Four-corners Aerosol Cloud Climate Experiment and Test-bed for Scaling (FACETS) for ARM '13

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Outline

- Team
- Motivation
- Why Four Corners?
  - High signal with good contrast (space time)
  - Anthropogenic + Biogenic + Dust
  - Orographic flows: Clouds susceptible to aerosols
- Platforms, Sites, Infrastructure
- Science Questions (input)
  - Hone and map onto ASR priorities ('11)

Four Corners: IPCC-AR4 models fail to reproduce observed precipitation variations while capturing temperature changes

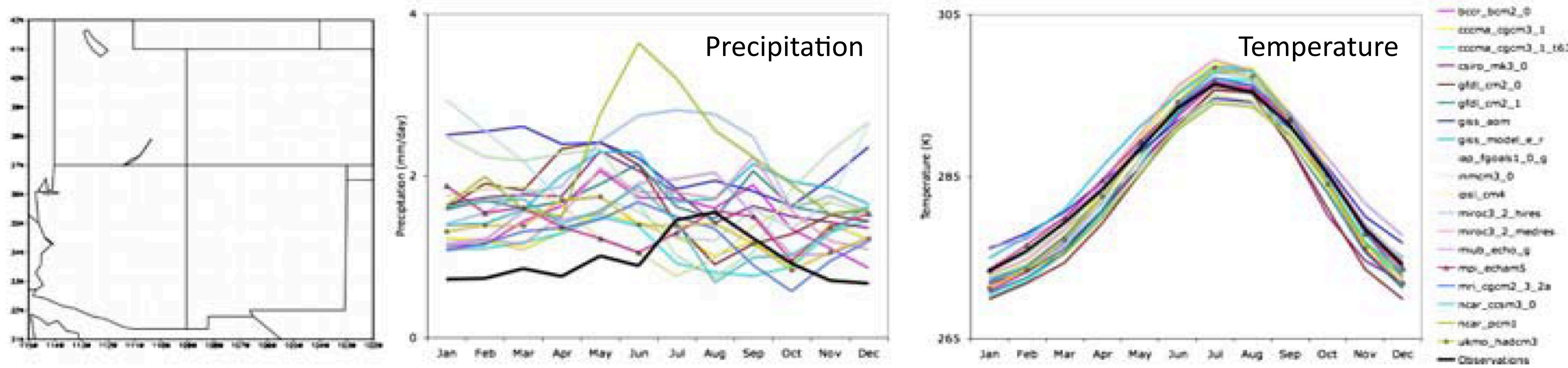


Fig. 1 (*Left*) Map of the Four Corners region, (*Middle*) Average Monthly Precipitation and (*Right*) Temperature from 1901–1999 from all the IPCC-AR4 models (*colors*) and observations (*black*) over the Southwestern US

Dominguez et al Climatic Change 2010

- Reasons include limitations in model parameterizations of:
  - Flows over complex terrain (Global (Walko), Regional (WRF-Test))
  - Aerosol sources, transformation and interactions (anthro, bio, dust)
  - Aerosol effects on clouds (warm/cold) & precipitation (rain/snow).
- Focus on a high aerosol region with distinct chemical regimes and good contrast that interact with orographic clouds that are particularly susceptible to aerosol.

Four-corners Aerosol Chemistry, Cloud and Climate Experiment and Testbed for Scaling (FACETS)

M. Dubey (LANL) Bill Cotton (CSU)

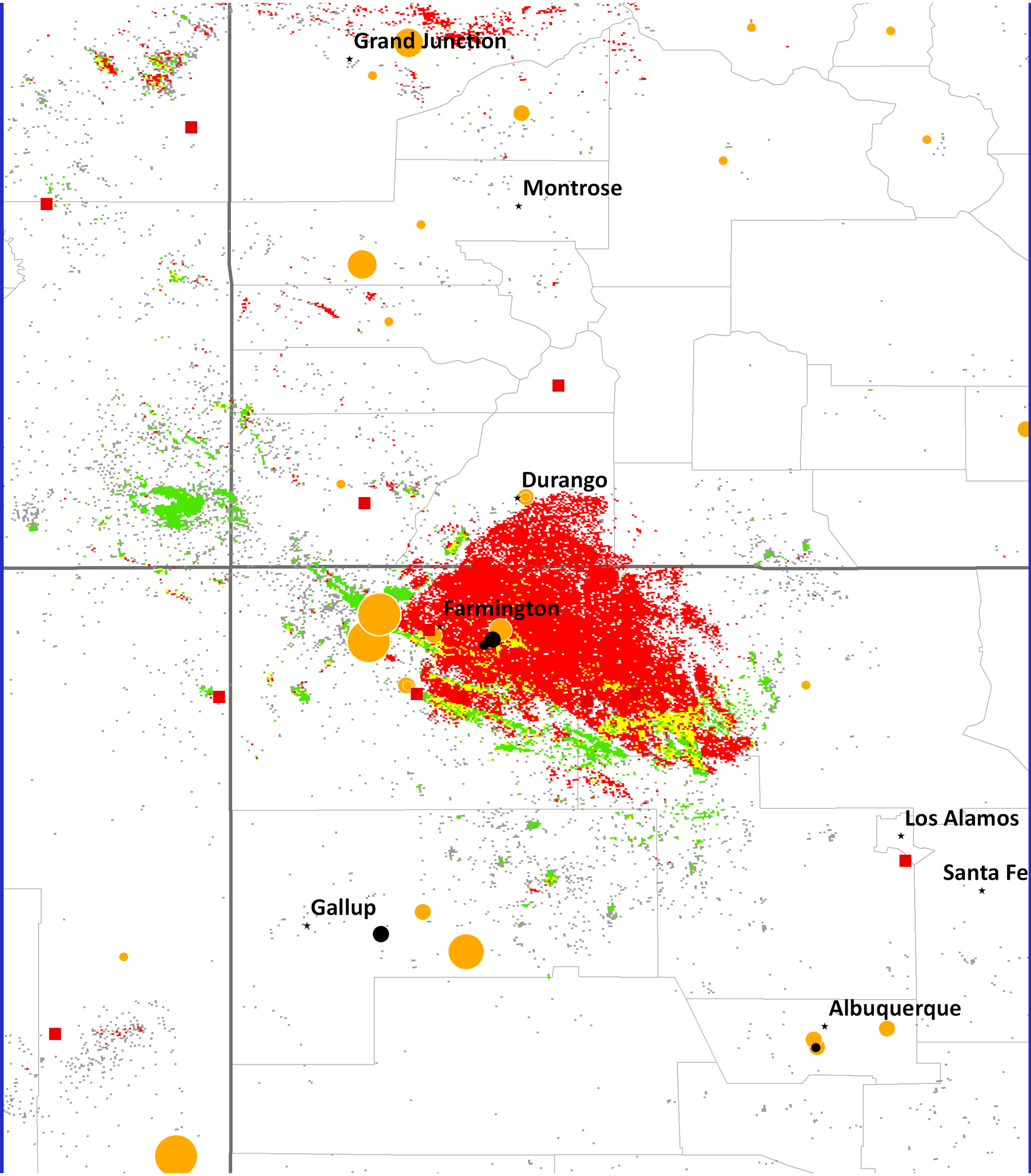
- Aerosol Chem/Optical Processes: Alla Zellenyuk, John Schilling, Dan Cziczo, Stephen Springston, Yin-Nan Lee, Steve Schwartz, Qi Zhang, Chris Cappa, Jose Jimenez, Rainer Volkhammer, Tim Onasch, John Jayne, Scott Herndon, Leah Williams, Mary Gilles, Jim Smith, Claudio Mazzoleni
- Aerosol-Cloud Microphysics: Thanos Nenes, Jian Wang, Marcus Petters, Don Collins, Sarah Brooks, David Noone
- CAPI-AMF2:
- Remote sensing: Petr Chylek, Brad Henderson, Steve Love, Connor Flynn, Rich Ferrare, Ralph Kahn
- Modeling: Bill Cotton, Bob Walko, Thanos Nenes, Rahul Zaveri, Jerome Fast, Eli Mlwaer, Keeley Costigan, Jon Reisner
- Carbon Cycle/Aerosol Precursors/Isotopes: Hope Michelsen, Mark Fisher, Ray Bambha, Tom Guilderson

Anthropogenic Sources (Local)

NOx (Power, Trans)

SOx (Power)

Organics (Trans, Gas Wells?, Fires)



Aerosol (anthro, bio, dust) transformation and microphysical interactions with clouds in well defined source regimes and orographic flows

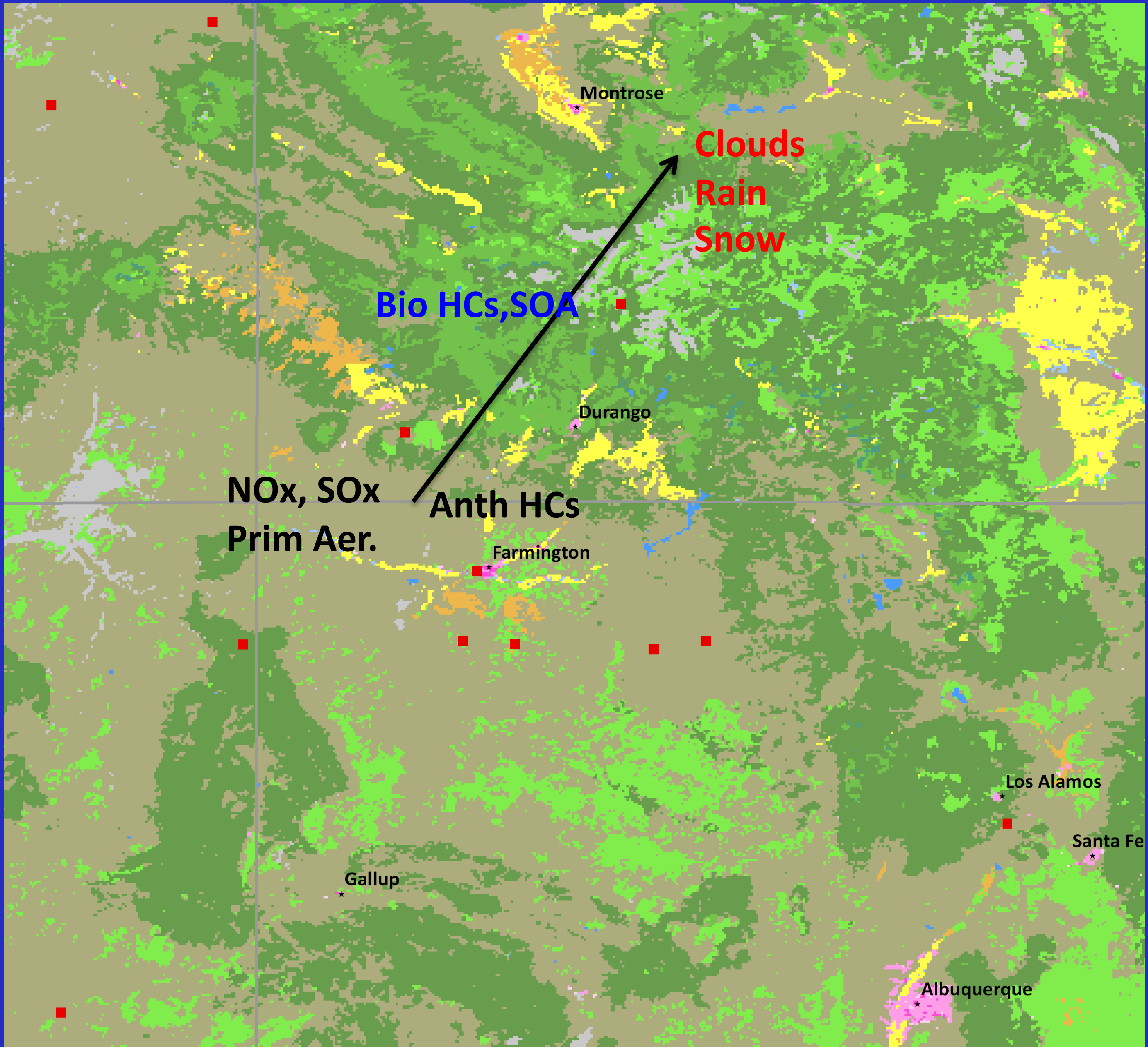
Multiscale

In situ
AAF-G1

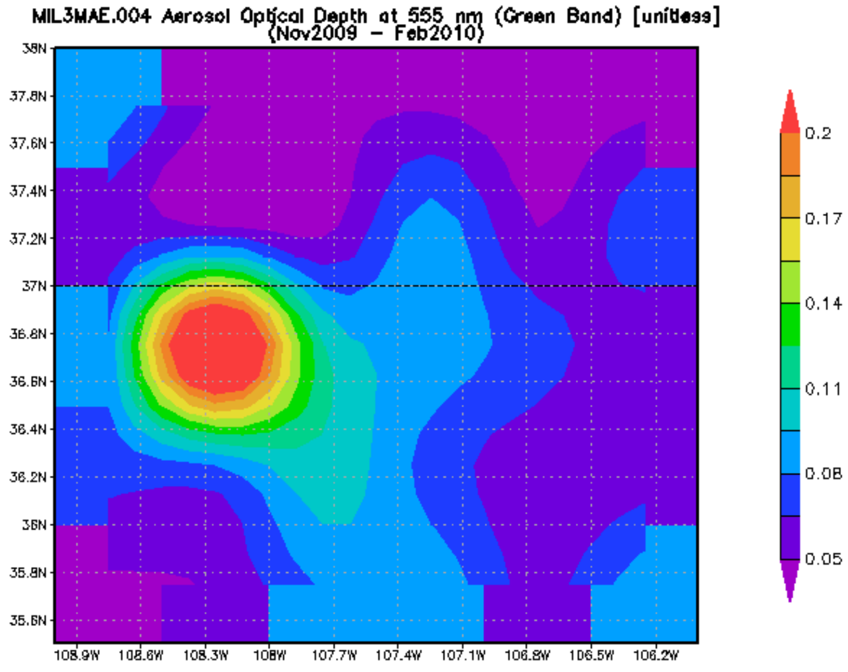
FTS
AMF2
MAOS (?)
T0-T1-T2
MAX-DOAS

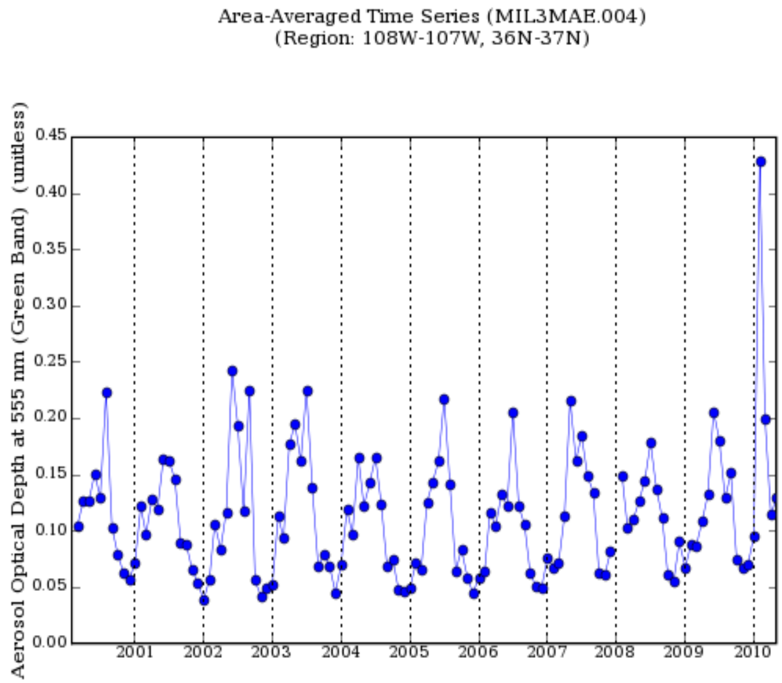
Satellite

Synergy
DOE led
NMED
IMPROVE
NADP
NASA



Aerosol Optical Depths MODIS over FC

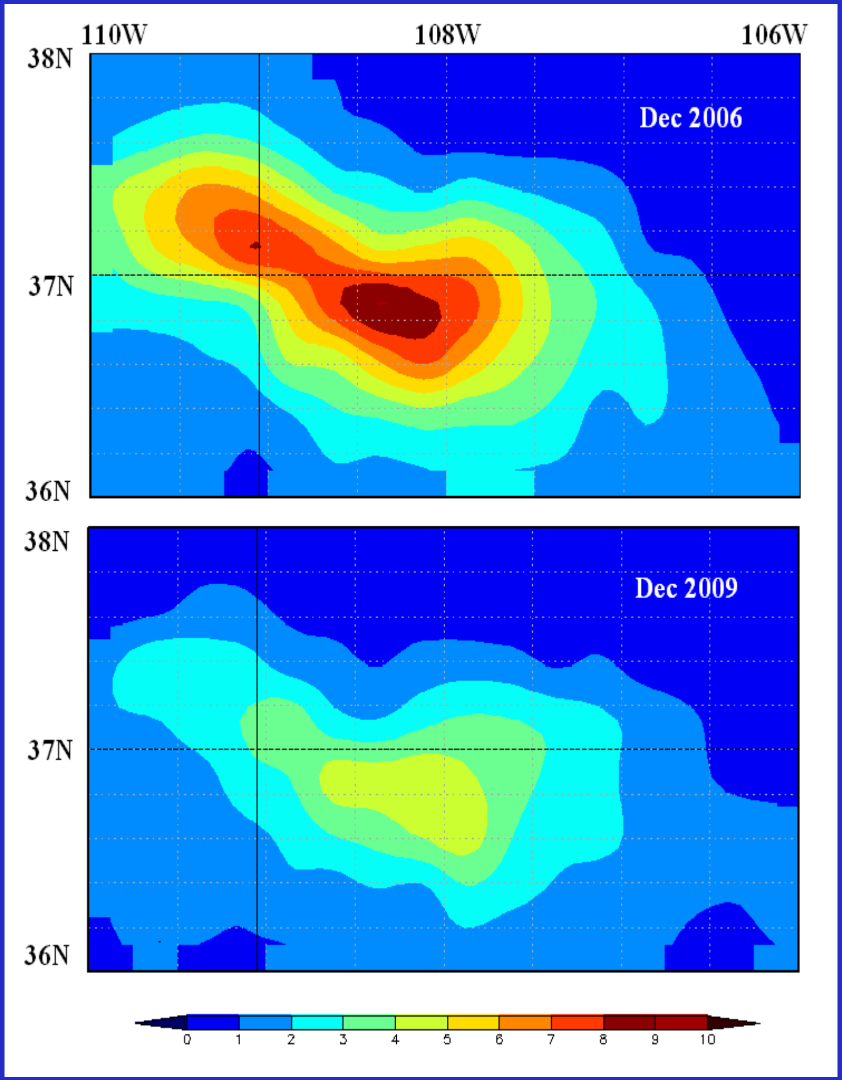




High signal and large spatial and temporal gradients that can be harnessed to sample a wide dynamical aerosol regimes that will be utilized to gain mechanistic insight into aerosol life cycle

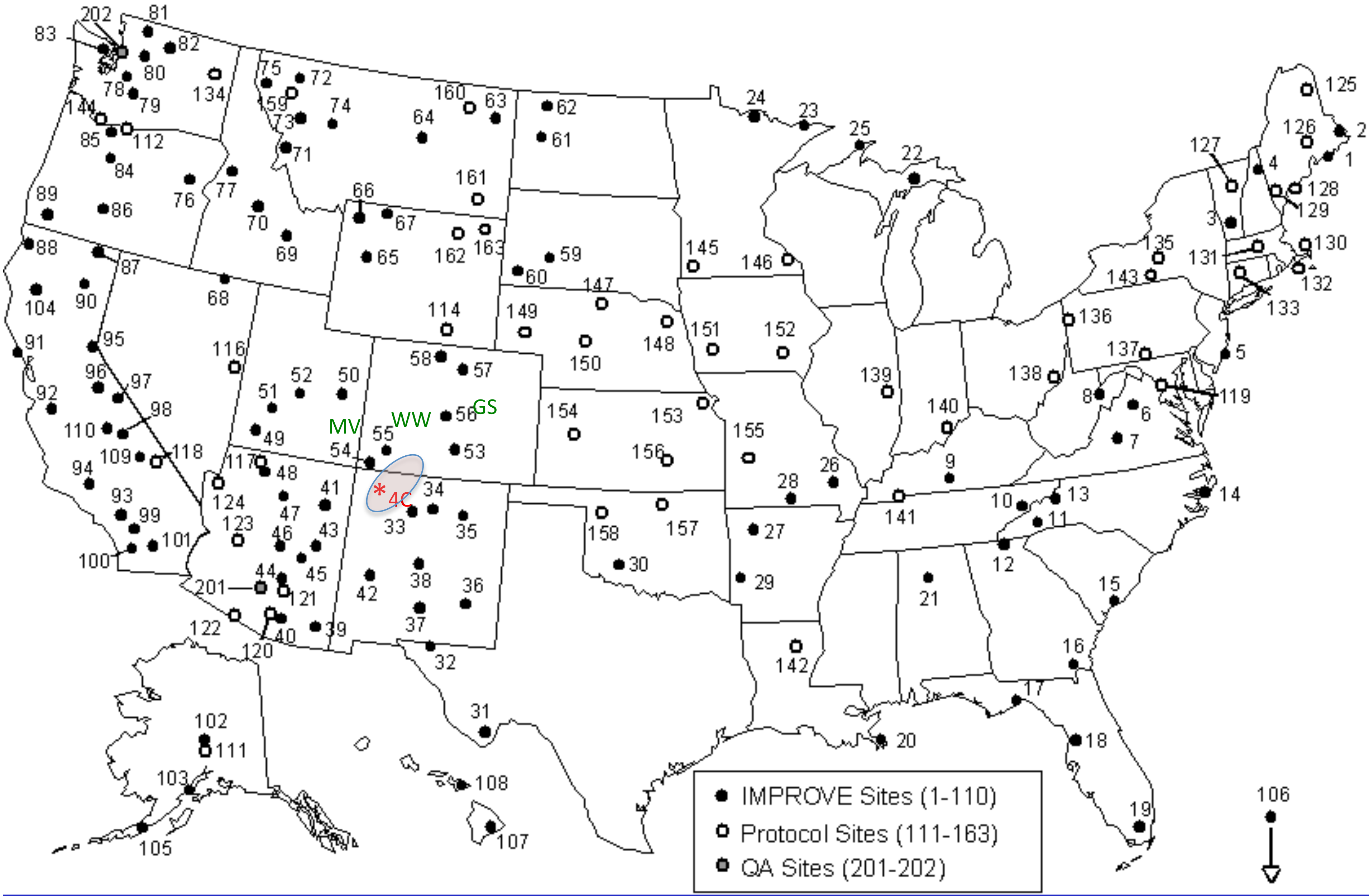
Large NO_2 plume over Four Corners from OMI

Regulations are reducing NOx n a regional scale , we have an opportunity to sample their effects on aerosol-cloud-precipitation and climate



Dubey and Chylek
In prepn. 2011

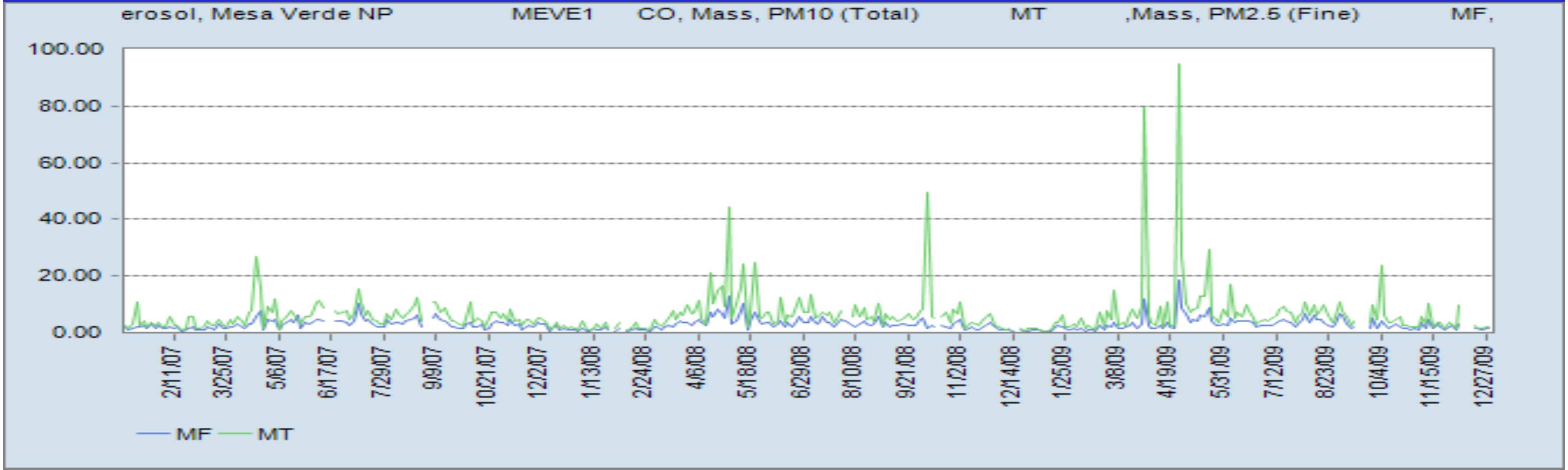
4C region IMPROVE-sites at edge of, not in 4C PP plume

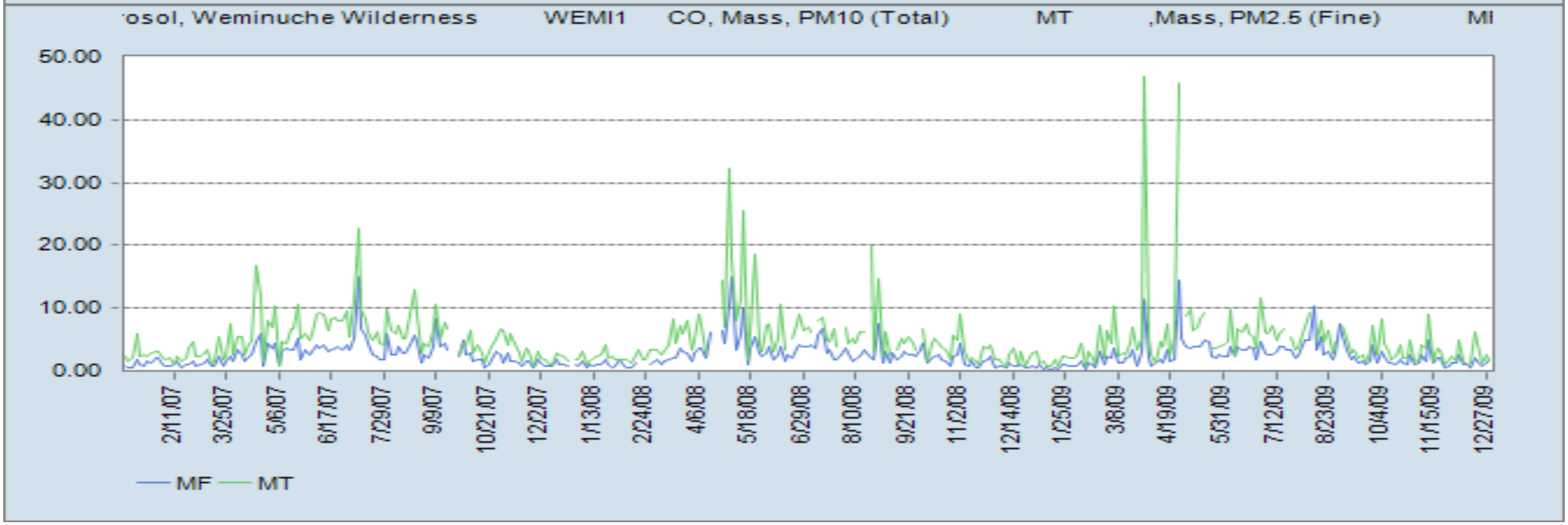


Aerosols Composition IMPROVE-Sites in 4C Area (2007-2009)

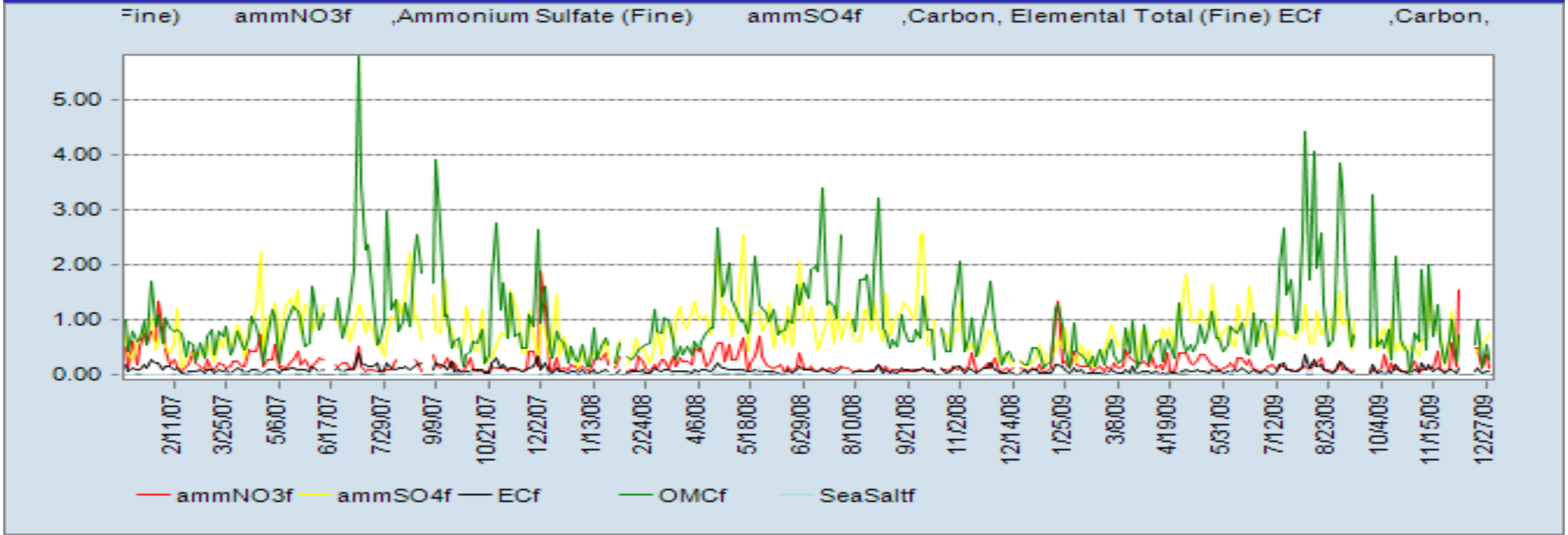
(3-day/week filter sampling, Relatively Clean, Upwind of FCPP, lower signal)

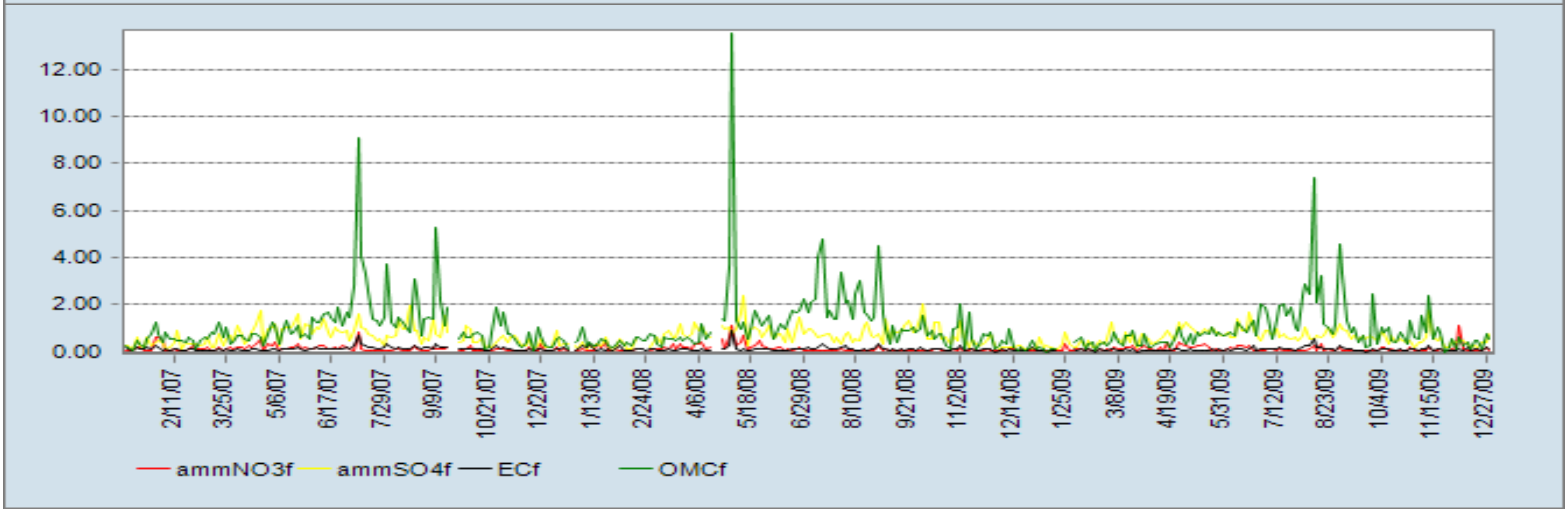
Provides Regional Background at edge of the PP perturbed region



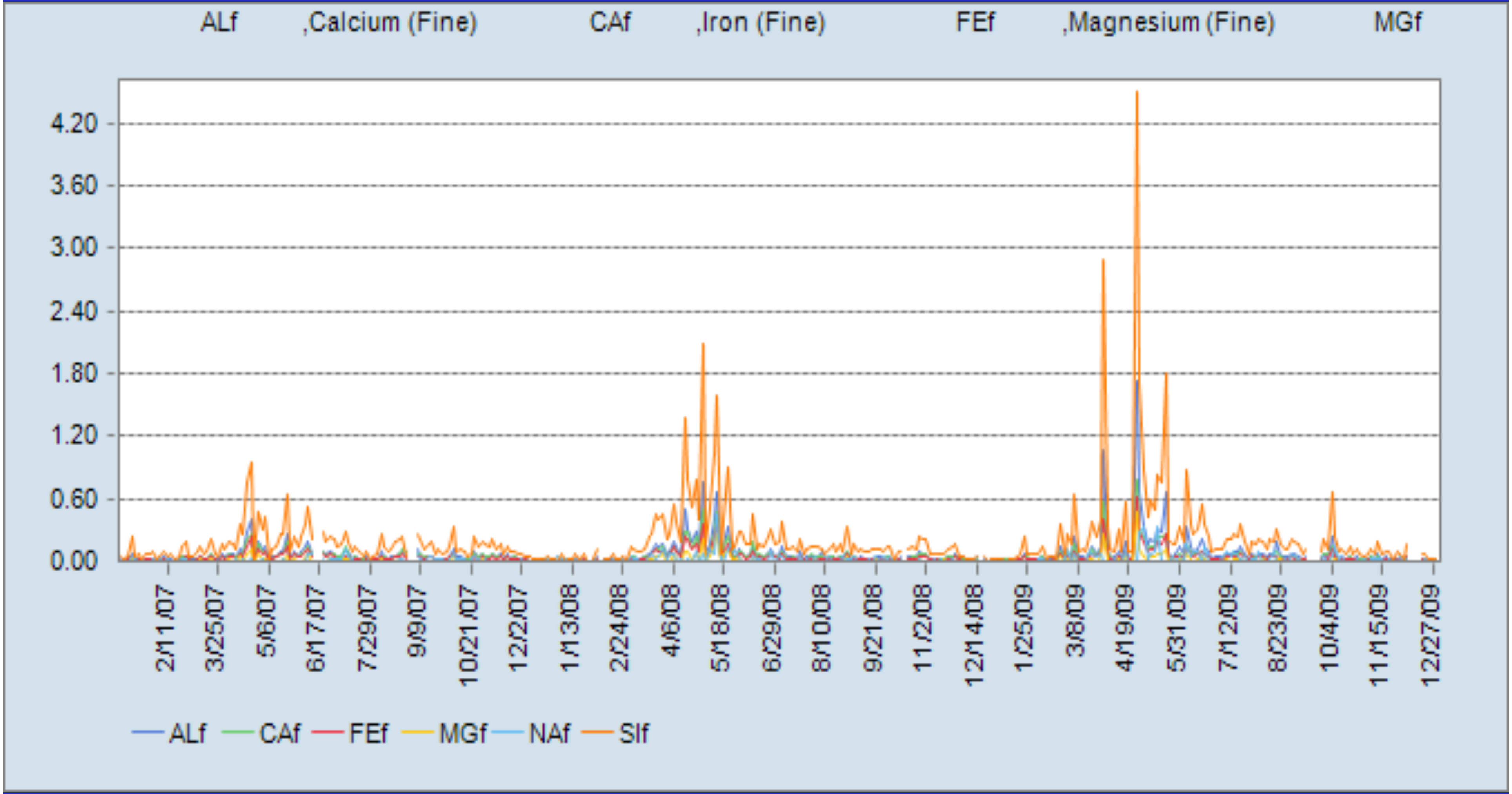


Region Bkg. Aerosol Comp (Fine, µg/m³): OC=AmS>AmN>EC

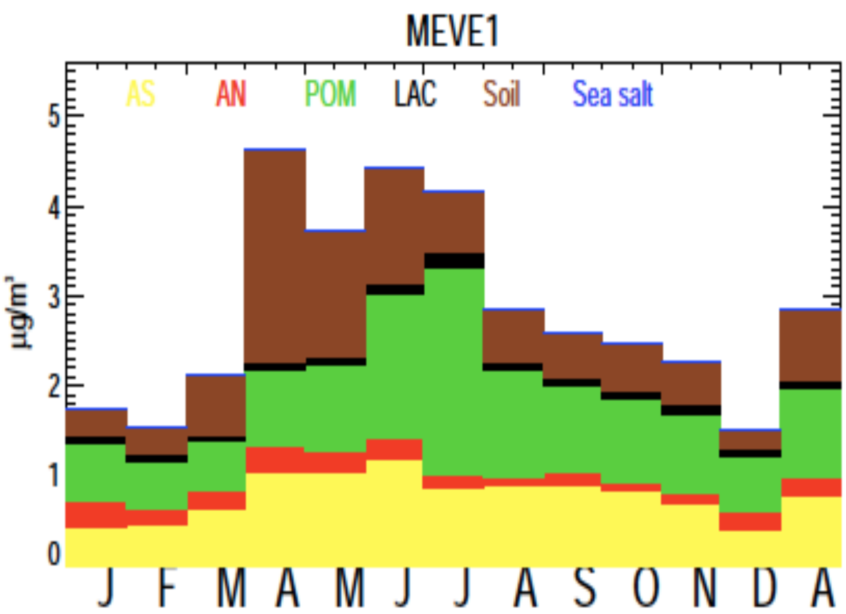


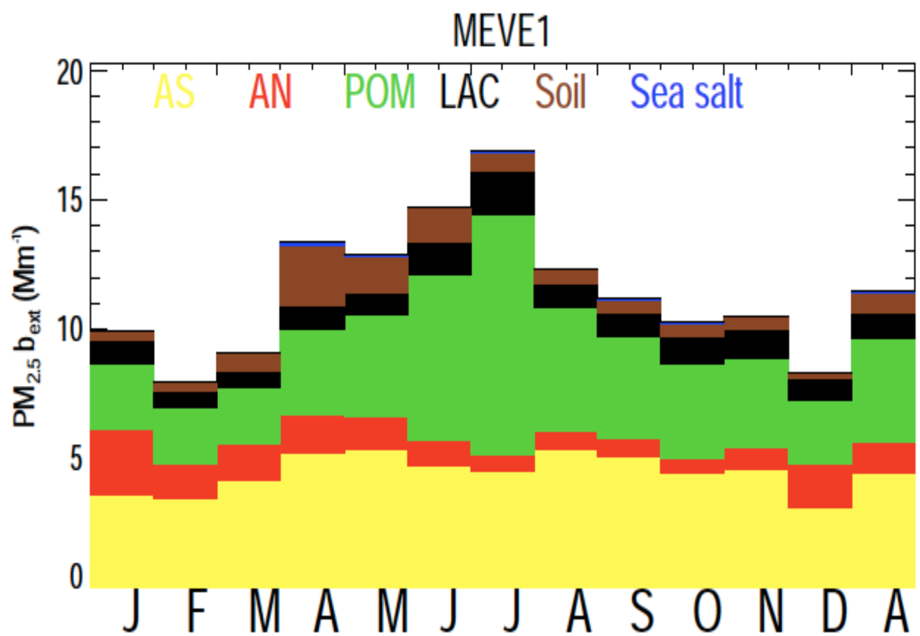


Region Element/Dust (f): (Si>Al, Ca, Mg, Fe, Na)

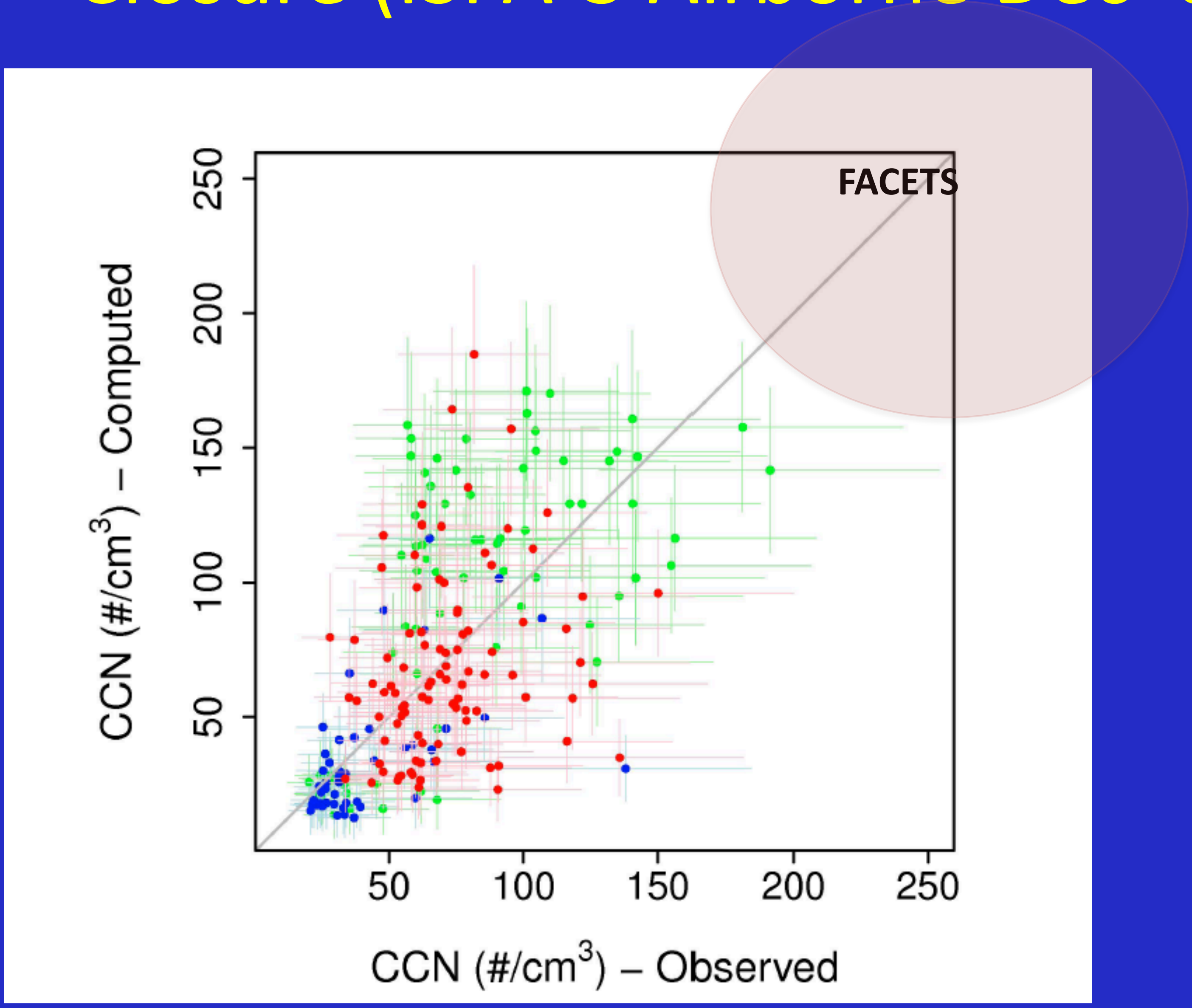


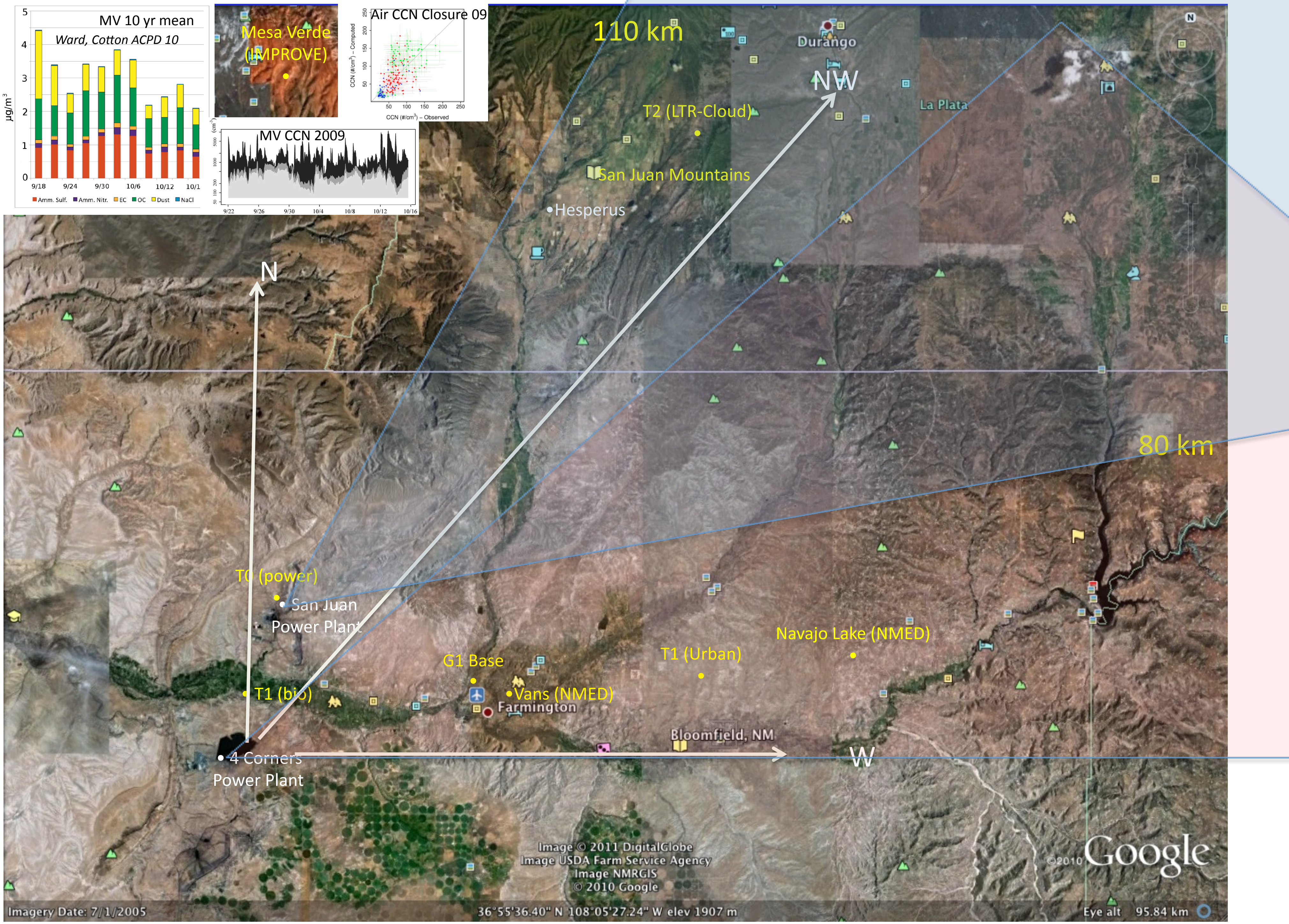
Monthly Mean Aerosol Composition ('05-'08)





CCN – Closure (ISPA-3 Airborne Dec '09)





MV 10 yr mean
Ward, Cotton ACPD 10
μg/m³
Amm. Sulf.
Amm. Nitr.
EC
OC
Dust
NaCl
Mesa Verde (IMPROVE)
Air CCN Closure 09
MV CCN 2009
110 km
Durango
NW
La Plata
T2 (LTR-Cloud)
San Juan Mountains
Hesperus
N
80 km
T0 (power)
San Juan Power Plant
Navajo Lake (NMED)
T1 (Urban)
G1 Base
T1 (bio)
Vans (NMED)
Farmington
Bloomfield, NM
4 Corners Power Plant
W
Image © 2011 DigitalGlobe
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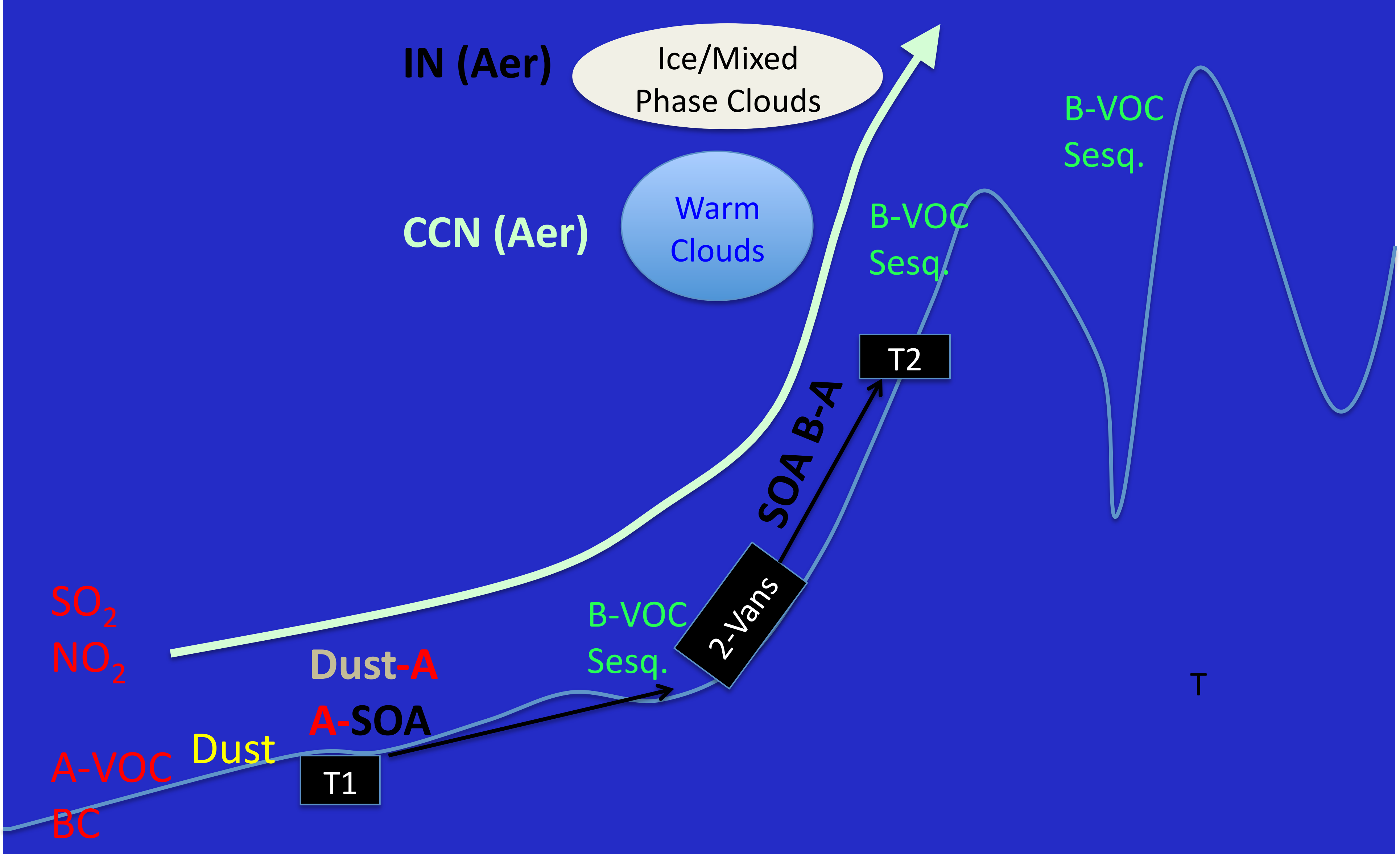
Image NMRGIS
© 2010 Google
©2010 Google
Imagery Date: 7/1/2005
36°55'36.40" N 108°05'27.24" W elev 1907 m
Eye alt 95.84 km

Vertical Section: Probe Aerosol Life Cycle & Interaction with Clouds in Orographic Flows



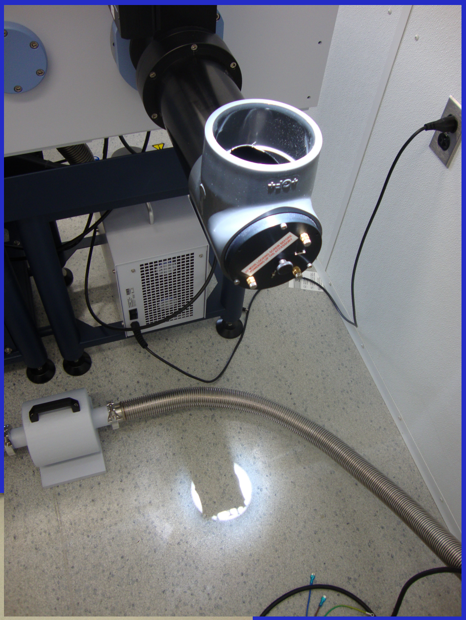
Instrumentation Suites/Platforms

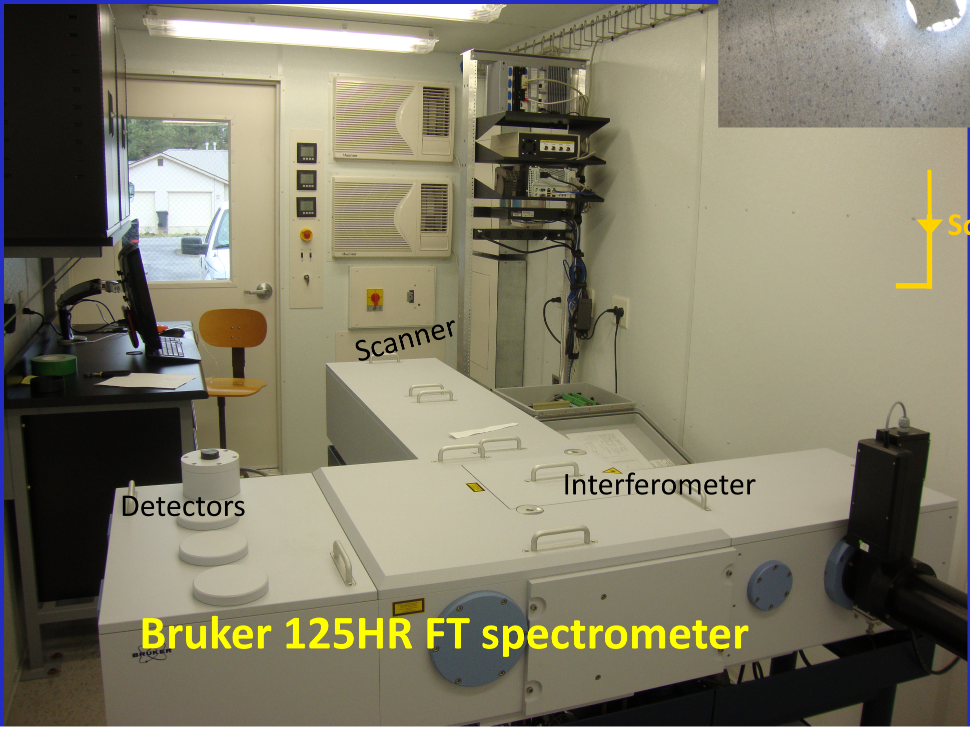
- Aerosol Chemistry: Single Particle Laser Ablation Time of Flight Mass Spec (SPLAT), PALMS
- Non Refractory Chem: Time of flight Aerosol Mass Spectrometers, Atmospheric Chemistry Species Monitor
- Reactive Gases: PTRMS, CO, NOx/y, SO_2, NH_3, O_3
- Microphysics: CCN, HDMA-CCN , IN-counter, ice particles
- Optical: SP2, PASS-3, PASS-UV, Ext, sizer, Polarization, Denuder
- Ultrafine Fine particle nucleation: (>1nm)
- Isotope analysis: $^{13}CO_2$, HOD, $^{14}CO_2$, ^{14}C-aerosols
- *In situ*: G1, T0, T1, T(bio), T(urban)
- Vans: Aerodyne (aerosol) and ATML (gas-isotope)
- Remote Sensing: Solar FTS, AMF-2, MAOS (8/13?), 4-STAR G1, B200 (HSRL, RSP-dust)

Processes to Probe: Questions to Answer

- Bio (Sesquiterpene) + Anthro => SOA
- Anthro + Bio (Isoprene) => SOA
- High NOx, SO_2, O_3 to Low (spatio-temp contrast)
- OA + Dust + Sulf => Mixing, Optical (MAC)
- OA + Dust + Sulf => CCN, IN
- Nightime (NO_3 aerosol life cycle)
- Ultrafine particle formation anthro-bio
- Scaling processes/data to climate models
- Test semiempirical parameterizations (SOA, coating BC-MACs , IN(size-dust), K

LANL Solar Tracking Fourier Transform Spectrometer





Solar Beam

AUTOMATED REMOTE SOLAR OBSERVATORY

Solar FTS to Monitor Power Plant Operational San Juan NM

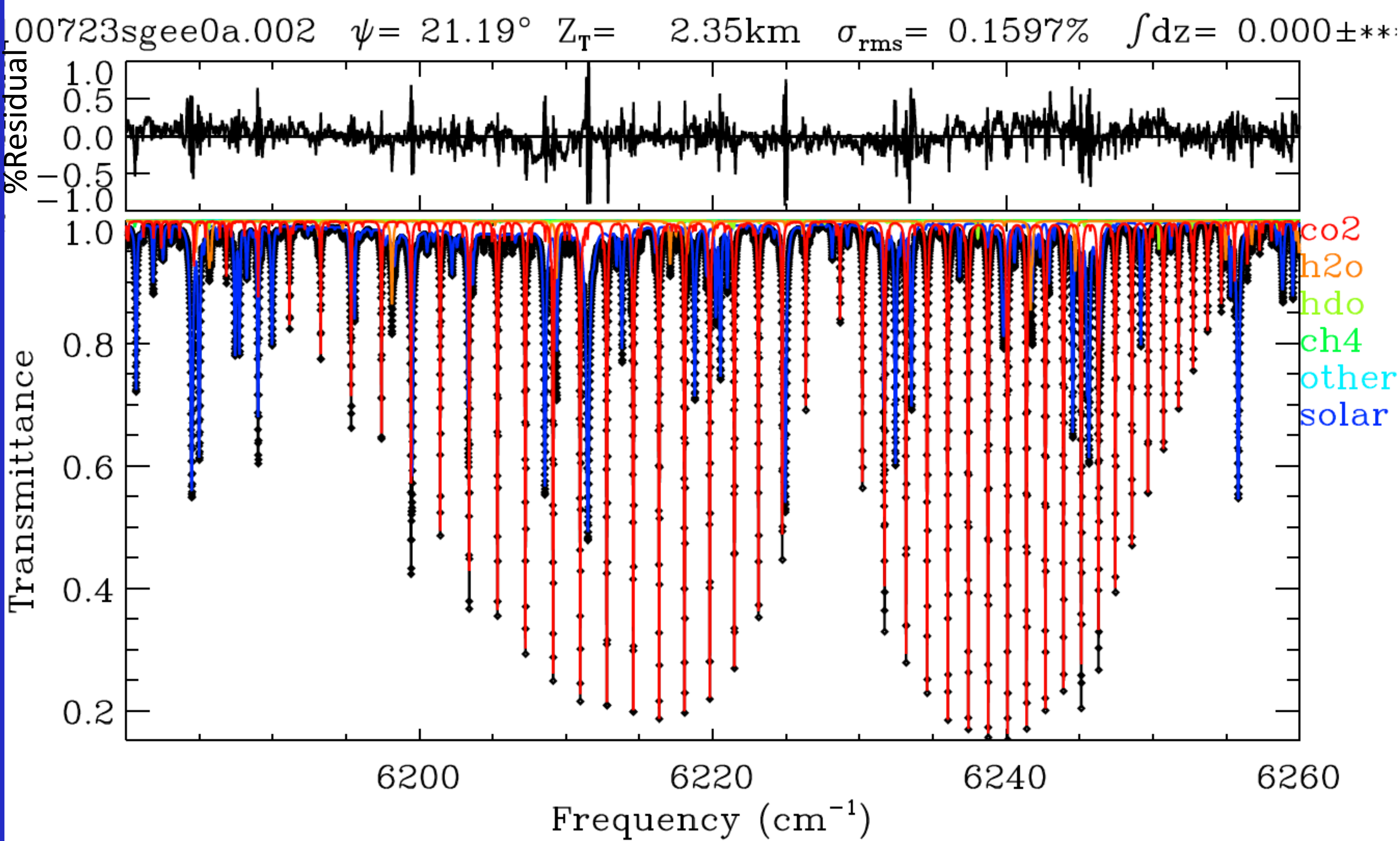
Goal: Separate CO_2 contributions fro high NOx and low NOx PPs using FTS data

https://tccon-wiki.caltech.edu/Sites/Four_Corners

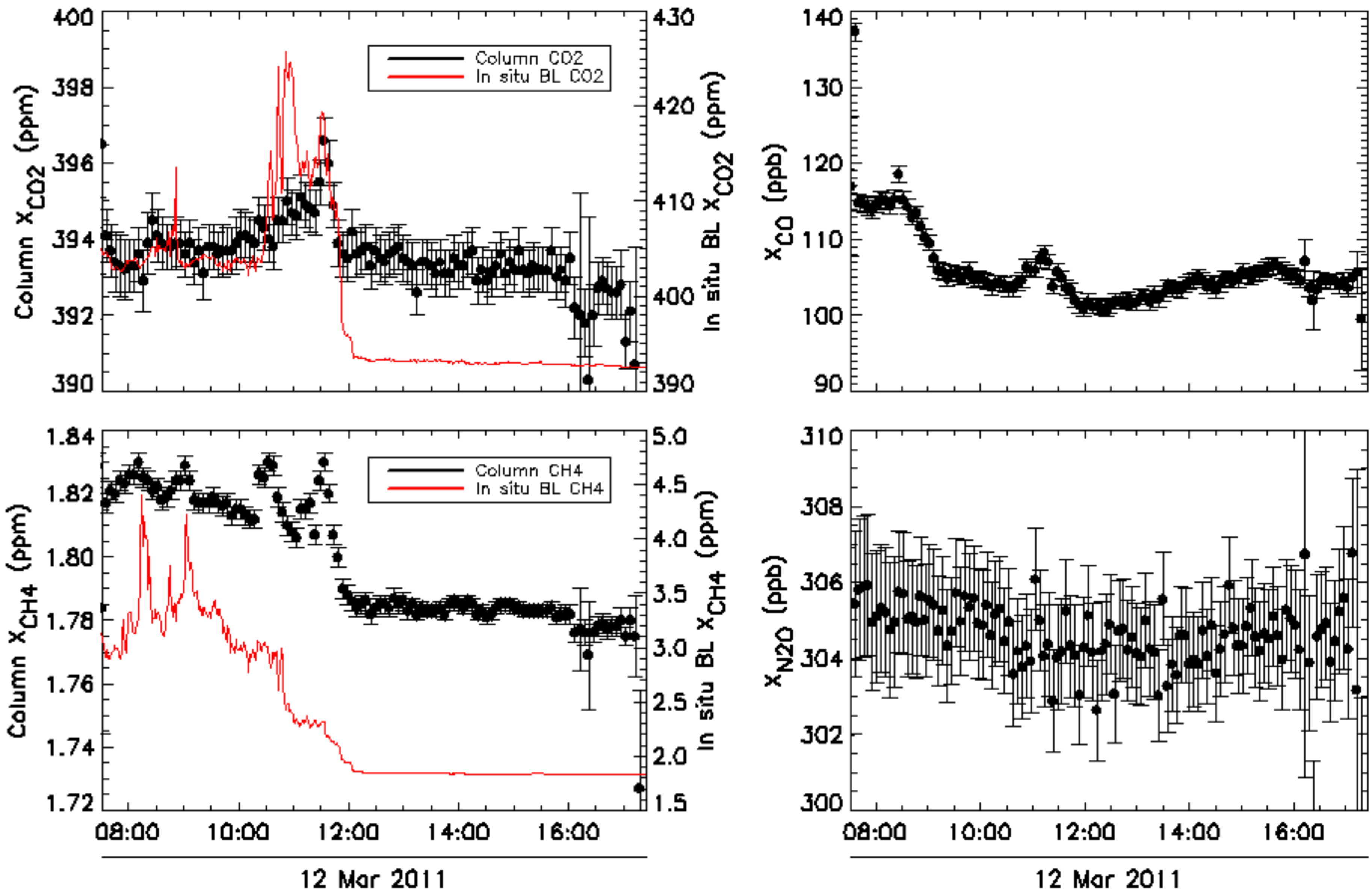
Four Corners PP
High NOx/CO_2

San Juan PP
Low NOx/CO_2

Solar Spectra Fit to Retrieve CO_2 and other gases



System operational starting 3/11/11 and data being downloaded. First analysis of GHGs and CO for 3/12/11



Aerosol Chemistry/Optical Properties

- What is the interplay of dynamics, chemistry and microphysics during the time evolution of the composition, size distribution and optical properties of the aerosols?
- How do wind-blown dust and anthropogenic aerosols mix and alter the optical properties
- How does this aged acidic plume (high SO2, NOx NH3 limited) interact with reactive sesquiterpenes emitted by pine forests to produce secondary organic aerosols and new particles?
- How do the aerosols affect the local and regional radiation budget *(optical closure)*? Fine (anthro) + Coarse (dust)
- How do aerosol formation differ between day and night?
- How effective is aerosol deposition in the upslope flows during day and night? Do models capture diurnal effects accurately?

Microphysical

- Are the aerosols in the outflow effective cloud condensation and/or ice nuclei *(CCN closure)*?
- When entrained in orographic flows how do they influence warm and cold clouds and precipitation processes?
- What is the interplay between dynamics, moisture and microphysics in CCN and IN activity of the mixed aerosols?
- What is the spatio-temporal heterogeneity in these properties and mechanisms?
- Do the regional aerosols impact rain and/or snowfall?
- Do process level models predict CCN activity from composition?
- Do regional scale LES models capture the observed interplay of dynamics and microphysics?

Scaling for Climate Models

- Develop systematic scaling methods that combine *in situ* data with high spectral and temporal resolution solar spectra of aerosol, water and chemistry on 10-100km scales (integrating over process level heterogeneities) relevant for climate models and satellite observations?
  - Do coarser climate models capture observed regional scale heterogeneities?
  - Are satellite derived aerosol optical properties consistent our scaled in situ measurements?
  - Can this scaling observe effects of humidity on aerosols (f (RH)) on a regional scale?
  - Are these regional f (RH) aerosol effects that effect radiation and clouds captured in climate models?

Field Observation: Modeling Strategy

- Use tracer (CO) normalization and photochemical (NOx/NOy) clocks to dissect aerosol processes
- Use ASR WRF-Chem testbeb (PNL, Fast) to examine mechanisms
- Use terrain following GCM (Walko/Cotton) with microphysics/chemistry to examine aerosol-cloud parameterizations


THANK YOU!
QUESTIONS?