Do severe storms across **Australia**, **Europe** and the **United States** share similarities? A comparison of atmospheric profiles and environmental predictors

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[5] European Severe Storms Laboratory, Wessling, Germany

1. Motivation

- Studies on storm environments for specific regions are heavily affected by local climatological features. For example, STP for tornadoes or lapse rates for large hail does not work as well in other parts of the world as in the United States.

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- To identify which environmental features share similiarities among continents for storms producing severe wind, tornadoes and large hail.

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- To identify which environmental features share similiarities among continents for storms producing severe wind, tornadoes and large hail.

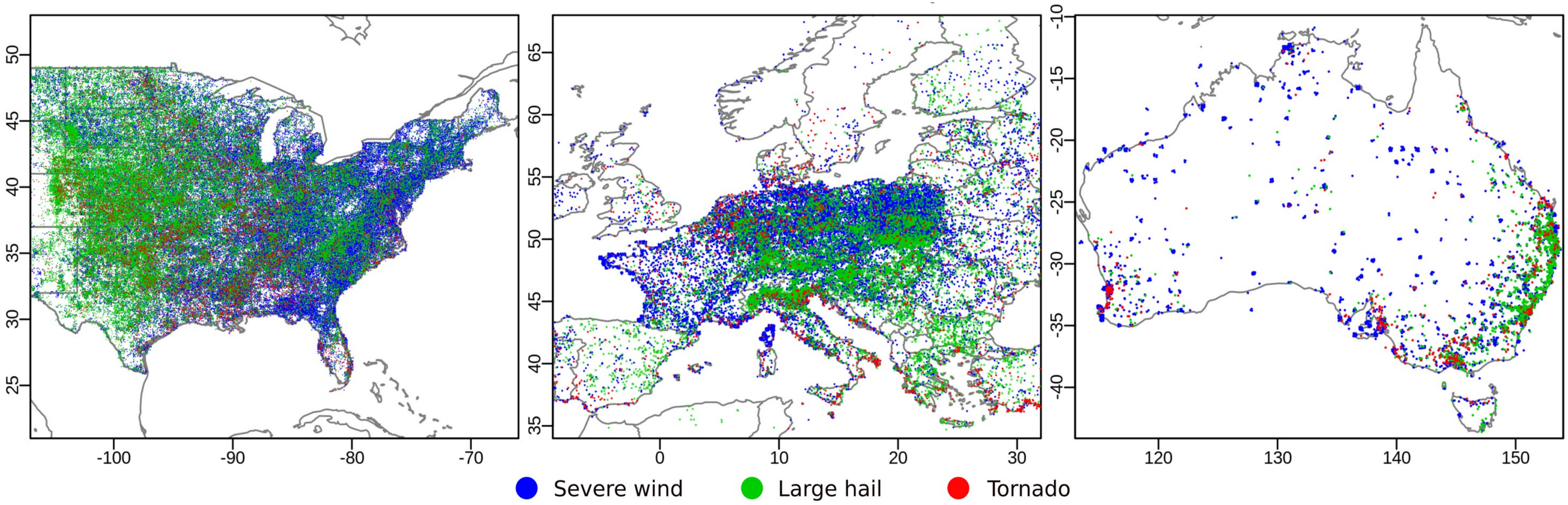
… and try to disentangle these results from local climatological features.

Datasets

Severe weather reports

- United States: SPC Storm Reports Database
- Europe: European Severe Weather Database
- Australia: Storm Reports of Australian Bureau of Meteorology

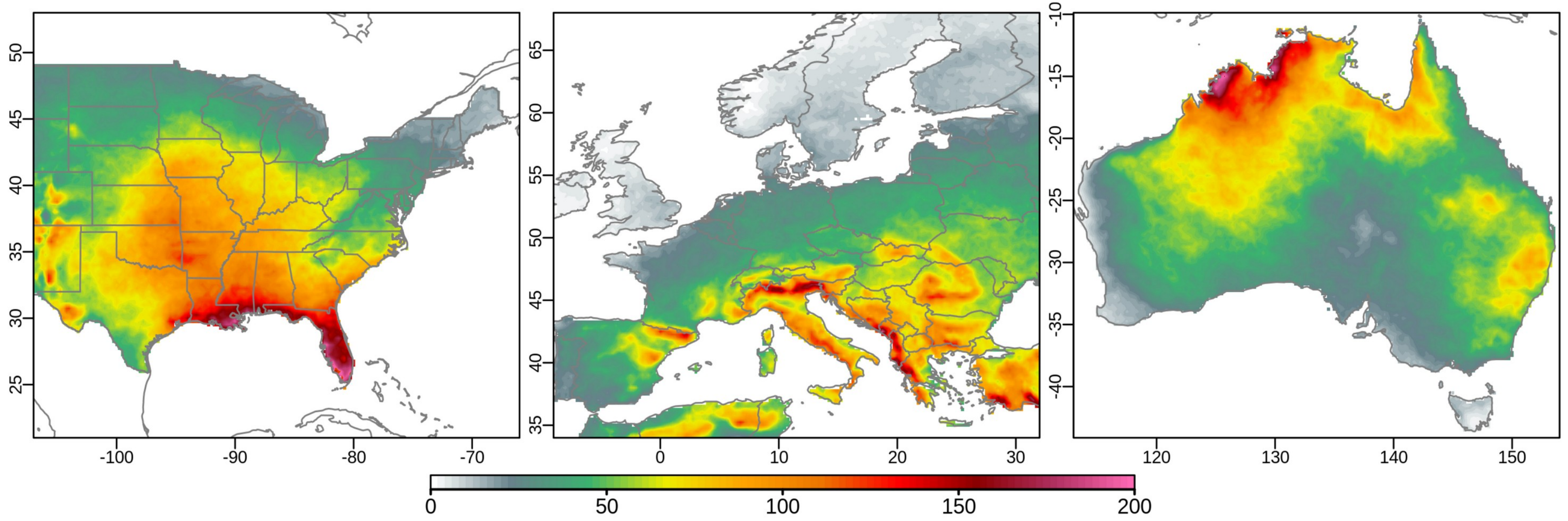
Severe weather reports (2000-2019)



Lightning data

- United States: National Lightning Detection Network (NDLN)
- Europe: Arrival Time Difference Network (ATDnet)
- Australia: Global Position And Tracking Systems (GPATS)

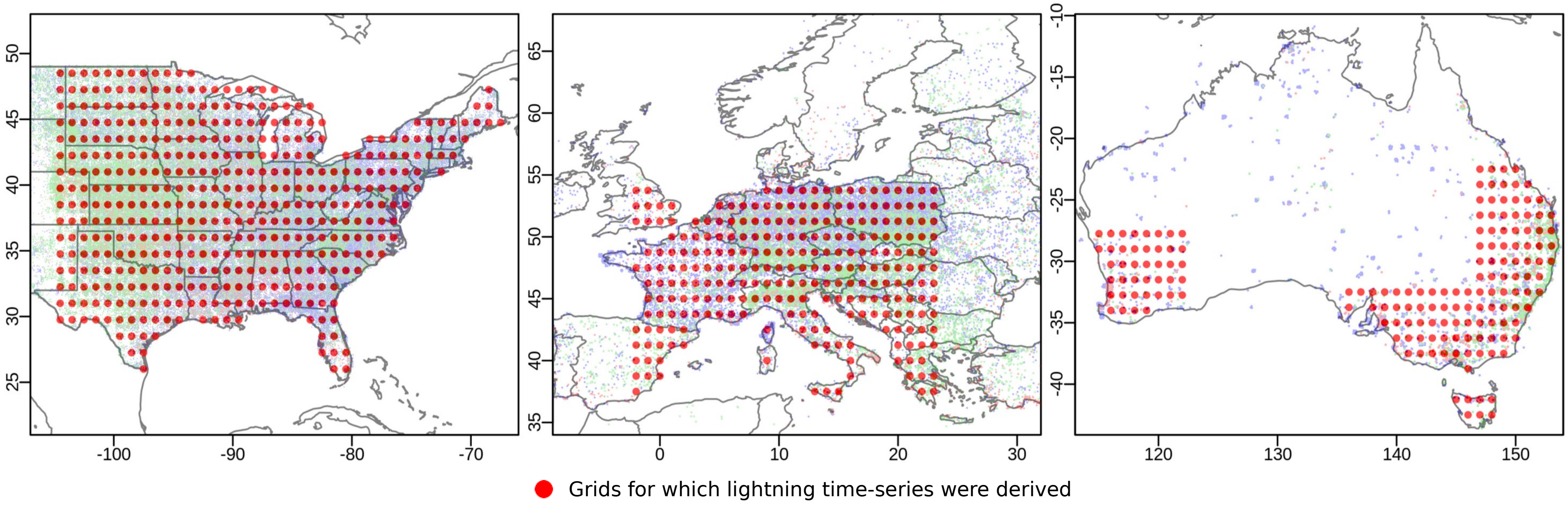
Annual mean number of thunderstorm hours (2000-2019)



Construction of non-severe lightning category

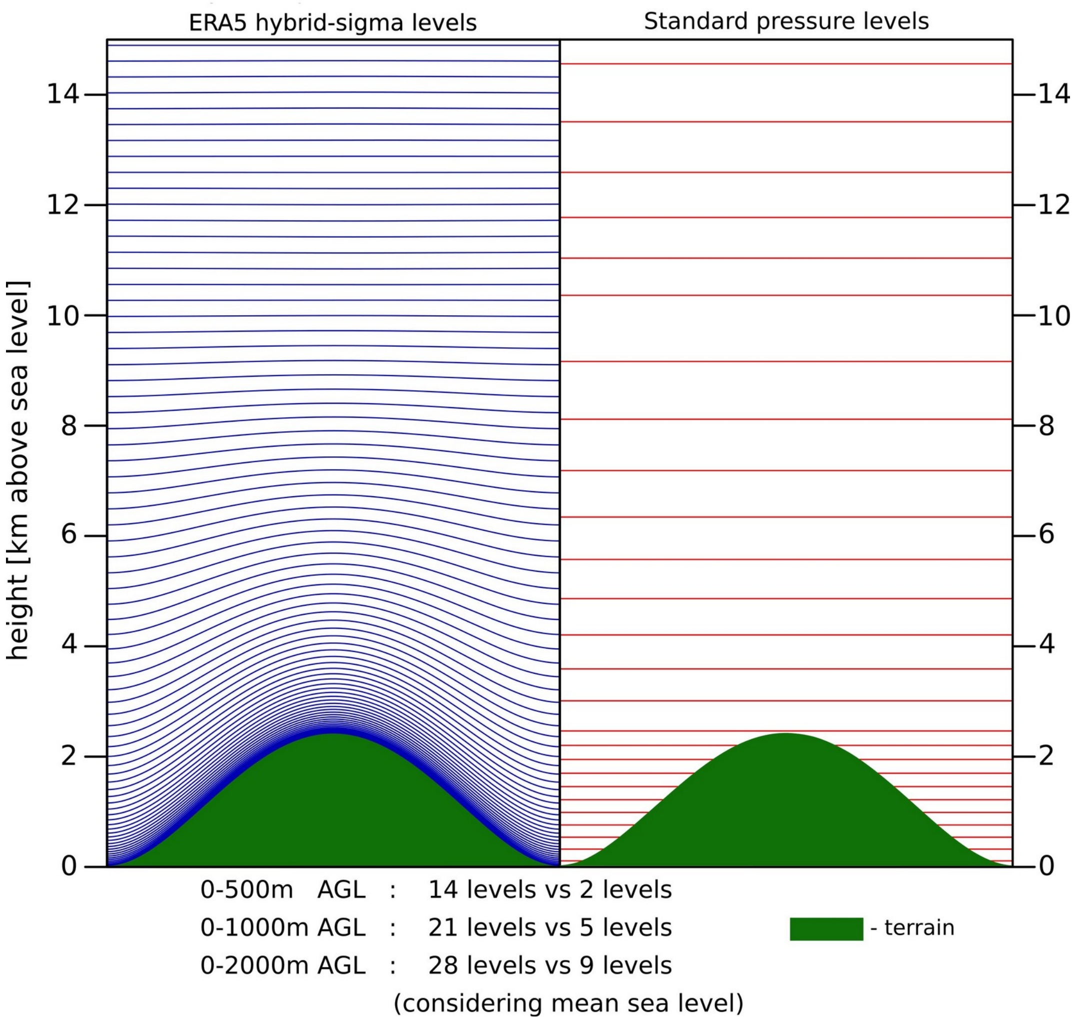
- Lightning was detected, but no severe wind, tornado, hail was reported +/- 3h and up to 150 km.
- Only grids in the area of good severe weather reporting coverage were considered.
- Only every 4th ERA5 grid is considered to reduce sample size (otherwise would be several millions).

Domain for non-severe lightning situations (2015-2019)



ERA5 reanalysis

- hybrid-sigma levels
- 0.25° x 0.25°
- 1-hour step
- raw profiles of z, p, q, t, u, v



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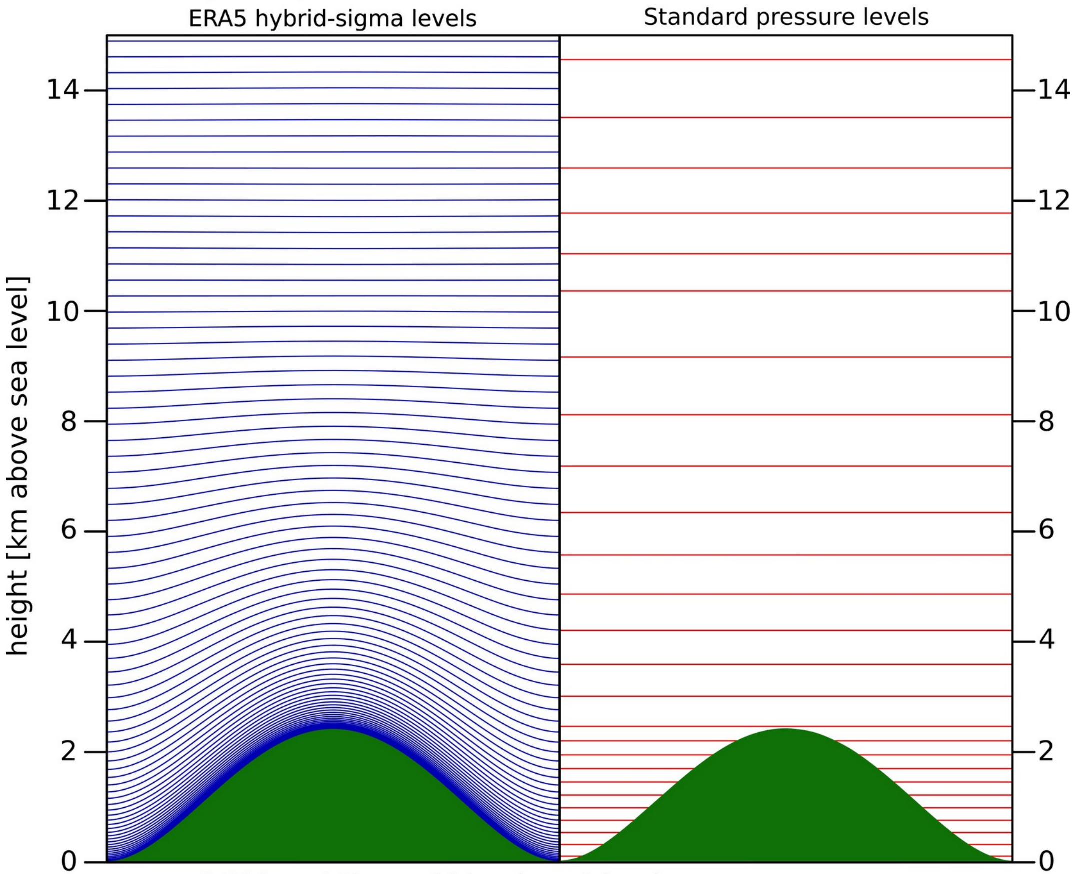
thundeR
rawinsonde package

www.rawinsonde.com



0-500m AGL : 14 levels vs 2 levels
0-1000m AGL : 21 levels vs 5 levels
0-2000m AGL : 28 levels vs 9 levels
(considering mean sea level)

- terrain

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201x
convective parameters

(composite parameters excluded)

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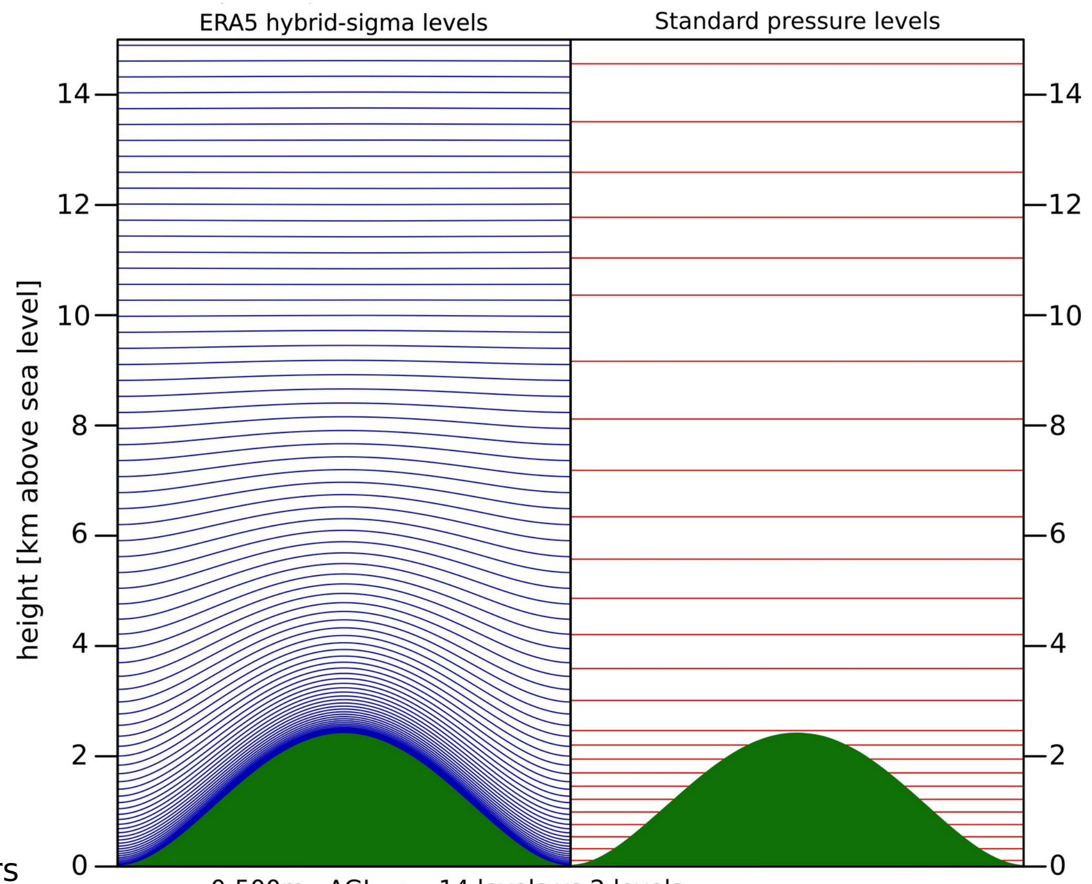

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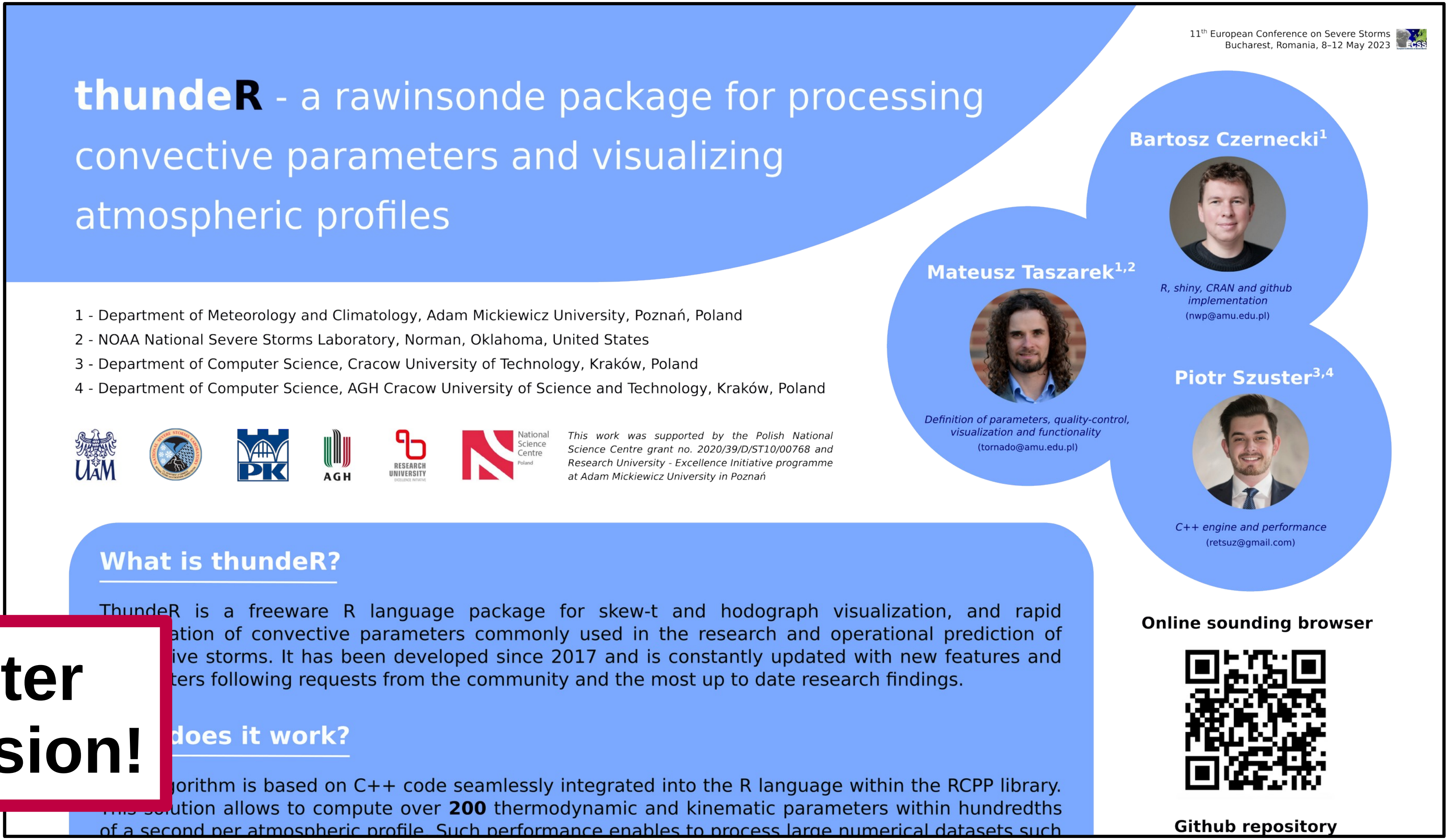

11th European Conference on Severe Storms
Bucharest, Romania, 8-12 May 2023

thundeR - a rawinsonde package for processing convective parameters and visualizing atmospheric profiles

Bartosz Czernecki[1]
R, shiny, CRAN and github implementation
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Mateusz Taszarek[1,2]
Definition of parameters, quality-control, visualization and functionality
(tornado@amu.edu.pl)

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C++ engine and performance
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2 - NOAA National Severe Storms Laboratory, Norman, Oklahoma, United States
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4 - Department of Computer Science, AGH Cracow University of Science and Technology, Kraków, Poland

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What is thundeR?

ThundeR is a freeware R language package for skew-t and hodograph visualization, and rapid ...ation of convective parameters commonly used in the research and operational prediction of ...ive storms. It has been developed since 2017 and is constantly updated with new features and ...ters following requests from the community and the most up to date research findings.

...does it work?

...gorithm is based on C++ code seamlessly integrated into the R language within the RCPP library. ...ution allows to compute over **200** thermodynamic and kinematic parameters within hundredths of a second per atmospheric profile. Such performance enables to process large numerical datasets such

Online sounding browser

Github repository

Poster session!

Table 1. Number of unique ERA5 profiles used in the analysis.

Domain	Non-severe lightning	Severe wind		Large hail		Tornado	
		Warm	Cool	Severe	Significant severe	Severe	Significant severe
United States	136935	109174	9360	63757	5882	9023	1315
Europe	67685	17616	4520	11702	2267	2102	249
Australia	30647	2271	902	1260	227	361	62

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Composite skew-ts
(buoyancy and RH averaging)

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- 1D Logistic Regression (deviance)
- 1D ROC curves (AUC)
- Random Forest (var. importance)

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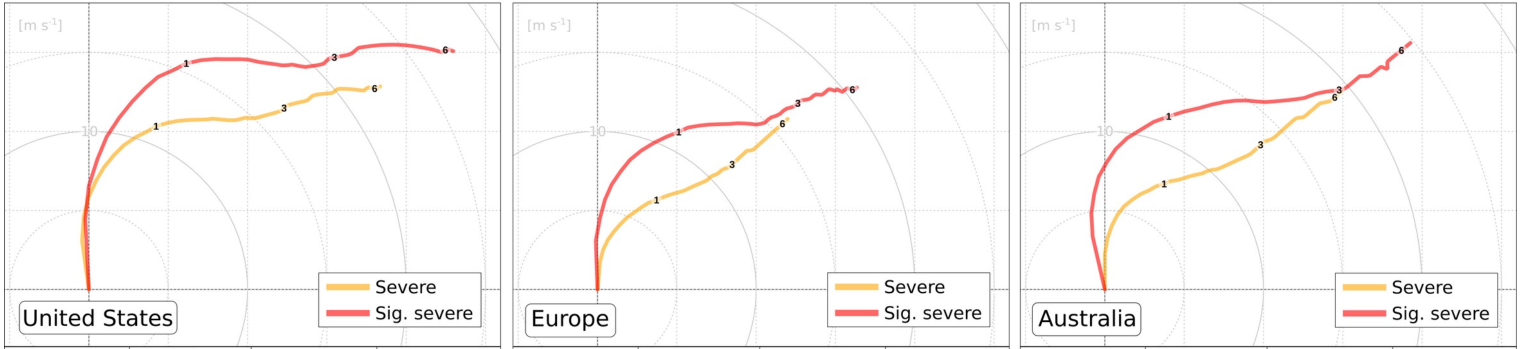
Parameter importance
(averaging with equal weights)

Results

A Tornado



United States

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
155	216	94	89	10.5	22.5	6.6	15.2
243	312	94	87	14.6	27.1	9.4	19.0

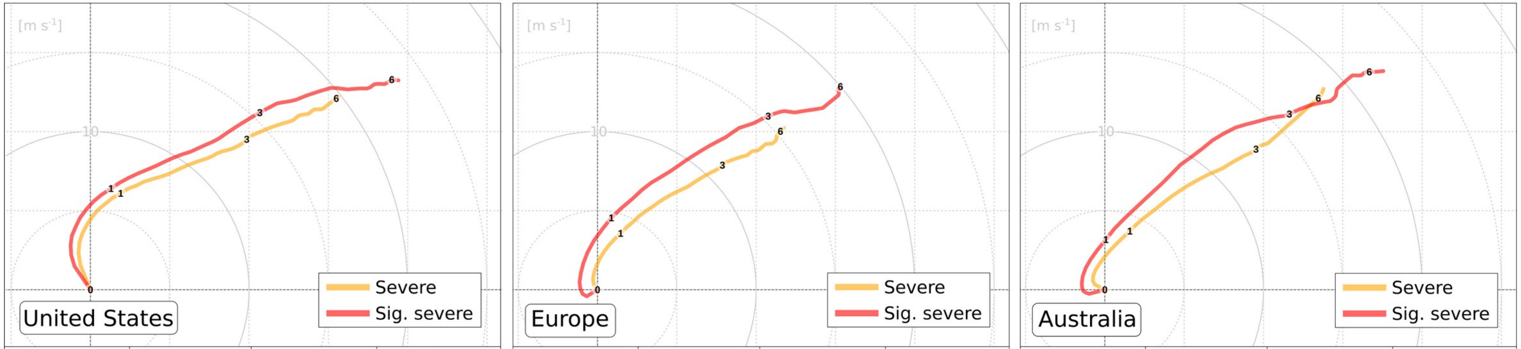
Europe

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
72	111	90	89	6.5	15.7	3.9	10.4
163	224	91	87	10.9	20.8	6.6	15.4

Australia

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
92	137	90	88	7.7	18.9	4.9	12.3
193	273	92	87	11.7	24.1	7.3	17.1

B Large hail



United States

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
86	152	91	89	6.4	19.6	3.7	12.3
98	184	89	88	6.5	23.2	3.8	13.8

Europe

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
43	106	91	92	3.9	15.3	1.7	9.5
68	172	73	84	4.6	20.0	1.6	12.6

Australia

SRH [m² s⁻²] 0-1 km	SRH 0-3 km	SV [%] 0-1 km	SV 0-3 km	BS [m s⁻¹] 0-1 km	BS 0-6 km	MW [m s⁻¹] 0-1 km	MW 0-6 km
49	123	78	86	4.1	18.1	1.7	10.9
51	182	65	83	3.2	21.6	1.3	12.9

Figure 1. Mean composite hodographs for (a) tornado and (b) large hail events across the United States, Europe and Australia.

Mean vertical profiles of relative humidity

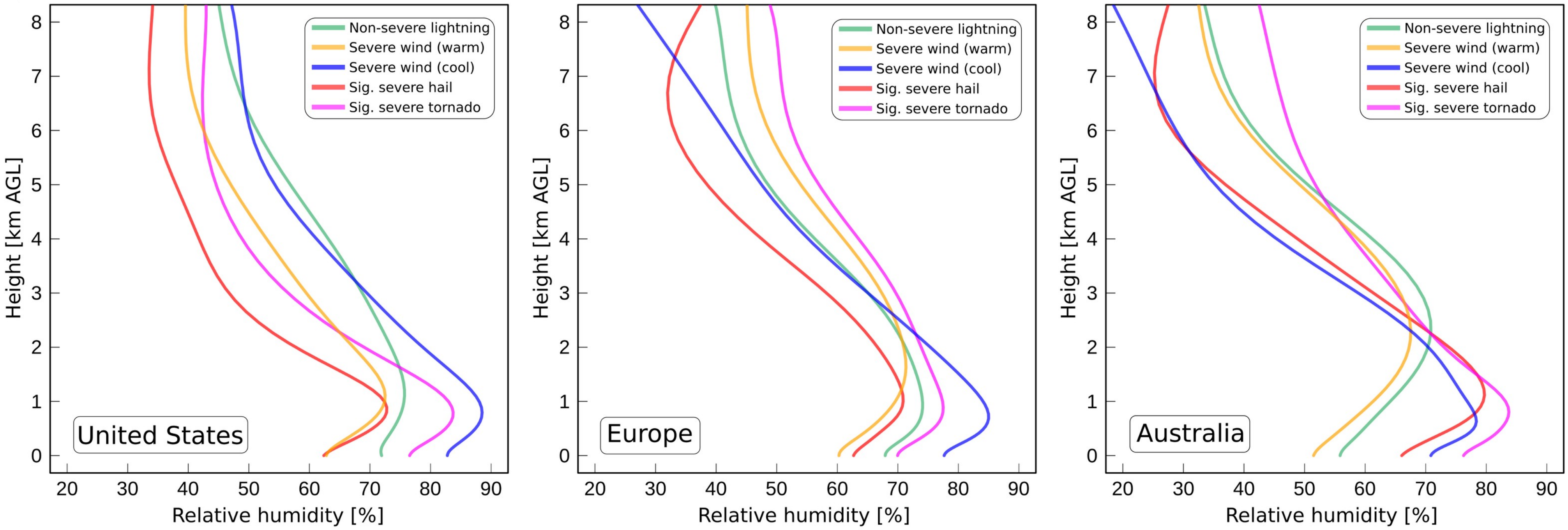


Figure 2. Mean vertical profiles of relative humidity for non-severe lightning and convective hazards across the United States, Europe and Australia.

Mean vertical profiles of wind speed

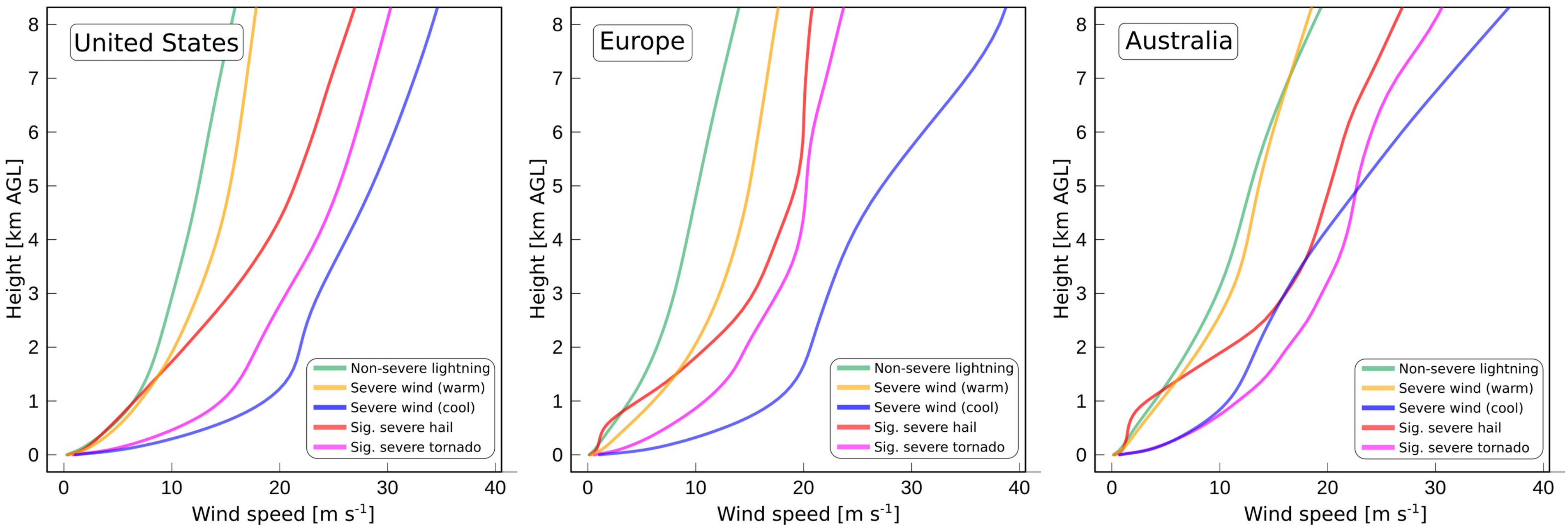


Figure 3. Mean vertical profiles of wind speed for non-severe lightning and convective hazards across the United States, Europe and Australia.

Mean vertical profiles of theta-e

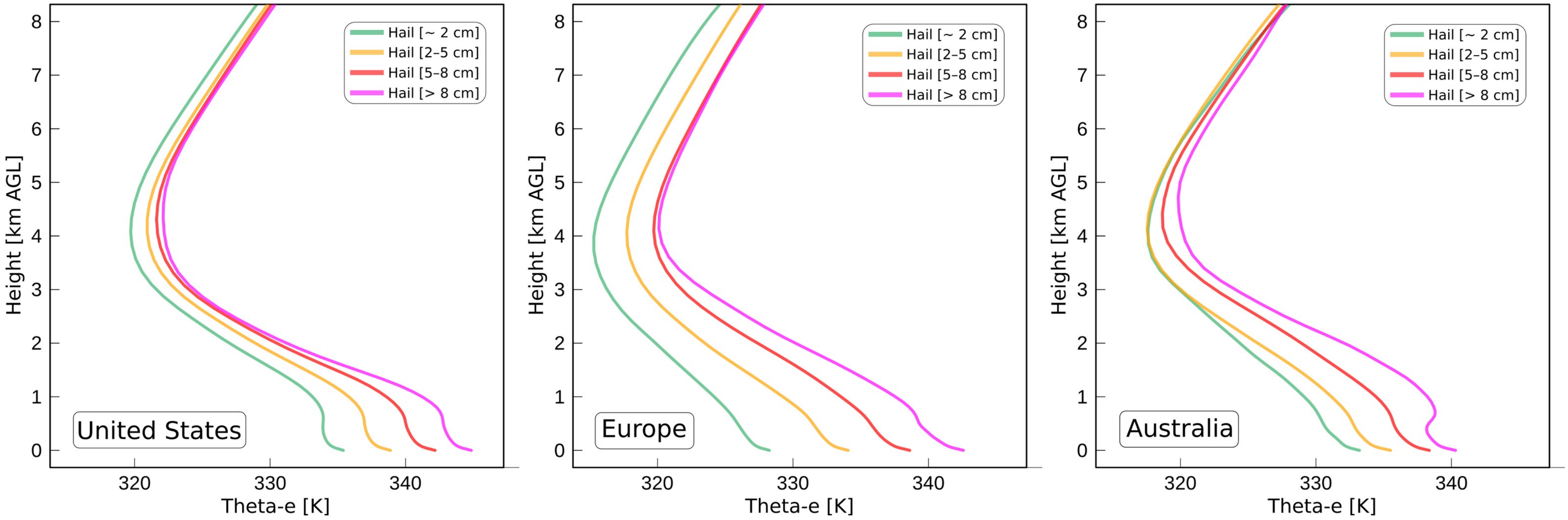


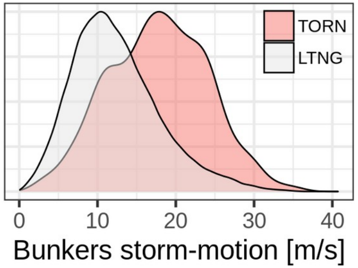
Figure 4. Mean vertical profiles of equivalent potential temperature for various hailstone sizes across the United States, Europe and Australia.

vs

Tornado given lightning detection (best predictors)

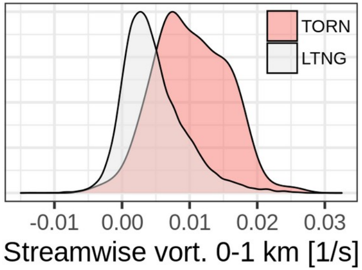
 vs 

Tornado given lightning detection (best predictors)



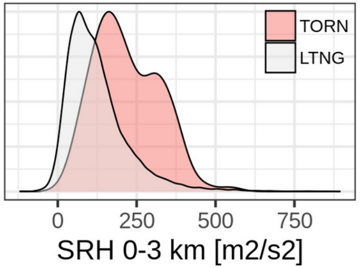
United States

1. Storm-motion vector (score: 100)
2. Effective shear (score: 83.6)
3. Mean wind 1-3 km (score: 80.7)



Europe

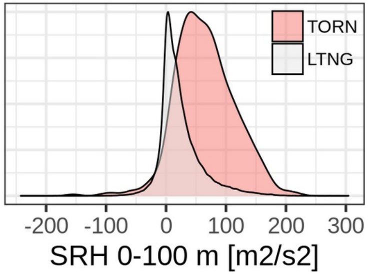
1. Streamwise vorticity 0-1 km (score: 83.5)
2. Storm-relative helicity 0-1 km (score: 80.4)
3. Bulk shear 0-1 km (score: 79.5)



Australia

1. Storm-relative helicity 0-3 km (score: 93.6)
2. Relative humidity 0-1 km (score: 92.9)
3. Streamwise vorticity 0-3 km (score: 83.9)

Combined best predictors



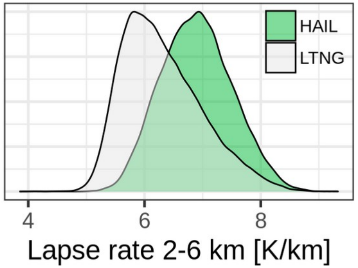
1. Storm-relative helicity 0-100m (score: 76.9)
2. Moisture flux 0-2 km (score: 74.1)
3. Mean wind 1-3 km (score: 73.2)
4. Streamwise vorticity 0-500m (score: 72.3)
5. Bulk shear 0-2 km (score: 70.9)

vs

Large hail given lightning detection (best predictors)

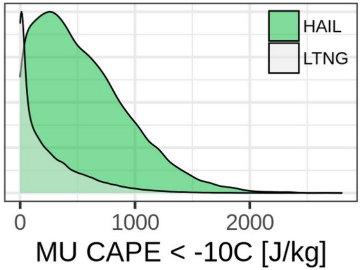

vs


Large hail given lightning detection (best predictors)



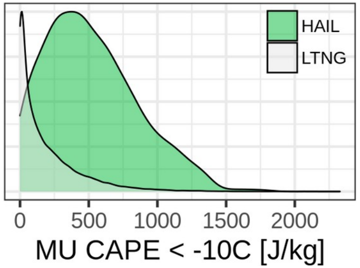
United States

1. Lapse rate 2-6 km (score: 100)
2. Storm-relative flow 0-2 km (score: 64.3)
3. Effective shear (score: 61.7)



Europe

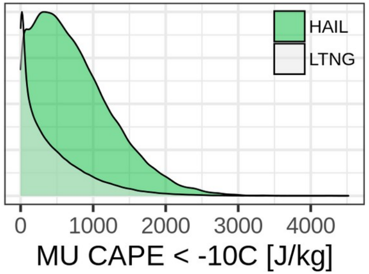
1. MU CAPE < -10°C (score: 99.9)
2. Effective shear (score: 84.8)
3. Storm-relative flow 0-2 km (score: 61.4)



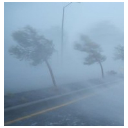
Australia

1. MU CAPE < -10°C (score: 99.7)
2. Effective shear (score: 84.7)
3. MU LI -10°C (score: 76.3)

Combined best predictors

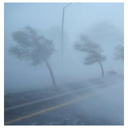


1. MU CAPE < -10°C (score: 82.6)
2. Effective shear (score: 75.0)
3. MU LI -10°C (score: 59.8)
4. Lapse rate 3-6 km (score: 58.5)
5. Storm-relative winds 0-2 km (score: 56.4)



vs

Severe wind given lightning detection (best predictors)

 vs 

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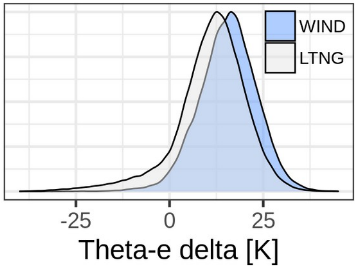
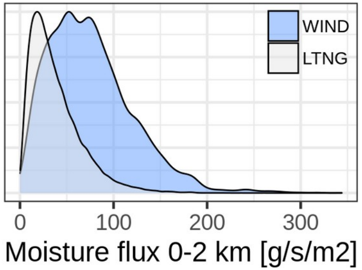


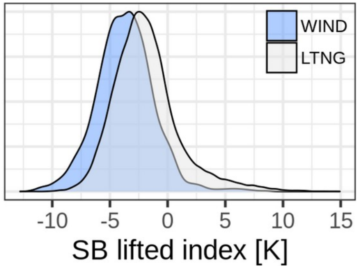
United States

1. Delta theta-e (score: 94.7)
2. DCAPE (score: 92.9)
3. Cold pool strength (score: 85.9)



Europe

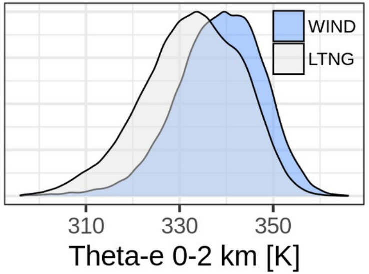
1. Moisture flux 0-2 km (score: 100)
2. Precipitable water (score: 72.9)
3. Mean wind 0-3 km (score: 72.3)



Australia

1. SB LI (score: 84.2)
2. SB CAPE (score: 76.9)
3. Cold pool strength (score: 75.9)

Combined best predictors



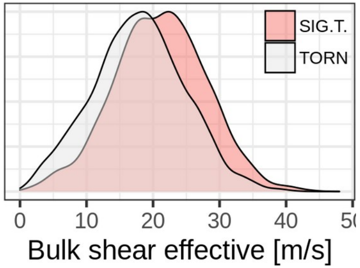
1. Mean theta-e 0-2 km (score: 64.8)
2. Cold pool strength (score: 63.8)
3. Precipitable water (score: 61.3)
4. DCAPE (score: 61.1)
5. Delta theta-e 0-4 km (score: 54.9)

 vs 

Significant tornado given tornado (best predictors)

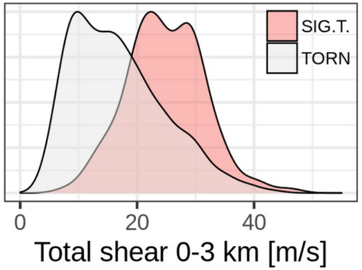
vs

Significant tornado given tornado (best predictors)



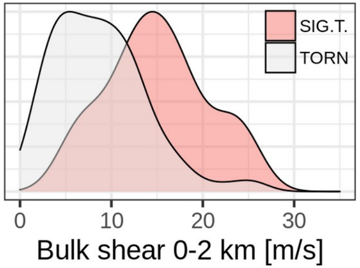
United States

1. Effective shear (score: 99.8)
2. Storm-motion vector (score: 97.3)
3. Mean wind 0-3 km (score: 80.4)



Europe

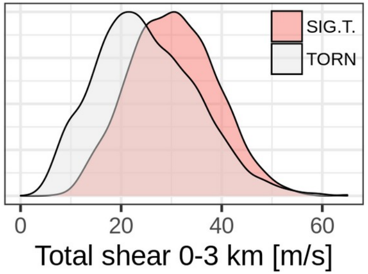
1. Total shear 0-3 km (score: 95.9)
2. Effective shear (score: 87.9)
3. Bulk shear 0-3 km (score: 85.8)



Australia

1. Bulk shear 0-2 km (score: 95.8)
2. Storm-relative helicity 0-3 km (score: 94.7)
3. Total shear 0-3 km (score: 80.2)

Combined best predictors



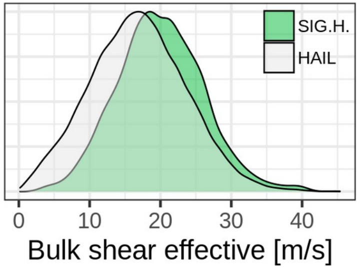
1. Total shear 0-3 km (score: 81.2)
2. Effective shear (score: 80.6)
3. Bulk shear 0-3 km (score: 80.2)
4. Storm-motion vector (score: 69.1)
5. Mean wind 1-3 km (score: 68.9)

vs

Very large hail given large hail (best predictors)

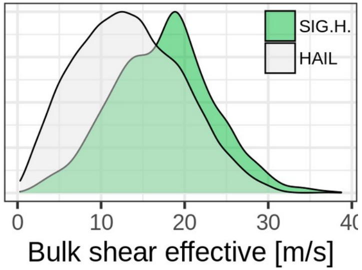
vs

Very large hail given large hail (best predictors)



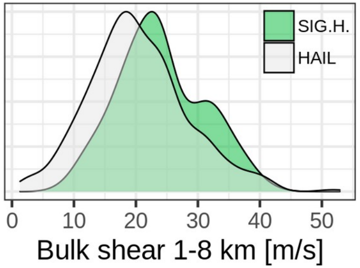
United States

1. Effective shear (score: 100)
2. Storm-relative winds in HGL (score: 84.2)
3. Bulk shear 1-6 km (score: 80.3)



Europe

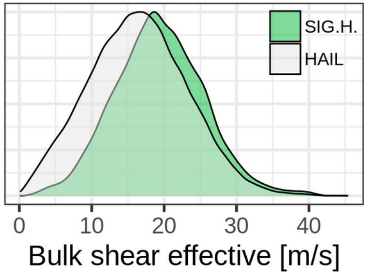
1. Effective shear (score: 99.2)
2. Storm-relative winds in HGL (score: 95.8)
3. Bulk shear surface to -10°C (score: 90.9)



Australia

1. Bulk shear 1-8 km (score: 94.5)
2. Storm-relative winds 0-2 km (score: 90.8)
3. Storm-relative winds in HGL (score: 84.9)

Combined best predictors



1. Effective shear (score: 91.3)
2. Storm-relative winds in HGL (score: 89.3)
3. Bulk shear surface to -10°C (score: 81.9)
4. Storm-relative winds 0-2 km (score: 77.4)
5. Bulk shear 1-8 km (score: 71.8)

vs

Very large hail vs significant tornado (best predictors)

 vs 

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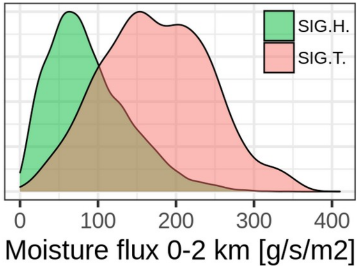
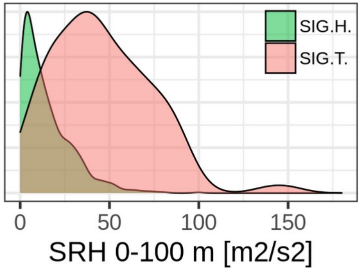


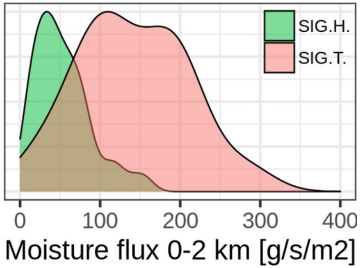
United States

1. Moisture flux 0-2 km (score: 100)
2. Mean wind 1-3 km (score: 92.3)
3. Storm-motion vector (score: 84.3)



Europe

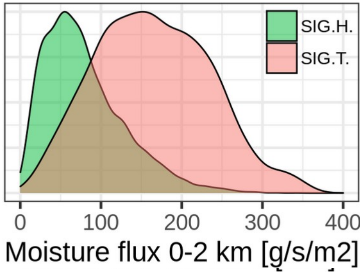
1. Storm-relative helicity 0-100 m (score: 96.7)
2. Streamwise vorticity 0-500 m (score: 87.8)
3. Mean wind 0-2 km (score: 82.1)



Australia

1. Moisture flux 0-2 km (score: 94.3)
2. Mean wind 0-1 km (score: 87.3)
3. Streamwise vorticity 0-500 m (score: 65.1)

Combined best predictors



1. Moisture flux 0-2 km (score: 85.2)
2. Mean wind 0-1 km (score: 81.6)
3. Storm-relative helicity 0-100 m (score: 81.1)
4. Streamwise vorticity 0-500 m (score: 73.9)
5. Bulk shear 0-500 m (score: 70.6)

Concluding remarks

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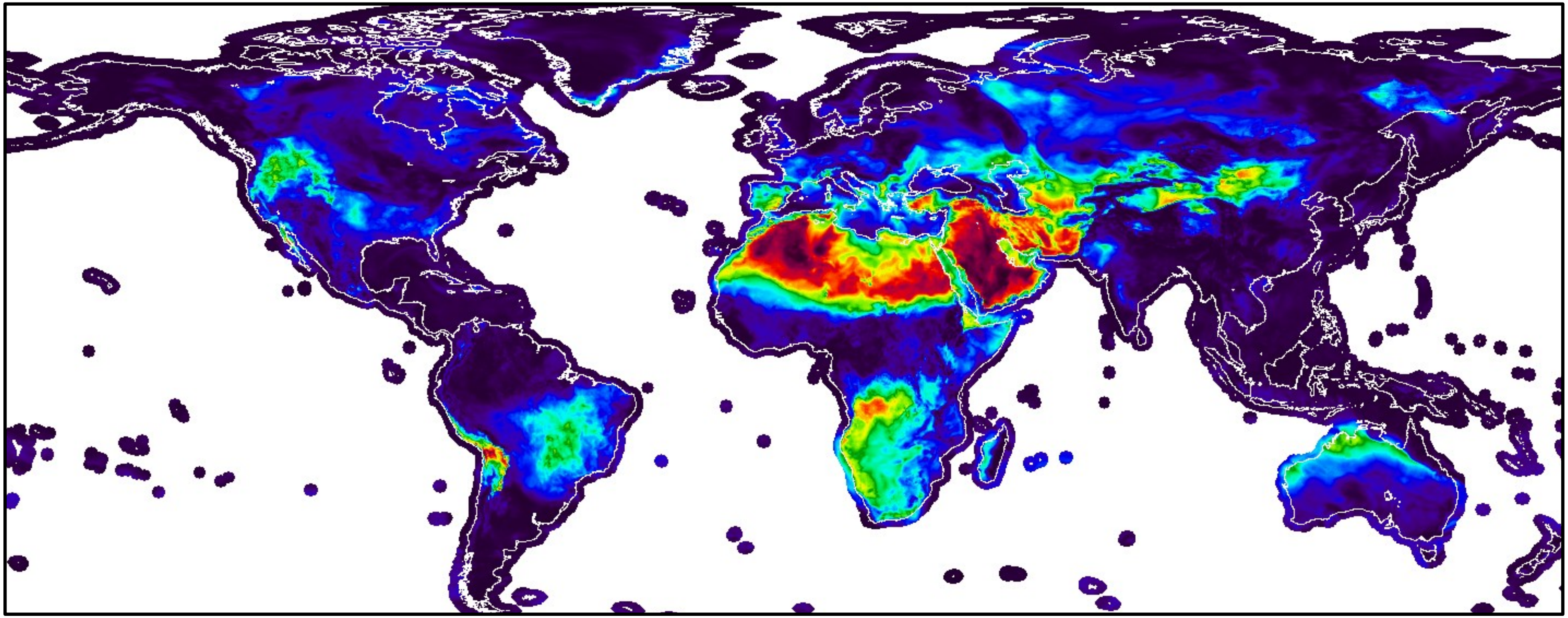
Future work will include data from South America and development of the machine learning model that will be used to study a global 80-year relationship between warming climate and convective hazards.



Interested in working with global ERA5 post-processed convective environment data?

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Large supercell on 22 May 2020 that produced 15 cm hailstones near Burkburnett in Texas (United States). Photography: Paulina Ćwik