Atmospherics at HiRes

Kai Martens and Lawrence Wiencke for the HiRes Collaboration
University of Utah, Department of Physics and
High Energy Astrophysics Institute, Salt Lake City, Utah, USA

1. Abstract

The High Resolution Fly's Eye observatory (HiRes) uses the atmosphere as a calorimeter. Understanding the properties of this calorimeter, primarily the atmospheric transmission, is critical to the reconstruction of air showers from the light observed at the detectors. HiRes uses lasers to probe the atmosphere while the detectors are operating. Atmospheric corrections are derived from measured light profiles of the laser tracks recorded by the same detectors that record tracks from air showers. The atmospheric molecular component is described by Rayleigh scattering in which the air density is derived from radiosonde data. We review the HiRes atmospheric monitoring program with emphasis on the corrections used to measure the air shower energy spectrum with stereo observation.

2. Introduction

Atmospheric monitoring at HiRes is an integral component of our data analysis [1]. It has come a long way from using a "standard" desert atmosphere (ICRC 1999, [2]) through an average measured atmosphere (ICRC 2001, [3]) as we had to do for the monocular analysis of our early data.

The HiRes detector consists of two sites (HR1 and HR2) separated by 12.6 km on the Dugway Army Proving Grounds in the Utah West Desert, USA. Each of these sites is equipped with a fully steerable frequency tripled YAG laser (355 nm), the laser pulses of which are recorded by the detector at the respective other site as they propagate through the atmosphere. A roving system using the same type of laser can be deployed in the field of view of both detectors sites simultaneously. As the two detectors use different electronics (flash-ADC at HR2 at versus sample-and-hold at HR1), the roving laser provides an important cross check not only for the relative and absolute photometric calibration of the two sites, but also for their respective reconstruction.

As of the end of last year we have installed another YAG laser to shoot pulses vertically into the atmosphere from the line connecting the centers of the two detector sites, HR1 and HR2. On that imaginary line the laser is located about 22 km from HR1 and about 34 km from HR2. Tracks from its laser pulses at various energies are now recorded regularly with the data from both sites. Details on this new addition to the

pp. 1–3

experiment are provided in [4].

Also new is an attempt to probe the atmosphere in the direction of extremely high energy candidates within a few minutes after their detection. Details on this effort are provided in [5].

Atmospheric information collected for purposes unrelated to our experiment by other organizations are currently being incorporated into our analysis. An important example of this are atmospheric temperature and pressure profiles obtained from radiosonde balloon ascents at local airports.

3. The Steerable Lasers at HR1 and HR2

The steerable lasers at HR1 and HR2 both fire a pattern of shots at various intensities and directions into the surrounding atmosphere. The patterns are symmetric about the line of sight between the two detectors to simplify assessment of the overall symmetry of the atmosphere. Sampling all azimuthal directions and elevations, most of the HiRes aperture is probed through the scattering of laser photons as recorded by the HiRes detectors HR2 and HR1 respectively.

For a simplified analysis the vertical shots from the HR2 steerable laser as seen by HR1 are used to determine a Vertical Aerosol Optical Depth (VAOD) of the atmosphere. Two other laser shot geometries from that same laser are selected to extract the horizontal scattering length. The latter shots also provide information on the scattering phase function.

If a laser shot hits a cloud within the field of view of HiRes, it is easily detected. Cuts on the specific laser patterns thus allow us to discard data that are compromised by the presence of clouds. Other means of detecting clouds by IR sensing are also available at HiRes.

3.1. Vertical Aerosol Optical Depth

The VAOD measurement is performed hourly on the vertical laser shots fired from HR2 as seen by HR1. It summarizes the total aerosol extinction the laser beam suffers due to the aerosols along its way up to 3.5 km, well above typical aerosol mixing layers.

3.2. Horizontal Aerosol Extinction Length and Phase Function

Two symmetrical laser shots originating from HR2 and passing to the north and south of HR1 are used to measure the horizontal extinction length and scattering phase function. These low elevation angle tracks leave long images across about eight mirrors on each side. These are used to measure the aerosol phase function through scattering angles from about 20 to about 170 degrees.

3.3. Inclined Shots: Tying it all together

Apart from the relatively simple task of probing for clouds, the pattern of azimuth and elevation angles sampled regularly every hour allows evaluation of atmospheric horizontal homogeneity over the sampled aperture. Results will be presented on the stability of the calorimetric medium read out by the HiRes detector.

4. Balloon Ascents

Twice daily balloons with radiosondes are launched from the airports at Elko, NV, and Salt Lake City, UT. The former is about 250 km west of HiRes, and the latter is about 100 km east of it. These instruments record detailed measurements of the temperature and pressure profiles throughout the atmosphere over these two (and other) places. Their data are made available over the Internet. A first evaluation shows that the average, season dependent profiles we used so far are acceptable at the 5% level. Improvement will be gained from introducing measured profiles directly, after they have been properly interpolated for the geographic locations involved. Progress on this matter will be reported at the conference.

5. Conclusion

The experience with and the detailed use of atmospheric monitoring data will be described in this talk. Atmospheric information routinely evaluated on an hourly basis during runtime is an important ingredient for identifying data collected under acceptable viewing conditions and reconstructing the energy and profiles of extensive air showers at HiRes.

6. Acknowledgments

This work is supported by U.S. National Science Foundation grants PHY-9322298, PHY-9974537, PHY-9974537, PHY-0098826, PHY 0071069, and PHY-0140688 in addition to Department of Energy grant FG03-92ER40732, and the Australian Research Council. We gratefully acknowledge the contributions from the technical staffs of our home institutions and the Utah Center for High Performance Computing. The cooperation of Colonels E. Fisher and G. Harter, the U.S. Army, and the Dugway Proving Ground staff is appreciated.

7. References

1. Springer, R.W., *et al.*, 2003, ICRC
2. Abu-Zayyad, T., *et al.*, 1999, ICRC, 3, 264
3. Jui, C.C.H., *et al.*, 2001, ICRC, 1, 354
4. Cannon, C., *et al.*, 2003, ICRC
5. Boyer, J., *et al.*, 2003, ICRC