Appendix A

Supporting Materials for Section 3

Data Completeness

Ozone (O_3)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
O_3	56-005-0123	Thunder Basin	AQD	5880	67	8760	100	8760	100	8784	100	8760	100	8760	100	8760	100	8784	100
O_3	56-005-0456	South Campbell County	AQD					4080	47	8784	100	8760	100	8760	100	8760	100	8784	100
O_3	56-013-0099	South Pass	AQD													7080	81	8784	100
O_3	56-035-0098	Jonah	AQD							1368	16	8760	100	8760	100	8760	100	2736	31
O_3	56-035-0099	Boulder	AQD									8000	91	8760	100	8760	100	8784	100
O_3	56-035-0100	Pinedale Gaseous	AQD									4416	50	8760	100	8760	100	8784	100
O_3	56-037-0200	Wamsutter	AQD											7200	82	8760	100	8784	100
O_3	56-041-0101	Murphy Ridge	AQD													8760	100	8784	100

Sulfur Dioxide (SO_2)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
SO_2	56-013-0099	South Pass	AQD													7080	81	8784	100
SO_2	56-037-0200	Wamsutter	AQD											7200	82	8760	100	8784	100
SO_2	56-041-0101	Murphy Ridge	AQD													8760	100	8784	100

Data Completeness continued

Nitrogen Oxide (NOx)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
NO_x	56-005-0123	Thunder Basin	AQD	5880	67	8760	100	8760	100	8784	100	8760	100	8760	100	8760	100	8784	100
NO_x	56-005-0456	South Campbell County	AQD					4080	47	8784	100	8760	100	8760	100	8760	100	8784	100
NO_x	56-013-0099	South Pass	AQD													7080	81	8784	100
NO_x	56-035-0098	Jonah	AQD							1368	16	8760	100	8760	100	8760	100	2736	31
NO_x	56-035-0099	Boulder	AQD									8000	91	8760	100	8760	100	8784	100
NO_x	56-035-0100	Pinedale Gaseous	AQD									4416	50	8760	100	8760	100	8784	100
NO_x	56-037-0200	Wamsutter	AQD											7200	82	8760	100	8784	100
NO_x	56-041-0101	Murphy Ridge	AQD													8760	100	8784	100
NO_x	56-005-0892	BA-4	AQD					8758	100	8780	100	8717	100	8760	100				
NO_x	56-005-0819	Jacobs Ranch	AQD					8756	100	8782	100	6574	75	8760	100				

Data Completeness continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
PM_{10} STP	56-001-0006	2	24 hr every 6th day	Laramie	AQD	61	100	61	100	61	100	61	100	61	100	61	100	61	100	60	99	61	100
PM_{10} STP	56-005-0099	1	24 hr every 6th day	Wright	AQD					3	5	62	102	61	100	61	100	61	100	60	99	61	100
PM_{10} STP	56-005-0456	1	24 hr every 3rd day	South Campbell County	AQD									122	100	89	73	115	95	125	103	126	103
PM_{10} STP	56-005-0456	1	24 hr every 6th day	South Campbell County	AQD							53	87										
PM_{10} STP	56-005-1002	3	24 hr every 6th day	Gillette	AQD	61	100	61	100	61	100	61	100	61	100	61	100	61	100	60	99	61	100
PM_{10} STP	56-013-0099	1	1-hr daily	South Pass	AQD		100													7080	81	8712	99
PM_{10} STP	56-013-1003	3	24 hr every 3rd day	Lander	AQD		100			122	100	121	99	122	100	122	100	122	100	121	99	122	100
PM_{10} STP	56-013-1003	3	24 hr every 6th day	Lander	AQD	61	100	69	113														
PM_{10} STP	56-013-1004	1	24 hr every 3rd day	Lander	AQD	122	100	106	87														
PM_{10} STP	56-021-0001	1	24 hr every 3rd day	Cheyenne	AQD													120	99	121	99	122	100

Data Completeness continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
PM_{10} STP	56-021-0001	5	24 hr every 3rd day	Cheyenne	AQD										100	122	100						
PM_{10} STP	56-021-0001	2	24 hr every 6th day	Cheyenne	AQD													61	100	71	117	61	100
PM_{10} STP	56-021-0001	5	24 hr every 6th day	Cheyenne	AQD																		
PM_{10} STP	56-025-0001	1	24 hr every 3rd day	Casper	AQD													92	76	121	99	124	102
PM_{10} STP	56-025-0001	3	24 hr every 3rd day	Casper	AQD											91	75						
PM_{10} STP	56-025-0001	2	24 hr every 6th day	Casper	AQD													46	76	62	102	61	100
PM_{10} STP	56-025-0001	3	24 hr every 6th day	Casper	AQD	61	100	61	100	61	100	61	100	99	162								
PM_{10} STP	56-029-0001	2	24 hr every 6th day	Cody	AQD	61	100	61	100	61	100	61	100	61	100	61	100	61	100	60	99	96	157
PM_{10} STP	56-033-0001	2	24 hr every 3rd day	Sheridan	AQD					122	100	121	99	123	101	74	61						
PM_{10} STP	56-033-0001	2	24 hr every 6th day	Sheridan		61	100	74	122														

Data Completeness continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
PM_{10} STP	56-033-0002	1	24 hr daily	Sheridan Police	AQD													243	67	242	66	366	100
PM_{10} STP	56-033-0002	2	24 hr daily	Sheridan Police	AQD													147	40	57	16		
PM_{10} STP	56-033-0002	3	24 hr daily	Sheridan Police	AQD	67	246	67	242	66	243	67	242	66	244	67	243						
PM_{10} STP	56-033-0003	1	24 hr every 3rd day	Sheridan Highland Park	AQD											41	34	122	100	121	99	122	100
PM_{10} STP	56-033-0003	2	24 hr every 6th day	Sheridan Highland Park	AQD																	61	100
PM_{10} STP	56-033-0099	1	24 hr every 6th day	Sheridan Arvada Elem. School	AQD					7	12	61	100	60	98	61	100	62	102	20	33		
PM_{10} STP	56-035-0098	1	1-hr daily	Jonah	AQD									1368	16	8760	100	8760	100	8760	100	2736	31
PM_{10} STP	56-035-0099	1	1-hr daily	Boulder	AQD											8146	93	8759	100	8760	100	8784	100
PM_{10} STP	56-035-0100	1	1-hr daily	Daniel South	AQD											4416	50	8760	100	8760	100	8757	100
PM_{10} STP	56-037-0007	2	24 hr every 6th day	Rock Springs	AQD	61	100	61	100	61	100	61	100	61	100	61	100	61	100	60	99	61	

Data Completeness continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
PM_{10} STP	56-037-0007	2	24-hr every 3rd day	Rock Springs	AQD																	117	96
PM_{10} STP	56-037-0200	1	1-hr daily	Wamsutter	AQD													7200	82	8760	100	8784	100
PM_{10} STP	56-039-0006	1	24 hr every 3rd day	Jackson	AQD									122	100	122	100	71	58				
PM_{10} STP	56-039-0006	1	24 hr every 6th day	Jackson	AQD			33	54	61	100	81	133										
PM_{10} STP	56-039-1006	1	24 hr every 3rd day	Jackson Fire	AQD															69	57	126	103
PM_{10} STP	56-041-0101	1	1-hr daily	Murphy Ridge	AQD															8760	100	8784	100

Data Completeness continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
$PM_{2.5}$ LC	56-005-0123	1	24 hr every 3rd day	Thunder Basin	AQD											122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-005-0877	1	24 hr every 3rd day	BTM 26-2	AQD	121	99	121	99	122	100	125	102	122	100	122	100	123	101	91	75		
$PM_{2.5}$ LC	56-005-0877	2	24 hr every 6th day	BTM 26-2	AQD													50	82	48	79		
$PM_{2.5}$ LC	56-005-0891	1	24 hr every 3rd day	BTM 36-2	AQD																	72	59
$PM_{2.5}$ LC	56-005-0891	2	24 hr every 6th day	BTM 36-2	AQD																	36	59
$PM_{2.5}$ LC	56-005-0892	1	24 hr every 3rd day	BA-4	AQD	106	87	81	66	104	85	121	99	123	101	122	100	122	100	91	75	72	59
$PM_{2.5}$ LC	56-005-0899	1	24 hr every 3rd day	BA-4	AQD	106	87	81	66	105	86	124	102	122	100	124	102	122	100	91	75	32	26
$PM_{2.5}$ LC	56-005-1899	1	24 hr every 3rd day	Buckskin	AQD																	39	32
$PM_{2.5}$ LC	56-009-0819	1	24 hr every 3rd day	Site 3	AQD	106	87	81	66	105	86	121	99	122	100	122	100	122	100	91	75	72	59
$PM_{2.5}$ LC	56-013-1003	1	24 hr every 3rd day	Lander	AQD			16	13	121	99	121	99	124	102	123	101	122	100	121	99	122	100

Data Completeness continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
$PM_{2.5}$ LC	56-013-1004	1	24 hr every 3rd day	Lander	AQD	122	100	106	87														
$PM_{2.5}$ LC	56-019-9000	1	24 hr every 3rd day	Cloud Peak	AQD											122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-021-0001	1	24 hr every 3rd day	Cheyenne	AQD	121	99	120	98	122	100	122	100	120	98	120	98	121	99	120	98	123	101
$PM_{2.5}$ LC	56-029-0001	1	24 hr every 3rd day	Cody	AQD																	73	60
$PM_{2.5}$ LC	56-029-9002	1	24 hr every 3rd day	North Absaroka	AQD											122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-033-0001	1	24 hr every 3rd day	Sheridan	AQD	122	100	122	100	122	100	121	99	122	100	68	56						
$PM_{2.5}$ LC	56-033-0002	1	24 hr every 3rd day	Sheridan Police	AQD	122	100	122	100	122	100	121	99	122	100	122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-033-0002	2	24 hr every 3rd day	Sheridan Police	AQD													61	50	60	49	61	50
$PM_{2.5}$ LC	56-033-0003	1	24 hr every 3rd day	Sheridan Highland Park	AQD											31	25	122	100	121	99	122	100
$PM_{2.5}$ LC	56-035-0705	1	24 hr every 3rd day	Pinedale	AQD											56	46	125	102	122	100	122	100

Data Completeness continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete	# Samples	% Complete
$PM_{2.5}$ LC	56-035-9000	1	24 hr every 3rd day	Bridger Wilderness	AQD											122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-037-0007	1	24 hr every 3rd day	Rock Springs	AQD																	110	90
$PM_{2.5}$ LC	56-039-0006	1	24 hr every 3rd day	Jackson	AQD			64	52	115	94	122	100	123	101	123	101	125	102	51	42		
$PM_{2.5}$ LC	56-039-1006	1	24 hr every 3rd day	Jackson Fire	AQD															69	57	123	101
$PM_{2.5}$ LC	56-039-9000	1	24 hr every 3rd day	Yellowstone NP	AQD											122	100	122	100	121	99	122	100
$PM_{2.5}$ LC	56-039-9000	2	24 hr every 3rd day	Yellowstone NP	AQD											122	100	122	100	121	99	122	100

Data Validity

Ozone (O_3)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
O_3	56-005-0123	Thunder Basin	AQD	5426	92	8190	93	7747	88	8122	92	8259	94	8280	95	8262	94	8056	92
O_3	56-005-0456	South Campbell County	AQD					3387	83	8101	92	8204	94	7390	84	8239	94	7088	81
O_3	56-013-0099	South Pass	AQD													5980	84	7667	87
O_3	56-035-0098	Jonah	AQD							1349	99	8086	92	8165	93	8334	95	2588	95
O_3	56-035-0099	Boulder	AQD									7681	96	8528	97	7623	87	8131	93
O_3	56-035-0100	Pinedale Gaseous	AQD									4332	98	8624	98	8665	99	8453	96
O_3	56-037-0200	Wamsutter	AQD											6859	95	8037	92	8295	94
O_3	56-041-0101	Murphy Ridge	AQD													8456	97	8576	98

Sulfur Dioxide (SO_2)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
SO_2	56-013-0099	South Pass	AQD													6097	86	7638	87
SO_2	56-037-0200	Wamsutter	AQD											6861	95	8137	93	8246	94
SO_2	56-041-0101	Murphy Ridge	AQD													8591	98	8637	98

Data Validity continued

Nitrogen Oxide (NOx)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	2001 Duration Code: 1-hr daily		2002 Duration Code: 1-hr daily		2003 Duration Code: 1-hr daily		2004 Duration Code: 1-hr daily		2005 Duration Code: 1-hr daily		2006 Duration Code: 1-hr daily		2007 Duration Code: 1-hr daily		2008 Duration Code: 1-hr daily	
				# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
NO_x	56-005-0123	Thunder Basin	AQD	5425	92	8306	95	7708	88	8226	94	8258	94	8280	95	7725	88	6218	71
NO_x	56-005-0456	South Campbell County	AQD					3074	75	7967	91	7614	87	7081	81	7007	80	7490	85
NO_x	56-013-0099	South Pass	AQD													5538	78	6279	71
NO_x	56-035-0098	Jonah	AQD							1317	96	8059	92	8329	95	8357	95	2328	85
NO_x	56-035-0099	Boulder	AQD									7626	95	8563	98	4222	48	5937	68
NO_x	56-035-0100	Pinedale Gaseous	AQD									4353	99	8573	98	8641	99	8590	98
NO_x	56-037-0200	Wamsutter	AQD											6909	96	7887	90	8213	93
NO_x	56-041-0101	Murphy Ridge	AQD													8558	98	8601	98
NO_x	56-005-0892	BA-4	AQD					7369	84	6799	77	7877	90	8526	97				
NO_x	56-005-0819	Jacobs Ranch	AQD					7468	85	8330	95	6282	96	6004	69				

Data Validity continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
PM_{10} STP	56-001-0006	2	24 hr every 6th day	Laramie	AQD	52	85	61	100	59	97	58	95	58	95	55	90	53	87	51	85	57	93
PM_{10} STP	56-005-0099	1	24 hr every 6th day	Wright	AQD					3	100	56	90	49	80	54	89	54	89	55	92	58	95
PM_{10} STP	56-005-0456	1	24 hr every 3rd day	South Campbell County	AQD									110	90	77	87	74	64	75	60	94	75
PM_{10} STP	56-005-0456	1	24 hr every 6th day	South Campbell County	AQD							48	91										
PM_{10} STP	56-005-1002	3	24 hr every 6th day	Gillette	AQD	53	87	58	95	52	85	57	93	52	85	58	95	59	97	50	83	59	97
PM_{10} STP	56-013-0099	1	1-hr daily	South Pass	AQD															6713	95	6209	71
PM_{10} STP	56-013-1003	3	24 hr every 3rd day	Lander	AQD					97	80	97	80	109	89	119	98	108	89	103	85	105	86
PM_{10} STP	56-013-1003	3	24 hr every 6th day	Lander	AQD	53	87	58	84														

Data Validity continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
PM_{10} STP	56-021-0001	1	24 hr every 3rd day	Cheyenne	AQD													113	94	107	88	115	94
PM_{10} STP	56-021-0001	5	24 hr every 3rd day	Cheyenne	AQD									109	89	104	85						
PM_{10} STP	56-021-0001	2	24 hr every 6th day	Cheyenne	AQD													54	89	67	94	57	93
PM_{10} STP	56-021-0001	5	24 hr every 6th day	Cheyenne	AQD	53	87	59	97	57	93	71	93										
PM_{10} STP	56-025-0001	1	24 hr every 3rd day	Casper	AQD													83	90	110	91	117	94
PM_{10} STP	56-025-0001	3	24 hr every 3rd day	Casper	AQD											91	100						
PM_{10} STP	56-025-0001	2	24 hr every 6th day	Casper	AQD													45	98	49	79	46	75
PM_{10} STP	56-025-0001	3	24 hr every 6th day	Casper	AQD	57	93	56	92	54	89	57	93	94	95								
PM_{10} STP	56-029-0001	2	24 hr every 6th day	Cody	AQD	59	97	56	92	60	98	60	98	53	87	60	98	57	93	45	75	83	86
PM_{10} STP	56-033-0001	2	24 hr every 3rd day	Sheridan	AQD					115	94	113	93	116	94	73	99						
PM_{10} STP	56-033-0001	2	24 hr every 6th day	Sheridan	AQD	51	84	73	99														

Data Validity continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
PM_{10} STP	56-033-0002	1	24 hr daily	Sheridan Police	AQD													216	89	237	98	363	99
PM_{10} STP	56-033-0002	2	24 hr daily	Sheridan Police	AQD													142	97	55	96		
PM_{10} STP	56-033-0002	3	24 hr daily	Sheridan Police	AQD	206	84	239	99	241	99	235	97	229	94	235	97						
PM_{10} STP	56-033-0003	1	24 hr every 3rd day	Sheridan Highland Park	AQD											36	88	110	90	105	87	120	98
PM_{10} STP	56-033-0003	2	24 hr every 6th day	Sheridan Highland Park	AQD																	60	98
PM_{10} STP	56-033-0099	1	24 hr every 6th day	Sheridan Arvada Elem. School	AQD					5	71	59	97	60	100	61	100	50	81	19	95		
PM_{10} STP	56-035-0098	1	1-hr daily	Jonah	AQD									1317	96	8226	94	8458	97	8464	97	2687	98
PM_{10} STP	56-035-0099	1	1-hr daily	Boulder	AQD											7931	97	7846	90	5024	57	8538	97
PM_{10} STP	56-035-0100	1	1-hr daily	Daniel South	AQD											4389	99	8717	100	8620	98	7118	81
PM_{10} STP	56-037-0007	2	24 hr every 6th day	Rock Springs	AQD	59	97	60	98	60	98	59	97	58	95	60	98	58	95	59	98		

Data Validity continued

Particulate Matter 10 STP (PM_{10} STP)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
PM_{10} STP	56-037-0007	2	24-hr every 3rd day	Rock Springs	AQD																	114	97
PM_{10} STP	56-037-0200	1	1-hr daily	Wamsutter	AQD													5889	82	8654	99	8435	96
PM_{10} STP	56-039-0006	1	24 hr every 3rd day	Jackson	AQD									116	95	120	98	70	99				
PM_{10} STP	56-039-0006	1	24 hr every 6th day	Jackson	AQD			29	88	50	82	69	85										
PM_{10} STP	56-039-1006	1	24 hr every 3rd day	Jackson Fire	AQD															63	91	117	93
PM_{10} STP	56-041-0101	1	1-hr daily	Murphy Ridge	AQD															8675	99	8748	100

Data Validity continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
$PM_{2.5}$ LC	56-005-0123	1	24 hr every 3rd day	Thunder Basin	AQD											115	94	91	75	98	81	92	75
$PM_{2.5}$ LC	56-005-0877	1	24 hr every 3rd day	BTM 26-2	AQD	108	89	112	93	103	84	105	84	114	93	103	84	89	72	77	85		
$PM_{2.5}$ LC	56-005-0877	2	24 hr every 6th day	BTM 26-2	AQD													47	94	41	85		
$PM_{2.5}$ LC	56-005-0891	1	24 hr every 3rd day	BTM 36-2	AQD																	61	85
$PM_{2.5}$ LC	56-005-0891	2	24 hr every 6th day	BTM 36-2	AQD																	34	94
$PM_{2.5}$ LC	56-005-0892	1	24 hr every 3rd day	BA-4	AQD	99	93	74	91	98	94	114	94	115	93	115	94	108	89	91	100	68	94
$PM_{2.5}$ LC	56-005-0899	1	24 hr every 3rd day	BA-4	AQD	92	87	46	57	83	79	109	88	114	93	115	93	103	84	79	87	22	69
$PM_{2.5}$ LC	56-005-1899	1	24 hr every 3rd day	Buckskin	AQD																	31	79
$PM_{2.5}$ LC	56-009-0819	1	24 hr every 3rd day	Site 3	AQD	83	78	49	60	93	89	113	93	108	89	111	91	106	87	70	77	63	88
$PM_{2.5}$ LC	56-013-1003	1	24 hr every 3rd day	Lander	AQD			16	100	120	99	119	98	113	91	115	93	116	95	110	91	119	98

Data Validity continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
$PM_{2.5}$ LC	56-013-1004	1	24 hr every 3rd day	Lander	AQD	118	97	105	99														
$PM_{2.5}$ LC	56-019-9000	1	24 hr every 3rd day	Cloud Peak	AQD											115	94	115	94	111	92	107	88
$PM_{2.5}$ LC	56-021-0001	1	24 hr every 3rd day	Cheyenne	AQD	112	93	107	89	108	89	114	93	115	96	107	89	115	95	113	94	113	92
$PM_{2.5}$ LC	56-029-0001	1	24 hr every 3rd day	Cody	AQD																	64	88
$PM_{2.5}$ LC	56-029-9002	1	24 hr every 3rd day	North Absaroka	AQD											110	90	111	91	84	69	107	88
$PM_{2.5}$ LC	56-033-0001	1	24 hr every 3rd day	Sheridan	AQD	121	99	119	98	115	94	113	93	110	90	58	85						
$PM_{2.5}$ LC	56-033-0002	1	24 hr every 3rd day	Sheridan Police	AQD	121	99	119	98	118	97	116	96	118	97	119	98	118	97	111	92	122	100
$PM_{2.5}$ LC	56-033-0002	2	24 hr every 3rd day	Sheridan Police	AQD													57	93	56	93	61	100
$PM_{2.5}$ LC	56-033-0003	1	24 hr every 3rd day	Sheridan Highland Park	AQD											27	87	120	98	119	98	120	98
$PM_{2.5}$ LC	56-035-0705	1	24 hr every 3rd day	Pinedale	AQD											48	86	115	92	105	86	83	68

Data Validity continued

Particulate Matter 2.5 LC ($PM_{2.5}$ LC)

Parameter	AQD ID	POC	Duration Code	Monitoring Station Name	Operating Agency	2000		2001		2002		2003		2004		2005		2006		2007		2008	
						# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid	# Valid	% Valid
$PM_{2.5}$ LC	56-035-9000	1	24 hr every 3rd day	Bridger Wilderness	AQD									116	95	117	96	112	93	113	93		
$PM_{2.5}$ LC	56-037-0007	1	24 hr every 3rd day	Rock Springs	AQD															98	89		
$PM_{2.5}$ LC	56-039-0006	1	24 hr every 3rd day	Jackson	AQD	60	94	65	57	97	80	99	80	90	73	114	91	47	92			60	94
$PM_{2.5}$ LC	56-039-1006	1	24 hr every 3rd day	Jackson Fire	AQD													63	91	118	96		

Minimum Detection Limit

Ozone (O_3)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	Count Valid Samples	Count Below MDL	Percent Below MDL
O_3	56-005-0123	Thunder Basin	AQD	62342	12	0.0
O_3	56-005-0456	South Campbell County	AQD	42409	548	1.3
O_3	56-35-0098	Jonah	AQD	28522	258	0.9
O_3	56-035-0099	Boulder	AQD	31963	45	0.1
O_3	56-035-0100	Pinedale Gaseous	AQD	30074	738	2.5
O_3	56-037-0200	Wamsutter	AQD	23191	681	2.9

Sulfur Dioxide (SO_2)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	Count Valid Samples	Count Below MDL	Percent Below MDL
SO_2	56-013-0099	South Pass	AQD	13735	13574	98.8
SO_2	56-037-0200	Wamsutter	AQD	23244	22207	95.5
SO_2	56-041-0101	Murphy Ridge	AQD	17228	15628	90.7

Nitrogen Oxide (NOx)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	Count Valid Samples	Count Below MDL	Percent Below MDL
NOx	56-005-0123	Thunder Basin	AQD	60146	10362	17.2
NOx	56-005-0456	South Campbell County	AQD	40233	2504	6.2
NOx	56-005-0892	BA-4	AQD	30571	16751	54.8
NOx	56-009-0819	Site 3	AQD	28084	22042	78.5
NOx	56-013-0099	South Pass	AQD	11817	6082	51.5
NOx	56-035-0098	Jonah	AQD	28390	10421	36.7
NOx	56-035-0099	Boulder	AQD	26348	19669	74.7
NOx	56-035-0100	Daniel	AQD	30157	29612	98.2
NOx	56-037-0200	Wamsutter	AQD	23009	484	2.1
NOx	56-041-0101	Murphy Ridge	AQD	17159	14810	86.3

Nitrogen Dioxide (NO_2)

Parameter	AQD ID	Monitoring Station Name	Operating Agency	Count Valid Samples	Count Below MDL	Percent Below MDL
NO_2	56-005-0123	Thunder Basin	AQD	60148	6211	10.3
NO_2	56-005-0456	South Campbell County	AQD	40233	3250	8.1
NO_2	56-005-0892	BA-4	AQD	30599	17725	57.9
NO_2	56-009-0819	Site 3	AQD	28297	22510	79.5
NO_2	56-013-0099	South Pass	AQD	11865	6475	54.6
NO_2	56-035-0098	Jonah	AQD	28484	11829	41.5
NO_2	56-035-0099	Boulder	AQD	26348	20541	78
NO_2	56-035-0100	Daniel	AQD	30100	29832	99.1
NO_2	56-037-0200	Wamsutter	AQD	23009	736	3.2
NO_2	56-041-0101	Murphy Ridge	AQD	17160	14838	86.5

Monitored Trends

AQS ID	Monitoring Station Name	Operating Agency	Pollutant	Slope	Intercept	Statistical significance	% change per year	First Year	Last Year	# of values	Trend classification
56-005-0123	Thunder Basin	AQD	Ozone	0	0.39	38.4	-0.28	2001	2008	8	Not significantly different from zero
56-005-0456	South Campbell County	AQD	Ozone	0	-1.73	89.42	1.43	2004	2008	5	Not significantly different from zero
56-005-0877	BTM 26-2	AQD	PM2.5	0.03	-61.29	43.13	0.47	2000	2007	8	Not significantly different from zero
56-005-0892	BA-4	ADQ	PM2.5	0.03	-50.57	23.76	0.46	2000	2008	9	Not significantly different from zero
56-005-0899	Buckskin	AQD	PM2.5	-0.01	30.5	8.96	-0.21	2000	2007	8	Not significantly different from zero
56-009-0819	Site 3	AQD	PM2.5	0.04	-84.63	52.29	1.09	2000	2008	9	Not significantly different from zero
56-013-1003	Lander	AQD	PM2.5	-0.28	567.32	91.78	-2.61	2002	2008	7	Not significantly different from zero
56-021-0001	Cheyenne	AQD	PM2.5	-0.14	275.46	99.06	-2.28	2000	2008	9	Decreasing
56-033-0001	Sheridan	AQD	PM2.5	-0.75	1515.77	99.3	-5.56	2000	2005	6	Decreasing

Monitored Trends continued

AQS ID	Monitoring Station Name	Operating Agency	Pollutant	Slope	Intercept	Statistical significance	% change per year	First Year	Last Year	# of values	Trend classification
56-033-0002	Sheridan Police	AQD	PM2.5	-0.4	820.37	99.93	-3.12	2000	2008	8	Decreasing
56-039-0006	Jackson	AQD	PM2.5	-0.44	878.86	98.91	-4.54	2001	2007	7	Decreasing
56-005-0123	Thunder Basin	AQD	NO2	0	0.22	99.88	-3.82	2001	2008	8	Decreasing
56-005-0456	South Campbell County	AQD	NO2	0	0.59	83.66	-5.27	2004	2008	5	Not significantly different from zero
56-001-0006	Laramie	AQD	PM10	-0.51	1051.09	92.69	-1.87	2000	2008	9	Not significantly different from zero
56-005-0099	Wright	AQD	PM10	0.21	-401.37	26.56	1.06	2003	2008	6	Not significantly different from zero
56-005-0456	South Campbell County	AQD	PM10	-0.09	189.88	13.71	-0.59	2003	2008	6	Not significantly different from zero
56-005-1002	Gillette	AQD	PM10	0.03	-44.96	6.47	0.15	2000	2008	9	Not significantly different from zero

Monitored Trends continued

AQS ID	Monitoring Station Name	Operating Agency	Pollutant	Slope	Intercept	Statistical significance	% change per year	First Year	Last Year	# of values	Trend classification
56-013-1003	Lander	AQD	PM10	-0.36	748.74	96.56	-1.46	2000	2008	9	Decreasing
56-021-0001	Cheyenne	AQD	PM10	-0.61	1238.99	96.11	-3.16	2000	2005	6	Decreasing
56-025-0001	Casper	AQD	PM10	-0.07	149.74	6.82	-0.3	2000	2005	6	Not significantly different from zero
56-029-0001	Cody	AQD	PM10	-0.78	1575.12	95.7	-3.75	2000	2008	9	Decreasing
56-033-0001	Sheridan	AQD	PM10	-0.71	1451.05	82.68	-2.1	2000	2005	6	Not significantly different from zero
56-033-0002	Sheridan Police	AQD	PM10	1.09	-2159.99	97.65	3.19	2000	2005	6	Increasing
56-037-0007	Rock Springs	AQD	PM10	0.39	-760.26	86.37	1.51	2000	2008	9	Not significantly different from zero
56-039-0006	Jackson	AQD	PM10	0.5	-982.12	53.04	2.12	2002	2006	5	Not significantly different from zero

Appendix A: Measured Concentration Analysis

Summary statistics for data from 2006-2008 for all AQD pollutants and sites meeting completeness criteria.

Pollutant Code	AQS Site	Site Name	N of cases	Mean	Standard Deviation	Minimum	Pct10	Pct25	Pct50	Pct75	Pct90	Maximum
SO_2	560130099	South Pass	13735	0.2	0.5	0	0	0	0	0	1	12
SO_2	560370200	Wamsutter	23244	0.5	0.7	0	0	0	0.4	0.8	1.1	11.4
SO_2	560410101	Murphy Ridge	17228	0.8	1.1	0	0	0.1	0.4	1.1	1.9	8.9
NO_2	560050123	Thunder Basin	22223	1.80	1.7	0	0	1	1	2	4	32
NO_2	560050456	Campbell County	21578	3.42	4.6	0	0	1	2	4	8	48
NO_2	560050892	Belle Ayr	8526	7.65	9.0	0	0	0	5	14	21	151
NO_2	560090819	Antelope	6004	2.69	5.5	0	0	0	0	4	9	43
NO_2	560130099	South Pass	11865	0.54	0.7	0	0	0	0	1	1	11
NO_2	560350098	Jonah	19087	11.98	13.2	0	1	2	7	18	30	148
NO_2	560350099	Boulder	18722	2.20	4.1	0	0	0	1	3	6	49
NO_2	560350100	Daniel South	25805	0.23	0.9	0	0	0	0	0	1	62
NO_2	560370200	Wamsutter	23009	6.16	6.8	0	1	2	4	8	15	63
NO_2	560410101	Murphy Ridge	17160	2.03	2.7	0	0	0	1	3	5	41

Pollutant Code	AQS Site	Site Name	N of cases	Mean	Standard Deviation	Minimum	Pct10	Pct25	Pct50	Pct75	Pct90	Maximum
O_3 - 8hr max	560050123	Thunder Basin	1055	46.0	11.6	18	32	37	45	54	62	81
O_3 - 8hr max	560050456	Campbell County	974	44.3	10.4	13	32	36	43	52	59	76
O_3 - 8hr max	560130099	South Pass	536	49.5	9.1	26	38	43	49	57	61	82
O_3 - 8hr max	560350098	Jonah	792	47.4	11.1	19	33	39	48	56	61	102
O_3 - 8hr max	560350099	Boulder	1010	50.7	10.8	24	37	43	51	58	63	122
O_3 - 8hr max	560350100	Daniel South	1063	47.6	11.2	0	36	41	48	55	60	82
O_3 - 8hr max	560370200	Wamsutter	975	46.0	10.3	12	32	39	47	53	59	87
O_3 - 8hr max	560410101	Murphy Ridge	714	46.2	9.3	23	35	39	46	53	59	73

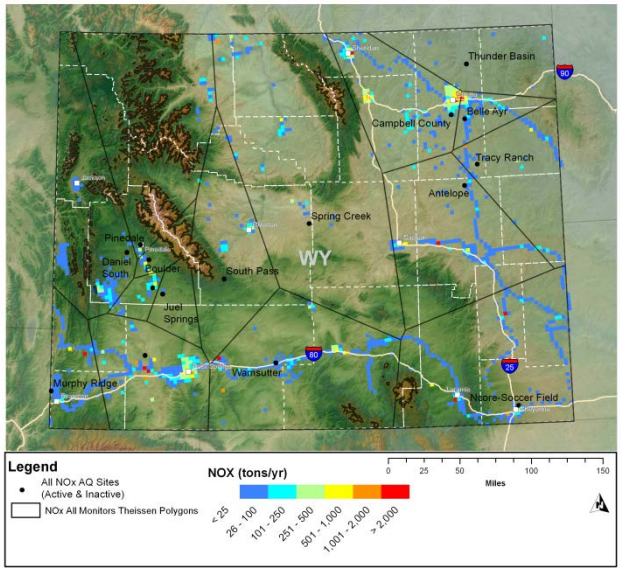
Pollutant Code	AQS Site	Site Name	N of cases	Mean	Standard Deviation	Minimum	Pct10	Pct25	Pct50	Pct75	Pct90	Maximum
$PM_{2.5}$	560050877	(BTM) 26-2	254	6.7	4.1	1.4	3.4	4.1	5.8	7.8	11.0	30.0
$PM_{2.5}$	560050891	(BTM) 36-2	95	5.4	3.3	1.4	2.3	3.3	4.6	6.8	9.5	17.3
$PM_{2.5}$	560050892	Belle Ayr	267	5.9	3.3	0.2	2.5	3.8	5.1	7.6	9.3	20.8
$PM_{2.5}$	560050899	Buckskin	204	5.5	4.0	0.8	1.9	3.0	4.6	6.6	9.9	30.9
$PM_{2.5}$	560051899	Buckskin Mine North	31	5.1	3.2	0.3	1.2	2.4	5.3	6.6	9.5	11.8
$PM_{2.5}$	560090819	Antelope	239	4.0	2.9	0.3	1.4	2.0	3.3	5.4	7.3	22.0
$PM_{2.5}$	560131003	Lander	345	7.8	5.8	0.3	2.9	4.0	5.8	9.5	16.3	34.9
$PM_{2.5}$	560210001	Cheyenne	341	4.4	2.6	0.1	1.6	2.5	4.0	5.7	7.2	19.6
$PM_{2.5}$	560290001	Cody	64	6.5	6.3	0.6	1.9	3.1	4.8	7.9	12.2	42.3
$PM_{2.5}$	560330002	Sheridan- Police St.	525	9.0	5.5	1.5	3.5	5.2	7.7	11.3	16.0	34.8
$PM_{2.5}$	560330003	Sheridan- Highland Pk	359	5.7	3.7	0.8	2.4	3.5	4.9	6.9	10.1	30.5
$PM_{2.5}$	560350705	Pinedale	303	6.4	4.7	0.5	3.0	3.9	5.3	7.5	10.8	49.8
$PM_{2.5}$	560370007	Rock Springs	98	6.7	3.7	0.7	3.1	4.2	6.1	8.4	10.5	24.3
$PM_{2.5}$	560390006	200 So Willow	161	6.2	4.1	1.3	2.8	3.5	5.3	7.2	11.7	23.3
$PM_{2.5}$	560391006	Jackson Fire Station	181	5.1	2.8	1.3	2.2	3.1	4.5	6.6	8.5	21.8

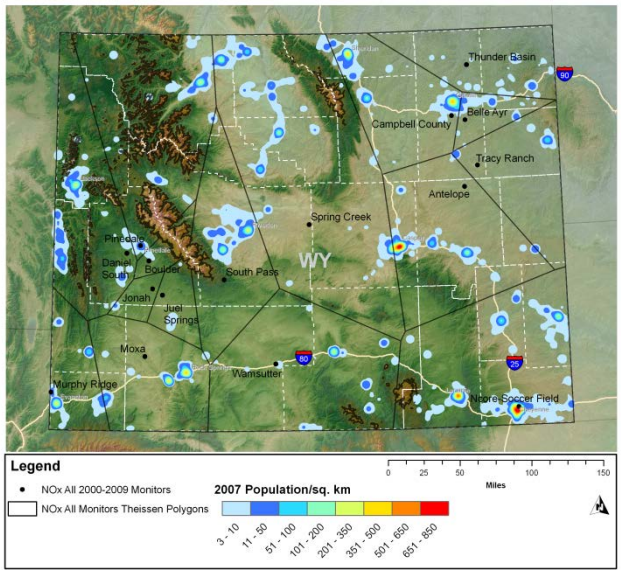
Pollutant Code	AQS Site	Site Name	N of cases	Mean	Standard Deviation	Minimum	Pct10	Pct25	Pct50	Pct75	Pct90	Maximum
PM_{10}	560010006	Laramie	161	17.2	9.9	1.0	7.0	11.0	16.0	21.0	28.4	60.0
PM_{10}	560050099	Wright	167	14.8	11.7	0.0	4.0	6.0	11.0	19.0	33.0	52.0
PM_{10}	560050456	Campbell County	192	11.7	13.3	0.0	3.0	5.0	8.0	13.0	23.3	116.0
PM_{10}	560051002	Gillette	168	17.6	11.6	2.0	6.0	9.0	15.0	23.0	32.0	62.0
PM_{10}	560131003	Lander	317	16.9	8.8	0.0	8.0	11.0	16.0	22.0	27.0	80.0
PM_{10}	560210001	Cheyenne	460	11.8	6.3	1.0	5.0	7.0	11.0	15.0	19.0	47.0
PM_{10}	560250001	Casper	405	15.6	8.8	1.0	6.0	9.0	15.0	21.0	26.0	71.0
PM_{10}	560290001	Cody	185	10.9	9.7	0.0	3.0	4.0	8.0	15.0	21.0	75.0
PM_{10}	560330002	Sheridan- Police St.	782	17.5	19.7	0.0	0.0	0.0	13.0	29.0	43.0	152.0
PM_{10}	560330003	Sheridan- Highland Pk	396	14.6	8.1	1.0	5.0	9.0	13.0	19.0	26.0	53.0
PM_{10}	560330099	Arvada	70	13.2	12.0	0.0	3.0	5.0	9.0	17.0	34.0	45.0
PM_{10}	560370007	Rock Springs	231	21.6	12.0	2.0	8.0	13.0	20.0	27.0	36.0	84.0
PM_{10}	560390006	200 So Willow	74	17.4	10.7	3.0	7.0	9.0	16.0	21.0	25.0	63.0
PM_{10}	560391006	Jackson Fire Station	176	14.2	10.0	0.0	5.0	7.5	13.0	19.0	24.9	78.0

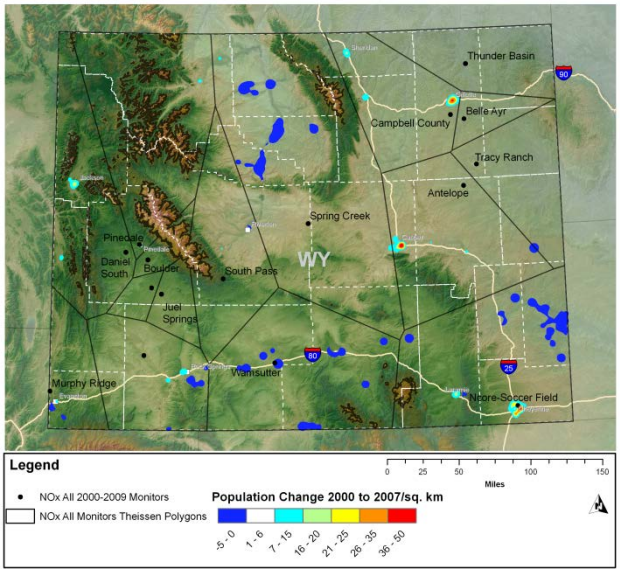
Appendix B

Supporting Materials for Section 4

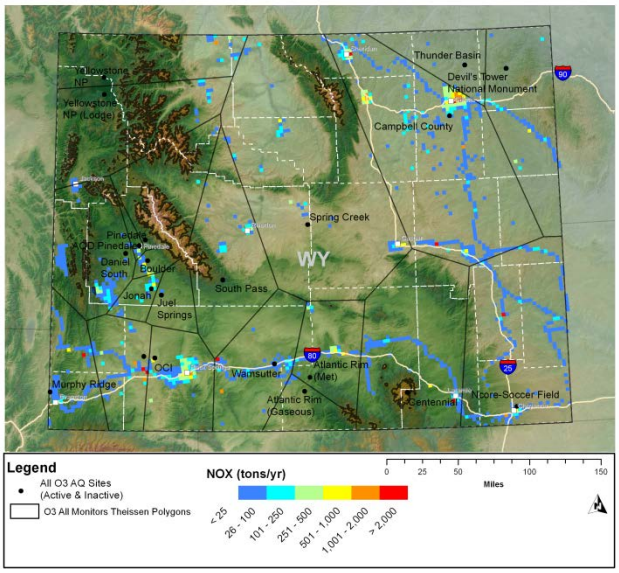
No_x: Gridded Emission and Population Graphics

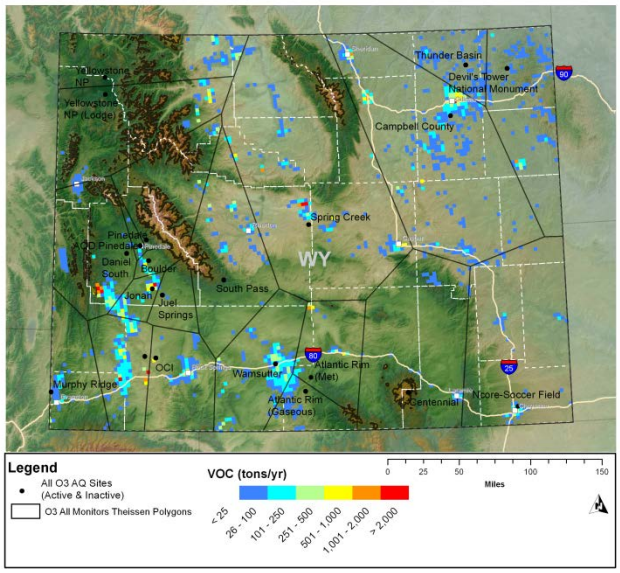


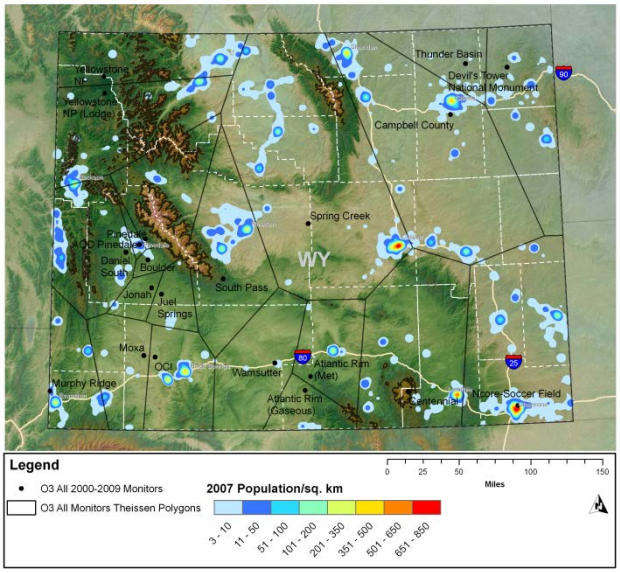


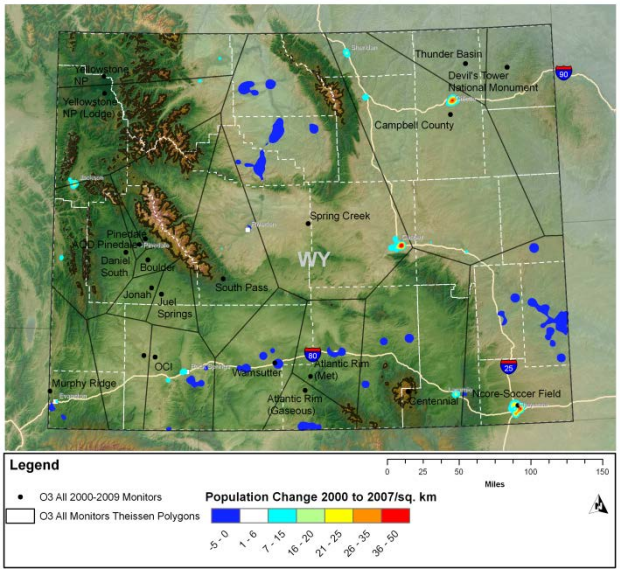


O_3: Gridded Emissions (NO_x and VOCs) and Population Graphics

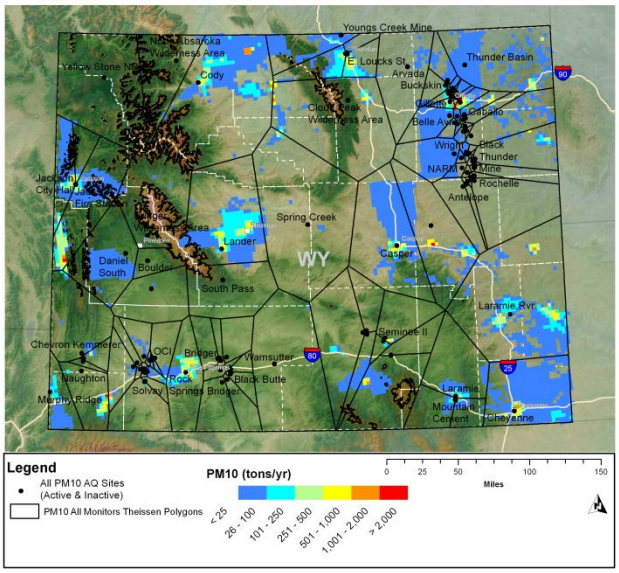


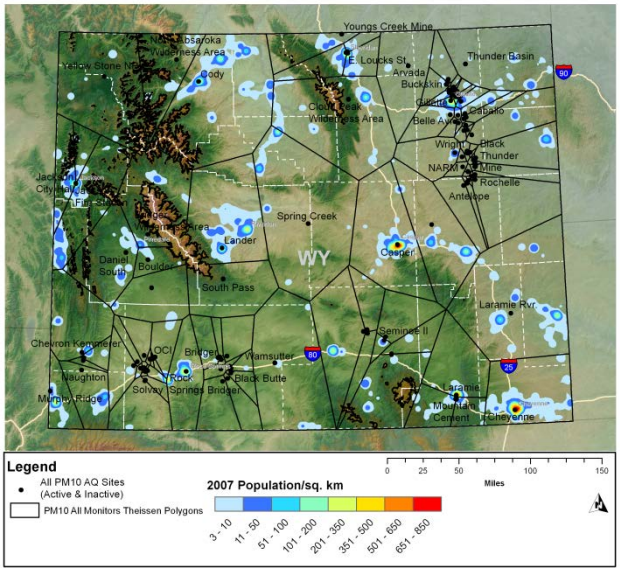


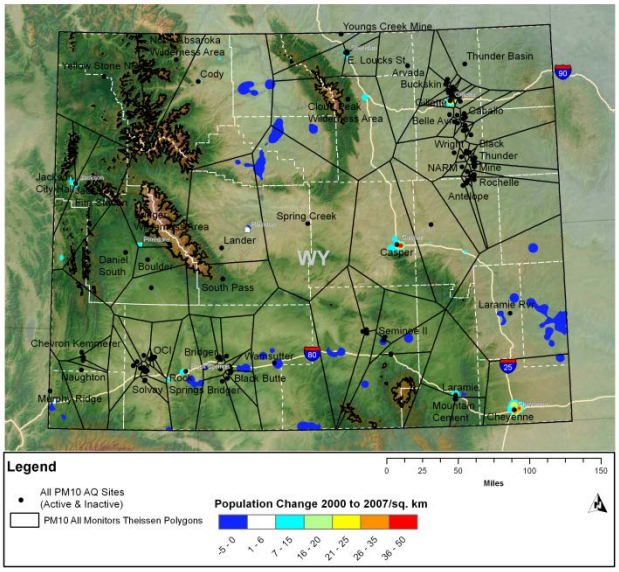




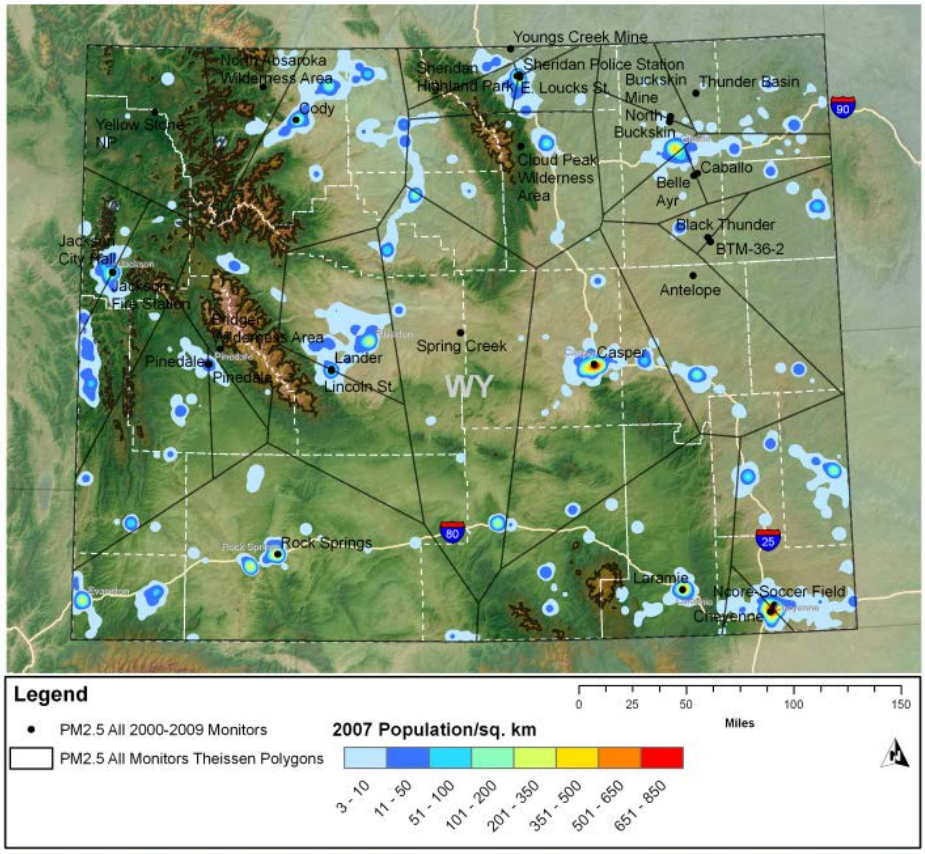
PM_{10}: Gridded Emission and Population Graphics

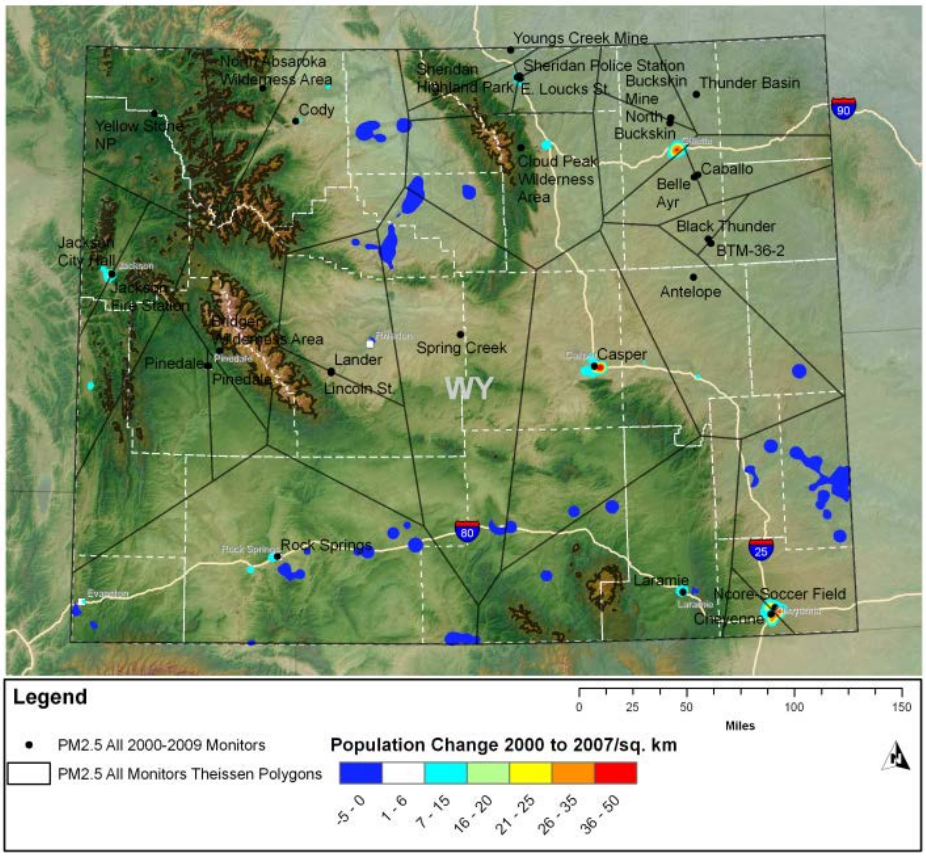




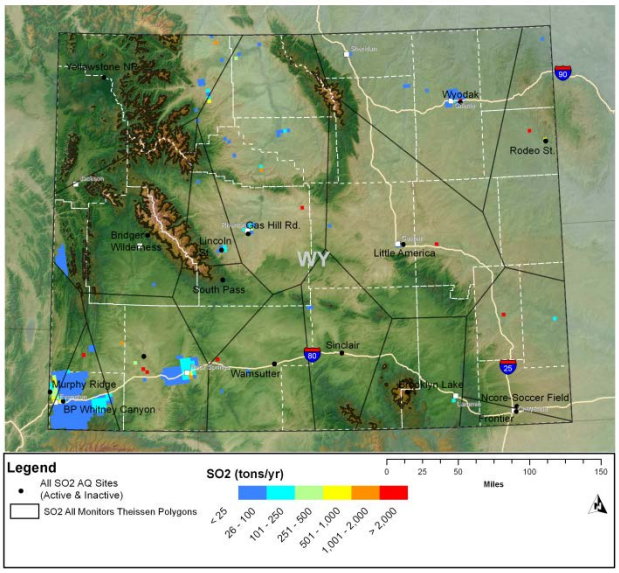


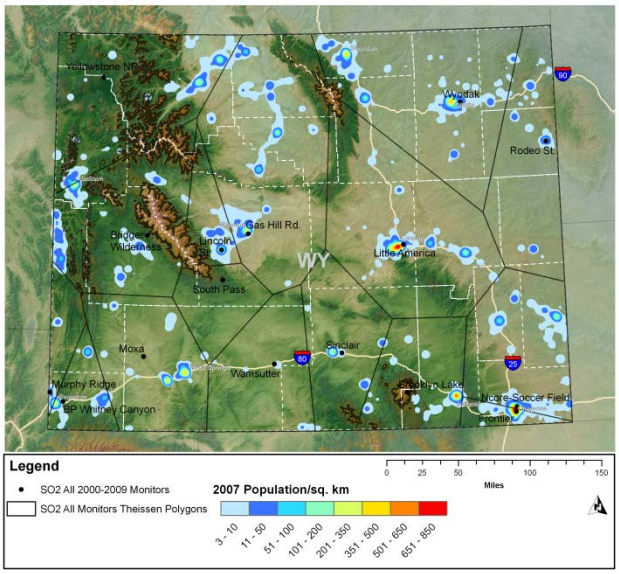
$PM_{2.5}$: Population Graphics

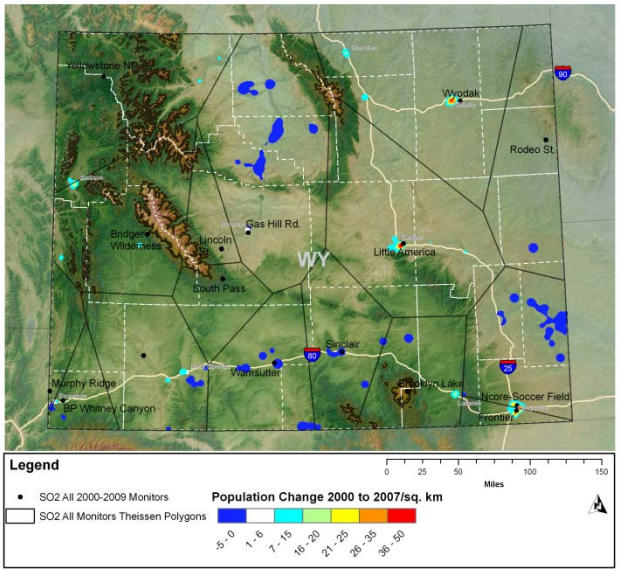




SO_2: Gridded Emissions and Population Graphics







Appendix C

Supporting Materials for Section 5

Industrial Monitoring in Wyoming

AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-007-0100	Sun Dog	Anadarko	X	X			
56-007-0099	Jolly Roger	Anadarko					
56-007-0826	Seminoe II	Arch Coal Company			X		
56-007-8110	Site 811 UW	Arch Coal Company			X		
56-007-8120	Site 812 DW	Arch Coal Company			X		
56-031-0805	PM10 Collocated	Basin Electric			X		
56-037-0868	Site 868	Black Butte Coal Company			X		
56-037-1236	Upwind	Black Butte Coal Company			X		
56-037-1414	Pit 14	Black Butte Coal Company			X		
56-037-1868	I-80	Black Butte Coal Company			X		
56-037-2004	Office	Black Butte Coal Company					
56-037-0852	Site 852	Black Butte Coal Company			X		
56-005-0857	Site 4	Black Hills Power					X
56-041-0002	Whitney Canyon	BP					
56-037-0860	JB-4	Bridger Coal Company			X		
56-037-0867	JB-5	Bridger Coal Company			X		
56-037-2860	JB-2	Bridger Coal Company					
56-005-0886	C-8	Caballo Coal Company			X	X	
56-005-0908	C-9	Caballo Coal Company			X		

Industrial Monitoring in Wyoming (p.2)

AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-005-2908	C-1 Met	Caballo Coal Company					
56-005-0826	RA-23 (Hilltop)	Caballo Coal Company			X		
56-005-0895	RA-24 (North)	Caballo Coal Company			X		
56-023-0800	Site 800	Chevron Mining, Inc.			X		
56-023-0814	SB-111	Chevron Mining, Inc.			X		
56-023-0815	SB4B	Chevron Mining, Inc.			X		
56-041-CC	Carter Creek	Chevron USA					
56-037-0010	Site 1P	FMC			X		
56-037-0862	Site 7	FMC			X		
56-037-0866	Site 866-B	FMC			X		
56-037-1002	Site 002	FMC			X		
56-005-0802	BA-1	Foundation Coal					
56-005-0892	BA-4	Foundation Coal		X		X	
56-005-0893	BA-3	Foundation Coal			X		
56-005-0808	EB-3S	Foundation Coal			X		
56-005-0900	EB-5	Foundation Coal			X		
56-005-0906	EB-2	Foundation Coal			X		
56-037-0012	Site 3B	General Chemical			X		
56-037-0013	Site 1B PM10 Collocated	General Chemical			X		
56-037-0014	Site 4B	General Chemical			X		

Industrial Monitoring in Wyoming (p.3)

AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-005-2908	C-1 Met	Caballo Coal Company					
56-005-0826	RA-23 (Hilltop)	Caballo Coal Company			X		
56-005-0895	RA-24 (North)	Caballo Coal Company			X		
56-023-0800	Site 800	Chevron Mining, Inc.			X		
56-023-0814	SB-111	Chevron Mining, Inc.			X		
56-023-0815	SB4B	Chevron Mining, Inc.			X		
56-041-CC	Carter Creek	Chevron USA					
56-037-0010	Site 1P	FMC			X		
56-037-0862	Site 7	FMC			X		
56-037-0866	Site 866-B	FMC			X		
56-037-1002	Site 002	FMC			X		
56-005-0802	BA-1	Foundation Coal					
56-005-0892	BA-4	Foundation Coal		X		X	
56-005-0893	BA-3	Foundation Coal			X		
56-005-0808	EB-3S	Foundation Coal			X		
56-005-0900	EB-5	Foundation Coal			X		
56-005-0906	EB-2	Foundation Coal			X		
56-037-0012	Site 3B	General Chemical			X		
56-037-0013	Site 1B PM10 Collocated	General Chemical			X		
56-037-0014	Site 4B	General Chemical			X		

Industrial Monitoring in Wyoming (p.4)

AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-005-0884	West	Kiewit			X		
56-005-1899	North	Kiewit				X	
56-001-0800	East TEOM	Mountain Cement			X		
56-001-0802	West	Mountain Cement					
56-001-0801	North TEOM	Mountain Cement			X		
56-037-0812	Site 3	OCI Of Wyo, LTD			X		
56-037-0898	Site 4	OCI Of Wyo, LTD			X		
56-037-0851	Site 851b	Pacificorp			X		
56-037-0901	Site 901	Pacificorp			X		
56-037-2851	Met	Pacificorp					
56-023-0820	Naughton	Pacificorp			X		
56-005-0088	NA-8	Powder River Coal Company			X		
56-005-0869	RO-1	Powder River Coal Company			X		
56-005-1111	Met	Powder River Coal Company					
56-005-1900	NA-7	Powder River Coal Company			X		
56-005-0881	Site 4 PM10	Rio Tinto			X		
56-009-0850	Site 5 PM10	Rio Tinto			X		
56-009-0851	Site 6 PM10	Rio Tinto			X		

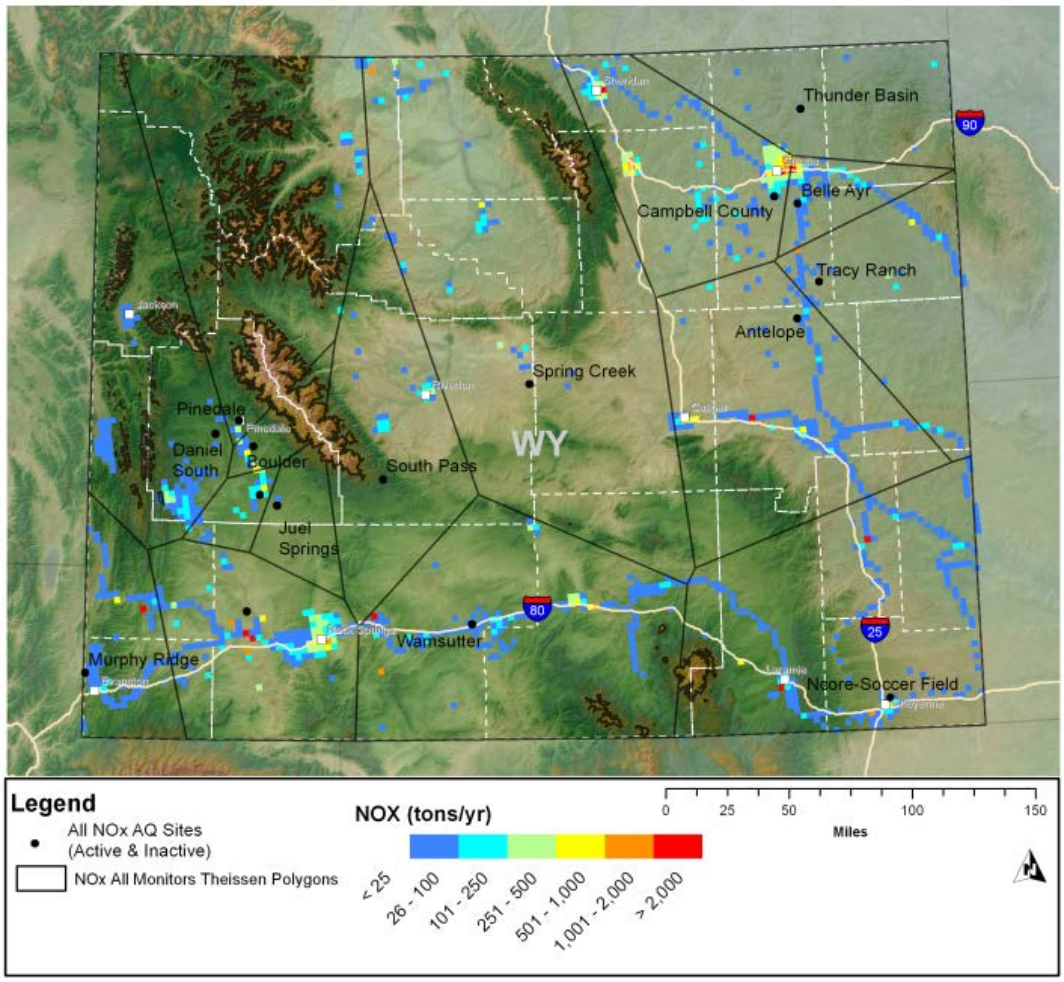
Industrial Monitoring in Wyoming (p.5)

AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-009-2819	Met	Rio Tinto					
56-005-0883	CRC-W	Rio Tinto			X		
56-005-0885	CRC-E	Rio Tinto			X		
56-005-0889	CRC-S	Rio Tinto			X		
56-005-1000	CRC-Met	Rio Tinto					
56-005-0875	JRM-3	Rio Tinto			X		
56-005-0894	JRM-4	Rio Tinto			X		
56-005-1917	JRM- Met or JRM #5	Rio Tinto			X		
56-037-SIM	Simplot	Simplot Phosphates					
56-025-2601	Sinclair - Casper	Sinclair Casper Refining Co.					X
56-007-0850	Sinclair - Sinclair	Sinclair Wyoming Refining Co.					X
56-037-0847	P1	Solvay Chemicals Inc.			X		
56-037-0848	P2B PM10 Collocated	Solvay Chemicals Inc.			X		
56-037-SMET	P3 Met	Solvay Chemicals Inc.					
56-005-0907	Site 12 Met	Thunder Basin Coal Company					
56-005-1115	Met	Thunder Basin Coal Company					
56-005-1877	Site 25	Thunder Basin Coal Company			X		
56-005-1915	Site 9	Thunder Basin Coal Company			X		
56-005-0841	CCM 7-1	Thunder Basin Coal Company			X		

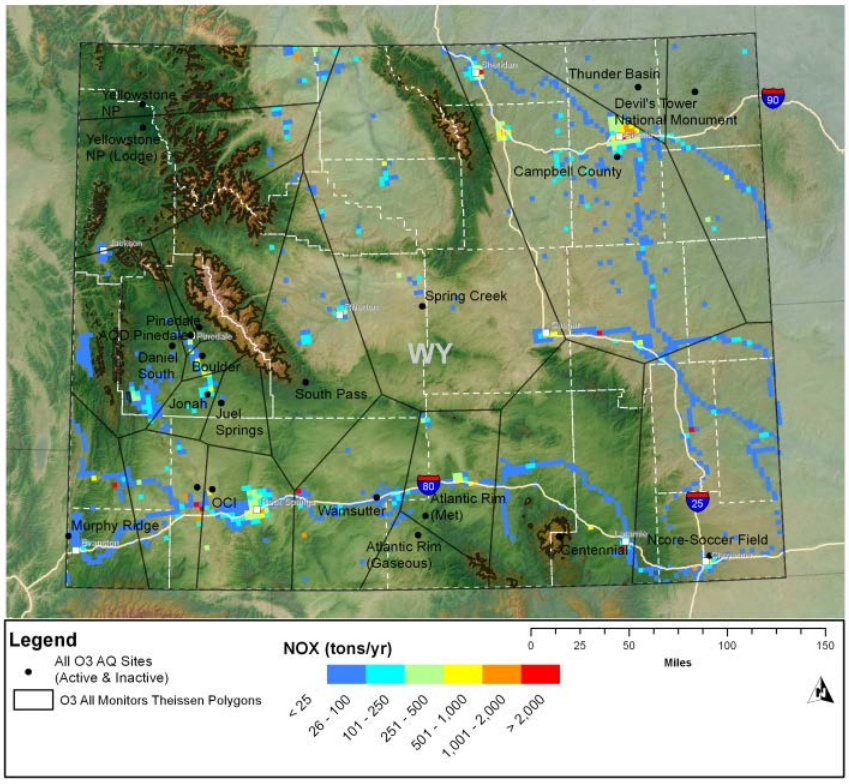
Industrial Monitoring in Wyoming (p.6)

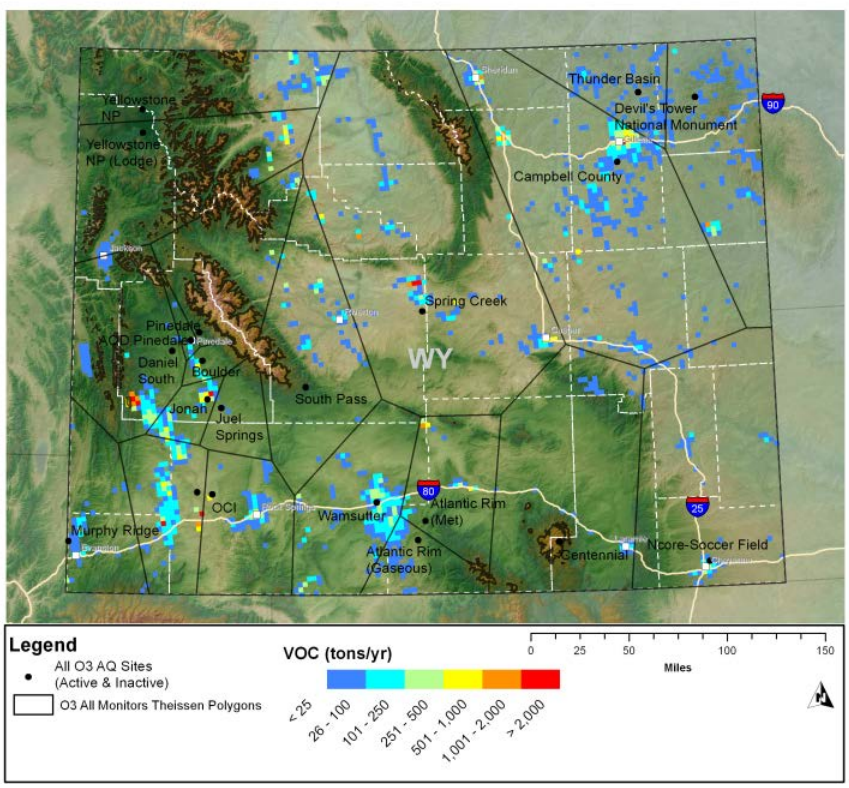
AQS ID	Monitoring Station Name	Operating Agency	Ozone	NO_2	PM_{10}	$PM_{2.5}$	SO_2
56-005-0890	CCM-26-1	Thunder Basin Coal Company			X		
56-005-1112	Met	Thunder Basin Coal Company					
56-013-0232	Spring Creek	WDEQ - AQD	X	X	X	X	
56-005-0879	Met	Western Fuels - Wyoming					
56-005-1879	Site 2	Western Fuels - Wyoming			X		
56-005-1896	Site 3	Western Fuels - Wyoming			X		
56-023-2000	Opal Gas Plant	Williams					
56-005-0901	CP-1 - Wydak Site 1 North	Wyodak Resources Development Corp.			X		
56-045-0800	Newcastle	Wyoming Refining					
56-033-NA15	Site 1	Young's Creek Mining Company					
56-005-1110	Spotted Horse	Anadarko					

NO_x: Gridded Emissions

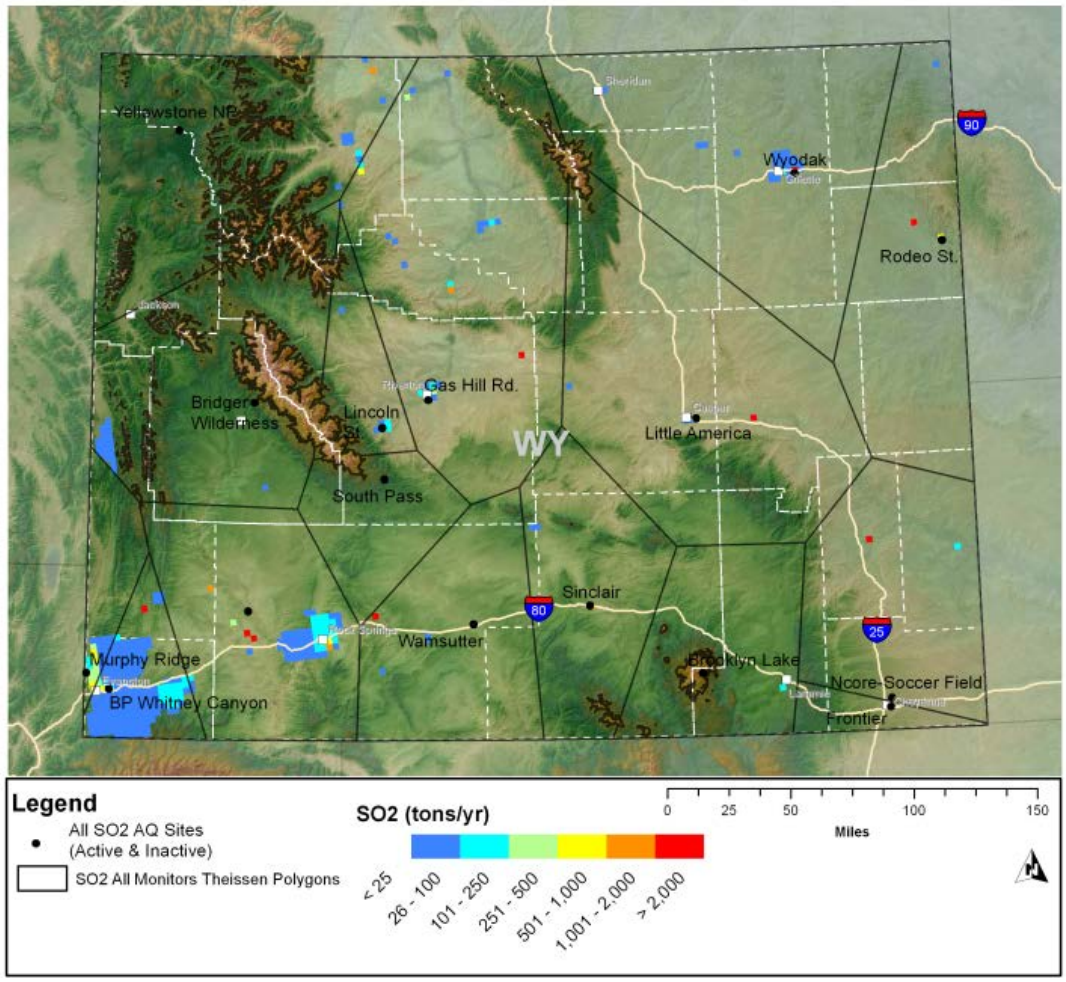


O_3 : Gridded Emission of NOx and VOCs

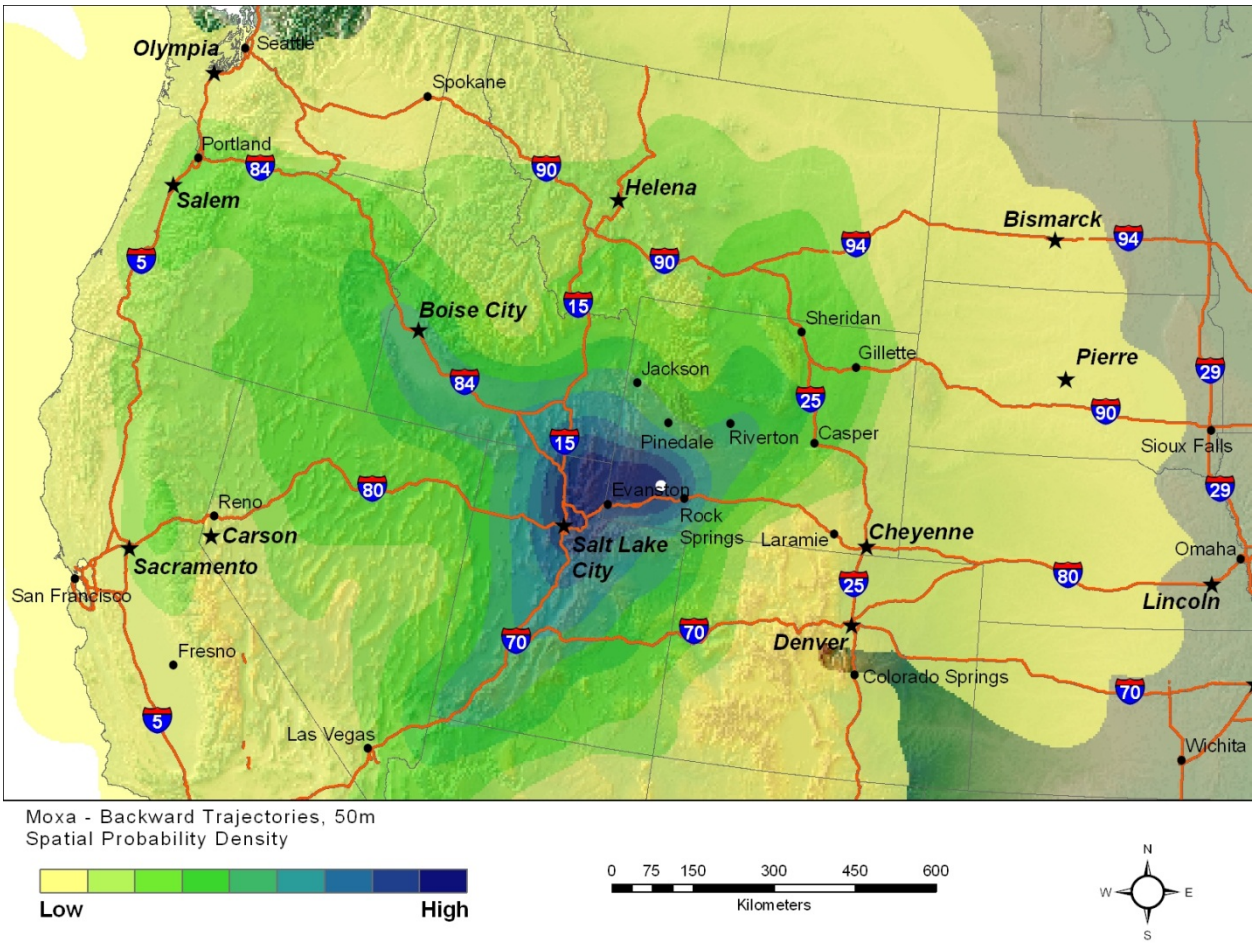




SO_2: Gridded Emission



Spatial Probability Density from Moxa Monitoring Station



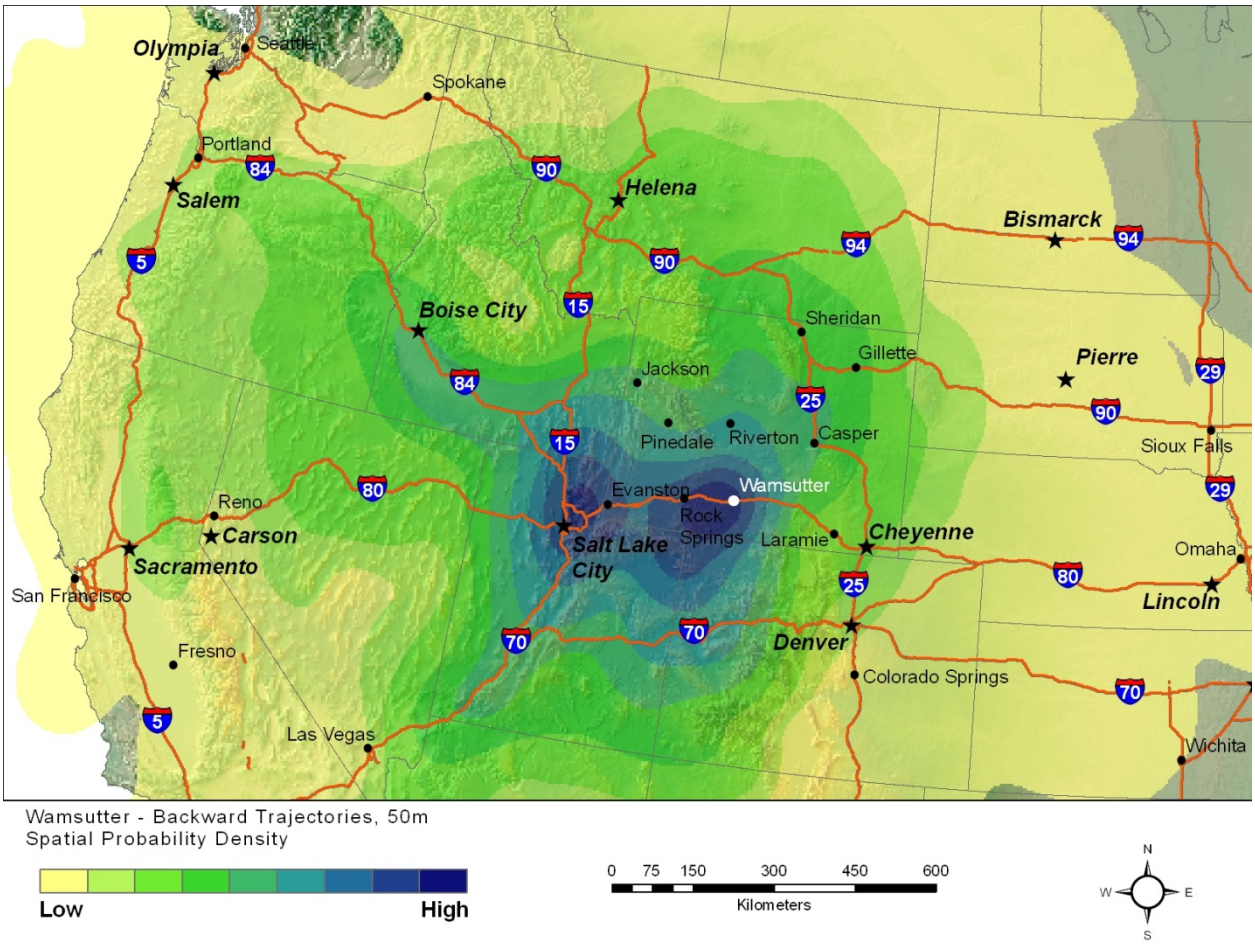
Moxa - Backward Trajectories, 50m
Spatial Probability Density

Low High

0 75 150 300 450 600
Kilometers

N W E S

Spatial Probability Density from Wamsutter Monitoring Station



Wamsutter - Backward Trajectories, 50m
Spatial Probability Density

Low High

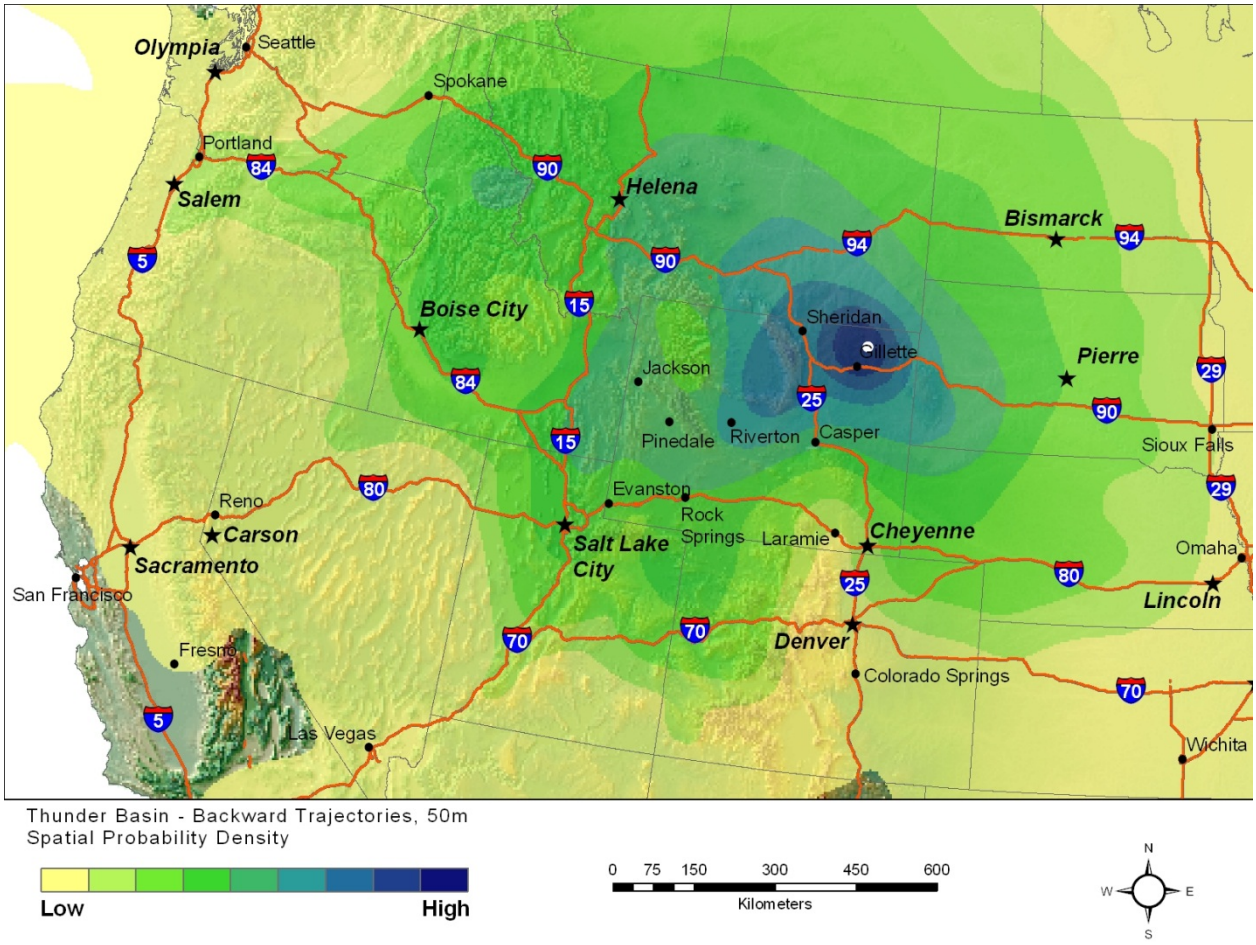
0 75 150 300 450 600
Kilometers

N W E S

Appendix D

Supporting Materials for Section 6

Spatial Probability Density for Thunder Basin Monitoring Station



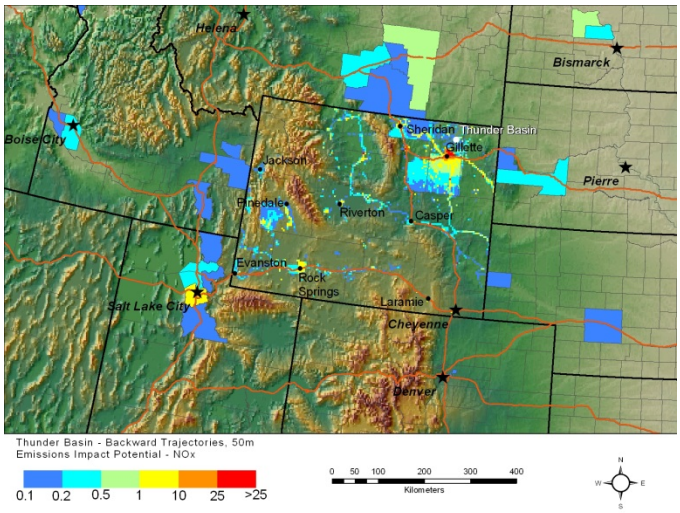
Thunder Basin - Backward Trajectories, 50m
Spatial Probability Density

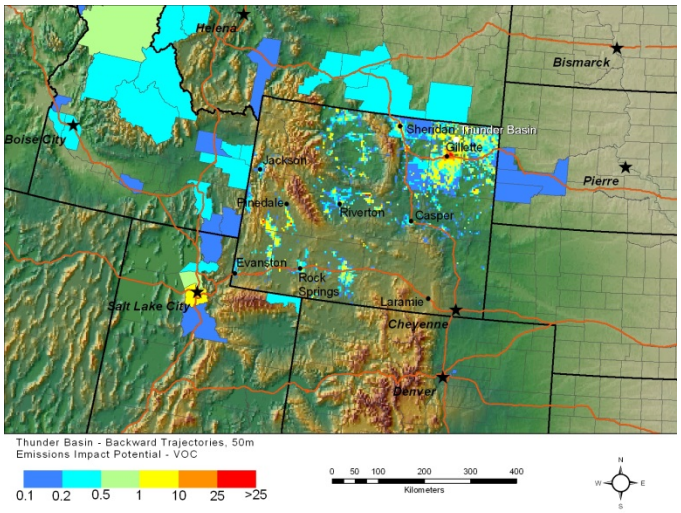
Low — High

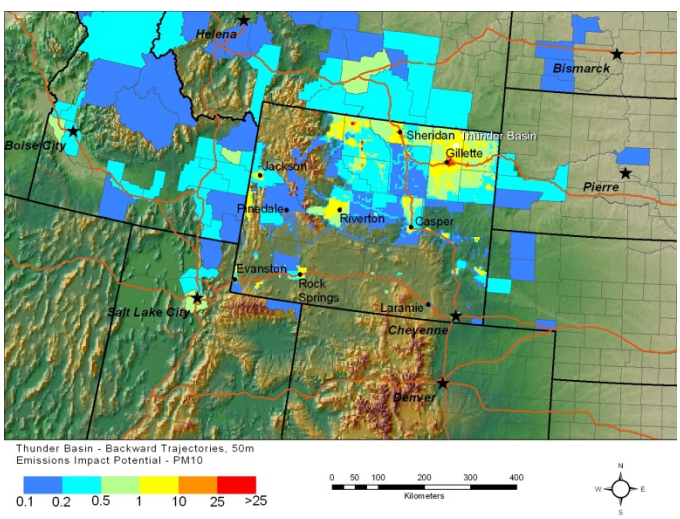
0 75 150 300 450 600
Kilometers

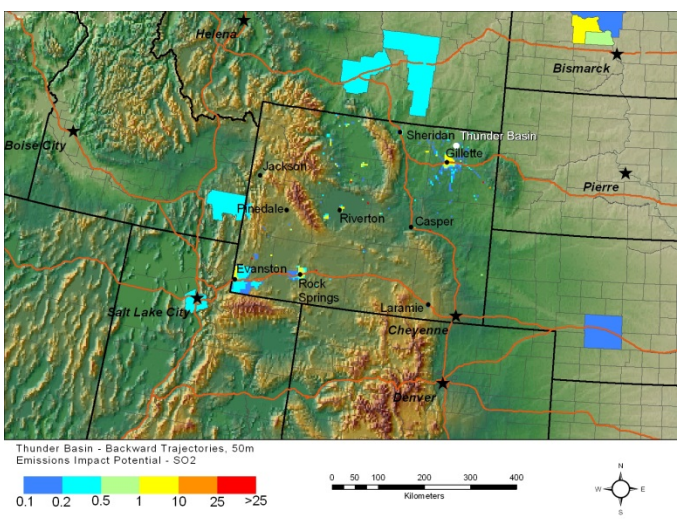
N W E S

Emission Impact Potential for Thunder Basin Monitoring Station

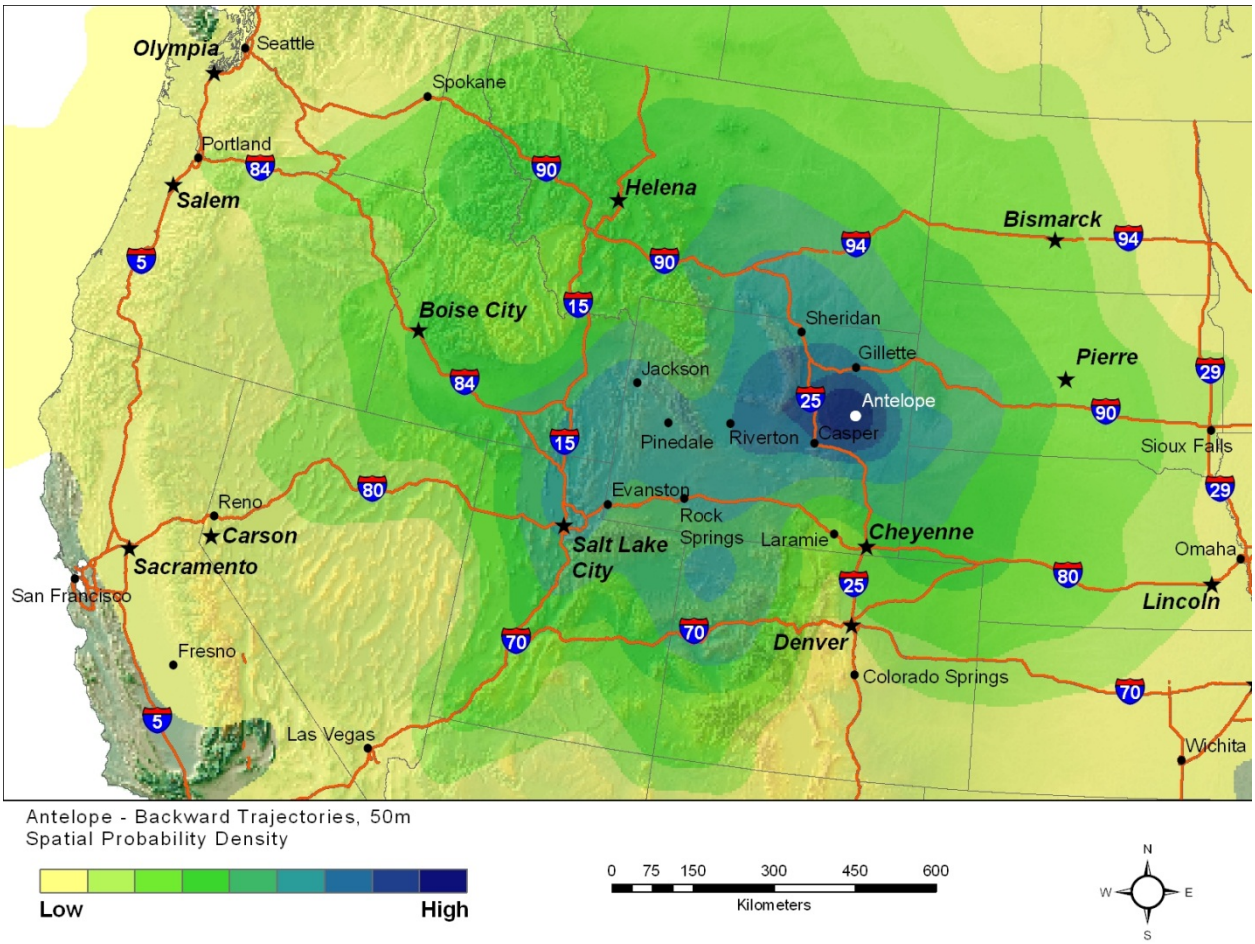








Spatial Probability Density for Antelope Monitoring Station



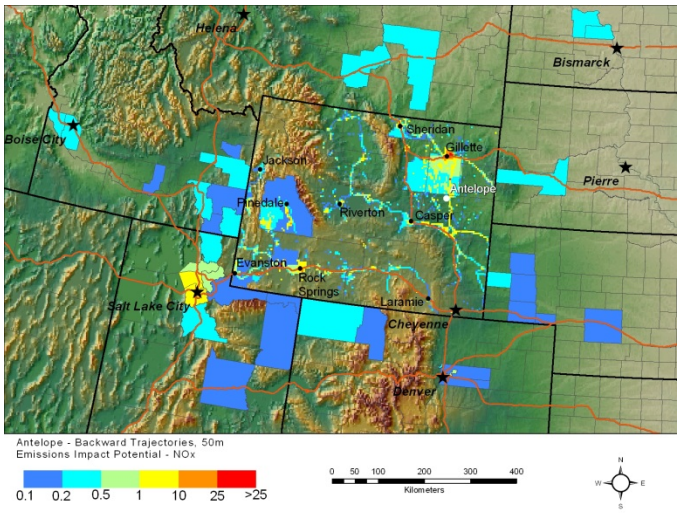
Antelope - Backward Trajectories, 50m
Spatial Probability Density

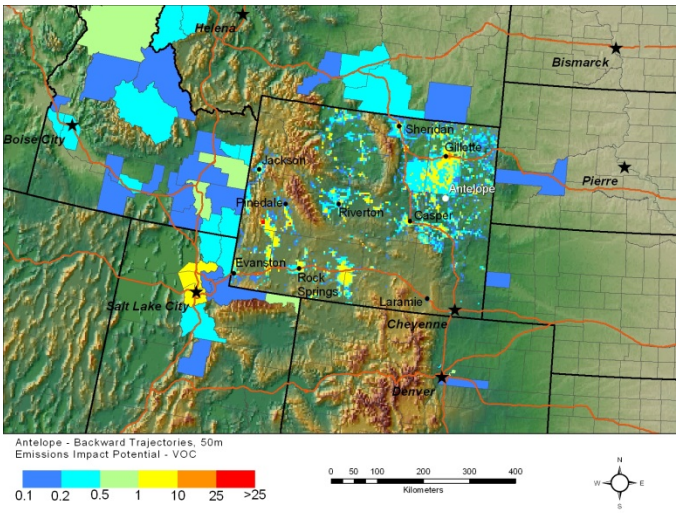
Low — High

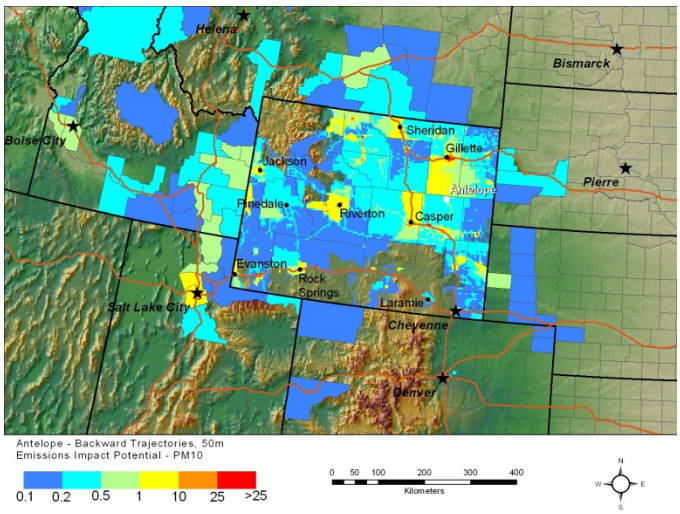
0 75 150 300 450 600
Kilometers

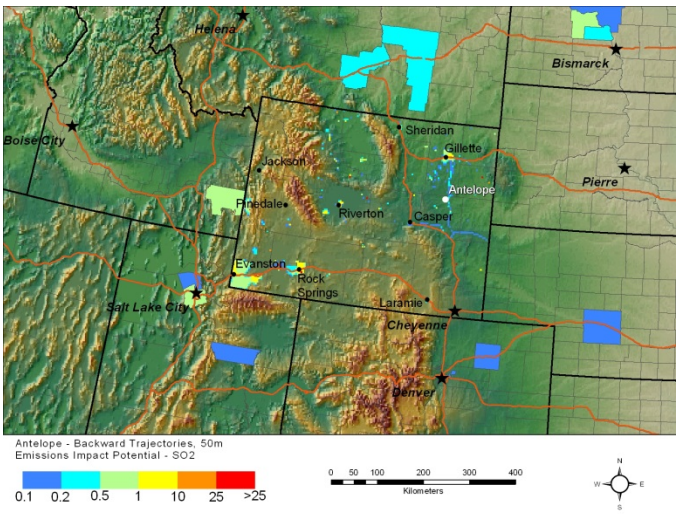
N W E S

Emission Impact Potential for Antelope Monitoring Station

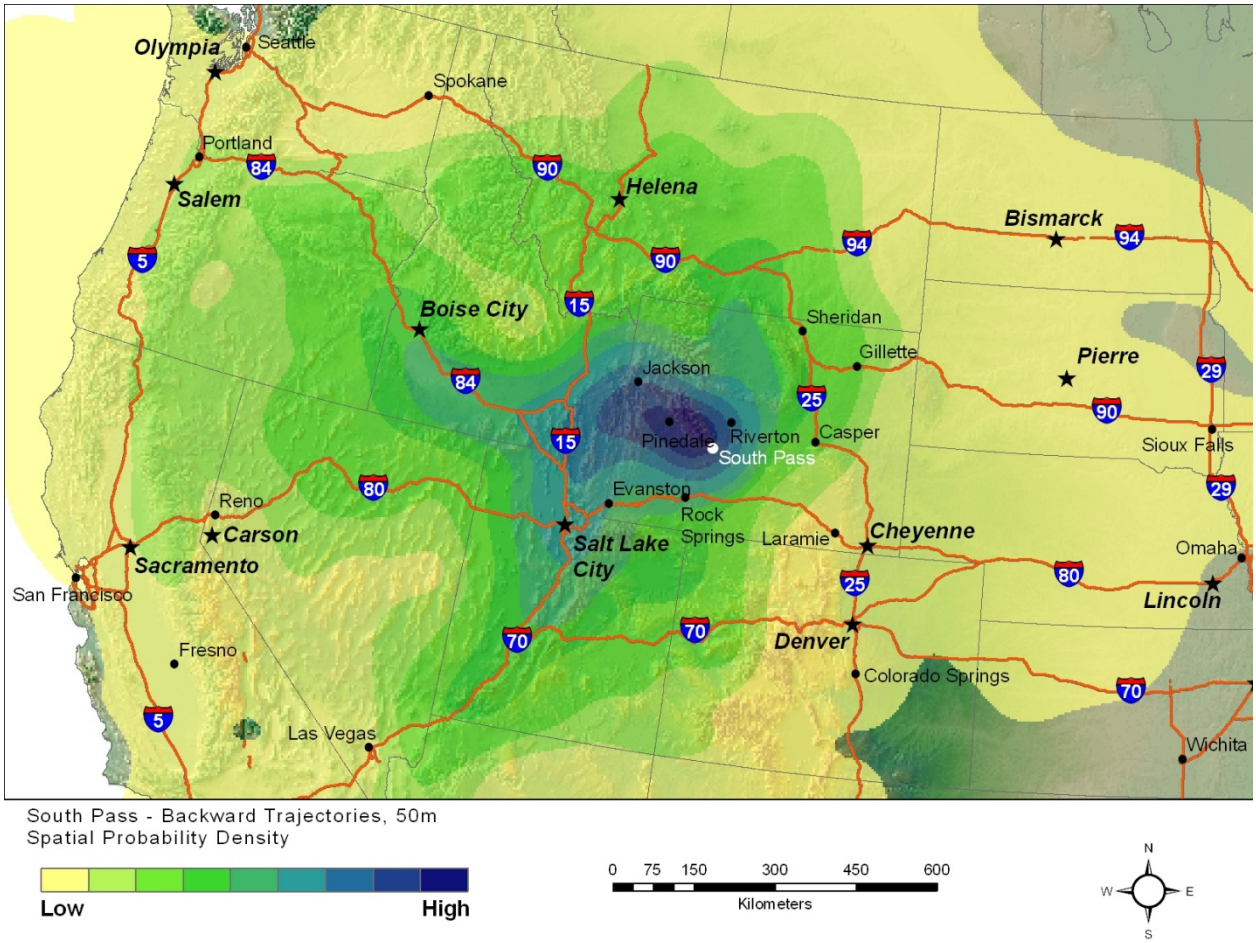








Spatial Probability Density for South Pass Monitoring Station



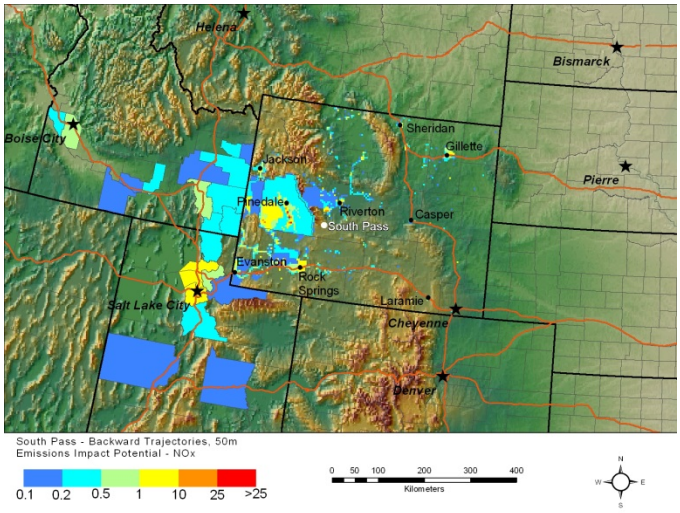
South Pass - Backward Trajectories, 50m
Spatial Probability Density

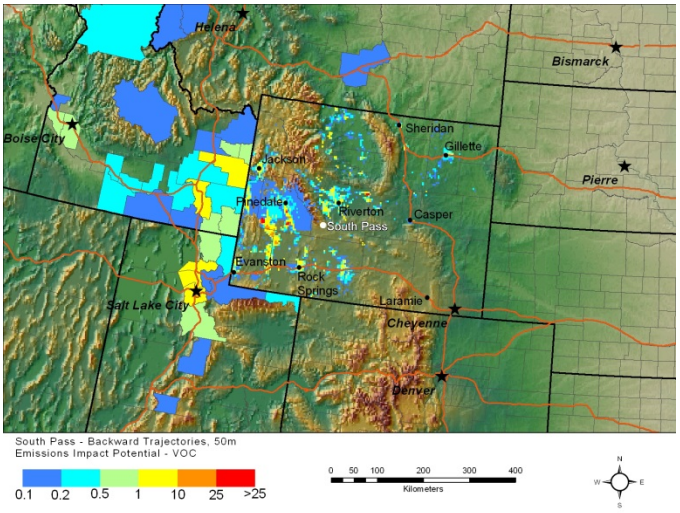
Low — High

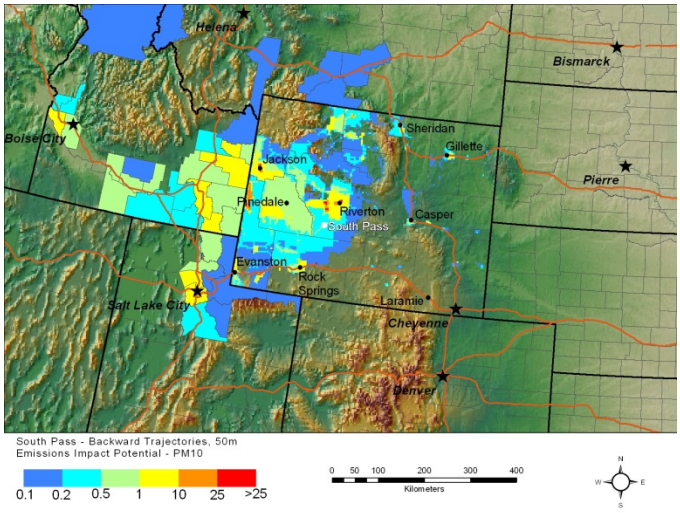
0 75 150 300 450 600
Kilometers

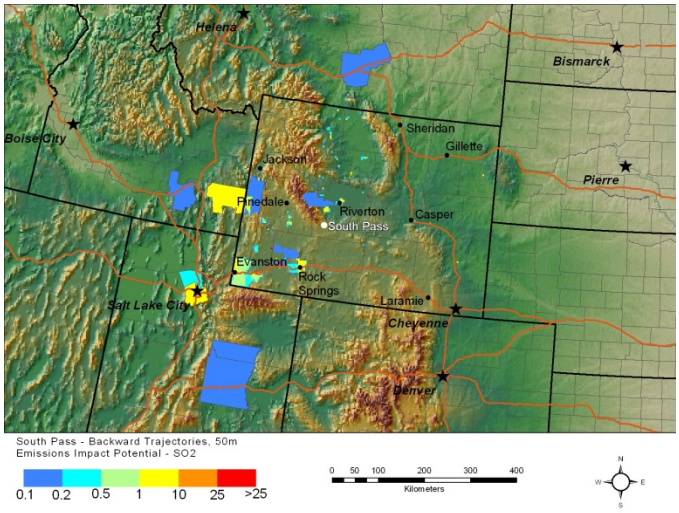
N W E S

Emission Impact Potential for South Pass Monitoring Station

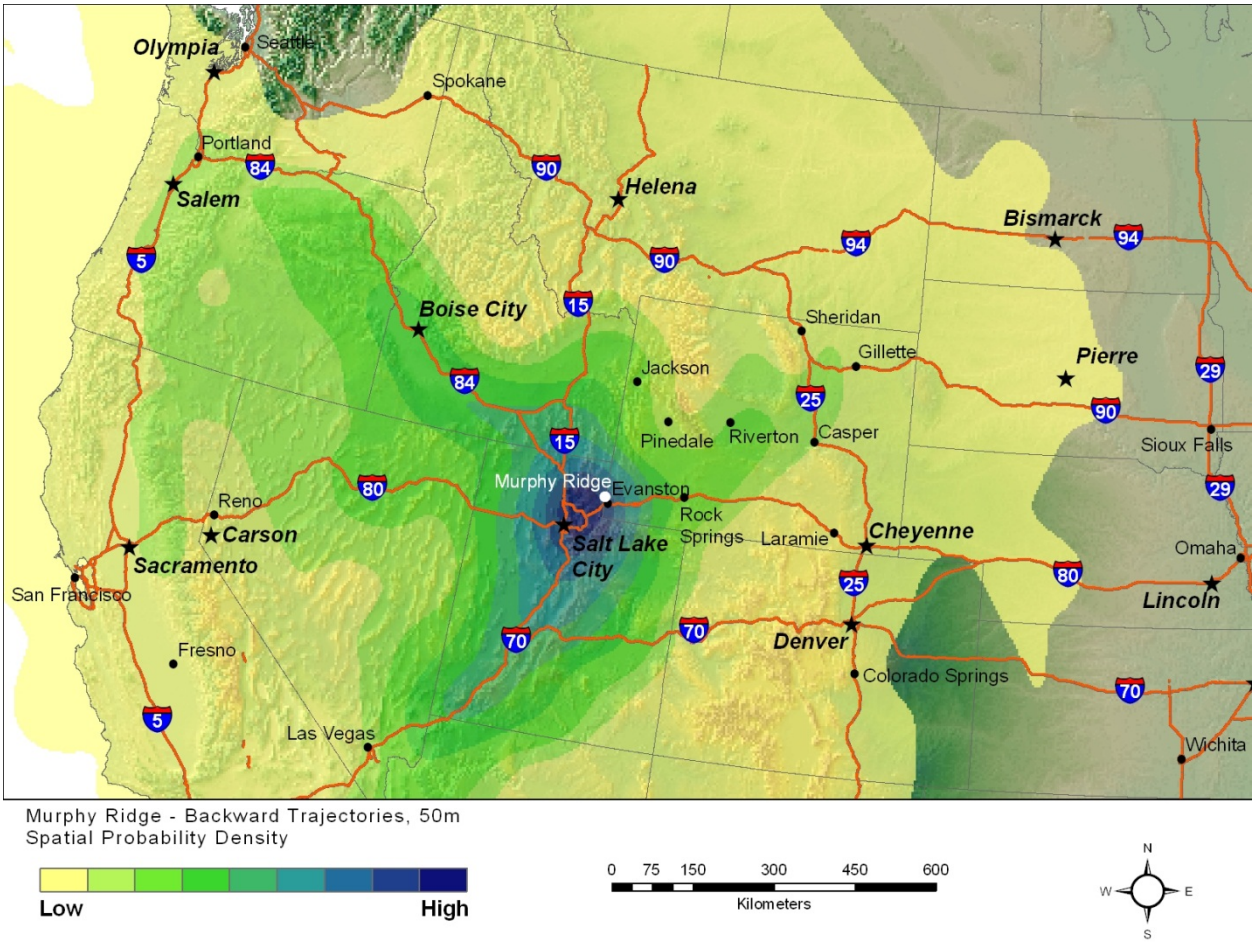








Spatial Probability Density for Murphy Ridge Monitoring Station



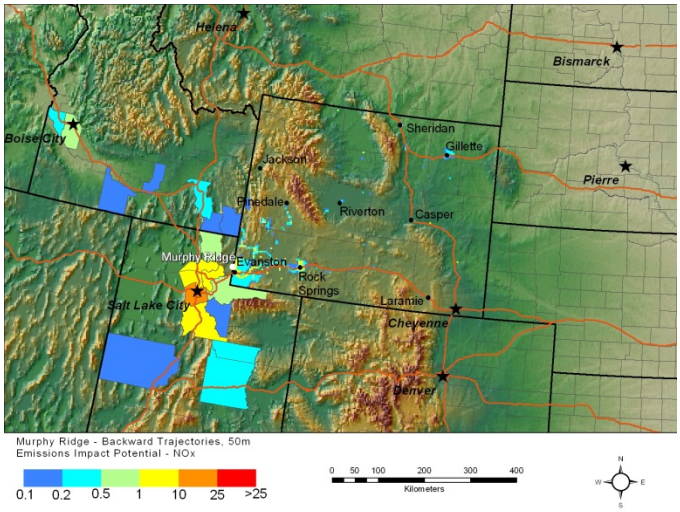
Murphy Ridge - Backward Trajectories, 50m
Spatial Probability Density

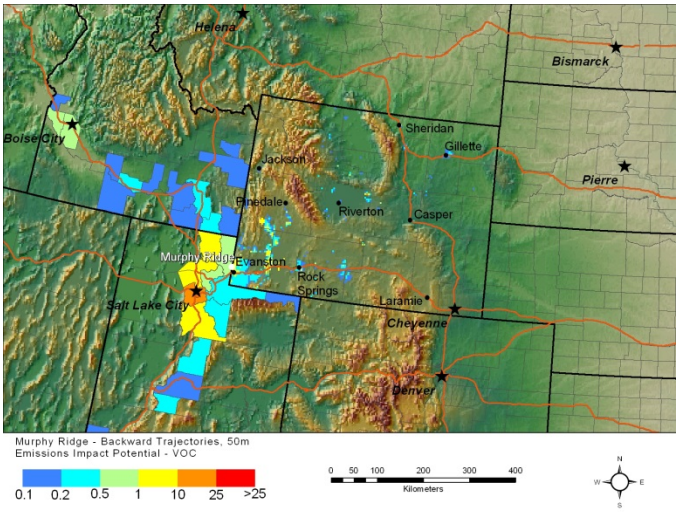
Low High

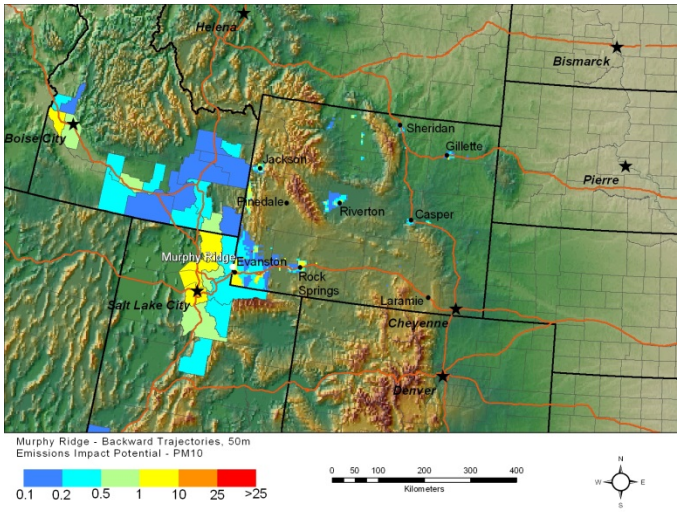
0 75 150 300 450 600
Kilometers

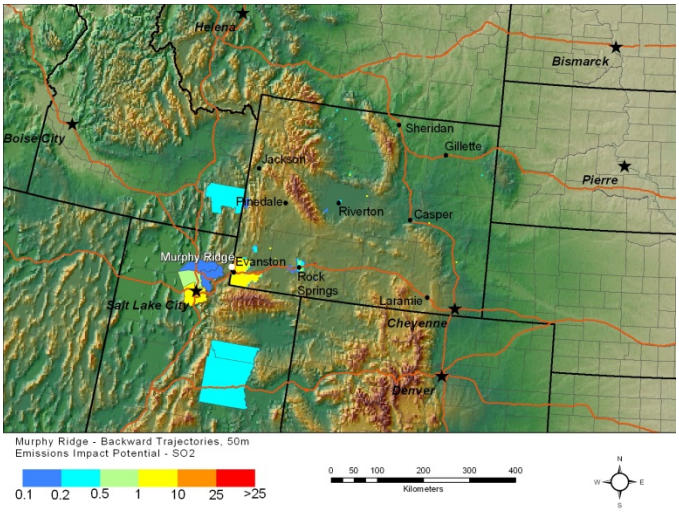
N W E S

Emission Impact Potential for Murphy Ridge

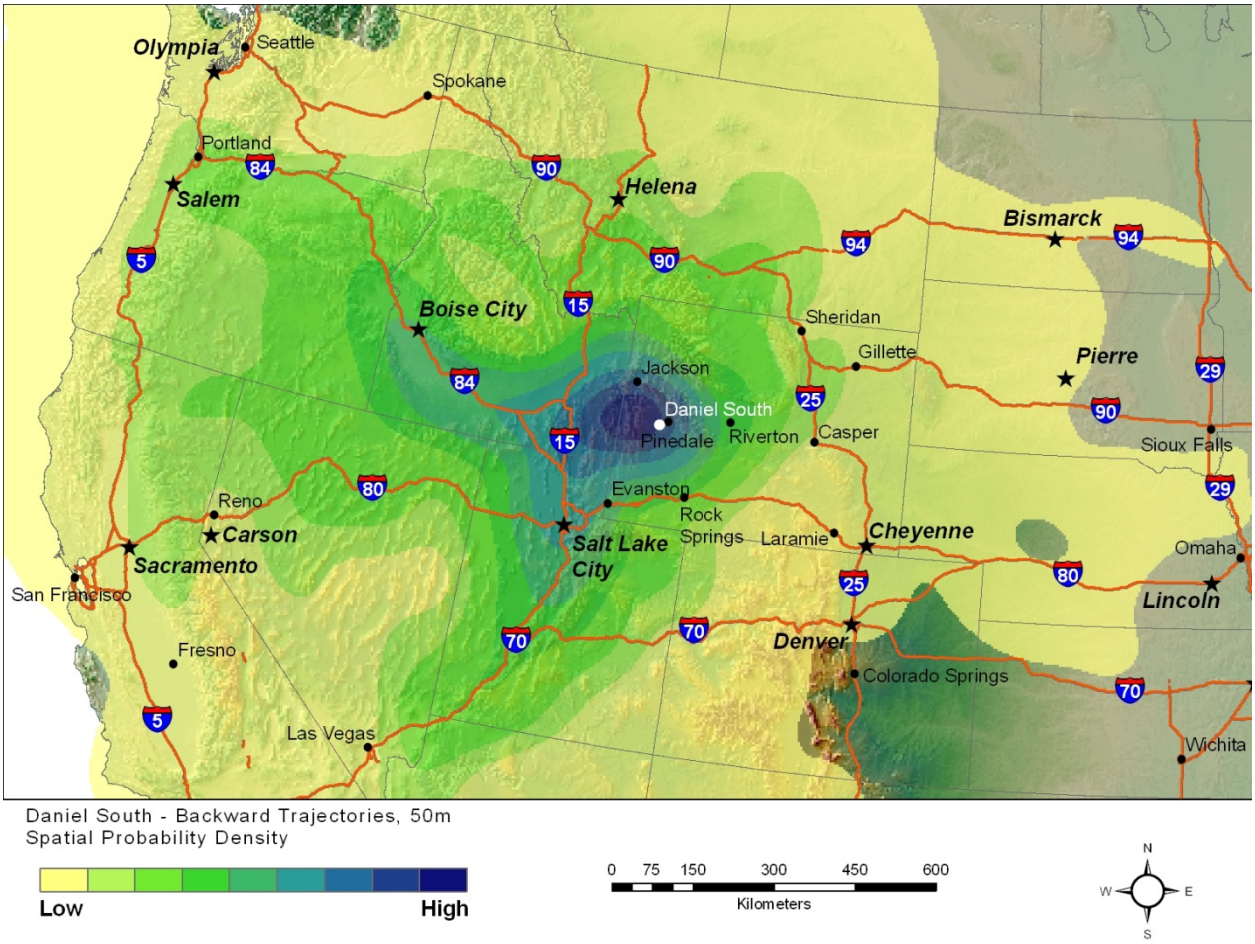








Spatial Probability Density for Daniel South Monitoring Station



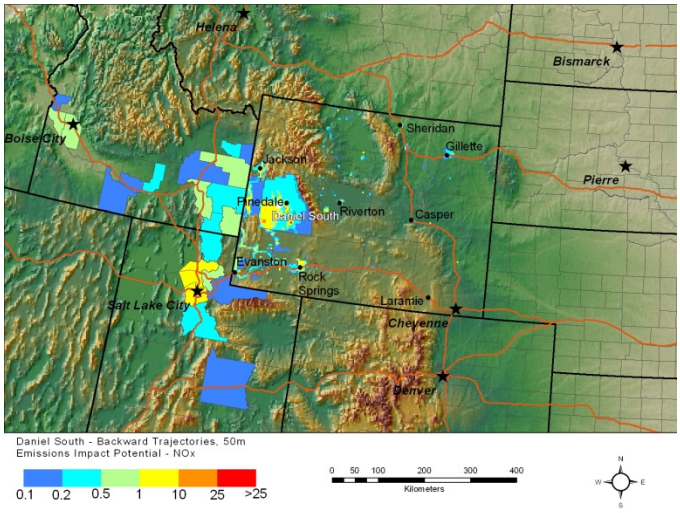
Daniel South - Backward Trajectories, 50m
Spatial Probability Density

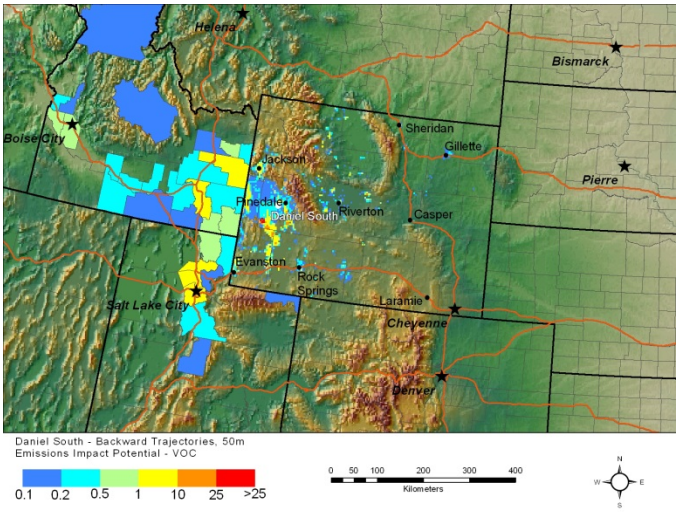
Low High

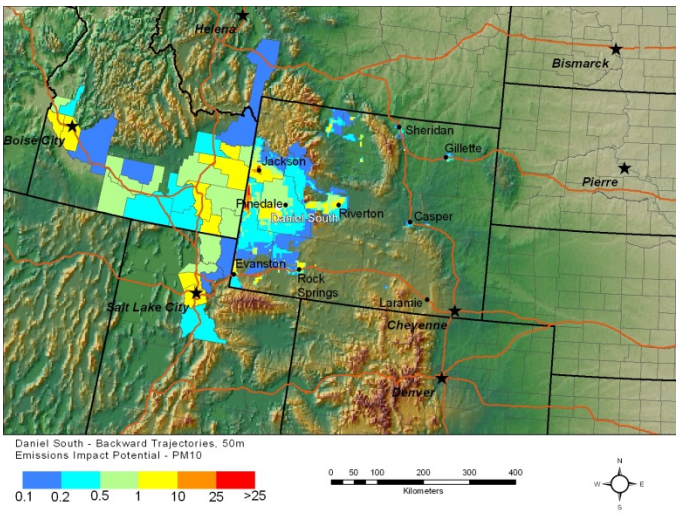
0 75 150 300 450 600
Kilometers

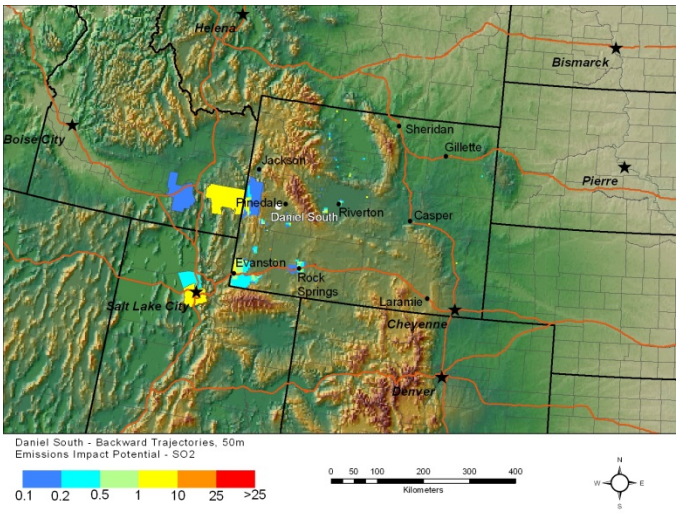
N W E S

Emission Impact Potential for Daniel South Monitoring Station





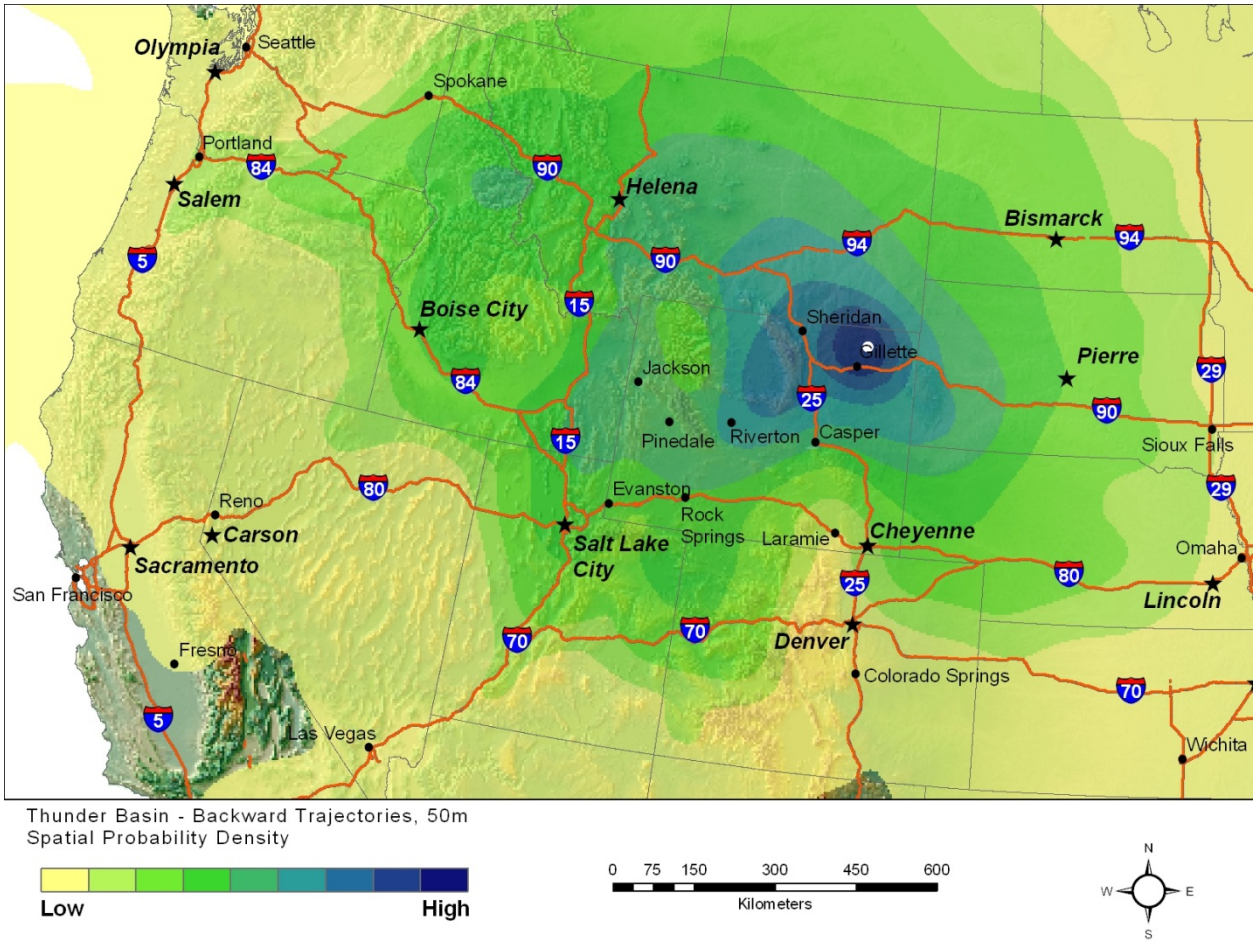




Appendix E

Supporting Materials for Section 7

Spatial Probability Density for Thunder Basin Monitoring Station



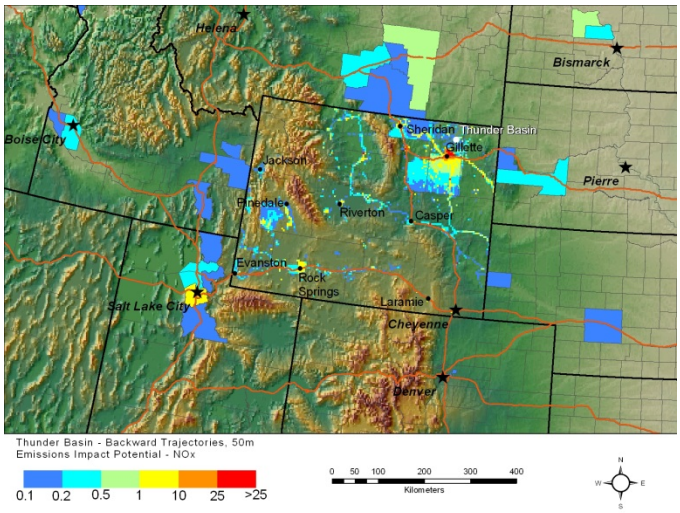
Thunder Basin - Backward Trajectories, 50m
Spatial Probability Density

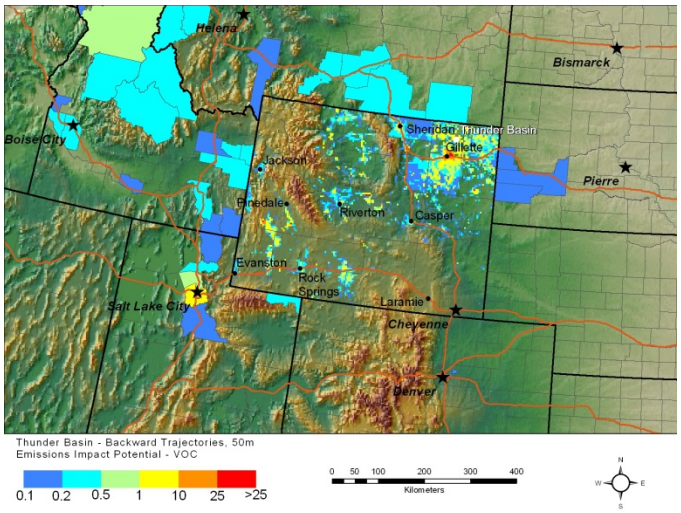
Low — High

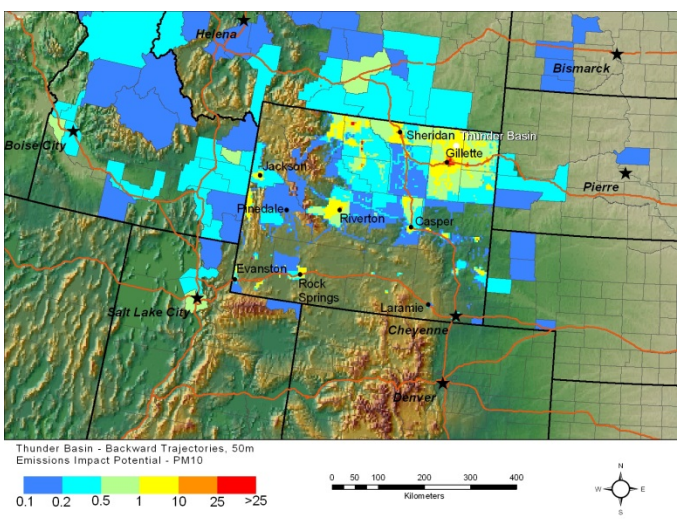
0 75 150 300 450 600
Kilometers

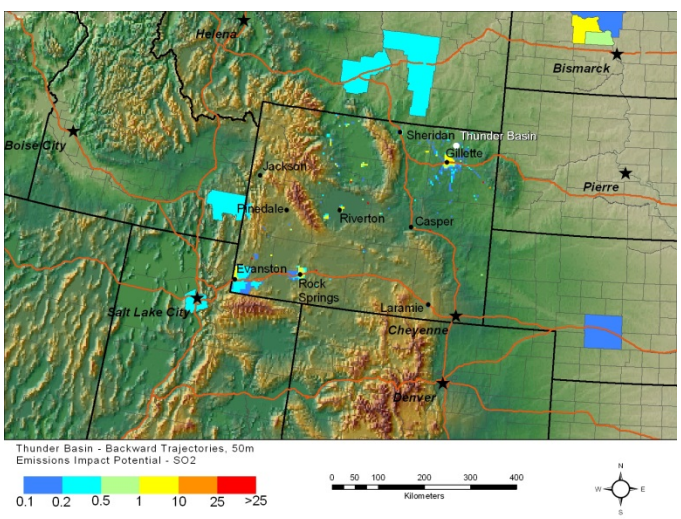
N W E S

Emission Impact Potential for Thunder Basin Monitoring Station

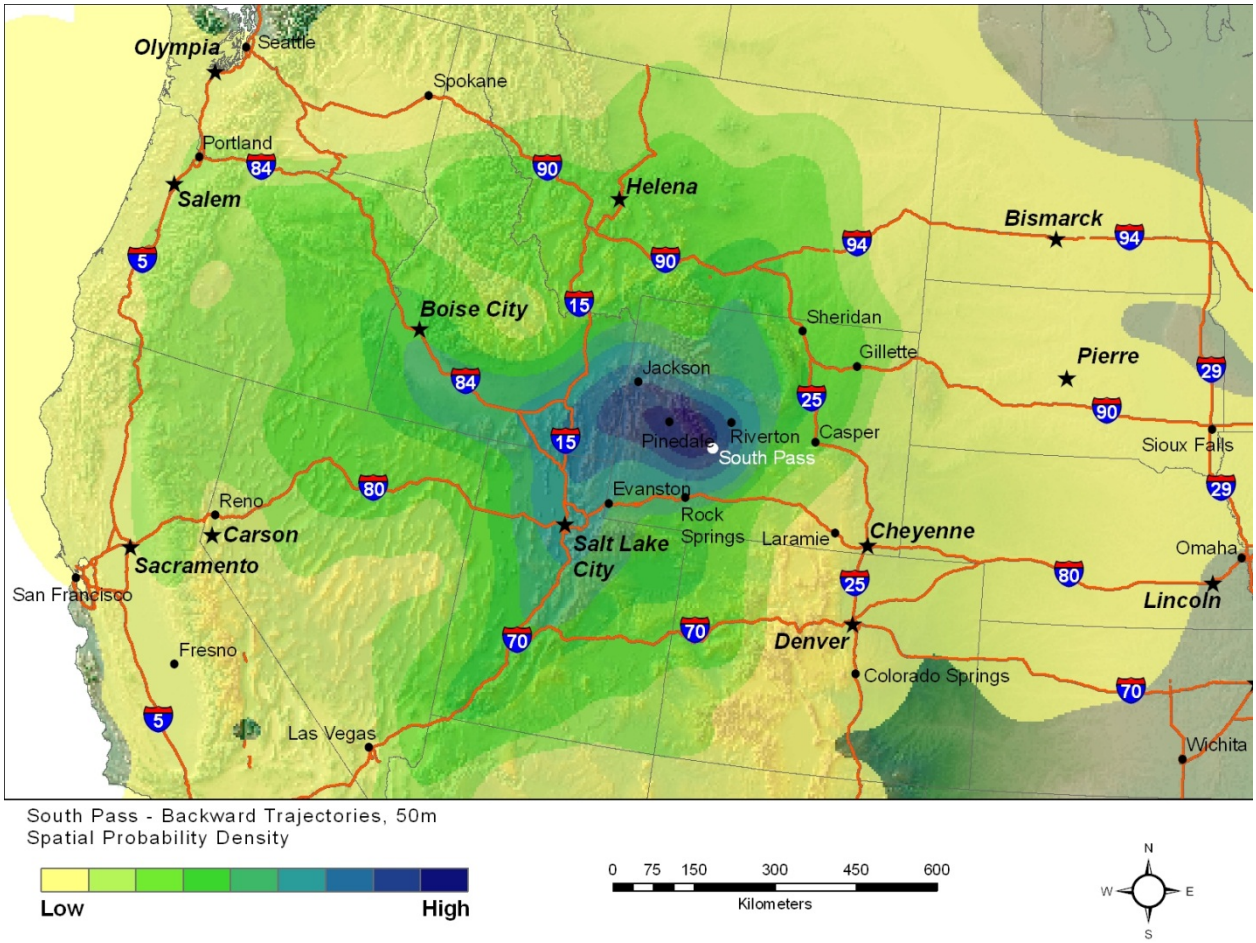








Spatial Probability Density for South Pass Monitoring Station



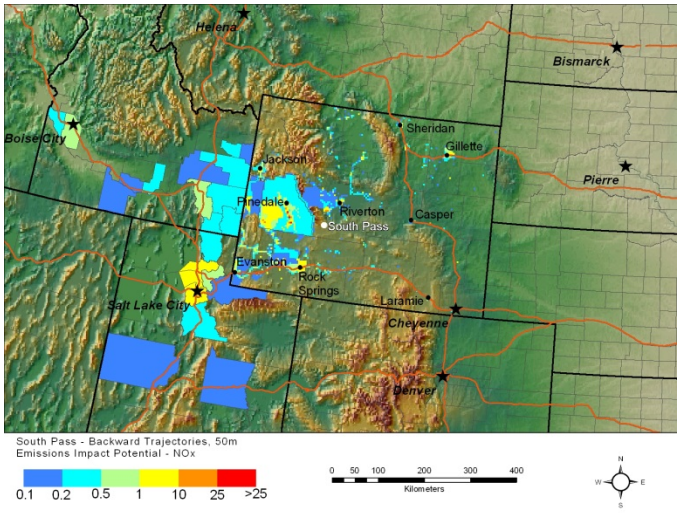
South Pass - Backward Trajectories, 50m
Spatial Probability Density

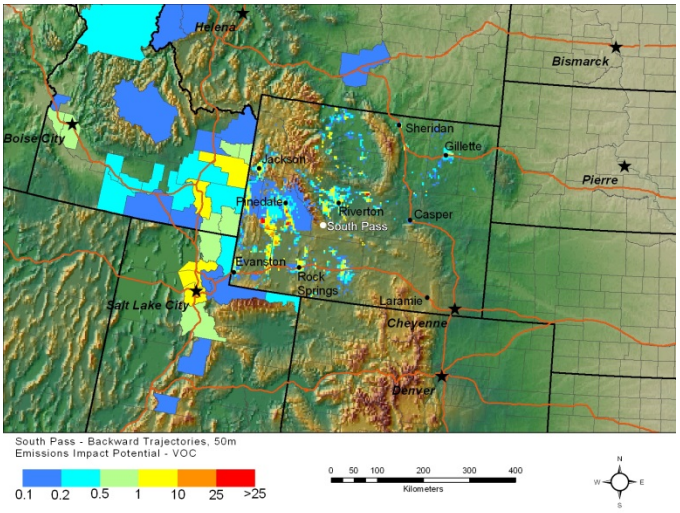
Low — High

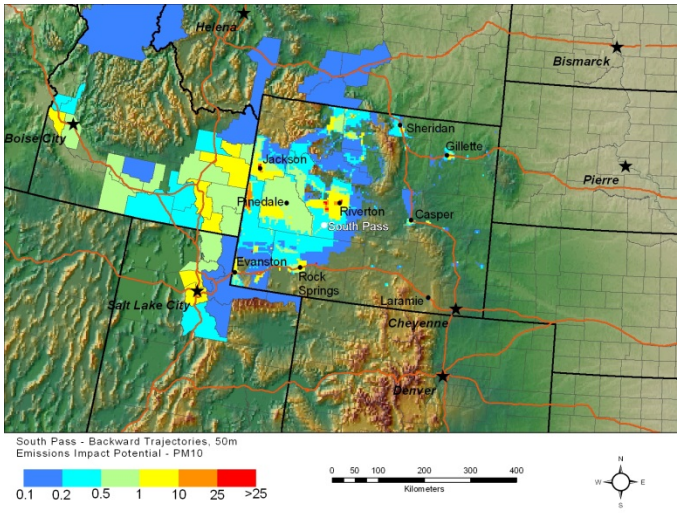
0 75 150 300 450 600
Kilometers

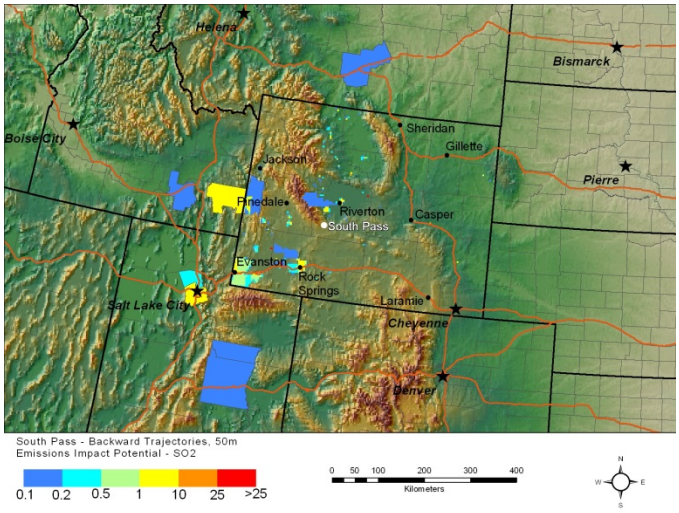
N W E S

Emission Impact Potential for South Pass Monitoring Station

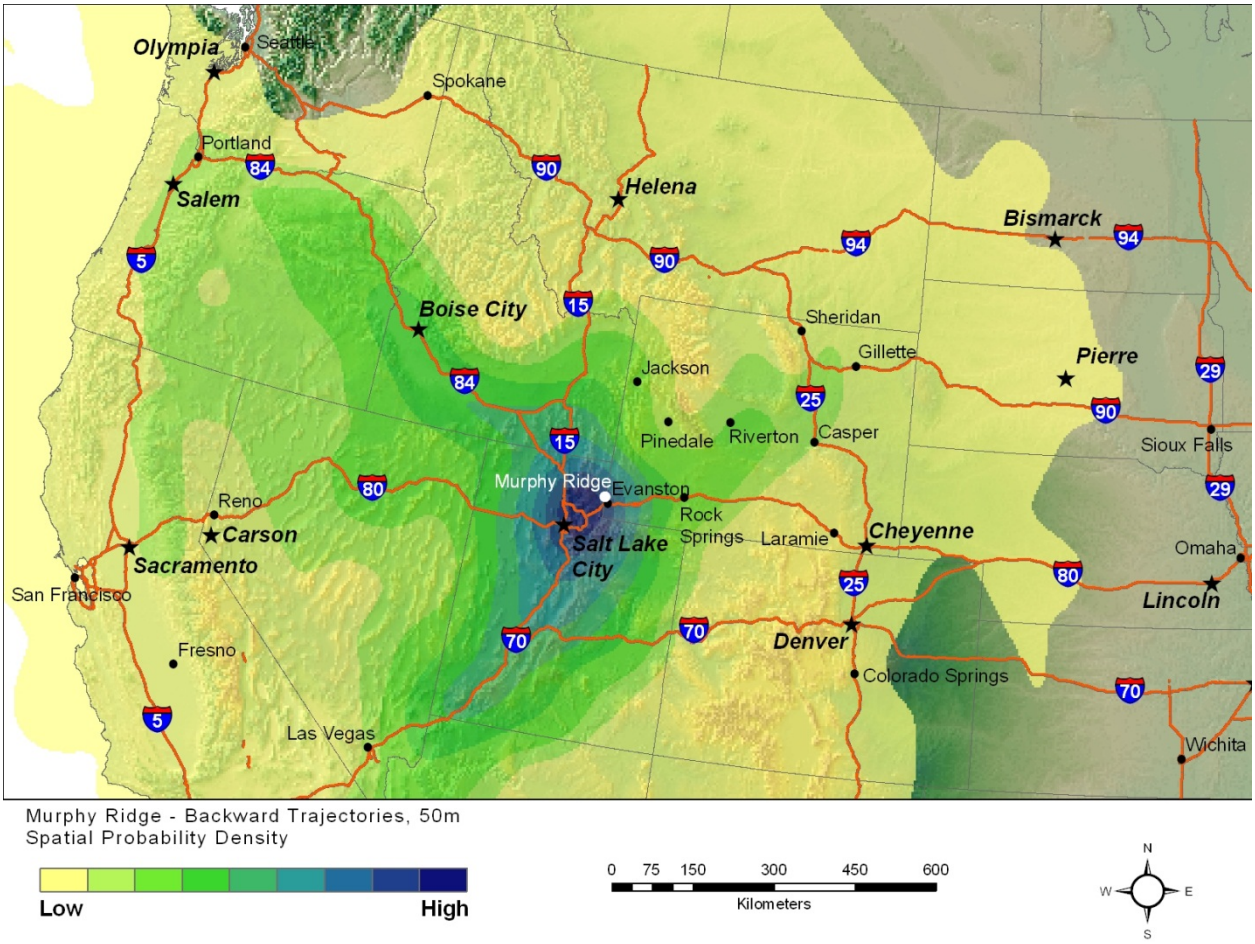








Spatial Probability Density for Murphy Ridge Monitoring Station



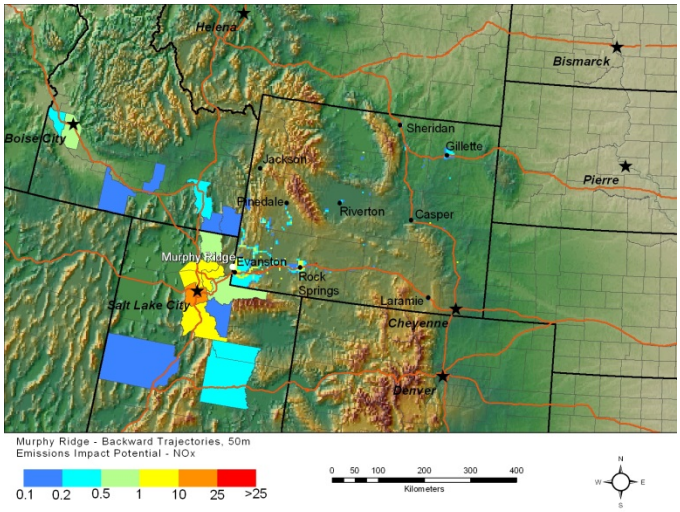
Murphy Ridge - Backward Trajectories, 50m
Spatial Probability Density

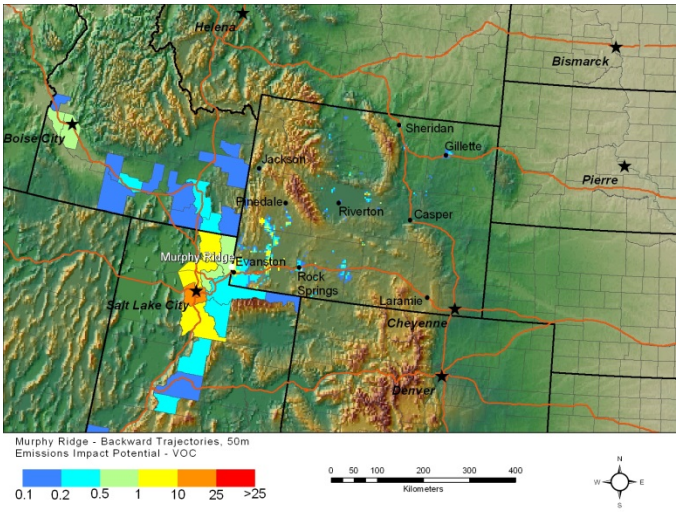
Low High

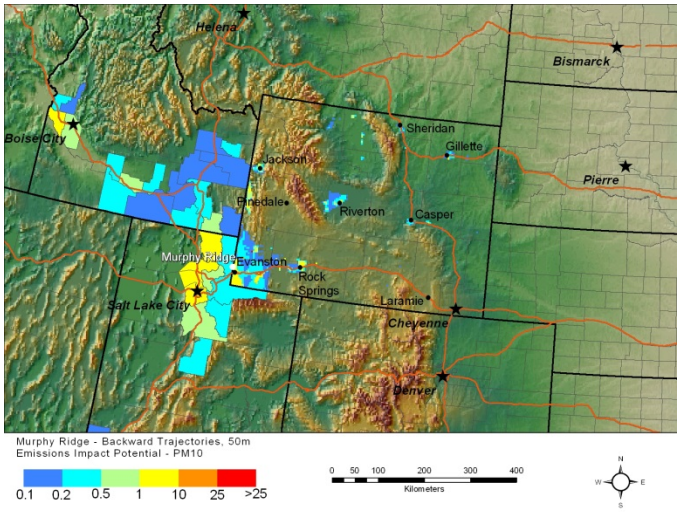
0 75 150 300 450 600
Kilometers

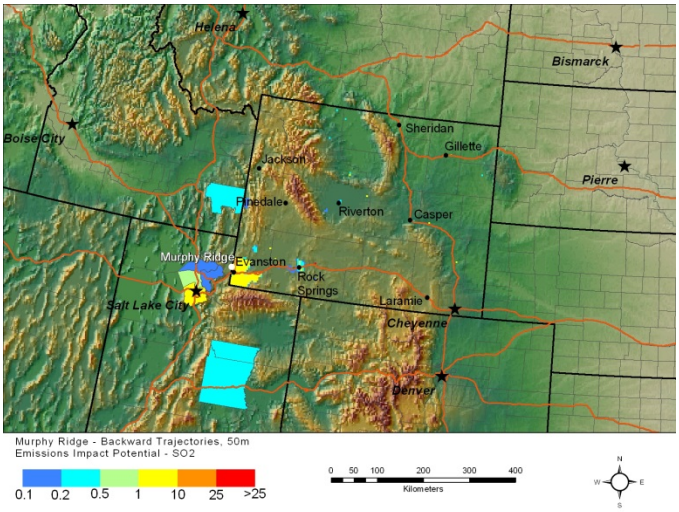
N W E S

Emission Impact Potential for Murphy Ridge

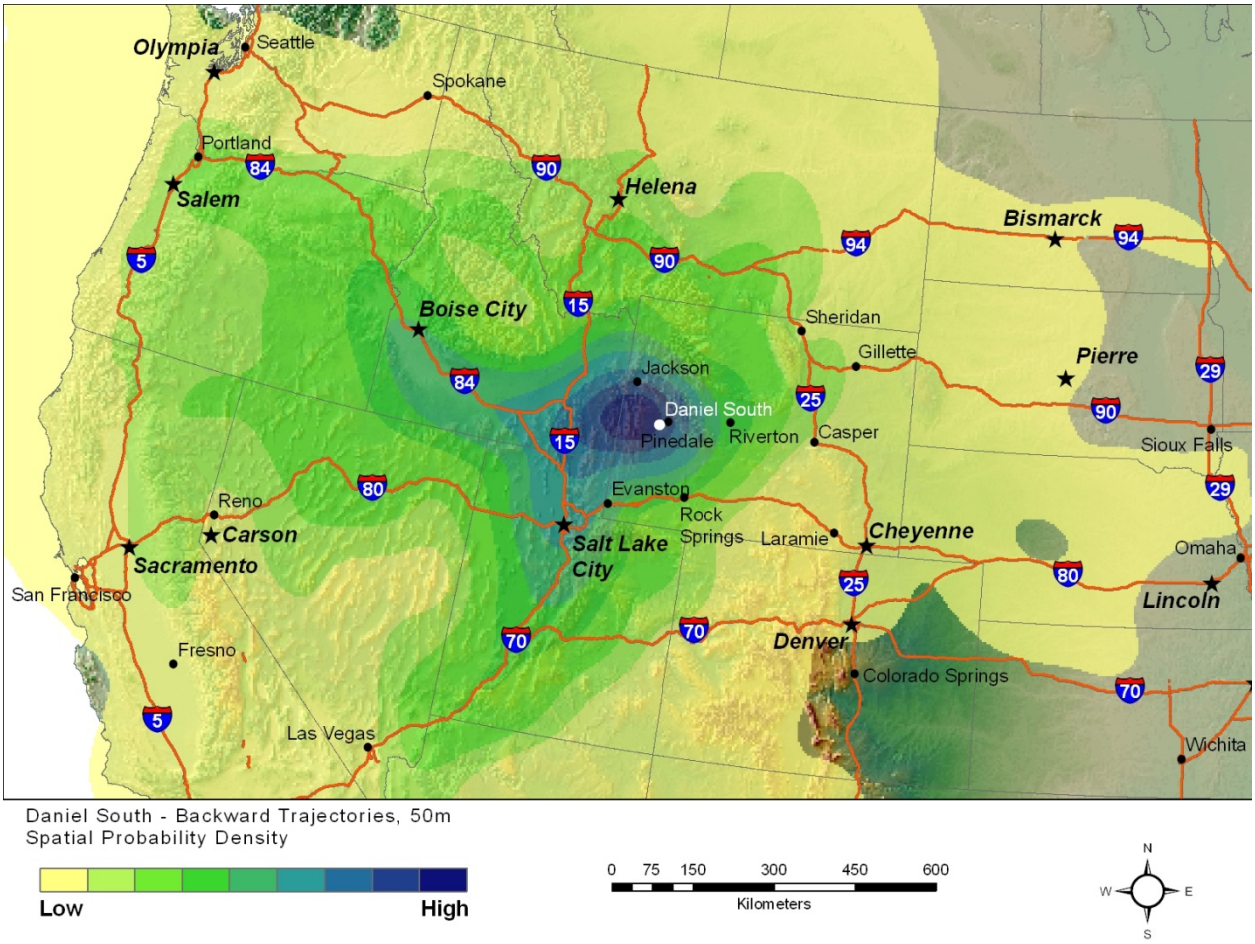








Spatial Probability Density for Daniel South Monitoring Station



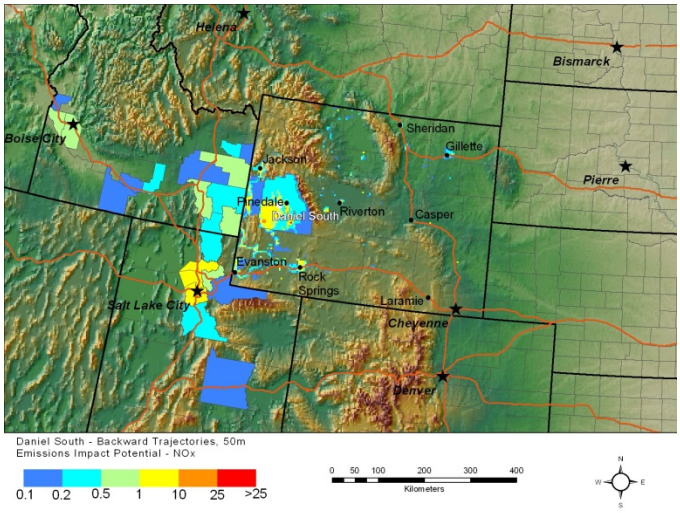
Daniel South - Backward Trajectories, 50m
Spatial Probability Density

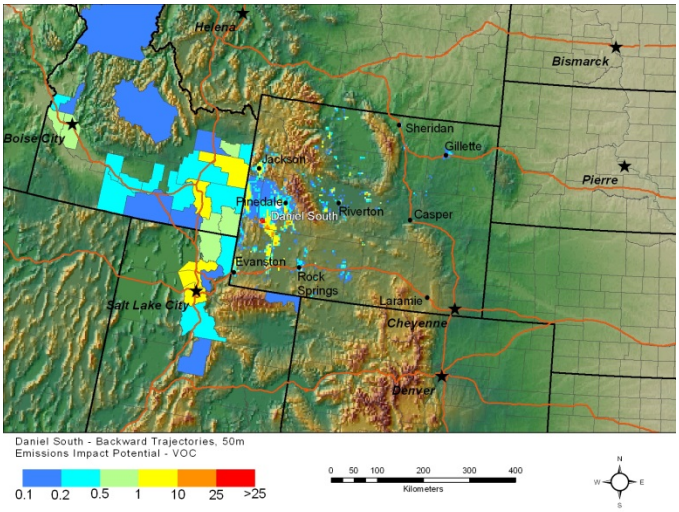
Low High

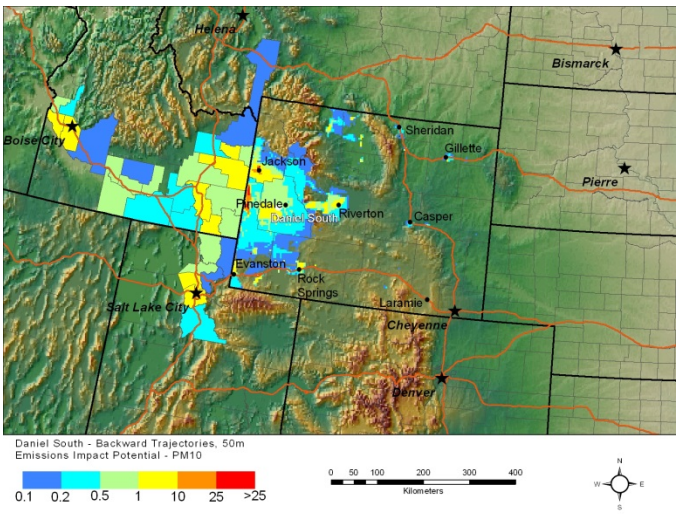
0 75 150 300 450 600
Kilometers

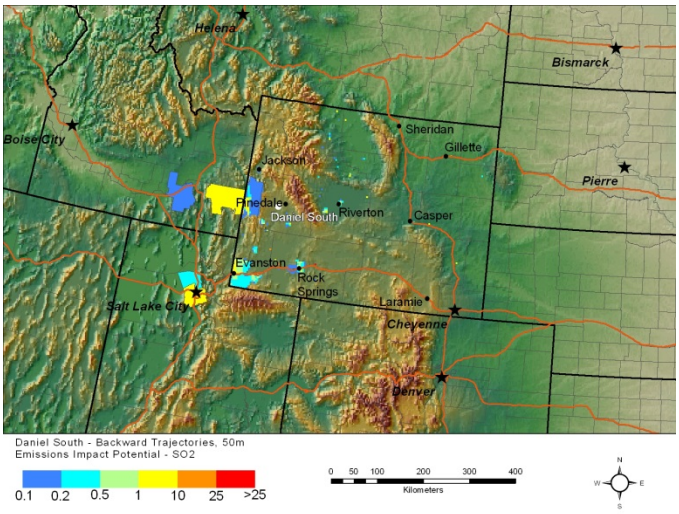
N W E S

Emission Impact Potential for Daniel South Monitoring Station

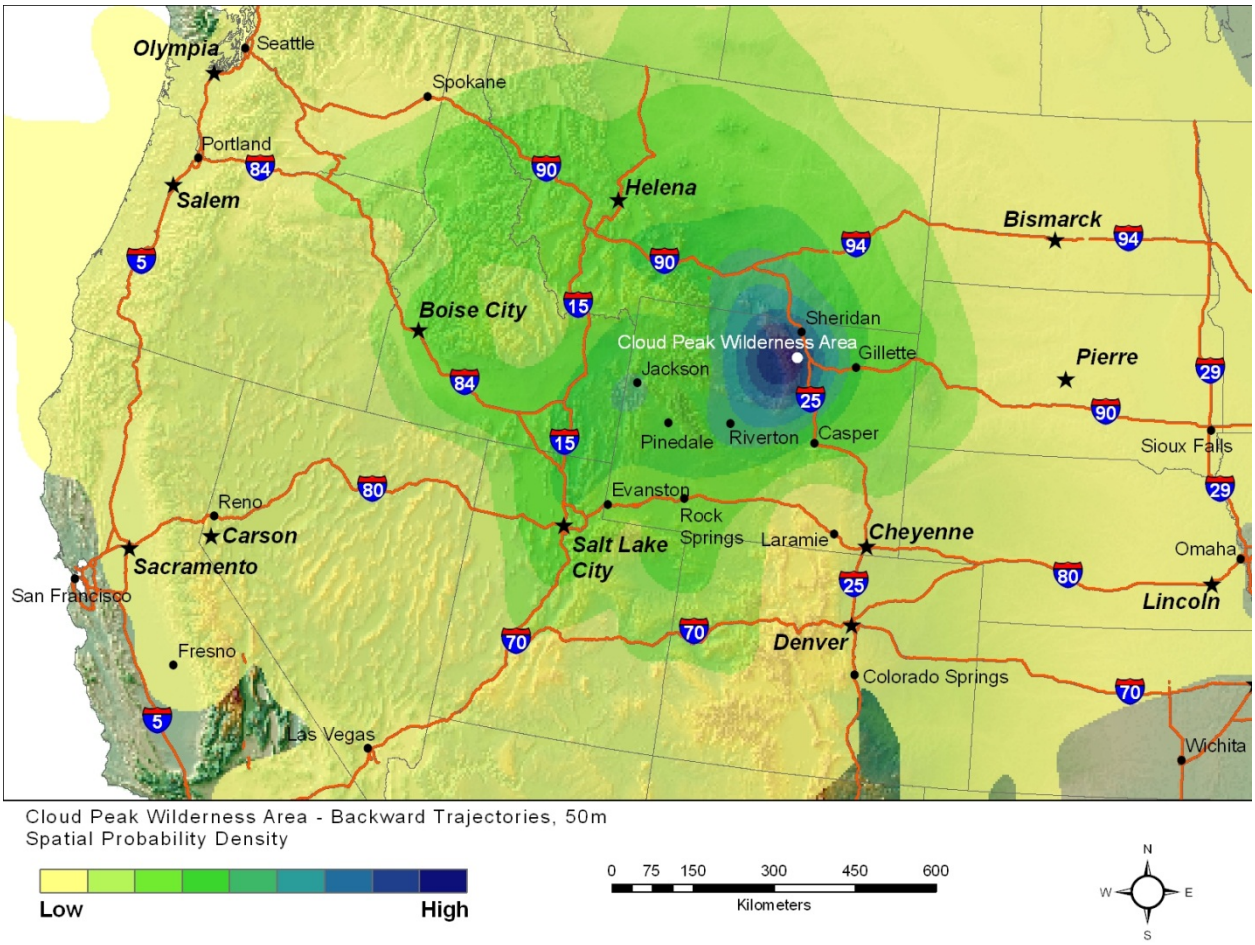








Spatial Probability Density for Cloud Peak



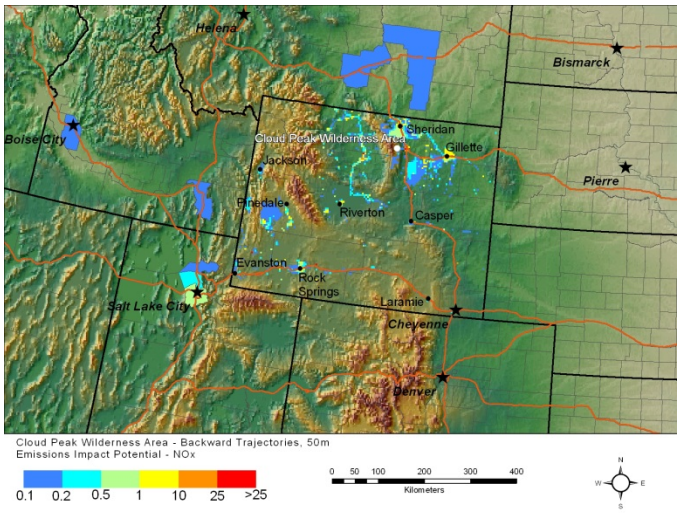
Cloud Peak Wilderness Area - Backward Trajectories, 50m
Spatial Probability Density

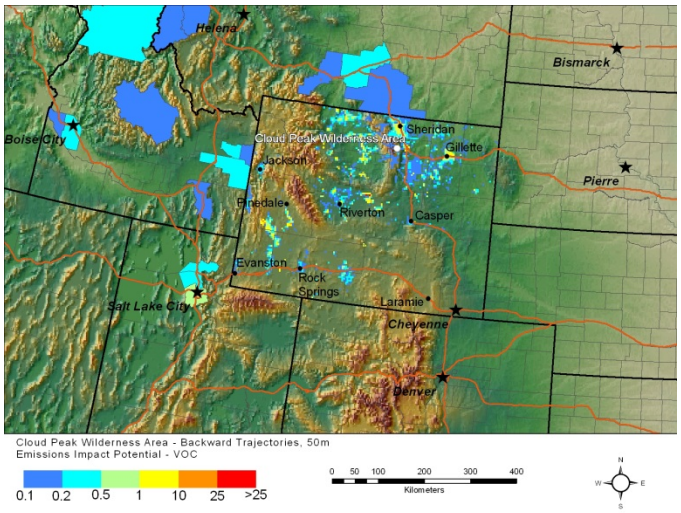
Low — High

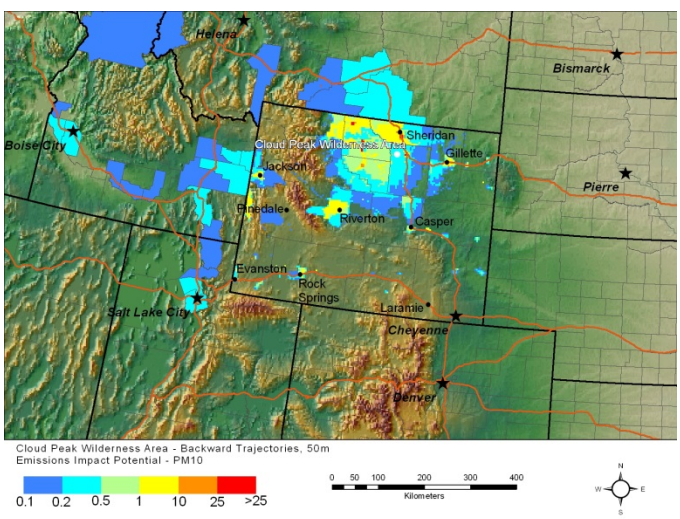
0 75 150 300 450 600
Kilometers

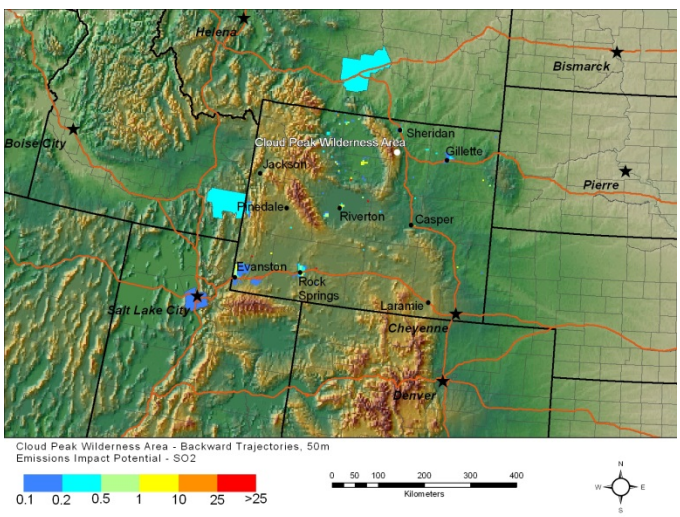
N W E S

Emission Impact Potential for Cloud Peak









Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

September 2, 2010 STI-910028-3954

To: Cara Keslar, Wyoming Department of Environmental Quality

From: Dianne Miller, Ken Craig, Jennifer DeWinter, Clinton MacDonald, Steve Reid, and Hilary Hafner

Re: An Air Parcel Transport Corridor Analysis for Sublette County, Wyoming

Executive Summary of Results

When air movement is tracked for many days, patterns can emerge that show common pathways through which air moves from one location to another. These pathways are called transport corridors. Analyzing transport corridors and their alignment with known pollution source areas can indicate how often pollution may be transported into one area from another. To understand transport in and within Sublette County, Sonoma Technology, Inc. (STI) performed an air parcel transport analysis. The results of this analysis are primarily meant to assist the Wyoming DEQ Air Quality Division (AQD) with the identification of potential locations for air quality monitoring sites in the northern region of the Wyoming Range to monitor pollutants entering Wyoming and Sublette County.

In particular, STI performed analyses to address the following questions posed by the Wyoming DEQ:

1. What is the frequency of potential emissions impacts from pollutants transported into Sublette County from out-of-state sources?
2. Where are the transport corridors through which air parcels travel into Sublette County?
3. How well do the transport corridor patterns correlate to surface meteorological observations?
4. What is the uncertainty in the air parcel transport corridor analysis?

A summary of our findings for each question follows.

1: What is the frequency of potential emissions impacts from pollutants transported into Sublette County from out-of-state sources?

Significant potential emissions impacts are observed from local sources in Sublette County (primarily related to oil and gas production) and from transported emissions originating across the Snake River Plain of southeastern Idaho and the Great Salt Lake area of north-central Utah. In addition, potential emissions impacts are particularly high when originating from counties with large population centers, such as Bannock County, Idaho,

(Pocatello area) and Salt Lake County, Utah (Salt Lake City area). **Figure A** shows the winter emissions potential density plot for NO_x at the Juel Springs site. High emissions impact potential means there is a high likelihood of emissions affecting a monitoring site (in this case, Juel Springs). Note that discontinuities along state boundaries in the figure are a result of different emissions data resolution.

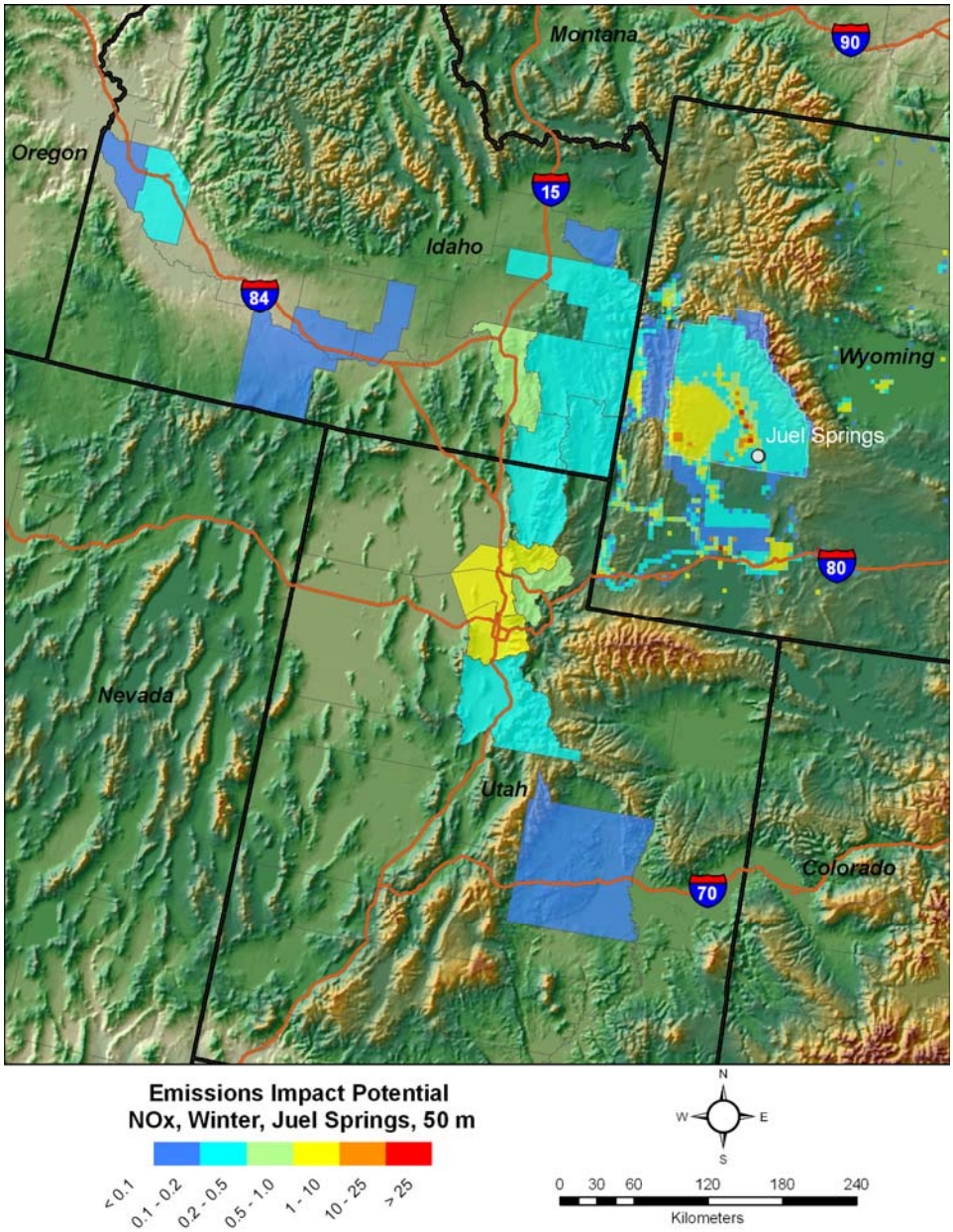


Figure A. Winter emissions impact potential density plot for NO_x at the Juel Springs site.

2: Where are the transport corridors through which air parcels travel into Sublette County?

Air parcel trajectories indicate predominantly westerly and northwesterly transport into Sublette County for trajectories arriving at all receptor sites (see **Figure B**). Occasionally, air

parcels originated from the north, south, or east into Sublette County. In general, no specific transport corridors are evident, regardless of site and season. However, there tends to be more low-level transport through the gap at the north end of the Wyoming Range for air parcels arriving at sites located along the Wind River Range in central and northern Sublette County. In addition, low-level transport into Sublette County tends to be more northwesterly in the fall than in the winter.

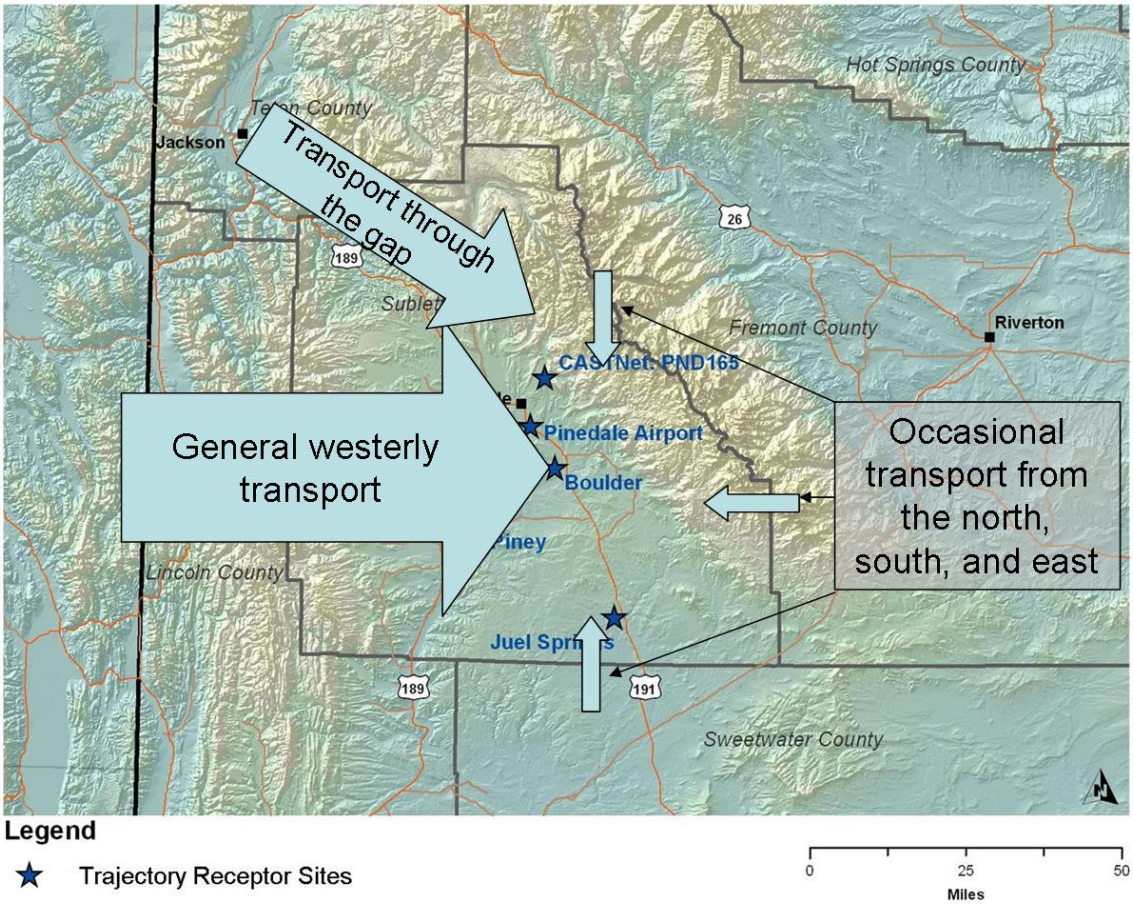


Figure B. Area of transport into Sublette County.

3: How well do the transport corridor patterns correlate to surface meteorological observations?

The site-specific surface wind data do not accurately represent transport of air within and/or above the boundary layer in Sublette County. Therefore, to evaluate transport, modeled wind fields must be used. However, surface wind data from these locations are important to validate the modeled wind fields at the site locations used to calculate the trajectories.

4: What is the uncertainty in the air parcel transport corridor analysis?

Air parcel paths were created using modeled wind data. Uncertainty in the air parcel corridor analysis can be attributed to two main factors: (1) uncertainty in the wind data set used

to calculate the horizontal movement of the air parcel paths and (2) uncertainty in the method used to calculate the vertical movement of the air parcels.

When air parcel paths were calculated using two common, yet different wind data sets, the resulting paths showed similar transport pathways. Therefore, the choice between which wind data set to use was not critical for understanding the general transport patterns over many days. However, for precise analysis of source/receptor relationships on individual days, the uncertainty in the trajectory paths (measured by a difference between the results using different wind data sets) is modest; thus, results for individual days should be viewed with caution. For example, when the two data sets were used to calculate air parcel paths, transport distances were within 60 km of each other, on average, and transport directions within 15 degrees of each other after 24 hours of parcel movement.

When air parcel paths were calculated using two different vertical motion schemes, the differences were small in the summer and large in the winter. In the summer, for 24-hour air parcel paths, the transport distances were usually within 60 km of each other, and transport direction was usually within 15 degrees. For 24-hour air parcel paths in the winter, however, the transport distances were usually within 125 km, and transport direction was usually within 20 degrees. Because of the large uncertainty in the winter, further analysis was done to determine the more accurate model vertical motion method, which was used to address questions 1, 2, and 3.

Technical Approach

Technical details of the methodology and results used to address each question can be found in the **Appendix.** Figures and tables showing the following information are provided in electronic format:

- SPD maps and transport statistics correlation tables generated in the HYSPLIT model uncertainty analysis
- SPD maps generated in the transport corridor identification analysis
- Transport statistics correlation tables generated in the transport corridor identification analysis
- EIP maps generated in the emissions impact potential analysis

Appendix: Methodology and Results

Project Overview

To understand transport in Sublette County, STI performed an air parcel transport analysis. The results of this analysis will allow the Wyoming DEQ Air Quality Division (AQD) to identify potential locations for air quality monitoring sites in the northern region of the Wyoming Range to monitor pollutants entering the state and Sublette County.

In particular, STI performed analyses to address the following questions:

A. Where are the transport corridors through which air parcels travel into Sublette County?
B. What is the uncertainty in the air parcel transport corridor analysis?
C. How well do the transport corridor patterns correlate to surface meteorological observations?
D. What is the frequency of potential emissions impacts of pollutants transported into Sublette County from out-of-state sources?

To address these questions, we performed an analysis of air parcel transport that occurred on each day from 2005 through 2009. The analysis included

1. Trajectory uncertainty analysis
2. Trajectory corridor identification
3. Trajectory comparison with surface wind
4. Emissions impact potential analysis

The following sections present details of our methodology and associated findings.

Trajectory Uncertainty Analysis

Methodology

To generate air parcel paths, STI used the Transported Emissions Assessment Kit (TEAK) and Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. HYSPLIT is a widely used model that calculates the path of a single air parcel from a specific location and height above the ground over a period of time; this path is called a trajectory. For example, the model can calculate the 72-hour trajectory of an air parcel that arrived in Pinedale on August 12, 2010, at 12:00 p.m. Air parcel locations (trajectory points) are calculated for every hour in each 72-hour trajectory. The TEAK is then used to group the HYSPLIT trajectory points to generate spatial probability density (SPD) maps over a given period of time, such as all winter days in a five-year period. SPD maps show the probability that an air parcel will move through a given point as it moves to a specific location. **Figures 1a and 1b** show an example of the individual trajectory points (Figure 1a) and the resulting SPD map (Figure 1b) for air moving into Pinedale in October 2008. The 72-hour trajectories were calculated every four hours for each day in October, resulting in a total of 124 trajectories and 2,976 trajectory end points.

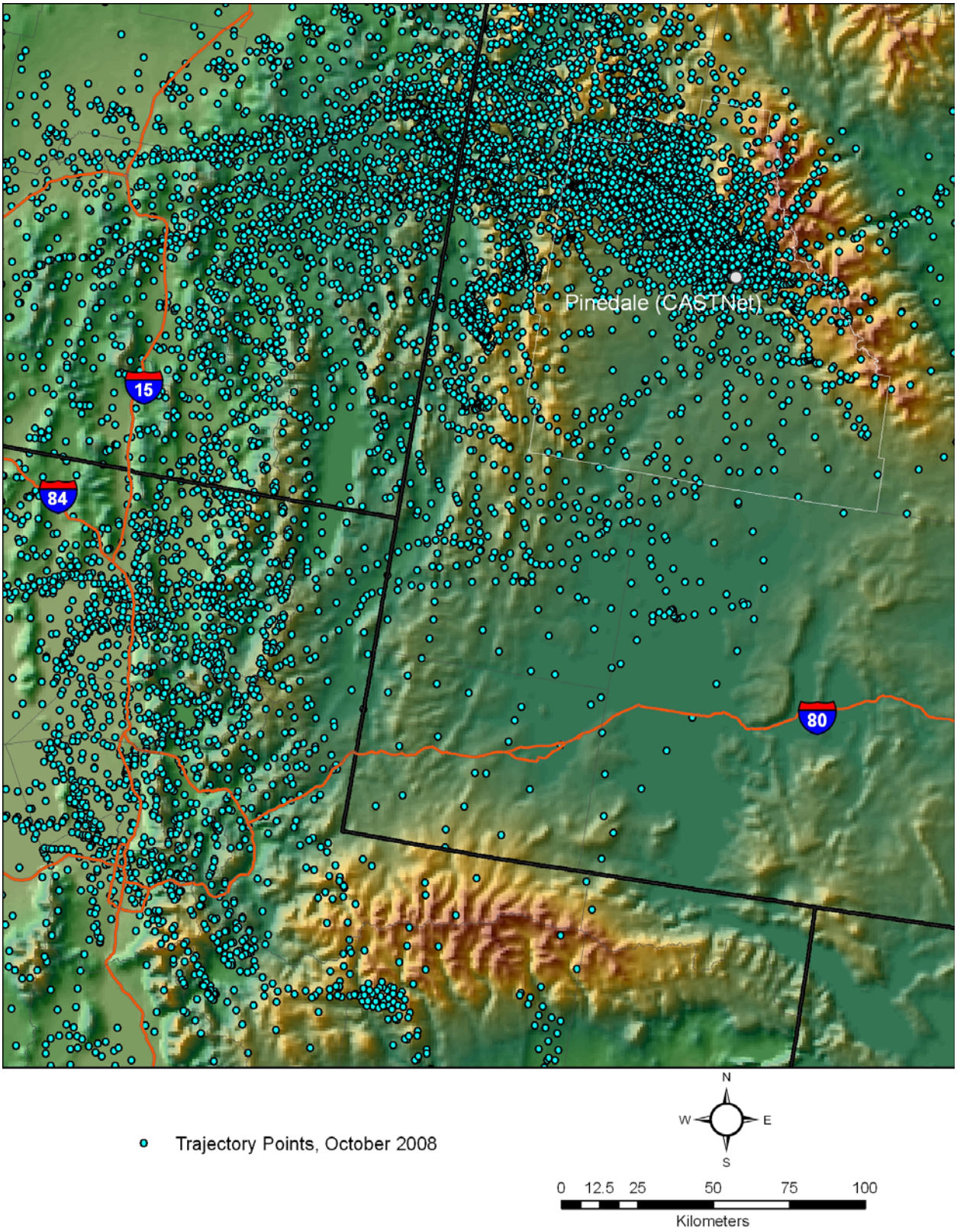


Figure 1a. Trajectory points for air parcels arriving at the CASTNET Pinedale receptor site at 50-m height in October 2008.

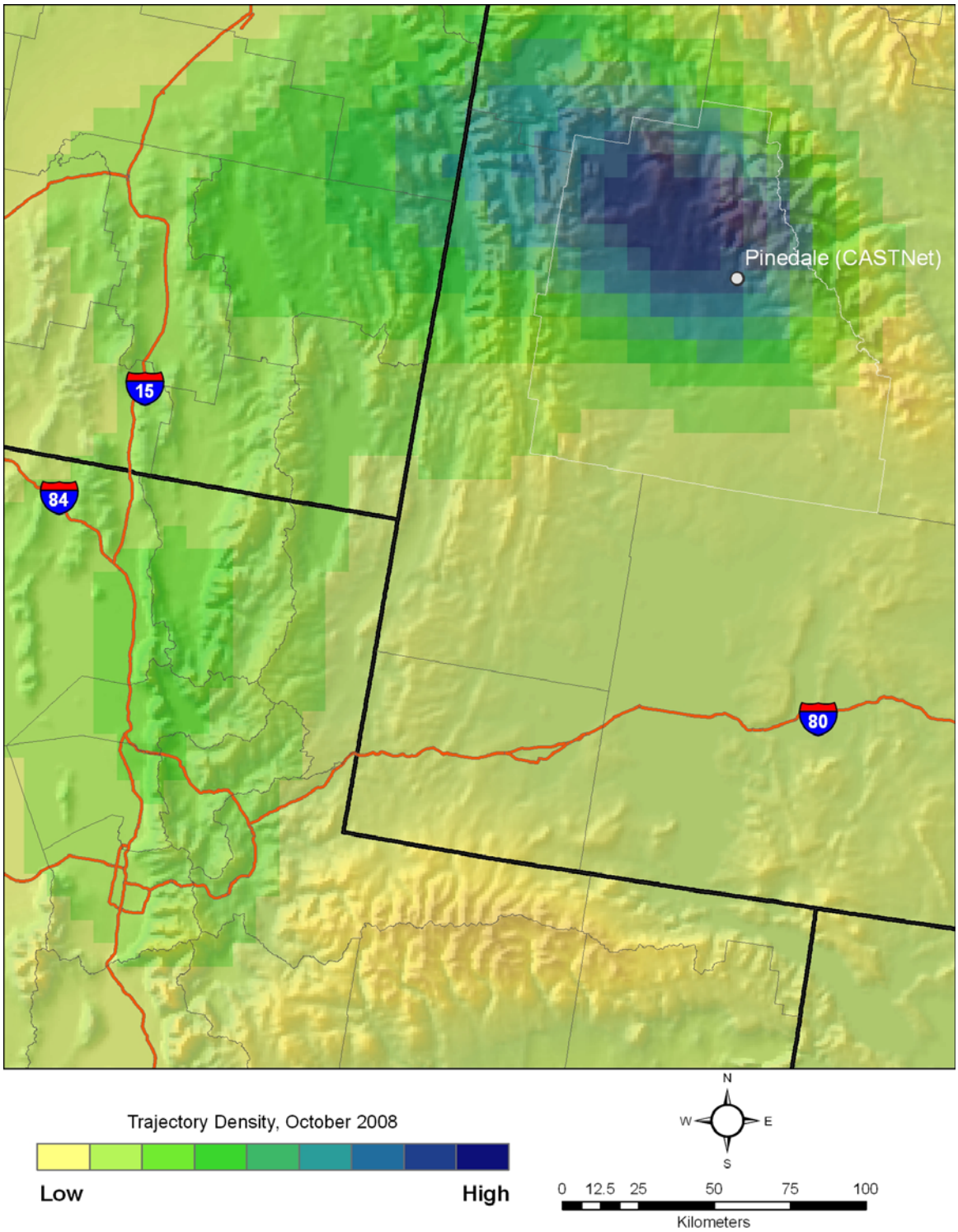


Figure 1b. SPD map for the CASTNET Pinedale receptor site at 50-m height in October 2008. The colors represent the fraction of trajectories that passed over a location.

Before running TEAK, several decisions about the model runs needed to be made, including the model data set to use; duration of model runs; number of years of data to use; selection of modeling options for vertical motion, trajectory heights, receptor locations, or trajectory origins; trajectory start times; and the height of the top of the model. The options selected for each of these inputs are shown in **Table 1.** Two of the most important decisions for this analysis were the selection of (1) an input model data set and (2) the appropriate vertical motion scheme.

Table 1. HYSPLIT model input parameters.

Parameter	Value
Model data	40-km EDAS
Run time (trajectory length in time)	12-, 24-, 48-, and 72-hour end points
Date range	Jan. 2005—Dec. 2009
Vertical motion scheme	Sigma (constant height)
Starting heights	50, 300, 700 m (agl)
Receptor locations	CASTNet PND 165, Boulder, Daniel South, Juel Springs, Pinedale Airport, Big Piney stations
Starting hours (MST; 24-hour clock)	1, 5, 9, 13, 17, 21
Top of model	10,000 m (agl)

To make these decisions, STI evaluated the uncertainty of the HYSPLIT model output before running HYSPLIT and TEAK for the full 5-year data set.[1] Two sets of sensitivity experiments were performed to evaluate HYSPLIT trajectory model uncertainties due to (1) spatial resolution of the wind field data sets and (2) vertical motion scheme. The two wind field data sets compared were 12-km resolution data from the North American Mesoscale (NAM) model and 40-km resolution data from the Eta Data Assimilation System (EDAS). The EDAS stopped using the Eta model and began using the NAM model in June 2006; therefore, EDAS 40-km data after June 2006 are aggregated from the NAM 12-km data. Both data sets cover North America at a 3-hour temporal resolution. The two HYSPLIT vertical velocity methods compared were the Omega scheme, which uses vertical velocities directly from the meteorological model data set, and the Sigma scheme, which calculates the vertical velocity required to maintain trajectories on a constant internal vertical model level. This level follows the terrain; therefore, the trajectories remain at approximately the same height above the ground. HYSPLIT simulations comparing meteorological data sets used the Sigma vertical velocity method, while simulations comparing vertical velocity methods used the EDAS data.

For testing purposes, HYSPLIT 72-hour backward trajectories were initiated at sites in Pinedale and in the Jonah Field at 50 m, 300 m, and 700 m agl every 12 hours (at 0500 and 1700 MST) from July 7, 2007, to July 23, 2007, (summer period) and from January 16, 2009, to

[1] We used five years of meteorological data for this analysis to adequately account for interannual variation in weather patterns.

January 29, 2009 (winter period). These dates capture meteorological conditions over Wyoming ranging from stagnant days with weak dispersion and short transport to stormy days with strong dispersion and long transport; this minimizes the possibility of bias in the uncertainty analysis due to unrepresentative weather conditions. The Pinedale and Jonah sites were selected so the uncertainties could be evaluated for both near-mountain sites and valley locations.

SPD maps from HYSPLIT trajectory output were generated using TEAK for each receptor site, height, vertical velocity method, and wind field data set for the summer and winter periods. SPD is a tool for aggregating an ensemble of trajectories; it gives an overall picture of transport under certain conditions (e.g., certain times of the year, specific air quality events, etc.) The HYSPLIT model is run for multiple start hours to capture the transport pattern over the 24-hour sampling time. Data points for each hour back to the total run time are created for each trajectory and incorporated into a database. These data points are then mapped within the GIS as spatial probability density values. The SPD maps indicate where the airmass was likely to have originated from. The SPD maps were subjectively analyzed to characterize differences arising from different HYSPLIT vertical velocity methods and meteorological data sets. The SPD maps from the uncertainty analysis can be found in the electronic files provided with this document.

In addition, a correlation analysis of transport statistics computed from HYSPLIT trajectories was performed to quantify differences between trajectories computed with the different meteorological data sets and vertical velocity methods. Transport statistics provide an estimate of where air parcels originate and how they behave en route to a location. Specific metrics calculated include scalar wind run, resultant (vector) transport distance[2], resultant (vector-averaged) wind direction, and recirculation factor (R)[3]. Scalar wind run is the total physical distance traveled by an air parcel; resultant transport distance is the net distance traveled by an air parcel. For example, if a car completes one lap around a 1-mile track, the scalar distance traveled is 1 mile, but the vector distance is 0 miles. Resultant wind direction indicates the direction from which the air parcel originated. Recirculation factor is the ratio of the vector transport distance to the scalar transport distance. If the recirculation factor is 1, the wind field along the path of the air parcel was constant in speed and direction throughout the period. If the recirculation factor is 0, the wind field was such that there was no net movement of air during the period (i.e., air is recirculated). Transport statistics were computed for each trajectory at 12-hour intervals (e.g., 0-12 hours, 0-24 hours, etc.) using a method developed by Allwine and Whiteman (1994).

Table 2 summarizes the comparative statistics used to quantify the differences between transport statistics due to differences in wind field data sets and the vertical velocity methods[4].

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[2] Note that the vector transport distance is not a trajectory, but a wind run. It quantifies the transport assuming that the wind observed by the surface observation is spatially consistent through the maximum transport distance.

[3] The recirculation factor is the ratio of the resultant transport distance to the scalar transport distance (wind run). When R is equal to 1, straight-line, steady transport has occurred during the integration period. When R is equal to zero, no net transport has occurred during the integration period. Periods when R values are close to 1, combined with transport distances of a few hundred kilometers, would typically characterize good ventilation conditions. Conversely, low values of R represent periods of stagnation or recirculation.

[4] Positive wind direction differences indicate clockwise differences in wind direction, and directional differences are limited to ±180°.

For all statistics involving differences, the Sigma results were subtracted from the Omega results and the EDAS results were subtracted from the NAM results. This information is important for interpretation of the bias only.

Table 2. Summary of comparative statistics.

Comparative Statistic	Definition	Equation
Bias	Mean difference	$\frac{1}{n}\sum_{j=1}^{n}\left(X_j - Y_j\right)$
Gross difference	Mean absolute difference	$\frac{1}{n}\sum_{j=1}^{n}\left\|X_j - Y_j\right\|$
Correlation coefficient	A measure of the interdependence of two variables. Values close to 1 indicate high correlation.	$\frac{\sum_{i=1}^{n}(X_i Y_i) - \frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)}{\sqrt{\left(\sum_{i=1}^{n} X_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} X_i\right)^2\right)\left(\sum_{i=1}^{n} Y_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} Y_i\right)^2\right)}}$

To illustrate how the comparative statistics were analyzed to generate the results presented below, **Table 3** shows statistics for the comparison of the Sigma and Omega vertical motion methods for the Pinedale receptor site in the winter at the 12-hour end point. As noted in **Table 3a**, at 50 m at the Pinedale receptor location, the average difference in vector and scalar transport distances between the trajectories created using the two vertical motion methods were 33 km and 40 km, respectively. This indicates that the Omega vertical motion method tended to calculate longer transport distances than the Sigma vertical motion method. The average difference in transport direction was 1 degree, indicating little bias between the vertical motion methods. **Table 3b** shows the average absolute error (gross error) for the same metrics. For the trajectories at 50 m, the average absolute difference in vector and scalar transport distances were 34 km and 42 km, respectively, and the average absolute difference in transport directions was 30 degrees. **Table 3c** shows the average correlation coefficient. For the 50-m trajectories, the values range from 0.69 for scalar transport distance to 0.814 for recirculation factor. These correlation coefficients are relatively high, indicating that the trajectory paths are generally similar over the 12-hour period. The complete set of comparative statistics for each receptor site and season are presented in the electronic files provided with this document.

Table 3. Comparative statistics between the Sigma and Omega vertical motion methods for the Pinedale site and height in winter at the 12-hour end point: Table 3a shows bias, Table 3b shows gross error, and Table 3c shows correlation coefficient.

Table 3a. Bias.

Site	Height (m agl)	Recirculation	Vector Transport Distance (km)	Scalar Transport Distance (km)	Transport Direction (degrees)
Pinedale	50	0.016	33	40	1
Pinedale	300	-0.038	9	13	-5
Pinedale	700	-0.012	29	35	1

Table 3b. Gross error.

Site	Height (m agl)	Recirculation	Vector Transport Distance (km)	Scalar Transport Distance (km)	Transport Direction (degrees)
Pinedale	50	0.066	34	42	32
Pinedale	300	0.055	15	17	11
Pinedale	700	0.035	504	59	6

Table 3c. Correlation coefficient.

Site	Height (m agl)	Recirculation	Vector Transport Distance (km)	Scalar Transport Distance (km)	Transport Direction (degrees)
Pinedale	50	0.814	0.762	0.69	0.753
Pinedale	300	0.873	0.972	0.967	0.636
Pinedale	700	0.83	0.586	0.516	0.742

Results

Through analysis of all comparative statistics presented in the electronic files provided with this document, the following key findings of the HYSPLIT trajectory uncertainty analysis were generated.

- Individual trajectories based on the 12-km NAM and 40-km EDAS data sets are often quite different because the two data sets characterize local terrain-induced flows differently. However, aggregate flow patterns based on the aggregate effect of multiple trajectories over a significant period of time are similar.
- In an aggregate sense, trajectories calculated using the 12-km NAM and 40-km EDAS data sets are quantitatively and qualitatively similar. Overall SPD patterns were very similar at both receptor locations and at all three receptor heights. The mean absolute difference in 72-hour transport directions for all receptors was less than 20 degrees for

the summer and winter periods. The mean absolute difference in 72-hour transport distance for all receptors was 111 km and 162 km for summer and winter, respectively.

- When the mean wind flow is parallel to valleys and canyons, trajectories based on the NAM 12-km data tend to follow the valleys and canyons through the mountain ranges more realistically than trajectories based on the EDAS 40-km data. The higher-resolution NAM data resolves finer-scale topographical features, which results in improved characterization of local valleys and canyon flows.
- When the wind flow is perpendicular to the mountain ranges, trajectories based on both the NAM 12-km and EDAS 40-km data sets are similar because both data sets characterize the wind flows between and around large mountain ranges similarly.
- Uncertainties at shorter time scales (e.g., 12 hours) may be more important than uncertainties at longer time scales, depending on the location and strength of local emission sources.
- During the summer, differences in meteorological data sets drive wind direction differences in the near field, while differences in vertical motion method drive wind direction differences in the far field.
- Winter trajectories based on the Sigma vertical motion method tend to remain more localized than those based on the Omega method.

Wind Trajectory Analysis

Methodology

After completing the uncertainty analysis, STI ran TEAK and HYSPLIT to generate back trajectories every four hours in 2005 through 2009 from six representative sites (receptor locations) in Sublette County at three heights. The receptor locations are shown in **Figure 2**.

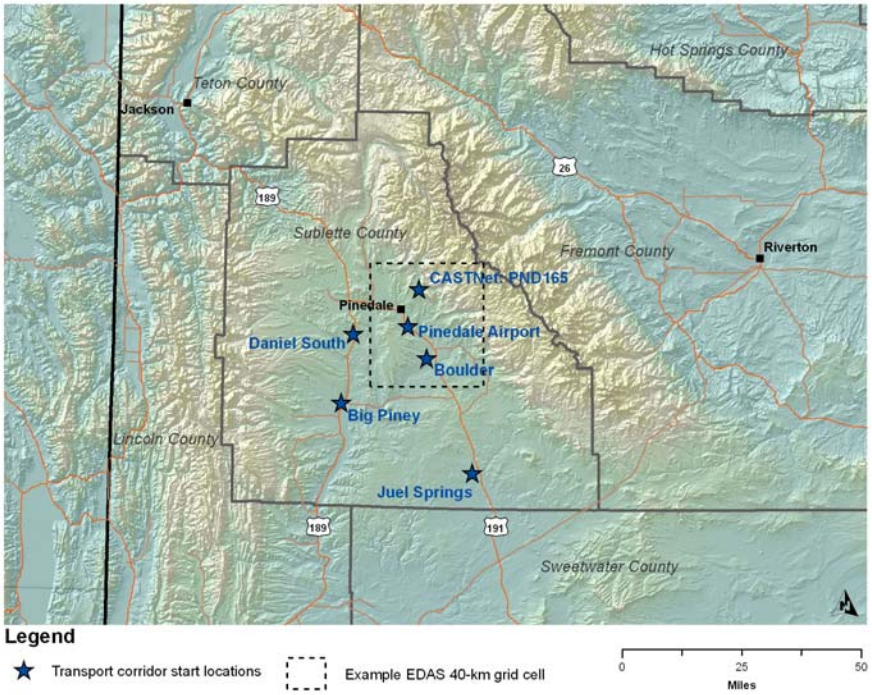


Figure 2. The back trajectory starting points and an example 40-km EDAS grid cell.

Based on the results of the model uncertainty analysis and data availability, the HYSPLIT model was run using data from the EDAS and the Sigma method for vertical motion. In addition to receptor locations, additional required input parameters include the model data set, duration of model runs, number of years of data, selection of vertical motion method, trajectory heights, trajectory start times, and height of the top of the model. **Table 4** lists the input parameters and values used for the Sublette County transport corridor analysis.

Table 4. Input parameters required to run the HYSPLIT model and preliminary values for use in this study.

Parameter	Value
Model data	40-km EDAS
Run time (trajectory length in time)	12-, 24-, 48-, and 72-hour end points
Date range	Jan. 2005—Dec. 2009
Vertical motion scheme	Sigma (constant height)
Starting heights	50, 300, 700 m (agl)
Receptor locations	CASTNet PND 165, Boulder, Daniel South, Juel Springs, Pinedale Airport, Big Piney stations
Starting hours (LST; 24-hour clock)	1, 3, 5, 9, 13, 17, 21
Top of model	10,000 m (agl)

Back trajectory start points, or receptor locations, are selected by identifying locations from which the back trajectories will emanate. In this case, six start points were chosen that correspond to the locations of air monitoring sites in and around Sublette County. Figure 2 shows the locations of the back trajectory start points used for this analysis. Also shown in Figure 2 is an example of a 40-km grid cell relative to the distance between starting points. Note that three of the starting points fall within one 40-km grid cell. The HYSPLIT model accounts for the sub-grid cell locations of start points by spatially interpolating the start point location from the center point of the 40-km grid cell, which enables the model to accurately capture spatial flow patterns.

Multiple starting heights are used to capture transport paths at different altitudes in the atmospheric boundary layer and are determined on the basis of the average daily maximum atmospheric boundary layer height. Multiple starting times are used to cover variations in meteorology over a 24-hour period. We used starting heights of 50 m, 300 m, and 700 m agl and starting hours of 1, 3, 5, 9, 13, 17, and 21 LST.

Trajectory durations are typically determined according to the potential long-range transport of air pollutants of interest. Particulate matter (PM) may settle out in a few hours or a day, while NO_x and SO_2 may travel for three or more days (Seinfeld and Pandis, 1998). Typically, 72-hour back trajectories are used for this type of analysis. Running 72-hour trajectories produces interim trajectory end points as well, including 12-, 24-, and 48-hours. For this analysis, we ran 72-hour back trajectories and analyzed the results of multiple end points (12-, 24-, 48-, and 72-hour).

The vertical motion setting controls the vertical motion of the air parcels for the trajectory runs. In past studies, STI has found that when using HYSPLIT to run back trajectories, the vertical motion calculation setting is important and depends on the regional atmospheric conditions. For example, in a study in Sacramento, California, the isobaric method, which allows air parcels to move vertically by following constant pressure surfaces, provided the most representative results for the stable atmosphere that exists during $PM_{2.5}$ episodes in Sacramento. Based on the results of the uncertainty analysis, we determined that the Sigma vertical motion scheme was the most representative method for Sublette County; therefore, we used this scheme for the trajectory analysis.

After calculating the back trajectories, SPD maps were produced for each site, height, season, and end point. The seasons were defined as follows: winter – December through February; spring – March through May; summer – June through August; and autumn – September through November. The SPD map for the Juel Springs receptor at 50 m in the winter is shown in **Figure 3**. The complete set of SPD maps used to identify potential transport corridors into Sublette County can be found in the electronic files provided with this document.

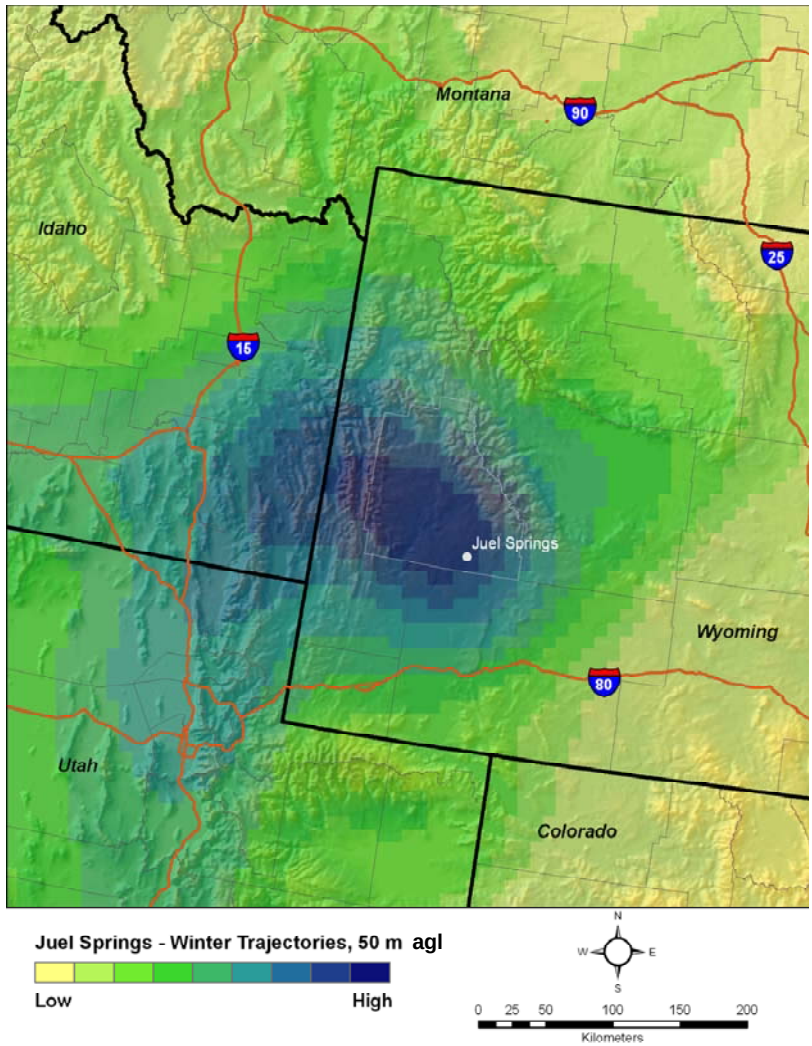


Figure 3. SPD map for the Juel Springs receptor site at 50-m height in winter. The colors represent the fraction of trajectories that passed over a location.

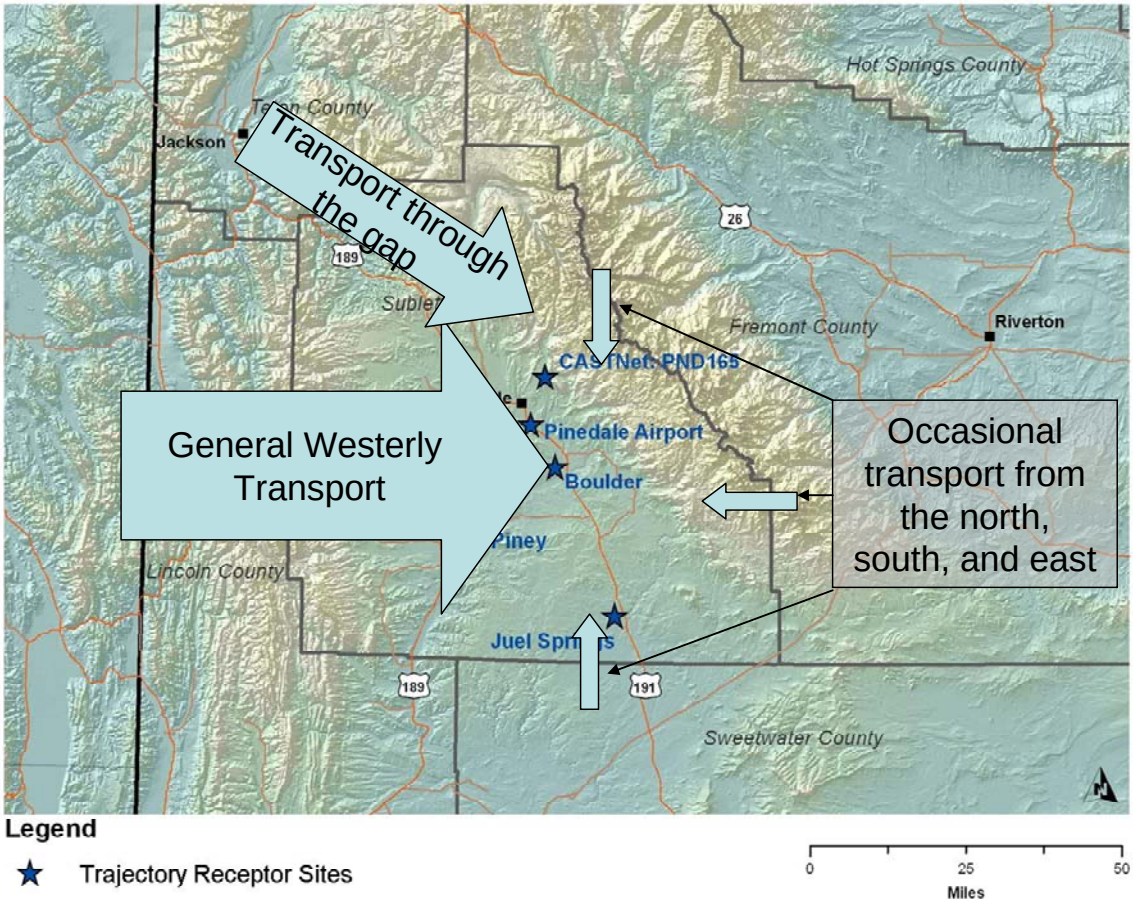


Figure 4. Area of transport into Sublette County.

Results

The key findings of the HYSPLIT wind trajectory analysis are as follows and are visualized in **Figure 4**

- Air parcel trajectories indicate predominantly westerly transport into Sublette County for trajectories arriving at all receptor sites and starting heights.
- Occasionally, air parcels originate from the north, south, or east into Sublette County.
- No specific transport corridors are evident, regardless of site and season. However, there tends to be more low-level transport through the gap at the north end of the Wyoming Range for air parcels arriving at sites located along the Wind River Range in central and northern the Sublette County.
- Low-level transport into Sublette County tends to be more northwesterly in the fall than in the winter.

Trajectory Comparison with Surface Wind

Methodology

After identifying the potential transport corridors, we completed a surface wind correlation analysis to determine whether wind measurements from existing surface meteorological stations can be used to estimate air parcel transport. The correlation analyses addressed the following questions:

- How well do the surface transport statistics compare with the HYSPLIT transport statistics?
- Which surface meteorological stations compared well with the HYSPLIT trajectories and which did not?
- How did the surface-to-HYSPLIT comparison change by season?

The first step was to select representative surface meteorological stations that lie within or in close proximity to the transport corridors identified in the wind trajectory analysis. The selected sites were all from the National Weather Service, Federal Aviation Administration, and Department of Defense ASOS (Automated Surface Observing System) network and the Bureau of Land Management and U.S. Forest Service Remote Automated Weather Stations (RAWS) network; these sites are shown in **Figure 5**. Four of the five sites selected—Hoback, Burro Hill, Big Piney, and Jackson—had data records for the entire 2005 through 2009 analysis period. However, the fifth site, Kelly, did not begin reporting data until 2007. Because no other stations were available in this region, the analysis was completed with the data available from the Kelly site.

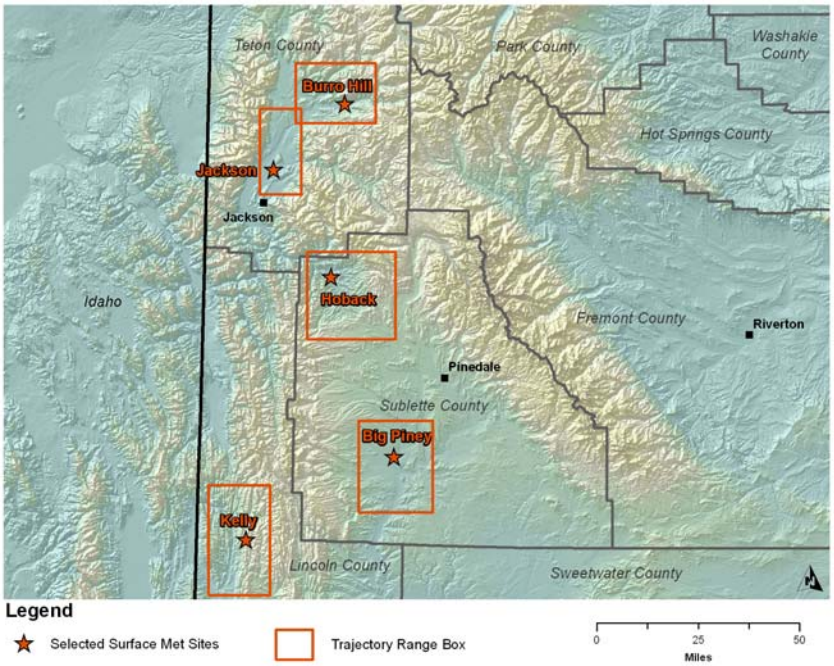


Figure 5. Surface meteorological sites selected for comparison to HYSPLIT model output. The red boxes indicate the geographic range through which a trajectory could pass to be within range of the site.

Once the surface sites were selected, the HYSPLIT trajectory points that passed within range of each site were flagged. The range of each site was determined by looking at topography in the area. The red boxes on Figure 5 show the range assigned to each location.

Transport statistics were calculated from the tagged HYSPLIT trajectories. Surface transport statistics were calculated to correspond to the same periods as the HYSPLIT model runs. Integration times of 6 to 24 hours were used to capture short- to mid-range transport flow patterns. The resulting transport statistics (recirculation factor, scalar transport distance, vector transport distance, and transport direction) were compared to the HYSPLIT transport statistics. Correlation analyses for various groupings (i.e., starting height, end-point time, and season) were used to compare all parameters. For all statistics involving differences, the HYSPLIT results were subtracted from the surface station results. This information is important for interpretation of the bias only.

Results

The key findings of the surface-to-HYSPLIT wind comparison are as follows:

- The surface transport statistics compared poorly, in general, with the HYSPLIT transport statistics at all heights, sites, and seasons. Therefore, the surface wind data will not accurately represent transport of air within and/or above the boundary layer in Sublette County. However, surface wind data from these locations are important to validate the meteorological modeled wind fields at the sites used to calculate the trajectories. Some example statistical results are as follows:

  - For 24-hour trajectories, scalar and vector transport distances calculated from the surface data were, on average, about 100 km shorter than the HYSPLIT transport distances at 50 m and about 400-500 km shorter than the HYSPLIT transport distances at 700 m.
  - For 72-hour trajectories, scalar and vector transport distances calculated from the surface data were, on average, about 200-500 km shorter than the HYSPLIT transport distances at 50 m and about 900-1,600 km shorter than the HYSPLIT transport distances at 700 m.
  - For both 24-hour and 72-hour trajectories, transport directions calculated from the surface data were, on average, generally within 90 degrees of the HYSPLIT transport directions at all heights.
- None of the surface meteorological stations compared well with the HYSPLIT trajectories, regardless of season or receptor location. However, some sites compared better than others. For example:
  - The error in transport direction between the surface sites and HYSPLIT was significantly lower at the Hoback and Kelly sites, averaging less than 40 degrees, which was approximately half the error of the other sites.
  - Vector and scalar transport distances had the least error at the Jackson and Burro Hill sites.
- There was no significant difference in the surface-to-HYSPLIT comparison of transport statistics by season.

Emissions Impact Potential

Methodology

To assess the potential impacts of upwind and out-of-state emissions sources on receptor locations in Sublette County, STI used TEAK to perform an emissions impact potential analysis. After generating SPD maps for each receptor site from HYSPLIT trajectory output (see the Trajectory Corridor Identification section for information about SPD), we used TEAK to combine the SPD results with spatially resolved emissions data for Wyoming and county-level emissions data for surrounding states. Wyoming emissions data were compiled from data provided by Wyoming DEQ and the 2005 National Emissions Inventory (NEI) and spatially allocated to a 4-km resolution grid domain using source location coordinates and available land cover and land use data (Pollard and Reid, 2010). County-level emissions data for surrounding states were obtained from the 2005 NEI. The differences in emissions' spatial resolution results in some discontinuity in EIP maps across state lines.

Figure 6 illustrates the procedure for combining the SPD results and emissions inventory data within TEAK. This figure also shows examples of the resulting emissions impact potential density plots that provide information about the potential for specific upwind areas to impact receptors of interest. STI prepared volatile organic compounds (VOC), NO_x, SO_2, and PM_{10} emissions impact potential plots for Sublette County receptor locations by season.

Results

Figures 7 and 8 show autumn and winter emissions impact potential plots for the Juel Springs site based on trajectories with a start height of 50 m. These plots represent the impact of

transported emissions on Sublette County; plots for remaining sites, start heights, and seasons can be found in the electronic files provided with this document.

For the Juel Springs site, emissions impact potential densities are very similar for the autumn and winter seasons, as significant impact potentials are observed from local sources (primarily related to oil and gas production) in Sublette County and from transported emissions originating across the Snake River Plain of southeastern Idaho and the Great Salt Lake area of north-central Utah. Potential emissions impacts are particularly high for counties with population centers, such as Bannock County, Idaho, (Pocatello area) and Salt Lake County, Utah, (Salt Lake City area). Across pollutants, the pattern of emissions impact potential densities is generally similar, although some variations can be observed.

For NO_x emissions, key out-of-state emissions source areas include Weber, Davis, and Salt Lake counties in Utah, and to a lesser extent, Bannock and other neighboring counties in southeastern Idaho. On-road mobile sources are the largest source of NO_x in these regions of interest, accounting for 44% of NO_x emissions in Bannock County, Idaho, and at least 50% of NO_x emissions in Weber, Davis, and Salt Lake counties in Utah. Several large point sources of NO_x exist in Salt Lake County, including the Bingham Canyon copper mine and production operation. It should also be noted that potential NO_x impacts are observed as far away as Ada County in western Idaho, where the city of Boise is located.

For SO_2 emissions, the spatial pattern of emissions impact potential densities is very similar to that of NO_x. However, SO_2 emissions are primarily produced by large industrial point sources, which are concentrated in Caribou County, Idaho, and Salt Lake County, Utah. The key SO_2 source in Caribou County is P4 Production LLC, a phosphate mining company, while Salt Lake County is home to a number of refineries and smelters that produce SO_2.

For VOC emissions, key out-of-state emissions source areas again include Weber, Davis, and Salt Lake counties in Utah and Bannock County in Idaho. On-road mobile sources and “non-point”[5] sources such as solvent utilization, gas stations, and residential wood combustion are the largest sources of VOC emissions in these regions.

For PM_{10} emissions, key out-of-state emissions source areas include Davis and Salt Lake counties in Utah and Bonneville, Bannock, and Franklin counties in Idaho. For Idaho counties, unpaved-road dust is the dominant source of PM_{10} emissions, while in the Utah counties, fugitive dust from construction activities and paved road dust are the dominant sources of PM_{10}. Note, however, that large particles, such as those in unpaved road dust or construction activities, are not likely to be transported more than a few kilometers.

[5] Non-point sources are stationary sources that are too small and numerous to be treated on an individual basis in emissions inventories.

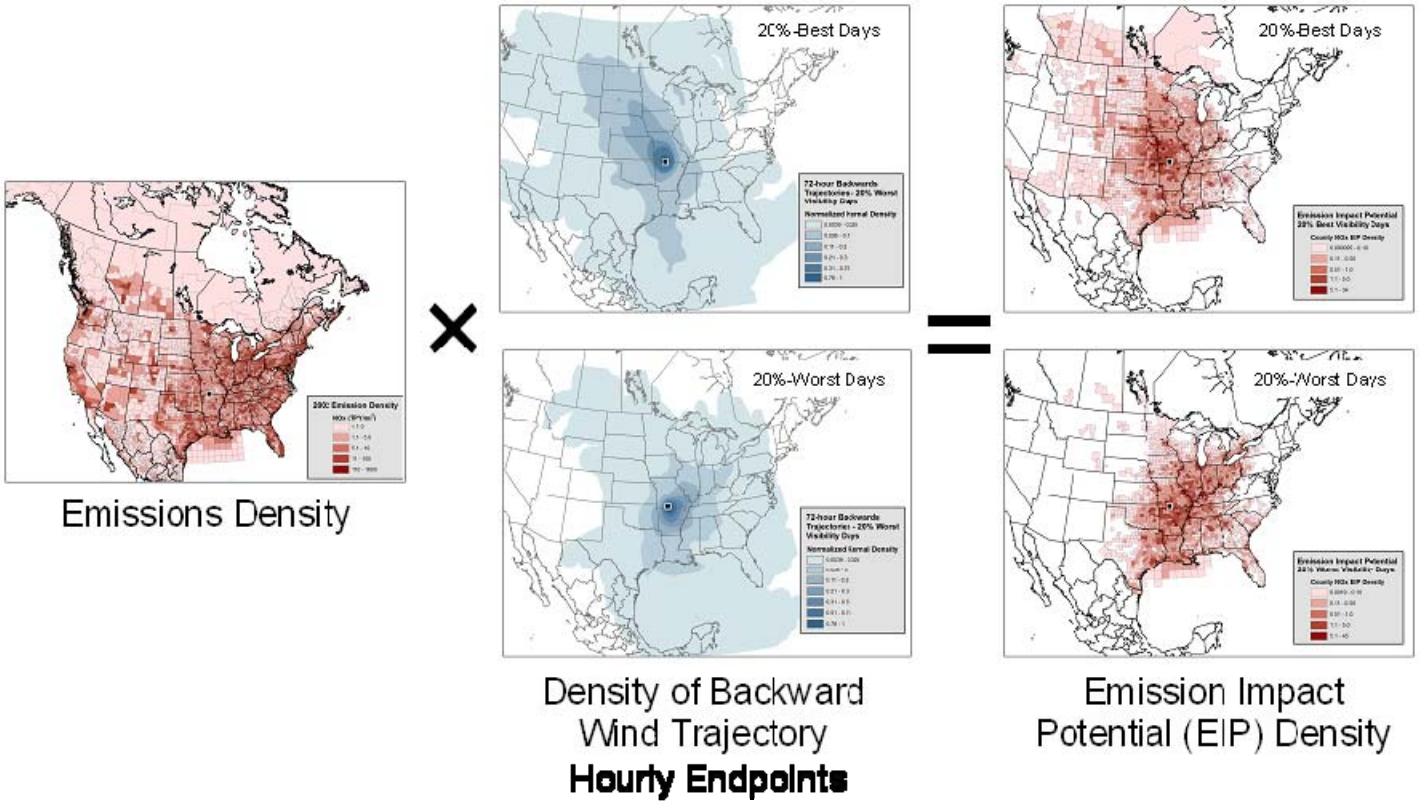


Figure 6. Illustration of the procedure used to combine SPD and emissions inventory data.

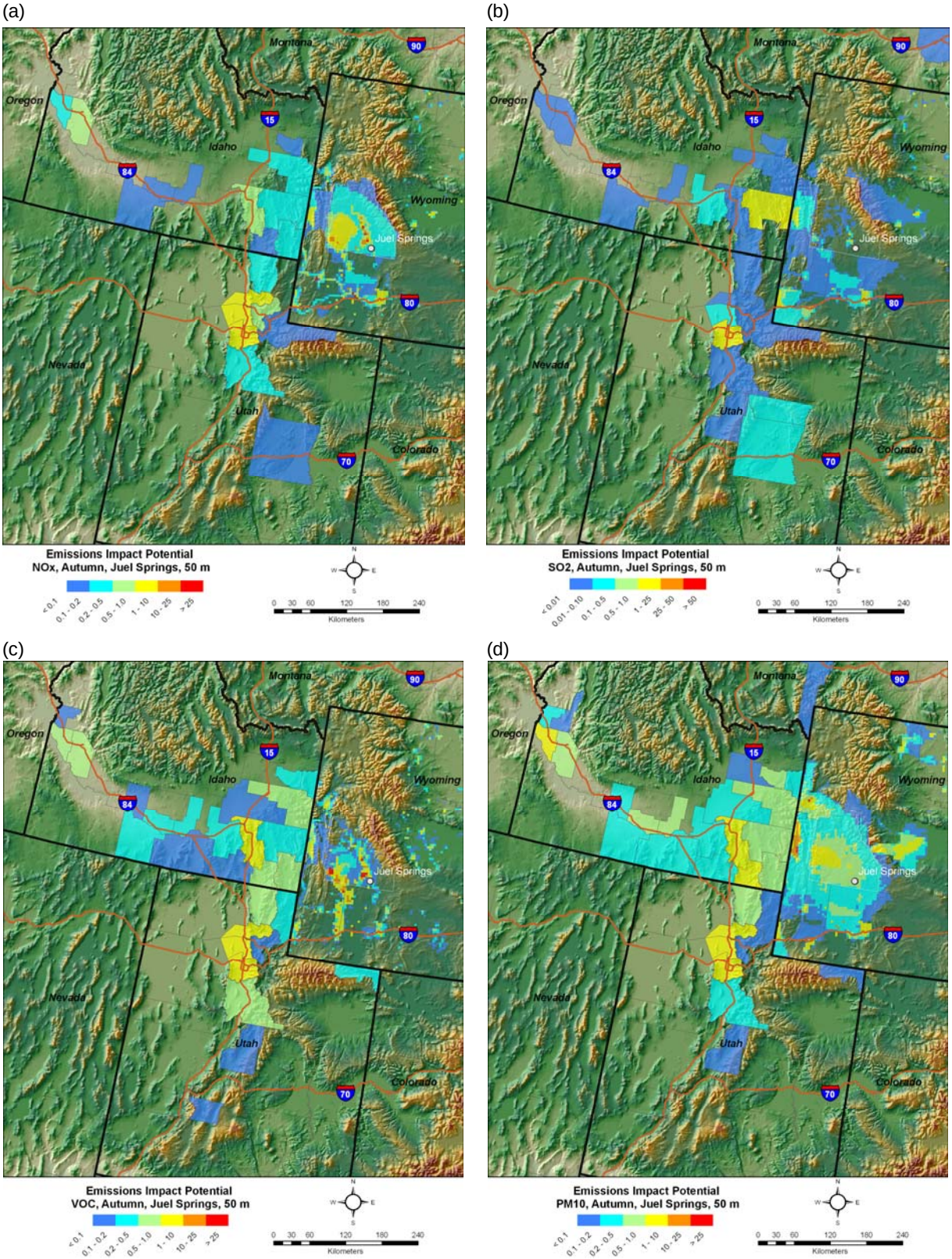


Figure 7. Autumn emissions impact potential density plots for the Juel Springs site for (a) NO_x, (b) SO_2, (c) VOC, and (d) PM_{10}.

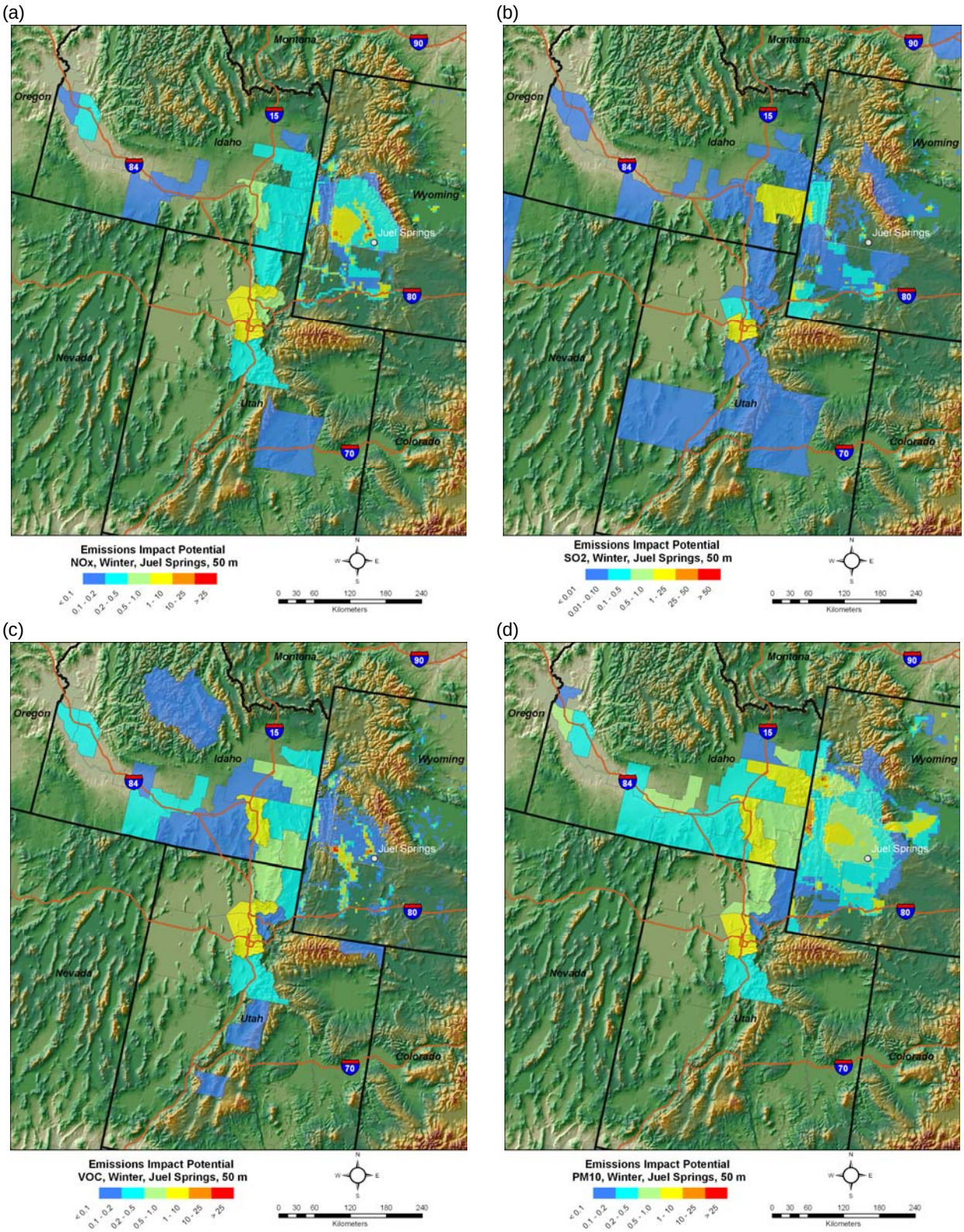


Figure 8. Winter emissions impact potential density plots for the Juel Springs site for (a) NO_x, (b) SO_2, (c) VOC, and (d) PM_{10}.

References

Allwine K.J. and Whiteman C.D. (1994) Single-station integral measures of atmospheric stagnation, re-circulation, and ventilation. *Atmos. Environ.* **28**, 713-721.

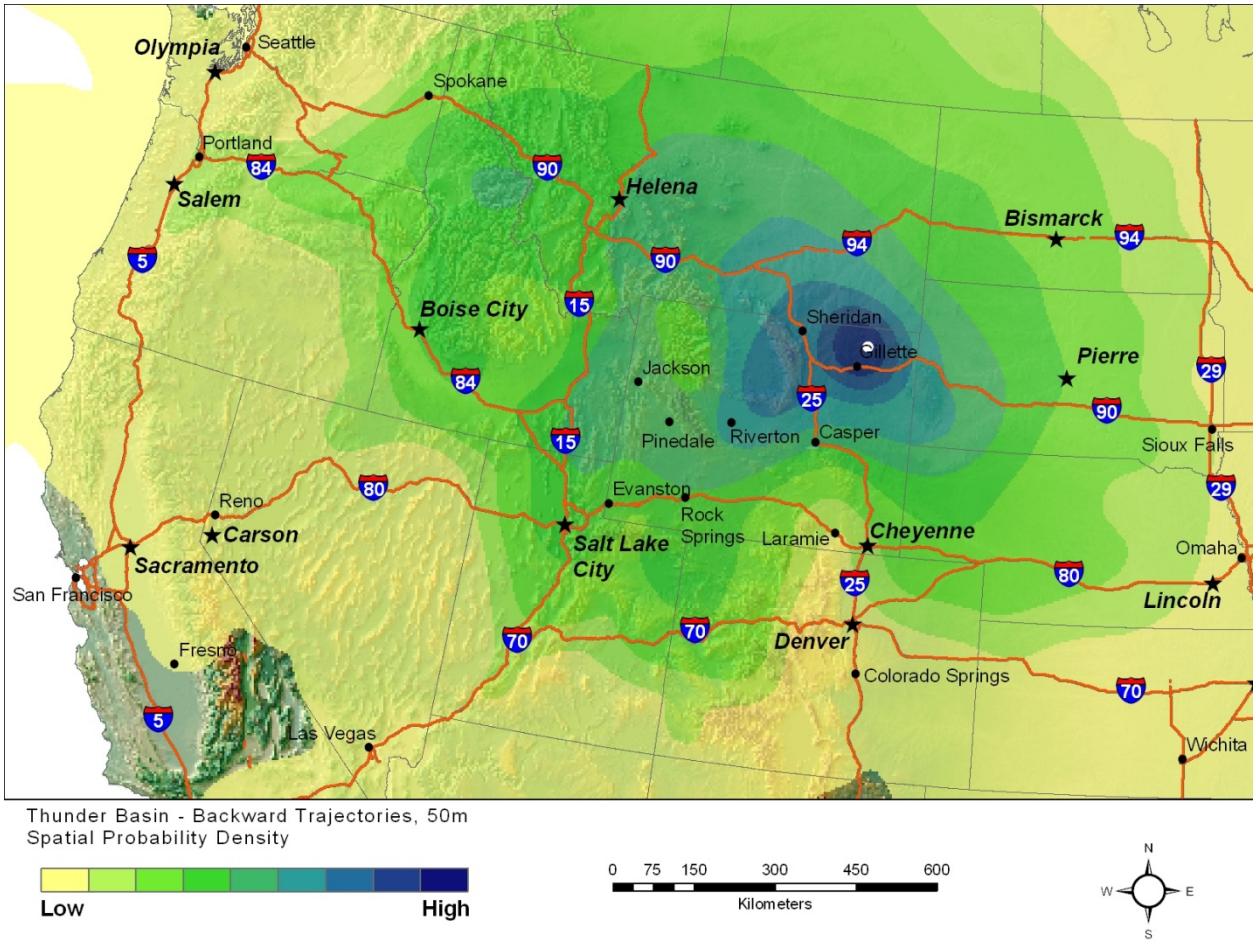
Pollard E.K. and Reid S.B. (2010) Wyoming statewide air monitoring network assessment Task D: emissions estimate. Technical memorandum prepared for the Wyoming Department of Environmental Quality, Cheyenne, WY, by Sonoma Technology, Inc., Petaluma, CA, STI-910019-3891, June 3.

Seinfeld J.H. and Pandis S.N. (1998) *Atmospheric chemistry and physics: from air pollution to climate change*, J. Wiley and Sons, Inc., New York, NY.

Appendix F

Supporting Materials for Section 8

Spatial Probability Density for Thunder Basin Monitoring Station



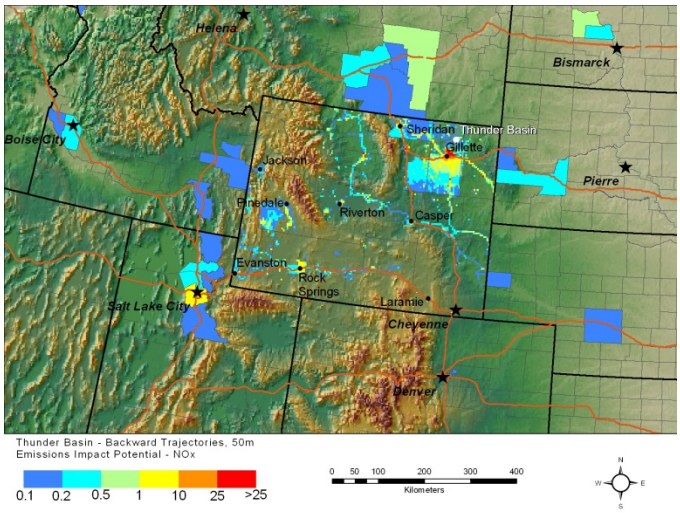
Thunder Basin - Backward Trajectories, 50m
Spatial Probability Density

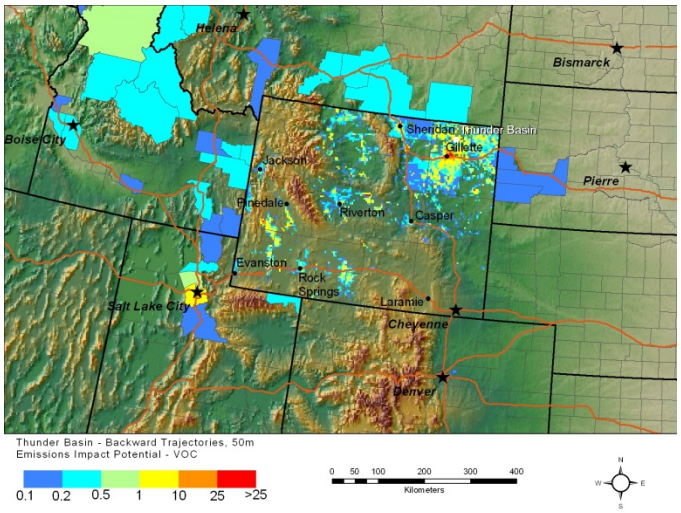
Low — High

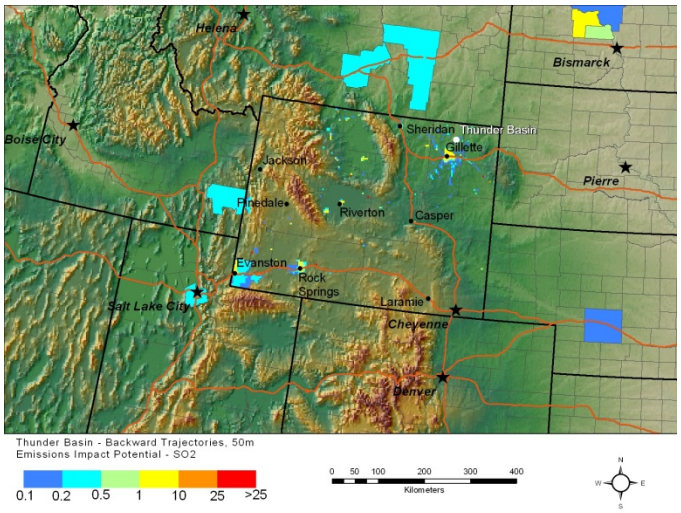
0 75 150 300 450 600
Kilometers

N W E S

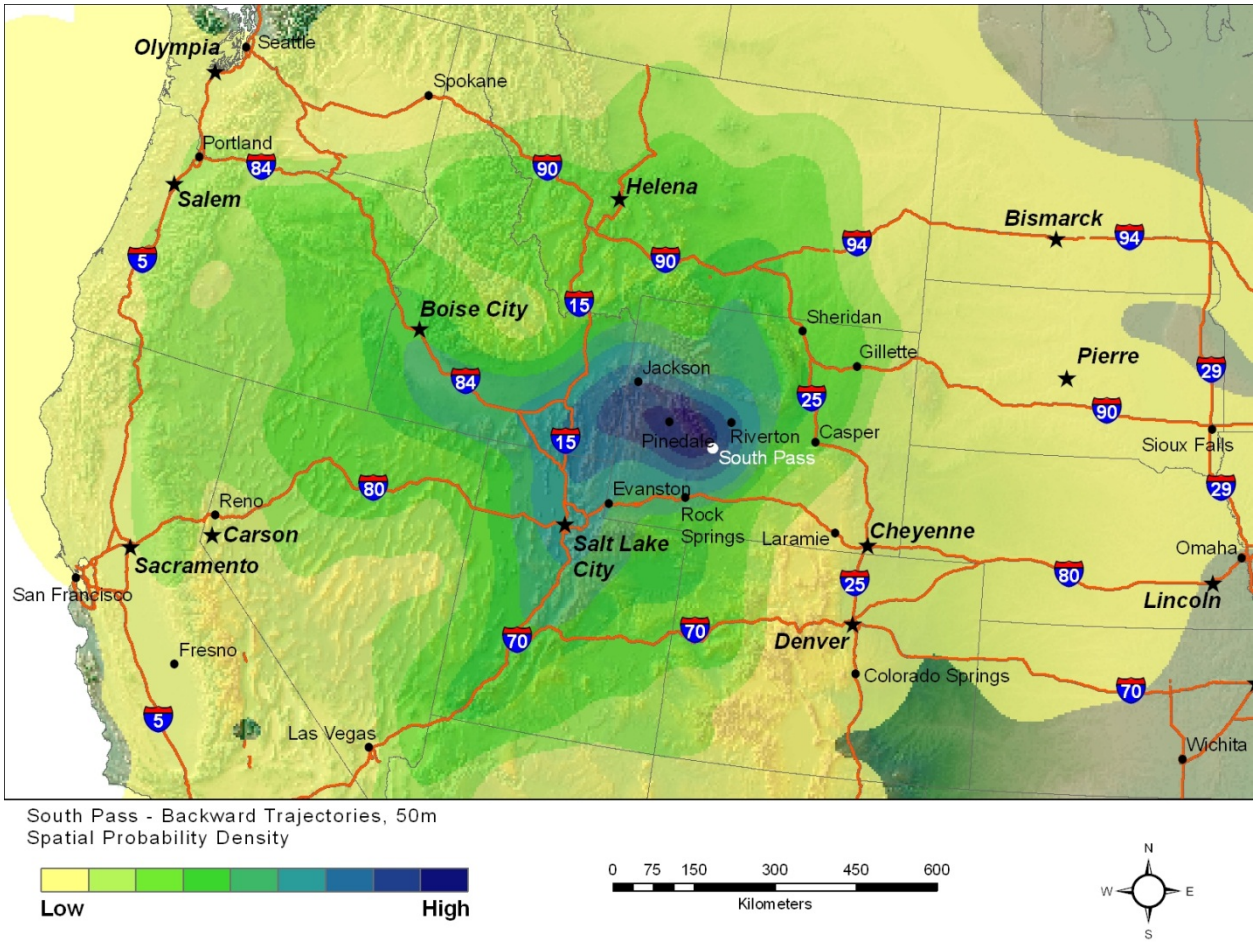
Emission Impact Potential for Thunder Basin Monitoring Station







Spatial Probability Density for South Pass Monitoring Station



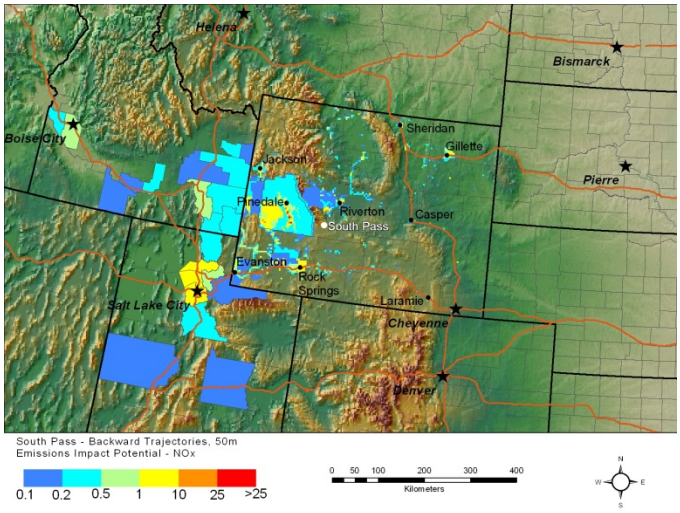
South Pass - Backward Trajectories, 50m
Spatial Probability Density

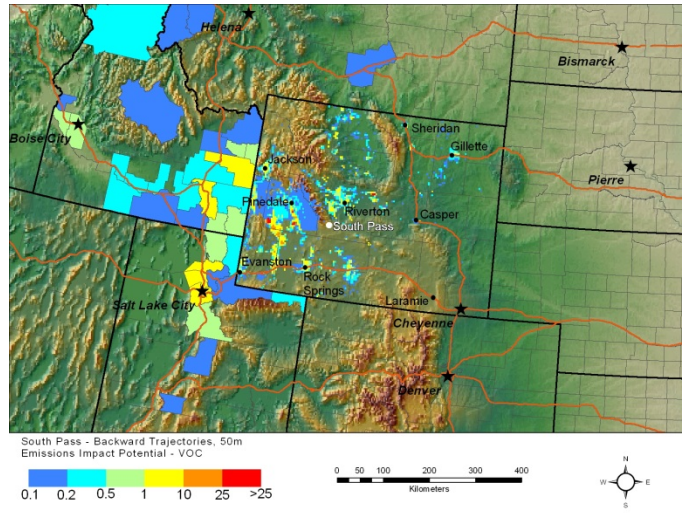
Low — High

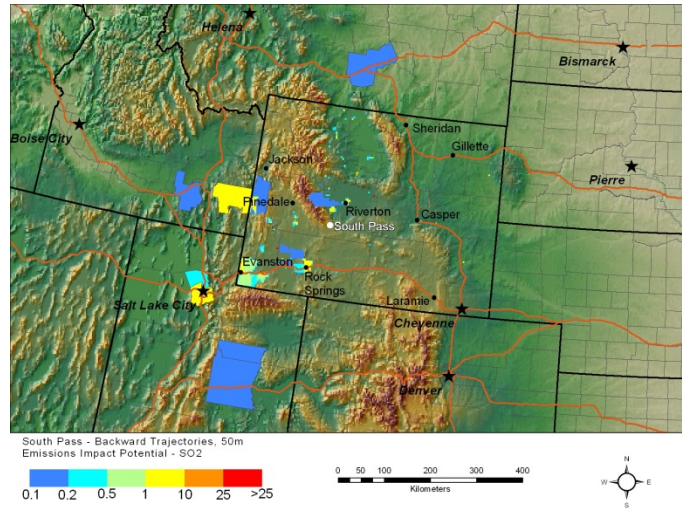
0 75 150 300 450 600
Kilometers

N W E S

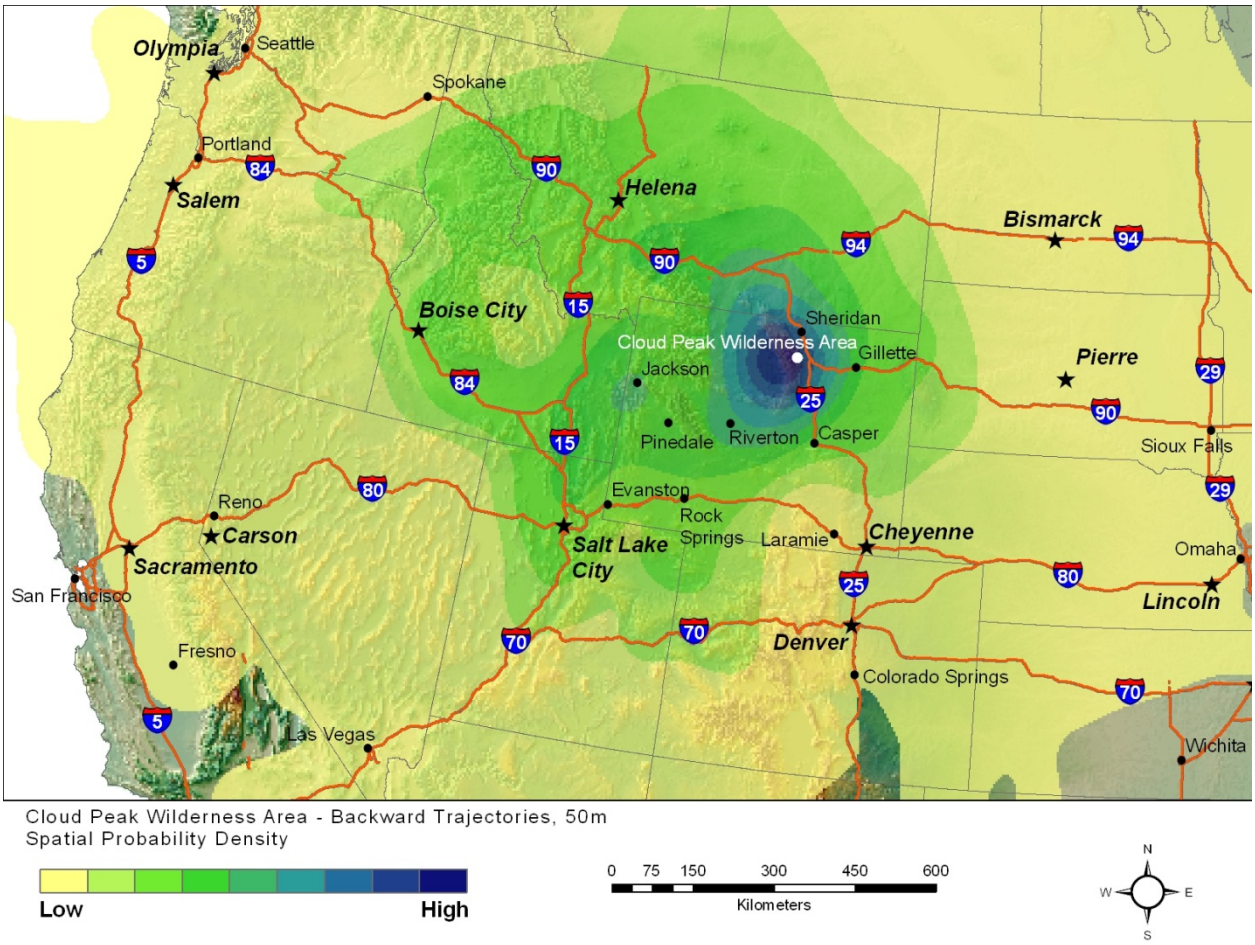
Emission Impact Potential for South Pass Monitoring Station







Spatial Probability Density for Cloud Peak



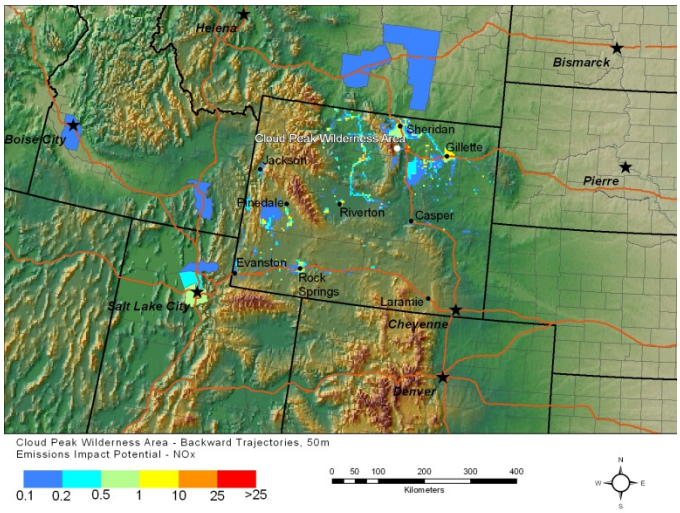
Cloud Peak Wilderness Area - Backward Trajectories, 50m
Spatial Probability Density

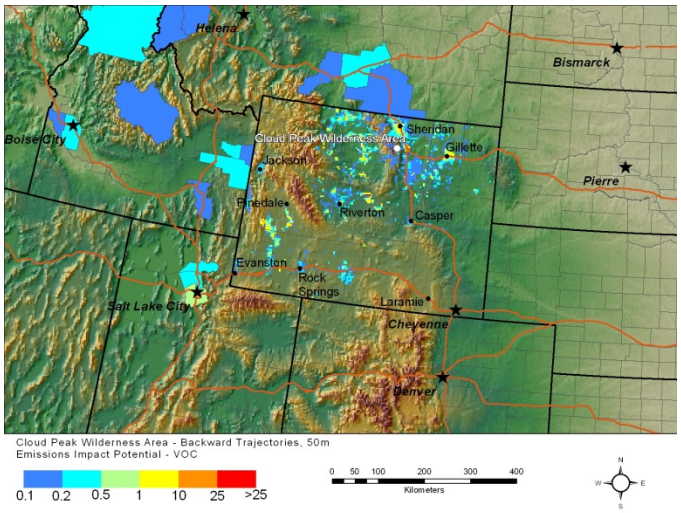
Low — High

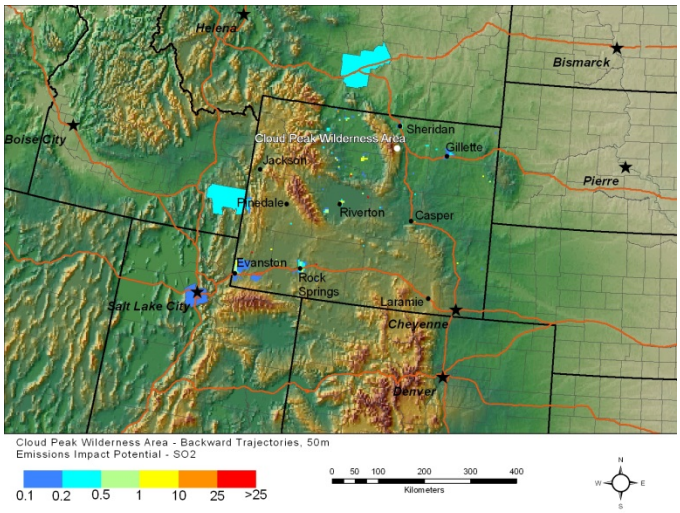
0 75 150 300 450 600
Kilometers

N W E S

Emission Impact Potential for Cloud Peak



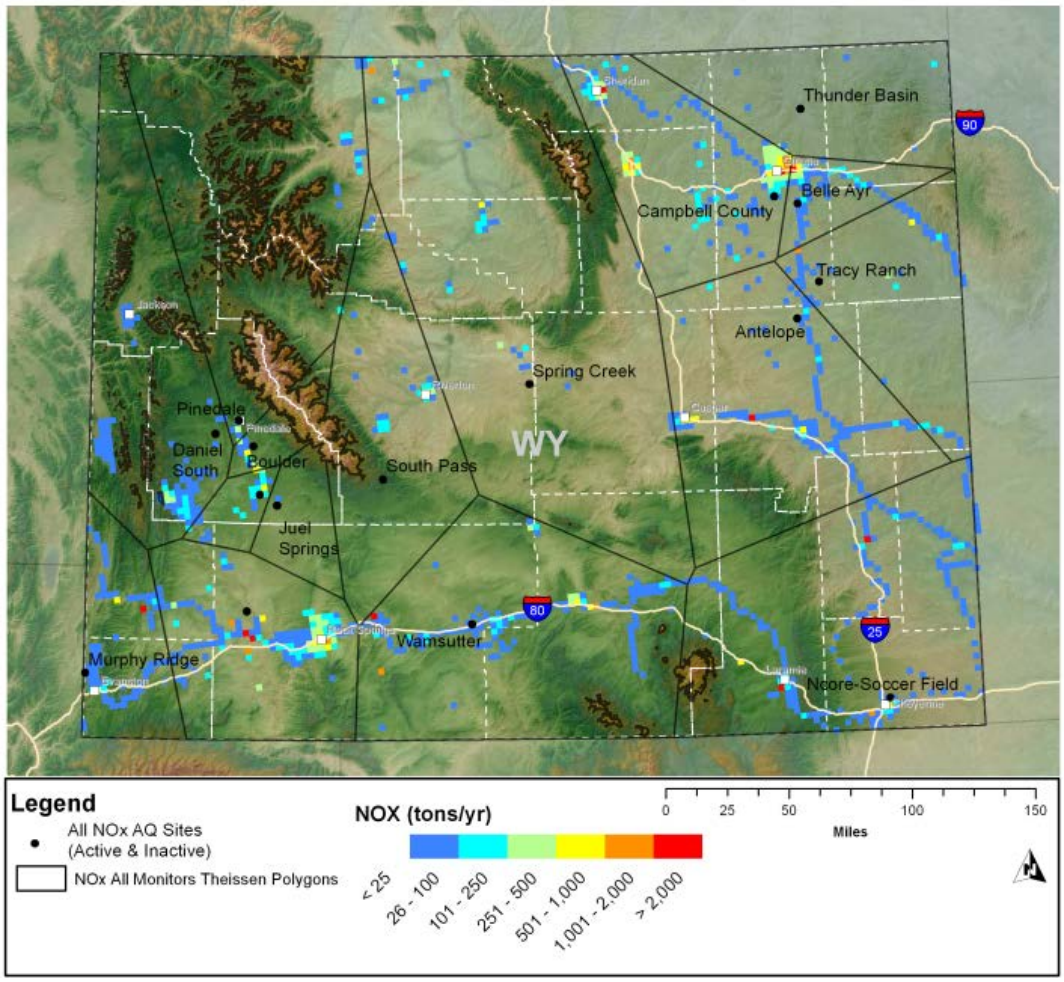




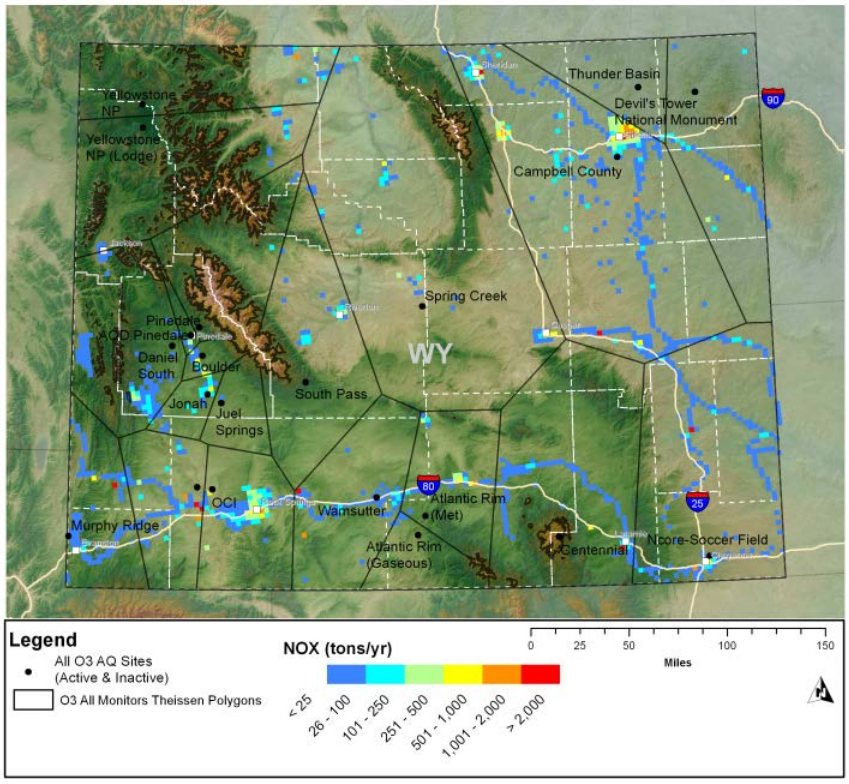
Appendix G

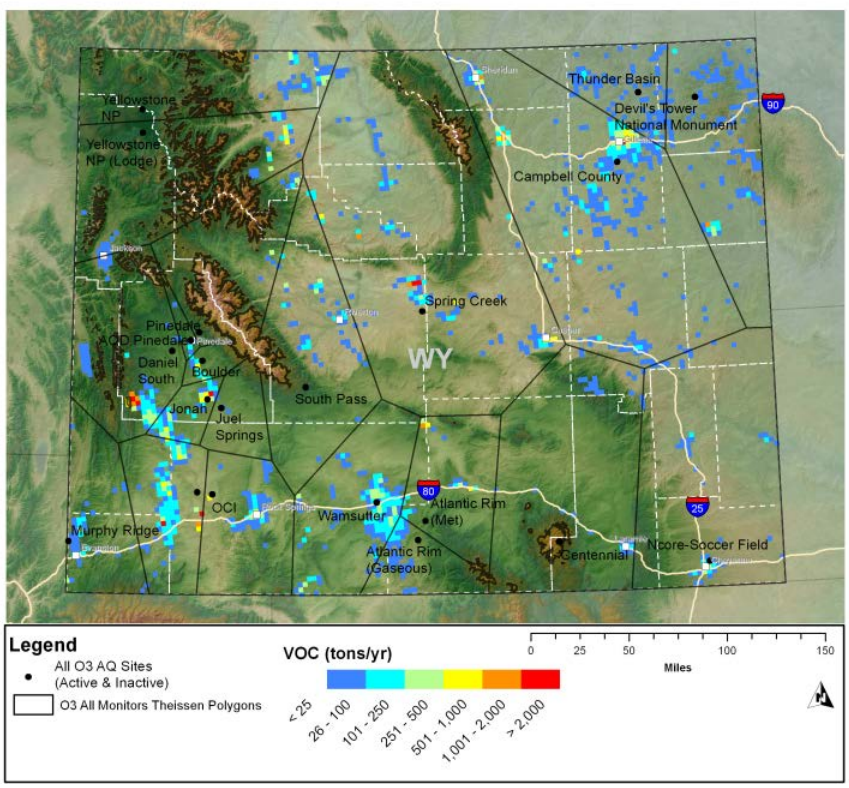
Supporting Materials for Section 9

NO_x: Gridded Emissions

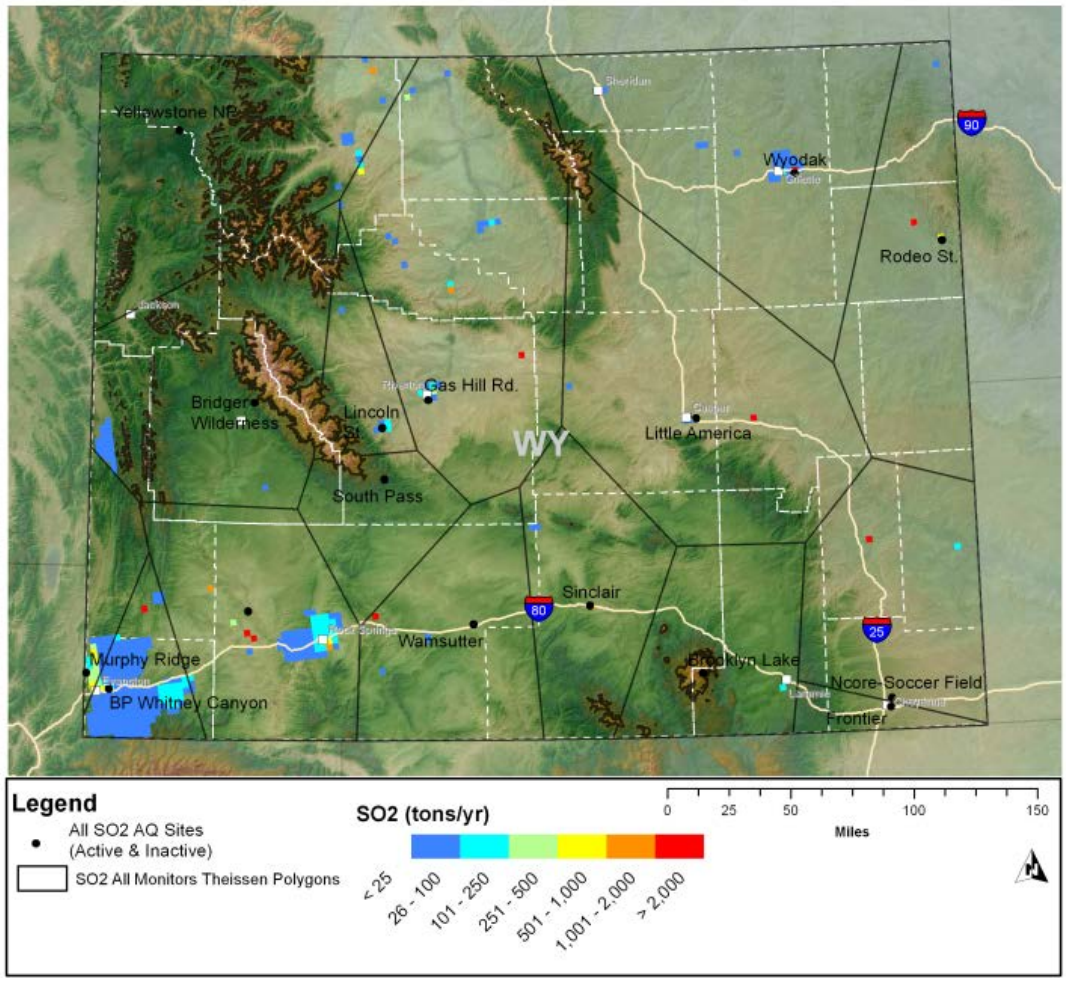


O_3 : Gridded Emission of NOx and VOCs

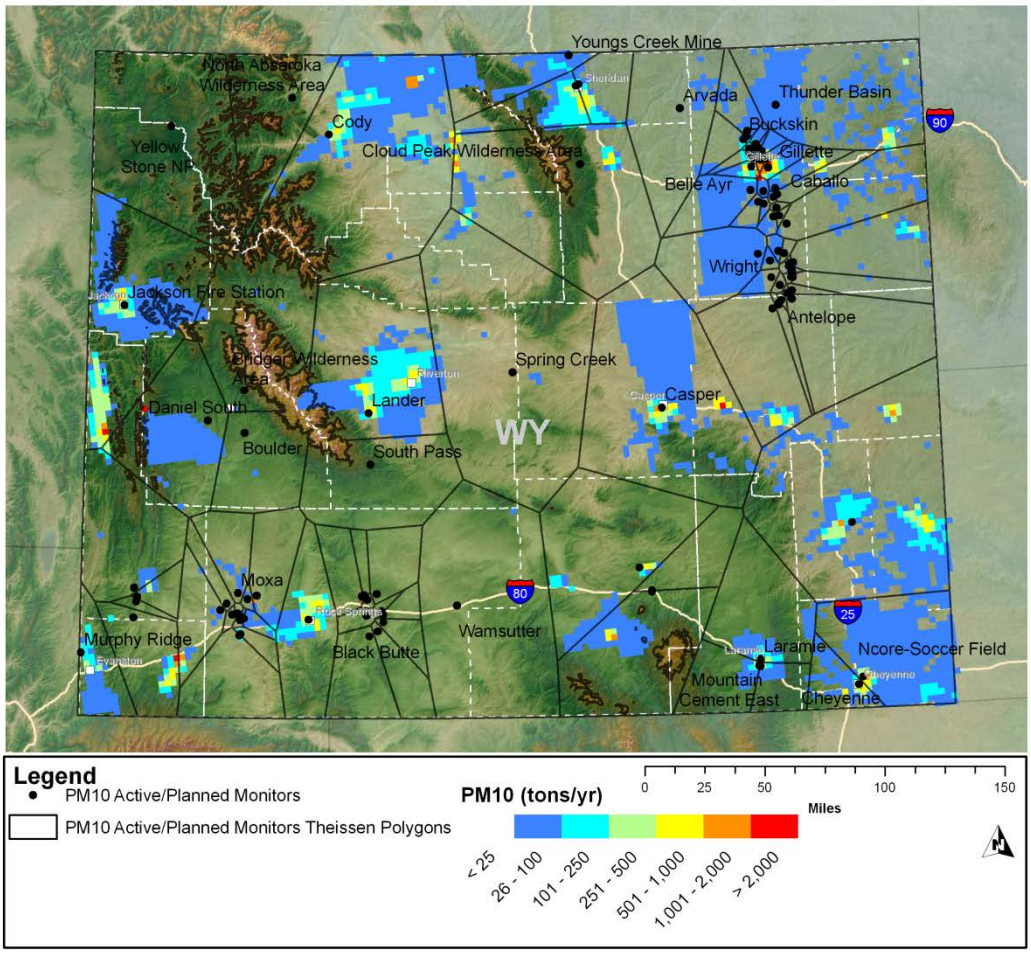




SO_2: Gridded Emission



PM_{10}: Gridded Emission and Monitoring Stations



Appendix H

Supporting Materials for Section 10

Wyoming Meteorological Monitoring

AQS ID	Monitoring Station Name	Monitoring Network
56-005-0123	Thunder Basin	AQD
56-005-0456	Campbell County	AQD
56-013-0099	South Pass WYDot	AQD
56-035-0098	Jonah Field	AQD
56-035-0099	Boulder	AQD
56-035-0100	Daniel South	AQD
56-035-0101	Pinedale	AQD
56-037-0200	Wamsutter	AQD
56-041-0101	Murphy Ridge	AQD
56-001-0802	Mountain Cement	Industrial
56-005-0802	Belle Ayr BA-1	Industrial
56-005-0857	WYODAK Site 4	Industrial
56-005-0879	Dry Fork DF-1	Industrial
56-005-0892	Belle Ayr BA-4	Industrial
56-005-0895	Rawhide North	Industrial
56-005-0899	Triton Coal	Industrial
56-005-0900	Eagle Butte Mine	Industrial
56-005-0907	Black Thunder Mine Site 12 Met	Industrial
56-005-1000	Cordero Rojo Complex	Industrial
56-005-1110	Anadarko Spotted Horse Met Station	Industrial
56-005-1111	NARM Met Station	Industrial
56-005-1112	Coal Creek Mine Met Station	Industrial
56-005-1115	Black Thunder Met Station	Industrial
56-005-1899	Buckskin Mine North Site	Industrial
56-0051-917	Jacob Ranch Mine Site 5	Industrial
56-005-2841	Coal Creek Mine Met Station	Industrial
56-005-2908	Caballo Mine Met.	Industrial
56-007-0099	Atlantic Rim Met.	Industrial
56-007-0100	Atlantic Rim Gaseous	Industrial
56-007-0826	Seminoe II Mine Site	Industrial
56-007-8110	Elk Mountain Site 811UW	Industrial
56-009-0819	Antelope Site 3	Industrial
56-009-2819	Antelope Mine Met Station	Industrial
56-013-6001	Riverton - Gas Hill Rd	Industrial
56-023-0814	Chevron Kemmerer Mine SB-111	Industrial
56-023-0815	Chevron Kemmerer Mine SB-IV	Industrial
56-023-0820	Naughton Power Plant	Industrial
56-023-2000	Opal Met Station	Industrial
56-037-0013	General Chemical Site 1	Industrial
56-037-0862	FMC - Granger #7	Industrial
56-037-0898	OCI #4	Industrial
56-037-1002	FMC TRONA SITE 002	Industrial

Wyoming Meteorological Monitoring continued

AQS ID	Monitoring Station Name	Monitoring Network
56-045-0800	Wyoming Refining	Industrial
KBPI	Big Piney	METAR
KBYG	Buffalo	METAR
KCOD	Cody	METAR
KCPR	Casper	METAR
KCYS	Cheyenne	METAR
KDGW	Douglas	METAR
KEVW	Evanston	METAR
KGCC	Gillette	METAR
KJAC	Jackson	METAR
KLAR	Laramie	METAR
KLND	Lander	METAR
KP60	Yellowstone Lake	METAR
KPNA	Pinedale R Wenz	METAR
KRIW	Riverton	METAR
KRKS	Rock Springs	METAR
KRWL	Rawlins Municipal	METAR
KSHR	Sheridan	METAR
KWRL	Worland	METAR
56-011-1013	Devils Tower NM - Joyner Ridge Trail	NPS
56-039-1011	Yellowstone NP	NPS
56-039-1012	Yellowstone National Park - Old Faithful	NPS
ANDW4	ANDERSON RIDGE	RAWS
BECW4	BECHLER	RAWS
BUJW4	BURGESS	RAWS
BYDW4	Boyd Ridge	RAWS
CAMW4	CAMP CREEK	RAWS
CDAW4	CRANDALL	RAWS
CMRW4	CASPER MOUNTAIN	RAWS
CMWW4	COYOTE MEADOWS	RAWS
COWW4	COW CREEK	RAWS
DODW4	DODGE CREEK	RAWS
DVLW4	DEVILS TOWER	RAWS
ECEW4	ECHETA	RAWS
EGLW4	EAGLE	RAWS
ELKW4	ELKHORN	RAWS
ERAW4	BURRO HILL	RAWS
ESTW4	ESTERBROOK	RAWS
GCRW4	GRASS CREEK DIVIDE	RAWS
GTGW4	GRAND TETON	RAWS
HAFW4	HALF MOON	RAWS
HHRW4	HYATT HIGH	RAWS
HOBW4	HOBACK	RAWS

Wyoming Meteorological Monitoring continued

AQS ID	Monitoring Station Name	Monitoring Network
KLYW4	KELLY	RAWS
LEIW4	LEIGH CREEK	RAWS
MCRW4	MILL CREEK	RAWS
MUDW4	MUDDY CREEK	RAWS
PCRW4	POKER CREEK	RAWS
QADW4	QUADRANT	RAWS
RATW4	RATTLESNAKE MTN.	RAWS
RHKW4	ROCHELLE HILLS	RAWS
SAWW4	SAWMILL PARK	RAWS
SNOW4	SNOW SPRINGS CREEK	RAWS
SPKW4	SCHOOL HOUSE	RAWS
SPLW4	SPLIT ROCK CREEK	RAWS
WRVW4	WIND RIVER	RAWS