Modification of Precipitation Processes by Complex Terrain: What are we learning from The Olympic Mountains Experiment: **OLYMPEX**

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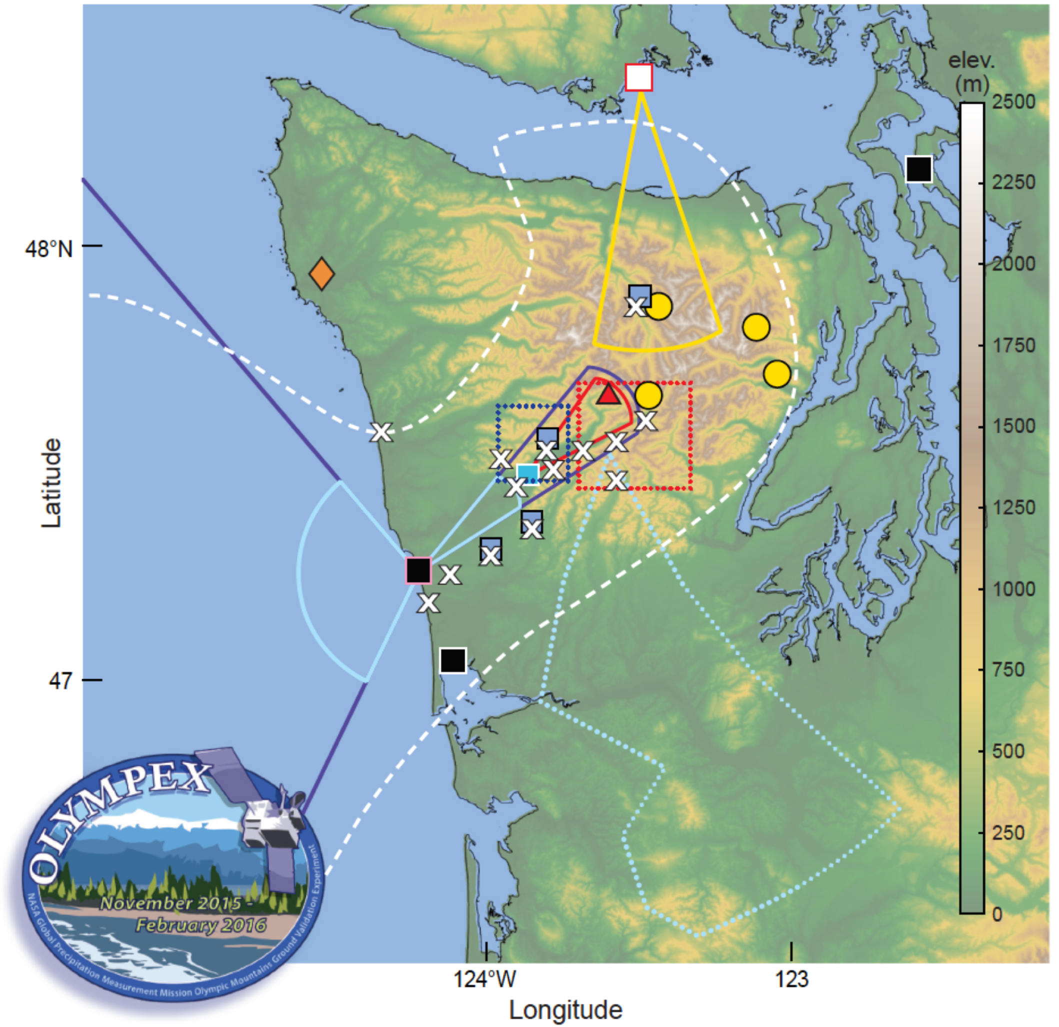


OLYMPEX

Observed landfalling winter midlatitude cyclones

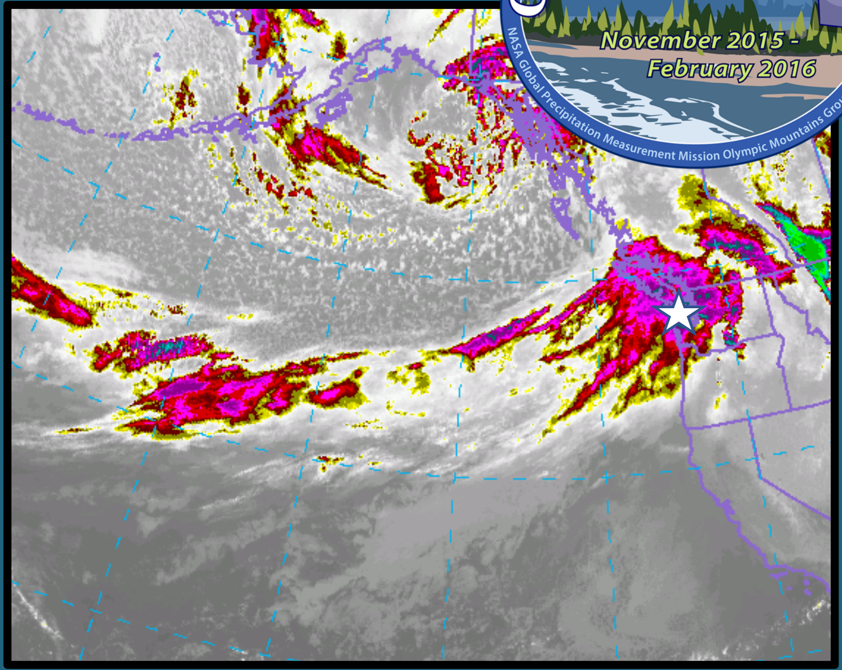
Observational Strategy 2015-2016

- **Ground network** of disdrometers, gauges, snow cameras (season)
- **Multiple ground radars** on coast, in Quinault river valley, leeside (Nov – Jan)
- **3 aircraft** – in situ and remote sensing (Nov – Dec)
- **Soundings** on coast and Vancouver Island (Nov – Dec)

The OLYMPEX Field Campaign

OLYMPEX
November 2015 - February 2016
NASA Global Precipitation Measurement Mission Olympic Mountains Ground Validation Experiment

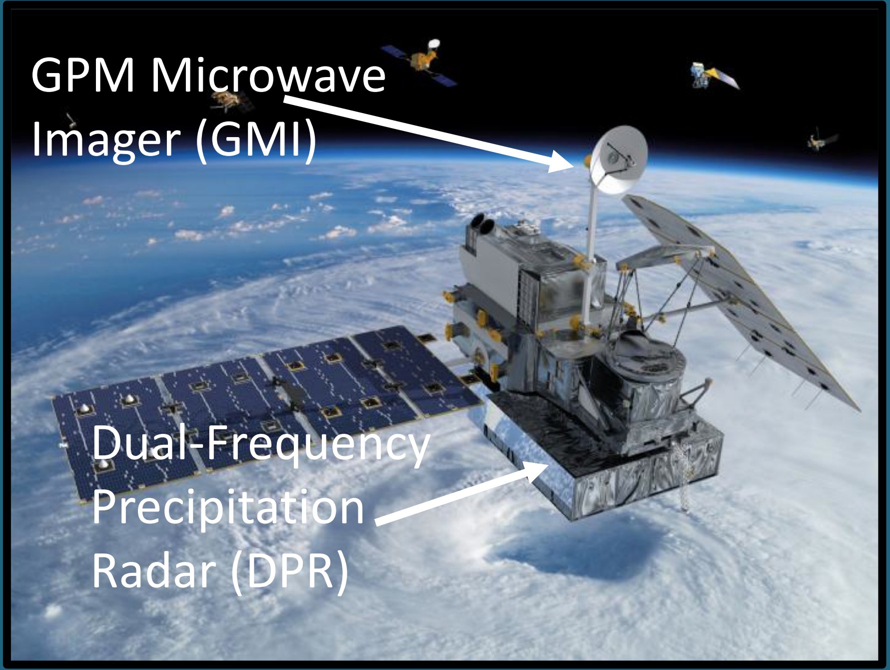
OLYMPEX goal: Physical validation of precipitation algorithms for GPM



OLYMPEX goal: Measure the modification of precipitation processes by complex terrain

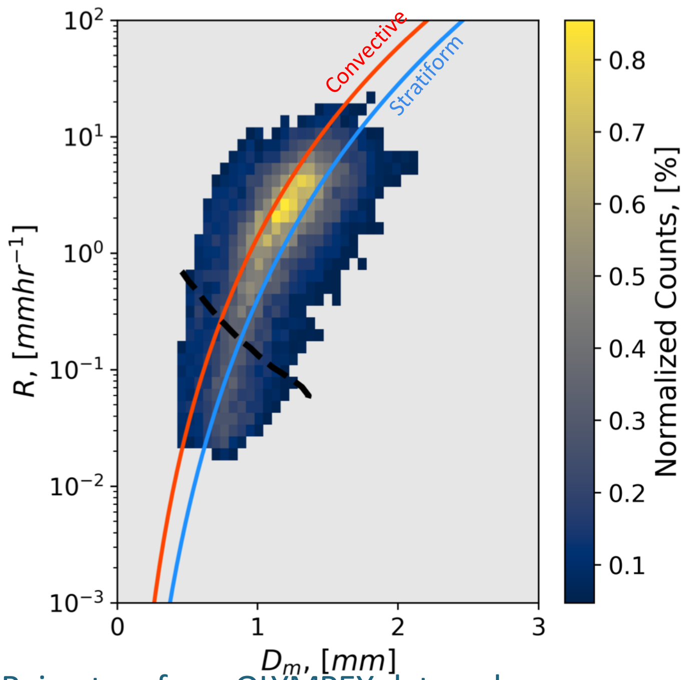
Goal this presentation: **Current status towards achieving these goals**

The Global Precipitation Measurement (GPM) Core Satellite

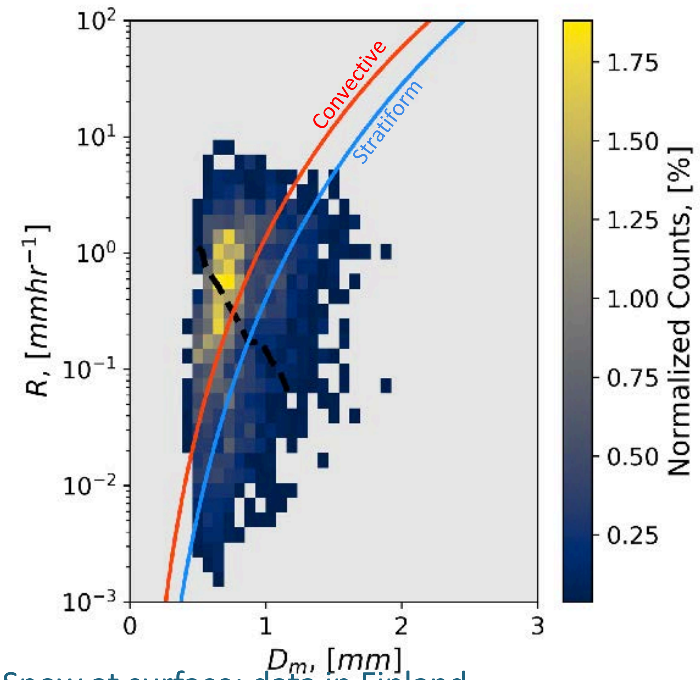


- Rain and Snow retrievals rely on assumptions about the particle size, mass and fall speed of precipitation particles
- OLYMPEX measured these quantities so these assumptions can be validated or corrected
- New methods are being developed to leverage the dual-frequency capabilities of DPR to retrieval additional microphysical quantities

Physical validation of GPM precipitation algorithms



Rain at surface: OLYMPEX data only



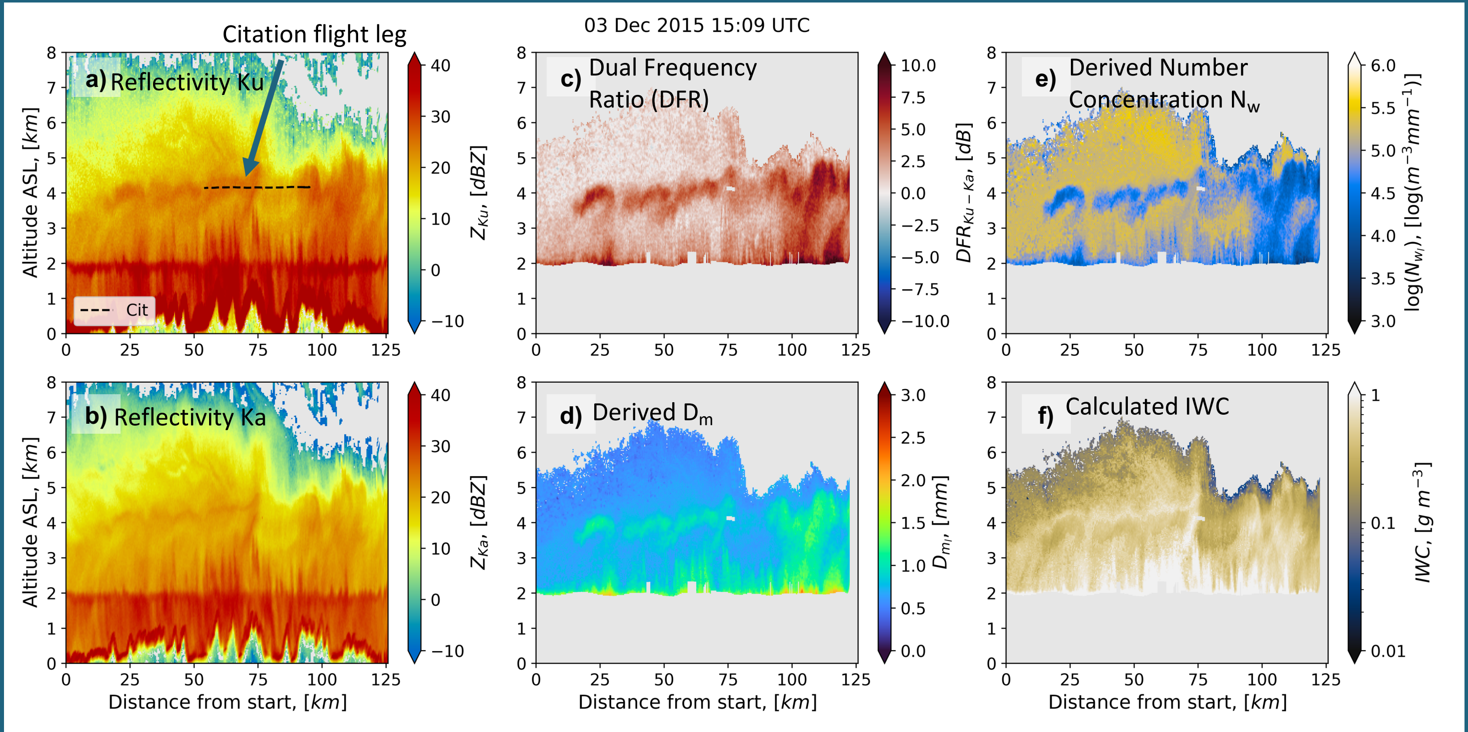
Snow at surface: data in Finland

R – D_m relationship currently used for GPM algorithms works well for rain, but not for snow

Relationship between precipitation rate (R) and mass weighted mean diameter (D_m) using data collected during OLYMPEX and other field campaigns

Chase et al. 2020
And Chase 2020, personal communication

Physical validation of GPM precipitation algorithms



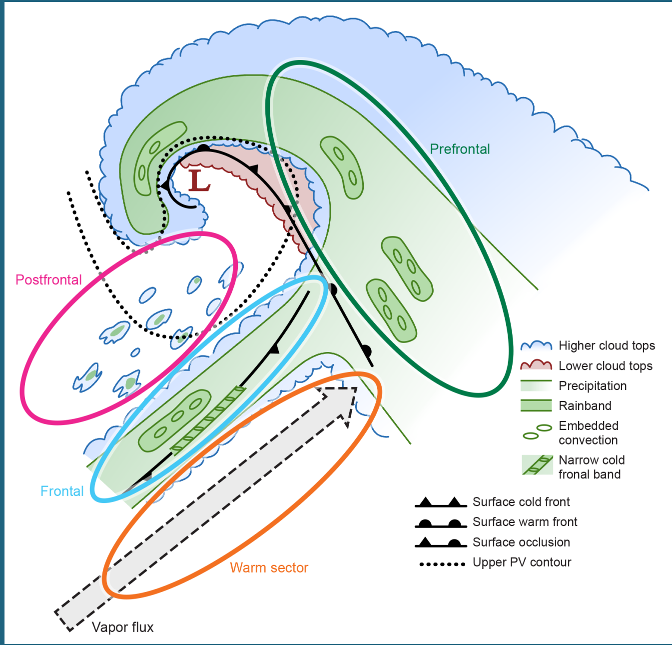
New algorithm more accurately retrieves IWC and D_m than current GPM algorithm

New Neural Network algorithm being developed using OLYMPEX data for retrieving Dm, Nw and IWC from Dual Frequency Ratio (DFR) and temperature.

Chase, Nesbitt and McFarquhar 2020, personal communication

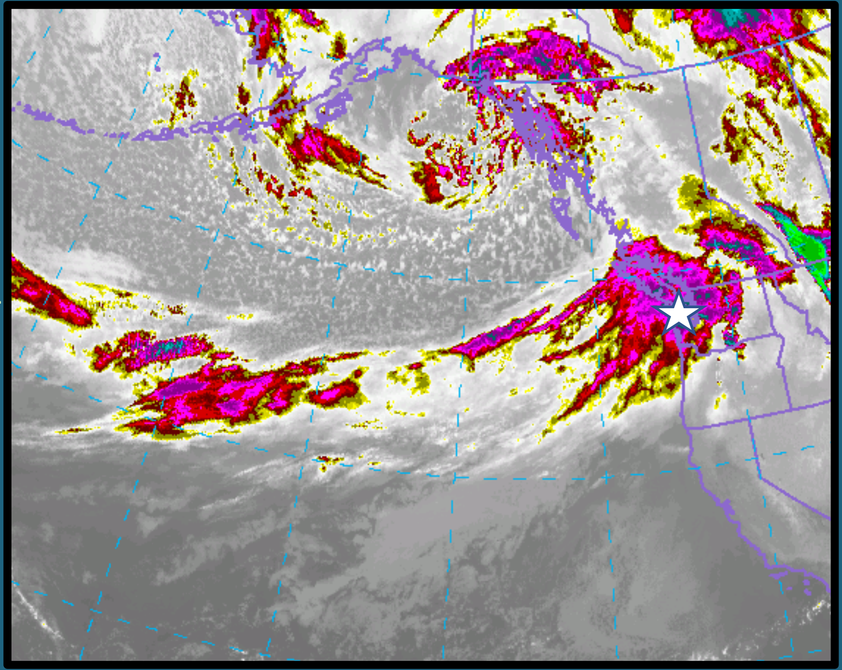
Goal 2: Modification of Precipitation by Complex Terrain

Overarching result: most pronounced modification of precipitation process occurs during environmental conditions of warm sector periods of midlatitude cyclones



Prefrontal:
Increasing IVT, ML
Stable
Veering winds (easterly at surface)

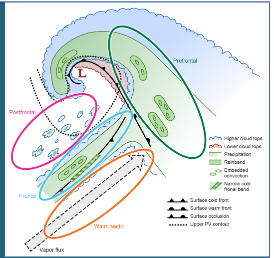
Warm Sector:
High IVT
High Melting level
Near neutral stability

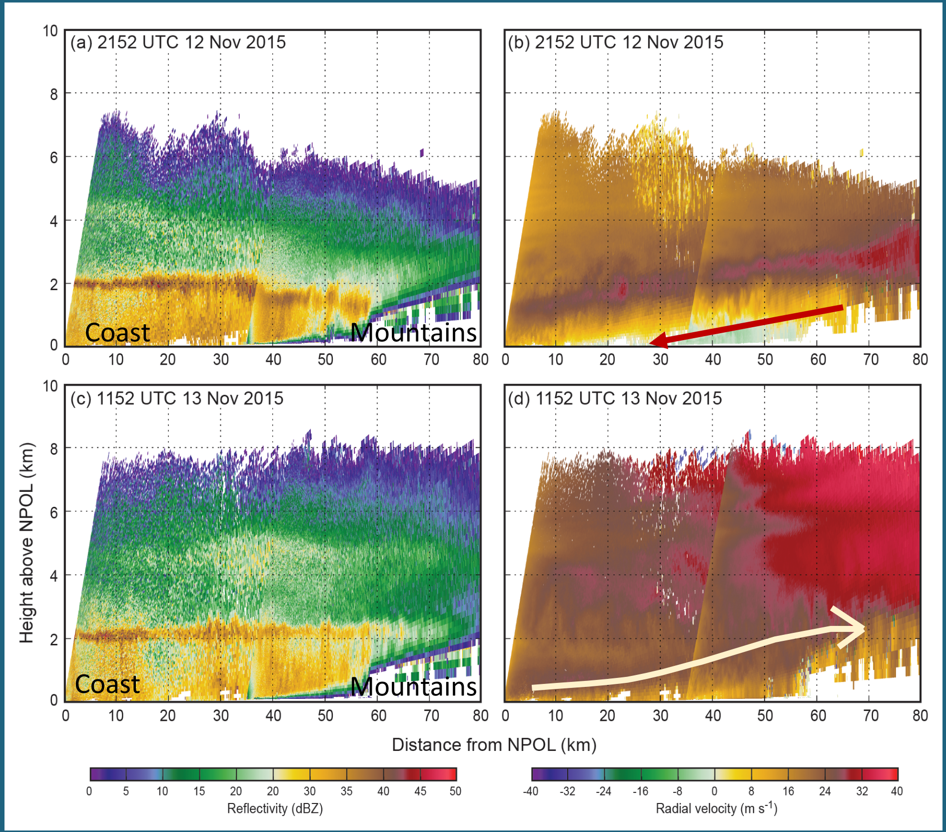


OLYMPEX goal: Measure the modification of precipitation processes by complex terrain

Figure from Houze et al. 2017 and also Zagrodnik et al. 2018

Precipitation Processes during warm sector periods of landfalling storms: Easy lifting of low level jet





Prefrontal:

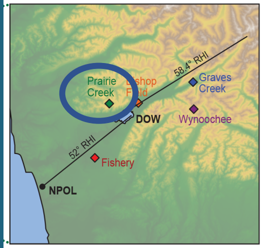
- Offshore directed low level flow and shear
- Enhanced reflectivity and precipitation maximum shifted upstream
- Precipitation amounts modest

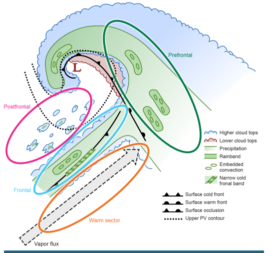
Warm Sector:

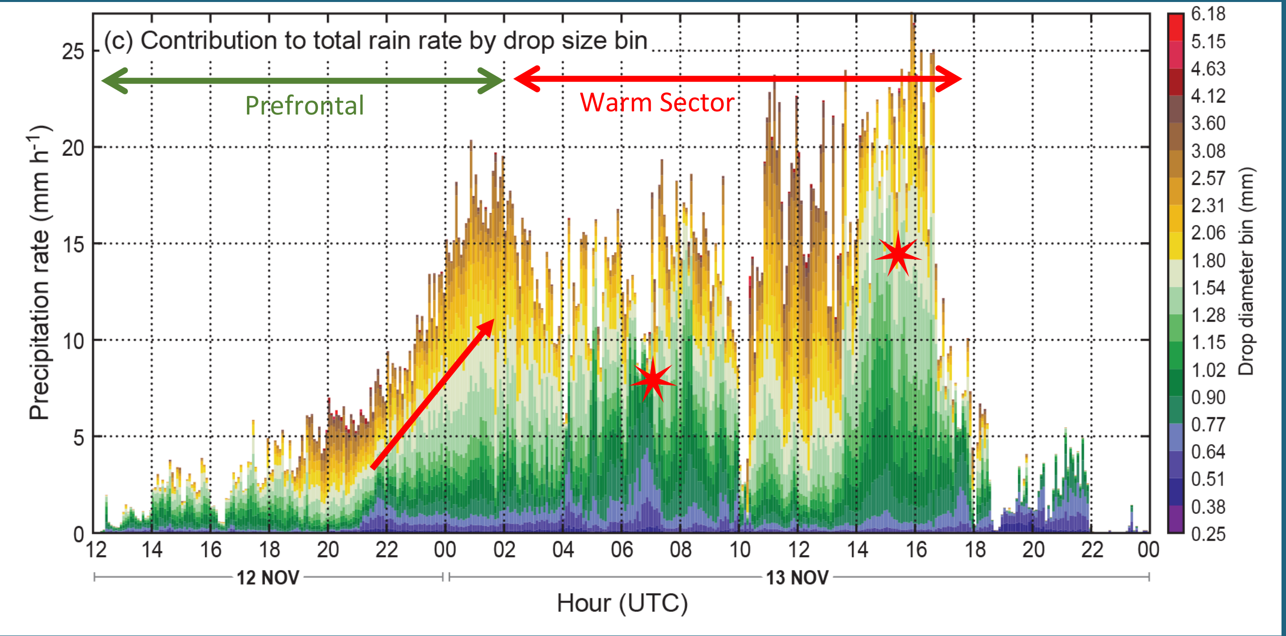
- Strong, deep onshore directed flow
- Lifting of low level jet
- Enhanced reflectivity both below the brightband in warm layer and above the brightband in ice layer
- Heavy precipitation on windward slopes

Figure from Zagrodnik et al. 2018, similar conclusions in Purnell and Kirshbaum 2018

Precipitation Processes during warm sector periods of landfalling storms: Warm rain processes important







Prefrontal:

- Rainrates modest during early prefrontal period
- During ramp-up to warm sector, increasing contribution by small drops to total rainfall

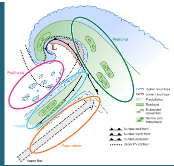
Warm Sector:

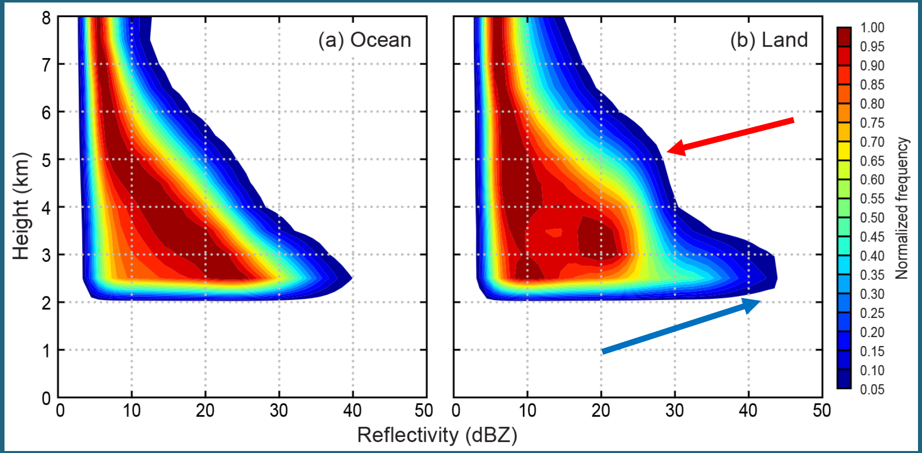
- Have several periods when contributions to total rainfall is primarily from small/medium drops ✶

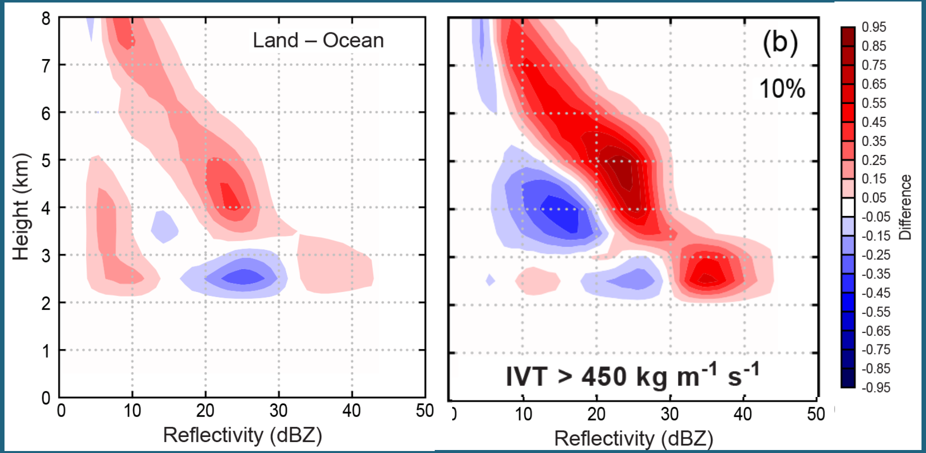
Other studies also point to importance of warm rain processes:
Conrick and Mass 2019, Naeger et al. 2020,

Figure from Zagrodnik et al. 2018

Precipitation Processes during warm sector periods of landfalling storms: Enhancement in ice layer over terrain







Contoured Frequency by Altitude Diagrams

- Normalized by level
- ALL NPOL RHIs over ocean and over land
- Show distinct enhancement over terrain
- Higher reflectivity at Bright Band (blue arrow) over land
- Higher reflectivity above Bright Band (red arrow) over land (secondary reflectivity maximum)

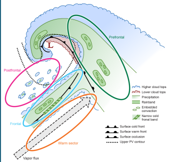
Previous talk DeLaFrance et al. examines the nature of this secondary reflectivity maximum

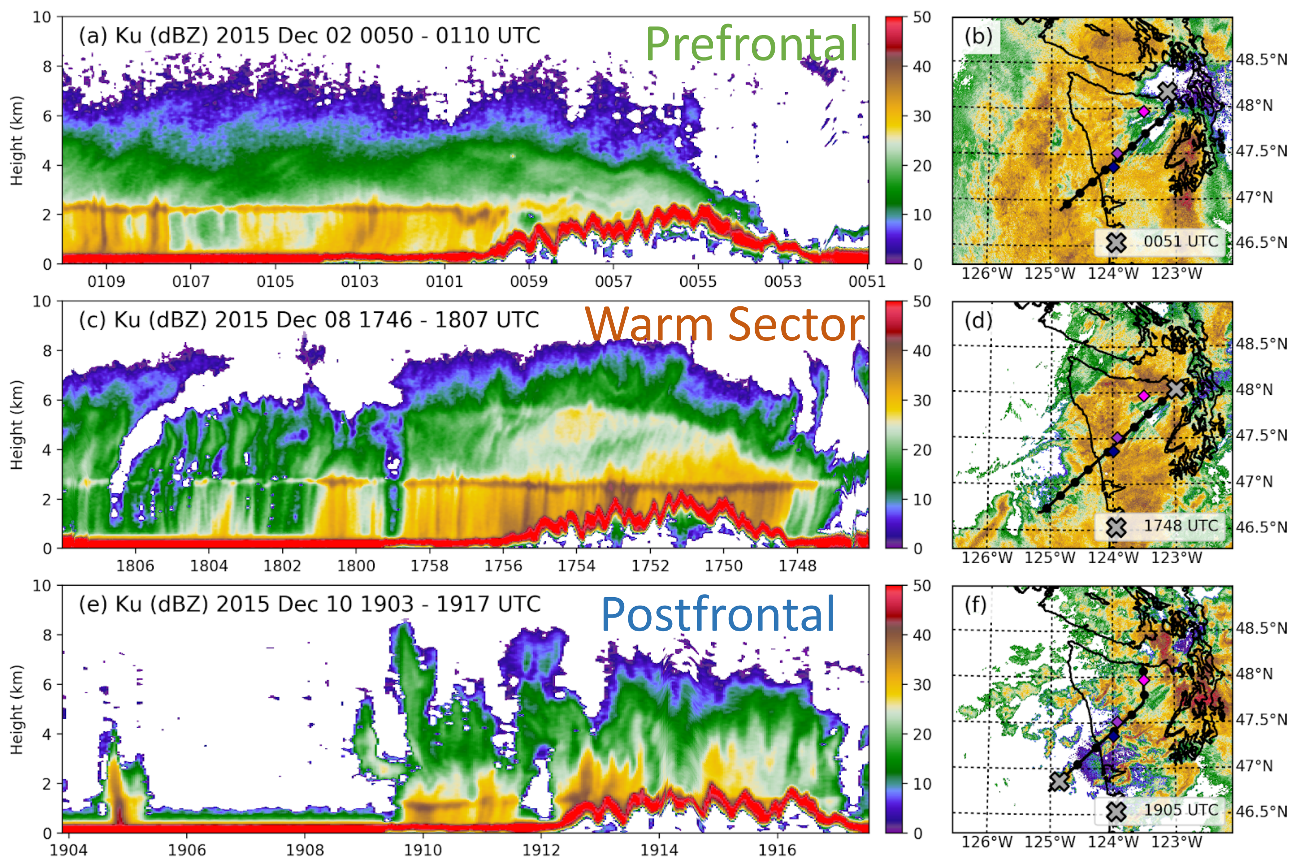
Difference CFADS

- Red = higher occurrence of that reflectivity/height bin over land
- Ocean/Land differences more pronounced under environmental conditions seen during warm sectors (IVT shown)
- High melting level, SW winds and neutral conditions similar results to IVT

Figures from McMurdie et al. 2018

Precipitation Processes during warm sector periods of landfalling storms: Ice layer enhancement, spillover to the lee side



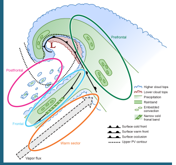


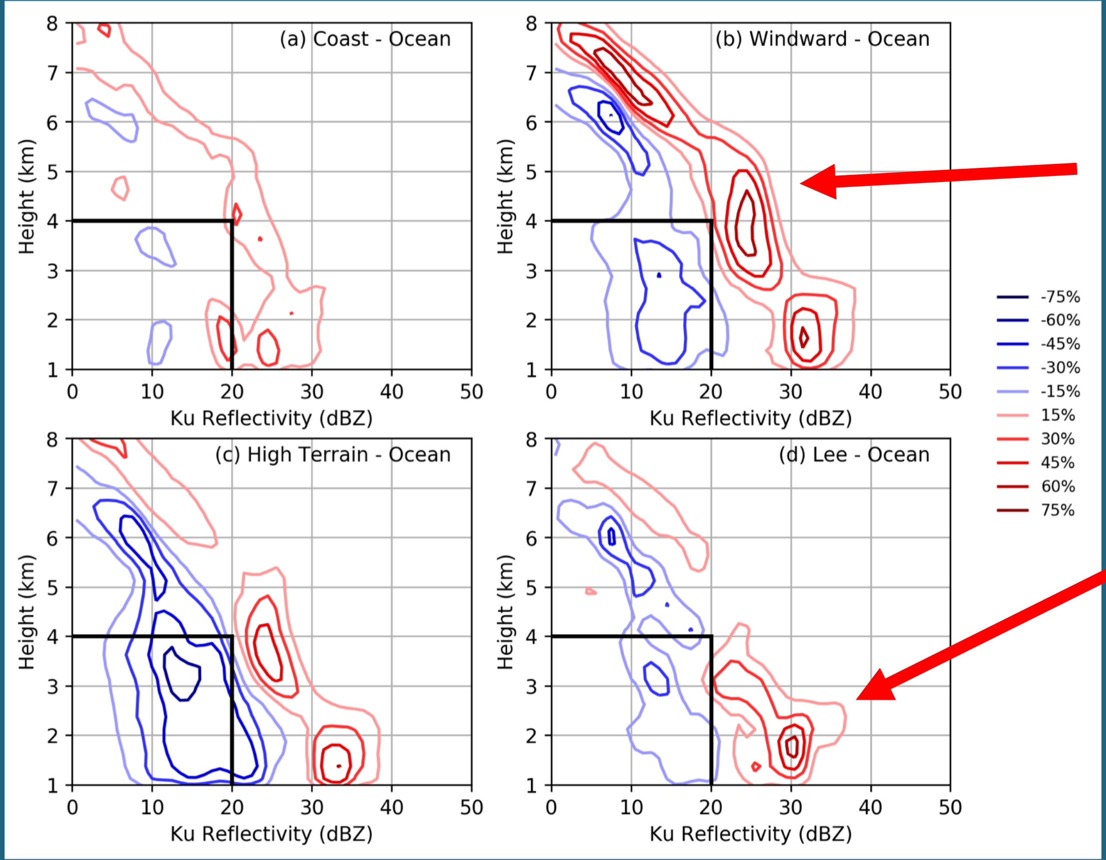
Cross sections of reflectivity (Ku) from aircraft radar (APR-3)

- Prefrontal has strongest rainshadow
- Warm sector precipitation crosses barrier
- Postfrontal showers more intense over land

Figure from Zagrodnik et al. 2019

Precipitation Processes during warm sector periods of landfalling storms: Ice layer enhancement, spillover to the lee side





Warm Sector CFAD differences (relative to the ocean)

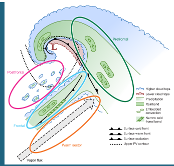
- Windward: deep enhancement over full vertical profile
- Consistent with McMurdie et al. 2018

- Lee enhancement most pronounced near/below brightband suggesting spillover

Figure from Zagrodnik et al. 2019

New study by Rowe et al. also examines leeside processes

Summary of precipitation processes and their modification by complex terrain



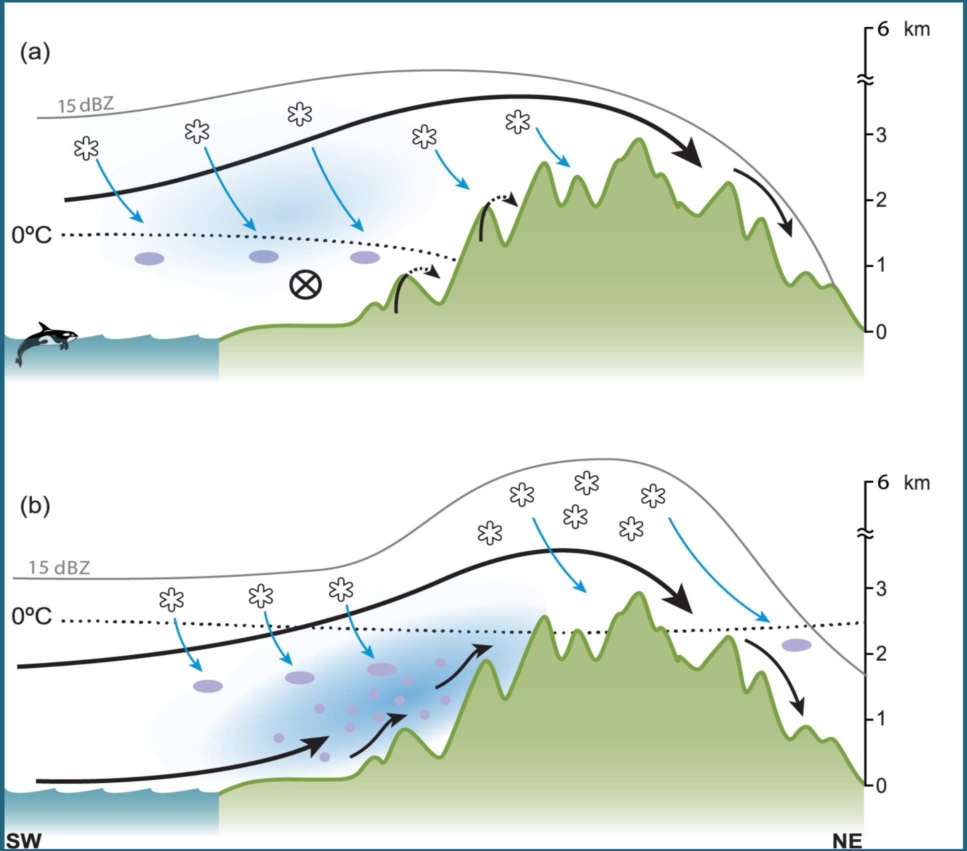


Figure in Zagrodnik et al. 2020, in review

Prefrontal

- Nearly no warm rain layer enhancement
- Ice layer enhancement upstream of terrain
- Significant rain shadow on lee side

Warm Sector

- Lower/liquid layer enhancement begins at coast and most pronounced on lower windward ridges
- Upper/ice layer enhancement directly over high terrain, spilling over to the lee side
- Enhancement is a complex mix of liquid and ice precipitation processes

The OLYMPEX Field Campaign

Highly successful field campaign and has resulted in over 30 published papers. Full list can be found at: http://olympex.atmos.washington.edu/Publications.html

✓ OLYMPEX goal: Physical validation of precipitation algorithms for GPM

Chase et al. 2018, GRL:
https://doi.org/10.1029/2018GL077997

Chase et al. 2020, ATM:
http://dx.doi.org/10.3390/atmos11060619

And Chase, personal communication

✓ OLYMPEX goal: Measure the modification of precipitation processes by complex terrain

Houze et al. 2017, BAMS:
doi:10.1175/BAMS-D-16-0182.1

Zagrodnik et al. 2018, JAS:
doi:10.1175/JAS-D-17-0168.1

McMurdie et al. 2018, JGR:
https://doi.org/10.1029/2018JD029161

Zagrodnik et al. 2019, JAS:
doi:10.1175/JAS-D-18-0279.1

Acknowledgements

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The author, Lynn McMurdie (in blue coat) accompanying the crew on a typical steadily rainy day to install a Pluvio and Parsivel deep within the Olympic National Park