A Detailed Analysis of Frontal Precipitation in a Decadal Convection-Resolving Regional Climate Simulation over Europe

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Introduction

- Fronts are a **major source of precipitation** – both normal and extreme – in the extratropics [3, 4].
- **Resolving deep convection** improves modeled precipitation, e.g., the diurnal cycle of summer convection or convective organization at fronts [1, 9].
- **Intense convective precipitation** near fronts is often found in typical places, e.g., in narrow cold-frontal rainbands or near cold surges in occluding systems [5, 2].
- We study **precipitation related to fronts over Europe** in a kilometer-scale regional climate simulation, investigating **spatial, front-relative, and temporal** distributions of regular and extreme precipitation.

Methods

- Identify **weather systems** as features:
  - **Fronts**: 850 hPa Θ_e, cold & warm [based on 7]
  - **Cyclones**: SLP, multicenter [based on 6]
- **Track features** over time with **new tool**:
  - Based on overlap and size comparison
  - Complex tracks with mergings and splittings
  - Objective splitting of huge cluster tracks

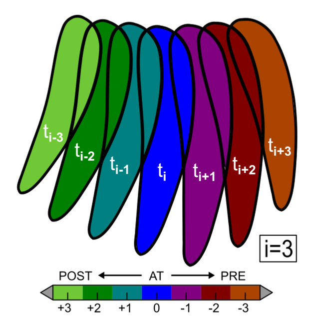

Figure 1: Illustration of front track area projection at one timestep.

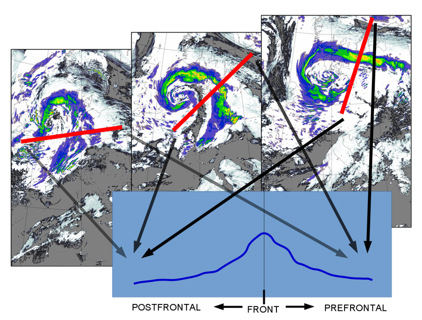

Figure 2: Computation of the mean precipitation distribution across a front.

- Determine **front-relative areas** by track projection:
  - **Near-frontal**: Where is the front right now?
  - **Postfrontal**: Where has the front been lately?
  - **Prefrontal**: Where will the front be soon?
- Isolate **influence of other processes**:
  - **Cyclone center**: use cyclone mask
  - ***Concurrent*** **front**: overlap of near-frontal areas

Data

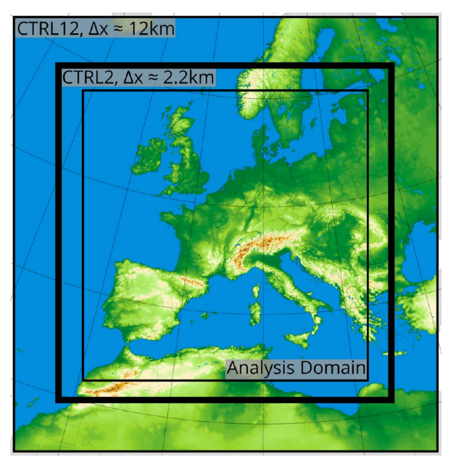

Figure 3: Model domains [from 9]

- Ten-year **continental-scale** regional climate simulation over Europe with **resolved deep convection** [8, 9]
- COSMO-GPU @ 2.2 km, 1542 × 1542 × 60 grid
- Nested in 12 km model driven by ERA-Interim
- Project **crCLIM** (SNSF-Sinergia CRSII2_154486/1)
- *www.c2sm.ethz.ch/research/crCLIM.html*

Case Study (I): Synoptic Overview and Track Areas

- Summer cyclone Uriah, 24-27 June 2007, with a strong cold front and a weak warm front.
- Fronts occlude as they roll up; precipitation band wraps around the cyclone center.

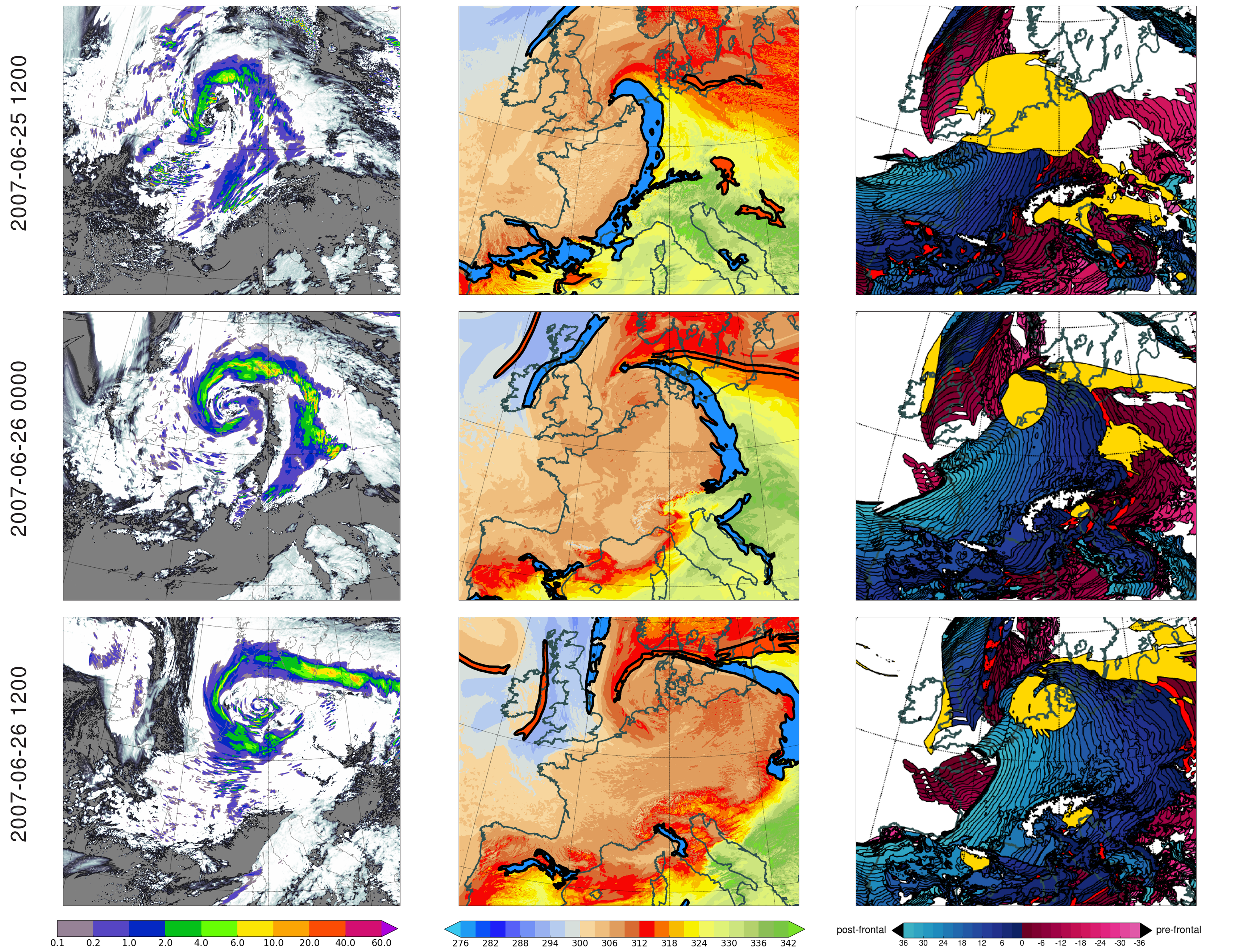

Figure 4: Shown are (left) cloud cover (grayscale) and precipitation in mm/h (colors); (center) synoptic cold (blue) and warm front features (red) and Θ_e in K at 850 hPa (colors); and (right) cold-front-relative areas (colors), with cyclone and concurrence areas ($\leq$ 6 h to warm front) in yellow.

Extreme Hourly Precipitation

- Events defined by exceedence of the local 99.9th percentile, computed over the full time series.
- Fronts contribute mainly during summer afternoons/evenings and summer/fall nights; cold fronts more so than warm fronts.

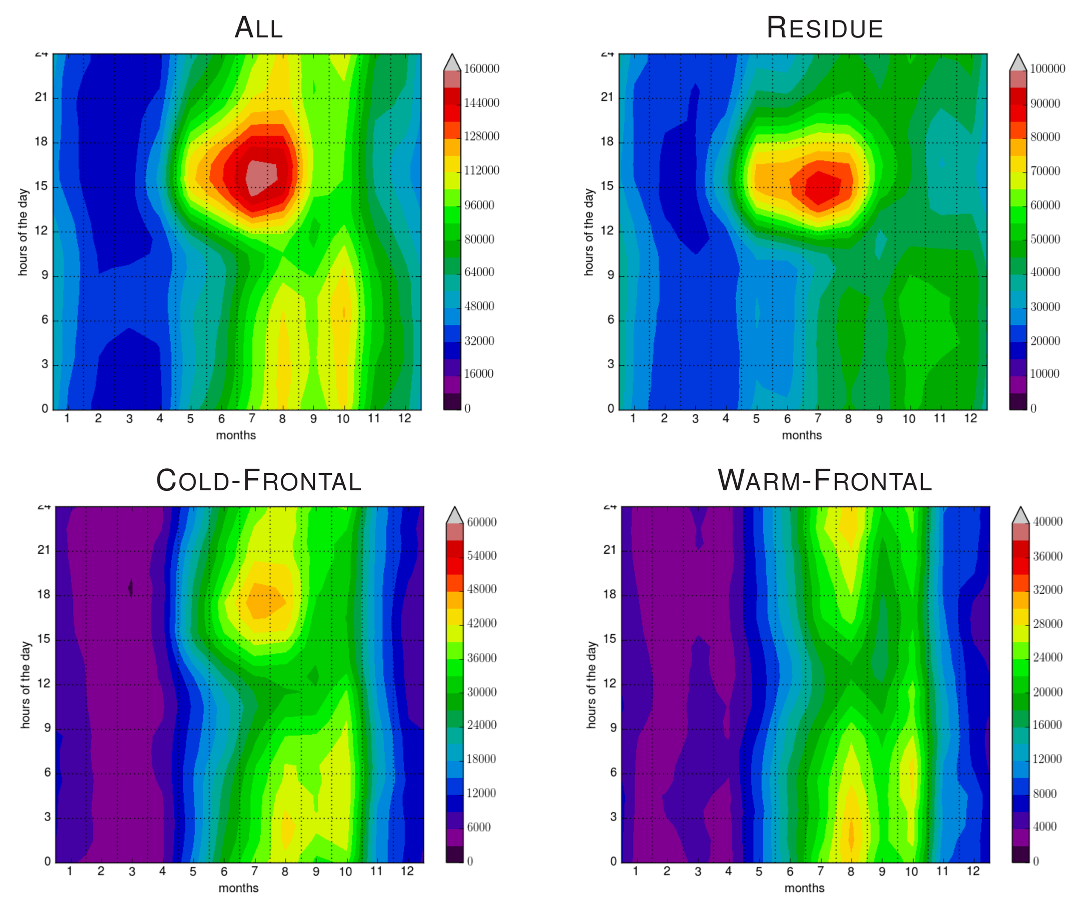

Figure 5: Mean number of extreme precipitation events, in counts per month, over the whole domain from 2000 to 2008. The horizontal axes comprise the months, the vertical axes the hours of the day. Frontal events occur within 12 h of a respective front. Note the different contour levels.

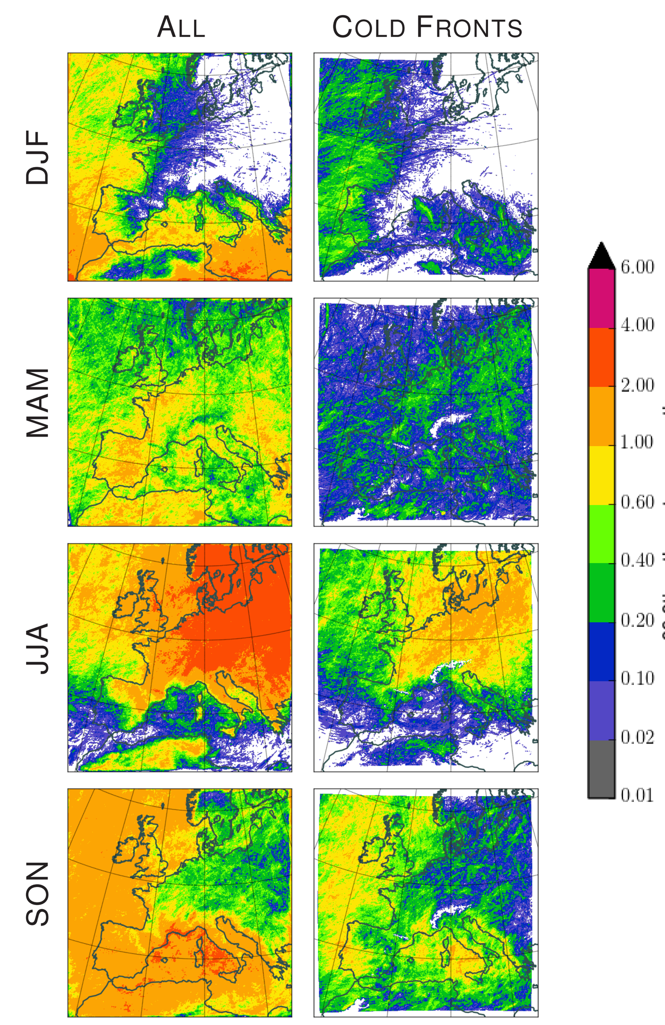

Figure 6: Seasonal monthly-mean extreme precipitation event count from 2000 to 2008. Cold-frontal events occur within 12 h of a front.

Case Study (II): Precipitation Analysis

- The cyclone and the cold front produce most of the precipitation, the warm front only little.
- Widespread residue remains, not all of which we might classify as *nonfrontal*.

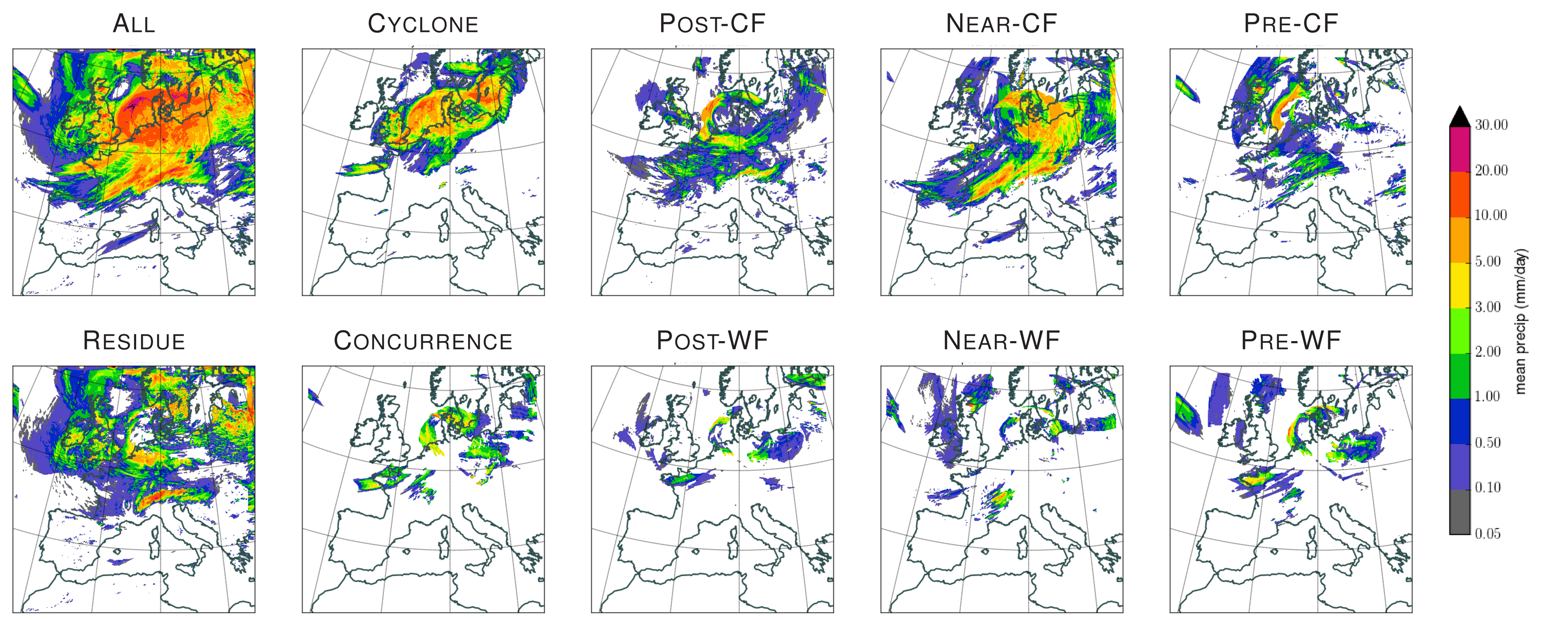

Figure 7: Mean daily precipitation sum in mm/day from 2007-06-24 0000 UTC to 2007-06-27 2300 UTC for cold- and warm-front-relative components (CF and WF), among them pre-frontal (-19 h to -7 h), near-frontal (-6 h to +6 h), post-frontal (+7 h to +19 h), and concurrence (overlapping near-frontal).

- Most precipitation is produced within 6 h of the cold front, at intensities from 1 mm/h to 20 mm/h.
- Warm-frontal precipitation is mostly restricted to near the cyclone center or the cold front.

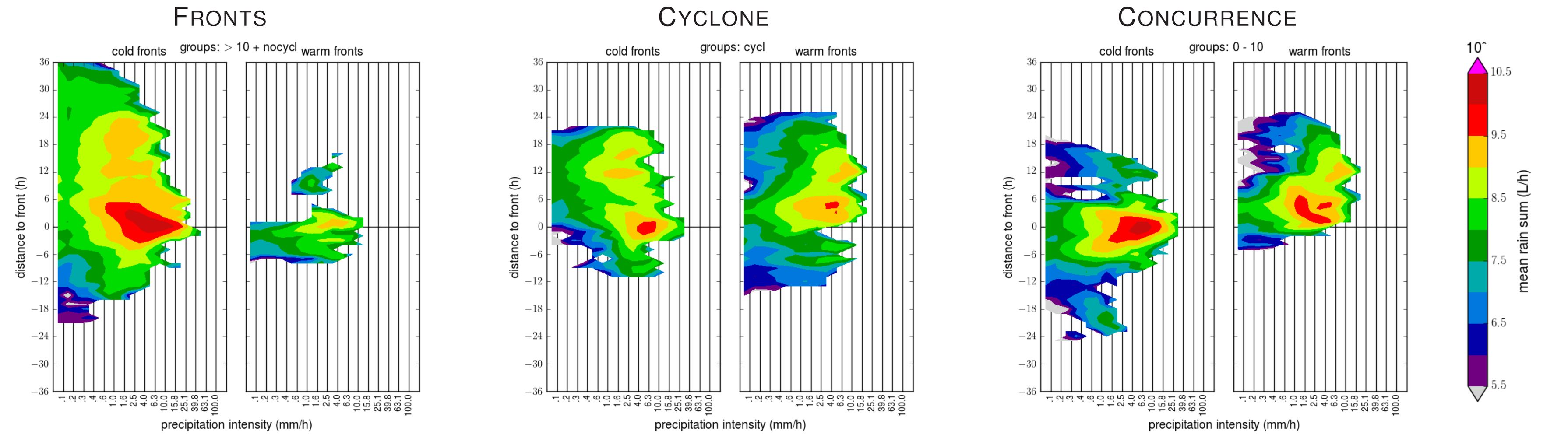

Figure 8: Composite of cross-frontal precipitation sum (L/h), with distance to the front in hours from top (postfrontal) to bottom (prefrontal), as a function of intensity in mm/h from left (light) to right (strong), for three regimes: (left) front in isolation; (center) near the cyclone center; (right) near the other front (near-frontal here defined as -10 h to +10 h). Cold fronts are shown in the left panels, warm fronts in the rights.

Summary and Outlook

- Based on front tracks, we can disaggregate the precipitation field into prefrontal, frontal, and postfrontal components. Furthermore, distributions of cross-frontal precipitation can be compiled.
- Extreme precipitation shows strong seasonal and diurnal cycles, both at and away from fronts. Overall, most extremes, by far, occur during summer afternoon. For fronts, nighttime extremes during summer/fall are almost as frequent.
- Analogous analyses will also be conducted for other variables like wind.

References

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12 December 2017, AGU Fall Meeting, New Orleans