Synoptic and mesoscale weather situations associated with tornadoes in Europe

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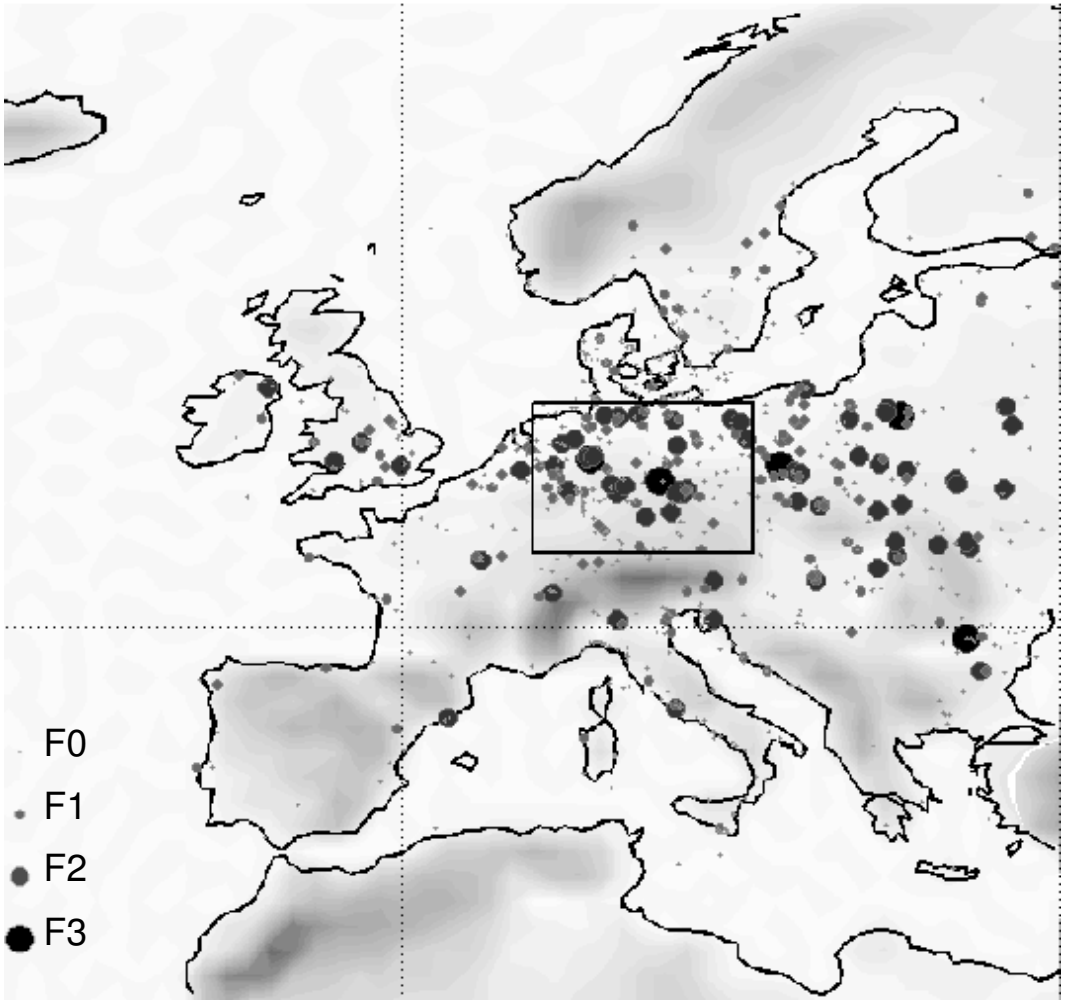
Tornado events in Europe in 2005 and 2006



Data source:

European Severe Weather Database (ESWD)

(www.eswd.eu)

Circle size:

Intensity according to Fuijta scale

Questions

1) Are convective indices (used in the US) also applicable to Europe?

→ *Composite analysis of - convective available potential energy (CAPE),*
- storm-relative helicity (SRH),
- energy helicity index (EHI)

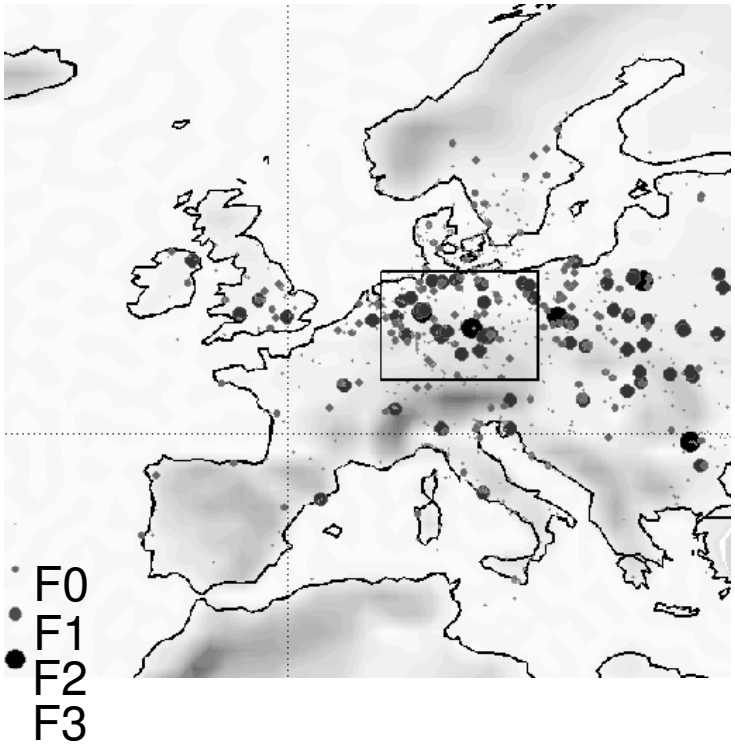
2) Which flow patterns precondition the atmosphere for tornadoes in Europe?

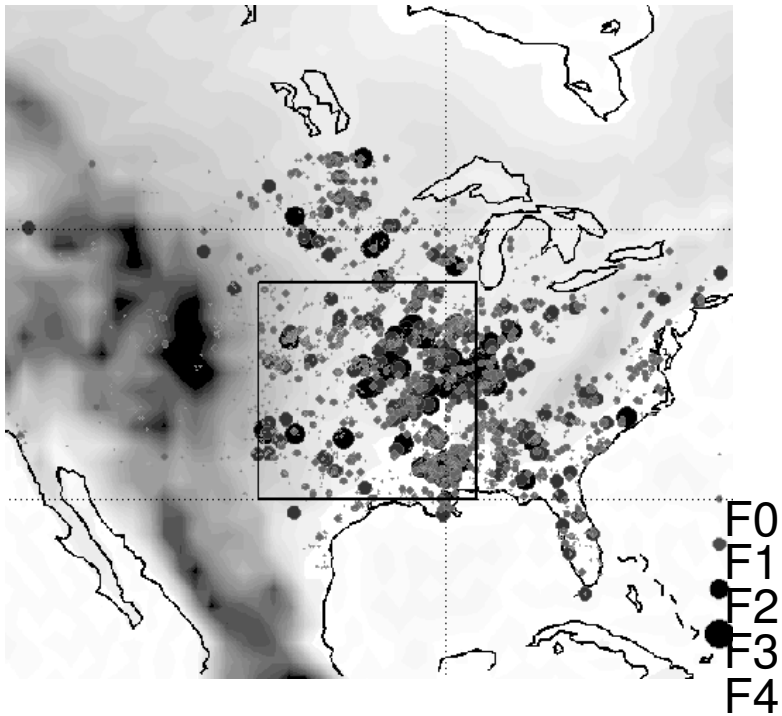
→ *Lagrangian backward trajectories to find orgin of air masses at tornado position*

3) What are the synoptic situations in Europe and are they similar to the US ones?

→ *Case and composite analysis of - potential vorticity (PV),*
- equivalent-potential temperature (Θ_e)

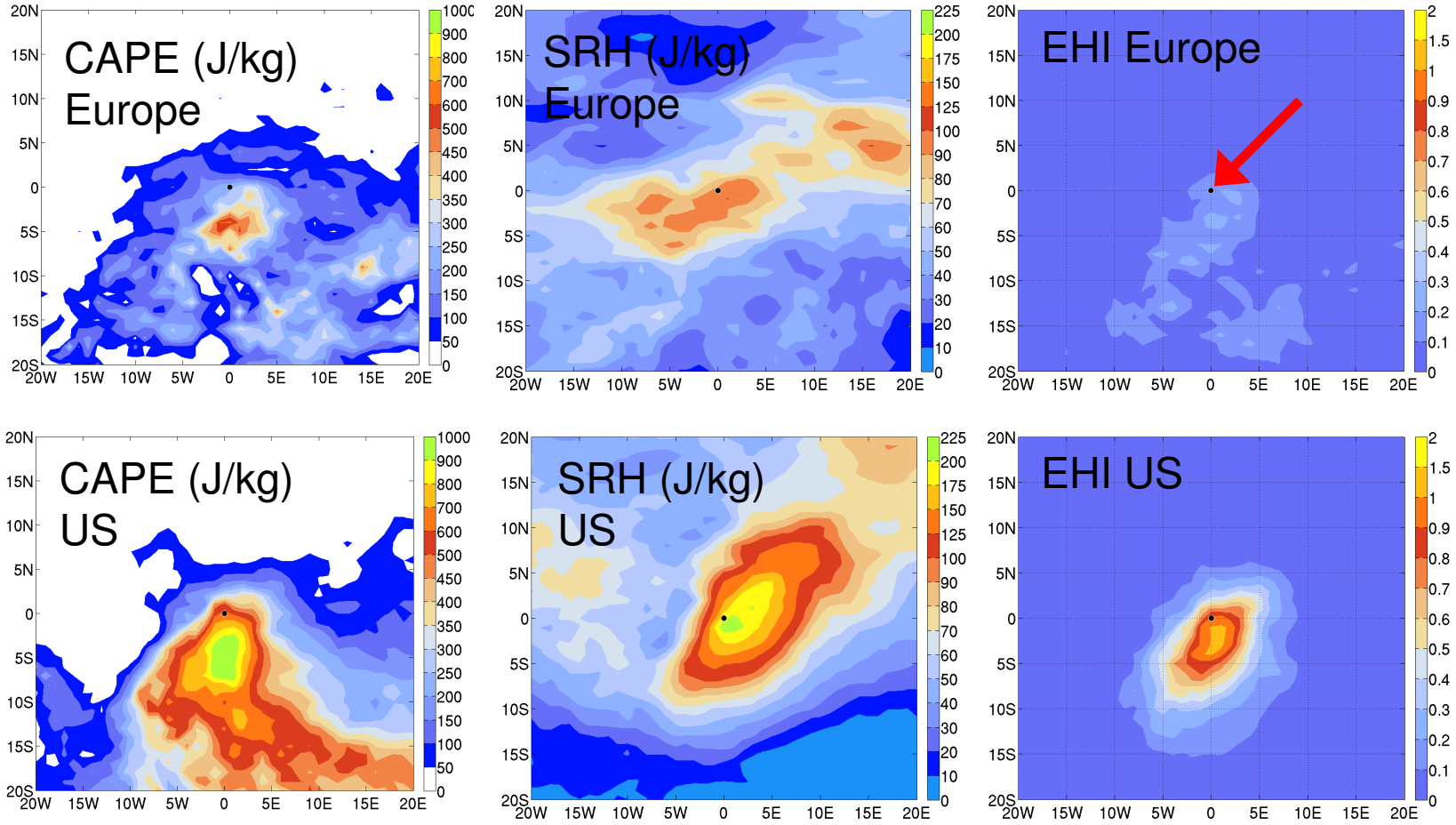
Data & Methodology





- only F2 tornadoes within the black box considered (15 events)
- tornado outbreaks considered as a single event
- ECMWF analysis data with a horizontal resolution of 1° x 1°
- Comparison with 40 US tornadoes (from NCDC data base)

Question 1: convective Indices – geographical pattern

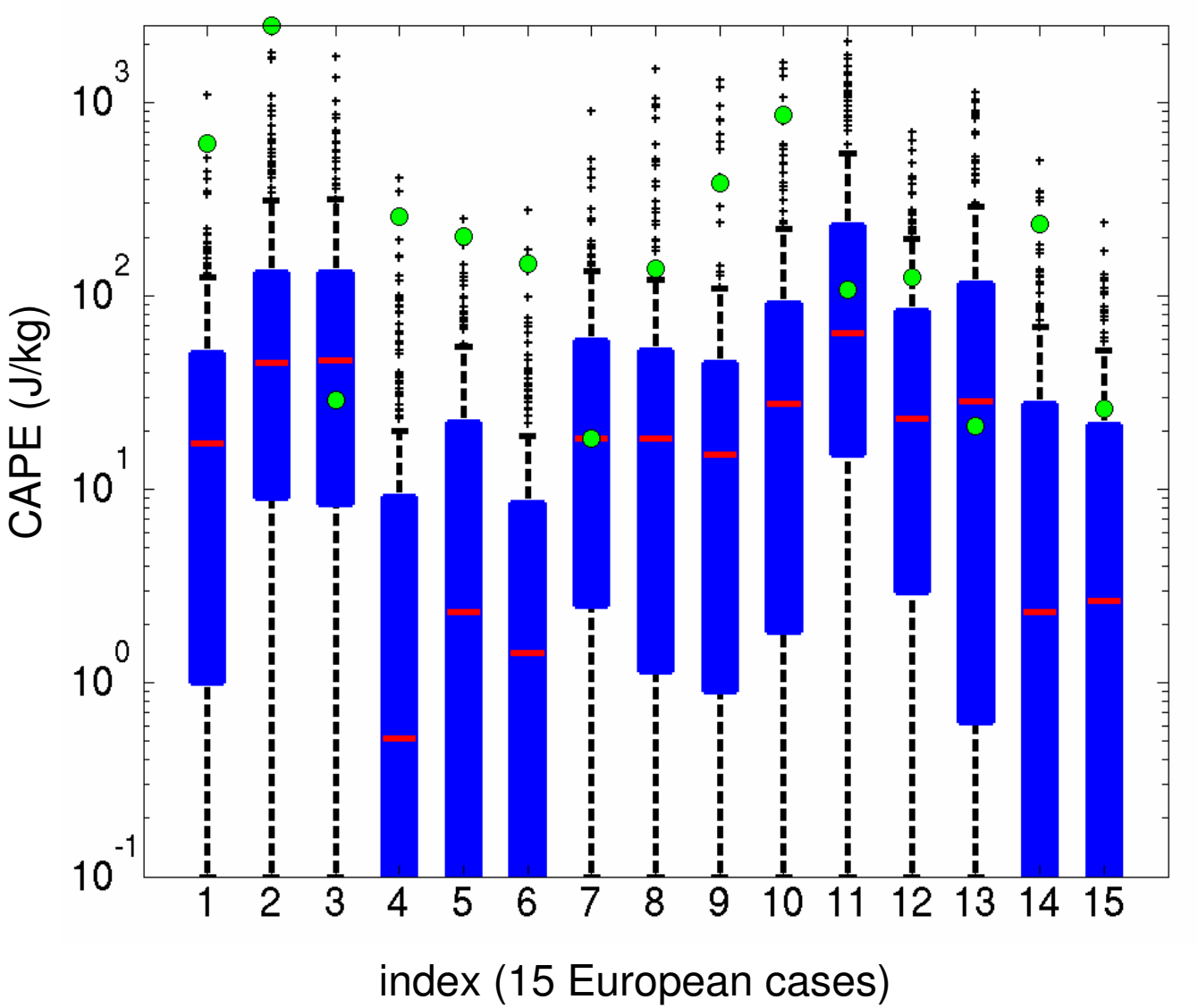


✓ Composites for 15 European cases and 40 US cases, tornado centered at figure

✓ CAPE, storm-relative helicity (SRH), energy helicity index (EHI) show distinct feature

✓Values in US are significantly larger than in Europe

Question 1: convective indices – how extreme?



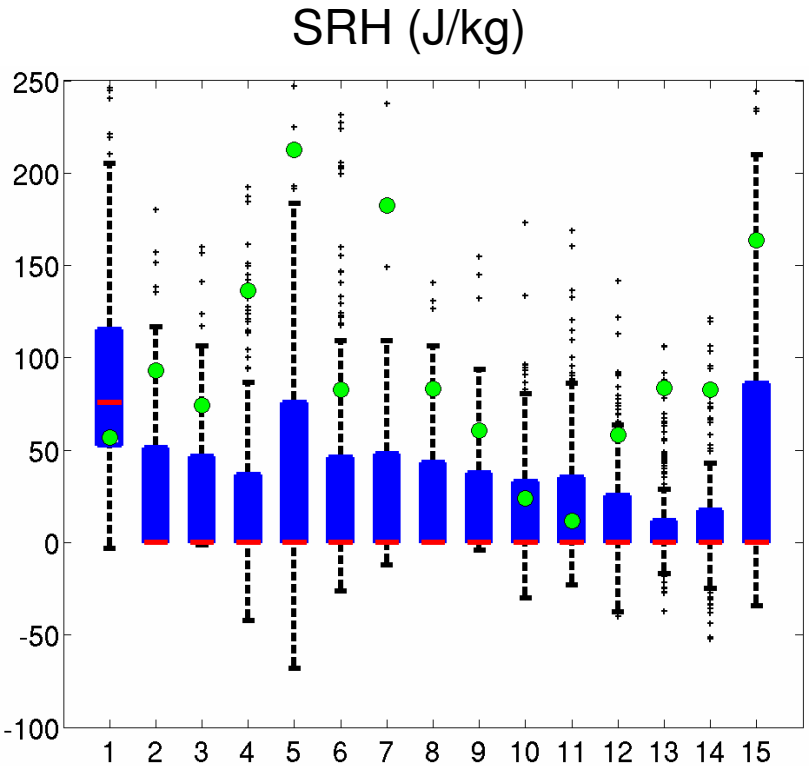
Boxplots:

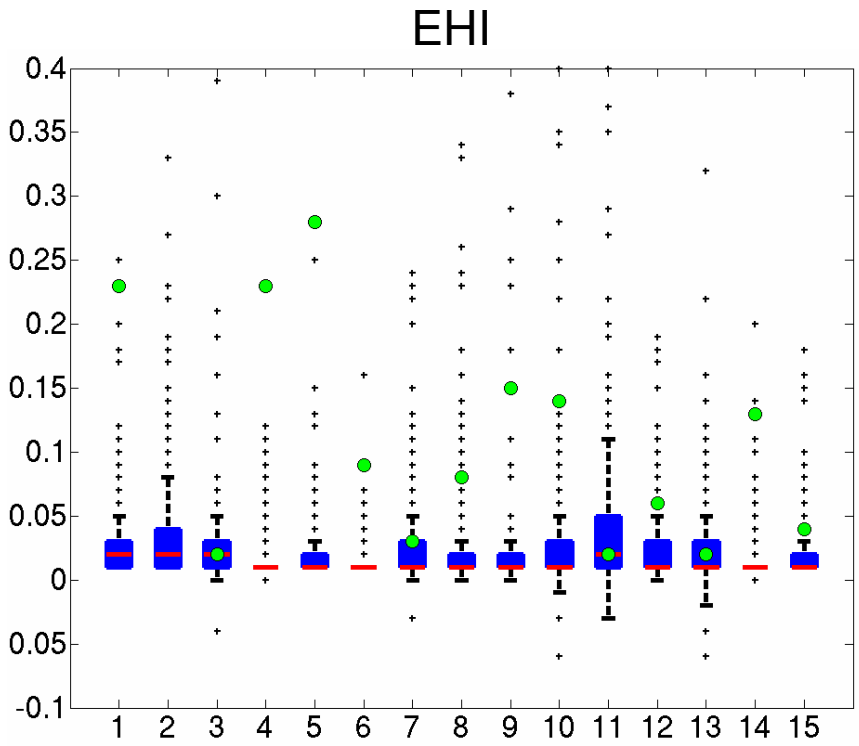
- local monthly climatology (values ±15 days before and after the event)

Green dots:

- parameter values during the 15 events

Question 1: Convective Indices

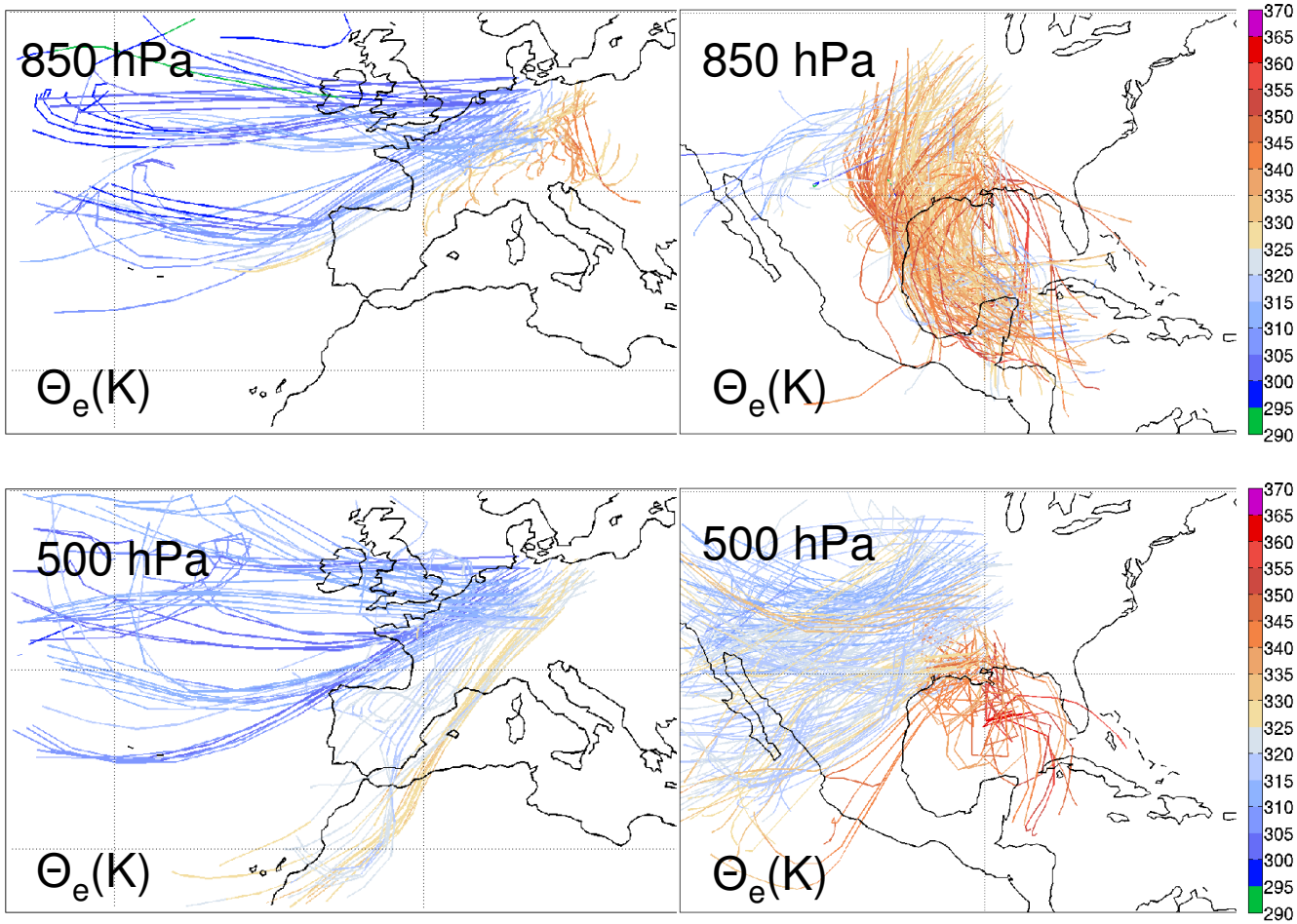




- all three severe storm indices are in the upper percentile of their distribution

- absolute values relatively small

Question 2: Lagrangian backward trajectories - Θ_e



- 72h backward trajectories
- started at tornado position
- start level 850 & 500 hPa
- tracing equivalent-potential temperature (Θ_e)

Europe:

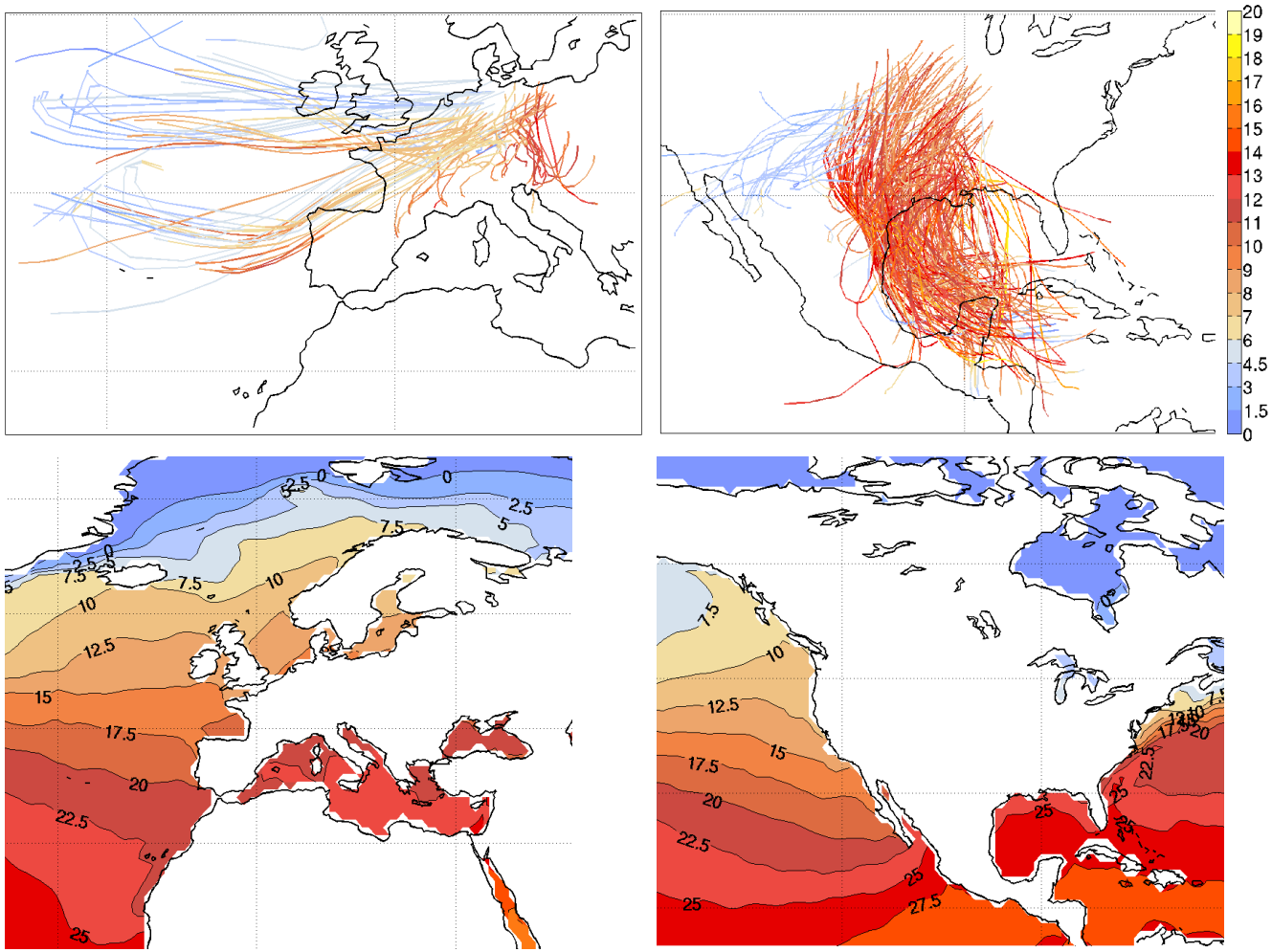
- weak turning of wind with height
- slight differences of Θ_e advection at both levels

US:

- strong turning of wind with height
- large differences in Θ_e advection

Question 2: Lagrangian backward analysis - Moisture

Q@850hPa (g/m^3)



mean SST (°C)

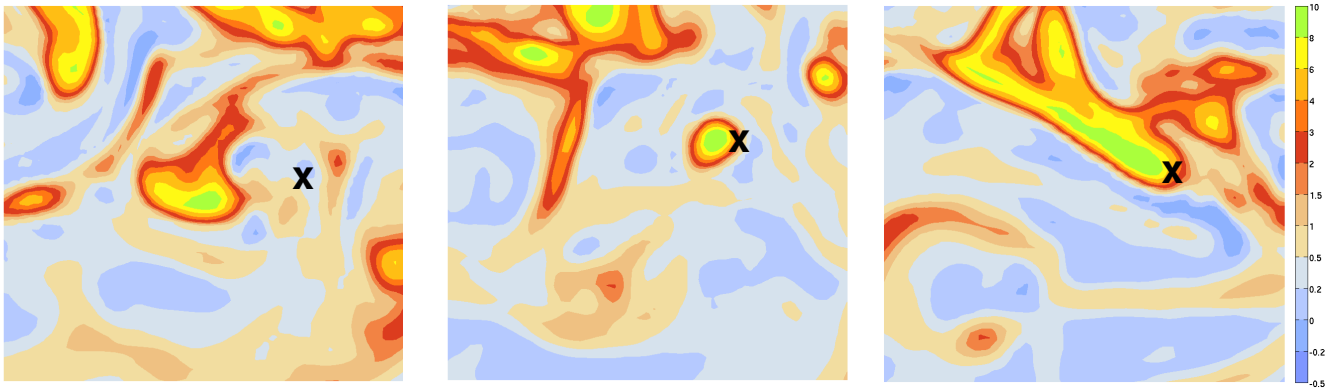
-Tracing specific humidity

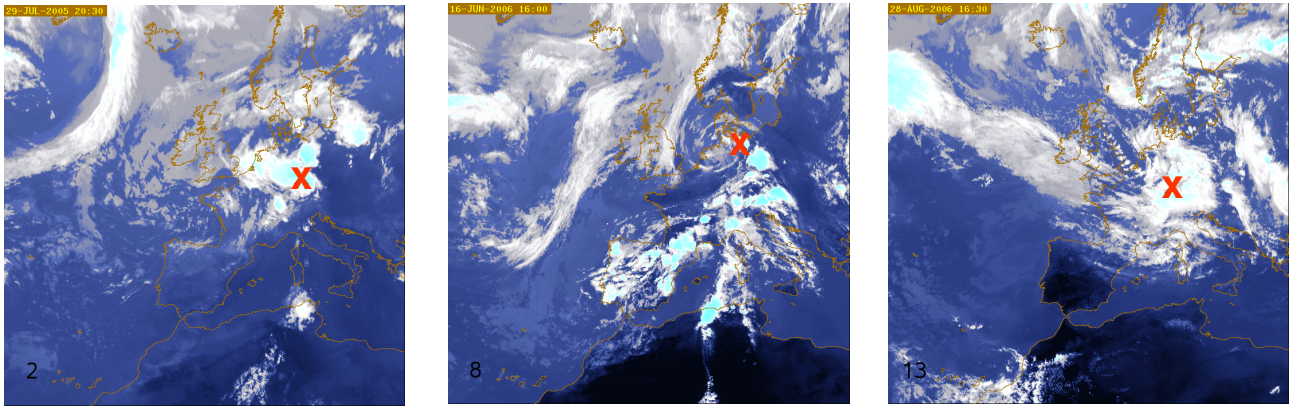
- **Europe:** moisture flux from Atlantic in most cases
- relatively low values of specific moisture
- Alps hinder flow from the South

- **US:** moisture flux from Gulf of Mexico in nearly every case
- high values of specific moisture
- no orographic barrier

Question 3: Synoptic weather situations

PV@300 hPa (PVU)

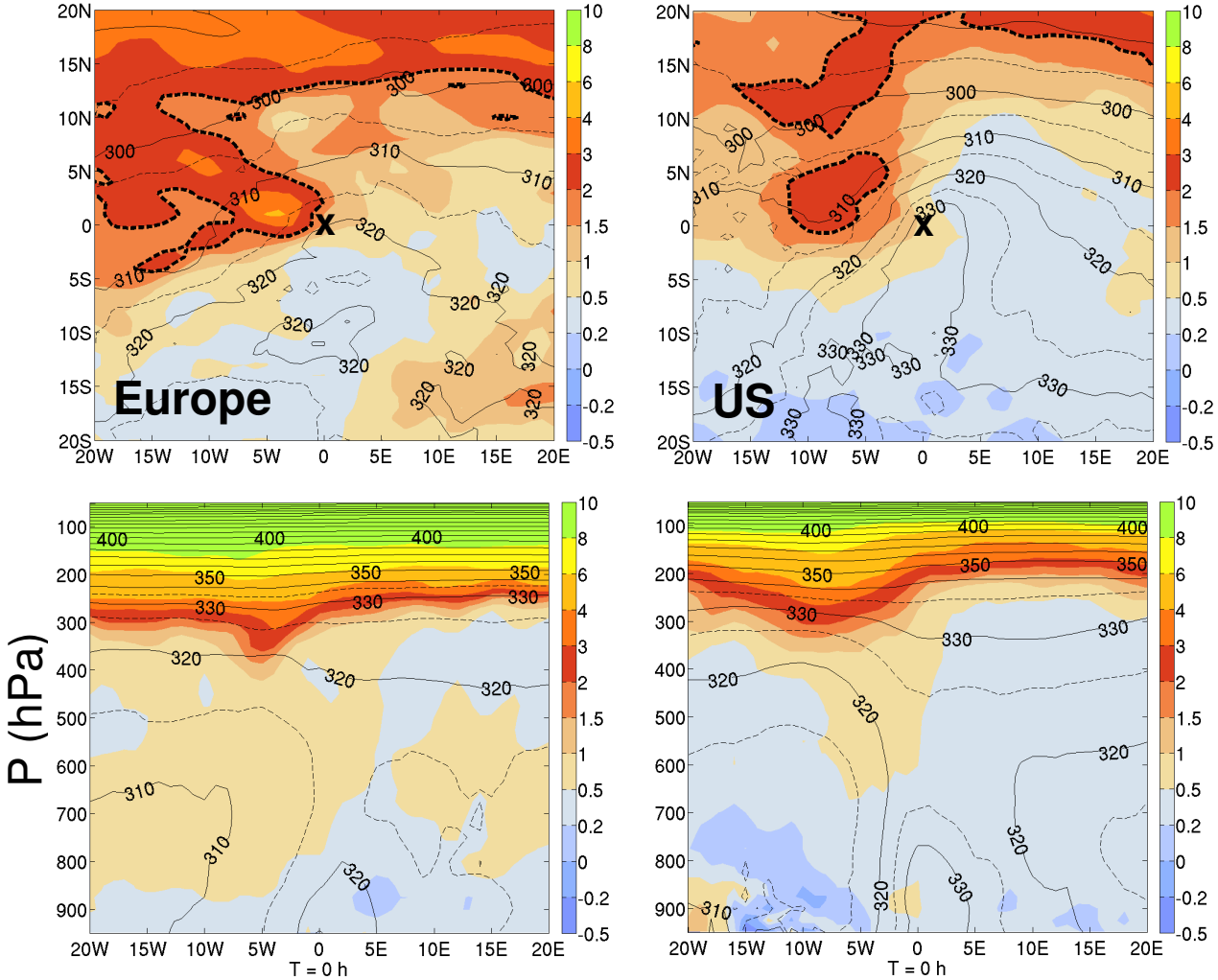




IR images during tornado event

- 14 of 15 European have PV anomaly in closer environment (<200 km)
- large differences of the shape of the PV features and of the cloud patterns
- lead to destabilization, forced lifting and enhanced low level moisture fluxes
- 13 of 15 cases are associated with low-level features (e. g. fronts, convergence, short-wave trough)

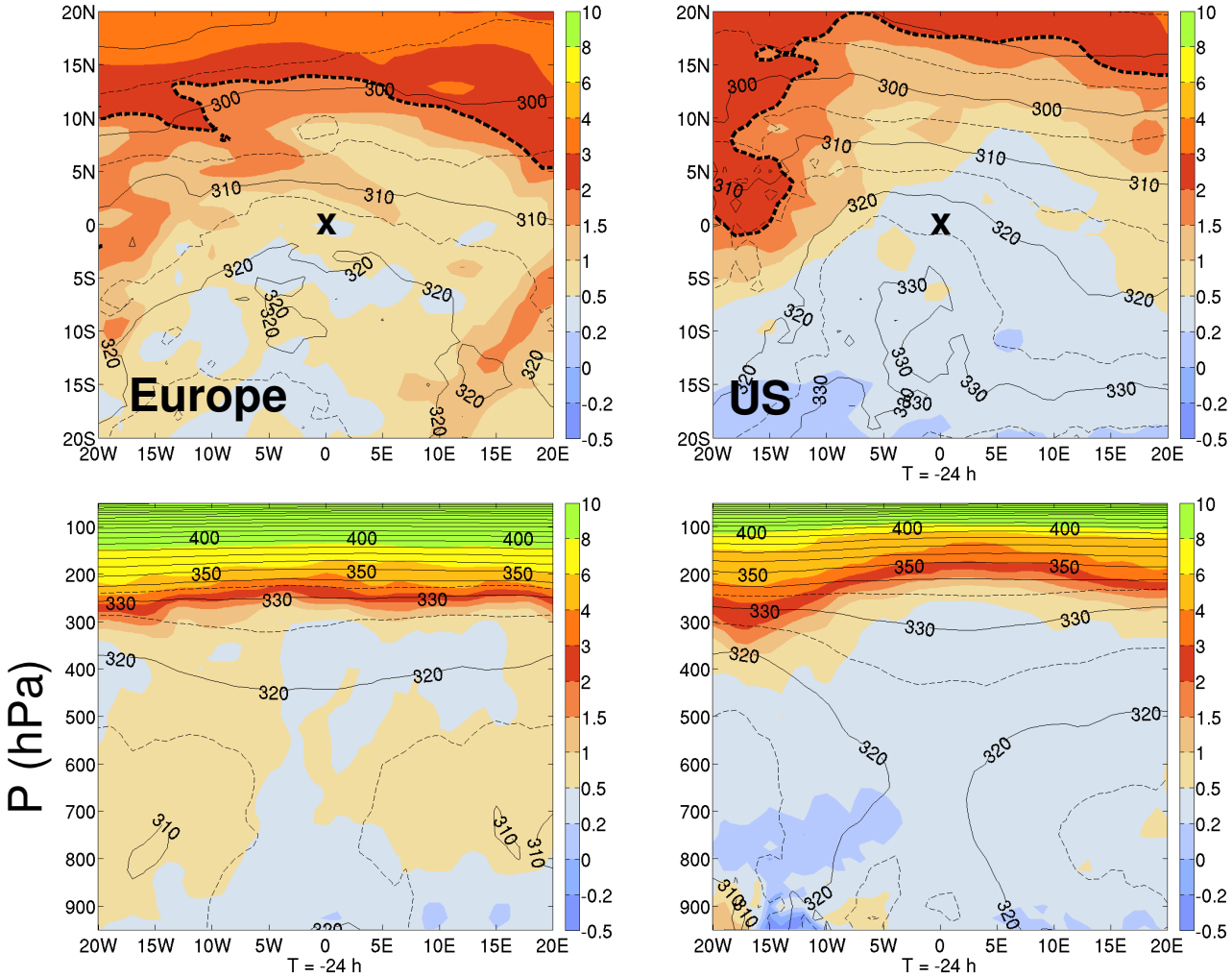
Question 3: Synoptic weather situations



Composite
PV@300 hPa (PVU) and Θ_e@850 hPa (K)

- Composite with similar upper-level PV pattern
- significantly higher Θ_e gradient in the US

WE Crosssection compo.
PV (PVU) and Θ_e (K)



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WE Crosssection compo.
PV (PVU) and Θ_e (K)

- temporal evolution indicates a correlation between upper-level PV anomalies and tornado genesis

Conclusions

Question 1: Applicability of convective indices for tornado forecasting

- CAPE, SRH and EHI on average significantly lower than in the US
- convective indices usable if used with respect to the local climatology

Question 2: Flow pattern responsible for preconditioning

- **Europe:** orographic barrier (Alps) hinders moisture flux from the South
- main source region is the Atlantic with lower SSTs
- much less turning of wind with height (helicity)

- **US:** moisture flux from the Gulf of Mexico (higher SSTs)
- higher vertical Θ_e gradients

Question 3: Synoptic situations in Europe

- many cases with upper-level PV anomaly west to the tornado position
- PV anomaly leads to: destabilization, forced lifting, and enhanced low-level moisture flux > preconditioning of the Atmosphere for tornadoes