The Cherenkov Telescope Array Site Search Campaign

Atmospheric Considerations

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For the CTA Collaboration
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HELMHOLTZ ASSOCIATION

cta cherenkov telescope array

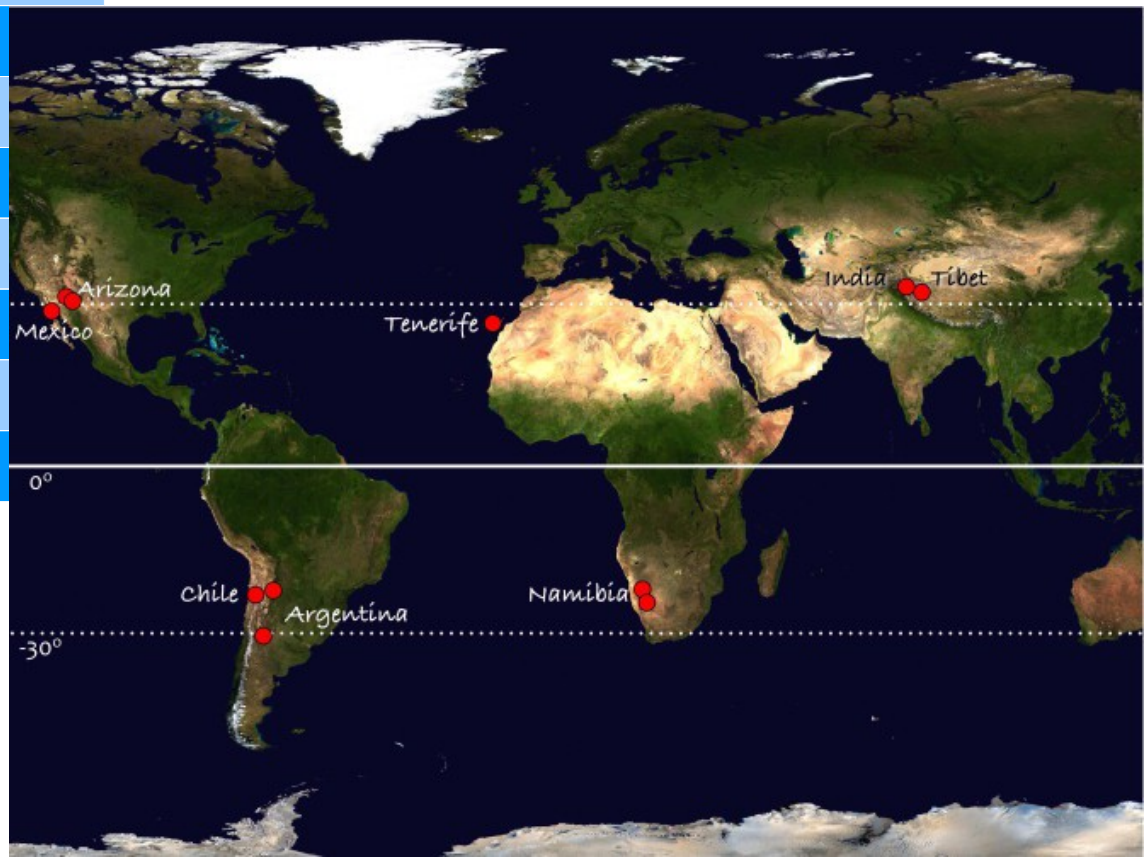
DESY

Introduction

- CTA aims at improving the sensitivity by an order of magnitude with respect to HESS, MAGIC & VERITAS
- CTA will consist of 2 observatories (one in the Southern and one in the Northern hemisphere)
- Basic requirements for the site are:
  - A flat area of 10 km^2 in the South and 1 km^2 in the North
  - Site elevation bet. 1500 and 3800 m.a.s.l.
  - The slope of the ground must be less than 8%
  - More than 70% of night good for observations
  - Winds not exceed 50km/h for observations
  - Seismic accel. below 5$m.s^{-2}$ to occur with prob. of <10% in 50 years

CTA Candidate Sites

Name	Country	Elevation
Leoncito	Argentina	2600
San Antonio de los Cobres	Argentina	3600
Armazones	Chile	2400
HESS	Namibia	1850
Aar	Namibia	1650
Tenerife	Spain	2200
Meteor Crater	USA	1700
Yavapai	USA	1650
San Pedro Martir	Mexico	2500

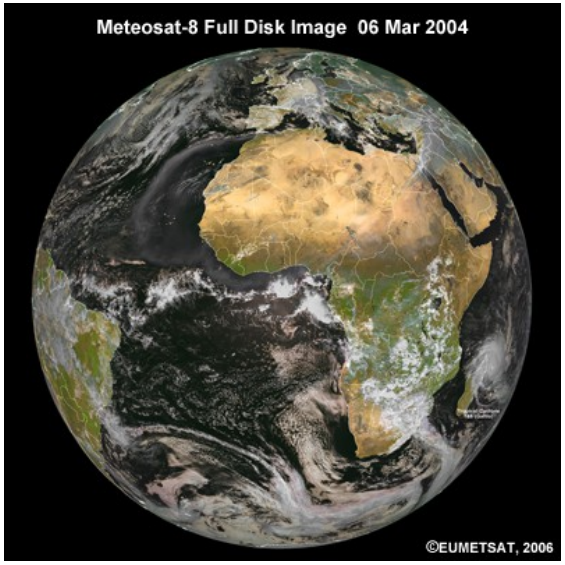


Site Quality Evaluation & Site Characterization

- **The site testing on 3 sources of information**
  - **Instrumentation at sites: developed by CTA and local**
  - **Numerical weather simulations**
  - **Satellite data → see Michael PROUZA's talk**
- **The environment at the CTA sites**
  - **Local conditions (Wind, Humidity, Temperature, Pressure)**
  - **Atmosphere (Clouds, Aerosols, etc...)**
  - **Darkness quality (NSB)**

Satellite Data

- **Polar satellites (MODIS)**
  - Much closer to the Earth, better resolution
  - But, typically only one fly-over per day, and thus poor temporal resolution
- **Geostationary satellites (Meteosat, GOES)**
  - Far away – poorer resolution
  - But – very good temporal resolution (e.g. Meteosat takes 1 image per 15 minutes) and very wide field of view (possibility of comparison of multiple sites in one image)
- **Field of view**

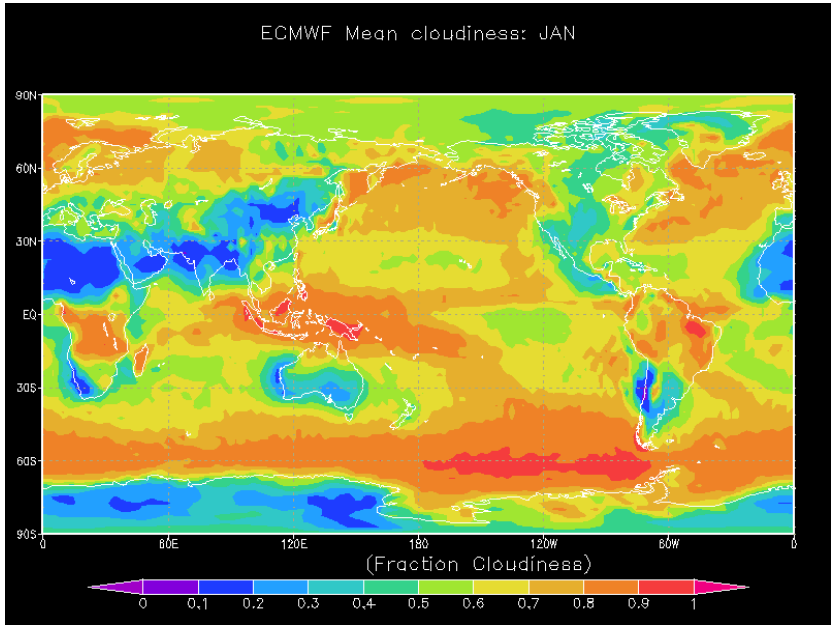


SENES Simulations

- **The SENES simulations provide long-term (10+ year) evolution for important environmental quantities:**
  - **Wind, Temperature, Humidity, Pressure, Cloud information**
- **Forecasting system from 2-step process**
  - **Collect global base temperature and pressure observational data**
  - **Weather model – WRF-NMM (U.S. Operational forecast model)**
  - **Fine (1km x 1km) resolution modeling**
- **We have for each candidate site**
  - **10 years of simulations for each site (2001-2010)**
  - **Ordered simulations concurrent with Atmoscope data**
  - **Simultaneous data used to validate SENES simulations**

FriOWL Database

- **Developed for ESO for the E-ELT project**
- **The database is a combination of observational data (satellite, radio-sondes, weather stations) and meteorological model output**
- **FriOWL provides global atmosphere and surface condition**
  - **For long term period >40years (Sept 1957 to Aug 2002)**
  - **...but poor angular resolution 1px~300km**



ATMOSCOPE Weather Station

> Reinhardt MWS 4M Weather Station

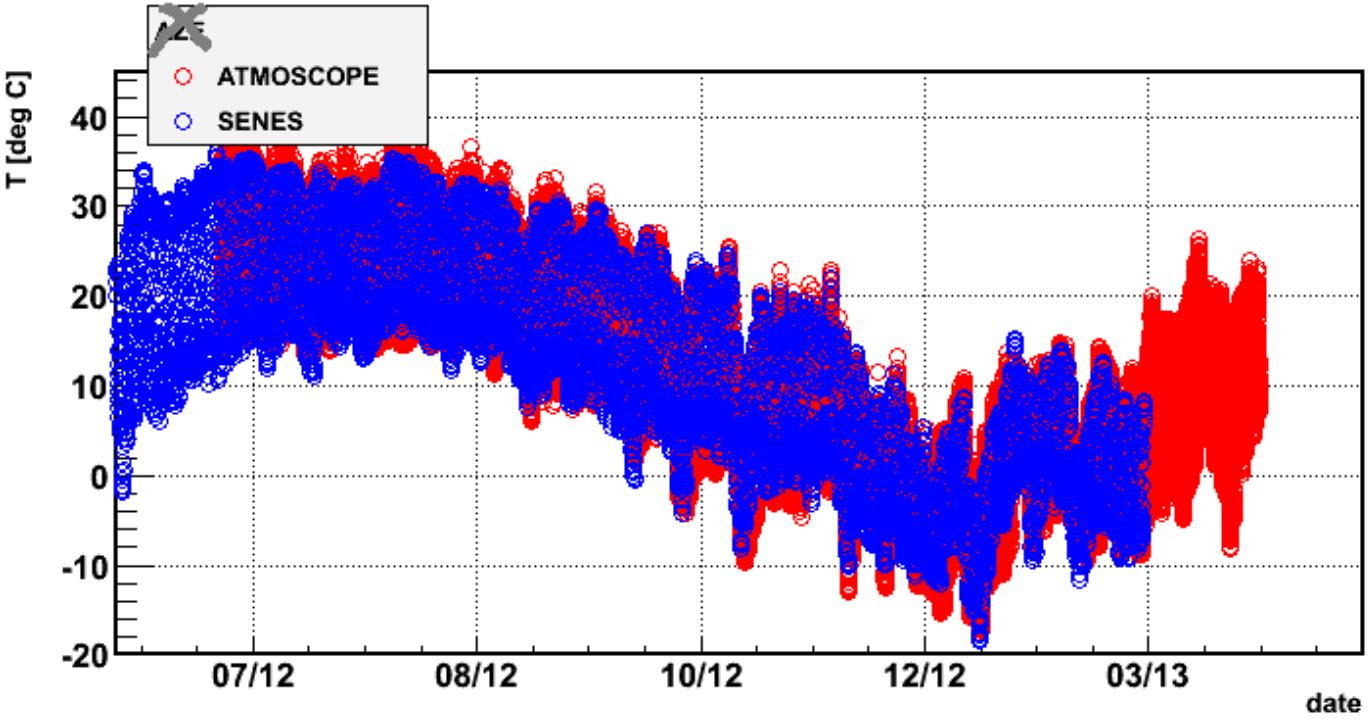
- Temperature: -40 ℃ to 60 ℃ (±0.5 ℃)
- Relative Humidity: 0% to 100% (±2%)
- Absolute Pressure: 600hPa to 1100hPa (±0.8hPa)
- Wind speed: above 1.3m/s up to 42m/s (±0.5m/s)
- Wind direction: accurate to 5 deg above 0.5m/s
- Humidity sensor guaranteed accurate down to 11%

SENES – ATMOSCOPE Comparison

- ATMOSCOPE data & SENES simulations
- Cross-checking the SENES results with ATMOSCOPE data
- Correlations and corrections
- Using the SENES to extend the ATMOSOCPE data

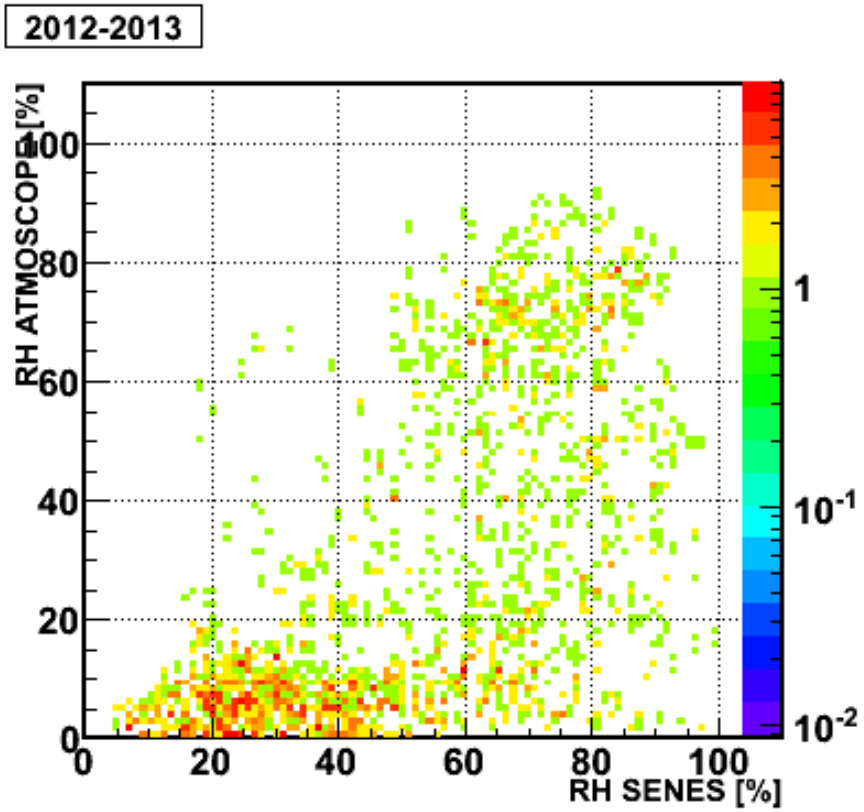
SENES – ATMOSCOPE Cross-check

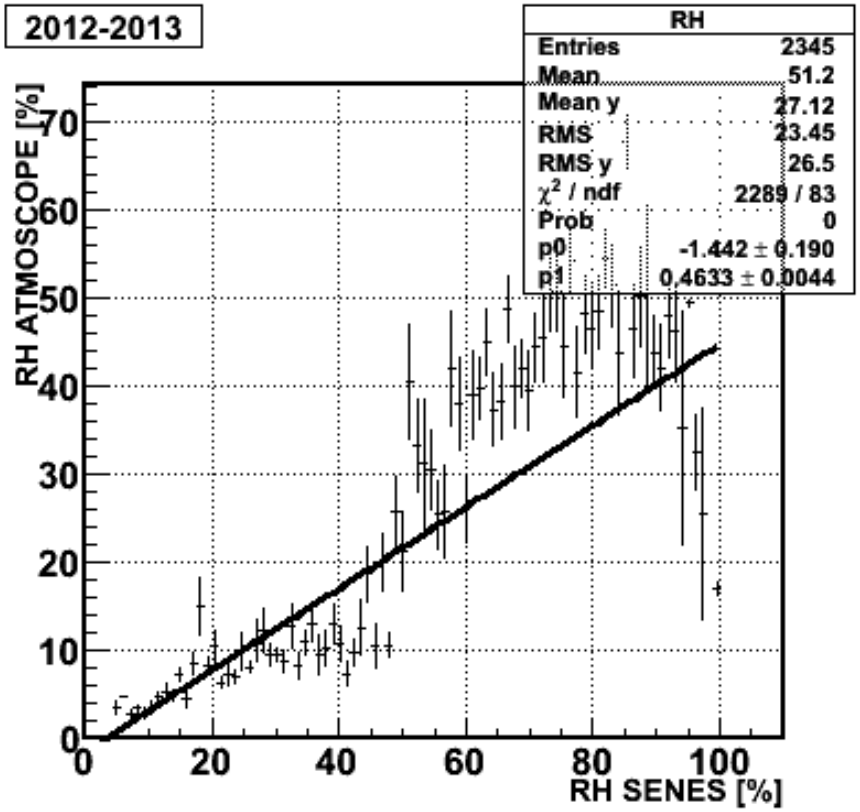
- SENES information provided at hourly intervals for 10+ years
- Simultaneous ATMOSCOPE coverage for ~ 10 months
- How do results compare?



SENES – ATMOSCOPE Cross-check

- **The agreement between SENES and ATMOSCOPE should be evaluated for each site and each variables**

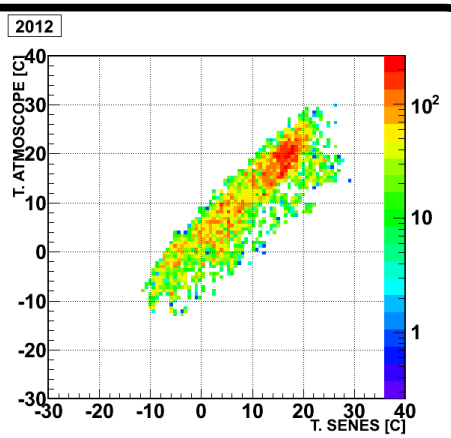




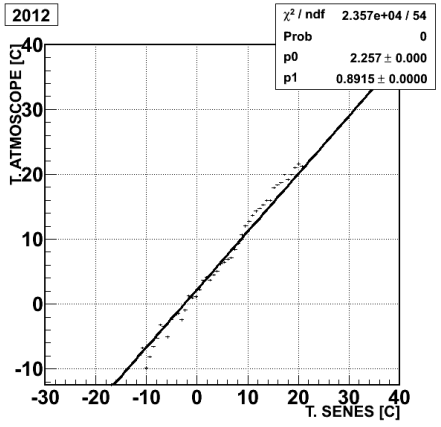
SENES & ATMOSCOPE

> Finding the answer is a 4-step process:

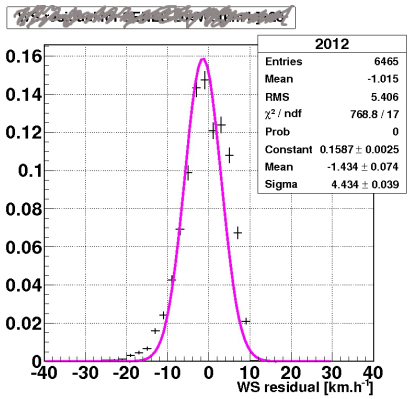
Find Correlation



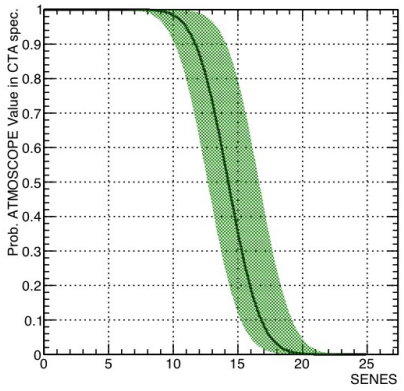
Apply Correction



Fit Residual



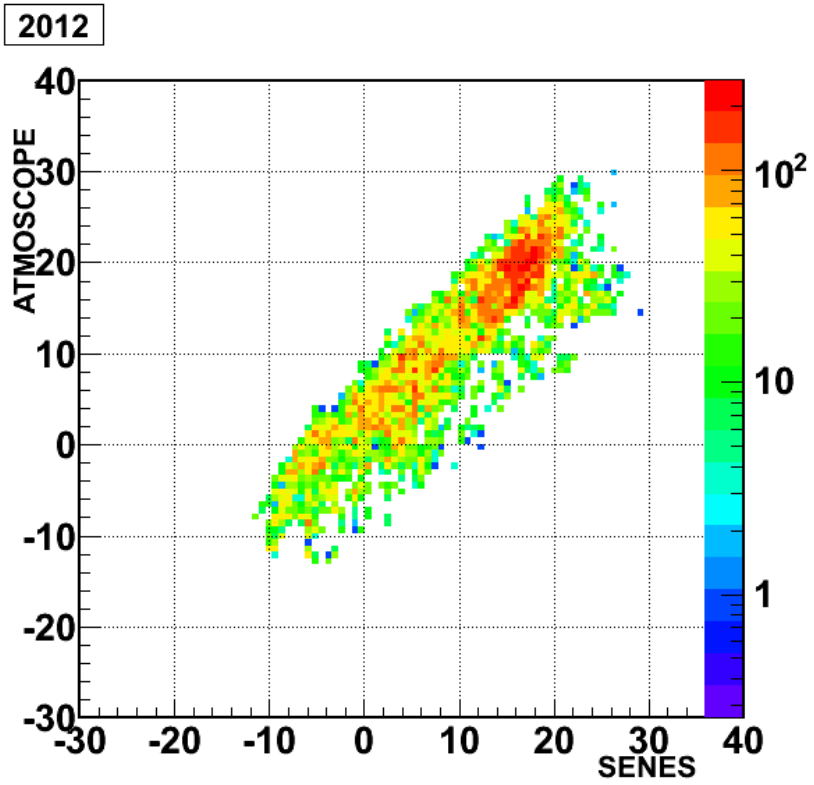
Calculate Probability



SENES & ATMOSCOPE

> Correlation:

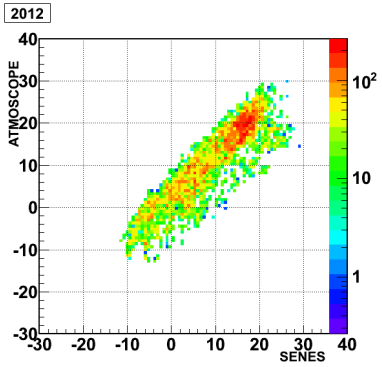
- Expect linear correlation
- May be different behavior in different quantity range
- Practically – interested in extremes

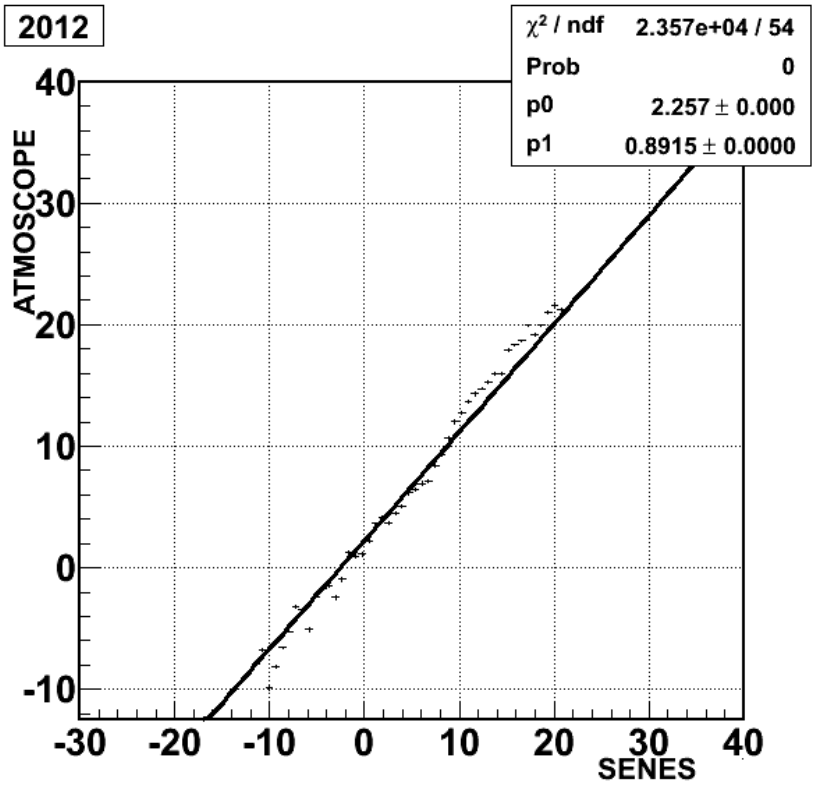


SENES & ATMOSCOPE

> Fit & Correction

- Unbinned fit with simple 1st-order polynomial
- Apply corrections to the SENES predictions



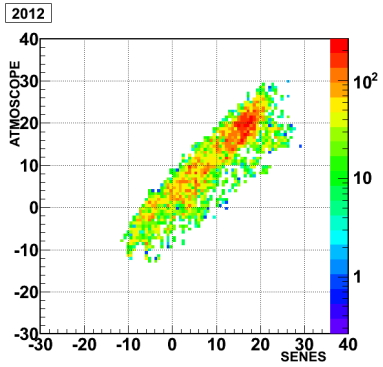


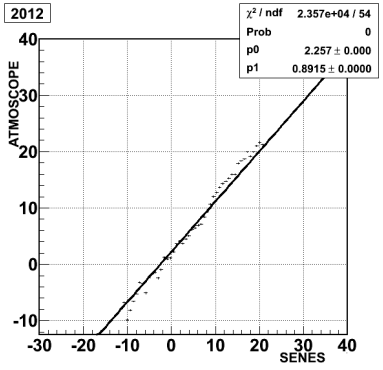
DESY

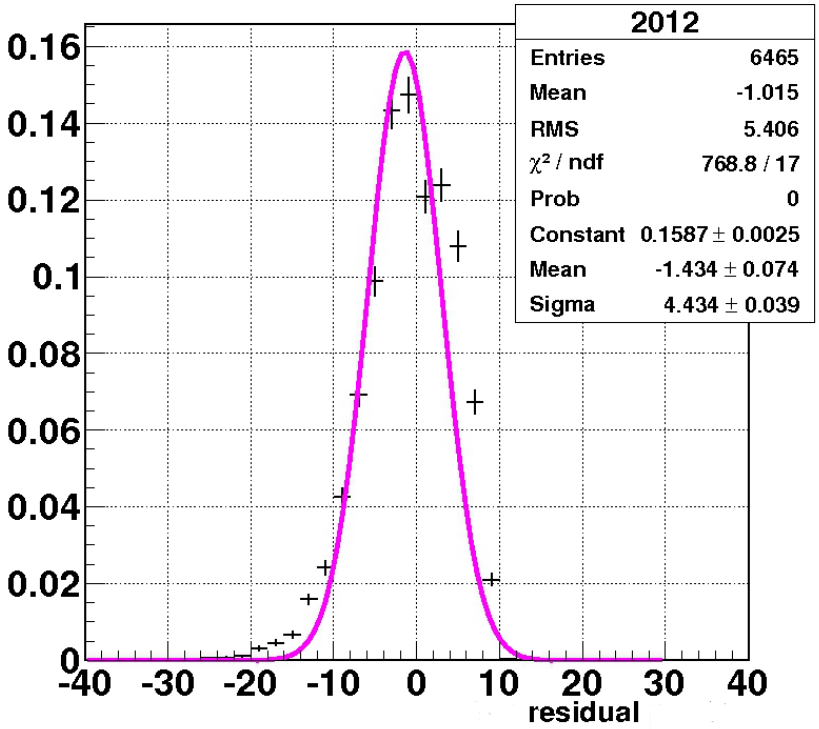
SENES & ATMOSCOPE

> Calculate & fit residuals:

- Unbinned maximum-likelihood Gaussian fit
- Ideally normal,... but possibly anything
- Cut results based on quality of Gaussian fit

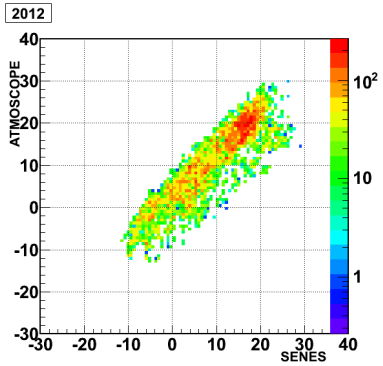


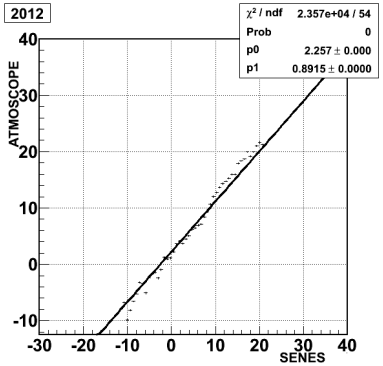


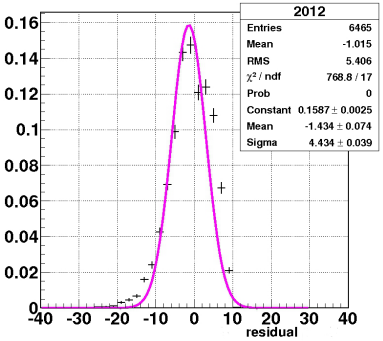


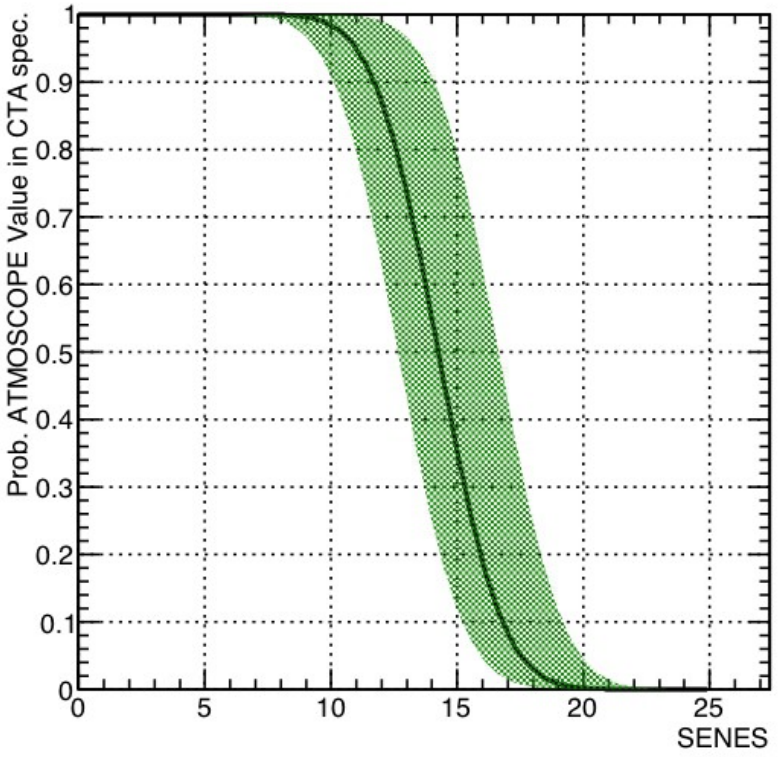
SENES & ATMOSCOPE

- **Calculate probability of true value within CTA spec:**
  - **From fitted Gaussian, calculate normalized integral over range where true value in specifications**
  - **Calculate 1-σ error**









Estimating Observing Time

- From the SENES-ATMOSCOPE correlations and probability distributions, sensible estimates of site environmental quantities can be derived from the archive of 10 years of SENES simulations
- Monte Carlo including temperature, humidity, wind, etc... to determine if hour is good for observations (MC method)
- Alternative calculation can be performed – assume no year-to-year variation and use SENES averages to 'fill in' missing ATMOSCOPE data (Correction method)

Correction Method

- **Assume no year-to-year variation and calculate the % time lost is using SENES to fill in the months without ATMOSCOPE**
- **Example: Assume only have simultaneous ATMOSCOPE/SENES data for January, February**
- **Cuts on observing time:**
  - **Temperature: -15 ℃ to 20 ℃**
  - **Average wind speed: <36km/h**
  - **Humidity: [5% to 90%]**
  - **Dewpoint: 2 ℃ above**

$$A = \frac{\left(\frac{ATM_{lost}}{ATM_{total}}\right)\Big|_{Jan.,\,Feb.}}{\left(\frac{SENES_{lost}}{SENES_{total}}\right)\Big|_{Jan.,\,Feb.}} \rightarrow \left(\frac{ATM_{lost}}{ATM_{total}}\right)\Big|_{Mar.-Dec.} = A \times \left(\frac{SENES_{lost}}{SENES_{total}}\right)\Big|_{Mar.-Dec.}$$

Summary

- The site characterization depends on 3 main sources of informations (simulations, ground based data, satellite)
- For most sites, ground based data will gather a year of data
  - Insufficient to make a comprehensive comparison of the sites
  - We must use several long term data sources
  - To validate the long term data sources, we are conducting a comparison between the ground based data and the numerical weather simulations
  - The correction & the MC methods provide good agreement on time lost evaluation
- The site decision will also take into account the estimate of the infrastructure cost.
- The CTA site decision process is currently under way. We expect to have a final recommendation at the end of 2013

DESY