Precipitation and Fronts in a Convection-Resolving Decade-Long Simulation over Europe

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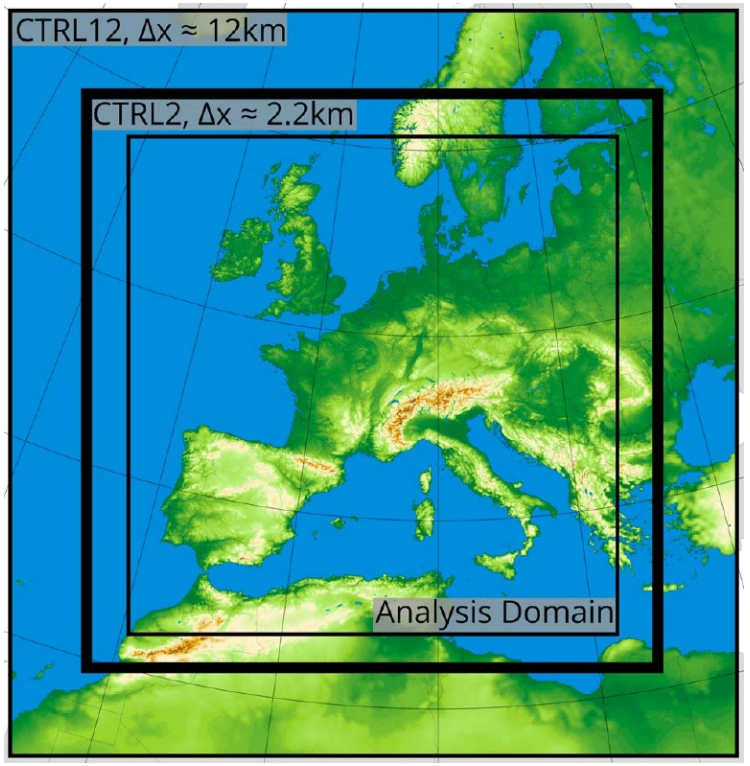
Project crCLIM

- **Ten-year European-scale** regional climate simulation with **resolved deep convection**
- **Better precipitation** due to resolved deep convection, e.g.,
  - summer **diurnal cycle** (Ban et al. 2014)
  - convective **organization at fronts** (Leutwyler et al. 2017)
- Setup (Leutwyler et al. 2016):
  - **COSMO-GPU** (4.19, soon 5.X)
  - **2.2 km** (1542 × 1542 × 60), 20 s
  - 12 km nest driven by **ERA-Interim**
- Most **analysis** to be conducted ***on-the-fly*** with new simulation-analysis tools interface (Di Girolamo & Hoefler, ETHZ D-INFK/SPCL)



Domain (Leutwyler et al. 2017)

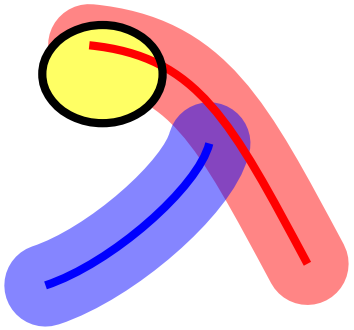
www.c2sm.ethz.ch/research/crCLIM.html

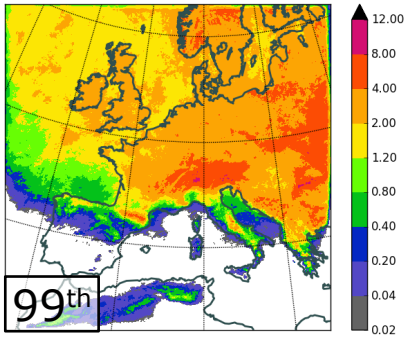
Project crCLIM (SNSF-Sinergia CRSII2 154486/1)

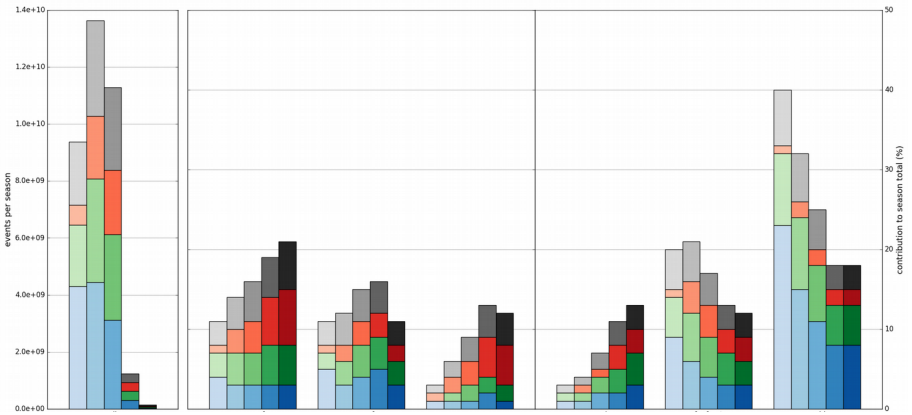
ETH zürich CSCS MeteoSwiss PRACE

Part I

Frontal Precipitation



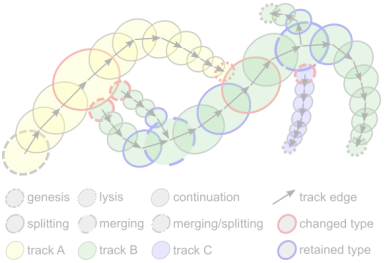


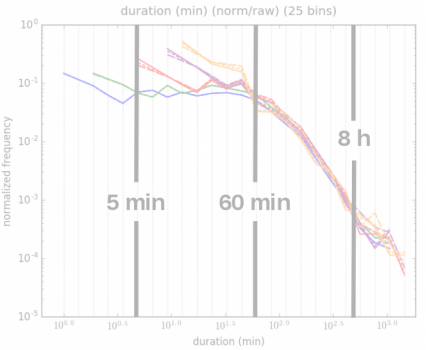


Ruedisuehli, Sprenger, Leutwyler, Wernli (in prep.)

Part II

Precipitation Tracking





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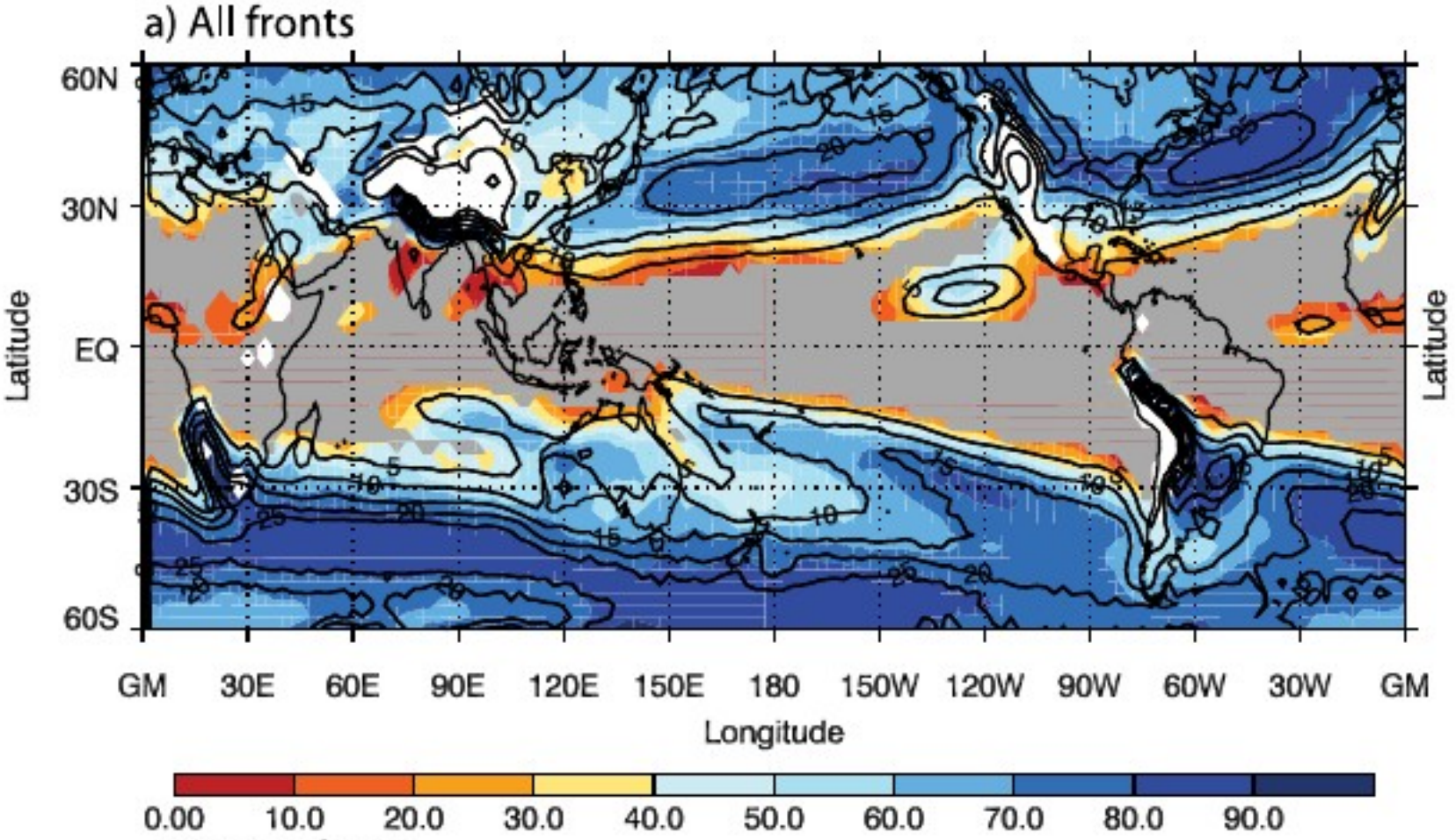
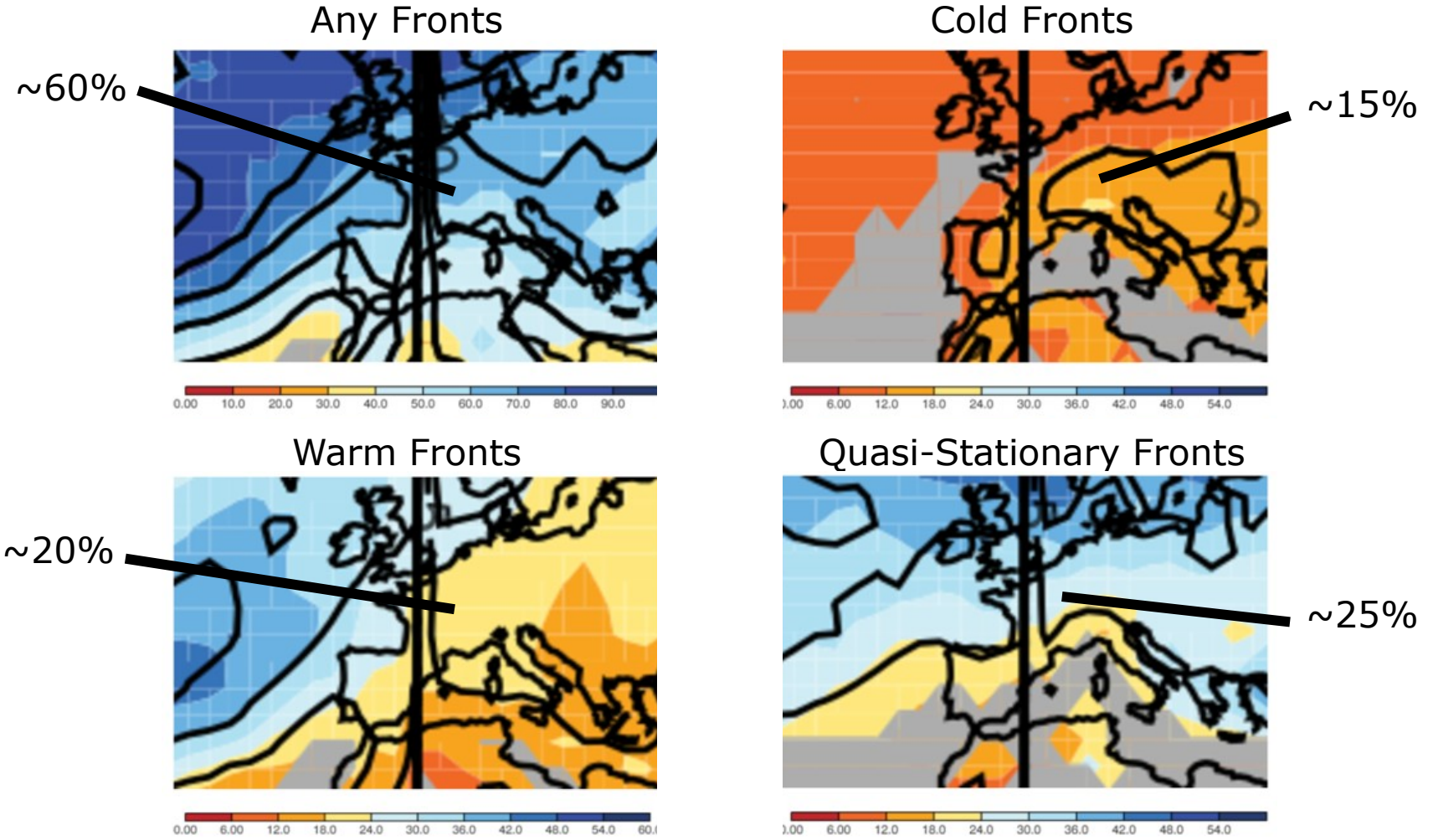
Frontal Precipitation



Contributions of fronts to global precipitation, 1997-2008 (Catto et al. 2012).
Resolution: 6 h, 2.5°; allocation: 24 h period, 5° box.

Frontal Precipitation



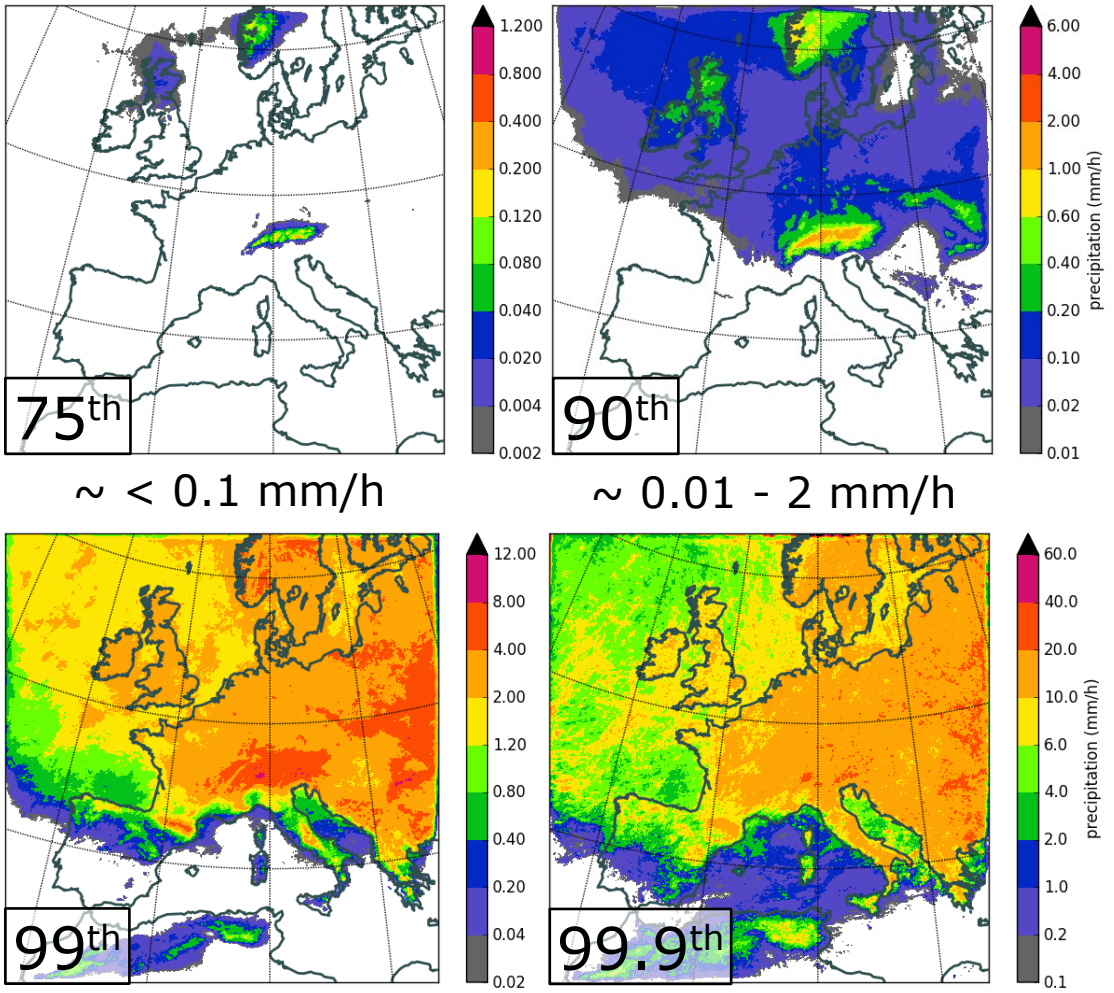
Contributions of fronts to precipitation in Europe, 1997-2008 (Catto et al. 2012).
Resolution: 6 h, 2.5°; allocation: 24 h period, 5° box.

Precipitation Intensity Groups

- **Monthly local percentiles** of hourly precipitation, incl. dry (one value per grid point)
- **Intensity** groups:

	-	75th	dry/very light
75th	-	90th	light
90th	-	99th	moderate
99th	-	99.9th	heavy
99.9th	-		extreme

- "**Event**": Any value in a certain percentile range (1 h x 2.2² km²)
- **Caveat**: temporal and spatial event extents not considered

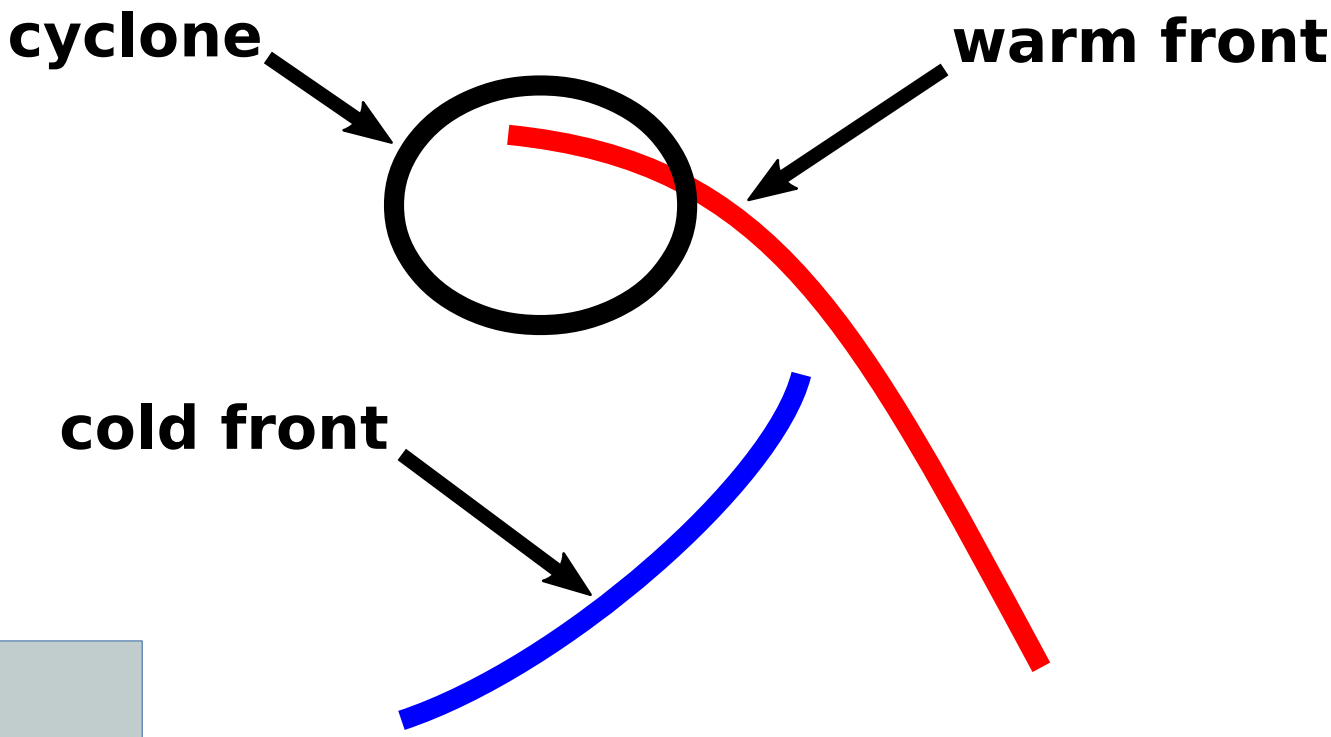


Local percentile maps for July 2000-2008

Fronts and Cyclones

Fronts

- **THE @ 850 hPa** (Jenkner et al. 2010)
- **Cold** vs. **Warm**
- **Tracked** over time
- **Synoptic** vs. Local



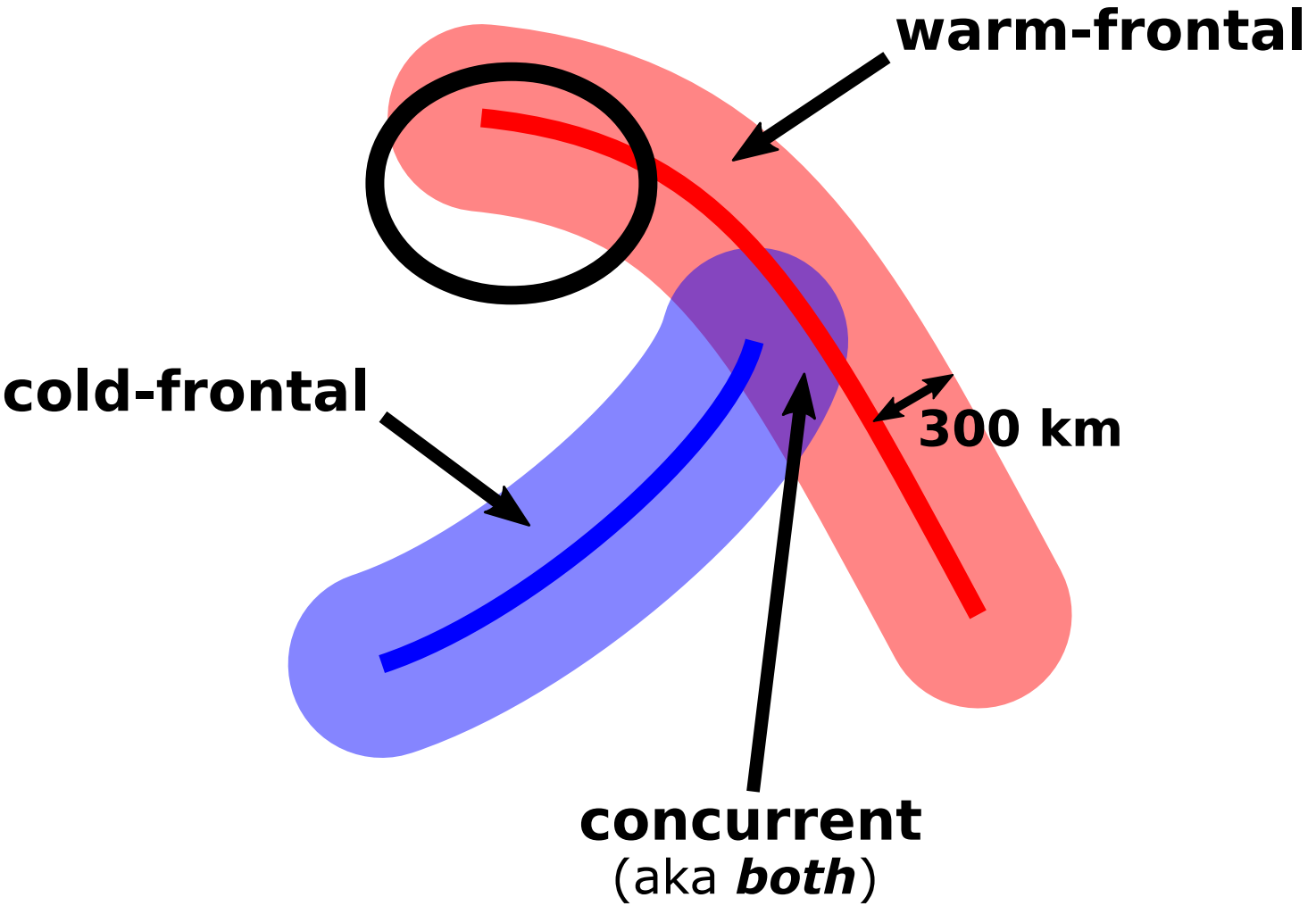
Cyclones

- **SLP contours** (Wernli and Schwierz 2006)
- **Multi-center** (1-3) (Hanley and Caballero 2012)
- **Tracked** over time

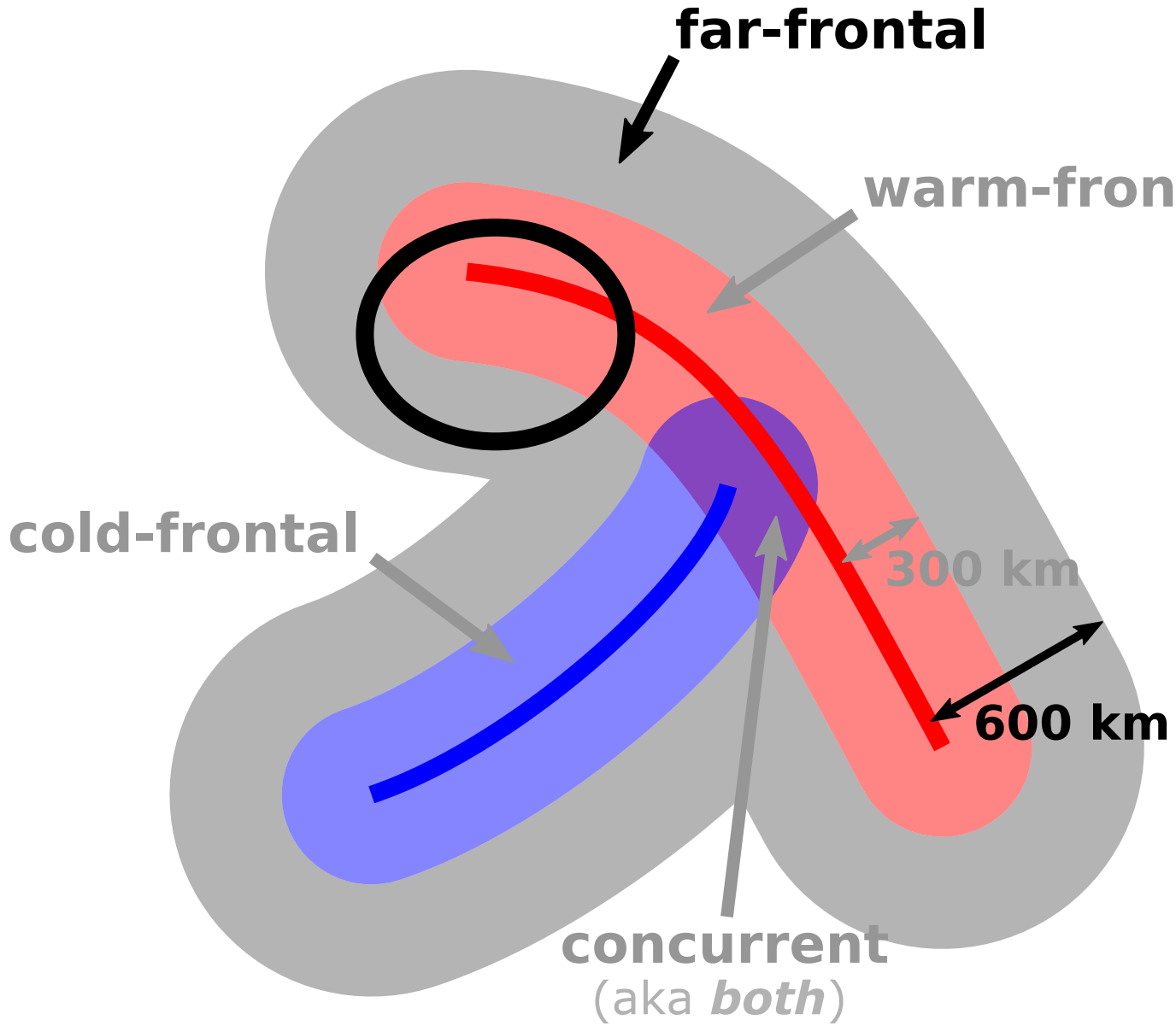
Tracking

- New tool for **high resolution**
- Based on **overlap** and **size**
- **Mergings** and **splittings**

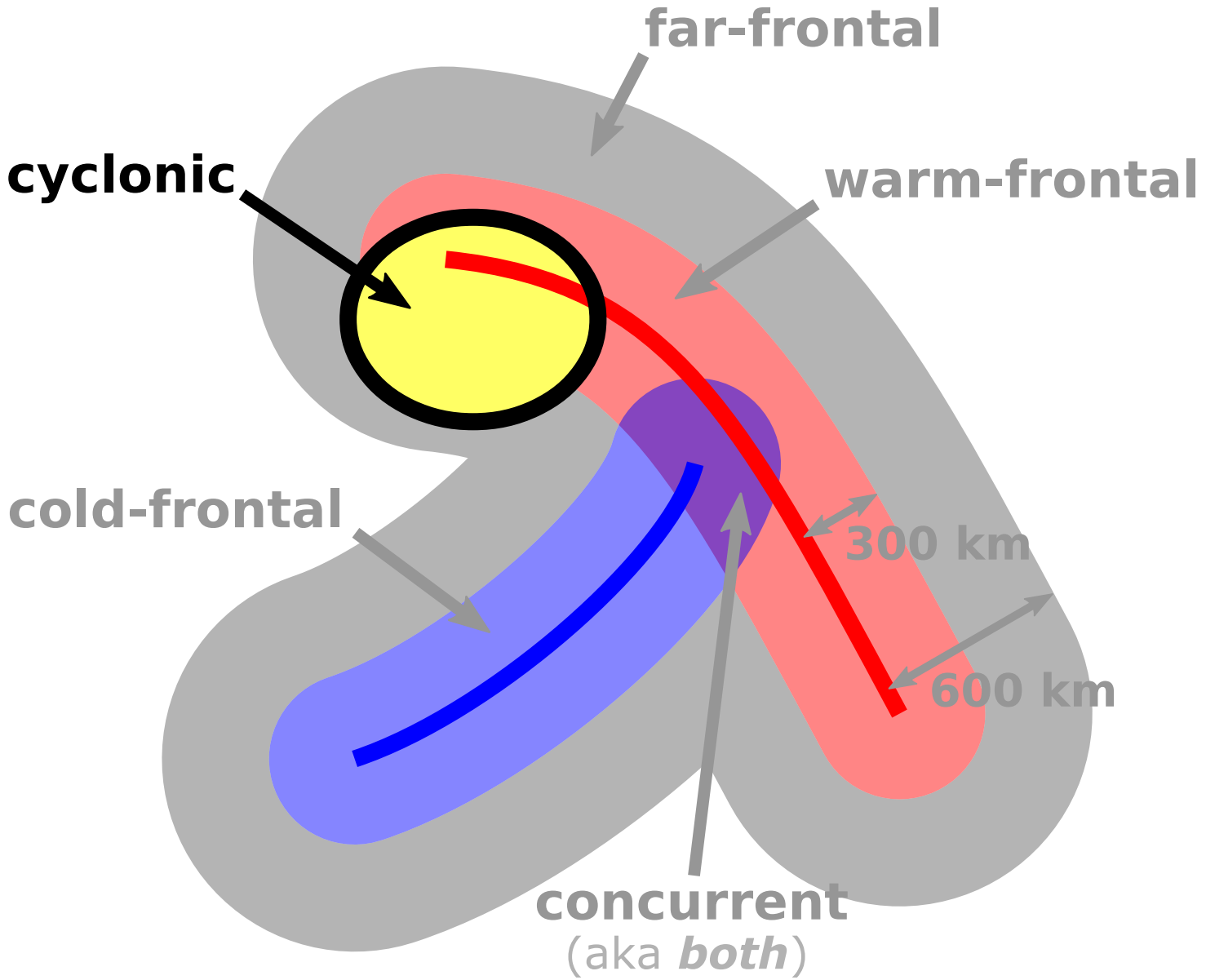
Frontal and Cyclonic Components



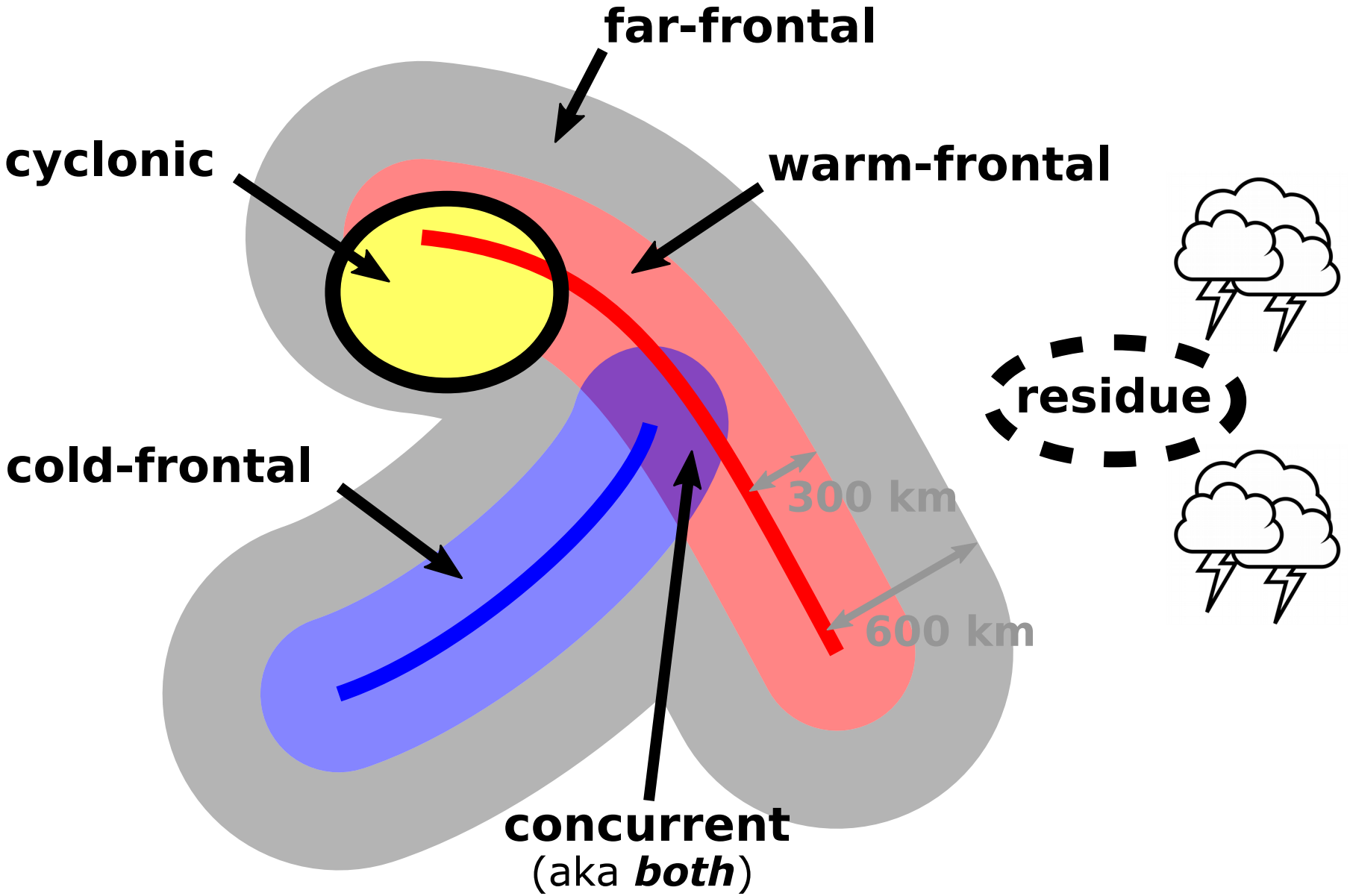
Frontal and Cyclonic Components



Frontal and Cyclonic Components



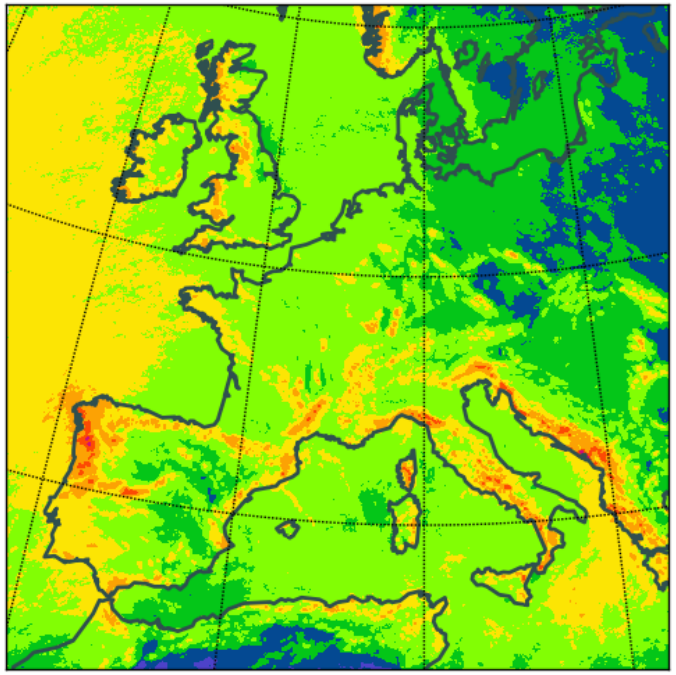
Frontal and Cyclonic Components



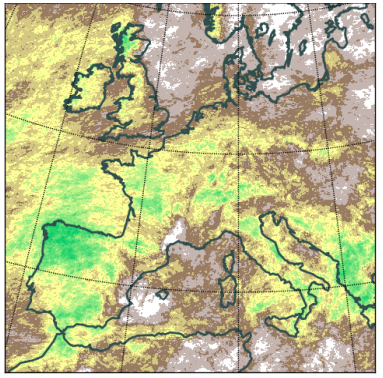
Heavy Precipitation (99th - 99.9th)

total

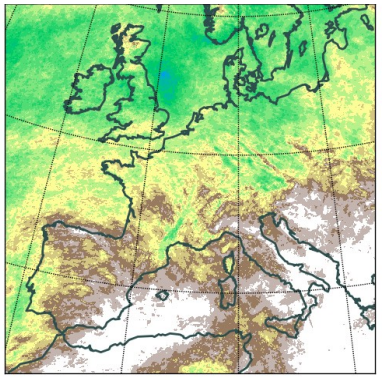
DJF 2000-2008



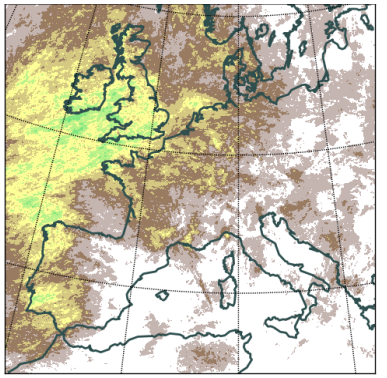
cold-frontal



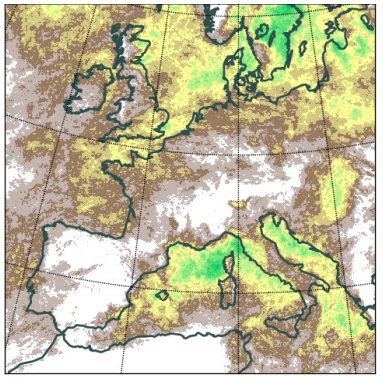
warm-frontal



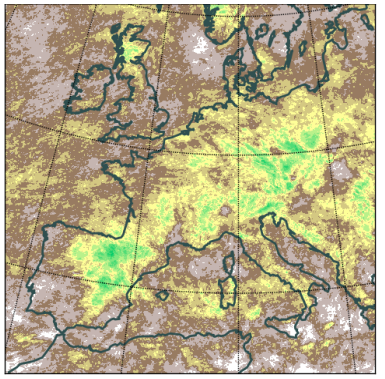
both



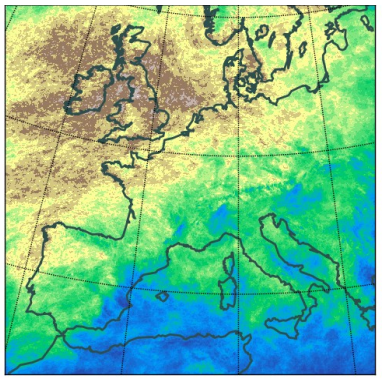
cyclonic

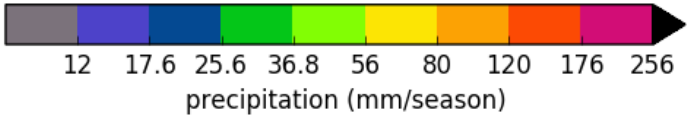


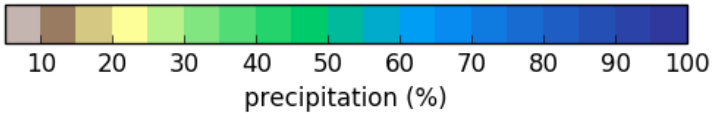
far-frontal



residue

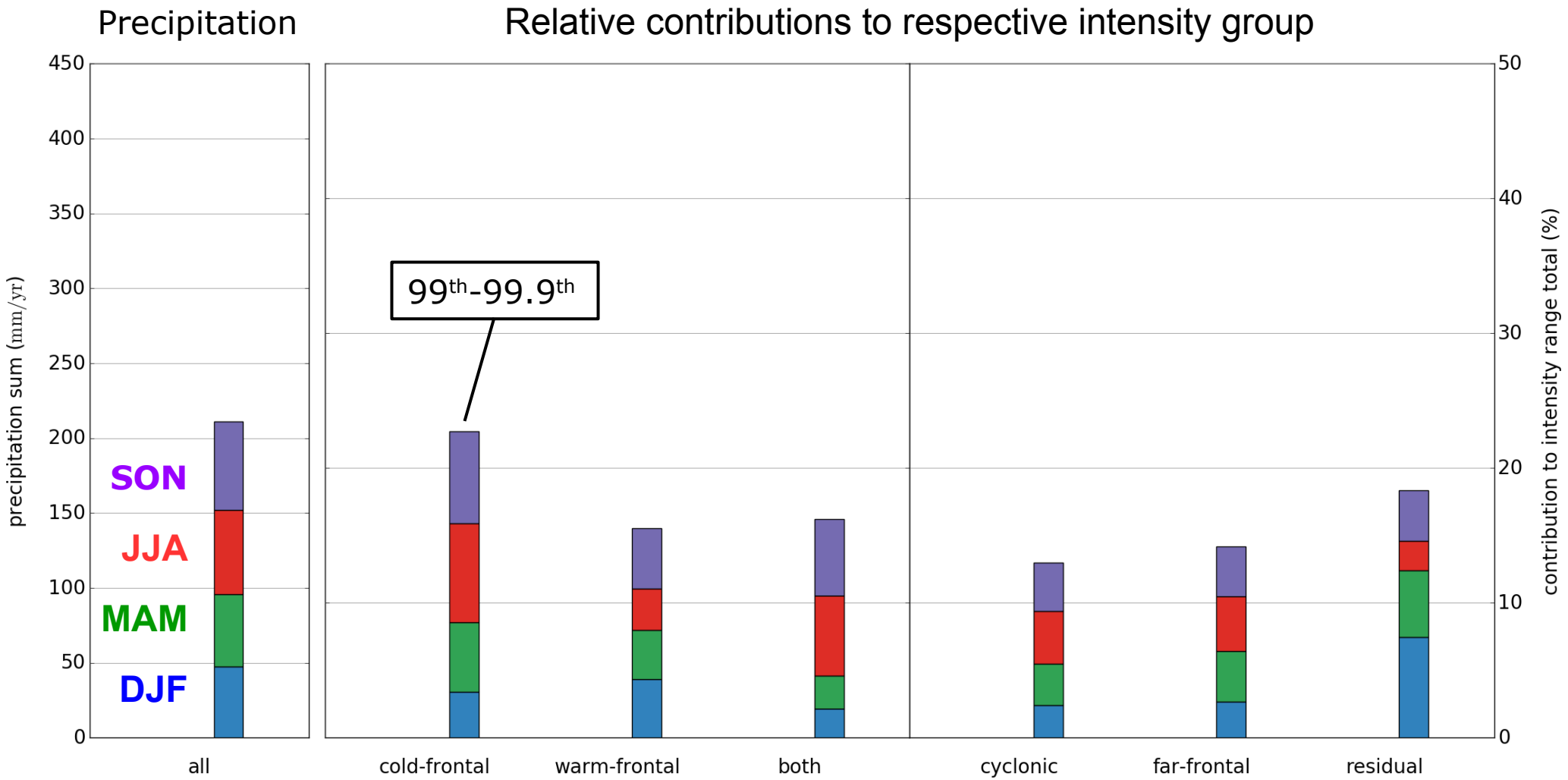






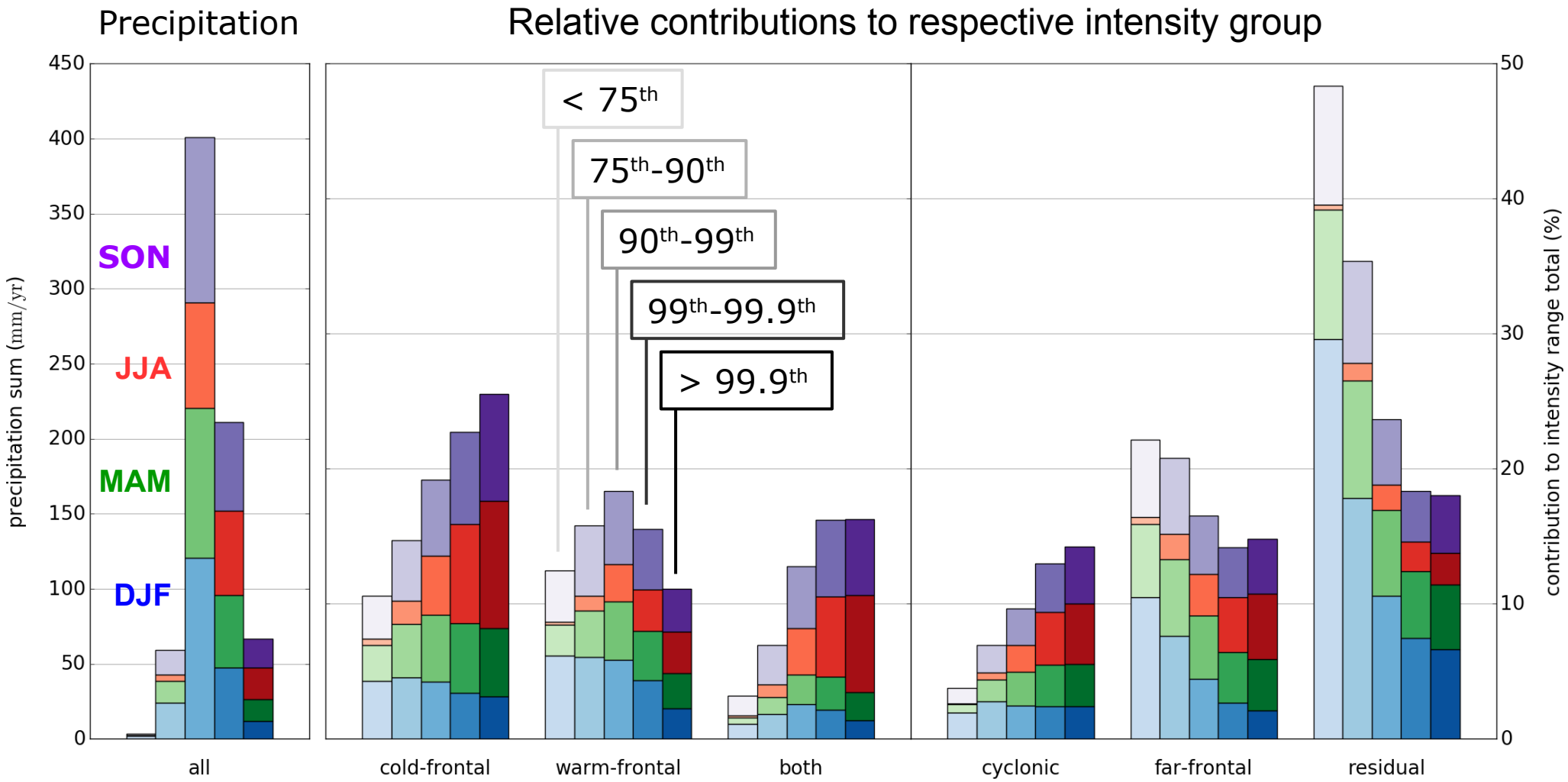
High (warm-) frontal contributions; Mediterranean: **cyclones** and **residue**

Precipitation 2000-2008



- **> 80%** of intense precipitation can be **related to fronts or cyclones**
- **> 55%** related **directly to fronts** (within 300 km)

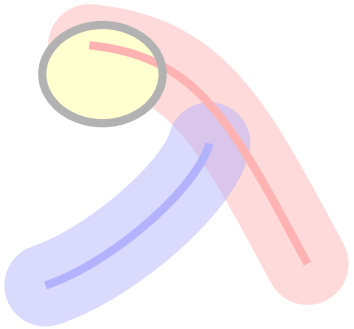
Precipitation 2000-2008

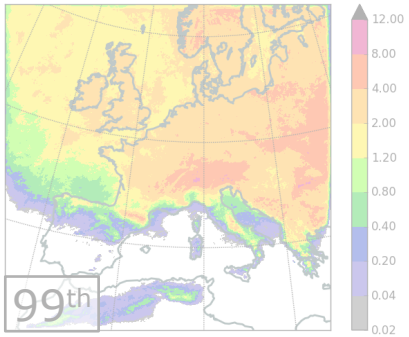


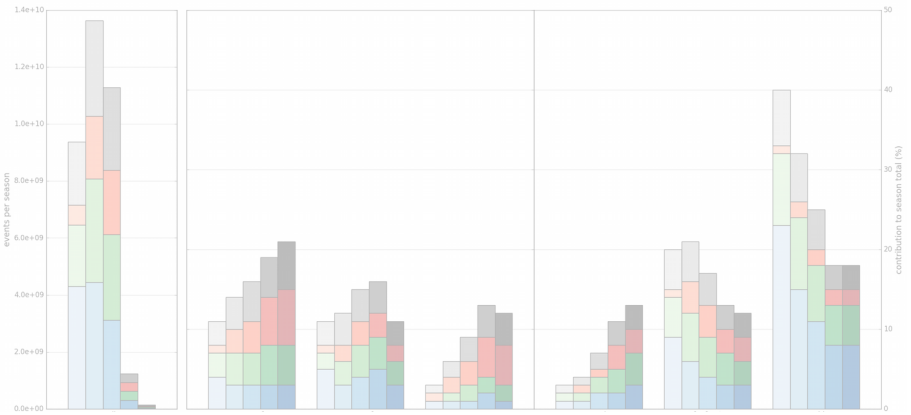
- **More intense** → more **near-frontal/cyclonic** (mainly due to summer)
- **Less intense** → more **far-frontal/residua**l (mainly due to winter)

Part I

Frontal Precipitation



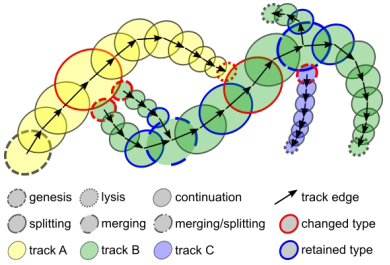


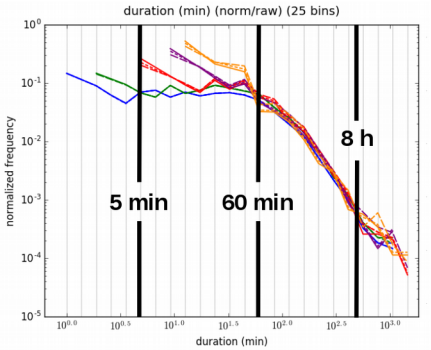


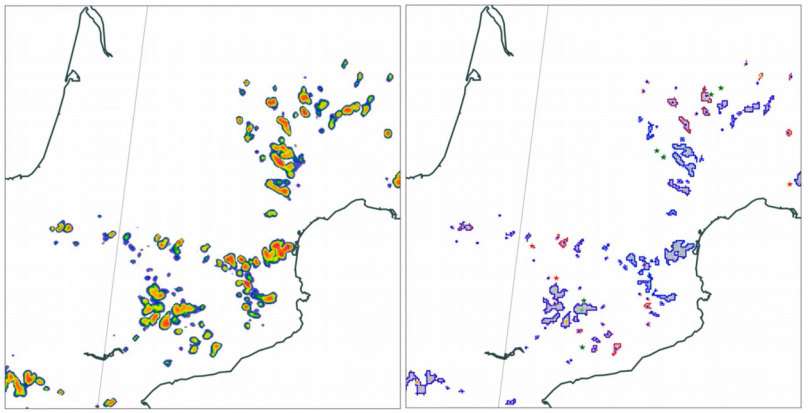
Ruedisuehli, Sprenger, Leutwyler, Wernli (in prep.)

Part II

Precipitation Tracking



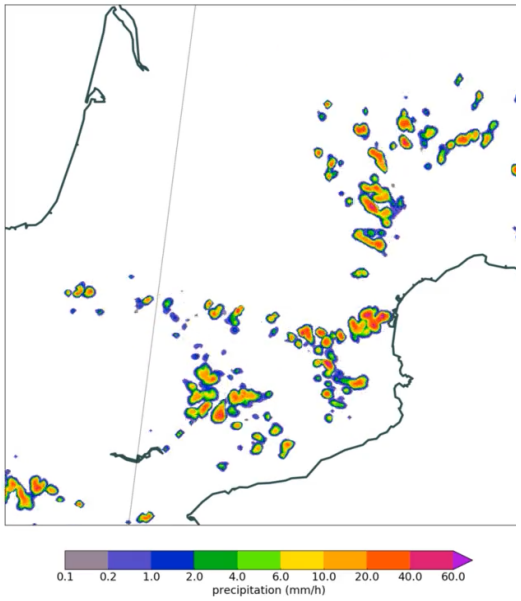


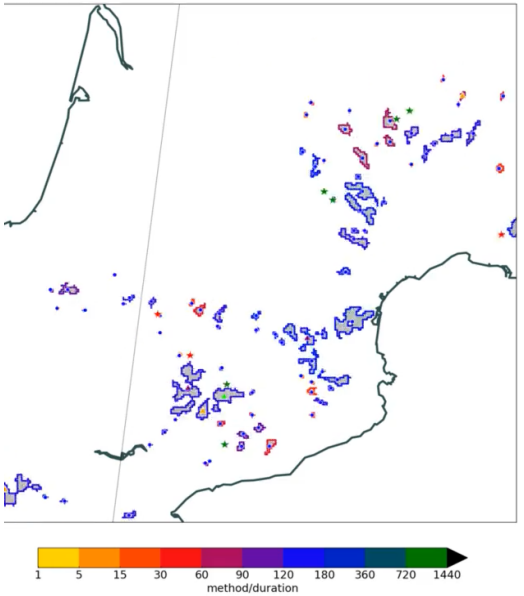


Ruedisuehli, Sprenger, Mosimann, Leutwyler, Wernli (in prep.)

Precipitation Tracking Setup

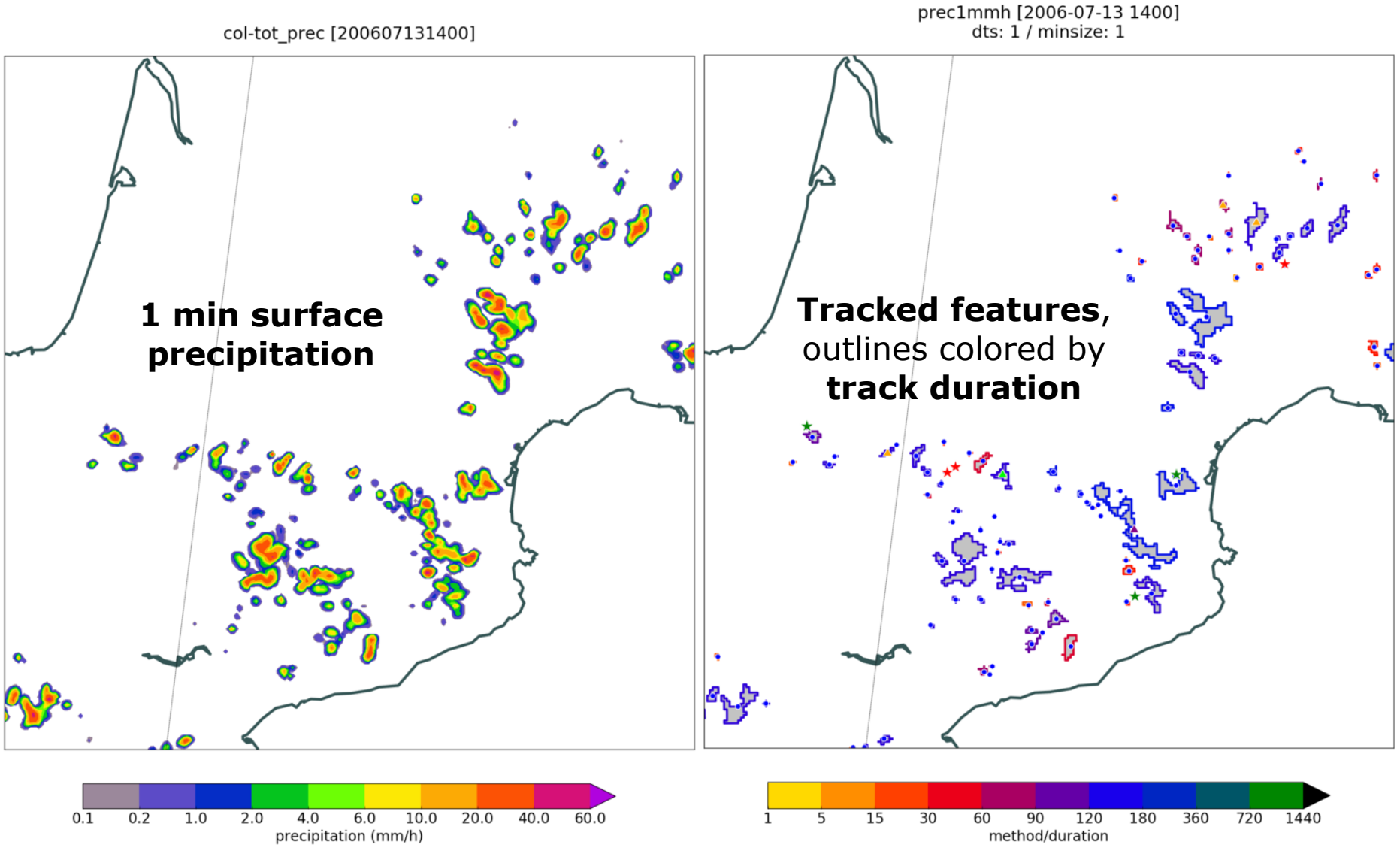
- Goal: **Minute-scale** cell tracking for a **decade** (previously: either hour-scale or short period)
- Now: find **best setup** with case studies
- Later this year: **Ten-year run** (1999-2008)
- Data: **1 min** surface **precip.**, > 1 mm/h (*) (**summer convection**, 11-15 July 2007)
- **Minimum temporal resolution** for results comparable with full 1 min resolution?
- Test **temporal resolution**:
  1 min, 2 min, 5 min, 10 min, 15 min (*)



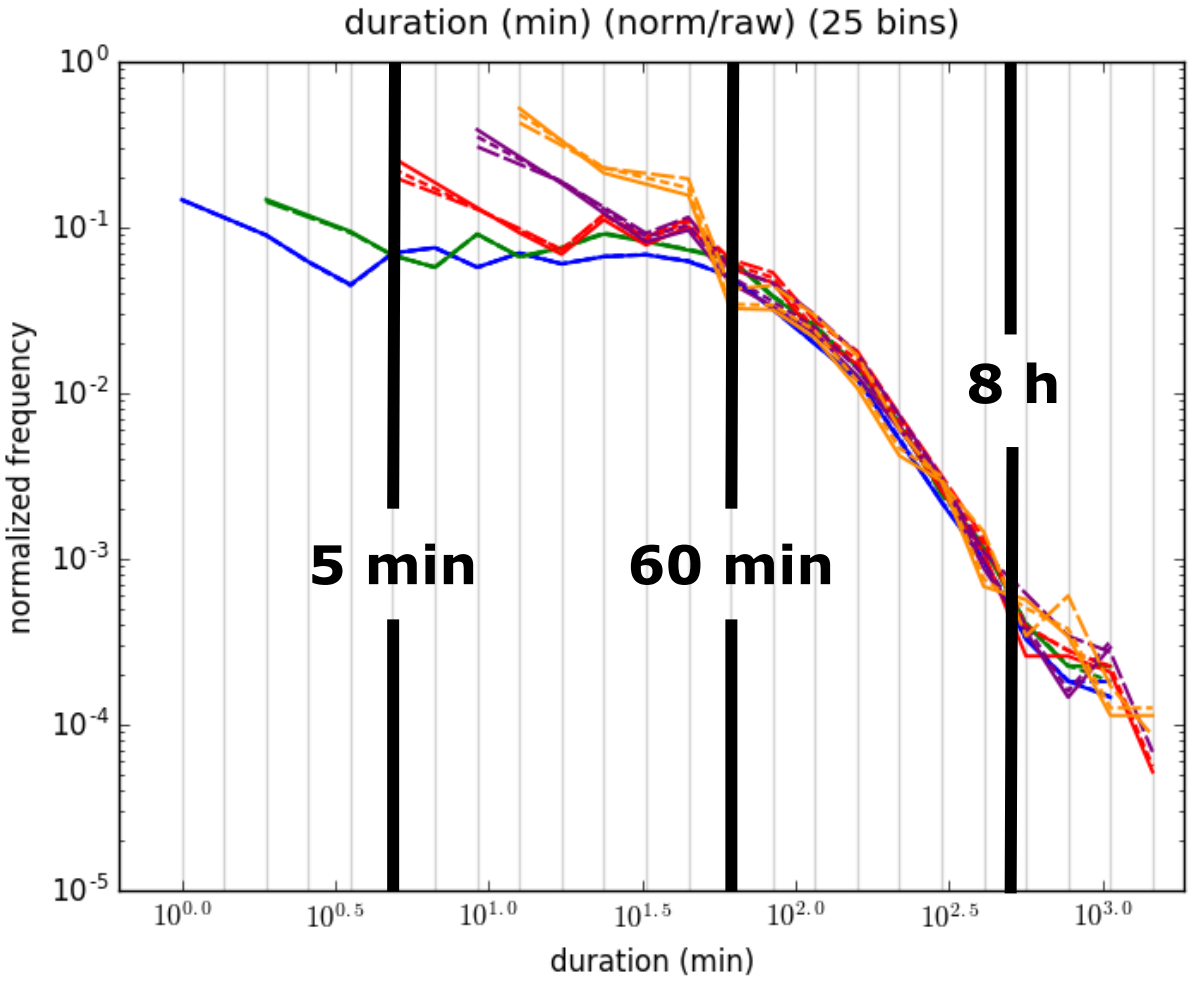


(*) Caveat: for temp. res. < 1 min, data is strided, not accumulated
→ induces penalty: less overlap → tracking not as good as possible

Pyrenees, 13 July 2006



Track Durations (normalized)



Temporal Resolution

1 min

2 min

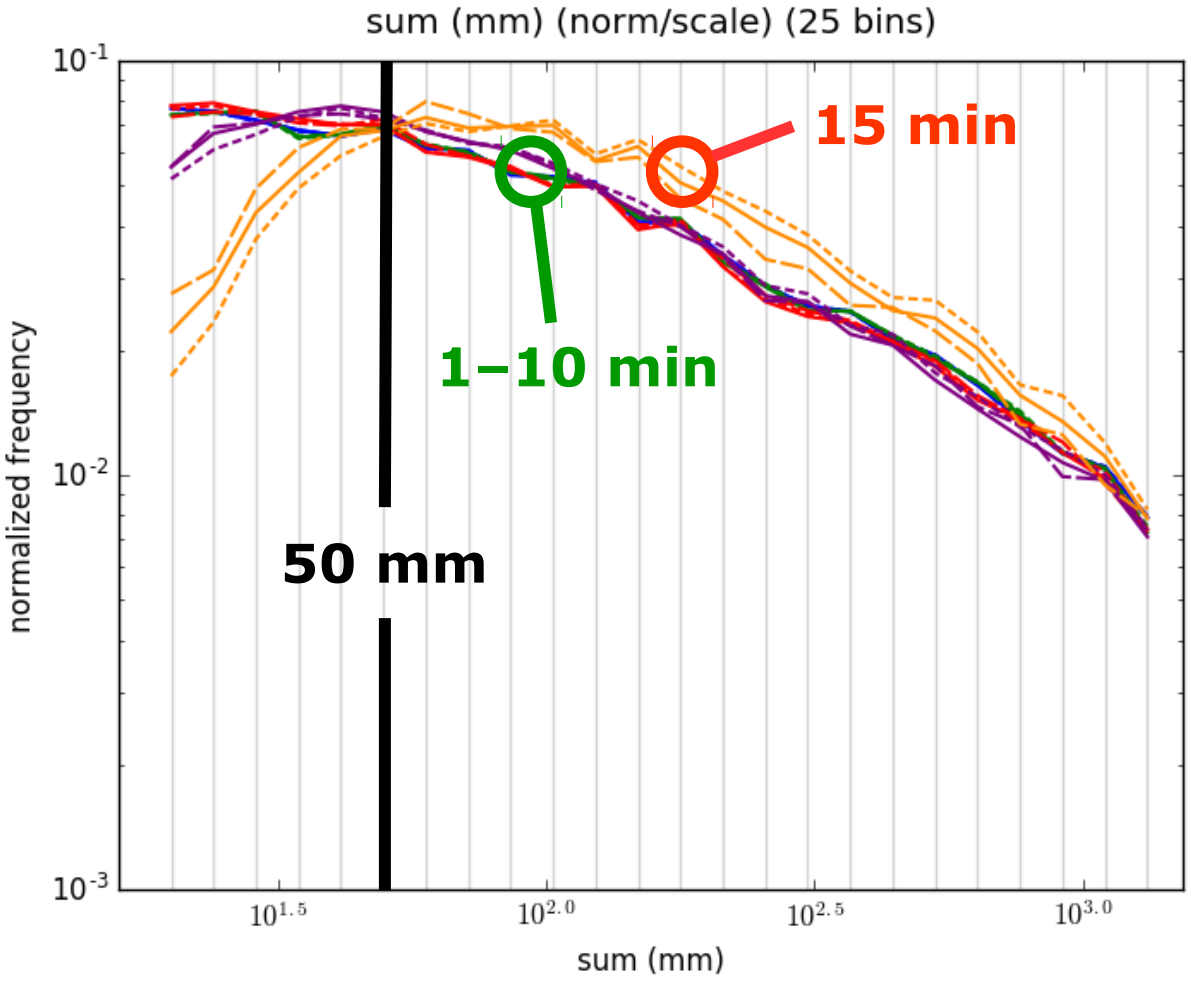
5 min

10 min

15 min

- Temporal resolution mainly influences short tracks (< 60 min)
- Effective temporal resolution ~ 5x tracking timestep

Sum Per Track (normalized)



Temporal Resolution

1 min

2 min

5 min

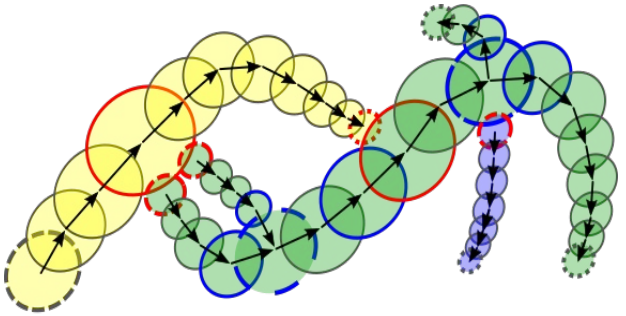
10 min

15 min

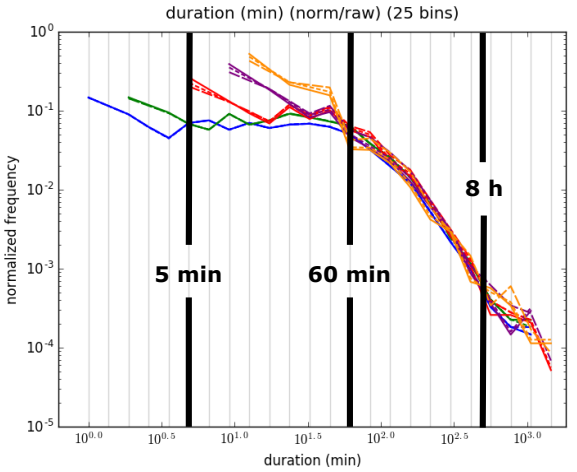
- Clear outlier: 15 min (far fewer weakly precipitating tracks)
- 1 min to 10 min similar for > 50 mm

Summary (I)

- **Feature tracking**:
  - **New tool** applicable to fronts, cyclones, precipitation cells, …

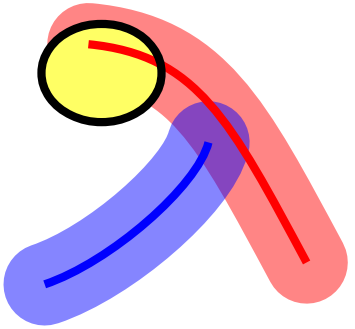


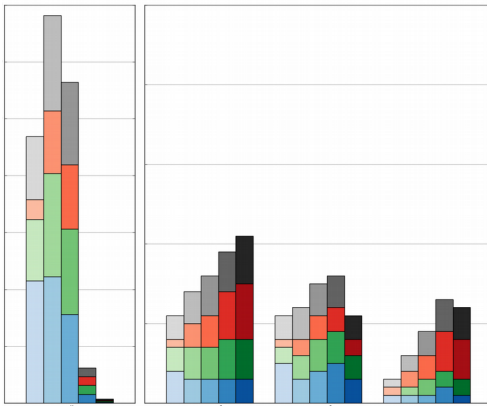
- **Precipitation cell tracking**:
  - **Temporal resolution** mainly affects short-lived tracks.
  - Temporal resolution of **several minutes** likely sufficient



Summary (II)

- **Precipitation and fronts**:
  - Relate **hourly precipitation** to **fronts** and **cyclones** (by intensity).
  - **~80%** of **intense to extreme** precipitation related to fronts and cyclones, **>50%** directly to **fronts**.
  - **Summer**: high shares of **heavy precip**., especially at **cold fronts**.
  - **Winter**: high shares of **light precip**., especially **far from fronts**/cyclones.





THANK YOU

References

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Hanley, J. and Caballero, R. (2012). Objective identification and tracking of multicentre cyclones in the ERA-Interim reanalysis dataset. Quarterly Journal of the Royal Meteorological Society, 138(664):612–625.

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Leutwyler, D., Fuhrer, O., Lapillonne, X., Lüthi, D., and Schär, C. (2016). Towards European-scale convection-resolving climate simulations with GPUs: a study with COSMO 4.19. Geosci. Model Dev., 9(9):3393–3412.

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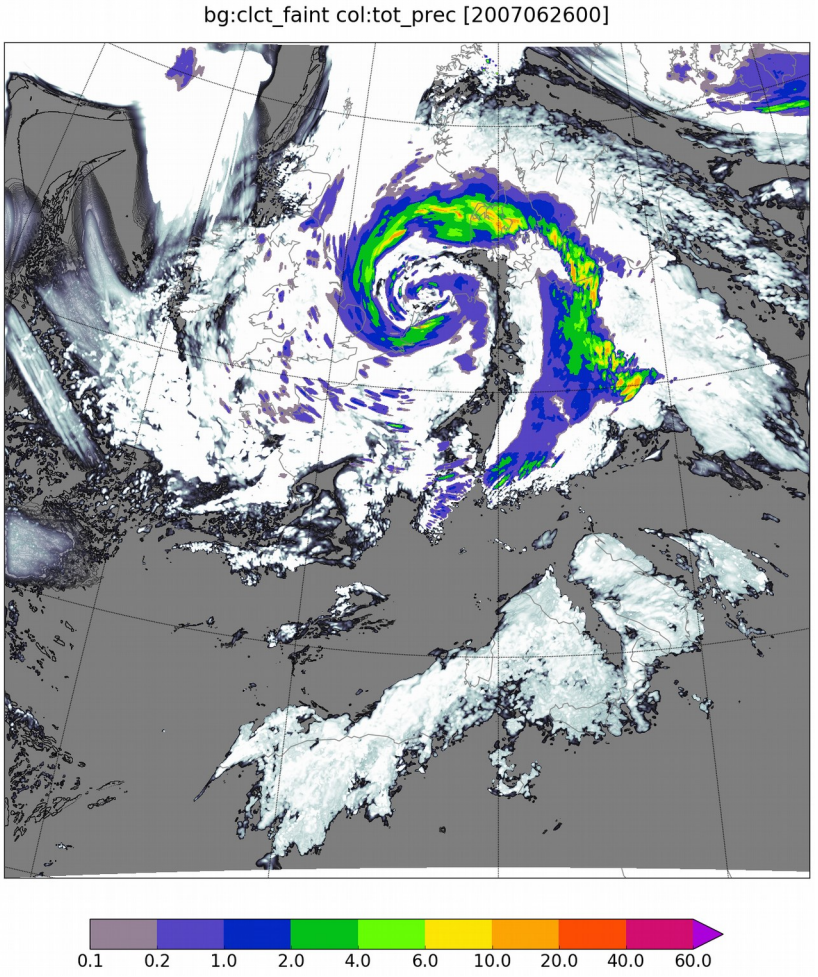
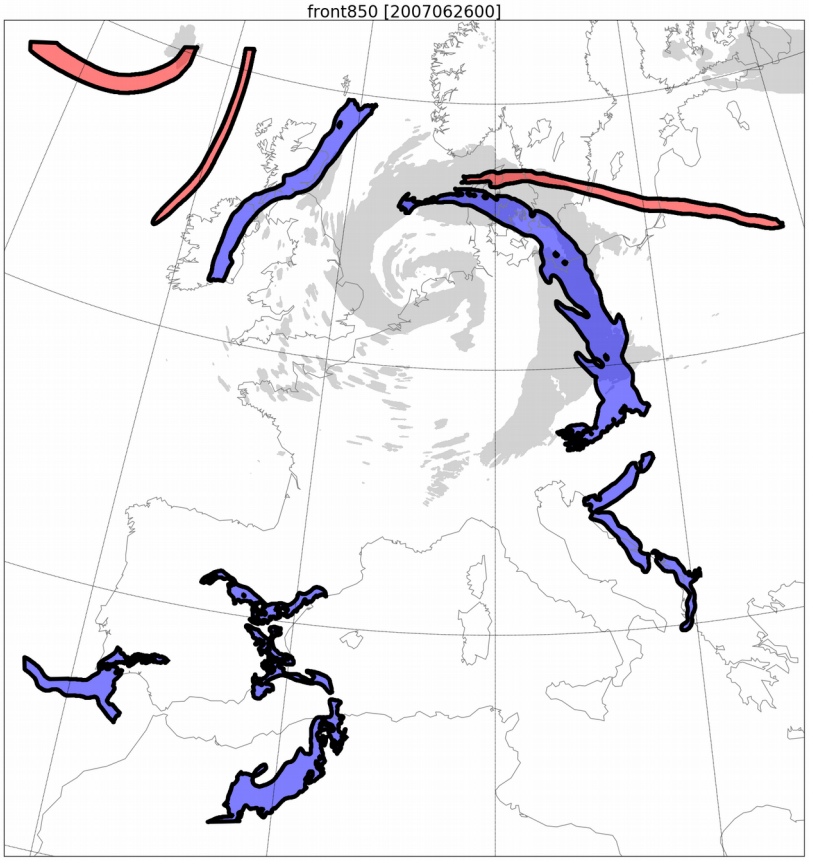
Wernli, H. and Schwierz, C. (2006). Surface Cyclones in the ERA-40 Dataset (1958–2001). Part I: Novel Identification Method and Global Climatology. Journal of the Atmospheric Sciences, 63(10):2486–2507.

Front Tracking (26 June 2007)



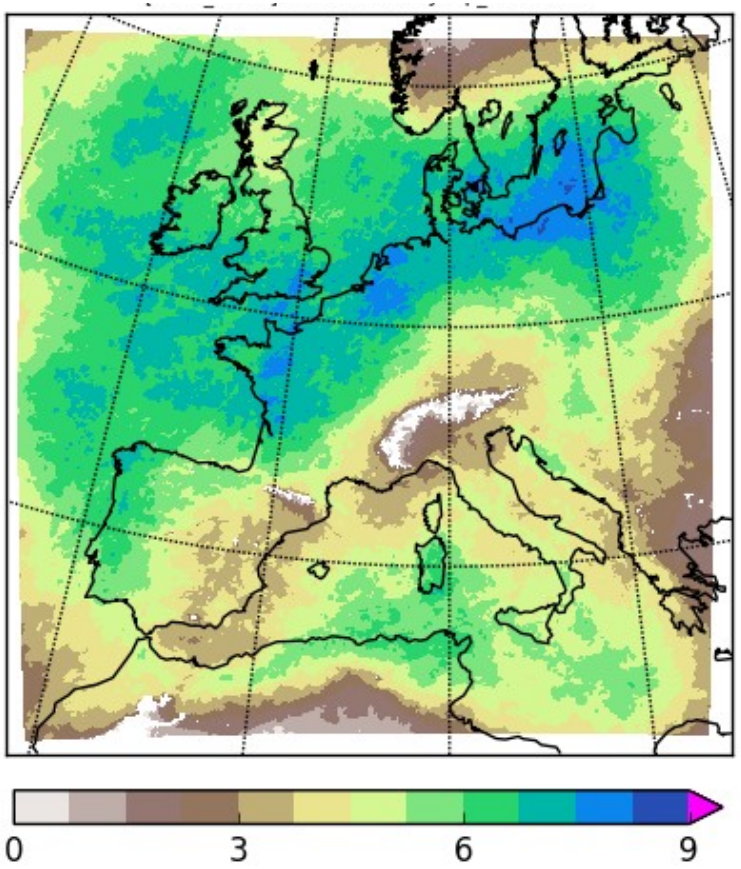
Clouds and surface precipitation



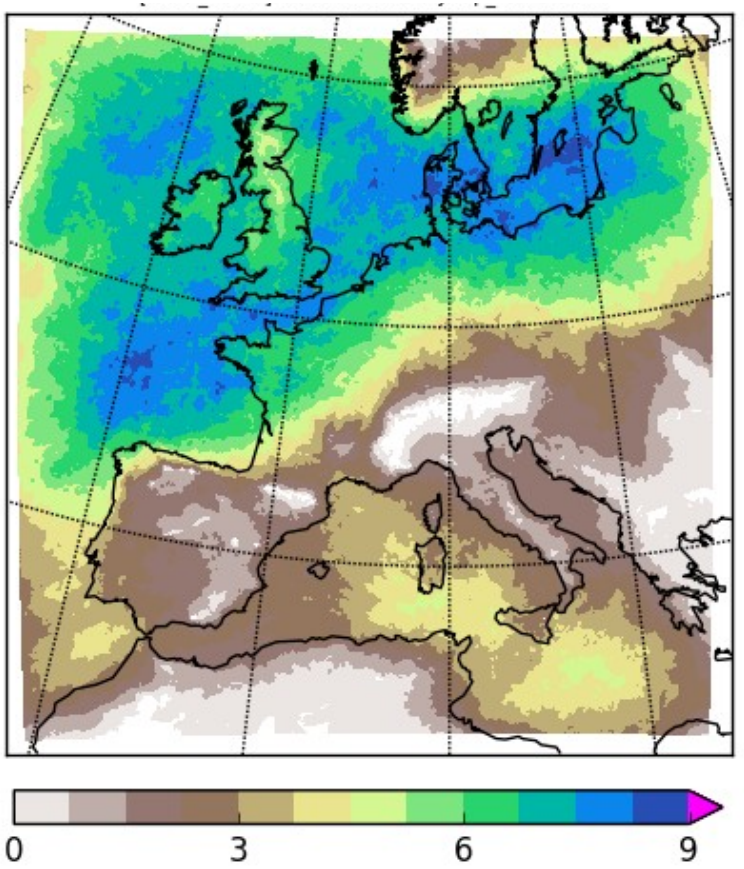
Synoptic cold and warm fronts based on THE at 850 hPa

Synoptic Fronts (2007)

Cold Fronts

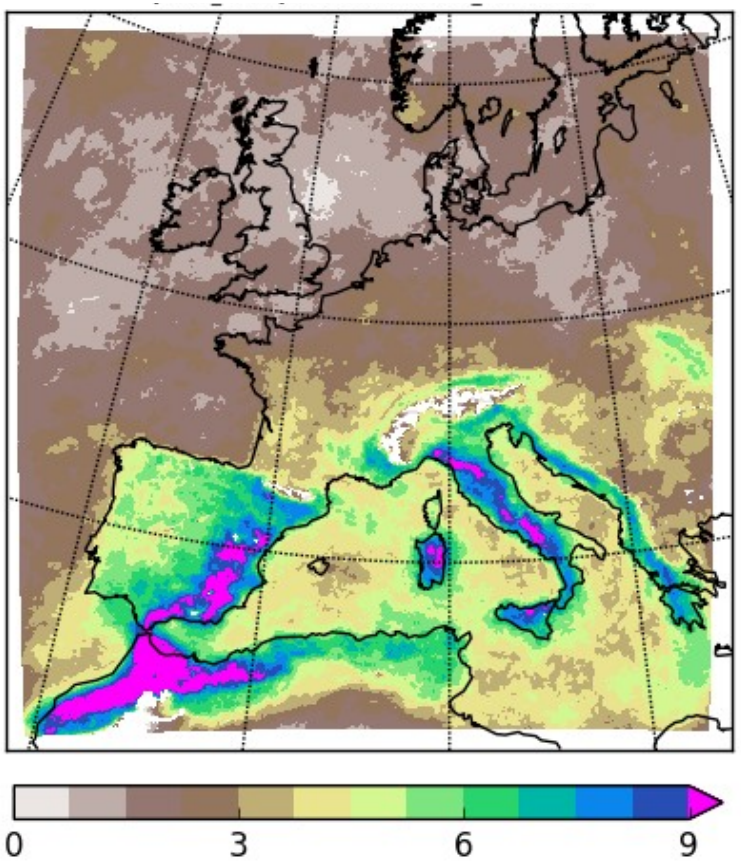


Warm Fronts

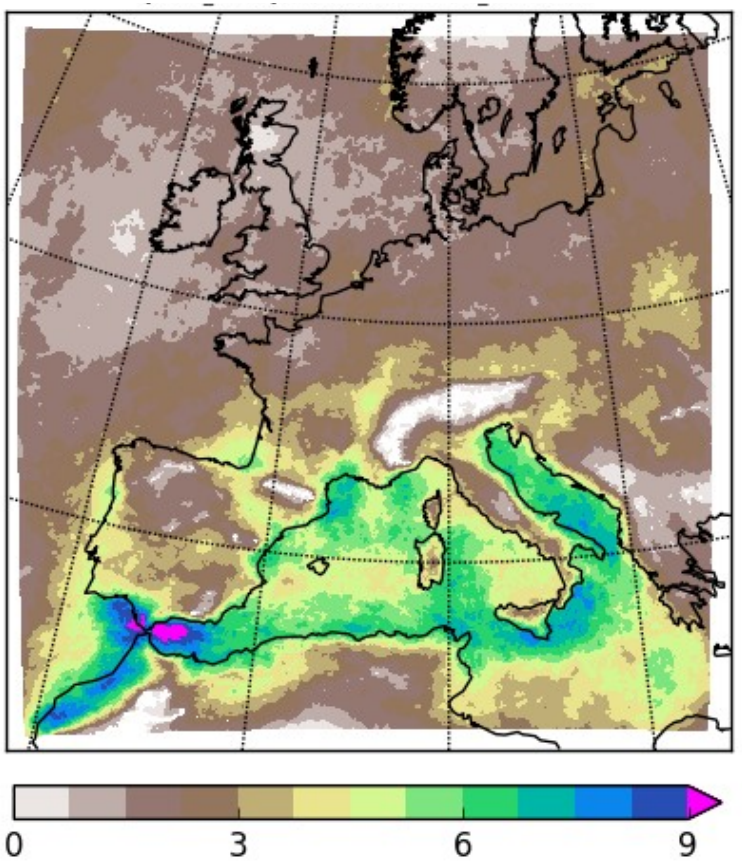


Local Fronts (2007)

Cold Fronts

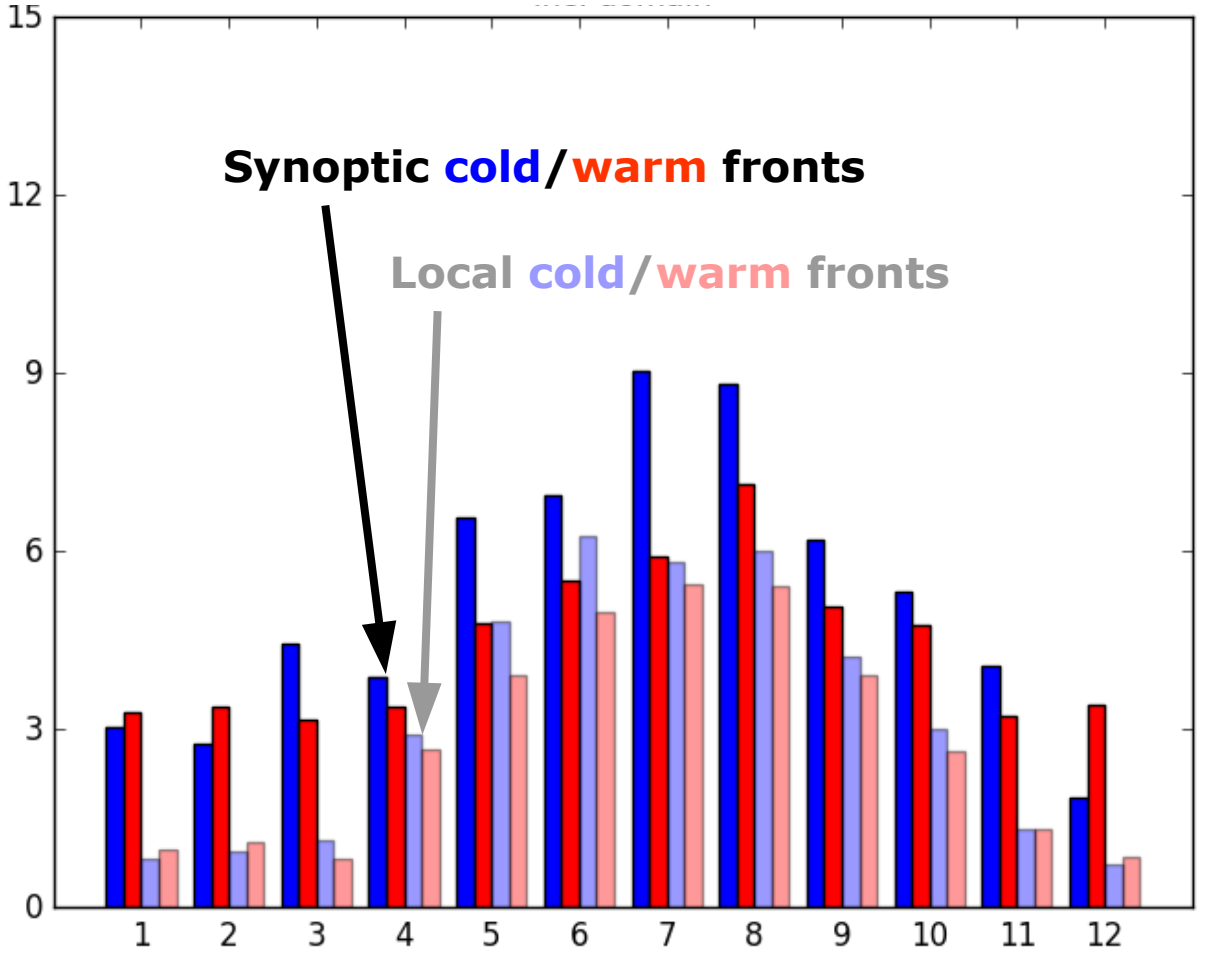


Warm Fronts



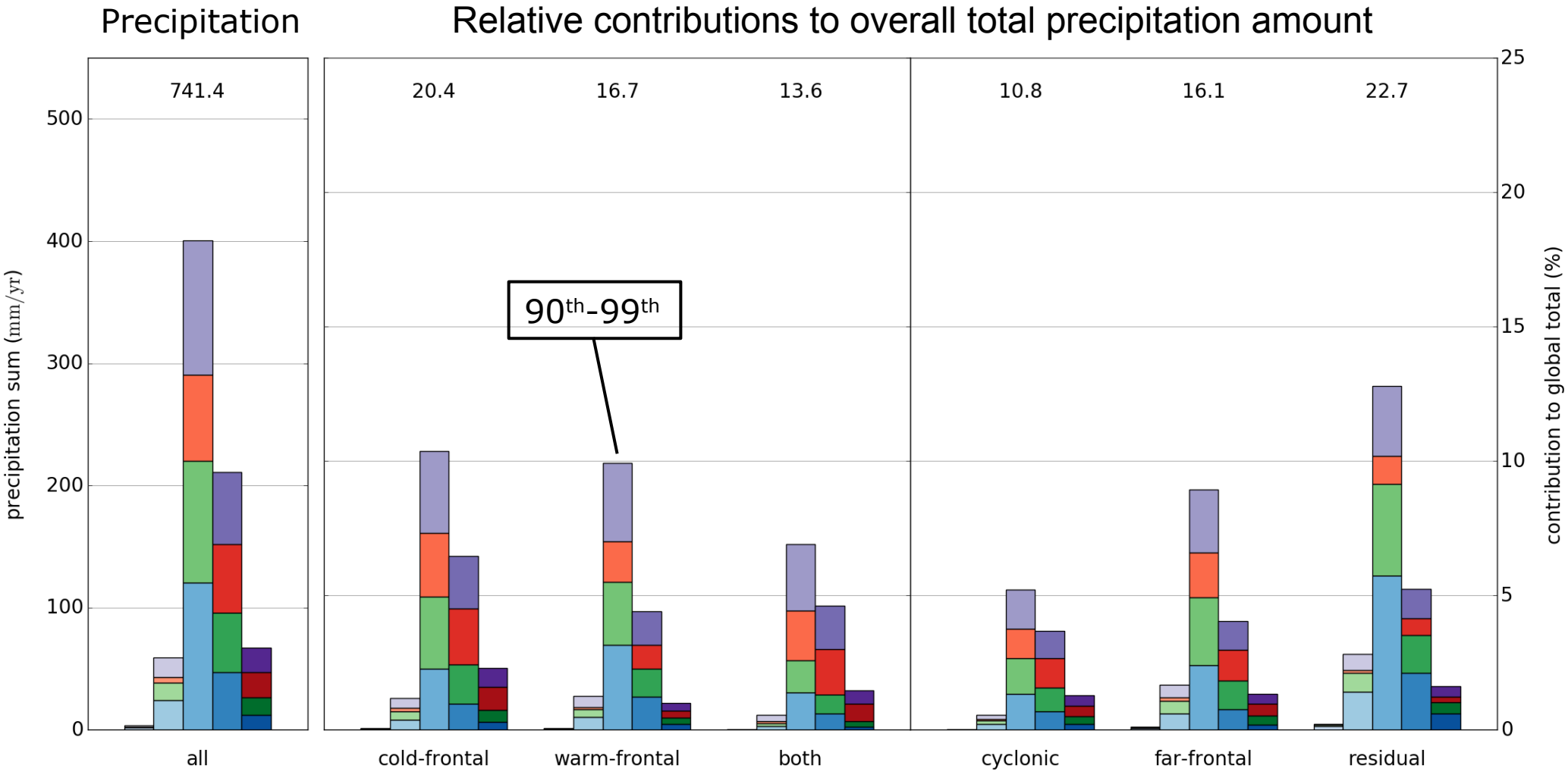
Of thermal origin, mainly during summer. Distinguished from synoptic fronts based on track properties (size, stationarity).

Monthly Front Frequencies (2007)



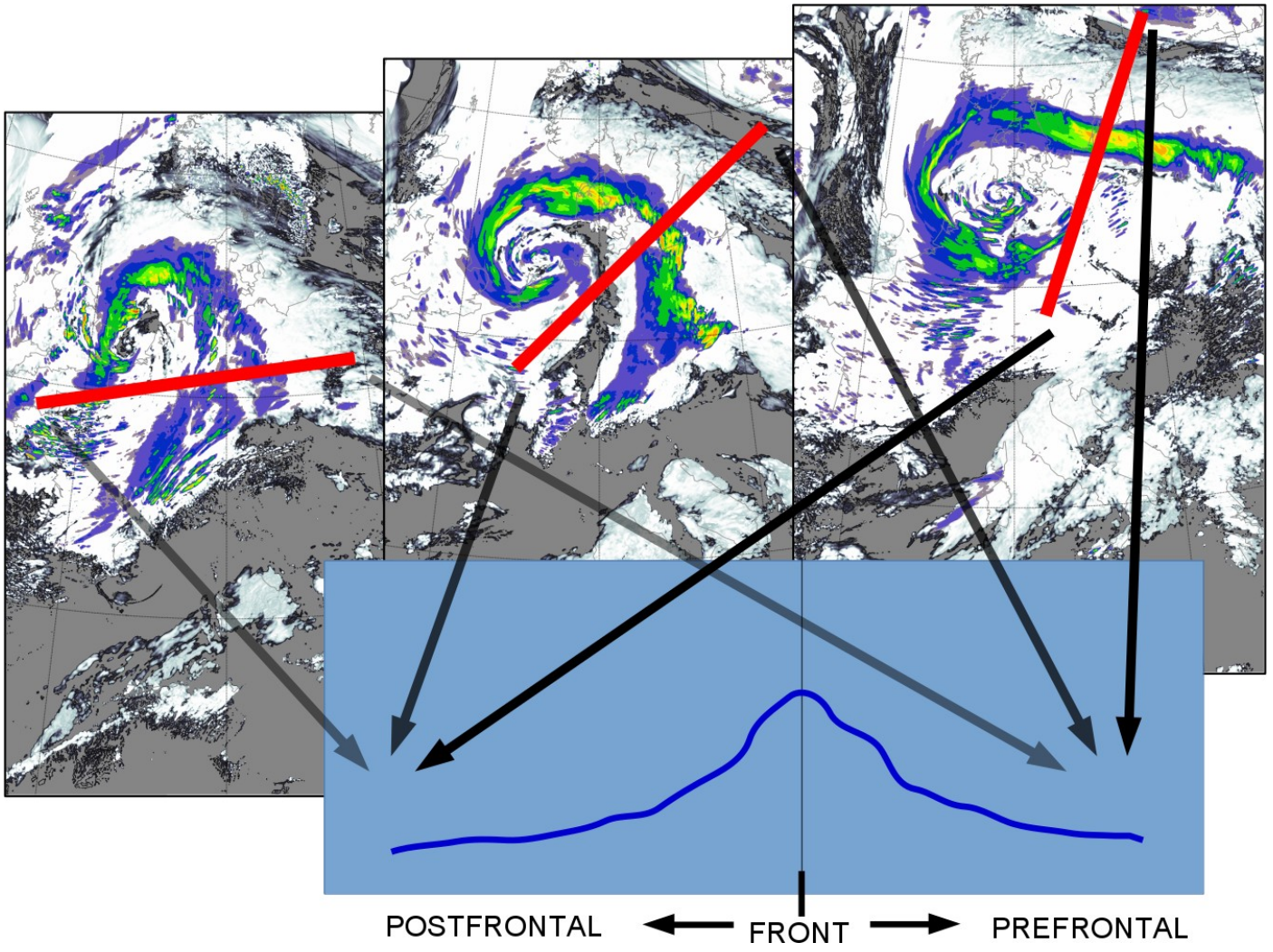
Front tracks per month

Precipitation 2000-2008

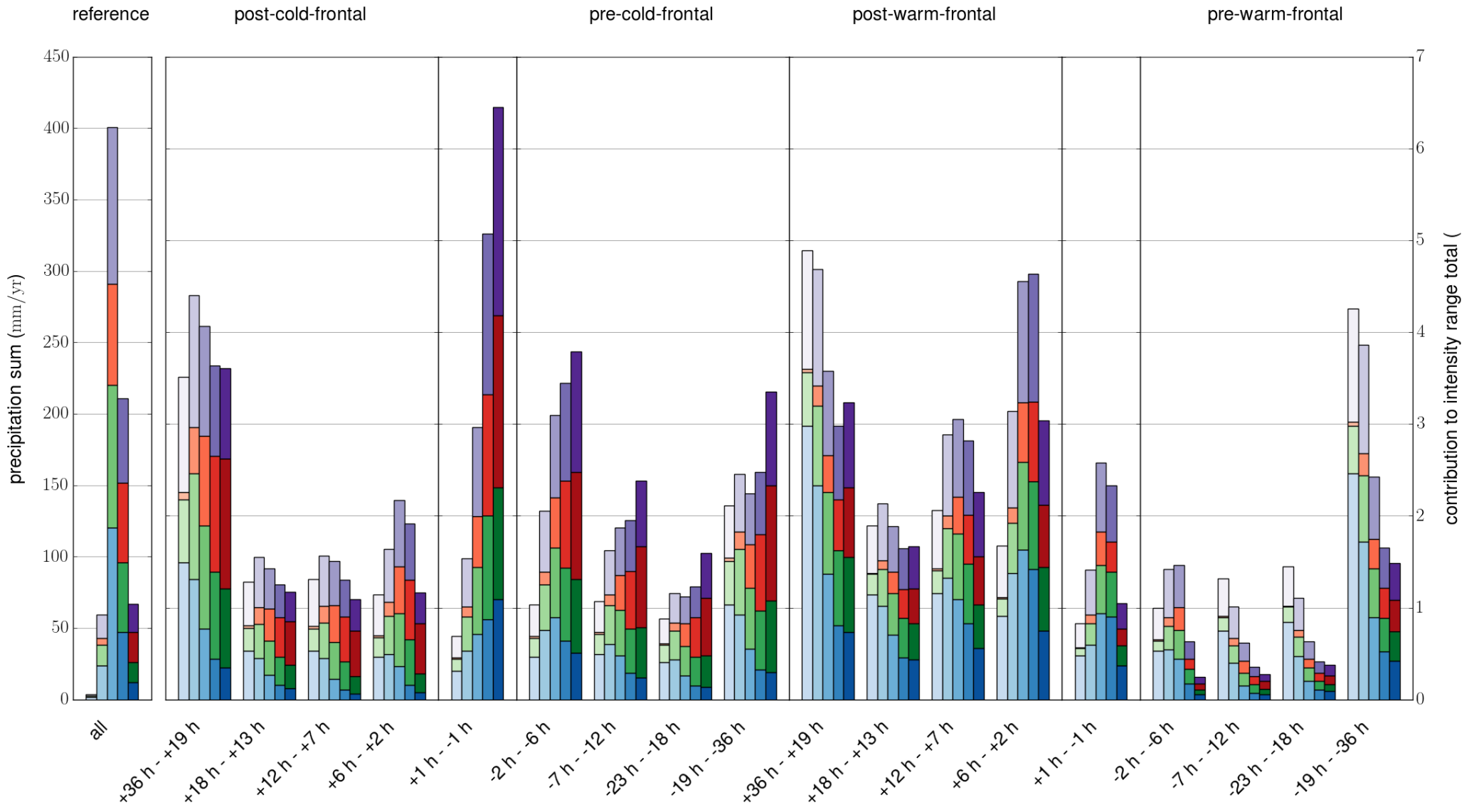


- **~50%** within **300 km of a front**, ~16% within 300-600 km, ~11% in cyclones
- **>50%** (400 mm) **moderate** (90^{th}-99^{th}), ~30% (211 mm) intense (99^{th}-99.9^{th})

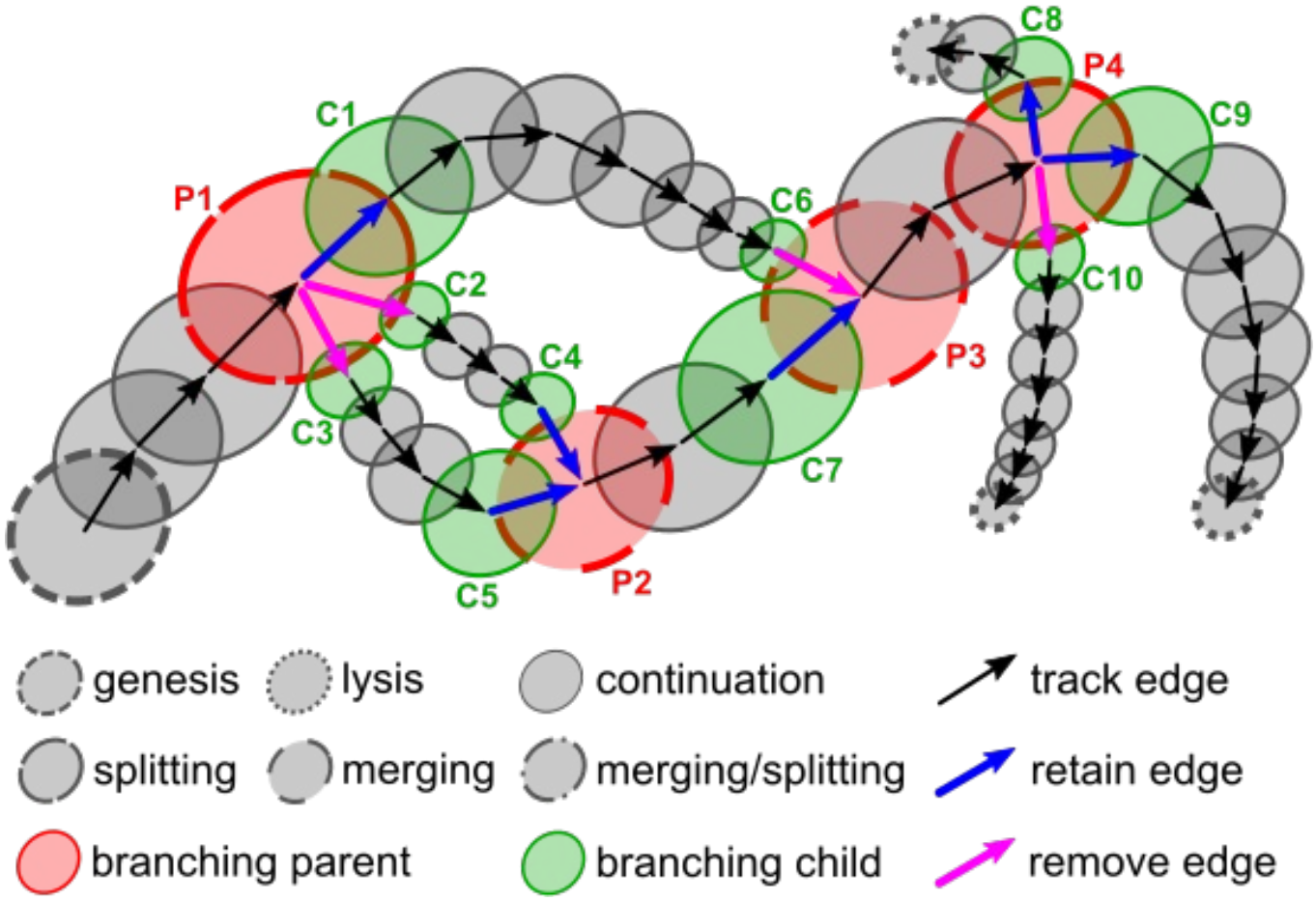
Cross-Frontal Precipitation



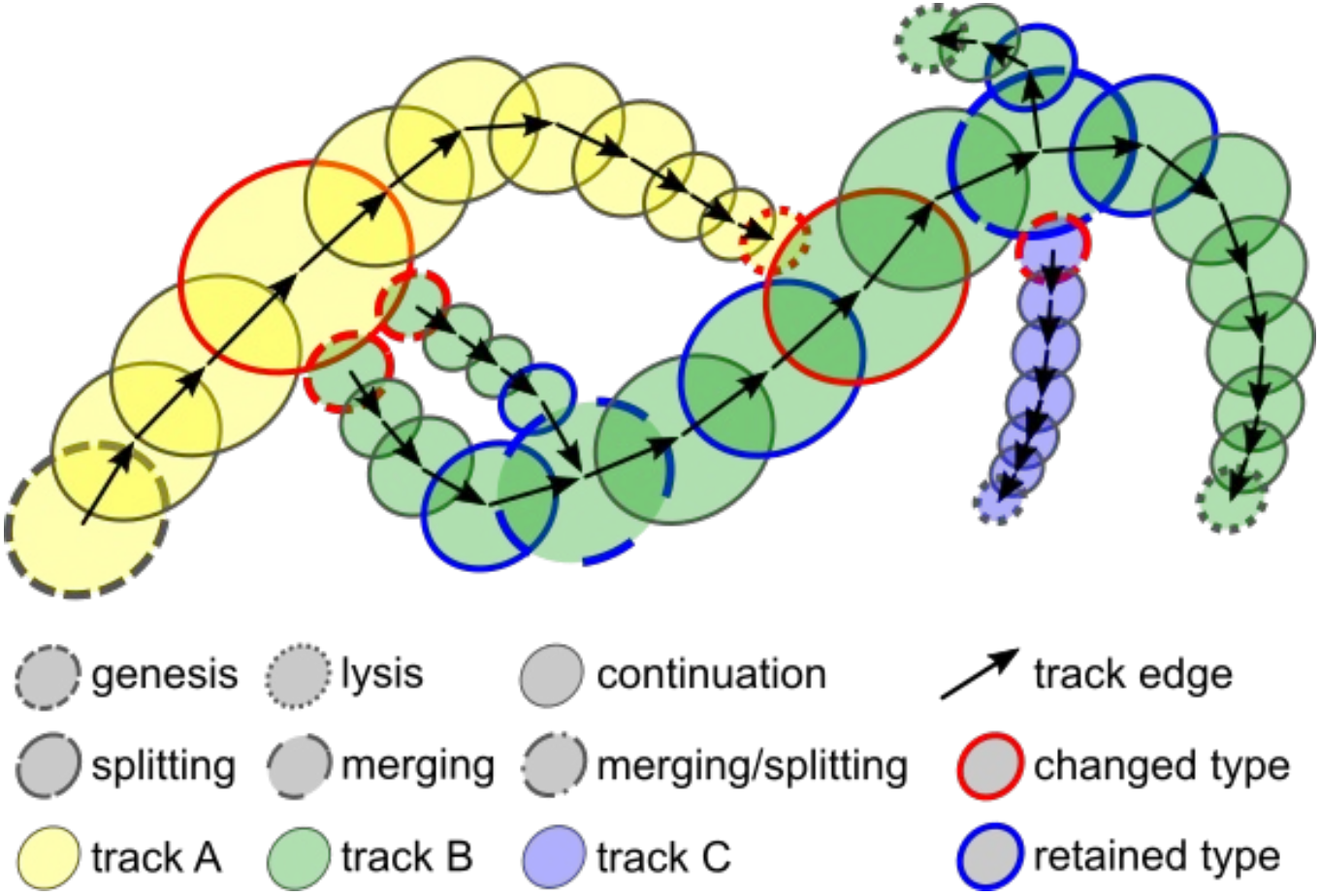
Front-Relative Precipitation



Anatomy of a Feature Track

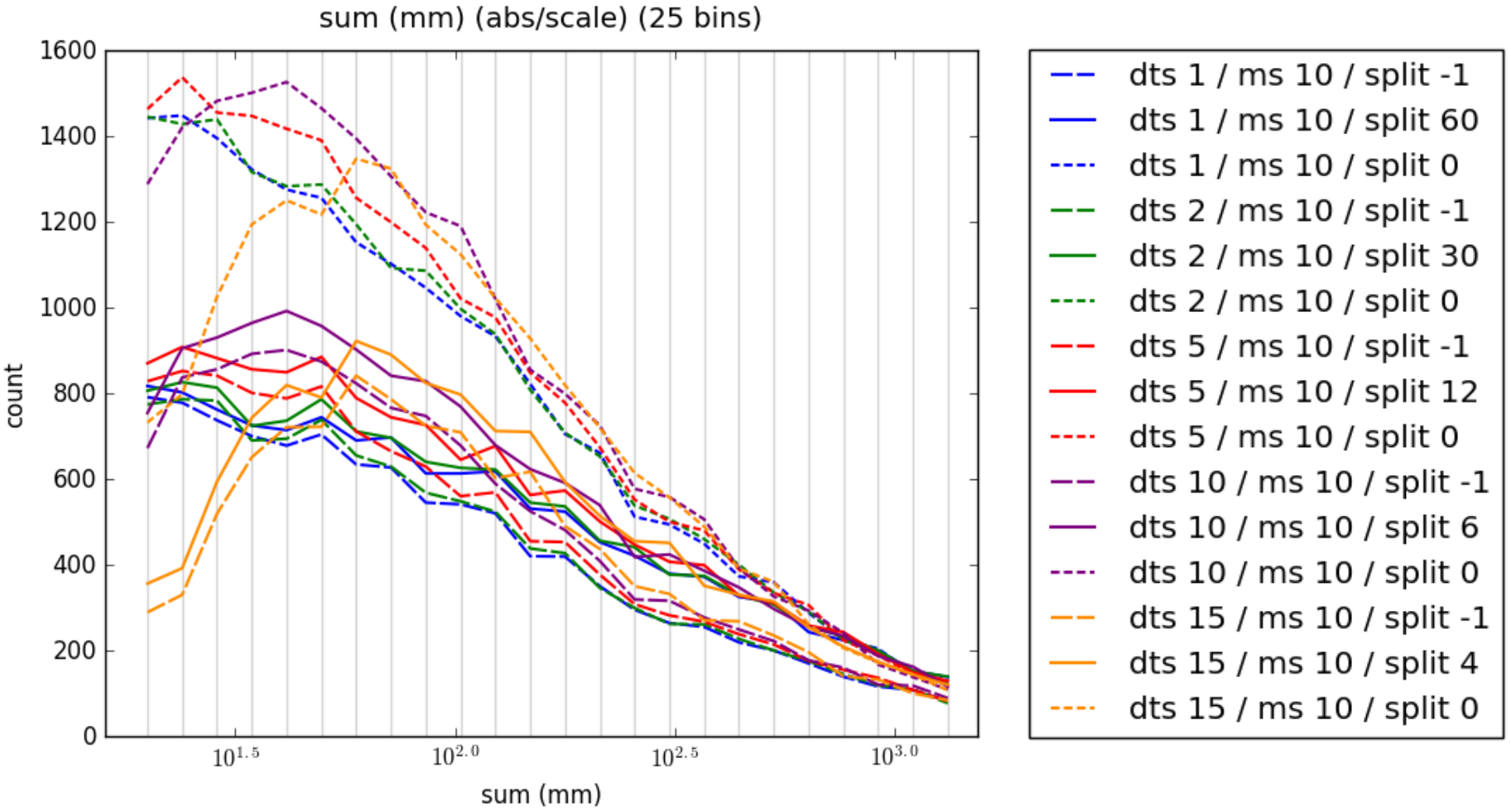


Feature Track Splitting



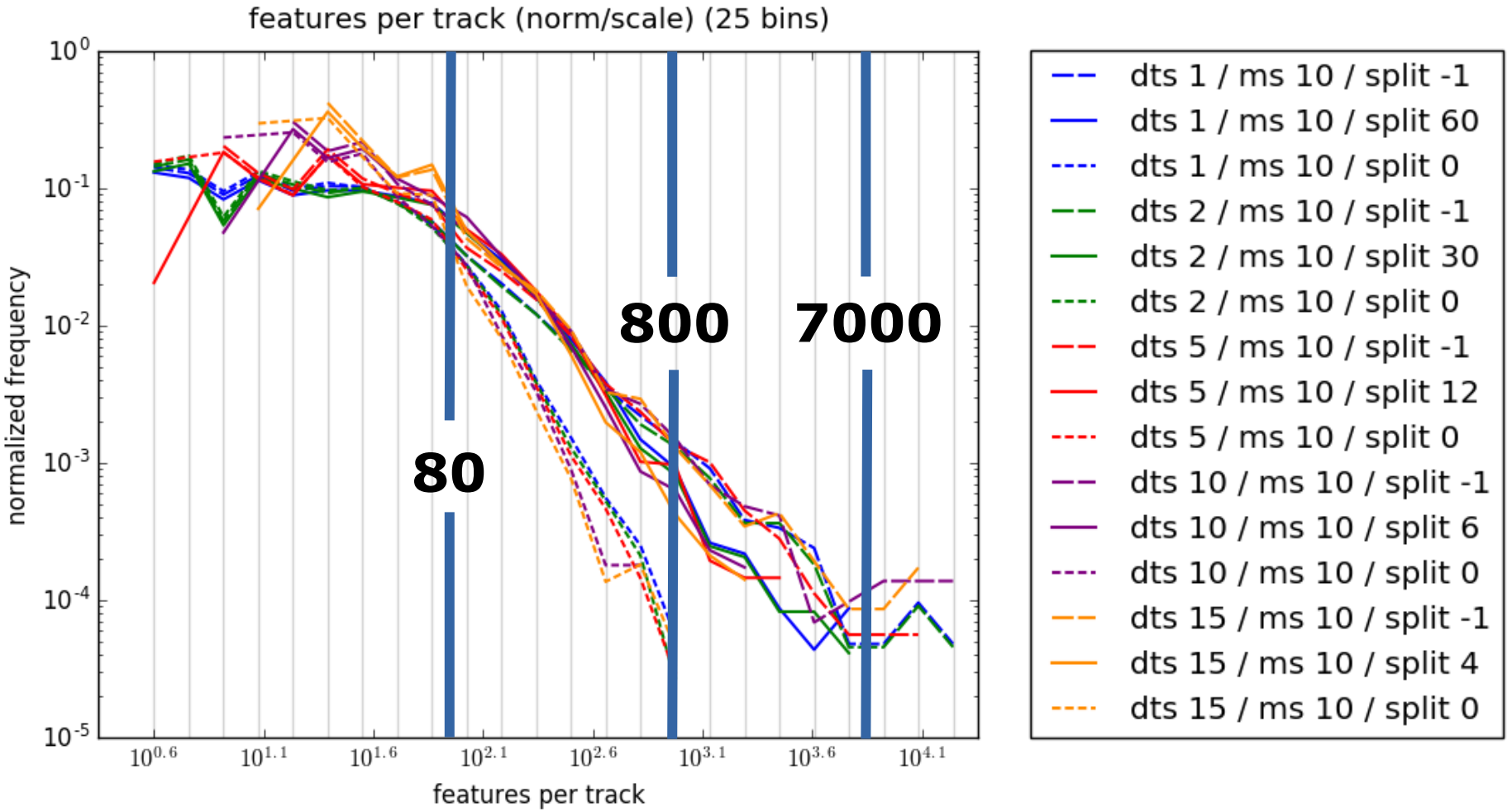
- Separate branches that don't interact for too long
- Example: Split cluster-like track into three subtracks

Track Splitting - Sum Per Track



- 0: eliminate all branchings → almost doubles number of small tracks
- 60/30/12/6/4: moderate splitting → reduces number of very big tracks

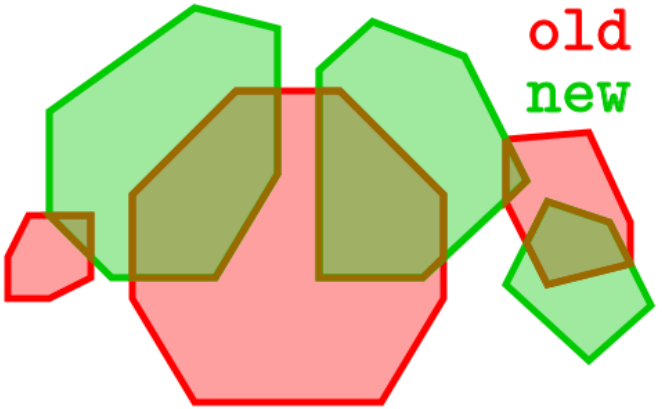
Track Splitting - Track Sizes



- Mergings/splittings frequent for > 80 features in original tracks
- Biggest fully linear tracks: 800 features (i.e., 13.3 h)

Tracking Probabilities

- **Correspondence**: which features at t_{old} are related to which at t_{new}?

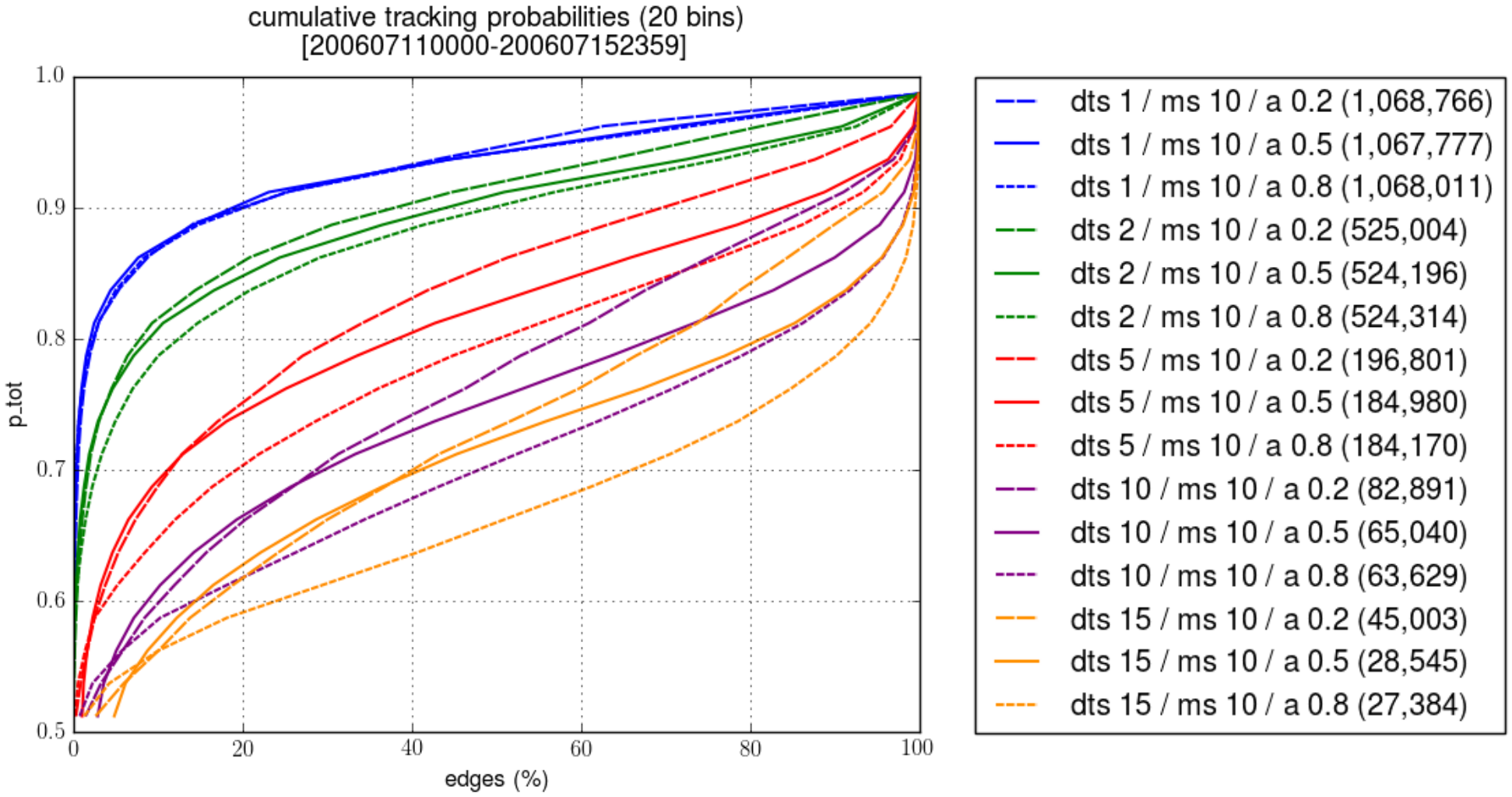


- **Components**:
  - Relative size (p_s)
  - Relative overlap (p_o)
- **Tracking probability**:

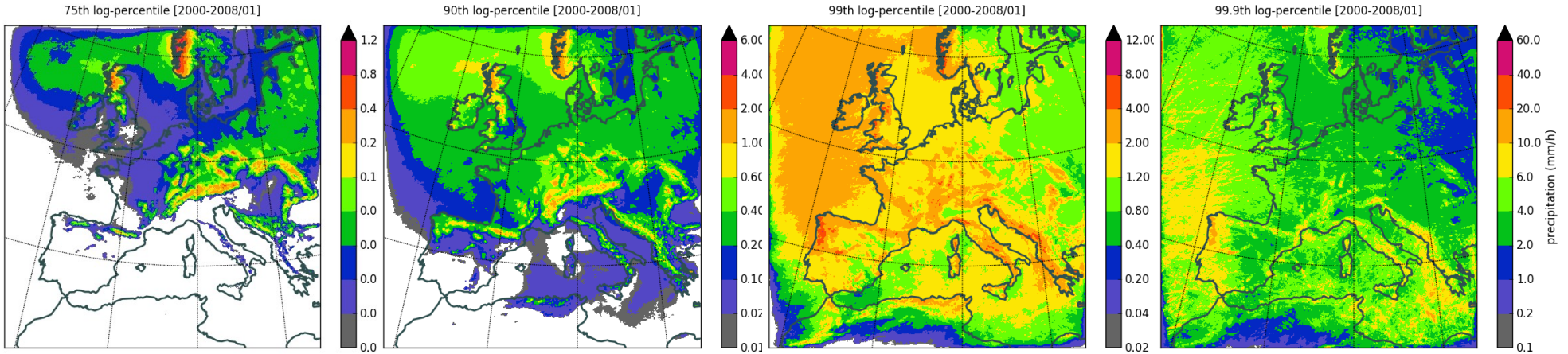
$$p_{tot} = f_s * p_s + f_o * p_o$$

- **Confidence measure** of algorithm

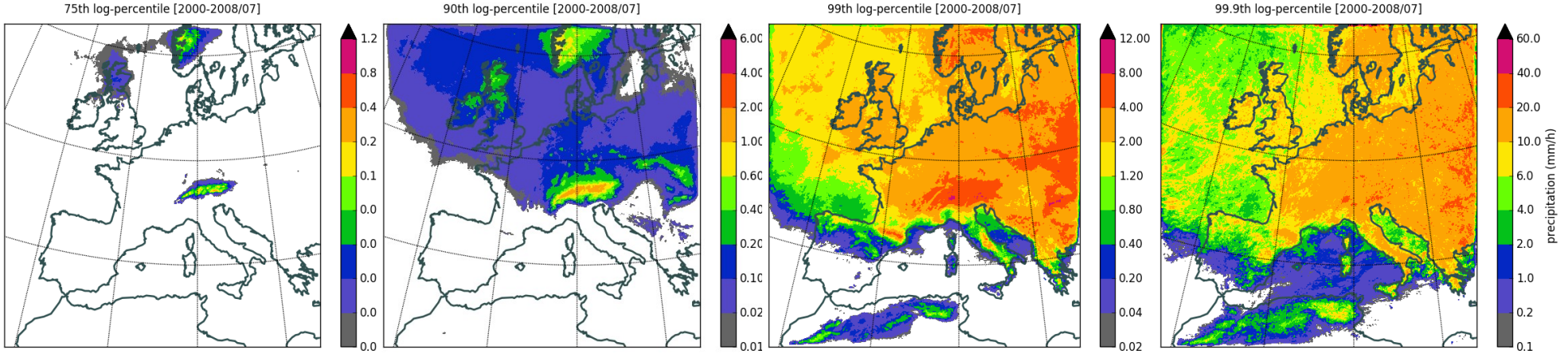
Total Tracking Probabilities



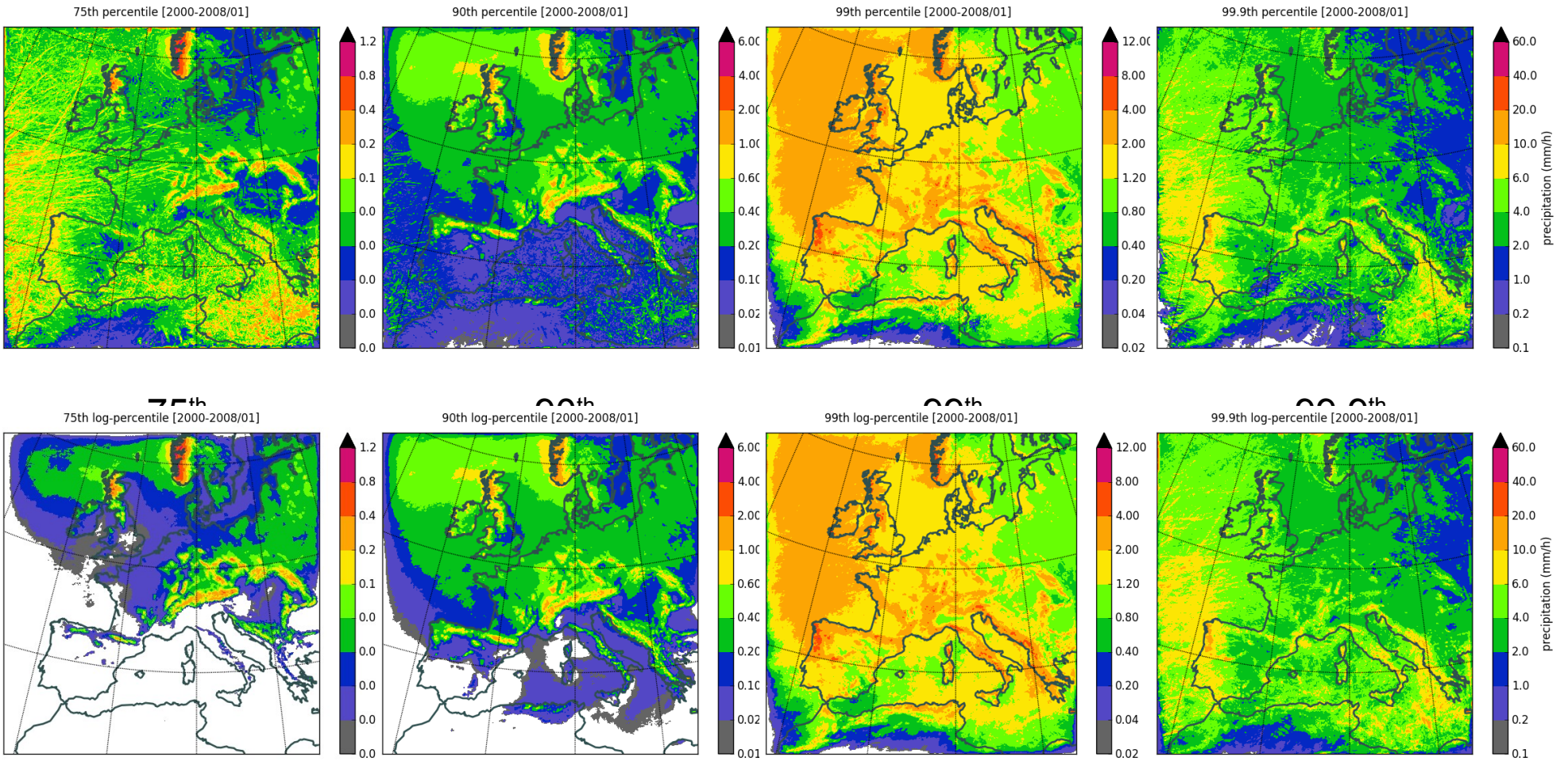
Percentile Maps (Jan & Jul '00-'08)



75th 90th 99th 99.9th



Bonus: CDO Percentile Pitfall



- Discrete percentiles (101 bins) imprecise for lower percentiles
  → Light precipitation much more frequent than heavy
- Workaround: log10 transformation before sorting, 10^ afterward