

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

Date 13 Jan 01	Flight Number 1850	Experimental Observations  		
Project name IMPROVE PHASE 1 (IOP #4)				
Engines on time 1503 UTC	Engines off time 2050 UTC			
Departure airport Paine	Arrival airport Paine			
Flight Scientist signature Peter V. Hobbs				
Pilot signature		A = 46° 54' / 124° 06' B = 46° 26' / 124° 50' C = 47° 12' / 124° 12'  Well-defined but weak (cold or warm-frontal) rainband, associated with occlusion, situated between C and B and oriented approx. east-west. Flew from A to B at 4000 ft. Then vertical stack between B and C at 3, 5, 7, 6.5, 9, 11, 13, 15, 20, 23, <del>25</del> and 1.4 kft. Not much LW in band but good ice particle imagery. Not much precip. <del>at</del> below cloud base toward end of flight (rainband dying?). PNNL operating at C.  Good measurements in cloud and precip over Olympics (on return to Paine) and in descent to Paine field.		
Surface met. & visual obs. at takeoff Scattered cloud, no precip. Moon visible				Ac
				As
				Ns
				Sc
		St		
		Cu		
Cb				
Research crew Hobbs Ransno Spurgeon Gray Wilson } Gerry Larry		Equipment failure Ser Squawk List (CPI, 20x worked for first time on IMPROVE.)		

Flight 1850  
January 13, 2001  
Voice Transcription  
IMPROVE

2nd Draft

675

PH: Flight 1850, 13 January, Saturday. On board are Hobbs, Rangno, Spurgeon, Gray, and Wilson, pilots Larry Sutherland and Jerry Rhode. We're heading out to off the Washington coast where we'll be flying a similar route to what we've flown for the last couple of flights, namely, southwest of Westport. There's a stationary rainband about 40 miles southwest of Westport and initial instructions are that we'll be doing a stationary fixed profile through that rainband.

7:16 AM

DS: Standby. Don't start anything, Peter. You can log on, but the data system is not up yet.

PH: There was broken cloud at Paine Field on takeoff. The moon could be seen. No precip at Paine Field on takeoff at 1514 UTC.

7:17 AM

PH: Can we open up the data system now?

7:18 AM

DS: Just a second. I'm starting all the servers right now. Go ahead.

AR: Just getting back to the bubble here. We just past through some stratocumulus clouds at. Oh, my computer is not setup.

7:24 AM

PH: We're getting CPI images on this flight the first time for IMPROVE. The CPI has just come back from SPEC and it seems to be working.

7:25 AM

PH: In clear air all the liquid water meters are zero except for the DMT, which is showing its usual noise, with occasional larger peaks on the DMT in clear air going up to 0.17 g/m<sup>3</sup> or so.

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\* AR = Art Rangno, DS = Don Spurgeon, GG = Grant Gray, JR = Jerry Rhode (pilot), LS = Larry Sutherland (pilot), PH = Peter Hobbs, TW = Tom Wilson

7:27 AM

PH: Hello Larry.

LS: Okay Peter. Go ahead.

PH: Just making sure we got contact.

LS: We have and I think it's going to be IFR in the area out there, so probably 2,000 ft is as low as the center is going to let us go today on an IFR clearance.

PH: Okay. Fine.

LS: But that's going to be above freezing.

PH: Yes. So whatever the lowest height we can get, let's do it. Until I give you any update, we'll stick to the points that are on that chart you showed me.

AR: Setting up the computer with CPI and now we're underflying a ledge of stratocumulus cloud. It looks like there's a little precip coming out of it. I see it on the CPI. Looking back toward the east I don't see much evidence of precip behind us, so it's very light precipitation. Forward, however, the precipitation increases. This is a part of the northwest/southeast band that we're flying in. It's interesting that it isn't altostratus but stratocumulus and lower stratocumulus below us.

DS: Art, the 2-DC looks to be working pretty good right now.

AR: It certainly does.

7:28 AM

GG: HVPS seems to be looking pretty good.

7:29 AM

GG: The CPI seems to be clipping some of the images.

DS: It does that. It has some kind of an algorithm that tries to box the image. Sometimes it doesn't quite make the right decision on where the edges on that thing go particularly on a real odd shape.

GG: Yes. It looks as if it's making a lot of mistakes. I don't remember from KWAJEX that it made that many mistakes.

DS: Those must be fairly large particles that are in the trigger area, but are off to one side or the other.

GG: Well it looks as if some of the particles would just go in the box. I'm just wondering if there's some threshold that we might be able to modify a little bit. Not right now. We'll just let it go for this run.

DS: Yes. I'd have to think about that.

GG: It's just that there's just more clipping then I would think would be tolerable. I guess the radar is about ready to come up.

7:31 AM

LS: Art, are you up?

7:32 AM

DS: Would you like to take to him? I can have him put on a headset.

LS: It's not important. I was just going to ask him how his duct is back there. Are you guys warm enough back there?

DS: Actually the duct is really comfortable right now touching it. It's a little cool yet, but it will probably come up.

LS: Okay. Do we have coffee on board?

DS: Sure. Would you guys like a cup?

LS: Two of them.

DS: Okay. I'll get them in just a second.

7:33 AM

PH: The PVM has got a lot of noise on it now.

AR: The moon is clearly visible through overcast, which is not the case earlier I'm pretty sure.

DS: Yes. The PVM on the display is showing a lot of variations, so there's maybe snowflakes or something.

7:33 AM

PH: The FSSP-100 seems to be working okay.

7:34 AM

PH: Haven't seen any action from the J-W. I'm wondering if it's switched on or working.

AR: I don't think we've really gone through any cloud there except right after takeoff.

PH: I just see nothing on the J-W, which always makes me suspicious, but we'll see when we go through some decent cloud.

AR: There's no liquid water I don't think in any of the probes so far except for that one cloud on the climb out.

PH: Well we've had some FSSP activity in flight.

AR: Right. It's only 1 or 2/cc, so it's seeing the ice out there not any droplets.

PH: Okay. On the largest bin on the FSSP here, No. 15 channel, what size is that?

AR: It's about 44 to 47 microns in diameter.

PH: Is it roughly a linear scale on the bins?

AR: Right. They are about every few microns beginning about 2 to 5 micron particles fall in the first channel.

PH: Okay. The CPI looks great.

AR: Yes. Isn't that marvelous? Now we just have to hope that it keeps going and we don't have kick it the whole flight.

PH: Right. As long as it's working, I wouldn't even touch it.

AR: Yes. I don't want to get near it. My sweater had a lot of static electricity and I was thinking that maybe I could cream something.

PH: For the first time I see some activity on the J-W. I don't know if Don just did something to it. He's fiddling with something there.

AR: It looks like we're coming into some thicker cloud for a while back there for a few minutes. After the precip began the moon came out. It was gone before that and now it's gone again. So we're coming into some thicker clouds over us.

PH: I'm going to try to contact the radar.

TW: Hey Don?

AR: It looks like we might have lost the 2-DC.

7:37 AM

LS: Hello Peter.

GG: I think he's talking to the radar right now, Larry.

LS: Okay. 3,000 ft is as low as we're going to get on an IFR clearance out here today, but that's going to be above the freezing level you might tell him.

GG: Roger that.

7:38 AM

AR: Still uniform precipitation situation here. No sign of upper or lower cloud decks. The moon has disappeared and now I see that's most likely because we were descending and hence the cloud above us was increasing for that reason. No turbulence this flight so far and, with the weak synoptic system, none expected. There are weak offshore winds and weak winds aloft something like 10 to 20 knots at 500 mbars out of the south.

7:39 AM

PH: Larry?

LS: Go ahead Peter.

PH: Are we still set for 2,000 ft for the lowest leg?

LS: They say 3,000 ft is the lowest they're going to let us go unless we are VFR. But if we break out, we'll just go on down as low as we want to.

PH: Okay. On the track out, we'll do 3,000 ft between the points that you've got on your chart there. But then subsequently when we're at higher levels, they want us to go over that NW Battelle site. I can give you the lat/long of that.

LS: Okay. Is that the one up?

PH: It's just north of about 20 to 30 miles north of Westport.

LS: It's 47°12' and 124°12'.

PH: Correct. What's the lowest elevation we can go over that? We don't need to go inland. We just need to touch it as we come up to the coast.

LS: Probably it's going to be a hard one to predict for me, Peter. That's going to have us in Whiskey 237 too.

PH: Yes I know. That's why I'm asking what's the lowest we can be there.

LS: As long as we stay in Whiskey 237 and don't go right up to the site, stop about 3 miles short of it, we can go right down as low as we want.

PH: So 3 miles short. All right. Good.

LS: I'm assuming that Whiskey 237 is clear out here.

PH: I don't know about that. Let me check on it.

LS: Okay. That was something that Mark was going to check for us every morning.

PH: I'll check.

7:42 AM

AR: Flight conditions continuing to be diffuse. No cloud detail visible. We're just flying in precipitation at about t-stair or -4°. Everything seems to be working pretty well.

LS: Peter.

PH: Yes Larry. According to Mark, Whiskey 237 as far as he knows is not reserved today.

LS: Yes. I got the same thing from the Center. We've got IRF traffic below us. So we're not going to be able to get lower than 4,000 ft until he's clear and we're over the first point. So we're just going to orbit here until he gives us 3,000 ft and then we'll proceed outbound.

PH: Why don't we proceed outbound at this altitude and then come back at a lower altitude when it's clear?

LS: Okay.

7:44 AM

AR: Conditions remain unchanged at 154336 UTC. Finally we hit a little droplet cloud here, a few per cc in a droplet-looking spectra. All probes working well, 2-DC, HVPS.

PH: We've just past our Point A. That's the beginning of our northeast point at 46°54'/124°06'.

LS: Seattle Husky 1. We'll start our leg now at 4,000 ft and pickup to 3,000 ft when it's clear below us.

PH: Were you on right line there, Larry?

LS: No.

PH: We're restricted to 4,000 ft at the moment as we head out toward Point B to the southwest. It's our southwest Point B, which is 46°26'/124°50'.

AR: Since we're down low, could we point the radar up?

7:46 AM

PH: Larry?

LS: Go ahead Peter.

PH: So when we reach our southwest point, we'll want to come back as low as we can and go as far to the northeast as we can toward that Battelle site.

LS: Okay. So from the southwest point you were blocked after that.

PH: From the southwest point, we go back toward the northeast back to our Point A at as low an altitude as you can get and we want to continue going toward the northeast toward the Battelle northwest site as far as we can toward that site.

LS: You want to go back to the Point A first and then go to the Battelle site?

PH: Correct. Yes.

LS: Okay.

7:48 AM

AR: Our radar is suggesting in the upward pointed mode, that the tops above us are only about 3 kilometers or there about.

PH: Are you playing with the J-W, Don? Great spikes on the J-W maybe Don's playing with it.

DS: There's a bad place in this pod that seems to get occasionally (gathled). I've got to move it just a little bit one way of the other to get it working again.

AR: 154730. Conditions are unchanged, amorphous cloud system, no evidence of layering or any detail as we fly in this precipitation, which sometimes has columnar crystals, but is mainly quasi-spherical suggesting that cloud tops are well below  $-10^{\circ}$ .

7:49 AM

AR: The moon continues to be not visible.

7:50 AM

AR: Taking a peak downward, I can see the sea surface or at least a darkening due to the sea surface with some stratus fractus clouds scudding by. It looks like there's a buoy light off the left wing in the water, so I can see out that far. That would be out about a mile at about 10 o'clock. The sky is brightening possibly because of thinning clouds or because the sun is getting higher in the sky. Just now it's brightened quite a bit over the last few seconds.

7:51 AM

PH: Are we at research speed, Larry?

LS: Affirmative.

7:52 AM

AR: Passing off behind the right wing is another buoy or possibly a ship out about a mile.

TW: Don?

DS: Go.

TW: Go to "chat."

DS: Okay.

AR: Stratus fractus seems to be increasing below the aircraft now from scattered to what looks like broken coverage now.

7:53 AM

AR: The CPI continues to work pretty well it would appear from back here. It's 155238.

7:54 AM

AR: Wind direction and wind speed 165 at about 7 meters per second looks excellent.

PH: Larry?

LS: Go ahead.

PH: When we go back on our in trip back to the northeast, let's go directly from our southwest point directly toward the PNNL location instead of back to our original northeast point.

LS: Okay. That would be better for us.

7:55 AM

AR: Looking vertically I still can see no sign of cloud detail. Down below we seem to have overcast stratus/stratocumulus.

PH: Static temperature here at 3,700 ft is  $-0.3^{\circ}$  on my readout.

AR: I think that's  $-2.7^{\circ}$  t-stair.

7:56 AM

PH: Getting very nice images on the CPI, irregulars and occasional columns. I saw a notched column there, quite nice, a little notch at the end. It looked like single crystals. I don't see any aggregation. Another notched column.

7:57 AM

PH: No liquid water here.

AR: Yes. It appears the only liquid water clouds are down below the aircraft, shallow stratus fractus, shallow stratocumulus.

PH: Yes. We hope to go lower on the return trip. This is as low as they could get coming out on this outward trip.

AR: Although I can't detect it, on the other hand, the radar is indicating the clouds above us may only go about 3 kilometers or 10,000 ft, so we may have some

shallow cloud top. No where up there is a liquid water top at the kind of temperature you'd find.

PH: The radar tops are at 17,000 ft.

AR: On the Westport?

PH: Yes. But we may get more of that rainband on the leg back in, which will be more to the north than this outward leg.

AR: Actually that's pretty close because using our TANS-alt we would be indicating a top of around 15,000 ft. I'm sure Grant might find a little more sensitivity and get it even up a little bit higher. So that's fairly close agreement.

PH: That's agreement between what?

AR: The upward pointed radar top that we're getting and the Westport radar.

PH: Okay. Because I thought you said earlier that your tops were 13,000 ft.

AR: Well they're about 15,000 ft if you take into account our flight level, which is almost 4,000 ft. I guess that would be about 14,000 ft. I misspoke. I miscalculated. It should be about 14,000 ft because as I say Grant might find a little bit more right at this second. When was that report from Westport?

PH: That was about 5 min ago.

AR: I'll check it again here.

8:00 AM

PH: Is the controller upward and downward radar in easy reach for you, Art, so that you can switch it at will.

AR: No. I have to ask Grant to do it because it's up where Tom is sitting. I could run up there I guess and do it.

PH: It's something you should know how to do because sometimes it would more convenient for you to rush back and switch it where you want it.

AR: That's right. I'm just letting them do, so I don't do anything strange. But I think it's just a toggle switch.

8:01 AM

PH: Just looking at the liquid water what we've had of it, it looks to me as if the PVM and the FSSP are in reasonable agreement. I don't think the DMT is doing much of a job with these low liquid waters that we occasionally encounter. The other two, the J-W and the DMT, are not as good today. The J-W is not too bad. It's probably as good as you can get it, Don. It's the DMT that has these spikes on today.

AR: Grant was tweaking the radar a little bit and checking out some different range gauge samples. It looks like the top was running about 4,500 meters above us. So that's really close to what the Westport radar is showing because that would make it around 17,000.

PH: Good. Art, you'd better come and look at the CPI. It's sort of flashing away a bit here, faster than it should I think.

AR: You know, we're into some liquid water clouds. That's probably the reason, but I'll go look.

DS: It looks pretty good, Art.

PH: Yes. I think that's it. I think we've just come into some liquid water, so mainly drops we're seeing. It's probably okay.

LS: Peter, we're at Point B. We're going back now to the point up there north the radar site.

PH: Okay. Let's call it the Battelle site. What altitude will the return trip be?

LS: No lower than 4,000 ft it looks like.

PH: We can't get down lower?

LS: Let me call the Center and see if that guy is clear yet.

PH: Yes. If we could get down lower, it would be great.

AR: The CPI looks good. It's triggering on all the droplets, which are tens of thousands per liter and back there the ice was probably a few per liter.

8:04 AM

AR: Tom, do you copy?

TW: Yes.

AR: One of the things I am noticing with the 2-D probe is there is a lot of duplicate images for some reason and sometimes even triplicate and it looks like the same frame.

TW: I don't understand. You say like two strips are exactly alike?

AR: Probably duplicates of the same particle or even triplicates of the same particle. You'll see it if you watch it. You'll see something that is clearly some kind of artifact. I don't know why.

TW: If you can, spot the strip number.

8:06 AM

AR: Okay. Constant level. We have gone through a fairly large wind shift from 160° to 170° true to about 190° to 195° now. Now a minute ago it was over 200°, but anyway there has been a wind shift in here. So we must be going through the surface near the surface front or wind-shift line.

PH: We also just did a 180° turn. Maybe the winds were not reliable in that turn possibly.

AR: Yes. You might be right. I wasn't paying attention to that.

LS: Peter, we've got a clearance now to 3,000 ft. So I'll call you when we're on our northbound course.

PH: Okay. Thanks Larry.

TW: Art, are the drop sizes looking good, I mean the shapes and stuff?

AR: Looking excellent.

DS: My thought on it, particularly if those are the smaller particles that you're seeing, is that may not be an artifact per se. The thing may be running fast enough to take a couple images of it.

AR: No. They were the larger ones actually is where I was noticing it. I was noticing it quite a while. If you look now, you'll see some of that happening as we get back into some precip.

8:07 AM

AR: We've got some significant liquid water here, 0.6 g/m<sup>3</sup>. We're in the boundary layer, stratocumulus.

PH: We've come down to 3,000 ft. We've made our turn at our southwest point and we're heading back toward the northeast, but a more northerly track now that will take us directly to the northerly Binet site, which is also where Battelle has its microwave radiometer. So our temperature here is +0.5°C.

AR: Well it's actually misreading, Peter, it's about -1.8°C. I think you're looking at the Rosemount temperature, which is incorrect.

DS: You're being paged by the pilots, Peter.

PH: It says static temperature is what I'm looking at. Standby. Yes Larry.

LS: We're down at 3,000 ft now, but we're going to have to delay out here just a second before, about 5 min before, going northbound. We're going to go back to our Point B and start from there to your next point and by that time this guy should be clear.

PH: Okay Larry.

AR: There's a fair amount of supercooled drizzle here.

PH: So Art, this reading that says static temperature is now saying 1.4°, where is that from?

AR: It's probably from the Rosemount. Apparently it's not labeled fully. You probably should be looking at t-statr. You have to have your text file updated because both the Shadin and the t-statr are below freezing.

PH: What's the most reliable static temperature?

DS: t-statr.

PH: Okay. t-statr. I'd better have that then.

TW: Art, my guess is that it's probably a display thing that it's cycling through and it's redrawing the next strip one up and it looks the same maybe.

AR: Yes.

TW: Maybe post-flight we can double check and make sure there is no duplicate strips.

PH: Drops on the CPI, so we're certainly warmer than 0°C. I've got t-statr up here now, which was reading -1°C, but the CPI is showing drops.

AR: Right. As I was saying we're going through a lot of supercooled drizzle in cloud drops.

PH: Okay.

AR: Up at  $-1^{\circ}$  to  $-2^{\circ}\text{C}$  it shouldn't pose an icing problem.

DS: Tom to "chat."

PH: There's no icing on my hemispherical window.

AR: Right. At  $-1^{\circ}$  to  $-2^{\circ}\text{C}$  the ram affect of temperature won't allow icing to develop.

8:11 AM

PH: Our pattern was disrupted here because of air traffic problems. We've turned back toward the southwest and back to our original southwest point and we'll do another  $180^{\circ}$  turn here soon and hope to then get our clearance at 3,000 ft to head toward the northerly Binet site. We've got one aircraft that's below us out there that's causing us problems.

8:12 AM

PH: Occasional big spikes on the J-W, but it's quiet at the moment. One big spike there.

8:13 AM

AR: Conditions continue unchanged as we do some maneuvers here to avoid air traffic. Amorphous precipitating looking sky above us. Just as I say that it breaks open and I see a thin spot with the sun lighting up.

PH: We've almost completed our turn and should be heading back toward the northeast shortly.

AR: Lighting up a higher precipitating layer. Down below we continue to have broken cumulus fractus, stratus fractus, stratocumulus. Its kind of a melange of those kinds of clouds and an intermediate layer. It looks like it might be droplets now. So something is going on here that I didn't see before. It could be a higher altocumulus layer that the sun is underlighting.

8:14 AM

AR: The ocean surface is visible in this area and I'll take a closer look here. Standby  
1.

8:15 AM

AR: Isolated white caps suggesting winds below 15 knots. It looks like a near surface stratus fractus layer and then we seem to be flying in something that is a separate layer above that, although at times I'm sure they would merge. The winds are kind of back into the southeast. Apparently what I was looking at was winds in a turn that made me think there had been a wind shift.

8:16 AM

AR: Still flying in supercooled drizzle. It seems doubtful that is coming from the higher altocumulus. Now we just hit some more of the merged clouds with liquid water content rising up to maybe around 0.5 I think it was.

PH: Went through some good liquid water here. It's the highest liquid water we've had, with all three probes are tracking each other pretty well in these higher values. When I say high it's like 0.2, 0.3, those sort of values maybe going up to 0.5 in peak values, even 0.6 g/m<sup>3</sup> peaks.

LS: Peter?

PH: Yes.

LS: It might be that we have to take a 360° out here to delay a little while to let this guy get a way from us. He's got an IFR clearance at 3 and he's over the Hoquiam VOR. So is that going to be a problem for you?

PH: No. Whatever you have to do, Larry.

LS: We'll stay at 3,000 ft, but we've got to stay at least 20 miles.

PH: 3,000 ft is good and, of course, as soon as possible we want to head out toward that Battelle site.

LS: We're on our way now.

PH: Oh, I thought you said you had to do another 360°.

LS: No. We did the 360° and we're 32 miles south of that site now.

PH: Good. That's what I thought. Who is this guy that's down below us?

LS: Some guy doing approaches at Hoquiam, but we just found out that he's clear now so we can proceed on in.

PH: Thank you.

8:18 AM

LS: Peter, what's your plan after we reach this next point?

PH: Standby Larry. I'll get it from the Westport radar.

LS: Okay. We're 15 min from that point right now.

AR: We're seeing another area of under-lit altocumulus clouds through the very thin clouds that must be precipitating a little bit here. Correction, maybe they aren't because I don't see any supercooled drizzle any more. This is columns and possibly some quasi-spherical particles suggesting low-temperature origin below  $-10^{\circ}\text{C}$ , but right now mainly columns and needles. Looking also in this kind of weak area we've now come into definitely an in-between major precip area. I see cloud tops are about the level of the aircraft off the right wing through a stratocumulus deck there, very flat, smooth tops. Now we're heading back into more precip and the tops that I just saw are disappearing. Still make out the under-lit altocumulus cloud.

PH: Larry?

LS: Go ahead.

PH: After we reach the Battelle site, we'll head back toward the southwest at 5,000 ft back to the same southwesterly point as before.

LS: Roger.

AR: Those clouds that lower deck must have been the clouds responsible for the higher liquid water content. They also seemed to be lofted above a surface layer of stratocumulus based probably at 1,500 to 1,000 ft, which seemed to connect to them at various places around the plane.

PH: Getting some crystals on the CPI now. The temperature is  $-1^{\circ}\text{C}$ .

AR: Right. We left some supercooled drizzle back there with hardly any, very few crystals in it to now we're getting stuff that I think is coming from this higher altocumulus layer, which at times I've actually seen under-lit by the sun back there.

PH: Yes. This is a very good situation to look at.

8:21 AM

AR: So in sum, there must be about 4 layers. There's the lowest stratus fractus/stratocumulus. A layer that sits on top of that that looked very stratiform. A layer somewhere between the highest altocumulus layer shedding crystals down

to this level and the altocumulus layer itself, which is probably spawning most of the precip at this level at this time since we have lost our supercooled drizzle for the most part.

8:22 AM

AR: And the lowest layer would be described as overcast with breaks in coverage here for the last few minutes. I see a hole going by the right wing now. No white caps visible. Probably too far away.

8:23 AM

AR: Getting aggregates now.

8:24 AM

PH: No liquid water here just crystals.

AR: Visibility is quite good in here as we go through another hole.

PH: Mainly irregular crystals.

AR: But visibility decreases ahead. Cloud coverage down to broken. Definitely heavier precip and cloud ahead. They seem to merge altogether in one uniform band or bank of amorphous cloud. I can see no detail dead ahead. Now I have to see if it's an optical illusion caused by the widespread light precip.

8:25 AM

PH: Not much aggregation as far as I can see, which is sort of a surprise at this temperature. Occasional columns.

AR: Well I'm seeing quite a few aggregates in the 2-DC. I think the CPI is really meant to look at those small particles. There maybe a bias there. Also the other problem is the aggregates tend to break up and go across looking as smaller particles than they really are.

PH: That's a good thing to be aware of then on the CPI because all you seem to see are single particles. It could be very misleading in analysis.

8:28 AM

AR: The visibility did decrease in the vicinity of the aircraft, so I guess that was kind of a real enhancement ahead of the precipitation, although we did not go through any water clouds at least yet. The coastline coming into view now. I stepped away to look for a piece of paper. So visibility is now quite good here.

PH: So the main rainband is roughly over the Westport radar and as moving toward the northeast. So that's why this track that we're taking now that takes us up toward the north Binet site will take us through the main rainband. Whereas, if we had kept on the radial directly toward the Westport radar, it wouldn't have been as good. So we've achieved two things by taking this more northeasterly track and that is it will take us over the Battelle microwave and go through the main rainband.

AR: During that time that I stepped away, the amount of cloud coverage below the aircraft has decreased to widely scattered.

PH: We're approaching the north Binet/Battelle microwave site now. It's just a short distance ahead of us.

8:33 AM

PH: Just coming on shore here.

AR: The temperature has dropped about a degree here in that couple of minutes I was away. It went from  $-1.9^{\circ}\text{C}$  to running about  $-2.7^{\circ}\text{C}$ . That's t-stat. However, Shadin t-stat is holding at  $-1^{\circ}\text{C}$ , so I'm thinking maybe that's a little more correct at this time.

PH: Art, as we come up to the north Binet site, this would be a good time to make some detailed observations as to whether we're in cloud or not and what we're seeing, etc.

AR: Roger that. I will do, put it on the tape.

PH: I'm not seeing any liquid water here.

LS: Peter, we're climbing to 5,000 ft now.

PH: Larry, we're over the Battelle site and we're climbing up to 5,000 ft. Let's climb up over that site.

LS: Okay.

AR: What was interesting is that just then we had an increase in needles and columns after we had been seeing these sort of amorphous, spherical, quasi-spherical particles. So there was a little change in the microstructure just then. We're flying in mainly precip, no cloud below us. We did not sample in liquid water and I did not see other than scruffy stratus fractus any low cloud below us at the PNL site. Above us is gray overcast. It's not as thin as it looked before. It looks a little more contiguous and solid. I don't see any detail, although I know from

the earlier sightings that we had some altocumulus-like tops of this nimbostratus deck. I expect to see mainly ice and precip until we get to the top I would guess here.

8:36 AM

PH: Larry.

8:37 AM

AR: These crystals by the way appeared to be largely unrimed. There are some that appear to be spherical and rather rough and they're very small. I think they're those smallest drops maybe.

PH: We're making our 180° and as we.

LS: Hello Peter.

PH: Yes Larry.

LS: The Center wants to know what our future plans are when we're operating up in this leg in this area.

PH: We're going to be going backward and forward on the leg we just ran and increasing our altitude probably by 2,000-ft steps up to about 17,000 ft.

LS: Okay.

PH: We just make our 180° turn and we're just heading back now right through the north Binet site. The turn there will take us over the site again as we head back toward the southwest at 5,000 ft.

AR: I want to revise my description from unrimed, which some are, to lightly rimed and unrimed, and crystals being aggregates from lower temperature regions and small columns and needles. I haven't seen any liquid water yet, so maybe there's something between the altocumulus layer and this level.

8:39 AM

AR: Lots of duplicate particles on the 2-D just then at strip #1197 I would say. I'm guessing because it went by too fast.

PH: Just going over the north Binet site now according to my position map.

AR: Indicating pretty much the same situation as before, a couple of scruffs of stratus fractus, overcast, possibly two layers. Maybe I'd better add to that altocumulus description.

PH: No liquid water here. Irregular crystals.

AR: Altocumulus on the top with possibly an intervening layer between the altocumulus and the flight level. Crystals again are lightly rimed, unrimed and mainly quasi-spherical aggregates from lower temperatures below  $-10^{\circ}\text{C}$ . A few columns and needles originated at temperatures above  $-10^{\circ}$  suggesting the liquid cloud between here and the  $-10^{\circ}\text{C}$  level.

8:41 AM

PH: Art?

AR: Roger.

PH: As you know, we're heading back toward the southwest. If we break out of the rainband as we may do, we may not have to go as far southwest as we did earlier on. So keep an eye for breaking out and at that point we'll do our 180 and go back in.

8:42 AM

AR: We've climbed to 6,000 ft and we're on our way back southwest. I see nothing changing except the sky is brightening above us. So we're going to go back into that kind of weak area of precip in which the clouds separated into two or three distinct layers. I think we went through there at about 2,700 ft. Lots of columns and needles here. We're flying right at  $-6^{\circ}\text{C}$  or so and yet we haven't hit any more liquid water and that suggests that there is some liquid water just above us or at least there was some at some point.

PH: Well on the next return track, we'll go back at 7,000 ft and see what we get. Lots of columns on the CPI.

8:44 AM

AR: It certainly is a suggestion of a layer between now, between us and the altocumulus layer, which would probably be around 15 to 17,000 ft. You can't really see it going by the aircraft though on top here. I keep looking for it, but I haven't seen it.

8:46 AM

AR: Things continue unchanged. Some hint of the upper layer. Some hint of an intermediate layer and down below is some stratus fractus. Coverage is broken now. We're flying in visibility-reducing precipitation. Cloud detail below the plane is visible out to maybe three-quarters of the way down the wing tip. It was in this direction that the lower clouds tended to thicken up. It's kind of in keeping with the Envirocam satellite image (IR) this morning, which showed the lower tops to the west of the highest tops in this system. I'm thinking there that the thickest low clouds would also be out back and behind, so to speak, the highest cloud tops with this weak rainband system.

PH: Art.

AR: Roger.

PH: The wind speeds are very low.

AR: Yes. They look pretty good today. In fact by the coast there it was almost down to zero or 1 knot, 2 knots. I forget exactly where that was. It was probably within the last 20 min.

PH: About 10 knots now.

AR: Right. That kind of varies with this system. It's very weak. Not much out here either at the surface of aloft because we're kind of in the trough core. It looks like they've shifted here too, just almost in the couple of minutes before we began to speak about it, it looks like the winds have come from the southeast to the southwest. Now they're really wide.

8:49 AM

PH: Everything seems to be going well at the moment. The rainband is stationary and we'll be flying the lower levels and we'll be working our way up through it. Most of the instrumentation seems to be working. So this should be the first IMPROVE flight in which we've got all the imagery of the particles that we wanted. I guess the only thing that is not being done is to record the radar. Can Grant go on the headset?

AR: He's coming on now. I've noticed the temperature has increased about a degree and a half since our turnaround point.

GG: This is Grant.

PH: Grant, go on "chat."

8:52 AM

AR: Still lots of needles now. We kind of went through an area of less needles, but there's lots of needles now and still no liquid water at this level. Liquid water cloud, the stratus/stratocumulus broken coverage below is well below this flight level. So they have to be come from above and there must some thin, very clean droplet cloud just above us. In fact, now just as I say that it looks as if we're getting back into some supercooled droplets, small drizzle drops, maybe on the order of 100 microns or so. Now we're getting some FSSP. We are getting liquid water. I really can't see much going by the wing and the droplet concentration only about 22. So this is the type of cloud we saw at about 3,000 ft earlier. This must be kind of the origin area for these needles and columns, although ironically we don't have any of those right now. They would be spawned by the aggregates and so forth falling into this thin layer. That is the thin droplet layer.

8:53 AM

AR: The winds are starting to pick up again in direction 190° at 4.5 meters per second or 9 knots. Now it says 210°, but that maybe an artifact. In some sense it's acting like a weak warm front since the temperature has been rising at this level and probably a degree and a half over a couple of minutes. I think it will show up as a fairly substantial change. I think too, although I can't verify it, that the wind did change direction for maybe about 30°.

8:54 AM

AR: The wind change looks pretty solid now at 200° to 210° at about 8 knots or 4 meters per second. Clear icing on the bubble.

8:55 AM

DS: Tom, go to "char."

AR: I start to see a little thin spot off the right wing. Breaking out here.

PH: We're not far from our point, so I think we might as well go to our southwest point.

AR: Very nice altocumulus layer above spawning crystals. As you look back toward our position, the base of the precip lowers into the clouds below. At this end they comprise more than just the stratus fractus. It looks like they're piled up into a very stratiform smooth cloud with not much detail. No protuberances at all more like a fog bank that is maybe just 100 ft to 200 ft below our flight level back there at its highest point. Right now it's probably more in the way of 300 or 500 ft below our flight level. Looking further out, the ice producing layer rises and thins to altostratus combination altocumulus with a couple of other layers of altocumulus...

END TAPE 1, SIDE 1

AR: ...out on the top. It definitely has some depth to it of maybe a kilometer in a lofted layer. Very complicated out here in the clearing anyway. The cloud tops passing the left wing at flight level. I didn't quite make them. Also passing off the right wing. I hope we'll touch some of these.

PH: Larry?

LS: Go ahead Peter.

PH: We've broken out here, so we might as well do our turn. We're pretty much at our southwest point any way. Let's return at 7,000 ft.

LS: Okay. Climbing to 7,000 ft.

8:58 AM

AR: Tom, could you turn the radar to the down position for just a moment here?

8:59 AM

AR: It didn't seem to do anything. Tom, do you copy?

PH: We're making our 180° turn to head back toward the northeast. We're in clear air here near our southwesterly point. Cloud below us and cloud above us.

9:00 AM

AR: Sun's disc as seen through ground glass now behind the left wing.

PH: Larry?

LS: Go ahead Peter.

PH: No flights Sunday or Monday.

LS: Okay.

PH: Any one on the headset, no flights Sunday or Monday.

AR: Yes. My wife just pointed out it's Martin Luther King Holiday on Monday. It's the one that always creeps up and you never know it's coming.

PH: Right. So soon after New Year. We'll take it anyway.

AR: You bet.

LS: Peter, we're north bound now.

PH: North bound at 7,000 ft.

LS: Affirm.

AR: Radar is indicating well and that is it's doing well. Multiple layers above us. A big return within the first third division.

PH: Art.

AR: Roger.

PH: We can adjust these heights, you know, to get into something more interesting. They're not cast in concrete. We're coming back at 7,000 ft at the moment.

AR: I noticed we went through some supercooled drops in drizzle and just after we had gone through some columns. I kept wondering where these columns and needles were coming from because I couldn't really see anything. So I think probably by going up this increment we may get to the top of that little liquid layer that was playing the role of being the spawner of these columns and needles.

PH: So 7,000 ft should be good, huh?

AR: It's right at the top of that Hallett-Mossop temperature zone and so I think it is going to work out pretty well.

PH: Good.

9:05 AM

AR: It looks like we've got a northwest wind now. I know we turned a while back there, but it's looking pretty solid this northwest.

PH: Yes. It's picked up again also to 10 knots.

AR: Say that could be. The shortwave was supposed to dive down the coast and not linger in this area too long. So maybe this is something that is real. It just sort of dissolves down toward California.

PH: Are you getting good 2-D imagery?

AR: Yes. It look really good. The only problem I've seen is that some images are duplicated on the same plane for some reason. Like right now if you were to pull it up you would see what I mean.

PH: Can I pull it up?

AR: You should be able to.

PH: How do I do that? Maybe someone can show me.

AR: You hit that applications tab and then there should be an icon there. If it's not there, then Tom hasn't set it up so you can see it.

PH: How's the 1-DC doing?

AR: Fabulous. Tom found the software bug and it's doing excellently.

PH: Okay. If Tom's not doing anything maybe he can come up and help me here.

9:07 AM

PH: At 7,000 ft we've got about  $-7.5^{\circ}\text{C}$ .

9:08 AM

PH: Still in clear air here as we head back to the northeast.

AR: Yes. It looks like we're just overflying that drizzle producing layer with the needles. It looks like we can probably stay in that layer or if you wanted to go up and look at what was dropping into it.

PH: What do we need to do, go up? How far?

AR: Well on the way down it would probably be 400 ft to 500 ft.

PH: Okay. Larry?

LS: Go ahead.

PH: Can we drop 500 ft?

LS: Affirmative.

PH: Let's do it.

AR: Larry, we want to get into this kind of fog-like cloud just below us.

LS: Okay.

AR: And because it is so diffuse I'm having even a hard time judging how far below it is, so I'll let you know when we go in.

9:09 AM

AR: Just getting into the top of this now, Peter and Larry.

PH: Right. Just picking up a little bit of liquid water.

AR: I think this might be a pretty good level right here, Peter. What do you think?

PH: Yes. Let's hold it here Larry.

9:10 AM

DS: I'm going to restart this. We've given you a new version, which will be cleaner as far as display.

AR: Don is going to restart my computer, so I won't be able to see anything for just a minute.

DS: No. I'm not restarting your computer. I'm just restarting one application.

AR: Thanks Don. One application, so I won't be able to look at the 2-D for a minute. But if I was looking, you'd see those short columns and probably needles starting up and the other bigger kind of particles dropping down from this altostratus/alto cumulus layer that we have above this level.

PH: Yes. Seeing some columns. Nice columns on the CPI as well as drops.

AR: Roger. We may not get the bigger aggregates in that thing.

PH: Notice the J-W is reading systematically higher than the PVM.

AR: Yes. It may have an offset problem.

PH: The FSSP is somewhere between the two.

AR: I'll take a look at it. But at least, think of our blessings here, at least we got something.

PH: The DMT is out of it as usual.

9:12 AM

AR: We've got quite a few aggregates here.

PH: Yes. You just don't really see those aggregates on the CPI. Probably the magnification is too big or something.

AR: I think the sample volume is fairly small too. That's part of it. Plus they're so few in number compared to the small particles and that's probably the real reason.

PH: Would you ask Tom to come up, Art?

AR: I think he's coming up right now.

TW: Yes.

AR: I did that via the "chat" channel.

9:13 AM

AR: We're flying in and out of the top of a layer located completely within the Hallett-Mossop riming-splintering zone with all the prerequisites, the big droplet spectrum. By big I mean expansive. Drops out to 30 to 40 microns and so probably an area where we're getting a lot of riming and splintering. The FSSP concentrations occasionally up to 100. Liquid water contents, however, being rather low in what I've seen in the last minute or two, about 0.01 or so. Even though we're at cloud top, we may be a little too close to cloud top judging by that liquid water. Better keep an eye on it here for a minute and see what we get. There's 90 still only 0.01, so that's a narrow droplet spectrum, 0.01 liquid water content.

9:14 AM

AR: Oh heck. I'm going to have to backtrack on that. I was looking at the 1-D cloud probe concentrations and not the FSSP concentrations, which have been down around 1 or 2. So those comments earlier when I was talking about.

PH: I have the 2-D imagery up now, which is very nice to be able to look at all that.

AR: All those comments about 70 and 100 were based on the 1-D cloud probe concentration, for Pete's sake, and not the FSSP-100. When we dipped into cloud top, we did have stuff in the 20s and 30s and 40s that was actually from the FSSP.

9:16 AM

AR: We've continued on this whole leg to have a northwest wind at about 10 knots or so. I'm thinking that it must be real and, if it is, we may see some rapid dissipation of this whole thing here. The tops of that layer we were flying in has descended below us now.

9:17 AM

PH: All right. We're still proceeding toward the northeast back toward the PNL microwave radiometer site. There operating has been confirmed. We've dropped from 7,000 ft down to 6,500 ft to get into more cloud. So everything is proceeding pretty well.

9:18 AM

AR: I'm noticing maybe on the radio there, Peter, the tops of that layer that we were flying in the upward part of were lowering. Now we've kind of exited. So we kind of came up the side of the top a few minutes ago and now it's kind of nonexistent.

PH: Do you want to adjust the height?

AR: Well I suppose you want to go up at some point and there's nothing we can get here any more and we're almost on the PNL site.

PH: Larry, let's climb until we get back in cloud again as we go over this land site.

LS: Okay.

AR: I don't know if there's much above us, Peter, without a big, big climb. The layer that we were going through the tops we have left behind us. The only thing we have done there now is sort of cumulus fractus, stratus fractus and precipitating cloud above us that may have a water top way up there at 15,000 to 17,000 ft.

PH: Well we might as well start our climb now since we've got to do it anyway. We're not getting anything here.

AR: I notice now out of the haze there's something ahead. It looks like maybe a little bit more of that layer cloud there. So if you wanted to go through that, we might still nip that without a climb if we are staying at this level or a slight descent. It's hard to tell it's so amorphous out there.

PH: Why don't you direct Larry?

AR: Larry, this is Art in the back. It looks like there's a little cloud at this level. Are we in that? I can barely make it out. It looks like it's still a little below us. It's kind of fog-like cloud maybe 300 ft below or so.

LS: Yes. I think you're probably right.

AR: Can we get into that for just a second or at least as we go over that PNL site?

LS: Sure can.

9:21 AM

AR: The FSSP concentrations are probably going to be really low in this, probably 10, 20 or something like that. It's so darn thin looking.

PH: At least we're picking up something here now.

LS: What do you think, Art, does that look like it to you now?

AR: Yes. It's pretty clean. There's only a few per cc. I haven't even seen a 10 yet. I think it's the best we can do with whatever is here, although we're kind of in and out. It wasn't much of a layer.

PH: We want to climb to 9,000 ft for the leg back, so we could start that climb now as we do our turn.

AR: Yes. I think that's a good idea, Peter, because we're not going to get much out this layer. It's pretty nebulous and sparse coverage.

LS: You say you want to climb now to 9,000 ft, Peter?

PH: Yes Larry.

9:22 AM

AR: The sun's disc is not visible in this location. We have over PNL some stratus fractus almost transparent they're that thin. A really kind of nebulous stratus-like layer at our flight level back there, which was about 6,000 maybe 5,500 ft even. It's kind of sparse in coverage. Droplet concentrations are probably 10 or so. Then above us we have precip falling from what I believe will be an altocumulus-like topped layer of altostratus. We shall see on that, however, when we get up there. I'm kind of guessing right now because I really don't see the altocumulus cloudlets from below.

9:23 AM

AR: Getting some nice big lightly rimed aggregates perhaps a couple of millimeters in maximum dimension. They contain holes and great detail and that's the reason for the lightly unrimed aggregates. Probably unrimed is closer to the truth.

9:25 AM

PH: Art?

AR: Roger.

PH: Have you seen anything on the HVPS today?

AR: Have I seen anything? It seems to be working great.

PH: Is it working now?

AR: It was just a second ago.

PH: I just pulled mine up for the first time on this flight and it's not showing anything just lines.

AR: Right this second you're right. I don't see anything going by, but within 10 s now there will certainly be particles zipping on by.

PH: Let me know when you see something because I've got nothing at the moment.

9:26 AM

AR: On that last squawk sheet it seemed like a problem with that darn thing came when we were climbing or descending. It just doesn't seem to like changes in temperature, pressure or something.

PH: Yes. I think that's right. Got lots of images on the CPI.

AR: I almost forgot about that. That would be amazing and it would be really nice to know that we didn't have to baby it the whole flight.

PH: Okay. Don just took care of my problem on the HVPS. I don't know what it was. It was not doing anything, but it's now showing the little blips.

AR: I've got the same problem back here. I'll try hitting the end key sometimes and maybe that's what he did.

9:28 AM

AR: Right. Sometimes if you hit the end key, the key marked "end," and bring it up to date. I guess it got stuck because the same thing back here happened. I saw those same lines. Now I've got particles.

PH: At 9,000 ft. We're on our return back to our southwest point. It looks like a good altitude. It looks like a good altitude. We're picking up images.

AR: Yes. We're at the bottom of the dendritic crystal zone.

PH: Right,  $-12^{\circ}\text{C}$ . They've done a great job on these displays, Art. It's really a very good depiction now.

AR: Clearly, when we got Tom, we went to another level is my opinion.

9:29 AM

PH: Don?

DS: Go.

PH: The J-W is offset again. We should be reading zero here.

9:30 AM

PH: Don's playing with the J-W trying to zero it. That's the rheostat you want to replace isn't it?

DS: Yes. I'm just as close as I can get to zero right now without there being something odd.

PH: It looks pretty good now.

9:31 AM

AR: We're continuing in amorphous conditions. By that I mean there's no cloud detail visible above the aircraft and usually it means when I say that then something happens, but anyway we're just flying in precipitation. It's uniformly gray above us, kind of a bright gray. Then below I can see the stratus stratocumulus clouds that we sampled a little bit of in those last couple of legs. Coverage there appears to be overcast at this local. t-stat is  $-12^{\circ}\text{C}$  and continues to increase just a little bit in this heading to the southwest.

PH: Don?

9:33 AM

AR: You might have to reach him on "chat." Sun's disc is becoming very apparent off the left wing. Now it looks like ice cloud actually all the way up through that path. I guess when I thought of altocumulus topped precipitating altostratus is not going to be realized at least out that away off the left wing, which would be

toward the east since it's morning, a very gigantic conclusion. Looking overhead all I see is ice clouds. So I know it's here somewhere though. I definitely saw some altocumulus topped precipitating clouds.

9:34 AM

PH: Larry?

LS: Go ahead Peter.

PH: We will probably break out of this cloud before we reach our southwest point. So when we break out, we'll make a turn and you can make the turn sort of back toward the northeast so we save time rather than make the turn to the southwest as you did last time. Then we'll be heading back to the northeast at 11,000 ft.

LS: Okay. I think we're out of it now, so we'll go ahead and start our 8260 here.

PH: One moment. Let's just check with Art and see what he thinks.

AR: We're still flying in light precipitation actually.

PH: We'll give you the word, Larry, when to make the turn. Okay Larry?

AR: Yes. I think it even thickens up ahead here. We're kind of in a between band possibly situation.

PH: This is too early to make the turn here.

LS: Okay. We'll stay here for the time being.

PH: We'll let you know.

LS: Okay.

PH: When you get a moment, Larry, you should come back here and see the sort of things we're getting back here. It's sort of interesting.

LS: Okay.

9:36 AM

AR: We're still getting a northwest wind. It was more west-northwest by the coast and has turned more to pure northwest now. That would fit synoptically what you'd be expecting. Now we're starting to begin to see the end of this back at you, Peter. Underneath us is a precipitating layer, however, that we sampled earlier that's going to continue for a while even though we're in a clear spot here.

PH: I'm just going to talk to Larry for a moment.

JR: We're starting to break out now.

AR: Peter, do you copy?

9:37 AM

AR: Jerry thanks. We're still getting ice crystals coming down from that higher layer and then they're going down into that lower layer. So it's still part of the precip scene out here even though it looks like it's maybe completely clear, but we really still have something going on. I don't know how important they think it is. Tom?

TW: Yes.

AR: Could you turn the radar to the down position for a couple of minutes?

TW: It is down.

AR: Oh.

TW: I mean I just turned it down.

AR: Peter, we've got precip all the way to the ground here even though it didn't look like much at this level it's certainly getting enhanced in the layer below us.

PH: I was just talking to Larry. He came up to see the CPI. We've broken out now, right? So we'll do our turn here, Art.

AR: We're still flying in precip and it's quite enhanced as it falls into that lower layer below us.

PH: Something has just come back on. I thought we had stopped. Larry? Jerry?

JR: Yes. What do you need, Peter?

PH: Keep straight on for the time being. We'll tell you when to turn.

JR: Okay. Do you want to climb?

PH: No. Keep the same altitude.

JR: Okay.

AR: We're indicating precip all the way to the ground here.

PH: We keep jumping the gun on that turn.

AR: That's because it looked pretty good back there a bit ago and you do get excited about it. Pretty soon though, it's just going to be some ice crystals at this level as virga. It's not falling all the way down because that's what I noticed coming out before. It kind of lifts and goes back away from the precipitating cloud. So at some point you could fly forever and still be getting ice crystals, which are outside the rainband area.

PH: Does the 35 GHz radar look okay?

AR: It looks fabulous.

PH: Up and down?

AR: Up and down we're getting great returns, very sensitive. You can just tell by looking up and seeing the weakness of the cloud above us, so to speak. It was just a thin ice crystal cloud and yet it's getting a good return from it.

PH: Since we're not recording that, you need to just put on the tape what you're seeing.

AR: Roger.

PH: Hopefully by the next flight we'll have it recorded.

AR: Roger. Now about in here is where the precip at the ground has stopped last time. Even though we're still in ice crystals, the rain at the ground is going to be coming to an end here almost in the next minute or less I'd say. You can look below and see what's happening. It's kind of getting a tattered low cloud and these crystals just probably aren't even making it down there now.

PH: Right.

9:41 AM

PH: So I plan to just keep backward and forward. We'll do 11, 13, 15, and then 17. That should put us at the top.

AR: Again even though we're at almost 10,000 ft, the temperature increased about 2° on this leg from the northeast end to the southwest end, but the wind is backed as well into a 270 now compared to the 310, 320 we were getting in the middle of this leg.

9:42 AM

PH: How do you tell what size these particles are in the 2-D image?

AR: In the vertical span, it's 800 microns or about a millimeter say.

PH: Between those little vertical lines?

AR: Right.

PH: Right across the screen.

AR: The biggest image you can see in the up/down direction is about a millimeter or a little less, 800 microns actually.

PH: Okay. In the up/down.

AR: Right. Of course they can extend out as long as they go, but in the up/down direction you can only see 800 microns max.

9:43 AM

AR: Because you can see so many edges and so forth, it would be considered generally unrimed crystals maybe some light riming possibly, but probably not even lightly rimed. Now it looks like we've cleared the crystals going into the lower layer and so the only thing we have below us is possibly a lower layer that might be having some drizzle.

LS: Peter, it looks like you have some more weather coming in down here to the southwest.

PH: Yes. We're not interested in that, Larry, though. We can do our turn here. Let's do our turn back toward the northeast and as we turn climb to 11,000 ft.

LS: Okay.

AR: This is very much like the area we turned in last time, so I think we're pretty relative here where the rainband is going, pretty relative to the same point with regard to it.

9:44 AM

AR: Right below us, a little droplet cloud there just went by, 57/cc. That's interesting. I didn't expect that. Right below us is where the overcast ended probably just a mile or so to the east of our turnaround point. After that it's kind of broken coverage with bands of overcast, I guess you'd say. Skies underneath us extending out to the north and northwest and a very chaotic situation is indicated by the little altocumulus cloud that we just sampled and there's another one

coming up around on this side just a wisp, however, shred clouds. There's even cumulonimbus out there to the distant south. Looking back it's altostratus with lowering precip base in the rainband.

9:46 AM

AR: The sun is brightly out and is almost capable of producing shadows. I can just see the shadow of my figure here, so that gives an indication of optical depth of the altostratus above us. There are still no sign of altocumulus at that level. Sun dogs on either side of the sun. As we climb we got back into the ice crystals falling out of the altostratus layer.

9:48 AM

AR: The sun is dimming now as we head back into me lower base of the altostratus and by base I mean the bottom of the precip. The sky is still relatively blue above us and there are ice crystals.

9:49 AM

AR: Blue skies still apparent between patches of what appears to be cirrus spissatus. We seem to be flying in kind of an amorphous ice cloud probably representing the precipitating cloud and then I suspect that the cirrus has separated from that cloud.

PH: Art?

AR: Roger.

PH: On the CPI the image sizes are given in brackets aren't they in microns, is that correct?

AR: Right. Maybe it's in a whole box though as I recall, but it should trim the image. It should be about the size of the image.

PH: And what's this time? The time seems to be local time.

AR: Is it on the CPI computer? It probably should be reset to UTC time because that could be a big problem.

PH: Yes. It's currently set on local time. That needs to be put on UTC.

AR: Right. I don't think it had a very good clock in that PC because it seemed to me there were some problems with that. So that's I'm glad you mentioned it because we need to check all the time.

PH: It looks okay. It agrees on the minute pretty much with our system, but certainly it must go on UTC. You'd better tell Tom.

AR: We're just passing through a saddle region of cloud tops, but this more enhanced region of cloud top deepening upward.

PH: Better not change the time on this flight.

DS: We'll have to change it for the next one.

PH: Right. Eight hours on. So for the tape recorder the CPI is on local time for this flight. I'm coming off the headset.

AR: There seem to be multiple layers of ice cloud up here and some liquid water as a matter of fact. There is some altocumulus embedded in a higher layer of cirrus/altostratus at about 10 to 11 o'clock. So it's very complex up here with still a higher cirrus spissatus layer above that. So we've probably got about 3 layers of ice cloud.

9:53 AM

AR: We're about to re-enter an enhanced tops at the northeast end of the band or bands of precipitation. I'm getting the impression this is falling apart, but that maybe because of the altitude here. Looking back I can see some complex patterns in a very high cirrus estimated at above 25,000 msl and then some patchy cirrus below that, but above our flight level. Now we're going back into the amorphous cloud and precip that we've been flying in that's been producing precip to the ground. We seem to be entering that right now, although I have yet to see crystal move on the 2-D display, but I do see particles going by the HVPS.

9:58 AM

TW: Hey Don.

DS: Yes.

TW: It looks like it might have stopped. I'm not sure.

DS: You can just go reset them just for the general purpose.

TW: Okay.

DS: Yes. It had gone to sleep. It's awake now.

TW: I don't know why it does that.

9:59 AM

DS: I'll go ahead and restart the driver as well.

AR: Are you talking to me, Don?

DS: Negative. I was talking to Tom. We had a momentary 2-DC sleep problem there, Art. We just kind of woke it up again.

AR: Okay. That's what I was talking to Tom, but I think he was on the other channel.

DS: Yes. I think I'll wander back over to "chat" because I can hear what's going on in this channel as well.

10:00 AM

AR: Winds have continued to be out of the northwest here now. They're approaching the northeast end of our line and they've picked up in velocity, which is reasonable since we're now at 10,500 ft TANS-alt, about 295 at 25 knots, 22 knots. The sun's disc barely visible now.

PH: Art?

AR: Roger.

PH: What was the temperature at 9,000 ft?

AR: It varied from about  $-12.5^{\circ}\text{C}$  at the northeast end to  $-10.5^{\circ}\text{C}$  at the southwest end.

PH: Here we're at  $-15^{\circ}\text{C}$  or so.

AR: Roger. That's been decreasing along this track too. It was in the  $-14^{\circ}\text{C}$  there when we started.

PH: We sort of skimmed the bottom of the dendritic zone and the top of it. We didn't really get right in the middle of it.

AR: I think right here. Wouldn't  $-15^{\circ}\text{C}$  be the maximum growth zone for dendrites?

PH: For dendritic crystals it's  $-12^{\circ}$  to  $-14^{\circ}\text{C}$ .

AR: I thought it was  $-18^{\circ}\text{C}$ .

PH: You maybe right.

AR: Those numbers slip away, don't they?

PH: I used to know all those numbers, but they're going like everything else.

AR: I know.

PH: I think it's  $-14^{\circ}$  to  $-17^{\circ}\text{C}$  actually.

10:02 AM

AR: I think that's right because actually I was thinking of stellar crystals and sectored plates and that kind of thing that fall just outside that core that you mentioned.

10:03 AM

AR: The sun brightening as we head now and continuing in the northeast direction. I haven't seen any sign of droplet clouds at the top of this. It's kind of a disappointment.

PH: So no liquid water here.

LS: Peter, do you want to climb to 13,000 ft at the end of this leg?

PH: Yes. That's correct, Larry, just the same thing. We'll do our turn over the Battelle site, climb to 13,000 ft and go back to the southwest.

LS: Roger.

10:04 AM

AR: The sun has dimmed a bit as we get to the Battelle site and I can see strands or fall streaks I guess you'd call them if you were to look at them at radar. Now one is going by the sun back behind the tail in which the sun's disc disappeared for just a microsecond and now it's gone completely again. Now it's just barely visible, barely having a bright spot there. As we make that turn also we have broken out into a large clearing looking eastward toward the Cascade Mountains. Now you can see the Olympic Mountains out there off about 2 o'clock.

10:06 AM

AR: So as those mountains came into view, the Olympic Mountains, they seemed looking back to definitely be at the northeast end of this rainband. Then is back looking down toward the rainband, the thicker part of it, and so while it's lifting and thinning to the northeast looking back toward the sun the sun's disc is dimly visible at times because of the deeper ice cloud in that direction.

10:07 AM

AR: No liquid water cloud in view.

PH: Looking downward over land here as we make our turn, I can barely see the ground. Looking upward I can see the sun.

AR: Roger that. Looking below I don't see much in the way of low cloud along the coastline, so it's very reminiscent of the other passes where there was little cloud in the vicinity of the PNL site.

LS: Peter, 13,000 ft now and southbound on track.

PH: Thank you.

10:08 AM

AR: Probably on this path, Peter, when we pass out of this elevated area of air crystals and then go through some cool air for a while, but then probably come into some more ice crystals a little further down the road.

PH: Okay. John just told me the rainband is pretty much oriented west-east through the Battelle site, the north Binet radar antenna site.

AR: Yes. This seems to be the area where they have the thickest cloud above us that's for sure because the sun's disc is now almost completely gone. I can just barely make out where it is and up until this part of the rainband or bands I could see the sun pretty much the whole track.

10:09 AM

DS: I've switched wing probes to inverter #2 to see if we can eliminate some of the noise on the A-to-D channel.

LS: Art, how's the heat back there?

AR: It's fine back here, Larry.

LS: Okay.

AR: It's not really warm, but right now it's probably just about right. Thanks for asking.

10:10 AM

PH: It should be noted here that although we're flying over the PNNL site, where they have the microwave radiometer, they may be interested in water only stratus clouds. So this is really not a very good case as far as they're concerned.

AR: The sun is brightening.

10:11 AM

AR: Larry, what's our flight ceiling today?

LS: Well if we're in the clear, Art, 25,000 ft at least.

AR: That is if we break out the cloud here and then get some clear air?

LS: Affirm.

PH: We're now heading back from our northeasterly point over the north Binet antenna back to the southwest at 13,000 ft.

10:12 AM

AR: It's dimming a little bit in this region. There's a deeper mass of ice cloud located near the coast and it should be just prior to the breakout here into the saddle region and then kind of toward the middle of our trek.

PH: It's been a very smooth so far. No turbulence.

10:13 AM

AR: The sun is remaining about the same intensity as before. I'm a little surprised because I thought we had broken out by now, so I'm not sure what's going on here.

PH: From the point of view of the microwave radiometer at the PNNL site, because of the very low liquid water contents here, which that instrument is supposed to detect, it may be a good test of how much ice crystals interfere with their measurements.

10:15 AM

AR: Conditions continuing as before, not much change. The sun is still moderately bright. Not bright enough to produce shadows yet. It's beginning to look like we're reaching that westerly endpoint of this enhanced upward area of ice cloud.

10:17 AM

AR: It looks like some separation of layers beginning to take place off the left wing now brightening below the sun. More detail in the cirrus overhead now starting to become visible.

10:18 AM

AR: This is that hole we were in before, so we left the enhanced cloud top back there near the coast and now there's a gap and then another band of ice cloud and precipitation that appear to go to the ground ahead.

10:19 AM

AR: It looks like there's enough ice now coming from the higher layer. It probably won't go completely without ice crystals here in this little hole.

PH: I'm still seeing a few on the CPI.

AR: Yes. Right. I'm sure it's not getting down to those lower clouds. It's more like flying at the bottom of some cirrus or altostratus. Then it will thicken up ahead and then I believe it still gets to the ground. I'm positive off the left wing anyway. The right wing is a little more enigmatic, but it certainly thickens into what I think it appears to be two kind of distinct rainbands on the radar.

PH: Yes. The CPI still picks up a few now and again, but the 2-D doesn't. The 2-D just clicked over there.

AR: Roger. I saw that. I'm guessing the concentrations are probably well below 1 per liter with that rate of 2-D turnover.

PH: Something we could add to the 2-D readout is the concentration. It's something for Tom to do down the line.

AR: Roger. It's been mentioned.

10:20 AM

PH: Static temperature and dew point almost identical here maybe 1° difference.

10:22 AM

AR: Now entering this other enhanced area of ice. Now we seem to be exiting the thickest part of that second patch of ice and it's looking very chaotic now, multiple layers of cirrus. That higher layer that I mentioned before with the complex patterns certainly above 20,000 ft msl. This kind of amorphous ice cloud with really not much structure in it that we're flying in right now that may go up to 15,000 to 20,000 ft someplace in there. It's very difficult to say. The

tops are not uniformly at the same height of this ice cloud. Larry, are we pressurized today?

LS: Yes Art. The cabin is at about 5,800 ft.

10:26 AM

AR: We're breaking out further. It looks like that same lump of ice cloud. That would be the third one now. Kind of hole here, a bit of a hole.

PH: We're just coming up to our southwesterly point here.

LS: Peter, do you want to go to 15,000 ft on the way back here?

PH: Yes. That's correct Larry. Go back at 15,000 ft.

LS: We're about 2 miles from the point.

PH: When we finish our climb and I don't think we'll be very far off cloud top at 15,000 ft I don't think. We may have to go up one more step. Do the prospects look any better for doing our low-level pass that we never did at the beginning?

LS: Yes. I'm sure we can get that.

PH: We might want to do that at the end.

LS: You're still going to be limited to 3,000 ft though.

PH: Okay.

AR: I think that was the level we did that first run at. I remember seeing TANS-alt at 2,700 ft.

PH: Yes. We did one at 3,000 ft before. We probably won't want to do 3,000 ft again, but maybe we could do one at 2,000 ft.

LS: Peter, I was talking to the Center there. What was your last comment there?

PH: We did one at 3,000 ft right at the beginning, so we would want to do one at 2,000 ft if we can.

LS: I thought we did our first one at 4,000 ft.

PH: Well we started off at 4,000 ft and then we came back at 3,000 ft.

LS: That's right. Okay. If the conditions have improved down there, we can probably go down as low as we want to.

PH: Okay. What we're really looking for is the finer sort of remnants of precipitation coming out of this system. So we won't want to be completely in clear air, but it could be pretty clear, you know, just precip without cloud.

LS: Okay.

PH: But anyway that's looking ahead. We're going to be going back at 15,000 ft.

LS: Okay.

10:29 AM

AR: Now I see some sloping fall streaks here off the right wing from this precipitating cloud and in fact off the left wing they're kind of concentrated into streaks that slope from the sun's position off to the right here. It looks like we're heading southwest. It's kind of sloping from the southeast to northwest. Patches of blue sky visible, although you're looking at it through ice crystals. There are a couple of droplet clouds up here. Little wisps of ragged cumulus fractus type just went back behind the tail.

10:30 AM

AR: I'm going to step away and get some dark glasses on. Looking back we have altostratus above the aircraft at least 1 to 2 kilometers in extent above the flight track and the fall streaks from that do go down into this lower ice cloud. As we go ahead, we're coming into a region of enhanced tops.

PH: Art, what's our normal research speed at this altitude?

AR: I'd say we would be well over 100 meters per second, 105, 110.

PH: That's as slow as they can go?

AR: I think around 100 to 105 is about as slow as they can go at this altitude. I haven't looked to see what it is. I'll check.

PH: That's what it is.

AR: Actually 100. Yes. That's pretty good. I guess that's because it's so cold today.

DS: I'm about to change the tape. Somebody filled it up.

AR: Yours truly.

END TAPE 1, SIDE 2

DS: ...because the tape was not yet running.

PH: Okay.

AR: Yes, Peter, we'd be in and out of these tops and this higher layer there is a separation zone here the higher layer of sort of cirrus altostratus is putting crystals down into this lower ice cloud. So it's kind of a merged layering situation. The top of that higher layer would probably be above 20,000 ft I'm guessing.

PH: Maybe we should aim for that higher layer, or at least see what's coming out of it on the return run. Is the tape back on?

DS: Yes.

PH: We have just started our return trip back to the northeast at 15,000 ft. Although there's a higher layer of cloud above us, we are near the tops of this particular layer.

AR: Yes. In some regions we're near the top and then other regions it just goes on up to that higher layer deep within both systems with the highest top probably being as I said above 20,000 ft. Back there just a minute ago, we were near the tops of the lower ice cloud.

PH: What do you think will be a good altitude to go back to the southwest?

AR: You probably won't see much crystal change. I'd try 20,000 ft.

PH: We can adjust that.

AR: Right.

PH: Larry?

LS: Go ahead.

PH: When we do the return back to the southwest, we're going to want to go up to about 20,000 ft.

LS: That should be no problem.

AR: The reason why I suggested the big jump is because there doesn't seem to be a lot of structure changes between here and the higher levels. It's not until we get in

that higher cloud, which actually like some of the cirrus we saw in the Arctic does have a lot of structure in it, wisps and strands and that kind of stuff.

PH: What we might want to look at is if anything from the upper-level cloud, the one at 20,000 ft, is actually getting down into this level. So we might want to run below 20,000 ft somewhere and above this height.

AR: You're certainly right that when we get there and we look back we can probably pick a better level than maybe just a wild shot at 20,000 ft. All that stuff back there about 1 min ago was coming from the higher cloud. We couldn't distinguish the lower one from the higher one back there about a minute ago and now you can kind of distinguish them even though we're flying in ice crystals.

PH: Are you getting cold back there now?

AR: No. I had a cup of coffee and I'm warmed up and the only thing that is cold is this ring.

PH: My feet are getting cold.

10:37 AM

AR: I can really get the sense of separation between that rainband back there and the one ahead because now we're just flying in this big vault area. A little cirrus, a few ice crystals mix down below us and a few scruffy stratus and stratocumulus clouds are near the surface.

10:38 AM

PH: Larry?

LS: Go ahead.

PH: We could do with a little bit more heat back here. My feet are getting cold.

LS: Okay.

10:39 AM

AR: There's a very nice fall streak off the right wing at 1 o'clock or so. It slants down from upper right to lower left with the plane. It looks like we're going to go in it.

PH: Why don't you direct Larry into it?

AR: I think we're going to go in it. It slopes down right it looks like pretty much into our path.

PH: Do you have radar pointing up?

AR: It's pointing down right now. We've got rain all over the ground.

TW: Art, do you want me to point it up now?

AR: Yes.

TW: It is.

DS: Art?

AR: Roger.

DS: I just took a background a moment ago. It's pretty quiet out there. It was before it got more active and we're getting better images again.

AR: Great Don. Good job.

10:42 AM

AR: We're getting great returns from the radar in the up position and they suggest that the cloud top would be somewhere around in this deeper area about 1 kilometer above our flight level. Correct, 2 1/2 kilometers. Boy!

PH: That's another 5,000 ft?

AR: That's right.

PH: That's what you guessed, 20,000 ft.

AR: I think it probably goes higher than that only because the radar probably doesn't see the tiniest little crystals up there, but anyway the whole point of that long thing was to mention how helpful that could be in these kind of situations.

PH: That old display we used to have that was just the old 35 GHz strip chart. You remember those brown things we used to unroll. That was actually very good.

AR: Yes. Exactly, you could see those fall streaks on there. It's too bad we can't at least get a hard copy even if we can't digitize it. That would be kind of nice to look at for the time line.

PH: We still have that old unit for recording. If we have any of the paper left, we could probably do that.

AR: Yes. On the other hand once we get that digitizer card maybe Tom will display another window on these laptops.

PH: I'm sure he will if we give him the challenge. I don't think Tom could do that actually. I don't think he's good enough.

TW: I'm ready to land right now actually.

PH: Are you feeling sick?

TW: Sick of ridicule.

10:45 AM

PH: Tom, you should look at some of those old strip charts, which we have in the lab, because they're very instructive of the type of display that we'd like to get from the radar.

TW: Okay.

AR: We seem to have gone through the thickest part of the ice cloud over us. The sun is quite bright now after having been moderately dim there about a minute ago and as we approach the northeast end of our line.

10:47 AM

PH: Larry?

LS: Go ahead Peter.

PH: When we get over our point to the northeast there, we'll do a spiral climb to 20,000 ft. We may adjust it as we go up just to put us in the best cloud. It should put us near cloud top.

LS: Okay.

10:48 AM

AR: Right over PNL I think the radar is showing cloud top sloping downward here, these ice crystals. So we may get to it before 20. I'm saying it's about 1,500 meters now. Then I think what we're going to see is a separate layer that at this point is not interacting with this layer ice cloud. Getting a nice halo now.

10:49 AM

AR: We're starting to make our turn after passing over PNL. We have two layers of cloud at least the one at our flight level. The one above our flight level probably something below that near the ground, but I'm not able to see it at this point because of the ice crystal cloud below us. It looks like the crystals from the higher layer at this point are interacting with the lower cloud layer. So a minute ago I was thinking that maybe it wasn't going to interact, but certainly they are here. We're doing our climb to about 20,000 ft.

10:51 AM

PH: We're over the north Binet site, PNNL site, and we're starting our climb from 15,000 ft up to cloud top.

AR: These deeper cloud tops have moved a little bit closer to PNL from offshore and you can see that same separate zone out to the east toward the Olympic Mountains with the higher thin cirrus above. Then again here off the right wing both the higher cirrus and the current ice crystal cloud look like they merge together.

PH: I'm seeing a subsun here.

10:53 AM

PH: So I think what we'll do, Art, is we'll do this pass back to the southwest near cloud top and then we'll return back to the northeast at the lowest altitude we can that puts us in precip and I think that will be about it.

AR: That sounds good to me.

PH: Can you think of anything else that we should do?

AR: Not really. I think we covered it pretty well. I think our steps are actually a little finer than I think we've been doing before. I think we've been doing 3,000 ft generally all the way up and down. I think that today we did the little smaller stuff.

LS: Peter, we're going to take one more circle here to get you to 20,000 ft before we start southbound.

PH: Okay Larry. Art will give you a fine adjustment on the best altitude that we want.

LS: Roger.

AR: This is going to be really chaotic, Peter, because you can see off the right wing there if you look out you've got still the separation between that highest layer and some tops down lower. Then about 3 o'clock to 1 o'clock you see there's a big

saddle in the lower clouds yet. So if we want to be in the very highest layer, we're going to have to do some more climbing to on 20.

PH: I think what we want is to get any particles coming from the highest layer that are getting down to the feeding the layer below us now. We're just interested in that interaction between the highest layer and the layer we've just been flying in.

AR: Roger. We'll see what we can find. Certainly as we climb we'll get a better perspective and once we get to our destination height we'll have a pretty good idea of it I think.

PH: In other words, we're not all that interested in what's coming out of the highest cloud unless it's getting down to this layer below us.

AR: Yes. That's the way I'd look at it too, absolutely, because they look like they merge together as one in the deepest parts of these rainbands. As is the case off the right wing there about 2 o'clock, you really don't see any separation right now.

10:55 AM

AR: He's up at 20,000 ft, but as you can see there's lots of stuff coming from that higher layer. Judging by the movement above the plane, it's still about a kilometer up there. The radar is suggesting about a kilometer as well or something in that area. It would be near cloud top of the merged ice cloud.

PH: Apart from the subsun are you seeing any ice optics?

AR: I saw a halo. There's a faint halo now and there has been a mock sun or sun dogs actually. That was much earlier though.

PH: A 22° halo?

AR: Roger. Peter, I think he's going to go back at 20 K unless we want to go up to that higher layer, which is indeed sending some crystals down in here at least in this location.

PH: Well, as I said before, we just need to look at the crystals coming into the top here. So if we're above the top of this layer below us, then we're looking at crystals coming from the higher cloud and that's as high as we need to go probably and we'll know what's feeding into the lower cloud.

AR: Roger. We're breaking out of that enhanced top today. It merged together and now we'll see more separation between this high cirrus and the lower ice cloud I think. We ought to make that a crystal \_\_\_\_\_ as you can tell, but anyway it's sure looking almost like we have.

PH: It looks as if maybe 20 might do it.

AR: I think 20,000 ft is a pretty good altitude. By the way, in this area you can see ahead there's all that cold, but I see a full 22° halo. So there's ice out there.

PH: Larry, it looks as if 20,000 ft might do it for us on the return trip to the southwest.

LS: Okay. We're there now.

AR: We're coming into that saddle region and there will be very few if any ice crystals here for a few minutes and then we'll go back into that second enhanced area down at the southwest end. That again would be merged with the highest cirrus and I can see some uncinus out there, little fall streaks, very fine fall streaks in that higher cirrus ahead and to the left, to the southwest.

PH: As we head back to the southwest, Art, you just tell the pilots to adjust the altitude as you see fit.

AR: My guess is there's not much between where they're falling from. We're probably looking at a kilometer above us in that highest layer. So I don't know if there's any need to go up to 22,000 to 24,000 ft to get that stuff unless you think there's a real need for it. It would look gorgeous on the CPI because that's what it's made to do is to capture those tiny guys and maybe that's worth doing.

PH: I think we're more interested in what's reaching this level than what is above us.

AR: Yes. I doubt the radar on the ground is going to see this cirrus uncinus up there that's putting the crystals out.

PH: Larry, so what all this means is we'll go back at 20,000 ft.

LS: Okay. What's your plan for going down for that next leg?

PH: On the return to the northeast, which will probably be our last leg, I would just like that low altitude of 2,000 ft or whatever puts us into the precip below cloud base.

LS: We'll see what it looks like down there anyhow.

AR: It looks like we should be coming into a few crystals almost any second now. Getting the full halo again off the left wing.

11:00 AM

LS: Peter, on the way home, are you going to want to go that Olympic transition route there?

- PH: Let me check on that. I'll get back to you.
- AR: I'm flying right at what appears to be an ice cloud top looking out the right wing. In fact it resembles it very much because of its brown color and the blue sky above it a haze layer. Still seeing the full halo on the left though as we have deeper ice clouds and less indication of a top off the left wing. So we're flying in a transition zone or a sloping zone of ice crystals. Above us we have cirrus fibratus and a small cirrus uncinus.
- PH: Larry.
- LS: Go ahead Peter.
- PH: There will be no need for the Olympic Mountain transect today because there is no precip over the Olympics.
- LS: Okay.
- AR: That's right. You can see those mountains quite clear as we got to our endpoint a couple of times. Looking at that fine structured cirrus above us, I believe that is nearly formed cirrus in which the crystals have not yet gotten to this height. Ahead though is older cirrus.
- PH: Getting a few little ones on the CPI but very few.
- AR: Ahead is a mass of older ice clouds.
- PH: Adjust the altitude if you need to, Art.
- AR: He's coming into this heavy stuff now that seems to emanate from the very highest, oldest cirrus. Do you those concentrations and particles should be increasing pretty rapidly here over the next minute?
- PH: Actually we're almost due west of the Westport radar here and John just told me that the back edge of the rainband is just about over the radar now. So as we head southwest, we should come out of it pretty quickly according to the radar.
- AR: Again, when you get to this level, you don't know with the radar in the up position and you don't know if there's anything down there. This may just be from the ground with a patch of cirrus/altostratus with nothing anywhere near the ground.
- PH: Do a little switch to the looking down.
- AR: Yes. I'm going to do that.

PH: And then put it up again.

11:03 AM

AR: Don's gone over to switch it now.

PH: Art, I'm doing the flight scientist forms and the other form today, but you might want to draw one of your sketches showing the various clouds and interactions that we can put into the log today.

AR: Roger. The radar in the down position is indicating precip to the ground. It's probably not very much, but it looks like it's virga. Then it almost disappears and then it looks like a bit of enhancement just before you get to the ground. So perhaps a stratocumulus layer that a few particles are falling into and then they're able to survive and grow a little bit. Interesting, take a look down and see if I can see anything down there.

PH: I'm going to talk to John.

11:04 AM

AR: Looking down the bubble it certainly looks downward from the side bubble here, it certainly looks solid all the way to the ground. I can't see right to the sea surface or something that would be a dead give away if it wasn't reaching the ground.

11:05 AM

AR: Continuing to have a faint halo off the left engine. It's kind of an amorphous cloud and not much layering indicated until just in the middle of the sentence that we're starting to see a breakout here. The lower clouds on the sea surface are now becoming visible. They are not visible, however, on the right wing indicating that there are more ice cloud and fall streaks off the right wing.

11:06 AM

DS: We are getting some good images nonetheless, Art.

AR: Roger Don.

11:08 AM

PH: So we're heading back. We're almost there actually back to our southwesterly point at 20,000 ft; although we chose not to climb right to the highest cloud, but rather to fly at 20,000 ft to sample the crystals falling from that higher cloud into the cloud decks below.

AR: One thing that occurs to me, Peter, the crystals in these deeper areas of the ice cloud have been bigger than I thought they would be. I'm just wondering if maybe going up another 3,000 ft to really get those small guys would be worth it, so it would make the gray profiles start a little tinier if they were crystal.

PH: Yes. Okay. I mean another leg, but we can do it. I think we've got time.

AR: Are we kind of heading southwest now so we just go up on the way back home and pass over a previous leg and then head home, would that do it?

PH: I want to do the lower leg as well, so we have to go back to the northeast and then back out again to the southwest at the lower leg, you know, that 2,000 ft leg.

AR: Roger. Say if these crystals are millimeter size as you can see them fly by, you know, almost a millimeter in some cases. So there's a far amount of gray going on up there even though we'd be out of cloud for a far amount of time too.

PH: Let me talk to Larry. Larry?

JR: He's in back, Peter.

PH: A little change in plan. I'd like when we get to our southwest point to climb to 23,000 ft and head back toward the northwest at 23,000 ft.

JR: Okay. You want to climb to 23,000 ft at this point and head back.

PH: When we get to our southwest point, yes. We're not quite there yet, are we?

JR: We've got about 6 miles to go.

PH: Then let's climb to 23,000 ft and head back and then the final run will be out to the southwest at the lowest altitude we can get and then we can head home.

JR: Okay.

11:11 AM

PH: I think we can do our climb here, can't we, Art? We're pretty much broken out.

AR: Yes. I don't see any reason why. We're not out of the ice crystals, but we're out of the main stuff.

PH: Jerry, let's do our climb to 23,000 ft here.

AR: Something resembling cirrocumulus up here above the aircraft, although I think it's ice. It has the little cloudlets.

11:12 AM

PH: I'm getting columns and plates on the CPI now.

AR: I notice in this area that the crystals are noticeably smaller.

LS: Okay guys, the oxygen is available. The cabin is up to about 11,000 ft now. You'll probably want to start using some.

PH: Okay Larry. So we're going to head back to the northeast at this altitude, which will give us those little crystals coming out of this highest cloud. Then we'll do a spiral descent at that northeast point down to as low as they can allow us to do our run back out to the southwest and that will be it.

LS: Okay.

AR: This is very reminiscent of our work in the Arctic where we'd see this sort of amorphous cloud and then a highly structured cloud seemingly very thin topping it out or maybe even with a little separation.

11:14 AM

PH: We're -38°C here now.

AR: Above us we've got that fine structured cirrus and some of it we're actually in it. I'd say there are maybe three sets of thin, thin layers of cirrus right above us some of which we were actually partly in just a minute ago.

DS: Does it show up on the radar?

AR: I'd be amazed just because the crystals are going to be so darn small, but you can try it.

DS: Okay. Sounds good.

AR: Peter, looking off about 2 o'clock there you get a nice view of this layering and this kind of amorphous cloud below the structured cloud.

PH: Right.

AR: If you look and watch the stuff go by, there are certainly three layers, the one that we're in (we were just in a second ago), and there will be two or three layers above us.

PH: Well that's the old story of hunting cirrus, you never quite do it.

AR: Well I guess so.

PH: Lots of stuff up here, but I think we're just about at our 23,000 ft.

11:16 AM

AR: It looks like we're going to be at the top of the main amorphous layer and the structured layer doesn't appear to be shedding very many ice crystals down into this more fog-like ice cloud that we're just popping out.

11:17 AM

AR: Back there and still here we're seeing ice crystals in the tops of the main precip layer and complicated structures above us that for the most part do not seem to be shedding ice crystals in this position, although there is an uncinus and fibratus aspect to it. It looks like, at least going by the right wing, now maybe one of the trails does go into the amorphous cloud.

PH: What's the cabin altitude here, Larry?

LS: The cabin is at 12,200 ft, Peter, and your oxygen is available.

11:19 AM

AR: Still see ice crystal cloud going rapidly by the plane indicating that we're near the tops of that cloud and then moving much more slowly as the well structured highest layer having some striations in it. The ice cloud here is fairly thick judging by the fact that I can't see the higher ice cloud very well. The sun is not producing a halo that I can detect. Well maybe there's just a hint of one now. We must be going into some thicker ice cloud.

11:20 AM

PH: We made our southwest point and at that point we climbed to 23,000 ft. It puts us near the in and out of the tops of this cirrus and we're heading back toward the northeast point at this altitude.

11:21 AM

AR: Conditions continuing as before. Flying in a pretty good amorphous ice cloud region here producing a halo, visible halo behind us.

PH: It still seems to be mainly junk crystals on the CPI.

AR: I think Tim called some of those nuggets. Anyway that's another name for them.

PH: There are all sorts of irregular shapes. I would have expected to have seen some symmetrical crystals here.

11:22 AM

DS: How is the 1-D looking to you, Art?

AR: Hang on. I haven't checked it in a while.

11:23 AM

AR: Yes. Excellent. Looking at the concentrations of over 100 per liter and that's kind of what you'd expect up here as the crystals get smaller then they go into the 1-D probe instead of the 2-D and the HVPS and all that because they get smaller and smaller.

DS: Yes. Good. I've been watching the bar graph, but I haven't been looking at any actual numbers. I took another background for us when we were turning around because everything got pretty quiescent and the CPI is doing a little bit better.

AR: Yes. We do have a little broken out, but there is a saddle I believe up ahead. But it maybe that we're just too close to that higher layer. I'll let you know. I'm still looking for that and I'll let you know when it comes.

DS: Yes. We need to do something with that. Any fall out would probably be best.

AR: I don't know how much the camera and those heaters like this  $-40^{\circ}$  air.

DS: They're not keeping up with it.

PH: That J-W is still reading  $0.03 \text{ g/m}^3$  here where it should be reading zero, so it's drifted up again.

DS: Yes. I can't get it any closer to zero without falling too far off the other side.

PH: Okay.

DS: That's a bad spot.

PH: The CPI images are much darker now than they were at the beginning of the flight. They're not as clear as they were.

AR: We were talking about that and looking for a clear spot where SPEC suggests taking a background when the camera gets a little out of kilter. They say it's best done when you're out of crystals.

PH: Okay.

11:25 AM

AR: I think these last two passes are going to be pretty good because of the drop in crystal sizes aren't estimating. The normal size must have been at this level about half or less of the size we saw down at 20,000 ft, which infers a lot of gray in this upper part of this cirrus. I don't know if there was that much gray down below there it seemed like each level pretty much had similar crystals, but I'm not exactly 100% confident of that.

PH: How much higher is the cirrus above us?

AR: By the rate of movement, it's probably another 3,000 ft to that highest wisp that we see going by, maybe 4,000 ft.

PH: Yes. It's always higher than you think.

11:26 AM

AR: In the next 30 s we should be clearing the crystals. In about 30 s from now we should be crystal clear.

PH: Maybe that's where that term originated, crystal clear.

AR: Yes. Here's a good spot, Don. Peter, there's nothing ahead at this point in front of us.

PH: Okay.

AR: Peter, a nice uncinus back behind you there about 4 o'clock, 5 o'clock.

PH: Yes. I'll give Don a chance to get the background before we start descending.

11:29 AM

AR: It looks like a little droplet cloud top off there just ahead of the right wing and below, out about 4 or 5 miles.

DS: Okay. I got us a good background.

AR: Great.

PH: Larry?

LS: Go ahead Peter.

PH: As we head toward our northeast point, we can start a descent now, but let's do it about 500 ft/min.

LS: Okay Peter.

AR: That could be 46 min to the surface.

PH: Well I want to be in cloud as we sort of near the main cloud top as we come over the Battelle site, so that we do most of our descent over the Battelle site.

AR: I got you.

LS: Peter, I guess I cut you out there. I was talking to the Center.

PH: Sorry. I was meant to be talking to Art. It's okay.

11:31 AM

PH: So Art, I think at this rate of descent we may sort of get into cloud and do our main descent over the Battelle site.

AR: That would make a nice crystal graupel flake. It looks like the tops there are going to be quite a bit lower than what we had back offshore though.

PH: On the 2-DC I'm getting just lines. Oh, it's come back online now, very small particles.

AR: Yes. It's from that cirrus just above the flight level here and actually we're going into it now. A little patch of cirrus there that's what did that.

LS: So Peter, when we're over the point, do you still want to maintain that 500 ft/min let down?

PH: Yes. Are we clear to do a low-level run out to the southwest?

LS: Not yet.

PH: They're working on it.

LS: It's going to take us about 40 min to get down.

PH: Maybe we can speed that up a bit. Let's go down at 1,000 ft/min.

LS: Okay.

DS: Be warned that the probes may fog at that rate of descent.

PH: Yes. That's why I was trying to keep it slow, but I don't want to spend 40 min doing a descent. My feet are too cold.

11:33 AM

AR: What was our peak altitude? It was 23,000 ft wasn't it?

PH: Yes. 23,000 ft.

AR: We're descending now, right?

PH: Descending yes. We're near 20,000 ft now.

AR: For a minute I thought he was going to hold at 23,000 ft and then go over Battelle from 23,000 ft.

PH: That's why I had him go 500 ft/min as he approached Battelle.

AR: Roger. It's really clear out there now. Whenever we go away from Battelle it's probably not going to be exactly what's over Battelle. You can look out the window and see how "noisy" it is cloud-wise.

PH: Yes. Battelle doesn't really matter because it's not a situation they're particularly interested in. So it just be for our own benefit we're doing this descent.

AR: Roger.

PH: What we're looking for for them is an all water low-level stratus cloud.

AR: Yes. That's right. When you mentioned that I remembered that is what their goal was in IMPROVE.

11:34 AM

PH: We're just over land now and we'll do a spiral. We've been descending for a few minutes, but we'll continue our spiral descent down to 2,000 ft just over the north Binet site.

AR: We're coming into a thick fall streak here from a heavy patch of cirrus popping out above the aircraft.

11:35 AM

LS: Peter?

PH: Yes.

LS: I think we're going to have to steepen up our descent because we're basically going to run out of time getting down to that endpoint if we don't get down a little bit quicker.

PH: Steeper than 1,000 ft/min or will that do it?

LS: Well less than 1,000, how's that?

PH: A 1,000 ft/min is fine. The reason I don't want to descent quicker is it fogs up all our instruments.

LS: Okay.

PH: Also Larry, we're not going to have to go all the way out to our southwest point at that low altitude. I think we'll break out before we get about half way there.

LS: Okay. Do you want to be below clouds if you can?

PH: Yes. In precip below cloud.

LS: Okay.

11:36 AM

PH: Larry, in this descent we want to go through as many of these cloud layers as we can that we've been working our way up through.

LS: Okay.

11:37 AM

AR: Definitely some little altocumulus clouds above the aircraft now and they do have some ice crystals falling from them. I don't know if we went through any or not. It's possible in that fall streak that we went through some droplet cloud. It would put it in the  $-30^{\circ}\text{C}$  range.

11:38 AM

PH: I just spoke to John at the radar site and the rainband is weakening, but what there is of it is pretty much between the S-Pol radar and the north Binet site. So that's where we're going to be going through it out on our southwest track and we'll break out of it about half way out toward our southwest point on our low-level pass. So that's when we're pretty much finished with the profiling.

11:39 AM

PH: A very bright subsun.

11:40 AM

AR: It looks like the HVPS has gone out on us.

PH: Misted up.

AR: I think that's what causes that.

PH: So 1,000 ft/min is too much for it.

DS: I think it might be fine. I mean the FSSP is not active, the OAP is not active. I'm getting an occasional thing on the 2-DC, but they're real, real tiny.

AR: I get this big green square in the middle of my HVPS image.

DS: That's just the diagnostic record.

AR: It just went away.

DS: Yes.

AR: Did you do anything?

DS: Nope. That big square is a display of a diagnostic record.

TW: Actually on that particular one, I think that one is just from the HVPS has problems descending and I think part of the lens gets filled up with water or something like that and just reads that piece of water for a really long time.

PH: Yes. That's why I didn't want to descend faster even though it's going to take us about 20 min to get down to 2,000 ft because on that low-level pass the HVPS will be important. So I hope it comes back up.

DS: It looks like it's basically back up already.

11:42 AM

Flight 1850

AR: We're descending over PNL in which is just an ice cloud. It looks like it may go close to the ground.

PH: Larry?

LS: Go ahead.

PH: Let's try descending a little bit faster maybe 1,300 ft/min.

LS: Okay.

PH: I can see we're sort of running out of time here.

11:44 AM

AR: Yes. It looks like we're just going to be in crystals pretty much most of the way down. There's no sign of any droplet cloud in that area at least of any coverage. It's probably still further offshore. I can see a little irisation as I look at the sun and the altocumulus up there confirming the liquid phase. This is a patchy thin altocumulus by the way, I should say, not covering more than scattered. Probably more like 30% coverage at this point in the vicinity of the aircraft. Most of that is located to the west and southwest.

PH: For the tape this is IMPROVE IAP #4.

11:46 AM

PH: Just going through the  $-10^{\circ}\text{C}$  level.

11:47 AM

PH: Is your HVPPS still blocked out, Art?

AR: It was as of a minute ago. It came back as Don indicated earlier and then it went out again on the way down and now it's working.

PH: Okay.

11:48 AM

DS: Art, the width of 1-DC from side to side is about 1 cm forward resolution.

AR: The 1-D probe is 20 microns.

DS: Probably not the 1-D but the 2-DC.

PH: The CPI doesn't seem to be working.

AR: Yes. It really suffers from that condensation effect going down. That was a perpetual problem in KWAJEX.

DS: Yes.

AR: Don, in the vertical with the particles that are topped out are 800 microns, so it would be the size in the vertical.

DS: Yes. That's from side to side is about 800 microns?

AR: Right.

DS: That's on the 2-DC?

AR: Right.

PH: Yes. Roughly a millimeter from top to bottom. No sizing really that's useful on the HVPS is there on this display because the images are so small.

AR: Right. You should be able to pull up a histogram of sizes.

PH: Okay.

DS: That's on SPEC's software that never worked. I'm not sure we have that built into ours yet.

AR: Isn't that the lower window? Right now it should be the one on the lower left if you pull that up. I might not be remembering that correctly maybe that's from KWAJEX.

DS: On the windows there is a deeper window and a housekeeping window.

AR: I'll show you what I mean.

PH: We're near 4,000 ft now, -3°C.

11:50 AM

PH: Art?

IS: Peter, we're heading for the point now and we're out of 3,500 ft. Do you want to get below these little scattered clouds out here?

PH: Yes. Just below those bases and head out toward out southwest point and hopefully we'll pick up a bit of precip if we're just below cloud base.

LS: Okay.

PH: This rainband we've been working is dying out on us and it's basically situated between this location and Westport. I think as we go further south beyond Westport we'll run out of it.

LS: Okay.

AR: Yes Peter.

PH: On this histogram you just pulled on the CPI, what's the difference between the red and the green?

AR: I didn't remember off hand. I think one is particle counts and maybe one is concentrations. I remember what it is. One includes all the particles and the other one I think is the particles that have been photographed.

PH: Because they look quite different. One is a nice histogram, you know, it has a nice peak and the tail to it. That's the green. The red is a bit more erratic.

AR: Yes. I'll have to read the manual again, but I'm pretty sure that's what it is. There are two concentrations available for that and one is based on the camera, which is only a few particles and might look irregular. So I'm guessing that's the red one. Then one is based on all the particles we go through.

PH: I think it's probably right because the red is labeled particle total 30 and the green is labeled particle total 306.

LS: Peter, we're down at 1,500 ft now and it looks like we're going to be just below that cloud base up ahead of us.

PH: Good Larry.

AR: Yes. That would make sense. You'd get a better profile with the bigger number.

PH: We're just coming up to the shoreline. We're over land at the moment just coming up to me shoreline heading southwest. Some scud below us and main cloud base above us. Larry is going to try to bring us down below this lowest cloud below us, Art, but why don't you work with Larry to fine-tune this to get us into any precip.

AR: Roger.

PH: It may thicken up a bit as we head southwest at least for a while it may thicken up.

AR: Right. That's just exactly what will happen.

PH: Past the shoreline and over the water now.

AR: Right. He's at cloud base right now. He's just passing under the last little wisp of low cloud before we go into a huge area which we'll just underfly sort of altostratus/nimbostratus without much lower cloud.

PH: Okay. I'm not picking up anything on any of the probes at the moment.

AR: Right there with that little turbulence was a little stratus fractus. It might have got in the FSSP. We might have been just below it.

PH: I'm not getting anything on the CPI.

AR: Right. There's probably no precip to the ground here. This is stuff that is falling out but didn't quite make it to the ground. It got down to about 3,000 ft on the last time I saw anything on the 2-D move. Then I look again. We're picking up some noise on the 2-D right this second.

PH: None of the imaging probes are picking up anything useful at the moment.

AR: Right. But as we head in this direction, we'll be heading into some very, very light rain reaching the surface.

PH: I guess that's what we want.

AR: This looks pretty well tuned to just about the best part of it.

11:55 AM

PH: What's our altitude, Larry?

LS: About 400 ft.

AR: Now coming into view are some lower stratus/stratocumulus clouds underneath this higher precipitating layer.

DS: The 2-DC is kind of acting like it maybe fogged up.

PH: The 2-DC and nothing on the CPI either or the HVPS. It looks as if that descent killed us.

DS: I'm starting to get a little bit of stuff on the HVPS now, but the 2-DC is kind of acting like it may have fog or something on it. The FSSP and 1-D probe are working however.

AR: I think the 2-DC will work here in a minute once we get some raindrops. For some reason it seems to fix itself when it does this when you get into some precip.

11:56 AM

AR: This is a little different looking sea than we saw the last time out here I'll tell you that.

PH: We're not seeing anything here, are we? There's no precip or anything here.

AR: I think there are sprinkles ahead, but that's all we've got coming out of this to the ground.

PH: Do you think we should go up a little bit higher?

AR: We're going to be coming under some clouds here shortly.

PH: We'll stay here then. We're under some thicker cloud now, right?

AR: Right. The last flight Larry was estimating that the swells were 20 to 30 ft and the surface was about 40 to 45 knots. They were the biggest white caps I've ever seen. I swear some of them were as big as football fields.

PH: The 2-DC is looking strange now. The CPI is trying to do something.

AR: I'm beginning to wonder now if I didn't mistake this sea haze for some sprinkles. We're going to be flying under this stratus/stratus fractus back here. I think any drops now are going to be few and far between that make it down here because they've got to come from that higher layer completely.

PH: Should we go up?

AR: Yes. I'd say we're going to have to go up to 2,000 to 3,000 ft to even see anything dropping out of this.

PH: Larry, let's climb 1,000 ft.

LS: Okay.

11:59 AM

PH: Just went through some thin scud, the lowest level cloud, as we started a little climb here.

AR: Peter, I just went up to the window there and we are in a few very, very light sprinkle here. So we're just not seeing it on the 2-D.

PH: We're not seeing it on anything are we?

AR: It's something you might see on the CPI, but I kind of even doubt that because the sample volume is pretty small on that thing.

PH: What about the 1-D?

AR: I'm going to check.

TW: Don to "chat"

PH: I don't see anything on the 1-D at the moment. We're between layers here. We're just above this broken scud.

AR: I think the HVPS is picking some stuff up. There are definitely some raindrops out there and I think its bigger volume is helping it. If we were standing in the rain, you'd hardly even notice it was raining it's that sparse.

PH: It's the same looking out in the rain ahead.

AR: What?

PH: No change looking ahead.

AR: Right. There's nothing better or worse ahead. It will continue doing this for probably another 5 min possibly.

PH: Not too much more we can do here really, is there?

AR: Not really. You can see the lower cloud. Until we get pretty much under the back end of the altostratus here that's producing this pickle, then you start to get in some heavy stratocumulus and it has a little cumulus bubbling in it and very moderate bubbles ahead anyway. That probably would have some drizzle or warm rain in it, but that may not be related to anything you're seeing on the radar, I don't think.

PH: Okay.

12:02 PM

END OF TAPE 2, SIDE 1

AR: Peter, now we're not even getting drops on the window. So I think maybe even though the cloud doesn't look any different to me, I suppose we could have a few more sprinkles ahead because ahead would be that enhanced area of cloud tops that we kept flying into at the southwest end. There may be a sprinkle or two at the southwest end.

PH: I think we've done enough now, Larry. We can head home.

LS: Okay Peter.

PH: Thanks very much.

LS: Right.

AR: Right. Because what's a sprinkle you know. We'll go back through it as it's coming over this way anyway. I think it's dissipating by the minute.

12:03 PM

TO SUMMARY

12:18 PM

TW: Art to "chat."

12:19 PM

PH: Larry?

12:22 PM

PH: Larry or Jerry? Picking up CPI images again as we go over the Olympics here.

12:23 PM

PH: Lots of HVPS images and CPI images in the lee of the Olympics.

12:25 PM

PH: Even though this wasn't designed to be an Olympic transect, it maybe of some interest. Getting nice particle spectra plots, histogram plots, on the CPI.

12:28 PM

PH: We should keep it going. There's good data in the lee of the Olympics. When we come back, these transects are important. Has anybody been looking at the video to make sure they're okay?

DS: I don't know.

PH: On earlier IMPROVE flights?

DS: I don't know. I haven't. But if I can see it through my window here, then it's being recorded.

PH: Yes. We'd better get Debbie to listen to one of the IMPROVE tapes.

DS: We've already talked to her about that and it's not much better.

PH: Okay. She's way behind. She's really hardly got going on the SAFARI yet. It's not that she doesn't work hard, she does, but it's just piling up.

DS: Yes.

12:30 PM

PH: We've continued to get good imagery on particle cloud measurements as we head in to Paine Field.

12:32 PM

GG: Interesting coincidence, we got a GPS glitch right at the same place going out and coming back.

PH: I wonder if that could in any way be associated with the NEXRAD radar on Whidbey Island?

GG: That's a thought, a factor of two in frequency.

12:36 PM

GG: Is that on Whidbey or Camano?

PH: Whidbey I think. But if we got it from that radar, you'd think we'd get it from the S-Pol as well.

GG: Yes. They should be fairly close in frequency.

PH: We seem to be over shooting our destination. I guess they like to come in from the northwest of it.

GG: I'm sure that Air Traffic Control is telling them where to go. It's probably for traffic clearance considerations.

12:37 PM

PH: Have you been watching the roll angle at all, Grant?

GG: I have. It seems to me that we had, at least here in the Seattle area, a built-in bias of about 1.3°. I made a little modification of my personal definitions file to take that out. What I'd like to do is get the plane out again on the ramp and carefully measure again the apparent roll angle and then make sure we have that number plugged in properly.

PH: Okay. It's not important for this project. That's something to leave to when IMPROVE is finished, but it will be important next summer.

GG: Right.

PH: The CAR will be back aboard next summer for CLAMS.

12:38 PM

PH: We're coming in for our approach. Let's keep the instruments on as long as we can.

12:40 PM

PH: Still getting good measurements as we come into our approach to Paine Field. Getting more rain here than we had out on the coast.

12:41 PM

PH: Coming into land.

12:43 PM

PH: You can switch the CPI off now.

12:44 PM

PH: Should I turn this power switch off here?

DS: One more time.

PH: Turned the power switch off on the CPI?

DS: Yes.

PH: I'm turning it off now.

DS: I'll take care of that one as I bring the rest of the system down. I'm in the process of copying the data right now and that's going to take a few minutes.

PH: Good landing by Jerry.

DS: He's getting more practice. All these guys when they first start flying this thing it takes them a few landings to figure out where the heck the wheels are.

12:45 PM END OF TAPE

#### Summary of UW Flight 1850

12:03 PM

PH: I'm going to start the summary. We've been working a fairly weak rainband but well defined on the radar. Initially situated fairly stationary southwest of the S-Pol radar. As the flight went on it moved a bit toward the northeast and ended up mainly between the radar and the north Binet site. It was well defined but weak rainband associated with an occluded system. I'm not quite sure whether it was a cold frontal rainband or warm frontal. But we worked it pretty well at many different levels, starting off at 4,000 ft, then 3,000, 5,000, 7,000, 9,000, 11,000, 13,000 15,000 and then 20,000 ft. Then at 23,000 ft as we went backward and forward between our southwesterly point, which was about 40 miles southwest of Westport. Our northeasterly point, which ended up being pretty much the same for all those legs, was the north Binet site where Battelle NW was also operating their microwave radiometer. The big news on this flight was that all our imagery was up most of the time. That was the CPI and the HVPS, as well as the 2-DC and 1-DC. That's the first IMPROVE IOP where all the things we really need were working. So that was very good work by Don, Grant and Tom to get all that finally up. We're now heading back. Art, do you want to jump in?

AR: Roger. The synoptic situation was a very weak low-pressure center located offshore of Astoria and light offshore flow and the trough moving into the coast was actually moving into the coast as an upper-level ridge was building along the coast. So it wasn't much of anything that's for sure. Our passes today, as far as the clouds go, are the first pass started out at about 4,000 ft. We dropped down to 3,000 ft to get into some clouds that along the coast had very minimal droplet cloud much like we have right now, scattered cumulus fractus, stratus fractus. Then as we penetrated further offshore as is the case now, we intercepted increasing amounts of stratocumulus that virtually reached our flight level at

3,000 to 4,000, 5,000 ft. In that we saw, I'm going to have to back up here a little bit. We intercepted a layer at about 4,000 to 6,000 ft that was located (this was on our first pass to the southwest I believe it was) in the Hallett-Mossop rimming-splintering zone at very, very low droplet concentrations in the 10s per cc. It was providing a target for the aggregates that were falling from the deep altostratus/nimbostratus layers piled up over this to apparently cause rimming and splintering. Not only did that occur, but in that  $-3^{\circ}$  to  $-8^{\circ}$  temperature zone, but there were also times when there was supercooled drizzle and supercooled small drizzle drops of the 100-micron variety. So that broad spectrum provided in that cloud provided an interesting aspect to precipitation development in this system, which otherwise would be on the minimal side. Above that layer, we intercepted no liquid water and it was all just a matter of depositional graupel as near as I could see on the crystal types. That continued up to the 20,000 ft level when then we saw that perhaps we could tweak cloud top level a little bit. Then there was a larger drop-off in size from the 20,000 to 23,000 ft level suggesting that that near cloud top region was an area for very rapid growth of ice crystals. Then, if my memory serves me right, a slower growth all the way down until that interesting interaction with the Hallett-Mossop stratus/stratocumulus cloud located I think it was 4,000 to 5,000 or 6,000 ft that we intercepted on one of our first legs in the southwest track.

PH: Art, let me interrupt you here. As we head back home, and as we climb through 6,000/7,000 ft just to the north of Westport radar, we're going through probably the strongest part of this rainband. We're getting good images on the 2-D and on the CPI. The rainband is actually strongest now over the land, as it has moved toward the northeast during the course of this flight. So the climb we're doing now up and over the Olympics should document the rainband as it moves over the land.

AR: I notice I was starting to repeat myself like most older people, but I wanted to finish up by saying that there also are some embedded altocumulus clouds. We didn't actually sample them, but some can be seen off the right wing now up in that  $-25^{\circ}$  to  $-35^{\circ}$  C temperature zone. We just didn't happen to hit any. The other thing our experience at cloud top was very reminiscent of what we saw in the Arctic kind of an amorphous fog-like cloud with crystals gradually diminishing in size with height. Then above that we have this very complicated structure of lowering and striations in an often completely separate cirrus cloud. That would have been located in the 25,000 to say 30,000-ft range. That would have been like fibratus and uncinus-types of cirrus.

12:11 PM

AR: Along with that I just remembered to mention the risings and the saddle, the humps and saddles, in the cloud top in these banded structures that we saw. That was in the lower amorphous fog-type ice cloud.

12:12 PM

PH: I just asked John to do an RHI out toward the northeast from the Westport radar since we're getting good measurements here as we head back home in that direction. Any more summaries from the engineers? Anyone want to say anything?

AR: They might be on "chat."

12:13 PM

AR: I can mention that the radar worked really well for the first time on the downward position.

GG: The previous problem was due to the wave guide of the antenna being cross guided.

PH: I can't hear you very well, Grant. Can you speak closer to the mike?

GG: Okay. Usually I wind up over driving it. The radar had the antenna cross guided. That's why we weren't getting anything out at the bottom. Now it's operating well enough that we can actually see the airplane on the second return.

PH: So the radar is working well both looking upward and downward, but we're still not recording. Art's made some comments on the tape of what he's been seeing on the radar. You're going to draw those sketches of the cloudscape, Art.

AR: Right.

PH: Go ahead Grant. Any more?

GG: We also noticed in the ever none ending chase for this noise problem that when we got up to altitude around 20,000 to 23,000 ft all A-to-Ds, except for a couple that I think we know where the problem is back at the instrument, they all quieted down. So there's something very strange going on here.

PH: Don, anything?

GG: It can even be as odd as electrostatic discharge from the aircraft or something like that.

DS: Well, Art's probably already said it but all the probes that Grant and I worked on, the 2-DC, HVPS, CPI and 1-DC, and the radar all worked this flight.

PH: Very good. I think you should all take 2 days off.

DS: I'll probably sleep for 2 days.

PH: Does Tom have anything to say?

TW: Not really. Just along for the ride.

PH: As I said in my e-mail to you, now that we're much better off in terms of having things up at least for a while, the three of you can sort of trade off so that we only need two onboard probably.

TW: I do have a new map available that I'll probably put on for the next flight. It's a little cleaner than the last one. A little better colors than yellow and blue.

PH: Actually this map is pretty good. The only thing that I suggested on an earlier flight is that you extent it a bit further down toward the southwest.

TW: Yes. That's what this one does actually.

PH: Okay.

GG: Also, Tom, I'd just like to say that all your effort on the HVPS and the 2-D have really paid off. It's pretty darn clean.

DS: Yes. We're into the third or fourth rendition of the 2-D software as we eliminated hardware glitches and allowed Tom to eliminate software glitches.

TW: Yes. There's just a couple little blips left and I think we'll figure those out real soon.

PH: Something you could add to the 2-DC imagery is a digital readout of the concentration.

TW: Okay.

PH: The number of particles per liter would be a good number to have.

TW: Yes. I'll have to go over with Art on how to compute that.

PH: Okay. It's looking good. All the displays are looking good.

12:17 PM

GG: Notice that the J-W has gone berserk now.

PH: The J-W at the moment I'm reading zero. You say it's gone berserk. It looks okay.

GG: Maybe this was about 12 min ago actually it was pretty noisy. Oh, I'm sorry.  
That was PYRANOMETER UP.

PH: Yes. Those look crazy.

GG: I've lost control of the mouse here for some reason.

PH: I think all the liquid water probes are okay except for the DMT as usual that's  
very noisy. We're not getting any signals. So it's just doing its noisy business.

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