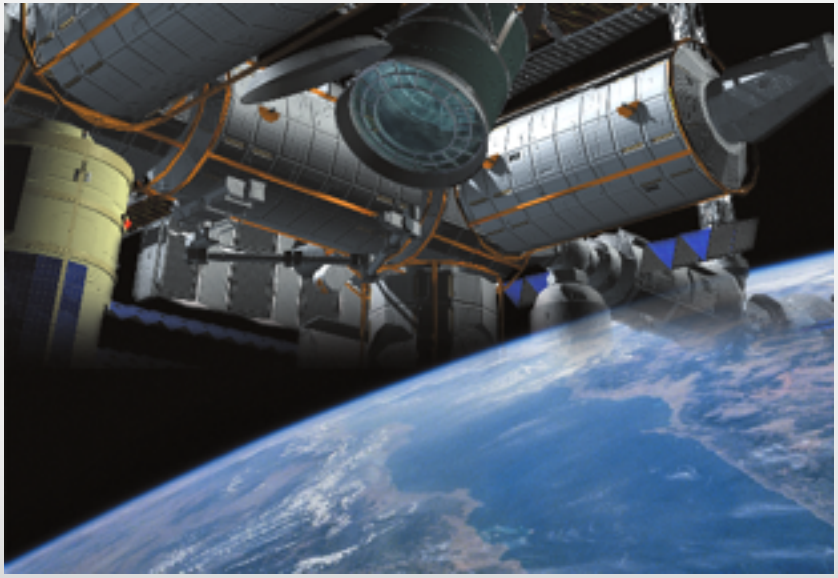
Impact of lightning on JEM-EUSO, and correlation between lightning and cloud-top altitude



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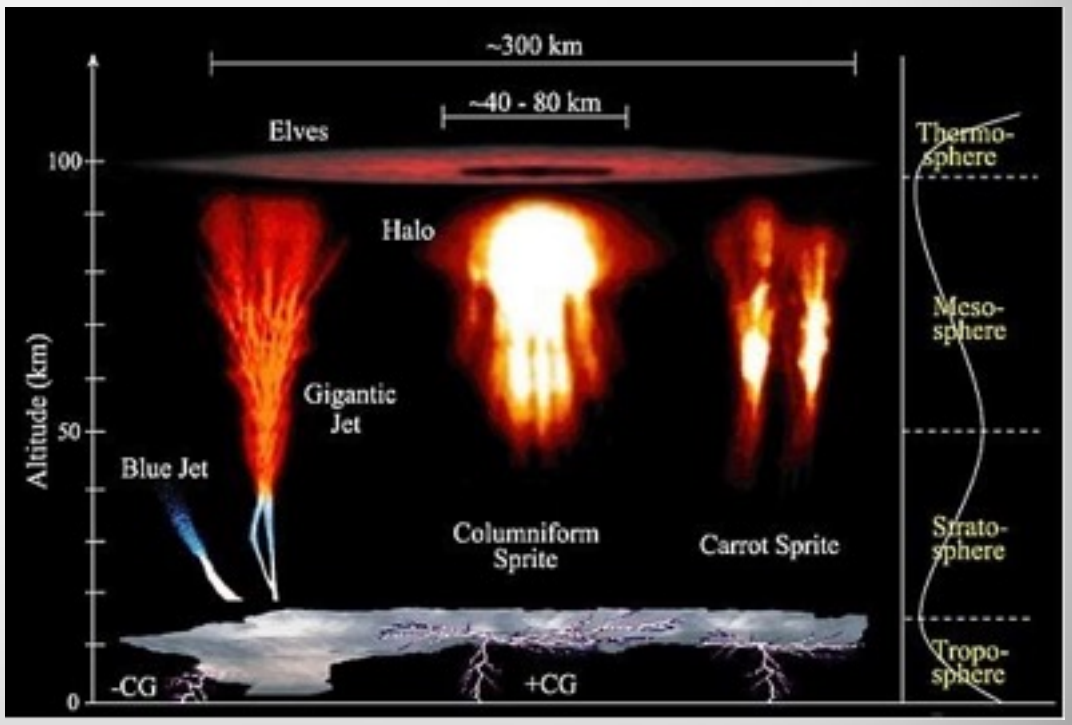
Summary

- Problem statement
- Methodology
- Study area
- Lightning results
- Cloud results
- Conclusions



Problem statement

JEM-EUSO sensor detects Extensive Air Shower (EAS) on the International Space Station (ISS) at the altitude of approximately 400 km.

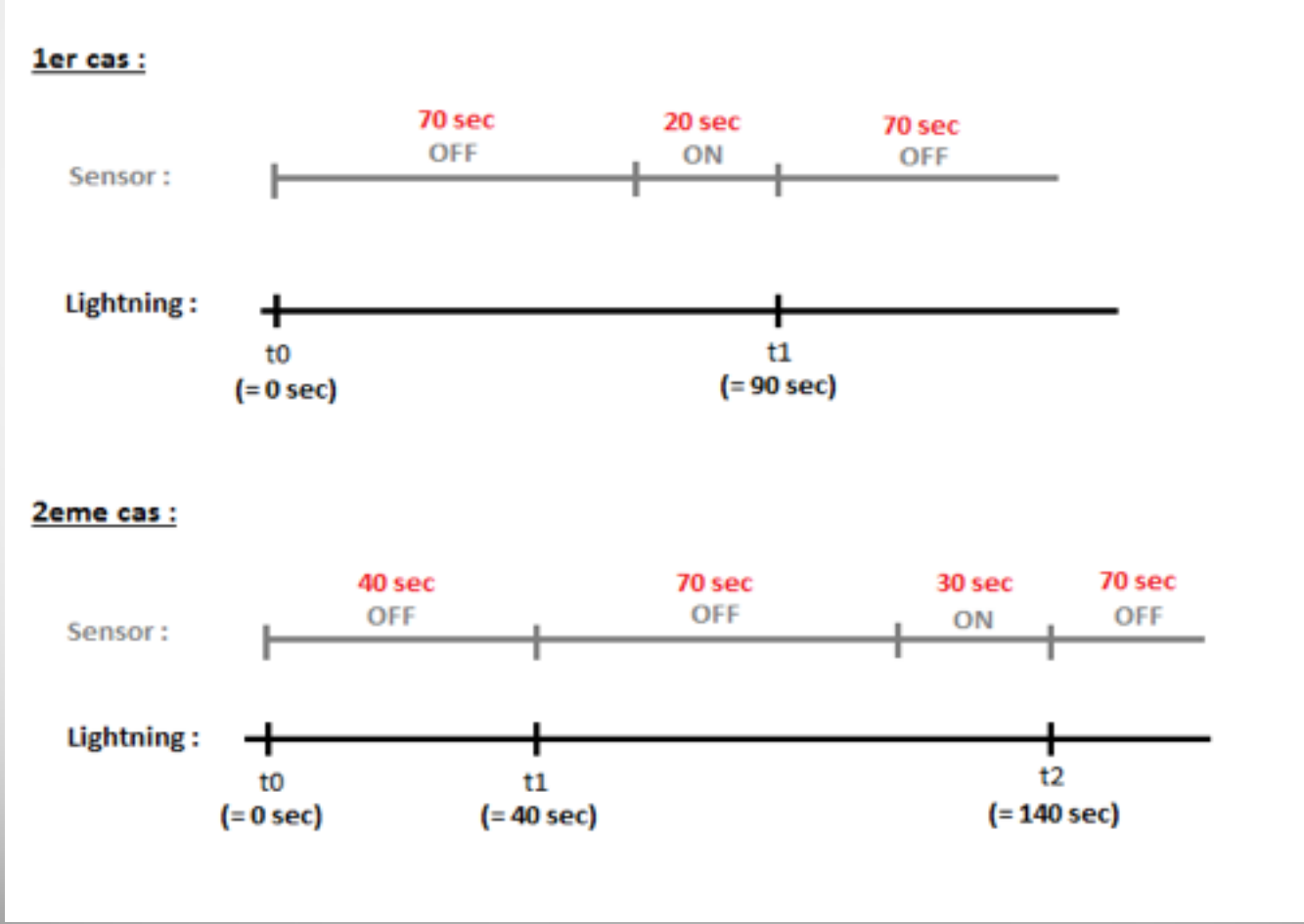
The sensor is a super wide-field telescope that detects extreme energy particles with energy above $3x10^{19}$ eV.

The lightnings are too bright for the JEM-EUSO sensor.

When a lightning is detected
the sensor is switched off for 70 sec.

JEM-EUSO duty

Both cases presented by our sensor :



Methodology

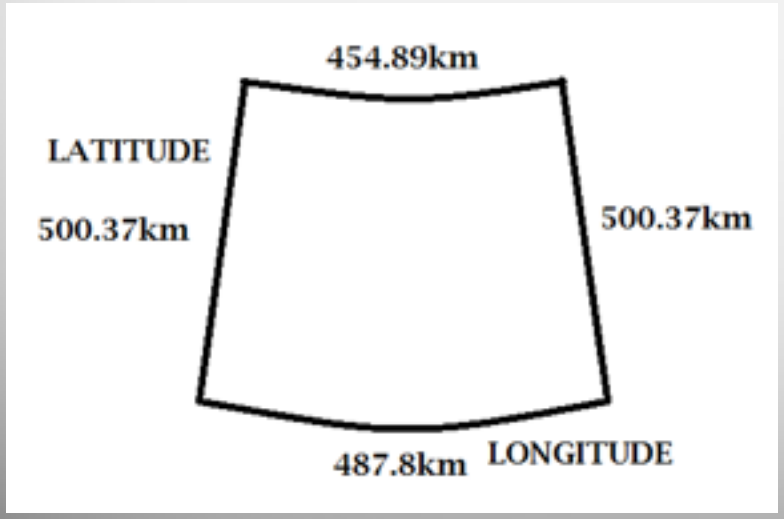
Data is retrieved from Sistema Italiano Rilevamento Fulmini (SIRF) broadband electromagnetic antennas with GPS. They detect the electromagnetic field emitted by lightning cloud-to-ground (about 10% of all lightnings).

Analysis has been perfomed using the R software and the QGis software.

Quality check : days with less than 6 signals, have been ignored.

Study Area

The study area is comprise between 43N and 47.5N, and between 5E and 11E.



The extension in kilometers.

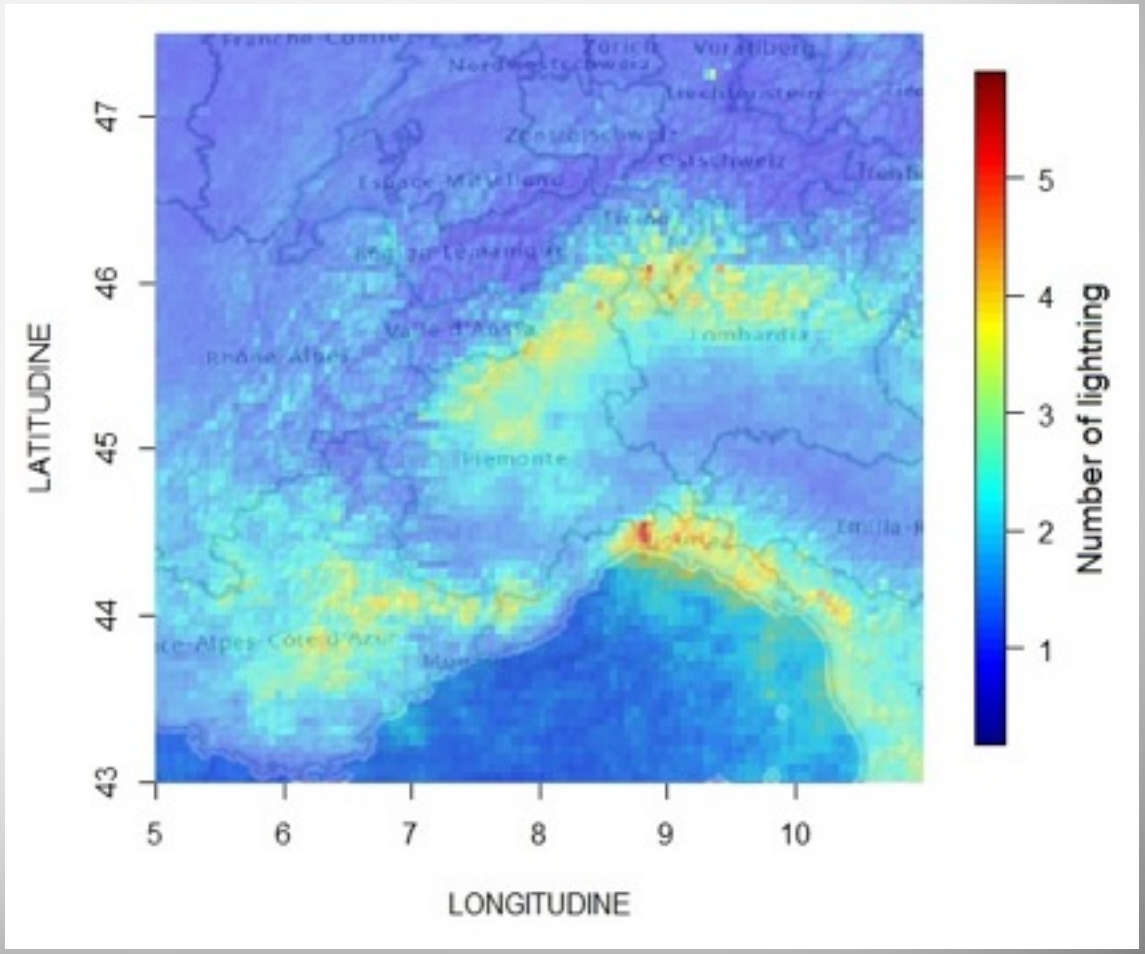
It is roughly the same area as that of the sensor JEM-EUSO.

Lightnings results

Lightning results – Annual average distribution

Number of the Cloud-to-Ground (CG) lightnings per km²/ per year (2001 - 2012).

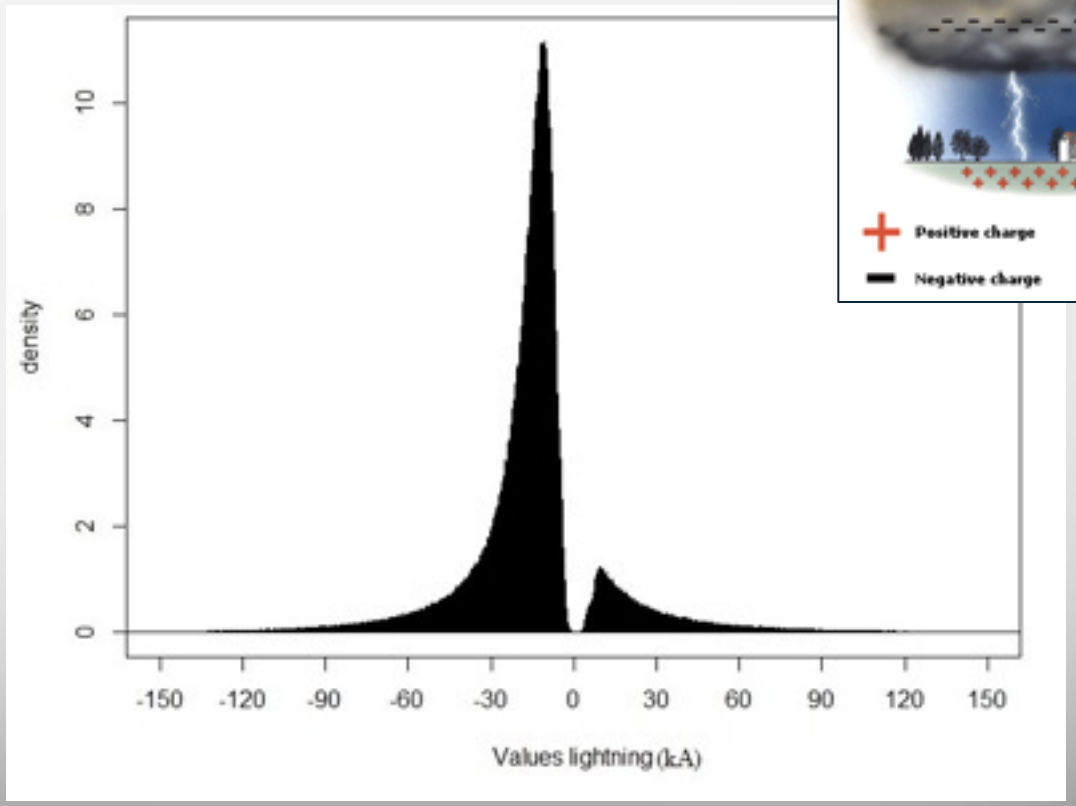
With a resolution of 1°/ 18.



Lightning results – Values distribution

Density of the lightnings depending on the values.

(2001 – 2012)



CG- : 86,31%
CG+ : 13,69%

Lightning results – NASA database

The NASA obtained a map from Optical Transient Detector (ODT) and Lightning Imaging Sensor (LIS).

The spaceborne optical sensor OTD on the MicroLab-1 satellite, collected data from May 1995 to March 2000.

LIS on the Tropical Rainfall Measuring Mission (TRMM) satellite, collected data from 1998 until today.

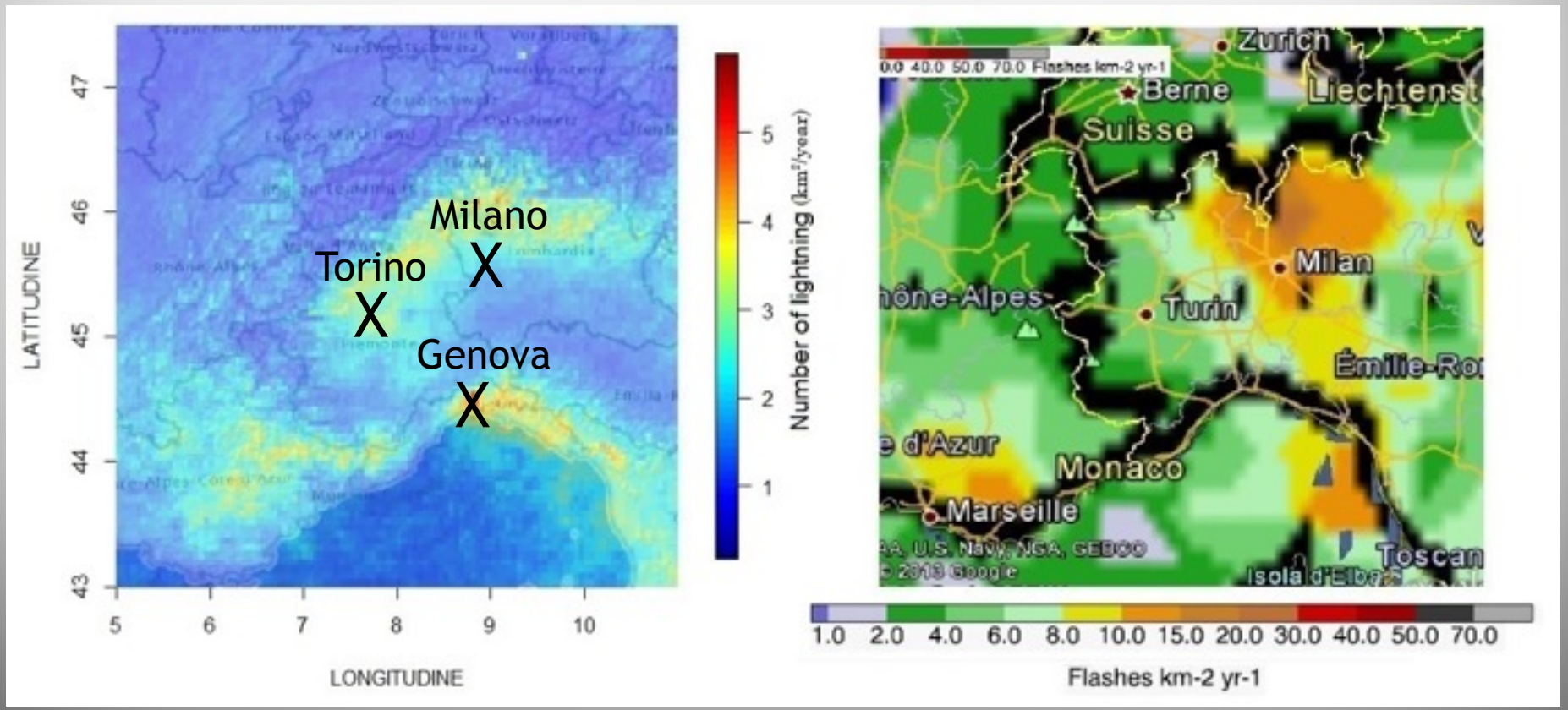
Qualitative comparison CG annual distribution with the NASA database combined LIS and ODT for a resolution of 0,5°.

Lightning results

Generally the same, but also differences.

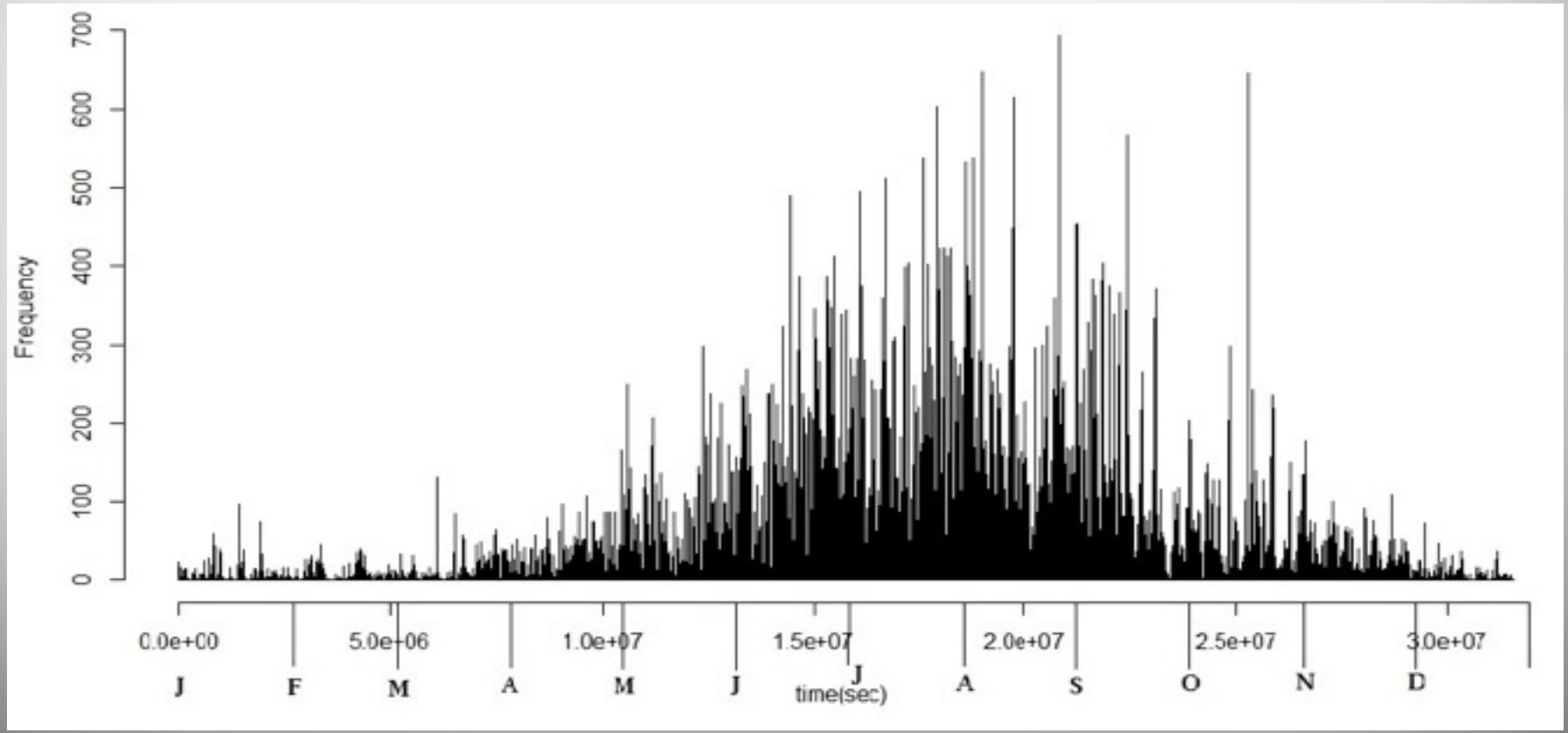
SIRF, CG lightnings

NASA, IC+CG lightnings



Lightning results – Annual distribution

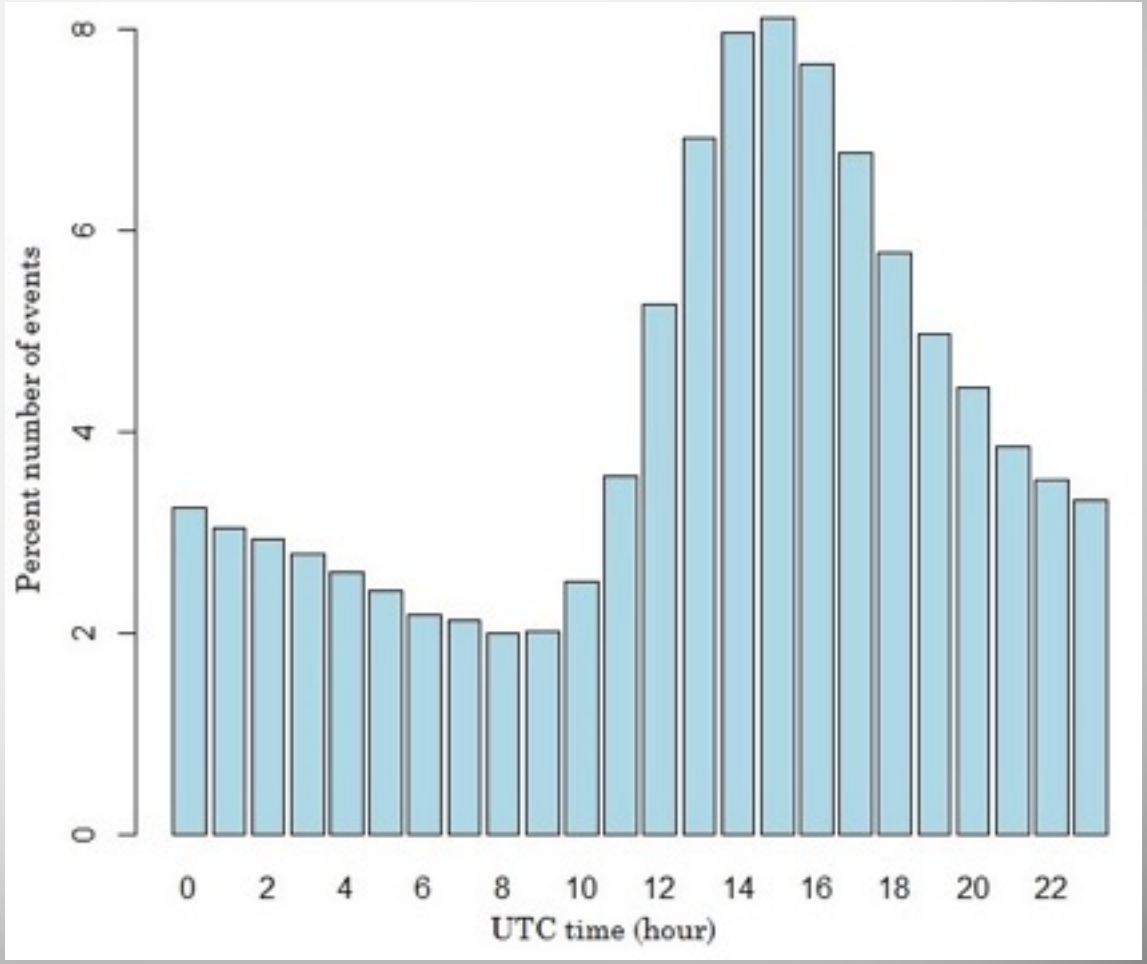
Lightning density over one year (2001 – 2012).
The frequency is the number of observations per day.



Lightning results – Hourly distribution

The percentage of lightning depending on the hours of the day.

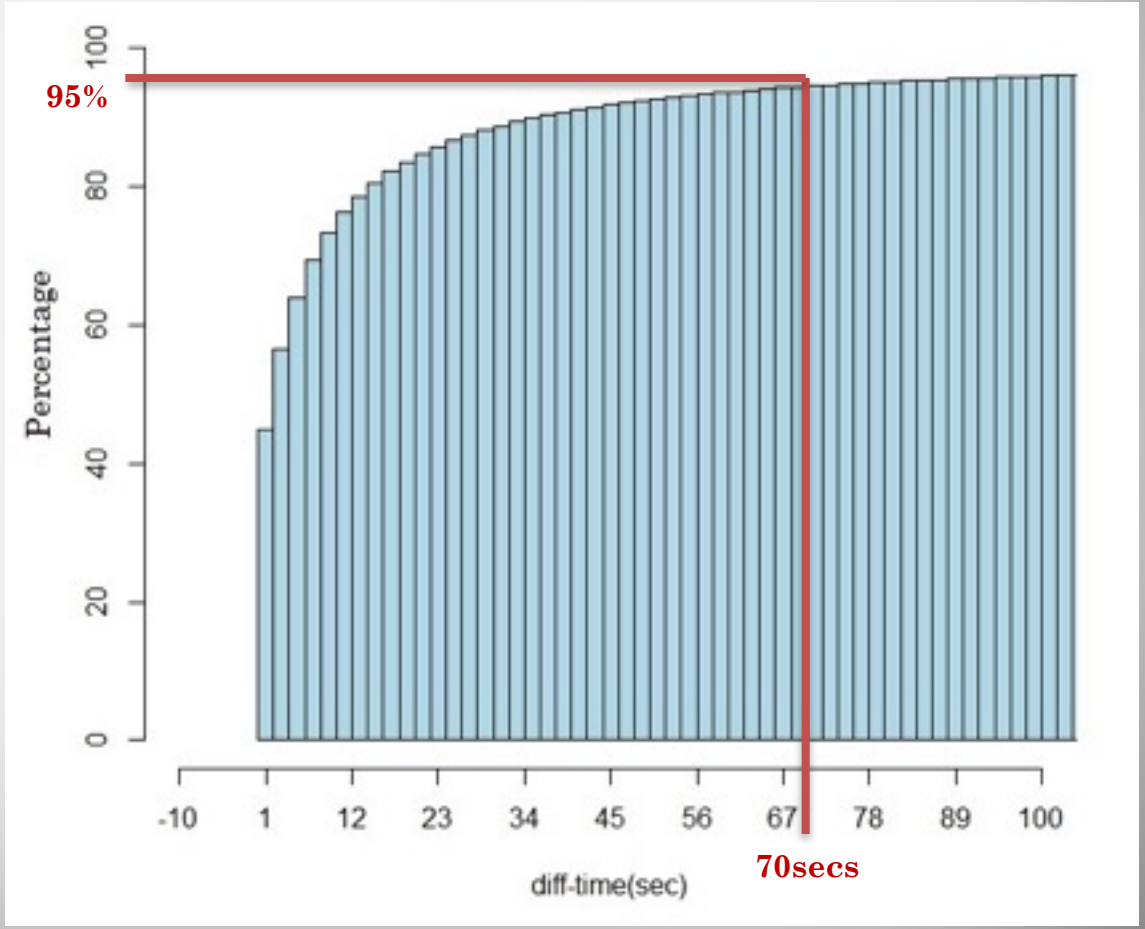
(2001 – 2012)



Lightning results – cummulative distribution

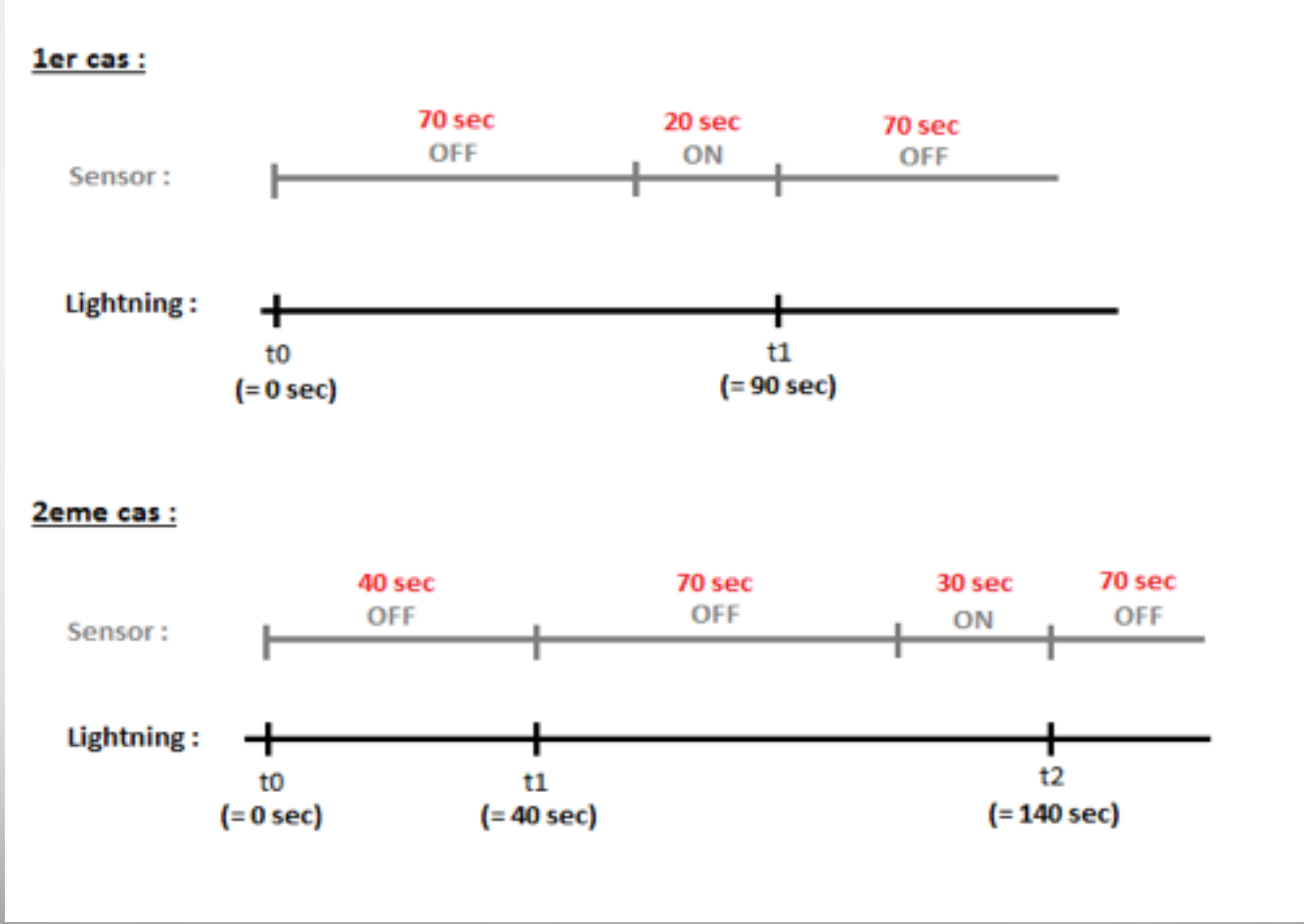
Time difference between two lightnings for 2001.

For 70 secs, about 95% of the events that took place.



JEM-EUSO duty

Both cases presented by our sensor :



Lightning results – Night/Day

The number of lightnings during the day time and night time calculated with the function « suncalc » in R.

	day	night	total
2001	199064	120843	319907
2002	250664	170831	421495
2003	263095	109119	372214
2004	198348	87952	286300
2005	221498	115626	337124
2006	242917	87779	330696
2007	160619	73514	234133
2008	165030	74781	239811
2009	151013	70748	221761
2010	132897	68187	201084
2011	190090	80625	270715
2012	181735	82695	264430
2001 - 2012	2356970	1142700	3499670
percent	67.35 %	32.65 %	100 %

Lightning results – Time on/off

We calculate the time on and off for the night time only.

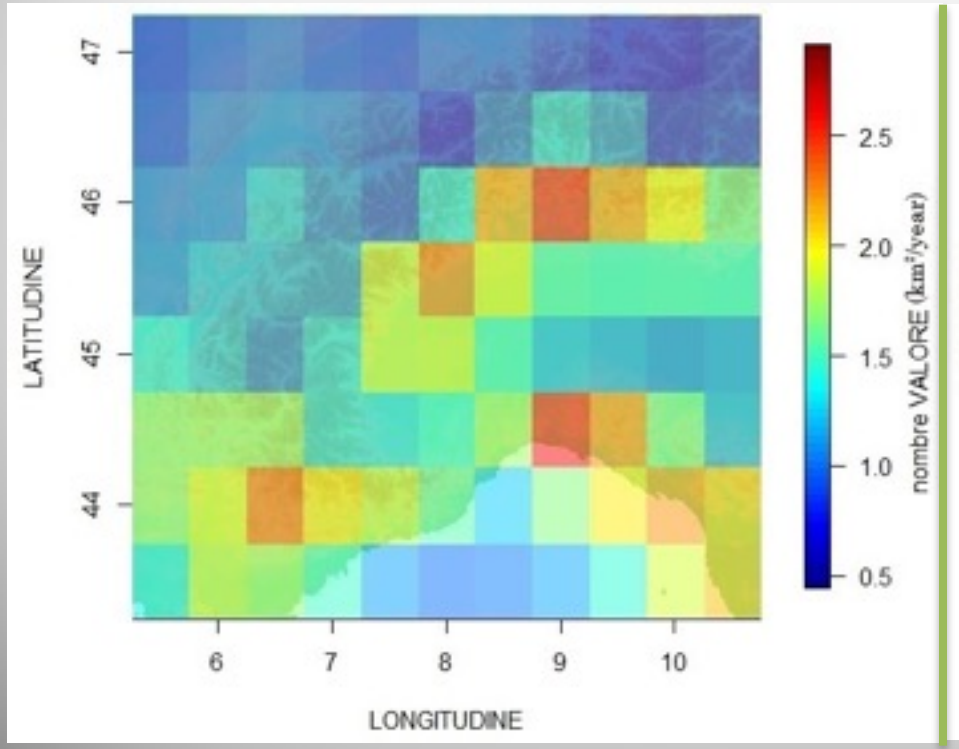
	time on percent	time off percent
2001	93.04 %	6.96 %
2002	88.90 %	11.10 %
2003	91.28 %	8.72 %
2004	91.41 %	8.59%
2005	91.67 %	8.33 %
2006	91.64 %	8.36 %
2007	92.43 %	7.57 %
2008	91.65 %	8.35 %
2009	92.36 %	7.64 %
2010	91.80 %	8.20 %
2011	92.32 %	7.68 %
2012	92.40 %	7.60 %

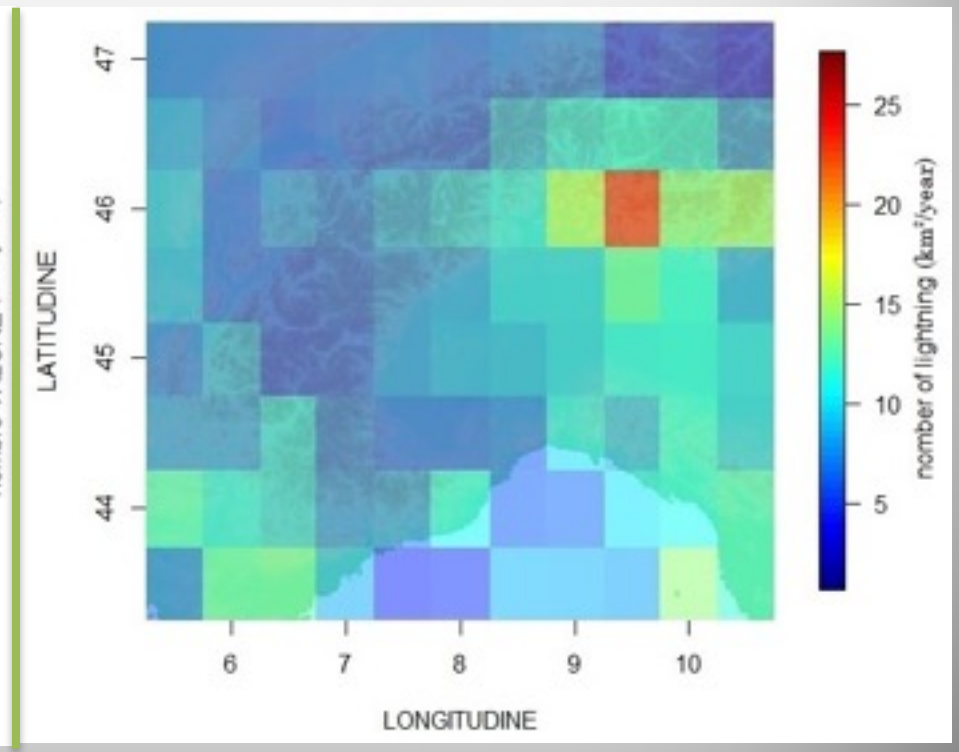
average : time on = 91.74 %
time off = 8.26 %

Lightning results – Average annual distribution

SIRF (CG lightning) (2001 – 2012)

NASA (IC+CG lightning) (1998 – 2010)





Resolution (1/2)°

Lightning results – Comparison

Comparison between SIRF and NASA data base.

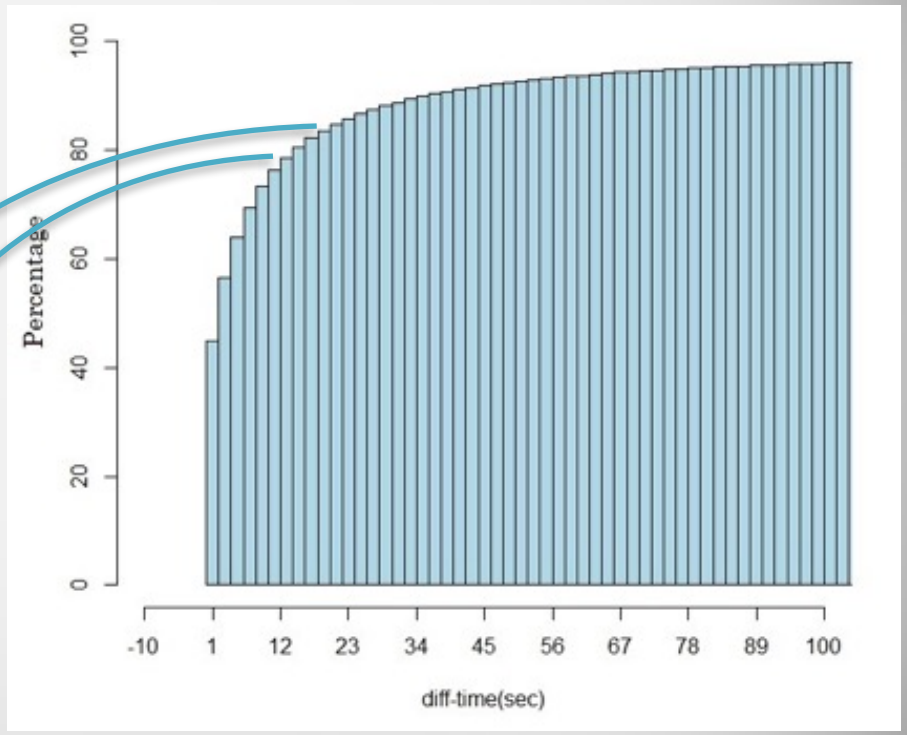
	(CG)	(IC+CG)
	SIRF	NASA
years	2001 to 2012	1998 to 2010
resolution	0.5° x 0.5°	0.5° x 0.5°
area : (longitude) (latitude)	[5.25 : 10.75] [43.25 : 47.25]	[5.25 : 10.75] [43.25 : 47.25]
min (flashes/km^2/year)	0,44	0,61
max (flashes/km^2/year)	2,92	27,65
mean (flashes/km^2/year)	1,31	6,32

Factor 5 between the means, and a factor 10 between the averages.

Lightning results –
Creation fake lightnings

Real lightning :

Real+fake lightning :



We create a new data base including « real+fake » lightning from the first data base including just the real lightnings.

Lightning results –
Time on/off with fake lightning

We extrapolate the last results with only CG lightning, and we extract ramdomly 4 or 9 events from cummulative distribution.

	Multiply by 10		Multiply by 10	
	08/02/2001 : 984 events		20/10/2001 : 15808 events	
	time on	time off	time on	time off
real	67.89 %	32.11 %	27.77 %	72.23 %
real+fake	53.10 %	46.74 %	20.39 %	79.56 %
	ratio time off :	1.46	ratio time off :	1.10

	Multiply by 5		Multiply by 5	
	08/02/2001 : 984 events		20/10/2001 : 15808 events	
	time on	time off	time on	time off
real	67.89 %	32.11 %	27.77 %	72.23 %
real+fake	58.75 %	41.25 %	22.73 %	77.27 %
	ratio time off :	1.28	ratio time off :	1.07

Lightning results –
Time on/off with fake lightning

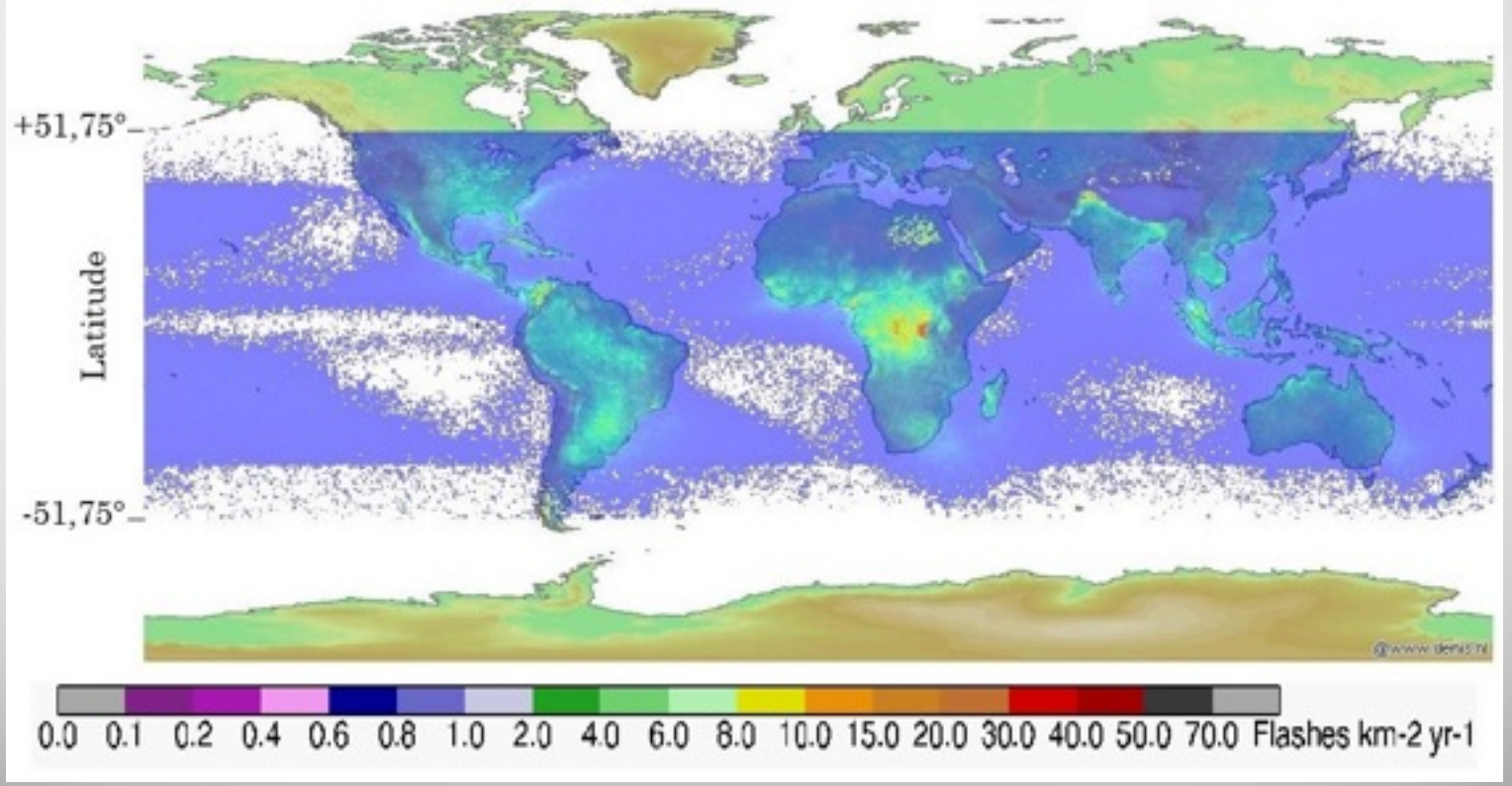
With only CG lightning, time off = 8,26%

The time off increases in the two cases :

Factor 5, time off = 9,38%
Factor 10, time off = 10,66%

Lightning results – Distribution for ISS trajectory

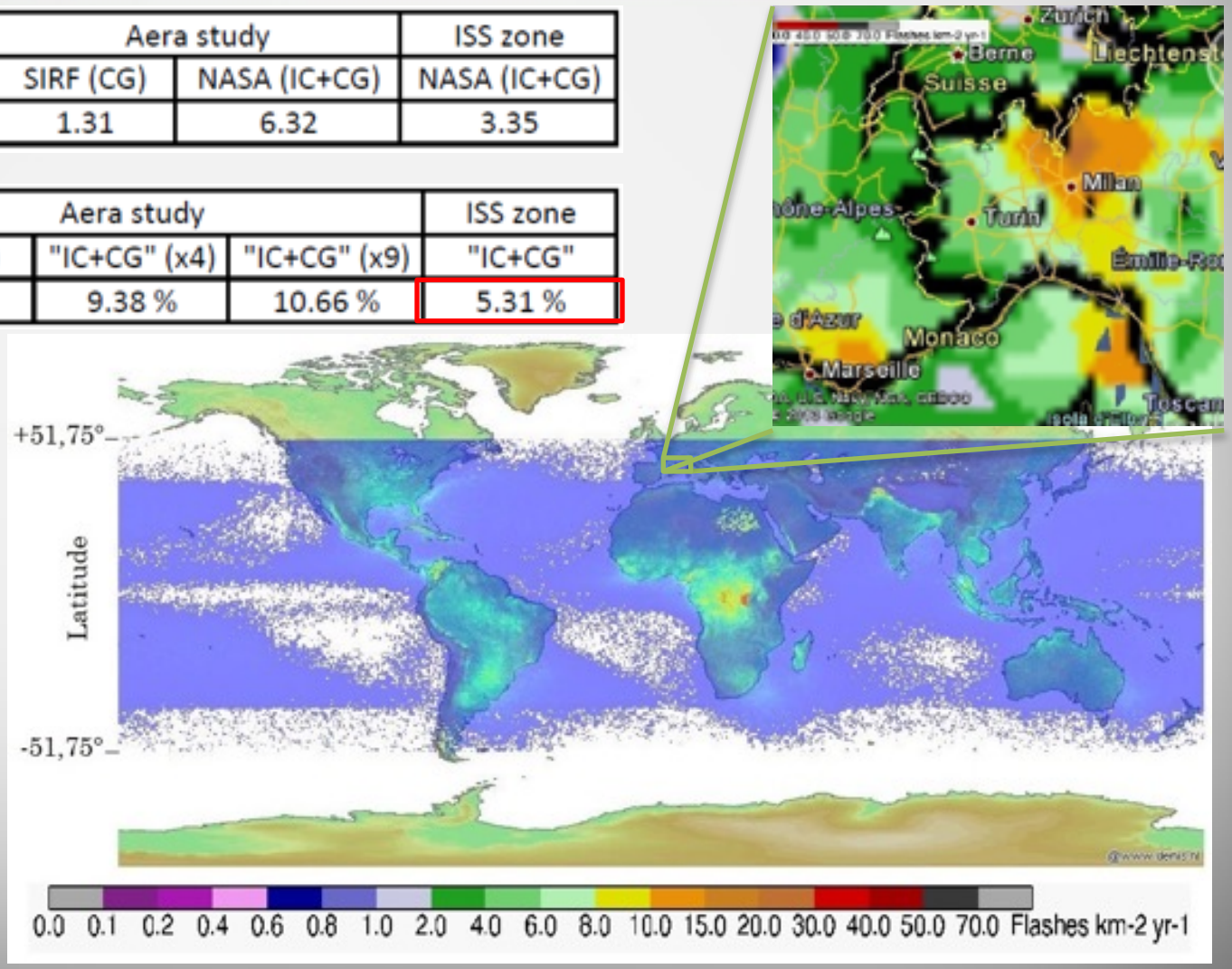
Area overflown by ISS :



Lightning results – Distribution for ISS trajectory

	Aera study		ISS zone
	SIRF (CG)	NASA (IC+CG)	NASA (IC+CG)
average (flash/year/km²)	1.31	6.32	3.35

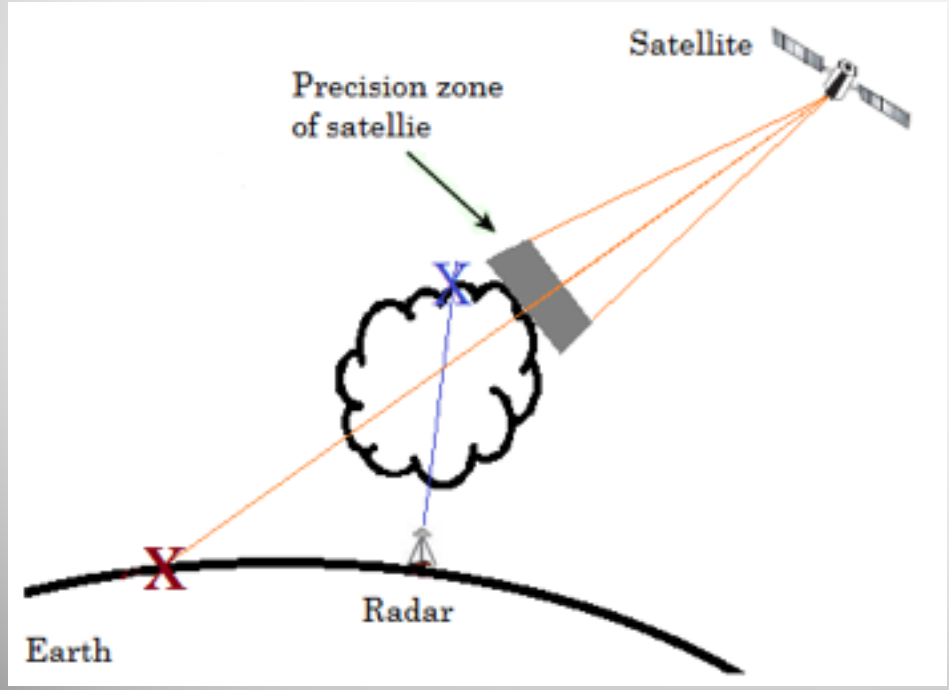
	Aera study			ISS zone
	SIRF (CG)	"IC+CG" (x4)	"IC+CG" (x9)	"IC+CG"
time off	8.26 %	9.38 %	10.66 %	5.31 %



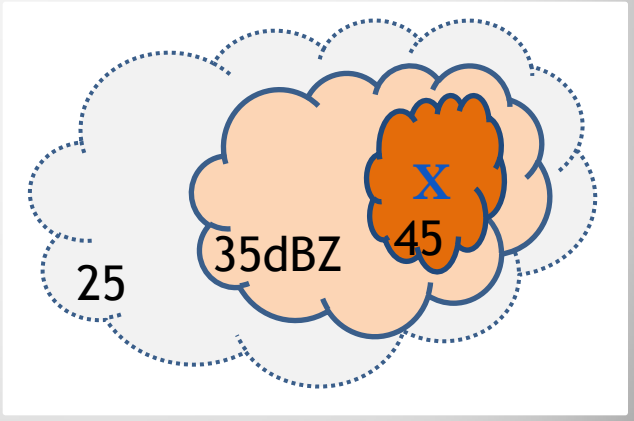
Cloud results

Cloud results

Determination of the cloud top by a radar and a satellite.



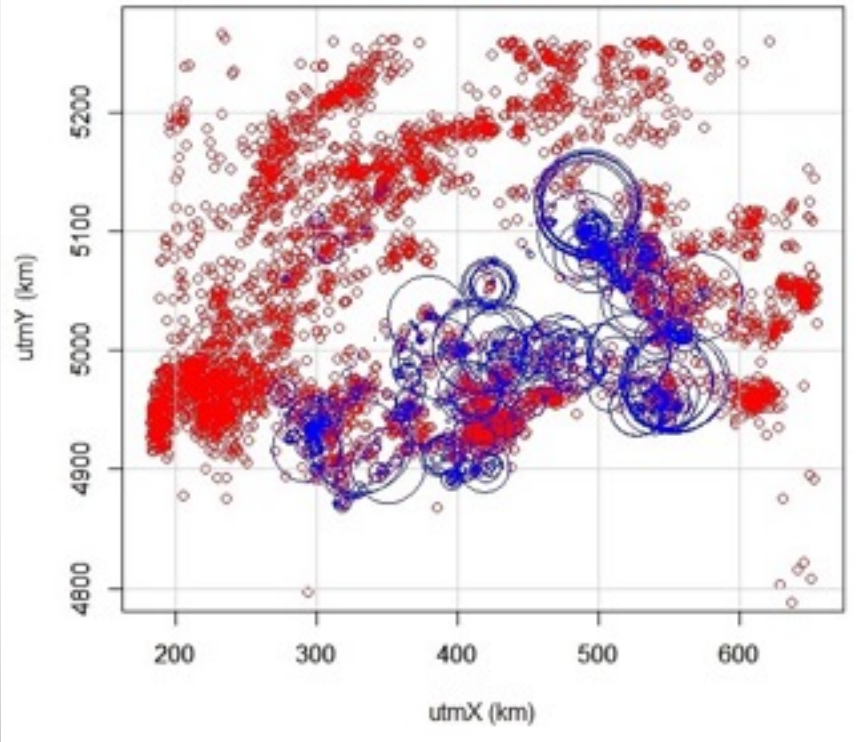
Radar



Decibels relative to reflectivity Z (dBZ)

Cloud results

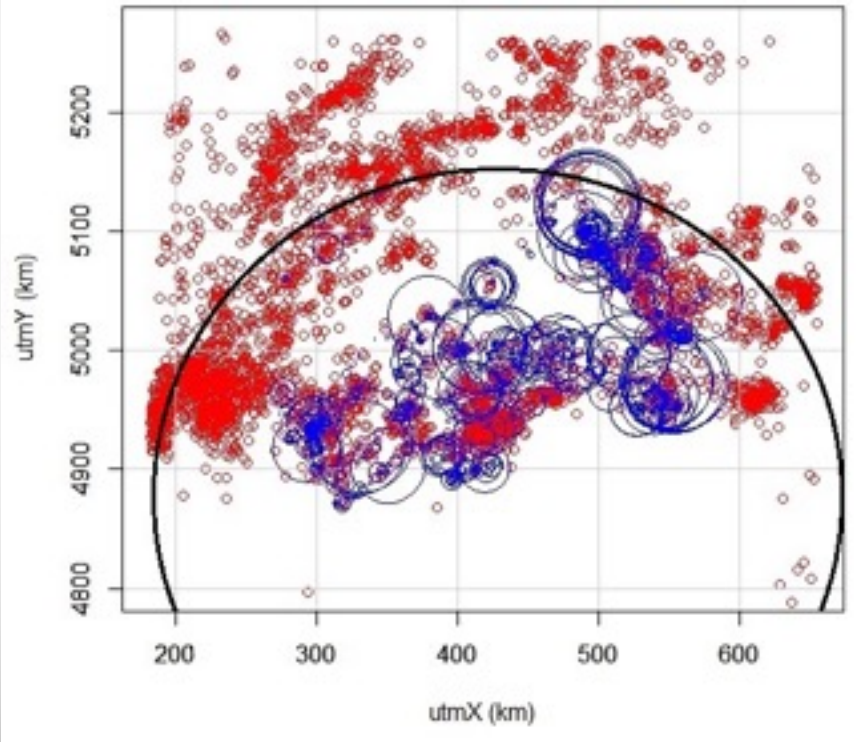
Location of the lightning storms (red) identified by the radar (blue circles, with dimension proportional to the area).



2 may 2013

Cloud results

Location of the lightning storms (red) identified by the radar (blue circles, with dimension proportional to the area).

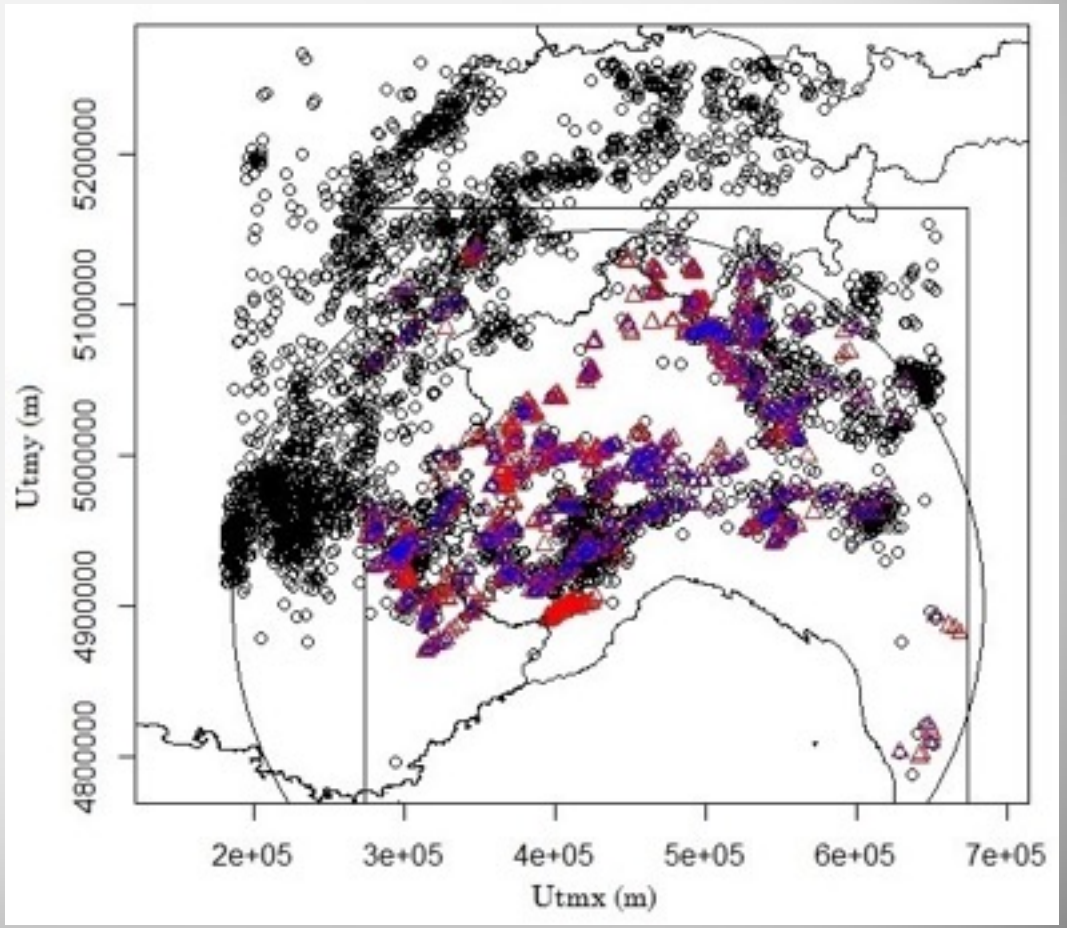


2 may 2013

Cloud results – Correlation between clouds and lightnings

Lightnings (blue circle) and clouds (red triangle) including in the area detection.

Lightnings not detected (black circle).



Cloud results – Height of cloud

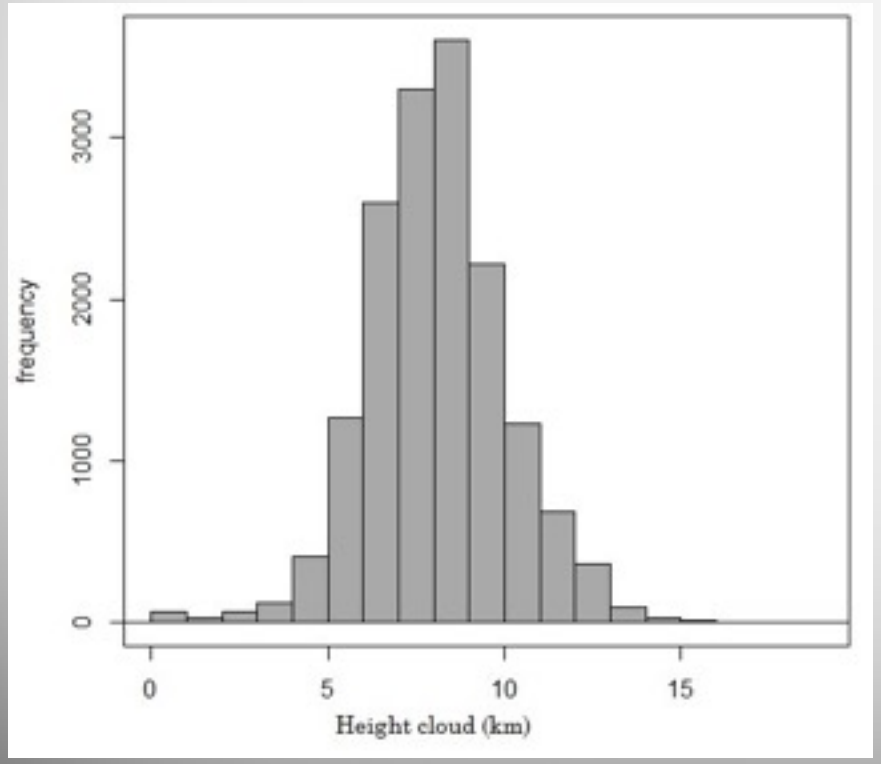
High cloud : > 6,5 km
Middle cloud : between 3,2 km and 6,5 km
Low cloud : < 3,2 km

	10 may 2013				2 may 2013			
	satellite	radar	satellite	radar	satellite	radar	satellite	radar
	number		fraction		number		fraction	
high cloud	817	817	44,04	53,93	817	817	60,74	74,21
middle cloud	792	604	42,70	39,87	440	188	32,71	17,08
low cloud	246	94	13,26	6,20	88	96	6,54	8,72
total events	1855	1515			1345	1101		

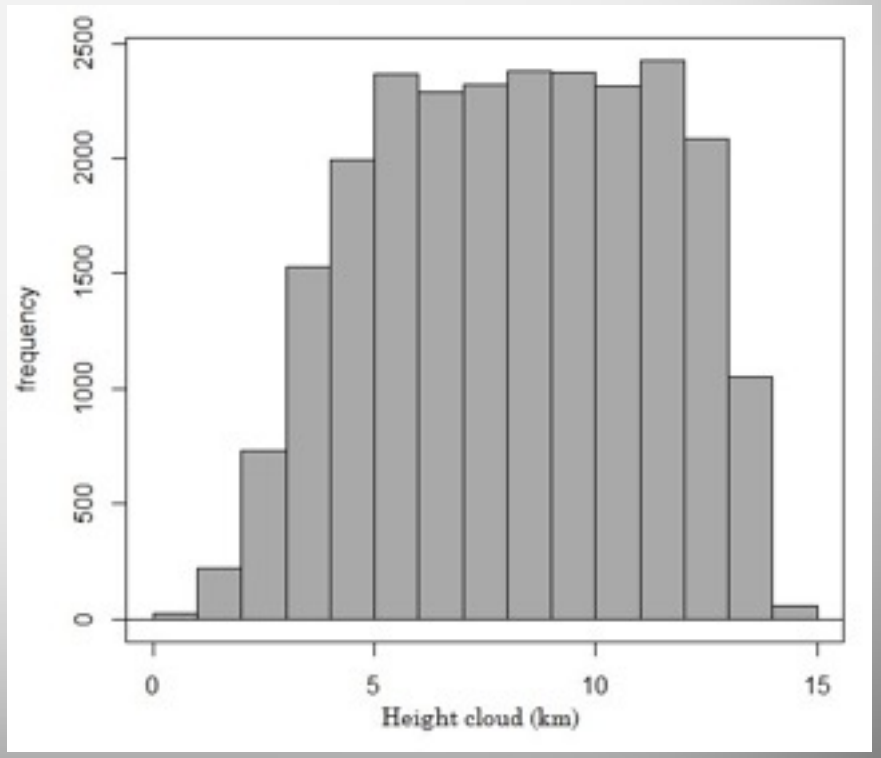
Cloud results – Distribution if the top cloud

For 1 year (2012)

Radar



Satellite



The new result about the correlation between lightning and cloud for 1year.

- for the satellite we have:
- high cloud : 16087 ; 66.58%
- middle cloud : 6850 ; 28.35%
- low cloud : 1222 ; 5.06%
- hc+mc+lc = 24159 (number total of events)
- for the radar I should rerun the program to get the exact numbers of percentage.

Conclusion

Analysis of CG lightnings from 2001 to 2012.

Comparison between different dataset (SIRF and NASA).

Most lightnings occur during daytime, summertime and over land.

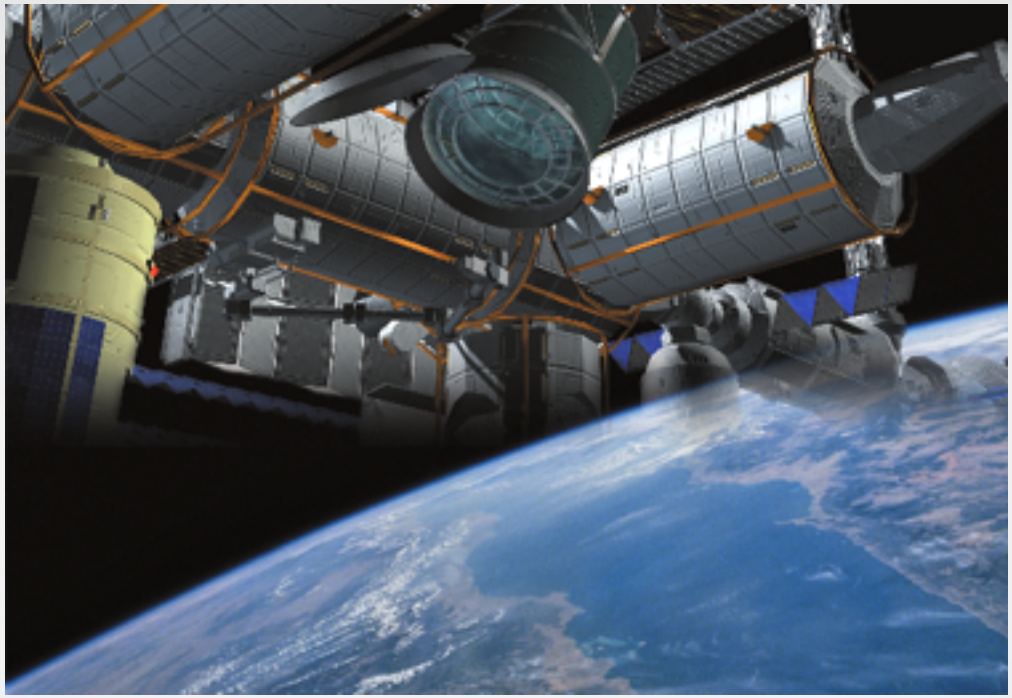
In our area the time off is 8.26%. With the extrapolate for the ISS zone, the time off becomes 5.31%.

Most clouds are causing lightning are high or middle. That change anything in the time off.

Perspective

To analyze the ISS zone and with all parameters (light, cloud, etc…) and to calculate the time on/off for this area.

Doing a map with the average of the time on/off.



Thank you for your attention!