Improvements to the Infrared Cloud Detection System at the Pierre Auger Observatory

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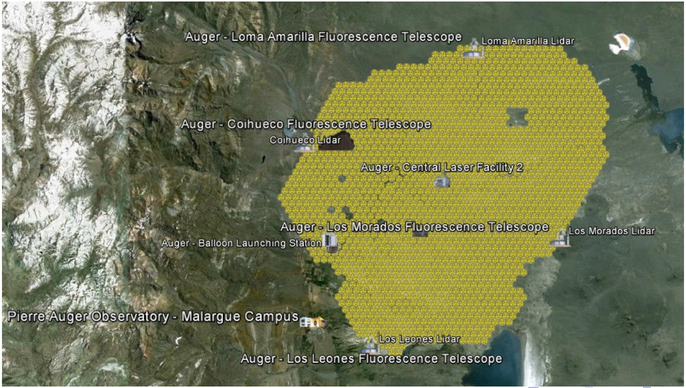
Overview

- **Background**
- **Possible areas of improvement**
  - → Automation & Reliability
  - → Data Quality
    - → Image Artefacts
    - → Image Presentation
    - → Data effectiveness
  - → Cloud Position Analysis
- **Potential Extra Applications**

Background: Pierre Auger Observatory

- Near Malargue, Argentina 69W, 35S, 1400m above sea level.
- Measures Arrival directions and energies of high energy particle that interact with our atmosphere.
- 4 Nitrogen Fluorescence detector (FD) telescope sites each one covering a $180^o \times 30^o$ view over the 1600 tank surface detector array.



Background: Clouds and the Observatory

- Clouds Scatter Nitrogen Fluorescence light produced by cosmic ray interactions in the atmosphere producing peaks and troughs in the air shower profiles measured.
- Attenuation of fluorescence light by cloud between fluorescence detector and shower causes troughs.
- Peaks caused by intense Cherenkov beam directed along the axis of the shower being scattered sideways towards the fluorescence detector.

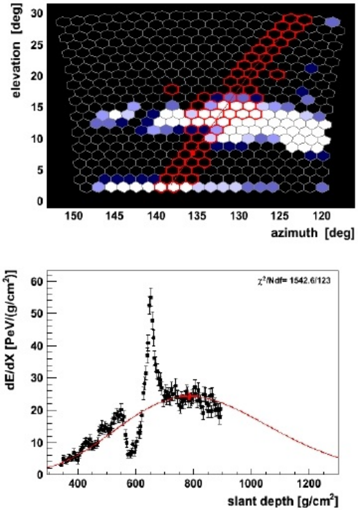


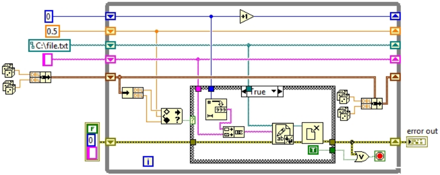
Figure: FD cosmic ray air shower profile and cloud mask.

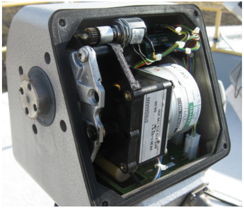
Background: Cloud Camera System

Figure: Pan & Tilt motor system with infrared camera attached inside a housing.

- **Cloud Camera Data Analysis**
  - → Reads in raw image files and produces Fluorescence Detector cloud masks.
- **Cloud Image Capture Process**
  - → Control Pan & tilt motor system and infrared camera.
  - → Captures images of Fluorescence Detector field of view every 5 minutes.
  - → Produces full sky images for weather observations.

- Labview: Graphical based programming language created by National Instruments.

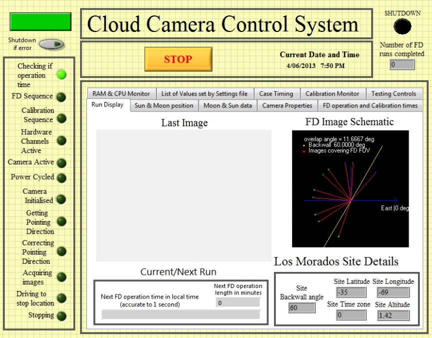


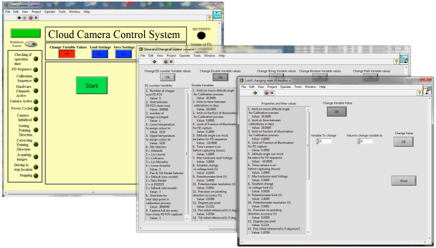


- We are using Labview in conjunction with a NI PCI-6023E card that contains:
  - → 8 digital lines which we use to control power to the pan & tilt and camera.
  - → 24bit counters which we use to control the amount of movement in both pan and tilt.
  - → Digital to analogue converters which we use to measure potentiometers which give us the cameras pointing direction.

Automation & Reliability: Labview GUI

- Labview has allowed for development of a Graphical User Interface (GUI).
- With the GUI we are able to:
  - → Fully control all settings.
  - → Configure the system into a number of different operational states.
  - → Save configurations of the system to file for automatic loading.





Automation & Reliability: Image Processing

- Labview has also allowed for more complex image analysis tasks.
- Real time Canny edge detection filtering made it possible to calibrate the cameras pointing direction via the moon.
- Calibration corrects for the non level mounting of the system, the systems knowledge of true east & horizon and the relationship between the pan & tilts angular movement and there voltage readings.

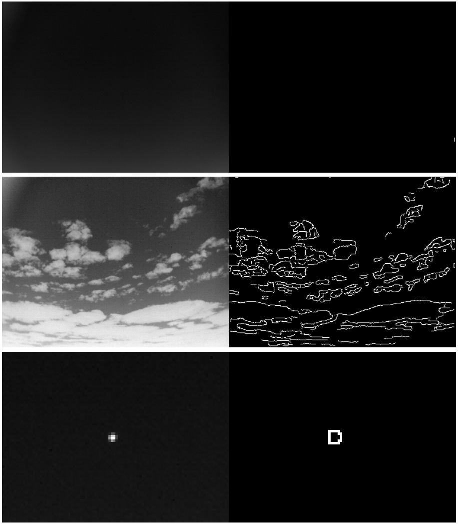


Figure: Canny edge detection applied to clear sky, cloudy and moon images.

Data Quality: Data Quality

- Data Quality has 3 aspects:

  → Artefact removal,

  → Full sky image presentation and

  → Effectiveness of the data in terms of it being used in the post processing cloud detection phase.

Data Quality: Current System Limitations

- Ambient temperature dependent image artefact at Coihueco site.
- New cameras needed to improve image quality.

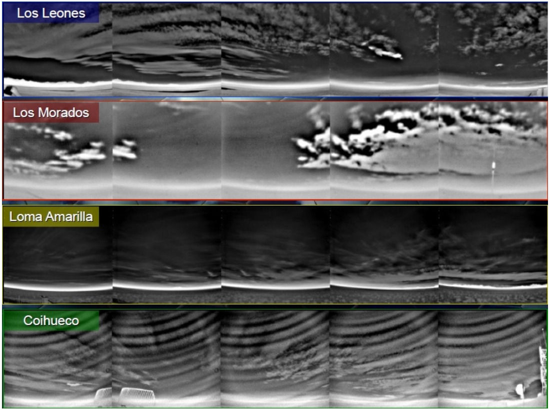
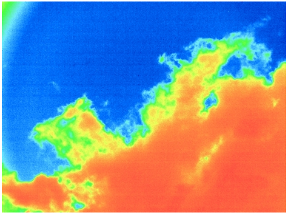


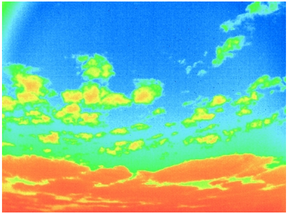
Figure: Old Cloud camera system Fluorescence Detector field of view images.

Data Quality: New Infrared cameras

- Gobi-384 radiometric microbolometer array infrared camera:

- $8 - 14\mu$m spectral response.
- 384 by 288 pixel array.
- 50^o horizontal field of view.
- 50mK temperature resolution.





Data Quality: Full Sky Images

- Radiometric nature of the new cameras also makes it easier to distinguish the difference between cloud and clear sky.

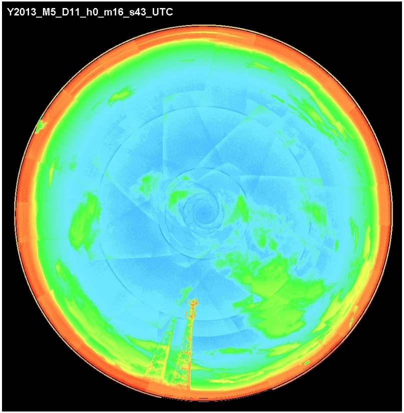


Figure: New Cloud camera system full sky image (not fully calibrated).

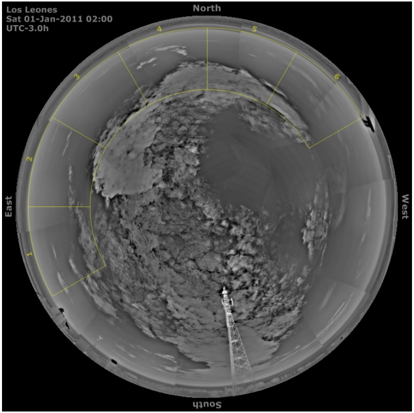


Figure: Old Cloud camera system full sky image.

Data Quality: Data effectiveness

- Results of better organisation of the system:

  → 50% reduction in the size of data produced while outputting 40% more data via compression and saving of data in Jpeg2000 format.

  → Automation of data exportation to the secure storage system at CC-IN2P3 Lyon.

Cloud Detection Processes: Cloud Detection Processes

- Cameras signal is highly dependent on atmospheric water vapour content due to atmospheric window band-pass.
- Current system can falsely identify high levels of water vapour content as cloud.
- We are currently investigating simulating the cameras response using Atmospheric Radiation Transfer routines and Atmospheric profile data from the Global Data Assimilation System (GDAS).
- This could help simplify the amount of image processes required to determine cloud locations.

Potential Extra Applications

- Investigate the possibility of determining other atmospheric properties that could be related to the intensity of the radiometric signals.
- Investigate the cameras sensitivity to different cloud and aerosol conditions.

Thank You

References

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Xenics
Xenics Infrared Solutions
www.xenics.com.