Aerosols and Climate Change at the Bolivian Andes

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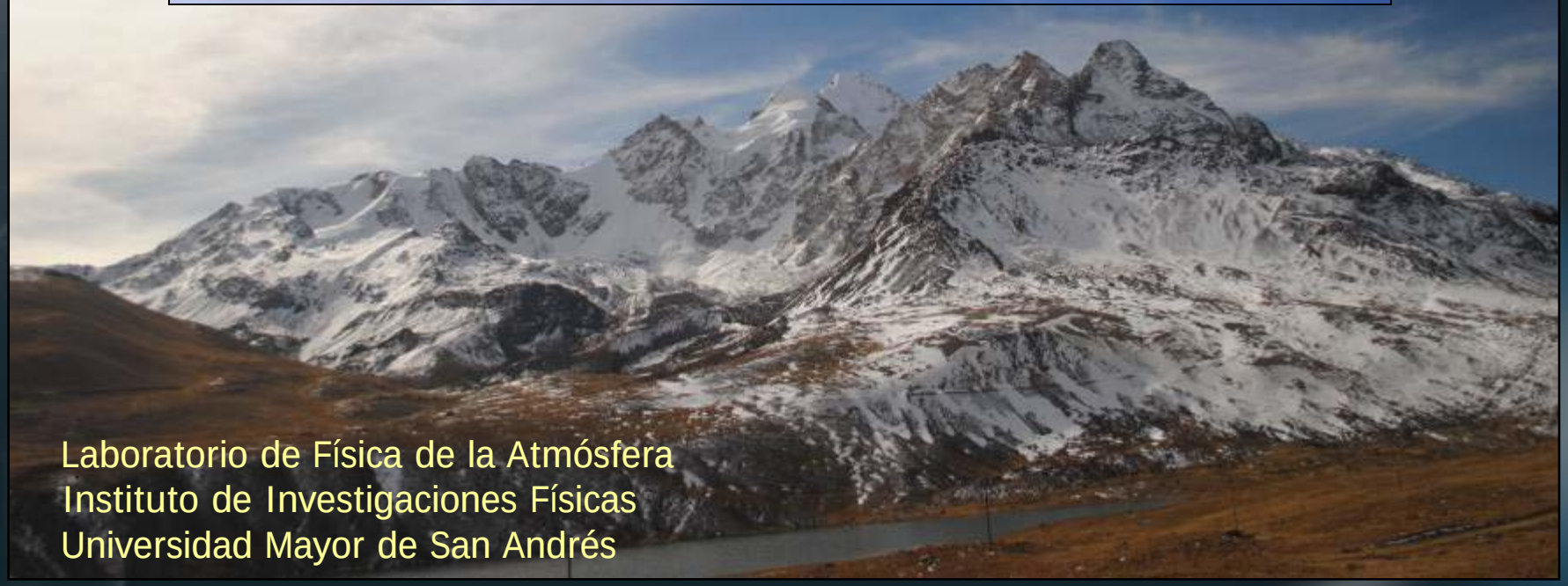

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INCA, September 2013

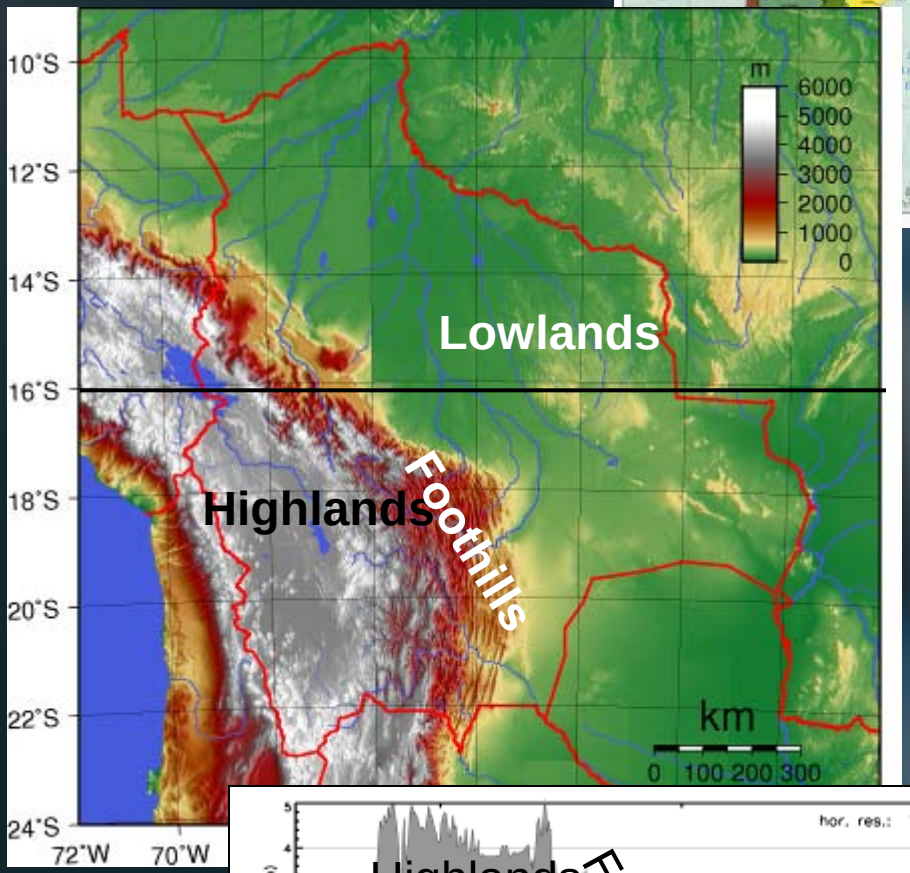
Outline

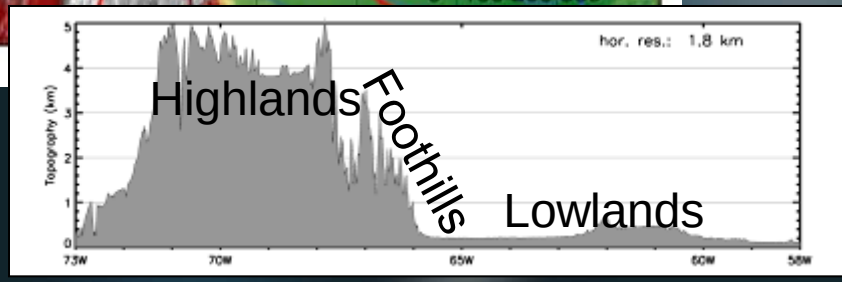
- Aerosol transport to the Andean region
  - Motivation
  - The new GAW station
  - First preliminary results
  - A campaign at La Paz metropolitan area
- Climate modeling at the region

Motivation

- 10 Mio. inhabitants
- 1 Mio. Sq. km

- Complex topography
- Three distinct climate zones
- Tropical physics and dynamics





Motivation

- Absorbing aerosols contribute to changes in optical properties of snow and ice by changing their albedo.

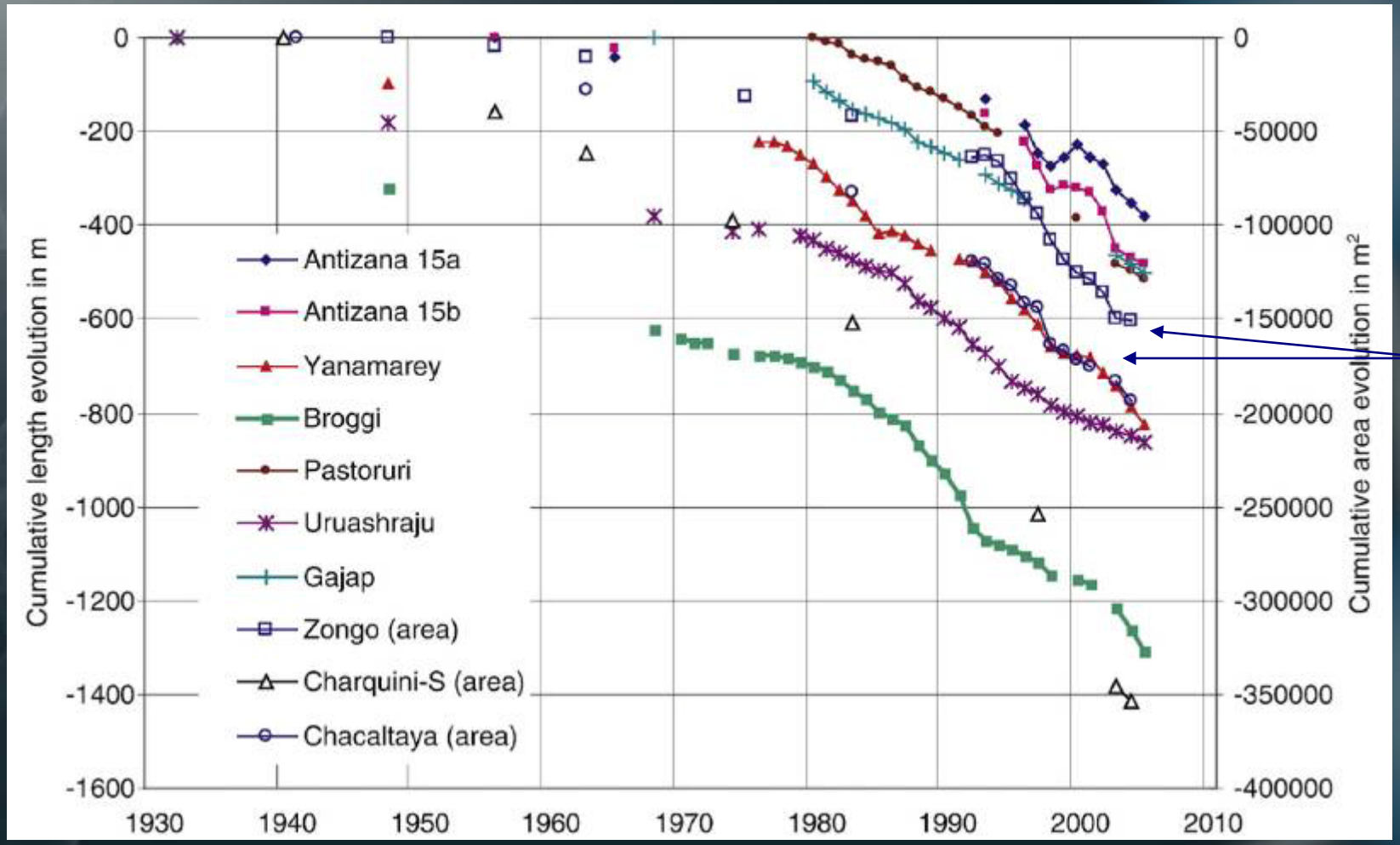
Infuence of 1 gram of black carbon distributed over a square meter of snow (Niwot Ridge, CO)

Motivation

- In particular, black carbon (BC) has an important role as a climate forcing agent. It absorbs more solar light per unit mass than any atmospheric aerosol material.
- Recent studies (Lau et al., 2010) suggest that at least part of the observed warming in the Himalayas could be due to aerosols transported from sources located far from the region.
- Some studies suggest that BC could be responsible up to 30% of the glacial retreat at this region.

The Andean case

Glacier retreat in the Andean region

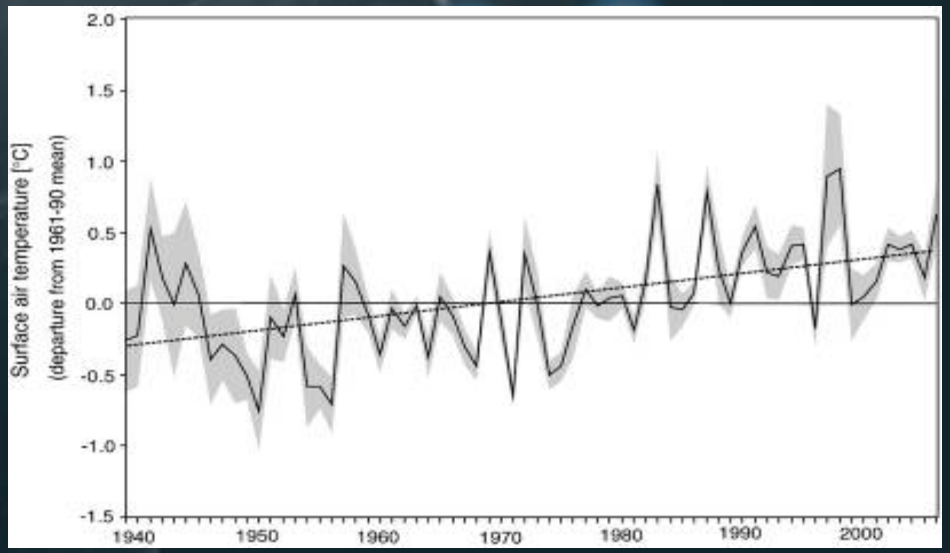


(Vuille et al., 2008)

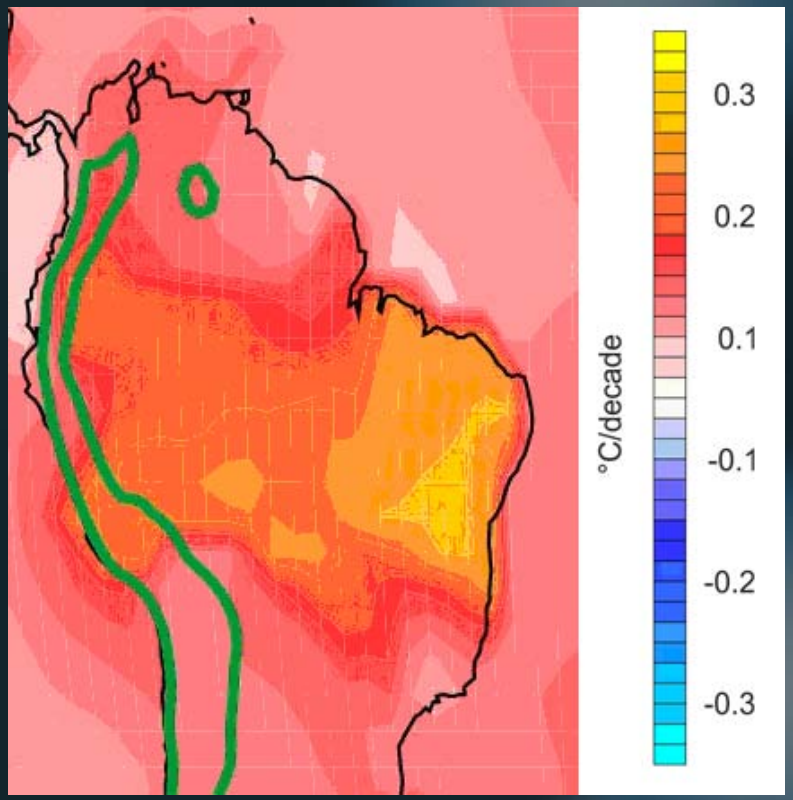
Temperature trends

- Temperature trends in the region (~0.10-0.20º C/decade), however, do not seem to account for the rapid retreat of the last two decades

Temperature anomalies



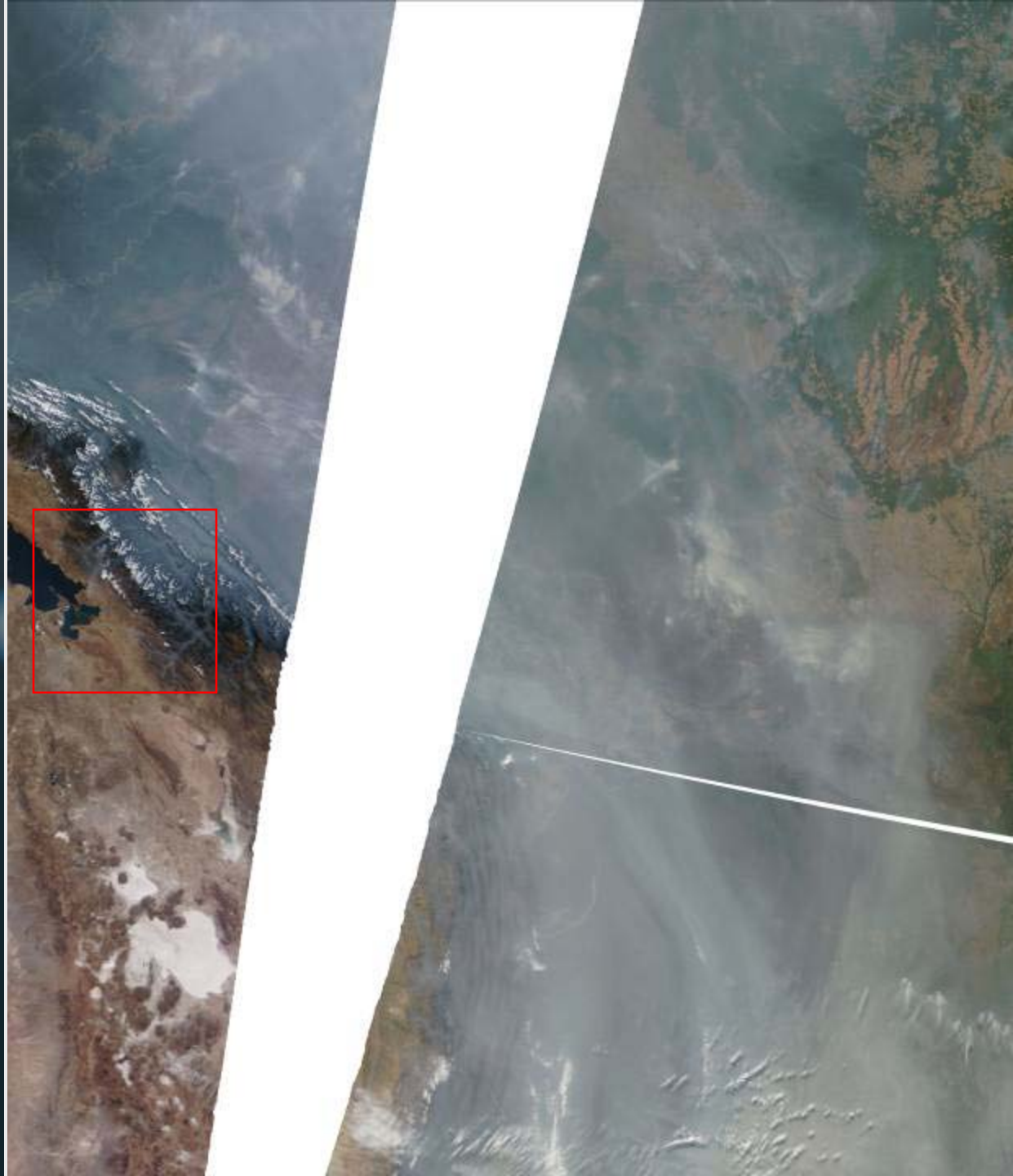
(Vuille et al., 2008)



Linear trend in annual mean temperature from the NASA/GISS data (Hansen et al. 2010) from 1900 to 2012. Green lines indicate topography above 1000 m asl.

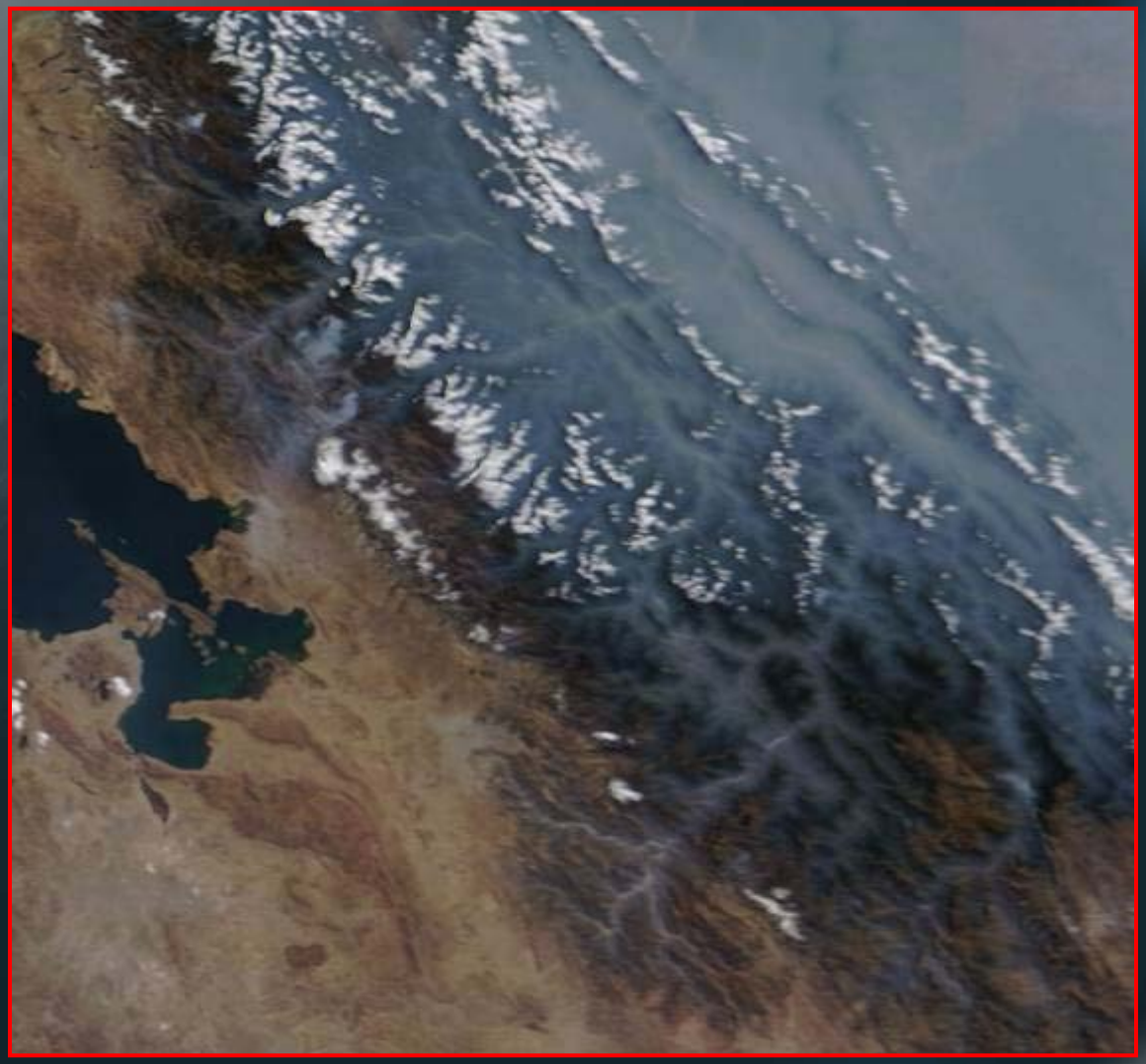
Smoke over Bolivia

August 19, 2010



From MODIS on-board of Terra

Smoke transported above Andean mountains



A new Chacaltaya/GAW Station

Location


Chacaltaya
~22 km
Aeropuerto El Alto
Planetario
LFA
Google earth

GAW/CHC Chacaltaya Station
(5240 masl)

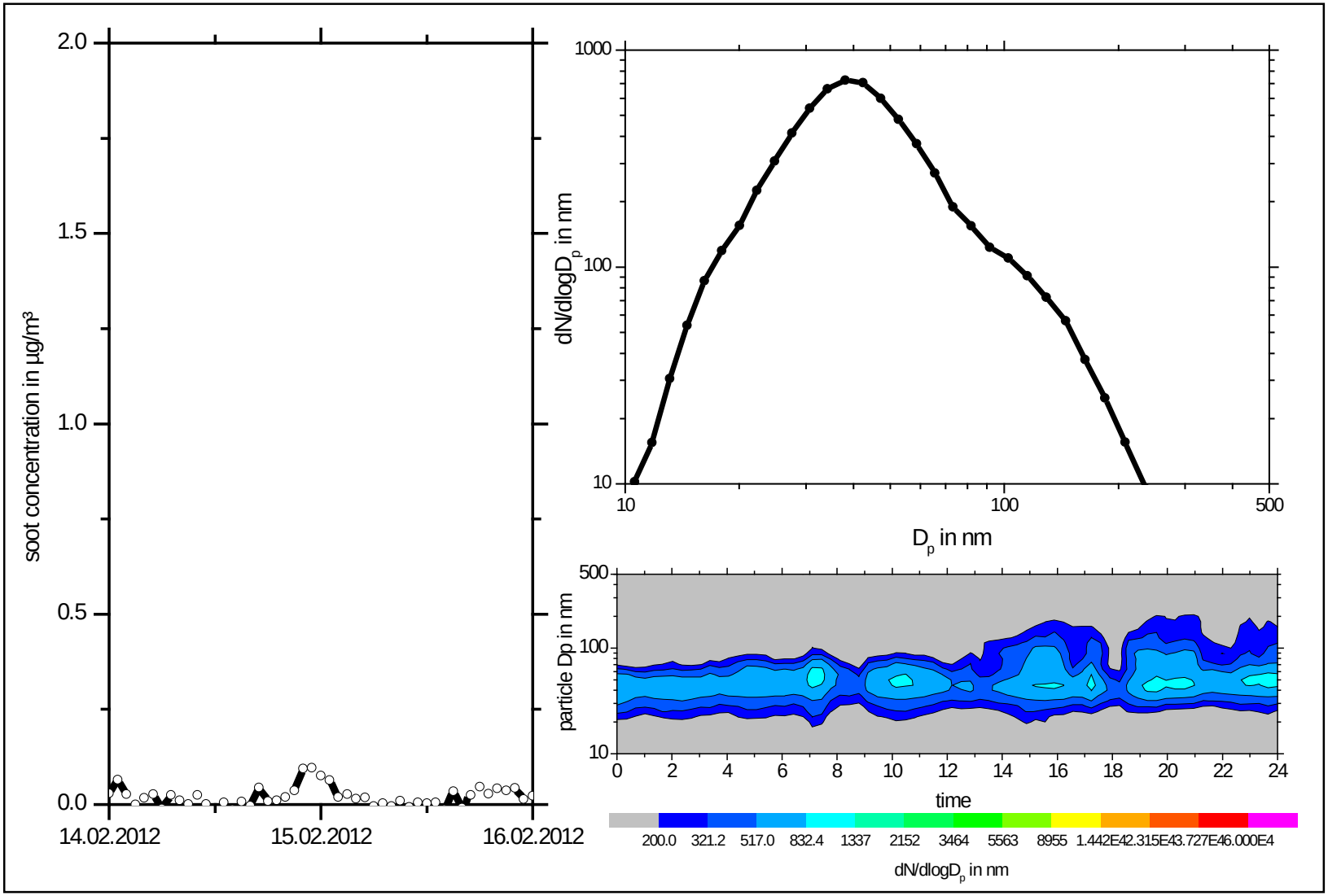
Cota-Cota

Medidor de CO_2

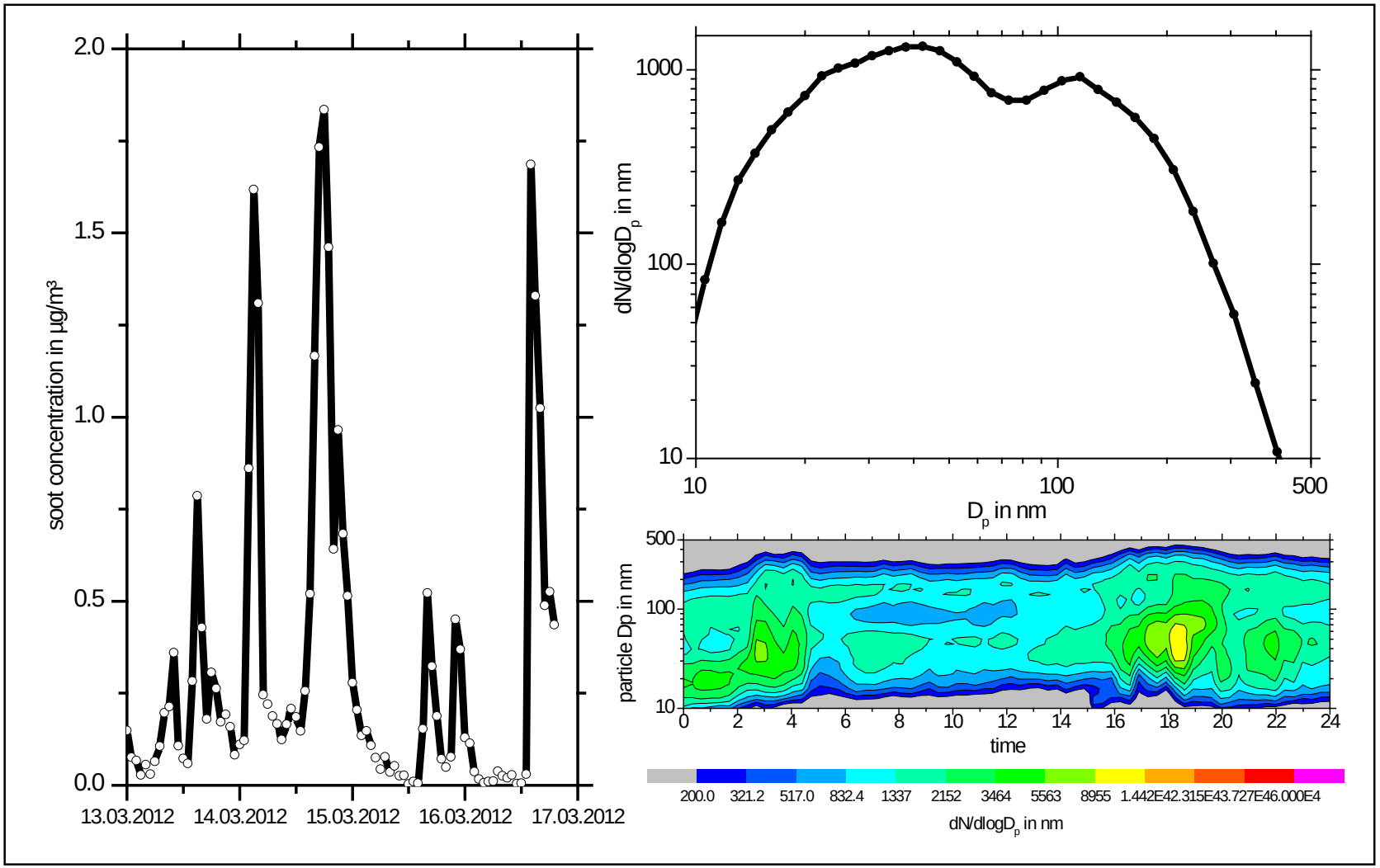
CO

LIDAR

Clean air mass



Pollution transported from the city

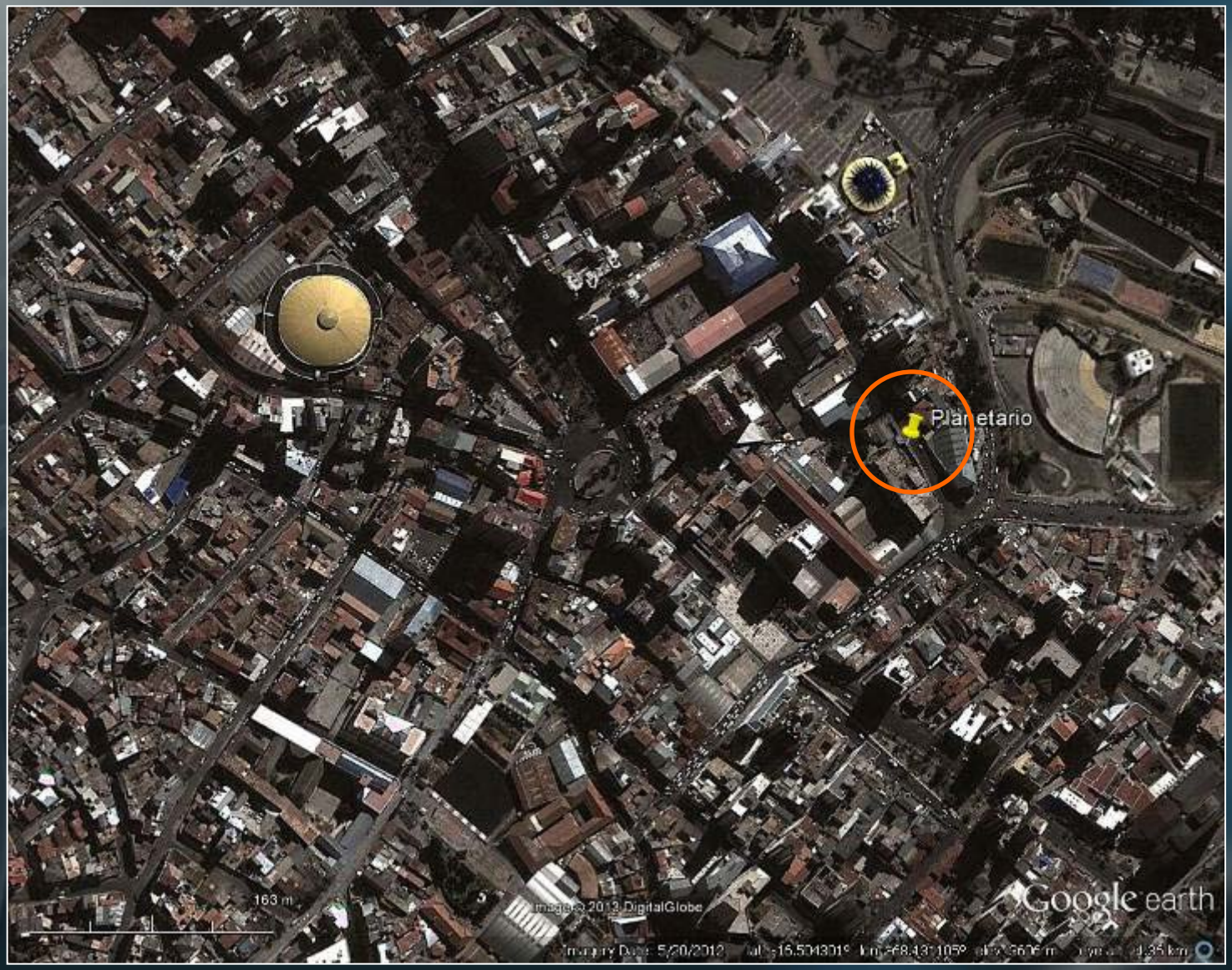


A campaign at La Paz metropolitan area

Measurement sites

AASANA (El Alto)

Planetarium (La Paz)



Instruments

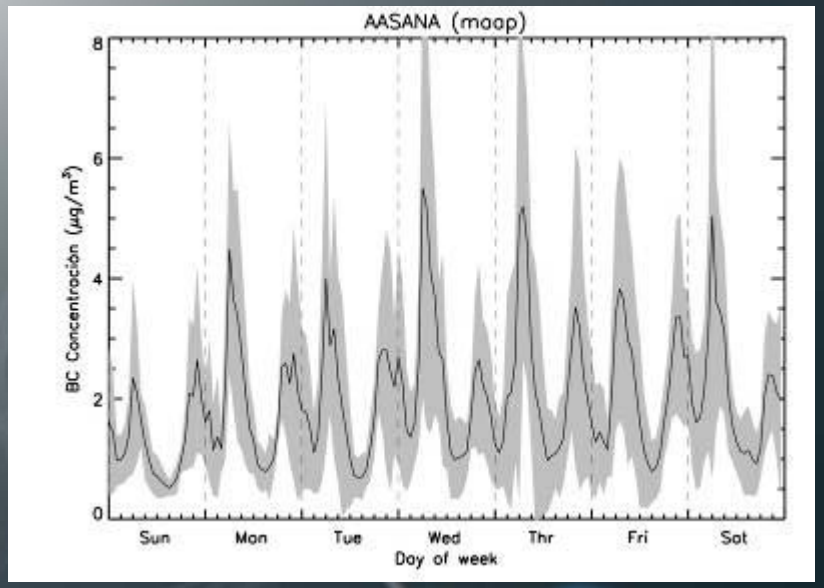
MAAP:
λ=670 nm

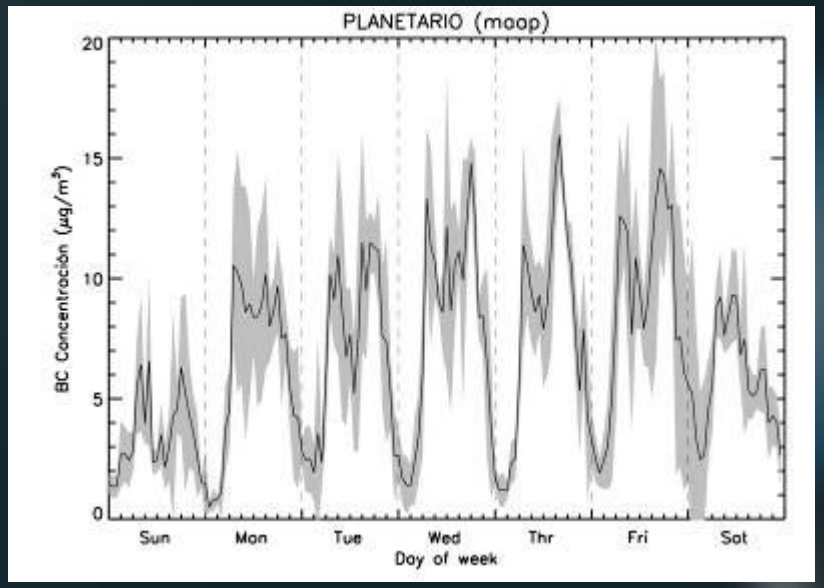
Horiba
APMA-370:
0.05 ppm res

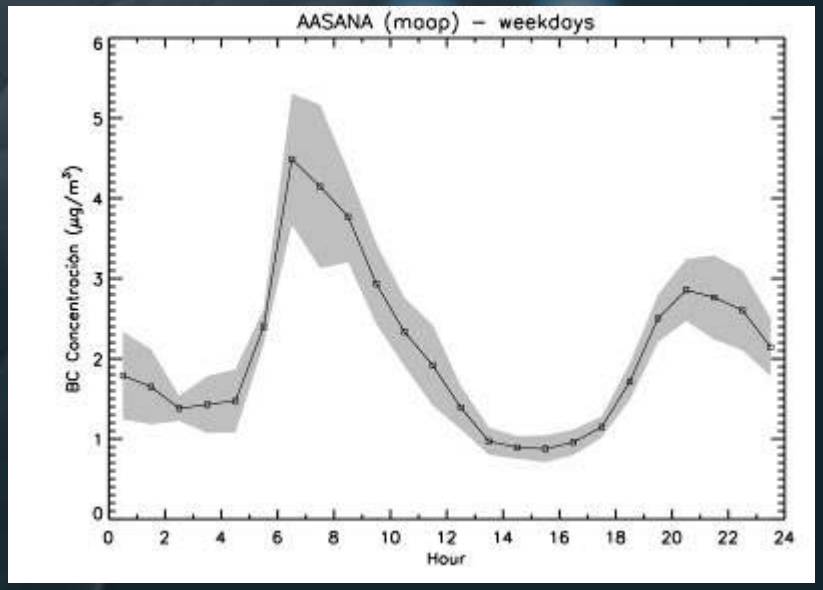
SMPS:
10-800 nm

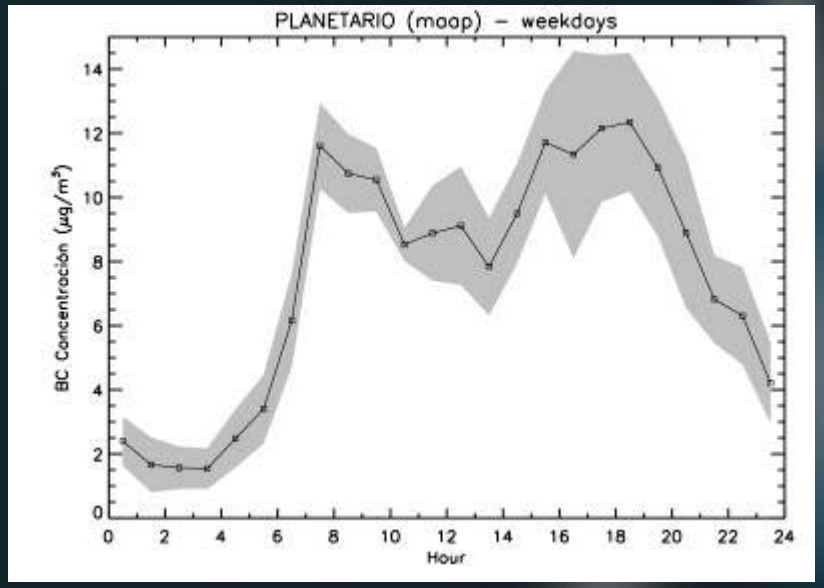
+
meteorology

Results









El Alto

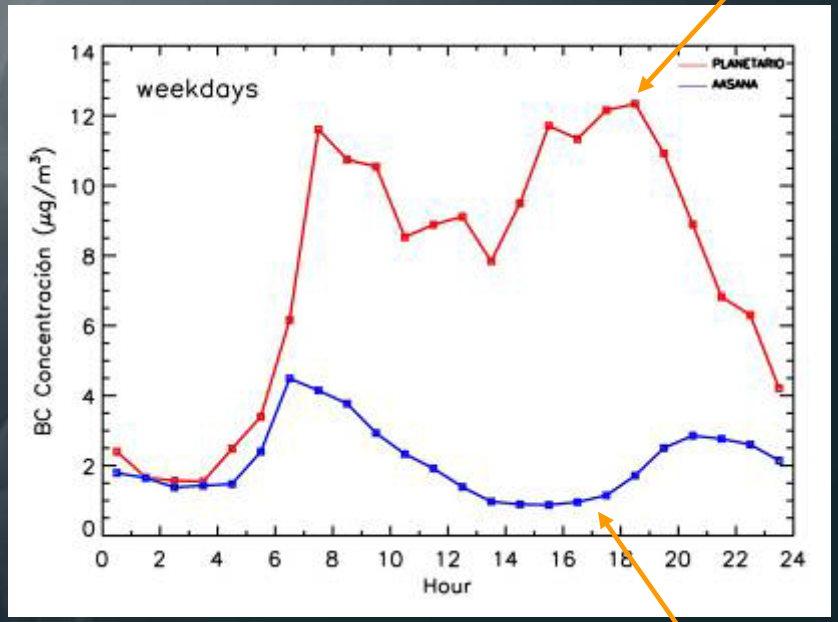
La Paz

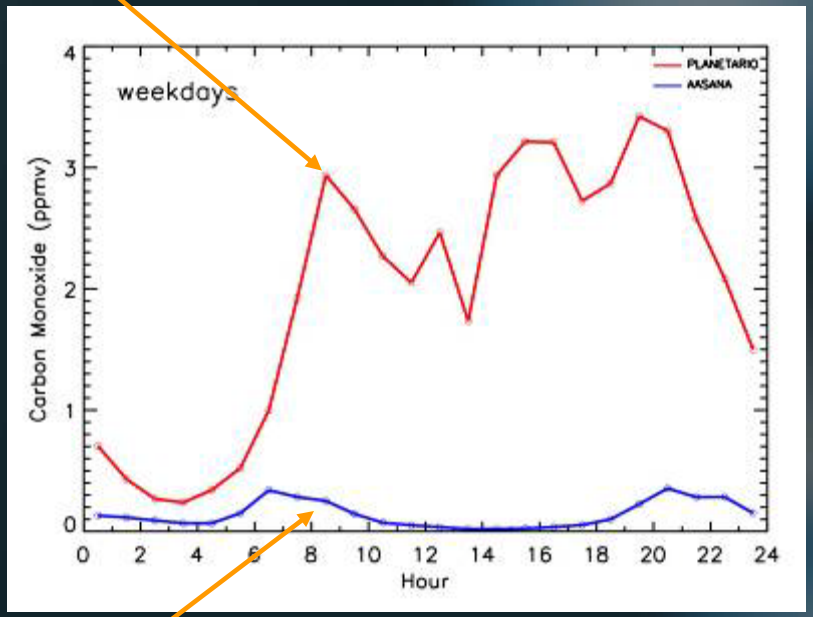
Comparison between locations

Black Carbon

Near source

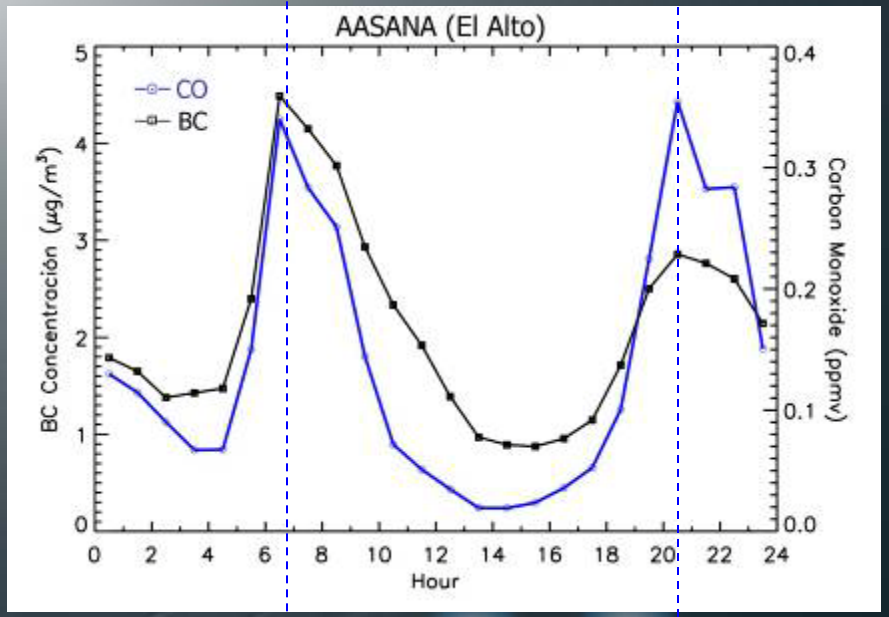
Carbon Monoxide

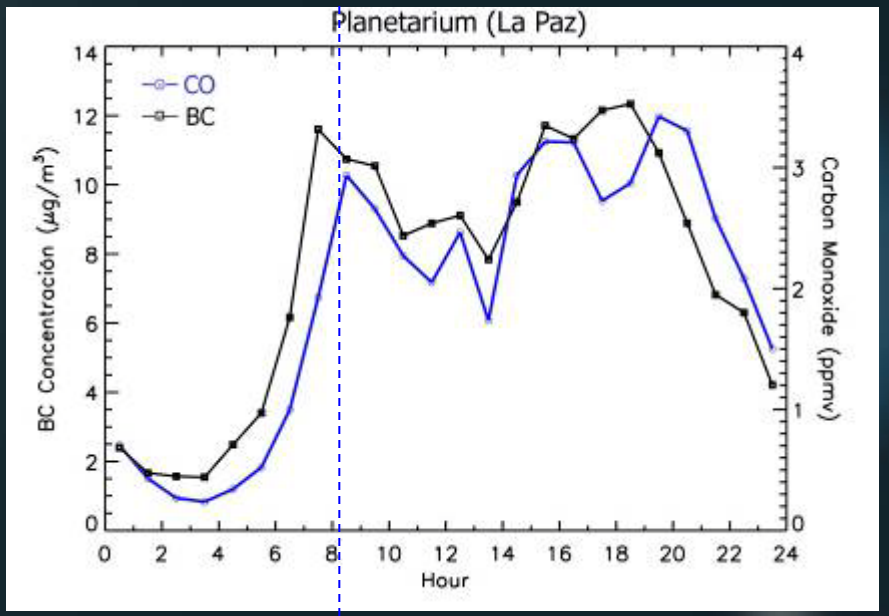


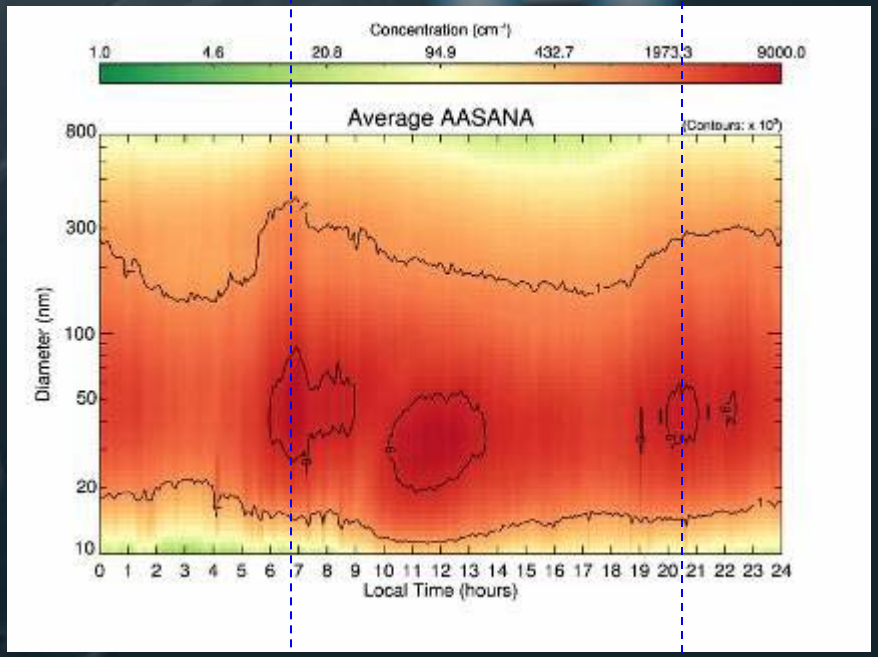


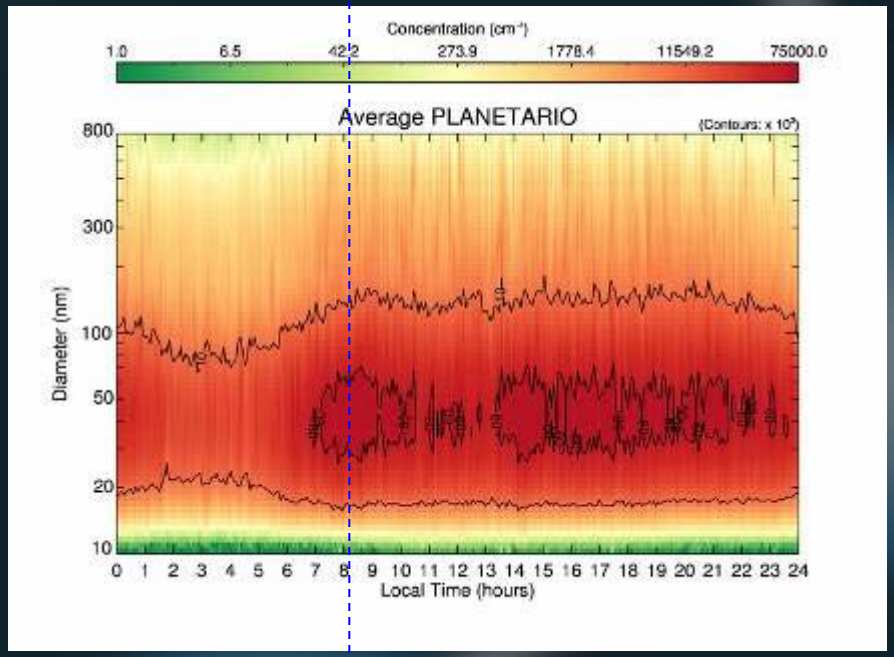
Urban Background

Mean Values

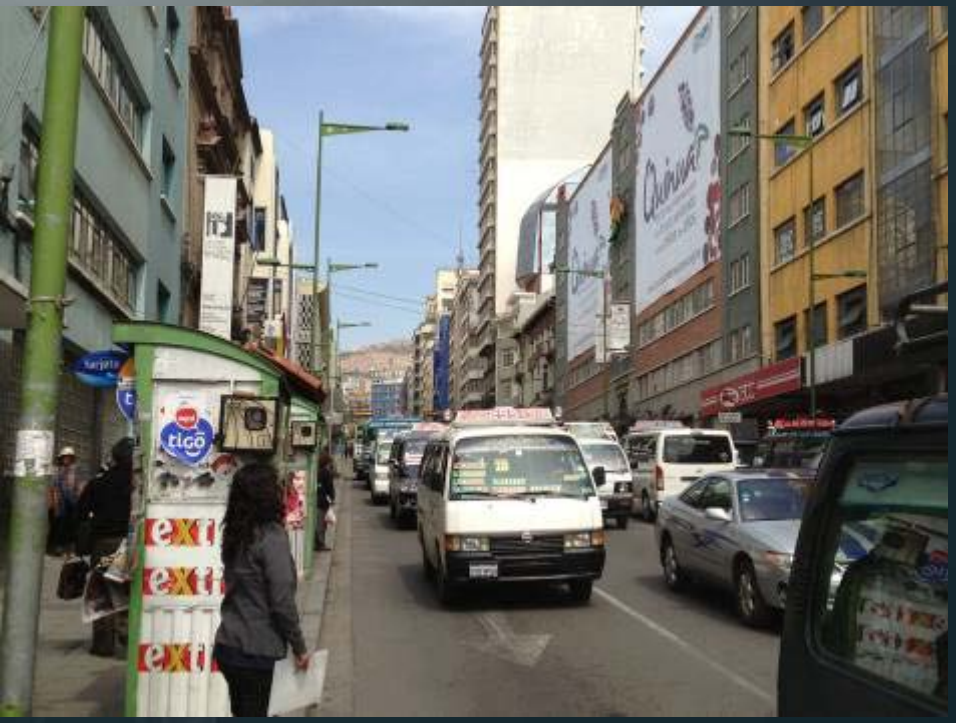

AASANA (El Alto)
CO
BC
BC Concentración (μg/m³)
Carbon Monoxide (ppmv)
Hour


Planetarium (La Paz)
CO
BC
BC Concentración (μg/m³)
Carbon Monoxide (ppmv)
Hour

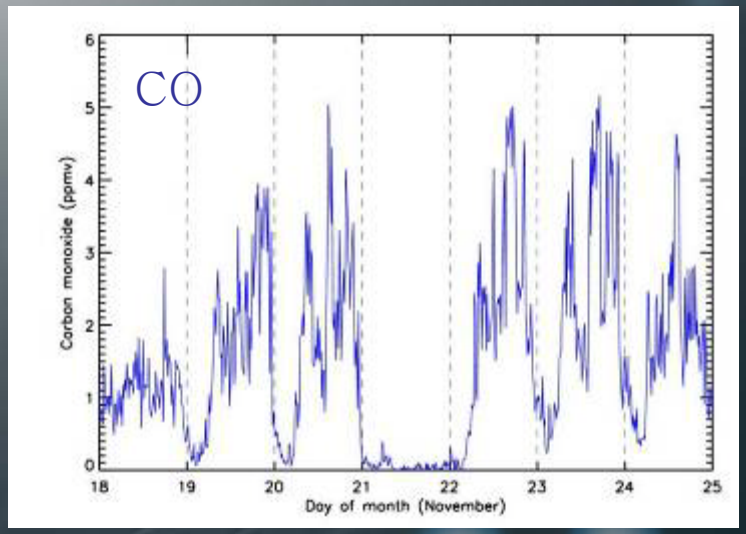

Concentration (cm⁻³)
1.0
4.6
20.8
94.9
432.7
1973.3
9000.0
Average AASANA
(Contours: x 10³)
Diameter (nm)
Local Time (hours)

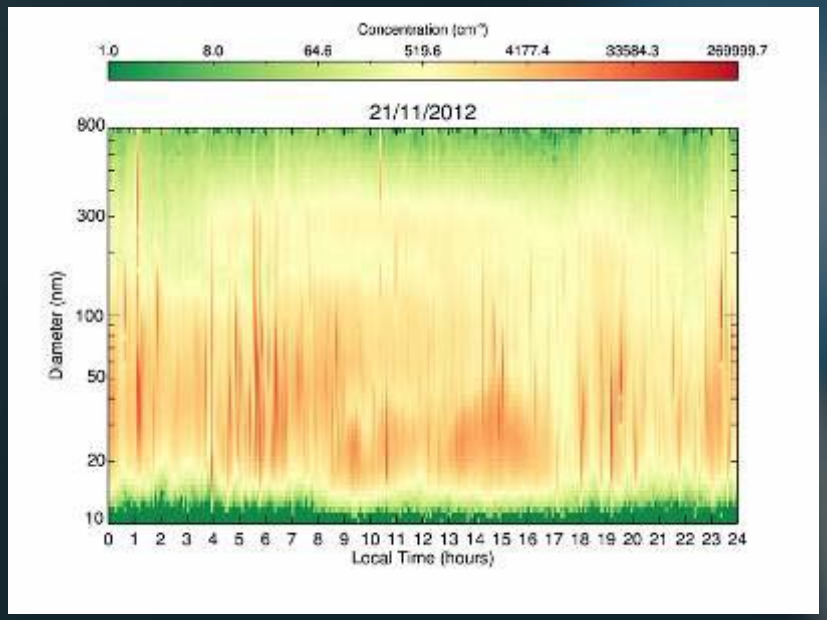

Concentration (cm⁻³)
1.0
6.5
42.2
273.9
1778.4
11549.2
75000.0
Average PLANETARIO
(Contours: x 10³)
Diameter (nm)
Local Time (hours)

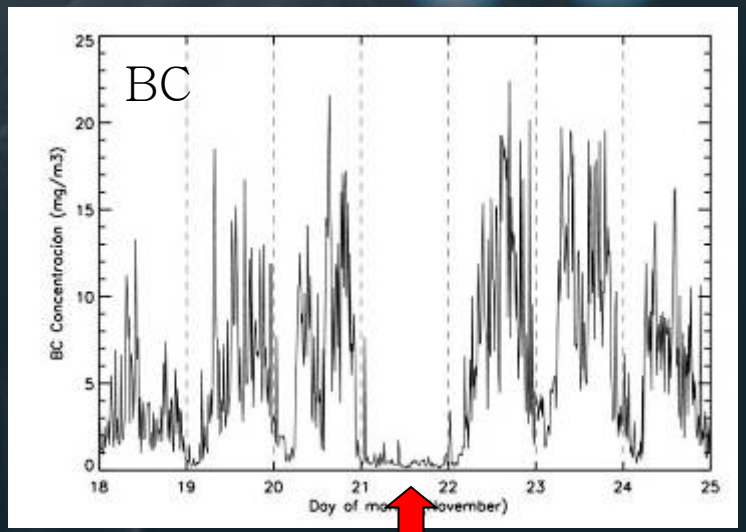
19 November 2012 – Census day!



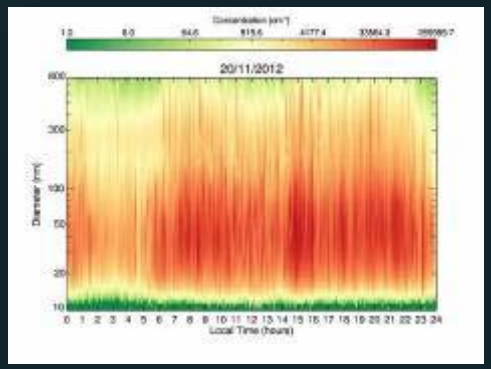
A case study: Census day (Nov 21, 2012)



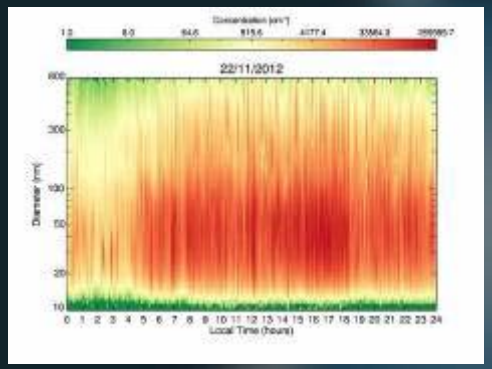




No-traffic



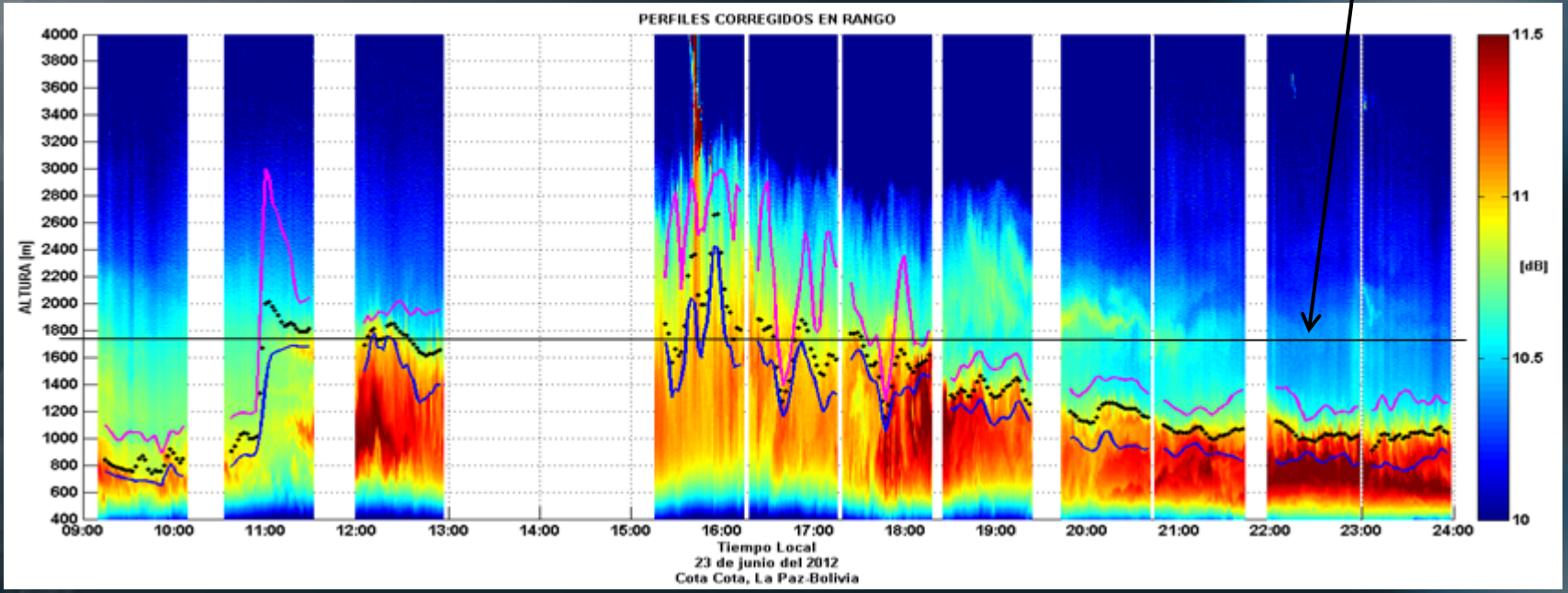
Previous day



Next day

Boundary Layer with the LIDAR system

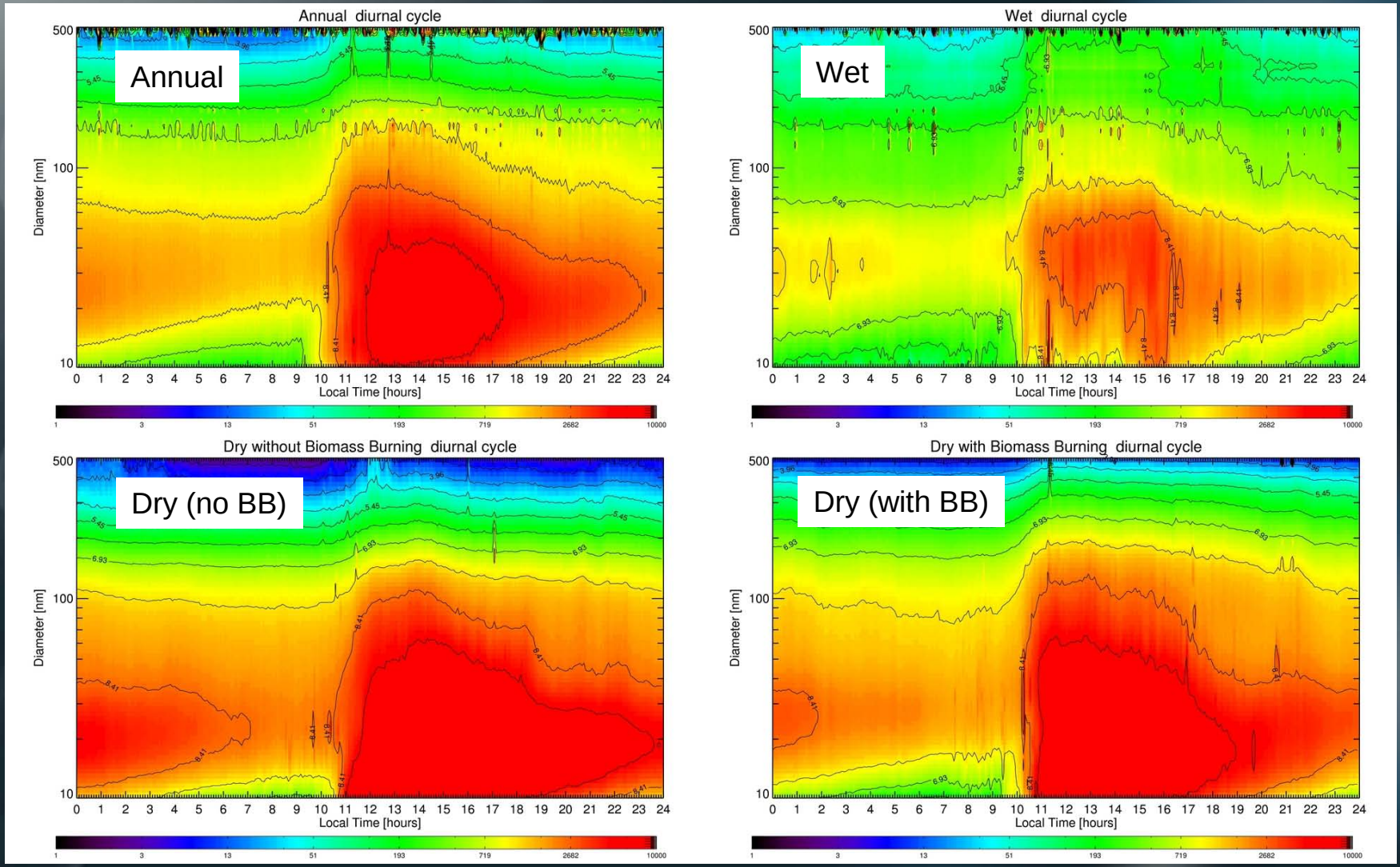
Chacaltaya GAW station elevation



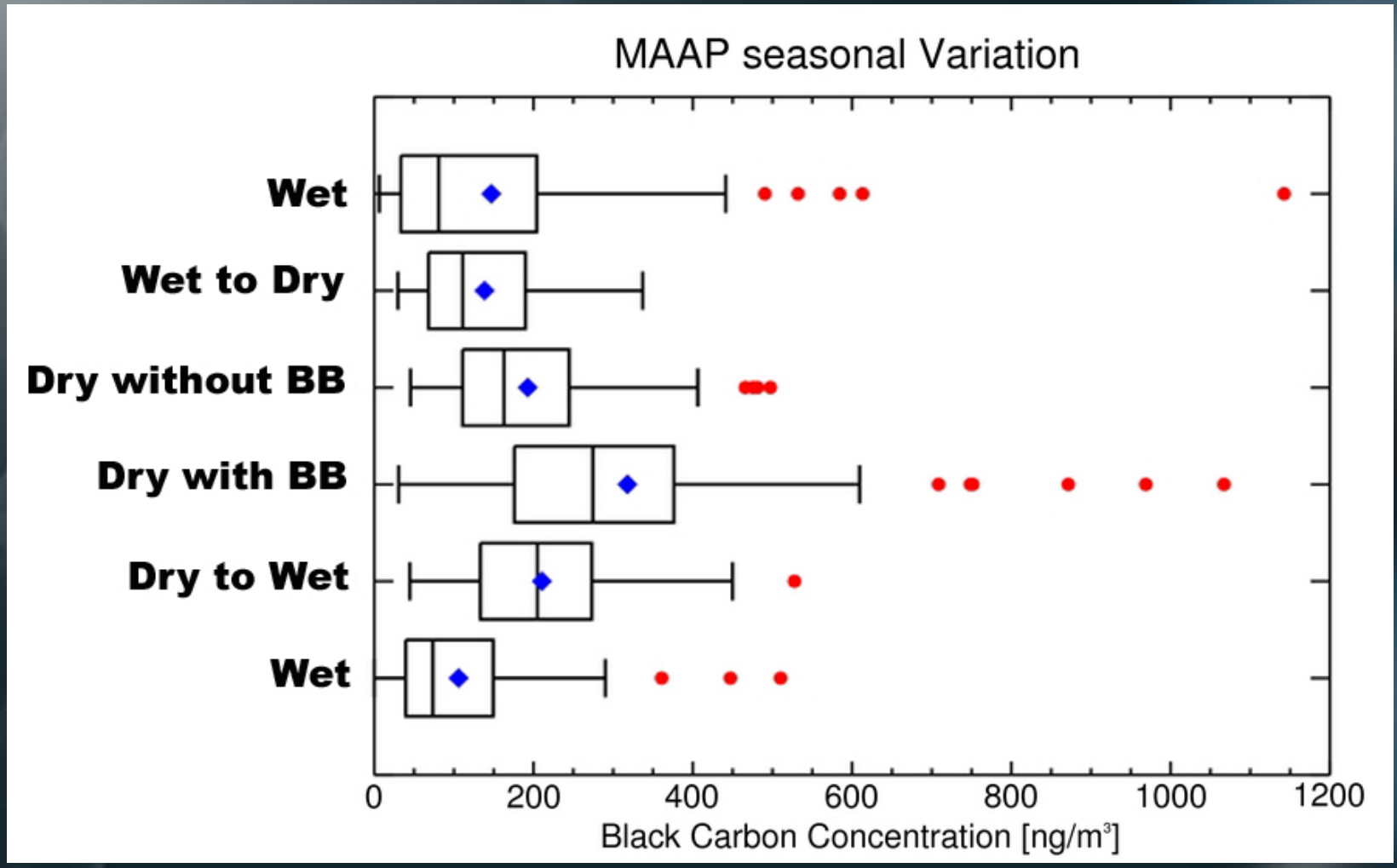
Data taken during June 23 of 2012, from 09:00 to 24:00.

LIPAZ - LIDAR

Biomass burning:
Data from SMPS



Biomass burning:
Data from MAAP



High-Resolution Dynamic Downscaling of CMIP5 Output Over Bolivia

Thomas Reichler[1] & Marcos Andrade[2]

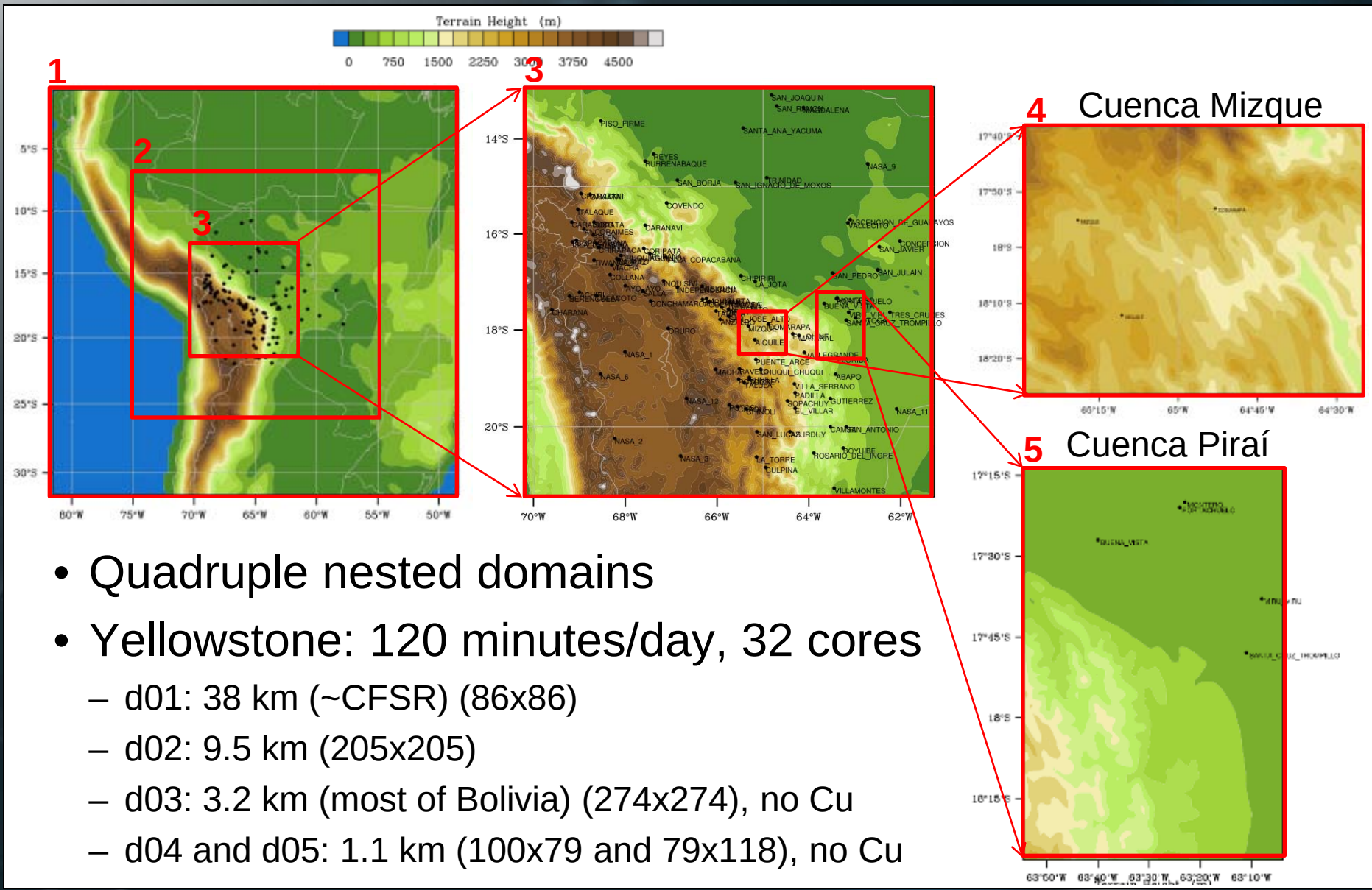
[1]Department of Atmospheric Sciences
University of Utah

[2]Laboratorio de Física de la Atmósfera
Instituto de Investigaciones Físicas
Universidad Mayor de San Andrés

Technical Implementation

- WRF-ARW V3.X; NOAH LSM
- Dynamical regional downscaling at **3** and **1** km
  - NCEP-CFSR (38 km)
    - 6 hourly
    - 20 years: 1991-2010
  - CMIP5 models
    - RCP8.5
    - 20 years: 2041-2060
    - 4 selected models
- 100 simulation years
- New NCAR's Yellowstone system

Resolution and Domains



- Quadruple nested domains
- Yellowstone: 120 minutes/day, 32 cores
  - d01: 38 km (~CFSR) (86x86)
  - d02: 9.5 km (205x205)
  - d03: 3.2 km (most of Bolivia) (274x274), no Cu
  - d04 and d05: 1.1 km (100x79 and 79x118), no Cu

Coupling Strategy

Initial and lateral Boundary Conditions for outer WRF domain:

- Present-day control simulation: 6-hourly CFSR
- Climate change simulation: 6-hourly CFSR, anomaly corrected with monthly mean CMIP5 (RCP8.5)

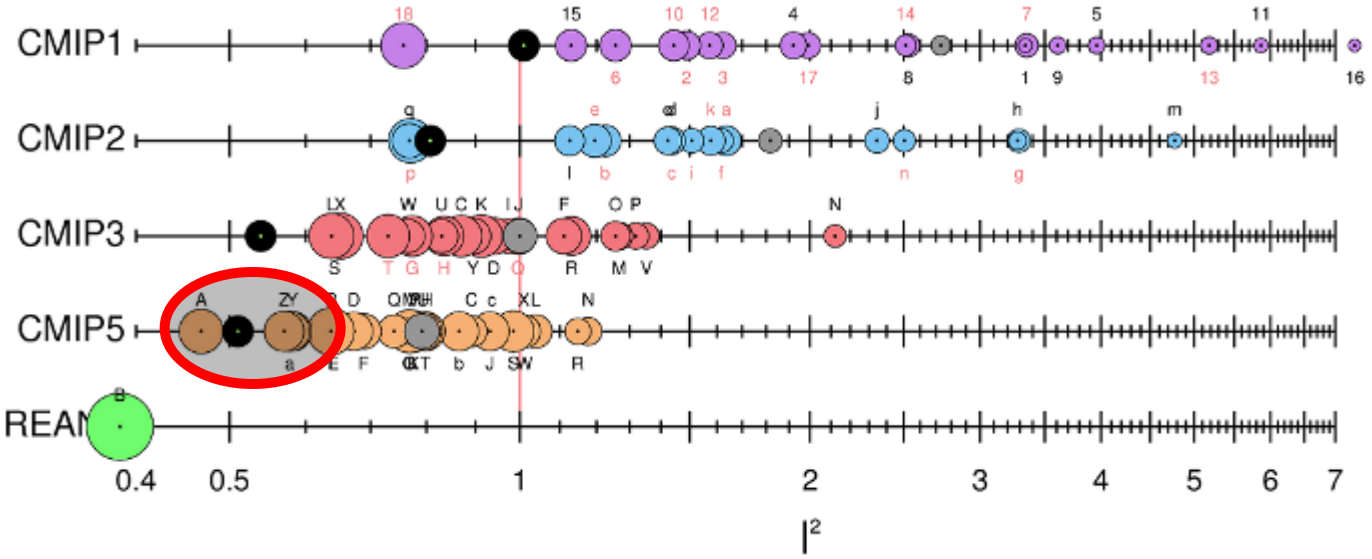
$$ICBC_i = CFSR + \overline{CC_i}$$

$\overline{CC_i}$: mean climate change signal from model i
$CFSR$: 6-hourly CFSR reanalysis, present climate

- Primary impact is on large-scale planetary waves and thermodynamics
- Weather patterns entering domain boundary are structurally identical in control and climate change simulation
- Rasmussen et al. (2011), Schär et al. (1996), Kawase et al. (2009), and Hara et al. (2008)

Selection of Climate Models

- We use four climate models. Which ones?
- Model performance test for mean climate; globally and over South America (Reichler and Kim, 2008):



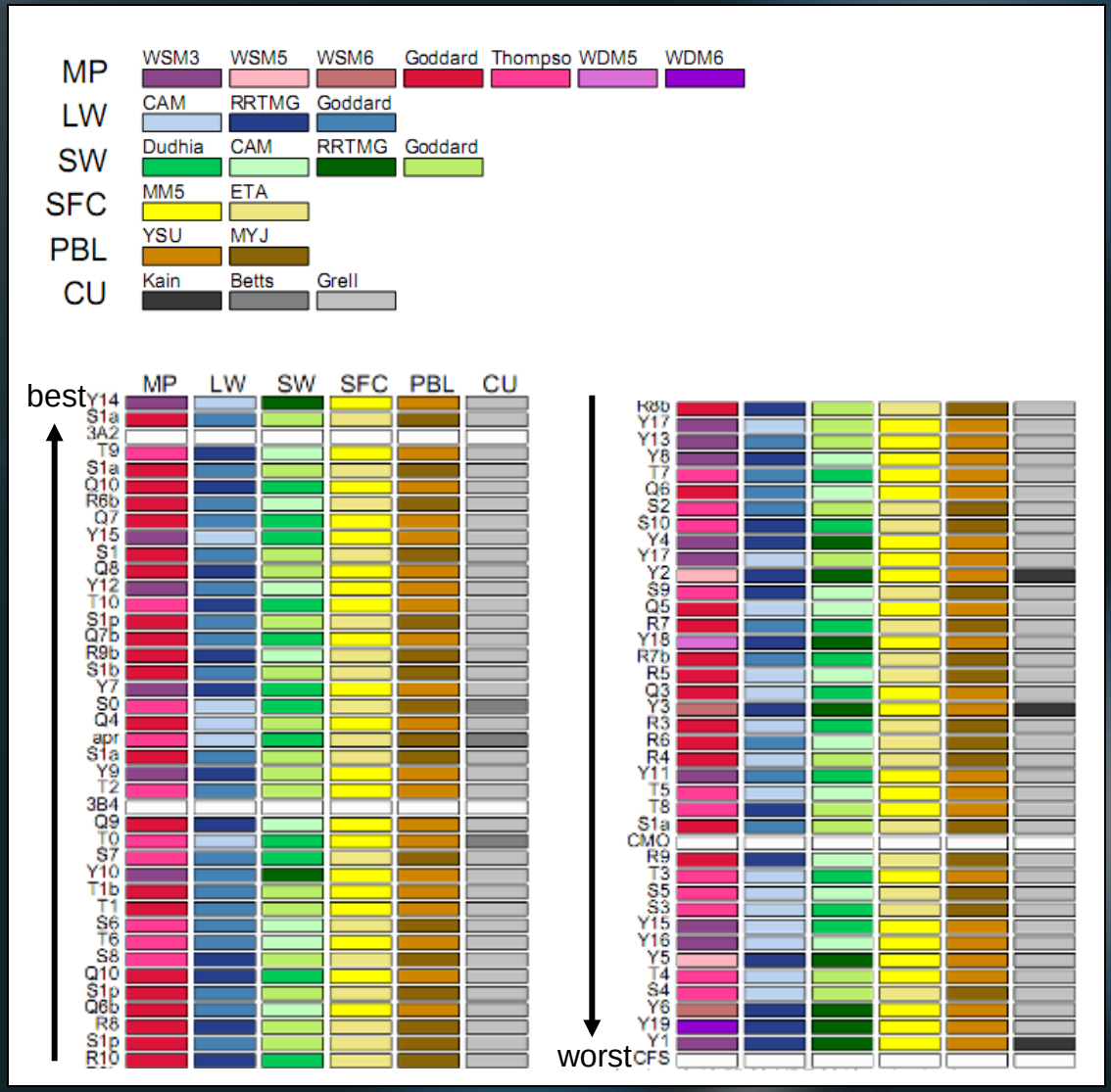
- Selected models:
  - CSIRO-ACESS1-0, MPI-ESM-MR, GFDL-CM3, NCAR CCSM4

WRF is Not Just One Model!

- WRF contains different physics and dynamics parameterizations
  - microphysics
  - longwave radiation
  - shortwave radiation
  - surface layer physics
  - land surface physics
  - planetary boundary layer
  - cumulus clouds
  - shallow convection
  - diffusion and damping
  - etc.
- Large number of different model configuration
- Finding the best configuration is difficult and unphysical, but it allows optimizing WRF to the specific domain

Sensitivity Experiments

- 75 experiments
- January 2003
- Mostly physics: MP, LW, SW, SFC, PBL, CU
- Also: spectral nudging and perturbed initial conditions

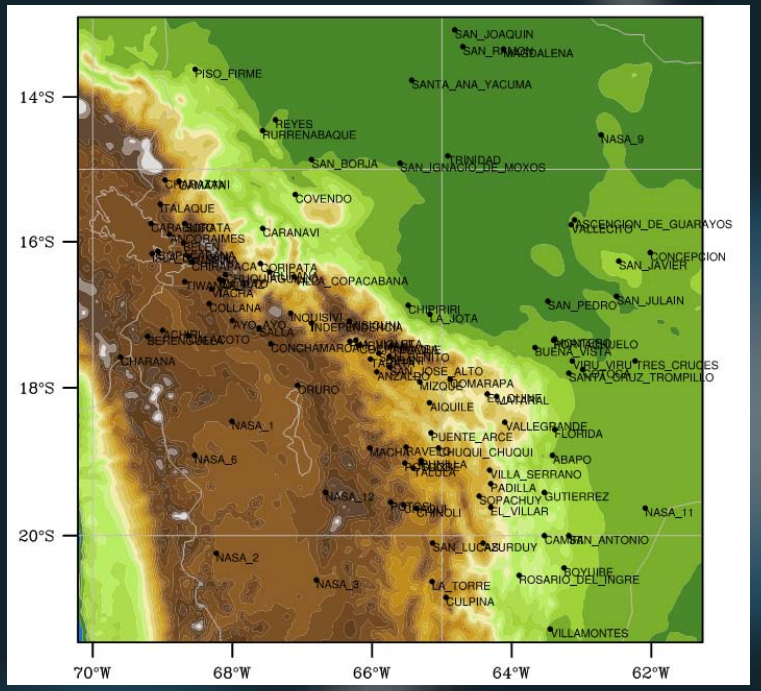


Validation Data

- Precipitation only:
  - January 2003

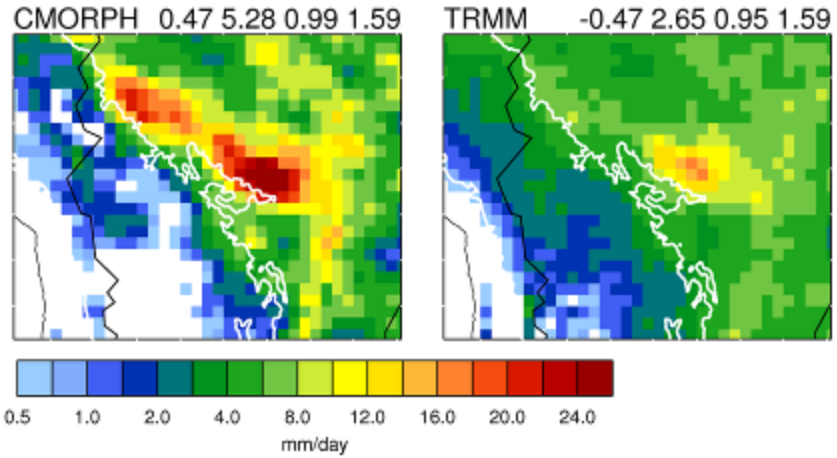
1. Gridded satellite-data
   - CMORPH
   - TRMM: 2A25, 3B42, 3B43

2. In-situ station data from Bolivian National Weather Service



Monthly Mean Precipitation

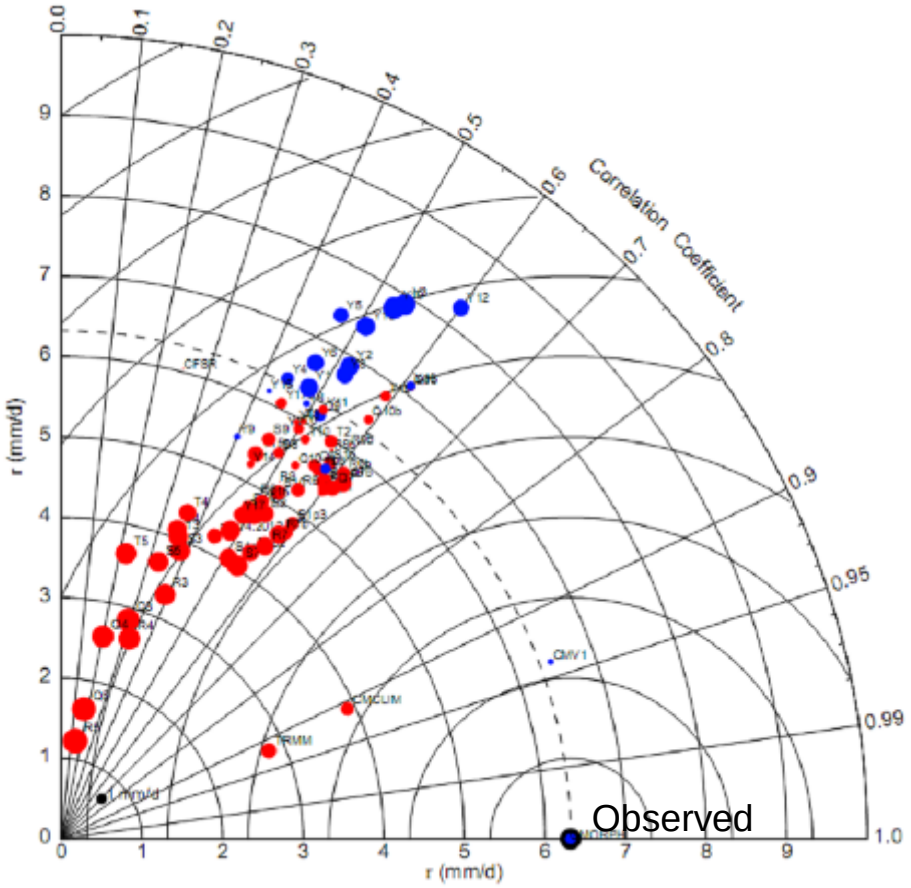
January 2003



1. bias
2. stddev
3. corr
4. crms

Monthly Mean Precipitation

- Jan 2003, domain 3



modified from: Taylor 2001

Combined Ranks

- Rank models according to simulation performance for Jan monthly mean precip.
  - 3 statistics: mean bias, spatial correlation, and center RMS error
  - all three model domains

CMORP 237	CMV1 224	CMCLI 200	TRMM 198	S1p3 191	S1 191	S1p1 187	Q7 183	R6 175	T1 173	S1p2 169	Q6 168	R7 164	Q10 163	Y17 162
R6b 160	S1a 160	R9 158	S1ap3 157	R8 157	Y15 156	S1b 154	Y11 152	R9b 151	Y10 149	T2 147	Q6b 146	Y13 145	Q10b 143	Q8 143
R10 142	T1b 140	Q7b 140	Y7 139	R8b 139	R7b 135	S1ap1 135	Y14 134	S2 129	T10 128	T8 128	T9 127	S8 123	Q9 119	Y9 118
Y16 117	S10 115	T7 112	T6 109	S7 108	Y17b 108	Y12 104	S9 102	Y15b 95	S6 93	T0 91	S1ap2 81	Y4 80	Y8 78	CFSR 75
Y5 73	T4 73	apr14 69	Y6 69	S4 63	R3 62	Y2 58	T3 58	S3 58	Y18 57	Y1 53	Y3 53	Y19 51	S5 45	R4 38
Q3 32	Q4 21	T5 19	Q5 16	R5 13										

Cumulative rank range: max 237 (= 79*3*1)

Current Project Status

- We just finished the 20 year simulations for present-day climate, using CFSR reanalysis as boundary conditions
- Next: 4 climate model simulations
- Projected to be finished by the end of this year

Summary

- The LFA is currently working in three key issues in the region:
  - Transport of particulate matter
  - Climate Modeling
  - Data homogenization (not mentioned on this talk)
- In the long term, the LFA expects to maintain a regional station measuring both gases and aerosols
- With this goal in mind we are training young people