Explicit simulations of electrified mixed-phase clouds of the HyMeX-SOP1 experiment with the MesoNH mesoscale model

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Motivations:

- High-quality observations of the cloud electrical activity with a **LMA**[(*)] during the «**HyMeX» SOP1 field experiment** (Fall 2012)
- Simulation of real cases to evaluate an explicit « Atmospheric Electricity » module developed in MesoNH

LMA: **L**ightning **M**apping **A**rray is manufactured by the New Mexico Tech., Socorro, NM

Outlines of the presentation

- Short overview of the electrical scheme of MesoNH and its extension to real case simulations

- First real meteorological simulations of **«HyMeX» cases:** Sept, 5 and Sept, 26, 2102 over the Cévennes area (South of France)

Recent ref: Barthe et al., GMD, 2012; Pinty et al., AR, 2012

Electrical scheme of MesoNH

Very few CRM (Mansell et al., 2002; Barthe et Pinty, 2007) have a complete 3D electrical scheme.

electrical charges + **electric field** + **lightning flashes**

Coupling with cloud μphysics & dynamics and physics of ions

Numerical method

$$\varepsilon \cdot \nabla \cdot \vec{\mathrm{E}} = q_{total}$$

(Eq. is solved for V with $\vec{\mathbf{E}} = -\vec{\nabla} V$ and BC)

Conceptual model leaders & branches

Prod. of charges $\xrightarrow{E>E_{trig}}$ **Sink of charges**

Electrical scheme of MesoNH

- Until now all the studies were performed for idealized deep convective cases observed in the US (eg. CCOPE, STERAO, STEPS) or in Germany (EULINOX) with flat terrain conditions.

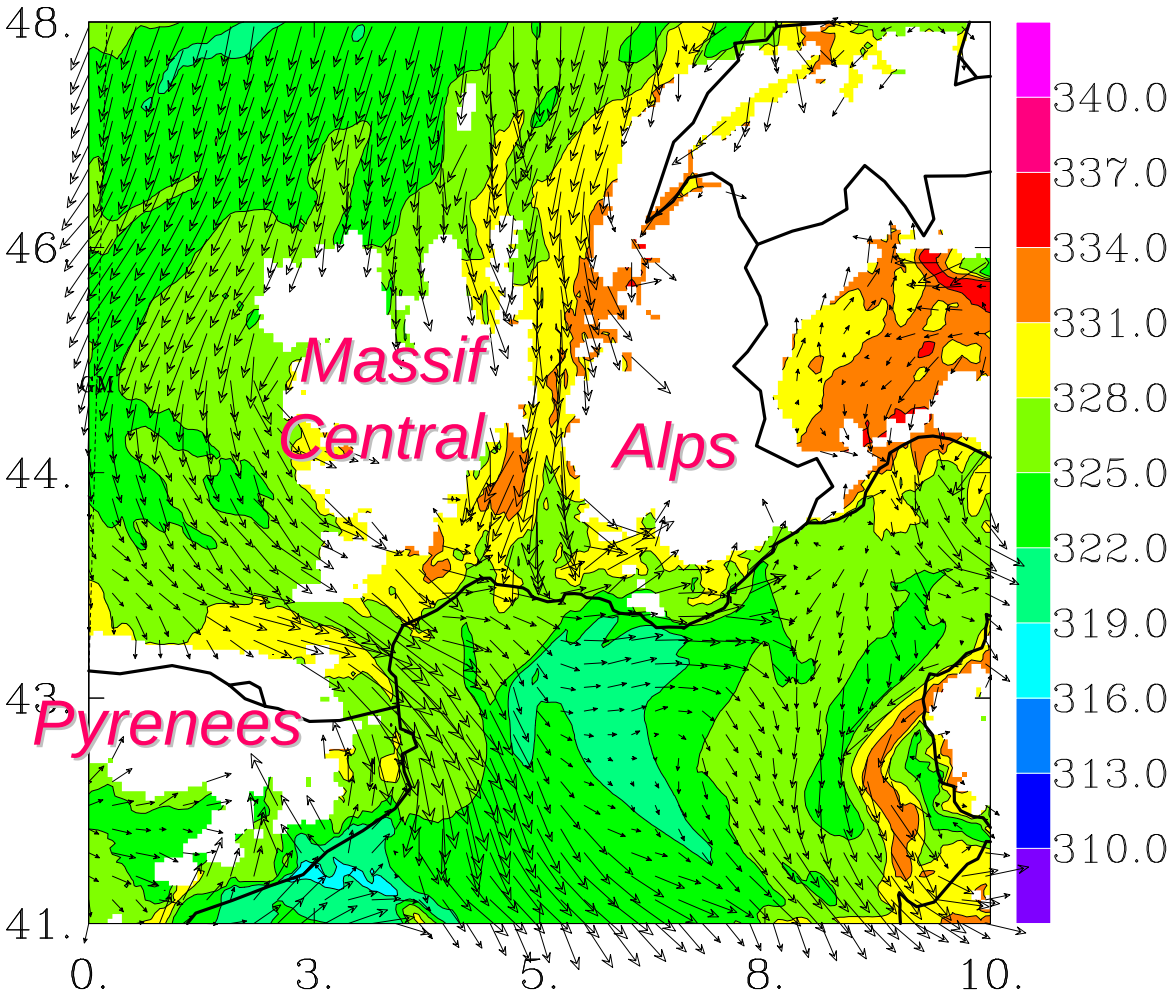
- In contrast, this study attempts to simulate electrified precipitating clouds in real case over orography and to compare with LMA data

- Preliminary work:
  - Set-up of an iterative scheme to compute E over orography (vertical terrain-following coordinate)
  - High resolution (km scale) ➔ large computational domain ➔ parallelized code to run on Nproc computers ➔ need to recode and to simplify the lightning flash scheme

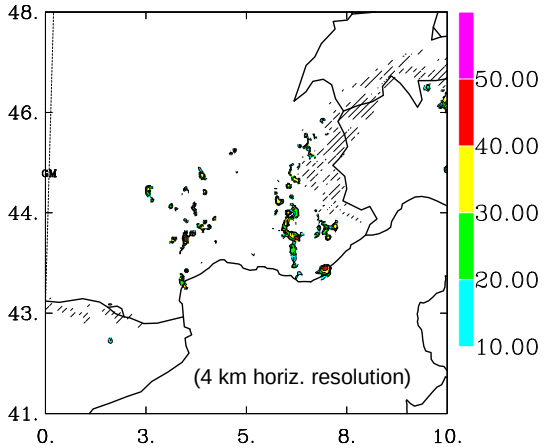
The 05 Sept. 2012 Case
Synoptic situation

(Low-level situation at 15 UTC, after 9 h run from 20120905_06UTC AROME analysis)

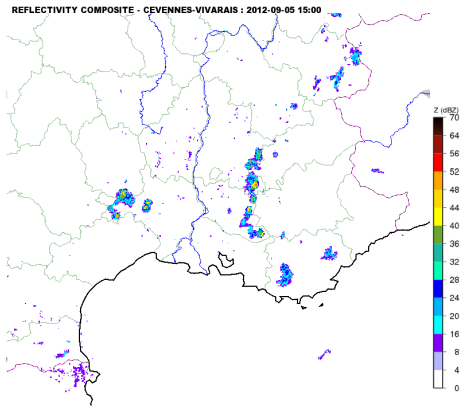
950 hPa equiv. Pot. Temp. and Wind



Radar (dBZ) at z=2000m



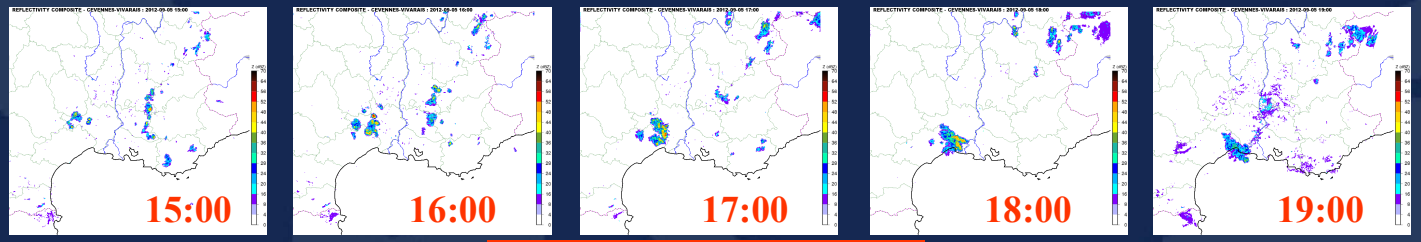
Reflectivity composite



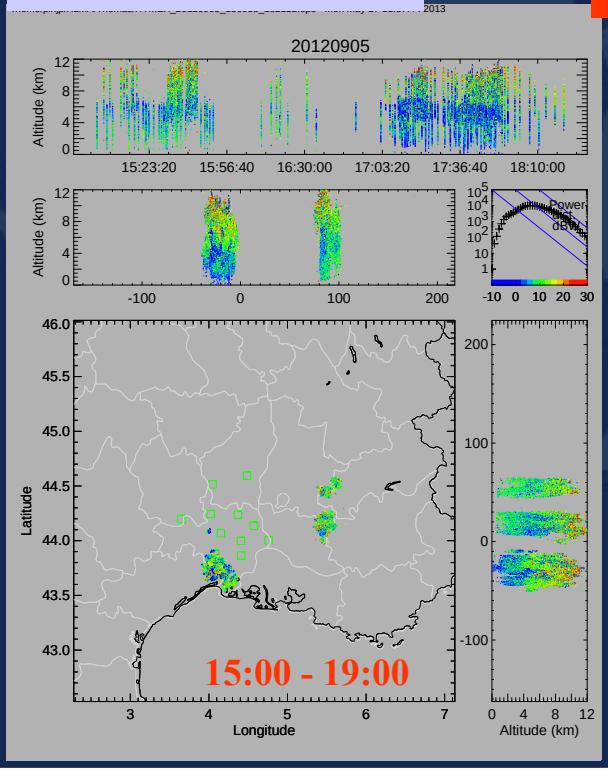
HyMeX
TTO1-h / Ti / 6

First Model Results (1/2)

First setup of the simulations: 192x192 gridpoints @ 4km and 384x384 gridpoints @ 1km



LMA data 15-19

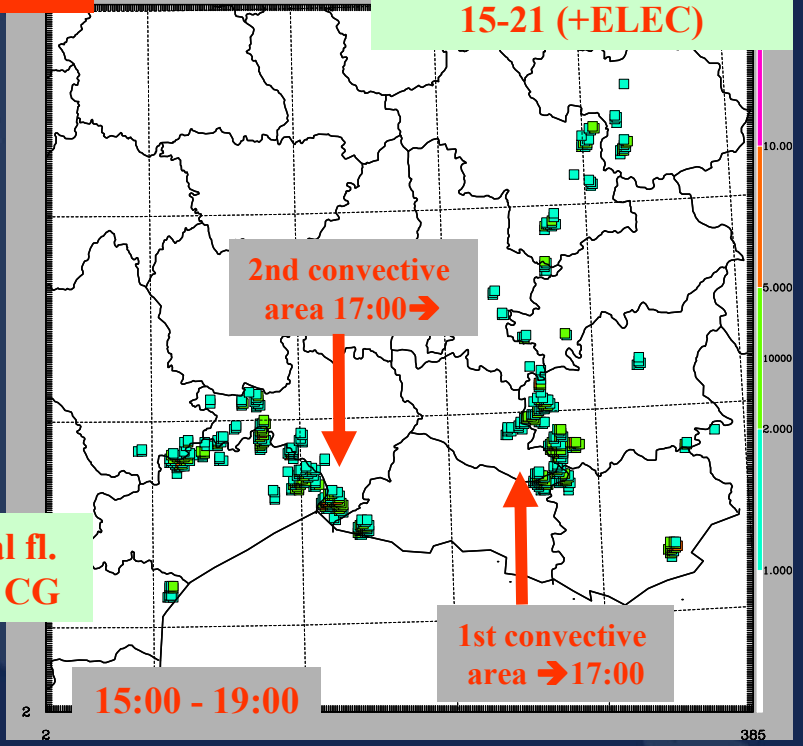


5 Sept. 2012 CASE

183 big fl.
3 medium fl.
111 small fl.
1325 fl. frag.

1686 total fl.
with 362 CG

MesoNH: 06-15 then 15-21 (+ELEC)



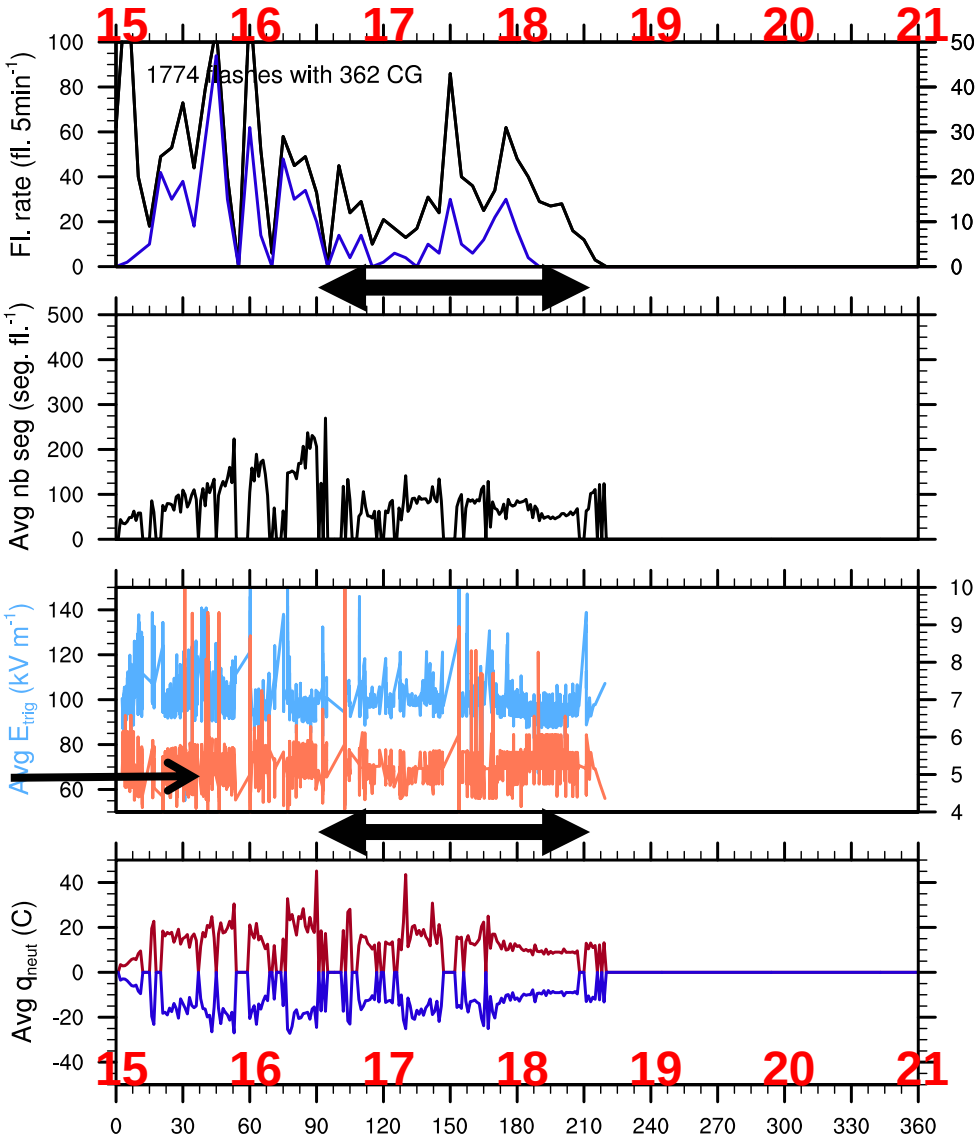
The 5 Sept. 2012 Case
Flashes between 15:00-21:00

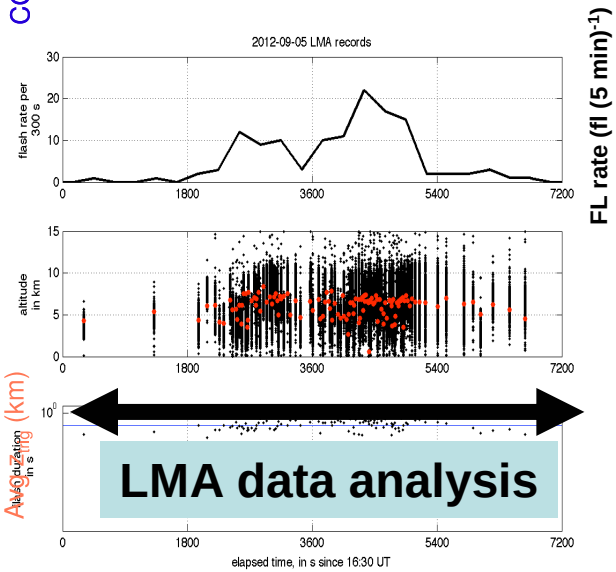
sustained lightning activity (IC flashes)

Branch density

Triggering altitude at ~5 km and ~8 km height

Neutralized charges

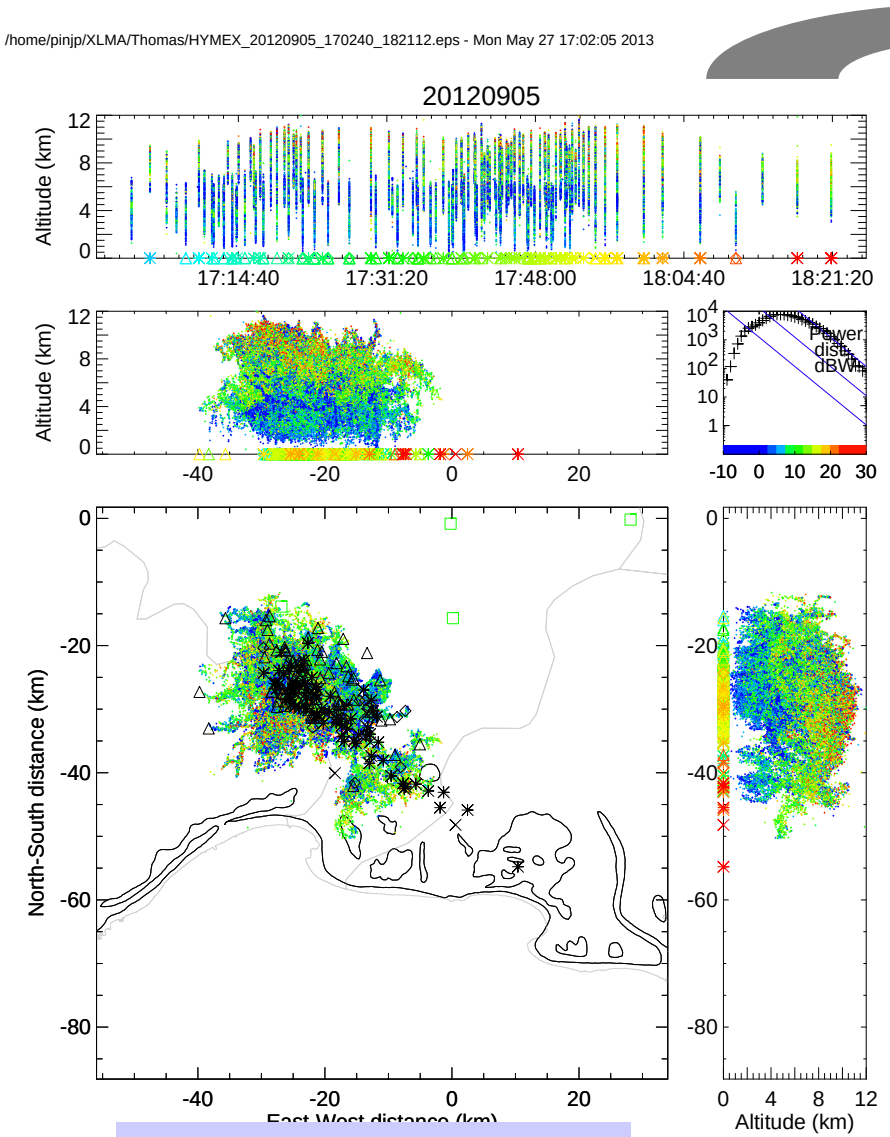




Good:
- init/decay of the elec. activity
- flash triggering at 2 alt.

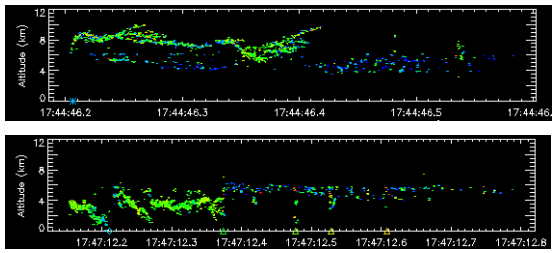
Bad:
- excess of flash (additional cells)

The 5 Sept. 2012 Case
Electrical charges : 05 Sept 17:45

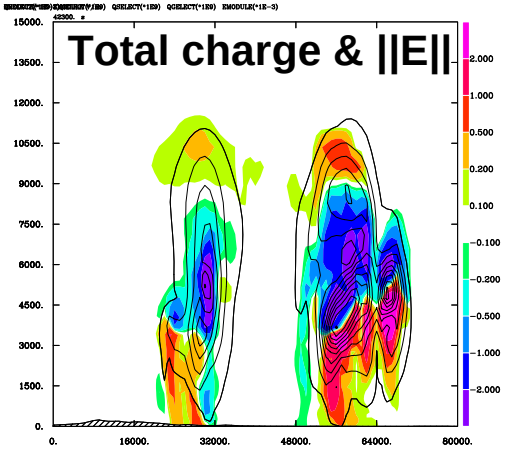


LMA & EUCLID data

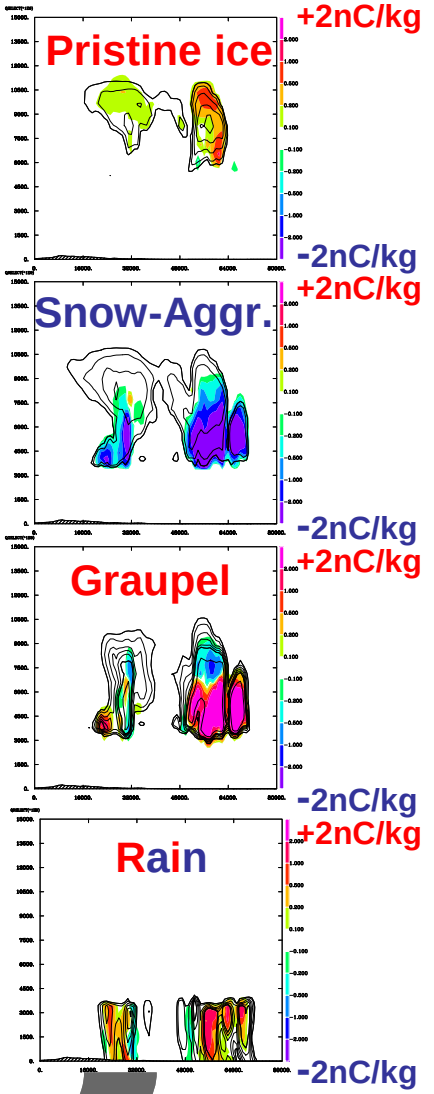
High & Low flashes



➔ Tripole charge structure

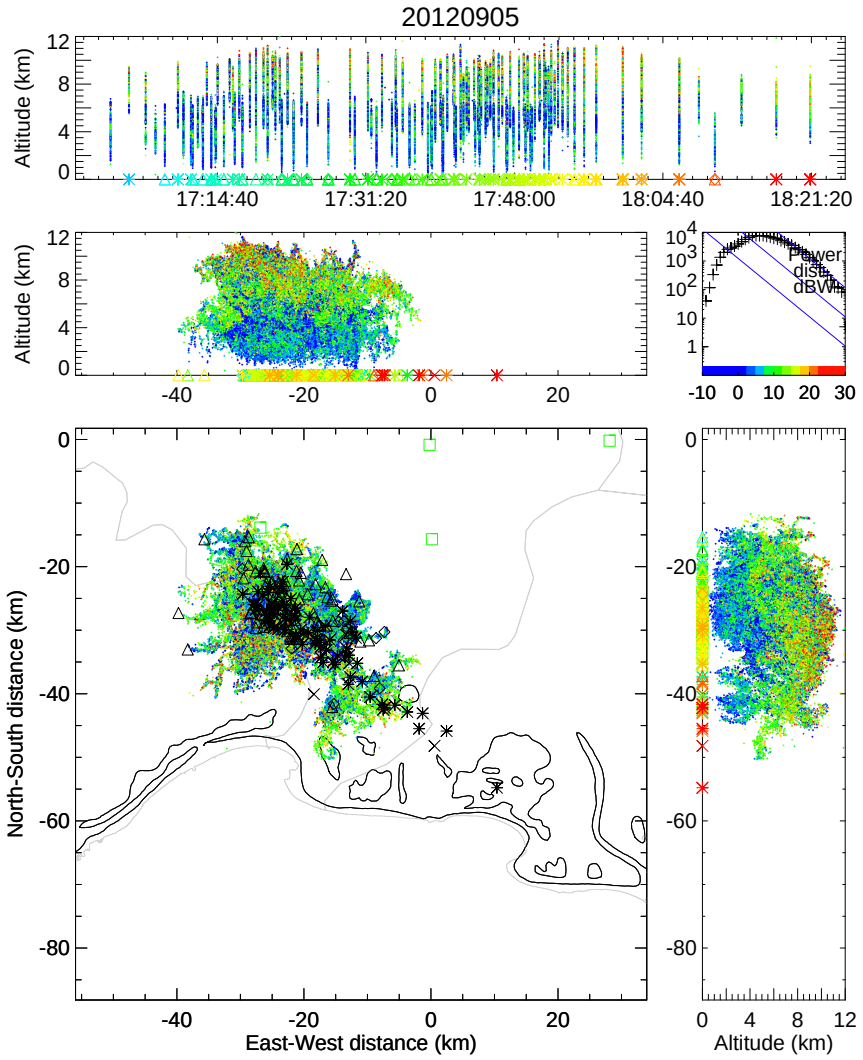


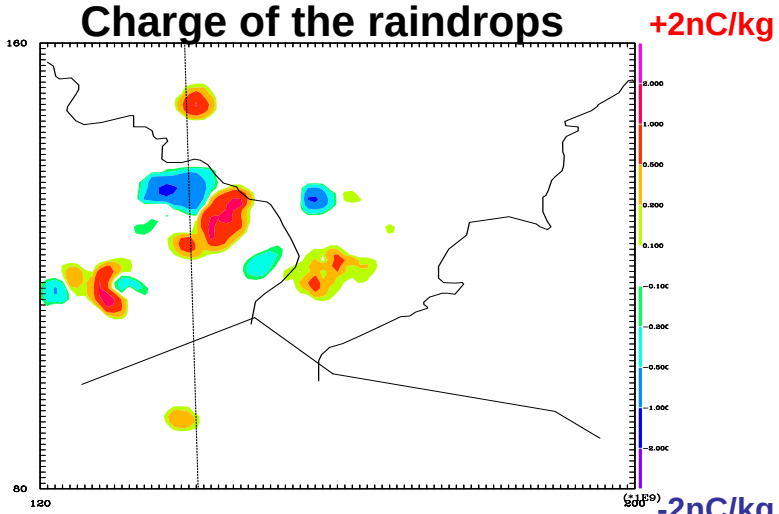
||E|| max ~ 100 kV/m

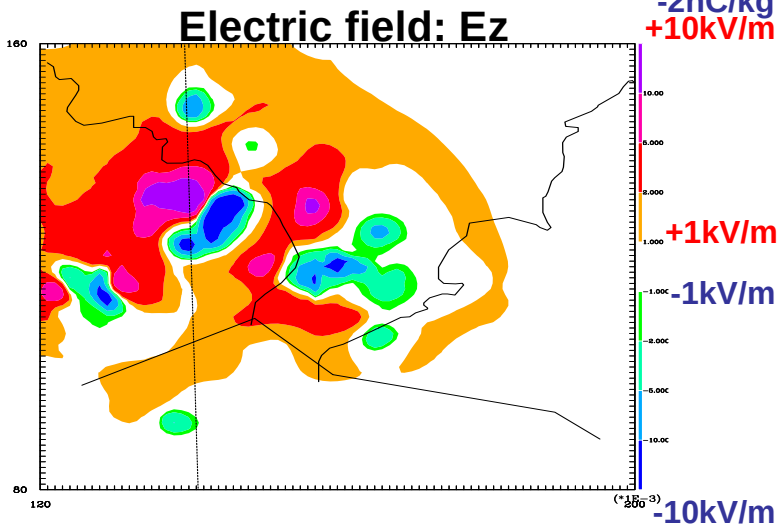


The 5 Sept. 2012 Case
Surf. electrical state : 05 Sept 17:45

/home/pinjp/XLMA/Thomas/HYMEX_20120905_170240_182112.eps - Mon May 27 17:02:05 2013







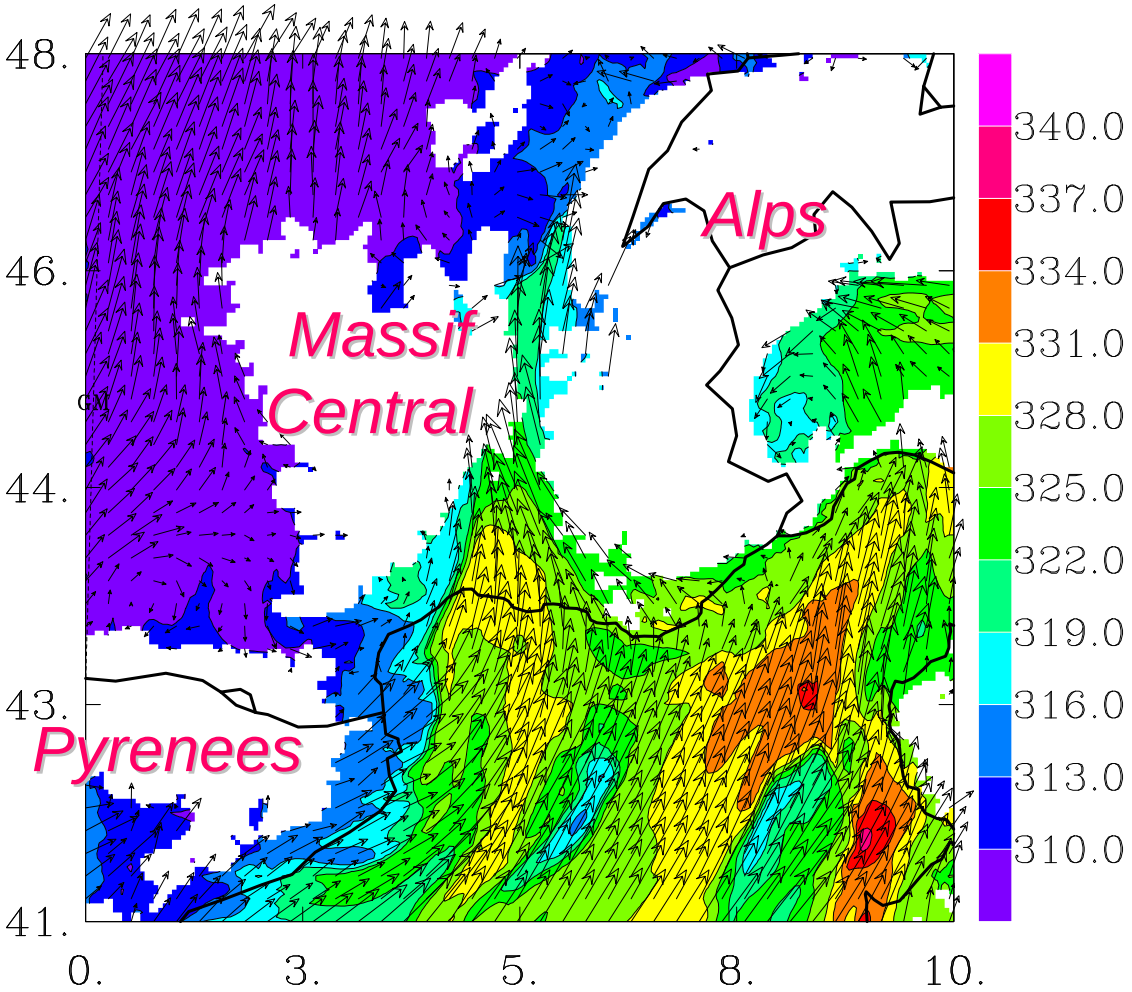
LMA & EUCLID data

Ground Level

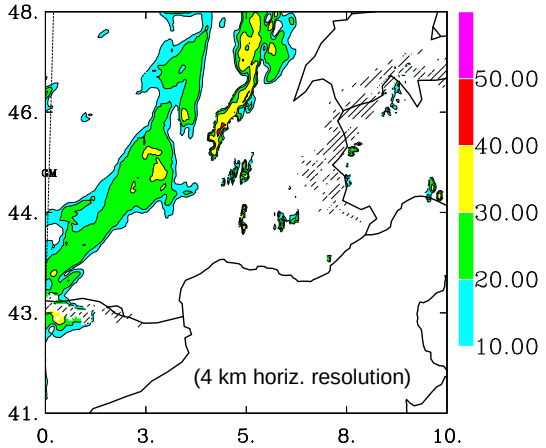
The 26 Sept. 2012 Case
Synoptic situation

(Low-level situation at 04 UTC, after 4 h run from 20120926_00UTC AROME analysis)

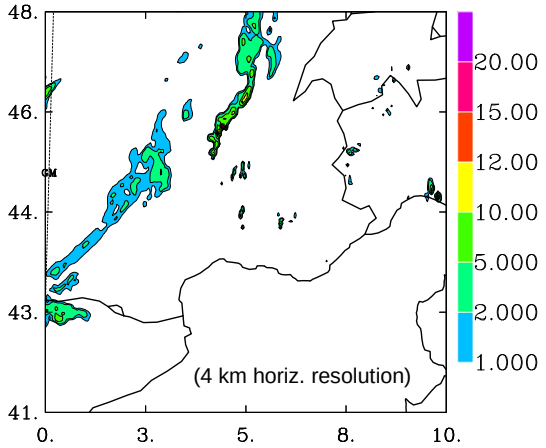
950 hPa equiv. Pot. Temp. and Wind



Radar (dBZ) at z=2000m



Precip rate (mm/h) at GL

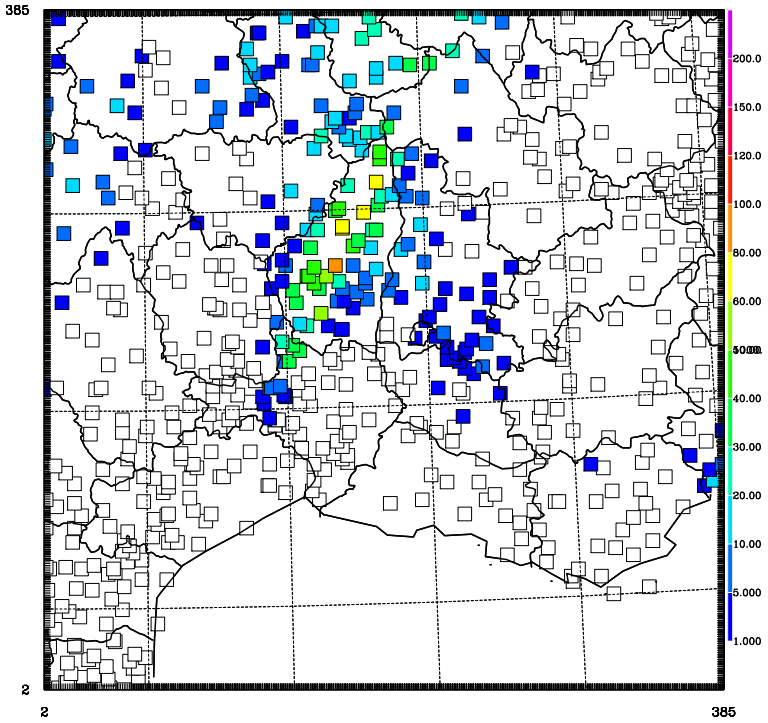


The 26 Sept. 2012 Case
Rainfall (log scale)

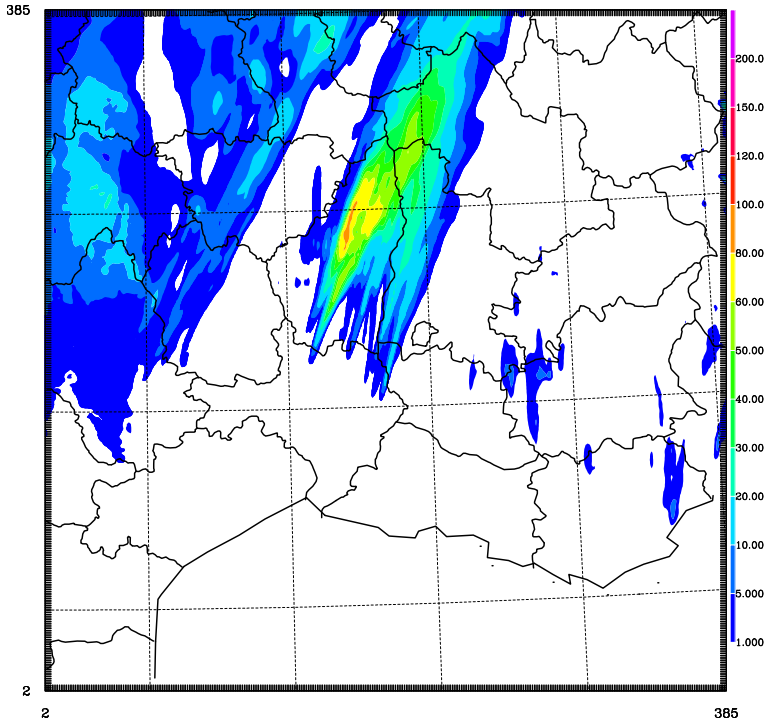
Domain 384x384 km (resol. 1 km, 60 levels)

{26 Sept 04:00}-{26 Sept 12:00}

Max=89 mm (Ardèche)



MesoNH: Max=94.05 mm



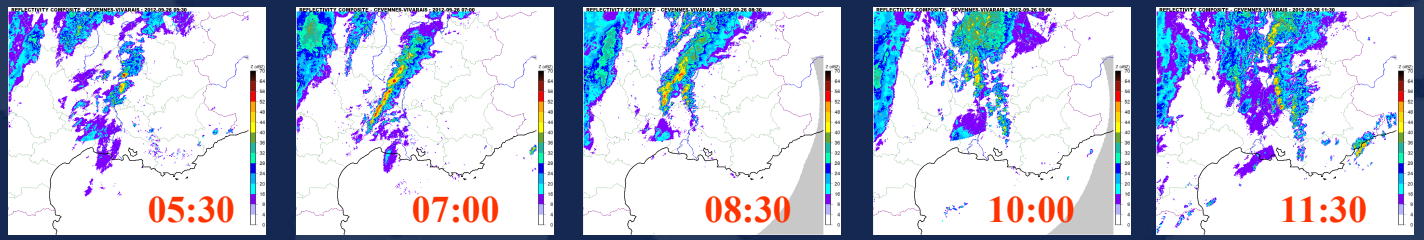
8 h grid-nested run with explicit «Electricity» module

- Initial state = 4 h model run from **20120926:00UTC «Arome» analysis**
- 4-km 3-h External Lateral forcing with «Arome» analyses (at 2.5 km)

HyMeX
TTO1-h / Ti / 12

First Model Results (2/2)

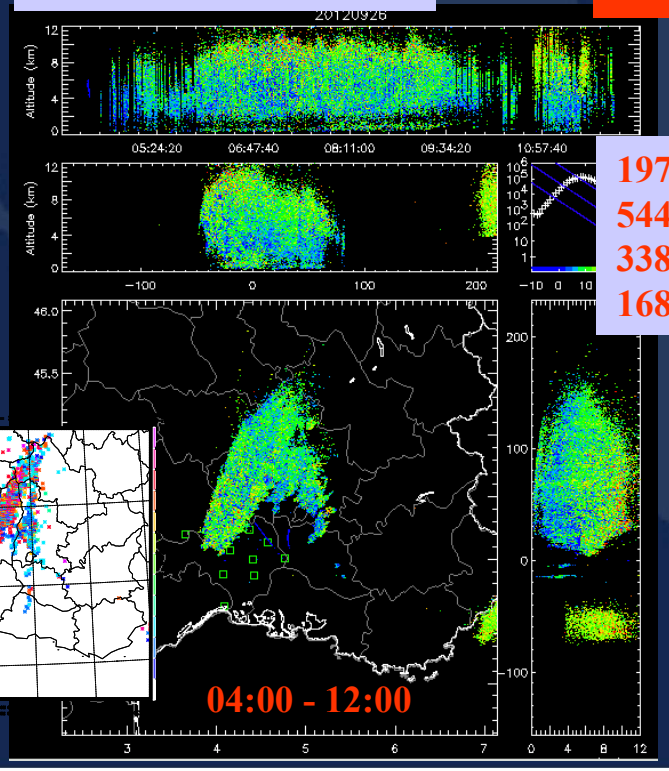
First setup of the simulations: 192x192 gridpoints @ 4km and 384x384 gridpoints @ 1km



LMA data 04-12

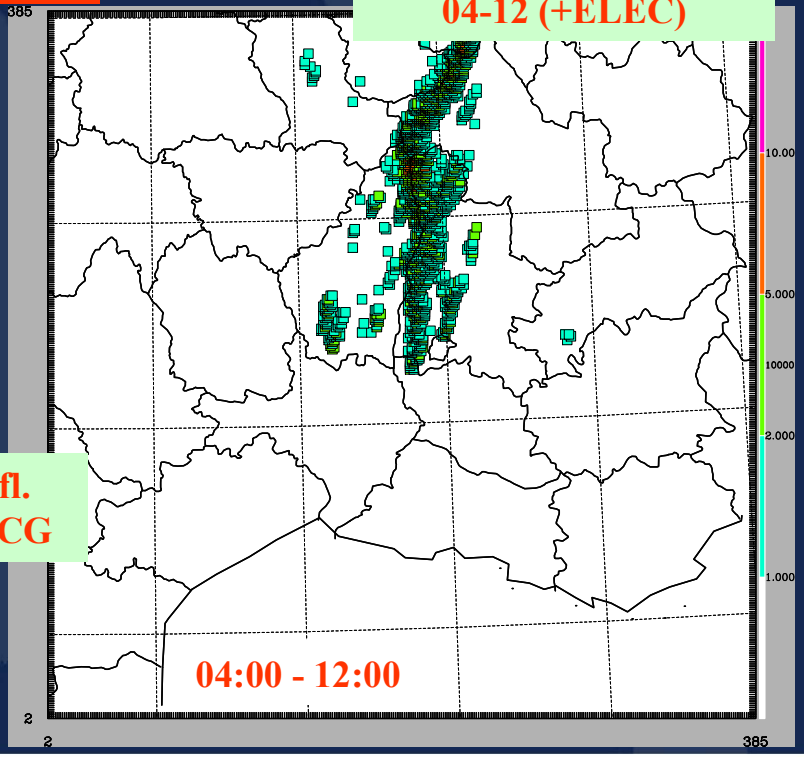
26 Sept. 2012 CASE

MesoNH: 00-04 then 04-12 (+ELEC)



1970 big fl.
544 medium fl.
338 small fl.
1684 fl. frag.

5207 total fl.
with 1709 CG

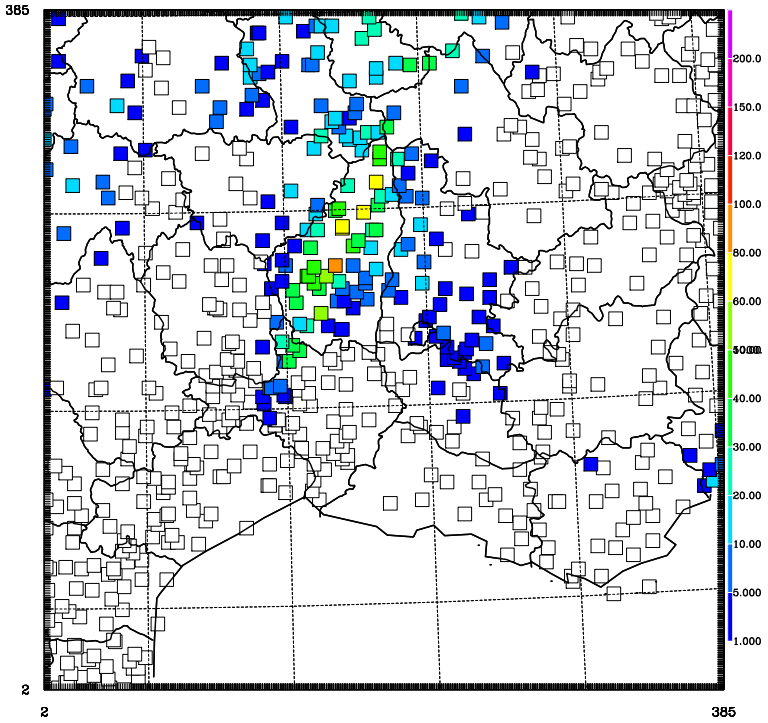


The 26 Sept. 2012 Case
Rainfall (log scale)

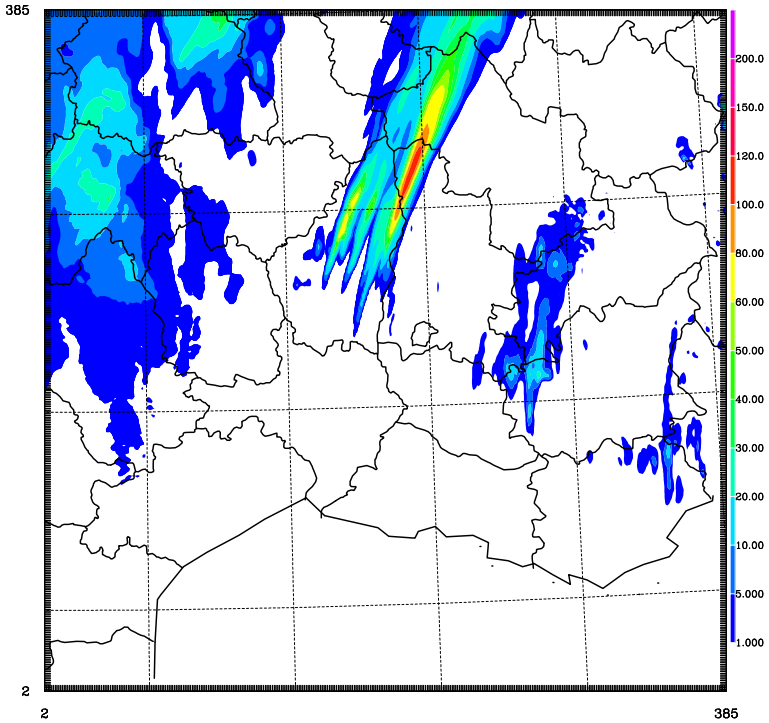
Domain 384x384 km (resol. 1 km, 60 levels)

{26 Sept 04:00}-{26 Sept 12:00}

Max=89 mm (Ardèche)



MesoNH: Max=112.85 mm

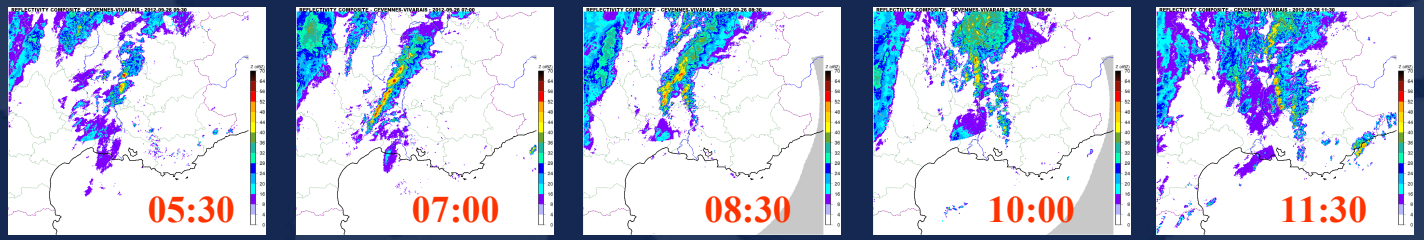


8 h grid-nested run with explicit «Electricity» module

- Initial state = 10 h model run from **20120925:18UTC «Arome» analysis**
- 4-km 3-h External Lateral forcing with «Arome» analyses (at 2.5 km)

First Model Results (2/2)

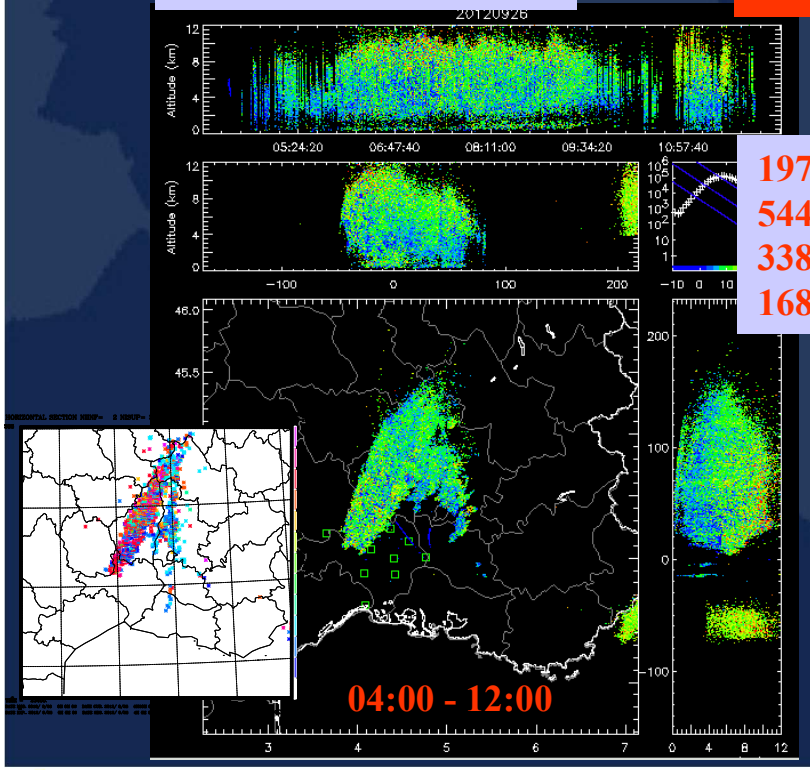
First setup of the simulations: 192x192 gridpoints @ 4km and 384x384 gridpoints @ 1km



LMA data 04-12

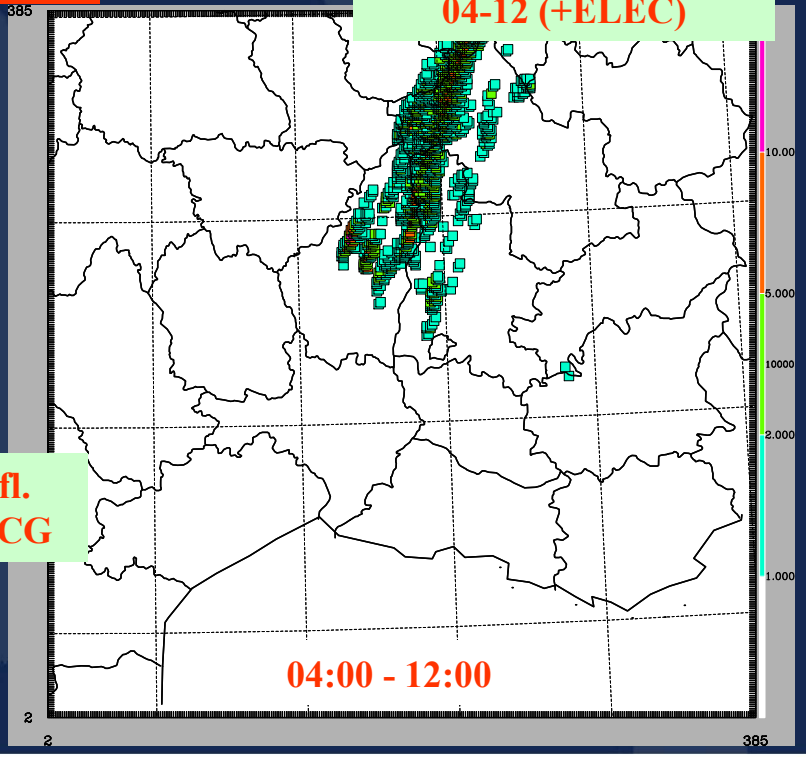
26 Sept. 2012 CASE

MesoNH: [18]-04 then 04-12 (+ELEC)



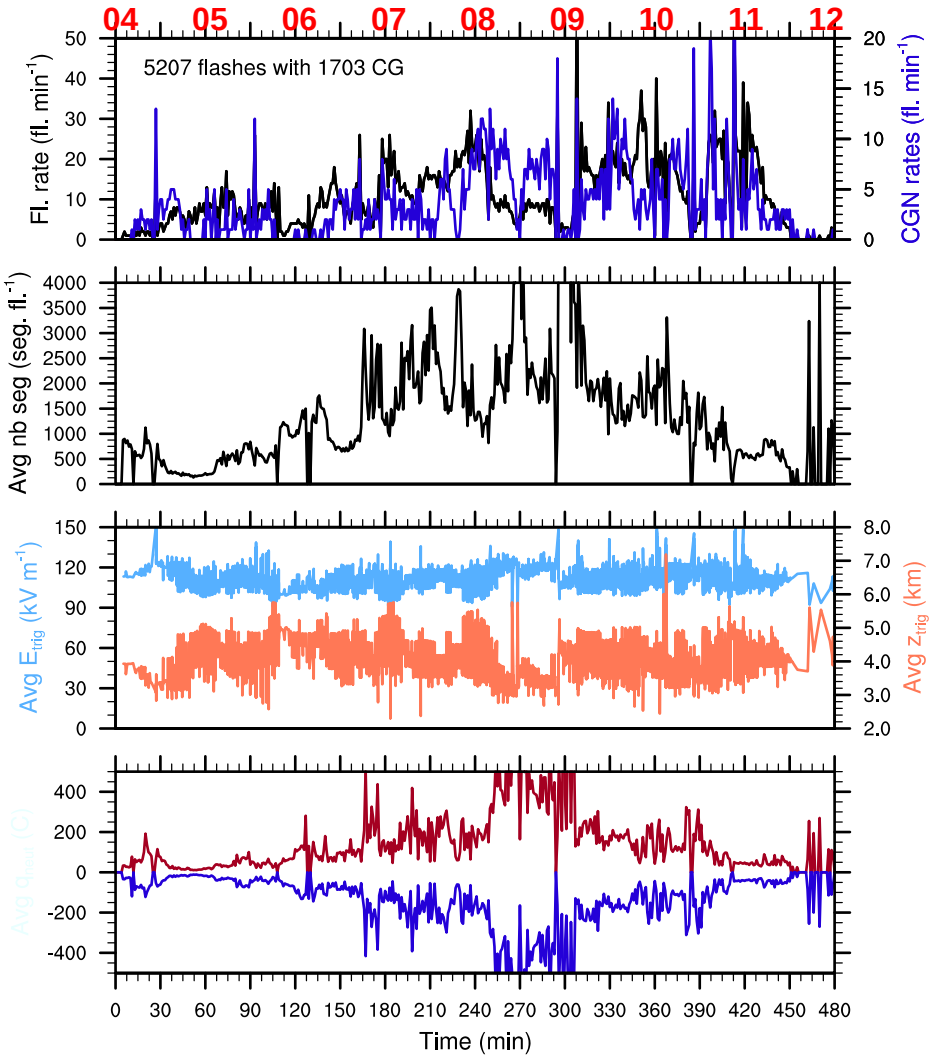
1970 big fl.
544 medium fl.
338 small fl.
1684 fl. frag.

5795 total fl.
with 1904 CG

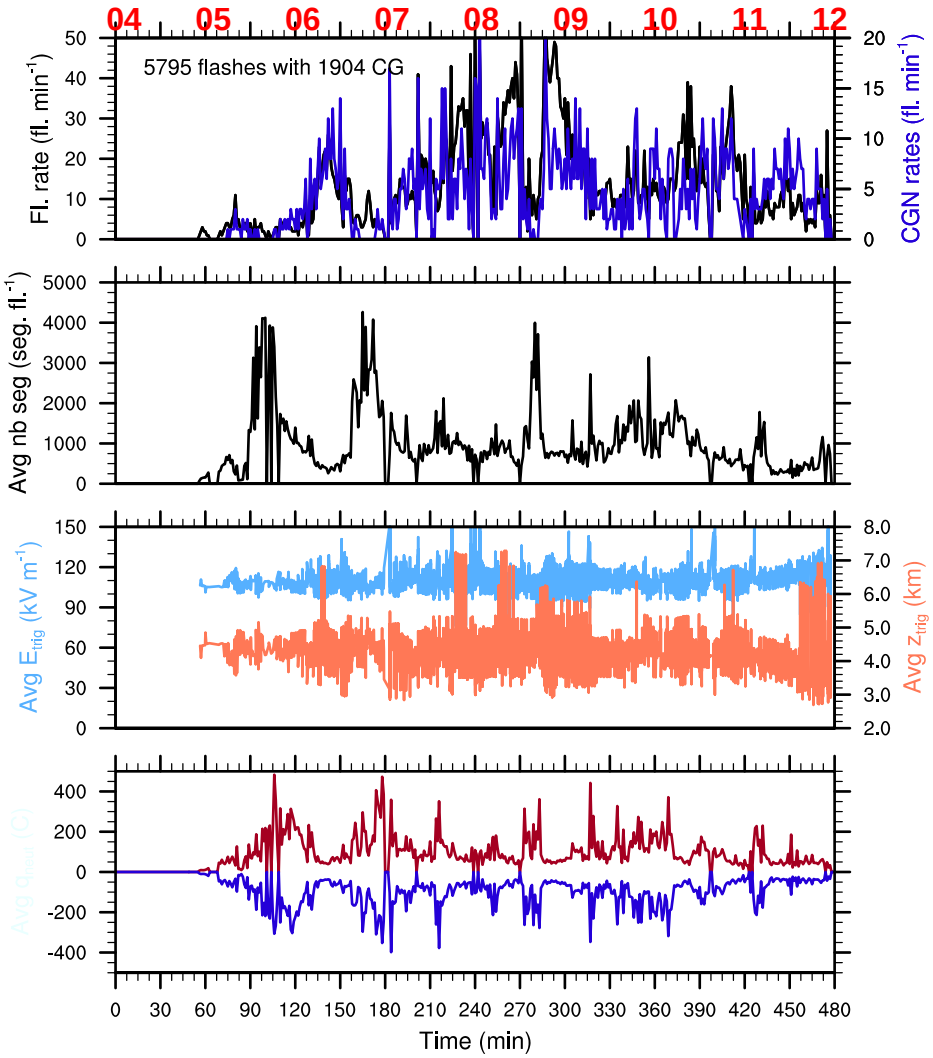


The 26 Sept. 2012 Case
Flashes between 04:00-12:00

run from 20120926:00UTC «Arome» analysis



run from 20120925:18UTC «Arome» analysis



Conclusion

- The «Electrical Module» of the Cloud-Resolving Mesoscale Model MesoNH is able to simulate explicitly **3D electrified clouds** on **multiprocessor computers** over complex terrain at km scale

- **First real meteorological** «HyMeX» **simulations** are performed with a preliminary evaluation of the scheme against **LMA data** (and other lightning detection networks) ➔ **location of the convective cells !**

- **Perspective:** Intensive study of **«HyMeX»** cases mostly based on comparison to **LMA** observations:
  - Check the 3D structure and fractal dimension of the flashes
  - Check the altitude of flash triggering, the cloud polarity and the sensitivity to charge separation parameterizations (Takahashi vs Saunders et al.), etc.
  - Improve criteria to select IC and CG flash types
  - … to introduce «flash data» in the 3DVAR assimilation scheme of «Arome» at Météo-France

Electrical charging rate
vs
Microphysical growth rate

- **Transport terms: advection, sedim.**
- **Transfer terms, i.e. coll., melt., …**

$$\left(\frac{\partial q}{\partial t}\right) = \frac{q}{r}\left(\frac{\partial r}{\partial t}\right)$$

r: mixing ratio, q: electrical charge

- **No-inductive charging**

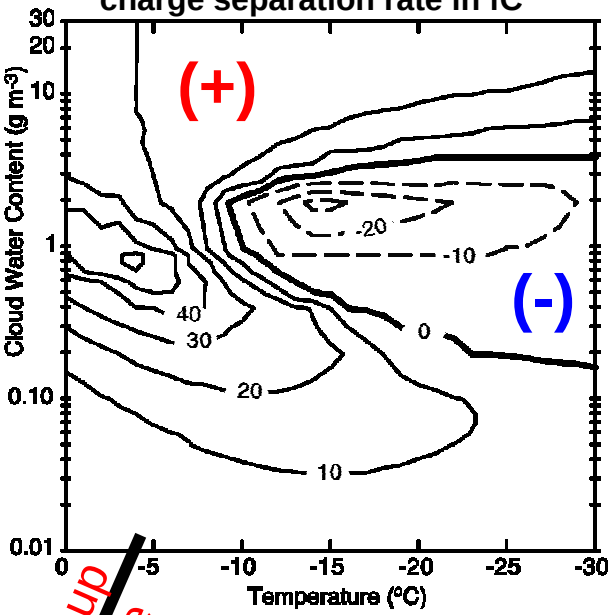
$$\left(\frac{\partial q_x}{\partial t}\right) = \int_0^\infty \int_0^\infty (1 - E_{xy}) \Delta q_{xy}^{Tak} K_{xy} n_x n_y \, dD_x \, dD_y$$

$$\left(\frac{\partial r_x}{\partial t}\right) = \int_0^\infty \int_0^\infty E_{xy} m_x m_y K_{xy} n_x n_y \, dD_x \, dD_y$$

E_{xy}: collection efficiency

$1\text{-}E_{xy}$: rebounding efficiency

Takahashi's(1978) diagram of charge separation rate in fC

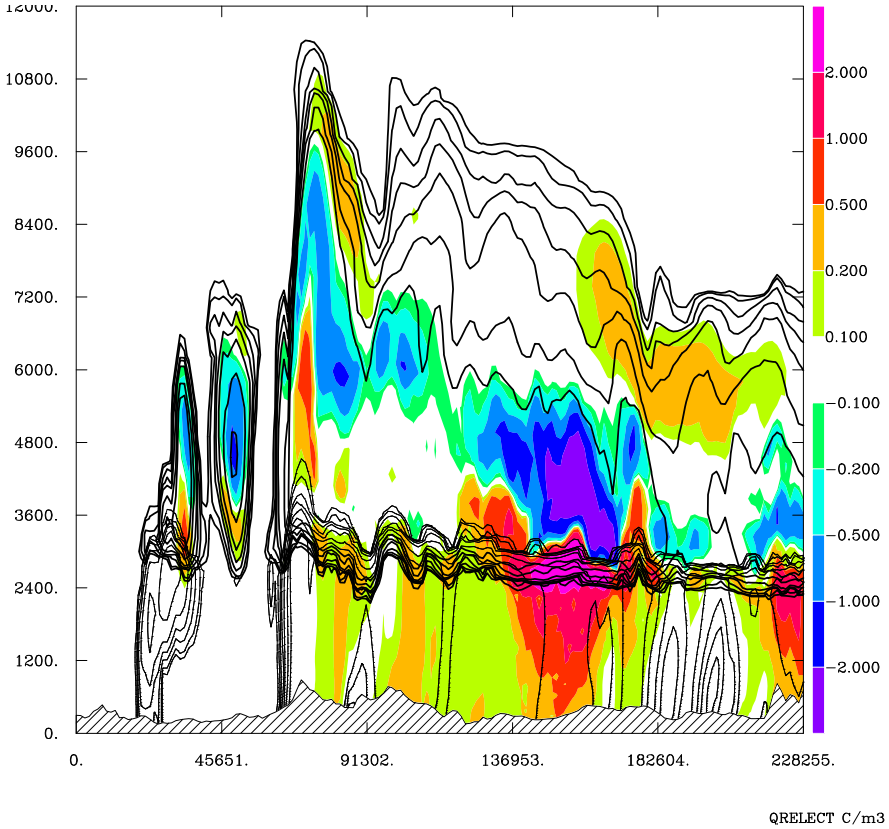


look-up table

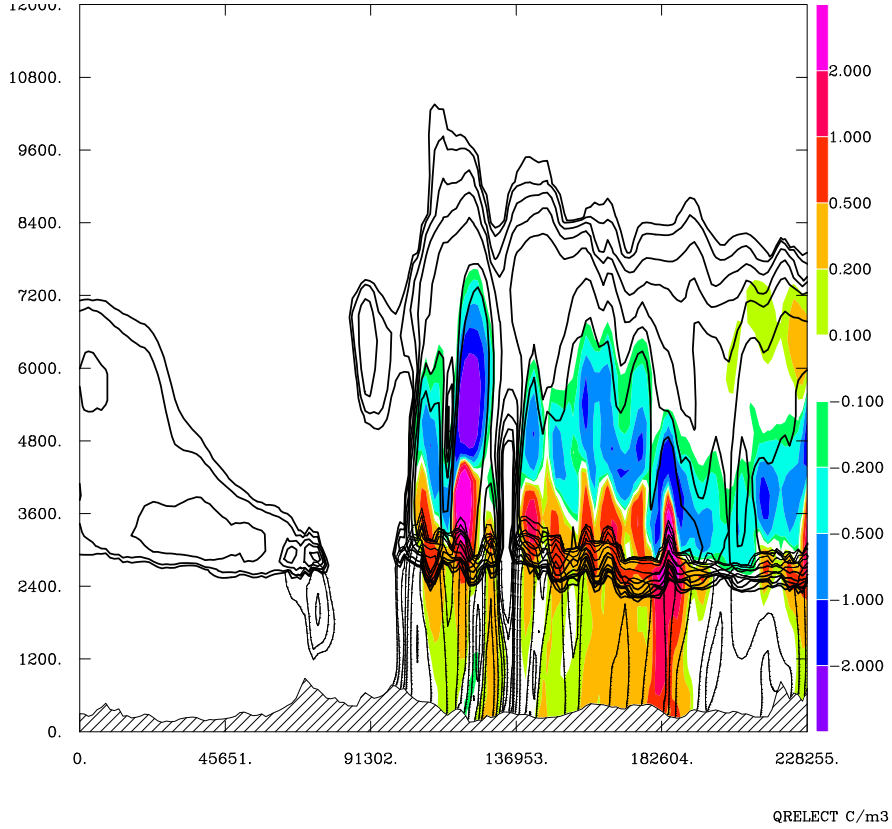
$$\Delta q_{xy}^{Tak} = \delta q \times Min\left(10{,}5 \times (D_x/D_0)^2 \times (V_y/V_0)\right)$$

The 26 Sept. 2012 Case
Electrical charges at 08:00

run from 20120926:00UTC «Arome» analysis



run from 20120925:18UTC «Arome» analysis



- **Bipolar** electrical structure on the vertical
- Rain is **positively** charged almost everywhere