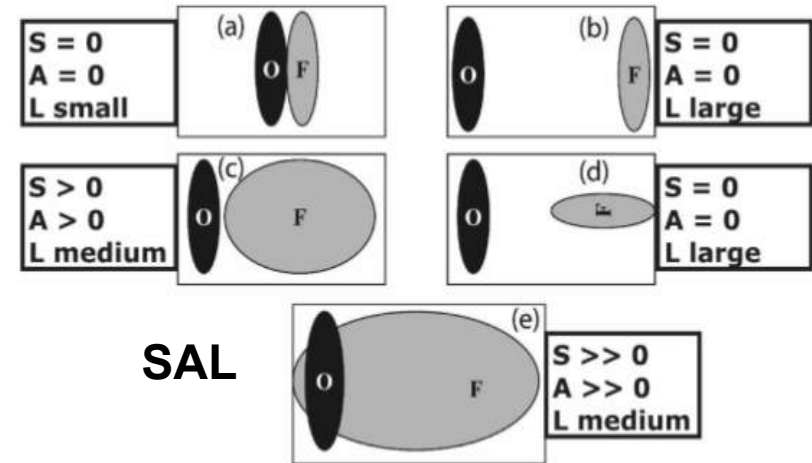


Spatial Verifications vs. Point Verifications Applied to Clouds and Precipitation



**Categorical Scores
Contingency Table**

		Observed		
		Yes	No	Total
Forecast	Yes	a	b	a+b
	No	c	d	c+d
	Total	a+c	b+d	n



- 1.) Motivation
- 2.) Point Scores
- 3.) VERA Analyses
- 4.) SAL Verification
- 5.) Case Applications
- 6.) Summary and Conclusions

Johannes Jenkner, Andrew Oberthaler, Dieter Mayer, Manfred Spatzierer

UBIMET ☀️ ☁️ 💧

Acknowledgements to Heini Wernli (ETH Zurich)

Motivation

Point Scores ↔ Spatial Scores

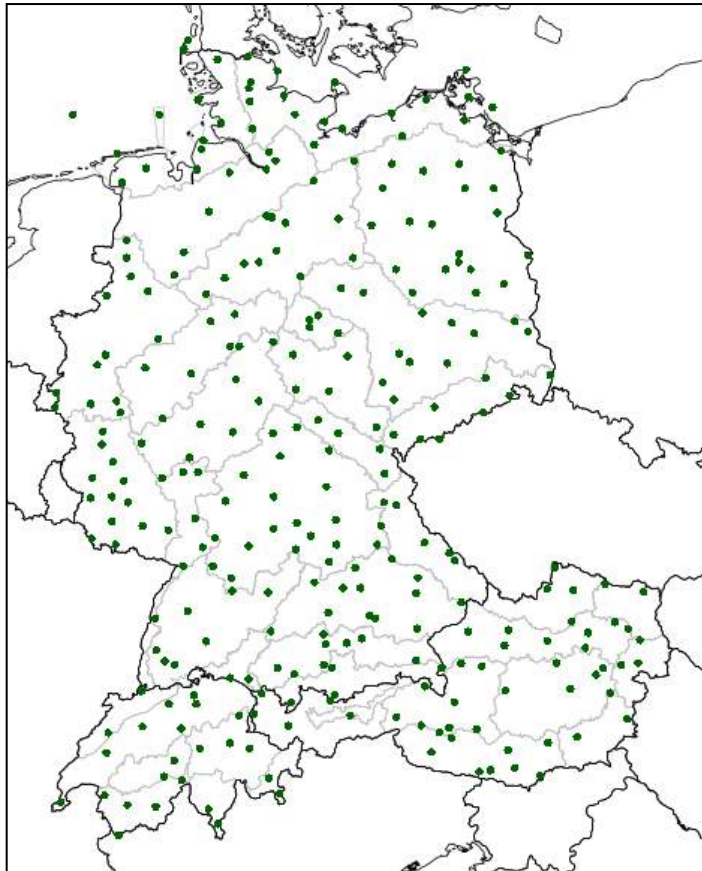
Categorical Scores ↔ SAL-Verification

Goal	Point Scores	SAL
Meaningful aggregate results	?	?
Results representative of domain	?	?
Scores are sensitive to forecast attributes	✓	?
Scores are proper	✗	?
Identification of underlying model errors	✓	?
Unequivocal ranking of forecast models	?	?

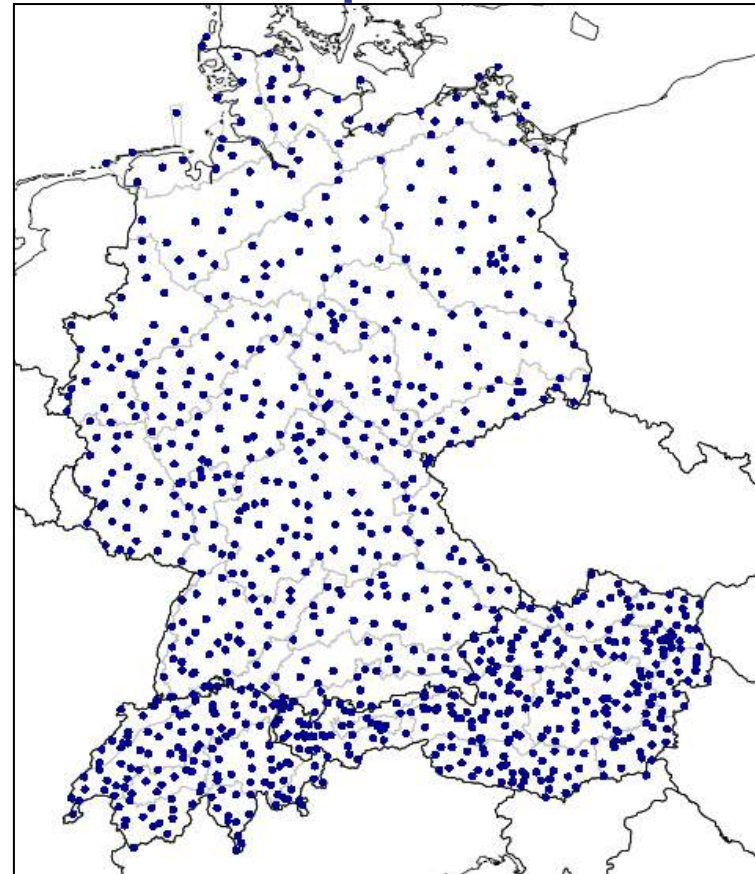
Point Scores

Station Locations

Clouds



Precipitation



a) Verification at each station location (nearest model gridpoint)

b) $0.04^\circ \times 0.04^\circ$ verification grid obtained from VERA analysis

VERA Analyses



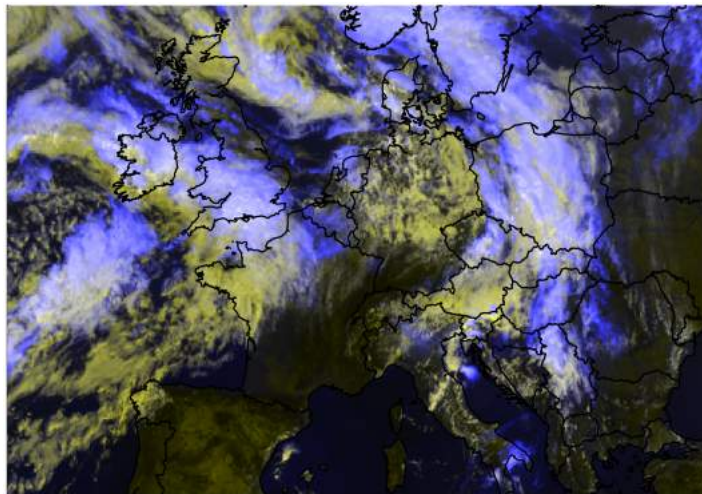
Combination of multiple input parameters and data sources



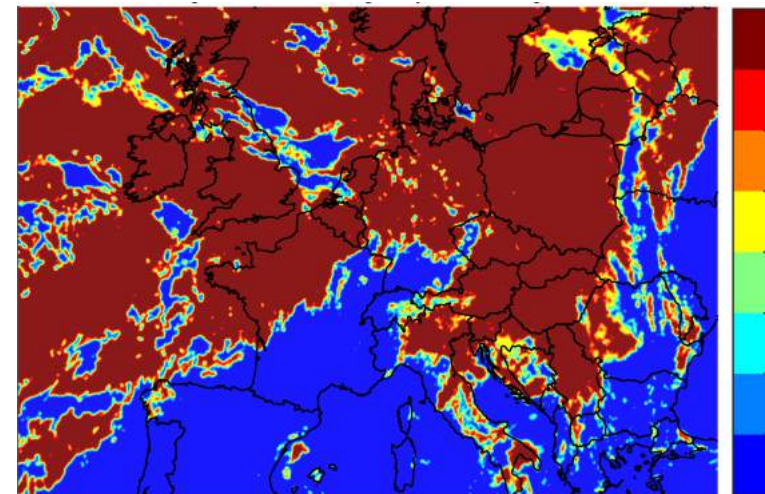
Cloud Cover

- Blending of satellite channels (VIS+IR) with analyzed surface temperature
- Computation of channel differences and comparison with predefined thresholds
- Aggregation of low, medium and high clouds

Yellow: VIS portion, Blue: IR portion



Final cloud product



VERA Analyses



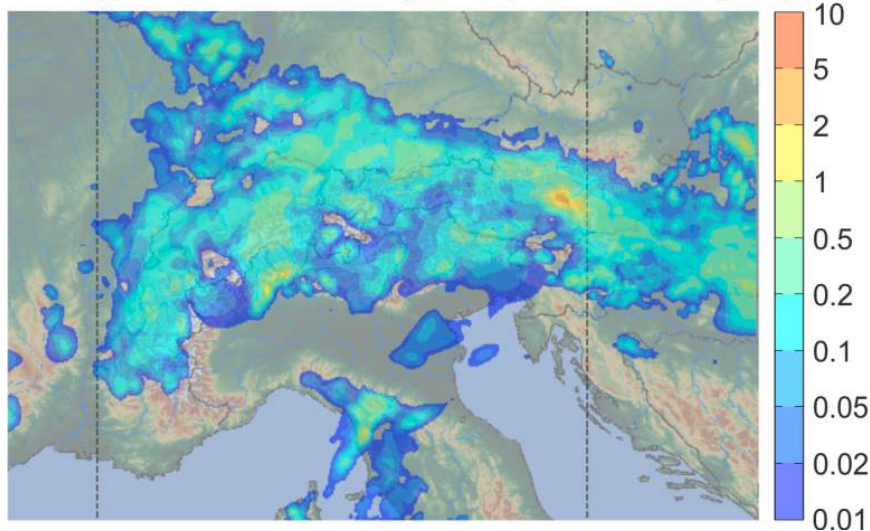
Minimization of spatial curvature by thin-plate spline interpolation



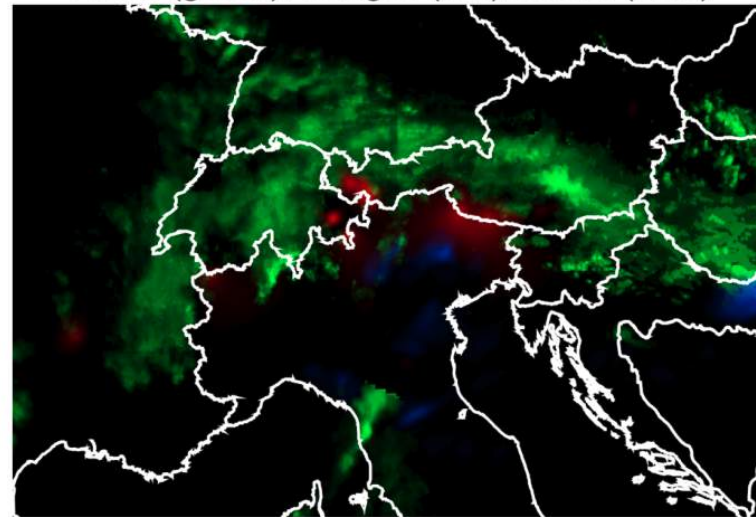
Precipitation

- Blending of station reports with RADAR data
- NWP estimates step in over areas without station data
- VERA-type interpolation of quotient between RADAR and station data

Precipitation Sum 15. May 2015, 07:00-07:10 [mm]



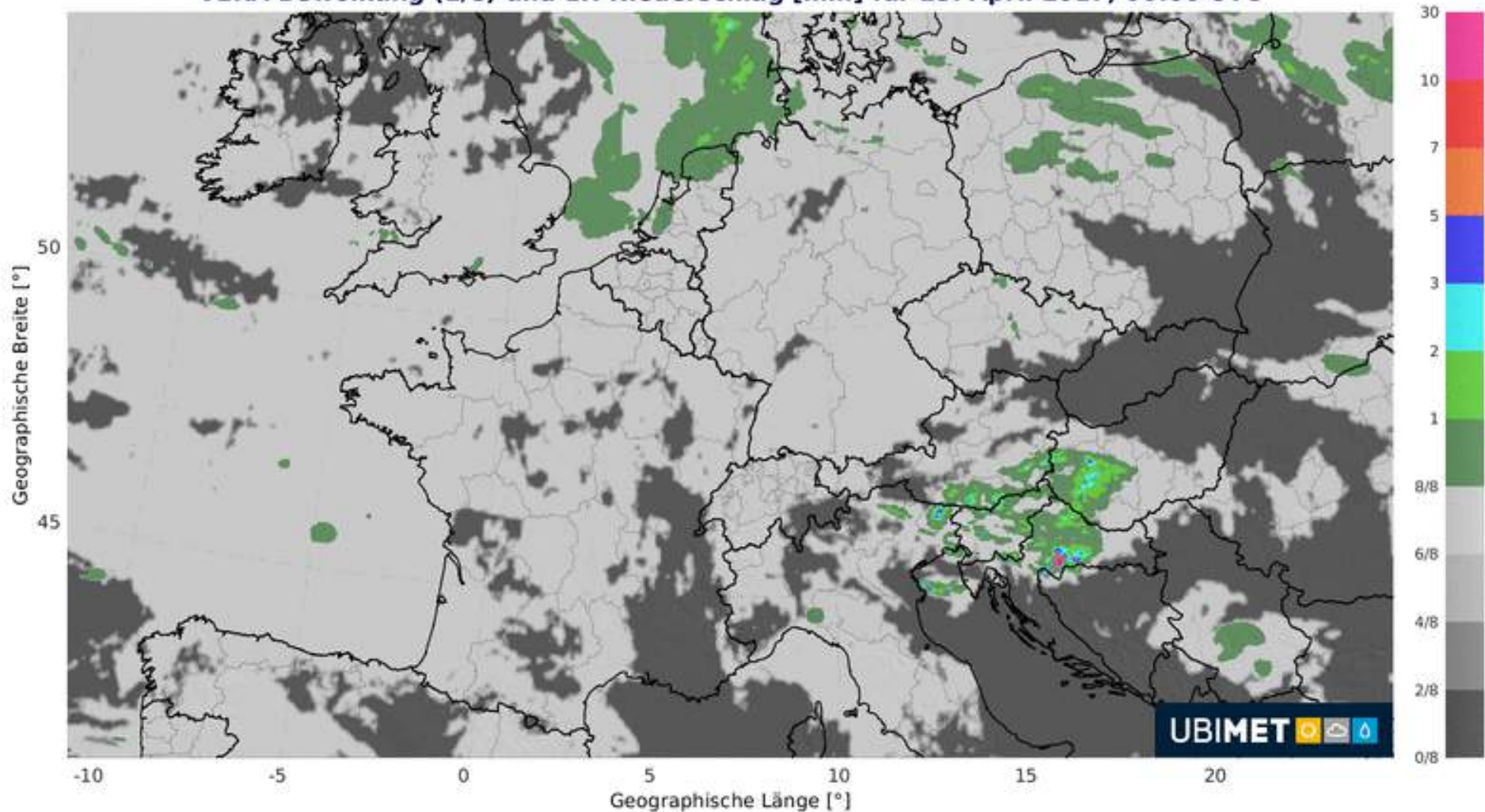
RGB Composit
Radar (green), Gauges (red), Model (blue)



Case Application 1

Two Lows Travelling from the North Sea to the East/Southeast
2017-04-15 00 UTC until 2017-04-20 00 UTC

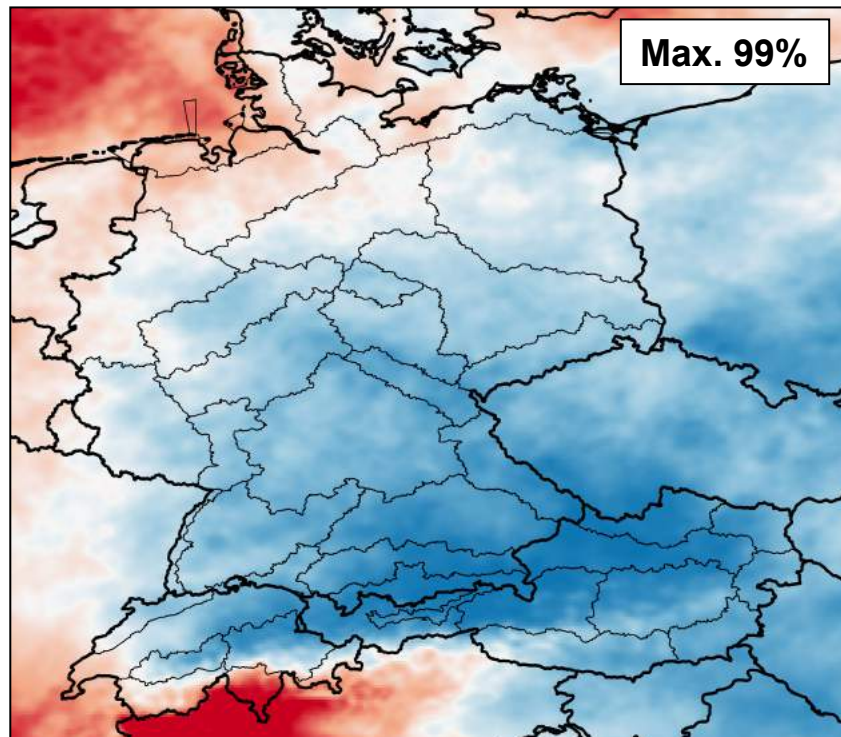
VERA Bewölkung (1/8) und 1H Niederschlag [mm] für 15. April 2017, 00:00 UTC



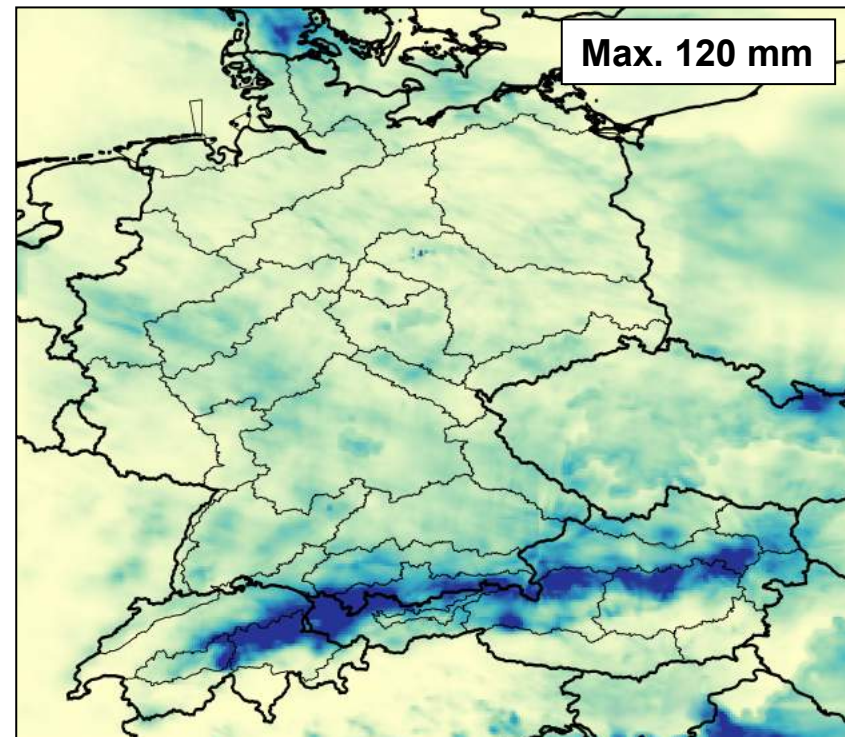
Case Application 1

Two Lows Travelling from the North Sea to the East/Southeast
2017-04-15 00 UTC until 2017-04-20 00 UTC

Mean Cloud Cover



Precipitation Sum



Case Application 1: Cloud Cover

GFS

ECMWF

WRF

Critical Success Index AVERAGE: 0.81

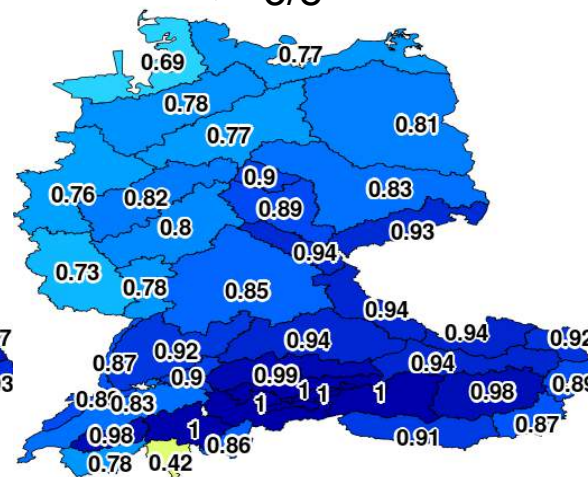
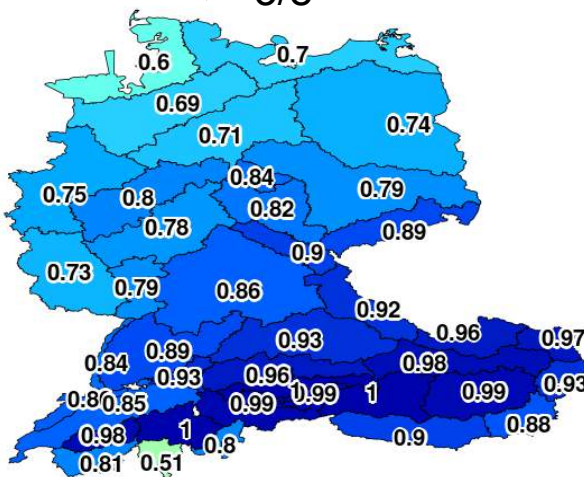
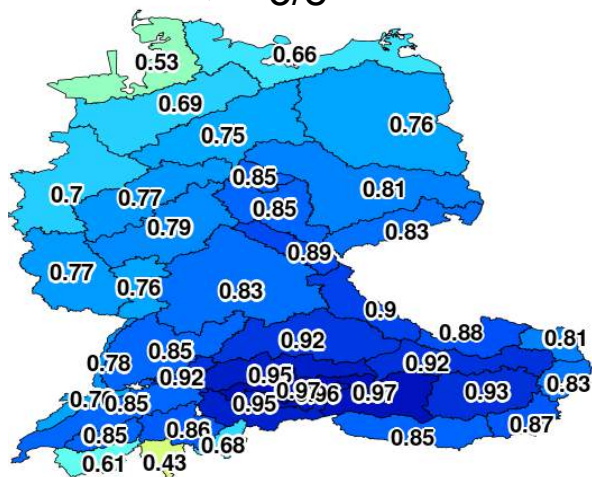
Critical Success Index AVERAGE: 0.86

Critical Success Index AVERAGE: 0.87

$\geq 3/8$

$\geq 3/8$

$\geq 3/8$



Critical Success Index AVERAGE: 0.59

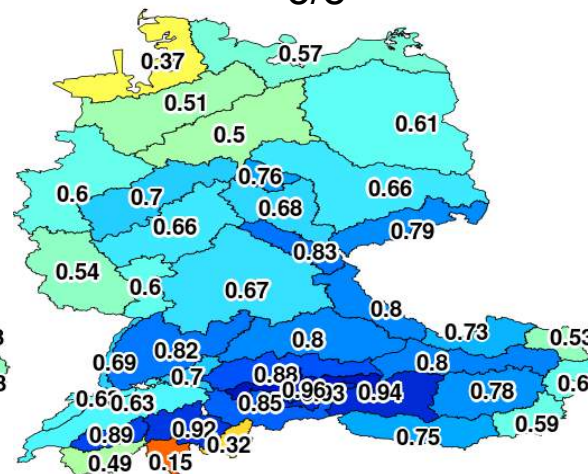
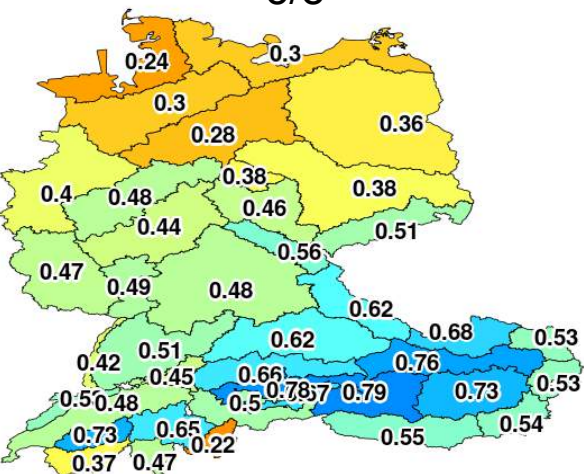
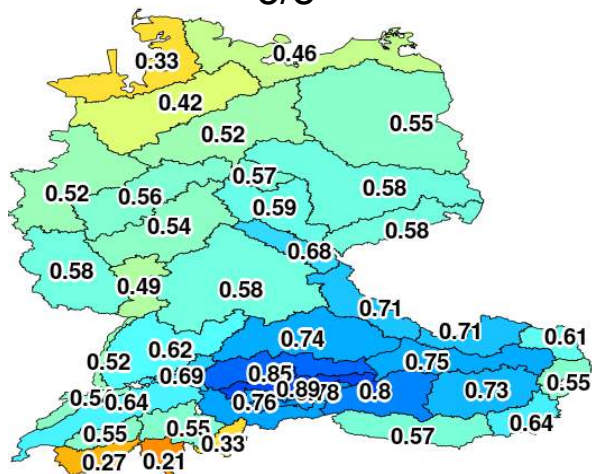
Critical Success Index AVERAGE: 0.51

Critical Success Index AVERAGE: 0.68

$\geq 5/8$

$\geq 5/8$

$\geq 5/8$

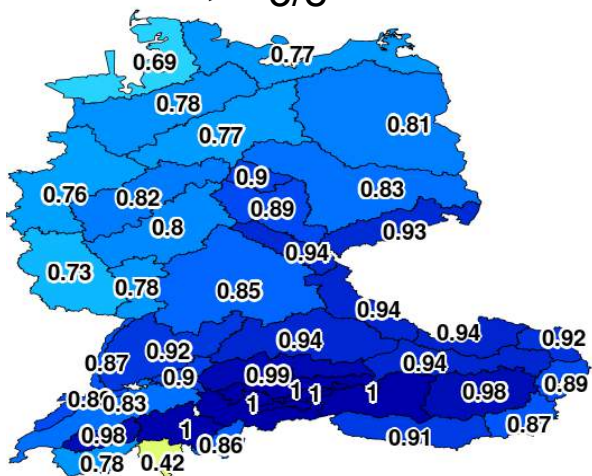


Case Application 1: Cloud Cover

WRF station-based

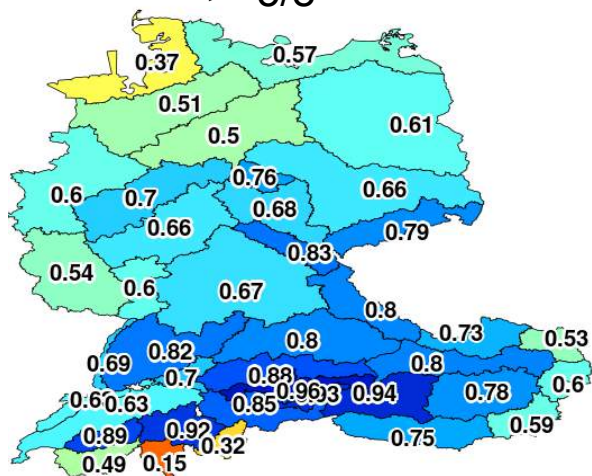
Critical Success Index AVERAGE: 0.87

$\geq 3/8$



Critical Success Index AVERAGE: 0.68

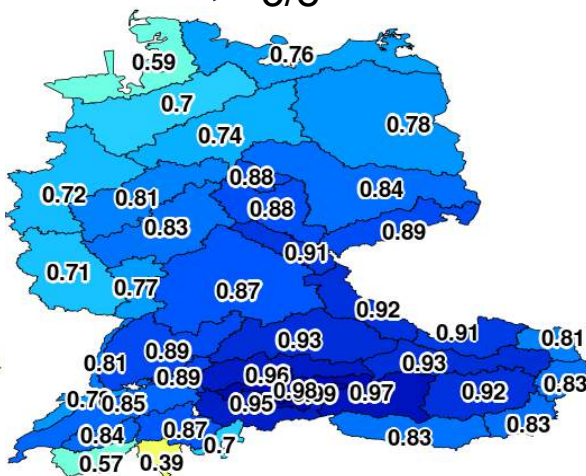
$\geq 5/8$



WRF grid-based

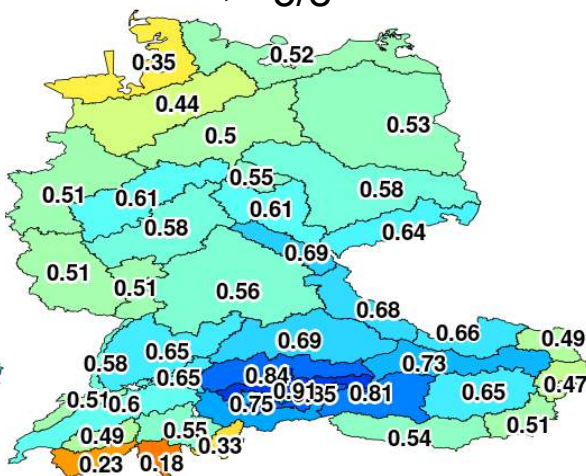
Critical Success Index AVERAGE: 0.83

$\geq 3/8$



Critical Success Index AVERAGE: 0.58

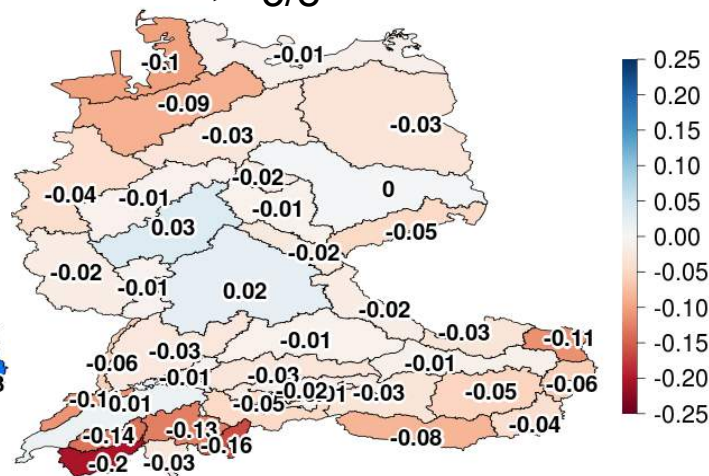
$\geq 5/8$



Difference

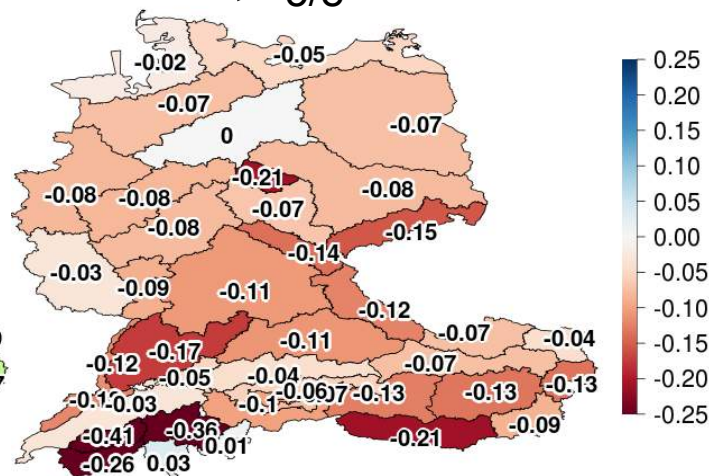
Diff. in Critical Success Index AVERAGE: -0.04

$\geq 3/8$



Diff. in Critical Success Index AVERAGE: -0.1

$\geq 5/8$

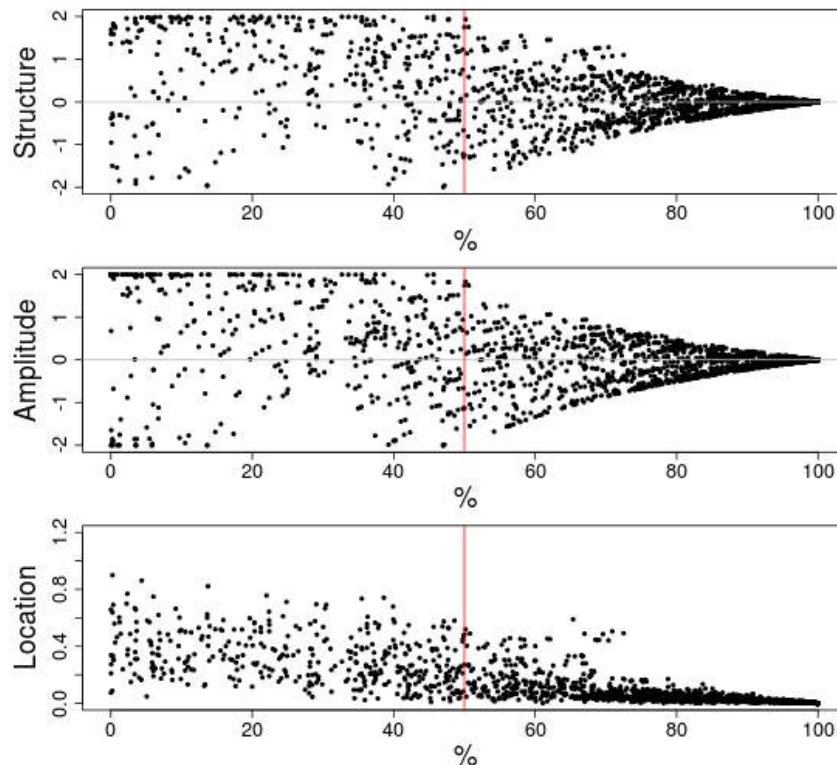


SAL Verification

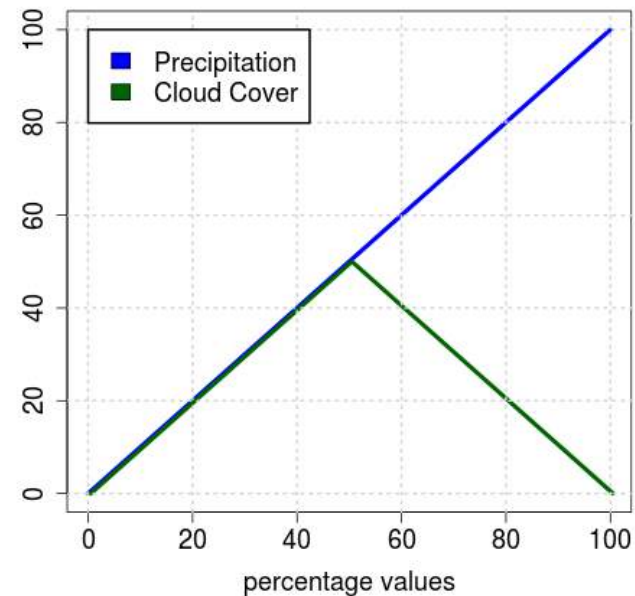
- Object-based verification over predefined domain
- Split of total error into components:
 - **Structure** (object too small / large or too peaked / flat)
 - **Amplitude** (rain volume too low / high)
 - **Location** (displacement in object locations)

**0.04° x 0.04°
Verification Grid**

Typical SAL values for clouds



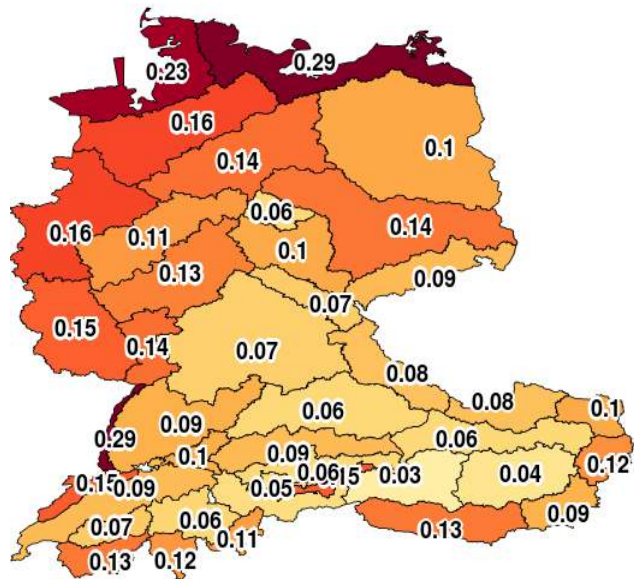
Weighted aggregation
with intensity threshold:
(fcst.+vera)/2



Case Application 1: Cloud Cover

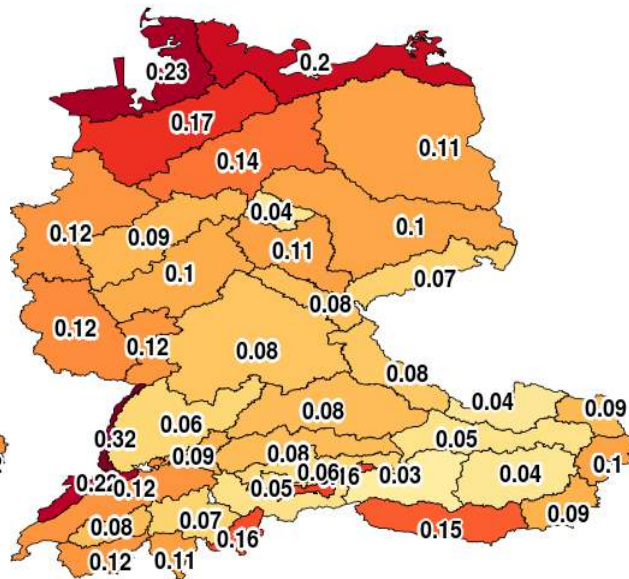
GFS

SAL L-component AVERAGE: 0.11



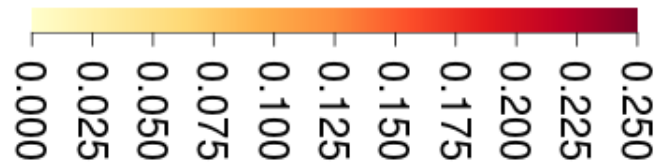
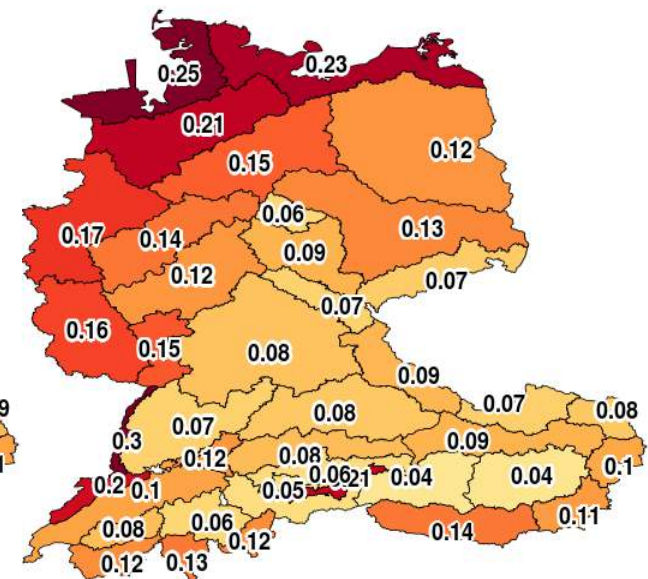
ECMWF

SAL L-component AVERAGE: 0.11



WRF

SAL L-component AVERAGE: 0.12



(Object locations match) $0 < L < 2$ (Object locations totally displaced)

Case Application 1: Precipitation

GFS

ECMWF

WRF

Critical Success Index AVERAGE: 0.41

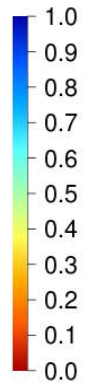
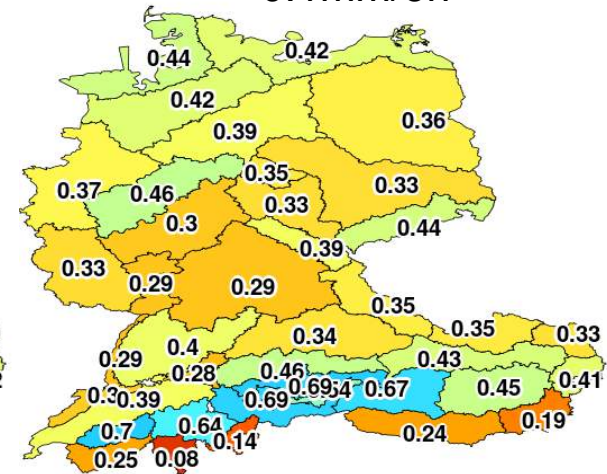
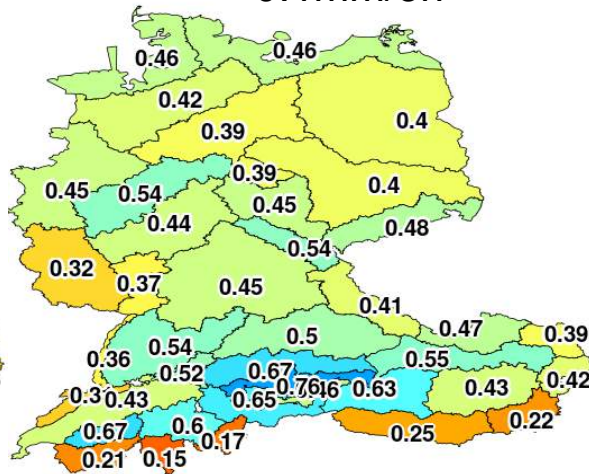
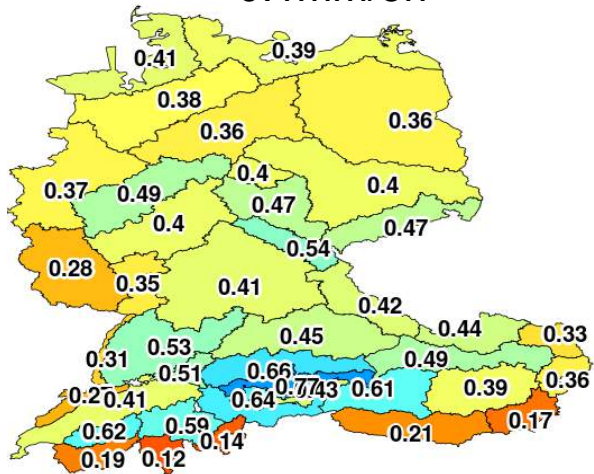
Critical Success Index AVERAGE: 0.44

Critical Success Index AVERAGE: 0.39

> 0.1mm/3h

> 0.1mm/3h

> 0.1mm/3h



Critical Success Index AVERAGE: 0.17

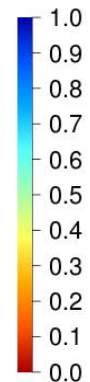
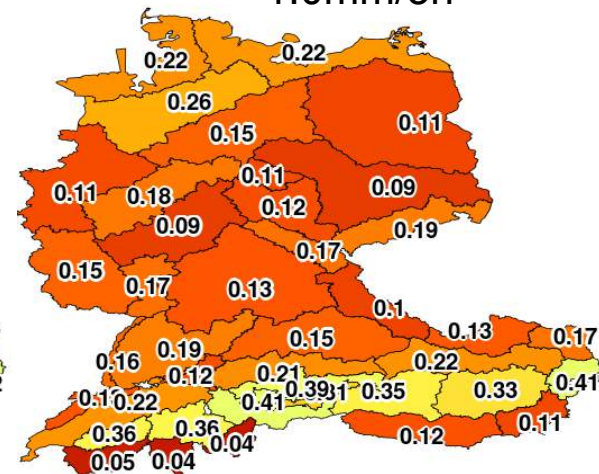
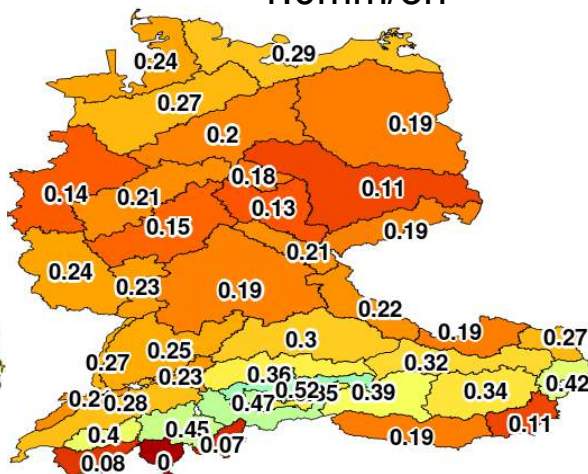
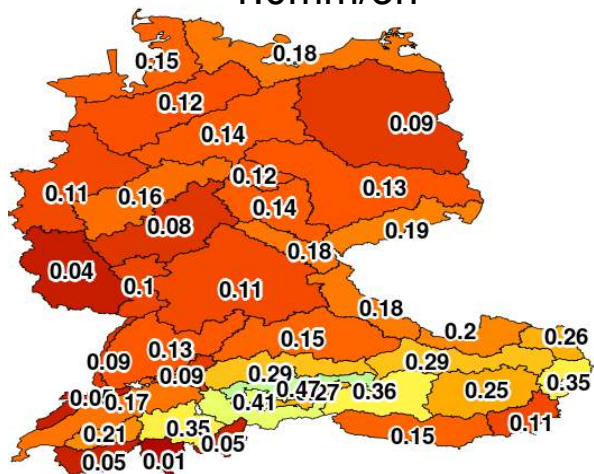
Critical Success Index AVERAGE: 0.25

Critical Success Index AVERAGE: 0.19

> 1.0mm/3h

> 1.0mm/3h

> 1.0mm/3h

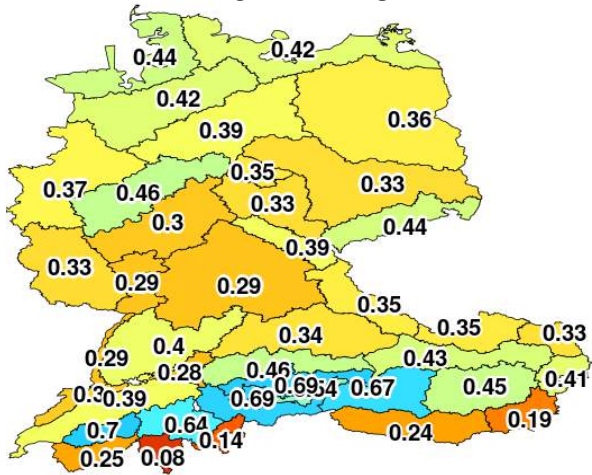


Case Application 1: Precipitation

WRF station-based

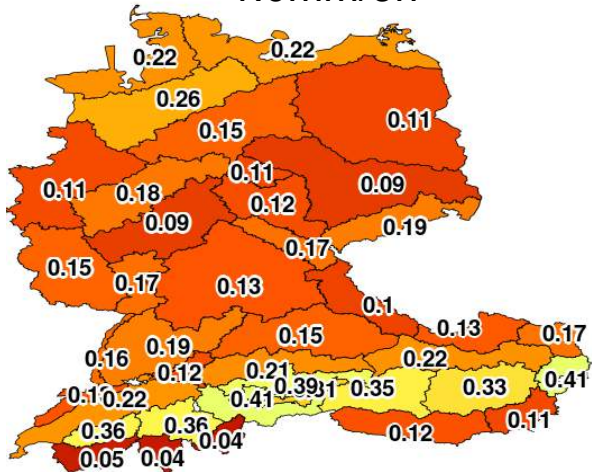
Critical Success Index AVERAGE: 0.39

> 0.1mm/3h



Critical Success Index AVERAGE: 0.19

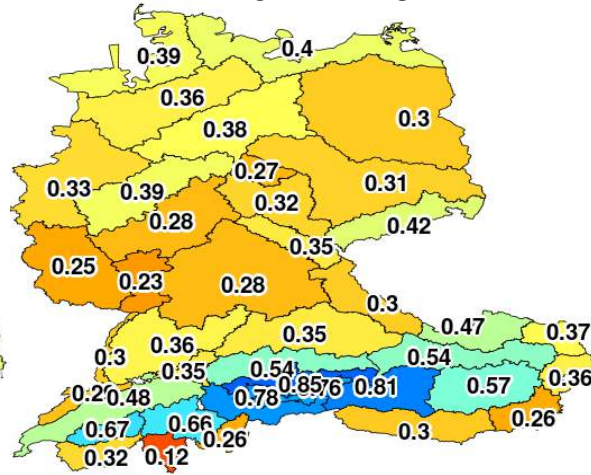
> 1.0mm/3h



WRF grid-based

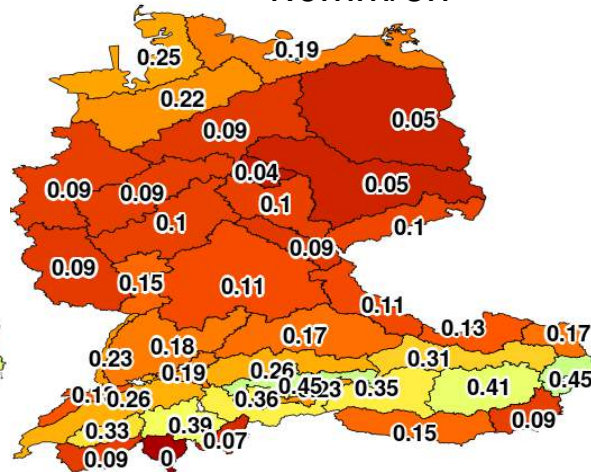
Critical Success Index AVERAGE: 0.41

> 0.1mm/3h



Critical Success Index AVERAGE: 0.18

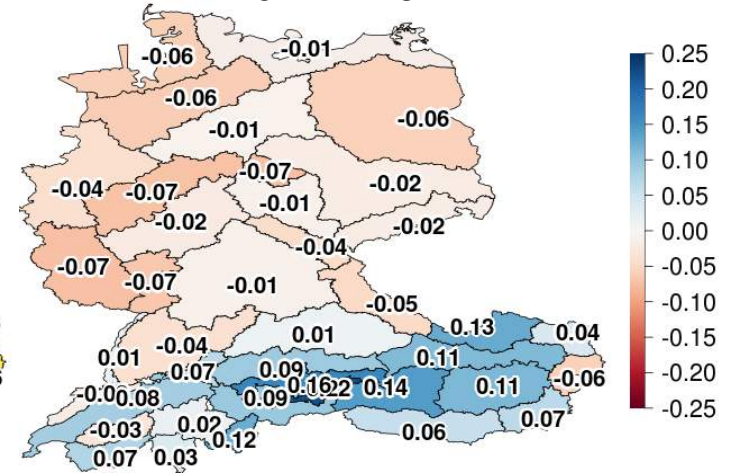
> 1.0mm/3h



Difference

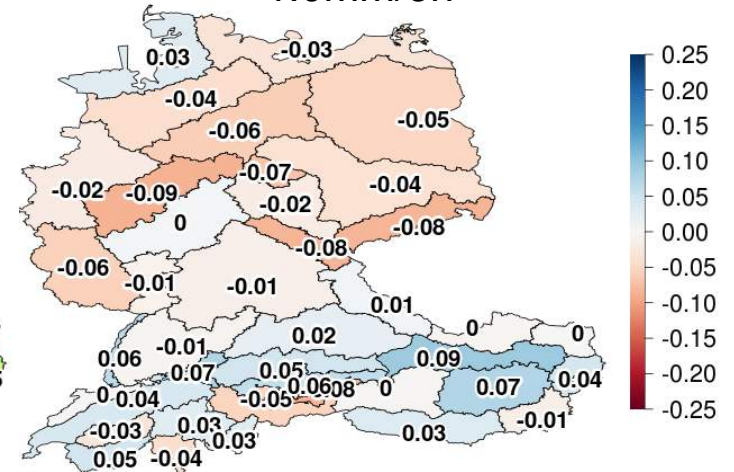
Diff. in Critical Success Index AVERAGE: 0.02

> 0.1mm/3h



Diff. in Critical Success Index AVERAGE: 0

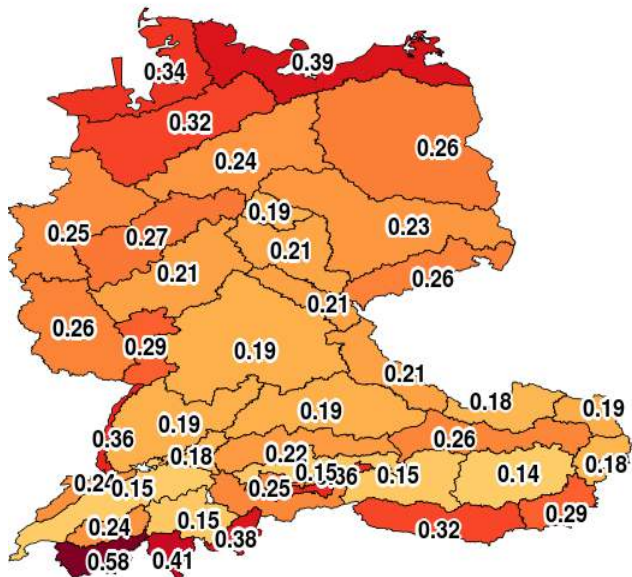
> 1.0mm/3h



Case Application 1: Precipitation

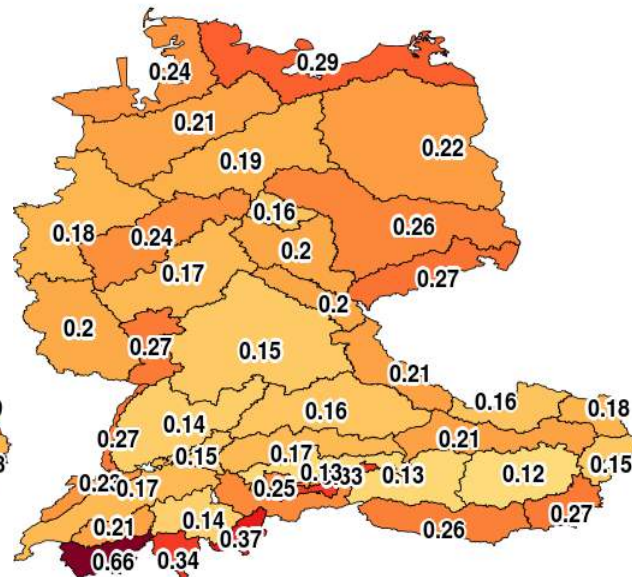
GFS

SAL L-component AVERAGE: 0.25



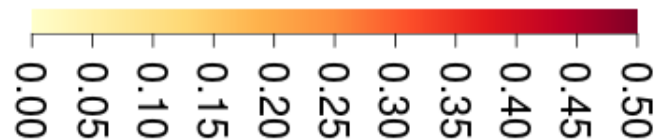
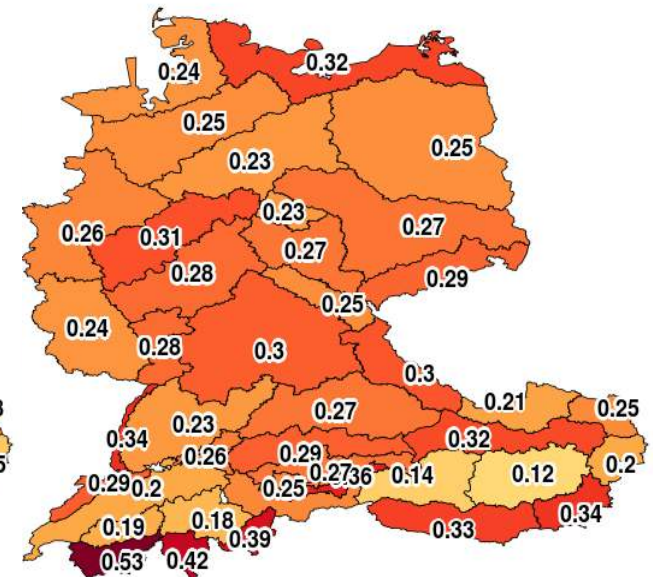
ECMWF

SAL L-component AVERAGE: 0.22



WRF

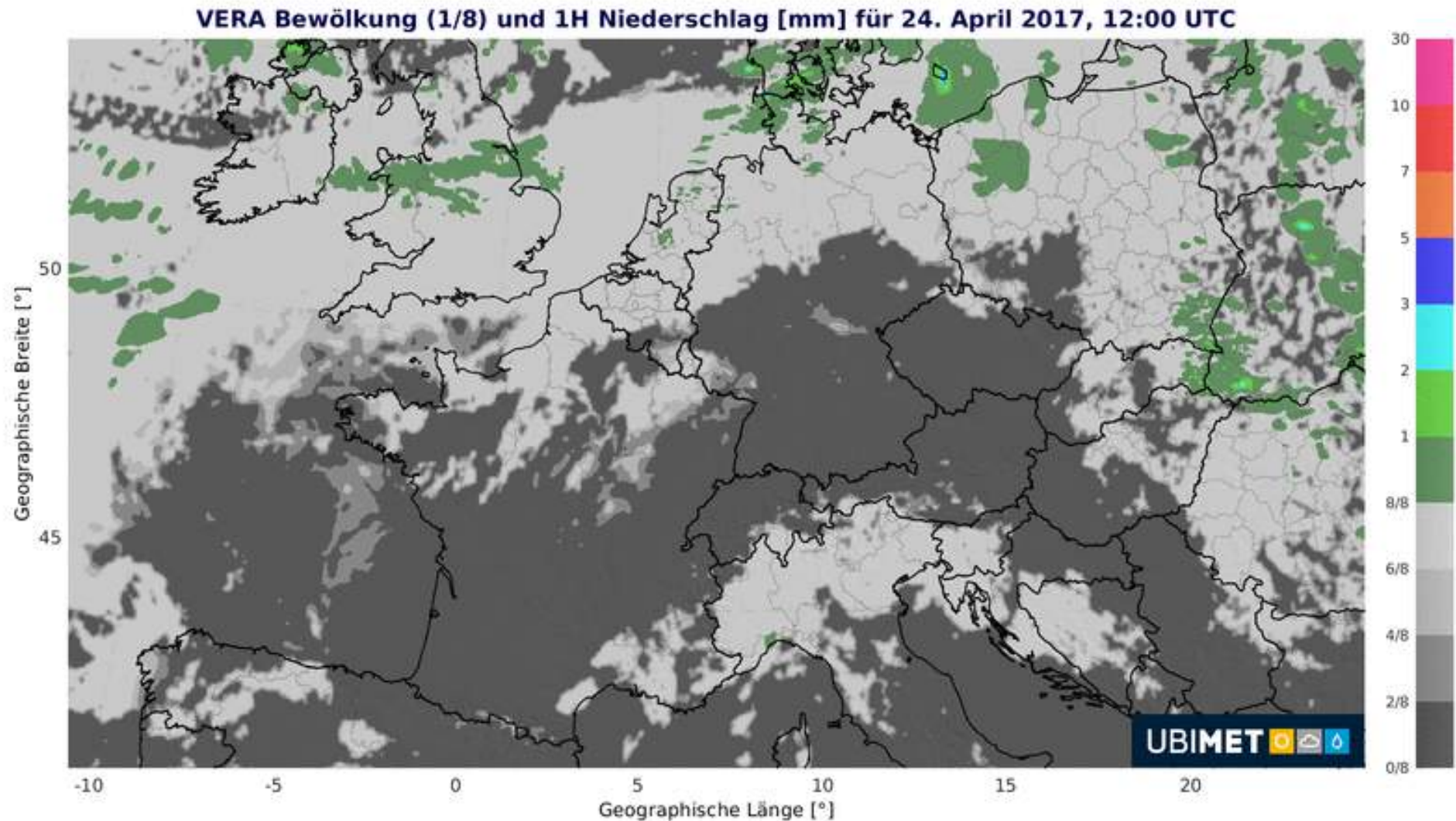
SAL L-component AVERAGE: 0.27



(Object locations match) $0 < L < 2$ (Object locations totally displaced)

Case Application 2

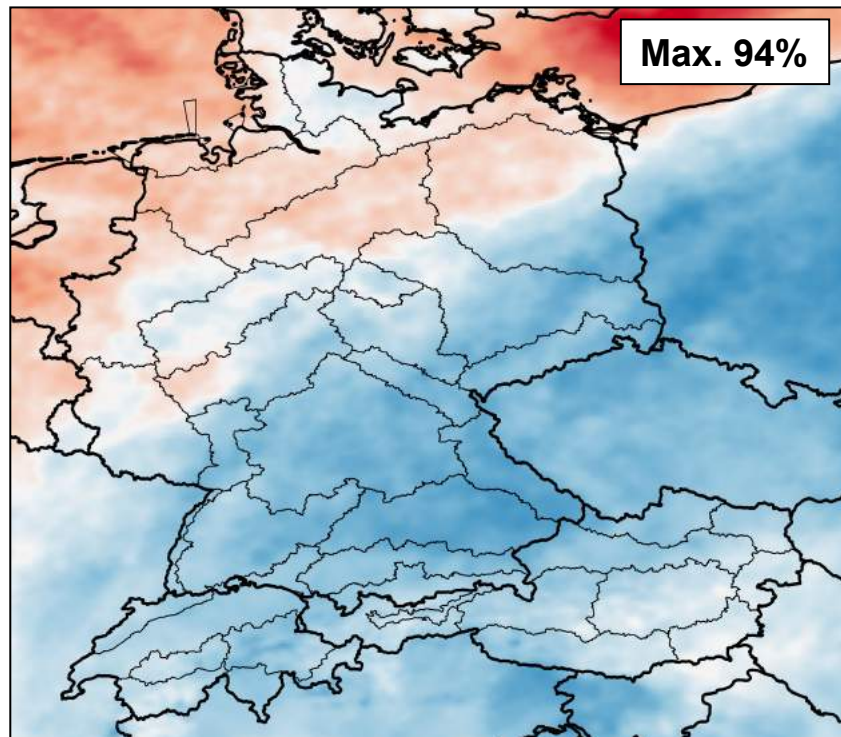
Steering Low over the Baltic Sea and Lee Cyclogenesis south of the Alps
2017-04-24 12 UTC until 2017-04-29 12 UTC



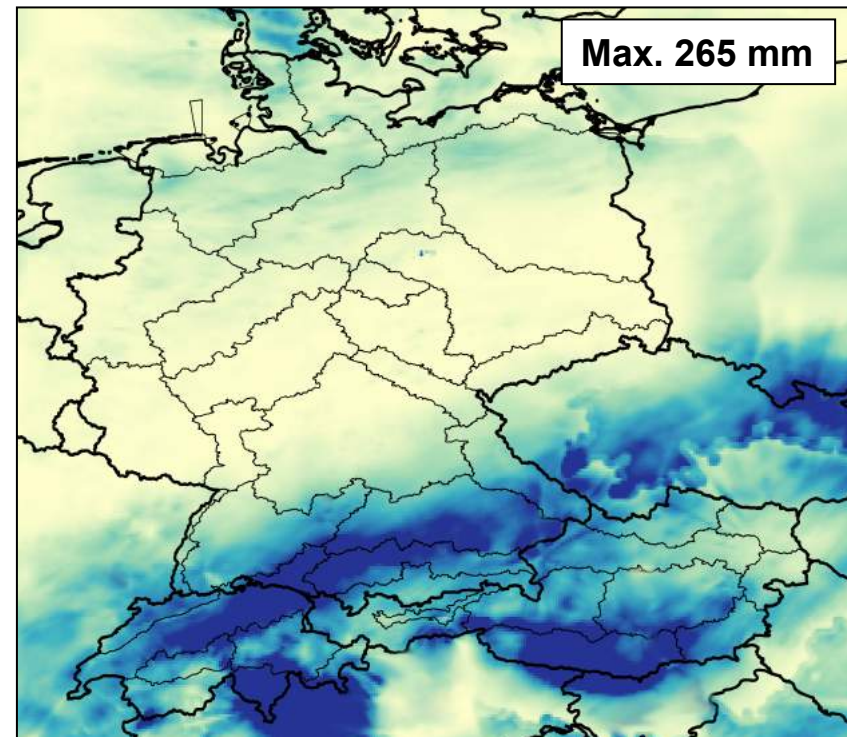
Case Application 2

Steering Low over the Baltic Sea and Lee Cyclogenesis south of the Alps
2017-04-24 12 UTC until 2017-04-29 12 UTC

Mean Cloud Cover



Precipitation Sum

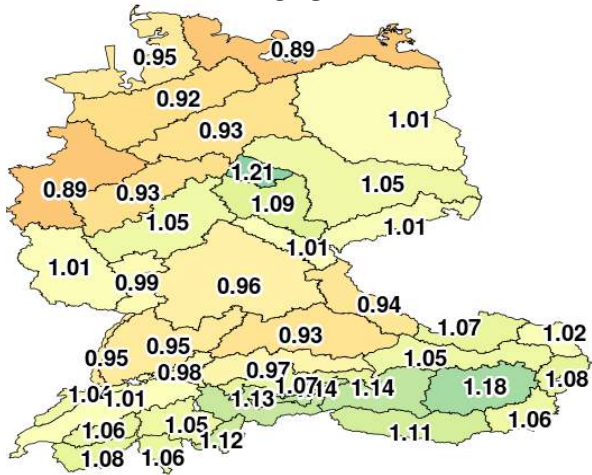


Case Application 2: Cloud Cover

GFS

Frequency Bias AVERAGE: 1.03

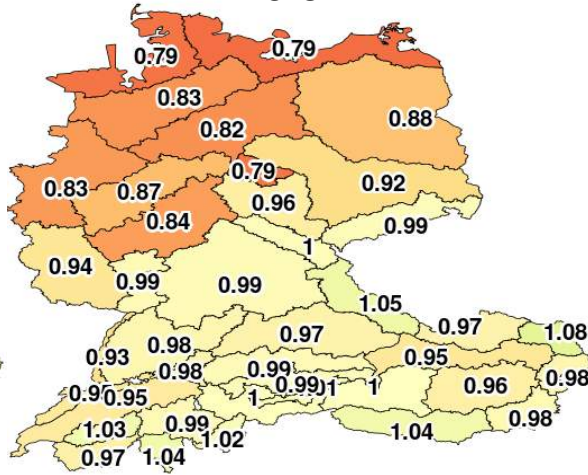
$\geq 3/8$



ECMWF

Frequency Bias AVERAGE: 0.95

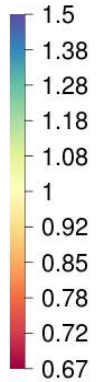
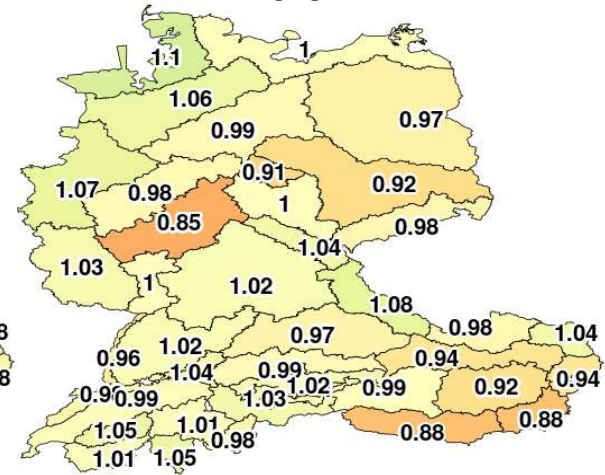
$\geq 3/8$



WRF

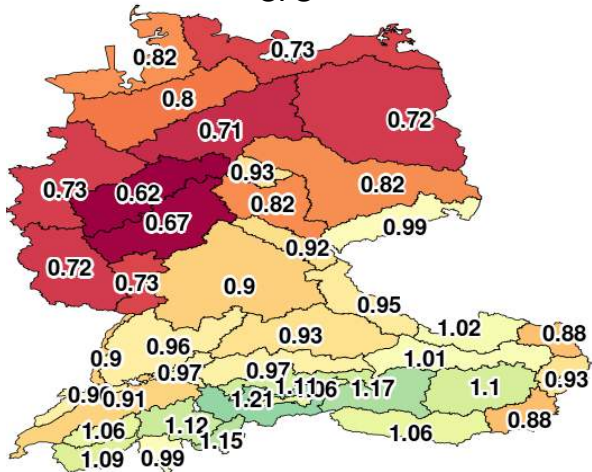
Frequency Bias AVERAGE: 0.99

$\geq 3/8$



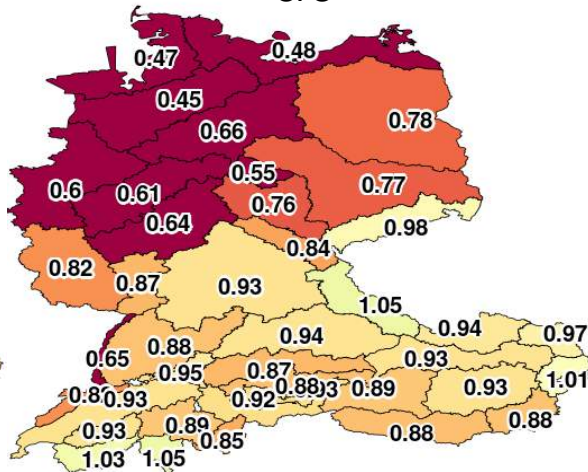
Frequency Bias AVERAGE: 0.93

$\geq 5/8$



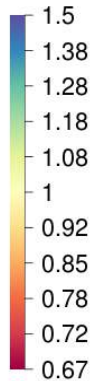
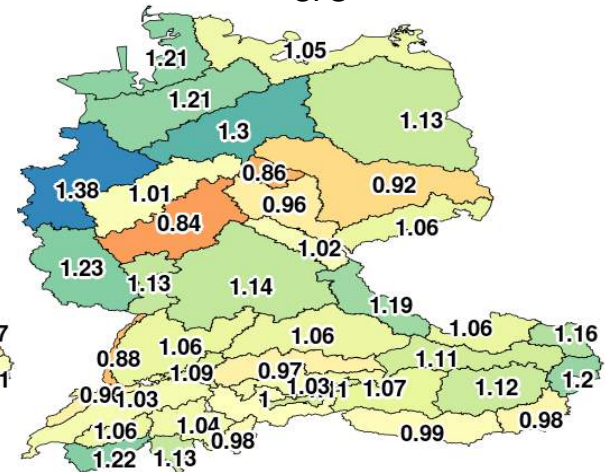
Frequency Bias AVERAGE: 0.83

$\geq 5/8$



Frequency Bias AVERAGE: 1.07

$\geq 5/8$

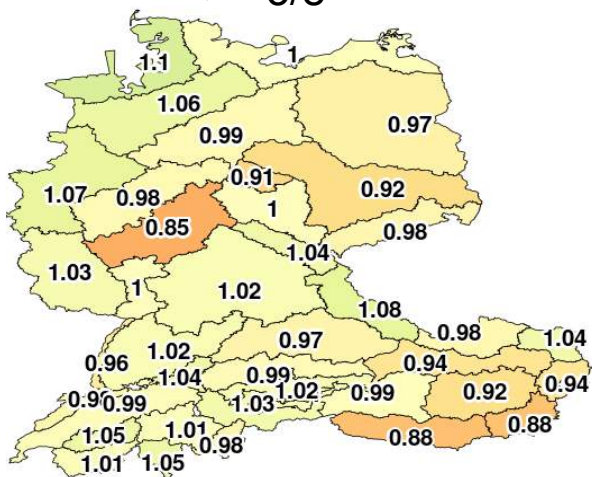


Case Application 2: Cloud Cover

WRF station-based

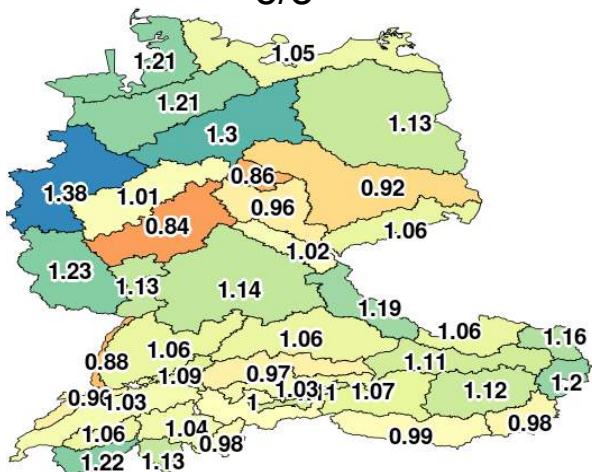
Frequency Bias AVERAGE: 0.99

$\geq 3/8$



Frequency Bias AVERAGE: 1.07

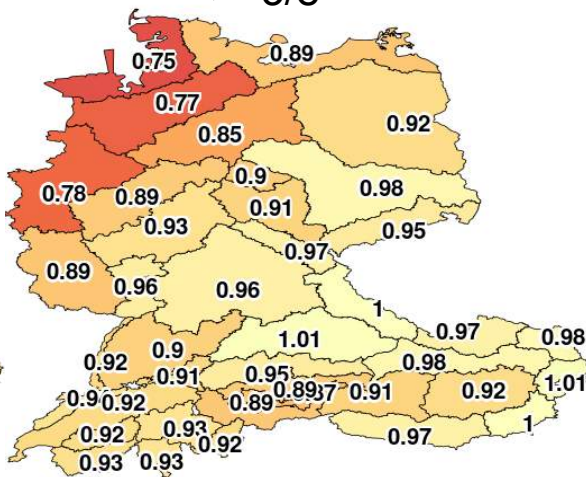
$\geq 5/8$



WRF grid-based

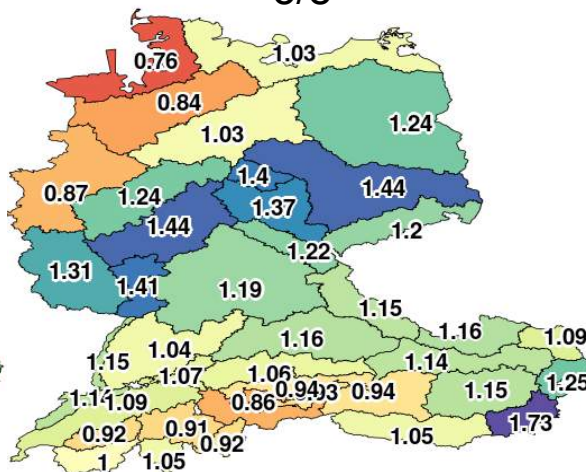
Frequency Bias AVERAGE: 0.92

$\geq 3/8$



Frequency Bias AVERAGE: 1.12

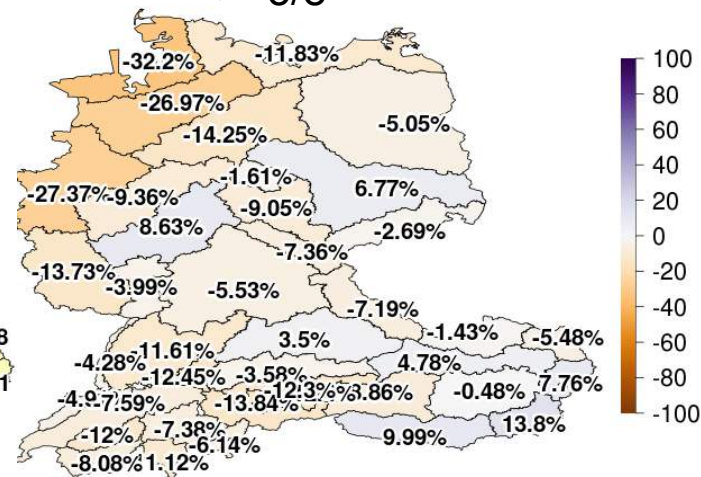
$\geq 5/8$



Difference

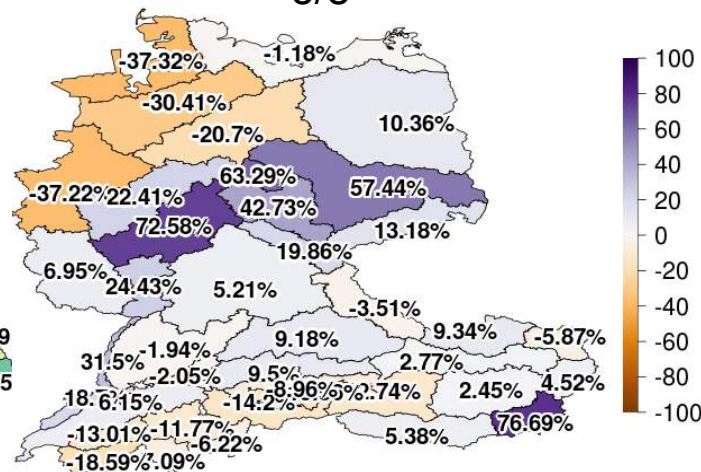
Diff. in Frequency Bias AVERAGE: -6.67 %

$\geq 3/8$



Diff. in Frequency Bias AVERAGE: 6.66 %

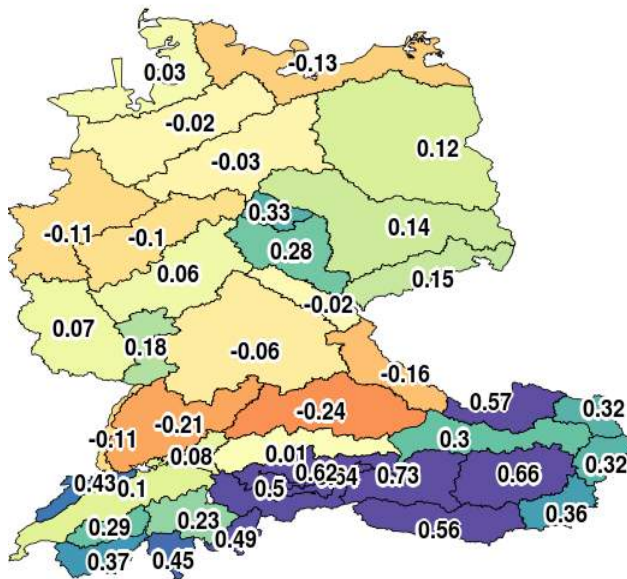
$\geq 5/8$



Case Application 2: Cloud Cover

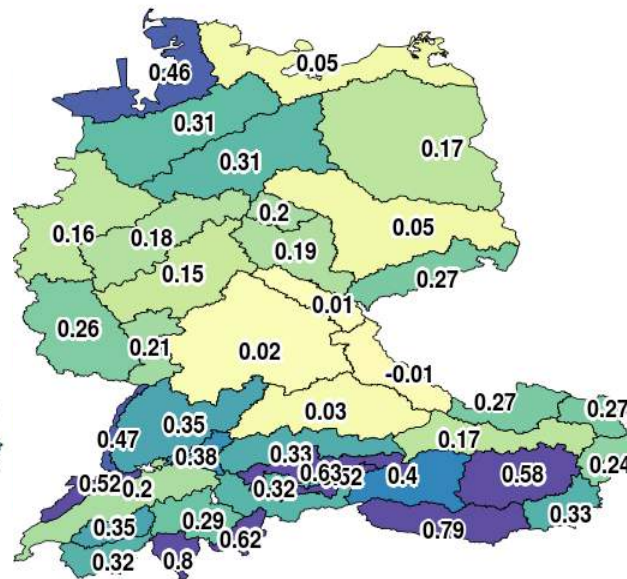
GFS

SAL S-component AVERAGE: 0.2



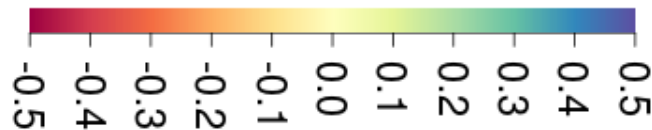
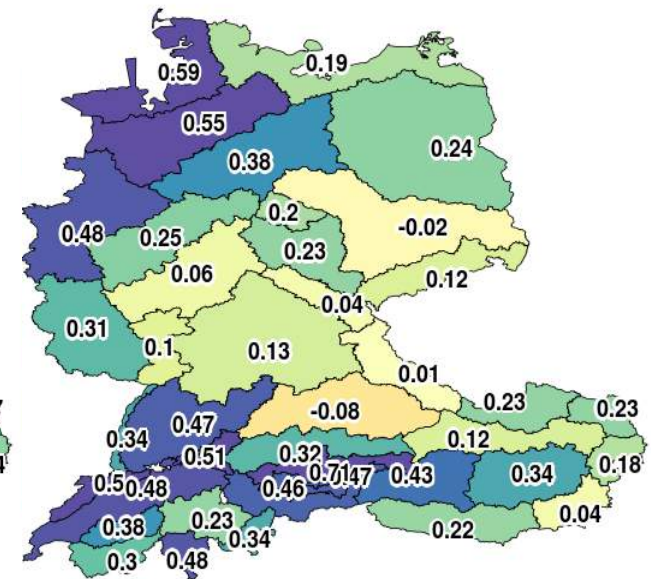
ECMWF

SAL S-component AVERAGE: 0.3



WRF

SAL S-component AVERAGE: 0.29

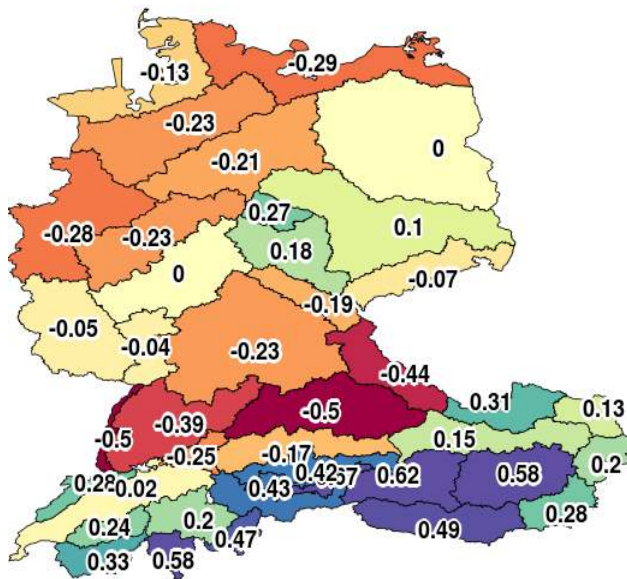


(Objects too small or peaked) $-2 < S < 2$ (Objects too large or flat)

Case Application 2: Cloud Cover

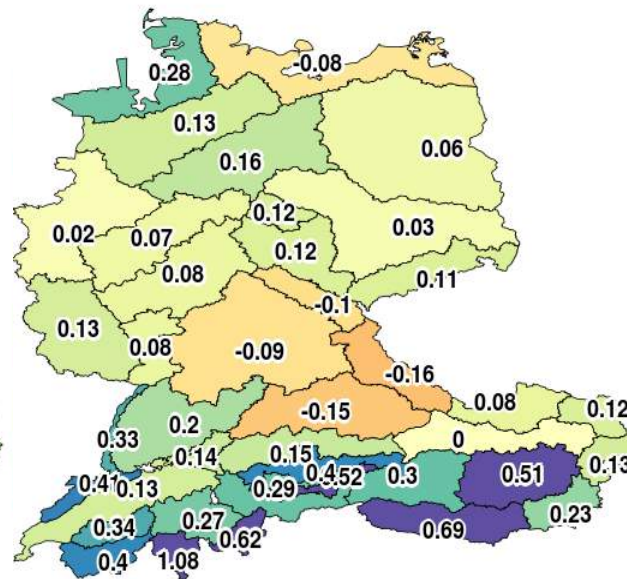
GFS

SAL A-component AVERAGE: 0.07



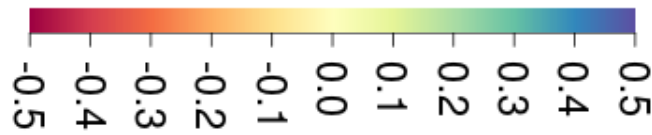
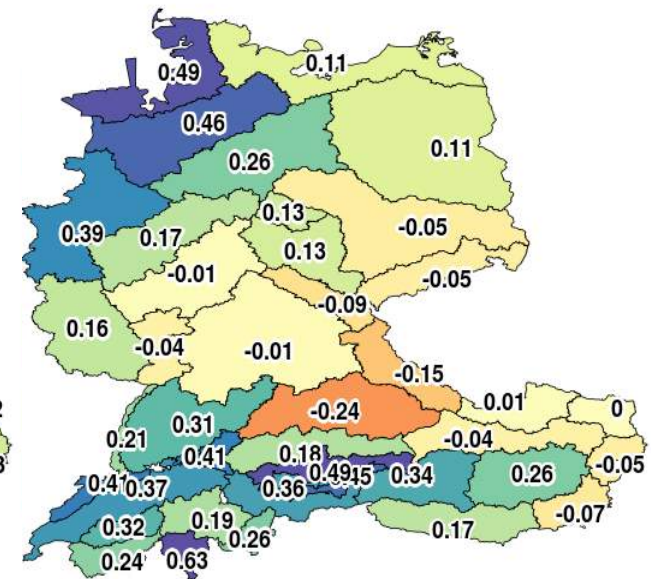
ECMWF

SAL A-component AVERAGE: 0.2



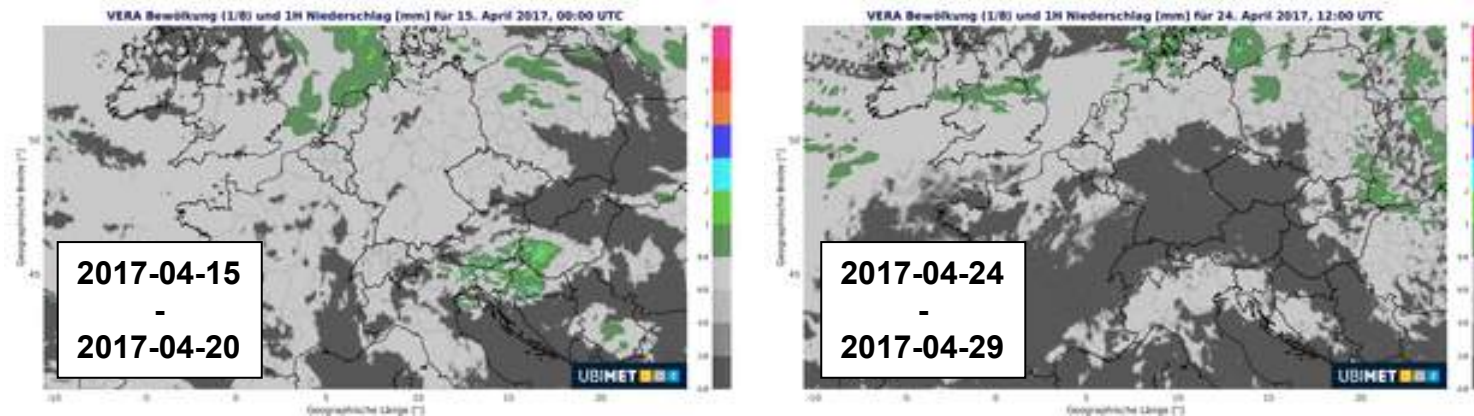
WRF

SAL A-component AVERAGE: 0.18



(Volumes too low) $-2 < A < 2$ (Volumes too high)

Summary and Interpretation



Goal	Point Scores	SAL
Meaningful aggregate results	✗	✓
Results representative of domain	✗/✓	✓
Scores are sensitive to forecast attributes	✓	✓
Scores are proper	✗	✗
Identification of underlying model errors	✓	✓
Unequivocal ranking of forecast models	?	?