Site Climatology at ORM

What we already know...

Markus Gaug, UAB

Site Climatology at ORM

- Molecular profiles
- Aerosol profiles
- Weather data

Molecular profiles

Molecular profile

Has effects on size of Cherenkov light pool (via shower altitude and Cherenkov angle) and transmission of Cherenkov light

- E_{rec} scales directly with optical transmission, i.e. integrated density from emission point to ground
- E_{rec} scales approximately with $\boldsymbol{\rho_c \approx (h_{med} - h_{obs})^{-2}}$ because of the modulation of the Cherenkov angle and median shower height.

  Bernlöhr, Astrop. Phys. 12 (2000), 255
- A_{eff} more complicated, needs simulations

Molecular profile

Has effects on size of Cherenkov light pool (via shower altitude and Cherenkov angle) and transmission of Cherenkov light

Have excellent Data Assimilation models for La Palma (for free) for temperature and pressure (i.e. density):

- Global Data Assimilation System (GDAS) from **ground to 25** km a.s.l. ftp://arlftp.arlhq.noaa.gov/pub/archives/gdas1/
- The NRLMSIS-00 model for **20 to 100 km** a.s.l. http://ccmc.gsfc.nasa.gov/modelweb/atmos/nrlmsise00.html
- The ECMWF has been tested by INFN Torino with very encourageing results http://weather.unisys.com/ecmwf/index.php
- The IG2 model has been tested as well, but does **not agree** well at these altitude ranges (at least for temperature).

Molecular profile

Has effects on size of Cherenkov light pool (via shower altitude and Cherenkov angle) and transmission of Cherenkov light

For molecular absorption not so clear…

- Only O_3, CO_2 and NO_X are (perhaps) relevant for us!
- The IG2 model has been used by INFN Torino, claimed to be accurate, but not yet cross-calibrated with our instruments (or other databases).
- The effect is small though (at least much, much smaller than the density effects)

Molecular profile

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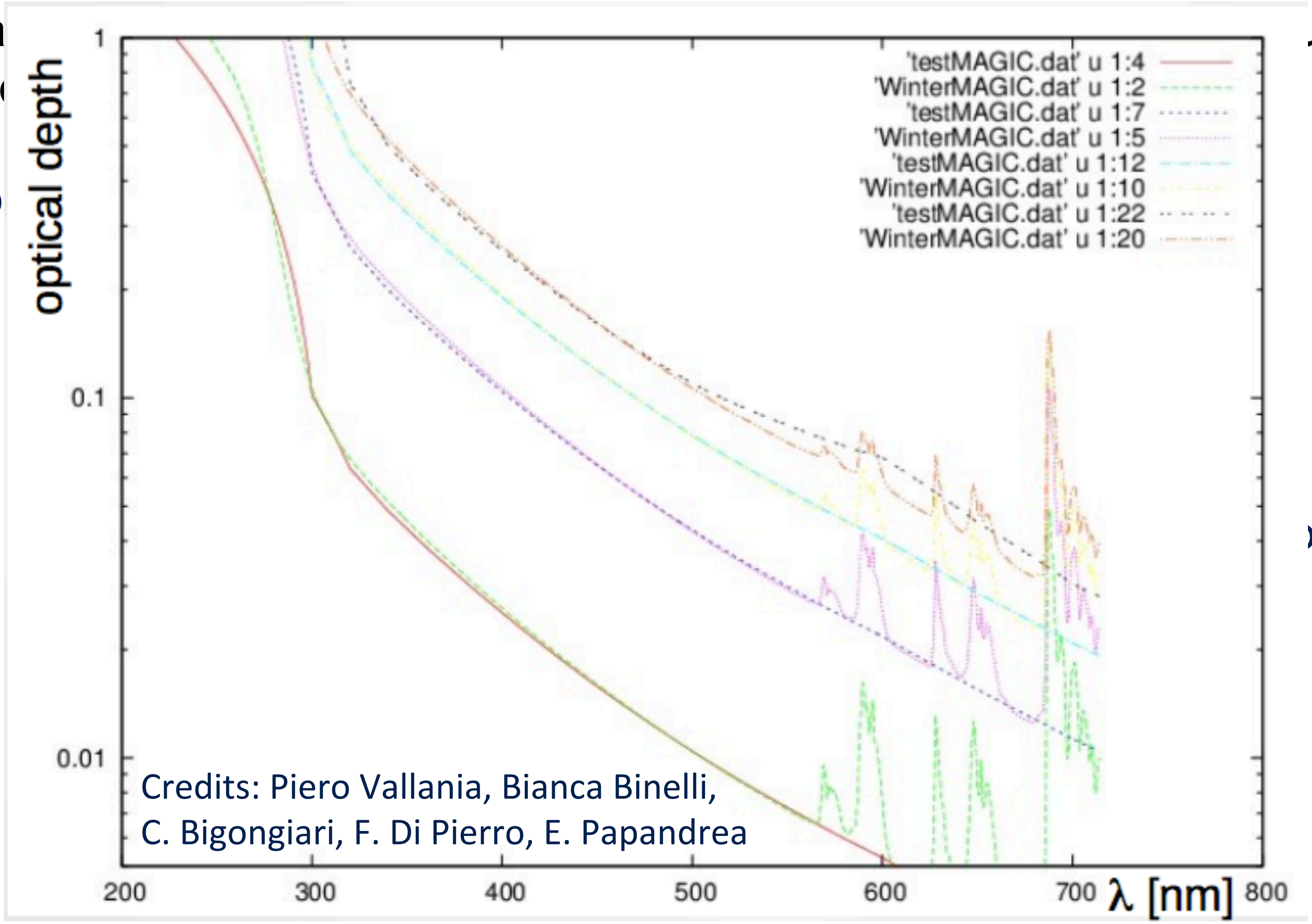
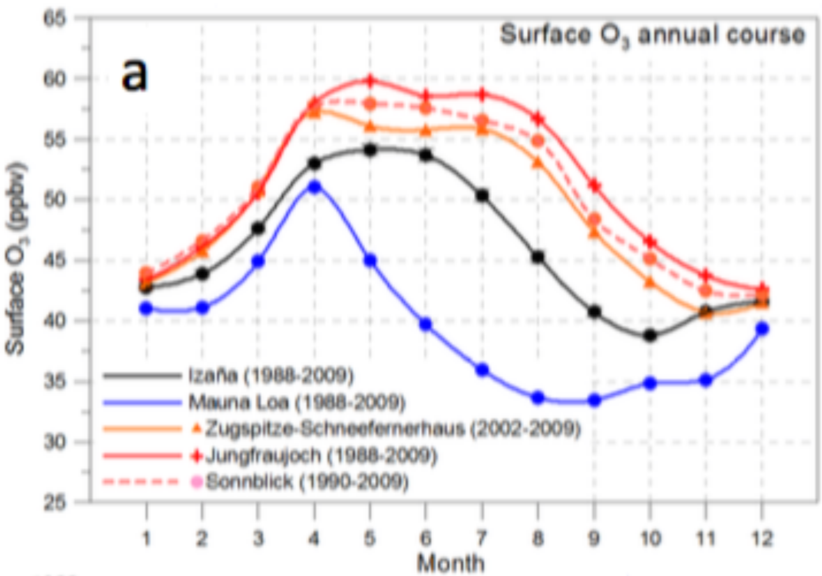


Molecular profile

Ozone has been studied in detail at Izaña (Tenerife), 2400 m a.s.l.



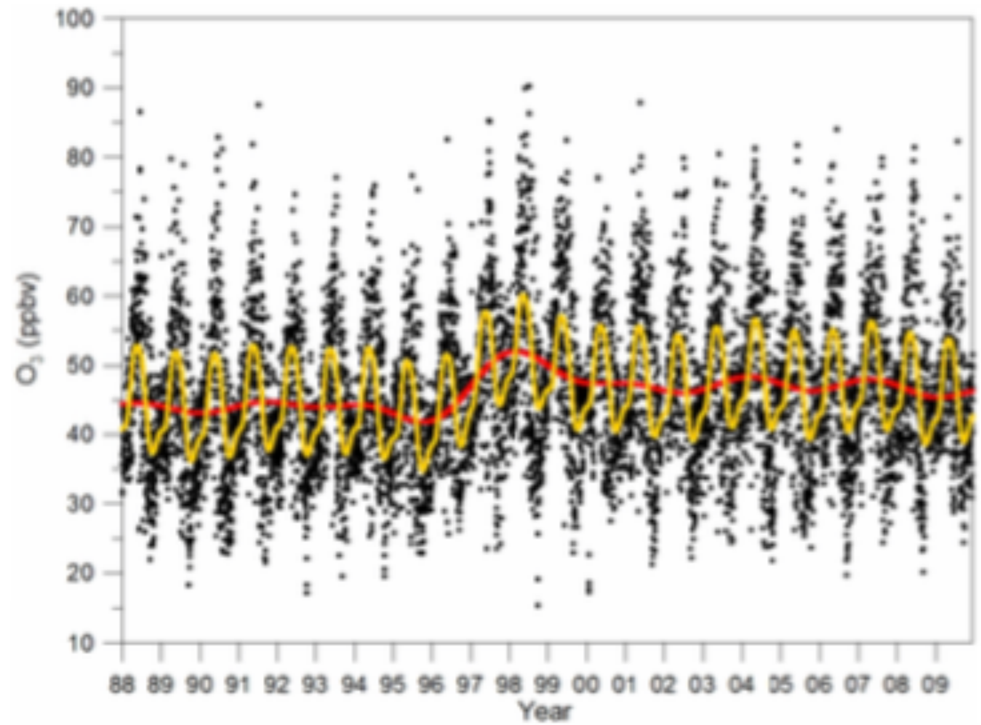


Fig. 2. Surface O_3 daily night means (black dots), interannual trend (red line) and interannual trend plus annual cycle at IZO from 1988 to 2009.

E. Cuevas et al., "**Assessment of atmospheric processes driving ozone variations in the subtropical North Atlantic free troposphere**", Atmos. Chem. Phys., 13, 1973–1998, 2013

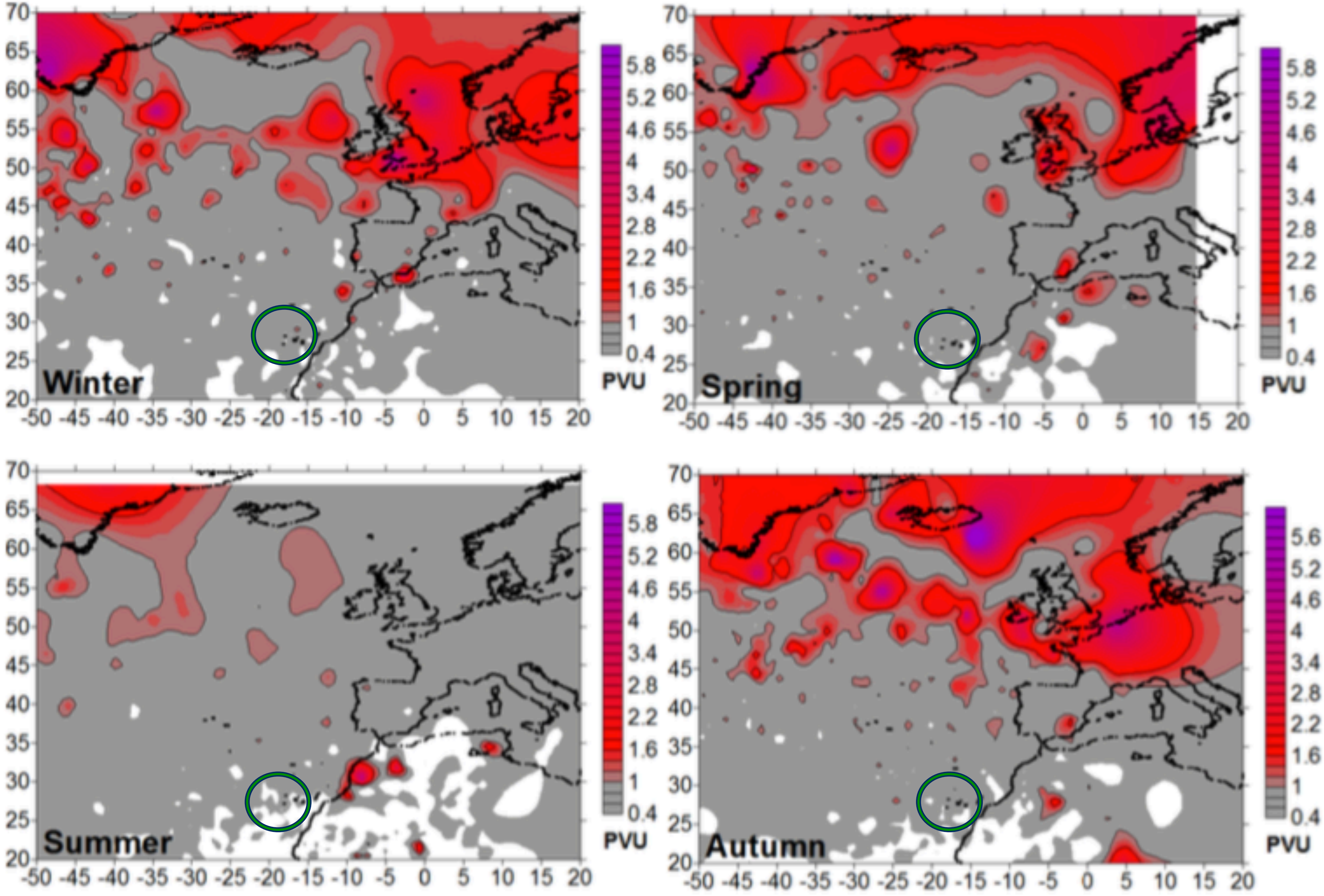
Molecular profile

Ozone at high troposphere is correlated with a parameter called "Potential vorticitiy" (PV), measured in units of PVU.

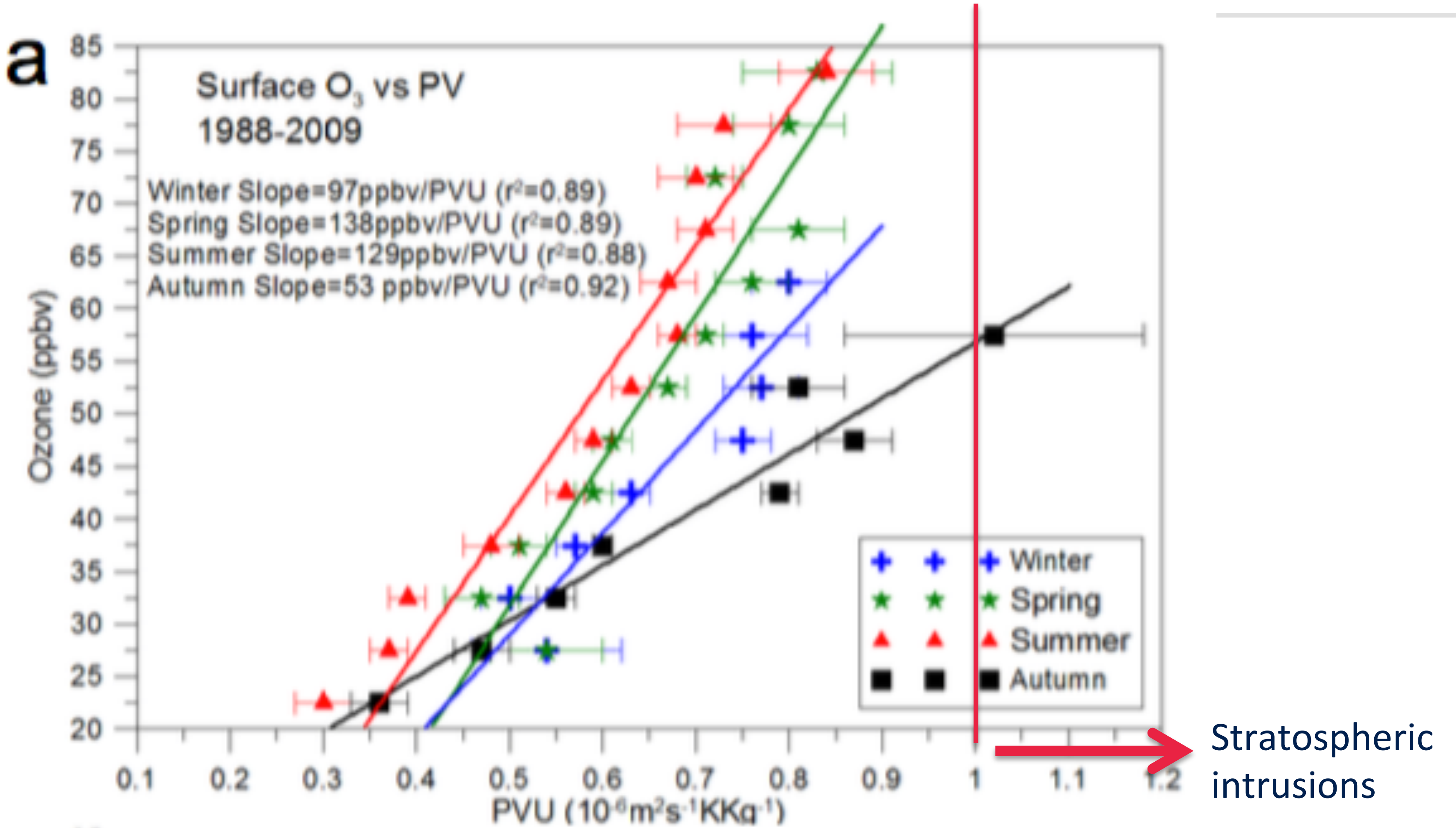
Situations with PVU>1.0 indicate stratospheric intrusions into the upper troposphere and hence high O_3 concentrations.

E. Cuevas et al., "**Assessment of atmospheric processes driving ozone variations in the subtropical North Atlantic free troposphere",** Atmos. Chem. Phys., 13, 1973–1998, 2013

PV_{max} maps for winter (JFM), spring (AMJ), summer (JAS) and autumn (OND) in the period 1988–2009.



Molecular profile



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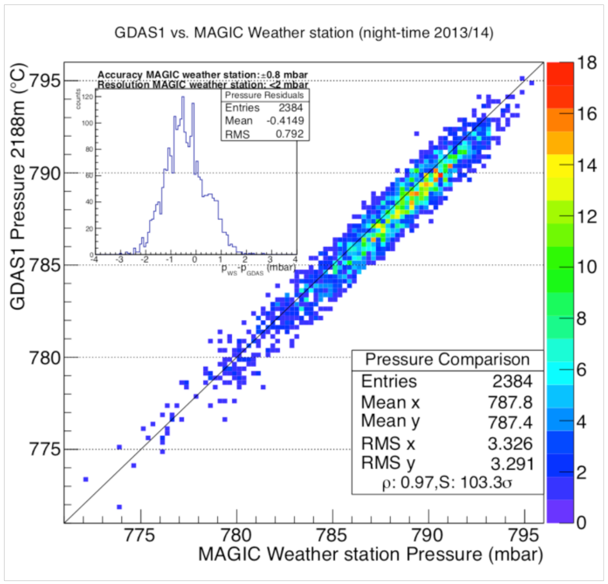
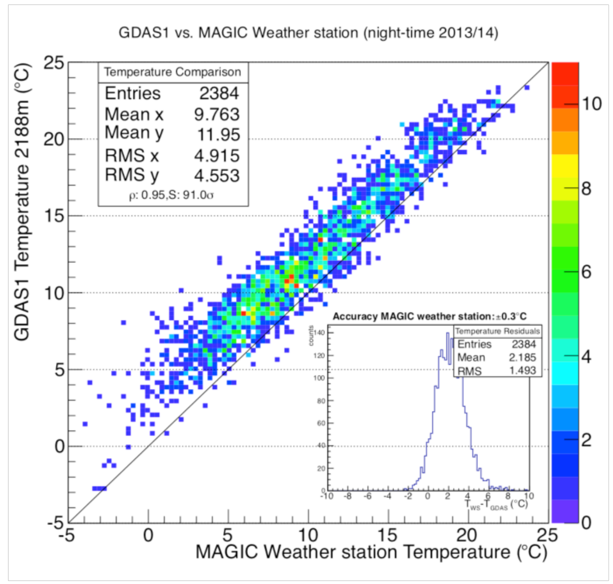
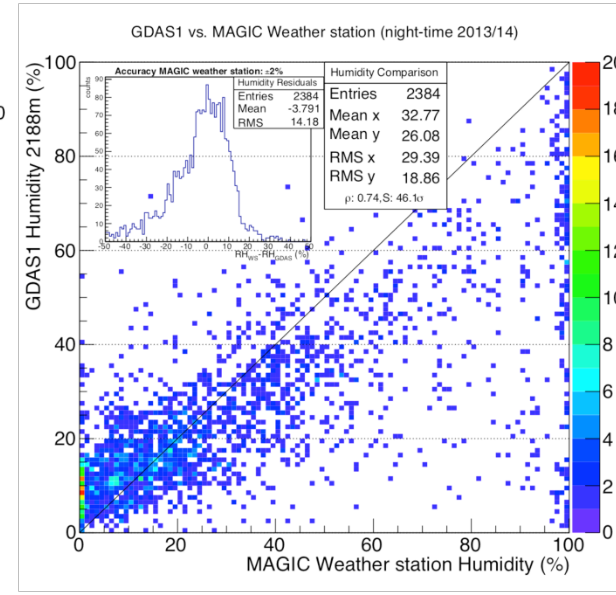
Molecular profile

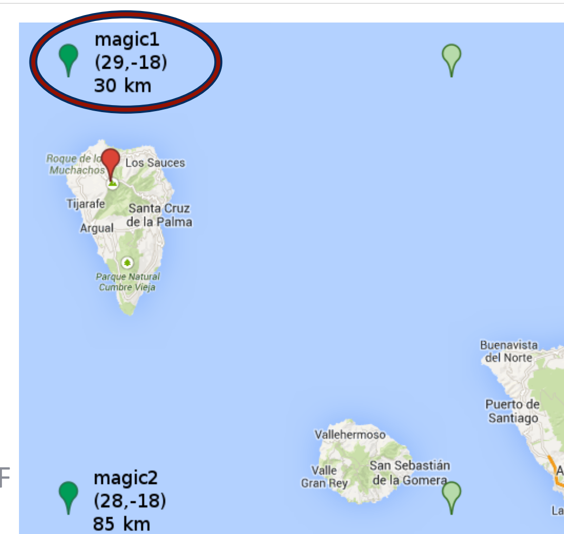




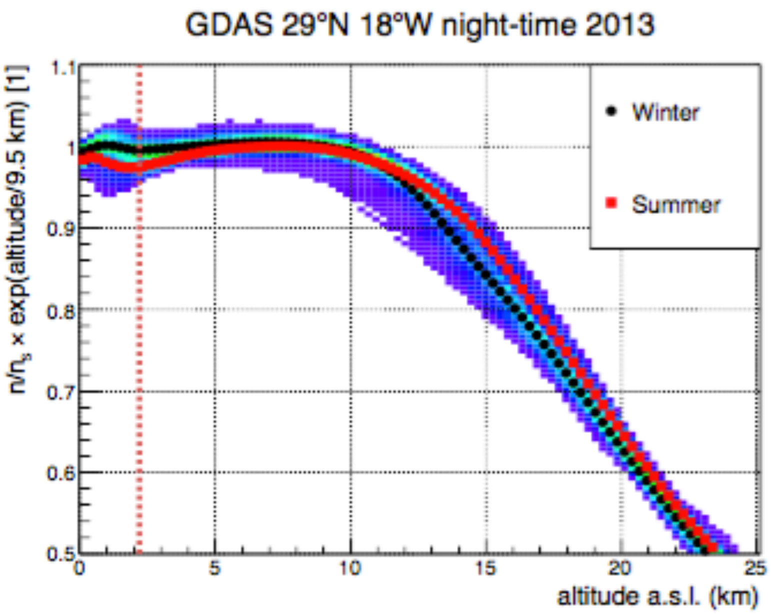


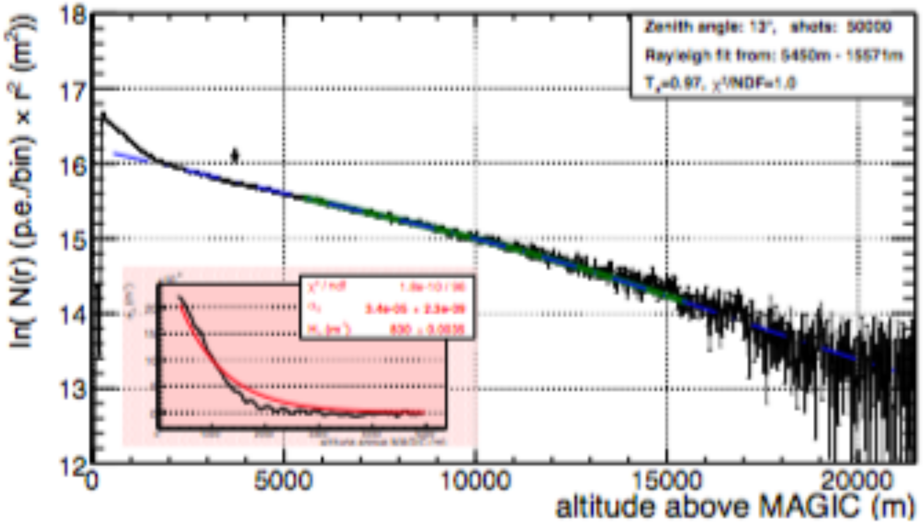
Cross-correlation with MAGIC weather station

- GDAS combined with NRLMSIS-E
- Perfect match for pressure comparison
- Systematic shift for temperatures can be explained by local ground effects (inverse for day-time data)
- Even correlation for humidity is good
(difficult because of very local variation)



Molecular profile

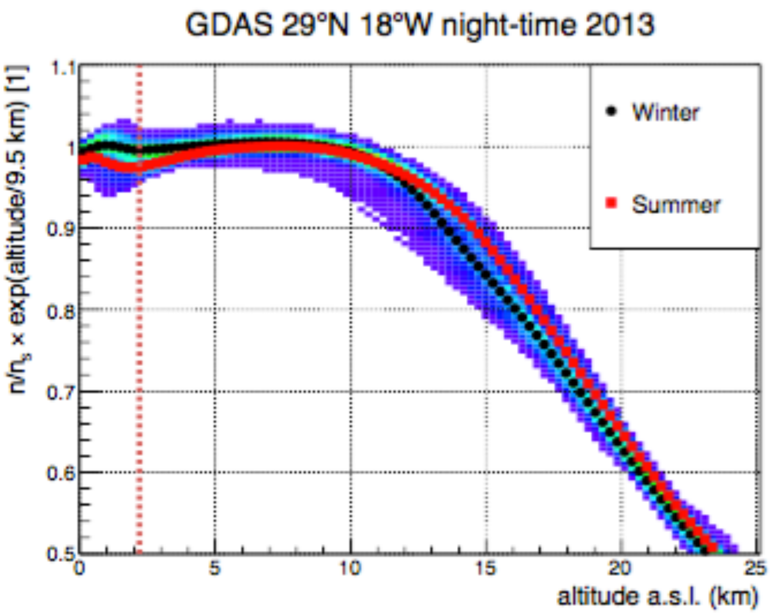


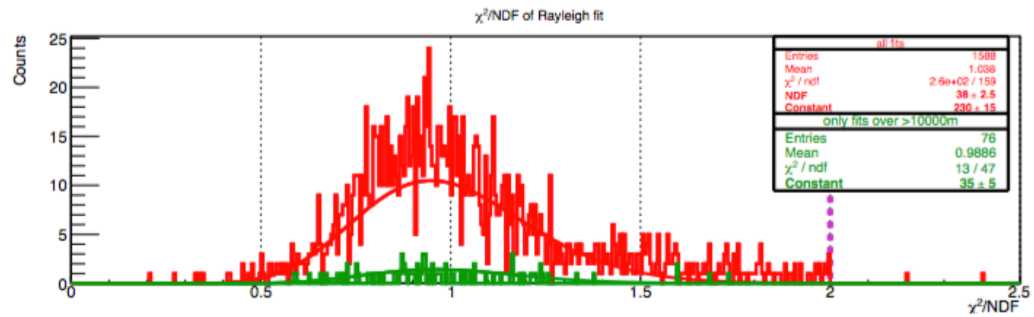


Cross-correlation with the MAGIC LIDAR

- GDAS combined with NRLMSIS-E
- The LIDAR is sensitive to the molecular profile during clear nights
- We see a significant improvement from linear fits to “GDAS-fits”.
- The GDAS fits yield correct χ^2 distributions!

Molecular profile





Cross-correlation with the MAGIC LIDAR

- GDAS combined with NRLMSIS-E
- The LIDAR is sensitive to the molecular profile during clear nights
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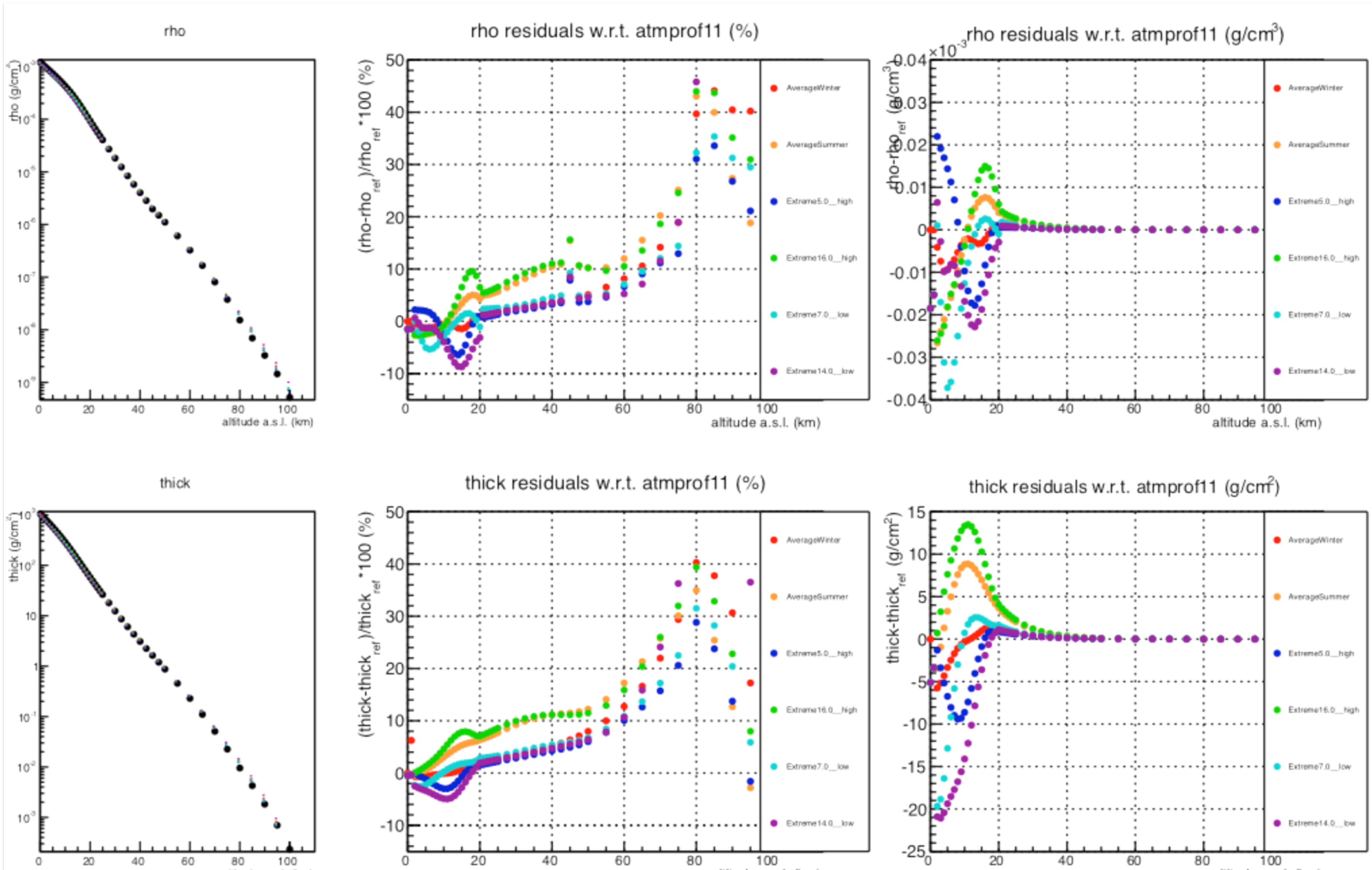
Molecular profile
Simulation input for the MC studies



Molecular profile

Simulations and first result are shown on Wednesday morning by Federico di Pierro (INFN Torino)

Wednesday, 22 June 2016

09:30 - 11:30 MC simulations for different atmospheres

Convener: Dr. Maria Concetta Maccarone (IASF-Palermo/INAF, Istituto di Astrofisica Spaziale e Fisica Cosmica di Palermo/Istituto Nazionale di Astrofisica)

09:30 **CTACG ressources and technical aspects of the CTA MC simulations** *20'*
Speaker: Dr. Luisa Arrabito (LUPM/IN2P3)

09:50 **MC simulations for non-optimal Atmospheric Conditions** *30'*
Speaker: Federico Di Pierro (INFN Torino)

10:20 **Atmospheric simulation in Prague - status, results and plans** *15'*
Speaker: Michal Vrastil (FZU AV CR, v.v.i.)

10:35 **Atmospheric correction in data pipeline: Period / run-wise simulations.** *25'*
Speaker: Dr. Gernot Maier (DESY)

10:55 **Open discussion with DATA** *35'*
Speakers: Dr. Raquel de los Reyes (MPIK), Dr. Gernot Maier (DESY), Mr. Juan José Rodríguez Vázquez (CIEMAT)

Aerosol profiles

Aerosol profiles

Has potentially strong effect on extinction of Cherenkov light

- Aerosol enhancements of ground layer (“calima”) and clouds (cumulus and cirrus)
- Strong dependency on time and altitude
- Strong energy dependency in case of clouds
- Have analyzed more than 3 years of good quality MAGIC LIDAR data
- Taken synchroneously with science data (5 deg. offset)

Aerosol profiles

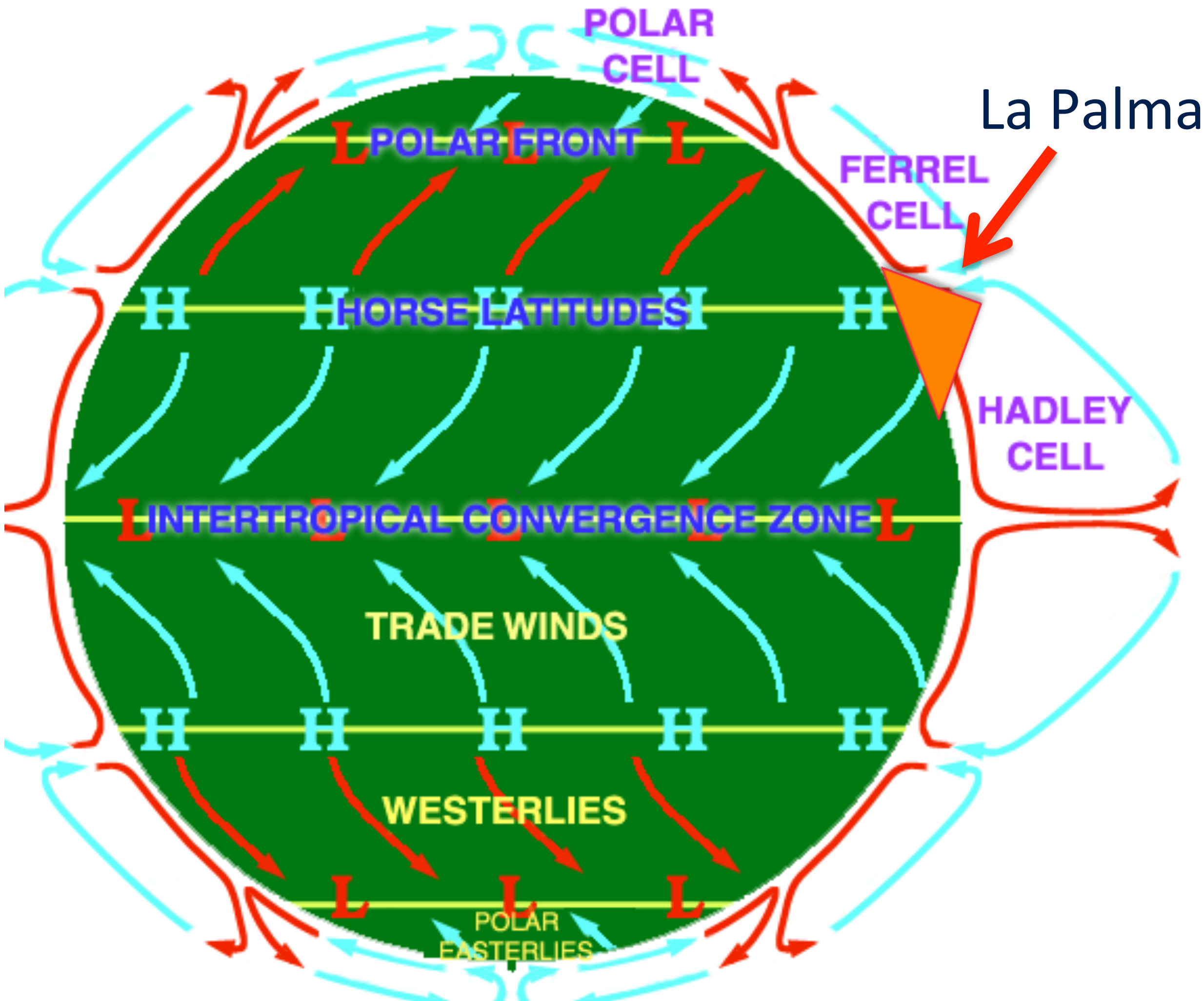
Are very well studied on La Palma, using:

- **3 years of continuous MAGIC LIDAR measurements**
- **Almost 10 years of the TNG dust counter**
- **20 years of Sun photometer measurements (Izaña, Tenerife)**
- **Extremely detailed aerosol characterization with state-of-the-art equipment at IARC (Izaña, Tenerife)**

Aerosol profiles

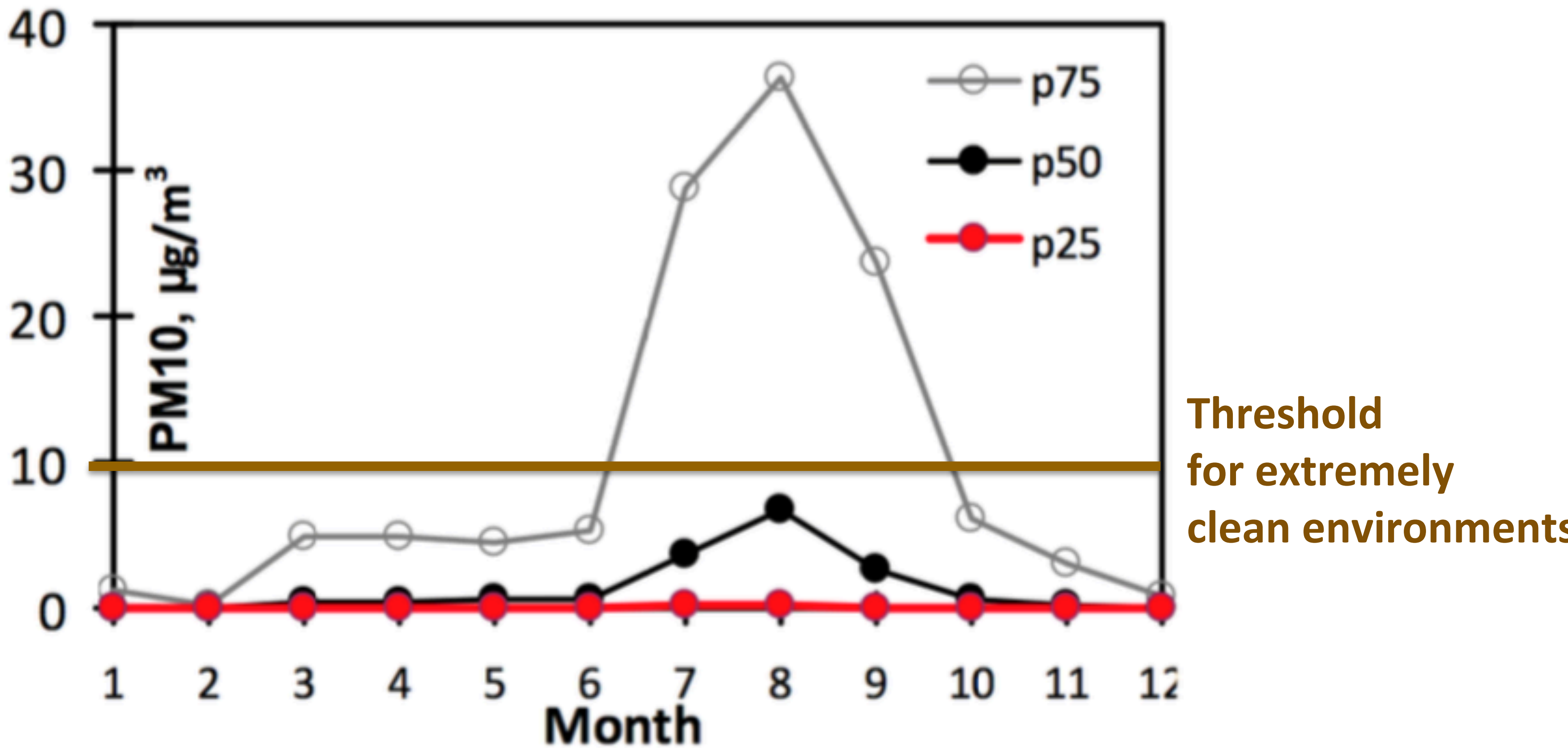
The Island of La Palma is affected by:

- the **trade winds below 1800 m a.s.l.**
- the **descending dry air** transported by the Hadley cell along the tropopause **above 1800 m a.s.l.**



Aerosol profiles

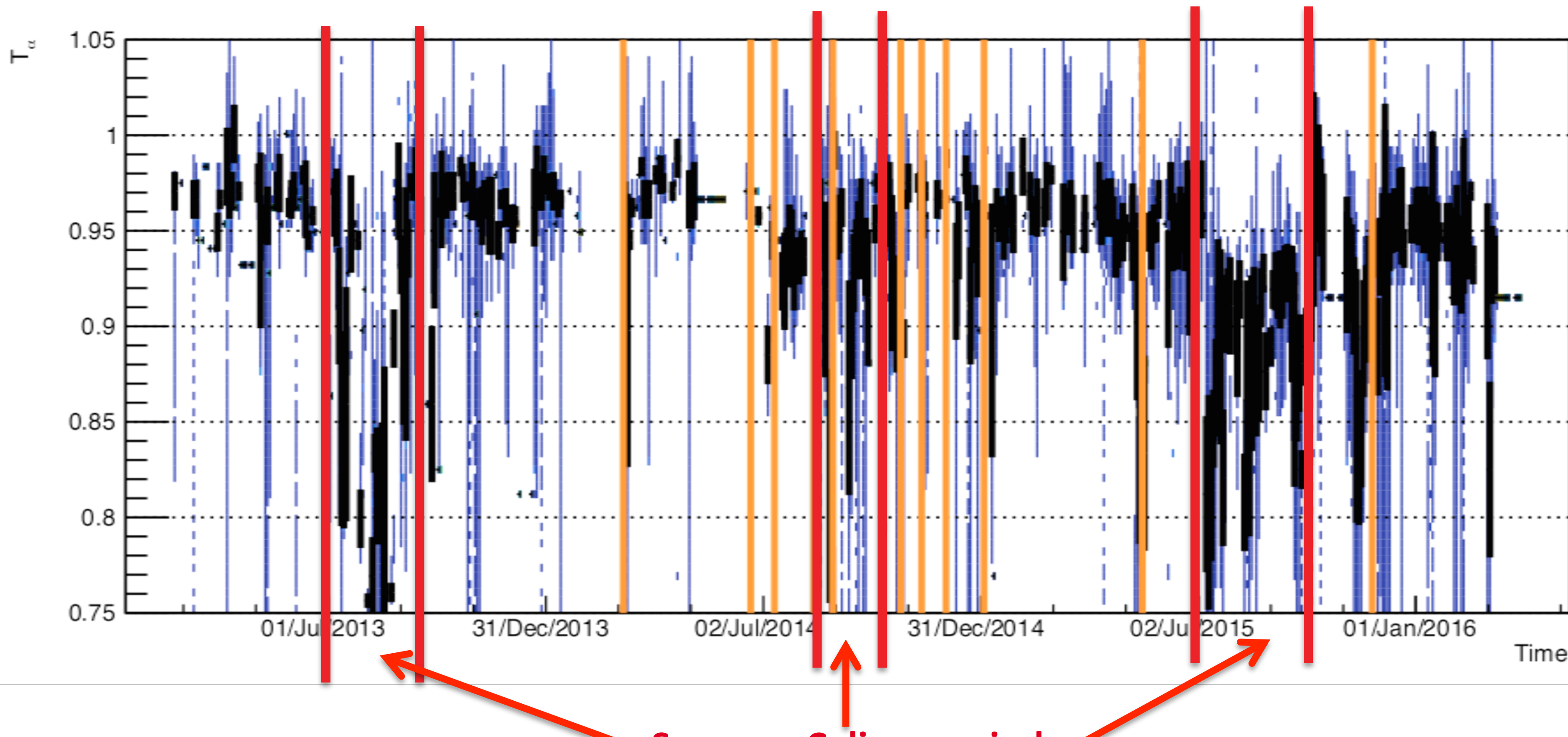
PM_{10} distributions obtained at Izaña, Tenerife (2400 m a.s.l.)



E.Cuevas and J. M.Baldasano,
"Report on the Incidence of African dust intrusions at the Astronomical Observatories of the Canary Islands: characterization and temporal analysis", Izan˜a Atmospheric Research Centre of AEMET and the Earth Sciences Department, 2009.

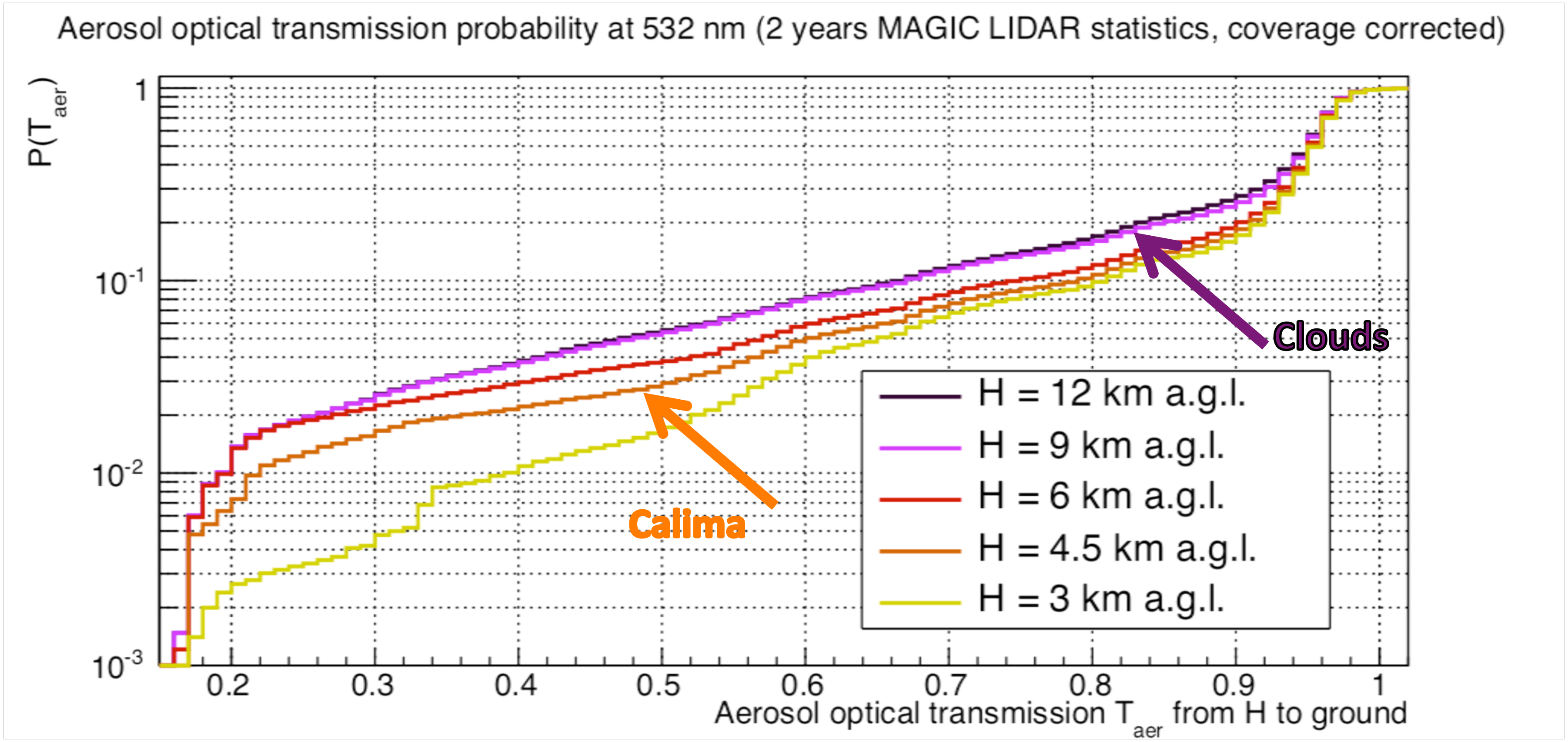
Aerosol profiles

Aerosol Transmission over time from MAGIC LIDAR (absolutely calibrated with the Sun photometer data from Izaña)



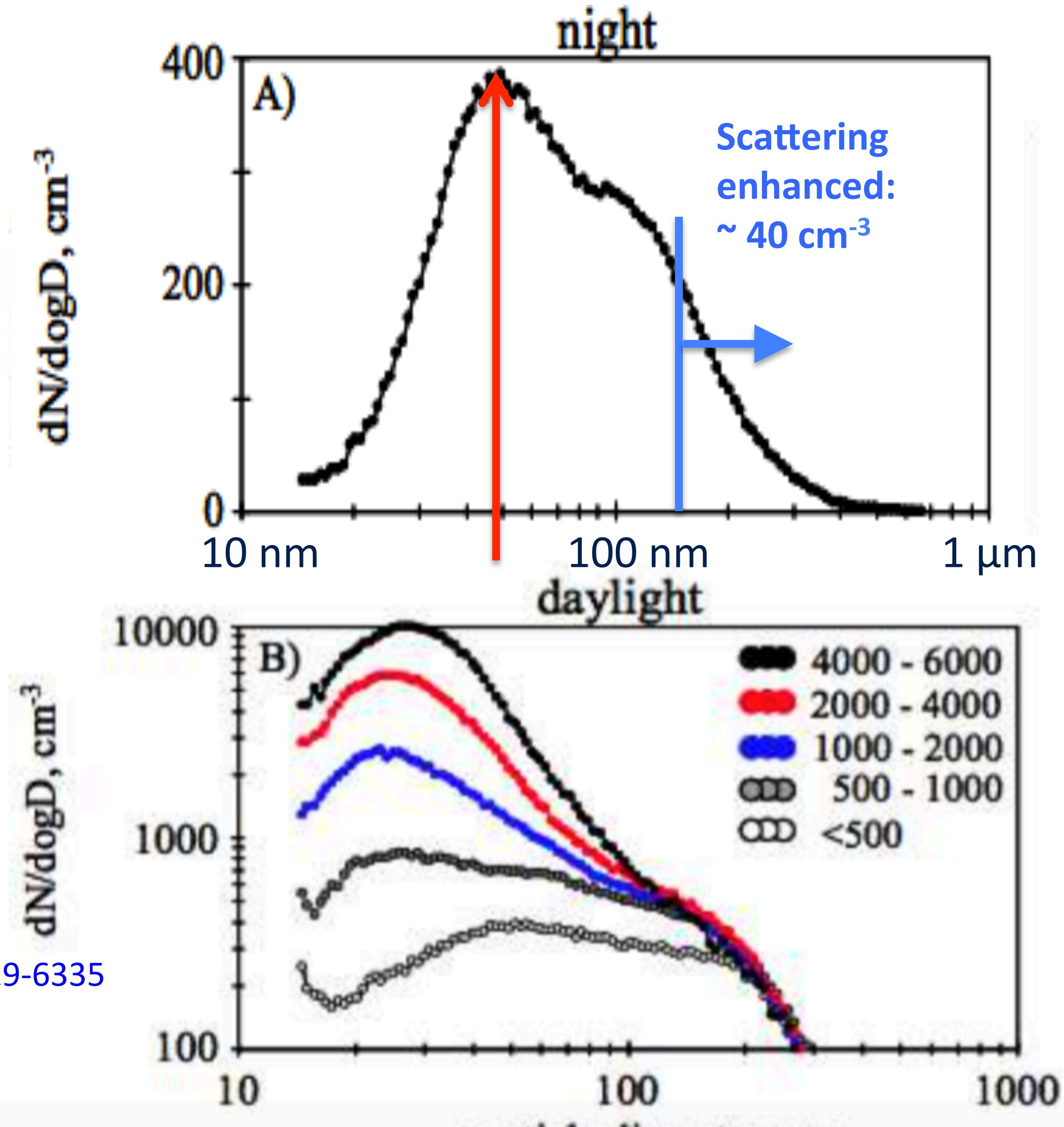
Aerosol profiles

Aerosol Transmission probability map from MAGIC LIDAR



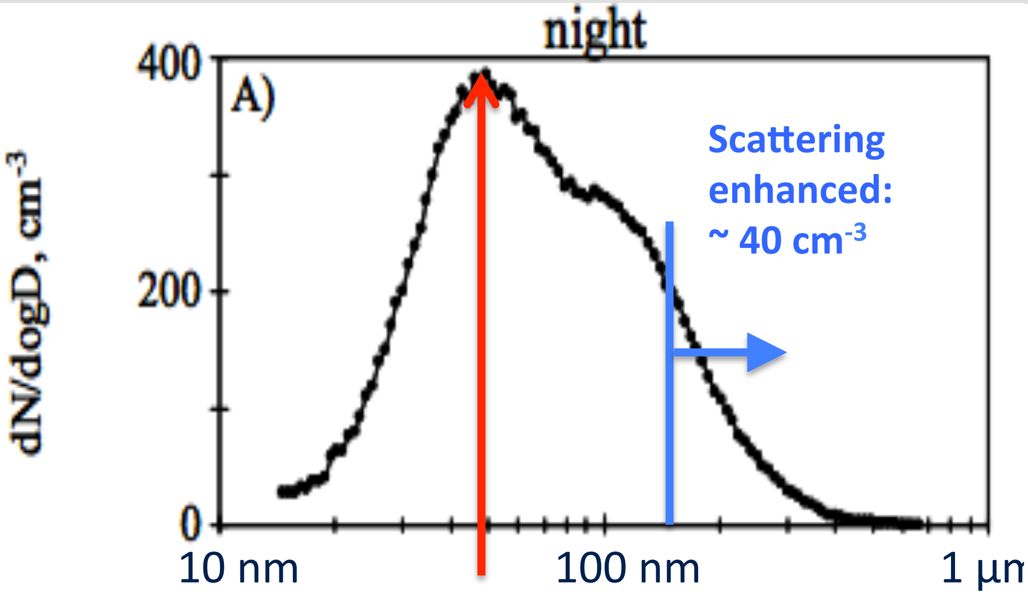
Particle size distributions

Measurements at Izaña (Tenerife) **support idea of "aged aerosols" that travel downwards**

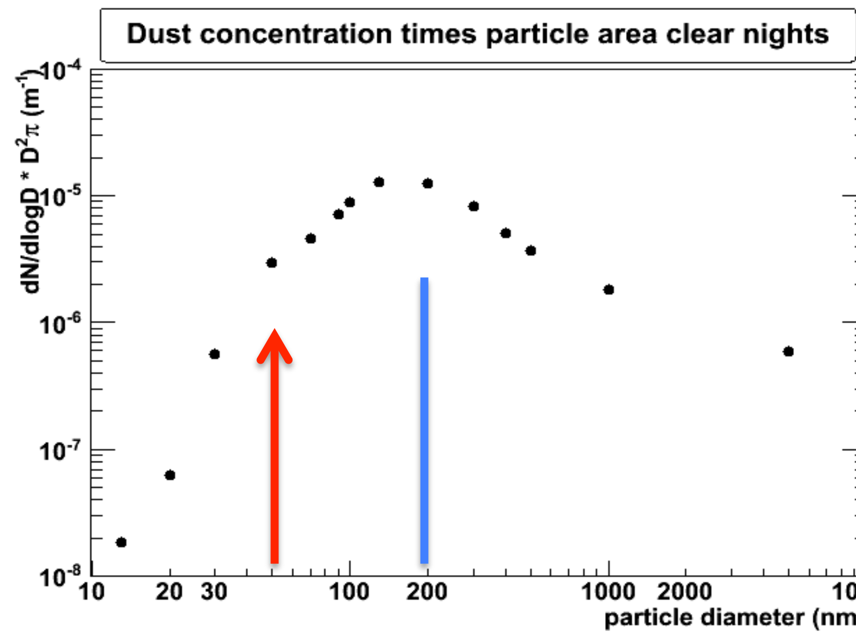


Rodríguez S. et al., "Atmospheric nanoparticle observations in the low free troposphere during upward orographic flows at Izaña Mountain Observatory",
Atmospheric Chemistry and Physics 9 (2009) 6319-6335

Particle size distributions



mode: 50 nm

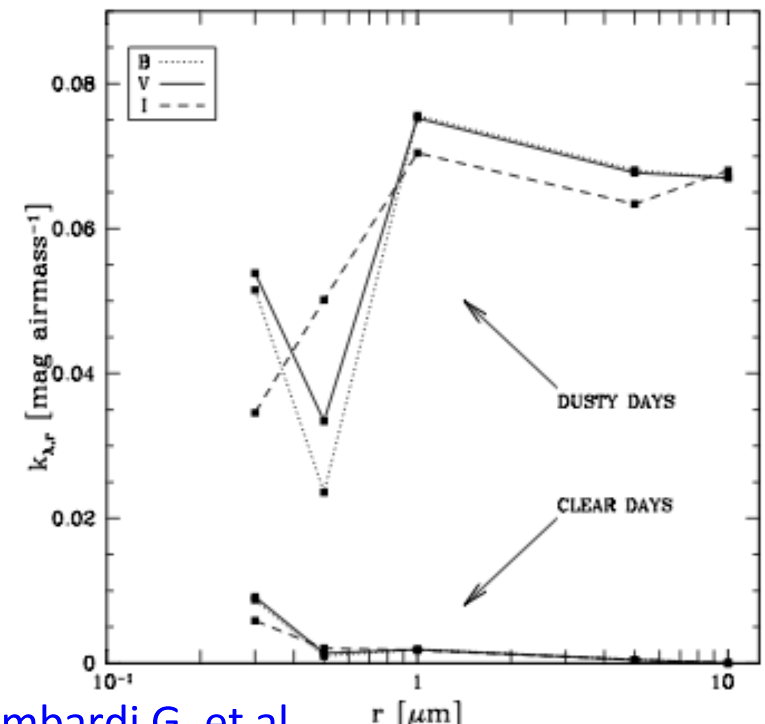


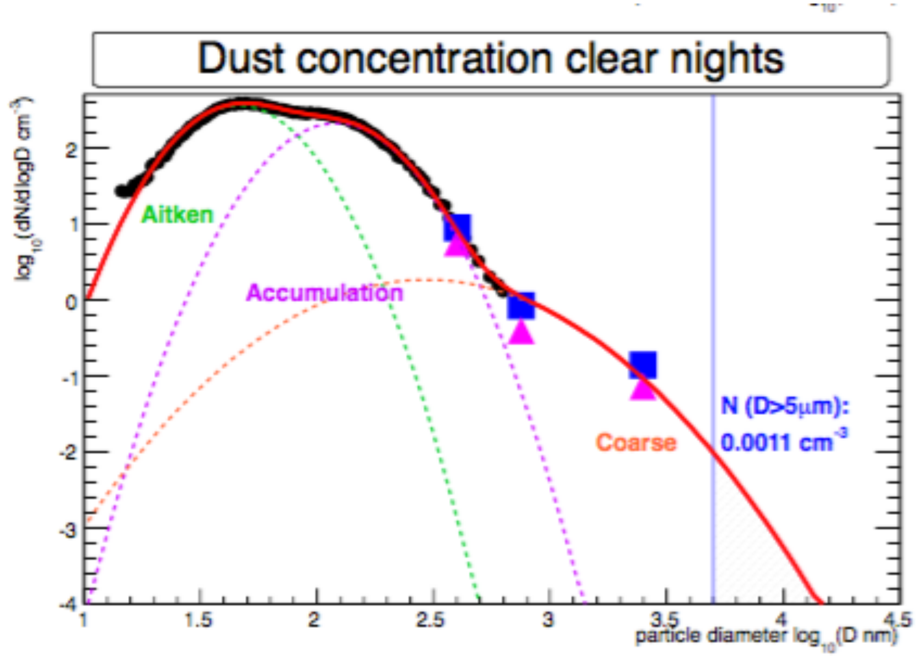
Simplified (pure “Mie”) ***extinction coefficient***

$$k(\lambda,r) = Q_{ext}(n,r,\lambda)\, \pi r^2 N$$

Particle size distributions

CAMT extinction measurements: agree well with Izaña data



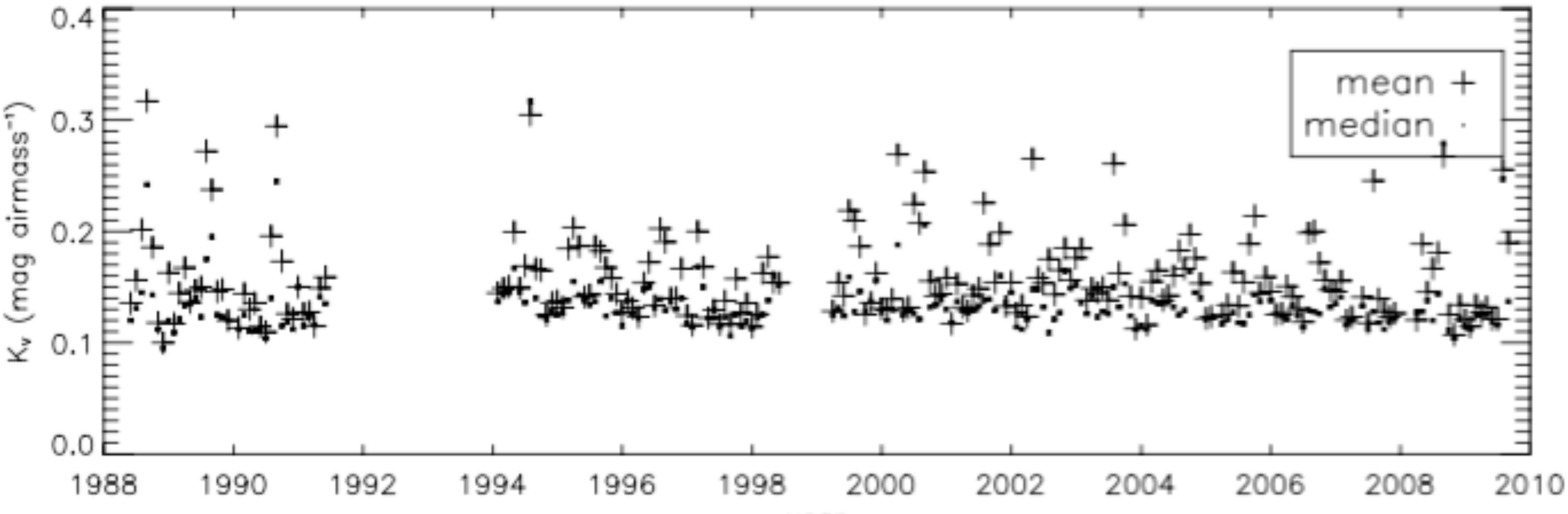


Lombardi G. et al.,
"El Roque de los Muchachos Site Characteristics II:
Analysis of atmospheric dust and aerosol extinction",
A&A (2008) arXiv:0802.3947v2

Aerosol Extinction coefficients

20 years data base from the Carlsberg Meridian Telescope

García-Gil A., Muñoz-Tuñón C., Varela A. M. "Atmosphere Extinction at the ORM on La Palma: A 20 yr Statistical Database Gathered at the Carlsberg Meridian Telescope", PASP 122 (2010) 1109.



Aerosol optical extinction coefficients

20 years data base from the Carlsberg Meridian Telescope

García-Gil A., Muñoz-Tuñón C., Varela A. M. "Atmosphere Extinction at the ORM on La Palma: A 20 yr Statistical Database Gathered at the Carlsberg Meridian Telescope", PASP 122 (2010) 1109.

TABLE 2

SUMMARY OF k_V STATISTICS (IN mag airmass^{-1})

Parameter	Summer	Rest of the Year	All Data
Ndata	1685	2351	4036
Median	0.131	0.129	0.130
Mode	0.120	0.121	0.121
Mean	0.183	0.144	0.161
Std	0.119	0.061	0.092

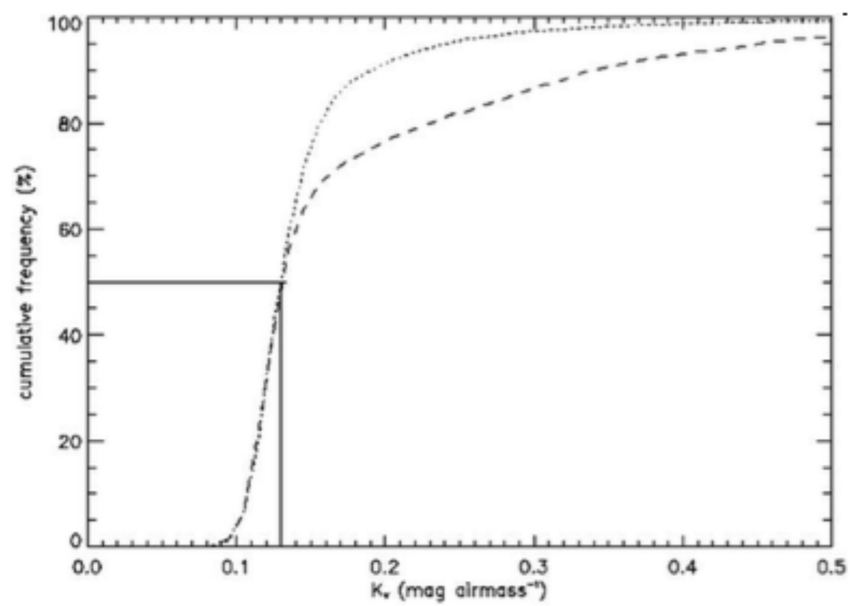


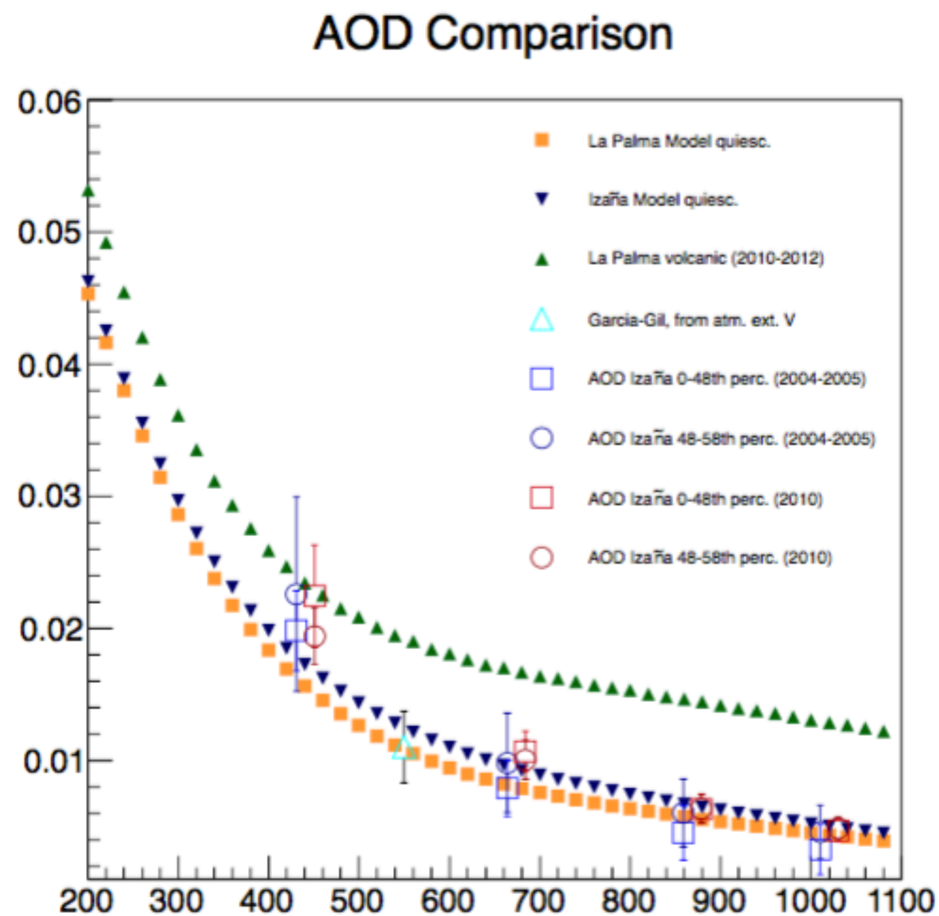
FIG. 2.—Seasonal trend: Cumulative frequency of k_V for the summer months (June–September: *dashed line*) and the rest of the year (*dotted line*). Note that the median value is 0.13 both in the summer months and during the rest of the year.

Aerosol AODs

Converting the

- particle size distributions to **extinction coefficients**
- and converting these into **AODs**

yields a **consistent picture** between the different data sets available for the clear night at La Palma



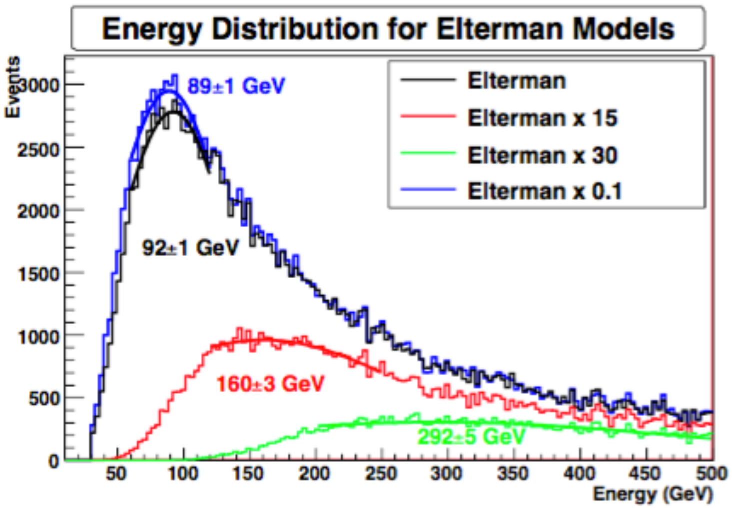
Aerosol profiles

Impact of aerosol intrusions and clouds on IACT data

- Has been studied for MAGIC only by Garrido et al. (ICRC 2013, ID 0465 and **arXiv:1308.0473**) and is part of the CTA Atmospheric Calibration Strategy: COM-CCF/130311 https://portal.cta-observatory.org/recordscentre/Records/COM/COM-CCF/lidar_loi2.pdf

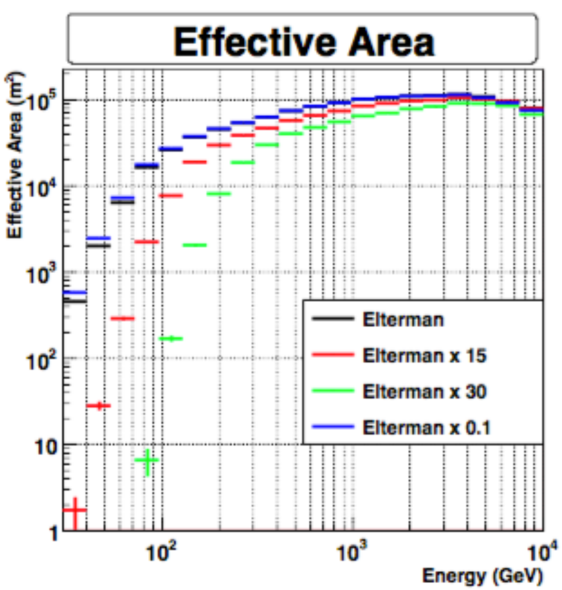
- Needs confirmation and extension of energy range for CTA

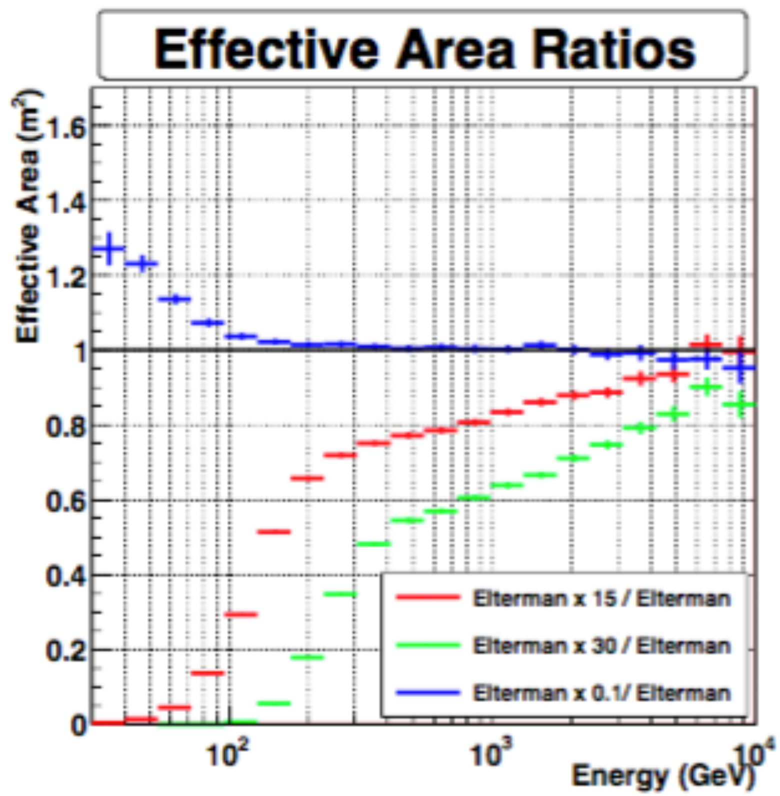
Impact of aerosol intrusions on IACT data



Different simulated cases of "calima":

- **OD*15**
- **OD*30**
- **OD*0.1**





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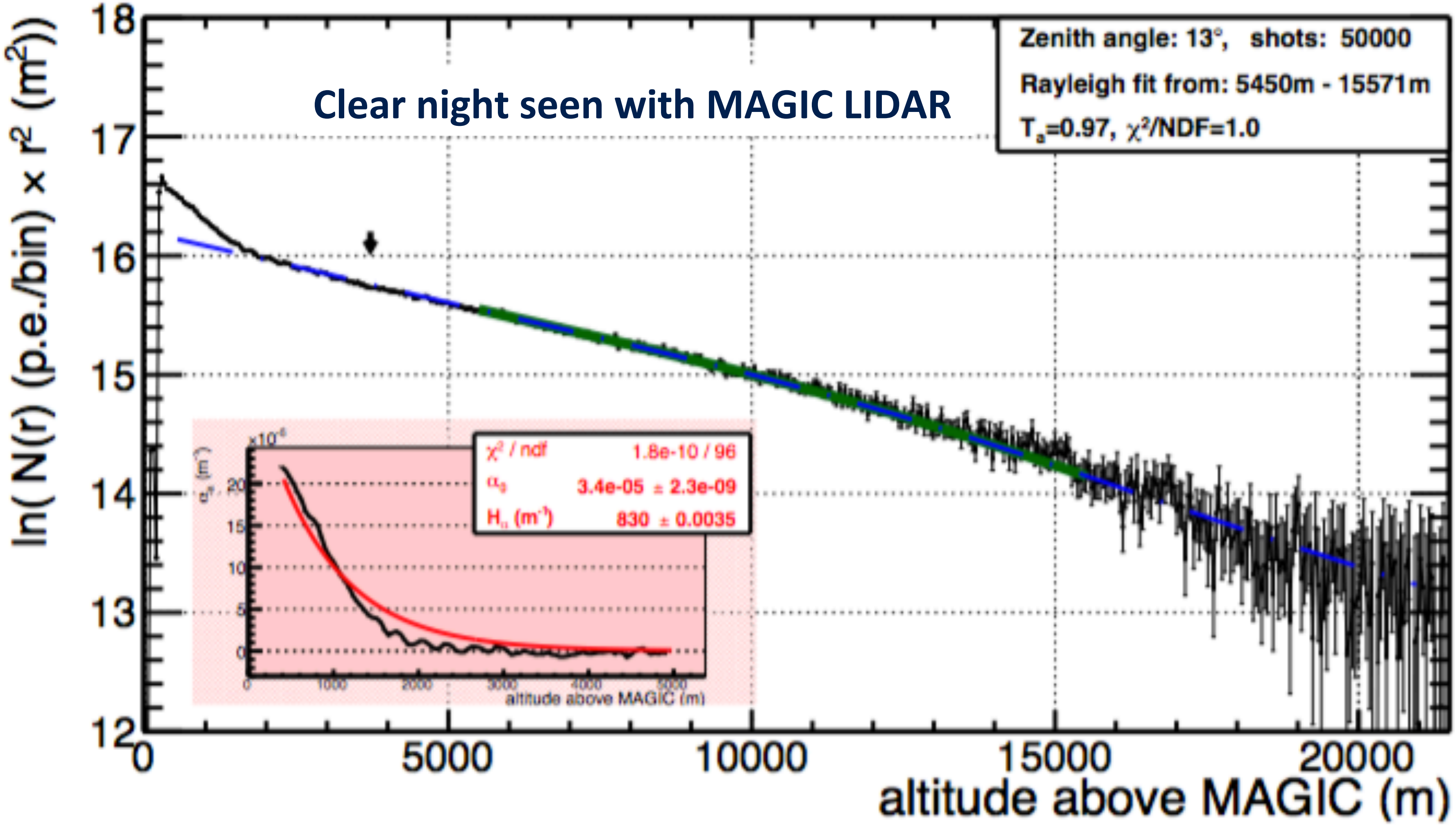
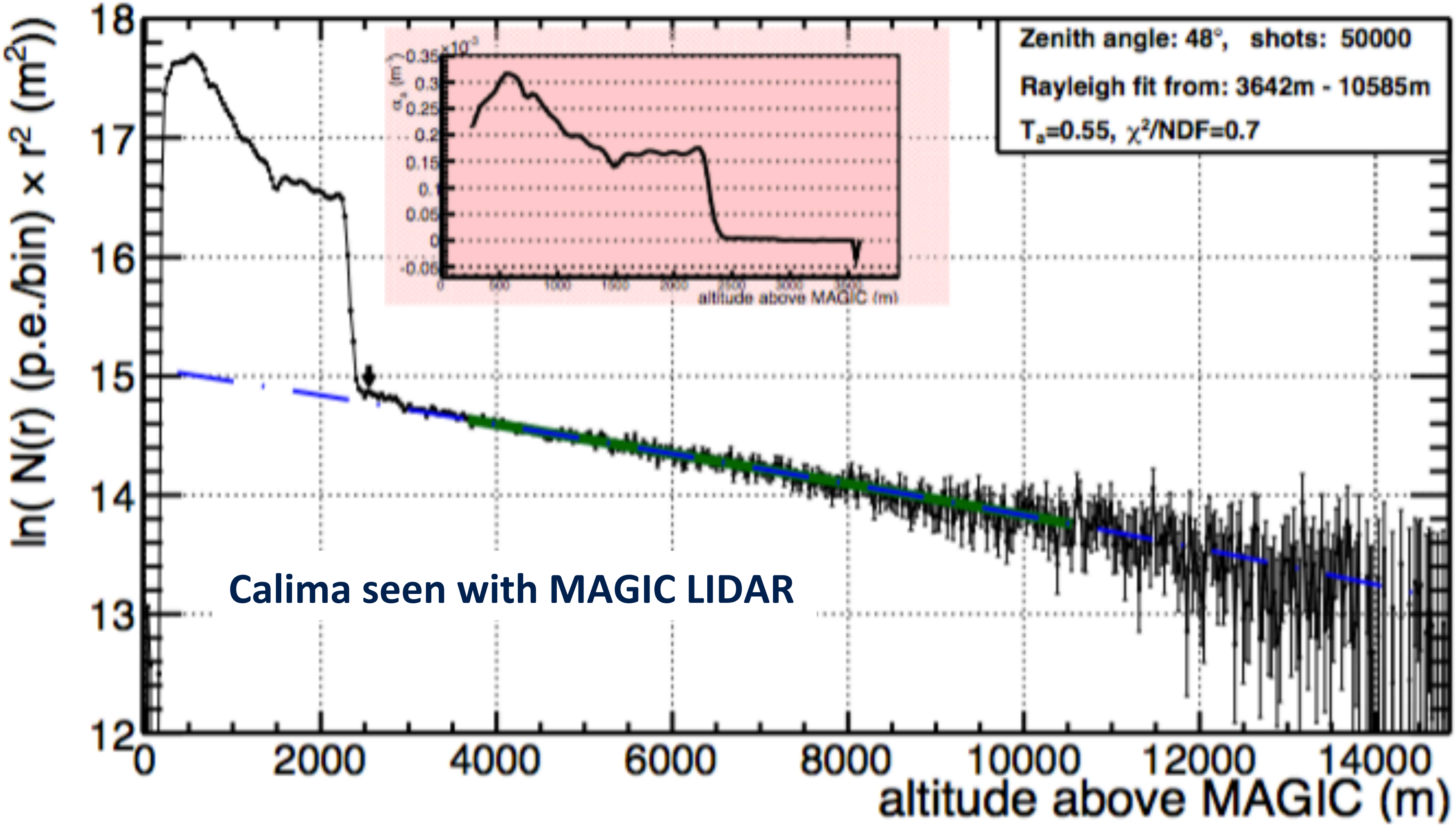
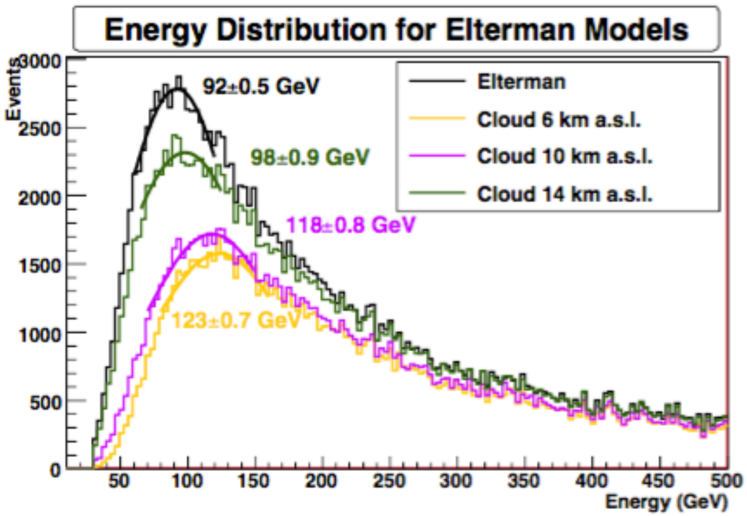
Impact of aerosol intrusions on IACT data



Impact of aerosol intrusions on IACT data

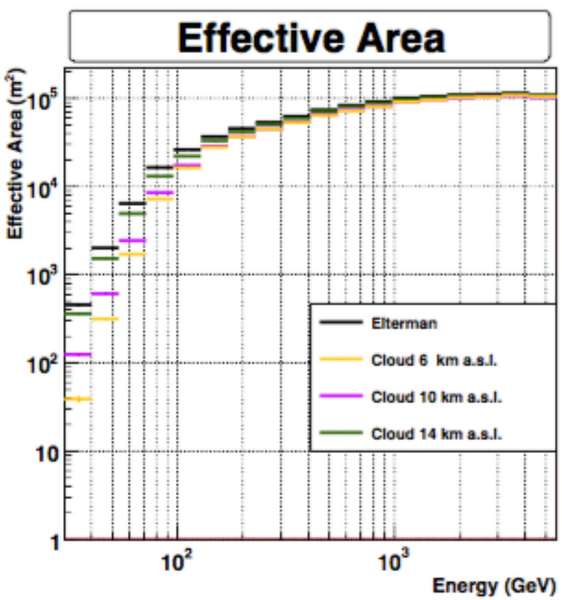


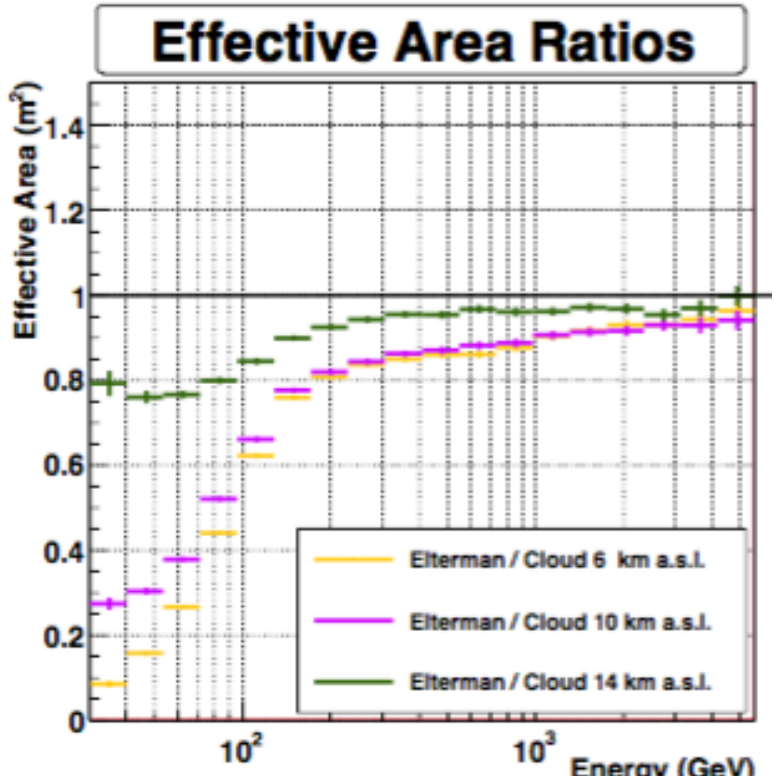
Impact of clouds on IACT data



Simulated "cloud" at 3 different altitudes:

- 6 km (cumulus)
- 10 km (cirrus)
- 14 km (volcanic debris)





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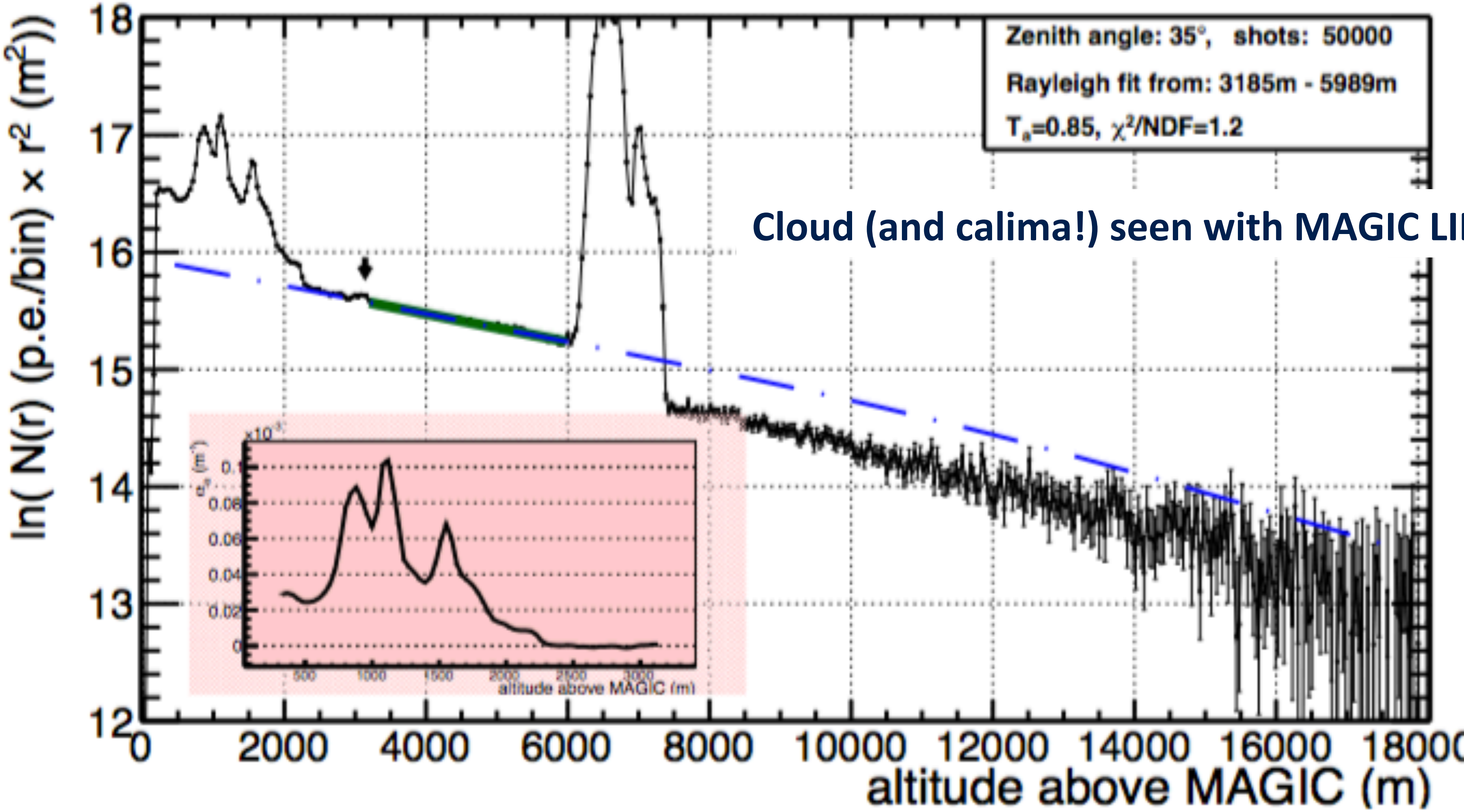
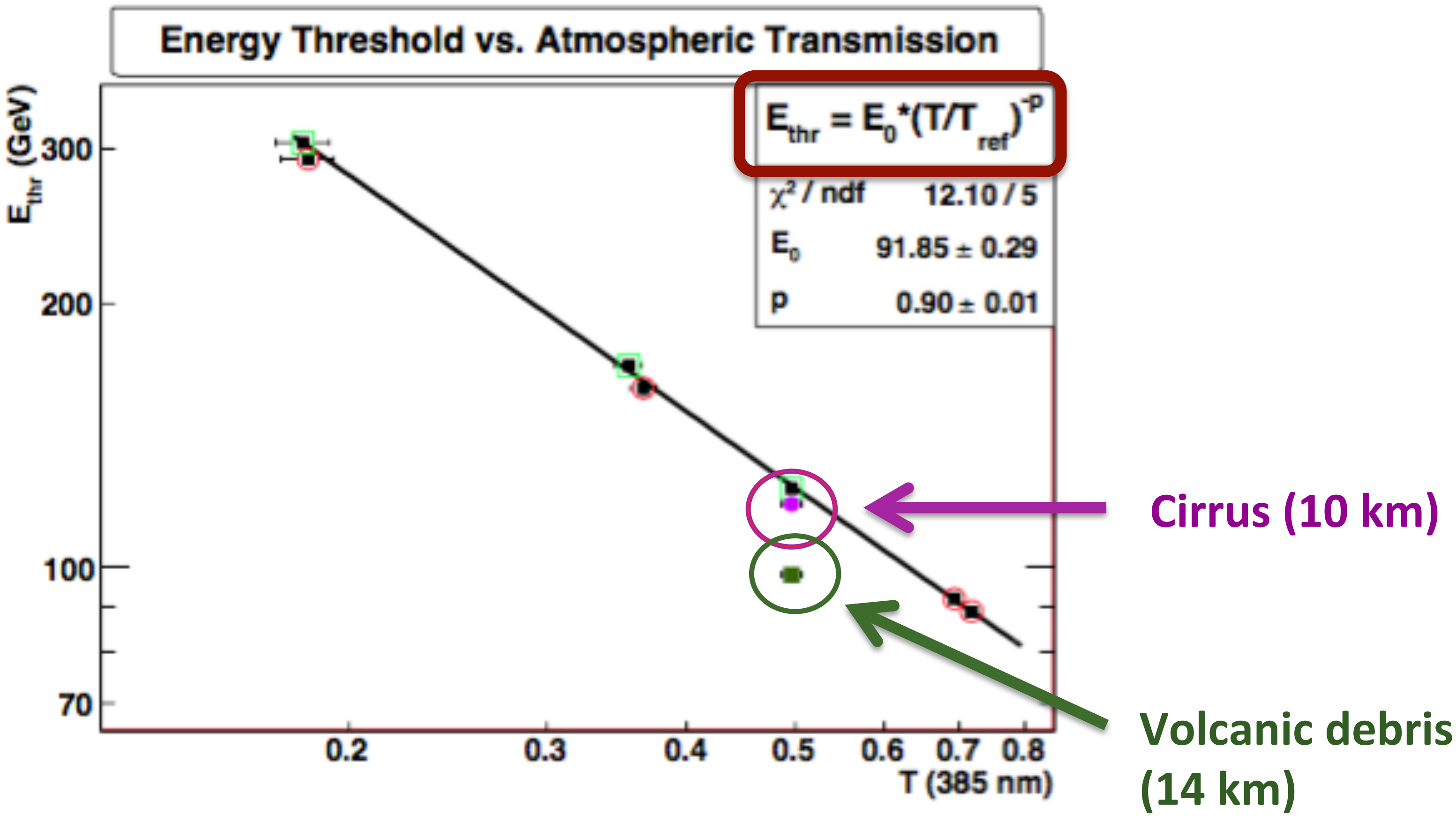
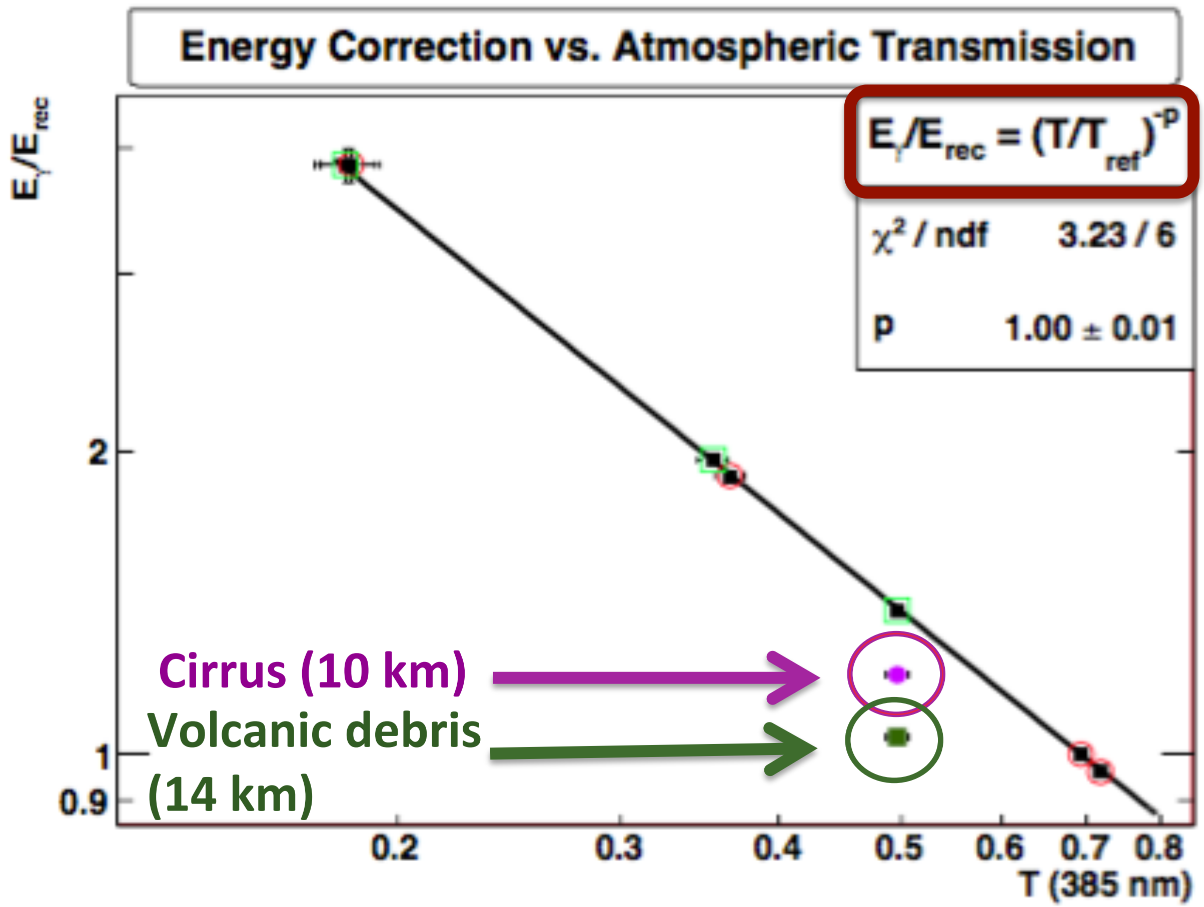


Cloud (and calima!) seen with MAGIC LIDAR

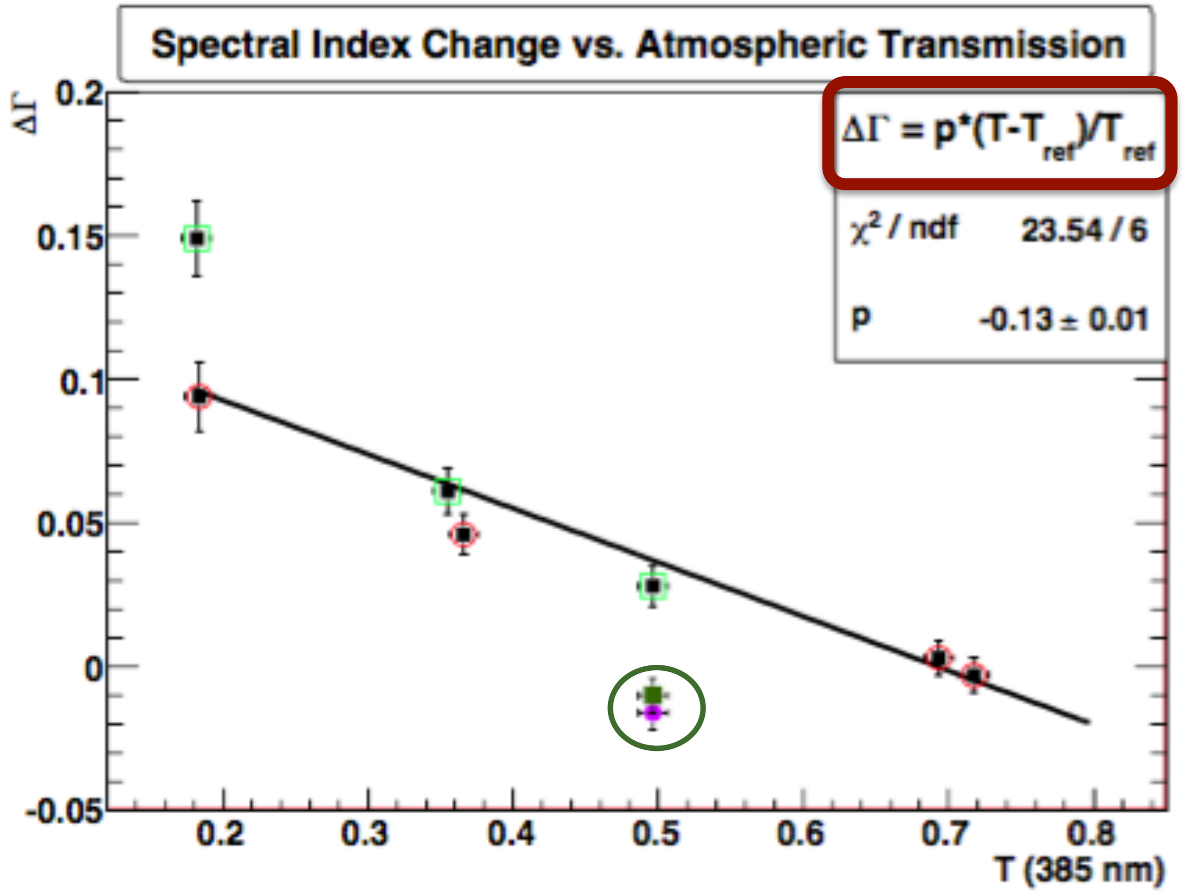
Impact of aerosols (calima and clouds) on IACT energy threshold



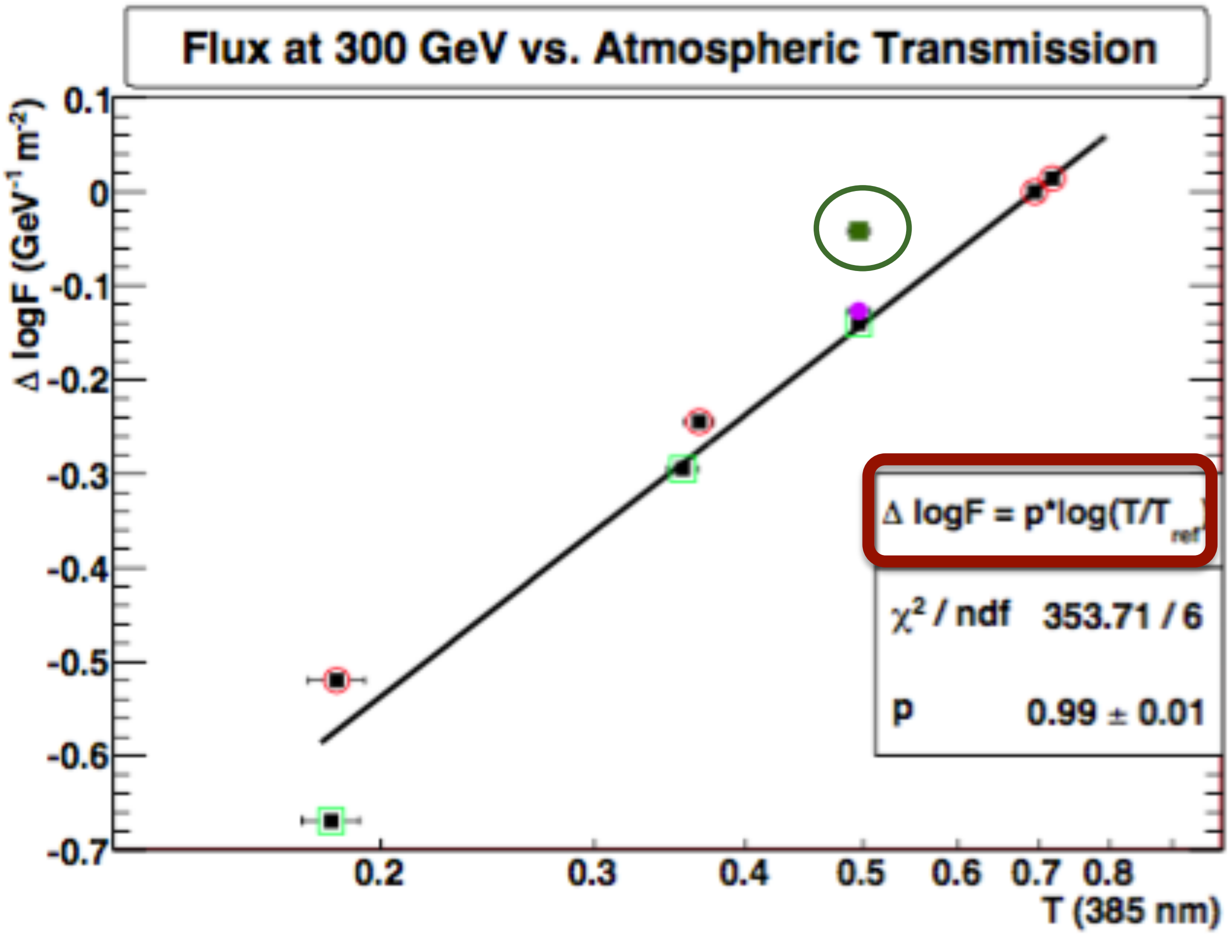
Impact of aerosols (calima and clouds) on IACT on energy scale



Impact of aerosols (calima and clouds) on IACT reconstructed spectral index

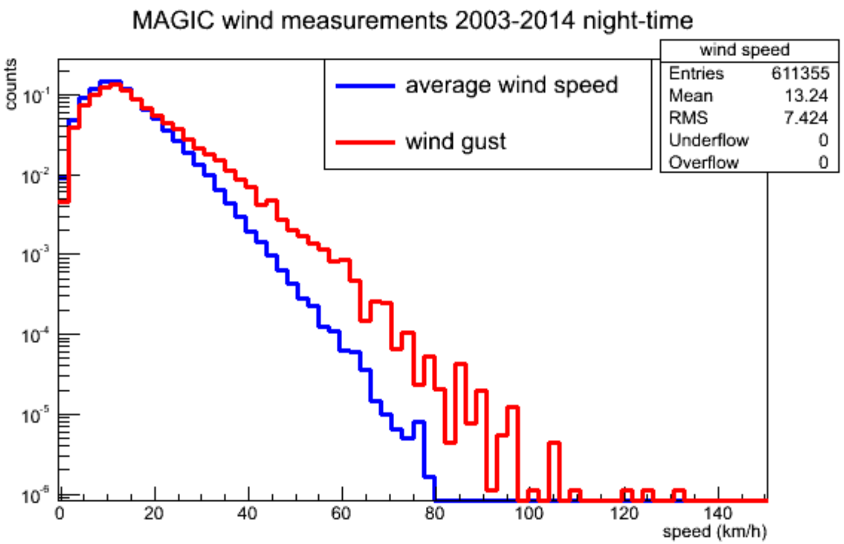


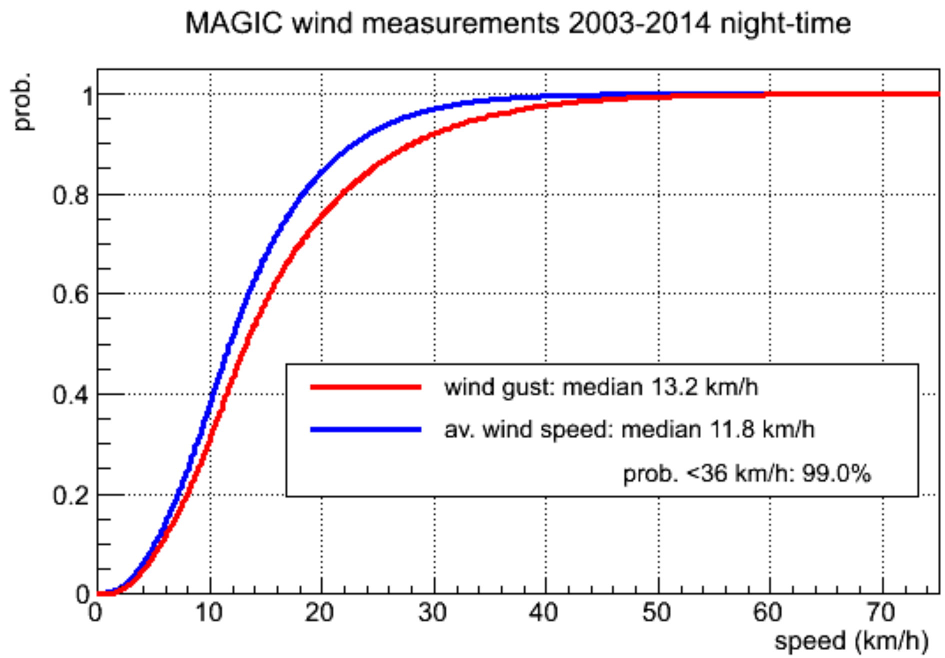
Impact of aerosols (calima and clouds) on IACT reconstructed flux



12 years of MAGIC weather station data

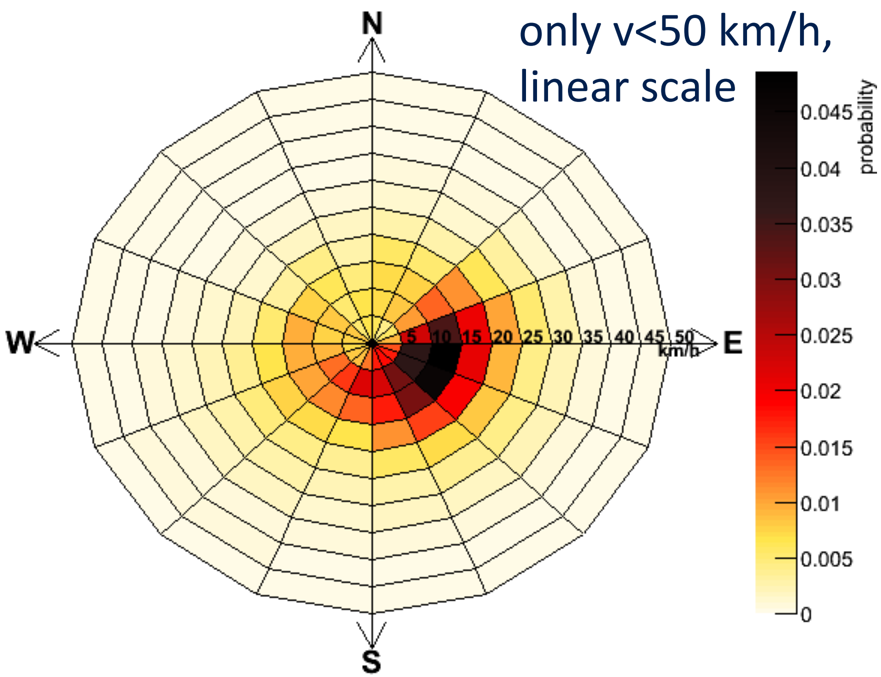
Wind measurements

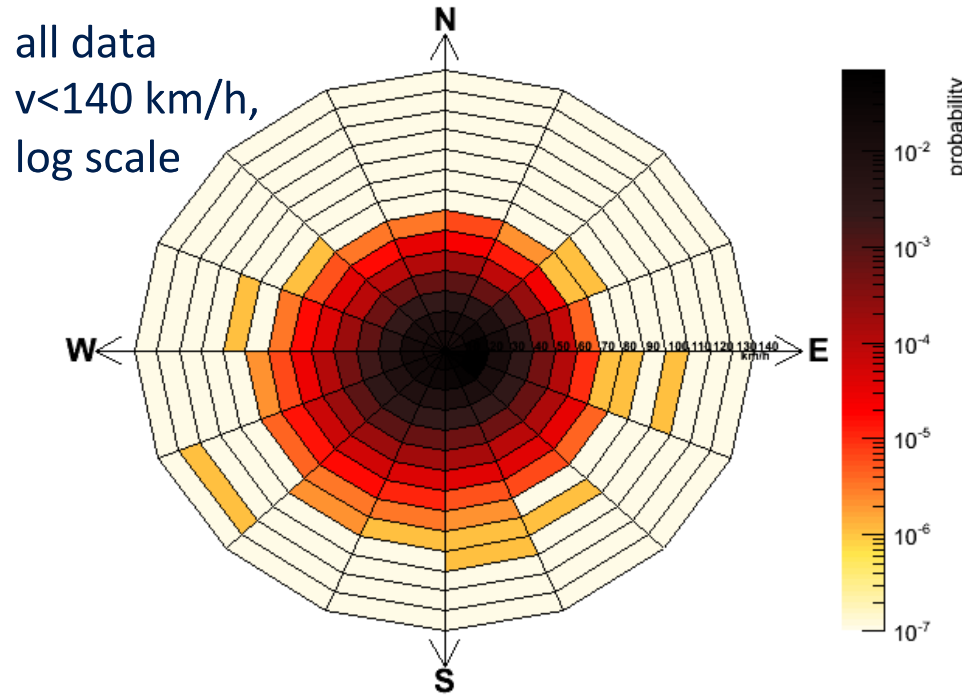




- Large data base of weather data from the roof of the MAGIC control house.
- Still need to study the wind at different altitudes (and possibly different points across the CTA area).

Wind measurements

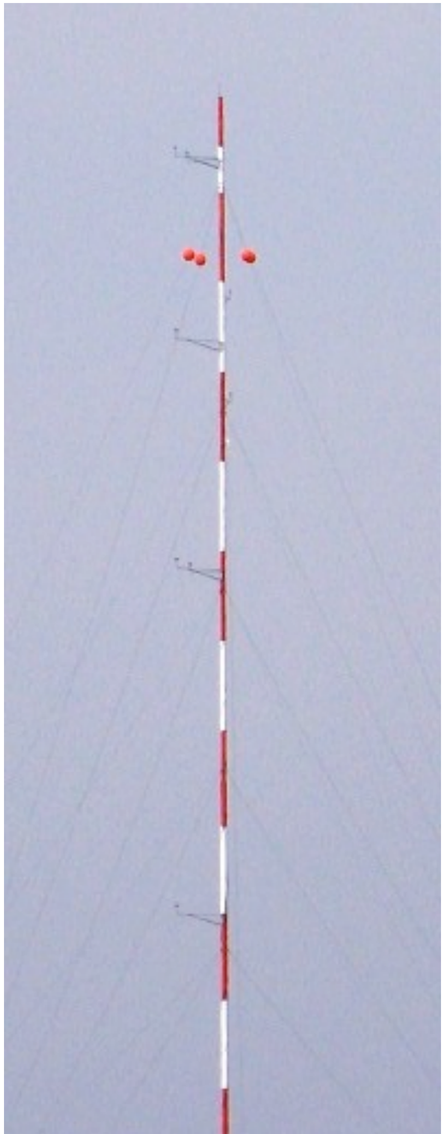




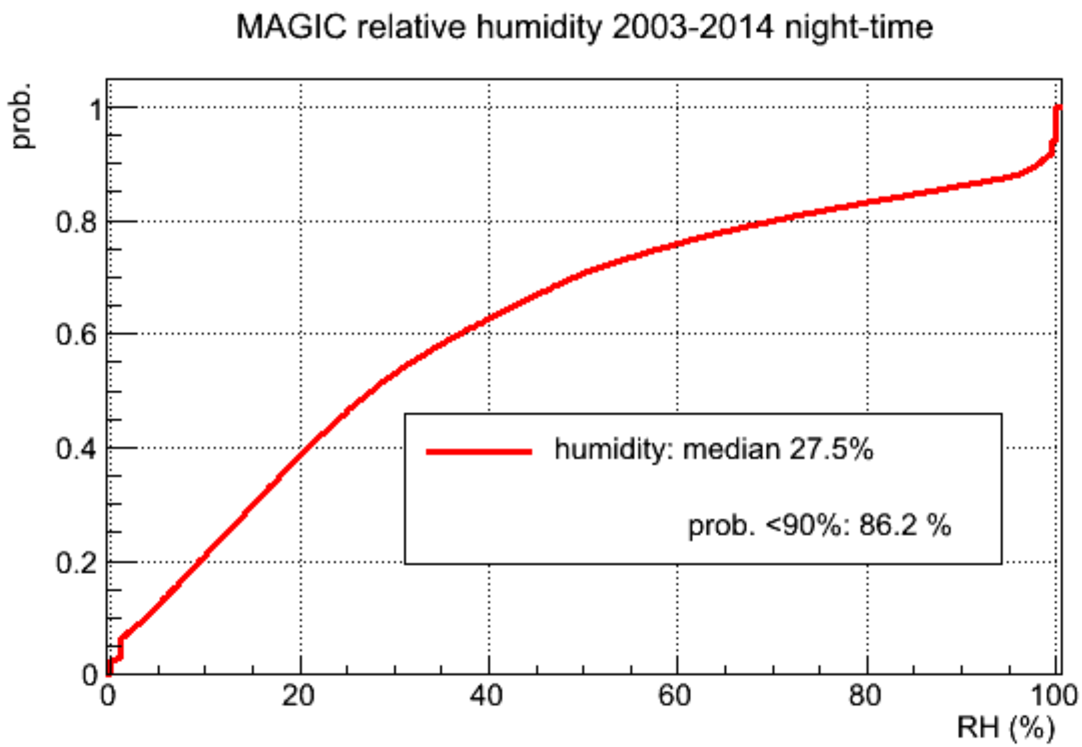
- **Wind** comes preferably from **ESE**
- **Storms** come preferably from a **wide range** covering **E-S-W**

Wind measurements

- 30 m tower at the LST site would be needed to measure the altitude profile.
- Included the tower in the first call to the Spanish FEDER funds (to be released in Autumn this year).
- Some conflict with the LST1, but are confident to collect still enough data before the mirrors are mounted.



Humidity measurements and rain



- Noted some hysteresis in our humidity sensor
- **Also rain is possible with RH<90% !!**
- **Need additional rain sensors**

Rain and humidity sensors

- Up to now, rain/humidity is only measured at one point (roof of MAGIC control house)
- However, clouds drift sometimes up the mountain, may affect parts of the CTA array without being seen at the MAGIC site. Not much known about statistics of this effect.
- Plan to install several rain/humidity sensors across the CTA area and characterize gradients across the terrain.