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Ambient ammonia and hydrogen sulfide concentrations at a beef cattle feedlot in Texas

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Abstract. *Concentrations of ammonia (NH_3) and hydrogen sulfide (H_2S) in ambient air were semi-continuously measured at a 50,000-head cattle feedyard in Texas panhandle in three seasons: fall 2002 (10 days), winter 2003 (14 days), and spring 2003 (15 days). Sampling was conducted at 1.5 m above the ground at one location each season at the western fence line of cattle pens. Gas* *concentrations were measured using continuous analyzers housed in an onsite instrument shelter. Measured concentrations were upwind or downwind of the feedyard pens depending on the wind direction. Wind directions, wind velocity, and air temperature were measured to correlate them with measured concentrations. Higher concentrations were measured when the sampling port was located downwind from the feedyard. The average NH_3 concentrations for the fall, winter, and spring based on hourly-averages were 429 ppb, 475 ppb, and 712 ppb, respectively. The highest hourly average of 5,270 ppb for NH_3 was measured in the spring 2003, followed by the 2,890 ppb in the fall 2002. The average H_2S concentrations for the fall, winter, and spring based on hourly-averages were 7.73 ppb, 0.73 ppb, and 2.45 ppb, respectively. The highest hourly average of 34.9 ppb for H_2S was measured in the spring 2003, followed by the 29.6 ppb in the fall 2002. The NH_3 and H_2S concentrations had a characteristic daily pattern with two local maximums in the early afternoon and early evening hours. The lowest concentrations were always measured during the night. The experimental setup worked well and proved itself to be reliable in widely different weather conditions and operational for unattended and automated measurements.*

Keywords. Ammonia, hydrogen sulfide, beef cattle feedlots, air quality.

INTRODUCTION

Hydrogen sulfide (H_2S) is one of target gases typically measured at livestock operations. H_2S has a characteristic rotten egg smell and can typically be detected at as low as 7 ppb level. Some evidence exists that low concentrations of $_{H2S}$ can potentially affect human health (Legator et al., 2001). More than half of the U.S. states regulate H_2S in ambient air. In Texas, the ambient air ground level concentration maximums are defined as 80 ppb (30 min average) on residential, business or commercial property and 120 ppb (30 min average) for other property (State of Texas, 1976). The thresholds for workplace exposures that are applicable to confined manure storage area defined as (1) "OSHA General Industry PEL: 20 ppm ceiling for 10 min once only if no other measurable exposure occurs and 50 ppm peak", (2) OSHA Construction Industry PEL: 10 ppm (15 mg/m^3) TWA, (3) ACGIH TLV: 10 ppm (14 mg/m^3) TWA; 15 ppm (21 mg/m^3) STEL, and (4) NIOSH REL: 10 ppm ceiling for 10 min.

Several research groups reported measurements of ambient NH_3 and H_2S concentrations in or near beef cattle feedlots. McGinn et al. (2003) measured NH_3 concentrations 3 m off the perimeter of 3 feedlots with 6,000, 12,000, and 25,000-head capacities, respectively, using chemiluminescence-based continuous analyzer. In addition, open path laser was used to measured ammonia concentrations 200 m downwind the 12,000 and the 25,000 feedyards. These measurements were conducted for approximately 8 days in between mid May and July. McGinn et al. (2003) reported average NH_3 concentrations of 227 ppb, 800 ppb, and1,420 ppb for 3 feedyards. Mean daily concentrations ranged from 115 ppb to 2,600 ppb. Alberta Environment (2000) measured a maximum 1 hr NH_3 concentrations adjacent to a feedlot of approximately 1,380 ppb. Koelsch et al. (2004) measured daytime total reduced sulfur (TRS) concentrations with a portable meter at 3 beef cattle feedlots in Nebraska with 5,000, 7,000, and 10,000 head capacities. This study was conducted in the spring, summer, and the fall and involved sampling for approximately 1 week at each feedlot per season for perimeter sampling and approximately 2 months for feedlot center sampling. Sampling locations were located inside a feedlot and at a property line, sometimes nearly 1.6 km away from the source. Koelsch et al. (2004) reported. The average TRS concentrations ranged from 0.000 to 0.013 ppm for seasonal averages, with a the maximum observed concentration at 0.030 ppm that was likely unrelated to the feedlot. Feedlot center observations ranged from 0.001 ppm to 0.028 ppm for seasonal averages. The seasonal averages for spring and summer were typically higher than those associated with the fall season. In this research, we conducted semi-continuous day- and nighttime measurements at 1 beef cattle feedlot in Texas. These measurements were accompanying another experiment to determine NH3 and H2S fluxes from cattle pens (Baek et al. 2003, Koziel et. al. , 2004).

MATERIALS and METHODS

Site selection and sampling time

Concentrations of NH_3 and H_2S in ambient air were semi-continuously measured at Feedyard C in northwestern Texas in three seasons: Fall 2002 (10 days), Winter 2003 (14 days), and the Spring 2003 (15 days). Air sampling was conducted at the western fence line of cattle pens. Figure 1 shows the approximate location of sampling points for each season. Measured concentrations were measured when this location was upwind or downwind of the feedyard pens depending on the wind direction. Sampling port was located 1.5 m (~5 ft) above the ground. The sampling locations were chosen for a series of experiments to determine NH_3 and H_2S flux from pens (Baek et al., 2003, Baek et al., 2003, Koziel et al., 2004). These locations were not optimal for ambient air monitoring. However, we still used them to elucidate information about the ranges of measured concentrations that could be useful for future experiments.

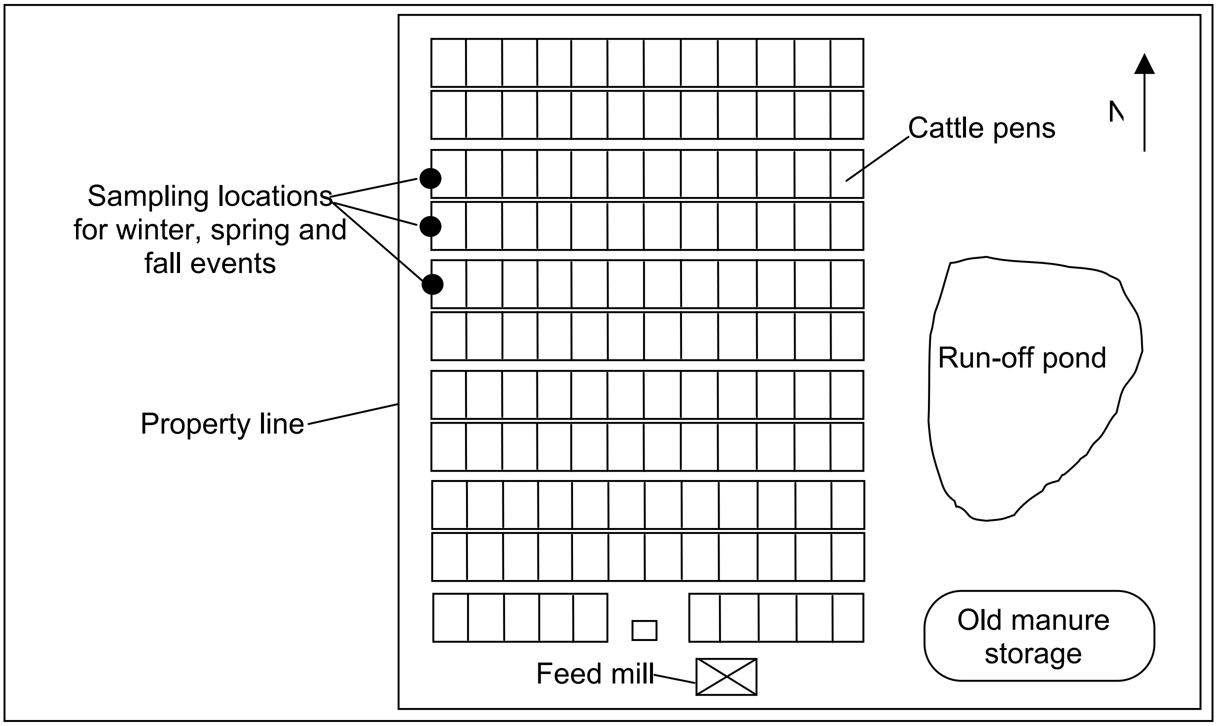

Figure 1. Schematic of sampling locations for semi-continuous measurements of ambient air NH_3 and H_2S concentrations at a 50,000-head capacity commercial beef cattle feedlot in Texas in 3 seasons.

NH_3 and H_2S analyzers

Ammonia concentrations were measured with a continuous NH_3 analyzer (model 17C, from Thermo Environmental Instruments, Franklin, MA) with 0.5 % precision of full scale and 120 sec of the 0 to 90% response time with 10 sec averaging was used to measure ammonia concentrations inside the chamber. A NH_3 analyzer is a combination of NH_3 converter and an NO-NO_2-NO_x analyzer. The analyzer was calibrated daily using UHP-grade air, certified standard span NH_3 gas in air (50 ppm) and NO in nitrogen (50 ppm) (AirGas Southwest, Amarillo, TX).

Hydrogen sulfide concentrations were measured using a continuous H_2S analyzer (model 45 C, from Thermo Environmental Instruments, Franklin, MA) housed in an onsite instrument shelter. The analyzer was calibrated daily using UHP-grade air, certified standard H_2S gas in N_2 (2 ppm) and SO_2 in N_2 (1 ppm) (AirGas Southwest, Amarillo, TX).

Data acquisition and data analysis

A Campbell Scientific data logger CR23X was used as an automated data acquisition system. The system recorded 60 sec rolling average concentration measurements. Concentrations of NH_3 and H_2S were measured during three, 10 min intervals in each hour. However, only the last 3 min of each 10 min interval were used for data analysis due to the minimum time required to obtain a stable measurement reading. Data were downloaded daily. Average 3 min concentrations were averaged on 1 hr basis. It was assumed that H_2S represents a major fraction of the total reduced sulfur concentration measured, i.e., the ambient air concentrations of other sulfur-containing gases were assured negligible.

RESULTS and DISCUSSION

Table 1 summarizes the mean hourly concentrations of NH_3 and H_2S measured at a beef cattle feedyard in Texas.

Table 1. Summary of hourly averages, hourly minimums, and hourly maximums of NH_3 and H_2S concentrations in ambient air measured at a 50,000-head capacity beef cattle feedyard in Texas in the Fall 2002, Winter 2003, and Spring 2003.

		Hourly averaged NH_3 concentrations (ppb)		Hourly averaged H_2S concentrations (ppb)	
Season	Number of Measurement Days	Mean (st. dev.)	Min - Max	Mean (st. dev.)	Min - Max
Fall 2002	10	429 (507)	106 - 2,890	7.73 (4.36)	2.19 - 29.6
Winter 2003	14	475 (409)	108 – 2,280	0.73 (0.63)	0.12 – 3.50
Spring 2003	15	712 (686)	2 – 5,270	2.45 (3.18)	0.15 – 34.9

Hourly mean NH_3 concentrations ranged from 712 ppb in the spring to 475 ppb and 429 ppb in winter and fall, respectively. Hourly mean H2S concentrations ranged from 7.73 ppb in the fall to 2.45 ppb and 0.73 ppb in spring and winter, respectively. The maximum mean hourly concentrations were measured in the spring for both gases, i.e., 5, 270 ppb (NH_3) and 34.9 ppb (H_2S). The absolute maximums (average of the last 3 min of 10 min measurement) for the entire experiment were: 4,300 ppb (fall), 3,210 ppb (winter), and 6,000 ppb (spring) for NH_3 and 31.2 ppb (fall), 1.41 ppb (winter), and 41.4 ppb (spring) for H_2S, respectively. Ammonia concentrations were generally 2 orders of magnitude higher than H_2S concentrations. Hourly means of measured concentrations were highly variable for both gases.

Measured H_2S concentrations were always lower than the ambient air ground level concentration maximums for the State of Texas defined as 80 ppbv (30 min average) on residential, business or commercial property and 120 ppbv (30 min average) for other property for the State of Texas (1976). Also, the hourly average of measured H_2S concentrations were negligible compared to the thresholds for workplace exposures defined as (1) “OSHA General Industry PEL**:** 20 ppm ceiling for 10 min once only if no other measurable exposure occurs and 50 ppm peak”, (2) OSHA Construction Industry PEL**:** 10 ppm (15 mg/m^3) TWA, (3) ACGIH TLV**:**

10 ppm (14 mg/m^3) TWA; 15 ppm (21 mg/m^3) STEL, and (4) NIOSH REL**:** 10 ppm ceiling 10 min. The State of Texas currently does not regulate NH_3.

Figures 2 and 3 summarize the hourly averages of NH_3 and H_2S concentrations in ambient air measured in the Fall 2002, Winter 2003, and Spring 2003, respectively. Each data point in represents the average of all hourly mean for a given hour within the same season. The error bars represent one standard deviation around the hourly means. Ammonia and H_2S concentrations had a characteristic daily pattern with two local maximums in the early afternoon and early evening hours. The lowest concentrations were always measured during the night. The fist maximum in the early afternoon is consistent with the daily patterns observed for NH_3 and H_2S flux from cattle pens at the same feedyard (Baek et al. 2003, Koziel et al. 2004). The reason for the 2^{nd} apparent maximum is not known. Possible cause could be atmospheric inversions in late evening hours.

Figures 4 and 5 present correlations of all measured concentrations with wind direction. Typically, ammonia concentrations were higher for winds between 0 and 180 degrees, i.e., when the cattle pens were upwind from sampling location. The only apparent exception is the relatively high concentrations measured in the spring and westerly winds. The reason for these elevated concentrations are not known. Possible sources of ammonia could be land applications of ammonia upwind of the feedyard. Correlations associated with H_2S are similar. However, fewer high concentrations were measured when the feedyard was upwind of sampling location. For the fall and spring seasons, there is an apparent source associated with westerly winds. This source is less visible for the winter seasons because the measured concentrations were very low. Possible source for H_2S could be exhaust of diesel engines traveling on the (1) feeding alley between the pens and the western property line and (2) North-South interstate highway approximately 2.5 km to the west from the feedyard.

Measured H_2S concentrations were generally consistent with those measured by Koelsh at all (2004) in and around cattle feedlots in Nebraska (Koelsch et al., 2004). Measured NH_3 concentrations were also within the same order of magnitude as those measured in the late spring and summer in Alberta, Canada (McGinn et al., 2003).

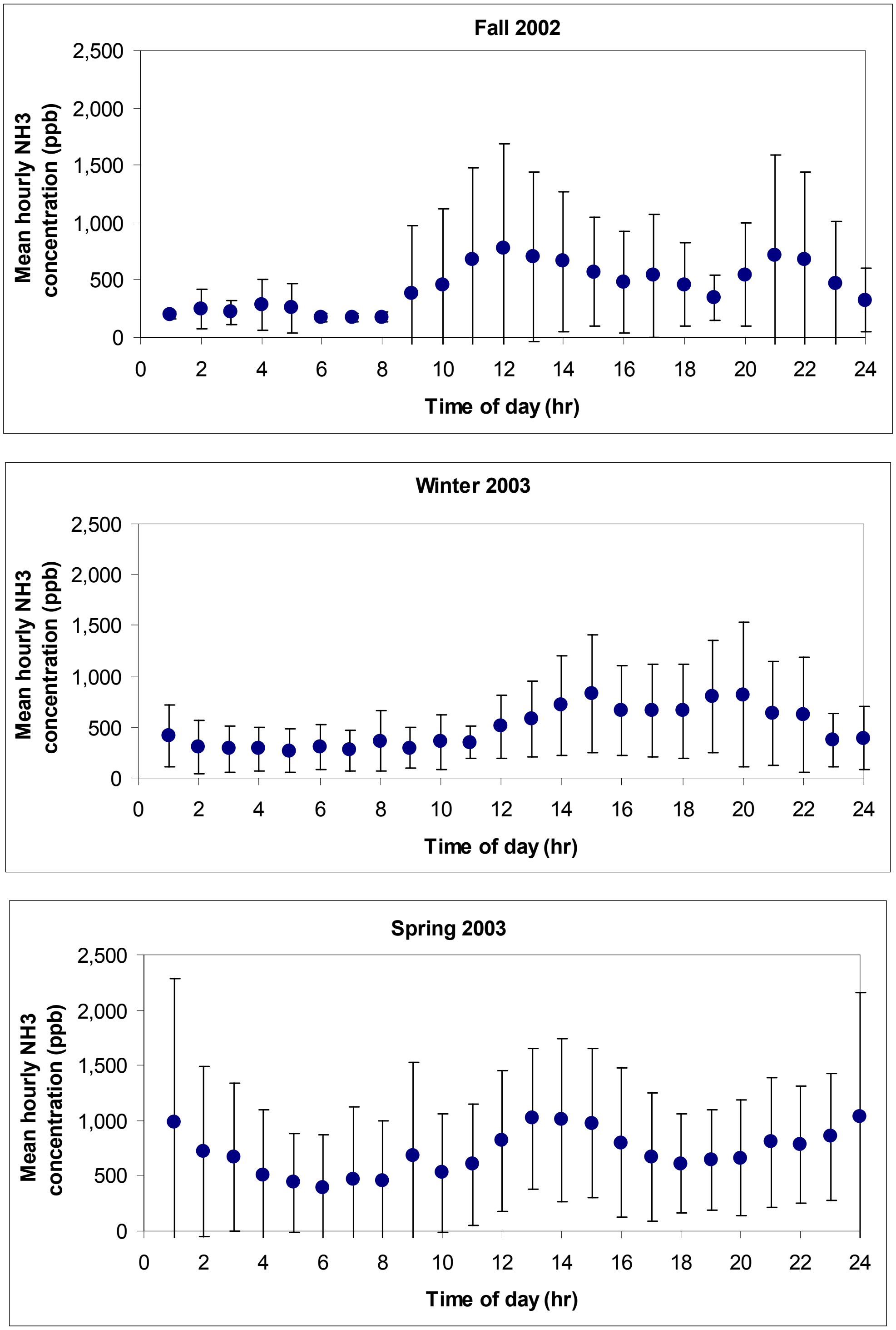

Figure 2. Summary of hourly averages of NH_3 concentrations in ambient air for the fall, winter, and spring seasons.

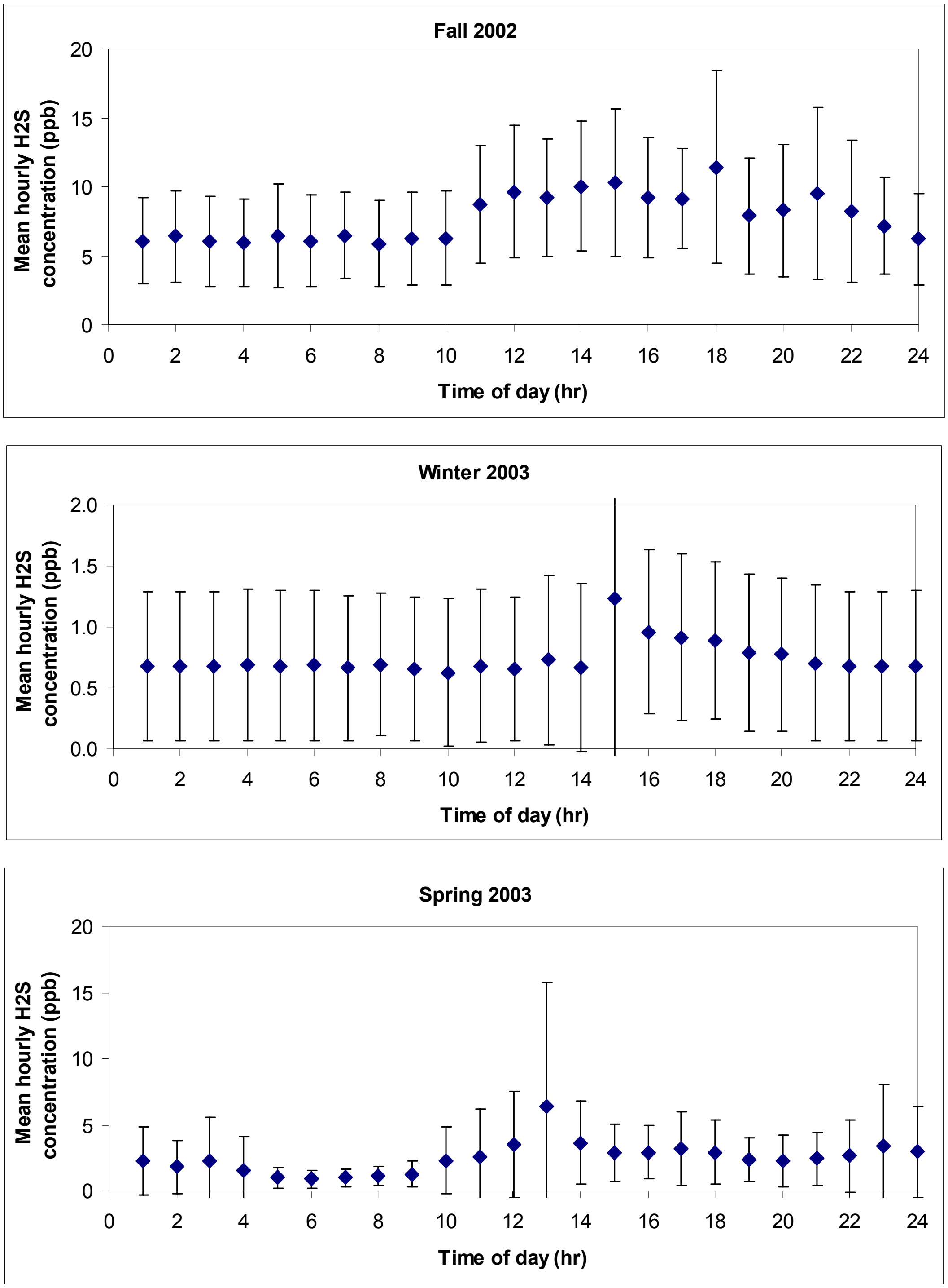

Figure 3. Summary of hourly averages of H_2S concentrations in ambient air for the fall, winter, and spring seasons. Note: vertical scale for the "Winter 2002" plot is reduced 10 times.

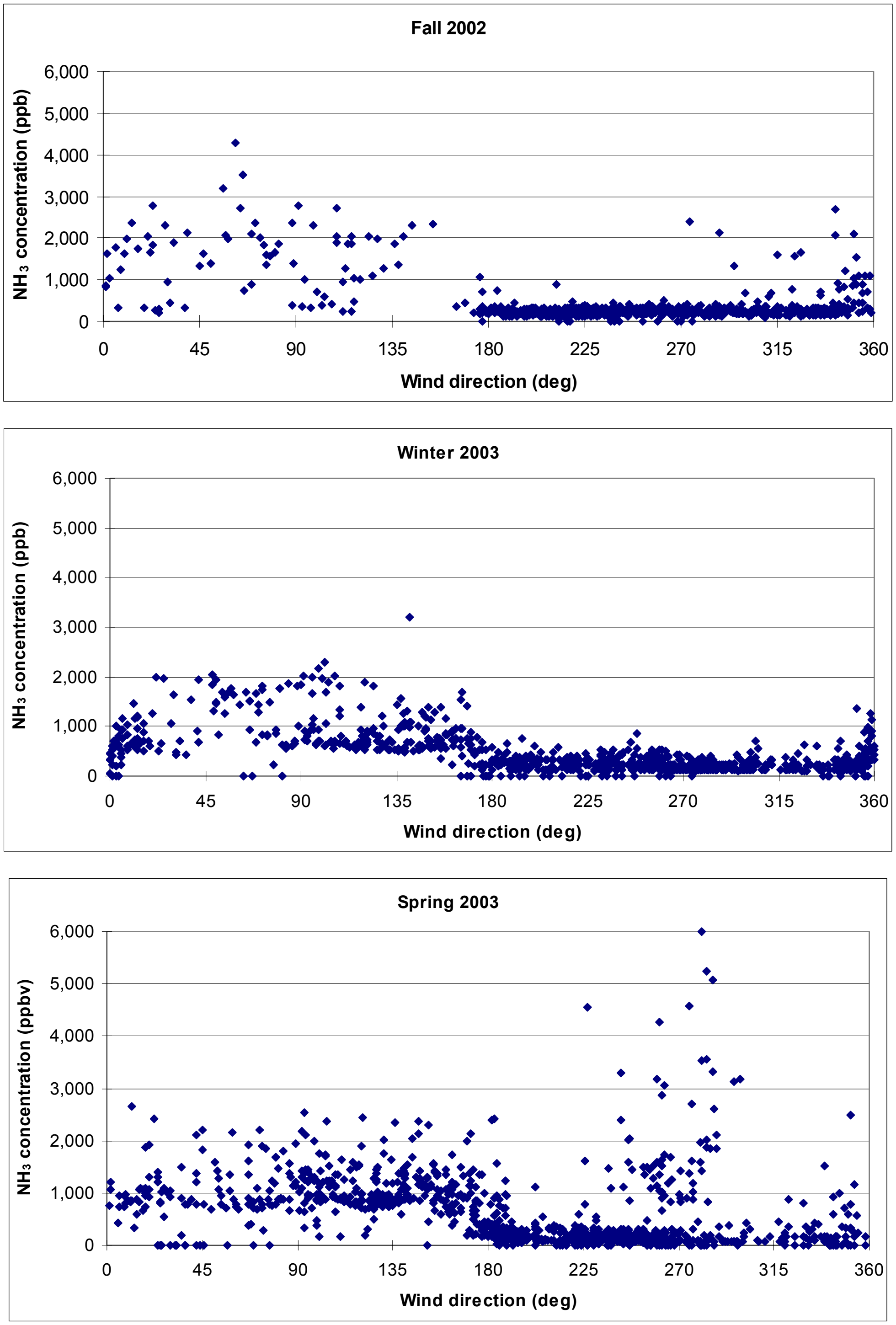

Figure 4. Seasonal correlations between wind direction and measured ambient NH_3 concentrations.

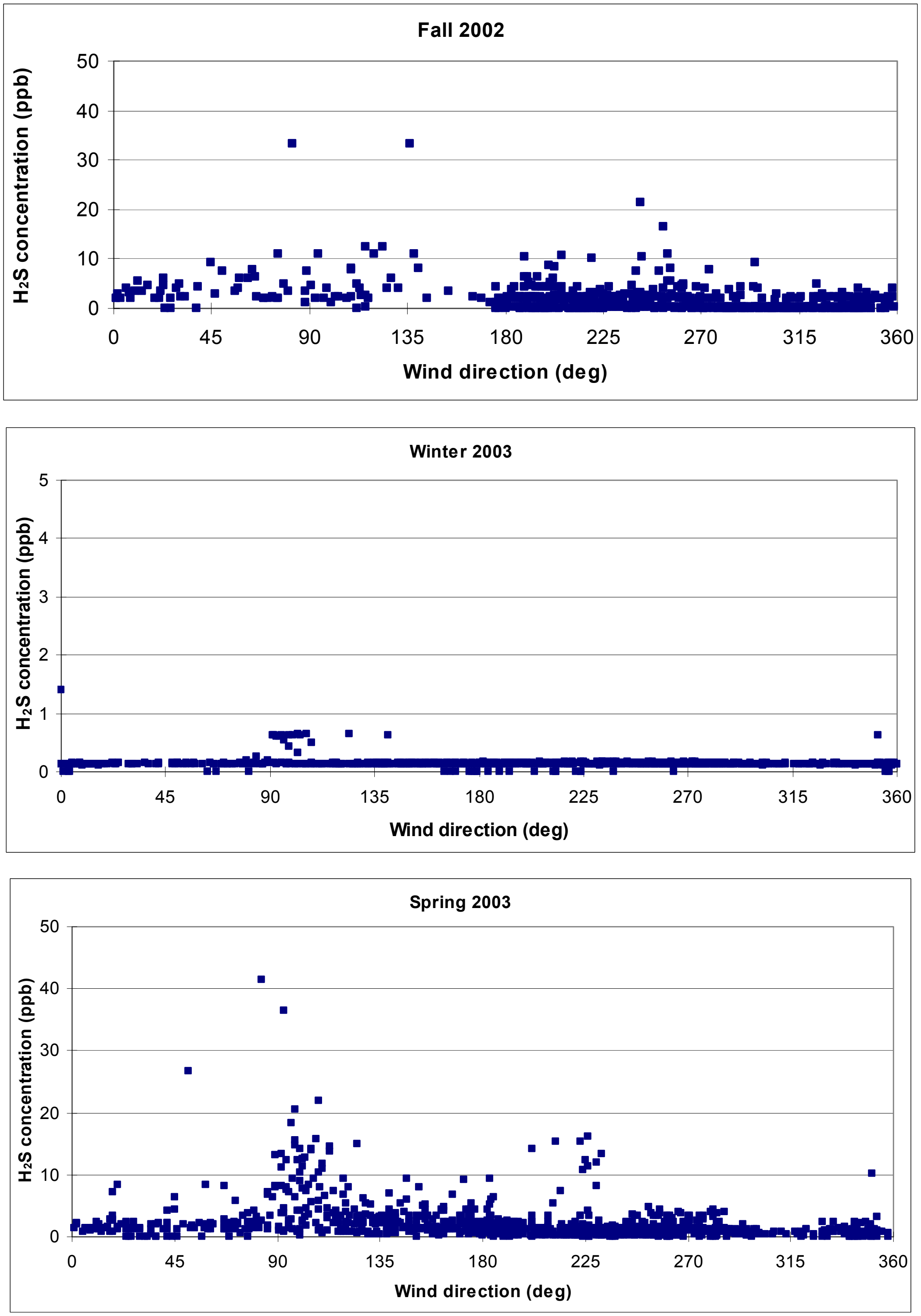

Figure 5. Seasonal correlations between wind direction and measured ambient H_2S concentrations.

CONCLUSIONS

The following preliminary conclusions can be made based on this research:

(1) Measured springtime and fall NH_3 and H_2S concentrations were higher than those measured in winter.

(2) Measured concentrations had a characteristic diurnal pattern with 2 maximums in early afternoon and early evening. The lowest concentrations were measured at night.

(3) Typically, higher measured concentrations were measured when the sampling location was situated downwind from the pens. However, some elevated concentrations from other, unknown sources unrelated to pens were also measured at a lesser frequency.

(4) It is very likely that the H_2S concentrations would not exceed the State of Texas regulatory thresholds (currently set at 80 ppb for residential, business, and 120 ppb for “other property” categories, respectively) for 3 spring, fall, and winter.

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