Workshop: Climate change and weather modelling

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Modelling severe thunderstorm risk in Europe

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Severe thunderstorms

1. Definition

2. Research on severe thunderstorms and climate change

3. Observations

4. Modelling the future climate

European Severe Storms Laboratory

Severe Thunderstorm Definition

We call thunderstorms **severe** if they are accompanied by either...

Hail larger than 2 cm diameter

Severe wind gusts exceeding 25 m/s (90 km/h)

A tornado

Heavy rain causing flash flooding

Severe Thunderstorm Definition

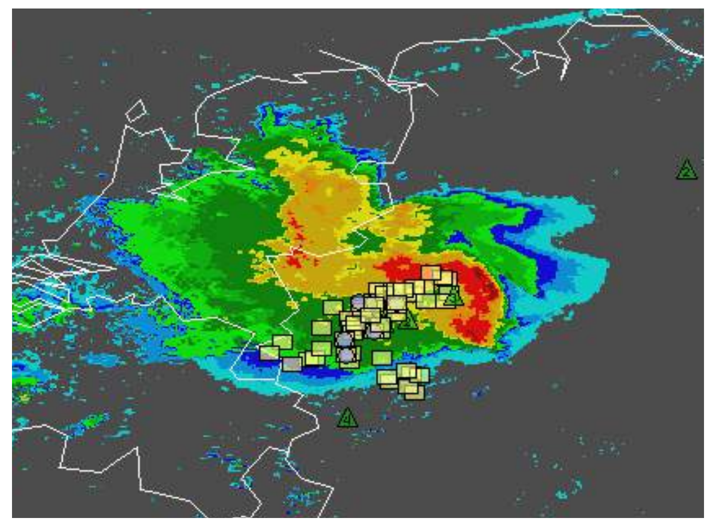
An example:

Severe wind gusts with a convective system in Germany on 9 June 2014

Type of damage:

Railways and motorways blocked by fallen trees and other objects.
Overhead lines damaged.

Total damage: 800 million euro
Recovery time: up to 1 week.



Radar image of the storm system.

State-of-the-art Research

- More research in USA than in Europe
- In recent decades, increasing variability of tornado outbreaks in USA

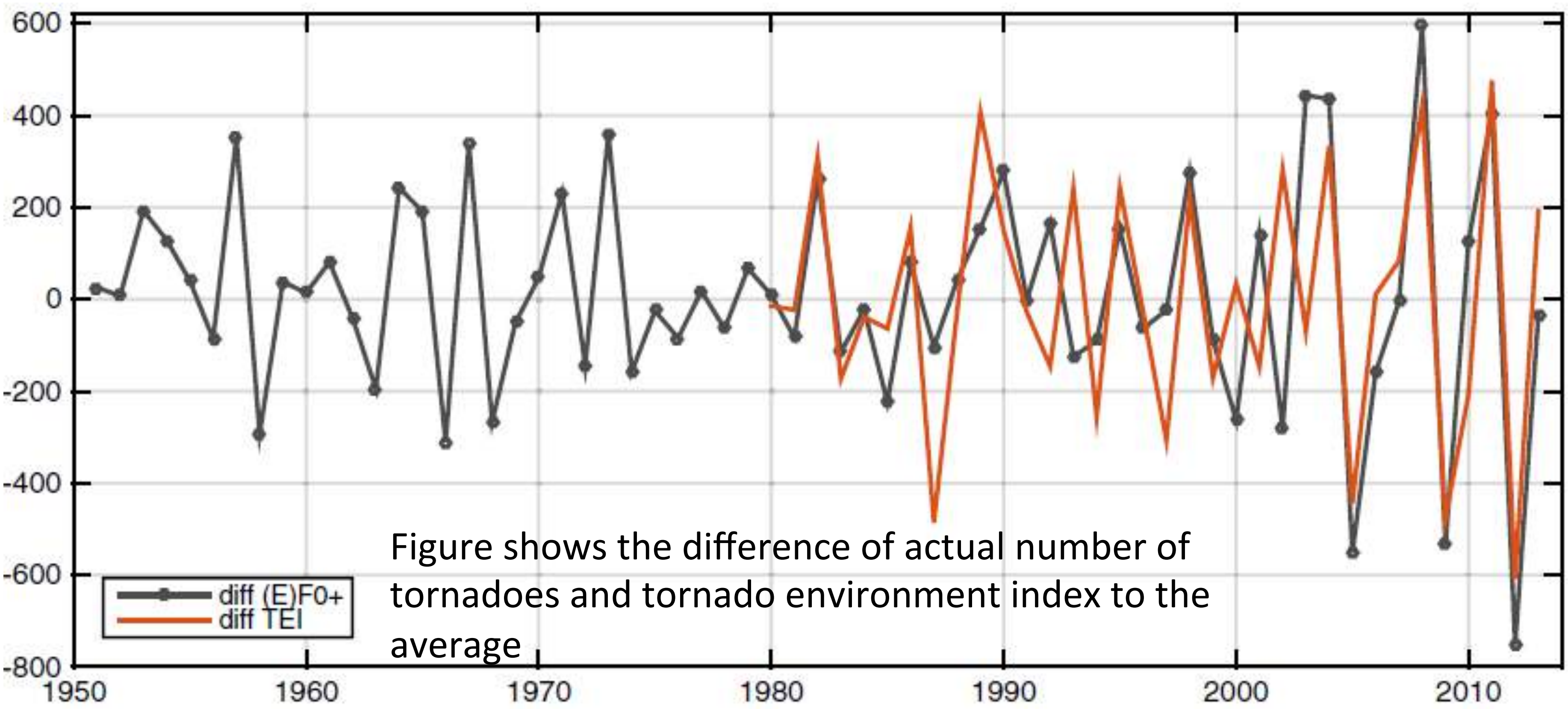
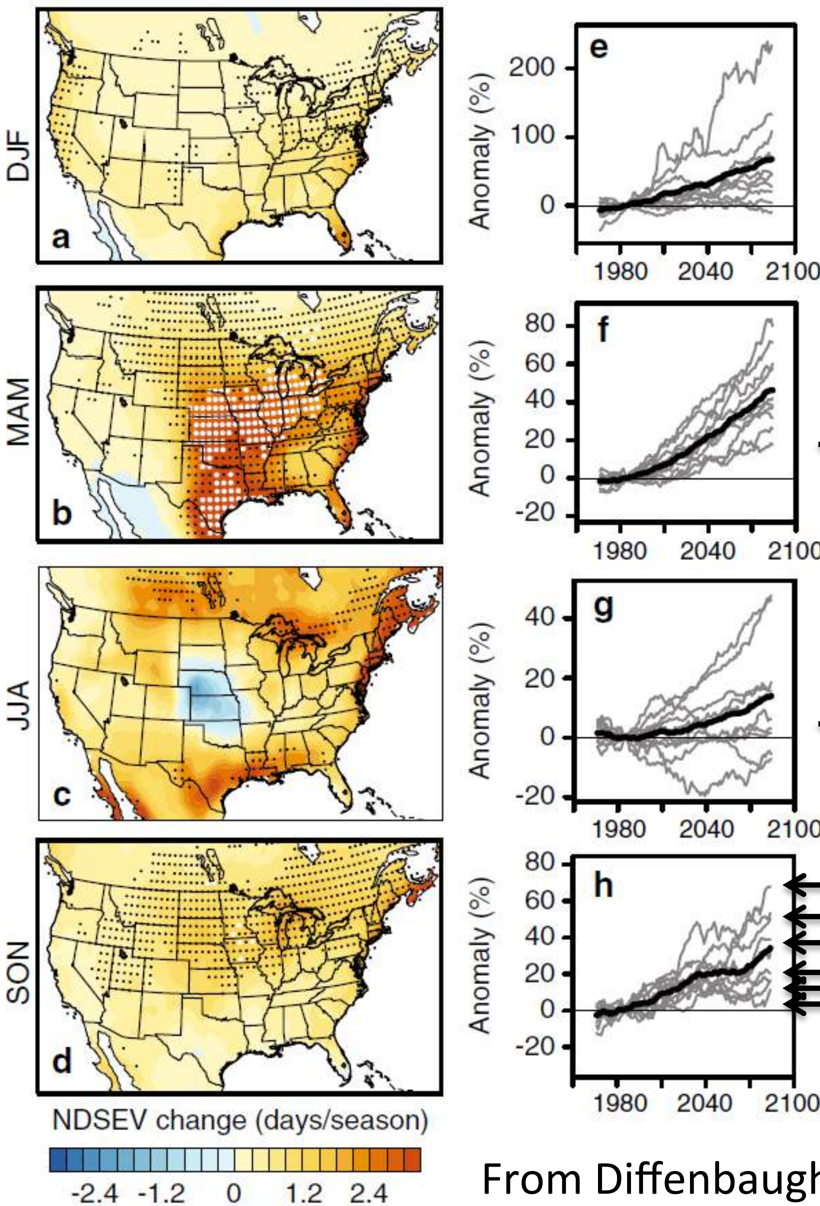


Figure shows the difference of actual number of tornadoes and tornado environment index to the average

Change in environments supportive of storms (rcp 8.5 scenario) in the USA.



- For USA and Australia: robust increase of severe weather environments in the rcp 8.5 scenario up to 2090

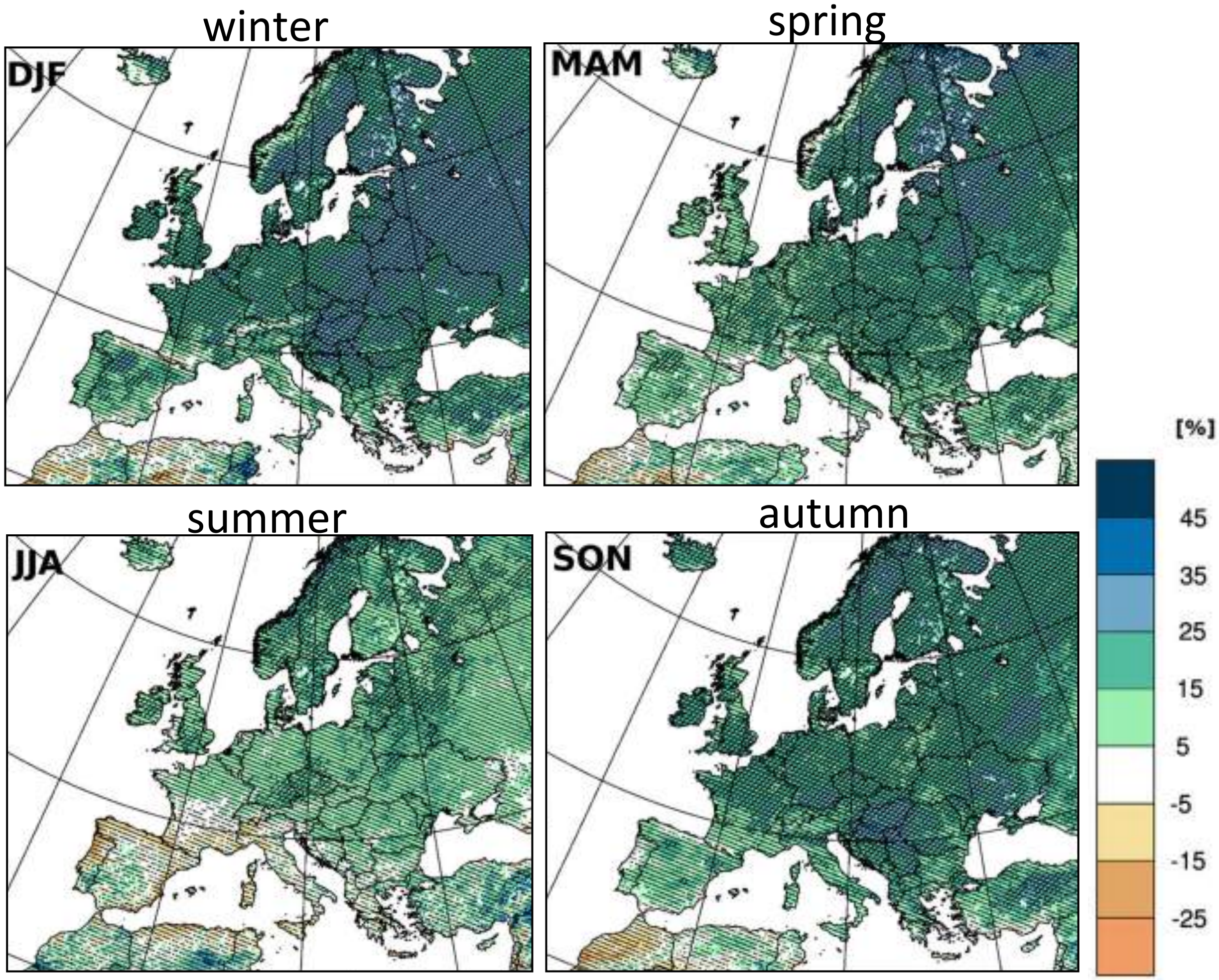
Significant, robust increase in spring

Less confidence in summer
More regional variability

Each of these lines are simulations by different climate models

From Diffenbaugh et al. (2013)

What about Europe?



Changes in **heavy precipitation events** according to regional EuroCordex climate simulations (scenario rcp 8.5). From Jacob et al. (2014).

More water vapour in the air at higher temperatures leads to heavier rainfalls.

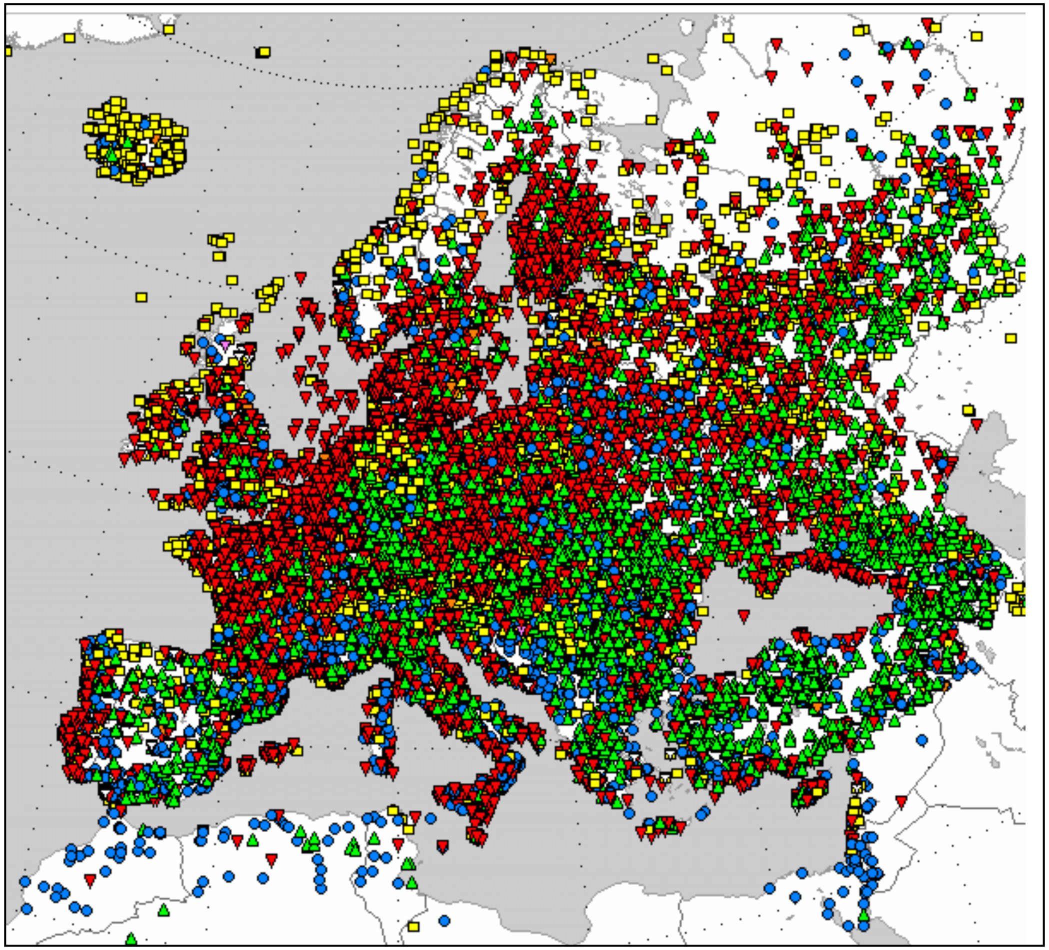
Q: What about **severe thunderstorms?**

A:We are about to find out in RAIN!

European Severe Weather Database (ESWD)

- Operated since 2006
- Contains almost 100 000 reports
- Collects media and storm spotter observations

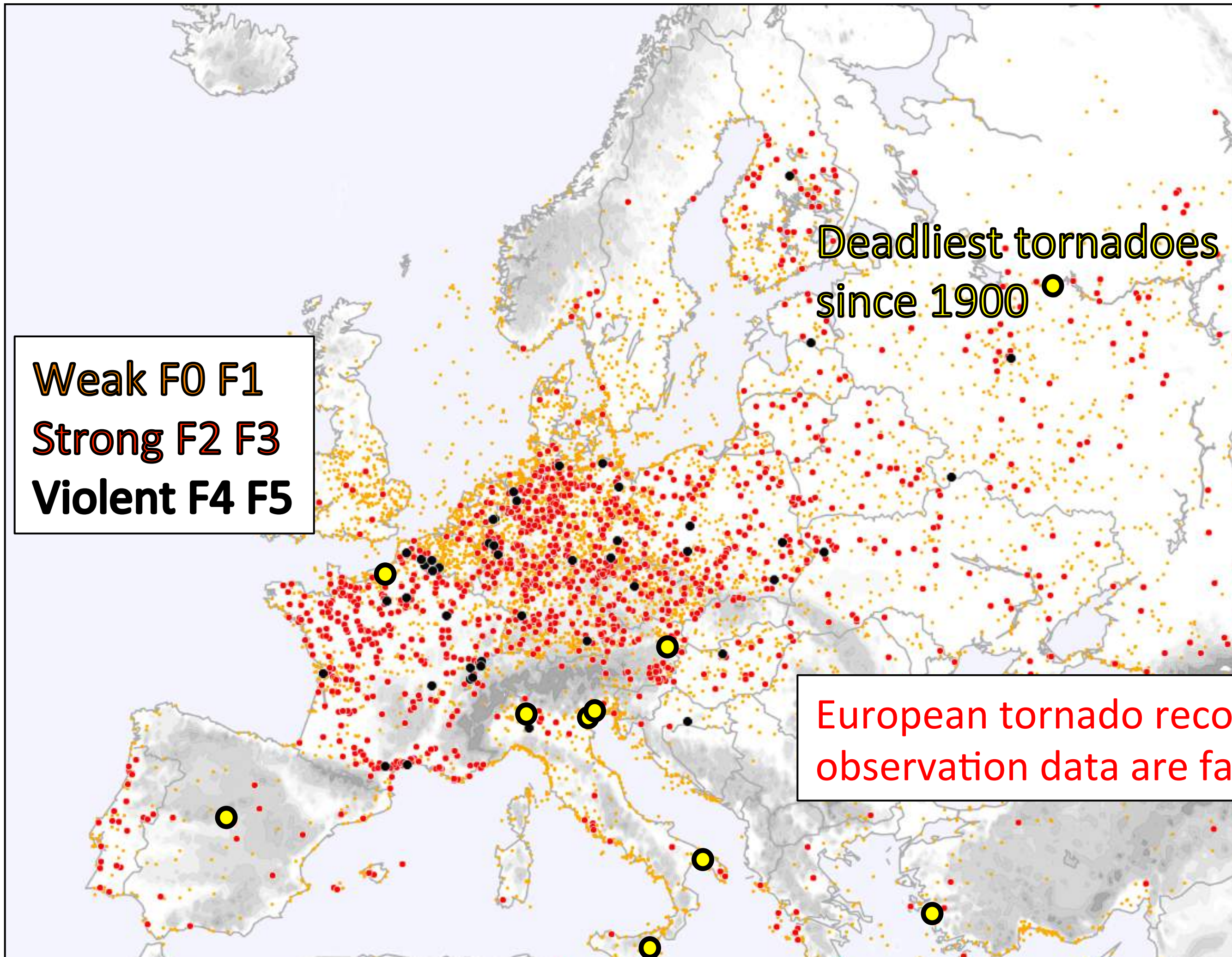
Website:
www.eswd.eu



- Tornadoes
- Severe wind gusts
- Large hail
- Extreme rainfall

ESWD Tornado reports in Europe

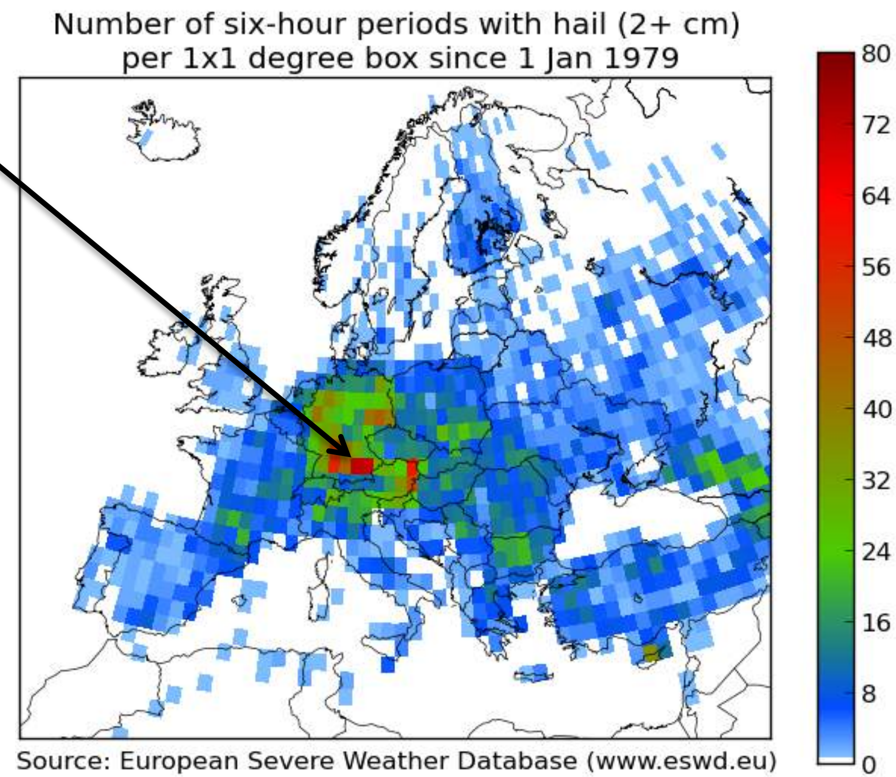
- Southern Europe - most deadly tornadoes
  - fewer reports than Central Europe?



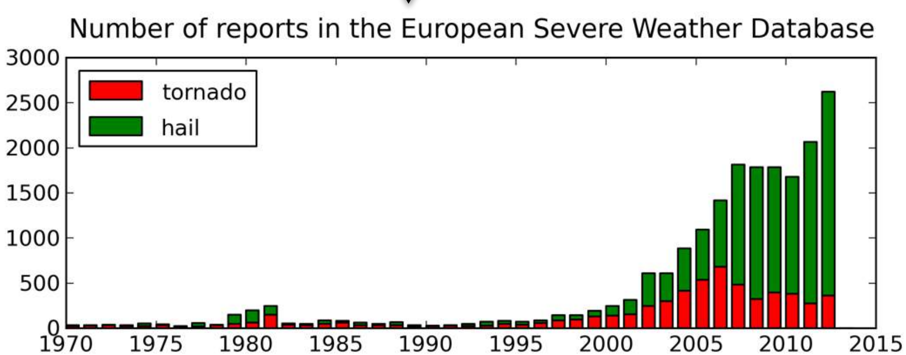
European tornado record indicates that observation data are far from complete!

Climatology using ESWD reports

Southern Germany and Eastern Austria „the hail region“



Large increase in severe weather after 2000…

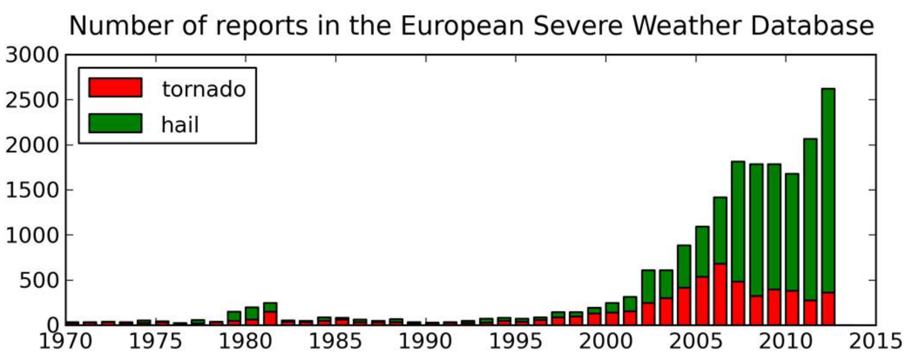


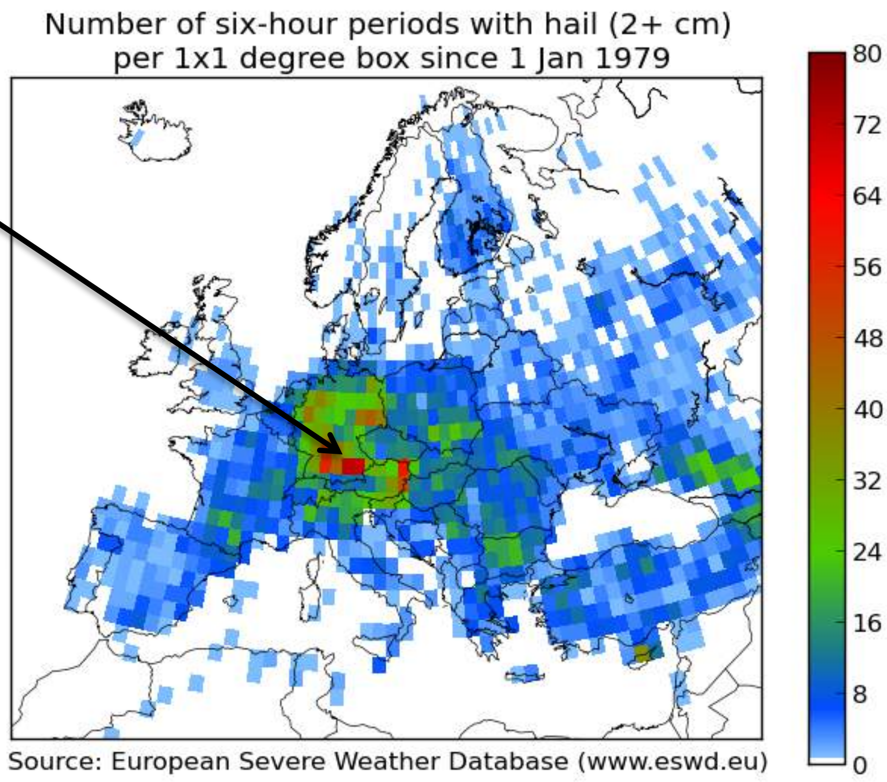
Climatology using ESWD reports

➢ Reports inhomogenuous in both time and space!

ESSL locations ☺, active voluntary severe weather observers.

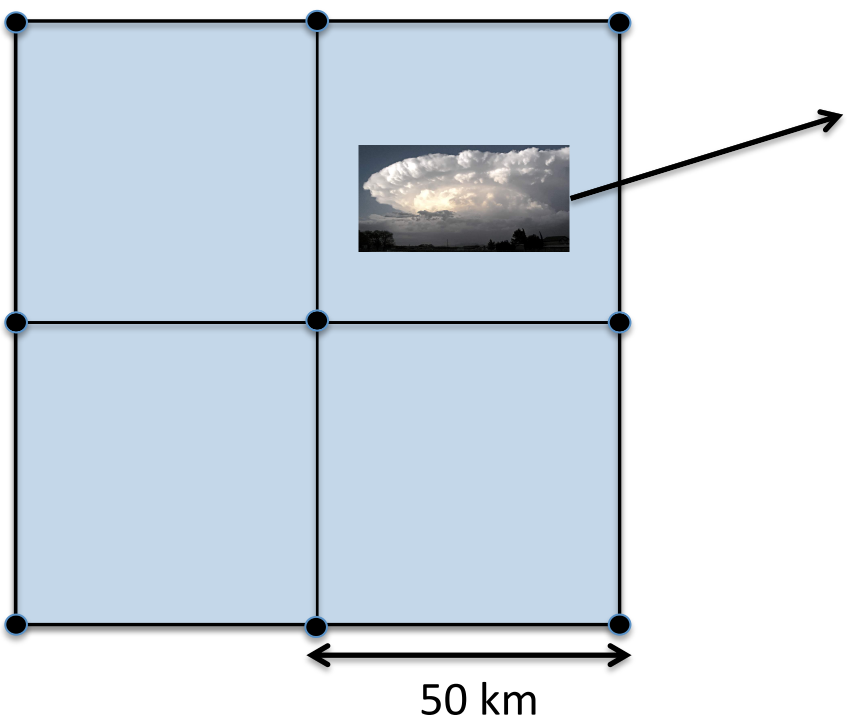
Reporting strongly increased with more spotters





Numerical modelling

- Very high resolution models (1 – 4 km) can simulate thunderstorms
- Cannot accurately simulate severe phenomena (hail, tornadoes, severe wind gusts)
- Are not available on climate timescales



Thunderstorm occurs on sub-grid scale

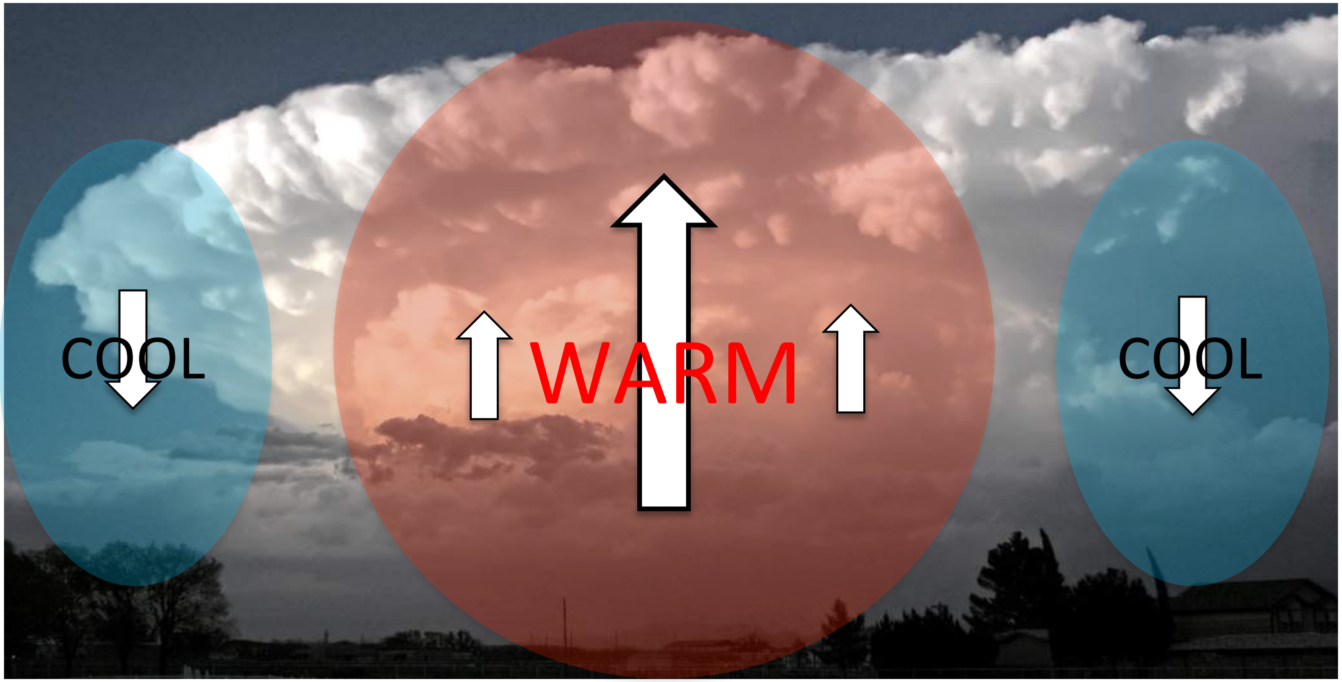
However, we can study environments conducive to storms!

Environments of severe thunderstorms

- **Key parameters** of the storm environment are simulated by coarse climate models

Environments of severe thunderstorms

➢ **Key parameters** of the storm environment are simulated by coarse climate models



1. Convective Available Potential Energy (CAPE)

- energy released because of temperature differences

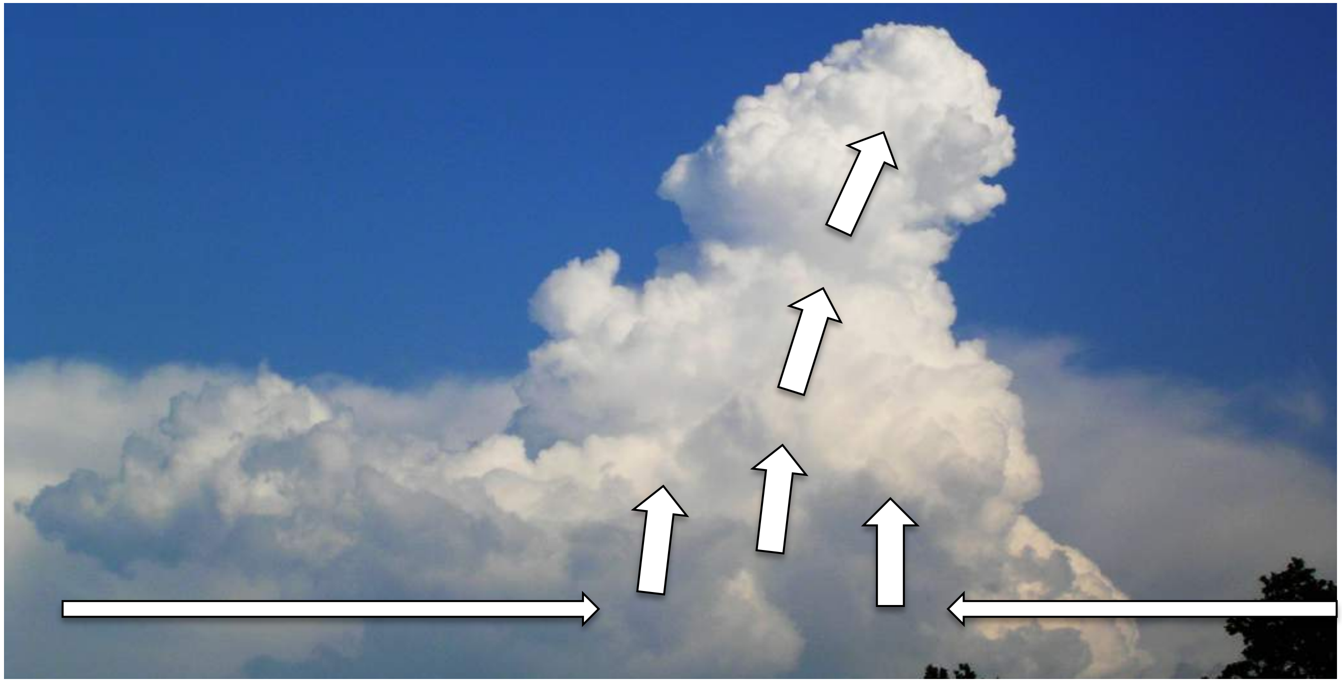
Environments of severe thunderstorms

- **Key parameters** of the storm environment are simulated by coarse climate models

1. **Convective Available Potential Energy (CAPE)**
   - energy released because of temperature differences
2. **Vertical wind shear**
   - causes storm rotation: **supercells**, long-lived severe storms

Environments of severe thunderstorms

➢ **Key parameters** of the storm environment are simulated by coarse climate models



1. **Convective Available Potential Energy (CAPE)**
   - energy released because of temperature differences
2. **Vertical wind shear**
   - causes storm rotation: **supercells**, long-lived severe storms
3. **Lifting of air**
   - necessary to trigger the storm in the first place

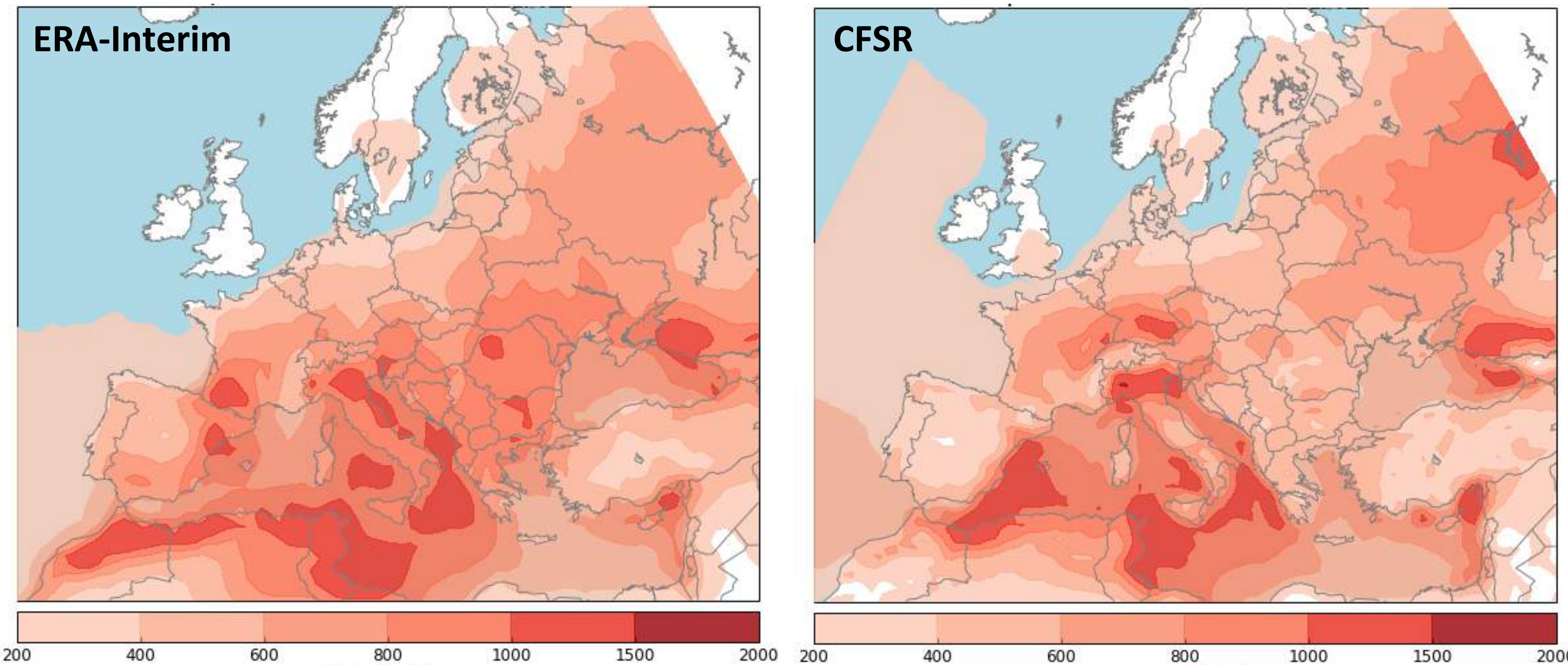
Global re-analysis data

- **Model runs for the past conditions – 1979 to 2014**
- **6 hly data**

1. **Era-Interim (ECMWF)**
    - Resolution around 55 km (0.75°*0.75°)
2. **CFSR (NCEP)**
    - Resolution around 38 km (0.5°*0.5°)

CAPE in "reanalysis runs" of past conditions (1979 to 2014)

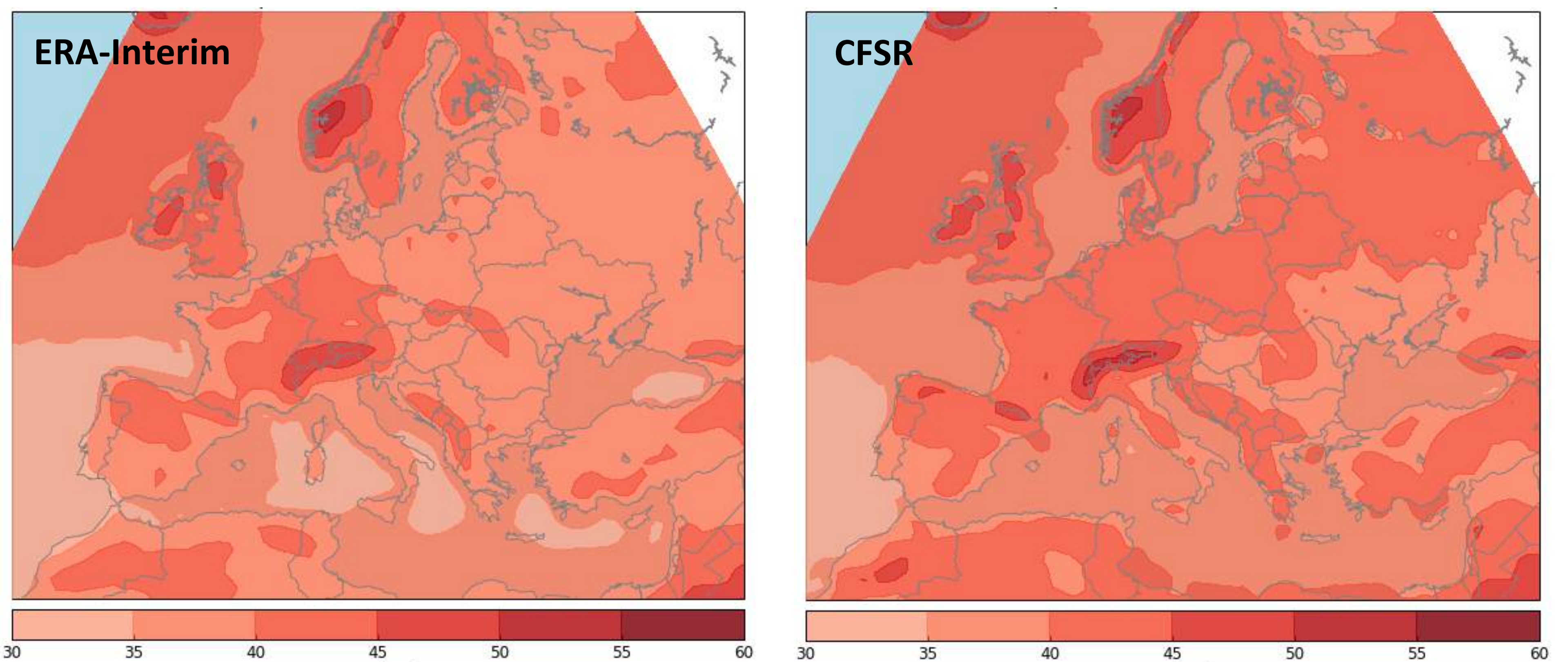
- Highest values over / close to the Mediterranean Sea



99th percentile of CAPE (J/kg)

Wind shear in "reanalysis runs" of past conditions (1979 to 2014)

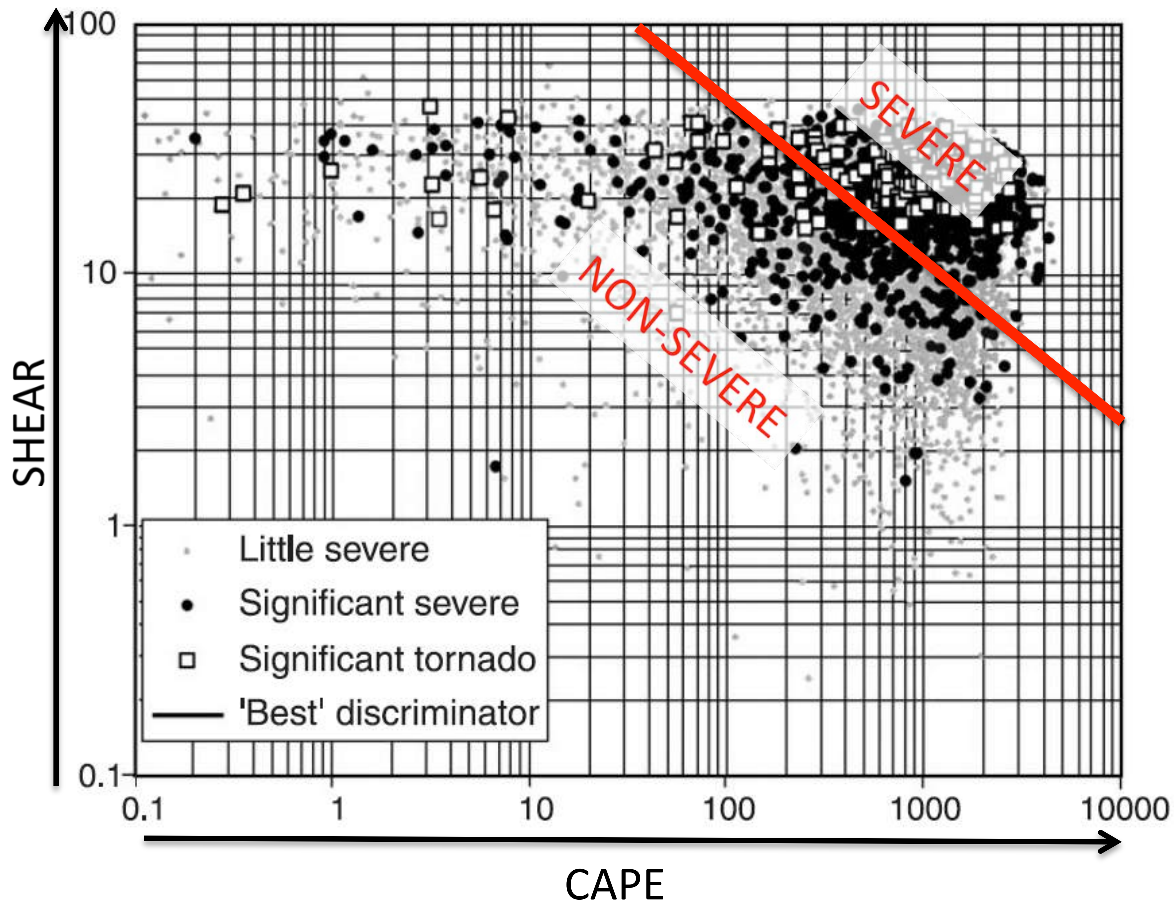
- Highest values over NW Europe and over the mountains



99th percentile of 10 m to 6 km (above ground level) wind shear (m/s)

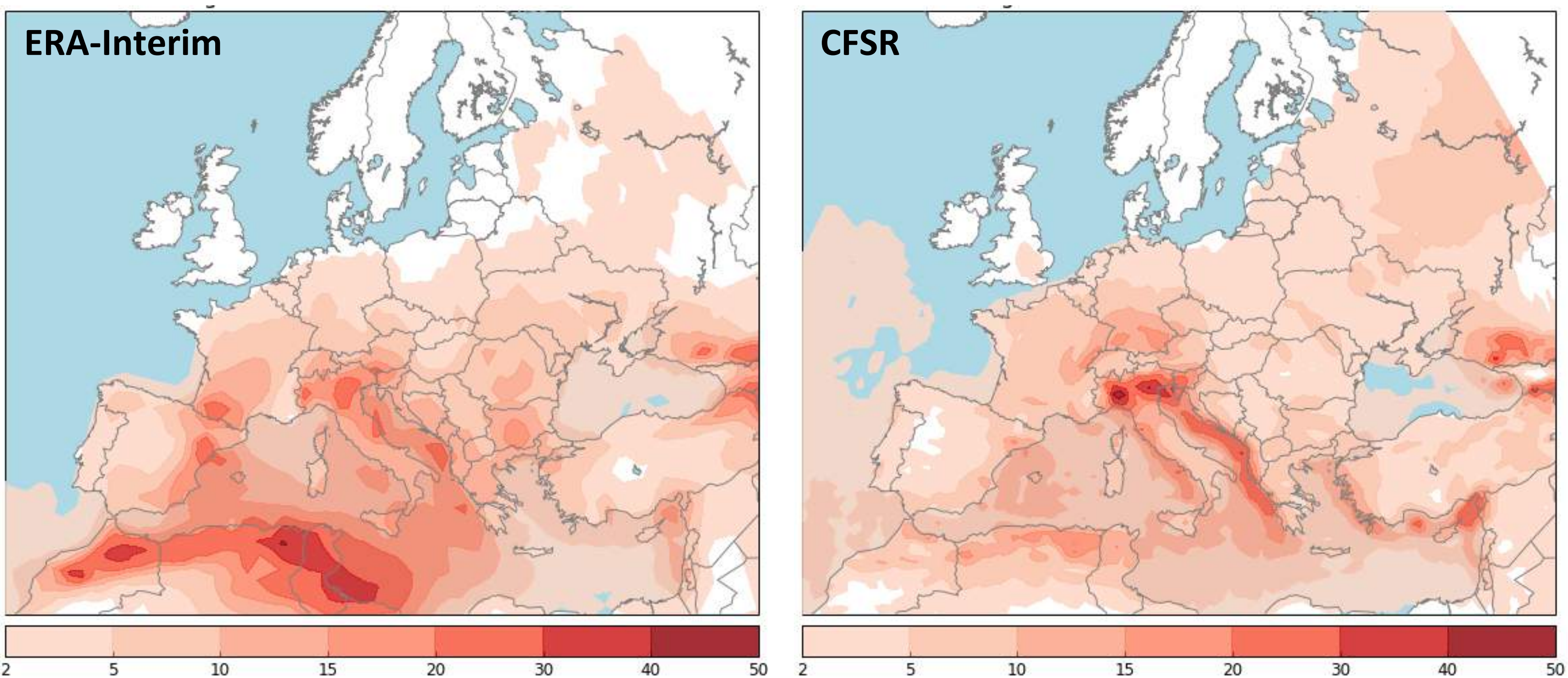
CAPE and wind shear together

- What matters is overlap of CAPE and wind shear
- **Threshold method (Brooks et al. 2003):**



Average annual number of severe situations (1979-2014)

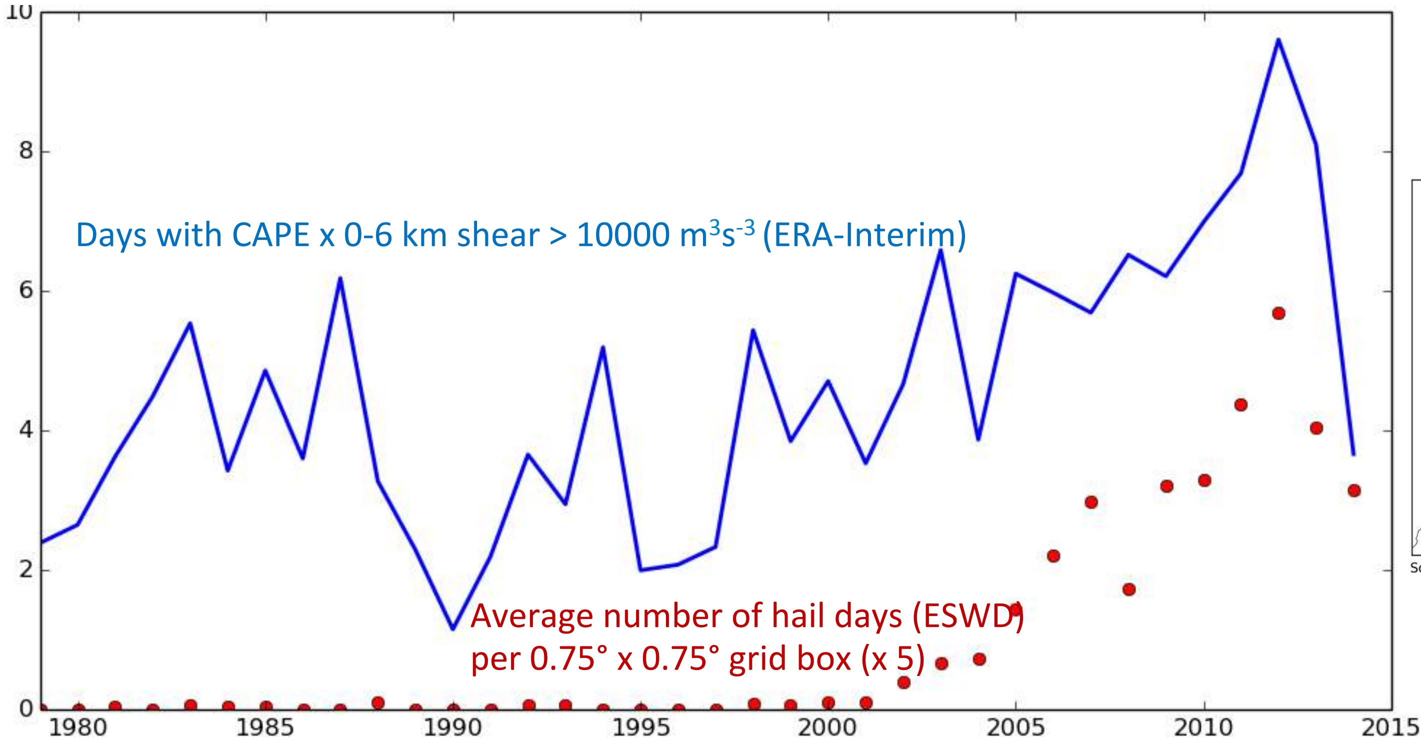
- Large differences between two models

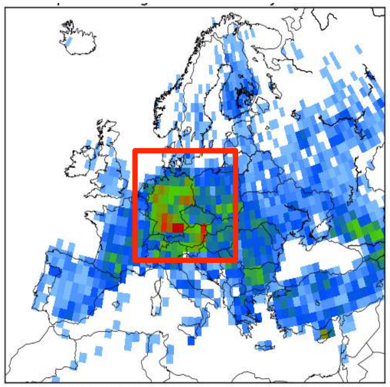


Severe situation = CAPE-shear threshold exceeded + precipitation modelled in next 6 h

Interannual variability in Central Europe

- Large interannual variability in severe situations
- Overall positive trend apparent





Source: European Severe Weather Database (www.eswd.eu)

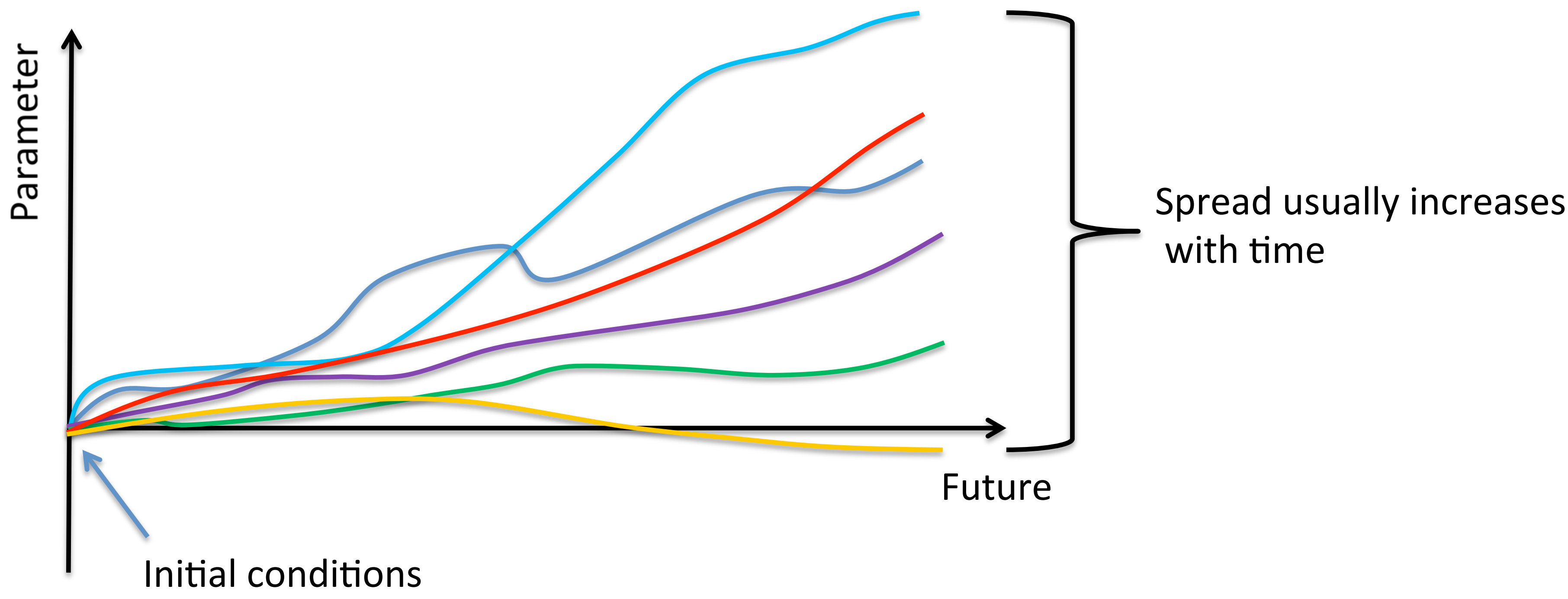
Modelling the future

- using EUROCORDEX models (http://www.euro-cordex.net/)
- 0.44° grid (around 30 km resolution)
- Different emission scenarios (RCP 2.6, RCP 4.5, RCP 8.5)
- Historical period 1971 – 2000
- Future period 2021 – 2050, 2071 – 2100

Image source: http://www.euro-cordex.net

Ensemble approach

- Different models = different solutions
- Numerous possibilites instead of one



Conclusions

- Current knowledge: more moisture = more severe thunderstorms?
- Observations not reliable enough for climatology
- Climatology deduced from CAPE, shear and precipitation patterns
- Future environments from EUROCORDEX models

Stay tuned for our results scheduled for March 2016!

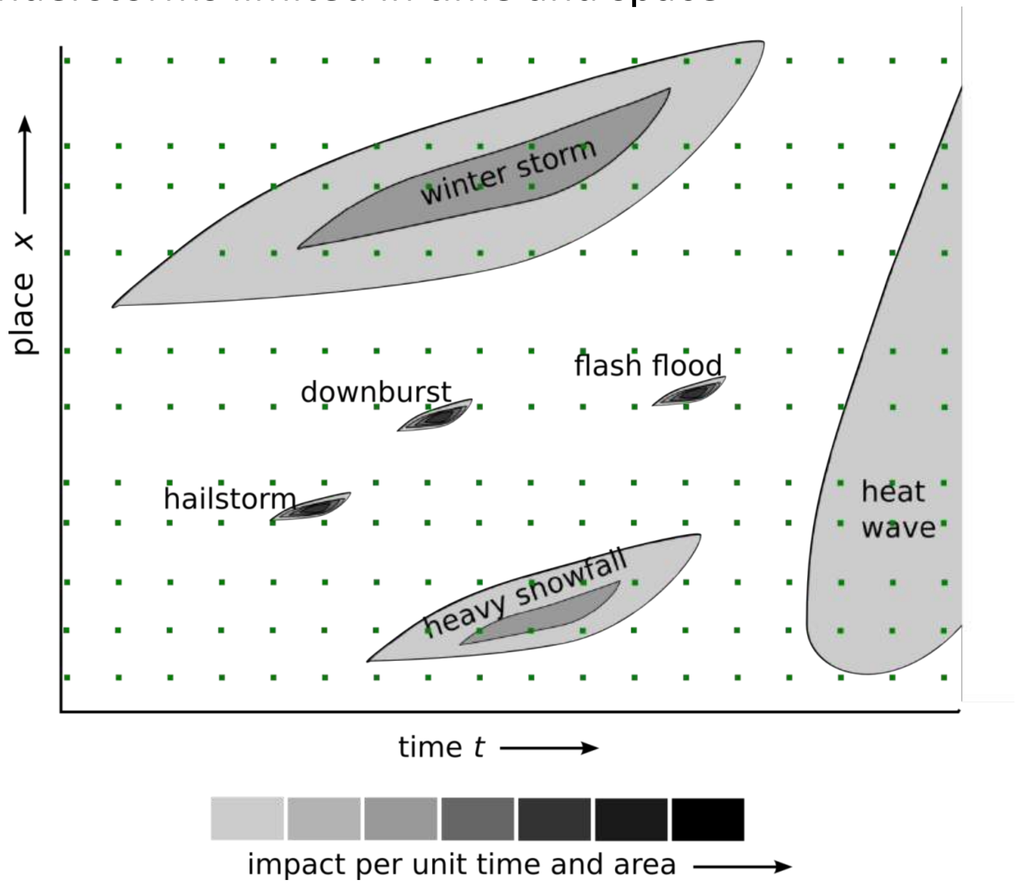
References

- Diffenbaugh N.S., Scherer M., Trapp R.J., 2013: Robust increases in severe thunderstorm environments in response to greenhouse forcing. *Proceedings of the National Academy of Sciences of the United States of America*, 110, 16361-16366. doi: 10.1073/pnas.1307758110.

Observations of severe thunderstorms

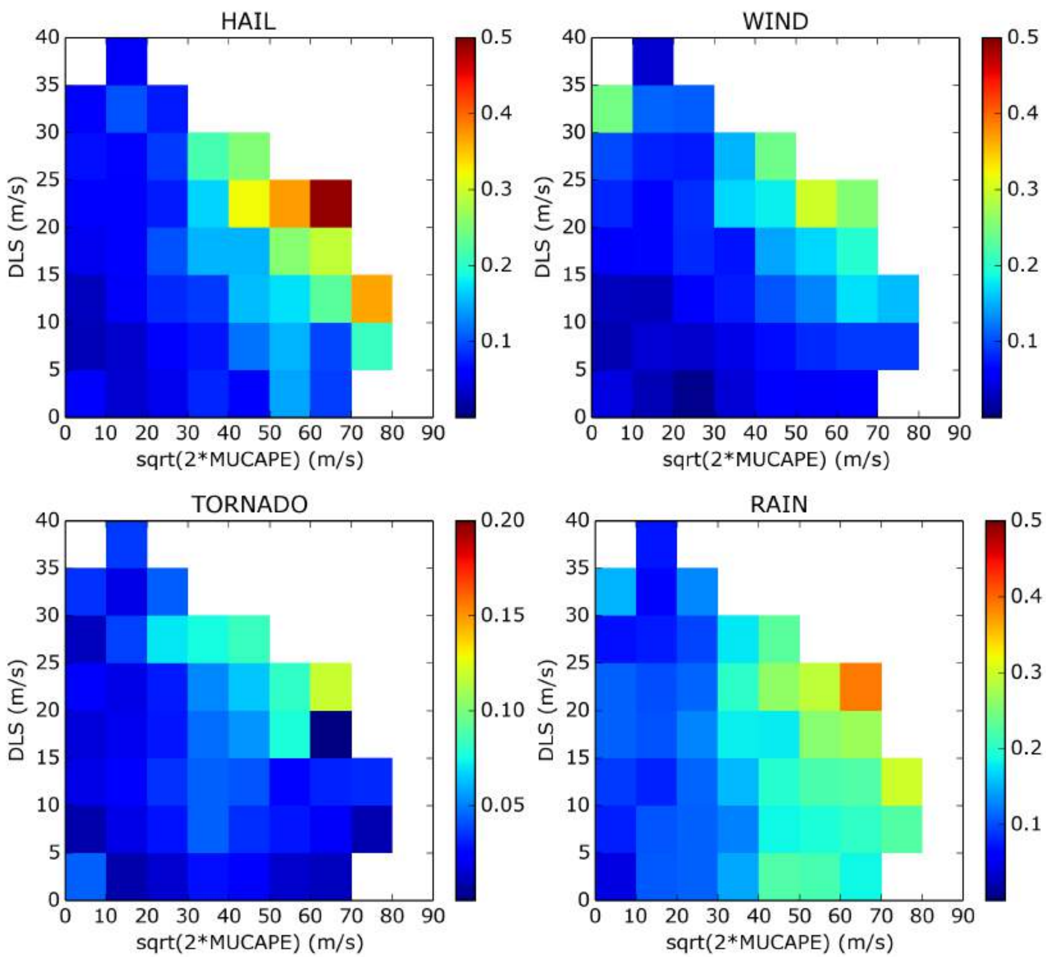
- Observation networks often miss severe thunderstorms

- REASON: thunderstorms limited in time and space



What if we consider severe phenomena separately?

Different thunderstorm phenomena exhibit different patterns w.r.t. CAPE and shear



Also, no clear threshold values. Probability rather changes gradually.

Probability of severe weather based on 16 421 sounding measurements

How can we work with probabilities?

We can separate the problem into two parts:

1. **Probability of initiation** (Pi) What is the probability that in given conditions a thunderstorm will form?

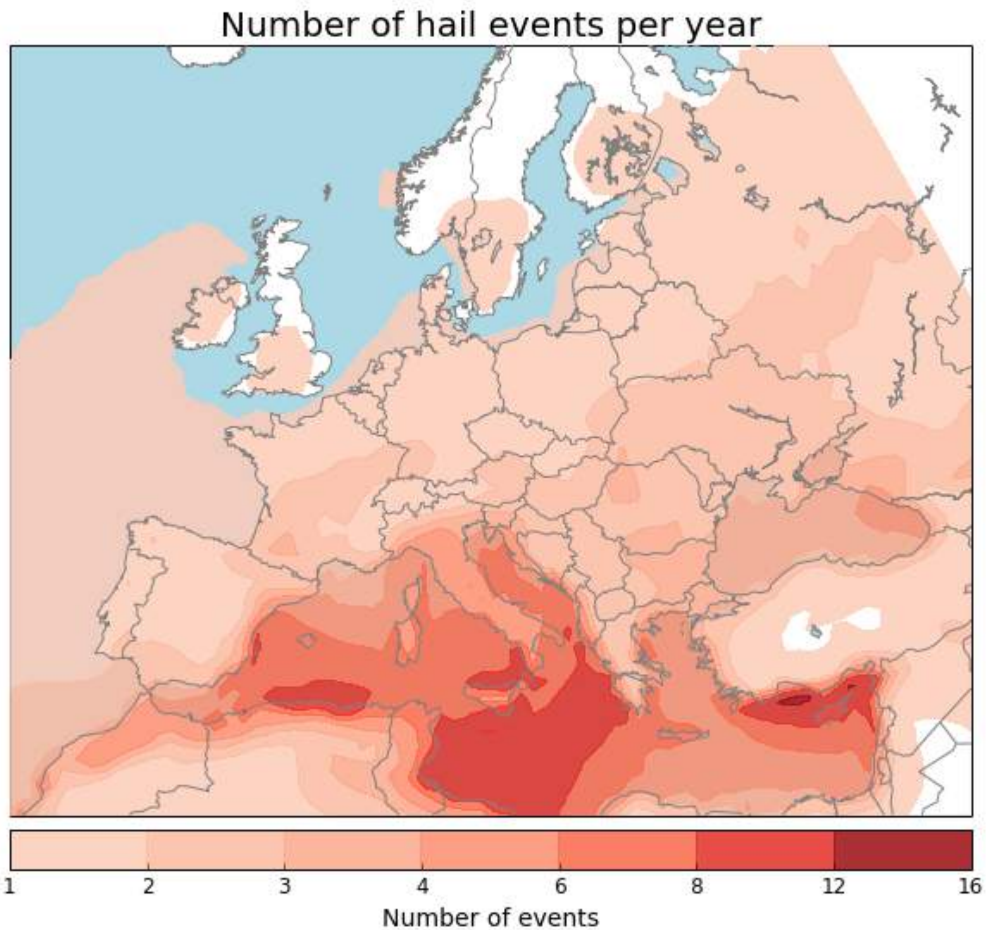
2. **Probability of severe** (Ps) What is the probability that in given conditions a thunderstorm will become severe?

Final probability can be calculated as their product:

$P = Pi * Ps$

Applying this to ERA-Interim data

Big maximum over the Mediterranean!



Why?

Very moist layer just over the sea contributes to strong instability

This layer is often very thin.

How much does it matter?

Need to consider other versions of parameter