European Severe Storms Laboratory

FONA Mittelfristige Klimaprognosen BMBF

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Probabilistic Modeling of the European Severe Thunderstorm Climate

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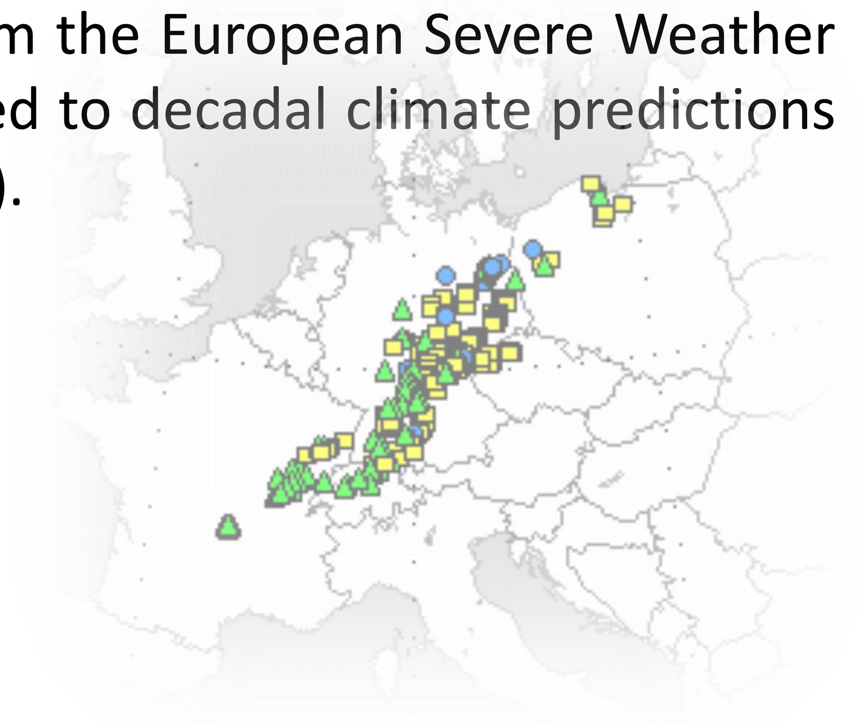
1. Introduction

We model the occurrence probability of severe weather – **severe wind gusts (>25 m/s)**, **tornadoes**, **large hail (>2 cm)**, and **excessive rain (flash floods)** – with predictors on the scale of global reanalyses and climate forecasts. The relationship between various predictors and severe weather probabilities is established with logistic regression models based on ERA-Interim reanalyses (Δx = 0.75°; available 1979-2013) and quality-controlled observations from the European Severe Weather Database (ESWD; reliably high coverage in central Europe since 2006). Afterwards it is applied to decadal climate predictions from the MPI-ESM system (Δx = 1.875°; 15 ensemble members per year initialized 1960-2011).

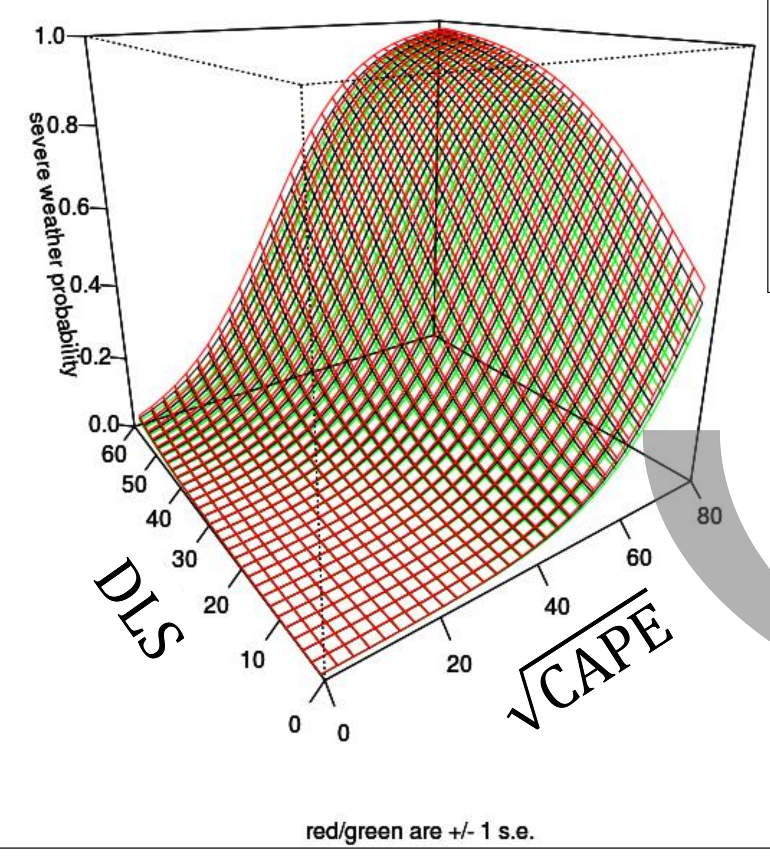


2. Methodology

We tested **linear logistic regression** and **additive logistic regression** models.

- Preliminarily two predictors: $\sqrt{\mathrm{CAPE}}$ and deep-layer shear (DLS)
- Maximum likelihood estimation of severe weather probability +/- standard error

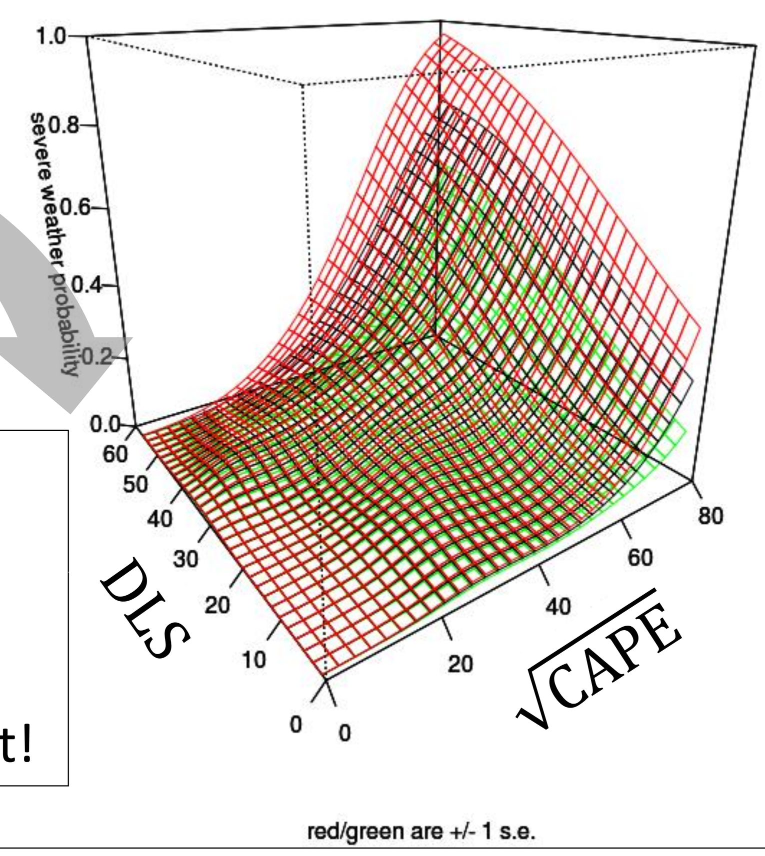
Linear logistic regression



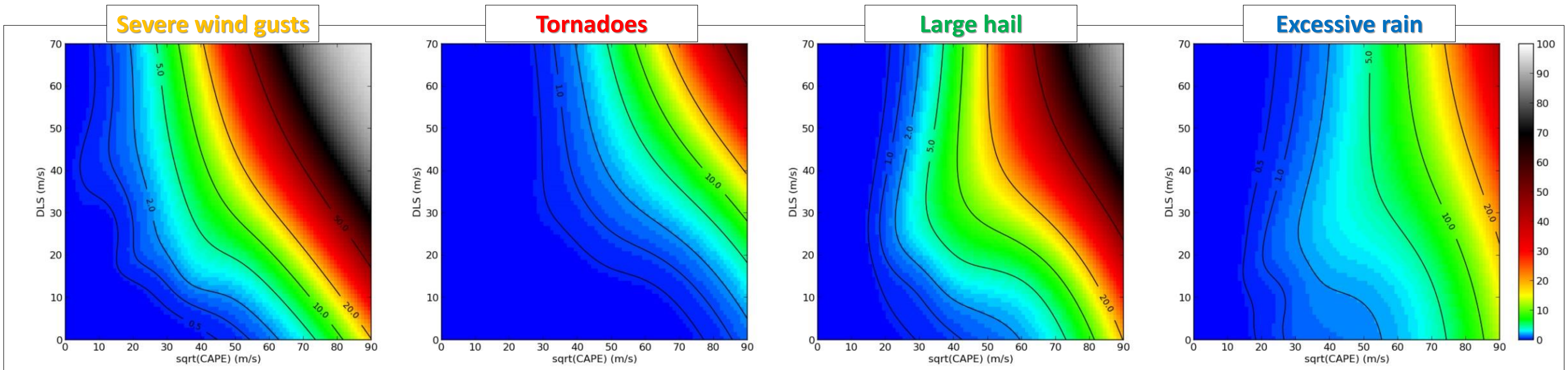
- Modeled numbers of severe events do not fulfill χ^2 test (function too „stiff")
- Linear logistic regression obviously not flexible enough, hence generalization to smooth additive predictors

- Higher number of degrees of freedom can add „bulges" and „dents" to probability plane
- Extra degrees of freedom useful according to Likelihood Ratio Test!

Additive logistic regression



3. Modeled severe weather probabilities [%]



← relatively stronger dependence on DLS | relatively stronger dependence on CAPE →

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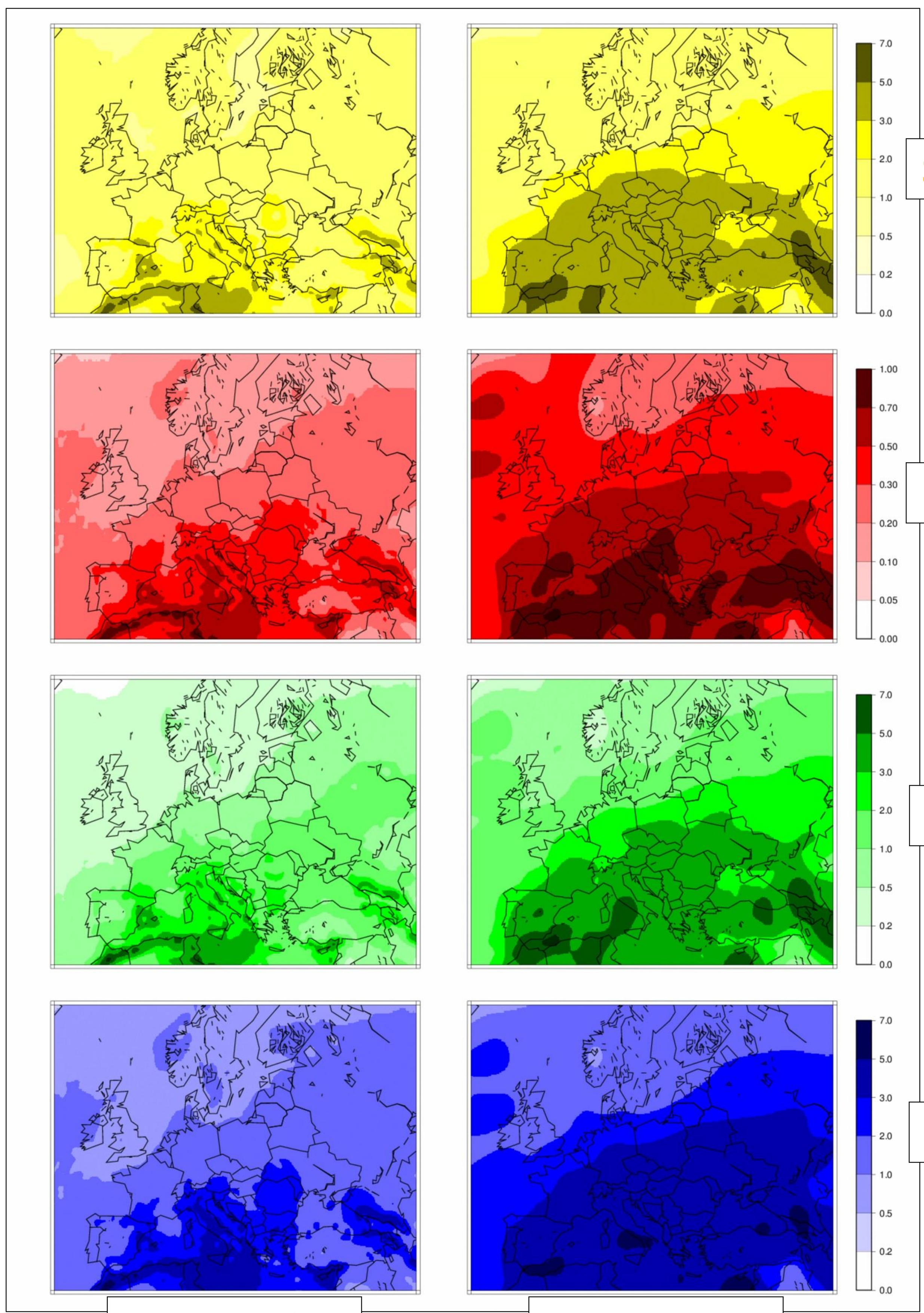
4. ERA-Interim reanalyses vs. MPI-ESM climate hindcasts

Modeled annual number of severe weather events per 0.75° x 0.75° box, 1979-2013 average:



Severe wind gusts

Tornadoes

Large hail

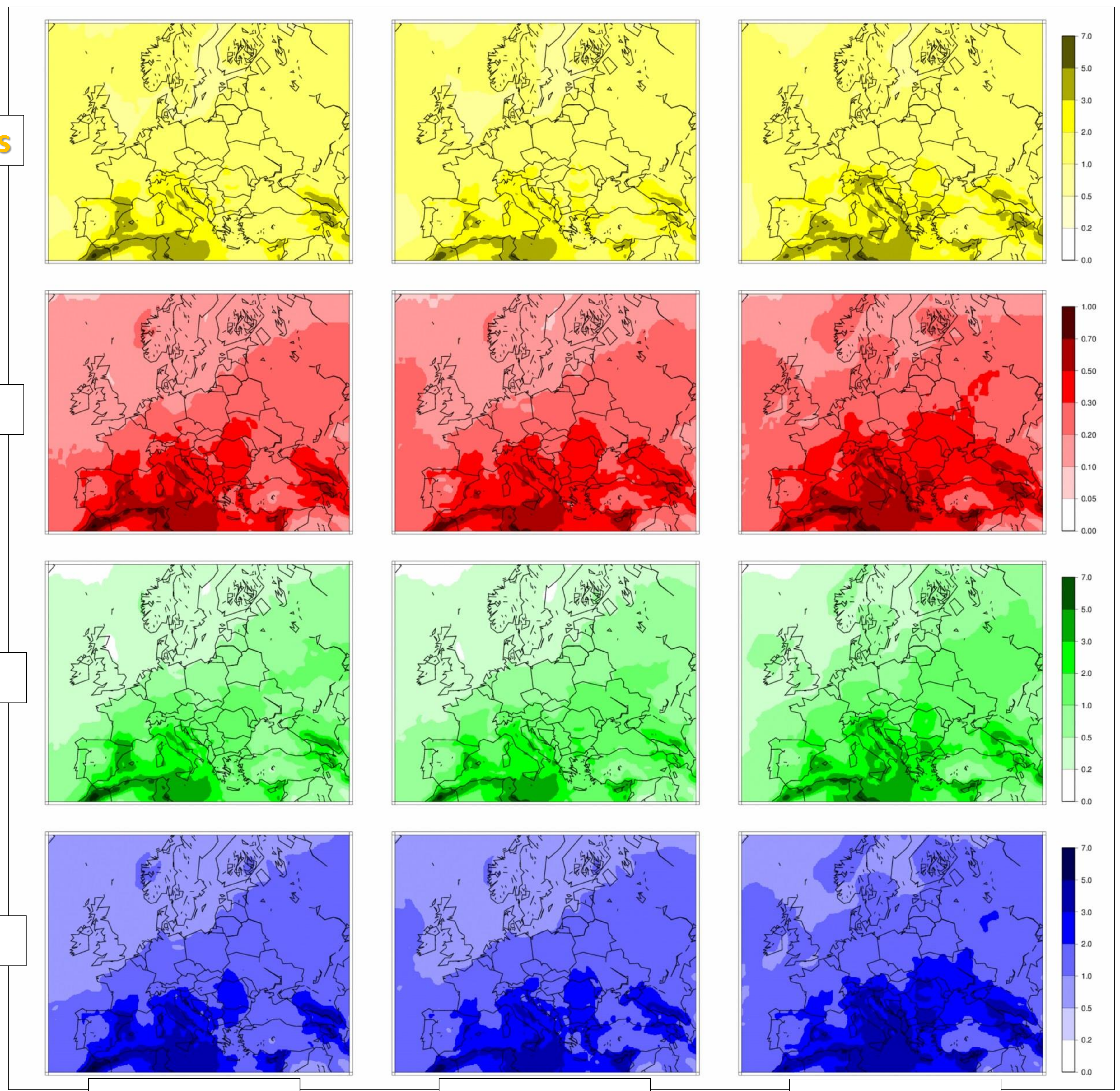
Excessive rain

ERA-Interim, 1979-2013

MPI-ESM, 1979-2013

5. Decadal trends in ERA-Interim reanalyses

Modeled annual number of severe weather events per 0.75° x 0.75° box, decadal averages:



ERA-Interim, 1981-1990

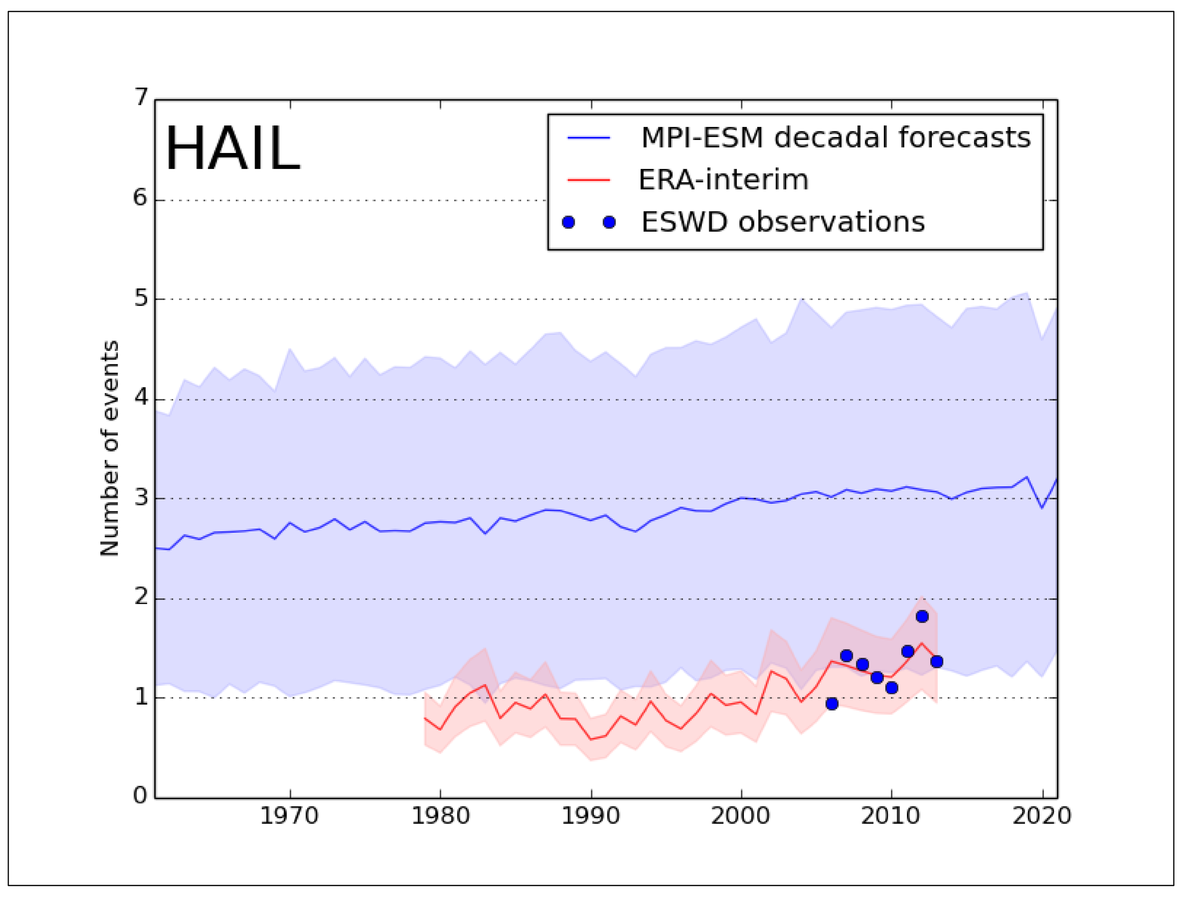
ERA-Interim, 1991-2000

ERA-Interim, 2001-2010

Performance of MPI-ESM:

- Overestimation of severe weather events due to simulation of too much CAPE (too cold mid-troposphere and too moist lower troposphere)
- Large-scale patterns well captured, but regional subtleties missed

Time series of modeled annual number of large hail events per 0.75° x 0.75° box averaged across 10 central European countries (means and 95% confidence bands):



Decadal evolution:

- Weak decrease in SW Europe, no trends otherwise from 1980s to 1990s
- Pronounced increase from 1990s to 2000s
- Mostly tied to increase of CAPE, little change in DLS

6. Further plans

- Test alternative predictors for latent instability (e.g., maximum buoyancy) and vertical wind shear (e.g., low-level shear)
- Introduce third predictor for likelihood of convective initiation
- Find objectively best set of predictors for each severe weather type
- Apply bias correction to MPI-ESM climate hindcasts

Acknowledgments: This study was funded by the German Federal Ministry of Education and Research (BMBF) as part of the MiKliP research programme under grant 01LP1117A.

References:

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