Observations for high-impact weather and their use in verification

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Deutscher Wetterdienst

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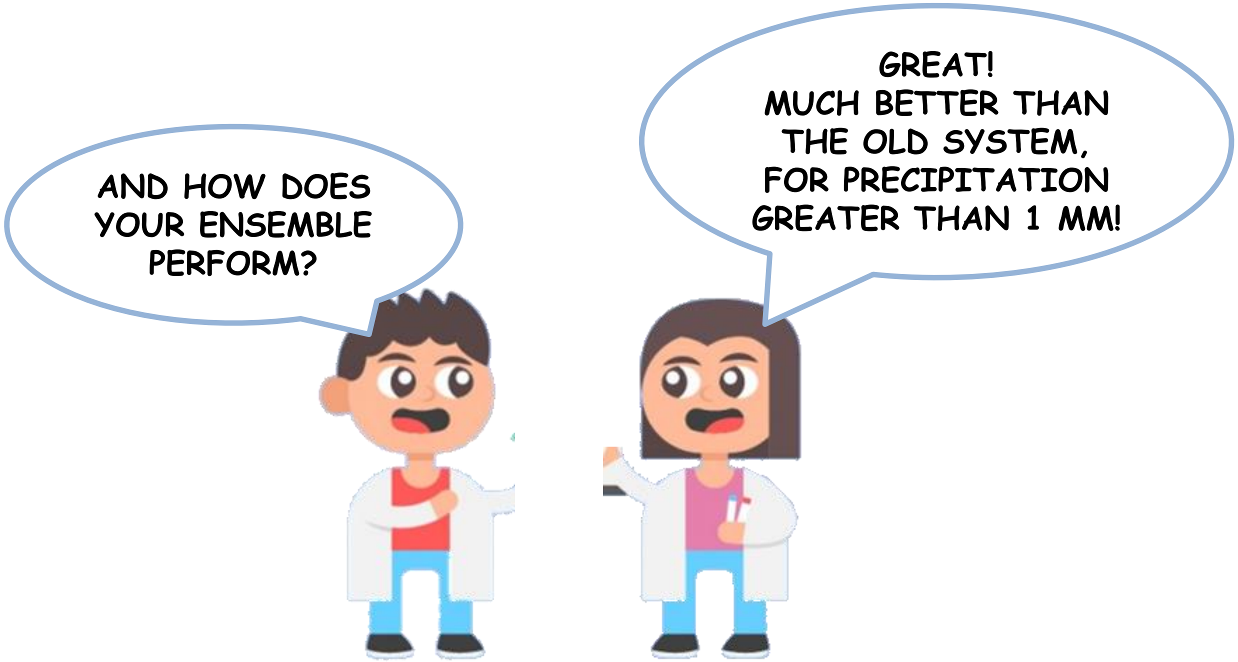
Outline

- Verification of products for high-impact weather
- Creating the pair
  - identify the predicted quantity
  - looking for suitable observations
  - matching between forecasted and observed quantities
- Some observations
- Some applications to thunderstorms and fog verification
- Concluding remarks

A (personal) motivation

- Development of convection-permitting models
- Convection-permitting ensembles operational in many weather centres
  - computationally very expensive

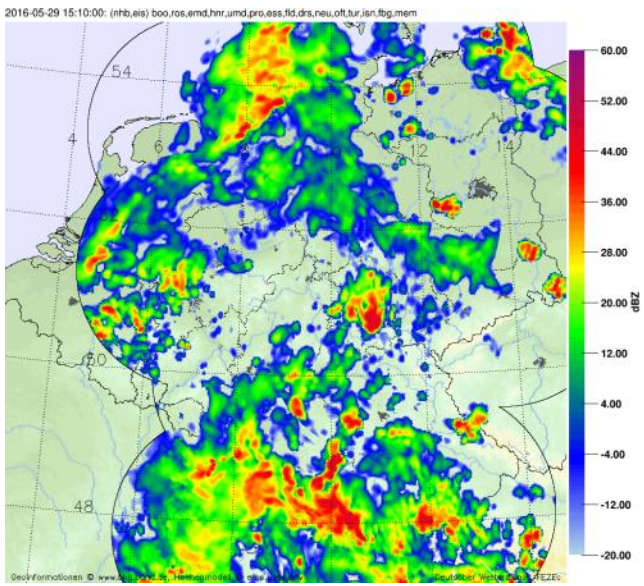


High-impact weather verification

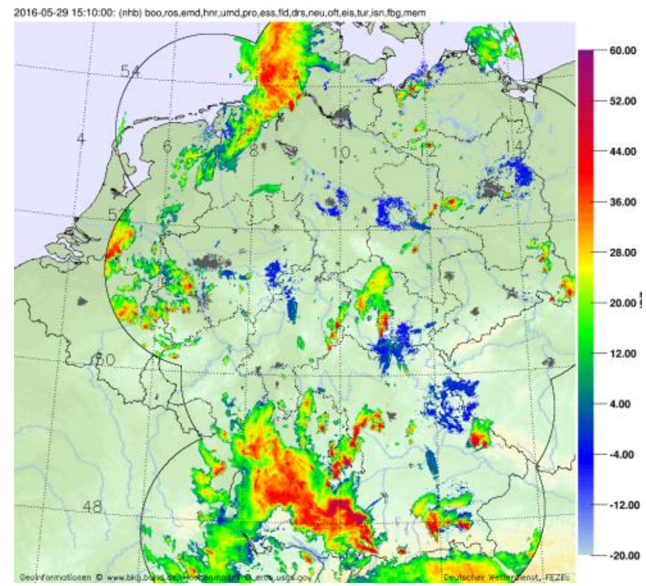
- Verification of forecasts of high-impact weather is more and more needed by the operational centres
- The newly developed products used in operations for the forecast of high-impact weather need to be verified
  - complement the traditional verification of the meteorological parameters involved in the occurrence of a high-impact weather phenomenon (precipitation, temperature, wind) with a specific verification of these products
- The verification of these products requires a different approach to the objective verification process

Conservative (?) approach: homegeneity between forecast and observation

Predicted radar reflectivity



Observed radar reflectivity



- model results in observation space (dBZ)
- comparing apples with apples (?)

Creating the pair

the predicted quantity:

- define the quantity or object to be verified, which is selected as representative of the phenomenon
- e.g. for thunderstorm: not the accumulated precipitation itself, but precipitation can be an ingredient for the definition
- a quantity which can be either directly observed, or for which an "observable" exists, being highly correlated to it

the observed quantity:

- measurements which permit to observe a quantity really representative of the high-impact weather phenomenon
- should have a usable spatial and temporal coverage and a documentation of the quality
- include the observation uncertainty: e.g. use observed data coming from different sources

Creating the pair

matching between prediction and observation:

- the matching in the prediction-observation pair should be ensured!
- e.g.: is “thunderstorm cell” - “at least one lightning” a suitable pair?
- a preparatory step is needed:
  - if climatologically (statistically over a long period) there is a good correlation between them, it can be assumed that one can provide the reference for the other and objective verification can be performed
  - this may involve the definition of thresholds (of both quantities) to be used to identify the objects to be compared
  - an important part of this process is to assess spatial and temporal representativeness and to suitably average or re-grid forecasts and/or observations

Matching between prediction and observation

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obs: lightning

0 1 10 50 100 1000

Number of lightnings

obs: radar

1 10 50 100 1000

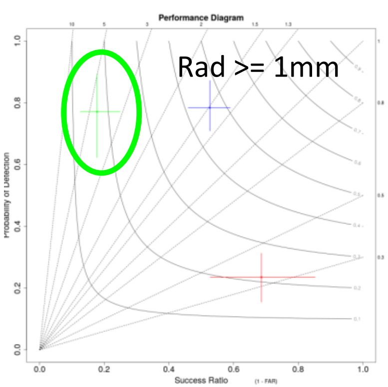
Precipitation (mm)

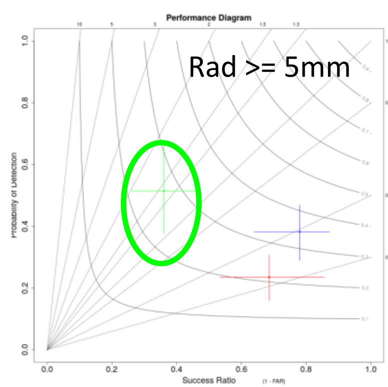
forecast: ensemble

0 10 30 50 100

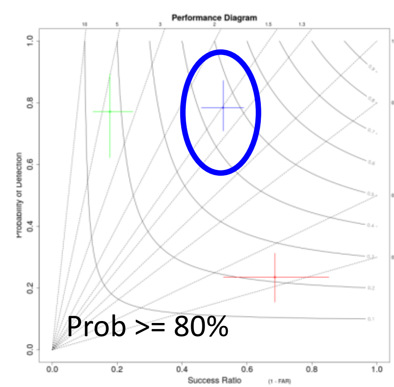
Probability of rain > 1mm

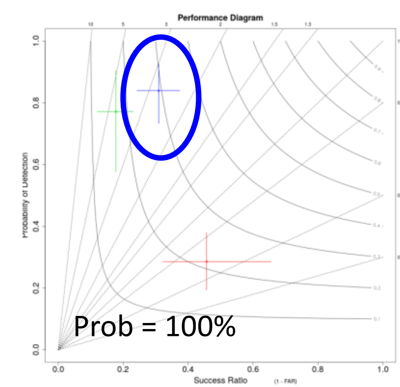
radar vs lightning





ensemble vs radar





Data matching – some questions

- Lightning:
  - How many lightnings are needed to “catch” a thunderstorm?
- Radar estimate of precipitation:
  - Which threshold indicate a “significant” precipitation?
- Ensemble:
  - Which threshold indicate a “significant” precipitation? Likely different from the one of the radar
  - Use of average or maximum or a percentile?
  - How to spatialize probabilities? And which probability threshold should we use to consider the event detected?

Observations: **lightning detection**

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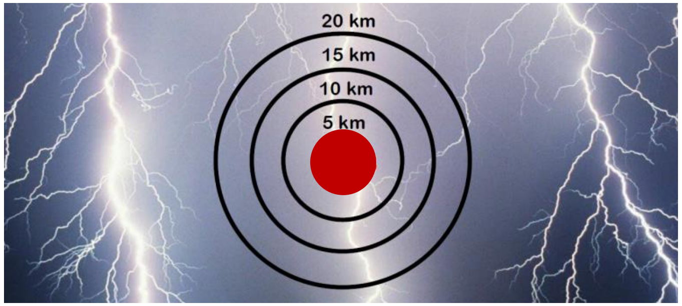
- several ground based networks, national and international
- detection from satellite: data over data-sparse regions (e.g. oceans)
- some issues on data usage:
  - how many strokes are needed to detect the occurrence of a thunderstorm (identification of thresholds)
  - consider a surrounding of the detection point as area interested by the phenomenon (and how big)
  - how to identify the no-lightning event
  - combine with other observations (radar, satellite) to improve the detection of the phenomenon



Observations:
nowcasting products

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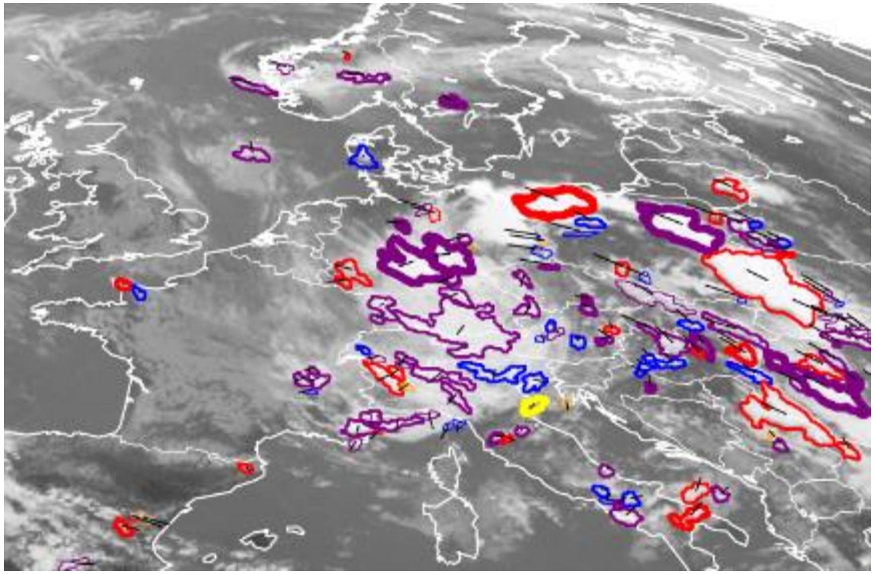
- National Meteorological Services develop tools for nowcasting, where data from different sources (satellite, radar, lightning, ...) are integrated in a coherent framework
- mainly to detect high-impact weather phenomena
- the variables object of nowcasting (thunderstorm cells, hail, ...) can become observable against which to verify the model forecast
- consider the step 0 of the nowcasting algorithm as a sort of "analysis"
- strengthen the link with the nowcasting, to explore the possible usage of the variables/objects identified through nowcasting algorithms for forecast verification



Convection Working Group

https://www.essl.org/cwg/

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1. Pre-Convective Environment

Refers to the 4-D thermodynamic and wind field present before the convective initiation occurs.

Useful tools:

NWP data, Radiosonde and aircraft measurements
MSG GII/RII Product – instability & moisture
iSHAI Products – instability & moisture
HRW Product – wind fields
METOP/IASI level2 – temp & moisture vert. profiles

2. Convective Initiation

Refers to the process where an existing cumulus cloud begins rapid vertical growth.

Useful tools:

Radar, lightning data
Cloud Type
Cloud Top Temperature and Height
Cloud Microphysics
Convection Initiation – demonstrational
Optimal Cloud Analysis – demonstrational

3. Mature Convective Storm

Refers to the presence of convective clouds with tops at or above their local equilibrium level

Useful tools:

Radar, lightning data
RDT Product – storm tracking
Precipitating Clouds
CRR Product – precipitation
NEFODINA
Overshooting Top Detection
MSG Sandwich Product (HRV+IR10.8 enhanced)
Lightning Density

✓ OT climatologies have been demonstrated in several peer-reviewed studies (see Additional Information), enabling assessments of climatological severe storm risk and regional/temporal storm distributions.

✓ OTs detected near ~60% of wind, hail, and tornadic storms.

✓ The first product of its kind for discriminating likely aircraft engine icing conditions at the storm cell scale.

X It is impossible to identify only the OT updraft areas and none of the nearby cold outflow using IR imagery alone.

Suitable RGB Imagery for Convection monitoring at different stages of development (EUMeTrain Quick Guides)

SEVIRI HRV Cloud RGB
SEVIRI Severe Storms RGB
SEVIRI Day Microphysics RGB

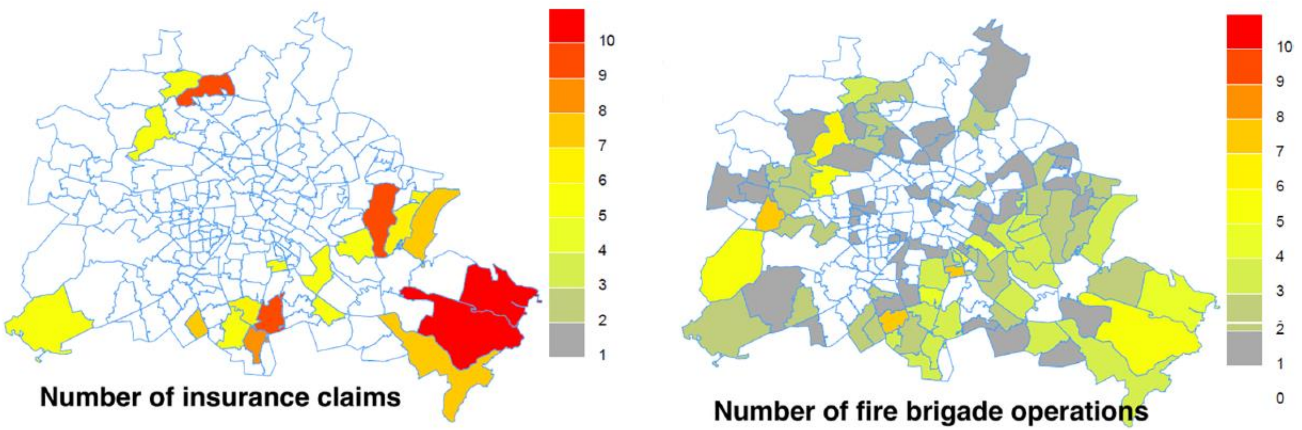
Suitable RGB Imagery for providing visual information on atmospheric water vapour content in cloud-free areas (EUMeTrain Quick Guides)

SEVIRI Night Microphysics RGB
SEVIRI 24 Hour Microphysics RGB
SEVIRI Dust RGB

EUMETSAT
ARSO METEO Slovenian Environment Agency
EUMETSAT NWC SAF
CZECH HYDROMETEOROLOGICAL INSTITUTE
NASA

Observations:
reports

- organised databases: e.g. the European Severe Weather Database of the European Severe Storms Laboratory: https://www.eswd.eu/
- data from insurances
- data from citizens, cars, …
- impact data (emergency calls, fire brigade operations, …)
  - very high spatial resolution



Summer convection case over Berlin area

Pardowitz, 2018

Applications of **fog** verification:
SAL metric

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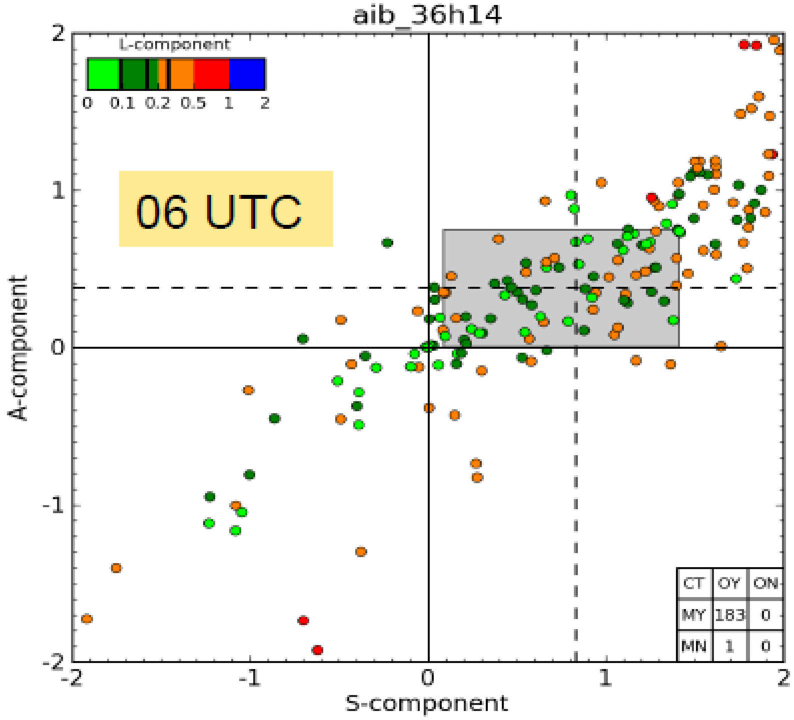
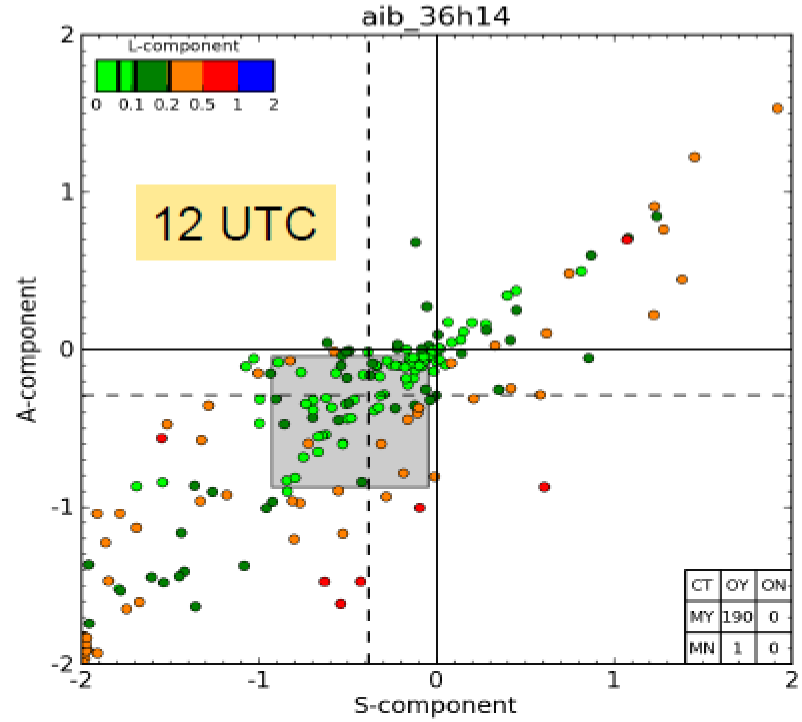
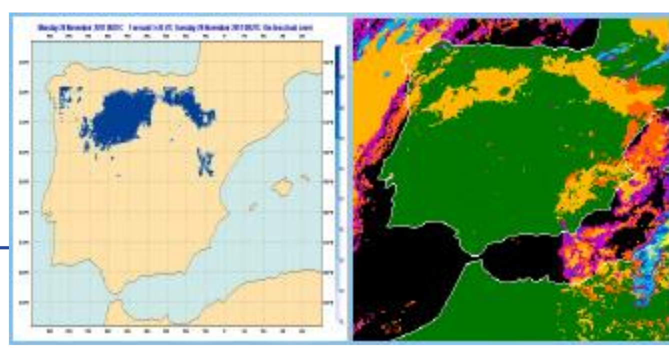
Simulated: AROME model at 2.5 km hor. res., low clouds
Observed: Cloud Type Product (NWC-SAF, Satellite Application Facility for Nowcasting)





Morales et al., 2013



http://www.nwcsaf.org/

EUMETSAT

Applications of **fog** verification:
Fractions Skill Score

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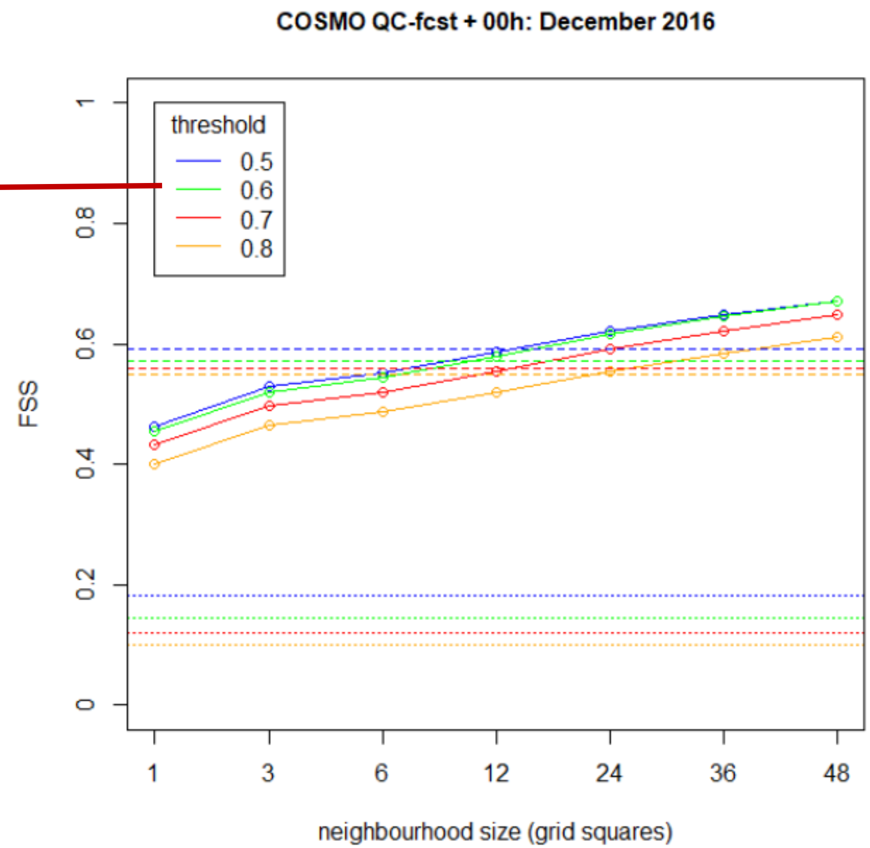
Simulated: COSMO model at 7 and 2.8 km hor. res., Liquid Water Path
Observed: Satellite data (channel combination) to give a Cloud Confidence Level (CCL)

Threshold for computation of FSS from observed data (CCL)



Grid-points with high- or mid- level clouds are filtered out (using NWC-SAF Cloud Type), both in observation and forecast

Ehrler, 2018; Westerhuis et al., 2018

Applications of **fog** verification: **reports at locations**

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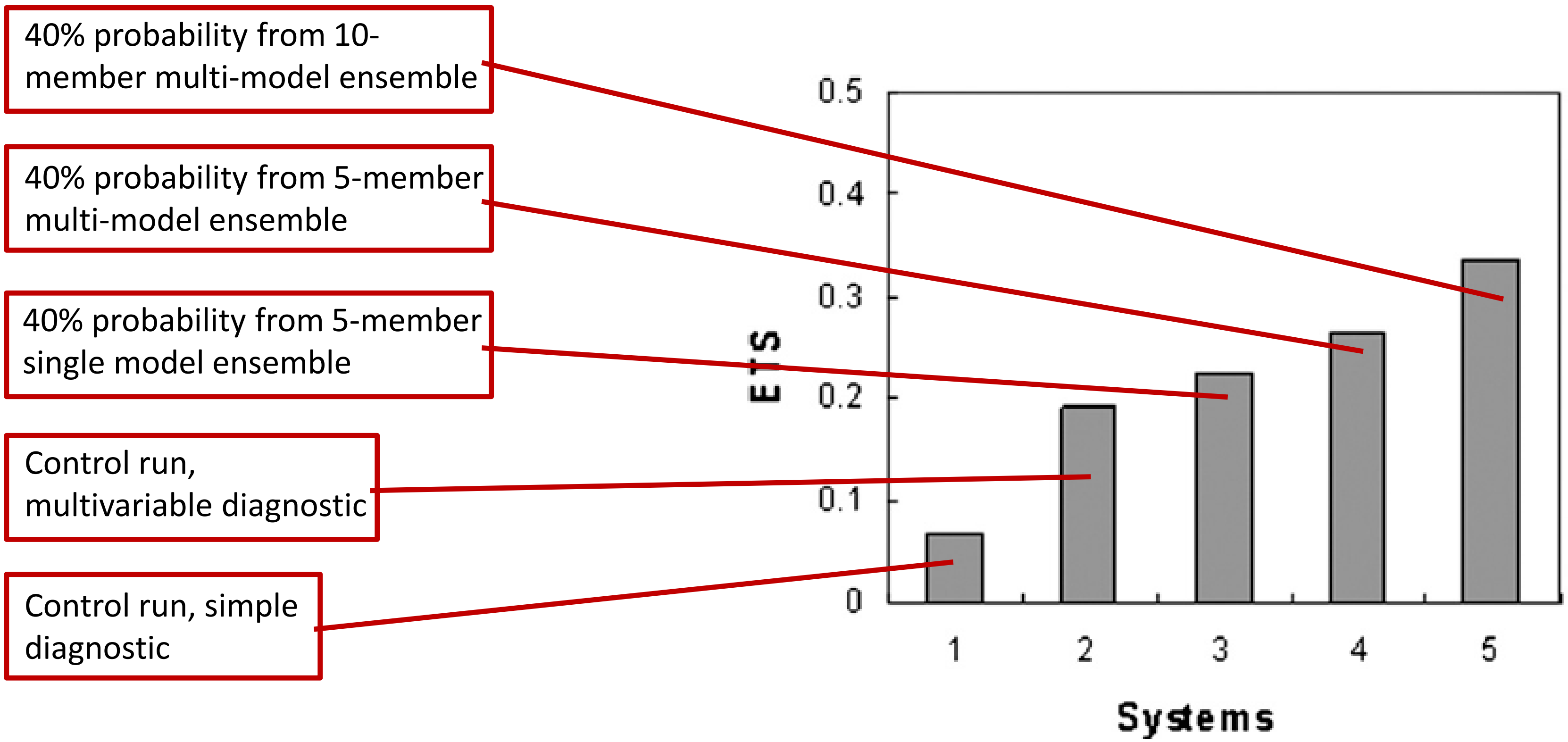
Simulated: SREF ensemble for Beijing Olympics 2008 + multivariable diagnostic method
Observed: fog reports issued by local weather services or airports in 13 cities in eastern China

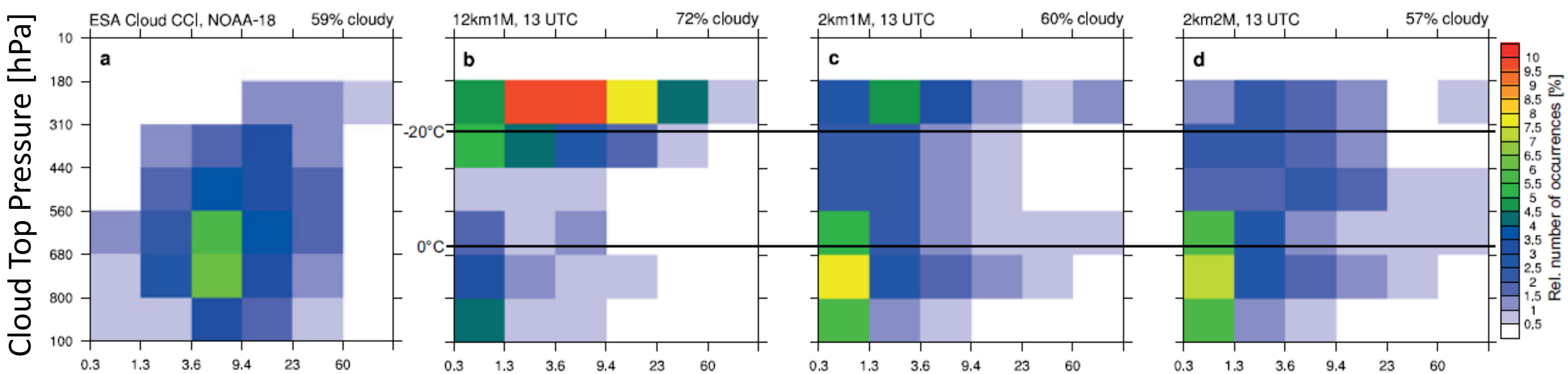


Zhou and Du, 2010

Applications of **thunderstorm** verification: **cloud properties from satellite**

Simulated: COSMO model at 12 and 2 km + RTTOV
Observed: satellite-derived (AVHRR on NOAA-18 satellite)

observed | simulated: 12 km | 2 km 1M | 2 km 2M



Cloud Optical Thickness | Cloud Optical Thickness | Cloud Optical Thickness | Cloud Optical Thickness

Histograms of cloud frequency

Keller et al., 2015

Applications of **thunderstorm** verification: **reports and lightning**

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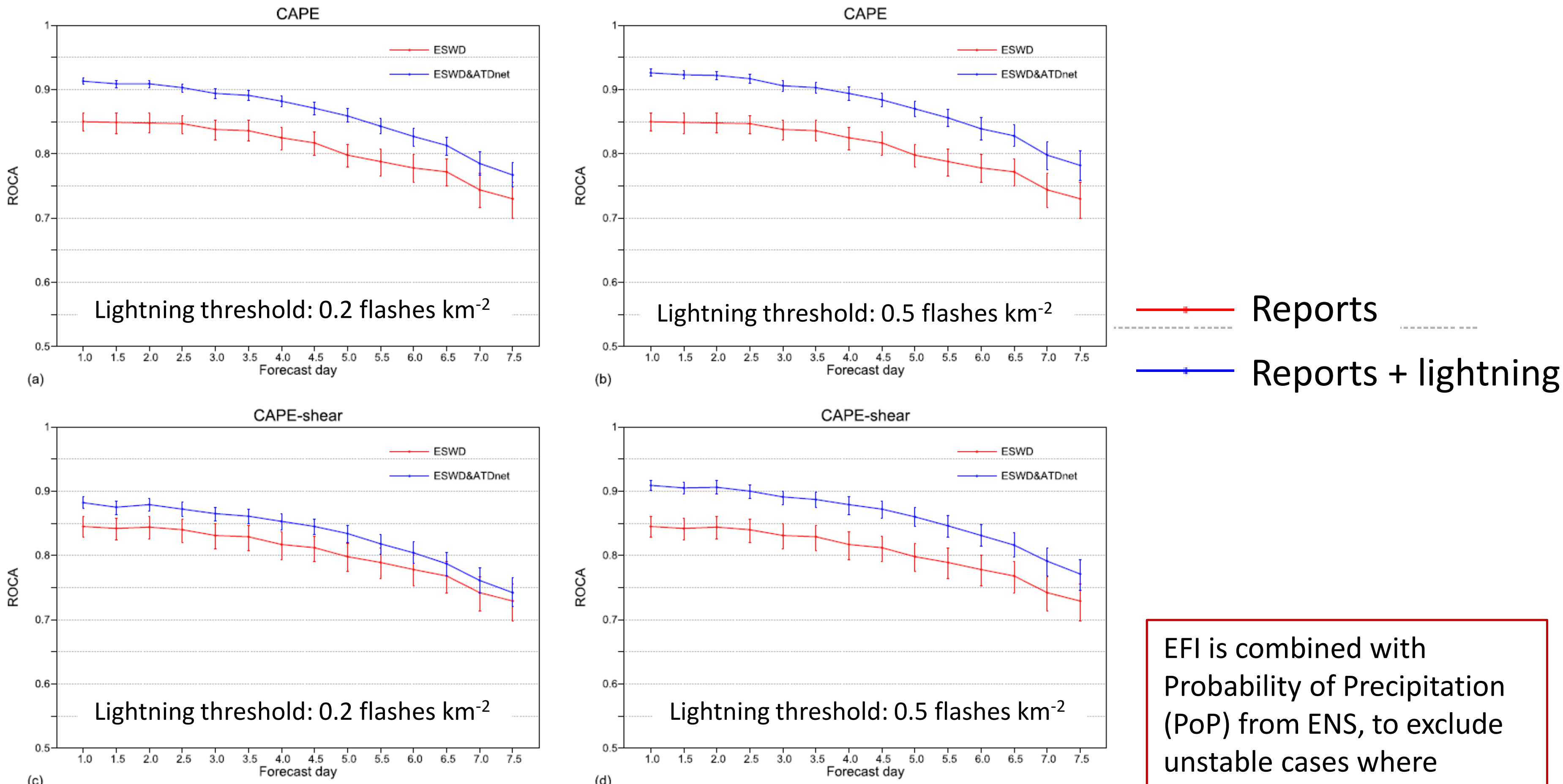
Simulated: EFI of ECMWF ENS for CAPE and a composite CAPE-shear parameter
Observed: Reports provided by ESSL; Reports from SPC; lightning data from ATDnet



Tsonevsky et al., 2018

EFI is combined with Probability of Precipitation (PoP) from ENS, to exclude unstable cases where convection does not initiate

Applications of **thunderstorm** verification: lightning, pointwise vs areal method

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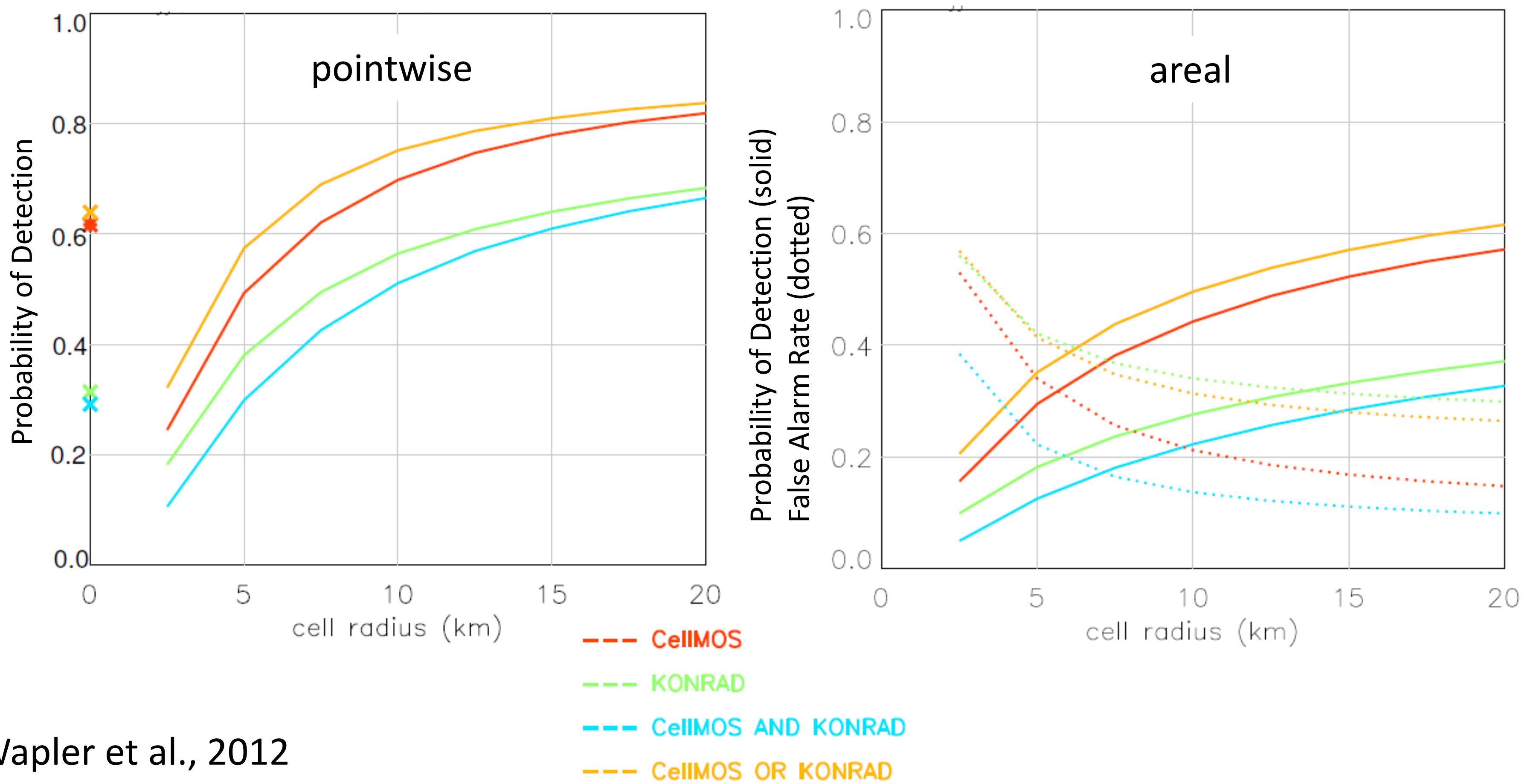
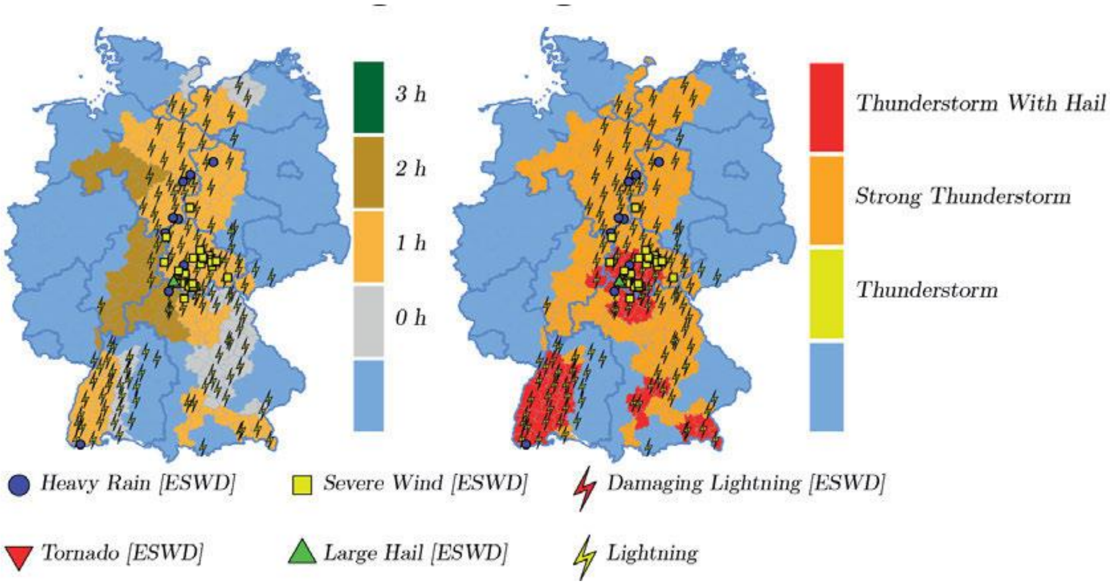
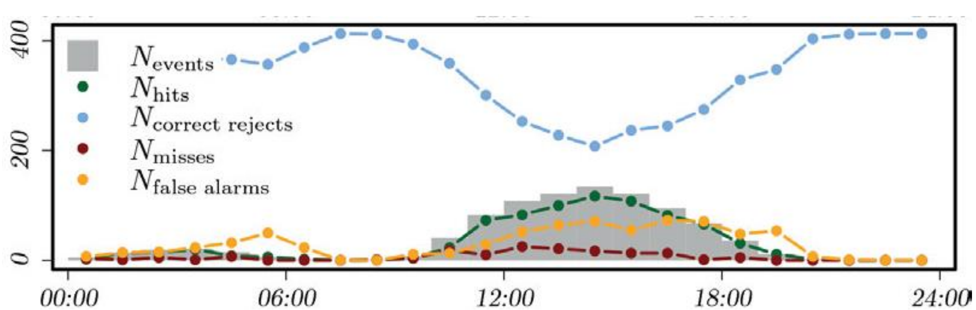
Simulated: Cells detected by 2 nowcasting algorithms
Observed: lightning (LINET)

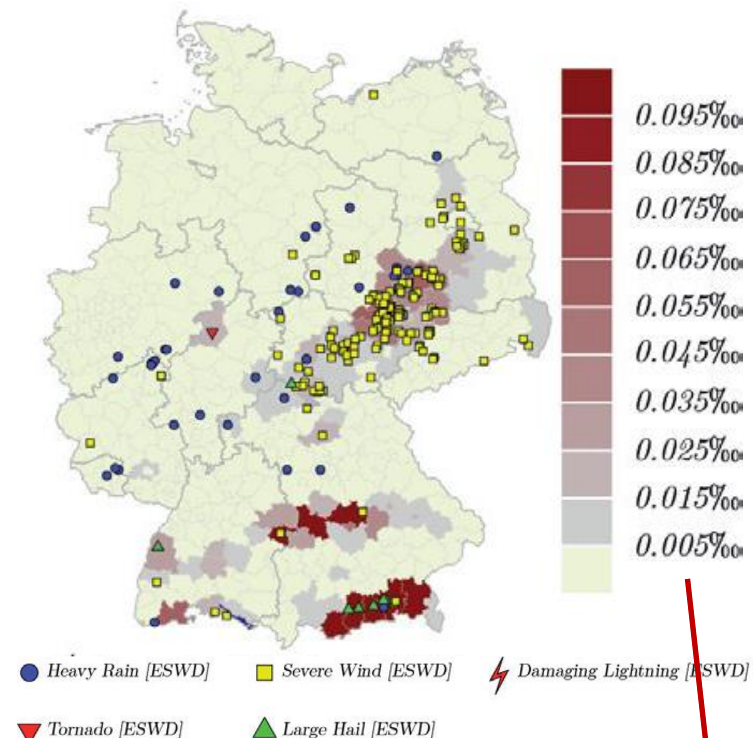


Wapler et al., 2012

Applications of **thunderstorm** verification: reports and insurance







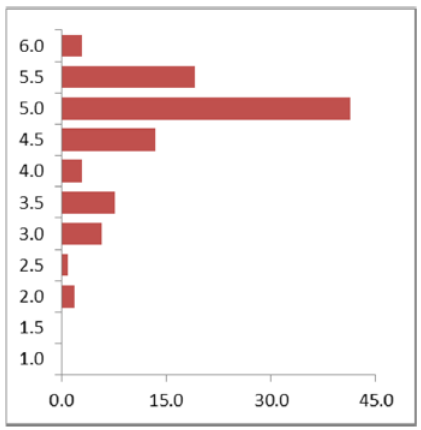
Loss ratio (per thousand) on district basis

Wapler et al., 2015

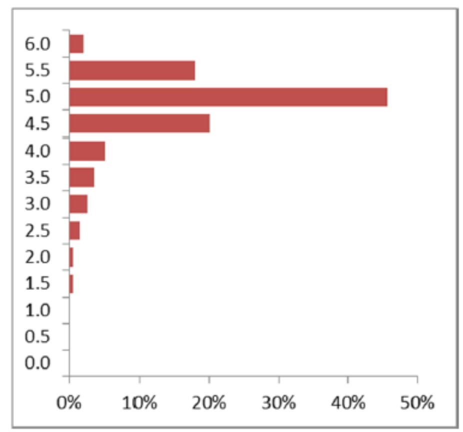
Applications of **thunderstorm** verification: **subjective evaluation of testers**

Simulated: thunderstorm warning from nowcasting sent to the testers
Observed: testers subjective evaluation

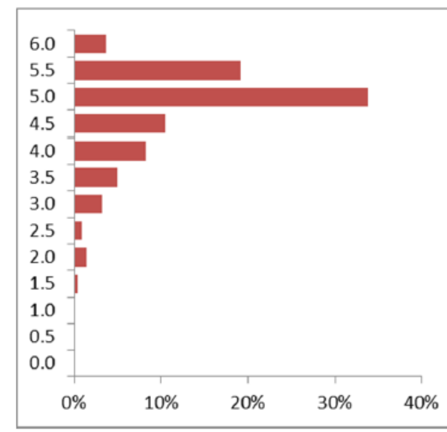
Experimental Thunderstorm Information from MeteoSwiss:
a ***developing*** */* ***moderate*** */* ***severe*** */* ***very***
severe *thunderstorm*
is expected in the next XX min. in (NAME of municipality).



2014 (104 responses)



2015 (195 responses)



2016 (219 responses)

2014	2015	2016
POD: 75 %	POD: 88 %	POD: 67 %
FAR: 25 %	FAR: 33 %	FAR: 29 %

subjective evaluation of the beta tester (feedback after each warning)

Gaia et al., 2017

Applications of **thunderstorm** verification: fire brigade operations

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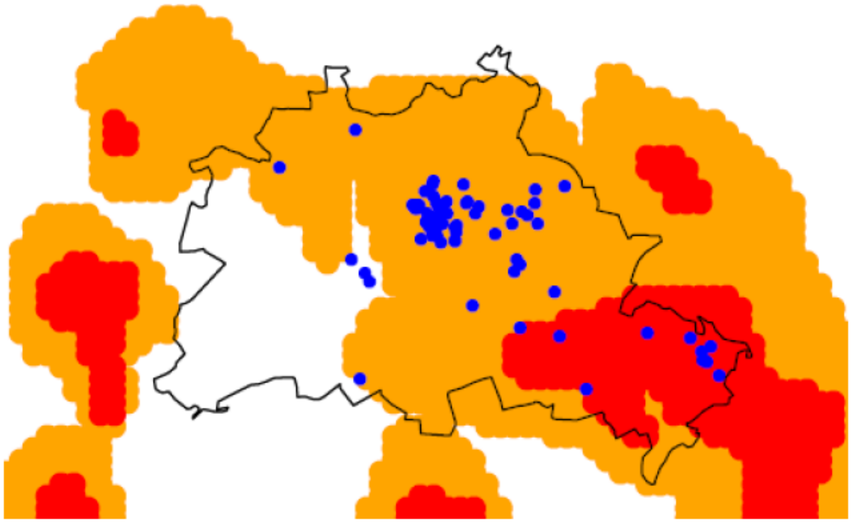
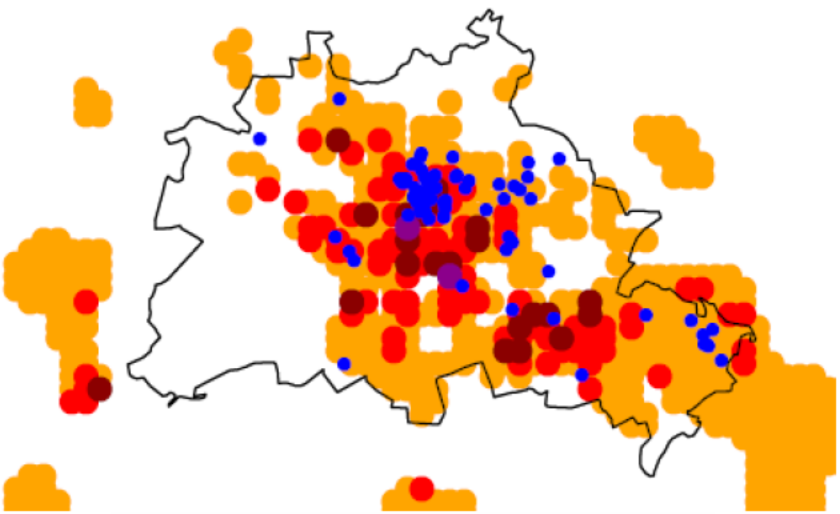
Simulated: „footprint“ of convective cell detected by a nowcasting algorithm
Observed: fire brigade operations (water related)





strong dependence also on exposure and vulnerability

Pardowitz and Göber, 2017

Concluding remarks

- Use of new observations for verifying products for high-impact weather
- Careful matching between predicted and observed quantities
- Data quality and data uncertainty assessment: usage of multiple data sources
- Closer cooperation with nowcasting, where products for high-impact weather detection are developed, which can be used for forecast verification
- Usage of reports, impact data, crowdsourcing data
- Fuzzy/spatial approaches often adopted, due to the non-exact matching between forecast and observation

Thank you for your attention!

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