Request for EPA Concurrence as Exceptional Events for 2012 Wildfire Impacts on $PM_{2.5}$ Monitor Values at Salmon and Pinehurst Idaho

Draft

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Table of Contents

Executive Summary xi
1 Conceptual Model 1
1.1 Overview 1
1.2 Source Area and Affected Region 2
1.3 Emissions 3
1.4 Weather Phenomena Contributing 4
1.4.1 Temperatures 4
1.4.2 Precipitation 7
1.4.3 Drought Conditions 8
1.4.4 Transport Weather Conditions 10
1.5 Path and Timeline from Source Area to Monitors 13
1.5.1 Analysis of Winds and $PM_{2.5}$ Frequencies 13
1.5.2 Direct Advection from Source to Monitors Conceptual Model Description 18
1.5.3 Salmon Valley Flows Conceptual Model Description 18
1.5.4 Pinehurst Valley Flows Conceptual Model Description 19
1.6 Concentration Patterns 20
1.6.1 Temporal Patterns 20
1.6.2 Spatial Patterns 22
2 Not Reasonably Controllable or Preventable (nRCP) 26
2.1 Source Areas Contributing to the Event 26
2.2 Basic Controls Analysis 28
3 In Excess of Historical Fluctuations (HF) 29
3.1 Salmon Historical Fluctuations 29
3.2 Pinehurst Historical Fluctuations 33
4 Clear Causal Relationship (CCR) 37
4.1 Similarity of Chemical Composition of Measured Pollution with that Expected from Sources Identified as Upwind 37
4.2 Occurrence and Geographic Extent of the Event 37
4.3 Alternative Hypotheses 38
4.3.1 Prescribed Fires 38
4.3.2 Crop Residue Burning 38
4.3.3 Residential Wood Combustion 39
4.3.4 Other Forms of Open Burning 39
4.3.5 On-Road Mobile Sources 39
4.4 Scenarios 40
4.5 Scenario 1: Valley Flows from North and Northeast—Mustang Complex 44

4.5.1 Description of Typical Weather Conditions and Transport Winds 44
4.5.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 46
4.5.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 46
4.5.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 48
4.5.5 Alternative Hypotheses..... 48
4.6 Scenario 2 : Direct Plume Impact—Mustang Complex 48
4.6.1 Description of Typical Weather Conditions and Transport Winds 48
4.6.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 50
4.6.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 50
4.6.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 52
4.6.5 Alternative Hypotheses..... 52
4.7 Scenario 3: Drainage From South or Southeast—Halstead 52
4.7.1 Description of Typical Weather Conditions and Transport Winds 52
4.7.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 54
4.7.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 55
4.7.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 57
4.7.5 Alternative Hypotheses..... 57
4.8 Scenario 4: Direct Plume Impact—Halstead..... 57
4.8.1 Description of Typical Weather Conditions and Transport Winds 57
4.8.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 59
4.8.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 59
4.8.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 61
4.8.5 Alternative Hypotheses..... 61
4.9 Scenario 5: Regional Transport 61
4.9.1 Description of Typical Weather Conditions and Transport Winds 61
4.9.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 63
4.9.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 63
4.9.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 65
4.9.5 Alternative Hypotheses..... 65
4.10 Pinehurst Scenario 1: Regional Transport 65

4.10.1 Description of Typical Weather Conditions and Transport Winds 65
4.10.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 67
4.10.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 67
4.10.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 69
4.10.5 Alternative Hypotheses..... 69
4.11 Scenario 2: Local Stagnation..... 69
4.11.1 Description of Typical Weather Conditions and Transport Winds 69
4.11.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded 71
4.11.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question 71
4.11.4 Comparison of Event-Affected Days to Specific Nonevent Days..... 72
4.11.5 Alternative Hypotheses..... 73
5 Affects Air Quality (AAQ)..... 73
6 Human Activity Unlikely to Recur or a Natural Event (HAURL/NE) 73
7 No Exceedance “But For” this Event (NEBF) 74
8 Mitigation 77
8.1 EER Mitigation Requirement..... 77
8.2 Air Pollution Emergency Rule 77
8.3 Press Releases..... 78
8.4 Daily Interagency Update Reports 78
8.5 Air Filters..... 79
9 Procedural Requirements..... 79
10 References..... 80
Appendix A. Monitor Values..... 82
Appendix B: Salmon EER Daily Summaries 86
Appendix C: Pinehurst EER Daily Summaries 176
Appendix D: Alternative Sources 188
Appendix E: Mitigation—Stage 1 Forecast and Cautions, Daily Monitor Summary and Press Releases 198
Appendix F: News Stories 234

List of Tables

Table A. Monitor values DEQ is requesting EPA concurrence (EPA 2013b). xii
Table B. Summary of DEQ demonstration in this report meeting EER elements..... xiv
Table 1. Salmon wind direction frequency by hour of day (left block) and relative contributions to $PM_{2.5}$ concentration by sector and hour of day (right block). 17

Table 2. Pinehurst wind direction frequency by hour of day (left block) and relative contributions to $PM_{2.5}$ concentration by sector and hour of day (right block). 17
Table 3. July 30–October 13, 2012, wildfires greater than 40,000 acres contributing to Idaho smoke (NIFC 2013). 27
Table 4. Statistics of $PM_{2.5}$ concentrations during fire period. 30
Table 5. Average, 95th and 99th percentile values for Salmon monitor, 2008–2011. 31
Table 6. Percentile rankings for Salmon $PM_{2.5}$ monitor values (99% indicates 99% or above)... 32
Table 7. Statistics of 24-hour $PM_{2.5}$ concentrations recorded in Pinehurst during the wildfire season in 2008–2011 and 2012..... 34
Table 8. Average, 95th, and 99th percentile of $PM_{2.5}$ during the wildfire period, from 2008–2011 data. 35
Table 9. Percentile ranking for the monitor values requested in this demonstration, relative to unaffected days in the same period from 2008–2011 (99% indicates 99% or above). .. 35
Table 10. Estimated contribution of Salmon values that would not have occurred "But For" the 2012 wildfires. The two right-hand columns represent the range of concentration contributed by wildfires. 75
Table 11. Estimated contribution of Pinehurst values that would not have occurred "But For" the 2012 wildfires. The two right-hand columns represent the range of concentration contributed by wildfires. 76
Table 12. Number of days under a DEQ-issued Stage 1 Air Pollution Forecast and Caution 78
Table 13. DEQ compliance with procedural requirements of the Exceptional Events Rule. 79

List of Figures

Figure 1. Area burned by wildfires in the geographic areas affecting Idaho, 2001–2012 (NIFC 2013). 1
Figure 2. Area burned in 2012 by state (NIFC 2013). 2
Figure 3. Fires active in the Northwest during the approximate period of exceptional events, July 30, 2012 to October 15, 2012. Significant fires are labeled and the Salmon and Pinehurst monitor locations are denoted by yellow stars. 3
Figure 4. The 2012 average daily wildfire emissions for the period July 7 through October 18, compared to other source categories from all anthropogenic emissions for 2011 from the 2011 National Emission Inventory (EPA 2013c). 4
Figure 5. Idaho mean temperature anomaly, August 2012—departure from 1981–2010 normal http://www.wrcc.dri.edu/wwdt/archive.php?region=id (WRCC 2013). 5
Figure 6. Idaho mean temperature anomaly, September 2012—departure from 1981–2010 normal http://www.wrcc.dri.edu/wwdt/archive.php?region=id (WRCC 2013). 5
Figure 7. Idaho mean temperature percentile, August 2012 http://www.wrcc.dri.edu/wwdt/archive.php?folder=mdn1per (WRCC 2013). 6
Figure 8. Idaho mean temperature percentile, September 2012 http://www.wrcc.dri.edu/wwdt/archive.php?folder=mdn1per (WRCC 2013). 6
Figure 9. Idaho precipitation anomaly, August 2012—percent of 1981–2010 normal http://www.wrcc.dri.edu/wwdt/archive.php?folder=pon1 (WRCC 2013). 7

Figure 10. Idaho precipitation anomaly, September 2012—percent of 1981–2010 normal http://www.wrcc.dri.edu/wwdt/archive.php?folder=pon1 (WRCC 2013). 8
Figure 11. Idaho Palmer Drought Severity Index (PDSI), August 2012 http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi (WRCC 2013). 9
Figure 12. Idaho Palmer Drought Severity Index (PDSI), September 2012. http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi (WRCC 2013). 9
Figure 13. Idaho Palmer Drought Severity Index (PDSI), October 2012 http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi (WRCC 2013). 10
Figure 14. September 8, 2012, 500-millibar height contours showing an Omega block and associated high pressure ridge over Idaho http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 11
Figure 15. August 18, 2012, 500-millibar height contours showing an Omega block and associated high-pressure ridge over Idaho http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 12
Figure 16. September 7, 2012, 500-millibar height contours showing a typical Rex block offshore and the associated amplified shortwave ridge over Idaho http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 12
Figure 17. Salmon area meteorological stations and wind direction sectors used in analysis along with local terrain. 15
Figure 18. Pinehurst meteorological station and wind sectors used in analysis along with local terrain. 16
Figure 19. Salmon seasonal average and maximum $PM_{2.5}$ concentration by hour of day, with wind direction frequencies, showing that up-valley flows from the North brought the highest $PM_{2.5}$ levels to Salmon. 19
Figure 20. Average and maximum monitor values at Pinehurst, before and during the period of wildfire contributions, with wind sector frequencies by hour..... 20
Figure 21 Timeline of Daily Mean $PM_{2.5}$ Concentrations in Salmon, Idaho, 2012..... 21
Figure 22 Detail during Wildfire Period in Timeline of Daily Mean $PM_{2.5}$ Concentrations in Salmon, Idaho, 2012 21
Figure 23 Timeline of Daily Mean $PM_{2.5}$ Concentrations in Pinehurst, Idaho, 2012..... 22
Figure 24. Fire season (August 1–October 15) period average $PM_{2.5}$ concentrations for 2012 and the previous 4 years showing concentrations throughout the region much higher in 2012 than in normal years (sources: EPA 2013b for cities; IMPROVE 2013 for Class I areas)..... 23
Figure 25. Fire season organic carbon (OC) and organic carbon to $PM_{2.5}$ ratio at IMPROVE sites in the Idaho region (IMPROVE 2013) for 2012 and 4 previous years showing that organic carbon, a species identifying smoke was unusually high throughout the Idaho region in 2012, compared to the previous years. 24
Figure 26. The 2012 wildfire period average $PM_{2.5}$ in comparison to the mean and 95th percentile upper confidence interval for the 2008–2011 period means, showing statistically significant increases in 2012 at every monitor in the region (EPA 2013b). 25
Figure 27. Fire size progression and personnel assigned to the Halstead and Mustang Complex, the major fires most affecting the Salmon, Idaho monitor. 28
Figure 28. $PM_{2.5}$ historical fluctuations in Salmon, Idaho, 2008–2011. 30
Figure 29. $PM_{2.5}$ concentration distribution for 2012 versus the previous 4 years, during the period July 30–October 12. Percent of days in each concentration range are depicted. 31

Figure 30. Salmon time series chart for the 2012 wildfire season (yellow circles) in comparison to the previous 4 years, 2008–2011 (colored bars). Days before and after the wildfire period are also included. 33
Figure 31. $PM_{2.5}$ historical fluctuations in Pinehurst, Idaho, 2008–2011. 34
Figure 32. $PM_{2.5}$ concentration distributions. 35
Figure 33. $PM_{2.5}$ concentrations during wildfires in 2012 compared to normal years. 36
Figure 34. Salmon smoke transport scenarios. 43
Figure 35. September 11, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 45
Figure 36. Surface weather analysis and station weather at 0500 MST, September 11, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 45
Figure 37. Aqua MODIS satellite image showing fire detects and smoke filling the Salmon valley. HYSPLIT model back trajectories show transport winds for all 24 hours on September 11, 2012. 46
Figure 38. Time series charts for September 11, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km, the environmental lapse rate (dotted line) indicates stable/stagnant conditions in the valley. 47
Figure 39. August 12, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 49
Figure 40. Surface weather analysis and station weather at 0500 MST, August 13, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 49
Figure 41. Aqua MODIS satellite image showing fire detects and smoke blowing toward the southeast, directly impacting the Salmon area. HYSPLIT model back trajectories show transport winds for all 24 hours on August 13, 2012. 50
Figure 42. Time series charts for August 13, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley. 51
Figure 43. August 12, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 53
Figure 44. Surface weather analysis and station weather at 0500 MST, August 12, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013). 54
Figure 45. Aqua MODIS satellite image showing fire detects and smoke blowing eastward from the Halstead fire, filling the Salmon and Lemhi valleys south of Salmon. HYSPLIT model back trajectories indicate valley flows from the south, August 12, 2012. 55
Figure 46 Time series charts for August 12, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley. 56

Figure 47. August 28, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 58
Figure 48. Surface weather analysis and station weather at 0500 MST, August 28, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 58
Figure 49. Aqua MODIS satellite image showing fire detects and smoke blowing north-northeastward from the Halstead fire, directly impacting the Salmon area, with HYSPLIT model back trajectories showing similar tracks for most hours on August 28, 2012. 59
Figure 50. Time series charts for August 28, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley. 60
Figure 51. August 8, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 62
Figure 52. Surface weather analysis and station weather at 0500 MST, August 8, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 62
Figure 53. Terra MODIS satellite image shows ground surfaces obscured by cloud and HYSPLIT model back trajectories approaching Salmon from the south and southwest, August 8, 2012..... 63
Figure 54. Time series charts for August 8, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley. 64
Figure 55. September 25, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 66
Figure 56. Surface weather analysis and station weather at 0500 MST, September 25, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 66
Figure 57. Terra MODIS satellite image shows light smoke throughout the region, with HYSPLIT model back trajectories intersecting smoke and/or HMS fire detects from fires in Washington and Oregon. 67
Figure 58. Time series charts for September 25, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days (top chart); wind speed and wind direction (middle chart); and temperature and solar radiation. 68
Figure 59. September 22, 2012, 500-millibar height contours and wind barbs at 0500 MST http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 70
Figure 60. Surface weather analysis and station weather at 0500 MST, September 22, 2012 http://www.hpc.ncep.noaa.gov/dailywxmap/ (HPC 2013)..... 70
Figure 61. Terra MODIS satellite image showing fire detects and dense smoke blanketing northern Idaho and trapped in the river valleys of central Idaho. HYSPLIT model back trajectories are very short indicating stagnant air. 71
Figure 62. Time series charts for September 22, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days

(top chart); wind speed and wind direction (middle chart); and temperature and solar radiation (bottom chart). 72

Executive Summary

The 2012 wildfire season was exceptionally severe in Idaho and surrounding states. Idaho and its neighboring states experienced the greatest land area burned by wildfires since before 2000. Idaho itself experienced the greatest acreage of burned land in the nation, and the next 5 states nationwide are all adjacent to Idaho.

The smoke from these fires was ubiquitous throughout the Pacific Northwest from August through early-October and Salmon, Idaho was severely impacted as a result of its proximity to the Mustang Complex and Halstead fire, as well as, the large number of other fires in the central Idaho Region. During the 2012 wildfire season, Salmon experienced 16 “Moderate” AQI days, 11 “Unhealthy for Sensitive Groups,” 21 “Unhealthy,” 6 “Very Unhealthy,” and 1 “Hazardous.” Pinehurst experienced 22 “Moderate” days and 1 “Unhealthy for Sensitive Groups” day.

To address high monitor values that result from natural exceptional events that are not reasonably controllable or preventable, the United States Environmental Protection Agency (EPA) promulgated the Exceptional Events Rule (EER) in 40 CFR 50 and 51 (72 FR 13560) on March 22, 2007. The EER allows for states to *flag* air quality data as *exceptional* and exclude those data from use in determining compliance with the National Ambient Air Quality Standards (NAAQS), if EPA concurs with the state’s demonstration that it satisfies the rule requirements.

As required in *Final Rule for the National Ambient Air Quality Standards for Particulate Matter* (Federal Register Vol. 78, No. 10, pp.3086 – 3287 1/15/2013), DEQ will be submitting a letter recommending designation status for the $PM_{2.5}$ annual NAAQS for all areas in Idaho, outside the five Indian Reservation Boundaries. In order to designate both Salmon and Pinehurst as attainment/unclassifiable for the annual $PM_{2.5}$ NAAQS, monitor values during the 2012 wildfire season that meet the criteria for exceptional events, must be excluded.

In accordance with the EER procedures, DEQ flagged many values at the Salmon, and Pinehurst $PM_{2.5}$ monitors and is requesting concurrence that certain flagged values, as indicated in Table A, are exceptional events. The flagged values over 35 $\mu g/m^3$ affect Idaho’s compliance with 24-hour NAAQS and the flagged values over 12 $\mu g/m^3$ affect Idaho’s compliance with the annual NAAQS. DEQ demonstrates in this report, and requests EPA concurrence, that these exceptional concentration values occurred as a result of primarily natural wildfires, that they were not reasonably controllable or preventable by the State of Idaho, and that they fully meet the criteria of the EER for excluding monitor values from the data used to determine compliance with the NAAQS.

The monitor values for Salmon and Pinehurst for which DEQ is requesting EPA concurrence as caused by an exceptional event, are summarized in Table A. A complete listing of monitor values from July 20 through October 25 is provided in Appendix A with an indication of which ones are included in this request and which DEQ believes meet the criteria for exceptional event, but are not included in the current request due to time constraints.

Table A. Monitor values DEQ is requesting EPA concurrence (EPA 2013b).

Salmon, Lemhi County Idaho Monitor Site AQS 16-059-0004		
Date	**POC**	**Daily Mean $PM_{2.5}$ Concentration, µg/m^3**
Primary, E-BAM Monitor Values		
8/10/2012	3	33.7
8/11/2012	3	37.2
8/12/2012	3	49.2
8/13/2012	3	96.5
8/14/2012	3	147
8/15/2012	3	67.3
8/16/2012	3	106.5
8/17/2012	3	96.6
8/18/2012	3	30.4
8/19/2012	3	34.5
8/20/2012	3	37.7
8/23/2012	3	35.9
8/24/2012	3	108.2
8/25/2012	3	91.3
8/26/2012	3	45.5
8/28/2012	3	58.2
8/29/2012	3	78.1
8/30/2012	3	132
8/31/2012	3	49.8
9/1/2012	3	69.4
9/2/2012	3	145.2
9/3/2012	3	186.9
9/4/2012	3	182.7
9/5/2012	3	97.8
9/6/2012	3	48.4
9/7/2012	3	53.1
9/10/2012	3	136.4
9/11/2012	3	214.3
9/12/2012	3	194.4
9/13/2012	3	153.7
9/14/2012	3	70.2
9/15/2012	3	162.1
9/16/2012	3	162.5
9/17/2012	3	112.3
9/18/2012	3	130.3
9/19/2012	3	135.5
9/20/2012	3	159.8
9/21/2012	3	153.5
9/22/2012	3	86.6
9/23/2012	3	44.3
9/25/2012	3	62.7
9/26/2012	3	37.4
9/27/2012	3	39.3

Salmon, Lemhi County Idaho Monitor Site AQS 16-059-0004		
Date	**POC**	**Daily Mean $PM_{2.5}$ Concentration, µg/m^3**
Co-located, FRM Monitor Values		
8/13/2012	1	85
8/19/2012	1	31.2
8/25/2012	1	77.8
8/31/2012	1	45.1

Pinehurst, Shoshone County Idaho Monitor Site AQS 16-079-0017		
Primary, FDMS Monitor Values		
9/14/2012	4	31.3
9/15/2012	4	43.6
9/22/2012	4	20.8
9/25/2012	4	18.4

(No co-located monitor values on these 4 days)

Many of the monitor values on days included in Appendix A but not listed in Table A were also affected by smoke based on DEQ analysis, however the values included in this request are focused only on lowering the annual design values (DVs) for Salmon and Pinehurst below 12 $\mu g/m^3$, the level of the annual NAAQS so that these two areas are designated attainment/unclassifiable in EPA's review of areas subject to the annual standard. DEQ reserves the right to request concurrence on the additional days in the future, within the regulatory 3-year time frame, in the event that future regulatory actions appear to be adversely affected.

Required Elements of the Exceptional Events Rule

The EER requires that demonstrations to justify data exclusion as exceptional events shall provide evidence that the event (a) affects air quality (AAQ); (b) is not reasonably controllable or preventable (nRCP), (c) is a natural event or is an event caused by human activity that is unlikely to recur at a particular location (NE/HAURL); (d) that there is a clear causal relationship (CCR) between the identified source and measurement under consideration; (e) that the event is associated with measured concentrations in excess of normal historical fluctuations (HF), including background; and (f) that there would have been no exceedance or violation of the standard but for the event (NEBF). In addition, the state must document that prompt public notification procedures and measures to reduce public exposure were followed and that the public comment process was followed in reviewing the demonstration.

Organization of this Report

The organization of this report is outlined in Table B, in which the report section and in some cases, the appendix, which addresses each element of the EER demonstration is identified.

An Exceptional Events documentation package will typically include detailed descriptions of the weather conditions, source and transport conditions and impact patterns for each monitor value/day in which concurrence is requested. Due to the magnitude of the 2012 wildfires and the large number of affected days, this approach is not feasible; however, DEQ observed that a number of transport scenarios occurred repeatedly in Salmon and Pinehurst throughout the period affected by wildfires. DEQ therefore describes the types of transport scenarios that occurred in detail with an example of each (Section 5), then in Appendices B (Salmon) and C (Pinehurst), detailed data is provided specific to each day being requested and the transport discussion is supplemented by identifying the type of scenario or scenarios involved for each day followed by a brief but complete description of the evidence for that day.

In addition to the complete listing of monitor values in Appendix A and summary information for each day in Appendices B and C, Appendix D contains crop residue burn decision summaries and prescribed fire data that relate to potential alternate sources of smoke. Appendix E provides information on days in which a Stage 1 Forecast and Caution was in effect in both Salmon and Pinehurst, prohibiting all open burning and advising residents of protective actions, example of a Stage 1 notification, State of Idaho press releases, and an example of the daily monitoring, modeling, and satellite summary report provided by DEQ to federal, state and local agencies, including local health districts assure they had appropriate information to assist residents in taking protective actions. Finally, Appendix F contains news articles for Lemhi County and Shoshone and Kootenai Counties regarding the fires, suppression activities, smoke advisories and other news about the fires.

Table B. Summary of DEQ demonstration in this report meeting EER elements.

EER Element	Sect.	Summary
Conceptual Model (EPA guidance, not an EER Element)	1	The conceptual model generally describes the wildfires and their origin and summarizes sources, the different kinds of weather systems, transport flows and valley-flow dynamics combining to transport smoke from the wildfires to the affected monitors.
Not Reasonably Controllable or Preventable (nRCP)	2	Discussion of wildfire causes (mostly lightning) and the fact that they are not reasonably controllable or preventable.
Exceeds Historical Fluctuations (HF)	3	Data provided includes: 1)Time series plots for multiple years, including the 2012 events. 2) Concentration frequency distribution charts for 2012 in comparison to 2008-2011. 3) Table of percentile values for each requested day at each monitor, in comparison to annual data and fire season data for previous 4 years, 2008–2011. 4) 24-hour temporal charts for each day (in Appendices B and C) showing hourly 2012 data affected by wildfire smoke versus 2009–2011 average and 95th percentile hourly values.
Clear Causal Relationship (CCR)	4	For each transport scenario, a detailed example for one day is described in Section 5 of the report. Then in Appendices B and C, data for each day is provided, including: 1) Description of how the specific data/images for the day support the scenario and explain how $PM_{2.5}$ travelled to the monitor. 2) Time series of $PM_{2.5}$, wind speed and direction at the monitor. 3) MODIS satellite images with HYSPLIT back trajectories showing paths from fires to monitors for every day requested. 4) Region-wide speciation data is provided in Section 1.6, showing ubiquitous fine carbon aerosol throughout region in this period. 5) Alternate hypotheses are addressed by identifying open burn bans and lack of nearby prescribed fires and crop residue burning. 6) News stories for some days are included in Appendix F.
Natural Event or Human Activity Unlikely to Recur at the same location (NE/HAURL)	5	The NE/HAURL criterion is met by previous discussions that the fires are *natural events*, *not reasonably controllable or preventable (nRCP)* and the demonstration that there is a Clear Causal Relationship between monitors and wildfire source areas (CCR).
Affects Air Quality (AAQ)	6	The AAQ element is met by demonstrating $PM_{2.5}$ in excess of historical fluctuations (HF) and a Clear Causal Relationship (CCR).
No Exceedance “But For” Event (NEBF)	7	A quantitative NEBF analysis is provided for each city/monitor/day, in tables comparing the observed values to the average and 95th percentile values expected for this time of year. The estimated concentration “But For” the fires is computed by subtracting the observed value from the average and the 95th percentile.
Mitigation	8	Complete information on Air Quality Advisories, press releases and daily informational reports are in Appendix E. In addition DEQ initiated the purchase of 43 air filters for Salmon schools (Sect 8.5)
EER Procedures	9	DEQ met EER procedural requirements for flagging, demonstration and public comment as summarized in this section.

1 Conceptual Model

This section describes the unusual severity of wildfires in Idaho in 2012 and how they affected most of the state for much of the August to early October period. The weather conditions antecedent to the fire season and during the fires are discussed as well as conceptual models for transport pathways between the wildfire sources and the monitors in Salmon and Pinehurst.

1.1 Overview

Wildfires occur every year in the Western United States, primarily in the summer and fall seasons. The 2012 wildfire season was the most active in the western United States in recent years as a result of unusually hot, dry summertime conditions. Over 7 million acres burned in the Geographic Area Coordinating Centers (GACCs) surrounding and affecting Idaho in 2012. Typically, the same area experiences less than 2 million acres burned (NIFC, 2013). This was the largest annual wildfire acreage for this area in the past 13 years, as shown in Figure 1. Of the 7.2 million acres burned in 2012, 83% of them were lightning caused.

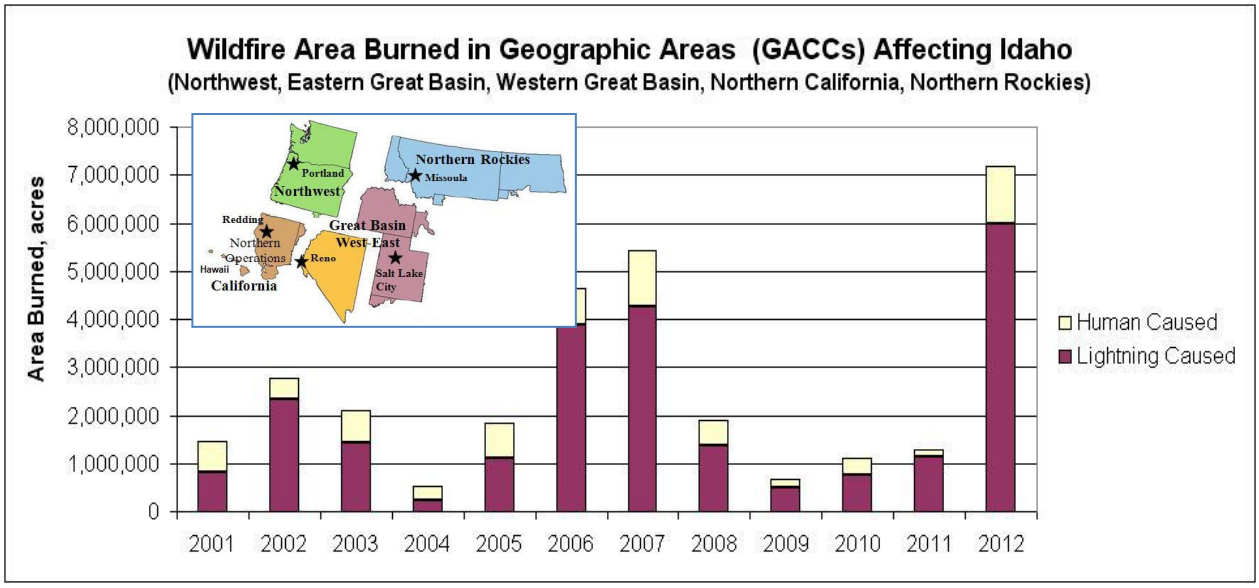


Figure 1. Area burned by wildfires in the geographic areas affecting Idaho, 2001–2012 (NIFC 2013).

Looking at the 2012 fire season across the entire nation, over 67,000 fires burned more than 9.3 million wildland acres. More acres were burned in Idaho wild land fires (1.67 million acres) than any other state as shown in Figure 2. The next 5 states in acres burned after Idaho are all adjacent to Idaho (Oregon, Montana, California, Nevada, and Utah) and combine to add another 4.7 million wildland acres. The prescribed burning in these top 6 states amounted to 200,000 acres or only 3% of their total burned area indicating very little or no contribution from prescribed burning (none in Idaho during the affected days as shown in Appendix D). Together the fire statistics clearly show that 2012 was the most active fire season, and likely smokiest period, for Idaho and the region surrounding Idaho since 2000 or earlier. In addition, very little of it resulted from prescribed burning.

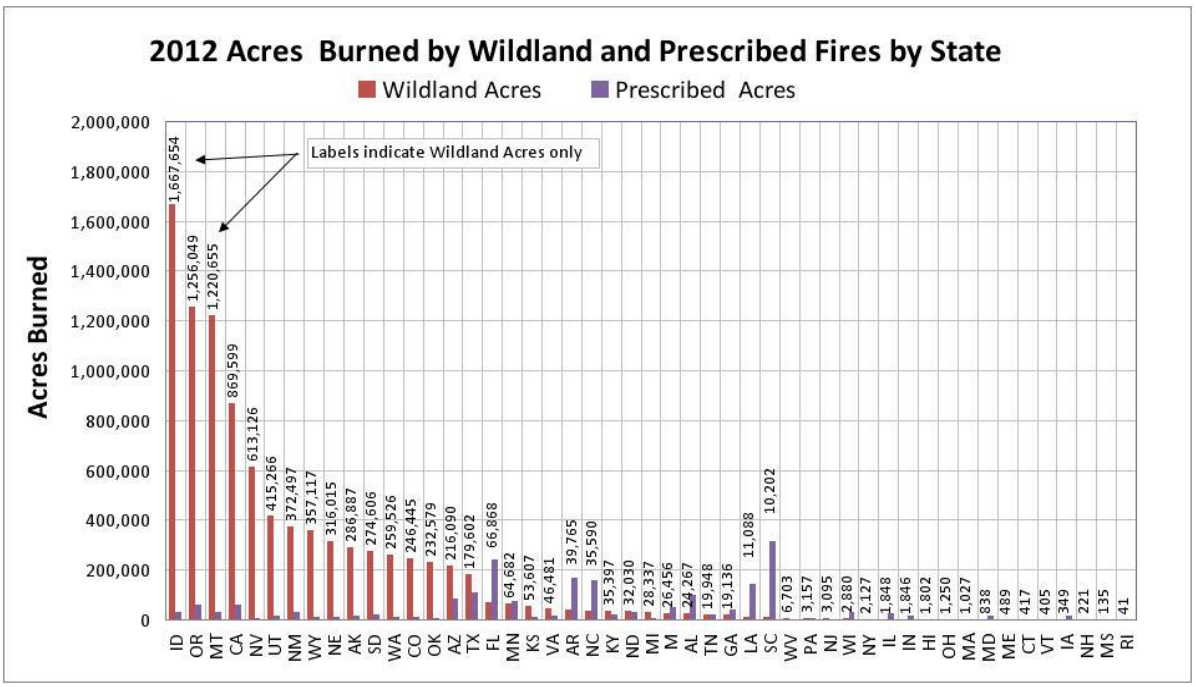


Figure 2. Area burned in 2012 by state (NIFC 2013).

1.2 Source Area and Affected Region

The fires most directly influencing Idaho during the period when exceptional events affected Idaho monitors are shown in Figure 3, a map of the satellite fire detects in the region, indicate the fires most directly responsible for impacting Idaho during the period when smoke affected Idaho monitors. The greatest smoke impacts and duration of smoky conditions occurred closest to the largest fires, primarily in and near Salmon, Idaho, although every monitor in and around Idaho experienced higher levels of $PM_{2.5}$ fine particulate matter from August through September 2012 (see Section 1.6). Small isolated fire detects in agricultural areas may result from crop residue burning; however, for most of the period of severe wildland fire impacts in Salmon and Pinehurst, Idaho Lemhi and Shoshone counties were under a *Stage1 Forecast and Caution* notification and all open burning, including crop residue burning, was not allowed under the Rules for the Control of Air Pollution in Idaho. The entire region including Idaho and surrounding states was affected by smoke from the widespread fires; however, as can be seen in Section 1.6, Salmon, Idaho, Selway-Bitterroot Wilderness Area, and Ravalli, Montana were the most severely affected areas due to their location adjacent to the Mustang and Powell SBW fire complexes.

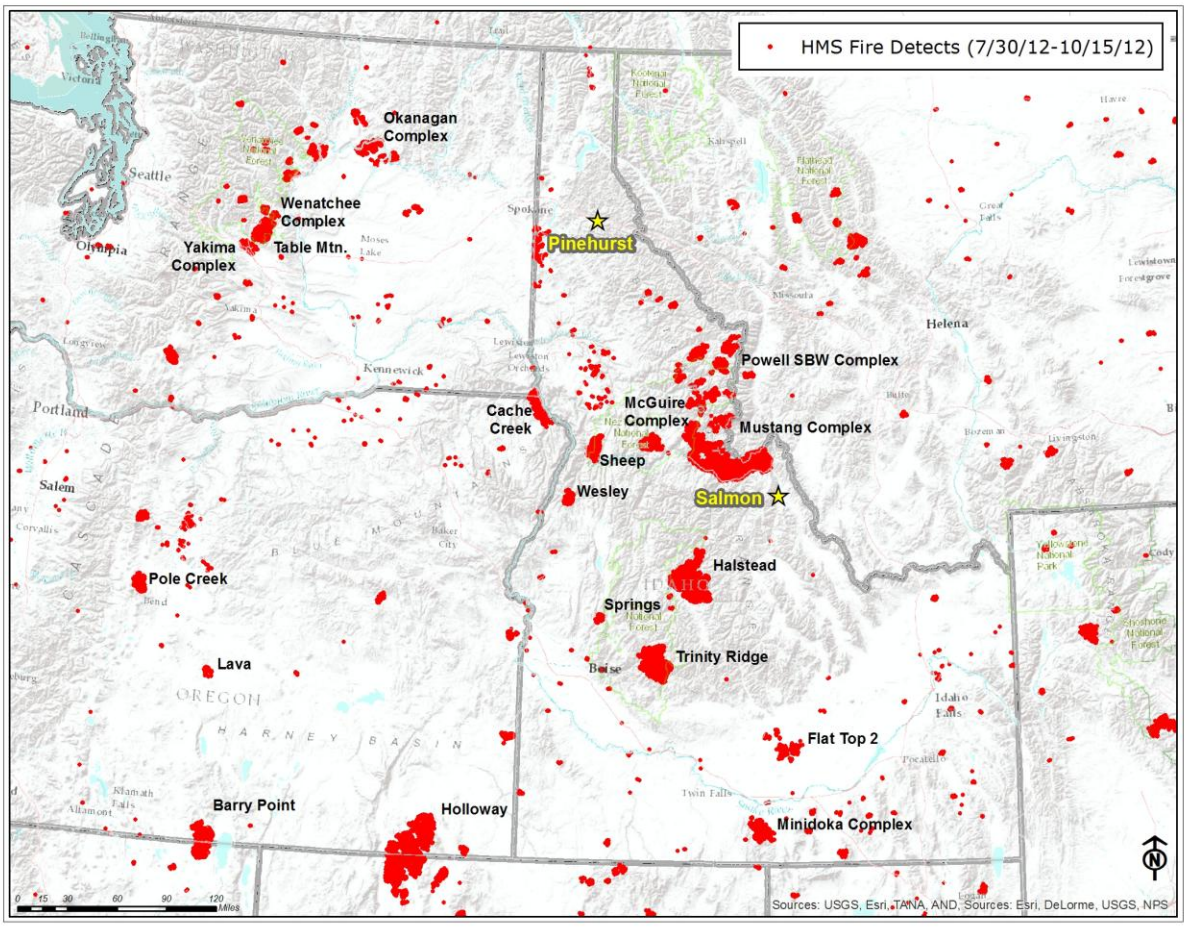


Figure 3. Fires active in the Northwest during the approximate period of exceptional events, July 30, 2012 to October 15, 2012. Significant fires are labeled and the Salmon and Pinehurst monitor locations are denoted by yellow stars.

1.3 Emissions

Wildfires produce very significant quantities of smoke and while it is difficult to determine exact quantities, wildfire emissions can be approximated. In addition, emissions from all other sources in the state of Idaho have been recently estimated as part of the 2011 National Emissions Inventory (NEI) (EPA 2013c). Wildfire $PM_{2.5}$ emissions for the state of Idaho were estimated using EPA and WRAP emission factors (EPA 2013, WRAP 2002) to total 76,300 tons in 2012 based on 1.67 million acres burned, most of it occurring from July through October. If the 2012 annual wildfire emissions are averaged over the period July 7 through October 18 to estimate a period-average daily $PM_{2.5}$ emission quantity, we arrive at an average of 734 tons per day. This daily average wildfire emission estimate is shown in Figure 4, in comparison to all other normal emission source categories in the state of Idaho from the 2011 NEI. Each value shown is an annual average divided by an approximate number of days that the source may occur. This approach allows an approximate comparison, although from different years. The comparison in Figure 4 makes it clear that 2012 wildfires produced many times more $PM_{2.5}$ on a daily basis than all anthropogenic source categories in a typical year. Furthermore, for any fires located in the same river valley as a monitor, such as portions of the Mustang Complex north of the Salmon

$PM_{2.5}$ monitor, the potential exists for wildfire smoke to cause extreme concentrations well in excess of any man-caused emissions. These fires can be identified with certainty as the only possible contributor to the extremely high $PM_{2.5}$ observed in Salmon, as well as the abnormally high $PM_{2.5}$ and organic carbon levels observed near Salmon, Pinehurst, and throughout Idaho, and neighboring states in 2012 (Section 1.6, Concentration Patterns.)

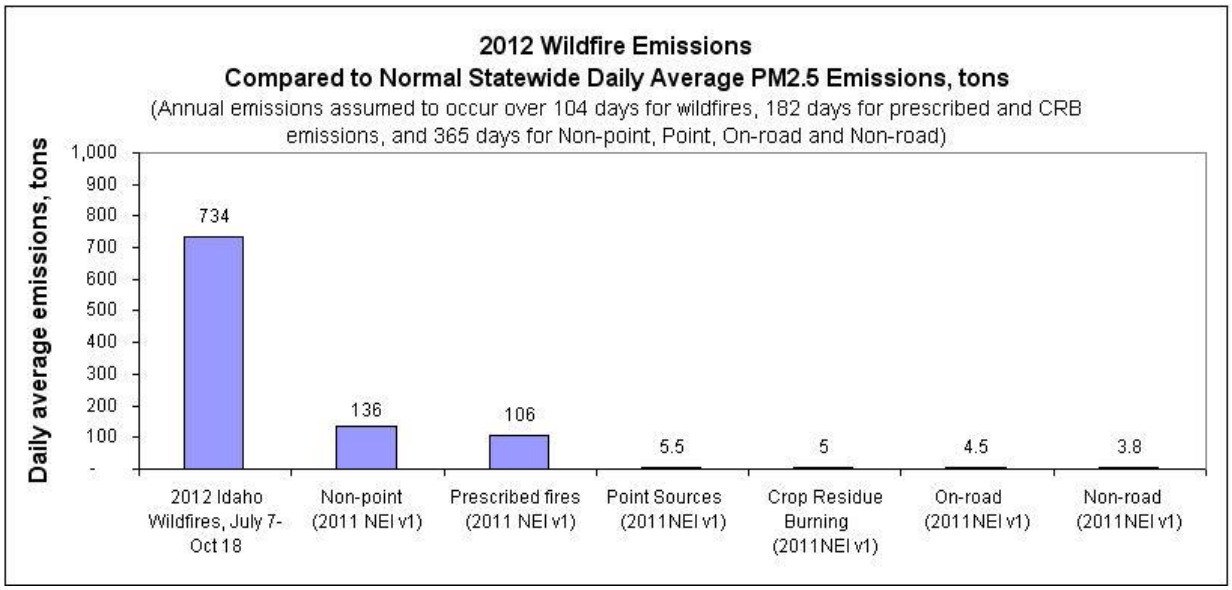


Figure 4. The 2012 average daily wildfire emissions for the period July 7 through October 18, compared to other source categories from all anthropogenic emissions for 2011 from the 2011 National Emission Inventory (EPA 2013c).

1.4 Weather Phenomena Contributing

1.4.1 Temperatures

Beginning June 2012, a ridge of high pressure persisted over the western United States which lead to a much warmer than normal summer for most of the country. Nationally, the summer (June–August) was the third warmest on record and included the warmest July on record. Worsening drought conditions across the West led to below normal live and dead fuel moisture and above normal Energy Release Component indices. Most of the West also saw increased fine fuel loading and below normal snowpack. The autumn (September–December) saw a continuation of the ridge of high pressure over the West which kept the heat in place over much of the western half of the nation with temperatures ranging from 2 to 6 degrees above normal and with mountain states experiencing temperatures 6–8 degrees above normal (Figure 5 through Figure 8). This ridge continued to suppress precipitation to the region during that time. (NIFC 2013).

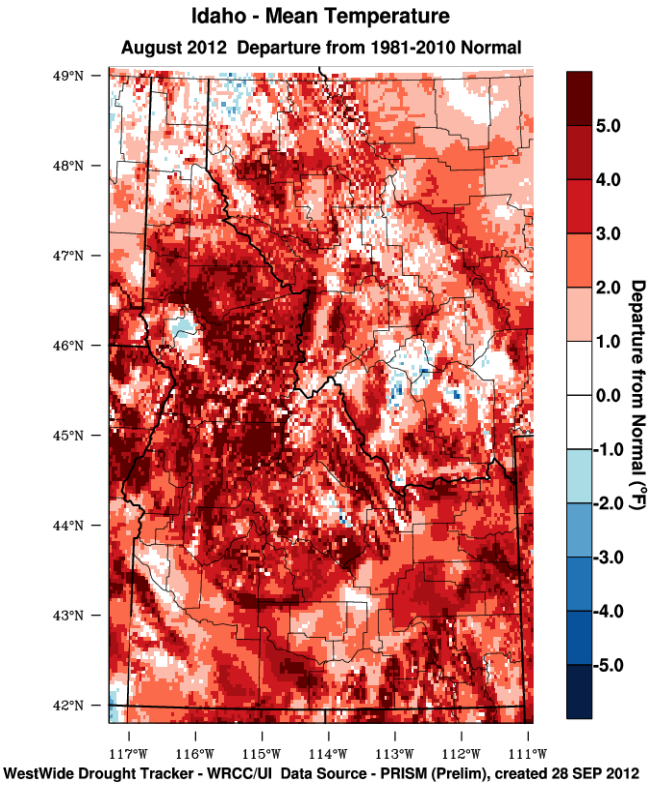


Figure 5. Idaho mean temperature anomaly, August 2012—departure from 1981–2010 normal *http://www.wrcc.dri.edu/wwdt/archive.php?region=id* (*WRCC* 2013).

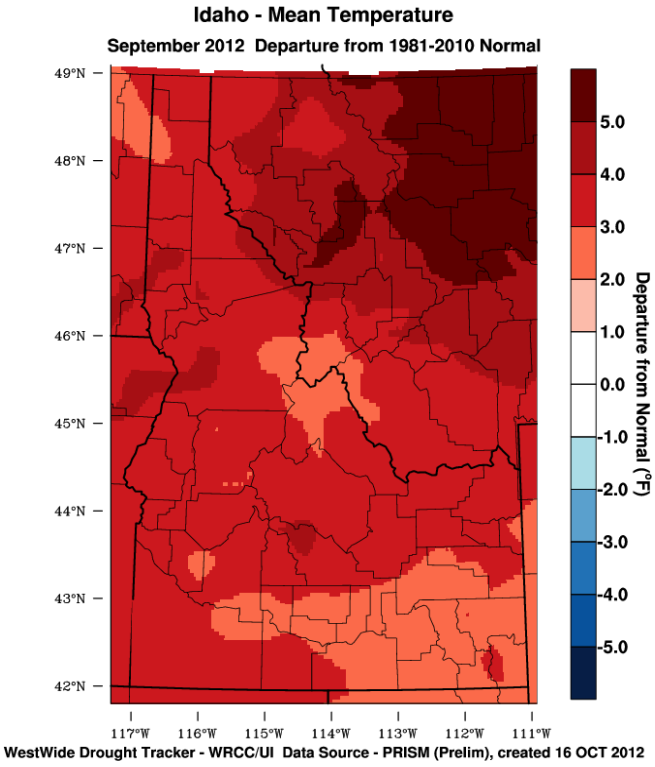


Figure 6. Idaho mean temperature anomaly, September 2012—departure from 1981–2010 normal *http://www.wrcc.dri.edu/wwdt/archive.php?region=id* (*WRCC* 2013).

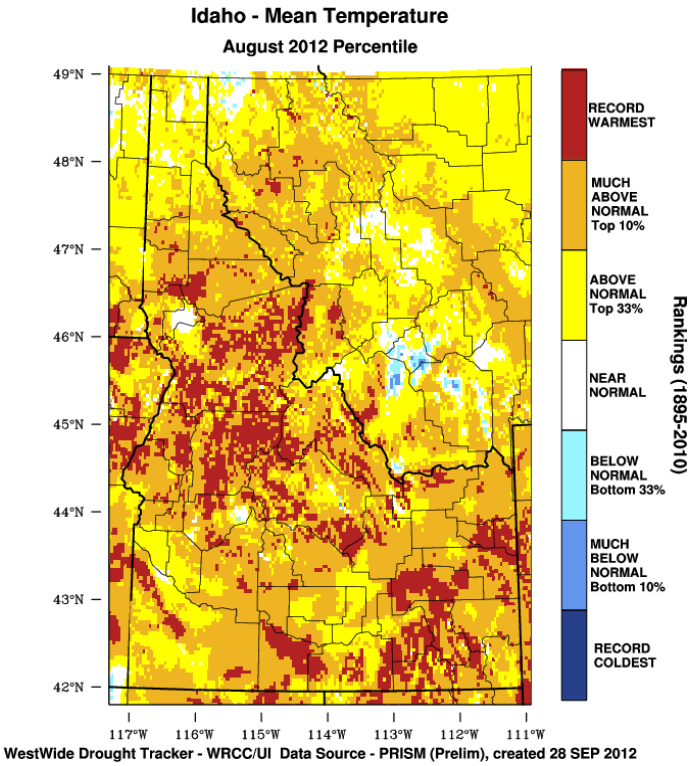


Figure 7. Idaho mean temperature percentile, August 2012 *http://www.wrcc.dri.edu/wwdt/archive.php?folder=mdn1per* (WRCC 2013).

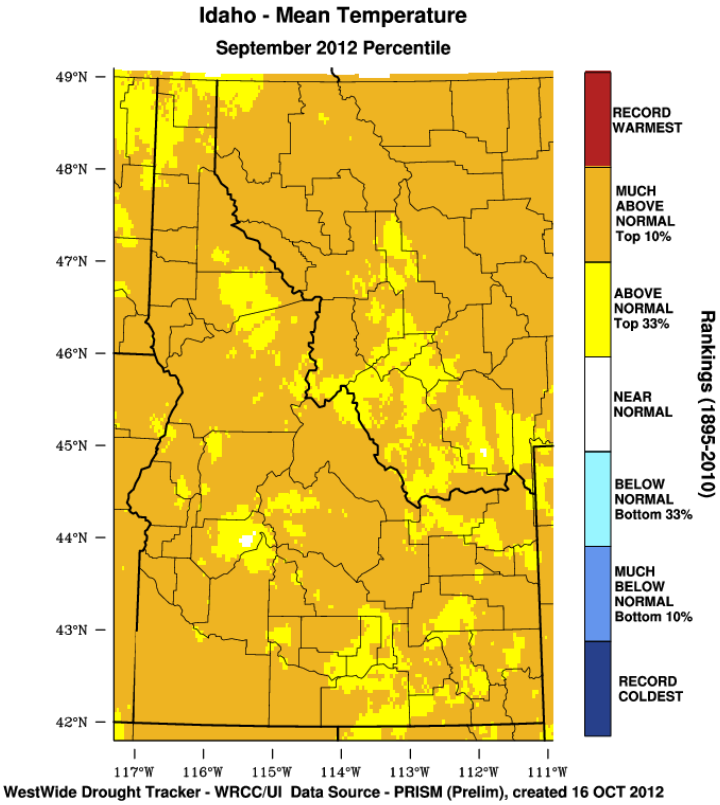


Figure 8. Idaho mean temperature percentile, September 2012 *http://www.wrcc.dri.edu/wwdt/archive.php?folder=mdn1per* (WRCC 2013).

1.4.2 Precipitation

Precipitation patterns across Idaho are quite complex, but generally, the north and west regions of Idaho experience precipitation maximums in winter and minimums in summer while eastern Idaho (particularly the Northeastern Valleys and Eastern Highlands) receive more than 50% of their annual precipitation during the months of April and September (WRCC 2013). Most of Idaho experiences less than 25% of normal monthly precipitation in August (Figure 9) and September (Figure 10). It should be noted that the monthly average precipitation values for southwestern Idaho are 0.36" in August and 0.62" in September, and 25% of this represents a loss of 0.09125" and 0.1555" in each month, respectively, so minute deviations can have large impacts (WRCC, 2013). The greater impact of this loss occurred in the southeast regions where, as mentioned previously, most of the precipitation is received during the summer months. As such, 25% represents a larger quantifiable value of moisture lost.

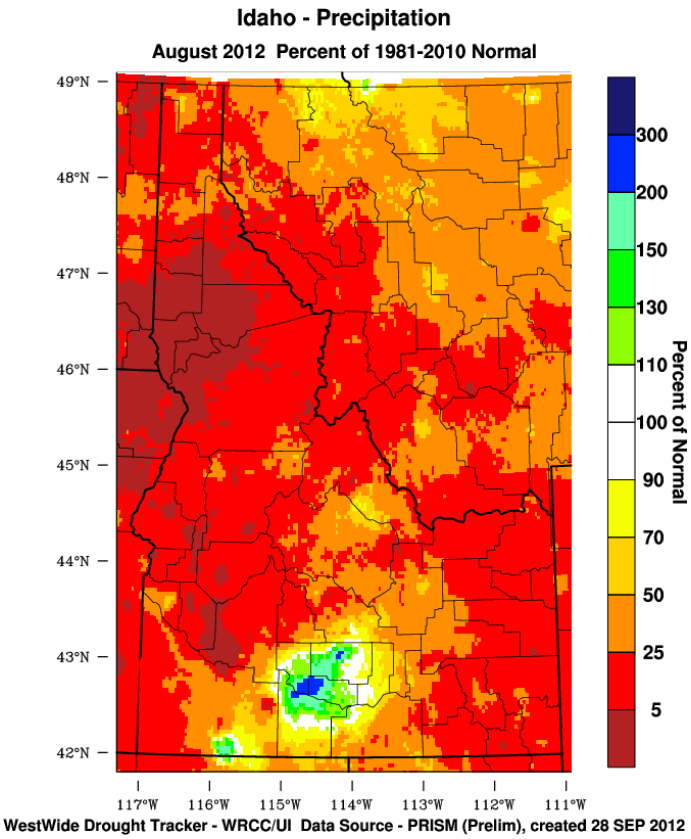


Figure 9. Idaho precipitation anomaly, August 2012—percent of 1981–2010 normal *http://www.wrcc.dri.edu/wwdt/archive.php?folder=pon1* (WRCC 2013).

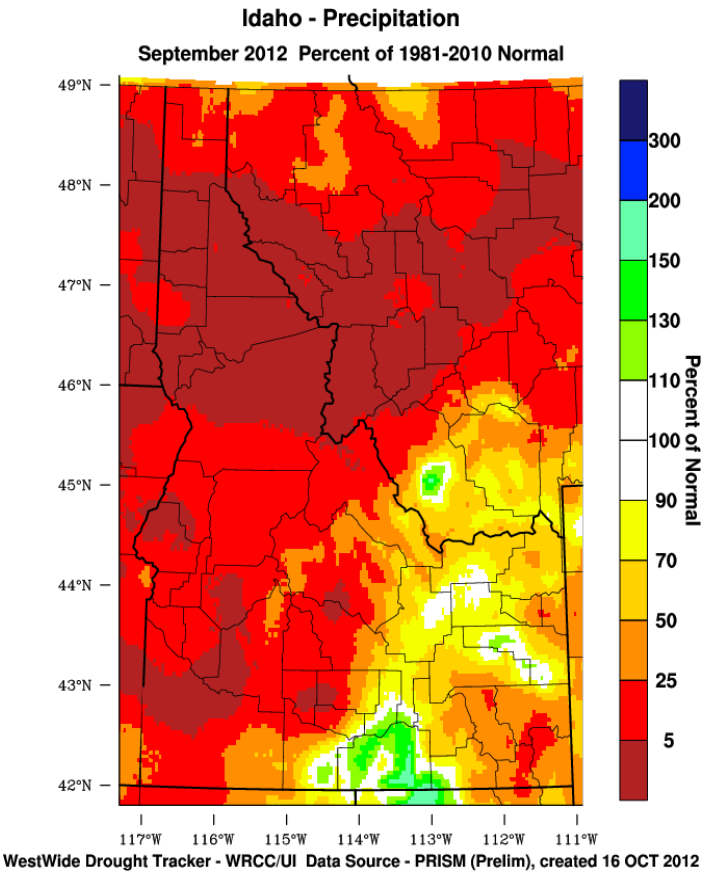


Figure 10. Idaho precipitation anomaly, September 2012—percent of 1981–2010 normal *http://www.wrcc.dri.edu/wwdt/archive.php?folder=pon1* (WRCC 2013).

1.4.3 Drought Conditions

The National Seasonal Significant Wildland Fire Potential Outlook (NIFC 2013) issued for June through August called for above-normal significant fire potential through much of Arizona, western New Mexico, western Colorado, south central Wyoming, the mountains of central Utah, southwestern Idaho, southeastern Oregon, western and northern Nevada, and the southern mountains of California. Worsening drought conditions in the West led to below normal live and dead fuel moisture. September began with a ridge of high pressure over the West and a trough of low pressure over the East. This kept high temperatures in place over much of the western half of the nation, while the eastern half remained relatively cool. As mentioned earlier, temperatures in the West ranged from two to six degrees above normal from California to the northern Rockies and into the northern Plains. The strong ridge in the West not only sent temperatures soaring, it suppressed rainfall over most of the region. The West Coast, the northern Great Basin, the northern Rockies and the northern Plains all had less than a quarter of normal precipitation for September. Northern Idaho experienced wetter-than-normal conditions for much of the summer, as storms from the Gulf of Alaska traveled along the Polar Jet and passed along the United States-Canadian border and traveled over the persistent ridge. This is evident in the Palmer Drought Severity Index (PDSI) metric for August through October as shown in Figure 11, 12, and 13. The northern and central Panhandle experienced consistent PDSI values of +2 or higher while the rest of the state experienced varying levels of moderate to severe to extreme drought conditions.

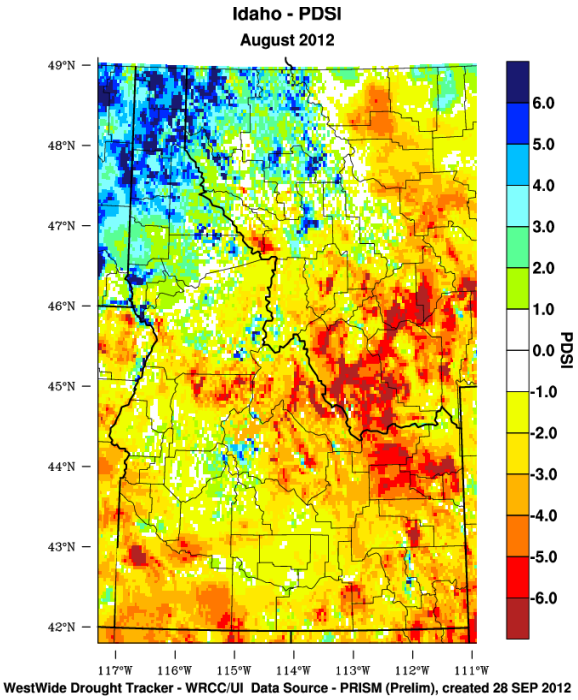


Figure 11. Idaho Palmer Drought Severity Index (PDSI), August 2012 *http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi* (WRCC 2013).

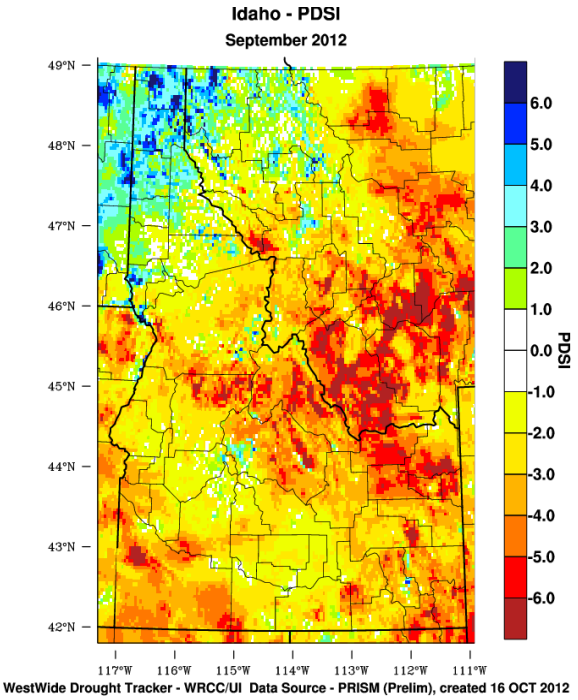


Figure 12. Idaho Palmer Drought Severity Index (PDSI), September 2012. http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi (WRCC 2013).

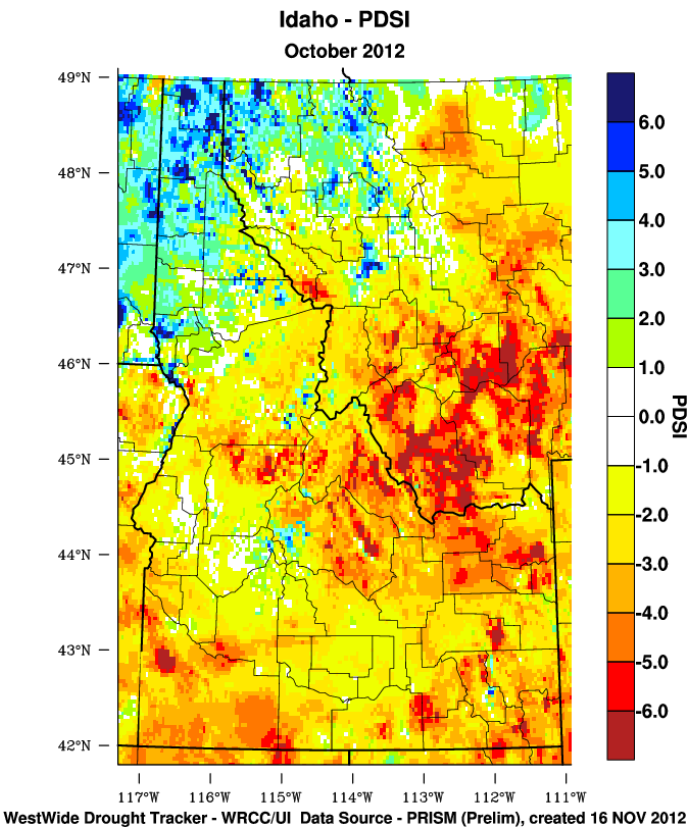


Figure 13. Idaho Palmer Drought Severity Index (PDSI), October 2012 *http://www.wrcc.dri.edu/wwdt/archive.php?folder=pdsi* (WRCC 2013).

1.4.4 Transport Weather Conditions

During the summer months in the northeast Pacific Ocean, a semi-permanent high pressure system, known as the North Pacific High, reaches its apex of strength and forces the polar jet to the north of the continental United States (CONUS) and the tropical jet to the south. During the fire season of 2012 (August, September, and part of October), this quasi-stationary high pressure system provided Idaho with consistent stagnant ridges of high pressure or blocking patterns (most common were the Rex block and Omega block) that limited zonal transport of the mid- and upper-level air masses. Typical patterns that affected Idaho during the summer of 2012 included the amplification of shortwave ridges by Aleutian low pressure systems tracking south along the eastern Pacific coast where they would then become cut off from the jet stream and either retrograde or remain quasi-stationary along the region from California to Washington. On occasion, this sequence of events would align with an upper level low over Hudson Bay, which would then create an Omega block with Idaho under or near the ridge axis. Another sequence of events that occurred several times over the summer was the development of a Rex block along the eastern Pacific, which would create a region of low level divergence over Idaho, and limit winds, vertical mixing, and zonal transport. The aforementioned blocking patterns limit vertical and zonal wind transport and are generally associated with subsidence, which is known for the warming properties that limit vertical mixing. Also notable was the potential role of the incumbent smoke in limiting daytime heating from insolation, and by proxy, the ultimate height of the transport layer which is driven by thermal mixing under such stagnant regimes. Figure 14 through Figure 16 represent examples of the upper-level (500 mb) atmosphere across the

CONUS at three separate dates during the summer of 2012, these were selected for their illustration of the blocking patterns that frequently impact the Pacific Northwest and Intermountain West in the summer. It is possible to see the developed Omega block with ridge axis slightly east of Idaho in Figure 14 while this same type of blocking pattern is more centrally located over Idaho in Figure 15. Finally, Figure 16 represents a Rex block pattern located offshore which forces strong ridging over Idaho. Such blocking patterns create stagnant atmospheric conditions with light wind speeds through the mixed layer and low mixing heights. As such, diurnal wind regimes typically become the primary wind direction mechanism.

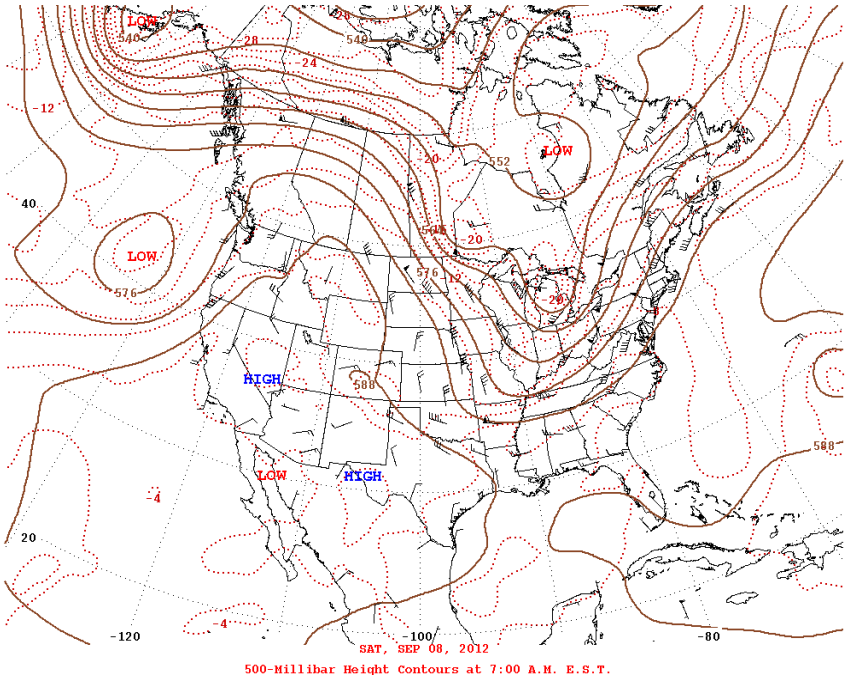


Figure 14. September 8, 2012, 500-millibar height contours showing an Omega block and associated high pressure ridge over Idaho *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

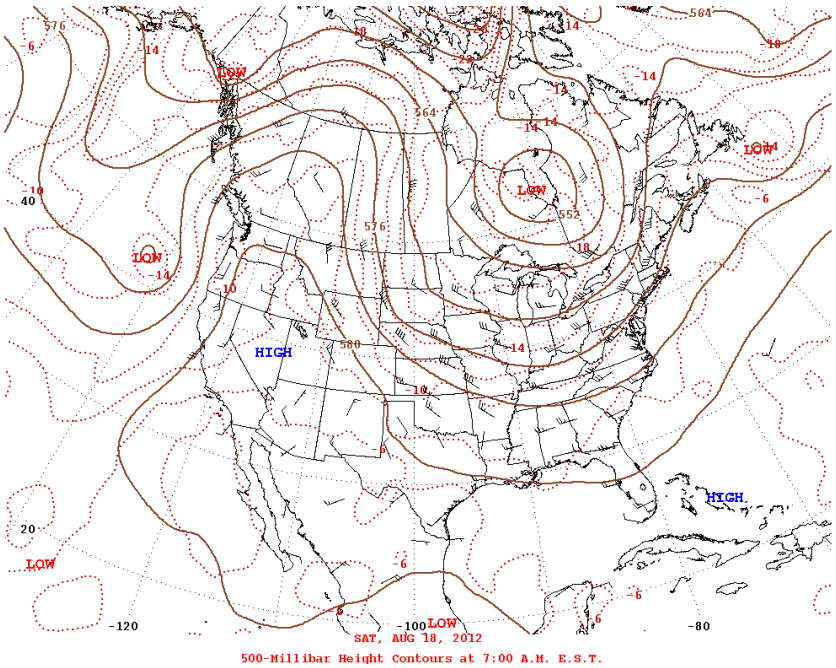


Figure 15. August 18, 2012, 500-millibar height contours showing an Omega block and associated high-pressure ridge over Idaho *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

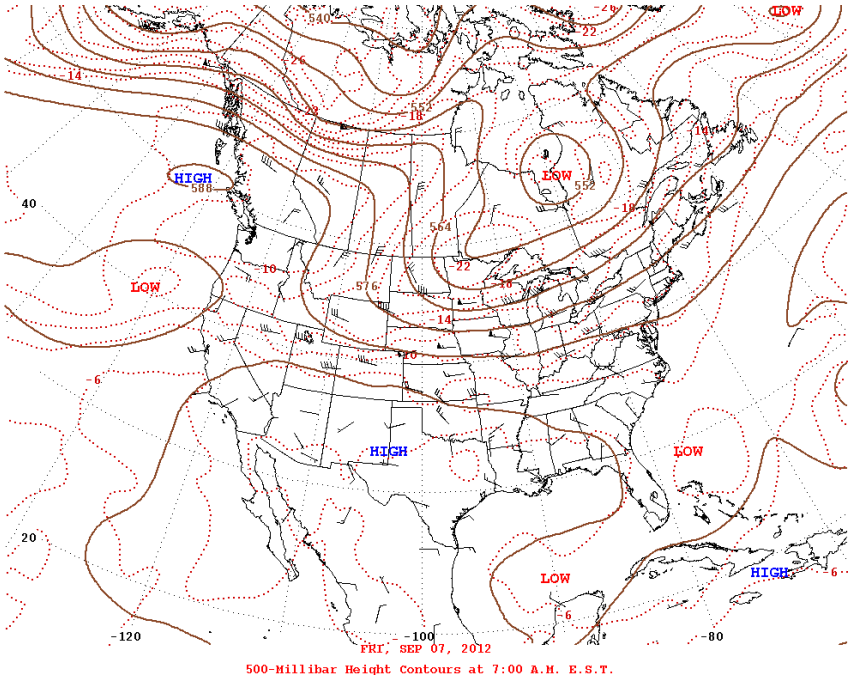


Figure 16. September 7, 2012, 500-millibar height contours showing a typical Rex block offshore and the associated amplified shortwave ridge over Idaho *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

1.5 Path and Timeline from Source Area to Monitors

There were many wildfires burning in Idaho during the July–October 2012 wildfire season, and the monitors at Salmon and Pinehurst were impacted by wildfire smoke on a multitude of days. Many paths and timelines contributed to the exceptional $PM_{2.5}$ values described in this document. At a conceptual level, the types of transport patterns observed by DEQ can be categorized into three essential conceptual models:

(1) direct plume advection from the wildfire source areas to the monitors, generally aligned along the daytime synoptic transport directions,

(2) terrain-mediated diurnal valley flows within the enclosed valleys containing Salmon and Pinehurst after the interception of advecting smoke plumes within some portion of the valleys. Of the second category, the valley flows may occur during either (a) up-valley daytime flows, or (b) nighttime/early morning drainage flows in the down-slope and/or down-valley directions, and

(3) regional transport from more distant fires, often in combination, making the entire region so smoky that individual contributors cannot be identified.

1.5.1 Analysis of Winds and $PM_{2.5}$ Frequencies

Hourly meteorological and $PM_{2.5}$ concentration data (DEQ, 2013) from Salmon and Pinehurst were analyzed for the general period of wildfire impacts to better characterize the conceptual models identified above and to understand the temporal patterns of wind direction frequencies and $PM_{2.5}$ concentrations. The hourly meteorological and $PM_{2.5}$ data were segregated into 60° wind direction sectors to broadly capture the potential terrain-influenced wind directions that may carry smoke into Salmon (Figure 17):

1. North or N (330° to 29.9^o) is selected to capture any daytime up-valley flows coming from the North end of the valley where the Mustang Complex frequently filled the valley with smoke as a result of advection across or into the upper valley, which is adjacent to the eastern end of the Mustang fire perimeter;
2. Northeast or NE (30°–89.9^o) is intended to capture any down-slope flow descending from the west slope of the ~ 10,000 foot Continental Divide down to the valley floor;
3. Southeast or SE (90°–149.9^o) is set to include any winds and trapped smoke that may flow down the Lemhi Valley into Salmon, presumably during night-time/morning drainage flow conditions;
4. South or S (150°–209.9^o) is intended to capture any down-valley flows that may bring smoke from the south, down the Salmon River Valley;
5. Southwest or SW (210°–269.9^o) is the approximate direction of any direct advection from the Halstead Fire to Salmon, or potentially during the night, any drainage flow from the direction of the mountain slopes to the west and southwest of Salmon.
6. Northwest, or NW (270°–329.9^o) is the approximate direction of any direct advection from the western end of the Mustang Fire or McGuire Complex Fire toward Salmon, or potentially if during the night, a down-slope, drainage flow direction from the mountain slopes to the west and northwest of Salmon.

It should be noted that all easterly flows fall into the NE or SE sectors, as there is no “East” sector with this sector arrangement; similarly for the westerly flows, all flows are categorized as

either NW or SW. Pinehurst also sits in a north-south trending valley so the same sectors were utilized to analyze the hourly winds and $PM_{2.5}$ diurnal patterns there as well. (Figure 18).

Salmon analysis. The wind direction/$PM_{2.5}$ temporal analysis for Salmon is shown in Table 1. The left-hand chart shows the frequency of wind directions by sector and hour of day, with frequencies normalized to 100% for each hour. The data set analyzed includes all data from July 20 through October 25, so many unaffected days are included. The left-hand table shows predominant up-valley flow from the north during the hours of strong solar heating from1000 through 1900, while the nighttime/early morning winds approach Salmon primarily from the NE, the direction of the foothills which slope gradually up to the Continental Divide to the NE. These NE down-slope drainage flows (~30%–48%) appear to predominate over the less frequent down-valley flows from the Salmon River valley to the south (~10%) and the Lemhi River valley to the SE (~20%–29%). Finally, there are some (~20%) night/morning flows from the north, presumably part of the NE sector down-slope flows, or perhaps side canyon low level jet flows from a more northerly direction that may push into a fairly stagnant valley just north of Salmon. Approximately 15 to 20% of the daytime wind directions and $PM_{2.5}$ approach Salmon from the NW and SW, and these flows are believed to include direct plume advection and impacts from the Mustang Complex and Halsted fire respectively. The right-hand table shows the normalized product of the wind direction frequency times the average $PM_{2.5}$ concentration. This table indicates by percent for each hour, the direction from which the most $PM_{2.5}$ arrives at the monitor. The pattern is remarkably similar to the wind direction frequencies on the left-hand side, suggesting that the valley was most typically filled with smoke in all directions from Salmon and the smoke approached the monitor from the same direction from which the wind approached. Any hour-direction combination (cell) in the right-hand table that exceeds its parallel cell in the left-hand wind direction frequency table, indicates that higher than average $PM_{2.5}$ concentrations arrived from that hour/direction than others (at 1100 and hours 1500–2000 from North, for example, both reflecting up-valley flows from the north.)

Pinehurst analysis. The wind direction/$PM_{2.5}$ temporal analysis for Pinehurst is shown in Table 2. Pinehurst is situated in a very small south to north trending valley with Pine Creek entering on the south end of the valley, flowing northward to exit the valley in a narrow outlet where the valley meets the east-west trending Silver Valley of the Coeur d'Alene River (see terrain and wind sectors in Figure 18). As a result of the Coeur d'Alene river intersecting the north end of the valley, Pinehurst experiences virtually no flow from the N and NE nor from the NW in the morning hours. The predominant daytime wind directions are from the NW and SW, the direction of the prevailing westerly synoptic flows. The nighttime drainage flows are almost exclusively from the south (~ 90%) until about 0800 in the morning when winds from the SE dominate. The right-hand chart, as before, shows the relative contribution of $PM_{2.5}$, as a product of the wind direction frequency times the average concentration for that hour-sector cell. For Pinehurst, the $PM_{2.5}$ contributions also closely reflect the wind direction frequencies, suggesting a uniformly mixed valley with $PM_{2.5}$ arriving in conjunction with most of the valley flows, but being enhanced in the afternoon NW winds (1500–1600) and morning SE winds (0800–1000). This probably reflects smoke advected from regional fires to the west (Washington State fires) and SE (Powell SBW and Mustang fires).

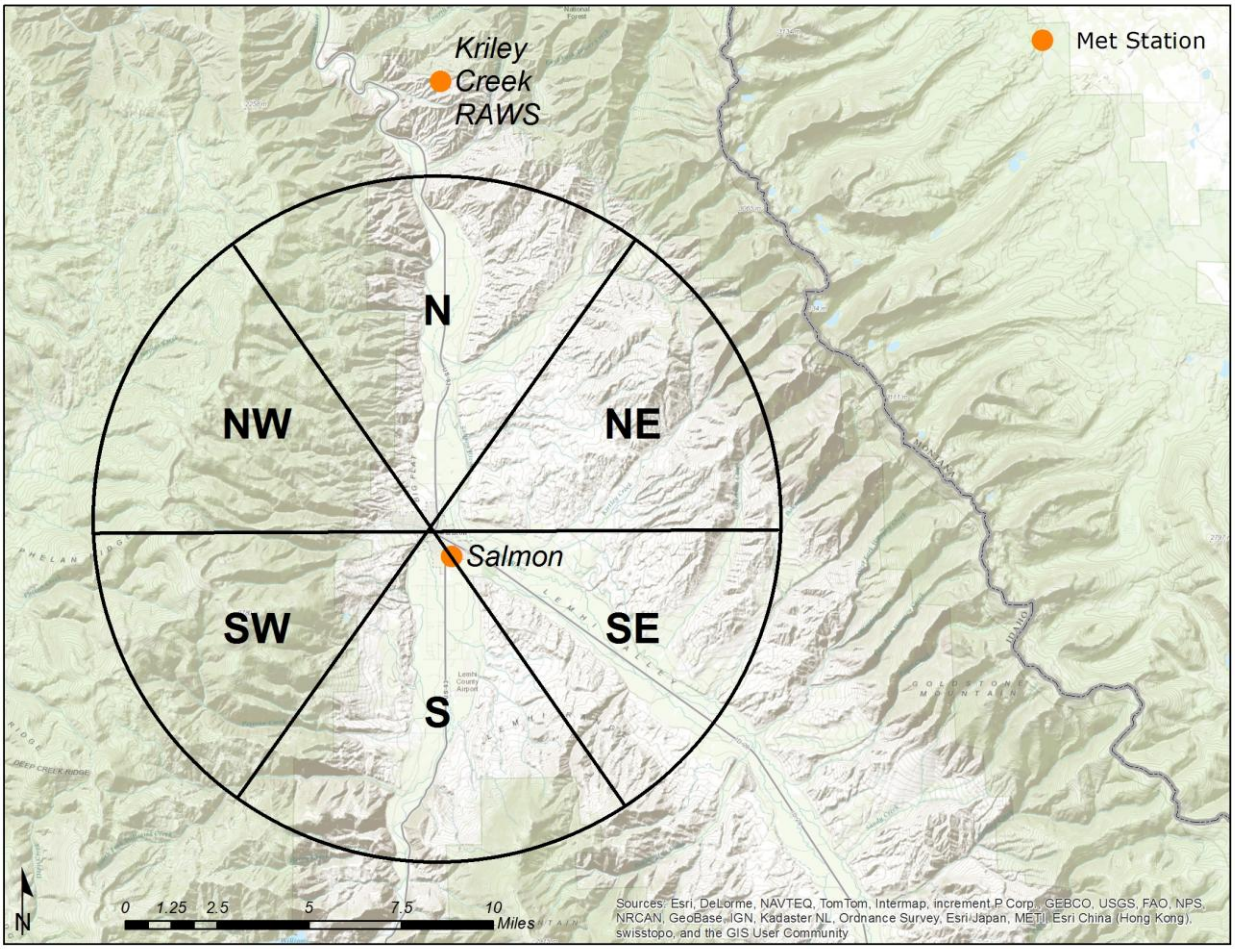


Figure 17. Salmon area meteorological stations and wind direction sectors used in analysis along with local terrain.

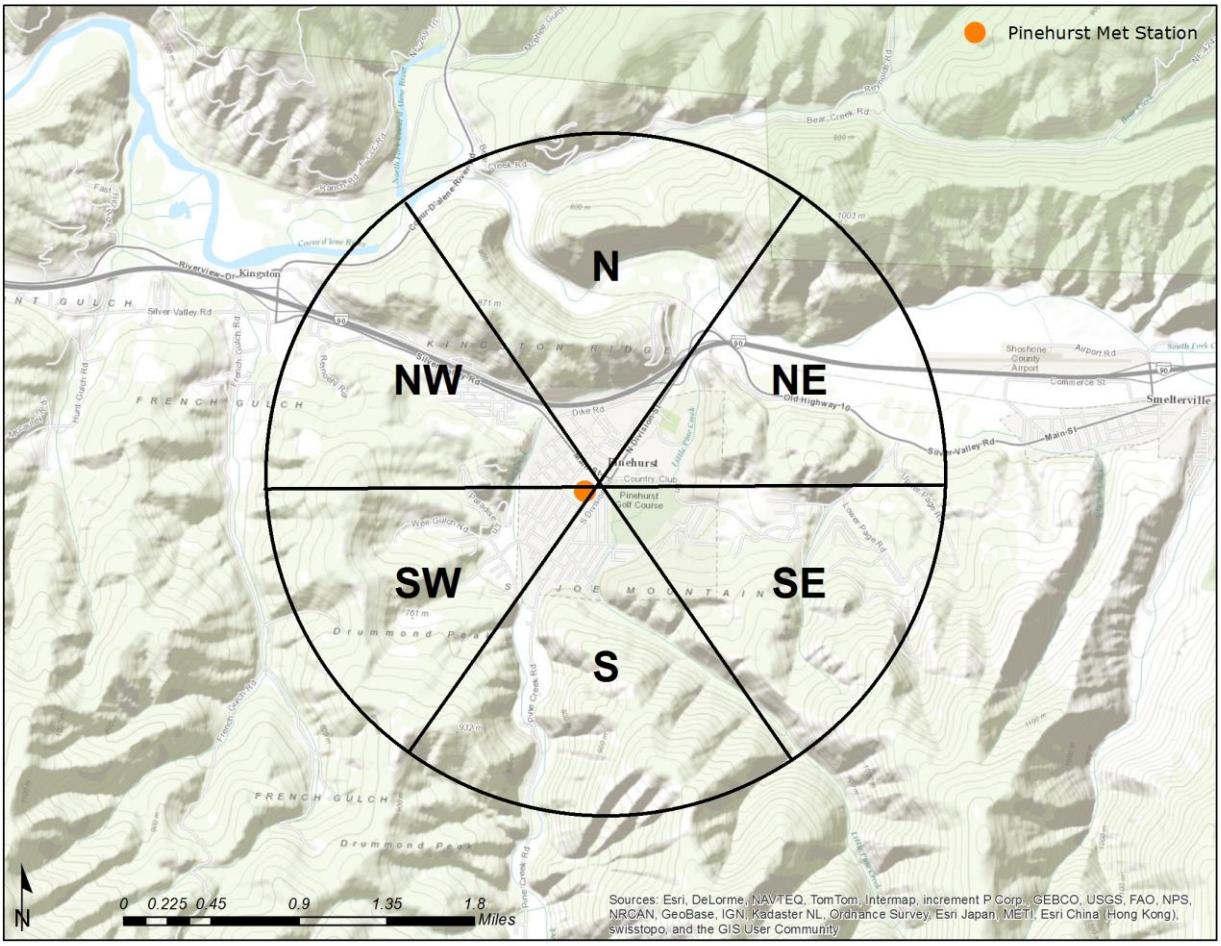


Figure 18. Pinehurst meteorological station and wind sectors used in analysis along with local terrain.

Table 1. Salmon wind direction frequency by hour of day (left block) and relative contributions to $PM_{2.5}$ concentration by sector and hour of day (right block).

Percent Frequency of Wind Directions by Sector (Shows the Wind Direction Frequency Only)							Percent Contribution to $PM_{2.5}$ (= Count x Average $PM_{2.5}$ (Shows where most of the PM is coming from by hour)						
Hour	N	NE	NW	S	SE	SW	Hour	N	NE	NW	S	SE	SW
1	22%	34%	5%	8%	21%	9%	1	19%	35%	6%	5%	25%	10%
2	21%	33%	7%	9%	24%	5%	2	24%	30%	6%	10%	28%	2%
3	16%	48%	5%	9%	16%	5%	3	9%	59%	6%	7%	11%	9%
4	16%	34%	4%	10%	29%	7%	4	13%	38%	8%	12%	22%	7%
5	20%	45%	4%	5%	21%	4%	5	18%	36%	7%	3%	31%	4%
6	23%	41%	3%	11%	20%	1%	6	16%	37%	7%	9%	30%	0%
7	23%	36%	2%	12%	23%	3%	7	20%	41%	6%	16%	17%	1%
8	20%	47%	4%	9%	17%	2%	8	25%	42%	7%	11%	14%	1%
9	26%	28%	9%	14%	17%	6%	9	25%	27%	11%	16%	17%	3%
10	42%	23%	13%	6%	11%	4%	10	43%	21%	13%	7%	9%	6%
11	48%	12%	17%	6%	10%	6%	11	59%	6%	17%	1%	11%	6%
12	46%	13%	22%	7%	7%	4%	12	51%	16%	15%	11%	6%	2%
13	57%	12%	13%	6%	4%	7%	13	57%	9%	14%	10%	1%	9%
14	48%	6%	14%	7%	8%	16%	14	48%	10%	19%	5%	3%	14%
15	39%	7%	14%	19%	3%	17%	15	49%	8%	11%	10%	5%	18%
16	37%	2%	18%	16%	11%	15%	16	45%	1%	14%	12%	12%	15%
17	35%	6%	14%	17%	9%	18%	17	43%	4%	11%	15%	6%	20%
18	36%	8%	16%	19%	5%	15%	18	43%	17%	9%	11%	3%	16%
19	32%	9%	16%	13%	20%	9%	19	39%	8%	26%	8%	8%	12%
20	30%	31%	13%	5%	15%	6%	20	50%	20%	9%	6%	13%	2%
21	31%	39%	6%	6%	16%	2%	21	33%	33%	3%	12%	18%	1%
22	27%	29%	6%	13%	20%	5%	22	25%	26%	12%	17%	19%	1%
23	29%	28%	5%	10%	21%	7%	23	29%	31%	7%	8%	18%	8%
24	17%	40%	8%	16%	10%	8%	24	19%	44%	3%	13%	13%	9%
Avg:	31%	25%	10%	11%	15%	8%	Avg	33%	25%	10%	10%	14%	7%

Table 2. Pinehurst wind direction frequency by hour of day (left block) and relative contributions to $PM_{2.5}$ concentration by sector and hour of day (right block).

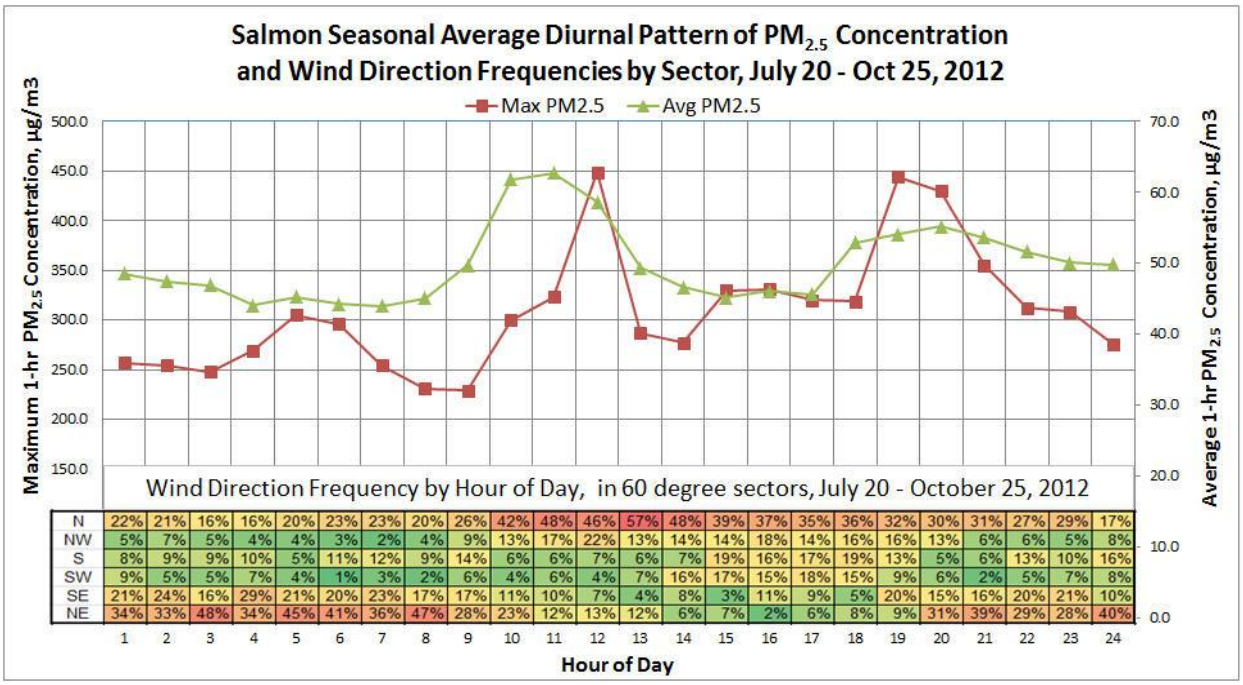
Percent Frequency of Wind Directions by Sector (Shows the Wind Direction Frequency Only)							Percent Contribution to PM2.5 (= Count x Average $PM_{2.5}$) (Shows where most of the PM is coming from by hour)						
Hour	NE	N	NW	SE	S	SW	Hour	NE	N	NW	SE	S	SW
1	0%	0%	0%	7%	87%	7%	1	0%	0%	0%	9%	85%	7%
2	0%	0%	0%	10%	77%	13%	2	0%	0%	0%	8%	85%	7%
3	0%	0%	0%	7%	90%	3%	3	0%	0%	0%	6%	93%	1%
4	0%	0%	0%	10%	87%	3%	4	0%	0%	0%	9%	89%	2%
5	0%	0%	0%	7%	80%	13%	5	0%	0%	0%	7%	86%	7%
6	0%	0%	0%	7%	90%	3%	6	0%	0%	0%	11%	88%	1%
7	0%	0%	0%	17%	77%	7%	7	0%	0%	0%	9%	83%	8%
8	0%	0%	0%	63%	37%	0%	8	0%	0%	0%	67%	33%	0%
9	7%	0%	0%	63%	30%	0%	9	10%	0%	0%	67%	23%	0%
10	0%	0%	0%	59%	34%	7%	10	0%	0%	0%	63%	30%	7%
11	0%	0%	7%	45%	28%	21%	11	0%	0%	4%	48%	24%	23%
12	0%	0%	14%	14%	24%	48%	12	0%	0%	12%	12%	26%	50%
13	0%	0%	28%	3%	10%	59%	13	0%	0%	25%	2%	10%	63%
14	0%	0%	59%	3%	0%	38%	14	0%	0%	60%	4%	0%	36%
15	0%	0%	59%	3%	0%	38%	15	0%	0%	67%	3%	0%	30%
16	0%	0%	59%	0%	3%	38%	16	0%	0%	65%	0%	4%	31%
17	0%	0%	17%	0%	10%	73%	17	0%	0%	17%	0%	18%	65%
18	0%	0%	7%	3%	43%	47%	18	0%	0%	3%	4%	36%	57%
19	0%	0%	0%	33%	57%	10%	19	0%	0%	0%	38%	56%	6%
20	0%	0%	3%	13%	80%	3%	20	0%	0%	1%	13%	85%	1%
21	0%	0%	3%	0%	93%	3%	21	0%	0%	0%	0%	95%	5%
22	0%	0%	0%	3%	90%	7%	22	0%	0%	0%	3%	96%	1%
23	0%	0%	3%	7%	87%	3%	23	0%	0%	1%	12%	86%	1%
24	0%	0%	0%	3%	93%	3%	24	0%	0%	0%	2%	97%	1%
Avg:	0%	0%	11%	16%	55%	19%	Avg:	0%	0%	11%	17%	55%	17%

1.5.2 Direct Advection from Source to Monitors Conceptual Model Description

The simplest conceptual model for transport of smoke from wildfires to affected monitors results when hot wildfire smoke plumes rise above the surrounding ridges and become entrained in the transport winds that are defined by the synoptic pressure gradient rather than by terrain-influences. When this occurs, typically during the daytime when the fires burn their hottest, the plumes may rise well above the terrain, transporting smoke for hundreds of miles, sometimes filling any valleys beneath their path with dense smoke. If it happens during the daytime, this type of impact may be characterized by a sharply rising then sharply descending concentration peak as the plume sweeps through a range of directions with the shifting winds. If it happens during the late afternoon or evening, the smoke from a direct impact event such as this may become trapped in the valley by the nocturnal radiation inversion, where it will subsequently participate in the valley-flow dynamics. While direct plume impacts can often be clearly seen travelling directly from fire to monitor in the twice daily MODIS satellite images, it is important to realize that synoptic winds shift and a direct plume impact may not be captured in the twice daily MODIS (Terra or Aqua) satellite "snapshots." NOAA's Ready-HYSPLIT model (Draxler 2003) was utilized for every day having a monitor impact to visualize the model-estimated air flow paths approaching the monitors for each hour of the day. Back -trajectories were initiated at 2300 and at 3 levels (surface, 500 m AGL and 1000 m AGL) every hour and extended back in time for 24 hours prior to their endpoint at the monitor location. The back trajectories typically parallel the visible smoke plumes observed by satellite imagery approaching a monitor; however, not always. In some cases, clouds obscure the smoke plume or a thick haze from multiple fires blanket the area, thereby obscuring specific plumes. Nevertheless, if a HYSPLIT back trajectory extending out from the monitor location passes over a fire detect area, or over visible smoke plumes from a fire, it is inferred that the smoke likely travelled along the path of the back trajectory to reach the monitor, or to intersect the valley containing the monitor, where it is subject to the diurnal valley flow patterns as described in the next sections. Thus satellite imagery, back-trajectories, and hourly time series of wind and $PM_{2.5}$ concentrations, provided in Appendix B and C may each provide some evidence of this type of source-monitor path.

1.5.3 Salmon Valley Flows Conceptual Model Description

As described in the Salmon wind direction and $PM_{2.5}$ analysis above, the valley flows observed in Salmon occur in two predominant regimes: (a) nighttime drainage flow, primarily down-slope flows from the NE, and, to a lesser extent, down-valley flow from the Lemhi River valley to the SE and the Salmon River valley to the south, and (b) up-valley northerly flow from the North Fork region south to Salmon. While stagnant valley conditions and direct advection from the fires (Section 1.5.1) brought smoke into Salmon from all directions, the highest concentrations generally occurred during the up-valley flow patterns from the north. This conclusion is demonstrated in Figure 19, where the average and the maximum $PM_{2.5}$ concentration for each hour are shown to peak around hours 10–12 (1000–1200) and again around 1800–2000 when the most prevalent wind direction is from the north. In specific day scenarios, this model is recognized by the wind and $PM_{2.5}$ time series charts. In addition, satellite images may show dense smoke in the valley and surface level back trajectories may indicate flows up and down along the valley axis (but not always).

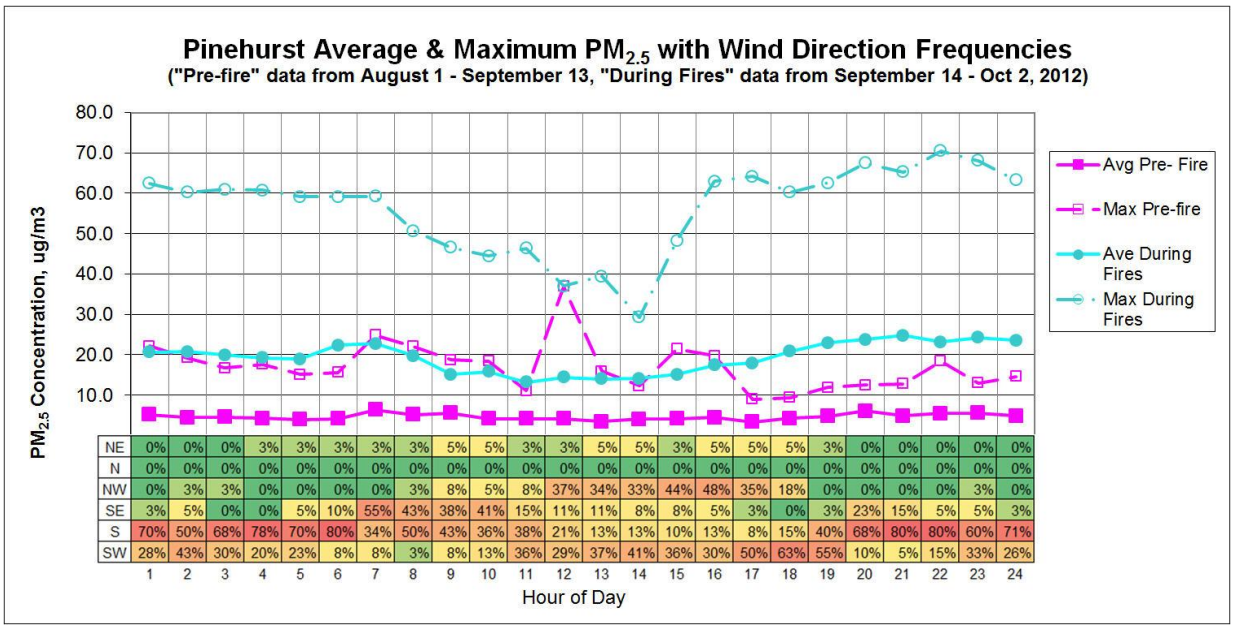


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	22%	21%	16%	16%	20%	23%	23%	20%	26%	42%	48%	46%	57%	48%	39%	37%	35%	36%	32%	30%	31%	27%	29%	17%
NW	5%	7%	5%	4%	4%	3%	2%	4%	9%	13%	17%	22%	13%	14%	14%	18%	14%	16%	16%	13%	6%	6%	5%	8%
S	8%	9%	9%	10%	5%	11%	12%	9%	14%	6%	6%	7%	6%	7%	19%	16%	17%	19%	13%	5%	6%	13%	10%	16%
SW	9%	5%	5%	7%	4%	1%	3%	2%	6%	4%	6%	4%	7%	16%	17%	15%	18%	15%	9%	6%	2%	5%	7%	8%
SE	21%	24%	16%	29%	21%	20%	23%	17%	17%	11%	10%	7%	4%	8%	3%	11%	9%	5%	20%	15%	16%	20%	21%	10%
NE	34%	33%	48%	34%	45%	41%	36%	47%	28%	23%	12%	13%	12%	6%	7%	2%	6%	8%	9%	31%	39%	29%	28%	40%

Figure 19. Salmon seasonal average and maximum $PM_{2.5}$ concentration by hour of day, with wind direction frequencies, showing that up-valley flows from the North brought the highest $PM_{2.5}$ levels to Salmon.

1.5.4 Pinehurst Valley Flows Conceptual Model Description

The conceptual model for wildfire impacts in Pinehurst are somewhat different than those in Salmon in that none of the wildfires were located in or near the same valley as the monitor. As a result, the wildfire impacts in Pinehurst, while conceptually similar, were much lower in magnitude and somewhat more difficult to distinguish from the normal patterns. The average and maximum values for each hour during the wildfire period of impact, and during late summer before the wildfire impacts are shown in Figure 20. For reference, the wind sector frequencies are repeated at the bottom of this chart in the same colored scheme, in which the most frequent directions are red and orange while the least frequent directions are green. Since the Pinehurst impacts are lower than Salmon impacts and not as clearly "exceptional" the average and maximum values for 40 days prior to the period of fire activity are also shown, to better demonstrate the influence of the fires in comparison to the "during fires" $PM_{2.5}$ average and maximum diurnal patterns. The chart in Figure 20 clearly shows that the average and maximum values for each hour are elevated over the "prefire" values, and the additional wildfire contribution appears to arrive (a) during nighttime drainage flow from the south where wildfire smoke was likely trapped each day, and (b) during the afternoon hours when flow from NW bring additional $PM_{2.5}$ during the afternoon (~ 1500–1700). These patterns support a conceptual model of regional transport from distant fires and valley flow transporting trapped smoke that persisted as a result of stagnant conditions.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
NE	0%	0%	0%	3%	3%	3%	3%	3%	5%	5%	3%	3%	5%	5%	3%	5%	5%	5%	3%	0%	0%	0%	0%	0%
N	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NW	0%	3%	3%	0%	0%	0%	0%	3%	8%	5%	8%	37%	34%	33%	44%	48%	35%	18%	0%	0%	0%	0%	3%	0%
SE	3%	5%	0%	0%	5%	10%	55%	43%	38%	41%	15%	11%	11%	8%	8%	5%	3%	0%	3%	23%	15%	5%	5%	3%
S	70%	50%	68%	78%	70%	80%	34%	50%	43%	36%	38%	21%	13%	13%	10%	13%	8%	15%	40%	68%	80%	80%	60%	71%
SW	28%	43%	30%	20%	23%	8%	8%	3%	8%	13%	36%	29%	37%	41%	36%	30%	50%	63%	55%	10%	5%	15%	33%	26%

Figure 20. Average and maximum monitor values at Pinehurst, before and during the period of wildfire contributions, with wind sector frequencies by hour.

1.6 Concentration Patterns

Temporal and spatial concentration patterns serve to characterize the increases in monitor values during the event and provide additional information regarding the source of the elevated $PM_{2.5}$ concentrations.

1.6.1 Temporal Patterns

The general diurnal concentration patterns for the days affected by the wildfires are characterized by the average and maximum concentration charts Figure 19 and Figure 20 shown in the previous section. The specific diurnal concentration patterns for each day proposed as "Exceptional Events" are shown in hourly time series charts in Appendix B (Salmon) and Appendix C (Pinehurst).

All daily mean $PM_{2.5}$ concentration values, including the co-located monitor values for the year 2012 are shown in Figure 21 and Figure 22 for Salmon and in Figure 23 for Pinehurst. Figure 22 is simply an expanded view of the elevated concentrations during the period of wildfire influence and includes the two week period of unaffected values before and after the season. These charts refer to the monitors by their "POC" or "parameter occurrence code" which merely identifies unique monitors co-located at the same monitoring site.

These figures show the specific monitor values included in this request, and other values which also appear to be affected by the wildfires, but are not included in this request due to time constraints. Together, the figures demonstrate that the temporal concentration pattern in the year 2012 was dramatically altered by the wildfires.

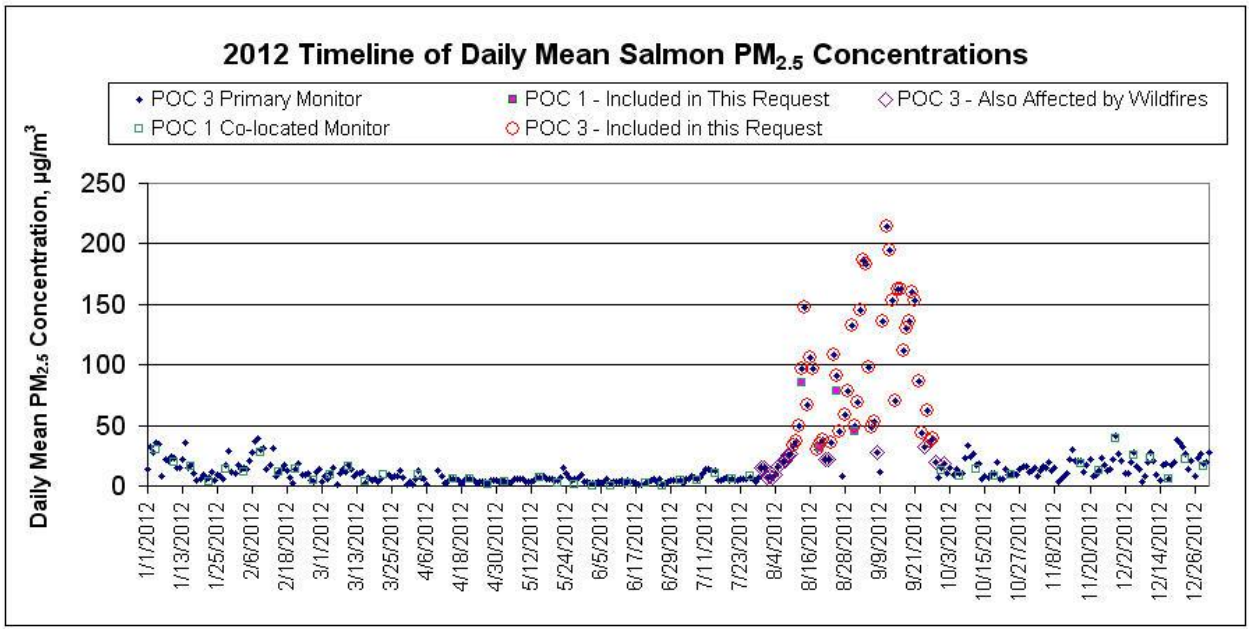


Figure 21 Timeline of Daily Mean $PM_{2.5}$ Concentrations in Salmon, Idaho, 2012

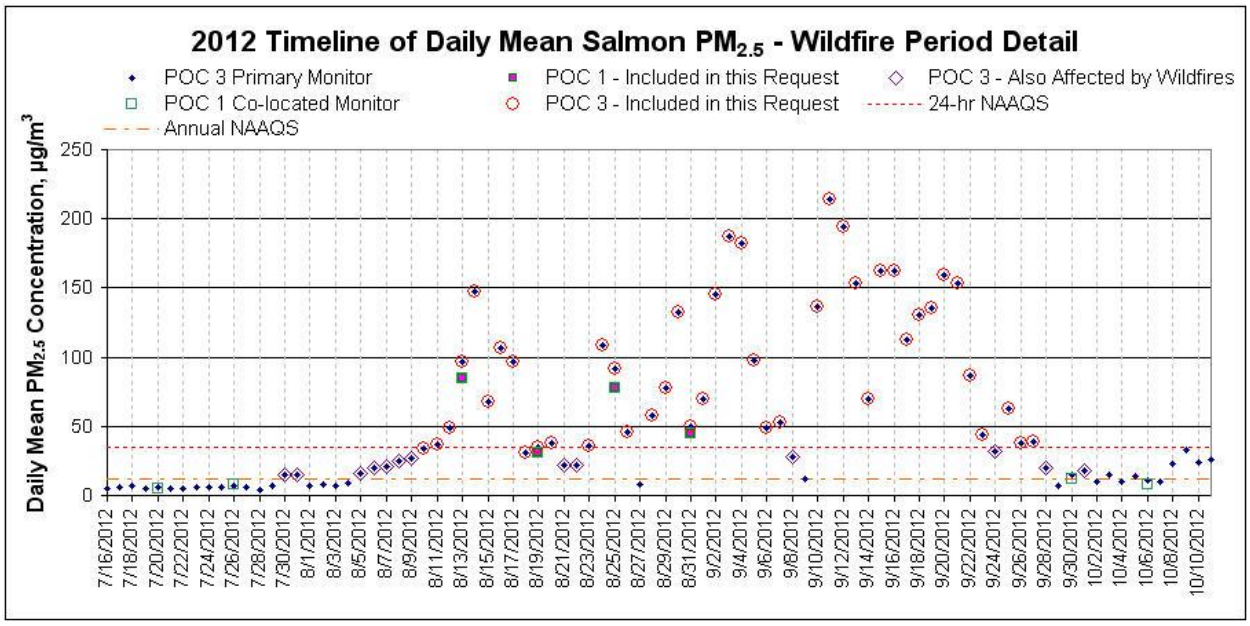


Figure 22 Detail during Wildfire Period in Timeline of Daily Mean $PM_{2.5}$ Concentrations in Salmon, Idaho, 2012

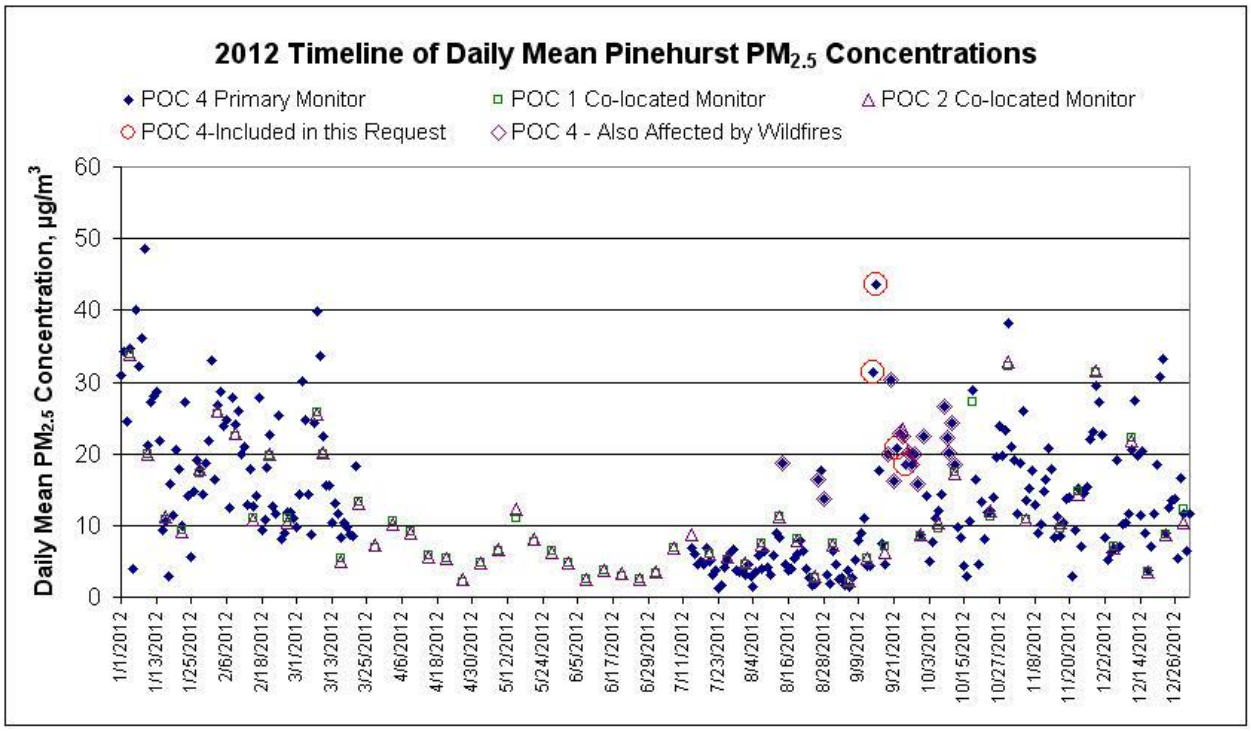


Figure 23 Timeline of Daily Mean $PM_{2.5}$ Concentrations in Pinehurst, Idaho, 2012

1.6.2 Spatial Patterns

The spatial concentration patterns during the 2012 wildfire season were higher than normal throughout the region, with particularly extreme increases in the east-central area of Idaho along the border with Montana. This pattern is clear in Figure 24, where the $PM_{2.5}$ at Salmon, Selway-Bitterroot, and Ravalli, Montana are many times higher than the wildfire period average for the preceding four years, and at most sites in the region were the 2012 concentrations are at least 2–3 times higher. To confirm that the $PM_{2.5}$ increase is due to smoke, the organic carbon (OC) and $PM_{2.5}$ concentrations were obtained from the IMPROVE visibility monitoring stations throughout the region (IMPROVE 2013). The OC and OC/$PM_{2.5}$ ratios based on the IMPROVE speciation data are shown in Figure 25. The similarity of the OC temporal/spatial pattern is very similar to the $PM_{2.5}$ across the region, confirming that the regional increase in $PM_{2.5}$ is due to combustion sources. The broad regional pattern, along with the emissions comparison in Figure 4, demonstrates that typical crop residue burning, wildland prescribed burning, industrial point sources, and nonpoint sources including residential wood combustion and all other forms of open burning are very small in comparison to the 2012 wildfire emissions and not capable of producing such a region-wide increase in the level of $PM_{2.5}$. Thus, we may conclude that the huge region-wide increase in $PM_{2.5}$ parallels the increase in carbon at all sites, and therefore can only be explained by the unusually severe and region-wide wildfires.

Finally, Figure 26 shows the comparison of the 2012 wildfire period averages for $PM_{2.5}$ sites across Idaho to the mean of period (2008-0211) averages (over the same time domain) and the 95th percentile upper confidence bound (UCB) on the annual values. The 2012 data were well above the 2008-2011 UCB, demonstrating that the result is statistically significant at all sites across the state.

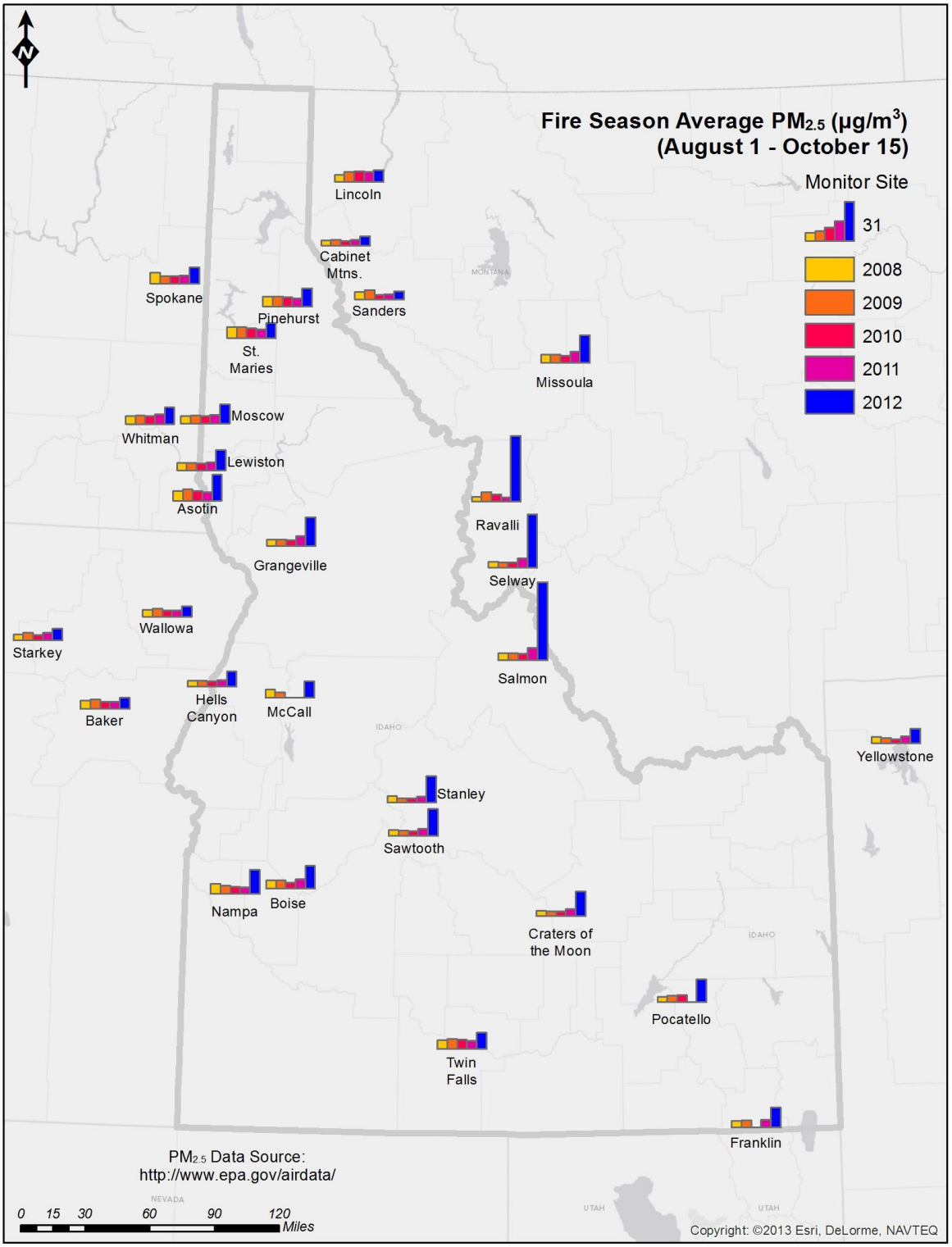


Figure 24. Fire season (August 1–October 15) period average $PM_{2.5}$ concentrations for 2012 and the previous 4 years showing concentrations throughout the region much higher in 2012 than in normal years (sources: EPA 2013b for cities; IMPROVE 2013 for Class I areas).

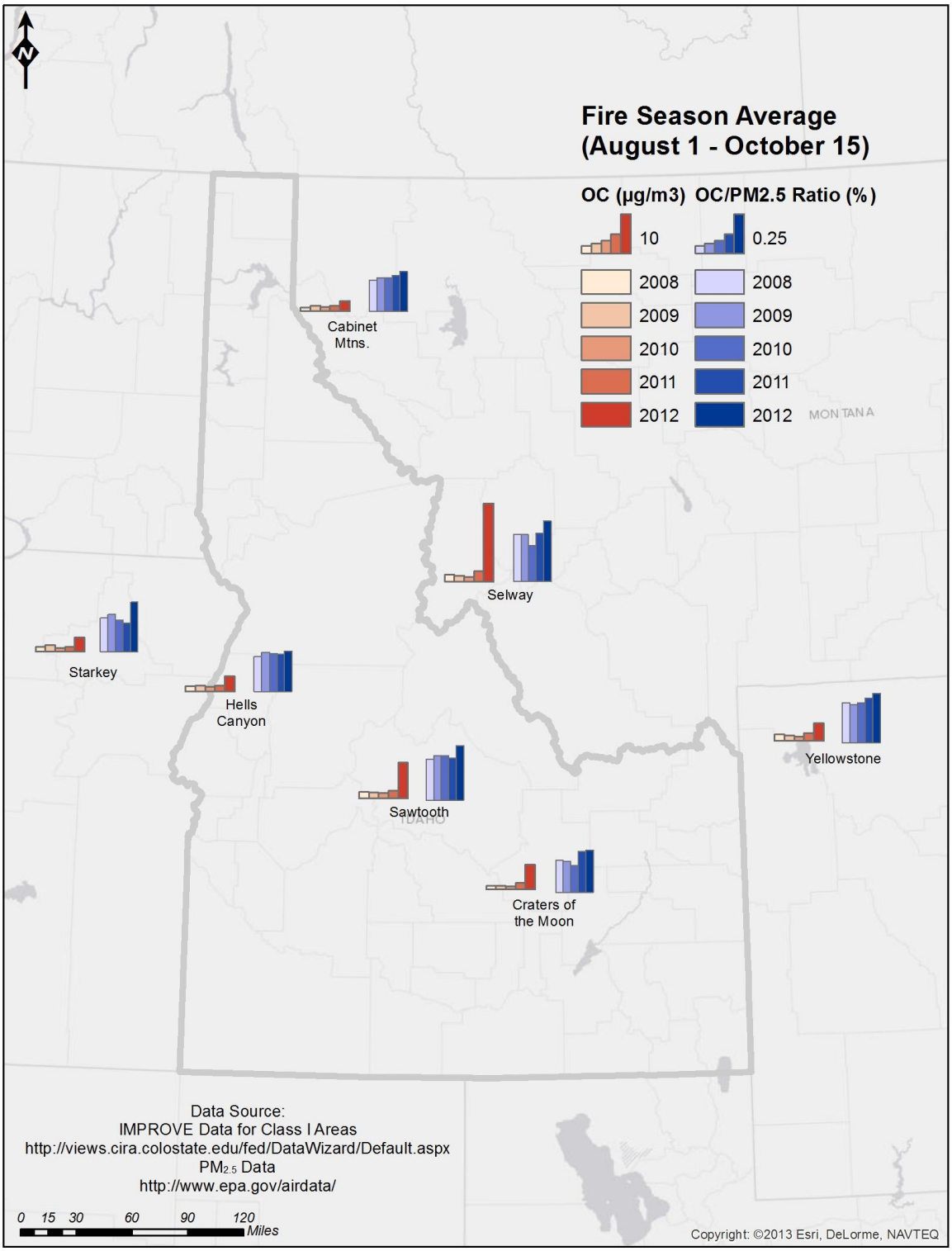


Figure 25. Fire season organic carbon (OC) and organic carbon to $PM_{2.5}$ ratio at IMPROVE sites in the Idaho region (IMPROVE 2013) for 2012 and 4 previous years showing that organic carbon, a species identifying smoke was unusually high throughout the Idaho region in 2012, compared to the previous years.

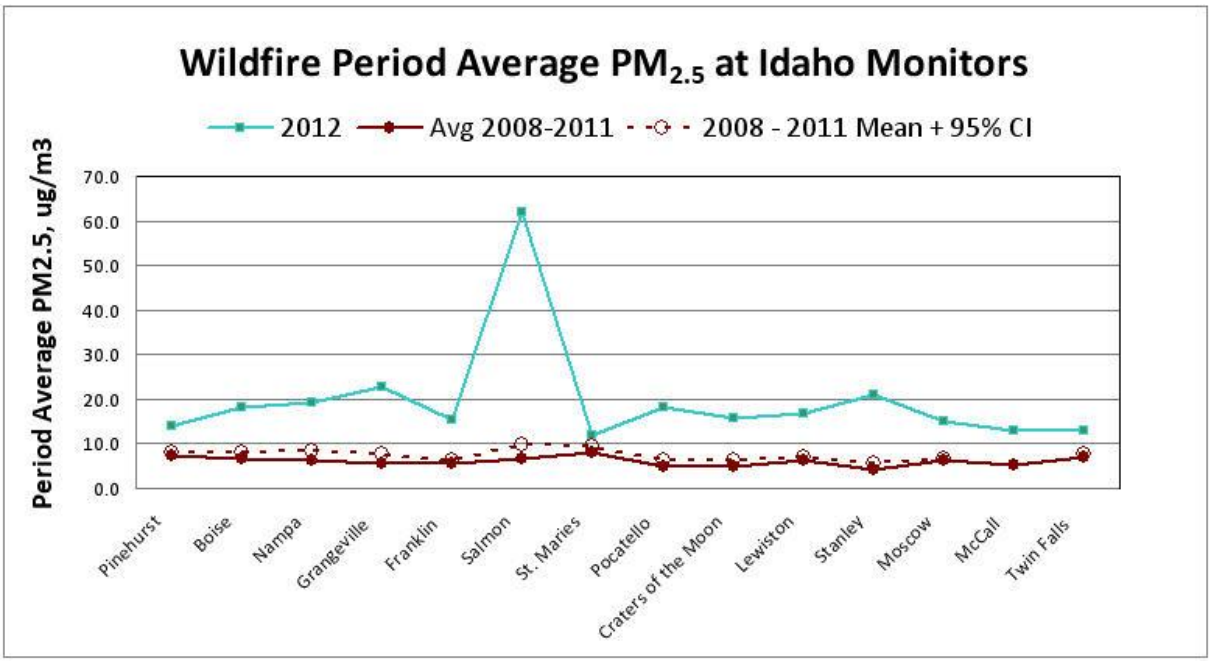


Figure 26. The 2012 wildfire period average $PM_{2.5}$ in comparison to the mean and 95th percentile upper confidence interval for the 2008–2011 period means, showing statistically significant increases in 2012 at every monitor in the region (EPA 2013b).

2 Not Reasonably Controllable or Preventable (nRCP)

2.1 Source Areas Contributing to the Event

This section demonstrates that the exceptional event, the primarily lightning-caused wildfires, was not reasonably controllable or preventable. The primary wildfires impacting Pinehurst and Salmon were lightning caused and managed under suppression strategies, either full suppression or point zone protection consistent with each specific forest's Fire Management Plan (e.g. see SCNF, 2012). This section only addresses the question of whether or not the wildfires were reasonably controllable or preventable. Section 4.3 of this document evaluates whether other types of $PM_{2.5}$ sources, such as prescribed burning, could have caused or contributed significantly to the elevated concentrations on the requested days. Section 8 of this document discusses the mitigation measures DEQ implemented to notify the public of deteriorating air quality as well as to control other sources of $PM_{2.5}$ emissions.

The primary wildfires influencing Salmon, Idaho $PM_{2.5}$ concentrations were the Halstead fire north of Stanley, Idaho, and the Mustang Complex northwest of Salmon. The primary fires influencing the Pinehurst, Idaho $PM_{2.5}$ concentrations were the Wenatchee Complex and Table Mountain Fires in Washington; the Cache Creek fire in Oregon; and the Powell SBW Complex in Idaho, although many other fires in the region likely contributed at various times. The start and end dates for each fire are shown in Table 3 (NIFC 2013). Additional fires over 40,000 acres are also listed in Table 3 because they all contributed to regional smoke and are also considered as partial contributors. The management strategy applied to each fire by the incident command teams is also included in Table 3.

Table 3. July 30–October 13, 2012, wildfires greater than 40,000 acres contributing to Idaho smoke (NIFC 2013).

Name	Manage-ment Strategy[c]	State	Start Date	Contain or Control Date	Size (Acres)	Cause Estimated	Cost of Resources Spent to Suppress
Mustang Complex[a]	FS/M[d]	ID	30-Jul	18-Oct	341,488	Lightning	$38,323,413
Halstead[a]	FS/PZP[e]	ID	27-Jul	18-Oct	181,948	Lightning	$1,625,000
Trinity Ridge	FS	ID	3-Aug	18-Oct	146,832	Human	$26,413,932
Flat Top 2	FS	ID	5-Aug	13-Aug	140,954	Lightning	$41,228,912
Minidoka Complex	FS	ID	8-Aug	23-Aug	97,616	Lightning	$600,000
Powell SBW Complex[b]	PZP	ID	20-Jul	5-Nov	67,611	Lightning	$5,801,271
Sheep	FS	ID	6-Sep	6-Nov	48,626	Human	$4,882,375
McGuire Complex	FS	ID	27-Aug	29-Oct	43,621	Lightning	$300,000
Miller Homestead	FS	OR	8-Jul	21-Sep	160,853	Lightning	$24,741,628
Barry Point	FS	OR	6-Aug	17-Sep	93,071	Lightning	$4,360,000
Cache Creek[b]	FS	OR	20-Aug	23-Oct	73,697	Lightning	$6,000,000
Holloway	FS	OR/NV	5-Aug	23-Aug	460,850	Lightning	$23,247,235
Barker Canyon Complex	FS	WA	8-Sep	15-Sep	81,155	Lightning	$11,250,000
Wenatchee Complex[b]	FS	WA	9-Sep	30-Oct	56,478	Lightning	$9,166,719
Table Mountain[b]	FS	WA	8-Sep	19-Oct	42,312	Lightning	$2,290,268
Rush	FS	CA	12-Aug	4-Sep	315,577	Lightning	$32,394,876
Chips	FS	CA	29-Jul	8-Sep	75,431	Unknown	$195,000
Lost	FS	CA	5-Aug	12-Aug	61,541	Lightning	$15,170,000
Bagley	FS	CA	18-Aug	22-Sep	46,011	Lightning	$53,300,000
North Pass	FS	CA	18-Aug	17-Sep	41,983	Lightning	$3,700,000

a. Primary fires affecting the Salmon Monitor, although other fires in the region contributed at times.
b. Primary fires affecting the Pinehurst Monitor, although other fires in the region contributed at times.
c. FS = Full Suppression; PZP = Point Zone Protection; M = Monitor
d. Mustang Complex was managed under FS 7/30 – 10/6, and under PZP from 10/6 to date of control.
e. Halstead Fire was managed under FS 7/30 – 8/11, and under PZP from 8/12 – 10/18.

The temporal progression of the fires and the smoke produced by them between the start date and the containment or "control" date are of interest to better understand how the source strength varied throughout the season. The daily "Situation Reports" (NIFC 2013b) provide operational estimates of the approximate fire perimeter sizes and personnel committed to each fire by the responsible federal land management agencies. Figure 27 demonstrates, for the two fires primarily influencing the Salmon, Idaho $PM_{2.5}$ concentrations, that these fires grew continuously throughout the wildfire season, and that considerable personnel resources were dedicated to suppressing the fires throughout the entire period until each fire stopped growing, around the end of September.

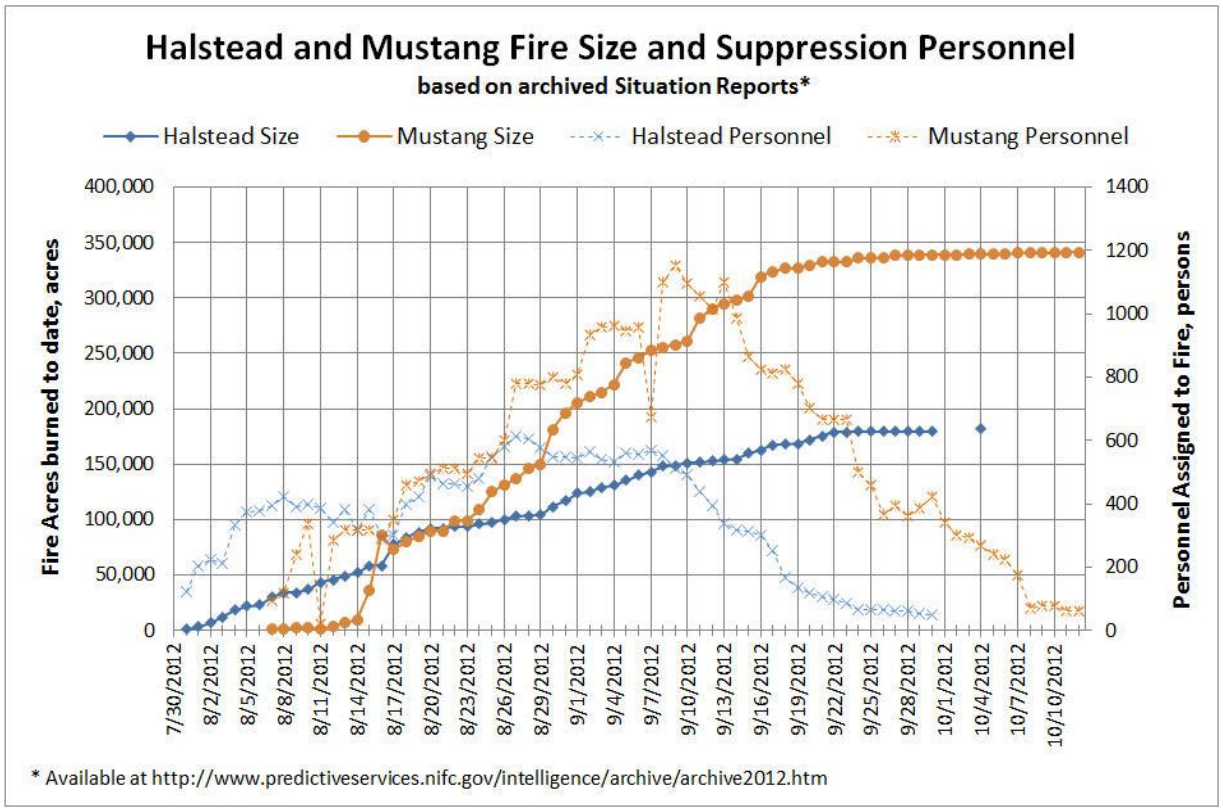


Figure 27. Fire size progression and personnel assigned to the Halstead and Mustang Complex, the major fires most affecting the Salmon, Idaho monitor.

2.2 Basic Controls Analysis

Based on the information provided in Table 3 of this submittal, lightning caused the Halstead and Mustang Complex fires that contributed the vast majority of smoke influencing the Salmon, Idaho monitor. The Halstead fire was managed under full suppression until August 11, at which time it was managed under point zone protection until controlled. The Mustang Complex was managed as point zone protection until October 6, at which time the fire was under a monitor status. The responsible agencies did their reasonable best to control the extent of these fires, as indicated by the funds spent to fight these fires (Table 3) and the personnel resources assigned to the two fires primarily affecting Salmon. As shown in Figure 27, at their peak staffing levels, 607 people were fighting the Halstead fire and 1152 were fighting the Mustang Complex. The Halstead effort utilized up to 10 crews, 40 engines and 10 helicopters at its peak, while the Mustang Complex effort utilized up to 20 crews, 100 engines and 7 helicopters at its peak. In addition up to 4 large C-130 aircraft from two different Airlift Wings operated out of the National Interagency Fire Center located in Boise, ID, in support of suppression efforts on the Halstead, Mustang, and Trinity Ridge Fires (NIFC 2013).

The primary fires affecting Pinehurst on the days requested as "exceptional" are the Wenatchee Complex, and Table Mountain fire in Washington, the Cache Creek fire in Oregon, and the Powell SWB Complex in Idaho. With the exception of the Powell SBW Complex, these fires were managed under the full suppression strategy. The Powell SBW Complex was managed under the point zone protection strategy. Many other fires in the region, included Table 3, also

likely contributed to the regional smoke conditions, and all these other fires were managed under full suppression strategy.

Therefore, in view of the fact that lightning caused the primary fires affecting Salmon and Pinehurst, the fact that all the fires were managed by Federal Land Managers under a form of suppression strategy (full suppression or point zone protection) and that a tremendous amount of human and material resources were spent to control or contain these fires, it is clear that emissions from these wildfires were not reasonably controllable or preventable.

3 In Excess of Historical Fluctuations (HF)

3.1 Salmon Historical Fluctuations

The $PM_{2.5}$ concentrations measured at Salmon during May through October, from 2008 through 2011 are presented in Figure 28. The data (EPA 2013b) shows that the $PM_{2.5}$ concentration could be elevated in different periods. The impact is often influenced by mixed emission sources; however, it can be seen that the overall $PM_{2.5}$ level more or less is evenly distributed from May through October with an average below 10 $\mu g/m^3$ and few peaks higher than 15 $\mu g/m^3$. It is believed that while $PM_{2.5}$ concentrations were also influenced by wildfires in these years, the impact was not significant. Using these data as the background to represent the normal historical fluctuations would therefore be a somewhat conservative approach since they likely include some wildfire smoke, which may also have been considered “exceptional.” The higher levels in later October are believed to reflect primarily the emissions from residential wood combustion as the heating season started, although some minor prescribed fire activity may be present in October.

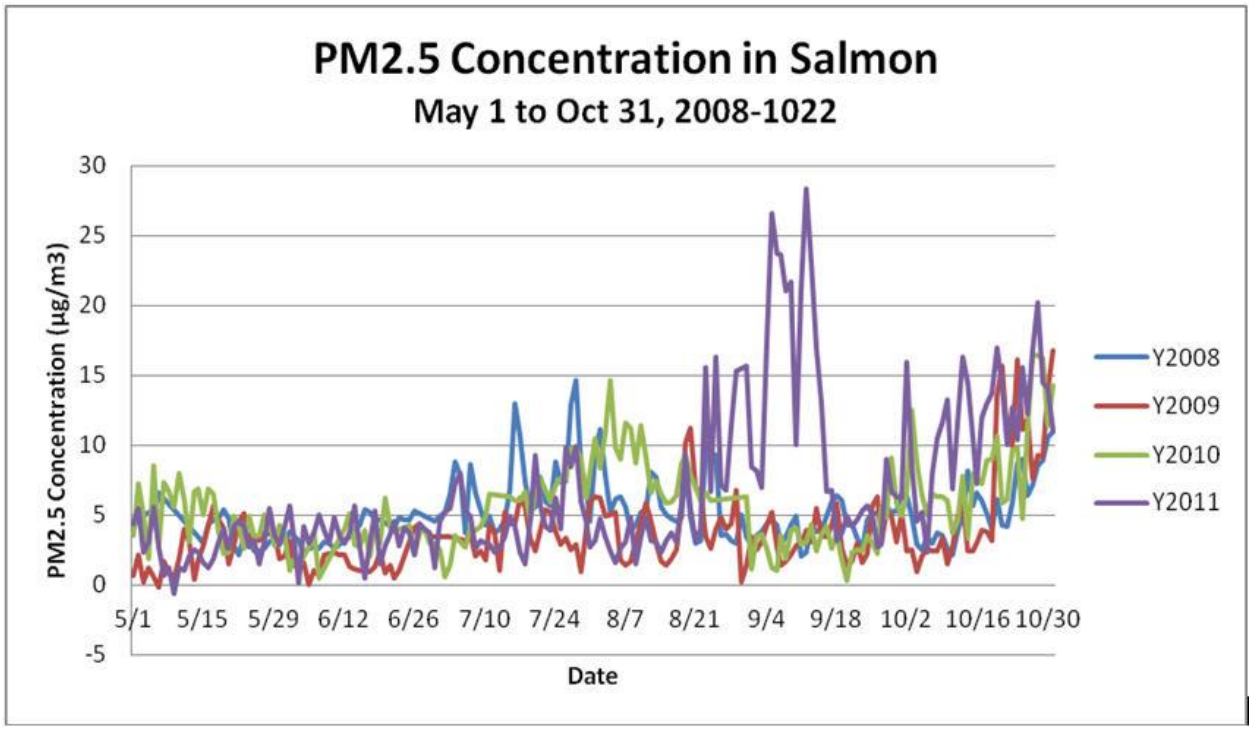


Figure 28. $PM_{2.5}$ historical fluctuations in Salmon, Idaho, 2008–2011.

Table 4 shows the statistics of $PM_{2.5}$ concentrations measured during the wildfire period from 2008–2011 and the same period in 2012. The statistics show clearly all key values are shifted greatly to higher levels in 2012 indicating $PM_{2.5}$ concentrations during this period in 2012 were influenced by the additional emissions.

Table 4. Statistics of $PM_{2.5}$ concentrations during fire period.

Statistics	2008–2011	2012
Mean	5.9	61.6
Standard Error	0.3	6.4
Median	4.8	37.2
Mode	3.0	10.5
Standard Deviation	4.5	56.5
Minimum	0.2	5.4
Maximum	28.4	214.3

Figure 29 shows the distribution of $PM_{2.5}$ concentrations from July 30–October 12 during 2008–2011 and during the same period in 2012. The 2012 distribution is a dual-mode distribution with the second mode of a much higher value (50–100 µg/m^3) compared to the mode of 2008–2011 distribution (0–5 µg/m^3). This pattern provides strong evidence that the period was impacted by an emissions source with a unique distribution.

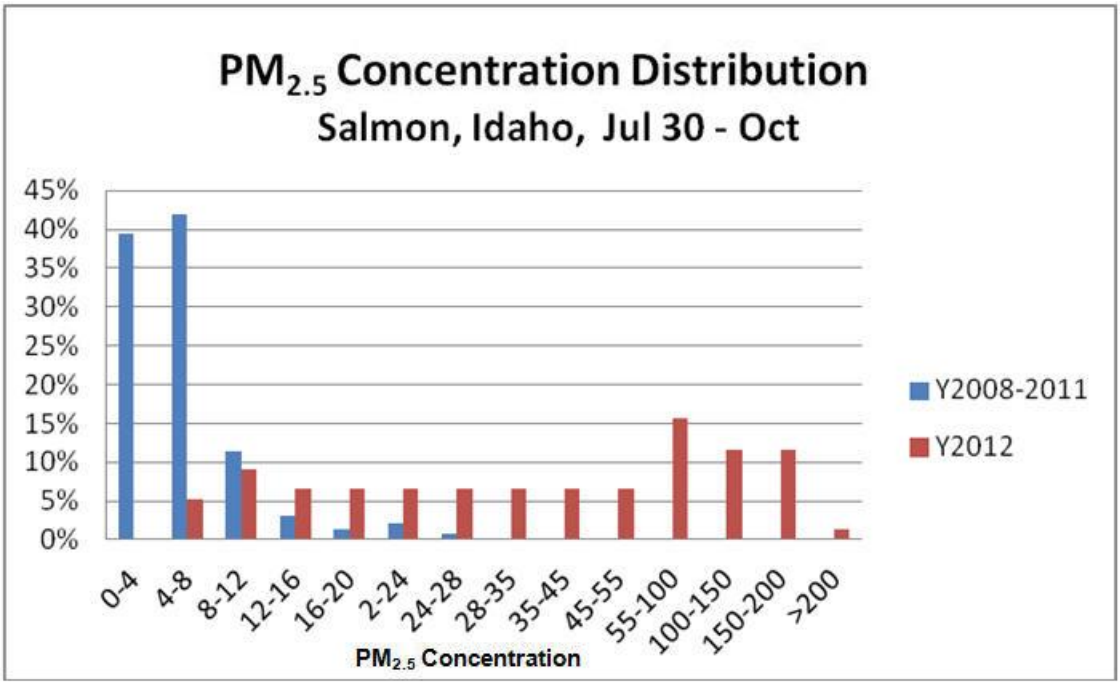


Figure 29. $PM_{2.5}$ concentration distribution for 2012 versus the previous 4 years, during the period July 30–October 12. Percent of days in each concentration range are depicted.

Table 5 shows the average $PM_{2.5}$ concentration and 95th and 99th percentile of concentrations at the Salmon monitor for 2008 through 2011, but for the approximate period of the 2012 wildfire season July 30 – October 12. The range of "normal historical fluctuations above the mean" is considered to be represented by the range from the average value to the 95th percentile value, in this case, 5.8 to 15.9 µg/m^3.

Table 5. Average, 95th and 99th percentile values for Salmon monitor, 2008–2011.

Average (µg/m^3)	95 percentile	99 percentile
5.8	15.9	23.7

The percentile ranking for the $PM_{2.5}$ concentrations at Salmon are listed in Table 6 in comparison to the 2008–2011 seasonal and annual datasets. All days higher than 15.9 µg/m^3 surpass the 95th percentile relative to the fire season average. The 2012 data set is not used to represent the historical fluctuations because there exist so many affected days, it would not provide a clear picture of the normal conditions.

Table 6. Percentile rankings for Salmon $PM_{2.5}$ monitor values (99% indicates 99% or above).

Date	2012 $PM_{2.5}$ ($\mu g/m^3$)	Percentile (Fire Season)	Percentile (Annual)
8/10/2012	33.7	99%	97%
8/11/2012	37.2	99%	98%
8/12/2012	49.2	99%	99%
8/13/2012	96.5	99%	99%
8/14/2012	147	99%	99%
8/15/2012	67.3	99%	99%
8/16/2012	106.5	99%	99%
8/17/2012	96.6	99%	99%
8/18/2012	30.4	99%	95%
8/19/2012	34.5	99%	97%
8/20/2012	37.7	99%	98%
8/23/2012	35.9	99%	98%
8/24/2012	108.2	99%	99%
8/25/2012	91.3	99%	99%
8/26/2012	45.5	99%	99%
8/28/2012	58.2	99%	99%
8/29/2012	78.1	99%	99%
8/30/2012	132	99%	99%
8/31/2012	49.8	99%	99%
9/1/2012	69.4	99%	99%
9/2/2012	145.2	99%	99%
9/3/2012	186.9	99%	99%
9/4/2012	182.7	99%	99%
9/5/2012	97.8	99%	99%
9/6/2012	48.4	99%	99%
9/7/2012	53.1	99%	99%
9/10/2012	136.4	99%	99%
9/11/2012	214.3	99%	99%
9/12/2012	194.4	99%	99%
9/13/2012	153.7	99%	99%
9/14/2012	70.2	99%	99%
9/15/2012	162.1	99%	99%
9/16/2012	162.5	99%	99%
9/17/2012	112.3	99%	99%
9/18/2012	130.3	99%	99%
9/19/2012	135.5	99%	99%
9/20/2012	159.8	99%	99%
9/21/2012	153.5	99%	99%

9/22/2012	86.6	99%	99%
9/23/2012	44.3	99%	99%
9/25/2012	62.7	99%	99%
9/26/2012	37.4	99%	98%
9/27/2012	39.3	99%	98%

Figure 30 shows the $PM_{2.5}$ concentrations during the 2012 fire period (yellow circles) against the concentrations for the same days in the years 2008 through 2011 (colored bars.) The historical (2008–2011) average and 95th percentile values (from Table 5) are also shown as dotted lines. Based on EPA guidance, the $PM_{2.5}$ concentrations above the 95th percentile level, 15.9 µg/m^3, may be generally attributed to the wildfires (if other EER elements support that conclusion).

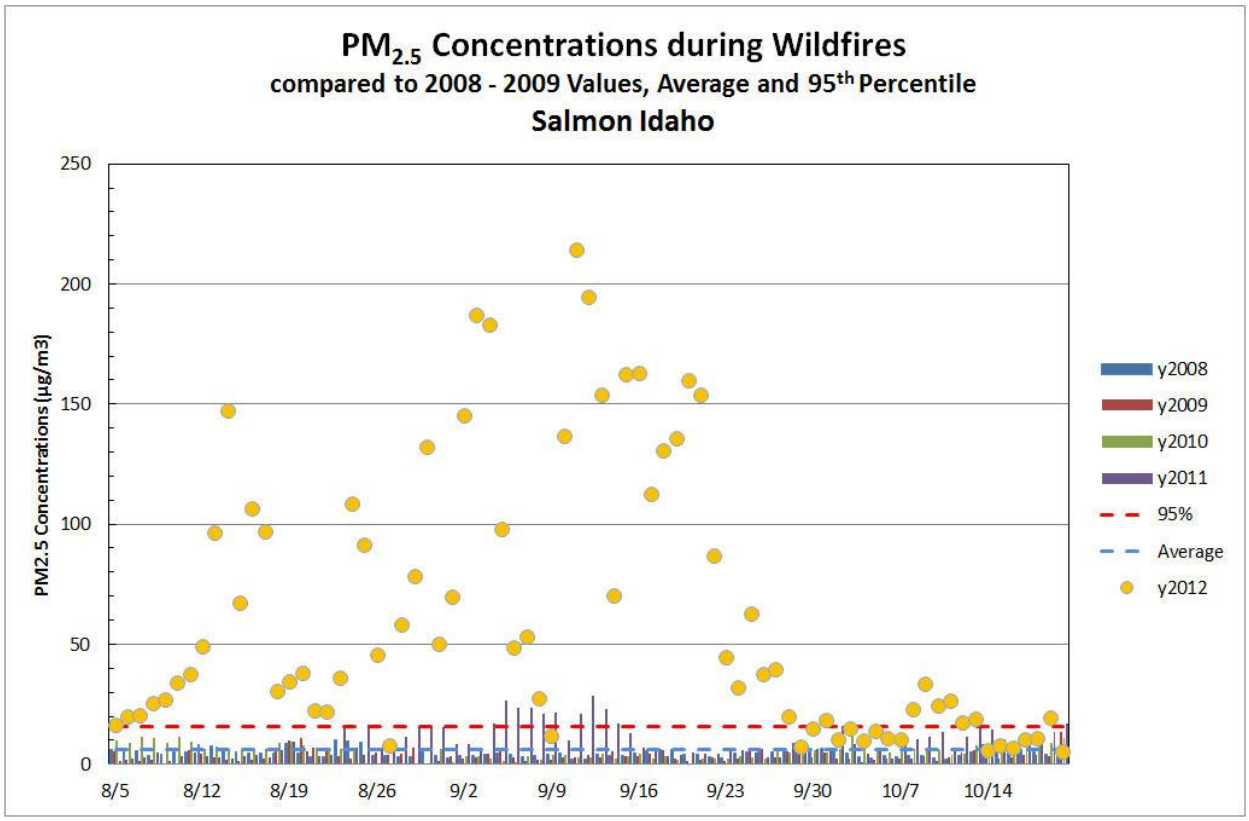


Figure 30. Salmon time series chart for the 2012 wildfire season (yellow circles) in comparison to the previous 4 years, 2008–2011 (colored bars). Days before and after the wildfire period are also included.

3.2 Pinehurst Historical Fluctuations

In Figure 31, the $PM_{2.5}$ concentrations measured at Pinehurst during May through October are shown for the years 2008 through 2011. The data shows that the $PM_{2.5}$ concentration could be elevated at different periods. The impact is often influenced by mixed emission sources; however, it can be seen that the overall $PM_{2.5}$ levels more or less are evenly distributed from June through mid-October with the average below 10 µg/m^3 and few peaks in the low 20s. It is believed that although $PM_{2.5}$ concentrations were also influenced by wildfires in these years, the

impact was not significant. Using these data as a background would be a conservative approach. The higher levels in later October reflect the emissions of wood burning as the heating season starts.

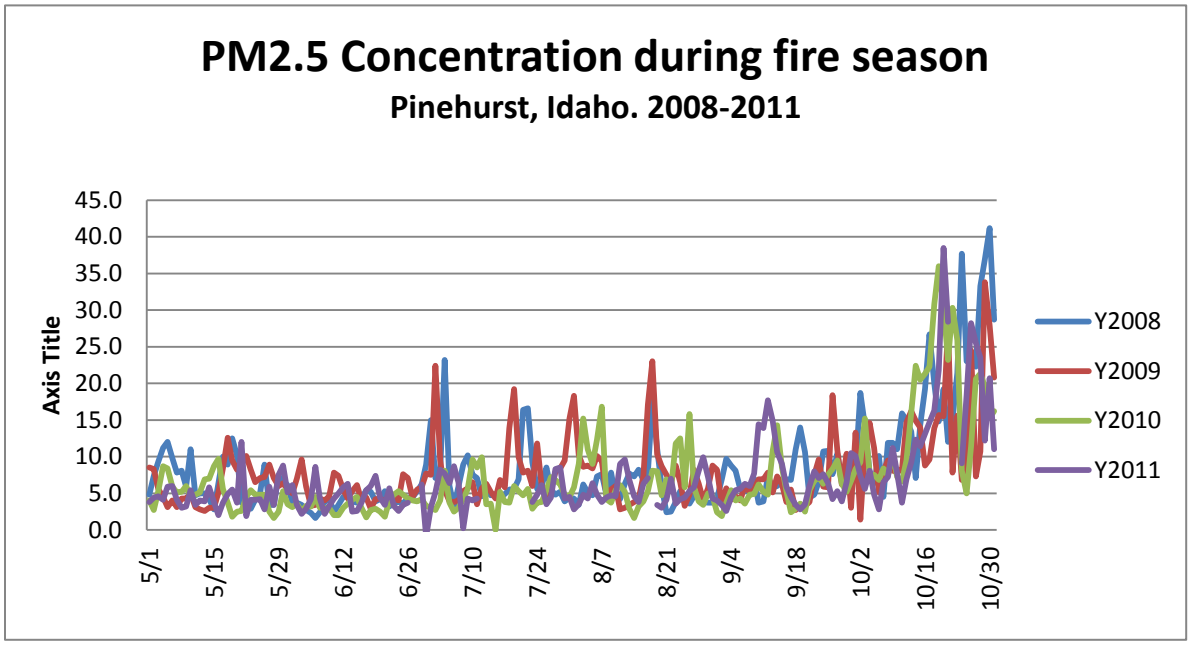


Figure 31. $PM_{2.5}$ historical fluctuations in Pinehurst, Idaho, 2008–2011.

Table 7 shows the statistics of $PM_{2.5}$ concentrations measured during the fire period from 2008-2011 and 2012. The statistics show clearly that all key values are shifted to higher levels in 2012 indicating $PM_{2.5}$ concentrations during this period in 2012 were influenced by additional emissions.

Table 7. Statistics of 24-hour $PM_{2.5}$ concentrations recorded in Pinehurst during the wildfire season in 2008–2011 and 2012.

Statistic	2008–2011	2012
Mean	7.0	11.1
Median	6.3	7.8
Mode	3.8	4.6
Standard Deviation	3.5	8.9
Minimum	1.4	1.5
Maximum	23	43.6

Figure 32 shows the distribution of $PM_{2.5}$ concentrations during 2008–2011 period and 2012. The 2012 distribution is a dual-mode distribution with the second mode of a much higher value (16–20 µg/m^3) compared to the mode of 2008–2011 distribution (4–8 µg/m^3). This pattern provides strong evidence that the period was impacted by the emissions with a unique source mixture.

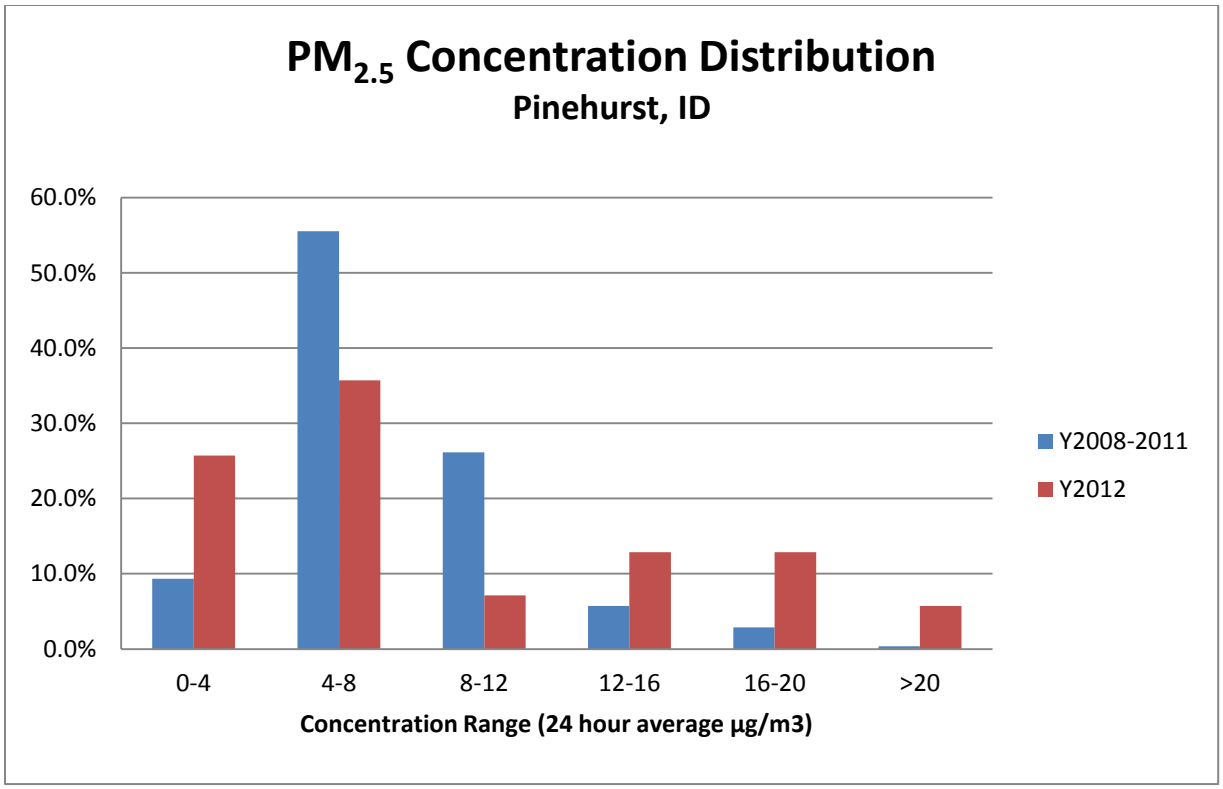


Figure 32. $PM_{2.5}$ concentration distributions.

Table 8 shows the average $PM_{2.5}$ concentration and 95 and 99 percentile of concentrations monitored in Pinehurst during the fire period in 2008 through 2011.

Table 8. Average, 95th, and 99th percentile of $PM_{2.5}$ during the wildfire period, from 2008–2011 data.

Average (µg/m^3)	95 percentile	99 percentile
7	15	18

Table 9 shows the percentile ranking for the $PM_{2.5}$ concentrations at the Pinehurst monitor for the days included in this request. All days requested are higher than 15 µg/m^3 and therefore are above the 95th percentile relative to the fire season average.

Table 9. Percentile ranking for the monitor values requested in this demonstration, relative to unaffected days in the same period from 2008–2011 (99% indicates 99% or above).

Date	$PM_{2.5}$	Percentile (Annual)	Percentile (Season)
9/15	43.6	99%	99%
9/14	31.3	95%	99%
9/22	20.8	83%	99%
9/25	18.4	78%	98%

Figure 33 shows the $PM_{2.5}$ concentrations during the 2012 fire period against the concentrations in the same period in years 2008 through 2011. The dashed lines indicate the average value and 95th percentile of the normal years during the same period (Table 8). A total of 23 days in which

the $PM_{2.5}$ concentrations were greater than 15 µg/m^3, the value of 95th percentile. Based on the EPA guidance, the excess of $PM_{2.5}$ concentrations above 15 µg/m^3 of these days would not be observed "but for" the regional wildfires.

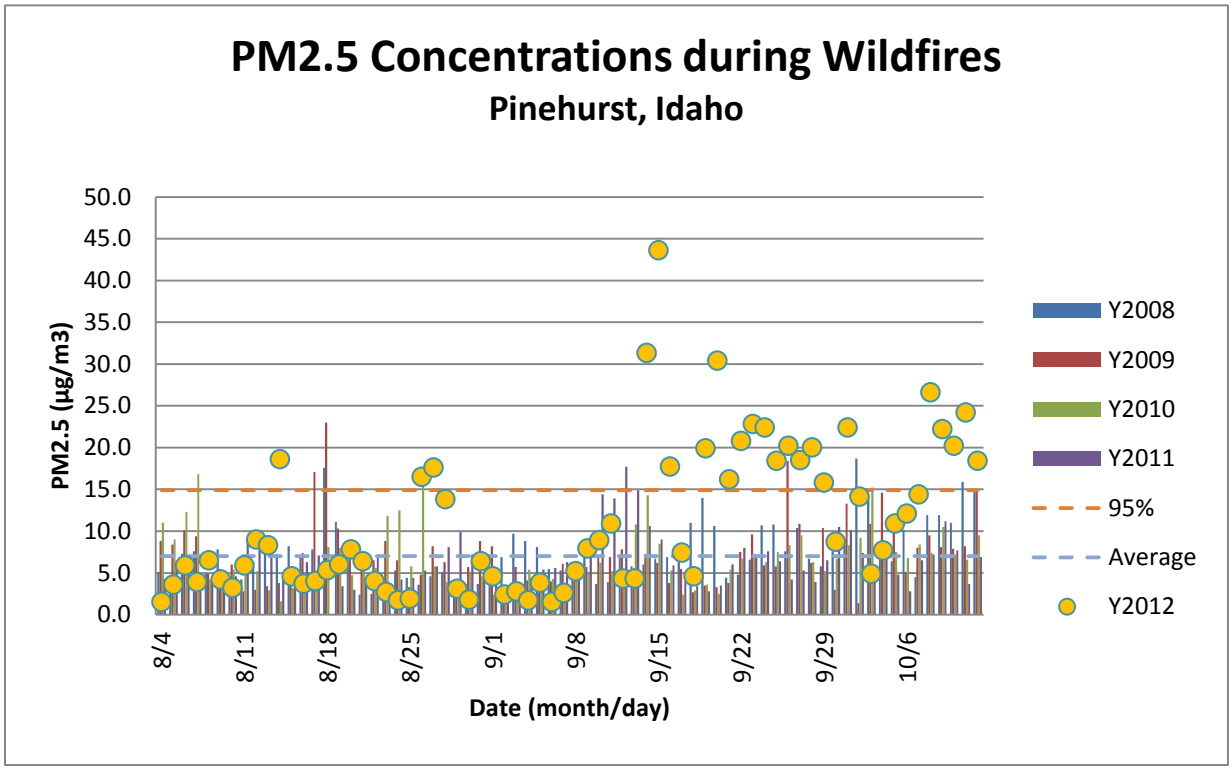


Figure 33. $PM_{2.5}$ concentrations during wildfires in 2012 compared to normal years.

4 Clear Causal Relationship (CCR)

A demonstration of a clear causal relationship between a source and monitor is generally a weight of evidence demonstration involving several elements. These elements will be covered in detail for a number of "scenarios" that DEQ found to recur periodically throughout the wildfire season, then in the Appendices, the CCR evidence for each day refers to the scenario or scenarios likely to have contributed on that day. In addition, in Appendix B (for Salmon) and C (for Pinehurst), DEQ will provide a concise description of how the evidence for that day demonstrates the clear causal relationship, along with a summary of each EER element for that day.

4.1 Similarity of Chemical Composition of Measured Pollution with that Expected from Sources Identified as Upwind

Chemical speciation data is not available from either Salmon, Idaho nor Pinehurst, Idaho during the 2012 wild fire monitoring days included in this request. However the IMPROVE aerosol speciation data collected and wilderness areas (IMPROVE 2013) provides information on the organic carbon levels across the region. Figure 25 shows the regional pattern of organic carbon and suggests that a the source is regionally widespread, even if such data is not available directly in Salmon or Pinehurst. However, the many news stories in these cities (samples of which are provided in Appendix F) revolve around the wildfires and smoke that affected these towns, leaving no doubt that the high $PM_{2.5}$ concentrations in Salmon and Pinehurst were due to wildfire smoke. The satellite images shown later in this section as well as in Appendices B and C, many of which show dense smoke plumes blowing from the fire-detects or source locations to Salmon, also leave no doubt where the high concentrations of $PM_{2.5}$ originated. Thus DEQ believes, the regional pattern of high organic carbon shown previously in Figure 25 leave no doubt that the unusually elevated, region-wide $PM_{2.5}$ in 2012 has a composition consistent with wildfire smoke. and that the regional organic carbon data obtained from the IMPROVE station aerosol speciation monitors shown in Figure 25, along with the other weight of evidence discussed above, provides sufficient evidence to demonstrate that the chemical composition of the high $PM_{2.5}$ levels in Salmon and Pinehurst resulted from wildfires.

4.2 Occurrence and Geographic Extent of the Event

Wildfires impacting the Salmon and Pinehurst airsheds during the 2012 wildfire season are shown in Figure 3. The major fires are numerous and well distributed around the northwest. The increased fine particulate matter, in terms of $PM_{2.5}$ and the organic carbon that composed much of it were also observed throughout the region, as shown in Figure 24 and Figure 25. These three figures define the geographic extent of the 2012 wildfire events in general. The extent of the event each day was often very complex due to the large number of source fires, however, MODIS satellite snapshot images are available to show the extent of smoke occurrence, at least during the morning Terra satellite pass (~ 1045 local time) and afternoon Aqua satellite pass (~ 1345 local time).

4.3 Alternative Hypotheses

One important element of the Clear Causal Relationship demonstration is to explore alternate hypotheses for potential sources. The discussion of composition and geographic extent in Section 1.6 make it very clear that the high $PM_{2.5}$ concentrations resulted from a source of biomass combustion due to the widespread, elevated organic carbon levels. While wildfires clearly caused most or virtually all the smoke, it is important to discuss potential alternative source hypotheses. The other sources of organic carbon are discussed in this section, then more briefly in each scenario within the CCR portion of the table for each day (in Appendix B and C).

The potential alternative sources described in this section include the normally expected anthropogenic sources of smoke. These sources are shown in Figure 4 to all be very small, on a statewide basis compared to the 2012 wildfire emissions. In addition, these routine sources of $PM_{2.5}$ occur at more or less similar levels from year to year and are therefore inherently included in the historical monitor values. Thus, the average and 95th percentile values of $PM_{2.5}$ during the period of wildfire impacts (see Historical Fluctuations, Section 3) already incorporate the contributions from these anthropogenic sources and any concentration above 15.9 µg/m^3 at the Salmon monitor, or 15.0 µg/m^3 at the Pinehurst monitor most probably cannot be significantly attributed to any of these potential alternative sources. Finally, since prescribed fires, crop residue burning and other open burning were restricted by burn managers and by the nearly constant Stage 1 Forecast and Caution in effect on all but 3 requested days throughout the period of affected days (see Appendix D) it is likely that far less than the "normal" contribution of $PM_{2.5}$ occurred from these anthropogenic sources.

4.3.1 Prescribed Fires

The magnitude of elevated smoke-related $PM_{2.5}$ concentrations suggests that only major wildfires can generate so much smoke or significantly contribute to such levels across an entire region. The emissions comparison in Figure 4 suggests that prescribed burning is very small in comparison to the 2012 wildfires in terms of $PM_{2.5}$ emissions. Prescribed burning in Idaho is regulated under IDAPA 58.01.01.614. All federal and state prescribed burners, as well as most large private prescribed burners, are members of the Montana/Idaho Airshed Group (Airshed Group). The Airshed Group members follow an operating guide that is based on basic smoke management techniques. Only two prescribed burns, on September 26, 2012, occurred during the wildfire season, August 1 through October 1 (Appendix D). Both prescribed burns occurred in the Hagerman/Balanced rock area identified as Blue Gulch Wildlife tracts of south-central Idaho. These prescribed fires were relatively small (100 acre and 80 acre broadcast burns) and are located sufficiently far from Salmon and Pinehurst to have negligible contribution to those monitors. The prescribed fires during the wildfire period are listed in Appendix D. All prescribed burning is prohibited when DEQ issues a Stage 1 Forecast and Caution.

4.3.2 Crop Residue Burning

Crop residue burning was severely restricted in the burn management areas near active wildfires. The Burn Decision Summary for the months of July through October is also provided in Appendix D. The summaries show that all crop residue burning was halted in the counties near Salmon and Pinehurst. Shoshone County and Lemhi County are not listed on the burn decision summaries because these are largely mountainous counties and no burns were approved in those

counties for July through October. In addition, the estimated crop residue burning emissions are typically around 850 tons per year, over 100 times lower than the 2012 wildfire emissions on a daily basis, as shown in Figure 4. All crop residue burning is prohibited when DEQ issues a Stage 1 Forecast and Caution.

4.3.3 Residential Wood Combustion

Both Salmon and Pinehurst are subject to the influence of residential wood combustion in the cold seasons. Residential wood combustion typically does not commence until the evening temperatures dip below about 40 ^{o}F, typically in October. Temperatures are shown in the hourly time series chart for each day included in Appendix B and C so it can be verified that none of the days included in this request dropped below these temperatures in the evening and therefore no significant residential wood combustion is likely to have contributed any significant emissions to any of these events. The latest monitor value included in this request was observed on September 25, 2012.

4.3.4 Other Forms of Open Burning

All open burning in Idaho, outside the five Indian Reservation boundaries, is regulated by DEQ under the Rules for Control of Open Burning (IDAPA 58.01.01.600). Open burning is included in the "Nonpoint" source category in the 2011 NEI emissions for Idaho (along with many other sources), and it can be seen from Figure 4 that no sources in that category come close to the average daily emission rate for wildfires that was estimated for the 2012 wildfire season. In addition, a Stage 1 Forecast and Caution, which prohibits all open burning, was in effect for all days for Pinehurst included in this request and all but 3 days for Salmon (see Appendix E). On those days in Salmon that open burning was not prohibited, the maximum amount of open burning expected to occur was the amount that typically occurs during the same period in a low-wildfire year; as discussed above, the normal level of open burning is already captured within the 95th percentile statistics for the four years prior to 2012. During the 2012 wildfire season, many members of the public did not burn due to the high fire danger risk. Therefore, it is not likely that open burning contributed to the elevated concentrations on the 3 requested days when a Stage 1 was not in effect. All open burning is prohibited when a DEQ Stage 1 Forecast and Caution is in effect, as was the case on 44 of the 47 days requested.

4.3.5 On-Road Mobile Sources

Finally, on-road mobile sources can often be a significant source category in large cities, but primarily for exhaust gases. Road dust and some exhaust emissions contain $PM_{2.5;}$ however, as shown in Figure 4, on-road mobile particulate emissions are extremely low compared to wildfires in 2012. It is not likely that on-road mobile emissions contribute any significant $PM_{2.5}$ in Salmon and Pinehurst to the $PM_{2.5}$ concentrations observed during the wildfire season.

4.4 Scenarios

Transport scenarios were developed from analysis and observation of the data as a way to group the daily events and to formulate the conceptual models described in Section 1. The Salmon events followed a limited number of typical behaviors for transporting smoke to the monitor, depending on prevailing winds and vertical stability. The location of the major fires, Halstead and the Mustang Complex, dominated within the transport patterns and created an environment where local conditions were paramount. The Salmon scenarios are shown in Figure 34. The Pinehurst scenarios were less obvious, but two were developed to delineate the days when long-range transport, as opposed to local stagnation, were the main drivers of smoke transport to the monitor. The scenarios are described in detail below with examples. In Appendix B (for Salmon) and Appendix C (for Pinehurst), each day is assigned one or more scenarios to describe DEQ's best judgment of the contributing transport conditions. It should be noted that on most days, multiple scenarios may contribute. Some uncertainty in the contributing transport paths for all parts of the day is not an indication that smoke did not impact the monitor. Please refer back to this section when reviewing the scenarios identified in Appendices B and C.

In the following examples, satellite images are all MODIS satellite products (NOAA 2013). Back trajectories superimposed on the MODIS images are produced using the Ready HYSPLIT model (Draxler 2003). Time series charts are based on Idaho DEQ $PM_{2.5}$ monitoring data obtained from AirData (EPA 2013b), and DEQ meteorological monitoring (DEQ 2013). In addition, MESOWEST data were used to obtain temperatures from the Kriley Creek meteorological station (Horel et al. 2000).

Notes on Satellite images and time series charts included in the CCR evidence below.

Hysplit Back-trajectories / MODIS Satellite Images

Daily satellite images are overlaid with HYSPLIT (Draxler 2003) back trajectories and HMS fire detects. Terra (morning) or Aqua (afternoon) RGB True Color images show a snapshot of the smoke at the time of the satellite pass. HYSPLIT back trajectories were run for the 24-hour period ending at 23:59 on each day. New trajectories start hourly and have starting positions at the source of 0 m AGL, 500 m AGL, and 1000 m AGL. HMS fire detects are all those identified by the MODIS satellites during the 24-hour period.

Terra and Aqua MODIS data for the MODIS Today website are acquired and processed at the *Space Science and Engineering Center* (SSEC) at the *University of Wisconsin-Madison*. Additional Terra MODIS data are acquired courtesy of the *Center for Rapid Environmental Assessment and Terrain Evaluation* at the University of New Mexico; the *Remote Sensing Applications Center* at the USDA Forest Service; the *Center for Space Research* at the University of Texas-Austin; and the *Direct Readout Laboratory* at NASA GSFC. Terra and Aqua MODIS data are obtained in real time via free and unrestricted direct broadcast courtesy of *NASA*. Software for converting MODIS data from raw telemetry to calibrated radiances provided courtesy of the NASA *MODIS Science Team*, the NASA *Ocean Biology Processing Group*, the NASA GSFC *Direct Readout Laboratory*, and the SSEC *IMAPP Project*. The Terra and Aqua direct broadcast processing system at SSEC was designed and implemented by Liam Gumley, Kathy Strabala, Steve Dutcher, Jerry Robaidek, Rosie Spangler, Janean Hill, and Doug

Ratcliff. The direct broadcast ground station at SSEC is a *SeaSpace TeraScan* 4.5 meter X-band system. MODIS True Color Images created by Liam Gumley, in collaboration with Jacques Descloitres and Jeff Schmaltz (*NASA Rapid Response*).

Time Series Charts for each "Date" Requested

Twenty-four hour time series charts are provided to depict the temporal pattern of hourly $PM_{2.5}$ concentration and meteorological parameters associated with each day. In addition, typical $PM_{2.5}$ concentrations during the same month in previous years when wildfires were not impacting Salmon are characterized by including their average and 95th percentile hourly values for comparison.

Top chart: "***Date" PM2.5 with Average and 95th Percentile for Month (2009-2011)***

2012 $PM_{2.5}$ – The orange circles and line indicate the hourly $PM_{2.5}$ concentration for each hour for each day affected by wildfires in 2012.

August/September/October Average – The blue line with filled blue triangle markers represents the average for the month for the three years prior to 2012. So each value represents 90 or 93 values averaged together. The October average only represents the days prior to October 15, to better represent the wildfire period.

August/September/October 95th percentile – The open blue triangles and dotted line represent the 95th percentile value for the identified month from the 2009 – 2011 data set. The 95th percentile is used to represent the upper limit of the normal historical fluctuations for each hour for the 24-hour normal range between "average" and 95th percentile. Hourly values above this line indicate an "exceptional" hourly value that is beyond normal for that hour and month.

Middle Chart: **"Date" Wind Speed and Wind Direction.**

Wind Speed – The purple diamonds and solid line represent the wind speed in meters per second (m/s) recorded at the DEQ met station on Highway 93 approximately 500 m south of US 28 in Salmon. The wind sensor is at 10 meters above ground level.

Wind Direction, deg – The blue open squares represent the wind direction for the hour, at the DEQ met station.

Bottom Chart: ***"Date" Solar Radiation, Temperature and Vert. Temp. Gradient***

V. Temp Gradient, K/km (Salmon only) – The open rust colored diamonds represent the vertical temperature gradient between the DEQ met station in Salmon at 3960 ft above sea level and the Kriley Creek RAWS met station located in the foothills north of Salmon at 5200 ft above sea level, downloaded from MESOWEST (Horel, 2002). Its location is show in Figure 17. The temperature gradient based on these two met stations is used to approximate a vertical temperature gradient- an indicator of atmospheric stability. A gradient greater than the environmental lapse rate, -6.5 K/km (degrees Kelvin per kilometer) is considered stable while a gradient lower than -6.5 K/km is considered unstable. This parameter can be used to identify days in which the surface temperature inversion does not break.

-dT/dZ = -6.5K/km (Salmon Only) – The black dotted line at -6.5 indicates the fixed environmental lapse rate, the vertical temperature gradient above which the atmosphere remains stable.

Temp. F – The green triangles and green line represent the temperature at 2 meters above ground as measured at the DEQ met station. It is included to indicate when the temperature dips below 40 degrees F, the point at which residential wood combustion is beginning to be used.

Solar Radiation, W/m2 – the larger blue filled circles represent the solar radiation, in Watts per square meter (W/m2) measured at the DEQ met station. The solar intensity and cycle indicates when solar driven up-valley flows may be expected and when gravity driven down-slope and down-valley flows may be prevalent before sunrise and after sunset.

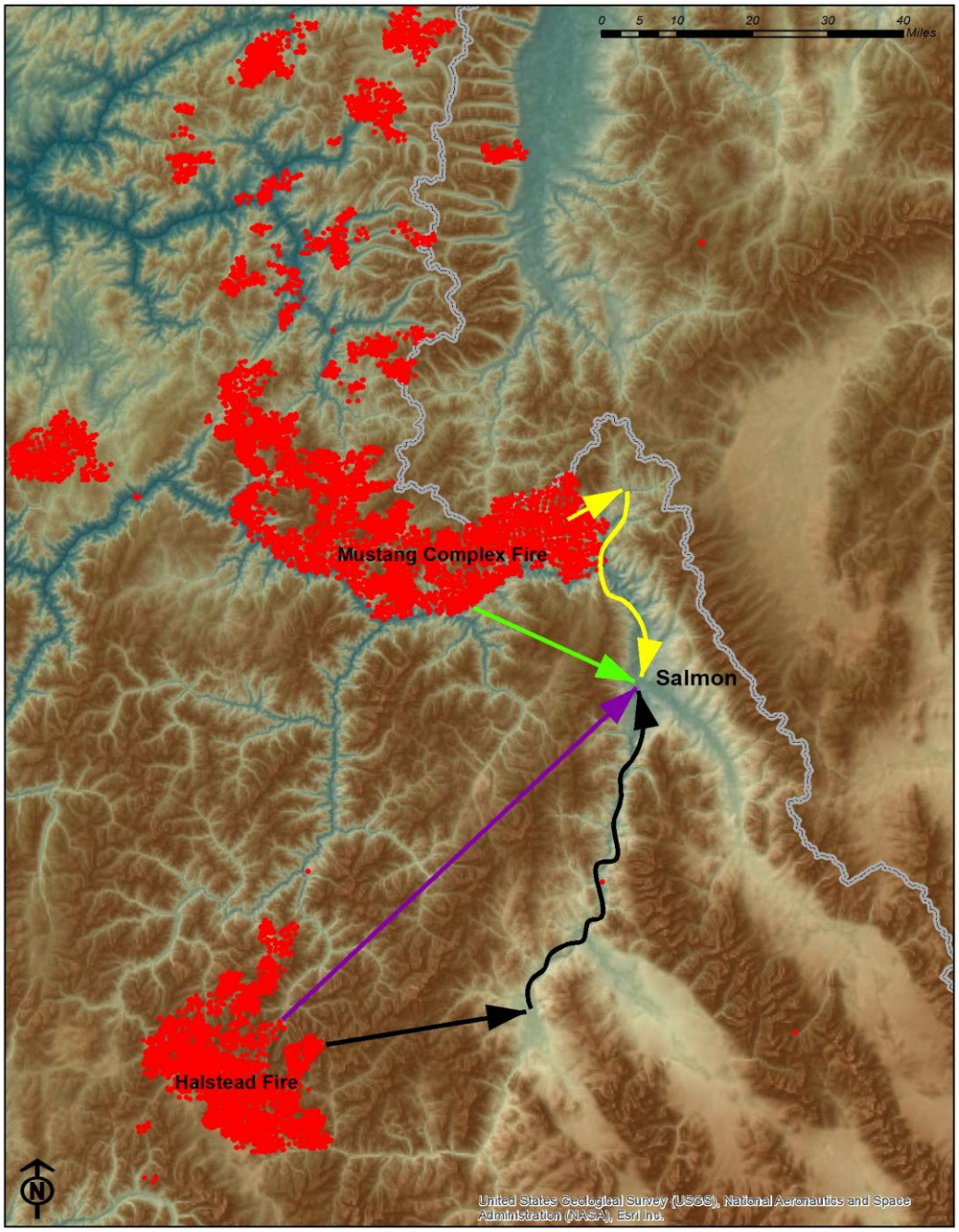


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Figure 34. Salmon smoke transport scenarios. This conceptual figure illustrates the general source and movement of smoke from the fire source to the Salmon monitor. The yellow arrows describe Scenario 1: smoke blows into the valley north of Salmon and then is carried by up-valley daytime flows to Salmon during the evening. This "valley-flow" scenario may also include nighttime down-slope drainage flows from the NE where the smoke was often trapped. The green arrows describe Scenario 2: smoke produced by the Mustang Complex fire blows in a plume directly toward Salmon. The black arrows describe Scenario 3: smoke produced by the Halstead fire blows towards the Salmon River valley to the south of Salmon or the Lemhi Valley further east and is then channeled by the valley terrain towards the monitor. The purple arrows describe Scenario 4: smoke produced by the Halstead fire blows in a plume directly toward Salmon. Scenario 5, regional transport, is not depicted in this figure.

Salmon Scenarios

4.5 Scenario 1: Valley Flows from North and Northeast—Mustang Complex

Scenario 1 describes the conditions that occur when smoke produced by the Mustang Complex to the north of Salmon travels via terrain-driven valley flow to reach Salmon, often in fairly high concentrations. Two types of valley flows were identified: (a) up-valley daytime flows driven by differential solar heating, or (b) nighttime/early morning drainage flows along the down-slope (NE) direction. An enormous amount of smoke was produced from the Mustang Complex due to the multiple fires burning across a large area and the dense smoke that filled the north end of the valley often flowed up-valley arriving in Salmon in the late morning (1000–noon) or around 1700–2000 in the evening. In addition, when the Mustang smoke was trapped against the peaks and foothills NE of Salmon it then became part of the nighttime drainage flow documented in the conceptual model to approach Salmon throughout the nighttime and early morning hours (~2100 through 0900).

Scenario Summary

- Smoke from the Mustang fire is pushed into the north end of the valley around North Fork and flows up-slope toward Salmon arriving in the afternoon or evening where it is trapped by the night time inversion.
- Characterized by high sustained concentrations overnight on the hourly trace and switch to local northerly winds at 1700 or 1800, corresponding with a sharp rise in concentrations.
- Satellite imagery from the morning pass often shows valleys filled with smoke.
- Back trajectories often do not contribute to identifying this scenario.

4.5.1 Description of Typical Weather Conditions and Transport Winds

The date September 11, 2012, was selected as an example for Scenario 1. Figure 35 shows the observationally-driven modeled output (500 mb height chart) and Figure 36 shows the observed surface chart for September 11, 2012. Aloft, a long wave trough is located over the Idaho air shed. The trough axis runs from the northern Panhandle southwest to the Monterey area of California. This produces south-southwest flow at the mid- to upper-levels of the atmosphere over Idaho. Note that the jet maximum is located well north of Idaho, somewhere over Manitoba and Saskatchewan. As such, the wind speed in the upper atmosphere over Idaho is relatively light, with speeds between 20–30 mph. The semi-permanent Four-Corners high pressure system is located to the east, downstream of Idaho and therefore has no influence on the weather in the western US on this particular day. At the surface, a high pressure located over Vancouver Island, coupled with a surface low over the Teton National Park-Yellowstone National Park creates a west-northwest surface wind. This mean flow is quite evident via the HYSPLIT back trajectories in the following satellite imagery. It is also possible to note that the complex terrain dictates the movement of the smoke, and in places, aides the transport as the valleys align with the mean flow where forced channeling can create accelerated or gusty wind conditions (Whiteman 2000).

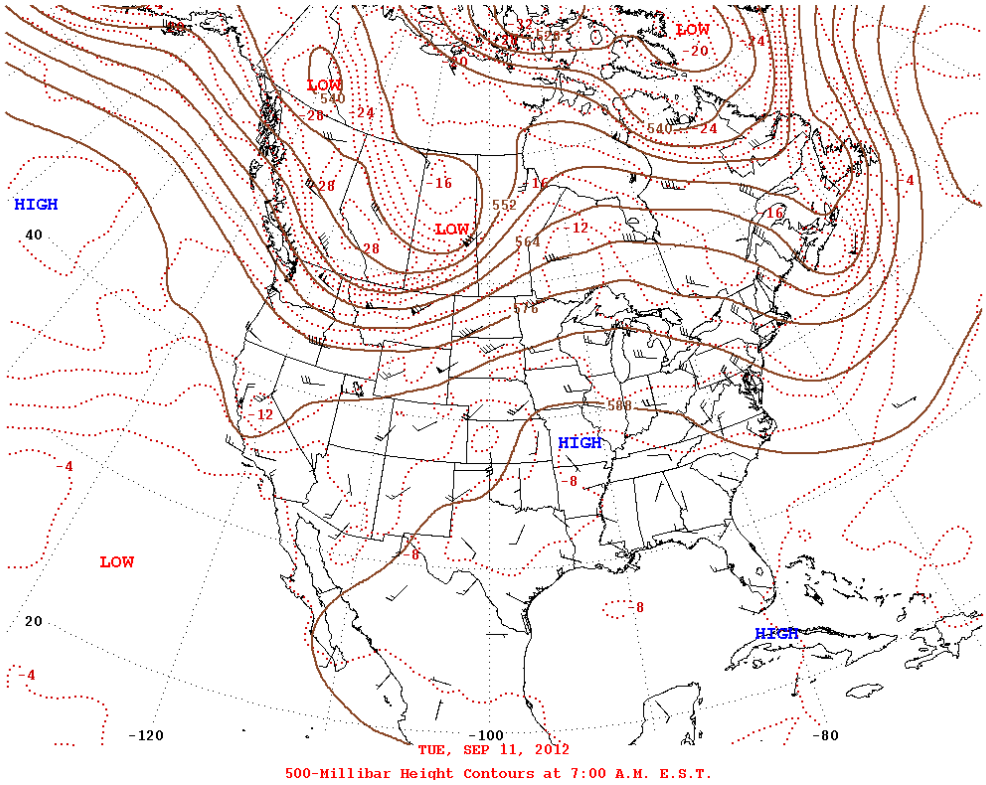

Figure 35. September 11, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

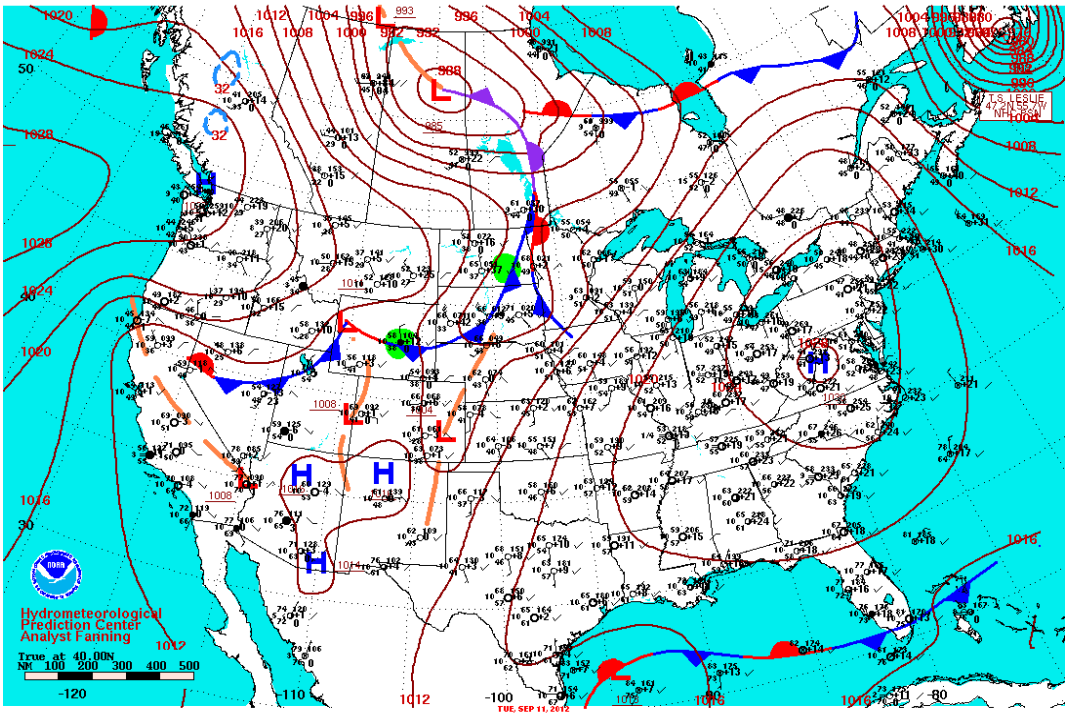

Figure 36. Surface weather analysis and station weather at 0500 MST, September 11, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.5.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, the afternoon satellite image (Figure 37) shows the Salmon Valley filled with smoke and the Mustang Complex to the north producing dense smoke that occupied the lower valley around North Fork due north of Salmon. Some back trajectories intersect the smoke and fire detects from the Mustang Complex, but the transport winds are predominantly northwest. This evidence points to the source regions of smoke in this scenario. The temporal variability of the 24-hour $PM_{2.5}$ concentrations and the wind direction provide evidence for the timing and direction of the smoke transport.

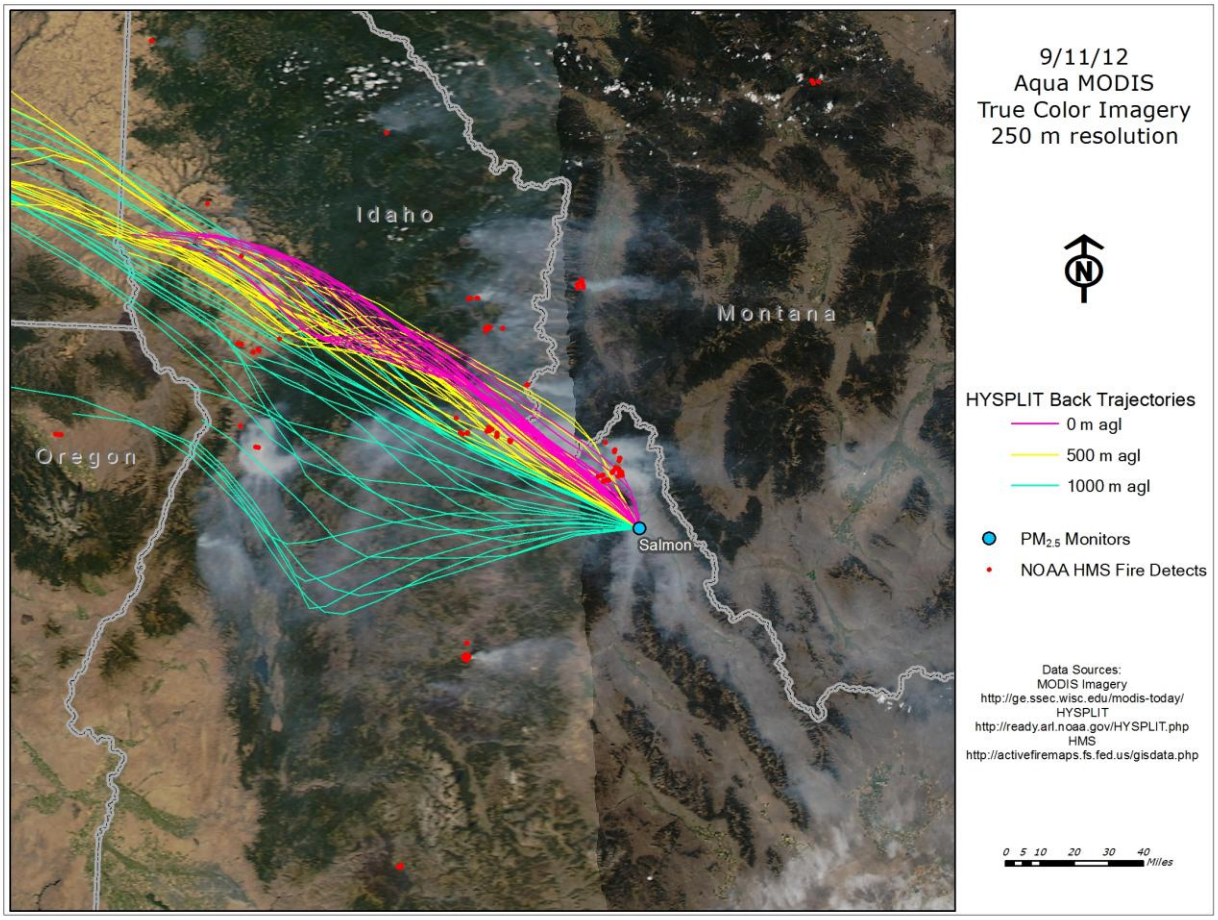

Figure 37. Aqua MODIS satellite image showing fire detects and smoke filling the Salmon valley. HYSPLIT model back trajectories show transport winds for all 24 hours on September 11, 2012.

4.5.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The top chart in Figure 38 shows that the $PM_{2.5}$ hourly trace spikes significantly at 1800 local standard time (LST), increasing to over 300 µg/m^3 in an hour. The concentrations then remain high throughout the night. The mechanism for this massive smoke advection to the monitor is the afternoon advection of dense Mustang Complex smoke into the northern end of the valley, followed by an up-valley daytime northerly flow bringing the Mustang Complex smoke south

into Salmon. The nocturnal inversion then traps the smoke in the valley overnight. The wind direction data supports this hypothesis, showing northerly winds preceding and concurrent with the spike and the elevated evening concentrations through 2000 LST.

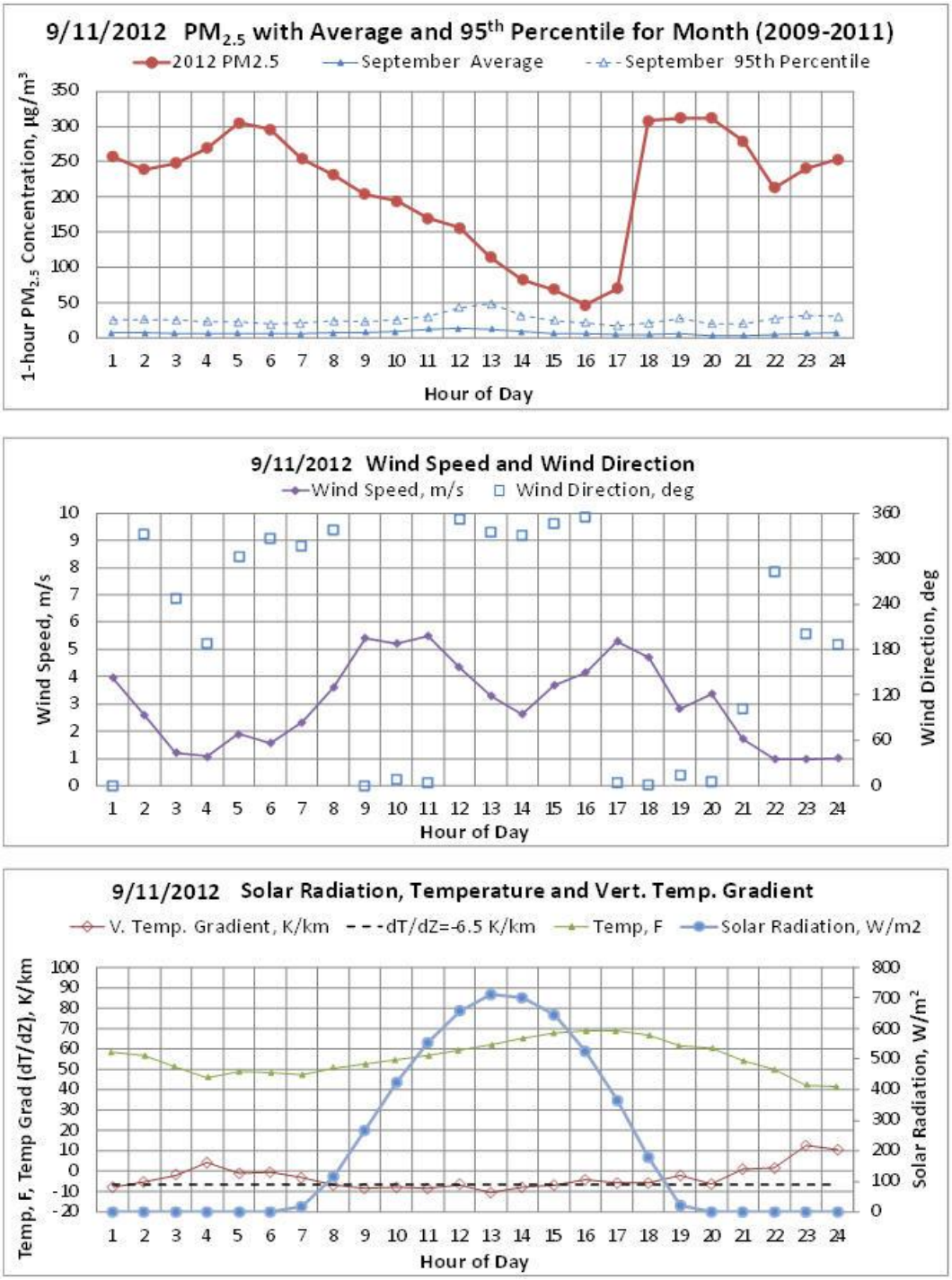

Figure 38. Time series charts for September 11, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km, the environmental lapse rate (dotted line) indicates stable/stagnant conditions in the valley.

4.5.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 38, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average and the monthly 95th percentile value for each hour. This will replace the normal approach of showing the 7 non-affected days before and after a 1 day event—we cannot do this because nearly all the days are affected. Any hourly $PM_{2.5}$ concentration value around or above the 95th percentile line are generally attributed to wildfire smoke.

4.5.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during September but rather typically begins in October. The daytime temperature on September 11 ranged from 50 ^{o}F in the evening to 70 ^{o}F during the day. Although the night-time lows reach ~ 40 °F, RWC does not typically begin until the daytime/evening temperatures are below 35 ^{o}F–40 ^{o}F. In addition, crop residue burning did not occur in the Salmon vicinity, and was not allowed for most of the period in Idaho. Prescribed burning did not occur on this day. No other source of smoke/PM2.5 is large enough to cause the levels exceeding 300 $\mu g/m^3$ observed September 11, 2012, in Salmon. Specific information on days when a Stage 1 Forecast and Caution was in effect and all open burning was prohibited, including crop residue burning, is provided in Appendix E.

4.6 Scenario 2 : Direct Plume Impact—Mustang Complex

Scenario 2 describes the conditions wherein the transport of smoke to the monitor is direct: the Mustang Complex fire produced smoke and the plume blew in the direction of the monitor. This type of scenario is easily observed and multiple pieces of evidence are provided to support it. The evidence for August 13 is described below as an example of this scenario.

Scenario Summary

- Smoke from Mustang Complex plume blows directly over Salmon.
- Characterized by a spike in concentration on the hourly trace (spike defined as at least a 15 $\mu g/m^3$ rise in an hour, with a corresponding fall).
- Spikes typically occur during the afternoon, when the fires are most active, smoke production is highest and transport winds are usually strongest.
- Satellite imagery shows a plume striking or pointing directly from fire to Salmon.
- Back trajectories align with plume direction and intersect visible smoke.

4.6.1 Description of Typical Weather Conditions and Transport Winds

This scenario is characterized by weak surface winds and nearly zonal transport flow, creating a situation in which impacts in Salmon are dictated by a direct interaction with the source fire and its plume. As indicated by the 500 mb height chart shown in Figure 39, one can see the nearly zonal winds aloft as a high pressure build over the Four-Corners region of the US. The surface chart, shown in Figure 40 indicates that a thermal low has developed over southeast Idaho and north Nevada; however, pressure gradients across the area (gradient is less than 1 mb/100 mi) are very lax, and observed winds in the Pocatello region are listed as calm (less than 5 mph). As

such, the zonal transport flow becomes the primary wind regime impacting Salmon on this day. This is also indicated in the visible satellite imagery in the figure below.

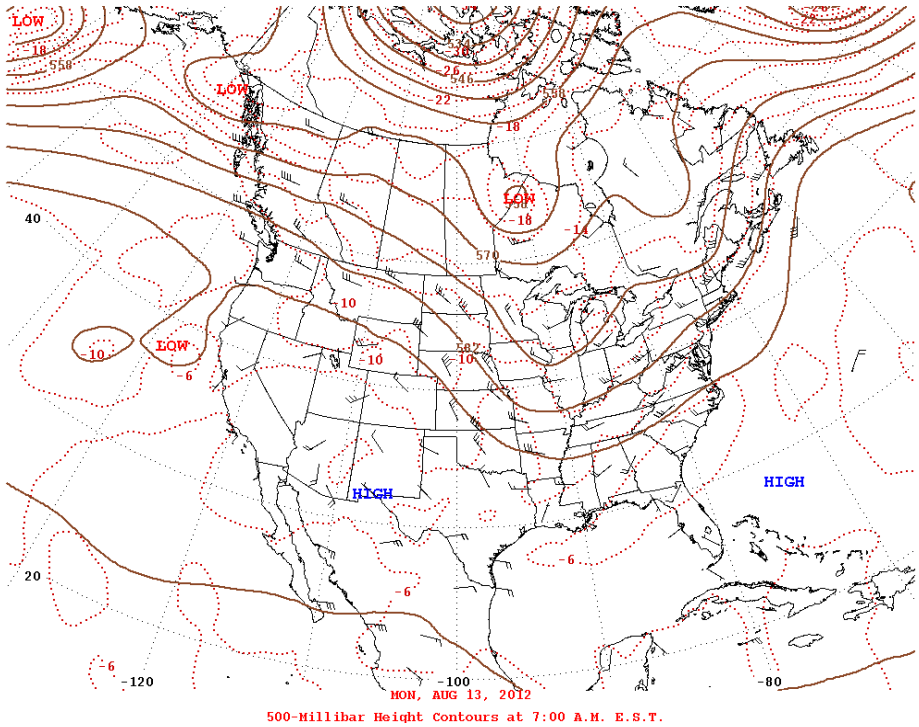

Figure 39. August 12, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

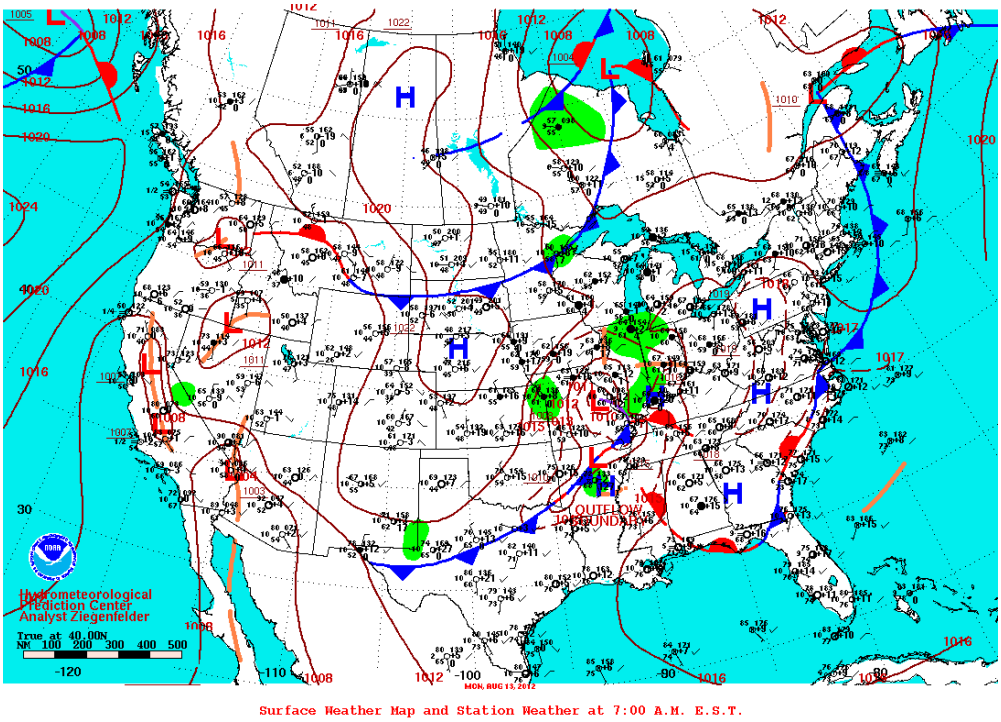

Figure 40. Surface weather analysis and station weather at 0500 MST, August 13, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.6.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, the afternoon satellite image (Figure 41) depicts a dense plume of smoke originating from the Mustang Complex angled towards and blowing straight across Salmon. Multiple back trajectories, at origin heights of 0 m AGL, 500 m AGL, and 1000 m AGL, intersect the plume and the source fire detects, demonstrating again that the air parcels arriving in Salmon moved directly from the Mustang Complex, thereby bringing smoke to the monitor.

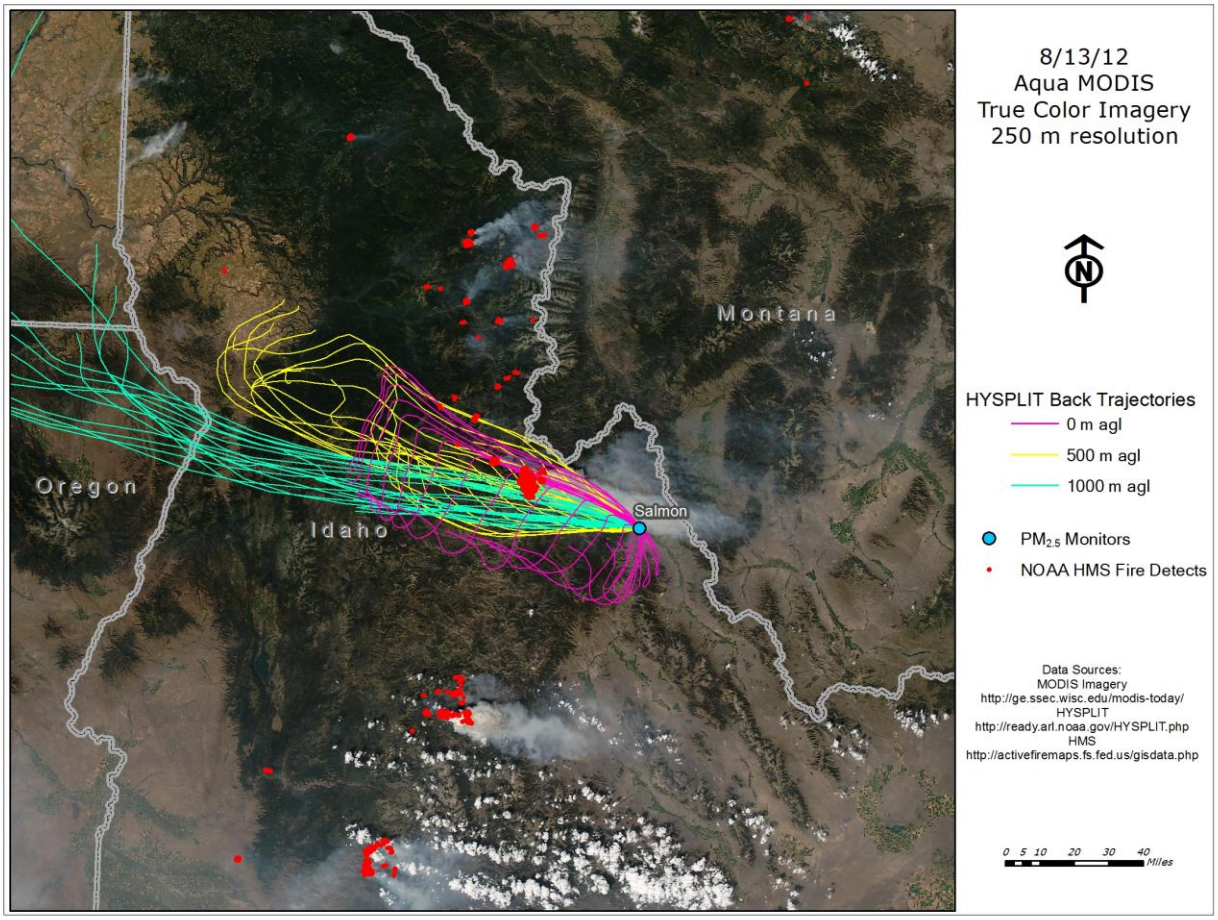

Figure 41. Aqua MODIS satellite image showing fire detects and smoke blowing toward the southeast, directly impacting the Salmon area. HYSPLIT model back trajectories show transport winds for all 24 hours on August 13, 2012.

4.6.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The 24-hour $PM_{2.5}$ concentrations show the classic signature of a direct plume impact on a monitor: a large spike between 1300 and 1800, rising about 300 $\mu g/m^3$ in two hours then decreasing. The wind speeds increase concurrently with the concentration spike.

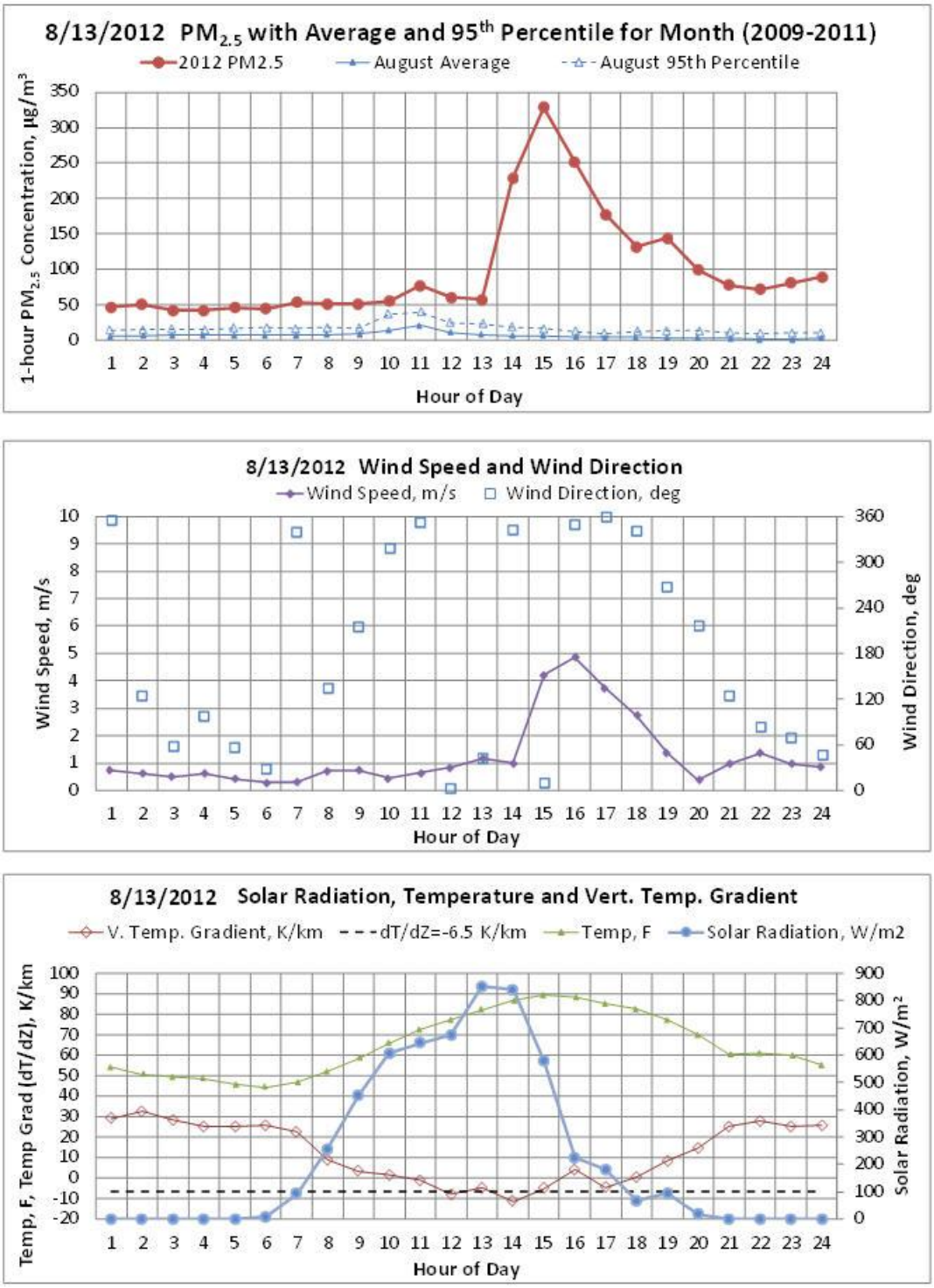

Figure 42. Time series charts for August 13, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley.

4.6.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 42, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. This will replace the normal approach of showing the 7 days before and after a one day event—we cannot do this because nearly all the days are affected.

4.6.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during in August nor in most of the wildfire season but rather begins in October. The daytime temperature on August 13 ranged from 60 °F in the evening to 90 °F during the day. Although the night-time lows reach ~ 45 °F, RWC does not typically begin until the daytime/evening temperatures are below 35 °F– 40 °F. In addition, crop residue burning did not occur in the Salmon vicinity, and was not allowed for most of the period in Idaho areas near Salmon and Pinehurst and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding 300 $\mu g/m^3$ observed on August 13, 2012, in Salmon (Figure 42). Specific information on days when a Stage 1 Forecast and Caution was in effect, thus prohibiting open burning provided in Appendix E.

4.7 Scenario 3: Drainage From South or Southeast—Halstead

Scenario 3 describes the conditions wherein smoke produced by the Halstead fire intercepts the upper Salmon River and/or Lemhi River valleys and is channeled by topography down-valley to the Salmon monitor. This scenario is not necessarily supported by back trajectories, due to model grid resolution, but the weight of evidence provided by satellite imagery.

Scenario Summary

- Smoke from Halstead fire is pushed eastward towards the Salmon River/Hwy 75 corridor that runs northeast from Challis to Salmon and/or towards the Lemhi valley further to the east.
- Smoke sinks into valley and is channeled by terrain to Salmon
- Not a primary scenario, e.g., this scenario only seems to occur in combination with other scenarios
- Characterized by high sustained concentrations overnight on the hourly trace and a switch to southerly or southeasterly local winds in the evening or overnight, corresponding with a sharp rise in concentrations
- Satellite imagery shows smoke from Halstead hitting the upper part of the valley and smoke visible in the valley going north towards Salmon
- Back trajectories are not a good indicator of this scenario, but the 0 m AGL trajectories may show surface air travelling north and south of Salmon, aligned with the valley

4.7.1 Description of Typical Weather Conditions and Transport Winds

This scenario is indicative of a situation where local diurnal forcing is the primary mechanism. In this event, the weather pattern is in a transitory phase into a strong upper level ridge over Idaho. In the 500 mb heights chart (Figure 43), an upper level ridge pattern is developing from zonal

flow over the Pacific Ocean. The ridge axis is located through the center of Idaho and runs due north into the Northwest Territories. Upper level winds are weak (at 15–20 mph) and from the west-northwest on this day. The Four-Corners high pressure system is located to the south and east of its usual geographic placement, but wind barbs indicate that it is growing to the north and west via south-southwest winds over Arizona and California. Given the light surface winds and lack of strong upper level flow, diurnal wind patterns typical for complex terrain (as theorized earlier) bring smoke generally to the east and into Salmon via several valley and basin channels that make up eastern Idaho. While difficult to relate the upper level and surface chart directly to smoke dispersion and transport, it is quite clear to see how the conditions of stagnation and limited vertical development associated with this type of weather pattern coincide with the visible satellite imagery below. HYSPLIT model surface trajectories (0 m AGL) in Figure 45 indicate strong influences from the diurnal wind regime in eastern Idaho to the north and south of Salmon.

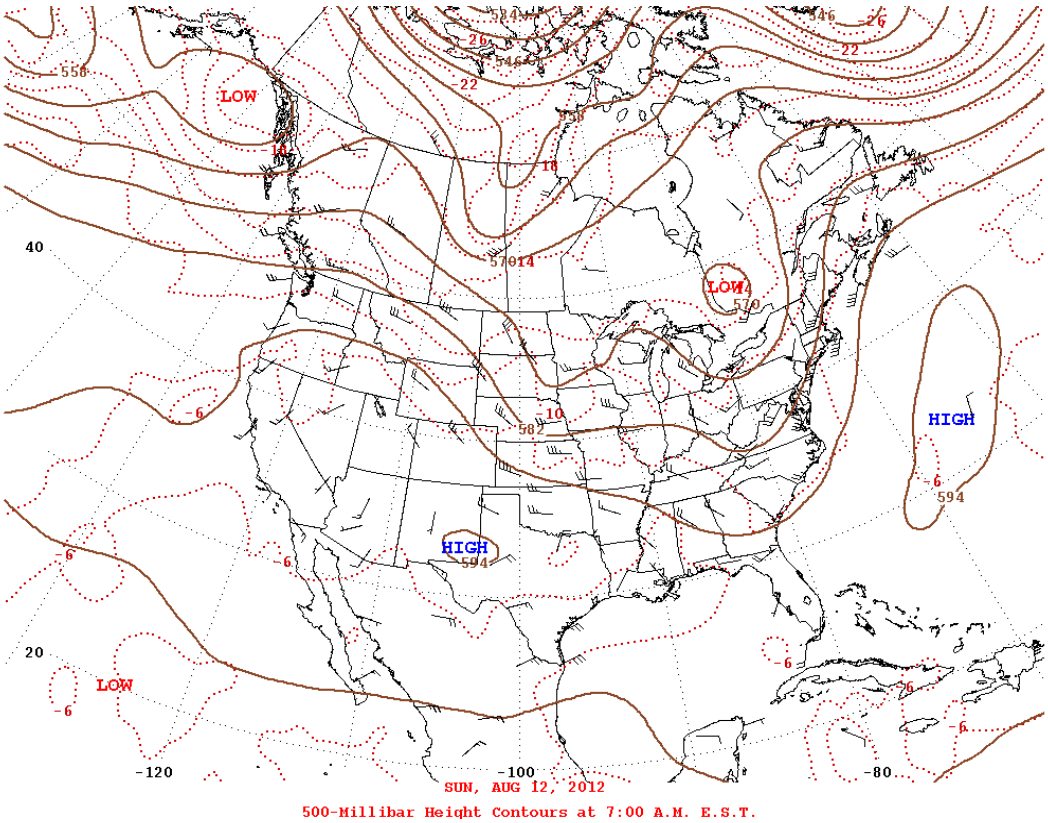

Figure 43. August 12, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

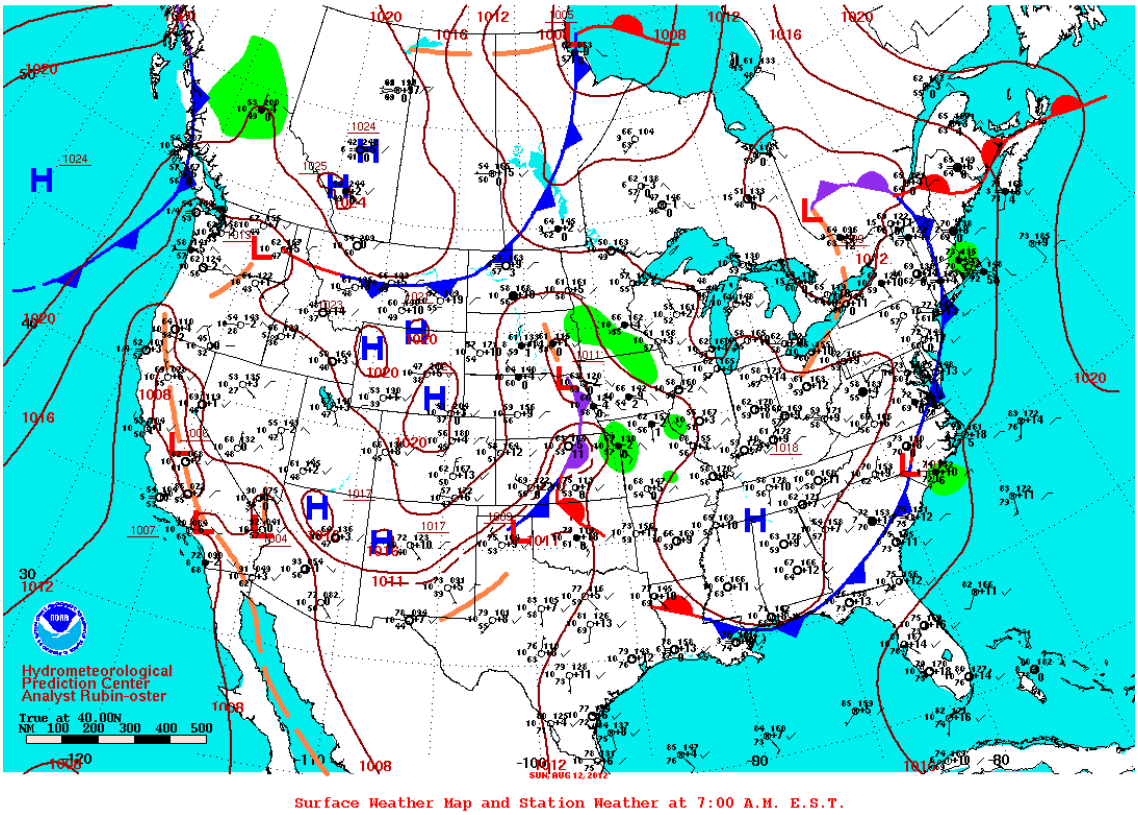

Figure 44. Surface weather analysis and station weather at 0500 MST, August 12, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.7.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, the afternoon satellite image (Figure 45) shows thick smoke plumes proceeding due east from the Halstead fire, intercepting the upper reaches of the Salmon River Valley. Light smoke is also visible in the Lemhi Valley, parallel and further to the east. The widespread smoke throughout southern Idaho, combined with the low wind speeds, indicates regional stagnation that allows local topographic and diurnal influences on smoke movement to dominate. The surface back trajectories (pink–0 m AGL) move north and south along the valley floor towards the monitor, suggesting that diurnal up-valley and down-valley flows occur during the 24-hour period.

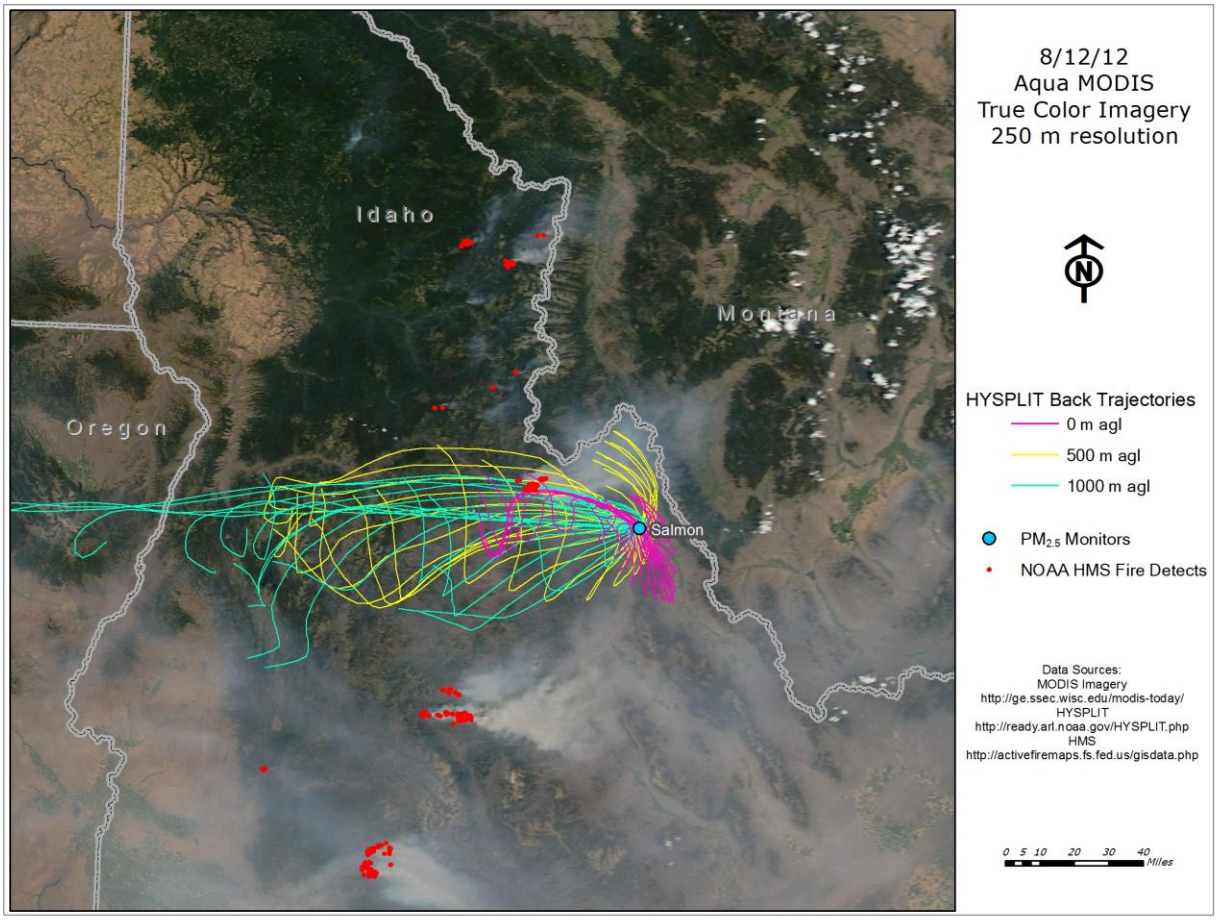

Figure 45. Aqua MODIS satellite image showing fire detects and smoke blowing eastward from the Halstead fire, filling the Salmon and Lemhi valleys south of Salmon. HYSPLIT model back trajectories indicate valley flows from the south, August 12, 2012.

4.7.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The $PM_{2.5}$ time series chart shown in Figure 46 shows that the concentrations were elevated throughout the day, dropping just below the hourly 95th percentile concentration at 1300 then rising to over 80 µg/m^3 in the late afternoon.

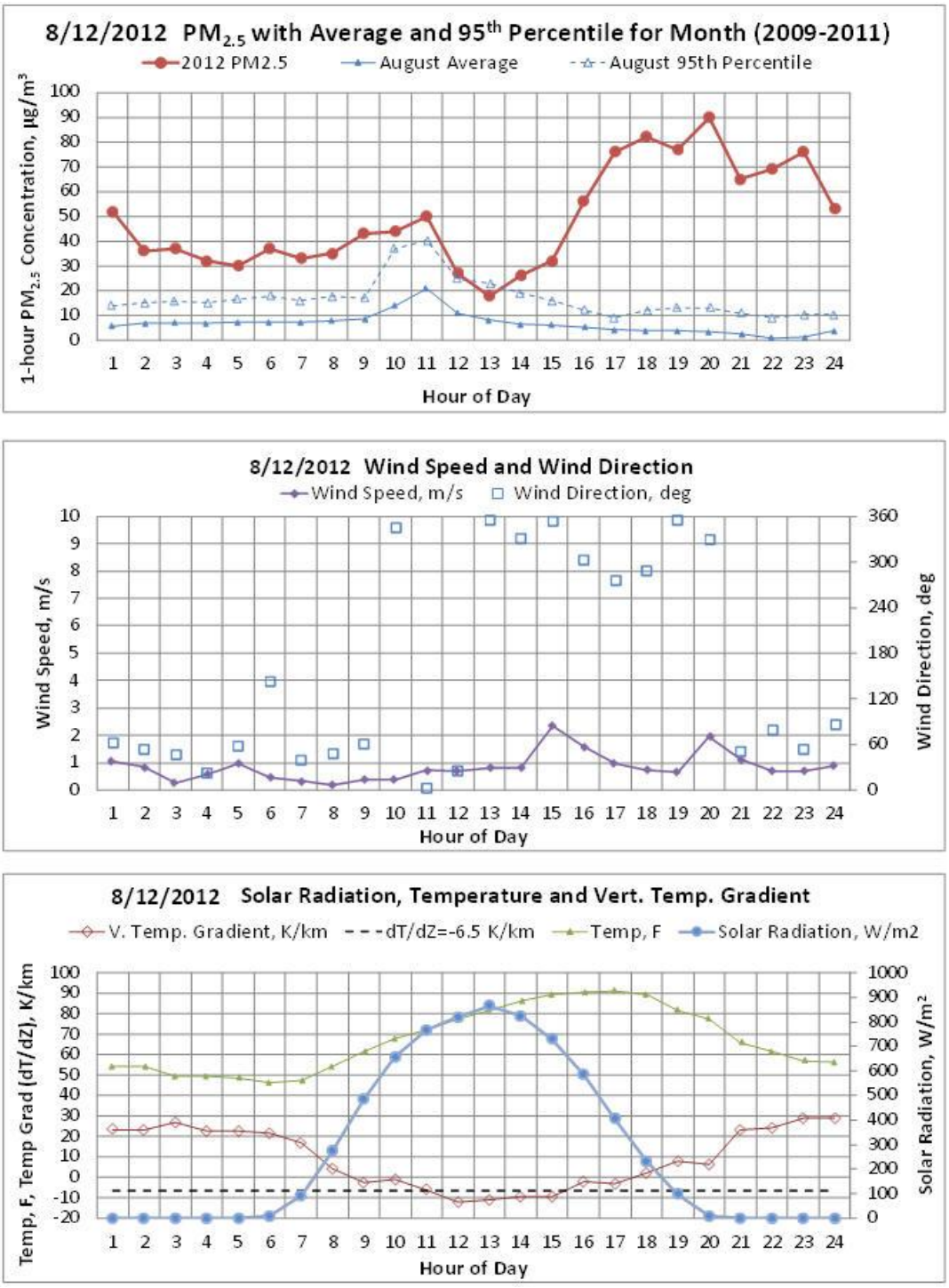

Figure 46 Time series charts for August 12, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley.

4.7.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 46, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. This will replace the normal approach of showing the 7 non-affected days before and after a 1 day event—we cannot do this because nearly all the days are affected.

4.7.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during in August nor in most of the wildfire season but rather begins in October. The daytime temperature on August 12 ranged from ~ 46 °F in the evening to 90 °F during the day. Although the night-time lows nearly reach 45 °F, RWC does not typically begin until the daytime/evening temperatures are below 35 °F–40 °F. In addition, crop residue burning did not occur in the Salmon vicinity, and was not allowed for most of the period in Idaho and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding 90 μg/m^3 observed on August 12, 2012, in Salmon. Specific information on days when a Stage 1 Forecast and Caution was in effect, thus prohibiting open burning provided in Appendix E.

4.8 Scenario 4: Direct Plume Impact—Halstead

Scenario 4 is similar to Scenario 2 in that smoke advects directly from the source to the monitor, in this case, from the Halstead fire. This type of scenario is easily observed and multiple pieces of evidence support it.

Scenario Summary

- Smoke from Halstead plume blows directly over Salmon.
- Characterized by a spike in concentration on the hourly trace (spike defined as at least a 15 μg/m^3 rise in an hour, with a corresponding fall).
- Spikes typically occur during the afternoon, when the fires are most active and smoke production is highest and transport winds are strongest.
- Satellite imagery shows a plume striking Salmon or pointing directly from fire to Salmon.
- Back trajectories align with plume direction and intersect visible smoke and/or fire detects.

4.8.1 Description of Typical Weather Conditions and Transport Winds

In this scenario, transport winds from the southwest advect smoke directly into the Salmon area. The upper level chart (Figure 47) indicates a typical summer wind pattern across the western US with an established upper level high pressure system over the Four-Corners with southwesterly flow and a ridge axis located to the east of Idaho. The August 28, 2012, surface chart (Figure 48) indicates a thermal low located over the Snake River Basin and the Nevada-Idaho-Utah border; however, again, surface winds across the region are very light with observations in Salmon, ID and Pocatello, ID indicated calm wind conditions. In this situation, vertical mixing during the afternoon is likely the primary driver in wind direction. This can be seen in the visible satellite

imagery below which also indicates that the HYSPLIT back trajectory follows this same southwesterly path (Figure 49).

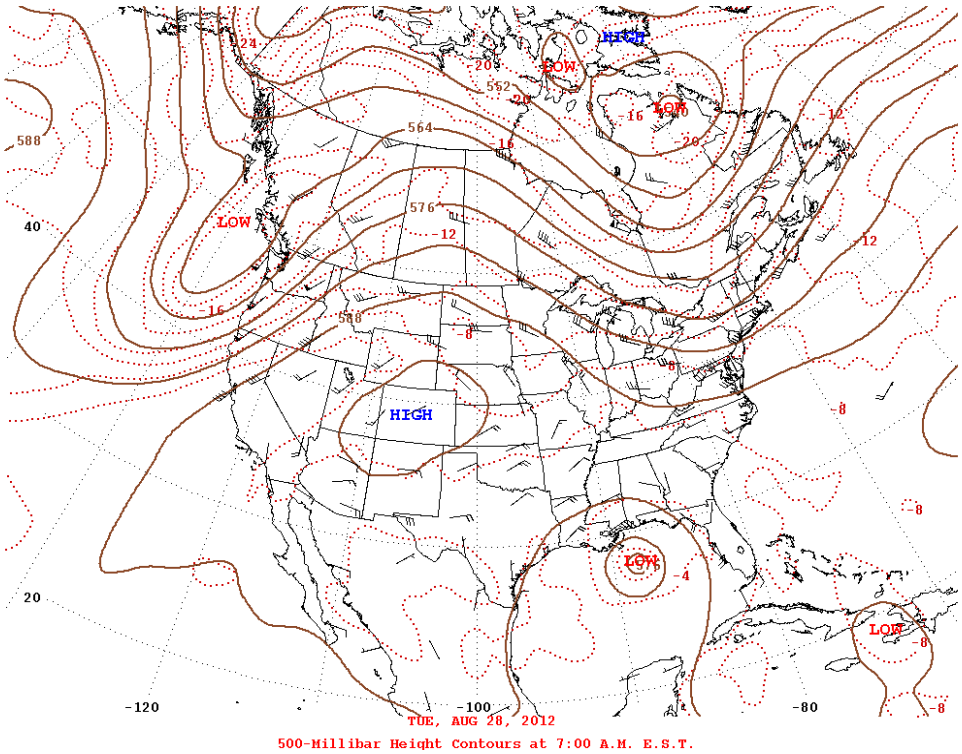

Figure 47. August 28, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

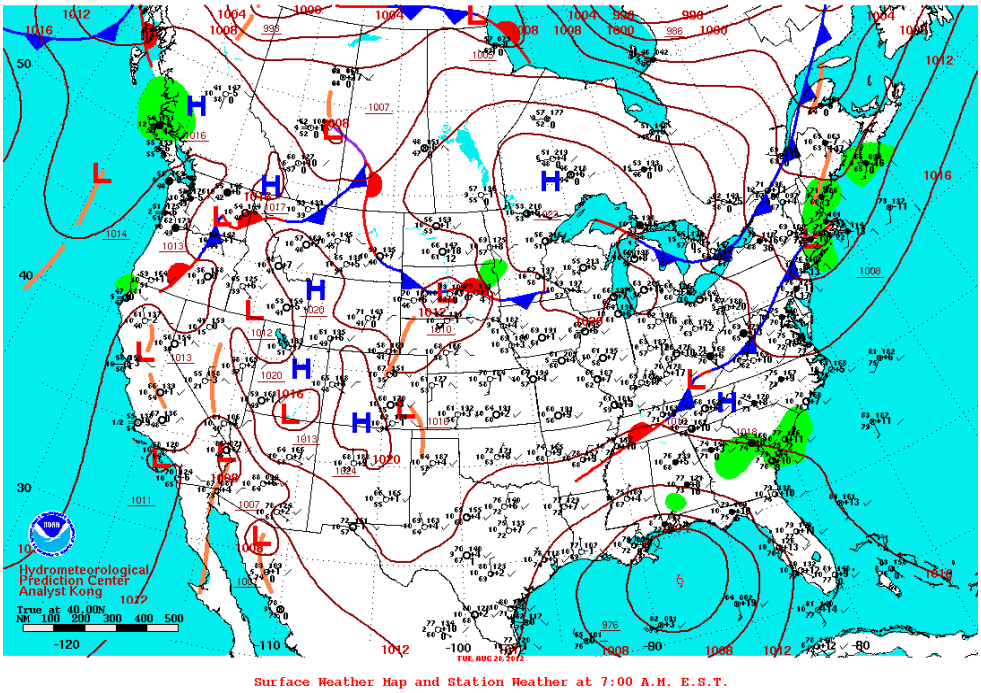

Figure 48. Surface weather analysis and station weather at 0500 MST, August 28, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.8.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, (Figure 49) the afternoon satellite image depicts many large plumes travelling north-northeast from their source fires. The Halstead plume is aligned to the west of Salmon in this snapshot, but there is visible smoke in Salmon and back trajectories align with Halstead smoke, signifying that the plume struck Salmon directly during the 24-hour period.

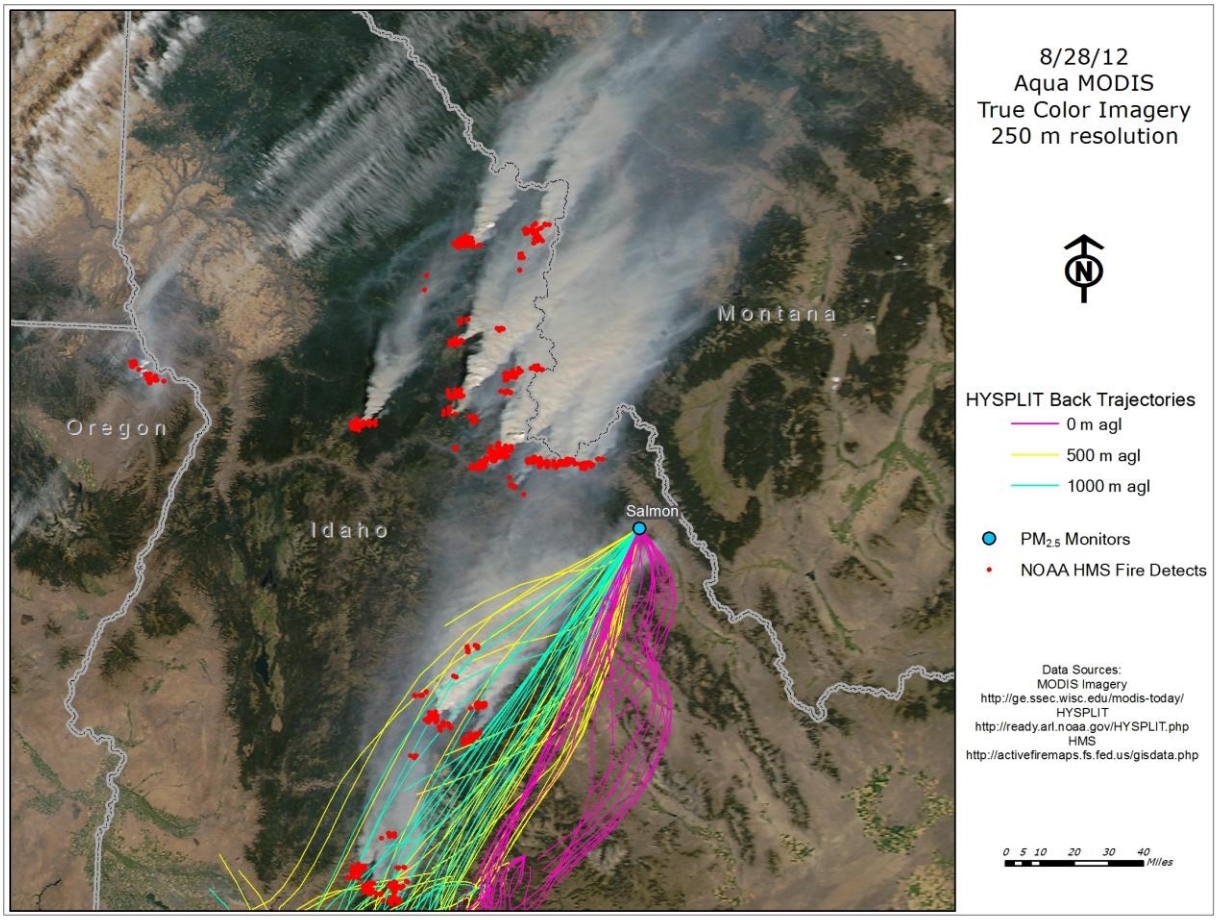

Figure 49. Aqua MODIS satellite image showing fire detects and smoke blowing north-northeastward from the Halstead fire, directly impacting the Salmon area, with HYSPLIT model back trajectories showing similar tracks for most hours on August 28, 2012.

4.8.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The 24-hour $PM_{2.5}$ trace spiked at 1800 and 1900, two hours after the winds had shifted south and then southwest, coinciding with the rapid rise in concentrations and an increase in wind speed.

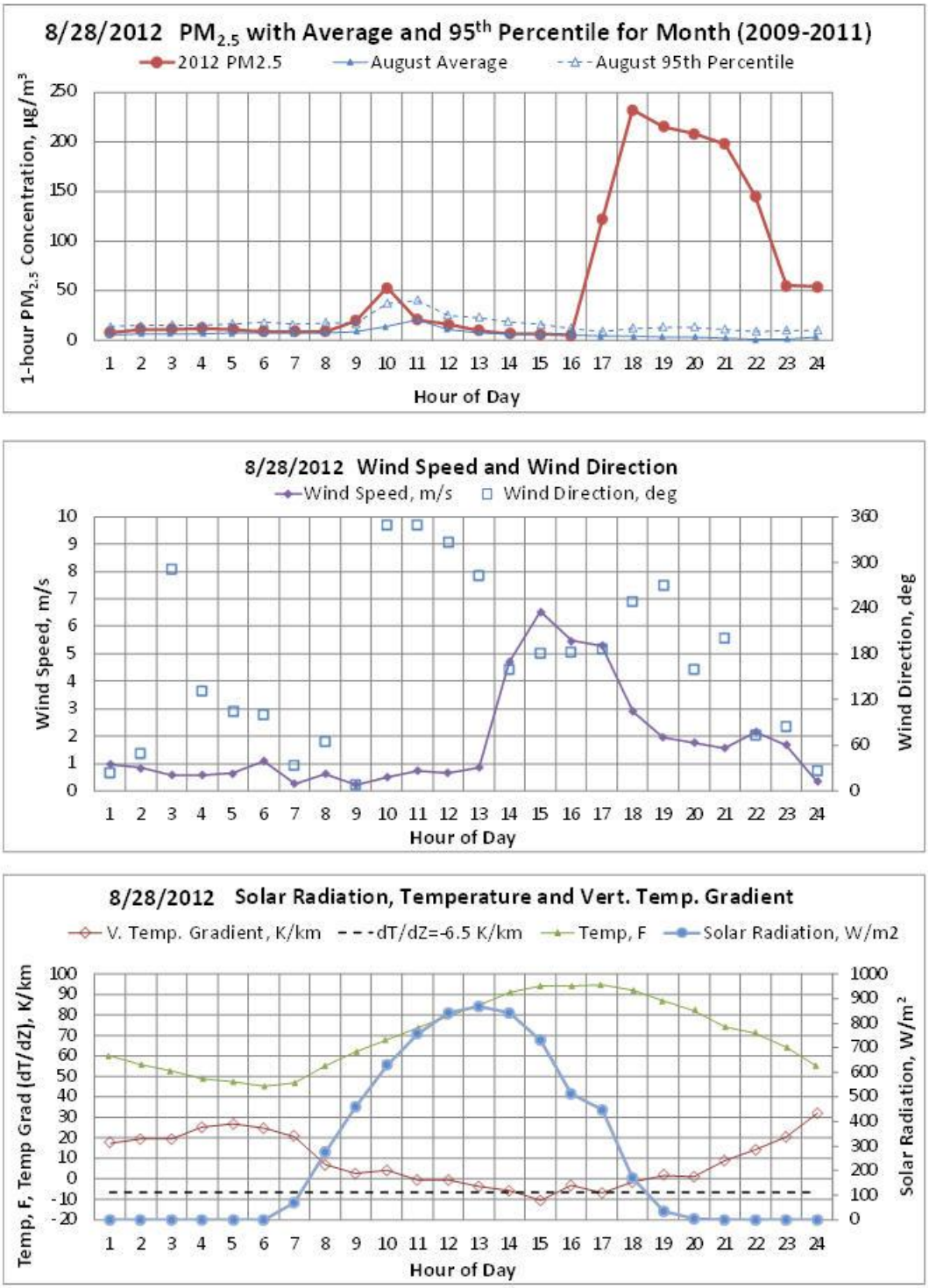

Figure 50. Time series charts for August 28, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley.

4.8.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 50, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. As seen in Figure 50, the large evening peak resulting from the Halsted plume exceeds 200 μg/m^3 for four hours in the evening on August 28, many times over the hourly 95th percentile values for those hours, 15.9 μg/m^3.

4.8.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during in August nor in most of the wildfire season but rather begins in October. The daytime temperature on August 28 ranged from over 50 °F in the evening to over 90 °F during the day (Figure 50, bottom chart). Although the night-time lows nearly reach 45 °F, RWC does not typically begin until the daytime/evening temperatures are below 35 °F–40 °F. In addition, crop residue burning did not occur in the Salmon vicinity, and was not allowed for most of the period in Idaho and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding 200 μg/m^3 observed on August 28, 2012, in Salmon. Specific information on days when a Stage 1 Forecast and Caution was in effect, thus prohibiting open burning provided in Appendix E.

4.9 Scenario 5: Regional Transport

Scenario 5 can be described as a regional transport scenario, in contrast to the more prevalent local scenarios that afflict Salmon. This scenario occurs in combination with other, more local, scenarios. It occurs when there is smoke available across the region (e.g., covering half of the state or originating in different states) and the synoptic winds are strong enough to transport smoke long distances.

Scenario Summary

- Smoke from fires located farther away than Halstead and Mustang Complex advect into Salmon.
- Fire sources can be within Idaho or from neighboring states.
- Not a primary scenario, e.g., this scenario only seems to occur in combination with other scenarios.
- Characterized by sustained, elevated concentrations on the hourly trace.
- Satellite imagery shows multiple fires in the region and a generally smoky area where contributions from individual fires are not obvious (or smoke is obscured by cloud).
- Back trajectories intersect multiple fires (or HMS fire detects).

4.9.1 Description of Typical Weather Conditions and Transport Winds

In this final scenario, several meteorological phenomena affect the transport of smoke from non-local sources into Idaho. First, the 500 mb height chart (Figure 51) indicates a high-amplitude ridge with the center of the high pressure extending into the Upper Snake River Basin, the Central and Southern Highlands in Idaho. The ridge axis is slightly to the east of Idaho. Given the intensity in amplitude of this ridge and the proximity of the ridge axis to Salmon, Idaho,

southerly flow is the primary transport component. As indicated in the HYSPLIT back trajectories (Figure 53), it is possible to note that both transport wind and local diurnal winds played a role in advecting smoke into the Salmon area. Due to cloud cover, it is difficult to definitely identify smoke source in the satellite imagery.

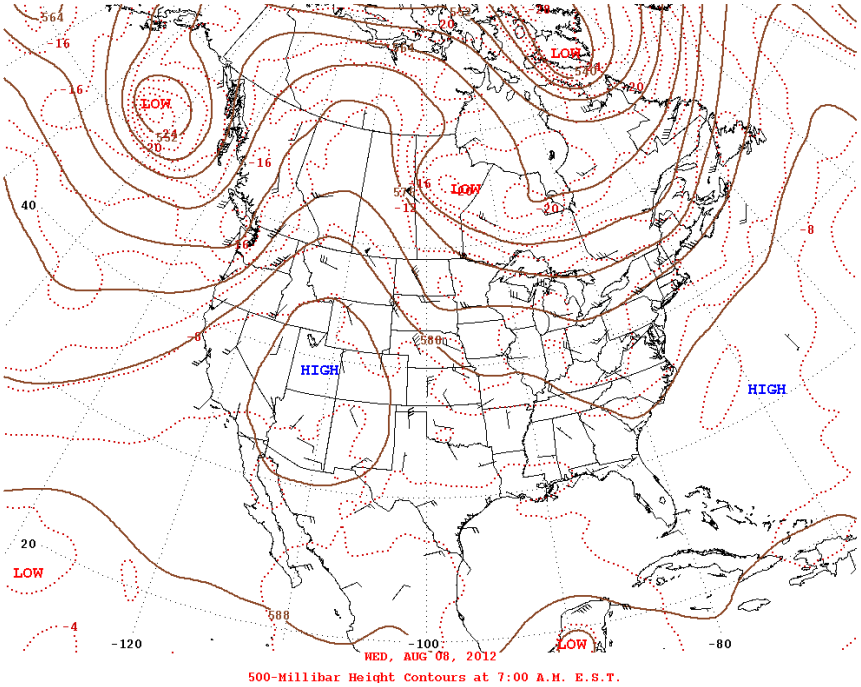

Figure 51. August 8, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

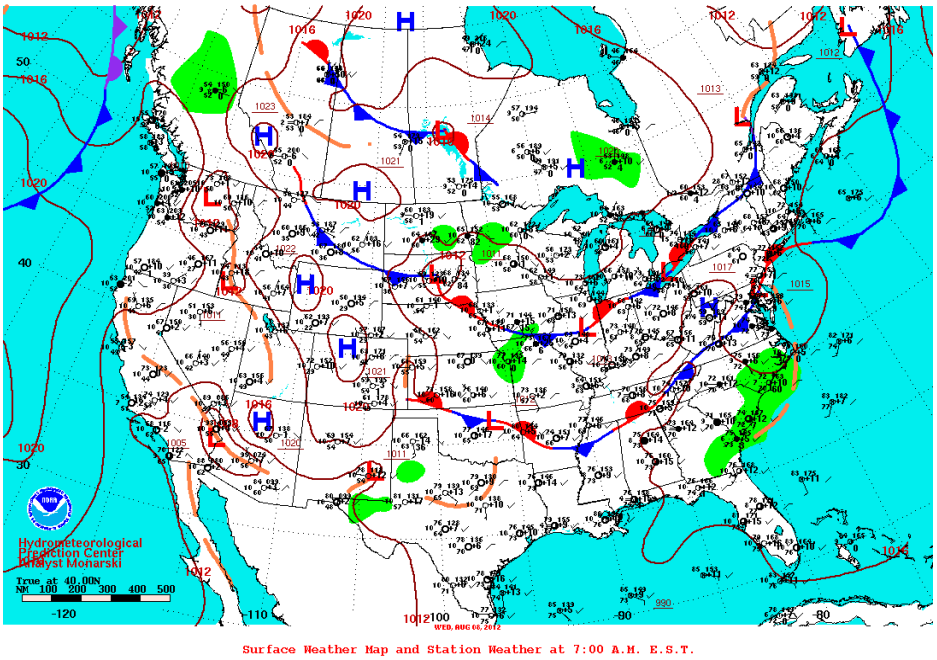

Figure 52. Surface weather analysis and station weather at 0500 MST, August 8, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.9.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, (Figure 53) it is the back trajectories that provide the strongest evidence for the scenario. The trajectories travel long distances and intersect multiple fire detects in southern Idaho and beyond. Cloud obscures much of the visible smoke, but we can deduce that there may be smoke located underneath the cloud because thick smoke is visible in a line trending southwest from the Mustang Complex and due west of Salmon.

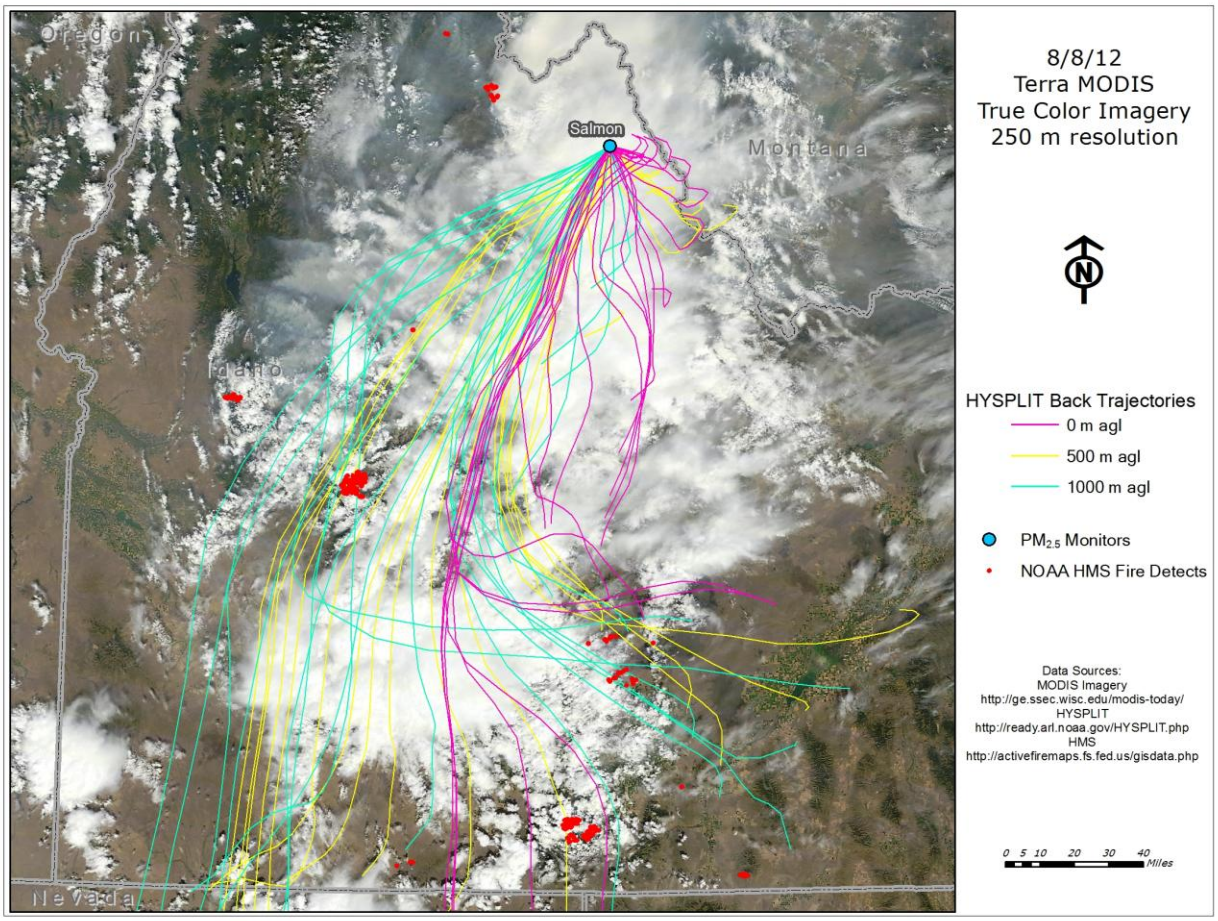

Figure 53. Terra MODIS satellite image shows ground surfaces obscured by cloud and HYSPLIT model back trajectories approaching Salmon from the south and southwest, August 8, 2012.

4.9.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The evidence from the hourly $PM_{2.5}$ trace and the local wind data is not definitive for this scenario. The concentrations are generally elevated throughout the day, which could be a result of continued advection of long-range, dispersed smoke or it could be a result of local smoke from fires whose production is decreased due to cloud cover and potentially increased relative humidities. The local wind data is influenced by valley terrain and does not necessarily reflect regional transport winds.

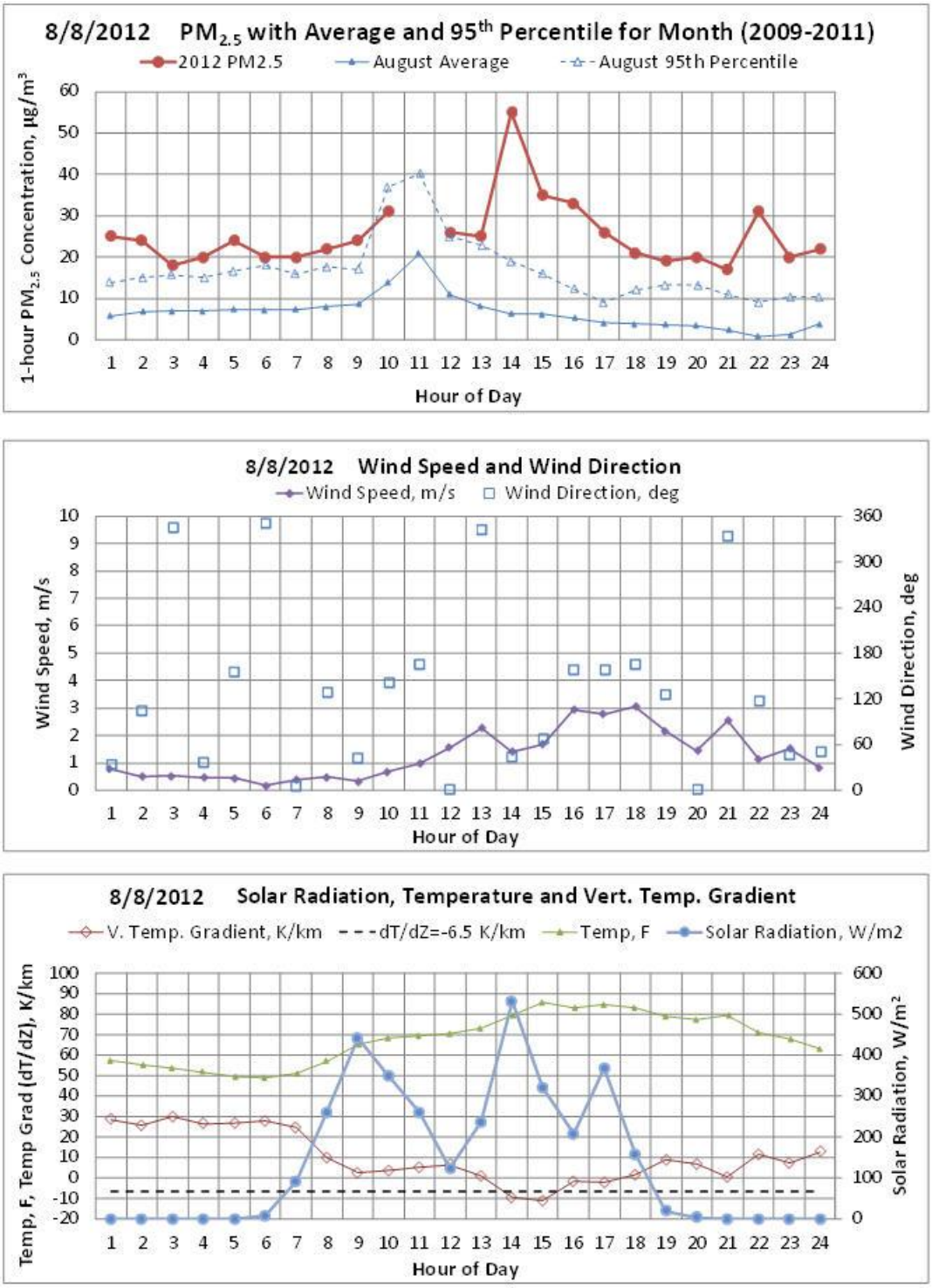

Figure 54. Time series charts for August 8, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for August days (top chart); wind speed and wind direction (middle chart); and temperature, solar radiation, and vertical temperature gradient (bottom chart). Temperature gradients above -6.5 K/km (dotted line) indicates stable/stagnant conditions in the valley.

4.9.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 54, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. As seen in Figure 54, the hourly $PM_{2.5}$ concentrations exceed the hourly 95th percentile value for most of the day and are twice as high for 5 hours during the day.

4.9.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during in August nor in most of the wildfire season but rather begins in October. The daytime temperature on August 28 ranged from ~50 °F at night to over 80 °F during the day. RWC does not typically begin until the daytime/evening temperatures are below about 35 °F–40 °F. In addition, crop residue burning did not occur in the Salmon vicinity, and was not allowed for most of the period in Idaho and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding the 95th percentile values for nearly the entire day as observed on August 8, 2012, in Salmon, and the day long elevated levels reflect the region-wide smoke that approached the monitor from every wind direction during the day. Specific information on days when a Stage 1 Forecast and Caution was in effect, thus prohibiting open burning provided in Appendix E.

Pinehurst Scenarios

4.10 Pinehurst Scenario 1: Regional Transport

Scenario 1 describes the conditions that occur when long-range smoke advects to the monitor in Pinehurst. During the 2012 fire season, there were no large fires burning near Pinehurst like the Salmon case, however, many large fires burned to the south of Pinehurst in central Idaho, and, during September, there were a number of large fires burning in central and eastern Washington. Smoke from these fires affected the air quality in Pinehurst. Since the smoke travelled longer distances, it was more dispersed and therefore, concentrations in Pinehurst increased less dramatically than in Salmon.

Scenario Summary

- Smoke from regional fires advect into Pinehurst.
- Fire sources can be within Idaho or from neighboring states.
- Characterized by sustained, elevated concentrations on the hourly trace.
- Satellite imagery shows multiple fires in the region.
- Back trajectories intersect fires (or HMS fire detects).

4.10.1 Description of Typical Weather Conditions and Transport Winds

The date September 25, 2012, was selected as an example for Scenario 1. The observationally driven modeled output of the 500 mb height contours are shown in Figure 55 and the surface chart is shown in Figure 56. Aloft, a weak Rex block became established over Idaho. This created very weak wind speeds and variable direction, as well as an area of weak or split flow. At the surface, there is a very weak pressure gradient which allows for diurnally driven mountain-

valley wind regimes to become the primary contributor to local wind patterns in the Silver Valley. This mean flow is quite evident via the HYSPLIT back trajectories in Figure 57. It is also possible to note that the complex terrain dictates the movement of the smoke, and in places, aides the transport as the valleys align with the mean flow where forced channeling can create accelerated or gusty wind conditions (Whiteman 2000).

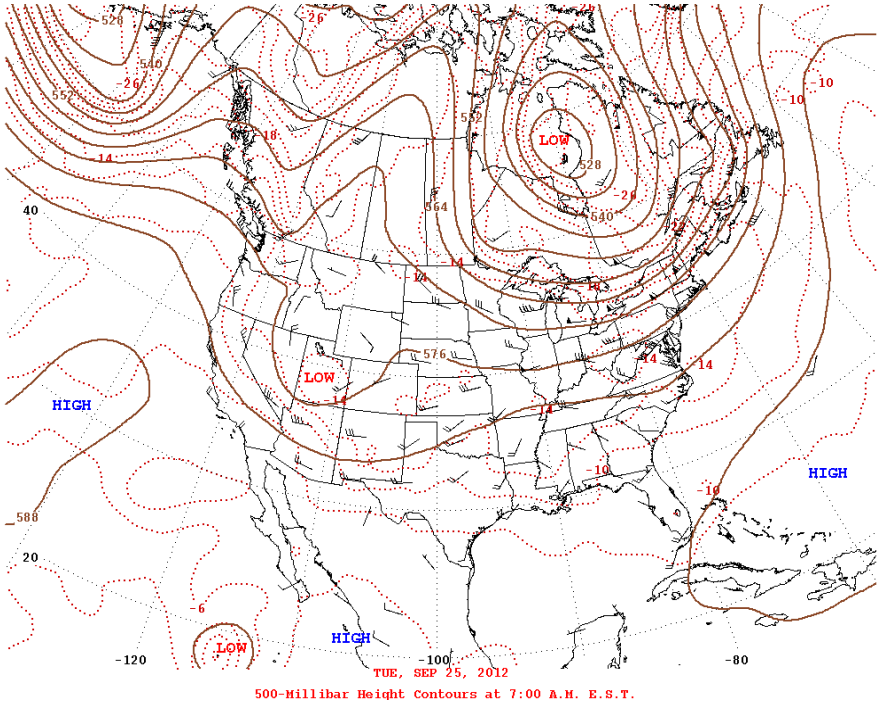

Figure 55. September 25, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

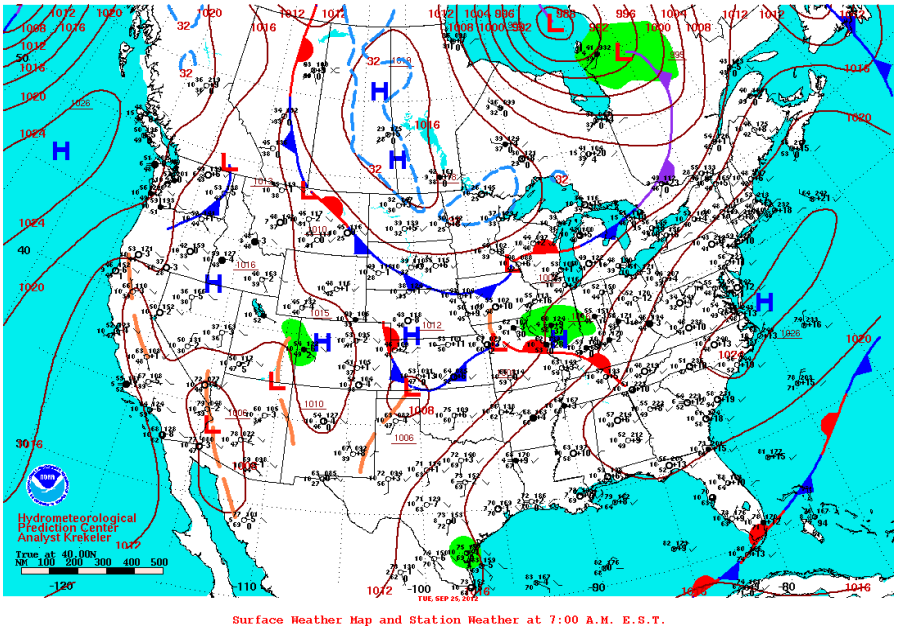

Figure 56. Surface weather analysis and station weather at 0500 MST, September 25, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.10.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, (Figure 57) the morning satellite image shows light smoke across the Panhandle, including in the Pinehurst area, and 1000 m AGL back trajectories intersecting multiple fire detects in central Washington and smoke in northern Oregon. Clouds obscure much of the smoke arising from the Washington fires, but examination of satellite images from previous days reveals significant smoke production at these fires.

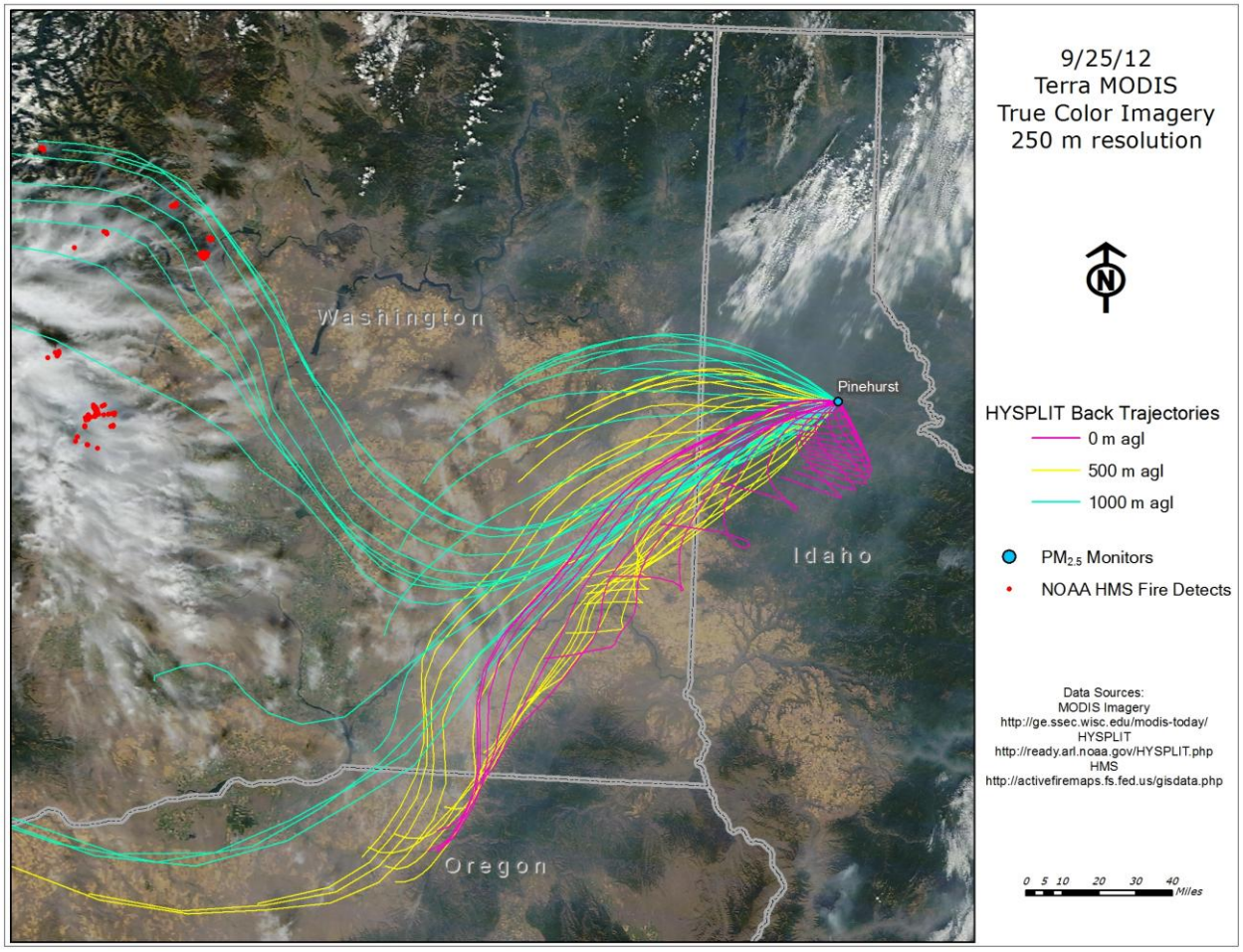

Figure 57. Terra MODIS satellite image shows light smoke throughout the region, with HYSPLIT model back trajectories intersecting smoke and/or HMS fire detects from fires in Washington and Oregon.

4.10.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The evidence from the hourly $PM_{2.5}$ trace and the local wind data indicate elevated levels overnight, clearing somewhat ~ 1100 then the midday concentrations rise again as the winds increase and approach from the west in agreement with the back trajectories.

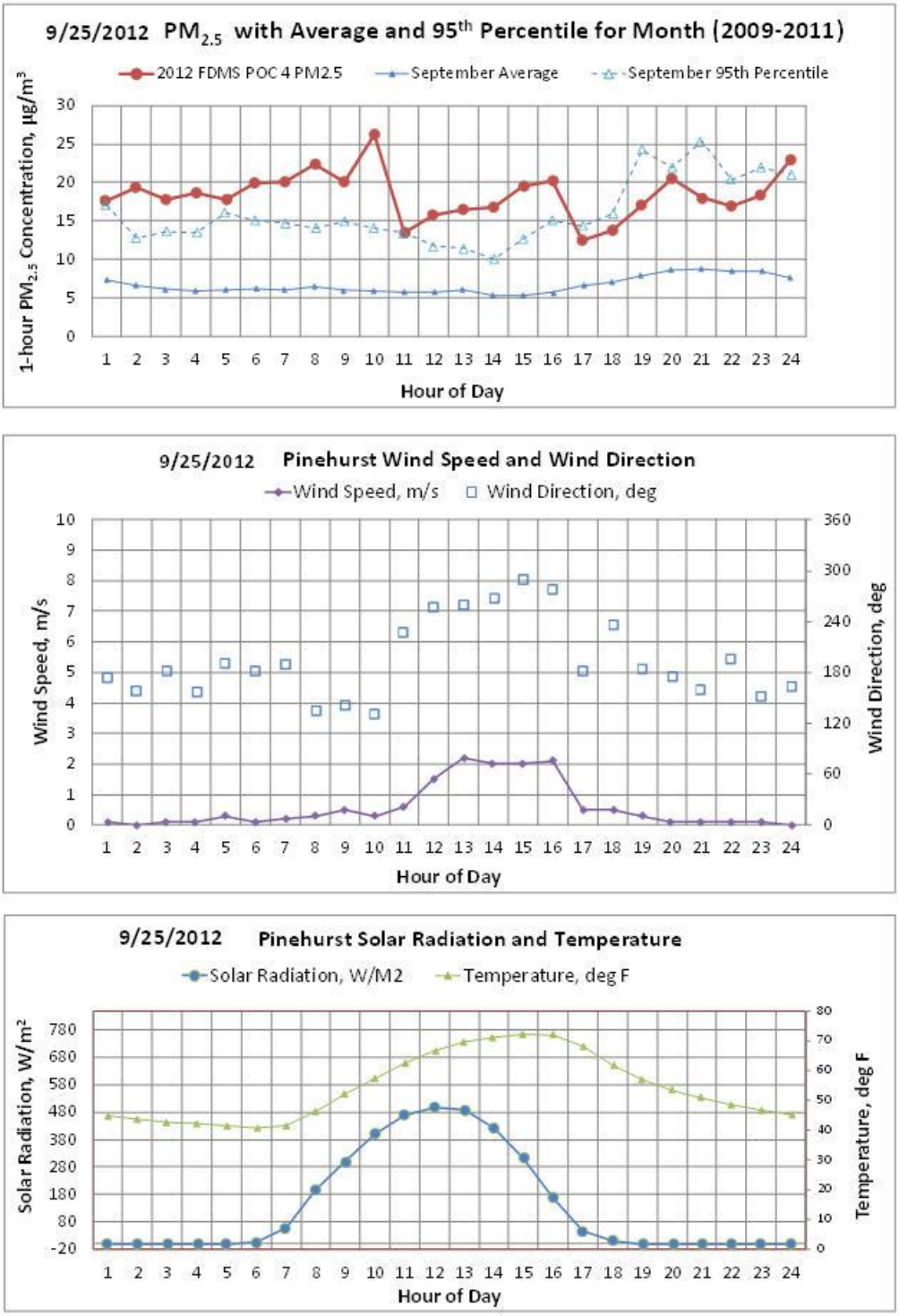

Figure 58. Time series charts for September 25, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days (top chart); wind speed and wind direction (middle chart); and temperature and solar radiation.

4.10.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 58, top chart, the $PM_{2.5}$ time series chart for each day includes the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. The hourly $PM_{2.5}$ concentrations in Figure 58 exceed the hourly 95th percentile value for most of the day including the overnight and daytime hours prior to 1700.

4.10.5 Alternative Hypotheses

Residential wood combustion does not occur to any great extent during September but rather typically begins for most people in October. The daytime Pinehurst temperature on September 25 ranged from the low 40s overnight to over 70 °F in the afternoon while RWC does not typically begin until the daytime/evening temperatures are below 35 °F–40 °F. In addition, crop residue burning did not occur in Shoshone County, near Pinehurst, and was not allowed by the State of Idaho for most of the period of regional wildfire smoke in most of northern Idaho and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding the 95th percentile values for nearly the entire day as observed on September 25, 2012, in Pinehurst and we must conclude that the day long elevated levels reflect the region-wide smoke that approached the monitor from the west and southwest directions during midday. Specific information on days when a Stage 1 Forecast and Caution was in effect, thus prohibiting open burning provided in Appendix E.

4.11 Scenario 2: Local Stagnation

Scenario 2 describes the conditions that occur when smoke advected to Pinehurst from wildfires remains trapped in the valley due to stagnant atmospheric conditions. Pinehurst's location in a small valley less than 2 km in diameter, and surrounded by mountains, causes smoke to become trapped in local nocturnal inversions which sometimes don't break for several days at a time due to the strength of the cold air pool.

Scenario Summary

- Smoke from regional fires advect into Pinehurst and is trapped in the small valley.
- Atmospheric conditions are stable.
- Pinehurst is too small to detect visible smoke from satellite imagery, but regional clues to stagnation include smoke trapped in river valleys
- Back trajectories do not travel far during 24-hour period, suggesting low wind speeds

4.11.1 Description of Typical Weather Conditions and Transport Winds

The date September 22, 2012, was selected to represent the second Pinehurst scenario of local stagnation. Below are the 500 mb chart (Figure 59) and observational surface chart (Figure 60). At the 500 mb level, it is evident that a highly amplified, strong (582 dm or higher) ridge pattern (driven by the strong embedded low pressure system upstream) with the ridge axis centered near Idaho contributed to stagnant conditions with light winds that inhibited horizontal and vertical mixing. The semi-permanent Four-Corners high pressure system, while on this specific date is relatively small, intruded into Idaho several times, reaching north of the Salmon River. At the

surface, a very weak pressure gradient existed which promoted weak winds that were driven by local topographic forcing, such as mountain-valley and mountain-plain diurnal wind patterns.

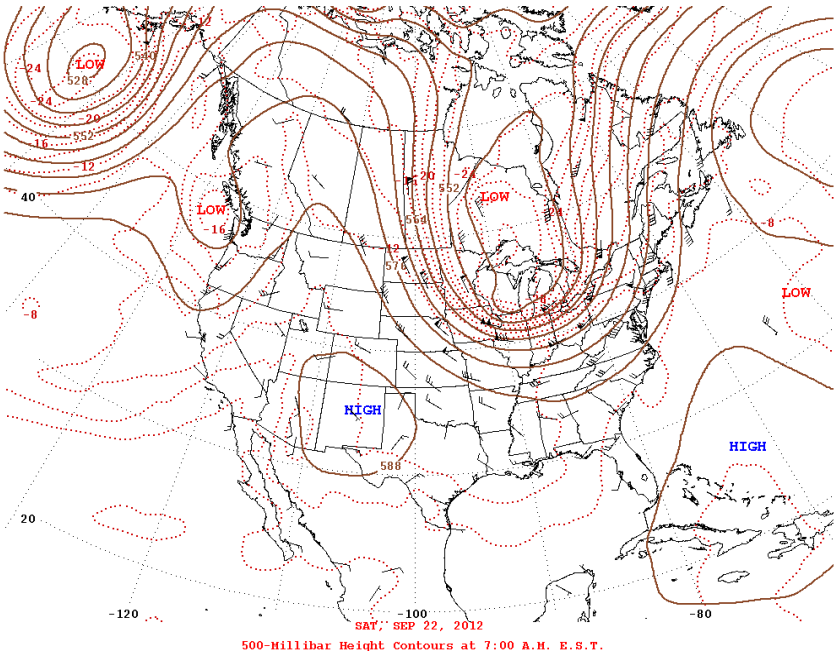

Figure 59. September 22, 2012, 500-millibar height contours and wind barbs at 0500 MST *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

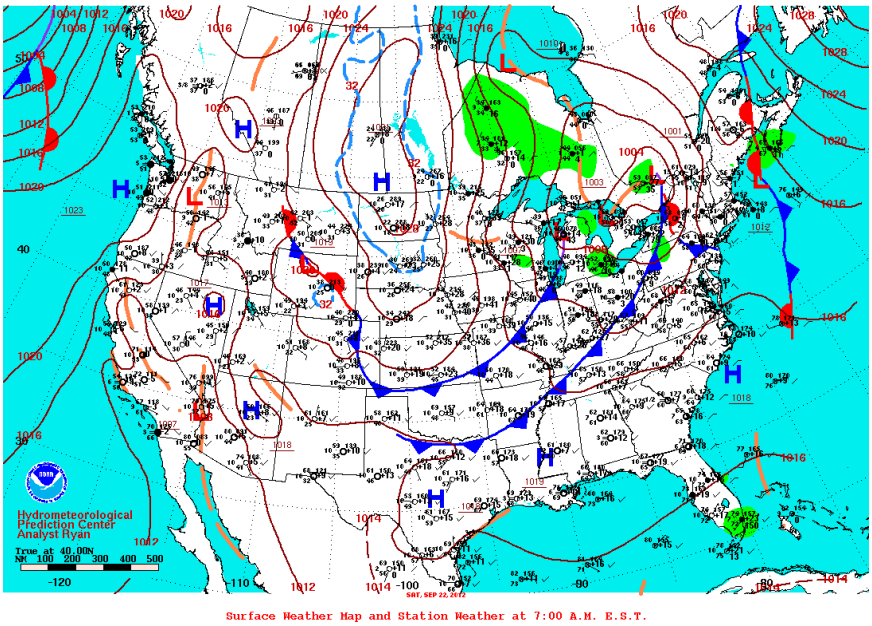

Figure 60. Surface weather analysis and station weather at 0500 MST, September 22, 2012 *http://www.hpc.ncep.noaa.gov/dailywxmap/* (HPC 2013).

4.11.2 Transport of Typical Emissions/Spatial Relationship between Sources and the Monitor(s) Where Measurements Were Recorded

In this example, the morning satellite image (Figure 61) shows dense smoke obscuring surface features throughout Idaho and Montana. South of Pinehurst, thick smoke can be seen trapped in the river drainages, implying the strength of the stagnant atmosphere. Back trajectories do not travel more than 50 miles during the 24-hour period, adding evidence of the low wind speeds and the generally stagnant conditions.

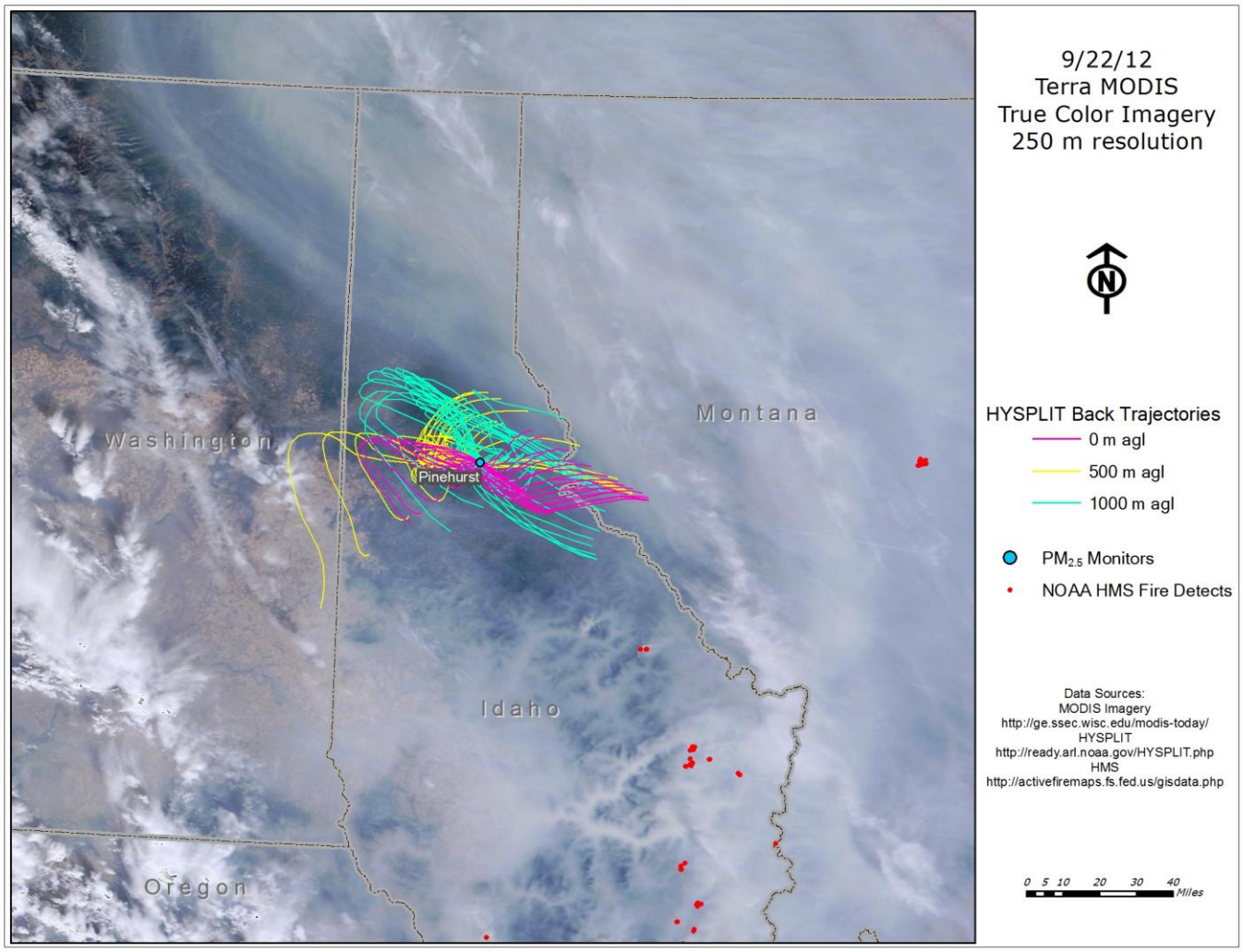

Figure 61. Terra MODIS satellite image showing fire detects and dense smoke blanketing northern Idaho and trapped in the river valleys of central Idaho. HYSPLIT model back trajectories are very short indicating stagnant air.

4.11.3 Typical Temporal Relationship Between the Wildfires and Elevated PM Concentrations at the Monitor(s) in Question

The hourly $PM_{2.5}$ trace (Figure 62) shows generally elevated and sustained concentrations above the hourly 95th percentile levels throughout the day, with an upwards trend. The very low wind speeds indicate why the valley does not clear out during the day.

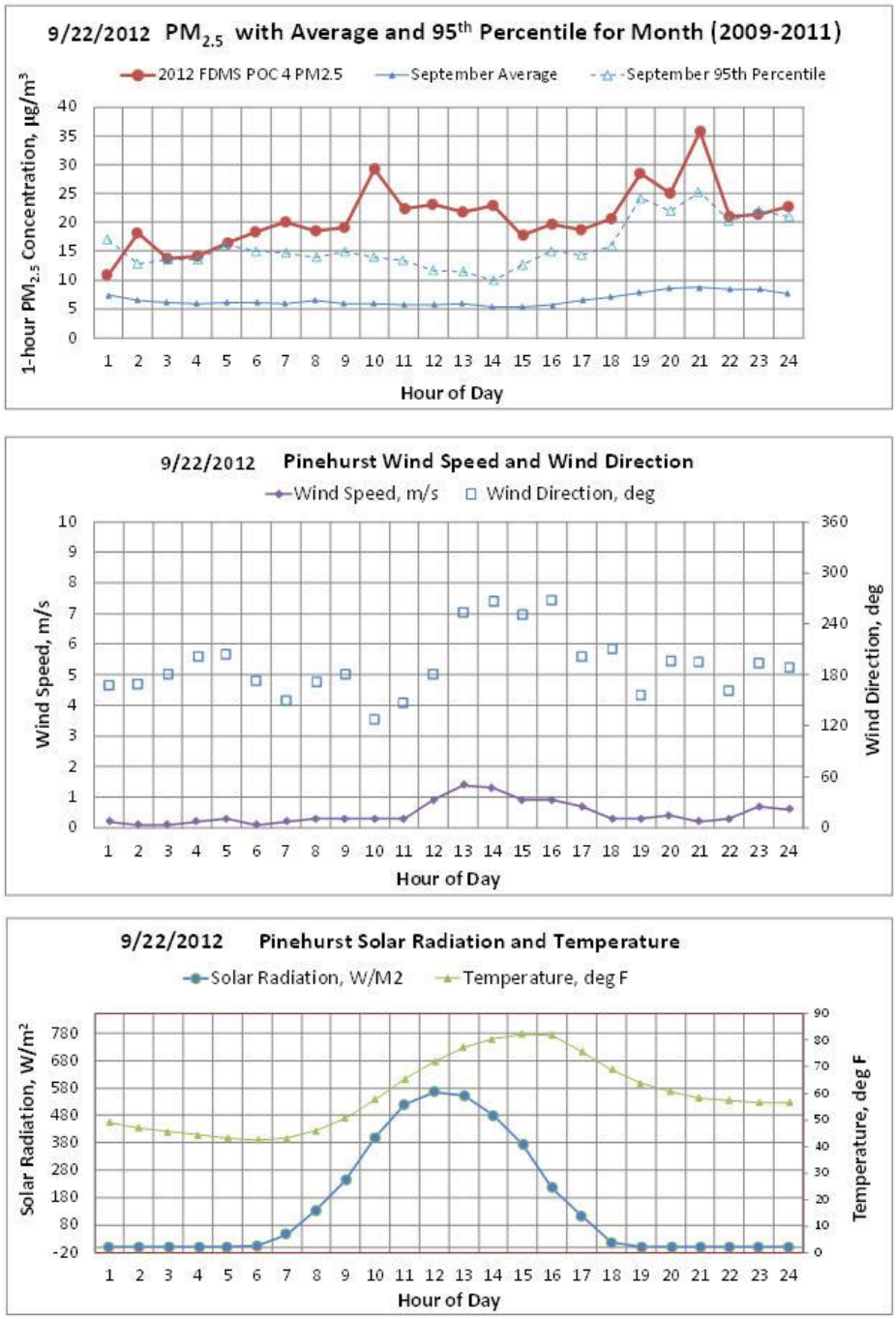

Figure 62. Time series charts for September 22, 2012, showing 2012 $PM_{2.5}$ concentrations versus historical (2009–2011) average and 95th percentile values for September days (top chart); wind speed and wind direction (middle chart); and temperature and solar radiation (bottom chart).

4.11.4 Comparison of Event-Affected Days to Specific Nonevent Days

As shown in Figure 62, top chart, the $PM_{2.5}$ time series chart for each day will include the typical "non-event" daily pattern for that day in 2011, 2010, and 2009 in terms of the monthly average for each hour, and the monthly 95th percentile value. The hourly $PM_{2.5}$ concentrations exceed the hourly 95th percentile values most of the day.

4.11.5 Alternative Hypotheses

Residential wood combustion (RWC) does not occur during in September nor in most of the wildfire season but rather typically begins in October. The daytime temperature on September 22 ranged from the low 40s overnight to over 80 °F during the day. DEQ believes the RWC does typically begin to pick up when the daytime/evening temperatures are below 35 °F–40 °F so there may be some minor RWC contribution on this day, but woodburning is believed to be limited in September as many people will likely conserver their wood supply until the cooler months. In addition, crop residue burning did not occur in Shoshone County and fire detects were not seen west of there in the traditional farming areas of Benewah and Latah counties. CRB activity was not allowed by the State of Idaho on this day and prescribed burning did not occur (Appendix D). No other source of smoke/$PM_{2.5}$ is large enough to cause the levels exceeding the 95th percentile values for the entire day as observed on September 22, 2012, in Pinehurst, and the day-long elevated levels reflect the region-wide smoke that filled the valley and remained trapped by stagnant conditions throughout the day. Specific information on days when open burning was prohibited, including crop residue burning, is provided in Appendix E.

5 Affects Air Quality (AAQ)

The EER requires that agencies must document that the identified source of an exceptional event truly affected air quality (AAQ) at the location of the monitor in question.EPA's Interim High Wind Guidance (EPA 2013) indicates that if Historical Fluctuations (in Section 3) and a Clear Causal Relationship (in Section 4) have been adequately demonstrated, then the AAQ element will have been met. DEQ believes that the Historical Fluctuations and Clear Causal Relationship evidence have been fully demonstrated and are very strong, and therefore the AAQ requirement is also met.

6 Human Activity Unlikely to Recur or a Natural Event (HAURL/NE)

The EER requires that agencies must document that the identified source of an exceptional event is either a natural event (NE) or a human activity unlikely to recur at the same location (HAURL) such as to affect the monitors in question again. EPA's Interim High Wind Guidance (EPA 2013) indicates that if an agency has adequately demonstrated that the source is a *natural event* or, if not natural, is a human activity unlikely recur at the same location and that there is a *clear causal relationship* between the identified source (s) and the affected monitor, then the HAURL/Natural Event criterion is also satisfied.

This primary fires affecting Salmon, Idaho (Halstead and Mustang Complex) as well as the majority of the other fires in the region were caused by lightning and are therefore of natural origin. Similarly, the Wenatchee Complex and Table Mountain in Washington and the Powell SBW Complex in Idaho, as well as several other fires which primarily affected the Pinehurst monitor were all lightning caused. Furthermore, the few human caused fires in the region are unlikely to recur for many years in the same location because the fuel is exhausted in their fire scars. Finally, the detailed data included in Appendix B for Salmon and Appendix C for

Pinehurst, demonstrate a clear causal relationship between source and monitor for each day that DEQ requests concurrence. Thus, the NE/HAURL criterion is also satisfied.

7 No Exceedance "But For" this Event (NEBF)

The EER 40 CFR 50.14(b)(1) directs EPA to exclude data only where an agency demonstrates an "exceptional event" caused a concentration in excess of a NAAQS. It must also be shown that the concentrations at the monitor would have been below the standard if the event had not occurred (i.e., "but for" the event.) The clear causal relationship information establishes the connection between the wildfires and the monitored value, and demonstrates that due to the burn bans in effect, and lack of crop residue burning and prescribed burning in these areas, no other significant source is capable of causing the high monitor values. Finally, the analysis of Historical Fluctuations in Section 3 demonstrates, in accordance with EPA "High Wind guidance" (EPA 2013) that these events exceed the normal range of historical fluctuations above the mean value. The difference between the monitored values at the Salmon and Pinehurst monitors and the normal range of historical fluctuations, bracketed by the historical average values and the historical 95th percentile values is assumed to represent the contributions of these wildfire events to the monitored value.

Table 10 below provides the quantitative NEBF for each monitored concentration at Salmon for which we seek concurrence. Table 11 provides the quantitative NEBF for each requested monitor concentration at Pinehurst. The range of concentrations in the right-most two columns of Table 10 and Table 11 demonstrate that the values above the 24-hour NAAQS of 35 $\mu g/m^3$ or the annual NAAQS of 12 $\mu g/m^3$ would not have occurred "but for" the regional wildfire event. If the NEBF evidence is uncertain, the weight of evidence including a lack of alternative sources that could cause such levels and smoke visible in satellite images covering the region is relied upon to make the case.

Table 10. Estimated contribution of Salmon values that would not have occurred "But For" the 2012 wildfires. The two right-hand columns represent the range of concentration contributed by wildfires.

Date	$PM_{2.5}$ Value at Monitor (µg/m^3)	Value–95th Percentile (µg/m^3)	Value–Average (µg/m^3)
8/10/2012	33.7	17.8	27.9
8/11/2012	37.2	21.3	31.4
8/12/2012	49.2	33.3	43.4
8/13/2012	96.5	80.6	90.7
8/14/2012	147	131.1	141.2
8/15/2012	67.3	51.4	61.5
8/16/2012	106.5	90.6	100.7
8/17/2012	96.6	80.7	90.8
8/18/2012	30.4	14.5	24.6
8/19/2012	34.5	18.6	28.7
8/20/2012	37.7	21.8	31.9
8/23/2012	35.9	20.0	30.1
8/24/2012	108.2	92.3	102.4
8/25/2012	91.3	75.4	85.5
8/26/2012	45.5	29.6	39.7
8/28/2012	58.2	42.3	52.4
8/29/2012	78.1	62.2	72.3
8/30/2012	132	116.1	126.2
8/31/2012	49.8	33.9	44.0
9/1/2012	69.4	53.5	63.6
9/2/2012	145.2	129.3	139.4
9/3/2012	186.9	171.0	181.1
9/4/2012	182.7	166.8	176.9
9/5/2012	97.8	81.9	92.0
9/6/2012	48.4	32.5	42.6
9/7/2012	53.1	37.2	47.3
9/10/2012	136.4	120.5	130.6
9/11/2012	214.3	198.4	208.5
9/12/2012	194.4	178.5	188.6
9/13/2012	153.7	137.8	147.9
9/14/2012	70.2	54.3	64.4
9/15/2012	162.1	146.2	156.3
9/16/2012	162.5	146.6	156.7
9/17/2012	112.3	96.4	106.5
9/18/2012	130.3	114.4	124.5
9/19/2012	135.5	119.6	129.7
9/20/2012	159.8	143.9	154.0
9/21/2012	153.5	137.6	147.7

9/22/2012	86.6	70.7	80.8
9/23/2012	44.3	28.4	38.5
9/25/2012	62.7	46.8	56.9
9/26/2012	37.4	21.5	31.6
9/27/2012	39.3	23.4	33.5

Table 11. Estimated contribution of Pinehurst values that would not have occurred "But For" the 2012 wildfires. The two right-hand columns represent the range of concentration contributed by wildfires.

Date	$PM_{2.5}$ Value at Monitor ($\mu g/m^3$)	Value–95th Percentile ($\mu g/m^3$)	Value–Average ($\mu g/m^3$)
9/14/2012	31.3	16.3	24.3
9/15/2012	43.6	28.6	36.6
9/22/2012	20.8	5.8	13.8
9/25/2012	18.4	3.4	11.4

8 Mitigation

8.1 EER Mitigation Requirement

The mitigation provisions of the EER (40 CFR§51.930) require that (EPA 2013):

(a) A State requesting to exclude air quality data due to exceptional events must take appropriate and reasonable actions to protect public health from exceedances or violations of the national ambient air quality standards. At a minimum, the State must:

> *(1) Provide for prompt public notification whenever air quality concentrations exceed or are expected to exceed an applicable ambient air quality standard;*
> *(2) Provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event; and*
> *(3) Provide for the implementation of appropriate measures to protect public health from exceedances or violations of ambient air quality standards caused by exceptional events.*

8.2 Air Pollution Emergency Rule

DEQ implements the Air Pollution Emergency Rule (IDAPA 58.01.01.550) which helps mitigate air pollution emergency episodes by prohibiting open burning and notifying the public of deteriorating air quality. DEQ provides daily air quality forecasts in each of its regions and issues a Stage 1 Forecast and Caution (Stage 1) when necessary to protect public health. A Stage 1 notification, which prohibits all open burning, includes information concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality. A Stage 1, indicating deteriorating air quality and providing information to help citizens take actions to mitigate their exposure, were issued in every county in Idaho during the 2012 wildfire season, as shown in Table 12. The dates which a Stage 1 was in effect for Shoshone and Lemhi Counties are shown in Appendix E, along with an example of the Stage 1 notification content.

Table 12. Number of days under a DEQ-issued Stage 1 Air Pollution Forecast and Caution

County	Number of days	County	Number of days
Ada	15	Gem	15
Adams	6	Gooding	3
Bannock	4	Idaho	36
Bear Lake	3	Jefferson	4
Benewah	8	Jerome	3
Bingham	3	Kootenai	8
Blaine	31	Latah	21
Boise	18	Lemhi (Salmon)	50
Bonner	8	Lewis	27
Bonneville	4	Lincoln	3
Boundary	8	Madison	4
Butte	4	Minidoka	3
Camas	22	Nez Perce	25
Canyon	15	Oneida	3
Caribou	3	Owyhee	15
Cassia	3	Payette	15
Clark	4	Power	3
Clearwater	29	Shoshone (Pinehurst)	8
Custer	31	Teton	4
Elmore	18	Twin Falls	3
Franklin	3	Valley	6
Fremont	4	Washington	15

8.3 Press Releases

In addition to the Stage 1 Forecast and Cautions, DEQ and the Idaho Department of Health and Welfare (IDHW), Division of Health both issued press releases periodically, which provided additional health protection information. Health protection information included a Centers for Disease Control (CDC 2013) fact sheet on protecting yourself from wildfire smoke and information relating wildfire smoke concentration and the AQI color scale to visual range that citizens can observe for them self to determine if they should take additional protective actions. The DEQ and IDHW press releases are also included in Appendix E.

8.4 Daily Interagency Update Reports

When the severity of the wildfire impact began to be understood, DEQ quickly began holding daily phone calls to provide a forum for gathering fire information from the federal agencies such as the US Forest Service (USFS) and the National Weather Service (NWS) with the intent of passing all available information on to other state and local agencies charged with more direct health protection such as the IDHW state office and the local health districts. The daily

interagency update reports provided during the daily conference calls were designed to disseminate monitoring data, forecasts, and satellite information to the other agencies so that all the agencies could have the best available information and pass it on to citizens. An example of the daily DEQ update reports is also included in Appendix E.

8.5 Air Filters

In addition to Stage 1 Forecast and Cautions, press releases, and Interagency updates, DEQ acted expeditiously to help the Salmon School District to mitigate student's health risk by assisting the Salmon School District with indoor air quality issues in the elementary and middle schools. DEQ purchased 43 HEPA filters for the Salmon School District. These filters helped improve the air quality inside the schools. During this time, Salmon experienced 1 day in the *Hazardous*, 6 days in the *Very Unhealthy*, and 21 days in the *Unhealthy* category for air quality.

9 Procedural Requirements

The EER establishes specific procedural requirements that an air agency must follow to request data exclusion (EPA 2013). Those requirements and DEQ's actions to meet them are summarized in Table 13.

Table 13. DEQ compliance with procedural requirements of the Exceptional Events Rule.

Exceptional Event Rule Procedural Requirements	DEQ Action/Intended Action
A State shall notify EPA of its intent to exclude one or more measured exceedances of an applicable ambient air quality standard as being due to an exceptional event by placing a flag in the appropriate field for the data record of concern which has been submitted to the AQS database... 40 CFR § 50.14(c)(2)(i).	DEQ notified EPA that it placed flags on numerous the monitor values originally thought to be affected by wildfires above the level of the annual $PM_{2.5}$ standard, 12 $\mu g/m^3$ and that we intended to request EPA concurrence to exclude some or all of them from the AQS database.
The placement of the flags and the submittal of an initial event description must be done *not later than July 1st of the calendar year following the year in which the flagged measurement occurred.* 40 CFR § 50.14(c)(2)(iii).	DEQ placed flags on all the monitor values described in this report in prior to July 2013.
A State that has flagged data as being due to an exceptional event and is requesting exclusion of the affected measurement data shall, after notice and opportunity for public comment, submit a demonstration to justify data exclusion to EPA not later than the lesser of, 3 years following the end of the calendar quarter in which the flagged concentration was recorded or, 12 months prior to the date that a regulatory decision must be made by EPA. A State must submit the public comments it received along with its demonstration to EPA. 40 CFR § (50.14(c)(3)(i)).	DEQ is submitting this package for public comment and intends to subsequently submit it to EPA by December 12, 2013 so that it is considered during the $PM_{2.5}$ designation process for the annual $PM_{2.5}$ NAAQS.
With the submission of the demonstration, the air agency *must document that the public comment process was followed.* 40 CFR § (50.14(c)(3)(iv)).	DEQ is presenting this demonstration for public comment in early November 2013 and anticipates completing the public comment process by December 5, 2013.

10 References

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