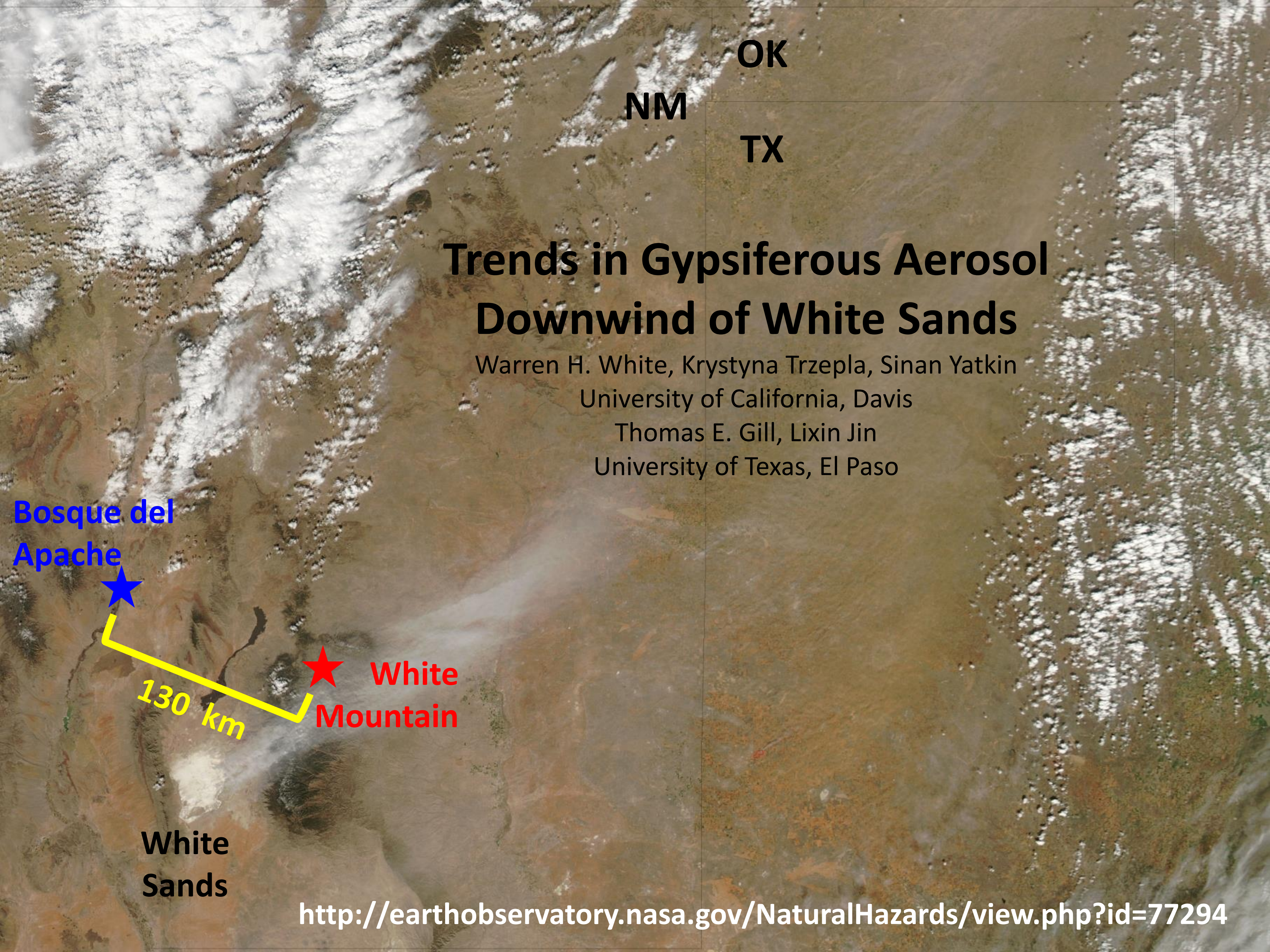
Trends in Gypsiferous Aerosol Downwind of White Sands

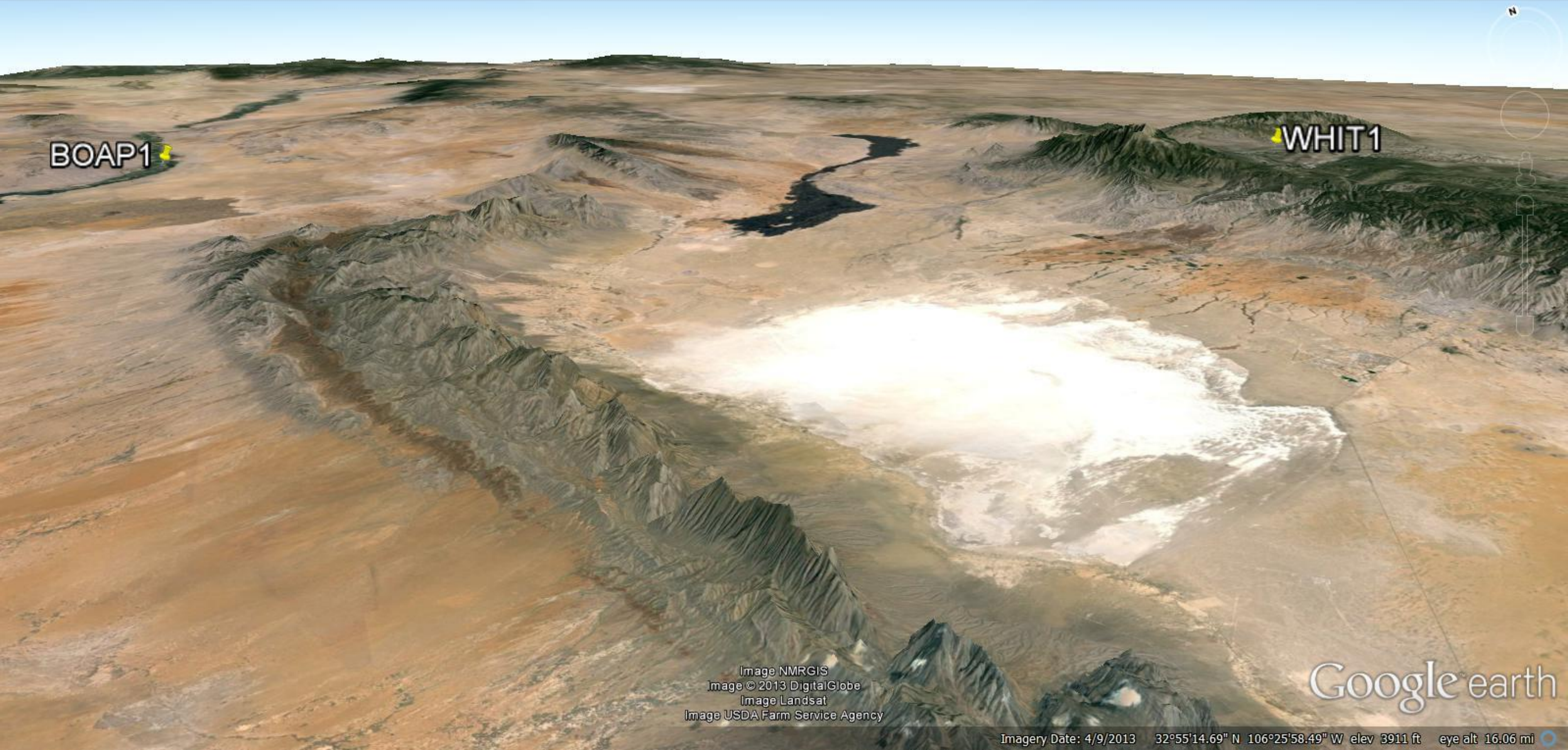
Warren H. White, Krystyna Trzepla, Sinan Yatkin
University of California, Davis
Thomas E. Gill, Lixin Jin
University of Texas, El Paso



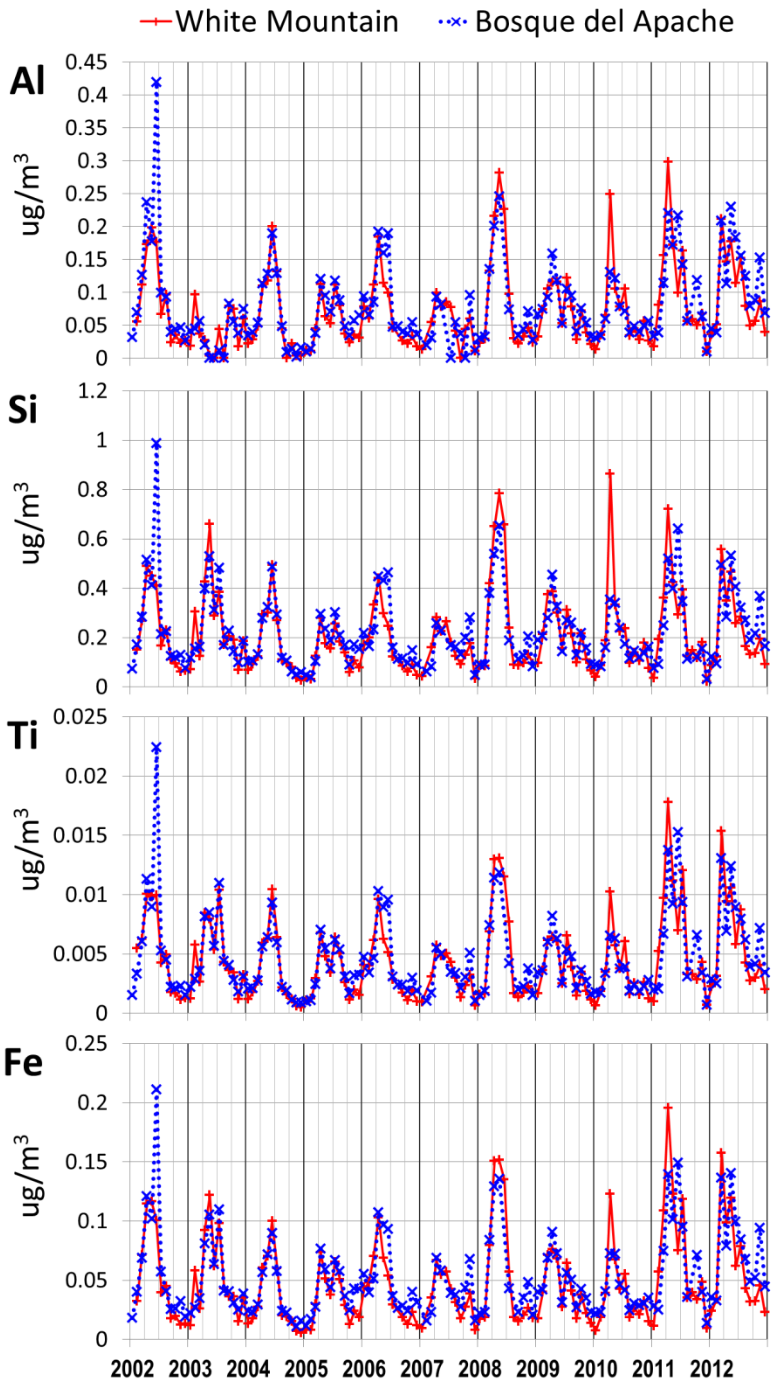
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=77294

The U.S. Forest Service has operated a sampler (WHIT) at White Mountain → since January 2002.

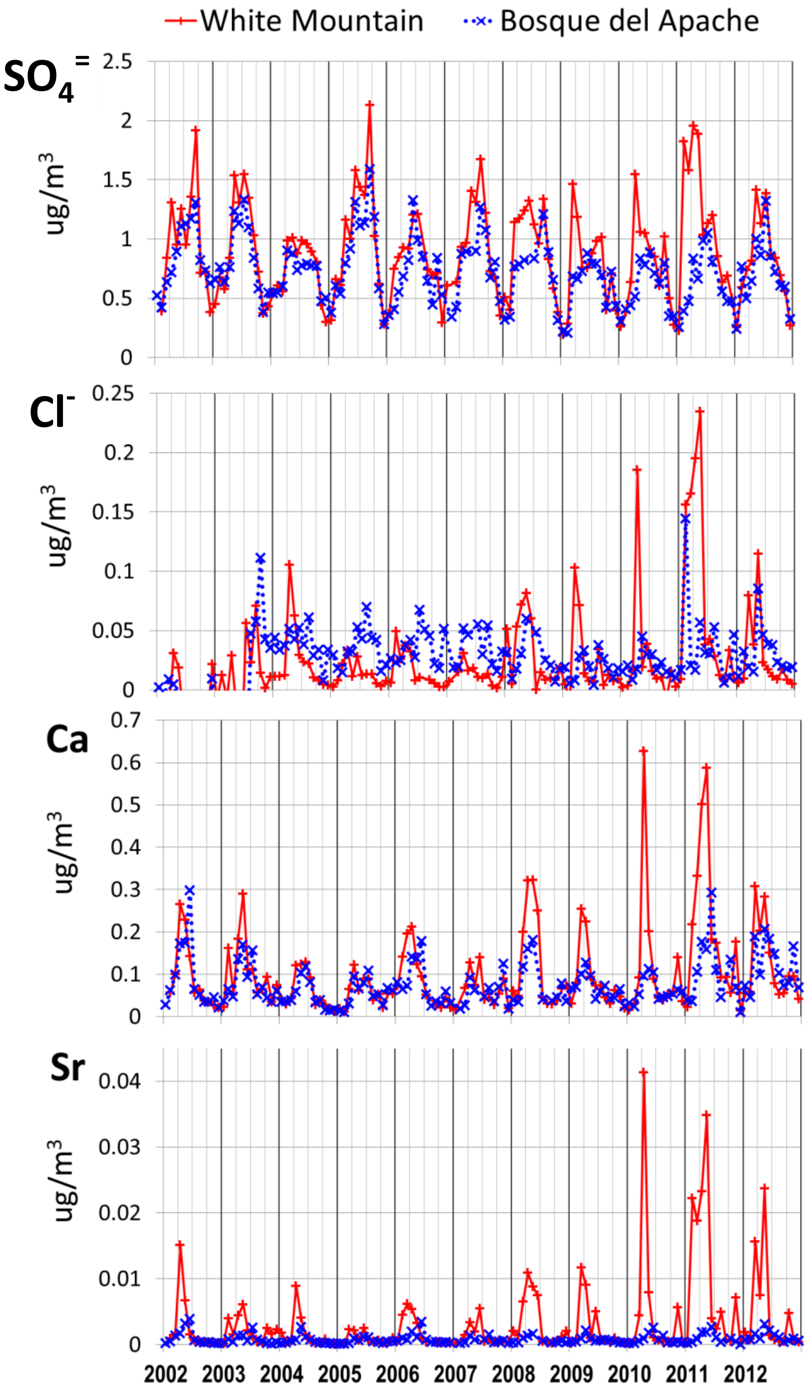
The U.S. Fish and Wildlife Service has operated a sampler (BOAP) at ← Bosque del Apache since 2000.



Monthly average concentrations of most major crustal elements correlate well between White Mountain and Bosque del Apache, reflecting the regional character of climate and geological factors.



In recent years a spring pulse of sulfate aerosol has appeared at White Mountain – and not at Bosque del Apache. In recent years this pulse is eclipsing the usual summer peak produced by atmospheric reaction of sulfur dioxide emissions. The sulfate increases have been accompanied by increased concentrations of chloride, calcium and strontium, suggesting a common origin as evaporite minerals.



Inter-species correlations, *r*, in White Mountain $PM_{2.5}$

2011-2012 elemental data are from Panalytical Epsilon 5 EDXRF instruments at CNL; ions Cl^- and $SO_4^=$ are from ion chromatography at RTI. →

crustal (silicate) factor

evaporite (gypsiferous) factor

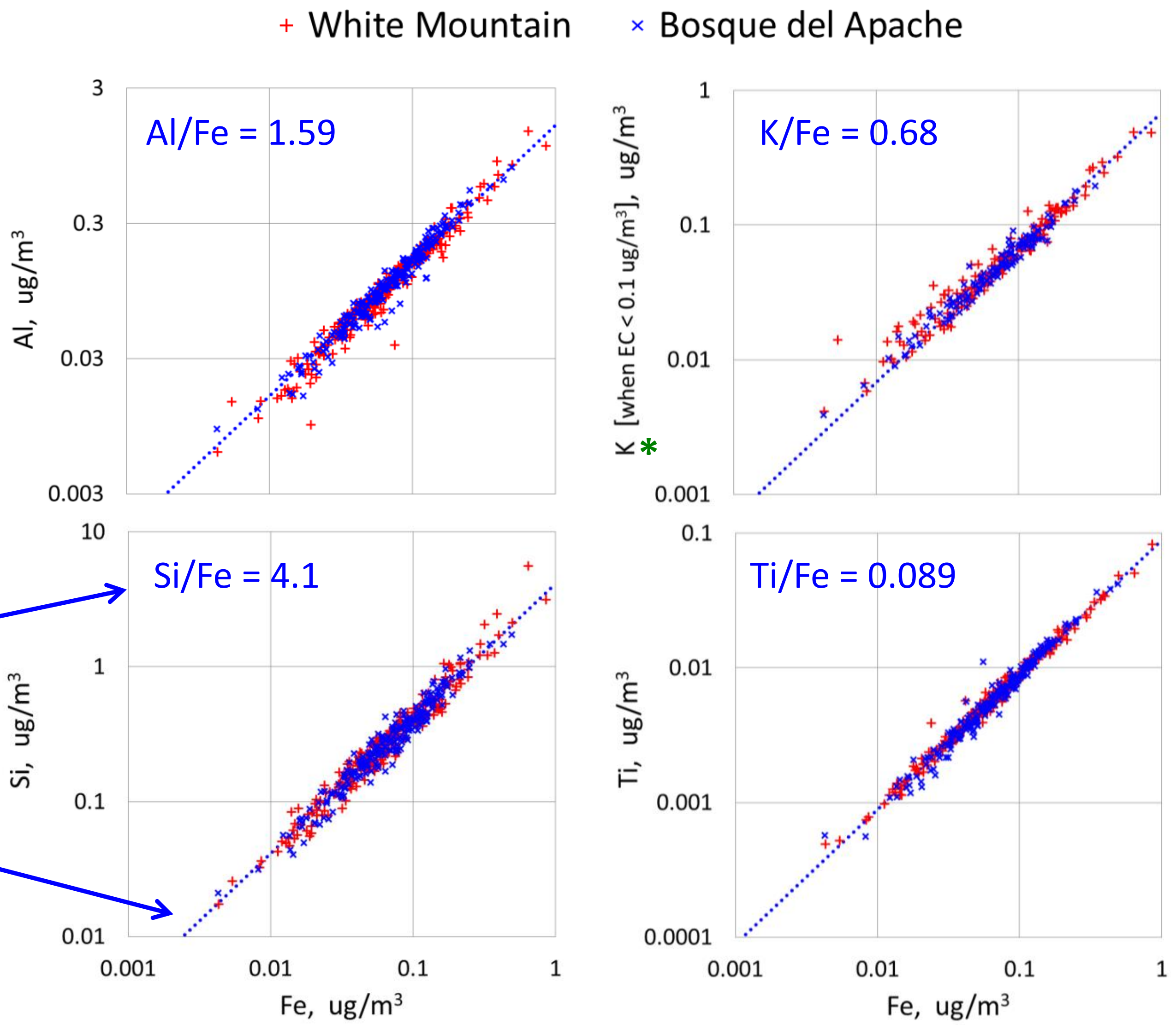
2011-2012	Al	Si	K	Ti	Mn	Fe	Rb	Na	Mg	Cl^-	Cl	Ca	Sr	V	Cr	Ni	Br	SO_4	S
Al	**1**	**0.99**	**0.94**	**0.98**	**0.95**	**0.99**	0.75	0.44	0.68	0.61	0.58	0.76	0.58	0.71	0.64	0.61	0.36	0.55	0.52
Si	**0.99**	**1**	**0.95**	**0.99**	**0.98**	**0.99**	0.79	0.44	0.69	0.62	0.60	0.79	0.61	0.72	0.62	0.61	0.37	0.55	0.52
K	**0.94**	**0.95**	**1**	**0.95**	**0.96**	**0.96**	0.77	0.45	0.72	0.68	0.64	0.83	0.65	0.74	0.58	0.61	0.52	0.62	0.60
Ti	**0.98**	**0.99**	**0.95**	**1**	**0.96**	**1**	0.79	0.45	0.67	0.61	0.59	0.78	0.6	0.71	0.61	0.62	0.35	0.55	0.52
Mn	**0.95**	**0.98**	**0.96**	**0.96**	**1**	**0.97**	0.80	0.42	0.69	0.63	0.61	0.8	0.63	0.73	0.61	0.61	0.40	0.55	0.53
Fe	**0.99**	**0.99**	**0.96**	**1**	**0.97**	**1**	0.79	0.46	0.7	0.64	0.61	0.8	0.62	0.72	0.63	0.62	0.36	0.56	0.54
Rb	0.75	0.79	0.77	0.79	0.80	0.79	**1**	0.41	0.58	0.56	0.56	0.68	0.57	0.54	0.43	0.43	0.20	0.48	0.44
Na	0.44	0.44	0.45	0.45	0.42	0.46	0.41	**1**	0.63	0.64	0.64	0.57	0.66	0.38	0.24	0.16	0.14	0.72	0.62
Mg	0.68	0.69	0.72	0.67	0.69	0.7	0.58	0.63	**1**	**0.94**	**0.92**	**0.93**	**0.92**	0.55	0.43	0.32	0.25	0.82	0.75
Cl^-	0.61	0.62	0.68	0.61	0.63	0.64	0.56	0.64	**0.94**	**1**	**0.97**	**0.91**	**0.92**	0.54	0.35	0.28	0.23	0.78	0.72
Cl	0.58	0.60	0.64	0.59	0.61	0.61	0.56	0.64	**0.92**	**0.97**	**1**	**0.91**	**0.93**	0.51	0.31	0.25	0.18	0.75	0.7
Ca	0.76	0.79	0.83	0.78	0.80	0.80	0.68	0.57	**0.93**	**0.91**	**0.91**	**1**	**0.92**	0.63	0.47	0.43	0.33	0.77	0.74
Sr	0.58	0.61	0.65	0.6	0.63	0.62	0.57	0.66	**0.92**	**0.92**	**0.93**	**0.92**	**1**	0.52	0.32	0.29	0.21	0.77	0.72
V	0.71	0.72	0.74	0.71	0.73	0.72	0.54	0.38	0.55	0.54	0.51	0.63	0.52	**1**	0.39	0.57	0.55	0.58	0.61
Cr	0.64	0.62	0.58	0.61	0.61	0.63	0.43	0.24	0.43	0.35	0.31	0.47	0.32	0.39	**1**	0.33	0.22	0.30	0.29
Ni	0.61	0.61	0.61	0.62	0.61	0.62	0.43	0.16	0.32	0.28	0.25	0.43	0.29	0.57	0.33	**1**	0.37	0.31	0.34
Br	0.36	0.37	0.52	0.35	0.40	0.36	0.20	0.14	0.25	0.23	0.18	0.33	0.21	0.55	0.22	0.37	**1**	0.42	0.49
SO_4	0.55	0.55	0.62	0.55	0.55	0.56	0.48	0.72	0.82	0.78	0.75	0.77	0.77	0.58	0.30	0.31	0.42	**1**	**0.98**
S	0.52	0.52	0.60	0.52	0.53	0.54	0.44	0.62	0.75	0.72	0.70	0.74	0.72	0.61	0.29	0.34	0.49	**0.98**	**1**

2002-2010 elemental data are from legacy EDXRF systems at CNL; ions Cl^- and $SO_4^=$ are from ion chromatography at RTI. →

2002-2010	Al	Si	K	Ti	Mn	Fe	Rb	Na	Mg	Cl^-	Cl	Ca	Sr	V	Cr	Ni	Br	SO_4	S
Al	**1**	**0.90**	0.78	**0.90**	**0.93**	**0.90**	0.81	0.48	0.68	0.53	0.53	0.75	0.6	0.38	0.28	0.11	0.41	0.43	0.47
Si	**0.90**	**1**	0.88	**0.90**	**0.92**	**0.95**	0.88	0.62	0.77	0.66	0.68	**0.90**	0.76	0.28	0.21	0.10	0.41	0.52	0.58
K	0.78	0.88	**1**	0.83	0.85	0.89	0.85	0.41	0.57	0.53	0.48	0.76	0.57	0.33	0.19	0.13	0.60	0.49	0.52
Ti	**0.90**	**0.90**	0.83	**1**	**0.91**	**0.97**	0.87	0.35	0.55	0.46	0.43	0.7	0.51	0.39	0.28	0.15	0.47	0.45	0.47
Mn	**0.93**	**0.92**	0.85	**0.91**	**1**	**0.93**	0.86	0.49	0.71	0.58	0.56	0.81	0.65	0.38	0.26	0.14	0.49	0.48	0.52
Fe	**0.90**	**0.95**	0.89	**0.97**	**0.93**	**1**	**0.91**	0.41	0.62	0.53	0.49	0.78	0.59	0.36	0.27	0.15	0.49	0.48	0.51
Rb	0.81	0.88	0.85	0.87	0.86	**0.91**	**1**	0.37	0.57	0.50	0.46	0.73	0.56	0.34	0.22	0.14	0.49	0.41	0.43
Na	0.48	0.62	0.41	0.35	0.49	0.41	0.37	**1**	0.84	0.80	**0.95**	0.82	0.89	-0	0	-0	0.06	0.46	0.56
Mg	0.68	0.77	0.57	0.55	0.71	0.62	0.57	0.84	**1**	0.78	0.86	**0.90**	**0.91**	0.06	0.12	0.03	0.14	0.47	0.55
Cl^-	0.53	0.66	0.53	0.46	0.58	0.53	0.50	0.80	0.78	**1**	0.86	0.81	0.82	0.05	0.04	0.04	0.13	0.54	0.57
Cl	0.53	0.68	0.48	0.43	0.56	0.49	0.46	**0.95**	0.86	0.86	**1**	0.88	**0.93**	0	0.02	0.01	0.07	0.5	0.59
Ca	0.75	**0.90**	0.76	0.7	0.81	0.78	0.73	0.82	**0.90**	0.81	0.88	**1**	**0.94**	0.15	0.12	0.07	0.28	0.55	0.63
Sr	0.6	0.76	0.57	0.51	0.65	0.59	0.56	0.89	**0.91**	0.82	**0.93**	**0.94**	**1**	0.06	0.05	0.03	0.13	0.51	0.6
V	0.38	0.28	0.33	0.39	0.38	0.36	0.34	-0	0.06	0.05	0	0.15	0.06	**1**	0.17	0.47	0.48	0.32	0.29
Cr	0.28	0.21	0.19	0.28	0.26	0.27	0.22	0	0.12	0.04	0.02	0.12	0.05	0.17	**1**	0.27	0.12	0.05	0.05
Ni	0.11	0.10	0.13	0.15	0.14	0.15	0.14	-0	0.03	0.04	0.01	0.07	0.03	0.47	0.27	**1**	0.26	0.2	0.17
Br	0.41	0.41	0.6	0.47	0.49	0.49	0.49	0.06	0.14	0.13	0.07	0.28	0.13	0.48	0.12	0.26	**1**	0.5	0.48
SO_4	0.43	0.52	0.49	0.45	0.48	0.48	0.41	0.46	0.47	0.54	0.5	0.55	0.51	0.32	0.05	0.20	0.50	**1**	**0.98**
S	0.47	0.58	0.52	0.47	0.52	0.51	0.43	0.56	0.55	0.57	0.59	0.63	0.6	0.29	0.05	0.17	0.48	**0.98**	**1**

Spring $PM_{2.5}$; March – May, 2005 - 2012

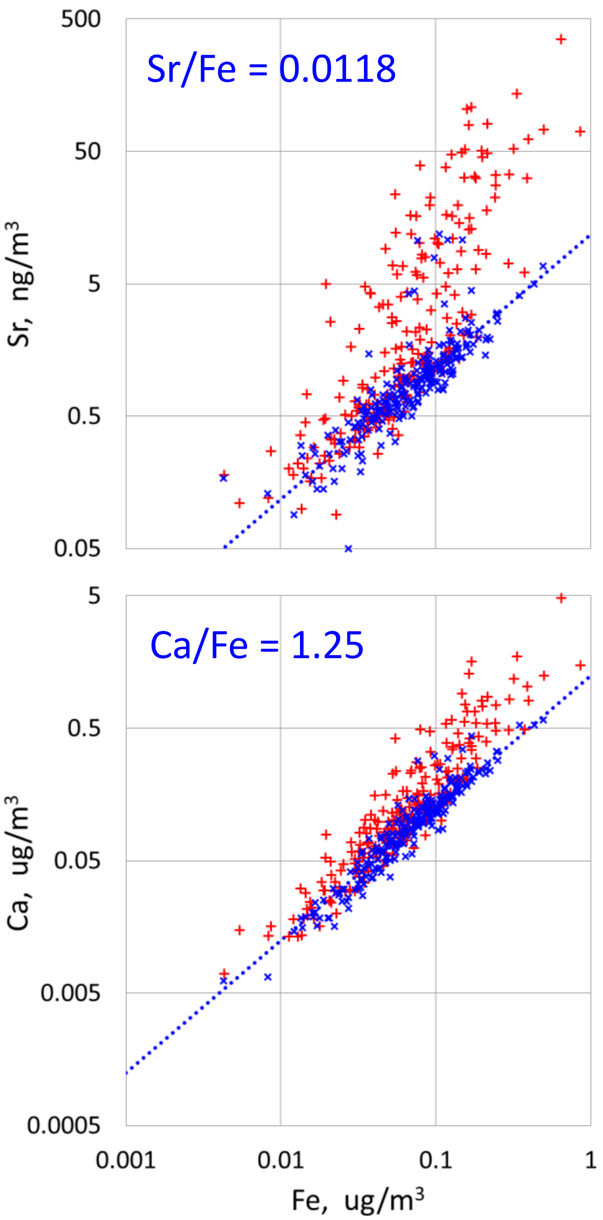
The composition of the crustal (silicate-based) dust component is consistent from year to year and similar between Bosque del Apache and White Mountain.

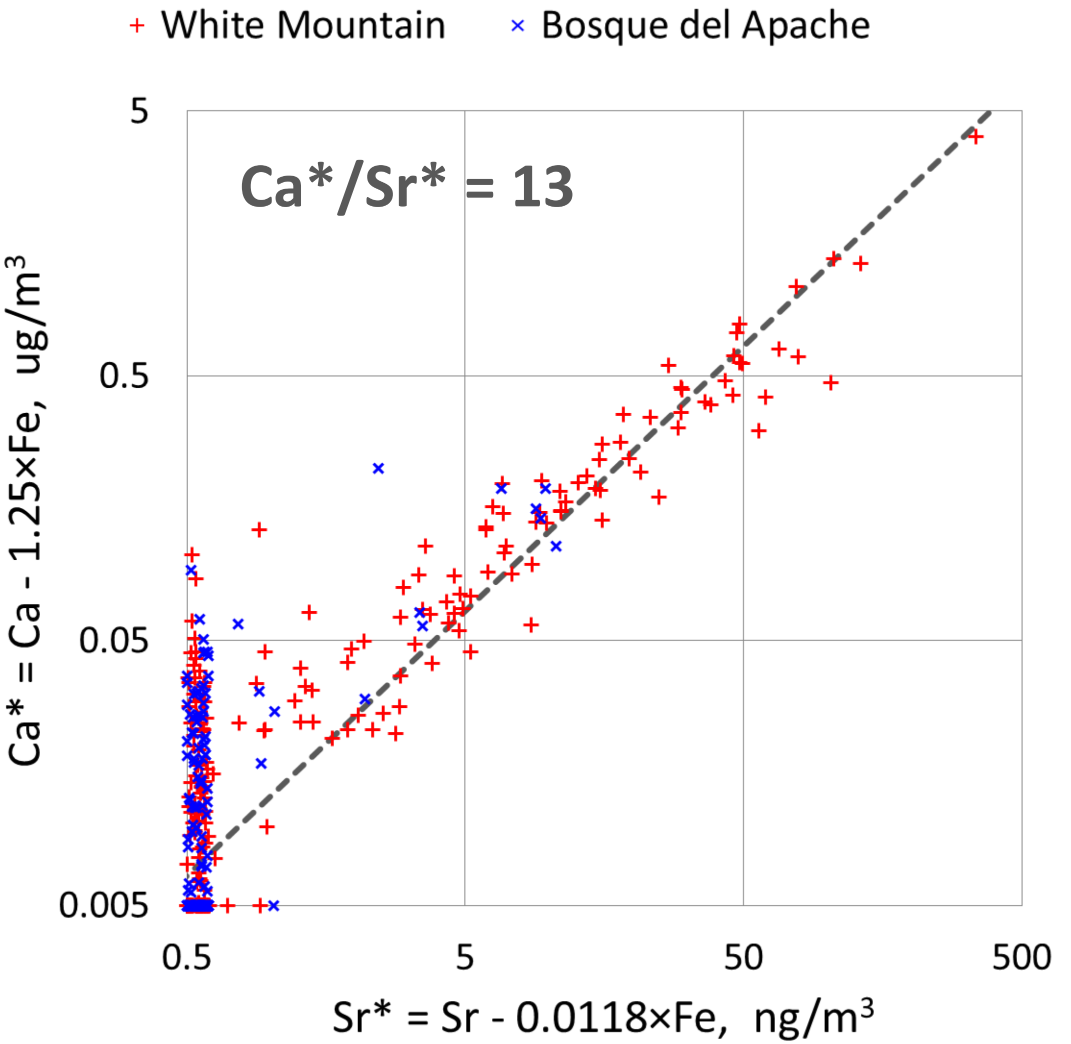


Median ratio at Bosque del Apache,
shown as dotted line.

* K is plotted only for samples with low elemental carbon (EC) values to exclude smoke events.

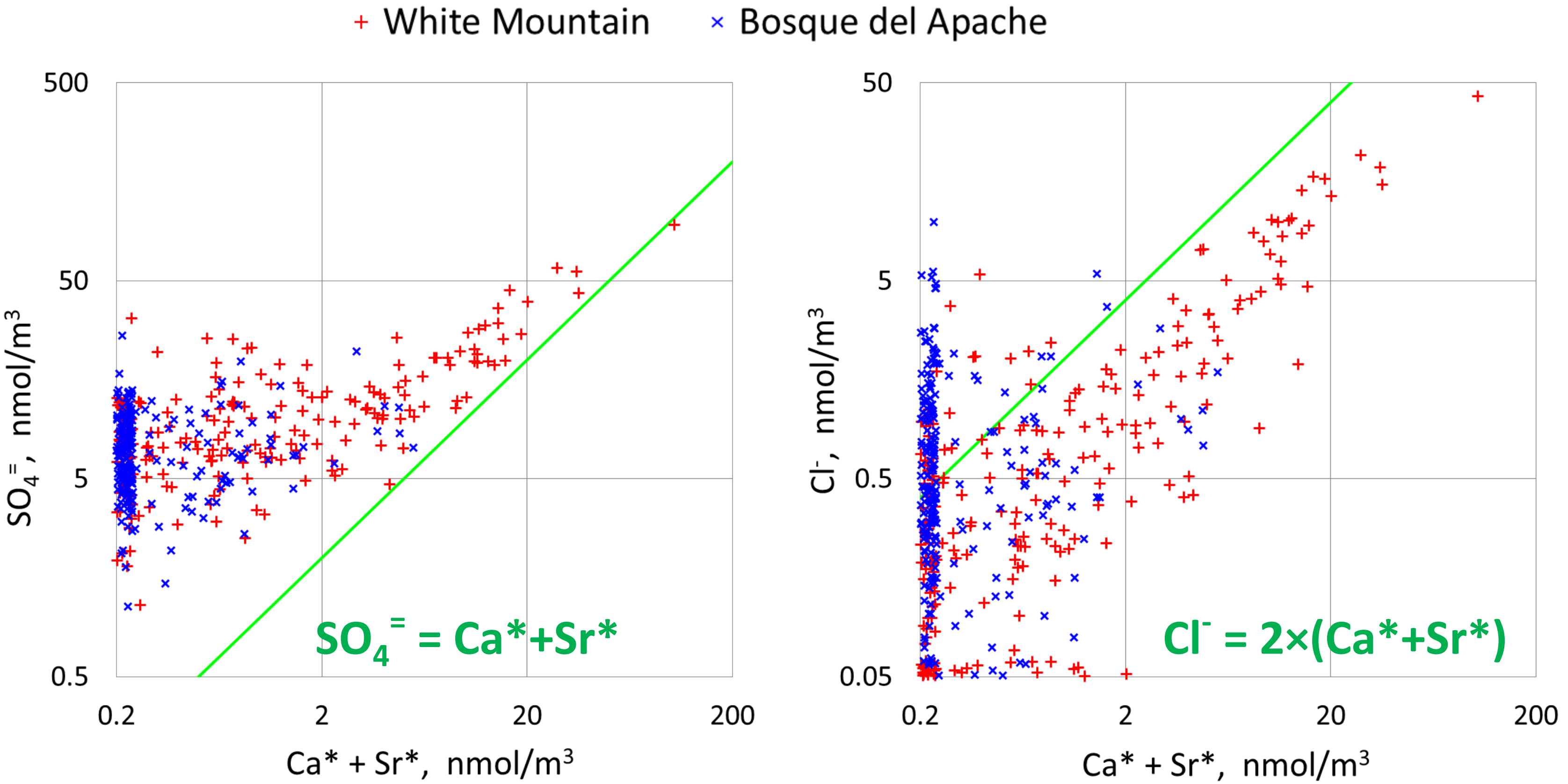
Spring $PM_{2.5}$; March – May, 2005 - 2012





↑ Excess (*evaporite*) calcium and strontium correlate well with each other. (Below-scale values are plotted at the boundaries, with jittering.)

Spring $PM_{2.5}$; March – May, 2005 - 2012

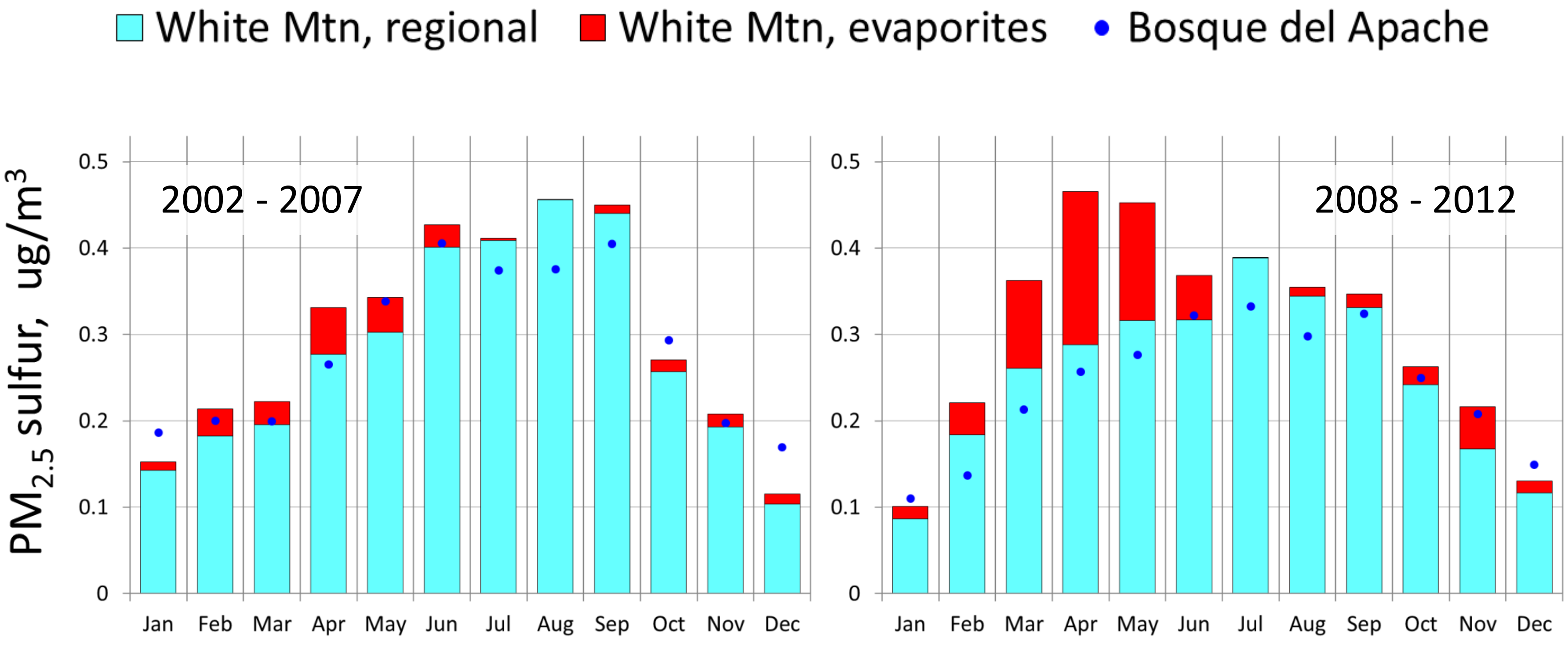


Sulfate appears to be the predominant anion associated with fine particles of evaporite Ca and Sr, although some chloride is also evident. A background of secondary ammonium sulfate is also contributed by regional haze. To a first approximation, the total S measured in White Mountain $PM_{2.5}$ can be apportioned as follows (concentrations in ug/m^3):

$S_{\text{regional}} = S_{\text{measured total}} - S_{\text{evaporites}}$,

$S_{\text{evaporites}} = 32.1[Ca^*/40.1 + Sr^*/87.6]$

$= 32.1[(Ca-1.25Fe)/40.1 + (Sr-0.0118Fe)/87.6]$.



According to this reckoning, White Sands evaporites account for

(a) most of the observed difference between sulfur concentrations at Bosque del Apache and White Mountain, and

(b) the recent increase observed in springtime sulfur concentrations at White Mountain.

PM_{10} ($D_{ap} \leq 10$ um) samples are routinely collected and weighed at all sites, normally without any chemical analysis. As part of an unrelated operational investigation, a few of these were analyzed by XRF, including some from White Mountain. In contrast to the pattern seen elsewhere, coarse particles at White Mountain often account for more than half the total measured sulfur.

Selected sample days, 2011 - 2012