The LASS project at the Pierre Auger observatory

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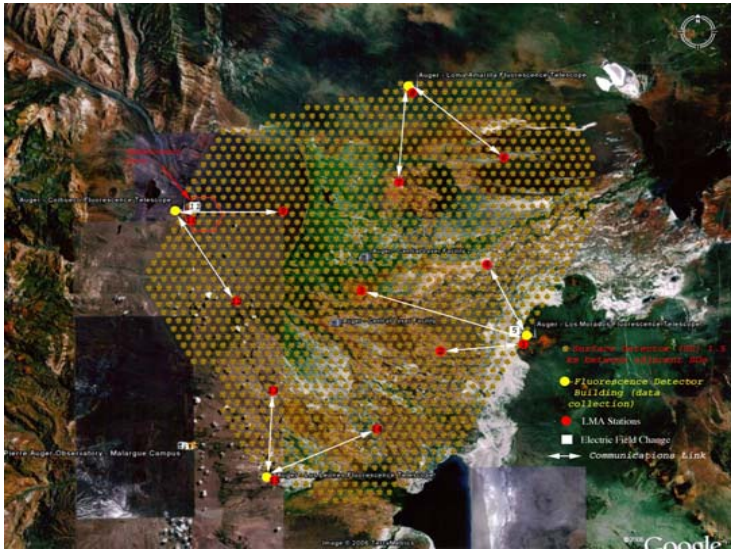


LASS = Lightning Air Shower Study

Goal: Lightning and Auger Measurements

Lightning above
Los Leones
telescope@Auger

➔ **Determine if there are space and time coincidences of initiated lightning discharges and air showers**

➔ **Provide a lightning database at Auger (Monitoring)**

➔ **Provide real-time alerts of lightning within 150 km to Auger**

Where does lightning occur?

-In thunderstorms

-In Snowstorms

-In Sandstorms

-In Clear Air

-Over Volcanoes

-Nuclear Detonations

-Jupiter

-Saturn

What kinds of lightning in thunderclouds?

-Cloud to ground discharges

-Inter cloud discharges

-Intra cloud discharges

-“Bolts from the blue”

-Forked/Beaded lightning

-Ribbon/Sheet lightning

-Transient Luminous Events

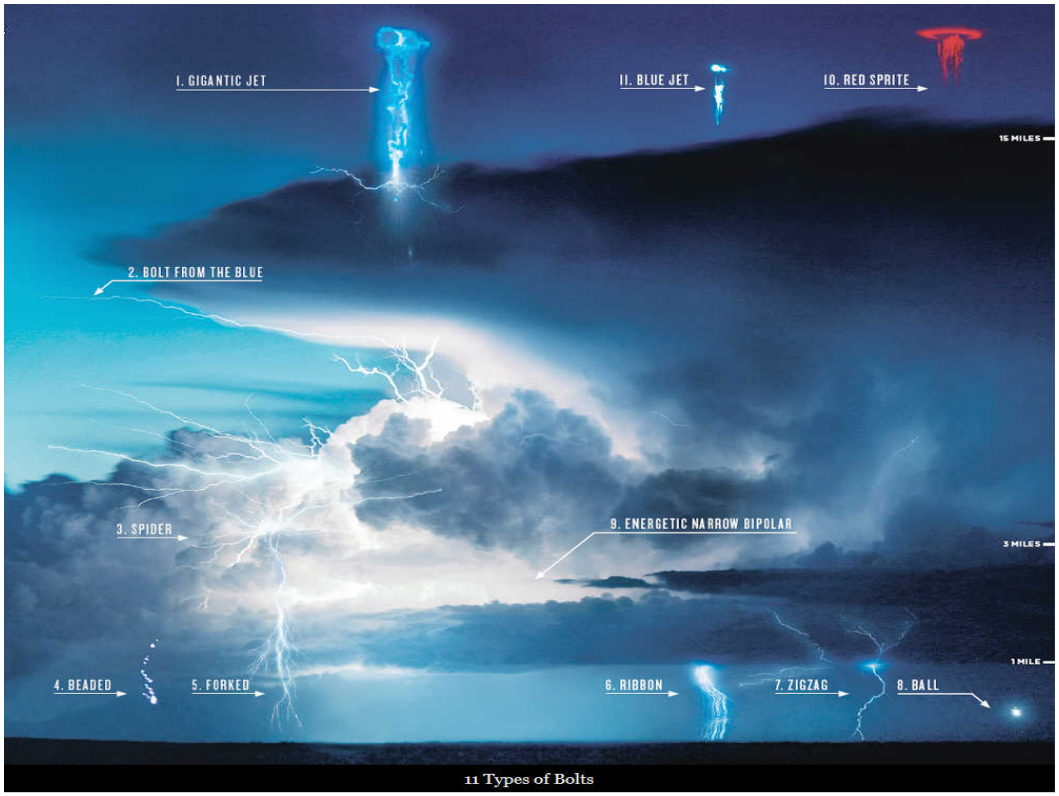
(Sprites, jets, elves, e.g.)

-Narrow Bipolar pulses

-Ball Lightning

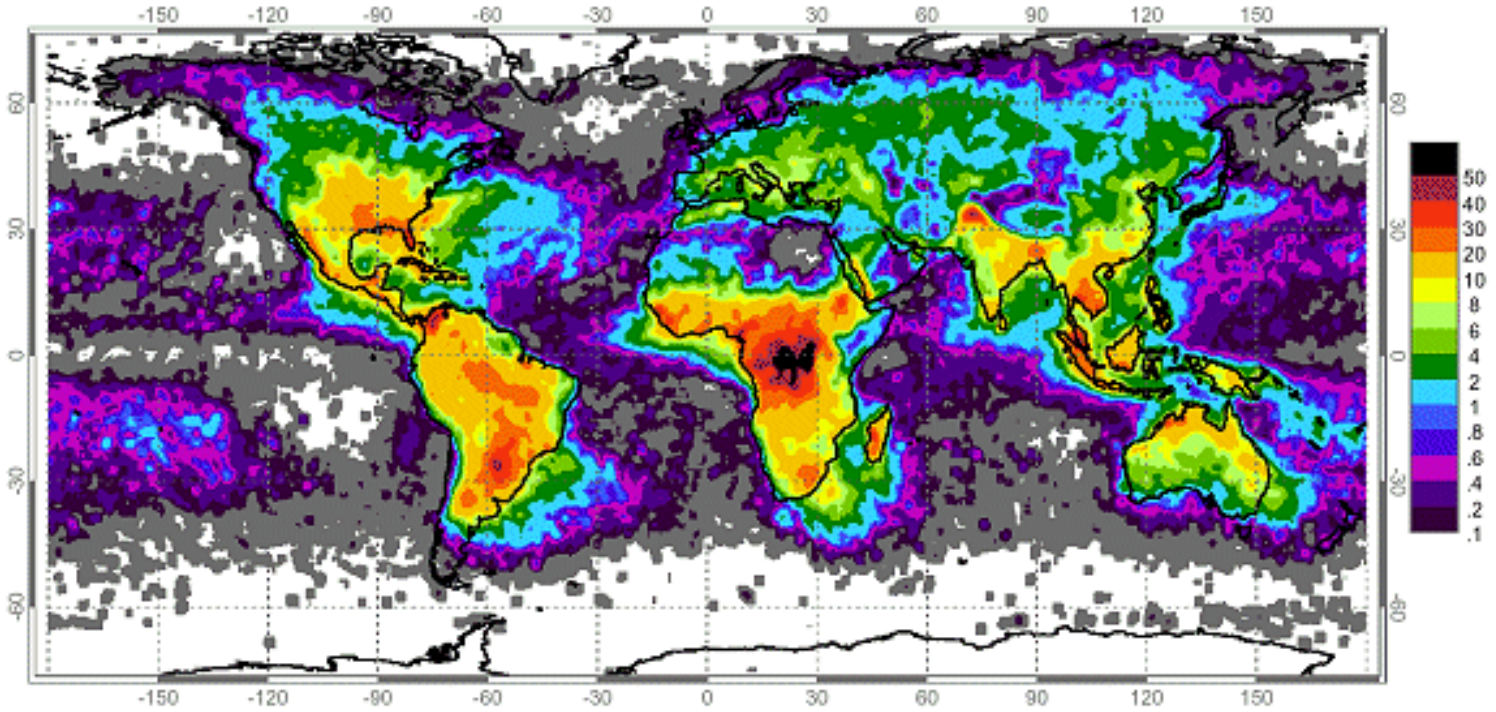
-Hot lightning

-Cold lightning



🡐 **All send radio signals!!**

Some lightning statistics



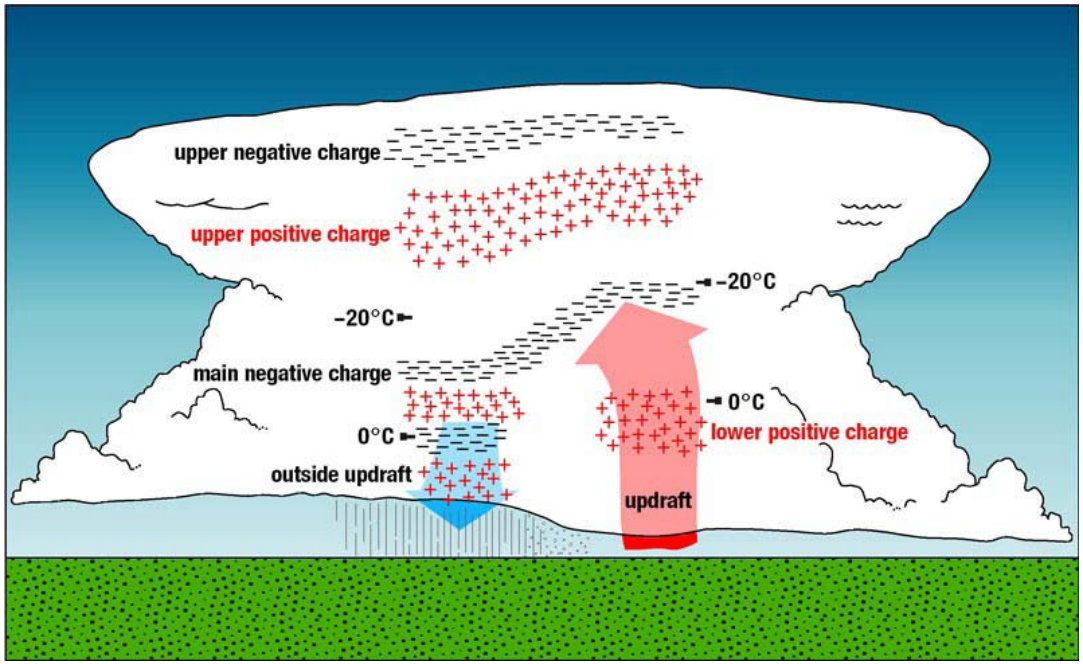
-16 million lightning storms in the world every year

-Empire State building hit 23 times/year

-More lightning deaths per year than by other weather phenomena

-Commercial aircraft struck once every 5000-10,000 hours flight time

Structure of a thundercloud



➔ **Formed when cold, dense air is aloft of warm, moist air**

-Warm, moist air rises in strong updrafts and the cold air descends

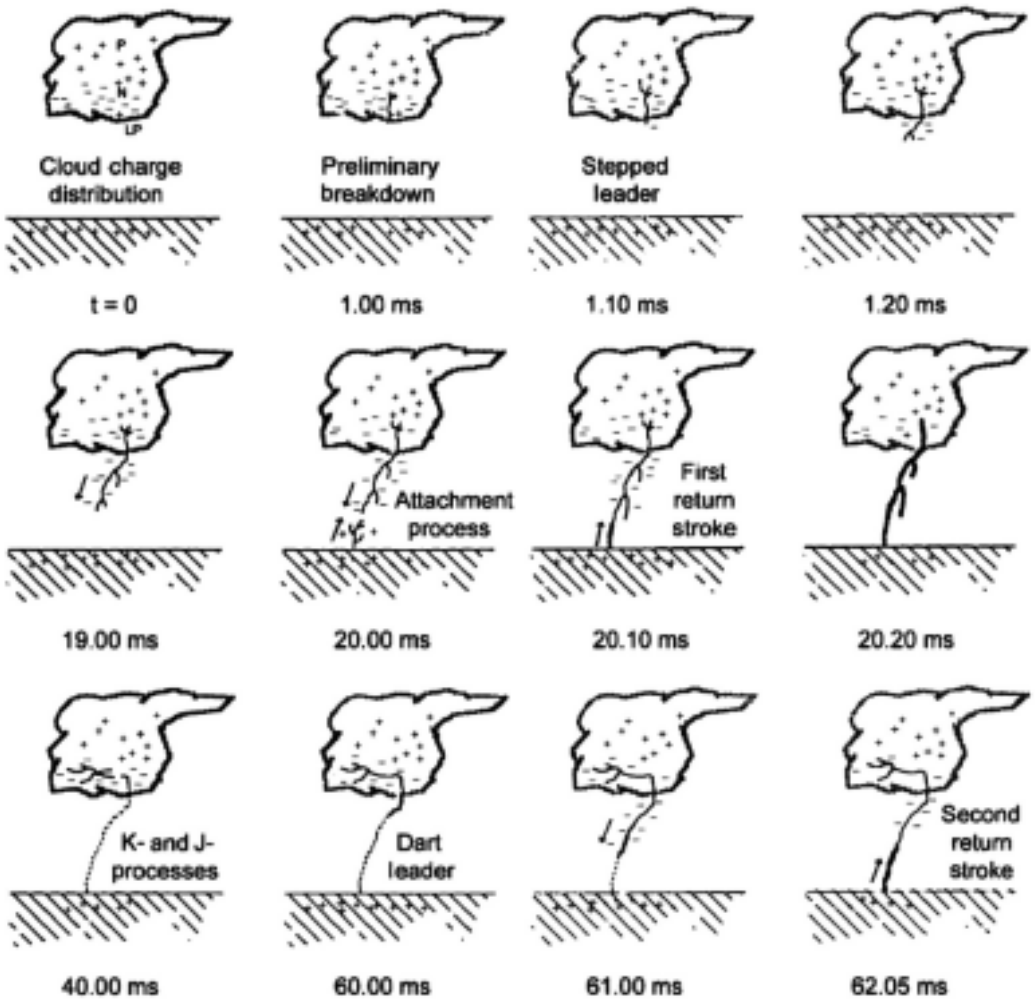
-It is thought that frictional forces between the rising water vapor and the descending ice crystals electrify clouds.

-Structure lasts 1-2 Hours

Atmospheric discharges development of a lightning (standard theory)

➔**Stepwise development of a lightning**

➔**Up to hundreds of milliseconds!**



Lightning = phenomenon still not fully understood

- **Main problem: How lightnings are initiated?**
  - Di-elektric breakthrough of the atmosphere?

    Problem: electric fields too small for classical breakthrough.

  - Initated by high-energy cosmic particles?

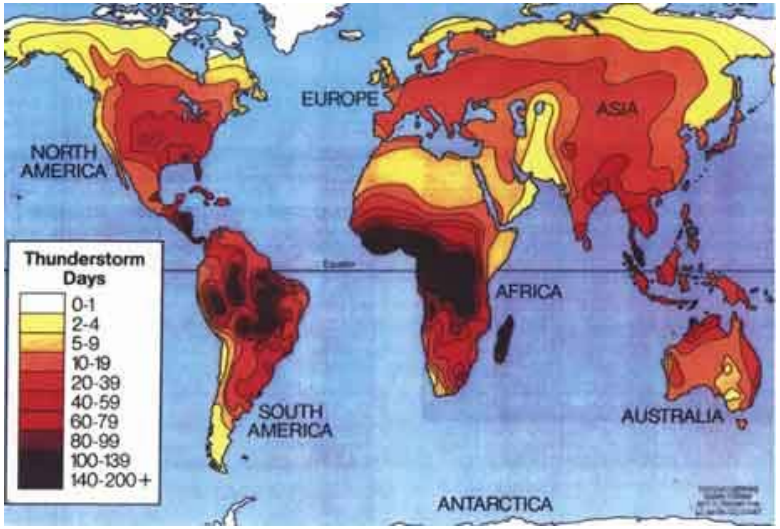
    or better: large densities of electromagnetic particles in a strong E-field in thunderstorm clouds?

➔ **Optical lightning observations**

➔ **Observations of E-fields**

➔ **Observations in radio**

Contrary to optical studies, with radio one can look into the clouds!



World distribution of lightning

Relativistic Runaway Breakdowns (RBB)

➔Avalanche breakthroughs by large electric fields!

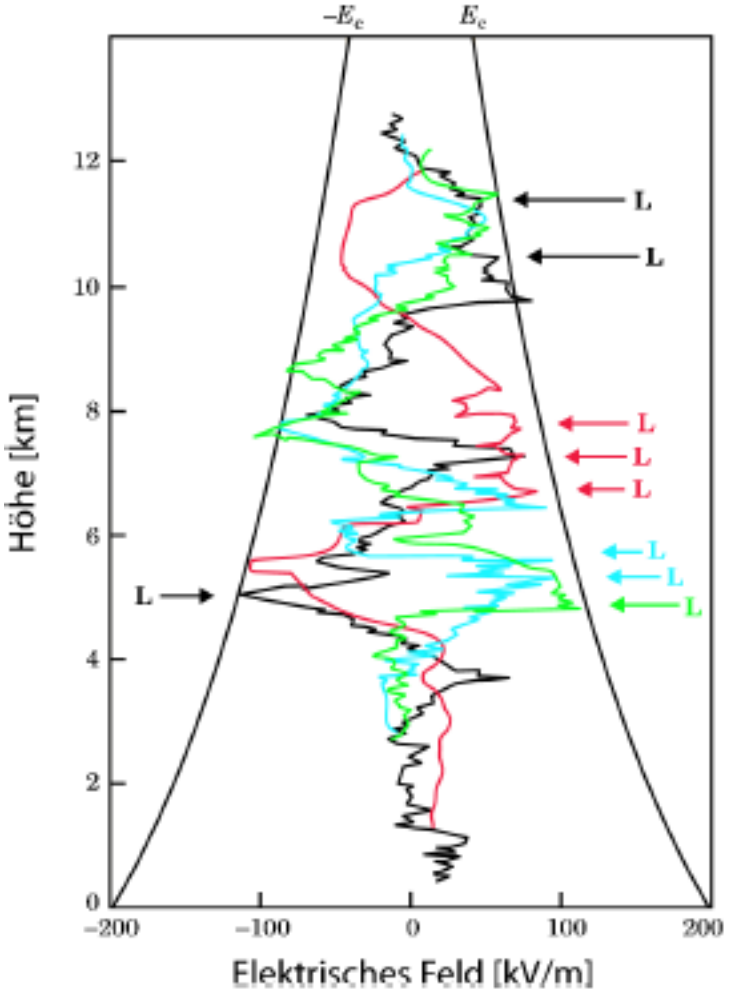
➔Ionization losses are smaller than energy gain in electric fields ➔ electron energy increases (~100MeV) ➔ electrons again seed electrons ➔ avalanche

➔ stepped leader (plot 3, last slide) could be RBB

➔ start of RBB (seed electrons) could be provided by EAS shower maximum

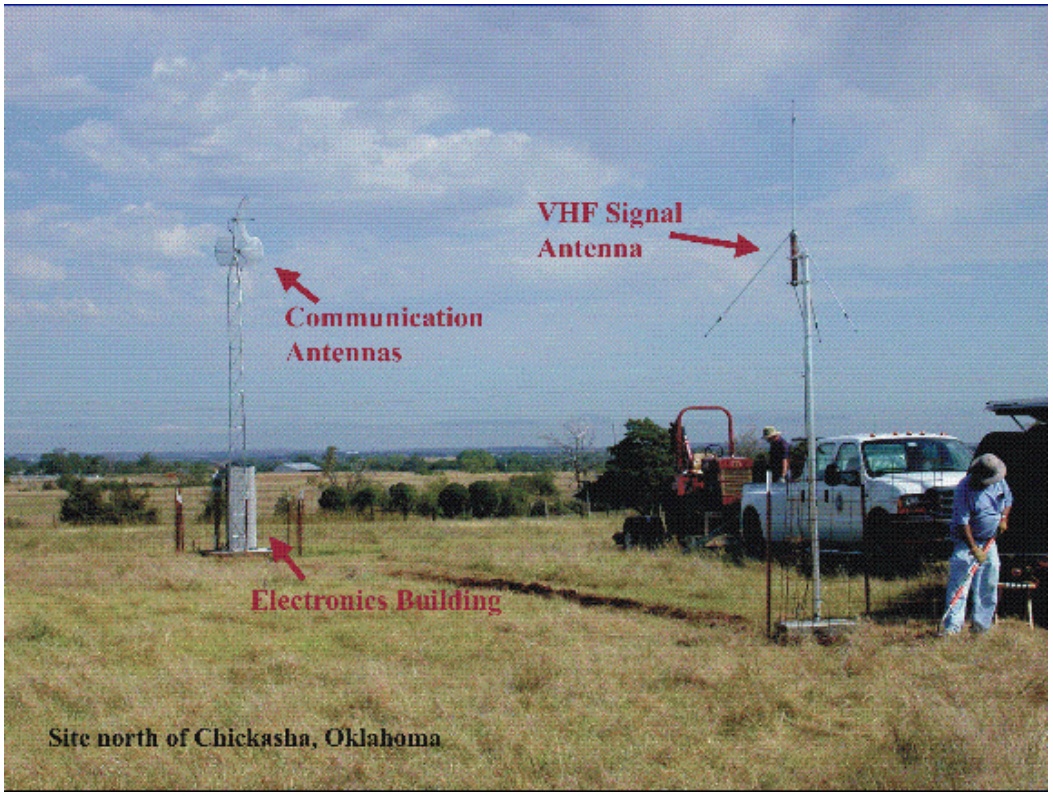
➔ **theory: EAS provide seed electrons for RBB and each lightning need as initiation a RBB!! (not proved)!**

The flux of high energy cosmic rays (~2km^{-2}s^{-1} for 10^{15} eV) is consistent with lightning frequency.



Balloon measurements in a thundercloud
L= lightning!

LASS aproach:
Lightning Mapping Array by Radio antennas

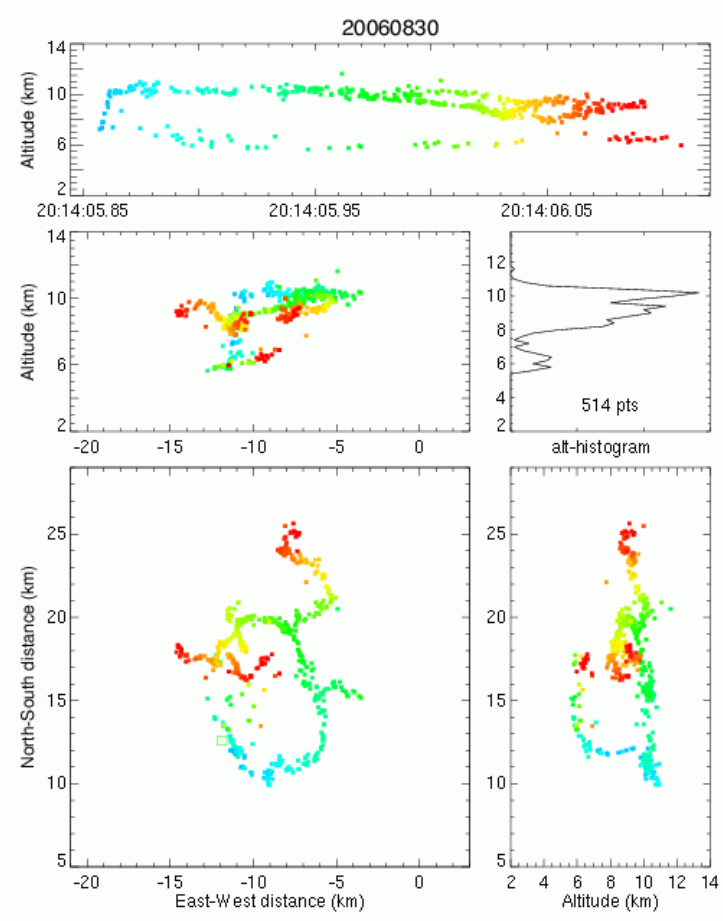


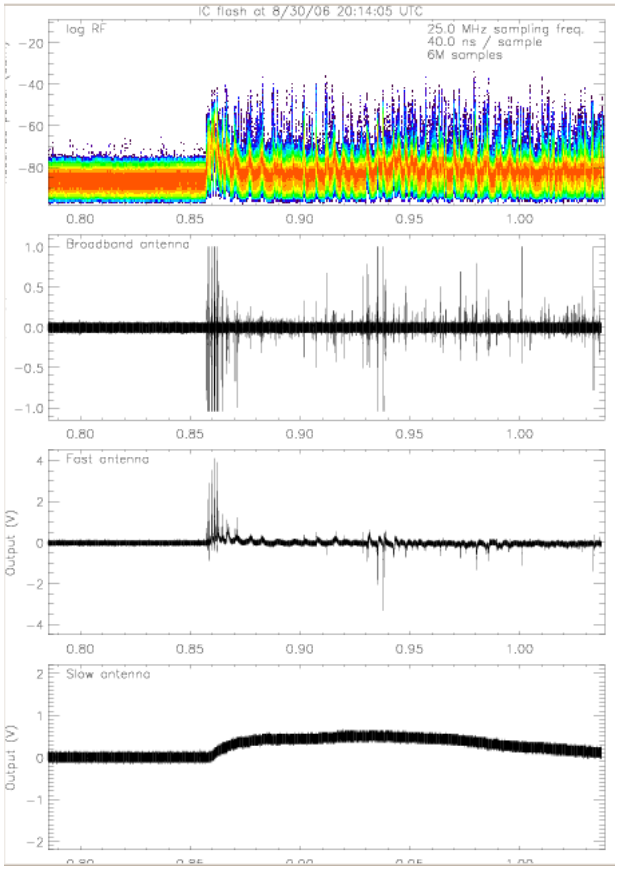
- Array (ca. 30km diameter) with several LMA Stations
  - unused TV frequency band (e.g. 60-66 MHz)
  - Detects peaks in radio in suczessive 80µs windows
  - <10m spatial resolution

(Paul Krehbiel)

Lightning Mapping Array: Multi-Measures

(Paul Krehbiel)





E-Field

Broad band antenna

„fast“ Antenna

„slow“ Antenna

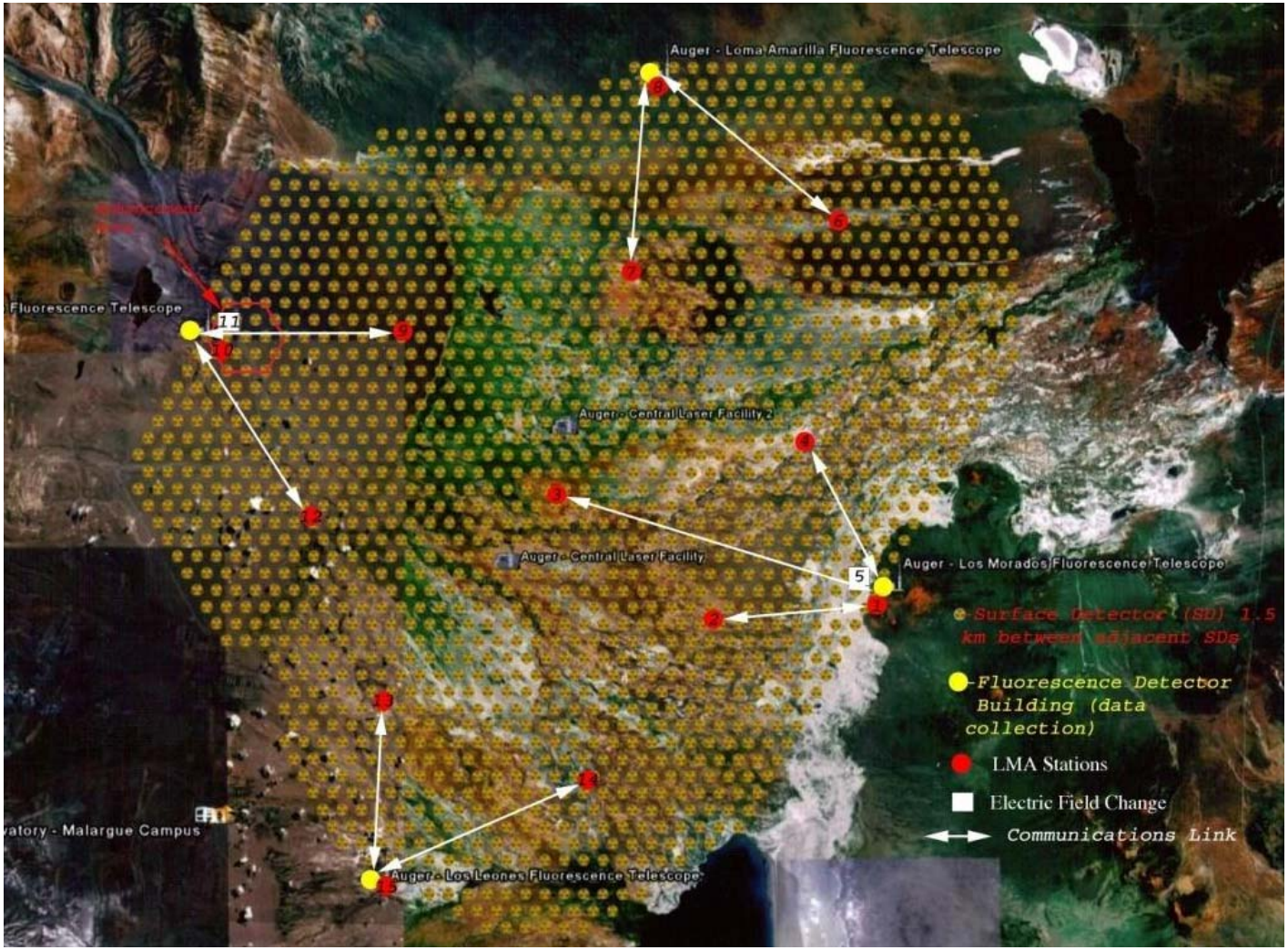
Electric field and radio observation of a cloud-to-cloud lightning with a LMA
➔ Very good time and spatial resolution ➔ mapping of the lightning

1 LMA Station also in LOPES

(Paul Krehbiel + LOPES)

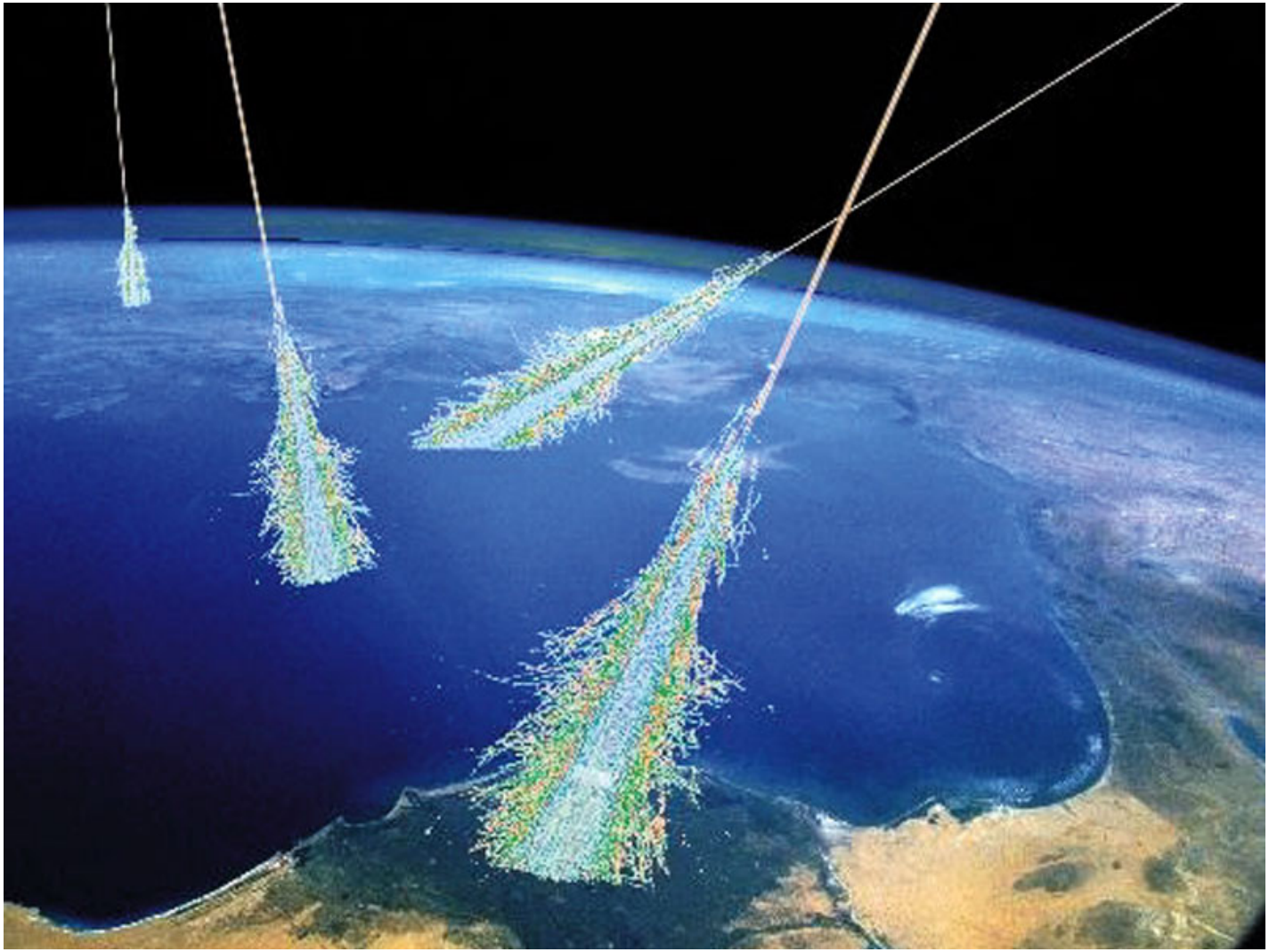
➔ **LMA and EAS- correlated measurement !!!**

➔ Lightning detection system at the Pierre Auger Observatorium

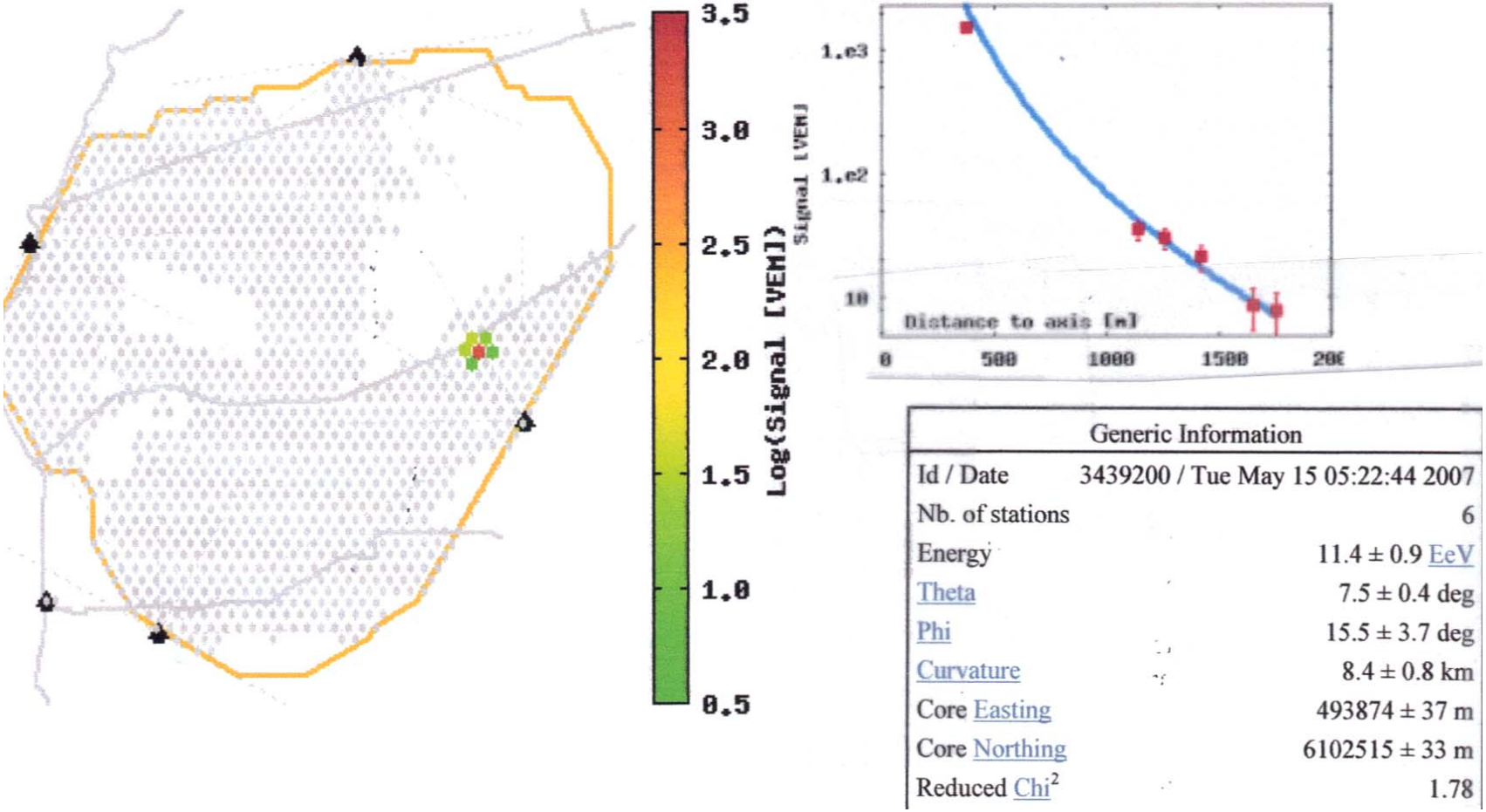


13 LMA stations
2 E-field mills

Cosmic Ray Showers



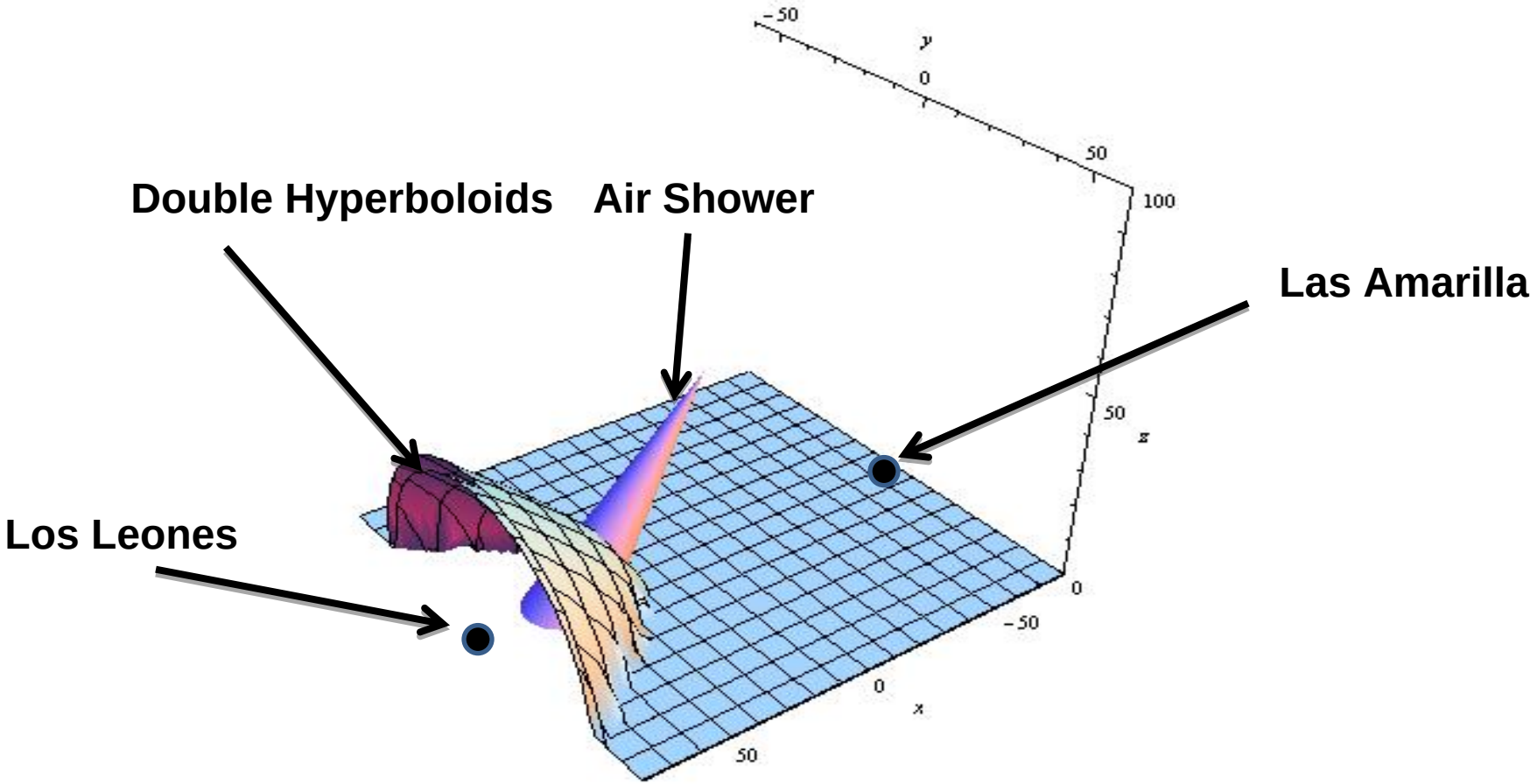
Auger surface detector reconstruction



Generic Information	
Id / Date	3439200 / Tue May 15 05:22:44 2007
Nb. of stations	6
Energy	11.4 ± 0.9 EeV
Theta	7.5 ± 0.4 deg
Phi	15.5 ± 3.7 deg
Curvature	8.4 ± 0.8 km
Core Easting	493874 ± 37 m
Core Northing	6102515 ± 33 m
Reduced Chi^2	1.78

Main goal of LASS: Cosmic Ray – lightning correlation

Way to analysis: Where a cosmic ray shower intersects the uncertainty volume of 2 lightning detectors



Second goal of LASS: Study of effects of lightning to standard Auger measurements

How lightning may affect Auger measurements:

-Flashes of broad-spectrum light

-X-Rays (200 keV) irradiating detectors

-Gamma Rays (20 MeV) irradiating detectors

-Radio emissions (ELF-VHF)

-Induced currents in circuits

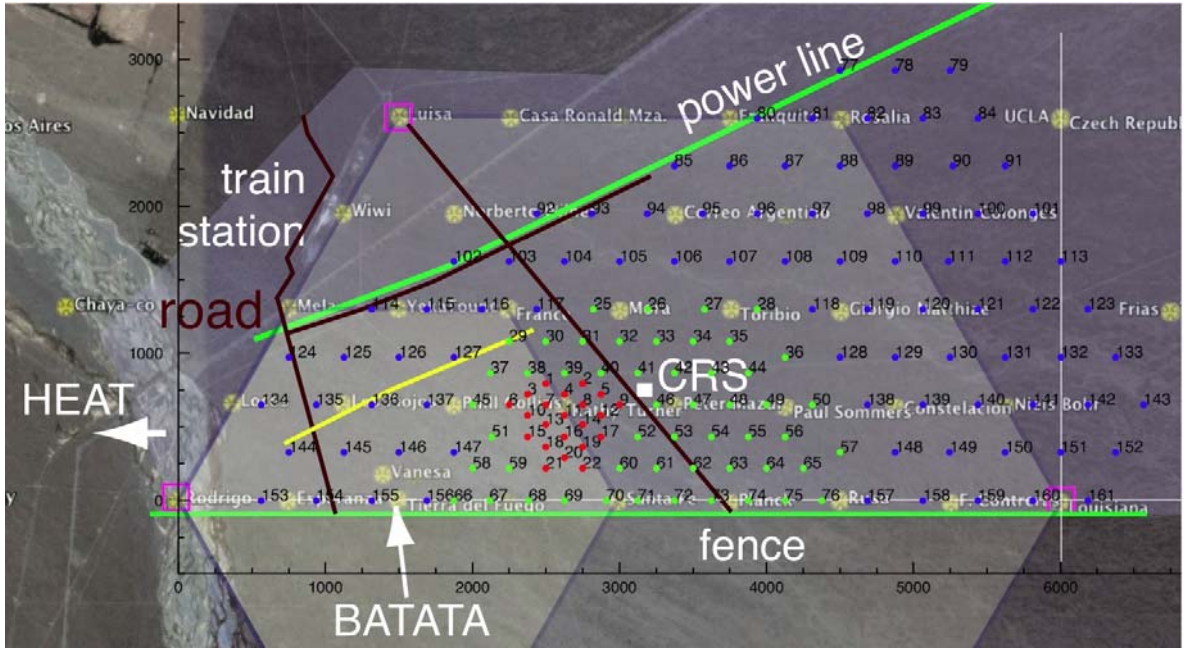
-Damage to instrumentation by direct hits

-E-Fields of thunderstorms may alter the expected distribution of particles in air showers

-Decreased signal/noise ratio for radio detection

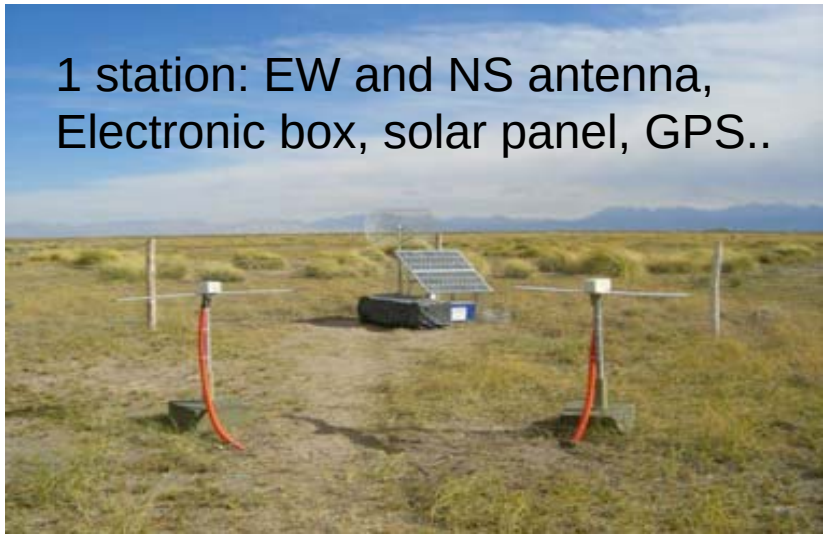
-…

Radio EAS-Detection at the Pierre Auger Observatory:

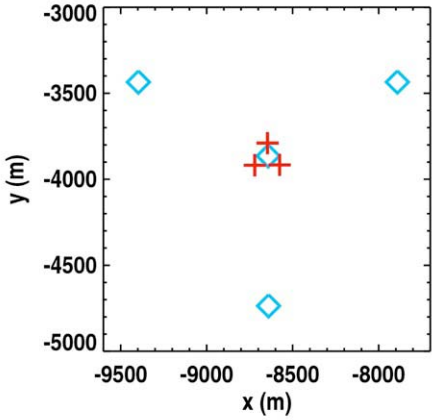


- Calibration of the EAS radio signal up to 10^{19}eV.
- 2006-10 test measurements in Argentina
- Set-up of first AERA-Antenna in summer 2010
- Super-Hybrid (particles, fluorescence, radio) - measurements

Radio EAS-Detection at the Pierre Auger Observatory: Test-Setup RAuger

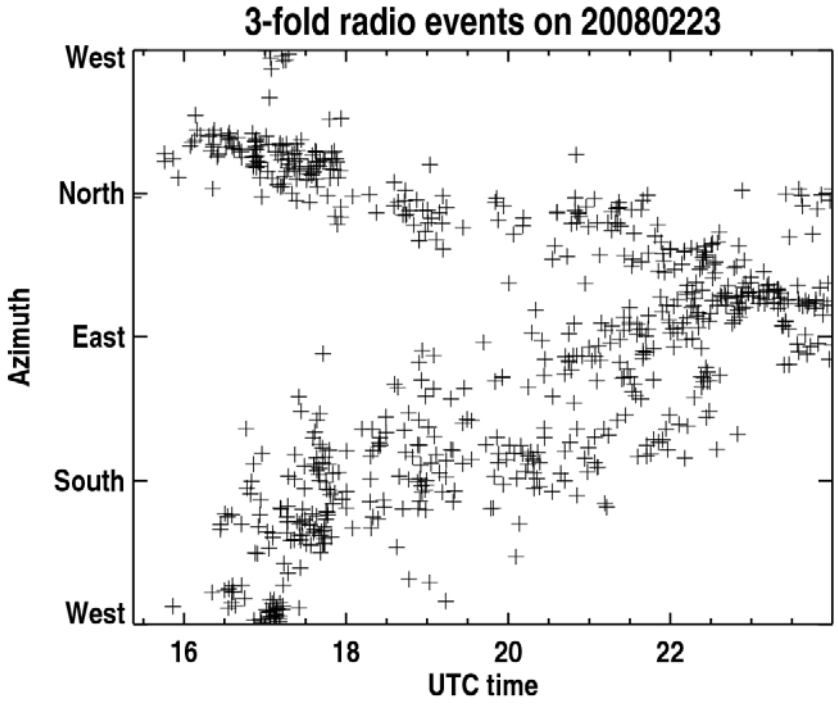


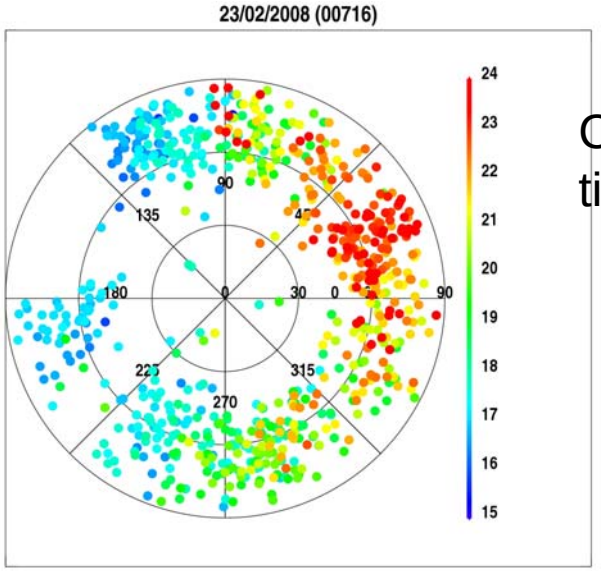
3 stations in center of SD-triangle
1 additional infill tank



- **Three antenna stations around SD tank**
- **Each station selftriggered (simple threshold)**
- **Three-fold events correlated with SD analysis**
- **See threefold events also from lightning**
- **Direction analysis possible with three-fold events**

RAuger: data of one remarkable thunderstorm day!





Color code: time

- **Time distribution and Skymap of direction of three-fold events (all lightnings)**
- **2 clouds merge**

SD – thunderstorm Pierre Auger Observatory: movie of passing a thunderstorm cloud the SD particle detectors

-SD scaler mode
-cloud from lower left to upper right corner

- **Slow increase of particles at the tanks before cloud!**
- **Abrupt decrease behind the cloud!**
- **Explanation?**

LASS: goals and how to follow:

➔ **Determination, if there is a causal connection between cosmic rays and lightning initiation**

Search for time and spatial correlations between lightning and EAS

➔ **Study of effects of strong electric fields to the radio emission of EAS**

Monitoring AERA measurements und correlation AERA-LASS measurements

➔ **Study, if strong E-fields, lightning or thunderstorms affect the particle component of EAS**

Correlation of LASS with SD measurements

➔ **Investigations, if far distant thunderstorms affects the fluorescence measurements**

Correlation of LASS with FD measurements

LASS = Lightning Air Shower Study

➔ Status:

- **2009: LASS agreement by the Auger Kollaboration**
- **2010: Installation of first two LMA stations**
- **2010: Funding applications**
- **2011-12: Installation**

➔ Praticipating groups:

- **Colorado State University (CSU), Pueblo, USA, W.Brown (PI, Auger)**
- **New Mexico Tech (NMT), USA, P.Krehbiel (LMA-expert, non-Auger)**
- **Florida Institute of Technology, USA, J.Dwyer (lightning-expert, non-Auger)**
- **Karlsruhe Institute of Technology, A.Haungs (Contact AERA)**
- **Auger Atmospheric Task group**
- **Auger Exotic Physics Task group**