

Forecasting extreme meteorological events over complex topography

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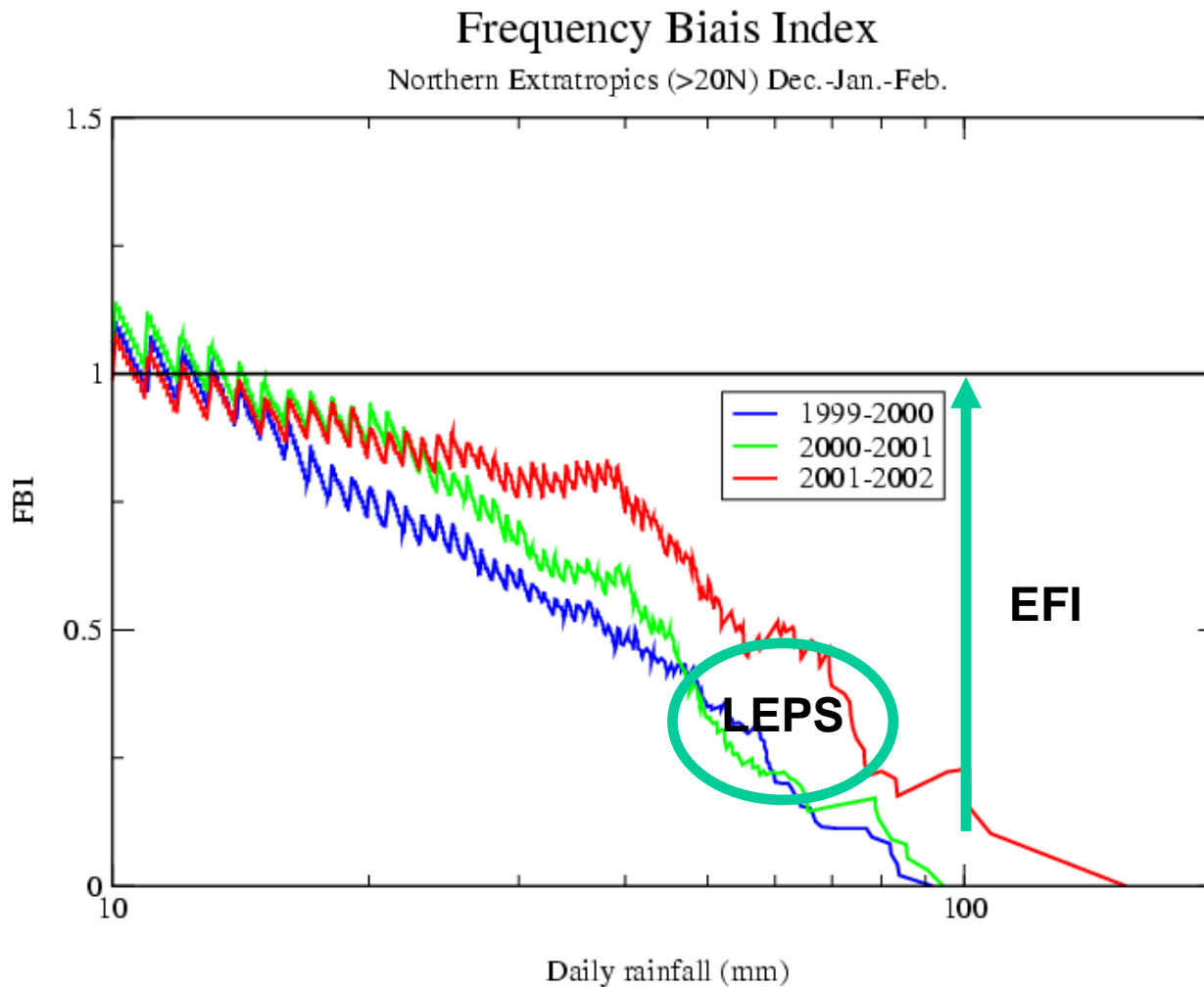


Probability forecasts



- Based on an Ensemble Prediction System (EPS)
- DMO
- Statistical interpretation
- Rescaling
-
- Not well suited for rare events:
 - Positive scores for $\text{prob}(rr > 10 \text{ mm/day})$
 - Negative scores for $\text{prob}(rr > 50 \text{ mm/day})$

ECMWF Medium range model “does” generate severe weather events: forecast/observed frequency ratio (FBI)



Three „downscaling“ techniques for extreme events



Extreme Forecast Index (**EFI**)

- rescale with respect to model climate

LEPS

- downscale ensemble with a LAM

Artificial neural Network (**ANN**)

- pattern recognition of extreme situations with respect to a given meteorological parameter

Three „downscaling“ techniques for extreme events (plan)



The final goal is to compare (HR vs FAR) the three techniques

A few recent cases (EFI and LEPS)

Presentation of ANN

Verification of ANN

Presentation of EFI

Verification of EFI

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A few recent cases

- November 2002 flooding
- Calvann 2.1.2003
- Rainfall of 30.4.2003

November 2002 flooding



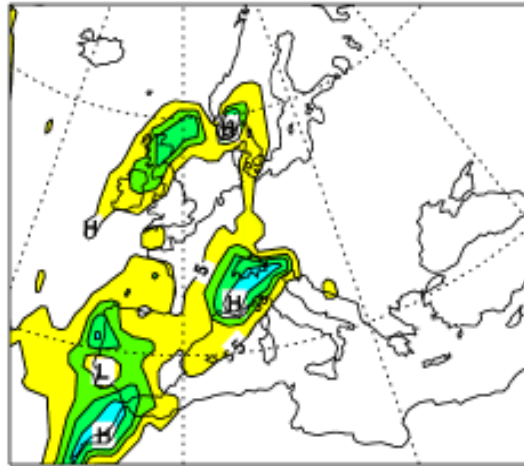
- 14-16th November
- Low over western Mediterranean
- Southerly current over the Alps
- Over 100 mm/day south of the Alps (classical)
- Geneva: 92 mm in one day (14th)
→ **Very exceptional**

ECMWF FORECAST PROBABILITIES

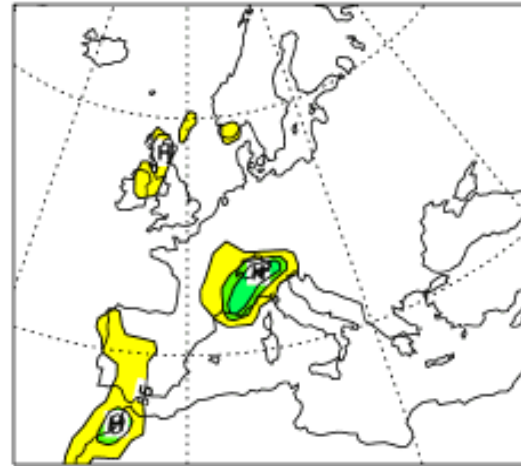
Tuesday 12 November 2002 12z, t+ 72 VT: Friday 15 November 2002 12z

DMO

24hr Total Precipitation greater than 10 mm



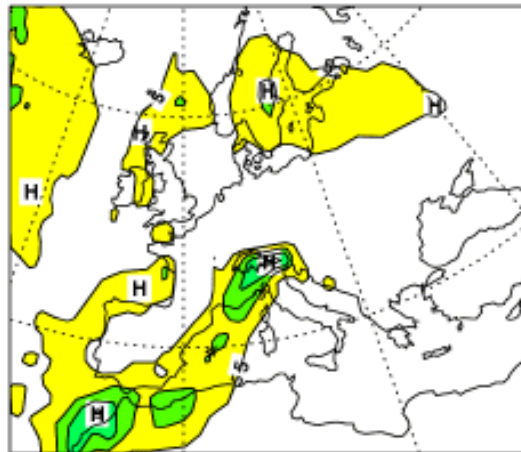
24hr Total Precipitation greater than 20 mm



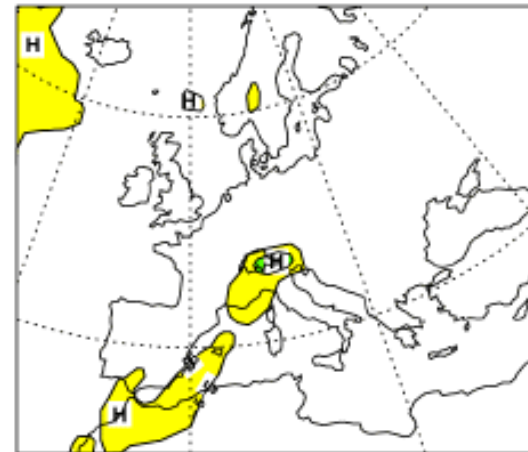
ECMWF FORECAST PROBABILITIES

Tuesday 12 November 2002 12z, t+ 96 VT: Saturday 16 November 2002 12z

24hr Total Precipitation greater than 10 mm

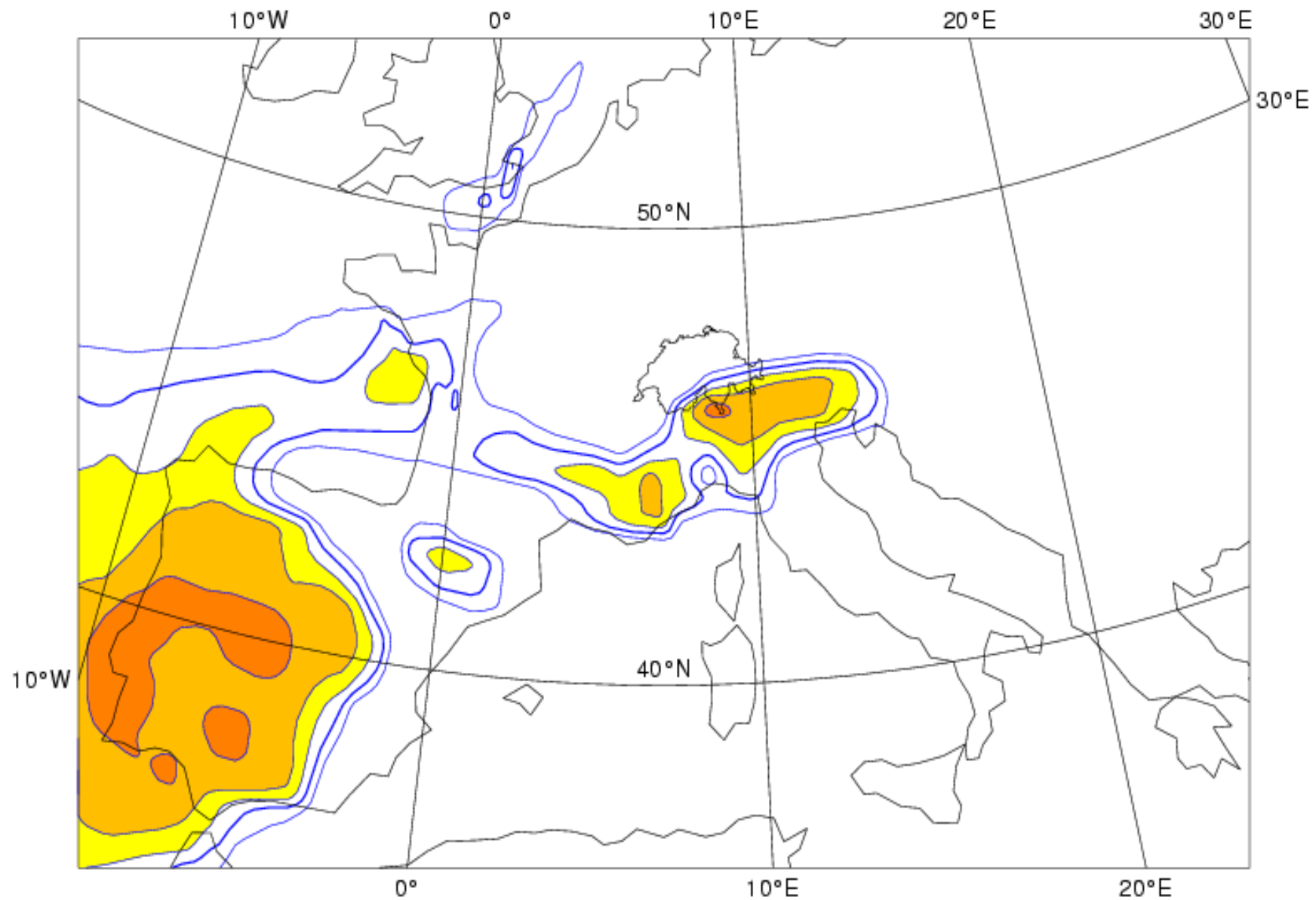


24hr Total Precipitation greater than 20 mm



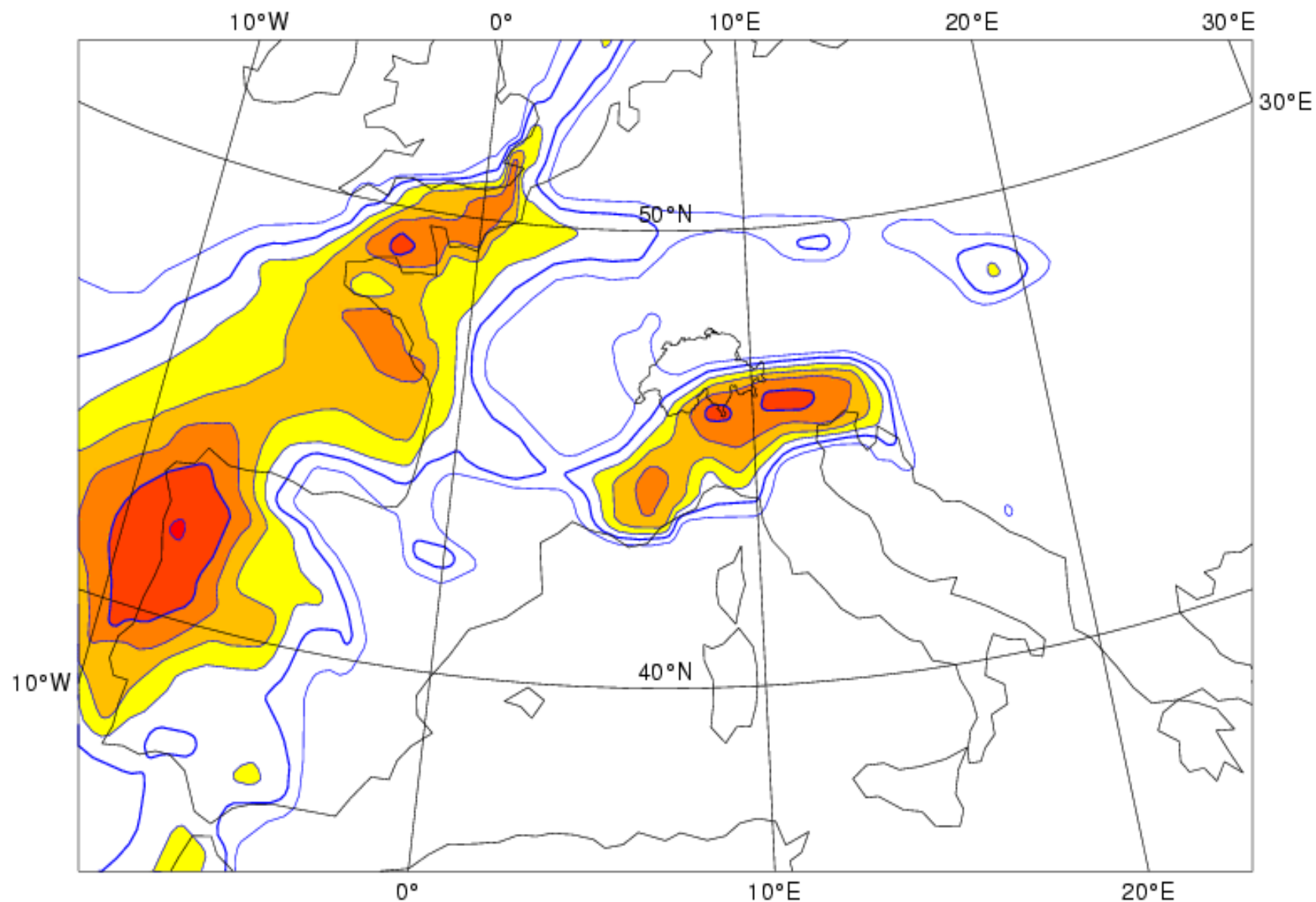
EFI3, 24h total precipitation 10.11.2002, +114h

0.5 - 0.6 0.6 - 0.7 0.7 - 0.76388L



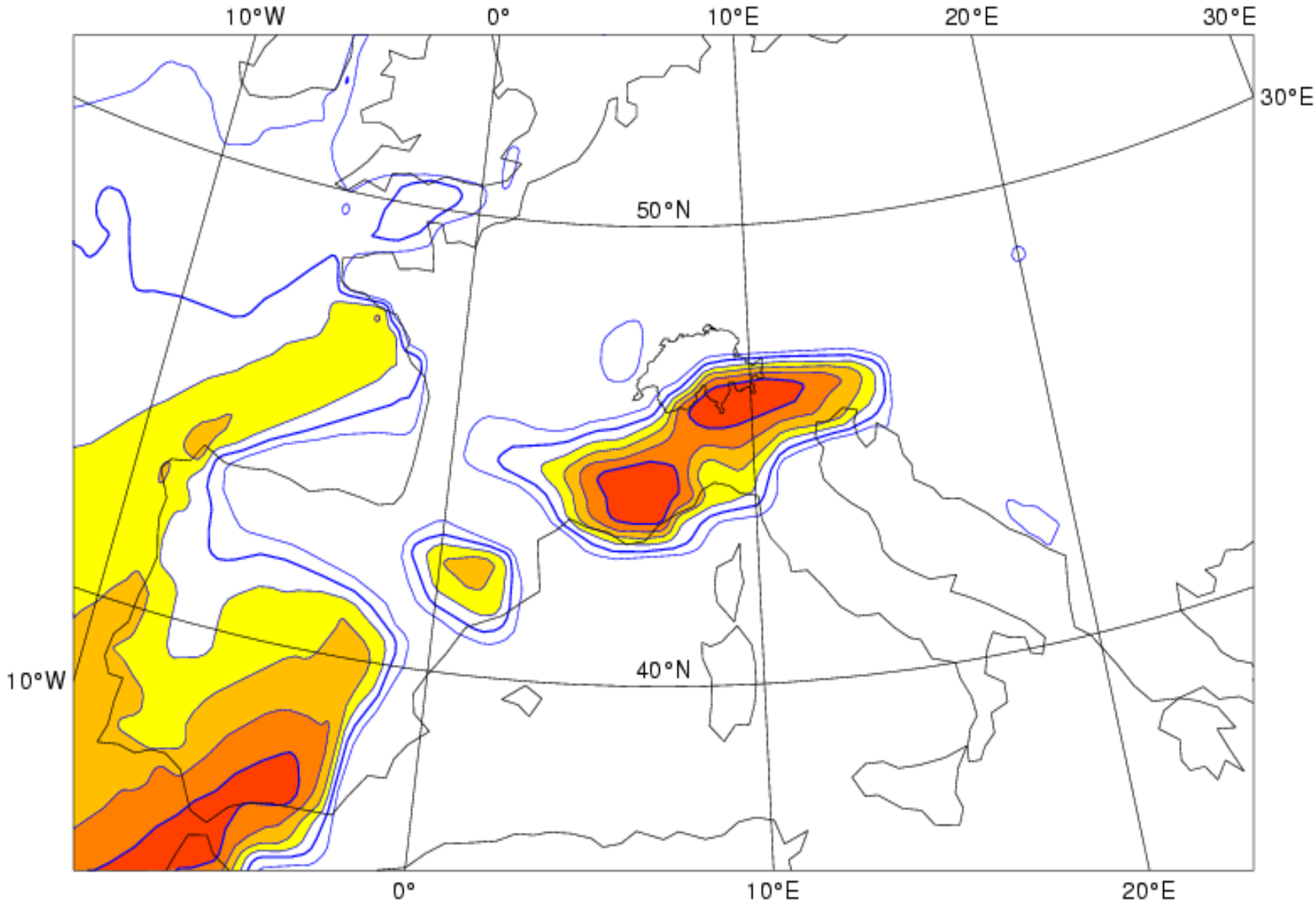
EFI3, 240h total precipitation 10.11.2002, +240h

0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 0.9 0.9 - 0.901990



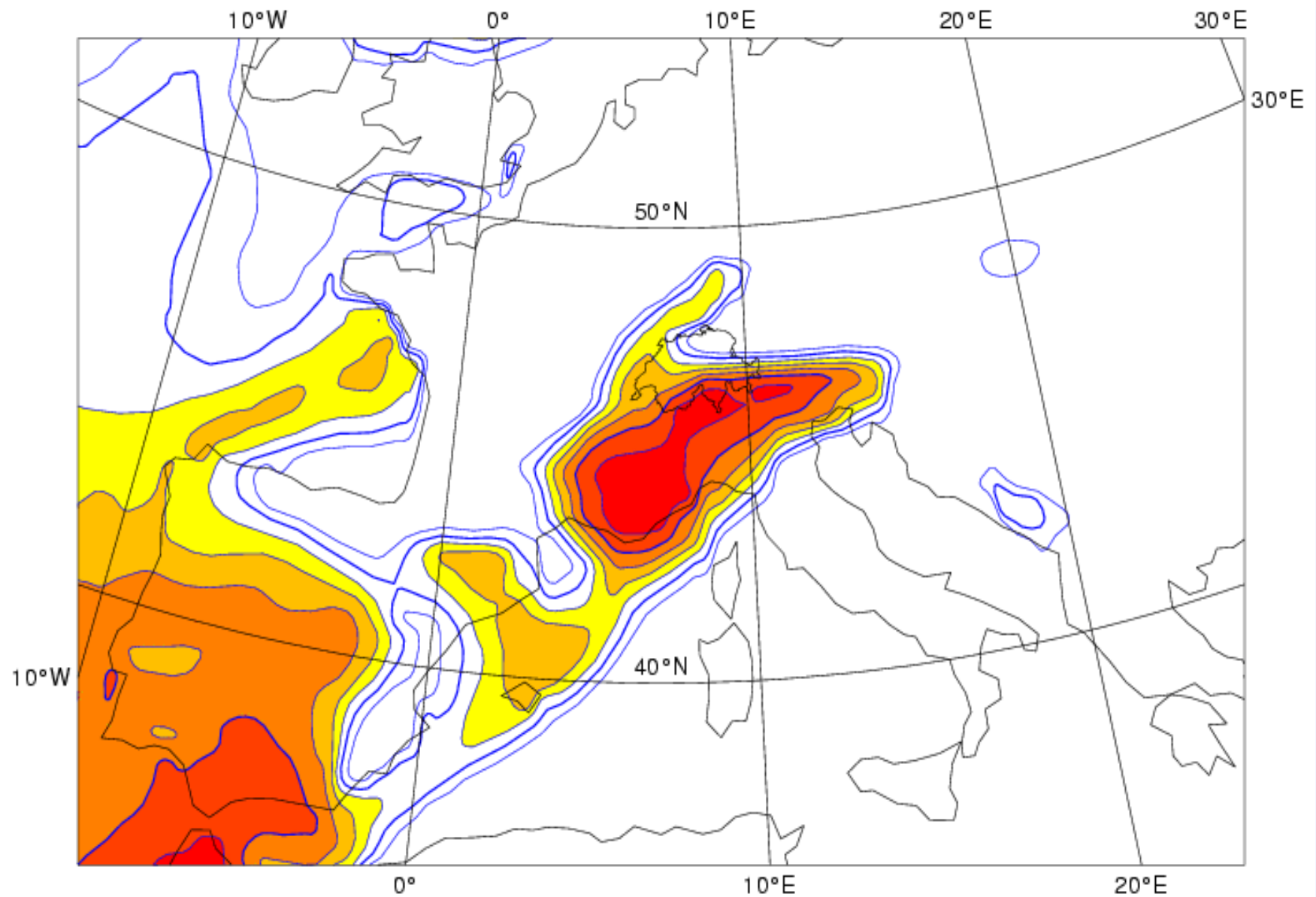
EFI3, 24h total precipitation 11.11.2002, + 90h

0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 0.897507



EFI3, 24h total precipitation 12.11.2002, + 66h

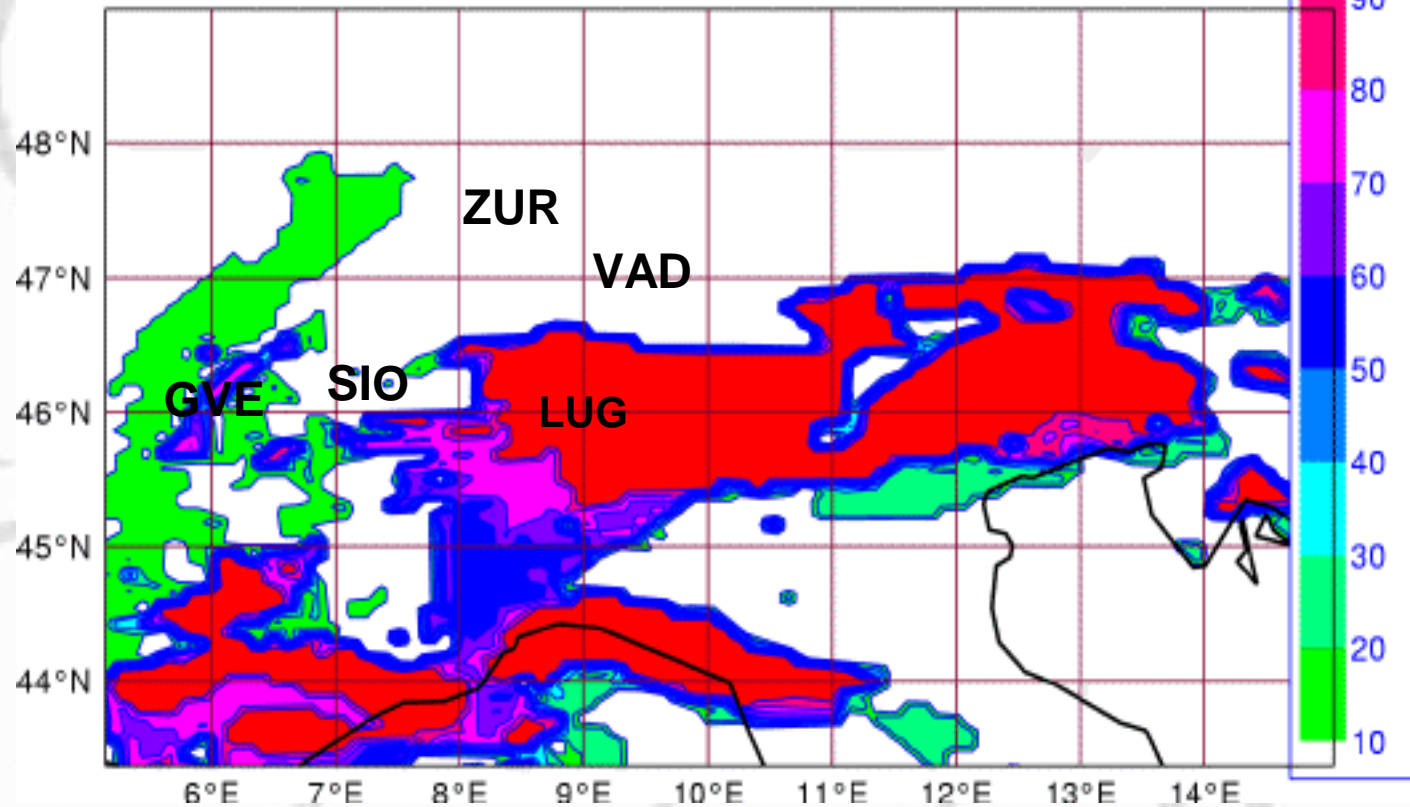
0.5 - 0.6 0.6 - 0.7 0.7 - 0.8 0.8 - 0.9 0.9 - 0.962731



LEPS rr>20 mm, 14.11.2002 12z – 15.11.2002 12z



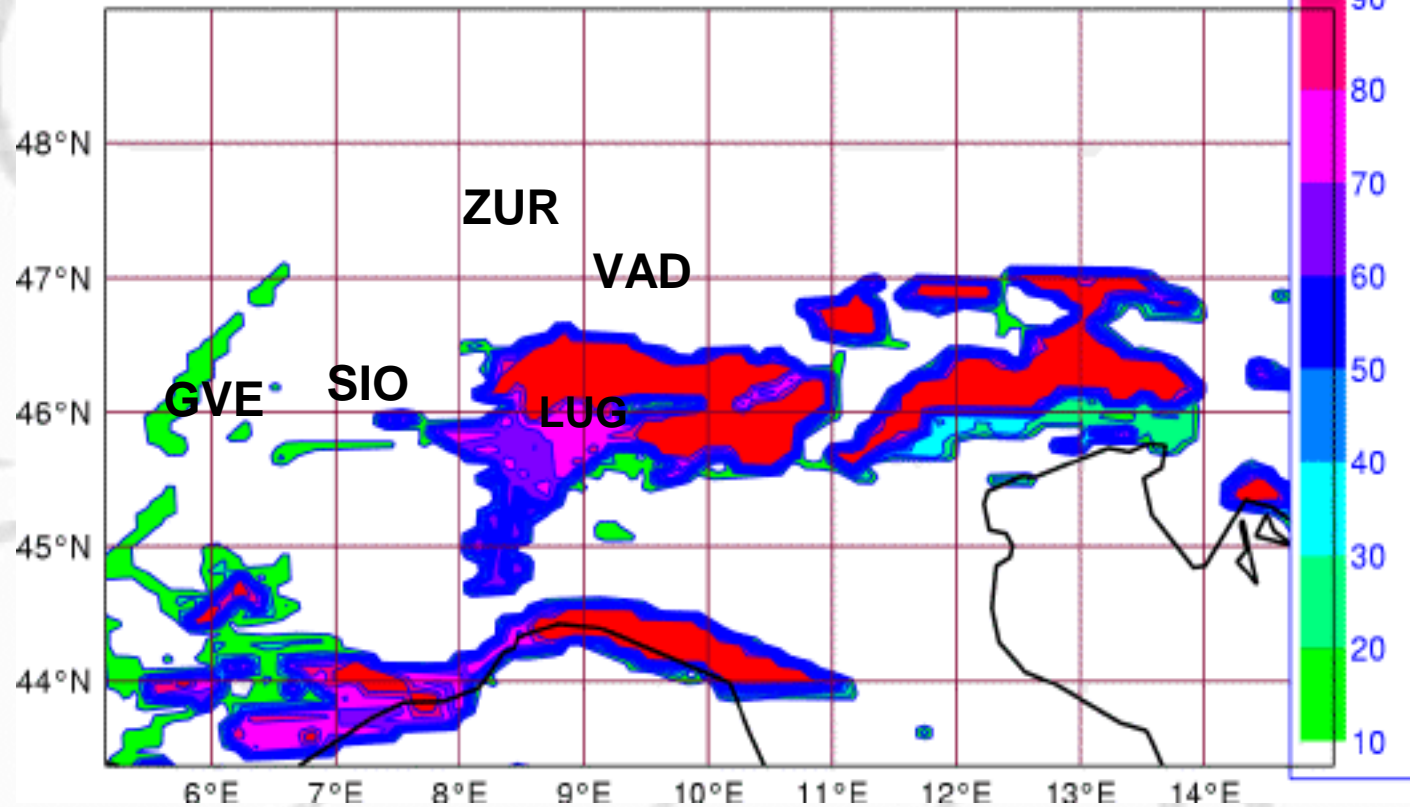
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast I+(48-72) VT: Friday 15 November 2002 12UT
Surface: total precipitation >0.200 10³ mm



LEPS rr>50 mm, 14.11.2002 12z – 15.11.2002 12z



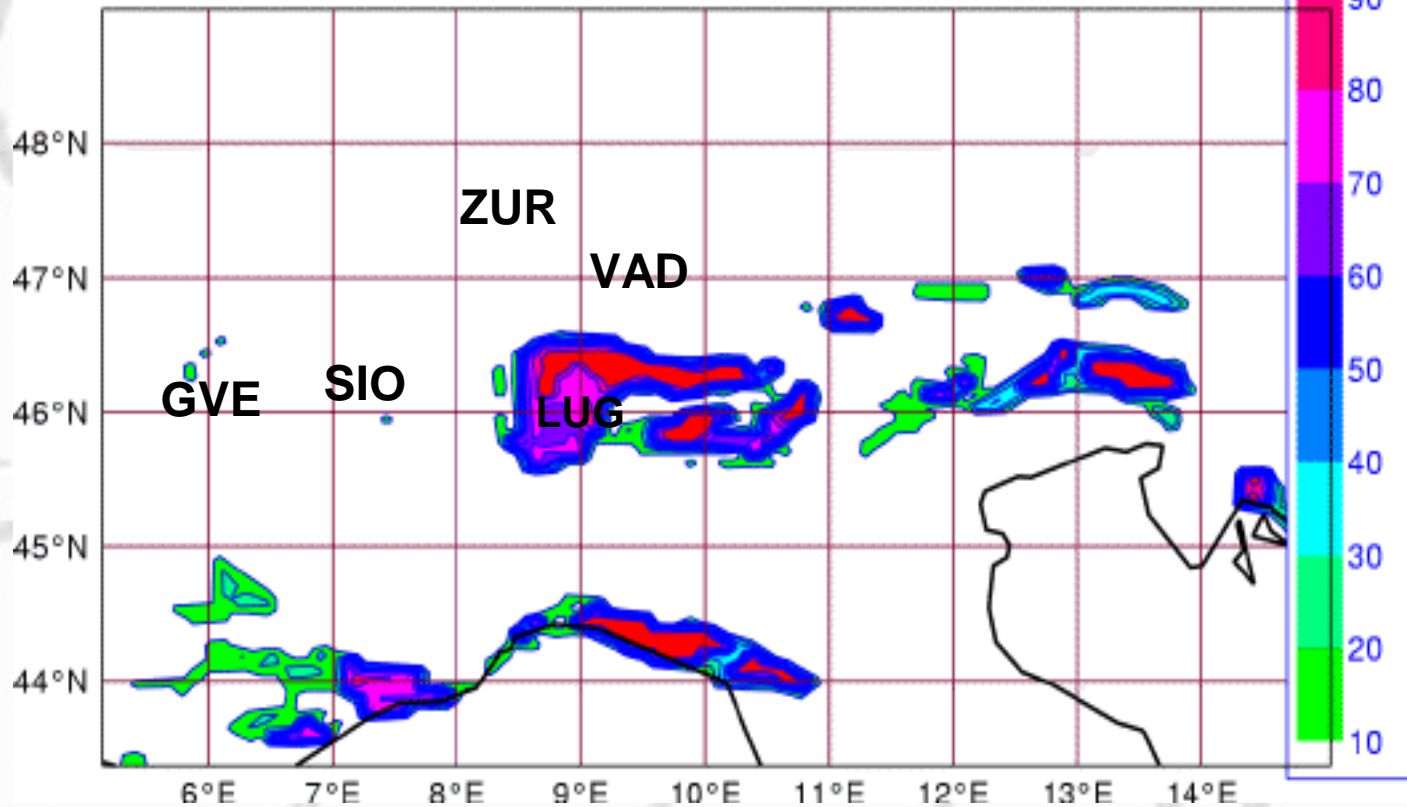
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast 1-(48-72) VT: Friday 15 November 2002 12UT
Surface: >0.500 10¹ mm



LEPS rr>100 mm, 14.11.2002 12z – 15.11.2002 12z



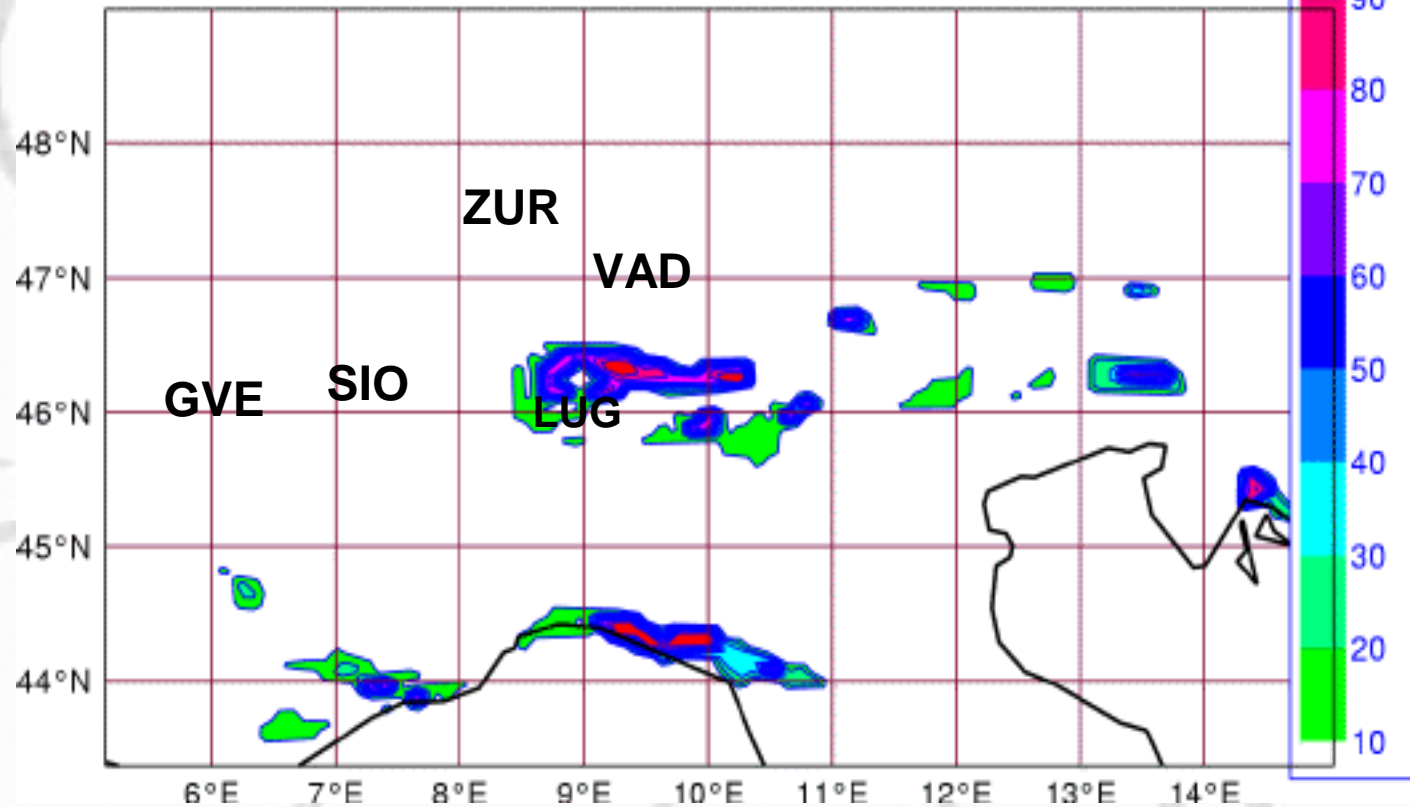
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast I+(48-72) VT: Friday 15 November 2002 12UT
Surface: >0.100 10¹ mm



LEPS rr>150 mm, 14.11.2002 12z – 15.11.2002 12z



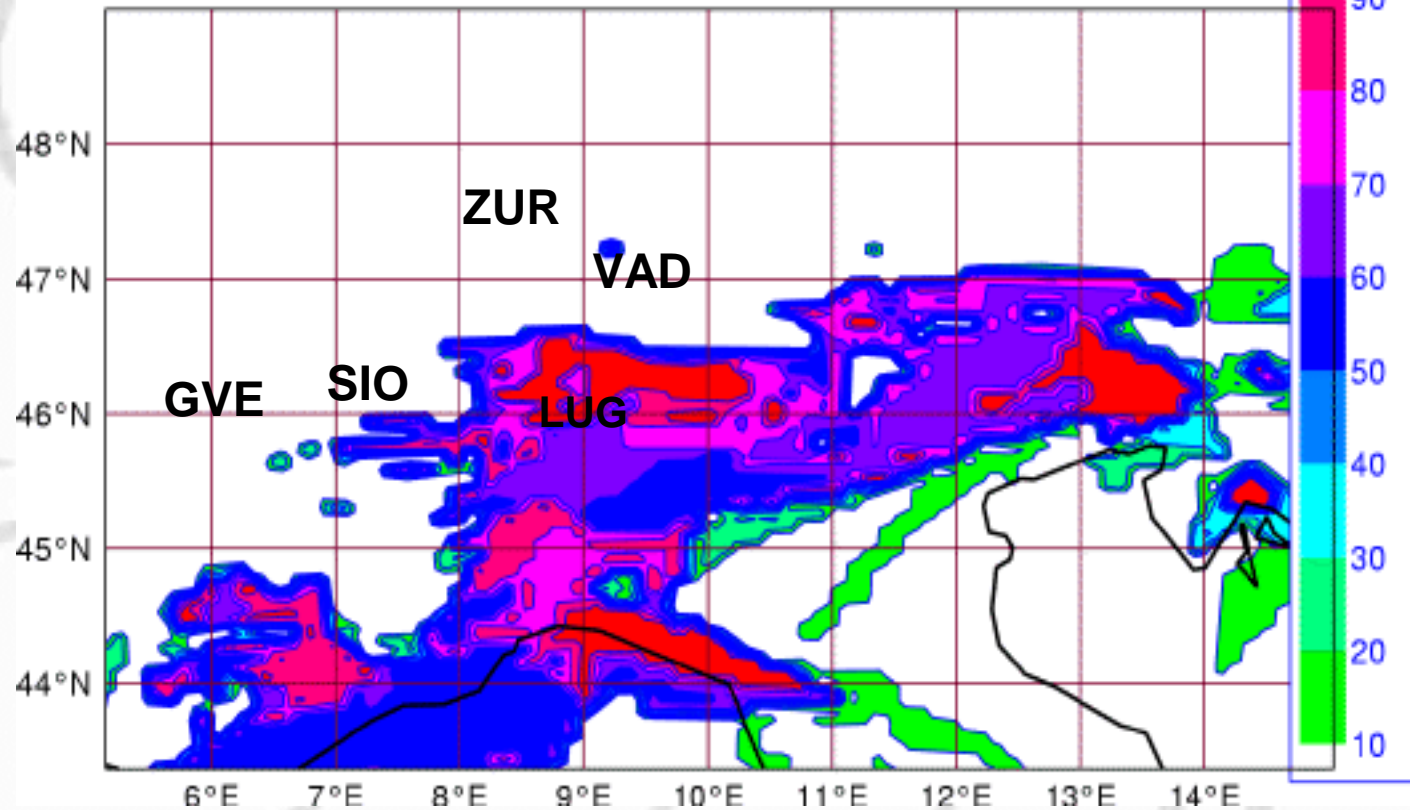
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast I+(48-72) VT: Friday 15 November 2002 12UT
Surface: >0.150 10¹ mm



LEPS rr>20 mm, 15.11.2002 12z – 16.11.2002 12z



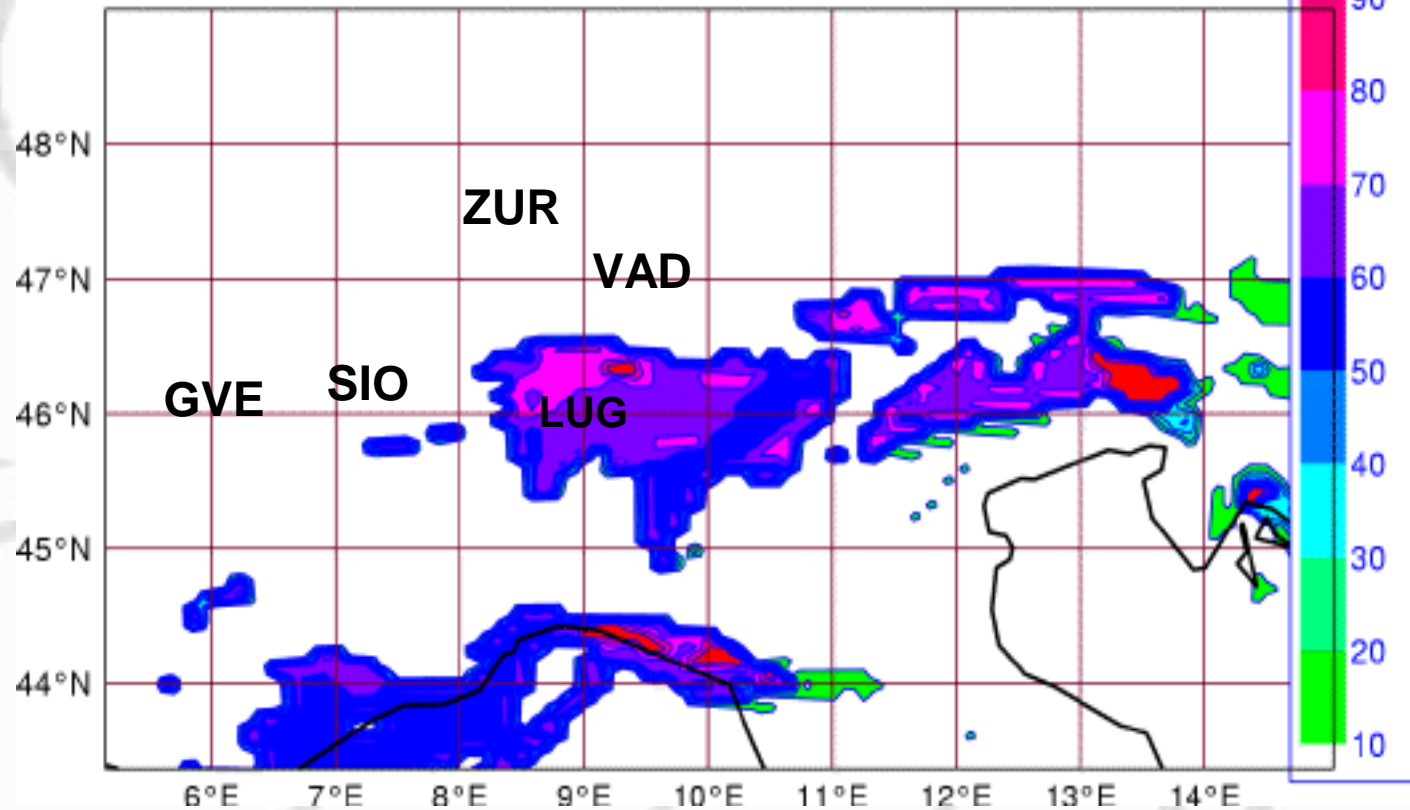
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(72-96) VT: Saturday 16 November 2002 12U
Surface: total precipitation >0.200 10³ mm



LEPS rr>50 mm, 15.11.2002 12z – 16.11.2002 12z



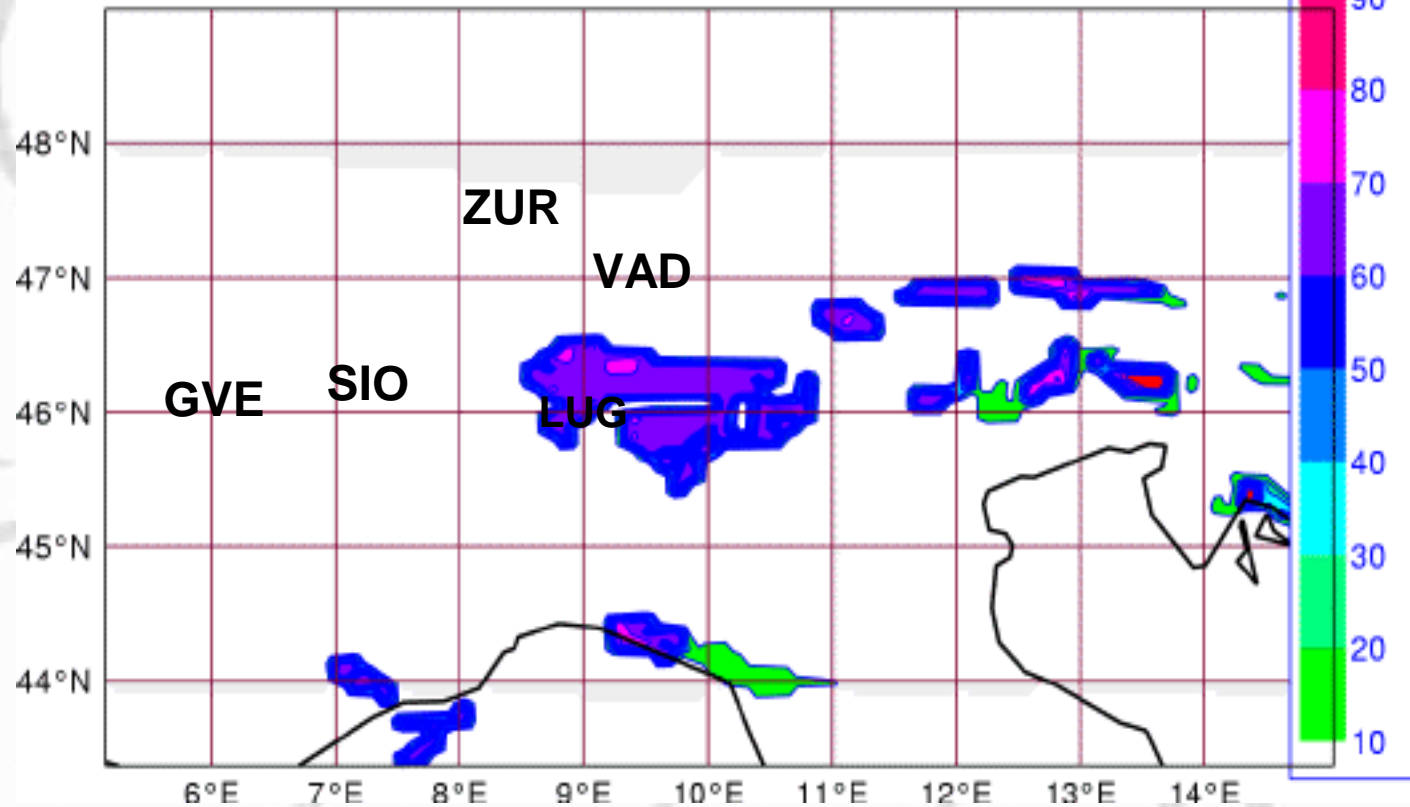
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(72-96) VT: Saturday 16 November 2002 12U
Surface: >0.500 10¹ mm



LEPS rr>100 mm, 15.11.2002 12z – 16.11.2002 12z



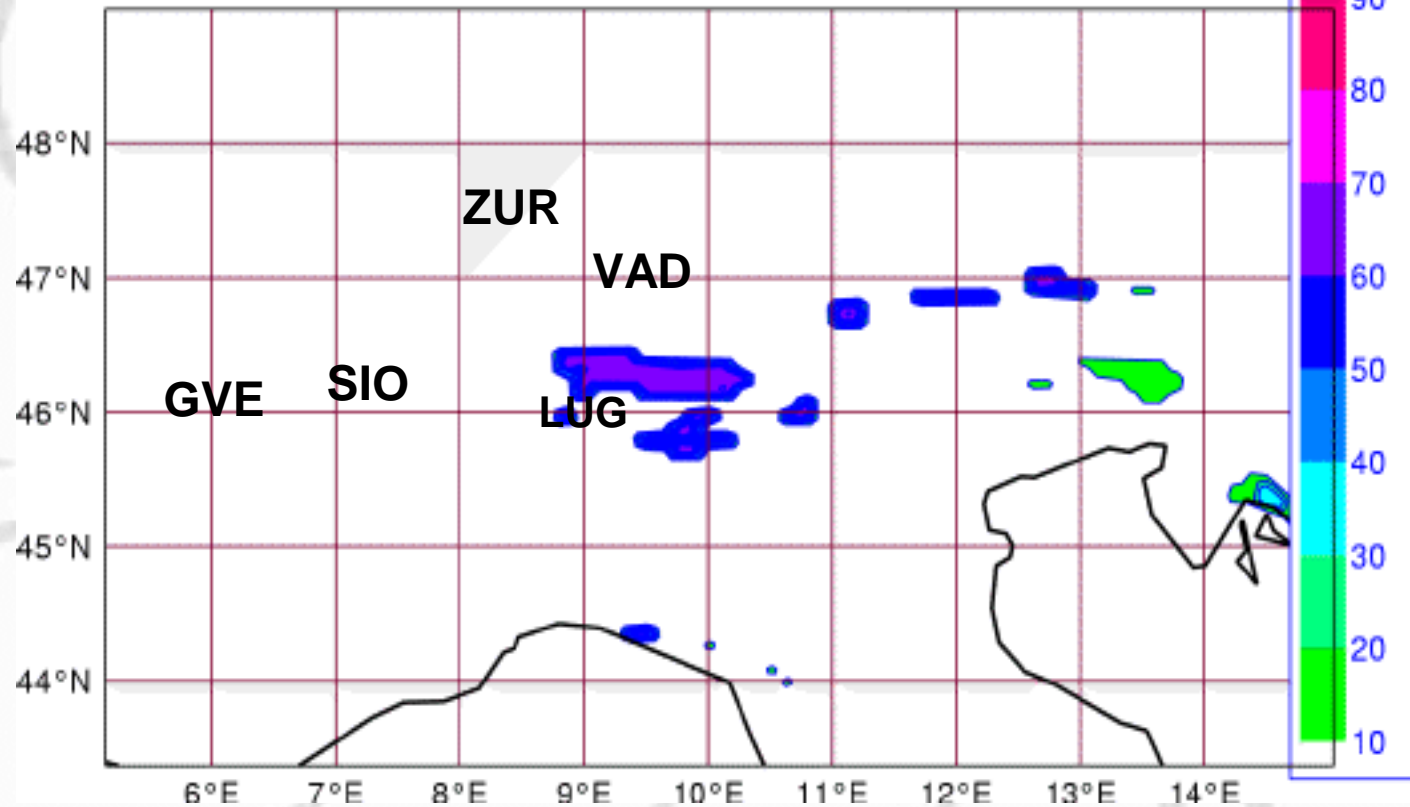
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(72-96) VT: Saturday 16 November 2002 12U
Surface: >0.100 10¹ mm



LEPS rr>150 mm, 15.11.2002 12z – 16.11.2002 12z



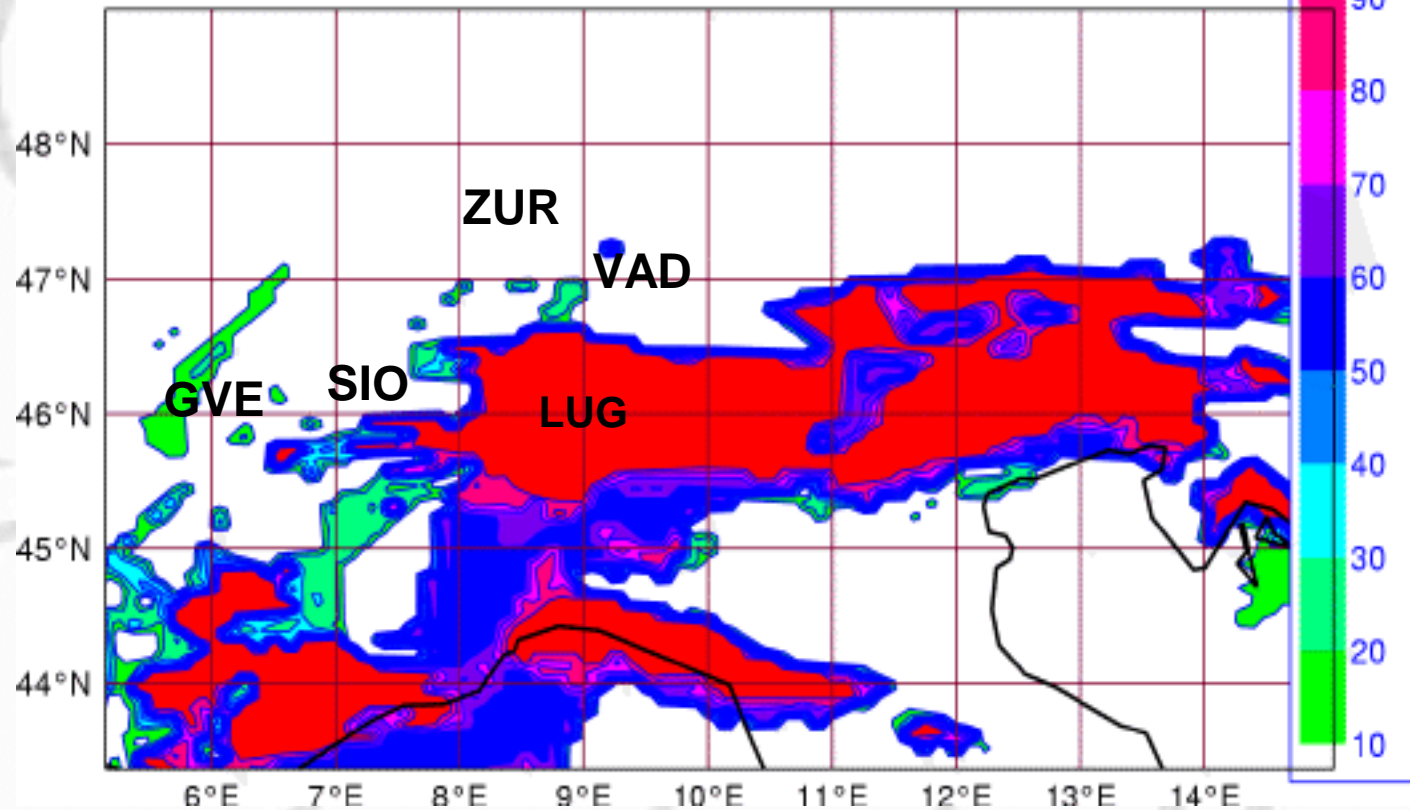
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(72-96) VT: Saturday 16 November 2002 12U
Surface: >0.150 10³ mm



LEPS rr>50 mm, 14.11.2002 12z – 17.11.2002 12z



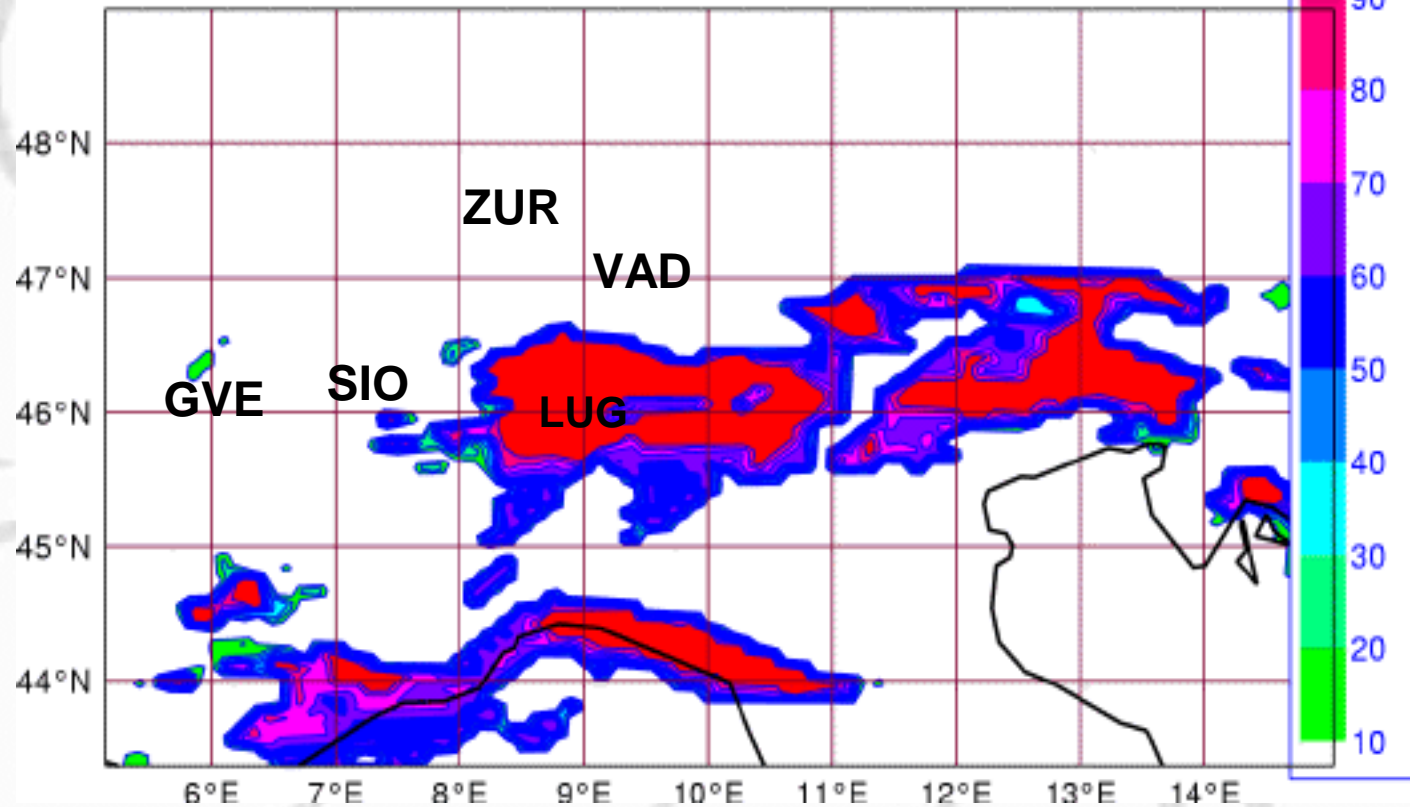
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(48-120) VT: Sunday 17 November 2002 12UT
Surface: total precipitation >0.500 10³ mm



LEPS rr>100 mm, 14.11.2002 12z – 17.11.2002 12z



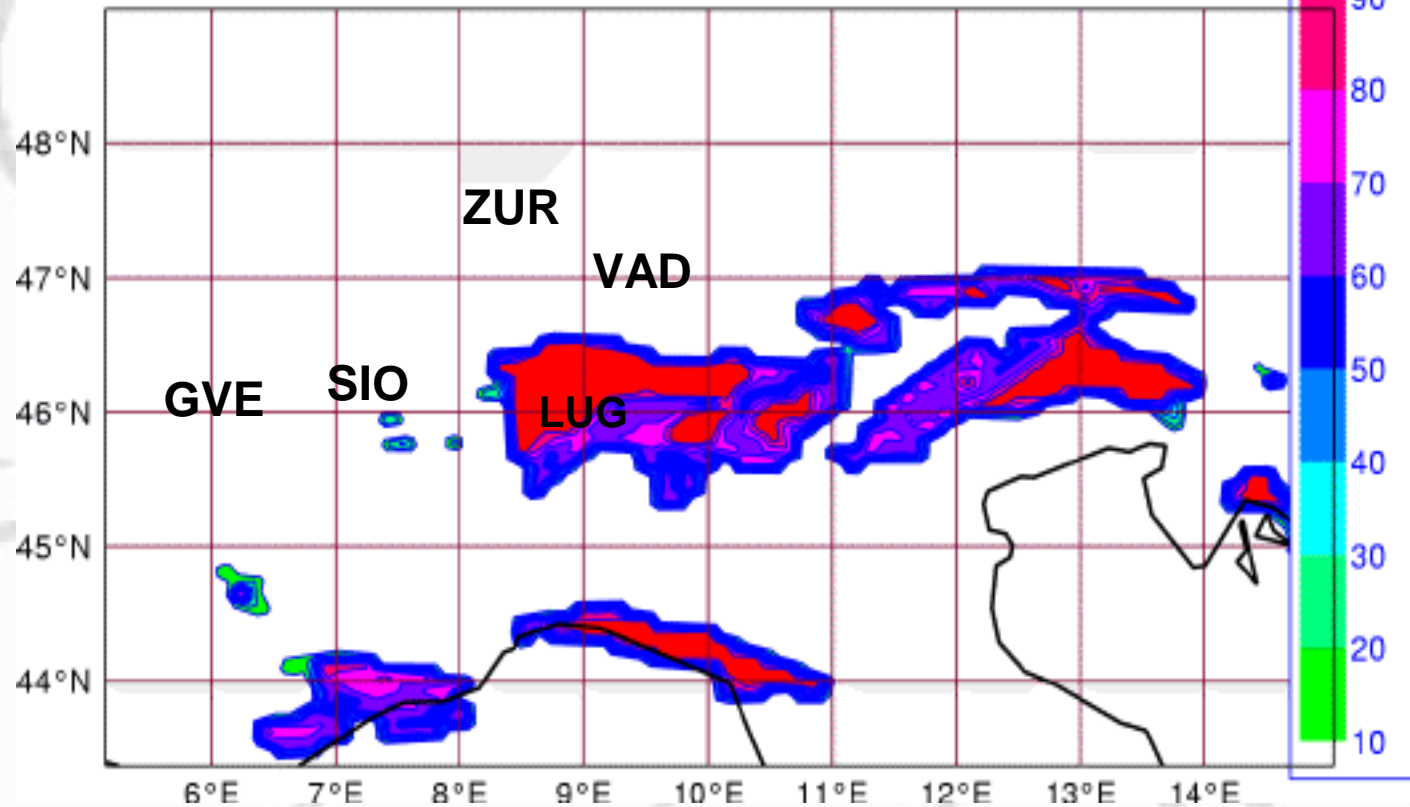
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(48-120) VT: Sunday 17 November 2002 12UT
Surface: >0.100 10³ mm



LEPS rr>150 mm, 14.11.2002 12z – 17.11.2002 12z



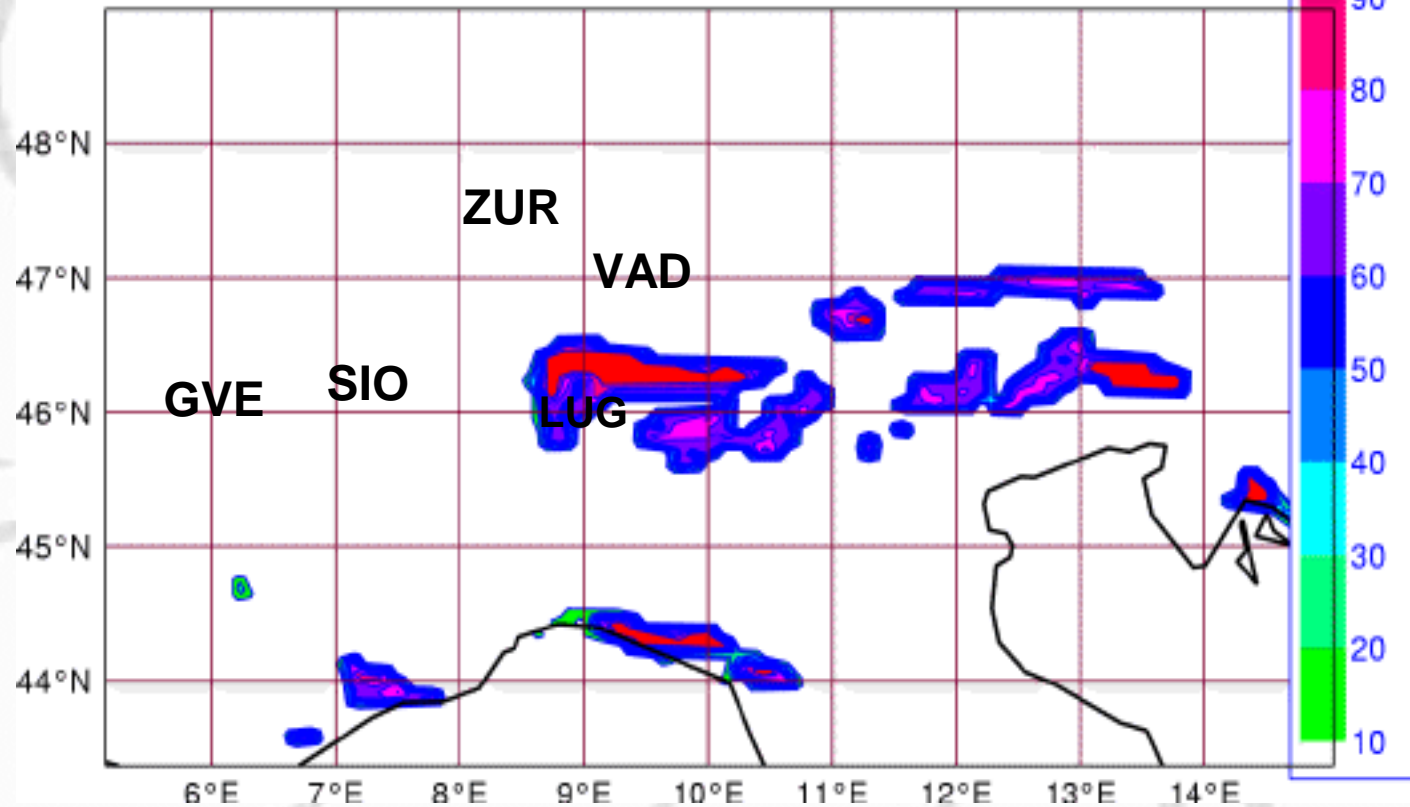
Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(48-120) VT: Sunday 17 November 2002 12UTC
Surface: >0.150 10³ mm



LEPS rr>250 mm, 14.11.2002 12z – 17.11.2002 12z



Tuesday 12 November 2002 12UTC ECMWF EPS Probability Forecast t+(48-120) VT: Sunday 17 November 2002 12UT
Surface: >0.250 10³ mm



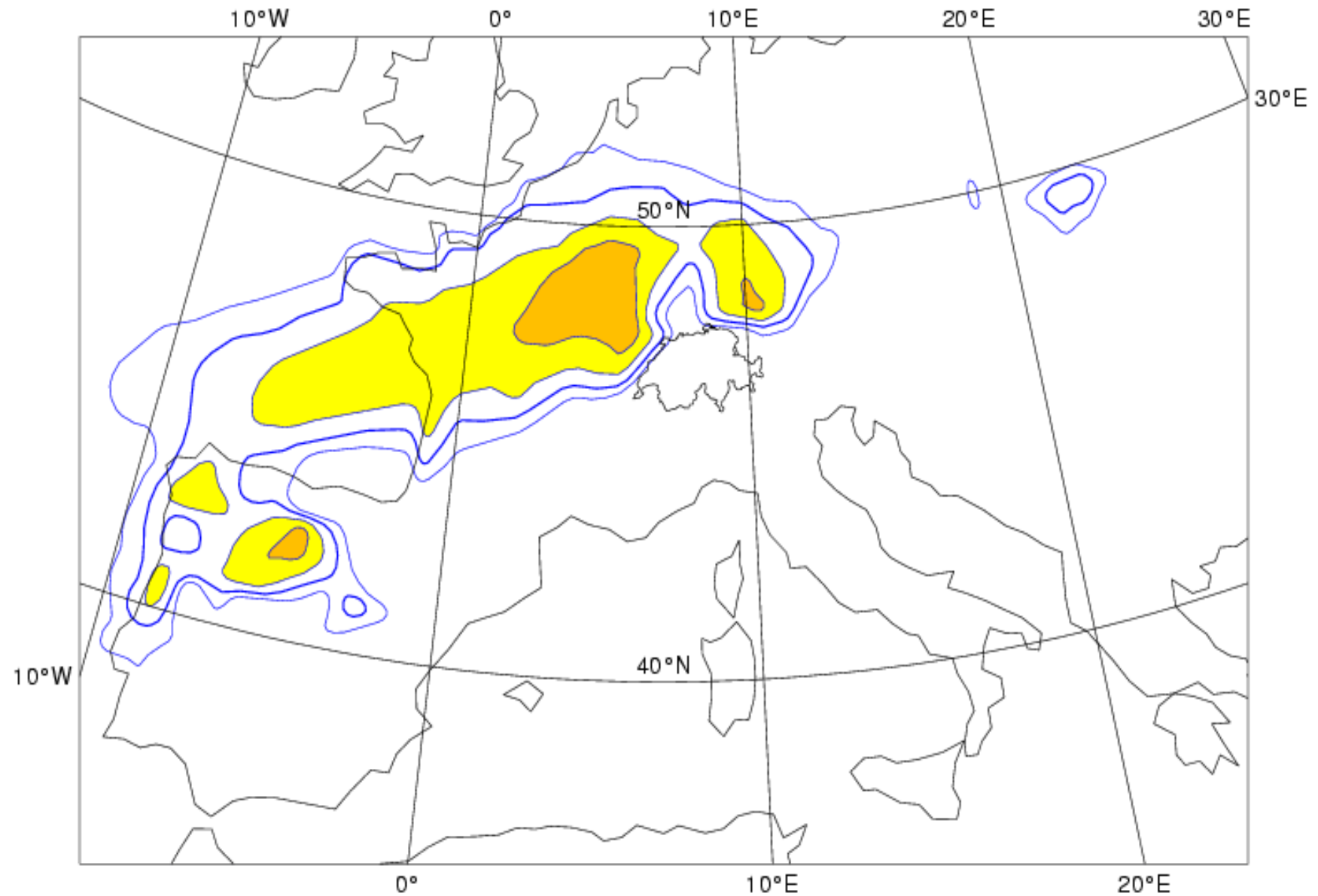
Storm Calvann 2.1.2003



- Close to the warning threshold:
 - 100 km/h gusts at low altitude
 - 130 km/h in mountains
- Touched northern Switzerland
- Early warning has been issued on 31.12.2002

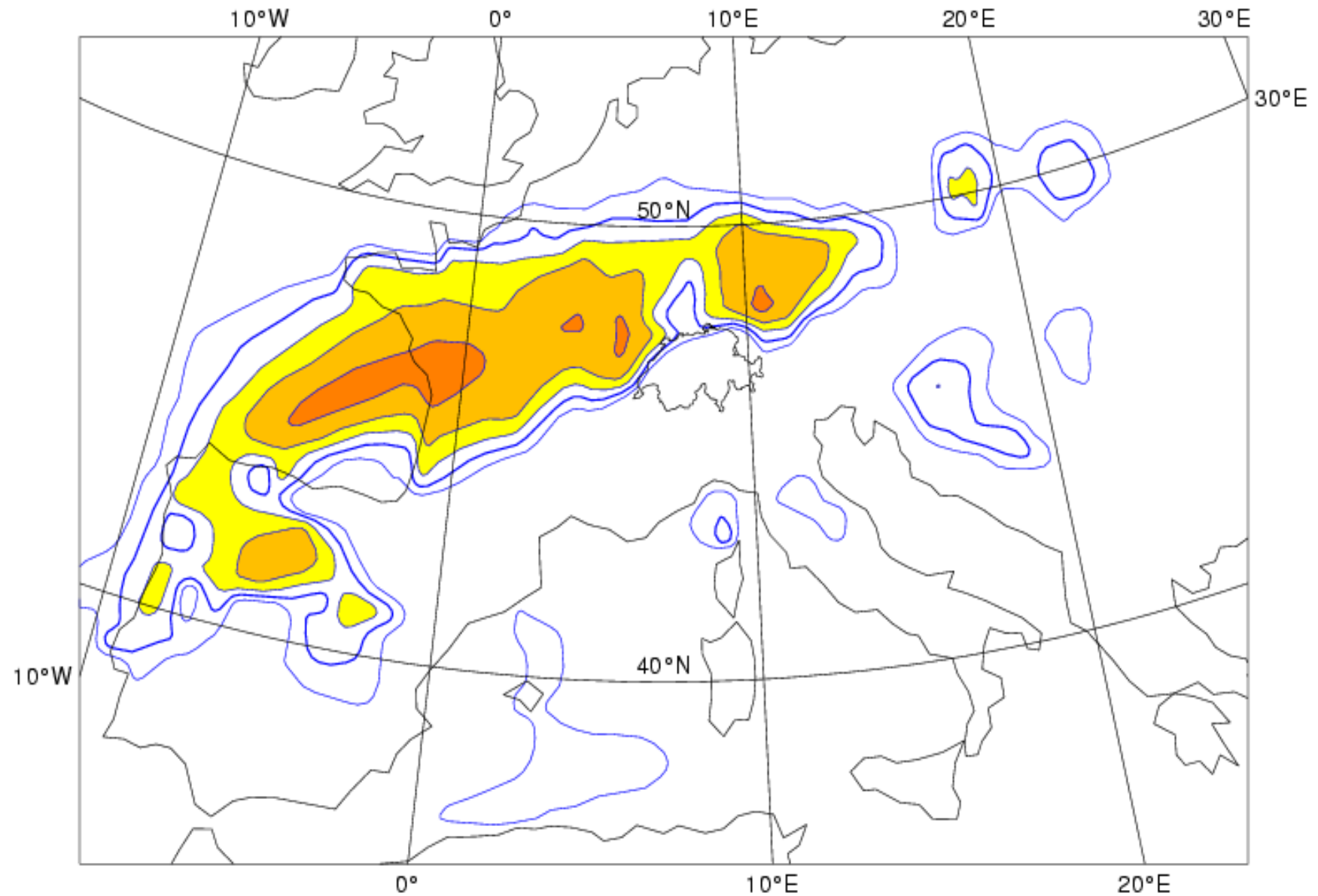
EFI3, 0-24UTC maximal wind gust 30.12.2002 12z, + 72h

0.5 - 0.6 0.6 - 0.672612



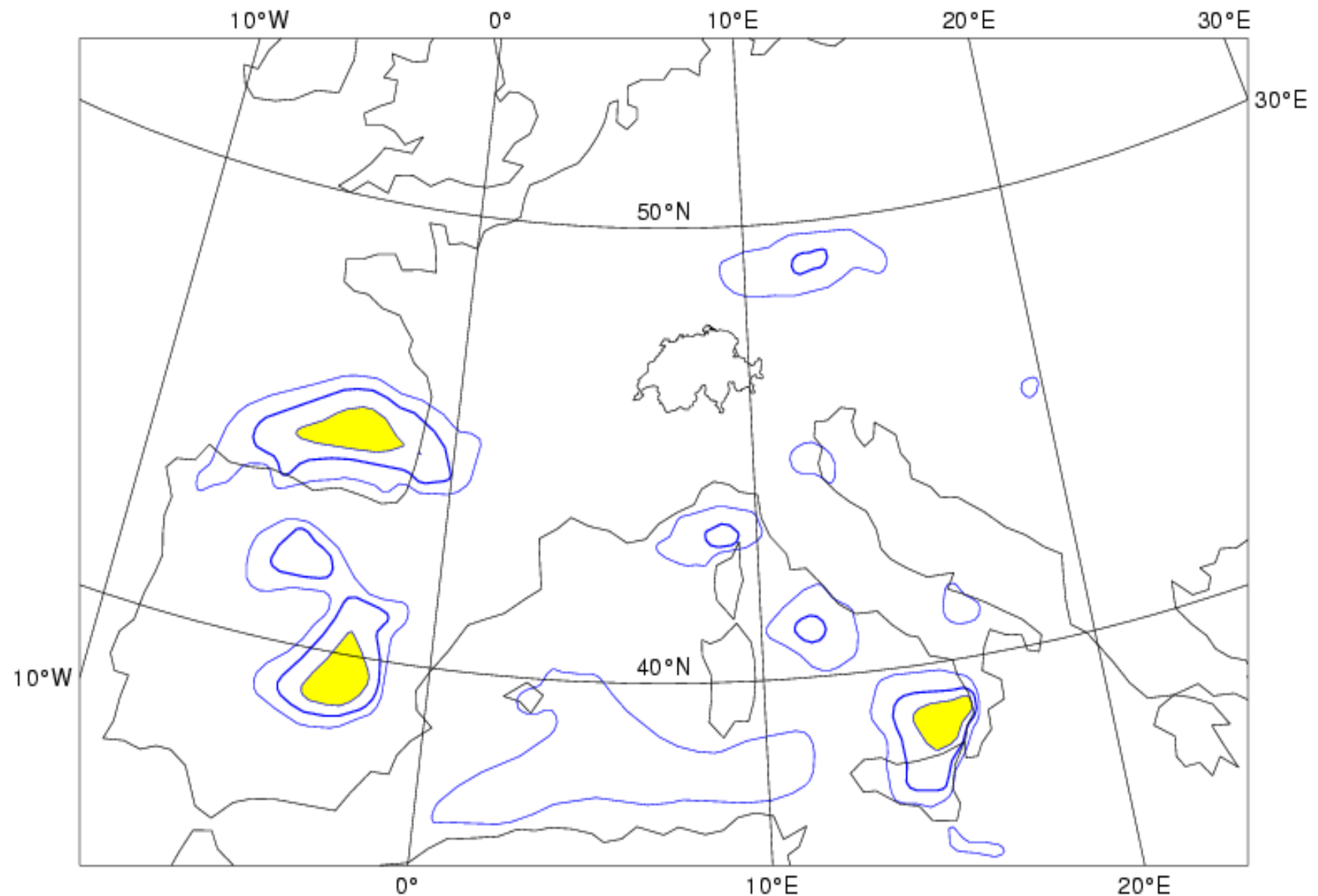
EFI3, 0-24UTC maximal wind gust 31.12.2002 12z, + 48h

0.5 - 0.6 0.6 - 0.7 0.7 - 0.754470



EFI3, 0-24UTC maximal wind gust 31.12.2002 12z, + 72h

0.5 - 0.58363L



Precipitation 30.4.2003



- Warning has been issued on the threshold:
 - 30 mm/ 12h
- For western Switzerland

Precipitation 30.4.2003



Niederschlagssumme Millimeter Code 30.04.03 01Z 01.05.03 00Z

.....

SHA 8

BAS 14

GUT 3

RUE 9

LAE //

TAE 7

FAH 23

KLO 10

STG 3

BUS 13

REH 11

SMA 6

HOE //

CHA 14

WYN 18

WAE 12

SAE 17

CDF 33

NAP 25 ? LUZ 9

VAD 7

NEU 18

BER 24

PIL 6

GLA 7

FRE 23

PAY 25

ALT 3

CHU 10

PLF 37

INT 18

ENG 7

WFJ 7

SCU 7

MLS 19

JUN //

GUE 14

DIS 12

DAV 7

DOL 35

PUY 36

ABO 13

GRH 12

PIO 49

HIR 48

SAM 16

CGI 23

AIG 21

MVE 14

ULR 11

ROE 79

COM 27

SBE 43

COV 12

GVE 23

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VIS 4

CIM 30

ROB

24

FEY 8

OTL 29

MAG 17

EVO 7

ZER 12

LUG 6

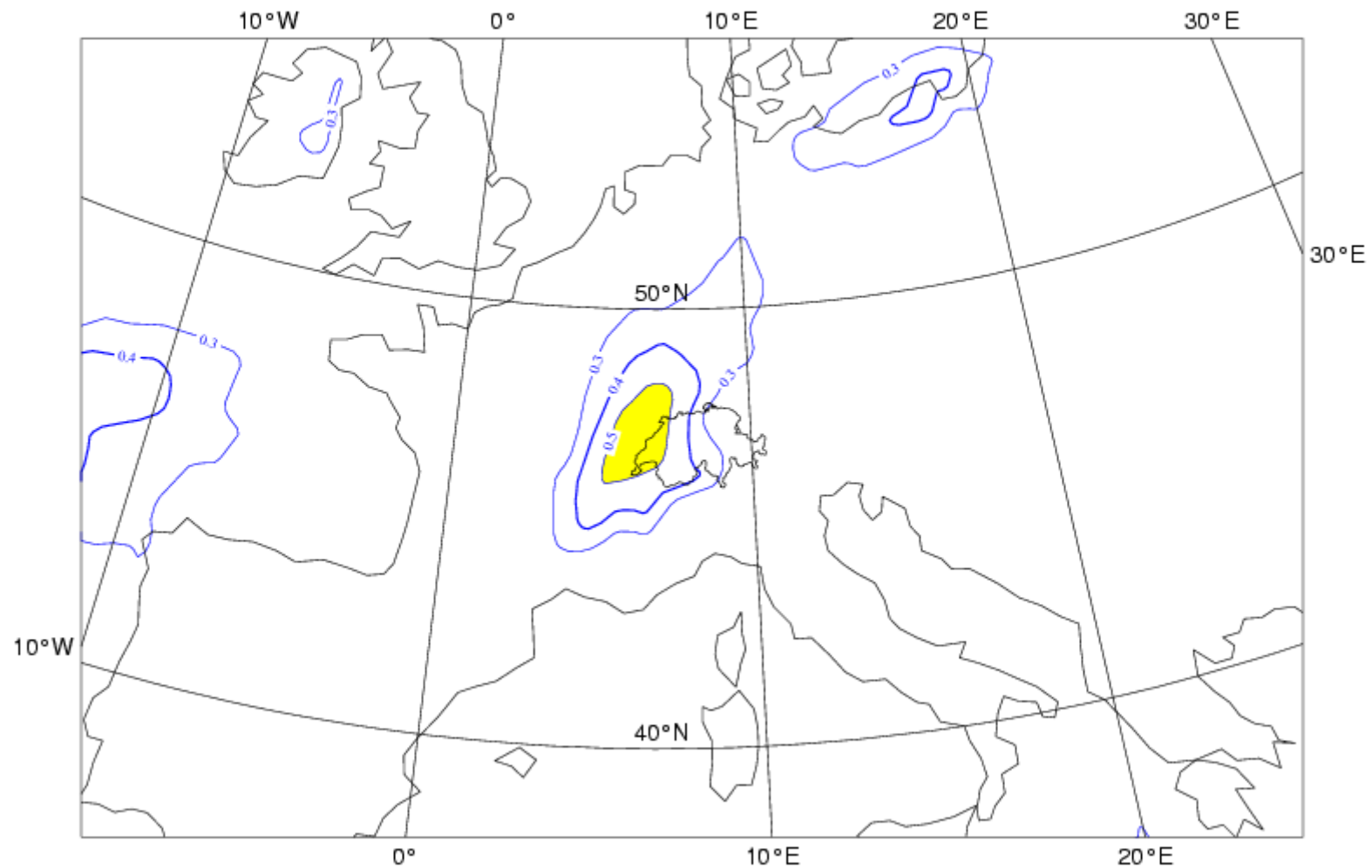
GSB 66

SBO 3



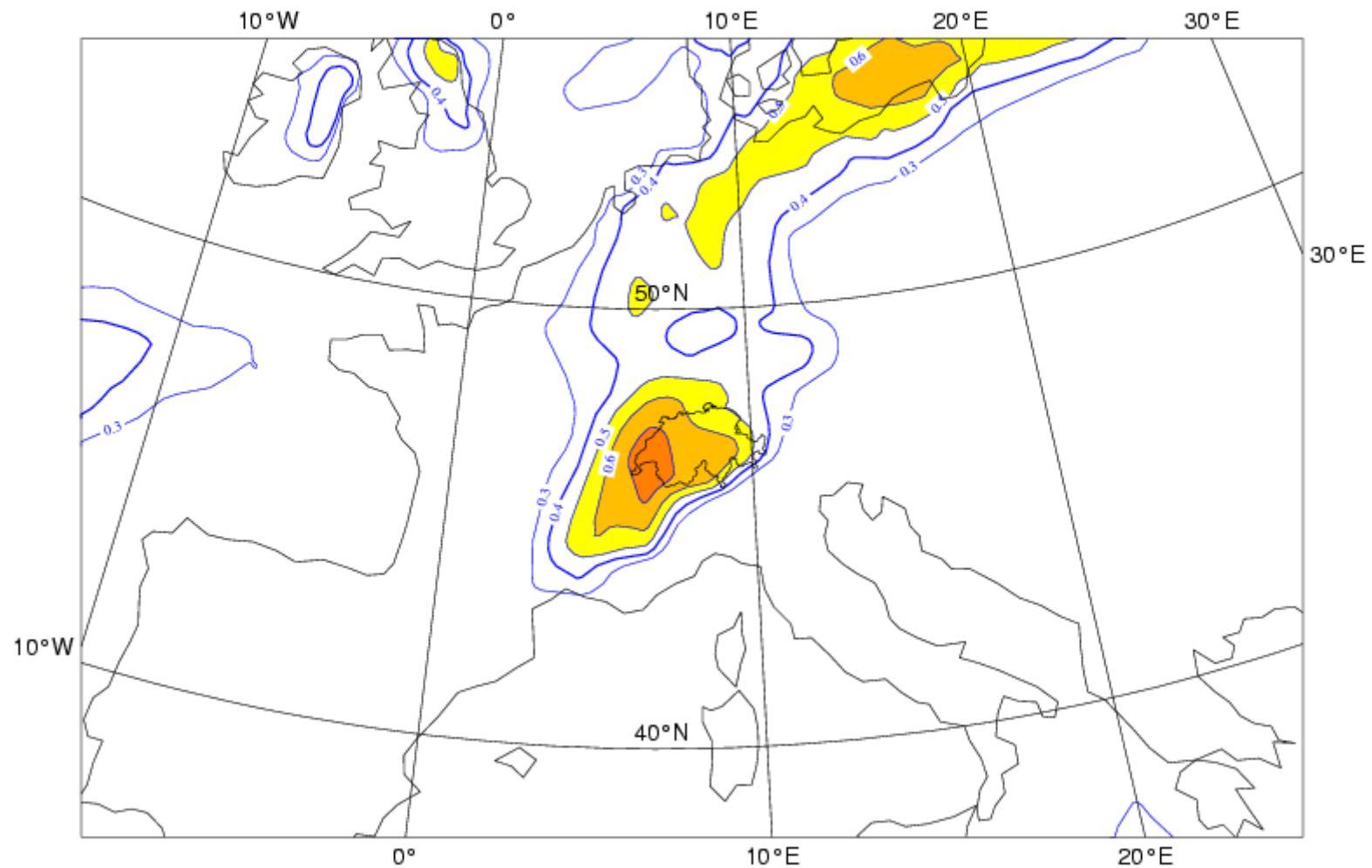
EF13, 24h total precipitation 27.04.2003 12z, + 90h, VT: Thursday 01.05.2003 06z

0.5 - 0.570027

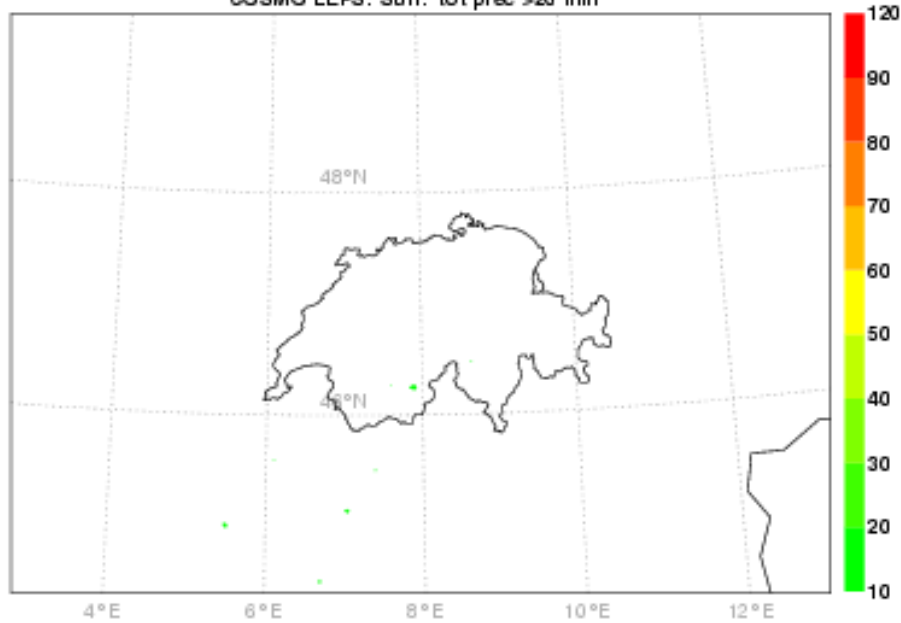


EFI3, 24h total precipitation 28.04.2003 12z, + 66h, VT: Thursday 01.05.2003 06z

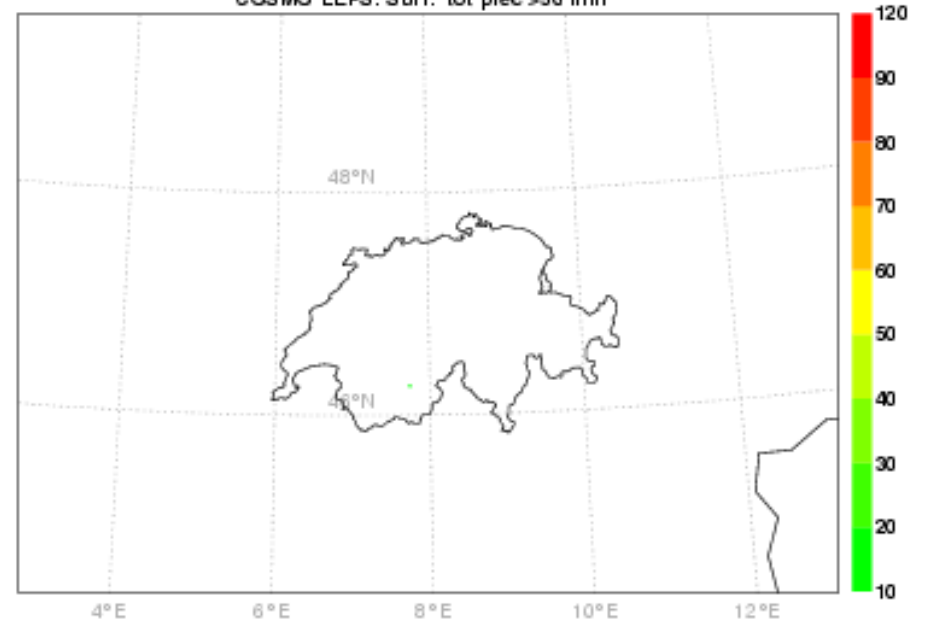
0.5 - 0.6 0.6 - 0.7 0.7 - 0.740490



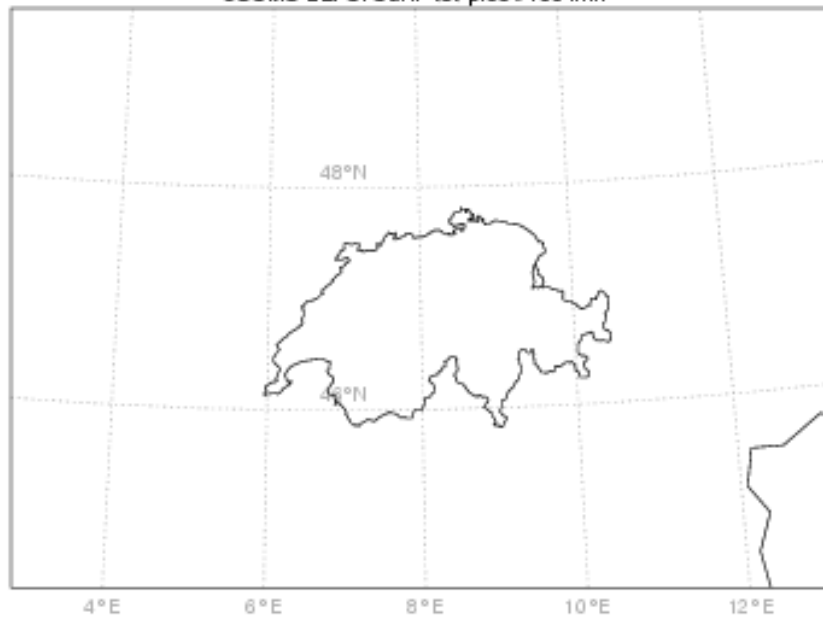
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(72-96) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >20 mm



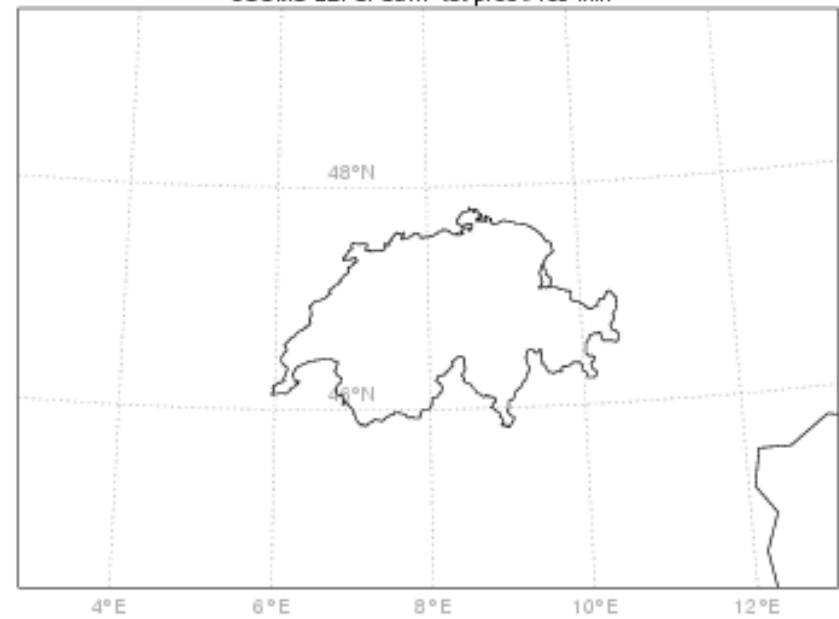
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(72-96) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >50 mm



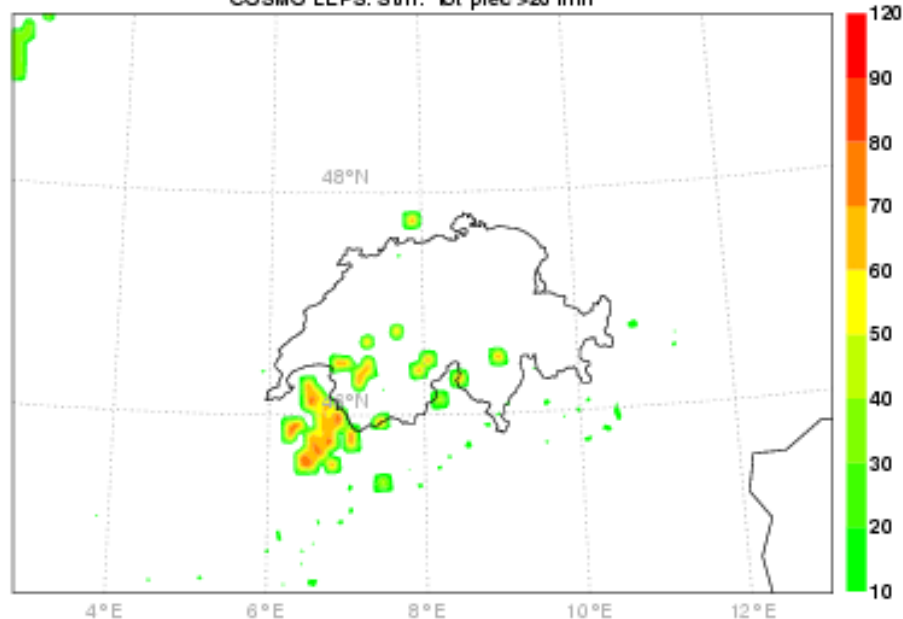
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(72-96) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >100 mm



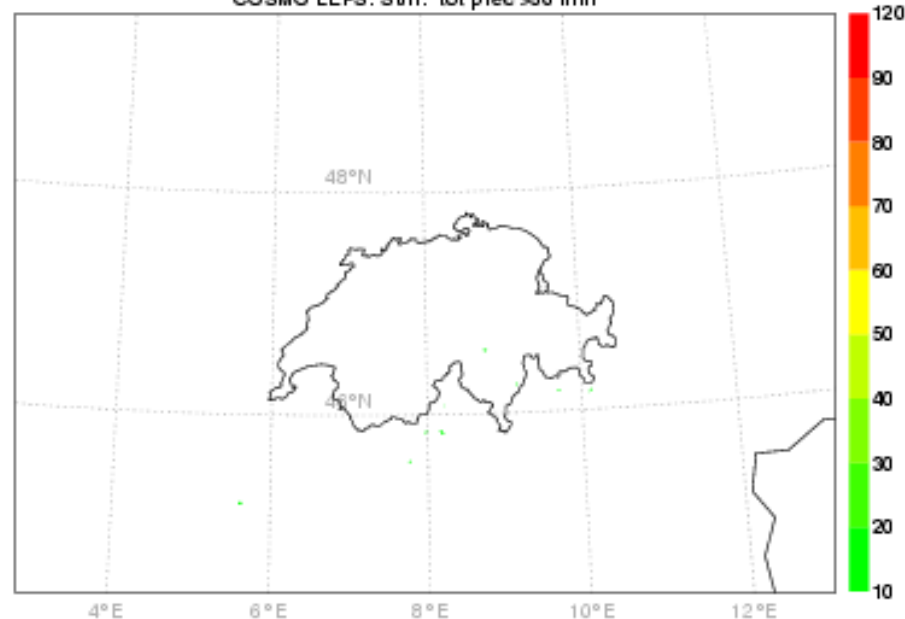
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(72-96) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >150 mm



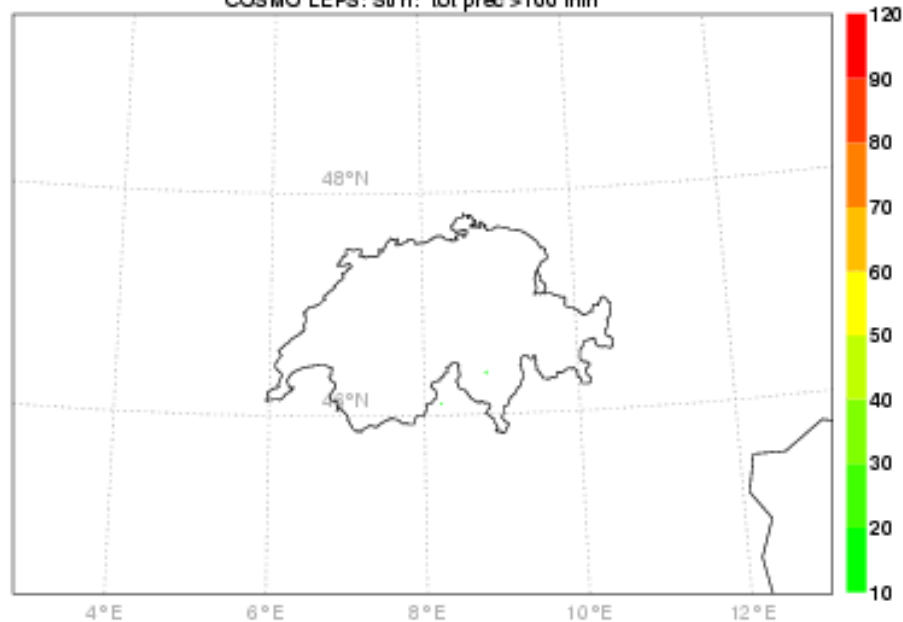
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(96-120) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >20 mm



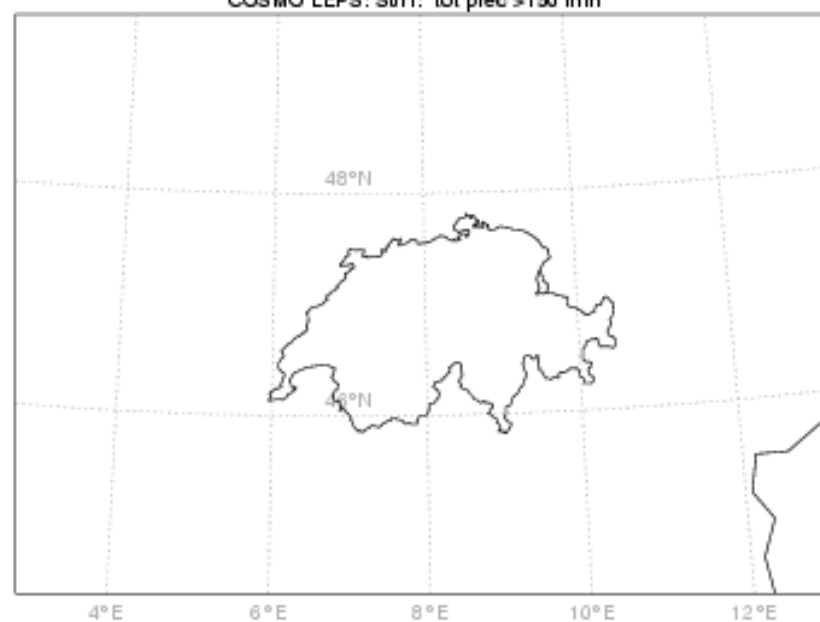
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(96-120) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >50 mm



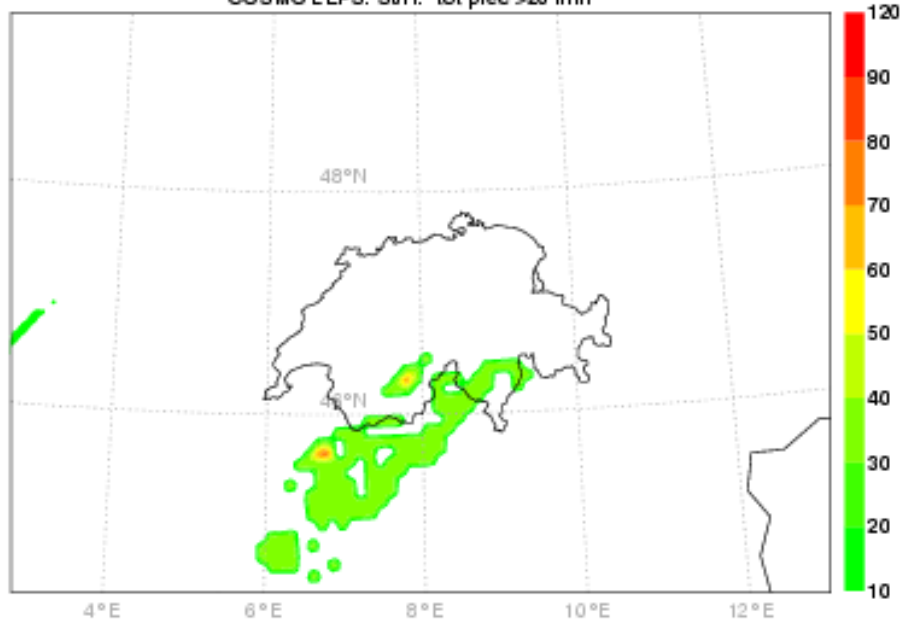
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(96-120) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >100 mm



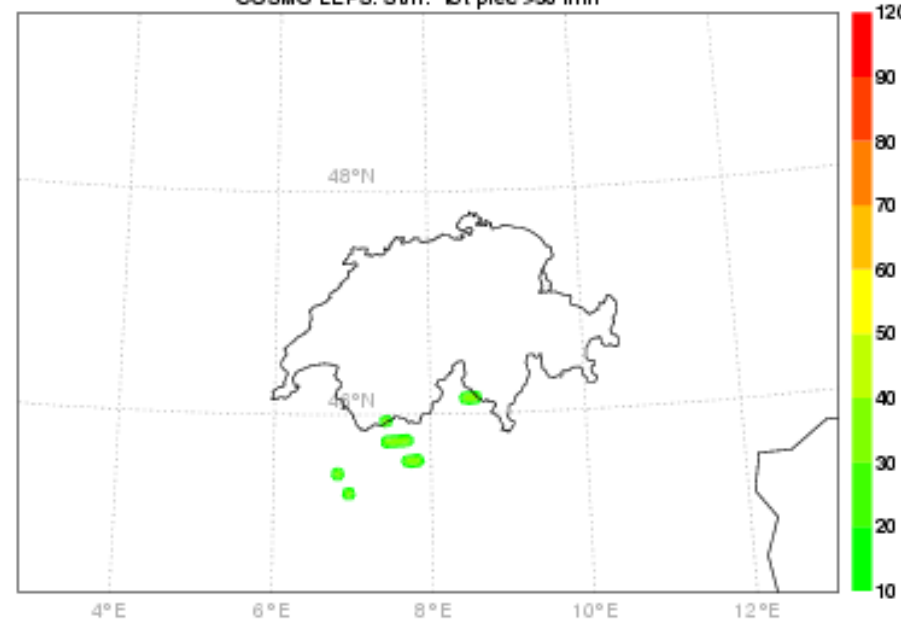
Sat 2003-04-26 12UTC ECMWF EPS Prob FC t+(96-120) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >150 mm



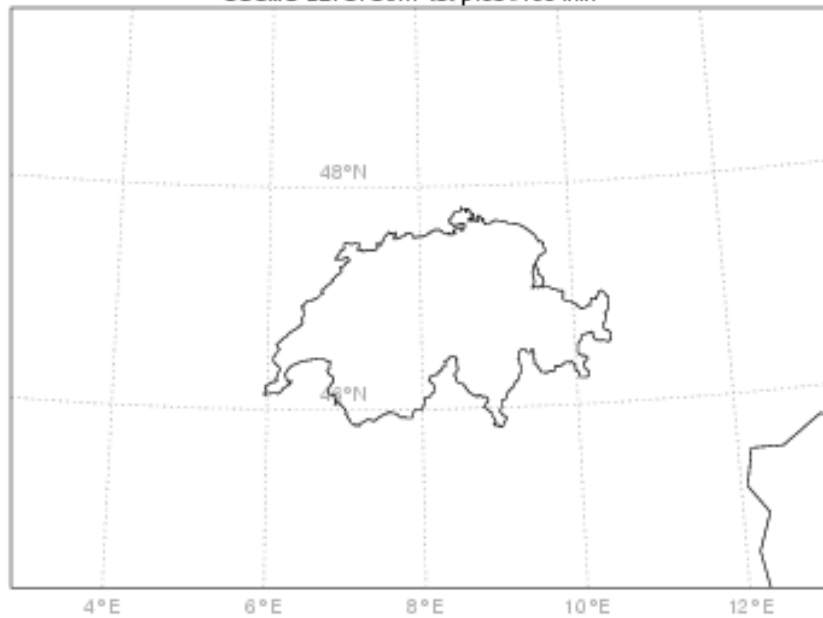
Sun 2003-04-27 12UTC ECMWF EPS Prob FC 1-(48-72) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >20 mm



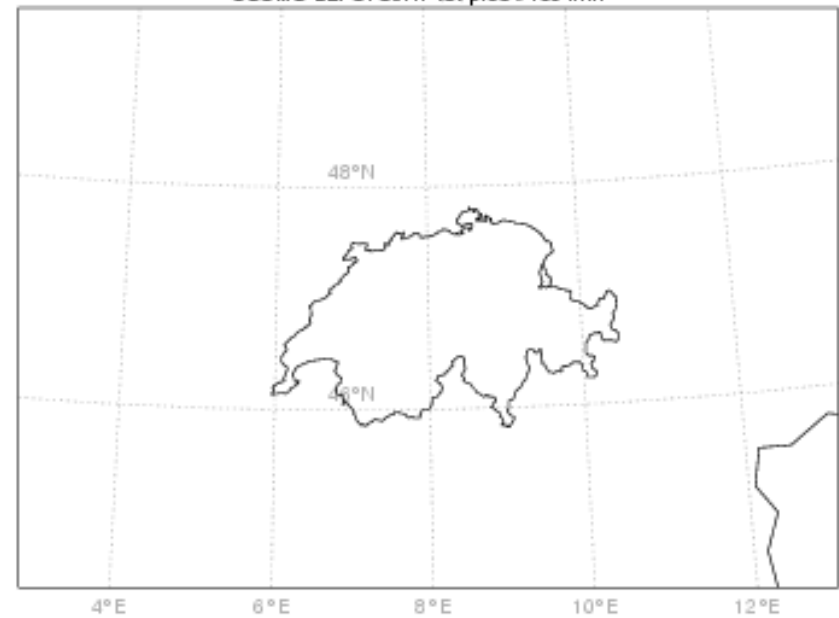
Sun 2003-04-27 12UTC ECMWF EPS Prob FC 1-(48-72) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >50 mm



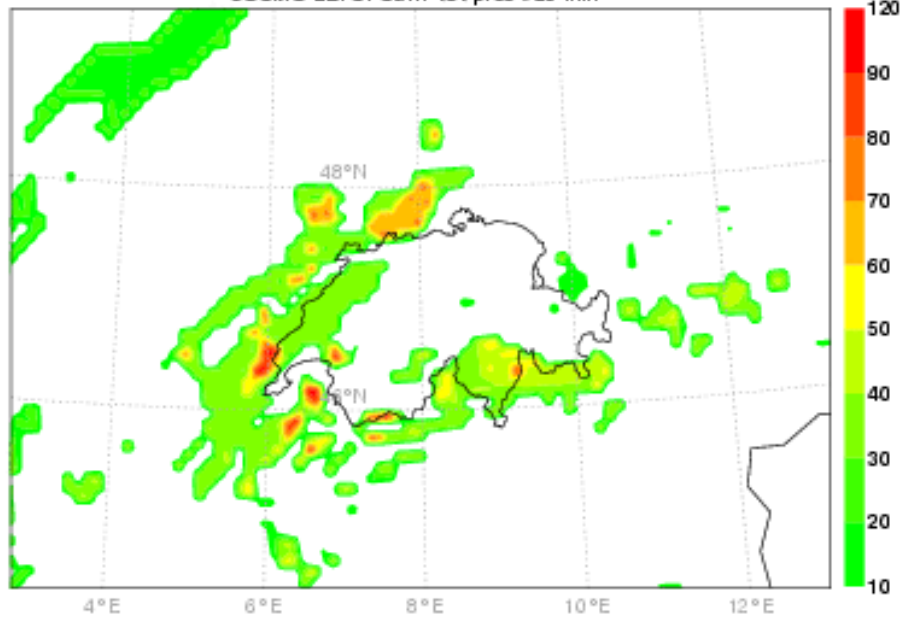
Sun 2003-04-27 12UTC ECMWF EPS Prob FC 1-(48-72) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >100 mm



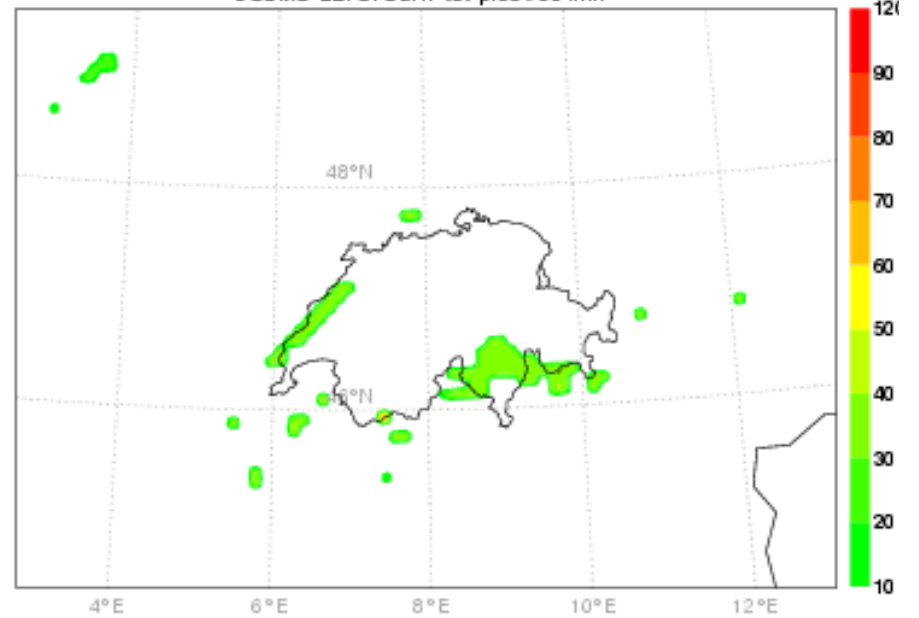
Sun 2003-04-27 12UTC ECMWF EPS Prob FC 1-(48-72) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >150 mm



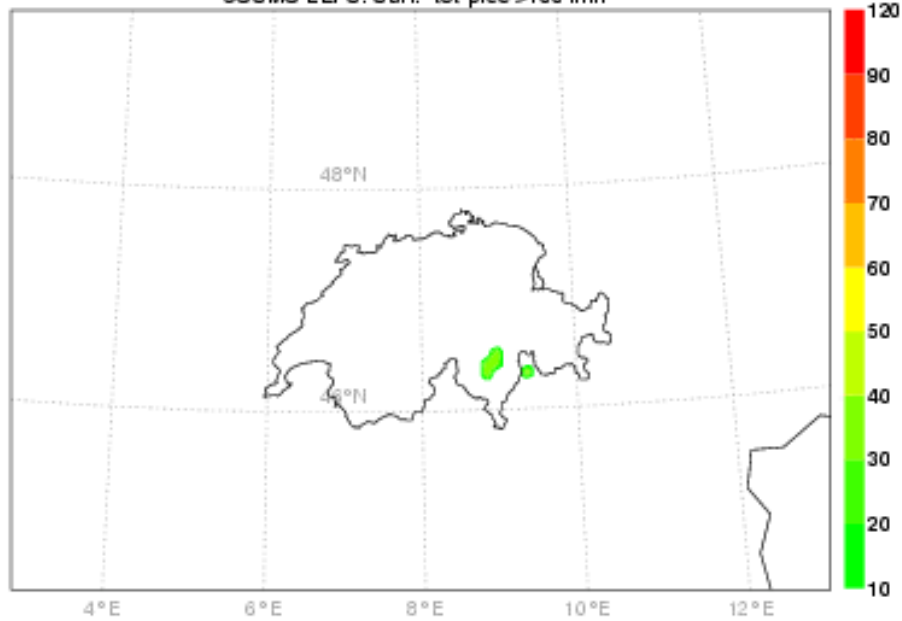
Sun2003-04-27 12UTC ECMWF EPS Prob FC t+(72-96) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >20 mm



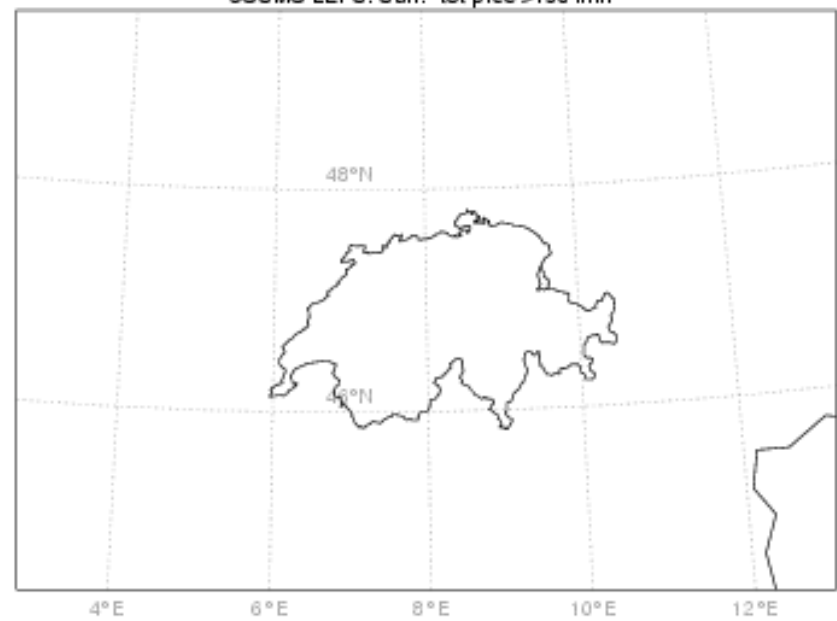
Sun2003-04-27 12UTC ECMWF EPS Prob FC t+(72-96) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >50 mm



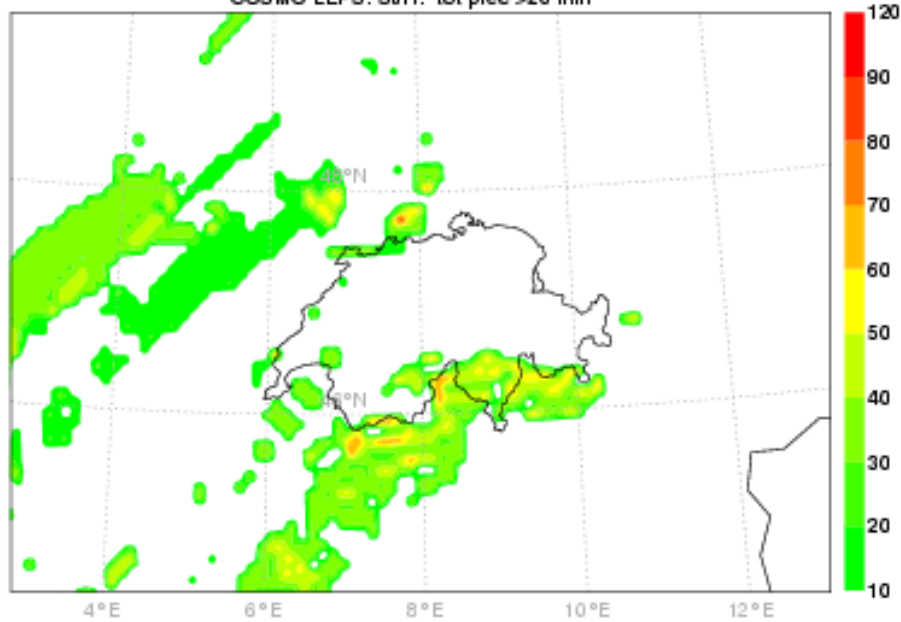
Sun2003-04-27 12UTC ECMWF EPS Prob FC t+(72-96) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >100 mm



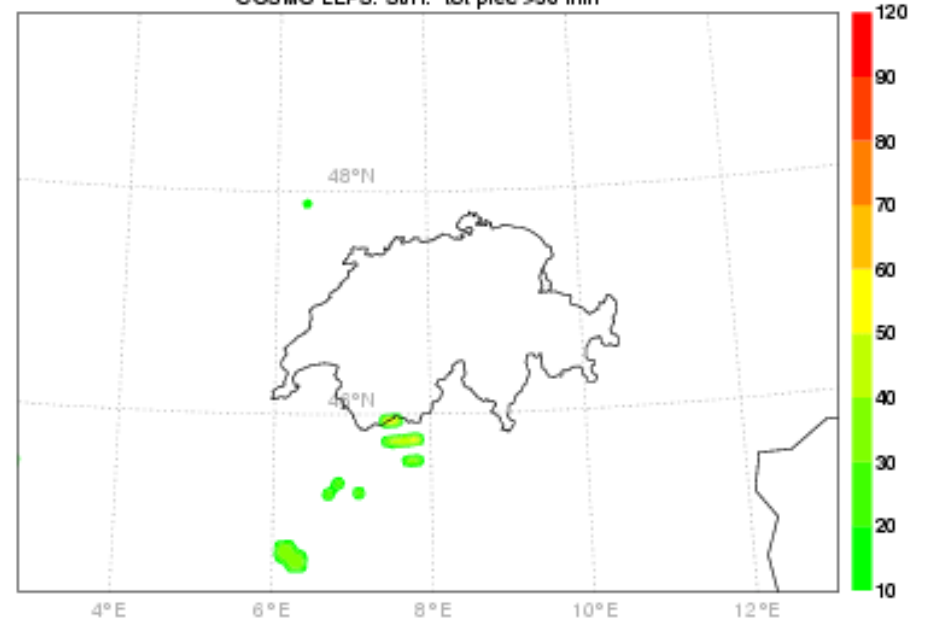
Sun2003-04-27 12UTC ECMWF EPS Prob FC t+(72-96) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >150 mm



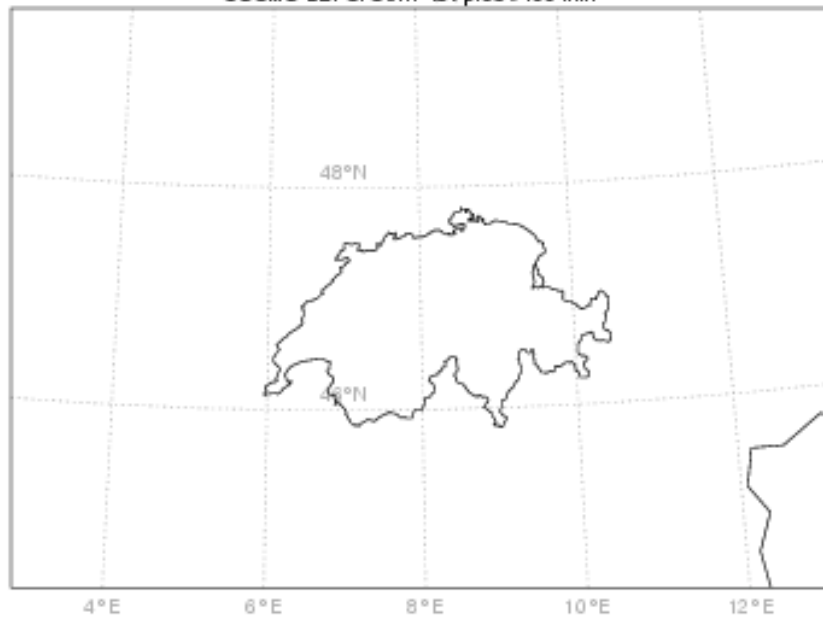
Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(24-48) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >20 mm



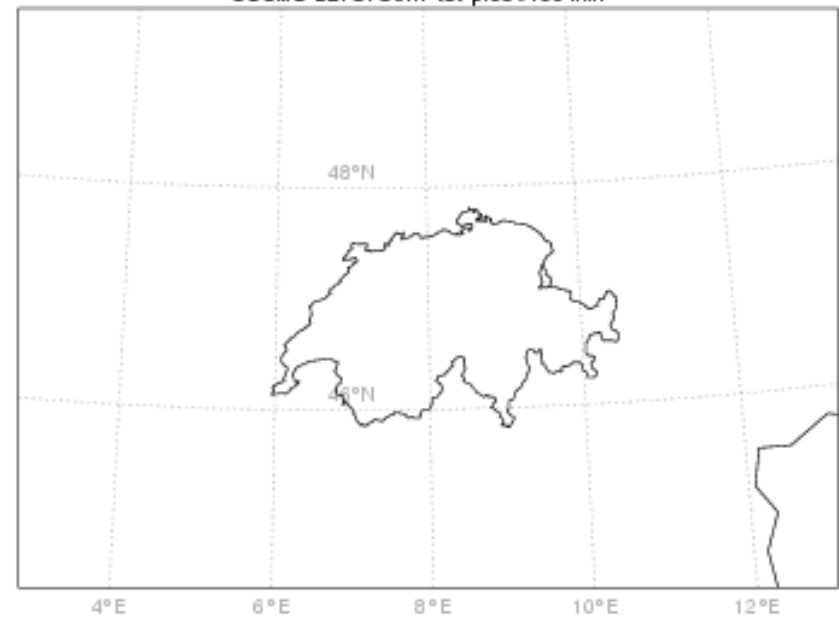
Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(24-48) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >50 mm



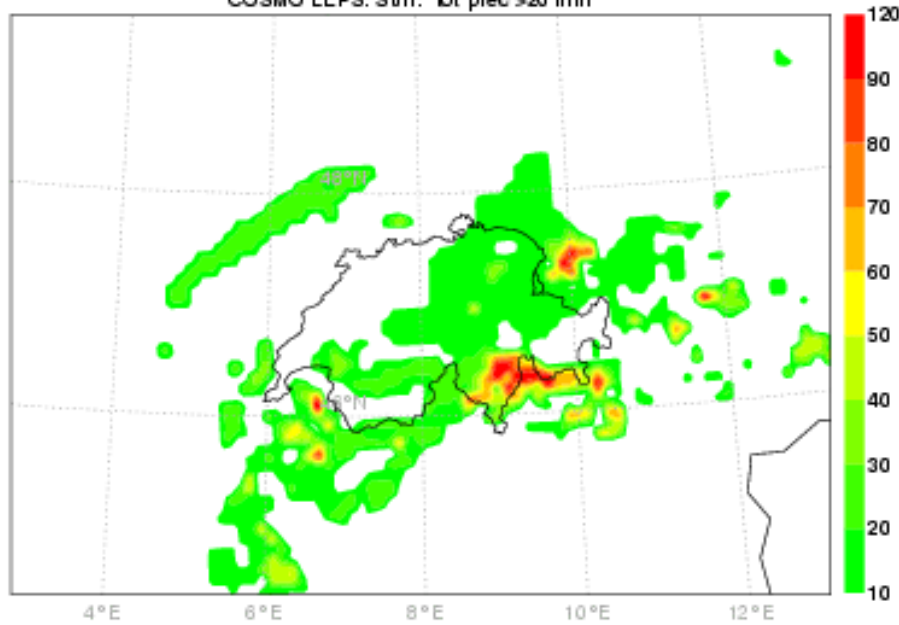
Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(24-48) VT: Wed 2003-04-30 12UTC
COSMO LEPS: Surf: tot prec >100 mm



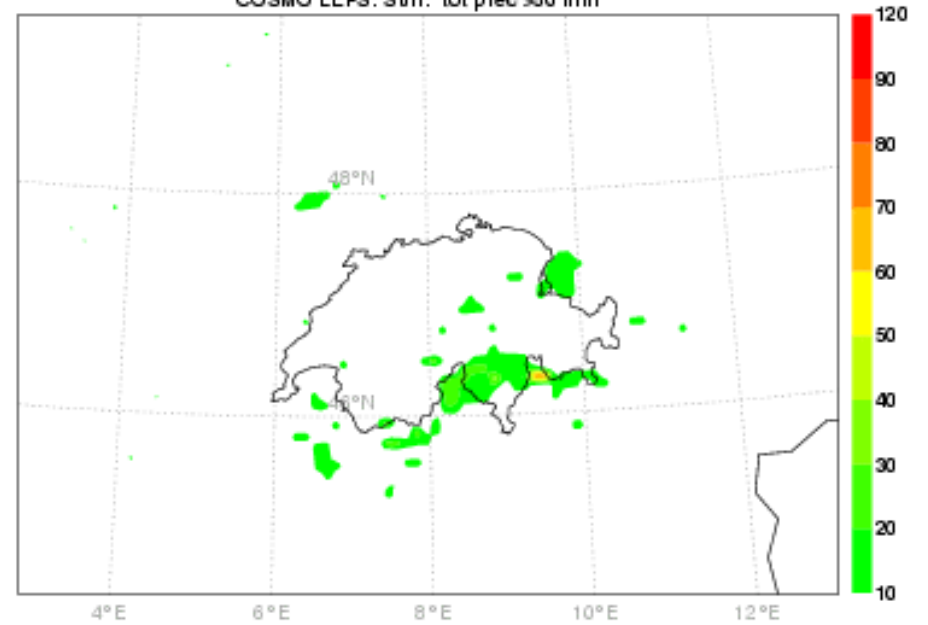
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COSMO LEPS: Surf: tot prec >150 mm



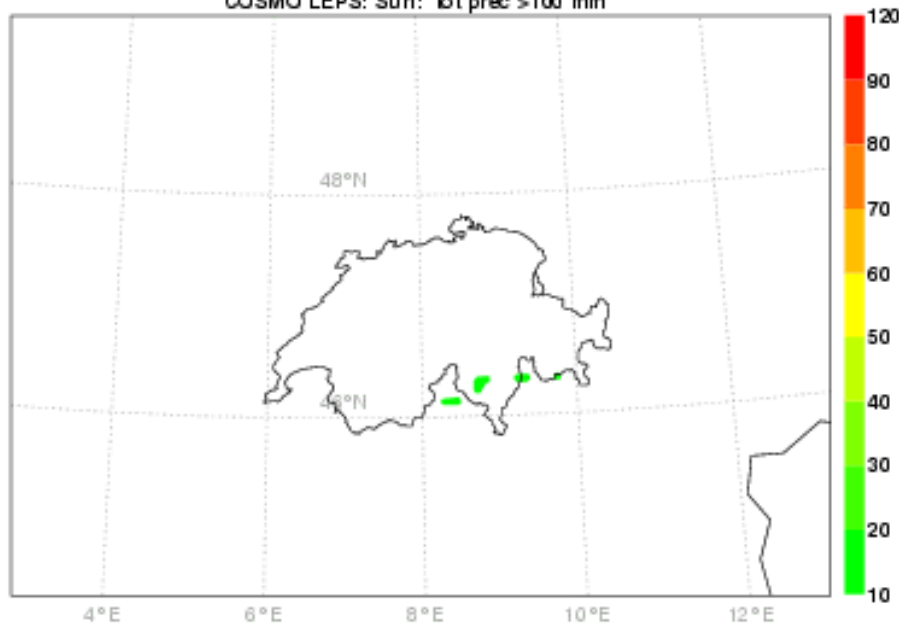
Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(48-72) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >20 mm



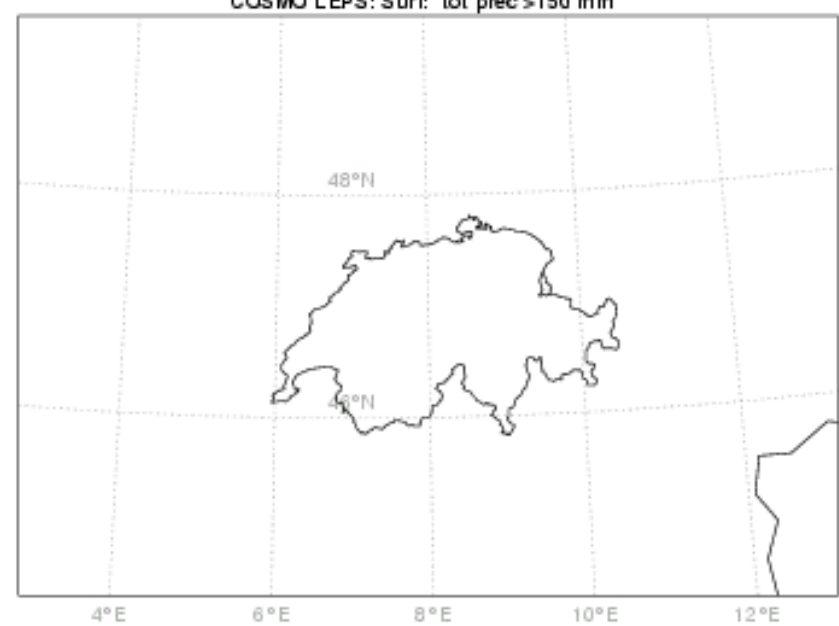
Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(48-72) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >50 mm



Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(48-72) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >100 mm



Mon 2003-04-28 12UTC ECMWF EPS Prob FC t+(48-72) VT: Thu 2003-05-01 12UTC
COSMO LEPS: Surf: tot prec >150 mm



Recognition of extreme events with ANN



- Old method:
- Self Organising Map (SOM) = classification of synoptic patterns with H500 and T850
- The classification is independent of the weather element
- Interpretation in terms of weather elements made in a second step: probability to exceed some threshold for each element of the classification

Recognition of extreme events with ANN



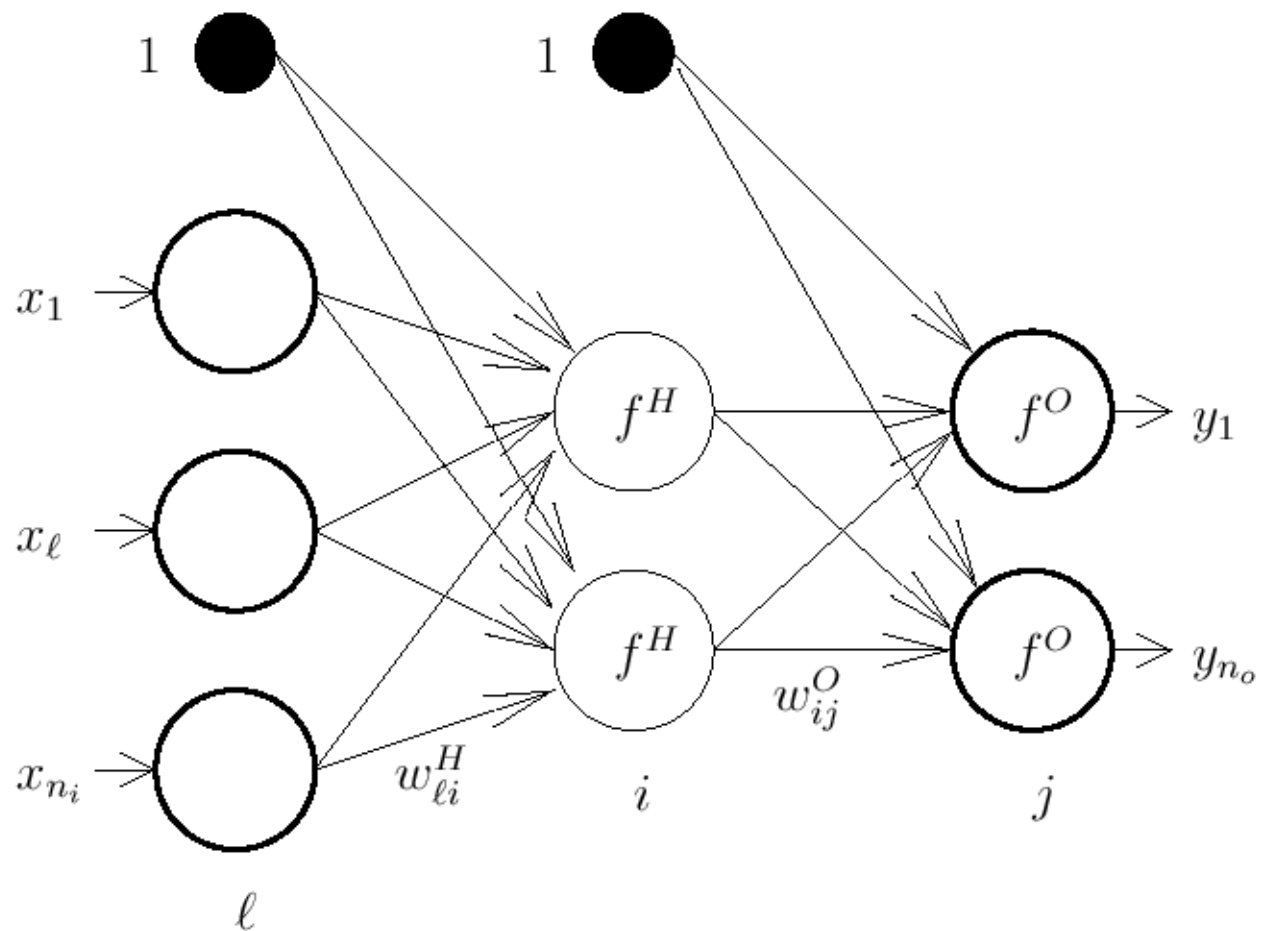
- New developments (R. Kretschmar)
- Supervised learning, classification is dependent on the weather element and the threshold.
- More predictors

Recognition of extreme events with ANN



Set	850 hPa	700 hPa	500 hPa	input features
A_L, A_H	T	-	Z	200
B_L, B_H	T	R	W, Z	400
C_L, C_H	R, T, U, V	R, Z	R, T, W, Z	1000
D_L, D_H	R, T, U, V	R, T, U, V, W, Z	R, T, W, Z	1400
\tilde{C}_L, \tilde{C}_H	first 250 PCA components of C_L, C_H			250
\tilde{D}_L, \tilde{D}_H	first 250 PCA components of D_L, D_H			250

FFNN: Feed Forward Neural Network



Verification: experiments

1. SOM with H500 and T850
2. SOM with 250 PCA
3. FFNN with 250 PCA
4. FFNN with 250 PCA and DMO rainfall as input
5. Station Lugano (south of the Alps)

Rescale DMO precipitation: event is realised when
RR exceeds 10mm, 20mm, 30mm,...

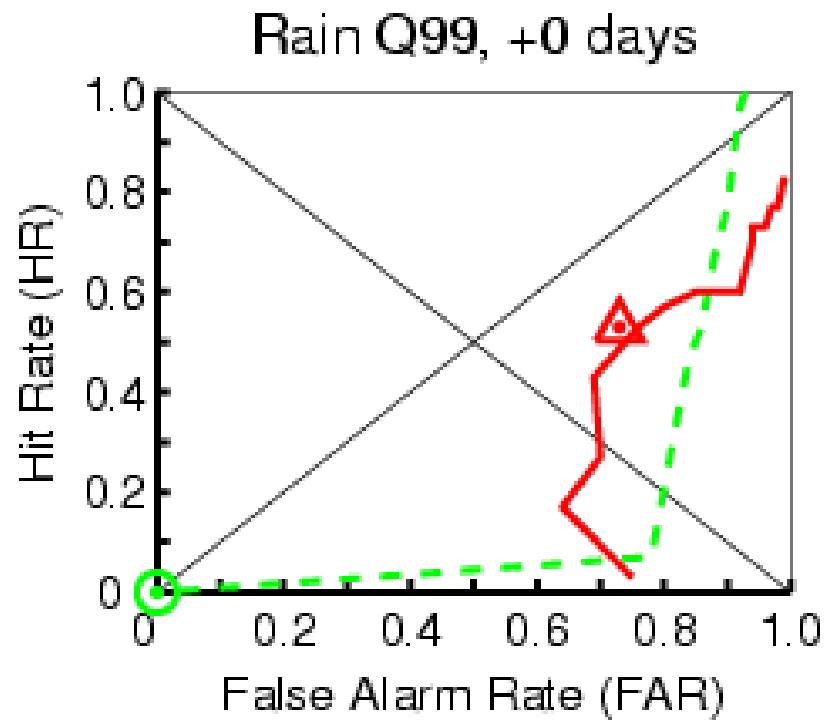
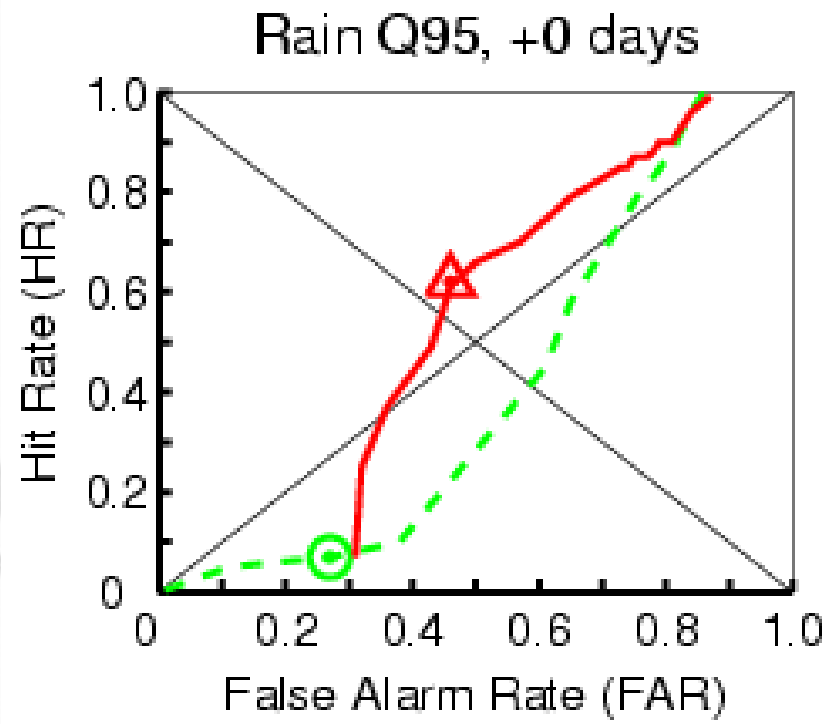
Verification: scores



Event	Observed	Not Observed
Forecasted	A	B
Not Forecasted	C	D

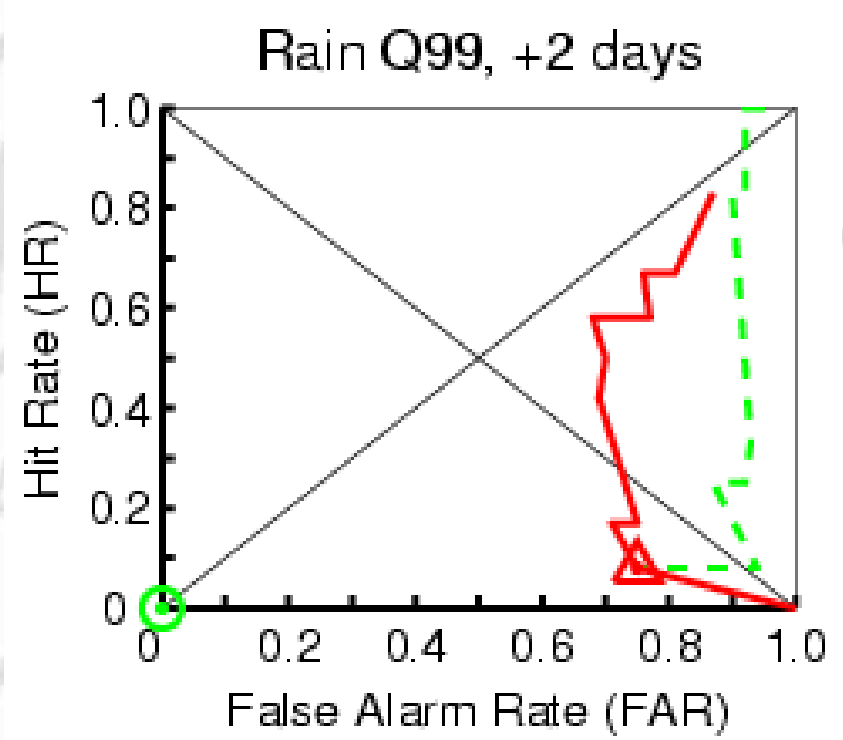
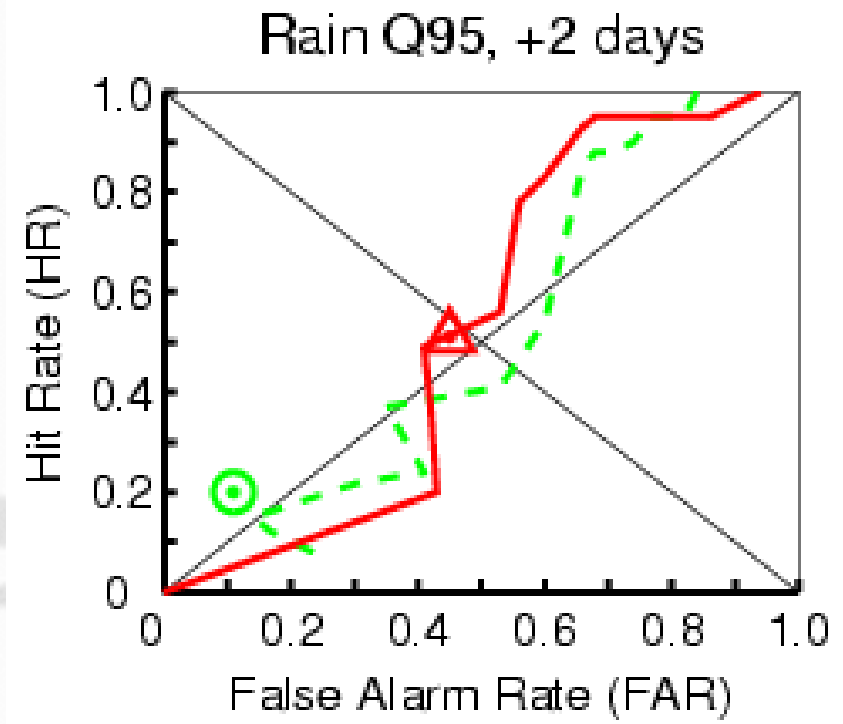
- **Hit Rate = $B / (A+C)$**
- **FAR = $A / (A+B)$**

Verification: scores



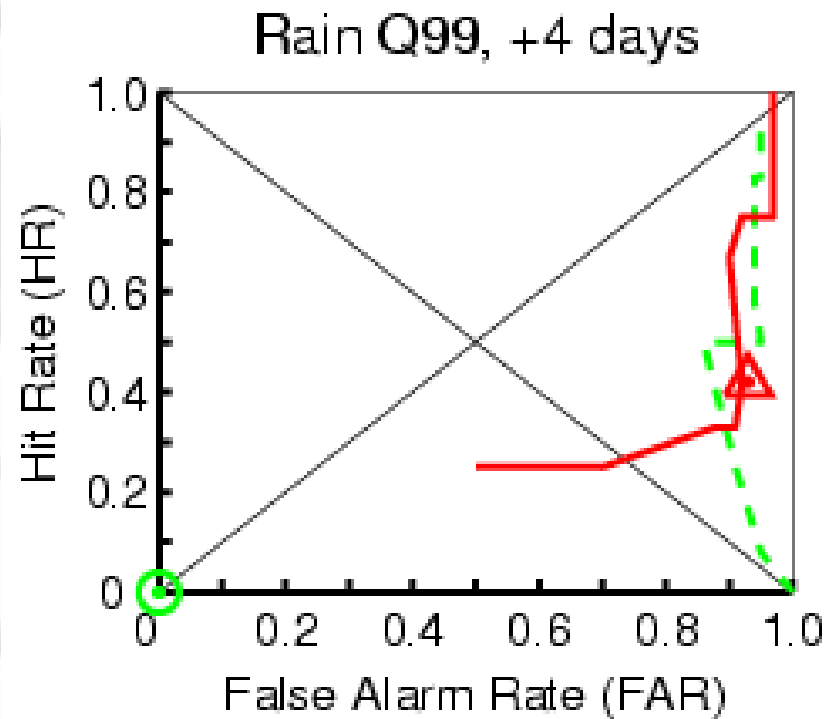
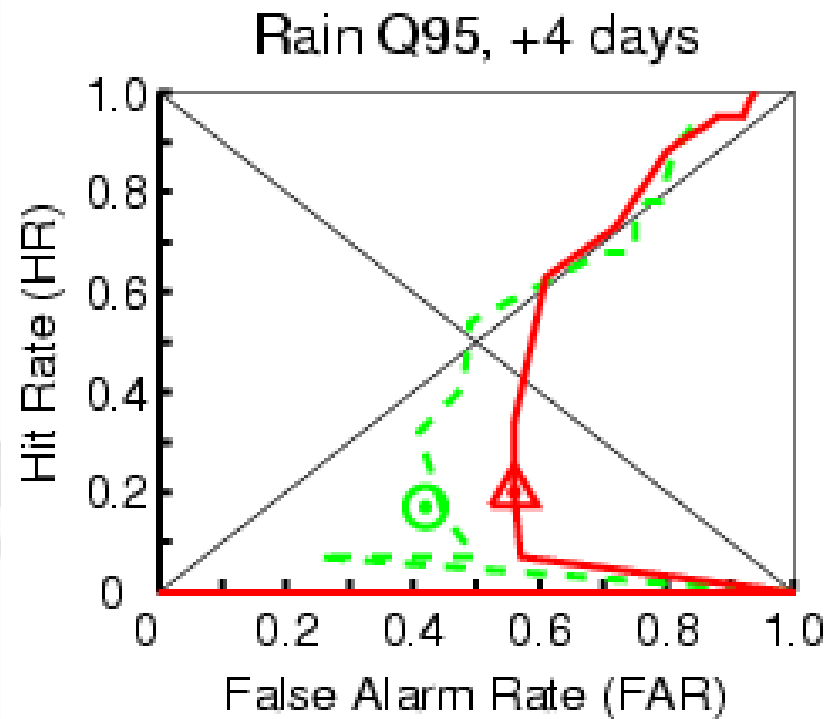
- SOM (unsupervised)
- FFNN (supervised)

Verification: scores



- Rescaled DMO (T511)
- FFNN with DMO RR as input

Verification: scores



--- Rescaled DMO (T511)

— FFNN with DMO RR as input

Conclusion



- Forecasting of rare events requests special treatment
- Downscaling / rescaling
- Hit rate is usable
- False Alarm Rate can be optimised
- DMO, EFI, LEPS, ANN have each their own qualities
- Define methods based on combinations of these techniques
- Critical eye of the forecaster is still requested, mostly for reducing the **False Alarm Rate**.