Implementation of Meteorological Model Data in Air Shower Reconstructions

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Overview

- GDAS Data Source and Description
- Comparison with Local Measurements
- Application to Air Shower Reconstructions
- Estimation of Reconstruction Uncertainties

Motivation

- Balloons with **radiosondes** are most accurate way of measuring height-dependent profiles of atmospheric parameters
- **Monthly average profiles** were compiled and used in reconstructions

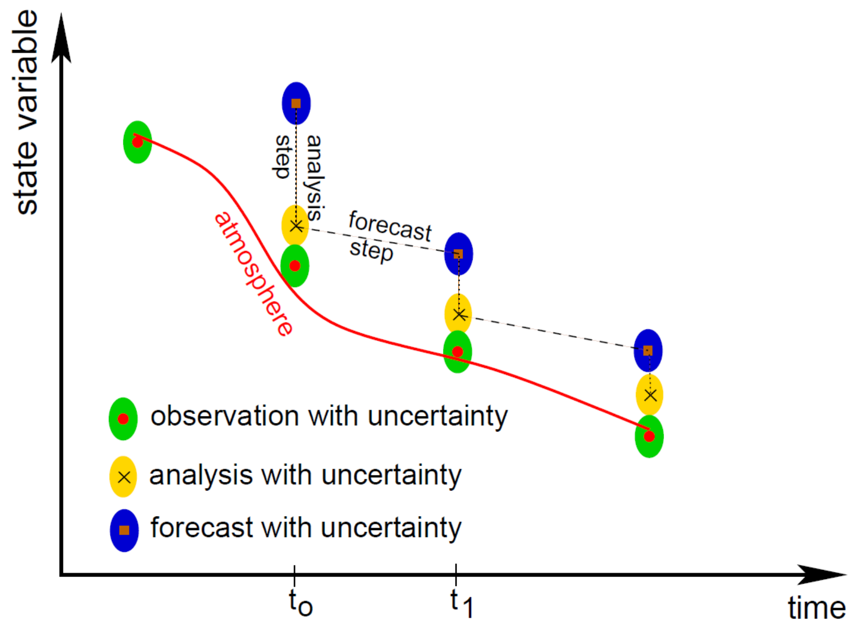
However:

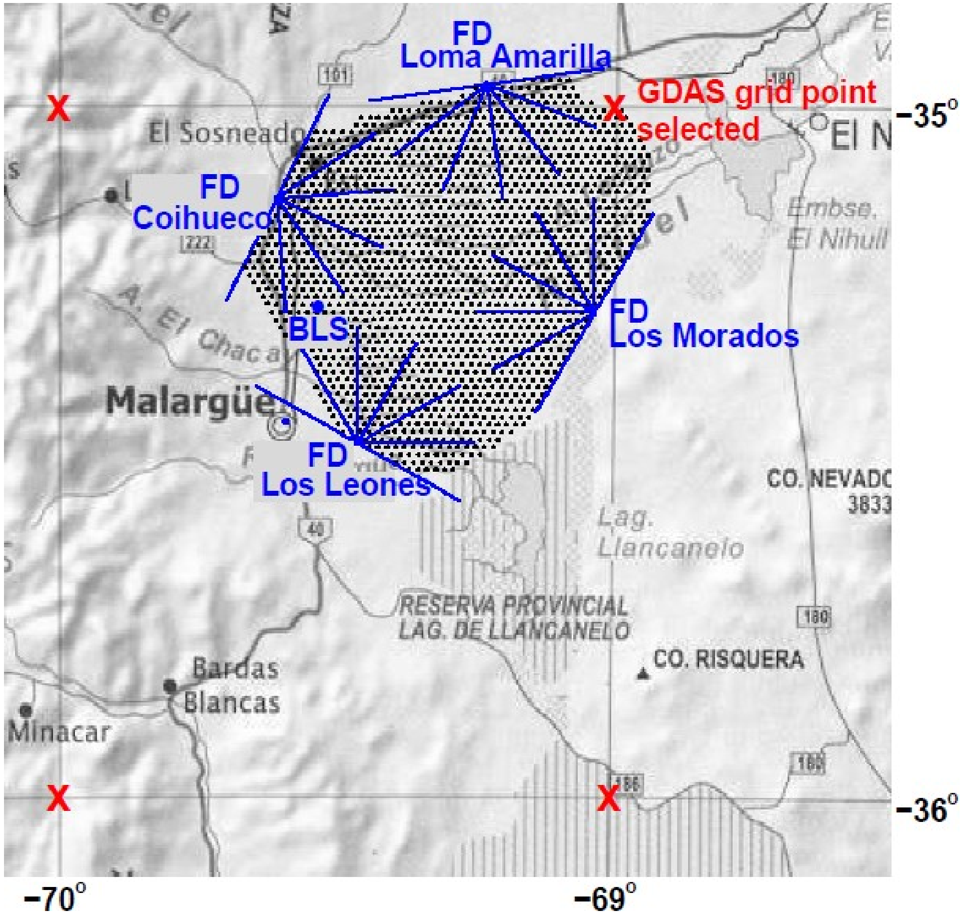
- Launches were performed at irregular intervals, several days apart
- Demanded large efforts
- Monthly models good description of local conditions
  - Without new launches not up-to-date
  - Some months better described than others

Therefore:

- Use **GDAS** as good, reliable, cost-effective alternative
- Provides temperature, pressure, relative humidity and many more

Global Data Assimilation System

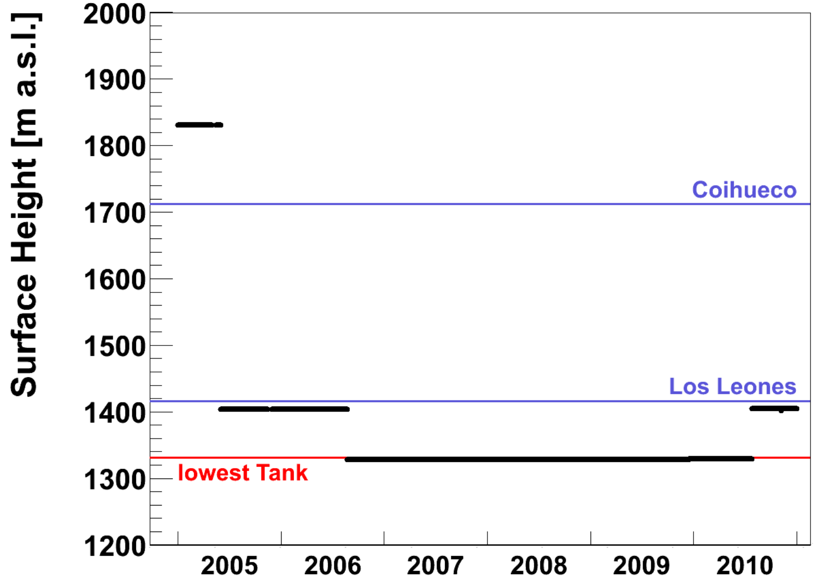




- Data available
  - for whole earth
  - 1° grid (180° x 360°)
  - every 3 hours
  - since January 2005
  - weekly for free on NCEP ftp

GDAS data

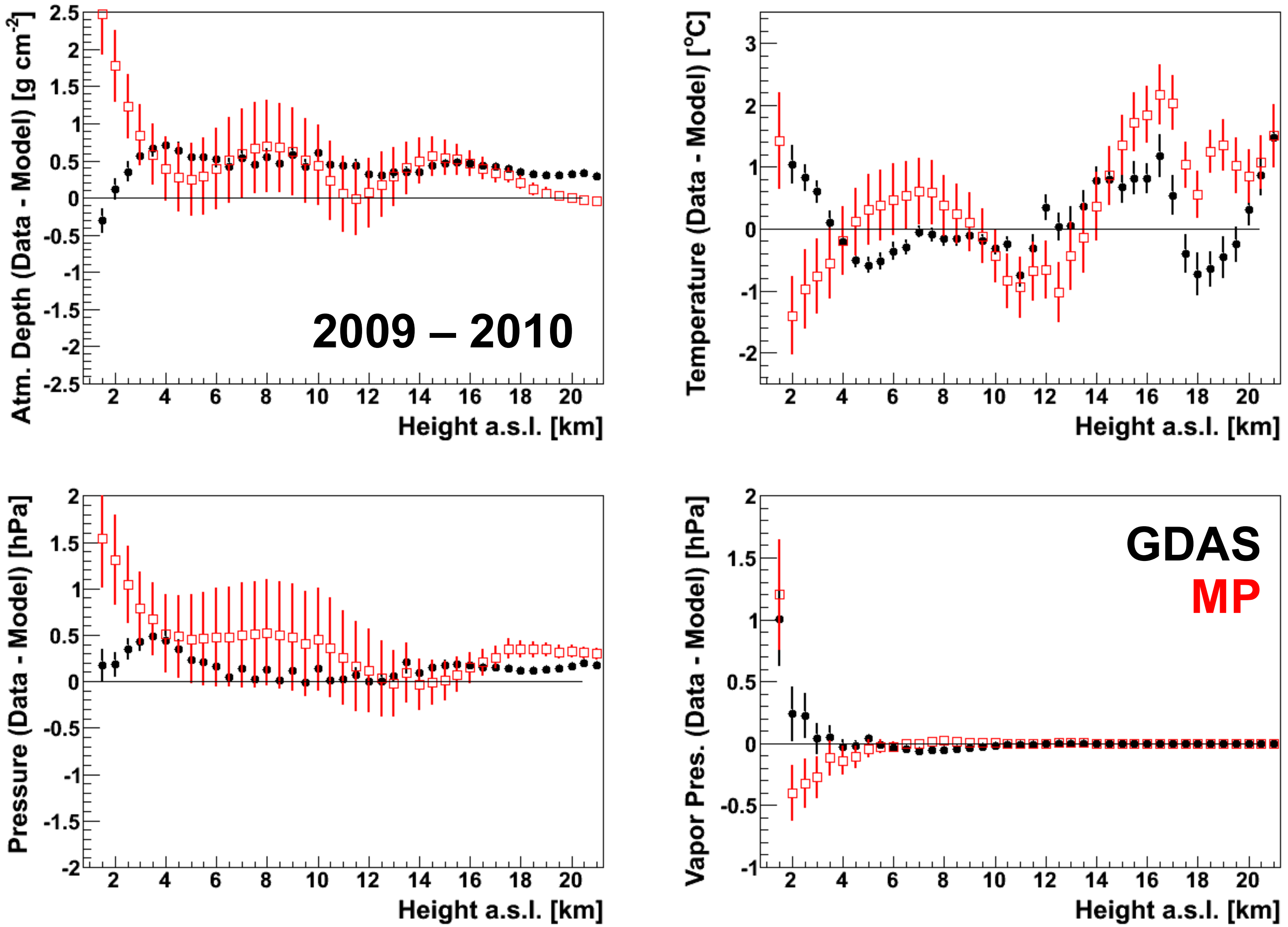
- GDAS provides temperature, pressure, relative humidity and many other values
  - Same as weather balloons
- Data at 23 fixed pressure levels between 1000 and 20 hPa
  - 5 below ground for AS
- Provides surface values
  - Problem with altitude at beginning until mid 2005
  - After June 2005 always below FDs



- Extrapolation for reconstruction down to 1000 m a.s.l.
  - Needed mostly for simulation
  - “real” data in field of view of FDs

Only use data after June 2005 from surface and pressure level 6 (850 hPa) and above

Balloons vs. Monthly Profiles



Fluorescence Calculation

- AIRFLY parameterization
- Normalization of Y_{337} to value of Nagano et al.
- Spectrally resolved, 34 transitions between 295 and 430 nm

$$Y_{\mathrm{air}}(\lambda, p, T) = Y_{\mathrm{air}}(337\mathrm{nm}, p_0, T_0) \cdot I_\lambda(p_0, T_0) \times \frac{1 + \frac{p_0}{p'_{\mathrm{air}}(\lambda, T_0)}}{1 + \frac{p}{p'_{\mathrm{air}}(\lambda, T_0)\sqrt{\frac{T H_\lambda(T_0)}{T_0 H_\lambda(T)}}}}$$

- Modifications
  - Temperature-dependent cross sections

$$\frac{H_\lambda(T)}{H_\lambda(T_0)} = \left(\frac{T}{T_0}\right)^{\alpha_\lambda}$$

  - Water vapor quenching

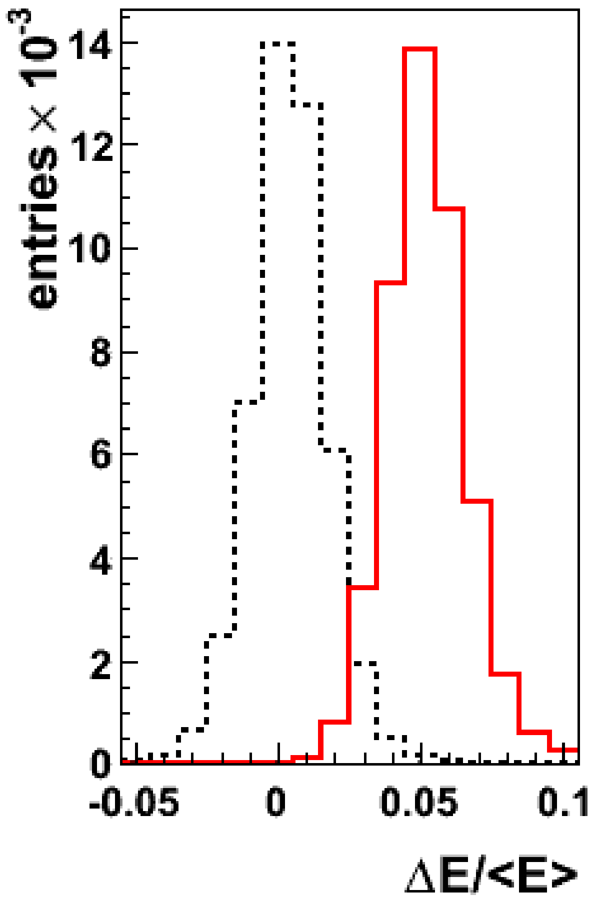
$$\frac{1}{p'_{\mathrm{air}}} \rightarrow \frac{1}{p'_{\mathrm{air}}}\left(1 - \frac{p_{\mathrm{h}}}{p}\right) + \frac{1}{p'_{\mathrm{H_2O}}}\frac{p_{\mathrm{h}}}{p}$$

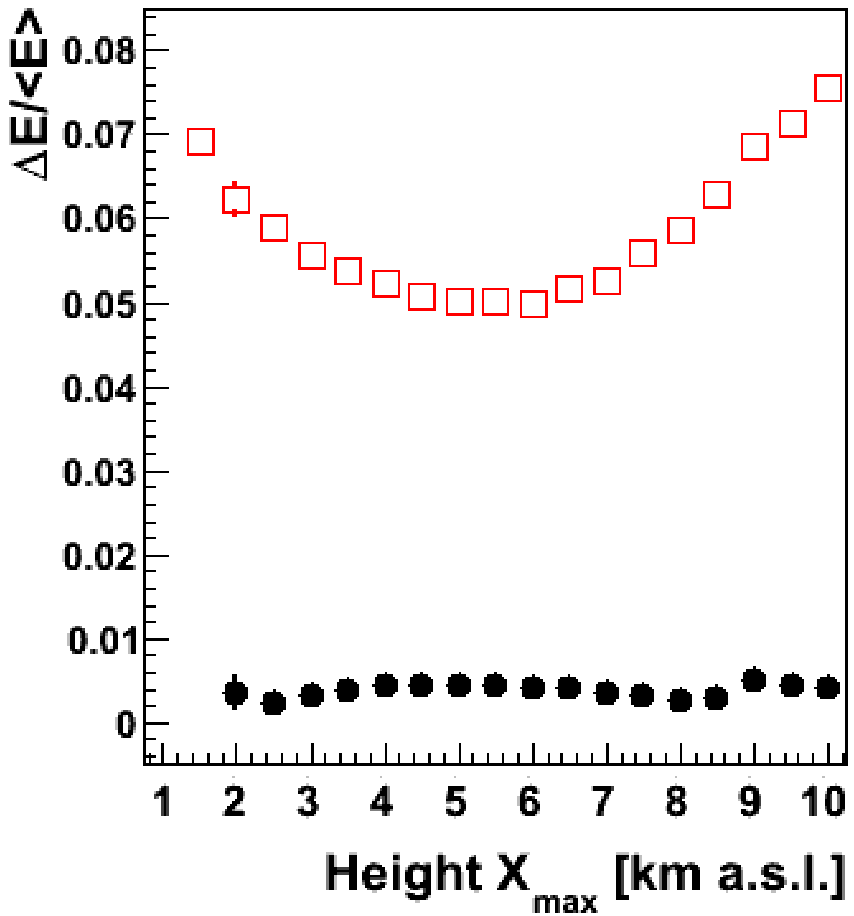
M. Ave et al. (AIRFLY Collaboration), Nucl. Instr. Meth. A597 (2008) 50

Shower Reconstructions

- Reconstruct data between June 2005 and December 2010
- Compare reconstructions
  - **$FY_{std, MP}$**
    - without vapor quenching and temp.-dep. cross sections
    - Monthly Average Profiles (MP)
  - **$FY_{mod, MP}$**
    - with vapor quenching and temp.-dep. cross sections
    - Monthly Average Profiles (MP)
  - **$FY_{mod, GDAS}$**
    - with vapor quenching and temp.-dep. cross sections
    - GDAS

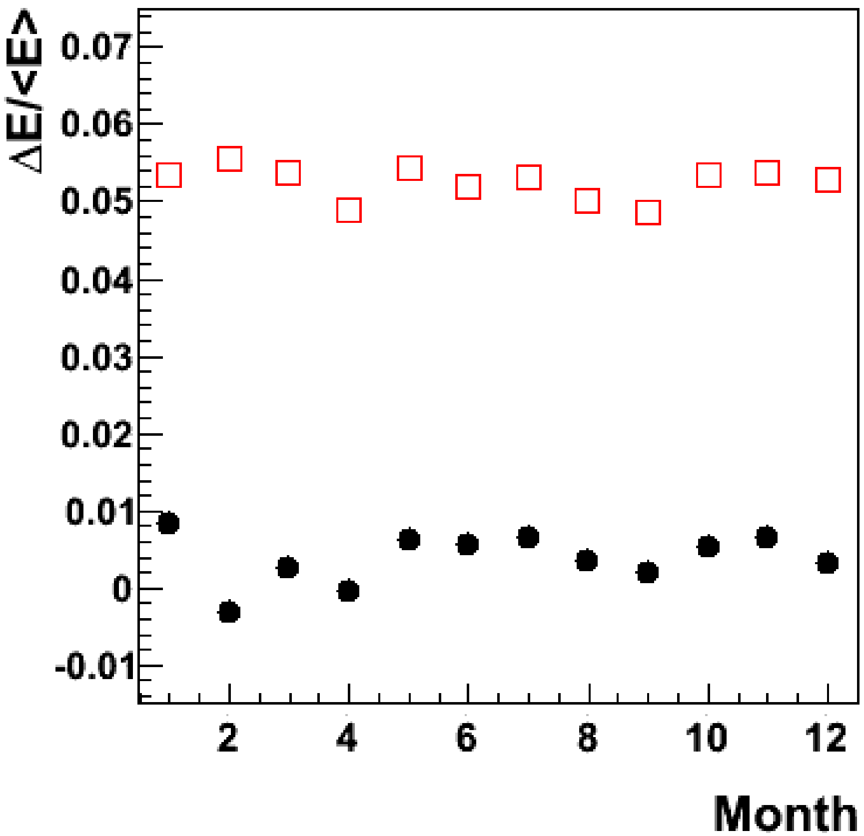
Energy



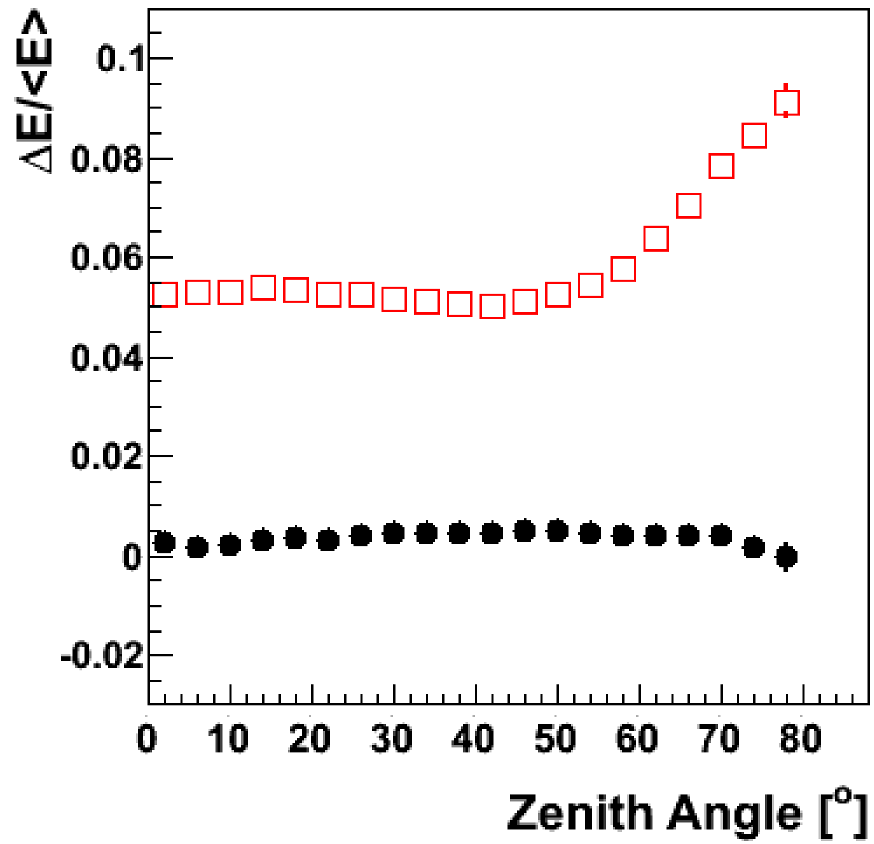


$FY_{mod, GDAS} - FY_{mod, MP}$	Mean 0.4%	RMS 1.4%
$FY_{mod, GDAS} - FY_{std, MP}$	Mean 5.2%	RMS 1.5%

Energy

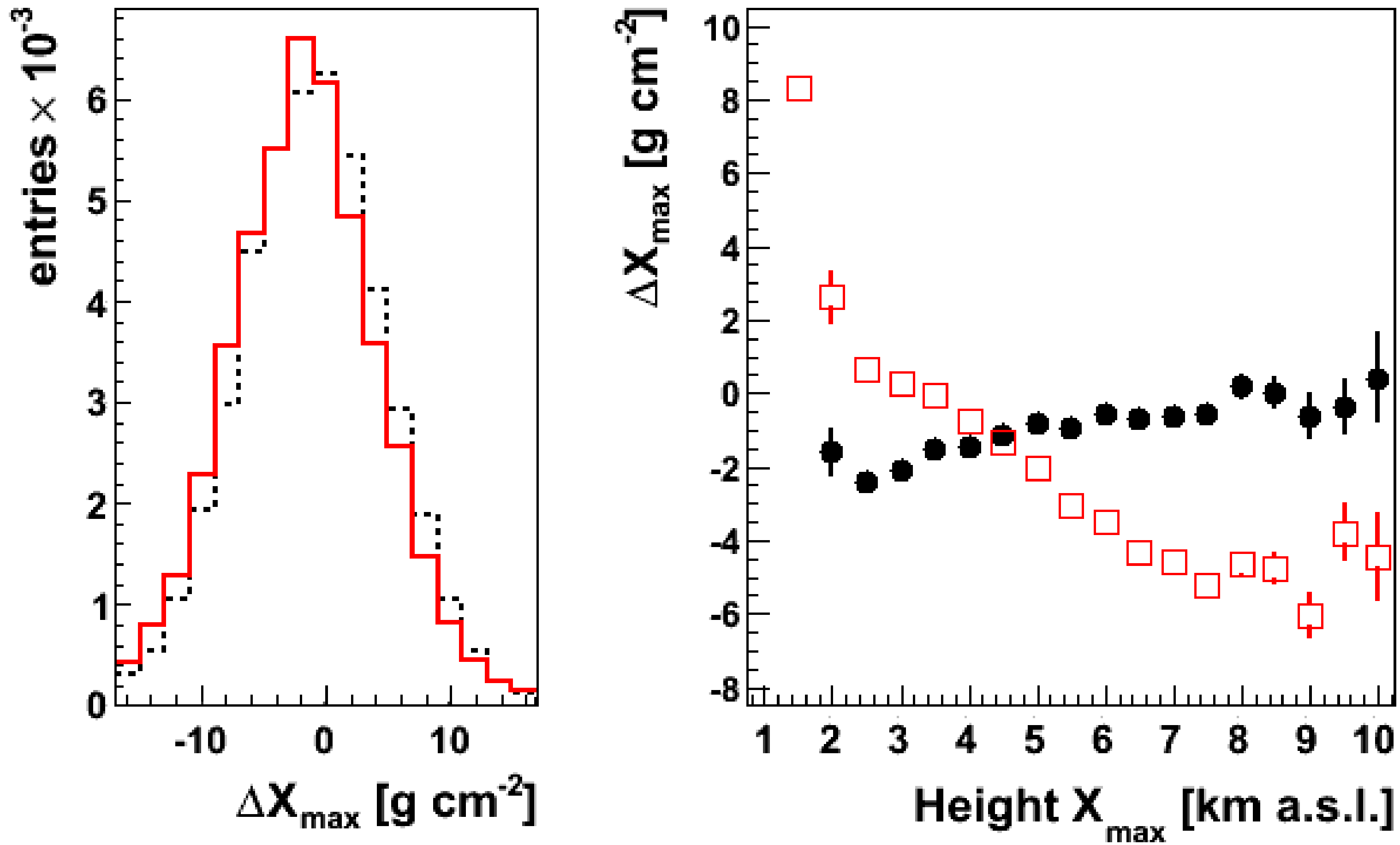


ΔE/<E>
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
2
4
6
8
10
12
Month



ΔE/<E>
0.1
0.08
0.06
0.04
0.02
0
-0.02
0
10
20
30
40
50
60
70
80
Zenith Angle [°]

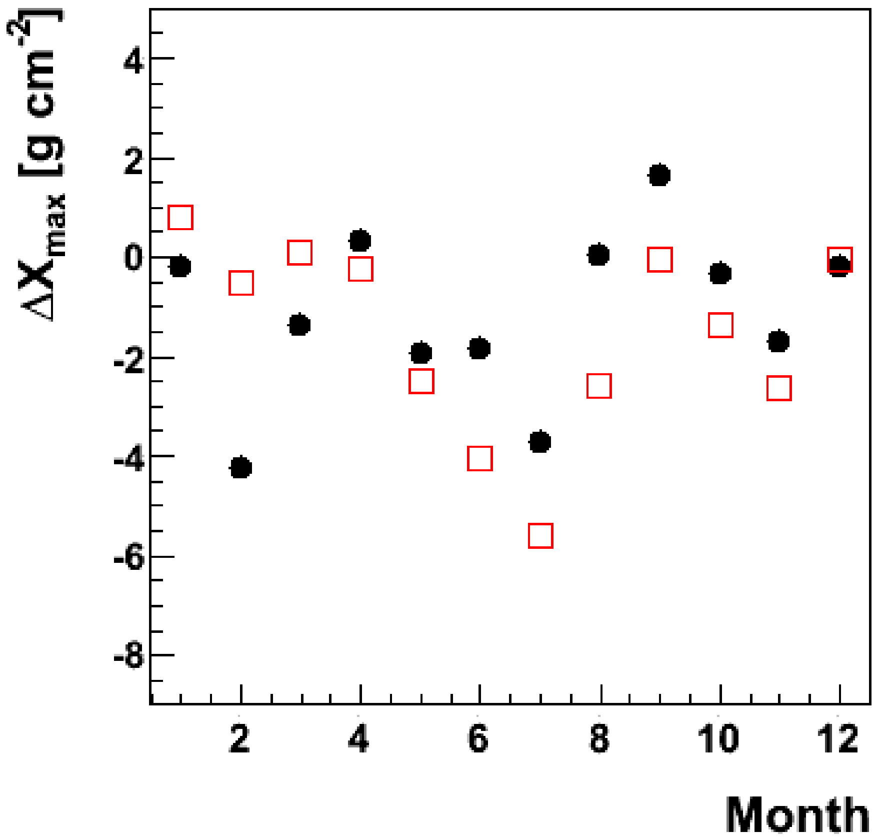
Xmax



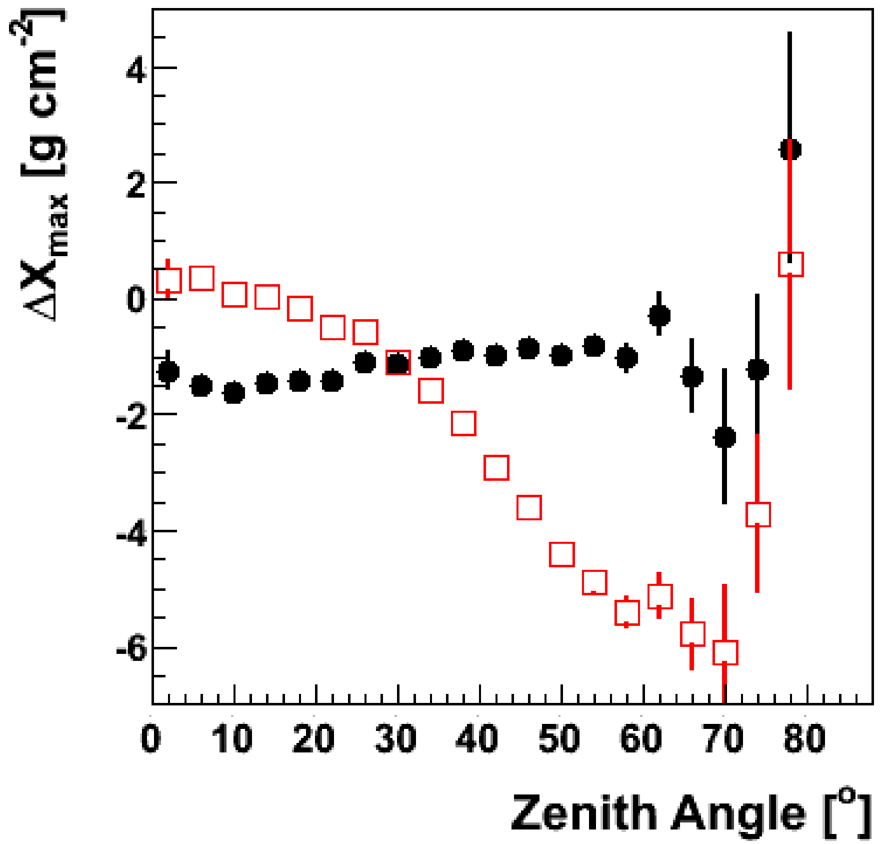
$FY_{mod,\,GDAS} - FY_{mod,\,MP}$ Mean –1.1 g cm^{-2} RMS 6.0 g cm^{-2}

$FY_{mod,\,GDAS} - FY_{std,\,MP}$ Mean –1.9 g cm^{-2} RMS 6.3 g cm^{-2}

Xmax



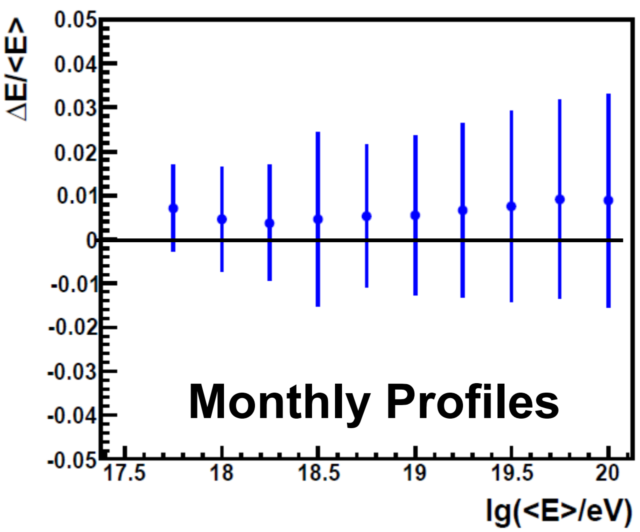
ΔX_{max} [g cm^{-2}]
4
2
0
-2
-4
-6
-8
2
4
6
8
10
12
Month

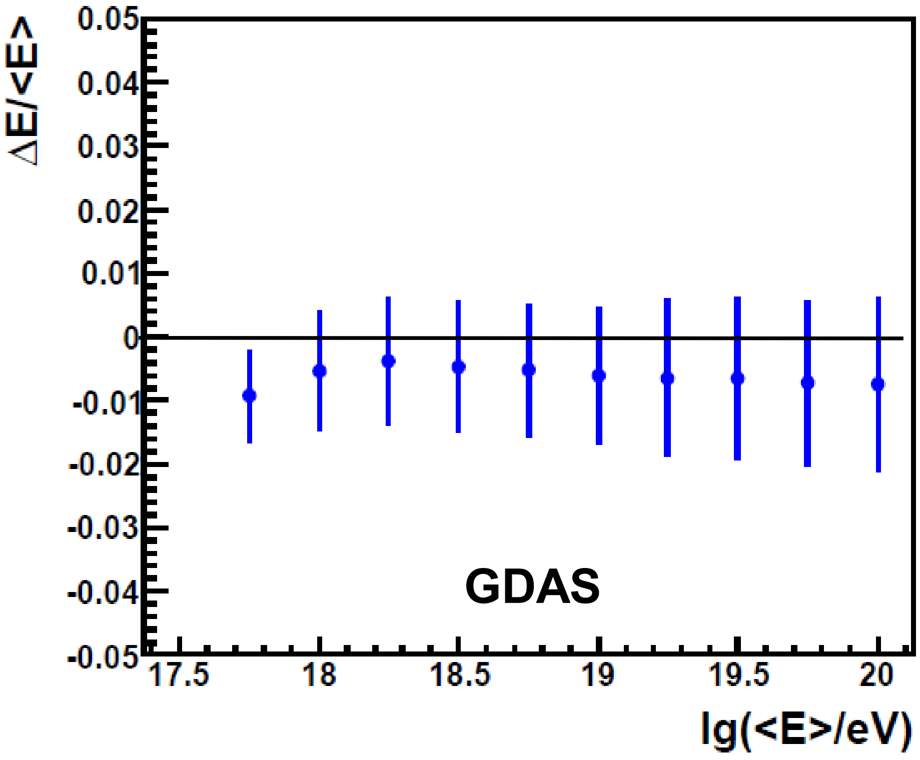


ΔX_{max} [g cm^{-2}]
4
2
0
-2
-4
-6
0
10
20
30
40
50
60
70
80
Zenith Angle [^{o}]

Reconstruction Uncertainties

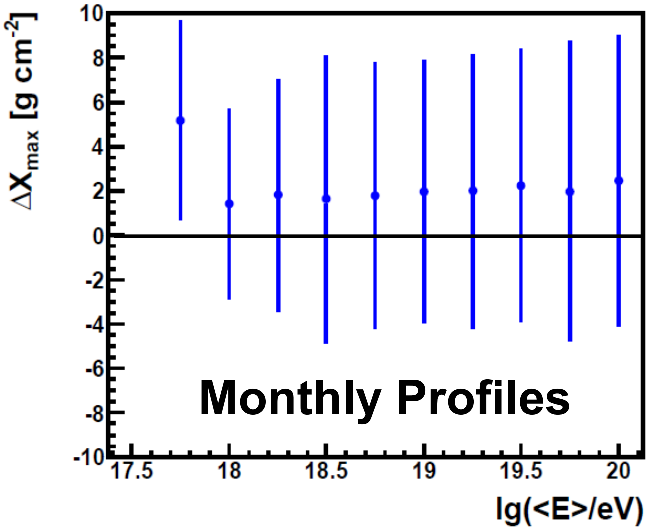
- Simulate p and Fe showers using atm. profiles from **109 cloud-free nighttime balloon launches**
- 3 reconstructions: using real profile, monthly profiles, GDAS
- Systematic offset: **below 1% in Energy**
- Low energies: **0.9%**
- High energies: **1.3%**

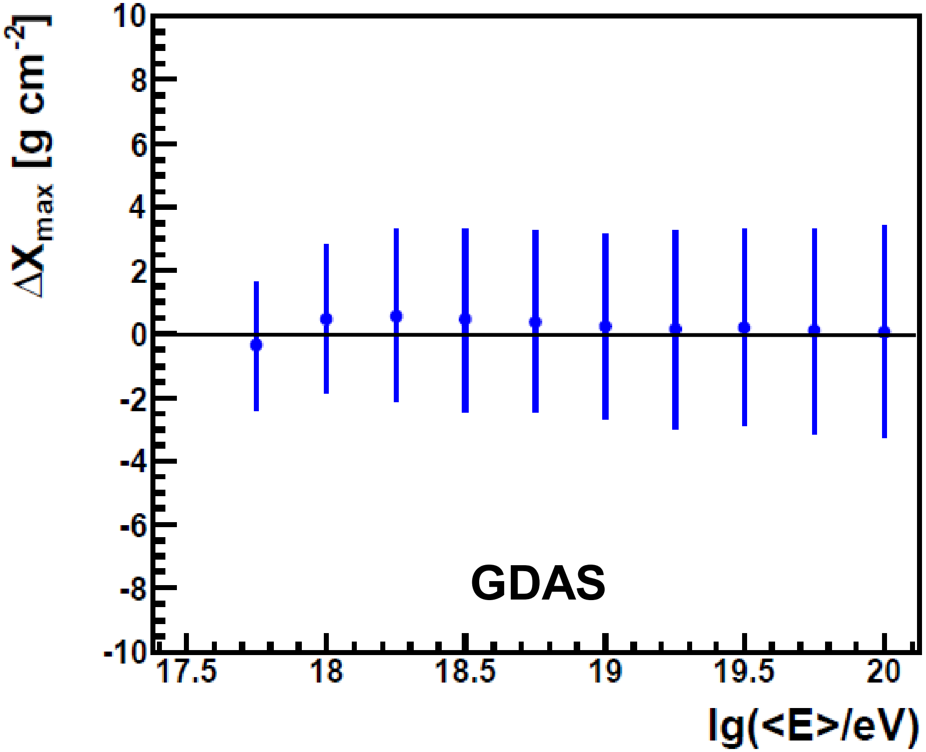




Reconstruction Uncertainties

- Simulate p and Fe showers using atm. profiles from **109 cloud-free nighttime balloon launches**
- 3 reconstructions: using real profile, monthly profiles, GDAS
- Systematic offset: **below 0.5 g cm^{-2} in X_{max}**
- Low energies: **2.0 g cm^{-2}**
- High energies: **3.5 g cm^{-2}**





Conclusions

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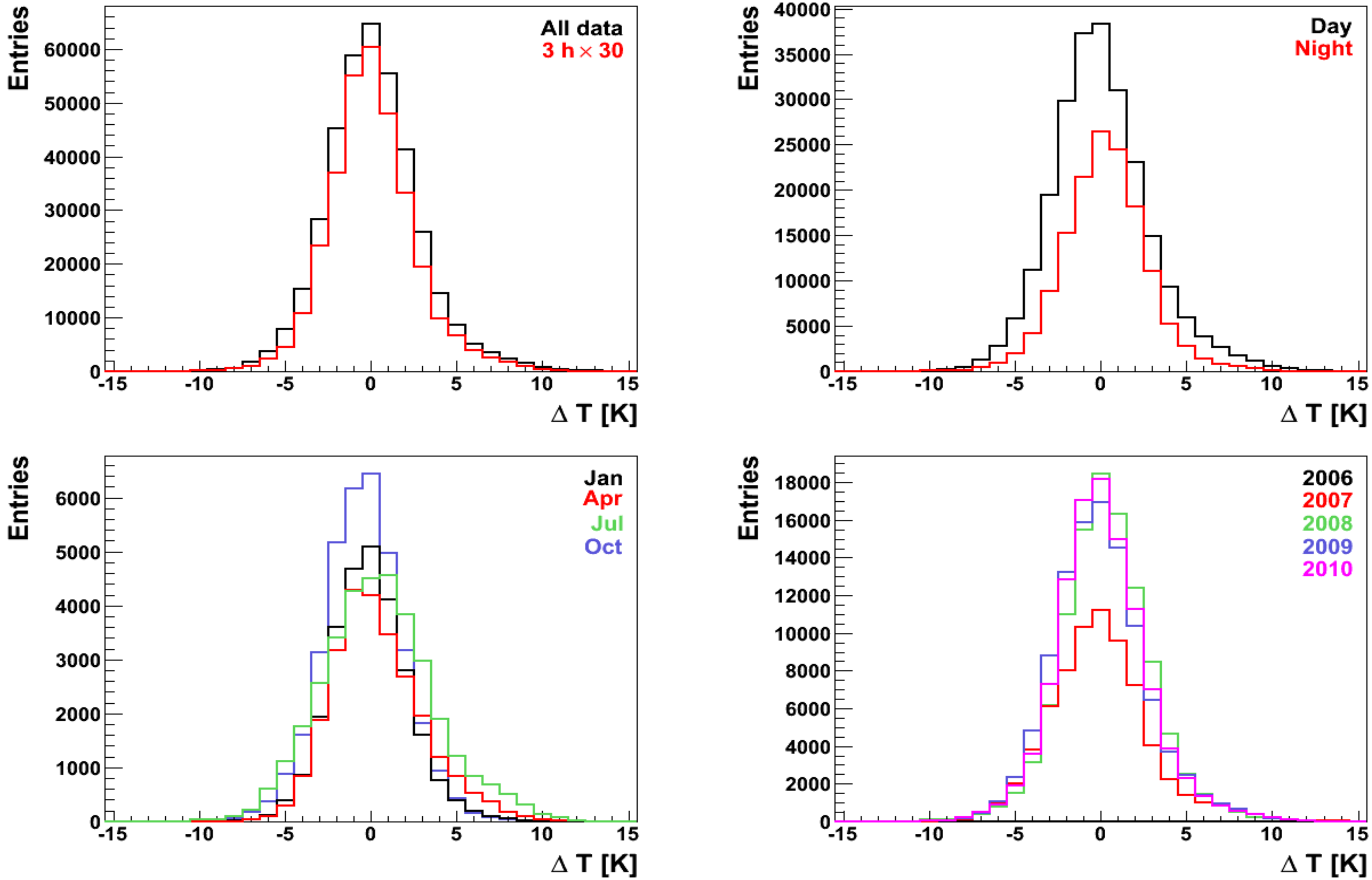
- Comparisons with on-site measurements confirm applicability of GDAS data
- GDAS and full atm.-dep. Airfly fluorescence model are currently best description of molecular atmosphere available
- Reconstruction uncertainty much smaller than with monthly models, **for medium to high energies half**

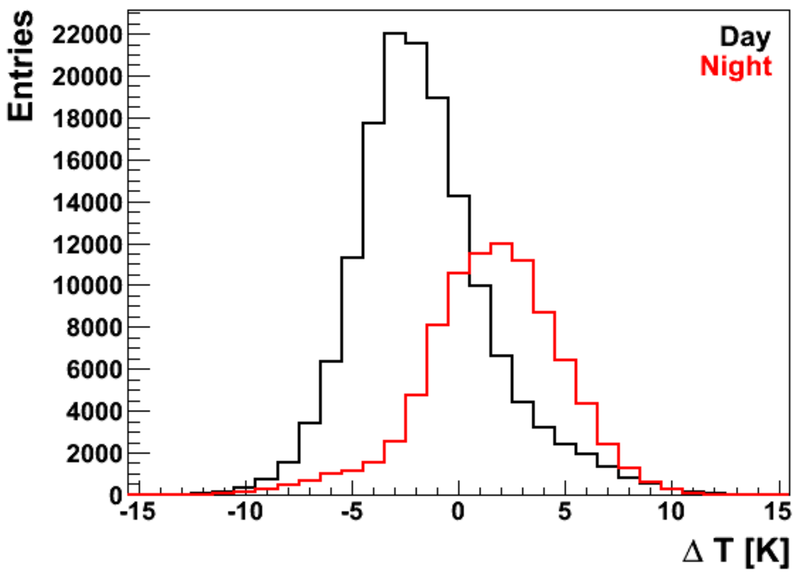
Thanks for your attention

Backup

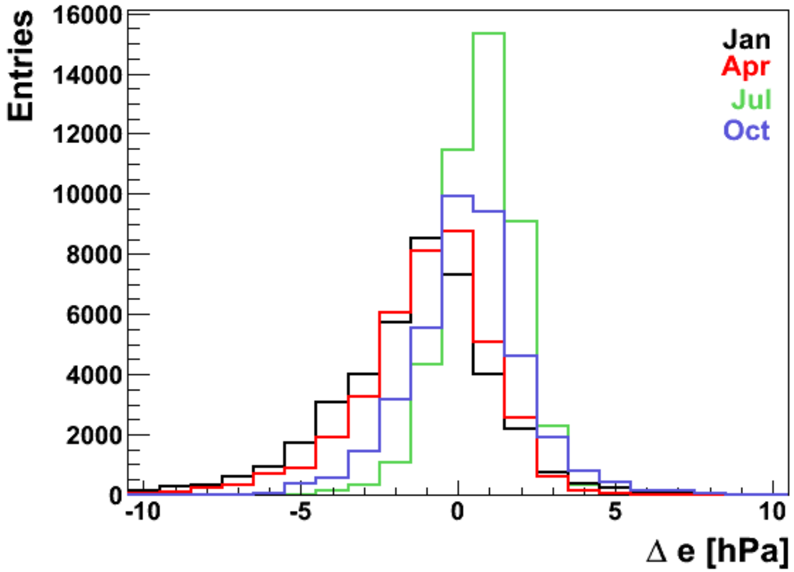
Temperature LM



Uncertainties



Temperature LA



Vapor Pressure CLF

- Weather stations are not sheltered
- Influences from surface, nearby buildings (metal containers)