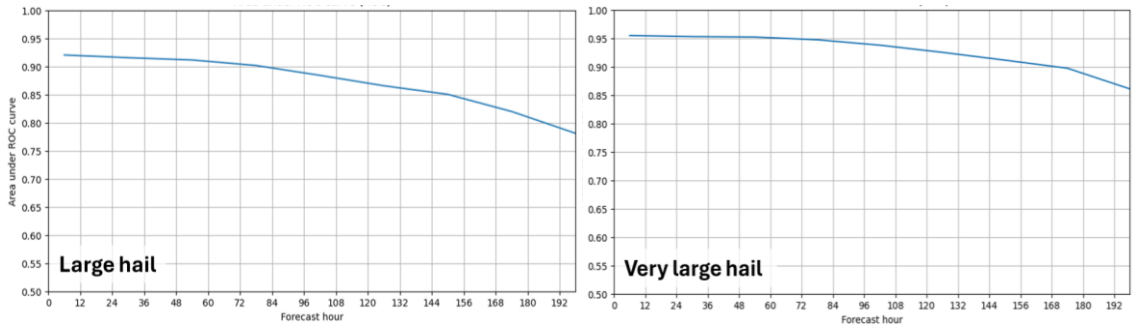


Figure 2-3. Area under ROC curve (AUC) for ≥ 2 cm and ≥ 5 cm hail forecasts as a function of increasing forecast lead time. A perfect forecast has an AUC of 1.0, and a forecast without skill, 0.5. The skill can be seen to decrease with increasing lead times up to 192 hours (9 days), first slowly, then more rapidly. Forecasts with an AUC of 0.7 or higher are generally considered useful.

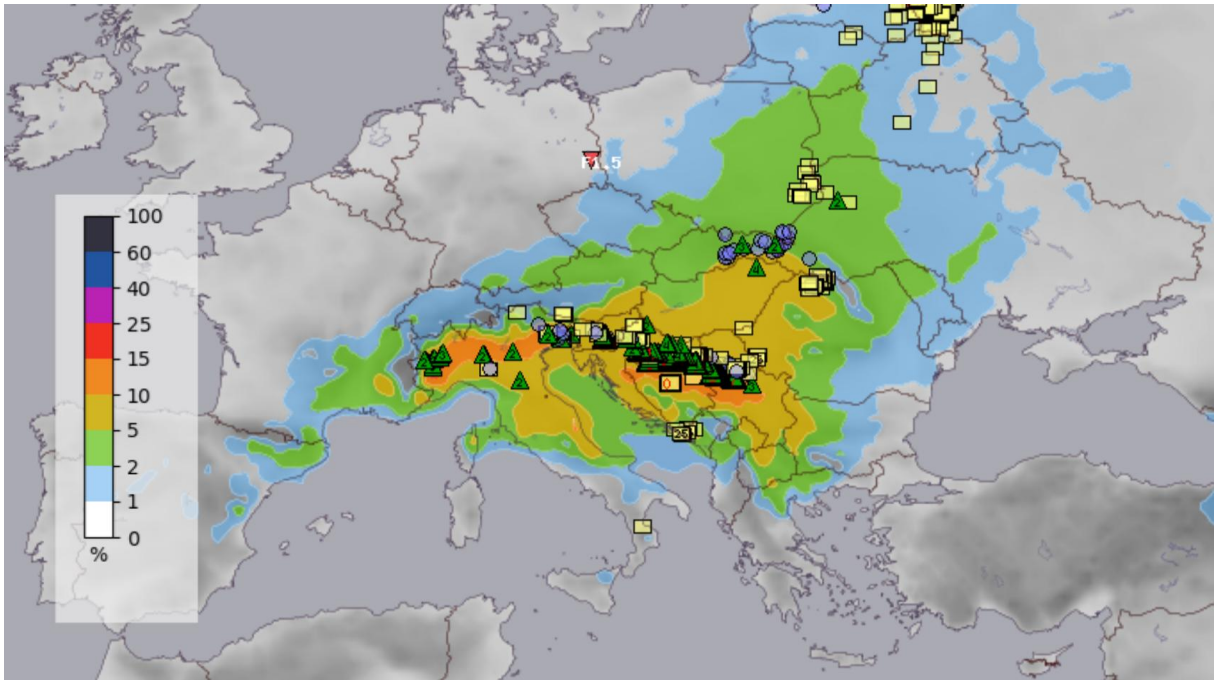


Figure 2-4. Forecast of 24-hour accumulated probability of hail ≥ 2 cm for 1 July 2024 06 UTC to 2 July 2024 06 UTC from 24 June 2024 00 UTC model run, which is a lead time of 7 days. Green triangles represent ESWD reports of hail ≥ 2 cm, yellow triangles severe wind gusts and blue circles heavy rainfall reports.

The last step of the project aimed to blend both the medium- and short-range forecasting methods to create seamless, optimized forecasts from a few hours to several days ahead of a severe weather event. For blending, we used the AR-CHaMo forecasts and the high-resolution convection-allowing ensemble C-LAEF run by the GeoSphere. This blending was

not fully completed within the year 2024, but the verification of some of past severe weather cases indicates that the two approaches effectively complement each other.

2.3 Research on major hailstorms across Europe and their hail swaths

In 2024, researcher Tomáš Púčik started a study investigating the characteristics of major hailstorms across Europe, carried out in collaboration with Mateusz Taszarek of the Adam Mickiewicz University in Poland. This study aims to improve predictions not only of the largest hail size within a storm, but also of its duration and the length of the resulting hail swath, as these are highly relevant to the amount of damage that such storms produce.

By autumn 2024, detailed data had been compiled on storms producing hail ≥ 5 cm in diameter, occurring between 2021 and 2024. For each case, we recorded maximum hail size, storm duration, hail swath length, and storm motion using the ESSL Weather Displayer and the ESWD. The analyzed storms produced hailstones ranging from 5 to 19 cm in diameter, with swath lengths spanning 10 to 686 km.

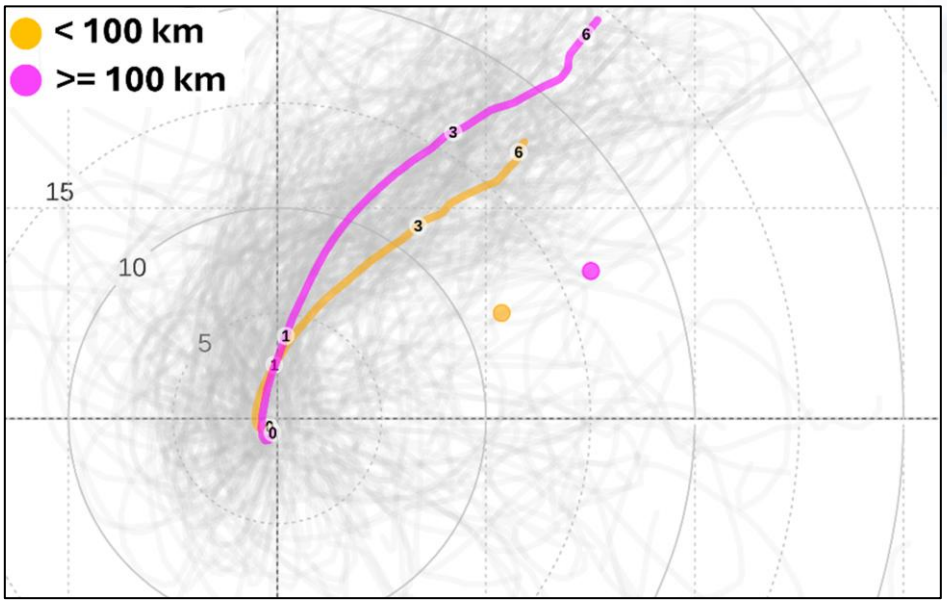


Figure 2-5. Mean wind profiles plotted as a hodograph for hailstorms producing hail swaths less than 100 km long and hail swaths reaching or exceeding 100 km. The hodograph curves trace the tip of the wind vector from 0 km (surface level) through 1, 3, and 6 km altitude. The longer distance from the origin of the "6" marker along the magenta curve shows that the wind speed was higher for storms with track lengths of 100 or more km. The dots represent the mean observed storm motion for category.

The results show that maximum hail size is influenced mainly by buoyancy, whereas hail swath length is best predicted by storm motion speed, storm-relative helicity, or storm inflow strength. Long-track storms also tended to develop in environments with lower cloud bases and generally weaker potential for strong cold pool formation.

An intermediate update about these findings was presented at the American meteorological Society's Severe Local Storms Conference in Virginia Beach, USA. The research is now being expanded to examine the spatial distribution of environmental parameters around hail swaths with the goal of improving forecasts of whether hailstorms will be short- or long-lived.

2.4 Collaborative project with ECMWF on medium-range severe weather forecasting

Funded by:	European Centre for Medium-Range Weather Forecasts (ECMWF)
Period:	since 2021
Carried out by:	ESSL Science & Training, Wiener Neustadt
ESSL employees:	Francesco Battaglioli, Pieter Groenemeijer, Tomáš Púčik

Within the framework of the collaboration between ESSL and ECMWF since 2021, 2024 saw the end of two-year project was in November 2024, and the start of a follow-up effort that began in December. The project concerns the Additive Regression Convective Hazard Models (AR-CHaMo) initially developed for detecting severe weather trends on climate timescales, which are now applied to the global 51-member ensemble predictions of the ECMWF. Trained using reanalysis data (ERA5), lightning detection data, and storm reports from Europe, the USA, and Australia, global experimental forecasts of severe weather probability with a lead time of up to 10 days. These forecasts will eventually be available on ECMWF's web presence.

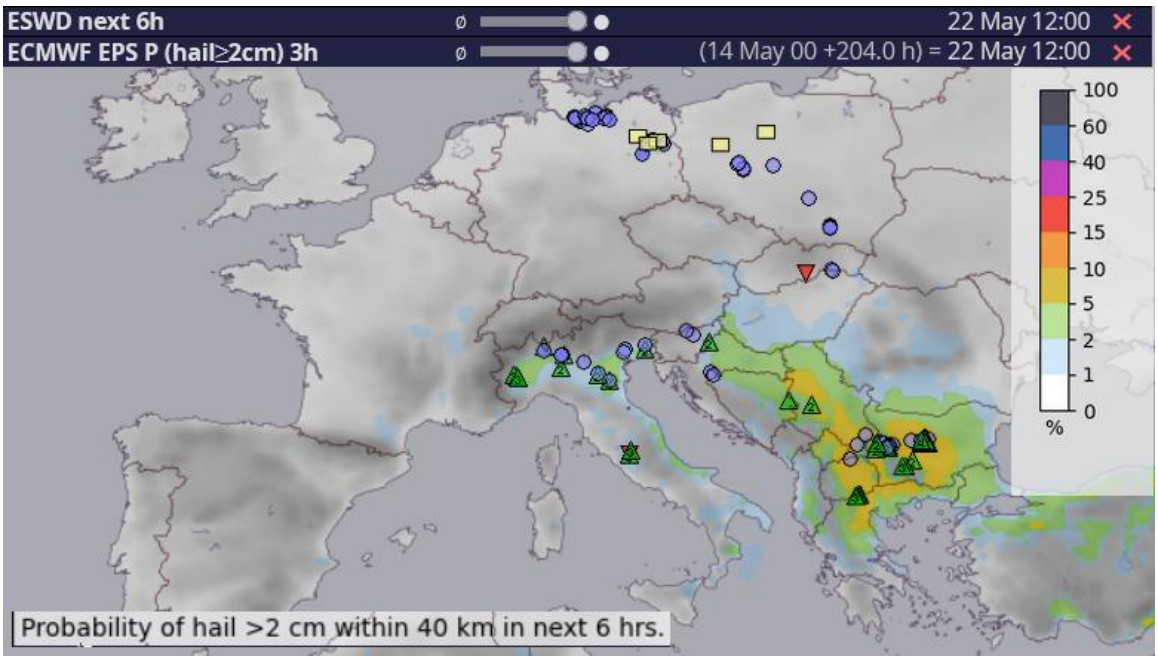


Figure 2-6. An AR-CHaMo hail forecast for +204 hours or 9 days showing the correct identification of the (shaded) area where hail reports (green triangles) ultimately occurred.

ESSL worked on a verification of hailstorms across Europe that was presented at the AMS 31st Conference on Severe Local Storms in Virginia. The results show that forecasts retain skill up to about ten days, although a diurnal cycle in scores points to known biases linked to convection. The analysis also indicates a tendency toward overprediction, which becomes more pronounced with longer lead times, but this can be corrected for.

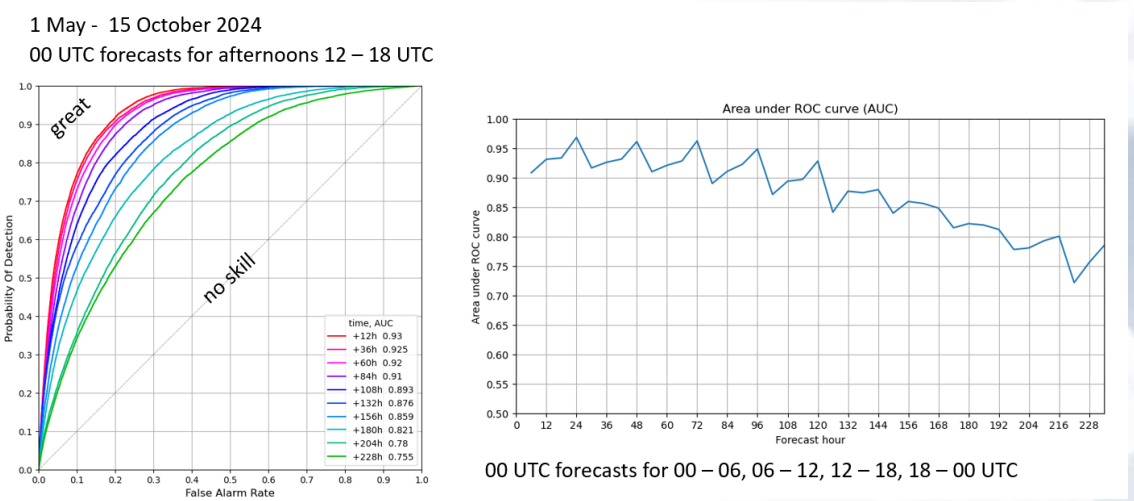


Figure 2-7. Verification scores of the AR-CHaMo hail model as a function of lead time, presented in a so-called Receiver Operator Characteristic (ROC) diagram (left) and the area under the ROC-curve as a function of lead time (right). As a very rough guideline, forecasts > 0.7 are considered useful, while 1 denotes perfect skill and 0.5 no skill.

In 2025, ESSL will focus on improving the lightning model which is part of all the other hazard models. Besides, the model for severe winds will be further improved by systematically analysing the failure modes and addressing them by a better selection of predictors.

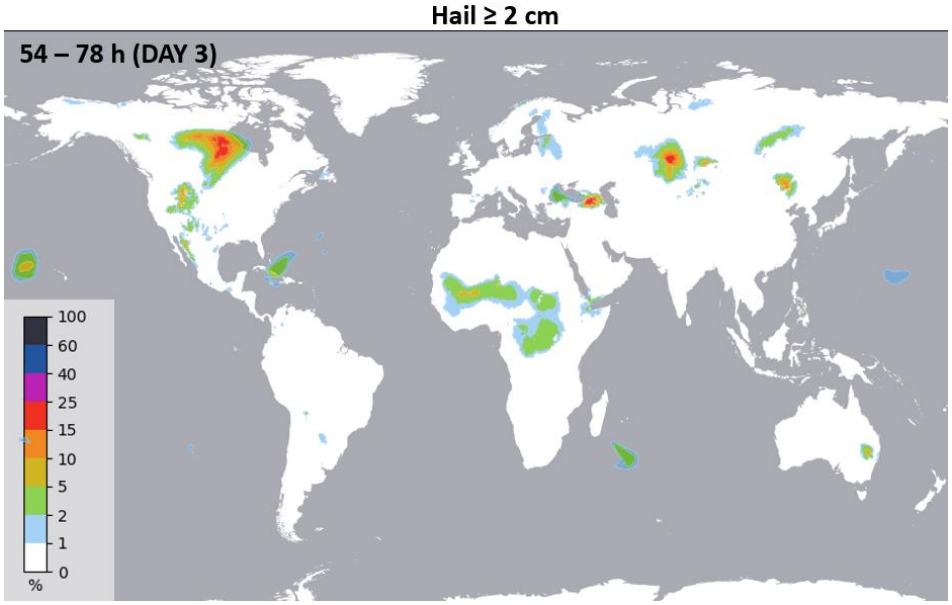


Figure 2-8. Example of a global forecast for large hail with 54 - 78 hours of lead time.

3 Testbeds in 2024

The Testbed is an ESSL initiative with two primary goals: to evaluate tools that support forecasting and warning processes, and to provide training in severe convection forecasting.

Seven Testbed weeks were organized during the 13th year of the ESSL Testbeds (Table 3-1). Five of the testbed weeks were conducted in collaboration with EUMETSAT the programme placed particular emphasis on training participants in the use of satellite-based products. During the other two weeks, the activity focused on nowcasting and warning systems as well as Numerical Weather Prediction model evaluation in cooperation with DWD and ECMWF. Four Testbed weeks took place during the summer and two weeks during the autumn to cover for the Mediterranean activity. Overall, participants ranked the Testbed with an average grade of 9.45 out of 10 points.

Table 3-1. Testbed weeks in 2024.

13 – 17 May 2024	ESSL-EUMETSAT Forecaster Testbed **at the ESSL Research and Training Centre in Wiener Neustadt, Austria**
3 – 7 June 2024	ESSL-EUMETSAT Forecaster Testbed in Darmstadt, Germany, at the EUMETSAT headquarters
17 – 21 June 2024	ESSL Testbed – regular week at the ESSL Research and Training Centre in Wiener Neustadt, Austria
24 – 28 June 2024	ESSL Testbed – expert week at the ESSL Research and Training Centre in Wiener Neustadt, Austria
1 – 5 July 2024	ESSL-EUMETSAT Forecaster Testbed at the ESSL Research and Training Centre in Wiener Neustadt, Austria
16 – 20 September 2024	ESSL-EUMETSAT Forecaster Testbed at the ESSL Research and Training Centre in Wiener Neustadt, Austria
7 – 11 October 2024	ESSL-EUMETSAT Forecaster Testbed at the ESSL Research and Training Centre in Wiener Neustadt, Austria

Figure 3-1. Happy participants (and instructors in the back) during the EUMETSAT-ESSL Testbed in October 2024.

3.1 The ESSL Testbeds

During both the regular and expert Testbed weeks, a total of 25 participants from 11 different countries took part: Austria, Croatia, Czechia, Germany, Hungary, the Netherlands, Poland, Slovakia, Spain, Switzerland, and the United Kingdom. While many were forecasters, some participants were developers of the products evaluated at the Testbed.

The main difference between the expert week and the regular week lies in the participants and the programme structure. The expert week often includes many invited returning visitors to ESSL. During this week, the introductory session on severe storm forecasting is omitted, the overview of the ESSL Weather Data Displayer is shortened, and more time is allocated for experts to lead discussions on severe weather topics. This setting also allows for the collection of more detailed product feedback. In contrast, the regular week is better suited for first-time participants, as it provides a step-by-step introduction to the forecasting process, starting from the fundamentals and progressing at a slower pace.

In 2024, the featured products were evaluated partly through direct discussions between participants and developers, and partly via feedback documented in questionnaires. Typically, participants worked in groups of two to four during dedicated online afternoon sessions, testing the products' ability to support accurate and useful forecasts and warnings.

The Testbed 2024 featured the following products:

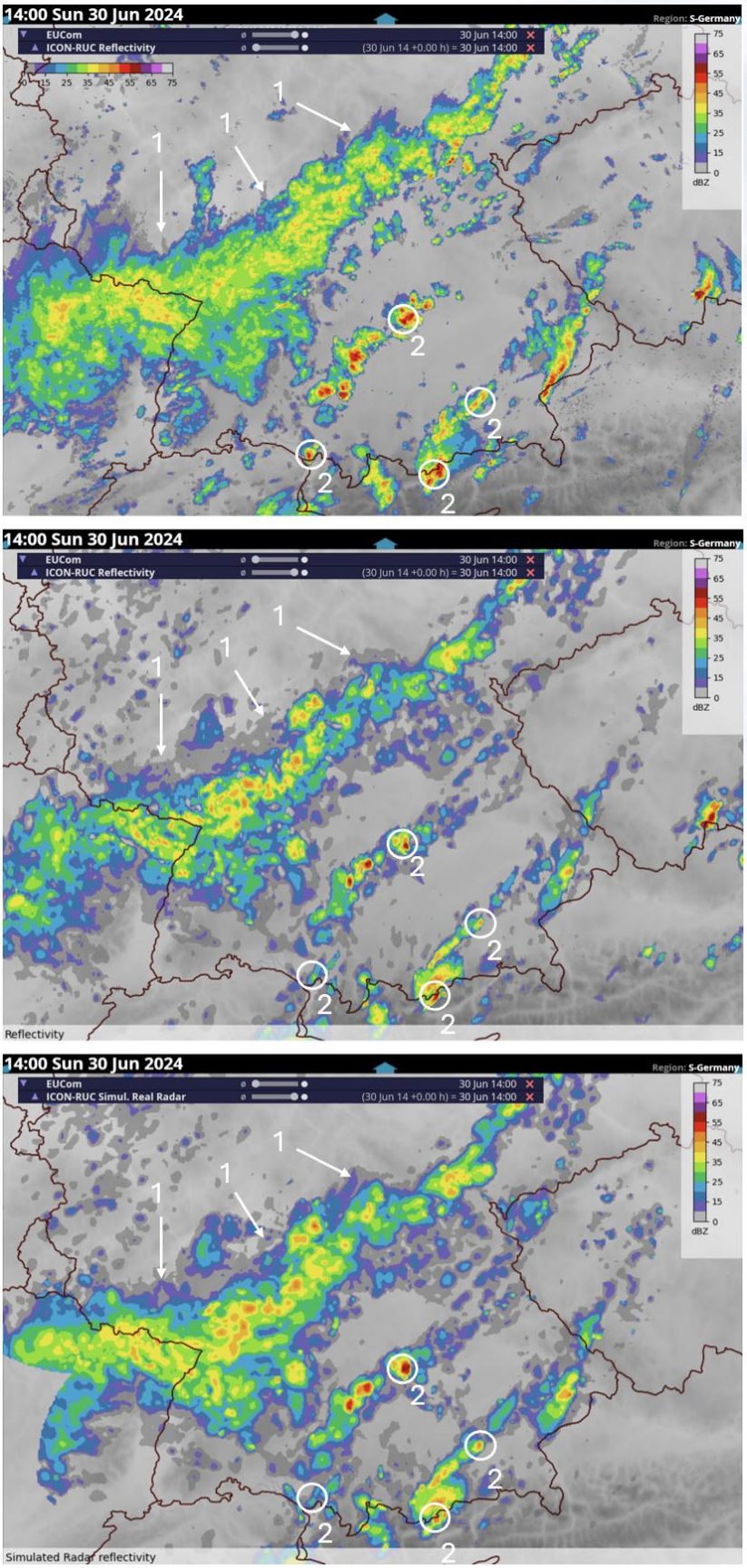
ICON-RUC-EPS (DWD)

Description:
ICON-RUC-EPS is a high-resolution, convection-allowing ensemble model developed within DWD's SINFONY project for seamless nowcasting up to 12 hours ahead. It runs every hour with rapid computation, enabling early access to forecasts. The system aims to provide accurate precipitation and convective storm forecasts when observation-based nowcasting loses accuracy. The forecasts of ICON-RUC and ICON-RUC EPS were evaluated with a focus on the risk of heavy precipitation events and the occurrence of large hail. Unique features of ICON-RUC-EPS are an aggressive hourly assimilation of radar and satellite observations, advanced microphysics with a two-moment scheme, a separate hail hydrometeor class, and Mie-scattering-based radar reflectivity, and a very high-frequency output, including 5-minute simulated radar reflectivity fields.

The ESSL Testbed 2024 evaluation found that ICON-RUC was well-received by forecasters, performing slightly better than ICON-D2 in areal coverage, local maxima, and total precipitation. While it produced reasonable precipitation totals, it tended to underestimate the affected area. Large-hail forecasts from ICON-RUC and its ensemble were rated highly useful. Simulated radar composites looked more realistic for stratiform precipitation, but the convective cells appeared a smoother than actual radar reflectivity.

KONRAD3D-SINFONY (DWD)

KONRAD3D-SINFONY is an object-based forecasting system that combines nowcasting (best for the first ~2 hours) with numerical weather prediction (better afterward) to provide seamless convective cell forecasts. Using 5-minute KONRAD3D radar cell data, it generates an observation ensemble, estimates maximum severity and lifetime, and predicts intensity changes with associated uncertainties. Initially tested in 2023, it was found to weaken well-organized storms too quickly and produce jumpy, overlapping cells in the pseudo-member product.



30 June 2024 14 UTC radar reflectivity composite (top), ICON-RUC standard grid point reflectivity output (centre), and ICON-RUC simulated composite product (bottom). Areas of interest further analysed in the Testbed report are indicated by numbered arrows and circles.

The product could be displayed as pseudo-members or as exceedance probabilities of cell severity. The pseudo-member visualization was updated so that member colours now reflect both intensity and probability, convex hulls were enlarged to reduce overlap, and member tracks were removed. The slow reduction of storm intensity was improved compared to 2023, but it was not fully resolved. Probabilistic outputs were preferred over pseudo-members, which still showed volatility in polygon placement, size, and intensity when many cells were close together. The system also tended to underestimate intensity in low CAPE and high shear environments. Overall, clear improvements of KONRAD3D-SINFONY were observed compared to the previous Testbed year.

Figure 3-2. An example of the visualisation of the pseudo-member product. Colour represents the intensity and the probability of the pseudo-members. Pseudo-members with black outlines represent the cells that have been detected by the KONRAD3D-EPS. Convex hulls without a pseudo-member inside represent the clusters of cells only based on NWP.

Radar Maxima Product (ICON-D2-EPS-MOS; DWD)

Appearing for the second time at the ESSL Testbed, the **Radar Maxima (ICON-D2-EPS-MOS)** product aims to give a clear overview of current precipitation and an extrapolation using statistical post-processing of ICON-D2-EPS forecasts. It summarizes these ensemble forecasts to highlight the most probable locations and intensities of precipitation, using the 95% quantile of precipitation within 40 km of each grid point. Its thresholds range from 1 mm/h to 40 mm/h, and the probabilities are statistically calibrated via a tailored MOS approach with logistic regression.

The 2024 Testbed evaluation showed that an issue of artifacts over complex terrain that occurred in 2023 had been resolved. It received mixed feedback as an operational product for use by forecasters. The feedback was critical about the amount of added value over other uncalibrated products. An issue with the EPS-MOS calibration was assumed to be the cause of an excessive reduction of the probabilities of heavy rainfall compared to uncalibrated probabilities.

INTENSE (DWD)

INTENSE is an ensemble-based nowcasting algorithm that uses radar composites to forecast precipitation. By generating multiple equally likely scenarios instead of a single “best guess,” it quantifies forecast uncertainty and supports scenario-based assessments, making it especially valuable for hydrological applications like flash flood forecasting and improving warning lead times.

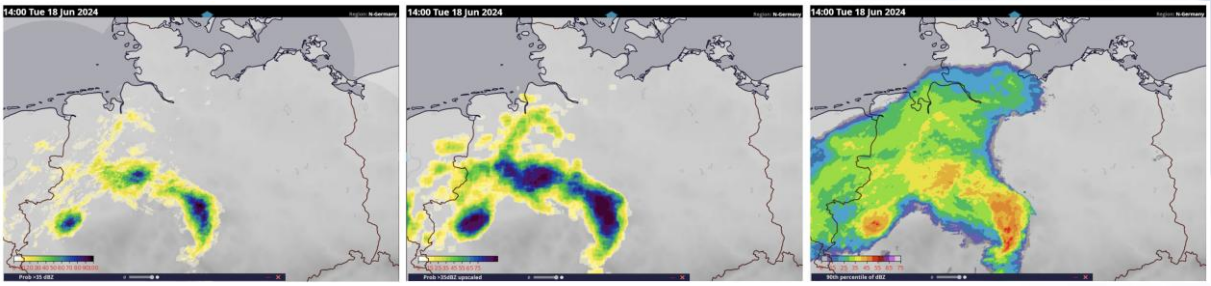


Figure 3-3. INTENSE Exceedance probability (left) and upscaled exceedance probability (centre) forecast for +60 minutes starting at 18 June 2024 at 1300 UTC for the threshold 35 dBZ. 90th percentile of dBZ for the same forecast (right).

AR-CHaMo (ESSL)

AR-CHaMo (Additive Regressive Convective Hazard Model) calculates the probability of (severe) thunderstorm hazards based on the larger-scale, pre-convective environments. Each hazard uses a different set of predictors. In the previous years,, the predictions for probabilities of lightning, (very) large hail were based on the deterministic ECMWF, ICON-EU, and GFS forecasts. In 2024, the new addition was the application of AR-CHaMo applied to 50-member ECMWF ensemble. A new version of ARCHaMO was developed with training regions across United States and Europe. Additionally, a model for severe wind gust prediction was developed. The evaluation was done as a part of the PreCAST project. Participants found the forecasts helpful even up to 7 days ahead of the event, especially for the events featuring more widespread severe weather. Severe wind gust model was found to underestimate the risk in many cases, while lightning was overforecast in some types of environments. Work on both models is is ongoing in 2025.

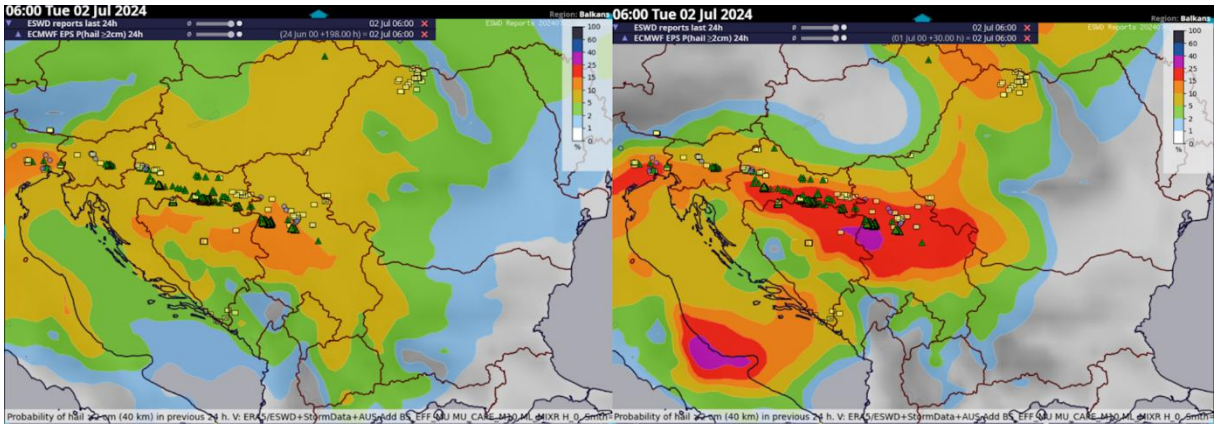


Figure 3-4. 24-hour accumulated probability of large hail from 1 July 2024 06 UTC till 2 July 2024 06 UTC using the forecast from 24 June 2024 00 UTC (left) and 1 July 2024 00 UTC (right).

C-LAEF Ensemble Forecasts

C-LAEF is the operational convection permitting ensemble system run by GeoSphere, which is based on the model AROME and is running operationally on the horizontal resolution of 2.5 km since 2019. In 2024, we evaluated a new version of the C-LAEF that is run at 1 km resolution and uses additional observations in data assimilation, plus a new perturbation scheme for creating the ensemble members. The evaluation was done as a part of the PreCAST project. All Testbed groups that evaluated the new model version considered it to be an improvement to the operational one with storms looking more realistic. However, it was also noted that the storms are too small compared to the radar observations and the model still transitions into the linear convective mode too fast.

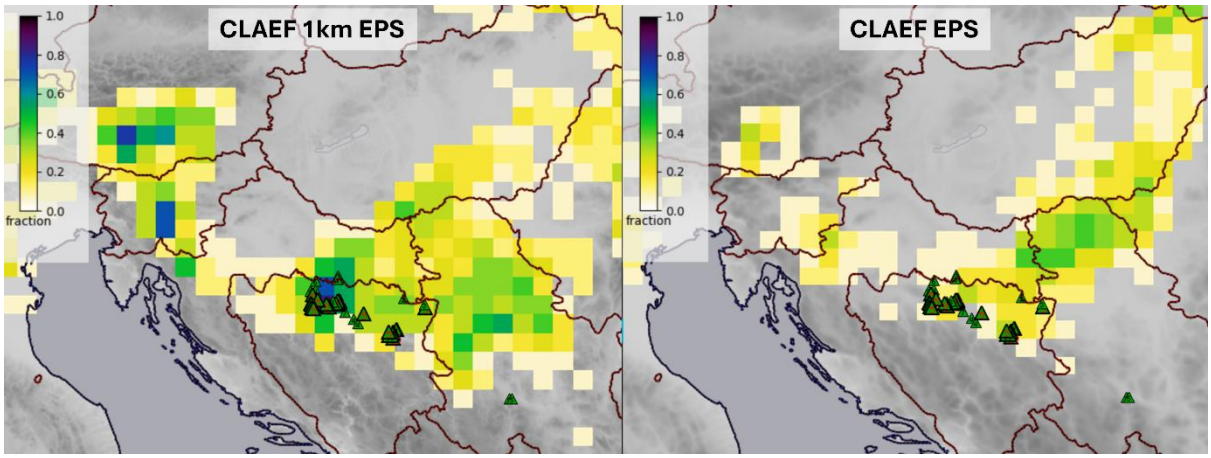


Figure 3-5. An upscaled probability of reflectivity exceeding 40 dBZ on 22 June 2024 at 17 UTC in C-LAEF 1 km and the operational ensemble. Note much higher probability in the 1 km version of the ensemble. At that time, numerous supercells with very large hail were ongoing across Bosnia.

3.2 EUMETSAT ESSL Forecaster Testbeds in 2024

At EUM Forecaster Testbeds, proxy or simulated products, or (pre-)operational data are used in a simulated operational environment, both to train forecasters and expose them to the data provided by the new MTG sensors and to collect feedback to identify the most useful products derived from the LI, FCI and IRS (proxy/simulated/per-operational) data for real-time applications. Forecaster Testbeds have a duration of 4½ days and involve working with a wide range of products. Typically, 15 participants take part in each of the Forecaster Testbed weeks.

Feedback on products implemented during the testbed are collected systematically and made available to EUMETSAT in synthesized form to foster further development of the products. Pieter Groenemeijer continued to lead the development of the ESSL Weather Data Displayer that was used for the ESSL-EUMETSAT Forecaster Testbeds. Tomas Púčik was the main trainer supported by Christoph Gatzen and other ESSL staff.

Figure 3-6. Group photo of the EUMETSAT-ESSL Forecaster Testbed held, as an exception, at the EUMETSAT headquarters in Darmstadt, Germany, in June 2024.

Testbed participants were contacted in early February 2025, which was 4 to 9 months after their participation, to provide feedback on the usefulness and sustainability. Until 20 February 2025, we were able to collect quantitative feedback from 50 (out of 72) participants via an online survey, i.e. a pleasing return rate of 69 %. The quantitative feedback confirms the positive and lasting impact of the offered testbeds: 82 % of the respondents found their testbed participation “Very or extremely useful”, 78 % answered that the storm forecasting, as it is done in the EUMETSAT ESSL Forecaster Testbeds, changed their way to do this in the everyday work. Out of those exposed to a critical forecast situation, nearly all respondents confirmed that the knowledge gained at the testbed helped in the real forecast situation of the past months. To the question whether they would suggest colleagues to come to the testbed and learn more about the newly

available satellite products, 3 % answered “Somewhat useful”, 17 % of the 50 respondents answered “It is quite useful”, while 80 % answered “Yes, I am fully convinced this would be very beneficial”.

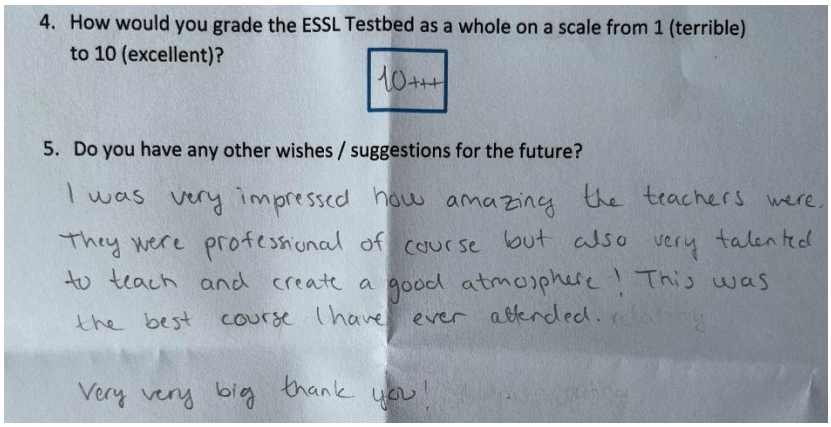


Figure 3-7. Feedback collected directly after the testbed.

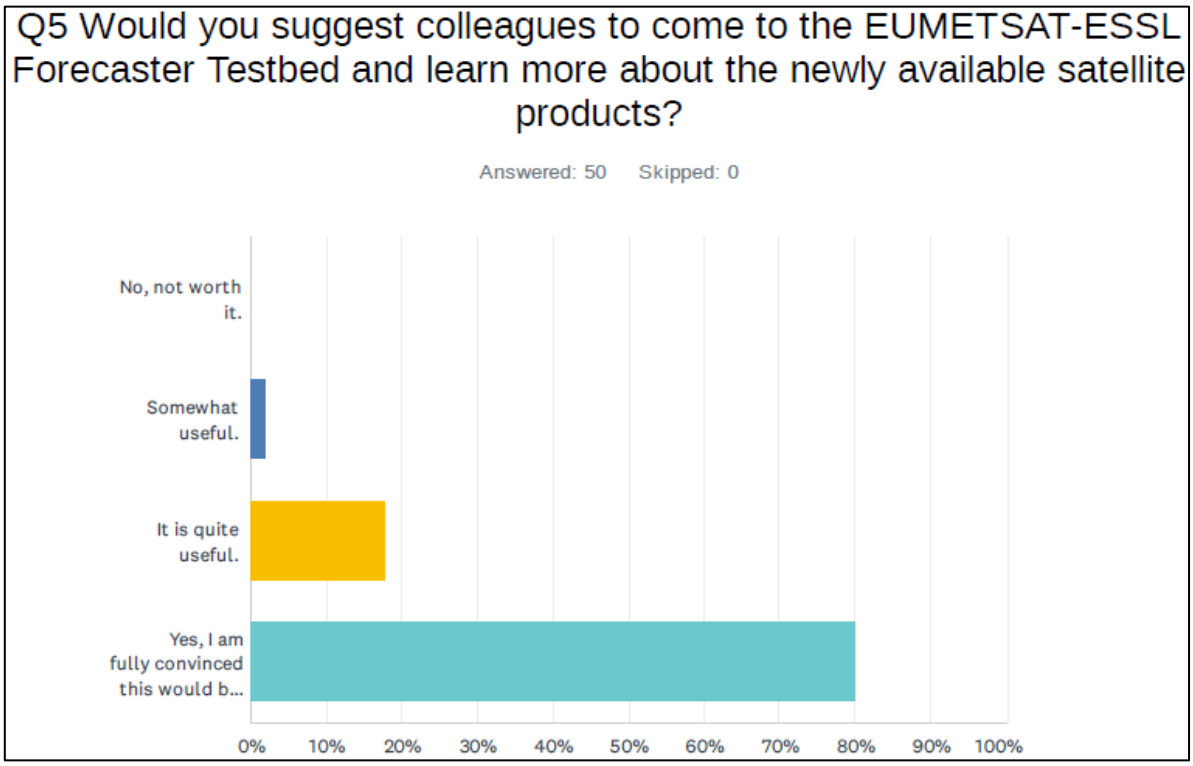


Figure 3-8. Feedback collected 4 to 9 months after testbed participation.

4 Workshops, courses and other activities

In 2024, ESSL organized a range of workshops and courses, thirteen in total, on a variety of topics.

4.1 Courses for forecasters

ESSL organized seven training courses for forecasters in 2024. Two courses were covering new topics and will be covered separately. Three standard courses were organized at the ESSL Research & Training premises in Wiener Neustadt. The first course, *Forecasting Severe convective storms*, took place between 15 and 19 April, followed shortly by the *Aviation forecasting of severe convective storms* between 22 and 26 April. In the autumn, another edition of *Aviation forecasting of severe convective storms* was organized between 25 and 29 November. All courses were split into a theoretical part with lectures in the morning and a practical part with case study exercises in the afternoon. The practical part was done in an operational with participants asked to issue a forecast or nowcast, applying the concepts that were studied in the morning.

Figure 4-1. A group photo taken in the garden from the Forecasting Severe convective storms course in April.

Two other courses were organized in 2024 outside of the ESSL premises. The first one was held in Torino, Italy in early May, involving forecasters from ARPA Piemonte and ARPA Liguria. Torino greeted us with a rainy and cold weather. Course on the forecasting of storms was given with regards to the very rich topography of the regions, from which the forecasters came. One of the course highlights was of course pasta, pizza, morning breakfast in the small coffee place and daily tiramisu (at least for the trainers that attended!). Another external course was organized in November in Sofia, Bulgaria for

BULATSA forecasters. The main topic of the course was how to best use the new MTG data in the forecasting and nowcasting severe storms. Course combined basic theory behind the (severe) convective storms with how each of the forecasting components can be addressed by using the satellite data. After the lectures we trained nowcasting convective initiation with the new RGBs and the severity of severe storms using the satellite and Lightning Imager data.

Figure 4-2. Group photo at the premises of BULATSA.

4.2 Radar meteorology and storm microphysics course

In December 2024, ESSL organised a course on the radar meteorology and storm microphysics, a new topic that we had not offered yet. The idea for this course had been discussed for a long time before, but finally in 2024, the time was right to do it. One of the main reasons for giving the course a go was the development of the in-house Radar Displayer at the ESSL that would allow us to work with practical case studies.

For the Radar Displayer, ESSL contracted developer Bram van 't Veen, who had earlier developed NL-Radar a tool written in Python to displayer single site radar data, including the various dual-pol and Doppler fields that more and more European weather services make available as open data. The result of Bram's work was a highly versatile web-based tool to inspect data from across Europe.

The radar course itself was delivered by Prof. Matthew R. Kumjian from the Pennsylvania State University. Matt is a leading expert on the topic of storm microphysics and radar meteorology and has a wealth of knowledge and experience that the course participants including the ESSL team could tap into.

Matt Kumjian gave lectures in the morning, which were combined with the afternoon exercises using the newly developed Radar Displayer. Each morning brought different

topics. The course started with the most basic radar parameters on Monday and then continued discussing microphysics and radar nowcasting possibilities of different severe weather phenomena in the subsequent days.

From Tuesday to Friday, the detection of hail, heavy rainfall, tornadoes, and severe wind gusts were covered. In the afternoon, participants would investigate in detail the radar appearance of storms for some of the famous cases of severe storms from the past.

This included 24 June 2021 supercell that produced giant hail and an IF4 tornado in southern Czechia, devastating and record-breaking hailstorms of 24 July 2023 in Italy or a derecho that struck Corsica on 18 August 2022. ESSL plans to organize more such courses in the future to improve the knowledge on the radar nowcasting of severe storms across Europe.

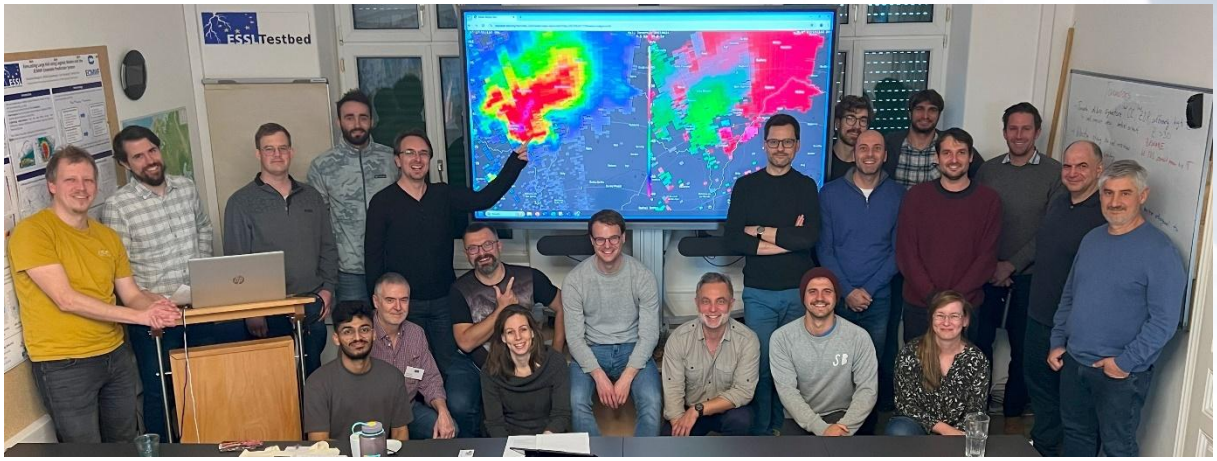


Figure 4-3. Group photo from the radar meteorology course. Can you recognize the storm that one of the participants is pointing at?

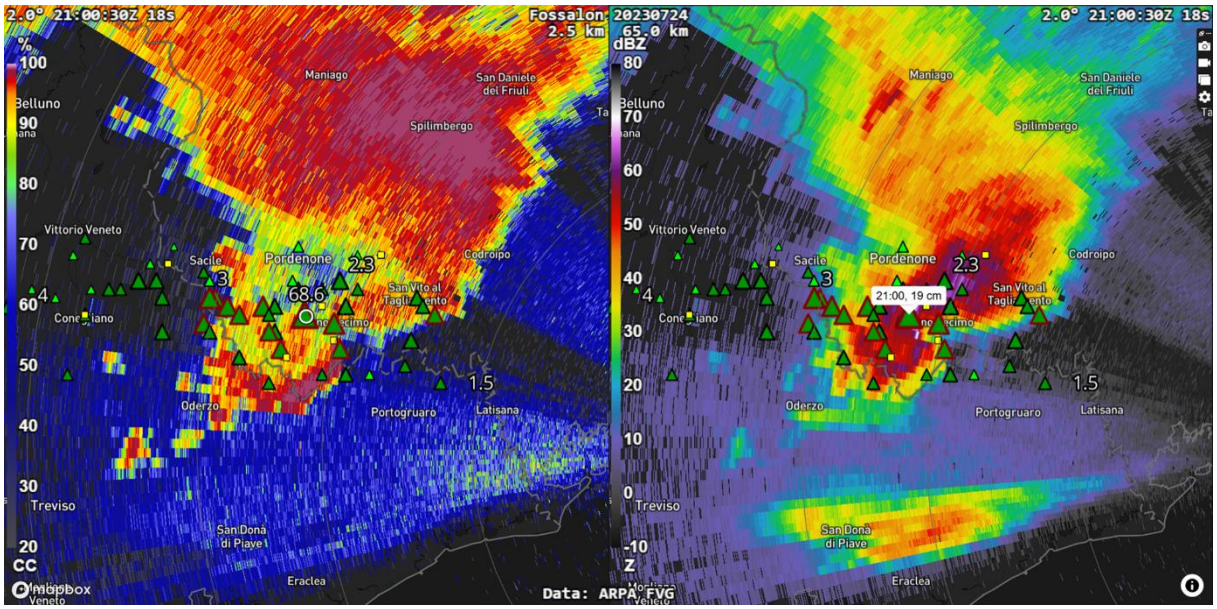


Figure 4-4. Example radar image from the radar displayer used at the course, showing correlation coefficient and reflectivity at the moment at which the 24 July 2023 hailstorm produced record-breaking 19 cm hailstone. Data courtesy of ARPA Friuli Venezia Giulia.

4.3 EUMETSAT ESSL Expert Workshops in 2024

At EUMETSAT ESSL Expert Workshops, participants investigate new MTG satellite products by investigating cases and providing feedback in a workshop format. Simulated data or proxy data from operational precursor missions are used as appropriate. Until mid-2024, this was especially the case for LI data. For IRS data, the use of proxy and simulated data will prevail into 2025 and possibly 2026. Product developers from EUMETSAT are involved in this phase. The main goal of Expert Workshops is to collect feedback to products. This contrasts with the Forecaster Testbeds that have a strong focus on training too.

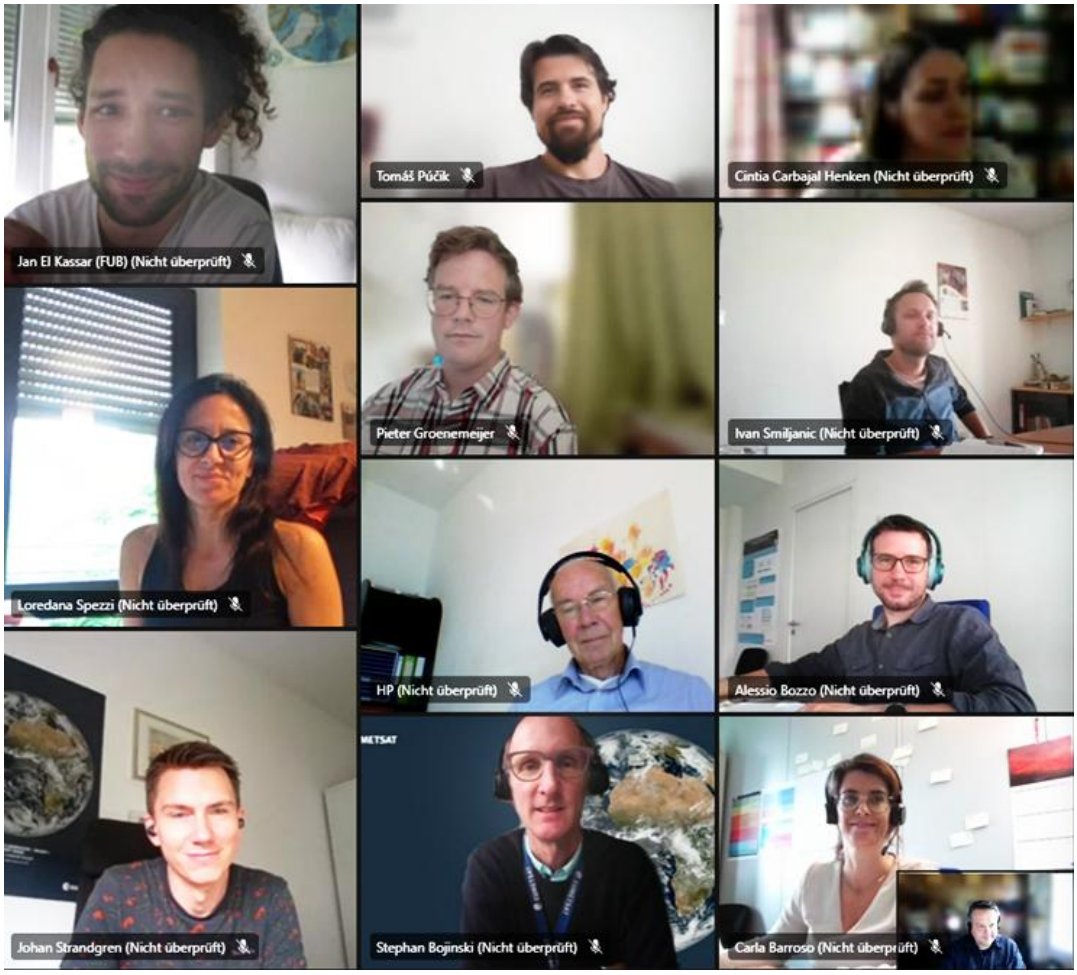


Figure 4-5. Group photo of the online event 22-23 May 2024.

Evaluations include various visualizations of FCI proxy data, i.e. RGBs, to detect convective storm features (overshooting tops, cloud phase, above-anvil cirrus plumes, initiating convection) and various stages of the storm lifecycle, and NWCSAF products based on (pre-) operational data. Other examples are the evaluation of various ways to visualize Lightning Imager data. Furthermore, the vertical profiles of temperature and humidity that characterize the pre-convective environment as retrieved from (simulated) IRS data, are subject of multiple testbeds. This includes comparisons with NWP data and the display of convective indices derived from the data. Each Expert Workshop deals with a small number of products.

The following Expert Workshops took place in 2024:

14 – 16 February 2024	Expert Workshop on early MTG-LI L2 test data cases (train the trainers) in Darmstadt at the EUMETSAT headquarters and online
22 – 23 May 2024	Expert Workshop on experimental FCI moisture imagery – online format
5 – 7 November 2024	Expert Workshop on MTG-LI (analysis of cases, validation data and visualizations, train the trainers) – online format
17 – 18 December 2024	Expert Workshop on MTG FCI L2 Geophysical Products (updates from developers, train the trainers, testbed preparatory) – online format

Results from the Expert Workshops were presented on several occasions like at the EUMETSAT ESSL Annual Forecaster Event held 12 March 2024 with more than 200 online participants. To date, EUMETSAT has not published reports from the Expert Workshops since they are considered work in progress, but EUMETSAT offers the workshop presentations on their public sftp site at the following URL:

https://sftp.eumetsat.int/public/folder/uscvknvooksycdgpmimjnq/User-Materials/MTGUP/

4.4 Online Course: Towards better written and oral weather communication

ESSL offered a new type of course to ARPA Liguria and ARPA Piemonte on Communication of Meteorological Content, which took place in an online form from 9 to 13 December 2024. Nineteen employees of these Italian regional weather agencies, many of them forecasters, attended. The course was given by Alois Holzer, who has worked as a media meteorologist at the Austrian Broadcasting Corporation ORF for more than 25 years and has chaired the Media Awards Committee of the European Meteorological Society (EMS).

Figure 4-6. Teacher (left top) and participants of the course.

The ARPAs indicated that two forms of communication were of most importance to them: warning messages and internal briefings. The starting point of the course was the identification of factors for message clarity, creation of mental images, and taking the perspective of the receivers of the message. Supportive language aspects were taught, which included a dive into neuroscience. Another covered topic was the discussion of different flavours of news posts and the awareness of what message this sends out. These flavours can range from "own PR" to "unscientific entertainment" with potential warning messages mixed into such a news stream.

Figure 4-7. Supportive tools in the communication toolbox.

As trust in the source of information is a crucial factor for believing into a warning message and finally acting, communication policy should carefully consider such flavours. A more technical aspect of communication is the structure of written messages.

Specifics about communication in life-threatening situations, including behavioural human aspects, were discussed as well. A model distinguishing 3 behavioural modes of weather forecast communication were distilled by Holzer, i.e., for "Business as usual", "Take care", and "Alert" respectively. Thoughts about the communication attitude in catastrophic situations completed the course curriculum.

4.5 Intercontinental cooperation

South America

In 2024, ESSL and researchers from South America started a collaboration, specifically with the Universidade Federal de Santa Maria in Brazil and the University of Buenos Aires in Argentina. The main contacts for this partnership are Prof. Ernani de Lima Nascimento

and Prof. Paola Salio, who are working to establish research infrastructure for studying severe storms in the region. The collaboration includes online meetings addressing research, practical and administrative matters, with a particular focus on sharing expertise in severe weather data collection and strengthening international cooperation. A key milestone in South America was the creation of the South American SAMHI severe weather database (Salio et al., 2024: https://doi.org/10.1175/BAMS-D-23-0063.1), data that is shared with ESSL as part of the collaboration. The partnership also covers the participation of South American researchers in ESSL events as a form of capacity building. In 2024, a first researcher took part in the ESSL Testbed.

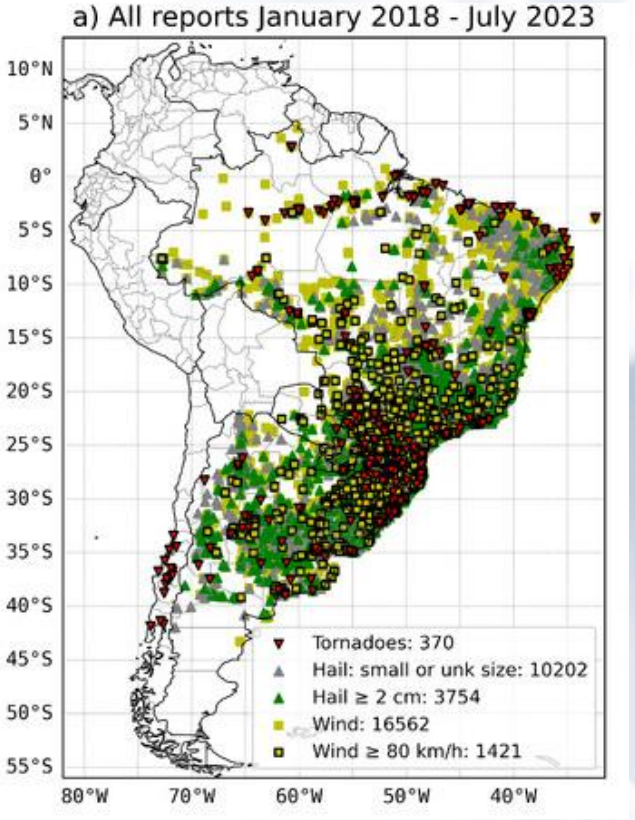


Figure 4-8. Severe weather reports collected in the SAMHI database. From Salio et al. (2024).

Canada: the Canadian Severe Storms Laboratory

In November 2024, ESSL Director Pieter Groenemeijer was invited to the founding event of the Canadian Severe Storms Laboratory or CSSL. CSSL is located at Western University in London, Ontario and was realized thanks to a CAD 20 Million investment from ImpactWX, a private foundation. Building on the pre-existing "Northern Tornadoes Project" and "Northern Hail Project," CSSL expands efforts to detect, document, and understand tornadoes, hail, downbursts, derechos, and flash floods across the country. It also leads the Northern Mesonet Project, integrating weather station data into a "network of networks" for real-time storm tracking.

Based at Western's engineering faculty, with a new facility planned for 2026, CSSL also trains students and engages the public with the aim of strengthening Canada's resilience to severe weather. Given the strong correspondence between CSSL and ESSL's missions, both strive for a mutually beneficial collaboration especially where skills and experience can complement each other, for example regarding the engineering background of CSSL and the forecaster training and climate research components of ESSL.

5 TIM Field Campaign preparations

Following preparatory contacts, talks and paperwork in 2023, ESSL aimed to bring the preparations for the TIM Field Campaign (Thunderstorm Intensification from Mountains to plains) to the next level in 2024. Letters of intent were collected and collaboration agreements closed. At ESSL, Alois M. Holzer and Stefan Eisenbach served as the main contact points for TIM related matters. In addition, Jannick Fischer (mainly affiliated with KIT in Germany), accepted the challenge to lead-author the TIM white paper. About a dozen of white paper core group meetings were held. On 26 March 2024, the first TIM Online Networking Meeting took place with all TIM members and partners being invited. Further such meetings were held on 18 June and 15 October 2024, all attracting a large audience.

Until the end of 2024, 24 partner institutions already formally joined the campaign. Next to the forming of the scientific consortium, industry partners were contacted. High interest was noted from the aviation industry specifically. An inventory of data provision offers was set up and topical working groups were formed during the year 2024. The main challenge remains the acquisition of the budget for the core activities of the campaign, which will remain in the focus of ESSL activities for TIM in the following year. ESSL is highly committed to bring the TIM campaign to life, as the strong need is proven by the scientific TIM white paper. The NHESS paper is available here:

> Fischer, Jannick, et al.: **Invited perspectives: Thunderstorm intensification from mountains to plains.** *Natural Hazards and Earth System Sciences*, **25**, 2629-2656, https://doi.org/10.5194/nhess-25-2629-2025

Figure 5-1.TIM member institutions as of December 2024.

6 Publications and Communications

In 2024, ESSL employees contributed to 6 peer-reviewed publications, gave 26 oral presentations and several dozen interviews to written and broadcast media, presented 9 posters, and wrote 6 reports.

6.1 Peer-reviewed publications

Authors employed or contracted by ESSL, or having an official function at ESSL are underlined.

Appearing in 2024:

- Ghasemifard, H., P. Groenemeijer, F. Battaglioli, and T. Púčik, 2024: **Do changing circulation types raise the frequency of summertime thunderstorms and large hail in Europe?** *Environ. Res.: Climate* **3,** 015008**,** https://doi.org/10.1088/2752-5295/ad22ec.

- Pilorz, W., Laskowski, I., Surowiecki, A., Taszarek, M., Łupikasza, E. (2024). **Comparing ERA5 convective environments associated with hailstorms in Poland between 1948–1955 and 2015–2022**. *Atmos. Res.,* 301, 107286. https://doi.org/10.1016/j.atmosres.2024.107286

- Púčik, T., D. Rýva, M. Staněk, M. Šinger, P. Groenemeijer, G. Pistotnik, R. Kaltenberger, M. Zich, J. Koláček, and A.M. Holzer, 2024: **The Violent Tornado on 24 June 2021 in Czechia: Damage Survey, Societal Impacts, and Lessons Learned**. *Wea. Climate Soc.*, **16**, 411–429, https://doi.org/10.1175/WCAS-D-23-0080.1.

  Surowiecki, A., N. Pilguj, M. Taszarek, K. Piasecki, T. Púčik, and H. E. Brooks, 2024: **Quasi-Linear Convective Systems and Derechos across Europe: Climatology, Accompanying Hazards, and Societal Impacts**. *Bull. Amer. Meteor. Soc.*, **105**, E1619–E1643. https://doi.org/10.1175/BAMS-D-23-0257.1.

Studies submitted in 2024, accepted in 2025:

Fischer, Jannick, Pieter Groenemeijer, Alois Holzer, Monika Feldmann, Katharina Schröer, Francesco Battaglioli, Lisa Schielicke, Tomáš Púčik, Bogdan Antonescu, Christoph Gatzen, and TIM Partners:
Invited perspectives: Thunderstorm intensification from mountains to plains. *Natural Hazards and Earth System Sciences*, **25**, 2629-2656, https://doi.org/10.5194/nhess-25-2629-2025

- Khodayar, S., J. Kushta, J.L. Catto, S. Dafis, S. Davolio, C. Ferrarin, E Flaounas, P. Groenemeijer, M. Hatzaki, A. Hochman, V. Kotroni, J. Landa, I. Lang-Ritter, G. Lazoglou, M. L. R. Liberato, M. M. Miglietta, K. Papagiannaki, P. Patlakas, R. Stojanov, G. Zittis, 2025: **Mediterranean cyclones in a changing climate: a review on their socio-economic impacts**, *Reviews of Geophysics*, **63**. https://doi.org/10.1029/2024RG000853.
- Kühne, Thilo, Bogdan Antonescu, Pieter Groenemeijer, and Tomáš Púčik, 2025: **Lightning Fatalities in Europe (2001–2020) Lightning Fatalities in Europe (2001–2020)**, *Wea. Climate Soc.*, **17**, 205–215. https://doi.org/10.1175/WCAS-D-24-0038.1
- Portal, Alice, Andrea Angelidou, Raphael Rousseau-Rizzi, Shira Raveh-Rubin, Yonatan Givon, Jennifer L. Catto, Francesco Battaglioli, Mateusz Taszarek, Emmanouil Flaounas, Olivia Martius, 2025: **Convective Environments Within Mediterranean Cyclones**, *Atmospheric Science Letters*, **26**. https://doi.org/10.1002/asl.1302

Links to all peer-reviewed ESSL publications can be found on the ESSL website at https://www.essl.org/cms/publications/scientific-publications/.

6.2 Scientific and Invited Presentations

Oral presentations

* Presentations at ESSL-organized courses are not listed

1. Groenemeijer, P., Alois Holzer, Tomáš Púčik, Francesco Battaglioli, Christoph Gatzen, 2024: **New nowcasting opportunities from MTG and lessons from ESSL Testbed evaluations,** Workshop on Integrated Nowcasting tools, EUMETSAT, Darmstadt 22 January 2024
2. Battaglioli, F., P. Groenemeijer, M. Taszarek, T. Púčik, A. Rädler, 2024: **Very Large Hail in a Changing Climate: Global Climatology, Trends and Losses**. 4th European Hail Workshop, Karlsruhe, Germany, 5-7 March 2024.
3. Púčik, T., Taszarek, M., Groenemeijer, P., Battaglioli, F., 2024.: **Pre-storm environments and storm-scale properties of the major hailstorms of 2021, 2022 and 2023 in Europe**. 4th European Hail Workshop, Karlsruhe, Germany, 5-7 March 2024.
4. Taszarek, M., Púčik, T., Allen, T., 2024.: **Common environmental features associated with large hail across Australia, Europe, and the United States**. 4th European Hail Workshop, Karlsruhe, Germany, 5-7 March 2024.
5. Púčik, T. 2024: **Some findings of ESSL-EUMETSAT workshops and Testbeds: With emphasis on mature storms and their detection,** EUMETSAT Convection Working Group, 10 April 2024.
6. Kuzmenko, L., and Púčik, T: **Ingredient-based forecasting of (severe) convective storms: A demonstration of the 7 August 2023 severe weather outbreak**, Baltic+ 2024 Forecaster Training Course, 19 April 2024.

7. Groenemeijer, P., and F. Battaglioli, 2024: **Severe convection: climate modelling and forecasting hazards relevant for aviation,** Presentation for the European Network on Impact of Climate Change on Aviation, European Union Aviation Safety Association (EASA), 16 April 2024.
8. Groenemeijer, Pieter, Francesco Battaglioli, Tomáš Púčik, Alois Holzer, and Mateusz Taszarek, **Severe Storms Research at** ESSL, EGU General Assembly 2024, Vienna, Austria, 14-19 April 2024.
9. Eisenbach, Stefan: **The IF scale and ESSL activities to infrastructure providers as energy grid operators and road administrations & weather services**, Invited presentation at Impact of Weather on Infrastructure Workshop, Vienna, 22 April.
10. Eisenbach, Stefan: **Presentation of TIM activities to the research community and governmental agencies**, DCNA working groups meeting, Vienna.
11. Holzer, A. M., 2024: **Report from the first ESSL Workshop on Severe Weather Warnings**, MeteoAlarm Meeting in Sarajevo, 15 May 2024.
12. Battaglioli, F. 2024: **When Nature Shows Its Power: Extreme Weather Events in Europe and Their Consequences**. Invited Presentation at CGS Labs, Ljubljana, Slovenia, 29 May 2024.
13. Groenemeijer, P. and S.E. Eisenbach: **Meteorological Projects & Field Campaign on Extreme Storms.** Invited presentation, AIRBUS, Toulouse, 29 May 2024.
14. Holzer, A.M., 2024: **Snapshots from the EUMETSAT-ESSL Expert Workshop on experimental FCI moisture imagery***,* Presentation at Convection working Group Online Meeting, 25 June.
15. Groenemeijer, Pieter, Alois M. Holzer, Tomáš Púčik, Francesco Battaglioli, Stefan Eisenbach, Jannick Fischer, **Radar products at the ESSL Testbed & the TIM field campaign**, *ERAD 2024,* Rome, 9-13 September
16. Groenemeijer, Pieter, **Research at the European Severe Storms Laboratory: history, Activities and Plans:** Invited talk at ANVI Italian Association for Wind Engineering, 22 July 2024.
17. Holzer, Alois M., Tomáš Púčik, Stephan Bojinski, Pieter Groenemeijer, Nataša Strelec Mahović, Ivan Smiljanić, 2024: **Deep blue eyes and other discoveries in early MTG imagery***,* EUMETSAT Meteorological Satellite Conference, 30 Sep – 4 Oct 2024.
18. Taszarek, M., Púčik, T., Allen, T., Nixon J. C., Groenemeijer, P., Peters J.M., Battaglioli, F., Dowdy, A. , 2024.: **What do large hail, tornado and severe thunderstorm wind environments have in common across continents?** 31st Conference on Severe Local Storms, Virginia Beach (VA), USA, 21-25 October 2024.
19. Battaglioli, F., P. Groenemeijer, T. Púčik, M. Taszarek, and A. Rädler, 2024: **Global Trends in Very Large Hail Frequency Using ERA5 and the Additive Logistic Regression Models (AR-CHaMo)**. 31st Conference on Severe Local Storms, Virginia Beach (VA), USA, 21 – 25 October 2024.
20. Púčik, T., Taszarek, M., Groenemeijer, P., Battaglioli, F., 2024.: **Pre-storm environments of the major hailstorms of 2021 to 2024 in Europe**. 31st Conference on Severe Local Storms, Virginia Beach (VA), USA, 21 -- 25 October 2024.
21. Groenemeijer, P., I. Tsonevsky, Battaglioli, F., Púčik, T., Taszarek, M: **Medium-range ensemble prediction of severe weather,** 31st Conference on Severe Local Storms, Virginia Beach (VA), USA, 21 – 25 October 2024.
22. Groenemeijer, P.: **The European Severe Storms Laboratory: From a far-fetched idea to a valued part of the European Meteorological Infrastructure**, Symposium on the launch of the Canadian Severe Storms laboratory, 29 October 2024.

23. Battaglioli, F., P. Groenemeijer, 2024: **Convective Hazard Evolution Under Climate Change – II (CHECC-II)**. ClimXtreme Meeting, Gießen, Germany, 11-14 November 2024.
24. Holzer, A.M., 2024: **Wo die meisten Menschen bei Unwettern sterben und die nötigen Konsequenzen für Mess- und Warnsysteme**, CGS Labs online event, 4 November 2024.
25. Holzer, A.M., 2024: **First results from the EUMETSAT ESSL Forecaster Testbeds 2024**, presentation at EUMETSAT Convection Working Group Splinter Meeting, 1 October 2024
26. Holzer, A.M., 2024: **Where people most frequently die in severe weather events,** online presentation for ARPA-Liguria and ARPA-Piemonte, 10 December 2024
27. Eisenbach, S., 2024: **Presentation of ESSL activities and the ESWD to the Austrian storm chasing community**, Skywarn Austria General Assembly, Spital am Pyhrn, Austria

Poster presentations

1. Battaglioli, F., P. Groenemeijer, M. Taszarek, T. Púčik, A. Rädler, 2024: Very Large Hail in a Changing Climate: Global Climatology, Trends and Losses. EGU General Assembly 2024, Vienna, Austria, 14-19 April 2024.
2. Battaglioli, F., P. Groenemeijer, I. Tsonevsky, T. Púčik, 2024: Additive Logistic Regression Models for Large Hail Prediction: from Forecasting to Climate, ESA-ECMWF Machine Learning Workshop, Frascati, Italy, 7-10 May 2024
3. Groenemeijer, Pieter, Alois M. Holzer, Thilo Kühne, Igor Laskowski, Gabriel Strommer, Thomas Schreiner, Tomáš Púčik, Bogdan Antonescu, and Tanja Renko: **The IF-scale: Reviewing past European tornadoes and differences with the EF-scale**, 31st Conference on Severe Local Storms, Virginia Beach (VA), USA, 21 – 25 October 2024.

6.3 Reports and other publications

Reports

Holzer, Alois and coauthors: **ESSL Expert Workshop on Severe Weather Warnings: from Expectations via Physical Ingredients to Impact-based Warnings and Beyond**, ESSL Report 2024/01 (link).

ESSL Report on the **Evaluation of DWD Nowcasting and Warning Products at the ESSL Testbed 2024**. ESSL Report 2024/02 (link).PhD Thesis

ESSL was happy to congratulate PhD student Francesco Battaglioli who was supervised by Pieter Groenemeijer on his promotion to Doctor in Physics at the Freie Universität Berlin with Prof. dr. Uwe Ulbrich as his promotor on the following thesis:

A Statistical Model for Large and Very Large Hail: Development, Global Climate Applications, and Use in Forecasting. Freie Universität Berlin, Berlin, Germany, 18 July 2024 (link).

Figure 6-1.
Dr Francesco Battaglioli

6.4 Notable press communications, outreach activities

This list does not include presentations give at ESSL-organized workshops, courses, or ESSL Testbeds, or ESSL-internal events.

Michou Baart de la Faille, Tomas Púčik, Pieter Groenemeijer, Stefan Eisenbach, Alois M. Holzer

- Press conference and online live expert talk: Europe needs Twisters campaign, 16 June.

Stefan Eisenbach:

- 9 December, Skywarn Austria General Assembly, Spital am Pyhrn, Presentation of ESSL activities and the ESWD to the Austrian storm chasing community

Alois M. Holzer:

- Radio interview: www.oe1.at podcast and real-time on ORF Ö1 Radio Mittagsjournal *Mehr Stürme in Europa?* 13 February.
- Podcast: *Tornadoes and other extreme weather events: How well prepared are we?* Tornados und andere Extremwetterereignisse: Wie gut sind wir vorbereitet?, 2 May. https://www.dcna.at/index.php/de/podcast.html
- SKYWARN MAGAZIN *Report on training course given by Alois M. Holzer for Skywarn members and storm spotters on 12 April 2024 at the ESSL premises*. ESSL-Vortrag für Skywarn Austria, Report in member magazine, June 2024.
- Newspaper article: www.noen.at and print edition of NÖN: *Gibt es in Österreich Sturm- und Unwetterjäger wie im Film „Twister"?*, 10 November.

Tomáš Púčik:

- Tornados: Falsches Verhalten aus Unwissen, interview with ORF, 17 July 2024: https://science.orf.at/stories/3225884/
- Participation in a documentary of ITV:*The Sinking of a Superyacht: How Safe is Your Voyage?* , 3 October. https://www.itv.com/watch/the-sinking-of-a-superyacht-how-safe-is-your-voyage/10a6173a0001B/10a6173a0001

Bogdan Antonescu:

- Interviews for Digi24 TV on severe weather events in Europe for about severe weather on 4 January, on tornadoes (29 April, 5 May, 23 May), on waterspouts and climate change (26 August), Storm Boris (14 September)
- Interview for Ecofrecvența (RFI) radio on extreme weather events on 15 March.
- Interview for kanal D on hailstorms in Romania, 5 June 2024
- Interview on recent hail events for Antena 3 TV, 21 June 21024
- Interview for SmartBox, Radio România Actualități, on extreme weather and climate change, 13 August 2024
- Interview for PressOne Online Magazine, on extreme weather and climate change, 2 September 2024
- Interview for EuroNews on the recent floods and severe storm events in Spain, 31 October
- Interview for TV Info on the recent floods and severe storm events in Spain, 31 October

Pieter Groenemeijer:

- Tornadoes and waterspouts: Europe's underestimated extreme weather threat?, Interview with BBC, 21 August, https://www.bbc.com/future/article/20240821-sicily-superyacht-disaster-how-do-waterspouts-form

- Met windsnelheid van 250 km/uur kan orkaan Milton ravage aanrichten: 'Eng hoe orkaan kan exploderen', Algemeen Dagblad newspaper, 9 September.
- Milton laat zien: Orkanen worden heviger door veranderend klimaat, newspaper Het Parool, 9 October 2024.

6.5 Outreach and Social Media

Outreach and Social Media

In 2024, ESSL maintained an active presence across its social media platforms, LinkedIn, Facebook, X (formerly Twitter), and Bluesky – a new platform adopted by ESSL in 2024 – to disseminate information on severe weather research, training initiatives, and collaborative projects. We also distributed four newsletters to our members and newsletter subscribers. In addition, ESSL published informative content on its website's News feed on topics such as the upcoming ECSS conference in 2025, statistics and analyses related to the flash flood in Valencia, an overview of hailstorms throughout the year, and looks into data from the new MTG lightning imager sensor.

On social media, the number of followers on LinkedIn continued to grow, reaching approximately 2,200 by the end of the year. A similar upward trend was observed on the X platform. LinkedIn enabled us to connect with individuals, organizations, and companies with shared interests in convective storms. In addition to research institutes and governmental agencies, ESSL engages there with a broad audience from the insurance sector and the aviation industry, who closely follow our work and regularly interact with our content.

The ESSL Facebook page was used to share news items, event announcements, ESWD summaries as well as interesting severe weather events, helping to foster community engagement and awareness.

ESSL's X account was used to provide real-time updates on severe weather events, research findings, and organizational activities, supporting timely information dissemination and strengthening public engagement. In addition to X, a few important messages were also shared on the BlueSky network.

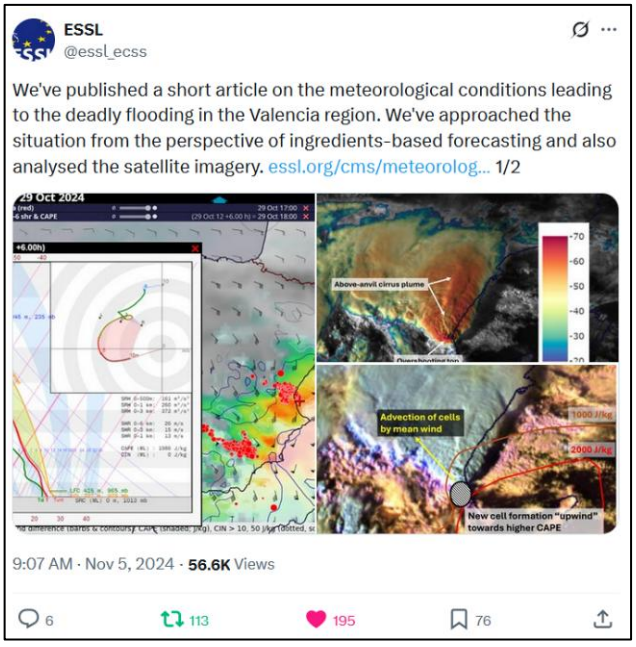


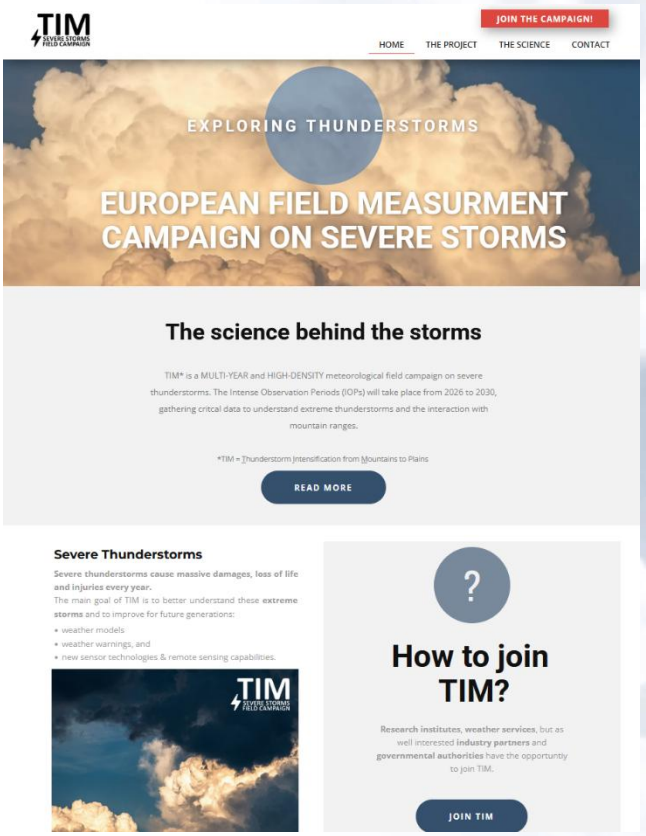
Figure 6-2. Posts on X advertising the ESSL news blog.

In 2024, approximately 18 posts were published on Facebook, and ESSL tweeted 19 times on the X platform. In

addition, ESSL retweeted a variety of posts from its employees and fellow scientists. A significant amount of attention was drawn to ESSL's X account by the announcement of the publication and analysis of the flood in Valencia. The post was reposted 113 times.

Europe Needs a "Twisters"-Campaign

In July 2024, ESSL promoted the TIM (Thunderstorm Intensification from Mountains to Plains) field campaign by inviting the press to an online presentation and Q&A with ESSL and other experts on plans for TIM.



A website to explain the background of the TIM campaign initiative was opened and can be visited at https://tim-campaign.eu.

Figure 6-3. The TIM website front page.

7 Financial and Administrative Report

7.1 Employment and Payroll Accounting

In 2024, the German non-profit research association "European Severe Storms Laboratory e.V." (ESSL e.V.) employed a full-time researcher for the whole year for the project CHECC-II/ ClimXtreme, a part-time ESWD quality control administrator, and a database programmer on a "mini-job basis", a form of minor employment according to German law.

The Austrian non-profit research association "European Severe Storms Laboratory – Science and Training" (ESSL-ST) employed three full time employees (Senior Trainer and PreCAST Researcher, the ESSL Director, and the ESSL Director of Operations), two part-time employees (the Assistant to the Board, and a Senior Project Advisor/Head of External Relations), two minor employments (ESWD quality control support and ESWD user support). Other tasks were taken over by temporary part-time jobs or voluntary workers (i.e., without payment), most importantly the tasks of the three Deputy Directors.

As in previous years, external payroll accountants (Mr. Andreas Schnaubelt Loewenstrasse 5, 86956 Schongau, Germany for ESSL e.V. in Germany and the Gneist Consulting Team Steuerberatungs GmbH in Wiener Neustadt for ESSL-ST in Austria) were mandated to handle taxes, social insurances and other administrative matters which would otherwise have exceeded ESSL's internal administrative capacity.

7.2 Auditing of the Annual Accounts

In accordance with the Articles of Association, ESSL e.V.'s finances for 2024 were audited by the ESSL Advisory Council based on the report on the annual accounts prepared by tax advisor Mr. Andreas Schnaubelt. This report states:

"Record of Income and Expenses

During our work, no indications occurred which would give raise for objections against the correctness of the record.

Financial Statements

During our work, no indications occurred which would give raise for objections against the correctness of the financial statements."

For ESSL-ST, a yearly external audit was done by WNW Scheicher & Partner GmbH Wirtschaftsprüfer in Wiener Neustadt. This audit is a requirement by the science funding agency of the government of Lower Austria. It was carried out independently of the regular audits of the two additional association-internal auditors that Austrian law requires from any association.

The external auditor stated under the header “Determination of the legality of the financial statements” (non authoritative translation from the German original):

“During our audit procedures, we ascertained compliance with the legal provisions and supplementary provisions of the association's statutes. In the performance of our duties as auditors, we have not identified any facts that may jeopardize the existence of the audited association or significantly impair its development, or that indicate serious violations of the law or the association's statutes by the management body or employees. No material weaknesses in the internal control of the accounting process have come to our attention."

7.3 The ESSL group

Since 2011, ESSL has consisted of two legal entities, the “European Severe Storms Laboratory e.V.”, in short ESSL e.V. (a non-profit association with seat in Weßling near Munich, Germany), and the “European Severe Storms Laboratory – Science and Training”, in short ESSL-ST (a non-profit association with seat in Wiener Neustadt, Austria). The latter is the legal body managing the ESSL Research and Training Centre and its related activities like the ESSL Testbed.

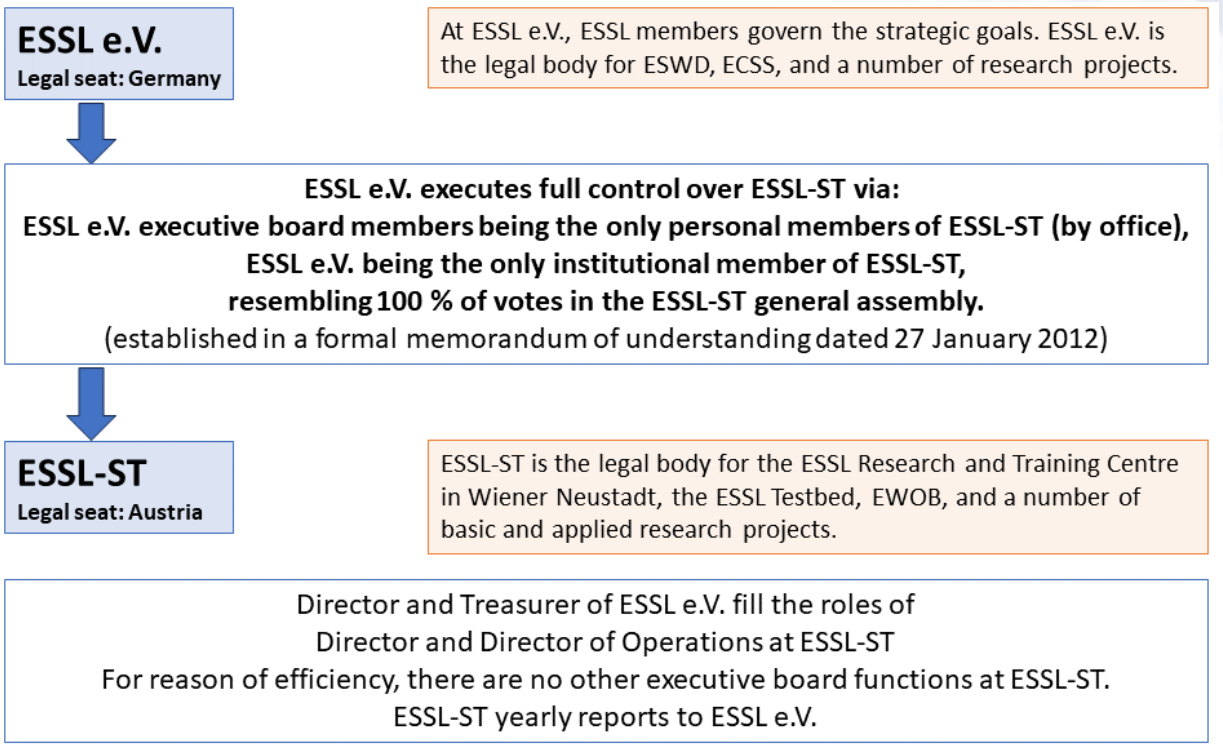


Figure 7-1. Schematic overview of the relationship between the two legal bodies of ESSL.

In recent years, ESSL received requests from full members, supporting members and non-members to provide certain products and services that of which the law requires them be taxed as commercial activities. This means that such activities may not be of a systematic nature within non-profit organisations such as ESSL e.V. or ESSL-ST. These products and services include extended or adapted versions of hazard models, consultancy services of various nature, or the licensing of the Weather Data Displayer to weather services.

To accommodate those requests, a subsidiary limited company ESSL Services GmbH was founded in 2024 by all current ESSL employees and officials, and ESSL e.V. and ESSL-ST. ESSL e.V. made a 24% investment of €2400, approved by the Advisory Council. ESSL-ST holds a share of 24% as well, so that, jointly, the German and Austrian non-profit associations hold 48% of the shares of the company.

When profits are paid out and not reinvested, they will benefit the non-profit associations as shareholders. An agreement was closed between ESSL e.V., ESSL-ST, and ESSL Services GmbH, stating that ESSL Services may use parts of the ESSL logo, but in return can only carry out business that does not counter the interest of the non-profit associations.

The most important practical outcomes of this arrangement are:

- Members and others can be delivered the requested services (displayer, hazard models, consultancy)
- The commercial activities in non-profits are minimized, ensuring continued compliance with taxation regulations.
- Synergies can benefit the non-profit associations (privately financed infrastructure and developments offered to the non-profits)
- In case of profit, a small extra income can result for the non-profit associations (a few 1000 EUR/year) and their employees (a few 100 EUR/year)
- Additional employment opportunities created by market for commercial activities supporting the continuity of ESSL.

7.4 Financial Status 2024

European Severe Storms Laboratory e.V.

The accounting year was dominated by income from membership fees. One basic research project (CHECC-II/ClimXtreme) added important funding from the Ministry of Research of the Federal Republic of Germany. The detailed Annual Accounts were presented to the ESSL Advisory Council and can be inspected in their original format and in person by each member at our secretariat. Digital copies of the full document can be requested from the ESSL Treasurer by ESSL members. Attachment A1 provides a condensed version of these Annual Accounts.

As required by the German tax authorities, in the detailed accounting 'cost centres' distinguish between the ideational branch of ESSL (*Idealistic Purpose*, i.e., management of the association and its core activities) and its branches directly serving the statutory purposes of the ESSL (*dedicated activities*). No activities were booked under the commercial type of branch (*economic activities*; minor activities of this kind would have been permissible), thus fulfilling the requirements of the tax authorities.

The following key figures from the Annual Accounts characterize the business conditions in 2024:

ESSL e.V. obtained € 290,000 from institutional membership fees and ESWD data fees, € 73,500 from the CHECC II project funded by the German Ministry of Research. We are thankful for personal membership fees of € 3,625 and donations of € 1,140 underlining the worth of ESSL activities for the severe weather community.

Total income amounts to **€ 374,592** (2022: € 580,728).

Total expenses amount to **€ 432,925** (2022: € 488,472).

The dominant cost factors were direct personnel costs with € 196,384, including taxes and social security; external costs related to scientific meetings (ECSS) of € 75,740; lump sums for personnel provided by ESSL-ST with € 60,000; office, IT and server costs shared with ESSL-ST € 61,917; other third-party and database services with € 54,809, and travel expenses with € 19,128.

The tight cooperation with the Austria-based association "European Severe Storms Laboratory – Science and Training" reduces costs for administrative work since common services and their associated costs are shared between the two associations. Personnel costs for management and administration were borne by this ESSL subsidiary.

At the end of the business year, liquid assets at ESSL's bank accounts amounted to € 110,157 (2023: € 123,426). At the end of the year, accounts receivables amounted to € 295 (2023: € 822), liabilities to € 67,015 (2023: € 2,434), deferred expenses (payments made for a different accounting period) to € 33,333 (2023: € 1,180), deferred income (payments received for future accounting periods) to € 20,000 (2023: € 13,000). The annual operating result is a negative € 58,333 (compare: positive € 95,356 in 2023, positive € 805 in 2022).

ESSL e.V. was ending the business year with a liquidity reserve that would cover expenses for approximately 3 months. A reserve for operating expenses (for the period before the membership fees are received in the following year) of € 62,431 (2023: € 83,030) was included in the "Assets and Liabilities" category of ESSL e.V., in addition to an amount of € 9,226 of "free reserve" in line with legal and ESSL internal regulations.

The financial planning for 2025 foresees enough liquidity until the end of the year with a stable income situation based on the project CHECC-II, and membership fee income.

European Severe Storms Laboratory - Science and Training

The annual accounts of the subsidiary association "European Severe Storms Laboratory – Science and Training" (ESSL-ST) can be summarized as follows:

At the end of the business year, liquid assets at its bank accounts amounted to € 136,935 (2023: € 200,555). The annual result is € -63,620 (2023: € 73,682). The reserve for operating expenses for the ESSL Testbed (necessary, as important payments are only received after the ESSL Testbed towards the end of the accounting year) was depicted as an amount of € 130,000 (2023: € 193,000). Comparing liquid assets with mean monthly expenses, ESSL-ST ended the business year with a small liquidity reserve for about 2 to 3 months. The remaining result of the year 2024 is a negative € 620 (2023: positive € 682).

The main income source in 2024 were the ESSL Testbed and related activities (such as EUMETSAT-ESSL Testbeds and Expert Workshops) with their main contributions from EUMETSAT (€ 265,429) and DWD (€ 64,750). Public project funding from the Austrian national science fund (FWF) amounted to € 78,289 (PreCAST project), public base funding from the Government of Lower Austria amounted to € 120,000. (Income from courses amounted to € 91,466.

Mirroring the expenses at ESSL e.V., income at ESSL-ST from third party personnel lump sums by ESSL e.V. amounted to € 30,000 (excluding deferred income of € 30,000; in total € 60,000); office, IT and server costs shared with ESSL-ST to € 26,271 (excluding deferred income of € 35,646; in total € 61,917). A finished project still provided € 5,091 of income.

The main cost factors were personnel costs with € 483,673, direct Testbed expenses with € 88,124, office rent, seminar space rent and insurance with € 42,229, and travel costs with € 30,970.

The total income of € 736,711 (2023: € 686,684) compares to total expenses of € 787,266 (2023: € 611,747). € 63,000 were released from the liquidity reserve for operating expenses. A tabular overview is provided in Appendix A1.

The financial planning for 2025 foresees a near neutral annual result.

7.5 ESSL Members

Members are at the core of ESSL and provide essential support to ESSL activities. Membership fees form an important source of income for ESSL. However, ESSL members are also important in catalysing the pursuit of the Association's goals. This type of support is sometimes provided in-kind and sometimes through financial support. In 2024, ESSL was happy to welcome a new institutional full member: ARPAE - Emilia-Romagna - Struttura Idro-Meteo-Clima, besides one individual full member, one individual supporting member, and as many as *nine* new institutional supporting members. The full member list as of 31 December 2024 can be found in Appendix A2.

7.6 Executive Board and Advisory Council

The Executive Board, the Advisory Council, and the General Assembly, which consists of all full members, constitute the three bodies forming the ESSL e.V. Figure 7-2 outlines some of their main responsibilities.

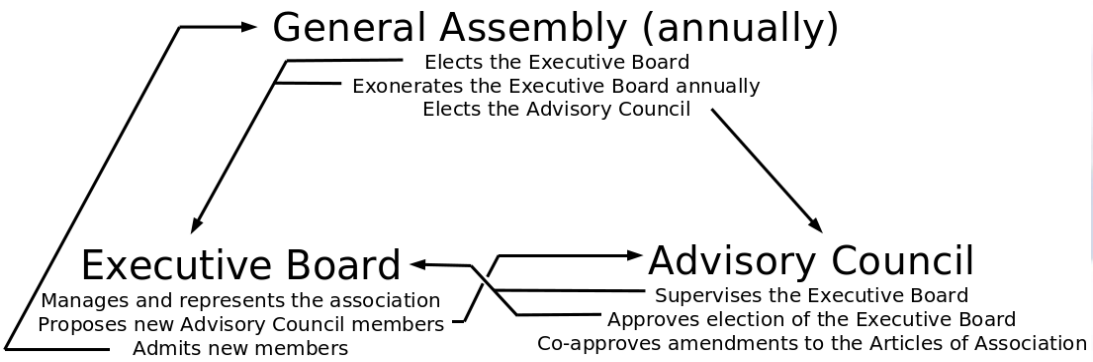


Figure 7-2. Bodies of the ESSL. The Advisory Council consists of six members from two groups - three members each: (1) Science, (2) NMHS / EUMETNET.

Executive Board

These following Executive Board members had been elected for a term until 31 December 2024 and were re-elected for another three-year term at the General Assembly of 2024:

Pieter Groenemeijer, Director
Bogdan Antonescu, Deputy Director
Michou Baart de la Faille, Deputy Director
Tanja Renko, Deputy Director
Alois M. Holzer, Treasurer

Advisory Council

In 2024, the Advisory Council consisted of:

- **Thomas Kratzsch** (DWD German Weather Service, Germany)
  1 Jan. 2023 – 31 Dec. 2026 (second term)
- **Piotr Ramza** (IMGW, Poland)
  1 Jan. 2024 – 31 Dec. 2027 (first term)
- **Clotilde Augros** (Meteo France)
  1 Jan. 2025 – 31 Dec. 2028 (first term)
- **Chris Weiss** (Texas Tech University, USA)
  1 Jan. 2025 – 31 Dec. 2028 (first term)
- **Mario M. Miglietta** (CNR-ISAC, Italy)
  1 Jan. 2025 – 31 Dec. 2028 (first term)
- **Olivia Romppainen-Martius** (University of Berne, Switzerland)
  1 Jan. 2024 – 31 Dec. 2027 (first term)

Appendix A1: Annual Accounts

The following presents in extract a copy of the "*Report on the Preparation of the Financial Statements for 2024*", as prepared by the financial auditor in Germany for ESSL e.V. (this page, figures of the previous years were added for comparison), and also the annual accounts as audited by the external auditor in Austria for ESSL-ST (next page).

ESSL e.V.

	2024	2023	2022	2021	2020
INCOME					
Membership fees institutional members and ESWD data fees	290.000,00	246.963,00	210.082,00	163.306,60	173.103,50
Membership fees personal members	3.625,00	3.520,00	3.995,00	3.805,00	3.422,72
Income from scientific meetings (ECSS)	0,00	64.441,75	0,00	0,00	0,00
Public project funding Federal Republic of Germany	73.500,80	103.838,01	134.000,00	94.000,00	50.000,00
Public project funding European Union	0,00	0,00	0,00	0,00	0,00
Applied research	0,00	147.000,00	0,00	0,00	0,00
Donations	1.140,00	150,00	355,00	1.005,00	1.502,18
Other interest receivable and similar income	1.181,95	0,00	0,00	0,00	
German VAT on sales and refunds	5.145,00	14.815,50	6.296,50	0,00	0,00
Total income	**374.592,75**	**580.728,26**	**354.728,50**	**262.116,60**	**228.028,40**
EXPENSES					
Personnel	196.383,80	208.979,81	203.955,96	154.404,99	73.258,73
Depreciations	8.743,66	6.321,35	2.638,00	3.323,00	1.260,98
Costs related to scientific meetings (ECSS)	0,00	75.740,52	0,00	0,00	0,00
Travel costs	19.127,85	13.397,04	13.783,41	333,56	3.959,62
Office costs and insurance	616,93	316,44	180,93	2.091,98	2.242,53
Phone and data (internet) services	1.720,19	1.703,52	3.357,82	2.097,50	3.877,55
Tax advisor including software	9.491,13	6.209,26	3.866,08	5.865,00	6.450,23
Third party services by ESSL Science and Training, Austria					101.523,21
Director and administration personnel lumpsum	60.000,00	60.000,00	60.000,00	60.000,00	
Office, IT and server costs	61.917,39	51.796,54	30.756,81	22.684,33	
Other third party services / data base service	54.809,00	31.223,65	21.495,00		
Value added tax	8.356,91	18.042,22	4.495,37	3.870,67	8.508,33
Third party services and other	11.758,74	14.742,41	9.393,86	6.491,33	10.429,90
Total expenses	**432.925,60**	**488.472,76**	**353.923,24**	**261.162,36**	**211.511,08**
Operating result	**-58.332,85**	**92.255,50**	**805,26**	**954,24**	**16.517,32**

Assets and Liabilities

	2024	2023	2022	2021	2020
Fixed Assets (office equipment)	14.887,00	19.996,00	2.305,00	2.768,00	2.942,00
Current Assets					
Receivables	295,49	822,46	0,00	0,00	0,00
Bank balances	110.156,61	123.426,14	50.386,51	54.443,06	42.333,48
Deferred Expenses	33.333,37	1.179,75	11.904,98	1.500,00	1.500,00
Assets total	**158.672,47**	**145.424,35**	**64.596,49**	**58.711,06**	**46.775,48**
Equity (own capital)					
Retained earnings brought forward	0,00	37.734,37	36.929,11	35.974,87	35.974,87
Reserve for operating expenses	62.431,47	83.029,95	0,00	0,00	0,00
Free reserve	9.225,55	9.225,55	0,00	0,00	0,00
Remaining result of the year	0,00	0,00	805,26	954,24	16.517,32
Deferred Income	20.000,00	13.000,00	25.000,00	20.000,00	9.900,00
Liabilities	67.015,45	2.434,48	1.862,12	1.781,95	900,61
Equity and Liabilities total	**158.672,47**	**145.424,35**	**64.596,49**	**58.711,06**	**63.292,80**

ESSL-ST

European Severe Storms Laboratory - Science and Training Cost centres overview 2024		
	Income	**Expenses**
General business	2,165.79 €	- 31,256.68 €
Membership fees and donations	2,887.84 €	- 3,100.00 €
Rent and insurance	2,875.18 €	- 42,229.35 €
Phone and internet	183.60 €	- 17,966.99 €
Testbed	6,350.50 €	- 88,124.00 €
DWD Testing	64,750.00 €	- 200.84 €
EUMETSAT framework contract	265,429.30 €	- 2,733.93 €
Seminars	91,466.18 €	- 5,252.53 €
Salaries (income: lump sums from ESSLeV)	30,000.00 €	- 483,673.64 €
Payroll accounting, tax advisor, external auditor	- €	- 9,225.27 €
Travel costs	6,334.62 €	- 37,304.38 €
Cost sharing with ESSLeV (infrastructure)	26,271.06 €	- €
Energy supply	- €	- 11,152.89 €
Asset management	117.16 €	- 2,671.39 €
PreCAST project	78,289.17 €	- €
Lightning sensor project	5,090.79 €	- €
TIM field campaign preparations	- €	- 16,917.64 €
ESWD and EWOB	33,000.00 €	- 14,516.32 €
ECSS	- €	- 20,940.28 €
Public basic funding, Government of Lower Austria	120,000.00 €	- €
Totals	735,211.19 €	- 787,266.13 €

Cost centres overview irrespective of neutral transfers on behalf of third parties and neutral internal bookings.

Annual Accounts	**1 Jan 2024**	**31 Dec 2024**
Bank accounts (short term liquidity)	200,555.49 €	136,935.60 €
Savings (mid term liquidity)	42,596.00 €	57,270.00 €
Fixed Assets	69,784.21 €	65,147.81 €
Total Assets	312,935.70 €	259,353.41 €
Annual combined operating and financial result		**- 63,619.89 €**

Remark: Due to bookkeeping standards, asset valuation is influenced by changing market prices of assets.

Endowment of reserve for operating expenses	- €
Release of reserve for operating expenses	63,000.00 €
Remaining result	**- 619.89 €**

Total reserve for operating expenses on 1 Jan. 2024	193,000.00 €
New total reserve for operating expenses on 31 Dec. 2024	130,000.00 €

Appendix A2: Member list 2024

The following table shows all ESSL members as of 31 December 2024, sorted according to their ESSL-ID (which corresponds in ascending order to the beginning date of the ESSL membership). Members joining ESSL in 2024 have an * next to their names. Those founding members who are still members are *printed in italic font*. The given country corresponds to their main residence or statutory seat, not necessarily their nationality.

Individual Full members

Dr. Bernold Feuerstein	*GERMANY*	Erik Dirksen	GERMANY
Dr. Pieter Groenemeijer	*NETHERLANDS*	Dr. Christoph Gatzen	GERMANY
Alois M. Holzer	*AUSTRIA*	Dr. Kathrin Riemann-Campe	GERMANY
Dr. Romualdo Romero	*SPAIN*	Dr. Koji Sassa	JAPAN
Dr. Fulvio Stel	*ITALY*	Dr. Tomáš Púčik	AUSTRIA
Jenni Rauhala	*FINLAND*	Marcus Beyer	GERMANY
Thilo Kühne	GERMANY	Dr. Lisa Schielicke	GERMANY
Helge Tuschy	GERMANY	Dr. Abdullah Kahraman	UK
Zhongjian Liang	GERMANY	Dr. John Allen	USA
Lionel Peyraud	SWITZERLAND	Dr. Anja T. Rädler	GERMANY
Thomas Krennert	AUSTRIA	Dr. Darrel Kingfield	USA
Dr. Johannes Dahl	USA	Stavros Dafis, PhD	FRANCE
Martin Hubrig	GERMANY	Michou Baart de la Faille	NETHERLANDS
Dr. Oliver Schlenczek	GERMANY	Dr. Jannick Fischer	GERMANY
Dr. Victor Homar Santaner	SPAIN	Dr. Tanja Renko	CROATIA
Dr. Bogdan Antonescu	ROMANIA	Dr. Mateusz Taszarek	POLAND
Dr. Michael Kunz	GERMANY	Dr. Katharina Schröer*	GERMANY

Individual Supporting Members

Casper ter Kuile	NETHERLANDS	Jan Jacob Groenemeijer	NETHERLANDS
Yowann Baunay*	FRANCE		

Institutional Full Members

DWD, Deutscher Wetterdienst	GERMANY
EUMETSAT	INTERNATIONAL
AUSTRO CONTROL	AUSTRIA
GeoSphere Austria, previously Zentralanstalt für Meteorologie u. Geodynamik	AUSTRIA
NMA, National Meteorological Administration of Romania	ROMANIA
FMI, Finnish Meteorological Institute	FINLAND
CHMI, Czech Hydrometeorological Institute	CZECHIA
Institute for Hydrometeorology and Seismology of Montenegro	MONTENEGRO
DHMZ, Meteorological and Hydrological Service of Croatia	CROATIA
SHMÚ, Slovak Hydrometeorological Institute	SLOVAKIA
Consorzio LaMMA	ITALY
KNMI, Royal Netherlands Meteorological Institute	NETHERLANDS
ECMWF, European Centre for Medium-Range Weather Forecasts	INTERNATIONAL
Croatia Control, Croatian Air Navigation Services, Ltd	CROATIA
Cyprus Department of Meteorology	CYPRUS
RHMSS – Republic Hydrometeorological Service of Serbia	SERBIA
Institute for Meteorology and Climate Research	GERMANY

Met Office	UNITED KINGDOM
ARPAL – Agenzia Regionale per la Protezione dell'Ambiente Ligure	ITALY
TLUBN – Thüringer Landesamt für Umwelt, Bergbau und Naturschutz	GERMANY
IMGW–PIB, Institute for Meteorology and Water Management	POLAND
Dep. of Economics & Management "Marco Fanno", Università di Padova	ITALY
Met Éireann	IRELAND
Università di Genoa	ITALY
Fondazione CMCC	ITALY
Météo-France	FRANCE
ARPAE - Emilia-Romagna - Struttura Idro-Meteo-Clima*	ITALY

Institutional Supporting Members

Münchener Rückversicherungs-Gesellschaft AG	GERMANY
Gallagher Re	UNITED KINGDOM
Deutsche Rückversicherung	GERMANY
Marsh Ltd per Guy Carpenter Limited	UNITED KINGDOM
RMS - Risk Management Solutions	UNITED KINGDOM
Renaissance RE Services Ltd	BERMUDA
Factory Mutual Insurance Company - FM Global	USA
Nowcast GmbH	GERMANY
Impact Forecasting LLC - AON Central and Eastern Europe a.s.	CZECH REPUBLIC
Arcturus B.V.	NETHERLANDS
Descartes Underwriting	FRANCE
riskine GmbH	AUSTRIA
FCM - Fermat Capital Management, LLC	USA
GreenTriangle AG	SWITZERLAND
Genillard & Co GmbH	GERMANY
RED (Risk, Engineering and Development) SpA	ITALY
A multinational financial services company	GERMANY
PriceWaterhouseCoopers GmbH Wirtschaftsprüfungsgesellschaft	GERMANY
Partner Reinsurance Europe SE Zurich Branch	SWITZERLAND
Inova Autoservices Group SA	SWITZERLAND
ALTACON d.o.o.	CROATIA
Mitiga Solutions SL	SPAIN
HOGO Rückversicherungsmakler- und beratung GmbH	AUSTRIA
MeteoIQ GmbH*	USA
DATA4RISK*	GERMANY
Swiss Re Management Ltd. *	FRANCE
Datenservice +*	SWITZERLAND
MSI GuaranteedWeather LLC*	GERMANY
Vayuh Inc. *	USA
University of Bari Aldo Moro*	USA
GIE AXA*	FRANCE
Peak Reinsurance Company Ltd.*	HONG KONG

Honorary Members

Birgit Büsing	GERMANY
Gregor Dotzek	GERMANY
Armin Dotzek	GERMANY
Dr. Charles A. Doswell III	USA

ESSL has a partnership with the European Meteorological Society (EMS) through a Memorandum of Understanding, is member of the Climate Change Centre Austria, and is a participating organization in the GEO Group on Earth Observations.