Operations Manual

for

IMPROVE-2
Oregon Cascades Orographic Study

26 November – 22 December 2001

Assembled by
Mark T. Stoelinga, Peter V. Hobbs, John D. Locatelli, and Clifford F. Mass

16 November 2001

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Oregon Cascades Orographic Study

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Principal Investigators

Cliff Mass
Office: 206-685-0910, cliff@atmos.washington.edu
Peter Hobbs
Office: 206-543-6027, phobbs@atmos.washington.edu
John Locatelli
Office: 206-543-5219, johnl@atmos.washington.edu
Mark Stoelinga
Office: 206-543-6235, stoeling@atmos.washington.edu
Brian Colle
Office: 631-632-3174, colle@cyclone.msrc.sunysb.edu
Bob Houze
Office: 206-543-6922, houze@atmos.washington.edu

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1. OVERVIEW

Regional mesoscale forecast models (such as Eta, COAMPS, and MM5) are becoming increasingly important tools for forecasting local weather systems. Prediction of precipitation is a particularly challenging problem since these models rely on bulk microphysical parameterization schemes that do not fully represent the physical processes involved in the production of clouds and precipitation. Since poor precipitation forecasts are due not only to inadequate microphysical schemes, but also to errors in model forecasts of moisture and vertical air velocity, it is important to separate these two types of potential errors when attempting to improve mesoscale models.

The goal of IMPROVE (Improvement of Microphysical PaRameterization through Observational Verification Experiment) is to simultaneously and comprehensively measure both basic-state and microphysical fields in a variety of precipitating weather systems, for the purpose of verifying and improving bulk microphysical parameterizations in mesoscale models. Specifically, the goal of IMPROVE is to obtain simultaneous in situ aircraft measurements, ground-based and airborne radar measurements, and other surface and upper-air observations of cloud microphysical processes, air flow, and thermodynamic structure, within precipitation systems. The first phase of IMPROVE (IMPROVE-1, the Washington Offshore Frontal Study) focused on studying clouds and precipitation forced by frontal dynamics over the northeastern Pacific Ocean. That field campaign was conducted in January-February 2001. The second phase of IMPROVE (IMPROVE-2, the Oregon Cascades Orographic Study) is focused on precipitation that is strongly forced by airflow over a topographic barrier. IMPROVE-2 will be carried out during the period 26 November – 22 December 2001. Measurements from both field campaigns will be used to perform comprehensive verification of cloud and precipitation microphysical processes parameterized in mesoscale models.

The IMPROVE-2 field project will be coordinated from the UW. The primary means of disseminating project information related to the IMPROVE-2 field study will be through the IMPROVE web site: http://improve.atmos.washington.edu, and through the IMPROVE Status Telephone Line (206-616-0578). Prior to the field study, the Web Site will have information on project preparation and operations plans. During the field study, the IMPROVE Web Site and Status Telephone Line will have information and instructions to participants regarding daily operations. The Web Site will also have logs of observations taken during each IOP. After the field study, the Web Site will also have information on IMPROVE data archives and research.

Two research aircraft will be used in IMPROVE-2: the UW's Convair-580 (hereafter, the CV-580), which is based at Paine Field in Everett, Washington, and the NOAA WP-3D Orion (hereafter, the P-3), which will also fly out of Paine Field. Coordinated research aircraft flights will be carried out over the Santiam River/Santiam Pass region of the Cascade Mountains in central Oregon (see Fig. 1 for a topographic map and Fig. 2 for a road map of the study area). In addition to the CV-580 and P-3 aircraft, the IMPROVE-2 study will employ the following observational platforms (see Fig. 1 for locations):

- The NCAR S-band polarimetric ("S-Pol") radar, deployed on the upslope side of the mountain range, ~10 km west of Sweet Home, Oregon
- A scanning radiometer (provided by NCAR) for measuring integrated liquid water and water vapor, to be deployed at Santiam Junction.

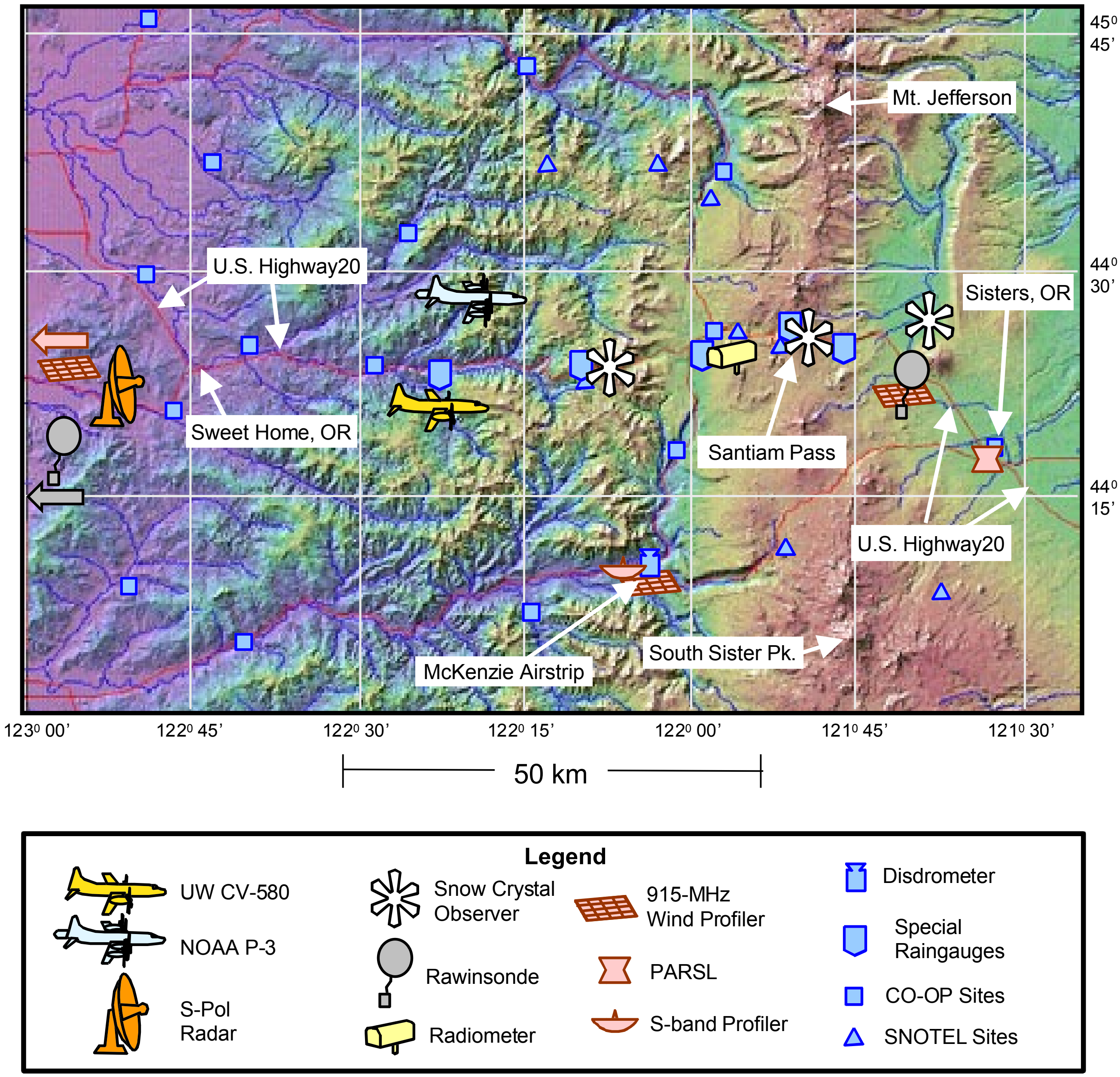


Figure 1. Observing facilities for IMPROVE-2.

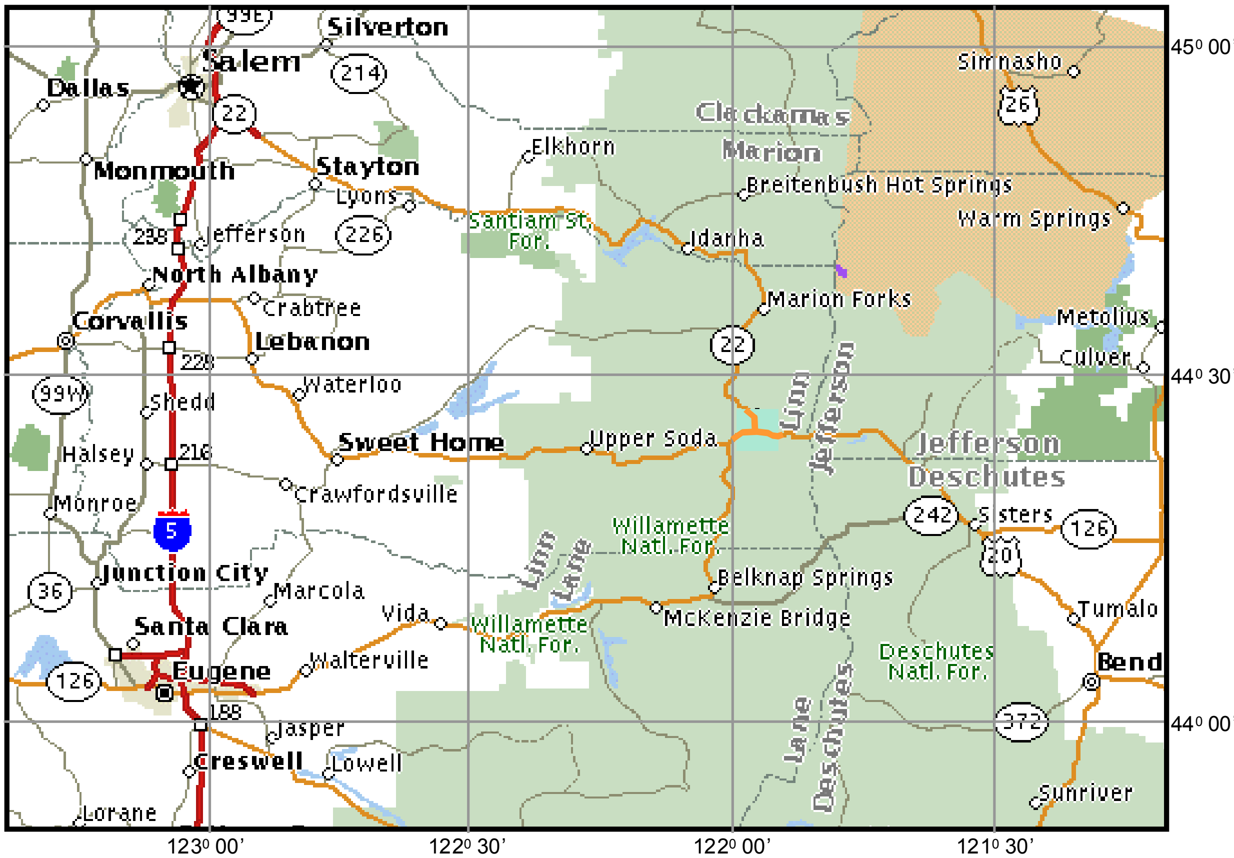


Figure 2. Road map of the IMPROVE-2 study area.

- A team of mobile ground-based observers of snow crystals, operating in the vicinity of Santiam Pass
- A special rain gauge network along the Santiam Highway (U.S. Highway 20) between Sweet Home and Sisters, Oregon
- Two NCAR Integrated Sounding Systems (ISSs), including 915-MHz wind profilers and sonde-launching capabilities, one in the Willamette Valley and the other in the immediate lee of the mountain range crest
- One mobile sonde facility operating along Interstate Hwy. 5 in the Willamette Valley
- Pacific Northwest National Lab's Atmospheric Remote Sensing Laboratory (PARSL), with various radars, lidars, and radiometers, deployed near Sisters, Oregon
- Two NOAA/ETL profiler sites: a 915-MHz wind profiler with RASS, an S-band vertically-pointing radar, and a 10-m meteorological tower (includes precipitation measurements), deployed near McKenzie Bridge, Oregon; and a 915-MHz wind profiler with RASS and a 10-m meteorological tower (includes precipitation measurements) deployed near Newport, OR
- A disdrometer, deployed near McKenzie Bridge, Oregon
- Special three-hourly NWS sonde launches from Salem, Oregon, during IMPROVE-2 study periods

2. PROJECT TEAMS AND CONTACTS

a) IMPROVE Information

IMPROVE Status Telephone Line: 206-616-0578
IMPROVE Web Site: http://improve.atmos.washington.edu

b) Coordinator

Cliff Mass
Office: 206-685-0910, cliff@atmos.washington.edu
Home: (deleted)

c) Data Managers

Stacy Brodzik
Office: 206-685-9993, brodzik@atmos.washington.edu
Home: (deleted)
Socorro Medina
Office: 206-685-0957, socorro@atmos.washington.edu
Home: (deleted)
Note: All data emails should be sent to **both** Stacy Brodzik and Socorro Medina

d) Forecasting Team

Ernie Recker, leader/organizer/primary contact
Office: 206-543-0238, ernie@atmos.washington.edu
Home: (deleted)
Mark Albright
Office: 206-543-0448, marka@atmos.washington.edu
Home: (deleted)
Brian Ancell
Office: 206-685-2183, bancell@atmos.washington.edu
Home: (deleted)
Don Atkinson
Office: 206-543-6290, dona@atmos.washington.edu
Home: (deleted)
Tony Eckel
Office: 206-543-9144, teckel@atmos.washington.edu
Home: (deleted)
Eric Grimit
Office: 206-543-1456, epgrimit@atmos.washington.edu
Home: (deleted)
Justin Sharp
Office: 206-685-8066, justin@atmos.washington.edu
Home: (deleted)

d) Forecasting Team (continued)

Rick Steed
Office: 206-685-2183, steed@atmos.washington.edu
Home: (deleted)

e) CV-580 Science Crew

Peter Hobbs, Aircraft Manager and Flight Scientist
Office: 206-543-6027, phobbs@atmos.washington.edu
Home: (deleted)
Art Rangno, Flight Scientist/Meteorologist
Office: 206-543-7643, art@atmos.washington.edu
Home: (deleted)
Don Spurgeon, Flight Engineer
Office: 206-543-7684, don@atmos.washington.edu
Home: (deleted)
Tom Wilson, Computer Support
Office: 206-543-7684, twilson@atmos.washington.edu
Home: (deleted)
Roy Rasmussen, CCN Counter Scientist/Operator (25 Nov –28 Nov)
NCAR (Boulder) Office: 303-497-8430, rasmus@ucar.edu
Seattle Residence: Silver Cloud Inn, 206-526-5200
Vidal Salazar, CCN Counter Scientist/Operator (26 Nov –15 Dec)
NCAR (Boulder) Office: 303-497-8380, vidal@ucar.edu
Seattle Residence: (deleted)

When any of the above are at the UW Hangar at Paine Field, they can be reached by telephone in the CV-580 Science Crew Office at 425-438-1595

f) CV-580 Flight and Ground Crew (McMillen Enterprises)

Ken McMillen, Chief Pilot
Home: (deleted), jmcmillen@olympus.net
Cell phone: (deleted)
Larry Sutherland, Pilot/Copilot
Home: (deleted), larr744@cs.com
Alexander Sutherland, Pilot/Copilot
Home: (deleted)
Cell phone: (deleted)
Jerry Rhode, Pilot/Copilot
Home: (deleted)
Eric Cooper, Pilot/Copilot
Home: (deleted)
Bob Eatwell, Aircraft Engineer
Home: (deleted), cv580e@aol.com

f) CV-580 Flight and Ground Crew (continued)

Calvin Ingram, A&P Mechanic
Home: (deleted)
Ben Blainedavis, Mechanics Assistant
Home: (deleted)

When any of the above are at the UW Hangar at Paine Field, they can be reached by telephone in the CV-580 Flight Crew Office at 425-745-9511. The fax number in the CV-580 Flight Crew Office is 425-348-3590.

g) P-3 Science Crew

Jim Roles, Project Manager
MacDill AFB Office: 813-828-3310 x3037, Jim.H.Roles@noaa.gov
Everett Residence: Best Western Cambridge Inn, Everett, 425-347-2555
Barry Damiano, Flight Director
MacDill AFB Office: 813-828-3310 x3073, A.Barry.Damiano@noaa.gov
Everett Residence: Best Western Cambridge Inn, Everett, 425-347-2555
Brad Colman, Lead PI, and Airborne Radar Scientist
Office: 206-526-6095 x224, brad.colman@noaa.gov
Home: (deleted)
Nick Bond, Flight Scientist
Office: 206-526-6459, nick@atmos.washington.edu
Home: (deleted)
Olivier Bousquet, Airborne Radar Scientist
Office: 206-616-9426, bousquet@atmos.washington.edu
Home: (deleted)
Brian Colle, Airborne Radar Scientist (participating from 2 Dec through 15 Dec)
SUNY/Stonybrook Office: 631-632-3174, colle@cyclone.msrc.sunysb.edu
Seattle Residence: (deleted)

When any of the above are at the UW Hangar at Paine Field, they can be reached by telephone in the NOAA P-3 Office at 425-423-0534.

h) P-3 Flight and Ground Crew

Brian Taggart, Flight Commander
MacDill AFB Office: 813-828-3310 x3025, Brian.K.Taggart@noaa.gov
Everett Residence: Best Western Cambridge Inn, Everett, 425-347-2555
NOAA personnel will also include two copilots, a navigator, an engineer, and several ground crew, all staying at the Best Western Cambridge Inn, 425-347-2555.

When any of the above are at the UW Hangar at Paine Field, they can be reached by telephone in the NOAA P-3 Office at 425-423-0534.

i) NCAR S-Pol Radar Team

J. "Vivek" Vivekanandan, Project Manager, and manager of radiometer
At S-Pol 23 Nov – 5 Dec 2001
NCAR (Boulder) Office: 303-497-8402, vivek@ucar.edu
Cell phone: (deleted)
Jim Wilson, Project Manager
At S-Pol 3 Dec – 23 Dec 2001
NCAR (Boulder) Office: 303-497-8818, jwilson@ucar.edu
Cell phone: (deleted)
Jon Lutz, Chief Radar Engineer
At S-Pol 15 Dec – 23 Dec 2001
NCAR (Boulder) Office: 303-497-2027, jon@ucar.edu
Cell phone: (deleted)
Don Ferraro, Chief Radar Engineer – Operations
NCAR (Boulder) Office: 303-497-2039, dferraro@ucar.edu
Cell phone: (deleted)

When any of the above are inside the S-Pol Radar Control Center, they can be reached by either of two cell phones with external antennas:
303-817-3182 (Engineer/Technicians' office)
303-817-0546 (Scientists' office)

All of the above will be staying at the Sweet Home Inn, 541-367-5137.

j) S-Pol Radar Scientists

Mark Stoelinga, Flight Track Coordinator
Office: 206-543-6235, stoeling@atmos.washington.edu
Vida, Oregon, residence: Wayfarer Resort, 541-896-3613, cabin 3
Cell phone: (deleted)
Radar Data Managers:
Stacy Brodzik
Office: 206-685-9993, brodzik@atmos.washington.edu
Sweet Home, Oregon, residence: Sweet Home Inn, 541-367-5137
Socorro Medina
Office: 206-685-0957, socorro@atmos.washington.edu
Sweet Home, Oregon, residence: Sweet Home Inn, 541-367-5137

When any of the above are inside the S-Pol Radar Control Center, they can be reached by either of two cell phones with external antennas:
303-817-3182 (Technicians' office)
303-817-0546 (Scientists' office)

k) Snow Crystal Observers

Jon Locatelli, Team leader/organizer/primary contact
Office: 206-543-5219, johnl@atmos.washington.edu
Camp Sherman, Oregon, Residence: Cold Springs Resort, 541-595-6711 (office)
541-595-1418 (cabin)
Cell phone: (deleted)
Matt Garvert
Office: 206-543-7643, garvert@atmos.washington.edu
Camp Sherman, Oregon, Residence: Camp Sherman Store, 541-595-6711
Cell phone: (deleted)
Greg Thompson (participating from 27 Nov – 12 Dec)
NCAR (Boulder) Office: 303-497-2805, gthompsn@ucar.edu
Sisters, Oregon, Residence: Big Red Barn Bed & Breakfast, 541-549-6425
Cell phone: (deleted)

l) Rain Gauge Network Deployment

Pascal Storck, Manager
Office: 206-685-3793, pxs@atmos.washington.edu
Home: (deleted)

m) Integrated Sounding System

On-site Scientists:
Mike Susedik, Project Manager/Engineer
In Oregon 6 Dec – 23 Dec 2001
NCAR (Boulder) Office: 303-497-8742, susedik@ucar.edu
Sweet Home, Oregon, Residence: Sweet Home Inn, 541-367-5137
Cell phone: (deleted)
Lou Verstraete, Project Technician
In Oregon 13 Nov – 8 Dec 2001
NCAR (Boulder) Office: 303-497-8732, louvers@ucar.edu
Sweet Home, Oregon, Residence: Sweet Home Inn, 541-367-5137
Cell phone: (deleted)
Gary Granger, Software Engineer at NCAR
NCAR (Boulder) Office: 303-497-8732, louvers@ucar.edu
Larry Kierulff, Sonde Launcher (Black Butte Ranch site)
Bend, Oregon, Residence: (deleted)
Cell phone: (deleted)

n) Mobile Upstream Sonde Unit

Stan Rose, Team Leader
Office: 206-543-5219, srose@atmos.washington.edu
Vida, Oregon, residence: Wayfarer Resort, 541-896-3613, cabin 1
Cell phone: (deleted)
LTjg Bruce Conway, Navy Reserve Coordinator
Whidbey Island NAS Office: 360-257-3454 x0384, conwayb@naswi.navy.mil
Cell phone: (deleted)

o) PNNL Atmospheric Remote Sensing Laboratory (PARSL) Team

Jim Mather
PNNL (Richland) Office: 509-375-4533, jim.mather@pnl.gov
Sisters, Oregon, residence: Comfort Inn Sisters, 541-549-7829
Cell phone: (unavailable at time of publication)
Kevin Widener
PNNL (Richland) Office: 509-375-2487, kevin.widener@pnl.gov
Sisters, Oregon, residence: Comfort Inn Sisters, 541-549-7829
Cell phone: (deleted)

p) NOAA/ETL Profiler Site

On-site Scientists:
Louisa Nance, Project Manager
In Oregon from 26 Nov to 11 Dec
NOAA (Boulder) Office: 303-497-6520, louisa.nance@noaa.gov
Eugene, Oregon, residence: Marriott Residence Inn, 541-342-7171
Cell phone: (deleted)
David White
In Oregon from 12 Nov to 22 Dec
NOAA (Boulder) Office: 303-497-6613, david.e.white@noaa.gov
Eugene, Oregon, residence: Marriott Residence Inn, 541-342-7171
Cell phone: (deleted)
Clark King, Field Project Manager
NOAA (Boulder) Office: 303-497-6381, clark.w.king@noaa.gov

q) Disdrometer

Sandra Yuter, Disdrometer Scientist
Seattle office: 206-685-1073, yuter@atmos.washington.edu
Hillsboro, Oregon, office: 503-628-7832

r) NWS-Seattle Contacts

Brad Colman, Science and Operations Officer
Office: 206-526-6095 x224, brad.colman@noaa.gov
Home: (deleted)
or, in his absence,
Chris Hill, Meteorologist-in-Charge
Office: 206-526-6095 x222, chris.hill@noaa.gov
Home: (deleted)

s) NWS-Portland Contact (for sondes at Salem, Oregon)

Steve Todd, Meteorologist-in-Charge
NWS (Portland) Office: 503-326-2340 x222, steve.todd@noaa.gov
Home: (deleted)

t) FAA Seattle ARTCC Contact for IMPROVE-2

Carla Vance, Air Space and Procedures Office
Office: 253-351-3556, carla.r.vance@faa.gov

3. GENERAL SCHEDULE FOR IMPROVE-2 OPERATIONS

IMPROVE-2 will be conducted from 26 November through 22 December 2001. Since both of the research aircraft are single-crewed, aircraft flights will generally be confined to an *Operations Period* of 7 AM – 10 PM Pacific Standard Time. Other observations that require human operation (sonde launches and snow crystal observations) are closely tied in with the research aircraft flights, and therefore, will also generally occur during the Operations Period, though some may be required a few hours earlier or later in order to bracket the aircraft flights. If a very good study case is developing that would necessitate aircraft flights outside of the Operations Period defined above, an exception to these time period limitations may be requested by the Coordinator, subject to flight crew duty constraints for both aircraft (described in Appendices C and D) and approval by the aircraft managers and pilots.

Because of the flexibility of the technical and scientific staff for the S-Pol radar, as well as the capability of S-Pol to gather data in an automated (unattended) scan cycle for extended periods of time, the S-Pol radar will be considered available for studying precipitation systems at any time (day or night, seven days per week), instead of being confined to the Operations Period defined above. This does not mean it will run continuously. Approximately 300 hours of radar operation time have been allocated for IMPROVE-2. This represents 46% of the total time period of the project. The purpose of the NCAR S-Pol radar is to determine the three dimensional distribution of microphysical processes in relation to the topography in precipitation over the windward slopes of the mountains west of the Cascade Crest. To achieve this objective a statistical sample of polarimetric variables plus reflectivity and radial velocity must be obtained between the radar site and the crest. The scan sequences have been designed to accomplish this statistical objective and provide information that will help connect the aircraft data, surface ice particle samples, and vertically pointing ETL S-band profiler data sets into a comprehensive data set documenting the orographic precipitation processes over the Cascades. It is anticipated that it will be possible to collect data in all of the precipitation events during the period of the projects, whether aircraft are flying or not. Therefore the radar will be activated during all precipitation events. If during the course of the project it appears that the radar hours could be used up before the flight hours are expended, a priority system will be invoked to give priority to radar operation during flight operations. Details of the radar modes of operation and scan cycles are described in more detail in Section 8.

The PARSL site will operate independently on a schedule to be determined by the PARSL site manager. However, the operating schedule will accommodate IMPROVE-related priorities of operating scanning lidar and radar equipment during IMPROVE-2 research aircraft flights, as well as the full suite of remote sensing equipment during PARSL overflights.

Automated observations (rain gauges, profilers, radiometer) will run continuously throughout the IMPROVE-2 study period. It is the responsibility of the individual on-site managers of these observing systems to see that they are operating properly on a regular basis.

Each weather system that is chosen for detailed study will constitute an *Intensive Observation Period*, or *IOP*. Each IOP will be assigned a consecutive number (e.g., IOP 1, IOP 2, …). An IOP will begin when manned observations commence, and will end when manned observations are stopped. The IMPROVE-2 Coordinator will specify the start and end time of each IOP.

4. DAILY SCHEDULE

a) Overview

The daily schedule for IMPROVE-2 is illustrated by the 24-hour "wheel" shown in Fig. 3. The short green bands in the inner circle illustrate the three shifts for the Forecasting Team. The long orange band in the inner circle shows the Operations Period. The yellow segment in the outer ring shows the time period of the Daily Planning Meeting. Key update times are shown as blue hash marks around the perimeter.

b) Preparation for Daily Planning Meeting

On a typical day during which an IOP is *not* occurring, the Mid-day Forecaster will monitor weather and forecasting data starting around noon (at the latest), in preparation for the Daily Planning Meeting at 1 PM PST. More details on the Mid-day Forecaster's schedule and responsibilities are given in Section 6c.

c) Daily Planning Meeting

The Daily Planning Meeting is a key event that takes place daily at 1 PM PST. On weekdays, this meeting will be held in the UW Department of Atmospheric Sciences Map Room (room 627 ATG at the UW), and will last no more than 30 minutes. The Coordinator, the Mid-day Forecaster, the CV-580 Manager, the P-3 Project Manager, the P-3 Flight Scientist, and any IMPROVE PIs in Seattle should attend the meeting. Anyone else is welcome to attend. At the Daily Planning Meeting, the Forecaster will present a short weather briefing. This will be followed by a discussion of any relevant issues (instruments, personnel status, etc.) that might impact potential operations through the end of the next day's Operations Period. Following these discussions, the Coordinator will make a preliminary decision on operations through the end of the next day's Operations Period, including a decision on whether or not to conduct research flights the next day, with tentative doors-close times for the CV-580 and P-3 if flights are planned. (“Doors-close time” literally means the time when the aircraft doors close just prior to the aircraft getting under way—all crew and passengers must be on board by this time.) Rawinsonde, snow crystal observer, and radar operations will also be planned through the next day. All contact persons will be given assignments through 10 PM of the next day. These decisions will be made, and instructions given, at 2 PM. They will be made available to all participants via an updated message on the IMPROVE Web Site and Status Telephone Line.

The Daily Planning Meeting may coincide with an ongoing IOP. In this case, the Daily Planning Meeting will still occur at its regularly scheduled time and place, but may be interrupted by the Coordinator’s management of the ongoing IOP. Aircraft personnel will be at the UW Hangar, or may be on a flight, so the Coordinator will notify the UW Hangar by phone of decisions for the next day’s operations.

On weekend days when an IOP is not occurring, PIs and other IMPROVE personnel will probably not be present at the UW. In that case, the Coordinator will confer with the Mid-day Forecaster by phone at 1 PM PST, in lieu of an actual Daily Planning Meeting in the UW Map Room. Aircraft Managers and Flight Scientists will be notified directly by phone of plans for the

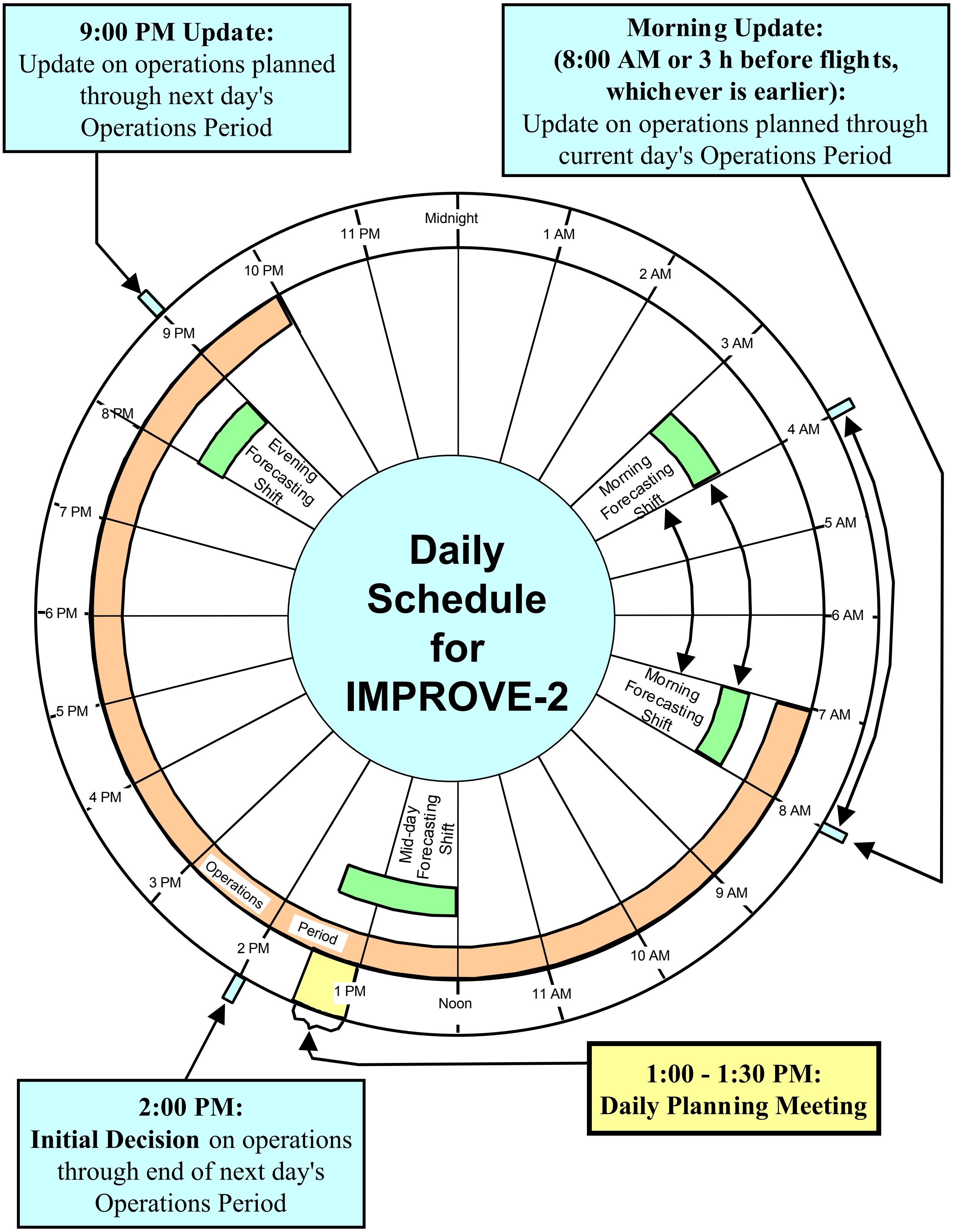


Figure 3. Daily schedule of key decision points, hours of operation, and forecasting shifts for IMPROVE-2.

next day's operations. Finally, on days in which both the current and following days have been declared official stand-down days (see Section 4e), there will be no Daily Planning Meeting.

d) 9 PM and Morning Updates

If radar operations are planned during the night, or if aircraft flights are planned for the next day, then following a consultation between the Evening Forecaster and the Coordinator, there will be an official 9 PM Update on IMPROVE-2 operations through the end of the next day's Operations Period. This update will include a decision by the Coordinator to go ahead with scheduled aircraft flights (with perhaps updated aircraft doors-close times), or to cancel the flights. The start time for radar operations that are planned to begin overnight will also be updated. These decisions will be made available to all participants via an updated message on the IMPROVE Web Site and Status Telephone Line.

If research flights are planned for the current day, then on the morning of that day there will be an official Morning Update (8 AM PST, or 3 h prior to scheduled research flights, whichever is earlier—see Fig.3) on IMPROVE-2 operations through the end of the coming day's Operations Period, after a consultation between the Morning Forecaster and the Coordinator. The Coordinator will make a decision to continue the scheduled flights (with perhaps updated aircraft doors-close times), or to cancel the flights. As with the 9 PM Update, the Morning Update will be made available to all participants via an updated message on the IMPROVE Web Site and Status Telephone Line.

e) Stand-Down Days

If it is reasonably certain at the time of the Daily Planning Meeting that there will be no IOP the next day, the Coordinator will declare a stand-down day. The period of a stand-down day will normally be 24 h, starting at midnight, although in special circumstances the Coordinator may adjust the period. All participants are free of their IMPROVE-related responsibilities during a stand-down day, EXCEPT for the Coordinator and the Mid-day Forecaster, and possibly the Evening Forecaster. The Mid-day Forecaster will still be required to forecast for the following day in preparation for the Daily Planning Meeting. The Evening Forecaster will still be required to prepare for and confer with the Coordinator prior to the 9 PM Update (if necessary).

Two consecutive stand-down days can be called if the forecast indicates a robust no-IOP situation for both the next day and the day after. In this situation, all participants are free of their IMPROVE-related responsibilities during the first stand-down day. Responsibilities during a second consecutive stand-down day will be the same as for a single stand-down day.

Due to predictability limitations, no more than two consecutive stand-down days will be declared at any Daily Planning Meeting. However, more than two consecutive stand-down days may eventually occur if dictated by the weather.

5. DATA MANAGEMENT

The management of data in IMPROVE-2 is designed to make available as much of the data as possible to all participants in as timely a manner as possible. To achieve this end, the management of data will be divided into two products. The first is a Perusal Data Set that will include a limited portion of non-quality checked data, with emphasis on rapid availability. The second is a Data Archive that will include all the IMPROVE-2 data, post-processed for quality control, which will be developed and made available after the field project is completed.

The goal in producing the Perusal Data Set is to gather a limited subset of key measurements that the IMPROVE-2 PIs want to view as quickly as possible after each IOP, into a central clearing house that will organize the data and make it available for display. The gathering and processing of the Perusal Data Set will be the responsibility of the Data Manager, and the central clearing house will be the UW Atmospheric Sciences computer system at the UW. For simplicity, all the data included in the Perusal Data Set will be in NetCDF format (with the exception of satellite imagery which will be in raster format) so that it can be displayed from a single data display software package. That package will be NCAR’s Zebra software. An IMPROVE Workstation in the UW Atmospheric Sciences Map Room will be running zebra and will be configured to view the Perusal Data Set. In the next section, among the responsibilities listed for each team are those that pertain to the delivery of data to the Data Manager for inclusion in the perusal data set.

The Data Archive will be developed after completion of the field project, and will involve further analysis and quality control of the raw data gathered. Information and updates on the data archive will be disseminated via the IMPROVE Web Site.

6. SCHEDULING AND RESPONSIBILITIES OF THE VARIOUS TEAMS

a) Coordinator

The Coordinator (Cliff Mass) is responsible for overall control of the IMPROVE-2 field project. The Coordinator will be on duty from 8 AM—5 PM Monday through Friday, plus during all research flights, during all Daily Planning Meetings, and for consultations prior to the 9 PM and Morning Updates.

Summary of Coordinator's Responsibilities:

- The Coordinator is responsible for overall operation of the field project.
- The Coordinator will chair the Daily Planning Meeting.
- At the end of the Daily Planning Meeting, the Coordinator will make an initial decision on operations through 10 PM of the next day, including whether or not to fly either or both aircraft the following day, with tentative doors-close times
- Prior to issuing the 2 PM Update, the Coordinator, in conjunction with the Mid-day forecaster, will determine forecasted values of the following parameters :
    - the 850, 700, and 500-hPa wind speed and direction at the middle of the study area (Twin Buttes, 44°20’N, 122°15’W), averaged over the time period of the planned aircraft flights.
    - the freezing levels at S-Pol and at Redmond, Oregon, during the potential aircraft flights
    - timing of frontal passage(s) at the middle of the study area during or within 6 h of the potential aircraft flights
- The Coordinator will schedule all other manned observations through 10 PM of the next day. These include S-Pol radar operation, special NWS sondes at Salem, mobile upstream sondes, lee-side sondes, and snow crystal observations.
- The Coordinator will disseminate these decisions and forecast information on the IMPROVE Web Site and Status Telephone Line by 2 PM. All IMPROVE personnel are responsible for availing themselves of this information (i.e., they will not be directly contacted by the Coordinator), with the following exceptions:
    - If any of the key aircraft contacts (CV-580 Manager, P-3 Project Manager, and P-3 Flight Scientist) are not physically present at the Daily Planning Meeting, they must be notified directly by phone of plans for the next day’s operations immediately after the meeting.
    - After the Daily Planning Meeting, requests for the next day’s special NWS sonde launches at Salem, Oregon, must be made by direct phone contact with the Portland NWS contact.
- If operations are a possibility overnight or the next day, then shortly before 9 PM the Coordinator will make an updated decision on IOPs through 10 PM of the next day after consultation with the Evening Forecaster, and will disseminate that decision at the 9 PM Update on the IMPROVE Web Site and Status Telephone Line.
- Early the next morning, if operations are a possibility during the coming day (through 10 PM), then shortly before 8 AM (or 3 h before scheduled flights, whichever is earlier) the Coordinator will make an updated decision on IOPs through 10 PM of the coming day

after consultation with the Morning Forecaster, and will disseminate that decision at the Morning Update on the IMPROVE Web Site and Status Telephone Line.

- If a CV-580 flight is planned, then in the morning of the day of the flight the Coordinator will run the "flight-track" program to generate an initial list of CV-580 flight-track end points. He will fax or email this list to the CV-580 Chief Pilot and Flight Scientist at the UW Aircraft Hangar (fax: 425-438-1595) at least 1.5 h prior to the scheduled doors-close time for the CV-580. The key piece of information will be the starting point for the stack (westernmost point of the highest leg). This is the point the CV-580 will initially head toward. The other leg end points will be used by the Flight Scientist in the event of loss of communication between the Flight Scientist and the Flight Track Coordinator at S-Pol.
- If flights are planned for either aircraft, the Coordinator will phone the Flight Scientist(s) at the UW Aircraft Hangar at least 1 h prior to scheduled doors-close time to discuss any meteorological or logistical issues regarding the upcoming flights.
- On the day of an IOP, the Coordinator will be responsible for making a decision to advance or delay scheduled operations, based on short-term forecasting of the weather. He will also be responsible for providing notification of such changes, directly by phone, to the Flight Scientists for the two aircraft, the mobile upstream sonde team leader, the ISS sonde launcher, the S-Pol radar control trailer, the manager of the snow crystal observers, and the manager of the PARSL site.
- During research flights, the Coordinator will maintain frequent telephone contact with the Flight Track Coordinator at S-Pol, to help provide guidance on aircraft routing decisions.
- The Coordinator will keep a record of pertinent information during an IOP, and will make a log entry on the IMPROVE Web Site at the end of each IOP, describing the meteorological situation and a summary of observations taken from each observing platform. This summary will also include an update on percent of key resources used (aircraft hours, rawinsondes) versus percent of project time completed.
- The Coordinator will declare stand-down days.

b) Data Manager

The Data Manager is responsible for collecting all data that is intended to become part of the Perusal Data Set (see Section 5) which will be a collection of NetCDF and raster files available for viewing on a workstation running the Zebra software package in the UW Atmospheric Sciences Map Room. The goal of all contributors to the Perusal Data Set, as well as of the Data Manager, is to make the Perusal Data available for viewing as soon as possible after it is collected. Below are listed the specific responsibilities of the Data Manager for handling each of the various types of data that will become part of the Perusal Data Set.

<u>Summary of Data Manager's Responsibilities:</u>

- After each CV-580 research flight, one of the CV-580 Engineers will email to the Data Manager a text file containing flight track and other flight-level data from that flight. The Data Manager will convert this file to NetCDF format and place it in the Perusal Data Set.
- After each P-3 research flight, the P-3 Flight Scientist will hand-deliver to the Data Manager a floppy disc containing flight track and other flight-level data from that flight.

The Data Manager will convert the data to NetCDF format and place it in the Perusal Data Set.

- After each P-3 research flight, Olivier Bousquet will process a subset of the radar data tape and produce NetCDF files containing Cartesianized vector winds and reflectivities from the P-3 tail radar. Oliver will make these files available to the Data Manager, who will add them to the Perusal Data Set.
- During IOPs, various files will be transferred via the NCAR internet satellite link from the S-Pol radar trailer to the UW computer system. These files will include hourly Cartesianized data derived from the RHI sector volumes in NetCDF format. The Data Manager will add these files to the Perusal Data Set.
- After IOPs, the Radar Data Manager at S-Pol will receive the data from the NOAA/ETL profiler site and will either bring them back to the UW and hand-deliver them to the Data Manager as soon as possible, or overnight-mail them to the Data Manager at the UW immediately. The Data Manager will convert the data to NetCDF format and add the files to the Perusal Data Set.
- The NCAR ISS data (both wind profiler data and sonde data) are continuously transferred (via phone link) to NCAR, where they are processed into NetCDF files and made available via the World-Wide Web. Periodically, the Data Manager will download these NetCDF files from the web and add them to the Perusal Data Set.
- After IOPs, the Flight Track Coordinator at S-Pol will receive the floppy discs with sounding data from the Mobile Upstream Sonde Team Leader. He will read the data text files and email them to the Data Manager, who will convert the text files to NetCDF format and add them to the Perusal Data Set.
- The data from both routine and special sondes launched at the NWS upper-air site in Salem, Oregon, will be sent to the UW as part of the standard operational weather data feed. The Data Manager will decode and convert this sonde data to NetCDF files, and add them to the Perusal Data Set.
- Satellite imagery covering the Pacific Northwest are routinely sent to the UW as part of the standard operational weather data feed. The Data Manager will convert selected imagery to raster format, and add them to the Perusal Data Set.

c) Forecasting Team

The Forecasting Team consists of three shifts—mid-day, evening, and morning. The Mid-day Forecaster's shift starts in late morning. His responsibility is to monitor the weather and examine forecast products, and then develop a forecast with emphasis on weather within the study area through the end of the next day's Operations Period (i.e., through 10 PM PST the following day). This monitoring and forecast preparation can be carried out at the UW, or at any location from which the Forecaster can obtain sufficient weather observation and forecast information.

After examining observations and forecast products, the Mid-day Forecaster prepares for the Daily Planning Meeting. At the Daily Planning Meeting, he provides an overview of expected weather in the study area through 10 PM of the next day, as well as longer-range guidance for the purpose of planning stand-down days. The Mid-day Forecaster is officially off duty at the end of the Daily Planning Meeting (~1:30 PM).

The start time of the evening shift is 8 PM. If operations are planned for the next day, then at ~8 PM the Evening Forecaster examines weather and forecast data and prepares an updated forecast for the weather in the study area through 10 PM of the next day. The Coordinator will consult with the Evening Forecaster at 8:30 PM PST in preparation for the official 9 PM Update on IMPROVE-2 operations. This consultation will typically be by telephone, although it may occur in person at the UW if both the Coordinator and the Evening Forecaster are present. They should make arrangements at the Daily Planning Meeting for how and where the consultation will occur. After the consultation is finished, the Evening Forecaster is off-duty.

If operations are planned for the coming day, then there will be a morning shift. The start time of the morning shift is variable: it will start at ~7 AM, or ~4 h prior to scheduled research flights, whichever is earlier. The Morning Forecaster examines weather and forecast data and prepares an updated forecast for the weather in the study area through 10 PM of that day. For early flights, a key component of this forecast will be imagery from the S-Pol radar (available through the IMPROVE Web Site, http://improve.atmos.washington.edu), which should be operating in the long-range mode (see Section 8 for more details on radar operation). The Coordinator will consult with the Morning Forecaster ~1/2 h before the Morning Update. This consultation will occur typically by telephone. The Morning Forecaster may choose to come to the UW for his shift, or to work from home.

Summary of Forecasting Team's Responsibilities:

- The Mid-day Forecaster will prepare and present a short weather briefing at the Daily Planning Meeting, with a detailed forecast for the IMPROVE-2 study area through 10 PM of the next day, and a more general forecast for the IMPROVE-2 study area for days 2-5.
- Included in the forecast should be the following specific forecasted parameters:
  - the 850, 700, and 500-hPa wind speed and direction at the middle of the study area (Twin Buttes, 44°20'N, 122°15'W), averaged over the time period of the planned aircraft flights—to be used for determining CV-580 flight track and sonde site.
  - the freezing levels at S-Pol and at Redmond, Oregon, during the potential aircraft flights—to be used by for planning by Snow Crystal Observers
  - timing of frontal passage(s) at the middle of the study area during or within 6 h of the potential aircraft flights
- If there is an IOP scheduled for any time through 10 PM of the next day, the Evening Forecaster will prepare a short weather briefing in preparation for a consultation with the Coordinator at 8:30 PM, in preparation for the 9 PM Update. This forecast should include any updates to the above-specified forecast parameters.
- If there is an IOP scheduled for any time through 10 PM of the coming day, the Morning Forecaster will prepare a short weather briefing, in preparation for a consultation with the Coordinator that will occur at 7:30 AM, or 3.5 h before a scheduled research flights, whichever is earlier. This forecast should include any updates to the above-specified forecast parameters.

d) CV-580 Team

Peter Hobbs is the manager for the CV-580 and will also generally be the Flight Scientist. He or his designee will attend the Daily Planning Meeting, and will take part in the decision to conduct research flights on the next day. The Coordinator will post a message on the IMPROVE Web Site and Status Telephone Line regarding the next day's operations, but Peter Hobbs (or his designee) will also directly contact the Flight Meteorologist (Art Rangno) and the Chief Pilot (Ken McMillen) about a decision to possibly fly on the next day.

At the 9 PM and Morning Updates, the Coordinator will make a decision to either (1) proceed with the upcoming day's flight at the previously decided aircraft doors-close time, (2) proceed with the flight at a revised aircraft doors-close time, and designate that new time, or (3) cancel the flight. All flight and science crews should take it upon themselves to obtain these two updates via the IMPROVE Web site or Status Telephone Line. The Morning Update will always occur a full 3 h prior to the most recently scheduled doors-close time, giving flight participants some opportunity to either hasten their arrival at Paine Field and pre-flight procedures if the Coordinator has requested an earlier doors-close time, or to delay their departure for Paine Field if the Coordinator has requested a later doors-close time.

After the official Morning Update, further adjustments to (or cancellation of) the research aircraft flights may still be made by the Coordinator, particularly for flights later in the day. A request to advance the flights will be accommodated by the CV-580 ground crew, pilots, and science crew to the best of their abilities. Such a request should be made with an awareness that the Flight Crew duty day may start earlier, and thus end earlier, than with the originally planned doors-close time. The maximum Flight Crew duty day (14 h) starts when the Flight Crew member arrives at Paine Field and ends when the CV-580 lands. See Appendix B for additional constraints on Flight Crew duties. A delay of a flight can also be ordered by the Coordinator, but the maximum Flight Crew duty day must be taken into account if the Flight Crew is already at or on their way to Paine Field (so that the start of their duty day cannot be postponed). Assuming 2 h is required for flight preparation, and that flights will be ~6 h in length, and that the maximum Flight Crew duty day is 14 h, this allows for a maximum delay of 6 h if the Flight Crew are already at or on their way to the hangar.

<u>Summary of CV-580 Science Crew's Responsibilities:</u>

Flight Scientist:

- The Flight Scientist will attend the Daily Planning Meeting on weekdays.
- If a flight is planned for the next day, the Flight Scientist will notify the rest of the Science Crew and the Chief Pilot after the Daily Meeting.
- If day-of-flight adjustments to the aircraft doors-close time are requested by the Coordinator, the Coordinator will notify the Flight Scientist, and the Flight Scientist will notify the rest of the Science Crew and the Chief Pilot of those adjustments.
- In the morning of the day of the flight the Coordinator will fax or email a list of CV-580 flight track end points to the CV-580 Chief Pilot and Flight Scientist at the UW Aircraft Hangar at least 1.5 h prior to the scheduled doors-close time for the CV-580. The key piece of information will be the starting point for the stack (westernmost point of the highest leg). This is the point the CV-580 will initially head toward. The other leg end points will be used by the Flight Scientist in the event of loss of communication between the Flight Scientist and the Flight Track Coordinator at S-Pol.
- Prior to the aircraft flight, the Coordinator will phone the Flight Scientist at the UW Aircraft Hangar to discuss any meteorological or logistical issues regarding the upcoming flights.

- The Flight Scientist will discuss the upcoming flight with the pilots (including destination, route to take, and main goals of flight).
- During flights, the Flight Scientist will maintain VHF radio communication with the Flight Track Coordinator at the S-Pol Radar, as well as with the P-3 Flight Scientist, and will adhere to the following:
    - He will operate on a frequency of 151.310 MHz.
    - If anyone complains about our use of this frequency, they should be informed that we have been granted permission to use this frequency by Clare Wren, Communications Director for the Oregon Department of Forestry, 503-945-7327.
    - He will refer to his own station as "Husky-1", the P-3 as “NOAA-42”, and the ground station as “S-Pol”.
    - If adjustments to the pre-planned flight track are recommended by the Flight Track Coordinator, they will be communicated to the Flight Scientist in lat/lon coordinates (degrees and decimal minutes), and he will communicate these to the Pilots. (Pilots have final say on where the aircraft should fly, based on safety and air traffic control considerations).
- In the event of loss of VHF radio communication with the Flight Track Coordinator, the Flight Scientist will make decisions regarding where the aircraft should continue its mission.
- The Flight Scientist will record on tape in real time the progress of the flight. On the return flight to Paine Field, the Flight Scientist will summarize the flight on tape and ask the Flight Meteorologist and Flight Engineers to do the same.
- The Flight Scientist will log pertinent information and observations on the UW CARG "Flight Summary" and "Timetable of Activities" forms for each flight.

Flight Meteorologist:

- The Flight Meteorologist will consult with the Flight Scientist on the conduct of a flight.
- The Flight Meteorologist will monitor the measurements for proper functioning of instruments (with emphasis on cloud and precipitation data).
- The Flight Meteorologist will record on tape the main features of observed weather and meteorological conditions.
- The Flight Meteorologist will, if asked, assist the Flight Scientist in the fine-tuning of the aircraft flight track.
- Toward the end of a flight, the Flight Meteorologist will summarize on tape the main findings of the flight from his viewpoint

Flight Engineers:

- Prior to take-off, the Flight Engineers will make sure that all research instruments are ready for the flight (clean, calibrated, hoods off, etc.).
- The Flight Engineers will be responsible for the proper functioning of the instruments. To the best of their abilities they will fix all malfunctioning instruments prior to the next flight.
- The Flight Engineers will be responsible for full and proper recording of data, video, and audio tape, for the marking of tapes with date and flight number, and for storage of the tapes.

- Toward the end of a flight, the Flight Engineers will record on tape any problems they were aware of during the flight, and other relevant comments.
- For the Perusal Data Set: At the end of each flight, one of the Flight Engineers will create a text file with aircraft flight track data and other flight-level parameters. This file should be immediately emailed to the Data Manager.

e) P-3 Team

The NOAA P-3 team will be managed by a Project Manager. The Flight Director (Barry Damiano) is a meteorologist who will direct the flight from onboard the P-3. The Flight Scientist (Nick Bond) will be in charge of overseeing the scientific aspects of the flight, and with communicating via VHF radio with the Flight Track Coordinator at the S-Pol Radar and with the CV-580 Flight Scientist. Both the Project Manager and Flight Scientist should attend the Daily Planning Meeting, and take part in the decision to conduct research flights on the next day. After the Daily Planning Meeting, the Coordinator will post a message on the IMPROVE Web Site and Status Telephone Line regarding the next day's operations, but the Project Manager will also be responsible for notifying the NOAA P-3 team (pilots, engineers, flight director, navigator, ground crew, etc.), and the Flight Scientist will be responsible for notifying the Airborne Radar Scientist scheduled for that particular flight, about a decision to possibly fly on the next day.

At the 9 PM and Morning Updates, the Coordinator will make a decision to either (1) proceed with the upcoming day's flight at the previously decided aircraft doors-close time, (2) proceed with the flight at a revised aircraft doors-close time, and designate that new time, or (3) cancel the flight. All flight and science crews should take it upon themselves to obtain these two updates via the IMPROVE Web site or Status Telephone Line. The Morning Update will always occur a full 3 h prior to the most recently scheduled doors-close time, giving flight participants some opportunity to either hasten their arrival at Paine Field and pre-flight procedures if the Coordinator has requested an earlier doors-close time, or to delay their departure for Paine Field if the Coordinator has requested a later doors-close time.

After the official Morning Update, further adjustments to (or cancellation of) the research aircraft flights may still be made by the Coordinator, particularly for flights later in the day. A request to advance the flights will be accommodated by the P-3 ground crew, pilots, and science crew to the best of their abilities. Such a request should be made with an awareness that the Flight Crew duty day may start earlier, and thus end earlier, than with the originally planned doors-close time. The maximum Flight Crew duty day (14 h) starts when the Flight Crew member arrives at Paine Field and ends when the Flight Crew member leaves the hangar. See Appendix C for additional constraints on Flight Crew duties. A delay of a flight can also be ordered by the Coordinator, but the maximum Flight Crew duty day must be taken into account if the Flight Crew is already at or on their way to Paine Field (so that the start of their duty day cannot be postponed). Assuming 2 h for flight preparation, ~6 h for the flight itself, 1 h for post-flight operations, and a maximum Flight Crew duty day of 16 h, this allows for a maximum delay of 7 h if the Flight Crew are already at or on their way to the hangar.

<u>Summary of P-3 Science and Flight Crew's Responsibilities:</u>

NOAA Project Manager:

- The Project Manager will attend the Daily Planning Meeting on weekdays.
- The Project Manager may want to directly notify key NOAA Flight and Ground Crew members of plans for the next day's operations after the Daily Planning Meeting (although this information will also be available on the IMPROVE Web Site and Status Telephone Line).

NOAA Flight Director:

- The Flight Director will attend the Daily Planning Meeting on weekdays.
- If a flight is planned for the next day, the Flight Director will notify the appropriate NOAA Air and Ground Crew, after the Daily Meeting.
- After arriving at Paine Field, the Flight Director will examine the Flight Strategy Diagram that has been faxed from the Coordinator, and should call the Coordinator if any clarification is required.
- The Flight Director will log pertinent information and observations in the standard manner for the P-3.
- For the Perusal Data Set: After the flight, the Flight Director will give the radar data tapes to the Airborne Radar Scientist and the flight-level data tape to the Flight Scientist. The cloud physics tapes should also be given to the Flight Scientist, though they will not be included in the Perusal Data Set.

Flight Scientist:

- The Flight Scientist will attend the Daily Planning Meeting on weekdays.
- If a flight is planned for the next day, the Flight Scientist will notify the Airborne Radar Scientist scheduled for that flight, after the Daily Meeting.
- If day-of-flight adjustments to the aircraft doors-close time are requested by the Coordinator, the Coordinator will notify the Flight Scientist, and the Flight Scientist will notify all P-3 Science Crew and the appropriate contact for NOAA Flight/Ground Crew.
- Prior to the aircraft flight, the Coordinator will phone the Flight Scientist at the UW Aircraft Hangar to discuss any meteorological or logistical issues regarding the upcoming flights.
- The Flight Scientist will discuss the upcoming flight with the Flight Director (including destination, route to take, and main goals of flight).
- During flights, the Flight Scientist will maintain VHF radio communication with the Flight Track Coordinator at the S-Pol Radar, as well as with the CV-580 Flight Scientist, and will adhere to the following:
    - He will operate on a frequency of 151.310 MHz.
    - If anyone complains about our use of this frequency, they should be informed that we have been granted permission to use this frequency by Clare Wren, Communications Director for the Oregon Department of Forestry, 503-945-7327.

    - He will refer to his own station as "NOAA-42", the CV-580 as “Husky-1”, and the ground station as “S-Pol”.
    - If adjustments to the pre-planned flight track are recommended by the Flight Track Coordinator, they will be communicated to the Flight Scientist in lat/lon coordinates (degrees and decimal minutes), and he will communicate these to the Flight Director. (Pilots have final say on where the aircraft should fly, based on safety and air traffic control considerations).
- In the event of loss of VHF radio communication with the Flight Track Coordinator, the Flight Scientist will determine if any deviations from the pre-planned flight track should be made, based on information at hand (again, Pilots have final say).
- The Flight Scientist will log pertinent information and observations in the standard manner for the P-3.
- The Flight Scientist should obtain from the Flight Director the cloud physics data tapes.
- For the Perusal Data Set: At the end of each flight, the Flight Scientist will obtain from the Flight Director the tape containing the flight track and other flight-level parameters. This tape should be hand-delivered to the Data Manager as soon as possible.

Airborne Radar Scientist:

- The Airborne Radar Scientist will consult with the Flight Scientist on the conduct of a flight.
- The Airborne Radar Scientist will monitor displays for the lower fuselage radar, the tail radar, and the cloud physics instruments, to check for proper functioning of instruments.
- For the Perusal Data Set: The Airborne Radar Scientist will obtain the radar data tapes from the Flight Director (and if the Airborne Radar Scientist is anyone other than Olivier Bousquet, he should hand deliver the tapes to Olivier at the UW). Olivier Bousquet will perform Doppler analysis on the tail-radar data and create Cartesian NetCDF files of Doppler velocities and reflectivity, and will make these files available to the Data Manager.

NOAA Flight and Ground Crew:

- All other NOAA personnel (pilots, engineers, navigator, ground crew, etc.) will follow standard NOAA/AOC procedures for P-3 research flights.

f) NCAR Radar Team

As described in more detail in Section 8, the S-Pol radar will operate in two basic modes: <u>long-range mode</u> (which uses horizontal polarization only) and <u>dual-polarization mode</u>. In long-range mode, there will be only one scan cycle employed: a <u>long-range surveillance cycle</u>. In dual-polarization mode, there will be two possible <u>research scan cycles</u> employed.

Because the two cycles that run in dual-polarization mode differ only in scanning strategy (elevation angles and scan rate), switching between them can be performed (using the antenna controller PC interface) either by the S-Pol Radar Scientists or NCAR personnel at S-Pol. However, switching between dual-polarization mode and long-range mode involves a change in PRF, number of gates, and gate spacing, as well as a switch to horizontal polarization only, all of which can be carried out only by an NCAR technician.

At the Daily Meeting, if precipitation is forecast to begin in the area covered by the NCAR radar through 10 PM of the next day, the NCAR radar team will be alerted to start radar operations at a designated time. This time will be recorded on the IMPROVE Web site and status telephone line. The NCAR radar team should check for this information sometime after 2 pm. They should also check again after the 9 pm and morning updates. The recorded messages will indicate the time at which to activate the radar. If precipitation is not within 100 km of the radar site at this time, the radar will operate in the long-range surveillance cycle. The radar will operate in this mode until precipitation is within 100 km of the radar site. At that time the radar will be switched to dual-polarization mode. One of the S-Pol Radar Scientists will confer with the Coordinator and make a decision as to when the radar should be turned off.

<u>Summary of NCAR Radar Team's Responsibilities:</u>

- The NCAR Radar Team will ensure to the best of their abilities that the S-Pol radar is operational at times requested by IMPROVE-2 scientists, and that data is being properly recorded when it is operational.
- The NCAR Radar Team will keep itself informed of project status through use of the IMPROVE Web Site and Status Telephone Line, after the Daily Planning Meeting (updated at ~2 PM), after the 9 PM Update, and after the Morning Update.
- The NCAR Radar Team will ensure that the Zebra radar display workstations and the radar control PC at the S-Pol site are operating properly.
- The NCAR Radar Team will ensure that the S-Pol Imagery Web Site is providing real-time radar imagery to the World-Wide Web.
- The NCAR Radar Team will switch the radar between dual-polarization mode and long-range mode when requested by the Coordinator or S-Pol Radar Scientists.
- The NCAR Radar Team will keep the Coordinator informed of any problems or anticipated down time for the radar at all times.
- The NCAR Radar Team will periodically check on the radiometer deployed at Santiam Junction to make sure it is operating properly. The Snow Crystal Observers will also check on the radiometer (for snow covering, etc.), and will report any problems to the NCAR Radar Team.

g) S-Pol Radar Scientists

The S-Pol Radar Scientists are the UW scientific personnel that will attend the radar during IMPROVE-2. At least one of the S-Pol Radar Scientists should be at the radar whenever it is operating. One of the S-Pol Radar Scientists will serve as Flight Track Coordinator, and this person should be at the radar whenever research aircraft flights are being conducted. The other S-Pol Radar Scientist will be referred to as the Radar Data Manager. When the aircraft complete all their research objectives and commence their ferry flights back to Paine Field, the S-Pol Radar Scientists will confer with the Coordinator as to whether or not to continue radar scans, for how long, and in what mode and cycle. If a choice is made to continue scans, one or both of the S-Pol Radar Scientists will continue to tend the radar, until the precipitation event is over, at which time the S-Pol Radar Scientist informs the NCAR Technician on duty that the radar can be switched off.

<u>Summary of S-Pol Radar Scientists' Responsibilities:</u>

Flight Track Coordinator:

- The Flight Track Coordinator will keep informed of project status through use of the IMPROVE Status Telephone Line after the key update points (2 PM, 9 PM, and Morning Updates).
- The Flight Track Coordinator will be responsible for ensuring that the radar is manned by one of the S-Pol Radar Scientists whenever an IOP is in effect.
- When on duty, the Flight Track Coordinator, in conjunction with the Radar Data Manager, will determine the mode and scan cycle of S-Pol.
- The Flight Track Coordinator will be on station at least 1 h prior to scheduled aircraft doors-close time when research aircraft flights are planned.
- During the research aircraft flights, the Flight Track Coordinator will observe radar scans to stay abreast of the mesoscale precipitation structure and evolution during the flights.
- During the research aircraft flights, the Flight Track Coordinator will maintain frequent telephone communication with the Coordinator (who will either be at the UW or at home, coordinating the IOP). These communications will keep the Coordinator updated on the progress of the research aircraft flights, and the precipitation structure and evolution as seen at S-Pol. They will also allow the Coordinator and Flight Track Coordinator to confer on how to plan flights and radar operation.
- During the research aircraft flights, the Flight Track Coordinator will maintain VHF radio communication with the Flight Scientists onboard the CV-580 and the P-3. This radio communication is necessary to inform the Flight Scientists of any suggested deviations from the original flight strategy, in order to maintain flexibility amidst weather conditions that have limited predictability. When communicating via VHF radio, the Flight Track Coordinator will adhere to the following:
    - He will operate on a frequency of 151.310 MHz.
    - If anyone complains about our use of this frequency, they should be informed that we have been granted permission to use this frequency by Clare Wren, Communications Director for the Oregon Department of Forestry, 503-945-7327.
    - He will refer to his own station as "S-Pol", the CV-580 as “Husky-1”, and the P-3 as “NOAA-42”.
    - If necessary, he will help guide the aircraft with updated endpoints for flight legs, which he will communicate to the Flight Scientists on the CV-580 or P-3 as lat/lon coordinates in degrees and decimal minutes.
- During the box patterns of a P-3 flight, the Flight Track Coordinator will contact the PARSL site by phone to let them know approximately when the box pattern will be completed, so that the PARSL Manager can check weather conditions to determine if a PARSL Overflight would be useful. If the PARSL Manager requests an overflight, the Flight Track Coordinator will communicate this request to the P-3 Flight Scientist. If the P-3 cannot carry out the request for an overflight, the Flight Track Coordinator will contact the PARSL site by phone to inform them.
- The Flight Track Coordinator will notify the CV-580 ground crew at Paine Field of any significant change in plans for the CV-580, as well as an estimated time of arrival at Paine Field as soon as it can be estimated.

- The Flight Track Coordinator will take notes on the mission from his perspective.
- The Flight Track Coordinator may be asked to perform the duties of the Radar Data Manager if the Radar Data Manager cannot be present.
- For the Perusal Data Set: The Flight Track Coordinator will download sounding data from the floppy discs that have been hand-delivered by the Mobile Upstream Sonde Team Leader, and will email or secure copy this data to the Data Manager at the UW as soon as possible.

Radar Data Manager:

- The Radar Data Manager will keep informed of project status through use of the IMPROVE Web Site or Status Telephone Line after the key update points (2 PM, 9 PM, and Morning Updates).
- When on duty, the Radar Data Manager, in conjunction with the Flight Track Coordinator, will determine the mode and scan cycle of S-Pol.
- The Radar Data Manager will be on station any time that the radar is scheduled to be operating.
- The Radar Data Manager is responsible for monitoring the continuous feed of radar sweep files from the NCAR network to the UW workstation, and the production of Cartesianized data files from the RHI sector volume.
- The Radar Data Manager may be asked to perform the duties of the Flight Track Coordinator if the Flight Track Coordinator cannot be present.
- The Radar Data Manager will inform the S-band On-site Scientist when the S-band profiler should be switched to coupled mode (whenever S-Pol goes into dual-polarization mode) or to uncoupled mode (whenever S-Pol goes out of dual-polarization mode).
- For the Perusal Data Set: The Radar Data Manager will ensure that periodic transfers of data to the UW are occurring during radar operation. This data stream should consist of the hourly Cartesianized data produced from the eastward RHI sector volumes.
- For the Perusal Data Set: The On-site Scientist for the NOAA/ETL Profiler will periodically provide to the Radar Data Manager the data for the S-band and 915-MHz profilers. These data should either be brought back to the UW and hand-delivered to the Data Manager as soon as possible, or overnight-mailed to the UW.

h) Snow Crystal Observers

Ground observations of snow crystals will be an important component of IMPROVE-2. they will provide information on the cloud microphysics associated with precipitation particles that are reaching the ground. These observations are an important compliment to the airborne cloud microphysical observations taken by the CV-580. The ground measurements will generally be taken during CV-580 flights. It will be desirable to gather observations from a few different points along the cross-mountain profile, but the necessity of observing unmelted crystals will limit these observations to terrain above the freezing level. Therefore, the snow crystal observers will be mobile, deploying themselves at various locations along the Santiam Highway (U.S. 22) depending on weather conditions. In general, John Locatelli will attempt to observe crystals at Camp Sherman, but will move up to Suttle Lake if it is not snowing at Camp Sherman. Matt Garvert will observe crystals at Hoodoo Ski Area. Greg Thompson will observe crystals at the lowest possible point west of (or at) the Tombstone Summit.

The snow crystal observation procedure involves gathering falling snow crystals on a glass slide, using a microscope to assess the types of crystals seen (according to the Magono and Lee classification scheme), recording those types as well as approximate proportions of each type, and taking one or more representative photographs of the crystal images. A standard form will be used by all snow crystal observers, and will include spaces for location, temperature, snow crystal information, and other observations.

<u>Summary of Snow Crystal Observers' Responsibilities:</u>

- The Team Leader will keep informed of project status through use of the IMPROVE Web Site or Status Telephone Line after the key update points (2 PM, 9 PM, and Morning Updates).
- The Team Leader will be responsible for determining when observations should begin and end (based on scheduled aircraft flights) and where those snow crystal observations should be taken (based on forecasted frontal passages and freezing levels), and for informing the other Snow Crystal Observers of those decisions.
- During IOPs, the Team Leader will maintain telephone communication with the Coordinator (who will either be at the UW or at home, coordinating the IOP), so that the Team Leader can be informed of the weather situation and the overall progression of the IOP, and so that the Coordinator can be updated on the execution of the snow crystal observations.
- The Snow Crystal Observers will take snow crystal observations every 15 minutes at various locations (of known latitude and longitude) along the Santiam Highway that are above the freezing level. The Team leader will cover the area from Santiam Pass eastward, and the other Snow Crystal Observer(s) will cover the area from Santiam Pass westward.
- The Snow Crystal Observers will take notes on any other aspects of precipitation intensity and evolution during the IOP, from their perspective.
- The Team Leader may be asked to launch sondes from the ISS site on the lee side if the regular sonde launcher is unable to perform that duty for any reason.
- The Snow Crystal Observers will periodically check on the radiometer deployed near Santiam Pass, to make sure it is free of snow and operating properly.

i) Rain Gauge Network

A network of 5 special rain gauges, capable of measuring solid or liquid precipitation, will be deployed along the Santiam Highway at the following locations (from west to east, with elevation and straight-line distance east of Sweet Home, OR):

1. Falls Creek (1500 ft AMSL, 28 km)
2. Jump-Off Joe Mountain (3500 ft AMSL, 46 km)
3. Santiam Junction (3800 ft AMSL, 62 km)
4. Santiam Pass (4800 ft AMSL, 62 km)
5. Corbett State Park (3600 ft AMSL, 77 km)

These rain gauge measurements will be used for verifying the precipitation output from mesoscale model simulations of the studied cases, and for assessing the ability of radar-based rain-rate retrieval to quantify rain rates within the domain of radar coverage.

Summary of Rain Gauge Manager's Responsibilities:

- The Rain Gauge Manager will periodically check on the rain gauge installations to ensure proper functioning of the equipment
- The Rain Gauge Manager will retrieve the rain gauges at the end of the IMPROVE-2 field study and provide the data to the IMPROVE-2 data archive.

j) Integrated Sounding System

The NCAR Integrated Sounding System includes a 915-MHz wind profiler and the capability to launch rawinsondes. Two such systems will be deployed in IMPROVE-2: one in the Willamette Valley (off of Irish Bend Road, ~9 km WSW of Halsey, Oregon), to monitor upstream upper-air conditions, and the other on the lee side of the Cascades (on the west side of Black Butte Ranch, 13 km NW of Sisters, Oregon), to monitor downstream upper-air conditions. Since there will also be a mobile upstream sonde launching system in the Willamette Valley, ISS sondes will be limited to the lee side ISS site. The ISS wind profilers collect and record data continuously, whereas the sondes are a manned observation. The plan for IMPROVE-2 is to launch the lee-side sondes continuously (approximately every 2 h) during the period when the research aircraft are airborne.

Summary of ISS Team's Responsibilities:

On-site Scientist:

- The On-site Scientist will periodically check on the ISS installations to ensure proper functioning of the equipment and proper transmission of data to the NCAR/ATD web site.
- The On-site Scientist will train the Sonde Launcher to launch sondes at the lee-side ISS site prior to the start of the field project (26 November).
- The On-site Scientist will respond to any reports by the lee-side sonde launcher of malfunctions of either the wind profiler or sonde-launching equipment.
- The On-site Scientist will keep the Coordinator informed of any problems or down time associated with the ISS wind profilers or sonde systems.

NCAR Software Engineer:

- The NCAR Software Engineer will ensure that data from both the wind profilers and the soundings are being transferred to NCAR.
- For the Perusal Data Set: The NCAR Software Engineer will ensure that NetCDF data from both the profiler and sondes are being continuously made available via the NCAR/ATD web site (http://www.atd.ucar.edu).

Sonde Launcher:

- The Sonde Launcher will keep informed of project status through use of the IMPROVE Web Site or Status Telephone Line after the key update points (2 PM, 9 PM, and Morning Updates).
- During IOPs, the Sonde Launcher will maintain periodic telephone communication with the Coordinator (who will either be at the UW or at home, coordinating the IOP), so that the Sonde Launcher can be informed of the weather situation and any adjustments to the sonde-launching schedule, and so that the Coordinator can be updated on the execution of the lee-side sonde launches.
- The Sonde Launcher will launch sondes continuously (approximately every 2 h) during the period of sonde observations, tracking balloons to burst or 100 hPa (whichever comes first).
- The Sonde Launcher will take notes on any aspects of observed weather related to the sonde launches (for example, if a rawinsonde rises into an isolated cloud, etc.), or any sonde mishaps that occurred during the IOP.
- The Sonde Launcher will report any equipment malfunctions, or direct any questions related to technical aspects of launching sondes from the ISS site, to the ISS On-site Scientist.

k) Mobile Upstream Sonde Unit

The UW is putting together a mobile sonde unit (including personnel, vehicle, trailer, helium and balloons provided by the UW, personnel provided by the U. S. Navy Reserves, sondes provided by NCAR/RAP, and a sonde data receiver provided by PNNL). This mobile sonde unit will be deployed along Interstate Highway 5 in the Willamette Valley to monitor upstream upper-air conditions. It is designed to be mobile so that it can be positioned upstream of the study area under conditions of potentially varying wind direction. The plan for IMPROVE-2 is to launch sondes from the mobile unit continuously (approximately every 2 h) during the period when the research aircraft are airborne, as well as possibly within 3 hours before or after the research aircraft flights to capture relevant synoptic-scale transient frontal features.

Summary of Mobile Upstream Sonde Team's Responsibilities:

- The Team Leader and Navy Reserve Sonde Launcher will keep informed of project status through use of the IMPROVE Web Site or Status Telephone Line after the key update points (2 PM, 9 PM, and Morning Updates).
- The Team Leader will determine the sonde site based on the forecast 700-hPa wind direction during research aircraft flights.
- The Team Leader will be responsible for coordinating the meeting place and time for the Mobile Upstream Sonde Launching Team for each IOP.
- During IOPs, the Team Leader will maintain periodic telephone communication with the Coordinator (who will either be at the UW or at home, coordinating the IOP), so that the Team Leader can be informed of the weather situation and any adjustments to the sonde-launching schedule, and so that the Coordinator can be updated on the execution of the mobile upstream sonde launches.

- The Mobile Upstream Sonde Team will deploy the sonde launching unit to a point along I-5 that is approximately upstream (based on the forecasted mean lower-tropospheric winds) of the study area. They will launch sondes continuously (approximately every 2 h) during the period of sonde observations, tracking balloons to burst or 100 hPa (whichever comes first).
- The Navy Reserve Sonde Launcher will take notes on any noteworthy aspects of observed weather related to the sonde launches (for example, if a rawinsonde rises into an isolated cumulus, etc.), or any sonde mishaps, that occurred during the IOP.
- The Team Leader will keep the Coordinator informed of any problems or down time associated with the Mobile Upstream Sonde Launch System.
- For the Perusal Data Set: As soon as possible after an IOP, the Team Leader will deliver to the Flight Track Coordinator the floppy discs with sounding data that were collected.

l) PNNL Atmospheric Remote Sensing Laboratory (PARSL) Team

PNNL will deploy an Atmospheric Remote Sensing Laboratory (PARSL), consisting of various radiometer, radar, and lidar instruments, as well as meteorological instruments. The PARSL's scanning radar and lidar will provide valuable data to IMPROVE-2 by mapping the lee-side cloud edge, and IMPROVE-2 research aircraft overflights (See Section 7) will provide in situ cloud microphysical data for validating PARSL remote sensing measurements of overhead cloud.

<u>Summary of PNNL Remote Sensing Team's Responsibilities:</u>
- The PNNL Remote Sensing Team will keep itself updated on IMPROVE-2 operations relevant to its remote sensing activities via the IMPROVE Web Site and Status Telephone Line.
- During periods when the CV-580 is flying, the PARSL site will conduct a series of RHI-type scans every 10 minutes with the scanning lidar. These RHI-type scans should range in elevation from 0-60º, and should be pointed at azimuths 250º, 260º, 270º, 280º, 290º, 300º, 310º, and 320º.
- During the box patterns of a P-3 flight, the Flight Track Coordinator at S-Pol will contact the PARSL site by phone to let them know approximately when the box pattern will be completed, so that the PARSL Manager can check weather conditions to determine if a PARSL Overflight would be useful. If the PARSL Manager requests an overflight, the Flight Track Coordinator will communicate this request to the P-3 Flight Scientist. If the P-3 cannot carry out the request for an overflight, the Flight Track Coordinator will contact the PARSL site by phone to inform them.

m) NOAA/ETL Profilers (S-band and 915 MHz)

The NOAA/ETL Profiler Site, located at McKenzie Bridge Airstrip, includes an S-band vertically pointing precipitation profiler and a 915-MHz wind profiler. Both profilers collect and record data continuously, and are periodically attended by an on-site scientist.

Summary of NOAA/ETL On-site Scientist's Responsibilities:

- The On-site Scientist will switch the S-band profiler to coupled mode whenever the S-Pol radar is in dual-polarization mode, and will switch the S-band profiler to uncoupled mode when the S-Pol radar is switched off or switched to long-range mode. The S-Pol Radar Data Manager will inform the S-band On-site Scientist when to make such switches.
- The On-site Scientist will periodically check on the profiler installation to ensure proper functioning of the equipment and proper recording of data.
- The On-site Scientist will keep the Coordinator informed of any problems or down time associated with the NOAA/ETL Profiler Site.
- For the Perusal Data Set: After each IOP, the On-site Scientist will deliver data to the Radar Data Manager at the S-Pol radar trailer.

n) Disdrometer

A Joss-Waldvogel disdrometer will be collocated with the NOAA/ETL Profilers at McKenzie Bridge Airstrip. The disdrometer collects and records data continuously, and is periodically attended by an on-site scientist. There is also a possibility that a PARSIVEL disdrometer will be deployed at the same site during a portion of the IMPROVE-2 field study.

Summary of Disdrometer Scientist's Responsibilities:

- The Scientist will periodically check on the disdrometer to ensure proper functioning of the equipment and proper recording of data.
- The Scientist will keep the Coordinator informed of any problems or down time associated with the disdrometer.
- The Scientist will retrieve the disdrometer data at the end of the field project.

o) Special NWS Sondes from Salem, Oregon

NWS sonde launches occur routinely at the standard upper-air synoptic times of 0000 and 1200 UTC. During IMPROVE-2, the NWS has agreed to launch up to 35 special rawinsondes from their Salem, Oregon, upper-air site at more frequent intervals. These extra sonde launches will be requested by the Coordinator for each IOP. After the Daily Planning Meeting, the Coordinator will notify NWS-Portland Contact by 3 PM with a request for special NWS rawinsonde launches at Salem during the next day, including specific times requested. These special launches will be requested only in support of aircraft operations, and will occur at the 3-hourly synoptic times of 0300, 0600, 0900, 1500, 1800, and 2100 UTC. Sonde flights should be tracked to balloon burst or 100 hPa, whichever is sooner.

Cancellation or adjustment of the requested special rawinsonde flights may occur. Such a request for cancellation or change in special launch times must be made by the Coordinator at least 3 hours before the first affected special launch time in order for that launch to not be charged against the agreed upon total number of special rawinsonde launches (i.e., 42 at each station).

Summary of Responsibilities of the NWS-Portland Contact:

- If special sonde flights are planned for the next day (through 10 PM), then by 3 PM of the current day the NWS-Portland Contact or his designee will receive requests for those special rawinsonde flights from the Coordinator, and will pass those requests along to the NWS rawinsonde facilities at Salem, OR, These requests may be updated by the Coordinator, but not less than 3 h prior to any affected special rawinsonde flight.

7. FLIGHT STRATEGIES

a) General strategy

The CV-580 will be used to gather in situ cloud and precipitation microphysical measurements. It will fly stacked legs within a fixed vertical plane across the mountain barrier. The P-3 will be used primarily to gather radar reflectivity and dual-Doppler velocity measurements to define the mesoscale environment. It will fly "box patterns" of level legs along the mountain barrier. These flight patterns will be exactly determined prior to take-off of the aircraft, so that pilots and flight scientists will have precise end points of all flight legs prior to take-off. However, to maintain a certain degree of flexibility in response to unanticipated changes or temporal variability in weather conditions, flight scientists on both aircraft will have the freedom to alter the flight strategy in-flight. These alterations will be made based on weather conditions seen from the aircraft, and equally importantly, on weather conditions seen from the ground-based radar by the Flight Track Coordinator who will be stationed at the S-Pol Radar. The Flight Track Coordinator will maintain contact with the flight scientists onboard both aircraft via VHF FM radio, in order to communicate (verbally) the broad weather picture seen from the radar, and to provide altered end points for flight legs if necessary.

Generally, the CV-580 and P-3 will either both fly or both not fly, but we leave open the option of flying only one aircraft if the other is grounded and if the meteorological situation is such that scientifically valuable observations can be gathered with just one aircraft. The relevant parameters for the two aircraft are shown in Table 1.

Table 1. Parameters for the CV-580 and P-3 Aircraft.

Aircraft	Maximum Altitude (ft)	Cruising Speed (kts)	Research Speed (kts)	Maximum Flight Duration (h)	Radio Call Sign	Tail Number
CV-580	23,000	270	165	6.75	Husky-1	N3UW
P-3	25,000	325	240	11	NOAA-42	N42RF

b) CV-580 flight strategy

The CV-580 flight strategy is seen best in a vertical cross-section across the mountain barrier (Fig. 4). It will be arranged as a slanted stack of legs, flown from the top down. The legs alternate between level eastward legs and descending westward legs. The slant is intended to approximately follow the trajectory of an envelope of precipitation particles that fall onto the highest point of the terrain barrier. There will be two choices for the vertical plane in which the stack will be confined: an E-W track and a NE-SW track (Fig. 5). Only the E-W track is shown in Fig. 4. The NE-SW track is similar, except for the details of the terrain profile, and the fact that it would not pass over the S-Pol radar. The top altitude of the stack, the lengths of the legs, the slant of the stack, and the track choice (E-W or NE-SW) will be optimized for the prevailing wind speed and direction, the depth of the precipitating cloud, and the CV-580 maximum flight duration (about 4 h 30 min on station). The bottom leg of the stack is flown at minimum IFR

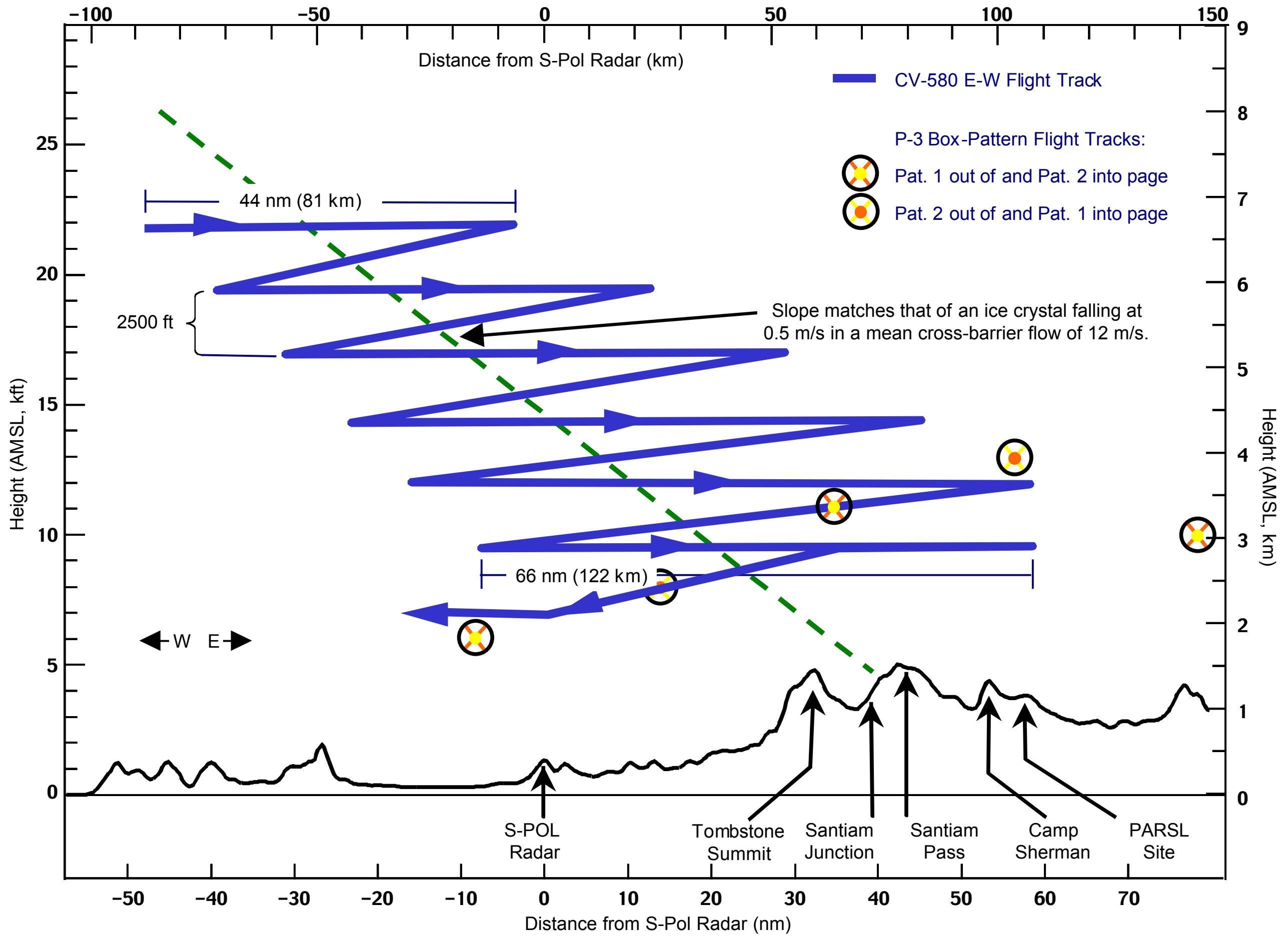
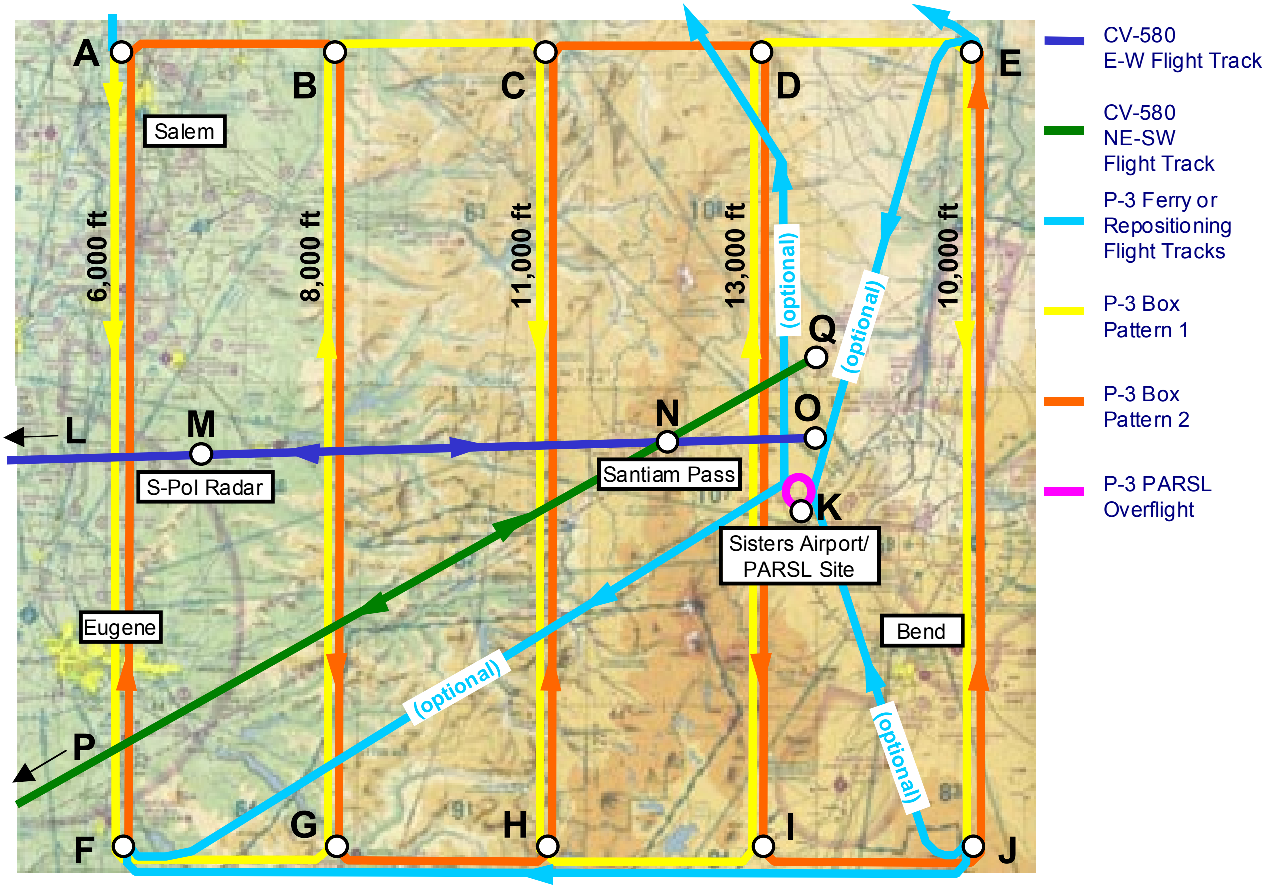


Figure 4. Vertical cross-section view of CV-580 E-W flight track and P-3 Box Pattern flight tracks.



Point	Latitude	Longitude
A	45º 01' 00" N (45º 01.00' N)	123º 02' 00" W (123º 02.00' W)
B	45º 01' 00" N (45º 01.00' N)	122º 34' 00" W (122º 34.00' W)
C	45º 01' 00" N (45º 01.00' N)	122º 05' 00" W (122º 05.00' W)
D	45º 01' 00" N (45º 01.00' N)	121º 37' 00" W (121º 37.00' W)
E	45º 01' 00" N (45º 01.00' N)	121º 08' 00" W (121º 08.00' W)
F	43º 46' 00" N (43º 46.00' N)	123º 02' 00" W (123º 02.00' W)
G	43º 46' 00" N (43º 46.00' N)	122º 34' 00" W (122º 34.00' W)
H	43º 46' 00" N (43º 46.00' N)	122º 05' 00" W (122º 05.00' W)
I	43º 46' 00" N (43º 46.00' N)	121º 37' 00" W (121º 37.00' W)
J	43º 46' 00" N (43º 46.00' N)	121º 08' 00" W (121º 08.00' W)
K	44º 18' 16" N (44º 18.27' N)	121º 32' 21" W (121º 32.35' W)
L	44º 19' 00" N (44º 19.00' N)	124º 30' 00" W (124º 30.00' W)
M	44º 23' 11" N (44º 23.18' N)	122º 51' 17" W (122º 51.28' W)
N	44º 25' 00" N (44º 25.00' N)	121º 50' 00" W (121º 50.00' W)
O	44º 25' 40" N (44º 25.67' N)	121º 30' 00" W (121º 30.00' W)
P	43º 16' 00" N (43º 16.00' N)	124º 30' 00" W (124º 30.00' W)
Q	44º 33' 25" N (44º 33.42' N)	121º 30' 00" W (121º 30.00' W)

Figure 5. Plan view of P-3 Box Pattern flight tracks, P-3 PARSL Overflight flight track, and CV-580 E-W and NE-SW flight tracks.

altitude across the mountain barrier. The CV-580 may choose to refuel at an airport close to the research area (such as Eugene or Redmond) to increase the potential on-station time by approximately 45 minutes, or possibly to allow for a second flight the same day.

c) P-3 flight strategies

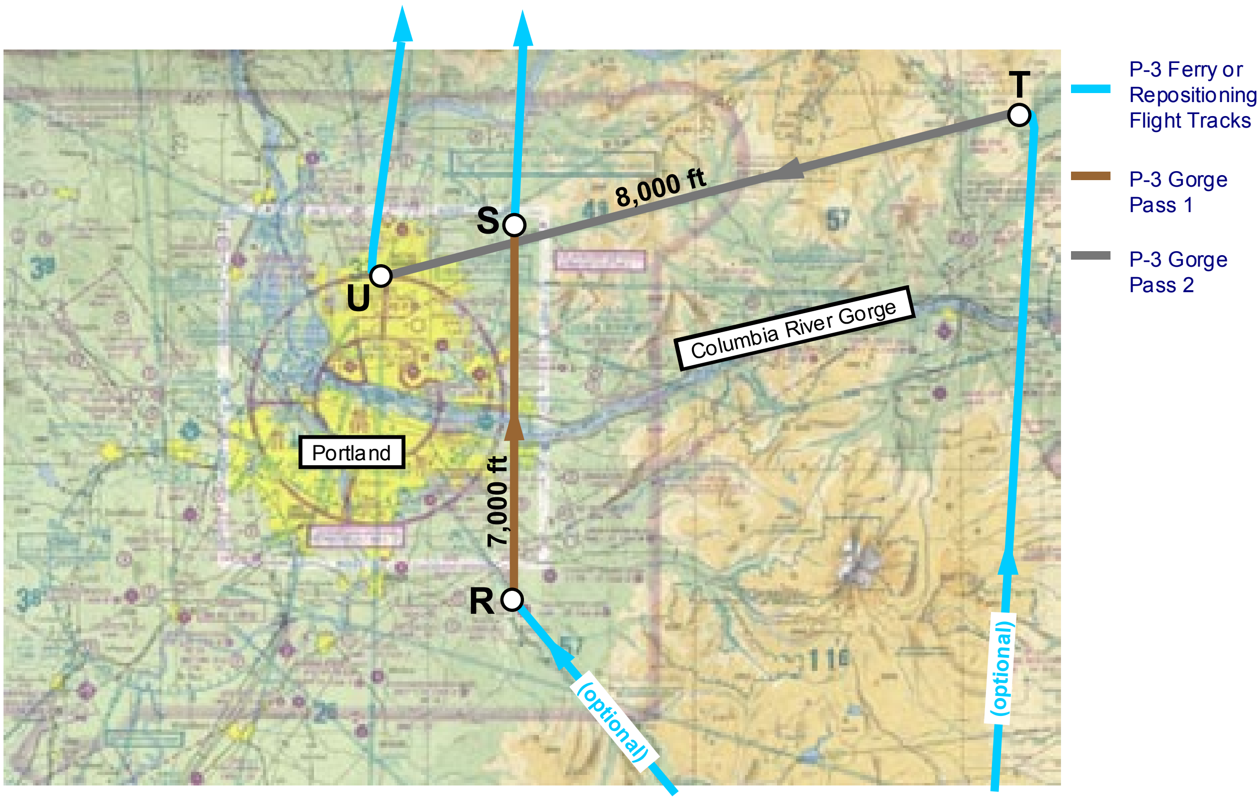
Box Patterns: The box patterns (Fig. 5) are intended to map out reflectivity and airflow over the region in which in situ (CV-580) measurements are being taken. The N-S legs are 75 nm (139 km) in length and are separated by 20 nm (37 km). Each N-S leg is flown at a level altitude (labeled on Fig. 5), which is the lowest possible altitude that does not drop below minimum IFR altitude anywhere along that leg. Two full box patterns will be executed during the flight, shown as Box Pattern 1 (yellow) and Box Pattern 2 (red) in Fig. 5. The legs of the two box patterns should exactly overlap—they are shown slightly offset for display purposes only. Assuming a research speed of 240 kt, each box pattern would take ~2 h 15 min to complete, plus a ~20-min connecting leg, for a total of ~4 h 50 min.

PARSL Overflight: The ground-based measurements made by the PNNL Atmospheric Remote Sensing Laboratory (PARSL) are made more valuable if accompanied by in situ cloud microphysical measurements over the PARSL site. Since the CV-580 is using its maximum flight duration to execute its stacked legs, the P-3 will be relied upon for making the PARSL overflights. Therefore, the P-3's standard compliment of microphysical probes (2D-C, 2D-P, FSSP, liquid water) should be on board and operating during IMPROVE-2. If favorable cloud conditions are in place over the PARSL site after completion of one or the other of the two box patterns, the P-3 may be asked (via a radio communication from the Flight Track Coordinator at the S-Pol radar) to divert to the PARSL site at that time and perform an overflight. These diversions are shown as the diagonal blue lines labeled "optional" in Fig. 5.

The PARSL overflight will consist of a vertical spiral profile that passes directly over the PARSL site at Sisters Airport. This spiral will be executed at a rate of 1 orbit per two minutes and 500 ft per minute climb rate, yielding 1000-ft vertical spacing. It will extend over a vertical depth requested by the PNNL scientist at the PARSL site (subject to minimum altitude restrictions).

Cross-mountain transect: Another optional track for the P-3 that may be requested by the Flight Scientist is a cross-mountain transect, which would occur in between the two box patterns. The purpose of such a track is to obtain flight-level data (particularly vertical velocity) across the mountain barrier at minimum IFR altitude, along the same line on which the CV-580 is flying. The cross-mountain profile is executed as follows: at the end of the first box pattern, the P-3 proceeds from point J (Fig. 5) to point O (or from J to K to O if a PARSL overflight is executed), and then along the line O-N-M, and then from point M to point F to commence the second box pattern. This flight track will only be executed by the P-3 if the CV-580 is still high enough so as not to cross altitudes with the P-3.

P-3 Gorge Pass: With the P-3 ferrying regularly across the Columbia River near Portland, there may be an excellent opportunity to study the airflow at the western exit of the Columbia River Gorge during a strong easterly wind event through the Gorge. If such conditions are in place and precipitation is occurring at the western exit of the Gorge, one of the two Gorge Passes (Fig. 6) will be executed during the return ferry flight of the P-3. Gorge Pass 1 is intended to gather reflectivity and dual-Doppler velocity measurements in the western exit region



Point	Latitude	Longitude
R	45º 19' 00" N (45º 19.00' N)	122º 21' 00" W (122º 21.00' W)
S	45º 49' 00" N (45º 49.00' N)	122º 21' 00" W (122º 21.00' W)
T	45º 58' 00" N (45º 58.00' N)	121º 23' 00" W (121º 23.00' W)
U	45º 45' 20" N (45º 45.33' N)	122º 35' 30" W (122º 35.50' W)

Figure 6. Plan view of P-3 Gorge Pass flight track.

of the Gorge. It should be flown at 6000 ft altitude, along the N-S line shown in Fig. 6. Gorge Pass 2 is intended to gather reflectivity and dual-Doppler velocity measurements in both the interior of the Gorge and in the western exit region of the Gorge. It should be flown at 8000 ft altitude, along the ENE-WSW line shown in Fig. 6 (which coincides with the Airway V 468). If a Columbia Gorge wind event is not in place, a direct ferry route will be flown.

8. S-POL RADAR OPERATION

a) Overview

The S-Pol radar will be used for weather surveillance and short-term forecasting; real-time support for aircraft guidance; and the gathering of reflectivity, Doppler velocity, and polarimetric data during targeted storm systems. The radar modes of operation and scan strategies are designed to satisfy all of these purposes. The primary site of radar operations, control, and real-time viewing and analysis will be at the S-Pol Radar Control Trailer, which is located at a remote hill-top site on privately owned timber land a few miles west of Sweet Home, Oregon. Limited radar imagery will also be available for viewing in real-time through the IMPROVE Web Site (go to http://improve.atmos.washington.edu, click on “IMPROVE-2”, and then click on "Real-Time S-Pol Imagery").

b) Radar modes of operation

The radar will operate in two basic modes: long-range mode and dual-polarization mode. When precipitation is anticipated but has not yet entered the study area, the radar will be operated in long-range mode for the purpose of weather surveillance. This mode uses horizontal polarization only, so that the radar can be run at a low PRF, allowing for long-range coverage. See Table 2 for details of the radar parameters in long-range mode. When precipitation is in the study area, the radar will be operated in dual-polarization mode, which allows for the gathering of polarimetric data. Because the radar sends out separate horizontally and vertically polarized pulses in this mode, it requires a higher PRF, decreasing the range of coverage. See Table 2 for radar parameters in dual-polarization mode. Switching between dual-polarization mode and long-range mode is a non-trivial procedure that can be carried out only by an NCAR technician at the S-Pol site. The switching process takes 5-10 minutes. If a switch is requested while the radar is unattended, the switch could take up to an hour, inclusive of the technician’s travel time to the radar site. Therefore, such switches should be minimized to approximately one or two per IOP.

Table 2. Parameters for the S-Pol radar in the two different modes of operation.

Mode	Gate Spacing (m)	Number Of Gates	Max. Range (km)	PRF (s^{-1})	Number of Pulses per Beam	Beams Per Second	Optimal Scan Rate ($° s^{-1}$)
Long-range	225	1040	234	600	64	9.4	9
Dual-polarization	150	1120	168	850 (425 for each polariz.)	128 (64 for each polariz.)	6.6	6

c) Scan cycles

When the radar is in long-range mode, it will operate in the long-range surveillance scan cycle, shown in Table 3. This is an approximately 5-minute cycle. The four PPI elevations are for surveillance of approaching precipitation systems. There is a reference chart provided (Fig. 7) which shows the height of the radar beam above ground for various elevation angles and ranges. The set of RHIs (RHI Set A in Fig. 8) is also for surveillance of approaching precipitation systems, allowing for determination of the vertical depth of the precipitation and the freezing level ("bright band").

Table 3. Long-range surveillance scan cycle.

Scan	Elevation or Azimuth Angle(s)	Time Required (s)	Elapsed Time (s)
Surveillance PPI Set	Elevations: 0.5°,1.45°, 2.4°, 3.35°	164	164
RHI Set A	28 azimuths over 135°-wide sector (spaced every 5°), generally facing westward; precise direction of sector chosen by S-Pol Radar Scientist(s); Elevation range: 0-30°	132	296

When the radar is in dual-polarization mode, it will operate in one of two research scan cycles, shown in Tables 4 and 5. Both are approximately 10-minute cycles, and begin with two PPI surveillance scans. These scans provide periodic views of the horizontal mesoscale structure of weather precipitation systems that are being studied. They are important for both real-time use to help direct aircraft flights and for post-field analysis of CV-580 data, providing larger-scale context in which to place the highly localized airborne microphysical measurements.

When the CV-580 is flying an E-W flight track (Fig. 5), the research scan cycle(Table 4) will include a set of two RHIs, in opposite azimuthal directions, that will slice through the vertical plane in which the CV-580 is flying (RHI Set B in Fig. 8). Like the PPI surveillance scans, this pair of RHIs is important both for providing the precipitation context both for real-time direction of aircraft and post-field analysis of in situ microphysical data. The final and longest part of the scan cycle is devoted to a set of closely spaced RHI scans (RHI Set D in Fig. 8) that produce a 3D volume of reflectivity, Doppler, and polarimetric data of the precipitation system. These scans cover a 61°-wide sector, centered (approximately) on a due east direction from the radar.

When the CV-580 is flying a NE-SW flight track (Fig. 5), the research scan cycle (Table 5) will include a set of six RHIs (spaced 1° apart, RHI Set B in Fig. 8) that can be pointed generally toward the west to examine the vertical structure of the precipitation that is approaching the study area. The precise direction of this RHI set is determined by the S-Pol Radar Scientists on a case-dependent basis. Since the CV-580 will not be flying along a radial from the radar, it will not be possible to produce an RHI scan along the flight track. However, the sector of closely spaced RHI scans will be shifted southward (RHI Set E in Fig. 8) to more

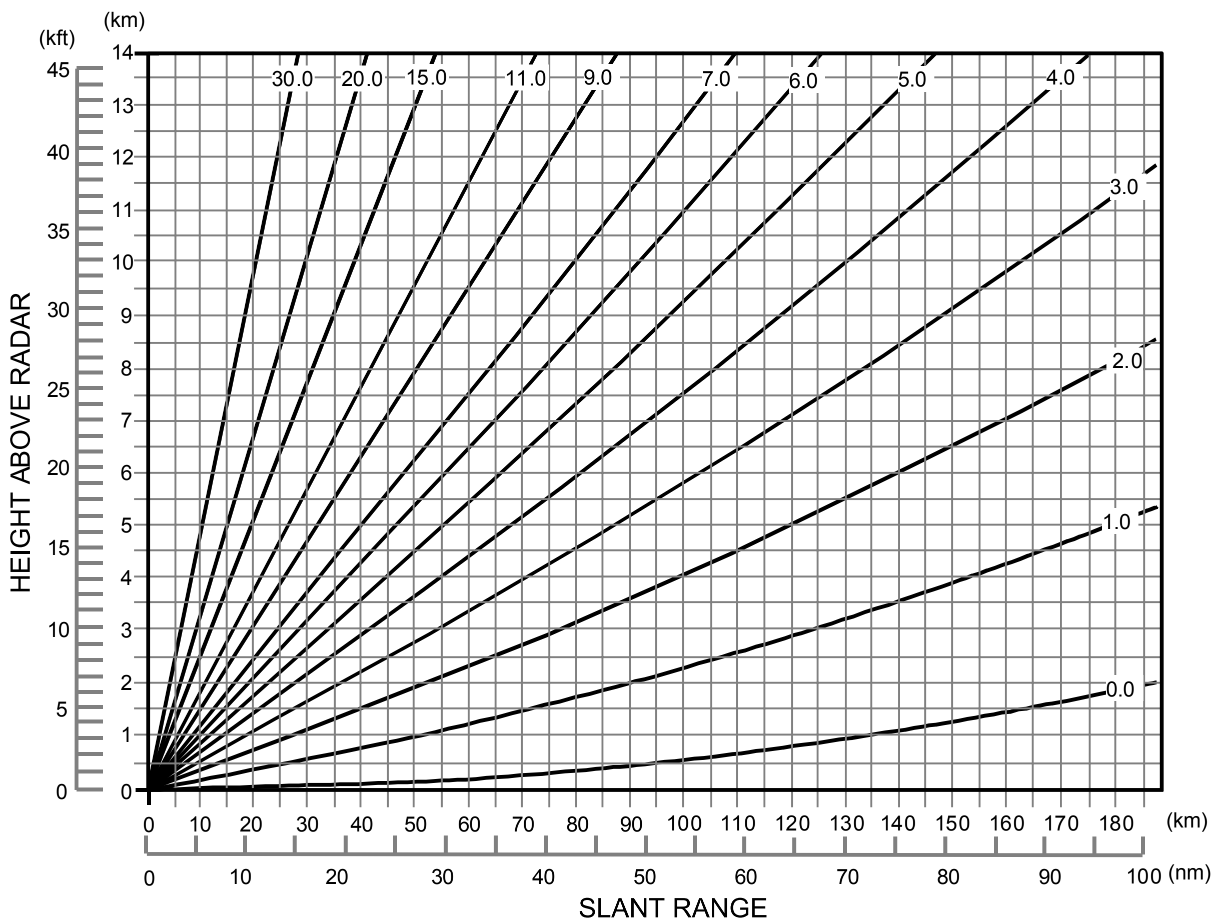


Figure 7. Range-height chart showing the height above ground of the radar beam for various elevation angles. The angles shown do not correspond to specific elevation angles in the IMPROVE-2 radar scan strategies. This chart is provided strictly for reference.

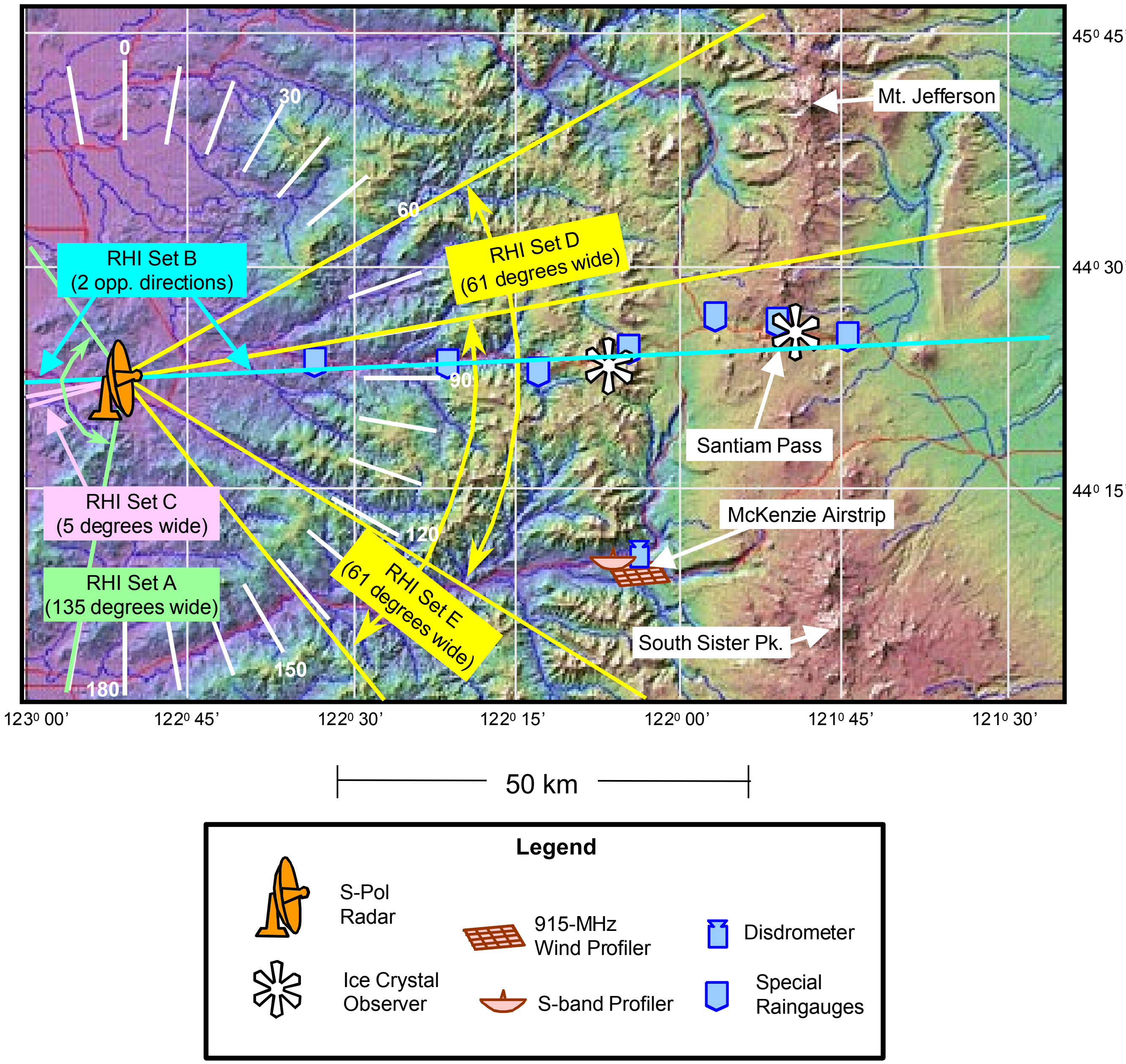


Figure 8. RHI scan sets for the S-Pol radar.

fully cover the NE-SW CV-580 flight track, and these data can be Cartesianized in real time so that arbitrary cross sections through the sector can be viewed.

Table 4. Research scan cycle with E-W CV-580 flight track.

Scan	Elevation or Azimuth Angle(s)	Time Required (s)	Elapsed Time (s)
Surveillance PPI Set	Elevations: 0.5°,1.45°	122	122
RHI Set B	Azimuths: 88.5° and 268.5°; Elevation range: 0-60°	36	158
RHI Set D	62 azimuths from 60° through 121° (spaced every 1°); Elevation range: 0-30°	444	602

Table 5. Research scan cycle with NE-SW CV-580 flight track.

Scan	Elevation or Azimuth Angle(s)	Time Required (s)	Elapsed Time (s)
Surveillance PPI Set	Elevations: 0.5°,1.45°	122	125
RHI Set C	6 azimuths over 5°-wide sector (spaced every 1°); direction of sector to be chosen by S-Pol Radar Scientist(s); Elevation range: 0-30°	50	172
RHI Set E	62 azimuths from 80° through 141° (spaced every 1°); Elevation range: 0-30°	444	616

Appendix A. INSTRUMENTS ON CV-580 AIRCRAFT FOR IMPROVE-2.

(a) Navigational and Flight Characteristics

Parameter	Instrument Type	Manufacturer	UW Computer Code
Latitude and longitude	Global Positioning System (GPS)	Trimble TANS/Vector	tans-lat (deg) tans-lon (deg)
True airspeed	Variable capacitance	Rosemount Model F2VL 781A	tasknt (kts)
Heading	From TANS/Vector	Trimble TANS/Vector	tans-azimth (0 deg is true north)
Pressure	Variable capacitance	Rosemount Model 830 BA	pstat
Pressure altitude	Computed from pstat assuming standard atmosphere	—	palt (ft)
Altitude	Global Positioning System (GPS)	Trimble TANS/Vector	tans-altft (msl, ft)
Altitude above terrain	Radar altimeter	Bendix Model ALA 51A	ralt (agl, ft)

(b) Communications

Parameter	Instrument Type	Manufacturer	UW Computer Code
2-way radio	Radios	Various	—
Air-to-ground telephone	Via Iridium satellite	Motorola	—

(c) General Meteorological

Parameter	Instrument Type	Manufacturer	UW Computer Code
Radar reflectivity	3 cm wavelength (pilot's radar)	Bendix/King (now Allied Signal)	—

(Cont.)

(c) General Meteorological (continued)

Parameter	Instrument Type	Manufacturer	UW Computer Code
Total air temperature	Platinum wire resistance	Rosemount Model 102CY2CG and 414 L Bridge	ttot (˚C)
Total air temperature	Reverse-flow	In-house	ttotr (˚C)
Static air temperature	Calculated from Rosemount total temperature	Rosemount Model 102CY2CG and 414 L Bridge	tstat (˚C)
Static air temperature	Reverse-flow thermometer	In-house	tstatr (˚C)
Dew point temperature	Cooled-mirror dew point	Cambridge System Model TH73-244	dp (˚C)
Absolute humidity	IR optical hygrometer	Ophir Corp. Model IR-2000	rhovo = Ophir2k absolute humidity (g/m^3). (Also, dp_o = Ophir dew point (degC). oairt = Ophir2k air temperature (degC). rh_o = Ophir2k relative humidity (%).)
Wind direction	Calculated from TANS/Vector and Shadin	Trimble	wind_dir
Wind speed	Calculated from TANS/Vector and Shadin	Trimble	wind_spd (kts)
Video image	Forward-looking camera and time code	Ocean Systems Splash Cam	—

(Cont.)

(d) Cloud and Precipitation Physics

Parameter	Instrument Type	Manufacturer	UW Computer Code
Cloud condensation nucleus spectra	Thermal diffusion chamber	Univ. of Wyoming/ NCAR	??
Liquid water content	Hot wire resistance	Johnson-Williams	lwjw0 = cloud liquid water content from JW (g/m^3)
Liquid water content	Hot wire resistance	DMT	lwdmt = cloud liquid water content from DMT (g/m^3)
Liquid water content; effective droplet radius; particle surface area	Optical sensor	Gerber Scientific Ins. PVM-100A	lwpvm = cloud liquid water from PVM (g/m^3). erpvm = PVM100A effective radius (μm). psapvm = PVM100A raw surface area (cm^2/m^3). sapvm = PVM100A surface area [corrected using fssp100 drop rate] (cm^2/m^3).
Liquid water content	Forward light-scattering	Particle Measuring Systems FSSP-1000	lwfsp
Size spectrum cloud particles	Forward light-scattering	Particle Measuring Systems FSSP-100	fsprt = fssp 100 total concentration (/cc). fspdn = fssp 100 particle concentration spectrum (/cc).

(Cont.)

(d) Cloud and Precipitation Physics (continued)

Parameter	Instrument Type	Manufacturer	UW Computer Code
Size spectrum of cloud and precipitation particles	Diode occultation	Particle Measuring Systems OAP-200X (1D-C)	cprt = oap200x total concentration (/litre). cpdn = oap200x concentration spectrum (/cc).
Images of cloud particles	Diode imaging	Particle Measuring Systems OAP-2D-C	tdcrt = 2DC total concentration (/cc). tdcdn = 2DC concentration spectrum (/cc).
Cloud and precipitation particle imagery	Digital holographic camera	SPEC Inc. Model CPI-230	—
Size spectrum of precipitation particles	256 photodiode CCD array	SPEC (1 channel HVPS)	—

(e) Radiation

Parameter	Instrument Type	Manufacturer	UW Computer Code
UV hemispheric radiation, one upward, one downward	Diffuser, filter photo-cell (0.295 to 0.390 μm)	Eppley Lab. Inc. Model TUVR	uvup = uv upward looking ($W\ m^{-2}$) uvdn = uv downward looking ($W\ m^{-2}$)
VIS-NIR hemispheric radiation (one downward and one upward viewing)	Eppley thermopile (0.3 to 3 μm)	Eppley Lab. Inc. Model PSP	pyrup = vis-nir upward looking ($W\ m^{-2}$) pyrdn = vis-nir downward looking ($W\ m^{-2}$)
Surface radiative temperature	IR radiometer 1.5˚ FOV (8 to 14 μm)	Omega Engineering OS3701	irtemp (degC) = surface temp. (˚C)

Note: PMD OAP-2D-P is not aboard but available "on bench" for quick installation if one of the precipitation probes should fail.

Appendix B. CV-580 FLIGHT CREW DUTY CONSTRAINTS

The following restrictions apply to the CV-580 Pilot-in-Command and Copilot (i.e., the "Flight Crew").

Definitions:

Flight hours[*]: the time the aircraft first moves under its own power for the purpose of flight until the moment it comes to rest at the next point of landing (i.e., "block-to-block")

Flight Crew Duty Period: the period of time that starts at the briefing time or when the crew starts being "on alert", and ends when the aircraft is shut down and secured

CV-580 Flight Crew Rest and Flight Duty Limitations:

a. maximum flight hours during any 24-h period	9
b. maximum flight hours during any 7 consecutive days	35
c. maximum flight hours during any 30-day period	110
d. maximum consecutive working days	6
e. maximum Flight Crew duty period (hours)	14
f. minimum Flight Crew rest period (hours)	12

[*] From the point of view of IMPROVE and cost accounting, CV-580 “flight hours” are defined as “engines on to engines off” instead of “block-to-block”.

Appendix C. P-3 FLIGHT CREW DUTY CONSTRAINTS AND DEFINITIONS

The following restrictions apply to all NOAA/AOC personnel that fly on the P-3 (i.e., the "Flight Crew").

Definitions:

Flight Crew Duty Day: the period of time that starts when a Flight Crew member reports to his/her designated place to begin mission preflight procedures to when he/she departs the work location after completion of the mission.

P-3 Flight Crew Rest and Flight Duty Limitations:

a. maximum consecutive working days	6
b. maximum Flight Crew duty day (hours)	16
c. minimum Flight Crew rest period (hours)	12

Take-off times should be set at least 12 h before the crew reports to work (to account for the minimum rest period). Thus, once the scheduled flight is ~15 or less hours away, take-off time cannot be advanced any more. It can be delayed, but any delay must take into account the maximum duty day of 16 h. Nominally, the pre-flight procedures require ~2 h, and the post-flight procedures take ~1 h, so for a planned 6-h mission, the maximum possible delay that will still permit a full mission and not exceed the duty day limit is 16 – 2 – 6 – 1 = 7 h.

If the takeoff schedule is shifted from predominantly daytime to predominantly nighttime or vice versa, then at least 24 h notice is required prior to take-off. Daytime flights are defined as those that begin between 0600 and 1800 local time. Nighttime flights are defined as those that begin between 1800 and 0600 local time.

Following 3 consecutive maximum endurance missions, the NOAA/AOC facility manager *may* authorize a 24-h down period.

Appendix D. LIST OF ACRONYMS AND ABBREVIATIONS

AFB: Air Force Base
ATG: Atmospheric Sciences/Geophysics Building (UW)
CV-580: UW Convair-580 Research Aircraft
CARG: Cloud and Aerosol Research Group (at the UW)
CCN: Cloud Condensation Nuclei
COAMPS: Coupled Ocean-Atmosphere Prediction System (U.S. Navy forecast model)
Eta: Eta-coordinate regional NWP model (maintained and operated by NCEP)
FAA: Federal Aviation Administration
FM: Frequency Modulation
IMPROVE: Improvement of Microphysical PaRameterization through Observational Verification Experiment
IMPROVE-1: IMPROVE Phase 1: Washington Offshore Frontal Study
IMPROVE-2: IMPROVE Phase 2: Oregon Cascades Orographic Study
IOP: Intensive Observation Period
ISS: Integrated Sounding System
MM5: Penn State University/NCAR Mesoscale Model Version 5
NAS: Naval Air Station
NCAR: National Center for Atmospheric Research
NCAR/ATD: NCAR Atmospheric Technology Division
NCAR/RAP: NCAR Research Applications Program
NCEP: National Centers for Environmental Prediction
NetCDF: Network Common Data Form
NOAA: National Oceanic and Atmospheric Administration
NOAA/AOC: NOAA Aircraft Operations Center
NOAA/ETL: NOAA Environmental Technology Laboratory
NWP: Numerical weather prediction
NWS: National Weather Service
P-3: NOAA WP-3D Orion Research Aircraft
PARSL: PNNL Atmospheric Remote Sensing Laboratory
PI: Principal Investigator
PNNL: Pacific Northwest National Laboratory
PPI: Plan Position Indicator
PRF: Pulse Repetition Frequency
PST: Pacific Standard Time
RHI: Range-Height Indicator
S-Pol: S-band Polarimetric Radar
SUNY: State University of New York
TBD: to be determined
UW: University of Washington
VHF: Very High Frequency
IFR: Instrument Flight Regulations