The climatology of Lightnings in COSMO-CLM

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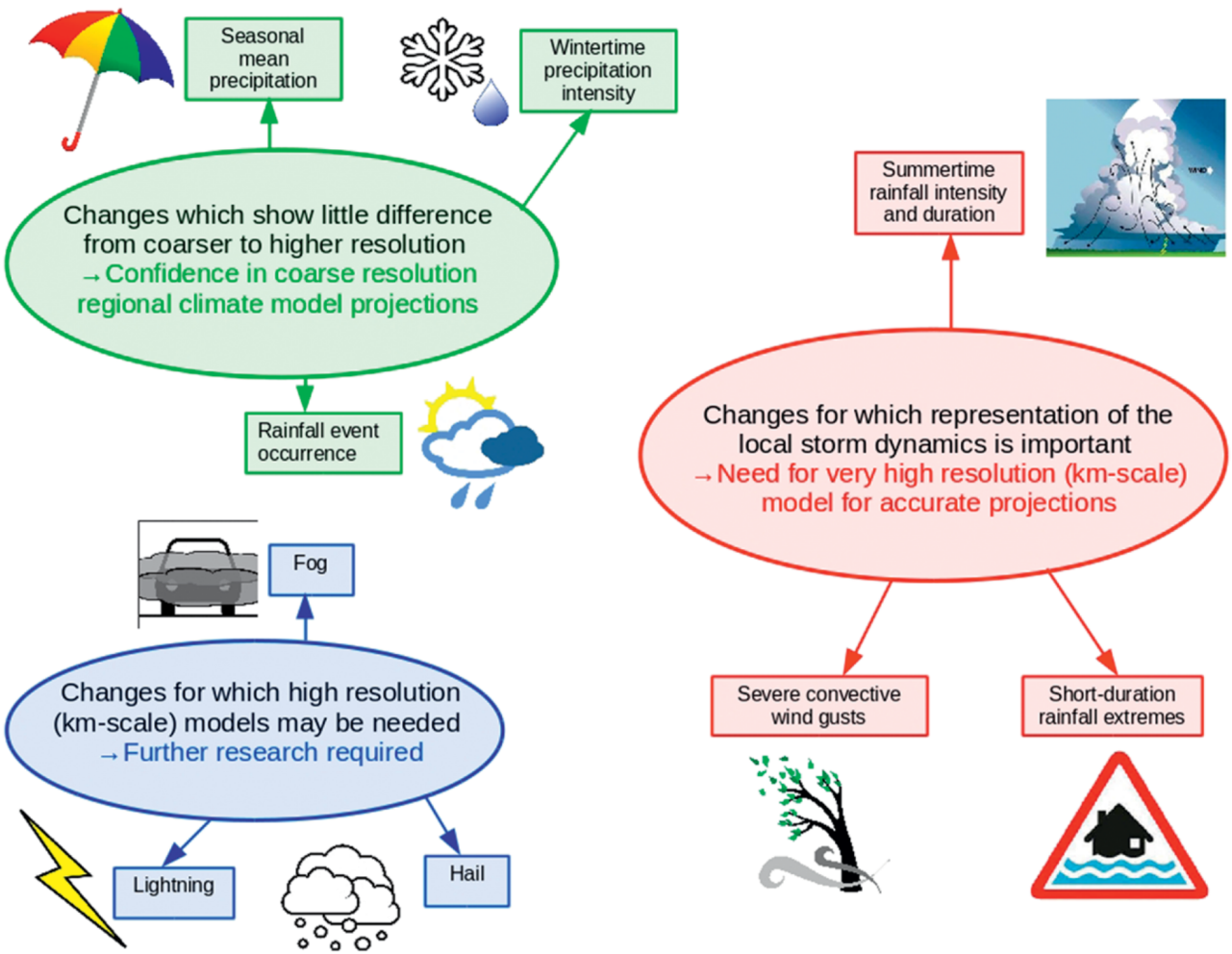


Kendon et al., BAMS (2016)

What is lightning ?

A natural electrical discharge occurring between a cloud and the ground or within a cloud, accompanied by a bright flash and typically also thunder.

What are the physical mechanisms behind lightning ?

- Charge separation occur in the cloud
- Many different theories for this
- Not everything is well understood

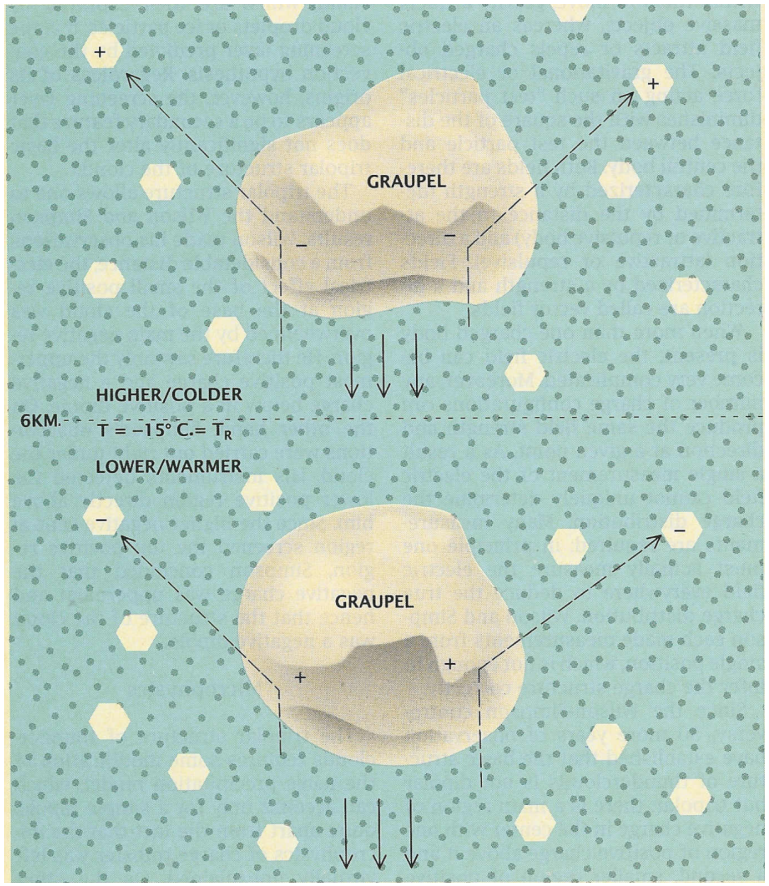
Source : John Moran

The noninductive ice-graupel mechanism

Main charging mechanism in thunderstorms

Theory :

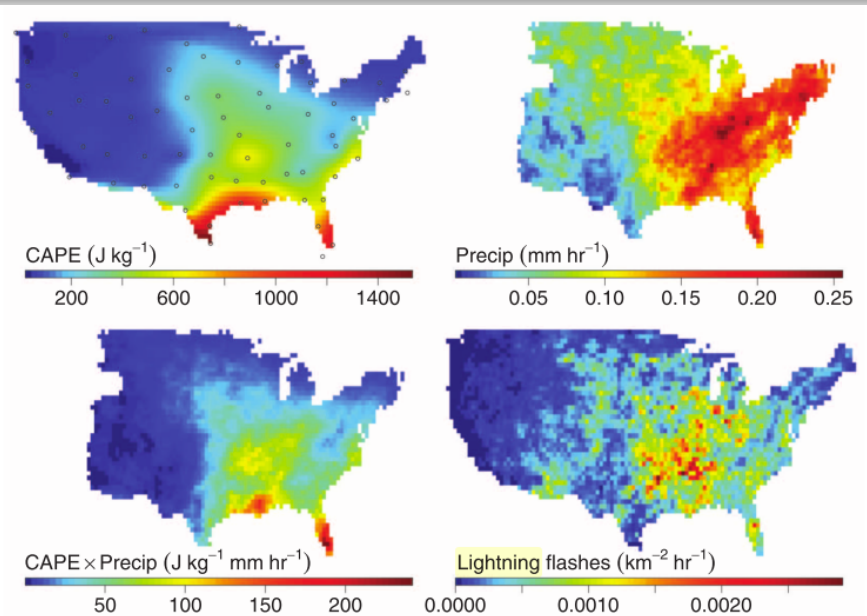
- Charge is efficiently separated by collision between graupel and ice particles with the presence of super cooled liquid water
- Charging zone from 0 to -40C
- Sign reversal charging depend on liquid water content (temperature and updraft)



Williams, American Scientist (1988)

Empirical representation : Romps et al. (2014)

- Many methods
- $CAPE \times Precip$
- In U.S. $\sim 12 \pm 5\%$ per degree celsius increase



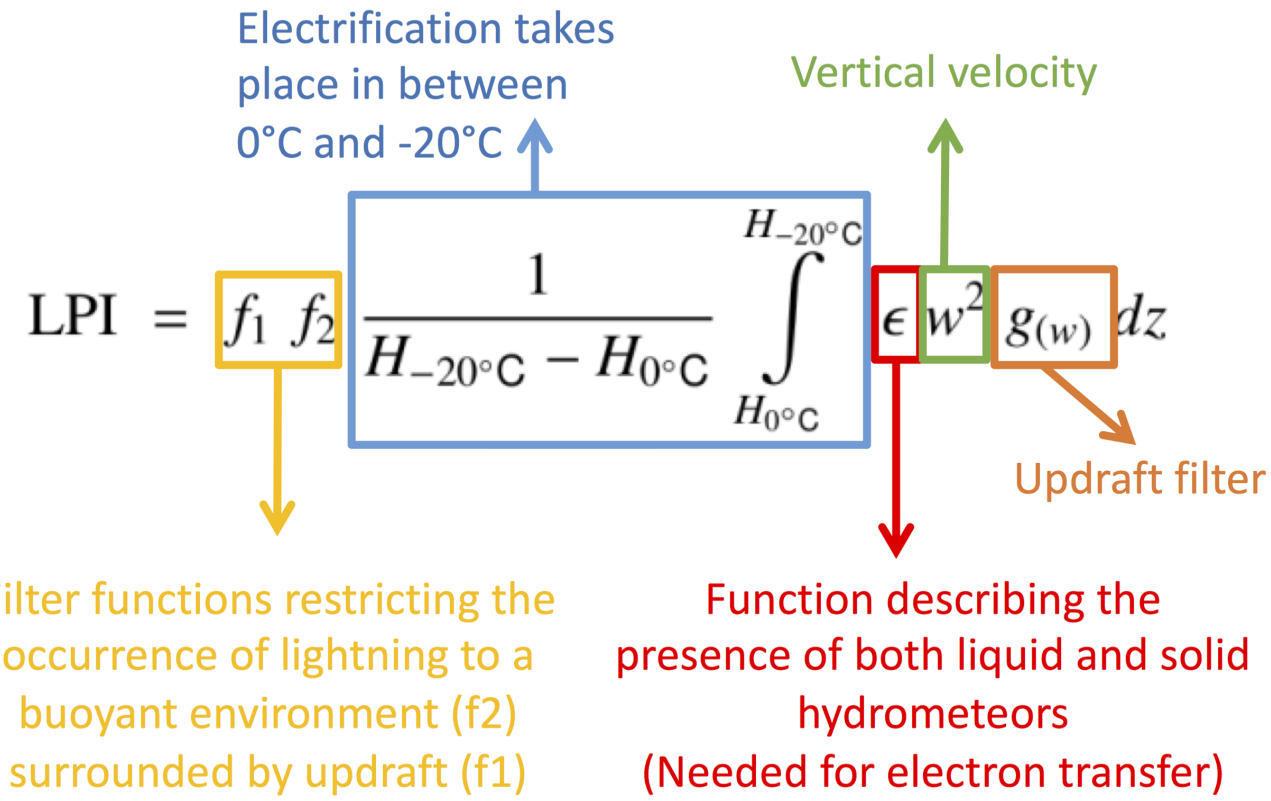
Representation in dynamical models

- Representation of vertical updraft
- Graupel/Ice/liquid water (sup. cooled)
- Representation of convective cloud

$\rightarrow$ **Convection-permitting model needed**

Parameterizations : The Lightning Potential Index (LPI)

Lightning Potential Index (LPI) from Yair et al. (2010), implemented by Ulrich Blahak in the COSMO5.3



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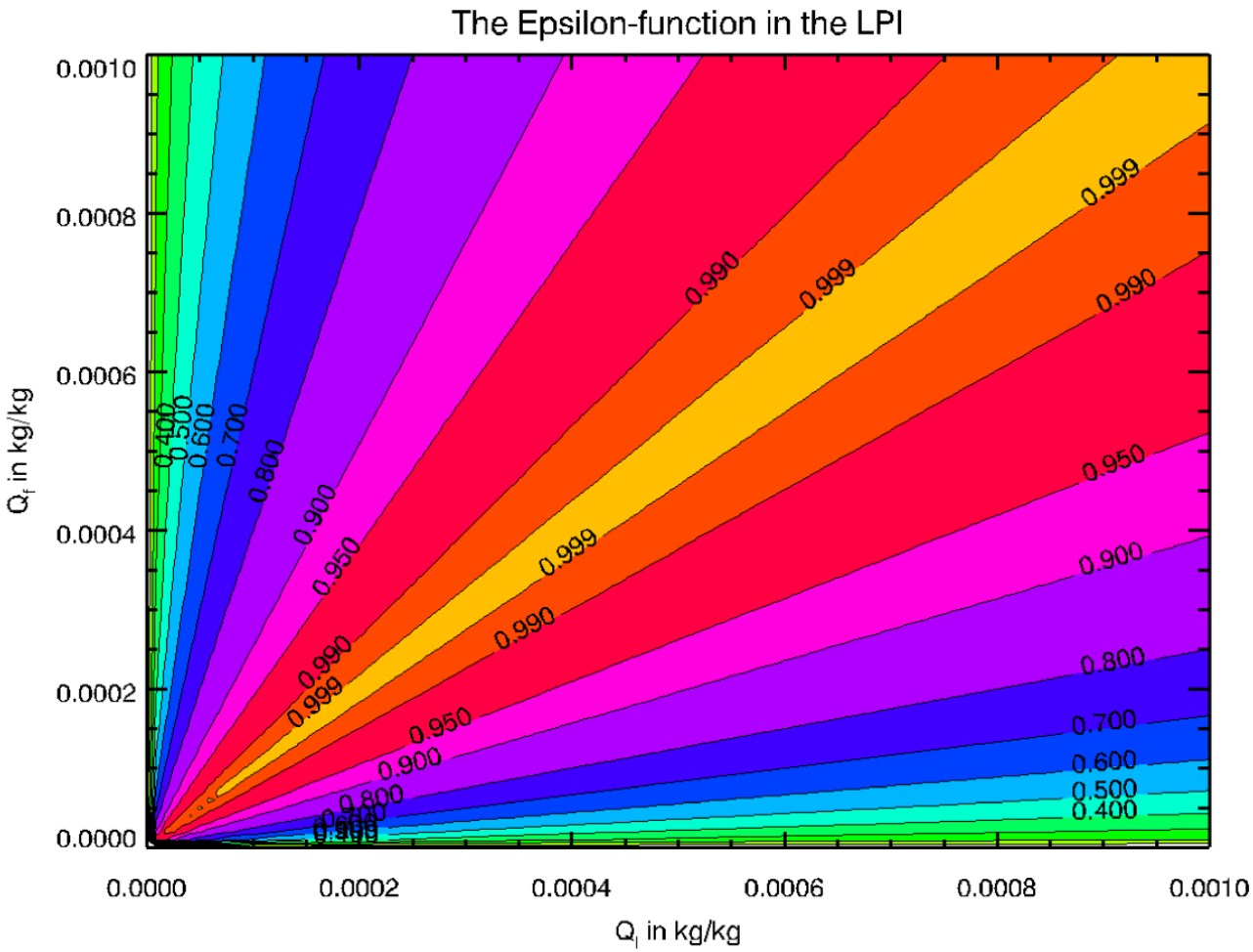


LPI

- LPI shows promissing results in NWP (pers. comm. Ulrich Blahak)
- Climate projections at CPS is possible
- validation needed on climate scale

$\rightarrow$ Is the LPI a good candidate for investigating lightning climatology ?

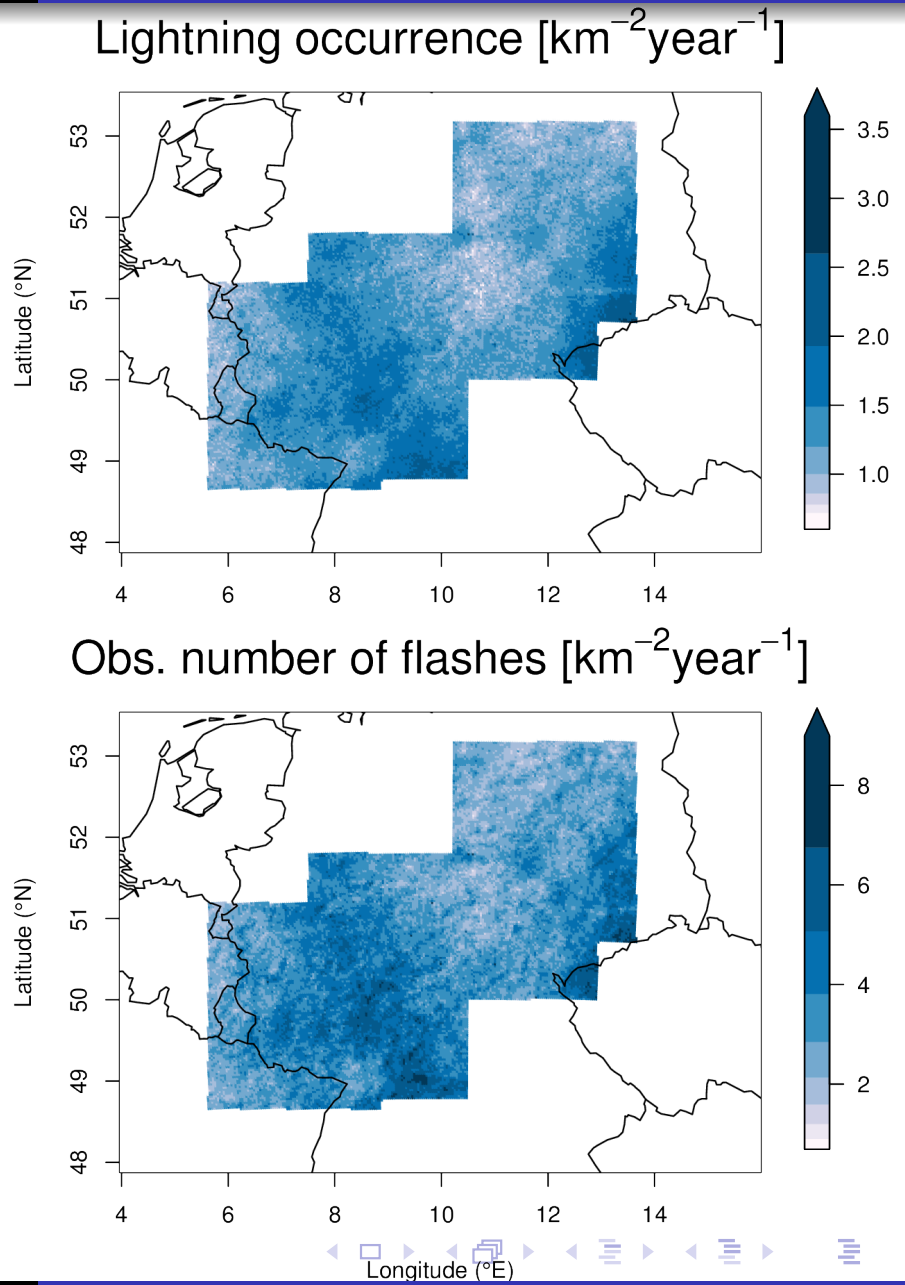
Empirical method

- Much cheaper
- No need for downscaling
- Can be applied to large ensemble

$\rightarrow$ Is there an added value of the LPI compared to empirical relation (e.g., $CAPE \times Prec$) ?

Observations

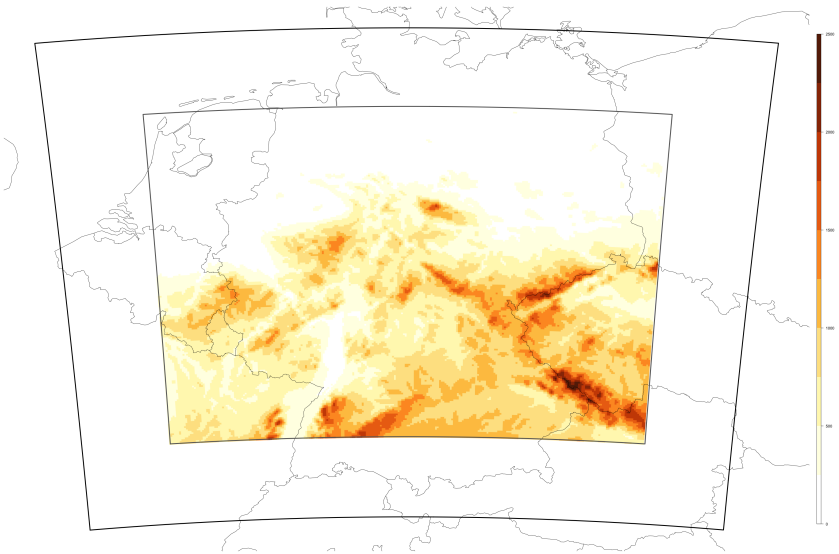
- BLIDS (Siemens)
- Period : 1999-2013
- Accurracy obs 300 - 800m
- Interpolated to model grid
- Interpolated to 15-min timestep
- Cloud-to-cloud and cloud-to-ground



COSMO-CLM setup 2.8km

Setup

- ~ 2.8 km (CPS)
- COSMO5.0clm7
- 1-moment with Graupel
- Implementation LPI
- ERA-Interim (1979-2015 with 2-year spin-up)

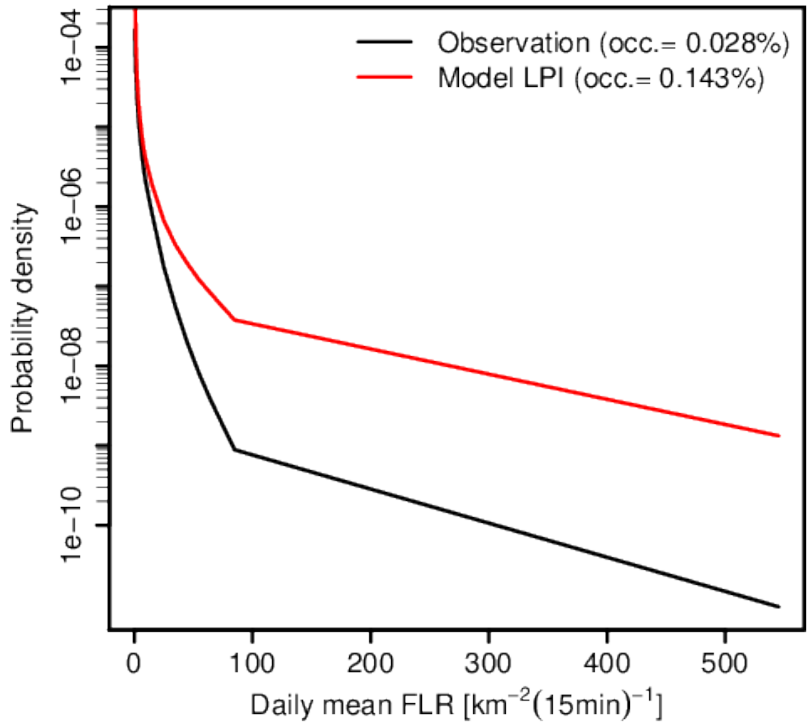


Raw LPI

- LPI is occurring too often
- LPI is values are too high

Adjusted LPI

- Cutoff value at 0.89
- Linear adjustement



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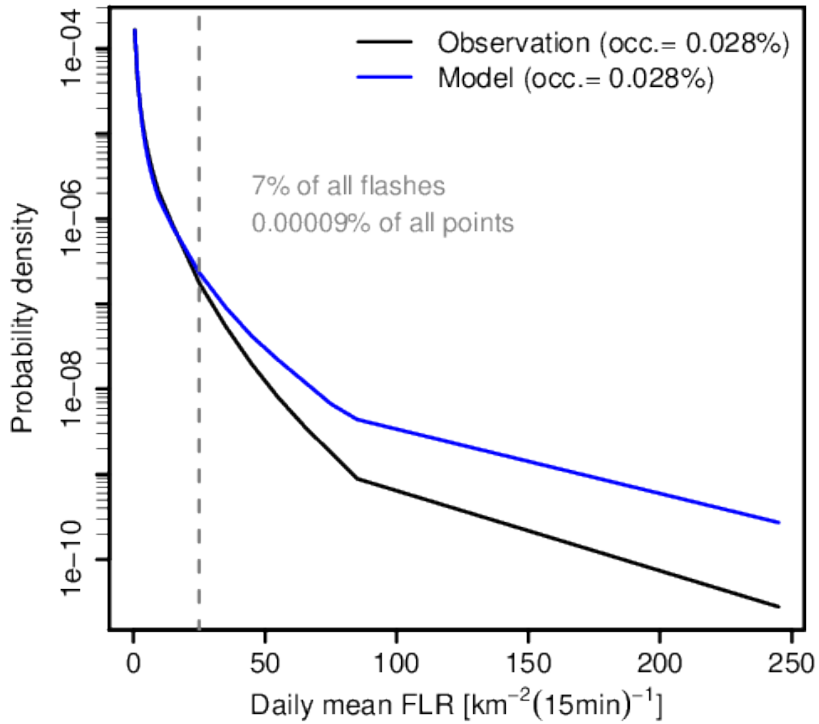
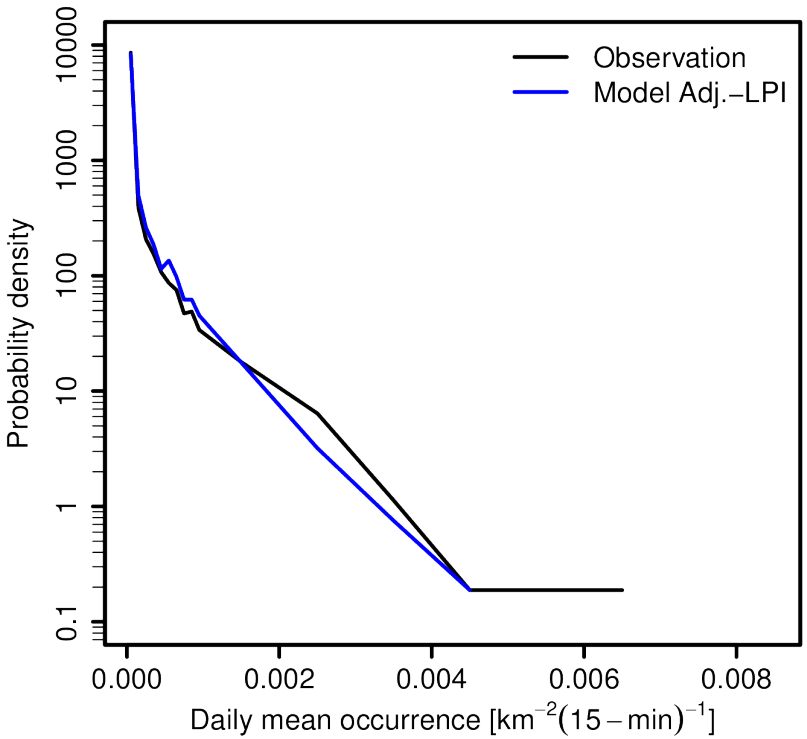
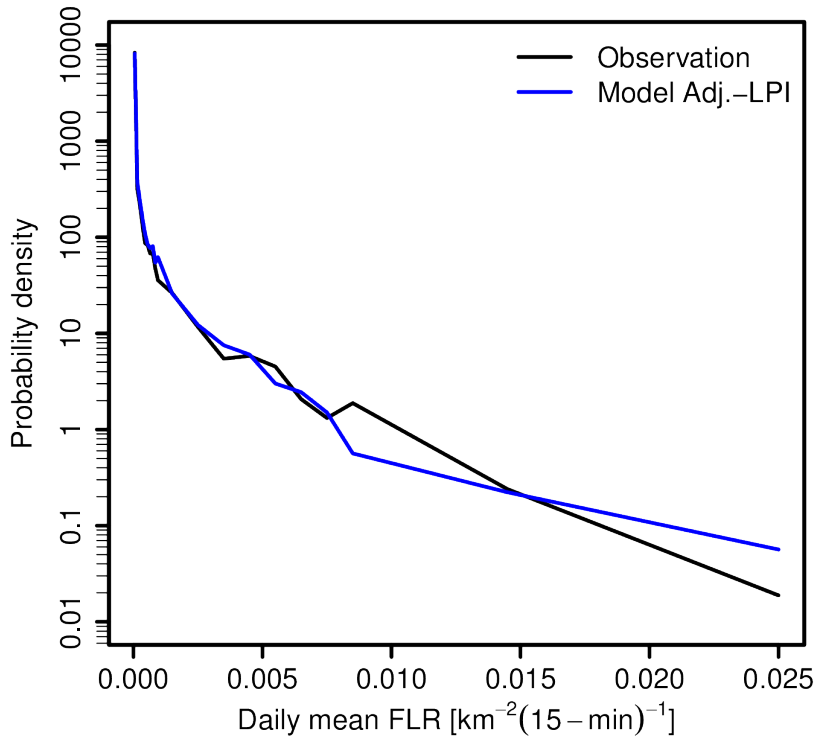
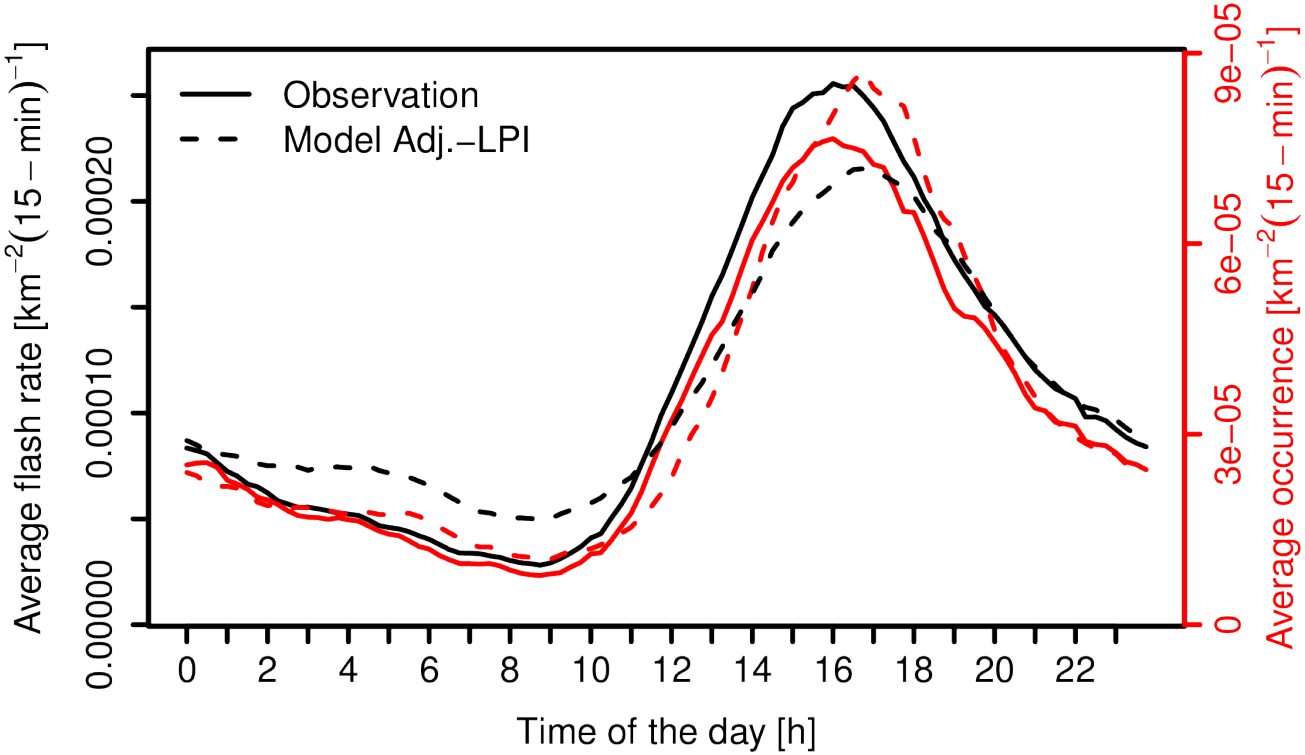






$\rightarrow$ Support the LPI-Adjustement

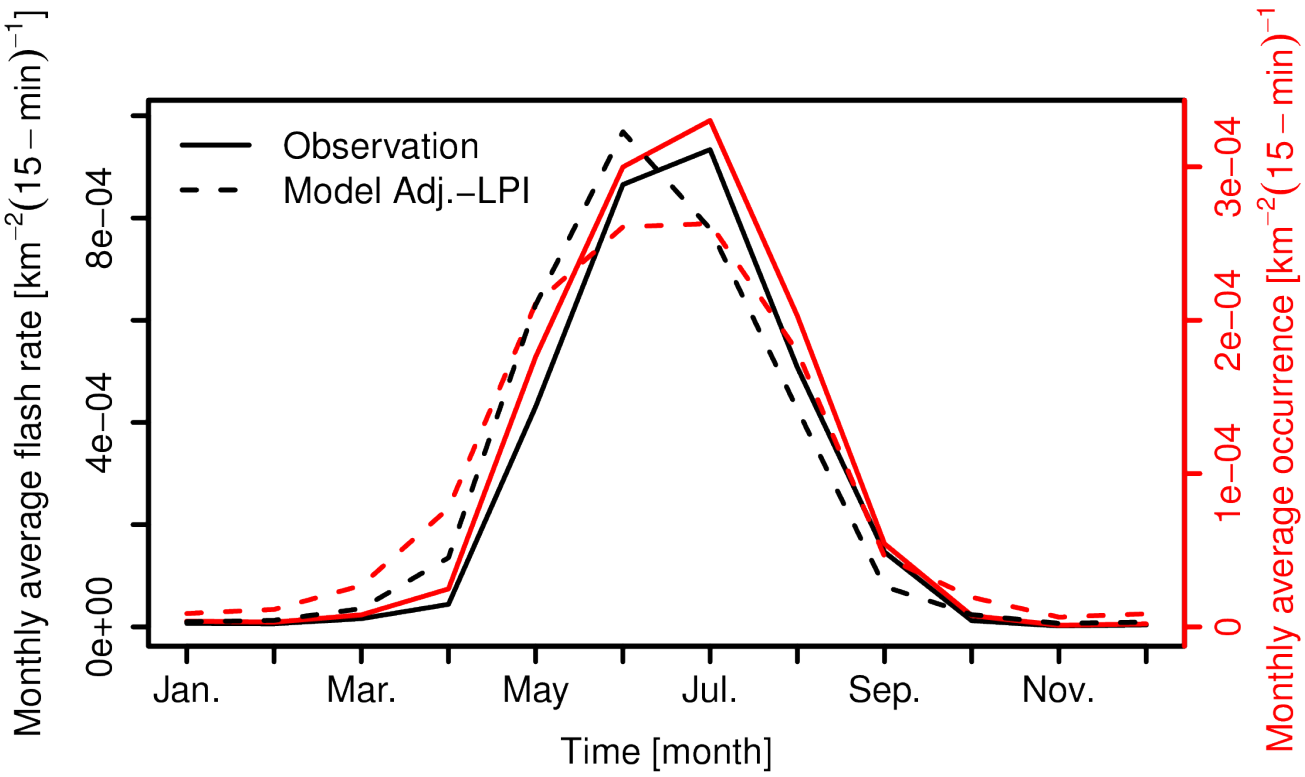


Flashes Occurrence

- General behavior
- Overestimation of the peak

Number of flashes

- General behavior
- Underestimation of the peak



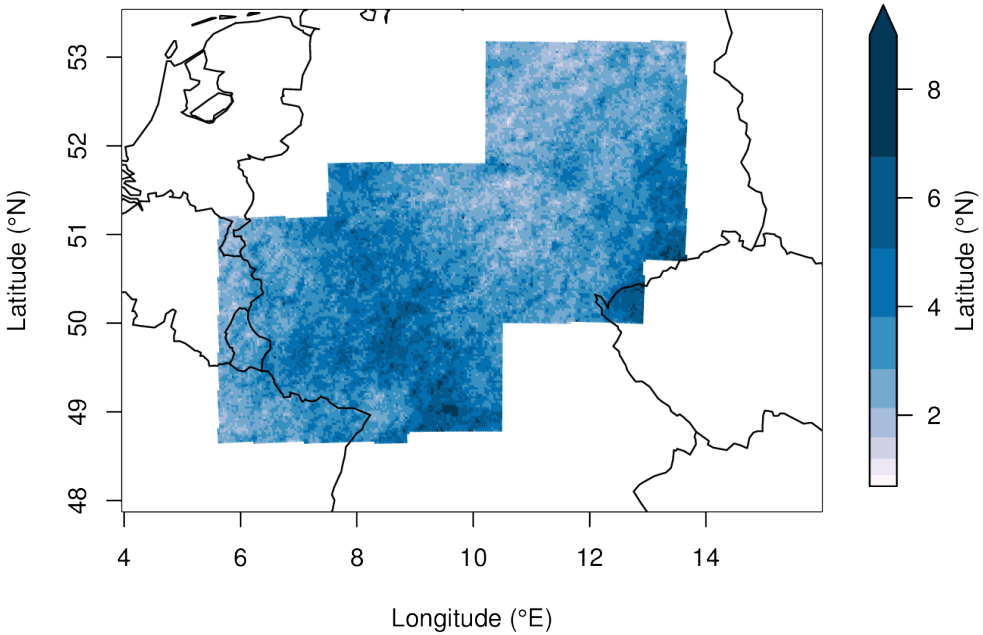
Flashes Occurrence

- General behavior
- Early peak

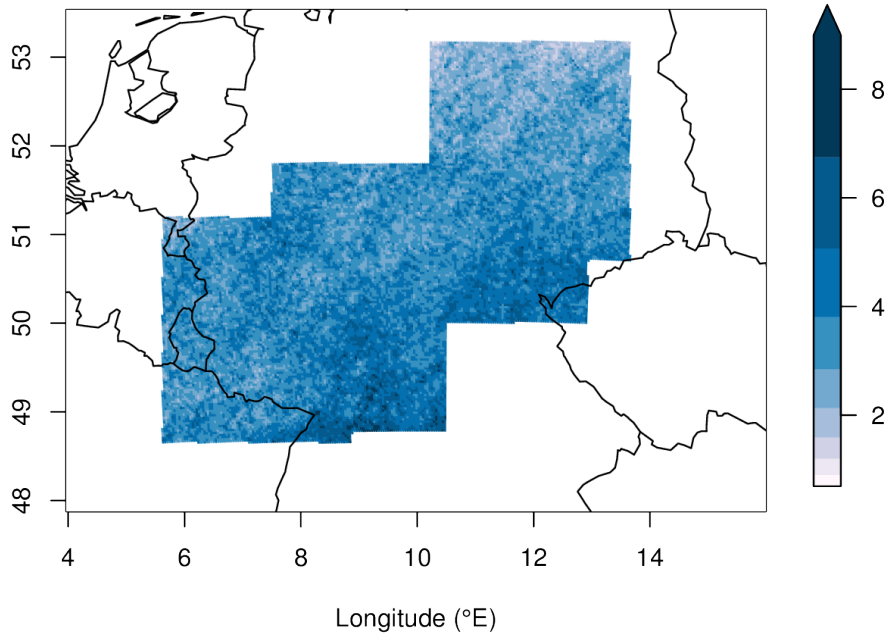
Number of flashes

- General behavior
- Early peak

Obs. number of flashes [$km^{-2}year^{-1}$]

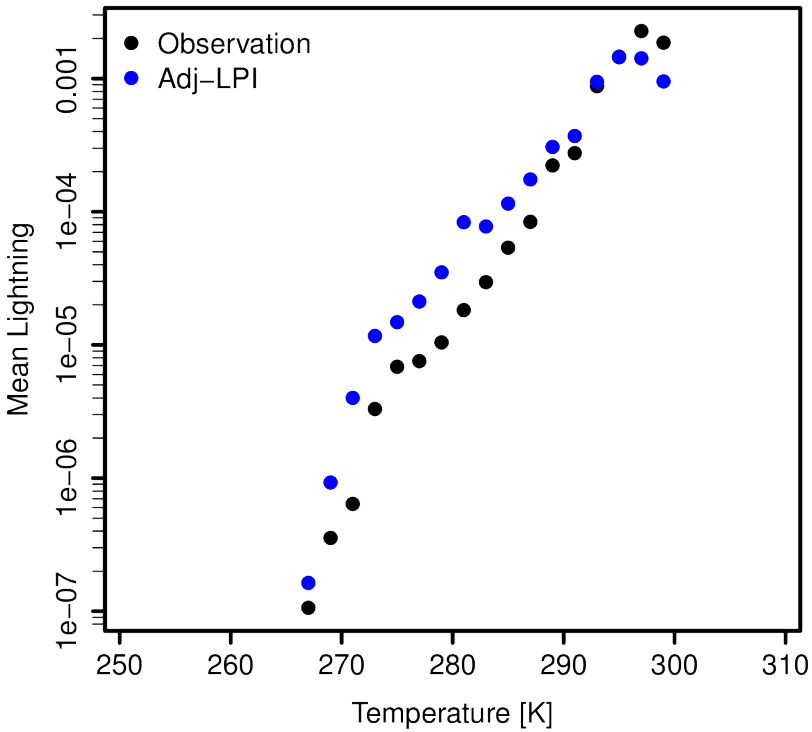


Mod. Adj.–LPI [$km^{-2}year^{-1}$]



→ Large-scale pattern is mainly reproduced

→ Missing local variability : Cloud-to-ground variability ?



Temperature scaling

- Three different slopes
- Slope well reproduced (break-up at the right temperature)
- Noise is removed on longer time-period (not shown)

$\rightarrow$ Bring confidence in using Adj.-LPI for studying different climatologies

Yes

- After Adjustement give reasonable 15-min distribution
- Adjustement is supported by daily distribution
- Daily and monthly cycles generally well reproduced
- Adj.-LPI temperature scaling fit the observed one

No

- Missing spatial distribution
- Is there a general mislocation of convective activity ?
- OR do we Need surface/soil lightning dependency ?

$\rightarrow$ Could be included in official COSMO-CLM version ?

Do we need LPI or are empirical methods enough ?

- Romps et al. (2014) : $CAPE \times PREC$
- High correlation with LPI
- Observed temperautre scaling improved with LPI

Climate projections

- Three 30-year simulations have been performed
- Temperature-scaling unchanged
- Diverge from $CAPE \times PREC$