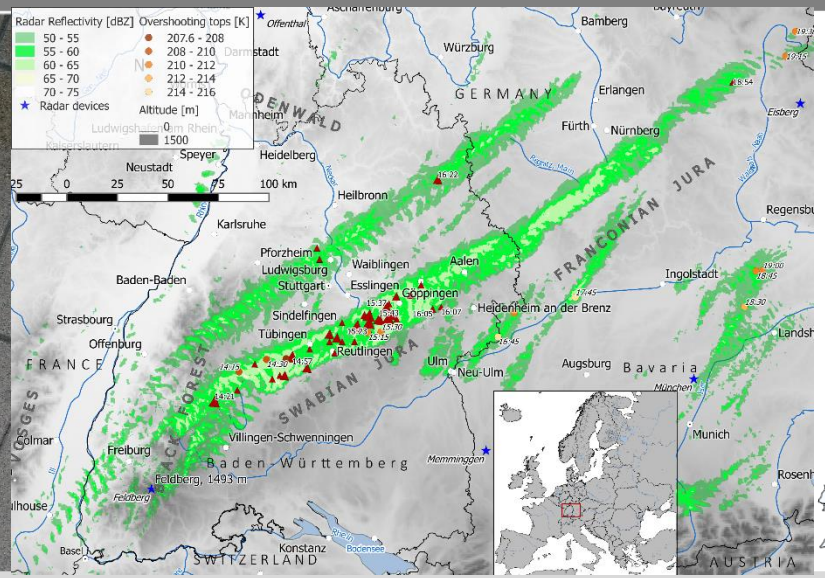
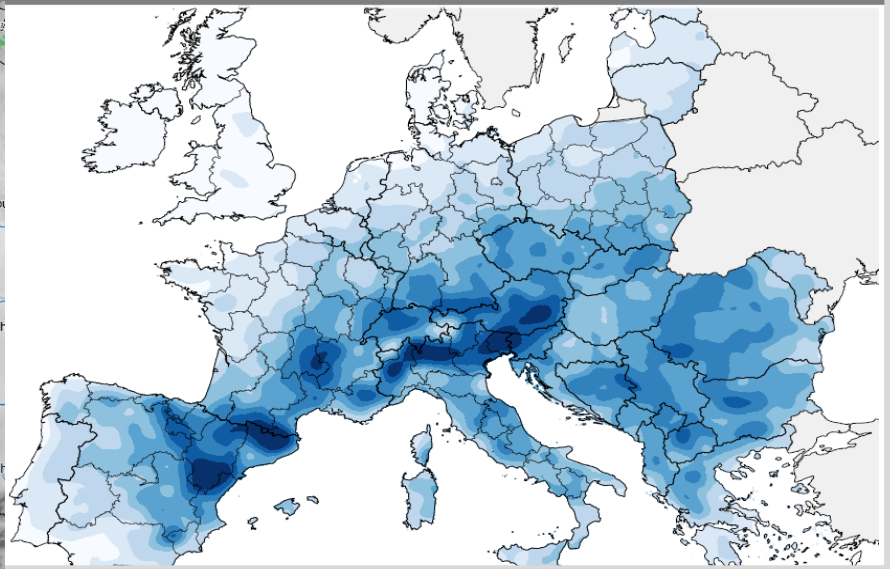
Karlsruhe Institute of Technology

Quantifying Severe Convective Storm Hazard in Europe

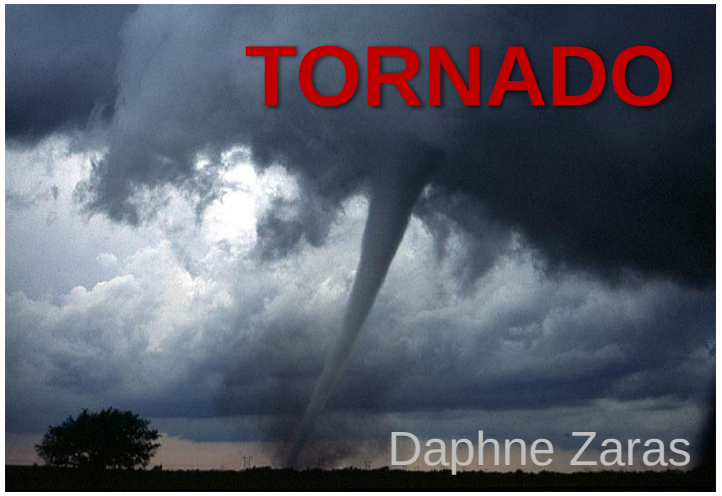
Heinz Jürgen PUNGE

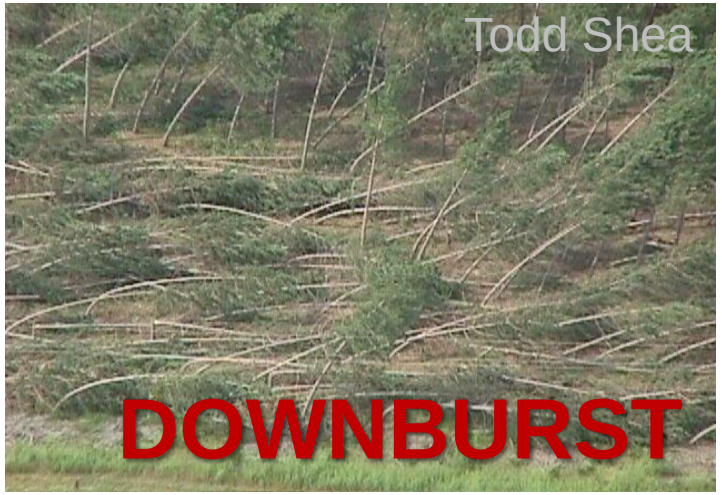
INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH – TROPSPHERE DEPARTMENT





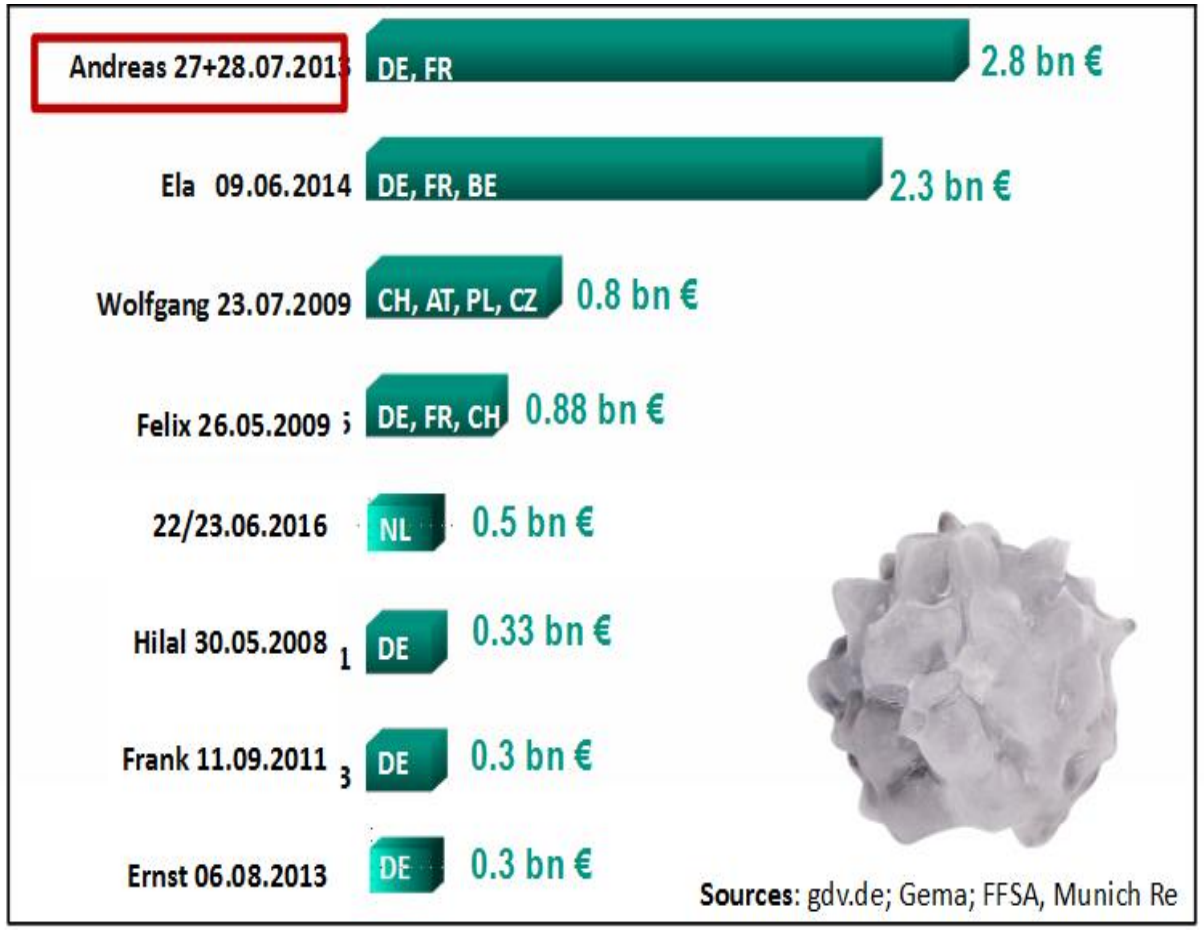
Perils in Severe Convective Storms

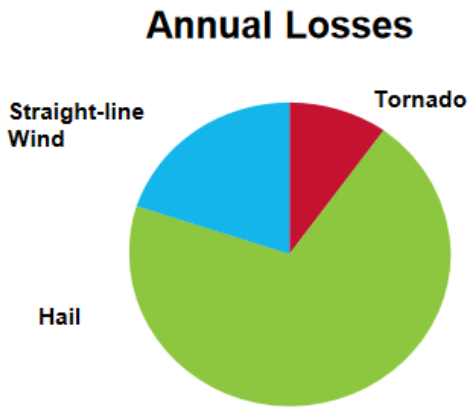




Convective Storm Losses

Convective storm losses

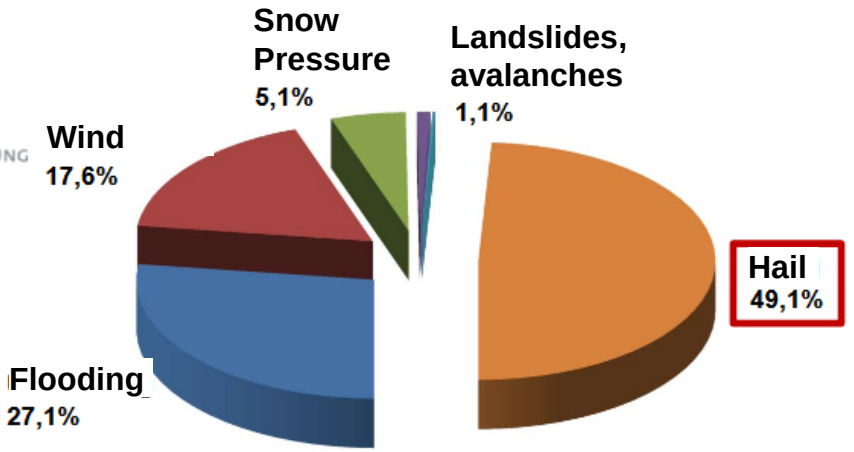




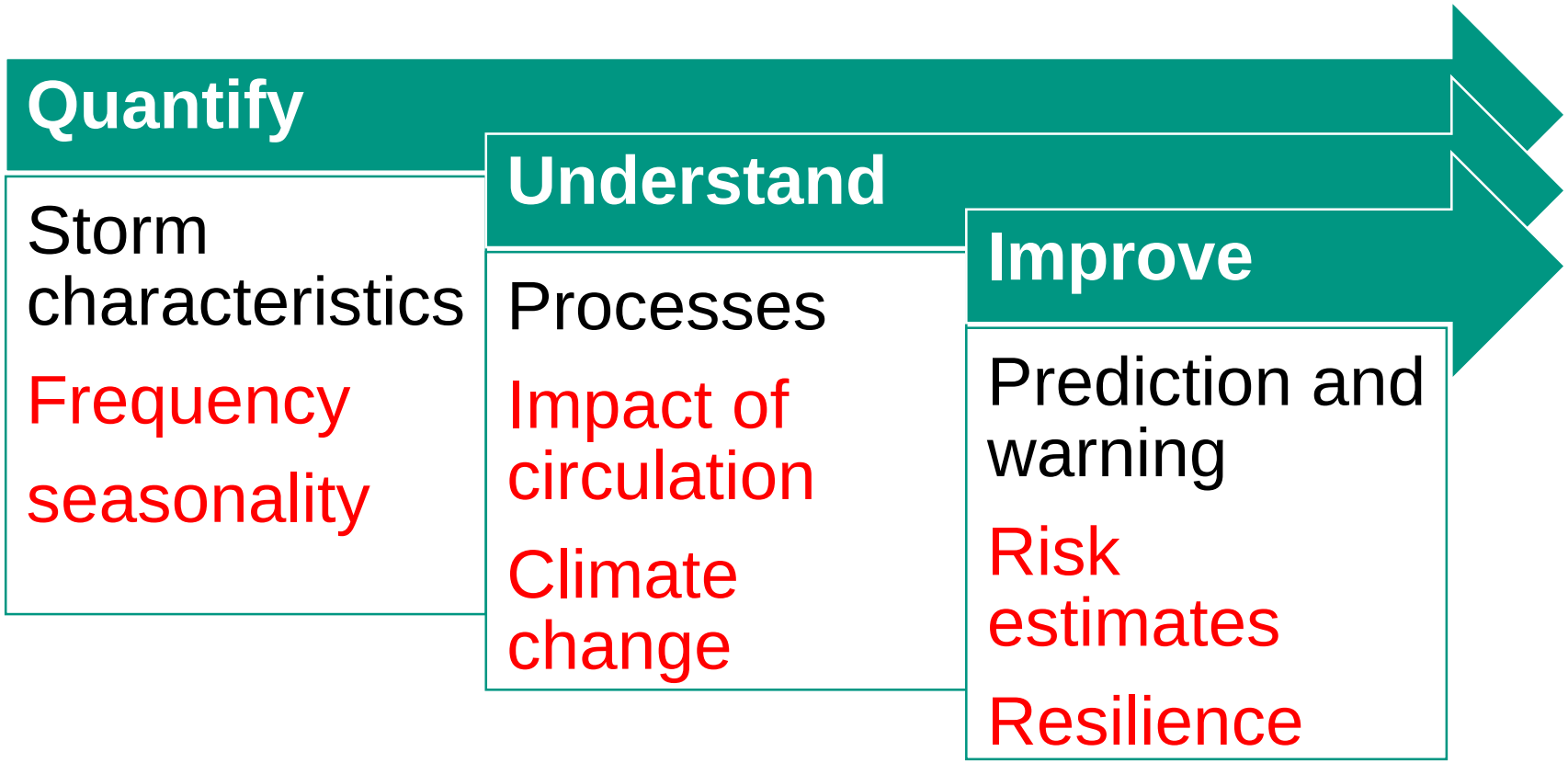
Zürich

GVZ GEBÄUDEVERSICHERUNG KANTON ZÜRICH

Building damage by hazard, 2006-2015

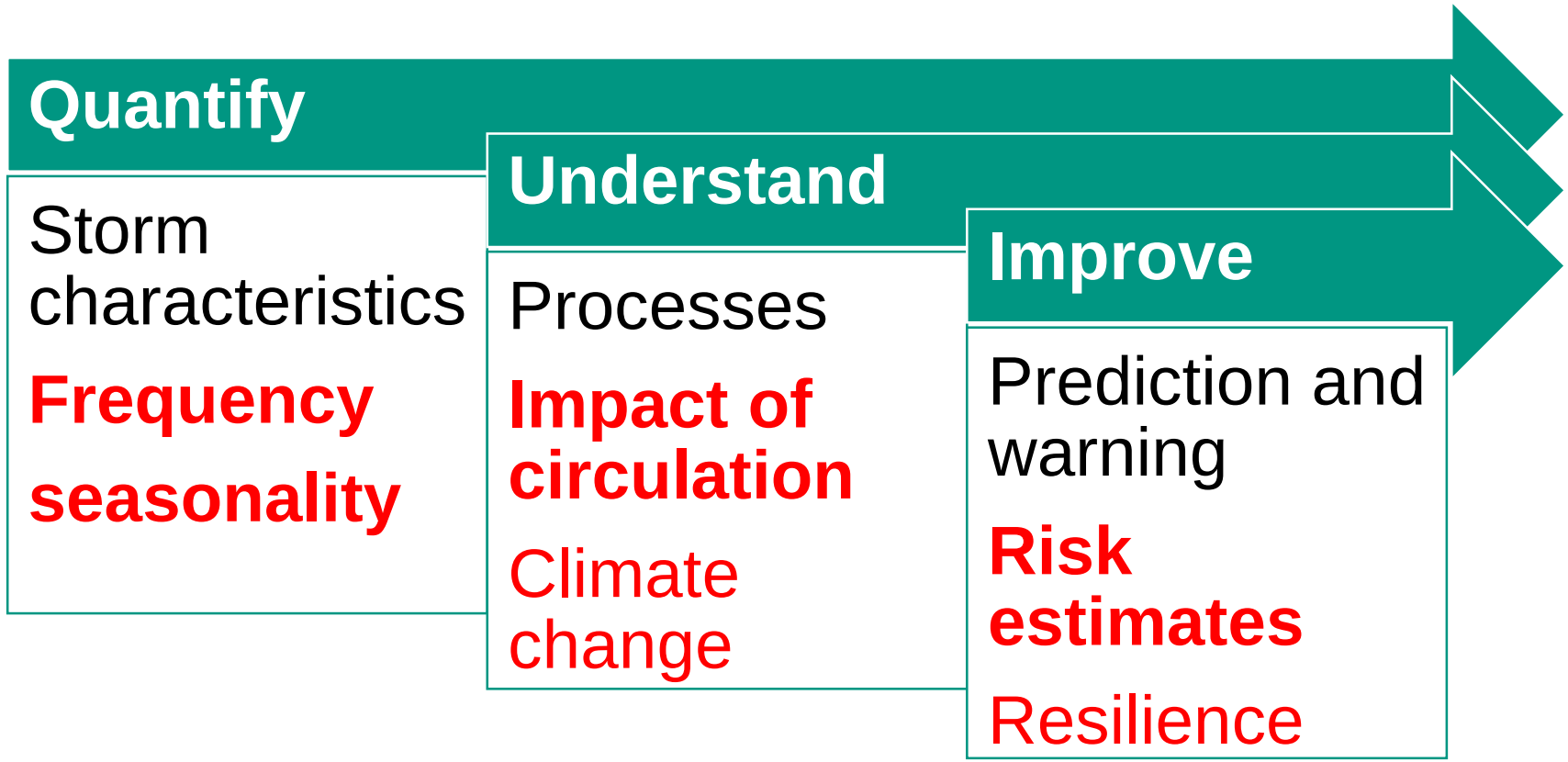


Challenges in Convective Storms Research



- Raise awareness
- Limit losses

Challenges in Convective Storms Research



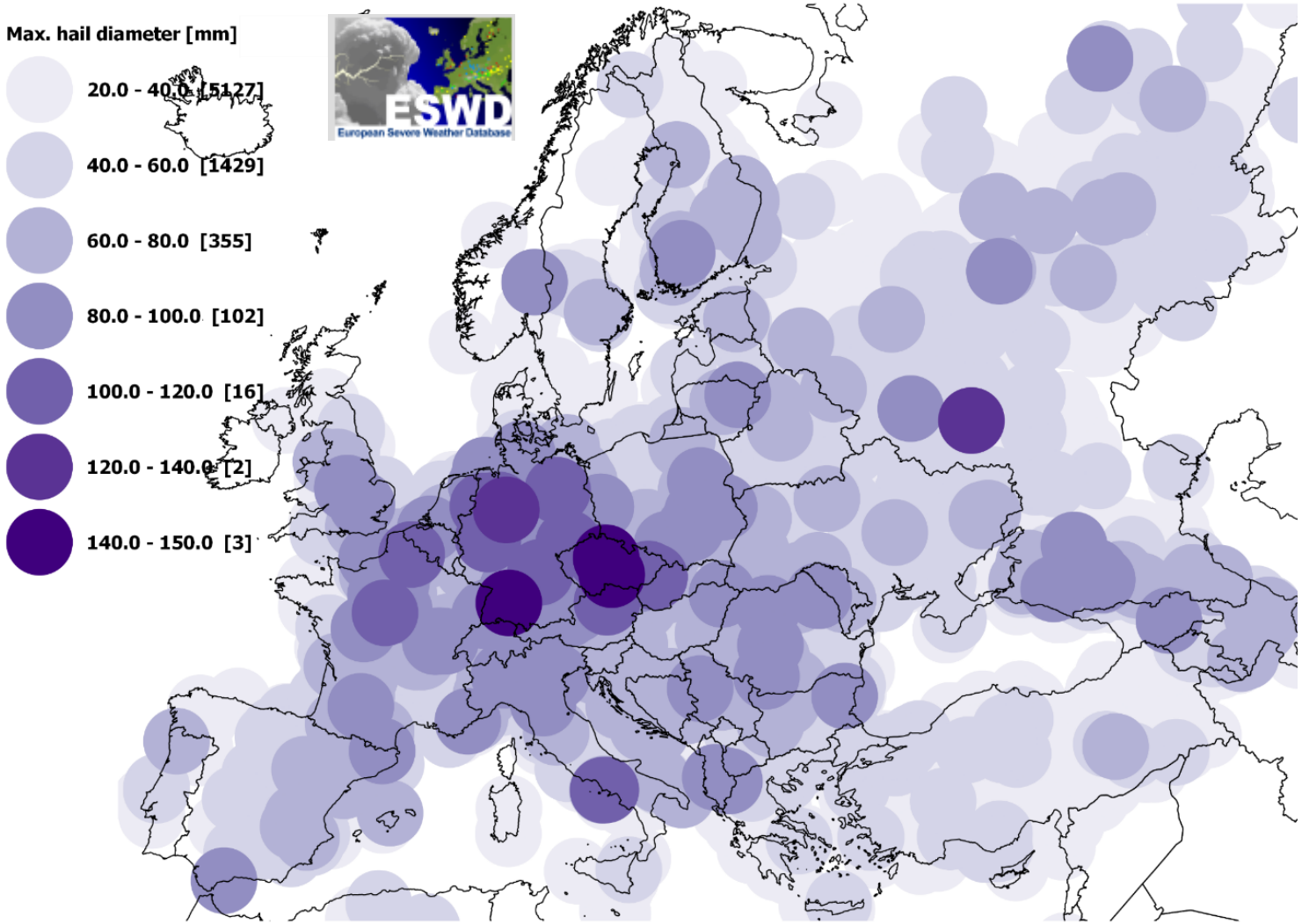
- Raise awareness
- Limit losses

I Quantify Characteristics

Example hail:

- Detect storms from reports / radar / lightning / satellite sensors
- Estimate climatology from long time series

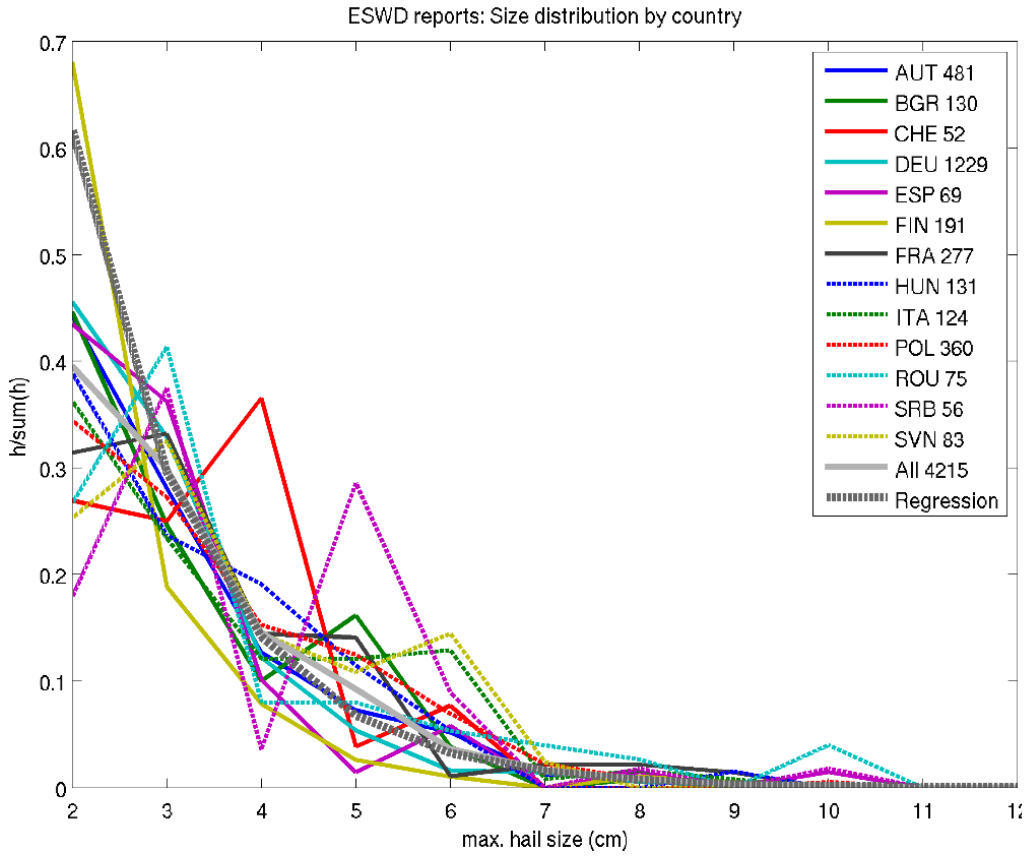
Reported hailstone sizes in Europe

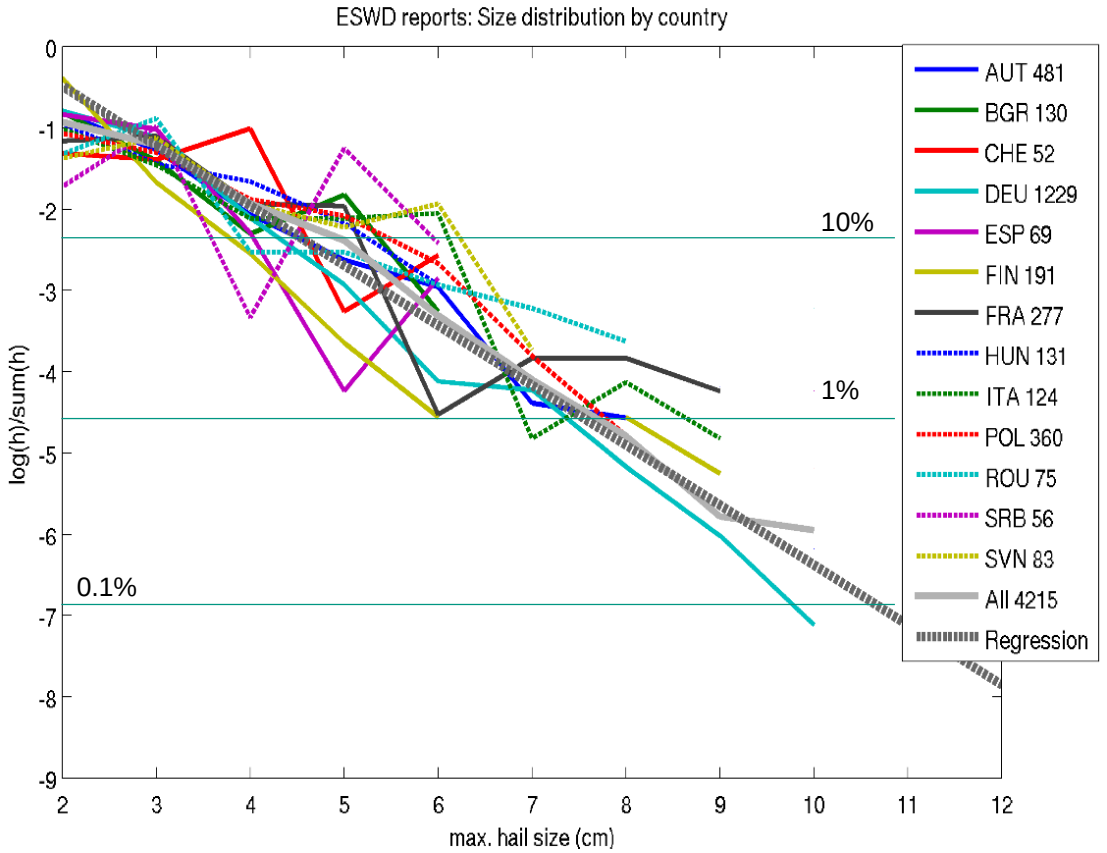


Databases like ESWD, EWOBS collecting information from

- news reports
- trained spotters
- apps

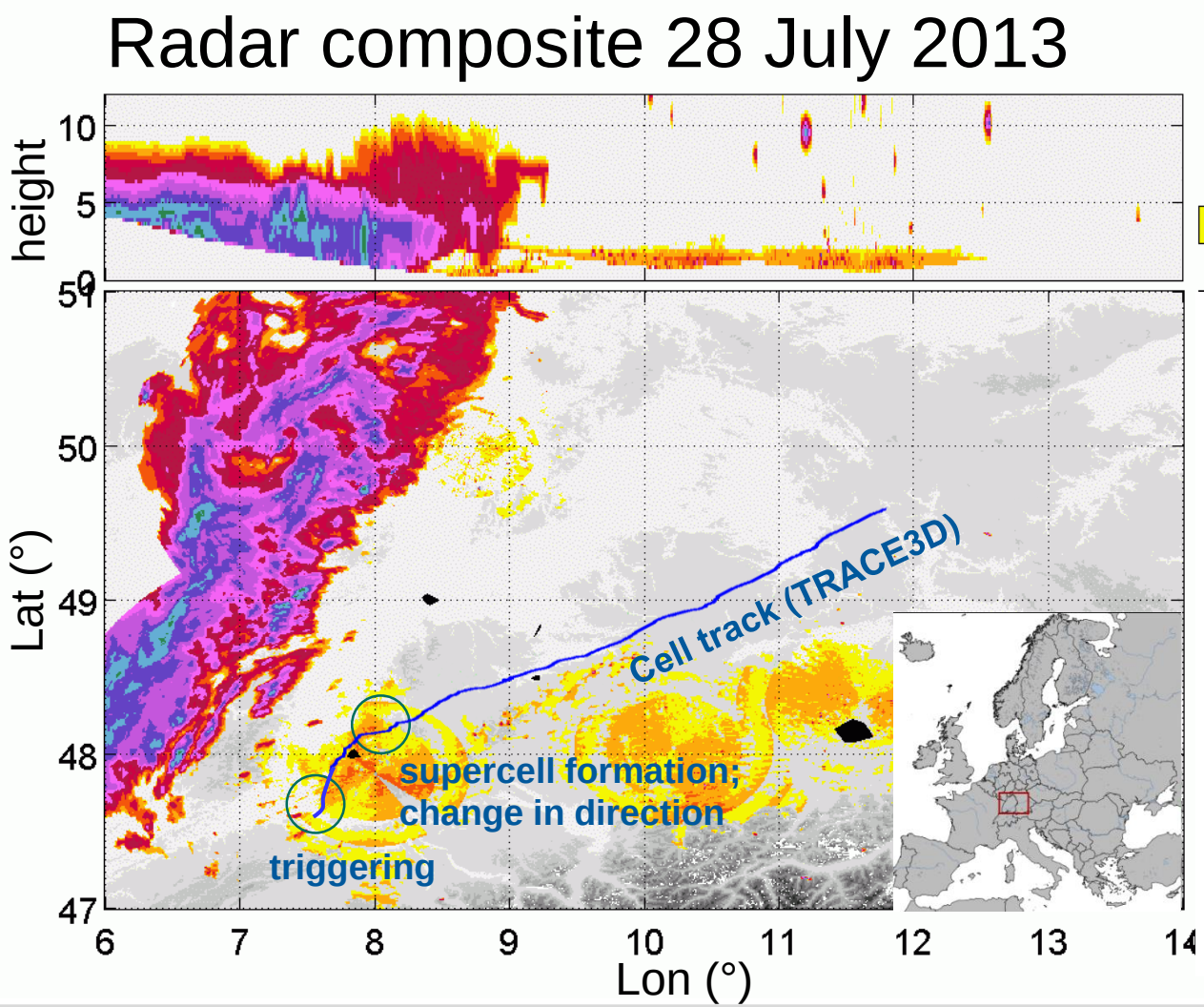
Size spectrum of hail





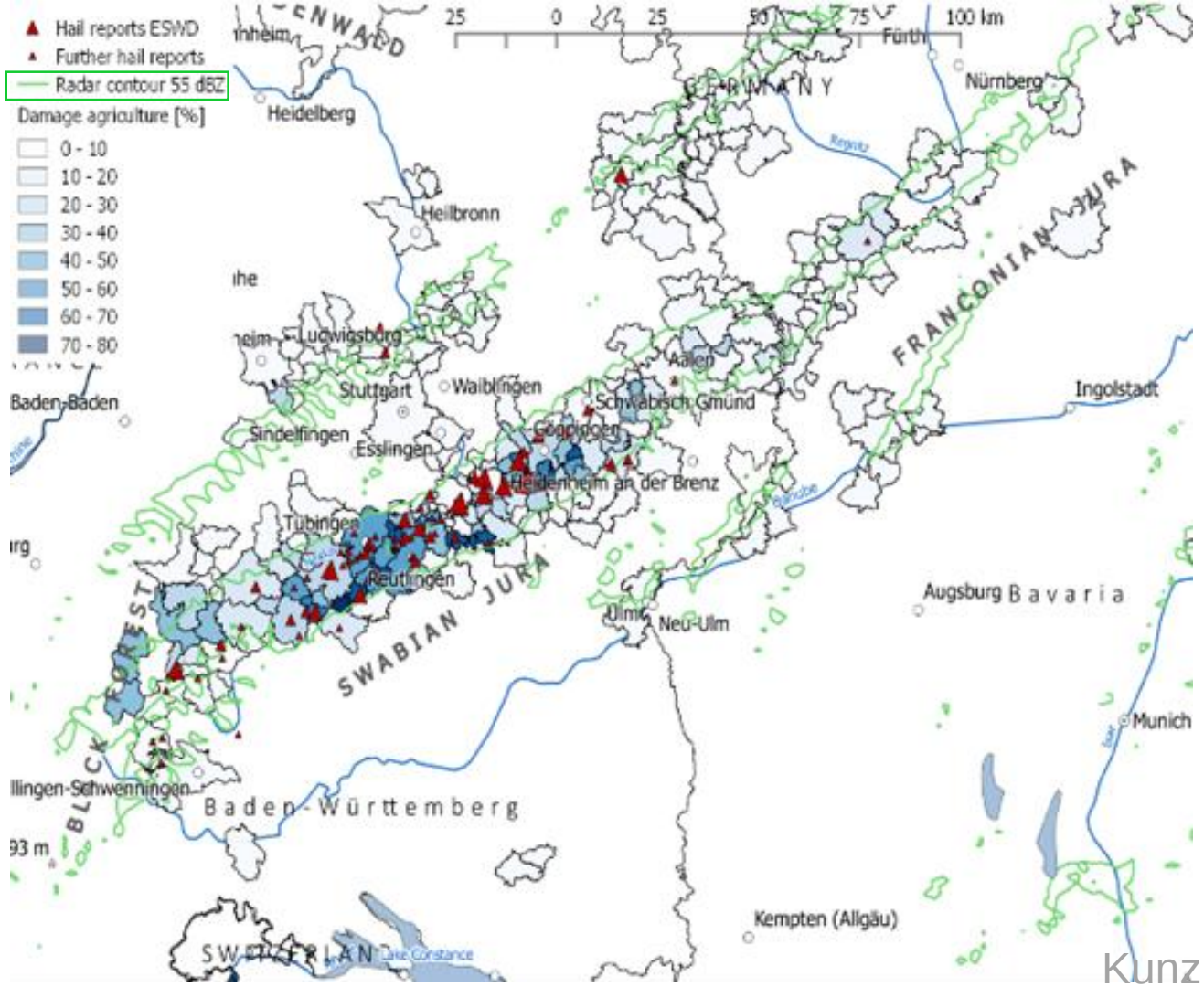
$p(dmax=d) \sim \exp(-\lambda d);\ \lambda \approx 0.76$

Hail observation by weather radar



- Reflectivity over 55 dBZ, over a large column
- Hail echo is independent of polarization, in contrast to rain

Reutlingen 28 July 2013 hailstorm



Footprint:

Radar product

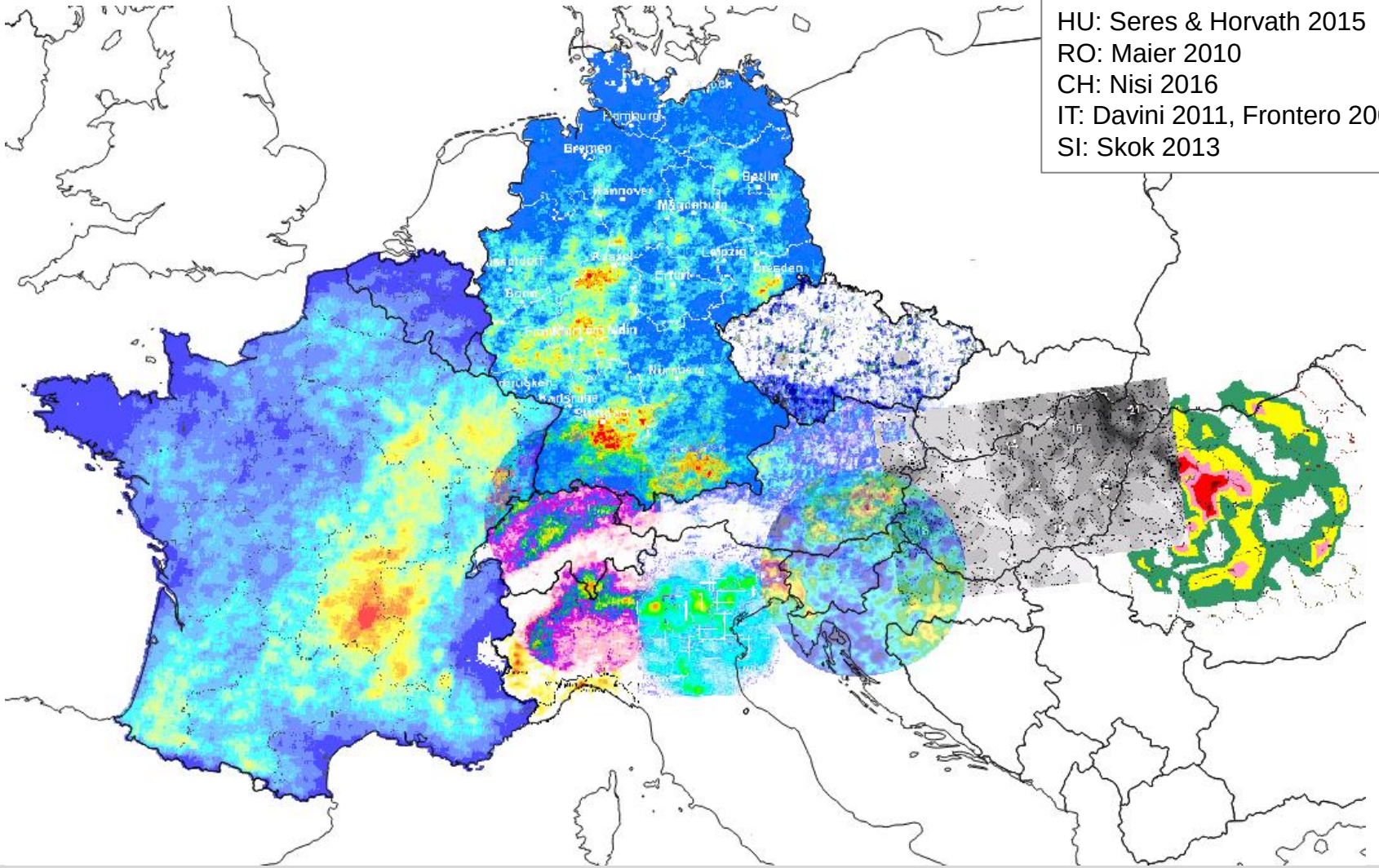
vs.

Agriculture damage

Kunz et al, submitted to QJRMS

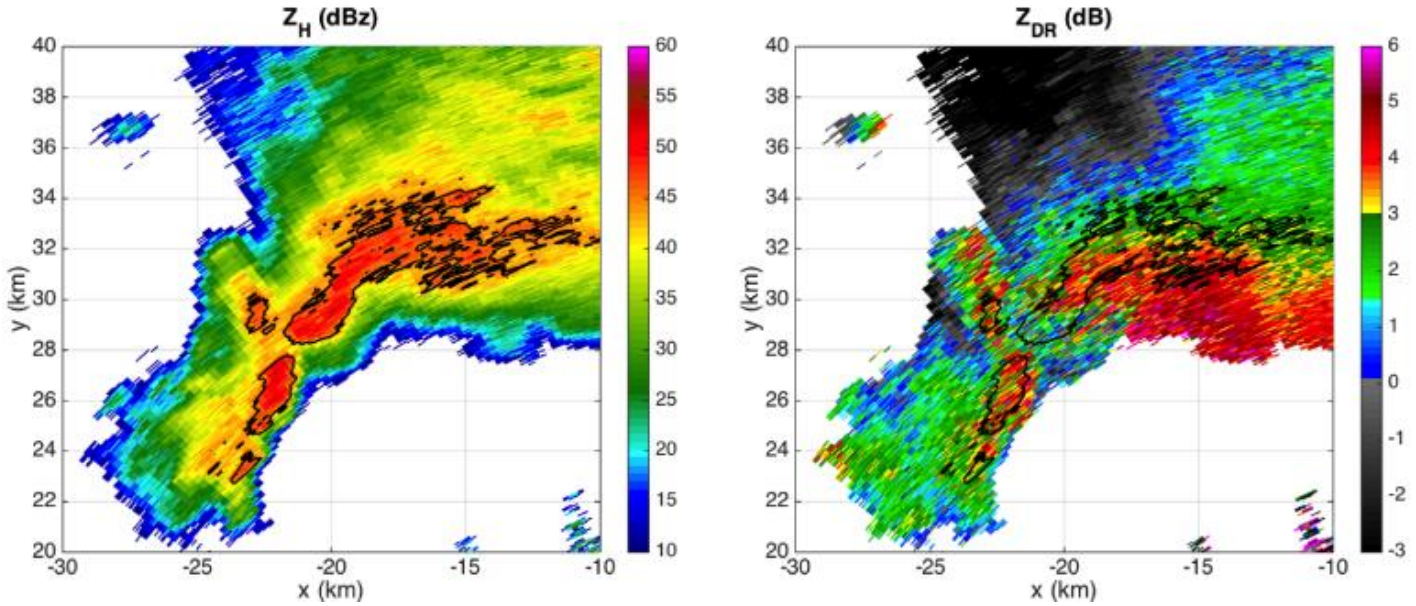
Hail climatologies using radar

Sources:
DE: Puskeiler 2016
CZ: Skripnikova 2013
FR/BE: Fluck 2016
AT: Kaltenböck 2015
HU: Seres & Horvath 2015
RO: Maier 2010
CH: Nisi 2016
IT: Davini 2011, Frontero 2008
SI: Skok 2013



Radar: Technological advances

- Dual Polarization: distinguish tumbling hailstones from oblate drops
- Higher scanning frequency, spatial resolution
- Improved algorithms for storm detection (e.g., machine learning)



Kumijan et al. JAMC 2017

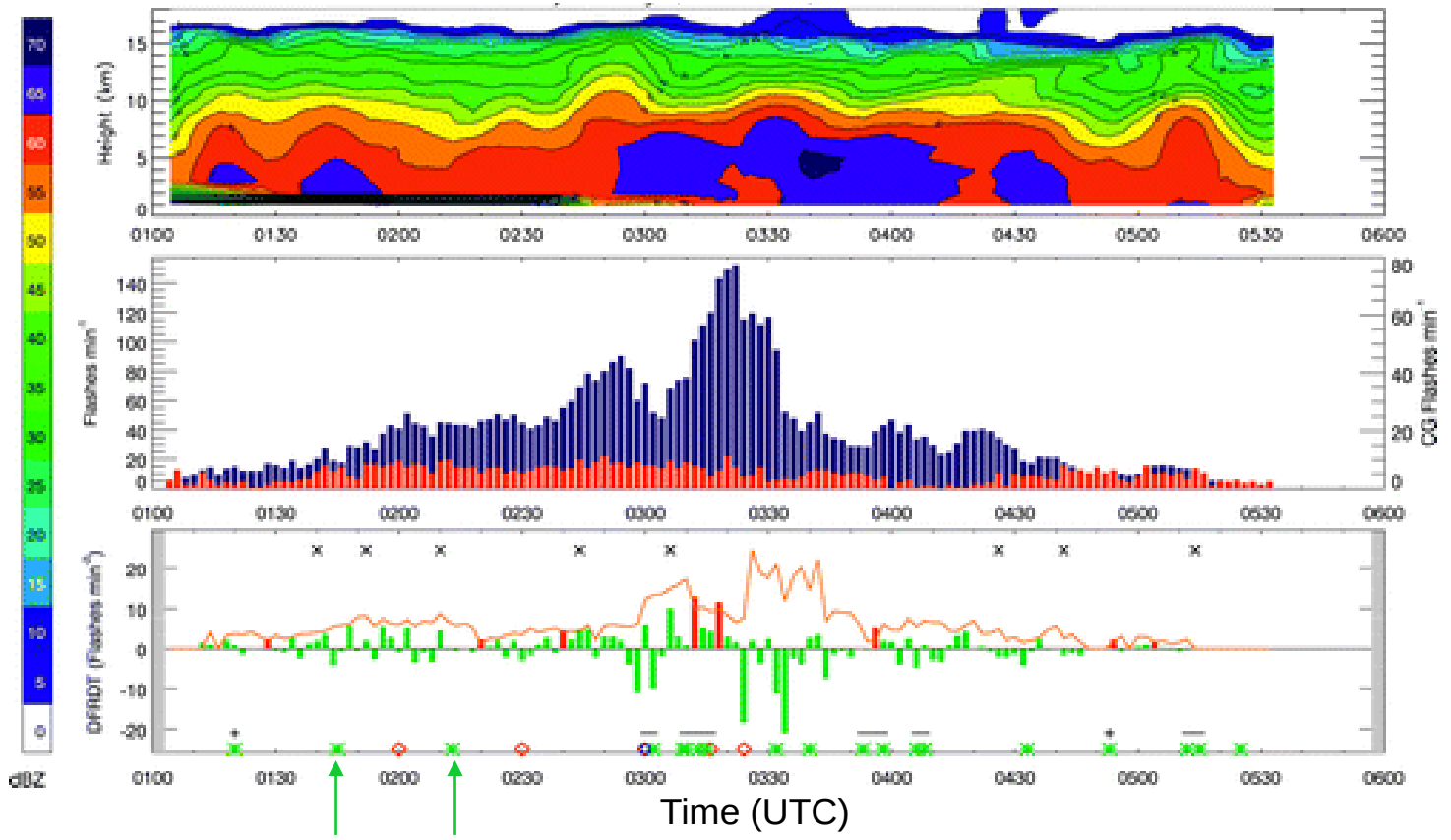
Lightning (Jumps) concept

Hailstorm in Alabama, 04 Aug 2006

Radar Reflectivity

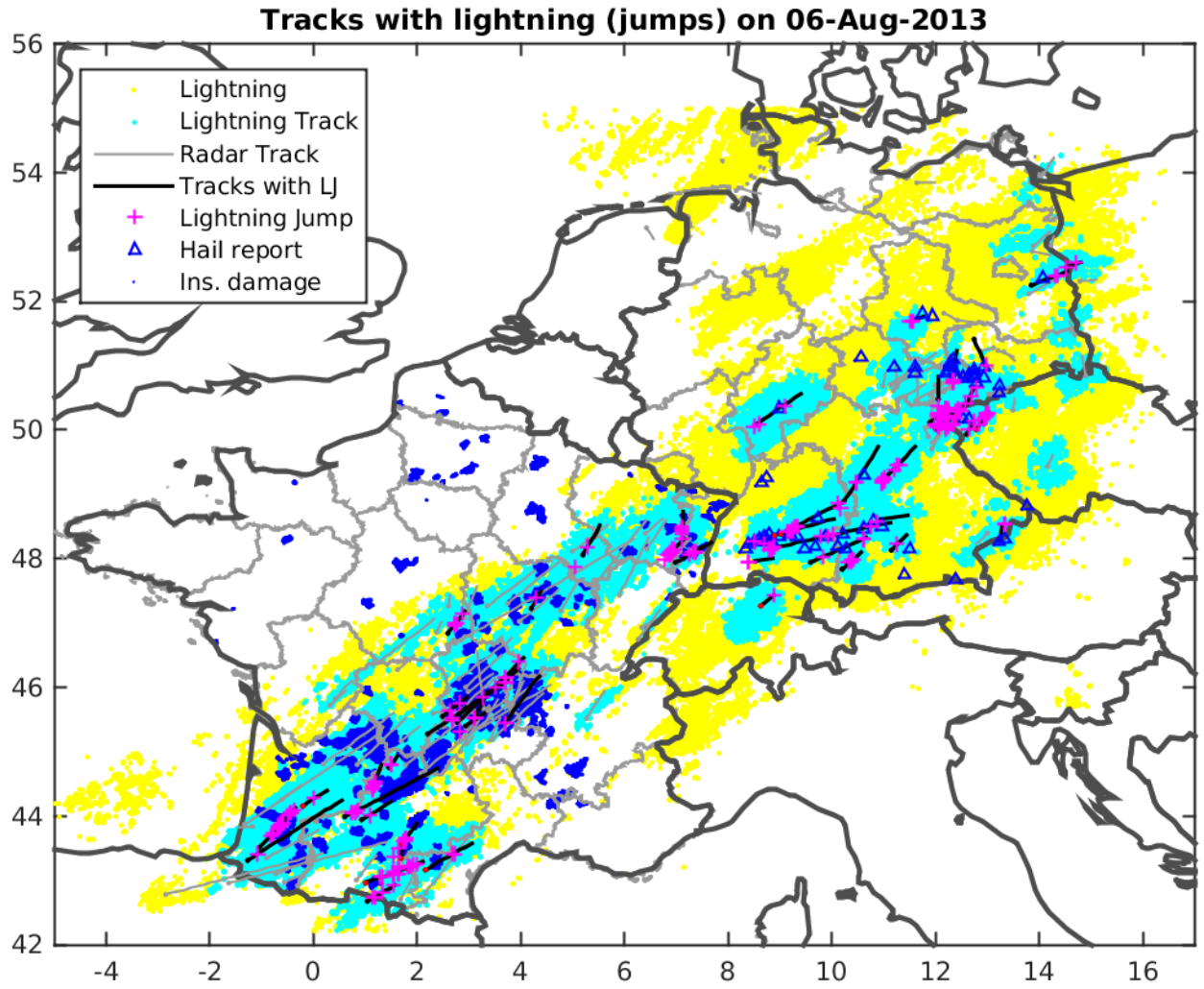
Cloud-to-ground flash rate

Rate of change, „Lightning Jumps“

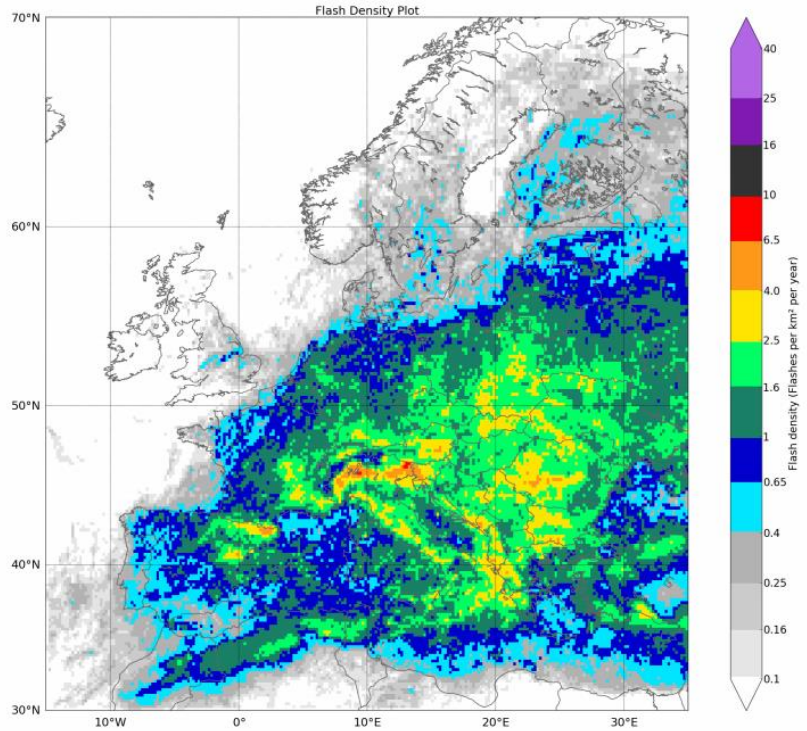


Schultz WAF 2011

Lightning (Jumps)



Flashes per year 2008-2012

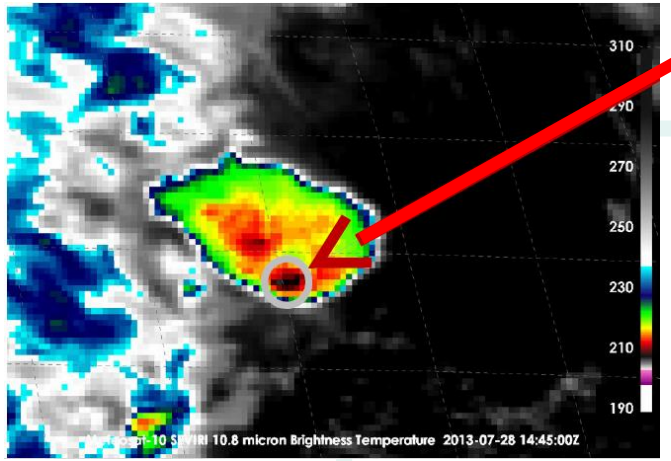


Anderson and Klugmann, NHESS 2014

Hail observations: Satellite

- Overshooting tops (OTs): intrusions of convective cloud to lower stratosphere
- Indicator of very strong convective updrafts
- Detection of cold pixels in IR satellite imagery

Meteosat



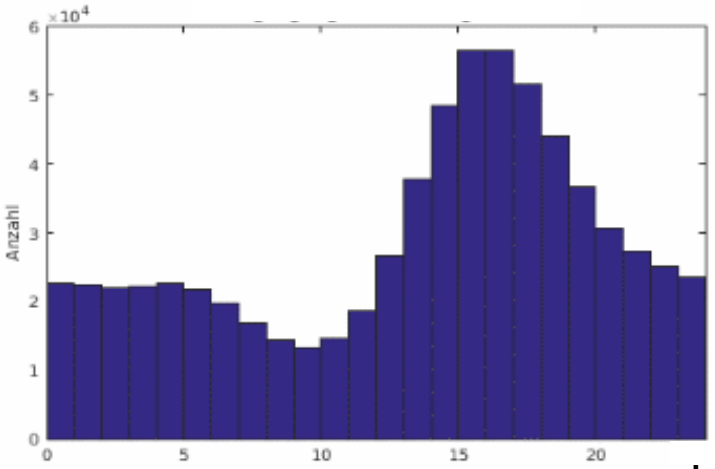
OT

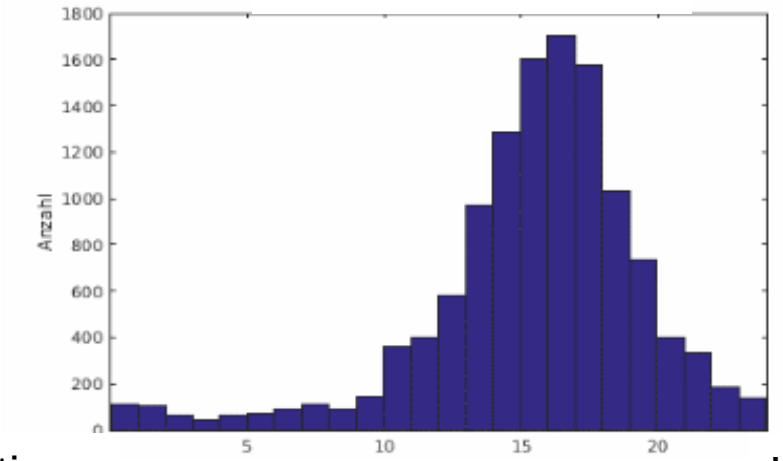
Meteosat (MSG):
SEVIRI instrument
cloud top temperatures

28 July 2013,
13-17 UTC

Daily cycle

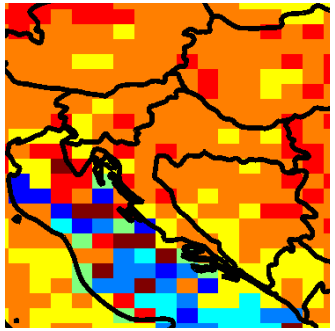
Over-shooting tops

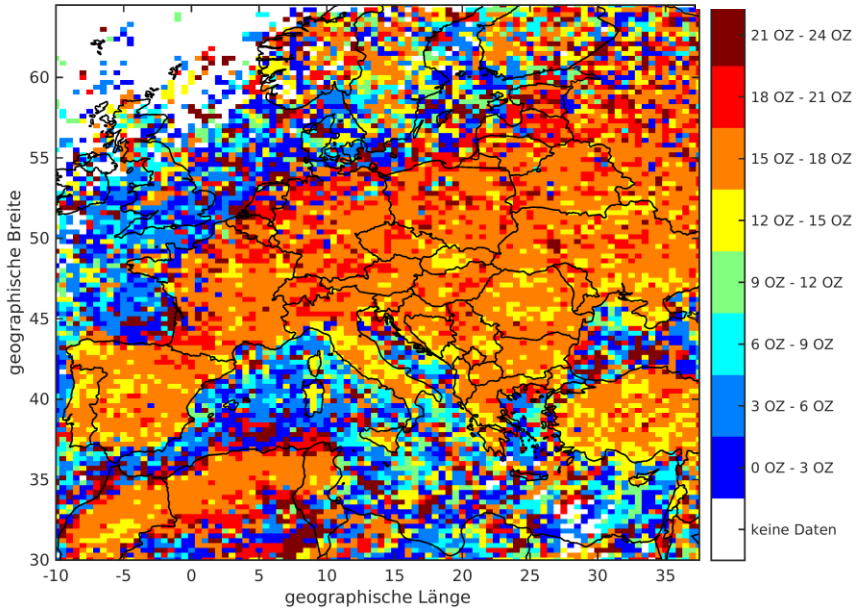




Hail reports

Local time





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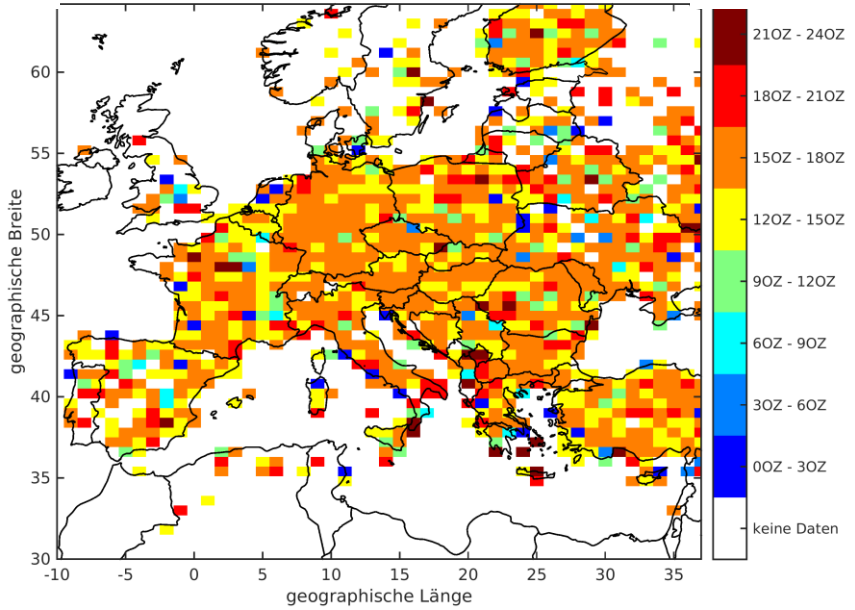
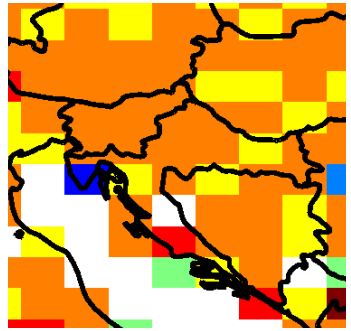
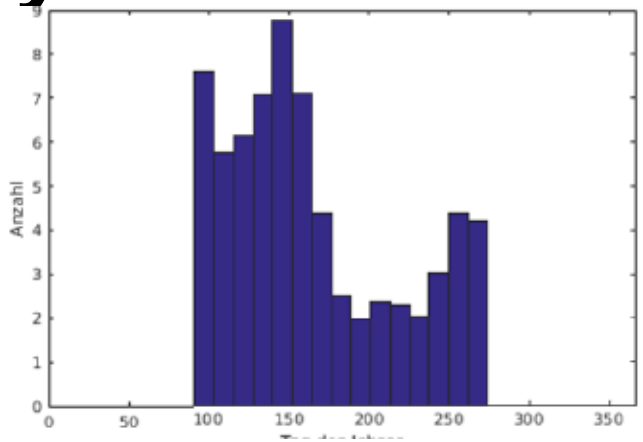
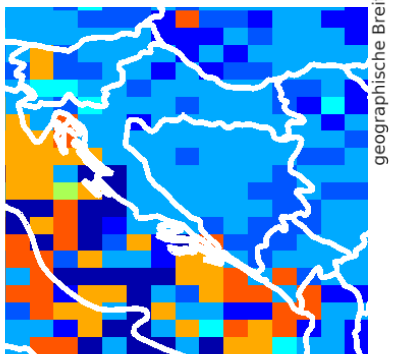


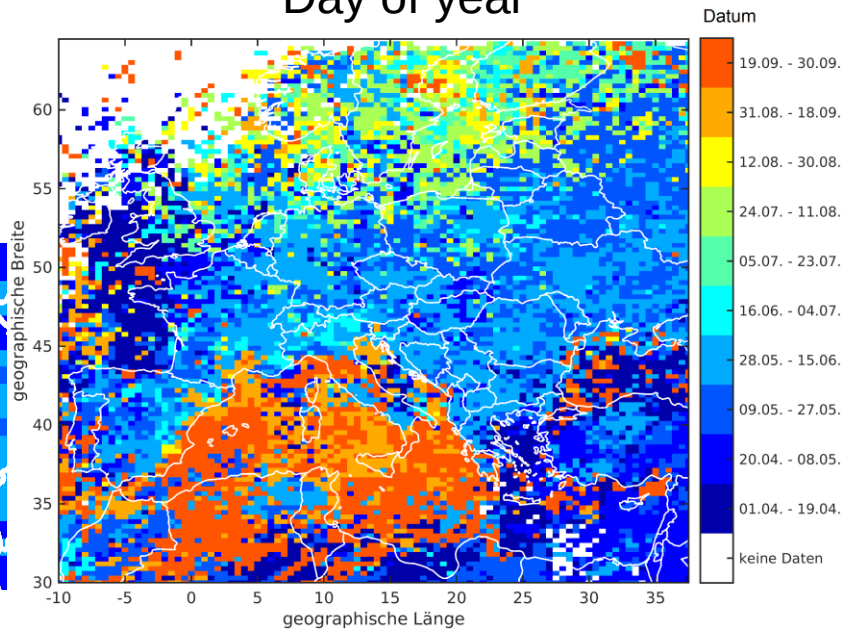


Annual cycle

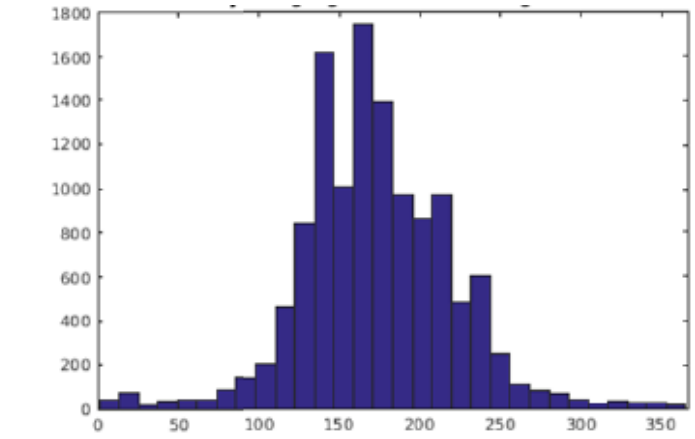
Over-shooting tops

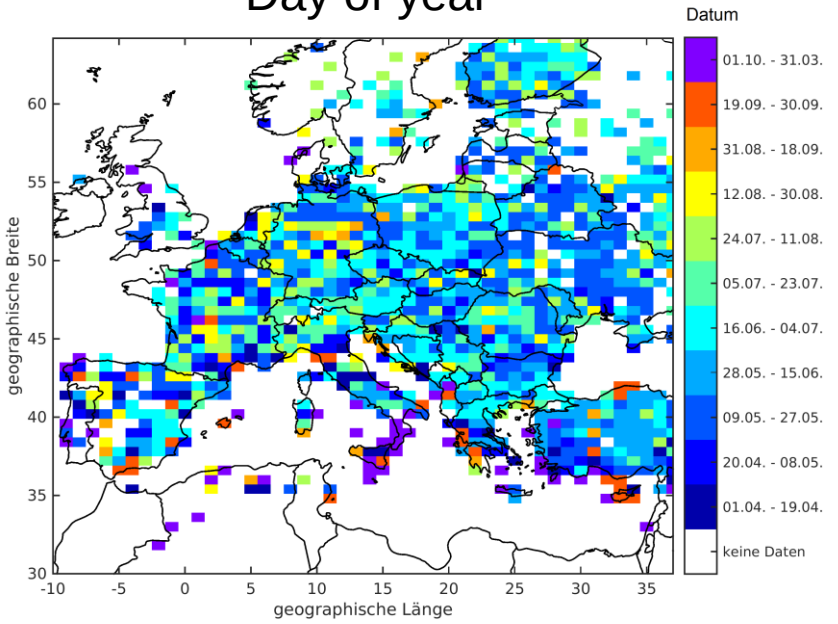


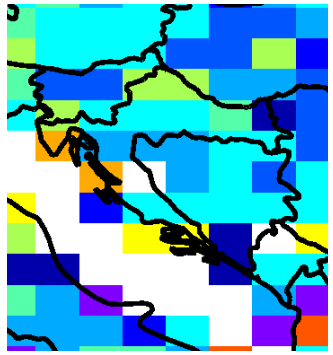




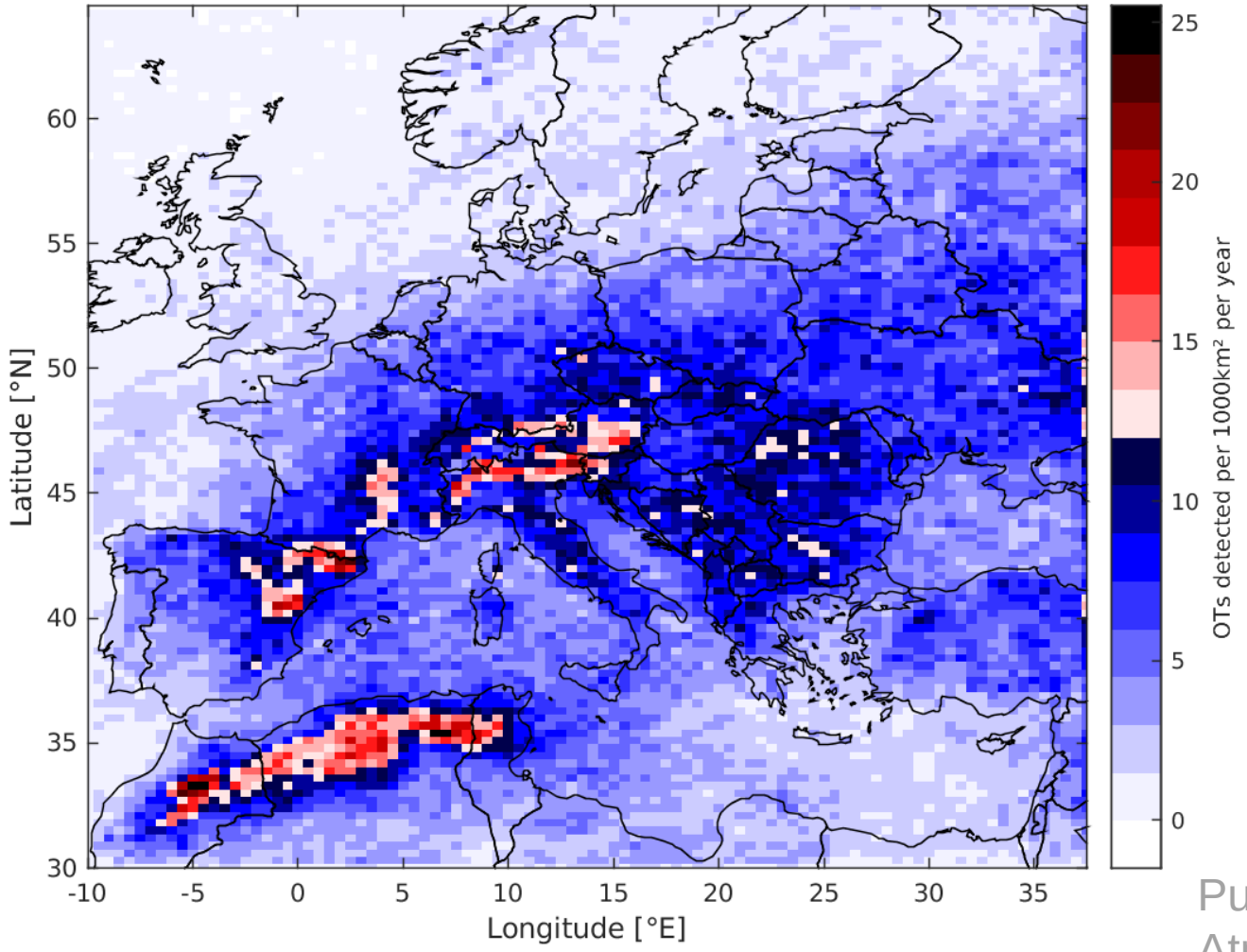
Hail reports







OT frequency Europe 2004-2014



MSG SEVIRI

15-minute scan interval

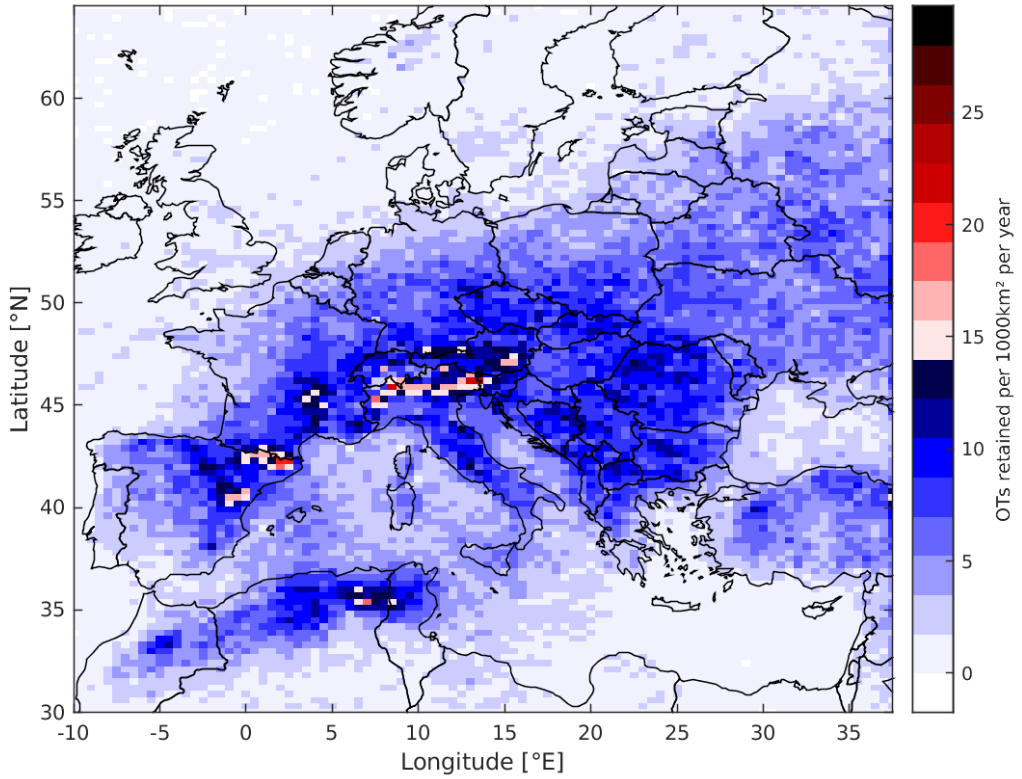
April to September

Punge et al., Atmos Res 2017

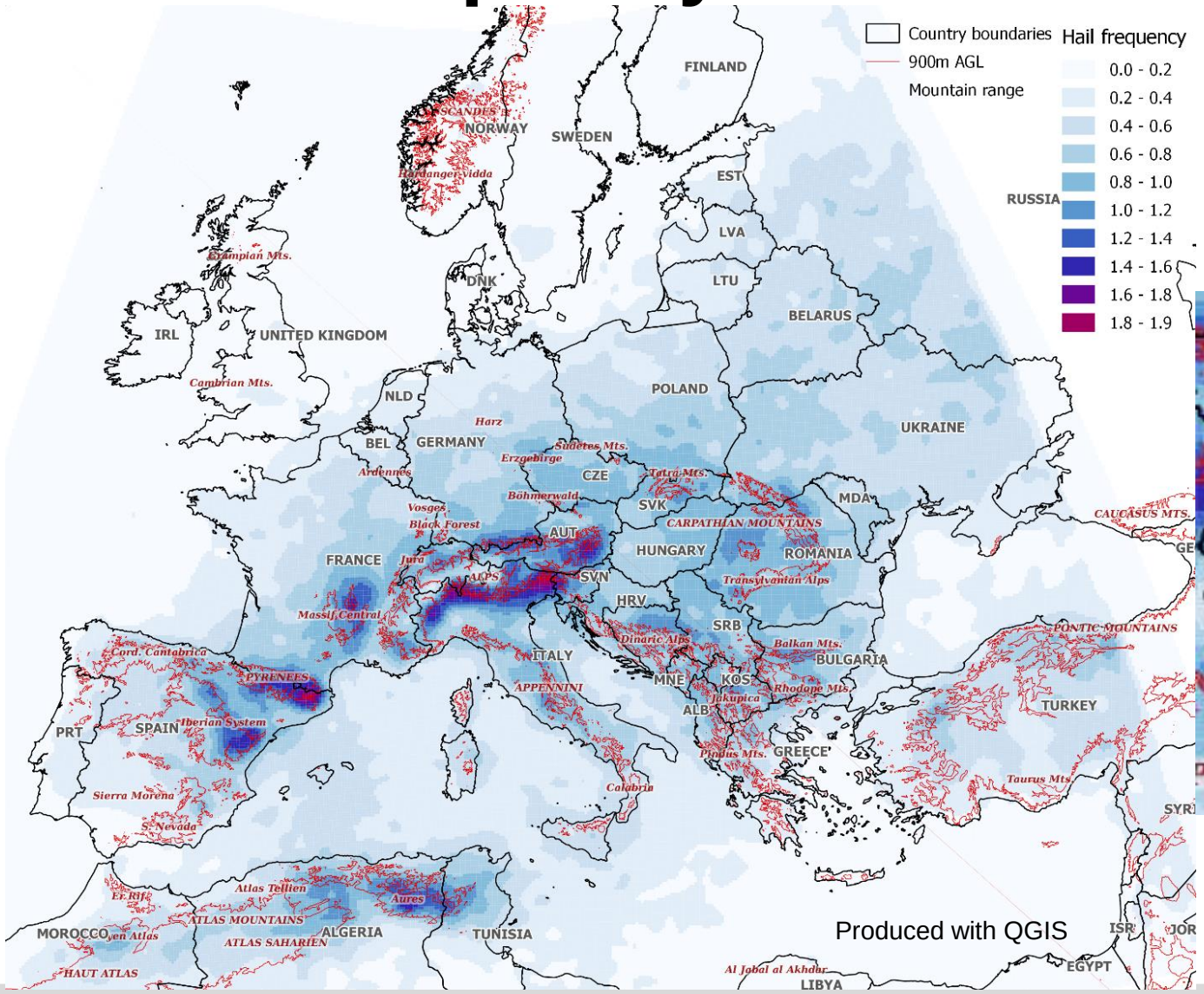
OT frequency Europe, filtered

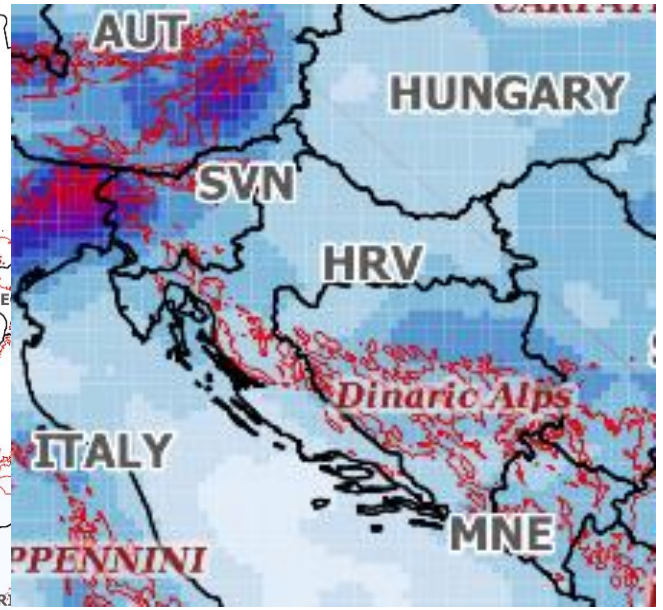
Filtered for:

- CAPE > 5 J/kg
- Bulk wind shear > -0.97m/s
- Freezing level height, <4420m



Continental hail frequency estimate for Europe

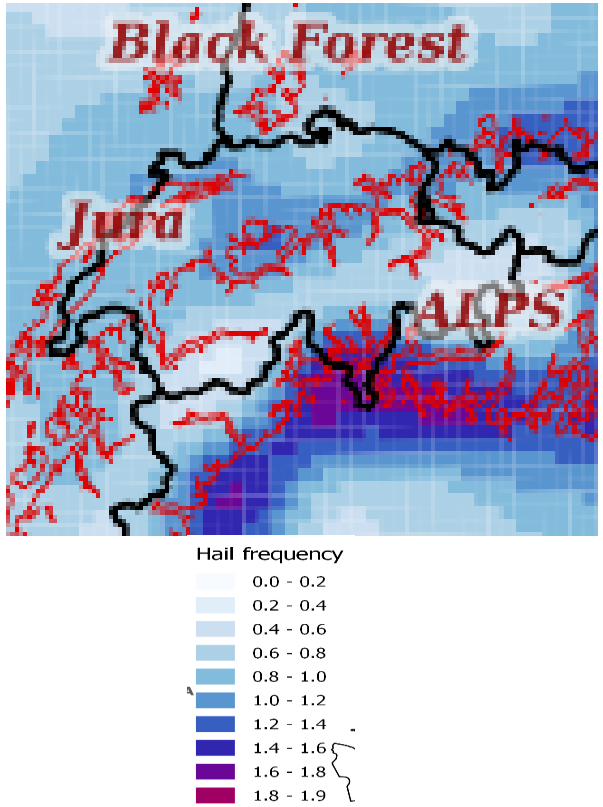


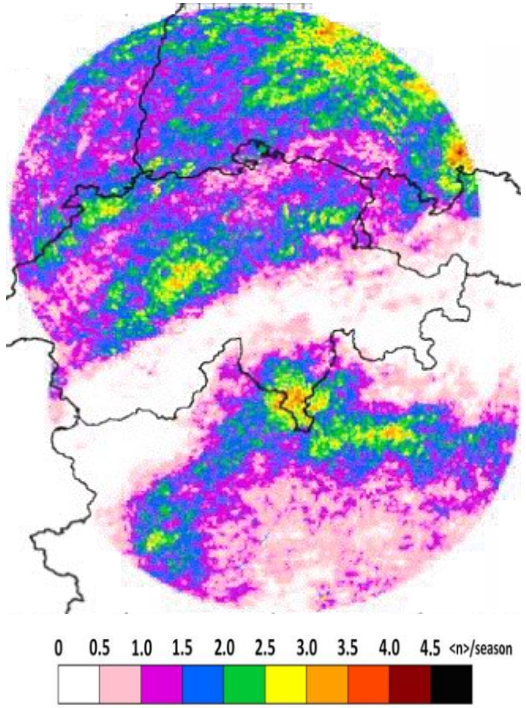


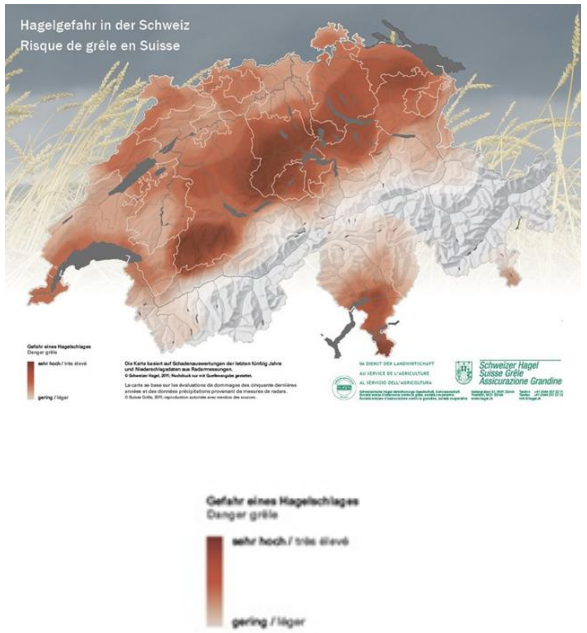
Occurences per year and 100 km²

Punge et al., Atmos Res 2017

Continental hail frequency estimate



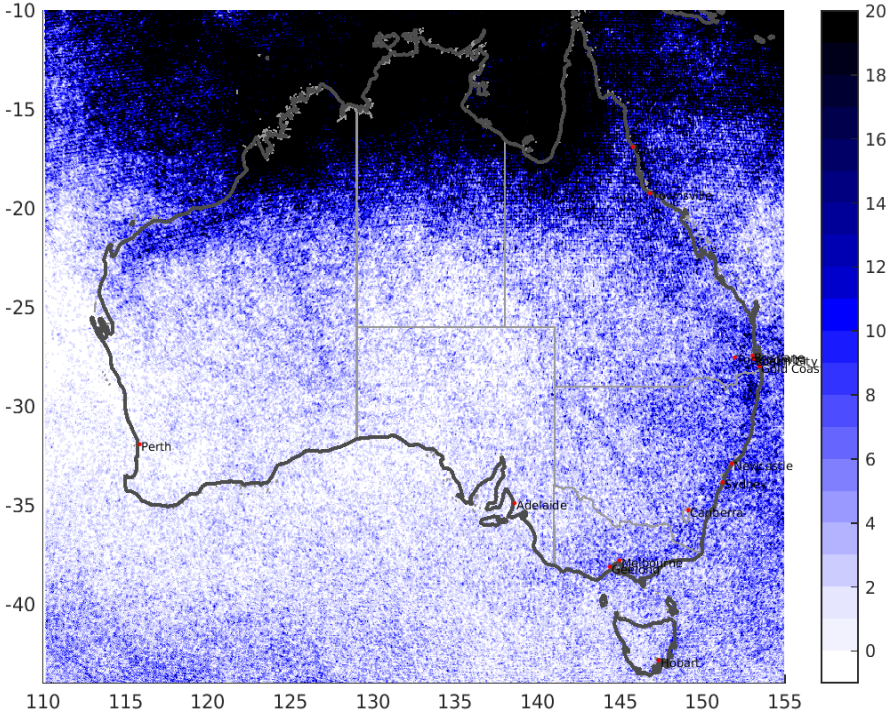


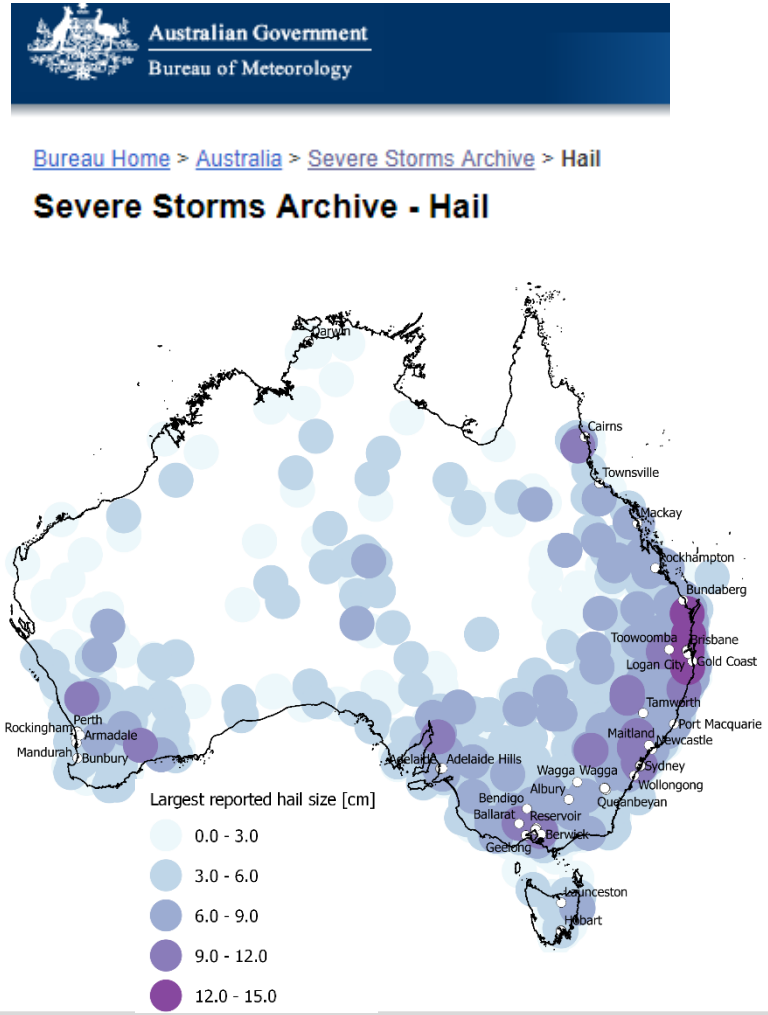


Punge et al, Atmos Res 2017 Nisi et al, QJRMS 2016 Swiss Hail (insurance)

Overshooting top hail proxy for Australia

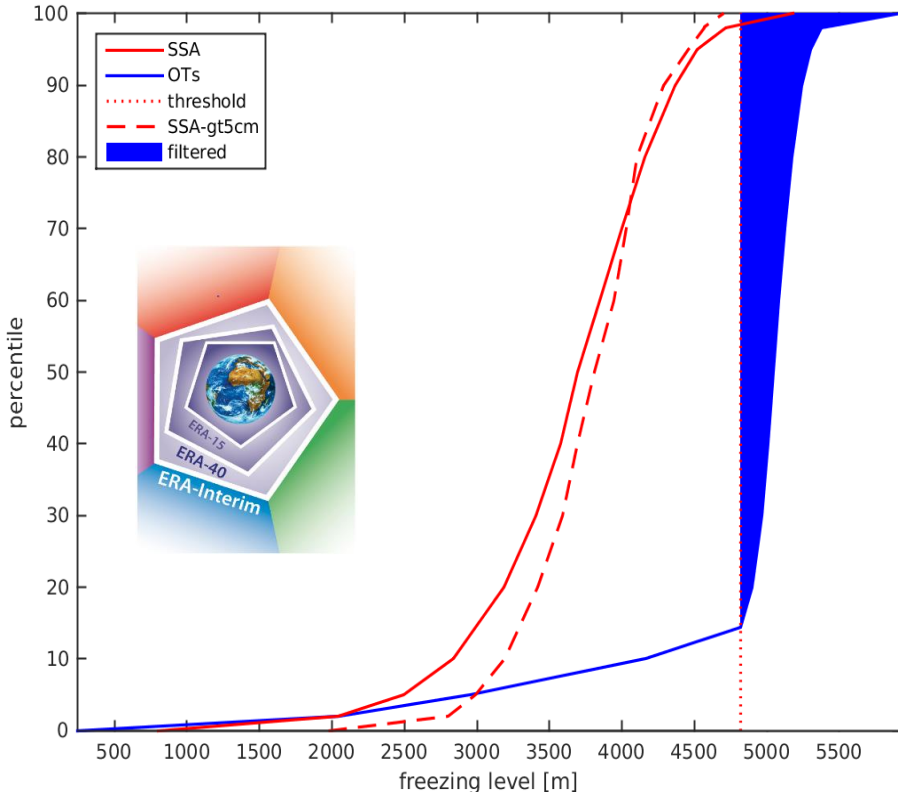
OT count from
JMA MT-SAT hourly
scans (2005-2015)





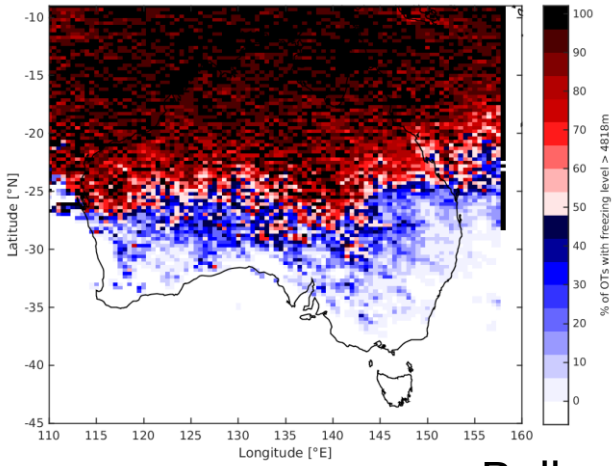
Overshooting top hail proxy for Australia

Filter OT data with reanalysis of hail report conditions

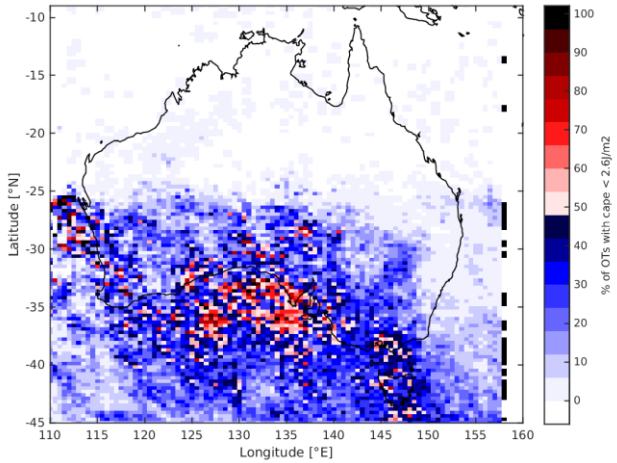


Bedka et al 2018

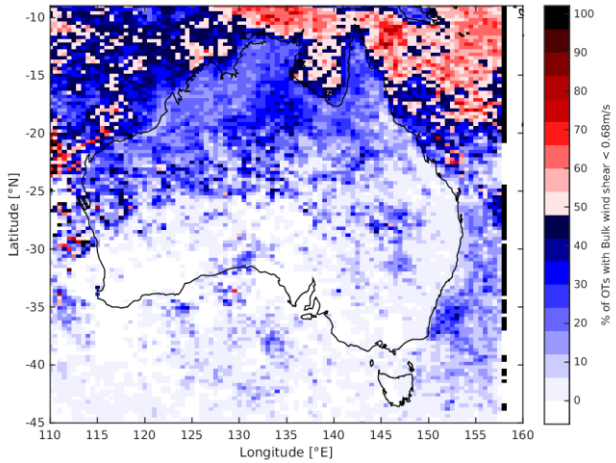
Freezing Level height



CAPE



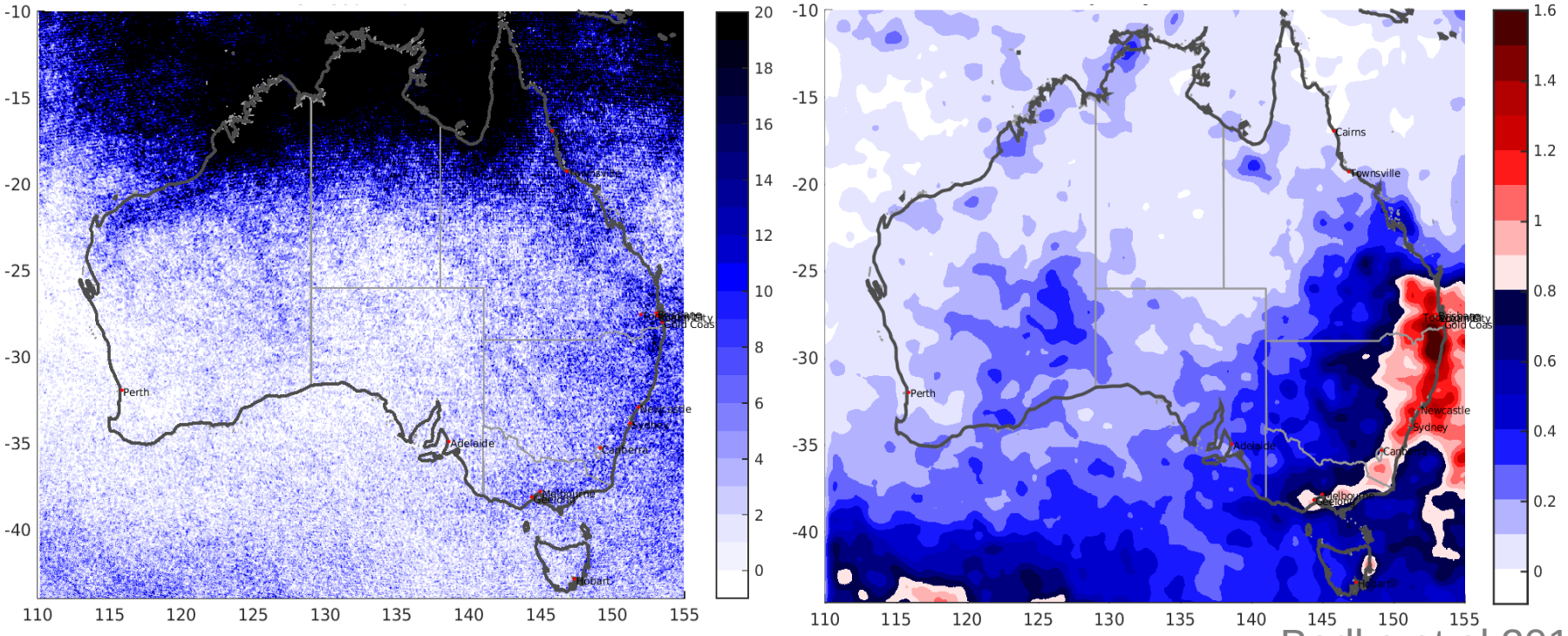
Bulk wind shear



Overshooting top hail proxy for Australia

Before filter

After filter

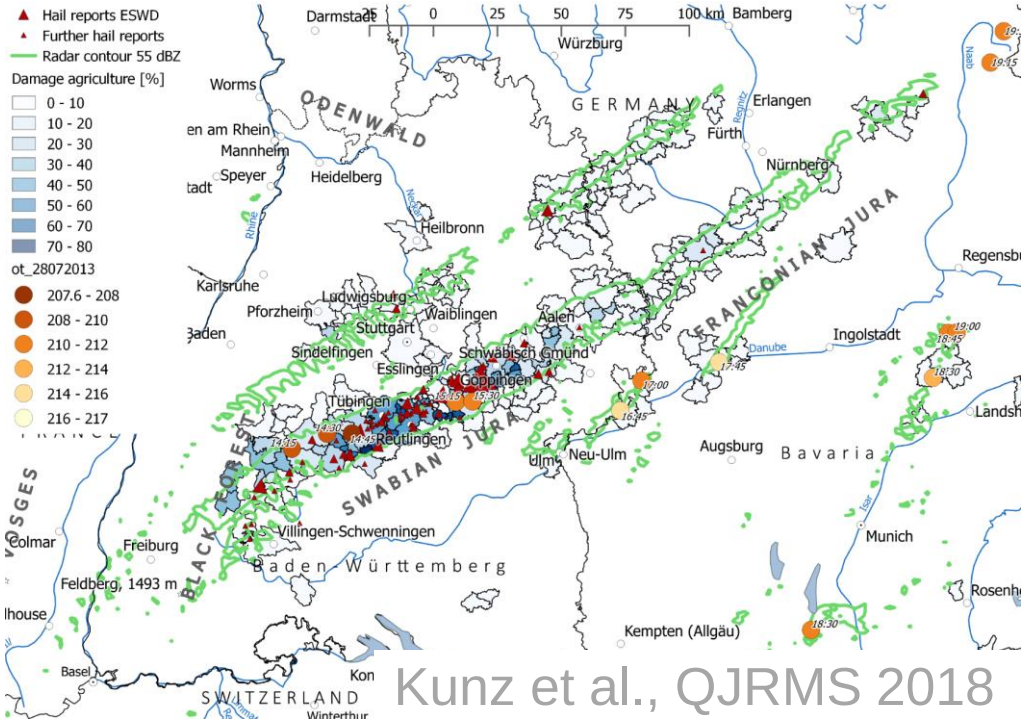


Bedka et al 2018

Novel technology: Satellite detection

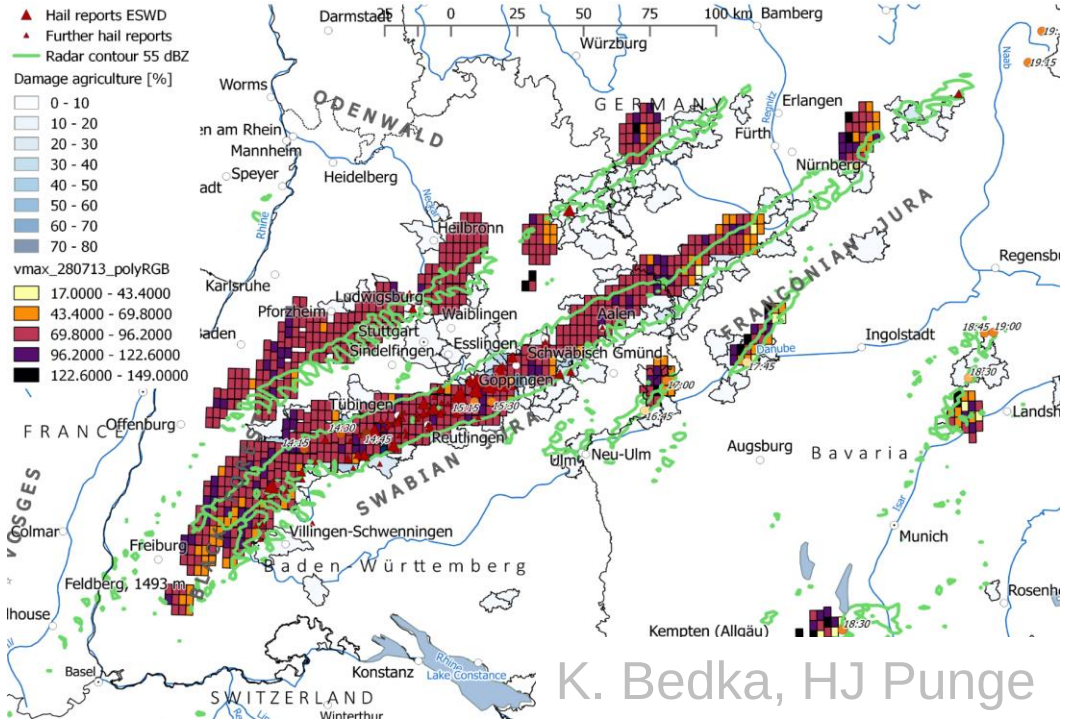
- Improved coverage with latest generation of satellites (1-5 min, 1-5 km)
- Combining data from spectral bands
- Improved algorithms (automated pattern reognition, machine learning

28 July 2013 hail track from radar



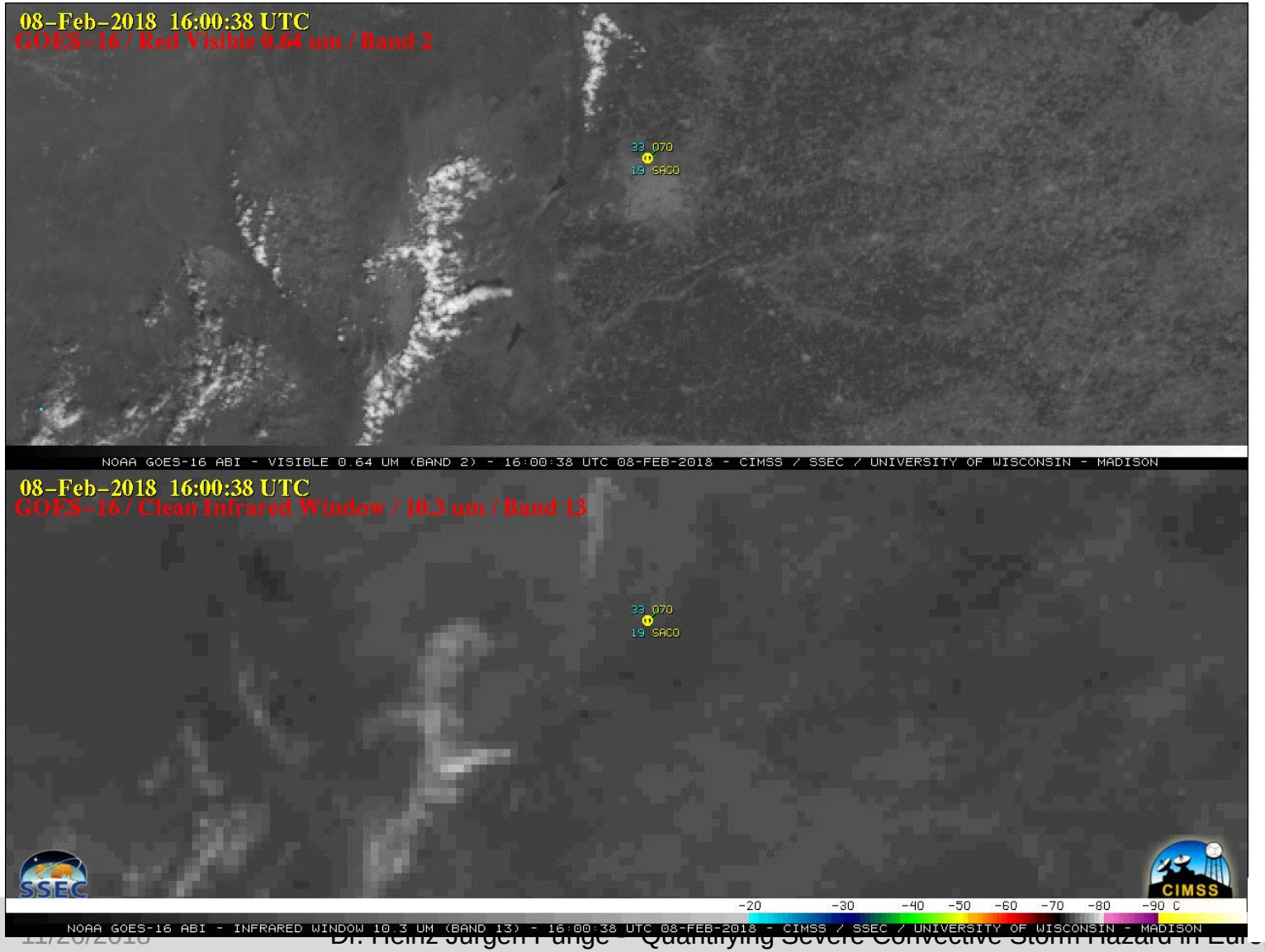
Kunz et al., QJRMS 2018

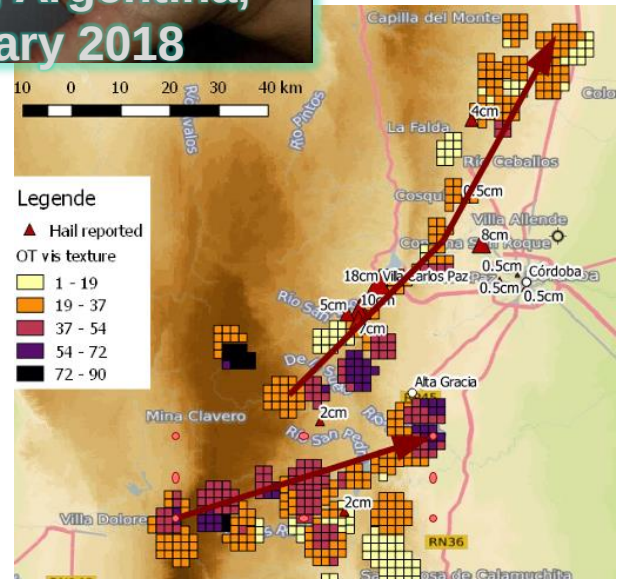
Satellite OT vs radar-derived track



K. Bedka, HJ Punge

Novel technology: Satellite detection





OT method: Bedka and Khlopenkov, 2016

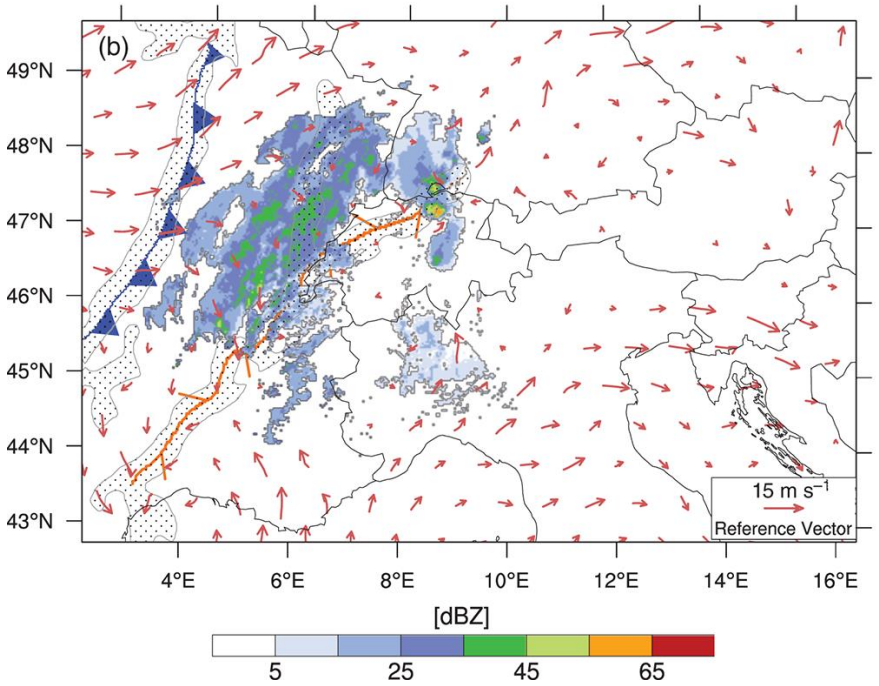
II Understanding storm frequency

- **Insolation**
- **Weather Systems**
- **Topography**
- **Distance to sea**
- **Land surface type**

II Understanding storm frequency

- Insolation
- **Weather Systems**
  - SW flow along trough
    - Surface temperature
      - ↑ Vertical temperature gradient
    - ↑ Moisture content
  - Lower-level convergence
    - ↑ Dynamic Lifting
- Topography
- Distance to sea
- Land surface type

Switzerland: Storms forming in pre-frontal convergence area

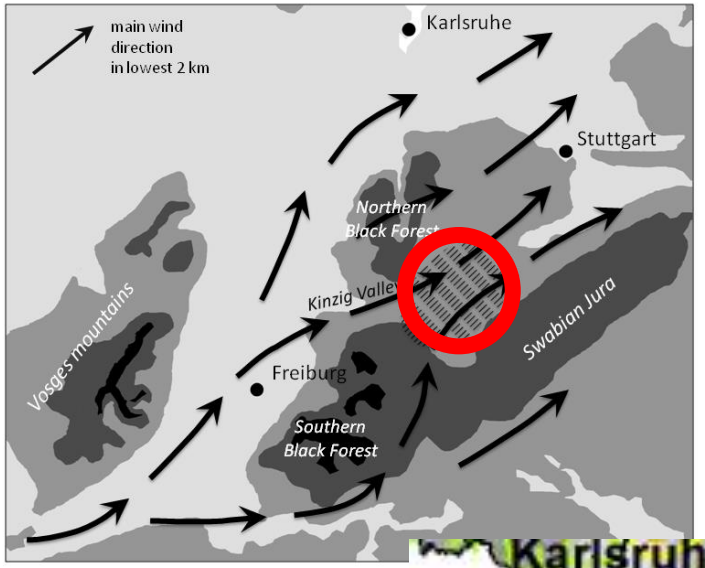


Schemm et al., Atmos Sci Lett 2016

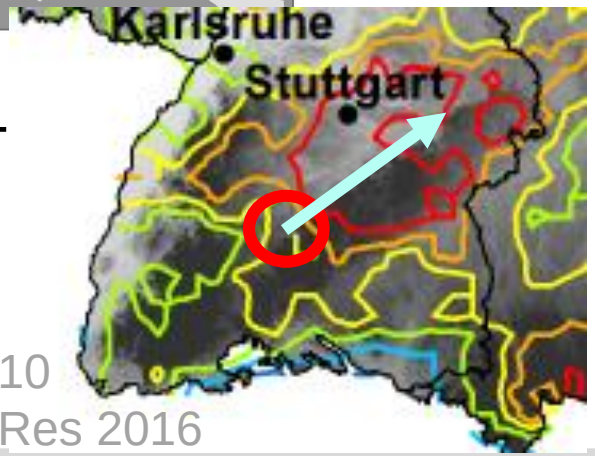
II Understanding storm frequency

- Insolation
- **Weather Systems**
  - Transport of warm air from SW
    - ↑ Vertical temperature gradient
    - ↑ wind shear
- **Topography**
  - Convergence
    - ↑ Dynamic lifting
- Distance to sea
- Land surface type

Flow around regime in Black Forest



$$Fr = \frac{U}{N\,H} < 1$$

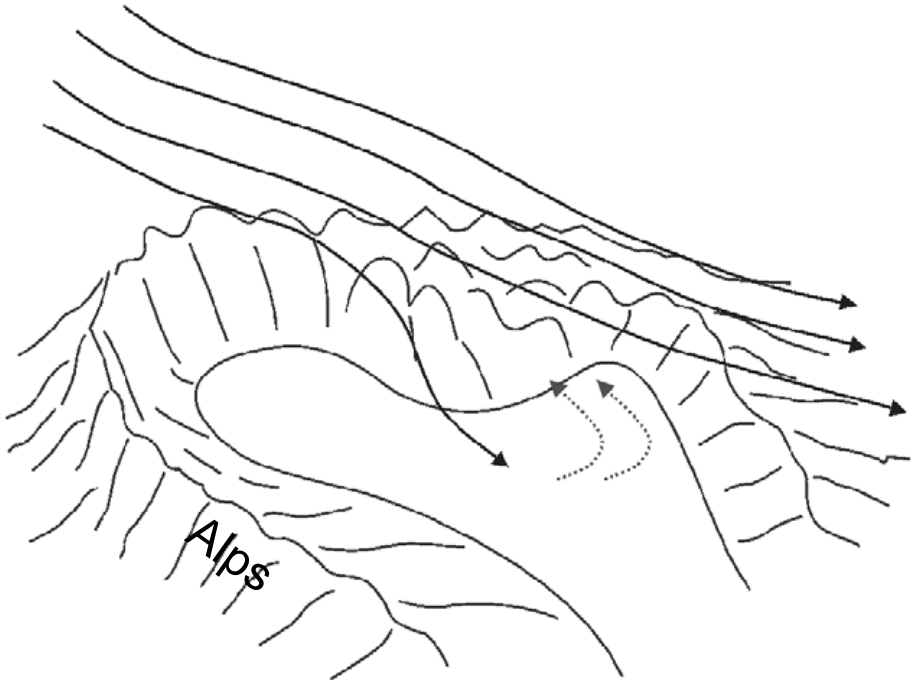


Kunz and Puskeiler, MZ, 2010
Puskeiler and Kunz, Atmos Res 2016

II Understanding storm frequency

- Insolation
- **Weather Systems**
  - Lower-level convergence
    - ↑ Dynamic lifting
  - Cold air influx at altitude
    - ↑ Vertical temperature gradient
  - Wind shear
- **Topography**
  - Heated mountain flanks
    - ↑ Thermal lifting
- Distance to sea
- Land surface type

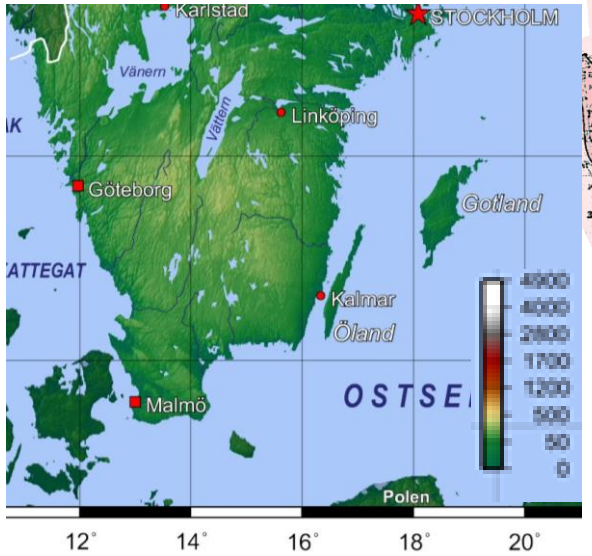
Storm formation in NE Italy



Giaiotti, Atmos Res 2003

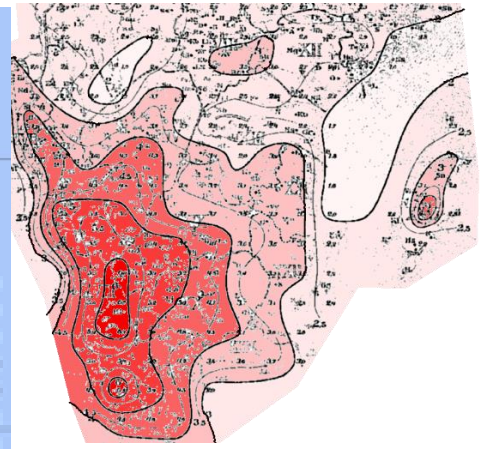
II Understanding storm frequency

- Insolation
- Weather Systems
- Topography
- **Proximity to sea**
  - Sea breeze
    - ↑ Wind shear
  - Cool air advection
    - ↓ Vertical temperature gradient
    - Delayed annual cycle
  - Moisture advection
    - ↑ Moisture content
- Land surface type



wikipedia

Hail frequency in Southern Sweden



Hamberg 1916

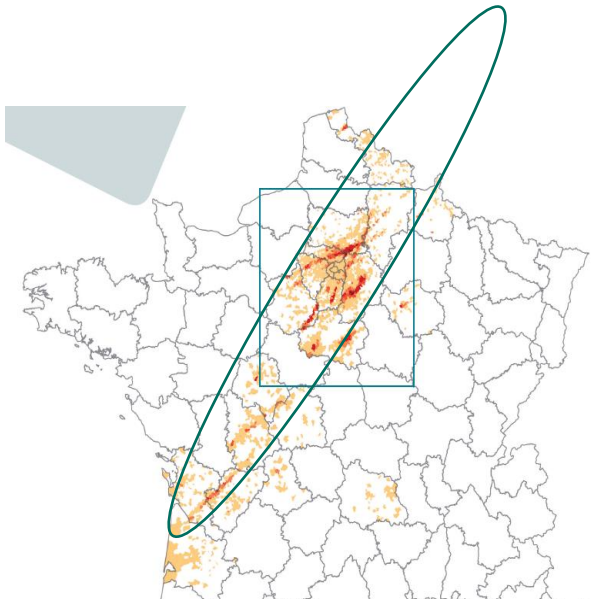
III Improved risk estimates

What is a rare event?

… happens once in 200 years.

How do we know what it looks like?

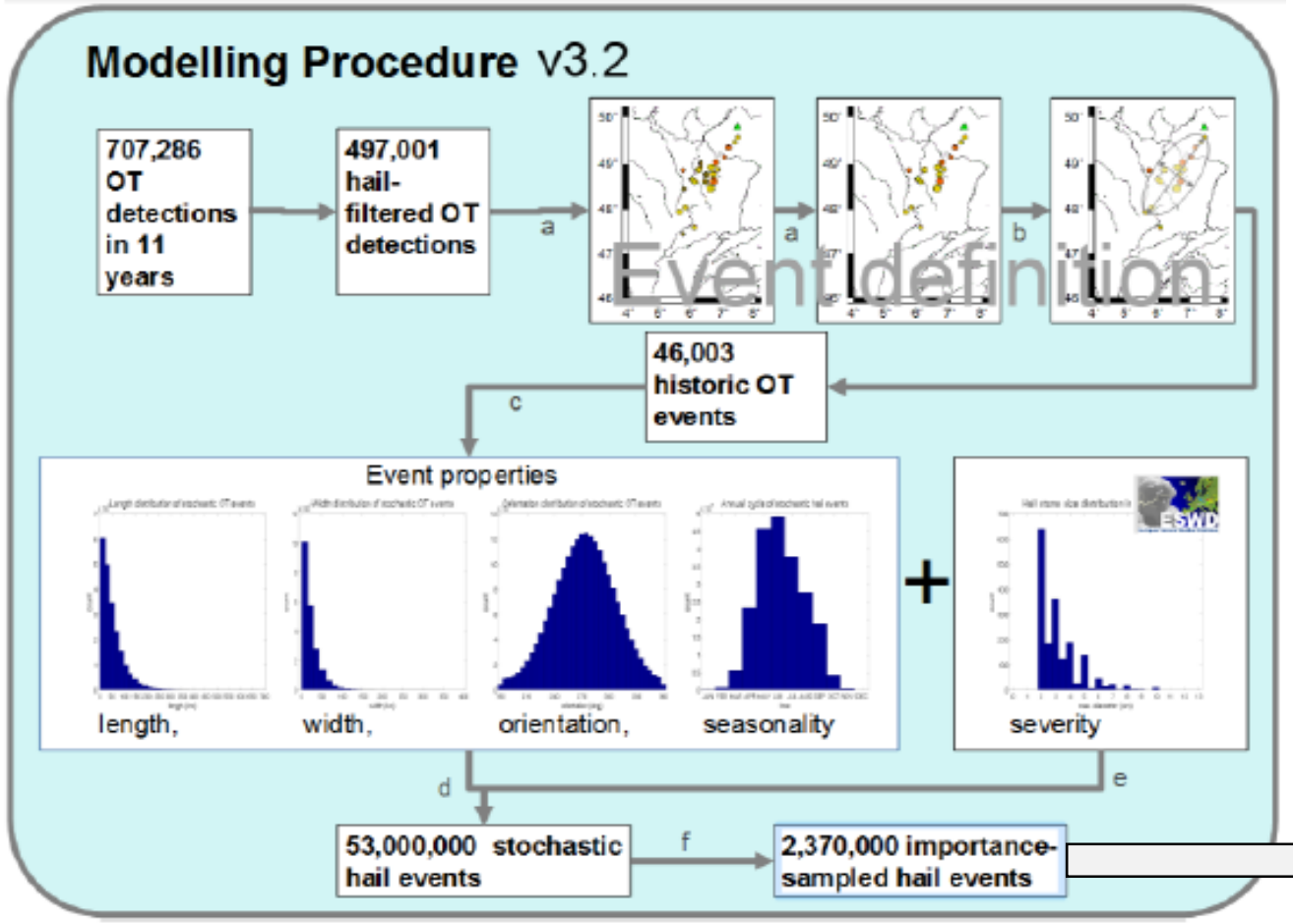
… statistics!



7-10 June 2014 **vs. 13 Juli 1788**

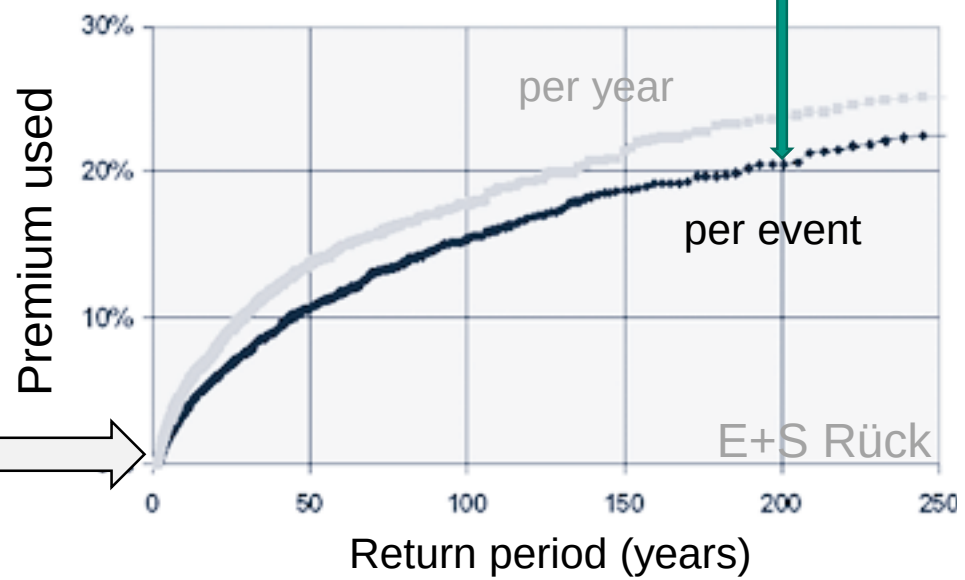
Severe thunderstorms with large hail in France, Belgium, Netherlands

Hail risk modelling



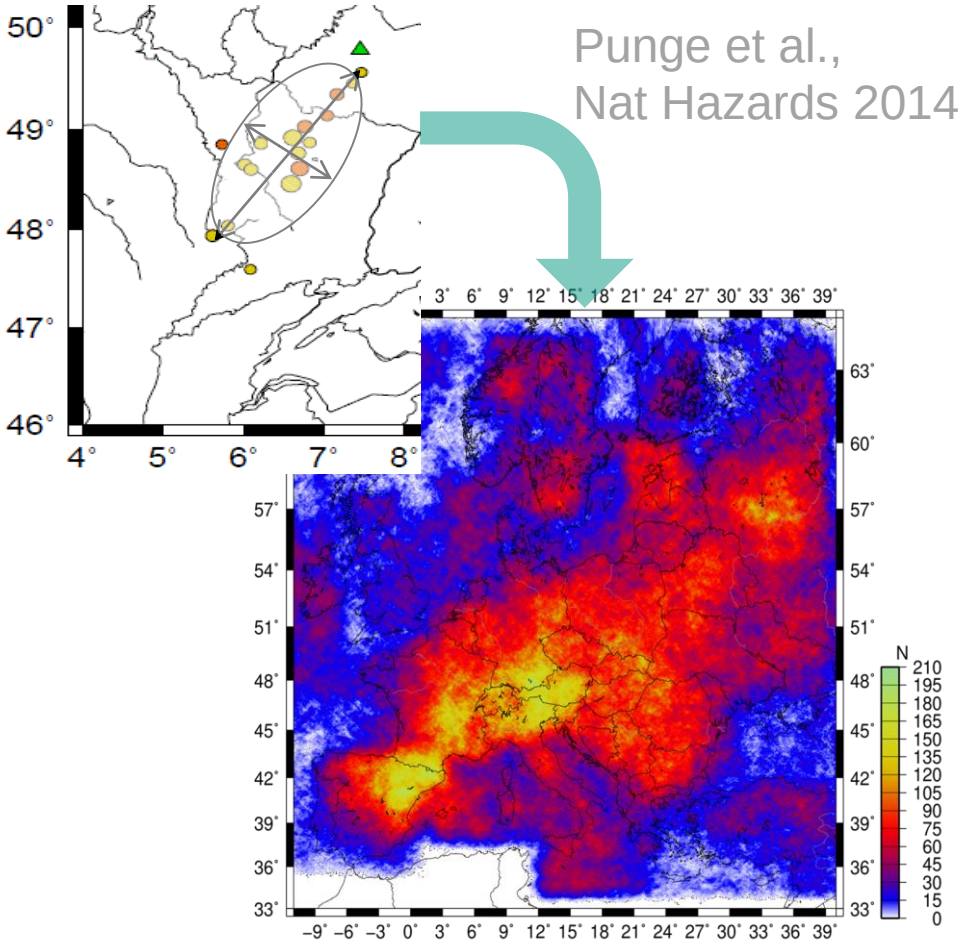
Probable maximum loss in 200 years

PML 200



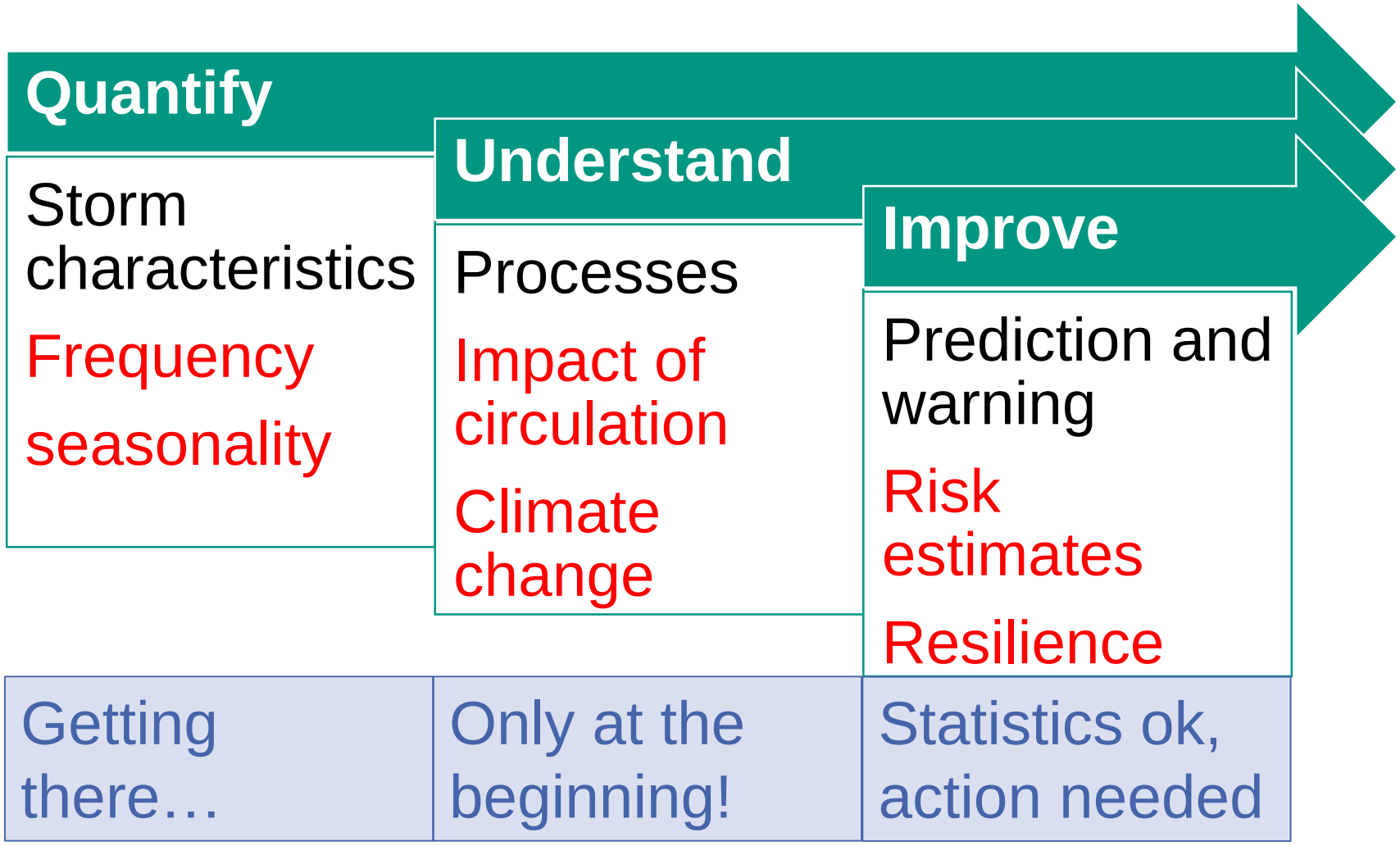
Willis Re European Hail Model

- Stochastic generation of >1.000.000 events (over land; ~5.000 years)
- Reliable spatial distribution of events
- Methods consistent for all European areas
- Add portfolio data to estimate loss vs. Return period, e.g., PML200



Number of stochastic hail events per grid box (~1 km²) in (estimated) 225 years

Challenges in Convective Storms Research



- Raise awareness
- Limit losses