TIMELINE FOR UNIVERSITY OF WASHINGTON FLIGHTS

Date: 13 Dec 2001

UW Flight Number: 1900

Goals of Flight: Cloud and precipitation observations in a vigorous storm for IMPROVE-II (1st of Two Parts)

Period of Flight (Engines on to engines off: UTC):
Engines On 2131; Off 0327 ⇒ 5h 56 min

Locations: Central Oregon (IMPROVE II - study area)

Weather Conditions: Strong WSW flow preceding a cold front associated with a vigorous storm.

Main Accomplishments:

This flight was carried out during a period of moderate-heavy precipitation in the study area in conditions of strong (40+ ms^{-1}) west-southwesterly flow. The SW-NE oriented stack flown by the Convair-580 mostly coincided with the lawnmower survey by the NOAA P-3. The positioning/timing of the aircraft was very good; the back edge of the main precipitation band tended to be right about at the SW end of the Convair's individual flight legs. The precipitation and clouds were quite deep, probably close to 8 Km at least near the start. Excellent data quality from the HVPS; some suspicious looking data from the 2D-C probes at times. The meteorological state parameters appeared to be reasonable. This flight represents one if not the best case study to date fro. IMPROVE

Approx UTC Time	Activity
2131	Engines On
2136	Out of Blocks
2143	Takeoff
2203	Ferry in Constant P
	2D-C down
2218	Winds 250 @ 28 ms^{-1} (15 K')

Approx UTC Time	Activity
2220	2D-C Back but Images
	Look Bad and suspiciously low
	concentrations
2230	Trying to restart 2D-C probe system
2244	HVPS temp. down (very shortly)
2249	Larger crystals on HVPS
2304	2D-C looking OK
2322	At SW Starting Alt.; Begin 1st Run
	20 K' Wind 250 @ 45 ms^{-1} T = -18, -19
2334	End of 1st Leg
2336	End Leg Heading SW (20-18K')
2352	No visual sign of back edge of band
2357	End of 2nd Leg
2359	Starting 3rd Leg Heading NE
	18K' Wind 245 @ 42 T = -16, -17
0005	S-Pol and P-3 reporting echo
	tops of 7 & 8 Km; latter seems more likely
0012	End of 3rd Leg
0015	Start of 4th Leg (18-16K')
0025	Everything working fine, appears
	to be low LWC (~0.01 g/m^3)
0035	Wind speeds dropping off 42 to 32 ms^{-1}
0039	End of 4th Leg
0041	Start of 5th Leg Heading NE
	16 K' Wind 250 @ 31 T = -14, -16
	2D-C looks kind of bad (will cycle power)
0057	End of 5th Leg
0101	Start of 6th Leg Head SW 16-14K'
0120	A bit more intense precip,
	stronger winds, & turb. at SW end of leg
0126	End of 6th Leg; CLR slot at
	flight level right at end
0130	Start of 7th leg Heading NE
	14K' Wind 250 @ 40 ms^{-1} T -12, -13
	Light OCNL MOD Chop in SW end

Report prepared by: Nick Bond

Date: 13 Dec 2001

303
817 0546

43 41.2 123 32.6 16K

Approx UTC Time	Activity
0141	Much more smooth
0145	End of 7th leg
0148	Start of 8th leg heading SW (14-12K')
0149	Locally enhanced winds over Santiam Pass (~48 ms-1)
0200	Some Riming and small Patches of High LWC
0217	End of 8th leg
0221	Start of 9th leg heading NE
	11K' Wind 255@32ms-1 T~-8
0228	Hitting some ChR patches
0229	2D-C out then back
0237	End of 9th Leg; considerable precip. in lee of Cascade crest (aloft)
0240	Start of 10th Leg (Stepped Descent)
0243	Apporently Cracked a window
	Short patches w/ precip in lee of crest 10K' T~-6°C
0257	Hitting MOD chop
0304	Shed Ice on Window
0309	End Last leg; Heading for EUG
0324	Landed EUG
0329	Engines Off

Report prepared by: Nick Bond

Date: 13 Dec 2001

Flight 1900
December 13, 2001
Voice Transcriptions*
IMPROVE-2

9:48 PM

AR: Just passing the freezing level here at 790 to 800 mb. It's about 6,000 to 5,500 ft.

9:53 PM

AR: No sign yet of droplet cloud here above the freezing level, which is good. The sky is dark, amorphous. No detail, that is, above the aircraft and all around the aircraft. Earlier, before we ascended so far into this, there was a lower overcast stratocumulus into which this precip was falling. There's no trace of any icing on the aircraft yet. Meaning I haven't missed anything so far while I was setting up a computer.

9:54 PM

AR: Tom, do you copy?

TW: Yes.

AR: Another problem, the 2-D was dead there, but now it's coming to life. It was imaging junk, noise, and now we're starting to get some images, so that's great.

9:55 PM

NB: Hey Art, Nick here.

AR: Roger Nick.

NB: What liquid water measurement would you recommend?

AR: Look at the FSSP integrated liquid water and L-W PVM. They are the two that are really tracking very well together, so there's some confirmation on what's out there.

NB: Okay. Thanks.

9:57 PM

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* AR = Art Rangno, KM = Ken McMillen, LS = Larry Sutherland, NB = Nick Bond, TW = Tom Wilson, ZS = Zan Sutherland

TW: For the record, it seems like the computer has booted up okay this time with full power. So we'll just let them keep running.

10:00 PM

AR: We're getting a pretty steady stream of little altocumulus-like clouds embedded in this thing at around 10,000 ft. I don't see any icing, however, on any of the airframe or anywhere yet. Nick, is the plan to go down there at about 10,000 ft, is that it?

NB: I was going to check with the front. I think typically we have gone at 10,000 ft through Puget Sound here, but I'd like to be 20,000 ft when we get into the pattern.

AR: I see. I'm, of course, a little paranoid about icing and it suddenly occurred to me as we flew through the freezing level that maybe we should go down near the freezing level about –2° and then that way we'd be ice free and then spiral up to 20,000 ft. Well, just a passing thought here.

NB: I'd better check with the front of the plane now about when we're going up.

AR: Right. There may be nothing up there.

NB: Ken, Nick here.

KM: Go.

NB: I just wanted to confirm that we were on the same page about our starting point. I assume that you're heading for 43°28.1' and 124°02.5'.

KM: Is that the extreme end of the southwest-northwest track?

NB: That's correct.

KM: Yes. That's where we're headed.

NB: We'd like to be 20,000 ft, if we can get there, at that point.

KM: Fine.

10:02 PM

AR: Tom, it looks like the 2-D has died.

10:03 PM

ZS: Nick, this is Zan here.

NB: Go ahead.

ZS: That lat/long you gave me, that's not the farther west point, right? Have you moved that in along that northeast-southwest track?

NB: Yes. That's apparently so. I just checked that out myself. So if we could head for that point that I gave you, that is the 43°28.8' and 124°02.5', I think that would be a good place to start.

ZS: Okay.

TW: Is it back, Art?

AR: Negative. It's not here. Maybe I should restart my display.

10:04 PM

TW: I need to cycle power on the 2-D probes. Is it okay to stop it just for a second? Okay. Let me know what happens, Art. You know sometimes the 2-D, when we get up high, it will quit working. Then right when we get to the study area you drop down like 1,000 ft and it starts working again. It looks like right now we're just getting blank strips.

10:06 PM

TW: This is kind of the main computer over here, so I don't like to run too much stuff on here. That's why I kind of look at yours instead of running it on mine.

10:08 PM

TW: Nick, what time did you have for engines on?

NB: I had 2131.

10:09 PM

AR: Tom, any thoughts on the 2-D other than cycling the power?

TW: I tried that about three or four times. I can do that again.

AR: Okay. That's not a good sign at all.

TW: On previous flights we've had it die all the way to the study area and then it starts up.

AR: Right. But I don't remember the blank images before. I remember it wasn't responding to particles, but I don't remember quite what we're seeing here. But maybe it has to warm up again. When we climb to 20,000 ft, I don't know.

NB: Yes. We're not going to get any warmer anytime soon.

AR: Right. I'm not sure it's related to warming up, but we just don't know what it is.

TW: All right. I'll try it again.

AR: It looks like as we climbed we exited that little altocumulus layer there at I guess it was 9,000 ft. I said 10,000 ft, but I believe it was closer to 9,000 ft on tans-alt. Oops. There's a little more up here at this higher level. That is a little droplet cloud, puff. No detectable icing however other than a little spot on the forward part of the dome here; but other than that I don't see on the airframe, other than that trace up there by the tail light.

10:11 PM

AR: Looking up it looks like I see some droplet cloud above the aircraft now. We're flying in snow.

10:12 PM

AR: This is at 12,100 ft now. I'm about 75% sure there's droplet clouds just above us.

NB: Is it possible it's just the display, but the data is actually being recorded on the 2-DC?

AR: I think it's what you see is what you get, but I'll let Tom answer that.

DS: You're right. On the 2-DC is what you see is what you're recording.

10:13 PM

NB: So if we don't have that, for the precip particles it's basically the HVPS is all we've got, right?

AR: That would appear to be the case because the other instrument that would cover the small sizes is not working properly either. That's the 1-DC.

NB: Do we know that isn't working or is has that just kind of started during the flight.

AR: No. That hasn't been working maybe for this whole project. I went back and looked at some of the spectra and Peter and Don Spurgeon are aware of that and they've had higher priorities like the CPI, which of course isn't on board either which really diminishes things too.

10:14 PM

AR: The 2-D looks like it's trying to come back, but the images don't look very good though.

10:20 PM

AR: Do you notice, Nick, that we had that droplet cloud. Actually, I mentioned we would top out one around 9,000 ft when we were going up to 11,000 ft, but it's been droplets all the way since about the time we reentered that higher layer somewhere around 11,500 ft. We are starting to pick up a little more ice here and there on the airframe.

NB: Yes. How are you able to tell these droplets aside from just seeing them on the icing?

AR: That's on the FSSP-100. Anything probably above 5, normally when there's ice out there, I'm sure you've noticed, a few counts on the FSSP per cc is probably not water, almost certainly not. When it gets up to 10 to 20 to 30, as we're seeing now, that's certainly water. It should be reflected in the PVM as well.

NB: Yes. I have noticed that the PVM has been running around 0.1 grams per meter cubed or so.

AR: To be honest, that might be more correct because the FSSP is going to be measuring some of those ice crystals and adding that into the integrated liquid water. So it does tend to run a little bit on the high side in these kinds of situations.

TW: It looks like the 2-D is giving us strips, but they don't look good.

AR: Roger that. It almost looks like the true airspeed isn't quite right, but I'm not sure. It's not really stretched out, but it certainly doesn't look like 25-micron pixels or shaping those particles.

TW: The true airspeed that we sent to it is on the display of the 2-D strip. It's 122 I'm sending it.

AR: Yes. Okay. It's not defaulting to 80 or something.

TW: No. It looks like I see a lot of the same particles go by.

AR: Welcome to ice crystal analysis.

TW: Well, I'm joking. I mean exactly the same particle.

AR: I know what you were saying.

TW: In the same position.

AR: I don't know how that would happen. An interesting observation, I'll keep watching for that.

NB: I haven't gotten the same impression.

10:23 PM

AR: Another thing I'm noticing here, Tom, is the concentrations don't look correct to me. They're down around a few per liter. I don't think that's quite right. I'm not positive, of course, but just comparing it with the HVPS and the amount of activity there.

10:24 PM

NB: I'm temporarily going offline here to talk to Mark on the radio and see if he has any status on the P-3.

10:25 PM

TW: Art?

AR: Roger.

TW: Was the 2-D ever working on this flight?

AR: Yes, it did.

TW: Okay.

10:27 PM

ZS: Nick, are you there? Does anyone back there have a wind readout?

AR: Roger. It's about 235 at about 60 knots.

ZS: Thank you very much.

10:31 PM

AR: Since I said that, it's turned out 240 at 60 knots. I don't know if 5° makes any difference, but we're closer to 240°.

ZS: Thanks Art.

AR: The 2-D has died altogether. The frames are not refreshing on the 2-D. We're flying in a tremendous amount of aggregates and ice crystals.

10:33 PM

AR: It's now updating again. That is the 2-DC is now updating again at 223310. Nick, are you online? Zan, the wind has come around a little bit more here just in the last couple of minutes since I talked to you. It's 250° now and it's 70 knots, some kind of upper feature, some real turning of the wind I think.

ZS: I'm showing 251° at 71 knots and I've got some stuff plugged into RGPS.

AR: Roger. It was 235° to 240° there. I was staring right at it, so something has happened here. Nick, are you available? No contact, he's on the radio.

TW: What happened, Art?

AR: Just the wind shifted a little bit up here in the last couple of minutes.

10:35 PM

AR: Tom, do you know if we can recover accurate 2-D concentrations?

10:36 PM

NB: Just for the record, our winds look to be about 8-10 meters per second stronger than forecast by the MM5 model at least earlier this morning. The directions look about the same as progged and the air temperatures are about the same but quite a bit stronger flow.

AR: Roger Nick. Zan was asking for a wind measurement back here a few minutes ago and I watched it for a little bit, 235°-240° at 30 meters per second, and then 3 or 4 min later it suddenly went to 250° at almost 80 knots at times. I don't know. It seemed like it was real feature. He was concurring if the wind was out at 250° now. Do we have a good 10-4 on the front?

NB: Yes. I haven't gotten into the details of the timing of the front itself.

AR: Roger. I noticed on the satellite imagery that there were two heavy bands. One big one right off the coast before we took off and then something a little bit lesser behind it, lower tops. It's one of those situations where either one could have been the front. Also we have the data line on the 2-D display that we determine what our 2-D concentrations are (in flight are) not correct. They're off by a considerable amount with the probe thinking that the whole buffer is only 1 particle. We're getting these 1 per liter, 3 per liter kind of concentrations where it ought to be up probably in the hundreds.

10:39 PM

ZS: For planning for everyone, about 36 min to arrive at our first westerly-southwesterly point.

NB: Thank you.

10:41 PM

AR: Tom, it looks like the 2-D imagery has quit again.

TW: I was just giving it a little break because what we're getting right now is pretty useless.

AR: You don't think you can recover the concentrations from what we're getting?

TW: We'd probably have to go through every strip and do it by hand.

AR: Yikes!

TW: Seriously, I mean there's line. It would be really ugly. You won't be able to do any kind of particle separation on the strips or anything.

10:42 PM

NB: It looks like the HVPS just kind of quit too.

10:44 PM

NB: The 2-DC is starting to look better.

TW: Yes. Glimmers of hope. We're starting to see timing bites.

10:45 PM

AR: The FSSP concentrations have dropped off to 012 and the visibility down the wing definitely improved noticeably. So there was something out there.

However, at the same time, the amount of icing that would have been expected from a tenth to two-tenths that seemed to be indicating back there did not accumulate. So I'm beginning to think it might have been just very little liquid water. Certainly the sizes of the drops are not being indicated correctly.

10:46 PM

AR: Sky continues dark, no sign of any thin spots.

10:47 PM

TW: I'm going to stop the 2-D probe for a second and do a couple more experiments.

NB: Art, look at how much bigger the crystals are on the HVPS now.

AR: Wow! Now we're starting to see some monsters out there.

10:49 PM

NB: Liquid water contents are sometimes up to 0.3 now also.

AR: I don't know if that's right to be honest, Nick. Because now that we've been going through this tenth of an inch FSSP liquid water, there just has not been the ice accumulation that you would have had over an hour to 30 min or something like that with that kind of liquid water content. So I think it's seeing more ice maybe than I gave it credit for.

NB: Yes. It was just kind of a burst there. For the most part, it was 0.05 or so.

AR: Right. But the FSSP, if you look back at the long record, it had a long, long spell of 0.1 or 0.2 g m^{-3}. Yet, I wasn't seeing anything build up on the tail light back there like I would normally see on this structure or our radiometer right next to the bubble. So I think maybe either the drops are smaller. I think there are drops out there, but I think they're just smaller than what the FSSP is indicating, which puts them in channels 8, 9, 10. That would be up around 25-30 microns and those guys would be collecting all over the airplane. Something is off. At the same time back there the FSSP dropped down to 0, 1, 2, and there was a little spot back there where the visibility along the wing was definitely much better. I mean it was noticeably better compared to times when we were indicating 10 to 20 per cc. So there's something out there (when the FSSP is higher), but it's either smaller drops (which aren't producing ice on the aircraft) or (those concentrations are due to) ice (only).

10:51 PM

TW: It seems like the 2-D is like half working.

AR: Roger. I saw some pretty good strips back there a minute ago, concentrations 180 or something like that.

10:52 PM

TW: I think it might be a matter of sending Charlie out on the wing to reset the cards inside the probe maybe.

AR: It doesn't look like he's doing much right now. He's reading. Tom, can you tell what the draw is by the J-W?

TW: What do you mean the draw?

AR: The amperage. You remember we shut it down the other day and it was drawing 25 amps or something.

TW: Yes. I think right now it's shut down. We turned it off because it really wasn't working.

10:53 PM

TW: It looks like the 2-D is coming around.

10:57 PM

ZS: Nick, this is Zan.

11:00 PM

ZS: Nick, from Zan.

AR: The sky seems to be darkening here at 230340.

11:03 PM

AR: Now I can see a little droplet clouds going by, so I'll have a little more confidence that the FSSP is measuring some droplet cloud.

11:04 PM

AR: You can see it starting to turn a little bit white now.

TW: I can order those particles for you if you want, Nick, or you can just look at it the way they are.

AR: I think they are being ordered.

TW: I was asking Nick.

AR: Say again.

TW: I was talking to Nick.

AR: Sorry.

11:05 PM

ZS: Nick, from Zan.

NB: Hi Zan. Nick here.

ZS: I don't know if you have it yet, but just trying to stay ahead of the game. Do you have a northeast coordinate?

NB: Yes. I was just thinking that same thing. Right now what I have is 43°58.5' and 122°53.4'.

ZS: Thank you.

NB: It will take us no time at all to get there with the big tailwind we'll have.

ZS: Yes. We're probably going to have 85 knots of tailwind.

11:08 PM

NB: Just for everybody's information, the P-3 did take off and so it will be out here joining us pretty soon.

11:09 PM

KM: Nick, we're leveling off at a pressure altitude of 20,000 ft.

11:15 PM

AR: Continuing to fly in the high concentrates of ice crystals. According to the 2-D several hundred just counting all particles.

11:18 PM

NB: It took a while, but we're just about to start in on the pattern.

ZS: Nick, we're just starting our course reversal over our first southwest point.

NB: Thanks.

11:19 PM

AR: Since the 2-D came back in, it's mainly the crystal type has appeared to be unrimed or slightly rimed. Flying at –20 at 232016 and the crystals are rather complicated in shape and some quasi-spherical crystals indicating that they might have been rimed on the way down, yet others appear quite dry with holes within them. There is no sign of bullet rosettes.

11:20 PM

AR: Which is running –20.5°C at tstat-r. Starting out at our southwest position at tans-alt 197.

11:23 PM

NB: Zan, Nick here.

ZS: Go ahead Nick.

NB: I've got a western endpoint once we get to the end here to kind of aim for.

ZS: Go ahead.

NB: It's 43°34.5', 123°48.0'.

ZS: Got it. Do you want to do the descending to 18,000 ft or stay here or what?

NB: We'd like to descend to 18,000 ft on that southwest bound track.

ZS: Okay.

11:27 PM

ZS: Just listening in on the radio and talking with S-Pol, the P-3 has started their pattern and they're in solid precip. It looks like the main precip band, at least according to the S-Pol radar, is just off of Astoria right now and they time it kind of into the Cascades in about a little more than 2 hr. So it looks like the timing is really good for us.

11:28 PM

AR: Look out there about 1 o'clock, Nick. There's a break slot coming up.

NB: Yes. I see what you mean. My window is a little bit kind of condensed up here.

AR: I have to admit I'm pleasantly surprised by how uneventful this flight has been.

TW: Could someone let me know when we're in clear air and will zero the liquid waters?

AR: There shouldn't be any liquid water right here, Tom.

TW: All right, I'm going to zero the PVM.

AR: Okay. In about 10 s we're going to come into some droplet clouds though, so you've got about 10 s---maybe they'll be a little bit above us, however.

TW: Done.

AR: Thank you.

11:32 PM

TW: It's amazing. We've collected more HVPS data this flight so far than any other flight ever, total.

AR: Wow!

11:33 PM

AR: A patch of barely visible blue sky bounded by it looks like droplet cloud, estimated 3,000-4,000 ft above aircraft.

11:34 PM

NB: It looks like our winds are getting kind of flaky here, but maybe the co-pilot's airspeed indicator is having some trouble again.

AR: Is this our endpoint, Nick?

NB: Yes. It is.

11:35 PM

AR: I didn't notice any temperature change from one end to the other of this line segment, north-southwest to northeast. The one thing noticeable was that we tended to get into a rather somewhat chaotic area of the cloud situation with some

layering becoming evident from the constant diffuse situation that we find ourselves flying in almost all day today.

11:37 PM

AR: Sky darkening as we head toward the southwest. The time is 233855.

11:39 PM

ZS: Does anyone have a wind readout back there?

AR: Nick maybe talking to Center down there. It's 245° at about 38 meters per second or about 80 knots.

ZS: Thank you.

11:41 PM

AR: Continuing pretty much the same crystal types. They appear to be mainly unrimed. I haven't really seen any what I would call bullet rosettes. It looks like they're either fractured or aggregated into larger crystals on the way down. I have to say once in a while there does seem to be a rimed particle or two as indicated by a lack of detail around the edges. The 2-D working quite well now and it has for probably the last half hour.

11:42 PM

NB: Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new northeastern endpoint for you once we complete this leg.

ZS: Go ahead.

NB: It's at 44°07.8' and 122°31.3'.

ZS: Okay. Copy that. You're going to want that one level at 18,000 ft?

NB: Correct.

11:44 PM

NB: Art, Nick here.

AR: Roger Nick.

NB: Mark Stoelinga reports that he sees the back edge to this, at least this kind of more intense precip band, about just west of the coast, due west of Sweet Home or the S-Pol radar. So when we get to the end of this leg, you might be looking forward and see if you see anything in the sky.

AR: Roger Nick. Will do.

11:45 PM

NB: For what it's worth, he says, he didn't give a number, but he says it's kind of moving in at a pretty good clip. It's not surprising given the strength of the flow here. But he thinks our pattern will be in the thick of it as we kind of transition toward the northeast.

AR: Just on this next leg? Yes, I guess that's right. Okay. We'll look for something eventful. But as you know just as you were describing, this is so far the classic prefrontal dry crystal environment.

11:47 PM

AR: Will it make anything out, Nick?

NB: Yes, I sure don't see anything or any sort of, you know to quantitatively change in any of the HVPS stuff or anything like that.

11:51 PM

AR: Tom, when I do an XY plot for altitude versus static temperature, is that the whole flight?

TW: I'd have to check. It depends on your settings. I can come back there. Hold on.

AR: Thanks.

11:52 PM

AR: About 2 min ago I looked straight down out of the side bubble and there is a droplet cloud layer down there, but I was unable to estimate how far below the aircraft, solid overcast of some kind. At that point it appeared as though we're flying in a little bit thinner precipitation. That's why that was seemingly visible.

11:55 PM

NB: Well, correct me if I'm wrong, Art, but I don't see much difference in the character of the precip between here and that 20,000 ft. But it's definitely more crystals and bigger ones.

AR: Roger. I think that's correct. Even looking at the temperature a while back there, you probably notice that we had a degree or a degree and a half drop.

NB: Yes. I don't see any sign of any kind of transition in the winds or anything, but I would suspect, if we're out here long enough, the cooler air up in the west will come in.

AR: Right. I was just struck that it seemed to occur over about a 2-min period. I was looking at that, looking for something to come through, because of Mark's comment that you relayed to me. Then all of a sudden there it goes. You're right. The wind really didn't do much. It looked like it was backing for a second but then now it's come back to 240°-245°.

12:00 MIDNIGHT

NB: It will be interesting to see if we see the same thing that is in the forecast soundings and that is as we get a little lower here the winds actually decreasing with height. Apparently the warmest air is being drawn up just ahead of the system and so we're in the situation where we're actually getting kind of a northeasterly thermal wind.

AR: Yes. That will be interesting. I did pull up the Salem cross section from the MM5 just before we boarded the plane. Looking at those low-level winds too just before, pretty impressive. The other thing that was impressive was the astounding drop in the freezing level immediately behind the front, which I took to even be probably in real life might be even a little sharper.

NB: Yes. On this set of legs, I don't think we're going to be getting into that, but we may well be in the second set.

AR: Roger. Is the plan to land at "duck international airport"?

NB: That's right. You might want to put your Husky cap in your back pocket or something.

AR: Right. How low do we go in the first set of legs here?

ZS: Nick, from Zan.

NB: Hi Zan, Nick here.

ZS: How are we doing on a southwest coordinate?

NB: Yes. I'd like to go to 43°40.9'/123°33.4'. Again on this one on the southwest bound descending from 18,000 ft to 16,000 ft.

ZS: Okay.

12:02 AM

AR: Continuing Nick, how low do we go on this first set of legs?

TW: He's on the radio.

AR: Thanks.

12:03 AM

AR: We seem to be going through the warming zone here, temperature 17.7°-17.6°. The wind is not doing anything.

12:04 AM

AR: The time of this increase was 000450 and we're now at 000528.

12:05 AM

NB: I just talked to the P-3 and Mark Stoelinga at the S-Pol. They're estimating independently but consistently something like 7-8 kilometer echo top, which is consistent with ours. You know it was at least 20,000 ft of course. Seen quite a bit of spillover over the top of the terrain into the eastside of the Cascades, but markedly lower precipitation rates there. Finally, the P-3 is right now at 11,000 ft and Brian is characterizing what it's getting as just a light to at most moderate icing at a temperature of –6°.

AR: Roger. Thanks for that nice report, Nick, and while you're on the radio there we went back through that temperature change of about a degree in probably 30 s to 1 min, no wind shift. Maybe it's related orography or something down there.

NB: Well, I don't know. You know there are all kinds of waves rattling around up here. I don't know. It could be just one of those things.

AR: Right, exactly. It might even be associated within the band itself. It's a little cooler where the air is being lifted a little better.

12:07 AM

NB: I guess I'm kind of surprised it wasn't if indeed the echo top was as low as just, I don't know, a kilometer above the plane that we didn't see kind of brighter sky there.

AR: That's exactly right.

NB: So I'm inclined to think that air was probably actually up to 25,000 ft or something.

AR: Yes. That's right. Because if it had been a kilometer, I can tell you, the sun's disc would have been visible at least through ice cloud.

NB: Who needs radar when you have Art?

AR: But I can be wrong. I consider, for example, being wrong when I thought we were in some liquid water cloud on the ferry flight down here and the ice is just not building up and the FSSP was in that way over 10 (10, 20, even 25) and yet the spectrum was very broad. So you should have been seeing ice building up over a period of time and it never happens. So obviously it either drops below say, well below 20 microns, or they just weren't out there. It was all due to ice. The discrepancy between the PVM and the FSSP certainly suggests ice was the cause.

12:09 AM

AR: The other reason why we wouldn't have seen the sun, Nick, if the cloud top really was only a kilometer, is if you do have that upside-down cloud. The temperatures aren't terribly low here and it's not impossible that at –25° to –30°C you would have that liquid top and in the optical depth to be much greater in those droplet clouds. Sometimes what makes a cloud top look a lot higher is if you think it's all ice above you.

NB: How often does that really happen?

AR: We used to see it every time we went to the top of storms in the CYCLES project. There would be this little altocumulus-like cloud at the top and sometimes it wasn't there, but oftentimes that's because it's between bands and there's just not the upward motion to support it. That seems to come from the fact that nature abhors deposition ice nuclei. It seems to only want to produce water saturation first.

12:11 AM

AR: Nick, did Mark offer an estimate of where he thought that front was and when it might go over the Willamette Valley and all that?

NB: No. He didn't give any estimate there and I didn't ask actually.

AR: Right. The P-3 is doing the low legs, is that it?

NB: Yes. They're doing their lawn mower pattern with mostly north-south oriented legs. I think they're kind of in their third one or middle one right now.

AR: Roger. I understand.

NB: They're actually a little bit ahead of us. We've got a head start on it, but they flew down here so much faster than us.

AR: Roger.

NB: I certainly think like the steady state assumption over for a course of a few hours is probably pretty good for these clouds though.

AR: Yes. Do you know how much longer we're going to be up?

NB: I think they're going to be doing a full duration. So they'll be repeating their lawn mower pattern at least another time and kind of take it from there.

AR: From top to bottom?

NB: Well, they'll cross the mountains and then do it from west to east again.

AR: Okay. I don't know. I start thinking about icing again if that front goes by there's going to be huge increase in icing. You know, as the whole thing becomes more unstable and it slammed up the slopes. So they might think they're having light to moderate icing now, but if they get in that frontal zone and, thereafter, it's going to be pretty. I just can't imagine it won't be horrendous.

NB: Yes.

AR: That's why I'm thinking maybe Mark should keep them advised if they see something coming because that postfrontal stuff, of course, fits that classical pattern of the onset of riming and graupel and that kind of thing.

12:16 AM

AR: The other thought was that the MM5 anyway showed that freezing level going down to 950 mb. So there's not a lot of out if you pick a tremendous amount of icing up going westbound say and you hit this unexpectedly.

NB: Right. I'm sure what they would do is climb up. They have a lot of deicing and just if they get out of the water, even though they're cold, they can do pretty well.

AR: Good to hear.

NB: Hey Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new northeast point for you once we kind of turn the next corner.

ZS: Okay. Go ahead.

NB: That's 44°17.0'/122°09.2'.

ZS: Okay. You got it and that will be level at 16,000 ft, right?

NB: Correct.

12:17 AM

AR: The 2-D has been pretty ratty here over the last few minutes. Lots and lots of partially imaged particles and none of the end lines that designate the start and end of a particle, that is those vertical lines as seen on the display.

12:26 AM

AR: Still no icing as we make our turn here. Correction, we're not making our turn here. It was a misperception on my part. We're only a few minutes from the end of the southwest leg. There has been no icing, let me repeat, and the sky conditions continue diffuse, no identifiable cloud layers above or below at this point. The time is 003109.

12:36 AM

AR: The FSSP is showing 10-20/cc. I cannot see puffs of cloud going by, but there is some indication of haze or some degradation of visibility down the wing to the radar pod. It's definitely not clear so those particles are out there. It's just a question of the phase. The PVM is indicating only about half the liquid water content, but it is responding to something going by. So I think there maybe some small drops out there. We're really not picking up any ice. However, there is certainly no enhancement on the top of the Pilewskie rod. There's just the trace of whiteness there. So if there are drops out there, they are very small. I don't see any change in the sky here as we get close to our southwest end point.

12:40 AM

AR: I didn't see any sign of change in the clouds out here, Nick. I guess we're at our southwest endpoint. We just went past it and I certainly didn't see anything in particular. Maybe the particles were a little bit bigger back up the road compared to the endpoint and that's about it. Again, no liquid water.

NB: Yes. I agree. The winds dropped off markedly. I don't know necessarily the significance of that is, but early on that track they were 42 meters per second or something and then toward the end they were like 31 meters per second. Mark Stoelinga reported with S-Pol that there was some evidence that some of the heaviest precip was at the western end of that band. Anyway, I think we're kind of just solidly in it.

AR: Roger Nick. That was a good observation on that wind. I completely ignored that. I was stuck on the temperature and I didn't notice the temperature dropped a degree as we descended from the east point to the northwest point, but there was no step anywhere along the line that I could tell.

NB: Note that our direction now we have 240 or so at 30 meters per second. So there's a little bit of kind of warm advection on that switch at 250, but something of a hint of a warm advection-type wind profile.

12:43 AM

NB: As soon as I saw that, of course, the winds come up around more like 250 or so, so scratch that.

AR: I know what you mean.

12:44 AM

AR: One thing I haven't seen any good 2-D strips in a long, long time, mostly junk.

TW: I'll try cycling the power and see if that helps.

NB: Hey Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new southwest point for you.

ZS: Go ahead.

NB: It's 43°47.3'/123°18.8'.

ZS: Okay. That one will be descending to 14,000 ft?

NB: Affirmative.

ZS: Thanks.

AR: Tom, that seemed to help. There's quite a few more good ones now.

12:45 AM

AR: Just a comment on the crystals. They have continued to appear unrimed to me with the isolated exception of some rather roundish ones that suggest there could have been some light riming above, but for the most part they definitely appear unrimed from our highest leg down to this leg.

12:51 AM

AR: It looks as if we might have lost satellite because we're not getting an update on tans-alt or winds. Pressure altitude 165, that's about 700 ft higher than our actual altitude.

12:57 AM

AR: As we made our turn, there was no distinguishing aspect of these crystals or liquid water content or anything in particularly, no wind shifts, no temperature change. Generally running about –17.5°C reverse raw-t on this leg at 16,000 ft. Now we'll be descending I think to 14,000 ft by the southwest endpoint.

12:58 AM

AR: 010257, almost nightfall, no stars visible. Continuing unrimed crystals. No liquid water except maybe traces. There is certainly no icing on the Pilewskie rod.

1:03 AM

NB: Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new northeast point for you. It's 44°26.3'/121°47.1'.

ZS: Got it and that's a level leg at 14,000 ft, right?

NB: Correct.

1:06 AM

AR: Tom, you might trying recycling the power on the 2-D again. There's almost no good strips now.

NB: I think he just tried that.

1:07 AM

NB: Well, Art, it does look like our liquid water contents are kind of creeping up as we make our way down.

AR: I was wondering. I keep waiting to hit the top of some embedded stratocumulus, you know, that would give us a real bump of liquid water, but it hasn't happened yet.

1:08 AM

NB: You know, our temperature hasn't changed much as we've gone down here and I wonder if maybe we are kind of in a sort of frontal zone, which is kind of an isothermal layer. That would explain the kind of vertical wind shear we're seeing.

AR: Yes. That could be. The font is supposed to be at least by MM5, I would guess, it was supposed to be in this area, is that right, by now?

NB: Well, it's hard to say. There's a baroclinic band by whether it's truly a front at this level or not.

AR: Roger.

1:13 AM

AR: There are sidelights that are being used to shine out toward the ray dome on the right side and off the left wing I think they're looking at it for icing and I do see droplet cloud going by, slow concentrations. Probably the FSSP is saying 19-20. Now we're getting some significant liquid water cloud.

NB: Art, sorry, I was on the other one. I get the impression that it's kind of picking up here.

AR: Right, just in the last few seconds. Looking out these headlights that they have shining on the forward wing there and I can see some droplet clouds going by and I then I see the FSSP is getting 20-30 and liquid water contents are up there pretty significantly. I actually see a little icing.

1:19 AM

AR: The wind has picked up here again, Nick.

NB: Yes, it sure has. What we saw last time sometimes when. There's some turbulence there too. When we start picking up icing and airspeed indicated that the wind is based on kind of gets flaky, but this looks real.

AR: I would agree it looks real because there's still just a trace of icing on like the light up there, which is one of the main things I look at at night.

NB: I suppose it's still kind of cold to have much in the way of ice too, –12° to –13°C.

AR: Well, I would, actually, at this temperature and even down to about –20° we were picking up supercooled drizzle and it was piling up in a hurry. For the end in this case, you have all that ice falling down in and the orographic lifts it, we hope, will make a big difference.

1:22 AM

AR: I see now we're out in the Willamette Valley, so my comment about orographic lift isn't appropriate.

1:23 AM

AR: Maybe this is just lee turbulence off the coast rain.

NB: It could be. I wouldn't be surprised if we're right near the western edge of the bay end with some sort of frontal activity there too.

AR: Yes, we'll look for something to happen. Actually, I see the temperature is starting to fall now again.

1:24 AM

AR: Of course, it's gone up as soon as I said that.

1:25 AM

AR: A huge cooling there at 1:00 o'clock slot. That's a dusk slot.

NB: Yes, sure enough, kind of pretty.

AR: Now you can see if we're going to hit anything or not. It looks like we're toward the top of some of the higher domes. It looks like we might hit one here in a minute but other than that.

NB: We'll make our turn here any second I'd say.

AR: Roger and it looks like we will pick something up in the turn.

1:26 AM

AR: Well, we missed that one. We were turned away from it. It looks like we will be entering some cumuliform tops here in the next 30 s to a minute.

1:28 AM

AR: They were not protruding much above the flight level.

1:29 AM

AR: They should have been right in here, so I guess it's just ice cloud.

NB: It looks like the 2-DC might be behaving itself again a little better.

AR: Really, it's come to life quite nicely.

1:30 AM

AR: It looks like some indications of weak droplet cloud passing through the light the pilots are using to shine on the leading wing.

1:33 AM

AR: 013356, no stars visible. I have yet to see any stars on this flight.

1:34 AM

NB: Zan, Nick here.

1:38 AM

LS: Go ahead Nick, I missed you.

NB: Yes, I just have a new southwest point for you.

END OF TAPE 1, SIDE 1

NB: ...123°04.2'.

LS: 43°53.7' and 123°04.2'.

NB: That's right.

LS: Okay.

1:40 AM

NB: I got a recent report from the P-3. They're redoing their lawn mower pattern. At the north end of the westernmost leg on their radar, they see widespread precipitation coverage, but much more convective in nature with cells popping up to something like 4.5 kilometers or so.

AR: Is that in our area, Nick, or is that out over the valley or upslope?

NB: Essentially I think it's west of the study area. But while we're doing basically the southwest to kind of northeast part of it, they're up now in the kind of northwest corner and I think they're even looking a little further out to the west. I guess the main message is that there's a much more convective-type precipitation coming in with something like a 4.5 kilometer top, so that's decidedly higher than some of what we've been seeing in the post-frontal region.

1:43 AM

AR: No stars visible east endpoint, in and out of droplet cloud. Looking at the side light they have on that's pointed toward the ray dome.

1:46 AM

AR: As we turn it looks like we're getting some of the bigger aggregates that we've seen on this leg and if I recall correctly.

1:47 AM

NB: Art, are those kind of some of the first dendrites I'm seeing on the 2-DC?

AR: I've seen other ones that kind of resemble that, but I'd say you're right that they're certainly looking a little more like they're reflecting that temperature range.

NB: Right. I wasn't sure how sharp it was or whether it was just mostly at –12° where you could really see them well or just what.

AR: Right. Going downward, yes, you would see them down at the bottom of that zone, which would be...

KM: We're headed back southwest bound and we're out of 14,000 ft for 12,000 ft.

NB: Yes, that's correct.

AR: In general though I've been kind of bored out of my mind here with the lack of change. There isn't much of anything here on all these legs.

NB: I know what you mean.

AR: I don't know if the winds are still recovering from our turn, but look at the velocity there. There's just ramming up the slope and now it's not doing much.

1:48 AM

NB: Yes, it is impressive there. It is getting up 48-49 meters per second.

AR: It's going to take a long time to get to that southwest endpoint. I wonder how much research time we have left?

NB: I think it's on the order of 1.5 hr.

1:49 AM

NB: Sorry guys, I was on the wrong channel, but a question came up. About how much more time do we have on station if we're going to refuel at Eugene?

KM: Check your switches back there please.

NB: Ken, this is a question for you actually.

1:50 AM

NB: Ken or Larry, Nick here.

AR: We're coming into some heavy precip here.

NB: Ken or Larry, Nick here.

LS: Go ahead Nick.

NB: I have a new northeast point for you.

KM: Go ahead.

NB: It's 44°33.4'/121°30.0'.

KM: 44°33.4'/121°30.0'.

NB: Correct.

1:53 AM

NB: I was also wondering how much time we have on station here assuming a landing in Eugene?

1:54 AM

TW: Calvin did some formula and it's going to get rough.

KM: One more hour.

NB: Thanks.

TW: So you might want to buckle up.

AR: Who did that?

TW: Calvin.

AR: Yes, I wouldn't be surprised.

NB: I'm going to talk to Mark at the S-Pol now, so I'll be offline for a bit. I don't know if you heard, but we have about an hour on station.

AR: Ken, is your radar up on the wing?

KM: Say again.

AR: Is your radar working?

KM: We've got it turned down right now. We can turn it on.

AR: I was just wondering if that's helpful. I guess it doesn't matter.

KM: It's working.

AR: Thanks.

1:56 AM

NB: Ken, Nick here.

KM: Go ahead.

NB: Does that hour on station account for landing at Eugene?

KM: Yes. We're halfway close to Eugene. It depends on which end of the leg we end on.

NB: Yes. The way we will end very near Eugene. I calculate to complete the pattern it might take us more like an hour and 25 min.

KM: An hour and how much?

NB: An hour and 25 min or so, but I'll try to fine-tune that.

KM: Okay. We'll see what we've got here.

NB: I know these big winds have kind of slowed us down in the net.

AR: The ray dome is loading up with some ice as we get a little lower with these tops.

2:00 AM

KM: What you've got is an hour from now.

NB: Okay. So at that point you want to be close to an airport to land?

KM: Right.

NB: Okay.

AR: Just starting to get some pretty heavily rimed particles as you can see and the ice on the ray dome has expanded by a factor of about 3 in just 2 min I think.

NB: My bubble has suddenly now just starting to kind of ice up.

2:01 AM

AR: This is the highest liquid water we've seen, 0.4 g m^{-3} there for a second.

2:04 AM

AR: Now, Nick, it does look there are clusters of drizzle drops in this stuff.

TW: He's on the radio.

AR: We're getting some pretty high liquid water contents here, Ken, with some small to 300 micron freezing drizzle drops as well.

KM: Thank you.

2:05 AM

NB: Art, have we punched out of this?

AR: In and out, we just had a long segment, maybe a minute of half a gram to four-tenths, with drizzle drops.

TW: We're still in some stuff, right?

AR: We were out for a second and now we're coming back into it. As you can see, there's nothing falling in from above into this stuff. It looks like the icing might have creamed the HVPS.

TW: And the 2-D. I don't know, I guess it is back, isn't it?

AR: I think it's okay to keep updates here though.

2:07 AM

NB: Ken and Larry, Nick here.

LS: Go ahead Nick.

NB: To be on the conservative side, I think we can do one more back and forth across the mountain, so that means we'll have one less leg than we had hoped to do. That's okay. But what I'd like to do here at the southwest end, is to descend down to 11,000 ft and do a northeast leg at 11,000 ft. Then coming back for our final southwest track to do it at the minimum altitude across the pass and stepping down on the west side and then land at Eugene.

LS: Okay.

NB: I calculate that will take 40 min or so.

LS: Okay.

TW: Is the second flight looking at a full duration?

AR: I don't think they can fly more than 8 hr in a day, but it's probably up to the pilots.

NB: I think they have, since they have three pilots, they can fly more, but I don't know. I was going to check on that.

AR: That's a good point. I forgot about the third pilot. Also the next pass, Nick, is going to be risky. You're losing the high shield that was dropping all the ice into the supercooled cloud. I think as long as we have an out, I don't think you want to

see a half a gram, three-tenths even, for more than a couple of minutes at this point.

NB: Right.

AR: With drizzle, which is going to be a little bit heavier down lower. It will convert to ice as it goes along, but you may find those drizzle drops are maybe 500 microns instead of 200 microns.

LS: Nick, you did want to continue our descent on this leg to 11,000 ft?

NB: Yes. That's right.

AR: You've got the phenomenal upslope flow 240° at 70 knots and probably is not going to be much lower at the next level down. So we just want to make sure we have an out.

NB: Okay. I hear you.

AR: That's the morbid Art talking. There's some crystals coming down from higher up. Well no, I take that back. That's probably not from higher up, too small.

NB: It looks like both HVPS and the 2-DC are working.

2:13 AM

NB: Art, right now it doesn't seem that bad in here to me.

AR: That's right. We've gotten out of that. We're kind of over the Willamette and I think also what must have happened is there is an ice fall from a higher layer that decimates the low cloud. Apparently that area where we had that 0.5 in drizzle drops there was certainly nothing coming at least very little coming from aloft in that area. So there must be a break in that shield or at least a thinning of the shield aloft is my guess now. I suppose the pilots know when they have too much ice.

2:17 AM

TW: Art, was it a lot colder when we were up at like 16,000 ft?

AR: Yes.

TW: Is that affecting the 2-D, do you think, because it's working absolutely perfect now?

AR: I know. There hasn't been a hiccup here for I don't know an hour or more maybe.

TW: And yet I've changed nothing.

AR: Yes. It shouldn't be that way and I start thinking of the laser being old because we try to get 5 years out of them instead of changing them every 1 or 2 years.

TW: Are those lasers expensive?

AR: I think they only run about $1,000, but you do have to send it back to the manufacturer. I'm pretty sure.

TW: So about 1 hour flight time it would fix it.

AR: That's just a guess at the top of my head. That could be easily checked. I think Jack (Russell) used to be able to check the laser power in flight. I don't know if you still have those dials. I think they're supposed to read about 1.4 volts when they're on full.

2:19 AM

TW: Do you know if the 2-DP and the 2-DC use the same laser?

AR: I'm not sure.

2:20 AM

NB: I'm going to call the S-Pol now, so temporarily offline.

2:21 AM

AR: There are some big aggregates out there.

2:23 AM

TW: Hey Art.

AR: Roger Tom.

TW: If you had a 2-D histogram size bins, how many bins, what sizes would you start at, and what would be the size of the bins?

AR: 50 microns say or 100.

TW: 50 starting at 100?

AR: The width of the microns would be say 50 or 100, and then it would start at 0 to 100, 100 to 200 or 199.

TW: Up to about what, 3 millimeters or something?

AR: Yes.

TW: I finished that software, so I can test it on the next flight.

AR: Great!

2:27 AM

NB: I'm back on here. It looks like for the first time I thought I saw some needles kind of joining in the game.

AR: Right. I think we're getting close to that area where we lost a lot of the crystals coming down into the lower layer and had that elevated liquid water. It will be interesting to see if we catch up to it again.

NB: Tom, I think the 2-DC is kind of on the fritz.

AR: It was clear, but obviously it's snowing now, and you're absolutely right. Tom, did you catch that?

TW: No. What was that?

AR: The 2-DC is stuck.

2:29 AM

NB: There we go. It's back. Thanks.

2:30 AM

AR: Probably a few drizzle drops out there now.

2:31 AM

AR: Notice, Nick, the HVPS doesn't have any enlarged particles. I think this is that same area where we lost the input from aloft.

NB: Yes.

AR: They definitely look like drizzle drops at times there.

NB: Now is it kaput? Is the HVPS working, Tom?

AR: Yes, I think it's working. There just may not be any large particles out there. I'm looking down that light they're shining on the wing and I don't see anything.

NB: Yes.

2:32 AM

NB: We should see our liquid water contents drop way off now as we just kind of get past the crest.

2:34 AM

ZS: Nick, from Zan.

NB: Zan, Nick here.

ZS: Do you have a new coordinate for the end on the southwest?

NB: Yes. You can use 44°00.1'/122°49.6'.

ZS: Okay. This will be stepping down with the terrain?

NB: That's correct. Then once we hit that point, which is going to be a point near Eugene, then we can land there.

ZS: Okay. Are you going to be underneath the clouds for a specified amount of time?

NB: It depends if we can get underneath them and how much time we can fly around in the Willamette.

ZS: Okay. We'll take a look at it when we get closer to that.

2:36 AM

AR: We just completed our downwind pass, southwest to northeast, and we went through another high zone of liquid water about 0.4 g m^{-3} sustained at times perhaps even a little higher and intermittent bursts of drizzle drops and other areas where crystals were falling from higher or lower temperatures.

NB: Hey Art, Nick here.

AR: Roger Nick.

NB: Just interesting how hard it's precipitating here in the lee.

AR: I think with the winds you have, I think there's so much carry over from the precip generated up here that the ice crystals, needles and that sort of thing, probably only the graupel is getting on the west side.

NB: Yes. That's what I was thinking, exactly. The Sisters site there was reporting heavy rain a couple of hours ago.

AR: What's that elevation?

NB: I don't know, something like 4,000 or 5,000 ft.

AR: I'll be darned.

2:37 AM

NB: Art, what do you think the cloud base will be at in the Willamette Valley?

AR: Oh, I would guess something like 1,500 ft or broken, 3,000 ft overcast, that kind of situation. It should be well mixed and bases will be right on the surface except for maybe some stratus fractus scud.

NB: Right, I was trying for Vidal trying to get him some time with the CN counter kind of below cloud base.

AR: Right.

NB: Only about 2,000 ft is all we can do in the Willamette.

AR: Right. Actually I think we got to 1,500 ft last time, but I'm not exactly positive on that.

NB: Yes. We did get to 1,500 ft some, but it was kind of starting for a while at 2,000 ft.

2:39 AM

AR: Continuing no stars visible, 024030.

2:40 AM

AR: Nick, this side bubble here in the back has got a crack in it. Larry just pointed that out.

NB: Okay. What are the implications?

AR: I think we ought to depressurize, which will probably be fine at this elevation. I don't think you want to fly with this.

NB: Well, are we going to be able to limp home or are we?

AR: That's a good question. I think probably we might if we stay at a low elevation probably; but I'll let the pilots, of course, rather than guess, which I'll probably be wrong anyway.

NB: Do you think the ice did it?

AR: I don't know. It doesn't look like anything extraordinary in the way of icing. We have taken some ice flying off the plane every so often here in these flights, but I don't remember anything hitting that bubble.

TW: Maybe you should get out of the bubble, Art.

AR: Yes.

NB: Yes. There haven't been anymore struck today than yesterday.

AR: I don't think we've gotten warm enough to have anything fly off anyway.

NB: I've heard some stuff hit.

AR: Okay. I haven't heard a darn thing, but I have heard a couple of pops. Not on the last flight, I wasn't on it, but before that I think Peter heard something. I would think we would have noticed a crack of this magnitude. I do remember one other time we had a cracked bubble on the top here and I think we drilled a little hole in it to stop the crack at the end of the crack.

2:43 AM

AR: We should be coming back into those low clouds here any second. It will be interesting to me, Nick, to see if this drizzle survives. My impression is that it might form up there near cloud top and start on it's way down, but it would freeze.

NB: Okay.

AR: Sort of a time dependency.

2:44 AM

NB: I'm finding it a little bit surprising that there isn't a little more kind of lee wave activity here with 65 knots of wind hitting this barrier.

AR: Yes.

NB: I'm not that keen on necessarily getting tossed all around, but it's just kind of why not this time.

AR: Yes. Maybe the wave is breaking further down the stream.

NB: There may not be enough stability to kind of really support it.

AR: That's a good point too. Also I noticed that in this same area now we're getting those lower temperature crystals falling into this stuff that was devoid of them earlier. So that higher shield is progressing and that will probably help our icing situation a bit. There are some nice dendrites there a while back.

2:46 AM

NB: Nick here.

ZS: Go ahead Nick.

NB: I was just wondering what you have in store for us. Are we still going to land in Eugene?

ZS: Yes. We're just starting to let down here with the terrain. We should be getting a lower altitude here and we are about 60 miles from Eugene, so your final point was just short of Eugene I think east about 20 miles. So we'll get down there and let down there in the Willamette. We aren't going to have really enough fuel to do anything but go in and land at Eugene.

NB: Okay. With regard to the window whether that means we can do any more science today.

ZS: We'll just wait and take a look at that on the ground once we got all the ice and we can take a really good look at it.

NB: Thank you.

2:48 AM

AR: Seeing some phenomenal ice particle concentrations back there probably in the 500 to 1,500 real crystals above sizes 100 microns and along with that a continuing backdrop of droplet cloud having water contents of about 0.1.

2:53 AM

AR: It's quite the snow storm out there Nick.

TW: He's on the radio.

AR: We're getting phenomenal concentrations of particles, ice crystals here along with a steady backdrop of a little liquid water, a tenth of a gram. Usually you think of high ice crystal concentrations going with no liquid water because the ice is taking up the liquid water. It's just a testament to how much water is being shoved up the slope here by these 55-50 knot winds.

TW: How's the ice situation out there?

AR: Not as bad. I haven't looked for a couple of minutes, but the last time I looked they weren't at quite the peak of the first two flight where we really piled it up here on top of that Pilewskie rod. I would guess by now it's getting to that same level and we've got a flashlight to look at it. I'm judging by the ray dome out there off the right wing, which is illuminated by that light. Fortunately, we're going to be near the temperature where this stuff will start melting off.

TW: It's definitely hitting up here.

2:56 AM

AR: Nick?

NB: Yes, I'm here.

AR: I just noticed it looks like the temperature is starting to fall again, so that really would indicate we're going through some kind of maybe frontal wind shear zone. I think it was getting up to –4.5°C and now we're down to –5.2°C. I think we're been descending.

NB: Yes we have. We're at, I think, 8,000 ft now. I don't have that great a reason why it should be kind of so choppy here.

AR: In that 55 knot wind.

NB: It's not like there's any more shear. Well, maybe there is a bit more shear down here too.

AR: It's probably a little more unstable. Actually, I thought we were lower than we were.

NB: I'm still uncertain of which temperature I should be looking at. You said the reverse flow thermometer was kind of more reliable. Is that correct?

AR: Roger.

NB: It looks like we're hitting a far amount of water now.

AR: You know, I didn't see a single drizzle drop on the way down here to this lower level. I don't know if they were frozen on the way down or disintegrated.

NB: How do they fall relative to the crystals? If they're that small, do they really fall out any faster than the crystals?

AR: Absolutely and that's certainly part of it. But back there where we were devoid of the higher crystals falling into that stratocumulus, that was the area I was looking for some drizzle drops, but even there it didn't seem like any of those made it down. Sometimes though if they're freezing in the Hallett-Mossop zone, there's this stickier thing, you know, when you get freezing rain and then sleet. It gets cold enough to produce sleet and you get stickier drops and there's sudden evidence that those disintegrate.

3:01 AM

AR: I was just thinking, Nick, there might be that wind shear too down in the Willamette where you get that channeled southerly flow and you have those little gradient southwest flow and maybe we're getting close to that. See if that's there.

NB: I think that certainly does exist there just like in Puget Sound. We're up a bit high for that perhaps but maybe not. We're at 7,000 ft now or so.

AR: Roger. Right after I said that I started looking at the altitude. I keep thinking we're going down. You're right. I think it's too high for that.

3:02 AM

TW: Calvin says we're going to be landing in 5 min. I'm going to start shutting the data system down here.

NB: Can you hold off for just a bit.

TW: Maybe like a minute or something.

NB: That would be helpful, just a minute if you could.

3:04 AM

NB: We're not even to the endpoint of this leg really yet.

AR: Yes. I'm thinking orbit for a second so we can collect that data. Tom, are there keystrokes to close these windows?

TW: You can hit alt-F4.

AR: I guess I wasn't hitting it hard enough or something.

TW: Or alt-x.

3:05 AM

TW: Are they breaking off now?

NB: I'll check with them. Zan, Nick here.

ZS: Go ahead.

NB: We know we're close to landing, but we would like to continue this leg and land late enough after this leg so we can turn off the data systems. So what's your estimated landing time?

ZS: We've got 2 min to finish this leg and from there it's only going to take us 8 or 9 min to vector around to land at Eugene.

NB: Okay, 8 or 9 min is fine. Thanks.

ZS: Okay.

3:06 AM

ZS: Nick, that's the end of the leg and we're turning toward Eugene and it will probably be about 8 min until landing.

NB: Thank you.

ZS: I'm off. I'll talk to you on the ground.

NB: Okay. We're done with the leg, anytime.

TW: Okay.

3:08 AM

END OF TAPE

Summary of UW Flight 1900*

This flight took place as one of the strongest of all IMPROVE-2 frontal systems passed over the Oregon Cascades. The winds at 850 and 600 hPa were 50-80 knots out of the southwest, with extensive warm air advection producing overrunning cloud layers and a well-developed orographic cloud over the Cascades. The satellite imagery before the flight showed two rainbands with a thin zone of separation between them about to make landfall on the Oregon coast. The first rainband appeared to be the stronger, or at least had the colder tops.

The ferry portion of the flight consisted of a stepped ascent to near 20,000 ft MSL by the time the research legs began at the southwestern end point. Embedded droplet clouds (shallow altocumulus-like clouds) were encountered intermittently above the freezing level within otherwise a deep, featureless ice cloud. However, there was little ice buildup en route to the research area, indicating very low liquid water contents and small droplets.

The first research leg, starting from the SW endpoint at 20,000 ft MSL was flown in deep and diffuse precipitating cloud with little internal detail or indication of layering. A thinning in the ice and precipitation occurred a few minutes en route to the NE end point at 2328 to 2334 UTC. At this time a droplet, altocumulus-like cloud estimated 3,000-4,000 ft above the aircraft and some blue sky could be seen above the aircraft through a "haze" of ice precipitation.

Other than this brief respite, deep and diffuse clouds with little internal detail were flown in until reaching the 14,000 ft MSL in the series of slantwise descents from 20,000 ft MSL. Embedded droplet clouds were encountered at almost every level and leg. Droplet concentrations were very low (~10-30 cm^{-3}). During the descent from 16,000 to 13,000 ft MSL the aircraft encountered more droplet clouds with substantially higher droplet concentrations (>50 cm^{-3}) and higher liquid water contents (LWC). The LWC reached as high as 0.4 g m^{-3} in the wettest regions of these clouds. Supercooled drizzle drops were briefly encountered in these clouds at -13°C and still more (concentrations >300 per liter) at about -9°C adjacent to regions with extremely high ice concentrations (some >500 per liter) consisting of mainly sheaths and needles. The supercooled drops resulted in a rapid but brief icing buildup on the aircraft. Also, brief regions were encountered in these lower clouds where precipitation did not appear to be falling into them from the higher layer; at other times, irregular rimed aggregates, probably dendrites, were observed.

It was in these lower clouds, beginning around 13,000 ft MSL that heavily rimed particles were observed in the 2-DC imagery for the first time on this flight. Thus, while droplet clouds were frequently present at elevations above 13,000 ft MSL, the low liquid water contents and small droplets apparently did not affect precipitation tremendously through appreciable riming, but rather they were indicators that water saturated conditions existed throughout this storm in spite of high ice particle concentrations (10s to 100s per liter).

No stars were visible at any time above the aircraft, even when snow was not falling from the relatively thick cloud layer above, and the aircraft was above the lower deck of droplet clouds encountered at about 13,000 ft MSL.

During the final leg, in which the aircraft descended along the "MVA" altitudes toward the SW en route to a landing at Eugene, Oregon, liquid water and high ice particle concentrations in the hundreds to thousands per liter were simultaneously observed in the lowest portions of these clouds, a somewhat unusual occurrence that demonstrated the

* No verbal summary of this flight was recorded onboard the aircraft. This summary was written post-flight by A. Rangno and P. Hobbs.

high rate of production of condensate in the upslope regions of the Oregon Cascades in this powerful storm.

Increases in temperature during level flight, and sometimes increases in droplet clouds at 20,000, 18,000, 14,000, and in the descent leg to 11,000 ft MSL in the research area, and at the end of the level pass at 11,000 ft MSL, suggested that the aircraft flew through a frontal boundary. However, little change in wind direction was noted with the temperature changes.

A cooling of 2°C was also observed at about 5500 feet in the very short, level leg to Eugene. This demonstrated strong cold air advection behind the front.

Instrument problems consisted of erratic operation of the 2-DC. Early in the flight it had several outages and was restarted several times. Also, even when working, ice concentrations were unrealistically low at times. An entire 2-DC buffer would contain only one or two ice particles because the probe was not separating one particle from another, but rather counting many particles as a single particle while calculating the volume of the entire strip. Such 2-D buffers will have to be excised lest particle concentrations be erroneously low. Normal operation of the 2-DC occurred later in the flight.

There was no CPI data, and the DMT and J-W hot wire probes did not function. However, reliable LWCs were obtained with the FSSP-100 and the PVM-100 probes. The latter probes were in good agreement with one another during the flight.

The 1-D spectra are suspect in flight since quasi-Gaussian shapes were being produced for spectra instead the Marshall-Palmer shape normally produced by this probe in precipitation. For example, for the whole flight, Channel 11 averaged about 3 times more than adjacent Channels 10 and 12.

Flight 1900
December 13, 2001
Voice Transcriptions*
IMPROVE-2

9:48 PM

AR: Just passing the freezing level here at 790 to 800 mb. It's about 6,000 to 5,500 ft.

9:53 PM

AR: No sign yet of droplet cloud here above the freezing level, which is good. The sky is dark, amorphous. No detail, that is, above the aircraft and all around the aircraft. Earlier, before we ascended so far into this, there was a lower overcast stratocumulus into which this precip was falling. There's no trace of any icing on the aircraft yet. Meaning I haven't missed anything so far while I was setting up a computer.

9:54 PM

AR: Tom, do you copy?

TW: Yes.

AR: Another problem, the 2-D was dead there, but now it's coming to life. It was imaging junk, noise, and now we're starting to get some images, so that's great.

9:55 PM

NB: Hey Art, Nick here.

AR: Roger Nick.

NB: What liquid water measurement would you recommend?

AR: Look at the FSSP integrated liquid water and L-W PVM. They are the two that are really tracking very well together, so there's some confirmation on what's out there.

NB: Okay. Thanks.

9:57 PM

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* AR = Art Rangno, KM = Ken McMillen, LS = Larry Sutherland, NB = Nick Bond, TW = Tom Wilson, ZS = Zan Sutherland

NB: Go ahead.

ZS: That lat/long you gave me, that's not the farther west point, right? Have you moved that in along that northeast-southwest track?

NB: Yes. That's apparently so. I just checked that out myself. So if we could head for that point that I gave you, that is the 43•28.8' and 124•02.5', I think that would be a good place to start.

ZS: Okay.

TW: Is it back, Art?

AR: Negative. It's not here. Maybe I should restart my display.

10:04 PM

TW: I need to cycle power on the 2-D probes. Is it okay to stop it just for a second? Okay. Let me know what happens, Art. You know sometimes the 2-D, when we get up high, it will quit working. Then right when we get to the study area you drop down like 1,000 ft and it starts working again. It looks like right now we're just getting blank strips.

10:06 PM

TW: This is kind of the main computer over here, so I don't like to run too much stuff on here. That's why I kind of look at yours instead of running it on mine.

10:08 PM

TW: Nick, what time did you have for engines on?

NB: I had 2131.

10:09 PM

AR: Tom, any thoughts on the 2-D other than cycling the power?

TW: I tried that about three or four times. I can do that again.

AR: Okay. That's not a good sign at all.

TW: On previous flights we've had it die all the way to the study area and then it starts up.

AR: Right. But I don't remember the blank images before. I remember it wasn't responding to particles, but I don't remember quite what we're seeing here. But maybe it has to warm up again. When we climb to 20,000 ft, I don't know.

AR: The 2-D looks like it's trying to come back, but the images don't look very good though.

10:20 PM

AR: Do you notice, Nick, that we had that droplet cloud. Actually, I mentioned we would top out one around 9,000 ft when we were going up to 11,000 ft, but it's been droplets all the way since about the time we reentered that higher layer somewhere around 11,500 ft. We are starting to pick up a little more ice here and there on the airframe.

NB: Yes. How are you able to tell these droplets aside from just seeing them on the icing?

AR: That's on the FSSP-100. Anything probably above 5, normally when there's ice out there, I'm sure you've noticed, a few counts on the FSSP per cc is probably not water, almost certainly not. When it gets up to 10 to 20 to 30, as we're seeing now, that's certainly water. It should be reflected in the PVM as well.

NB: Yes. I have noticed that the PVM has been running around 0.1 grams per meter cubed or so.

AR: To be honest, that might be more correct because the FSSP is going to be measuring some of those ice crystals and adding that into the integrated liquid water. So it does tend to run a little bit on the high side in these kinds of situations.

TW: It looks like the 2-D is giving us strips, but they don't look good.

AR: Roger that. It almost looks like the true airspeed isn't quite right, but I'm not sure. It's not really stretched out, but it certainly doesn't look like 25-micron pixels or shaping those particles.

TW: The true airspeed that we sent to it is on the display of the 2-D strip. It's 122 I'm sending it.

AR: Yes. Okay. It's not defaulting to 80 or something.

TW: No. It looks like I see a lot of the same particles go by.

AR: Welcome to ice crystal analysis.

TW: Well, I'm joking. I mean exactly the same particle.

AR: I know what you were saying.

TW: In the same position.

AR: It's now updating again. That is the 2-DC is now updating again at 223310. Nick, are you online? Zan, the wind has come around a little bit more here just in the last couple of minutes since I talked to you. It's 250• now and it's 70 knots, some kind of upper feature, some real turning of the wind I think.

ZS: I'm showing 251• at 71 knots and I've got some stuff plugged into RGPS.

AR: Roger. It was 235• to 240• there. I was staring right at it, so something has happened here. Nick, are you available? No contact, he's on the radio.

TW: What happened, Art?

AR: Just the wind shifted a little bit up here in the last couple of minutes.

10:35 PM

AR: Tom, do you know if we can recover accurate 2-D concentrations?

10:36 PM

NB: Just for the record, our winds look to be about 8-10 meters per second stronger than forecast by the MM5 model at least earlier this morning. The directions look about the same as progged and the air temperatures are about the same but quite a bit stronger flow.

AR: Roger Nick. Zan was asking for a wind measurement back here a few minutes ago and I watched it for a little bit, 235•-240• at 30 meters per second, and then 3 or 4 min later it suddenly went to 250• at almost 80 knots at times. I don't know. It seemed like it was real feature. He was concurring if the wind was out at 250• now. Do we have a good 10-4 on the front?

NB: Yes. I haven't gotten into the details of the timing of the front itself.

AR: Roger. I noticed on the satellite imagery that there were two heavy bands. One big one right off the coast before we took off and then something a little bit lesser behind it, lower tops. It's one of those situations where either one could have been the front. Also we have the data line on the 2-D display that we determine what our 2-D concentrations are (in flight are) not correct. They're off by a considerable amount with the probe thinking that the whole buffer is only 1 particle. We're getting these 1 per liter, 3 per liter kind of concentrations where it ought to be up probably in the hundreds.

10:39 PM

ZS: For planning for everyone, about 36 min to arrive at our first westerly-southwesterly point.

10:49 PM

NB: Liquid water contents are sometimes up to 0.3 now also.

AR: I don't know if that's right to be honest, Nick. Because now that we've been going through this tenth of an inch FSSP liquid water, there just has not been the ice accumulation that you would have had over an hour to 30 min or something like that with that kind of liquid water content. So I think it's seeing more ice maybe than I gave it credit for.

NB: Yes. It was just kind of a burst there. For the most part, it was 0.05 or so.

AR: Right. But the FSSP, if you look back at the long record, it had a long, long spell of 0.1 or 0.2 g m^{-3}. Yet, I wasn't seeing anything build up on the tail light back there like I would normally see on this structure or our radiometer right next to the bubble. So I think maybe either the drops are smaller. I think there are drops out there, but I think they're just smaller than what the FSSP is indicating, which puts them in channels 8, 9, 10. That would be up around 25-30 microns and those guys would be collecting all over the airplane. Something is off. At the same time back there the FSSP dropped down to 0, 1, 2, and there was a little spot back there where the visibility along the wing was definitely much better. I mean it was noticeably better compared to times when we were indicating 10 to 20 per cc. So there's something out there (when the FSSP is higher), but it's either smaller drops (which aren't producing ice on the aircraft) or (those concentrations are due to) ice (only).

10:51 PM

TW: It seems like the 2-D is like half working.

AR: Roger. I saw some pretty good strips back there a minute ago, concentrations 180 or something like that.

10:52 PM

TW: I think it might be a matter of sending Charlie out on the wing to reset the cards inside the probe maybe.

AR: It doesn't look like he's doing much right now. He's reading. Tom, can you tell what the draw is by the J-W?

TW: What do you mean the draw?

AR: The amperage. You remember we shut it down the other day and it was drawing 25 amps or something.

NB: Yes. I was just thinking that same thing. Right now what I have is 43•58.5' and 122•53.4'.

ZS: Thank you.

NB: It will take us no time at all to get there with the big tailwind we'll have.

ZS: Yes. We're probably going to have 85 knots of tailwind.

11:08 PM

NB: Just for everybody's information, the P-3 did take off and so it will be out here joining us pretty soon.

11:09 PM

KM: Nick, we're leveling off at a pressure altitude of 20,000 ft.

11:15 PM

AR: Continuing to fly in the high concentrates of ice crystals. According to the 2-D several hundred just counting all particles.

11:18 PM

NB: It took a while, but we're just about to start in on the pattern.

ZS: Nick, we're just starting our course reversal over our first southwest point.

NB: Thanks.

11:19 PM

AR: Since the 2-D came back in, it's mainly the crystal type has appeared to be unrimed or slightly rimed. Flying at –20 at 232016 and the crystals are rather complicated in shape and some quasi-spherical crystals indicating that they might have been rimed on the way down, yet others appear quite dry with holes within them. There is no sign of bullet rosettes.

11:20 PM

AR: Which is running –20.5•C at tstat-r. Starting out at our southwest position at tans-alt 197.

11:23 PM

NB: Zan, Nick here.

AR: Wow!

11:33 PM

AR: A patch of barely visible blue sky bounded by it looks like droplet cloud, estimated 3,000-4,000 ft above aircraft.

11:34 PM

NB: It looks like our winds are getting kind of flaky here, but maybe the co-pilot's airspeed indicator is having some trouble again.

AR: Is this our endpoint, Nick?

NB: Yes. It is.

11:35 PM

AR: I didn't notice any temperature change from one end to the other of this line segment, north-southwest to northeast. The one thing noticeable was that we tended to get into a rather somewhat chaotic area of the cloud situation with some layering becoming evident from the constant diffuse situation that we find ourselves flying in almost all day today.

11:37 PM

AR: Sky darkening as we head toward the southwest. The time is 233855.

11:39 PM

ZS: Does anyone have a wind readout back there?

AR: Nick maybe talking to Center down there. It's 245• at about 38 meters per second or about 80 knots.

ZS: Thank you.

11:41 PM

AR: Continuing pretty much the same crystal types. They appear to be mainly unrimed. I haven't really seen any what I would call bullet rosettes. It looks like they're either fractured or aggregated into larger crystals on the way down. I have to say once in a while there does seem to be a rimed particle or two as indicated by a lack of detail around the edges. The 2-D working quite well now and it has for probably the last half hour.

11:42 PM

AR: Tom, when I do an XY plot for altitude versus static temperature, is that the whole flight?

TW: I'd have to check. It depends on your settings. I can come back there. Hold on.

AR: Thanks.

11:52 PM

AR: About 2 min ago I looked straight down out of the side bubble and there is a droplet cloud layer down there, but I was unable to estimate how far below the aircraft, solid overcast of some kind. At that point it appeared as though we're flying in a little bit thinner precipitation. That's why that was seemingly visible.

11:55 PM

NB: Well, correct me if I'm wrong, Art, but I don't see much difference in the character of the precip between here and that 20,000 ft. But it's definitely more crystals and bigger ones.

AR: Roger. I think that's correct. Even looking at the temperature a while back there, you probably notice that we had a degree or a degree and a half drop.

NB: Yes. I don't see any sign of any kind of transition in the winds or anything, but I would suspect, if we're out here long enough, the cooler air up in the west will come in.

AR: Right. I was just struck that it seemed to occur over about a 2-min period. I was looking at that, looking for something to come through, because of Mark's comment that you relayed to me. Then all of a sudden there it goes. You're right. The wind really didn't do much. It looked like it was backing for a second but then now it's come back to 240•-245•.

12:00 MIDNIGHT

NB: It will be interesting to see if we see the same thing that is in the forecast soundings and that is as we get a little lower here the winds actually decreasing with height. Apparently the warmest air is being drawn up just ahead of the system and so we're in the situation where we're actually getting kind of a northeasterly thermal wind.

AR: Yes. That will be interesting. I did pull up the Salem cross section from the MM5 just before we boarded the plane. Looking at those low-level winds too just before, pretty impressive. The other thing that was impressive was the astounding drop in the freezing level immediately behind the front, which I took to even be probably in real life might be even a little sharper.

AR: Roger. Thanks for that nice report, Nick, and while you're on the radio there we went back through that temperature change of about a degree in probably 30 s to 1 min, no wind shift. Maybe it's related orography or something down there.

NB: Well, I don't know. You know there are all kinds of waves rattling around up here. I don't know. It could be just one of those things.

AR: Right, exactly. It might even be associated within the band itself. It's a little cooler where the air is being lifted a little better.

12:07 AM

NB: I guess I'm kind of surprised it wasn't if indeed the echo top was as low as just, I don't know, a kilometer above the plane that we didn't see kind of brighter sky there.

AR: That's exactly right.

NB: So I'm inclined to think that air was probably actually up to 25,000 ft or something.

AR: Yes. That's right. Because if it had been a kilometer, I can tell you, the sun's disc would have been visible at least through ice cloud.

NB: Who needs radar when you have Art?

AR: But I can be wrong. I consider, for example, being wrong when I thought we were in some liquid water cloud on the ferry flight down here and the ice is just not building up and the FSSP was in that way over 10 (10, 20, even 25) and yet the spectrum was very broad. So you should have been seeing ice building up over a period of time and it never happens. So obviously it either drops below say, well below 20 microns, or they just weren't out there. It was all due to ice. The discrepancy between the PVM and the FSSP certainly suggests ice was the cause.

liquid @ top cloud layer

12:09 AM

AR: The other reason why we wouldn't have seen the sun, Nick, if the cloud top really was only a kilometer, is if you do have that upside-down cloud. The temperatures aren't terribly low here and it's not impossible that at –25• to –30•C you would have that liquid top and in the optical depth to be much greater in those droplet clouds. Sometimes what makes a cloud top look a lot higher is if you think it's all ice above you.

NB: How often does that really happen?

AR: We used to see it every time we went to the top of storms in the CYCLES project. There would be this little altocumulus-like cloud at the top and sometimes it

12:16 AM

AR: The other thought was that the MM5 anyway showed that freezing level going down to 950 mb. So there's not a lot of out if you pick a tremendous amount of icing up going westbound say and you hit this unexpectedly.

NB: Right. I'm sure what they would do is climb up. They have a lot of deicing and just if they get out of the water, even though they're cold, they can do pretty well.

AR: Good to hear.

NB: Hey Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new northeast point for you once we kind of turn the next corner.

ZS: Okay. Go ahead.

NB: That's 44•17.0'/122•09.2'.

ZS: Okay. You got it and that will be level at 16,000 ft, right?

NB: Correct.

12:17 AM

AR: The 2-D has been pretty ratty here over the last few minutes. Lots and lots of partially imaged particles and none of the end lines that designate the start and end of a particle, that is those vertical lines as seen on the display.

12:26 AM

AR: Still no icing as we make our turn here. Correction, we're not making our turn here. It was a misperception on my part. We're only a few minutes from the end of the southwest leg. There has been no icing, let me repeat, and the sky conditions continue diffuse, no identifiable cloud layers above or below at this point. The time is 003109.

12:36 AM

AR: The FSSP is showing 10-20/cc. I cannot see puffs of cloud going by, but there is some indication of haze or some degradation of visibility down the wing to the radar pod. It's definitely not clear so those particles are out there. It's just a question of the phase. The PVM is indicating only about half the liquid water content, but it is responding to something going by. So I think there maybe some small drops out there. We're really not picking up any ice. However, there is certainly no enhancement on the top of the Pilewskie rod. There's just the trace of

ZS: Okay. That one will be descending to 14,000 ft?

NB: Affirmative.

ZS: Thanks.

AR: Tom, that seemed to help. There's quite a few more good ones now.

12:45 AM

AR: Just a comment on the crystals. They have continued to appear unrimed to me with the isolated exception of some rather roundish ones that suggest there could have been some light riming above, but for the most part they definitely appear unrimed from our highest leg down to this leg.

12:51 AM

AR: It looks as if we might have lost satellite because we're not getting an update on tans-alt or winds. Pressure altitude 165, that's about 700 ft higher than our actual altitude.

12:57 AM

AR: As we made our turn, there was no distinguishing aspect of these crystals or liquid water content or anything in particularly, no wind shifts, no temperature change. Generally running about –17.5•C reverse raw-t on this leg at 16,000 ft. Now we'll be descending I think to 14,000 ft by the southwest endpoint.

12:58 AM

AR: 010257, almost nightfall, no stars visible. Continuing unrimed crystals. No liquid water except maybe traces. There is certainly no icing on the Pilewskie rod.

1:03 AM

NB: Zan, Nick here.

ZS: Go ahead Nick.

NB: I have a new northeast point for you. It's 44•26.3'/121•47.1'.

ZS: Got it and that's a level leg at 14,000 ft, right?

NB: Correct.

1:06 AM

NB: Yes, it sure has. What we saw last time sometimes when. There's some turbulence there too. When we start picking up icing and airspeed indicated that the wind is based on kind of gets flaky, but this looks real.

AR: I would agree it looks real because there's still just a trace of icing on like the light up there, which is one of the main things I look at at night.

NB: I suppose it's still kind of cold to have much in the way of ice too, –12• to –13•C.

AR: Well, I would, actually, at this temperature and even down to about –20• we were picking up supercooled drizzle and it was piling up in a hurry. For the end in this case, you have all that ice falling down in and the orographic lifts it, we hope, will make a big difference.

1:22 AM

AR: I see now we're out in the Willamette Valley, so my comment about orographic lift isn't appropriate.

1:23 AM

AR: Maybe this is just lee turbulence off the coast rain.

NB: It could be. I wouldn't be surprised if we're right near the western edge of the bay end with some sort of frontal activity there too.

AR: Yes, we'll look for something to happen. Actually, I see the temperature is starting to fall now again.

1:24 AM

AR: Of course, it's gone up as soon as I said that.

1:25 AM

passed through back edge of ULF precip band.

AR: A huge cooling there at 1:00 o'clock slot. That's a dusk slot.

NB: Yes, sure enough, kind of pretty.

Alt ≈ 4.3 km

AR: Now you can see if we're going to hit anything or not. It looks like we're toward the top of some of the higher domes. It looks like we might hit one here in a minute but other than that.

NB: We'll make our turn here any second I'd say.

AR: Roger and it looks like we will pick something up in the turn.

1:26 AM

NB: I got a recent report from the P-3. They're redoing their lawn mower pattern. At the north end of the westernmost leg on their radar, they see widespread precipitation coverage, but much more convective in nature with cells popping up to something like 4.5 kilometers or so.

AR: Is that in our area, Nick, or is that out over the valley or upslope?

NB: Essentially I think it's west of the study area. But while we're doing basically the southwest to kind of northeast part of it, they're up now in the kind of northwest corner and I think they're even looking a little further out to the west. I guess the main message is that there's a much more convective-type precipitation coming in with something like a 4.5 kilometer top, so that's decidedly higher than some of what we've been seeing in the post-frontal region.

1:43 AM

AR: No stars visible east endpoint, in and out of droplet cloud. Looking at the side light they have on that's pointed toward the ray dome.

1:46 AM

AR: As we turn it looks like we're getting some of the bigger aggregates that we've seen on this leg and if I recall correctly.

1:47 AM

NB: Art, are those kind of some of the first dendrites I'm seeing on the 2-DC?

AR: I've seen other ones that kind of resemble that, but I'd say you're right that they're certainly looking a little more like they're reflecting that temperature range.

NB: Right. I wasn't sure how sharp it was or whether it was just mostly at –12• where you could really see them well or just what.

AR: Right. Going downward, yes, you would see them down at the bottom of that zone, which would be…

KM: We're headed back southwest bound and we're out of 14,000 ft for 12,000 ft.

NB: Yes, that's correct.

AR: In general though I've been kind of bored out of my mind here with the lack of change. There isn't much of anything here on all these legs.

NB: I know what you mean.

AR: I don't know if the winds are still recovering from our turn, but look at the velocity there. There's just ramming up the slope and now it's not doing much.

KM: One more hour.

NB: Thanks.

TW: So you might want to buckle up.

AR: Who did that?

TW: Calvin.

AR: Yes, I wouldn't be surprised.

NB: I'm going to talk to Mark at the S-Pol now, so I'll be offline for a bit. I don't know if you heard, but we have about an hour on station.

AR: Ken, is your radar up on the wing?

KM: Say again.

AR: Is your radar working?

KM: We've got it turned down right now. We can turn it on.

AR: I was just wondering if that's helpful. I guess it doesn't matter.

KM: It's working.

AR: Thanks.

1:56 AM

NB: Ken, Nick here.

KM: Go ahead.

NB: Does that hour on station account for landing at Eugene?

KM: Yes. We're halfway close to Eugene. It depends on which end of the leg we end on.

NB: Yes. The way we will end very near Eugene. I calculate to complete the pattern it might take us more like an hour and 25 min.

KM: An hour and how much?

NB: An hour and 25 min or so, but I'll try to fine-tune that.

KM: Okay. We'll see what we've got here.

TW: And the 2-D. I don't know, I guess it is back, isn't it?

AR: I think it's okay to keep updates here though.

2:07 AM

NB: Ken and Larry, Nick here.

LS: Go ahead Nick.

NB: To be on the conservative side, I think we can do one more back and forth across the mountain, so that means we'll have one less leg than we had hoped to do. That's okay. But what I'd like to do here at the southwest end, is to descend down to 11,000 ft and do a northeast leg at 11,000 ft. Then coming back for our final southwest track to do it at the minimum altitude across the pass and stepping down on the west side and then land at Eugene.

LS: Okay.

NB: I calculate that will take 40 min or so.

LS: Okay.

TW: Is the second flight looking at a full duration?

AR: I don't think they can fly more than 8 hr in a day, but it's probably up to the pilots.

NB: I think they have, since they have three pilots, they can fly more, but I don't know. I was going to check on that.

AR: That's a good point. I forgot about the third pilot. Also the next pass, Nick, is going to be risky. You're losing the high shield that was dropping all the ice into the supercooled cloud. I think as long as we have an out, I don't think you want to see a half a gram, three-tenths even, for more than a couple of minutes at this point.

NB: Right.

AR: With drizzle, which is going to be a little bit heavier down lower. It will convert to ice as it goes along, but you may find those drizzle drops are maybe 500 microns instead of 200 microns.

LS: Nick, you did want to continue our descent on this leg to 11,000 ft?

NB: Yes. That's right.

you still have those dials. I think they're supposed to read about 1.4 volts when they're on full.

2:19 AM

TW: Do you know if the 2-DP and the 2-DC use the same laser?

AR: I'm not sure.

2:20 AM

NB: I'm going to call the S-Pol now, so temporarily offline.

2:21 AM

AR: There are some big aggregates out there.

2:23 AM

TW: Hey Art.

AR: Roger Tom.

TW: If you had a 2-D histogram size bins, how many bins, what sizes would you start at, and what would be the size of the bins?

AR: 50 microns say or 100.

TW: 50 starting at 100?

AR: The width of the microns would be say 50 or 100, and then it would start at 0 to 100, 100 to 200 or 199.

TW: Up to about what, 3 millimeters or something?

AR: Yes.

TW: I finished that software, so I can test it on the next flight.

AR: Great!

2:27 AM

NB: I'm back on here. It looks like for the first time I thought I saw some needles kind of joining in the game.

ZS: Do you have a new coordinate for the end on the southwest?

NB: Yes. You can use 44•00.1'/122•49.6'.

ZS: Okay. This will be stepping down with the terrain?

NB: That's correct. Then once we hit that point, which is going to be a point near Eugene, then we can land there.

ZS: Okay. Are you going to be underneath the clouds for a specified amount of time?

NB: It depends if we can get underneath them and how much time we can fly around in the Willamette.

ZS: Okay. We'll take a look at it when we get closer to that.

2:36 AM

AR: We just completed our downwind pass, southwest to northeast, and we went through another high zone of liquid water about 0.4 g m^{-3} sustained at times perhaps even a little higher and intermittent bursts of drizzle drops and other areas where crystals were falling from higher or lower temperatures.

NB: Hey Art, Nick here.

AR: Roger Nick.

NB: Just interesting how hard it's precipitating here in the lee.

AR: I think with the winds you have, I think there's so much carry over from the precip generated up here that the ice crystals, needles and that sort of thing, probably only the graupel is getting on the west side.

NB: Yes. That's what I was thinking, exactly. The Sisters site there was reporting heavy rain a couple of hours ago.

AR: What's that elevation?

NB: I don't know, something like 4,000 or 5,000 ft.

AR: I'll be darned.

2:37 AM

NB: Art, what do you think the cloud base will be at in the Willamette Valley?

AR: I don't think we've gotten warm enough to have anything fly off anyway.

NB: I've heard some stuff hit.

AR: Okay. I haven't heard a darn thing, but I have heard a couple of pops. Not on the last flight, I wasn't on it, but before that I think Peter heard something. I would think we would have noticed a crack of this magnitude. I do remember one other time we had a cracked bubble on the top here and I think we drilled a little hole in it to stop the crack at the end of the crack.

2:43 AM

AR: We should be coming back into those low clouds here any second. It will be interesting to me, Nick, to see if this drizzle survives. My impression is that it might form up there near cloud top and start on it's way down, but it would freeze.

NB: Okay.

AR: Sort of a time dependency.

2:44 AM

NB: I'm finding it a little bit surprising that there isn't a little more kind of lee wave activity here with 65 knots of wind hitting this barrier.

AR: Yes.

NB: I'm not that keen on necessarily getting tossed all around, but it's just kind of why not this time.

AR: Yes. Maybe the wave is breaking further down the stream.

NB: There may not be enough stability to kind of really support it.

AR: That's a good point too. Also I noticed that in this same area now we're getting those lower temperature crystals falling into this stuff that was devoid of them earlier. So that higher shield is progressing and that will probably help our icing situation a bit. There are some nice dendrites there a while back.

2:46 AM

NB: Nick here.

ZS: Go ahead Nick.

NB: I was just wondering what you have in store for us. Are we still going to land in Eugene?

NB: Yes, I'm here.

AR: I just noticed it looks like the temperature is starting to fall again, so that really would indicate we're going through some kind of maybe frontal wind shear zone. I think it was getting up to –4.5•C and now we're down to –5.2•C. I think we're been descending.

NB: Yes we have. We're at, I think, 8,000 ft now. I don't have that great a reason why it should be kind of so choppy here.

AR: In that 55 knot wind.

NB: It's not like there's any more shear. Well, maybe there is a bit more shear down here too.

AR: It's probably a little more unstable. Actually, I thought we were lower than we were.

NB: I'm still uncertain of which temperature I should be looking at. You said the reverse flow thermometer was kind of more reliable. Is that correct?

AR: Roger.

NB: It looks like we're hitting a far amount of water now.

AR: You know, I didn't see a single drizzle drop on the way down here to this lower level. I don't know if they were frozen on the way down or disintegrated.

NB: How do they fall relative to the crystals? If they're that small, do they really fall out any faster than the crystals?

AR: Absolutely and that's certainly part of it. But back there where we were devoid of the higher crystals falling into that stratocumulus, that was the area I was looking for some drizzle drops, but even there it didn't seem like any of those made it down. Sometimes though if they're freezing in the Hallett-Mossop zone, there's this stickier thing, you know, when you get freezing rain and then sleet. It gets cold enough to produce sleet and you get stickier drops and there's sudden evidence that those disintegrate.

3:01 AM

AR: I was just thinking, Nick, there might be that wind shear too down in the Willamette where you get that channeled southerly flow and you have those little gradient southwest flow and maybe we're getting close to that. See if that's there.

NB: I think that certainly does exist there just like in Puget Sound. We're up a bit high for that perhaps but maybe not. We're at 7,000 ft now or so.

ZS: Nick, that's the end of the leg and we're turning toward Eugene and it will probably be about 8 min until landing.

NB: Thank you.

ZS: I'm off. I'll talk to you on the ground.

NB: Okay. We're done with the leg, anytime.

TW: Okay.

3:08 AM

END OF TAPE

high shield thinning patches, no crystals falling in from above @ times

Summary of UW Flight 1900*

This flight took place as one of the strongest of all IMPROVE-2 frontal systems passed over the Oregon Cascades. The winds at 850 and 600 hPa were 50-80 knots out of the southwest, with extensive warm air advection producing overrunning cloud layers and a well-developed orographic cloud over the Cascades. The satellite imagery before the flight showed two rainbands with a thin zone of separation between them about to make landfall on the Oregon coast. The first rainband appeared to be the stronger, or at least had the colder tops.

The ferry portion of the flight consisted of a stepped ascent to near 20,000 ft MSL by the time the research legs began at the southwestern end point. Embedded droplet clouds (shallow altocumulus-like clouds) were encountered intermittently above the freezing level within otherwise a deep, featureless ice cloud. However, there was little ice buildup en route to the research area, indicating very low liquid water contents and small droplets.

The first research leg, starting from the SW endpoint at 20,000 ft MSL was flown in deep and diffuse precipitating cloud with little internal detail or indication of layering. A thinning in the ice and precipitation occurred a few minutes en route to the NE end point at 2328 to 2334 UTC. At this time a droplet, altocumulus-like cloud estimated 3,000-4,000 ft above the aircraft and some blue sky could be seen above the aircraft through a "haze" of ice precipitation.

Other than this brief respite, deep and diffuse clouds with little internal detail were flown in until reaching the 14,000 ft MSL in the series of slantwise descents from 20,000 ft MSL. Embedded droplet clouds were encountered at almost every level and leg. Droplet concentrations were very low (~10-30 cm^{-3}). During the descent from 16,000 to 13,000 ft MSL the aircraft encountered more droplet clouds with substantially higher droplet concentrations (>50 cm^{-3}) and higher liquid water contents (LWC). The LWC reached as high as 0.4 g m^{-3} in the wettest regions of these clouds. Supercooled drizzle drops were briefly encountered in these clouds at -13°C and still more (concentrations >300 per liter) at about -9°C adjacent to regions with extremely high ice concentrations (some >500 per liter) consisting of mainly sheaths and needles. The supercooled drops resulted in a rapid but brief icing buildup on the aircraft. Also, brief

* No verbal summary of this flight was recorded onboard the aircraft. A summary has been reconstructed from other comments recorded on the flight.

/cc * 1000 = /L