Lightning Meteorology

Some examples of lightning related research in atmospheric science by the Italian community

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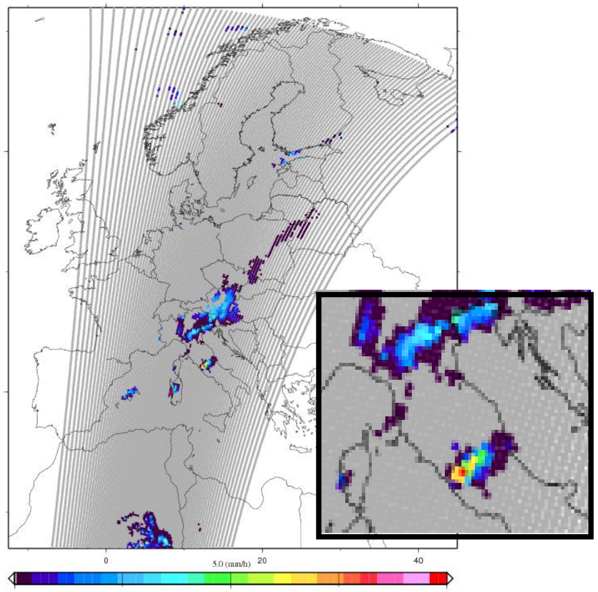
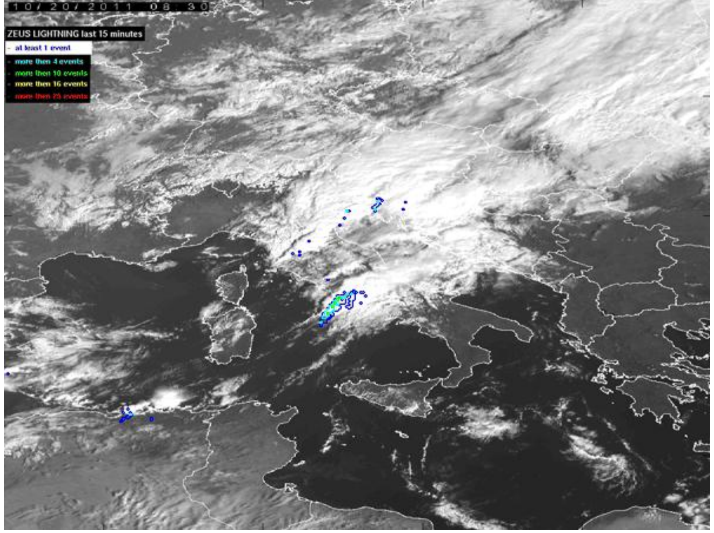
OUTLINE

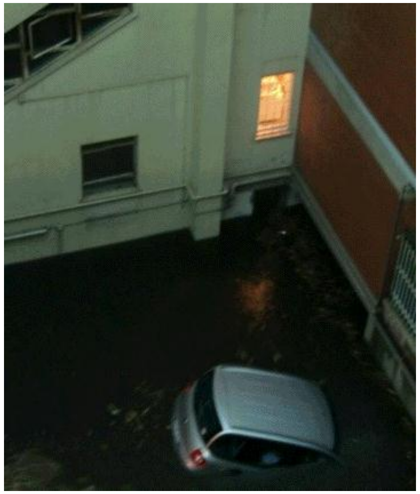
- Instantaneous precipitation retrieval from passive sensors (SEVIRI IR, SSMIS, AMSU)
- Precipitation nowcasting (SSMIS, AMSU)
- Multisensor study of cloud electrical properties
- Cloud electrification modeling:
  - 1D Explicit Microphysics Thunderstorm Model
  - Calabria Regional Atmospheric Modeling System
- Transient Luminous Event observation and effects on NOx production

Roma, 20 October 2011

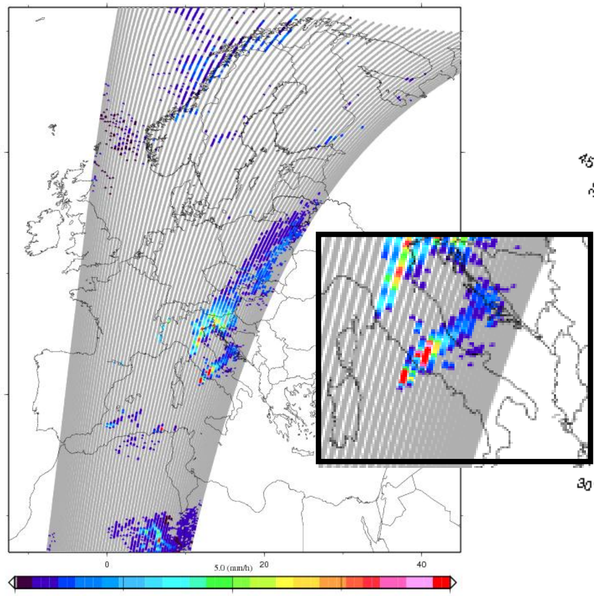
EUMETSAT H-SAF PR-OBS-2 Instantaneous Rain Rate from Crosstrack MW Scan



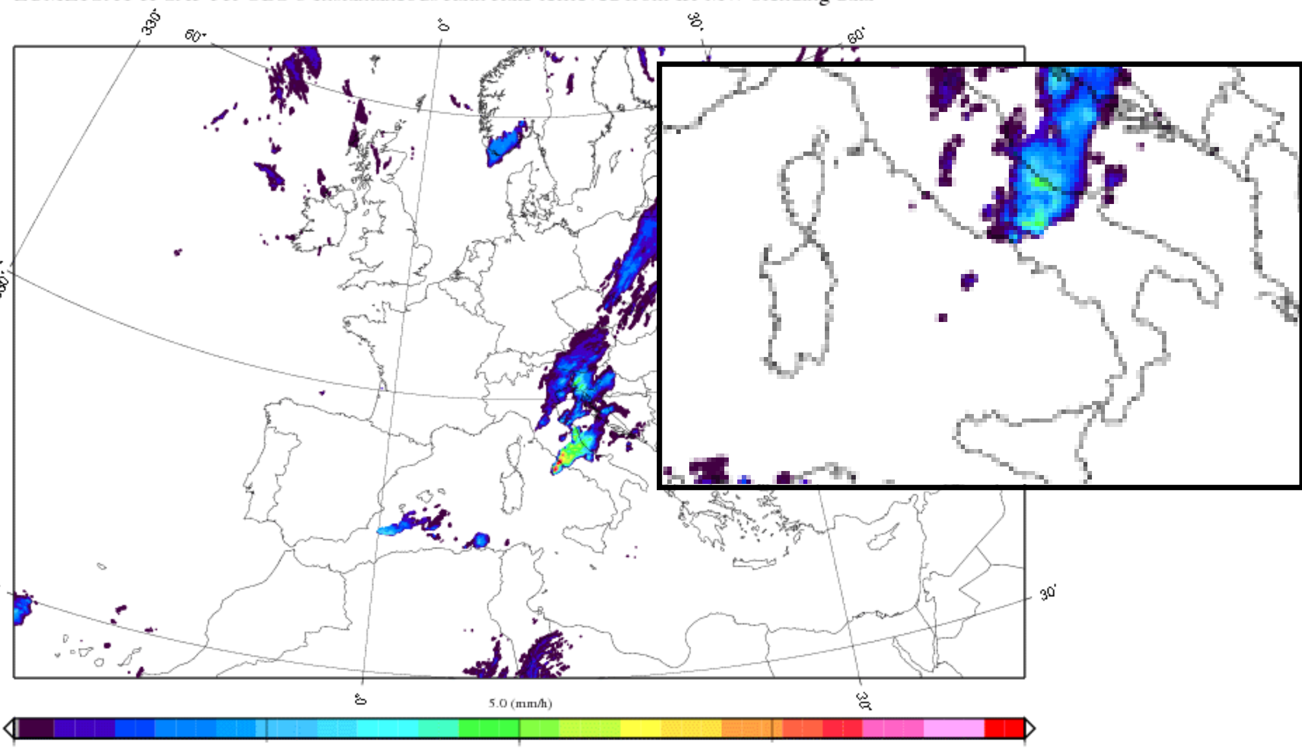




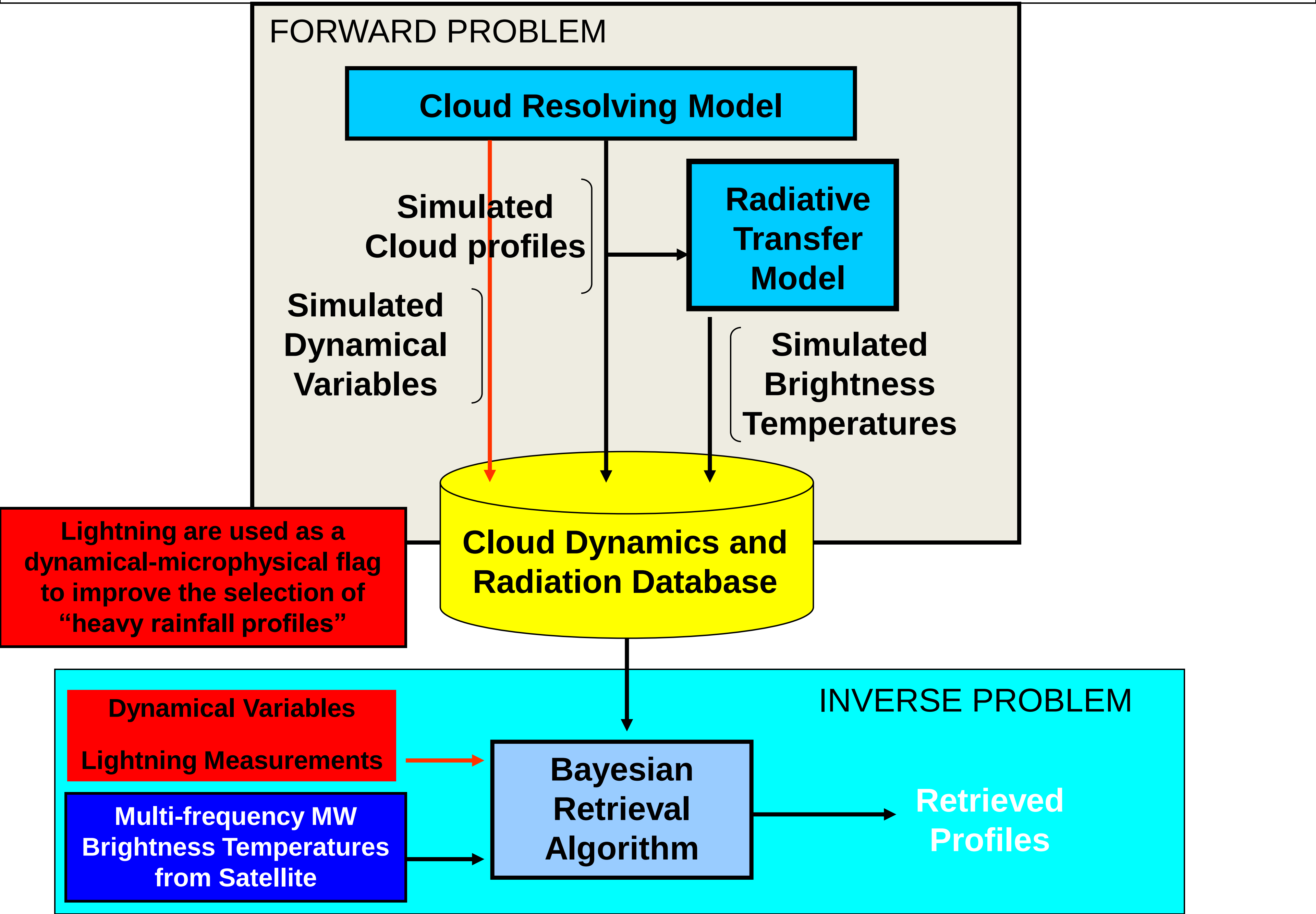
EUMETSAT H-SAF PR-OBS-1 Instantaneous Rain Rate from Conical MW Scan



EUMETSAT H-SAF PR-OBS-3 Instantaneous Rain Rate retrieved from IR-MW blending data



Cloud Dynamics & Radiation Database (CDRD) Algorithm



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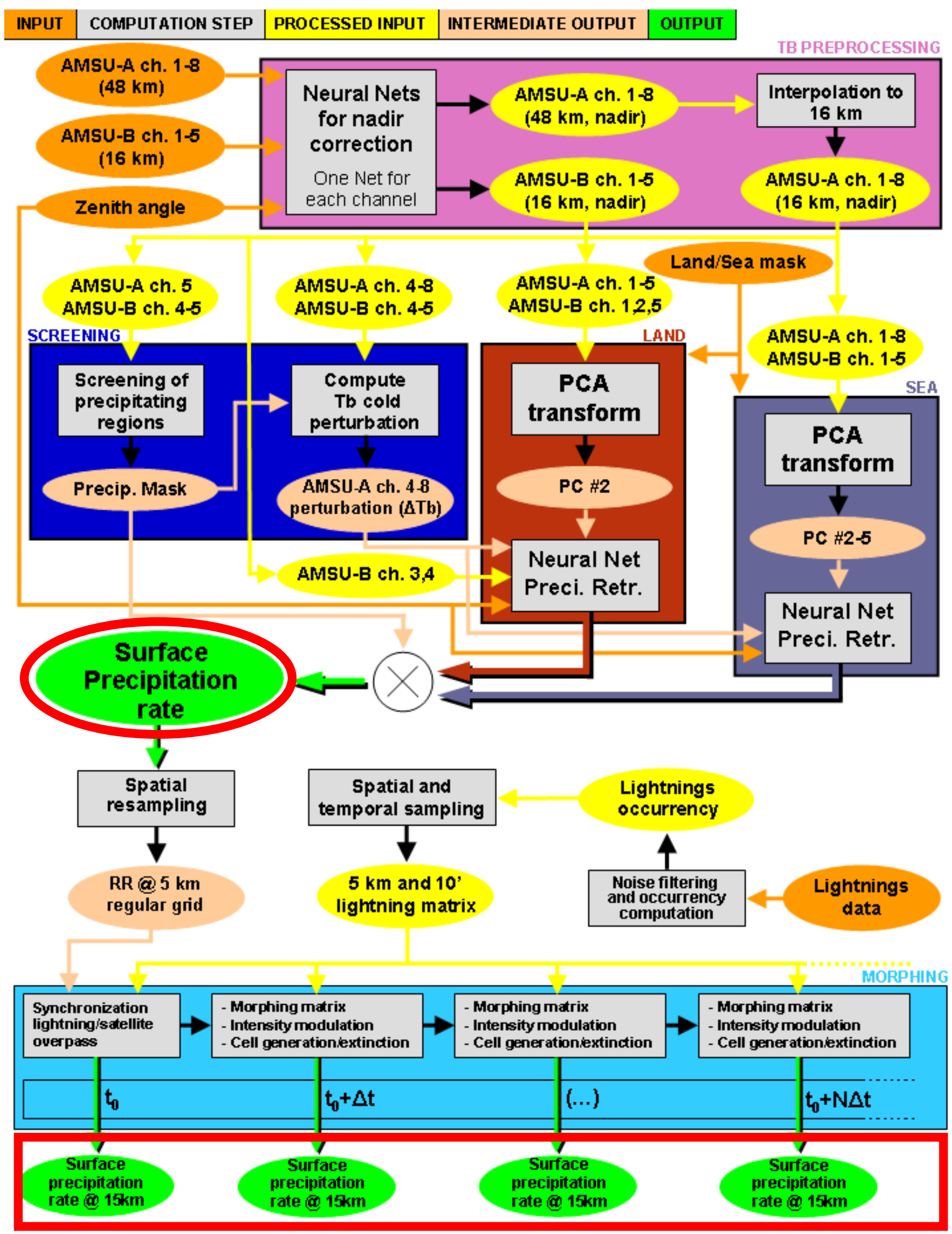
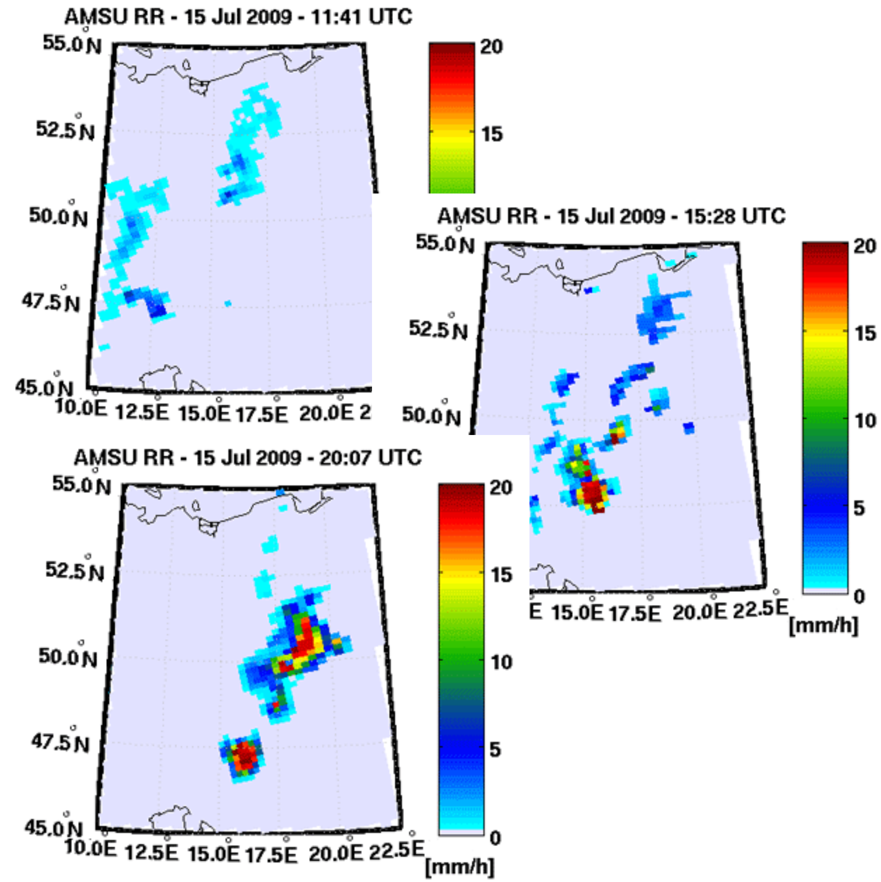
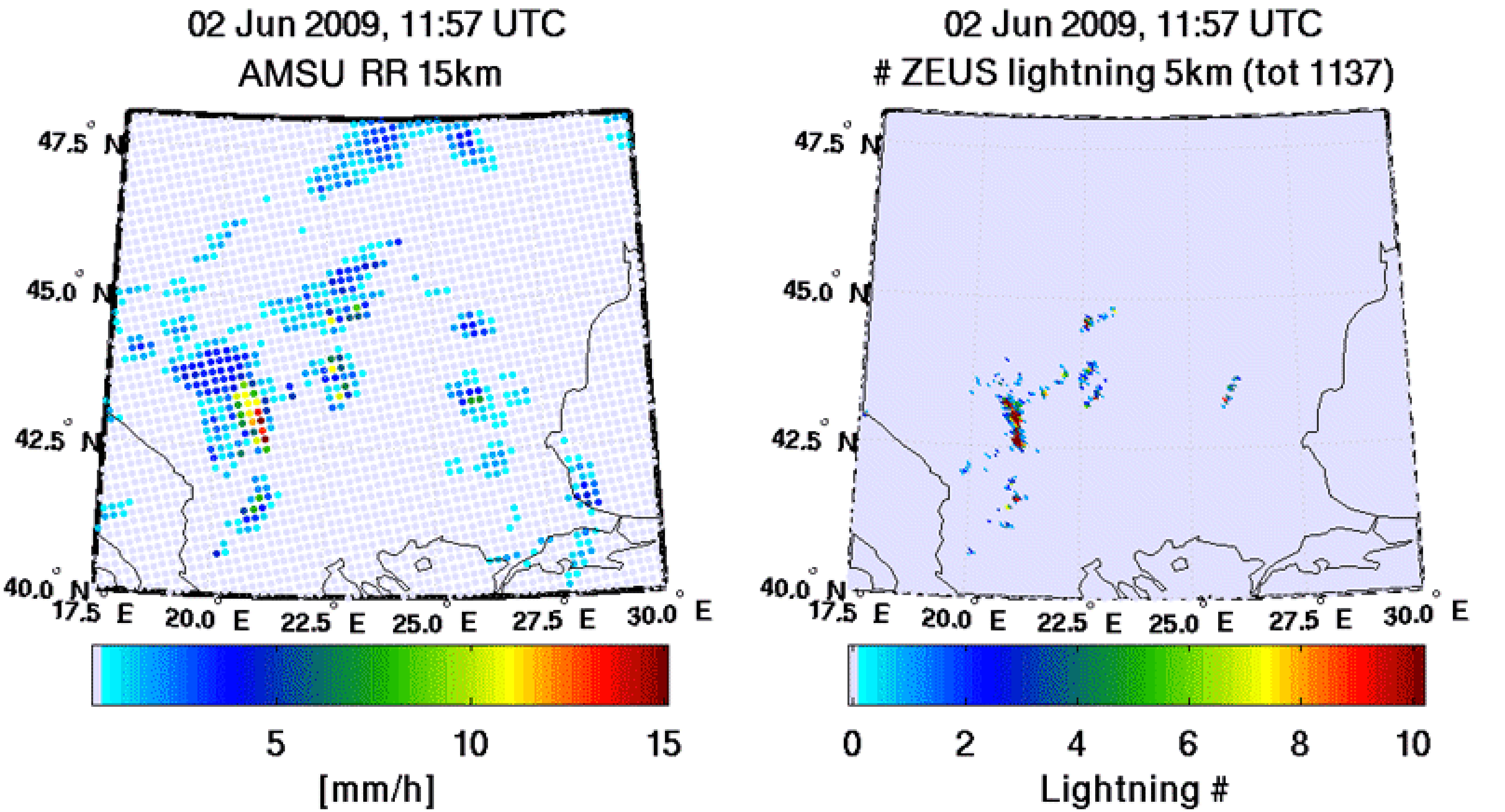
Microwave-lightning cooperation for precipitation nowcasting





Near real time precipitation

Case study – Balkans, 22-06-2009



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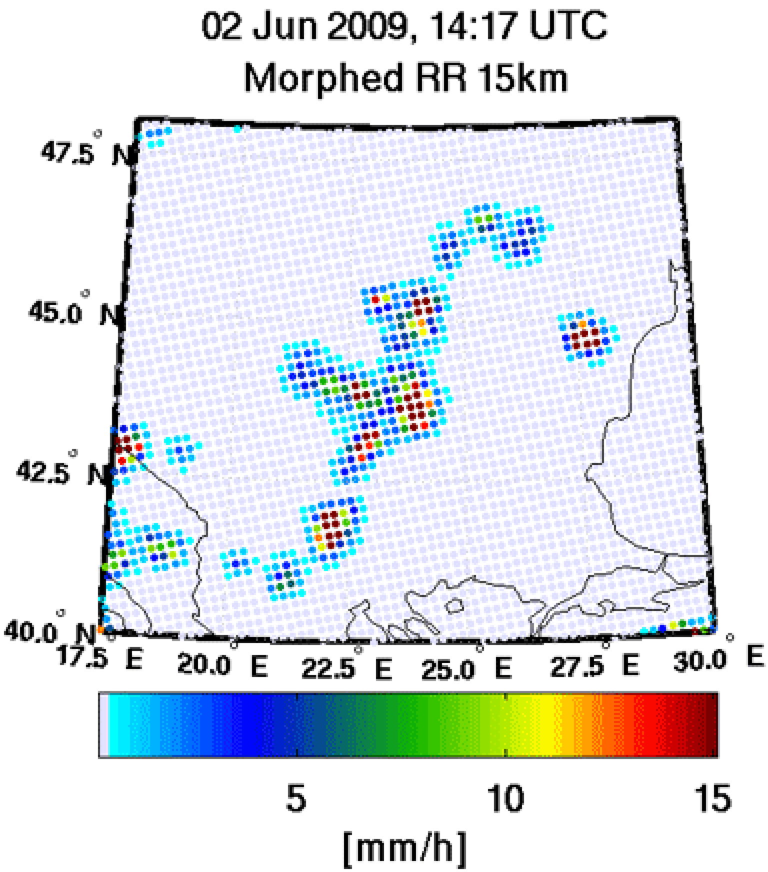
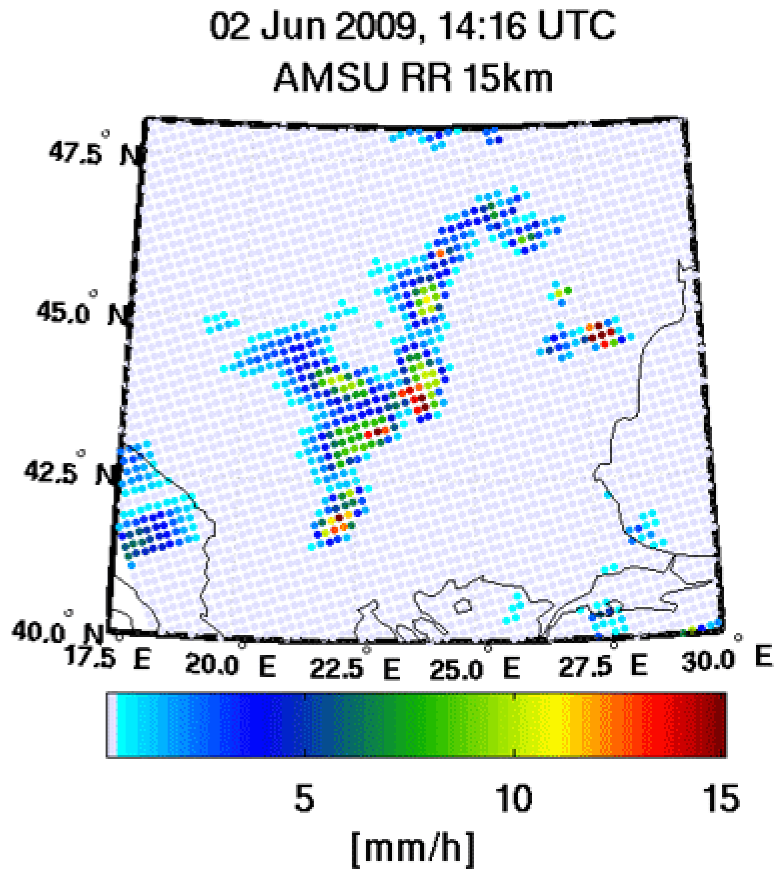
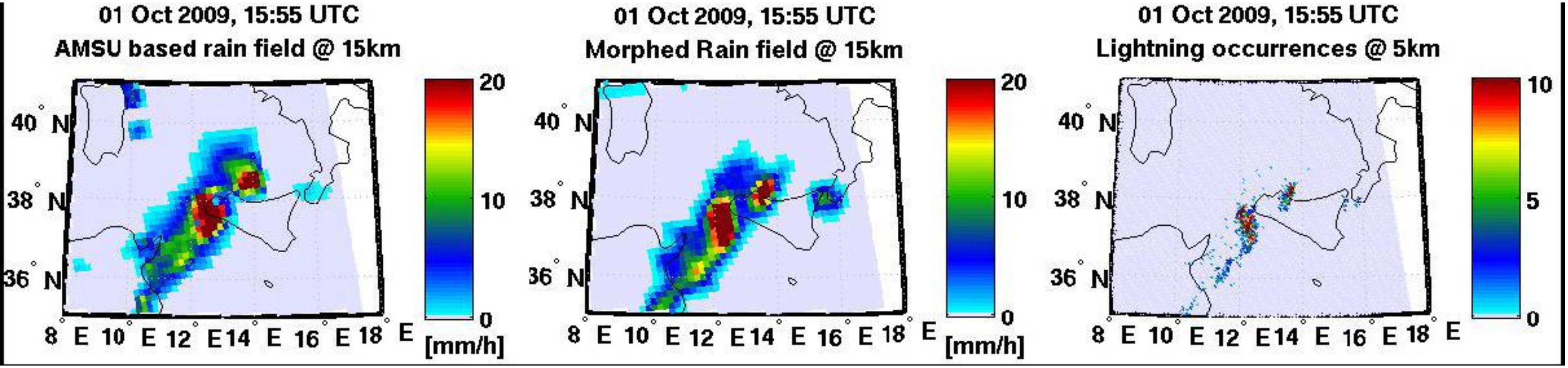




Microwave-lightning cooperation for precipitation nowcasting



MW-retrieved rainfall fields (left panel) and morphed rainfall fields (middle panel) at 15:55 UTC over southern Italy region on October 1, 2009. The morphed rainfall fields are computed using the MW-retrieved rainfall fields at 13:00 UTC in conjunction with lightning data from 13:00 UTC to 15:55 UTC. As a reference, simultaneous lightning occurrences at 15:55 UTC are also shown (right panel) *(from Dietrich et al., 2011).*

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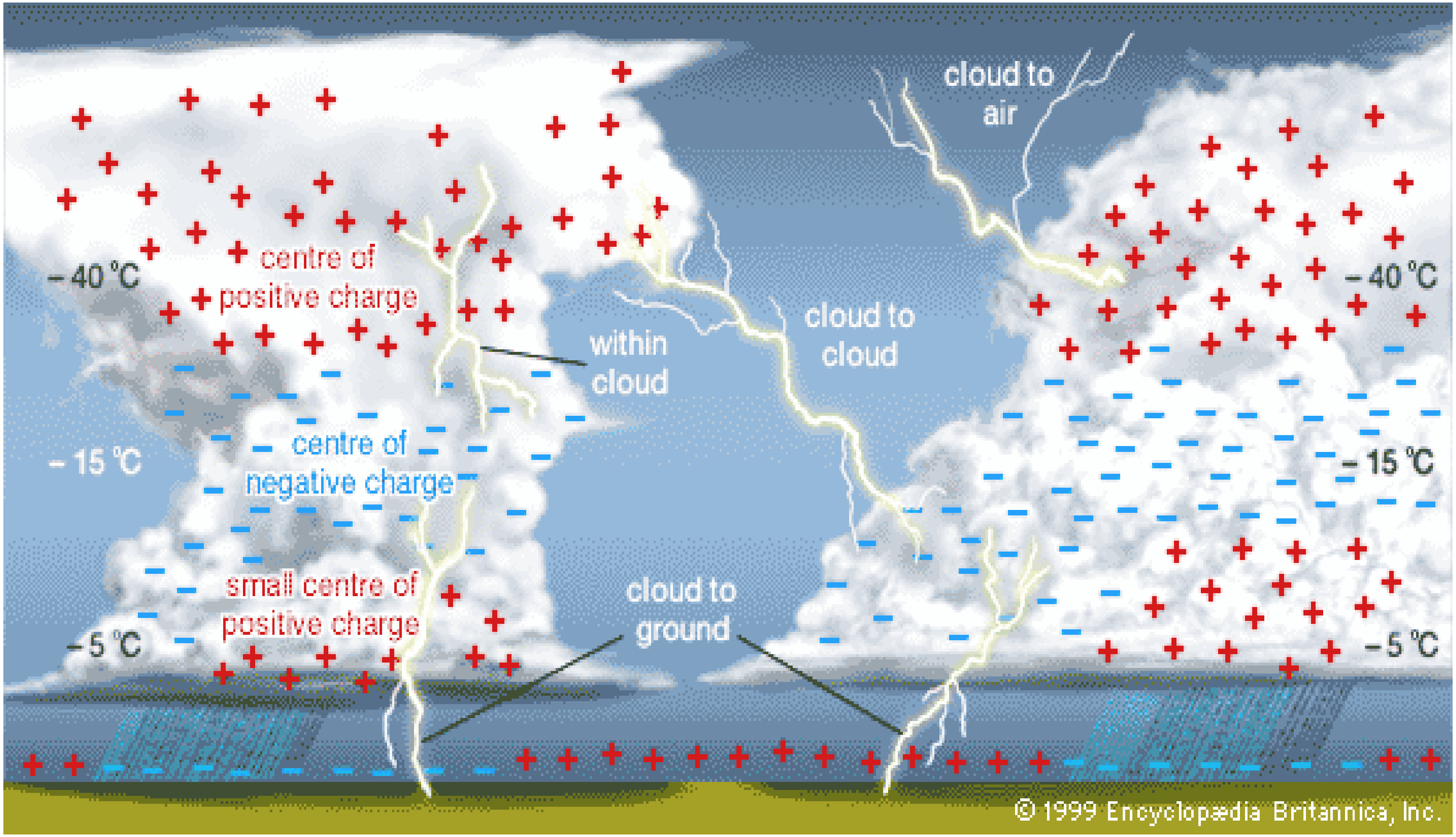
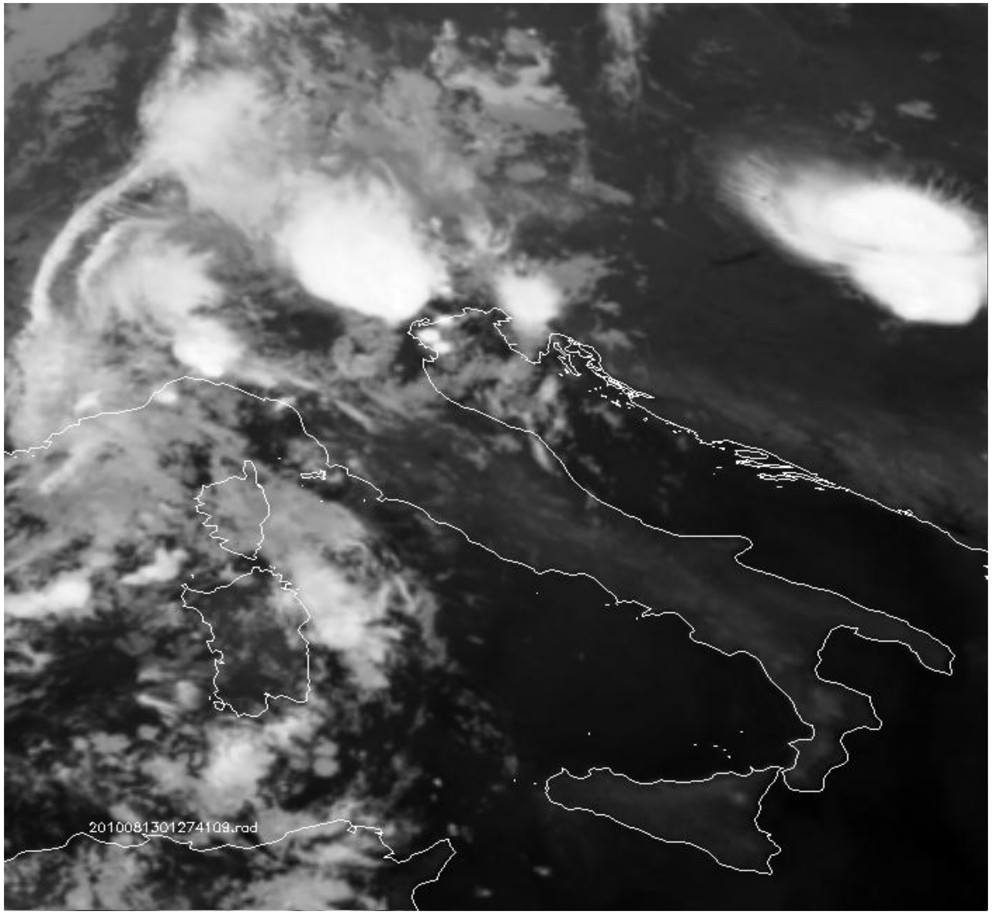
Investigating 3D cloud structure



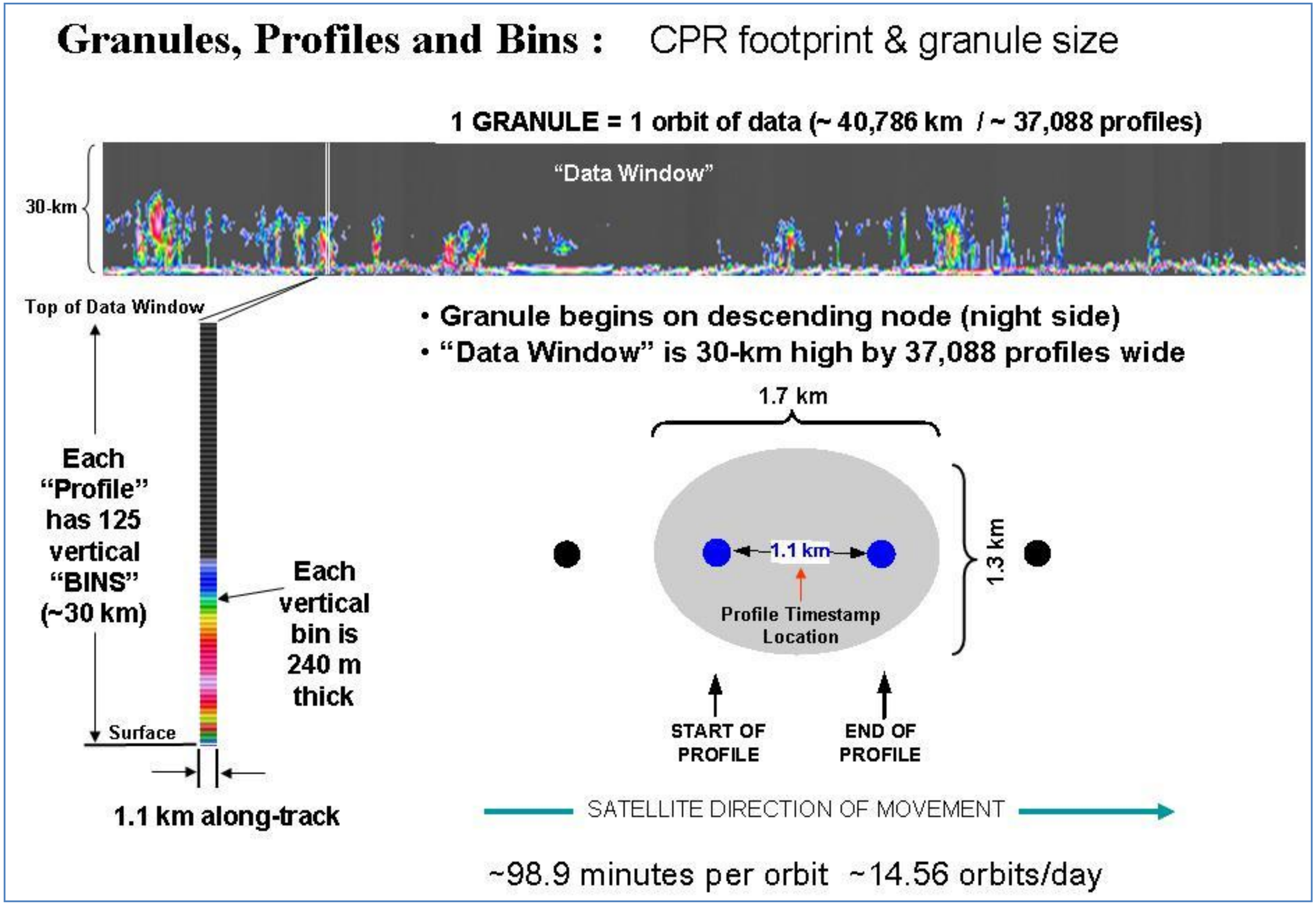
Padova event, 13/08/2010

M. Buiat, F. Porcù, University of Ferrara



SEVIRI, channel 9	λ= 10,8 μm (IR)

CLOUDSAT: Characteristics of CPR data (94 GHz)



Cloud profile data:

- **reflectivity**
- **IWC**
- **LWC**
- **effective radius**

Padova event, 13/08/2010, 01:29 coincidence with CLOUDSAT overpass

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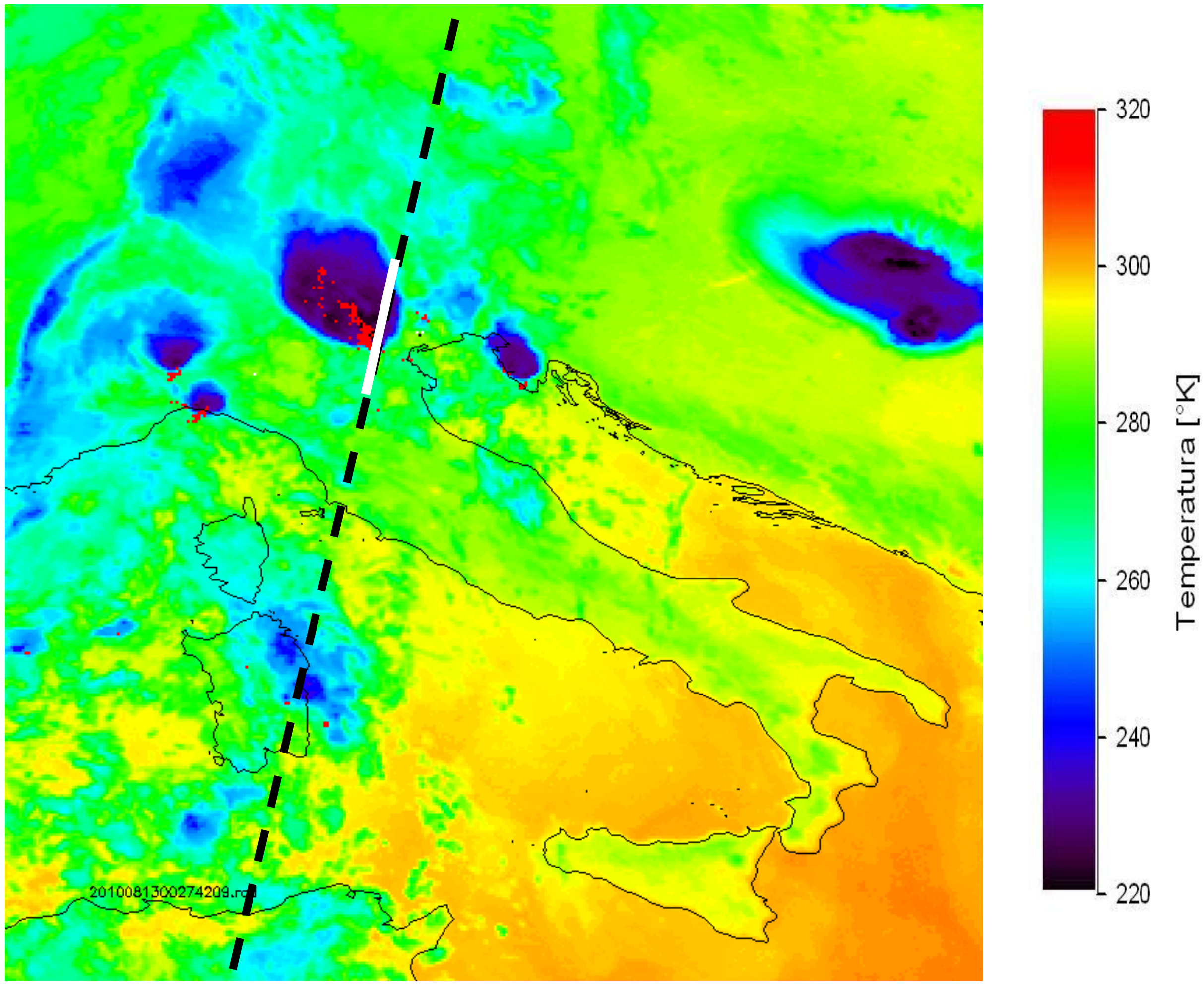

+ lightning: 10 minutes (01:25 – 01:35)

Padova event, 13/08/2010, 01:29

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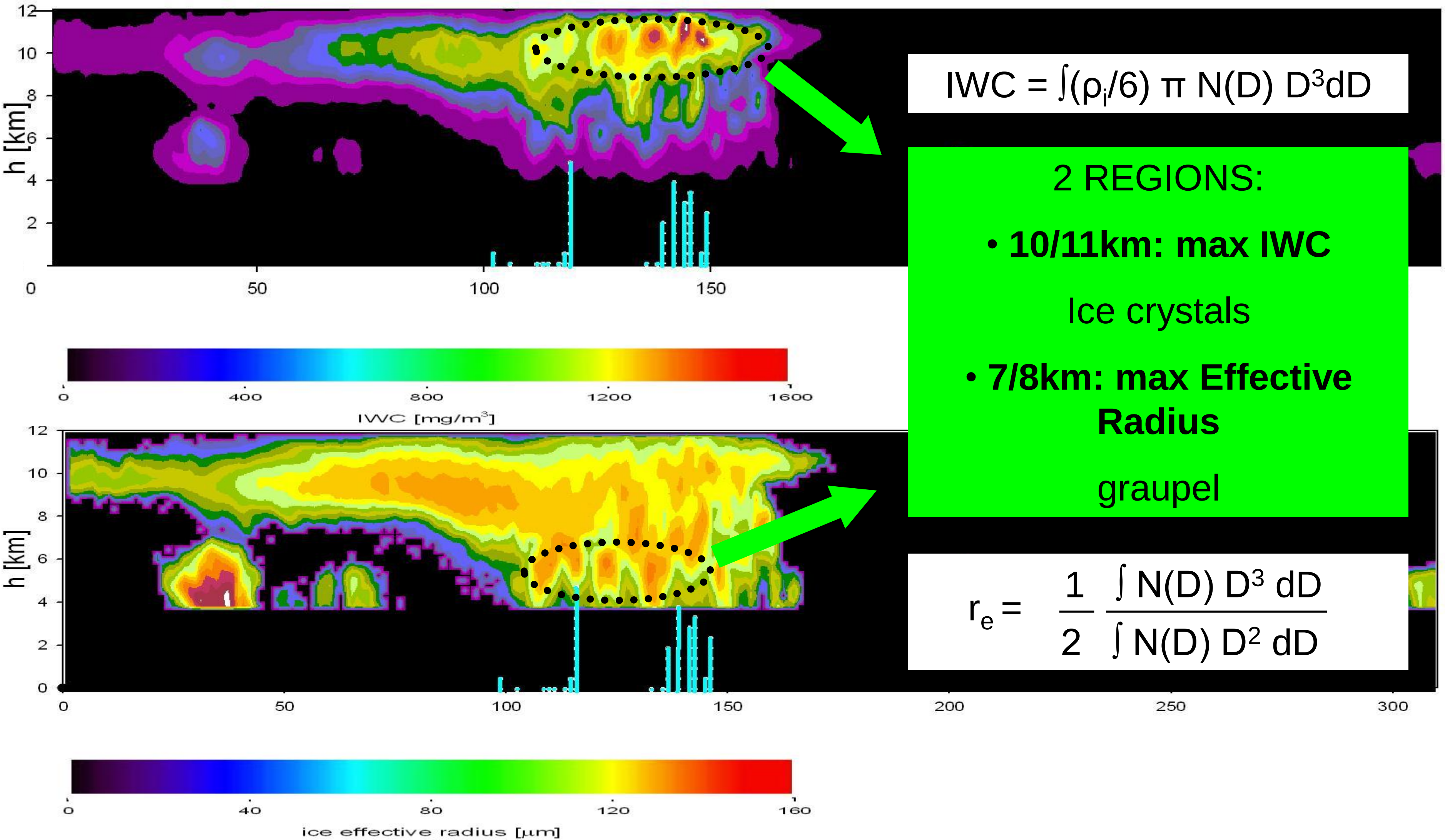

$$IWC = \int (\rho_i/6)\, \pi\, N(D)\, D^3 dD$$

2 REGIONS:

- **10/11km: max IWC**

Ice crystals

- **7/8km: max Effective Radius**

graupel

$$r_e = \frac{1}{2} \frac{\int N(D)\, D^3\, dD}{\int N(D)\, D^2\, dD}$$

Profiles of IWC and Effective Radius

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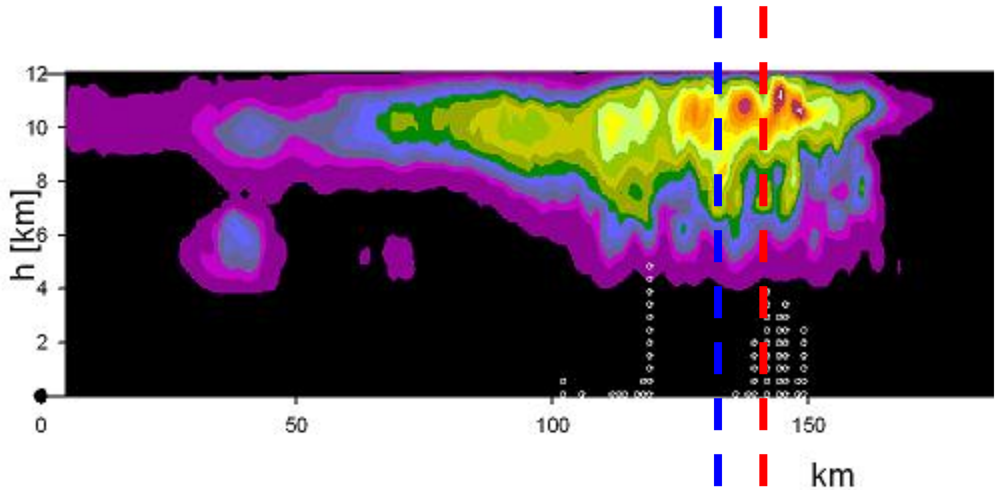

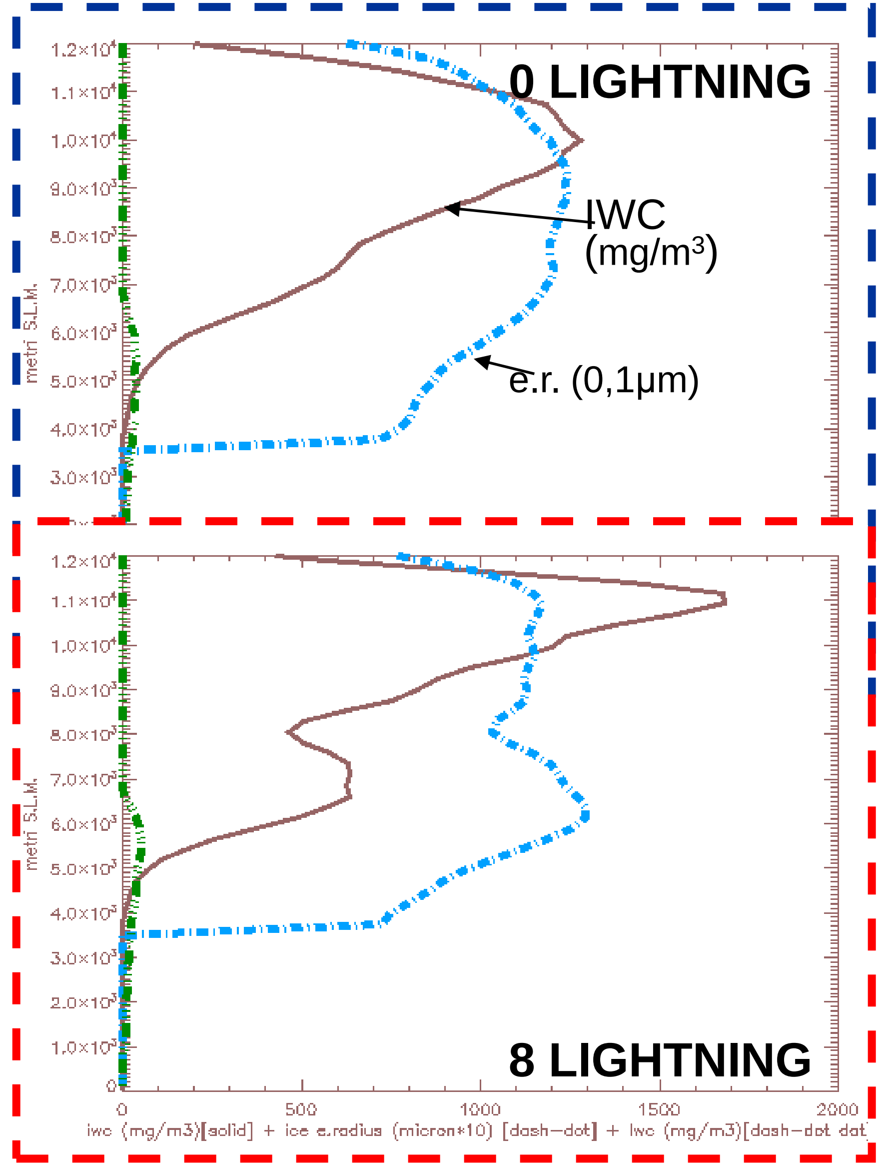

# flash	IWC_{max} (mg/m³)	$e.r._{max}$ (µm)
0	1270	120
8	1700	135

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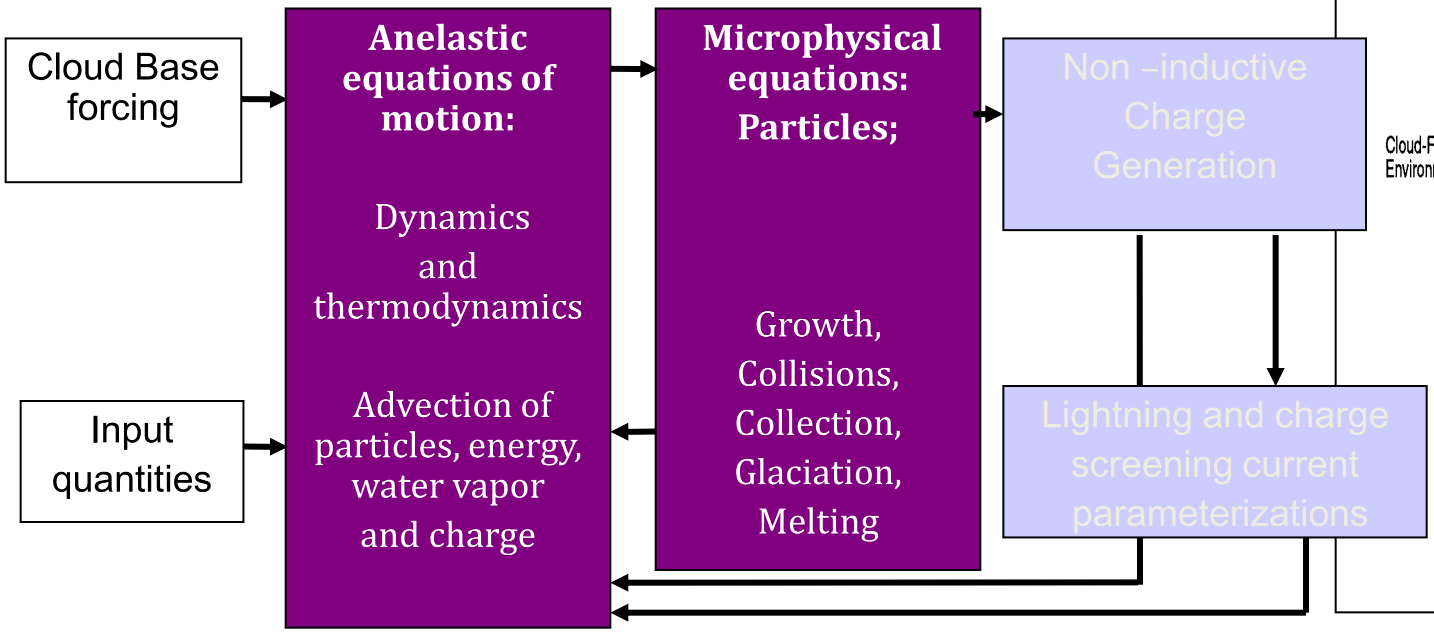
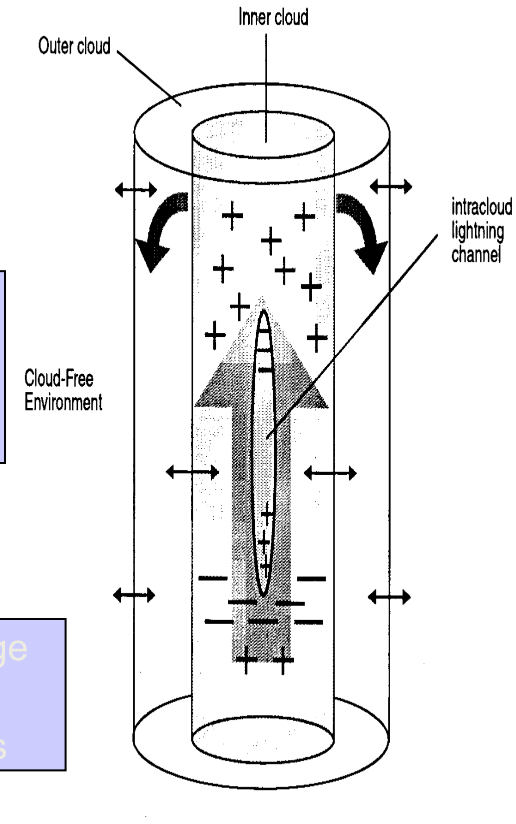
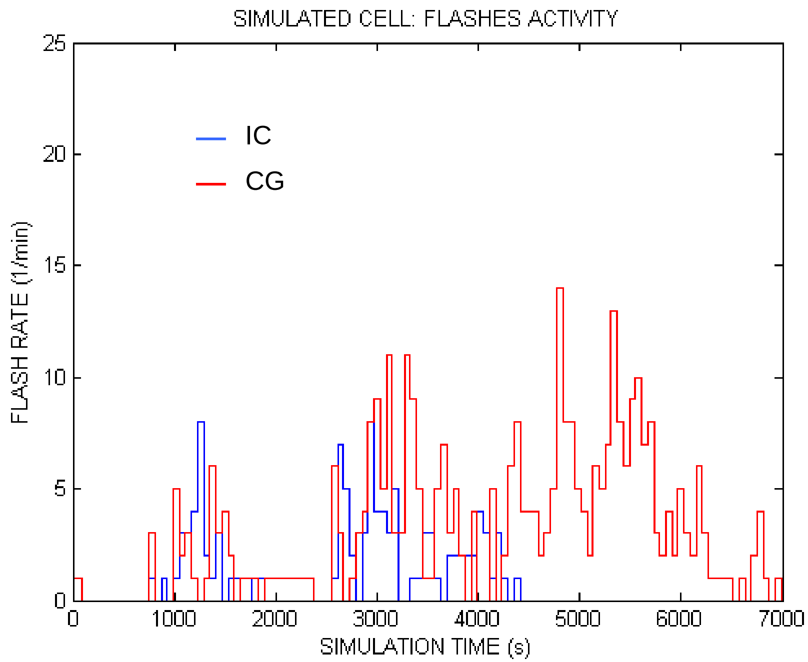
Lightning modeling:
Explicit Microphysics Thunderstorm Model (EMTM)

The model (Solomon and Baker, 1996, 1998, Solomon et al., 2004) consists of 2 cylindrical regions and includes dynamics, entrainment, explicit microphysics, electrification and a lightning parameterization.

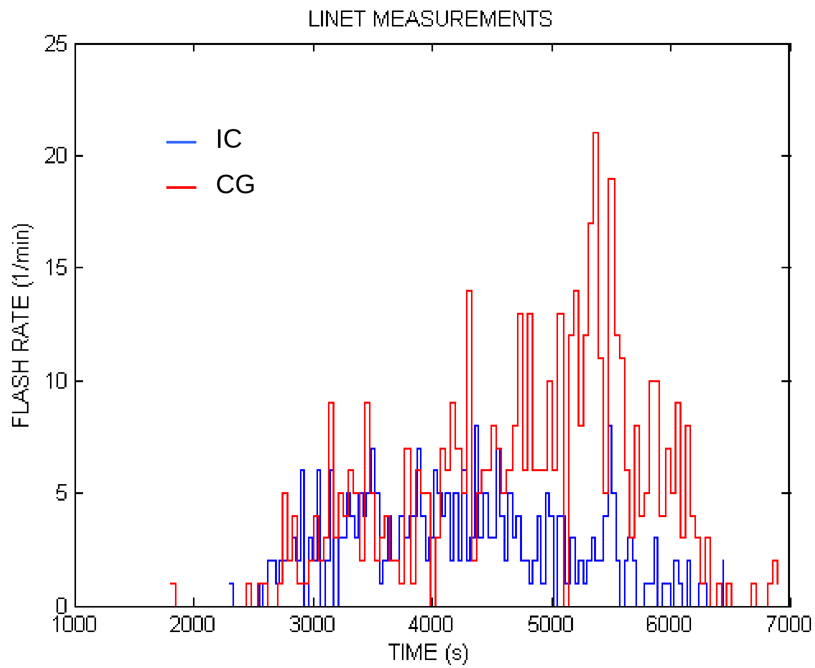




Cell over Rome - 2 July 2009
model results - measurements comparison



Histogram of lightning simulated by the EMTM model. There are IC and CG first, as the cloud develops the CG lightning become predominant.



Histogram of lightning activity of the selected cell measured by LINET network. Also here is well shown the different behaviour of IC and CG as the cell develops.

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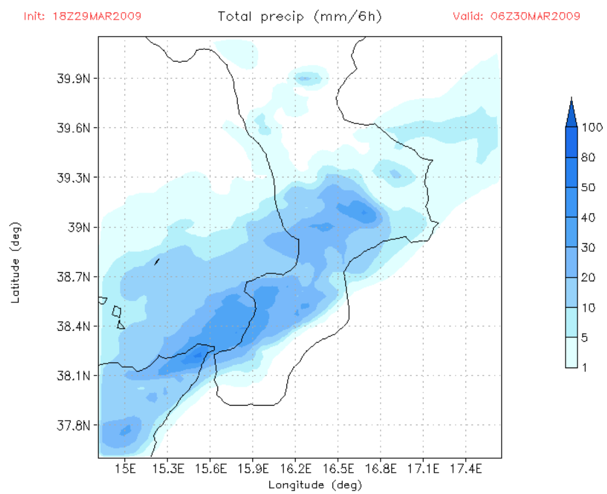
CRAMS MODEL

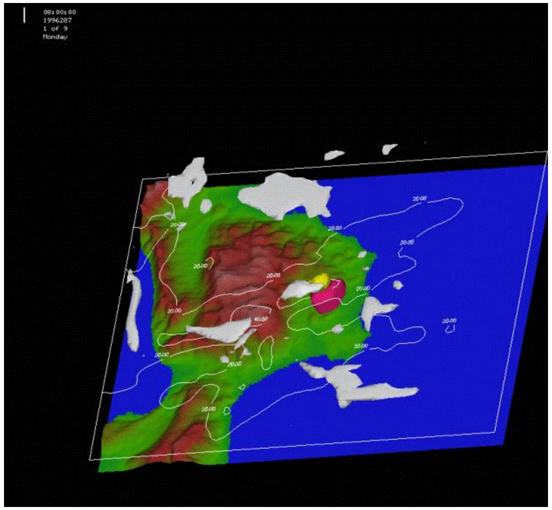
- The model CRAMS (Calabria Regional Atmospheric Modeling System) is a non-hydrostatic model derived from the RAMS model. It can be used both for research and operational purposes in regions with complex orography.

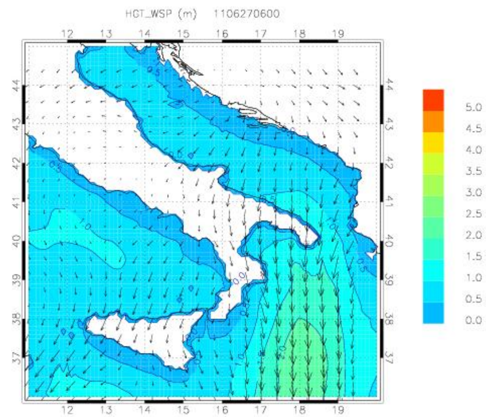
- CRAMS is used to make the weather forecast over Calabria at 2.5 km horizontal resolution. This weather forecast is used by the "Centro Funzionale della Regione Calabria" to issue the forecast over the Region.

- CRAMS is coupled with a general purpose data assimilation system, which can solve the analysis with different methods (2D-Var, 3D-Var, Optimal Interpolation).

- The output of CRAMS is used to initialize wave models and agro-meteorological models.







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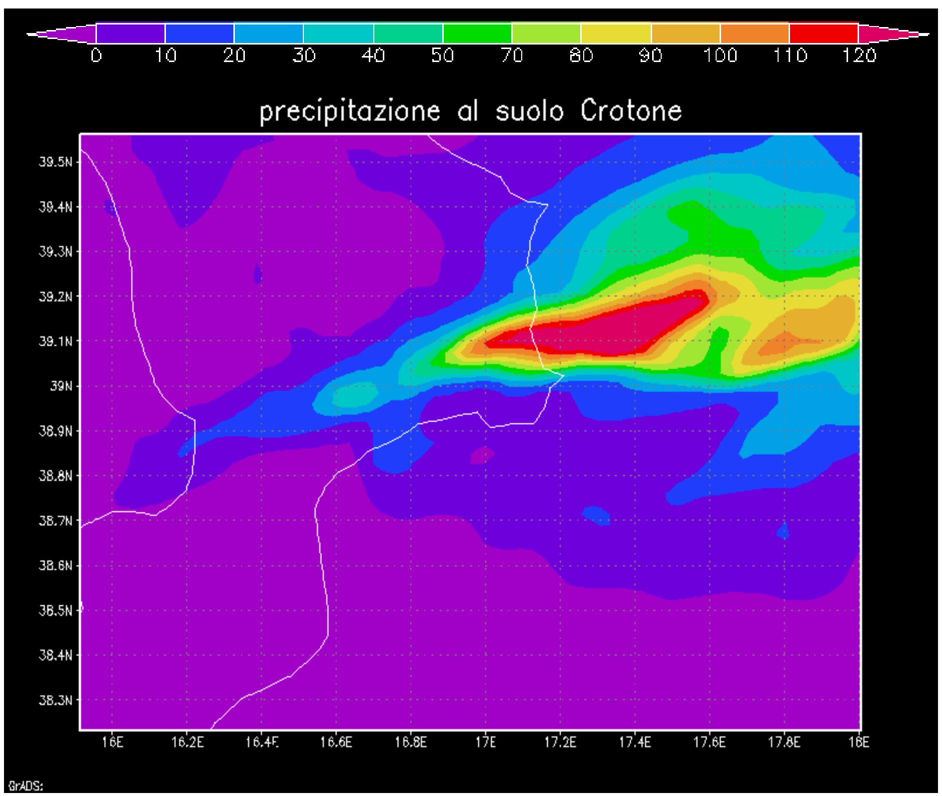
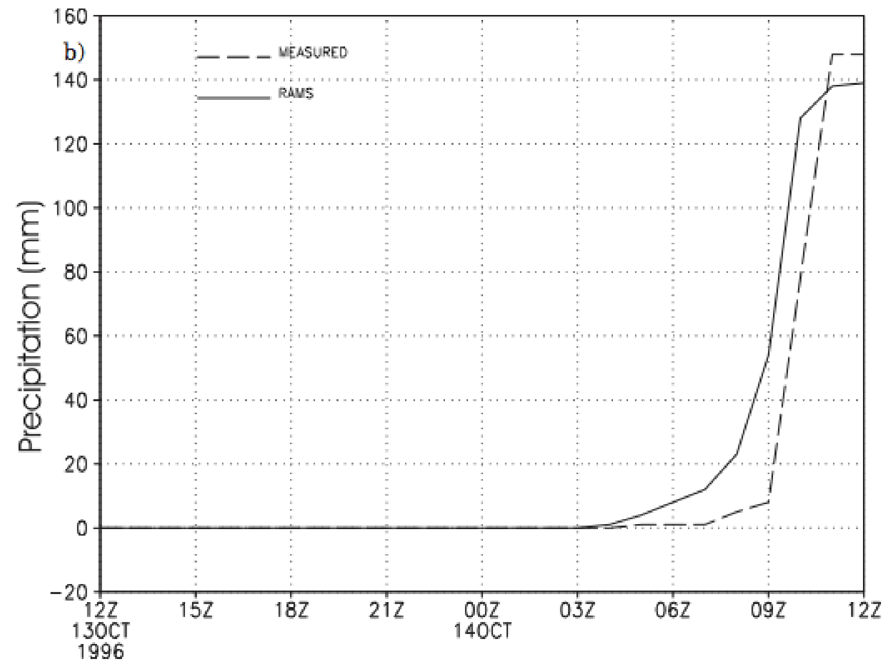
DEEP CONVECTION STUDIES

-CRAMS has been used to study the deep convection, mainly over Calabria.
-The Calabria region is an interesting test-site: the presence of the sea-land contrast and of elevated mountains near the coast are key ingredients for flood and flash-flood occurrence, as in the case of the Crotone flash-flood on 14 October 1996.

Precipitation (mm) simulated between 00 and 12 UTC on 14 October 1996



Comparison between the rainfall simulated by CRAMS and measured at Crotone Airport on 14 October 1996



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LIGHTNING MODELING

The Dahl et al. (2011)* methodology has been implemented in the CRAMS

-**The idea underlying the parameterizations is that the graupel region contains the negative charge and the ice region contains the positive charge. The charging rate *j* increases with the graupel mass, and the discharge strength *ΔQ* increases as the charge volume increases.**

-**The "graupel region" is defined as the region above the 263 K isotherm where the mass of graupel is greater or equal to 0.1 g/m^3.**

-**The "ice region" is defined as the region where the sum of cloud ice and snow is at least 0.1 g/m^3.**

-**The flash rate (s^{-1}) is given by:**

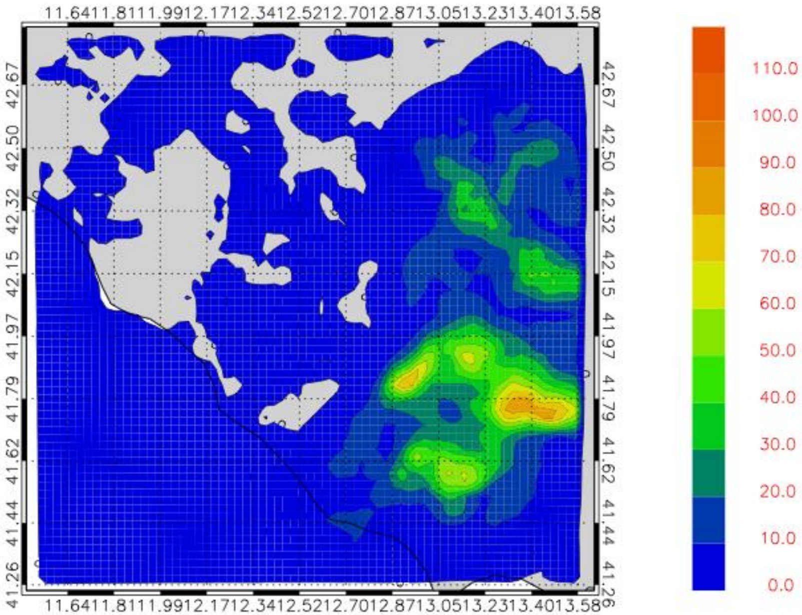
$$f = \gamma j \frac{A}{\Delta Q}$$

where $\gamma=0.9$ is the lightning efficiency, *j* is the charging current density (A/m^2), A (m^2) is the area of the capacitor plates, ad *ΔQ* (C) is the lightning charge.

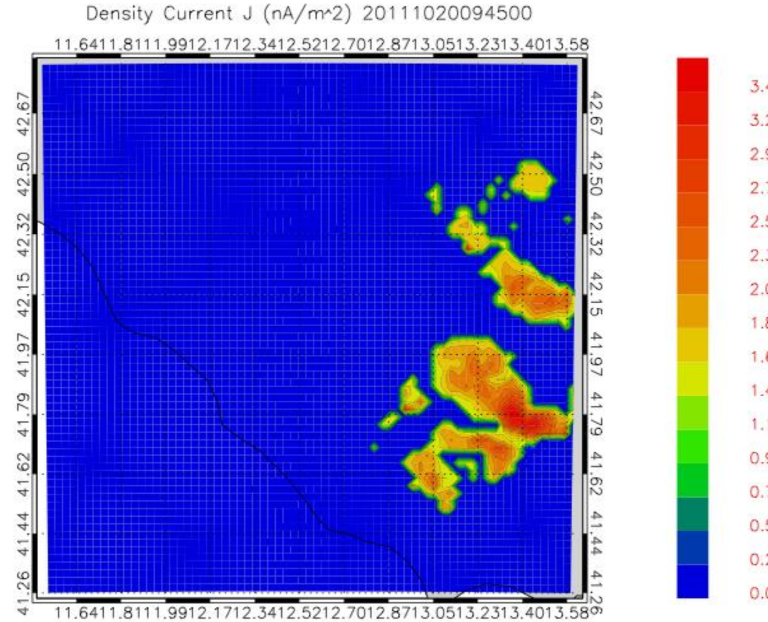
* *Dahl et al. (2011): Monthly Weather Review Vol. 139, 3112-3124*

The 20 October 2011 test case occurred in Rome

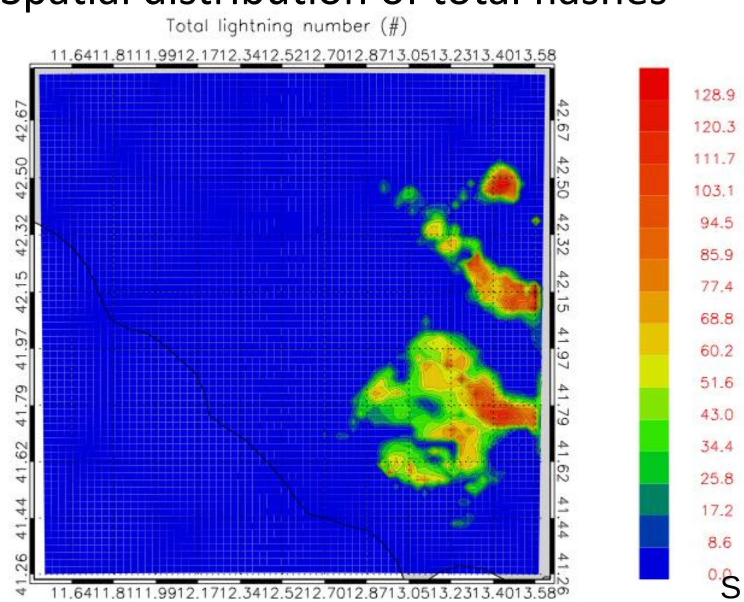
Total precip (mm) between 06 and 12UTC



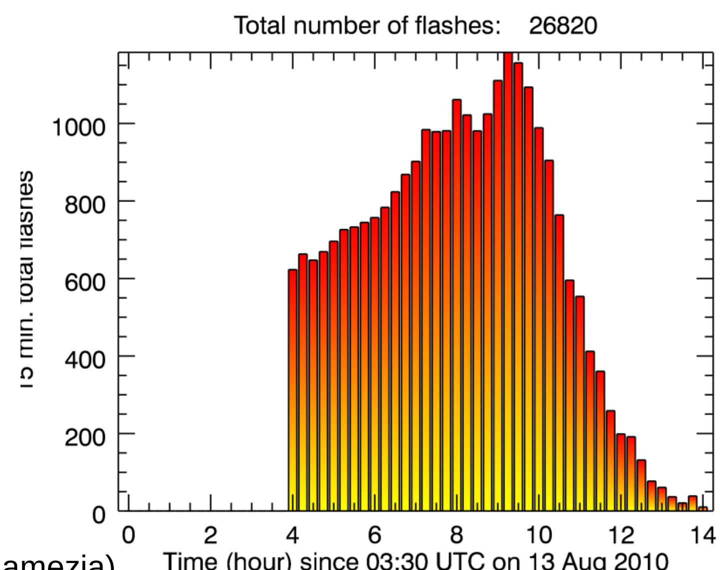
Density current at 09:45 UTC



Spatial distribution of total flashes



Accumulated flashes versus time



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Observation of chemistry of transient luminous events (TLEs)

Fig 1: a sprite observed above Lake Garda, Northern Italy

When thunderstorms occur in the troposphere, they change the atmospheric electric field above them. Every 1000 lightning flashes, this change is strong enough to trigger a spark at 70 km altitude. In a few milliseconds the spark grows into a sprite, a huge discharge tens of km tall and wide (see Fig. 1). Can sprites change atmospheric NOx? MIPAS was used to look at NOx at 50 km altitude above thunderstorms (Fig. 2) and compare it to background NOx. NOx above thunderstorms was found to be higher than background NOx (Fig. 3). Did MIPAS observe the first signs of sprite-NOx? Ongoing observations will try to prove it.

Arnone et al. 2008GRL, Arnone et al. 2009PSST

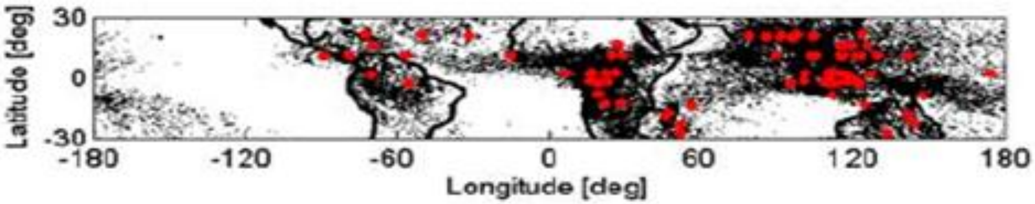


Fig 2: MIPAS observations in coincidence with thunderstorms (red dots)

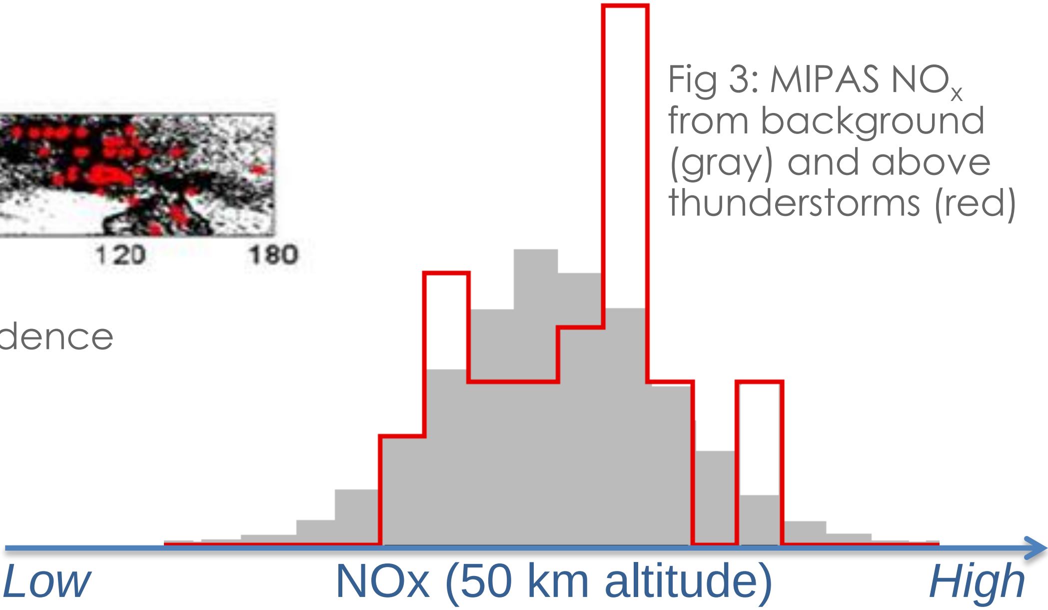


Fig 3: MIPAS NO_x from background (gray) and above thunderstorms (red)

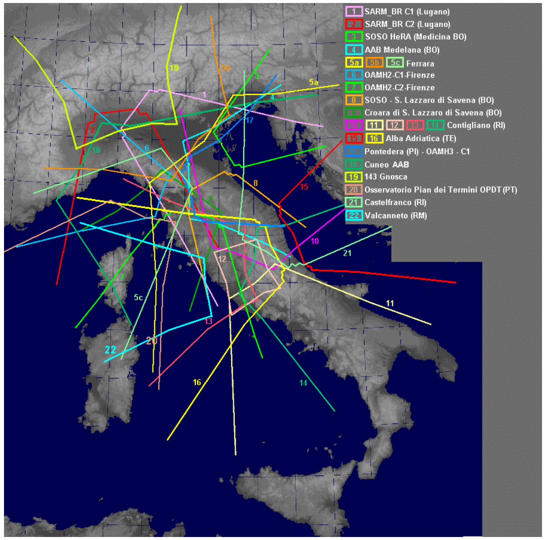
Observations of TLEs from Italy

Spritewatch experimental system at **Mount Cimone** Italian Climate Observatory
http://www.isac.cnr.it/cimone/node/131
In collaboration with the group of P. Bonasoni.

Remotely controlled linux-based acquisition system.

Italian Meteor and TLE Network: (http://www.imtn.it/)

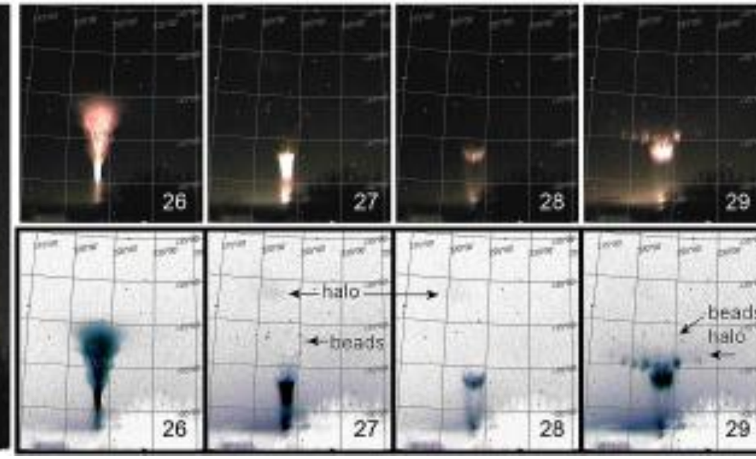
- 20 stations (over 30 cameras) based in Italy and Switzerland.
- Since January 2009 recorded over **950** TLEs: *sprites, elves, a gigantic jet* and various *upward lightning events.*

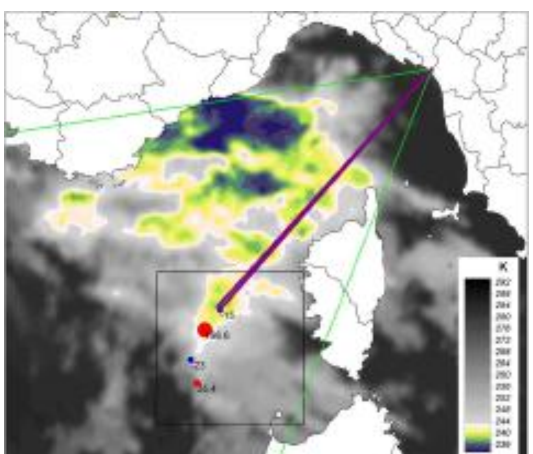


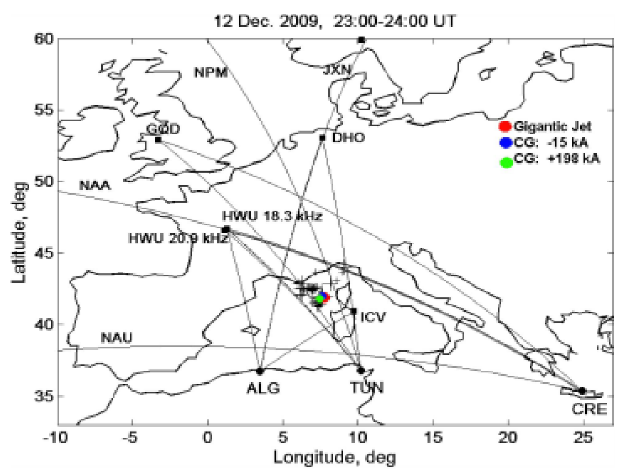
Study of TLEs observed from Italy

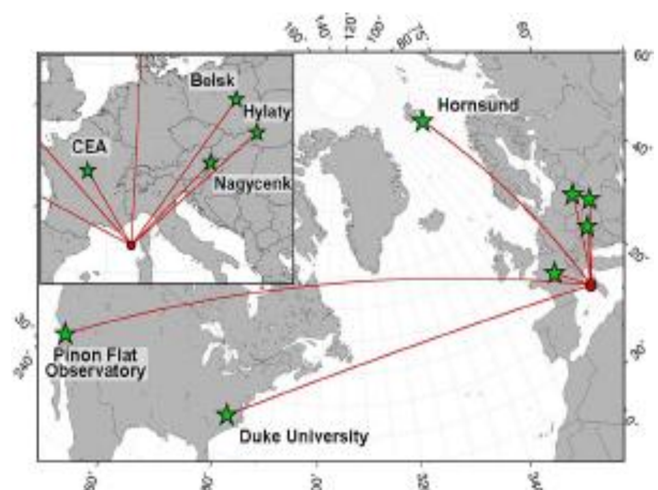
First European Gigantic Jet observed by the Italian IMTN amateur network on 12 Dec 2009 close to Corsica

Contribution to van der Velde et al.2010JGR and Neubert et al.2011JGR. Haldoupis et al.2012JGR in preparation.

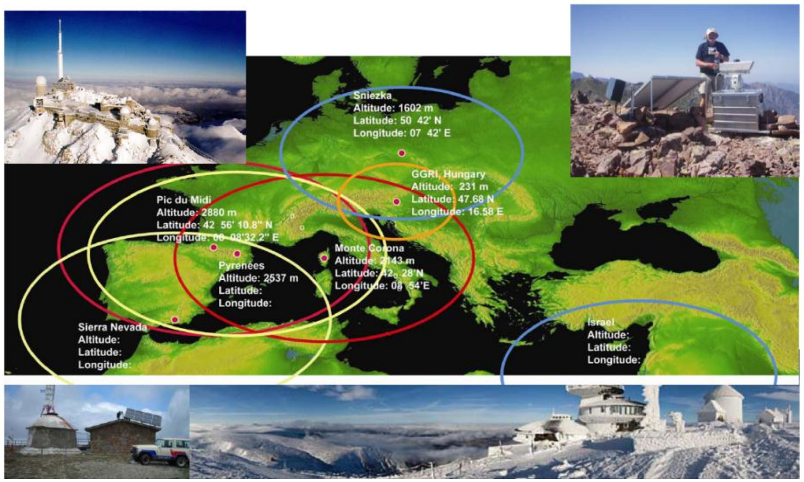


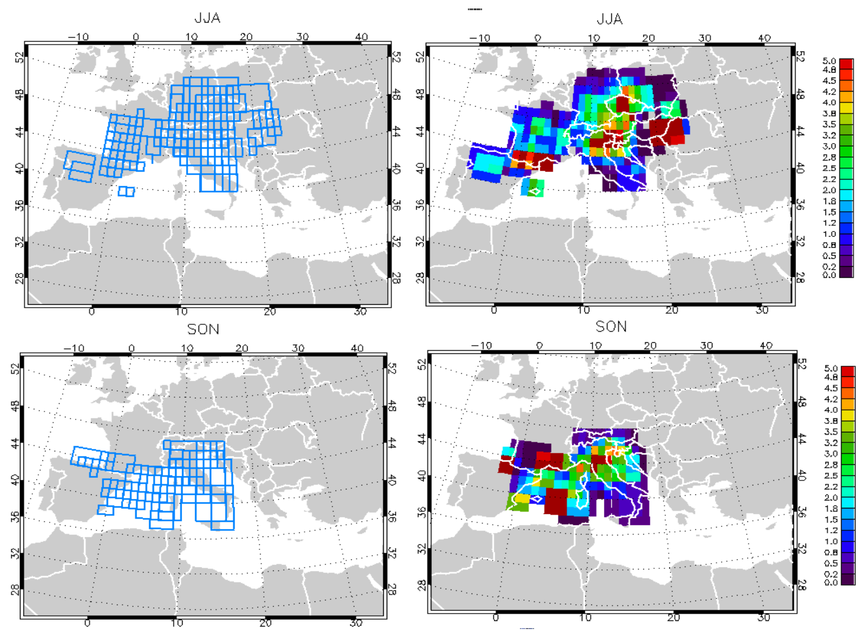






Coordination of Eurosprite observations of TLEs





TLE observations from Eurosprite partners are coordinated and catalogued into the **Eurosprite database** at ISAC-CNR Bologna (ref E. Arnone, see contributions at TEA-IS workshops). Contribution to Chanrion et al. 2007, Neubert et al. 2008, Arnone et al. 2008IRF.

First distribution and seasonal cycle of TLEs over Europe (Arnone et al. ACP2012 in preparation).

Participation in **ESA-ASIM** scientific team and **TEA-IS network**.

Some Considerations

There is a growing interest in the Italian community in cloud electrification and its applications to atmospheric science

All shown researches make use of LINET data (see Betz presentation) and will benefit from the ongoing increment of the number of LINET sensors

Further improvements are expected in lightning monitoring from space: Geostationary Lightning Mapper on GOES-R and Lightning Imager on Meteosat Third Generation (see Biron presentation)

Apart LIS-TRMM for tropical regions, presently there is a lack of lightning observation at mid-latitude from LEO satellites, ISS and airplane.

Space missions like AETHER (see following sessions and round table) are important also in this perspective