2 – 27 June 2014
ESSL Research and Training Centre
Wiener Neustadt, Austria

ESSL Testbed 2014
Operations Plan

Version of 24 June 2014

The ESSL Testbed 2014 is organized in cooperation with the Austrian Central Institute of Meteorology and Geodynamics (ZAMG).

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1. Introduction and goals

1.1 ESSL Testbed Approach

The ESSL Testbed will evaluate forecasting and nowcasting tools and techniques of convective high-impact weather. Within the Testbed, occurrences of high-impact weather across Europe will be investigated during one or more annual test periods of a number of subsequent weeks.

The Testbed's concrete aims are...

1. to assess the ability of new diagnostic products based on satellite measurements, numerical weather prediction, radar and standard weather observations to correctly indentify (upcoming) severe weather events (e.g. via subjective and objective verification procedures).
2. to obtain feedback from forecasters regarding these products, both with respect to their performance and to operational needs and constraints. This feedback helps the product developers to refine and optimize them, thereby accelerating their successful operational deployment.
3. to familiarize the forecasters of the European National (Hydro-)meteorological Services with the best use of the new products
4. to enhance the forecasters' overall skills in forecasting of convective high-impact weather, by providing training by internationally known forecasting experts who teach scientifically-motivated forecasting techniques. The training is performed through remote learning in cooperation with EUMETCAL and "hands on" at the ESSL Training Centre.

The overall aim in the Testbed is to ***stimulate interaction between and among developers and forecasters*** which benefits the forecasting and warning process at European National Meteorological Services. The participants therefore include the persons from the following groups:

- weather forecasters from forecasting agencies worldwide and especially from Europe's National (Hydro-)Meteorological Institutes
- researchers/developers from these agencies and from international organizations such as EUMETSAT
- renowned experts on forecasting techniques

The Testbed is loosely modelled after its US counterpart, the Hazardous Weather Testbed Spring Experiment, an annual programme in which several branches of the National Oceanographic and Atmospheric Administration (NOAA) cooperate, including the Storm Prediction Center (SPC) and the National Severe Storms Laboratory (NSSL).

1.2 Facilities

Fig 1. The ESSL Training Centre in Wiener Neustadt, Austria

The ESSL Testbed is located in the ESSL Training Center in Wiener Neustadt, a historical imperial city 45 km south of Vienna and 60 km southeast of the Vienna International Airport. The main train station of Wiener Neustadt with frequent trains to Vienna and other Central European Destinations is only 300 m away, thus within walking distance.

The Testbed facilities are housed on the first floor of an Art Deco Style house (Fig. 1) near the town center of Wiener Neustadt. The Testbed and briefing rooms are situated on 150 m², which also include the secretariat and break rooms.

2. Operations

2.1 Overview

The operations include the following three fundamental components:

1. **Forecasting**
2. **Verification**
3. **Evaluation**

Within the forecasting activities, participants operationally use the experimental forecast products to generate a forecast. After the period for which the forecast was valid has passed, they are verified against observations. Finally, the use of the experimental forecast products is evaluated. Below, these activities are described in more detail.

In addition, there are

- expert lectures (**lecture of the day**)

Within a daily online session, remote participants will receive a briefing of the forecasting, verification and evaluation efforts and are asked to provide feedback and questions. Subsequently, the "lecture of the day" will be transmitted online.

The daily Testbed programme is shown in the Tables 2 and 3, below.

Programme on first day of the week

On-site registration: 08:00 – 08:45 h local time.

Time (local, UTC)		Activity	Description
08:45	0645	Welcome presentation	Presentation of organizational and local matters. Round of introductions.
09:00	0700	Introduction to the ESSL Testbed	Presentation of the concept of the ESSL Testbed and of the available tools.
Part of programme with remote participation			
11:00	0900	Daily briefing	Online weather briefing, discussion of current weather situation and forecasts and subjective evaluation with remote participants - done on the first day by the ESSL Testbed staff.
followed by		Lecture of the day	30 minute expert lecture on forecasting techniques, given by developers of forecast tools or forecasting experts.
~ 12:30		Lunch break	
14:00	1200	Forecast operations	The participants will be split into two groups, each dealing with a particular forecast period. Green Room: Day 1 forecast and Nowcasting Experimental probabilistic convective forecast for the present day. Map Room: Day 2 – 5 forecast Experimental probabilistic convective forecast for day 2, and for day 3 - 5.
17:30	1530	End	End of forecast operations.
18:00			Social programme: Guided City Tour

Table 2. The Testbed's Monday programme

Daily Programme Tuesday – Friday

Time (local, UTC)		Activity	Description
08:45	0645	Verification	Subjective verification of yesterday‘s experimental convective forecasts compared to ESWD severe weather reports, satellite and radar data.
09:15	0715	Forecast operations	The participants will be split into two groups, each dealing with a particular forecast period. Green Room: Day 1 forecast Experimental probabilistic convective forecast for the present day. Map Room: Day 2 forecast Experimental probabilistic convective forecast for day 2.
Part of programme with remote participation			
11:00	0900	Daily briefing	Online weather briefing, discussion of current weather situation and forecasts and subjective evaluation with remote participants: summarizing new insights, preliminary findings, and topic areas needing further examination.
followed by		Lecture of the day	30 minute expert lecture on forecasting techniques, given by developers of forecast tools or forecasting experts.
~ 12:30		Lunch break	
14:00	1200	Forecast tool performance evaluation	Participants jointly discuss forecast tool performance, answer questions
14:30	1230	Forecast operations	Green Room: Nowcasting Short-range forecast and issuance of experimental watches for 2 hours at 15:00, 16:00 and 17:00 local time. Map Room: Day 3 - 5 forecast Experimental probabilistic convective forecast for day 3 - 5. After the finished day 3 - 5 forecast the team can also switch to nowcast-mode. If the weather situation is unusually calm, the programme for both teams will be altered: Studies of past severe weather situations, or severe weather forecasting training by an expert.
1730	1530	end	End of forecast operations. Weather permitting, activities may be continued.

Table 3. The Testbed’s daily programme

2.2 Experimental convective forecasts

On a daily basis, participants will prepare experimental forecasts for severe weather. These forecasts differ in time range, validity time period, domain, and quantities to be forecast. They range from Nowcasts, that have a validity time of two hours starting at the moment the forecasts issuance, to Day 5 forecasts, that deal with the weather occurring four days ahead. The forecasts will be issued using a program to draw lines are drawn to designate areas in which a particular probability of severe weather or lightning is expected. In addition, a short(!) text to explain the forecast rationale is to be given.

Table 3 lists the types of forecasts that are to be issued

Type	**Deadlines (UTC)**	**Validity (UTC)**	**Forecast type** The percentages refer to the probability of one or more events within 40 km of a point	**Domain**
Nowcast	1300 (1500 CEST) 1400 (1600 CEST) 1500 (1700 CEST)	1300 – 1500 1400 – 1600 1500 – 1700	warning with indication of expected severe weather type	selected sub-domain
Day 1	0855 (1055 CEST)	0900 – 0600 (next day)	thunder 15 % thunder 50 % level 1 (> 5% severe) level 2 (> 15% severe) level 3 (> 15 % extreme)	selected sub-domain
Day 2	0800 (1000 CEST)	0600 (next day) – 0600 (day + 2)	thunder 15 % thunder 50 % level 1 (> 5% severe) level 2 (> 15% severe) level 3 (> 15 % extreme)	selected sub-domain
Day 3	0855 (1055 CEST), on Mondays: 1300 (1500 CEST)	0600 (day + 2) – 0600 (day + 3)	any severe weather	Europe
Day 4		0600 (day + 3) – 0600 (day + 4)	any severe weather	Europe
Day 5		0600 (day + 4) – 0600 (day + 5)	any severe weather	Europe

Table 4. Forecasts at the testbed.

The forecasts are issued at fixed times and deal with a particular forecast domain. In the case of the Day 3, Day 4, and Day 5 forecasts, the domain is Europe, whereas the Nowcasts and Day1 and Day 2 forecasts are issued for a sub-domain that is decided based on the pre-conceived likelihood of severe weather occurring within that sub-domain. The subdomains can be seen in Figure 2. An example of a forecast is given in Fig. 3.

Many of the predictands of the various forecasts relate to the probabilities of severe weather and extreme weather, which for the ESSL Testbed are defined as in Table 4.

Severe weather	**Extremely severe weather**
• hail 2.0 cm or larger in diameter • wind gusts 25 m/s or higher • any tornado • rainfall causing significant damage	• hail with 5.0 cm diameter or larger • wind gusts 32 m/s or higher • tornado F2 or higher
The quantities to be forecast in the Day 1-5 forecasts are the probabilities that lightning / severe / extreme weather occurs within a radius of 40 km of any given point.	

Table 5. ESSL Testbed criteria for severe weather.

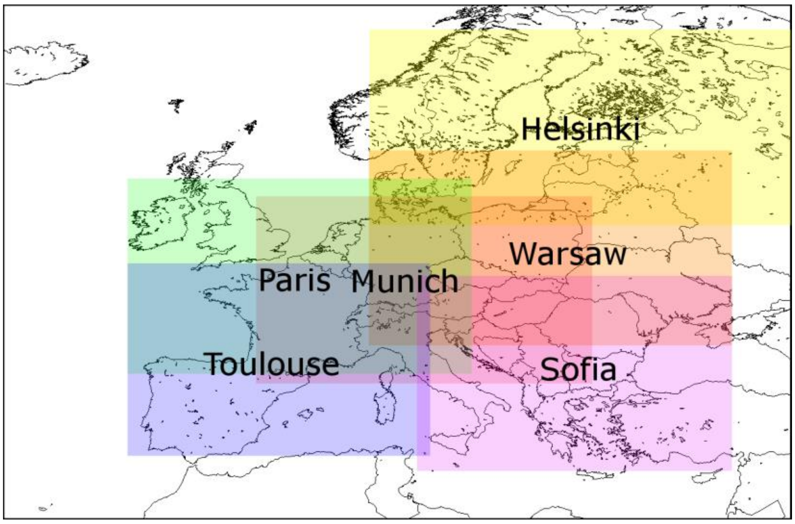
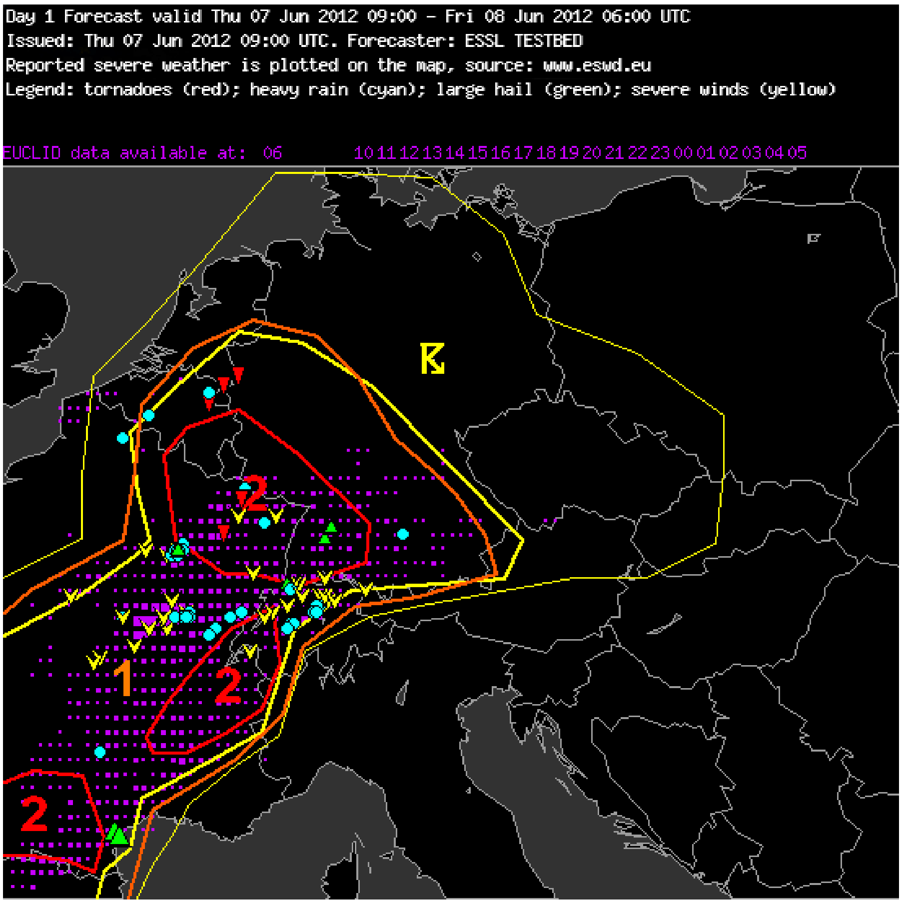


Fig. 2. The full ESSL Testbed domain and the six subdomains for which forecasts are to be made.



a.

b.

Fig. 3: Day 1 forecast map for the domain Munich showing the areas drawn to depict low (15 – 50 %) thunderstorm probability (inside the thin yellow contour) and high (> 50%) thunderstorm probability (inside the thick yellow line), as well as a level 1 and 2 of severe weather threat (see Text and Tables 1 and 2 for definitions). The map also shows the data to verify the forecast, i.e. the observed severe weather reports from the European Severe Weather Database: heavy rain (blue circles), tornadoes (red triangles), yellow V's (severe wind > 25 m/s), and large (>= 2 cm) hail (green triangles), as well as lightning detected by the EUCLID network (purple).

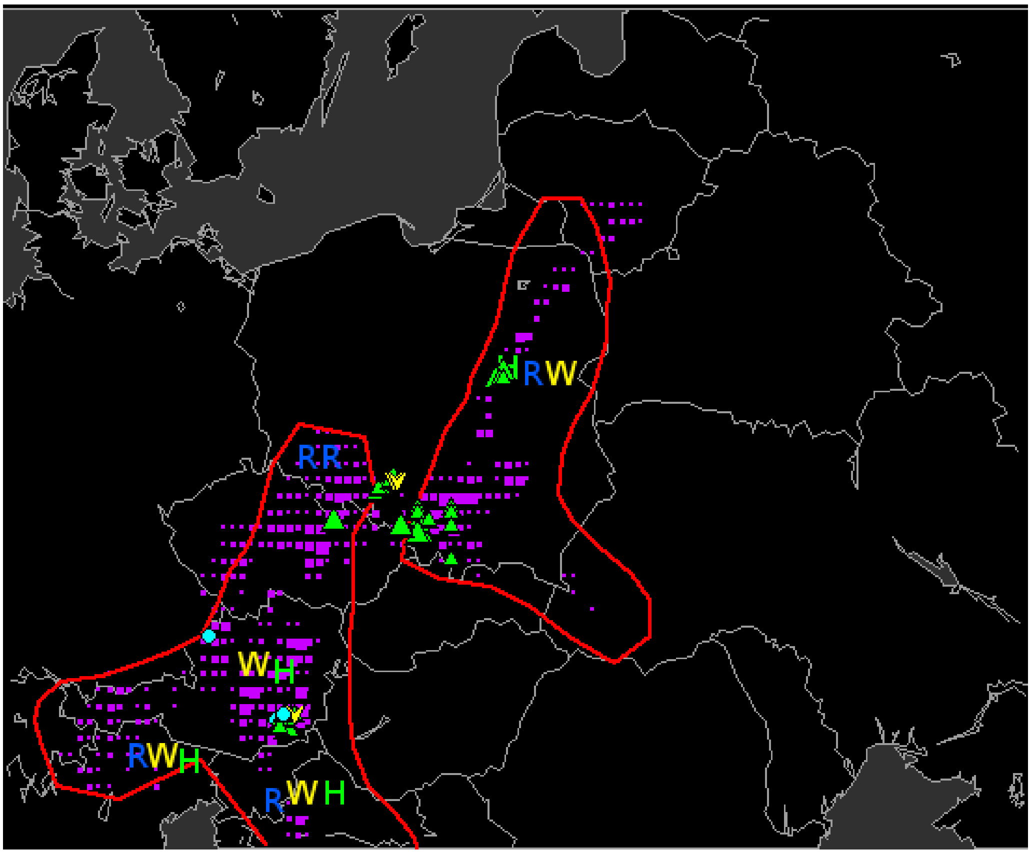


Fig. 4: Nowcast map with verification data. The map shows areas outlined by red contours within which thunderstorms are expected within the next two hours. The characters W, H, and R indicate that a threat of wind, hail or rain is expected, respectively. The symbols, as in Fig. 3.a., denote the occurrence of such phenomena according to reports entered into the ESWD.

Nowcasts

During the afternoon session, starting at 14:45 local time, one or both of the Testbed teams will work on issuing severe weather warnings for smaller areas within the domain of the day. These are supposed to be warnings for severe weather issued two hours ahead of time.

Climatology

In case almost no convection is expected across the entire domain, the time slots for forecasting the current weather are used for studying historical cases, or for forecaster training sessions.

Fig 4. shows the coverage of high-impact weather during the Testbed period in previous years. The average number of monthly reports is approximately 1000. Considering that the domain covers the entire European continent (except for Islands and the extreme eastern parts), the weather is usually interesting enough somewhere over Europe.

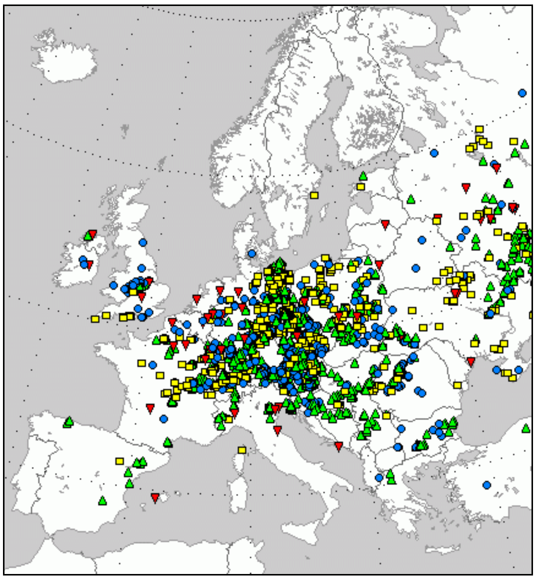


Fig. 5. Severe weather coverage during the Testbed period in 2012; yellow rectangles: severe wind gusts, red triangles: tornadoes, blue circles: flash floods, green triangles: large hail (source: ESWD, www.eswd.eu).

2.3 Forecast verification

During the *verification* slots, the forecasts will be verified subjectively against observed high-impact weather as collected in the European Severe Weather Database (ESSL) and against lightning data. Areas outside of the lightning detection network will be validated using satellite imagery as a proxy for the occurrence of convection. The outcome of the verification procedure is to establish the magnitude of the discrepancies between forecast and observations and to identify possible causes. Such causes may be poor guidance by particular data, poor interpretation of the available data or other reasons.

2.4 Evaluation and reporting

In the evaluation sessions, the value of the individual products to the forecast will be assessed. These assessments result from discussions within the group of participants. At 14:15, a plenary discussion will be held. In addition, sub-groups of participants may be asked to report on the performance of a particular forecast-supporting product. There are three ways in which the feedback is collected:

1. Questionnaires

Questionnaires have been developed for each forecast-supporting product, in collaboration with the responsible researcher/developer. The answers given to these questions will be filled in during the evaluation session, at least once per group per week, but, if needed, more frequently. The collected answers will be sent to the researcher/developer after the conclusion of the Testbed.

2. Testbed Blog

The Testbed blog is a web site (**www.essl.org/testbed/blog**) on which several texts with illustrations on the work at the Testbed will be posted on a daily basis, both by Testbed staff and participants. The posts discuss the forecasting, the products and their performance, as well as general impressions.

3. Direct communication with the developer

Most researchers/developers will be present at the Testbed at a given time. This gives the opportunity to directly interact, discuss and collect feedback on the forecast-supporting products.

2.5 Expert Lectures

Lectures are presentations 30 minutes in length, that will be disseminated online with support from EUMETCAL following the *Daily Briefing*, starting approximately at 0930 UTC (1130 local time). The lecturers include experts on forecasting, modelling, remote-sensing or other relevant topics. These will include scientists from European weather services and overseas, and from international organizations like

EUMETSAT and ECMWF as well as forecasters with a great expertise in the forecasting of convective high-impact weather. A list of speakers is available in **Appendix 2**. Since some changes occur, please visit the Testbed info page for the most current schedule: http://www.essl.org/testbed/info

Participation schedule

Testbed Groups

Participants to the Testbed, forecasters and scientists/developers, will be assigned to each of five groups. These groups will have sizes of approximately 10 persons, not including Testbed staff.

On-site and remote participation

It is recommended that participants first participate one week remotely, followed by a week on site at the ESSL Training Centre in Wiener Neustadt. All participants will however be able to take part in all online sessions. The online participation involves connecting to the Testbed through Saba Meeting teleconferencing system (provided by EUMETCAL) as well as participating in the Daily Briefing, and attending the *Lecture of the day.* These activities take place from 0900 UTC to approximately 1030 UTC. Participants of the first Testbed week will not have the possibility of prior remote participation, but are welcome to attend remotely later.

2.6 Standard tools at the Testbed

Testbed Data Interface

Data of all experimental products as well as conventional meteorological data are displayed through the Testbed Data Interface, which is a collection of intranet pages, that are accessed through a web browser. These pages include the *Multi-Model* page that displays output from several NWP models simultaneously and the *Nowcast* page that allows the user to overlay several layers of satellite, radar, NWP, and observational data as well as various experimental products. For the 2014 Testbed, the data will be made available to remote participants, through the internet. The web page to access is www.essl.org/testbed/data. Participants will receive a valid username and password to gain access also from their home institution for the duration of the Testbed.

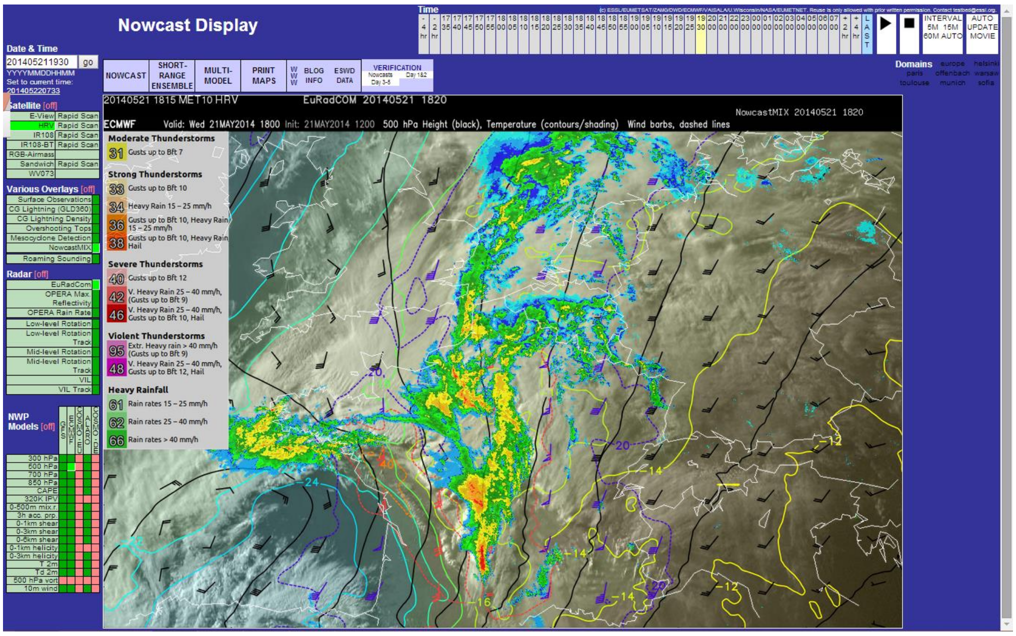


Fig. 6. Nowcast Display

Testbed Participant Page

On a dedicated web page, background information on the experimental products and techniques, beyond the information contained in this Operations Plan is gathered. The web page to access is www.essl.org/testbed/info.

Workstations and printing

ESSL's Research and Training Centre is equipped with 5 workstations that the participants will use to access the Testbed Data Interface. One of the pages of the Testbed Data Interface provides maps of surface observations, that can be printed in A3 format and analysed using provided colour pencils.

Available Standard Meteorological Data

In addition to the experimental products described in the following sections, the following "standard" meteorological is available through the Testbed Data Interface:

NWP

- ECWMF IFS data is provided by ZAMG.
- COSMO-EU (source: DWD)
- COSMO-DE (source: DWD)
- COSMO-DE-EPS (source: DWD; is part of the testing programme)
- ALARO5 (source: ZAMG)
- GFS (source: NCEP)

Satellite

From Meteosat 9 (available every 15 minutes):

- E-View, High Resolution Visible, IR-10.8, IR-10.8 (color enhanced), Airmass-RGB, WV-7.3

From Meteosat 8 RapidScan service (available every 5 minutes):

- E-View, High Resolution Visible, IR-10.8, IR-10.8 (color enhanced)

From these products, a “Sandwich Product” is created, both from Meteosat 9 and from MeteoSat8 RapidScan data.

Radar imagery

- The European radar composite OPERA is made available by ZAMG through an agreement with EUMETNET
- The West-European radar composite EuRadCom is provided by DWD

Observations

- Severe weather observations are available from the European Severe Weather Database.
- SYNOP and METAR surface observations of Europe
- Radiosonde data are available on the internet through the University of Wyoming and the University of Oklahoma

Lightning data

- The GLD360 product by Vaisala which is part of the testing programme, and, secondly, data from the ground-based EUCLID network which can be accessed through a web interface.

3. Forecast-supporting products

A wide range of tools that support the forecaster in early operational or pre-operational stage (Forecast-Supporting Products) are evaluated at the ESSL Testbed. For example, new versions or configurations of numerical weather prediction models, new techniques to extract information from satellite, radar and other remote sensing data. This includes new visualizations and ways to combine different types of meteorological data relevant to the prediction of high-impact weather. The products up for evaluation in 2014 are listed in Table 2, and described in the sections that follow.

Forecast-supporting Product	Developer	Description
3.1 Mesocyclone Detection Algorithm	DWD	Radar-based algorithm to detect and assign severity levels to mesocyclones, based on Doppler velocity data from radars in the German national radar network
3.2 VIL-(Track)	DWD	Radar-derived vertically integrated liquid product.
3.3 Rotation (-Track)	DWD	Doppler-radar-derived shear/rotation at several levels, and corresponding tracks.
3.4 NowCastMIX	DWD	Grid-based system combining nowcast data from multiple sources using fuzzy logic
3.5 GLD360	VAISALA	Global Lightning Detection network
3.6 Overshooting Top Detection	SSAI @ NASA	Algorithm to detect overshooting thunderstorm tops
3.7 COSMO-DE (-EPS) Visualizations	DWD	Various visualizations of high-resolution convection-permitting ensemble NWP model, and several parameters to compare with remote-sensing.
3.8 European Severe Weather Database	ESSL and partners	Database of severe weather events filled with reports in near real-time

Table 6. Forecast-supporting products.

3.1 Mesocyclone Detection Algorithm

Thomas Hengstebeck (DWD)

Data basis

In the 5 min scan strategy of the DWD radar network 10 sweeps corresponding to 10 elevations ranging from 0.5° to 25° build up a 3D-volume for each radar site. The quality controlled basic data of this volume scan are provided as input for the MDA (Hengstebeck et al., 2011). The quality control includes the removal of spoke and ring artefacts, a clutter removal (static and dynamic clutter), an attenuation correction, the interpolation of “holes” within the reflectivity data and a speckle remover. A dual-PRF unfolding error correction is applied to the radial velocity data. The MDA uses the radial wind (Doppler wind) information of a volume as detection basis. The further classification of a detected mesocyclone, i.e. the severity estimation, is based on both radial wind and reflectivity information. A detected mesocyclone cell is assigned a time stamp corresponding to the time of the scan begin, the so-called reference time, which is 0, 5, 10, 15, etc min after the full hour.

Description of Algorithm

General remarks

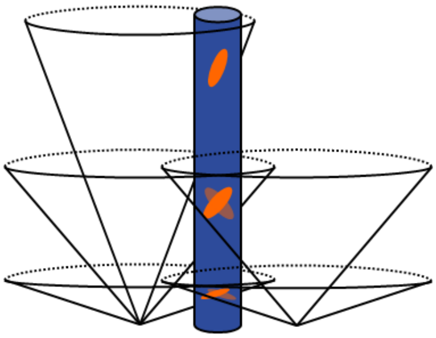
A mesocyclone (often found in connection with the updraft in supercells) is an atmospheric vortex field, which can be described by a so-called “Rankine Combined Vortex“-model (Zrnic et al., 1985). Here, one distinguishes between an outer and inner region of rotation. In the outer region, the rotation smoothly merges into the overall wind field. However, the inner region is characterized by rigid rotation and shows constant and high values of azimuthal shear. This region of high azimuthal shear – in the Doppler wind data visible as central part of the typical rotation dipole - is the signature that is searched for by the automatic mesocyclone detection algorithm. The algorithm follows the approach described in (Zrnic et al., 1985).

Pattern Vectors and Features

A so-called "pattern vector"-method is used for identifying regions of high azimuthal shear, i.e. in each radial wind sweep one tries to find contiguous azimuthal sequences of pixels with high azimuthal shear. The found pattern vectors are filtered with respect to the values of azimuthal shear and specific angular momentum and are grouped to so-called features (spatially correlated pattern vectors). The features are filtered according to symmetry criteria: Since a feature ideally resembles a complete rotation signature, it should have roughly equal extensions in range and azimuth directions. The "pattern vector-feature"-search is performed for each sweep of each volume (all radar stations) yielding a list of geo-referenced features (i.e. features with latitude / longitude coordinate pairs).

Meso-Objects

Within the above described list vertically aligned features, i.e. features with similar latitude / longitude coordinates, are searched for. A group of such features resembles a so-called mesocyclone-object (see Figure), which is classified as mesocyclone-cell with related severity level after validation. (In NinJo an upside down triangle symbol with color coding of severity index is visualized).



A vertically aligned group of geo-referenced features (orange patches) forms a mesocyclone object (depicted as blue cylinder).

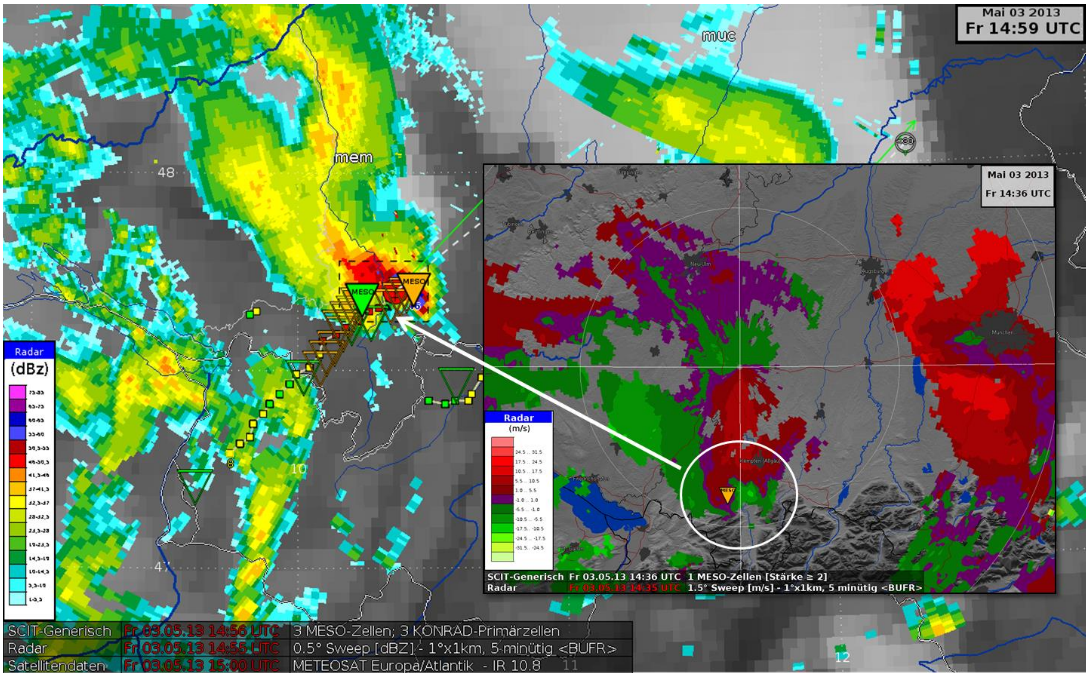
The validation is done with the help of the reflectivity data. Properties of the region of the detected mesocyclonic rotation like mean / max. reflectivity, cell-based VIL (vertically integrated liquid water), VIL density , height of lowermost detected rotation signature over ground, total height of rotational column and echo top height are calculated.

The severity level is determined by applying thresholds to these cell-characteristics. The severity levels 2-5 imply mesocyclonic rotation with increasing strength and clearness. Severity-level 1 rather serves for test / tuning purposes, but may also give hints to early stages of rotation. The latitude / longitude-coordinate-pair of the mesocyclone-cell is determined as shear weighted mean of the lowest 3 km of the mesocyclone object. Table A1 shows the basic thresholds.

Meso cell attributes		**Severity-Level**				
		1	**2**	**3**	**4**	**5**
Max. dBZ	≥	10	30	40	50	55
Avg. dBZ	≥	10	20	25	35	40
Height agl [km]	≤	5	3	2.5	2	1.5
Meso Height [km]	>	0	0	2	4	6
VIL [kg m^{-2}]	>	2	5	10	20	30
Echo top height [km]	>	1	3	4	5	7
VIL dens. [g cm^{-3}]	>	0	1	1.5	2	2.5
Max. shear [m/s/km]	>	0	0	0	15	20
Max. mom. [m/s·km]	>	0	0	0	150	200

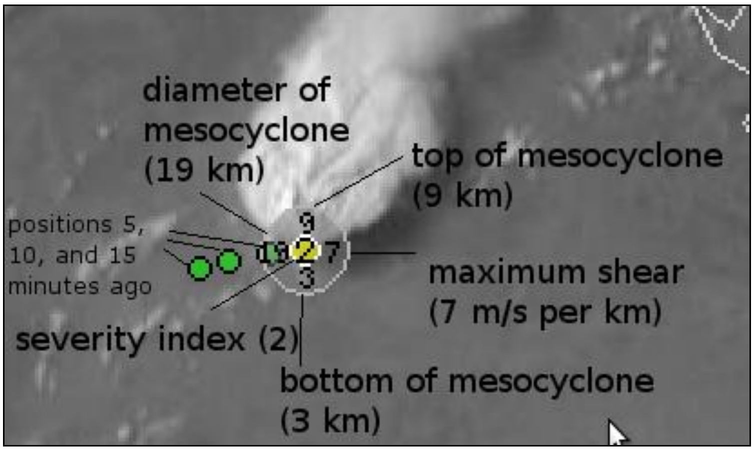
Table A1: Basic thresholds for severity estimation.

Some of the mesocyclone attributes, in particular VIL, are affected by the geometrical resolution, which naturally changes with the distance from the radar. Therefore a fuzzy logic scheme is used, which allows a slight violation of the thresholds. This means that e.g. VIL my drop by as much as 4.5% below the threshold of the current severity class without a change of the severity (adjustable value).



Example of mesocyclone detections visualised by means of the NinJo workstation system at DWD. This weather case is addressed in the next two sections as well (VIL and rotation products).

For the ESSL Testbed, the algorithm has been integrated into the Nowcast Display. The figure explains which parameters are shown.



Visualisation of a mesocyclone detection in the Testbed Nowcast Display.

At the 2014 ESSL Testbed, a new set of severity levels will be available for comparison with the set above, called the “strict” version. Here, shallow and very small mesocyclones are filtered out completely.

Hengstebeck, T., D. Heizenreder, P. Joe and P. Lang (2011): The Mesocyclone Detection Algorithm of DWD*, 6th European Conference on Severe Storms, 3-7 October 2011, Palma de Mallorca, Spain.*

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

3.2 Vertically integrated liquid water (VIL) and VIL-Track

Thomas Hengstebeck (DWD)

Data basis

The quality controlled 3D-reflectivity data are used as input (see section 3.1).

Description of Algorithm

For the VIL calculation the following formula is used (Greene et al., 1972):

$$VIL = \Sigma_i \, 3.44 \times 10^{-6} \, [(Z_i + Z_{i+1})/2]^{4/7} \, \Delta h_i$$

Here, the sum is carried out over different height layers. Z_i and Z_{i+1} are the reflectivity at the bottom and top of the i-th layer with the thickness Δh_i. The units are as follows:

$[Z] = mm^6/m^3$

$[\Delta h] = m$

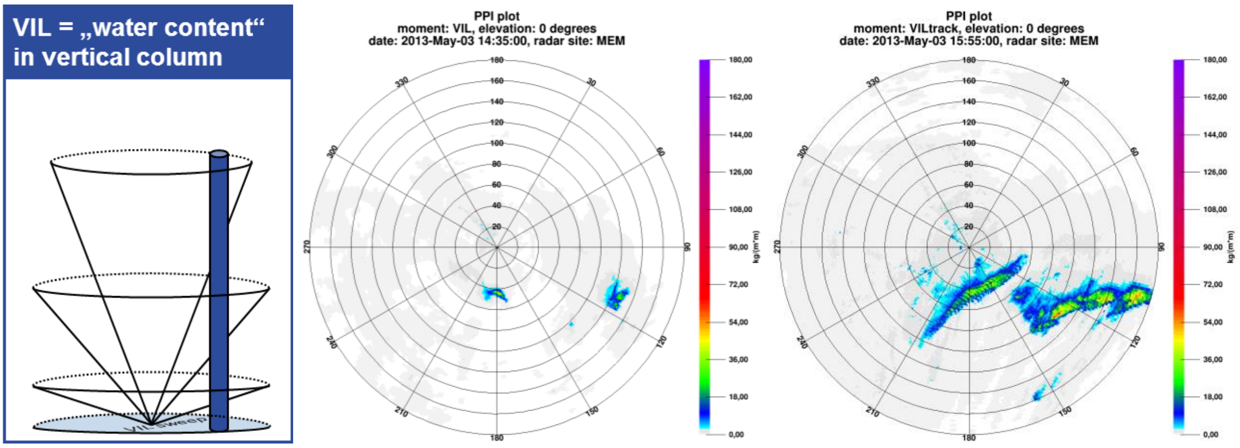
$[VIL] = kg/m^2$ or mm

Above given formula indirectly contains a Z-R relation, the water equivalent is derived under the assumption of a Marshall Palmer drop size distribution. Details can be found in (Greene et al., 1972).

The VIL product at DWD is generated for each radar site independently using the 3D-reflectivity volume (see figure below) *without* need for an intermediate CAPPI generation. First an empty “VIL sweep” with elevation angle 0° is created, which is shown on the left side of the figure below as light blue lowermost sweep. For each range-bin of this sweep (pixel in the polar sweep grid) a VIL value is calculated by integrating exactly vertical using above given equation. The reflectivities Z_i are taken from the intersected sweep data, which implies that the layer thickness h_i is not constant.

A so-called VIL Track is created by accumulating VIL sweep products from a certain time interval, which should be chosen large enough to visualize tracks of moving cells. Currently, this time is set to 3 hours. In the accumulation procedure each pixel of the VIL Track sweep is assigned the maximum value of all VIL values for this pixel in the corresponding VIL sweep products.

Composites of both radar site related VIL and VIL Track products are generated using the maximum value criterion in regions of overlapping radar scans.



Left: VIL value calculation for a single pixel of the polar VIL sweep coordinate grid. Observational data at DWD contains 10 sweeps. Here, 3 sweeps are depicted for illustration purposes. Middle: VIL sweep as derived from observational data (see label for details). Right: Corresponding VIL Track.

Interpretation guidelines

VIL can be used for a classification of storm severity (Kitzmiller et al. 1995). VIL values exceed 10 kg/m^2 in convective events (thunderstorms); the higher the VIL, the more severe the storm. NowcastMix uses the VIL product as one of its input data sets. The VIL Track product is useful for depicting paths of moving cells. It should be noted that VIL overestimates the “water content” when hail is present (especially water coated hail). In the VIL formula, as given above, the reflectivities are always interpreted as belonging to liquid hydrometeors. However, this overestimation pronounces severe storms, which make VIL a kind of “storm severity indicator”.

There are unavoidable geometrical influences on the VIL radar product, which should be taken into account when interpreting VIL values: In the vicinity of a radar station (< ca. 20 km) precipitation in larger heights is not captured by the radar scan, so that possibly too low VIL values are observed in the corresponding radar site related VIL product. On the other hand, in large distance to the radar site (> ca.100 km) the spatial resolution of the radar scan is limited and precipitation close to ground may not be captured (overshooting precipitation). Thus, possibly too low and imprecise VIL values can be expected. Both draw backs are mitigated by the use of VIL and VIL Track *composites*, but are still noticeable e.g. at border regions.

Greene, D.R. and R.A. Clark (1972): Vertically Integrated liquid Water - A New Analysis Tool*, Monthly Weather Review,* ***100****, 548–552.*

Kitzmiller, D.H., W.E. McGovern and R.F. Saffle (1995): *The WSR-88D severe weather potential algorithm, Weather and Forecasting,* ***10,*** *141–159.*

3.3 Rotation and Rotation-Track

Thomas Hengstebeck (DWD)

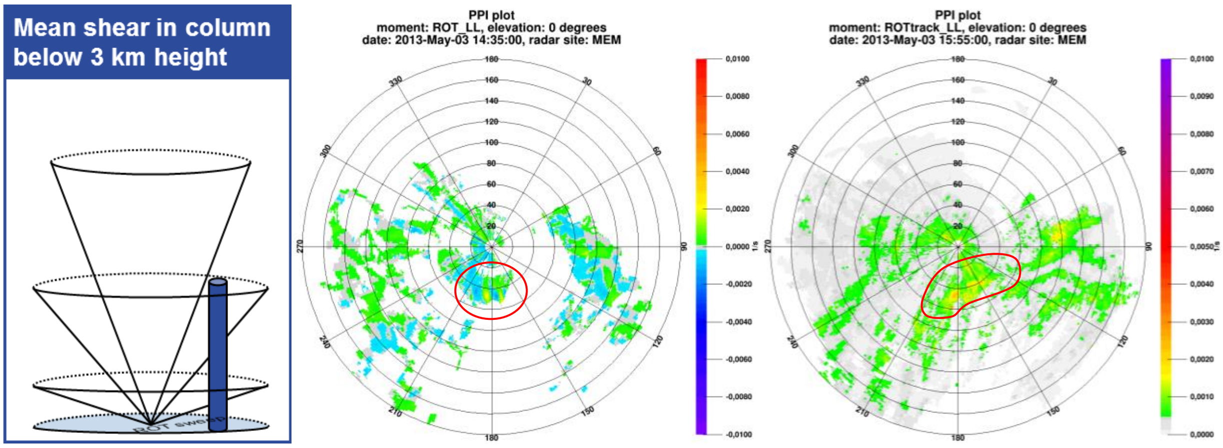
Data basis

The quality controlled 3D reflectivity and radial velocity radar data are used as input (see section 3.1).

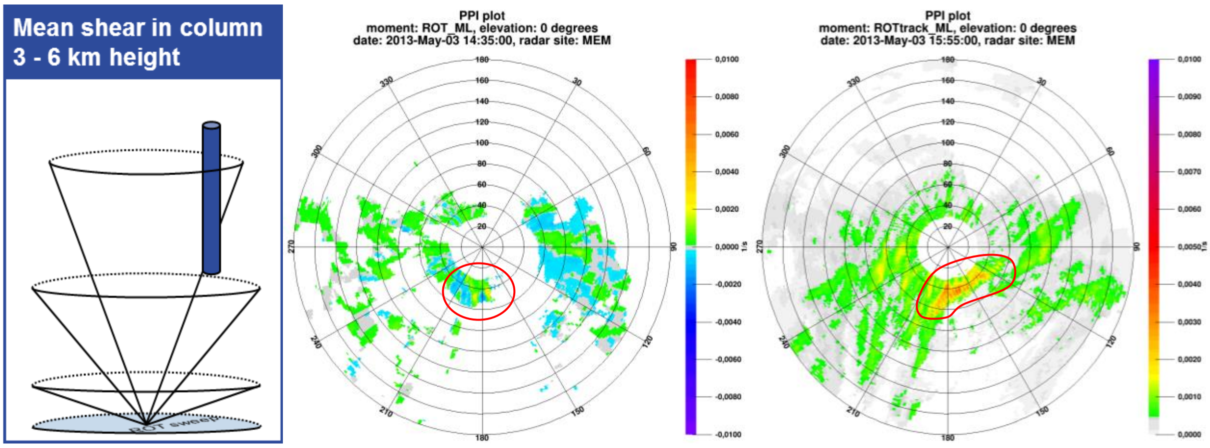
Description of Algorithm

The rotation product is meant for visualising the azimuthal shear connected with rotation in meso-(anti)cyclones. The data processing for the rotation algorithm starts by applying a smoothing filter to each radial velocity sweep of the 3D Doppler volume. Subsequently, the azimuthal shear is calculated pixelwise averaging over 3 azimuthally adjacent range bins.

The resulting 3D-volume of azimuthal shear sweeps is then further processed (see also the figures below). In analogy to the VIL product, a 0°-elevation sweep is generated. Each pixel within this sweep is assigned a value corresponding to the average azimuthal shear in the vertical column above the pixel. For the low level (LL) rotation product the column extends from 0 to 3 km above ground level (agl). In case of the mid level (ML) rotation product the column is ranging from 3 to 6 km height agl. A minimum reflectivity of 5 dBZ is necessary for a shear value to enter the averaging procedure.



Left: low level rotation (ROT-LL) value calculation for a single pixel of the polar “ROT” sweep coordinate grid. Middle: ROT-LL sweep from observational data (see figure label for details). Right: ROT-LL Track (time interval for accumulation is 3 hours). Compare also figure in section 3.1 (mesocyclone detection). In this weather case, the rotation is more restricted to higher atmospheric layers as can be seen from the ROT-ML product (next figure).



Left: mid level rotation (ROT-ML) value calculation for a single pixel of the polar "ROT" sweep coordinate grid. Middle: ROT-ML sweep from observational data (see figure label for details). Right: ROT-ML Track (time interval for accumulation is 3 hours).

Both LL and ML rotation products show positive (cyclonic) and negative (anti-cyclonic) shear. The related track products are obtained by pixelwise accumulating the maxima from the LL and ML rotation products of the last 3 hours (which corresponds to 36 sweep products due to the 5 min scan strategy), so that only positive shear is picked up.

The rotation and rotation track products are inspired by (Smith et al., 2004). However, it was found that picking up the maximum value in the column leads to noisy rotation products, so that finally the mean value was preferred.

For both rotation and rotation track products, which are related to a radar site, composite products are generated. In case of the rotation products (LL and ML), in regions of overlapping radar scans the shear value is taken, the absolute value of which is largest. In case of the track products only positive azimuthal shear is evaluated. The more frequently occurring cyclonic vortices are represented by an area of positive shear (centre of rotation) flanked on two sides by negative shear values (regions where the rigid rotation of the inner core merges into surrounding wind field). Accumulating both positive and negative shear values (by investigation of absolute value) would result in a complicated picture showing two negative rotation tracks beside each positive rotation track and vice versa.

Interpretation guidelines

Rotation and rotation track products should be used in addition to the mesocyclone detection as verification check. Moving rotating cells are expected to produce tracks of high azimuthal shear visible in the rotation track product. The low level and mid level rotation track products can help to distinguish between close to ground (implication for possible occurrence of tornadoes) and mid level atmospheric rotation.

A discussion of non-mesocyclonic signatures can be found in (Miller et al., 2012). Here it is stated that “significant vertical shear near the surface can cause false high azimuthal shear values very close to the radar” (Miller et al., 2012, p. 577) and that “bands of high azimuthal shear values associated with linear meteorological phenomena like outflow boundaries and bow echoes also appear in the rotation track fields” (Miller et al., 2012, p. 580).

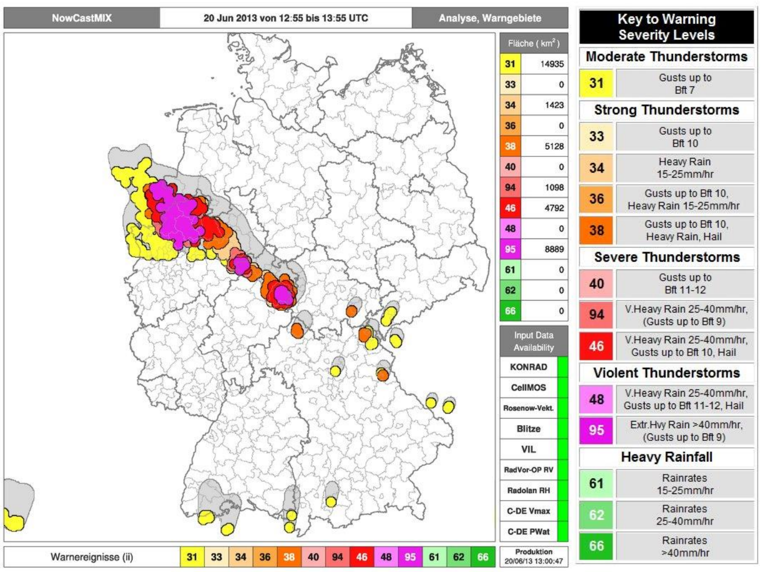
Smith, T.M. and K.L. Elmore (2004): The Use of Radial Velocity Derivatives to Diagnose Rotation and Divergence, *11th Conference on Aviation, Range, and Aerospace Meteorology, 2004.*

Miller, M.L., V. Lakshmanan and T. Smith (2012): An Automated Method for Depicting Mesocyclone Paths and Intensities, *Weather and Forecasting, 2012*

3.4 NowcastMix

Paul James (DWD)

The GermanWeather Service’s AutoWARN system integrates various meteorological data and products in a warning decision support process, generating real-time warning proposals for assessment and possible modification by the duty forecasters. These warnings finally issued by the forecaster are then exported to a system generating textual and graphical warning products for dissemination to customers. On very short, nowcasting timescales, several systems are continuously monitored. These include the radar-based storm-cell identification and tracking methods, KONRAD and CellMOS; 3D radar volume scans yielding vertically integrated liquid water (VIL) composites; precise lightning strike locations; the precipitation prediction system, RadVOR-OP as well as synoptic reports and the latest high resolution numerical analysis and forecast data. These systems provide a huge body of valuable data on rapidly developing mesoscale weather events.



However, without some form of pre-processing, the forecasters could become overwhelmed with information, especially during major, widespread summer convective outbreaks. NowCastMIX thus processes all available nowcast data together in an integrated grid-based analysis, providing a generic, optimal warning solution with a 5-minute update cycle, combining inputs using a fuzzy logic approach.

The method includes optimized estimates for the storm cell motion vectors by combining raw cell tracking inputs from the KONRAD and CellMOS systems with vector fields derived from comparing consecutive radar images. Finally, the resulting gridded warning fields are spatially filtered to provide regionally-optimized warning levels for differing thunderstorm severities which can be managed adequately by the duty forecasters. NowCastMIX thus delivers an ongoing real-time synthesis of the various nowcasting and forecast model system inputs to provide consolidated sets of most-probable short-term forecasts. More information is given in James et al. (2011).

3.5 Vaisala GLD360

Ryan Said, Teppo Rouvi (VAISALA)

In 2009, Vaisala launched the Global Lightning Dataset GLD360. GLD360 data is produced by a Vaisala owned and operated lightning detection network that provides uniform, high quality lightning information across the globe. Data delivered includes CG stroke and cloud lightning information – and it can be delivered to the customer in real time.

Patented sensor algorithms and extreme sensitivity give GLD360 sensors the ability to detect lightning at distances up to 9,000 km. Each GLD360 sensor provides both direction and time-of-arrival information. Scientific studies have shown that lightning networks using a combination of direction and time-of-arrival sensor information provide significant detection efficiency and redundancy improvements over lightning networks using time-of-arrival sensor information alone. Through its GLD360 offering Vaisala provides the highest quality global lightning data in the market:

- Location Accuracy (LA): The median cloud-to-ground lightning stroke location accuracy 2-5 km
- Detection Efficiency (DE): 70% for cloud-to-ground flashes and >5% for cloud flashes with near uniform coverage around the globe (ref. the DE map in the Figure 1 below).
- Polarity & Peak Amplitude (kA): Unique to the GLD360 is the ability to provide polarity & peak amplitude (kA), which is typically the reserve of precision networks. The GLD360 polarity classification is greater than 90% and peak current estimates are accurate to within 25 % of the peak current value.

To ensure GLD360 provides the high level of network performance described above, validation studies have been performed in North America, Europe, and are now ongoing in South America. The results of these studies show that GLD360 has a CG flash detection efficiency of 70% or greater and a median CG stroke location accuracy of 2-5 km in all three regions.

Long-range severe weather detection has traditionally been limited by data gaps, leading to situations where people have late or no warnings. GLD360 is the only severe weather data set that has no data gaps and provides a nearly uniform, global coverage. GLD360 routinely detects over 1.5 million lightning events across the world each day.

As your global window, the GLD360 provides immediate access to a world-wide lightning dataset, anywhere around the globe. Vaisala thus has a unique offering that supports:

- Ability to detect and characterize lightning in areas of the world where meteorological observations may be partially lacking or absent.
- Lightning as a radar proxy or radar complement where weather radar information is limited or nonexistent.

- The ability to extend the range of lightning being assimilated into weather models and enhance the foresight of advancing weather systems.
- Quality lightning warnings on a truly global scale.

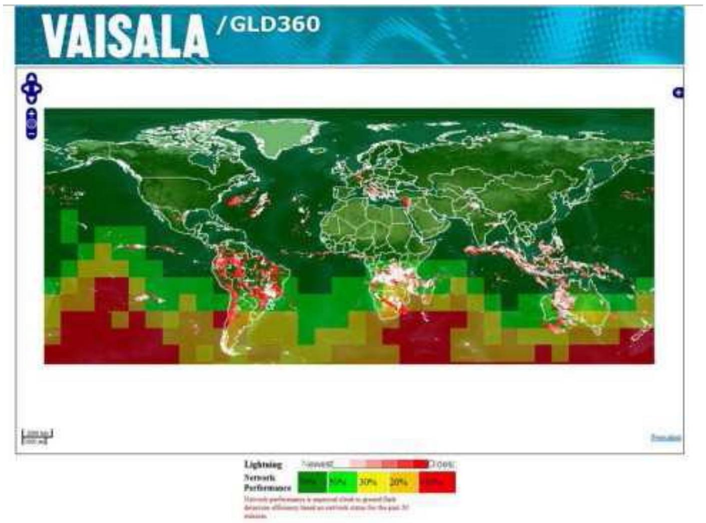


Figure: The global detection efficiency map for GLD360.

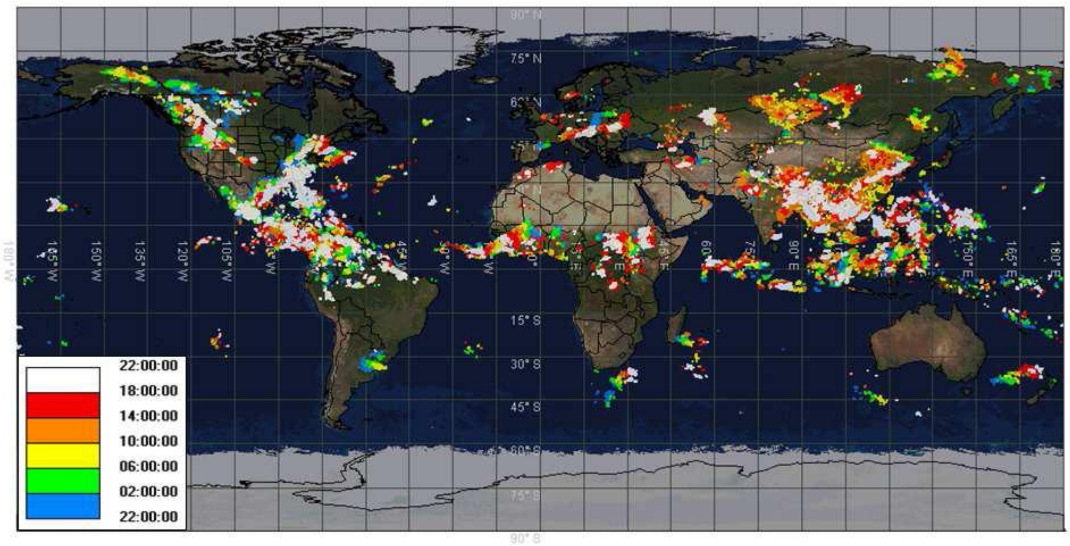
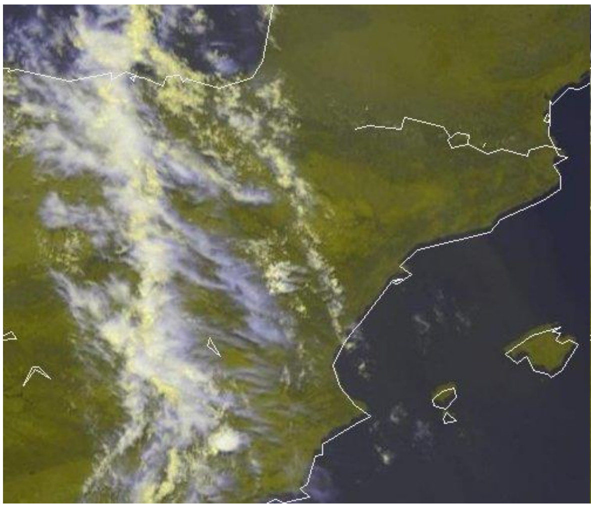
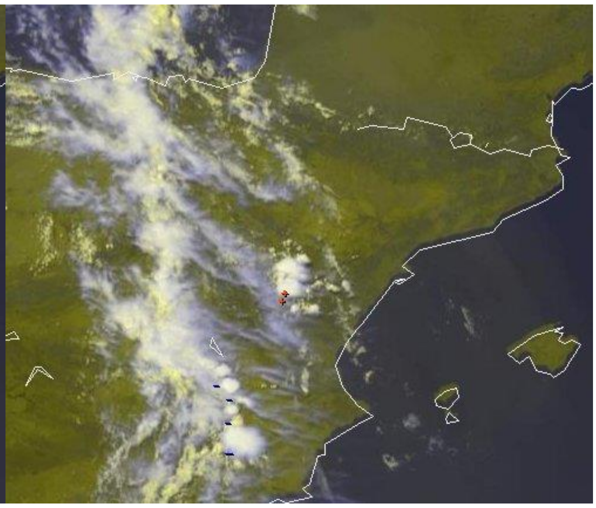
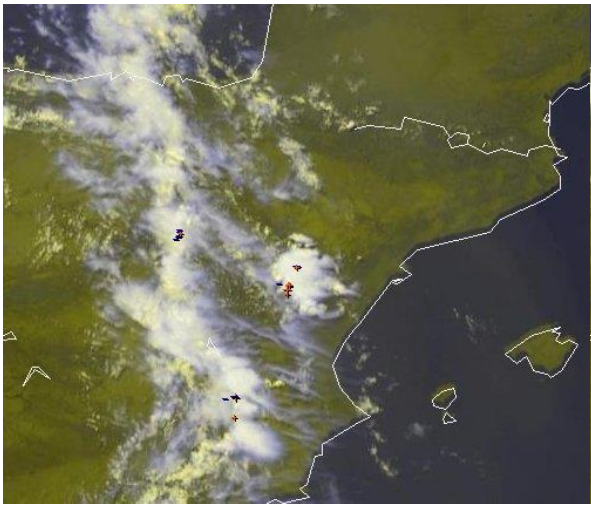
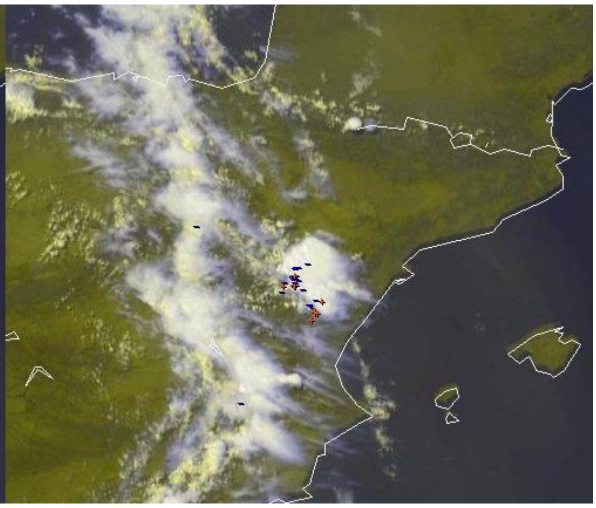


Figure: Global image showing more than two million lightning events reported by GLD360 on 22-23 June 2011. Colors show age of lightning events in 4-hour intervals starting on 22 June at 22:00 and ending on 23 June at 22:00.

1230 UTC

1300 UTC

1330 UTC

1400 UTC

E-View satellite imagery (source: EUMETSAT/ZAMG/ESSL) with GLD360 overlay on 27 June 2012.

3.6 Overshooting Top Detection

Kristopher Bedka, Science Systems and Applications, Inc. @ the NASA Langley Research Center

Overshooting tops (OTs) are produced by deep convective updraft cores of sufficient strength to rise above the storms' general equilibrium level near the tropopause region and penetrate into the lower stratosphere. OTs appear in ∼11 μm longwave IR window imagery as a small cluster (< 15 km diameter) of very cold pixels relative to the surrounding cirrus anvil cloud. An OT with a significant vertical protrusion above the surrounding cirrus anvil cloud can act as an obstruction to the jet stream wind flow. OTs often inject a significant amount of water vapor into the lower stratosphere which can condense to form a cirrus plume which resides at a height above the primary cirrus anvil cloud. A region of anomalously warm IR brightness temperatures (BTs) is often found downstream of the OT region in conjunction with the above-anvil cirrus plume which radiates at the stratosphere temperature that is warmer than the primary anvil. These two processes combine to produce patterns in IR satellite imagery known as the "cold-ring" or the "enhanced-V signature" (see Figure below). Cold-ring signatures are often found in regions of weaker jet stream winds than enhanced-V signatures, though a storm top pattern can evolve between a V- and cold-ring signature throughout the storm lifetime (Setvak et al. 2010). The combination of the cold OT signature and downstream warm region within the enhanced-V or cold-ring will be referred to here as an anvil thermal couplet (ATC).

Thunderstorms with OTs frequently produce hazardous weather at the Earth's surface such as heavy rainfall, damaging winds, large hail, and tornadoes. Maximum radar reflectivity and precipitation echo top height is found at or near the time of OT detections (Dworak et al. 2012). Turbulence and lightning are often concentrated near the OT region, indicating that OTs represent significant hazards to ground-based and in-flight aviation operations. Thunderstorms with a strong ATC signature (i.e. OT minus warm region BT diff > 8 K) have been shown to be especially severe (Brunner et al. 2007). Dworak et al. (2012) and McCann (1983) show that the OT and enhanced-V signatures can appear 30 minutes before the onset of severe weather on the ground, providing a forecaster with crucial situational awareness and possibly additional warning lead time.

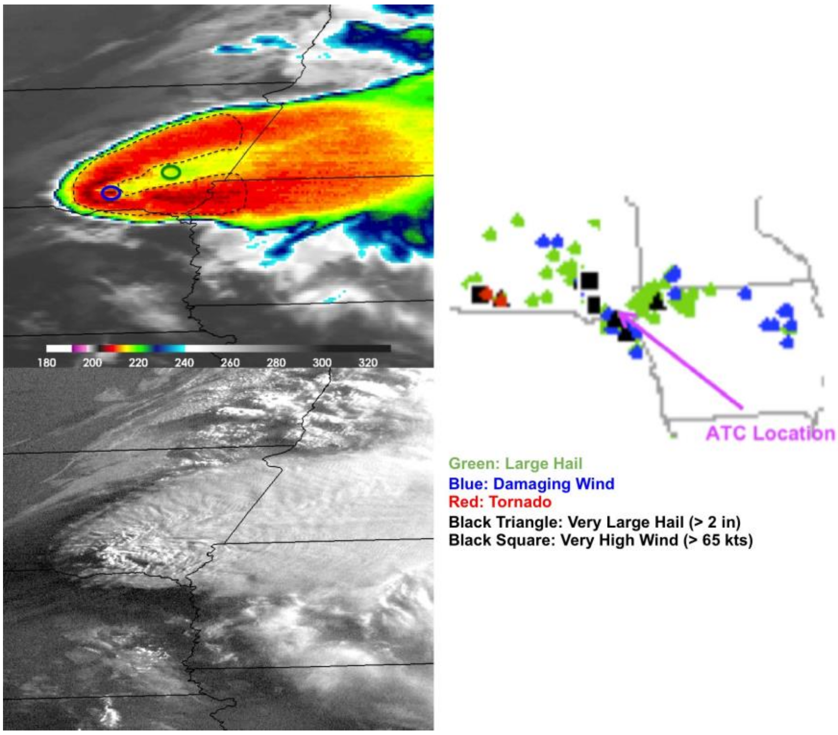


Figure. (upper-left) An enhanced-V producing storm over the U.S. Northern Plains in GOES-12 IR window channel imagery on 9 July 2009. The enhanced-V signature is outlined with a dashed line, the objective OT detection is shown with a blue circle, and the downstream warm region detection is shown with a green circle. (lower-left) GOES-12 Visible channel image for the same scene. (right) Severe weather reports associated with this storm. The location of the storm in the GOES image is shown, indicating that the storm was producing significant severe weather at the time of OT and enhanced-V detection.

Objective satellite-based OT and ATC detection algorithms have been developed for the GOES-R Aviation Algorithm Working Group (Bedka et al. 2010; Bedka et al. 2011). As the OT and ATC are often small in size and short-lived, the algorithms perform optimally with ≤ 2 km spatial and ≤ 5 min temporal resolution imagery but they can be applied to current 15 min 3 km MSG SEVIRI and 4 km GOES imagery. The OT detection component uses a combination of IR window channel brightness temperatures (BTs), a NWP model tropopause temperature forecast, and OT size and BT criteria defined through analysis of OT producing storms in GOES, MODIS, and AVHRR imagery. The enhanced-V/cold-ring ATC detection algorithm requires detection of the OT. A set of spatial IR BT and BT gradient checks are performed throughout the anvil cloud surrounding the OT to identify a significant downstream warm region that composes the ATC. Validation studies indicate an OT detection POD and FAR of ~30-50% and 6-20% for current geostationary image inputs, respectively, depending on the dataset used to define an OT event. ATC detection has not been validated for current geostationary imagery.

Two products will be provided via a webpage for evaluation within the 2012 ESSL Testbed: 1) an OT detection mask, and 2) an ATC (i.e. enhanced-V or cold-ring) detection mask.

3.7 COSMO-DE (-EPS) visualizations

DWD (Lars Wiegand, Susanne Theis, Ulrich Blahak and others) / Pieter Groenemeijer (ESSL)

COSMO-DE-EPS is an ensemble of the German Weather Service's high-resolution, convection permitting model COSMO-DE (COnsortium for Small-scale MOdelling - DEutschland). Different initial and boundary conditions of the ensemble members are obtained from four different COSMO runs at 7 km which are in turn driven by different global NWP models (ECMWF IFS, DWD GME, NCEP GFS and UKMO UM) and varying parameters during the assimilation phase. Additionally, the ensemble members use varying model physics parameters.

3.7.1 Visualizations of the ensemble

Visualization of large volumes of ensemble data is a challenge. For example, in plotting the average and standard deviation of forecast quantities much information is lost. For a field like radar reflectivity such a display would not make much sense. In past years, ESSL has evaluated several visualization of high-resolution ensemble data. For several parameters the methods where by the most extreme value of any ensemble member at each location was plotted was compared to plotting contours of ensemble members exceeding a threshold and the pointwise probability of exceedance. As a logical next step, a 'probability of exceedance' will now be computed using the methods described by Ben Bouallègue and Theis (2013). These products called 'fuzzy' and 'upscaled'. The fuzzy method is a smoothing method that enlarges the ensemble sample size by including neighbouring forecasts and the upscaled method modifies the reference area of probabilities. At the Testbed, we will collect forecaster feedback on these products and compared them with the traditional pointwise or local probabilities.

At the 2013 Testbed it was noted that small-scale variations in convective parameters such as CAPE (Convective Available Potential Energy) and CIN are simulated by the COSMO-DE and COSMO-DE-EPS models, and that these may be relevant for the development and life cycle of convective storms. At the 2014 Testbed, we will visualize various statistical measures of the distribution of CIN and CAPE and investigate whether they can benefit forecasting convective storms by characterizing the pre-convective environment more accurately than coarser models.

3.7.2 Particular model fields

There are several ways to characterize whether simulated convective storms are prone to produce large hail, some of which have also been tested at NOAA's Hazardous Weather Testbed. A candidate quantity that can be made available easily by DWD is the total integrated graupel (total graupel). At the Testbed, we will perform a subjective assessment of whether this parameter, preferably treated in an ensemble sense, can be used to indicate the probability of large hail with up to 27 hours lead time (i.e. the forecast time of the COSMO-DE model). In addition, several new radar products have been developed at DWD that can, in principle, be simulated by a convection-permitting model like COSMO-DE, the rotation and rotation track products. We will perform an initial comparison of vertically integrated liquid and compare those directly that to the values derived from radar measurements. We will investigate whether the information that is thus obtains supports storm forecasting beyond the information from measures such as (simulated) reflectivity. Secondly, COSMO is able to compute rotation in thunderstorm updraughts. We will compare these to the new radar-derived rotation and rotation-track products.

General assessment of model performance

As at previous Testbeds, the ESSL team and the participants will monitor the overall performance of the COSMO-DE and COSMO-DE-EPS models, and will provide related feeback. Points of attention will include any tendencies to under- or overforecast convective initiation, the storm life cycle and secondary initiation of storms.

A complete list of visualized parameters will be added and be available at the Testbed.

3.8 European Severe Weather Database, ESWD

Pieter Groenemeijer, Thilo Kühne, Alois Holzer (ESSL)

The ESWD (Groenemeijer et al, 2004, 2009; Dotzek et al, 2009) is a dataset of severe weather reports managed by ESSL. The dataset is fed by observations from cooperating National (Hydro-)Meteorological Services, networks of voluntary observers, the general public and by ESSL itself. The following categories of severe weather are included in the ESWD at this time:

- straight-line wind gusts (v > 25 m s-1)
- tornadoes
- large hail (diameter > 2 cm; or layer > 2 cm)
- heavy precipitation
- damaging lightning strikes
- and several others

The ESWD database can be run in a *Nowcast mode* that features a map showing the reports in real-time as they are reported by its various sources. At the Testbed, the ESWD's usefulness for both nowcasting and forecast verification purposes will be evaluated.

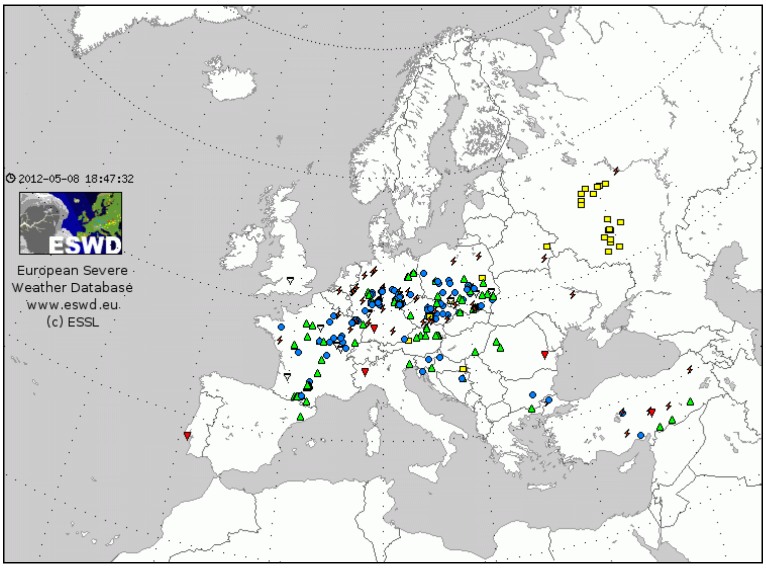


Figure: Example ESWD database display with several rain (blue), hail (green), tornado (red) and severe wind reports (yellow) plotted.

Appendix 1: List of on-site participants

As of 22 May 2014

Week 1: 2 – 6 June

Heinz Fritzl – AustroControl, Austria
Thomas Kumpfmüller – AustroControl, Austria
Josef Lang – ZAMG, Austria
Santa Buholce – LEGMC, Latvia
Lech Buchert – IMGW, Poland
Teppo Rouvi – VAISALA, Finland
Stefano Zanini – MeteoSwiss
Lars Wiegand – DWD, Germany
Dean Gill – MeteoSwiss
Christoph Gatzen – ESTOFEX / ESSL
Georg Pistotnik – ESSL
Mateusz Taszarek – ESSL
Alois Holzer – ESSL
Georg Pistotnik – ESSL
Pieter Groenemeijer – ESSL

Week 2: 10 – 13 June

Julia Fruntke – DWD, Germany
Witold Wiazewski – IMGW, Poland
Piotr Szewczak – IMGW, Poland
Paavo Korpela – FMI, Finland
Niko Tollman – FMI, Finland
Monika Kaseja – IMGW, Poland
Eveliina Tuovinen – FMI, Finland
Bogdan Antonescu – U. Manchester, U.K.
Christian Pehsl – ZAMG, Austria
Paul James – DWD, Germany
Thomas Hengstebeck – DWD, Germany
Darrel Kingfield – OU/NSSL/NOAA, USA
Tomas Pucik – SHMÚ, Slovakia
Georg Pistotnik – ESSL
Mateusz Taszarek – ESSL
Alois Holzer – ESSL
Georg Pistotnik – ESSL
Pieter Groenemeijer – ESSL

Week 3: 16 - 20 June

Mathias Rudolph – DWD, Germany
Olga Mätlik – EEA, Estonia
Janusz Zielinski – IMGW, Poland
Meda Daniela Andrei – RNMA, Romania
Alexander Ohms, ZAMG – Austria
Michal Mercik, IMGW – Poland
Andreas Hostettler – MeteoSwiss
Anja Westermayer – MunichRE, Germany
Darrel Kingfield – OU/NSSL/NOAA, USA
Georg Pistotnik – ESSL
Thilo Kühne – ESSL
Kathrin Riemann-Campe – ESSL
Mateusz Taszarek – ESSL
Alois Holzer – ESSL
Georg Pistotnik – ESSL
Pieter Groenemeijer – ESSL

Week 4: 23 - 27 June

Judita Liukaityte – LHMS, Lithuania
Mateusz Barczyk – IMGW, Poland
Piotr Zurawski – IMGW, Poland
Stefan Laps – MeteoGroup, Germany
Andreas Frank – ZAMG, Austria
Andreas Tschapek – DWD, Germany
Dennis Dalter – MeteoGroup, Germany
Tomislav Kozaric – DHMZ, Croatia
John Hart – SPC/NOAA, USA
Helge Tuschy – DWD, Germany
Mateusz Taszarek – ESSL
Alois Holzer – ESSL
Georg Pistotnik – ESSL
Pieter Groenemeijer – ESSL (Mon-Tue)

Appendix 2: Expert Lectures

Expert lectures are daily returning lectures (30 minutes plus 15 minute question time) on a specific topic, starting after the Daily Briefing at 11:00 l.t. / 0900 UTC has ended, i.e. between 11:30 and 11:45 l.t. (0930-0945 UTC). They are intended both for the audience on site and for remote participants that can follow the presentation through the Saba Meeting teleconferencing software.

Day		**Speaker**	**Topic (preliminary title)**
Monday	2 June	David Schultz (U. Manchester)	Scientific Forecasting
Tuesday	3 June	Thomas Hengstebeck (DWD)	Mesocyclone detection and radar products
Wednesday	4 June	Lars Wiegand (DWD)	COSMO-DE-EPS
Thursday	5 June	Ryan Said (VAISALA)	Lightning Detection
Friday	6 June	Christoph Gatzen (ESTOFEX)	Predicting severe wind gusts
Tuesday	10 June	Darrel Kingfield (NSSL/NOAA)	Overview of NOAA/NWS Decision Assistance.
Wednesday	11 June	Paul James (DWD)	The NowcastMIX
Thursday	12 June	Thomas Hengstebeck (DWD)	Mesocyclone detection and radar products
Friday	13 June	Tomas Pucik (SHMU/U. Brno)	Sounding-based Severe Weather Predictors
Monday	16 June	David Schultz (U. Manchester)	Fronts and Severe Convection
Tuesday	17 June	Lars Wiegand (DWD)	COSMO-DE-EPS
Wednesday	18 June	Darrel Kingfield (NSSL/NOAA)	Diagnosing Storms with Polarimetric Variables
Thursday	19 June	Georg Pistotnik (ESSL)	Supercell Rotation
Friday	20 June	Anja Westermayer (MunichRe)	Severe Storms Environments from ERA data
Monday	23 June	Helge Tuschy (DWD/ESTOF.)	Forecasting Convective Flash Floods
Tuesday	24 June	John Hart (SPC/NOAA)	Overview: Severe Weather Forecasting
Wednesday	25 June	Thomas Hengstebeck (DWD)	Mesocyclone Detection and Radar Products
Thursday	26 June	John Hart (SPC/NOAA)	Supercell Tornado Forecasting
Friday	27 June	Georg Pistotnik (ESSL)	Locally Modified Environments for Supercells