Aircraft Flight Log for the University of Washington, Cloud and Aerosol Research Group

Date: 1-18-01	Flight Number: 1851
Project name: IMPROVE	Duration: 3:14
Engines on time: 2016 UTC	Engines off time: 2330 UTC
Departure airport: PAE	Arrival airport: PAE
Flight Scientist signature: D. Bond / G. Rancon	
Pilot signature:	

Surface met. & visual obs. at takeoff: E30@7R–

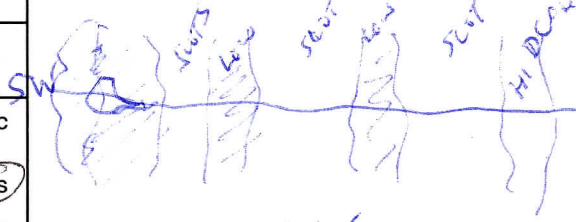
Clouds sampled: Ac, As, Ns, Sc, St, Cu, Cb

Research crew: BOND, WILSON, SPUHLER, RANCNO

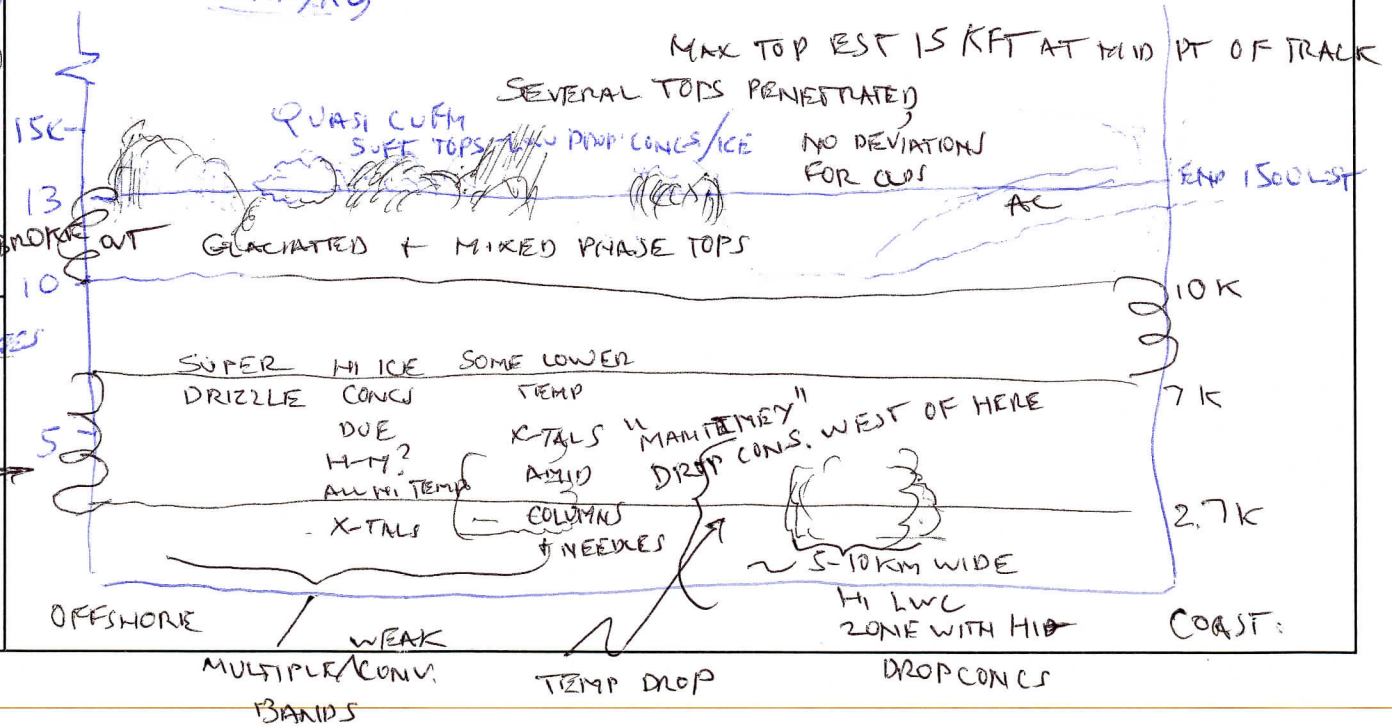
Equipment failure: HVPS on CIP counters; 35 GHz radar not recorded

Experimental Observations

THE MEASURABLE FEATURE OF THIS FLT WAS THE NUMBER OF SLOTS IN THE MID & HI CLDS OVRHD, THE NUMBER OF QUASI-CONVECTIVE N-S ORIENTED RAINBANDS, THE VERY HIGH DROPLET CONCENTS IN THE FEEDING PORTION OF THE FIRST OFFSHORE RAINBAND INTERCEPTED, AMOUNT OF VARIABILITY IN THE TYPES OF PRECIP, SUPERCOOLED DRIZZLE, ICE MULTIPLICATION, ASSOCIATED W CLD TOPS TPG OUT TO ~15KFT CLOUNTING SHOULDER & MAX TOPS). LOWEST CLD TOP TEMP ≥ –15°C.



PLAN VIEW OF FIRST LEG



Flight 1851
January 18, 2001
Voice Transcriptions*
IMPROVE

OK
2nd Draft

12:31 PM

AR: These days it takes a few minutes to get the system up. t-stat –1°, t-statr 0.6°. I believe we're going through the melting level and the inversion simultaneously part of the frontal inversion evidenced by undulatus at the base of stratocumulus clouds up around 4,000 to 5,000 ft. Presently we're at 7,000 ft. We have not hit any turbulence yet only the slightest chop or little bumps occurring right now at 7,000-ft tans-alt. In and out of droplet cloud here. The sky is uniformly overcast. Onboard today we have Nick Bond as flight scientist, Don Spurgeon (engineer). We have Tom Wilson who is doing some work on his computer right now, and myself, Art. Grant is working back at the office. The flight number is 1851 on 18 January 2001.

12:33 PM

AR: In spite of sitting in the rain, it looks like the HVPS is working and the 2-DC is working. So we're blessed there.

12:35 PM

AR: Only now after this many minutes am I able to get my computer set up with all the windows needed to keep track of the flight. So that's quite a lengthy process maybe 10 min.

12:37 PM

AR: Today's flight will be targeting a rainband marking a cold front and there will be some proceeding rainbands, which we're in right now, of the warm frontal or the cold frontal aloft type. I'm not sure which and I'll leave for others to determine later. At this point, we're breaking out on top of some altocumulus considering the elevation here we're at almost 10,000 ft and about 1,000 ft. About 1,000 ft below us is a layer. There's good visibility in the horizontal, no rule, but I can see some land off in the 5 o'clock/4 o'clock direction. The cloud above us is precipitation. It appears like altostratus. The sun's position is not visible at this point, so it's quite thick.

12:38 PM

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* AR = Art Rangno, DS = Don Spurgeon, JR = Jerry Rhode (pilot), LS = Larry Sutherland (pilot), NB = Nick Bond, TW = Tom Wilson

AR: About 12:20 we've closed in again. There's no separation between layers at this locale.

12:40 PM

AR: Even though the temperature is –6°C there are no columns or needles here only crystals of the dendritic quasi-stellar type and their fragments. This is from the 2-D probe. I'll check the CPI here.

NB: Art, are you trying to be just on record mode?

12:41 PM

AR: Testing 1, 2, 3. Can anybody here me? Did you try to talk to me?

DS: Testing 1, 2, 3.

AR: I had the volume turned down so low I couldn't hear that I was on "science" instead of "record," so I messed up. Sorry guys.

DS: Okay.

12:42 PM

AR: The sun's position is still not visible through the deep nimbostratus/altostratus appearing to be mostly glaciated above us. I guess there's no droplet clouds passing anywhere near the aircraft at this point above us.

12:43 PM

AR: We're between layers again. I see a separate layer below the aircraft now off behind the left wing. Off the right wing there is quite a bit more precipitation and layering is not evident.

12:45 PM

AR: Crystal types continue to be about the same, single crystals and fragments and aggregates. There is no indication of columnar or needle crystals. Good clearing here. We just broke out between layers. A thin altocumulus layer below us, at least one layer, and above us altostratus shedding a few ice crystals. This must be the break between the warm sector bands and the cold frontal band. The temperature has dropped a little bit here maybe evaporational cooling now that the air is dry and the crystals fall into it, about –6.7°C. Now we're back to –7°C.

LS: Nick, are you up?

NB: Yes. I'm right here.

LS: We're 37 miles to Hoquiam, which is about 10 min. What's your plan?

NB: When I talked to Mark at around 11:30, he said to go right over the radar and then out on radial along 240°.

LS: Okay. Do you want to go out to those coordinates he gave me or go out to 240 radial?

NB: I'll check in with John at the radar now. I assume that the coordinates he gave you are along that radial. He said he faxed you something at around 11:30/11:20. Did you get something like that?

LS: Yes. That's at 46°08'/126°.

NB: Yes. I believe that's just kind of at the north edge of that corridor. Is that correct?

LS: It's not at the edge, but it's in the corridor.

NB: Okay. Chances are that's what we're going to do, but I'll check in with John and get back to you.

12:48 PM

AR: Entering a zone of precipitation dropping out of the higher altostratus cloud ~~flowing~~ falling into the lower altocumulus layer below the aircraft. It's an overcast altocumulus layer I should add. The tops are fairly flat and we're getting some slight to light turbulence here probably evaporational cooling. Just a minute ago before we went into this precip I could see ~~on the side of it~~ some sunlit tops. Out in the distance they maybe 30 to 40 miles ahead. So there's a big thin spot clearing out there probably ahead of the cold frontal band. Clearing beginning to come back into view.

tops at 6K ASL
technically a "stratocumulus layer"
flt lvl ~10K

12:49 PM

AR: I was counting on the temperature. I don't know if it was impacted by noise at that time, but earlier in the flight at this level is about –6°/–6.2°C. Now it's running about –7°C. I'm not sure if that's an effect of evaporational cooling or a real gradient possibly associated with some upper level feature.

NB: Larry, Nick here.

LS: Go ahead.

NB: Yes. Those points are fine. One thing that we were told was that we'll probably want to do our increments at 3,000 ft rather than at 2,000 ft, but just because of the speed of the system so we can get through the whole stack in time. We'll do the first one down as low as you are comfortable. Then the next one right about the freezing level and then 3,000 ft intervals above that.

LS: Okay. It looks we're going to be IFR out here, so probably 3,000 ft is going to be as low as he let's us go in the corner.

NB: Okay. That's fine. We should still be below the freezing level there. It would be nice if we're below cloud base. But if those cloud bases are below 1,000 ft, then we're stuck.

LS: When we get to 3,000 ft, if I find a hole, I'll cancel and go down through the hole and we'll depend on finding a hole to get back up.

NB: Right. If it costs us any time to kind of lose the IFR clearance, it would be more important to get through the pattern than getting low if that's going to be any delay.

LS: Okay.

AR: I think there's some sunlit cloud tops off in the distance once we get past this altostratus here, a layer that's shedding ice crystals down here and aggregates down to our level. That must be the thin spot before the cold frontal band I'm guessing.

LS: Nick, do you want to go down to 3,000 ft crossing the radar site?

NB: Yes. That doesn't matter a great deal, but then I guess that would be okay. They don't give great data right overhead, so it's not a big deal as far as I know.

LS: Okay.

12:52 PM

AR: Just ahead Nick is that big clearing. I think this is would be the third spot we saw on the satellite image preceding that cold frontal band. In just another minute or two we should be breaking out.

NB: Yes. I see what you mean. Certainly I'm getting flooded with light now.

12:53 PM

NB: By the way, Art, I assume it makes sense to you, but it's okay for this low-level run to be at 3,000 ft. Basically we don't want to mess around if that's required to go lower.

AR: Roger.

12:54 PM

AR: Continuing in a precipitating layer dropping crystals into a lower stratiform layer. Now looking about 2,000 ft below the aircraft it seemed a little higher than that earlier. Looking off the left wing visibility is quite good. I can see probably more than 10 nautical miles off the left wing. Now I can look back and see some land surface through the virga precipitation falling out of this higher seemingly glaciated region.

12:55 PM

AR: Get ready to get your sunscreen out.

12:56 PM

AR: Large thin spot in the high clouds coming up here in about another 2 to 3 min. In fact it looks like it's going to have some clear…

DS: Would you guys like some coffee up there?

LS: That would be nice.

AR: Along with this we'll be passing. Standby 1. I'll check our location because we're dropping down now in elevation. We're down to about 6,500 ft. We're about to enter some cloud tops here shortly. These are more convective looking cloud tops than we saw that we've been overflying. It's just a perspective thing. About 10 s to cloud top.

entered tops @ 12:55:40 is clock off

12:57 PM

AR: Fairly opaque cloud going by here indicating a significant liquid water and higher droplet concentrations than perhaps normal. I did see 158 on one of the readouts and liquid water contents of about 0.5. I suspect it's been higher than that though. That was at the top of the stratocumulus clouds that probably were rooted in the boundary layer or pretty darn close to it. It had some cumuliform appearance to them and that will be evident in the video, but no excessively protruding tops. Here's 180. It's a little unusual probably due to the offshore flow again. The spectra is not too broad. It seems to be exceeding channel 10. Mainly the tail seems to be in 8 and 9.

12:59 PM

LS: Nick?

NB: Yes. Go ahead.

LS: Give me the coordinates on the radar site. I left that piece of paper in the office.

NB: Yes. I'll look it up in the booklet here in just a second.

1:00 PM

NB: That position is 46°54' N/124°6' W.

LS: Okay.

DS: Tom to "chat."

LS: Nick, we're at 3,000 ft and we're going to start proceeding now out to your point offshore.

NB: That's fine.

1:00 PM

AR: Nick, I don't know how important this is overall, but this cloud is producing precip of its own by coalescence without anything falling from above. Because we're under that thin spot and slotted clearing and judging by the liquid water, which is running about 0.3 g/m^3, we're probably about 1,500 ft above cloud base. In these kind of situations, as you might guess I'm sure, that most precip is the drizzle type and light rain type and comes out near the bottom where it's had a chance to collect more water. So I guess what I'm suggesting is it might be interesting to go down there if this kind of precipitation is important to IMPROVE to look at just how much this stratocumulus is putting out of its own before the deep precip piles on top of it.

NB: Yes. I see what you mean. I'm not inclined to since we can't get down below this with IFR conditions it might delay the other part of the work.

AR: Yes. I guess that's right. I'd forgotten about that. We can't just go down to 2,000 ft because we're not visible on the radar. Is that correct?

NB: Yes. I think that's the problem.

AR: Yes. I'd forgot.

1:02 PM

AR: Altocumulus visible. We just popped out just as I started to speak we popped above cloud top here at flight level, 2,700 ft on the tans-alt, and there's altocumulus perlucidis/altocumulus opacus off in the distance to the south through west through southwest. That must be the main frontal band back there. It looks like the clouds add another layer off to the horizon. Also noting a little haze layer just above cloud top here. Looking back it was a multilayered system. We have the tops of the stratocumulus below us and what we were flying in appears to have been a merged layer of stratocumulus connected with the lower layer. Also looking aloft I see an ice cloud up there, but it seems to be associated with this altocumulus perlucidis and opacus layer shedding ice in which the liquid elements have evaporated and that would be off the right wing mainly. Off the left wing the tops are mostly liquid.

LS: Nick, we can get VFI here if you want to go down.

NB: Yes. I guess we might as well. We're not getting much right here.

AR: Yes. Because you can see that everything is broken up even down below it's not going to be very at this point. Looking back it was definitely a multilayered warm cloud, but it certainly is very different ahead. So I have no desire to go below cloud base any longer if that's going to pose a problem, Nick.

NB: Yes. Larry, did you hear that, what Art said?

LS: No. I missed it all.

NB: Right now it doesn't really matter whether we're above or below these clouds here. So if it's any problem to go below, we might as well just hang out at this level and hope we get some real precip here in a little bit.

LS: Okay. We'll stay here at 3,000 ft.

1:05 PM

AR: Yes. It does look like this altocumulus/altostratus layer lowers and thickens ahead. So I guess the main bang is out there.

NB: Yes. I'm a little worried right now. Certainly we're not doing any good right here.

AR: I hope they don't want us to go back to whatever it was onshore because we'd sure be chasing a lot of clear air between whatever this is out here and however strong it is and back there. I'm guessing this must be a fairly narrow feature we're going

to be going back and forth in if we concentrate on this guy out here. Is that correct, Nick?

NB: It must be. I know they were talking about him moving 30 knots for what it's worth. Boy, it sure doesn't look like it's going to be happening real soon.

1:07 PM

NB: Larry, sorry to disturb you. What were our southwest endpoints again?

LS: 46°08' N/126°00' W.

1:09 PM

AR: Now passing across the sun is this north-south region of altocumulus topped altostratus with virga. It looks the virga gets down to our level just dead ahead or off to the right. We may see a couple of crystals but not much. Then coming into view is another slot in the north-south direction and then another thickening. That thickening maybe the actual front. Below us the low clouds have filled in and become overcast after they had broken up into between scattered and broken coverage there at the minimum. That was kind of below the sunny slot. So it's kind of interesting that the thickening and thinning aloft has also gone with the thinning with the boundary layer cloud.

1:11 PM

NB: So Art, I still see kind of a horizon there. It doesn't look like we're going to be in precip any time soon.

AR: This altostratus layer that's just ahead and overhead there maybe a crystal or two dropping out of that, but I agree. Then there's another clearing slot, another thin slot, and then another thickening of the clouds maybe that last thickening on the horizon is the last one before that marks the front edge of the front or the eastern edge of that front. But that's kind of a long time between crystals here.

NB: Yes. Our southwest endpoint is quite a way out here. The radar is just a little bit west of 124° and we're going out to 126°. We're not to 125° yet, so we're less than halfway through this low-level track. So I guess it's not time to panic, but I suspect we're going to be doing things right on the outer edge of the radar here for awhile.

AR: Yes. When you said 126° and Larry was repeating those points back to you, I looked at the map and I thought holy smokes that's a long way out there.

NB: Yes. I'm not sure what its range is. Let's see, that means we're about 80 miles away from the radar and that seems like in the research mode longer than it can see.

AR: Interesting. Just in those couple of minutes that we've been talking some more clarification has occurred in the clouds ahead. I think you can probably poke your head out that bubble and it looks a little discouraging because it doesn't look like what that band on the horizon or surely the next wasn't it. It looks like it's well beyond that. I think I'll run up front because the plane flies uphill and I can't see dead ahead very well.

NB: Right.

1:14 PM

AR: Yes. I can see a lot better up there. I think this thing just ahead here another few minutes is the beginning of the main rainband.

DS: So would that be a good time to get a background, Art?

AR: Any time in the next couple of minutes would be a good time, Don, because we're pretty much out of crystals. Actually they wouldn't be crystals anyway it's +7°C, so it would be raindrops. Thanks for asking there.

DS: Yes. I just got one. It looks good. Generally when we get in this stuff we don't have any time to get a background because it never stops.

AR: Yes. That's right.

DS: At this point everything is pretty much up to operating temperatures and stuff now.

AR: Yes. That's true. That's a good point. I have to say it's above operating temperatures here in the region of the bubble.

DS: You could ask them to turn the temp down a little.

AR: Larry, it's a little hot back here in the back. Could you turn the heat down just a bit?

LS: I think we've got it down as far as we can go right now. I'll tell you what. We'll be pressurized and maybe that will help.

AR: Okay. Well thanks for any effort.

1:16 PM

AR: It looks like the temperature is climbing a little bit, Nick. I guess that goes with getting into the pre-frontal environment or the immediate pre-cold frontal environment. Is that correct?

NB: Yes. That's true. My impression is I haven't been looking closely and the winds are coming up also and you tend to get that little kind of ribbon of warmer, faster moving air ahead of the front.

1:18 PM

AR: Sun's disc is barely visible through overcast altostratus. I would guess that even though we're not getting precip to the ground here on the satellite imagery, this little band of altostratus with virga probably looks pretty potent on the IR. Solid overcast underneath still. The temperature is continuing to climb almost 8.9°C. now.

1:19 PM

AR: Just ahead on the forward video some altocumulus clouds, a layer that's connected to or near the bottom of the virga coming out of the altostratus. That's a new layer suggesting increased upward motion in here.

1:20 PM

AR: Nice upward slope to the clouds ahead as we approach what must be the frontal rainband, so we'll be going back into a liquid topped clouds here shortly. I'd say we've added overhead a separate layer of altocumulus located near the base of the virga the altostratus or things are really starting to happen here. We'll be entering cloud here in the next few seconds. These clouds have a lenticular look suggesting some lift. As we start to enter them there's absolutely no cumuliform aspect to them whatever. Gee, droplet concentrations 250/cm^3. That's extraordinary. That's got to suggest offshore flowing air being uplifted in this zone.

1:22 PM

AR: There's something going on down below us. I'm getting like 0.8 grams per cubic meter liquid water and we're only flying at 2,800 ft according to the tans-alt, so that's definitely boundary layer air being shoved up here to this level at quite a pace.

NB: Yes. Well, I would expect we're definitely in the boundary layer.

AR: You didn't see that back in those other clouds. They were kind of stratified just over the radar in that area and the droplet concentrations weren't nearly as high as

this so it suggests and normal is the liquid water content. So anyway it's pretty interesting. I wonder if this could be the frontal boundary coming up already.

NB: Well I wouldn't be surprised. I guess we'll have a chance. I'm inclined to go all the way to the endpoint, so we'll see.

AR: Right. I'm with you there.

NB: You know we just have to kind of hang out here. I've got a note of where we entered the precip and so just kind of work on the west edge of the box here.

1:24 PM

AR: Saw 300/cc just then, 301 I guess it was. That was from the FSSP-100. I'm getting a little worried that it is a correct value. The FSSP is reading higher than the other probes in liquid water content.

1:26 PM

NB: Art, you might have noticed that those liquid water contents at least off the Johnson-Williams have really dropped off.

AR: Right Nick. So we're not in nearly so much liquid water now. So there's something back there. I don't know. But yet we certainly haven't gone through the front because I would image this one is going to have a pretty good clearing out the back side and probably a noticeable wind shift.

NB: That's right and it looks like our precip rate, at least looking out the window and what's coming through the 2-D probe, is every bit of what it was back there.

AR: Yes. If not more.

1:27 PM

AR: Gee, t-statr is down about 3° or 4°C though. That's interesting.

NB: Yes. I wonder how much of that is evaporational cooling though.

AR: Well we're in a droplet cloud. I wouldn't think there would be that much going on.

NB: Well I mean we were in the clear air before and the fate of this air might be similar to what it was back to our east-northeast.

AR: We're beginning to break out here a little bit too, so I don't know. I think maybe there might be more to this, but we'll find out. It's multi-banded.

1:28 PM

AR: We seem to be flying in a gradient here too. You probably can't tell too much out your side, Nick, but off the left wing we're between layers.

NB: Yes. I couldn't tell that from here. That just looks like we're embedded in clouds kind of.

AR: I can make out the altocumulus off the left wing pretty clearly.

1:30 PM

NB: One thing that is liable to be a result of being this far out is that we're not going to have much communication with the radar. I anticipate some problems there, so I suspect we're kind of on our own.

AR: Yes. Roger that. I suppose if we break out completely. I mean if we break out. There is still some precip off and off in this area, but it looks like another clearing potential ahead. It looks like it's clarifying right now as I talk to you. Gee, there's another thin slot here, but it looks like there's more clouds ahead. So it doesn't look like a true backside at least not yet.

NB: Yes. I definitely see what you're talking about now that there's a bit of a horizon at least on both sides of the plane.

AR: It looks about as far from cumuliform as you could get. So I'm sure that whatever that was back there was some kind of preceding band.

1:32 PM

AR: We're flying through another darkening band running seems in the north-south direction. The sun's disc is still visible through both droplet clouds and precipitation.

NB: Well that didn't take long. It looks like we're picking up some light stuff again.

AR: Right. Everything has darkened up again in the north-south looking line, so I think maybe here's another chance for a frontal intercept.

1:33 PM

AR: Definitely a little more ominous looking than the last precip band we went through.

1:34 PM

NB: So Art, on the way back, what kind of temperature do you think we should enforce, right above the freezing level?

AR: That's just what I was thinking before you said that.

NB: I just know that the frontal plane is going to want to know kind of the level and I would guess that the freezing might be 6,000 ft or so. So maybe we would want to go just a bit above that.

AR: That sounds good to me, Nick, 7,000 ft or so.

1:35 PM

LS: Hello Nick.

NB: Hi Larry. Nick here.

LS: We're 14 miles, which comes out to 6 min, from our endpoint. So do you want to climb 3,000 ft and go back the other way?

NB: Yes. We definitely want to get above the freezing level. So it might be as much as 4,000 ft, but somewhere between 3,000 and 4,000 ft.

LS: Okay. Right now I have a block up to 10,000 ft, so we should be good.

AR: Nick, did he understand that it was a climb of that amount or at that level, because sometimes there has been a miscommunication? We might go back at 3,500 ft.

NB: Larry, Nick here.

LS: Nick, did you call me?

NB: Yes. Just to clarify I want to make sure that was a climb of 3,000 or 4,000 ft and not up to 3,500 ft, but just checking.

LS: Right. We'll climb to 3,000 to 4,000 ft and you call the level off then.

NB: Sounds good. Thanks.

AR: I should talk, Nick, Mr. Incomprehensible in the voice transcripts.

1:36 PM

AR: Still continuing the deeper cloud. I haven't really seen any of the gradients. The rain seems to have picked up a little bit. A few droplets of the order of 5 to

10/cm^3, but no real bump of liquid water cloud nor can I see anything. Visibility around the plane is pretty homogeneous and only maybe a kilometer or so. It's really impossible to tell exactly, but not much visibility.

1:38 PM

AR: Temperature is running about +6° to 5.9°C. Our direction is still about 212 to about 20 meters per second. I haven't been able to make out the sun's position for several minutes now after that thin spot just preceding this new line of precip and we're not having any turbulence yet. Starting to pick up FSSP liquid water.

NB: Say Art, I notice that we're getting a lot bigger drops here on the 2-DC.

AR: Yes. It's looking a little more impressive that's for sure. We're starting to pick up some cloud liquid water in here too.

1:39 PM

NB: It would be nice if we broke out the back edge of this right near our turnaround point, then we'd really know how to kind of have the front back edge tagged.

AR: You bet. Gosh, from the satellite imagery it sure looked like there should be a spectacular clearing back here.

NB: Well I think we're just getting out of radar range rather than sort of anything else right now.

1:40 PM

AR: Another thing I'm noticing in here is liquid water being up around 0.3. It's fairly reasonable. But the droplet concentrations now are very maritimy, you know, in the low 30s, upper 20s, compared to that blob we went back there about 10 to 15 min ago, which was clearly offshore air being lifted up to this level, so certainly an interesting situation here.

1:41 PM

NB: Say Don, are you looking at the HVPS?

LS: Nick, here we go for the climb.

1:42 PM

AR: I guess we got to our endpoint without actually breaking out the backside here. That was kind of disappointing. Right in here, Nick, the HVPS is not seeing much. I think it probably has some water problems from that rain. It looks like

it's beginning to come back now. Do you think they care whether we get to the backside of this thing?

NB: I think they care more that we're in radar range.

AR: Yes. Maybe we'll get it the next time out here.

NB: Yes. If it's moving 30 knots changes are. So I should use the kind of reverse flow temperature here that's the most reliable to get the freezing level?

AR: That's affirmative, the t-statr.

1:44 PM

AR: Don is working to get the radar on, which has not been turned on to this point most likely due to an oversight on our part. The FSSP droplet concentrations continue in the upper 20s, low 30s per cm^3. Water content 0.2-0.3 g/m^3.

NB: So Larry, Nick here. Why don't you take it up to 7,000 ft? We still haven't hit the freezing level quite yet and I see we're right around 6,000 ft.

LS: Okay.

1:46 PM

LS: Nick, I'm at 7,000 ft, do you want to keep going?

NB: Let me confer with Art here. It looks like this is a good level, so why don't you go ahead and level out right here. You're heading the right way it looks. So that was a good maneuver there and let's head back right along that track.

LS: Okay.

AR: What I find interesting here, Nick, is the drizzle images at below freezing temperature, which suggests to me these tops aren't very cold above us.

temperature not corrected in-flight; WCS + 1.5°C

NB: Right now it seems like we're about –1°C. So is that where you would want to be?

AR: That looks fine to me certainly. Yes. I notice the Shadin t-stat is also at –1°C, so we have a little confirmation there.

uh oh... Hmmm. ok.

1:47 PM

AR: A thought just occurred to me, Nick. I suppose on the other side of this thing, this whole thing, the temperature will probably jump a couple or 3°C and that will put

us back into above freezing temperatures. What do you think about that possibility?

NB: What I recall is that the temperatures were warmer kind of on the northeast side of the precip and all within this band it was up through the constant 5 or 6 or 7.

AR: I was kind of figuring that it was running around 7 and 8 before it dropped down there.

NB: Yes.

AR: I guess we can see what happens here. What the heck?

NB: Right. Just as you mention it here, I see the temperature now, at least on the red temp, is down to about 0°.

AR: I don't think that works very often. That's a problem. It's not of scientific quality. That's the Shadin t-stat.

1:50 PM

NB: Say Larry, Nick here.

LS: Go ahead Nick.

NB: Chances are we're going to want make the northeast point here about when we get to the latitude of 46.5 or just a little bit north of there. We don't need to go all the way back to the radar and so just anticipate a turnaround point let's say right now 46.55 or something.

LS: Okay. How about a longitude on that?

NB: Good question. That would probably be around 125°C even or so.

LS: Okay.

NB: But that's approximate.

LS: Understand.

NB: As we get a little further into this leg and through most of this precip, I'm going to see if I can raise the coast radar again. I'll let you know when I'm cut offline.

LS: Okay.

1:51 PM

AR: Now we're getting some significant liquid water, you know, 0.6-0.7 g/m^3. I think I saw 0.8 there. Droplet concentrations down around 80, so again very maritimy air being lifted up to this level.

1:54 PM

AR: Liquid water dropping off now. It's reaching values of about 0.7 g/m^3 on the FSSP integrated liquid water. Looking for that slot.

NB: Larry, Nick here.

LS: Go ahead Nick.

NB: Just a slight modification to that turnaround point. Let's make it 46°40'/125°7' and we'd like to come back at 10,000 ft.

LS: So we've got about 5 miles to go before we make our turn.

NB: Yes. I see we're out of it right here, but it won't take us long to get there at this rate. Have you looked into getting clearance for higher altitudes?

LS: Not yet, but I'll get the block here pretty quick.

AR: It looks like we're not going to be back into that more eastward band that we hit coming out here, it that correct, Nick?

NB: Yes. That's correct. Yes, for whatever reason.

1:58 PM

NB: So is there any hope for the HVPS? Can it kind of dry out on its own or do you have to take it off and bake it or do something to it?

AR: I think it will come back.

NB: In case anybody tries to get a hold of me, Art, I'm going to try to talk to John again right now.

AR: I heard that.

1:59 PM

AR: As before there is no temperature change across this band at that last level, which was around 7,000 ft. We're turning and climbing as we exited the slot between this and the band to the east. We'll be climbing up to 10,000 ft as Nick was

saying and climbing up toward the base of the altostratus/altocumulus topped altostratus-shedding virga here. Right now we're entering some intermediate patch of altocumulus at flight level 7,850 ft. Looking back at that cloud system, there was no indication of cumuliform on the front side. It was just kind of stack upon stack on the front side emerging with precipitation.

LS: Nick, I'll let you call the level out here or do you just want to go up 3,000 ft?

AR: Larry, he's talking to the radar right now.

2:00 PM

NB: Larry, Nick here.

LS: Yes. Is it 10,000 ft you wanted on this one?

NB: That's correct.

LS: Okay.

2:01 PM

AR: There was a surprising amount of liquid water in that altocumulus layer there up to about 0.2 g/m^3. Droplet concentrations in the low 10s per cm^3 again. The HVPS continues malfunctioning here as it has for the last few minutes. Also we see no particles on the 2-DC, but I believe that's because we're not flying in precipitation at this time.

2:02 PM

AR: Starting to pick up some images on the 2-D probe. It looks like columns and splinters and we are in Hallet-Mossop riming zone. We do have some liquid water clouds, appreciable water about 0.3 g/m^3. So conditions are probably ripe.

2:03 PM

AR: Looking at the FSSP spectrum I do see that a minute ago anyway it was extending beyond channel 8 into 9, which would indicate drops big enough for the rimming-splintering mechanism, not a lot of splinters here or columns and needles, fairly low in concentration.

2:04 PM

NB: Hey Don, Nick here.

2:05 PM

AR: We made our turn to go back and had our full climb. You can see that we're very near cloud tops here at 10,000 ft and they extend to 14,000 or 15,000 ft maybe at most. Then there's a separate higher layer of altostratus/altocumulus. It looks like mainly ice cloud and that's situated over this particular band, so they give the impression on the satellite image that it is much deeper than it is. Flying in cloud free conditions.

NB: Could you repeat that, Art?

AR: I was just saying that as we made our turnaround cloud to 10,000 ft we were almost near the top of this frontal band. It has an overlying altostratus mostly ice cloud, but it's separated from this. It doesn't appear to be having any crystals fall into it. So I'm guessing on the satellite imagery that altostratus/cirrus topped probably at the cirrus level makes this band look much deeper and vertical extent that it does. But as you can see out the right wing, we're not too far from cloud top.

NB: Right. I notice the winds have come around a bit from the west. Yes. It kind of doesn't look that pre-frontalish now with the winds from 250°. Now that's from magnetic north. So refresh my memory, which way do I correct that?

AR: You're subtracting 21.

NB: Right. That's what I figured. So 230 winds, well that's okay. So it's kind of tricky to think about what we can do that's the most good. For what it's worth, the radar people don't know what's going on out here. They thought that it looked kind of cellular this band and that it might actually be a post-frontal rainband. That doesn't seem to make any sense to me.

AR: I'm guessing they're getting that from the patchy nature of this altostratus cloud overhead that now you can see out the right wing that has some thick and thin spots and sometimes that will show up as different temperature on the IR, which makes it look a little convective. Here we are coming back into the tops of this stuff.

NB: Right. Also what might be going on is that their beam angles are such that out this far they are probably looking up near this level than even the lowest beams rather than down where the real precip is.

AR: Yes. That's an excellent point. Yes. That's right.

NB: I guess right now we're doing decent stuff. We are getting some good images on the CPI and here the 2-D probe just kicked in. There are lots of nice needles and kind of assemblages of columns or whatever. It's pickup sticks out there.

AR: Roger that. Tops obviously aren't very low in temperature here judging by the fact you don't see any of the colder type of crystals. So I think it's an interesting case from that point because it's probably going to be a very noticeable precip band that comes into the coast and yet the tops are not going to be very cold probably warmer than –10°C.

NB: Right. I don't think we do much good flying between these cloud layers. I guess we just have to climb up to 13,000 ft here at the southwest end and see what we see. But if we are between cloud decks, I'd be almost inclined to repeat the stack going back down.

AR: Absolutely. I think the thing you'd want to check out is whether there are crystals falling from the higher layer into the lower layer acting as a trigger for the Hallet-Mossop rimming-splintering thing, and leave that in or leave that out in post-analysis as to why these crystals formed in such high number. I'm sure that looking at the frequency of the images that it's hundreds per liter.

NB: Do you have a good way of estimating right now? Like can you say that there's at least 3,000 ft of cloud, a reasonably thick cloud above us, and so forth?

AR: That was kind of my guess looking back at it when we were making our turn around actually was about 13,000 to 14,000 ft to clear it. The other thing I would use is the temperature. It really can't be below –10° if these crystals are telling us anything at all. So whatever that level is, that's probably where cloud top is going to be or even a little below. I think to answer your question, I'd go to 13,000 ft and take a look back as we get out the backside here. That's right, we never did get to the backside last time.

2:11 PM

NB: Are these small round things on the 2-DC liable to be supercooled cloud droplets or are they fragments of ice?

AR: They should be supercooled droplets. That's fairly common to see it mixed in with high concentrations of columns and needles in one place, and then someplace else ~~cooler~~ lower concentrations of needles and more supercooled drops, cloud drops and drizzle drops.

2:12 PM

AR: Just then it looked like there were some lower-temperature crystals here, so that does become a little more of an important question to see whether anything has fallen from the higher altostratus and is making it into this lower cloud to trigger this explosion of ice down here.

NB: Right. I saw a few of those just a few seconds ago. Now there is just a few more coming in. They are pretty patchy at this point.

AR: Yes. That's right.

2:13 PM

NB: The HVPS seems to be working fine now. I haven't been paying that close attention to it, so I don't know how long its been working.

AR: Roger. It's kind of been in and out. It seems like we've noticed a preference for it to go out during climbs and descents. It just doesn't like changes in temperature, pressure and maybe effects of condensation. Here comes the sun.

NB: Right. This was kind of a little hole that we hit before on the way out, so I wouldn't be surprised if this is steady state that we'll kind of get back in it in just a short while.

2:15 PM

AR: We almost have moderate looking little turrets here…

END OF TAPE 1, SIDE 1

NB: So Art, we're going back at 13,000 ft. It's clear we're not going to be in precip all of the time, even much of the time, but I guess you still think that's worth doing?

AR: Yes. I think we need to nail down the upper portion of this thing. That would be my thought. I mean, good grief, it's kind of presumptuous of me to suggest something for this type of project. I speak from an ice initiation viewpoint.

2:18 PM

AR: Certainly some fascinating microphysics on this leg, supercooled drops, ice, needles. It looks like temperatures from lower temperature regions and crystals from lower temperature regions.

NB: Say Larry, Nick here.

LS: Go ahead Nick.

NB: At that same turnaround point that we used before, it works again and tentatively we'll come back along this same line at to an endpoint of 46°30'/125°7' at 13,000 ft if you have the clearance for it.

LS: Okay. Give me those coordinates again.

NB: It's 46°30'/125°7' at the northeast end.

LS: Okay.

AR: Got a huge cloud bow behind the plane indicating large cloud droplets here near cloud top of these clouds anyway. It's kind of a saddle region back there.

2:20 PM

AR: Nick, one thing we could do too is sort of meander just a bit to make sure we hit as much cloud material as we can here near cloud top from that pass back.

NB: Right. Is that something you've had the pilots do before where they just kind of run right along the top of the cloud layer?

AR: Right. If you run into a gap and there's something 10° right, we take a little swerve and then continue to do that. So we fill up the path with clouds as much as possible and characterize the top with the biggest statistical sample as we can.

NB: Yes. That makes some sense to me. I don't know if we also want to get some statistics though actually on kind of how much the cloud tops stick above what levels, so to speak. You'd almost think like the whole region is maybe up as high as you'd go.

2:22 PM

AR: Yes. I just don't know if the tops are going to be capped by anything. Maybe we'd find an enhancement where they're far above the aircraft for 10% of the leg and maybe 70% of the leg we're getting cloud tops along that altitude.

NB: Yes. I know what you mean. We're getting to some kind of lower temperature crystals. I'm just worried about kind of the statistics of it. At least I know that we're getting meaningful statistics along these kind of straight tracks.

AR: Right. I think it doesn't really make any difference to me at all.

2:23 PM

AR: I can't see forward too well. I'm covered with clear icing here in the bubble. But looking back, you can see it appears to be soft cumuliform glaciated turrets at maybe 2,000 to 3,000 ft higher than our present flight level.

NB: So chances are we'll be just kind of nipping their top as we come back through.

AR: You're right. I didn't see everything. There maybe some a little taller than that because I say it doesn't like there's a real strong capping layer not that you'd even expect one, but sometimes you see the clouds kind of topping out at one layer.

2:24 PM

AR: I guess the question is, as we climb up here, how much cloud do you want to be in if the saddle regions come comprised with the majority of the leg? Do we still want to stay and get those taller ones that might be the precip producers?

NB: Yes. That's a good question. I'm going to try to raise John right now and see if he's got any thoughts on it. So I'll be kind of out of touch here for a little bit.

2:25 PM

AR: As we spiral up through almost it looks like 12,200 ft, it looks like we're above 90% of the clouds right now looking in all directions. A band of higher tops it looks like about this level or slightly higher off the right wing oriented in a north-south direction. That's probably the main "front". Looking back I see a fair amount of clearing and another band of altostratus. It looks like it's oriented more southwest/northeast rather than north/south.

NB: Hey everybody, Nick here. I just talked to the radar. This maybe our last leg. They're going to consider whether they want us to kind of do the stack going back down again on at least a couple legs of it. But right now I'm going to be hearing from them in about a minute.

AR: Roger Nick. It looks like we're flying just about in cloud top. If you look out the right wing, I'm sure you probably noticed that and that seems to be at about 3,000 ft. This seems to be an enhanced area maybe the band looking back there's nothing and kind of oriented in a north/south line. Lots of ice back behind and the cloud tops are lower and there are some big clearings/openings in the stratocumulus back behind us. So I'm guessing there must be some sort of modest wind shift in this region that we're coming upon right now.

2:29 PM

AR: Entering a cloud top shortly.

2:30 PM

AR: It's certainly deepening up in here. The sun's disc is gone.

NB: Yes and there is some pretty big crystals there showing up. I thought it was kind of interesting too. We hit some very light chop there like we were getting some little kind of convective bubble or something, forced convection perhaps.

AR: Right.

NB: But it looks like our kind of game is over right now. Well check that. We're going into another little clump perhaps.

AR: Yes. Little wisp. It's not completely glaciated. I don't see any liquid water, but sometimes the droplet concentrations are so low you get fooled.

2:36 PM

NB: Larry, Nick here.

LS: Go ahead Nick.

NB: If we could kind of continue on this line until 46°37'/124°49'. It's just a little further than we went before. Chances are we're going to be going home after that, but I'm going to call John right now.

LS: Okay. 46°37'/124°49'.

NB: Affirmative.

2:37 PM

AR: A nice mixed phase top.

2:38 PM

AR: Coming into a north-south band of enhanced convection here. We've had several such bands since the turnaround point. It doesn't really look like post-frontal convection, but it's certainly an animal that seems to be related to it in that there are soft cumuliform-like turrets. The droplet concentrations are so low it's hard to tell whether they're ice or liquid water or mixed phase for that matter.

2:39 PM

NB: So Larry and company, Nick here. This is it for us. So when we finish this leg to the 46°37'/124°49', we're basically going to be near the edge of the precip and the good stuff. There's nothing really between here and Paine Field according to the radar, so you can go and do whatever.

LS: We've got another 12 miles and then we're going to head for Paine Field.

2:40 PM

would be ≈ -14°C using cor. T static of -8.5 at this level

AR: We're continuing to fly right near cloud top. That last cloud top probably 2,000 ft above aircraft. That would have been about a minute ago. Above this we have an altostratus/altocumulus-type layer. We have some ice in some places, a little bit of ice, but it seems to be mostly liquid water looking at the sun's disc right now.

NB: Say Art, Nick here. I don't know if we can trust them, they seem to be basically behaving themselves, but the winds are roughly double what the prog had.

AR: Yes. I didn't look at the prog as far as winds go, but that's pretty strong. At this level it was expecting the winds to be half this?

NB: Yes. Something like 30 to 35 knots and I've been seeing 33 meters per second pretty systematically. Now it's done one tick.

AR: I see. That's kind of interesting. I mean the winds look pretty darn reliable here in the last few flights.

NB: Yes. They seem to be pretty close maybe a bit stronger than the prog in the lower level. But just in this last level, they have really kind of shoot up.

AR: Huh. I'll be darned.

NB: Actually the direction has come around a little bit from the kind of south-southwesterly to more kind of southerly. So that's kind of what the cold invection profile that's kind of weird.

AR: Yes. I still wonder what that first band was that we went through. It had that high liquid water. We were going out at 2,700 ft and suddenly liquid water went up. What really got me were those droplet concentrations of 250 and even one that was 300. Then, of course, there were the bands back behind that, but I really wonder. I thought I saw a temperature drop behind that, but you might be right about it being something to do with evaporational cooling mixed in there too. But anyway, I really wonder what that was because back out where we were was all maritime, you know, indicating long-fetch maritime flow in that whole region behind that initial thing.

2:43 PM

AR: And also I want to make the point that looking back there was no indication that the crystals were falling out from the higher altostratus/altocumulus deck that has bands oriented in the northeast/southwest direction. So it does appear that the precip was all generated by these clouds that are topping out around say 12,000-15,000 ft.

2:44 PM

AR: There's some kind of discontinuity in the cloud top texture. From what we have off the right wing and what's behind the right wing, definitely more cumuliform back there. It's not strong cumuliform. It's sort in the mounding category and now the tops in the panorama ahead of us are more stratocumulus-like.

2:46 PM

AR: Cloud top close to flight level here sloping upward to the east.

2:50 PM

AR: Sun's disc clearly visible through cloud tops and I suspect that at –11.5°C or so that there is ice underneath us. I can't see it because there are no breaks.

2:51 PM

AR: We descended out the bottom of the altocumulus layer at about 12,000 ft, temperature about –10°C, so it went from –11.5° to –10°C. I do not see any precip behind us. If there is any, it's extremely slight. Nor did I see any images on the 2-D cloud probe, very interesting. This would be in agreement with Hallet-Mossop because it looked like the spectra appears pretty broad and there was liquid water at least over a tenth near cloud top. I believe the spectra did go over the 25-micron size. We're now flying inland, I also notice, and there is a good view to the ground. As a result, there's a stratus/stratocumulus deck right on the ground just above ground level. Dead ahead is more precipitation.

2:55 PM

AR: We're starting to pick up precip from this higher altostratus deck that we've flown under since exiting the altocumulus deck back there. So the precip was not coming from the altocumulus deck.

3:01 PM

NB: So Art, Nick here.

3:05 PM

NB: Art, are you alive?

DS: Do you want to start the CPI back up again? I think we've gotten close to running out of disc space. There was a memory error message, which would stop it.

NB: Yes. I don't think we're doing anything that's that meaningful right now.

DS: Okay.

NB: Unless there was any kind of troubleshooting maybe you'd want to do it.

DS: No. I suspect the last file was getting ready to write. It probably just exceeded the size of the disc.

NB: So Art, Nick here. Do you want me to go first then?

AR: Yes. It doesn't matter. Sure go ahead. I'll follow you.

NB: Yes. That's right.

AR: I'll be focusing more on the microphysics stuff as much as I can.

NB: Right.

Summary of UW Flight 1851

NB: So this is Nick Bond, flight scientist, for the flight 1851 on 18 January. The weather was what we thought was a pre-cold frontal precipitation band. It turned out it had tops of something like 10,000-13,000 ft. In terms of the weather, it looked like it was about 5°-6°C at 3,000 ft with winds from 210 at 18 to 20 meters per second. Those were a bit stronger than prog. The winds at the top of our stack, which was at 13,000 ft, were from 170 to 180 at 30-33 meters per second. That was almost twice as strong as prog and not as much of a westerly component. That implies that wind profiling implies cold advection and I don't think the models really had this to any degree and that perhaps was why we didn't get quite as much synoptic life as anticipated and, therefore, maybe not as deep a precip band as we originally anticipated. Basically the instruments, the CPI worked very well. The 2-DC worked very well. There was a hiccup or two, but that's about it. The HVPS had a few problems at times, but was basically functioning itself. So it was a fairly complete data set on a run of the mill rainband with some corrugations to it, but certainly nothing that distinctive. Now I'll turn it over to Art.

AR: Roger. I thought the "slots" ~~corrugations~~ xwind really fit this well because I was beginning to call this the ~~slop~~ flight because there are so many undulations, thickenings and thinnings of the clouds both aloft and in the number of bands that we did run into out there. For me, this was clearly the best of all the IMPROVE flights because we got to cloud top and we actually could see what was going on out there. But down low, I felt there was an extremely interesting feature. A bit of a puzzle right now because after trucking through the precip on the way out there, we dropped down into the boundary layer. As we hit the first area of liquid water, which was sustained for probably 5 to 10 kilometers, at least a good minute or so, the droplet concentrations offshore were phenomenal for the marine environment, 250/cm^3

pretty regularly and a couple up to 300/cm^3, which you just do not see. That's a dead give away that the flows that were due to offshore air. The fact that we were seeing liquid water contents of 0.5 g/m^3 and even a little greater at 2,700 ft indicated the cloud base must have been right on the deck in order to produce that much liquid water at 2,700 ft. So clearly it was being sucked up there for some reason and I thought I saw also at that level a temperature drop of about 2° to 3°C over about a 1 to 3 min period. There was some question about whether that was a true frontal major. But clearly between that zone and further offshore, there was certainly an air mass contrast in terms of aerosol content because further out, when we got into the subsequent series of bands (and there were at least two or three), But out there the droplet concentrations were more typical of long-fetch maritime air being in the 10s per cc and sometimes even in the low 10s in some of the altocumulus out there and also equally high liquid water. In fact, even higher liquid water, at up around a gram per m^3 or so, between 0.5 and a gram, in some of the more active lift regions of the band. So that air was being lifted and any CCN was certainly activated by a pretty good updraft. So again it's a good sign that the difference was real and not due to different updraft velocities out there. That to me raises a question of where the front really was. Then going on these legs up to 10,000-13,000 ft, there was a tremendous variation in the differences in the precip mechanisms going on in those clouds. At times we saw at the freezing level, supercool drizzle indicating an all-liquid process. At other times it was at lower temperatures. We saw in the Hallet-Mossop temperature zone, jillians of ice needles and columns possibly being produced in situ there by either well probably not crystals falling from higher levels in some areas, but certainly in other areas where the tops were actually a little colder. I don't think any crystals fell from the higher layer, but certainly when we did our last pass at 13,000 ft there were tops and some of the highest tops probably reached 15,000 ft actually I would say and probably were certainly no. I doubt they were any colder than –15°C. So from the standpoint of precip and model ice, it's a very interesting case because of all the ice multiplication going on and the fact that the tops in these bands were, as you were pointing out, 10,000 to 13,000 to 15,000 ft maybe. But those temperatures were only maybe –5° to –15°C for the overall tops considering the saddle areas and enhanced cloud tops. Just to emphasize that at no time out in those areas did I see any virga reaching the ground from the overlying altocumulus/altostratus and banded clouds above the clouds that we sampled. Over and out.

3:14 PM END OF TAPE