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# Results of fuzzy verification methods with COSMO over Switzerland and Germany

work by Felix Ament, Tatjana Bähler, Tanja Weusthoff, Matteo Buzzi (MeteoSwiss), and Ulrich Damrath (DWD) compiled by Francis Schubiger (MeteoSwiss) presented by Marco Arpagaus

> 30<sup>th</sup> EWGLAM & 15<sup>th</sup> SRNWP meeting 7 October 2008, Madrid



### **Fuzzy verification**

- Beth Ebert has built up a collection of existing fuzzy forecasting verification scores in a toolbox
- define scales of interest; consider "average" features within each box









forecast

observation

0.9

8.0

0.7

0.60

0.5

0.3 0.20

0.1 0

-0.1

(© Beth Ebert)

 score depends on considered scale and threshold (defining an event)

(© Beth Ebert)

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# A Fuzzy Verification Toolbox

Fuzzy method	Decision model for useful forecast
Upscaling (Zepeda-Arce et al. 2000; Weygandt et al. 2004)	Resembles obs when averaged to coarser scales
Anywhere in window (Damrath 2004), 50% coverage	Predicts event over minimum fraction of region
Fuzzy logic (Damrath 2004), Joint probability (Ebert 2002)	More correct than incorrect
Multi-event contingency table (Atger 2001)	Predicts at least one event close to observed event
Intensity-scale (Casati et al. 2004)	Lower error than random arrangement of obs
Fractions skill score (Roberts and Lean 2005)	Similar frequency of forecast and observed events
Practically perfect hindcast (Brooks et al. 1998)	Resembles forecast based on perfect knowledge of observations
Pragmatic (Theis et al. 2005)	Can distinguish events and non-events
CSRR (Germann and Zawadzki 2004)	High probability of matching observed value
Area-related RMSE (Rezacova et al. 2005)	Similar intensity distribution as observed

Ebert, E.E., 2007: Fuzzy verification of high resolution gridded forecasts: A review and proposed framework. Meteorol. Appls., submitted. Toolbox available at <u>http://www.bom.gov.au/bmrc/wefor/staff/eee/fuzzy\_verification.zip</u>

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# Effect of "Leaking" Scores

Some methods assume no skill at scales below window size!



# Testbed: Spatial Translation



Example: Fractions skill score (Roberts, N., 2005)

Fraction skill score shows a very reasonable behaviour in case of translations.

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#### Spatial detection versus filtering O

Horizontal translation (XSHIFT) with variable displacement  $\Delta x$ 

- "Intensity scale" method can detect spatial scale of perturbation
- All other methods like the "Fraction Skill score" just filter small scale errors



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F. Ament, MeteoSwiss

0.67

0.32

0.02

0.00

0.00

0.00

0.00

32

0.89

0.80

0.57

0.33

0.24

0.21

0.17

32

0.97

0.92

0.65

0.59

0.53

32

# Expected response to perturbations



#### Summary in terms of contrast:



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- Leaking scores show an overall poor performance
- "Intensity scale" and "Practically Perfect Hindcast" perform in general well, but ...
- Many scores have problems to detect large scale noise (LS\_NOISE); "Upscaling" and "50% coverage" are beneficial in this respect

# Redundancy of scores

Correlation (%) of resulting scores between all score for all thresholds, window sizes – averaged over all types of perturbation:



# Conclusions

- Intensity scale (IS) is a very promising technique

   fast and able to detect a specific scale of an
   spatial error.
- The Fraction Skill (FS) and Practically perfect hindcast (PP) show also very good result – FS is very popular.
- Set should be completed by Upscaling (UP) to be aware of large scale error patterns.
- Area related RMSE (RM) shows good performance too, but has no intensity component and requires a lot of computational time.
- Leaking scores (FZ, JP, ME, PG, CS) should not be considered for COSMO purposes!
- Reliability (low STD) is good for all scores. Best performance shows Area related RMSE.







 88
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Verification on coarser scales than model scale: "Do not require a point wise match!"

Method	Raw Data	Fuzzyfication	Score	Example result
Upscaling	I       I	Average	Equitable threat score	Upscaling – ETS         41       0.34       0.34       0.30       0.25       0.21       0.07       -0.00         10       26       0.31       0.31       0.30       0.27       0.22       0.18       0.07       -0.00         15       0.29       0.29       0.28       0.25       0.20       0.16       0.06       0.01         19       9       0.28       0.27       0.26       0.23       0.19       0.15       0.06       0.01         10       0.26       0.25       0.22       0.17       0.14       0.05       0.01         10       0.26       0.25       0.24       0.22       0.17       0.14       0.05       0.01         10       0.26       0.25       0.24       0.22       0.17       0.14       0.05       0.01         10       0.25       0.4       1       2.5       4       10       25
Fraction Skill Score (Roberts and Lean, 2005)		Fractional coverage	Skill score with reference to worst forecast	41         0.83         0.81         0.80         0.75         0.67         0.60         0.35         0.15           41         0.83         0.81         0.80         0.75         0.67         0.60         0.35         0.15           41         0.83         0.75         0.73         0.68         0.59         0.61         0.28         0.11           41         0.72         0.70         0.67         0.61         0.52         0.44         0.22         0.06           15         0.72         0.70         0.67         0.61         0.52         0.44         0.22         0.06           19         9         0.68         0.65         0.62         0.56         0.46         0.39         0.19         0.06           10         0.57         0.54         0.56         0.49         0.39         0.32         0.14         0.03           1         0.57         0.54         0.55         0.45         0.35         0.28         0.11         0.02           0.1         0.25         0.4         1         2.5         4         10         25

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# Settings

- Nacc = 3h
- Thresh = [0.1, 0.2, 0.5, 1, 2, 5, 10, 20] (mm / 3h)
- Windows<sub>COSMO-CH7</sub> = [1, 3, 5, 9, 15]
- Windows<sub>COSMO-CH2</sub> = [1, 3, 9, 15, 27, 45]
- Methods = Upscaling (UP) and Fraction Skill Score (FB)
- Scores = ETS (for UP) and FSS (for FB)
- Fuzzy-package: Version April 2008

### Fuzzy Verification COSMO-2 – COSMO-7

JJA 2007, Verification against Swiss Radar Composite, 3 hourly accumulations, rain events



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# Score vs intensity, entire DOP

0



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### Fuzzy Verification COSMO-DE – COSMO-EU

JJA 2007, Verification against Swiss Radar Composite, 3 hourly accumulations, rain events



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### Fuzzy Verification COSMO-DE – COSMO-EU

JJASON 2007, Verification against Swiss Radar Composite, 3 hourly accumulations



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0.01 -0.01

-0.06 -0.02

-0.04 -0.03

5

-0.03 0.00

10

5

10

2

2

10

5

2



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**ETS Upscaling Summer 2008** Ω



**ETS Upscaling Summer 2008** O



### 17.01.2008 - 06.02.2008



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Fraction skill score

O

### Intensity scale skill score 17.01.2008 - 06.02.2008 24h precipitation sums

Intensity-scole - SS	Intensity-scale - SS	Intensity-scale - SS
00 <mark>0.74 0.69 0.48 0.24 <mark>-0.04-0.02-0.07</mark> 0.25 1.00</mark>	.60 -0.09-0.13-0.090.15 0.31 0.51 0.56 0.72 100	.60 0.13 <mark>-0.49</mark> 0.31 0.81 0.84 0.20 0.87 0.86 1.1
30 0.07 0.16 0.17 0.22 0.27 0.56 0.52 0.42 0.99	1.80 0.55 0.46 0.42 0.43 0.52 0.75 0.22 0.49 100	1.80 0.40 0.43 0.16 0.07 0.43 0.42 0.51 0.08 1.1
10 0.17 0.24 0.25 0.36 0.47 0.32 0.45 0.65 0.96	540 0.55 0.60 0.63 0.56 0.57 0.65 0.56 0.35 1.00	940 -0.26-0.51-0.21-0.33-0.18 <mark>0.11 0.11 0.34</mark> 1.1
20 0.40 0.38 0.41 0.46 0.54 0.56 0.51 0.34 0.99	1.20 1.68 0.72 0.67 0.70 0.65 0.70 0.68 0.58 1.00	1.20 -0.06-0.17-0.12-0.08 0.03 0.08 0.32 0.45 1.1
10 0.85 0.80 0.62 0.63 0.85 0.74 0.78 0.84 0.98	10 10 10.74 D.82 D.81 D.81 D.88 D.83 D.74 D.78 1.00	1.10 0.01 0.04 0.12 0.18 0.32 0.49 0.55 0.67 1.
05 <mark>0.65 8/70 9.75 9.75 9.77 9.82 9.82 9.87 9.99</mark>	1.05 Mass plas plas plas plas plas plas plas p	1.05 0.15 0.41 0.32 0.44 0.51 0.55 0.72 0.81 11
03 0.69 0.69 0.73 0.75 0.78 0.84 0.84 0.88 0.99	1.03 mas 0.67 0.66 0.67 0.65 0.66 0.66 0.69 0.99	1.03 0.12 0.12 0.20 0.47 0.57 0.72 0.76 0.81 0.1
0.1 0.2 0.5 1 2 5 10 20 50 20080119Threshold (mm/24h) 06_30 Intensity-scale - SS	0.1 0.2 0.5 1 2 5 10 20 50 20080120Threshold (mm/24h) 06_30 Intensity-scale - SS	0.1 0.2 0.5 1 2 5 10 20 5 20080121Thvehold (mm/24h) 06_3 Intensity-scale - SS
00 0.87 0.84 0.82 0.43 0.12 0.05 0.96 1.00 1.00	.60 0.71 0.38 -0.05013 0.69 1.00 1.00 1.00	.60 0.87 0.82 0.98 0.91 0.79 0.75 0.65 0.97 1.0
80 0.68 0.47 0.24 <mark>-0.01-0.02</mark> 0.47 0.81 1.00 1.00	1.80 0.52 0.52 0.61 0.47 0.60 1.00 1.00 1.00 1.00	1.80 0.75 0.75 0.88 0.76 0.53 0.46 0.51 0.81 1.0
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20 -0.52-0.85 <mark>-0.45</mark> -0.01 0.30 0.34 0.89 1.00 1.00	1.20 0.61 0.72 0.63 0.63 0.81 1.00 1.00 1.00 1.00	1.29 0.68 0.65 0.72 0.68 0.65 0.58 0.56 0.85 1.0
10 -0.61 <mark>-0.42-0.01</mark> 0.25 0.54 0.62 0.91 1.00 1.00	1.10 0.78 D.42 D.48 O.48 0.52 1.00 1.00 1.00 1.00	1.10 0.78 0.81 0.82 0.79 0.77 0.78 0.78 0.88 1.0
05 -0.57 <mark>-0.10</mark> 0.28 0.51 0.98 0.78 0.93 1.00 1.00	1.05 0.85 0.85 0.85 0.92 0.98 1.00 1.00 1.00 1.00	1.05 0.84 0.87 0.86 0.83 0.84 0.84 0.81 0.89 1.0
03 -0.52-4.50 <mark>0.31 9.52 0.37 0.78</mark> 0.34 1.60 1.60	1.03 8.04 8.68 8.90 6.94 6.96 1.00 1.00 1.08 1.00	1.03 0.85 0.68 0.87 0.65 0.85 0.86 0.84 0.83 0.1
0.1 0.2 0.5 1 2 5 10 20 50 200801247hreshold (mm/24h) 06_30 Intensity=scale = SS	0.1 0.2 0.5 1 2 5 10 20 50 20080125Threthold (mm/24h) 06_30 Intensity-scale - SS	0.1 0.2 0.5 1 2 5 10 20 5 20080126Threshold (mm/24h) 06_3 Intensity-scale - SS
60 0.78 0.62 0.30 0.14 -0.520.37 0.72 1.03 1.00	.60 0.59 0.47 0.54 0.52 0.42 0.30 0.88 1.00 1.00	.60 -0.100.12 0.53 0.67 0.53 0.66 0.60 0.98 1.0
80 0.07 -0.220.02 0.36 0.81 0.65 0.70 0.89 1.00	1.80 0.18 0.09 0.25 0.08 0.06 0.19 0.87 1.00 1.00	1.60 -0.16-0.14-0.35 <mark>0.15-0.01</mark> 0.40 0.70 0.91 1.1
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20 -0.40-0.27-0.13 <mark>0.29</mark> 0.86 0.60 0.85 0.89 1.00	1.20 <mark>-0.02</mark> 0.20 0.28 0.31 0.50 0.52 0.82 1.09 1.09	1.20 0.11 -0.15-0.010.11 0.20 0.31 0.28 0.77 1.4
10 -0.34-9.110.21 9.54 0.56 0.55 0.91 0.59 1.00	10 0.27 0.61 0.00 0.00 0.54 0.72 0.88 1.01 1.00	1.10 0.15 0.04 0.35 0.44 0.46 0.51 0.54 0.58 1.4
05 -0.020.16 0.37 0.62 0.84 0.85 0.95 0.99 1.00	1.05 0.52 0.59 0.58 0.65 0.14 0.81 0.92 1.00 1.00	1.05 0.44 0.35 0.53 0.61 0.67 0.74 0.76 0.83 1.0
0.32-0.00 <mark>0.33</mark> 0.61 0.84 0.87 0.96 0.99 1.00	1.03 (.48 0.58 0.5) 0.63 (1.34 0.84 0.93 0.91 1.00	1.03 0.41 0.43 0.57 0.65 0.70 0.79 0.80 0.94 1.0
0.1 0.2 0.5 1 2 5 10 20 50 20080130Threshold (mm/24h) 06_30 Intensity-scale - SS	0.1 0.2 0.5 1 2 5 10 20 50 20080131Threshold (mm/24h) 06_30 Intensity-scale - SS	0.1 0.2 0.5 1 2 5 10 20 5 20080201Threshold (mm/24h) 06_3 Intensity-scale - SS
0 0.29 0.04 0.00 0.30 0.45 0.87 0.97 1.00 1.00	.60 0.75 0.65 0.66 0.77 0.06 0.55 0.60 0.66 1.00	.60 0.00 0.03 0.64 0.59 0.54 0.75 0.08 0.99 1.0
0 0.45 0.50 0.51 0.33 0.48 0.89 0.96 0.99 1.00	1.80 0.67 0.41 0.75 0.66 0.59 0.27 0.40 0.63 1.00	1.80 0.05 <mark>-0.04-0.10</mark> 0.05 0.22 0.35 0.77 6.95 1.0
10 0.25 0.13 0.20 0.37 0.43 0.71 0.91 0.98 1.00	v49 0.09 0.05 0.45 0.40 0.10 0.16 0.03 <mark>0.86 1.00</mark>	140 -0.33-0.43-0.67-0.59-0.43 0.18 0.62 0.83 1.0
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0.1 0.2 0.5 1 2 6 10 20 50 200802040hreshold (mm/24h) 06_30	0.1 0.2 0.8 1 2 6 10 20 50 20080205Threshold (mm/24h) 06_30	0.1 0.2 0.5 1 2 5 10 20 5 20080206 hveshold (mm/24h) 06_3

Intensity-scale 60 DEE DES CAR 0.28 008-0190.45 100 100 00 031 030 084 087 038 032 087 038 10 82 0.68 0.28-0.07-0.14-0.18 0.38 180 0.61 0.58 0.21 0.31 0.29 0.49 0.61 0.88 1.0 140 0.19 0.42 -0.430.05 0.09 0.34 0.54 0.82 1 00 1.40 0.61 0.31 -0.17-0.35-0.17 0.01 0.43 0.91 120 0.01 0.08-0.41-0.300.11 0.27 0.53 0.99 120 0.50-0.44-0.71-0.41 0.03 0.40 0.51 0.85 1.0 05-0.23-0.03-0.14 0.48 0.54 0.65 0 110 0.05 -0.45-0.210.07 0.36 0.53 0.69 0.97 1.0 :05 -0.79001 0.25 0.52 0.57 0.78 0.98 1 00-0.00-7.010.30 0.54 0.07 0.78 03 19-1 19-0.220.28 0.51 0.71 0.81 0.89 1.0 210 15 5 65 0 20 0 70 C.1 0.2 0.5 1 2 5 10 20 50 20080117Threshold (mm/24h) 06 30 0.1 0.2 0.5 1 2 5 10 20 50 20080118Threshold (mm/24h) 06 30 Intensity-scale - SS 60 0.55 0.61 0.69 0.68 0.28 0.43 1.00 1.00 1.00 .80 ++ 0.57 0.86 0.69 0.81 0.34 140 46 0.53 0.55 0.67 0.68 0.87 120 0.58 0.51 0.57 0.64 0.76 0.92 1.00 1.00 1 110 147 0.65 0.69 0.74 6.79 0.95 1.00 1.00 1.0 :05 6 0.74 0.75 0.80 0.84 0.96 1.00 0.3 0.1 0.2 0.5 1 2 5 10 20 50 20080123Threshold (mm/24h) 06 30 Intensity-scale - SS 60 0.55 0.57 0.49 0.65 0.66 1.00 1.00 1.00 1.0 180 0.42 0.51 0.42 0.59 0.90 1.00 140 57 0.47 0.53 0.58 0.80 1.00 120 0.68 0.62 0.54 0.58 0.76 1.80 110 0 0.75 0.74 0.76 0.86

0.05

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Intensity-scale - SS 60 0.50 0.56 C.86 0.84 0.70 0.57 0.96 1.00 1.00 1.80 0.39 0.47 0.72 0.65 0.76 0.70 0.91 140 0.22 0.39 0.46 0.63 0.59 0.64 0.83 0.99 1.20 0.47 0.46 0.45 0.57 0.55 0.74 0 110 050 0.55 0.55 0.71 0.70 0.85 0.95 0.98 1.0 1.05 0.65 0.73 0.72 0.81 0.81 0.89 0.97 0.99 1.03 1.66 6.75 6.77 0.41 5.82 0.91 0.95 0.99 1.4 0.1 0.2 0.5 1 2 5 10 20 50 20080122Threshold (mm/24h) 06 30 Intensity-scale - SS .60 0.25-0.11-0.09-0.080.07 0.38 0.75 0.96 1.0 1.80 0.56 0.31 0.22 0.12 0.19 0.06 0.25 0.85 1.40 0.41 0.30 0.39 0.47 0.48 0.54 0.55 0.59 1.20 8.54 0.42 0.40 0.57 0.54 0.55 0.64 0.87 110 0.64 0.59 0.65 0.69 0.71 0.71 0.71 0.05 78 D 75 0 75 0 81 5 80 D 83 0 85 0 94 1 0 :05 7 0.85 0.85 0.85 0.91 1.00 1.00 1.00 1.00 UD3 18 0.77 0.78 0.83 0.82 0.84 0.87 0.94 1.0 103 8 9.57 9.56 9.58 6.93 1.00 1.00 1.00 1.0 0.1 0.2 0.5 1 2 5 10 20 50 20080127Threshold (mm/24h) 06 30 0.1 0.2 0.5 1 2 5 10 20 50 20080128Threshold (mm/24h) 06 30 Intensity-scale - SS Intensity-scale - SS 60 0.56 0.48 0.65 0.49 0.75 0.99 1.05 1.00 1.8 180 1.80 0.30 0.19 0.33 0.25 0.57 0.98 1.00 1.00 V40 0.23 0.19 0.27 0.32 0.35 0.95 1.00 1.00 440 28 0 81 0 90 0 91 0 90 1 00 120 1.20 0.23 0.26 0.27 0.29 0.66 0.94 1.00 1.00 5 0.84 0.88 0.88 0.96 1.00 110 1.10 0.50 0.47 0.49 0.49 5.72 0.94 1.00

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0.1 0.2 0.5 1 2 6 10 20 50 20080203hreshold (mm/24h) 06 30

# Conclusions (so far ...)



- Fraction skill score and Upscaling are the two fuzzy verification methods chosen inside COSMO, although Intensity-scale is also very promising.
- First results regarding COSMO 2.2/2.8 km vs COSMO 7km show:
  - some advantages for 2.2/2.8 km especially in regions where topography plays a major role and for situations with mesoscale character
  - 2.2/2.8 km has advantages for shorter accumulated periods.
  - 2.2/2.8km shows better scores for low thresholds and for small to medium space scales.

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### Another fuzzy method: SAL JJA 2007, catchment Danube, 24h-sums



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H. Wernli et al., Uni Mainz to appear in MWR



# Thank you for your attention!

Results of fuzzy verification methods with COSMO over Switzerland and Germany 30th EWGLAM &15th SRNWP meeting, 7 October 2008, Madrid

### C A (Fuzzy) Verification testbed Perturbations

Perturbation	Type of forecast error	Algorithm	Example
PERFECT	No error – perfect forecast!	-	
XSHIFT	Phase shift	Horizontal translation (10 grid points	
SCALE	Perfect structure but quantitatively wrong	Multiplication by a constant factor (e.g. 2)	
SMOOTH	High horizontal diffusion (or coarse scale model)	Moving Window arithmetic average	
DRIZZLE	Overestimation of low intensity precipitation	Moving Window filter setting each point below average point to the mean value	
BROWNIAN	No small scale skill	Random exchange of neighboring points (Brownian motion)	
LS_NOISE	Wrong large scale forcing	Multiplication with a disturbance factor generated by large scale 2d Gaussian kernels.	



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COSMO-7 better

COSMO-2 better



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# **COSMO-EU - COSMO-7 (2007)**

### JJA

### SON





COSMO-7 better COSMO-EU better



### COSMO-DE - COSMO-2 (2007)

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