**Flight 20170116_1**
Date: January 16, 2017
Scientists: Carrie (flight scientist), Lexie (back seat)
Pilots: Rob (pilot), JC (copilot)
Preflight: 11AM MST
Pulled onto tarmac: 12PM
Planned Takeoff: 2PM
Actual Takeoff: 2:34 PM
Touchdown time: 5:06 PM

Flight plan: North
Deviations from plan: Circled the US Magnesium plume 1.5 times instead of transecting it on either side.

Notes: We stayed below the boundary layer throughout the Salt Lake Valley, which seem to have a top around 6500 - 7000 ft. We spiraled right up to 12,500 ft, then spiraled left down into the Cache valley, where we were able to be in the boundary layer at 5100 ft (top was at about 5500). At 3:52 pm MST, heading southwest towards the lake, we visually saw a big plume off the right side of the plane, and maybe sampled some of it. At 4:13, approached the US Magnesium plume, and since the winds were very mild, we circled the plume at about 4800 ft, then climbed closer to 6000 ft to circle it again. 4:23 - headed back east across lake (it's reddish!), that's when I noticed the AMS filament had turned off and was not collecting data. Missed approach at Bollinder, then spiral up over the mountains, land at SLC.

**Flight 20170117_L1**
Date: 17 January 2017
Scientists: Dorothy (flight scientist), Ale (back seat)
Pilots: JC (pilot), Rob (copilot)
All times in MST
Preflight: 11:00
Pulled onto tarmac: 12:00
Planned takeoff: 14:00
Actual takeoff: 14:50
Touchdown: 16:48
Weather: Sunny, bright, very hazy, 1.7C
Flight plan: South to Provo
Deviations from plan: just a little redirect on takeoff

Notes:
On take off from the Salt Lake airport, the boundary layer height appeared to be about 6500 ft ASL. We were at that height for a while and were in and out of the boundary layer. At 14:27, we were over the Great Salt Lake, where visibility was very low due to haze and it was somewhat colder (-5C). At 14:38 we passed by "Garfield Tower." Unknown what the tower is, but there

were some small NOx plumes associated with it. NOx was higher and more variable on the city (east) side of the lake than the far side. During the descent into South Valley for a missed approach, there was a clear, high NOx layer between 4800 and 5400 ft ASL. At 14:57 we did the missed approach at South Valley, getting very close to ground level. At 15:14, we passed over the Hawthorne (?) Elementary school site and continued into the turn over the University at 15:16. At 15:23 we started the spiral up and found a boundary layer height of 6700 ft ASL. We topped out the spiral at 15:30 at 12500 ft ASL. At 15:35 we started our descent into the Utah Valley. There was a distinct O3 layer below 9300 ft ASL, and the boundary layer height was the same in the Utah Valley as Salt Lake (6700 ft ASL). Utah lake was about 70% frozen, with significant open water around the edges. Provo was ~70% snow covered. The Utah Valley had significantly lower NOx and particulates than the Salt Lake Valley. At 16:03 we did the missed approach at Spanish Fork. We then cruised over Utah Lake at 5000 ft ASL, where the air was very clean. The boundary layer was much lower than 500 ft ASL there and we couldn't get into it. Once we got over shore again, NOx and aerosol climbed back into the detectable range. We appended a box to the flight after cutting back into the Salt Lake Valley through the Jordan Narrows. From 16:26 to 16:31 we paralleled a busy highway, and passed through a few NOx plumes where sources were not clear. There were some factories and the highway nearby, which may have been contributing. In the box formation, on the mountain side, we were in and out of the high NOx. We ran the box consistently at 5400 ft ASL, with a slight deviation from the flight plan to avoid a hot air balloon. On the way back to the SLC airport, we passed a high NOx area, possible due to a very busy highway interchange, where rush hour was clearly starting. At 16:48 we also saw clear influence from a highway near the airport as we crossed low to the ground over it.

**Flight 20170117_L1** (Ale's Log)
Date: 2017 Jan 17 (local), 2017 Jan 17 (UTC)
Flight plan: Salt Lake and Utah Valleys

| | |
|---|---|
| Research scientists: | Dorothy and Ale |
| Pilot: | JC |
| Co-pilot: | Rob |
| 20:51 UTC | All ready to take off |
| 20:55 UTC | Headphones start to work |
| 20:56 UTC | Power switch … all smooth! |
| 20:59 UTC | Start taxi |
| 21:06 UTC | Start engine tests: engines at high RPM then low for 3 times |
| 21:07 UTC | Stop engine tests |
| 21:14 UTC | Taking off! |
| 21:15 UTC | Already up in the air, crawling and turning the Iodide CIMS switch on |
| 21:25 UTC | Check QCL chiller and laser T … all ok (Chiller 15 C, Laser 40.1 and 39.8) |

| | |
|---|---|
| 21:27:58 UTC | Start QCL zero |
| 21:31:00 UTC | Stop QCL zero |
| 21:49 UTC | Right turn |
| 21:57 UTC | First missed approach |
| 22:03:43 UTC | Start zero QCL |
| 22:06:43 UTC | Stop zero QCL |
| 22:12 UTC | Flying over golf court, we are close to the Hawthorne elementary school |
| 22:14 UTC | Flying over Hawthorne elementary school |
| 22:23 UTC | Start spiraling up, turning right |
| 22:26:36 UTC | Start zero QCL (at the end of the spiral) |
| 22:27:50 UTC | Stop zero QCL |
| 22:31 UTC | Still quite high, ~12,500 ft, squeaky clean air |
| 22:35 UTC | Start descent, spiraling down, left turn |
| 22:46 UTC | Second missed approach, ~100 ft |
| 22:56:25 UTC | Start zero QCL |
| 23:01:34 UTC | Stop zero QCL |
| 23:03 UTC | Third missed approach |
| 23:12 UTC | INTERESTING! Flying over Utah lake, NOy not present, aerosol mass loading medium-high |
| 23:46 UTC | Turning Iodide CIMS switch off |
| 23:47 UTC | Touch down |
| 23:51 UTC | AMS switched to filtered air while refueling |

End of **Flight 20170117_L1**

**Flight 20170117_L2**
Date: 17 January 2017
Scientists: Dorothy (front), Ale (back)
Pilots: Rob (pilot), JC (copilot)
All times in MST
No preflight
Refueling on tarmac: 16:49-17:41
Planned takeoff: 17:40
Actual takeoff: 18:06
Touchdown: 20:50
Weather: Sun had just set, there was still dusky light. -1C, still very hazy
Flight plan: North to Cache
Deviations from plan: Some porpoising over Salt Lake to find most interesting layers

Notes:
There was a slight power bump just after the crew was back on board. It was out for 1-2 seconds. The only instrument that went down during the bump was the UHSAS. All others kept

working. The issue with the power bump seemed to be the cart itself, rather than the transition to airplane power. The cart has been modified to, hopefully, fix this problem going forward. At 18:21 we passed through a strong NOx plume, the source of which was unclear. There were high concentrations of NOx and aerosol at 4900 ft ASL, but it was difficult to tell whether that was boundary or residual layer. After the first missed approach at Ogden, it was clear the boundary layer was very low (~4500 ft ASL), which meant we would only sample it on missed approaches. Directly above the boundary layer, there was not much happening, but there was a layer between 4700 and 4820 at the top of the residual layer where concentrations were much higher. At 18:36 we spiraled up to 12500 ft ASL. NOx increased from 5700 to 6500 ft ASL and we were out of everything at 7000 ft ASL. The temperature at 12500 was the same as the surface (-1C). At 18:48 we began the descent into the Cache Valley. In Cache, the top of the residual layer was 6500 ft ASL and the top of the boundary was about 4600 ft ASL. There was a small layer of enhanced NOx and particulate between 5000 5300 ft ASL. At 19:08, the pilots did a nice job avoiding Little Mountain at the north end of the flight plan. At 19:18, we began a slow climb over terrain. The top of the residual layer looked to be 6500 ft ASL, but all species showed slow dropoffs, so the boundary was non-obvious. At 19:22 we started the descent to the Salt Lake and species started climbing again around 6700 ft ASL. At 19:31 there was a factory on the right of the plane, with a plume coming at us. Over the Salt Lake, NOx was close to zero and NOy was ~10 ppbv. NOx climbed slightly (remained < 5 ppb) while crossing lake at steady altitude. The most interesting layer seemed to be a little higher than we were (at ~5300 ft ASL). At 19:46, there was a drop in O3 with corresponding increase in NOx. At 19:55, we began circling the US Magnesium plant. At 20:01, we got a nicer vertical profile through the US Magnesium plume, followed by a descent through plume at 20:03. At 20:14 there was a brief dropout in the met probe, which was fixed by resetting the software. At 20:23, we began the approach to Balinder in the Tooele Valley. In the Tooele Valley, the top of the boundary layer was 4340 and the top of the residual was 5600. At 10,000 ft ASL, the air was warm (0C), with no NOx or aerosol. O3 was ~43 ppbv. At 20:40 we cruised back toward the SLC airport at 10,000 ft. At 20:41 we began the descent into the the airport. The top of the residual in the Salt Lake Valley was 6400 ft ASL. There was another high NOx layer between 5900 and 6400 ft ASL. The top of the boundary layer was 4520 ft ASL.

**Flight 20170117_L2** (Ale's Log)
Date: 2017 Jan 17 (local), 2017 Jan 18 (UTC)
Flight plan: Cache Valley and Great Salt Lake

| | |
|---|---|
| Research scientists: | Dorothy and Ale |
| Pilot: | Rob |
| Co-pilot: | JC |
| 00:56 UTC | Start taxiing |
| 01:06 UTC | Taking off! |
| 01:06 UTC | Turning Iodide CIMS switch on |
| 01:10:30 UTC | Start zero QCL |
| 01:15:30 UTC | Stop zero QCL |
| 01:22 UTC | First missed approach |

| | |
|---|---|
| 01:25:00 UTC | Start zero QCL |
| 01:26:51 UTC | Stop zero QCL |
| 01:33 UTC | Second missed approach. Observing High ammonia!! |
| 01:38 UTC | CIMS mass 145 went down |
| 01:42:53 UTC | Start zero QCL |
| 01:46:55 UTC | Stop zero QCL (Elevation is 4500 ft, Air Temp outside is -1$^{o}$C, it's colder on the ground … we have a strong(?) inversion) |
| 02:00 UTC | Third missed approach, high ammonia with some stratification observed when climbing |
| 02:12:00 UTC | Start zero QCL |
| 02:13:20 UTC | Stop zero QCL |
| 02:20 UTC | JC takes a leak |
| 02:36:30 UTC | Start zero QCL |
| 02:47:00 UTC | Stop zero QCL |
| 02:47 UTC | Weird stuff while flying over the lake AMS sees Orgs and Sulfates, gas phase ammonia seems low, amm vs nitrate seems to be changed in the AMS, ozone going up. I suspect we are in the residual layer where the US Magnesium factory was injecting its exhaust during the day |
| 02:53:52 UTC | Start turning around US Magnesium factory |
| 03:03:30 UTC | Start zero QCL |
| 03:08:00 UTC | Stop zero QCL |
| 03:24:45 UTC | Third missed approach, ammonia goes down!?!? |
| 03:26 UTC | Pilots comment that they see a lot of haze |
| 03:27 UTC | Orgs in AMS kind of high |
| 03:32:05 UTC | Start zero QCL |
| 03:34:05 UTC | Stop zero QCL, this zero went down to the white line |
| 03:46 UTC | Turning Iodide CIMS switch off |
| 03:49 UTC | Touch down! |
| 03:50 UTC | Taxi |

End of **Flight 20170117_L2**

**Flight 20170118_L1**
Date: 18 January 2017
Scientists: Erin (front), Alex (back)
Pilots: JC (pilot), Rob (copilot)
All times in MST
Preflight: 11 AM
Planned takeoff: 14:00
Actual takeoff: 13:55
Touchdown: 16:18
Weather: Very hazy, clouds above Salt Lake

Flight plan: North to Cache
Deviations from plan: Some porpoising over Salt Lake to find most interesting layers. Up to ~8000ft between SLC takeoff and Ogden missed approach

Notes:
All instruments survived power switch. Noted that the NOxCaRD labels on the UDP tab of the flight scientist computer are incorrect. The plot labels are correct.

13:55 take-off
14:00 climbed to ~7700 ft and made it out of the boundary layer, NOx was < 1.0ppbv
14:03 started missed approach into Ogden, NOx increased above 1ppbv around ~6300 ft (top of Boundary layer)
14:07 low point of missed approach in Ogden, ~4400 ft.
14:07-14:19 cruised to Brigham at ~4800 ft, well within BL
14:19 started missed approach into Brigham
14:21 low point of Brigham missed approach, 4270 ft
14:22 started spiral up to 12,500ft. NOx dropped below 1ppbv ~6900ft (indicates top of boundary layer)
14:29 top of spiral at 12,500 ft, extensive visible haze in all surrounding valleys
14:31 start descent into Cache Valley
14:36 Boundary layer top observed on the way into Cache Valley is ~6300-6400ft
14:40 Low point of missed approach at Logan, 4390 ft
14:40-15:00 Cruising Cache Valley ~4900-5100ft. Observed relatively low NOx/NOy ratio and ~70 ppbv NH3
15:00 spiral out of Cache Valley. NOx dropped to < 0.5 ppbv at ~ 6400ft (top of BL, consistent with the height on the descent into Cache), there appeared to be a higher (aged?) layer where NOy did not drop to < 0.5 ppbv until ~8000ft
15:06 start descent into Bear Valley, NOy > 0.5 ppbv ~ 7000ft, NOx > 0.5 ppbv ~5700 ft (top of Bear Valley BL, lower than Cache)
15:15 reached edge of Salt Lake, visible frozen water below the plane. When we reached this point, NOx, NOy, and O3 all became spiky in nature where before they were relatively smooth
15:19 attempting porpoising over Salt Lake. Began with an ascent up above 7300ft in order to profile the entire BL over the lake. The top of the BL was ~5900 ft (similar to Bear Valley). NOy was elevated above 0.5 ppbv until 7300ft.
15:25 Began descent over Salt Lake. NOy began increasing ~6000ft. Elevated layer of NOx ~ 5400ft. Aircraft leveled out at 4800ft and was stuck at this altitude due to clouds/fog above us. The relative humidity was ~ 95%
15:36 began circling U.S. Mg plant below the clouds ~4800ft. The smokestack plume was directed up into the cloud layer. Ox was lower (~30 ppbv) under the cloud layer than above it. There also appeared to be some O3 titration around the Mg plant.
15:41 left Mg plant and starting climbing out of clouds over the Salt Lake. There was a slightly elevated NOx layer ~6100ft above the clouds. The cloud level was ~ 5200 ft.
15:45 stuck above the clouds at ~6400ft on the SW transect over the Salt Lake.

15:55 NOx is essentially 0 ppbv over the lake but starts to increase once land is in sight. It looks like we flew over a small research station and they waved at us from the ground (probably wondering what we were up to. At this point, I also taught JC what NOx was and where it came from).
15:58 NOxCaRD signal once again got a little spiky over the shore
16:00 Visually, we may have flown out of the clouds at this point and back into haze. The RH was beginning to drop below 90%
16:02 low point of Tooele missed approach, ~4320 ft. Out of the missed approach, there was an elevated NOx layer between 5200-5600ft. There was a second elevated NOx layer at 6200ft but NOx dropped below 0.5 ppbv at 7200 ft.
16:05 spiral up to 10,000 ft to get back into Salt Lake Valley
16:13 started descent into landing. Elevated NOx layer ~ 6400ft. Immediately before landing, NOy peaked ~50 ppbv. This may be the influence of the highway that we pass over immediately before landing.
16:18 Landed

**Flight 20170118_L2**
Date: 18 January 2017
Scientists: Carrie (front), Lexie (back)
Pilots: Rob (pilot), JC(copilot)
All times in MST
Preflight: N/A
Planned takeoff: 18:00
Actual takeoff: 17:40
Touchdown: 20:32
Weather: Very hazy, clouds above Salt Lake, -3 deg C
Flight plan: South over SLC and Utah Valley
Deviations from plan: Some porpoising over Salt Lake and Utah Lake. Added 4 boxes around Salt Lake City at different altitudes at the end of the flight.

Notes:
Climbed to 5500 ft MSL to clear the airspace, which is still within the residual layer, then dropped down to 5000 after a few minutes to head out over the Salt Lake. As we headed west over the lake, we ascended to about 6000 ft, but there were clouds/haze at 5800 which the pilots wanted to avoid, so we decided to stay mostly below it, porpoising between about 4800 and 5600 ft. As we did that, there was some definite layered structure in the NO2. At 17:50, pilots pointed out an unidentified research station directly below us. At 17:54, clouds cleared enough for us to climb to 6000 feet. Noticed a big NO2/particulates peak between 5700 and 5900 ft. By 17:58 we had traversed back over the lake and were crossing a busy road along the edge. The NOx levels rose as we started passing over residential areas. Ascended from 18:02 to 18:09 to 7200 ft (max cloud level was 8000 ft, but layer height was about 7000) in preparation for full profile at the South Valley missed approach. Missed approach at 18:12, then climb to 7000 ft by 18:18 or so. At 18:20, had to descend to 5400 ft to avoid haze. Between 18:20 and

18:32, we rastered through the SLC area, first at 5700 ft, then back down to 5300 ft to avoid haze. Passed the Hawthorne school site at 18:26, U of U at 18:27. At 18:32, began spiral up. Top of the layer was at 6600 ft, but we continued up to 11800 ft. Started the descent into Provo at 18:43, missed approach at 18:55, followed by a climb to 6000 ft. Between 18:57 and 19:02, looking for some layers between 5200 and 5400 but not seeing much. Top of the layer seems to be at about 5600. Continue porpoising slightly over the lake. At 19:20, see a huge spike of NO, but didn't visually see a source. At 19:24, passed through the Jordan Narrows. The pilots determined that we had plenty of fuel left, so we started doing the box pattern around SLC. First box at 19:28 at 5300 ft. Observing sharp peaks of NO2 on the east and west transects - possibly roads?. Second box at 19:42 at 5700 ft. Still lots of NO2 but possibly less spiky. Third box at 19:57 at 6000 ft, still plenty of NO2. At 20:08, visually seems like we passed into a place where the haze looks worse? Fourth box at 20:12 at 5550 ft. At 20:21 pilots determine we would be pushing our fuel level with a fifth box, so we head straight across the city to the airport. Ascend to 6000 ft, as per ATC, then land at 20:32.

**Flight 20170126_L1**

Scientists: Dorothy (front) Ann (back)
Pilots: JC (pilot) Rob (co)
All times in MST
Preflight: 10:30, included EMI test and engine running to charge battery
Free access to plane: 12:40
Planned takeoff: 14:00
Actual takeoff: 14:34
Touchdown: 17:15
Weather: Mostly cloudy, no haze, cloud cover on mountain tops, in the sun at takeoff
Flight plan: North to Cache valley
Flight plan deviations: Most spirals to less than 12500 and slightly offset to avoid clouds. Chased US Mag plume to SE after circle, followed into next valley

CIMS open at 14: 34. Minimal vertical structure in NOx after takeoff. At 600 ft AGL, NOx was in plumes, but total Ox was steady. At 14:40, we were over open fields with a mix of farm and suburban land. At 14:44 NOx increased as land below was more urban. 14:47, we turned R for the missed approach at Ogden. Ogden had some low fog/haze and the mountain tops were cloudy. 14:48 was the missed approach at Ogden. NOx showed enhancement near the ground, but Ox budget was constant. Moderate NOx plume right after missed approach, but source unknown. At 14:50, we followed a highway with light traffic at 4800 ft ASL, NOx had structure, but Ox was pretty steady. At 14:54, NOx dropped to 0, but Ox remained constant. At 14:57, we were over Brigham City, which had visible haze. In this area, NOx showed even more plumes, but Ox remained steady. 14:59, missed approach at Brigham City. O3 was titrated at the very bottom of the missed approach. NOx dropped pretty steadily out of the missed approach. At 15:00 we started the spiral toward 12000 ft. NOx close to 0 by 5300 ft, but Ox steady. At 15:08 we topped out the spiral and were over some cloud cover. 15:12 was the start of the descent

into Cache Valley. The spiral down was not constant to avoid clouds. It was cold aloft (-15C), -11 at 7000 ft. At 15:19 NOx showed slight uptick at 6200 ft, but definitely in boundary layer at 5400 ft. 15:20 was missed approach at Logan, O3 was not titrated. At 15:22 we were over farm land with very heavy snow cover with cows heavily congregating. There was visible haze in the Cache valley. 15:27 was the turn around the north side of Little Mountain. At 15:29 we were out of the sun, back under cloud cover. NO went to 0, with some NO2 and NOy. At 15:31 we were over a frozen river. 15:32 next to a large feedlot. Everything around was farmland with heavy snow covered except where cow-covered or actively plowing. At 15:38 we passed over a relatively large cow head. At 15:39 there were a few smaller herds. 15:42 was the L turn at the southern extent of the valley. At 15:43 there were a few factory plumes on R and L of airplane and heavy feedlot action around. There was one heavy NOx plume in here that nearly titrated O3. At 15:45 we were over a more populated area (Logan) with higher NOx, but still constant Ox. There was heavy haze/fog over Logan. Even the roofs in Logan were snow covered. At 15:47 we passed Utah State. At 15:48 we were back out over more open space; it was farmy, but with fewer cows. At 15:51 we started the climb out of Cache; the top of the boundary layer was right at 6000 ft. There were clouds directly above where we leveled out. At 15:57, we started the descent toward the lake. On the descent, the top of the boundary layer was 5150 ft. At 16:03 we began porpoising over the lake. The top of the boundary layer was at 5100 ft and we ascended to 5300. When dropping back over the lake there was nothing, even down at 4700 ft. There was fairly heavy snow cover over the salt flat area. At 16:08 we picked up a little signal when transitioning over some more bare ground. At 16:12 we did another profile up to 5500 ft and started down at 16:14. The top of the BL was at 4770 ft. At 16:20 we were back over snow cover and everything dropped back to 0, unknown if it was BL height or distance from sources. At 16:27 we circled US Magnesium. There was lots of O3 depletion with little NOx around. The main extent of the plume was between 4700 and 5700 ft. At 16:33 O3 was almost all gone with no NOx around. We tried crossing the plume downwind by following the O3 depletion. The plume seemed heavily spread- it was hard to find horizontal extent because we couldn't get out of it. We finally crossed out of the plume at 16:47. At 16:49 we were back over farmland with some cows below. At 16:51 we threw in an extra 360 to find some air traffic. At 16:53 we started the descent into Ballinder. There was much less snow cover in the Tooele Valley. At 16:55 we did the missed approach at Ballinder, which showed little vertical structure. O3 still showing destruction without corresponding NOx at slightly higher levels in the Tooele Valley. At 17:02 we began the descent into SLC. The BL was at 6350. At 17:14 there was heavy traffic on the highway. Touchdown at 17:15. There was a slight wait during taxi for an extra plane to be towed off the ramp.

**Flight 20170126_L2**

Scientists: Erin (front) Alex (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Preflight: 17:15, transition between flights
Planned takeoff: 18:00?

Actual takeoff: 18:19
Touchdown: 20:36
Weather: Mostly clear with snow at higher altitudes
Flight plan: South to Utah valley
Flight plan deviations: Could not spiral from Salt Lake Valley to Utah Valley, went through the Jordan Narrows instead. Did some porpoising over Salt Lake

Notes:
Good power switch. Met probe displayed an error message and would not display wind direction or wind speed. Unclear why it wasn't working. All other met variables were working.

18:19 Takeoff
18:20 Cruising at 5500ft over Salt Lake. NOx low during most of the takeoff
18:23 A few spiky NOx plumes while cruising
18:25 Started descending down over Salt Lake on western leg. Descended down to 4700ft, NOx still very low ~ 0 ppbv.
18:30 Start requested climb up to 7000ft, encountered visible snow around 5600ft.
18:36 NOx reached a minimum at 6000ft
18:39 Back over land in Salt Lake Valley, NOx remains low despite visible smoke stacks below
18:40 Cruising next to mountains, headed south in west salt lake valley at ~5400ft. NOx plume, maybe a power plant.
18:42 NOx plumes, appear to maybe be power plants or O&G wells (if those exist in SLV)?
18:44 Climb before South Valley missed approach, slight O3 titration @~6400ft
18:49 Start descend into South Valley
18:51 Slight increase in NOx @~5700 ft
18:52 Massive church #1 - appeared not to be emitting NOx
18:53 NOx plume shows up at ~5300 ft
18:55 Bottom of missed approach at 4645 ft. No obvious surface layer in terms of NOx and O3, on the way out of the approach, NOx dropped off again at ~5150ft
18:58 Massive church #2
18:58 NOx plumes, appear to be over highways and residential areas.
19:01 NOx plumes, plane appears to be over many highways
19:02 Over large shopping centers and many roads
19:10 First pass over U of U. Nox was low when the plane turned at the top of valley but increased again when the plane straightened out
19:13 NOx peak - canyon flow? Otherwise residential area
19:15 Climb at south eastern side of SLV. Elevated NOx all the way up to 6200ft and another elevated layer up until 6400 ft. We could not complete this spiral due to clouds and snow and our maximum altitude was ~6700ft. NOx was low at that altitude but not 0 ppbv.
19:19 NOx spike, possibly due to interstate.
19:20 Through Jordan Narrows en route to Utah Valley. There was slight O3 titration at the entrance of the narrows in Utah Valley

19:23 Cruising over lake at ~5300ft, large plume from large (power/processing?) plant that was traveling parallel to our flight path and the lake shore. The altitude of the plume was above the plane but we may have seen broad increases in NOx and NOy as we approached and passed by while over lake.
19:27 Missed approach at Provo, 4530ft was our lowest altitude. There appeared to be no surface layer as NOx and NOy were well mixed throughout the entire missed approach.
19:34 Cruising at ~5300ft for box in Utah Valley. Slightly elevated but flat NOx mixing ratios. Massive church #3
19:37 Large NOx plume but ground was dark directly below us, indicating no close point sources. There was an emitting plant in the distance off to the right of the aircraft
19:40 Flying over shopping center/congested area
19:41 Spanish Forks missed approach. Low point was 4560ft. Was hard to tell if there was a surface layer because we flew through the plume of a manufacturing plant during the descent, which had the highest NOx levels observed during this flight. NOx decreased to background levels at 4700ft so if there was a surface layer, it was very shallow.
19:45 Level leg ~5100 ft over Utah Lake. Well-mixed non-zero mixing ratios of NOx and NOy. According to Rob, Utah Lake was 95% frozen.
19:51 Headed straight towards large plant plume that we flew by back at 19:23.
19:52 Flew directly underneath the plume from this large plant. We were visibly below it and only had slightly elevated NOx and NOy mixing ratios when passing underneath and circling around to the north.
20:00 Plane back in Salt Lake Valley. NOx mixing ratios were relatively flat and constant in the Jordan Narrows
20:01 Starting first SLC box at 5200ft.
20:08 NOx was highest over downtown and the university
20:11 Saw same large mysterious plume on east side of valley headed south as at 19:13. Is this canyon flow into the valley?
20:13 Flying over residential areas.
20:15 Climb to 5600ft for the start of the second box
20:18 Wasn't seeing a lot of NOx so requested the second box be flown at 5500 ft.
20:27 End of boxes, return to SL airport at 5500 ft along highway
20:31 Spike in NOx due to highway overpass
20:32 Final approach. Did not see NOx plume over highway immediately before landing.
20:36 Landed.

Throughout the boxes, NOx was plumey and not seemingly well mixed. The same plumes appeared at the same places at both altitudes of the box.

**Flight 20170127_L1**

Scientists: Carrie (front) Lexie(back)
Pilots: JC (pilot) Rob (co)
All times in MST

Preflight: 7:45, transition between flights
Planned takeoff: 10:45
Actual takeoff: 11:00
Touchdown: 14:07
Weather: Sunny, hazy, -5 deg C, overcast in the Utah Valley
Flight plan: South to Utah Valley
Flight plan deviations: Two boxes over SLC added at the beginning, and two added at the end.

Notes:
During taxiing, back headset had some problems, so we pulled over for a minute. Either because of this or for an unrelated reason, the pilots had to ramp up the propellers for a minute, and NOxCaRD saw a ~1ppm peak of NOx.

Take off at 11:00 and ascend to 5500 ft. Power plant off to the left side of plane, but doesn't look like we went through the plume. Started the first box at 11:04 at 5200 ft, going clockwise. NOx is high (>90 ppbv in places) and spiky, UHSAS particle counts at over 500 counts, but smaller diameters than at end of last inversion? O3 is low (<~10 ppbv). NOx gets lower as we head south along the box. Second box begins at 11:19, at 5500 ft. At 11:34, finished with boxes, we head west to the lake, level at 5500 ft. NOx drops quickly, but we can't go any lower to see if we are above the layer because we are under ATC control as we pass Salt Lake International. At 11:40, start to descend a bit. As we pass through 5000 ft, start to see a bit more NOx/PM. At 11:43, do a quick porpoise between 4700 and 5100 ft to see if there is anything different, but its steady, so stay level at 4700 ft across the lake. On the way back, repeat one small porpoise, then back down to 4700 across the lake. At 11:54, pass by a huge tower emitting water vapor (?) at over 1200 ft. At 11:55 it visually appears that we are passing through it. By 11:57 we are back over land, ascending a bit to 5600 ft. At 12:02, we ascend through the clouds to get to top of layer which happens at about 7300 ft. We max out at 7500 ft and then begin missed approach into South Valley. At 12:04, pass back into the layer. It doesn't look very structured at all. 12:09 is the missed approach. Raster through SLC at 5200 ft. At 12:21, pilots point out possible house fire off our right side? But it's minor and we don't pass through the plume. At 12:31, begin spiral. We are out of the layer at ~7300 ft. At 12:38, complete spiral and we fly south so the pilots can look for a gap in the clouds so we can spiral down. They find one on the east side of the valley. Begin descent at 12:39. We get into the layer at around ~8000 ft (not sure exact height - I wasn't expecting it that early and was doing something else). At 12:48, notice a big spike in NOx, but am unsure of the source. At 12:50, do a missed approach at Provo, then go to 5200 ft to raster through Provo, since layer seems well mixed. At 12:57, notice power plant plume off the right side. 13:04 - missed approach at Spanish Forks. At 13:06, had to bank hard left to avoid another plane. Pass over the lake at 5000 ft. At 13:15, circle the power plant plume (Geneva Nitrogen?) twice at 5000 ft, then once at 5500 ft (A bit of mixup with the pilots I think -- we were headed north after two circles, when it sounded like JC didn't know we wanted a third, so we turned around). At 13:23 - through the Jordan narrows at 5500 ft. Start box #3 at 13:29 at 5500 ft, and box #4 at 13:44 at 5200 ft. Climbed back up to 5500 at 13:59 for final descent into Salt Lake International, landed at 14:07

**20170127_L2**

Scientists: Dorothy (front) Ale (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Preflight: N/A
Free access to plane: 14:15
Planned takeoff: 15:00
Actual takeoff: 15:07
Touchdown: 17:41
Weather: Bright, sunny, somewhat hazy. Perfect day
Flight plan: North to Cache valley
Flight plan deviations: Circled Zirconium plume. Didn't see anything. US Mag plume headed north, so couldn't chase. Did some extra passes through plume, including vertical profile.

Take off at 15:03, CIMS valve open immediately after wheels up. There was some vertical structure on takeoff, but we were ATC limited to 6000 ft, which was out of the BL. There was no evidence of inversion up to 6000 ft (-7 there.) The BL was around 5700 ft. At 15:07 we passed through a refinery plume and then paralleled a highway with moderate traffic. At 15:09 there was a large NOx plume of unknown origin right at the transition to open fields. At 15:10 it was open fields to the L of the plane and suburban housing to R. By 15:12 it was suburban all around. At 15:14 we were paralleling another highway with moderate traffic. Missed approach at Ogden at 15:16. There was small NOx structure on the way in, but not much happening at the bottom. At 15:18 we were over a mix of suburban housing and farmland all with very heavy snow cover. 15:20 was a slight turn to avoid some traffic. At 15:26 there was a fairly large cow herd to L of plane and we were back parallel to a highway with light traffic. 15:27 was MA at Brigham City. No was high, NO2 moderate and both dropped quickly above 4550 ft. The spiral up was interrupted at 15:29 to avoid traffic. NOy persisted to over 7700 ft. Temperature decreased all the way to top of spiral at -20C. At 15:39 we began the descent into Cache. The NOx just becan at 8000 ft and there was also no evidence of inversion in Cache. Cache has some haze, but was still sunny and bright. BL was at 5200 ft. At 15:47 we had a spike in NOx from a highway just before the MA. The MA at Logan was at 15:48. At 15:50 we were out over farm land with few cows so far. The first visible cows were to the L of the plane at 15:51. At 15:52 we were parallel to a moderately busy road while deep in farmland. The turn around Little Mountain happened at 15:54. Rob was super-chatty in this part of the flight. At 15:58 we were over a snaking, open river. At 15:59 there was a herd of cows in bare land to R. At 16:00 there was a large group of cows on bare land to L. At 16:01 there was a large feeding operation to L. Everything seemed pretty low through Cache. Possible BL issue due to heavy snow cover. At 16:08 there was a medium herd of cows directly below us. At 16:09 we passed over a freight train. At 16:10 there was a large feeding operation to the L. At 16:11 we passed through a plume from a "factory." This plume had high NH3, maybe some kind of manure processing? At 16:12 we were back over Logan and NOx was much higher. At 16:14 Utah State was to the R of

the plane. At 16:16 there was a significant feeding area to the L, then we were back over a suburban area. At 16:19 we began the climb out of Cache. NOx went to 0 at 5500 feet, NOy never got there. The descent to Bear Valley began at 16:23. Here was tiny NOx at 5500, but hard to tell if it was real. Everything was a little higher at 4900 ft. We passed over a fairly busy highway at 16:28. NOx was significantly higher at 16:29, but source unknown. At 16:30 there were a few small cattle operation to the L. At 16:32 there were several large cattle operations to L. At 16:33 haze was visible over the lake. There was heavy snow cover in the coastal area. At 16:39 we passed over some salt harvesting operations. At 16:40 we circled the zirconium plant, which showed nothing in NOxCaRD or AMS. At 16:44 we began a climb from 500 ft AGL, but it was interrupted due to traffic. We gave a second try at 16:45. BL around 5100 ft. At 16:57 we made the first pass of the US Mag plume at the upper boundary of the plume. The second pass through the heart of it at 5500 ft resulted in a strong smell of bleach/chemical in the cabin. The plume was fairly concentrated vertically, but spread significantly horizontally. The plume was moving north, so we could not track it downwind. We had a few loops and an extra vertical profile of the plume. At 17:10 we were back out over the lake. We did a porpoise over the salt flat area at 7:18, but there was no structure in NOx/O3. At 17:23 we were back over land and there was a small amount of NOx. 17:27 was the MA at Bolinder. There was a small NOx enhancement at the very bottom of the MA (like 20 ft AGL) probably just from airfield. There was a little NOx enhancement after the MA with a small vertical extent. This climb also showed no evidence of temperature inversion. At 17:34 we headed back to SLC. CIMS valve was closed at 17:41, just before touchdown. Touchdown was also 17:41. It was just at sunset with a very pink sky. We took a different landing and approach than usual (middle runway). There was still a very busy highway just before the airport.

**Flight 20170127_L2** (Ale's Log)
Date: 2017 Jan 27 (local), 2017 Jan 27 (UTC)
Flight plan: Cache Valley and Great Salt Lake

| | |
|---|---|
| Research scientists: | Dorothy and Ale |
| Pilot: | Rob |
| Co-pilot: | JC |
| 21:52 UTC | Start taxiing |
| 21:56 UTC | Plane is rocking sideways while still on the ground not moving, waiting our turn to get on the runway |
| 21:57 UTC | Taxiing some more |
| 21:02 UTC | on the runway |
| 21:03 UTC | Take off! |
| | Pilots say that we are limited to 6000 ft by ATC |
| 22:07 UTC | Flying through a plume of a refinery |
| 21:10:47 UTC | Start zero QCL |
| 21:13:37 UTC | Stop zero QCL |
| 22:16:57 UTC | First missed approach |
| 22:19:30 UTC | Start zero QCL |
| 22:22:20 UTC | Stop zero QCL |

| | |
|---|---|
| 22:27:30 UTC | Second missed approach |
| 22:36:15 UTC | Start zero QCL |
| 22:37:30 UTC | Stop zero QCL |
| 22:48:18 UTC | Third missed approach |
| 22:50:40 UTC | Start zero QCL |
| 22:53:40 UTC | Stop zero QCL |
| 23:04:55 UTC | Start zero QCL |
| 23:06:25 UTC | Stop zero QCL |
| 23:21:35 UTC | Start zero QCL |
| 23:23:05 UTC | Stop zero QCL |
| 23:27:40 UTC | Start zero QCL |
| 23:35:55 UTC | Stop zero QCL |
| 23:41 UTC | Boxing Zirconium Plant, very clean |
| 23:49:28 UTC | Start zero QCL |
| 23:52:30 UTC | Stop zero QCL |
| 00:01 UTC | Start boxing Magnesium Plant |
| 00:14:25 UTC | Start zero QCL |
| 00:16:25 UTC | Stop zero QCL |
| 00:26:20 UTC | 4th missed approach |
| 00:31:35 UTC | Start zero QCL |
| 00:32:35 UTC | Stop zero QCL |
| 00:41 UTC | Touch down! |
| 00:42 UTC | Taxiing |
| 00:43 UTC | Stop at the hangar |

End of **Flight 20170127_L2**

**Flight 20170128_L1**
Scientists: Erin (front) Alex (back)
Pilots: JC (pilot) Rob (co)
All times in MST
Preflight: 14:00
Planned takeoff: 17:30
Actual takeoff: 17:36
Touchdown: 20:26
Weather: Sunny/hazy
Flight plan: North to Cache valley
Flight plan deviations: Did a SLC box before heading north to Ogden. Circled ‘Mitchell’ Point Source when leaving Cache Valley (didn’t see any NOx). Porpoised over lake.

Good power switch
17:36 Takeoff
17:38 Flew over plants north of SLC airport, a lot of NOx observed
17:39 Headed over to downtown for first box @5500ft

17:40 Descended to 5300ft
17:41 NOx plume observed, highway out of canyon?
17:44 Unclear why NOx dropped at this point, wind direction? Canyon flow? Particle count also dropped with NOx.
17:49 Same decrease in NOx as was observed on the eastern side of the box at 17:44.
17:51 Huge NOx plume. Interstate? NOx increases to ~ 30ppbv as approaching downtown.
17:56 Flew directly over plant plumes north of downtown and east of the airport.
17:58 Following highway north, out of SLC. Out of the plant plumes at this point.
17:59 Plant plume visible on left. May have corresponded to NOx plume.
18:04 Flying over Ogden
18:08 Ogden missed approach
18:09 Lowest point at 4550ft, low levels of NOx at 5000ft and 4800ft.
18:10 Climbed to 5000ft after missed approach
18:14 visibly out of urban area, NOx decreases
18:19 Start of missed approach into Brigham city
18:21 Lowest point at 4265 ft. Strong surface layer of ~100 ppbv NOy within bottom 100ft. NOx was close to 0 ppbv.
18:22 Slightly elevated NOx levels at 6300ft.
18:23 NOy dropped to 0 ppbv at ~7500ft. Temperature increased during the climb up to ~10,800ft. After this point, the temperature dropped again with altitude.
18:30 Top of spiral to 12,000ft. Ox and NO2 appear noisy on the flight scientist computer. Temperature -6.6C
18:31 Start descent into Cache.
18:36 Temperature inversion ~8700ft on the way into Cache.
18:38 NOy increased above 0 ppbv at 7000ft. NOx increased at ~6700ft.
18:41 NOx increased again at 5500ft. Missed approach into Logan, lowest altitude 4510ft, 4750ft top of elevated levels of NOx. Surface layer apparent, less than 100ft in depth.
18:45 Cruising at 5200ft because we can't get lower no elevated NOx plumes at higher altitudes. NOx ~0, NOy ~5 ppbv.
19:05 NOx elevated
19:10 Found out that pilots can control light brightness along the runways
19:14 NOy dropped in concentration around 7400ft when we increased our elevation to exit the Cache valley.
19:22 Plant off to the right that Rob keeps seeing that is not on Steves emissions inventory map
19:23 Decided to circle the plant, NOx is not very high - Deemed the 'Mitchell Point Source'
19:29 Starting to porpoise over lake.
19:32 O3 decreases without increasing NOx at ~6300-6500 ft. Top of elevated NOy is ~7000ft
19:34 headed back down. O3 less than 5 ppbv @ 6200ft. O3 flat @ 5300ft and went up again. O3 depletion observed again at 4900ft.
19:41 Starting another porpoise up to 6500ft. More depletion @ 5900ft.
19:47 5200-5900ft - more O3 depletion

19:48 Mag. Corp plant. 1st box ~5000ft.
19:50 Spiral/second box around plume.
19:51 Flew into plant plume, which was vertical and mushrooming at the top (~5700ft). The cabin smelled like chemicals. We climbed to 6600ft.
19:53 Descended down
19:56 O3 depleted again to the southeast of the plant plume between 5300-6200ft.
19:58 Pilots tried changing prob pitch to the climbing pitch setting while flying a level leg so that Alex could test the sensitivity of his instrument.
20:05 Missed approach at Tooele, 4340ft is the lowest altitude. NOx was elevated at 4600ft going down and 4900ft on the way up. There was no apparent surface layer. No O3 depletion plume at 5900ft.
20:09 6700ft maybe the top of the residual layer as we climb to 10,000 ft to get back into SLC. There was no temperature inversion within 10,000ft. Many very fine particles ~60nm.
20:13 Descended briefly to 9500ft.
20:17 O3 elevated without NOx at 8900ft on the way back down into SLC. NOx was first elevated above 0 ppbv at 7000ft and had mutliple layers 6600ft, 6000ft, 5600ft, and 5400ft. NOx decreased at 5200ft and increased again @4800ft. The layer of highest NOx (~70ppbv) was ~200ft above the surface and not at the surface itself.
20:26 Landed

**Flight 20170128_L2**
Scientists: Carrie (front) Lexie (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: 21:00
Taxi: 21:12
Actual takeoff: 21:18
Touchdown: 00:35 (2017/01/29)
Weather: Hazy, no clouds, -4 deg C at SLC
Flight plan: South to Utah Valley
Flight plan deviations: Two boxes before, three boxes after over SLC. Porpoising over both lakes

Notes:
Climbing out of take off, see high NO2 (50 ppbv), some layering up through 5500 ft asl. Pass refineries off the left side of the aircraft at 21:20. Begin first box over SLC at 21:21 at 5300 ft. NOx levels seem pretty steady, not as spiky as we've seen in the past. NO2 slowly varying between 20 and 40 ppbv. Second box starts at 21:36 at 6000 ft. NO2 is lower here, closer to 10 ppbv. PM still very high though, and possibly peaking at higher sizes than yesterday? Finish the second box at 21:50 and head to the lake via the I-80 transit at 6000 ft. Descend to 5500 ft at 21:52. Begin porpoising over the lake at 21:55 between 4700 and 6500 ft. See a layer at 6200, a small one at 5800, big one at 4900. At 22:05, head back across the lake, still porpoising.

Seems like the top of the layer was at 6600, because NOx and NOy were really low, but later on, we see more higher up, so maybe this was just a layer? But we don't go any higher at this point, because I thought it was the top of the layer. Heading to the south valley at 22:14, staying at minimum altitude (5300 ft). NO2 starts to climb as we get into populated areas. Spiral to 8000 ft at 22:18. Big spike at 6900 ft, top of layer at 7300 ft. But on descent, starting at 22:23, don't see the same size peak at 6900, but see it at 5900 ft instead. Another peak at 5400 ft. Missed approach into South Valley at 22:27. ~30 ppbv NO2 in the surface layer below 200 ft agl. Pick 5900 ft as the altitude for the raster through SLC. NO2 is ~10 ppbv, NOy is ~20, but gets higher as we get closer to the city. Pass the U of U at 22:43. Begin spiral to 12,500 ft at 22:48. Not much structure? A general decline in NO2 as we head up. Seems we are out of the layer at 7300 ft, but there's a tiny spike of something at 8400 ft. Start descent at 22:57. At 23:00, reach the top of the layer at 6900, big peak at 5500, dip at 5200 ft. As we head into missed approach at Provo, surface layer at about 200 ft agl. Missed approach occurs at 23:06. At 23:06, start our raster through Provo at 5400 ft. Do a missed approach at Spanish Forks at 23:19, seems surface layer is about 400 ft agl. Go up to 5400 ft, then porpoise up to 6800 ft. Passing over lake between 22:21 and 22:30, see a few spikes in NO2, but it's not clear what the source is. Circle the power plant plume twice at 23:31, once at 5200 ft, then at 5500. Both times, see spikes as we pass south of the plume. On second circle, it visually appears that we are *in* the plume suddenly for a few seconds. Climb to 6000 ft for transit through Jordan Narrows at 23:35. Start box #3 at 22:42 at 6000 ft. Seeing more variation in NO2 signal at northern part of the box. At 23:57, descend to 5300 for box #4. Notice O3 titrates to 0 (with NOx) over U of U. At 00:10, climb to 6700 ft for box #5, but it seems we are out of the layer, so drop down to 6500 ft, which seems fine at first, but possibly we are passing in and out of the layer a bit. But decide not to change altitude, since we are halfway through the box already. Final box ends at 00:25. Transit to Salt Lake International at 6500 ft. Notice a big NO spike just before we land (possibly engines revving?). Land at 00:35.

**Flight 20170130_L1**
Scientists: Erin (front) Alex (back)
Pilots: JC (pilot) Rob (co)
All times in MST
Planned takeoff: 05:00, then 07:10
Actual takeoff: 07:29
Touchdown: 08:39
Weather: Hazy, low clouds

Flight plan: South to Utah Valley
Flight plan deviations: Planned on doing boxes and regular flight plan but couldn't due to low level clouds. Had to turn around after missed approach at Provo.

Notes:
Good power switch
07:33 Cut of the box after flying directly over downtown - due to clouds
07:35 Flew over refinery in SLC, NOx spike ~ 90 ppbv
07:40 Flying level over marsh at 4700ft, NOx and NOy much lower
07:43 Over open water of Great Salt Lake
07:49 Back over frozen marsh land
07:55 We were back over open water but at this point were back over frozen marsh
07:57 Started ascent over to South Valley. Sun came out. Above the clouds at 5900ft, elevated NOx layer at 6200ft
08:06 Temperature was increasing as transiting south towards the sun and South Valley. Well above the clouds at 8000ft.
08:10 Start descent into Provo.
08:13 Nox increases as starting to get into cloud top at 5800ft. Another NOx layer at 5300ft, 5000ft, and 4800ft.
08:15 Surface layer at 4620ft, bottom 100ft. O3 was not titrated in this layer.
08:17 Elevated NOx level 5200-5600ft. Visibility is too low in south valley so we are turning around and going home.
08:31 Starting final descent into SLC. Cloud top coincides with elevated NOx at 6100ft. O3 was almost titrated aloft and was elevated throughout the descent. There was no obvious surface layer with O3 titration at the airport.
08:39 Landed

**Flight 20170130_L2**

Scientists: Dorothy (front) Ale (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: Hard to say. Continual delay from first flight, but 11ish
Actual takeoff: 11:38
Touchdown: 14:40
Weather: Very hazy, mostly cloudy
Flight plan: South to Utah Valley
Flight plan deviations: Two boxes at the beginning, two and a half at the end
Breaker tripped during time on ground taking NH3 and met probe computer down

Shortly after takeoff NOx climbed to 80 ppbv. Box 1 was done at 5300 ft. SLC was mostly snow covered and very hazy. NOx stayed high through the box with few plumes. Ox was rock-solid steady, despite the high NOx. The second leg of the box began at 11:49 and NOx showed far

more plumes. At 11:54 we started the second box at 5600 ft. We took a hard right turn at 12:02 and it looked like NOxCaRD might be sampling engine exhaust. Second box looked similar to first (more plumes on second leg, similar total levels.) Things seem well mixed. At 12:07 we passed over a major highway interchange with some traffic, not heavy. At 12:09 the boxed were complete and we headed toward the lake at 5600 ft. There was light snow cover and an industrial looking area below. At 12:13 NOx dropped significantly while starting over the marshy area at the edge of the lake. At 12:14 we were briefly in a cloud. Things were generally pretty clean over the lake, we stayed steady at 500 ft AGL to avoid clouds. At 12:29 we passed over a road and freight area in the flats of the lake. Back over land at 12:30. At 12:31 it was a residential/suburban area below and NOx climbed quickly. At 12:34 there was a very large NOx spike (to 140 ppb), but could not identify source. Started climb at 12:36. NOx was 0 by 6000 ft. Small amounts of NOy lingered to 6500 ft. We then stayed at 6800 ft. At 12:41 we headed to the MA at South Valley and NOx climbed steadily through the descent. MA at South Valley at 12:43. There was heavy haze. We turned W out of South Valley, following ATC instructions to avoid traffic. At 12:45 we passed over a ton of oil cars. We began rastering the city at 12:47. At 12:50 we passed over a very large highway with moderate traffic and then ran parallel to the highway. Very large houses below at 13:02. 13:04 we began the climb. The BL was sharp at 6400 ft (a small amount of NOy persisted to 7800 ft.) There was also a strange, small NOx spike aloft, probably from sampling aircraft exhaust.At 13:13 we began the descent into the Utah Valley. The BL was very sharply defined at 5500 ft. NOx was highest nearest the top of the BL. There was a layer with significantly smaller NOx at 4800 ft. 13:23 was the MA at Provo, there was a layer at 5400 ft then we were quickly out of the BL. At 13:26 we were over farmland. We remained over mostly snow-covered farmland for a while. The only portions that were not snow-covered were plowed under or covered in cows. At 13:39 we were over Utah Lake, which was ~80% frozen. Over the first part of the lake, things were pretty steady. At 13:43 NOx got much higher and showed a lot of plumes. The UHSAS was showing very high particulates. At 13:46 we passed over the fertilizer factory. At 13:49 we circled the power plant, but it was hard to get in the plume due to very light winds. At 13:49 we passed over the fertilizer factory again. At 13:51 we did a vertical profile to get through the fanning part of the power plant plume. At 13:59 we were back in the Salt Lake Valley. NOx was much higher than the Utah Valley and Ox was slightly lower. We started box #3 at 14:00 at 5300 ft. At 14:04 we passed over a commuter train to the L. At 14:07 there was another commuter train below. At 14:10 we began the second leg of the box with somewhat lower NOx and UHSAS levels. At 14:11 we were over a highway with light traffic. We began the climb for box #4 at 14:14 to 5600 ft. At 14:17 the highway parallel to the box had moderate traffic. At 14:18 we passed a major highway interchange with moderate traffic. NOx was higher and showed more plumes at this altitude. At 14:20 we passed over another moderately busy highway interchange and then paralleled another commuter train just to our L. We climbed to the final “half box” at 14:28. We did this at 5800 because I got nervous about breaking out of the BL at 5900. At 14:35 we passed over the refinery near the airport and passed directly through the plume at 14:36. At 14:40 we passed over the highway near the runway. Touchdown was at 14:40.

**Flight 20170131_L1**

Scientists: Carrie (front) Lexie (back)
Pilots: JC (pilot) Rob(co)
All times in MST
Planned takeoff: 07:00
Actual takeoff: 11:58
Touchdown: 15:04
Weather: Very hazy, mostly cloudy
Flight plan: South to Utah Valley
Flight plan deviations: Two boxes at the beginning, two at the end

Notes:
The hazy layer is quite low, well below the tops of the mountains. At 12:00, we pass the industrial area north of downtown off our left side of the plane. NOx is high, spiking up to 90 ppbv. We begin box #1 at 12:02 at 5300 ft asl. As we head south, NOx and NOy are fairly steady, at about 50 to 60 ppbv. Big spike at 12:14, possibly over a highway? NOx and NOy get steadily higher and spikier at the north end of the box. Start box #2 at 12:16 at 5600 ft. NOx and NOy are similar to levels at 5300 ft, but again, spikier over north part of box, particularly when we go over highway. At 12:31 climb to 6500 ft to transit past Salt Lake International, per ATC request. Top of the layer seems to be about there. Descend to 4800 ft as we head out over the lake. Ox suddenly drops off, and the visibility suddenly gets very low (RH near 100%). Because of this, we can't do any porpoising over the lake, so we stay level at 4700 ft. NOx and NOy are both fairly low. At 12:42, it sounds like we turn back a little early, not sure. At 12:44, as we come back into sight of land, NOx, NOy and PM all get larger. At 12:48, we climb up to 5000 ft, and NOx increases. There's a huge spike at 12:51 as we are passing over those low flat buildings that Dorothy photographed. Some variation in NOx and NOy, possibly correlated with passing over isolated developed areas? At 12:54, start spiraling up to 8000 ft. Major dropoff at ~7000 ft, but low levels of NOy persist until 7500 ft. Max out at 7800 ft. On the way down, seems top of the layer is at 6900 ft, but then there's another big increase at 5500 ft. Missed approach in South Valley at 13:03. There doesn't seem to be a significant surface layer. Raster through SLC at minimum altitude (4900 ft). There's a lot of small diameter PM over downtown. We pass U of U at 13:18. At 13:23, we begin our spiral to 12500 ft, and start descent at 13:35. We are held at 7500 ft for a few minutes by ATC. See a small increase at 5800 ft and a huge increase at 5100 ft, which seems to be the top of this very shallow layer. A missed approach at Provo at 13:48, on the way up the top of the layer is closer to 5400 ft. Begin rastering south of Provo at 5000 ft (min alt) at 13:51. Passing over agricultural areas at 13:56, and PM is very high and NOx is lower. NOx gets high again as we get back into developed areas. At 14:00 a spike in NOx, possibly because we crossed over a highway? Missed approach at Spanish Fork occurs at 14:01. Start porpoising over the lake at 14:03 between 4900 and 5300. Seems like some reproducible NOx layers? Lake is mostly frozen except for a few small areas. At 14:10, there's a huge spike in NOx, but I'm not sure of the source. It's just we come back over into land. NOy peaks at 100 ppbv. We pass the ground site in Provo at 14:12 and then circle the plume 3 times, twice at 5000 (because NOxCaRD zeroed in the middle of it), and once at 5400, and NOx

is huge (150 ppbv). Maybe in and out of the layer, since there are some huge spikes. At 14:21, climb to 6000 for transit through Jordan Narrows, because of visibility issues. This takes us out of the layer. At 14:26, drop to 5300 for the first box. Again, NOx and NOy are steady in the south, spiky in the north. Climb to 5600 at 14:41 for second box. At 14:57, climb to 6000 for transit back to Salt Lake International. We are in and out of the boundary layer. At 15:01, a big engine rev, possibly sampled. Land at 15:04

**Flight 2017 0131_L2**

Scientists: Dorothy (front) Ale (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: ASAP after last flight
Actual takeoff: 15:57
Touchdown: 17:32
Weather: Very hazy, mostly cloudy, 1C before takeoff
Flight plan: North to Cache
Flight plan deviations: Heavily modified due to time restrictions (needed to land by 17:30) and visibility. No MA at Ogden, no southern extra over Cache, from Cache straight back to SLC

NOx increased with height out of the airport. Over factory plume at 15:59 (NOxCaRD zeroing at the time). At 16:01 we ran parallel to a highway with moderate traffic. NOx quickly dropped on the N end of the city. At 16:03 we were over an open marsh flat with some cattle. Both NOx and UHSAS were very low. At 16:07 we passed through a cloud. We climbed out of the cloud to 5300, where all concentrations were higher. We then spent some time between the two layers of clouds (more broken below.) At 16:10 we were out of the boundary layer at 6000 ft. We tried dropping in altitude and everything increased significantly at 5800. Dropped to 5500 and held as long as visibility allowed. At 16:13 we dropped to 5400, which looked about the same as 5500. Through most of this we were over undeveloped, snow-covered land. We then dropped to 4950 looking for clearing, but quickly combed again. We were able to hold at 5500 for a while, which seemed like the very top of the BL. At 16:19 we turned to the MA at Brigham. The surface had much lower concentrations than aloft. Everything increased around 4500 and we were out of the BL at 5600. There was O3 depletion coming out of MA, seemingly not caused by NOx. At 16:30 we hit some high clouds and so ended the spiral at 12000 ft. Winds were very high aloft. It looked like the winds might be mixing some stuff out of the top of the BL. The BL in Cache was at 5600 ft. The MA at Logan was at 16:37. At 16:39 we hung at 6000 ft, our minimum. NOx showed lots of structure. Everything was snow-covered farmland. All species were briefly low and flat, but there was nothing noticeably different around. At 16:43 we passed the Utah/Idaho border. At 16:45 we turned around the N side of Little Mountain. At 16:46 we began porpoising from 5000 to 6500 ft. The BL was at 5500 ft, but some species persisted higher. At 16:58 we began the spiral out from Cache. At 17:02 we began the descent back toward the lake. There was lots of vertical structure over the lake, so we kept porpoising. At 17:10 the descent was cut at 4900 due to clouds, so we began next ascent. We stayed mostly over snow-covered

flats/shore, not open water. At 17:23 we started back for the city where NOx showed a lot of structure and was mostly NO2. At 17:25 we were back over the suburban edges of the city. At 17:31 we dropped back into the SLC boundary layer and NOx was very high. It dropped with descent. The CIMS was closed just before wheels down at 17:32.

**Flight 20170201_L1**
Scientists: Erin (front) Alex (back)
Pilots: JC (pilot) Rob (co)
All times in MST
Planned takeoff: 11:00am
Actual takeoff: 11:19
Touchdown: 12:12
Weather: Very hazy,
Flight plan: North to Cache
Flight plan deviations: Bird strike at Brigham City, return early

Notes:
Before take-off, noticed that NOxCaRD measured aircraft exhaust when taxiing and turning around on the runway. Might want to look for periods of exhaust sampling when spiraling during other flights.

11:19 Limited to 6000ft by ATC
11:22 Down to minimum altitude
11:25 Reach minimum altitude ~4800ft. NOx is very large and spiky, flying over I-15.
11:29 Up to 5200ft, NOx mixing ratio decreases,
11:31 Ogden missed approach, minimum altitude 4475ft. Between 4700-4800ft, elevated NOx mixing ratio. No apparent surface layer.
11:33 Cruising at 4800ft
11:37 Over interstate
11:38 Open area, not residential or urban. Snow covered. Also over the interstate.
11:40 Fly over interstate and truck stop - no apparent NOx increase
11:41 Brigham City missed approach, lowest point 4255ft
11:42 Hit bird near left engine when coming out of missed approach. Climbed up to 6000ft to head back to SLC
12:03 Began climbing after flying into increased NOx region north of SLC. I think the ground elevation increased around this point, which might explain the increase in NOx.
12:09 Layer at 5800ft during approach to landing
12:12 Landed

**Flight 20170208_L1**
Scientists: Carrie (front) Lexie (back)
Pilots: Rob (pilot) JC (co)
All times in MST

Planned takeoff: 02:00
Actual takeoff: 02:11
Touchdown: 04:54
Weather: Clear, windy, 10 deg C on the ground
Flight plan: North to Cache
Flight plan deviations: Because of high winds, going around mountains instead of spiraling over to get to Cache and Tooele Valleys.

Notes:
Taxiing at 02:01, take off at 02:11. NOx is less than 5 ppbv and variable, O3 is ~45 ppbv. We start the first box at 02:15 at 5300 ft asl (700 ft agl). NOx is higher at the north part of the box. We pass over the spaghetti bowl at 02:27. At 02:28, head over to I-15 to transit past Salt Lake City International. We pass a refinery off the right side of the plane. Descend down to 5000 ft for transit to Ogden. At 02:32, cross over to the lake, since pilots are having trouble seeing I-15 in the dark? At 02:37, we pass directly over another refinery. NOx peaks right as we pass over it, then gets very quiet again. Missed approach at Ogden at 2:43. NOx is ~15 ppbv in the surface layer, which is only about 35 - 50 ft deep. We see a big spike coming out of missed approach, which coincides with the engines revving I think. At 02:45, begin transiting to Brigham City at 5000 ft. The missed approach at Brigham happens at 02:54, and again we see a very shallow surface layer. At 02:58, we climb to 7500 ft to transit over to Cache. It gets *very* turbulent during this time. Start to box around Cache at 7500 but it's so turbulent that I think the pilots decide to descend a little early? At 03:05, start to descend into Logan. At 03:07, start to see a little bit of NOy. Missed approach at 03:08, and again, see a very shallow surface layer. Start to do the box around Cache at minimum altitude. At 03:15, we are north of the hill and turning around. Start to see a little bit of NOy on the west side of the box. At 03:23, start ascent back up to 7500 ft. Lots of turbulence over the pass again. By 03:34, we are back at 5000 ft and heading towards the lake. By 03:39, we are over the lake, and start porpoising between 5000 and 6000 ft. No sign of any significant NOx, or of any O3 depletion events. At 03:56, stay level at 4900 ft as we approach US Magnesium. Circle the plume, which we can visually see is moving southeast. See a large NOx peak, and corresponding O3 depletion southeast of the plume. Climb to 5300 ft for a second circle. Either NOxCaRD zeros during the peak or we are above it. Make a decision to follow plume instead of making a third circle, to maximize the amount of time to chase plume. Zigzag three times through plume starting at 04:06 at 5100 ft. I think we see the plume, each time getting more diffuse. At 04:21, do a missed approach in Tooele Valley, followed by an immediate climb to 8000 ft. At 04:26, stay at 8000 ft for a NH3 zero. Then ATC asks us to stay there for transit back into SLV. We pass the Garfield tower at 04:30. ATC has us drop down to 6000 ft. We pass just south of the airport on our way to do the second box, which starts at 04:36, at 5300 ft. NOx looks pretty much the same as the first box. At 04:43, we are on the south end of the box, and seeing a few small NOx spikes. Then we transit back to Salt Lake International, and land at 04:54.

**Flight 20170208_L2**
Scientists: Dorothy (front) Ann (back)

Pilots: JC (pilot) Rob (co)
All times in MST
Planned takeoff: 06:00
Actual takeoff: 05:56
Touchdown: 08:50
Weather: warm (10C on ground), broken clouds, some moonlight
Flight plan: South to Utah Valley
Flight plan deviations: Never spiralled to 12000, mostly stayed below 8000 ft, two boxes at start and end at 5300 and 5600 ft.

Ox climbed and NOx dropped on climb right after takeoff. Then Ox very steady. At 5:58 we sampled the NOx plume over the refineries. At 5:59 there was a larger plume slightly after we were past the refineries, but maybe the same stuff since wind was from the N. 6:00 was the start of first box at 5300. Almost no non-NOx NOy during the first leg of box. Still very few cars out on roads. Turn at end of box at 6:06, NOx was slightly higher, but might be engine exhaust. At 6:08 we paralleled a highway where traffic was just picking up. At 6:12 we went over the major interchange, traffic still pretty light. 6:14 was turn into second box at 5600 ft. Everything seemed a little higher at this altitude. At 6:23 the met probe labview software went down for a while, so we're missing some altitude data in the notes. At 6:32 traffic was much heavier on highways, but farther away. At 6:34 we were at the minimum altitude over the lake. There was no NOx structure on descent or out over lake. At 6:42 we did a profile over the lake. At 6:46 we were at the bottom of the profile and NOx ticked up slightly and showed a little structure. At 6:49 was the first significant NOx plume while passing back over land. At 6:51 there was a NOx plume over the weird buried buildings. At 6:54 we started the climb before the MA at South Valley. The top of the BL was at 6100 ft on descent. Dawn was just breaking. At 6:59 we were parallel to a highway with some traffic. 7:01 we started in for the MA, NOx increased for most of the descent. It was highest at the minimum altitude at 7:02. At 7:03 we crossed over a highway with moderate traffic. At 7:04 the met probe came back and we passed over a wastewater treatment plant. At 7:09 we were over mostly open land with fairly busy highways through it, then quickly back over populated areas. Weirdly, NOx dropped when back over population. At 7:13 we passed over a highway. It was generally light at this point, but we haven't really seen the sun. At 7:17 we made the turn over Hawthorne Elementary. NOx was high there, but might have been aircraft exhaust. At 7:20 we were over the crazy mansions. At 7:26 we dropped in to the Utah Valley and the MA at Provo. At 7:27 we got the first glimpse of sun between the mountains. Ice on Utah Lake looks very thin, but still 85% cover. Everything was pretty low until we were below 5300 ft. The MA was at 7:33. NOx was clearly the highest right on the ground level. At 7:36 we were over fields with lots of cows. There was no snow cover and the fields were very wet. At 7:37 we got the first full view of the sun between the mountains. At 7:39 we were back over a suburban area. At 7:40 there were more fields, but only one cow visible. At 7:41 there were a bunch of horses below. At 7:45 we started the descent to Spanish Fork, with the MA at 7:46. Again, everything was highest right at the bottom. At 7:47 there were lots of cows below to L. At 7:50 we were over Utah Lake and things were low and quiet. At 7:50 there was a lot of ice overlap at this end of the lake. There were lots of star shaped holes in the ice over the lake. At

7:58 we circled the power plant and fertilizer plant. We were over the fertilizer plant. The power plant plume was not visible except briefly right above plant, so at 8:03 we did a vertical profile through where we thought the plume should be. It was fairly spread out vertically up to 6100 ft. At 8:08 we were over a dirt covered construction area. At 8:09 we were over a big intersection with a lot of traffic. At 8:10 we started the first box at 5300 ft. There was pretty heavy traffic. Several commuter trains below to L. At 8:16 we passed a big interchange with pretty heavy traffic. We turned over the stadium at 8:17. At 8:19 the sun was 80% up from behind the mountains, though it was somewhat cloudy above. At 8:23 we climbed to the second box at 5600 ft. It was very clear. We could see all the way across the Salt Lake. Both boxes showed basically nothing, so we declined the third box. At 8:38 we made the final box turn. The highway below had heavy traffic. At 8:42 there were two pretty big freight trains below. At 8:48 we just got into the stuff on descent at 5100 ft. It really got higher below 4700 ft with big spikes on way down. Touchdown was at 8:50 and we landed in the opposite direction than usual (facing south).

**Flight 20170209_L1**
Scientists: Erin (front) Alex (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: 00:00
Actual takeoff: 00:30
Touchdown: 08:50
Weather: warm, broken clouds, some moonlight, windy
Flight plan: South to Utah Valley
Flight plan deviations: Never spiralled to 12000, mostly stayed below 6500 ft due to high winds, one box at start, two at end at 5300 and 5600 ft.

Notes:
Before takeoff - the inside of the plane was very hot. AMS AP240 was starting to overheat and NOxCaRD NOx became noisy a few minutes prior to take-off

00:30 extremely high NOx > 100ppbv right at the start of take-off. This seemed to occur right when the plane started moving before leaving the ground
00:33 Passed over the university at 5300ft.
00:39 Very little NOx at 5300ft and nothing aloft so we didn't finish the first box and went on to start the flight plan. Very turbulent, 33 knot winds at 5600ft.
00:45 NOx noise might be starting to settle down, Ox is very noisy and coincides with turbulence (might be vibrationally induced noise and not real)
00:49 Descending to 4900ft over the lake.
00:52 starting to climb, there were only < 2 ppbv NOy at 4900ft.
00:53 NOx/NOy drop to zero ~5900ft
00:55 At the top of ascent at 6500ft, very little change in NOx but Alex said her observed layers of NH3

00:57 Start descent down from 6500ft, NOy increased around 5000ft
01:03 Back to minimum altitude of 4900ft.
01:06 back over land, visible plant plumes on lake edge
01:09 Climb to 5900ft
01:12 Climb to 6700ft, saw O3 increase and NOx decrease
01:15 On the descent, NOx increased at ~5900ft.
01:16 Setting up to do missed approach in South Valley, from North to South
01:18 Missed approach, lowest altitude 4670ft, no strong surface layer and NOx concentrations dropped around 5000ft. The pilots reported a little rain at the bottom.
01:24 Cruising at 5200ft - starting raster pattern across SLC, heading north. All NOx, O3, NOy are very flat and low
01:31 Pass over downtown and university, corresponding NOx peak
01:38 End of raster pattern, up to 6500ft to get into Utah Valley
01:46 Essentially no NOx or NOy at 6500ft once into Utah Valley
01:50 Provo Missed Approach - min altitude ~4550ft, strong surface layer ~4650ft (within 100 ft of surface). On the way into the missed approach, NOx increased from 0 ppbv at ~5800ft.
01:54 Doing south box @5300ft
01:59 Once again, NOx spike from an unknown source in sparsely populated area of Utah Valley. Interestingly, Alex also saw a very large NH3 spike here.
02:02 Start of Spanish Forks missed approach. Low point ~4580ft, NOxCaRD was zeroing during most of this missed approach but caught the end on the way out and saw a strong surface layer around ~4800ft. The absolute amount of NOx was higher than at Provo.
02:08 NOx levels drop once over the lake. It appears to be mostly frozen.
02:12 No visible plume coming from large power plant we usually sample in Utah Valley.
02:14 Quick, small NOx spike when circling plant.
02:16 Circled fertilizer plant. There was one small visible plume but based on the plume appearance, all the emissions were trapped in a lower surface layer.
02:17 Headed back to SLC at 6000ft
02:21 Back in Salt Lake City and descended down to 5300ft for first box
02:29 Passed over the university/downtown. NOxCaRD was zeroing during the majority of this time. Very turbulent.
02:36 Starting second box at 5600ft
02:41 Passed over downtown/univeristy - no NOx peaks at this higher altitude. We were also not as vertically close to downtown/university as we were on the first box.
02:58 Landed

**Flight 20170211_L1**
Scientists: Carrie (front) Lexie (back)
Pilots: JC (pilot) Rob(co)
All times in MST
Planned takeoff: 17:00

Actual takeoff: 16:49
Touchdown: 19:29
Weather: cool, breezy, just starting to clear up, 9 deg C on the ground
Flight plan: North to Cache Valley
Flight plan deviations: Adding a missed approach at Preston, ID in northern Cache Valley. No boxes

Notes:
Take off at 16:47, and open the CIMS valve at 16:48. Heading north towards Ogden at minimum altitude (5400 ft). NOx is <5 ppbv, with a few spikes as we pass over refineries, and gets a bit higher as we get further north, following I-15. Pass over a major intersection at 17:04, and a huge amusement park with go kart racing (fumes?) at 17:06. Start descending into Ogden at 17:10, missed approach at 17:11 with no observable surface layer, pass low over a light rail train at 17:12. Notice some snow on the ground between Ogden and Brigham, and possibly some flooding, cause it looks marshy, and the canals are all really full. At 17:16, we have to make a sudden sharp swerve to avoid a bird, but it doesn't look like it hit. Then some sudden turbulence at 17:20. Sudden spike in NOx at 17:22, not sure of source. The missed approach at Brigham City happens at 17:23, and there is a little bit of elevated NOy in surface layer. At 17:24, begin spiral to 12,500 ft, and NOy has dropped completely to zero by 8500 ft. O3 starts to increase up to 60 ppbv (from 45 on the ground) as we head over the Wasatch mountains. At 17:39, PM starts to get bigger, NOy returns as we descend past 8500 ft again. By 17:44, we are in the Cache valley and NOy continues to grow. Missed approach at Logan at 17:45, where we see a small increase in NOx at the surface layer. Sun is setting. Stay level at minimum altitude as we head north. Not seeing much going on. NOy is flat at about 2 ppbv or so. At 17:57, we do a missed approach at Preston, and again have to avoid some birds, but no swerving, just pass through the middle. Because the CIMS was seeing some vertical structure in the HCl trace, do one quick porpoise 5400 - 6000 ft as we head south at 18:00. By 18:03, we are back level at 5300 ft for the rest of the box through Cache. 18:06 - NOx still level at about 3 ppbv. At 18:10, have to climb to 700 ft agl because night has fallen. At 18:13, pass over a power plant of some kind. As we get closer to downtown Logan, NOy/NOx starts to climb close to 10 ppbv. We pass over downtown at 18:16, then turn left to head back out of the valley, climbing to 7500 ft. At 18:37, we are over the lake, and start porpoising, 5300 - 6000 ft. at 18:41, there are some unidentified lights off the right side of the plane. At 16:43, CIMS is seeing some more interesting HCl, so we search for the vertical layer and stay in it for a few minutes at ~5300 ft. At 18:46, we resume porpoising until we get to the lake. At 18:49, we reach the Mag Corp plume, circle it once at 4900 ft and pass right through the plume (can feel it!). NOx spikes to 130 ppbv, but it's very narrow. We circle it again at 5100 ft at 18:54, but see basically nothing because we are above it. At 18:55, we drop back down to 4900 ft and start to zigzag, but we are limited by terrain. Pass into middle of plume at 18:58, then turn in the middle and come back out. We stay at 4900 ft as we head back over the lake, just in case. At 19:08, start descending for missed approach at Bollinder, which happens at 19:10, no real surface layer. At 19:12, start spiral up, passing through some light clouds? At 19:18, pass right over the mountain station off to our left. We are seeing some periodic dips in O3 as we pass over the mountains. At 19:20, pass over

Garfield stacks on our right at about 8500 ft. We start our final descent at 19:21, and are routed to fly east south of the airport at 19:26, and NOx starts to climb. Land at 19:29.

**Flight 20170211_L2**
Scientists: Dorothy (front) Ale (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: 20:00
Actual takeoff: 20:32
Touchdown: 23:24
Weather: cool, clear, starry night, light breeze
Flight plan: South to Utah Valley
Flight plan deviations: Two boxes at start, two at end, all boxes run counterclockwise, some porpoising over city to see what was aloft

Right after takeoff at 20:33 it was somewhat colder aloft (1C), we headed over for the first box at 5300 ft. At 20:34 we were over the refineries, but still pretty high in altitude (5500 ft.) At 20:36 we started the first box. NOx showed some structure on the first leg, but no significant NOz. At 20:41 we did the first L turn of the box, NOx higher at end of box, most everything was higher at end of box. At 20:49 we made the turn and climb to the second box at 5600 ft. There was a distinct layer of AMS organics and NOx right on top of the first box. NOz was higher in box two. At 20:55 we did the L turn at the south end of the box, with a commuter train underneath us. NOx was similar in magnitude, but smoother on this leg, though levels climbed as we headed north. At 21:01 it got pretty bumpy, probably from canyon flows. At 21:02 we did the final L turn of the boxes and headed to FP2. At 21:04 we crossed the airport at 6500 ft. At 21:06 we took a slight R turn toward the lake and things got pretty low and steady, but there was some NOz present. At 21:13 we porpoised to look for structure, but didn't find any. Things dropped a little over 5600 ft. At 21:20 there was maybe slight O3 depletion, but might just have been a slightly different air mass. Otherwise, things were very steady everywhere over the lake. At 21:23 we were back over land. At 21:25 we passed over the weird buried buildings. At 21:27 the city looked pretty quiet with few cars on the road. At 21:28 we were at 6000 ft and everything was close to 0. At 21:29 we started to climb and things started to show a little noise. At 7600 ft, things were a little higher with some NOz. We topped out at 7800 ft with slightly higher levels on AMS and NOx, but definitely not out of layer. It was colder up there (-1C) At 21:35 we set up for the MA at SV, things climbed a little with the descent. Stuff ticked up slightly at 4900 ft. The MA was at 21:39 and showed no obvious surface layer. At 21:40 we rastered the city with some bumps and maybe corresponding structure? At 21:43 we started a porpoise to look for layers. At 21:47 we topped out the porpoise and the highest levels were there, but there was some structure throughout. At 21:49 we came back to 5800 and stayed for a little while. It was a little bumpy maybe from canyon flows. At 21:51 we were near the blinking U, and dropped back down to minimum altitude with more bumps from flows. At 21:57 we were out of everything by 8800 ft, with some O3 increase around 9000 ft. At 21:59, O3 got up to 65 ppb at 10000 ft and then dropped back to 50. There was some O3 structure aloft. At 22:04 there was a pretty big O3

spike at 10400 ft and we were out of it by 8500 ft. At 22:05 we just got into the NOx around 8000 ft. At 22:07 we ran the MA at Provo in the opposite direction from usual. Things were pretty constant throughout the descent. The MA was at 22:13, with no obvious surface layer. When we were back over the lake, with the moon reflecting off the water. The lake was probably only 20% frozen. At 22:20 we were back over a suburban area. At 22:22 there was a small increase in NOy, but it wasn't obvious why. At 20:24, NOx increased as we headed toward Spanish Fork. At 22:25 we did the MA at Spanish Fork and things were much higher. There was also a strong smell of bbq meat on this MA. At 22:29 the power plant plume was visible. At 22:33 the part of the lake we were over was completely ice free. At 22:37 we started circling the power plant and the ammonia plant. At 22:40 there was a small NOx increase, but seemed to be on wrong side of plant. The spike at 22:42 makes more sense. At 22:44 we were back over city lights and it was slightly bumpy and NOx showed some structure. At 22:46 we passed over a moving freight train and a 22:48 we were over a dirt construction pit. At 22:49 there was increasing NOx and structure while approaching the box. At 22:50 we started the box at 5300 ft. There was some neat structure on leg 1 and it was colder this time (-1C). At 22:54 it was bumpy again and the bumps increased along the leg. At 22:57 we made the turn at the N end of the box and it was still bumpy. At 23:03 we climbed to 5600 ft for the second box. Things were maybe slightly higher here, but there was less structure. At 23:05 some structure started to show up. The higher NOy spikes had less NOz than the flat areas. At 23:08 we started in the bumps again and NOx was lower. At 23:10 NOy was basically 0 and then we made the L turn for the 2nd leg of the box. At 23:11 stuff was higher again after the turn and back into the bumps. At 23:16 we made the final L turn for a ½ box before the airport and tried to climb to 5900 ft, but got sent back to 5500 ft by ATC. It was quite bumpy on the ride back to the airport and there was little structure with descent.

**Flight 20170212_L1**
Scientists: Erin (front) Reporter (back)
Pilots: JC (pilot) Rob (co)
All times in MST
Planned takeoff: 19:00
Actual takeoff: 19:14
Touchdown: 21:23
Weather: cool, clear, starry night
Flight plan: North to Cache
Flight plan deviations: Went passed Garfield stacks on the return to SLC and did not do a missed approach in Tooele Valley or spiral up to 10,000ft.

Notes:
19:17 Small layer at ~5400ft
19:18 When headed down to minimum altitude after take-off on the way to Ogden, there may have been a small layer at ~5600ft. This also may have been horizontal, not vertical structure due to changing ground elevation in the area.
19:20 Reached minimum altitude of 5000ft. About 5-10 ppbv NOy and there appears to be

some horizontal structure

19:21 Shopping centers below, but all parking lots are empty and there are few cars on the roads

19:23 passed over train, might have been a small corresponding NOx plume

19:25 NOx decreased as we climbed to 5200ft

19:28 Ogden missed approach. The first layer was at ~5000ft and the enhanced surface layer was about 200ft above the ground. On the way out of the missed approach, NOx decreased at ~4800ft.

19:29 Reported removed window in the back to take pictures

19:31 Flying over a more residential/less populated area. NOx decreased and became very flat.

19:34 Flew over large truck stop along the interstate

19:37 Brigham missed approach. NOx increased on the way down at ~ 4500ft and 4750ft on the way out. No birds

19:39 Began spiral up to 12,500ft

19:41 NOy mixing ratio dropped to zero around 7000ft

19:42 Pulled out of spiral briefly around 8000ft due to other air traffic in the region

19:43 Resumed spiral

19:50 Zeroed NH3 while at the top of the spiral. Started descent into Cache Valley

19:54 NOx increased from 0 ppbv at ~6500ft

19:57 Logan missed approach. Not a strong surface layer.

20:00 Flying level at 5200ft through Cache Valley

20:20 Elevated NOx levels as approaching Logan.

20:22 Ground elevation increased

20:23 Starting climb out of Cache Valley

20:27 NOy dropped to 0 ppbv around 7500ft. Zeroed NH3 at the top of the climb

20:30 Started descent

20:34 NOx levels increase around 5700ft. We are flying over a residential/sparsely populated area in Bear Valley

20:37 Flying over marsh. Appears somewhat frozen. Learned that the aircraft altitude, when flying, is measured by static pressure probes on the side of the aircraft nose. During missed approaches, the altitude above the ground is measured by a radar sensor on the bottom of the aircraft.

20:39 Began porpoise to 6500ft once we were over the lake and clear of the marsh where Alex has previously observed NH3 plumes

20:42 Reached top at 6500ft, no obvious O3 titration, NOx and NOy very low but steady.

20:45 Reached minimum of 5000ft, decided to do a second

20:50 Reached top at 7000ft. Noy was lower at this altitude but did not decrease all the way to 0 ppbv. There was a small peak at 6800ft on the way up that wasn't observed on the way down.

20:52 Small NOx increase at 6000ft

20:54 Reached minimum altitude of 5000ft.

20:56 Mag. Corp. plume is visibly at our altitude or slightly lower and is blowing to the south.

20:57 Flew through plume, was not mixing much since it was so narrow.
20:59 Second pass through plume. Could feel a bump when flying into the plume and could smell it. This pass also showed a very narrow plume.
21:01 Attempting to plume chase
21:02 Mag corp plume intercept #3
21:05 Headed over to garfield stacks, across the Salt Lake at 5000ft
21:11 A lot of NOx structure observed. There happened to also be turbulence and there was land visible off to the right of the plane.
21:13 Reached Garfield stacks, they were off to the right of the aircraft, there was a small NOx plume.
21:14 Spiraled up to 6400ft to resample the Garfield stacks. The plumes that were being emitted were vertical, unlike the Mag Corp plume that was very horizontal in shape. We also couldn't get too close to the stacks due to terrain on one side.
21:17 Climbed to 6500ft to return to SLC. Surprisingly, NOx increased with altitude. Maybe this is due to larger emission source in SLV.
21:21 Might have sampled aircraft exhaust. We did a tight turn with large prop angle.
21:22 During landing at airport, the surface layer appeared to be ~4600ft.
21:23 NOx decreased slightly right before landing. There also appeared to be non-NOx O3 titration.
21:23 Landed

**Flight 20170212_L2**
Scientists: Steve (front) Alex (back)
Pilots: Rob (pilot) JC (co)
All times in MST
Planned takeoff: 23:00
Actual takeoff: 22:39
Touchdown: 01:05 (approx)
Weather: cool, clear, non inversion conditions, but also light enough winds to make for some buildup of urban emission in the study area
Flight plan: South to Utah Valley
Flight plan deviations: No boxes on front end, 3 boxes at end. Skip transect over Great Salt Lake on front end of flight in order to save time.

10:41 5500', altitude set by ATC for immediately after takeoff. Fly south to downtown SLC at this altitude. NOx variable at 5-10 ppbv throughout.
10:44 ATC releases us, turn west and descend to 5000'. <5 ppbv NOy over this part of the valley.
10:48 Turn south along the west side of SL valley.
10:50 Start climb at southwest end of valley. Everything well mixed to >7000', with BL in two steps, one at 7400', second at 7700'. Level out at 7900'.

11:01 Low approach at south valley regional. Well mixed through much of the descent. Very tight surface layer at the bottom, with main gradient below 200' AGL. Nox-NOy=10 ppbv at bottom.

11:05 Level at 700' AGL, flying south. NOx&NOy more concentrated toward south end of valley.

11:09 Flying north along I-15 corridor. Plenty of structure in NOy on level leg. Is this canyon flow? 25 ppbv NOy between Hawthorne and University, but less concentrated at the north end of the transect over UU.

11:20 Start ascent at SE corner of valley. BL top 7500 - 7800', gradual rather than stepped decrease across this range.

11:27 Top of ascent. O3 @ 50 ppbv, nearly no particle counts

11:34 BL at 7500' on descent into Provo. Very consistent NOy, 5-10 ppbv & well mixed on descent over Utah Lake.

11:40 Missed approach at Provo. Noy to 15 ppbv in surface layer.

11:43 8 μg m-3 on AMS after Provo, with good amt of NOy. Level leg at 700' AGL.

11:45 NOx/NOy consistently 0.5 in both Utah and SL valleys.

11:50 Low approach at Spanish Fork. Lots of structure below 200'.

11:55 More NOy and particles over Utah Lake. AMS NO3- @ 6-11 μg m-3.

00:01 Uniform NOx & particles over most of Utah lake.

00:05 Lindon overapss

00:11 No intercept in NOx circuling the PP @ 700' AGL, but much clearer intercept at 1000' AGL

00:16 Over the pass between valleys. Stayed easily in BL the entire time.

00:21 1st box is at 5300' ASL. Pick up decent NOy ~1/2way into N. leg of 1st box. Persistent all the way to UU.

00:25 Lower pollution during southward transect along the E side of the valley.

00:31 Start second box, 6200' ASL.

00:36 Second box more uniform than the first, and NOx/NOy lower at this altitude.

00:45 Third box at 7100'

00:52 Quite uniform around third box. May be just at the top of BL at north end. Ox to 50 ppbv at points, and particle counts clearly lower.

00:59 Start approach to SLC