OLYMPEX Ground Validation Experiment
Field Operations Plan
(Version 2)

Preamble

This document is a comprehensive summary of the field plans, objectives and instrumentation to be deployed for OLYMPEX, as understood at the time of this writing. The objectives will be achieved by means of coordinated ground instruments for snow and rain, rawinsonde serial ascents, ground-based radar, aircraft with radars and passive microwave instruments to simulate the GPM satellite measurements, and airborne microphysical sampling. Measurements will be made over the ocean, on the windward side of the Olympic Mountains, over the snowfield in the high terrain, and on the leeside of the mountain range. An Operations Center at the University of Washington will be the base where all the components of the project will be coordinated day-to-day during the field operations.

1. General background of the OLYMPEX ground validation campaign for GPM

1.1 Ground validation goals for midlatitude precipitation

The primary objective of the Global Precipitation Mission (GPM) is to measure rain and snow globally especially in areas lacking surface observations or ground-based radar coverage. In order to achieve this goal, the GPM constellation of satellites must be able to detect solid and liquid precipitation over a wide range of intensities (from 0.2 mm hr^{-1} to 110 mm hr^{-1}), a wide range of locations (from ocean to complex terrain), and a wide range of regimes (light snowfall to intense convection). The core satellite of GPM was launched on 27 February 2014 and is instrumented with the GPM Microwave Imager (GMI) and the Ku/Ka band Dual Frequency Precipitation Radar (DPR). To satisfy the GPM measurement requirements and to assess how remotely sensed measurements of precipitation can be applied to a range of data applications (e.g. determining storm structures, monitoring flooding events and droughts) ground validation (GV) field campaigns are vital. We describe herein the Operations Plan for the comprehensive ground validation Olympic Mountain Experiment (OLYMPEX) for GPM to be conducted in Washington State during November – February 2016. This experiment will address a wide range of GV needs.

The Olympic Peninsula is an ideal location to conduct a GV campaign for GPM. It is situated within an active mid-latitude winter storm track in the northwest corner of Washington State. It reliably receives among the highest annual precipitation amounts in North America ranging from over 2500 mm on the coast to about 4000 mm in the mountainous interior. In one compact area, the Olympic peninsula ranges from ocean to coast to land to mountains, where the terrain height ranges from sea-level to elevations over 2000 m over a distance of approximately 50 km. This unique venue is of an ideal size for a field campaign involving aircraft, radars, and other ground-based sensors. OLYMPEX will be able to monitor the storm characteristics and processes over the ocean, their modification over complex terrain, and the resulting hydrologic impacts. OLYMPEX is ideally suited to quantify the accuracy and sources of variability and uncertainty inherent to GPM measurements in such a varied region of the midlatitudes.

OLYMPEX simultaneously addresses several basic GPM goals:

- Physical validation of the precipitation (rain and snow) algorithms for both the GMI and DPR.
- Assessing GPM precipitation uncertainty in mid-latitude frontal systems as a function of space and time scales, physical and dynamical mechanisms, precipitation intensity, storm structure, and underlying terrain.
- Quantifying the accuracy and uncertainty of the GPM precipitation data and its hydrologic applicability.
- Merging numerical modeling and satellite observations to optimize precipitation estimation in hybrid monitoring systems of the future.

Through a combination of surface-based instrumentation, snowpack monitoring strategies, multi-frequency radars, aircraft satellite simulators, aircraft and surface-based microphysical measurements, hydrologic measurements, and numerical model estimates, OLYMPEX will provide a comprehensive picture of the surface and in-cloud microphysical properties and their variability for a wide-range of meteorological and topographic conditions. The following sections will provide details of the Operations Plan for the OLYMPEX project.

1.2 Location and dates of the field project

OLYMPEX will take place on the Olympic Peninsula, the northwest corner of Washington State, as shown in Figure 1. Due to the mean southwesterly flow and frequent passage of midlatitude cyclones, the region is characterized by a wetter, windward side on the southern and southwestern side of the Olympic Mountains and a drier, leeward side located to the north and northeast of the Olympic Mountains. A majority of the focus of the campaign will be on the wetter SW side with radars and ground instrumentation placed to sample storms as they approach from the Pacific Ocean and are then modified as they traverse across the higher terrain. Two river basins will be the focus of the campaign, the Quinault River and the Chehalis (shown in Figure 2). The Quinault has headwaters in the high terrain of the Olympic Mountains and flows almost due westward towards the Pacific Ocean. The Chehalis has an upper branch, which originates in the higher terrain on the south side of the Olympics, and a lower branch located in southwestern Washington state to the south of the Olympics.

OLYMPEX will occur from fall 2015 through winter 2016. Different observational networks will have different time periods of operation. The ground instrumentation will be installed in the early fall 2015 (by September for the higher elevation locations and by mid October for the lower elevation locations) and will remain onsite until spring 2016. Precipitation and flooding of river basins in the Pacific Northwest is most frequent during mid-November through January. The radars will operate from November 1 through 22 December 2015. There will be a two-week break for the holidays, and then the radars will resume operations from 3–17 January. The aircraft will operate for a 6-week period, 10 November–22 December 2015.

1.3 Collaborative agencies in the Pacific Northwest

The land areas over which OLYMPEX will take place are on the Olympic Peninsula where large portions of the land are administered by the National Park Service (NPS), the US Forest Service (USFS), and the Quinault Nation (Figure 3).

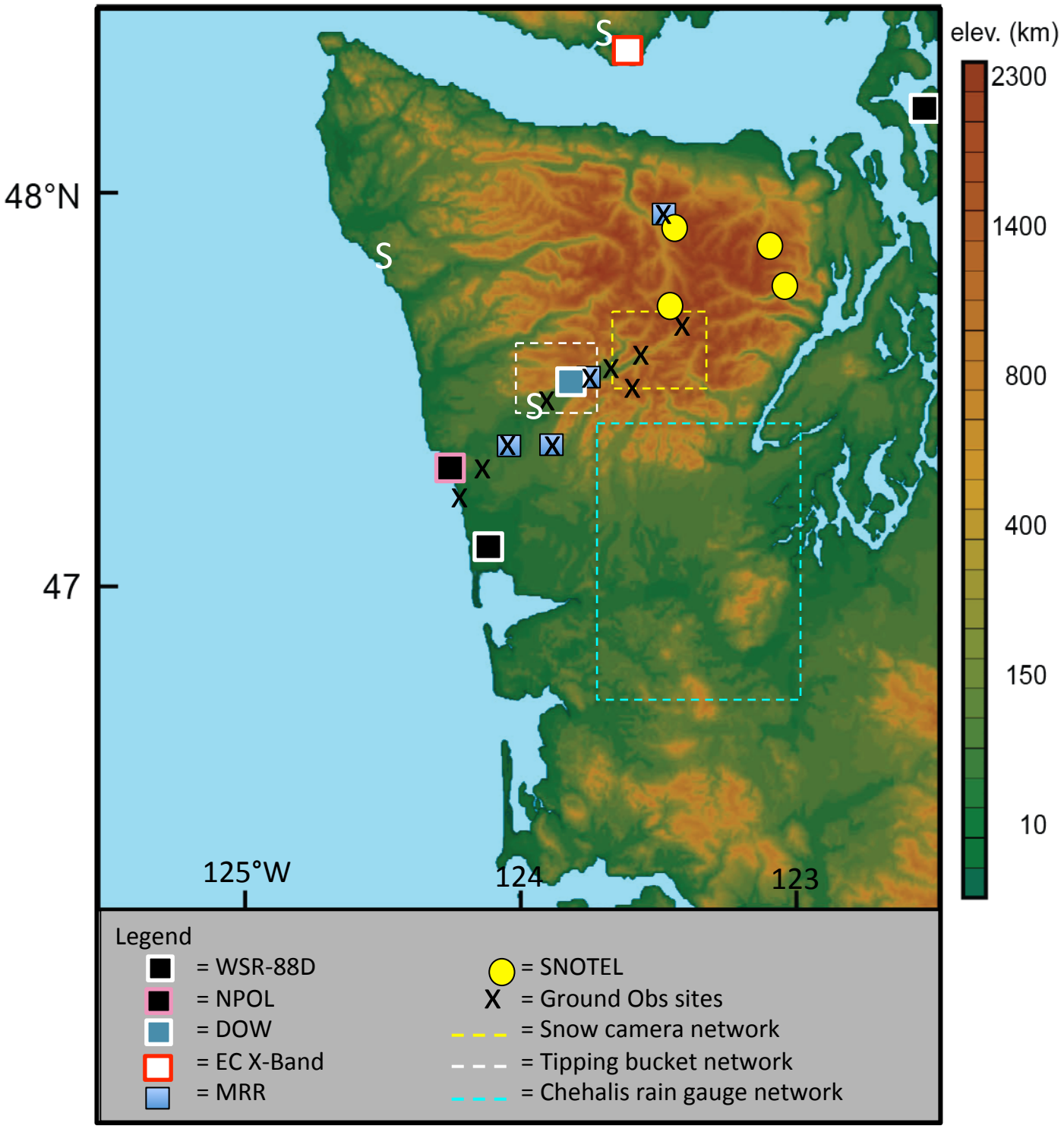

Figure 1: Map of ground observations for OLYMPEX. Radars shown as squares, SNOTEL sites as circles, key ground observing locations as X's and rain and snow networks as dashed boxes.

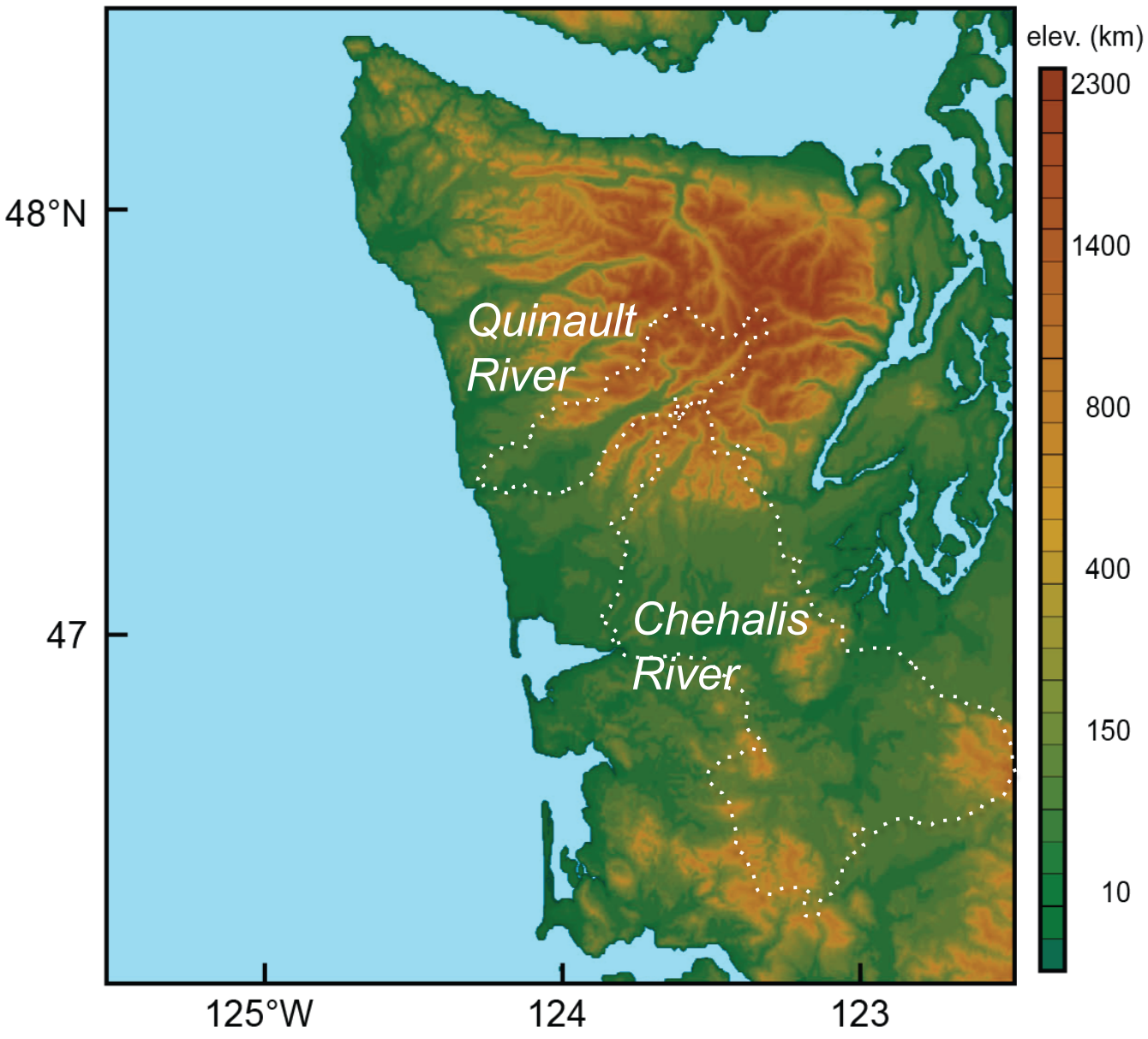

Figure 2: Map showing the location of the two river basins, the Quinault and the Chehalis, which will be the focus for hydrology for OLYMPEX.

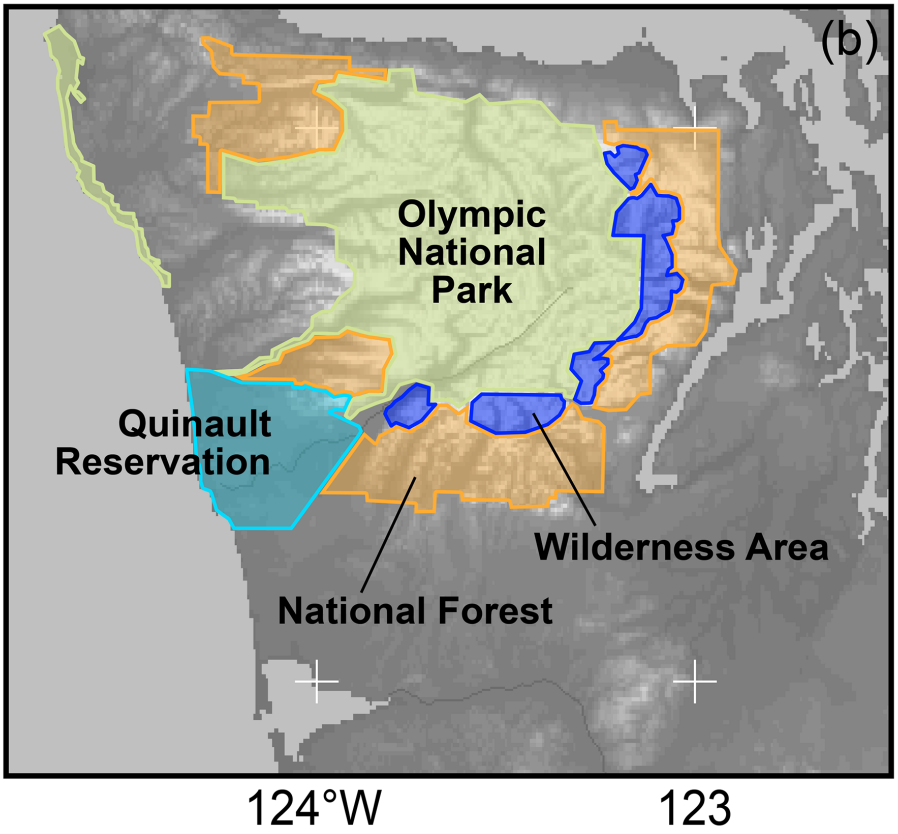

Figure 3: Map of the Olympic Peninsula with the locations of the boundaries for the Olympic National Park, the US National Forests and Wilderness areas and the Quinault Reservation.

National Park Service

The Olympic National Park covers most of the Peninsula, encompassing the high terrain and some sections of the Washington Coast. Consequently, much of the interior of the Peninsula is remote and access is limited to trails and unpaved roads that are closed in the winter. Any ground instrumentation that is placed in the Park will require special permits to insure that the installation, maintenance and operation of the instruments comply with the Wilderness Act of 1964 and have a minimum impact on the natural ecosystem. In addition, access to instruments installed at the high terrain may require 2-day hike on foot in winter conditions.

U. S. Forest Service

The USFS has jurisdiction over many areas immediately surrounding the Park, with some of these regions designated as Wilderness Areas. Any ground instruments installed within Forest Service land also require permits and access to the instruments will vary depending on the location. Some regions are quite remote with limited access by unmaintained roads. Other roads are gated in the winter for wildlife protection and require a special permitting process to obtain permission to make installations during the winter season.

Quinault Indian Nation

The Quinault Indian Nation (QIN) reservation covers a significant portion of the coastal and southwestern side of the Olympics, including the lower portion of the Quinault River. Much of the area is also remote with limited access via unpaved roads. Any instrumentation installed within the Reservation boundaries requires permits from the QIN. We have developed a working relationship with the QIN Department of Natural Resources and they have been very supportive of the OLYMPEX project and are working closely with us to insure its success. Most importantly the QIN will host the NPOL and D3R radars (see Section 6.1 below).

1.4 Partner projects

RADEX

An important partner within NASA is the RADEX (Radar Definition Experiment), which will make radar and passive microwave measurements with the ER-2 aircraft in coordination with the OLYMPEX DC-8 and Citation aircraft (see Section 7 below). The goal of RADEX is to obtain information that will advance the development of radars to monitor clouds from space, including where cloud processes are active in thin clouds and a wide range of ambient temperatures. These goals lead to the desire for the same type of measurements that are sought in OLYMPEX, so OLYMPEX and RADEX will work very well in a joint experiment.

Environment Canada

Environment Canada and NASA have a rich history of collaborating on ground validation activities in support of space-based missions. There is an existing collaborative agreement between the organizations to cover this type of activity (prior such programs being the Canadian CloudSat CALIPSO Validation Experiment in the winter of 2006/07 and the GPM Cold Season Precipitation Experiment in 2011/12). The Environment Canada contribution to OLYMPEX will be to support the validation of GPM products in complex terrain by monitoring the precipitation processes occurring on the leeside of the Olympic

Mountains. Operating on the southern tip of Vancouver Island, BC, they will provide rawinsonde ascents and radar measurements that will document leeside processes. The radar measurements will extend over the NASA instrumentation located on the leeside of the Olympic range, and the radar and rawinsonde data will be an ideal complement to similar measurements made by NASA and NSF facilities on the windward side of the Olympic Mountains. Environment Canada's participation also supports goals related to modelling and data assimilation studies in the Meteorological Research Division that use the West Coast (centered on Georgia Strait) version of High-Resolution Ensemble Kalman Filter (HREnKF) Forecasting system.

NSF/DOW

The National Science Foundation (NSF) is supporting a University of Washington grant under which a Doppler on Wheels (DOW) radar will be deployed during OLYMPEX. The objective being pursued under this DOW deployment is determination of the dynamical and microphysical processes leading to rapid growth and fallout of precipitation on the windward sides of mountain ranges. Obtaining these measurements in the context of the GPM ground validation measurements is seen as an opportunity for the NSF project to pursue its objectives. At the same time the DOW measurements will supplement the NASA NPOL radar measurements (see Section 6) by obtaining dual-polarimetric data in the Quinault Valley below the beam of the NPOL radar.

NOAA/HMT

The National Oceanic and Atmospheric Administrations Hydrometeorological Testbed (HMT) program is considering placement of an S-band profiler on the west side of the Olympic Mountains. Because of the uncertainty of this deployment, this facility is not yet represented in the subsequent sections of this draft of the operations plan.

2. Overview of Expected Weather during OLYMPEX

2.1 Expected storm tracks and typical upper level patterns

From October through May, frequent midlatitude cyclones and their frontal systems make landfall on the Olympic Peninsula from the west and southwest. The upper-level flow patterns associated with the frontal systems vary on timescales of days to weeks. Cluster analysis on 5-day averaged 500 hPa heights shows that the upper-level flow can be segregated into four regimes (Casola and Wallace 2007). In Figure 4, these patterns are shown and can be distinguished from one another by the location and amplitude of their respective ridges and troughs. The offshore trough (OT) has a ridge near the Bering Sea and a trough to the west of the North American west coast. The Alaskan ridge (AR) exhibits a high amplitude ridge centered in the Gulf of Alaska and northwesterly flow along the North American west coast. The coastal ridge (CR) has a ridge aligned with the North American west coast and the Rockies ridge (RR) exhibits a low-amplitude ridge along the Rocky Mountains with nearly zonal flow across the Pacific. The OT and RR patterns are associated with westerly or southwesterly flow and tracks of frontal systems impinging on the Pacific Northwest. They are also most often associated with high precipitation events in the Pacific Northwest. The RR pattern is the most common pattern during the fall and winter months. The AR pattern is associated with more northwesterly flow that can either be dry or associated with colder frontal systems. The CR pattern is a more quiescent pattern associated with a general lack of frontal passages and

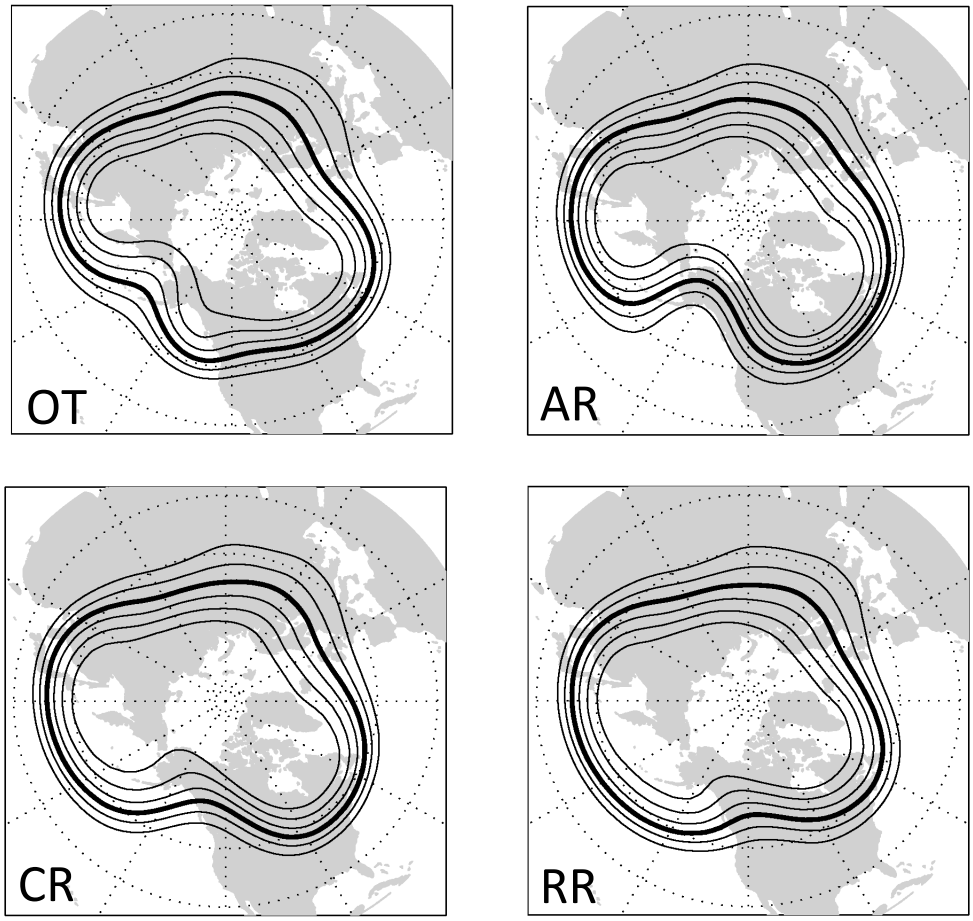

Figure 4: Four dominant regimes of the 500 hPa geopotential height patterns: Offshore Trough (OT), Alaska Ridge (AR), Coastal Ridge (CR) and Rockies Ridge (RR).

blocking of the mean westerlies. The AR and CR patterns are relatively infrequent but can at times interrupt the more normally rainy regimes.

The mean surface flow for the period November through March is southwesterly (Figure 5). This allows moisture-laden air from the Pacific to directly impinge on the Olympic Peninsula contributing to large annual precipitation totals. The air is further lifted over the Olympic Mountains enhancing the production of precipitation. Subsequently, the annual precipitation amounts range from 2500 mm on the coast to more than 4000 mm in the mountainous interior.

2.2 Frontal system sectors

The Pacific frontal systems passing over the Olympic Peninsula typically have three sectors, each with different environmental characteristics, cloud patterns, and precipitation characteristics. These sectors illustrated conceptually in Figure 6 are labeled as prefrontal, frontal and postfrontal.

Prefrontal sector

The prefrontal sector is located to the east and north of an occluded front or cold front and north of a warm front (if present). It is characterized by warm advection, rising melting level, and broad stratiform clouds with steady rainfall. The rain can either be light and drizzly or steady and heavy depending on the moisture content and the degree of synoptic- and meso-scale forcing.

Frontal Sector

The frontal sector is a broad, quasi-linear cloud shield within which a cold (or occluded) front and its associated frontal circulations contribute to the production of precipitation. It is characterized by a broad precipitating region called the wide-cold frontal rainband, and embedded within this rainband, there is a narrow region of high rainrates called the narrow-cold frontal rainband. The environmental characteristics can change rapidly with the passage of the front. For example, the melting level can drop in elevation sharply with frontal passage.

Postfrontal Sector

The postfrontal sector is situated behind (west) of the cold (or occluded) front and is characterized by cold advection, lowering melting level, conditional instability, and a field of small-scale convective clouds separated by clear air. The upper level trough and vorticity center is often co-located with this sector. Due to the deep cold advection over the relatively warmer oceanic water, the small convective clouds sometimes arrange themselves in hexagonal patterns labeled as open-celled convection. When postfrontal convective elements pass over land and are lifted over higher elevations, they often grow in scale and produce significant precipitation and snowfall over the higher terrain. The precipitation in this sector is showery in nature and can contribute significantly to the total rain and snowfall produced by the entire storm system.

3. Observational objectives and experimental strategy

An attractive feature of the Olympic Peninsula is that it offers the opportunity to test several observational challenges of GPM in midlatitude frontal systems over both ocean and adjacent complex terrain. The ability to observe such cloud systems is the primary difference between the Tropical Rainfall Measuring Mission (TRMM) and GPM. In the tropical latitudes

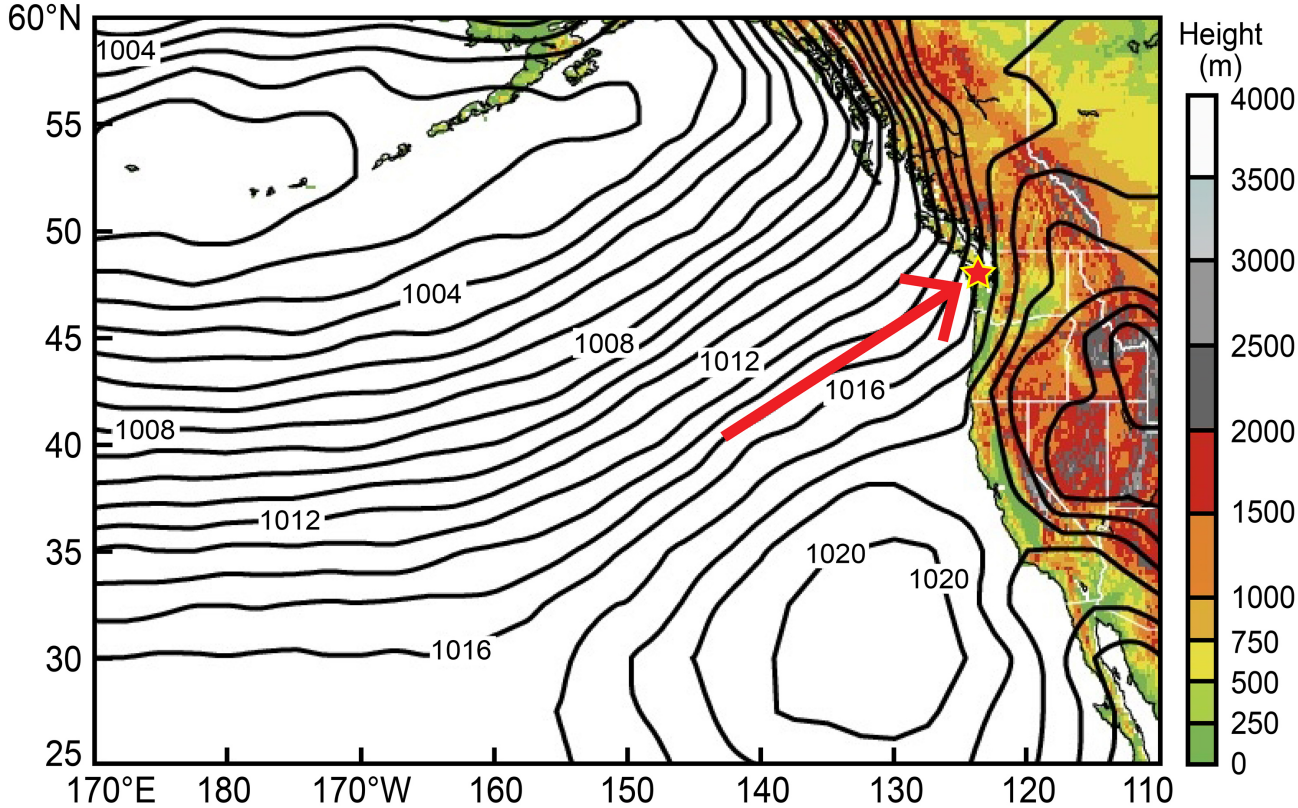

Figure 5: Long-term mean sea level pressure for the period November – February from Reanalysis Data (1979 – 2012). Star indicates location of the Olympic Peninsula and the arrow highlights the direction of the low-level flow.

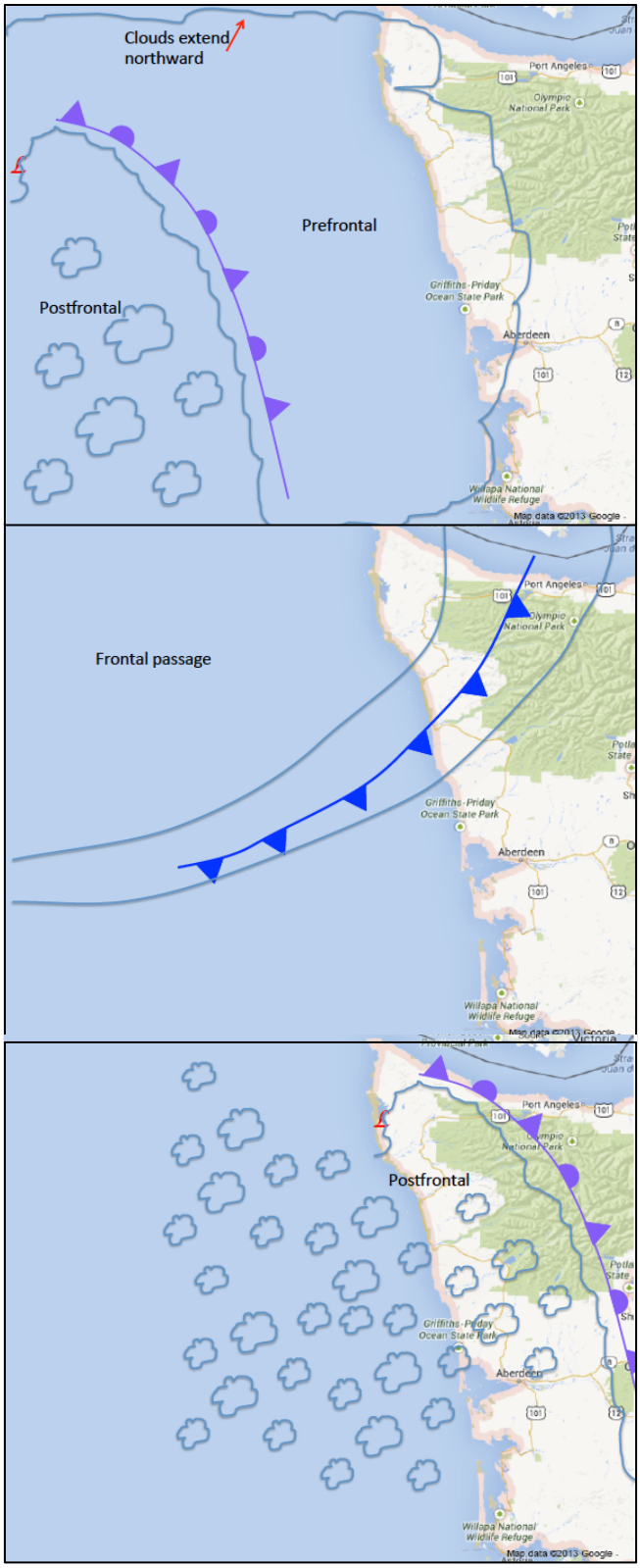

Figure 6: Idealized depiction of the three sectors of a typical midlatitude cyclone. Cloud outlines as seen from satellite imagery shown in blue, standard frontal symbols shown in blue (cold front) and purple (occluded front): Prefrontal (top), Frontal (middle) and Post Frontal (bottom).

surveyed by TRMM, the temperature gradient is weak and precipitation detection algorithms are consequently simplified, snow measurement is not required, and stratiform precipitation is a by-product of convection. In midlatitudes, horizontal temperature gradients are strong, snow measurement is required, and stratiform precipitation is produce by frontogenetical lifting rather than convective processes. In addition, detection of frontal precipitation from space is further complicated by two factors: convection is embedded in frontal clouds, and frontal precipitation is highly modified where it is passing over complex terrain. Finally, assessment of runoff and snowpack in midlatitudes by GPM is highly dependent on the ability of the satellite to detect frontal snow and rain over complex terrain. OLYMPEX is designed to address all of these aspects of midlatitude frontal rain in ways that will aid understanding of how will GPM is able to produce useful data in regions of midlatitude frontal precipitation. The observational objectives of OLYMPEX may be summarized by seeking answers to the following questions:

- How do microphysical and dynamical processes determine particle size distribution in rain and snow and how do they vary in the vertical over a wide range of temperatures with emphasis on variations of the processes across the melting layer?
- How do the microphysical and dynamical processes change as storms move from ocean to coast to land to windward side to high terrain to leeside of mountains?
- How do the microphysical and dynamical processes vary between prefrontal, frontal, and postfrontal storm sectors?
- Can GPM determine the buildup and melt-off of high-terrain snowpack over the full winter season?
- Can GPM determine the hydrologic response to storm passages?

To achieve answers to the above questions representing OLYMPEX objectives, the field program will consist of a strategy of coordinating a variety of ground-based and aircraft measurements. Figure 1 shows the locations of the ground-based instrumentation. Aircraft flights will supplement this network with measurements over the ocean, radars and ground instruments.

Serial rawinsonde ascents at 3-h intervals on the windward and lee sides of the Olympic range will provide the ambient temperature, moisture, and wind profiles, which undergo significant variation during the passage of storms and provide the essential context for making deductions about the microphysical and dynamical processes contributing to the frontal precipitation. Soundings upstream over the ocean will be provided by dropsondes from the DC-8 aircraft.

Surface rain measurements in the Quinault Valley will document how the rainfall and its drop size distribution vary from the coast inland and into the mountains. The radars will determine the vertical distributions of hydrometeors and associated cross-barrier winds as storms pass over the network. Aircraft will provide GPM proxy measurements with downward-looking radars and passive microwave sensors and in situ microphysical sampling within the context of all of the ground-based and airborne radar and radiometer measurements. These observational components of OLYMPEX will be supplemented by real-time regional modeling using the UW WRF ensemble.

4. Deployment of instrumentation for rain and snow measurements and in situ particle sampling at the ground

The existing surface network on the Olympic Peninsula consists of few Automated Surface Observing Systems (ASOS) stations, a Climate Reference Network (CRN) station, several Cooperative Observing (COOP) sites, Remote Automated Weather Station (RAWS) sites and four SNOTEL (SNOpack TELemetry) sites. With the exception of the SNOTEL sites, these observations are limited to coastal and lowland locations that surround the Olympic Mountains (see Figure 7). In order to document how the microphysical and dynamical processes change as storms move from ocean to land to high terrain, these observations will be supplemented with a variety of ground-based microphysical and precipitation gauge instruments in critical areas. The Quinault River basin is a narrow southwest-northeast oriented watershed on the windward side of the Olympic Mountains (Figure 2). As such it is ideally suited for concentrated radar and ground measurements. Raingauges and disdrometers will be distributed along the valley, radar coverage will be intensified there with six radars, rain gauges, and a supplemental snow observation strategy will be implemented to observe the buildup and melt-off of the snowpack at higher elevations. In order to improve the quantitative assessment of rainfall in the Chehalis River basin (Figure 2) and the hydrological response, an enhanced rain gauge network will be implemented throughout the Chehalis basin.

4.1 Quinault Area Instrumentation

Figure 8 shows the names and locations of OLYMPEX special ground instrumentation sites on the windward side of the Olympics. These sites are arranged to observe precipitation characteristics along the Quinault River Valley at various distances from the NPOL radar. These instrument sites will help document the variation of precipitation characteristics as a function of distance from the coastline and crest of the mountain range on the windward side of the Olympic range.

Table 1 lists the instruments that will be installed at each site. Note that the types of instruments at each site are determined by the availability of power, wireless signal strength, and accessibility. Sites such as Wallace Cabin, Fish Hatchery, and CRN are all lowland (elevations < 300 ft) sites with power and easy road access, so that a more complete set of instruments are possible and can include MRR, 2DVD, and Parsivel. Other lowland sites without power, such as the Seed Orchard, Bunch Field and Graves Creek campground can only have limited instrumentation such as tipping bucket rain gauges and a Parsivel and/or Pluvio supported with a battery and solar panel set up. Since these lowland sites are relatively accessible, batteries can be exchanged during regular checks. Therefore, only 1-2 deep-cycle batteries should be necessary at these sites.

There will be three high-elevation sites in the Quinault region. Neilton Point, at 2156 ft located on the southern ridge of the Quinault River, is within the rain/snow transition zone, i.e. where falling precipitation can be either rain or snow depending on the environmental temperature and the sector of the storm. This zone is not routinely observed in the Olympic Mountains and OLYMPEX, and instruments at this site will provide a rare opportunity to document the critical processes that occur within this zone. Neilton Point has power so that it will be possible to install a full suite of microphysical instruments including MRR, PIP, Hot Plate and Parsivel. The site is accessible by unpaved road that will require a 4WD vehicle (with chains) in winter. Therefore, access for maintenance may be somewhat limited during cold storm events.

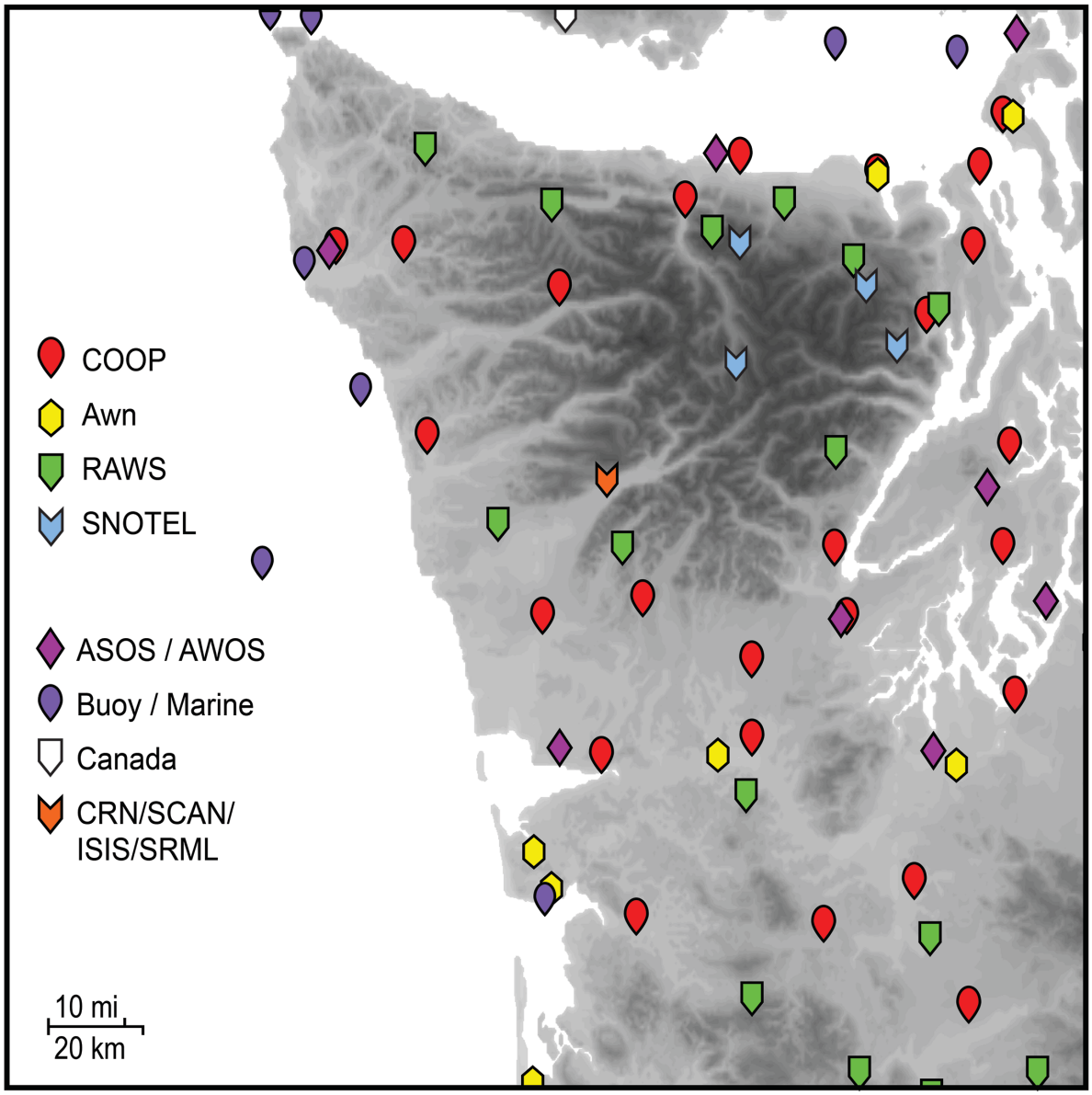

Figure 7: The existing network of surface observations in and around the Olympic Peninsula. ASOS, SNOTEL, RAWS, Buoy, CRN and Canadian sites all report various meteorological parameters hourly, the COOP sites report precipitation once a day.

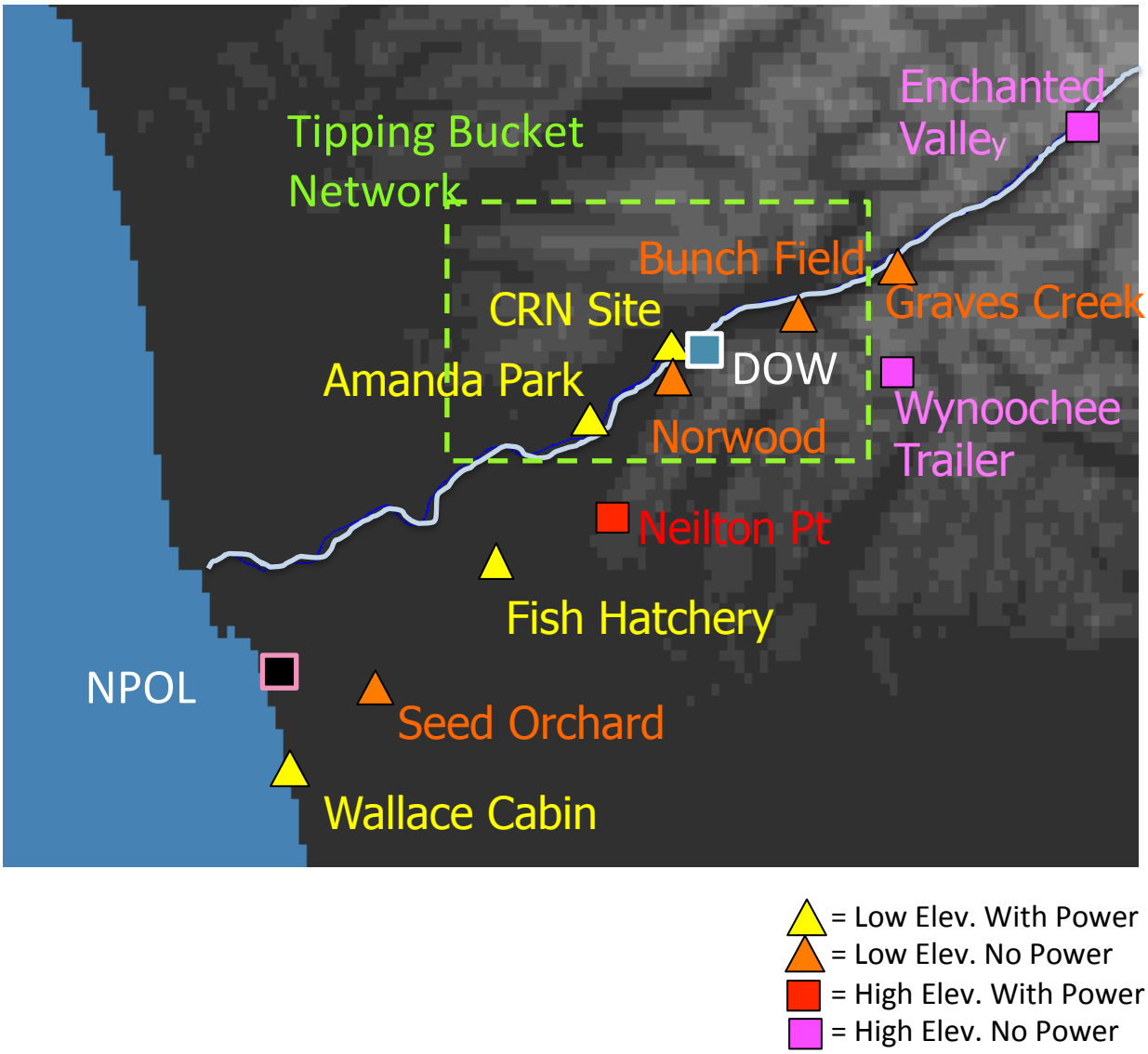

Figure 8: Locations of the surface network (triangles) and the NPOL and DOW radars (squares)that will be deployed for OLYMPEX. See Table 1 for the instruments to be installed at each site.

Table 1 Ground sites installed for OLYMPEX. Windward side stations listed in west to east order.

Name	Location	Elevation	Instruments: X = currently deployed, P= Planned, P*= Possible or under discussion								Power	Access
			MRR	PIP	2DVD	Parsivel	Pluvio	Hot Plate	Dual Tipping Gauge	Other		
Lee side												
Hurricane Ridge	47°58'13.73"N 123°29'55.38"W	5140'	X	X		X		X			Yes	Road, Winter Conditions
Windward side (Quinault Valley region)												
Wallace Cabin	47°12'29" N 12412'15.9"W	Sea level	P*		P*	P				X= Tip Gauge	Yes	Road
Seed Orchard	47°15'58" N 124°07'04"W	255'				P	P		P		No	Road
Fish Hatchery	47°21'32.4" 123°59'28.7"	170'	P		P	X			X		Yes	Road
Amanda Park	47°27'38.02" 123°53'43.57"	290'			P				P		Yes	Road
Norwood South Shore Road	47°29'36" 123°48'32"	220'			P*	P			P		Maybe	Road
Bunch Field	47°32'14.7" 123°40'53.0"	380'				P*			P	X	No	Road, short walk
CRN Site	47°30'49.8" 123°48'43.5"	285'	P		P	P					Yes	Road
GravesCreek Campground	47.572077°N 123.582554°W	563'				P	P*		P		No	Road and Trail
Neilton Pt	47°23'24.5" 123°52'03.2"	2156'	P*	P*	P	P		P*			Yes	Road, Winter Conditions
Enchanted Valley	47°40'16.86" 123°23'21.56"	2033'				P	P				No	Trail
Wynoochee Trailer	47°29'48.8" 123°34'41.2"	3160'				X	X				No	Road, winter conditions, trail

The other two high-elevation sites, Enchanted Valley and Wynoochee, are very remote and in wilderness areas. The Enchanted Valley site is within the National Park and is only accessible on foot via a 13 mile trail, much of which could be snow-covered. At 2033 ft, it too will be within the rain/snow transition zone. At this location, a remote APU (Pluvio and Parsivel) can be installed provided they are powered with a bank of 8 deep-cycle batteries and a solar panel. Initial tests of this type of set up have shown that the batteries can operate for a long period of time (2–4 weeks) without recharging as long as there are a few intermittent sunny periods for the solar panel to operate. The Enchanted Valley installation will require a special permission from the Park Service and that process is underway.

The high elevation site Wynoochee Trailer is within a National Forest Service designated Wilderness Area, for which the road is only open from 1 April 1 through 31 September. We plan to install an instrumented trailer (see Figure 9) about 9 miles inside the Wilderness Area boundary along FS Road 2270 at an open area just off the road. The instrument and battery set-up will be the same as at Enchanted Valley. Since this site is at 3160 ft, there will a lot of snow during the winter, and frequent maintenance may be required to dig out the trailer and instruments. During the winter, the road is gated and motor vehicle access is restricted. With permission from the Forest Service, we should be able to access the site with a vehicle up to the elevation of the snow pack, but then will need to hike (or possibly use a snowmobile) the rest of the way.

4.2 High Terrain Network and Snowpack Monitoring

As noted above, some instrumentation exists at higher elevations designed to monitor weather conditions, snow water equivalent of falling precipitation (either rain or snow) and snow pack accumulation. These stations are all at high elevations (~5000 ft) and include the four SNOTEL sites and the Northwest Avalanche Center (NWAC) site at Hurricane Ridge (see Figure 10). These are all long-term, permanent installations designed to support short-term weather forecasts for storms and avalanches and long-term trends in water supply.

In order to document microphysical properties at high elevations, a suite of instruments are installed at Hurricane Ridge near the NWAC site. Power is available at this site. The instruments are located on top of a generator house and include a PIP, MRR, Parsivel and Hotplate (see Figure 11). This installation coordinates with the observations made by the Environment Canada X-band radar located 50 miles north at Rocky Point on Vancouver Island. The Hurricane Ridge installation and the other three higher elevation sites within the Quinault area described above will document the variability of microphysical processes within and above the rain/snow transition zone.

The four SNOTEL sites and one NWAC site are insufficient to fully describe the accumulation of snow at all elevations over the Olympic Mountains. In order to gain additional information on the snow depth and its variability, a suite of remote cameras has been installed at 18 locations within the general area indicated in Figure 10. The cameras were installed during the late summer of 2014. Each camera is placed to take hourly pictures of a marked snow stake. Small remote temperature sensors are also placed near the snow cameras. The cameras and temperature sensors are left onsite throughout the winter and collected the following summer. The locations have been chosen to be close to historical snow course locations where snow depth measurements were made through the early 1970s and the locations are shown in Figure 12. Initial results from prior snow camera installations at the SNOTEL sites have shown this method to be an accurate and cost-effective way to determine

Figure 9: OLYMPEX Trailer instrumented with a Parsivel and Pluvio and powered by batteries and solar panel. It is currently deployed at Snoqualmie Pass.

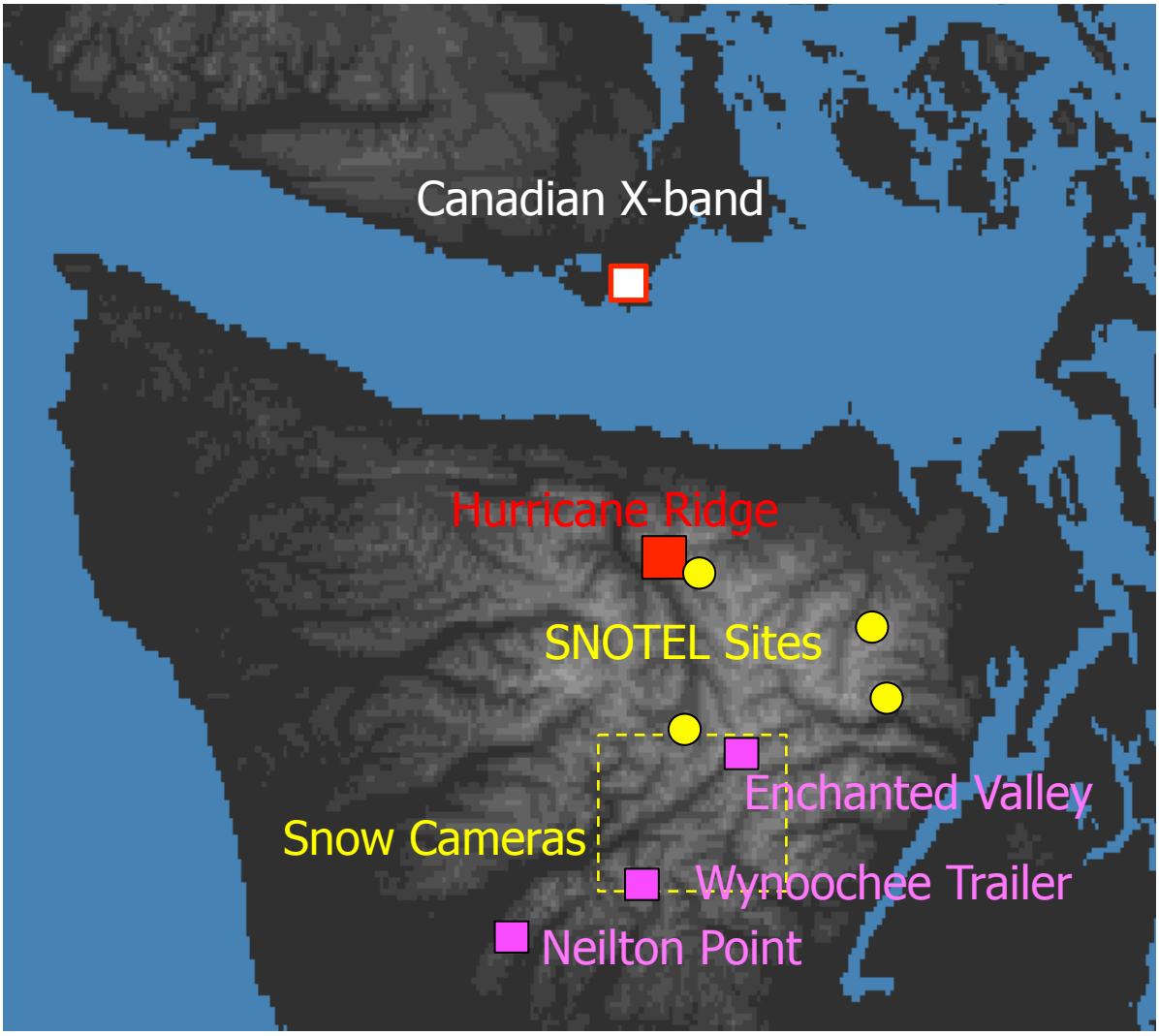

Figure 10: Locations of high terrain stations including SNOTEL, instruments at Hurricane Ridge, high elevation site Neilton Point and the remote sites of Enchanted Valley and the Wynoochee Trailer. The Canadian X-band is also shown for reference.

Figure 11: The suite of instruments installed at Hurricane Ridge on the north side of the Olympic Peninsula. They include a PIP, MRR, Parsivel and Hot Plate (not shown).

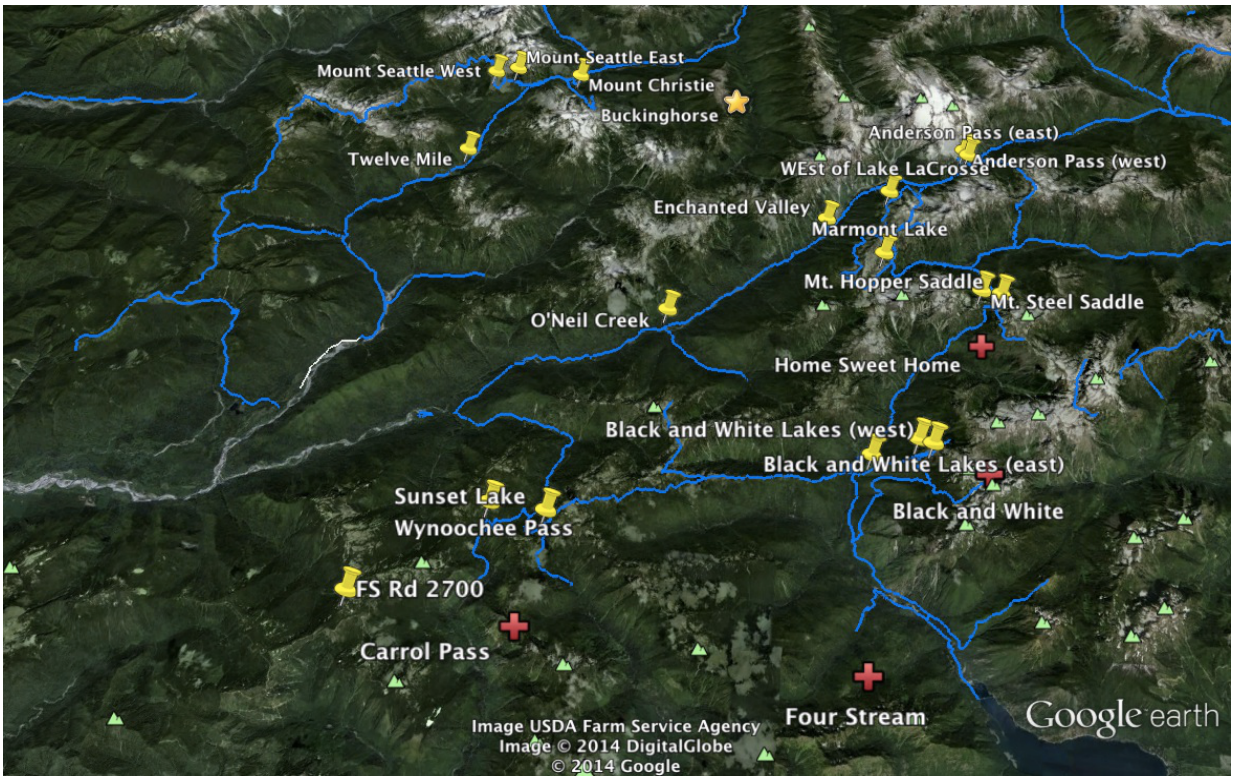

Figure 12: Locations of all the snow cameras installed for the 2014-2015 winter season.

snow depth. Snow water equivalent (SWE) estimates from the snow depth measurement require an estimate of snow density and research is ongoing to determine the best method to estimate density.

In addition to these measurements, the National Park Service performs snow surveys performed by observers flown in by helicopter, which will supplement the other snow measurements. It is possible that additional snow surveys could be made during OLYMPEX, funding permitting.

4.3 Tipping Bucket Rain gauge Networks

Quinault

The UW has installed a network of tipping bucket gauges that transect the ridge between the Quinault and Queets Rivers and includes two gauges along the coast (see Figure 13). This network has been deployed since ~2005 (Minder et al. 2008) and will be deployed up to and including the OLYMPEX time frame. These data are recorded in data loggers, which are retrieved manually at the end of the winter season. The data from some of the lower elevation gauges can be downloaded midseason, but the higher elevation gauges are usually inaccessible during the winter due to snow on the roads.

There will be approximately 20 additional dual-tipping bucket gauges available for OLYMPEX, 10 of which will be installed within the Quinault. These gauges can be monitored in real time provided there is sufficient cellphone coverage (which is not always available in the Quinault region). These gauges will be installed at the locations listed in Table 1(i.e. at the Seed Orchard, Graves Creek, etc.). The remainder of the gauges could be installed at additional locations of opportunity along the Quinault River transect, be used to expand rainfall estimates along the coast, provide additional rainfall estimates on the north side of the Olympics at elevations lower than Hurricane Ridge, or in the lowlands of the south side of the Olympic Mountains. The extent to which these additional gauges can be added will depend on the availability of personnel to deploy them.

Chehalis

A network of rain gauges will document the rainfall variability within the large Chehalis river basin. Existing COOP and RAWS sites are shown in Figure 7. These will be supplemented by 10 dual tipping bucket gauges and by an undetermined number of simple wedge gauges. These gauges will be placed at various elevations, and their locations will be determined by accessibility and data transmission considerations. The network is currently being designed and outreach by the UW Department of Civil and Environmental Engineering is ongoing to enlist observers to check the wedge gauges via the Community Collaborative Rain, Hail & Snow (CoCoRaHS) program.

4.4 Instrument maintenance and data transmission issues

Many of the planned and current ground instrument sites are extremely remote and maintenance and data transmission will require special considerations. Most importantly, personnel need to be identified to carry out manual tasks, and technology must be identified for automated data transmission wherever possible. Below is a list of requirements that must be satisfied at the various types of sites before the field phase of OLYMPEX.

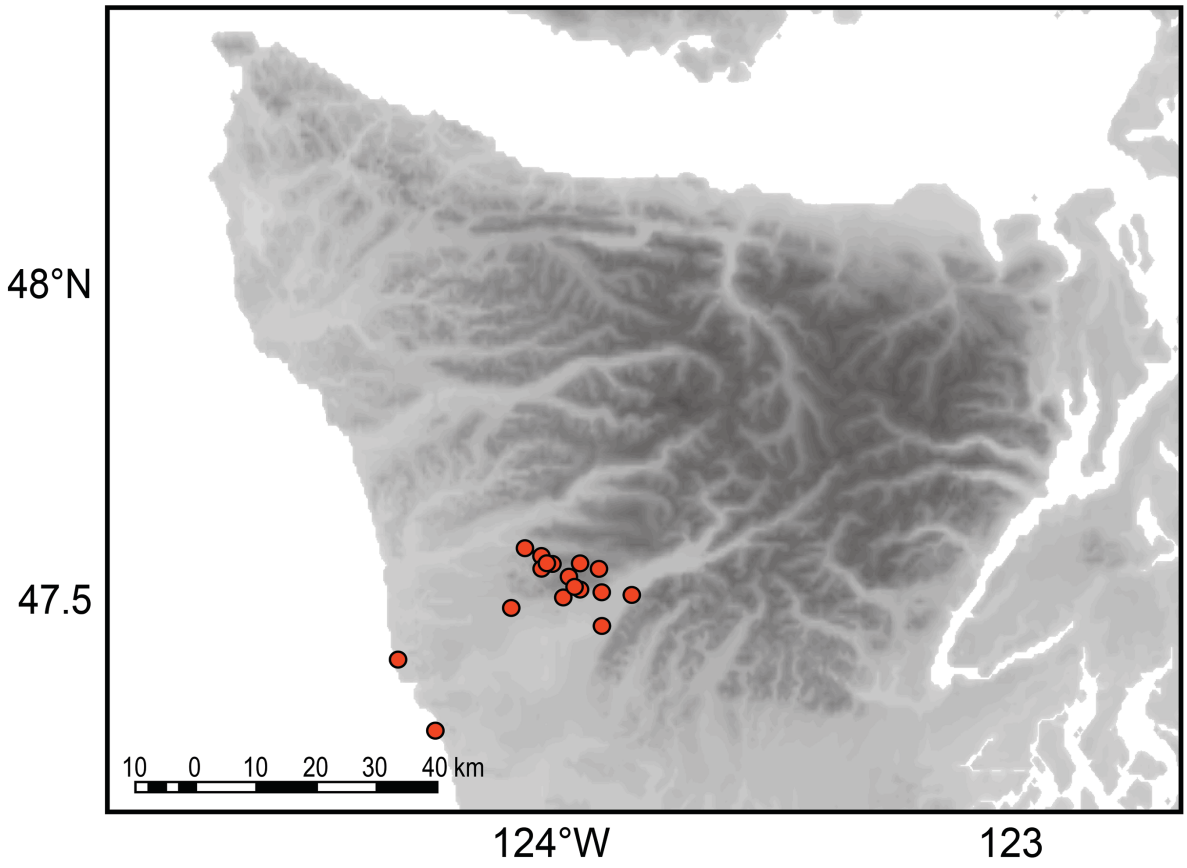

Figure 13: Locations of the UW tipping bucket rain gauge network.

Lowland installations with access and power

- Instrument maintenance whenever needed
- Cell coverage needs verification and if insufficient, then satellite transmission necessary (i.e. CRN site will need satellite transmission)

Lowland installations with access but no on-site power other than batteries

- Battery swap every 1-2 weeks
- Instrument maintenance as needed
- Empty Pluvio (if installed) after 16" of precipitation, or every 2-3 weeks

High elevation installations with access and power

- Snow and rime removal off instruments after big snow events or every 2 weeks
- Download data from computers
- Check instrument alignment after big wind events

High elevation installation with limited access and no power other than batteries

- Site visits every 2-3 weeks– will require winter backcountry travel and possibly overnight stay
- Snow and rime removal and digging out the trailer and instruments if snowpack is high
- Empty Pluvio
- Recharge batteries with generator if solar power was insufficient (i.e. no solar power during rainy/snowy periods)

Real-time data transmission is a potential problem at all ground sites. Cell phone coverage is limited, weak or non-existent throughout the Olympic Peninsula, especially in areas surrounded by tall trees and steep mountains. In many locations, satellite transmission may be the only viable option for monitoring the site real time. Therefore each site needs to be evaluated before the start of the project for data transmission issues.

5. Soundings

The backbone of the OLYMPEX dataset will be the storm thermal and wind structure revealed by soundings. Because the thermodynamic and dynamic conditions vary systematically as frontal systems make landfall over the Pacific Northwest, all specialized measurements of the OLYMPEX/RADEX dataset (surface observations, aircraft, radar) will need to be viewed in the context of where they are obtained in relation to the storm vertical structure prevailing at the time of observation. Without this contextual information it will be difficult to interpret the specialized data in terms of its implications for GPM and other satellite measurements in various synoptic and topographic situations. The 12 h soundings obtained by the NWS at Quillayute, WA, are too infrequent to provide this structure. During the CYCLES Project (Hobbs 1978), it was found that a time series of soundings at time intervals of 2-3 hours provided the background structure to interpret aircraft microphysical measurements in relation to storm structure.

To obtain the time series of storm thermal and wind structure during OLYMPEX cases, soundings will be launched at time intervals of ~3 h at a station (exact location to be determined) on the windward side of the Olympic Mountains and on the leeward side of the

Olympics at the Environment Canada X-band radar site on the south tip of Vancouver Island (Figure 1). These sounding time series will allow us to place the ground-based measurements obtained in the Quinault Valley and at Hurricane ridge accurately into their larger-scale thermal and flow pattern context. The conditions upstream of the Washington coast during storm passages will be documented by dropsondes from the DC-8 aircraft (see Section 7.2 below).

Sounding units will be provided by Colorado State University for the Quinault sounding site and by Environment Canada at the Vancouver Island site. The Quinault station will be manned by graduate students and/or postdocs. Because the number of available expendable sondes is limited by budgetary constraints, decisions will need to be made daily as to when to begin and end rawinsonde launches at the two sites. These decisions will be part of the daily Operations Center discussions (Section 8.1)

Each sounding taken will be plotted using standard software and made available to the Operations Center as soon as possible as both an image and raw digital data as soon as the sounding has been completed. Personnel for creating the sounding plots have yet to be identified.

6. Ground-based radars

A variety of radars will be deployed at the locations shown in Figure 14. Because of mountains, forests, and land-use restrictions, very few sites are suitable and available for the various radars. The sites shown in this Figure have been (or will be) surveyed to determine that they are appropriate for the type of radar to be operated at that location. The basic strategy is that the NWS WSR-88D radars on the Pacific Coast at Langley Hill, WA, and at Camano Island, WA, will provide the horizontal precipitation patterns via their standard tilt-sequence PPI scans. The NPOL radar and Environment Canada X-band radar will provide detailed radar coverage in RHI sectors as shown in Figure 14. NPOL will execute RHI sectors over both the Pacific Ocean for upstream conditions and over the Quinault Valley for conditions over the complex windward-side terrain. Three Micro Rain Radars (MRRs) and a Doppler on Wheels radar (DOW) will be located under the eastern NPOL RHI sector to provide information at low levels, below the beam of NPOL. Similarly, the Canadian X-band radar will provide detailed coverage on the leeside by conducting sector scans over the Hurricane Ridge site, where one MRR will be located. This radar coverage will document in detail the structures that will be observed by the GPM instruments (albeit, in less detail) and will document how frontal, orographic, and convective precipitation processes will be determining the precipitation profiles observed by GPM. The basic characteristics of the OLYMPEX ground-based radars are listed in Table 2, and further details are discussed below.

6.1 S-band radars

The broad background of reflectivity, radial velocity, and dual-polarimetric variables will be provided by the operational NWS WSR-88D operational radars at Langley Hill, WA, and Camano Island, WA. These radars have a wavelength of 10 cm (S-band), peak power of 750 kW, and a beamwidth of ~1°. The Langley radar tilt sequence mode includes an elevation angle at 0.2°. Because they are operational radars of the NWS, the Langley Hill and Camano Island radars will be running throughout the time period of the project.

The site for the NASA/NPOL radar has been surveyed and preparations for siting are underway with approval of the Quinault Nation (see Figure 15). This radar is S-band, Doppler, and dual-polarimetric. It has peak power of 850 kW and a beamwidth of 0.93°. NPOL will

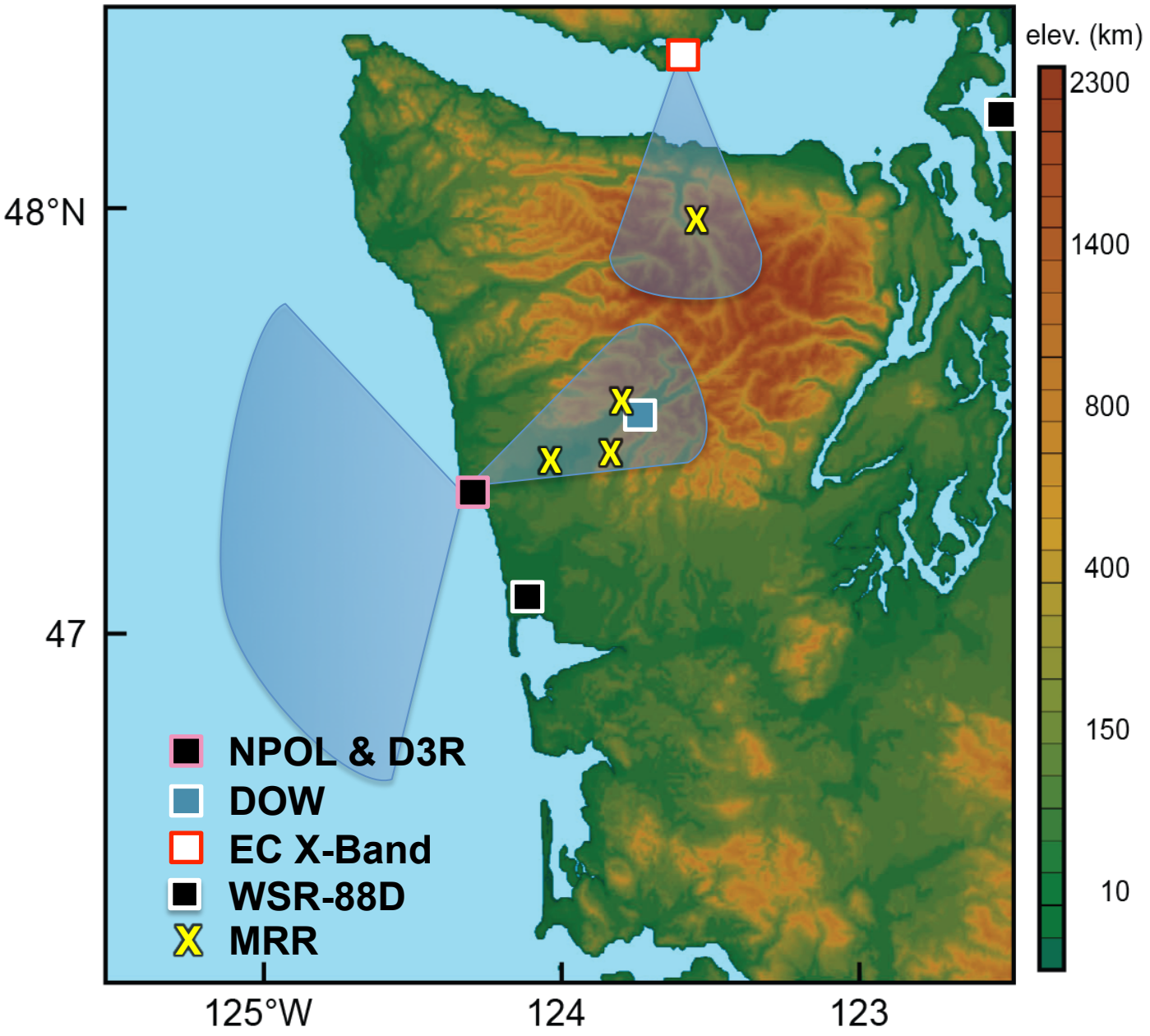

Figure 14: Locations of all the available ground radars for OLYMPEX and the RHI scanning regions for NPOL and EC X-band.

Table 2. Radars to be deployed in OLYMPEX. See text for further technical details. Undecided sites in red.

Radar	Location	Frequency	Scanning mode	Doppler	Dual-Pol.
NPOL	Tahola, WA	S-band	RHI sectors, low-level PPIs	yes	yes
D3R	Tahola, WA	Ka/Ku-band	RHI sectors, low-level PPIs	yes	yes
EC X-band	Rocky Point, Vancouver Island, BC, (48.31°N, 123.56°W)	X-band	RHI sectors, low-level PPIs	yes	no
DOW	Quinault Valley (site TBD)	X-band		yes	yes
MRR	Hurricane Ridge	K-band		yes	no
	Fish Hatchery	K-band		yes	no
	CRN site	K-band		yes	no
	Neilton Point or east of CRN	K-band		yes	no
NWS 88-D	Camano Island, WA	S-band	Operational PPIs down to 0.5 degrees	yes	no
	Langley Hill, WA	S-band	Operational PPIs down to 0 degrees	yes	yes

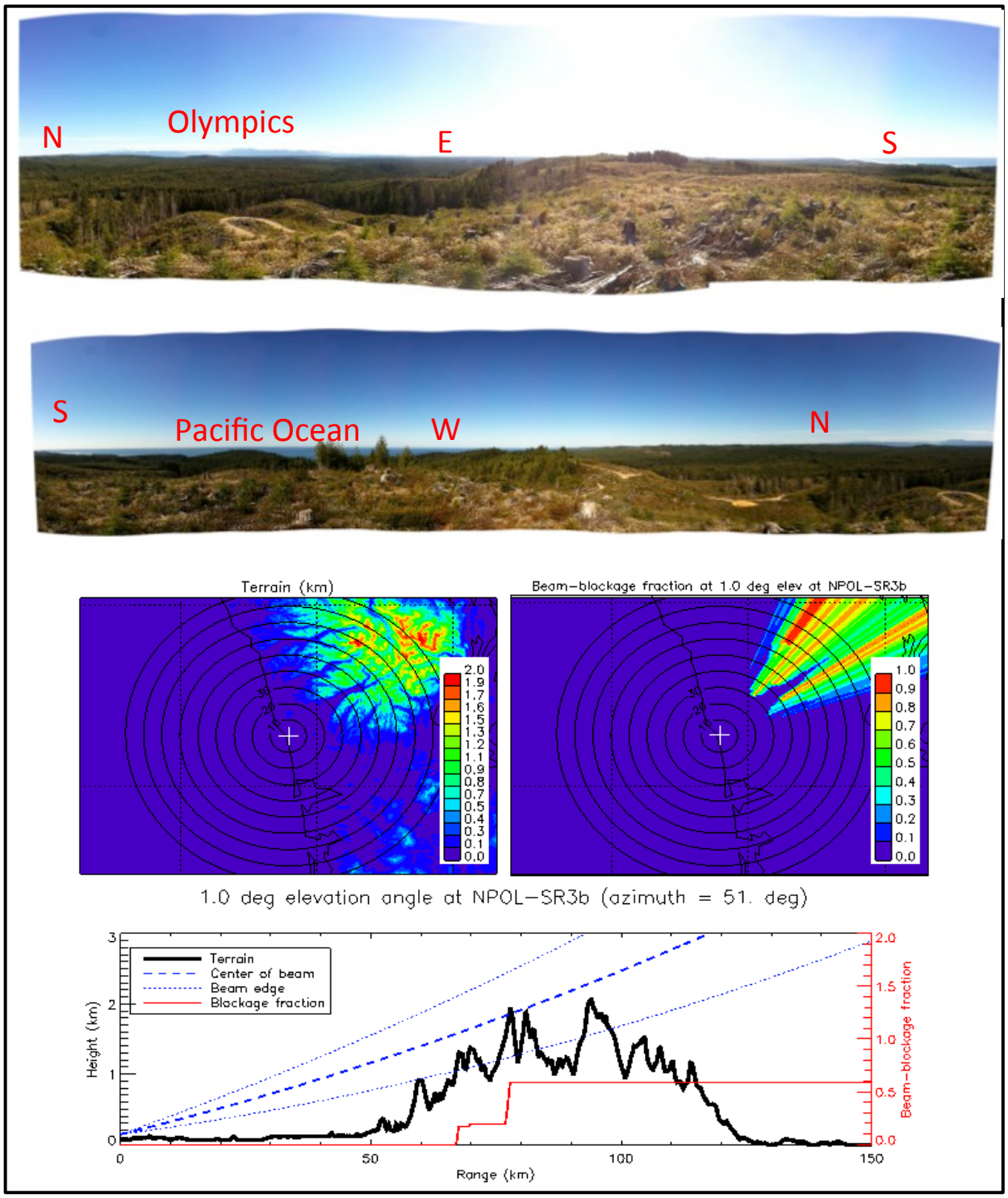

Figure 15: Panoramic views from the NPOL site (upper) and blockage estimates (lower). Note the clear view up the Quinault valley.

execute RHI scans in two sectors. One sector is located over the ocean, bounded by azimuths 210° and 326°, and will contain 40 RHIs. Each RHI will run from 0° to 45° elevation. The other sector is located over the Quinault Valley, bounded by azimuths of 30° and 60° and will contain 16 RHIs from 0° to 45° elevation. Site surveys confirm that these sectors have open views for scanning. Beam blocking is minimal. The NPOL will operate from 1 November – 22 December and from 3–17 January 2016.

6.2 X-band radars

A dual-polarimetric Doppler Radar on Wheels (DOW) is being deployed under an NSF project of R. Houze. The DOW will be placed in the Quinault Valley, within the eastern RHI sector of NPOL. It will scan in RHI mode up and down the valley to fill in dual-polarimetric signals and radial velocity data below the lowest beams of NPOL. The DOW (version 6 or 7 to be used in OLYMPEX) is truck mounted and operates at a frequency of about 9.4 GHz (wavelength ~3.2 cm), with a beamwidth of 0.93° and peak power of 500 kW. The DOW will operate from 10 November through 22 December 2015 and from 3–17 January 2016.

Environment Canada will operate a scanning X-band Doppler radar (SELEX METEOR 50DX) on the southern tip of Vancouver Island (probably at Rocky Point, 48.31°N, 123.56°W). It will scan over the Hurricane Ridge OLYMPEX ground site to provide radar coverage on the leeside of the Olympic Mountains that will complement the windward side coverage by NPOL and WSR-88D. The 50DX will be deployed together with an X-band Precipitation Occurrence Sensor System (POSS) bistatic radar. The POSS provides information on surface precipitation intensity and its associated microphysical characteristics. The Environment Canada operation will take place from 1 November – 22 December and from 3–17 January 2016.

6.3 Ka- and Ku-band radars

The NASA D3R radar systems have wavelengths in the Ku and Ka ranges, similar to the radars on GPM. The Ku frequency is 13.91 GHz (wavelength 2.16 cm); the Ka frequency is 35.56 GHz (wavelength 8.43 mm). Both radars are dual polarimetric. At Ku (Ka) the peak power is 200 W (40 W), and the beam width is 1°. The goal of the D3R deployment is to provide ground-based measurements that determine what the GPM radars may or may not be missing in midlatitude winter storms. This radar system will be located near NPOL and will be operated in a scanning mode that is compatible with NPOL. This scanning will consist of RHIs with elevation angles running from 0 to 90° in sectors both to the west (toward the ocean) and east (toward the Quinault Valley). These RHIs will be interspersed with a few low-level PPI tilts (which will be especially useful in determining the light rain measurements favored by the higher frequencies of the radar). This scanning will be done on the same 20 min schedule as the NPOL scanning. The D3R operation will coincide with the NPOL operation: 1 November – 22 December and 3–17 January 2016.

6.4 K-band Micro Rain Radars

OLYMPEX will deploy four vertically pointing Micro Rain Radars (MRRs) at the sites indicated in Figure 14. Three sites will document the vertical structure of the precipitating clouds on the windward side of the Olympic Mountains. These sites will be within the region of Quinault River sector scans of NPOL at three different distances from NPOL. These sites are at the Quinault Fish Hatchery, which is west of Lake Quinault, the CRN site, just east of Lake Quinault and a third site which could either be at Neilton Pt, the southern ridge defining

the Quinault Valley, or further east up the Quinault from the CRN site. The MRR operates as a continuous wave radar at 24 GHz, which corresponds to a wavelength of about 1.5 cm. The MRR radars will operate from 1 November 2015 through sometime in the spring of 2016.

7. Aircraft program

7.1 Time period of the aircraft program, participating aircraft and instrumentation

The OLYMPEX aircraft are the NASA DC-8 and the NASA/UND Citation. The aircraft program will run from 10 November 2015 – 22 December 2016. Table 3 lists the instruments likely to be on each aircraft. The DC-8 will function as a proxy for the satellite radar and passive microwave measurements. In addition, the DC-8 will launch dropsondes over the ocean, which will help describe the thermodynamic and wind environment of incoming storms, upstream of the ground-based rawinsonde sites (Figure 1). These soundings will also be important for evaluating the robustness of temperature and water vapor assumptions in GPM algorithms. The Citation will provide in situ microphysics. The RADEX aircraft is the NASA ER-2. From the OLYMPEX standpoint, it will also augment the satellite proxy measurements with radar and passive microwave measurements.

7.2 Basic flight modules

Flight modules are simple generic flight patterns that can be employed during the deployment of an aircraft. The geometry and details of the modules (end points, turn points, etc.) can be adjusted during flight planning or in flight by aircraft operators in consultation with the OLYMPEX Lead Scientist. It is nevertheless important to use similar flight modules from case to case so that at the end of the field phase the aircraft data will form a robust statistical sample for each of the three storm sectors (Figure 6). Here we present generic flight modules that can be used by the ER-2, DC-8, and Citation. These modules are designed such that they:

- Are suitable for any of the 3 sectors illustrated in Figure 6
- Are short enough that they can be repeated within a given aircraft deployment
- Can be executed singularly or in multi-aircraft mode
- Cover the oceanic region upstream of the Olympics, the windward side over the Quinault Valley network and the leeside Hurricane Ridge/Vancouver Island sector for storms affecting the Olympic Mountains
- Can be flown over the Chehalis watershed for storms primarily affecting that region
- Can be interspersed with a module to underfly a satellite overpass

Figures 16, 17, and 18 illustrate the generic flight modules for each of the three OLYMPEX/RADEX aircraft. Figure 16 illustrates a generic pattern for the ER-2. This pattern satisfies all of the requirements listed above. Note that this module overflies the regions covered by the primary OLYMPEX radars as shown in Figure 14, and it directly overflies the two primary radars NPOL and the EC X-band. In addition the northeast-southwest leg over NPOL overflies the surface instruments, DOW, and MRRs located in the Quinault Valley. That leg is therefore especially important. The legs over the Pacific Ocean allow for considerable sampling of thin, thick, low, and high clouds over the ocean before they are affected by the topography. The ER-2 will be at an altitude far above the tops of all clouds. Its radar and passive microwave sensors will act as a proxy for the GPM instruments. For RADEX

Table 3. Aircraft participating in OLYMPEX. Undecided instruments indicated in red.

Aircraft	Primary instruments	Measurements	Duration	Speed (kt)	PIs
DC-8	CoSMIR	Passive microwave at 50, 89, 165.5, 183.3+/-1,183.3+/-3, 183.3+/-8 GHz Cross track/conical scan, 0.7 km footprint	8-10 h	~400 above 20 kft ~380 at 10-20 kft ~250 below 10 kft	Tanelli Nesbitt Johnson
	APR2 or 3	Ku- and Ka-band radar, Doppler (0.4 m/s prec), swath ± 25°, 0.7-0.8 km footprint from 10 km altitude, sensitivity: ~0 dBZ (Ku), –17 dBZ (Ka) (also W-band, dual pol if APR-3)			
	Dropsondes	p, T, RH, wind			
	AMPR	10.7, 19.35, 37.1, 85.5 GHz			
ER-2	AMPR (radiometer)	10.7, 19.35, 37.1, 85.5 GHz; footprints 2.8, 2.8, 1.5, 0.6, respectively, at 20 km			Mace Marchand
	HIWRAP (radar)	13.91 GHz, 35.56 GHz (dual-pol. (LDR); nadir pointing), footprint ~1 km at 20 km			
	EXRAD (radar)	9.4 GHz (nadir); 9.6 GHz (scanning; 25 km swath at 20 km alt.); footprint 1.2 km at 20 km			
	CRS (radar)	94.15 GHz (nadir pointing); footprint ~0.16 km at 20 km			
	eMAS	Extended MODIS simulator, 38 spectral bands (0.4–14 μm); footprint 50 m at 20 km			
	CPL (lidar)	1064 (50 μJ), 532 (25 μJ), and 355 (50 μJ) nm; 5 kHz PRF; footprint ~ 30 m at 20 km			
Citation	King Hot Wire Probe	Liquid water, 0.02–5.0 g m^{-3}			Poellet Heymsfield McFarquhar
	CloudDroplet Probe (CDP)	Cloud droplet size distribution, 2–50 μm range			
	2D-S	Particle images, 10 μm–1280 μm			
	HVPS-3	Particle images, 150 μm–1.92 cm			
	CPI and/or CVI	Cloud particle images, several optional packages*			
	2DC	Particle images, 30–960 μm			
	Nevzorov	Total water content, 0.02 – ~1.5 g m^{-3}			
	Rosemount icing probe (RICE)	Supercooled water detection			
	CCN Counter	Aerosol concentration, >10 nm			
	TAMDAR	Backup aircraft tracking system (automated report of position, icing, turbulence)			

* Three possible options:

Option 1 – CVI, CPI, Basic Suite

The CPI (cloud particle imager) provides high resolution (2.3 um) particle images.

Issue: requires over 2000 W of power, has small sample volume, ice particle shattering problems

Impact: no Optional Probes

Option 2 – CVI, Basic Suite, Optional Probes

Impact: no CPI images; however, 2DS has 10 um resolution

Option 3 – CVI, Basic Suite, 2nd HVPS-3, Nevzorov, RICE

A second HVPS-3 would be mounted to measure horizontal cross section of precipitation particles. Retaining the Nevzorov would provide comparison with CVI for analysis of earlier campaign data.

Issue: requires 910 W of power

Impact: no 2DC, CPC, TAMDAR, or CPI

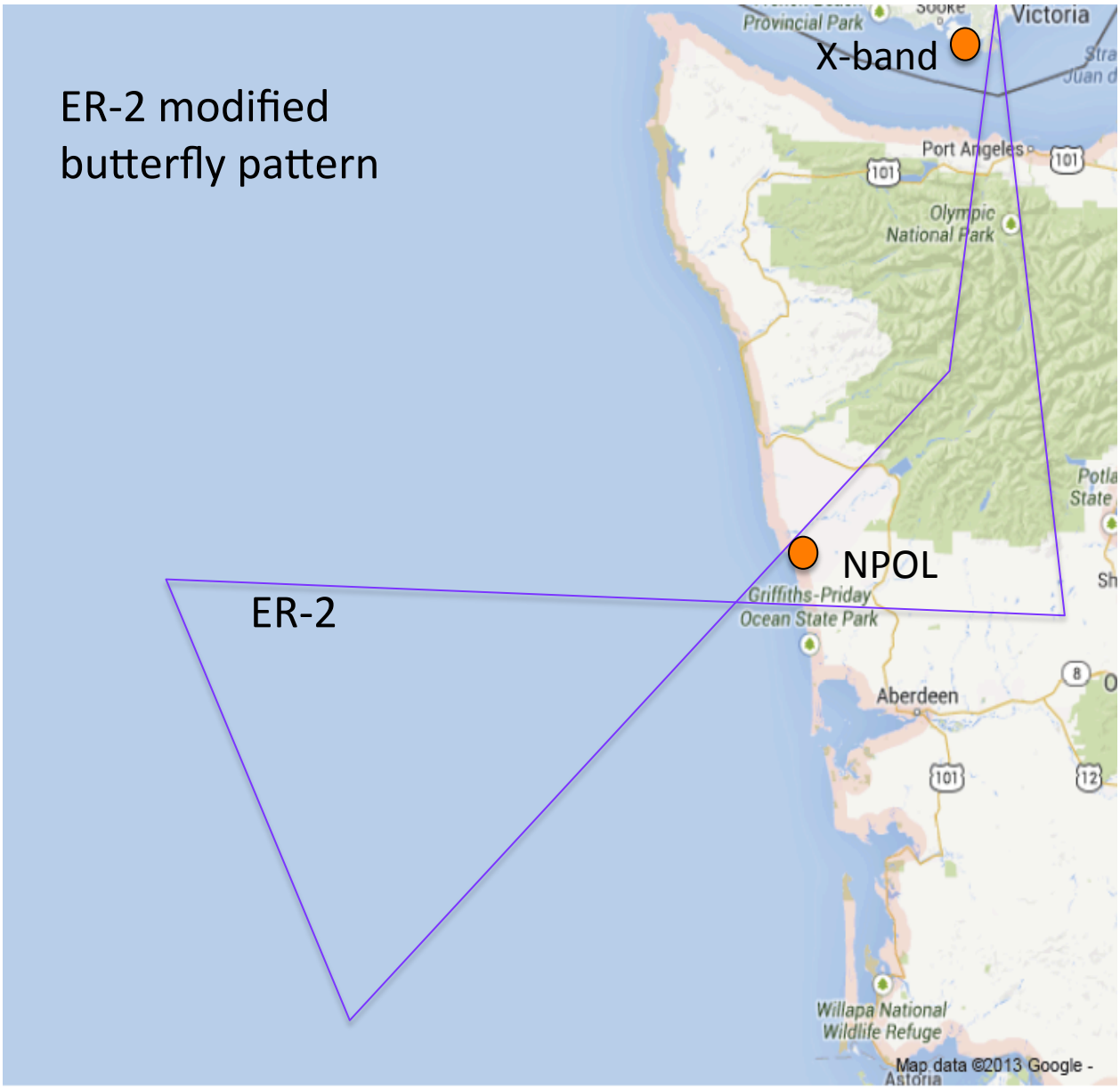

Figure 16: Generic flight module for the ER-2 aircraft

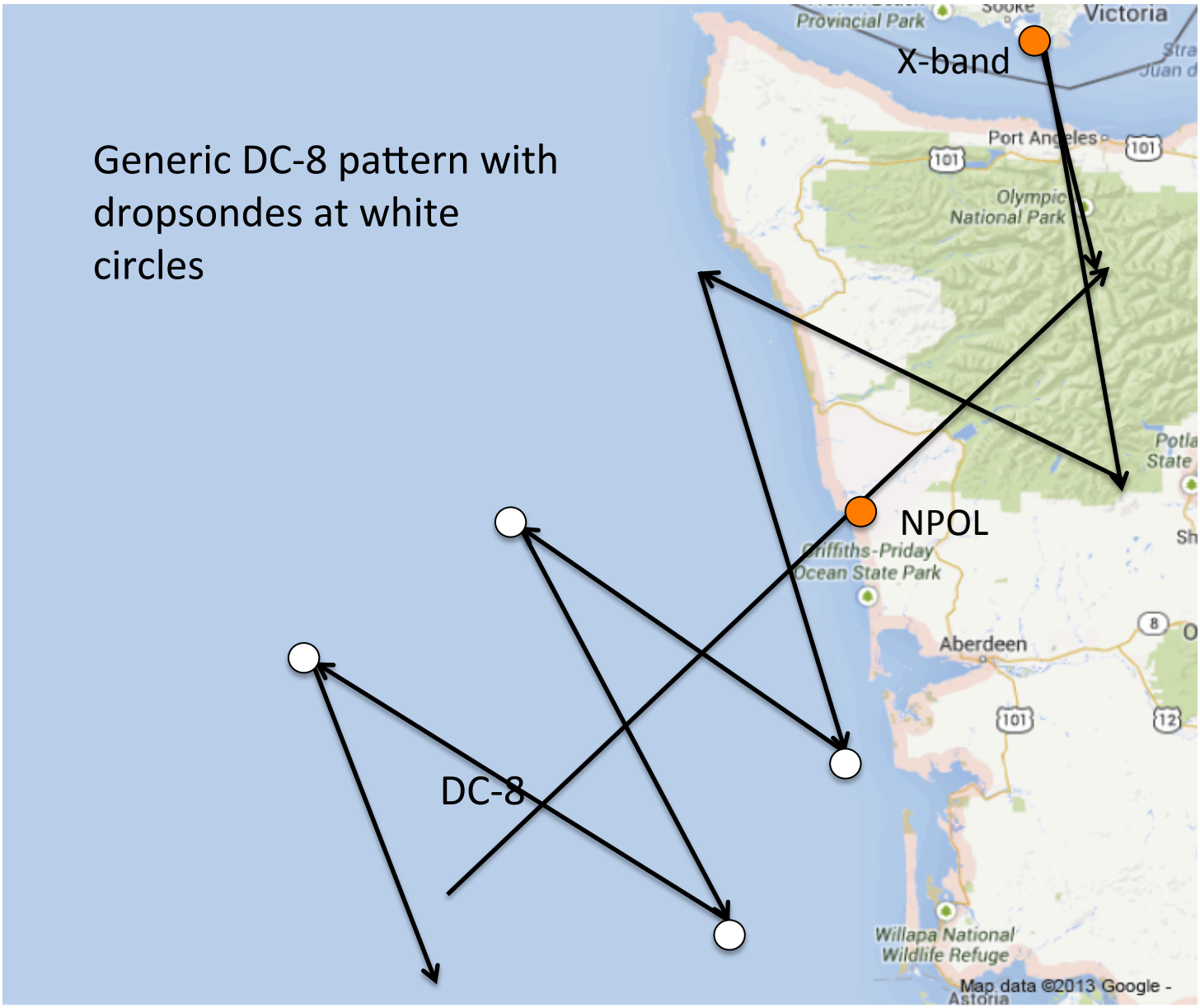

Figure 17: Generic flight module for the DC-8 aircraft.

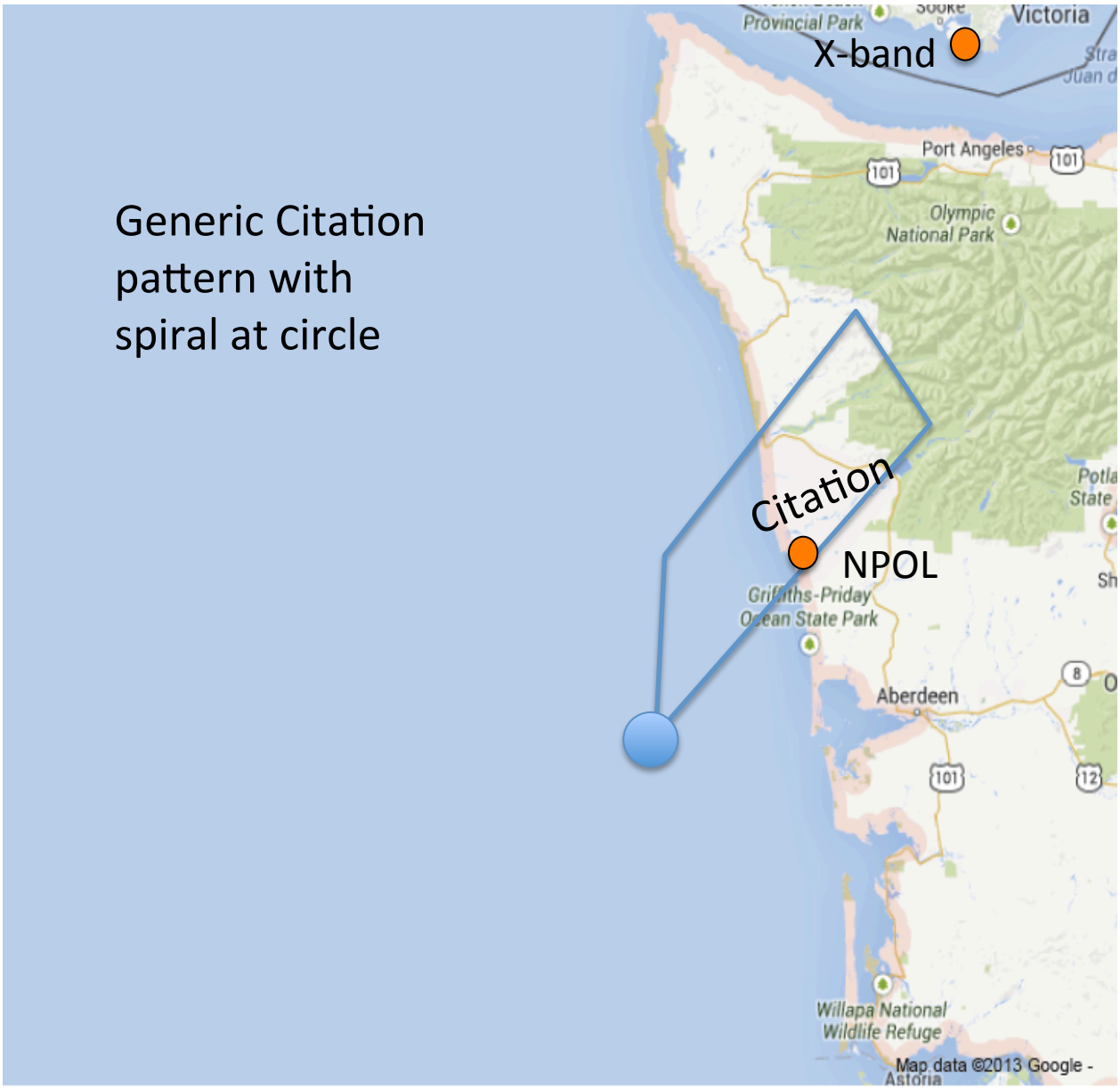

Figure 18: Generic flight module for the Citation aircraft.

objectives the ER-2 aims to sample thin and non-precipitating clouds, and the module in Figure 16 allows for such sampling in all of the sectors indicated in Figure 6.

The generic DC-8 flight module in Figure 17 covers the same region as the ER-2 module. Consistent with the ER-2 pattern, the DC-8 module overflies the areas of primary radar coverage with overpasses of NPOL and the EC X-band, the MRRs, and the surface instruments located in the Quinault Valley. The pattern also allows for dropsondes over the Pacific Ocean upstream of the Quinault Valley. The dropsondes are distributed horizontally to sample the typical storm sectors illustrated in Figure 6. The DC-8 dropsondes are necessary to sample the conditions upstream of the Olympic Mountains. They are an essential supplement of the rawinsondes to be launched over land both on the windward and lee sides of the Olympic Mountains. The locations of dropsondes in the indicated pattern is designed with the three storm sectors (Figure 6) in mind. The generic dropsonde pattern in Figure 17 will sample both sides of a front or a representative portion of a prefrontal or postfrontal regime, depending on which storm sector is present over the ocean. The DC-8 will fly at an altitude near or above cloud top to optimize the use of its radar and passive microwave sensors that will act as a proxy for the GPM instruments.

The generic flight module for the Citation aircraft is shown in Figure 18. The Citation has shorter duration (Table 3) so the module does not extend over as large a region as the ER-2 and DC-8 modules. The Citation module is a modified racetrack with one leg over the NPOL radar oriented northeast-southwest so that it overflies the ground-based instruments in the Quinault Valley. The module extends over the Pacific Ocean to sample clouds upstream of the Olympic Mountains, before they are modified by passage over the topography. The Citation's role in OLYMPEX and RADEX is to obtain in situ microphysical data on warm and cold cloud processes. It will therefore fly this module at a series of altitudes that cover a range of temperatures. Both OLYMPEX and RADEX seek microphysical information at the lowest temperatures that can be sampled by the aircraft and data on the variation of microphysical processes through the melting layer. For these reasons, some legs will be flown near the maximum altitude of the Citation, and the flight pattern will include a spiral down through the melting layer (i.e. radar bright band layer) that approximates the fall trajectory of an ice particle undergoing melting. The example in Figure 18 indicates such a spiral at the western end of the pattern, but the spiral could be placed at any location within the pattern, although it will be harder to execute to low levels over the terrain, especially since the bright band can be at very low altitudes.

Figure 19 shows how the generic flight modules for the three aircraft can be easily adapted to multi-aircraft coordinated flights. Each aircraft pattern includes a leg over the NPOL and Quinault Valley. Thus, airborne radar and passive microwave data, the ground-based radar measurements, in situ microphysical sampling, and surface rain and snow measurements will be co-located. Given the different aircraft characteristics, it is unrealistic to expect that these measurements can often be made precisely simultaneously; however, by flying these modules repeatedly and consistently throughout the duration of OLYMPEX, it will be possible to compile meaningful statistics for the prefrontal, frontal, and postfrontal storm sectors. These statistics can in turn be related to the statistics of GPM measurements of the Olympic Mountains. While individual case samples will be interesting, the statistical sample from OLYMPEX will likely be of the most value to GPM validation in the long run.

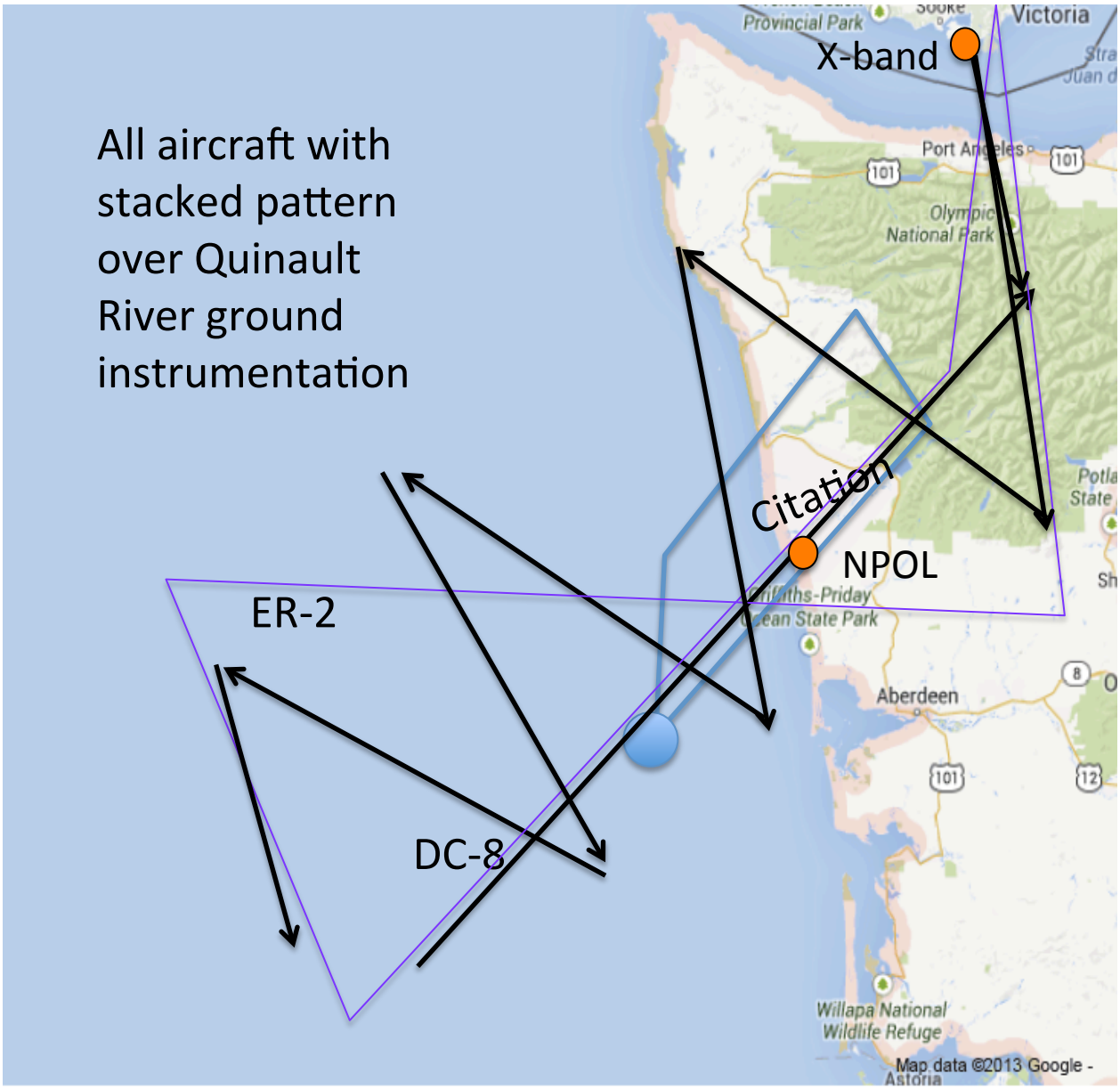

Figure 19: Generic coordinated aircraft flight modules.

7.3 Airborne and ground personnel

Each aircraft will have an Aircraft Project Manager (APM). During each sortie, the aircraft will each have a designated Airborne Mission Scientist (AMS) or pilot that will be the liaison between the aircraft operators and the OLYMPEX Lead Scientist (OLS). Daily decisions regarding flight plans (preferred modules, altitudes, spiral locations, dropsonde locations) that are made at the daily meeting (see Section 8.1) will be passed to the APM for each aircraft by the OLS. The APM will brief the AMS and aircrews, who will be responsible for executing the flight plans as closely as possible. The DC-8 and Citation will communicate during flights with the OLS via chat. The NPOL radar will have a lead scientist (NLS) who may sometimes also need to communicate with the AMS or OLS by chat. The OLS will be primarily responsible for the general concept of the mission, while the AMS and airborne crews will be responsible for the actual execution of the flights.

The actual conduct of the flights will be directed by a Flight Coordination Director (FCD) who will be located at the Operations Center (see further discussion in Section 8.2). The FCD will be the primary liaison between the OLS and the aircraft operators during flight. The FCD will communicate by chat and radio with the aircrews to coordinate the desires of the scientific leadership of the project with the practicalities of executing the mission.

8. Operations Center: Daily Meetings, Communication, Flight Coordination

8.1 Location and daily meetings

The center of operations for OLYMPEX/RADEX will be in Seattle, at the University of Washington (UW) Department of Atmospheric Sciences, where we will have excellent internet and communications capabilities, access to a full suite of current weather information, a forecast team, and real-time model runs with the UW WRF ensemble system. Daily operational decisions and monitoring of data and aircraft operations will be centered at the UW. The Department of Atmospheric Sciences will provide space for the Operations Center. The Operations Center will be the site of a daily meeting consisting of

- Weather briefing
- Project status review
- Status of all platforms and instruments
- Plans for the next 2 days for surface observations, radars, soundings, and aircraft.

OLYMPEX/RADEX will have operations distributed around the Washington and British Columbia. The NPOL and Environment Canada X-band radar operations will be located near Tahola, WA, and Victoria, BC, respectively. Sounding operations will also be conducted near these radar sites. As a result, a number of key project personnel will be at these remote sites. The aircraft will be staged from an airfield in western WA, probably Joint Base Lewis-McChord. The aircraft will be based at a location far from other operations.

Because of the distributed nature of the project, it will not be possible for all the major participants in OLYMPEX/RADEX to be housed close to a common geographical location. The daily meeting will therefore be held over the web with shared screen video and telephone audio. All project personnel will thus be able to participate in the meeting whether located at the UW or at a remote location. The decisions to be made daily include:

- When to begin and/or end serial sounding ascents and at what time intervals
- When to begin and/or end radar scanning if 24/7 operation is not employed

- When to launch aircraft on day 0, and outlooks for possible launches on days 1-2, accounting for crew rest and other factors
- Whether a GPM overpass will occur during the flight(s) and if so when and where the aircraft will breakout of other modules to underfly the overpass; the time and locations of overpasses will be known up to 7 days out.
- What type of storm modules to fly (Figures 16, 17, 18)
- Whether to coordinate aircraft and if so how

8.2 Communications and flight coordination

The Operations Center will be located in Room 627 on the 6th floor of the Atmospheric Sciences/Geophysics Building on the UW campus. Additional workspace for project personnel may be provided on the 1st floor. The daily meeting will be held in Room 627 at 10:00 am each day of the project. The meeting will be led by the OLS, who will alternate among Houze, Petersen, McMurdie, and others. When the above decisions are reached each day, the OLS will pass these decision to the sounding launch crews, the radar operators, and the aircraft crews. The aircraft decisions will be passed to the AMS for each aircraft by the OLS.

As noted in Section 7.3, an important function at the Operations Center will be that of the FCD, who will coordinate proposed operations with military and civil authorities as necessary, and during missions will maintain communication with and coordination of the aircraft in their execution of project objectives. Mission coordination/communication will be accomplished with the DC-8 and Citation via chat and with the ER-2 by radio. The web-based NASA Mission Tools Suite will be running at the Operations Center for monitoring of the aircraft flights in real time. The OLS will be responsible for monitoring the progress of flights along with the FCD and will remain in close contact with the FCD. The OLS will identify changes and/or adjustments to flights in real time and relay these desires to the FCD, who will or will not relay these to the aircraft as appropriate.

To facilitate the real time flight operations, a version of the NASA Mission Tools software will be running in real time. This web-based tool allows real time tracking of all of the aircraft whenever they are in flight.

8.3 Daily science summaries & other reports

One of the functions of the OLS will be to write a daily report of the science accomplished on that day. On active days, this report should be a narrative mini-case study of the phenomena that were observed and preliminary assessment of the insights that have been gained by the project on that day. This report should draw on all available information, from synoptic analysis, satellite, radar, and any aircraft or other observations that are available in preliminary form. (For examples of such reports see the daily reports from DYNAMO at http://www.atmos.washington.edu/~houze/DYNAMO-AMIE/)

9. Website for monitoring and cataloging project data

9.1 Website catalog

A key tool to be used both during and after the field phase is a web tool for organizing the dataset being collected, for both immediate quick-look viewing of the data and for linking to permanent archives. This website will be located at http://olympex.atmos.washington.edu/. It is viewable in preliminary form and will be fully developed by the time of the field phase. The website being developed by Stacy Brodzik uses features similar to the highly successful

NCAR/EOL/ data catalog websites, which are developed for every major NSF deployment. The website will provides project personnel with quick links to accumulated

- Operational products: satellite imagery, upper air soundings, surface and upper air maps, operational radar data imagery, SNOTEL data, raingauge data
- Model products: initial analyses and forecasts from the UW and other real-time systems
- Research products: images from the OLYMPEX radars (basic fields and derived products), plots of rain gauge and SNOTEL data, plots of aircraft data when provided
- Flight tracks: A record of the flight track of each aircraft for each aircraft mission.
- Reports: Daily full science summary by the OLS, daily reports from each radar site and from the overseer of ground observations, reports of the AMS for each aircraft flight. There will be a method for submitting these reports and publishing them on the website.

This website catalog will be a key tool for the daily monitoring of project. Note that it will provide not only current information, but it will accumulate the above information over the time period of the whole project. After the project information that can only be recorded on site or that must undergo certain data processing or quality control can be added to the website to make the project quick-look data readily available for on-demand viewing at any time during or after the field phase. This web catalog will be extremely useful for compiling the daily reports, especially the daily science summary by the OLS. It will also be a ready reference for working with the OLYMPEX dataset in the future.

9.2 Data flow from instruments to Operations Center

Another feature of the website catalog will be linkage to project datasets. The data collected by all the OLYMPEX instruments will be recorded at the site of the instrument (on the ground or on aircraft). Some datasets will be transmitted in real time to the Operations Center to support the website catalog, which will be the primary tool for real time monitoring of the field operations, as described above. Specifically data from NPOL, D3R, MRRs, and ground sites will be transmitted to the Operations Center to the extent possible. These transmitted data will be recorded at the Operations Center, where they will be processed for inclusion in image form on the website catalog.

Data recorded on site at the radars and ground sites will be delivered to the Operations Center. It is as yet undetermined how this delivery will occur—via internet or hand carried. These datasets will then be stored either at the UW or on a NASA archive server as appropriate. The website catalog will have password protected links to these datasets. As datasets become quality controlled after the project these datasets will be updated with new versions. Release of datasets will be determined by the GPM Ground Validation office.