GDAS/HYSPLIT models

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AtmoHEAD

Atmospheric Monitoring for High Energy Astroparticle Detectors
19–21 May 2014, Padova

Why Model Data?

- Ideal: Balloon launches, weather stations, LIDAR, …
  Reality: Constraints due to money, personnel and data taking
- Astroparticle detectors usually in remote areas, meteorological data from close-by sources (airports, cities, ...) is sparse
- Global models like GDAS for the molecular part of the atmosphere can replace the on-site measurements (except for validation purposes), they are free and done by people who know what they are doing
- Aerosol concentration changes quite rapidly and is very localized, so measurements unlikely to be replaced
- Air mass models like HYSPLIT can supplement our understanding of the origin and the properties of the aerosols
- Clouds are a different story (see talks on Wed afternoon)

Overview

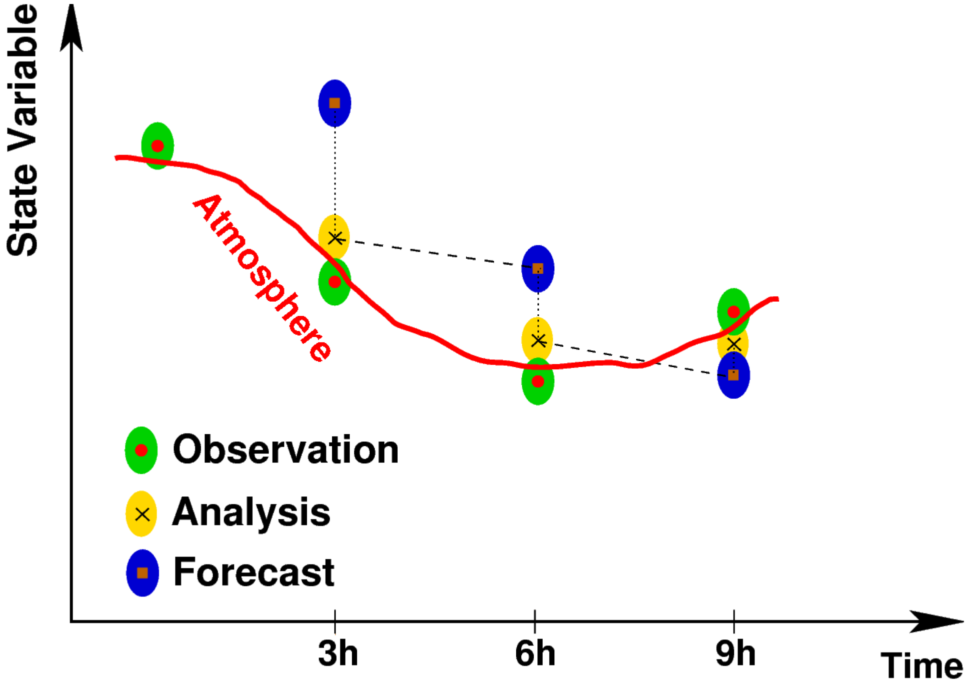
- GDAS – Global Data Assimilation System
  - Description of model and data
  - Validation of data using balloon launches and weather stations
  - Current Application (Pierre Auger Observatory, Colorado)
  - Future Use (MAGIC, CTA)

- HYSPLIT – Hybrid Single Particle Lagrangian Integrated Trajectory
  - Description of model and data
  - Validation of data
  - Studies of air masses at the Pierre Auger Observatory

Global Data Assimilation System (GDAS)

- GDAS is one of the computer analyses and forecasts by the National Centers for Environmental Prediction (NCEP)

- GDAS is used by the Global Forecast System (GFS) model to place observations into a gridded, 3D model space:
  - surface observations
  - balloon data
  - wind profiler data
  - aircraft reports
  - buoy observations
  - radar observations
  - satellite observations.



Global Data Assimilation System (GDAS)

- GDAS is run 4 times a day (0, 6, 12, 18 UTC). Model output is for the analysis time and 3, 6, and 9-hour forecasts.

- Post-processing
  - Converts data to 1 degree latitude-longitude (360x181) grids
  - Converts to 23 pressure levels
    (Level 1 corresponds to 20 hPa, Level 23 corresponds to 1000 hPa)

- Air Resources Laboratory (ARL)
  - Saves analyses and 3-hour forecast to produce a continuous data archive
  - Data are put into weekly files and made available online via ftp
  - 7-day archive file size is about 600 MB
  - Fill potential holes with 6-h and 9-h forecast

- http://ready.arl.noaa.gov/gdas1.php

Description of GDAS Data

- Data is in sequence, without any missing records
  - Index
  - Surface data
  - All data in each pressure level from the ground up
- Some cloud data included, but not main focus of GDAS

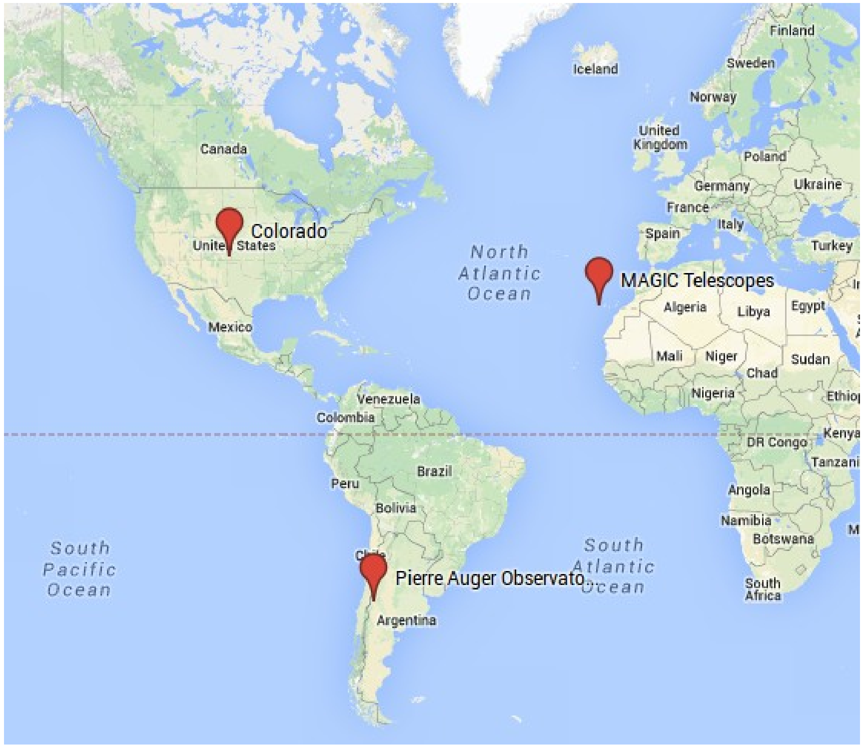
Field	Units	Label	Data Order
Pressure at surface	hPa	PRSS	S1
Pressure reduced to mean sea level	hPa	MSLP	S2
Accumulated precipitation (6 h accumulation)	m	TPP6	S3
u-component of momentum flux (3- or 6-h average)	N/m2	UMOF	S4
v-component of momentum flux (3- or 6-h average)	N/m2	VMOF	S5
Sensible heat net flux at surface (3- or 6-h average)	W/m2	SHTF	S6
Downward short wave radiation flux (3- or 6-h average)	W/m2	DSWF	S7
Relative Humidity at 2m AGL	%	RH2M	S8
U-component of wind at 10 m AGL	m/s	U10M	S9
V-component of wind at 10 m AGL	m/s	V10M	S10
Temperature at 2m AGL	K	TO2M	S11
Total cloud cover (3- or 6-h average)	%	TCLD	S12
Geopotential height	gpm*	SHGT	S13
Convective available potential energy	J/Kg	CAPE	S14
Convective inhibition	J/kg	CINH	S15
Standard lifted index	K	LISD	S16
Best 4-layer lifted index	K	LIB4	S17

Field	Units	Label	Data Order
Planetary boundary layer height	m	PBLH	S18
Temperature at surface	K	TMPS	S19
Accumulated convective precipitation (6 h accumulation)	m	CPP6	S20
Volumetric soil moisture content	frac.	SOLM	S21
Categorial snow (yes=1, no=0) (3- or 6-h average)		CSNO	S22
Categorial ice (yes=1, no=0) (3- or 6-h average)		CICE	S23
Categorial freezing rain (yes=1, no=0) (3- or 6-h average)		CFZR	S24
Categorial rain (yes=1, no=0) (3- or 6-h average)		CRAI	S25
Latent heat net flux at surface (3- or 6-h average)	W/m2	LHTF	S26
Low cloud cover (3- or 6-h average)	%	LCLD	S27
Middle cloud cover (3- or 6-h average)	%	MCLD	S28
High cloud cover (3- or 6-h average)	%	HCLD	S29
Geopotential height	gpm*	HGTS	U1
Temperature	K	TEMP	U2
U-component of wind with respect to grid	m/s	UWND	U3
V-component of wind with respect to grid	m/s	VWND	U4
Pressure vertical velocity	hPa/s	WWND	U5
Relative humidity	%	RELH	U6

GDAS for Astroparticle Detectors

Lamar, Colorado, USA

- 38N 102W
- Auger RnD site
- ARCADE
  (talk by L. Valore)



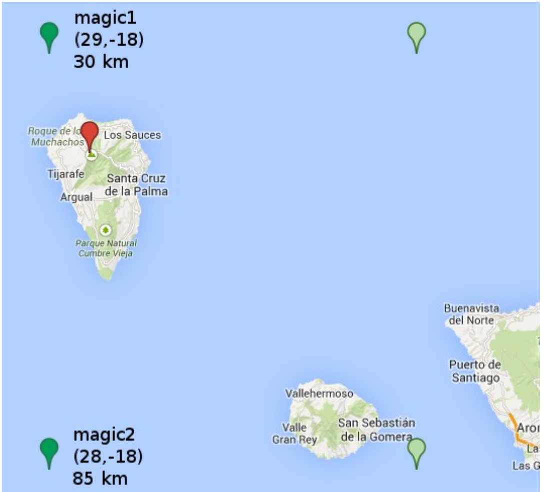
La Palma, "Spain"

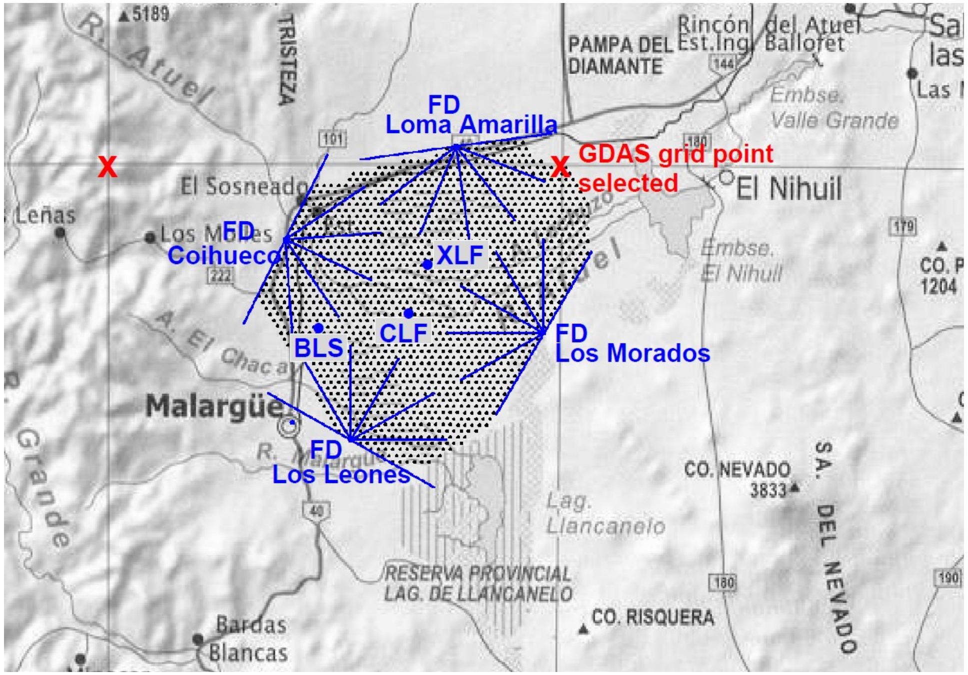
- 29N 18W
- MAGIC Telescopes

Malargüe, Argentina

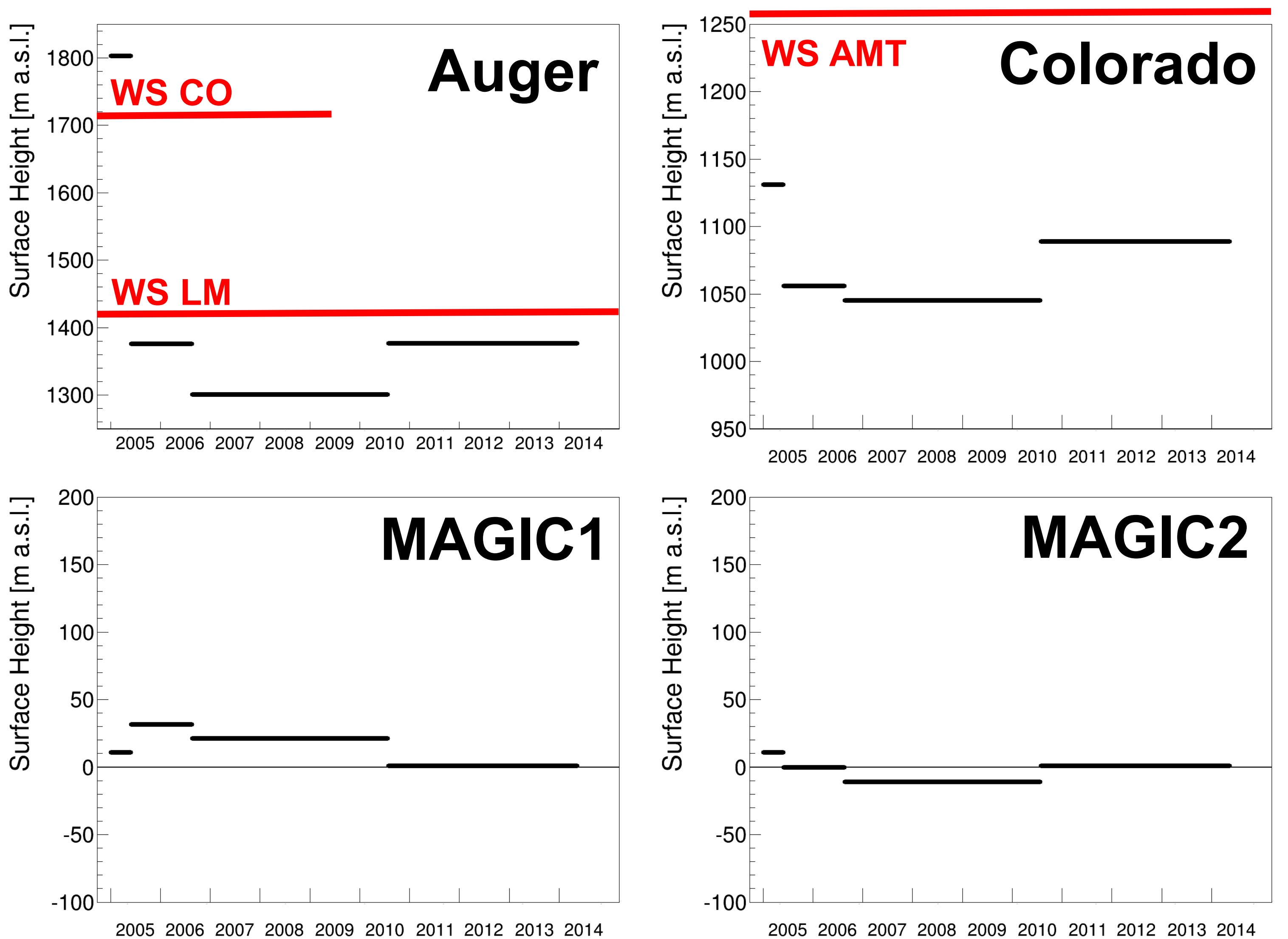
- 35S 69W
- Pierre Auger Observatory

Selection of Grid Point

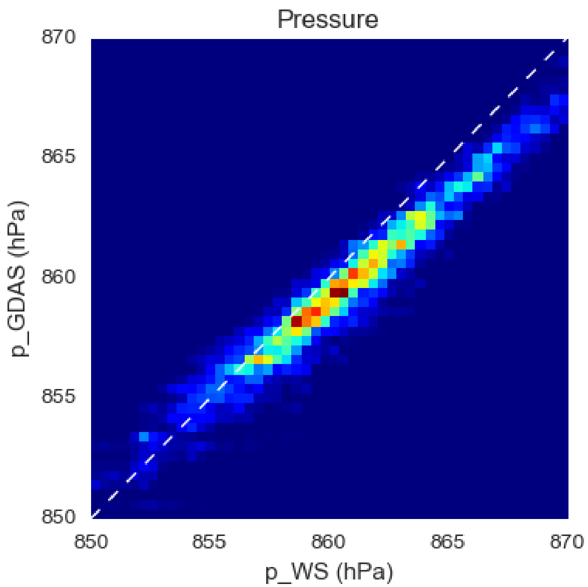


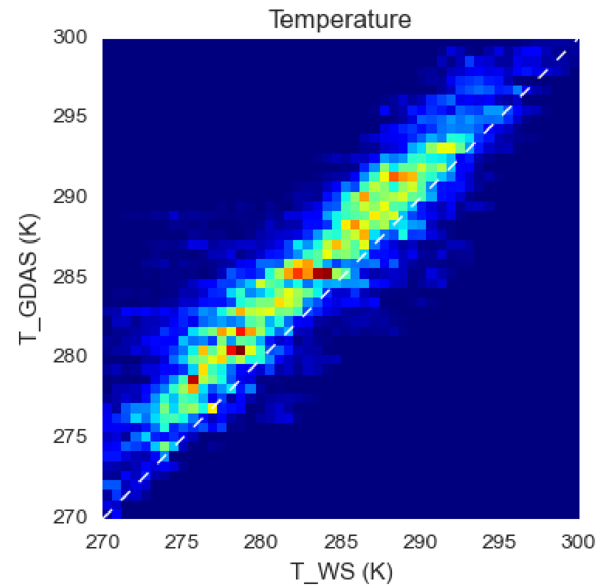


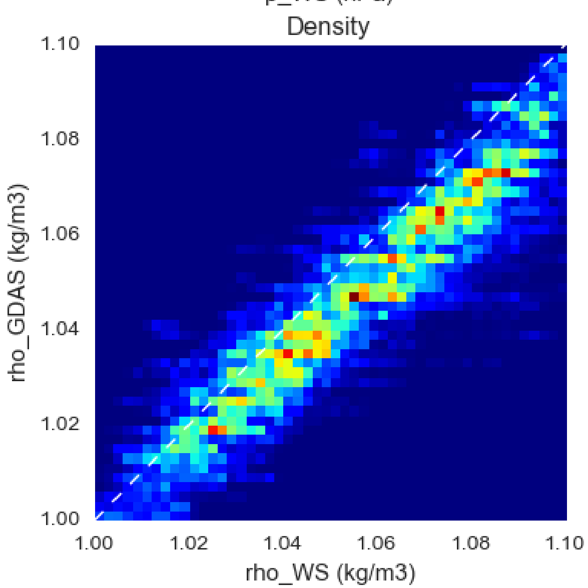
Surface Height

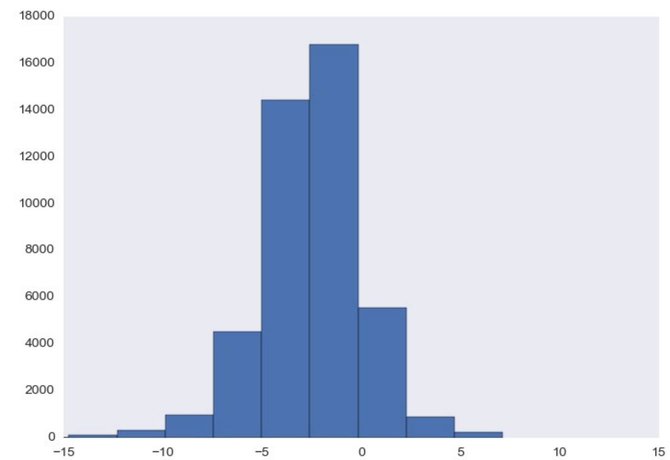


GDAS vs. Weather Station (Auger LM)

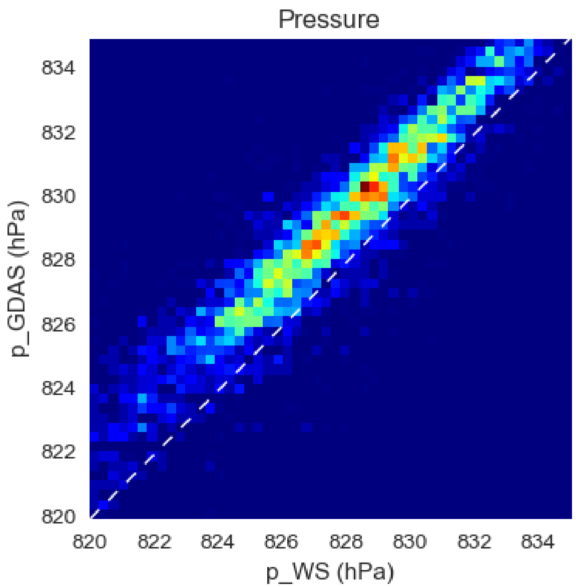


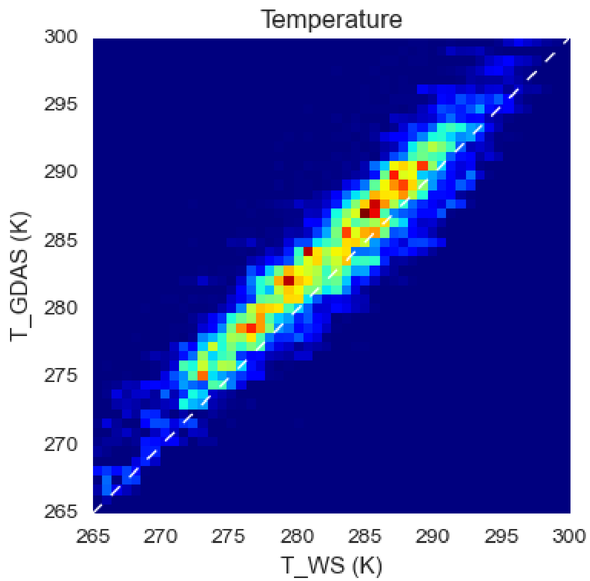


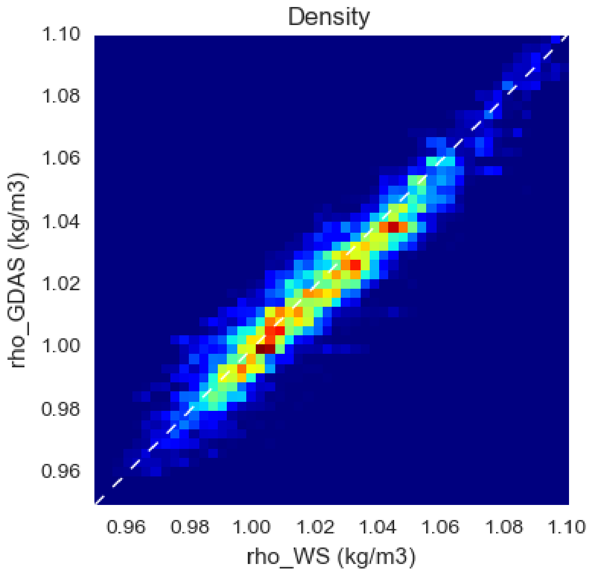


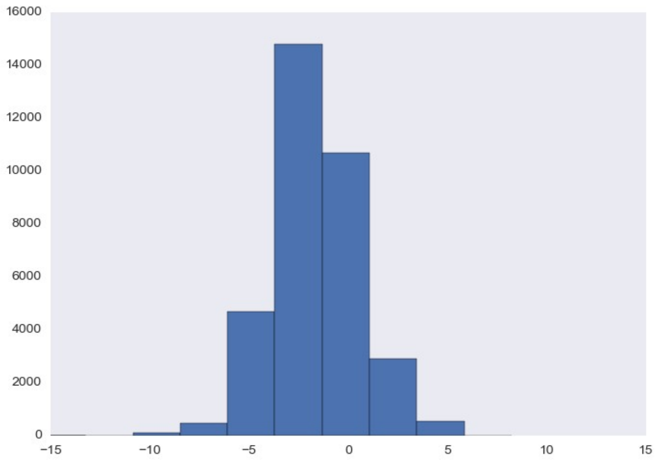


GDAS vs. Weather Station (Auger CO)

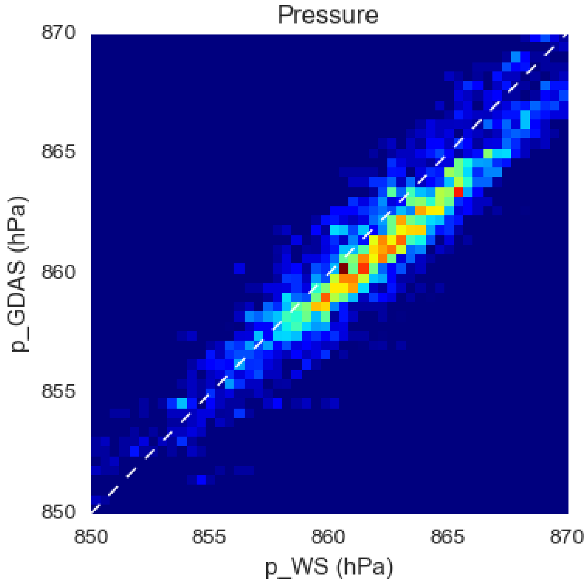


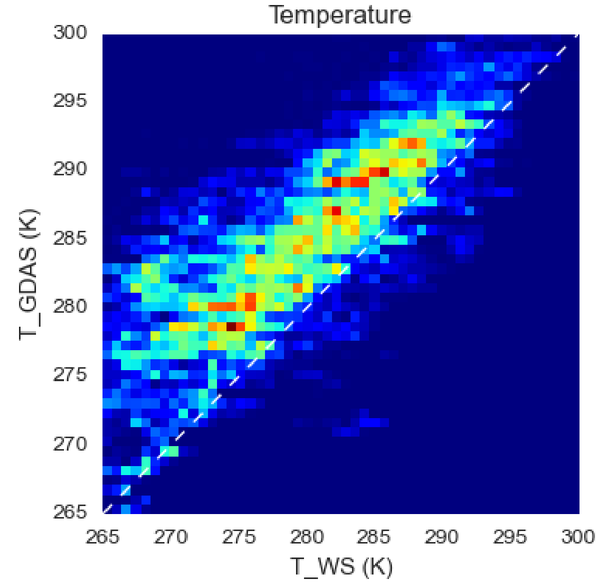


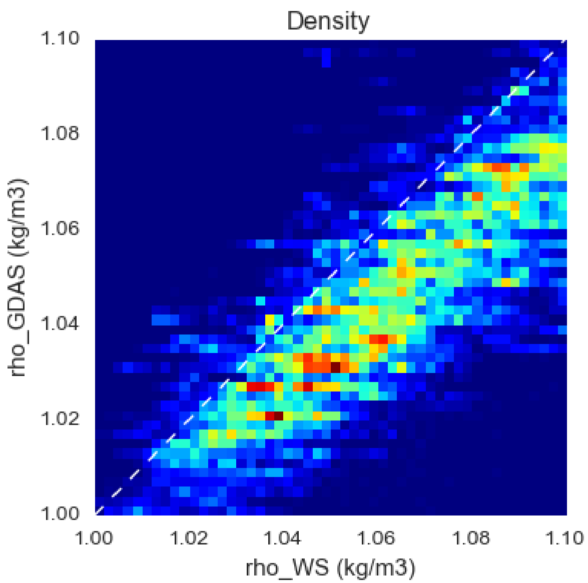


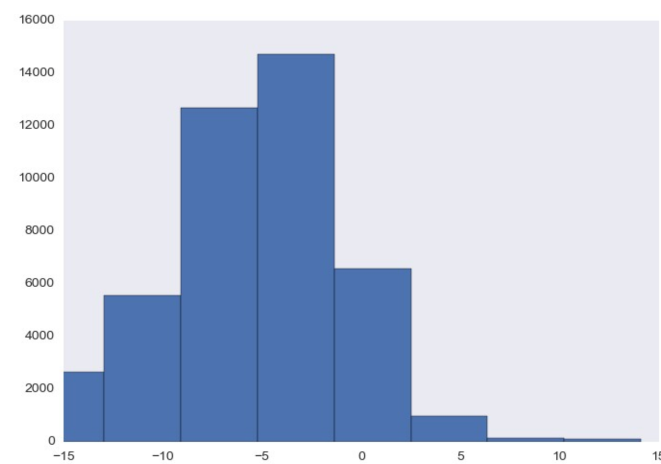


GDAS vs. Weather Station (Auger CLF)

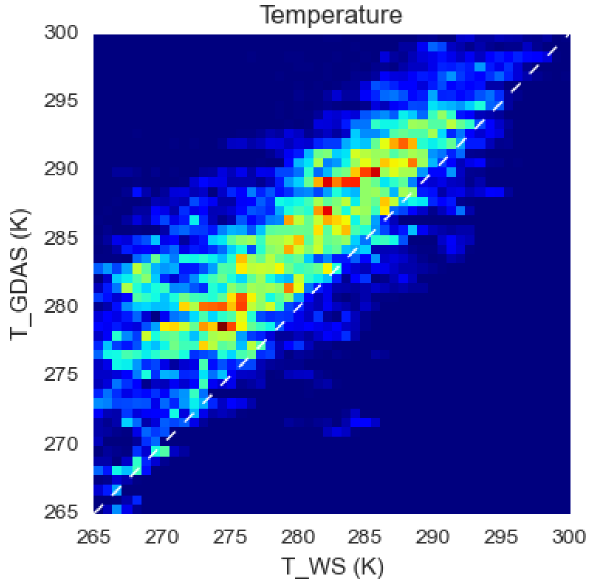


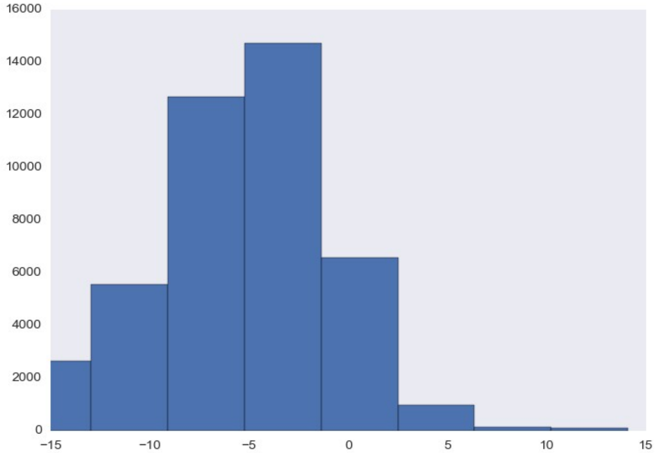




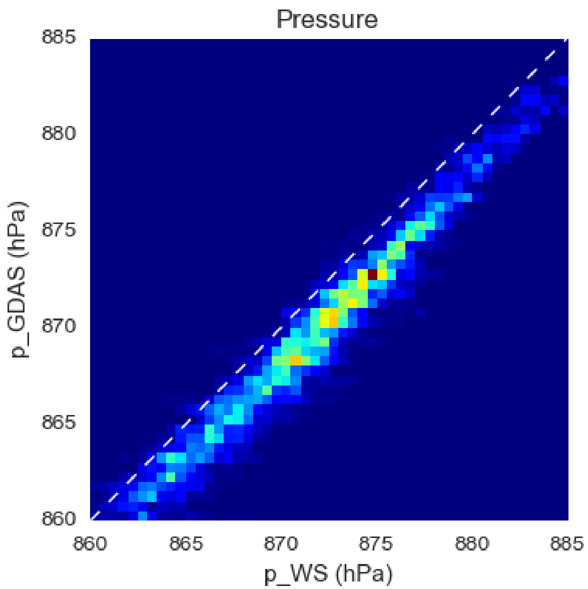


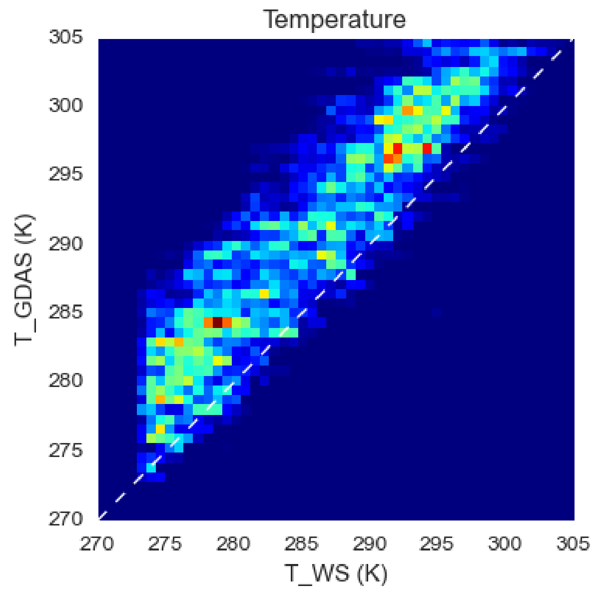
GDAS vs. Weather Station (Auger CLF)

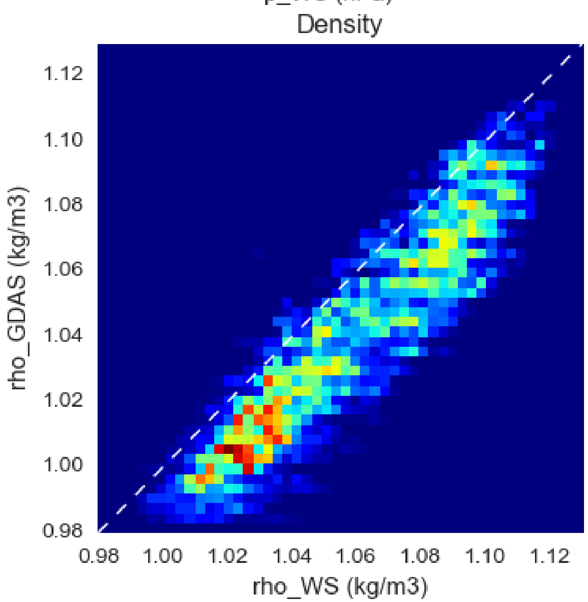


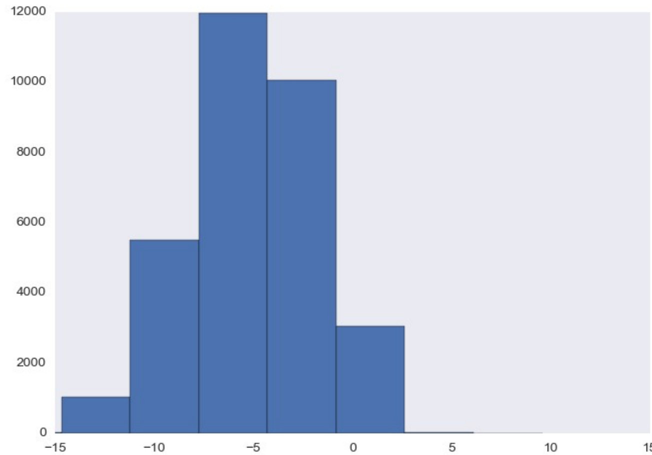


GDAS vs. Weather Station (Colorado AMT)

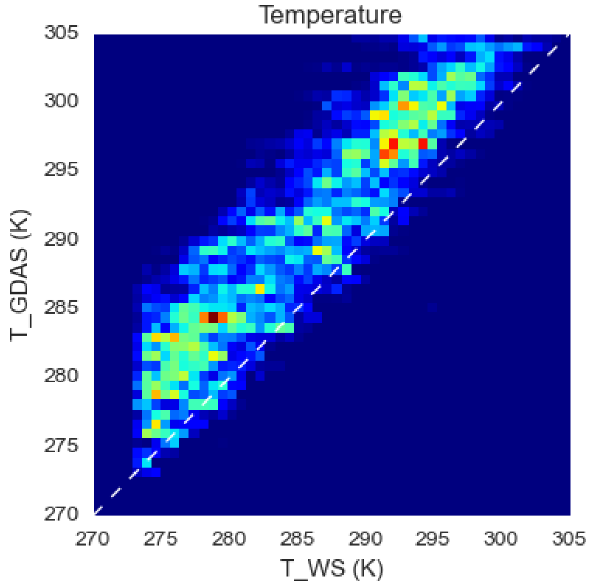


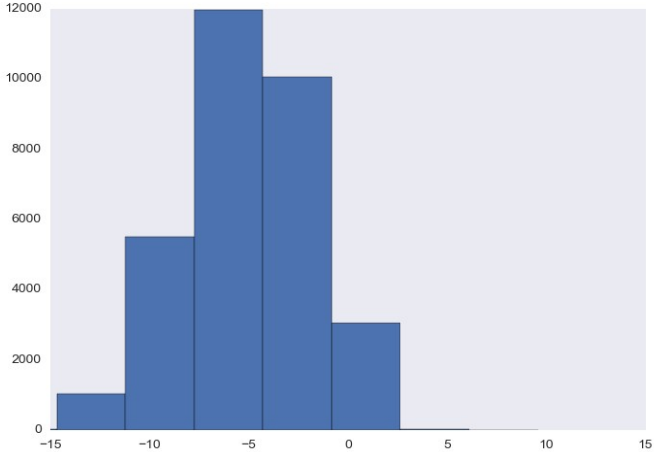




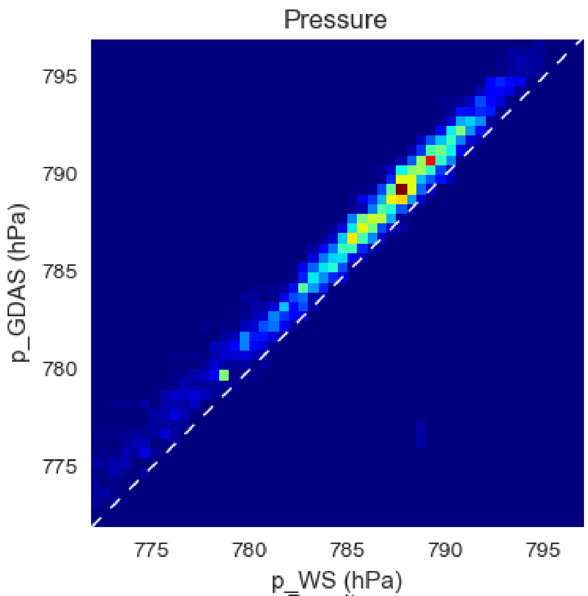


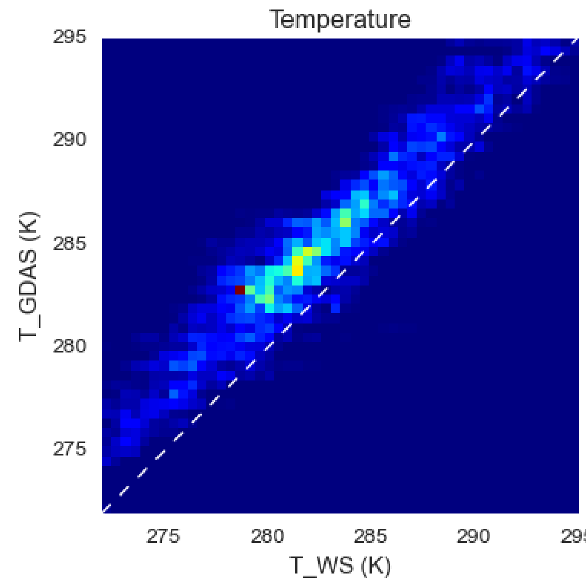
GDAS vs. Weather Station (Colorado AMT)

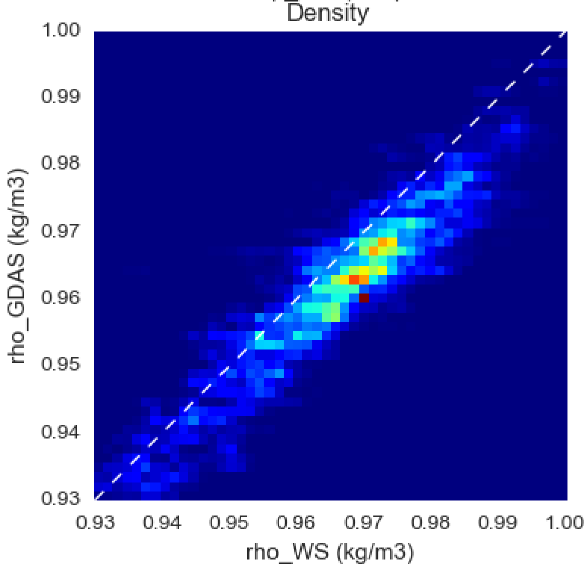


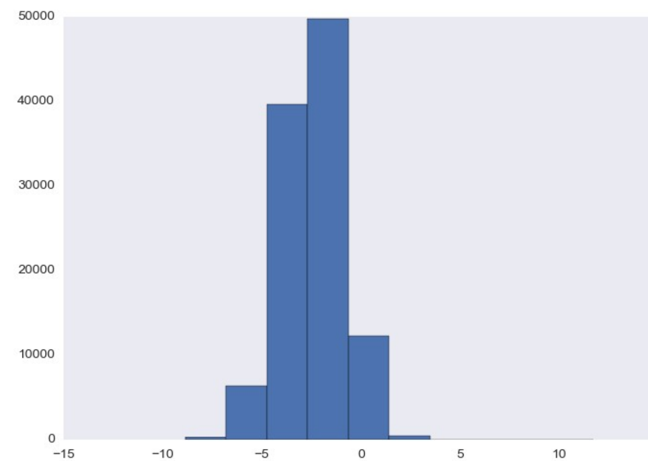


GDAS vs. Weather Station (MAGIC)

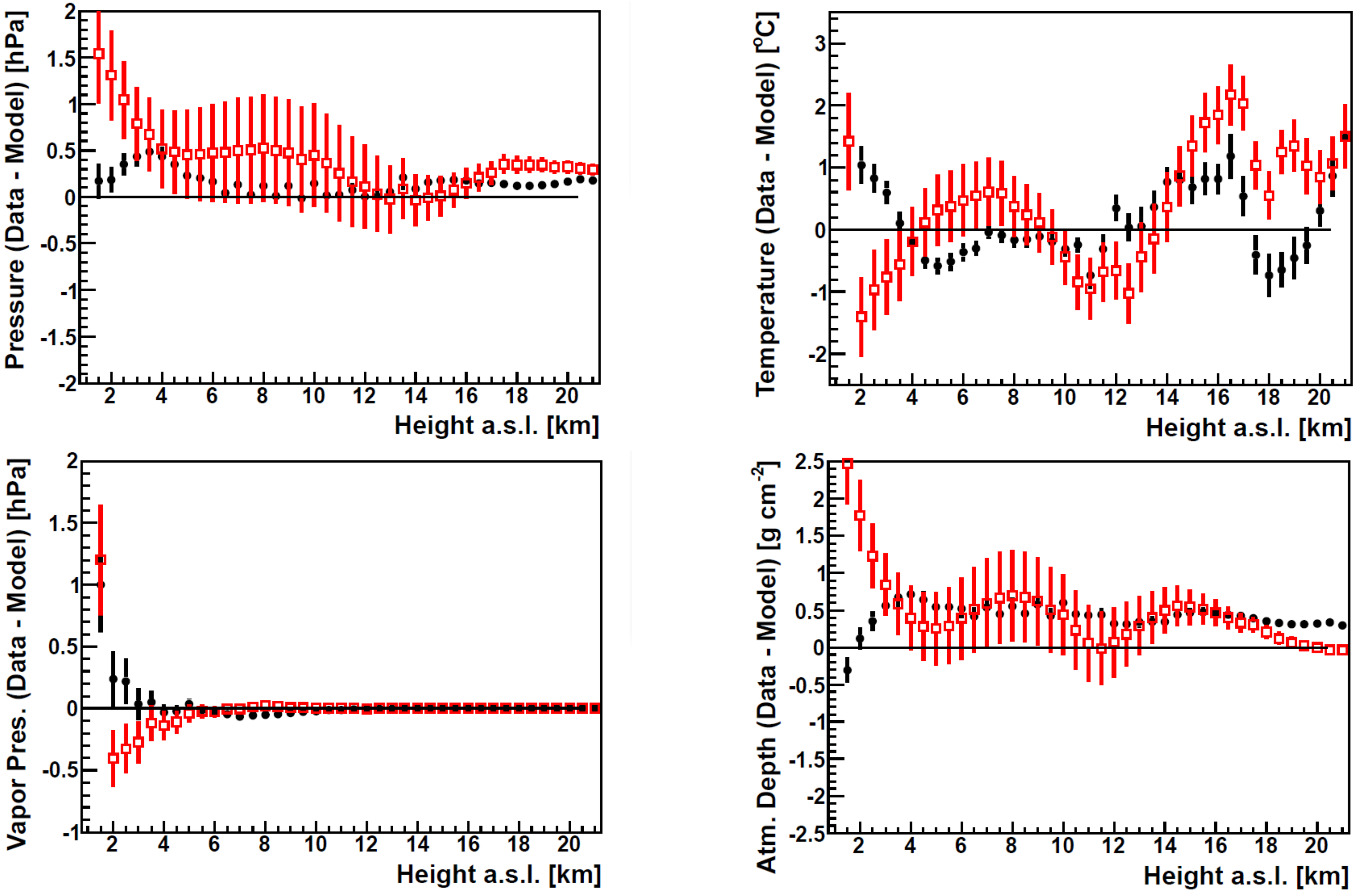




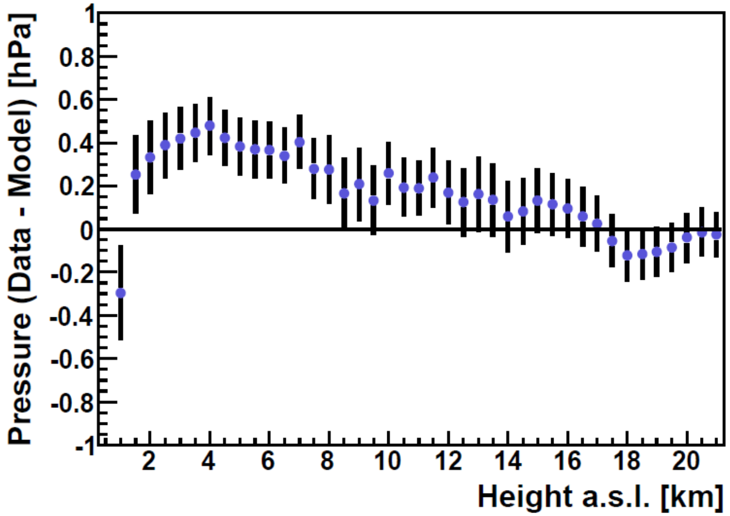


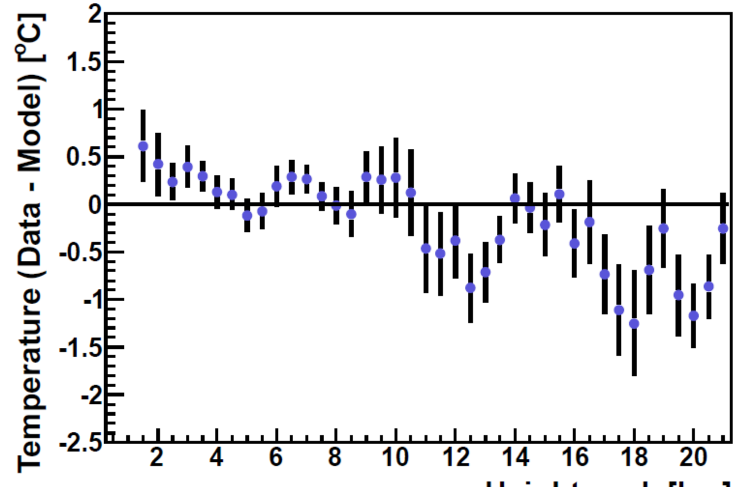


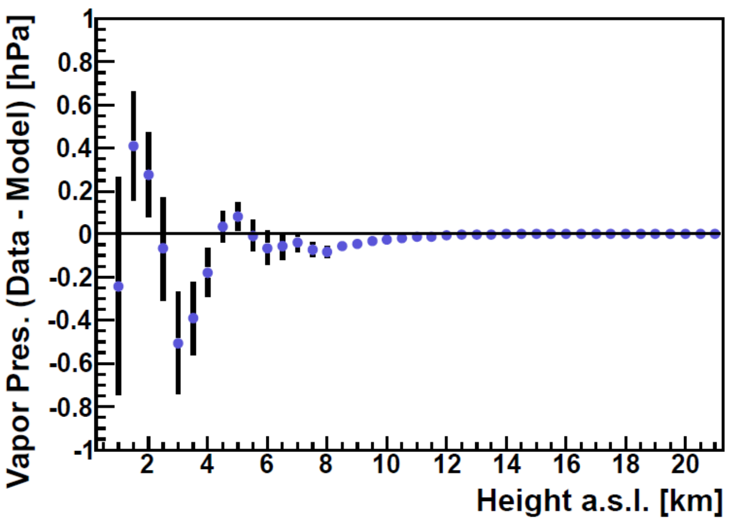
GDAS vs. Balloons (Auger)

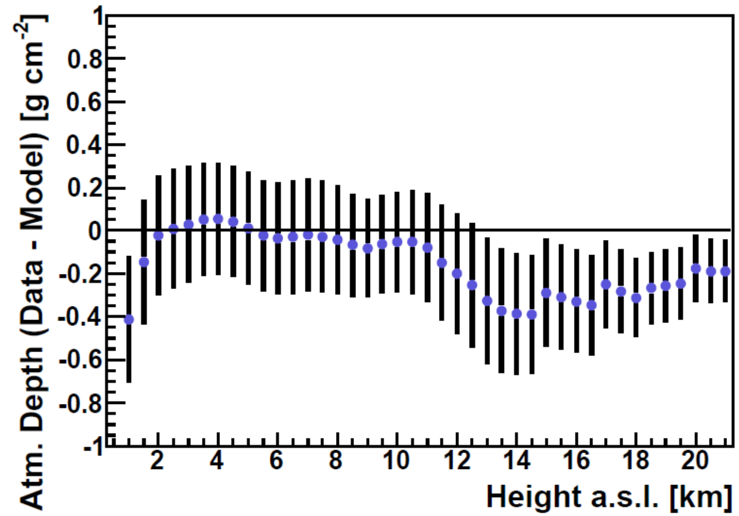


GDAS vs. Balloons (Colorado)

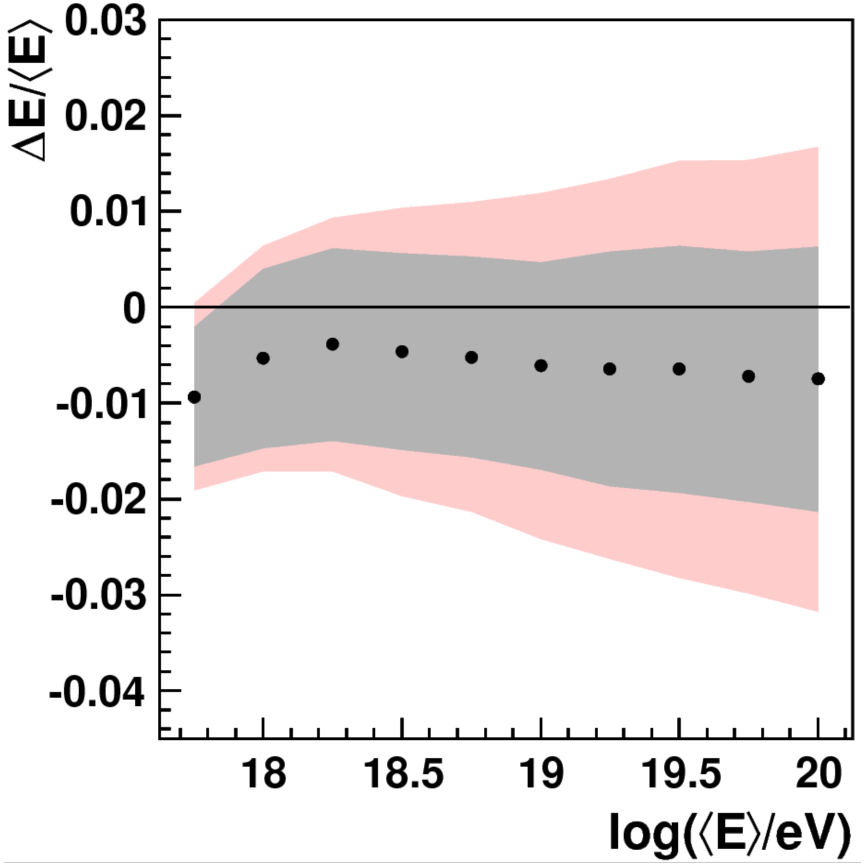


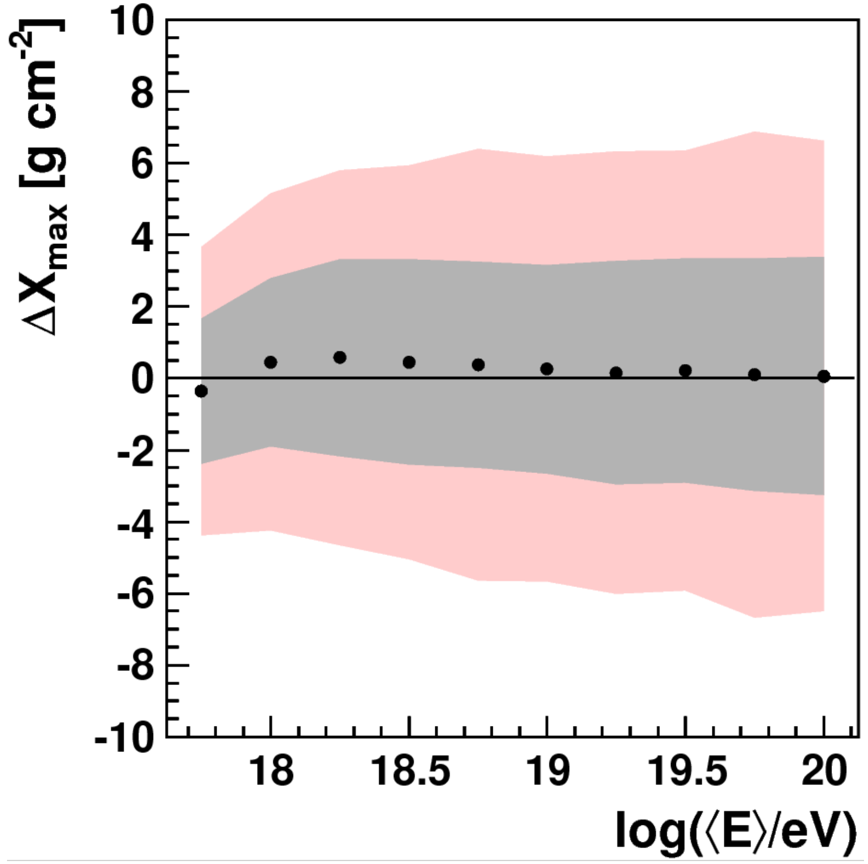






Effects on Systematics (Auger)





GDAS Summary

- Pierre Auger Observatory is successfully using GDAS data in data reconstruction and simulation for more than 3 years.
- Clear reduction of systematics on energy and shower depth estimation
- Reduction of cost and manpower for weather balloon program
- Implementation of GDAS data in MAGIC ongoing
- CTA will most certainly use GDAS from the beginning

HYSPLIT

- HYSPLIT model is a complete system for computing simple air parcel trajectories and complex dispersion and deposition simulations.

- The model can be run interactively on the Web through the READY system on our site (some restrictions apply) or the code executable and meteorological data can be downloaded.

- Sources:
  - http://www.arl.noaa.gov/HYSPLIT_info.php
  - Plots taken from Karim Louedec's 2012 ECRS talk

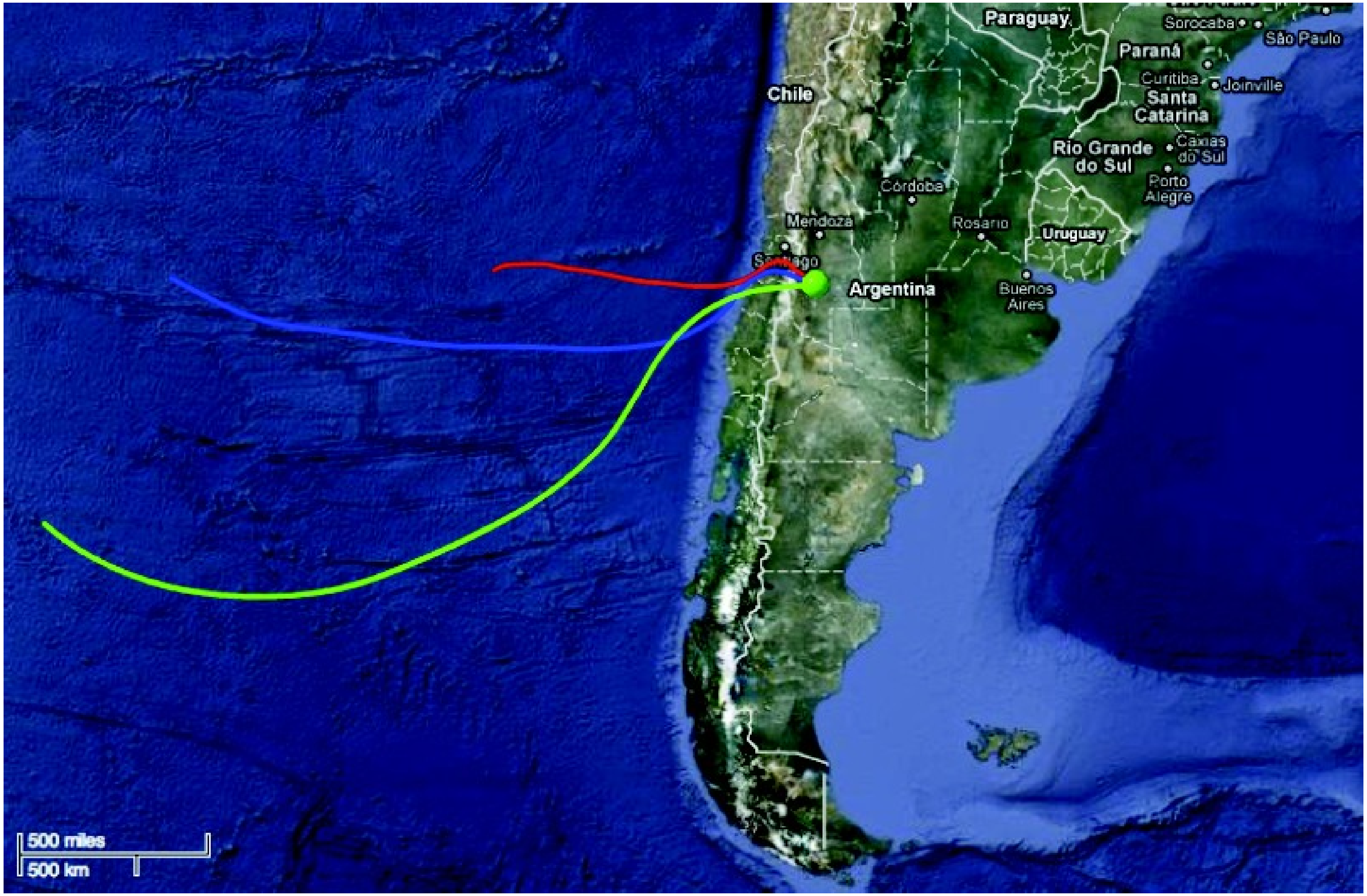
HYSPLIT Model Features

- Trajectories
  - **Single or multiple (space or time) simultaneous trajectories**
  - **Computations forward or backward in time**
  - Motion options: isentropic, isosigma, isobaric, isopycnic
  - **Output of meteorological variables along a trajectory**

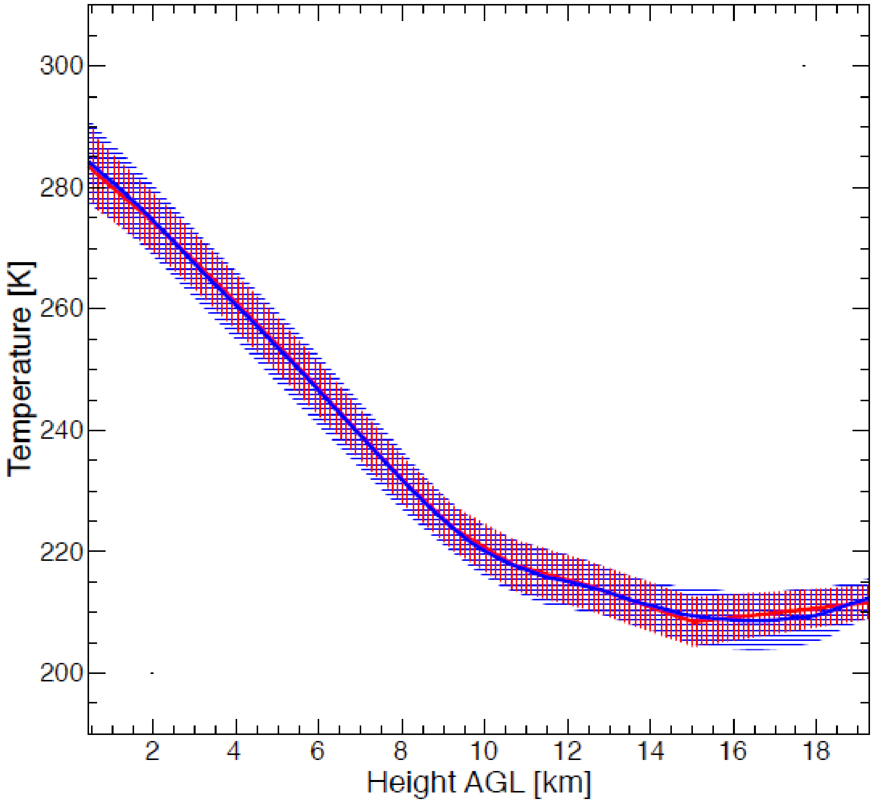
- Air Concentrations
  - **3D particle dispersion or splitting puffs**
  - **Instantaneous or continuous emissions, point or area sources**
  - Wet and dry deposition, radioactive decay, and resuspension
  - Emission of multiple simultaneous pollutant species

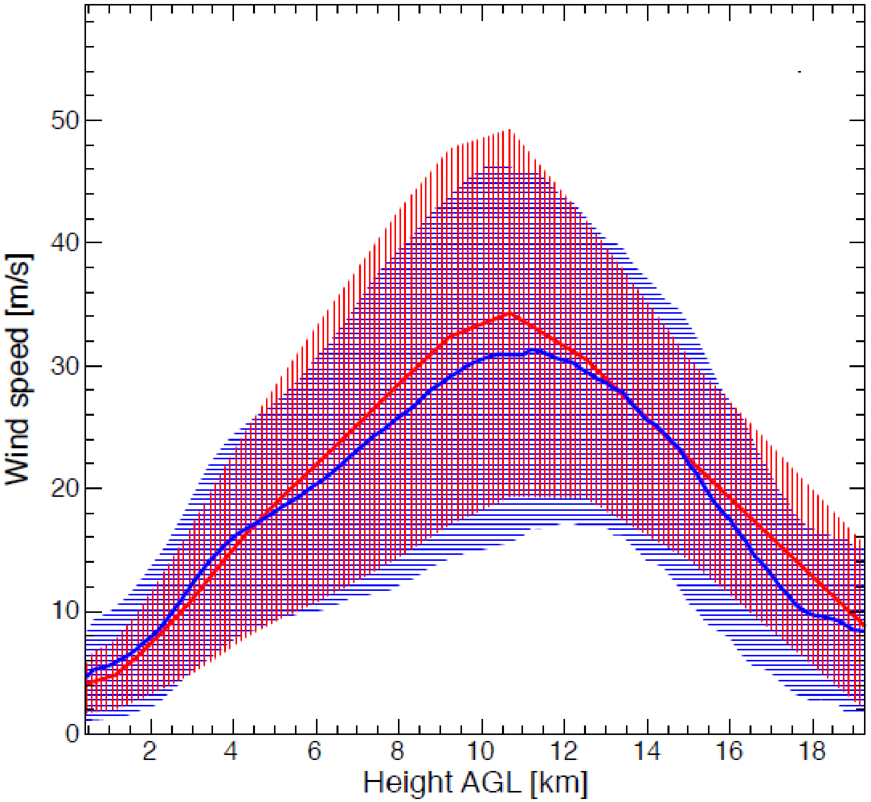
- Meteorology
  - Model can run with multiple nested input data grids
  - Links to ARL and NWS meteorological data server
  - **Access to forecasts and archives (including GDAS)**

HYSPLIT Trajectories



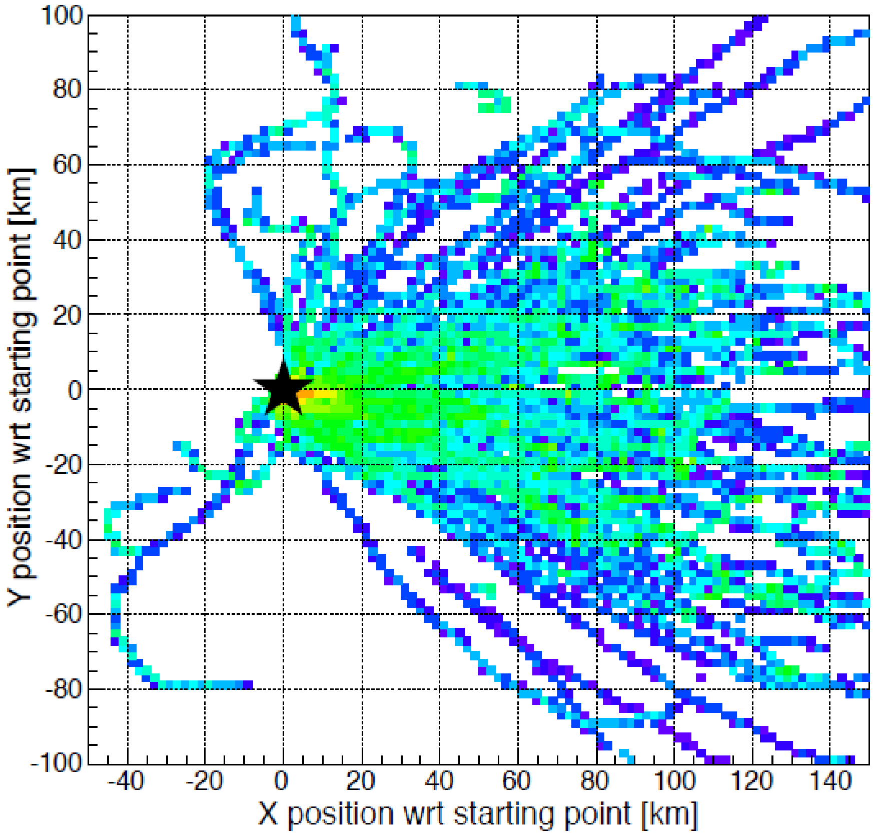
GDAS vs. Balloons (Auger)



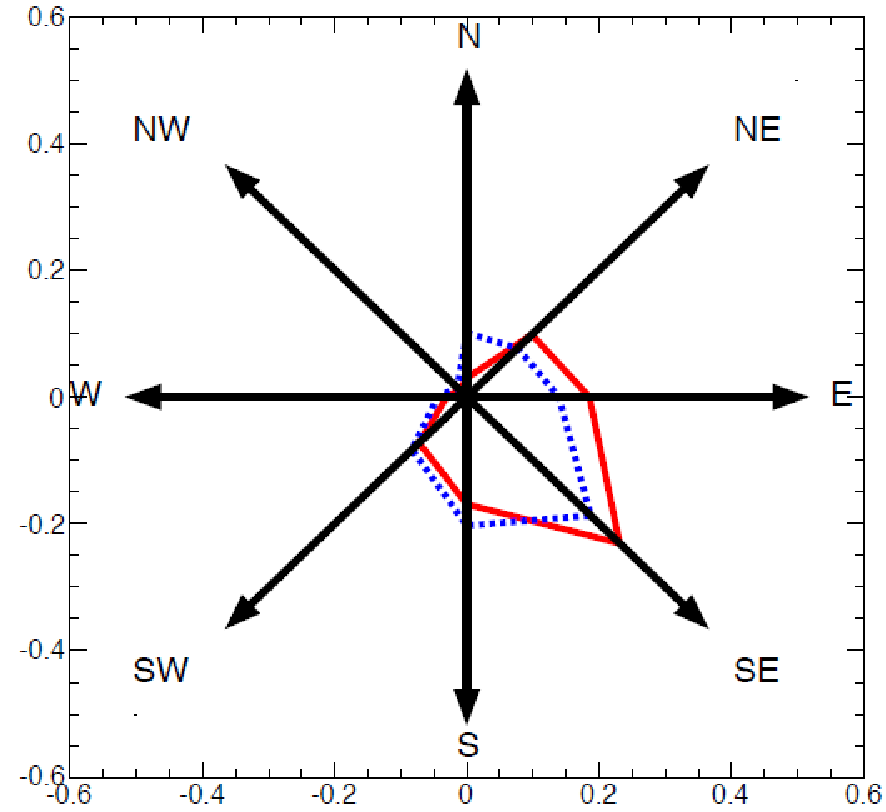


HYSPLIT Validation

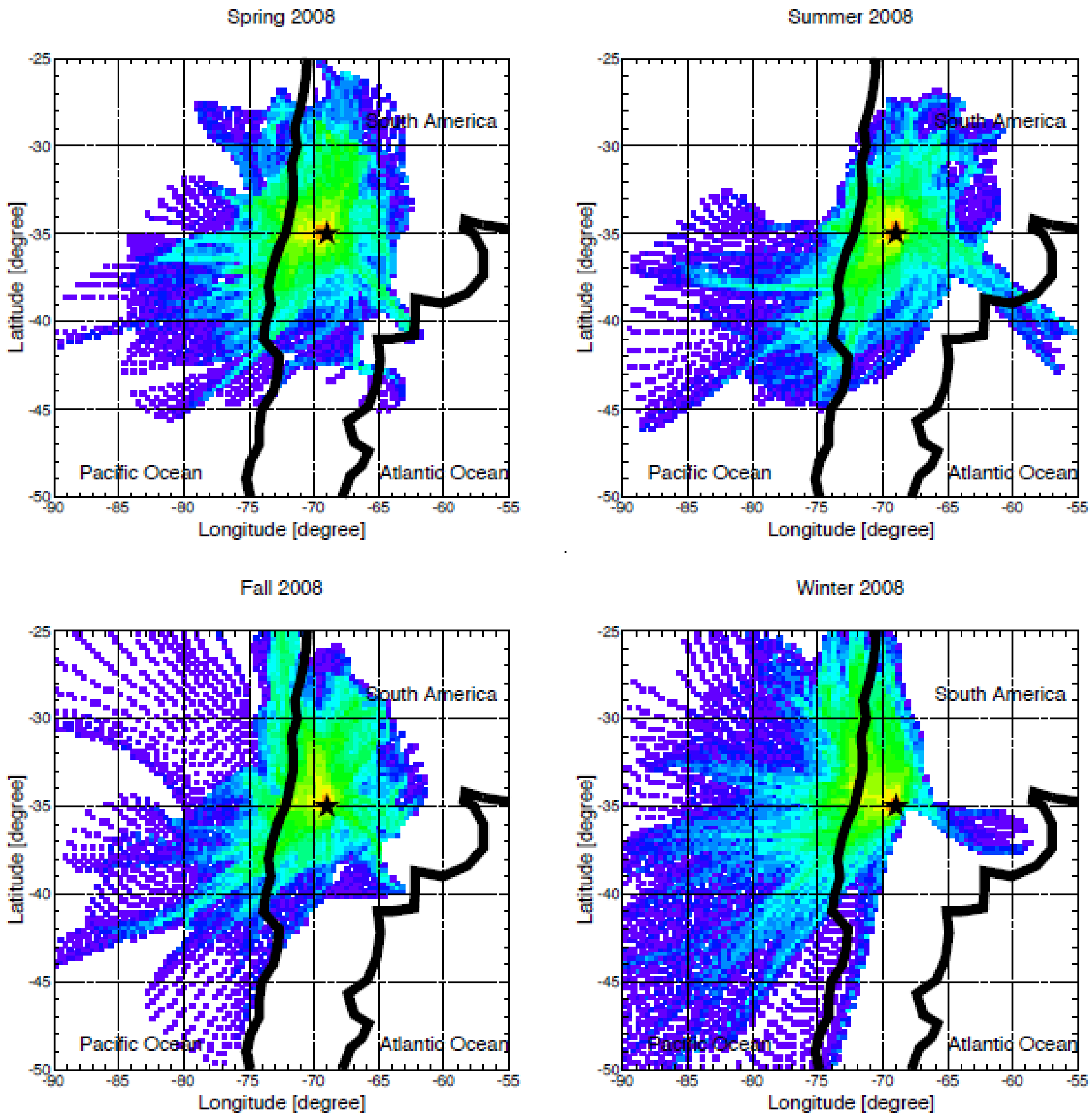
Distribution of balloon trajectories



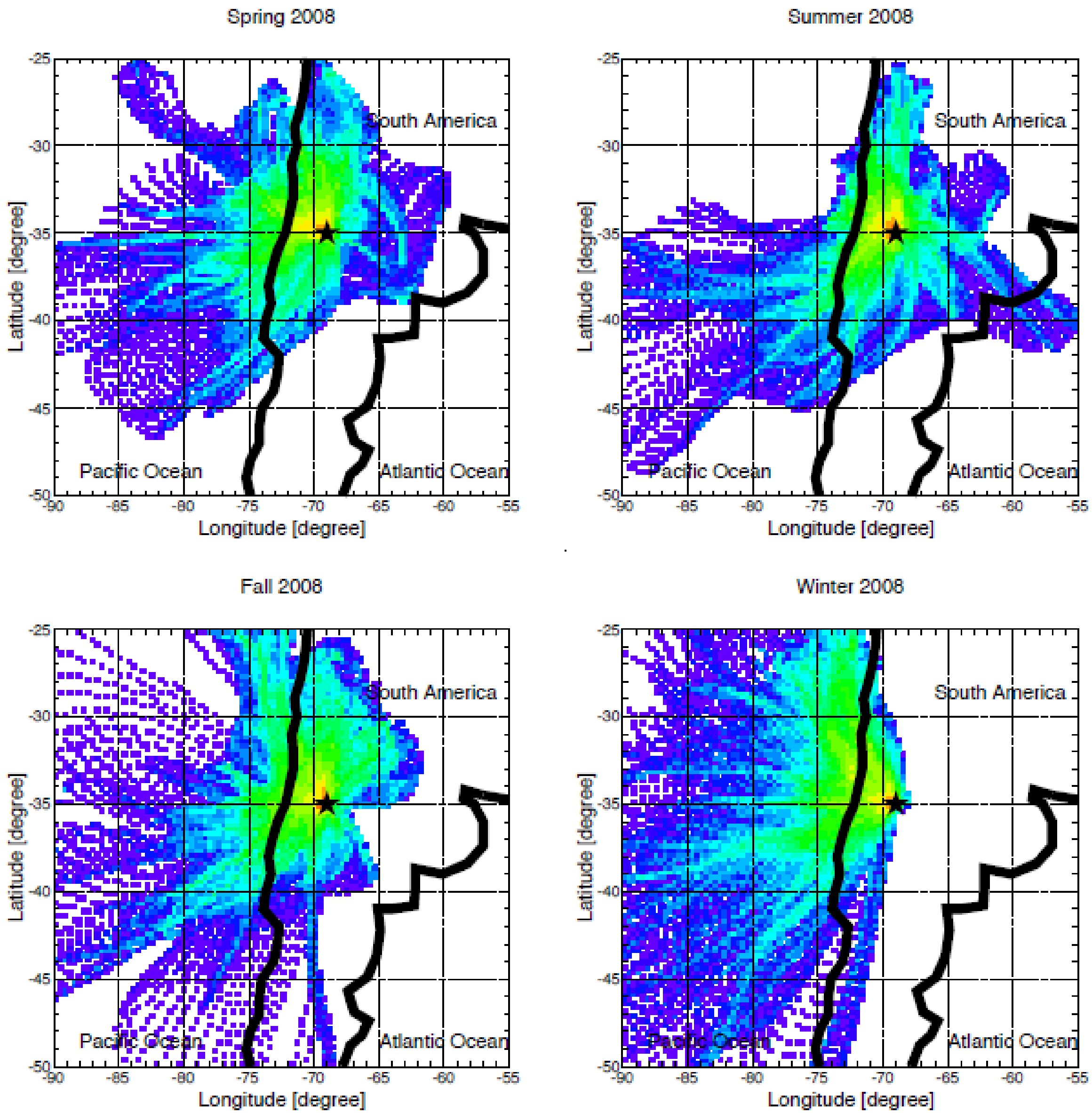
Air mass path directions



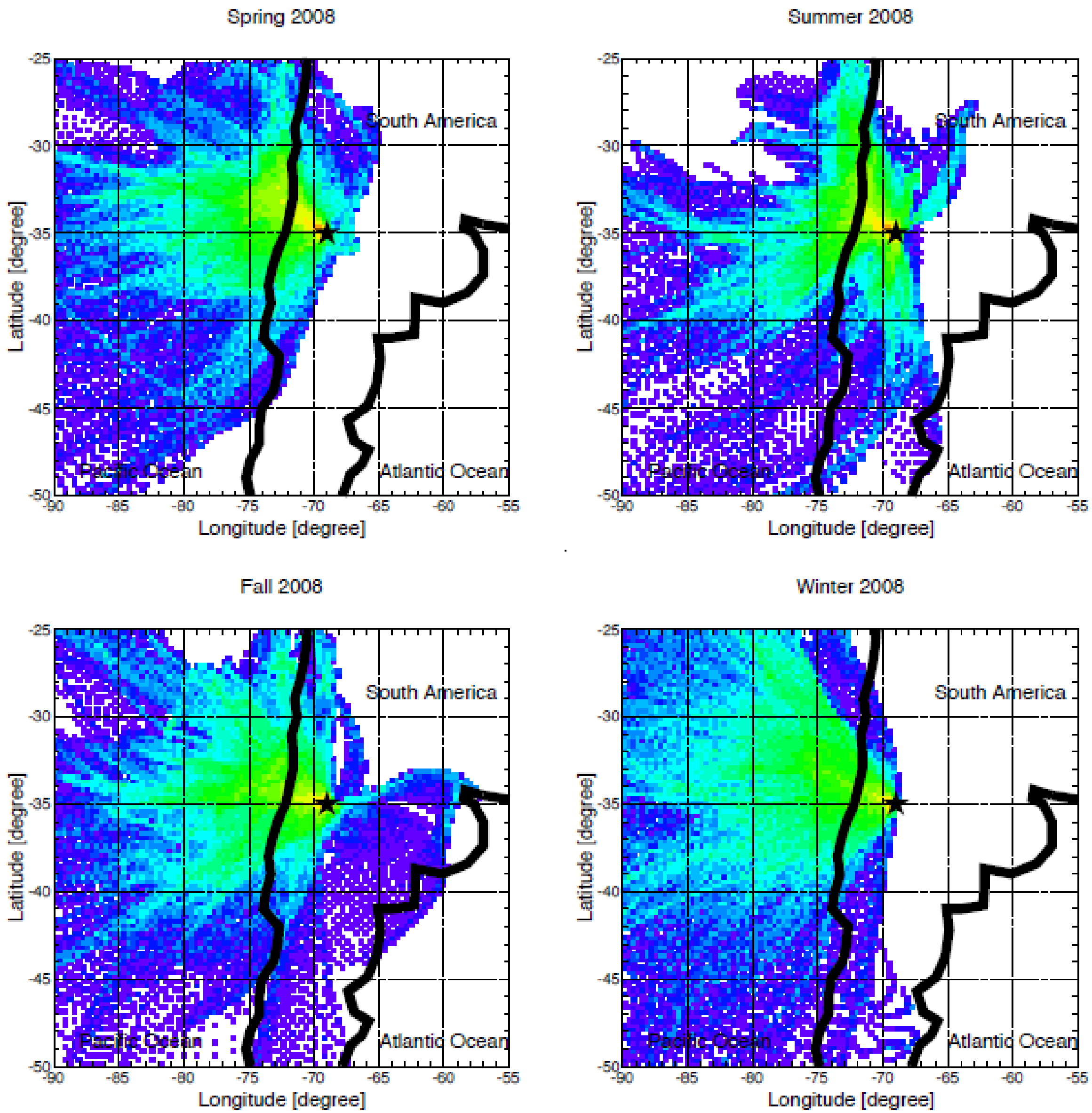
HYSPLIT 500m



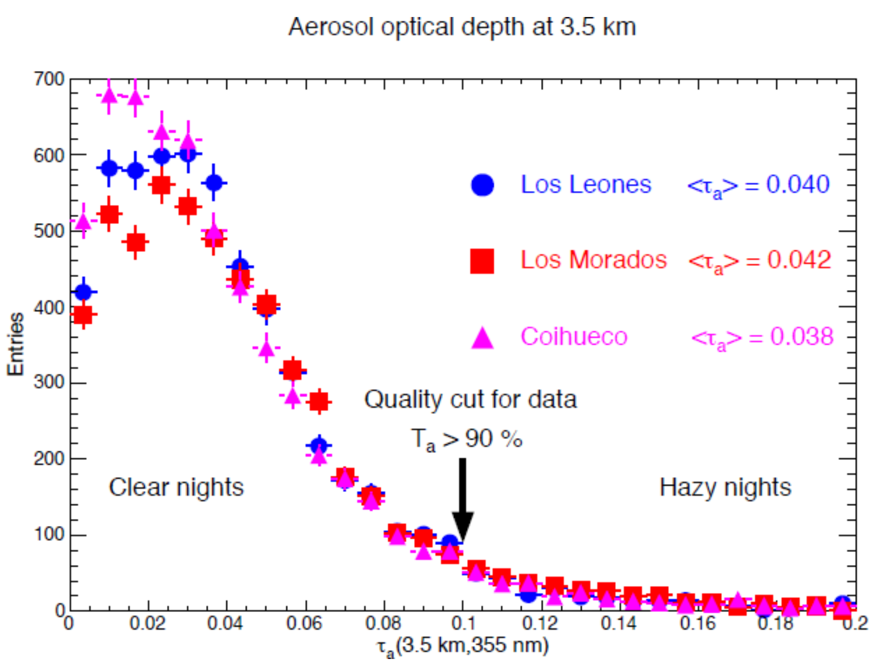
HYSPLIT 1000m

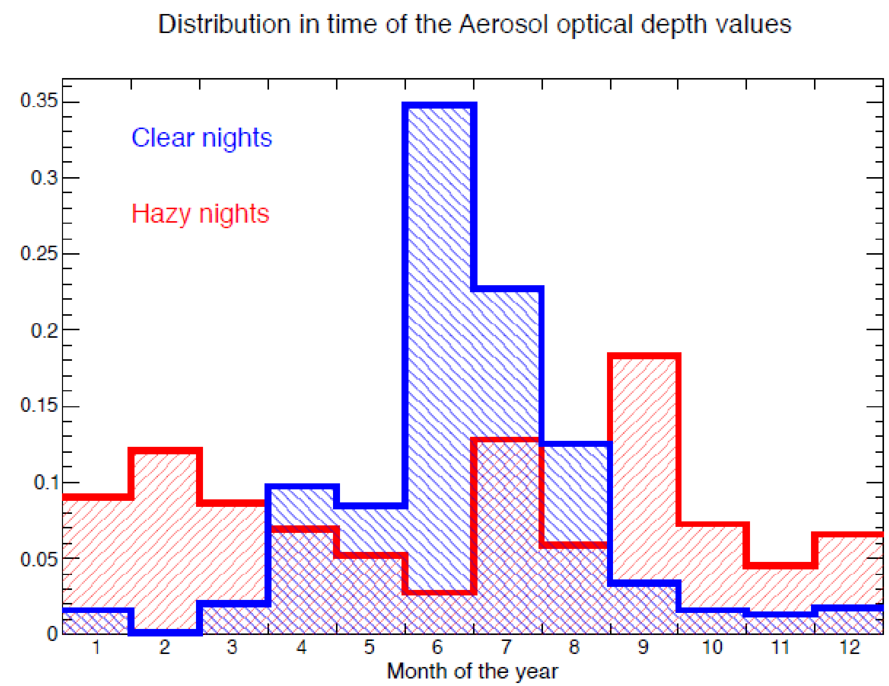


HYSPLIT 3000m



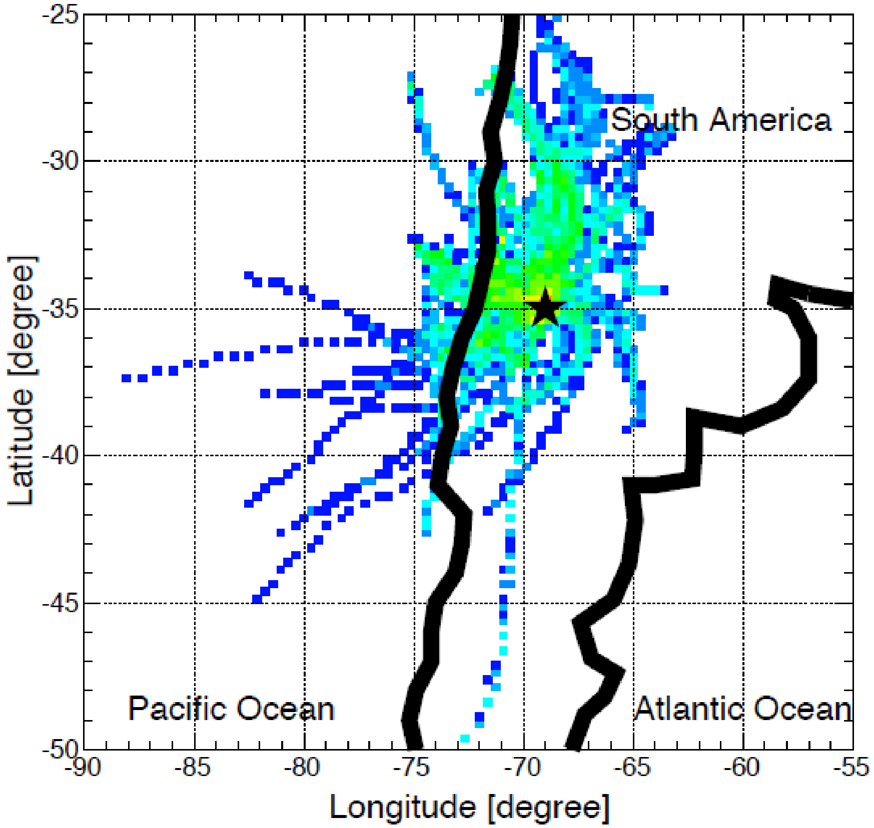
Aerosol Optical Depth



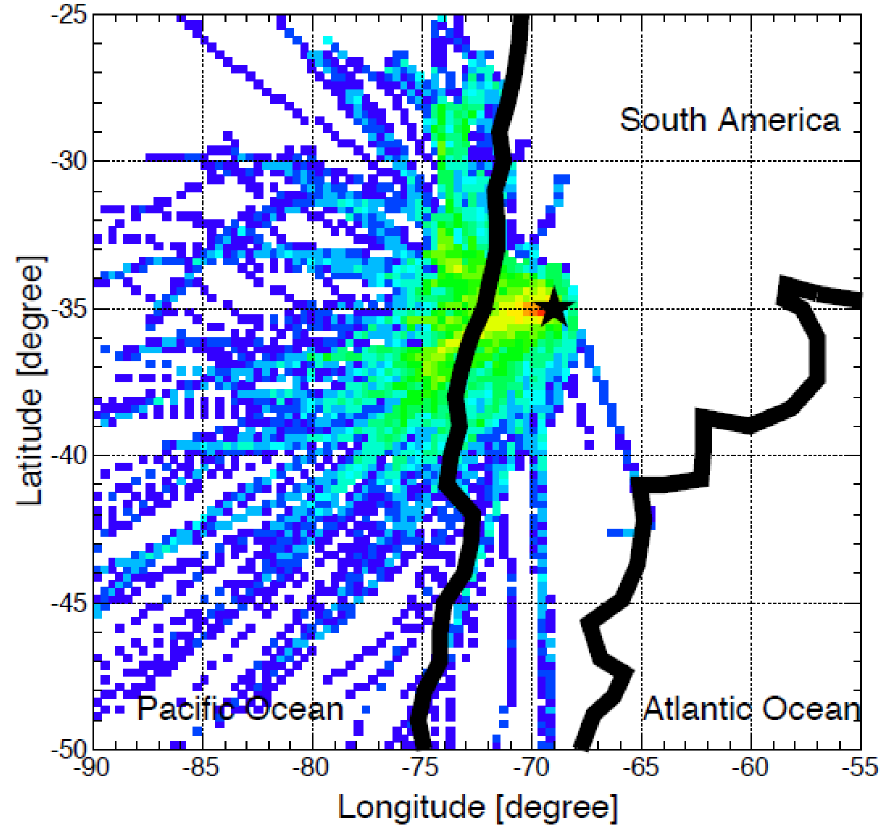


Clear/Hazy Trajectories

Distribution of trajectories: $0.10 \leq \tau_a(3.5\ \text{km}) \leq 0.30$



Distribution of trajectories: $0.00 \leq \tau_a(3.5\ \text{km}) \leq 0.01$



HYSPLIT Summary

- HYSPLIT analysis can give us a better understanding of air mass behavior affecting the Pierre Auger Observatory

- Different origin of air mass above the Observatory throughout the year

- Aerosol concentrations show a minimum Austral winter
  - Clean air masses transported from Pacific Ocean
  - Traveling above snowy soils and mountains to the Observatory

- Aerosol concentration peaks around September/October
  - Origin further inland in dusty areas
  - Air pollution transported from closer urban areas
  - Biomass burning in northern Argentina and Bolivia during the dry season

- Air mass transport plays a key role in the aerosol component present above the Pierre Auger Observatory, not just local sources

The End