Summary of Acoustic Ice Nucleus Counter Data Collection Efforts During SNOWIE

FINAL OPERATIONS REPORT • WINTER 2017

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1. BACKGROUND

The acoustic ice nucleus counter (AINC) was developed at the National Center for Atmospheric Research (NCAR) as reported by Langer (1973). The instrument is complex, but when operated with a thorough understanding of its functionality, has proven to be a very reliable means of detecting ice nuclei, especially those containing silver iodide (AgI). For recent examples, see Heimbach *et al*. 2008, Super *et al.* 2010, and Boe *et al*. 2014.

The Seeded and Natural Orographic Wintertime clouds – the Idaho Experiment (SNOWIE), was conducted in the mountains of southwestern Idaho from 7 January 2017 through 17 March 2017. Funded primarily by the National Science Foundation (NSF), SNOWIE was piggy-backed upon an existing operational cloud seeding program conducted by the Idaho Power Company (IPC), designed to increase snowpack and thus water supplies in the Payette River Basin within that state. In the interest of maximizing the scientific benefit of having SNOWIE research in the basin, IPC contracted with Weather Modification International (WMI) to deploy an AINC in the Payette target area during the SNOWIE operations period.

Measurements of AgI plumes in Wyoming (Boe *et al.* 2014) of ground-released AgI plumes revealed considerable plume variability, but on a number of occasions clearly revealed the transit of dense AgI plumes through that target area. It was believed that the Payette Basin deployment in the context of SNOWIE, funded by IPC, would yield similar results.

2. DEPLOYMENT

The location for the AINC deployment, along Idaho State Highway 21 approximately 80 km (line-of-sight) from Boise, was determined by IPC (Figure 1). However, only after the AINC arrived for deployment was it learned that the governance of the selected site did not allow overnight parking. An exception was requested, but denied. However, some 200 m lower (closer to Idaho City) along Route 21 was a turnout, a widening of the road, normally used only during the warm season. This spot was available for overnight parking, but unplowed, and thus, at the time, buried in 1 to 1.5 meters of dense snowpack.

After consultation with the U.S. Forest Service Idaho City District Ranger, Idaho Power was able to obtain a permit to use this site and arrange for this turnout to be plowed by the Idaho Department of Transportation with a rotary snowplow. Because the winter had to that point been extraordinarily active in terms of snowfall, the plow was extremely busy, and unable to do the clearing until 25 January 2017.

Finally, on 26 January, the AINC trailer, propane, portable generator, and the AINC itself were deployed on-site (Figure 2). The SNOWIE research began on 7 January 2017, so 19 days of the program were missed due to deployment issues. The AINC was pronounced on-line and ready to collect data late in the day of 26 January 2017.

3. DATA COLLECTION

3.1 Overview

Data collection for the SNOWIE intensive operations periods (IOPs) occurring after 26 January are summarized in Table 1. During the latter portions of IOP #9 (31 January) very short and occasional "bursts" of apparent IN were detected. These bursts were not indicative of actual ice nuclei however, but rather, an instrument problem traced to the AINC atomizer, which produces the CCN for the cloud chamber.

Figure 1. The site originally intended for the AINC deployment (green balloon) and the site eventually used (yellow balloon) are shown. Both are along Idaho State Highway 21. The site eventually used was approximately 220 m ESE of the original site, and some 13 m lower. The inset map (upper right) shows a zoomed-out perspective, with the City of Boise located in the lower left corner, and the yellow rectangle, some 80 km to the NE, the boundaries of the larger map.

If for any reason the atomizer produces CCN that are too large, even if only periodically, these CCN form large droplets that quickly fall through the chamber and exit through the sensor. Because of their unusually-large (for the AINC chamber) size, they produce the "bursts" of counts observed on 31 January as they exit the chamber and "flow" through the sensor. Thus, the data from that date cannot be used quantitatively.

Attempts to repair the atomizer in the field were unsuccessful, and a replacement was overnighted when it became clear that the atomizer was irreparable. The replacement atomizer was installed and tested on 5 February, and the AINC brought back on-line, again ready for data collection.

Though the AINC was available for data collection on 7 February (IOP #12), heavy snow on Highway 21 compelled the AINC operator to abort attempts to reach the AINC. The road was unplowed except during daylight hours, and snow accumulations had made the road impassable, even for his four-wheel drive vehicle.

Except for minor issues, the AINC remained on-line for the balance of the SNOWIE field program. Data were collected during IOPs 13-20.

The balance of Section 3 is devoted to more detailed descriptions of each of the data collection efforts, with plots of the resulting data and the interpretations thereof.

Figure 2. The AINC site along Highway 21 as it appeared late-day on 26 January 2017, after deployment. The cut through the dense snowbank was accomplished by the Idaho Department of Transportation with a rotary snowplow. This view looks WNW, upslope. The cut remained untouched by plows for the duration of SNOWIE, and gradually re-filled with snow. WMI photographs by Adam Brainard.

Table 1. Summary of AINC Data Collection Efforts

All Dates/Times UTC		AINC Data Collection		*Comments*
Date	***IOP***	***Start Time***	***Stop Time***	
31-Jan-17	09	19:45	23:00	First field data collection. Seeding from 20:39-21:06. Apparent atomizer issues; quantitative data invalid.
3-Feb-17	10	M	M	AINC down for atomizer replacement, after field repairs were unsuccessful. Unit was repaired and back in operation as of 5 Feb, but heavy snowfall prevented the operator from accessing the site.
4-Feb-17	11	M	M	
7-Feb-17	12	M	M	
16-Feb-17	13	23:30	01:14	No seeding. Operation normal, no IN detected above background.
18-Feb-17	14	20:58	01:42	Seeding from 22:11-00:00. Operation normal, no IN detected above background.
19-Feb-17	15	16:35	21:26	Seeding from 18:42-19:36. Possible hint of a plume, nothing certain.
20-Feb-17	16	14:28	19:15	Seeding from 15:15-16:32. Hint of a plume, but right at background levels. Far below amount needed for any microphysical effect.
21-Feb-17	17	14:09	20:01	No IN plume observed. Some minor contamination of sample air occurred (leak into chamber), but a real plume would have been readily detected.
22-Feb-17	18	12:00	16:24	Seeding from 12:00 - 13:57. No IN plume observed.
4-Mar-17	19	12:27	16:20	No seeding.
5-Mar-17	20	12:05	15:05	Elevated background. No plumes detected.

3.2 SNOWIE IOP #09 – 31 January 2017

In SNOWIE IOP #9, the seeding aircraft flew tracks number 4A, for two seeding passes, the first northbound, and the second, southbound. For this IOP, seeding was done with both 150g burn-in-place (BIP) pyrotechnics, and 20g ejectable (EJ) pyrotechnics. The BIPs each burn for ~4 min, and the ejectables for about 37 seconds as they fall ~1 km (3,000 feet).

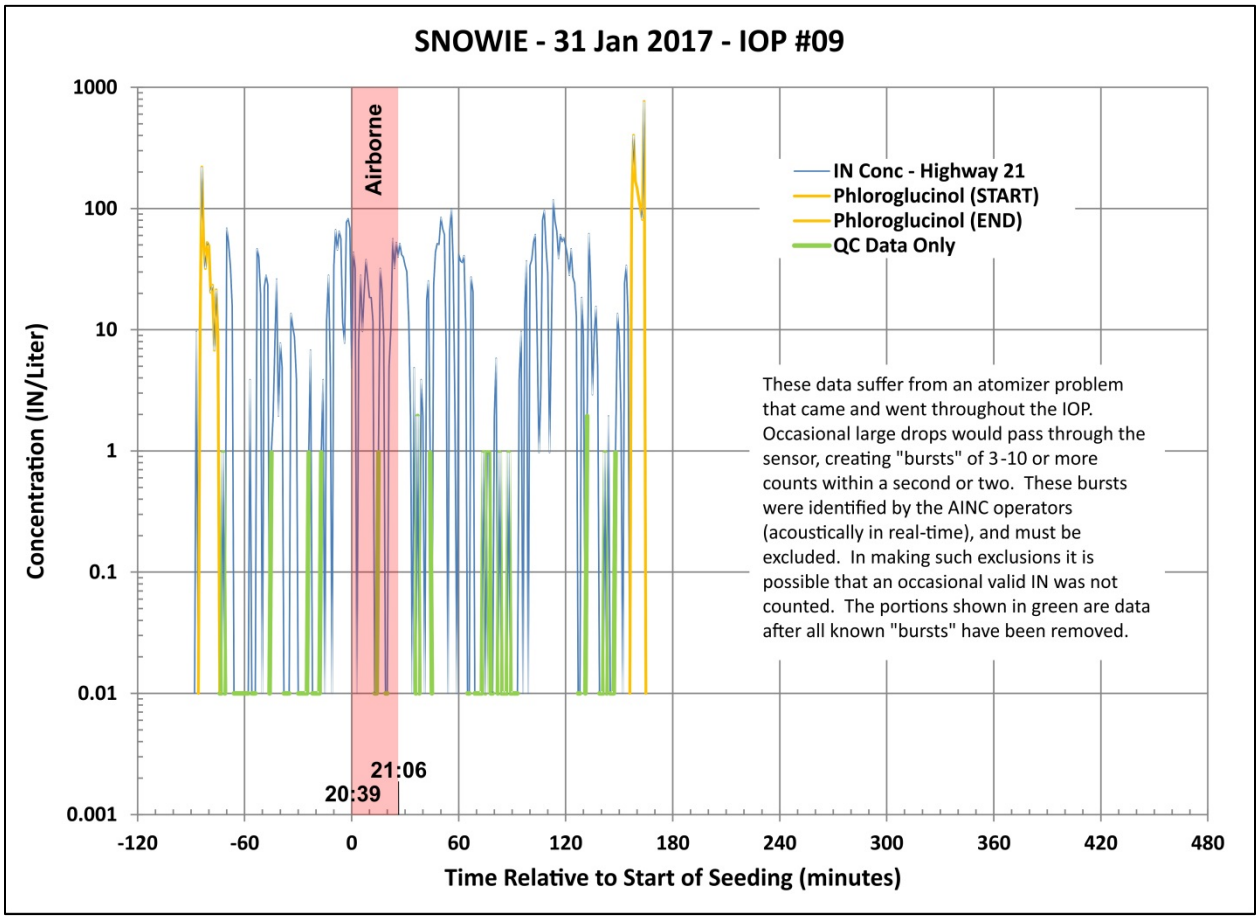

Figure 3. Data collection on 31 January 2017 was complicated by a problem with the AINC atomizer that produces the CCN needed for a dense cloud in the chamber. A cyclical pattern can be seen in the raw data (blue)as the atomizer problem waxed and waned. When these problematic data are excluded the usable data (green) remain. The airborne seeded period, shaded pink, was from 20:39 to 21:06 UTC. Before and after sampling, instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

In examining Figure 3, we see that after quality control measured were applied to eliminate the false signals produced by large droplets from the malfunctioning atomizer, there is rarely a concentration greater than 1 L^{-1}. Three 150g BIPs were burned at altitude during each seeding leg, simultaneously with twenty-seven 20g EJs. Seeding was done on Track 4A at 16,000 feet (4.9 km) MSL. The AINC was sited at 6,050 feet (1.8 KM) MSL, 3.1 km lower. The EJ pyrotechnics burn while they fall for about 1 km, resulting in a minimum seeding altitude of approximately 3.9 km MSL. For the airborne plume to have been detected at the surface, dispersion and mechanical mixing would have had to mix the lower

portions of the plume down an additional 2+ km, prior to passing the AINC location. Since data collection continued for over two hours after the airborne seeding ended, it appears this did not occur. Flight track 4A runs north-south, 64 km west of the AINC at the closest point. Winds at the time of seeding were essentially westerly at about 30 m s^{-1}. Thus, seeding aerosol would have reached the vicinity of the AINC within about 35-40 min. No plume was detected, however. Had precipitation been induced by the seeding and occurred at the AINC site, or AgI from seeding been scavenged by precipitation, the AINC would not have detected it, for the AINC does not sample the snow, but "clear air". Sampling is down through a tube with the opening facing downward, so precipitation is not ingested.

3.3 SNOWIE IOP #13 – 16 February 2017

Unfortunately, the data file for this IOP was inadvertently overwritten, though it is not entirely certain as to how it happened. The M200 is configured to save the file at the conclusion of each data collection effort using the date upon which the data collection ended, and on startup to create a new file only if a file of that name did not exist. Whether it was because of premature M200 power-down, or some other yet-to-be identified quirk, the one-minute data totals for this one IOP were lost.

The good news—if it can be considered such, is that the counter operated perfectly throughout, but no IN plume was detected. Thus, though the one-minute data were lost, it was almost exclusively zeros. As a safeguard, the number of IN detected is recorded manually by the operator every 15 minutes; those data are provided in Table 2.

The AINC operated normally throughout IOP #13. Data collection occurred from 23:38 through 01:08, a total of 84 minutes. Twelve IN were counted during the period. This equates to an IN concentration of (12/84)*0.97 = 0.14 per liter, where the constant (0.97) is determined by flow rate through the sensor, and counter efficiency. Such concentrations are consistent with environmental background, so it can be confidently stated that no IN plume was sampled.

Table 2. Manual Data Summary for IOP# 13, 16-Feb-2017			
Manual data collection, as recorded below, serves as a backup to the M200 data system and for a quick first look at the data. The Acoustic Signal Processor digital count displays were reset after each reading (this does not affect the M200 data). The 1-min data file was inadvertently overwritten, so the 15-min data shown below is the entire data set. No plume was expected, nor detected.			
Time (UTC)	***Time (MST)***	***Raw Counts***	***Notes***
23:30	16:30		Recording Started. Phloroglucinol test in progress.
23:38	16:38		Test reaction normal. Begin normal recording. +SN and gusty.
23:53	16:53	3	Light SN & light wind. ~31.5 deg F.
0:08	17:08	2	Flurries & light wind. Good cloud in chamber.
0:23	17:23	2	Same wx. ~32 deg F.
0:38	17:38	2	Overcast. ~33 deg F.
0:53	17:53	2	Broken sky. Calm wind. ~32 deg F. All systems normal.
1:08	18:08	1	Final regular count. Beginning phloroglucinol test.
1:14	18:14		Test normal. Shutting down.

3.4 SNOWIE IOP #14 – 18 February 2017

In this IOP, seeding with BIP and EJ pyrotechnics was conducted on Track 2B, at an altitude of 13,000 ft (4.0 km MSL). On each of the first three seeding passes one or two BIPs was burned while 55-60 EJs were fired at fairly regular intervals. After the third seeding pass, the north end of Track 2B had cleared, and so the fourth and final pass was shorter than the others, and only 30 EJs were fired, and no BIPs.

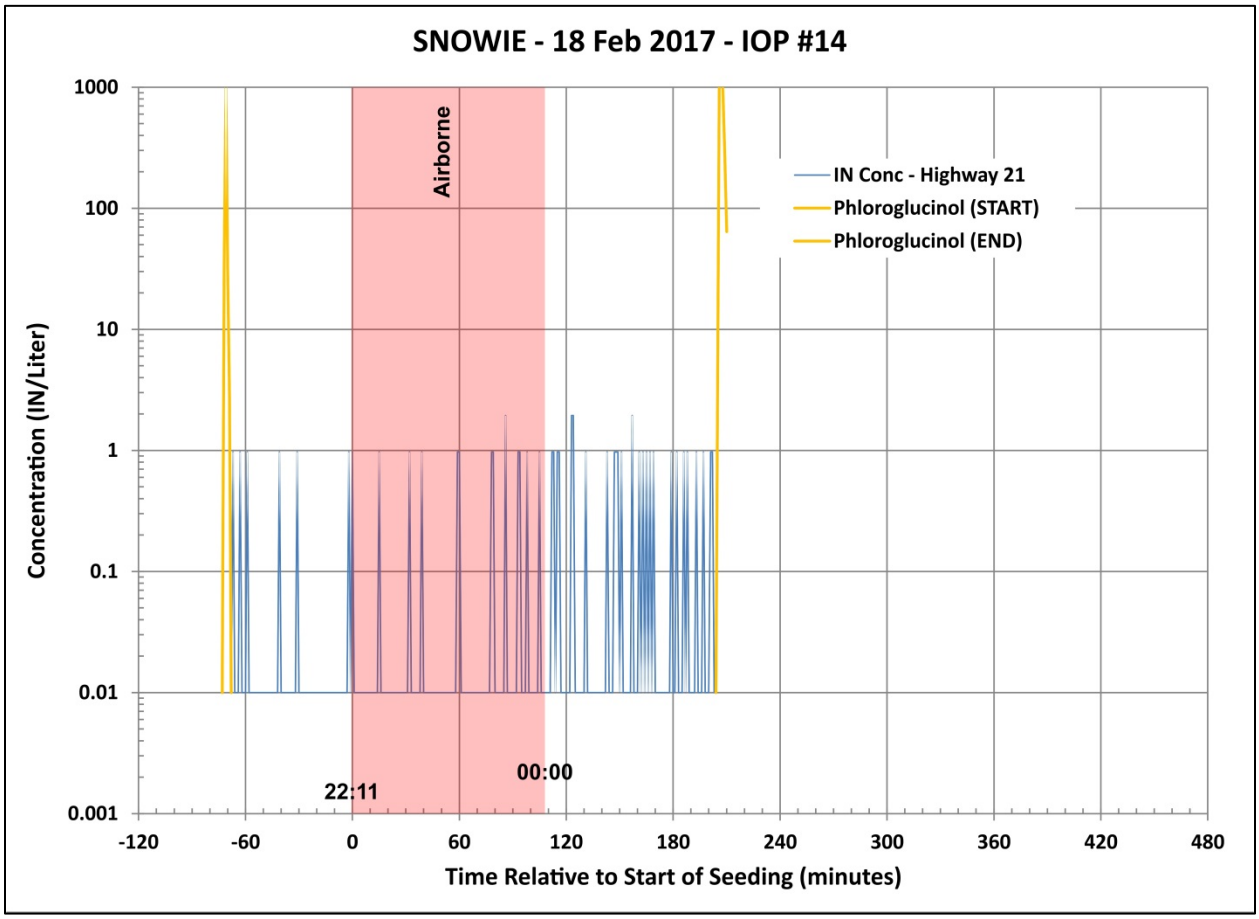

Figure 4. AINC data collection on 18 February 2017 began at 21:04 UTC, and concluded at 01:34 UTC on 19 February 2017. The airborne seeded period, shaded pink, was from 22:11 to 00:00 UTC. No seeding plume was observed. Before and after sampling, instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

Winds at flight altitude were south-southwesterly at 13 m s^{-1}, so the plume from the closest portion of the flight track, 32 km, would have approached the AINC about 40 min later. However, it appears the plume again passed the AINC aloft, for no plume was detected. With the flight level at approximately 4.0 km and an EJ fall distance of about 1.0 km, the bottom of the plume(s) would have been near 3 km, prior to any diffusion and mechanical mixing. The AINC was sited at 1.8 km, some 1.2 km lower, so the absence of a plume at the surface is not surprising.

3.5 SNOWIE IOP #15 – 19 February 2017

On 19 February 2017, IOP #15 saw the seeding aircraft fly Track 3A, which at the nearest point, is 47 km from the AINC. The seeding altitude was 13,000 feet (4.0 km) MSL on the initial pass, and 14,000 ft (4.3 km) on the subsequent five seeding passes.

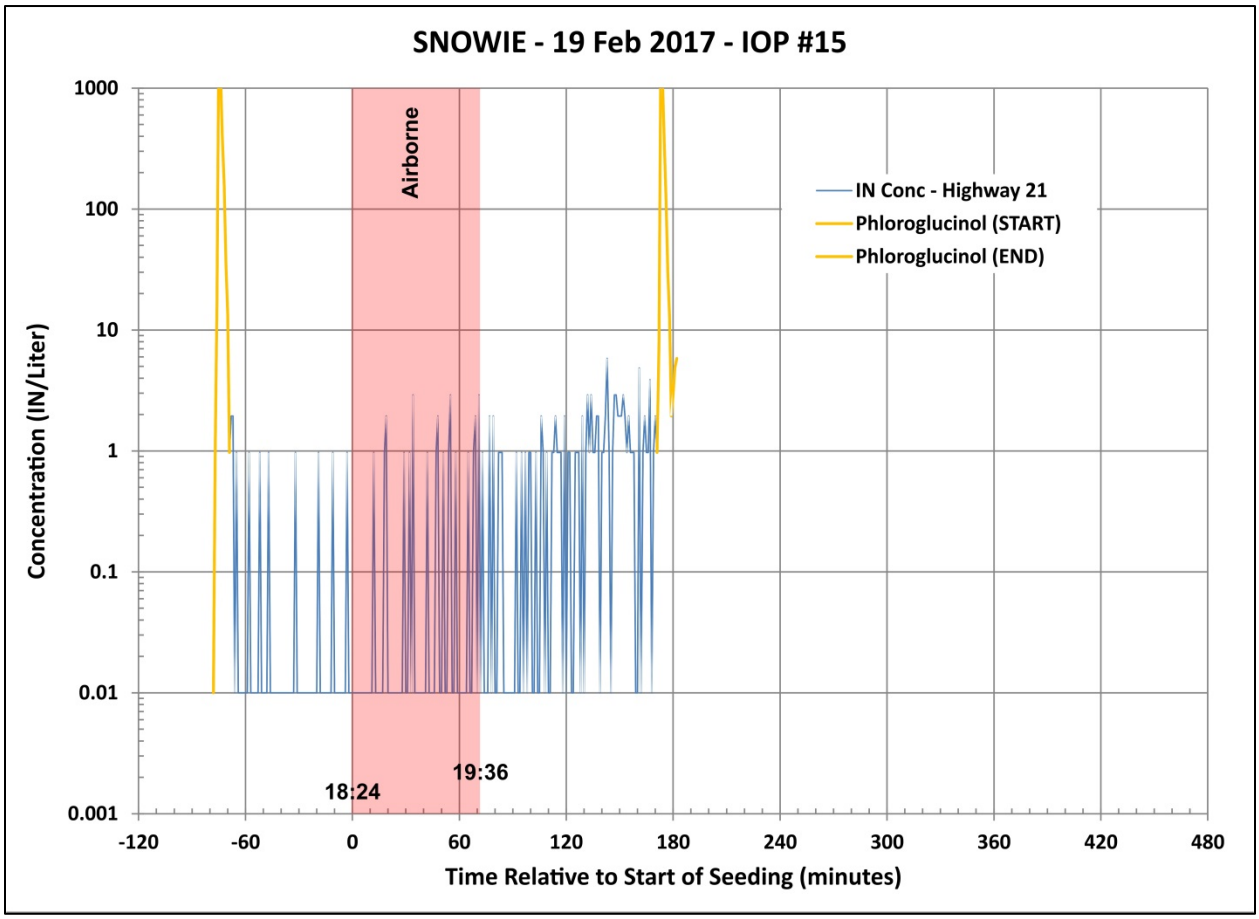

Figure 5. AINC data collection on 19 February 2017 began at 17:15 UTC, and concluded at 21:14 UTC. The airborne seeded period, shaded pink, was from 18:24 to 19:36 UTC. No definitive seeding plume was observed. Before and after sampling, instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

The latter portion of this IOP shows what appears to be a very faint IN plume. However, this is uncertain. At the time, the operator was quite unaware that anything might be amiss—and perhaps that was indeed the case. The counter may have been operating perfectly, and the observed signal, though very faint, may have been real. However, AINC observations during IOP #16 on the following day raise questions about this. This is discussed in Sec. 3.6, and illustrated in Figure 6.

3.6 SNOWIE IOP #16 – 20 February 2017

For IOP #16, airborne seeding was done on Track 3A, three passes, all at 13,000 feet (4.0 km) MSL. Fifty-five EJs were fired on each of the first two passes, and 50 more on the third. A single BIP was burned on the first pass. As noted previously, Track 3A is 47 km SW of the AINC at the nearest point.

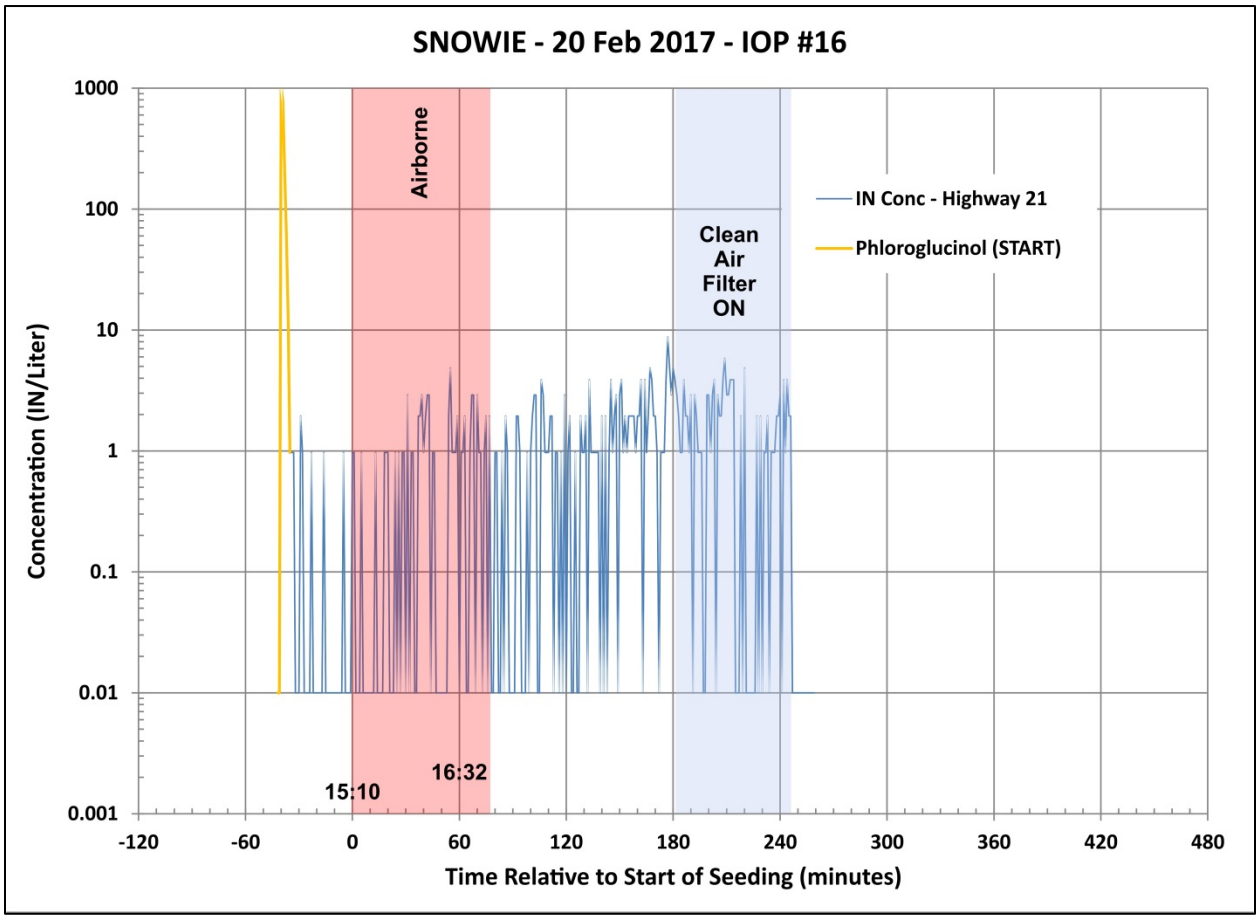

Figure 6. AINC data collection on 20 February 2017 began at 14:35 UTC, and concluded at 19:29 UTC. The airborne seeded period, shaded pink, was from 15:10 to 16:32 UTC. At approximately 15:35 the background increased slightly but perceptibly. A "clean air" filter was placed in the sample inlet line at 18:11, data collection during that time is shaded blue. Before sampling instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01. See the text for additional discussion.

Because the low concentration of IN persisted and even increased well after seeding ended, at 18:11 UTC a clean air filter was placed on the sample inlet. This is done whenever there are doubts as to validity of the data, that is, to eliminate the possibility of instrument problems. When this is done, the inlet air is scrubbed, and all IN removed. Within a few minutes after addition of the clean air filter, counts should drop to zero. In this case, the rate changed little, indicating that the counts, or at least a significant fraction of them, were not resulting from IN contained in the air being drawn in from outside.

Because of these "false" counts, the plume observed in very low concentrations must be disregarded.

3.7 SNOWIE IOP #17 – 21 February 2017

For IOP #17, airborne seeding with ejectable flares was conducted on Tracks 3A and 3B. Twenty EJs were fired from 13,000 feet (4.0 km) while on Track 3A on the first pass. The aircraft moved to Track 3B in search of "better conditions" for the second pass, during which another 72 EJs were fired. For passes three and four, the aircraft returned to Track 3A, but at 14,000 feet (4.3 km). Sixty EJs were fired during pass three, and 24 more on pass four.

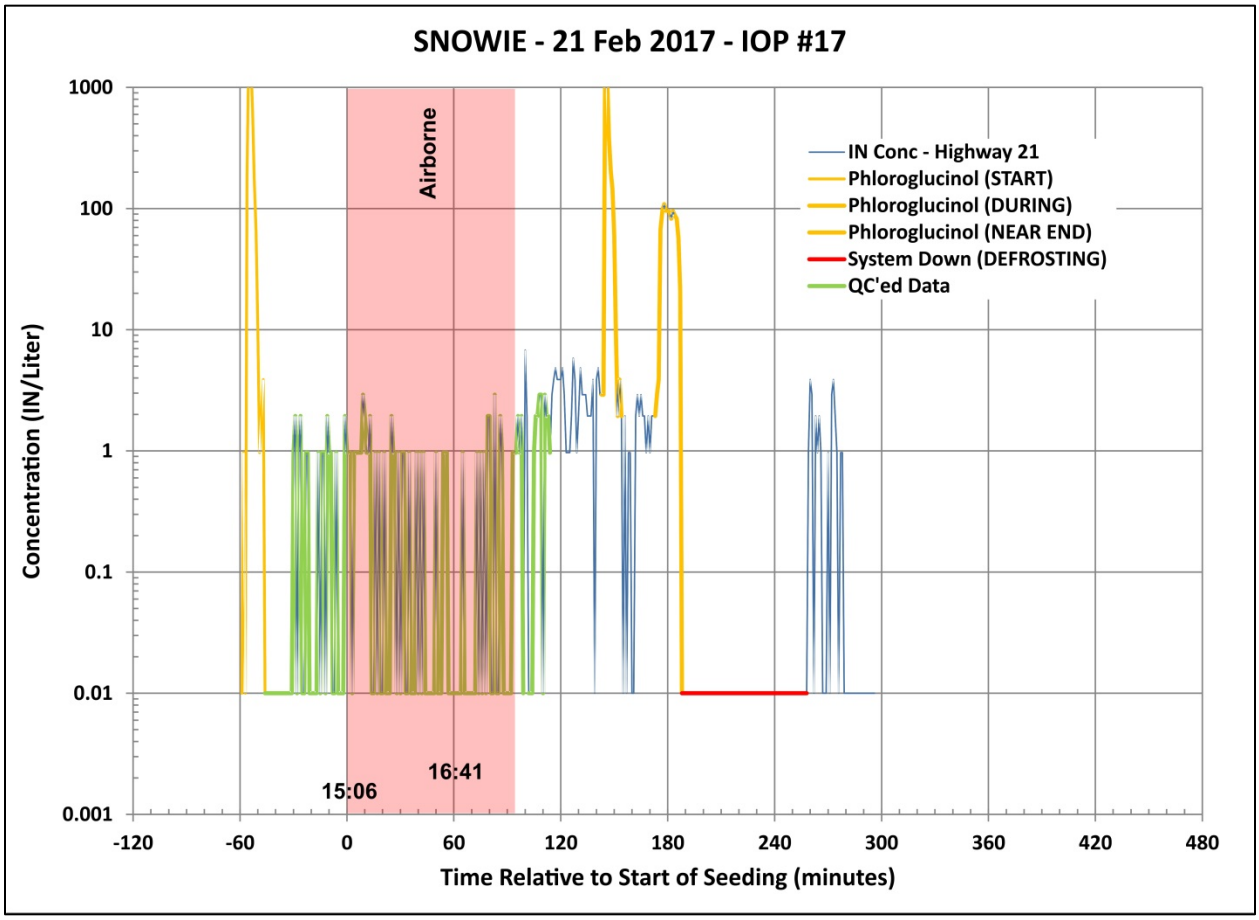

Figure 7. AINC data collection on 21 February 2017 began at 14:20 UTC, and continued until 17:00, when ice buildup in the AINC chamber necessitated shutdown for defrosting. Data collection resumed at 17:40 and finally concluded at 20:02 UTC. The airborne seeded period, shaded pink, was from 15:06 to 16:41 UTC. Ice built up on the chamber thermometers after several hours, and began to shed into the chamber itself, causing erroneous counts. Two injections of phloroglucinol were done (yellow) to test functionality, and though this was found to be OK, the ice build-up had to be dealt with, so the chamber was shut down to defrost. A "clean air" filter was placed in the sample inlet line at 17:15, data collection during that time is shaded blue. Before sampling instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01. See the text for additional discussion.

Two AINC problems occurred during this IOP. Within about 15 minutes after the airborne seeding concluded, a weak increase in the number of IN apparently occurred. However, the operator noticed that considerable buildup of crystalline ice had developed on the stems of the two dial thermometers within the chamber, and it we thought this increase might be instrumental in nature, that is, ice shed

from the thermometers. To check this, the clean air filter was put into the sampling line, but the instrument continued to count, indicating an internal source of the IN was present, *i.e.*, likely ice being shed from the thermometers. The solution for this is to warm the chamber, melting the ice, and then recooling before resuming operations. This was done, as shown in Figure 7 during the time between ~190 to ~255 min after seeding began. When operations resumed, however, the AINC continued to show low concentrations of IN, even with the clear air filter in place. With no ice in the chamber, the source had to be a leak in the chamber itself.

A vacuum pump downstream of the acoustic sensing element provides flow through the instrument, and consequently produces a negative pressure within it. If IN are present in the instrument environment, leaks may allow them into the chamber, resulting in false counts. This was apparently the case, for when phloroglucinol was sprayed around the chamber after the defrosting/recooling, increases in counts were observed, even with the clean air filter still in place.

With a leak present, the low "background" counts CANNOT be considered IN from seeding. It should be noted, however, that had even an IN plume of 10 L^{-1} (from seeding) been present, the instrument would have easily detected it even with the leak. However, no such plume was detected.

3.8 SNOWIE IOP #18 – 22 February 2017

The only ground-based seeding IOP for which IN sampling was done was #18, on 22 February 2017. Initially, two ice nucleus generators (INGs) were activated. Packer John and Garden Mountain were turned on at 12:06 and 12:08 UTC, respectively (Figure 8). Winds at the time (from BOI, 12Z) were 20 knots from the west. Thus, it is not likely that the IN from Packer John and Garden Mountain were transported directly toward the AINC, some 40 km distant to the ESE.

The Horsethief and Cascade INGs were added to the seeding at 13:39 and 13:49, respectively. Late in the event, the Comeback Mine and Mammoth Mine INGs were also activated due to their proximity to the AINC. The AINC IN plot for IOP #18 is shown in Figure 9.

Figure 8. The locations of the six INGs used in IOP #18 are shown relative to that of the AINC. The Mammoth Mine and Comeback Mine INGs were active only for the last 44 min of the seeding, and activated only because of their proximity to the AINC.

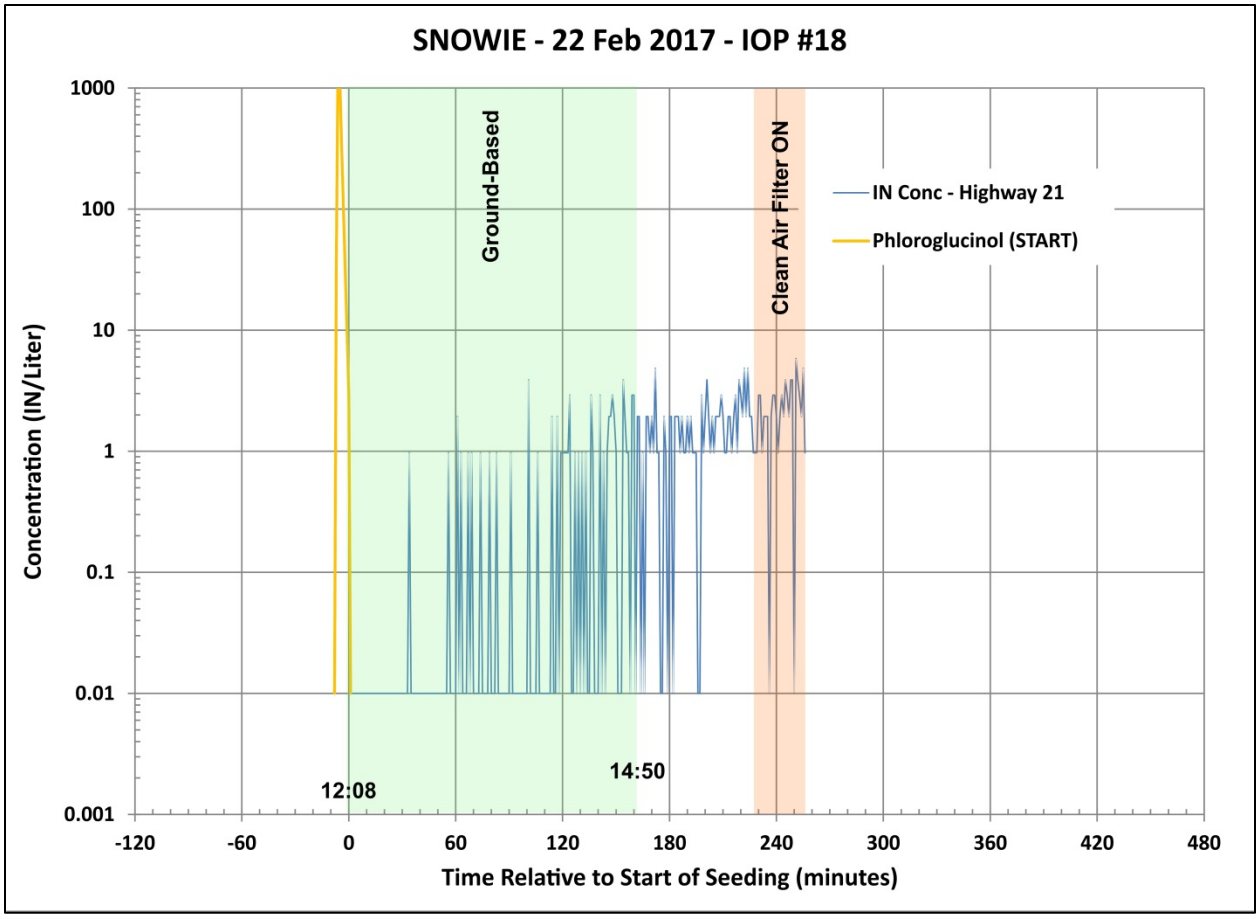

Figure 9. AINC data collection on 22 February 2017 began at 12:09 UTC, and concluded at 16:24 UTC. The ground-based seeded period, shaded green, was from 12:06 to 14:50 UTC. Near the end of the sampling period the operator noted that considerable ice had formed on the interior of the chamber lid, and placed the clean air filter in the sampling intake (pink). The low, but elevated IN count continued, suggesting that most if not all of the previous IN ostensibly detected in the hour previous may have been internal to the AINC, and not environmental. Before sampling, instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

Toward the conclusion of the seeding period, after the activation of the Mammoth Mine and Comeback Mine INGs, the number of IN detected increased slightly, and continued to gradually increase up until the time the operator noticed the ice buildup on the underside of the chamber lid and put the clean air filter into the sampling line. Since counts did not drop to zero with the clean air filter in place, it was apparent that the IN being detected were not external, at least for the most part. Efforts had been made to re-seal the chamber top and chamber thermometer ports, where leaks most commonly occur, so it would seem that the elevated background counts were likely due to increased ice within the chamber itself. Such ice tends, with passing time, to shed increasing(but small) numbers of particles which get counted the same as newly-activated IN—but they aren't.

Again, it should be noted that, had a significant IN plume been present at the AINC location it would have been detected above the elevated background.

3.9 SNOWIE IOP #19 – 4 March 2017

Seeding Track 3B was used for IOP #19 on 4 March 2017. The first pass was made at 14,000 feet (4.3 km) MSL, while seeding with 12 EJs. In search of better conditions, the altitude was dropped to 13,000 feet (4.0 km) MSL on the second pass. The seeding aircraft reported westerly winds, at 45 kts (23 m s^{-1}). Seeding was conducted using 39 EJs. The third, fourth, and fifth seeding passes were flown at 12,000 feet (3.7 km) MSL, and seeding utilized 36, 38, and 14 EJs, respectively. At the closest point, Track 3B is 24 km SW of the AINC.

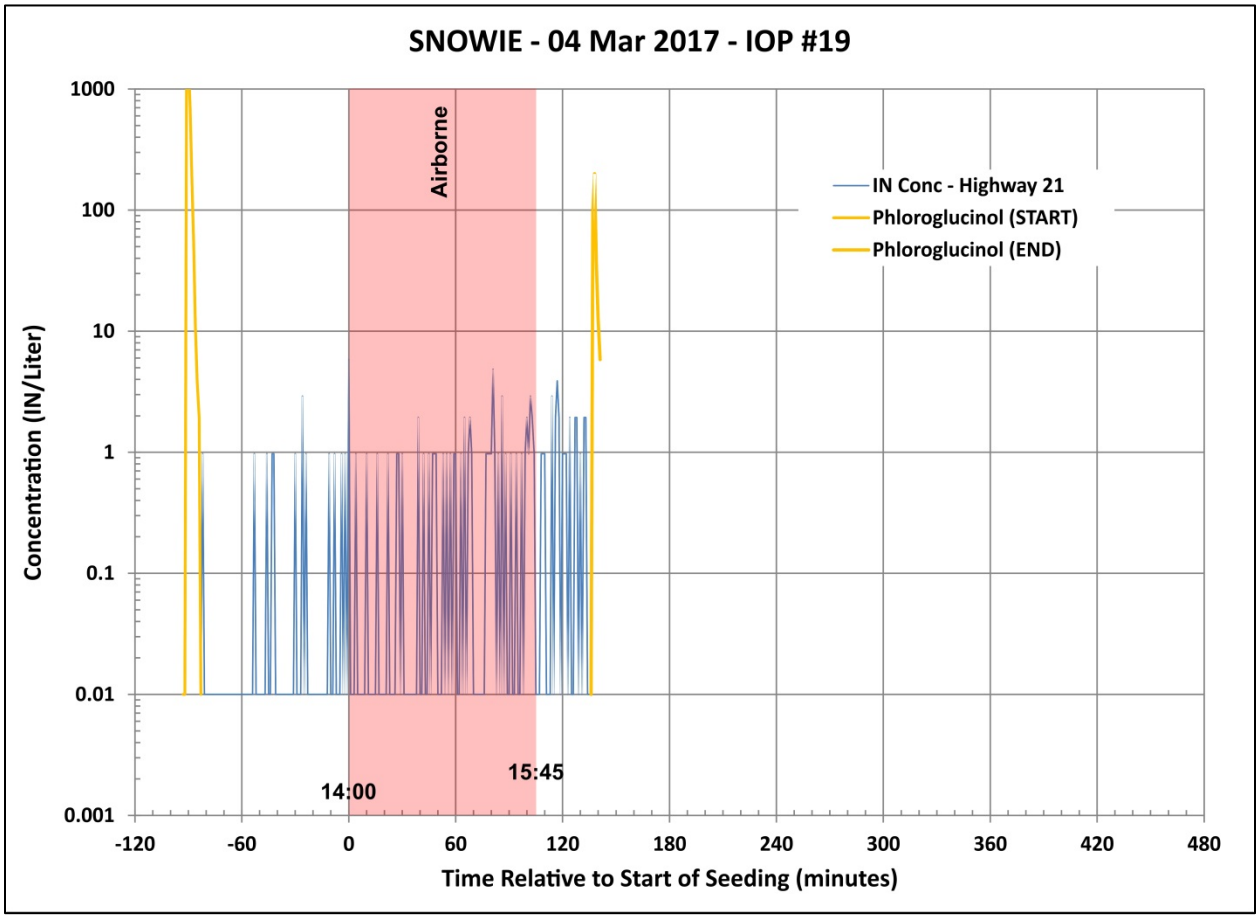

Figure 10. AINC data collection on 4 March 2017 began at 12:37 UTC, and concluded at 16:15 UTC. The airborne seeded period, shaded pink, was from 14:00 to 15:45 UTC. Before and after sampling instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

The AINC functioned well throughout the data collection period, though some ice buildup during the last half hour caused the "background" IN level to slowly rise. No seeding plume was observed.

3.10 SNOWIE IOP #20 – 5 March 2017

Intensive Operations Period #20 occurred on 5 March 2017. Four seeding passes were made on Track 3B at 13,000 feet (4.0 km) MSL, each using 45-49 EJs. At the closest point, Track 3B is 24 km SW of the AINC.

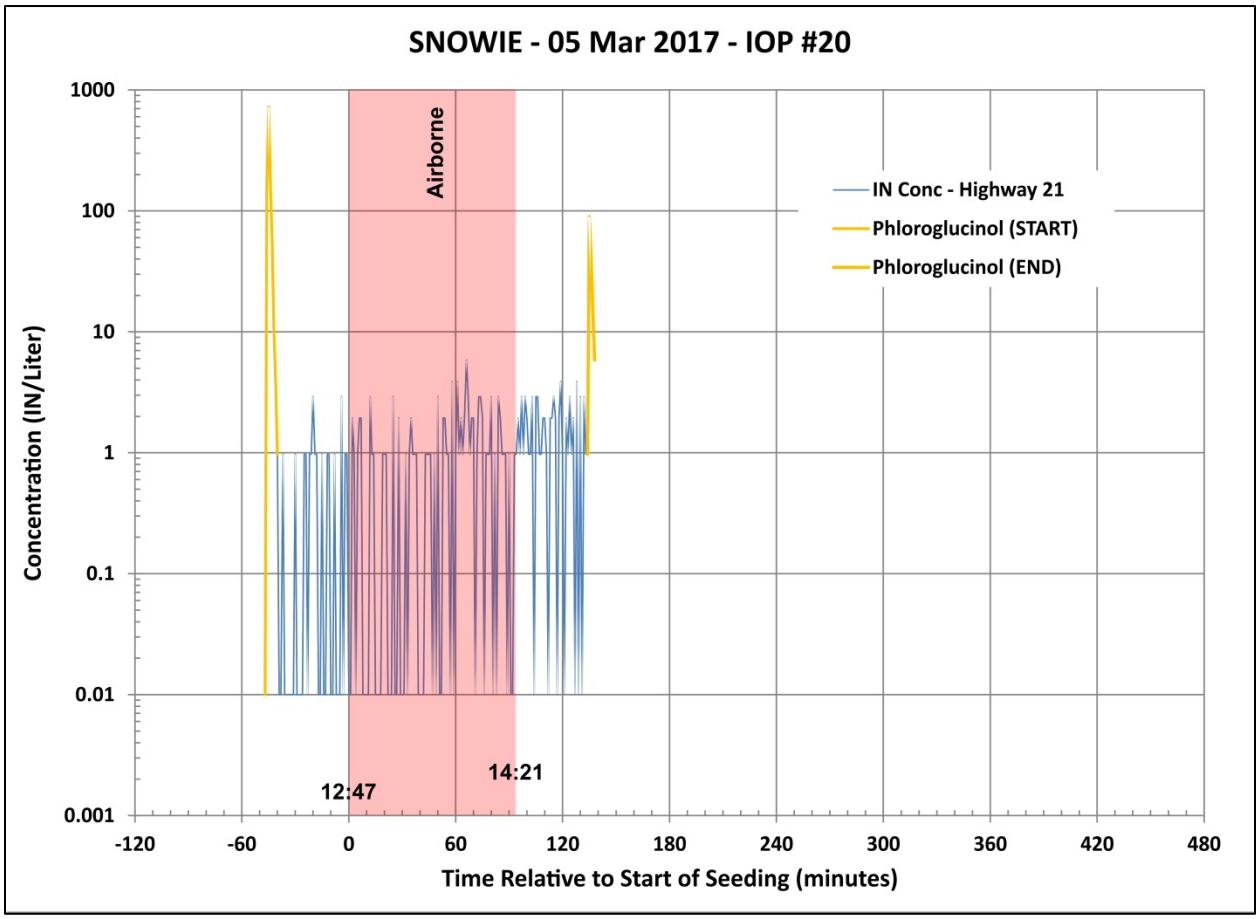

Figure 11. AINC data collection on 5 March 2017 began at 12:07 UTC, and concluded at 15:01 UTC. The airborne seeded period, shaded pink, was from 12:47 to 14:31 UTC. Before and after sampling instrument functionality was tested by the introduction, at the outside sampling inlet, of an ice nucleus surrogate, phloroglucinol (yellow). In order to show the data on a log scale, IN concentrations of zero are plotted as 0.01.

The AINC operated normally throughout the period, though ice buildup within the chamber continued to result in a gradual increase in the apparent "background" IN concentration. The aircraft track selected for seeding (3B) is relatively close to the AINC, being about 24 km upwind at the closest point, and winds were from the southwest at 40-50 kts (21-26 m s^{-1}). It is thus not at all surprising that no plume was observed.

4. A COMPARISON WITH AINC OBSERVATIONS IN WYOMING

Because no clear ice nucleus plumes were ever observed during SNOWIE, it may be helpful to provide an example of what a plume looks like when measured by an AINC. The example given is from the Wyoming Weather Modification Pilot Project (WWMPP, Figure 12).

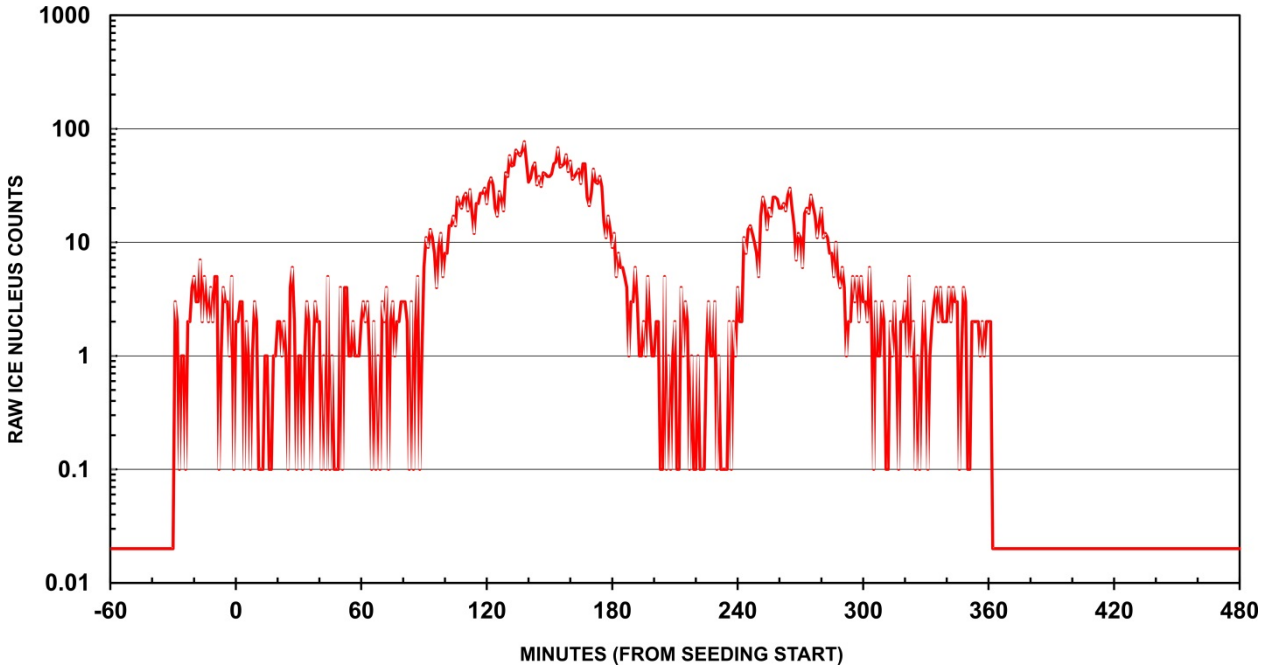

Figure 12. This plot, analogous to those presented earlier in this report, illustrates two plume encounters recorded during the Wyoming Weather Modification Pilot Project. The "background" is very similar to the graphics from SNOWIE. However, the plume encounters are very clear. This case differs from all but one SNOWIE case (IOP #18) as only that IOP involved ground-based seeding.

In the WWMPP case shown here, multiple ground-based generators were active on the upwind side of the mountain range being seeded; the AINC was sited not far from the range crest, on the downwind side.

While Figure 12 is an example of an obvious plume encounter, the plume shown is modest. Indeed, multiple plumes were observed during the WWMPP that had IN concentrations well beyond 100 L^{-1}, a few even near 1000 L^{-1}.

Such plumes were never recorded during SNOWIE.

5. SUMMARY

5.1. Deployment

Problems with siting delayed the deployment of the AINC. The site originally chosen by IPC was unavailable due to overnight parking restrictions. The alternate, not far removed but farther downslope, had to be plowed before it could be used, and because of the unusually-active weather, a capable plow was not immediately available.

Immediately after deployment a problem with the AINC atomizer resulted in the instrument being down for another week. Once the atomizer issue was addressed the AINC functioned properly for the balance of the field effort. A minor leak somewhere in the top or chamber side resulted in very minor increases in IN counts during the latter portions of most IOPs, but the increased "background" was still well below any rates that an encounter with AN IN plume would have produced.

5.2 Observations

Ice nucleus measurements were made with the AINC during twelve IOPs (Table 1). Of these twelve seeding events all but one were airborne. In all of the airborne seeding IOPs the minimum altitude of the seeding plume initially created by the falling EJs was well above the elevation of the AINC itself. The lowest seeding altitude was 12,000 feet (3.7 km), while the AINC was sited at 1.8 km MSL. Even allowing for the fall distance of the EJs (~1 km), the IN plume would have initially been nearly 900 m above. During most IOPs the seeding altitude was 13,000 or 14,000 feet (4.0 or 4.3 km), adding creating additional separation. This does not mean that detection of a plume from airborne seeding was impossible, but it does mean that considerable dispersion and mechanical mixing would have been necessary for such plumes to have reached the AINC elevation.

The AINC does not ingest precipitation, so any IN that nucleated ice and became precipitation would have been sampled. Likewise, IN scavenged by precipitation would also be removed from the free air. To have been sampled the IN would have had to mix downward, to the surface, so it is not surprising that no plumes—even modest ones (see again Figure 11)—were recorded.

When ground-based seeding was used in IOP #18, the ground-based generators initially activated were not upwind of the AINC. Ninety minutes after the start of seeding, two additional INGs ever farther north were engaged, but it wasn't until ~45 minutes before the end that the two INGs closest to the AINC were turned on. As shown in Figure 8, the Mammoth Mine and Comeback Mine INGs were located approximately 8 and 16 km west of the AINC, respectively. Both INGs were south of due west of the AINC, but certainly close enough to have had a chance of getting plumes to the AINC in the westerly flow present at the time. The seeding period was less than an hour, and winds, though westerly, were not strong, just on the order of 20 knots. No plumes were observed.

In Wyoming during the WWMPP, analogous ground-based seeding conditions resulted in plumes being detected about half the time, even though seeding was generally conducted for four hours. In this case, with a seeding duration of 45 minutes, the winds may have been too light or not quite the right direction to transport the plume all the way to the AINC. It is worth noting that a significant drainage lies between the Mammoth Mine ING and the AINC. This drainage slopes downward toward the north, from about 1700 m to 1150 m, near Lowman. If any channeling of flow occurred, the plumes from Mammoth Mine and Comeback mine might easily have been redirected to the north of the AINC.

In other AINC deployments in recent years the instruments have been used to observe and quantify AgI IN plumes produced by surface-based seeding, *e.g.* Super 1974, Super and McPartland 1975, Super and Huggins 1992, Super 1994, and Boe *et al.* 2014. All of these previous efforts were successful in identifying, at least at times, ground-released seeding plumes. None of them, however, attempted to detect plumes released in the air. This effort in SNOWIE thus marks the first known attempt to do so.

6. RECOMMENDATIONS

In the dozen AINC operations with seeding, only one was during ground-based seeding. All the others were with airborne seeding. In retrospect, it is not surprising that no plumes were detected.

If there is interest in further study of plumes from IPC INGs, the AINC should be deployed for the full winter, prior to winter's onset. Our experience has been that it is best for the operator to live with the instrument, as this eliminates travel. In the 2017 field effort, data collection did not occur on at least two occasions because the operator could not access the AINC due to poor road conditions. The cost of on-site living can be readily offset by the elimination of hotel bills.

Any such detection site should be as near to the target area as possible, or perhaps even within it. The AINC crew is not averse to travel via snowmobile or (for shorter distances) snowshoe. We have found that many locals with inholdings on the forests are often willing to allow such siting, and may also be able to provide power and internet.

7. REFERENCES

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