

# Extreme Forecast Index (EFI)

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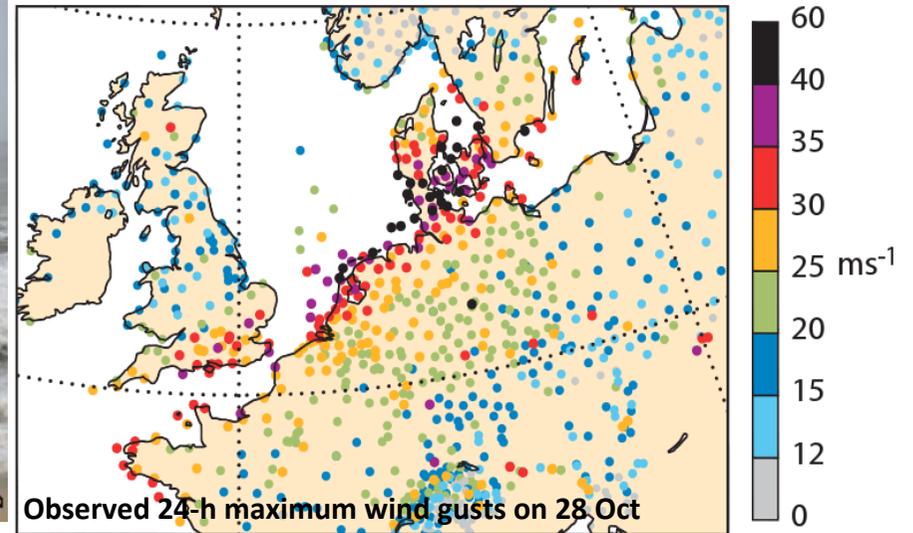
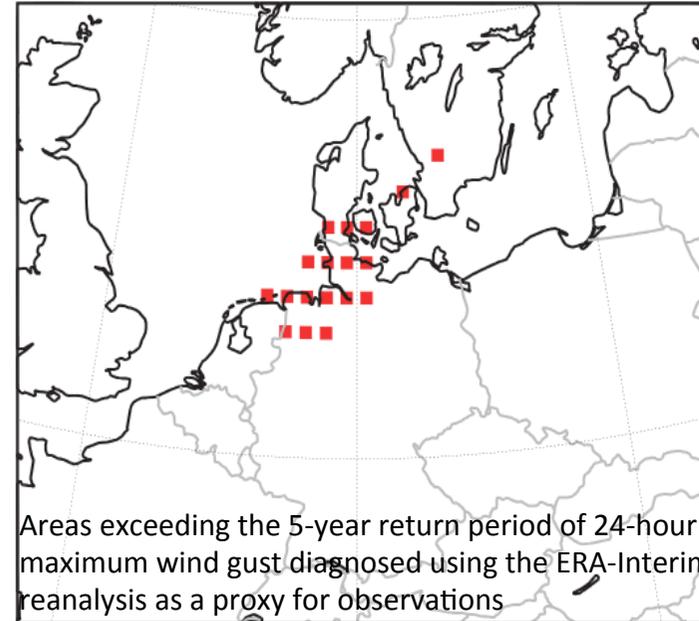
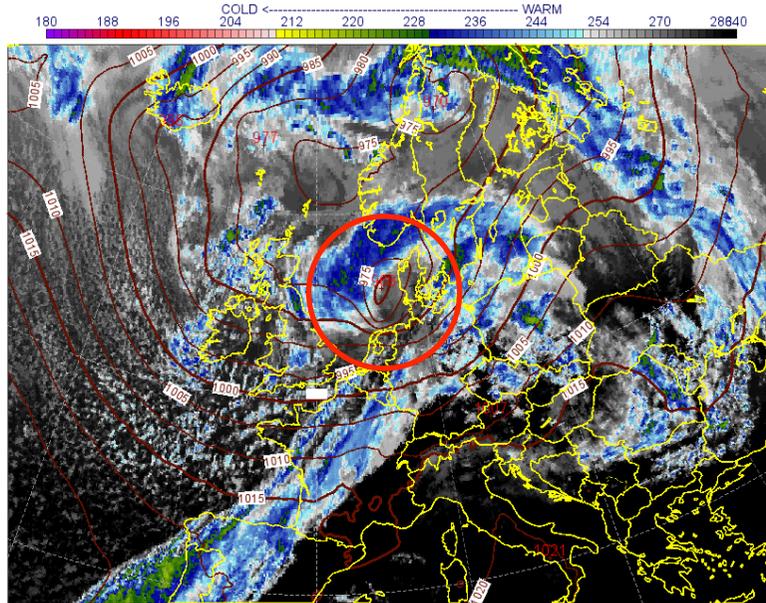
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Use and interpretation of ECMWF products, October 2017

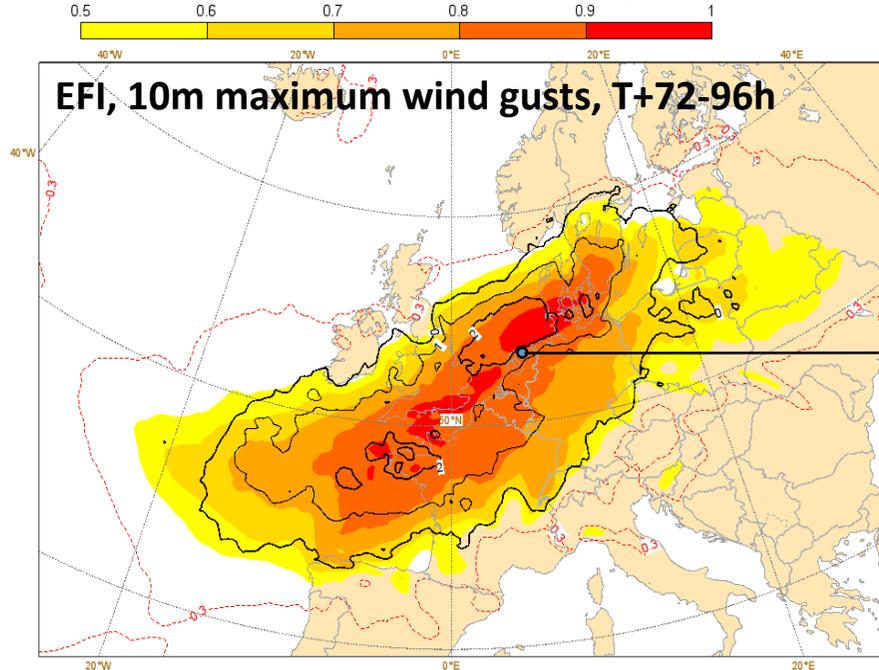
# St Jude Storm, 27-28 Oct 2013

METEOSAT 10 IR and MSLP AN 28/10/2013 12 UTC



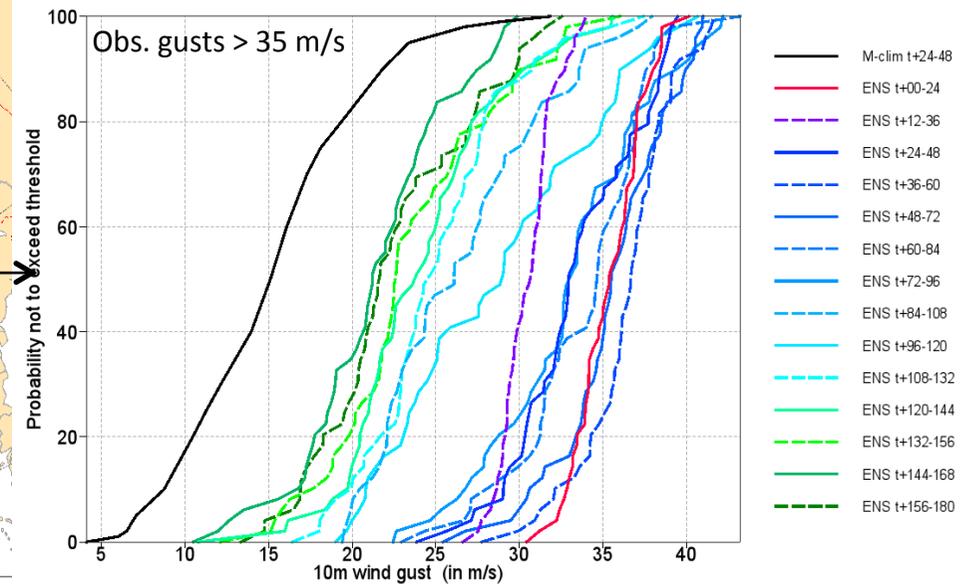
# St Jude Storm, 27-28 Oct 2013

Fri 25 Oct 2013 00UTC @ECMWF expver = 1 VT: Mon 28 Oct 2013 00UTC - Tue 29 Oct 2013 00UTC 72-96h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,10,15) for: 10m wind gust



## Cumulative Distribution Functions (CDF)

Cumulative Distribution Functions for 10m wind gust at 53.25°/5.34° VT: 28/10/2013 00UTC - 29/10/2013 00UTC

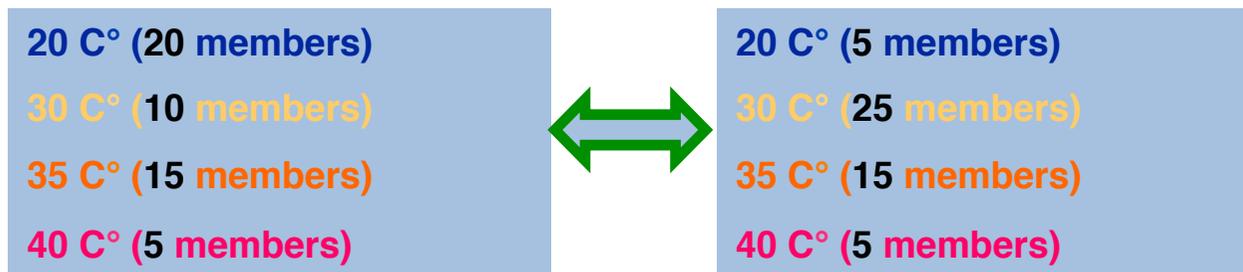


- EFI indicated a risk of a windstorm in the medium range. Positive SOT (black contours) showed that an exceptionally strong windstorm was likely.
- There was a sign of windier-than-normal conditions 7 days in advance with the last 7 runs predicting extreme wind (see CDF).

Windstorms in northwest Europe in late 2013, *ECMWF Newsletter No. 139*, 22-28

# Extreme Forecast Index (EFI)

- **Extreme Forecast Index (EFI)** is designed to measure how extreme a given ensemble forecast is.
- EFI is a measure of the difference between the ensemble forecast distribution and a reference distribution - **model climate (M-climate)**.
- EFI delivers model-climate-related information, therefore it can be used as an “alarm bell” for extreme weather situations over any area without defining different space- and time-dependent thresholds.
- Simple probabilities (e.g.  $> 32^{\circ}\text{C}$ ) will not highlight the differences in the distributions below. EFI will, by accounting for the distribution of all the ensemble members.



# The Model climate (M-climate)

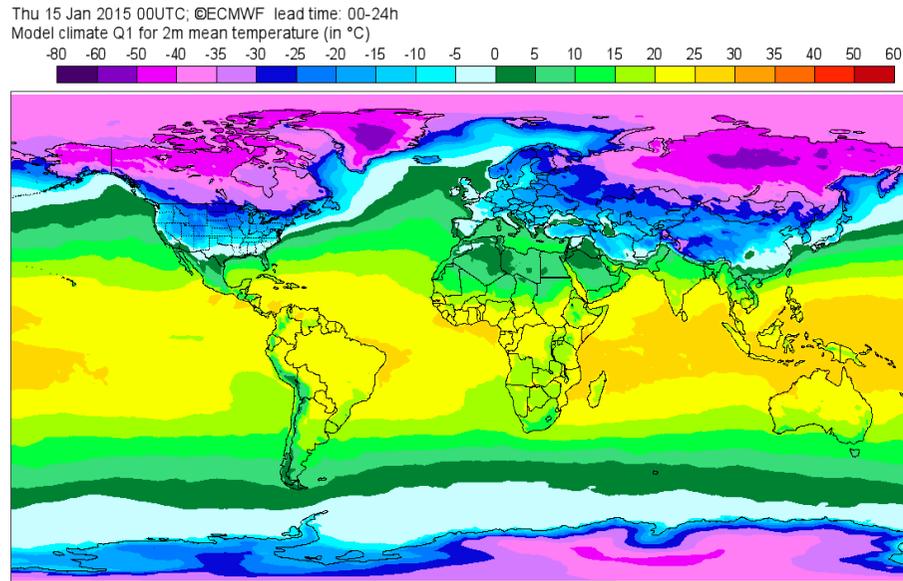
For climate related products like the EFI a reliable model climate is essential.

*Ideally* the model climate (M-Climate) is a large set of ensemble re-forecasts with the latest model configuration (used operationally) for a long enough period (e.g. 30 years).

The current M-climate (**since 12 May 2015**):

- Running an ensemble re-forecast suite with 10 perturbed ensemble members and the Control (**was 4 perturbed member + Control**)
- Always for the most recent 20 years with initial conditions taken from the ECMWF global atmospheric reanalysis ERA-Interim
- Re-forecast runs every Monday and every Thursday. Therefore climate files from the closest preceding run are taken. (**only Thursday runs before**)
- Model run for 46 days, post-processed fields as for ENS (data every 6 hours)
- Uses the latest model cycle (resolution/ physics / etc.)
- Allows an immediate adaptation of the EFI and other model climate related products to any upgrade of ENS

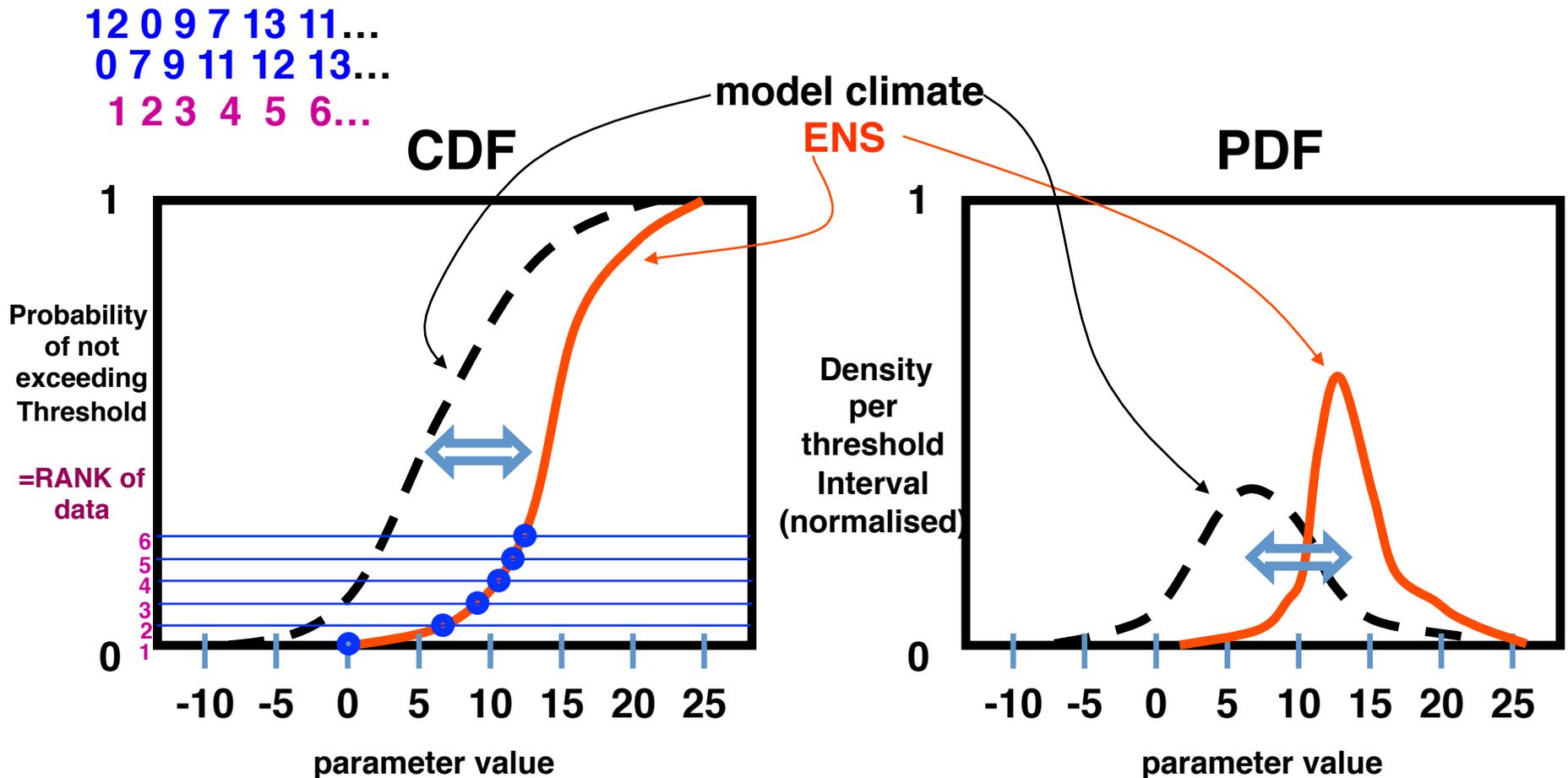
# Model climate (M-climate)



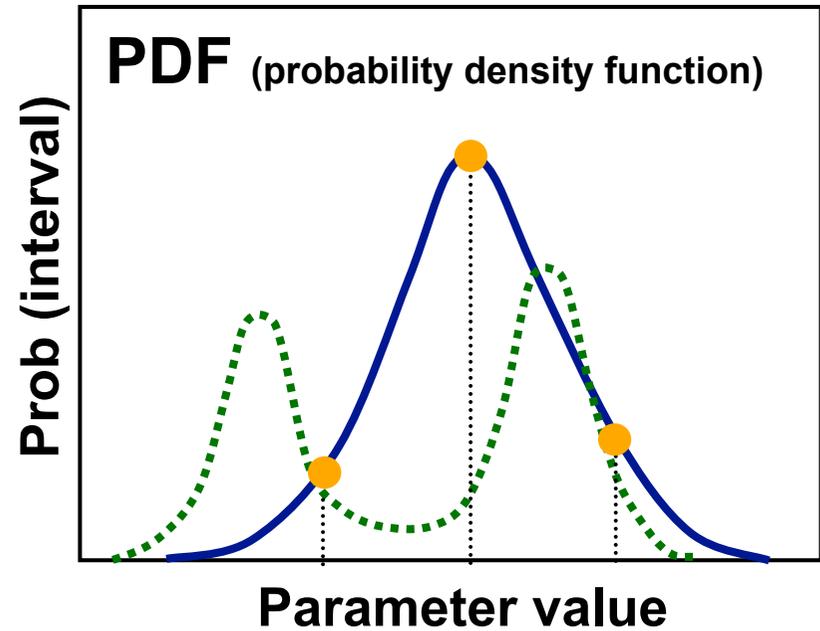
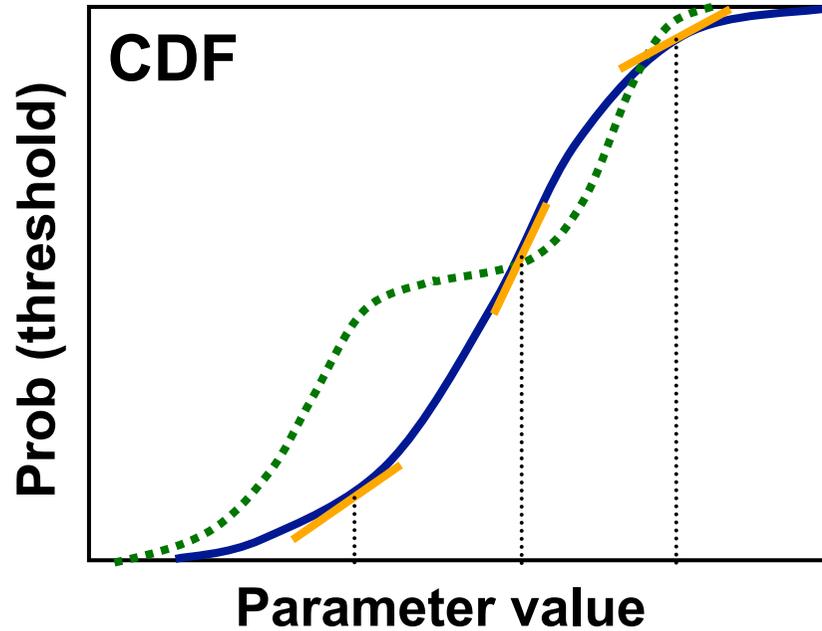
- To provide a robust, less noisy M-Climature, we do not use just one set of re-forecasts, but all nine sets within 5-week period centred on the week in question.
- M-climate sample size is: 20 years \* 11 ensemble members \* 9 re-forecast runs = 1980 re-forecast fields (were 500)
- Recent changes lead to:
  - ✓ Decrease of the noise in the tails of the M-climate distribution and considerable increase of the consistency of SOT forecasts;
  - ✓ Decrease of the jumpiness of the EFI forecast due to the seasonal trend.

# Extreme Forecast Index (EFI)

- The EFI is defined on the basis of the Cumulative Distribution Functions (CDF). The abnormality level in the ensemble is determined based on the position and shape of the distributions.



# How do CDFs and PDFs relate?

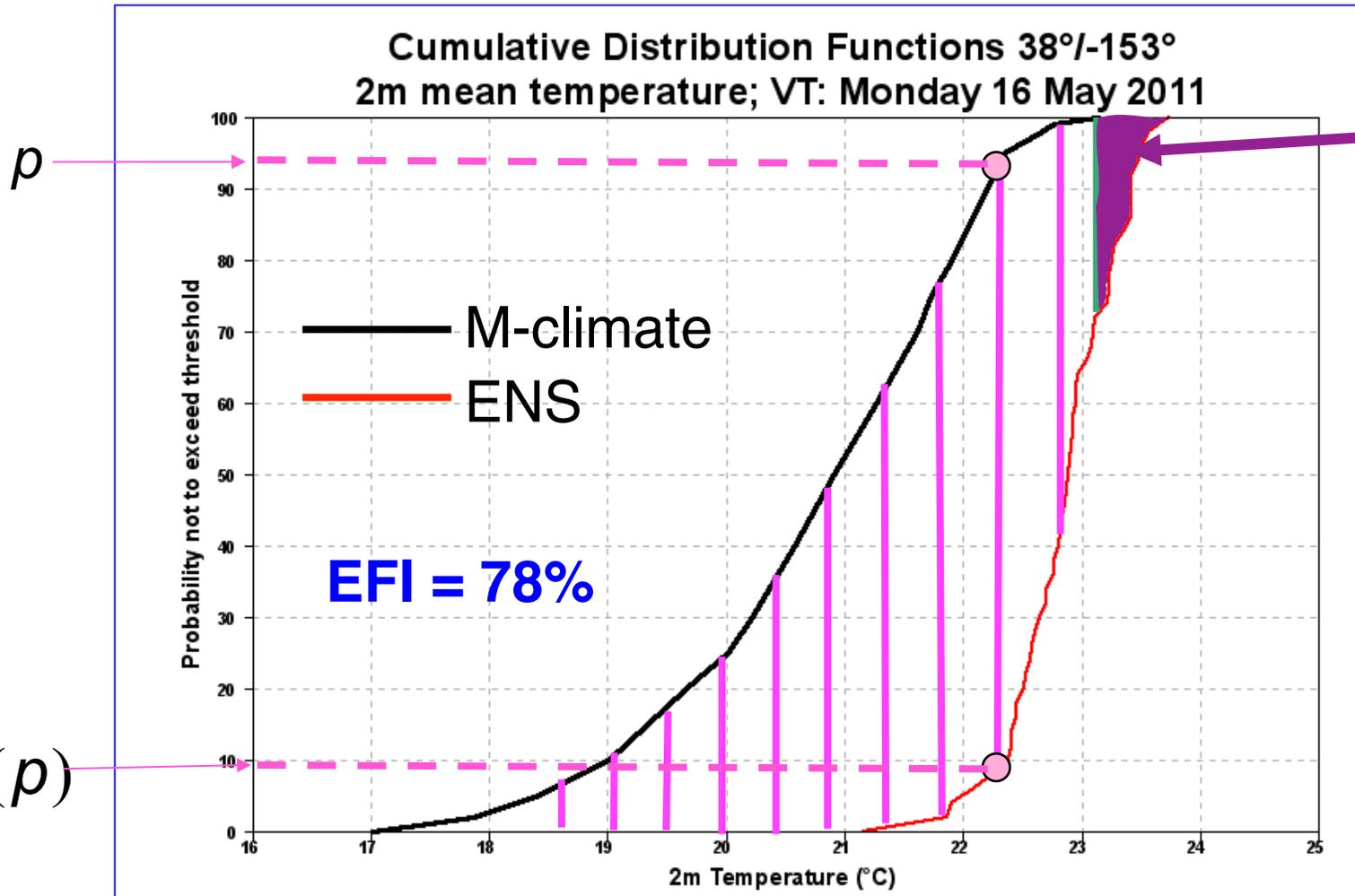


- The PDF (y-axis) value equals the slope of the CDF
- **Steeper CDF = narrower PDF = higher confidence in the forecast**
- A step in the CDF means a bimodal PDF

$$EFI = \frac{2}{\pi} \int_0^1 \left( \frac{p - F_f(p)}{\sqrt{p(1-p)}} \right) dp$$

Represented by pink lines below

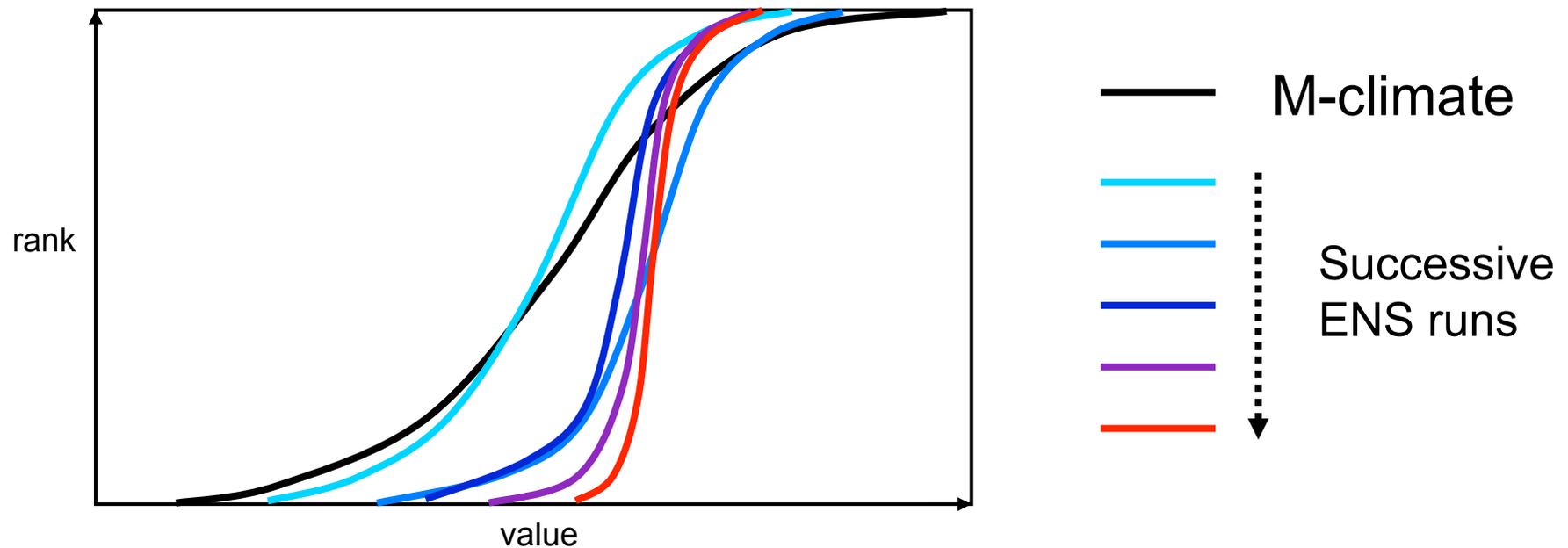
More weight to extremes of M-climate being a quadratic function of p



EFI takes no direct account of any ENS members beyond the M-climate extremes

$-1 \leq EFI \leq 1$   
 $-100\% \leq EFI \leq 100\%$

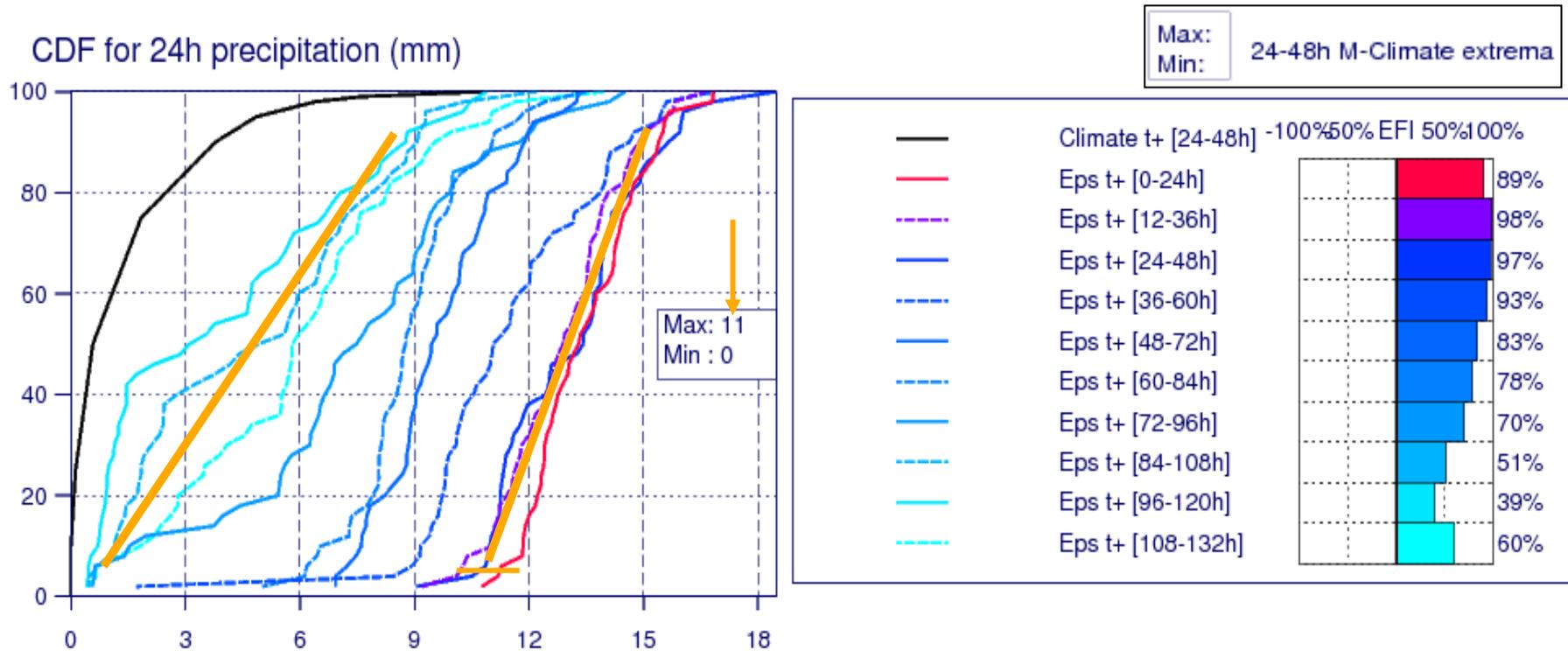
## How 'should' CDFs behave in successive ENS runs?



- At long lead times forecast CDF may be similar to the M-climate.
- Lateral variations in CDF position between successive runs should, mostly, become less (with time).
- CDF will tend to become steeper (with time), implying higher confidence.

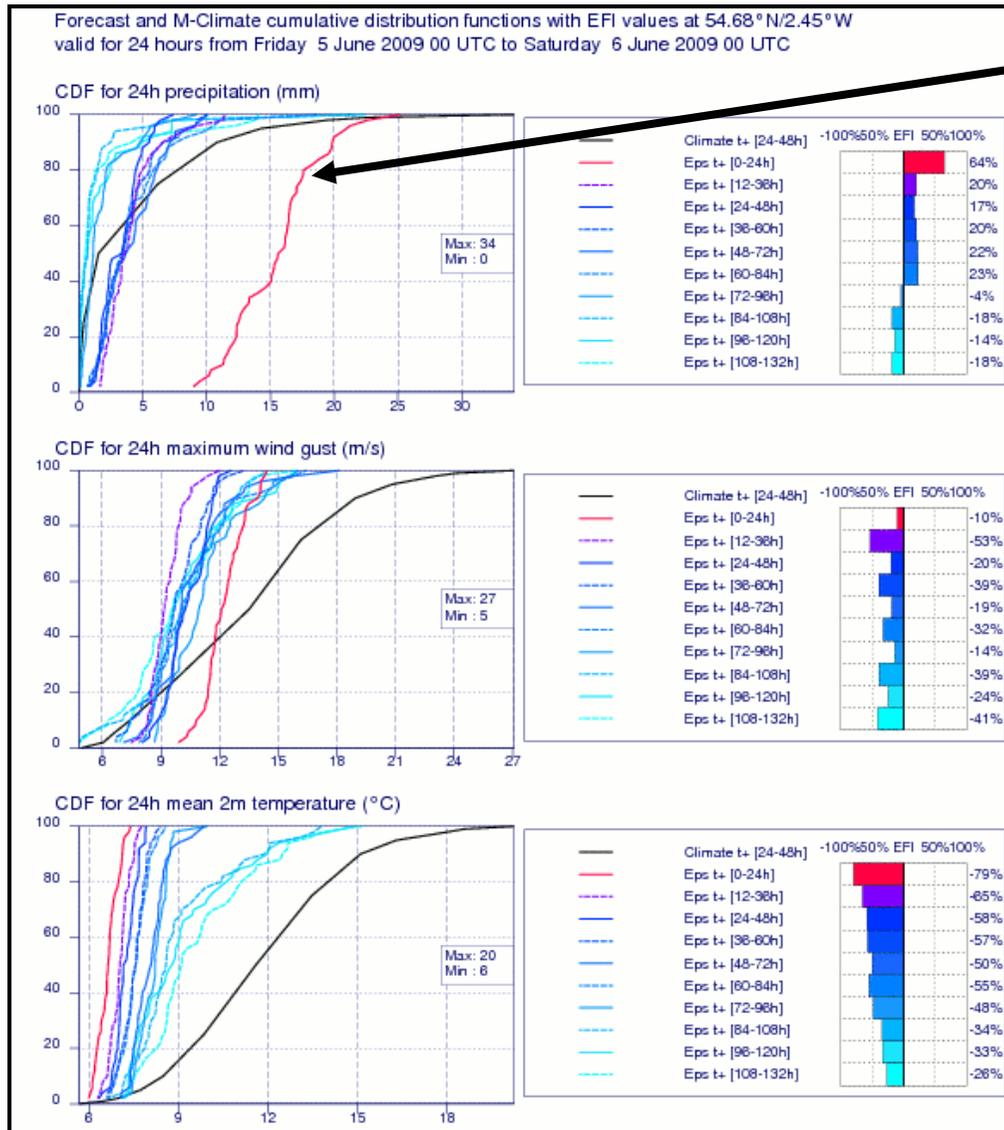
# An example

Forecast and M-Climate cumulative distribution functions with EFI values at 59.09°N/41.69°E valid for 24 hours from Monday 4 February 2013 00 UTC to Tuesday 5 February 2013 00 UTC



- The return period value of 24h precipitation for ~February is 11 mm (M-climate).
- ~ 95% probability of >11mm (blue line; t+24-48h)
- Steeper CDF slope on more recent forecasts signifies increasing confidence

# Counter example

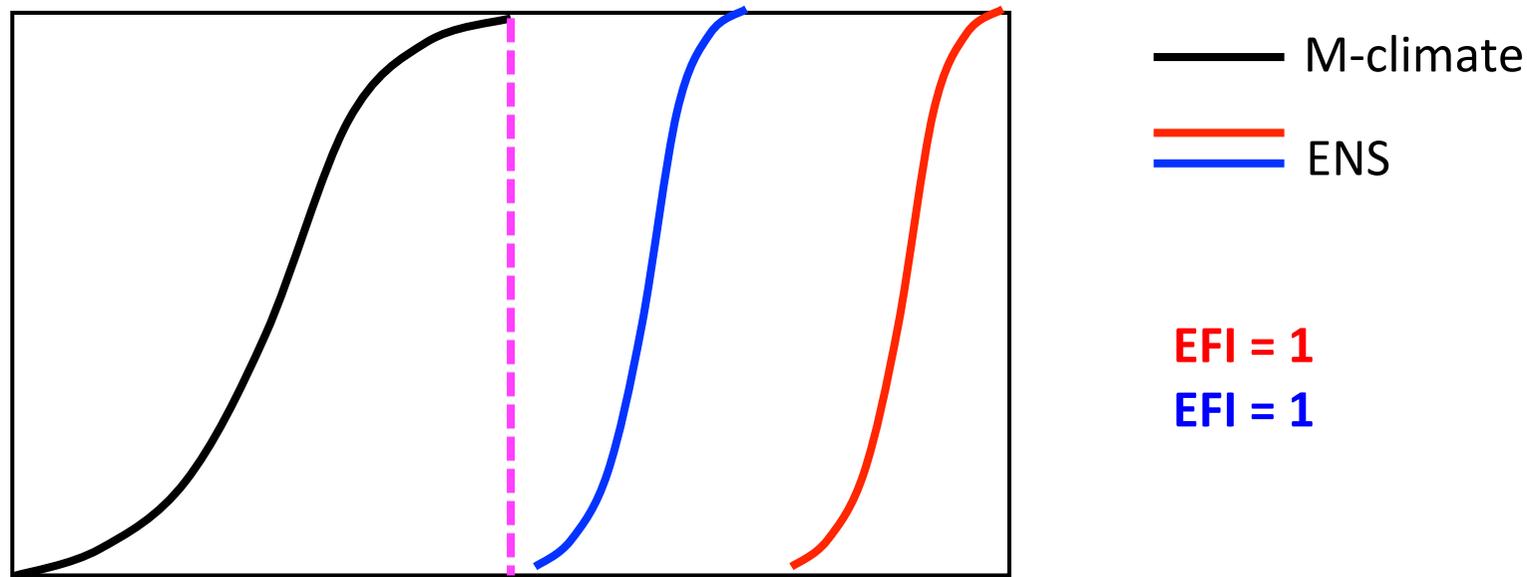


➔ N England rain – June '09 - low probability alternative became likely at short range.

# Some limitations of EFI

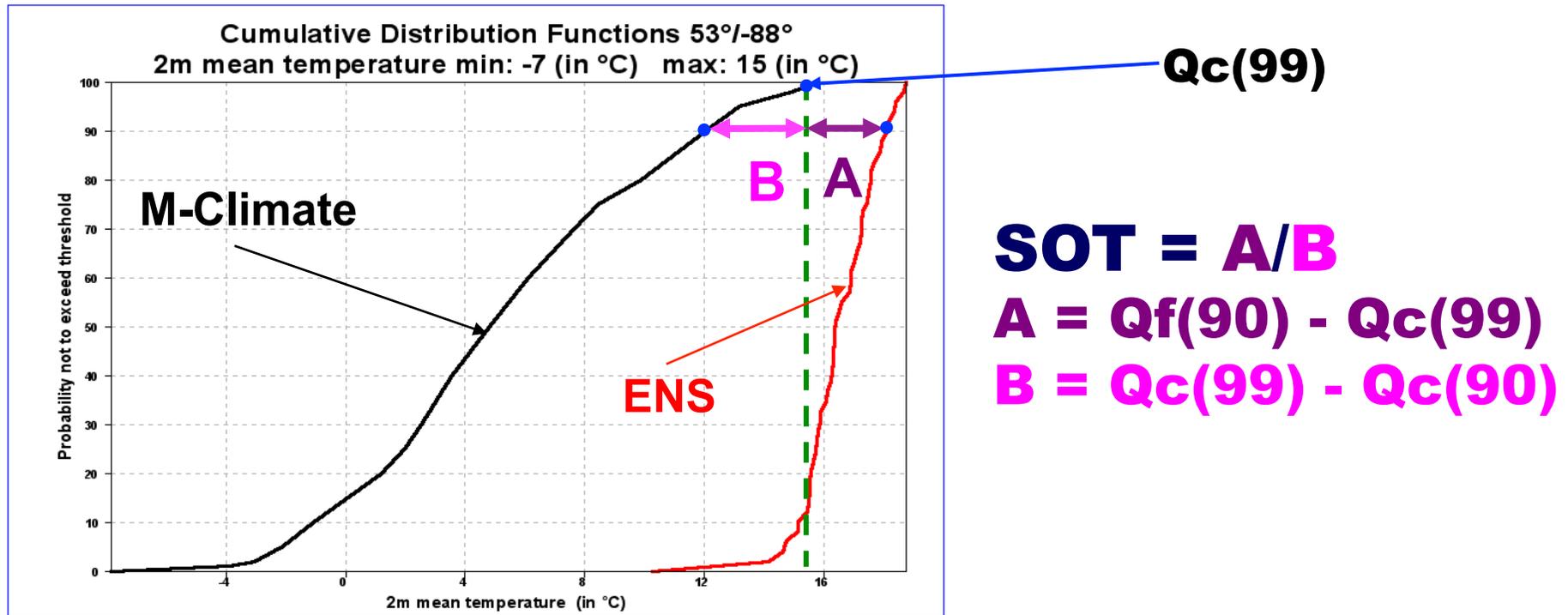
- Extreme does not *necessarily* mean high impact (eg 2mm rain in the desert)
- Past history also important but not directly accounted for (eg heavy rain when ground saturated)
- Windstorm impact can depend on whether trees are in leaf, whether ground is saturated...
- Products are only as good as the model output, e.g.:
  - ❖ Tropical cyclone representation is limited by resolution
  - ❖ Threat from intense, *very localised* convection unlikely to be fully captured

# Shift Of Tails (SOT)



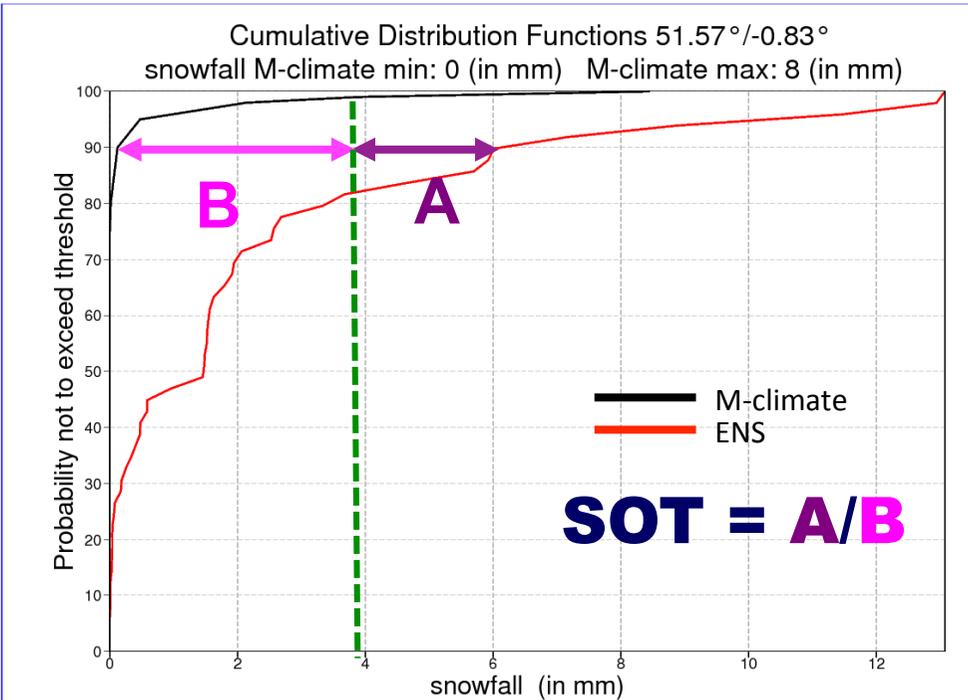
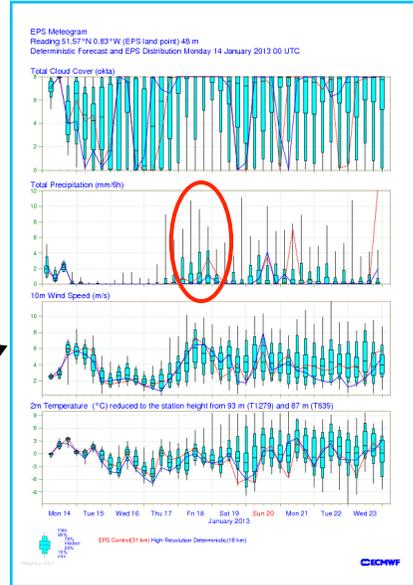
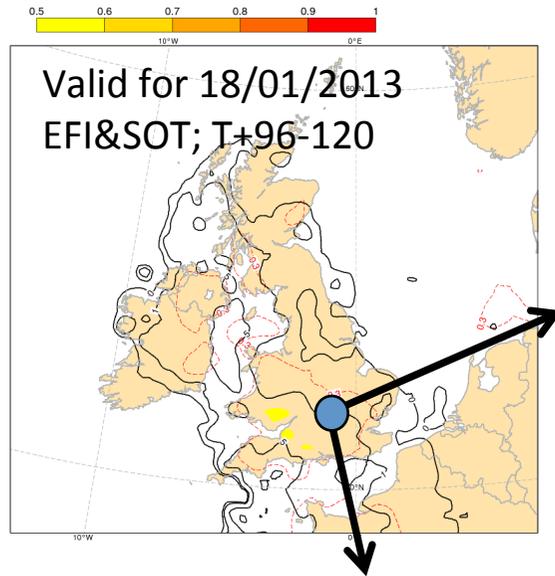
- As EFI does not take direct account for members which are beyond the M-climate, once EFI reaches its maximum value of 1 or minimum value of -1, it does not provide further information about the magnitude of extremity.
- Shift Of Tails (SOT) has been operational since 19 June 2012 to complement EFI by providing information about how extreme an extreme event might be.

# Shift Of Tails (SOT)



- SOT compares the tails of both distributions M-climate and ENS.
- SOT is based on 90<sup>th</sup> and 99<sup>th</sup> (upper tail) and 1<sup>st</sup> and 10<sup>th</sup> (lower tail for temperature only) percentiles
- **Positive** SOT values indicate that at least 10% of the ensemble is forecasting an extreme event; the higher the SOT the more extreme that top 10% is.

Mon 14 Jan 2013 00UTC @ECMWF VT: Fri 18 Jan 2013 00UTC - Sat 19 Jan 2013 00UTC 96-120h  
 Extreme forecast index and Shift of Tails (black contours 0,1,5,10,15) for: snowfall



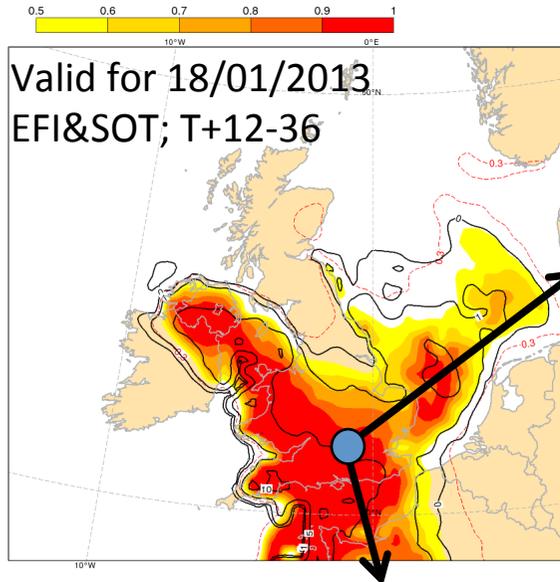
- SOT > 0 → at least 10% of the ensemble members are above the 99th M-climate percentile
- The higher the SOT value is, the further this top 10% of the ensemble forecasts go beyond Q99 of the M-climate.

In the example (Reading):

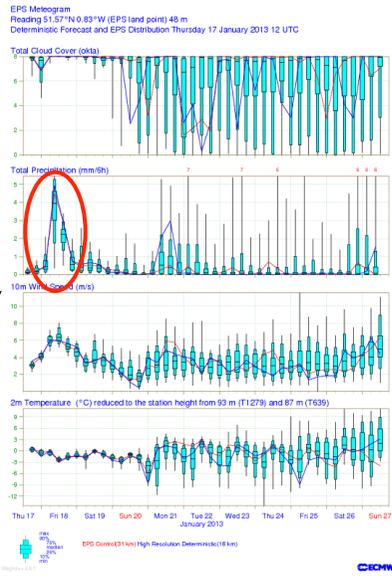
- ✓ EFI = 0.36
- ✓ SOT = 0.8

EFI positive → forecast suggests snow  
 SOT > 0 → there are ENS members predicting extreme snowfall (above the 99th M-climate percentile) but the forecast is uncertain (low EFI)

Thu 17 Jan 2013 12UTC @ECMWF VT: Fri 18 Jan 2013 00UTC - Sat 19 Jan 2013 00UTC 12-36h  
 Extreme forecast index and Shift of Tails (black contours 0, 1, 5, 10, 15) for: snowfall



Valid for 18/01/2013  
 EFI&SOT; T+12-36



**United Kingdom**

**Snow**

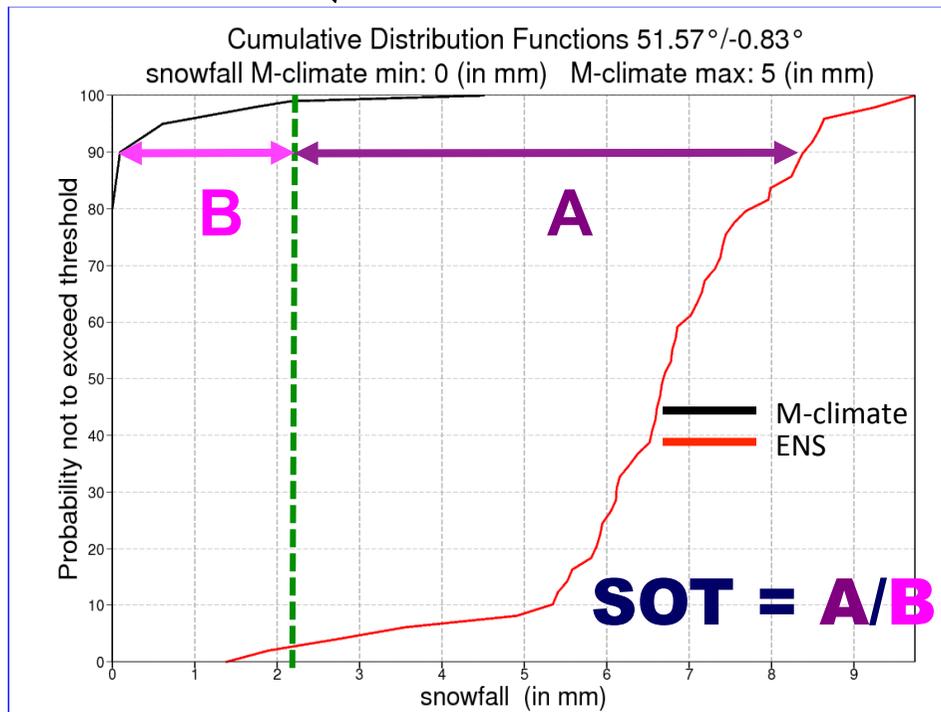
**Issued at:** 1230 on Thu 17 Jan 2013  
**Valid from:** 0300 on Fri 18 Jan 2013  
**Valid to:** 2100 on Fri 18 Jan 2013

A band of snow, heavy in places, will spread northeastwards across Wales and the southwestern half of England, during Friday morning, lasting through the afternoon and evening across much of Wales, the Midlands, southern and parts of southeast England. Winds will strengthen, leading to drifting of lying snow.

Many parts of the Red Warning area are likely to have 20-30 cm of snow with strong southeasterly winds causing blizzards, severe drifting of lying snow and thus severe disruption. The public should avoid all non-essential journeys.

Elsewhere, accumulations of more than 5-10 cm of snow will occur quite widely, with 15 cm in some western parts of the Amber area, falling within 3-6 hours. The public should be prepared for disruption, including altering travel plans.

Please watch for updates to these

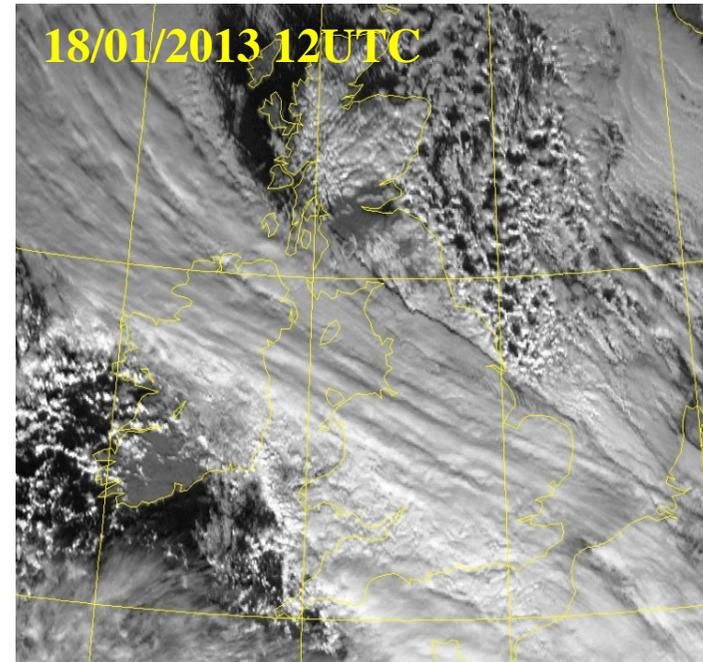
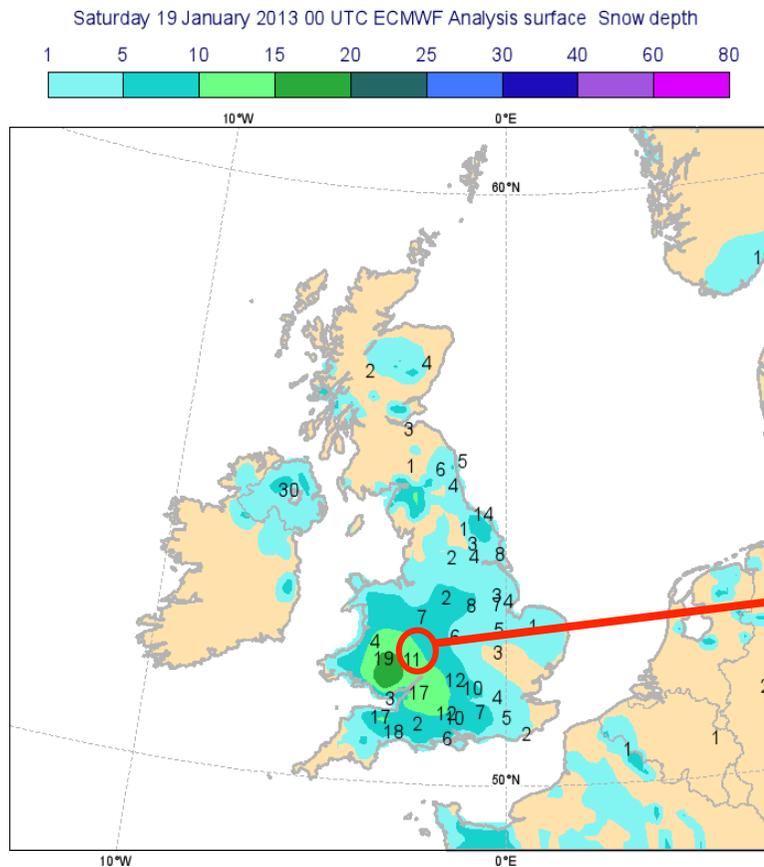


Forecast for Reading:

- EFI = 0.96
- SOT = 3.5
- ✓ High values of the EFI imply high confidence that extreme snowfall may happen.
- ✓ Higher SOT values indicate where the most exceptional snowfall amounts might occur (relative to climate).

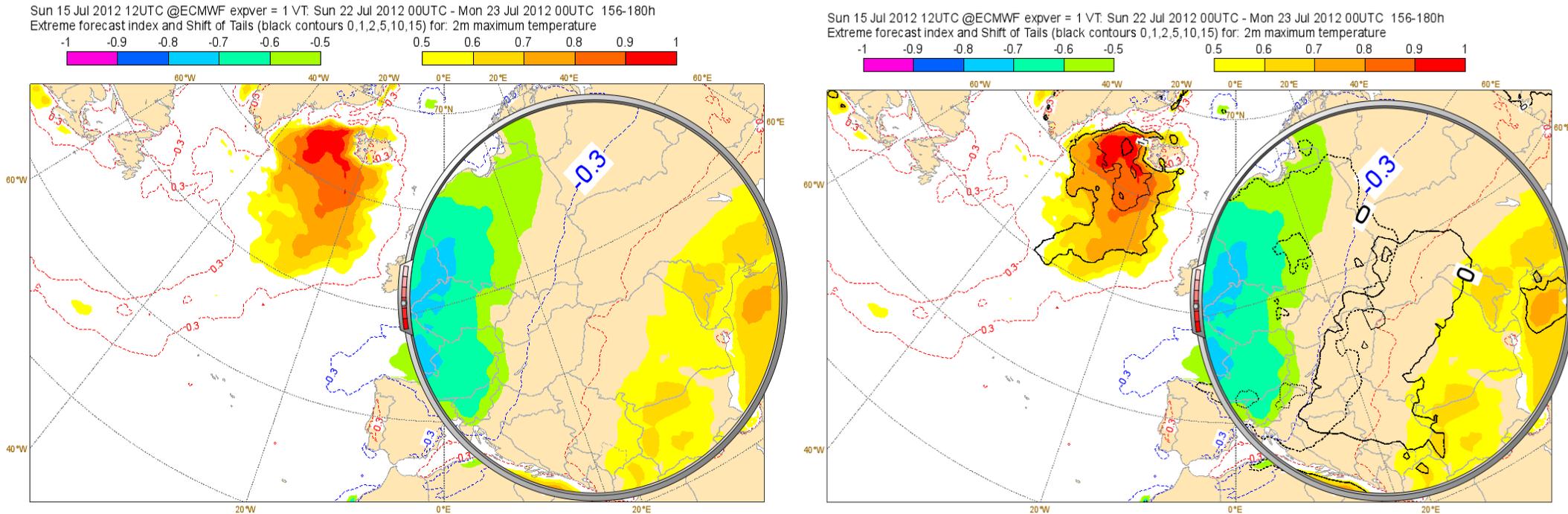
# The outcome

ECMWF snow depth analysis and observations representing the new snow depth for 24-h period from 18/01/2013 00UTC to 19/01/2013 00UTC



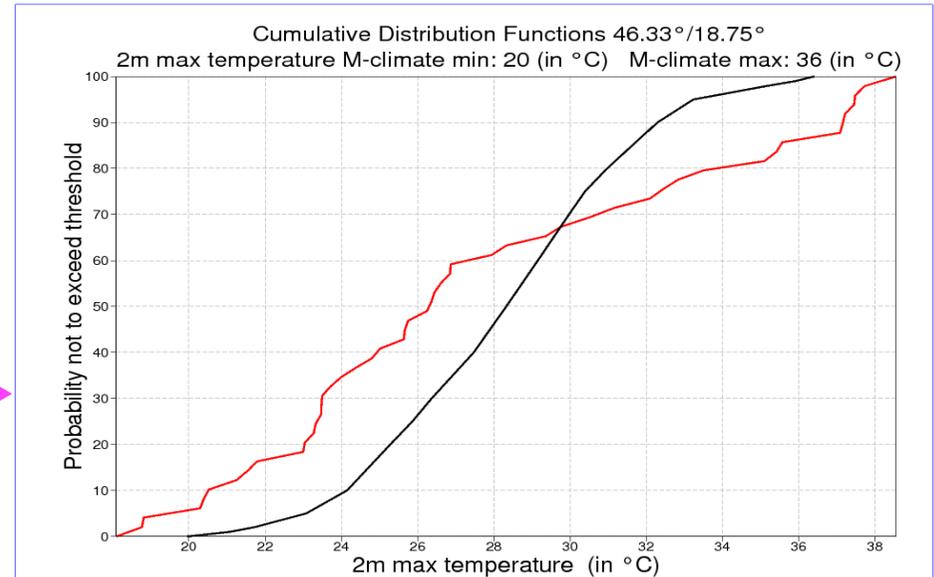
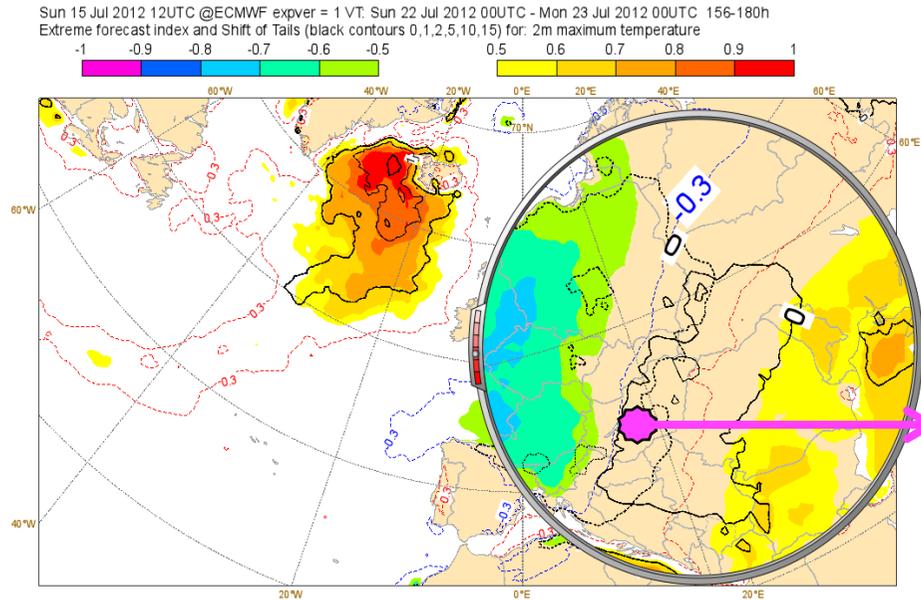
A beer garden in Bromsgrove. Credit: Sue Eden

# A case of very large uncertainty

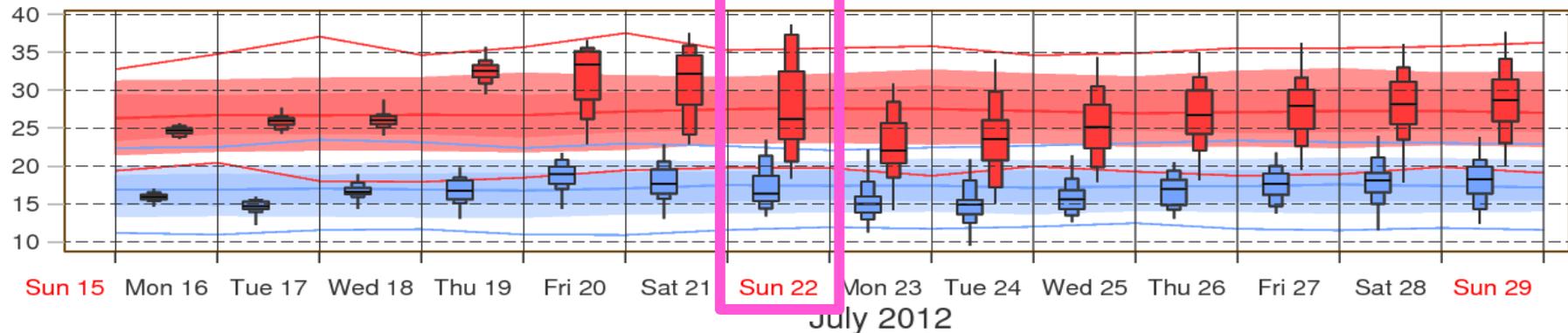


- EFI forecast shows cold conditions over Central Europe and hot weather to the east over the Balkans.
- SOT gives additional information. In the area between the cold and hot weather SOTs overlap. This is a signal of very uncertain forecast – over that area extremely low and extremely high temperatures are possible at the same time.

# A case of very large uncertainty



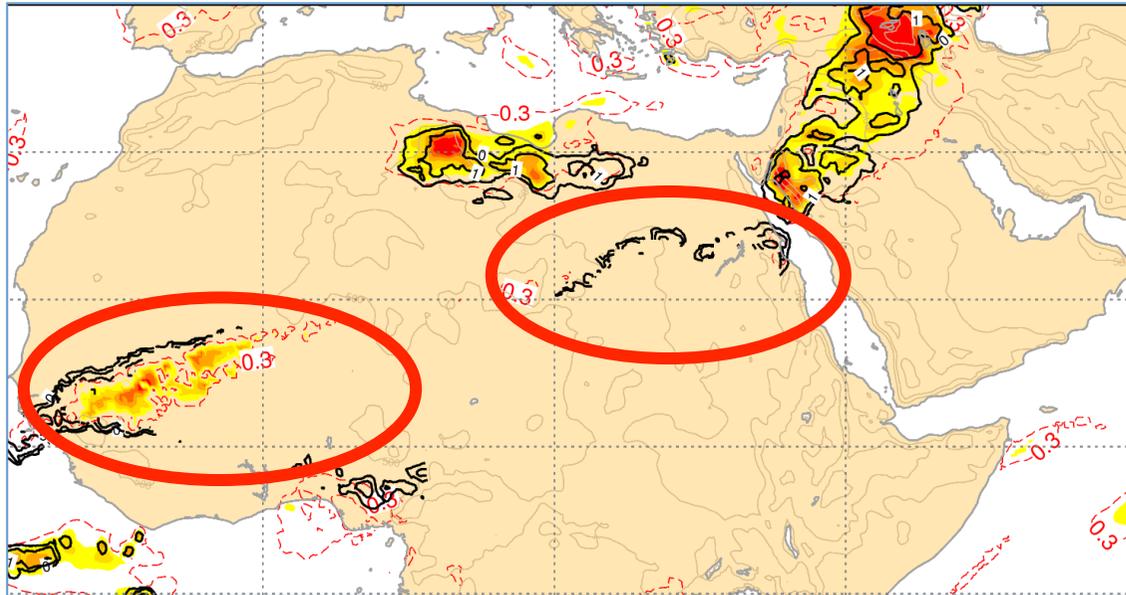
2m min/max temperature (°C) reduced to the station height from 129m (T319)



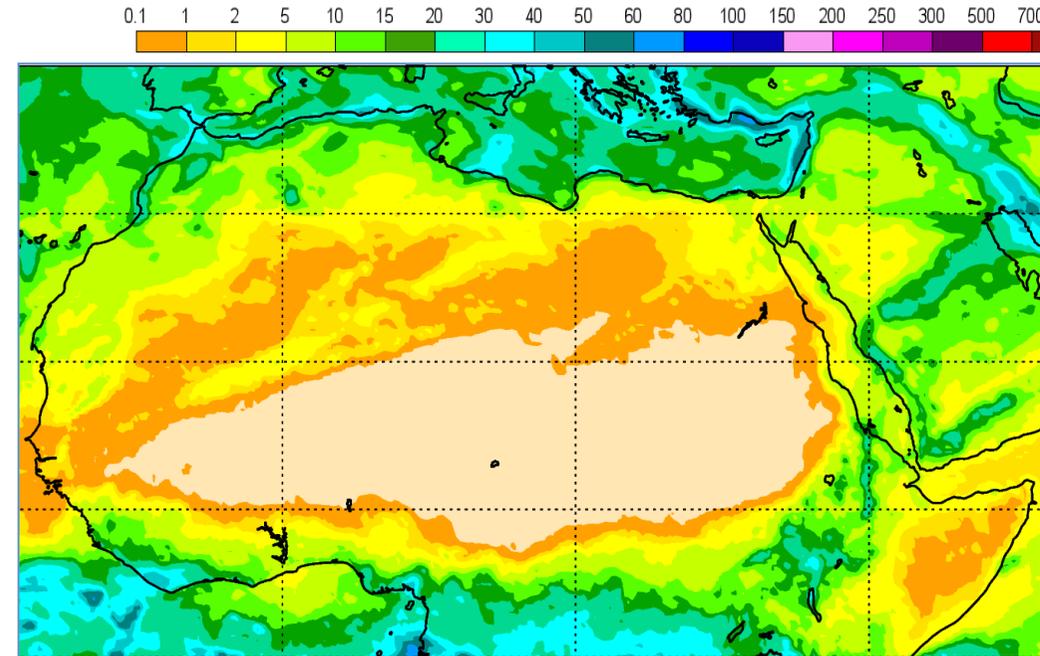
Some ENS members predict maximum temperature below the M-climate minimum, but some – above the M-climate maximum! This large uncertainty is related to the passage of a cold front

# Some limitations

## EFI & SOT for precipitation



## M-climate Q99



- SOT is not defined when M-climate  $Q_c(90) = Q_c(99)$  (to avoid division by 0). This leads to some noise on the plots. To avoid this and to close SOT contours for snowfall, SOT is arbitrarily set to -1 where not defined only for plotting purposes.

# Operationally available EFI fields

- In the current operational system every EFI field is based on a forecast range of 24 hours or longer.
- Since each meteorological parameter is valid for a period the content is either an accumulated value (e.g. precipitation), a mean over a period (e.g. temperature or mean wind) or an extremum (maximum or minimum) over that period (e.g. wind gust).
- Each 24-hour period variable is worked out as a post-processed value based on four 6-hour forecast time steps. E.g. a mean over a 00-00 UTC period is a mean of the 06-12-18 and the ending 00 UTC fields.
- *Importantly*, for wind gusts, the 6 hourly wind gust values used are maxima within the preceding 6 hours (diagnosed by interrogating the model run at every time step).

# Operationally available EFI fields

EFI and SOT parameters:

- 2-metre mean temperature index (2ti)
- total precipitation index (tpi)
- 10-metre mean wind speed index (10wsi)
- 10-metre maximum wind gusts index (10fgi)
- 2-metre minimum temperature index (mn2ti)
- 2-metre maximum temperature index (mx2ti)
- total snowfall index (sfi)
- maximum significant wave height index (maxswhi)
- CAPE (capei)
- capeshear (capesi)

\* Parameters in red available since 19<sup>th</sup> June 2012

\* Parameters in blue available since summer 2015

# Operationally available EFI fields

## 24h interval: parameters 2ti, tpi, 10swi, 10fgi, mn2ti, mx2ti, sfi, maxswhi

- 00 UTC: 00-24, 24-48, 48-72, 72-96, 96-120, 120-144, 144-168\*
- 12 UTC: 12-36, 36-60, 60-84, 84-108, 108-132, 132-156, 156-180

## 72h interval: parameters 2ti, tpi, 10swi

- 00 UTC: 00-72, 24-96, 48-120, 72-144, 96-168, 120-192, 144-216
- 12 UTC: 12-84, 36-108, 60-132, 84-156, 108-180, 132-204, 156-228

## 120h interval: parameters 2ti, tpi, 10swi

- 00UTC: 00-120, 24-144, 48-168, 72-192, 96-216, 240-360\*\*
- 12UTC: 12-132, 36-156, 60-180, 84-204, 108-228 , 240-360

## 240h interval: parameters 2ti, tpi, 10swi

- 00UTC: 000-240
- 12UTC: 000-240

## 360h interval: parameters 2ti, tpi, 10swi

- 00UTC: 000-360

\* available since 19<sup>th</sup> June 2012

\*\* available since 12<sup>th</sup> May 2015

- ① Selection bar
- ② M-climate
- ③ Additional tools
- ④ Help pages
- ⑤ Filters

**Filters**

Search

**Component**

- Atmosphere (7)
- Surface (23)

**Product type**

- ENS (27)
- Extreme forecast index (28)
- [show 3 more](#)

**Parameters**

- Mean sea level pressure (5)
- Ocean waves (1)
- Other (2)
- Precipitation (10)
- Snow (1)
- Temperature (11)
- Wind (14)
- [show 3 more](#)

### EFI 2m temperature

1

3

5

2

4

4

Mon 25 Sep 2017 00UTC @ECMWF t+0-24h VT: Mon 25 Sep 2017 00UTC - Tue 26 Sep 2017 00UTC

Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for 2m mean temperature

Thu 21 Sep 2017 00UTC @ECMWF VT: Mon 25 Sep 2017 00UTC - Tue 26 Sep 2017 00UTC 0-24h

2m mean temperature (in °C) Model climate Q99 (one in 100 occasions realises more than value shown)

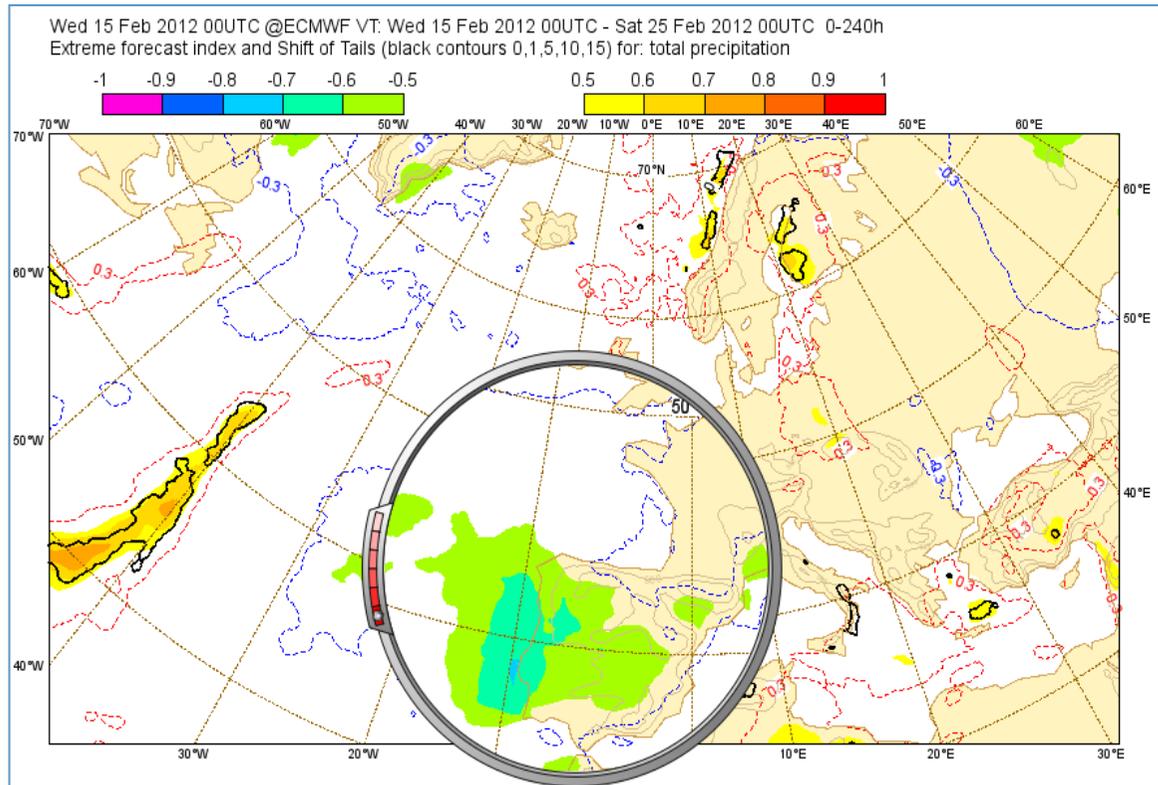
Plots show, on the left panel, EFI (shading and red/blue contours) together with the Shift Of Tails (SOT) index (black contours), whilst the right panel shows various M-climate quantiles (select which one using the drop down menu above). On the left panel orography contours are also shown (at 0.5,1,2,3 and 5 km, at ENS day 1-10 resolution).

► **Extreme forecast index (EFI)**

The EFI is an integral measure of the difference between the ensemble forecast (ENS) distribution and the model climate (M-climate) distribution. This allows the abnormality of the forecast weather situation to be assessed without defining specific (space- and time-dependant) thresholds. The EFI takes values from -1 to +1. If all the ensemble members forecast values above the M-climate maximum, EFI = +1; if they all forecast values below the M-climate minimum, EFI = -1. Experience suggests that EFI magnitudes of 0.5 - 0.8 (irrespective of sign) can be generally regarded as signifying that "unusual" weather is likely whilst magnitudes above 0.8 usually signify that "very unusual" weather is likely. Although larger EFI values indicate

# Negative EFI for precipitation

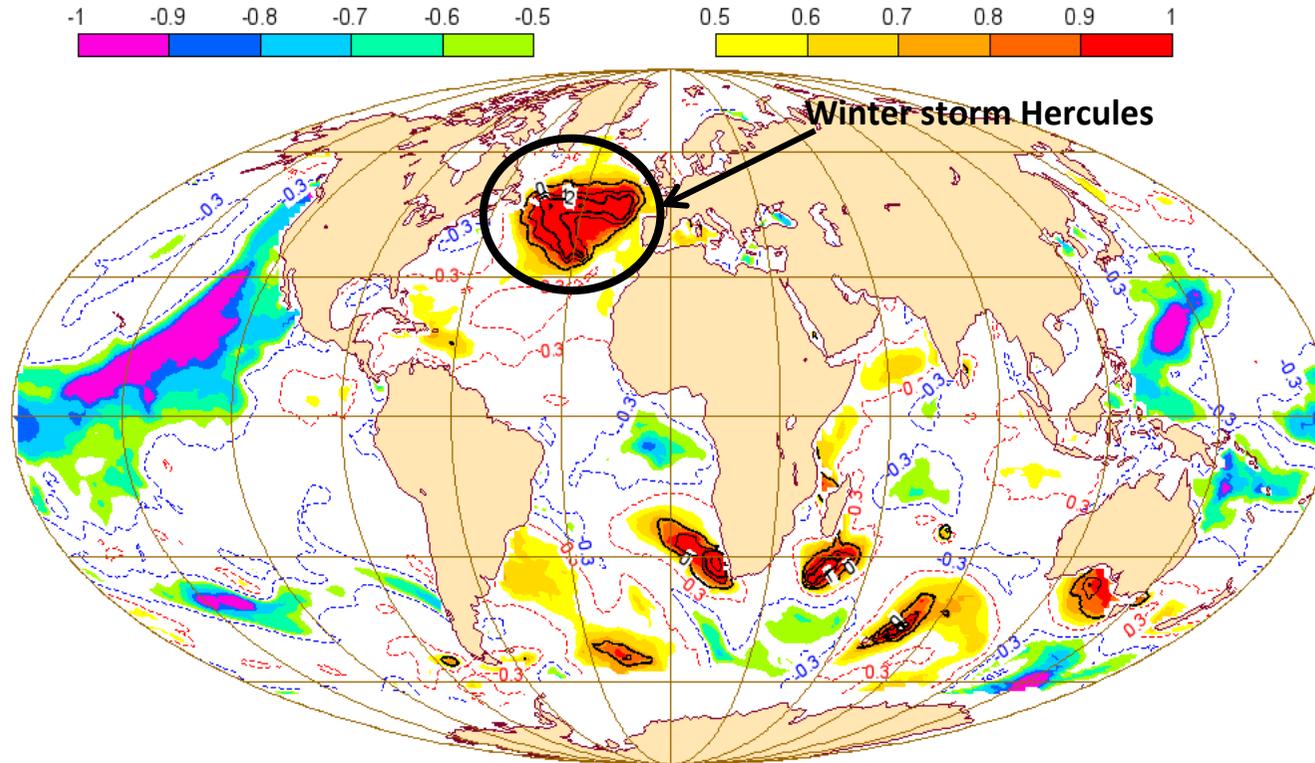
## A case of severe drought in Portugal in 2011-2012



- For 24-hour accumulations negative EFI for precipitation does not make sense because precipitation is bounded by 0 and in most of the places a dry day is not considered extreme anyway.
- For accumulations over longer periods negative EFI does make sense. It gives the risk of dry weather for a relatively prolonged period of time, e.g. 10 or 15 days.

# EFI for waves

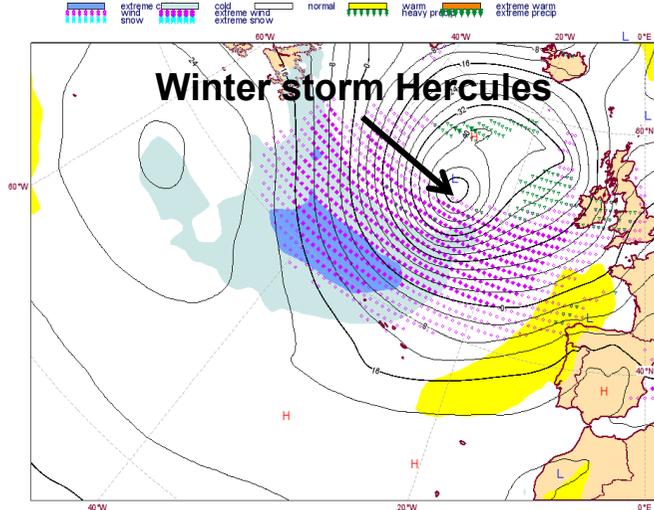
Sun 05 Jan 2014 00UTC @ECMWF expver = 1 VT: Sun 05 Jan 2014 00UTC - Mon 06 Jan 2014 00UTC 0-24h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,10,15) for: maximum significant wave height



- Negative EFI (calm sea) also plotted on the web.
- The winter storm Hercules generated waves up to 20 m in height on 5 and 6 January 2014.

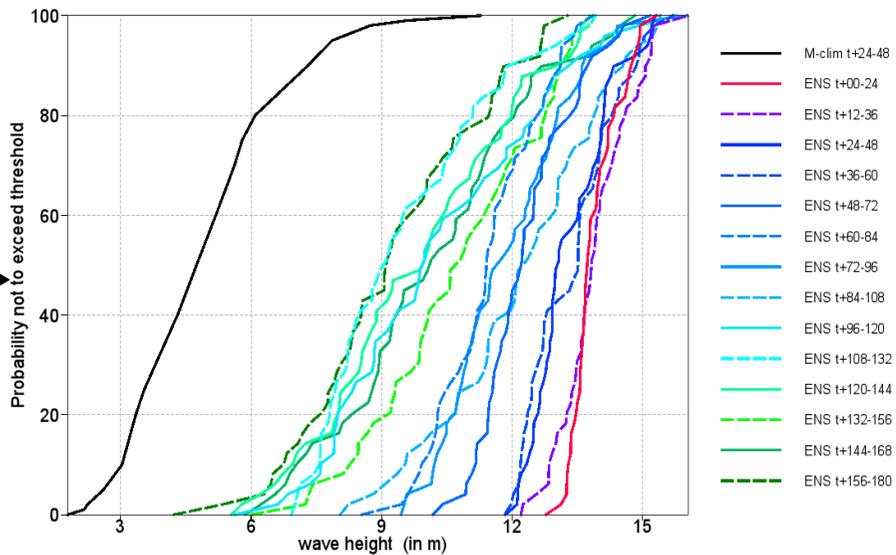
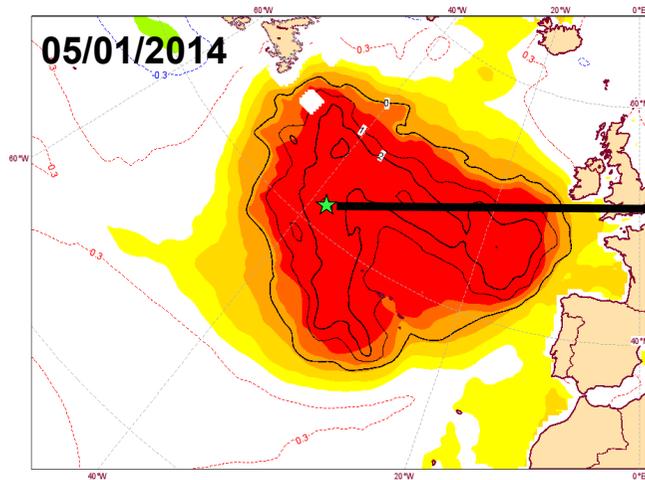
# Historic swell – Storm Hercules

Weather anomalies predicted by EPS: 20140105 00 UTC  
 1000 hPa Z ensemble mean VT: Sunday 05 January 2014 12UTC  
 and EFI values for 24h Total precipitation, snowfall, 10m wind gust and 2m temperature  
 VT: Sunday 05 January 2014 00UTC - Monday 06 January 2014 00UTC

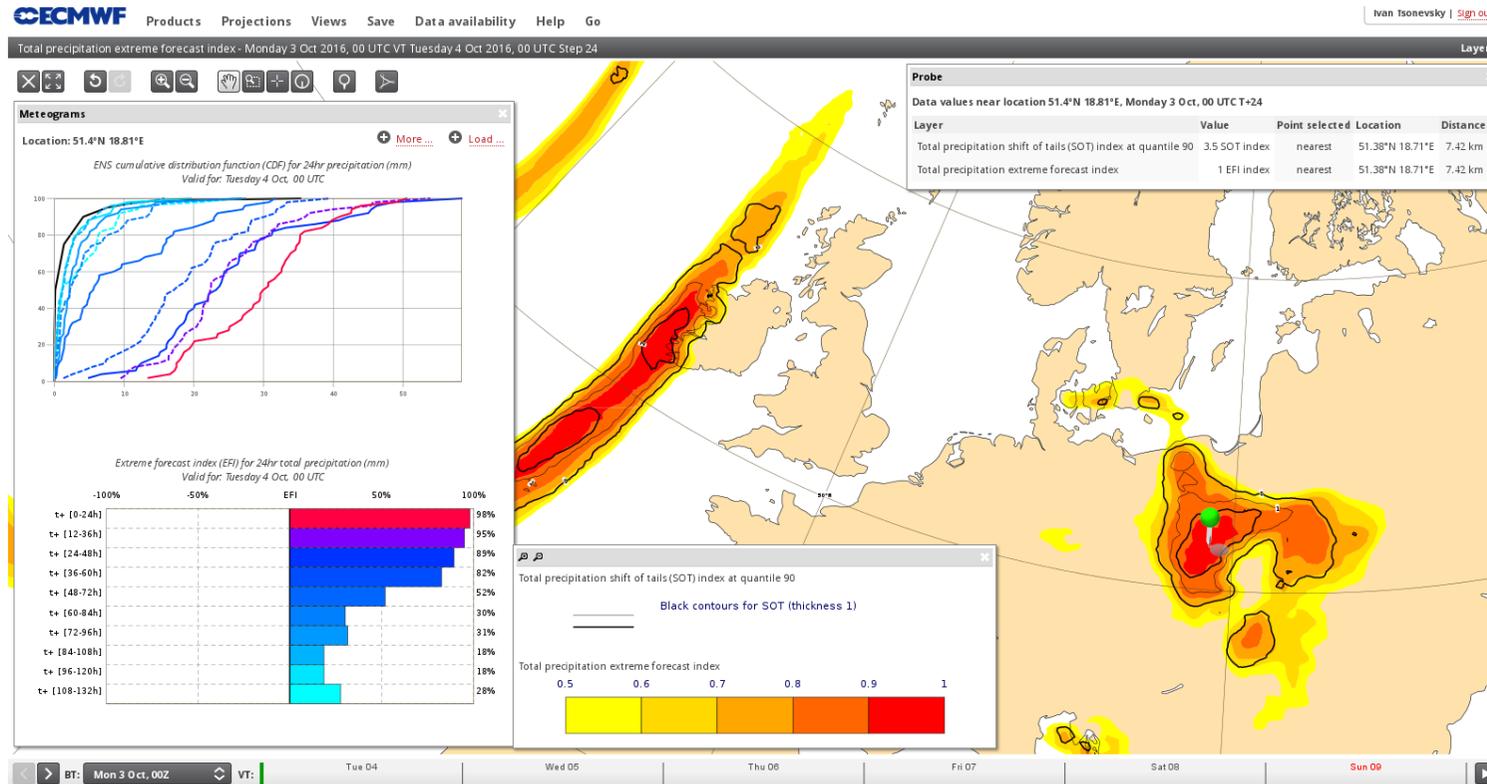


Cumulative Distribution Functions for wave height at 42.03°N-38.43°E VT: 05/01/2014 00UTC - 06/01/2014 00UTC

Sun 05 Jan 2014 00UTC @ECMWF expver = 1 VT: Sun 05 Jan 2014 00UTC - Mon 06 Jan 2014 00UTC 0-24h  
 Extreme forecast index and Shift of Tails (black contours 0,1,2,5,10,15) for: maximum significant wave height



# EFI on the ecCharts

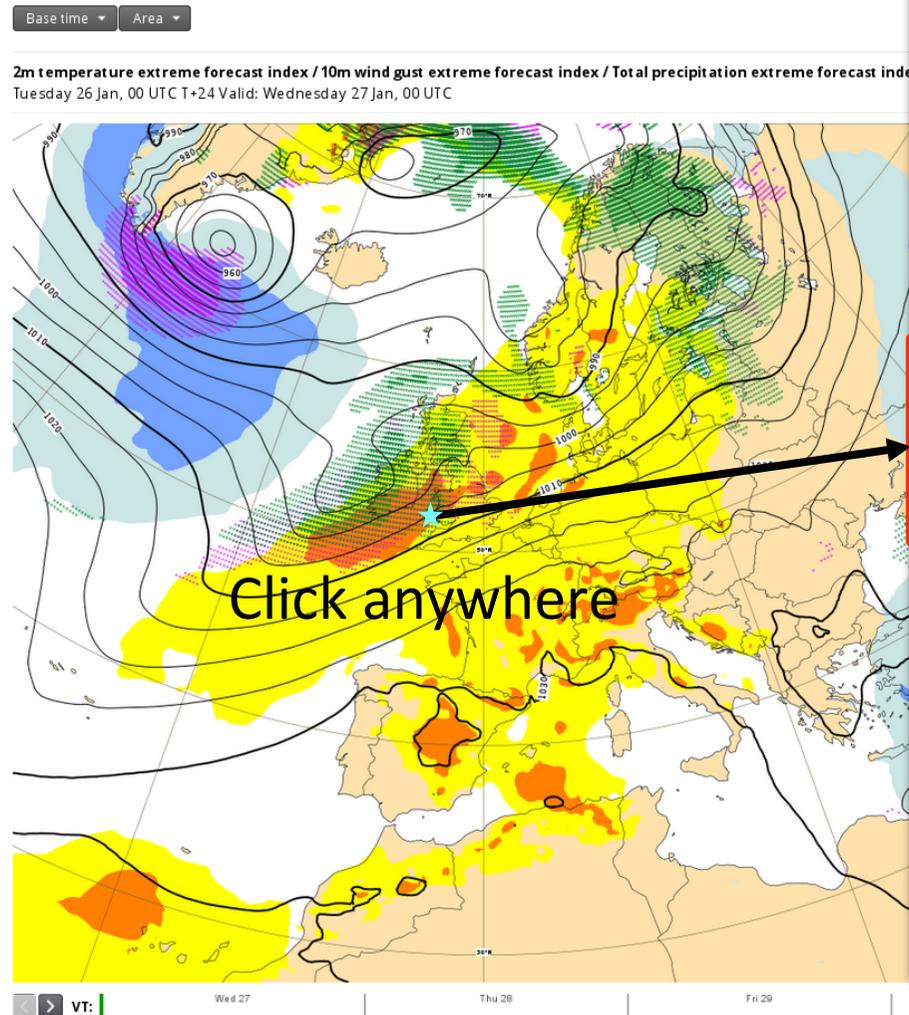


- EFI & SOT can be accessed via ecCharts at <http://wrep.ecmwf.int/forecaster/>.
- CDFs and EFI bar plot for a given location can be displayed as well, just for (2t, 2tmin, 2tmax, 10fg, tp) at the moment. More will be added soon.
- M-climate is available as well.

# Clickable charts

<http://www.ecmwf.int/en/forecasts/charts/interactive-charts>

Multi-parameter EFI (24-h up to valid time)



### Meteograms

Latitude:   
 Longitude:   
 Altitude:   
 Search:   
 Please note that the lat/lon will not be updated unless an item is selected from the drop-down list, otherwise the text will be treated purely as a label

Forecast and M-Climate cumulative distribution functions with EFI values  
 51.95°N 4.17°W  
 Valid for 24 hours from Tuesday 26 January 2016 00 UTC to Wednesday 27 January 2016 00 UTC  
 CDF for 24h precipitation (mm)  
 — 24-48h Climate extrema [Max = 44, Min = 0]

Lead time (t+)	EFI
t+ (0-24h)	87%
t+ (12-36h)	85%
t+ (24-48h)	72%
t+ (36-60h)	80%
t+ (48-72h)	81%
t+ (60-84h)	67%
t+ (72-96h)	64%
t+ (84-108h)	63%
t+ (96-120h)	65%
t+ (108-132h)	46%

CDF for 24h maximum wind gust (m/s)  
 — 24-48h Climate extrema [Max = 36, Min = 3]

Lead time (t+)	EFI
t+ (0-24h)	59%
t+ (12-36h)	53%
t+ (24-48h)	67%
t+ (36-60h)	70%
t+ (48-72h)	74%
t+ (60-84h)	67%
t+ (72-96h)	54%
t+ (84-108h)	54%
t+ (96-120h)	55%
t+ (108-132h)	43%

CDF for 24h mean 2m temperature (°C)  
 — 24-48h Climate extrema [Max = 11, Min = -6]

Lead time (t+)	EFI
t+ (0-24h)	78%
t+ (12-36h)	73%
t+ (24-48h)	75%
t+ (36-60h)	73%
t+ (48-72h)	66%
t+ (60-84h)	65%
t+ (72-96h)	62%
t+ (84-108h)	54%
t+ (96-120h)	35%

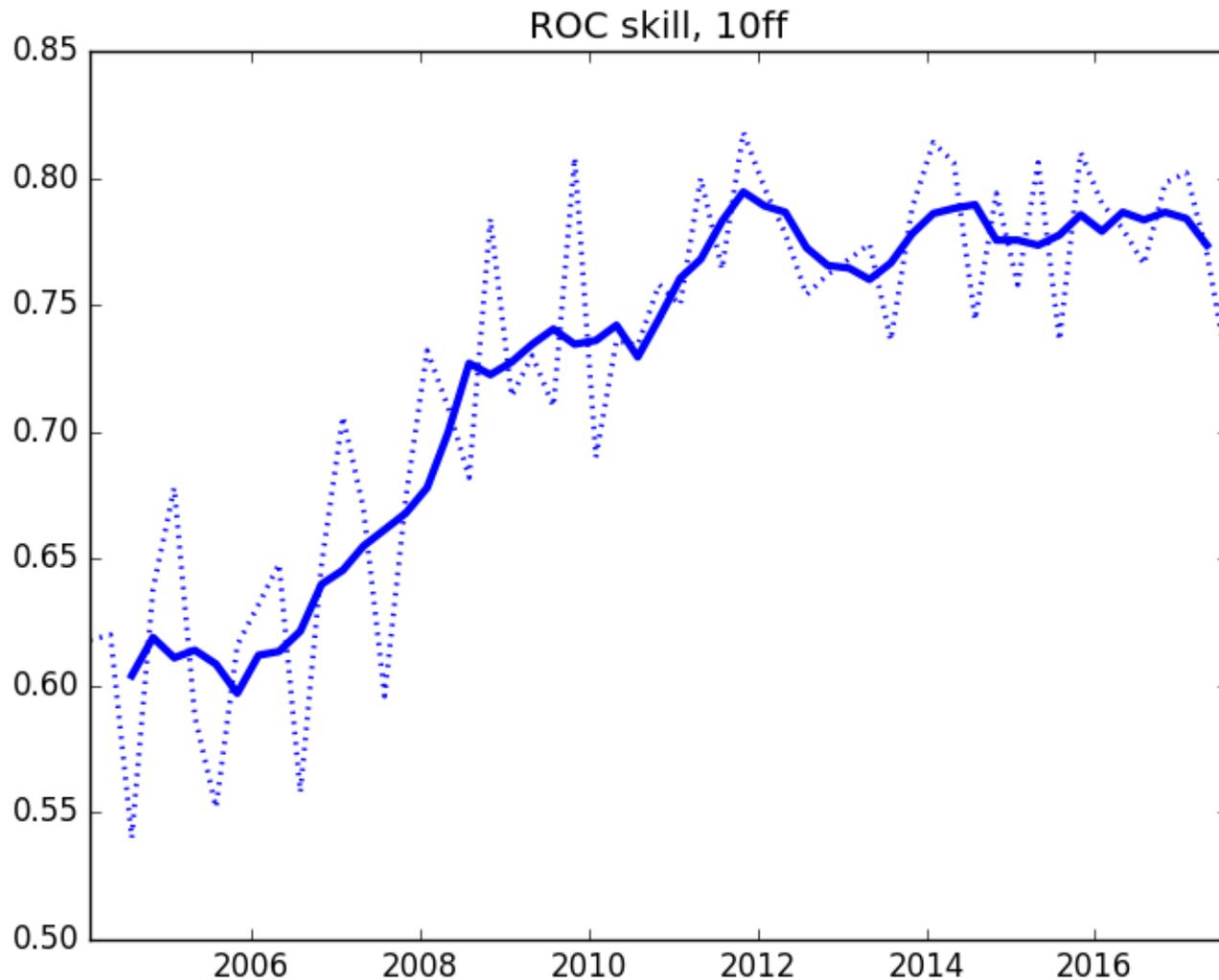
M-Climate: this stands for Model Climate. It is a function of lead time, date (+/-15days), and model version. It is derived by rerunning all member ensemble over the last 20 years twice a week (1980 realisations). M-Climate is always from the same model version as the displayed ENS data. On this page only the 24-48 lead M-Climate is displayed.

# EFI Verification

- Verification of the EFI has been done using synoptic observations over Europe available on the GTS.
- An extreme event is defined when the observation exceeds the 95th percentile of the observed climate for that station (calculated from a 15-year sample).
- The ability of the EFI to detect extreme events is assessed using the area under the Relative Operating Characteristic (ROCA). ROCA shows how good the model is at discriminating between severe and non-severe events.
- $$\text{EFI skill score} = \frac{\text{score} \downarrow \text{forecast} - \text{score} \downarrow \text{reference}}{\text{score} \downarrow \text{perfect forecast} - \text{score} \downarrow \text{reference}} = \frac{\text{ROCA} \downarrow f - 0.5}{1 - 0.5} = 2\text{ROCA} \downarrow f - 1$$

0 → no skill, 1 → perfect score
- The verification is done for 3 parameters: 2m mean temperature, 10m mean wind speed and total precipitation

# EFI Verification



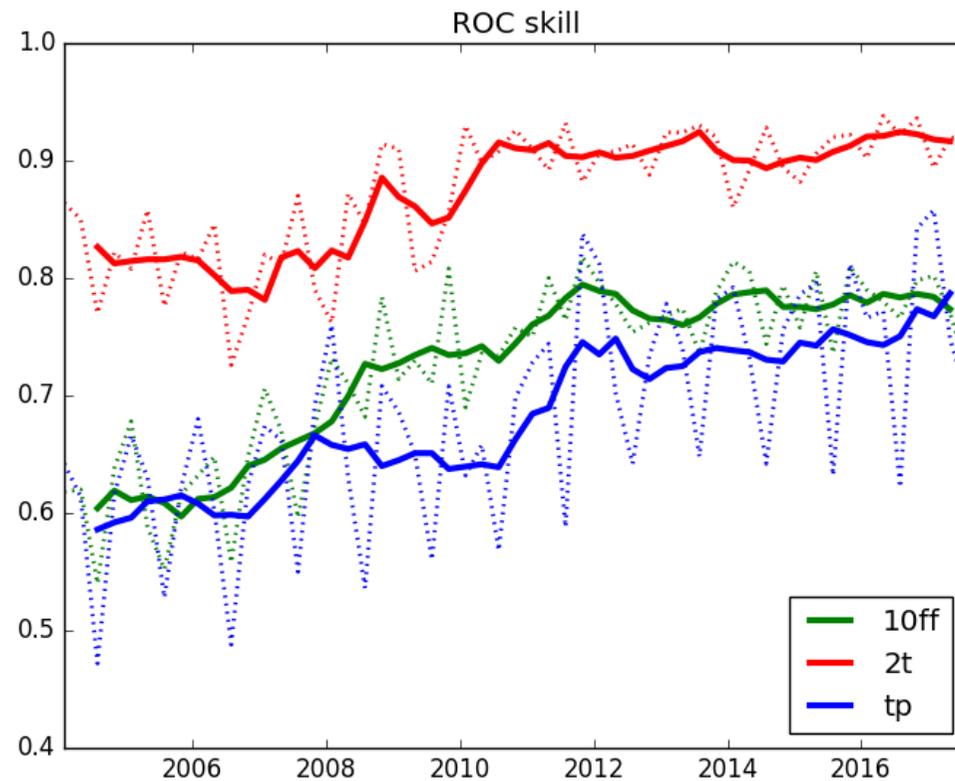
EFI Skill =  $2 \cdot \text{ROCA} - 1$

EFI Skill = 0 no skill

EFI Skill = 1 perfect score

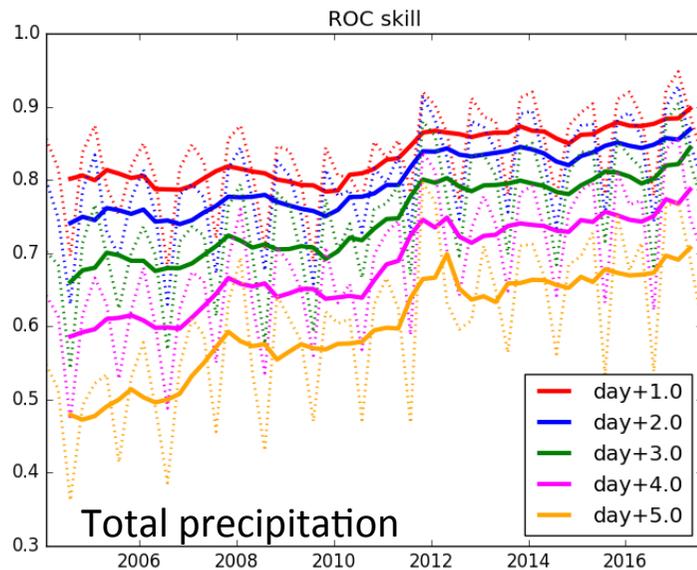
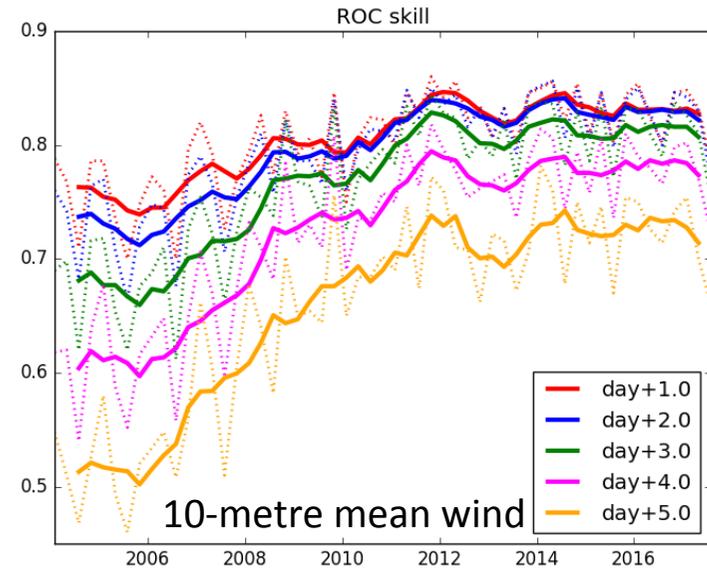
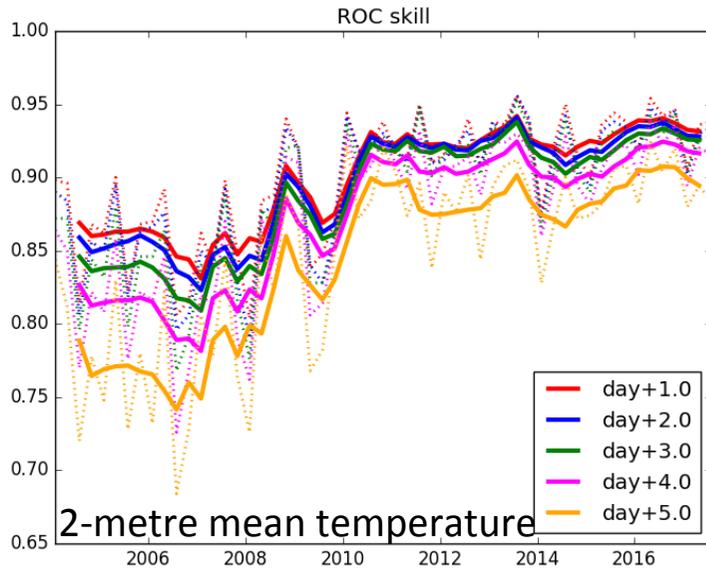
- **The plot shows the skill of the EFI for 10-metre wind speed (a supplementary headline score adopted by the ECMWF Council) at forecast day 4 (t+72-96h for 00UTC).**
- **The solid curve depicts a four-season running mean.**

# EFI Verification



- Solid curves show a four-season running mean and dashed curves show seasonal EFI skill scores **mean temperature (2t)**, **10 metre mean wind speed (10ff)** and **total precipitation (tp)** for day 4 (t+72- for 00UTC).
- The EFI for 2m temperature is more skilful than EFI for the other two parameters.

# EFI Verification



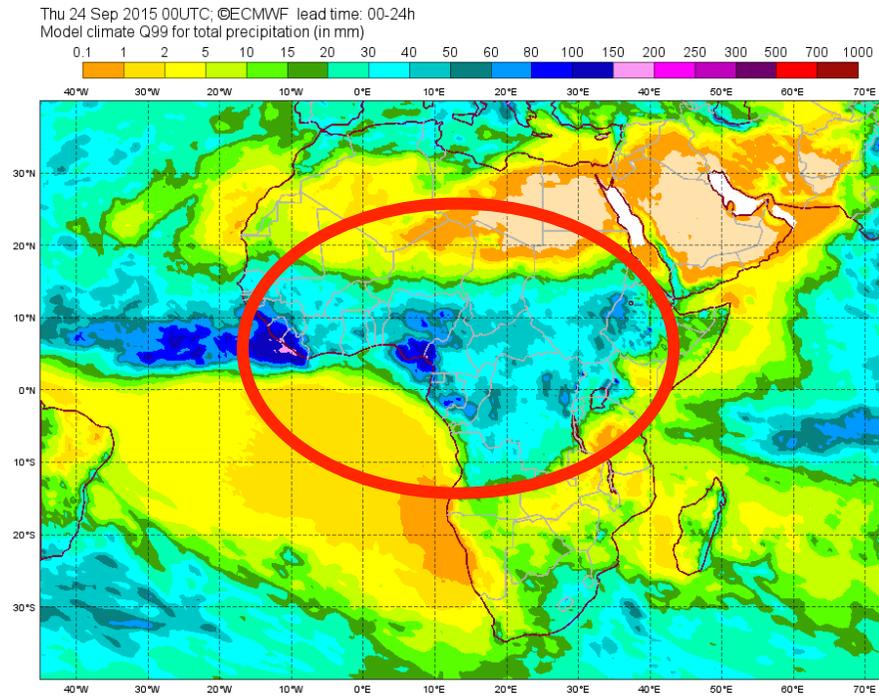
- EFI skill as a function of the lead time
- Notable seasonal cycle in the EFI skill especially for total precipitation with its minimum in summer

# Known issues

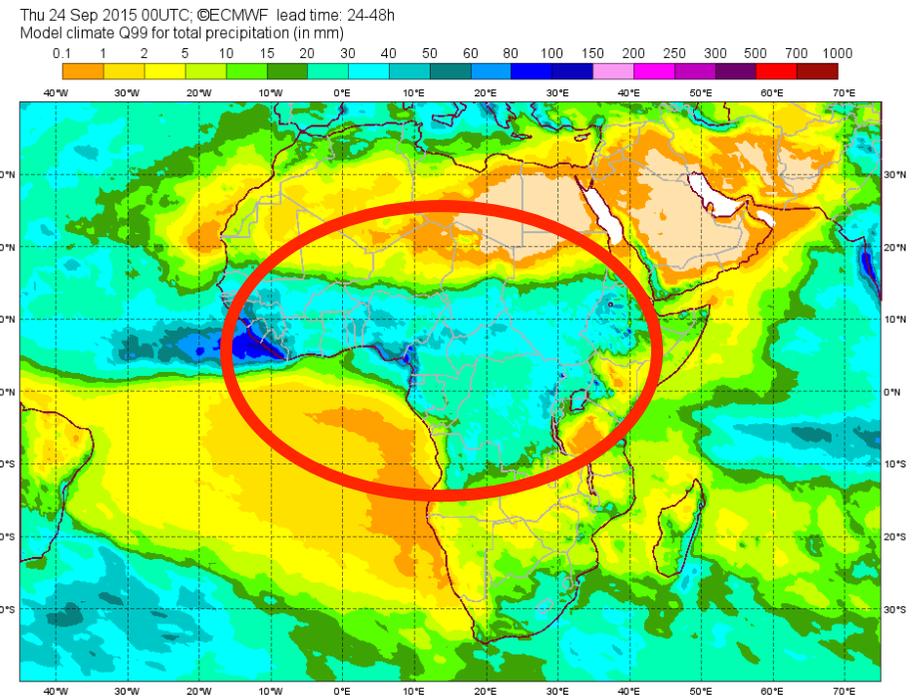
- **Re-forecast sample size is still not sufficient for providing robust climate:**
  - ✓ The increase of the sample size since May 2015 has considerably improved the M-climate but still:
    - There is still some noise, especially in the tails of the climate distribution.
- **M-climate is affected by the model biases:**
  - ✓ Jumpiness in the M-climate for different lead times
  - ✓ This does not affect the EFI/SOT
- **The EFI/SOT might be affected by a seasonal trend due to discrete change of the M-climate during transition seasons (spring and autumn) – an example will be shown.**

# Known issues – an example, tropical Africa

T+0-24h

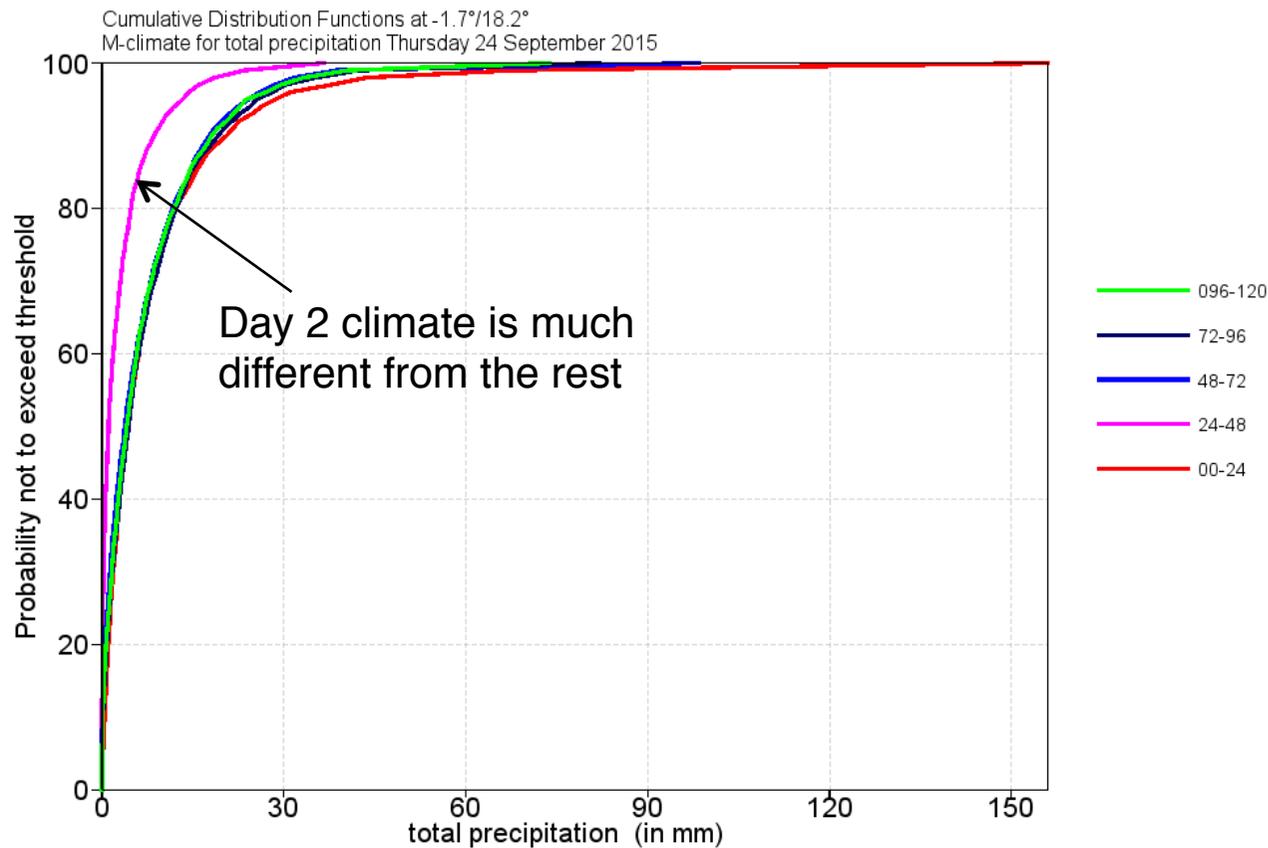


T+24-48h



- The striking difference between t+00-24h and t+24-48h climate is noticeable on these charts which represent 99<sup>th</sup> model climate percentile. Precipitation amounts corresponding to Q99 for 00-24h are much bigger than those for 24-48h.

# Known issues – an example, tropical Africa

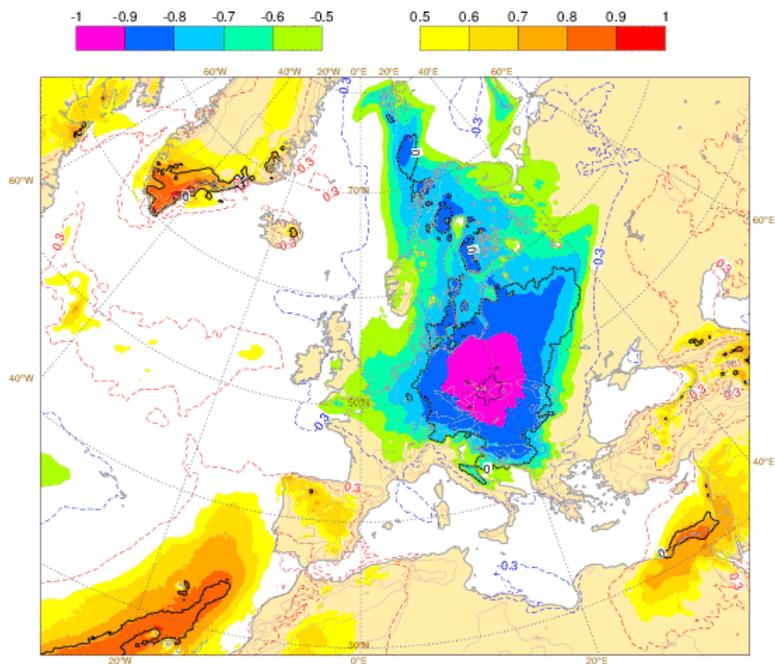


M-climate is not perfect. It is affected by model biases and therefore it depends on the lead time:

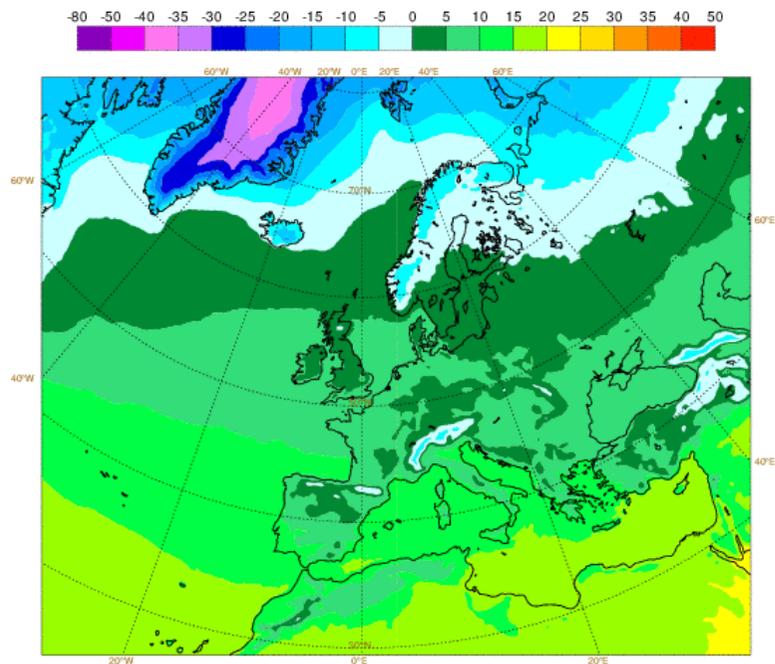
- Jumpiness in the M-climate for different lead times
- Ideally, this shouldn't affect the EFI

# Seasonal trend issue

Fri 05 May 2017 00UTC ©ECMWF t+96-120h VT: Tue 09 May 2017 00UTC - Wed 10 May 2017 00UTC  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for 2m mean temperature



Thu 04 May 2017 00UTC ©ECMWF VT: Tue 09 May 2017 00UTC - Wed 10 May 2017 00UTC 96-120h  
2m mean temperature (in °C) Model climate Q1 (one in 100 occasions realises less than value shown)



On the animation, the EFI valid for the same date is becoming less extreme although the forecasts are similar because the M-climate is becoming colder for shorter lead times. Suddenly the EFI jumps to more extreme values again after the update of the M-climate because the model climatology appears warmer after that update as we add one warm week and remove another cold week. The effect will be opposite for a case in autumn.

# Floods in Central Europe

June 2013



723

TECHNICAL MEMORANDUM

ECMWF forecast performance  
during the June 2013 flood  
in Central Europe

T. Haiden, L. Magnusson, I. Tsonevsky,  
F. Wetterhall, L. Alfieri, F. Pappenberger,  
P. de Rosnay, J. Muñoz-Sabater,  
G. Balsamo, C. Albergel, R. Forbes,  
T. Hewson, S. Malardel, D. Richardson

Forecast and Research Departments

June 2014

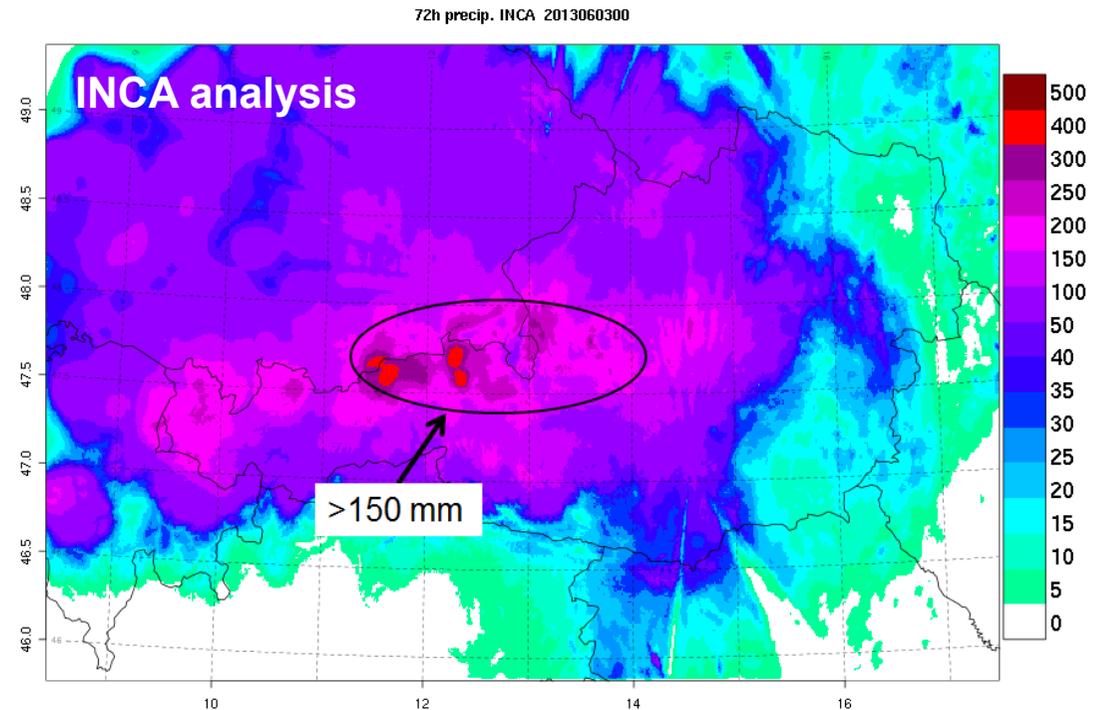
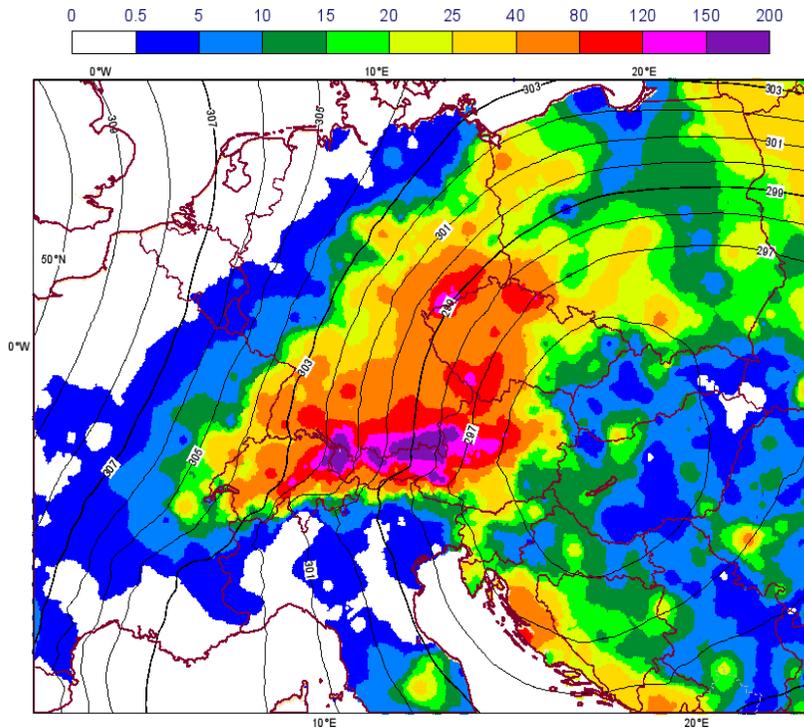
This paper has not been published and should be regarded as an Internal Report from ECMWF.  
Permission to quote from it should be obtained from the ECMWF.



European Centre for Medium-Range Weather Forecasts  
Europäisches Zentrum für mittelfristige Wettervorhersage  
Centre européen pour les prévisions météorologiques à moyen

# Analysis

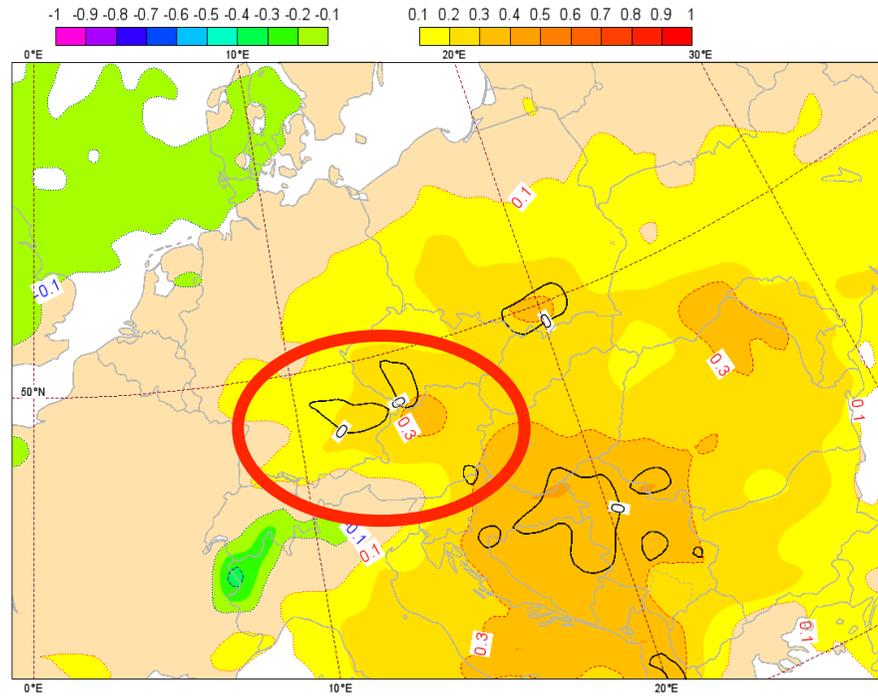
Observed rainfall interpolated on a grid and Z700  
(mean over the period) ECMWF analysis  
VT: 31/05/2013 06 UTC – 03/06/2013 06UTC



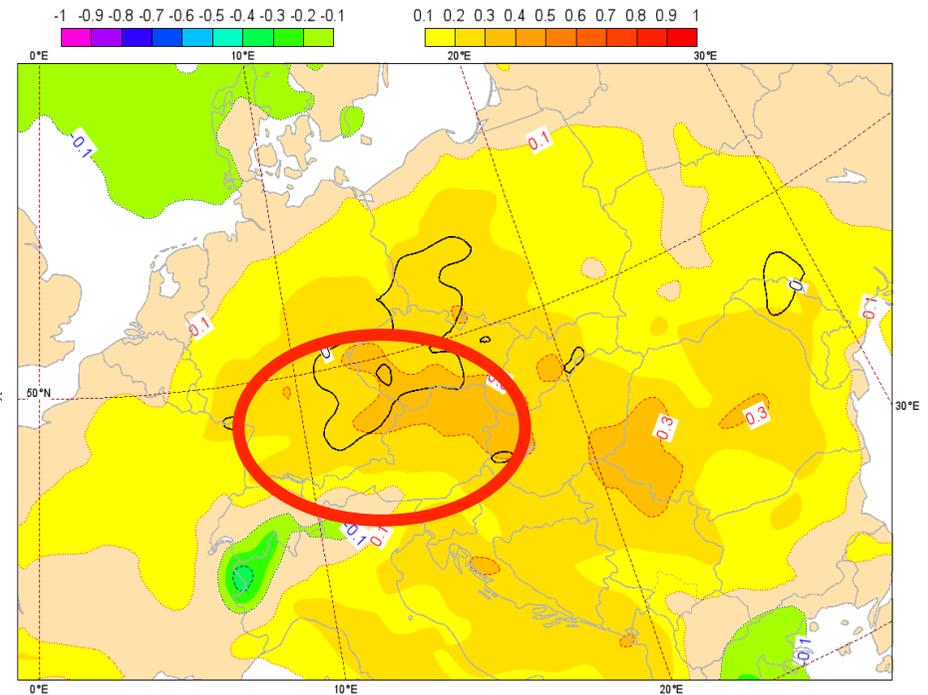
- A quasi-stationary low pressure system brought moist, warm air from the east and northeast into Central Europe causing massive amounts of rain in southern Germany and western Austria.
- Orographic enhancement of precipitation along the northern side of the Alps played an important role.

# EFI & SOT, total precipitation, T+240-360

Tue 21 May 2013 00UTC @ECMWF VT: Fri 31 May 2013 00UTC - Wed 05 Jun 2013 00UTC 240-360h  
Extreme forecast index and Shift of Tails (black contours 0,1,5,10,15) for: total precipitation



Wed 22 May 2013 00UTC @ECMWF VT: Sat 01 Jun 2013 00UTC - Thu 06 Jun 2013 00UTC 240-360h  
Extreme forecast index and Shift of Tails (black contours 0,1,5,10,15) for: total precipitation



- A remarkably strong signal in the EFI for this long lead time.
- Positive SOT values mark the areas where the forecast system predicts exceptionally heavy rain.

# EFI/SOT for forecasting severe convection

- Convective Available Potential Energy (CAPE) – the output from the IFS is the MUCAPE in the lowest 350 hPa:

$$CAPE = \int_{z \downarrow LFC}^{z \downarrow EL} g(\theta \downarrow e, up - \theta \downarrow e, sat / \theta \downarrow e, sat) dz$$

- CAPE SHEAR Parameter (CSP):

$$CSP = WS \downarrow l_1 \uparrow l_2 \sqrt{CAPE}$$

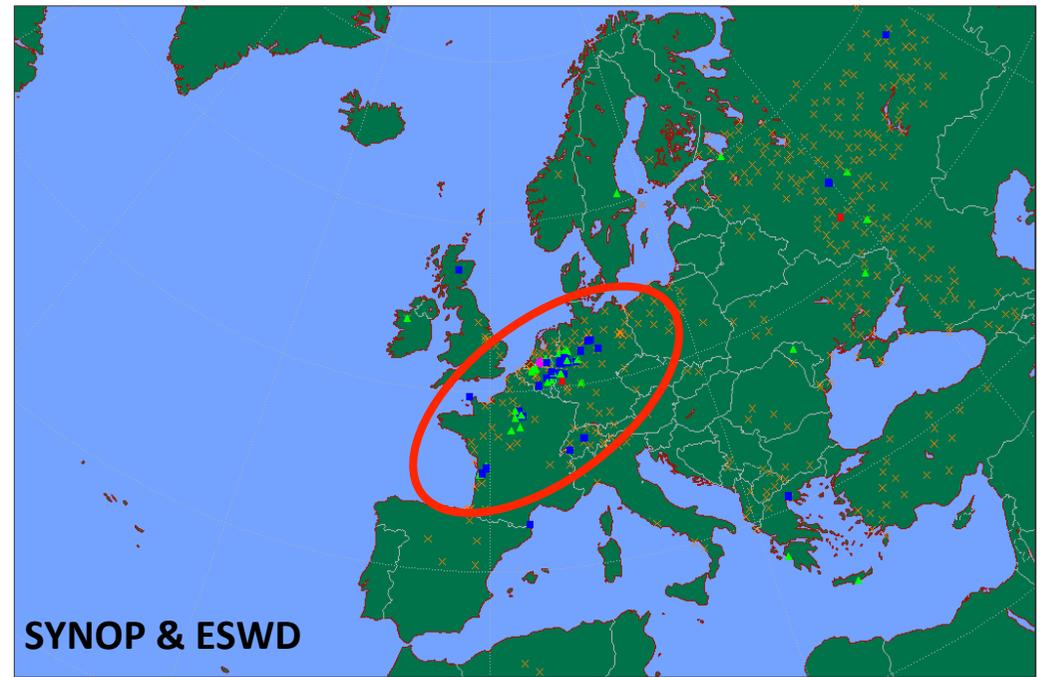
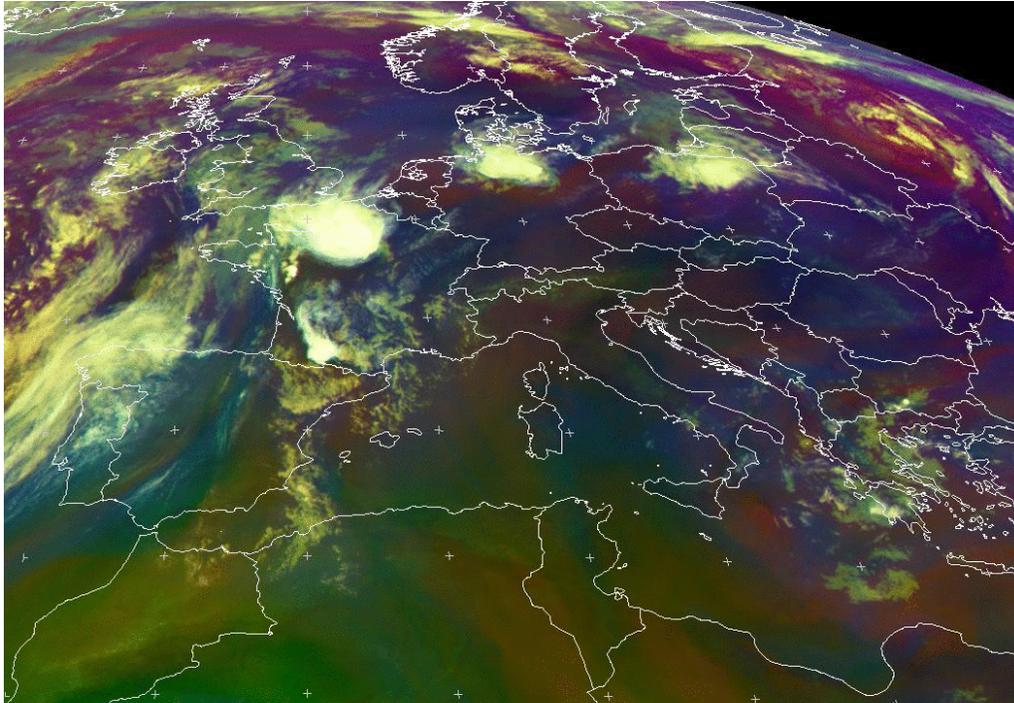
- $WS \downarrow l_1 \uparrow l_2$  - bulk wind shear between  $l_1=925$  hPa and  $l_2=500$  hPa;
  - $w \downarrow max = \sqrt{2} CAPE$  is the maximum vertical velocity in convective updraughts.
- Four values for each 24-hour period are considered and the maximum of these is retained.
- To avoid noise in the high latitudes, CAPE less than 10 J/kg is filtered out.

# Severe convection, 9 June 2014

✕ TS wind gusts (>25 m/s)    ▲ hail heavy precip (> 50 mm)    ✕ squalls    ▲ tornadoes

Severe weather reports for 09/06/2014

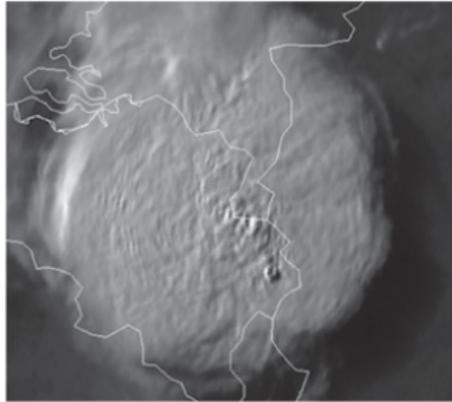
✕ TS wind gusts (>25 m/s)    ▲ hail heavy precip (> 50 mm)    ✕ squalls    ▲ tornadoes



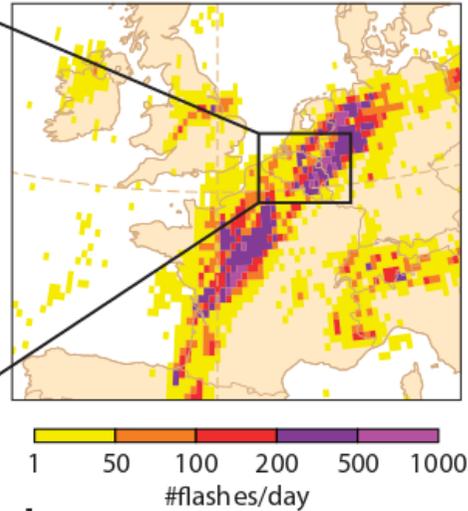
- Severe convection affected Western Europe on 9 June 2014.
- Deep moist convection developed along the western fringe of a hot air mass.
- Many weather reports of severe wind gusts and large hail in the European Severe Weather Database (ESWD).

# Severe convection, 9 June 2014

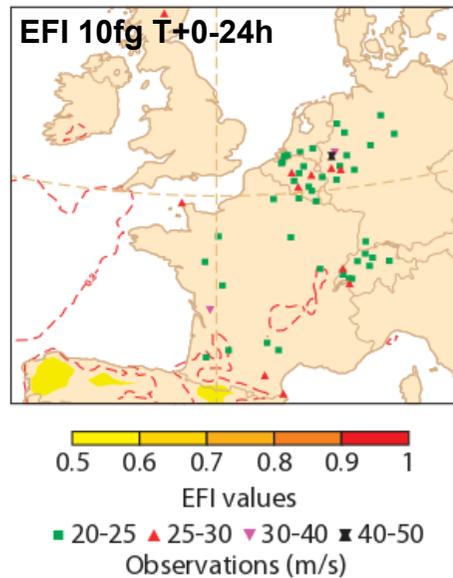
**a** Satellite



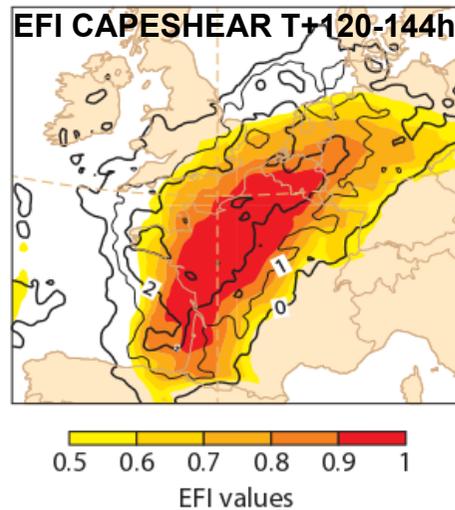
**b** Lightning



**c** Wind gusts



**d** CSP



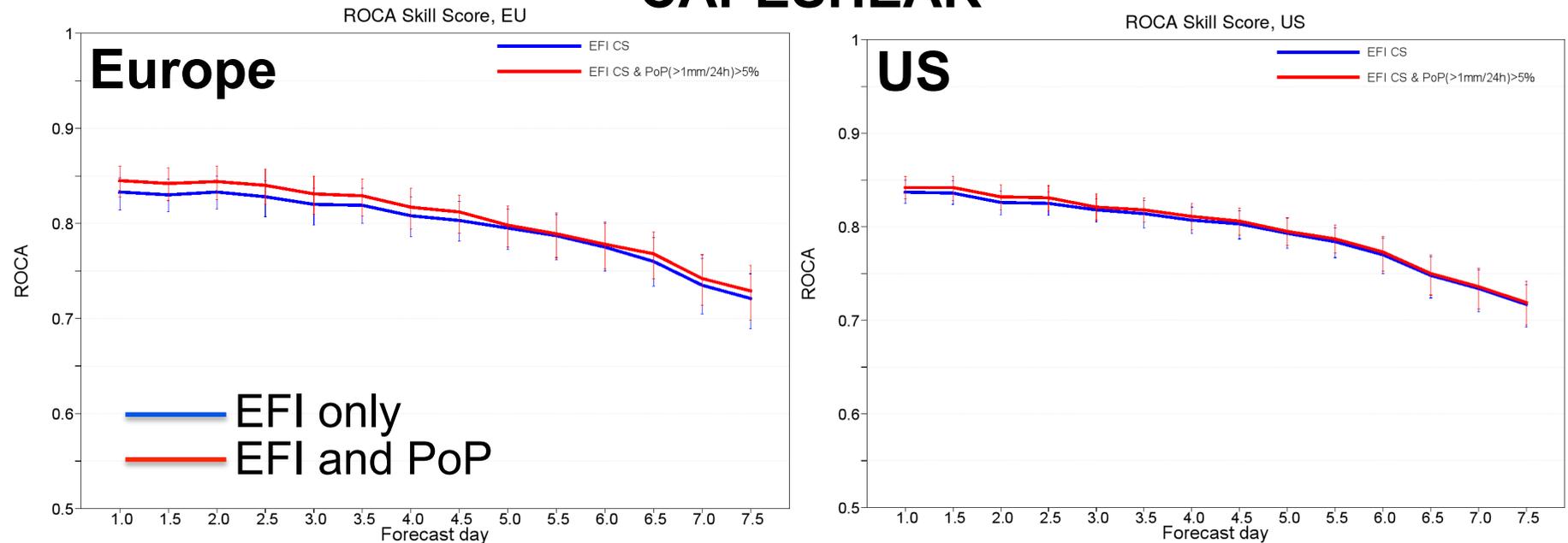
- Strong wind gusts were reported in France, Belgium, the Netherlands and Germany.
- The maximum wind gust at Düsseldorf airport was 42 m/s.
- The EFI gave no indication of severe wind gusts even in the short range (c).
- The EFI for CAPESHEAR reached values close to 1 six days in advance (d).

# Verification

- ROCA skill score to assess the ability of the forecast to discriminate between events and non-events.
- Data sources:
  - ✓ Lightning density derived from the ATDnet lightning detection system (UK Met Office) for Europe
  - ✓ European Severe Weather Database (ESWD) operated by ESSL
  - ✓ Severe weather reports (tornadoes, large hail and high winds) from the NOAA/NWS Storm Prediction Centre (SPC) for the USA
- Verification period: April – September (summer season in the NH)
- Two thresholds for lightning density: 0.2 and 0.5 flashes/km<sup>2</sup> per day (approximately 95<sup>th</sup> and 99<sup>th</sup> percentiles of lightning density distribution for the summer season)
- Verification is performed just for land points

# Verification

## CAPE-SHEAR



- Verification period is 1 April – 30 September 2016
- For Europe ESWD reports for tornadoes, severe wind and large hail used only
- EFI v. EFI and PoP (>1mm/day) > 5%
- Similar results for Europe and the US
- High skill well in the medium range.

# Some considerations and future plans

- The EFI provides signals of anomalous weather relative to the model climatology.
  - ✓ very low CAPE values (<10 J/kg) are filtered out to avoid insignificant signals in the areas of low CAPE values in the M-climate (e.g. Arctic in winter)
  - ✓ severe convection unlikely when climatological values of CAPE too low, e.g. continental Europe in winter (climatological maps provided)
- Both convective EFIs give guidance where convection is likely to be severe/anomalous if it could be initiated. Assuming sufficient instability is already present, an important forecast issue is the sufficiency of the lift to overcome CIN. *The challenge of knowing when, where, or even if the capping inversion will be overcome is one of several factors that make forecasting severe convection so difficult! (Charles Doswell III, 2000: Extratropical synoptic-scale processes and severe convection)*
  - ✓ Probability of precipitation could be used in conjunction with the EFI to determine the area where DMC is more likely to occur
- Instantaneous values of CAPE and CAPESHEAR to be replaced with maximum values during previous 6 hours (derived from the hourly model output) for the EFI computation (work in progress).

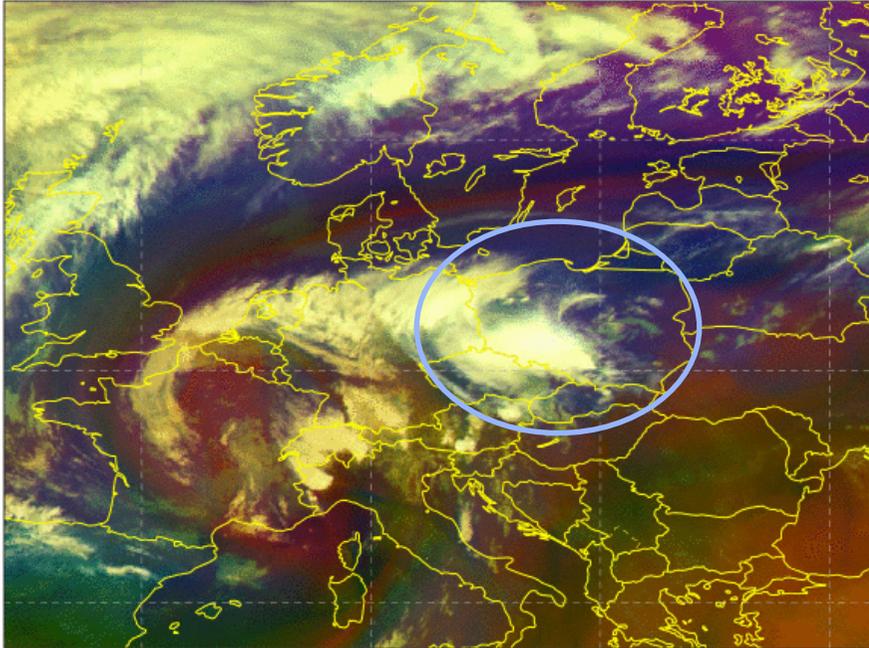
# Severe convection, Poland, 11/08/17



- 5 people killed during an outbreak of severe thunderstorms on Friday, 11 August 2017

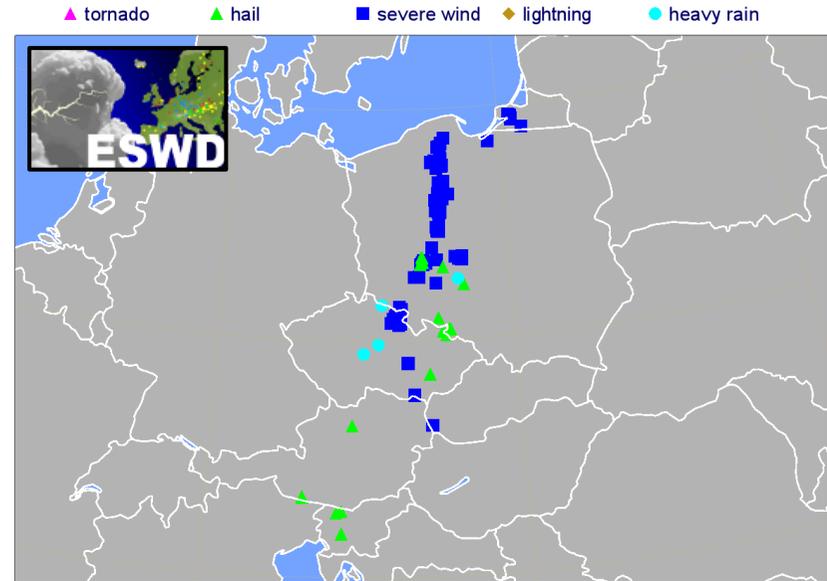
# Analysis

11 August 2017 00:00Z

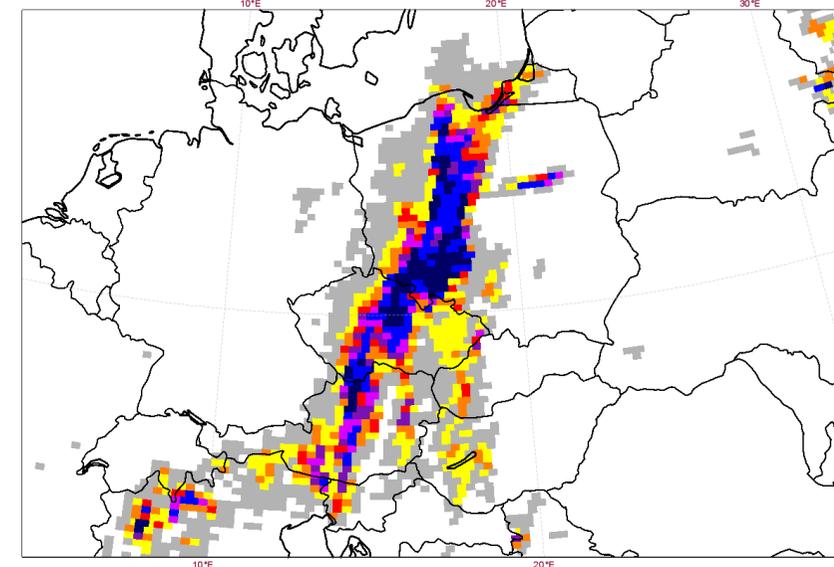


- On the eastern flank of upper low over Poland, a combination of very moist air in the boundary layer and EML with lapse rates  $> 7 \text{ }^\circ\text{C/km}$
- Favourable synoptic-scale conditions

Severe weather reports for Friday 11 Aug 2017

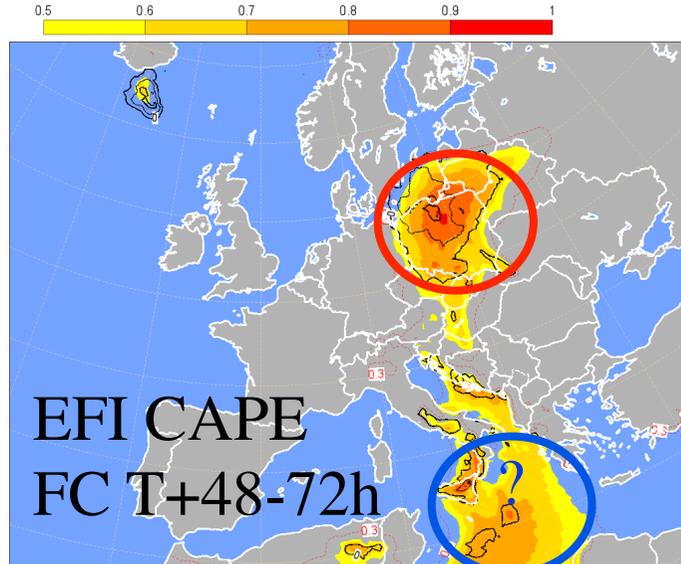


ATDnet Lightning density for Friday 11 August 2017

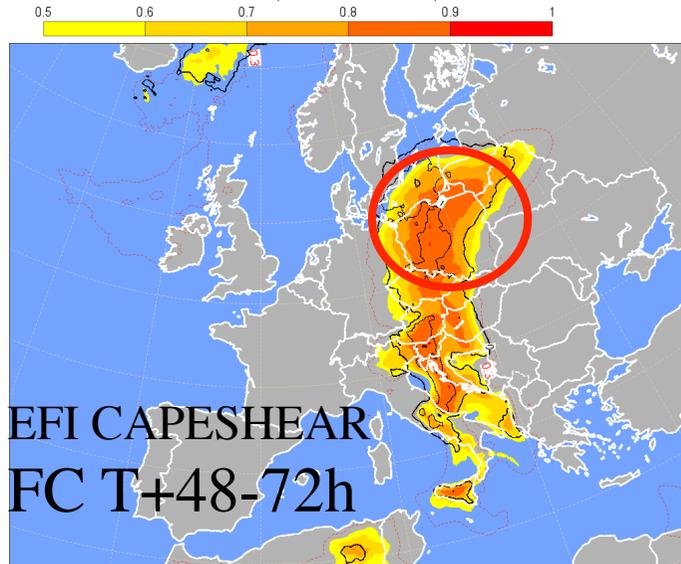


# Forecast v. observations

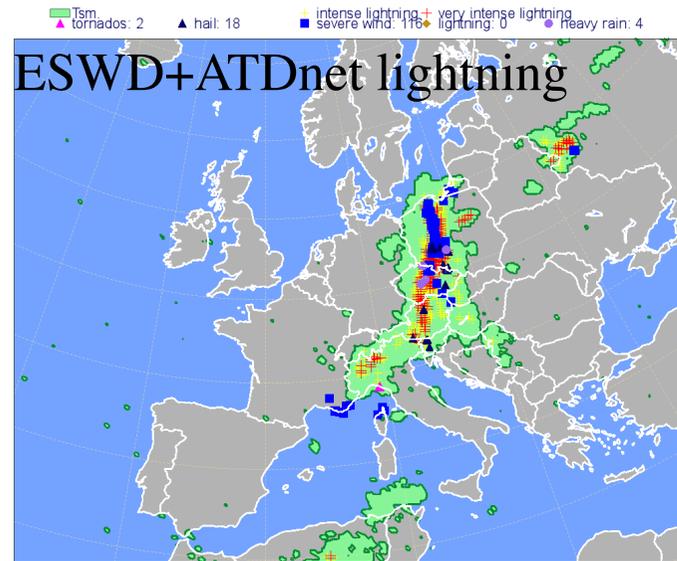
Wed 09 Aug 2017 00UTC @ECMWF expver = 1 VT: Fri 11 Aug 2017 00UTC - Sat 12 Aug 2017 00UTC 48-72h  
 Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPE



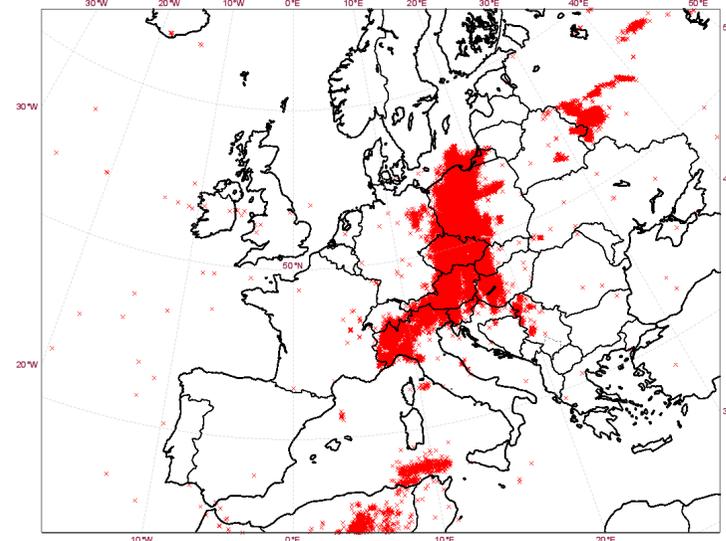
Wed 09 Aug 2017 00UTC @ECMWF expver = 1 VT: Fri 11 Aug 2017 00UTC - Sat 12 Aug 2017 00UTC 48-72h  
 Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPESHEAR



Convective activity for Friday 11 August 2017



ATDnet lightning flashes valid for 11/08/2017



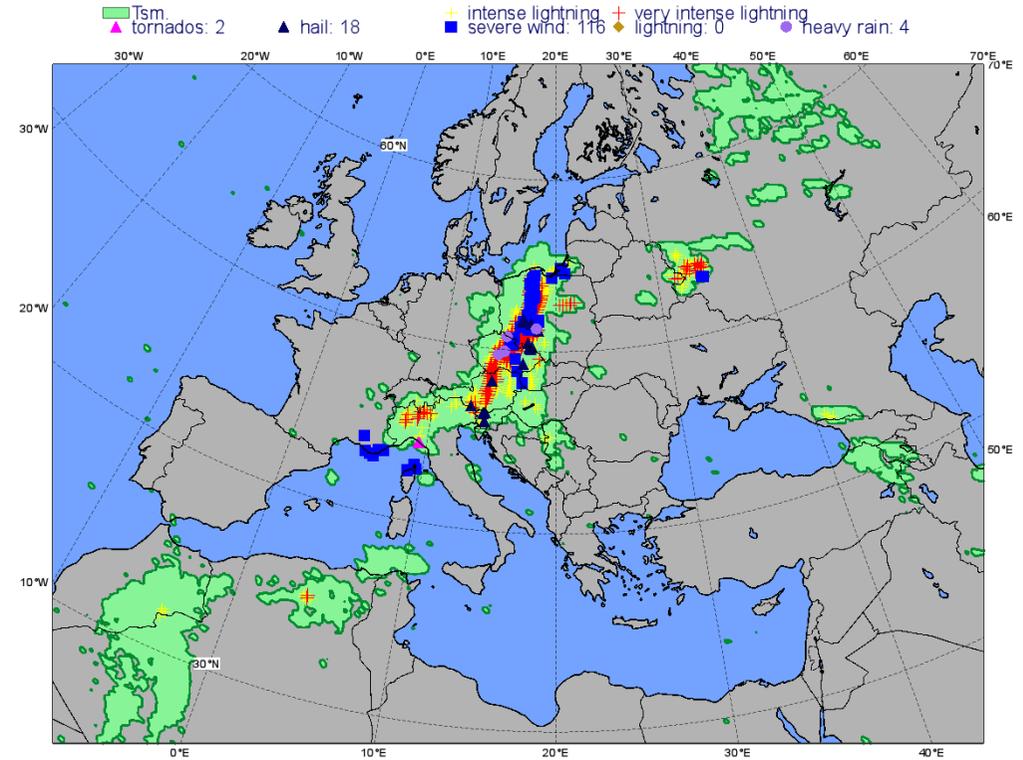
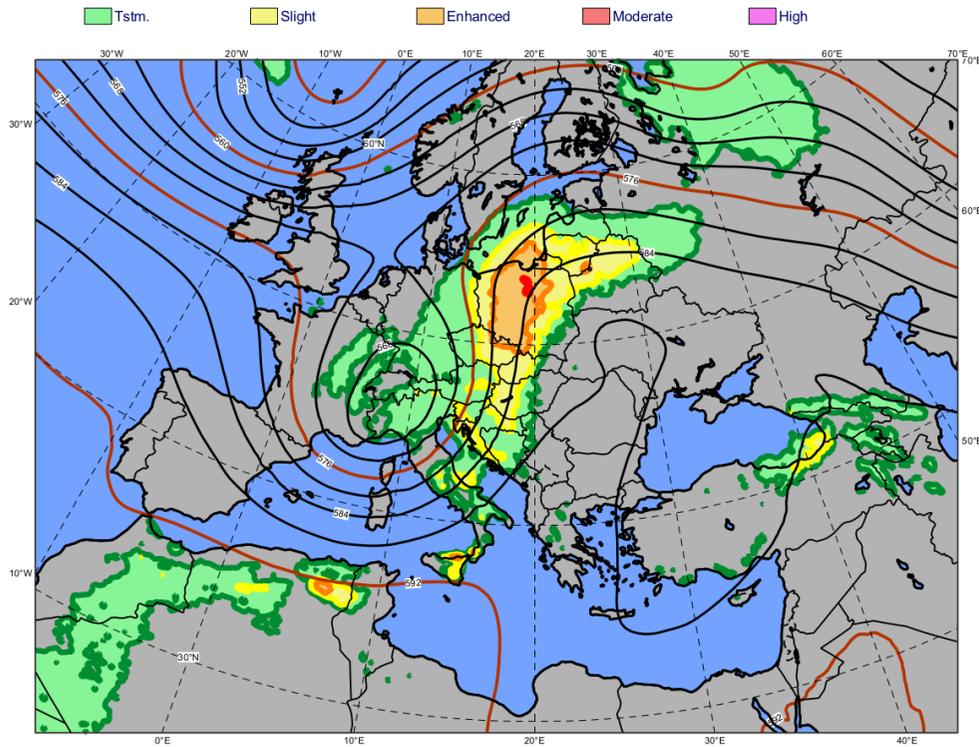
# Convective hazards product

FC T+48-72h

OBS

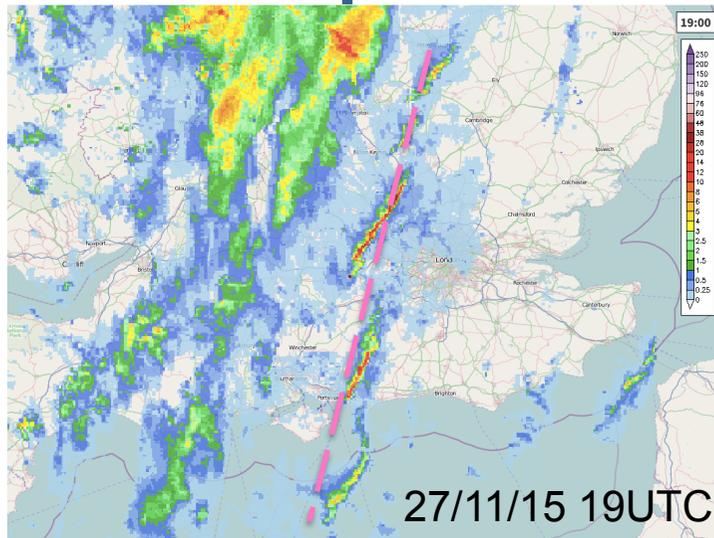
Convective Hazards, FC: T+48-72 for Friday 11 August 2017  
Z500 ensemble mean valid for the middle of the forecast window

Convective activity for Friday 11 August 2017

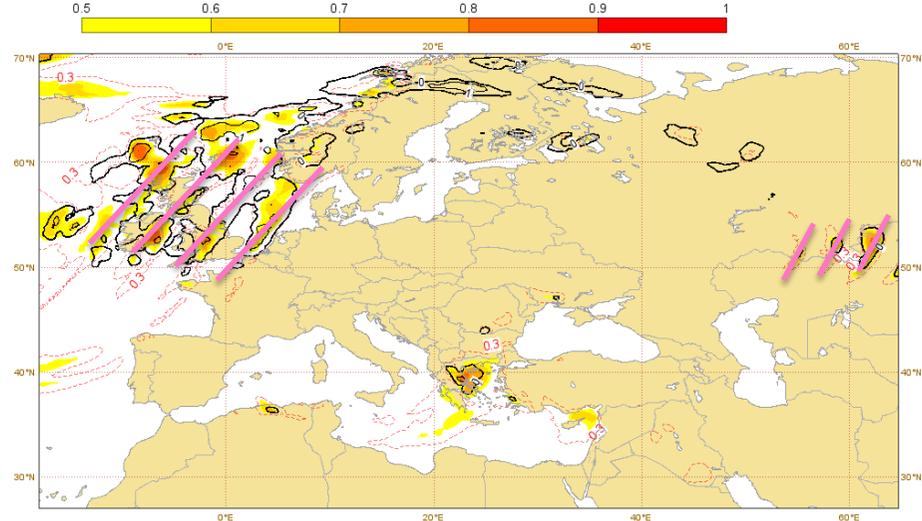


- Enhanced risk (orange): an area of organised storms with varying level of intensity
- Moderate risk (red) - widespread severe thunderstorms some of them intense; risk of supercell producing tornadoes and/or large hail (5+ cm dia.) or risk of an intense squall line with widespread damaging winds

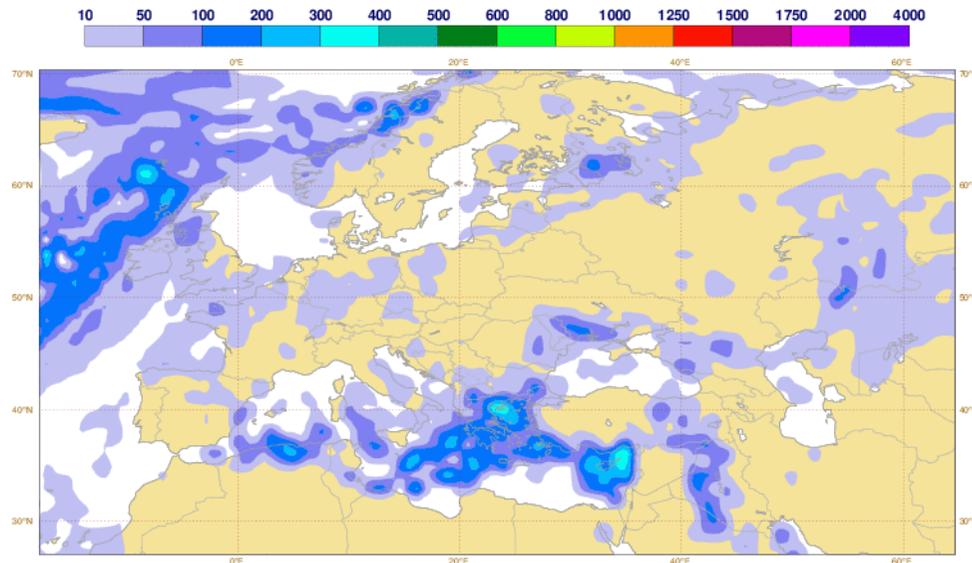
# A squall line along a cold front



Fri 27 Nov 2015 00UTC @ECMWF expver = 1 VT: Fri 27 Nov 2015 00UTC - Sat 28 Nov 2015 00UTC 0-24h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,8) for: CAPESHEAR



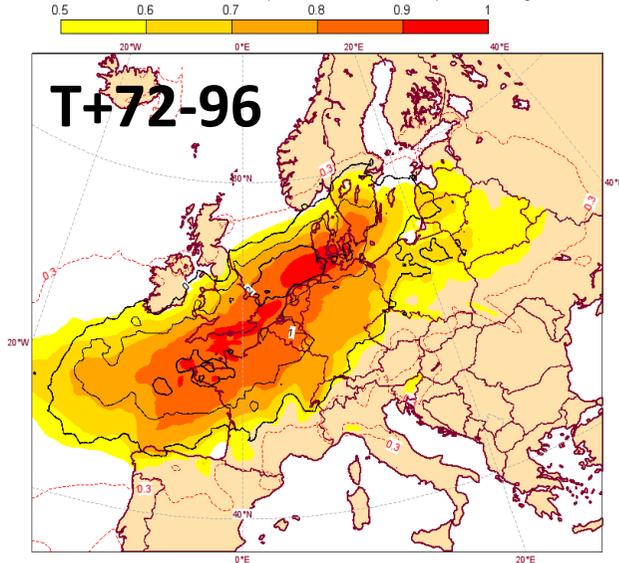
Fri 27 Nov 2015 00 UTC ECMWF CAPESHEAR T+6



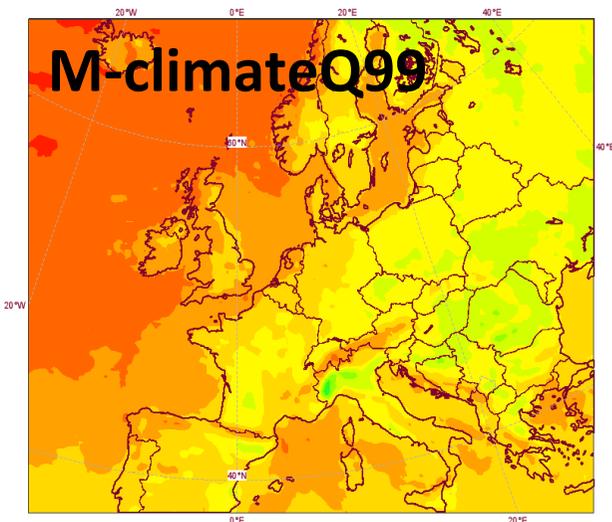
- The stripy structure is due to the combination of a fast moving front and 6-hourly discretization used for the computation
- This feature will disappear once maximum values start to be used instead of the instantaneous values

# St. Jude storm case

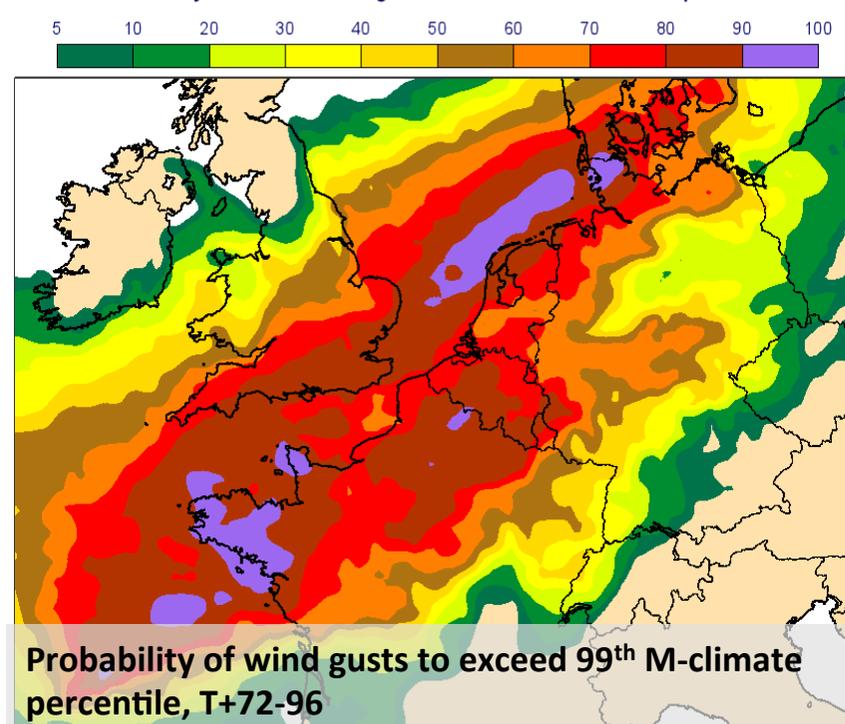
Fri 25 Oct 2013 00UTC @ECMWF expver = 1 VT: Mon 28 Oct 2013 00UTC - Tue 29 Oct 2013 00UTC 72-96h  
Extreme forecast index and Shift of Tails (black contours 0,1,2,5,10,15) for: 10m wind gust



Model climate Q99 (one in 100 occasions realises more than value shown) for 10m wind gust (in m/s)



25/10/2013 00 UTC ECMWF T+72-96h VT: 28/10/2013 00 UTC - 29/10/2013 00 UTC  
Probability of 10-metre wind gusts to exceed 99-th M-climate percentile



- M-climate can be used to compute probabilities of exceeding/not exceeding certain M-climate percentiles.

## Further Reading:

- ✓ User Guide to ECMWF forecast products, [http://www.ecmwf.int/sites/default/files/User\\_Guide\\_V1.2\\_20151123.pdf](http://www.ecmwf.int/sites/default/files/User_Guide_V1.2_20151123.pdf)
- ✓ **Tsonevsky, I., D., Richardson**, 2012: Application of the new EFI products to a case of early snowfall in Central Europe, *ECMWF Newsletter*, **No. 133**, 4.
- ✓ **Tsonevsky, I.**, 2015: New EFI parameters for forecasting severe convection. *ECMWF Newsletter*, **No. 144**, 27-32.



<http://www.ecmwf.int/sites/default/files/NL-144.pdf>