Precipitation Processes in Cyclones Passing over a Coastal Mountain Range: Recent Results from OLYMPEX

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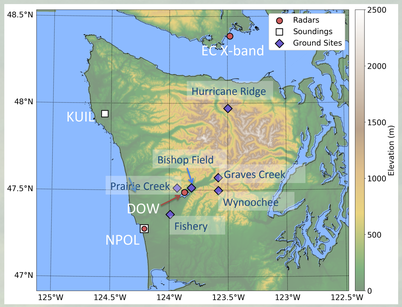
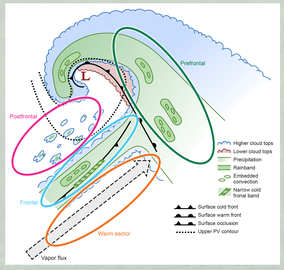
OLYMPEX - Goals

- Physical validation and verification of precipitation measurements by the GPM satellite
- Measure precipitation processes and their modulation by synoptic conditions and complex terrain



Field Campaign Overview

- OLYMPEX regions included ocean, windward and leeward side of the Olympic Mountains and the Quinault and Chehalis river basins
- **Radars**: S-Band (NPOL) and Ka- Ku-Band (D3R) X-band (DOW, EC-Xband)
- **Ground Network:** Parsivels, dual-tipping buckets, Pluvios, MRRs, Soundings
- **Aircraft:** DC-8 , ER-2 with satellite simulating instruments, Citation with microphysics
- **Snow Measurement:** SNOTEL and snow cameras, 2 lidar flights, PIP disdrometer at Hurricane Ridge.



Storm Sectors

Prefrontal

- Warm advection
- Stable
- Low-level SE flow
- IVT variable (can be high)
- Increasing melting level height

Warm Sector

- No advection
- Neutral stablity
- Low-level SW flow
- IVT High
- High melting level height

Cold Sector

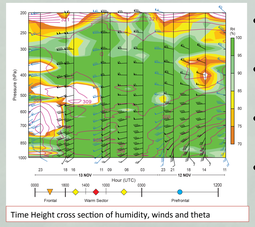
- Cold advection
- Unstable
- Low-level W or NW flow
- IVT Low
- Low melting level height

Frontal

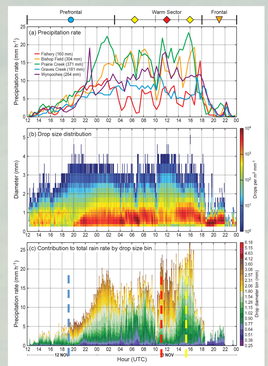
- Cold front passage
- Can have embedded convection along the front (NCFR)
- Abrupt changes in environmental conditions

12—13 November 2015 Atmospheric River Event

Ground Network – Disdrometer and Gauge Results

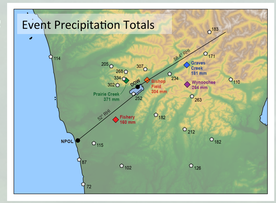


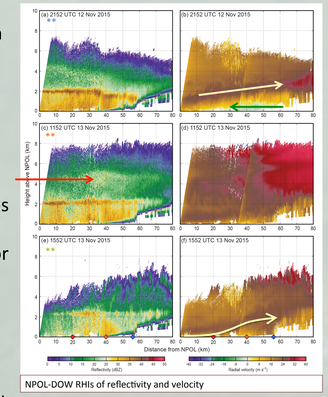
Time Height cross section of humidity, winds and theta



Vertical dashed lines correspond to the times of the 3 RHIs to the right →

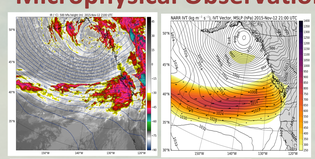
- Precipitation totals demonstrate extreme orographic enhancement
- Almost 4 times the precipitation on windward slopes compared to coast
- Windward slopes more precip than high terrain site
- Prefrontal period with low level veering winds, deep clouds
  - During prefrontal period all stations experience similar rain rates and there is weak down valley flow (green arrow)
  - As warm front approaches big ramp up of precipitation rates especially Prairie Creek
  - Increase of precipitation at Prairie Creek due to small drops
  - Small drops contribute to ~1/2 of total rain rate in warm sector due to lifting of low level jet
  - Secondary enhancement aloft during middle RHI period with large drops due to mesoscale feature aloft (red arrow)
  - Warm rain processes important



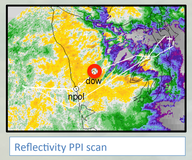


NPOL-DOW RHIs of reflectivity and velocity

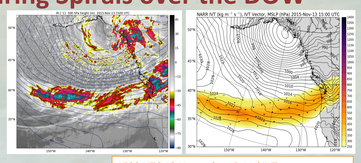
Microphysical Observations from Aircraft during Spirals over the DOW



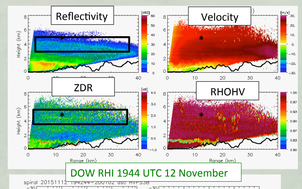
2100 UTC 12 November IR and IVT Prefrontal Period



Reflectivity PPI scan



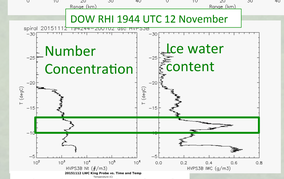
1500 UTC 13 November IR and IVT Warm Sector Period

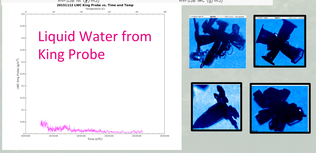


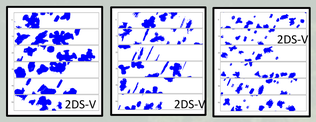
DOW RHI 1944 UTC 12 November

(← left) Prefrontal

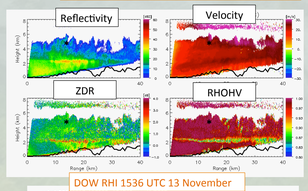
- Secondary enhancement aloft in reflectivity and ZDR
- Increase in number concentration and ice water content in region of upper-level reflectivity enhancement (green box)
- Low liquid water content
- Bullet rosettes, some aggregation, dendrites







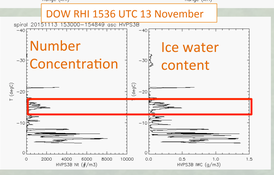
-9°C (4km) -17°C (5km) -26°C (6km)

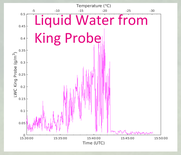


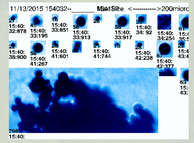
DOW RHI 1536 UTC 13 November

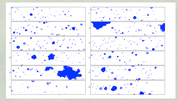
Warm Sector (right →)

- Generating cells in DOW RHIs
- Moderate number concentration and ice water content at Citation altitude (red box)
- High liquid water content at altitudes well above the melting level
- Lots of super-cooled water drops and rimed particles





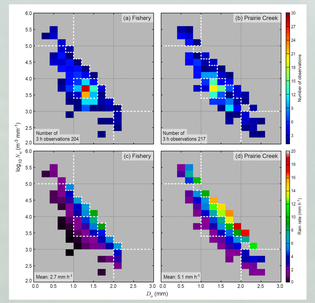




2DS-V 13 November

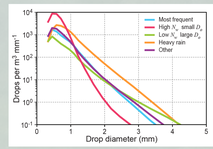
Surface Precipitation Characteristics – DSDs

Stratiform Precipitation



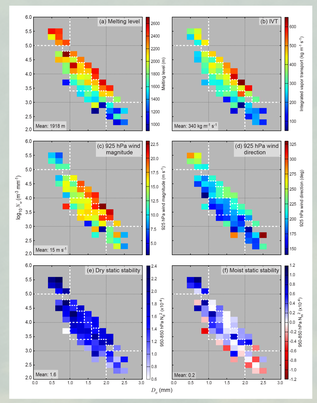
Four DSD regimes from Parsivel observations

- Most frequently occurring: Moderate N_w and D_o
- High concentrations of small drops, high N_w and small D_o
- Low concentrations of big drops, low N_w and large D_o
- Heaviest rain: High N_w and large D_o
- Fishery exhibits less variability in DSD than Prairie Creek



Overall DSDs at Prairie Creek (left)

- The high concentrations of small drops has a much different distributions than the others
- Heavy rain regime exhibits more drops of all sizes

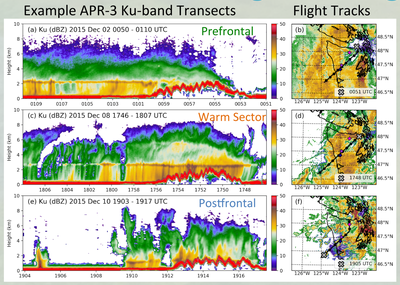


DSD variability with environmental conditions

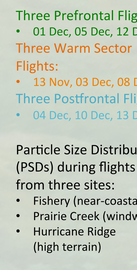
- The most frequently occurring regime has average melting level, average IVT, moderate low-level winds, generally from SW and mostly stable conditions
- The high concentrations of small drops regime has high melting level, moderate to low IVT, weak low-level winds from various directions.
- The low concentrations of big drops regime has low melting level, low IVT, winds with variety of strengths from generally westerly direction and unstable conditions
- The heavy rain regime has high melting level, high IVT, strong low-level winds from the SW and near-neutral stability

Surface DSDs during APR-3 Flights

Example APR-3 Ku-band Transects



Flight Tracks



Data description:

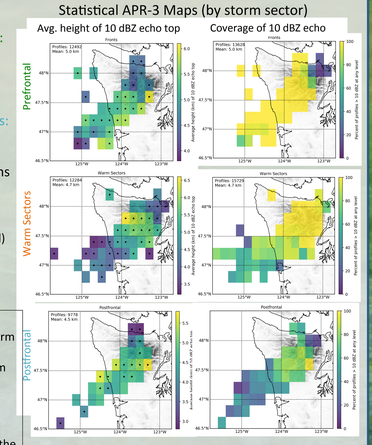
Three Prefrontal Flights:
- 01 Dec, 05 Dec, 12 Dec

Three Warm Sector Flights:
- 13 Nov, 03 Dec, 08 Dec

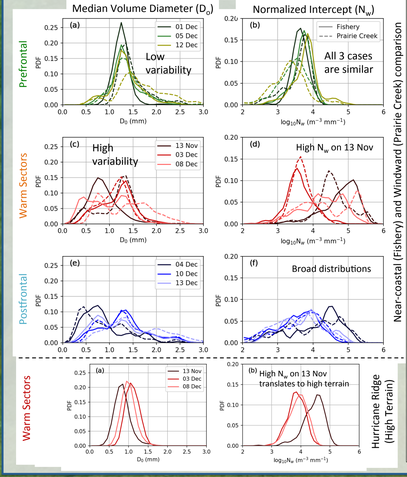
Three Postfrontal Flights:
- 04 Dec, 10 Dec, 13 Dec

Particle Size Distributions (PSDs) during flights from three sites:
- Fishery (near-coastal)
- Prairie Creek (windward)
- Hurricane Ridge (high terrain)

Statistical APR-3 Maps (by storm sector)



Rain PSDs by Storm Sector and Case



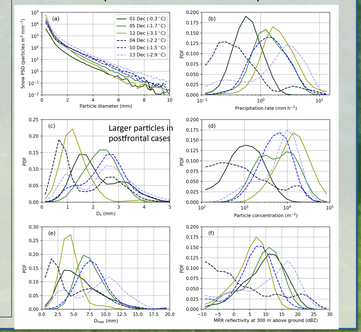
Results:

Prefrontal
- PSDs are narrow and uniform on the windward side, suggesting broad stratiform precip.
- The high terrain is more variable but with large numbers of small particles advected downwind from the deeper echoes on the windward side.

Warm sectors
- PSDs different at all three locations.
- Variability is high at the coast/windward sites due to sensitivity to low-level wind direction.
- High terrain less sensitive to wind direction
- N_W was consistently high on 13 Nov at all three sites.

Postfrontal
- PSDs are the most variable
- The precipitation is more widespread and stratiform-like over high terrain
- Heavier precipitation containing large particles (likely aggregates).

Hurricane Ridge Snow PSDs (Prefrontal & Postfrontal)



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See Houze et al., 2017, BAMS and Zagrodnik et al., 2018, JAS, Barnes et al. 2018, JAS and McMurdie et al. 2018, JGR for more information.