Describing the electrical nature of the Amazon thunderstorms during the 2nd GO-Amazon IOP and ACRIDICON-CHUVA Field Campaign

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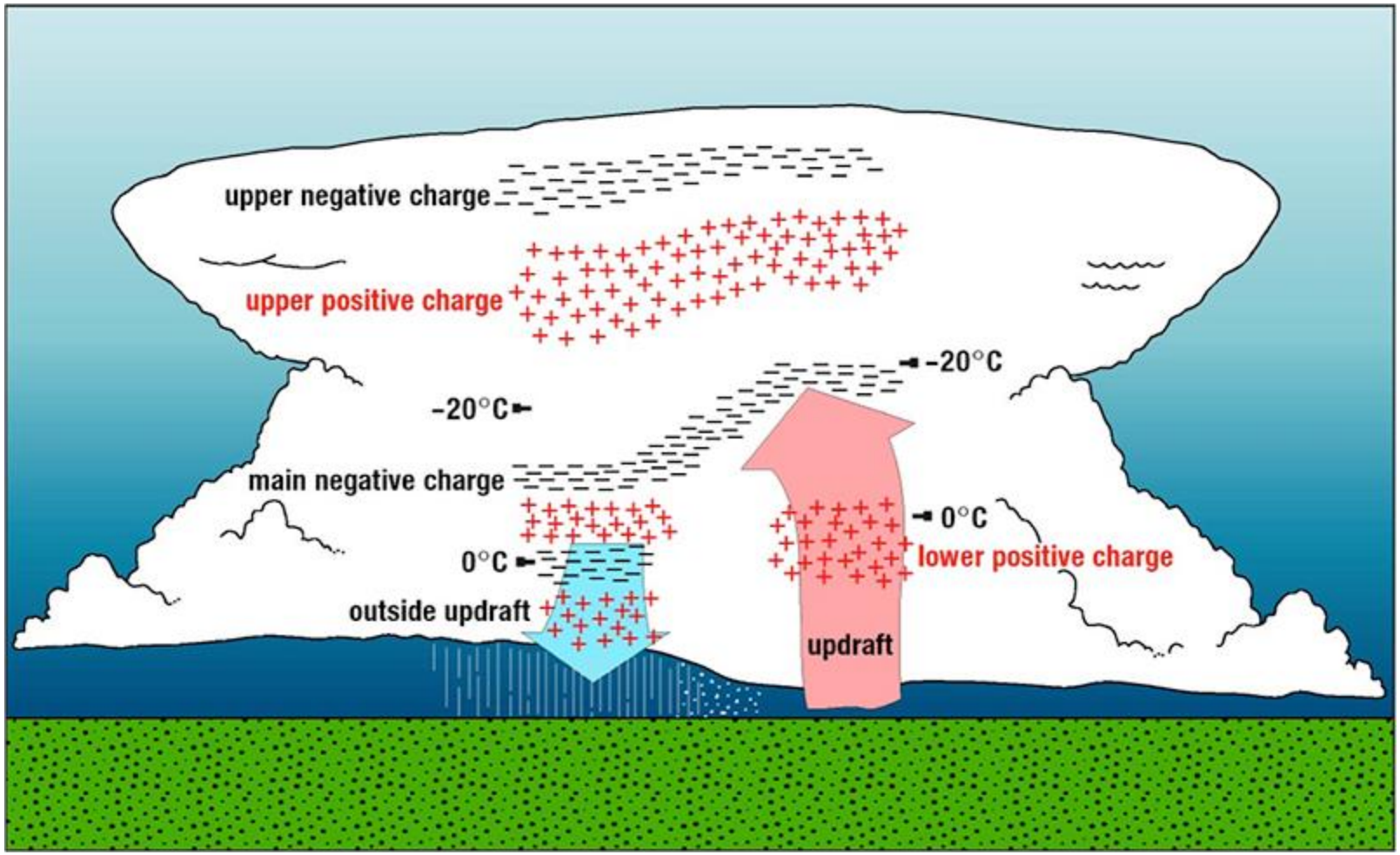
M. Lacerda – *University of Mato Grosso do Sul*

STORM-T



Stolzenburg, M., W. D. Rust, and T. C. Marshall (1998), Electrical structure in thunderstorm convective regions: 2. Isolated storms, J. Geophys. Res., 103(D12), 14079–14096, doi:10.1029/97JD03547.

The most efficient electrical charging mechanisms relies on the collision between ice crystals and graupel:

- It does not require an Electric field to polarize the particles
- The collisions happen in the presence of super cooled water droplets (riming)
- The charge transfer (+ or -) depends on:
  - LWC
  - Temperature during the collision
  - Size of the particles – velocity
  - Growth phase

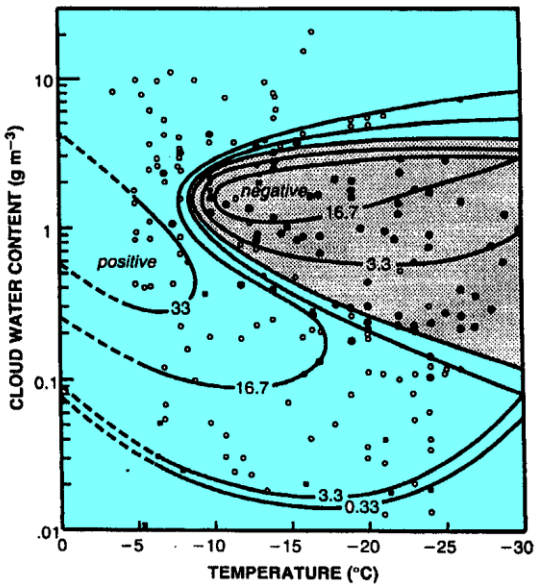


Fig. 3.12. Charge (in fC) gained by rimed graupel colliding with ice particles as a function of temperature and liquid water content. Open circles indicate that rimed graupel gained positive charge, solid circles indicate that it gained negative charge, and x's indicate that no charge was transferred. (Adapted from Takahashi 1978, with permission.)

Data Set: IOP 2 – *Sep-Oct 2014*

Lightning Networks:

STARNET - CG

LINET – IC + CG

Vertical Electrical Field:

Network of Field Mills

Rain Measurements:

Doppler S-Band – SIPAM – Manaus

Doppler Dual Pol – X Band – T3 – CHUVA

W Band (95 GHz) ARM Cloud Radar

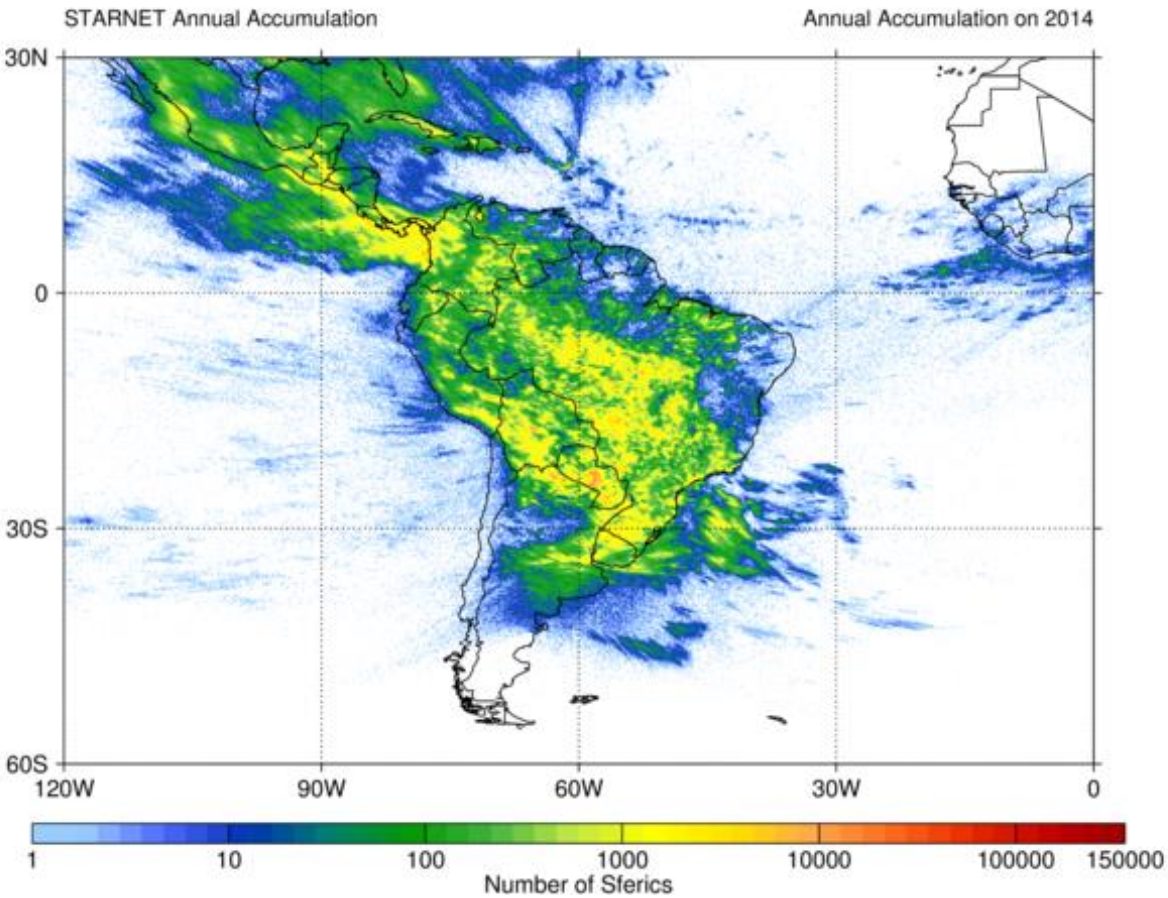
MRR (24 GHz)

STORM-T


T3 - Site
SIPAM-Radar
Rio Negro
Rio Negro
Paricatuba
AM-070
AM-449
Reserva Florestal Adolpho Ducke
COROADO
Manaus
EDUCANDOS
Nova Vida
São José
Iranduba
Rio Solimões
Manacapuru
Floresta
Salgada

STORM-T

- **Sferics Timing and Ranging Network – STARNET**

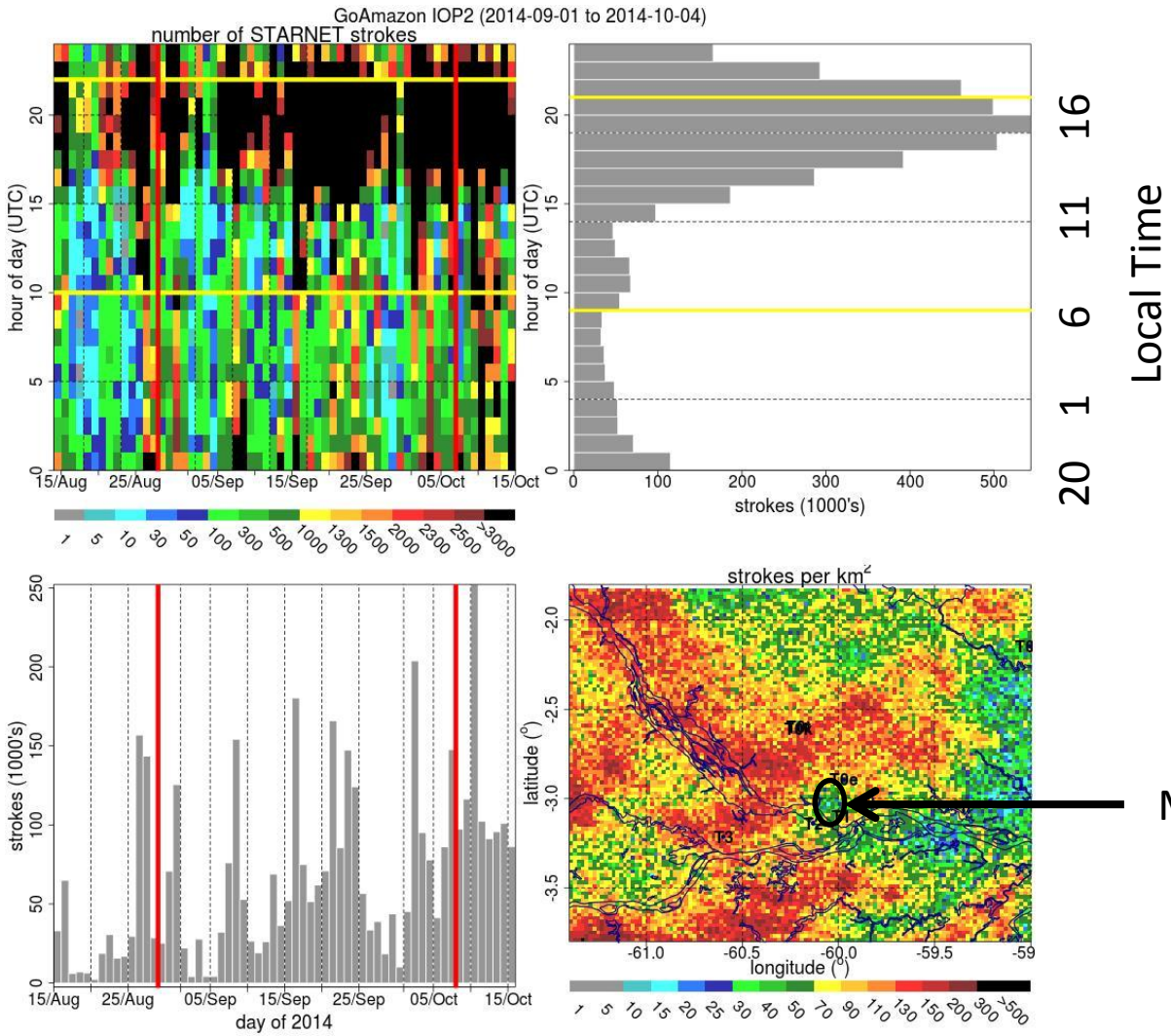


0.1 x 0.1 degree grid box

STORM-T

Summary of STARNET lightning data

IOP2



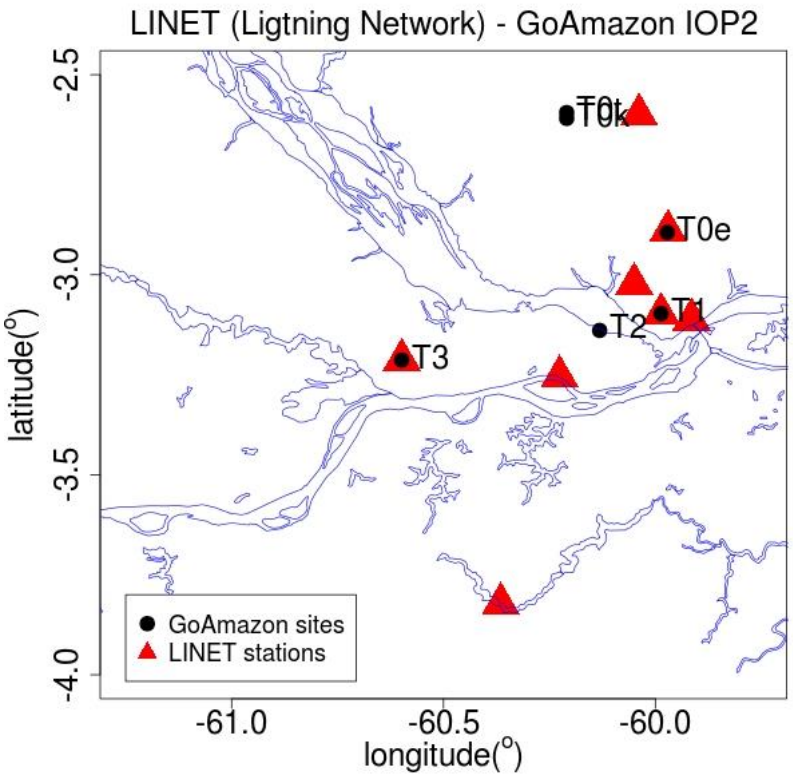
150,000 sferics

100,000 sferics

50,000 sferics

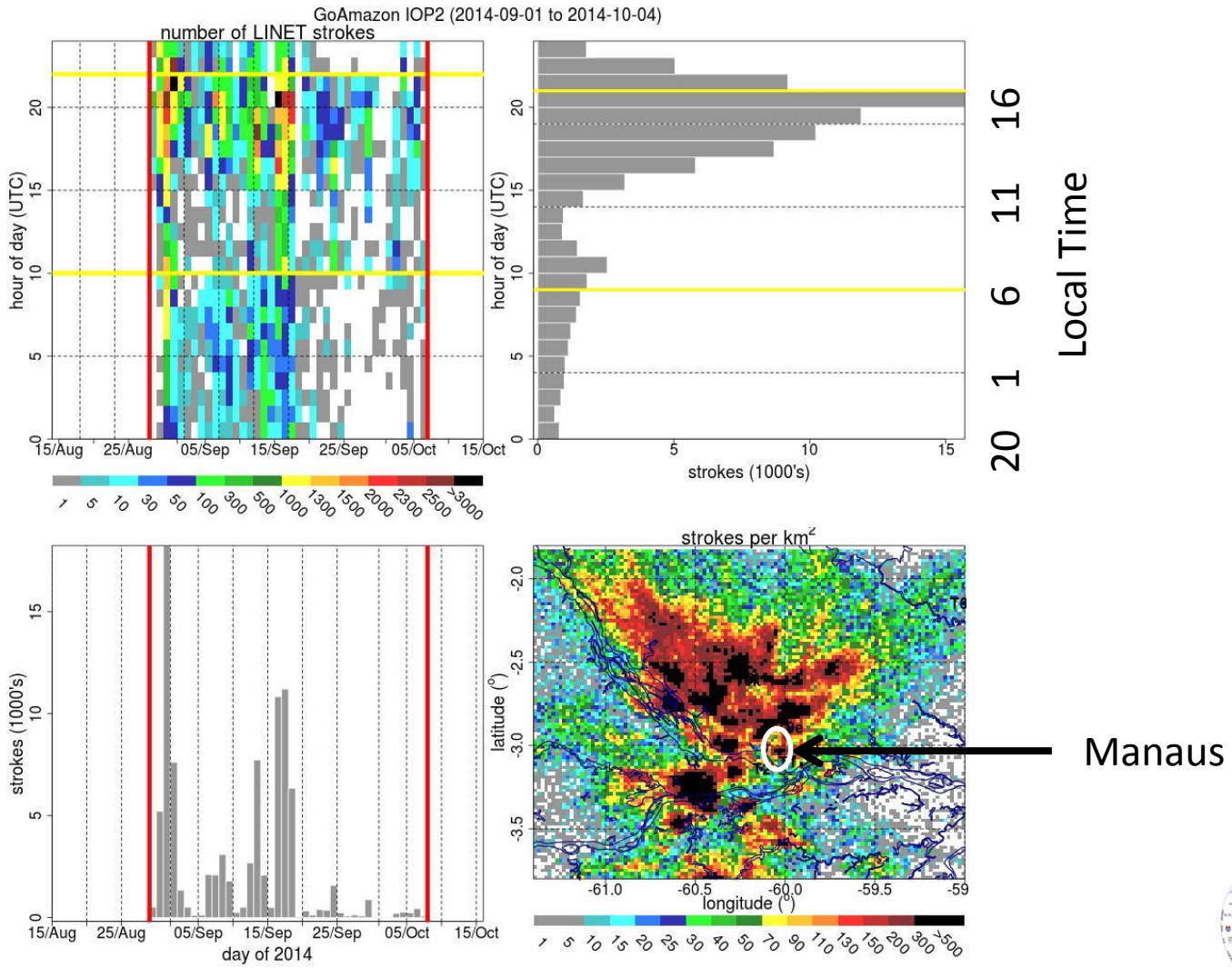
STORM-T

- 3D total (intracloud + cloud-to-ground) lightning data from DLR Lightning Network (LINET) during part of GoAmazon IOP2:
  - 29 Aug 2014 – 07 Oct 2014



STORM-T

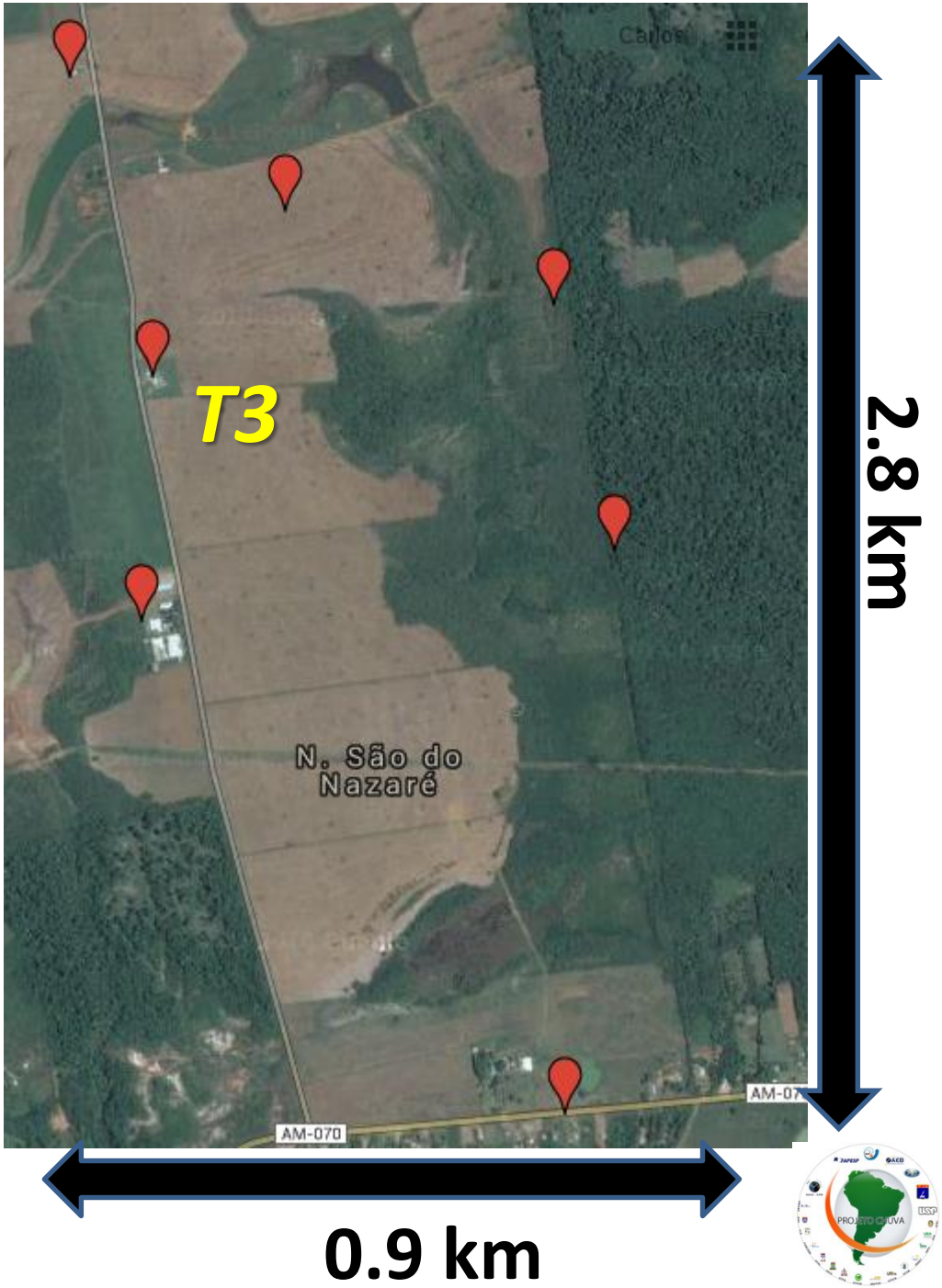
Summary of LINET lightning data **IOP2**



STORM-T

Network of 7 field mills

- 5 Campbels
- 2 Bolteks

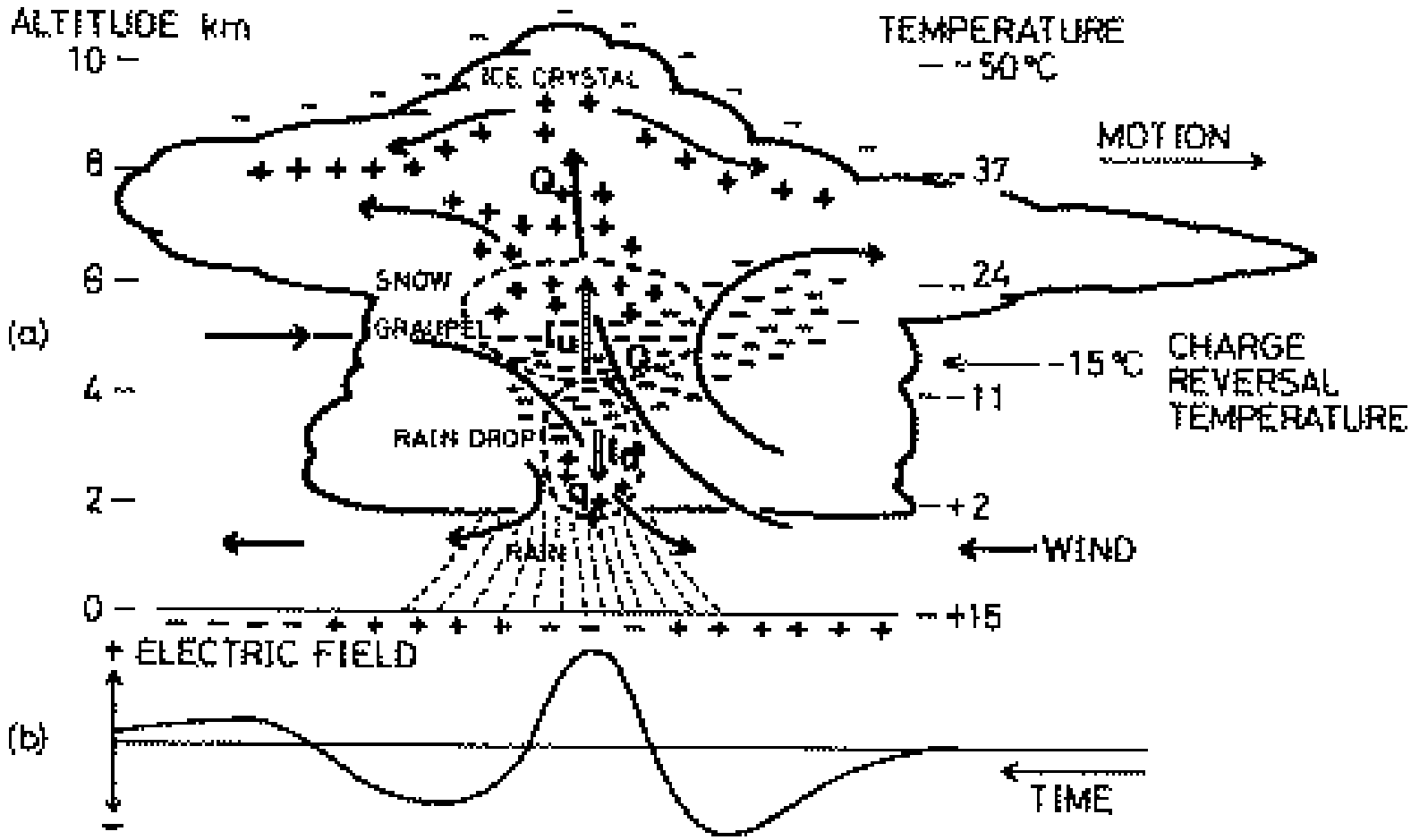


STORM-T

$$\vec{E} = \frac{1}{4\pi\varepsilon}\frac{q}{r^2}\hat{a}_r\left[\frac{V}{m}\right]$$

Electrical field from Coulomb´s Law

$$E = \frac{1}{4\pi\varepsilon}\sum_{i=1}^{Ncharges}\frac{q_i}{r_i^2}$$



Case Study:

September 8th, 2015

19-22 UTC

Total Lightning - LINET

3,067 IC + 1,213 CG Neg and 2,167 CG Pos

25 IC+CG per second – Maximum

Sferics – STARNET

2,174 Sferics

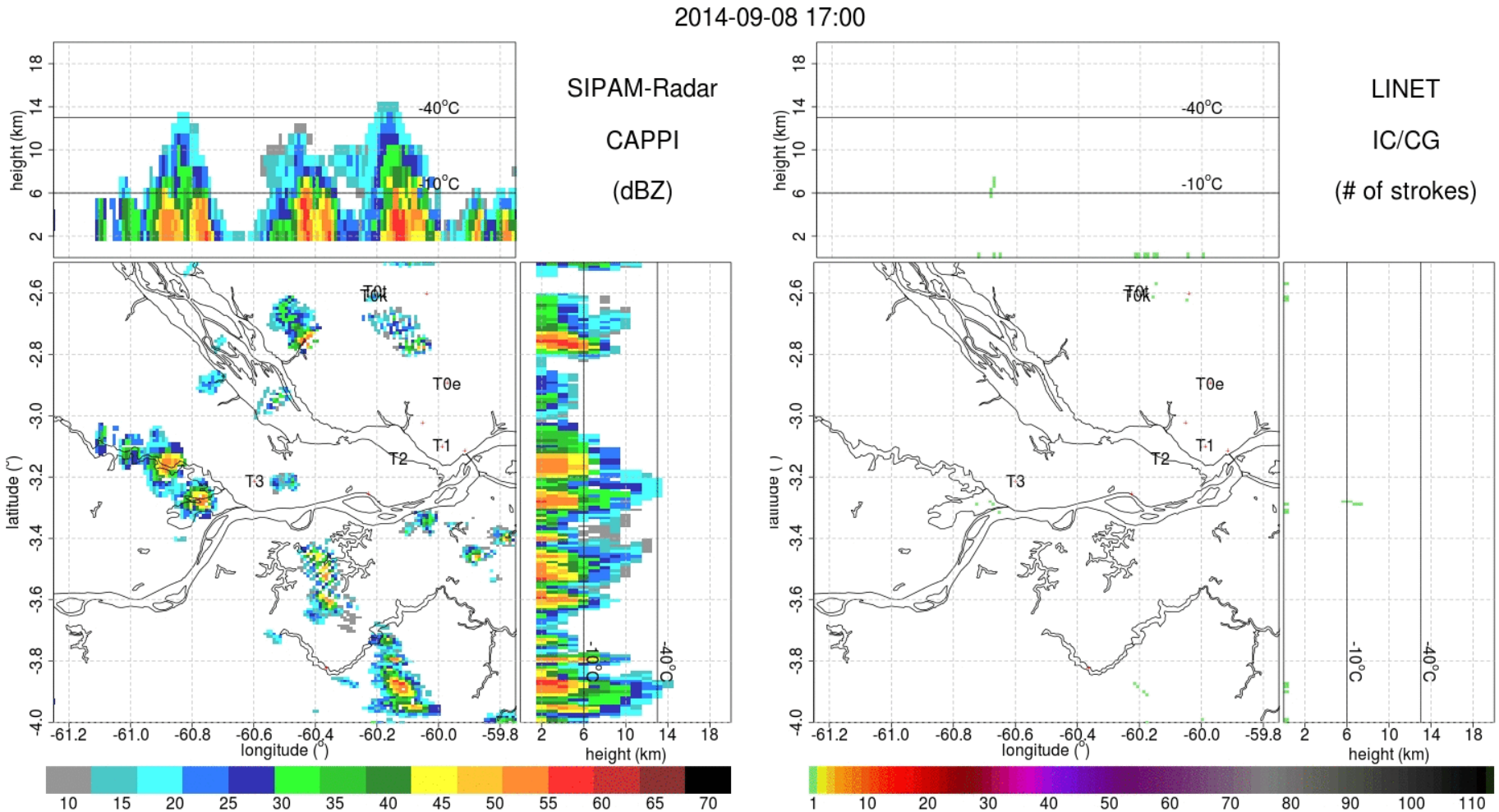
10 Sferics per second – Maximum

Field Mill

> 7 kV/m

STORM-T

SIPAM S-Band x LINET Sferics sources



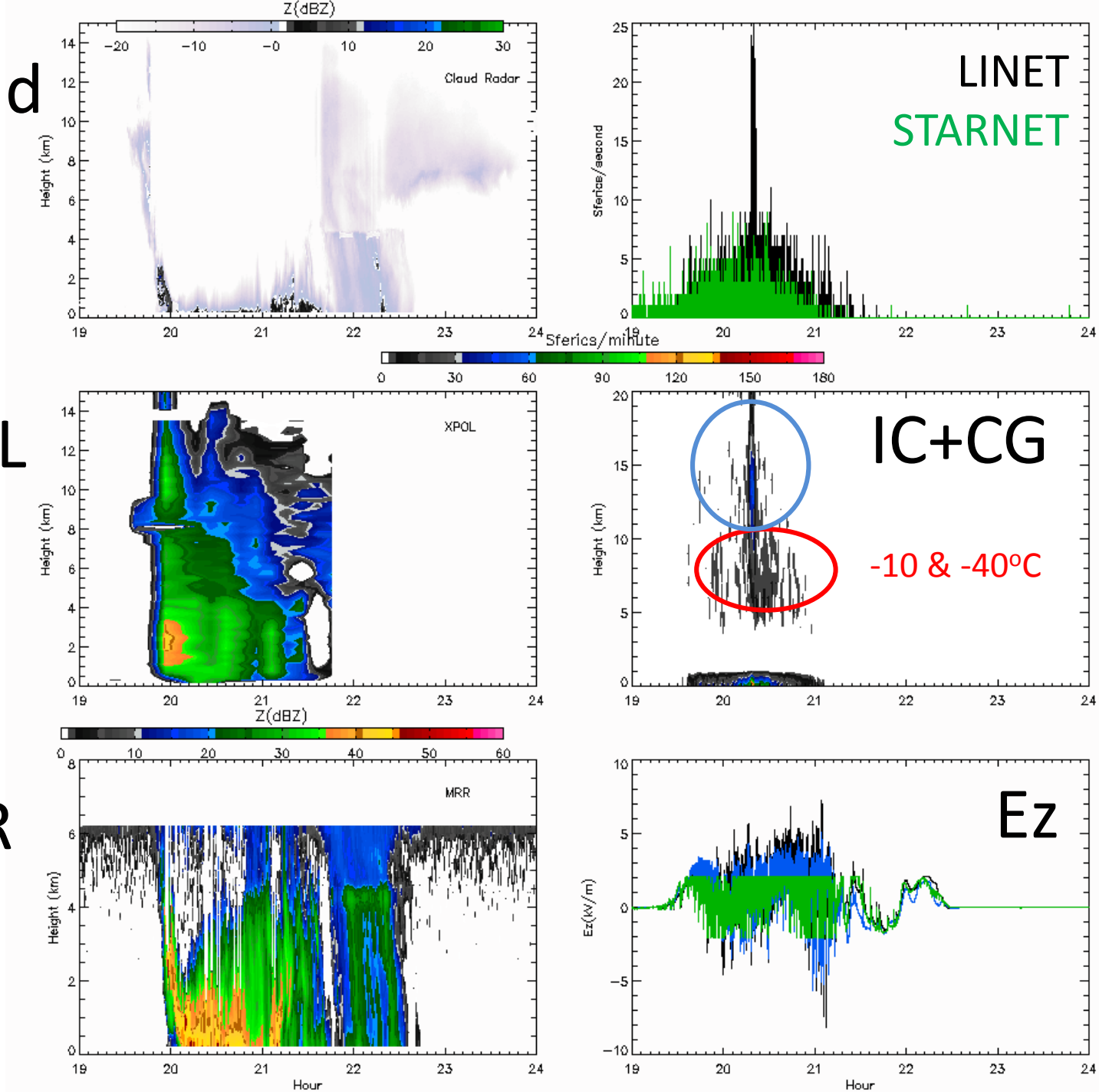
STORM-T

SUMMARY – T3

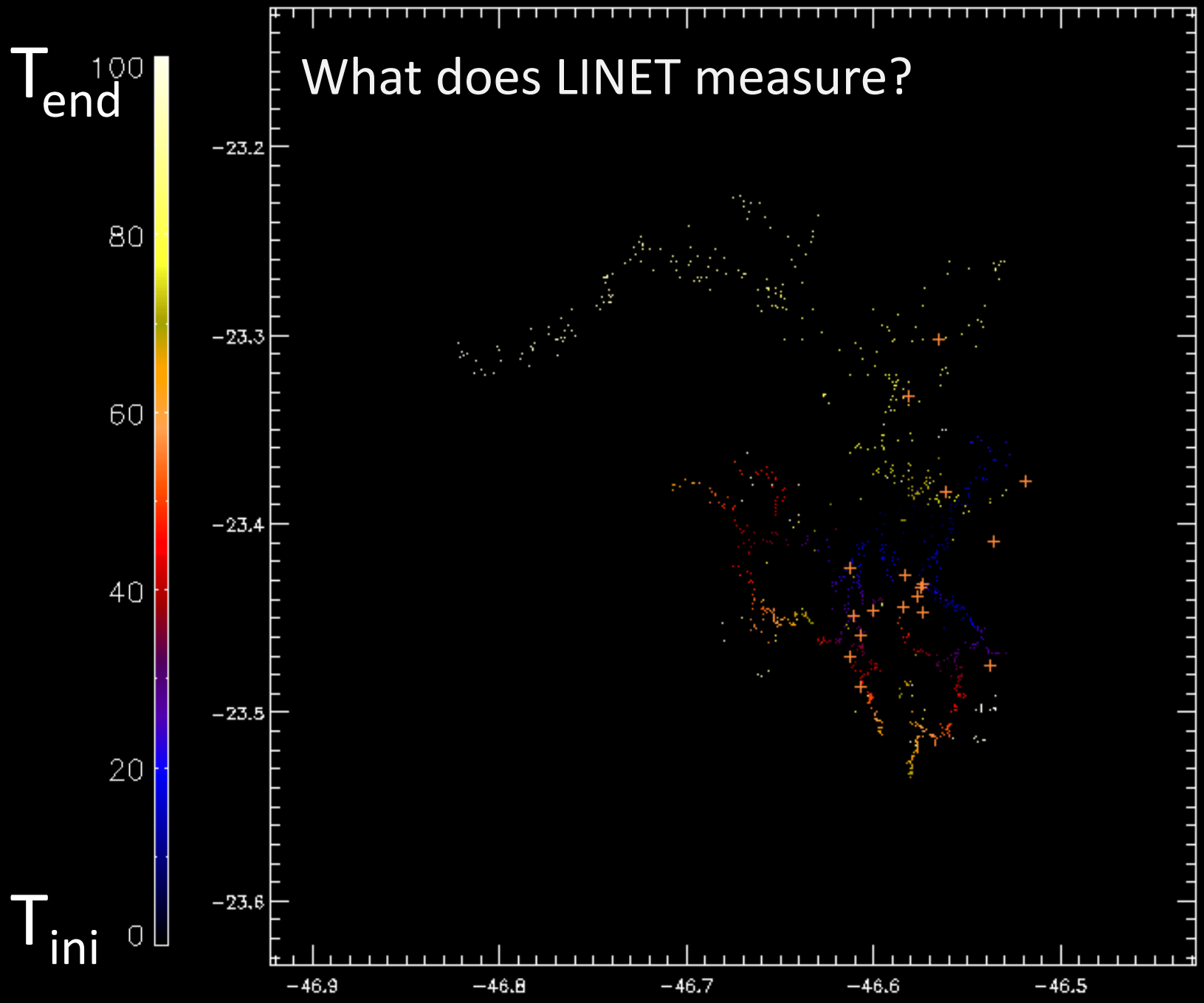
W-Band

XPOL

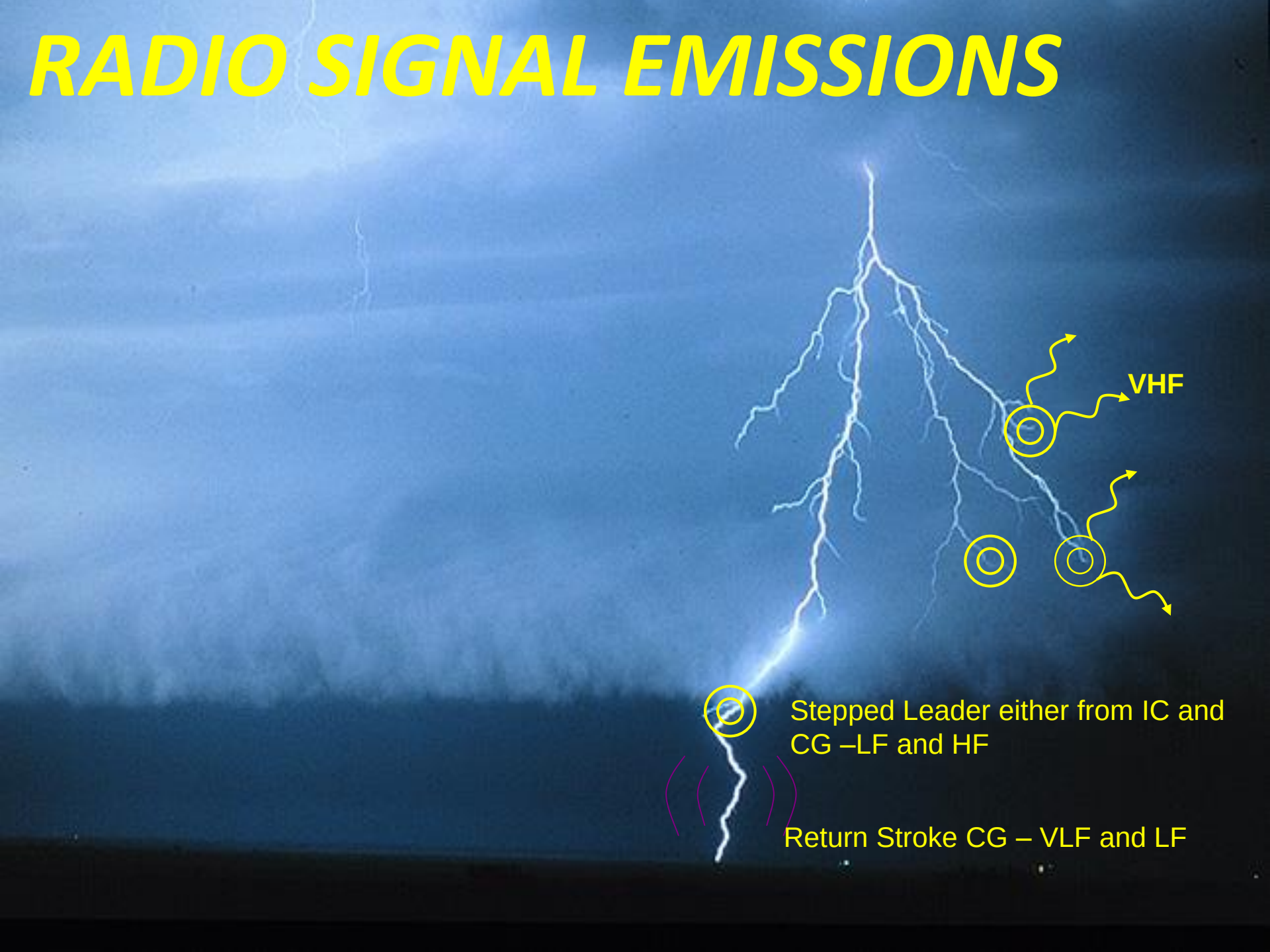
MRR

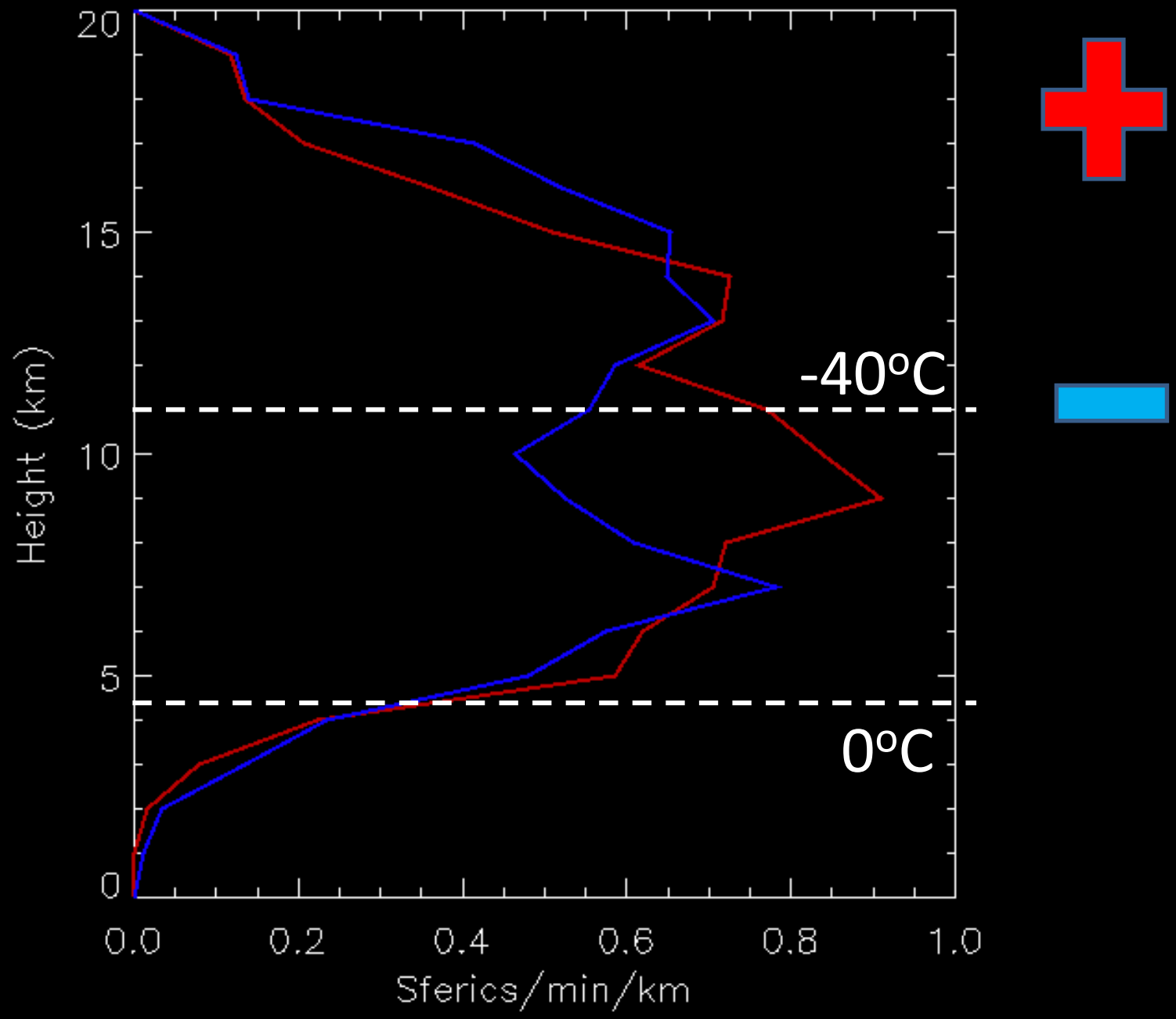


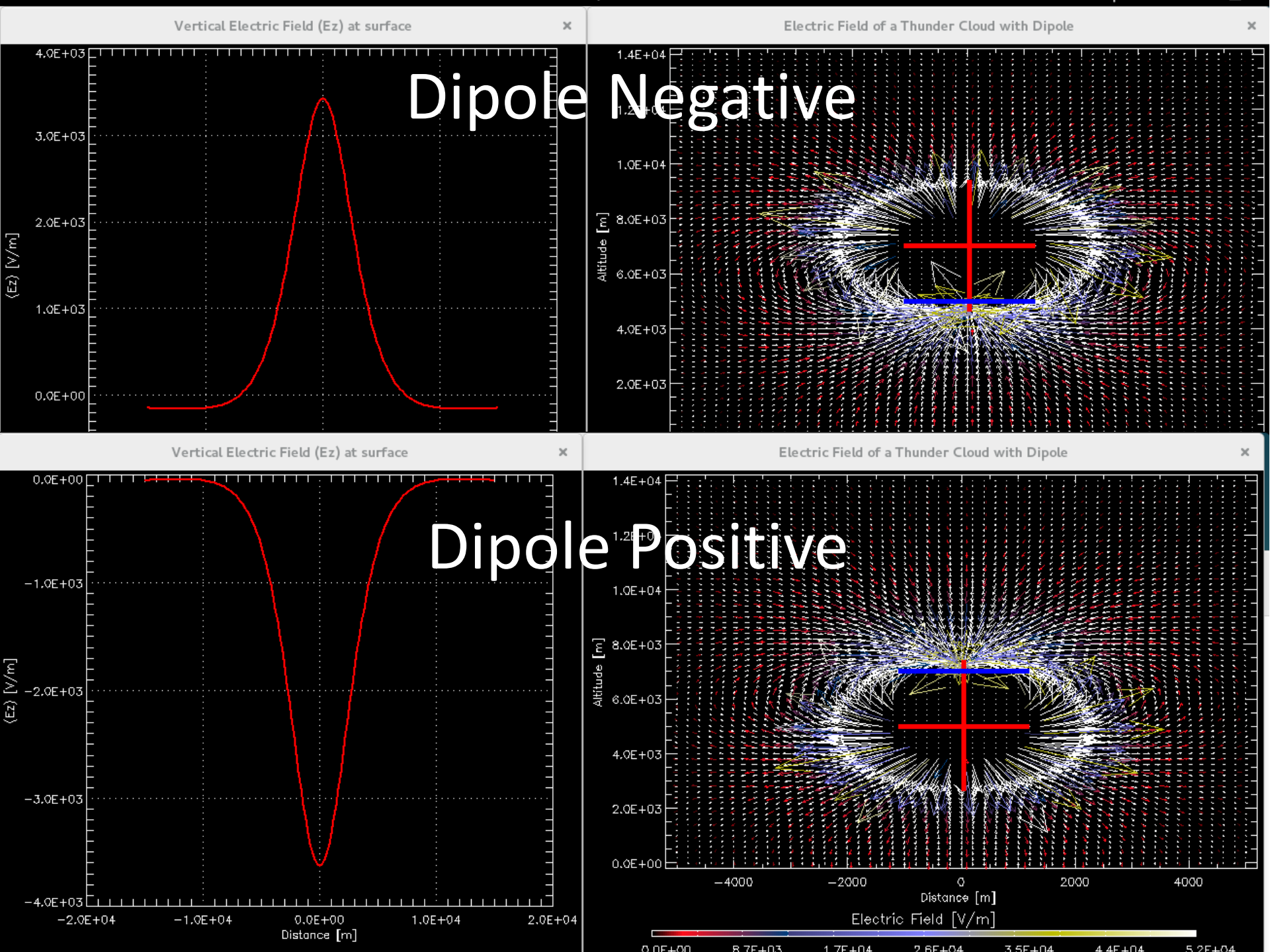
What does LINET measure?

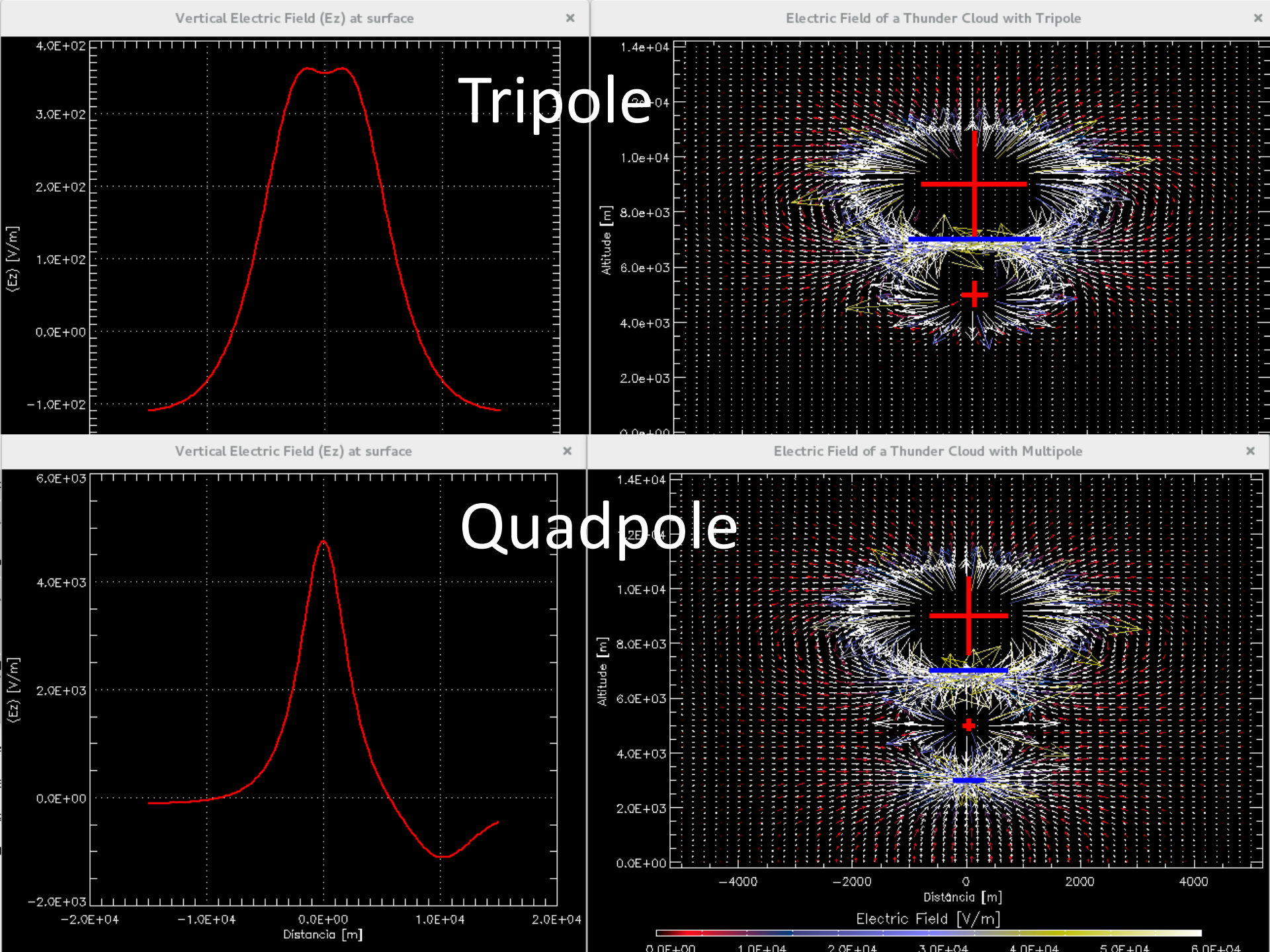


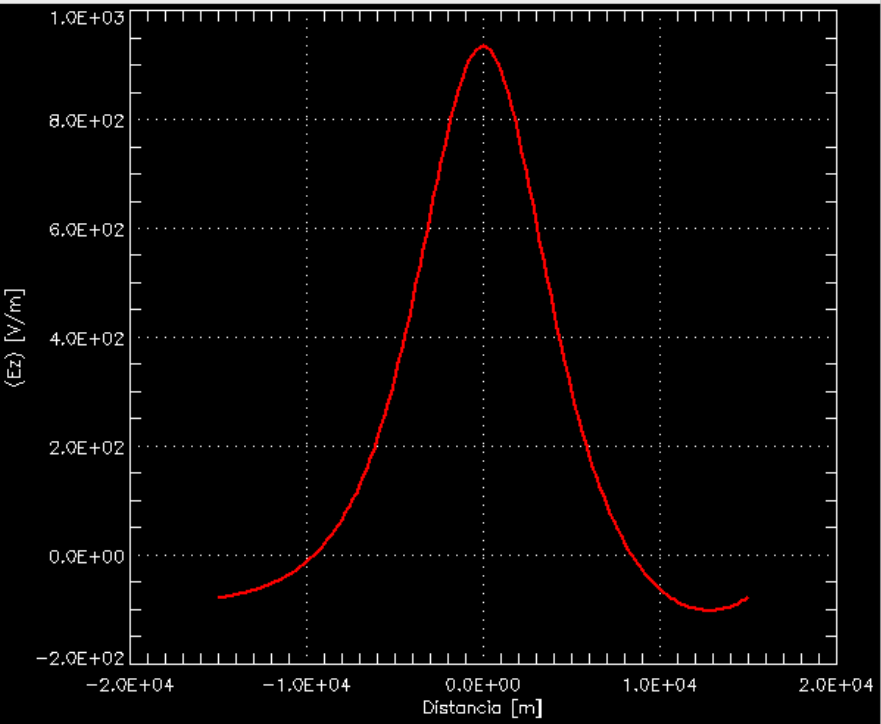
RADIO SIGNAL EMISSIONS

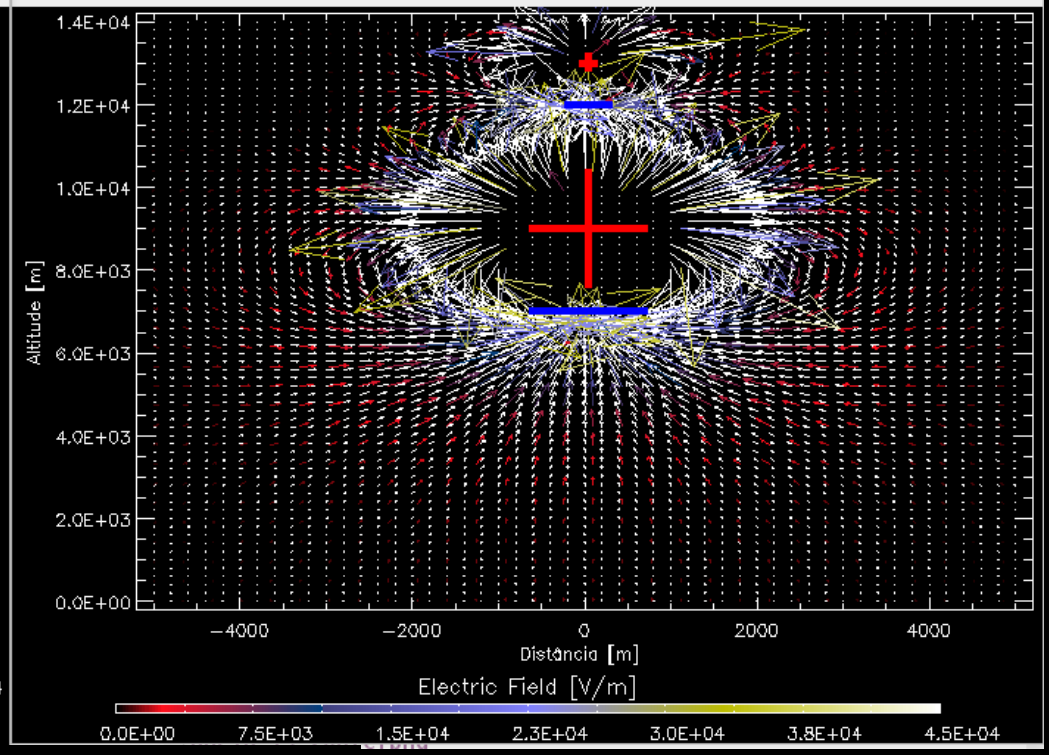


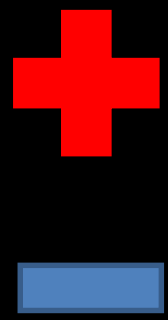

20
15
10
5
0
Height (km)
-40°C
0°C
0.0
0.2
0.4
0.6
0.8
1.0
Sferics/min/km

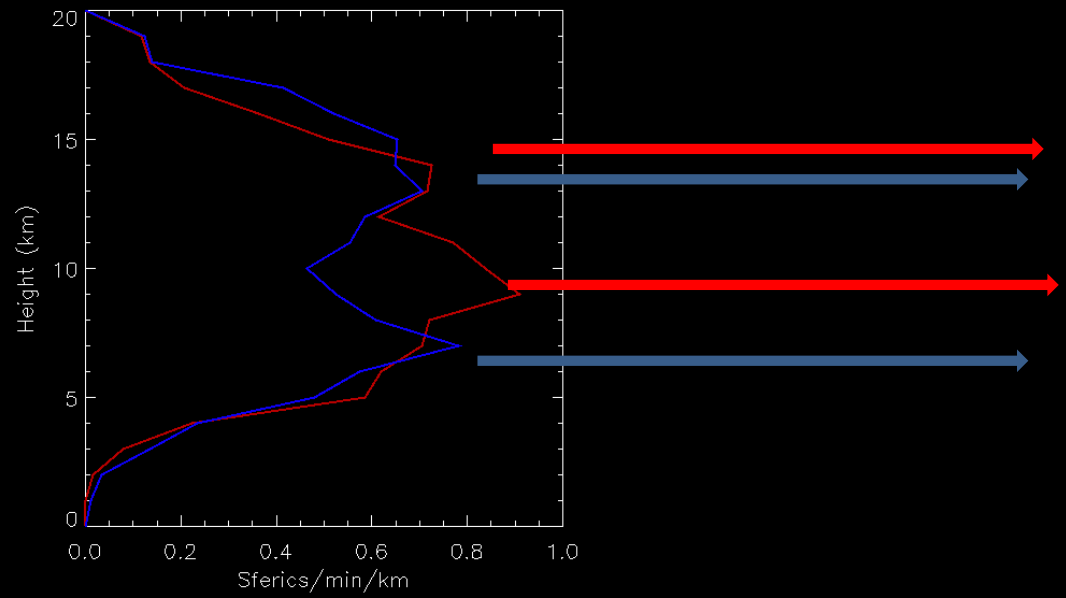

Vertical Electric Field (Ez) at surface
Electric Field of a Thunder Cloud with Dipole
Dipole Negative
Dipole Positive
⟨Ez⟩ [V/m]
Altitude [m]
Distance [m]
Electric Field [V/m]
0.0E+00
8.7E+03
1.7E+04
2.6E+04
3.5E+04
4.4E+04
5.2E+04

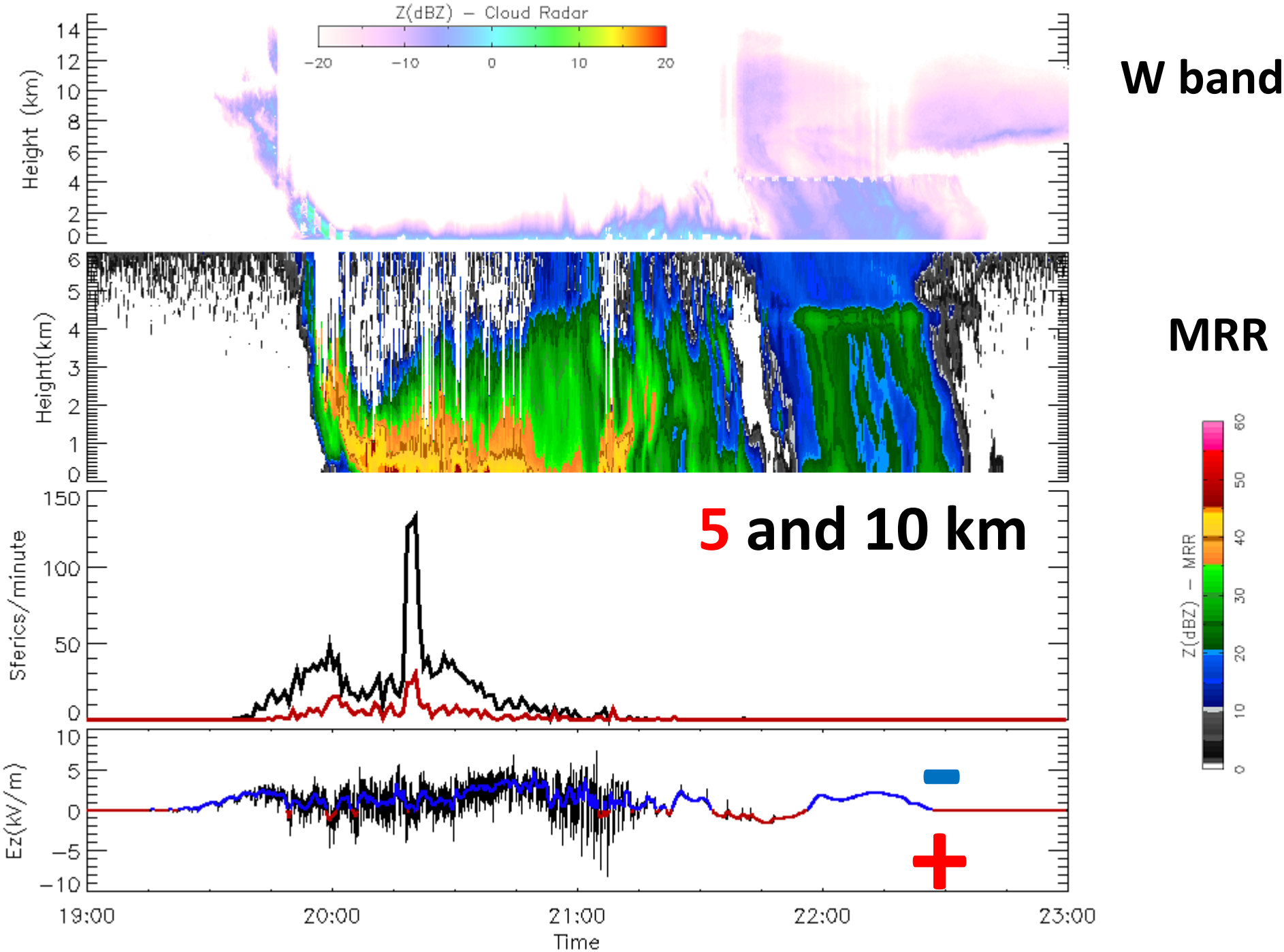

Tripole
Vertical Electric Field (Ez) at surface
⟨Ez⟩ [V/m]
4.0E+02
3.0E+02
2.0E+02
1.0E+02
0.0E+00
−1.0E+02
Electric Field of a Thunder Cloud with Tripole
Altitude [m]
1.4e+04
1.0e+04
8.0e+03
6.0e+03
4.0e+03
2.0e+03
Quadpole
Vertical Electric Field (Ez) at surface
⟨Ez⟩ [V/m]
6.0E+03
4.0E+03
2.0E+03
0.0E+00
−2.0E+03
−2.0E+04
−1.0E+04
0.0E+00
1.0E+04
2.0E+04
Distancia [m]
Electric Field of a Thunder Cloud with Multipole
Altitude [m]
1.4E+04
1.0E+04
8.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0E+00
−4000
−2000
0
2000
4000
Distancia [m]
Electric Field [V/m]
0.0E+00
1.0E+04
2.0E+04
3.0E+04
4.0E+04
5.0E+04
6.0E+04

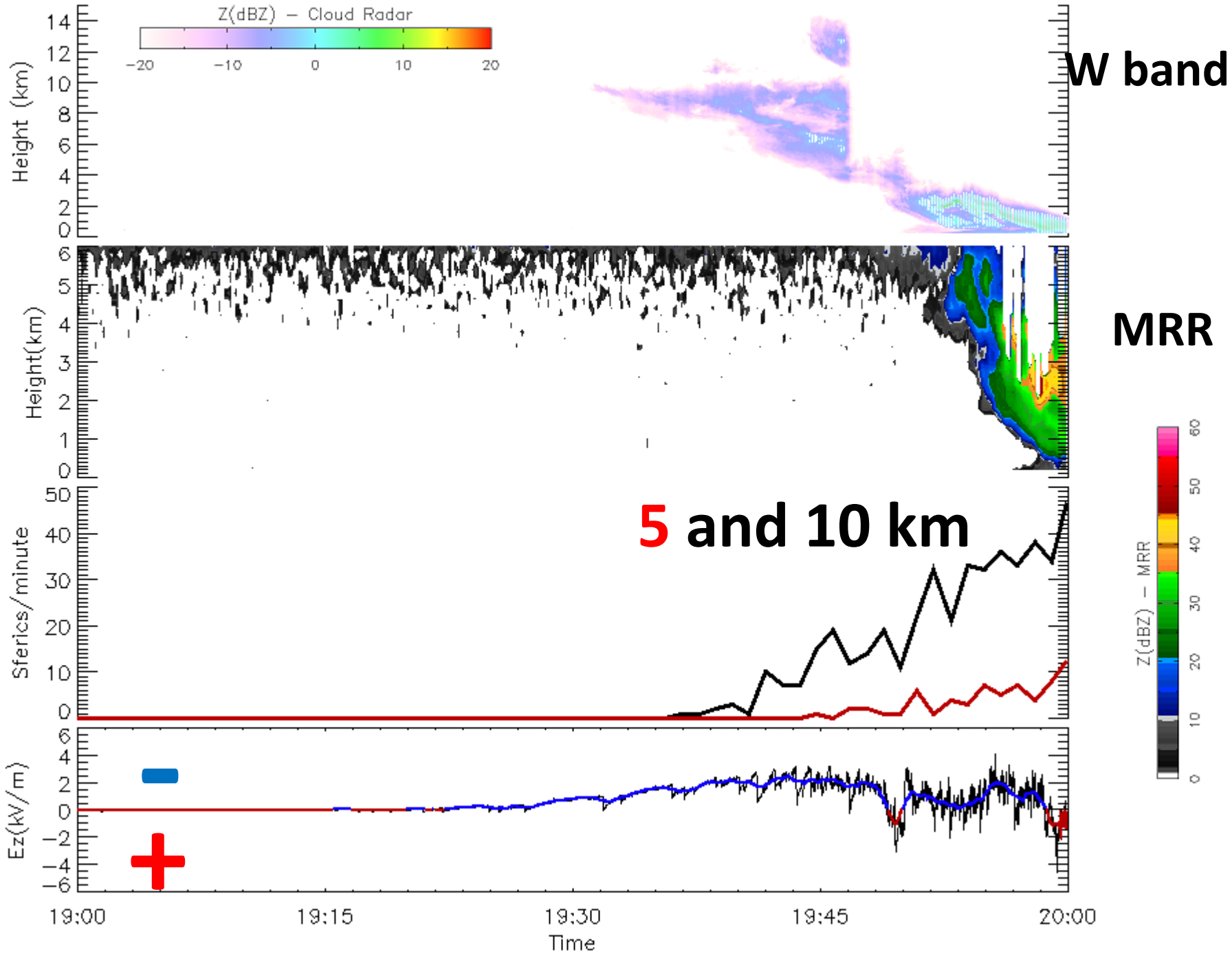

Vertical Electric Field (Ez) at surface
1.0E+03
8.0E+02
6.0E+02
4.0E+02
2.0E+02
0.0E+00
−2.0E+02
⟨Ez⟩ [V/m]
−2.0E+04
−1.0E+04
0.0E+00
1.0E+04
2.0E+04
Distancia [m]

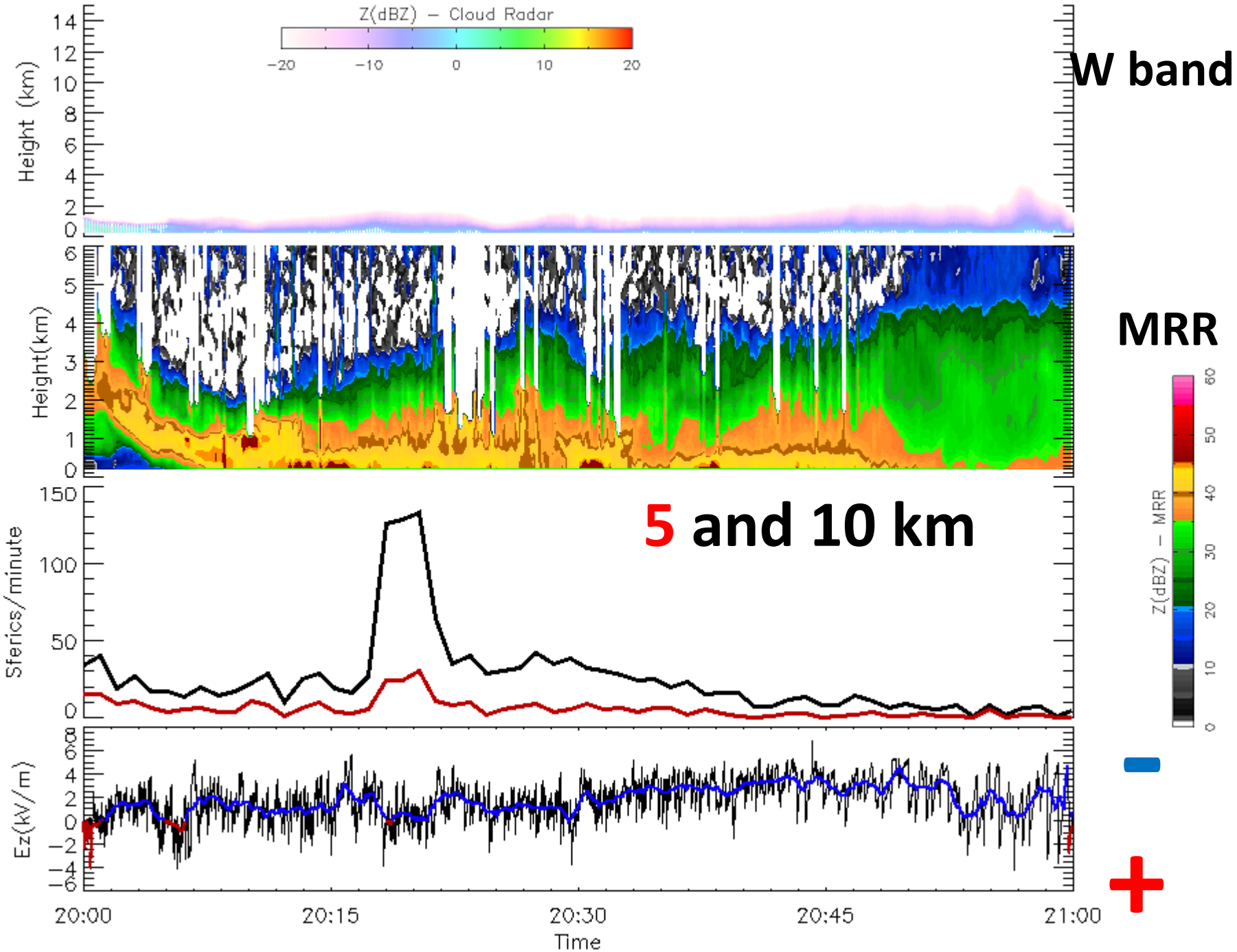

Electric Field of a Thunder Cloud with Multipole
1.4E+04
1.2E+04
1.0E+04
8.0E+03
6.0E+03
4.0E+03
2.0E+03
0.0E+00
Altitude [m]
−4000
−2000
0
2000
4000
Distância [m]
Electric Field [V/m]
0.0E+00
7.5E+03
1.5E+04
2.3E+04
3.0E+04
3.8E+04
4.5E+04

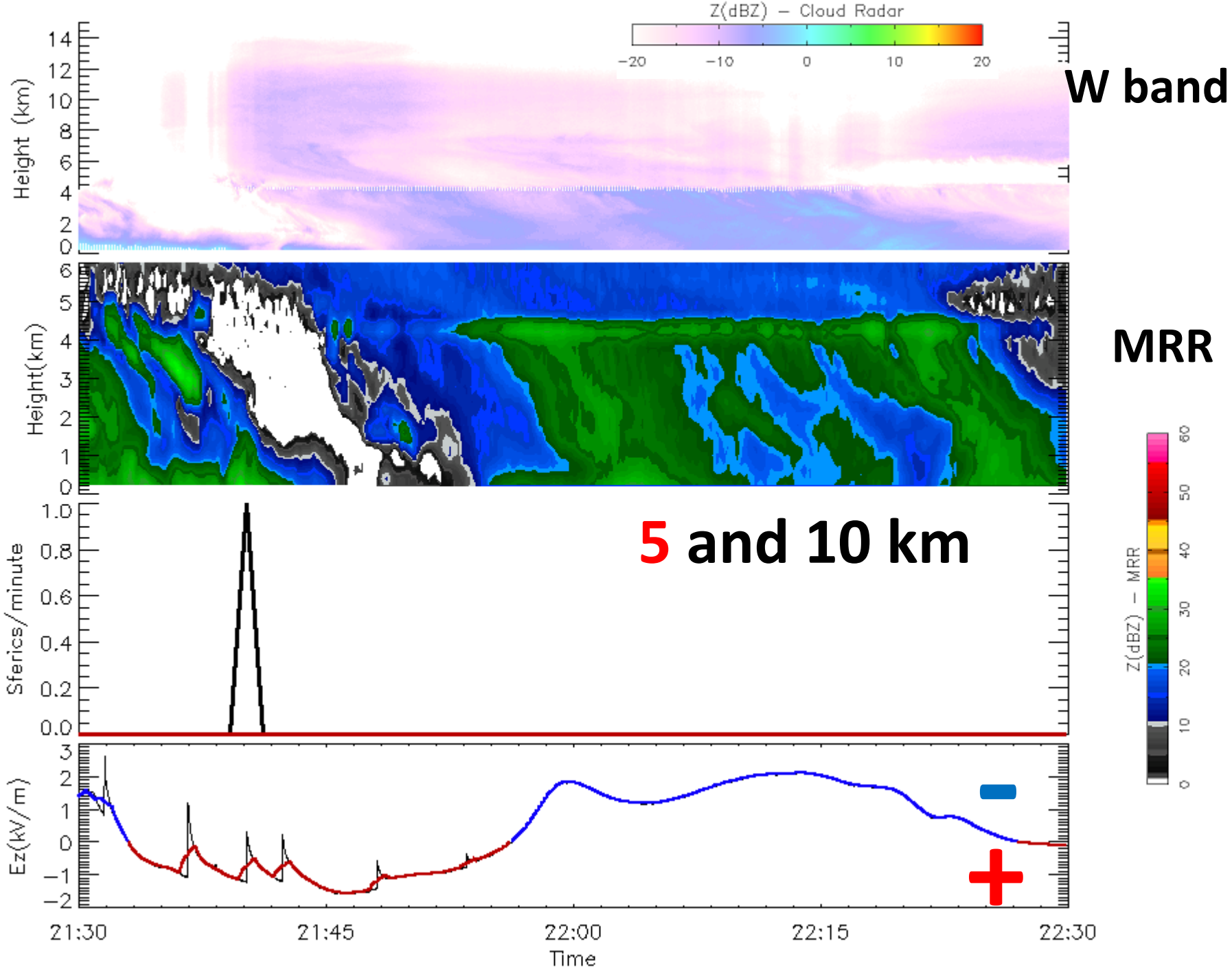



20
15
10
5
0
Height (km)
0.0
0.2
0.4
0.6
0.8
1.0
Sferics/min/km

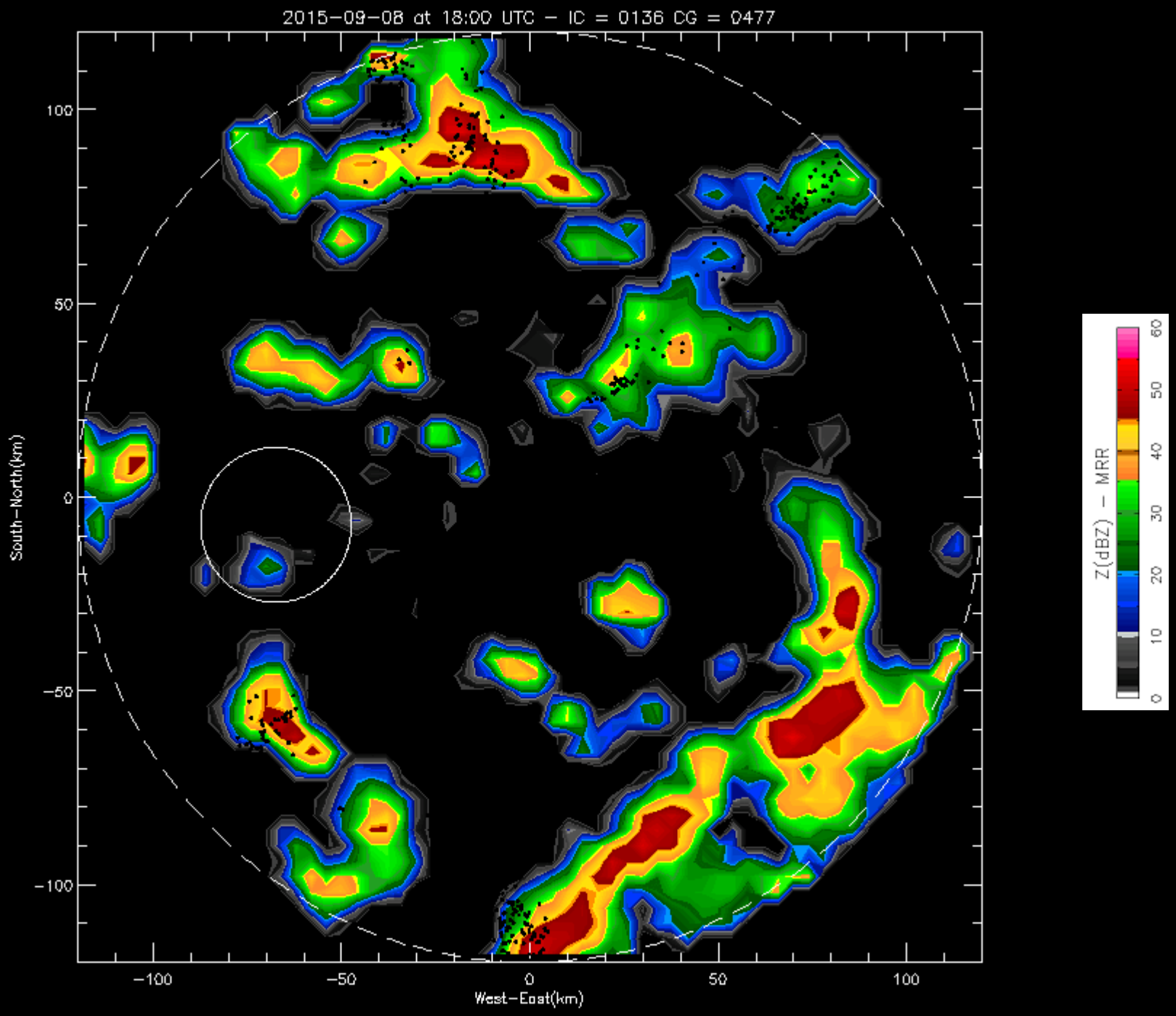

Z(dBZ) – Cloud Radar
−20
−10
0
10
20
Height (km)
W band
Height(km)
MRR
Z(dBZ) – MRR
0
10
20
30
40
50
60
Sferics/minute
5 and 10 km
Ez(kV/m)
19:00
20:00
21:00
22:00
23:00
Time


Z(dBZ) – Cloud Radar
Height (km)
W band
Height(km)
MRR
Sferics/minute
5 and 10 km
Z(dBZ) – MRR
Ez(kV/m)
19:00
19:15
19:30
19:45
20:00
Time

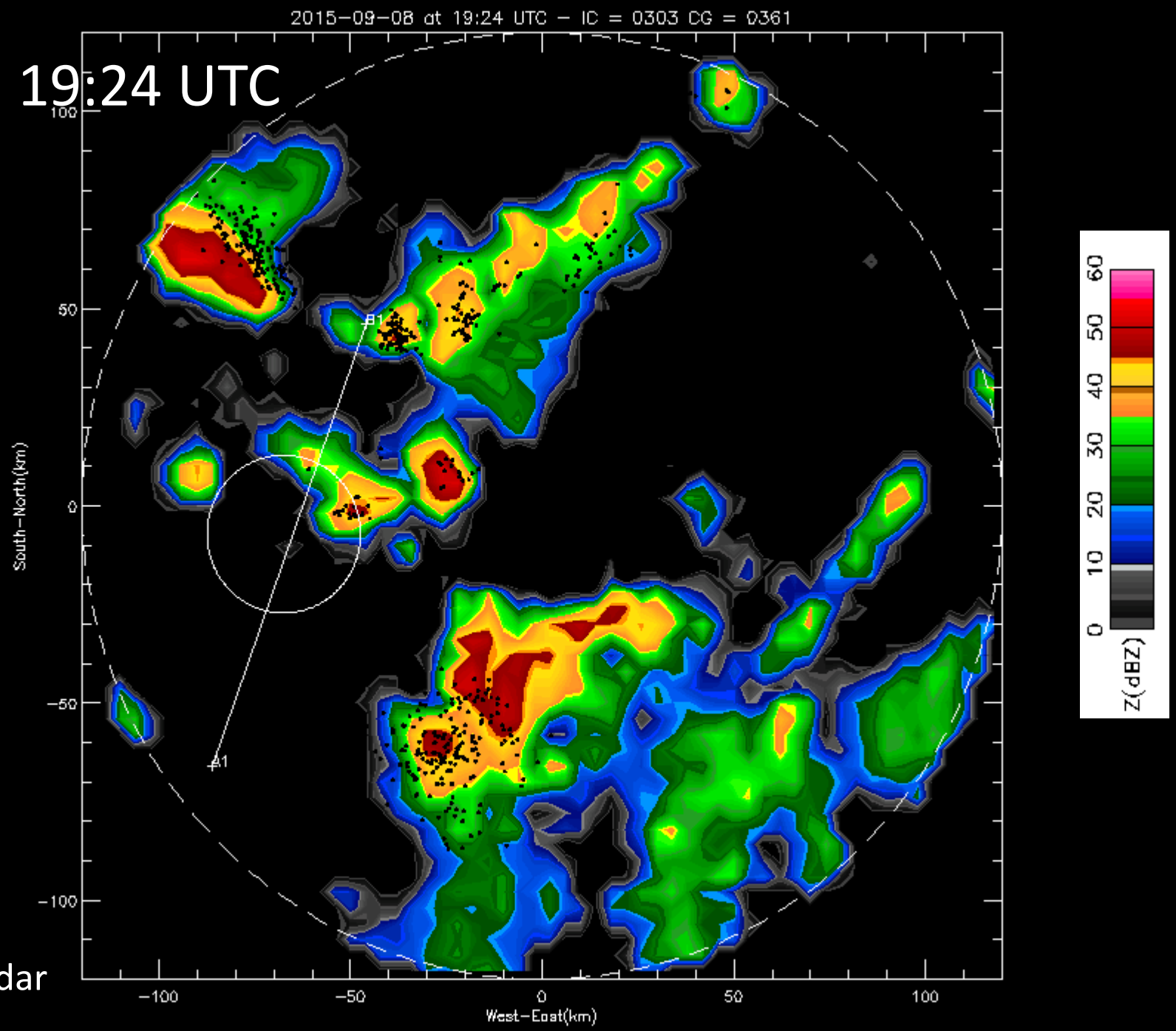

Z(dBZ) – Cloud Radar
−20
−10
0
10
20
Height (km)
W band
Height(km)
MRR
Z(dBZ) – MRR
Sferics/minute
5 and 10 km
Ez(kV/m)
20:00
20:15
20:30
20:45
21:00
Time


Z(dBZ) – Cloud Radar
−20
−10
0
10
20
W band
Height (km)
14
12
10
8
6
4
2
0
MRR
Height(km)
6
5
4
3
2
1
0
Z(dBZ) – MRR
60
50
40
30
20
10
0
5 and 10 km
Sferics/minute
1.0
0.8
0.6
0.4
0.2
0.0
Ez(kV/m)
3
2
1
0
−1
−2
21:30
21:45
22:00
22:15
22:30
Time

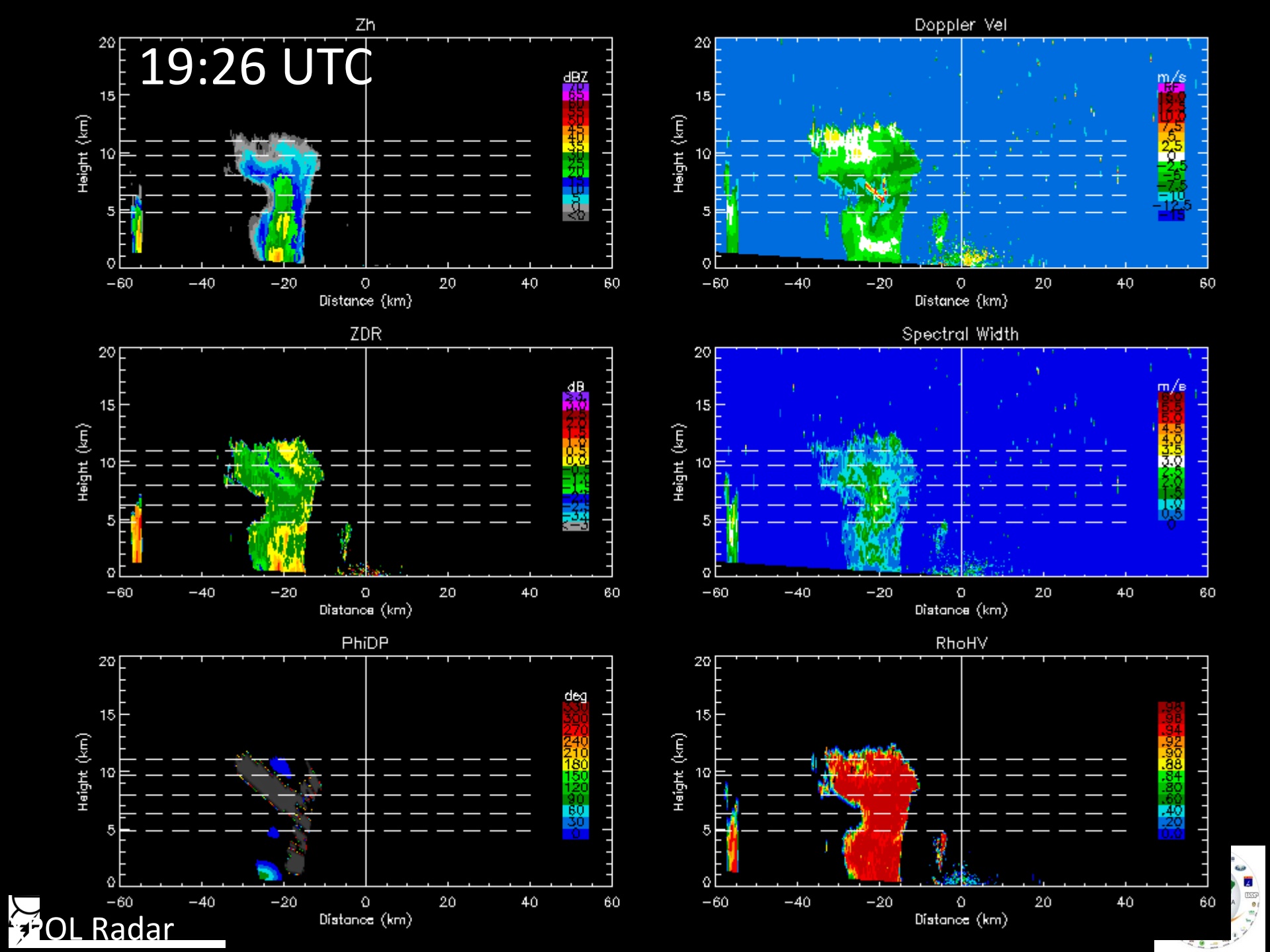
How does the thunderstorm evolve Temporally and Spatially?

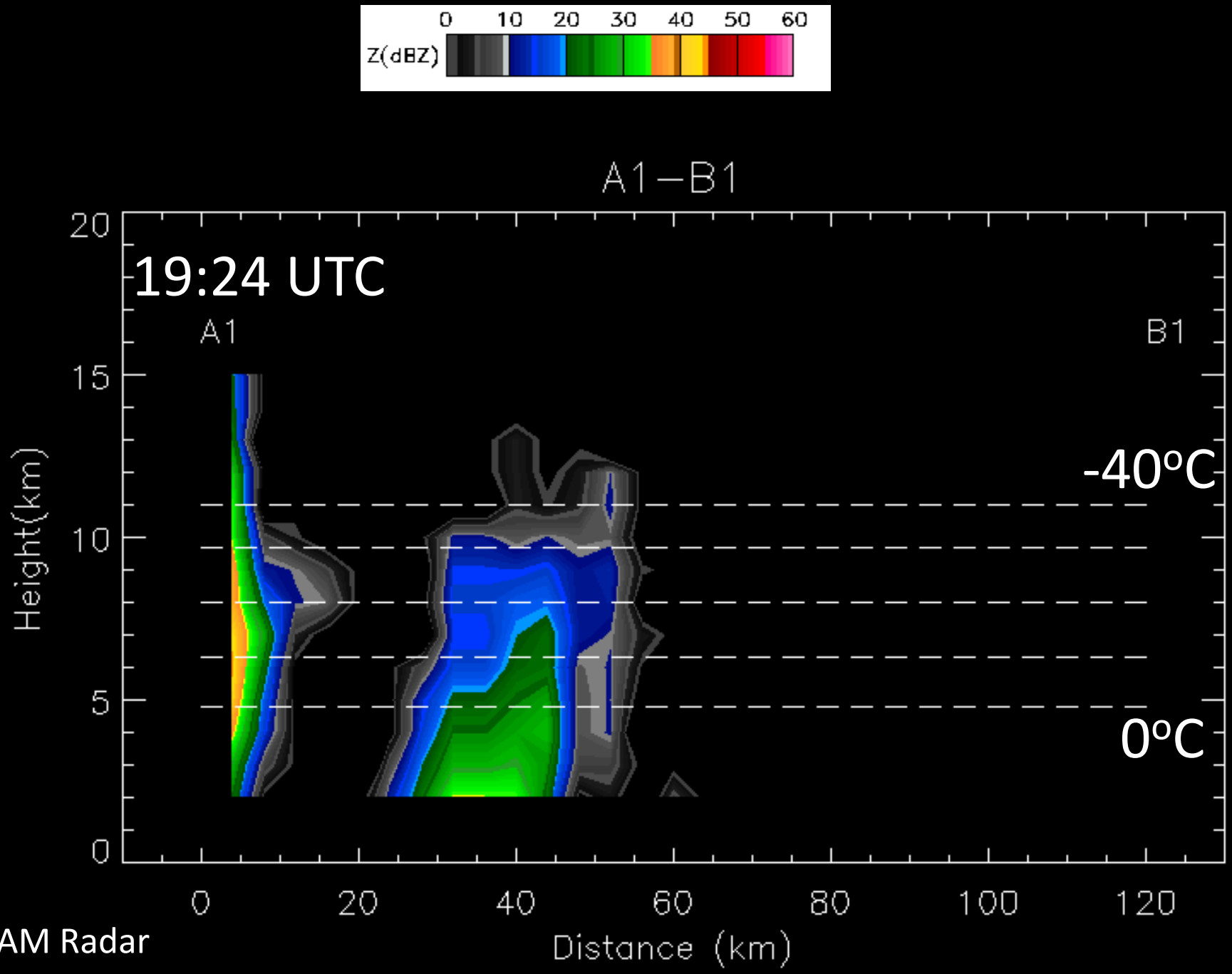

2015-09-08 at 18:00 UTC - IC = 0136 CG = 0477
South-North(km)
West-East(km)
100
50
0
-50
-100
-100
-50
0
50
100
Z(dBZ) - MRR
0
10
20
30
40
50
60

How does the thunderstorm look inside?

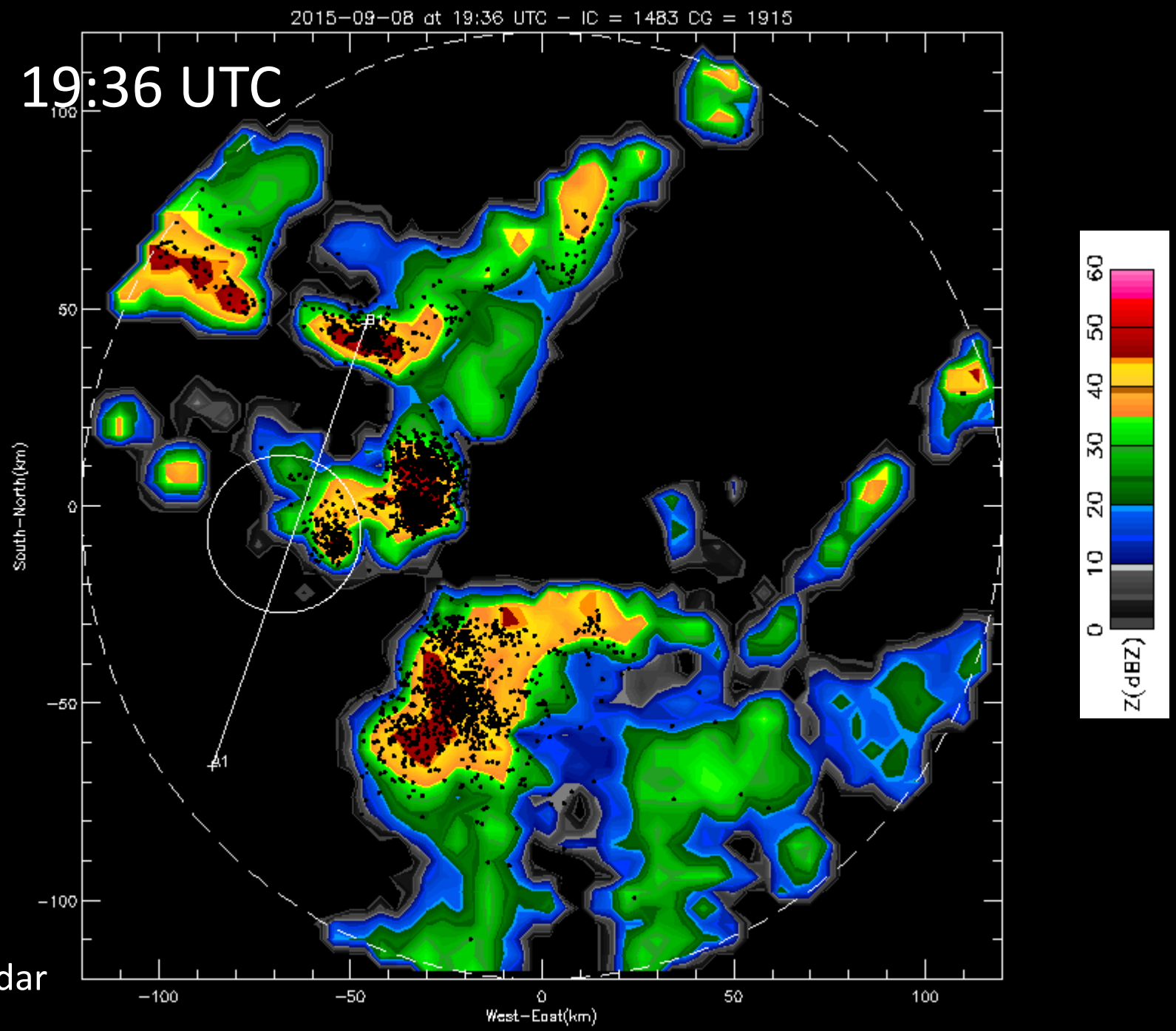

2015-09-08 at 19:24 UTC - IC = 0303 CG = 0361
19:24 UTC
South-North(km)
West-East(km)
100
50
0
-50
-100
B1
A1
Z(dBZ)
0
10
20
30
40
50
60

SIPAM Radar

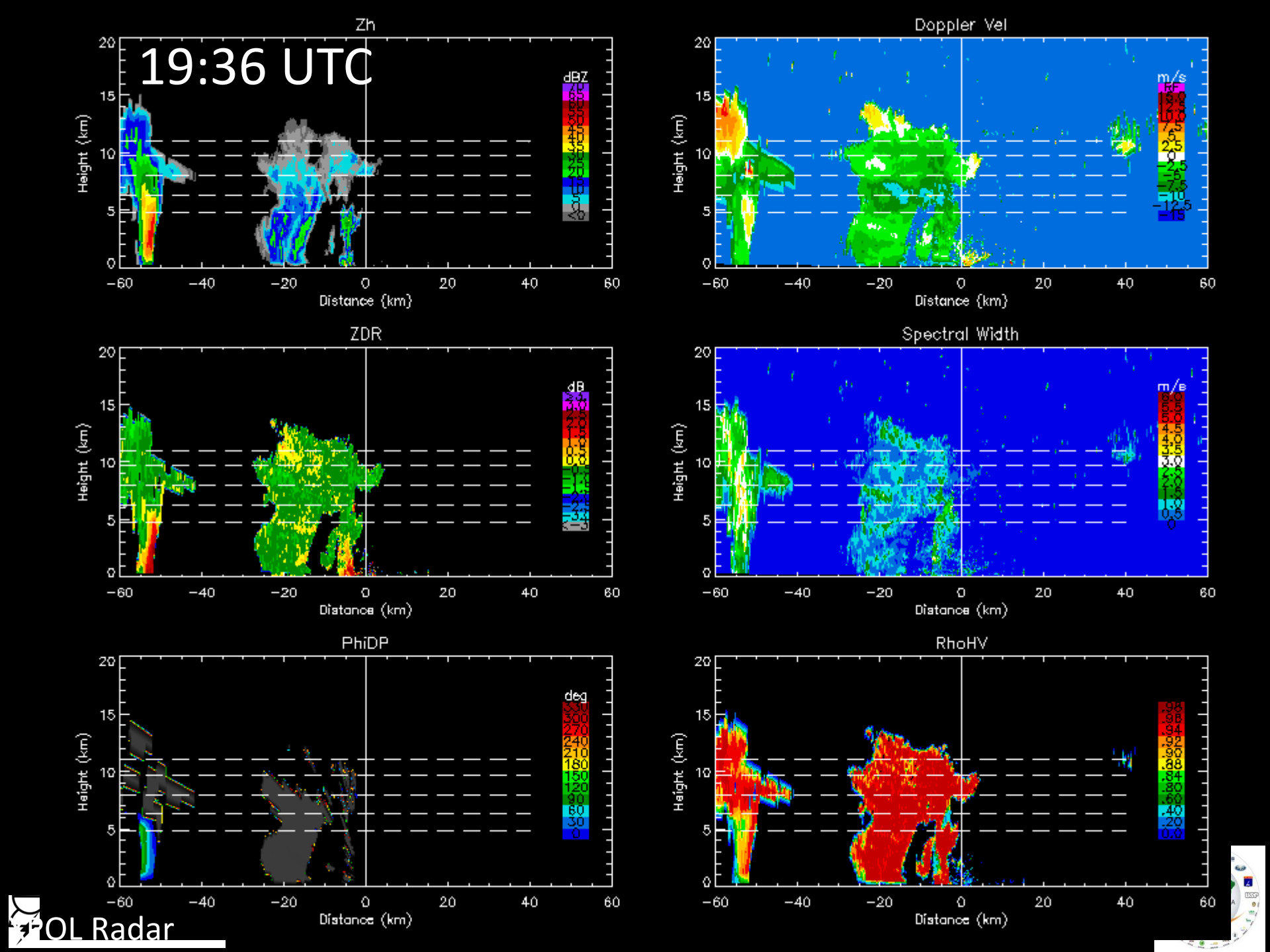

19:26 UTC
Zh
dBZ
Doppler Vel
m/s
ZDR
dB
Spectral Width
m/s
PhiDP
deg
RhoHV
Height (km)
Distance (km)
POL Radar

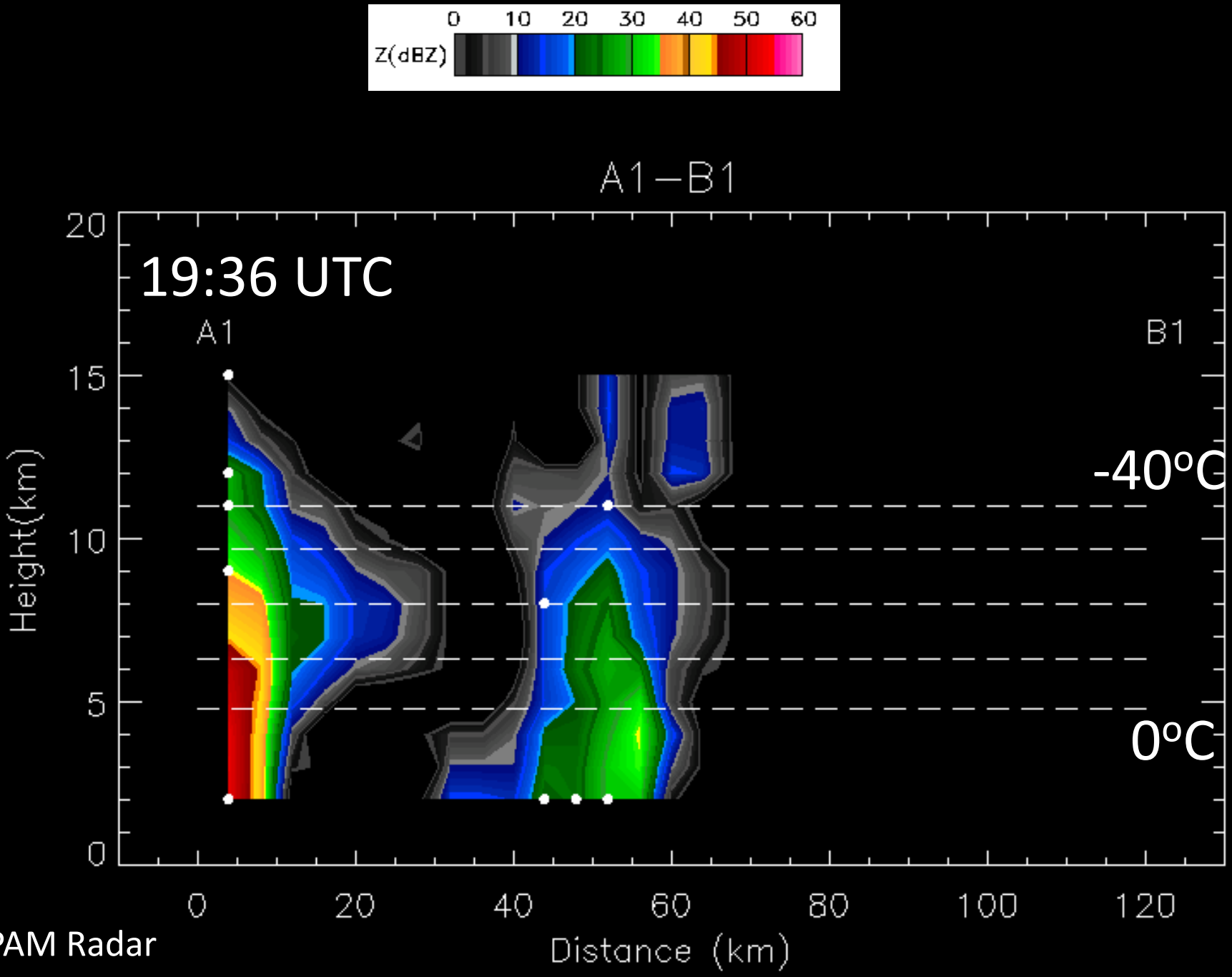

Z(dBZ)
0
10
20
30
40
50
60
A1–B1
19:24 UTC
A1
B1
-40ºC
0ºC
Height(km)
20
15
10
5
0
0
20
40
60
80
100
120
Distance (km)

SIPAM Radar

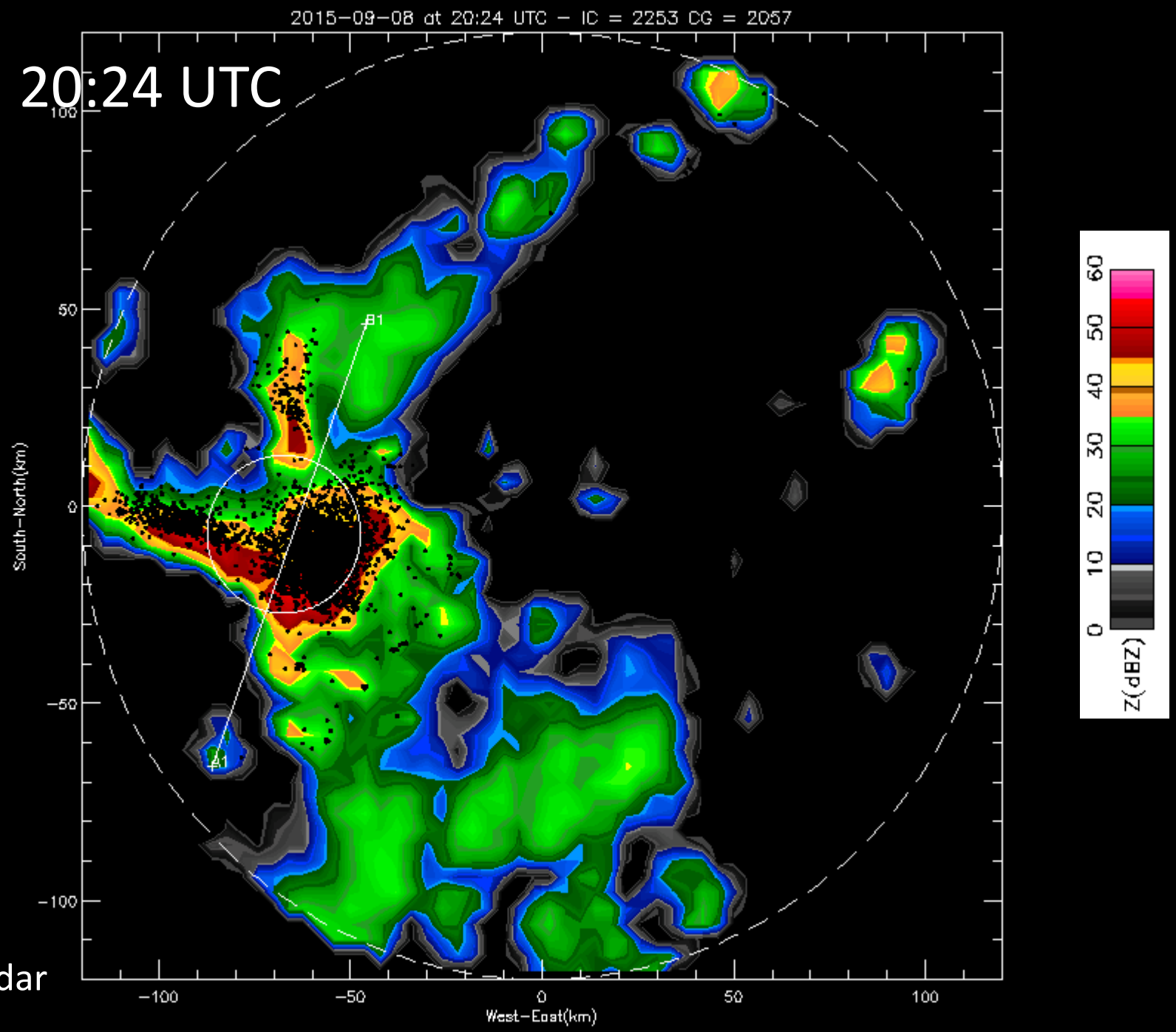

2015-09-08 at 19:36 UTC - IC = 1483 CG = 1915
19:36 UTC
South-North(km)
West-East(km)
100
50
0
-50
-100
-100
-50
0
50
100
B1
A1
Z(dBZ)
0
10
20
30
40
50
60

SIPAM Radar

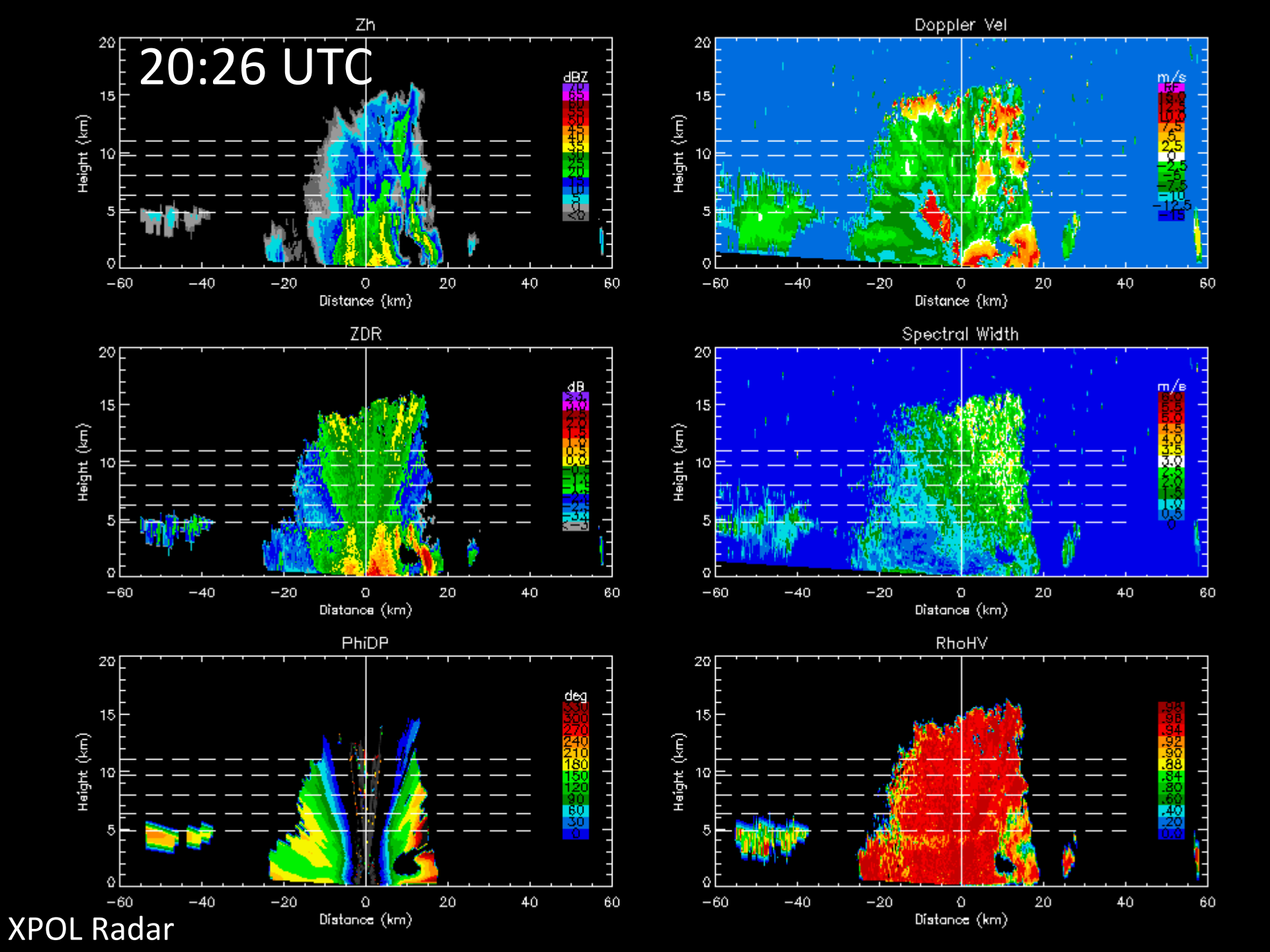

19:36 UTC
Zh
dBZ
Doppler Vel
m/s
ZDR
dB
Spectral Width
m/s
PhiDP
deg
RhoHV
Height (km)
Distance (km)
POL Radar

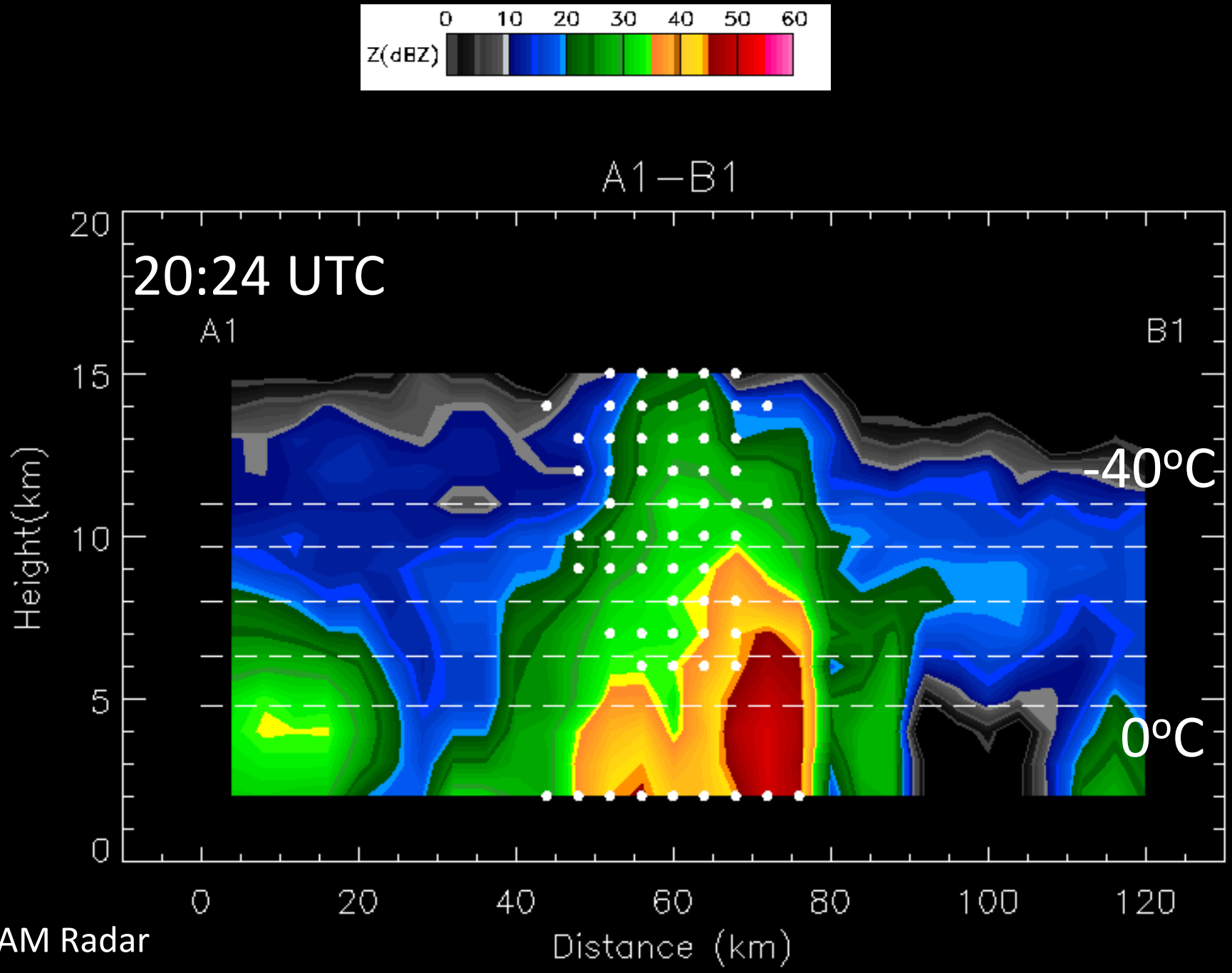

Z(dBZ)
0
10
20
30
40
50
60
A1–B1
19:36 UTC
A1
B1
-40ºC
0ºC
Height(km)
0
5
10
15
20
0
20
40
60
80
100
120
Distance (km)

SIPAM Radar

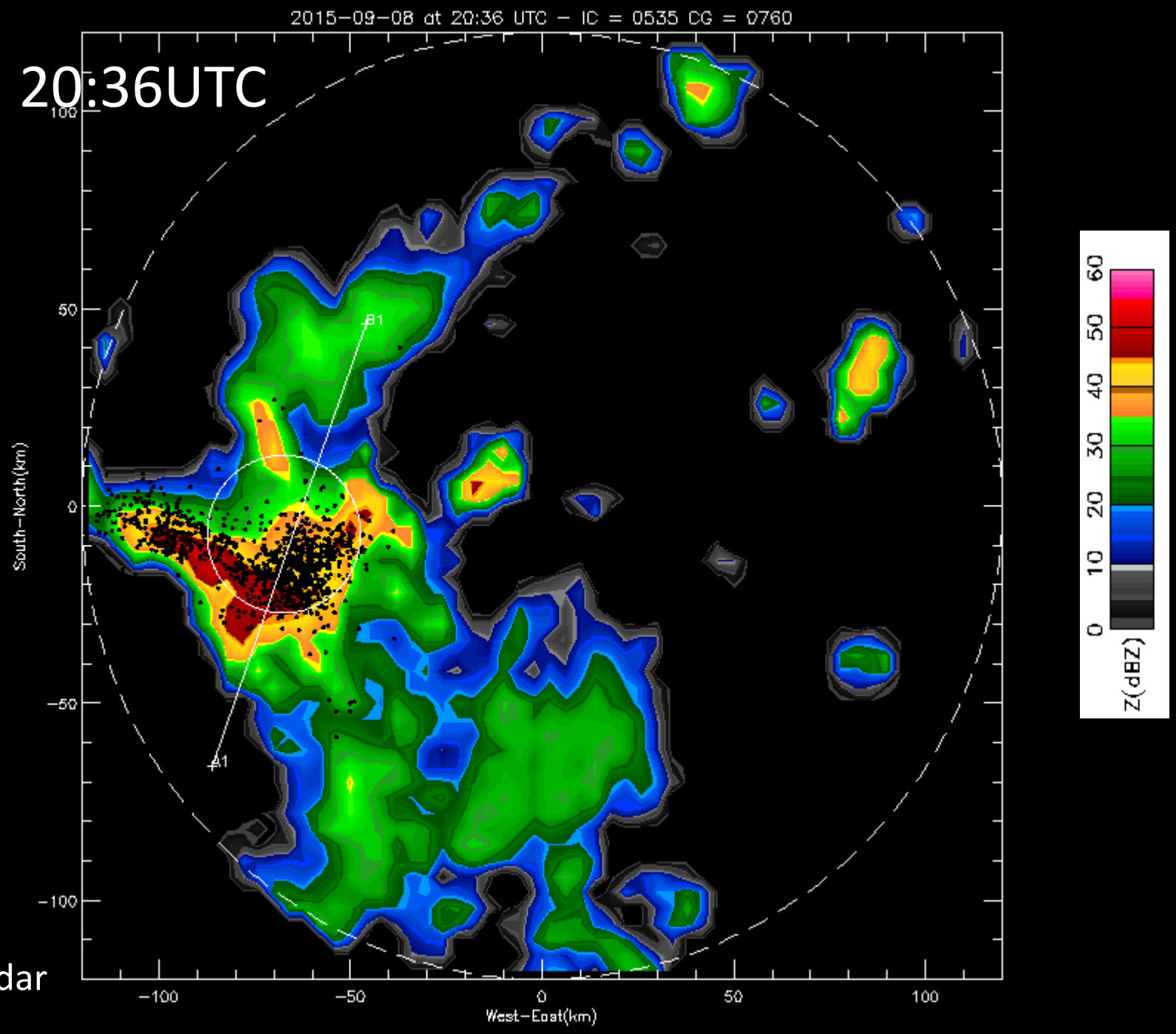

2015-09-08 at 20:24 UTC - IC = 2253 CG = 2057
20:24 UTC
B1
A1
South-North(km)
West-East(km)
100
50
0
-50
-100
-100
-50
0
50
100
Z(dBZ)
0
10
20
30
40
50
60

SIPAM Radar

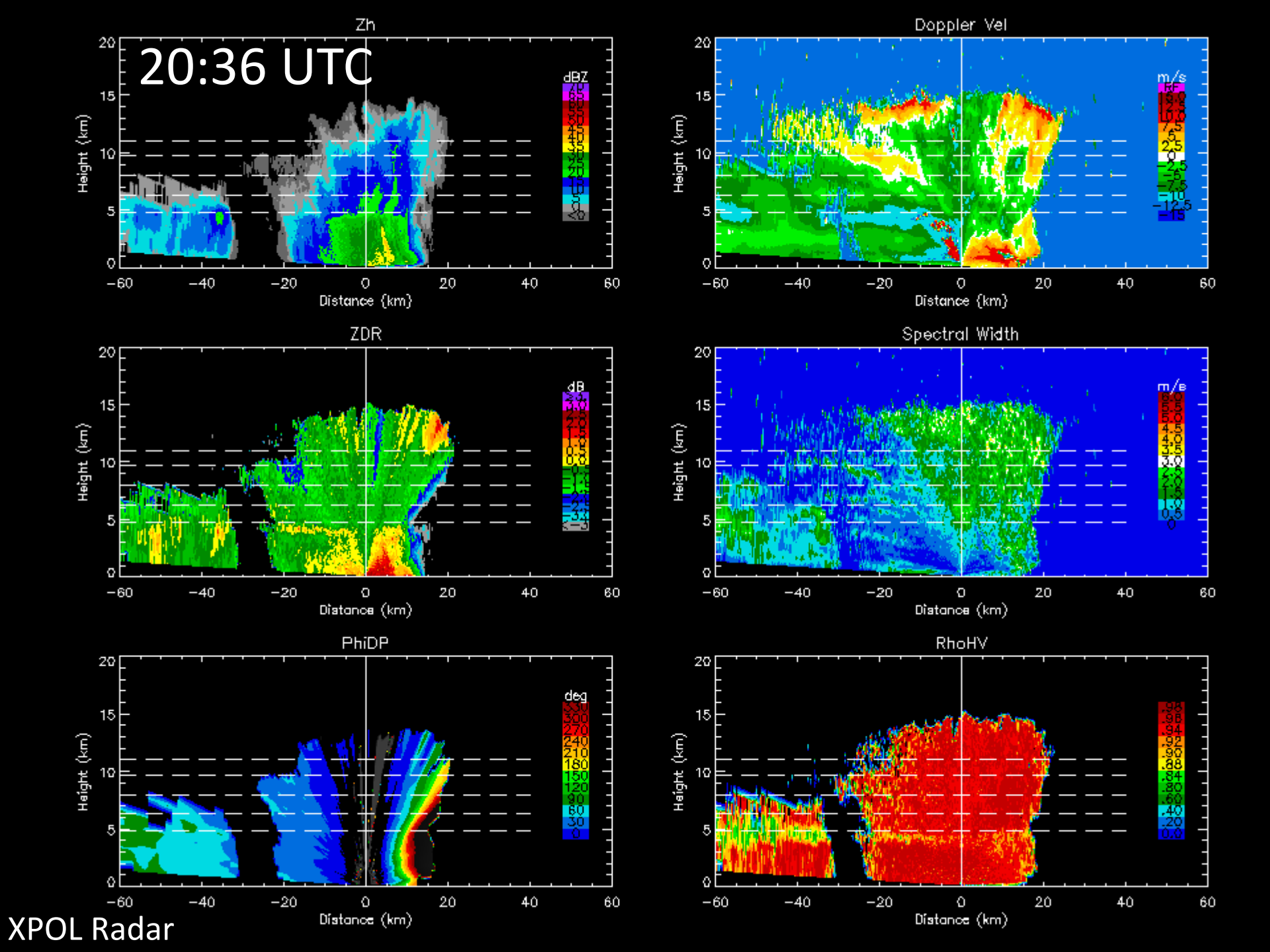

20:26 UTC
Zh
dBZ
Doppler Vel
m/s
ZDR
dB
Spectral Width
m/s
PhiDP
deg
RhoHV
Height (km)
Distance (km)
XPOL Radar

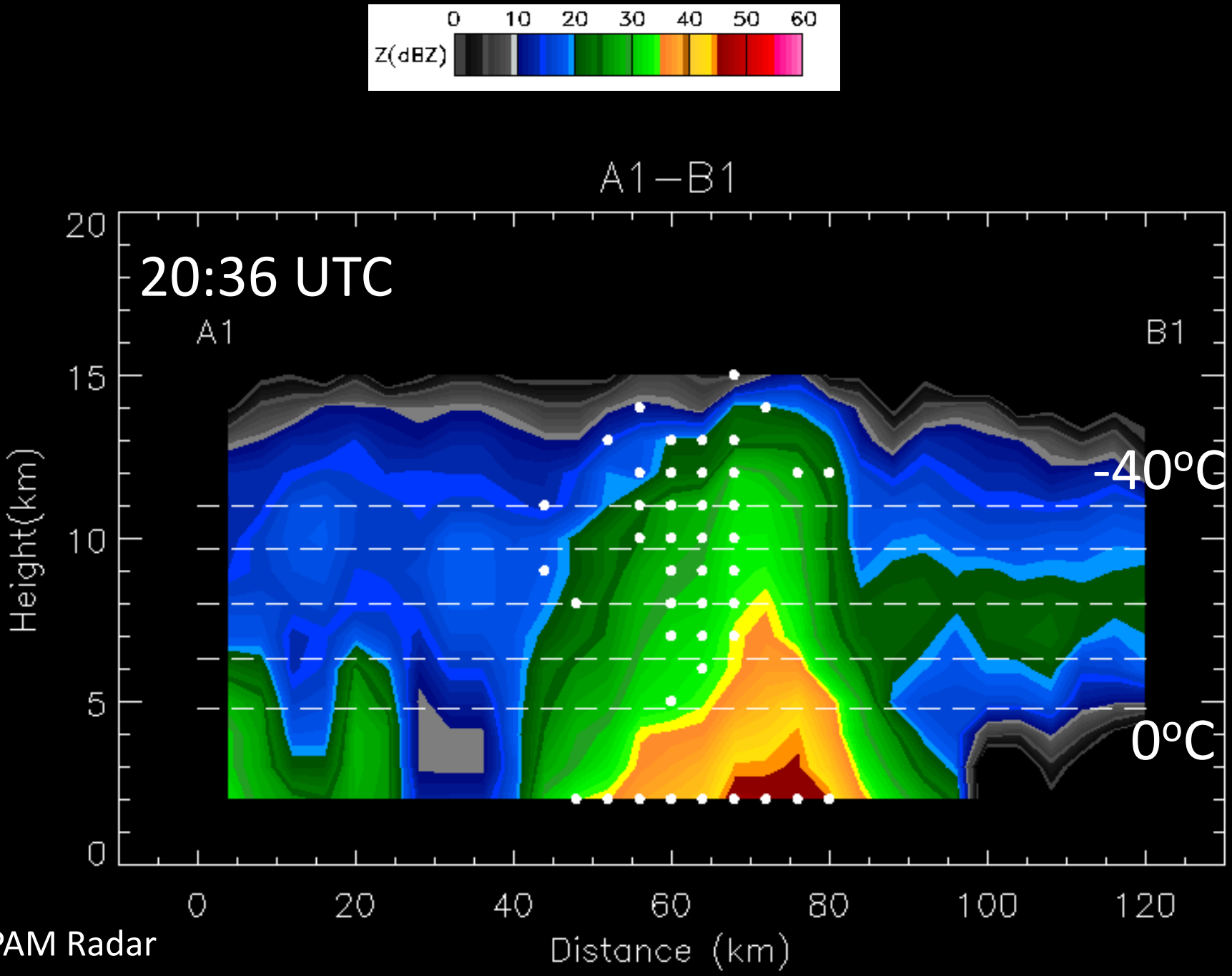

Z(dBZ)
0
10
20
30
40
50
60
A1–B1
20:24 UTC
A1
B1
-40ºC
0ºC
Height(km)
Distance (km)
0
5
10
15
20
0
20
40
60
80
100
120

SIPAM Radar


2015-09-08 at 20:36 UTC - IC = 0535 CG = 0760
20:36UTC
South-North(km)
West-East(km)
100
50
0
-50
-100
B1
A1
Z(dBZ)
0
10
20
30
40
50
60

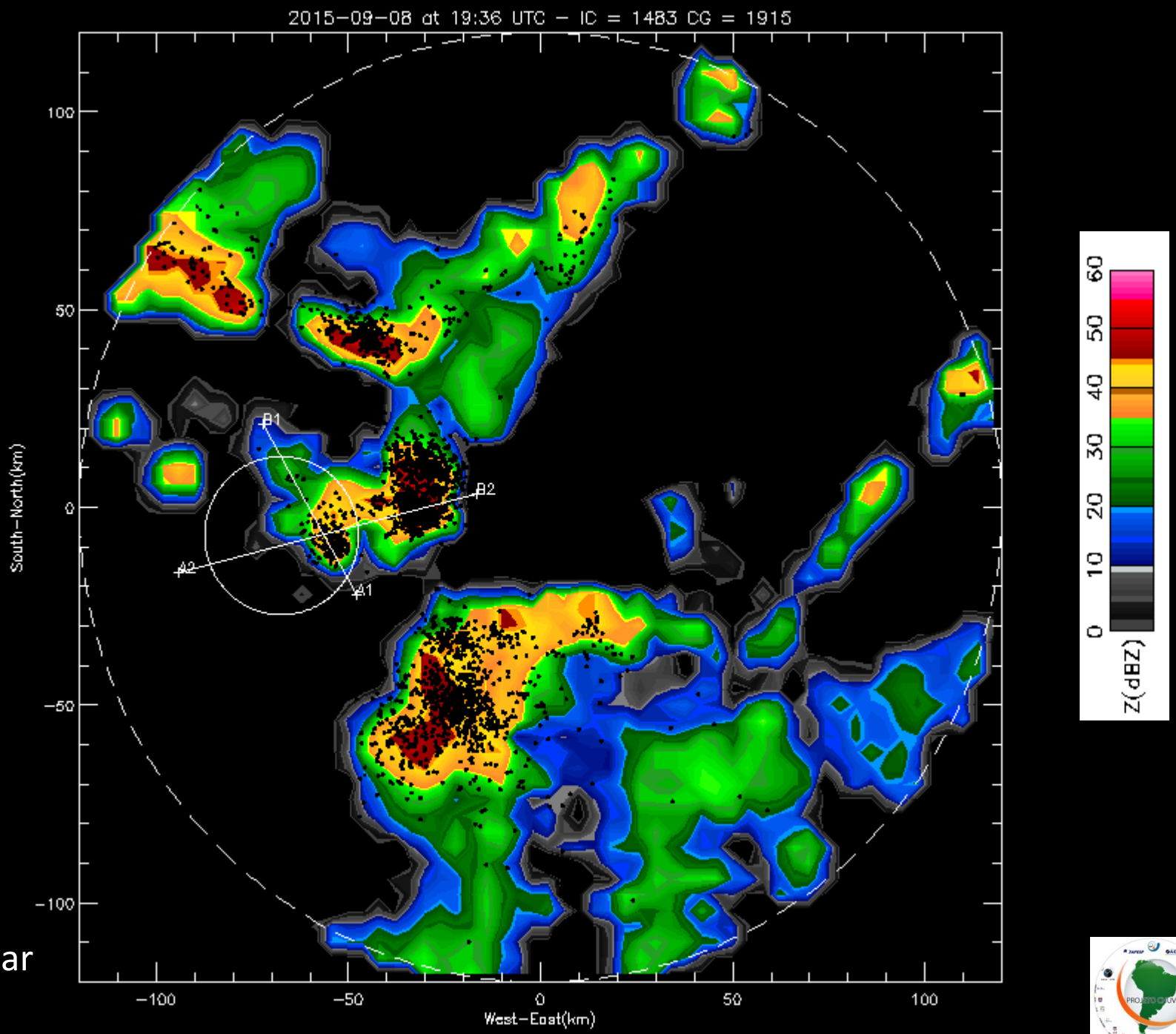
SIPAM Radar


20:36 UTC
Zh
dBZ
Doppler Vel
m/s
ZDR
dB
Spectral Width
m/s
PhiDP
deg
RhoHV
Height (km)
Distance (km)
XPOL Radar


Z(dBZ)
0
10
20
30
40
50
60
A1–B1
20:36 UTC
A1
B1
-40ºC
0ºC
Height(km)
0
5
10
15
20
0
20
40
60
80
100
120
Distance (km)

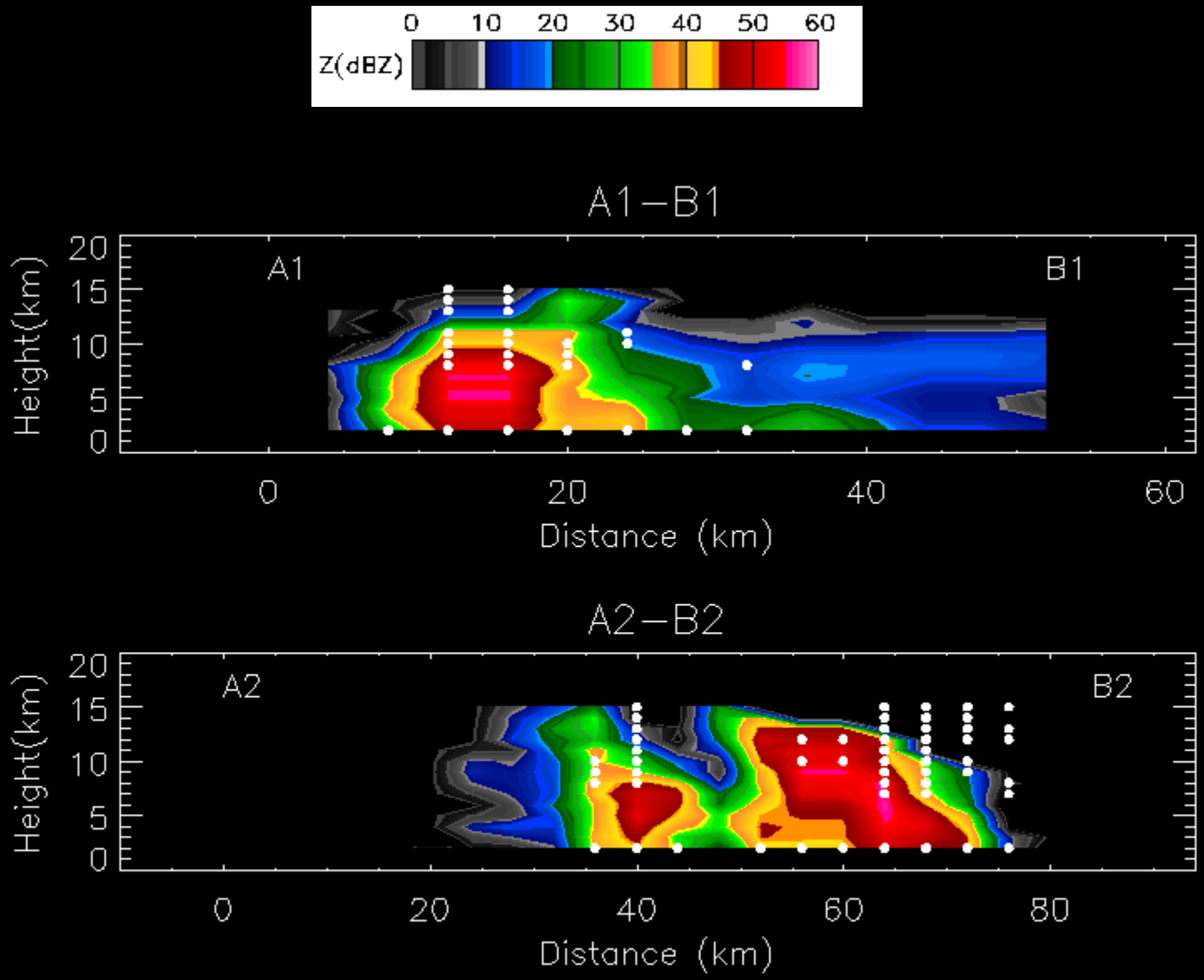
SIPAM Radar

What did happen to have these lightning spots?



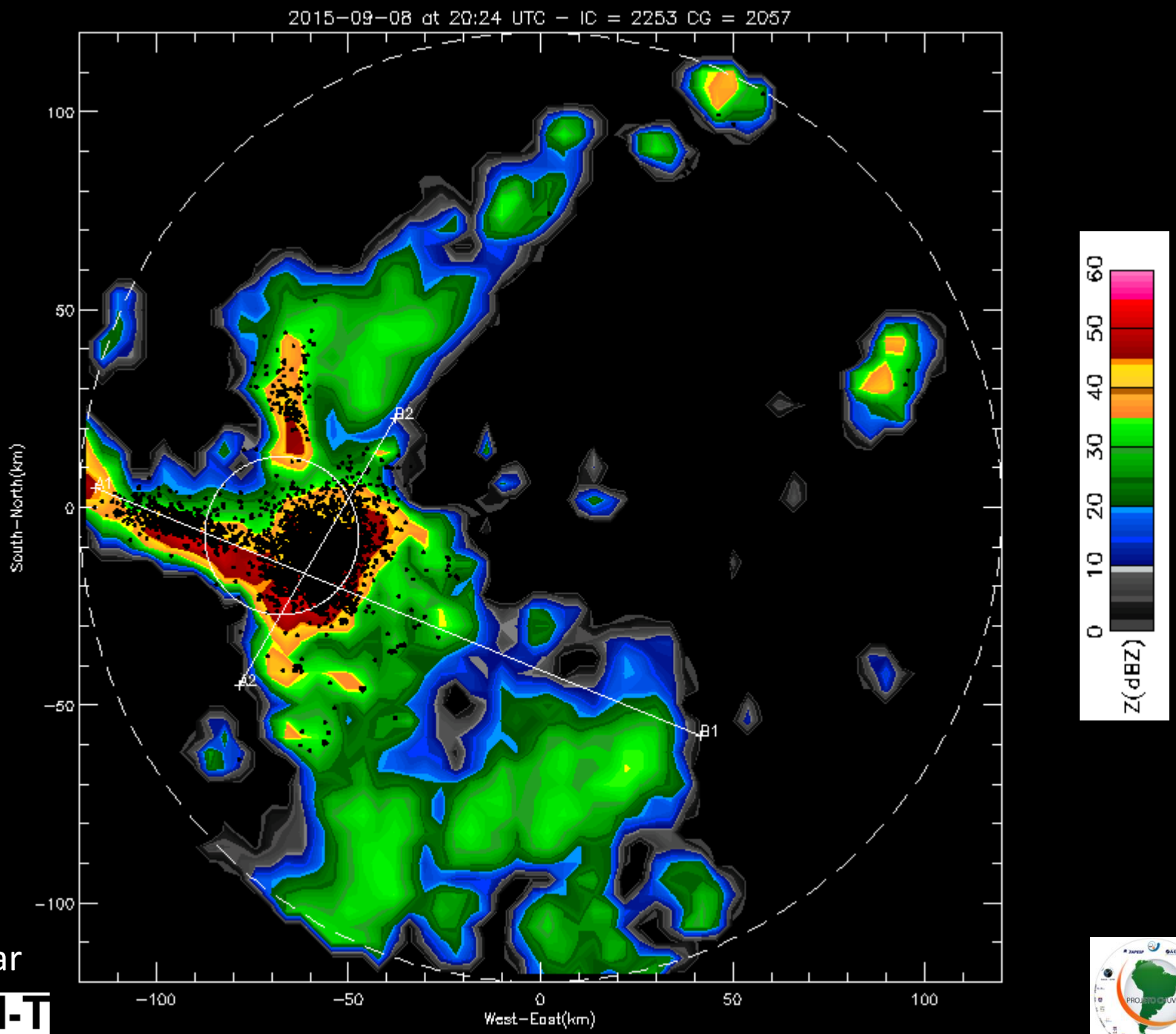
SIPAM Radar

STORM



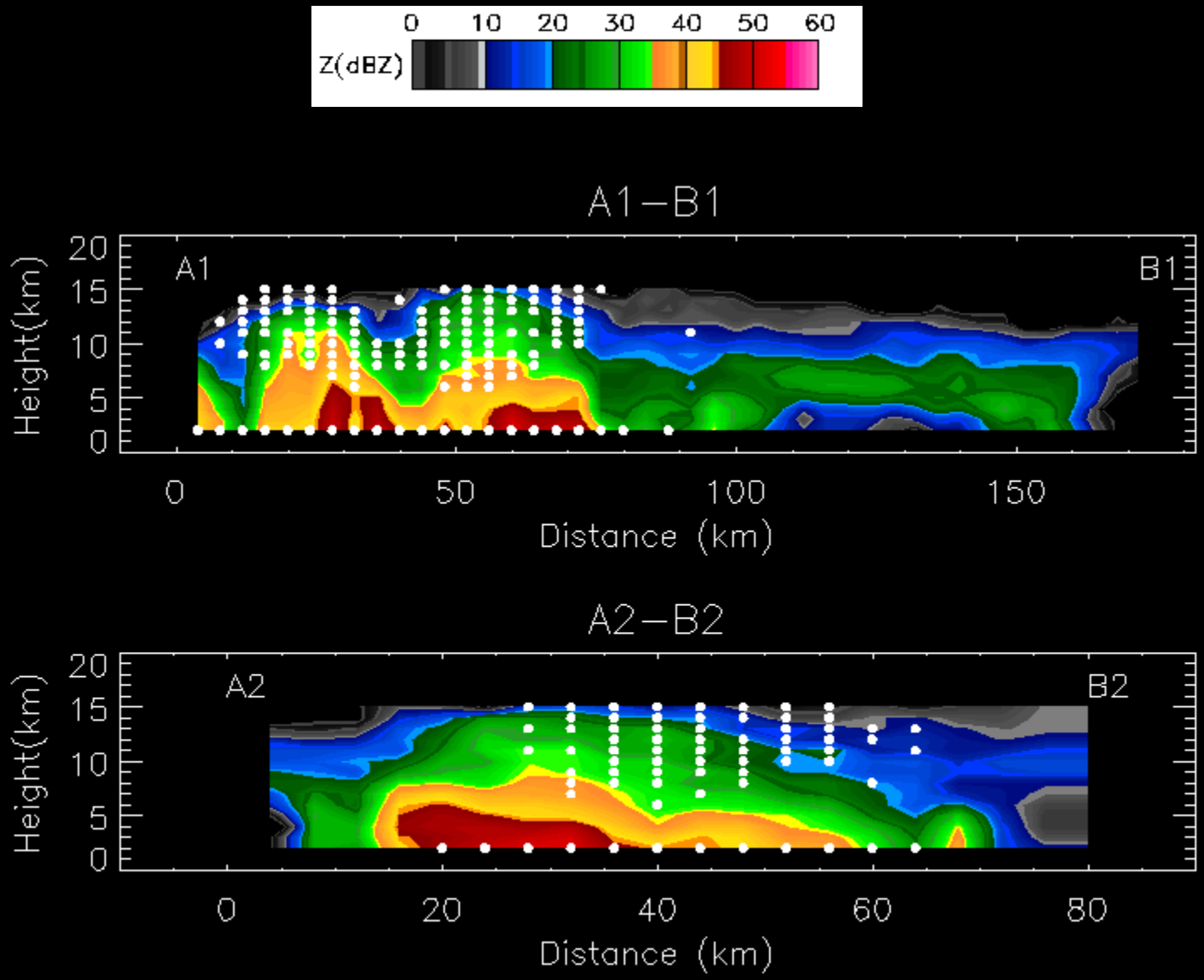
SIPAM Radar

STORM-T



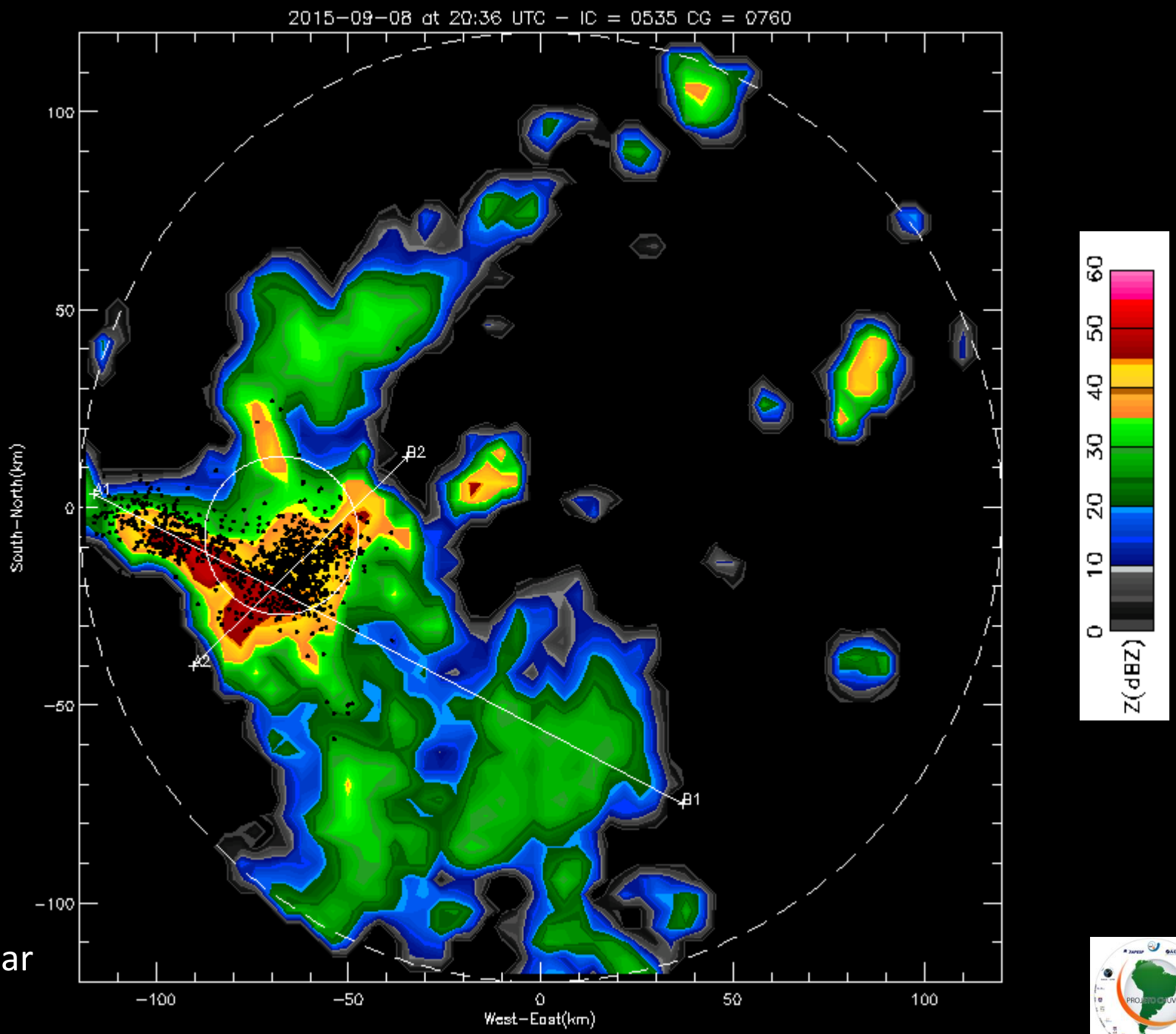
SIPAM Radar

STORM-T



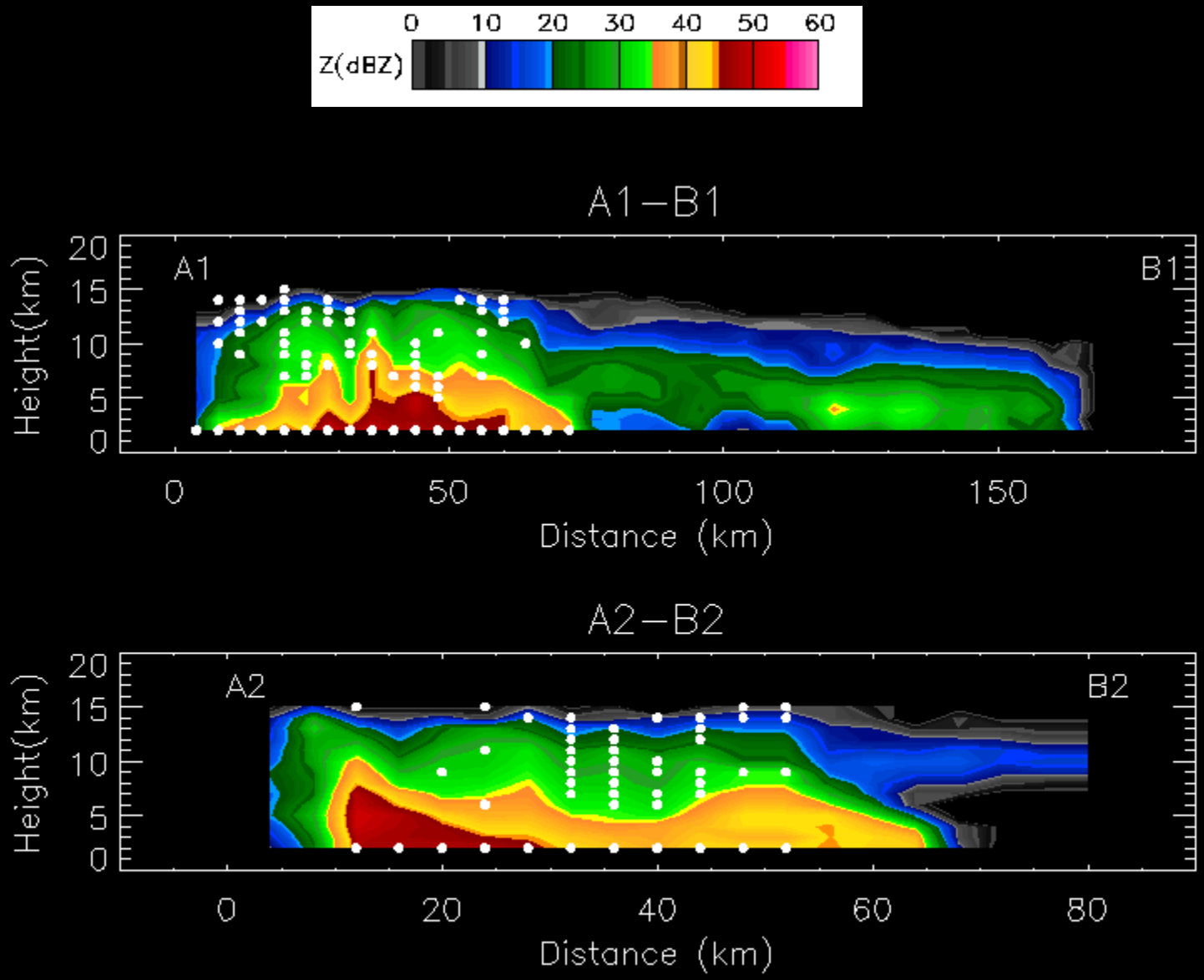
STORM-T

SIPAM Radar



SIPAM Radar

STORM



SIPAM Radar

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Conclusions

- Lightning activity increases as transition season advances from dry to wet
- Diurnal convection favors lightning activity
  - 16 trough 21 UTZ (12-17 Local Time)
- The river + city circulation play an important role on the convection/lightning enhancement, boosting the vertical shear.
- Vertical Electrical field oscillation points to Negative Di-Tri-Quadipole configuration.

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Conclusions

- IC charge density sources point to a Quadipole configuration:
  - Q- at -10/20 & -50°C and Q+ at -30 & -55°C
- CGs are observed over convective cores
- ICs are observed aloft over the turbulent cores
- 35 dBZ (S-Band) reaches as high as 10-12 km
- > 50 dBZ above 10 km over Severe Activity and tilted (shear).

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Next Steps

- Correct XPOL for power decay, rain attenuation and radome wetting.
- Apply hydrometeor classification
- Run the inverse problem of Coulombs Law by combining Ez, LINET and XPOL to infer the charge centers
- Inspect the role of turbulence and hydrometeor types on the lightning activity through numerical simulations.

Acknowledgements

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THANKS !!!!!
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