



Delivered via e-mail

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RE: Utah Petroleum Association's Supplemental Comments on the Proposed Rulemaking, Revisions to Section IX, Control Measures for Area and Point Sources, Part H, Emissions Limits & Amend R307-110-17

Dear Mr. Bird and UDAQ Staff,

The Utah Petroleum Association (UPA) submits these comments and attached documents on the proposed rulemakings: Revisions to Section IX, Control Measures for Area and Point Sources, Part H, Emission Limits, and R307-110-17, Section IX, Control Measures. This letter supplements and is in addition to other comments submitted by UPA and by its individual member companies under separate letters.

UPA was founded in 1958 and its members comprise every segment of the petroleum industry in Utah. UPA's members include four companies that own and operate refineries – i.e., Big West Oil LLC, Chevron Products Company, HollyFrontier Woods Cross Refining LLC, and Tesoro Refining & Marketing Company LLC – identified as major stationary sources subject to the emission limitations and other requirements proposed in this rulemaking.

UPA appreciates the opportunity to provide these comments and appreciates the Utah Air Quality Board's (AQB) decision to provide a 45-day comment period for the rulemaking actions. Furthermore, UPA appreciates the expertise and professionalism that the Utah Division of Air Quality (UDAQ) brings to its work in addressing the Salt Lake City Nonattainment Area's PM_{2.5} nonattainment issues and, particularly, in working with UPA to provide the association with information critical for forming these comments.

In a separate comments letter regarding this rulemaking, UPA stated that one of its principle comments is that UDAQ has failed to include control measures in its proposal that the State is legally obligated to adopt and which have the potential to make a very significant contribution to attaining and maintaining the 24-hour PM_{2.5} standard. This letter provides additional supplemental comments towards that end, specifically with respect to precursor chloride emissions and associated impact on PM_{2.5} formation in the Salt Lake nonattainment area.

The following two documents support UPA's supplemental comments in this letter and are attachments to this letter and part of these comments:

- "Clean Air Act Authority to Control Emissions from Sources Outside the Salt Lake City Nonattainment Area", Baker Botts, July 26, 2018
- "Contributions to Salt Lake City PM_{2.5} from Ammonium Chloride and Evidence for US Magnesium Corporation as its Significant Source", Ramboll, July 2018

As detailed in these two documents, chloride emissions participate in the formation of ammonium chloride in the Salt Lake City PM_{2.5} Nonattainment area, contributing up to 15% of the PM_{2.5} burden in Salt Lake City on PM_{2.5} exceedance days. The presence of chloride may not just be a direct contributor to total PM_{2.5} via formation of ammonium chloride, but also an indirect contributor to a heightened formation rate of nitrate via night time aqueous reactions and daytime photochemical oxidation driven by chlorine. Multiple studies have identified the U.S. Magnesium plant as a substantial anthropogenic source of chloride with air emissions of both gaseous chlorine and hydrochloric acid. Scientific research, routine ambient measurements, emission inventories, and modeling all show that U.S. Magnesium is the dominant source of chloride in the region and that emissions related to the lake, salt flats/playas, or road salting are negligible by comparison. Chlorine is clearly a precursor to PM_{2.5} in the Salt Lake nonattainment area.

The federal Clean Air Act, EPA regulations governing approval of PM_{2.5} State Implementation Plans (SIPs), and EPA guidance all require SIPs to include controls on sources of PM_{2.5} precursors, whether inside or outside the nonattainment area, if controls are necessary to achieve timely attainment. These attainment demonstration controls are independent of Best Available Control Measures. The attached Baker Botts paper provides more detail on these requirements.

As detailed above and in the attached Ramboll report, studies have shown that controls on U.S. Magnesium will reduce ammonium chloride and PM_{2.5} in Salt Lake City and could help to attain the PM_{2.5} National Ambient Air Quality Standard.

Based on current data and studies, UDAQ is required to impose controls on U.S. Magnesium as a necessary step towards achieving timely attainment, but the controls are conspicuously absent from UDAQ's controls strategy made public to-date. If Utah chooses not to impose attainment demonstration emission limits on the U.S. Magnesium plant, EPA has the authority to fill that gap by promulgating a Federal Implementation Plan (FIP).

UPA appreciates UDAQ's and the AQB's consideration of these comments. UPA and its members are available to discuss these comments and attached documents with you and your staff.

Sincerely,



Jennette King
Administrative Assistant

Attachments:

- “Clean Air Act Authority to Control Emissions from Sources Outside the Salt Lake City Nonattainment Area”, Baker Botts, July 26, 2018
- “Contributions to Salt Lake City PM_{2.5} from Ammonium Chloride and Evidence for US Magnesium Corporation as its Significant Source”, Ramboll, July 2018

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CLEAN AIR ACT AUTHORITY TO CONTROL EMISSIONS FROM SOURCES OUTSIDE THE SALT LAKE CITY NONATTAINMENT AREA

This memorandum reviews the State of Utah's authority and obligation under the federal Clean Air Act (the "Act") to regulate emissions of precursors of fine particulate matter ("PM_{2.5}") when a significant source of those precursor emissions is located within the state but outside of the nonattainment area. Specifically, this memorandum reviews Utah's authority and obligation to control chloride emissions from the U.S. Magnesium plant located to the west of Salt Lake City, but outside the Salt Lake City nonattainment area.

In summary:

- The Act requires states with Serious nonattainment areas to submit state implementation plans ("SIPs") providing for (1) attainment of the national ambient air quality standards ("NAAQS") for particulate matter by the applicable attainment date; and (2) provisions to ensure that best available control measures ("BACM") are implemented.
- The Act, EPA regulations governing approval of PM_{2.5} SIPs, and EPA guidance all require SIPs to include controls on sources of PM_{2.5} precursors, whether inside or outside the nonattainment area, if controls are necessary to achieve timely attainment. These attainment demonstration controls are independent of BACM.
- Atmospheric chloride is a precursor to PM_{2.5}. Studies have shown that the U.S. Magnesium plant is the only significant source of chloride emissions affecting the Salt Lake City area. The U.S. Magnesium plant's chloride emissions are above the level that EPA guidance suggests "contributes significantly" to nonattainment.
- Studies have also shown that controls on U.S. Magnesium will reduce ammonium chloride and PM_{2.5} in Salt Lake City and could help to attain the NAAQS.
- Based on the current data and studies, the State is required to impose controls on U.S. Magnesium as a necessary step towards achieving timely attainment.

Further discussion on each point is outlined below.

I. Legal Background

The Act establishes NAAQS for particulate matter and requires states to submit a State Implementation Plan (“SIP”) for each nonattainment area that has been designated “Serious.”¹ Pursuant to EPA’s regulations implementing the PM_{2.5} NAAQS, that SIP, also referred to in the implementing regulations as a “Serious area attainment plan,”² must include (1) a demonstration that the plan provides for attainment of the PM_{2.5} NAAQS by the attainment date; and (2) provisions to assure that BACM for the control of PM_{2.5} shall be implemented no later than four years after the date the area was classified as Serious.³ Additionally, the Act explicitly extends the SIP control requirements to precursors of particulate matter as well as particulate matter itself, provided that the precursor sources contribute significantly to the exceedance of the NAAQS.⁴

EPA finalized an updated SIP implementation rule for PM_{2.5} in August 2016.⁵ The updated rule retained the previous 24-hour PM_{2.5} NAAQS of 35 micrograms per cubic meter

¹ CAA § 189(b)(1); 42 U.S.C. § 7513a(b)(1); 40 C.F.R. § 51.1003. Although the Act establishes NAAQS for particulate matter that is ten micrometers or smaller (“PM₁₀”), courts have previously held that EPA’s regulations regarding PM_{2.5} should be governed not only by the general NAAQS requirements found at CAA section 172, but also by the requirements found in CAA sections 188-190, 42 U.S.C. sections 7513-7513b. *Nat’l Res. Def. Council v. EPA*, 706 F.3d 428, 435 (D.C. Cir. 2013). Therefore, the Act’s language regarding PM₁₀ SIP requirements is applicable to the PM_{2.5} SIP requirements as well.

² *See, e.g.*, 81 Fed. Reg. 58010, 58074 (Aug. 24, 2016) (referring to the SIP requirements in section 189(b) as “requirements for Serious area attainment plan submissions . . .”).

³ CAA § 189(b); 42 U.S.C. § 7513a(b), 40 C.F.R. § 51.1003. States may, under certain circumstances, seek an extension of the attainment date. For areas seeking an extension of the attainment date under section 189(e), the Act requires a demonstration that the attainment date is impractical and that the area will be in attainment by the most expeditious date possible. CAA § 189(b)(1); 42 U.S.C. § 7513a(b)(1). Because we understand that Utah is preparing a SIP submittal designed to focus on attainment by December 31, 2019, the extension criteria are outside the scope of this memorandum.

⁴ CAA § 189(e), 42 U.S.C. § 7513a(e). Although the SIP implementation rule defines “PM_{2.5} precursors” to include SO₂, NO_x, volatile organic compounds, and ammonia, the preamble to the rule states that it “does not include any national presumption that would allow a state to exclude, without a demonstration, sources of emissions of a particular precursor from further analysis for attainment plan or NNSR control requirements in a PM_{2.5} nonattainment area.” 40 C.F.R. § 51.1000; 81 Fed. Reg. at 58014, 58019. The preamble also acknowledges that in “[i]n some areas, less common ions such as chloride are also found in PM_{2.5} samples.” 81 Fed. Reg. at 58015.

⁵ The final rule became effective on October 24, 2016. 81 Fed. Reg. 58010 (Aug. 24, 2016). EPA first promulgated PM_{2.5} NAAQS in 1997. 62 Fed. Reg. 38652 (July 18, 1997). Those NAAQS became effective in 2005, and under the initial PM_{2.5} NAAQS the Salt Lake City area was classified as “unclassifiable/attainment.” 70 Fed. Reg. 944, 1009 (Jan. 5, 2005). The PM_{2.5} NAAQS was reevaluated in 2006, and the 24-hour PM_{2.5} standard was lowered to 35 micrograms per cubic meter to better reflect current scientific data, a level that was maintained in the 2012 reevaluation of the PM_{2.5} NAAQS. 71 Fed. Reg. 61144 (Oct. 17, 2006); 77 Fed. Reg. 38890 (June 29, 2012). Under that new standard, the Salt Lake City area was redesignated as a moderate nonattainment area. 74 Fed. Reg. 58688, 58696 (Nov. 13, 2009). In 2007 and 2008, EPA promulgated rules to assist states with developing their SIP submissions. 72 Fed. Reg. 20583 (Apr. 25, 2007); 73 Fed. Reg. 28231 (May 16, 2008). However, those rules incorporated only CAA section 172’s general NAAQS requirements rather than the CAA’s PM₁₀ NAAQS, and in 2013 a court remanded both rules to EPA for repromulgation. *Nat’l Res. Def. Council v. EPA*, 706 F.3d 428, 435 (D.C. Cir. 2013). The 2016 NAAQS SIP rule is the result of that repromulgation.

(“ $\mu\text{g}/\text{m}^3$ ”).⁶ Under this NAAQS, the Salt Lake City area was initially classified as a moderate nonattainment area.⁷

On May 10, 2017, EPA issued a final rule reclassifying Salt Lake City as a Serious nonattainment area due to its failure to meet the 24-hour $\text{PM}_{2.5}$ NAAQS by December 31, 2015.⁸ The reclassification became effective on June 9, 2017.⁹ The determination that Salt Lake City had not met the 24-hour $\text{PM}_{2.5}$ NAAQS was made by finding the 98th percentile value for 2013, 2014, and 2015 $\text{PM}_{2.5}$ levels, then averaging those three values.¹⁰ The three-year average of 98th percentile values for Salt Lake City was $45 \mu\text{g}/\text{m}^3$, which exceeded the NAAQS of 35.¹¹ Because the Salt Lake City area has been reclassified as a Serious nonattainment area, Utah is required to demonstrate in its Serious area attainment plan that the Salt Lake City area will attain the $\text{PM}_{2.5}$ NAAQS as expeditiously as practicable but not later than December 31, 2019, and include provisions to assure that appropriate control requirements will be implemented.¹² We understand that Utah’s Serious area attainment plan is still in development.

II. Authority for Control Measures on Sources Outside Nonattainment Areas

A. States Must Include Necessary Control Measures for Sources of $\text{PM}_{2.5}$ Precursors

Under section 189(b)(1)(B) of the Act, a state’s Serious area attainment plan must include provisions to assure that control measures will be implemented no later than four years after the area’s classification as Serious.¹³ Section 189(e) of the Act requires states to apply control requirements to sources of $\text{PM}_{2.5}$ precursors that contribute to exceedances of the $\text{PM}_{2.5}$ NAAQS.¹⁴ In that same section, Congress charged EPA with promulgating guidelines regarding the application of the control requirements to sources of $\text{PM}_{2.5}$ precursors.¹⁵ In its implementing regulation, EPA explicitly extended the control measures requirement to sources of precursors located outside the attainment area:

The state shall adopt control measures, including control technologies, on sources of direct $\text{PM}_{2.5}$ emissions and sources of emissions of $\text{PM}_{2.5}$ plan precursors located within the state but outside the Serious $\text{PM}_{2.5}$

⁶ 81 Fed. Reg. 58010, 58071.

⁷ 81 Fed. Reg. 91088, 91089 (Dec. 16, 2016).

⁸ 82 Fed. Reg. 21711, 21712 (May 10, 2017).

⁹ *Id.* at 21711.

¹⁰ See 40 C.F.R. § 50 Appendix N. The 98th percentile value for each year is calculated by listing the daily $\text{PM}_{2.5}$ values in descending order, then using the chart in Appendix N to 40 C.F.R. Part 50 to determine which value is the 98th percentile value. *Id.* For the purposes of determining attainment, the relevant years are the three most recent years that meet the regulatory data completeness requirements. *Id.*

¹¹ 82 Fed. Reg. 21711, 21713.

¹² *Id.*

¹³ CAA § 189(b)(1)(B), 42 U.S.C. § 7513a(b)(1)(B).

¹⁴ CAA § 189(e), 42 U.S.C. § 7513a(e).

¹⁵ *Id.*

nonattainment area if adopting such control measures is necessary to provide for attainment of the applicable PM_{2.5} NAAQS in such area by the attainment date.¹⁶

EPA reiterated this stance in the preamble to the recent SIP implementation rule: “[a] state may need to require emissions reductions on sources located outside of a PM_{2.5} nonattainment area if such reductions are needed in order to provide for expeditious attainment of the PM_{2.5} NAAQS.”¹⁷ Additionally, the state “*must* also adopt other emission reduction measures . . . if such measures in conjunction with other control measures would enable the area to attain the standard by the attainment date, or enable the area to advance the attainment date by at least 1 year.”¹⁸ Therefore, the state is required to impose controls on precursor sources outside the nonattainment area if controlling those precursors is a necessary step towards achieving timely attainment.

B. “Significant” Precursor Source Contribution to PM_{2.5} Levels

The Act requires states to include in their Serious area attainment plans control measures for sources of PM_{2.5} and precursors to PM_{2.5} that “contribute significantly” to PM_{2.5} levels in the attainment area.¹⁹ EPA guidance notes that when determining whether a PM_{2.5} precursor source “contributes significantly” to PM_{2.5} levels – and therefore must have controls included in the state’s implementation plan under the Act – a contribution threshold of 1.5 ug/m³ is one factor that distinguishes between significant and insignificant contributions.²⁰ Other relevant factors include the amount by which the precursor’s contribution exceeds the recommended contribution threshold; the severity of nonattainment; analyses of speciation data and precursor emission inventories; chemical tracer studies; measurement studies evaluating

¹⁶ 40 C.F.R. § 51.1010(d) (emphasis added); 81 Fed. Reg. 58010, 58159 (Aug. 24, 2016).

¹⁷ 81 Fed. Reg. 58010, 58080 (emphasis added). This echoes the Act’s requirement that states demonstrate attainment “as expeditiously as practicable.” CAA § 188(c)(2), 42 U.S.C. § 7513(c)(2).

¹⁸ 81 Fed. Reg. at 58083 (emphasis added).

¹⁹ CAA § 189(b), 42 U.S.C. § 7513a(b); CAA § 189(e), 42 U.S.C. § 7513a(e); 40 C.F.R. § 51.1010(a); *see also* CAA § 172(c)(6) (nonattainment plan provisions “shall include enforceable emission limitations, and such other control measures, means or techniques (including economic incentives such as fees, marketable permits, and auctions of emission rights), as well as schedules and timetables for compliance, as may be necessary or appropriate to provide for attainment of such standard in such area by the applicable attainment date”). If a source does not contribute significantly to PM_{2.5} levels, the state may submit an optional precursor demonstration, and if EPA approves the precursor demonstration then the state will not be required to include control measures for that source in its attainment plan. 40 C.F.R. §§ 51.1006(a)(1); 51.006(a)(2); 51.1010(a)(2).

²⁰ A 2016 draft guidance included a contribution threshold of 1.3 ug/m³. EPA, “Draft PM_{2.5} Precursor Demonstration Guidance,” Nov. 17, 2016, at 15-16, available at https://www.epa.gov/sites/production/files/2016-11/documents/transmittal_memo_and_draft_pm25_precursor_demo_guidance_11_17_16.pdf. However, in April 2018, EPA created an updated final version of the Technical Basis Document cited in the 2016 draft guidance. *Id.* at 12; EPA, “Technical Basis for the EPA’s Development of the Significant Impact Thresholds for PM_{2.5} and Ozone,” Apr. 2018, available at https://www.epa.gov/sites/production/files/2018-04/documents/ozon_pm2.5_sils_technical_document_final_4-17-18.pdf. That updated version of the technical basis document includes more recent data and adjusts the “significant contribution” threshold for the 24-hour PM_{2.5} NAAQS to 1.5 ug/m³. *Id.* at 48.

specific atmospheric chemistry in the area; and trends in ambient speciation data and precursor emissions.²¹

EPA guidance does not draw a distinction between PM_{2.5} precursor sources located in the nonattainment area and those that are located outside the nonattainment area. Regardless of the source's location, if its emissions of PM_{2.5} precursors contribute significantly to the PM_{2.5} NAAQS exceedance – therefore making control measures on those emissions necessary for expeditious attainment of the PM_{2.5} NAAQS – the state is obligated to impose controls.

III. Imposition of Control Measures on the U.S. Magnesium Plant

The U.S. Magnesium plant located outside the Salt Lake City nonattainment area is a source of chloride emissions – a known PM_{2.5} precursor – that contribute significantly to the NAAQS exceedance, through its air emissions of gaseous chloride and hydrochloric acid. According to a 2013 study, ammonium chloride and atmospheric chloride can be a significant source of winter PM_{2.5} in the Salt Lake City area, contributing up to 10-15% of the total PM_{2.5} on days where the 24-hour PM_{2.5} level exceeded 30 micrograms per cubic meter.²² In addition to determining the extent to which chloride and ammonium chloride emissions contributed to winter PM_{2.5}, the 2013 study also found that the one significant source of chloride emissions in the Salt Lake City airshed was the U.S. Magnesium plant located west of Salt Lake City.²³

Other possible sources of chloride emissions evaluated in the study – *e.g.*, road salting, industrial emissions from other sources, and biological activity linked to the Great Salt Lake – were not significant enough sources to account for the effect on PM_{2.5} levels.²⁴ The level of sodium was not as high as would be expected if the chloride emissions came from salt, and emissions from the Great Salt Lake were insufficient to account for the chloride emission levels.²⁵ In Utah's 2008 PM_{2.5} SIP, the U.S. Magnesium plant's reported estimate of chloride emissions was 579 tons per year, or 96.6% of the reported anthropogenic chloride emissions in the airshed.²⁶ More recent emissions data shows that the U.S. Magnesium plant is responsible for over 99% of chloride emissions from point sources in the state of Utah.²⁷

²¹ *Id.* at 17.

²² Kerry E. Kelly et al., "Receptor Model Source Attributions for Utah's Salt Lake City Airshed and the Impacts of Wintertime Secondary Ammonium Nitrate and Ammonium Chloride Aerosol," Feb. 20, 2013, available at <http://www.tandfonline.com/doi/full/10.1080/10962247.2013.774819>. The study was conducted by taking PM_{2.5} samples from monitors in Salt Lake City, Bountiful, and Lindon; performing source apportionment using two models, positive matrix factorization ("PMF") and Unmix; and then comparing that data to emissions inventories. *Id.*

²³ *Id.*

²⁴ *Id.*

²⁵ *Id.*

²⁶ *Id.*

²⁷ See Utah Department of Environmental Quality, "2014 Statewide Hazardous Air Pollutants – Point Sources," available at <https://deq.utah.gov/ProgramsServices/programs/air/emissionsinventories/docs/2016/2014-HAPs-Detail-by-County.pdf>; Utah Department of Environmental Quality, "2011 Statewide Hazardous Air Pollutants – Point Sources," available at _____

Although a refined analysis examining plume dispersion from the U.S. Magnesium plant was beyond the scope of the 2013 study, a screening-level plume study using the National Oceanic and Atmospheric Administration's ("NOAA's") online modeling system indicated that emissions from the U.S. Magnesium plant could easily be a "significant" contributor to the winter PM_{2.5} levels.²⁸ A trajectory analysis using 2011 emissions data and wind patterns identified several plausible paths for the transport of emissions from the U.S. Magnesium plant to Salt Lake City on days that had PM_{2.5} levels exceeding the 98th percentile values. A weight of evidence analysis synthesizing modeling results, available scientific studies, monitoring results, emissions reports, and other information concluded that the U.S. Magnesium plant is a significant contributor to PM_{2.5} levels in Salt Lake City and may contribute to PM_{2.5} not only directly (through formation of ammonium chloride) but also indirectly (through increasing the formation rate of other PM_{2.5} constituents).²⁹

The regulations implementing the Act require states to adopt control technologies for sources that emit PM_{2.5} or PM_{2.5} precursors "if adopting such control measures is necessary to provide for attainment of the applicable PM_{2.5} NAAQS in [Serious nonattainment areas] by the attainment date."³⁰ Given the relationship between atmospheric chloride and the formation of PM_{2.5}, the volume of chloride emissions from the U.S. Magnesium plant, and analyses regarding transmission of emissions from the U.S. Magnesium plant to Salt Lake City, scientific data indicate that chloride emissions from the U.S. Magnesium plant contribute significantly to PM_{2.5} exceedances in the Salt Lake City Area and controls will be required to achieve attainment with the PM_{2.5} NAAQS. In order to comply with the Act and the rule, Utah has not only the authority to impose controls on sources of PM_{2.5} precursors outside the nonattainment area, but also an obligation to do so.

Should Utah fail to include controls for the U.S. Magnesium plant's chloride emissions in its SIP, EPA would have authority to fill that gap by imposing a federal implementation plan ("FIP"). If the control measures in a state's SIP are "substantially inadequate to attain or maintain" the applicable NAAQS, EPA has the authority to issue a SIP call and promulgate a FIP imposing appropriate controls.³¹

In *Montana Sulphur & Chemical Company v. EPA*, 666 F.3d 1174 (9th Cir. 2012), the court held that EPA did not act arbitrarily and capriciously by issuing a FIP based on Montana's failure to control industrial SO₂ emissions linked to predicted NAAQS violations.³² The state of Montana had eliminated numerical emissions limits for flares from its SIP after concluding that

<https://deq.utah.gov/ProgramsServices/programs/air/emissionsinventories/docs/2013/03Mar/2011%20Statewide%20Point%20Sources-HAPsCountyDetails.pdf>

²⁸ Chris Emery and Sue Kemball-Cook, "Contributions to Salt Lake City PM_{2.5} from Ammonium Chloride and Evidence for US Magnesium Corporation as its Significant Source," July 2018.

²⁹ *Id.*

³⁰ 40 C.F.R. § 51.1010(d); 81 Fed. Reg. 58010, 58159 (Aug. 24, 2016).

³¹ CAA § 110(k)(5), 42 U.S.C. 7410(k)(5); *Montana Sulphur & Chemical Co. v. EPA*, 666 F.3d 1174, 1184 (9th Cir. 2012).

³² *Montana Sulphur & Chemical Co.*, 666 F.3d at 1179.

such limits were technically infeasible.³³ EPA then imposed a FIP containing numerical limits calculated at a level necessary to attain the NAAQS. A sulfur recovery plant challenged the FIP, arguing in part that the numerical emission limits were arbitrary and went beyond what was necessary to satisfy the NAAQS.³⁴ The court disagreed, finding that those limits were neither arbitrary nor capricious because they were based on emission rates that would just meet the NAAQS and because EPA had reasonably interpreted the Act to require them to achieve attainment.³⁵ The court upheld EPA's action in full. If Utah chooses not to impose attainment demonstration emission limits on the U.S. Magnesium plant, EPA has the authority to fill that gap by promulgating a FIP.

³³ *Id.* at 1191.

³⁴ *Id.* at 1192-93.

³⁵ *Id.*

Contributions to Salt Lake City PM_{2.5} from Ammonium Chloride and Evidence for US Magnesium Corporation as its Significant Source

Final Report

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EXECUTIVE SUMMARY

This paper presents a weight-of-evidence analysis that clearly identifies ammonium chloride as a significant contributor to fine particulate ($PM_{2.5}$) concentrations that exceed the National Ambient Air Quality Standard (NAAQS) in the Salt Lake City Serious Nonattainment Area, and indicates that US Magnesium Corporation is the single culpable source. We present evidence based on a literature review of recent scientific studies (Section 1.1), analysis of routine ambient $PM_{2.5}$ monitoring (Section 2), analysis of emission inventories for the region (Section 3), and photochemical modeling of particulate chloride performed using the Utah Division of Air Quality (UDAQ) modeling platform developed to support the Salt Lake City $PM_{2.5}$ State Implementation Plan (SIP) (Section 4).

Ambient $PM_{2.5}$ concentrations along the Wasatch Front commonly exceed the NAAQS during wintertime inversion events referred to as “persistent cold air pools” (PCAPs). Ammonium nitrate comprises the majority (up to 70%) of ambient $PM_{2.5}$ during winter exceedance episodes, and 40% at other times. Chloride emissions participate in the formation of ammonium chloride, which contributes up to 15% of the $PM_{2.5}$ burden in Salt Lake City on $PM_{2.5}$ exceedance days.

Researchers have measured significant contributions of aerosol chloride to elevated $PM_{2.5}$ concentrations, as well as high levels of nitryl chloride, a source of radicals for daytime photochemical production of secondary pollutants such as ozone and nitrate. Therefore, the presence of chloride may not just be a direct contributor to total $PM_{2.5}$ (via formation of ammonium chloride), but also an indirect contributor to a heightened formation rate of nitrate via night time aqueous reactions and daytime photochemical oxidation driven by chlorine.

Multiple studies have identified the U.S. Magnesium plant as a substantial anthropogenic source of chloride, with air emissions of both gaseous chlorine and hydrochloric acid. Aircraft flights during the 2017 Utah Winter Fine Particulate Study (UWFPS) detected plumes rich in halogens around and downwind of this facility. In fact, the highest concentrations of most halogens measured during the UWFPS were found in the U.S. Magnesium plume.

Our analysis of routine ambient measurements, emission inventories for the region, and emissions reports submitted by US Magnesium all suggest the influence of aerosol chloride from US Magnesium on Salt Lake City $PM_{2.5}$. Routine ambient measurements clearly show that during exceedance events, aerosol chloride concentrations at Salt Lake City monitors commonly surpass the level that the US Environmental Protection Agency (EPA, 2016) considers a “significant contribution” to 24-hour $PM_{2.5}$. UDAQ’s emission inventories indicate that US Magnesium total chloride emissions are consistently and by far the largest emissions of chloride in the region (4 times larger than all other chloride sources combined). Photochemical modeling using the current UDAQ January 2011 modeling platform confirms that US Magnesium contributes to high levels of ambient particulate chloride concentrations in the region, but shows a contribution to Salt Lake City $PM_{2.5}$ levels that is less than actually observed

at the Hawthorne monitor¹ in Salt Lake City during January 2011. It is difficult for meteorological models to simulate the slow, shifting winds typical of a PCAP. Winds patterns during the stagnant January 2011 PCAP episode may not be sufficiently well simulated for the photochemical model to replicate the actual source-receptor transport.

Scientific research, routine ambient measurements, emission inventories, and modeling all show that US Magnesium is the dominant source of chloride in the region (i.e., the contributions from emissions related to the lake, salt flats/playas or road salting are negligible by comparison). No other natural or anthropogenic source of chloride precursors appears to play an important role in the PM_{2.5} burden on exceedance days. Therefore, the weight of evidence suggests US Magnesium is a “significant contributor”, as defined by EPA (2016), to exceedances of the PM_{2.5} NAAQS in Salt Lake City. Although EPA does not identify chlorine as a precursor in the PM_{2.5} SIP rule (Federal Register, 2016), chlorine is clearly a precursor in this case, as it participates in the formation of ammonium chloride, which contributes up to 15% of the PM_{2.5} burden in Salt Lake City on PM_{2.5} exceedance days. Furthermore, in implementing this rule, EPA reiterates that a state may need to extend control measures to sources of precursors located outside the attainment area. Controls on US Magnesium will reduce ammonium chloride and PM_{2.5} in Salt Lake City and could help to attain the PM_{2.5} NAAQS. Therefore, controls on US Magnesium warrant further consideration as UDAQ develops emission control strategies.

¹ The Hawthorne monitor is the only Salt Lake City site where routine chloride measurements are made.

1.0 INTRODUCTION

The US Environmental Protection Agency (EPA) designated Salt Lake City, Utah, as a Serious Nonattainment Area for the 24-hour fine particulate (PM_{2.5}) National Ambient Air Quality Standards (NAAQS) (Federal Register, 2017). The new PM_{2.5} State Implementation Plan (SIP) Requirements Rule issued by EPA in August 2016 for Serious Areas (Federal Register, 2016) requires new SIP revisions that demonstrate attainment of the PM_{2.5} NAAQS by December 31, 2019. To provide the technical underpinnings of the Salt Lake City Serious Area PM_{2.5} SIP, the Utah Division of Air Quality (UDAQ) has developed a photochemical modeling platform that simulates conditions during a January 2011 persistent cold air pool (PCAP) event that resulted in exceedances of the PM_{2.5} NAAQS over multiple days. UDAQ has prepared emission inventories representing the years 2014, 2016 and 2019, from which the photochemical model will project future-year 24-hour PM_{2.5} Design Values (DV). Besides accounting for economic and population projections in the region, the 2019 emission inventory must reflect necessary local emission reductions for area and industrial point sources, as well as federal programs affecting on-road and non-road mobile sources, which will result in attaining the PM_{2.5} NAAQS.

Given that remaining control options for industrial sources in the Salt Lake City (SLC) Nonattainment Area (NAA) are approaching practical limits on efficacy (i.e, cost-per-ton and contribution significance) it is important to identify all remaining significant contributors to the local PM_{2.5} mass budget during exceedance events. In this paper, we present a weight-of-evidence analysis that identifies significant contributions to PM_{2.5} exceedance events from ammonium chloride, a chemical compound formed from a precursor (chlorine) whose emissions are overwhelmingly from a single facility (US Magnesium Corporation) in the form of both gaseous chlorine and hydrochloric acid. Figure 1 shows the spatial relation between the SLC NAA and the US Magnesium facility. The plant is located in eastern Tooele County on the western edge of Stansbury Bay of the Great Salt Lake, approximately 70 km due west of SLC.

The remainder of this section (Section 1.1) presents a brief literature review of the current state of knowledge on the presence of chloride and its contribution to PM_{2.5} in SLC. Later sections review evidence from SLC routine ambient monitoring of chloride (Section 2), reported regional emission rates of chloride precursors over the past several years (Section 3), and photochemical modeling of SLC region particulate chloride performed using UDAQ's current SIP modeling platform (Section 4).

1.1 Evidence from the Literature

1.1.1 Initial Chloride Assessment

Kelly et al. (2013; hereafter referred to as K13) were the first to report on the importance of secondary ammonium chloride particle contributions to high wintertime concentrations of PM_{2.5} along the Wasatch Front. K13 analyzed chemically speciated PM_{2.5} surface measurements from the Bountiful, Lindon and Salt Lake City Speciated Trends Network monitors (STN; now referred to as Chemical Speciation Network or CSN). They used two receptor-based source apportionment techniques referred to as "factor analysis" to identify the

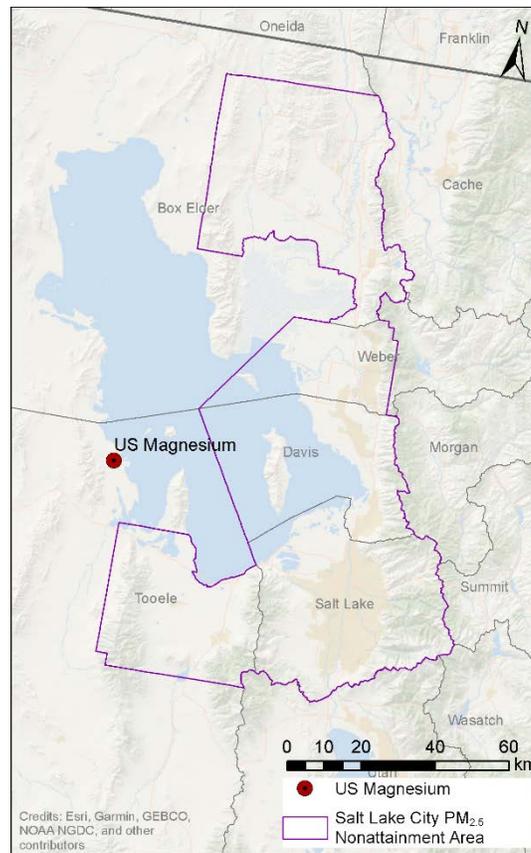


Figure 1. Map of the SLC PM_{2.5} NAA showing the location of the US Magnesium plant.

components and sources of measured PM_{2.5}: positive matrix factorization (PMF; Norris et al., 2008) and the EPA’s Unmix model (EPA, 2007). K13 supplied to these models over 200 days of measurements at each location during 2007–2011. During wintertime PCAP PM_{2.5} episodes (> 20 µg/m³), both methods showed large contributions from secondary PM_{2.5}, with ammonium nitrate consistently the largest contributor (60 to 80%) at all three monitors. The PMF analysis also identified secondary ammonium chloride, which contributed 10–15% of the total PM_{2.5} mass on days when the 24-hr hour PM_{2.5} concentration exceeded 30 µg/m³ (i.e., at least 3 to 4.5 µg/m³). The ammonium chloride mass only exceeded 3 µg/m³ during cold weather (maximum daily temperature < 10°C), when exceedances of the 24-hour PM_{2.5} NAAQS typically occur, consistent with present understanding of the thermodynamics of chloride aerosol formation (Pio and Harrison, 1987).

K13 cite Chang and Allen (2006), who describe the partitioning between gas and particle phases when nitrate, sulfate, and chloride are mixed with ammonia. Whereas sulfate always exists as an aerosol (regardless of a neutralizing cation such as ammonia), nitrate and chloride may exist as aerosols only when neutralized, otherwise they remain as nitric or hydrochloric acid gases, respectively. When ammonia levels are insufficient, sulfate is preferentially neutralized over other ammonium salts, and the other acids remain in gas phase. Ammonia-rich conditions occur when there is sufficient ammonia to neutralize all acids. Studies prior to K13

demonstrated that SLC is ammonia-rich during winter PM_{2.5} pollution episodes (UDAQ, 2011). K13 confirmed the presence of ammonium chloride aerosol at the three Wasatch Front monitors through an ion balance analysis that included key acids (nitrate, sulfate, chloride) and neutralizing cations (ammonium, sodium, potassium).

K13 concluded that ammonium chloride aerosol can be a significant source of wintertime PM_{2.5}. They considered three potential sources of atmospheric chlorine in the Salt Lake region: wintertime road salting, industrial emissions, and biological activity linked to the Great Salt Lake and surrounding marshes. K13 ruled out road salt as a possible source of chlorine based on low levels of measured sodium, as well as the absence of reports at that time of ammonium chloride aerosol in other urban areas that conduct road salting (see Section 1.1.4 of this document). They left biogenic emissions from the Great Salt Lake and surrounding area as a subject for further study (see Section 1.1.2 of this document). They reviewed UDAQ's 2008 anthropogenic emission inventory and determined that US Magnesium was the sole significant industrial source of chloride in the region, contributing 96.6% of the total reported anthropogenic chlorine emissions for the airshed. K13 performed screening-level dispersion modeling of the US Magnesium plume using the HYSPLIT trajectory model (Draxler and Rolph, 2012). From modeling they confirmed that *"chlorine emissions from US Magnesium, Inc., might be a significant contributor to aerosol chlorine observed at the three STN PM_{2.5} samplers along the Wasatch Front."*

1.1.2 Utah Winter Fine Particulate Study (UWFPS)

A consortium of investigators conducted the UWFPS to gain better understanding of PM_{2.5} constituents and precursors, their three-dimensional distributions, ambient chemistry, and related meteorological factors that occur during winter PCAP episodes (Baasandorj et al., 2018). Conducted during December 2016 through February 2017, this comprehensive field study included surface and aircraft intensive monitoring of two major PCAP/PM_{2.5} episodes during mid-January and early February. Investigators measured the highest aerosol concentrations during the second episode. The UWFPS performed aircraft sampling at low levels (below 600 m) to sample the polluted cold air pool, and included vertical profiling via missed approaches at the airfields. Flights occurred at different times of day, including at night, covering Cache, Utah and Salt Lake Valleys as well as transects over the southwest portion of the Great Salt Lake. The results of K13 informed certain UWFPS research questions; in particular, some flights were designed to study aerosol chloride and to evaluate the relative importance of natural and anthropogenic sources of chloride across the airshed. A suite of instruments measured halogens and provided the first measurements of reactive chlorine compounds in the region.

Consistent with previous monitoring and the K13 study, UWFPS investigators found that ammonium nitrate dominated during PCAP events (>70%), with lesser contributions from organic aerosols (~20%), sulfate (<9%), and "non-refractory" chloride² (<2%). The average distribution of mass among these components was similar in the Cache, Salt Lake and Utah

² UWFPS investigators state that "non-refractory" indicates chloride that is not due to lake salt, road salt or dust.

Valleys. However, there were spatial variations evident in the aircraft chloride measurements, with higher concentrations in the vicinity of the Great Salt Lake, and generally higher concentrations near the surface than aloft, consistent with a near-surface source of emissions, such as a facility stack rather than an aloft layer that might indicate regional transport from some other distant source. Measurements also consistently detected fine particulate alkali and alkaline metals (sodium, calcium, and magnesium) during the afternoon, possibly picked up over the Lake and shoreline playas and moved inland by the lake breeze circulation. The UWFPS report reiterates that in the presence of excess ammonia, hydrochloric acid will partition to aerosol particles thereby contributing to PM_{2.5} mass concentrations through the formation of ammonium chloride. Data analyses show that the measured ions were generally balanced during PCAP episodes, with the number of anions (Cl⁻, NO₂⁻, NO₃⁻, SO₄⁼) essentially equal to the number of cations (Na⁺, K⁺, NH₄⁺, Mg⁺⁺, Ca⁺⁺). This result is consistent with the results of K13.

The UWFPS found that halogen compounds including chlorine exist throughout the region at concentrations as high as coastal urban areas. Researchers identified the US Magnesium plant as the largest source of reactive halogens in the region based on aircraft observations showing the highest concentrations in the vicinity of that plant (Figure 2). In fact, the UWFPS reports some of the highest concentrations of these compounds ever measured in wintertime aircraft observations. Maximum molecular chlorine (Cl₂) exceeded 500 ppb during one nighttime plume transect, and typically ranged from 30 to 100 ppb. Furthermore, during multiple events, boundary layer ozone was depleted to zero corresponding to elevated halogen concentrations, which are known to catalytically deplete ozone (Figure 3). The UWFPS report seems to rule out lake and road salting activities as a source of chloride based on the lack of sodium relative to chloride levels, but indicates the need for additional analyses.

Besides significant contributions of aerosol chloride, investigators measured large quantities of nitryl chloride gas (ClNO₂) in areas rich in NO_x. Chloride aerosols are involved in the heterogeneous nighttime conversion of N₂O₅ (a NO_x “reservoir” species) to ClNO₂ and nitrate. The ClNO₂ photolyzes the next day into Cl atoms and NO_x, and so is a source of radicals for photochemical production of ozone and nitrate. Consistent with this fact, aircraft measurements show higher ClNO₂ over the NO_x-rich urban areas (Figure 4). The UWFPS report concludes:

“The recent analysis from Salt Lake City showing several $\mu\text{g m}^{-3}$ attributable to ammonium chloride aerosol, accounting for 15% of PM_{2.5} mass, suggests that this chemistry may be particularly active in that region. If so, the atmospheric chemistry of winter PM_{2.5} in northern Utah may be complex, with a nighttime residual layer component and a daytime photochemical component due to atomic chlorine.”

This means that the presence of chloride may not just be a direct contributor to total PM_{2.5} (via formation of ammonium chloride), but also an indirect contributor to a heightened formation rate of nitrate via nighttime aqueous reactions and daytime photochemical oxidation rates driven by chlorine.

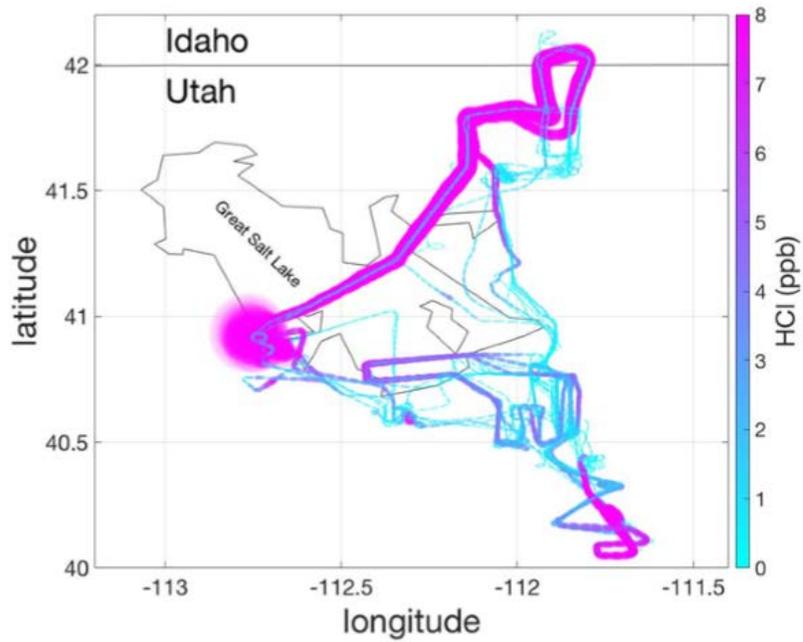


Figure 2. Spatial distribution of hydrochloric acid (HCl) during UWFPS aircraft flights. Color and line thickness indicate concentration levels (taken from Figure 3.44 of Baasandorj et al., 2018).

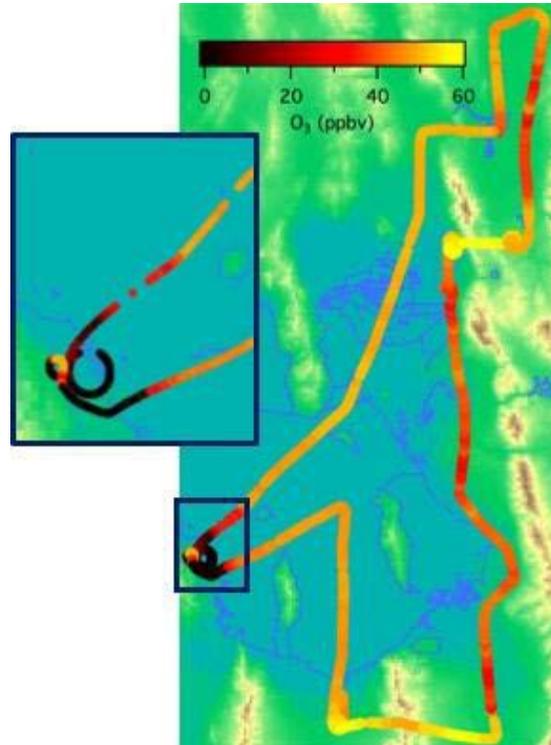


Figure 3. Spatial distribution of ozone during a flight on January 16, 2017 (taken from Figure 3.48 of Baasandorj et al., 2018).

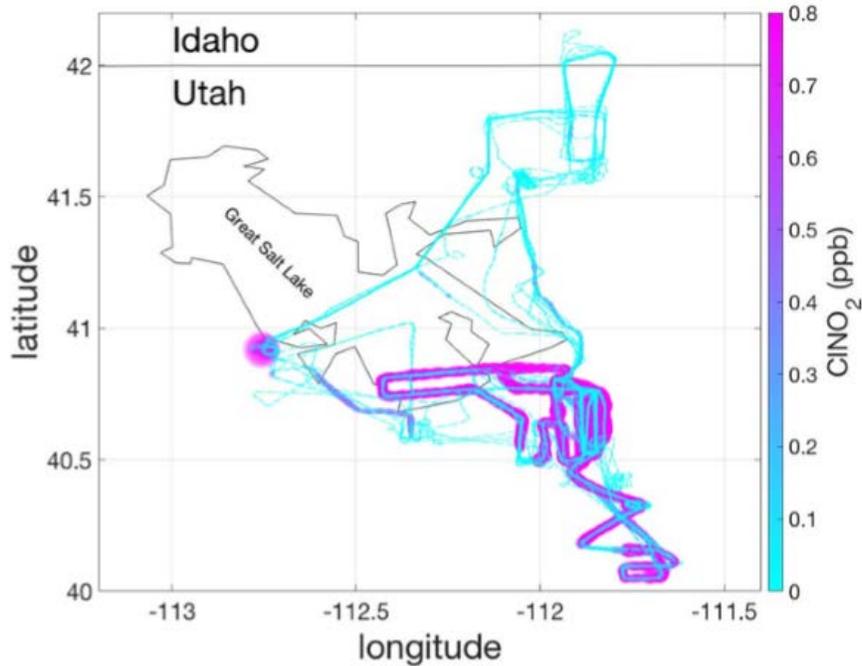


Figure 4. Spatial distribution of ClNO₂ during UWFPS aircraft flights (taken from Figure 3.49 of Baasandorj et al., 2018).

1.1.3 Summertime Measurements of Hydrochloric Acid (HCl)

Martin (2016) reports on a study that deployed 14 passive HCl samplers around the Great Salt Lake and in urban areas along the Wasatch Front during August-September 2015 (therefore did not include winter PCAP events). Investigators located one site in Cache Valley to provide a control site with minimal expected influence from the Great Salt Lake. The purpose of the study was to map the regional distribution of HCl concentrations, to identify hot spots associated with specific emissions sources, and to assess the importance of chlorine in driving atmospheric chemistry in the airshed.

Martin (2016) found:

“...observed ambient HCl concentrations were in the low ppb levels, in line with expected urban levels and those predicted by Stutz et al (2002) based on earlier measurements of ClO. However, it does not appear that the [lake] itself, the exposed shoreline and salt flats, nor the local [petroleum] refineries presented dominant sources of the observed HCl. Rather the investigators propose that the area’s observed HCl concentrations may strongly be influenced by the magnesium refinery on the lake’s western shore line. [Figure 5 below] ... shows a contour plot of the average HCl concentrations over the three sample periods and a clear west to east gradient can be observed. Additionally,

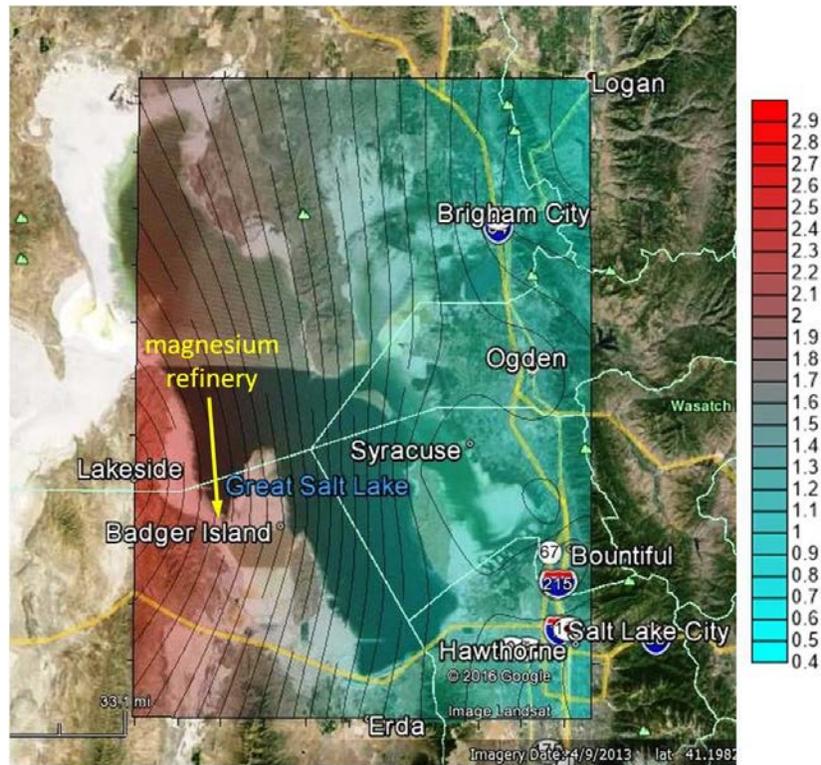


Figure 5. Contour plot of observed average ambient HCl (ppb) based on 14 passive HCl samplers located in the region (taken from Figure 3 of Martin, 2016).

the location of the primary magnesium refinery is shown to be located roughly between the Lakeside and Badger Island sampling locations.”

K13, Martin (2016) and the UWFPS investigators concur on the importance of US Magnesium in contributing to regional chloride concentrations.

1.1.4 Road Salt Contributions

As mentioned in K13 and the UWFPS report, the SLC area is rife with potential sources of salts and halogens, including industrial processes, salt flats and playas, and winter road salting during snowfall that commonly occurs during PCAP episodes. In particular, road salt is a potential source of particulate chloride that is not presently accounted for in the UDAQ emission inventory.

A paper by Kolesar et al. (2018) investigated the contributions of road salting to sodium and chloride PM_{2.5} based on a 2000-2015 analysis of snowfall rates and CSN speciated PM measurements at 25 urban locations across the US. SLC was not among the areas studied. Kolesar et al. verified that particulate sodium and chloride concentrations were three times higher on average in winter than summer for areas receiving more than 25 cm of average

annual snowfall. Similar to UWFPS findings, winter particulate chloride attributed to road salt can be comparable to chloride levels in coastal areas, but the study indicates concentrations typically reach just a few tenths $\mu\text{g}/\text{m}^3$, which is far below the chloride concentrations often measured during SLC $\text{PM}_{2.5}$ exceedance episodes. While Kolesar et al. found that particulate chloride and sodium levels were positively correlated with snowfall in snow-influenced cities, that relationship was complicated by various winter maintenance practices. The authors stress the potential impact on wintertime urban air quality from road salting, especially when considering that nitric acid in polluted urban environments can liberate chlorine from salt aerosols, thereby participating in photochemistry.

However, K13 downplayed road salt as an unlikely source of chlorine in SLC:

“Of the possible sources, road salting was deemed an unlikely source of chlorine given the relative absence of sodium in the observations as well as the absence of reports of ammonium chloride aerosol in other urban areas that conduct road salting in wintertime [at the time of their paper]. Sodium chloride is, however, a well-known source of gas-phase chlorine in coastal and marine areas through the reaction of nitric acid with sodium chloride and the release of hydrogen chloride. Because measured levels of ammonia in the atmosphere during wintertime along the Wasatch Front are high (UDAQ, 2011), atmospheric nitrate is expected to be fully neutralized by ammonia, and nitric acid levels should be extremely low, making the reaction of nitric acid with sodium chloride unlikely.”

The effect of road salting on ambient chemistry and $\text{PM}_{2.5}$ levels may be city-dependent and, to the best of our knowledge, has not yet been studied in SLC. While the science is not settled, the relatively small magnitude of the winter particulate chloride contributions from road salt found by Kolesar et al. is consistent with the conclusion of K13 regarding the minor role of road salt in influencing ammonium chloride concentrations in SLC during exceedance events.

2.0 EVIDENCE FROM MONITORING DATA

In Salt Lake County, UDAQ monitors $PM_{2.5}$ at the Hawthorne, Herriman and Rose Park sites. UDAQ measures speciated $PM_{2.5}$, including chloride, only at the Hawthorne site every three days (UDAQ, 2017). Figure 6 compares all measurements of total $PM_{2.5}$ and chloride at the Hawthorne monitor on days during 2011-2017 when both measurements were available. We infer ammonium chloride (NH_4Cl) concentrations by multiplying chloride measurements by 1.509 to account for associated NH_4 . EPA (2018) states that peak 24-hour average $PM_{2.5}$ impacts $> 1.5 \mu g/m^3$ can be considered “significant” contributions; we have adopted that threshold for this analysis. Values of NH_4Cl range from 0 to $9.4 \mu g/m^3$, with most NH_4Cl less than $1.5 \mu g/m^3$. However, NH_4Cl concentrations are always greater than zero, and often greater than $1.5 \mu g/m^3$, on all days when $PM_{2.5}$ concentrations exceed the $35 \mu g/m^3$ NAAQS.

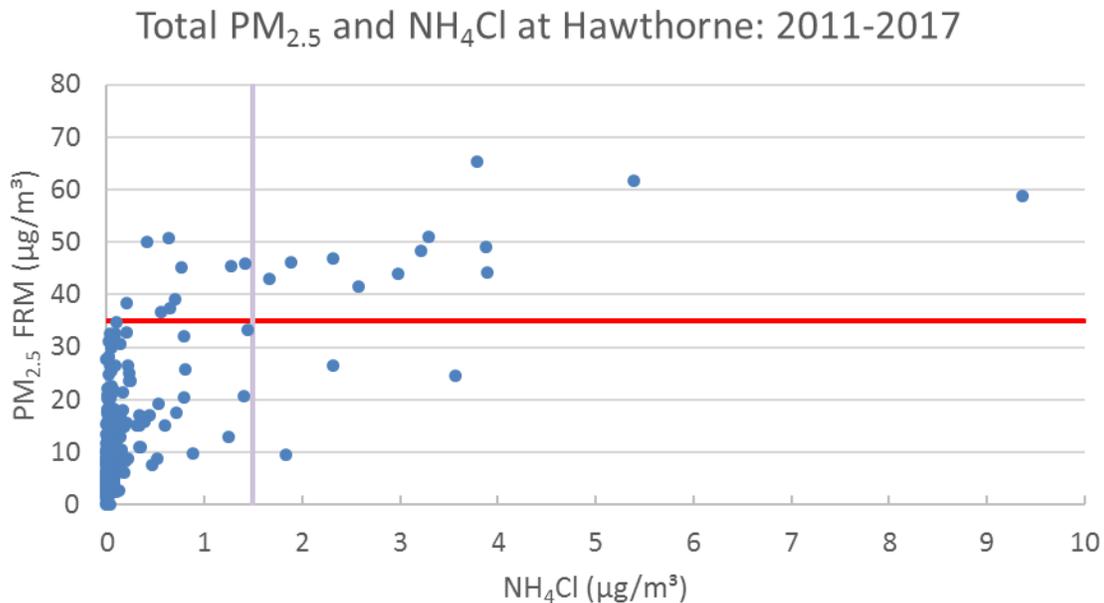


Figure 6. Hawthorne monitor concentrations of total $PM_{2.5}$ and NH_4Cl paired in time for all days over 2011-2017 when both species were measured. The horizontal red line indicates the $35 \mu g/m^3$ level of the $PM_{2.5}$ 24-hour NAAQS and the vertical purple line indicates the $1.5 \mu g/m^3$ EPA significance level.

Figure 7 shows Hawthorne monitor NH_4Cl and $PM_{2.5}$ concentrations for each day during 2011-2017 when both species were measured and the 24-hour $PM_{2.5}$ concentration exceeded $35 \mu g/m^3$. There are 21 days when the Hawthorne monitor exceeds $35 \mu g/m^3$, and NH_4Cl exceeds $1.5 \mu g/m^3$ on 12 (57%) of these days. While NH_4Cl is clearly not the sole contributor to high observed $PM_{2.5}$ concentrations at Hawthorne, it is present at Hawthorne on all exceedance days during 2011-2017. NH_4Cl is frequently measured at concentrations higher than $1.5 \mu g/m^3$, reaches concentrations as large as $9.4 \mu g/m^3$ (January 25, 2013), and contributes as much as 15% to total 24-hour $PM_{2.5}$ burden.

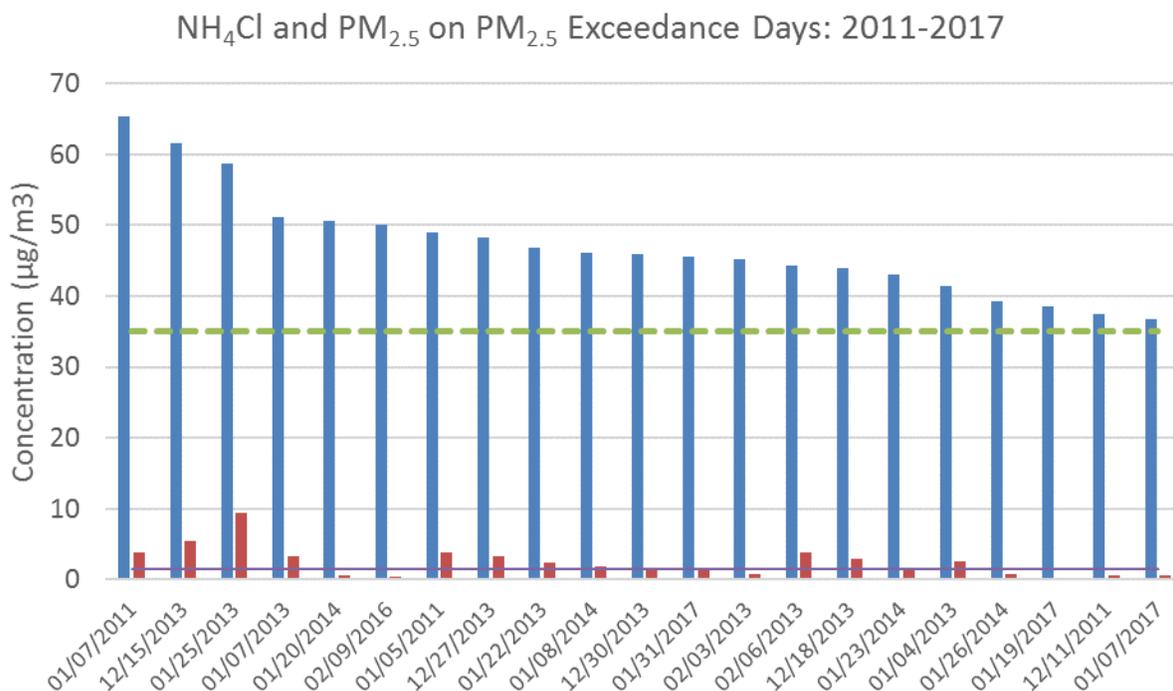


Figure 7. Hawthorne measurements of total PM_{2.5} and NH₄Cl for all days during 2011-2017 when both species were measured and when total PM_{2.5} exceeded the 35 µg/m³ NAAQS. Days are ranked from left to right by their total PM_{2.5} concentration. The horizontal green dashed line indicates the NAAQS and the horizontal purple line indicates the 1.5 µg/m³ concentration level.

Table 1 lists the top 8 days during each year from 2011-2017 with the highest values of 24-hour PM_{2.5} at Hawthorne. The 8th highest day of each year goes into the calculation of the Hawthorne PM_{2.5} design value when there are 351–366 creditable measurements for that year³. NH₄Cl concentrations greater than 1.5 µg/m³ occurred on 8 of the 14 top PM_{2.5} days during 2011-2017 when chloride was measured. NH₄Cl therefore increased the Hawthorne design values during this period.

Measurements of NH₄Cl and PM_{2.5} concentrations made at the Hawthorne monitor over a multi-year period show that NH₄Cl is typically present at the monitor on PM_{2.5} exceedance days and that the contribution of NH₄Cl to the PM_{2.5} burden frequently exceeds 1.5 µg/m³.

³ See 40CFRCH.1 Pt. 50, App. N for discussion of rank of the annual 98th percentile value in the descending sorted list of daily site measurement values for a given year.

Table 1. Top 8 24-hour PM_{2.5} days of each year during 2011-2017 at the Hawthorne monitor, and NH₄Cl concentrations inferred from measured chloride. Yellow shading indicates an NH₄Cl value > 1.5 µg/m³. Red text indicates the 8th highest value in each year that is used in the design value calculation.

2011				2012				2013				2014			
Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)	Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)	Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)	Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)
1	1/8/2011	68		1	9/18/2012	31.2	0.02	1	1/8/2013	69.2		1	1/1/2014	58.2	
2	1/7/2011	65.3	3.79	2	1/6/2012	29.4		2	12/31/2013	63.4		2	1/22/2014	49.1	
3	1/6/2011	55.9		3	11/15/2012	27.8		3	12/15/2013	61.6	5.36	3	1/20/2014	48	0.63
4	1/4/2011	50.7		4	1/3/2012	27.7		4	1/6/2013	59		4	1/3/2014	47.9	
5	1/5/2011	49	3.88	5	1/5/2012	26.7		5	1/25/2013	58.8	9.3	5	1/27/2014	45.6	
6	1/14/2011	43.4		6	9/17/2012	26.6		6	1/18/2013	58.2		6	1/8/2014	43.3	1.88
7	1/29/2011	42.6		7	1/4/2012	26.4	2.3	7	1/19/2013	57.5		7	1/21/2014	42.9	
8	1/15/2011	41.9		8	11/13/2012	26		8	12/14/2013	55		8	1/23/2014	41.4	1.65
2015 (N=364)				2016 (N=366)				2017 (N=365)							
Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)	Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)	Rank	Date	Combined Site PM2.5 (µg/m ³)	NH4Cl (µg/m ³)				
1	1/11/2015	51.1		1	2/10/2016	59.1		1	12/12/2017	62.5					
2	1/10/2015	44.1		2	2/12/2016	58.9		2	12/13/2017	51.2					
3	1/8/2015	43.1		3	2/11/2016	53.4		3	1/31/2017	45.5	1.27				
4	1/9/2015	37.9	2.45	4	2/13/2016	52.4		4	12/11/2017	45.2					
5	4/14/2015	31.6		5	12/30/2016	51.1		5	2/2/2017	42.2					
6	8/20/2015	30.6		6	2/9/2016	50	0.41	6	1/30/2017	41.1					
7	1/3/2015	29.2	0.83	7	2/8/2016	44.5		7	1/18/2017	39.4					
8	12/4/2015	29.1		8	2/14/2016	42		8	1/19/2017	38.5	0.21				

3.0 EVIDENCE FROM EMISSION INVENTORY DATA

In this section we first present evidence that the US Magnesium facility is by far the largest single source of anthropogenic chloride in the State of Utah. Later, we present evidence that UDAQ's modeled emission estimates for the January 2011 modeling platform underestimate the actual emissions that occurred during that period.

Chlorine is a hazardous air pollutant under the Clean Air Act, and so it must be addressed in facility permits. As a toxic chemical, chlorine emissions above certain levels must be reported to the Toxic Release Inventory (TRI) by facilities subject to the reporting requirements of the Emergency Planning and Community Right-to-Know Act (EPCRA). TRI information includes only selected industrial sectors using larger volumes of certain listed chemicals. The Utah Department of Environmental Quality (UDEQ) administers the EPCRA program in Utah and manages all associated data submitted by facilities subject to the reporting requirements of EPCRA. We reviewed the annual Utah TRI for several specific years (2011, 2014, 2016) pertinent to UDAQ's photochemical modeling to support the SLC NAA SIP. Tables 2 through 4 list top-ranked emitting facilities and chemical emissions from the three Utah TRI reports (UDAQ, 2012, 2016, 2017), which are typical for the intervening years as well.

In 2011, chlorine was the top chemical for TRI air releases (7.5 million lbs/year) and hydrochloric acid is the 2nd top chemical (2.3 million lbs/year). As both are precursors of particulate chloride, their combination is 9.8 million lbs/year, by far the largest air release in the state by nearly a factor of 25 over ammonia, the next most released compound. US Magnesium was the top facility for total air releases subject to TRI reporting (8.7 million lbs/year), which were nearly entirely chlorine and hydrochloric acid. The TRI report (UDAQ, 2012) explains that 2011 was an outlier year for US Magnesium emissions:

"U.S. Magnesium reported that an increase in emissions reported by the facility this year was the result of a major preventative maintenance activity on the chlorine reduction burner (CRB). The CRB was off-line for a period of approximately one month while the work was being performed. (Agency communication with the facility (Dec. 20, 2012))."

We understand that the maintenance resulting in the large increase in 2011 emissions occurred in October of that year (US Magnesium, 2011) and therefore did not impact UDAQ's January 2011 modeling episode.

In 2014, chlorine was again the top chemical for TRI air releases (decreasing from 2011 to 2.7 million lbs/year), while hydrochloric acid is the 2nd top chemical (decreasing from 2011 to 1.9 million lbs/year). Their combination was 4.6 million lbs/year, again the largest TRI release in the State by nearly a factor of 8 over ammonia. US Magnesium remained the top facility of releases subject to TRI reporting as the sum of chlorine and hydrochloric acid (4.2 million lbs/year).

Table 2(a). Top 10 facilities reported in the 2011 UDAQ TRI for releases to the air. Taken from UDAQ (2012).

Facility Name	Lbs/Year
1 US MAGNESIUM, LLC	8,658,915
2 ATK THIOKOL, PROMONTORY	507,618
3 PACIFICORP - CARBON PLANT	422,730
4 BRUSH RESOURCES INC, MILL	217,863
5 HEXCEL CORPORATION	171,596
6 INTERMOUNTAIN POWER GENERATING STATION	155,318
7 U.S. DOD USAF OGDEN AIR LOGISTICS CENTER	143,340
8 PACIFICORP HUNTER PLANT	134,398
9 TESORO REFINING AND MARKETING COMPANY	126,516
10 KENNECOTT UTAH COPPER SMELTER & REFINERY	99,957

Table 2(b). Top 10 chemicals reported in the 2011 UDAQ TRI released to the air. Taken from UDAQ (2012).

Chemical Name	Lbs/Year
1 Chlorine	7,472,197
2 Hydrochloric acid	2,300,487
3 Ammonia	436,386
4 Sulfuric acid	222,323
5 Hydrofluoric acid	202,625
6 Methylene chloride	94,190
7 Hydrogen cyanide	94,077
8 Hexane	77,886
9 Toluene	65,4735
10 Styrene	54,644

Table 3(a). Top 10 facilities reported in the 2014 UDAQ TRI for releases to the air. Taken from UDAQ (2016).

Facility Name	Pounds/Year
1 US MAGNESIUM, LLC	4,197,614
2 HEXCEL CORPORATION	343,414
3 PACIFICORP - CARBON PLANT	297,930
4 BRUSH RESOURCES INC, MILL	244,826
5 TESORO REFINING AND MARKETING COMPANY	131,651
6 INTERMOUNTAIN POWER GENERATING STATION	130,187
7 CHEVRON PRODUCTS COMPANY - SALT LAKE REFINERY	106,005
8 KENNECOTT UTAH COPPER SMELTER & REFINERY	104,656
9 SUNNYSIDE COGENERATION ASSOCIATES	67,786
10 PACIFICORP - HUNTINGTON PLANT	63,827

Table 3(b). Top 10 chemicals reported in the 2014 UDAQ TRI released to the air. Taken from UDAQ (2016).

Chemical Name	Pounds/Year
1 Chlorine	2,694,723
2 Hydrochloric acid	1,935,135
3 Ammonia	551,844
4 Hydrogen cyanide	225,188
5 Hydrofluoric acid	194,831
6 Sulfuric acid	119,836
7 Hexane	87,594
8 Toluene	75,131
9 Styrene	62,766
10 Xylene (mixed)	58,635

Table 4(a). Top 10 facilities reported in the 2016 UDAQ TRI for releases to the air. Taken from UDAQ (2017).

<u>Facility Name</u>	<u>Pounds/Year</u>
1 US MAGNESIUM, LLC	4,187,667
2 HEXCEL CORPORATION	356,120
3 ATK THIOKOL, PROMONTORY	316,010
4 HOLLY REFINING & MARKETING COM PANY-WOODS CROSS	200,500
5 TESORO REFINING AND MARKETING COMPANY	198,593
6 BRUSH RESOURCES INC, MILL	187,375
7 CHEVRON PRODUCTS COMPANY- SALT LAKE REFINERY	113,028
8 KENNECOTT UTAH COPPER SMELTER & REFINERY	100,502
9 U.S. ARMY DUGWAY PROVING GROUND	98,440
10 U.S. DOD USAF OGDEN AIR LOGIST ICS CENTER	94,222

Table 4(b). Top 10 chemicals reported in the 2016 UDAQ TRI released to the air. Taken from UDAQ (2017).

<u>Chemical Name</u>	<u>Pounds/Year</u>
1 Hydrochloric acid	2,579,482
2 Chlorine	2,201,293
3 Ammonia	598,791
4 Hydrogen cyanide	277,532
5 Sulfuric acid	159,129
6 Hexane	121,407
7 Toluene	95,284
8 Hydrofluoric acid	75,310
9 Methylene chloride	72,297
10 Hydrogen sulfide	63,783

In 2016, chlorine was the 2nd top chemical for TRI air releases (decreasing from 2014 to 2.2 million lbs/year), while hydrochloric acid was the top chemical (increasing from 2014 to 2.6 million lbs/year); their combination was 4.8 million lbs/year, again the largest TRI release in the State by nearly a factor of 8 over ammonia. US Magnesium remained the top facility of releases subject to TRI reporting as the sum of chlorine and hydrochloric acid (4.2 million lbs/year).

We evaluated the most recent 12-year trend in annual chlorine and hydrochloric acid emissions from US Magnesium as reported in the TRI (Figure 8). Chlorine and hydrochloric acid fugitive and stack emissions comprise 99.95% of total TRI emissions reported by the facility. Total emissions of chlorine plus hydrochloric acid increased by 1% over the period shown. However, chlorine decreased to 69% of 2005 emissions while hydrochloric acid increased to 190% of 2005 emissions. Total emissions peaked in 2011 to 159% of the 2010 emissions and more than twice the 2016 emissions.

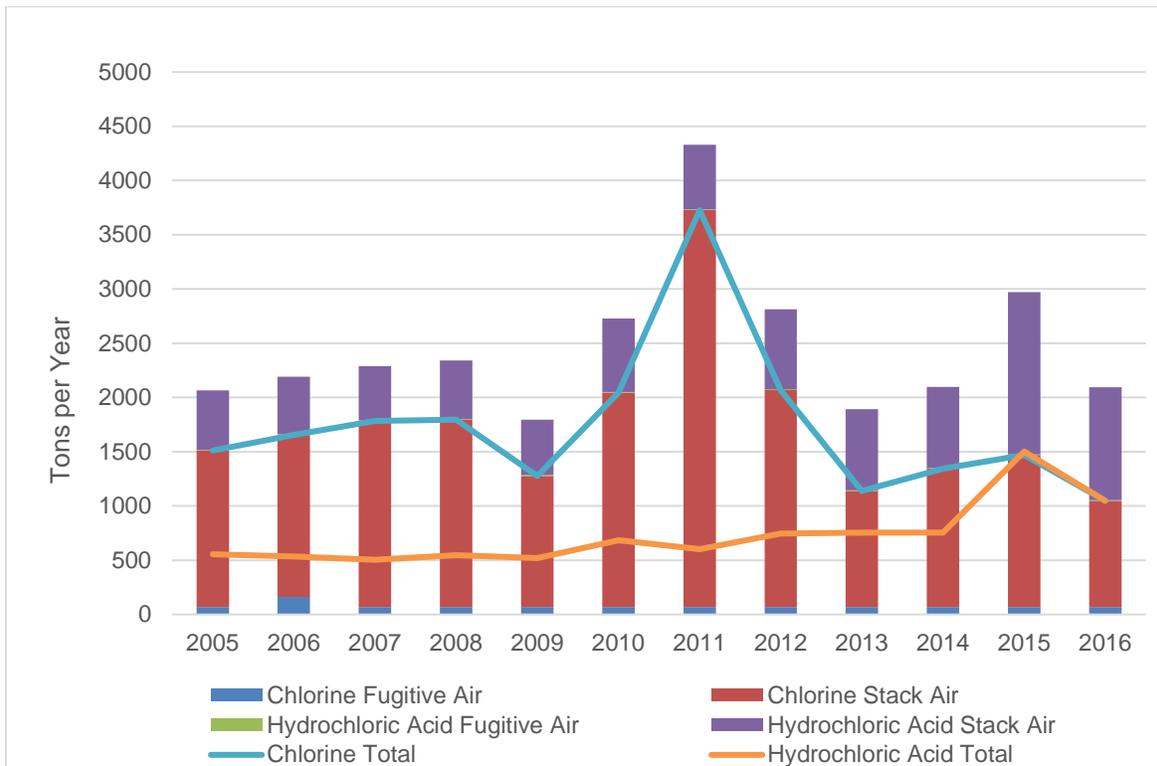


Figure 8. 2005-2016 trends in TRI-reported chlorine and hydrochloric acid emissions from the US Magnesium facility, for both fugitive and stack air releases. Data obtained from: <https://www3.epa.gov/enviro/facts/tri/ef-facilities/#/Release/84074MXMGNROWLE> (accessed on February 6, 2018).

We evaluated chlorine-related emissions in the UDAQ 2014 photochemical modeling point source emissions inventory developed to support the SLC NAA SIP⁴. UDAQ prepared point source emissions for each day of the January 2011 modeling episode. Emitted chlorine compounds include molecular chlorine (Cl₂), hydrochloric acid (HCl), and particulate chloride. Chlorine photolyzes quickly in the atmosphere to form hydrochloric acid. Both emitted and secondary hydrochloric acid can form particulate chloride when neutralized by cations such as ammonia or sodium. Any emitted and secondary particulate chloride in abundance over available cations will convert back to gaseous HCl.

US Magnesium must submit and certify monthly chlorine emission reports that provide estimates of daily emission rates. Although US Magnesium's monthly emission reports list daily chlorine emission estimates, we found that UDAQ set daily Cl₂ and HCl emissions in the modeling point source inventory to monthly-averaged emissions from the January 2014 emission report. UDAQ derived particulate chloride emissions from annual criteria PM_{2.5} emission estimates reported for the facility in UDAQ's submission to the 2014 National Emission Inventory (NEI). UDAQ applied a speciation profile⁵ to the US Magnesium facility emissions that assigns 17% of criteria PM_{2.5} emissions to particulate chloride. UDAQ has not reported their rationale for using this speciation profile; we include speciation information here to show the assumed fraction of PCL from US Magnesium's total PM_{2.5} emissions. If PM_{2.5} emissions at the facility are dominated by chloride, then this split may contribute to under estimates of particulate chloride emissions.

Based on the UDAQ 2014 modeling inventory, four sources emit Cl₂: 1 within/near SLC, 1 in central Morgan County east of the Wasatch range, and 2 at US Magnesium. The 2 US Magnesium sources emit nearly 2000 times more Cl₂ than the other 2 sources combined. A total of 26 stacks emit HCl: 4 are at US Magnesium, others are co-located with SLC Cl₂ sources, and others are scattered around the state. The 4 US Magnesium sources emit 1.6 times more HCl than all other 22 sources combined. A total of 147 stacks emit PCL: 5 are at US Magnesium and emit 10.2 times more PCL than all other 142 sources combined. In total, US Magnesium emits chloride compounds (chlorine plus hydrochloric acid) at a rate over 4 times higher than the combination of all other sources in Utah.

UDAQ set total chloride emissions from the US Magnesium facility at about 6 tons per day (TPD) on each day of the January 2011 modeling episode (this emission rate is based on the January 2014 average rate). A UDAQ enforcement order finalized in mid-2017 indicates a number of violations of US Magnesium's Title V permit, including emissions exceedances and lack of required annual emission tests. US Magnesium submits "breakdown reports" when they have a failure in their system that results in excess chlorine emissions. A breakdown report for January 4, 2011 shows an excess of 9 tons of chlorine emissions over a 4.5-hour period, resulting in a

⁴ Note that UDAQ has moved from a 2014 "base year" to a 2016 year to support the SLC NAA SIP.

⁵ Profile 91139, "Sintering Furnace - Composite, Mixture of Baghouse and Uncontrolled", was applied to a single source category that accounts for 90% of PM_{2.5} emissions from US Magnesium: 30% crustal (dust), 25% unspecified primary PM, 17% chloride, 13% sodium, 10% sulfate, 4% organic, <1% elemental carbon.

total of 12 tons emitted on that day. The actual January 2011 average chloride emissions were over 10 TPD, nearly twice as high as the January 2014 average. In 2011 US Magnesium emitted chloride at a rate over 8 times higher than all other sources in Utah, assuming that all other sources had similar emissions in 2011 and 2014.

4.0 EVIDENCE FROM MODELING

We have presented evidence that ammonium chloride is present at Hawthorne, contributes to exceedances of the PM_{2.5} NAAQS, and that US Magnesium is by far the largest source of the ammonium chloride precursors. Models can be used to evaluate a possible causal link between an emissions source and high values of measured pollutants. To assess the transport linkage between US Magnesium and SLC, we employed gridded wind fields from UDAQ's January 2011 modeling platform to calculate 48-hour forward and backward trajectories using the HYSPLIT model (Draxler and Rolph, 2012). We started forward trajectories at the coordinates of the US Magnesium facility to determine the path of an air parcel from the facility. We ended backward trajectories at the Hawthorne monitoring site in SLC to determine the origin of air arriving at the monitor; in particular, we assessed whether the back trajectories extended over the US Magnesium facility.

We extracted three-dimensional wind fields for HYSPLIT from the two nested modeling domains, which include gridded wind data at 1.33 km (inner grid) and 4 km (outer grid) resolution (Figure 9). To account for potential influences from vertical wind shear, which may be significant during stable stagnation periods, we calculated trajectories for a surface release and for an elevated release 100 m above the ground. All trajectories remained within 500 m of the ground, within or below the capping inversion. Note that these trajectory calculations represent single-point particle paths and thus consider only the resolved advective component of the overall transport motion. Thus, these trajectories do not account for turbulent diffusion effects, which likely dominate the transport process under stagnant PCAP conditions and contribute to plume dilution. With single-point particle paths, uncertainty grows with trajectory distance and duration; uncertainty is compounded during light-wind/stagnation and recirculation events, such as the conditions during the January 2011 modeling episode. Our choice to calculate 48-hour trajectories was sufficient to assess multi-day circulations under stagnant conditions, and limited the effects from growing error related to the fidelity of the wind field evolution. That is not to say, however, that actual source-receptor couples cannot extend longer than 48 hours under such conditions.

Figures 10(a) and (b) show 48-hour forward and backward trajectories, respectively, calculated for January 7-9 using wind fields from the UDAQ January 2011 modeling database. The trajectories indicate a meandering path between the source and receptor, with winds moving eastward across the Lake then north on January 7-8, then moving south along the Wasatch Front on January 8-9. Figures 11(a) and (b) show similar trajectories for January 8-10; winds initially move south from the source on January 8-9, then curve eastward into southern SLC and Utah Valley on January 9-10. These trajectories indicate a plausible multi-day transport path from US Magnesium and SLC receptors during the modeling episode. Trajectories calculated for other days of the episode showed northerly and/or southerly flow and did not clearly indicate transport between US Magnesium and SLC.

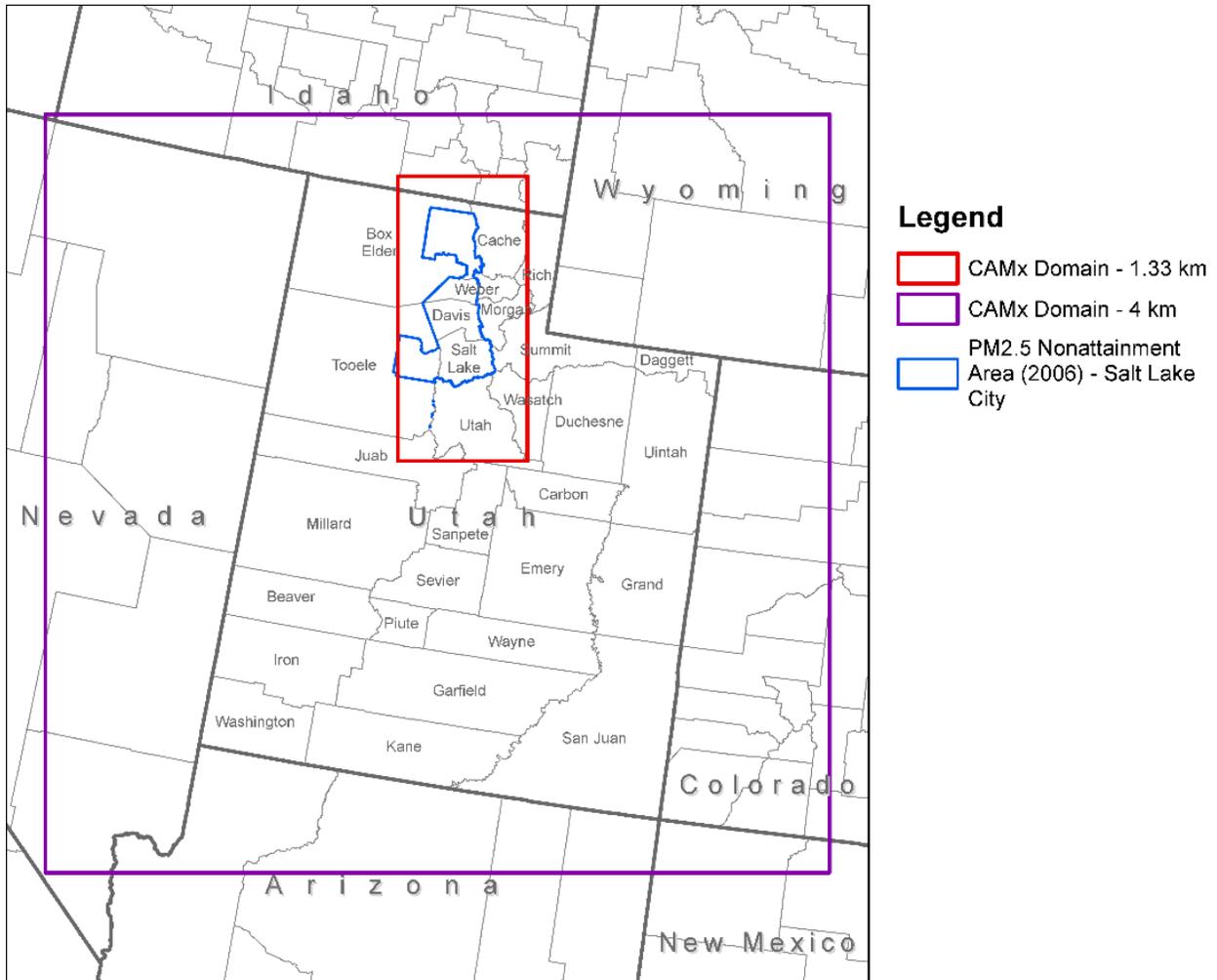


Figure 9. Depiction of the UDAQ nested modeling grids with 4 km grid resolution (outer domain) and 1.33 km grid resolution (inner domain). The SLC NAA is shown for reference.

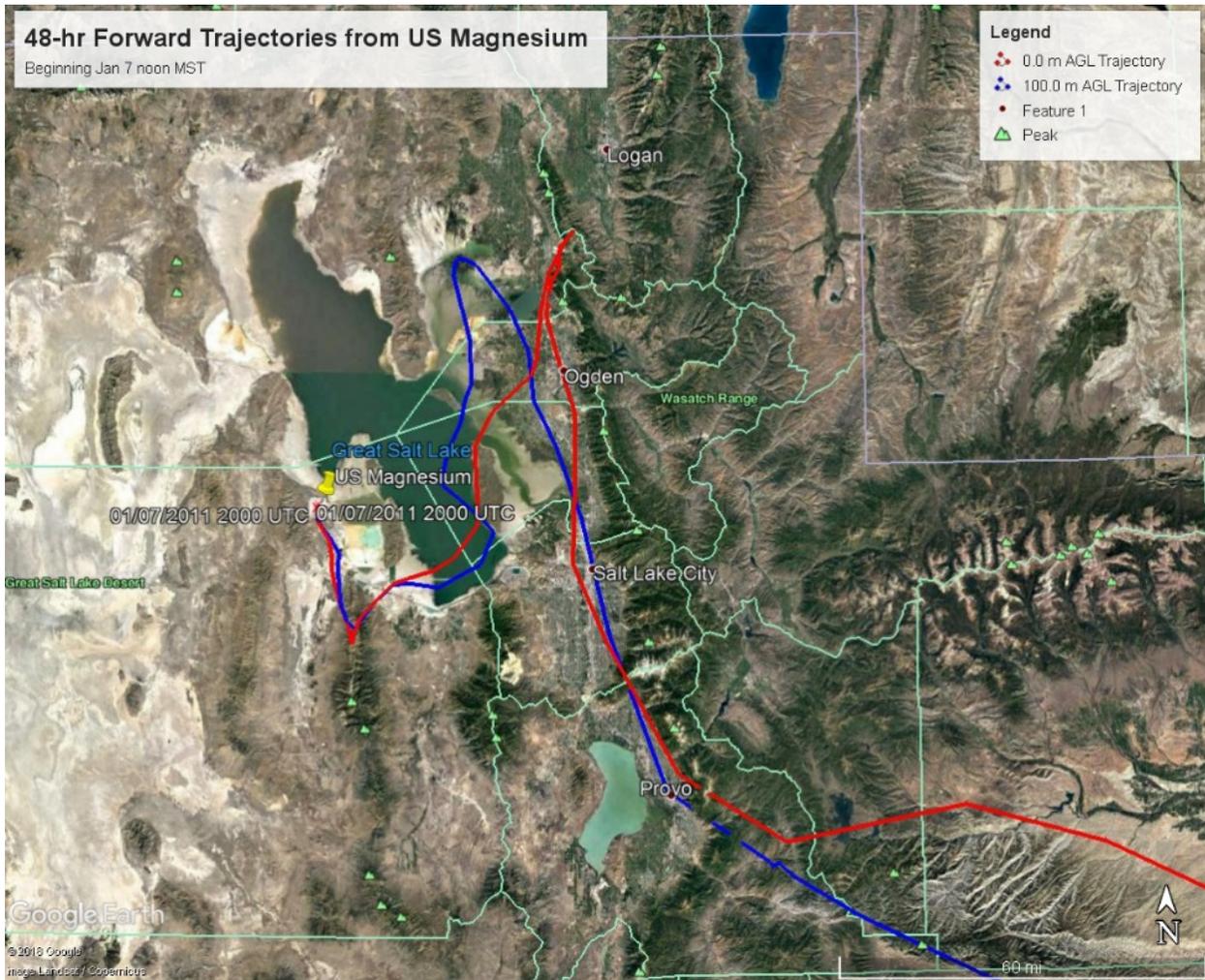


Figure 10(a). 48-hour forward particle trajectories calculated by HYSPLIT for January 7-9, 2011 using wind fields from the UDAQ January 2011 modeling database. Red trajectories are from a surface release, blue trajectories are from a release at 100 m above ground. Forward trajectories start from the US Magnesium facility.

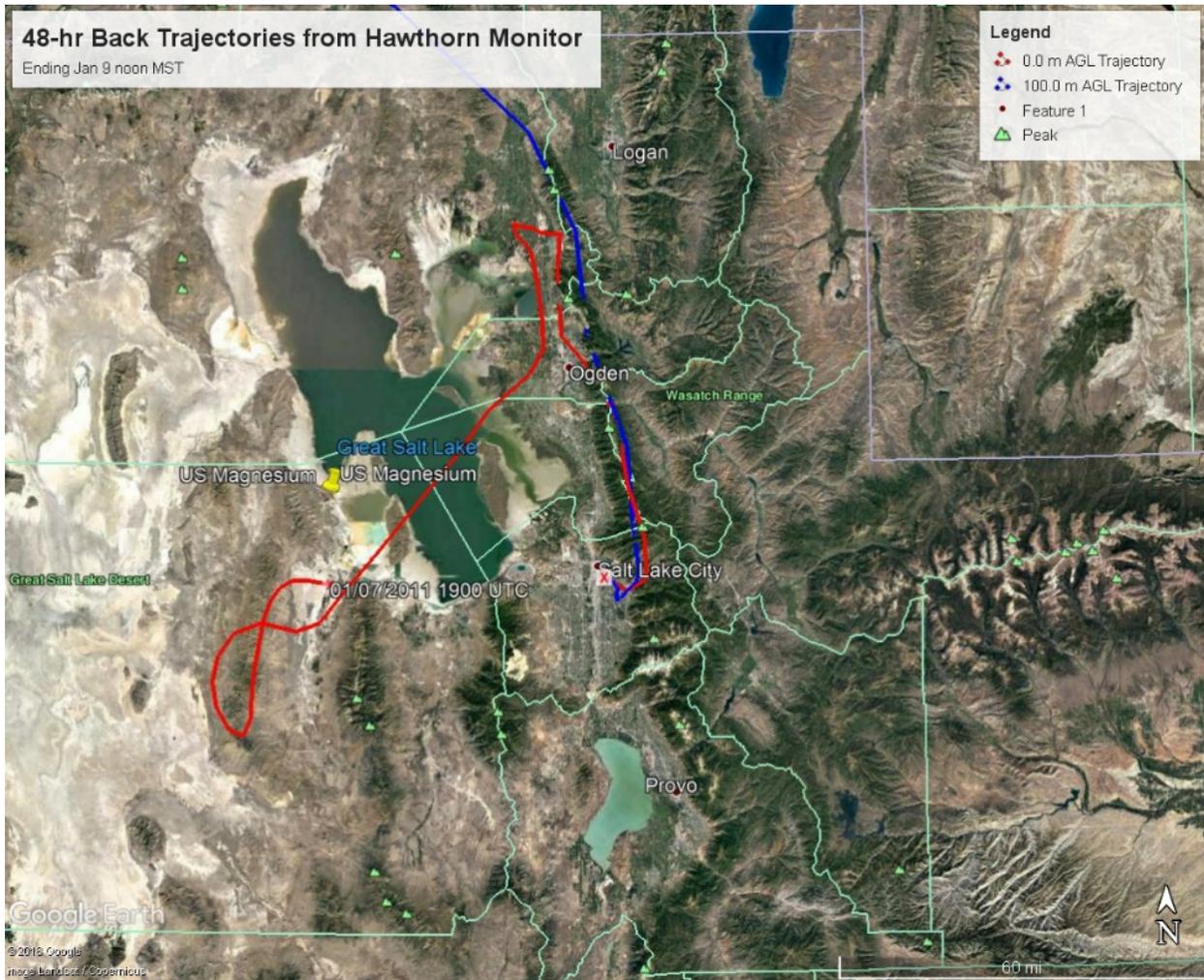


Figure 10(b). As in Figure 10(a), but for backward particle trajectories calculated by HYSPLIT for January 7-9, 2011. Backward trajectories end at the Hawthorne monitoring site in SLC.

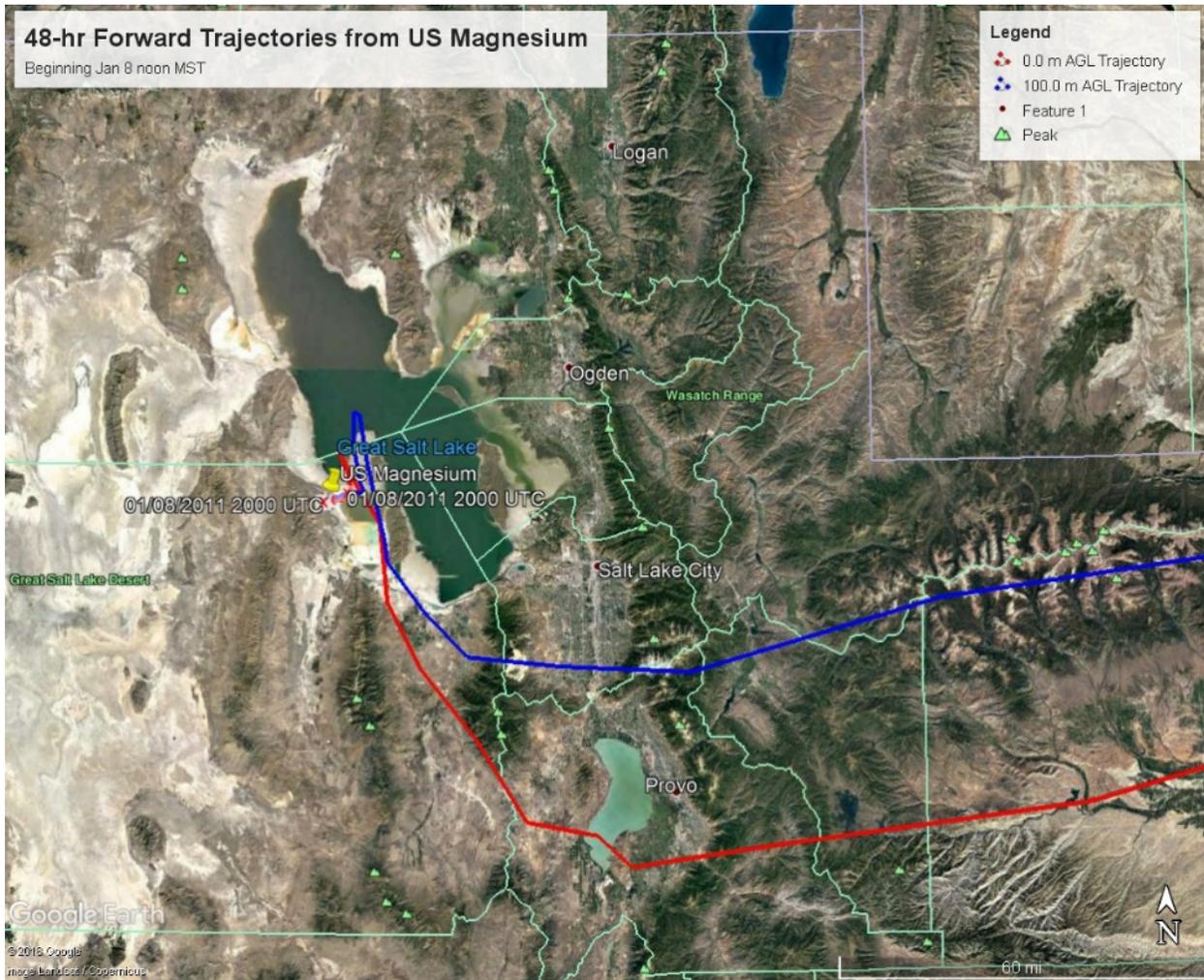


Figure 11(a). As in Figure 10(a), but for forward particle trajectories calculated by HYSPLIT for January 8-10, 2011. start from the US Magnesium facility

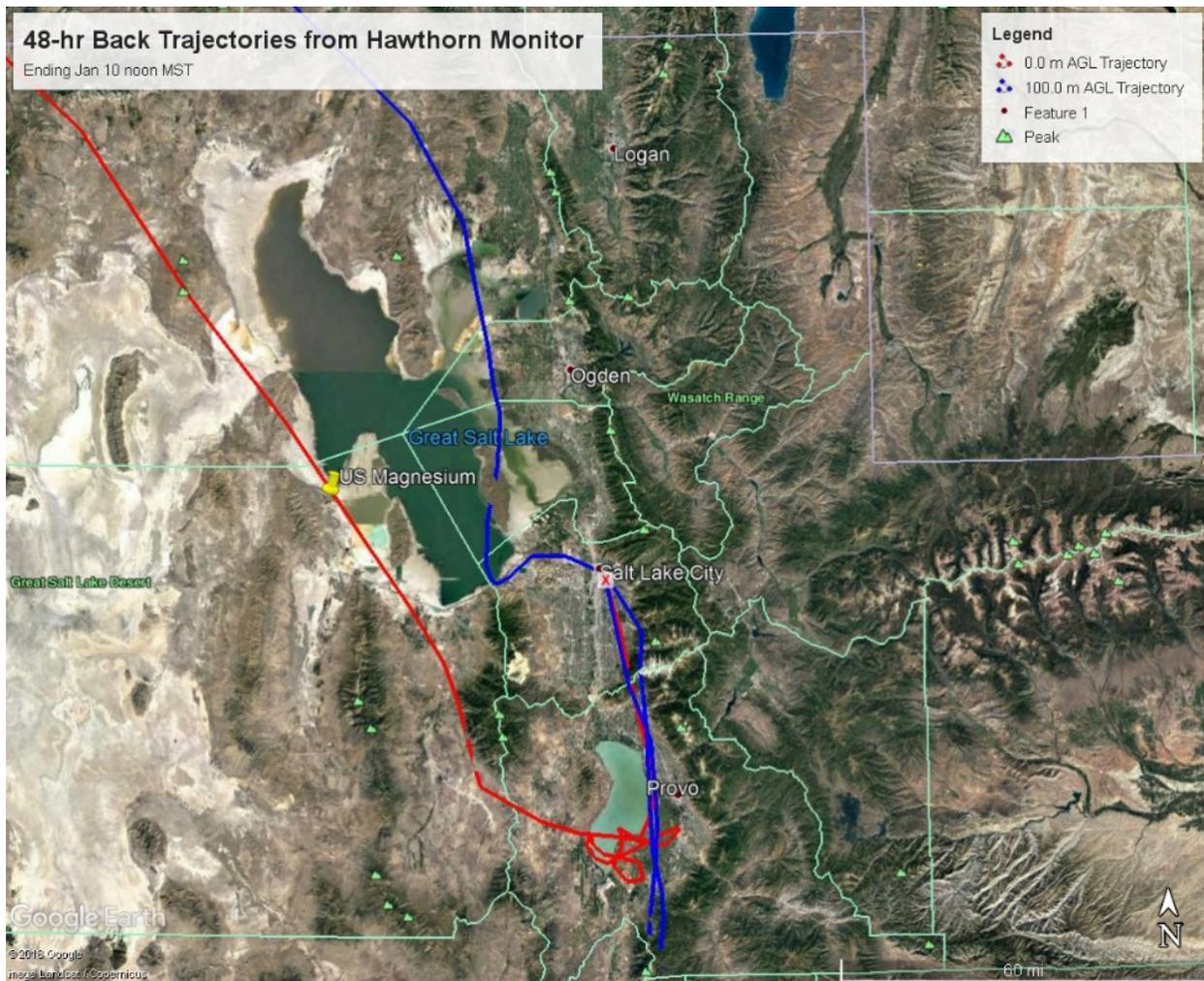


Figure 11(b). As in Figure 10(a), but for backward particle trajectories calculated by HYSPLIT for January 8-10, 2011. Backward trajectories end at the Hawthorne monitoring site in SLC.

Unlike particle trajectory paths, UDAQ’s photochemical model simulates the total three-dimensional dispersion of emission plumes, including both advective and diffusive components. From UDAQ’s modeling output files, we extracted 1-hour and 24-hour particulate chloride concentrations for each day of the January 2011 episode. The day with maximum chloride concentrations coincided with the day of peak measured PM_{2.5} concentrations at SLC monitors: January 7. Figure 12 shows resulting particulate chloride concentrations at 5 PM on January 7 reaching into western SLC with concentrations of roughly 1 µg/m³. Figure 13 shows 24-hour particulate chloride concentrations on January 7. In both figures, the US Magnesium facility on the western edge of the modeling grid is clearly the dominant source of chloride in the model. The pattern is remarkably similar to the measured chloride concentration patterns shown in

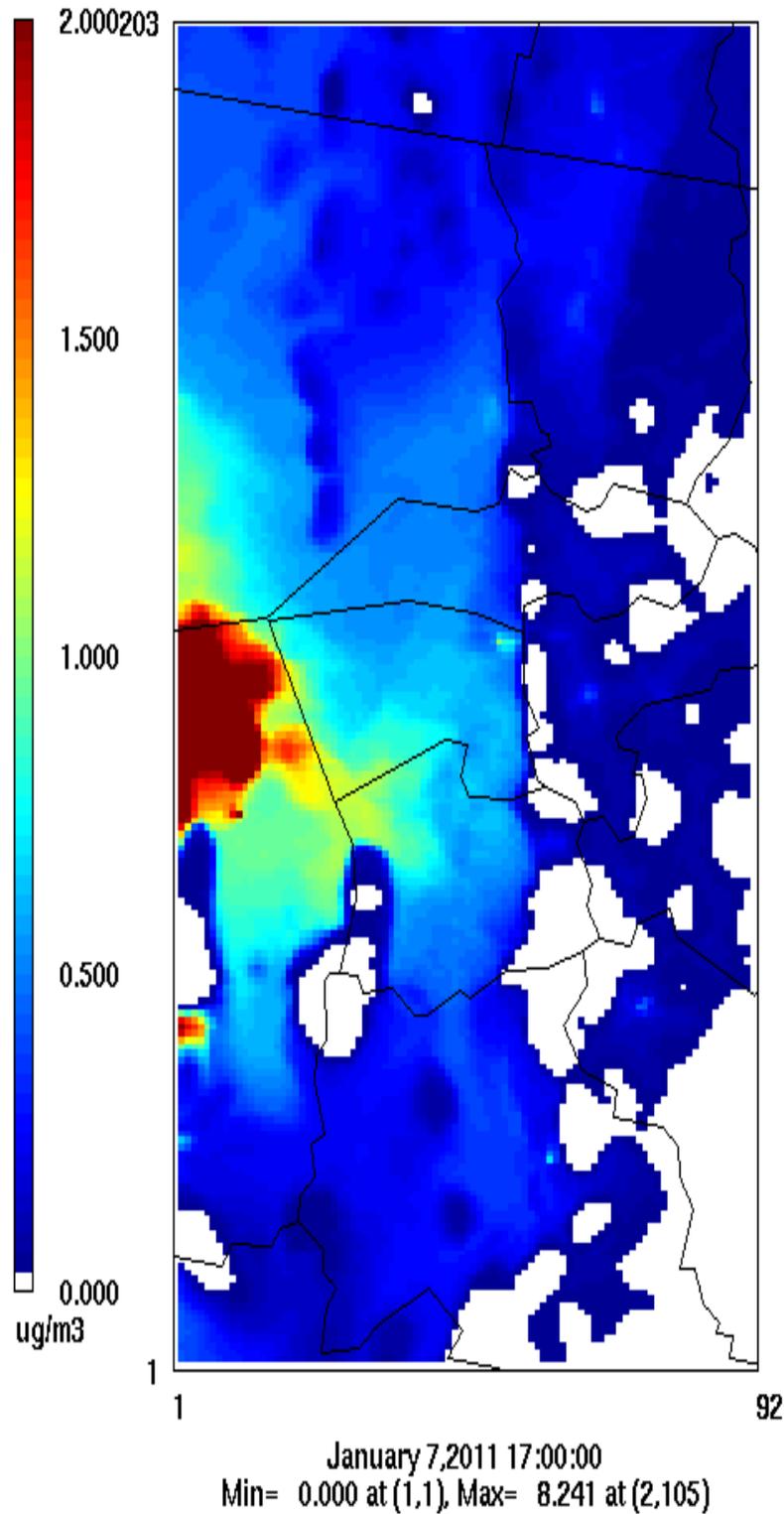


Figure 12. Simulated 1-hour particulate chloride concentration pattern at 5 PM on January 7, 2011. Results extracted from the UDAQ modeling platform using 2014 base year emissions.

**CAMx v6.40 2011 UDAQ1.33km
PCL - 2011/01/07**

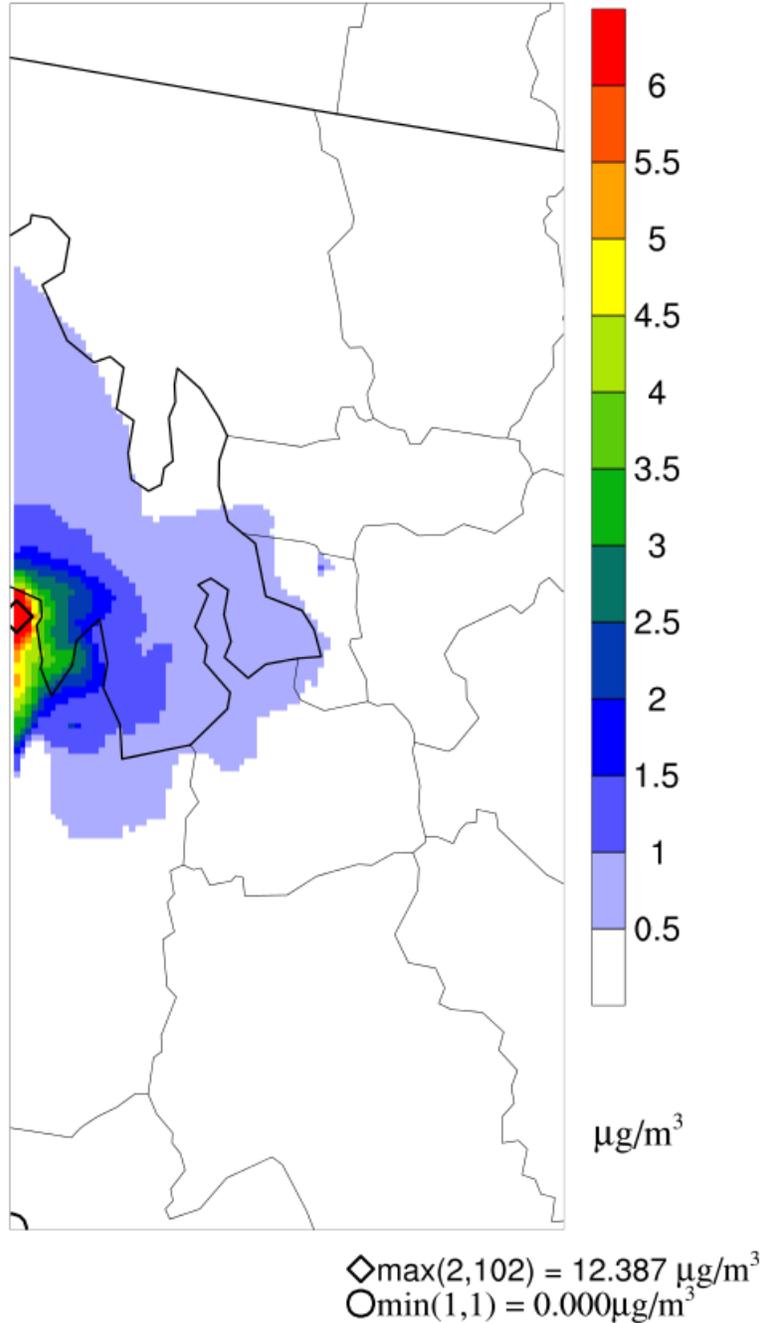


Figure 13. Simulated 24-hour particulate chloride concentration pattern on January 7, 2011. Results extracted from the UDAQ modeling platform using 2014 base year emissions.

Figure 5 (Martin, 2016) and is consistent with a chloride concentration field that is driven by a single facility.

The current UDAQ January 2011 modeling platform confirms that US Magnesium contributes to high levels of ambient particulate chloride concentrations in the region, but shows lower modeled chloride concentrations in SLC $PM_{2.5}$ than are observed at the Hawthorne monitor. Winds patterns during the stagnant January 2011 PCAP episode may not be sufficiently well-simulated to replicate the actual source-receptor transport, which is a common issue with the meteorological model employed in this case. These results suggest that US Magnesium can contribute to SLC $PM_{2.5}$ concentrations, but the contribution is underestimated in the UDAQ's modeling platform.

5.0 CONCLUSIONS

In this paper, we have presented a weight-of-evidence analysis that clearly identifies ammonium chloride as a significant contributor to SLC PM_{2.5} concentrations that exceed the NAAQS during wintertime PCAP events. Our review of recent scientific studies and current photochemical modeling conducted by UDAQ, as well as our analysis of routine ambient PM_{2.5} monitoring and emission inventories for the region, support the finding that US Magnesium is the dominant source of chloride in the region through its emissions to air of gaseous chlorine and hydrochloric acid. No other natural or anthropogenic source of chloride precursors appears to play a meaningful role in the PM_{2.5} burden on winter PCAP exceedance days. For example, concentrations from winter road salting have been shown in other cities to reach just a few tenths $\mu\text{g}/\text{m}^3$, which is well below the chloride concentrations typically measured during SLC PM_{2.5} exceedance episodes.

The presence of chlorine may not just be a direct contributor to total PM_{2.5} (via formation of ammonium chloride), but also an indirect contributor to a heightened formation rate of nitrate via night time aqueous reactions and daytime photochemical oxidation rates driven by chlorine.

The weight of evidence suggests that US Magnesium is a “significant contributor,” as defined by EPA (2016), to exceedances of the PM_{2.5} NAAQS in the SLC NAA. Controls on US Magnesium will reduce ammonium chloride and PM_{2.5} in Salt Lake City and could help to attain the PM_{2.5} NAAQS. Therefore, controls on US Magnesium warrant further consideration as UDAQ develops emission control strategies.

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APPENDIX A

Author Biographies

Appendix A Author Biographies

Mr. Chris Emery has 27 years of experience in numerical modeling and analysis of urban and regional air pollution and meteorology. His expertise includes design, development and application of air quality modeling systems. Chris co-authors the Comprehensive Air Quality Model with extensions (CAMx)—a regional nested grid photochemical model with Plume-in-Grid and Probing Tool extensions. He also prepares the CAMx User’s Guide, and manages public distributions of CAMx and support programs. He has delivered CAMx training for numerous US and international clients including private, governmental, and academic institutions for over fifteen years. He has applied a variety of models for private and public clients, in both local and regional regulatory arenas, throughout the US and abroad. His projects have included ozone, particulate matter (PM₁₀ and PM_{2.5}) and carbon monoxide modeling to support regulatory planning; determining effects of alternative and innovative air quality management strategies; analyzing source contributions and emission sensitivity; modeling fate of toxic air pollutants; studying prospective and retrospective air quality trends; estimating North American background ozone; and simulating source impacts on national parks and wilderness areas. Chris has applied and evaluated meteorological models and global chemical transport models to develop inputs needed by regional photochemical modeling applications. He has served as a member of the American Meteorological Society’s Board of the Urban Environment.

Dr. Susan Kemball-Cook has over 20 years of experience in atmospheric physics and model development and application. Her expertise includes photochemical modeling, emission inventory development, global and regional climate modeling, and climate change risk assessment. Sue has managed projects assisting several Texas Ozone Near Nonattainment Areas in staying in attainment of the National Ambient Air Quality Standard for ozone. These projects have included quantifying ozone transport, emission inventory evaluation using satellite data, exceptional event analysis, control strategy evaluation, and conceptual model development. She has led numerous CAMx modeling projects, including the first evaluation of CAMx performance in the upper troposphere/lower stratosphere against aircraft data and the development of a capability to more accurately model the stratospheric contribution to background ozone. Sue has worked on air quality impact assessments for Texas shale gas development and has managed air quality and air quality related values (AQRVs) impact assessments for numerous National Environmental Policy Act (NEPA) studies for proposed oil and gas developments in the western U.S. She has extensive experience in application and evaluation of CAMx, CMAQ and WRF in NEPA studies and in oil and gas emission inventory development.