Ground-based measurements of precipitation during OLYMPEX

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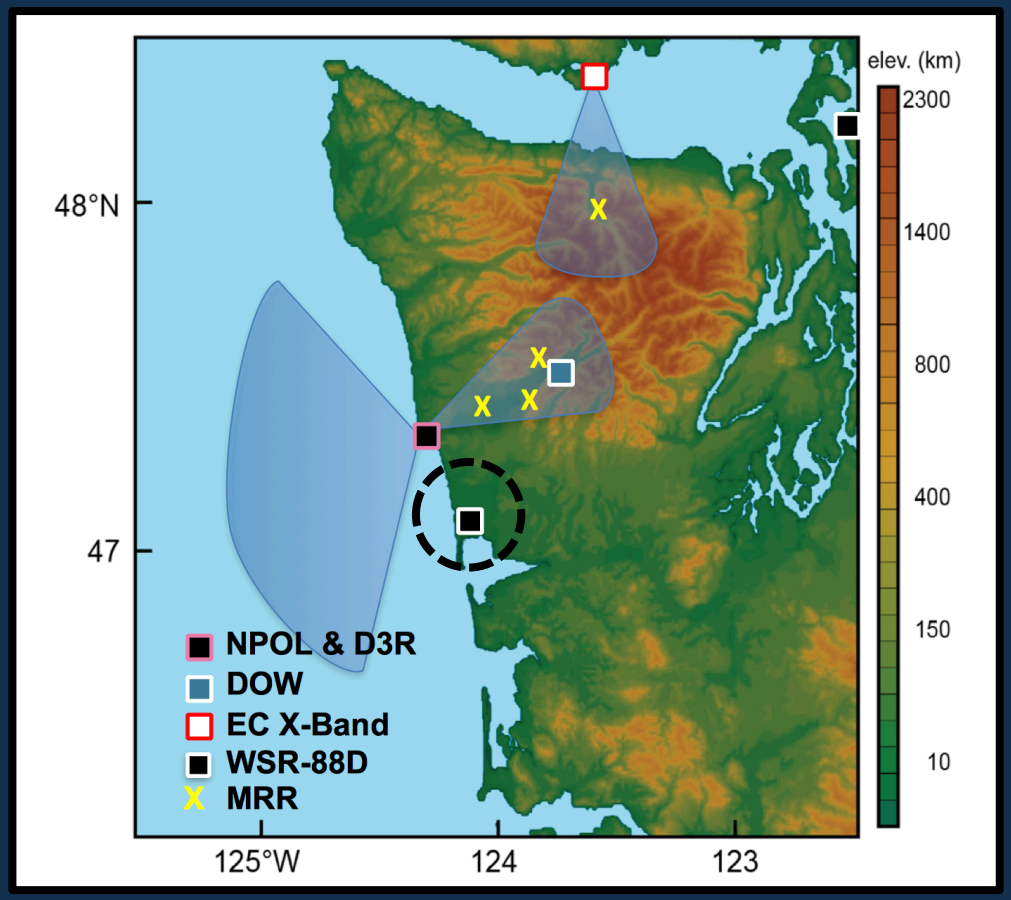
Short Course: "Validation of the Rain/Snow GPM Satellite Data in the Olympic Mountains: UW and NASA"

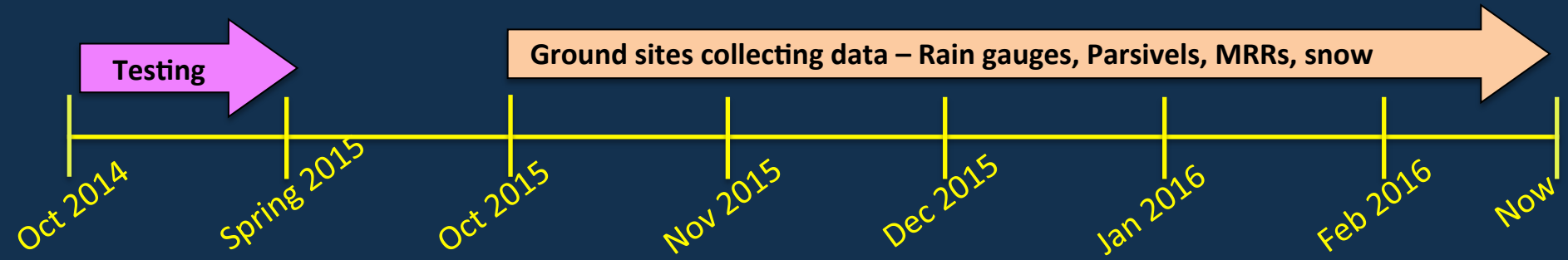
Western Snow Conference

Seattle, WA

18 April 2016

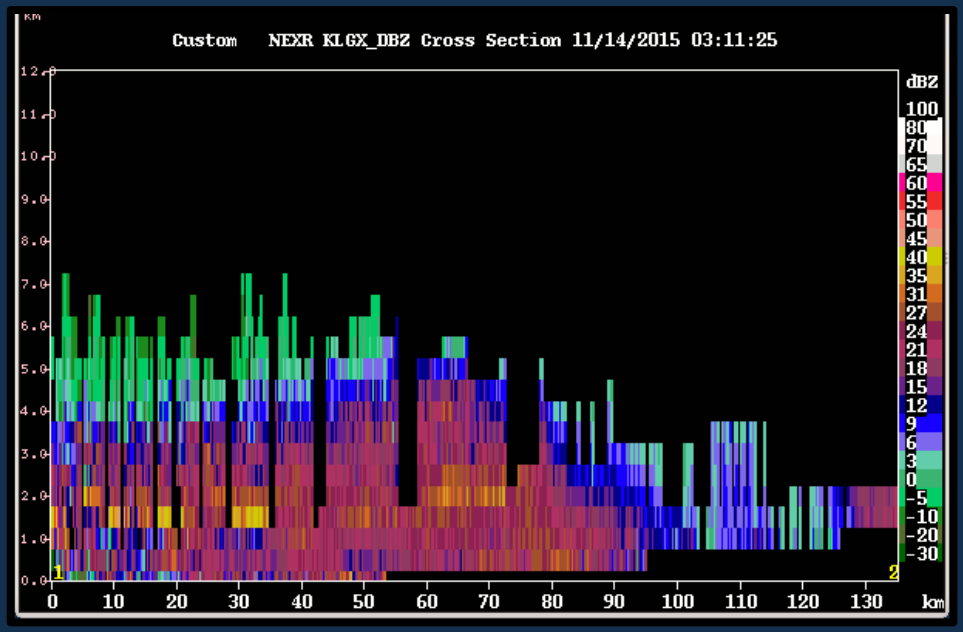
Ground-based Scanning Precipitation Radars - KLGX

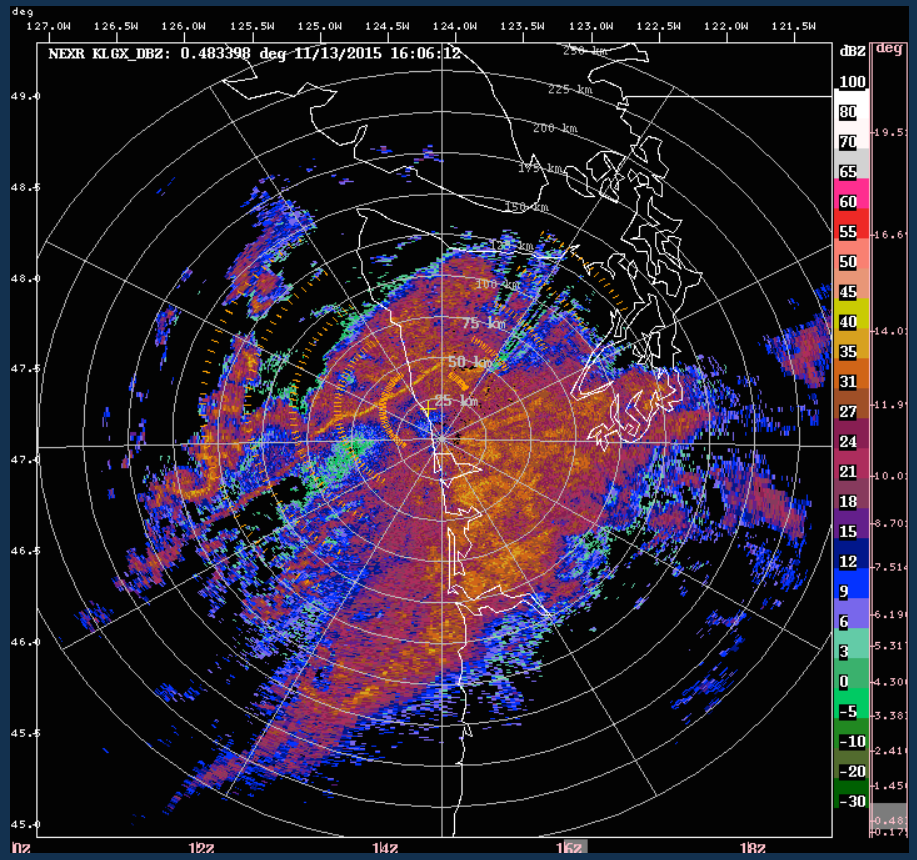




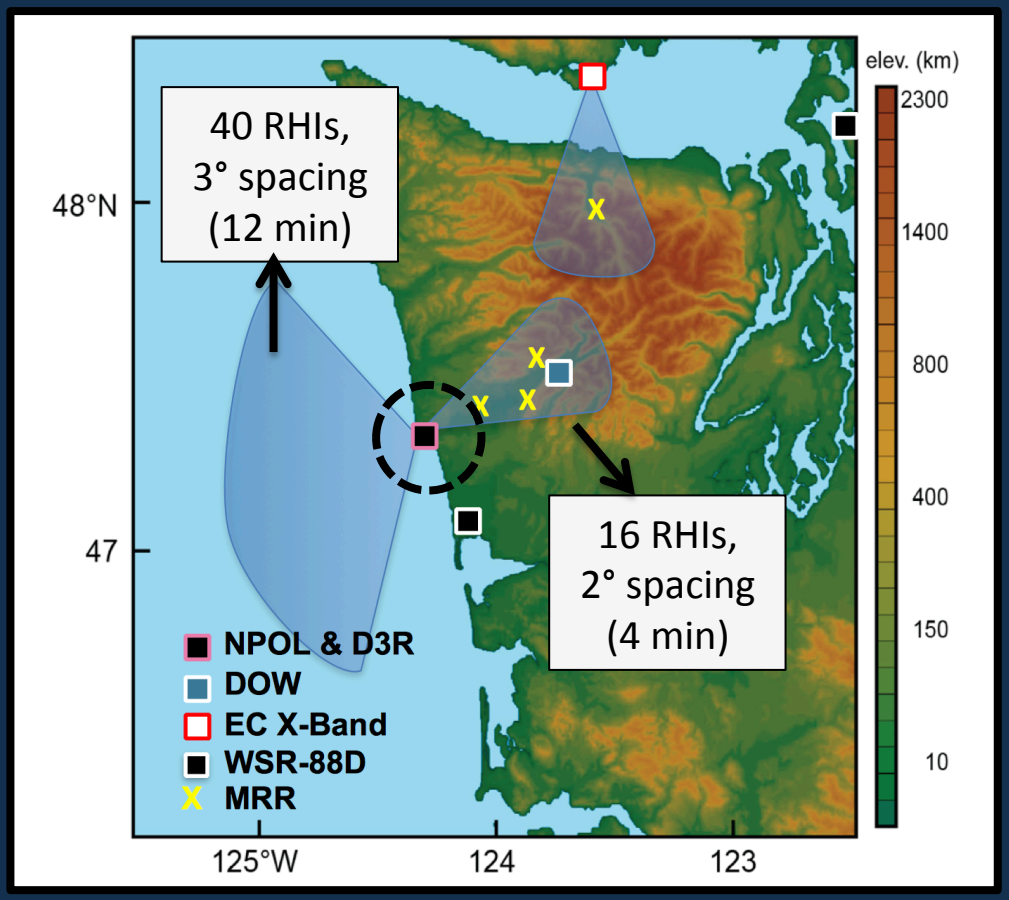
KLGX

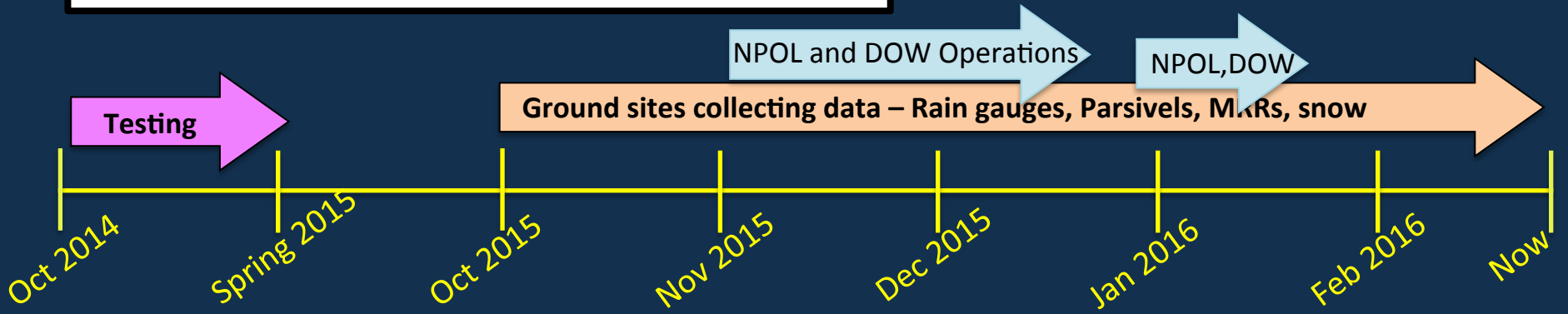
- Full-volume scans every 5 minutes
- Good for precipitation estimates
- Not ideal for microphysical studies



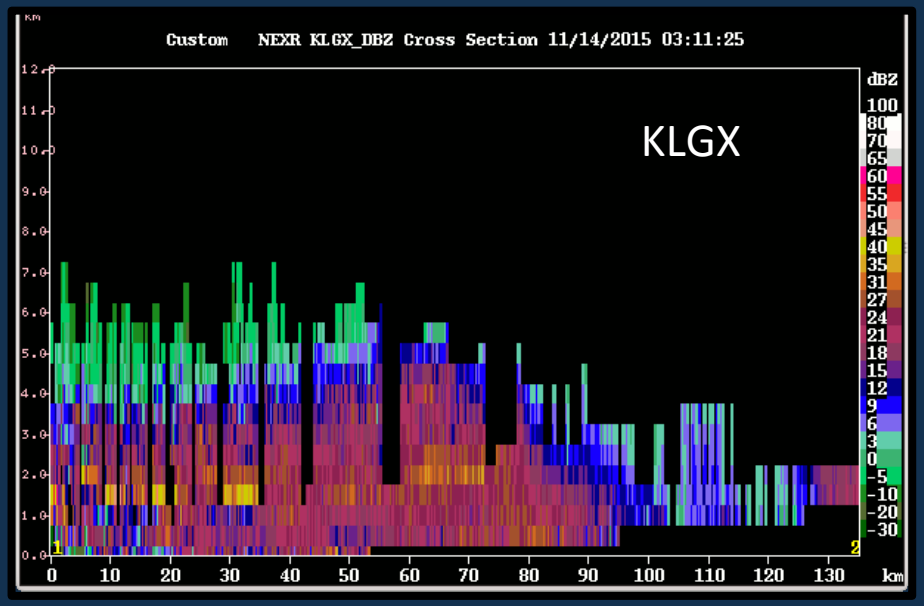


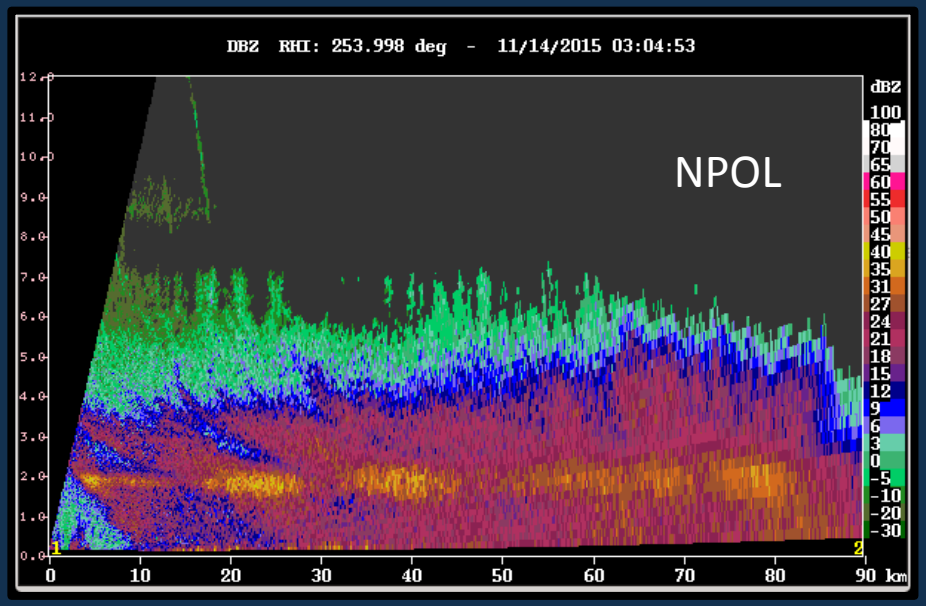
Ground-based Scanning Precipitation Radars - NPOL

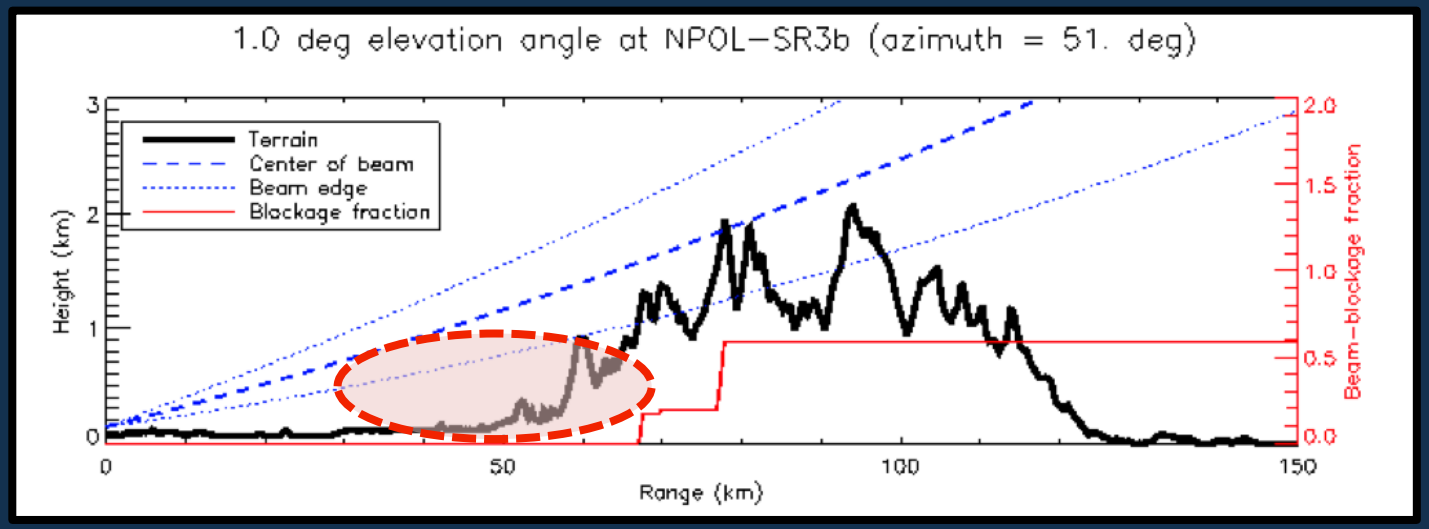




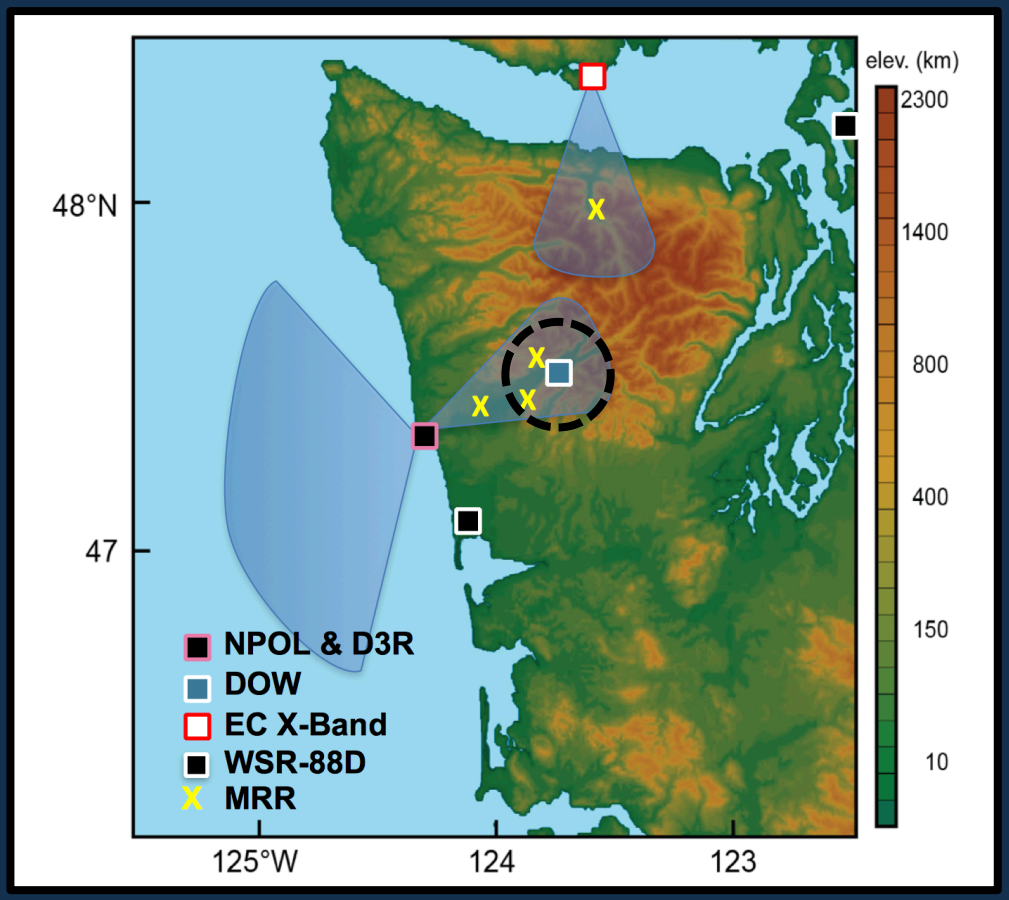
NPOL

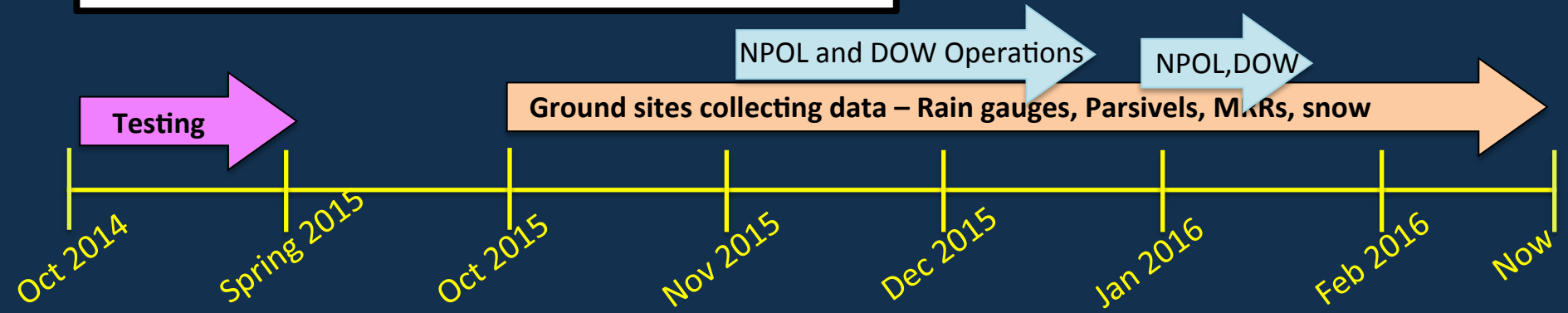

Custom NEXR KLGX_DBZ Cross Section 11/14/2015 03:11:25
KLGX
dBZ
km


DBZ RHI: 253.998 deg - 11/14/2015 03:04:53
NPOL
dBZ
km

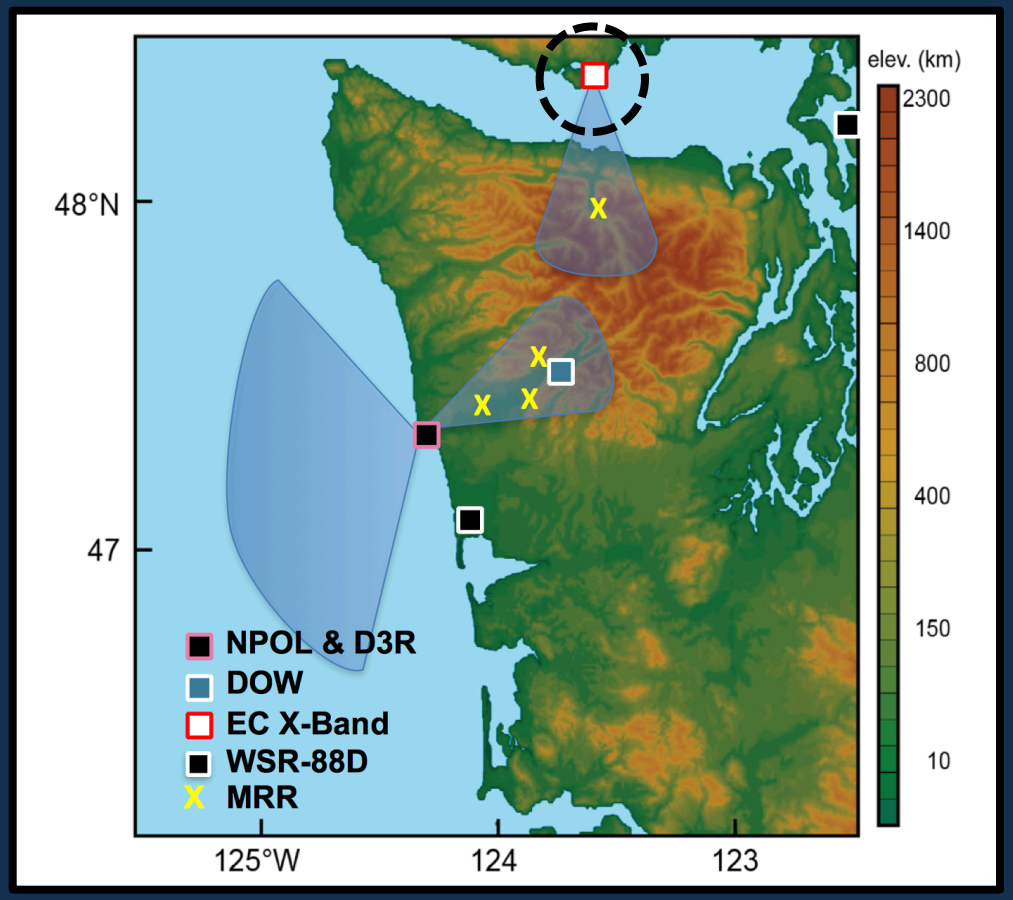

1.0 deg elevation angle at NPOL–SR3b (azimuth = 51. deg)
Terrain
Center of beam
Beam edge
Blockage fraction
Height (km)
Range (km)
Beam-blockage fraction

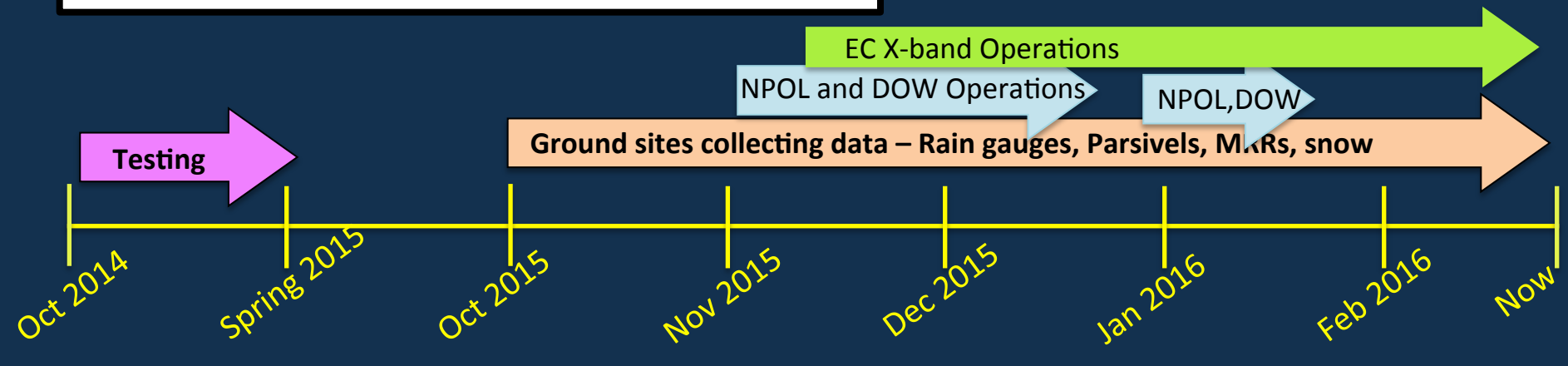
Ground-based Scanning Precipitation Radars - DOW



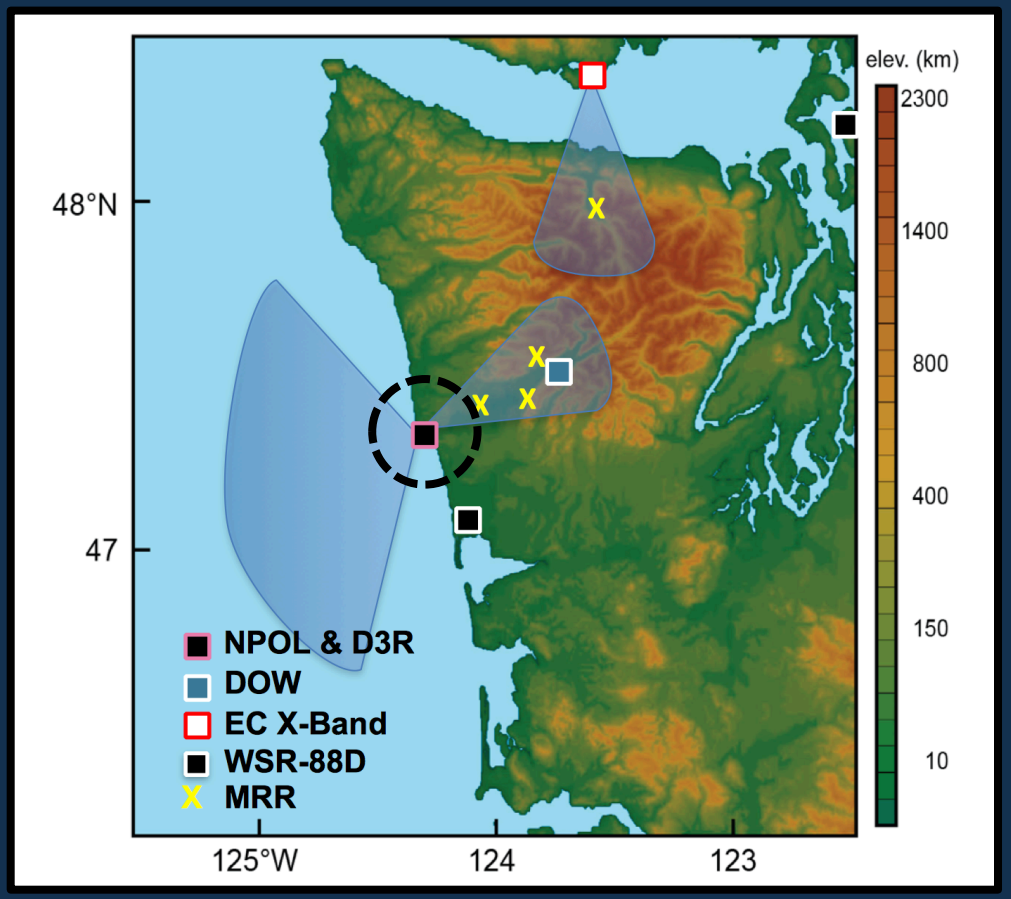


Ground-based Scanning Precipitation Radars – EC





Ground-based Scanning Radars – D3R



EC X-band Operations

NPOL and DOW Operations

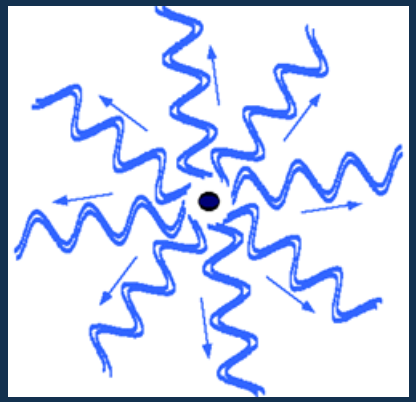
NPOL,DOW

Testing

Ground sites collecting data – Rain gauges, Parsivels, MRRs, snow

Oct 2014 | Spring 2015 | Oct 2015 | Nov 2015 | Dec 2015 | Jan 2016 | Feb 2016 | Now

Radar reflectivity



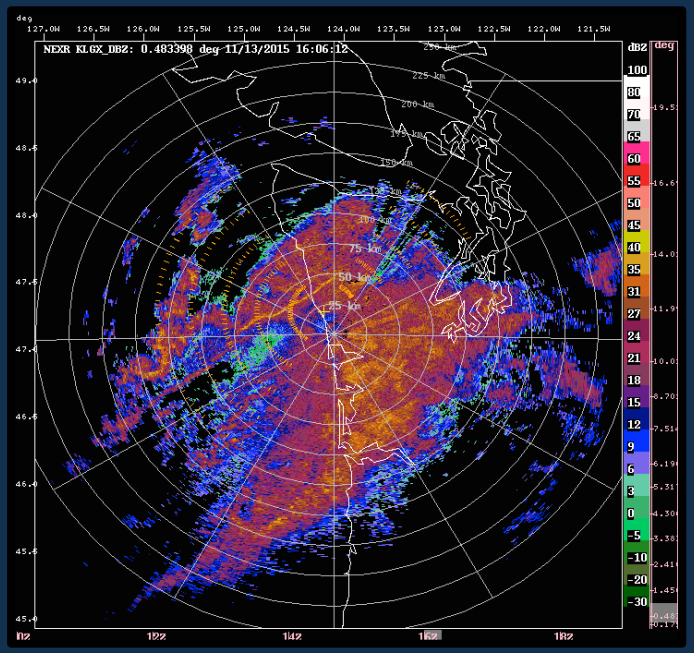
- Backscatter: Energy scattered back to receiver
  - P_t: 10^5 – 10^6 W
  - P_r: 10^{-13} – 10^{-14} W

$$P_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3 R^4} \sigma$$

$$\sigma_i = \frac{\pi^5 |K|^2 D_i^6}{\lambda^4}$$

- Depends on:
  - Size (wavelength)
  - Shape
  - State (Liquid/Ice)

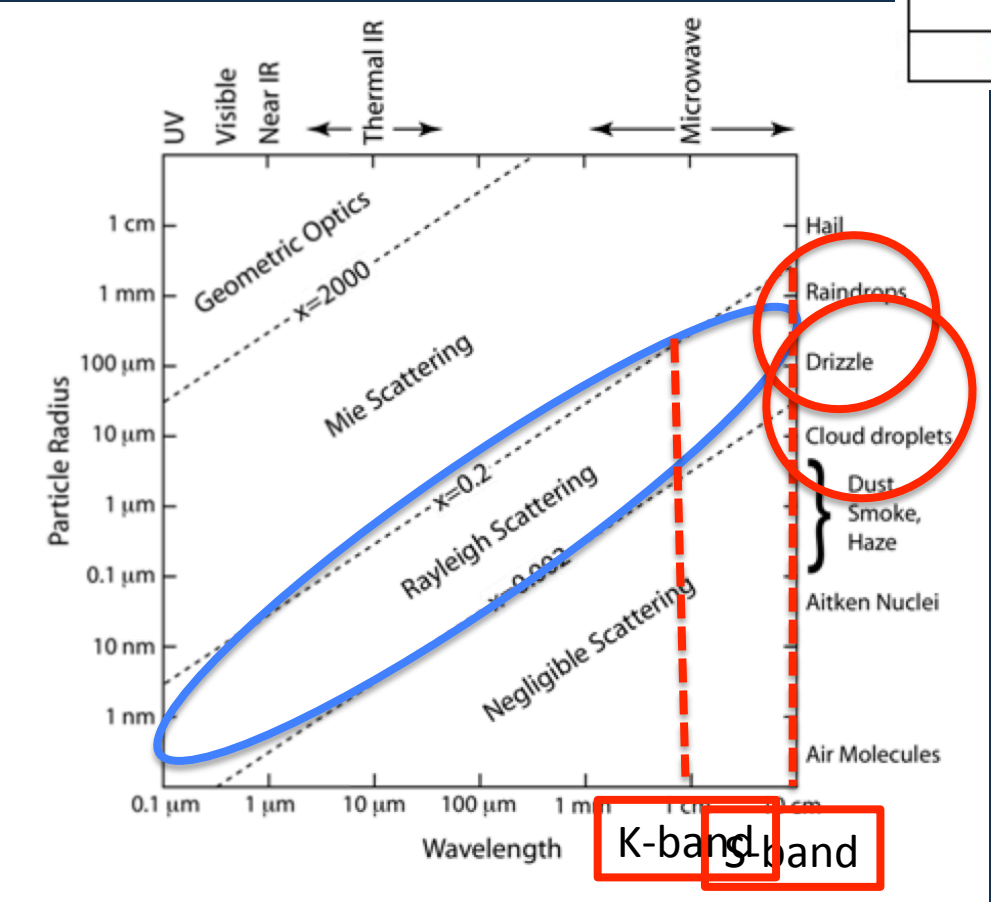
$$Z = \sum_{i=1}^{n} D_i^6$$



Radar wavelengths

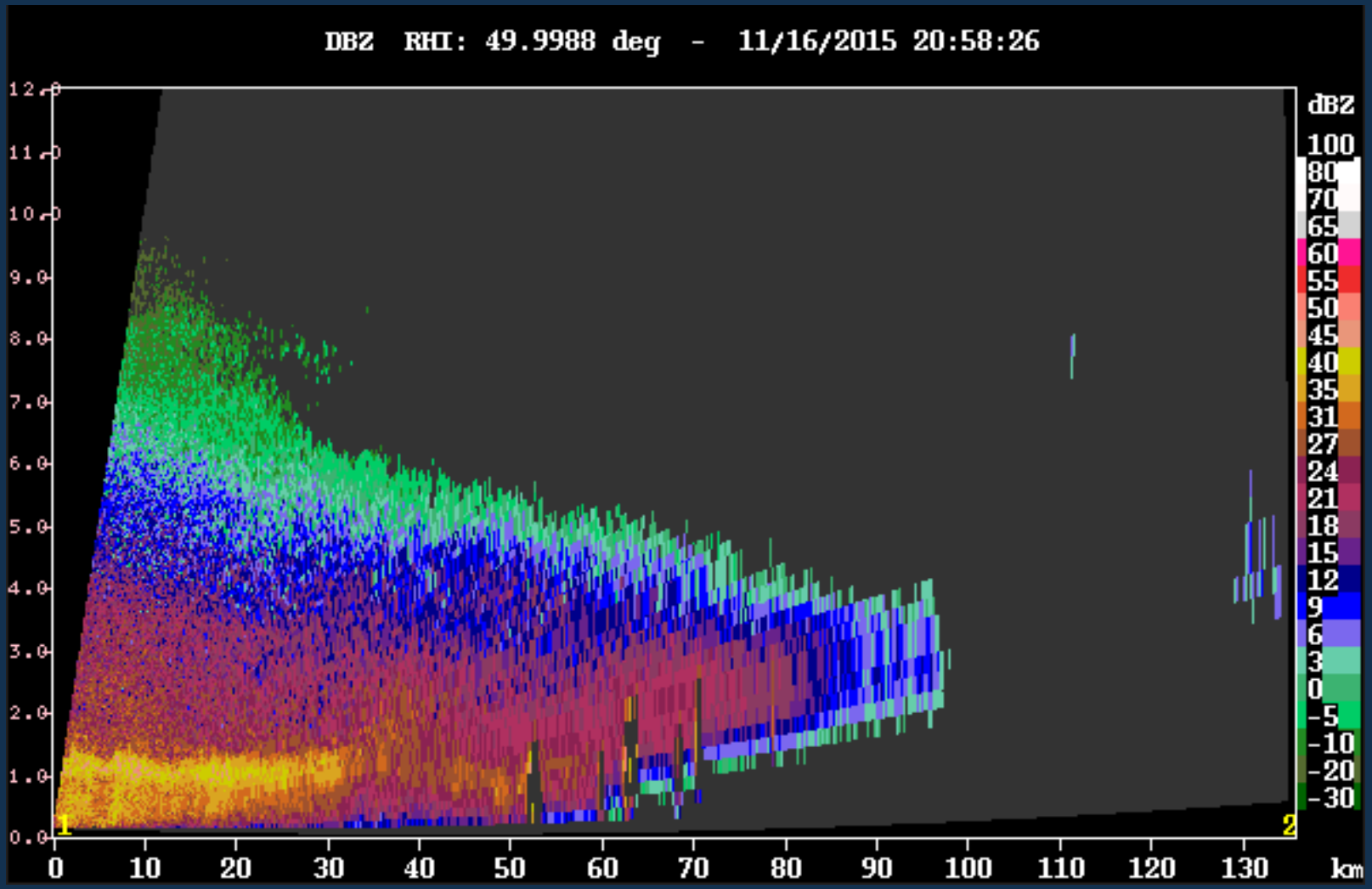
Higher frequency, smaller antenna

Radar Band	Frequency (GHz)	Wavelength (cm)
Millimeter	40 to 100	0.75 to 0.30
Ka	26.5 to 40	1.1 to 0.75
K	18 to 26.5	1.7 to 1.1
Ku	12.5 to 18	2.4 to 1.7
X	8 to 12.5	3.75 to 2.4
C	4 to 8	7.5 to 3.75
S	2 to 4	15 to 7.5
L	1 to 2	30 to 15
UHF	0.3 to 1	100 to 30



- Rayleigh: Hydrometeors small compared to wavelength
- X, C, S, and L: precipitation
- K, mm: clouds

NPOL (S-band) - Valley

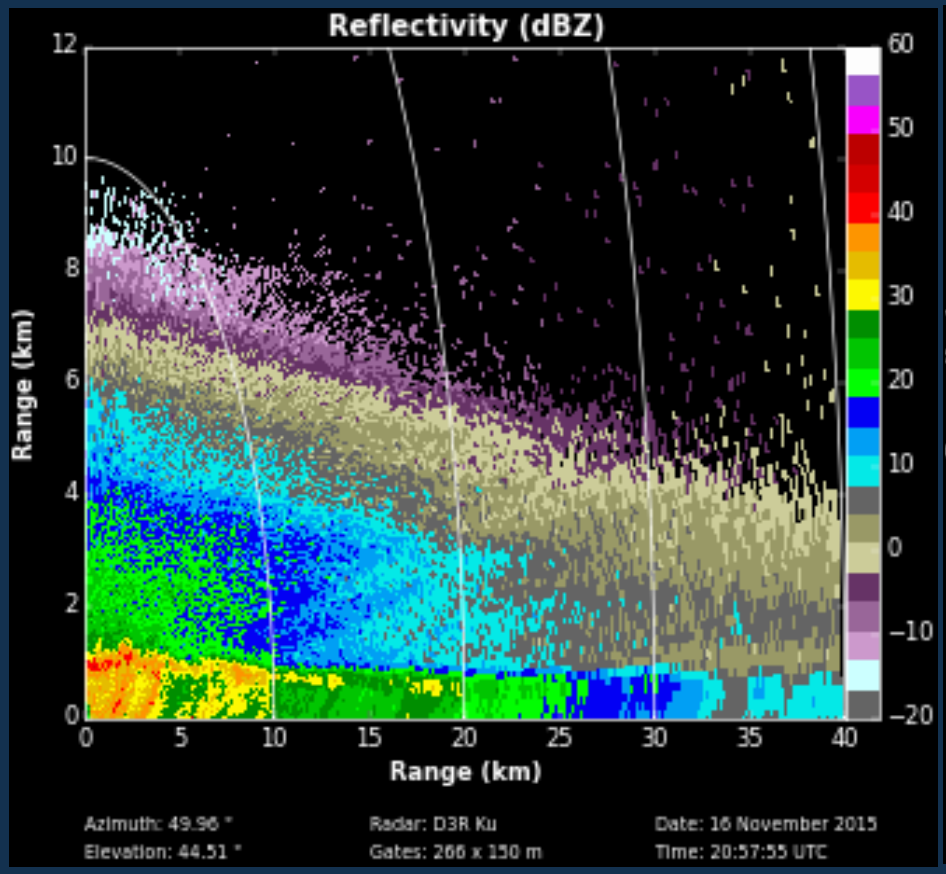


Height (km)

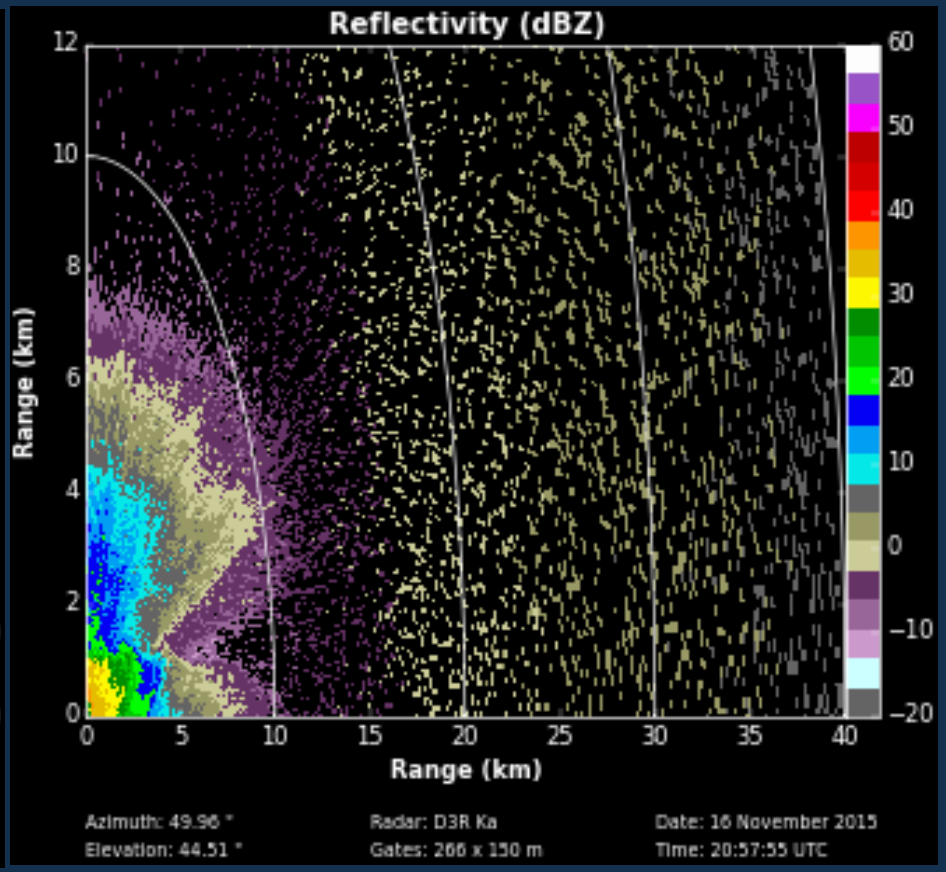
Distance from NPOL (km)

D3R (Ka-/Ku-band) - Valley

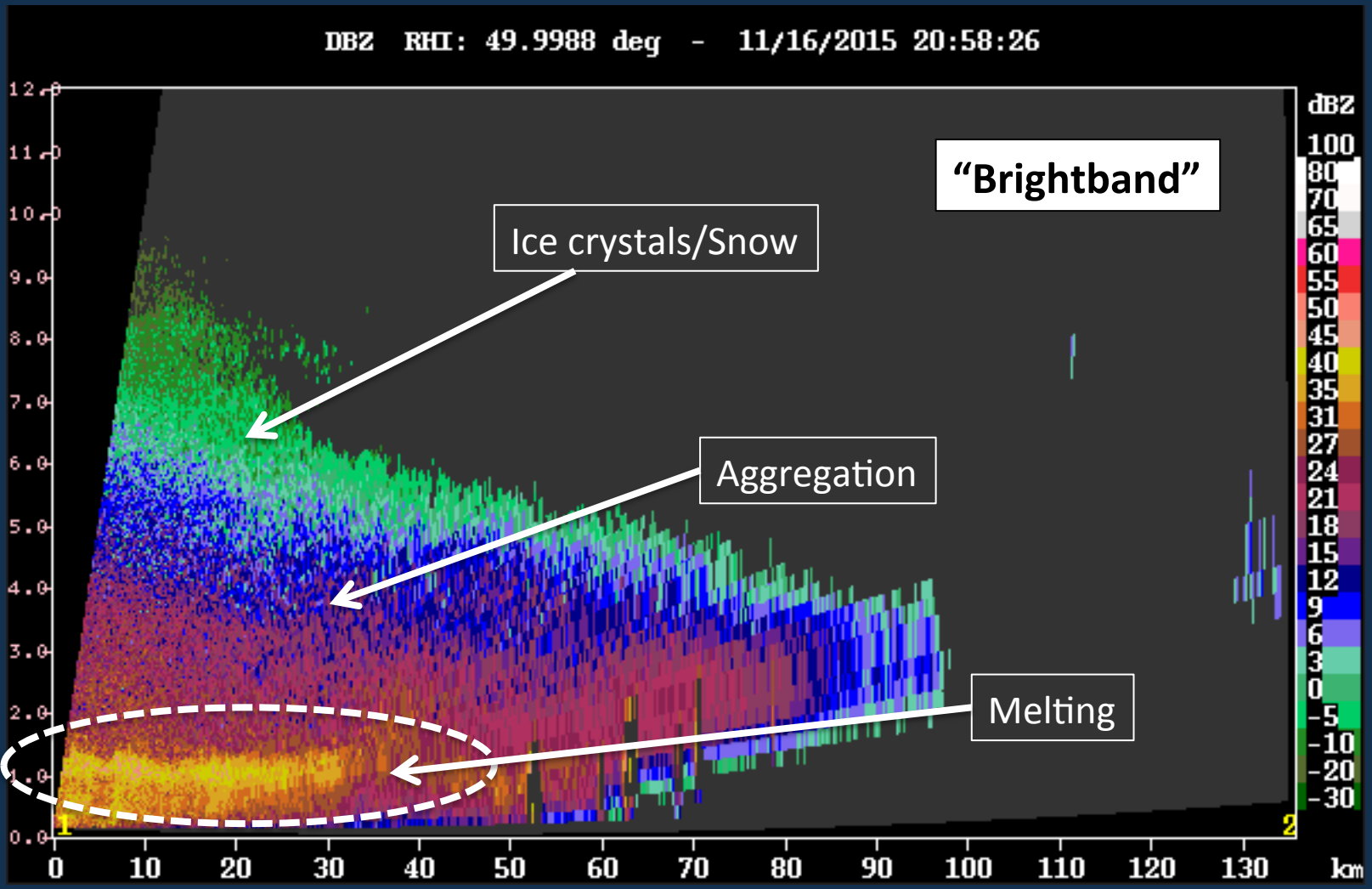
Ku



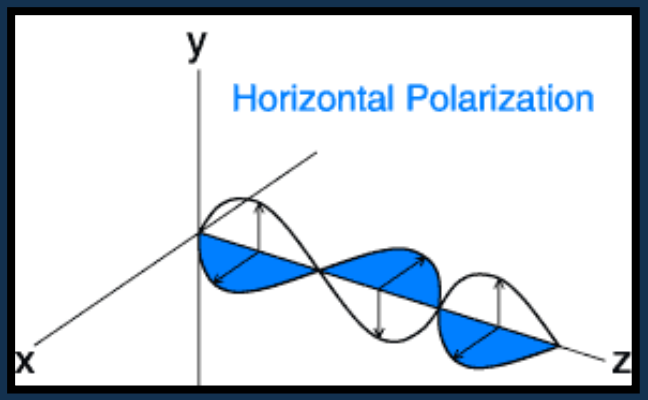
Ka

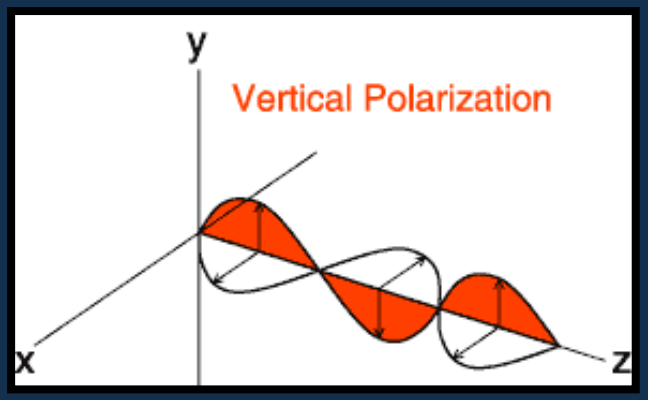


NPOL (S-band) - Valley

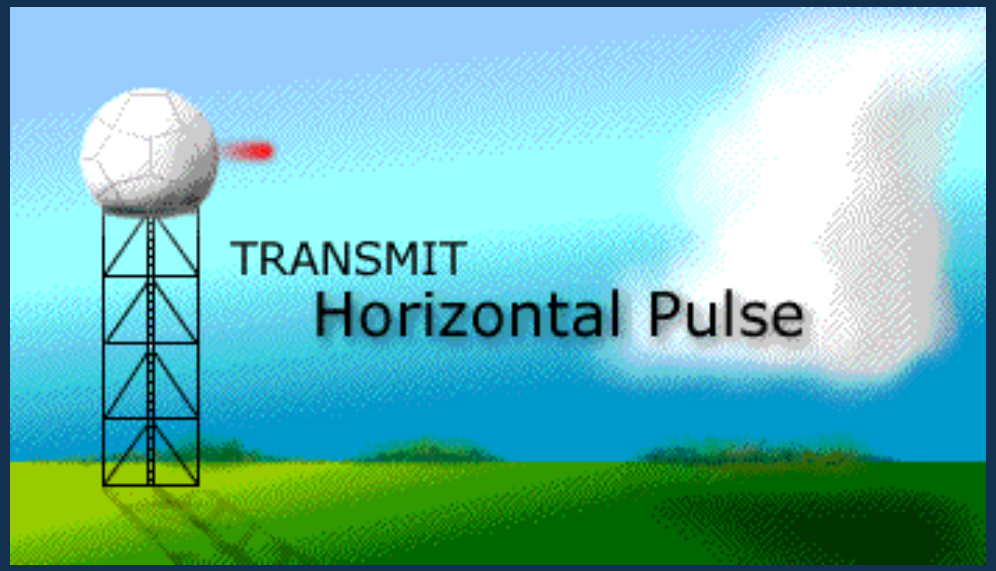


Dual-polarization



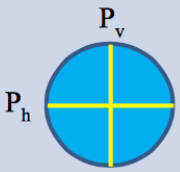
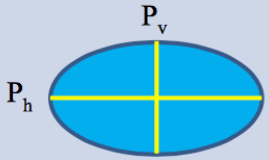
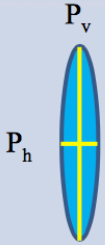


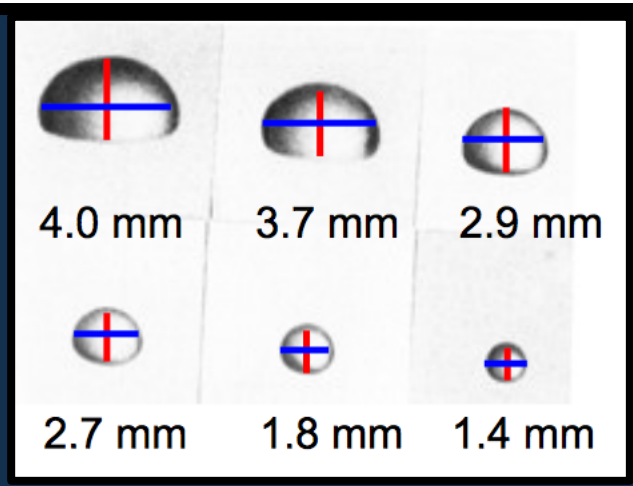
- Alternating or simultaneous transmission of both horizontally and vertically polarized waves

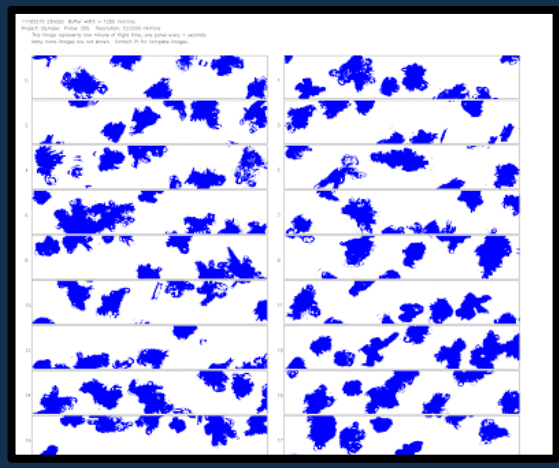


Differential Reflectivity

$$Z_{DR} = 10 \log_{10}(Z_{HH}/Z_{VV})$$

Spherical (drizzle, small hail, etc.)	**Horizontally Oriented** (rain, melting hail, etc.)	**Vertically Oriented** (i.e. vertically oriented ice crystals)
		
$Z_h \sim Z_v$	$Z_h > Z_v$	$Z_h < Z_v$
$10 \log_{10}\left(\frac{Z_h}{Z_v}\right) = 0$	$10 \log_{10}\left(\frac{Z_h}{Z_v}\right) > 0$	$10 \log_{10}\left(\frac{Z_h}{Z_v}\right) < 0$
ZDR ~ 0 dB	**ZDR > 0 dB**	**ZDR < 0 dB**

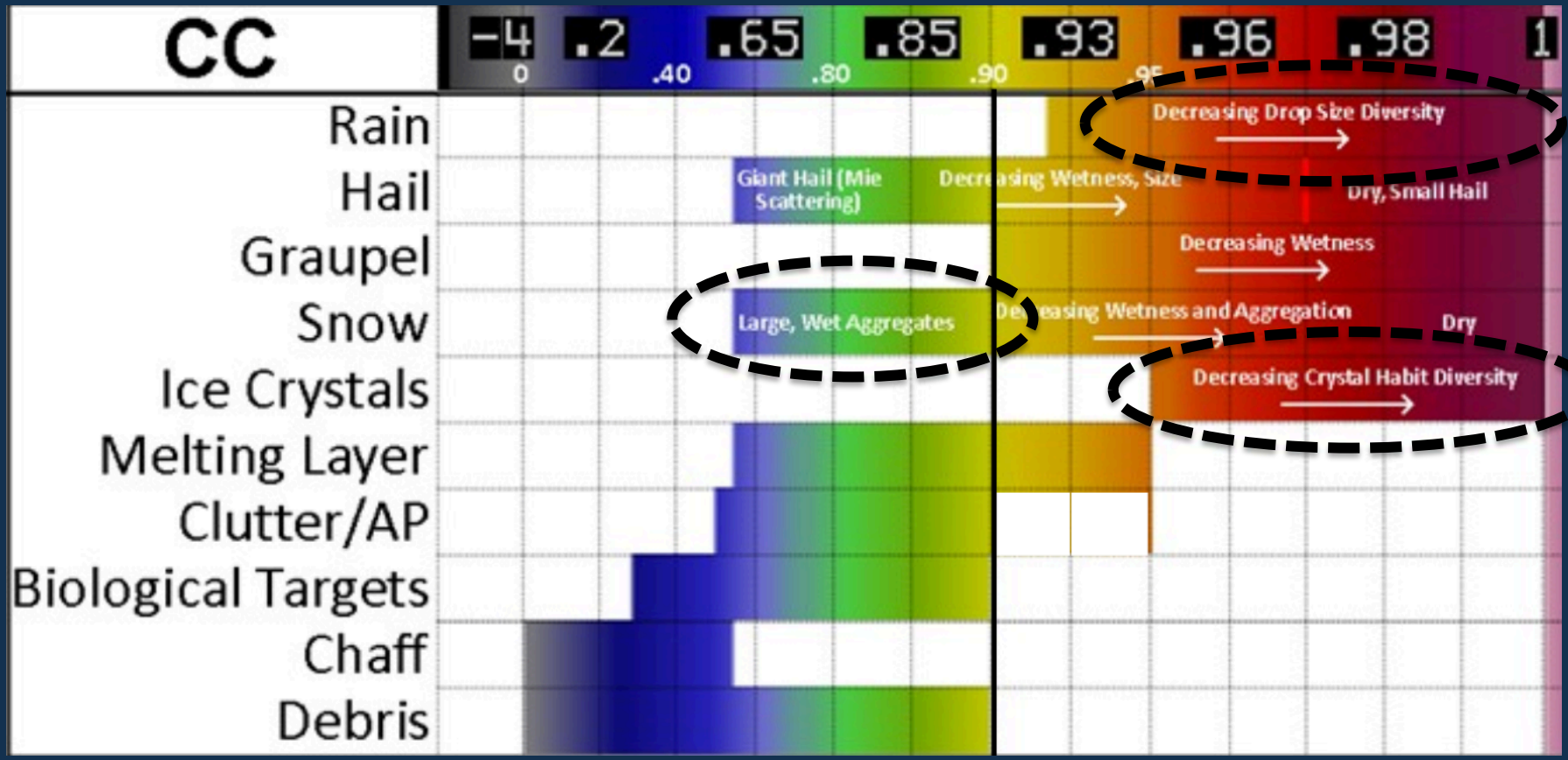




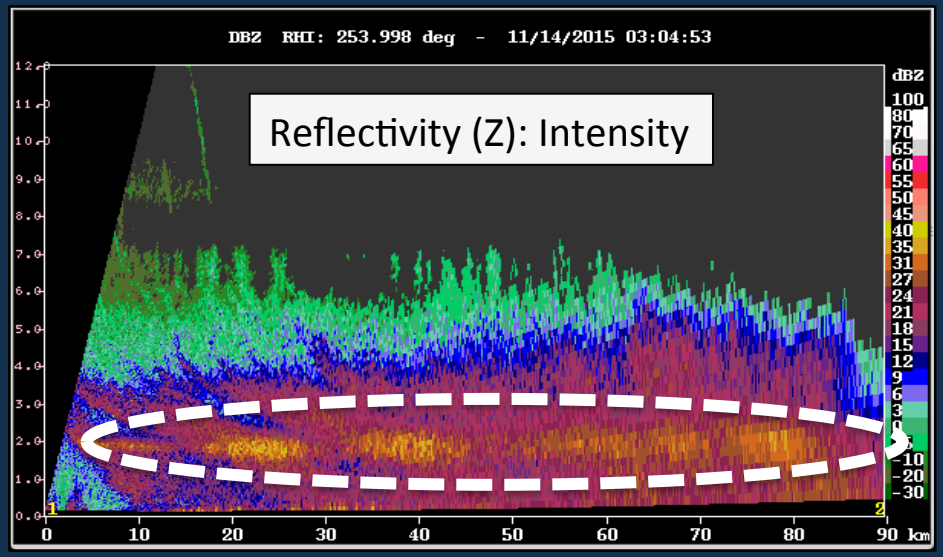
Z_{DR} = +2 to +4 dB (columns)
Z_{DR} = +3 to +6 dB (dendrites / plates)
Z_{DR} = 0 to +1 dB (aggregates)

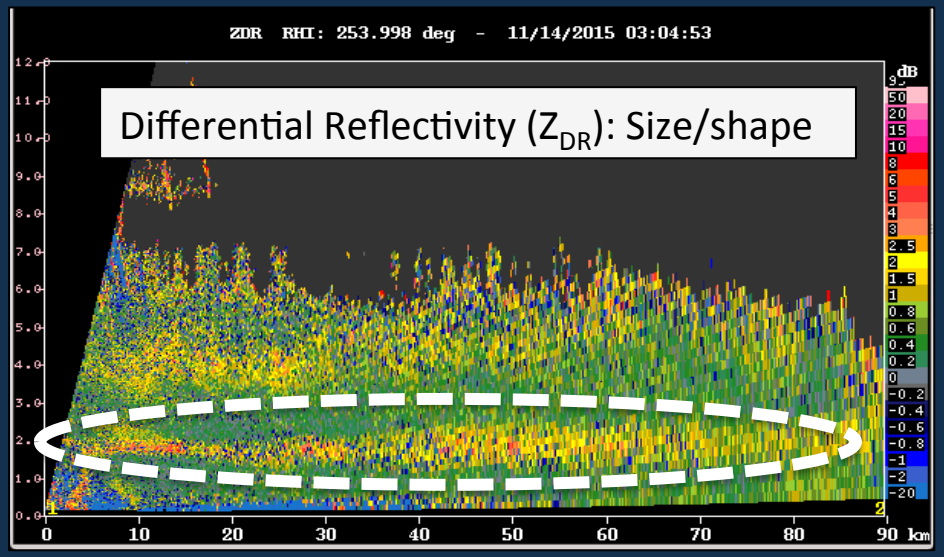
Correlation Coefficient

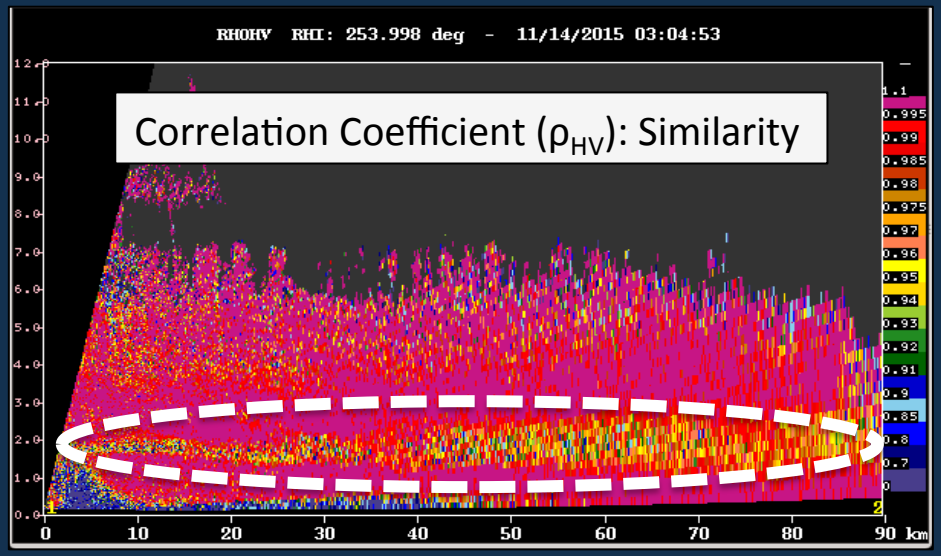
Measure of the **similarity** between horizontal and vertical returns from a pulse volume

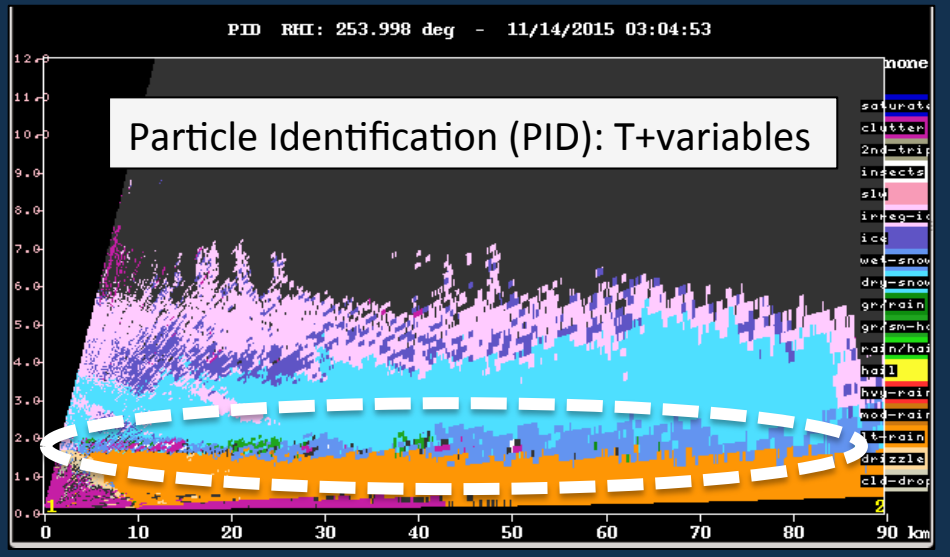


Brightband

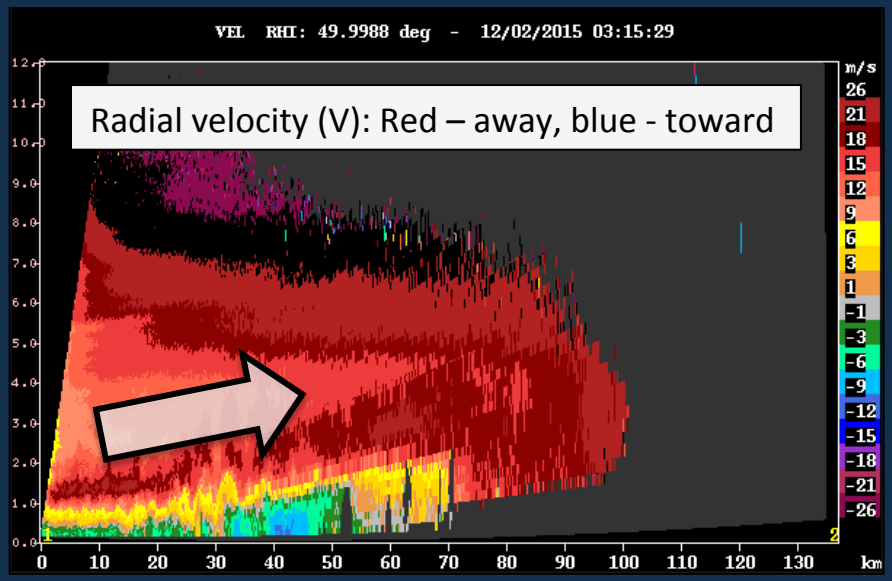

DBZ RHI: 253.998 deg - 11/14/2015 03:04:53
Reflectivity (Z): Intensity
dBZ
90 km

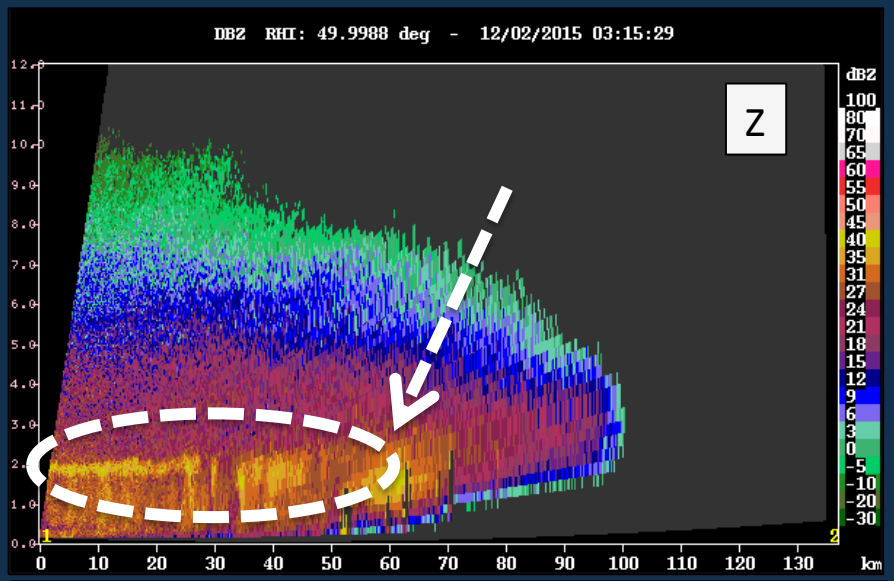

ZDR RHI: 253.998 deg - 11/14/2015 03:04:53
Differential Reflectivity (Z_{DR}): Size/shape
dB
90 km

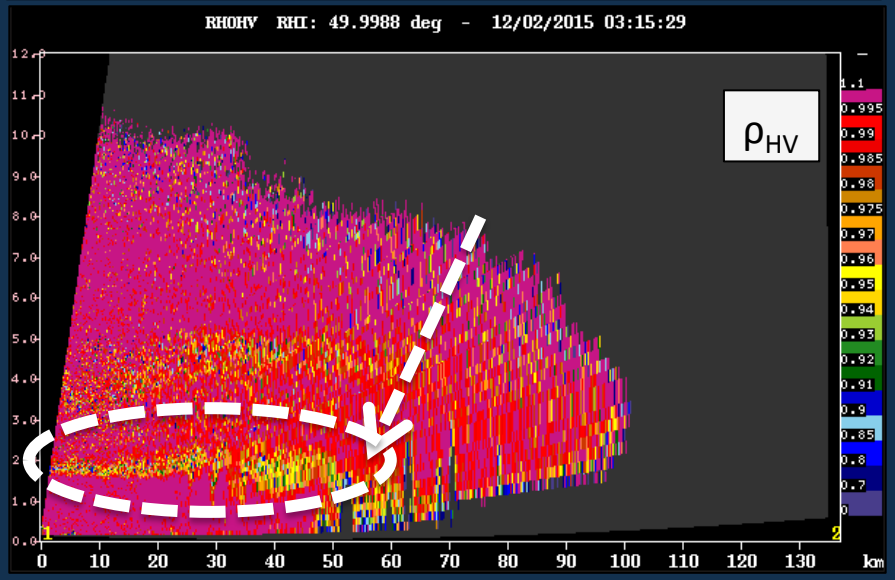

RHOHV RHI: 253.998 deg - 11/14/2015 03:04:53
Correlation Coefficient (ρ_{HV}): Similarity
90 km


PID RHI: 253.998 deg - 11/14/2015 03:04:53
Particle Identification (PID): T+variables
90 km

Role of terrain







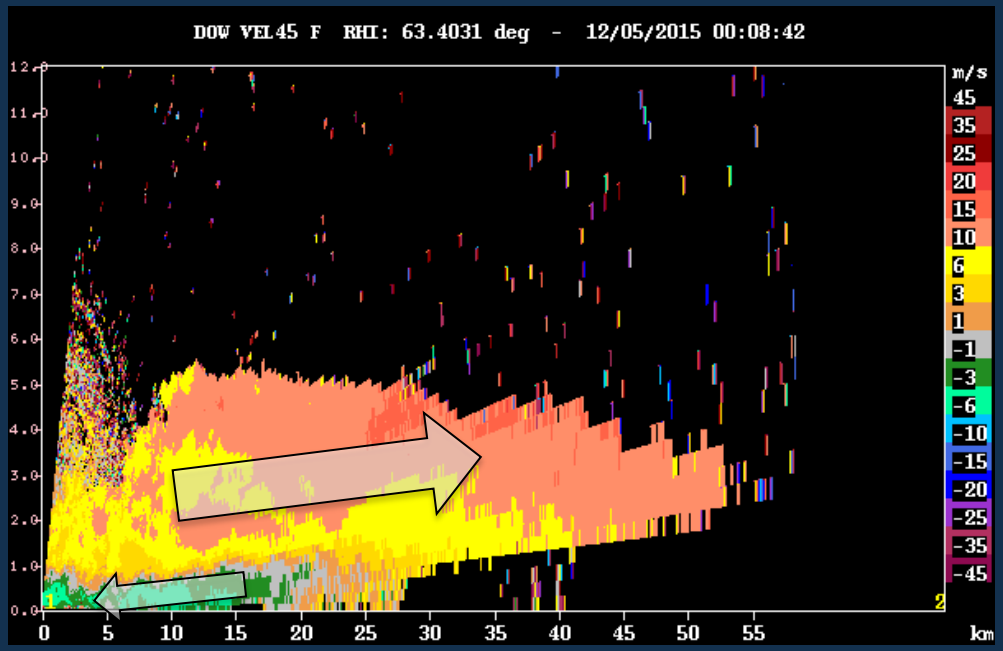
Lifting air (upstream of mountains)

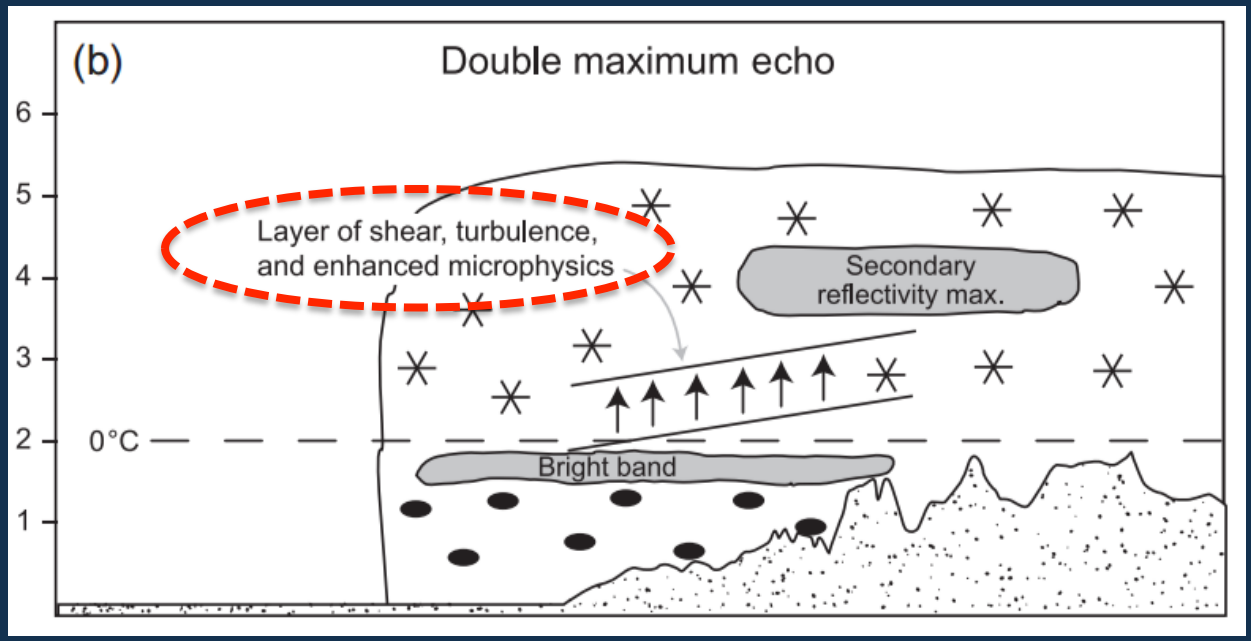
Precipitation **enhancement**

Dipping of brightband
- Latent cooling (melting)
- Melting distance
- Adiabatic cooling (forced ascent)
- Preexisting cold air

Valley flow

Turbulence





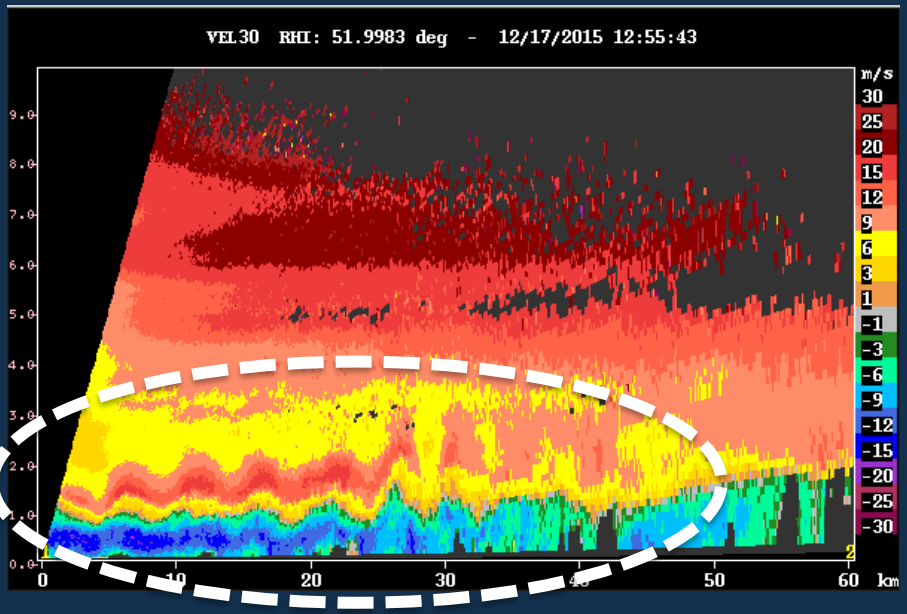
Medina et al. (2007)

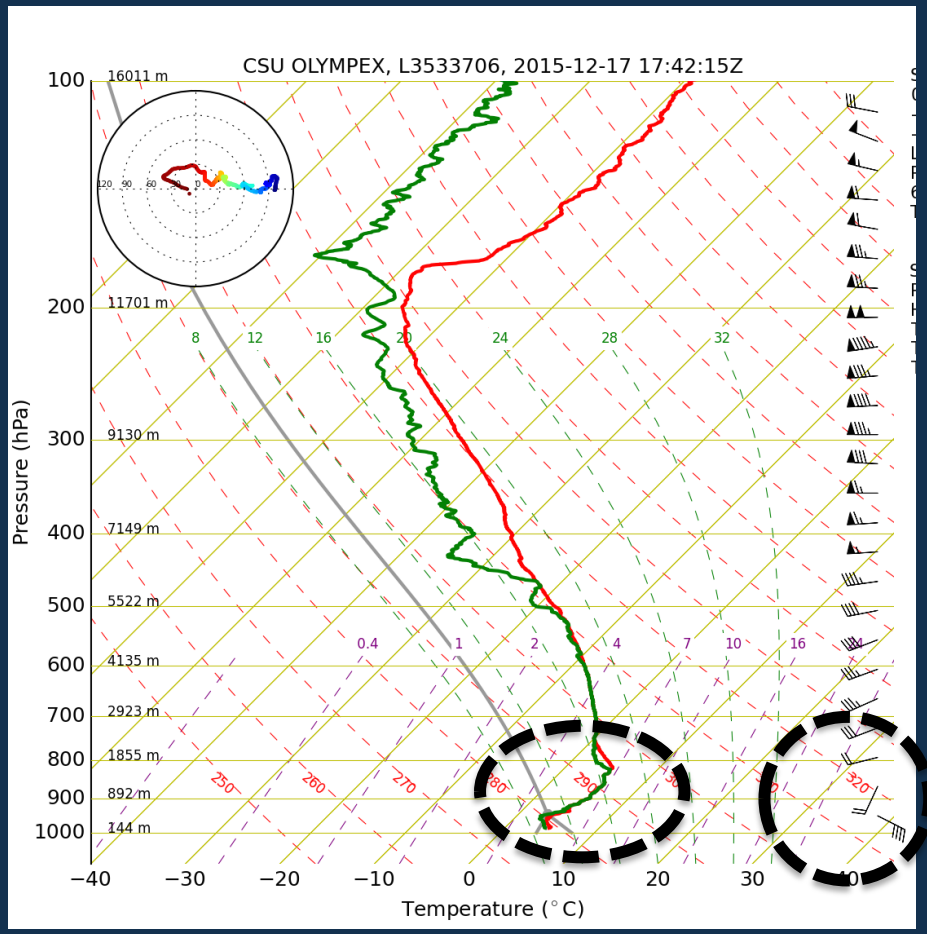
Kelvin-Helmholtz waves

17 Dec 2015

Kelvin-Helmholtz waves, observed for 5 hours (valley and ocean) by NPOL in stable layer with strong directional wind shear

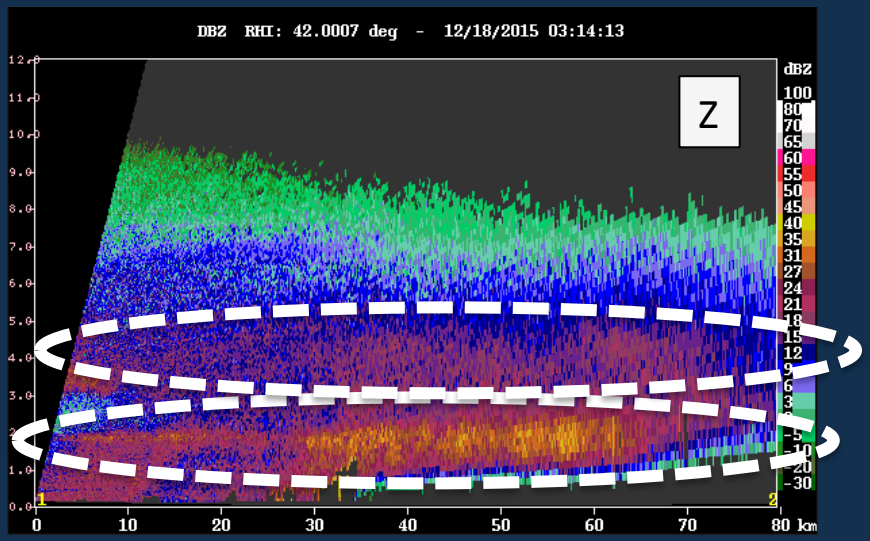
Role in **enhanced microphysics**

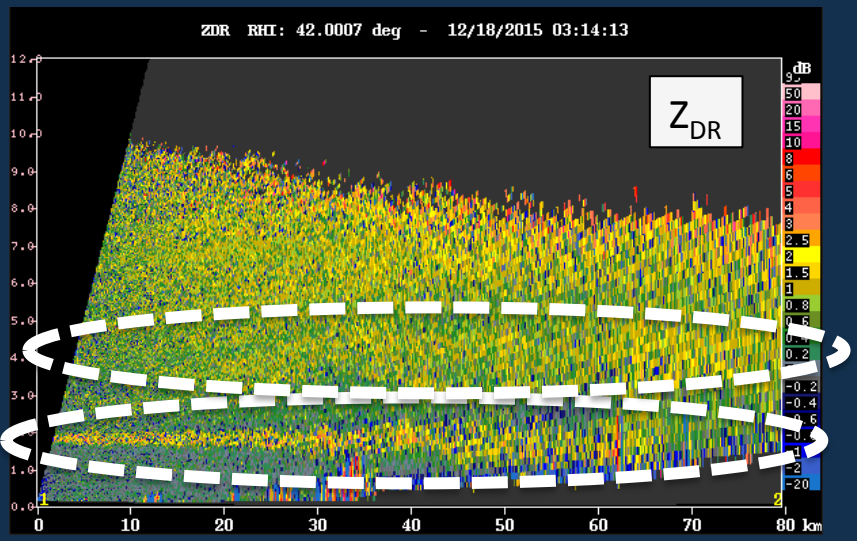


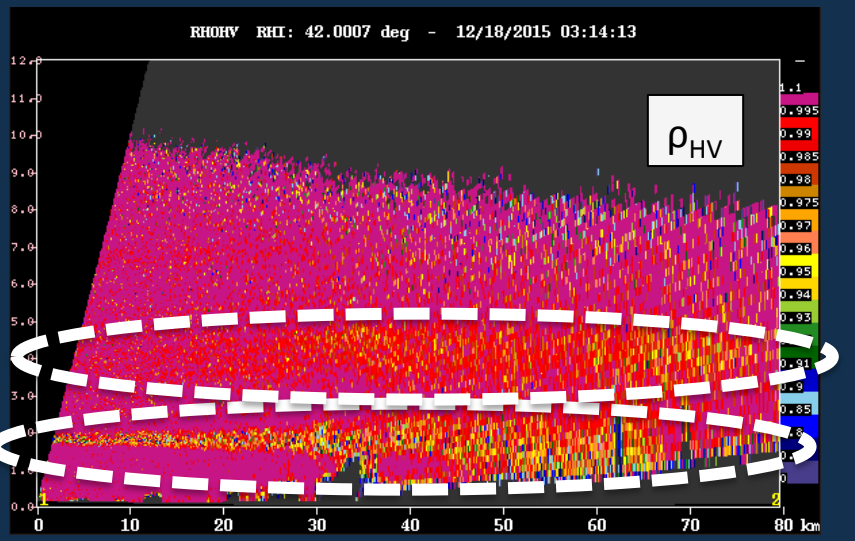


Microphysical processes

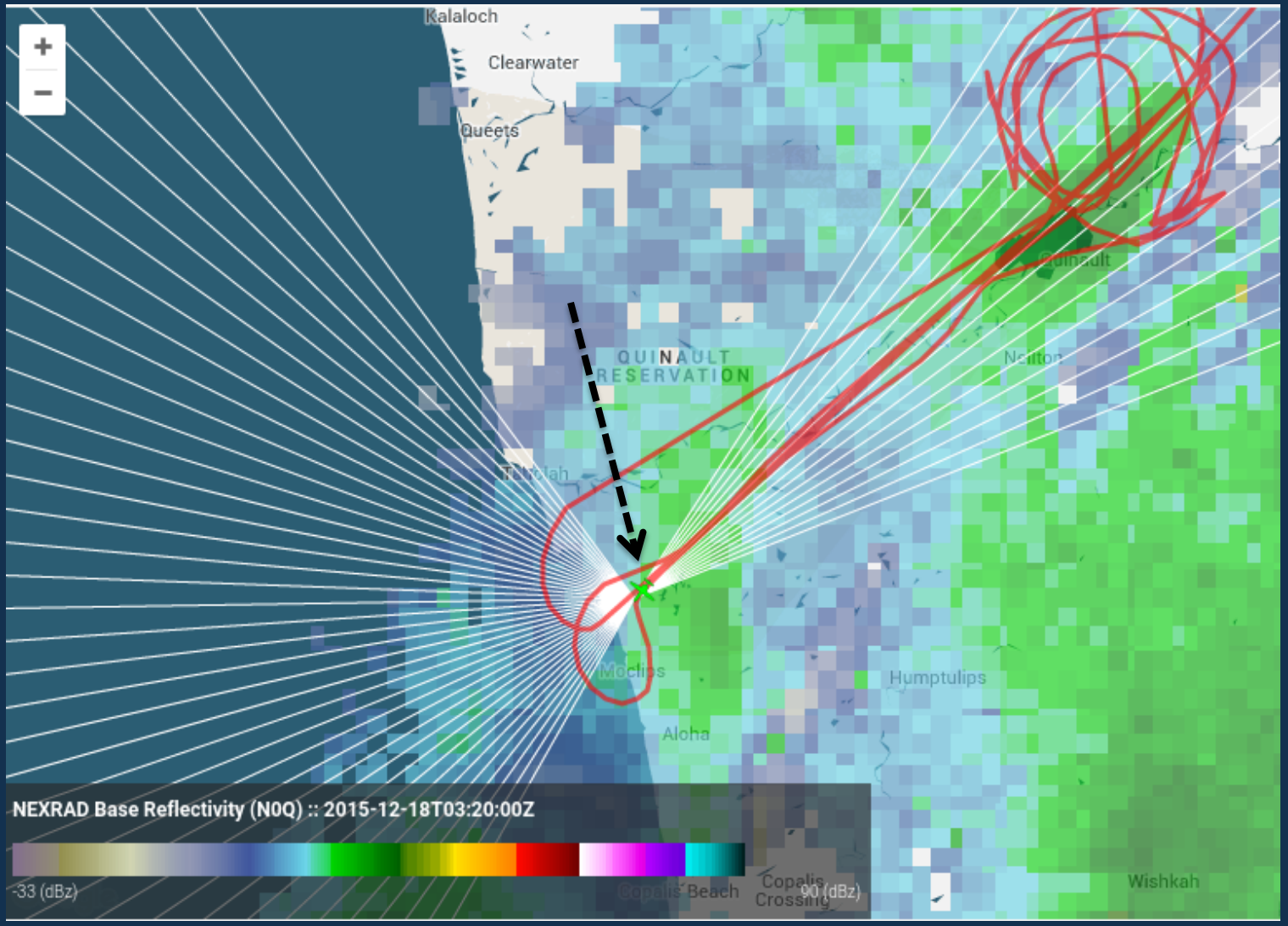
18 Dec 2015



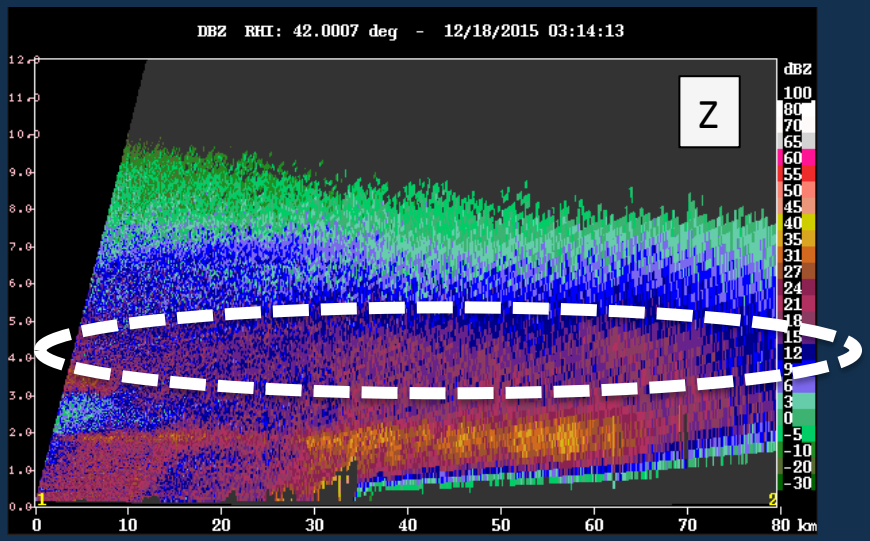


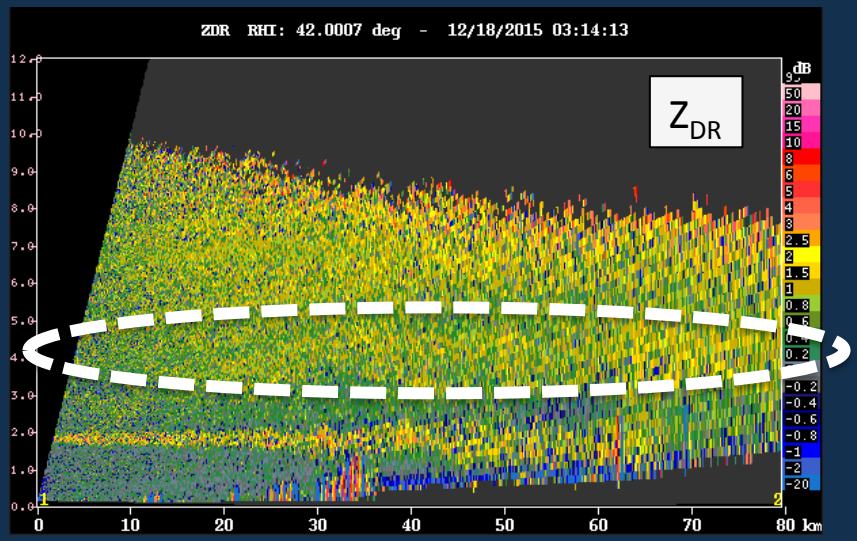


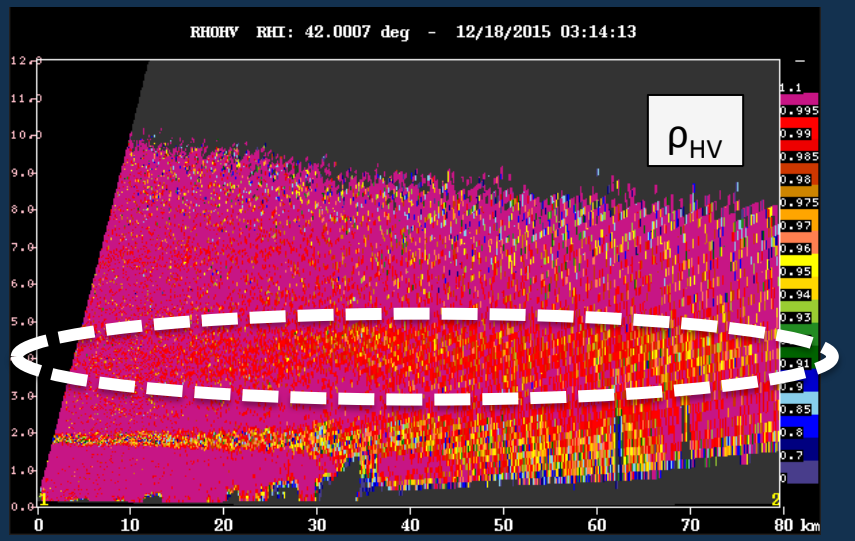
In-situ Aircraft Data



Microphysical processes



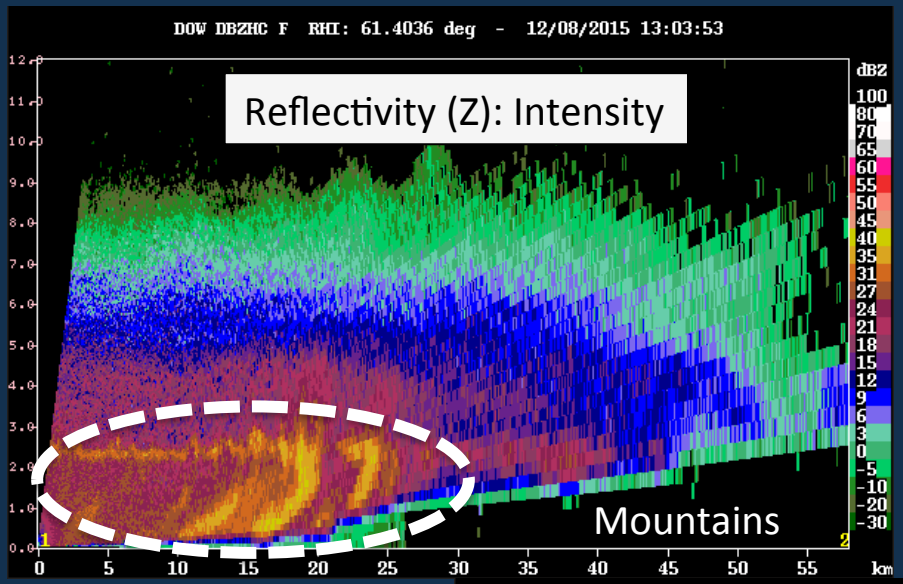


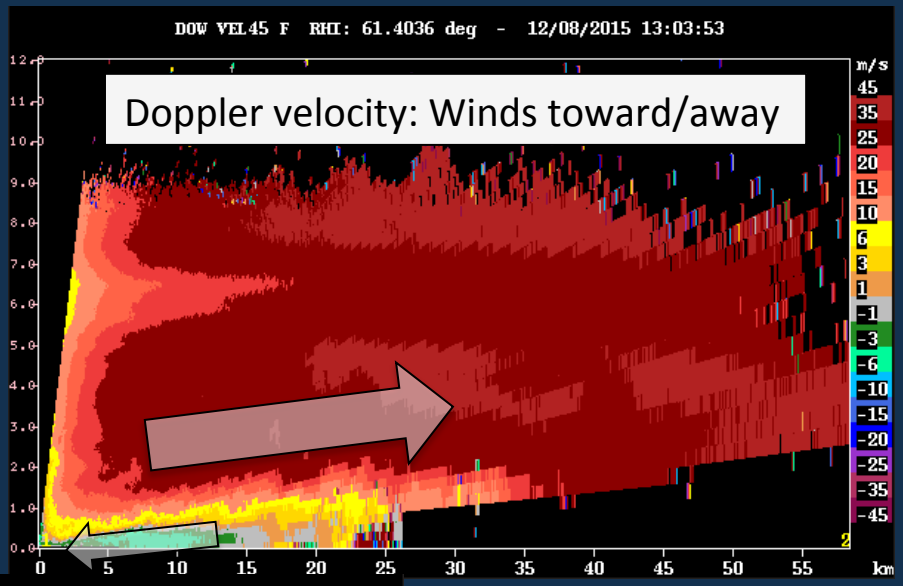


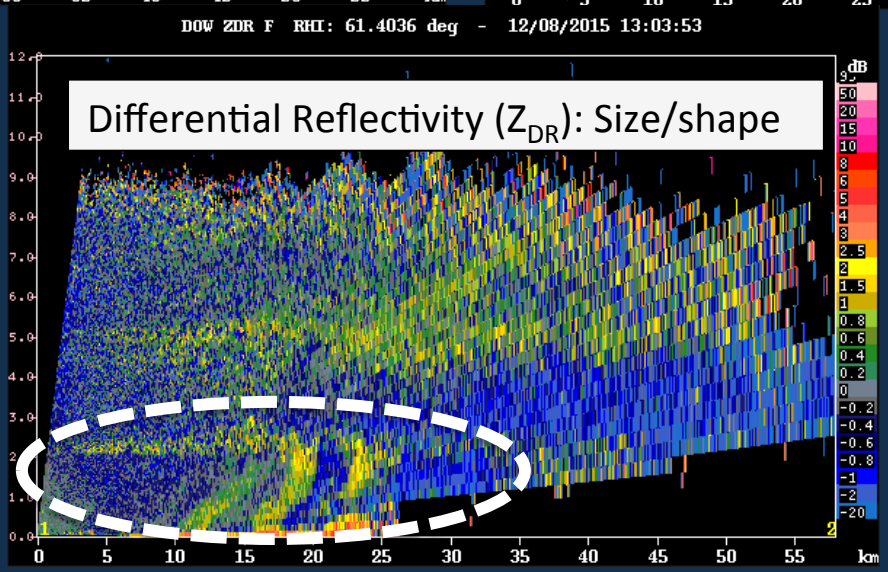
Citation: Flying at 14,000 FT (~ 4 km), noted ***plates***, ***capped*** columns, and ***plate*** aggregates

→Dendritic growth zone, aggregation

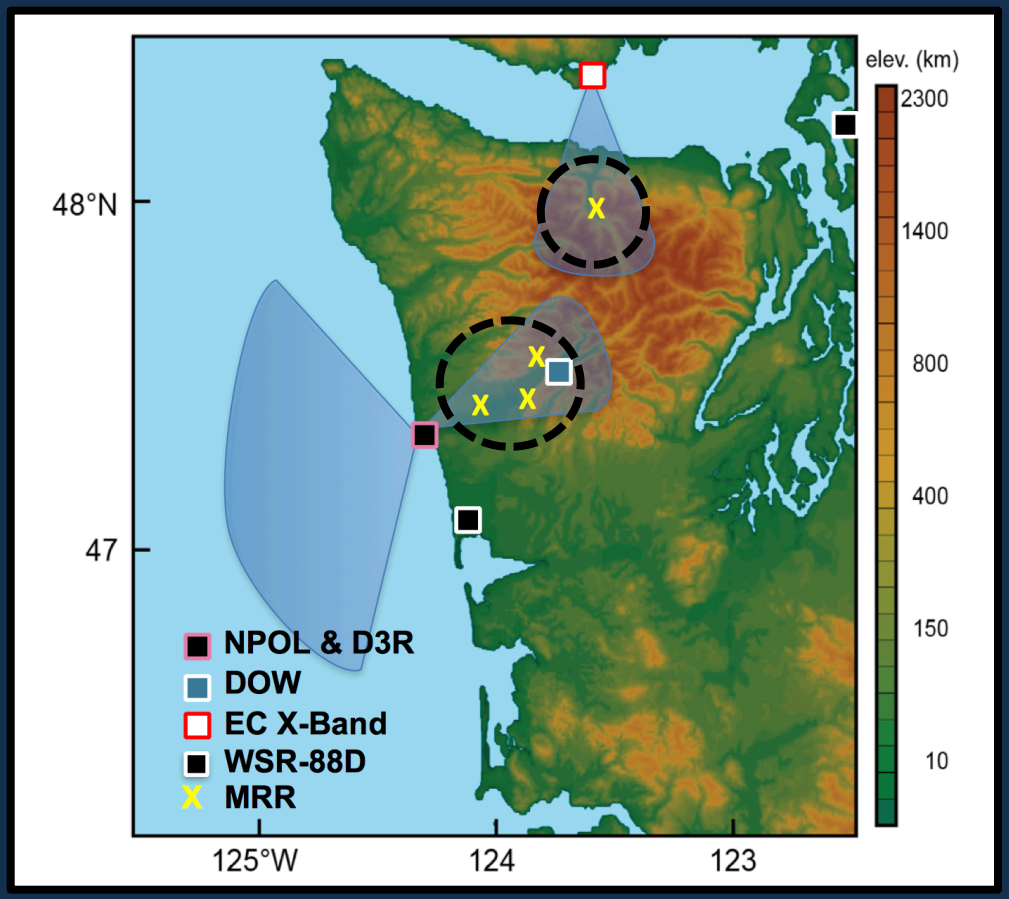
DOW radar data

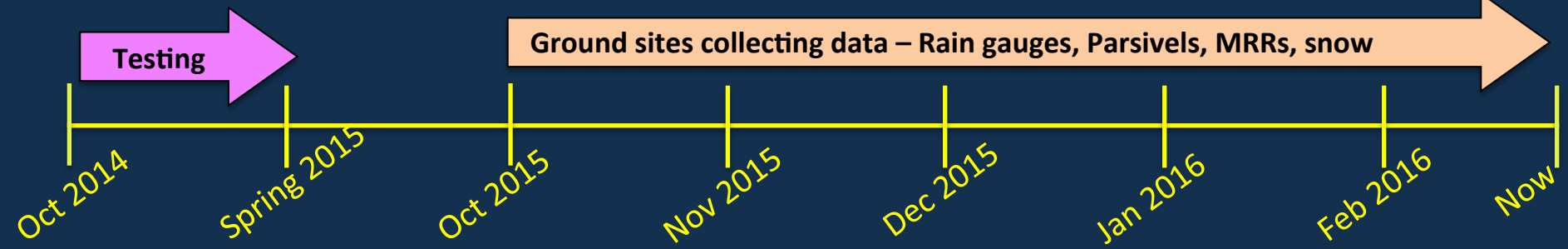




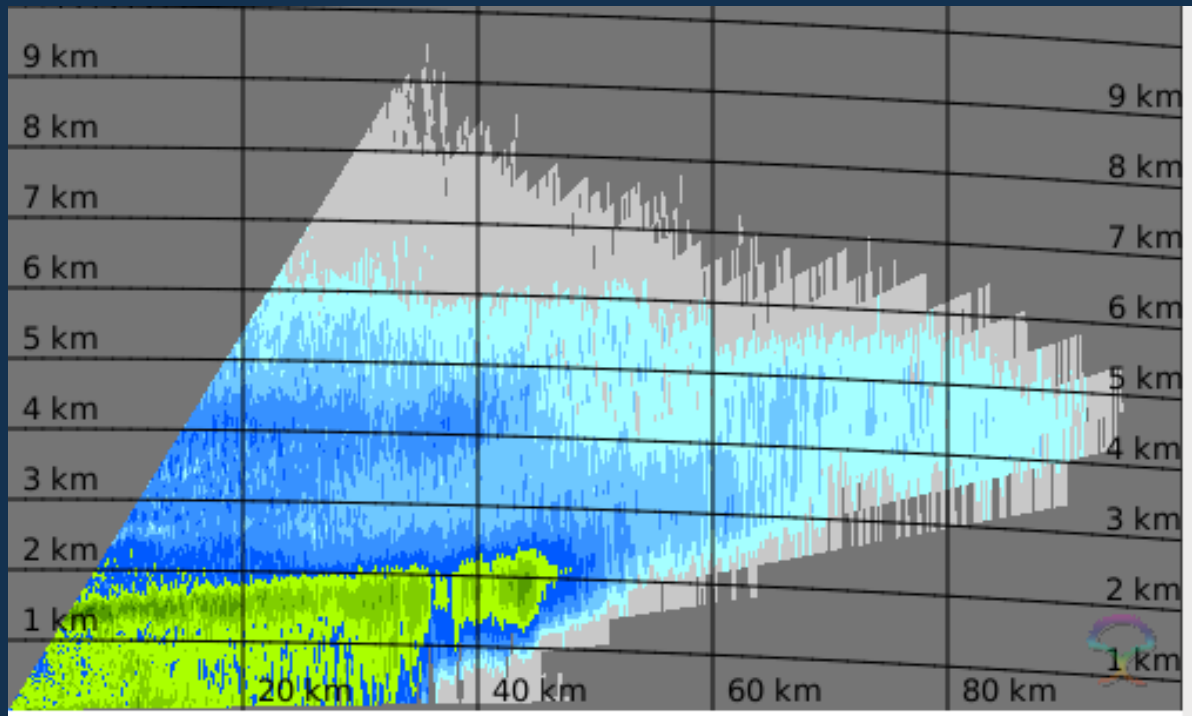


Ground-based Vertically Pointing





EC radar looking toward Hurricane Ridge



Distance from radar ⟶

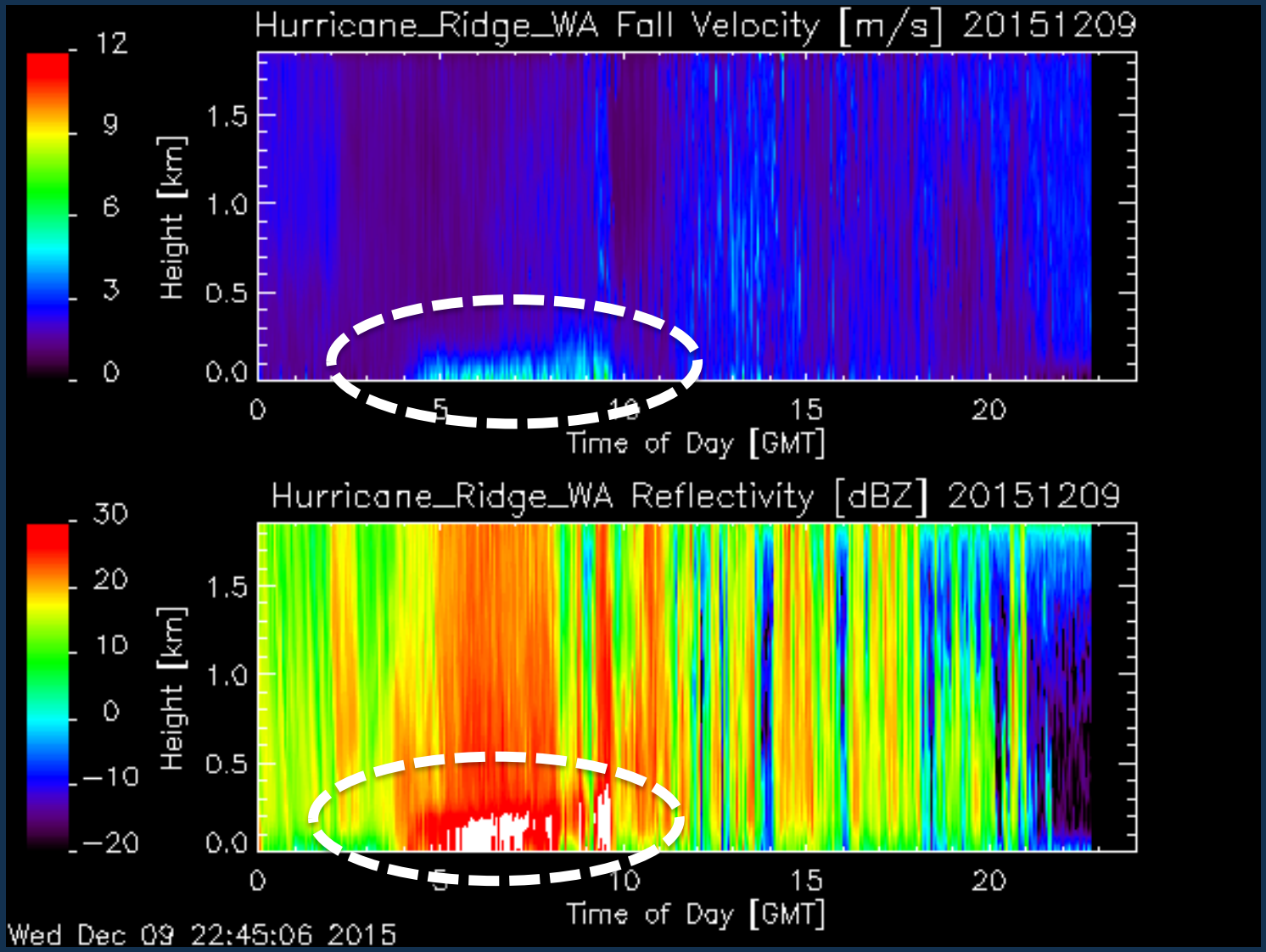
RHI (dBZ)
04:41 / 09-Dec-2015
KING_CAX01

64.0 dBZ
52.0 dBZ
40.0 dBZ
28.0 dBZ
16.0 dBZ
-10.0 dBZ

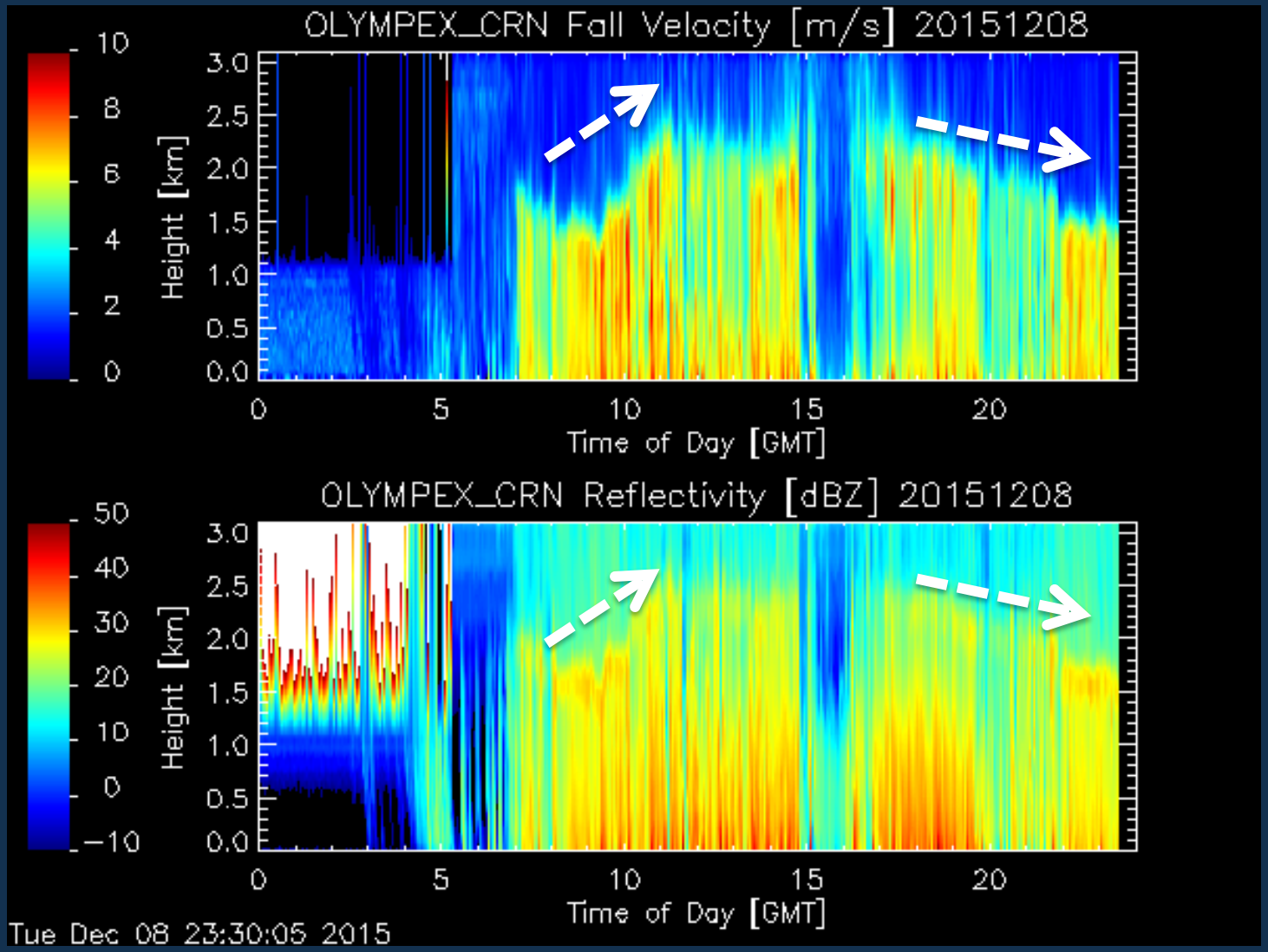
Pdf File:	RHI_C.rhi
Clutter Filter:	DFT 6
Time sampling:	64
PRF:	1000 Hz
Range:	100 km
Height:	0.000 km to 10.000 km
Hor Res:	0.200 km/pixel
Vert Res:	0.033 km/pixel
Elevation:	0.1 deg to 15.1 deg
Azimuth:	181.0 deg
Data:	Radar Data

Rainbow® Selex ES GmbH

Micro Rain Radar (MRR)

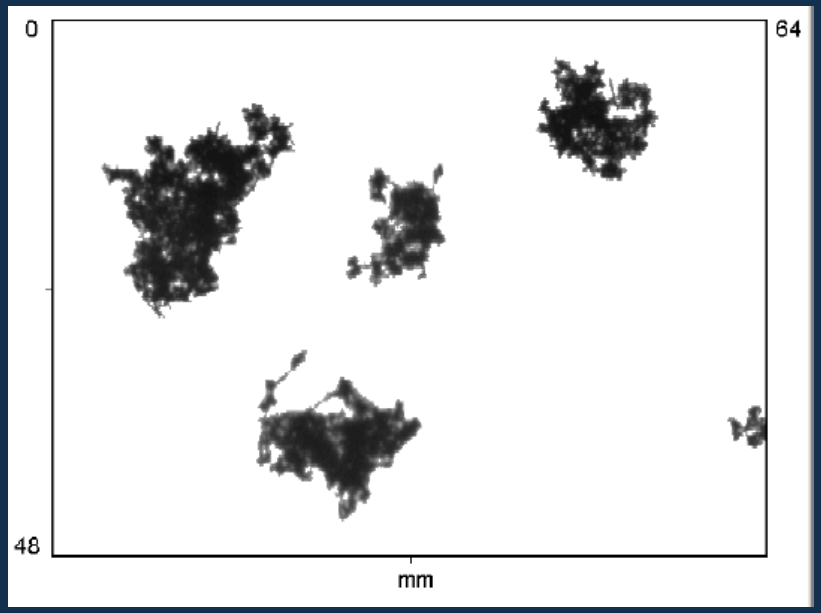


Micro Rain Radar (MRR)

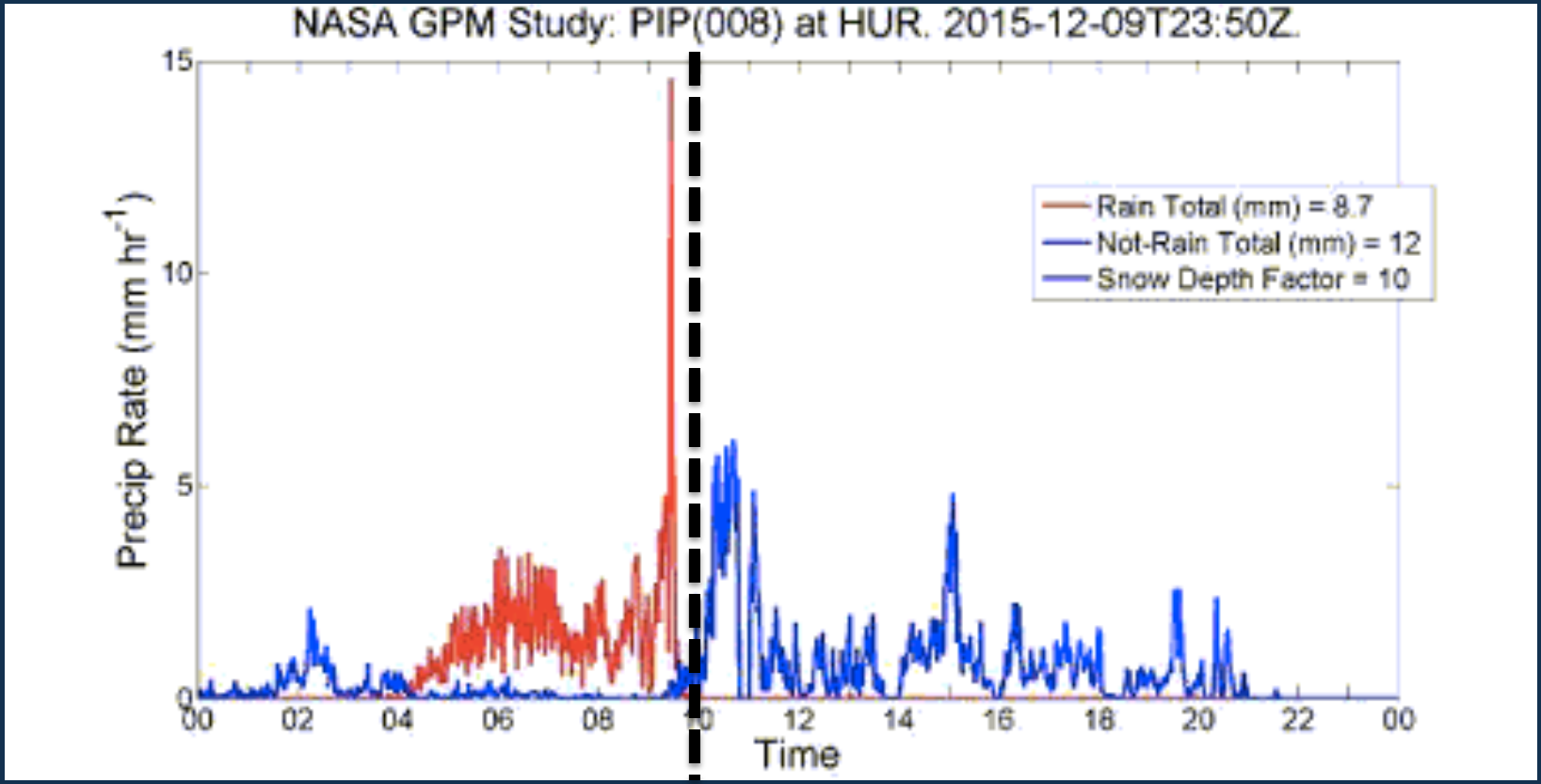


Particle Imaging

- **Particle Imaging Probe (PIP)**
  - Developed for aircraft (high winds)
  - Particle Video Imaging: high frame-rate records of grey-scale images
  - Particle size and fallspeed measurements (snow)

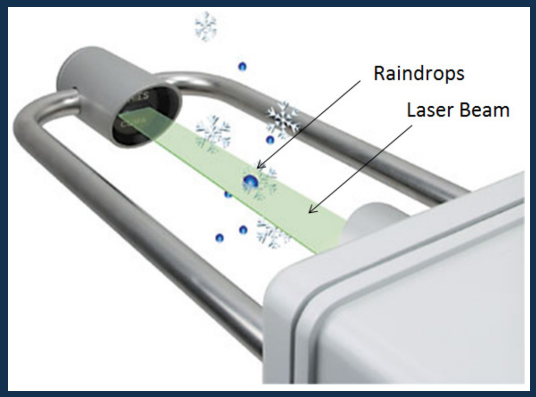


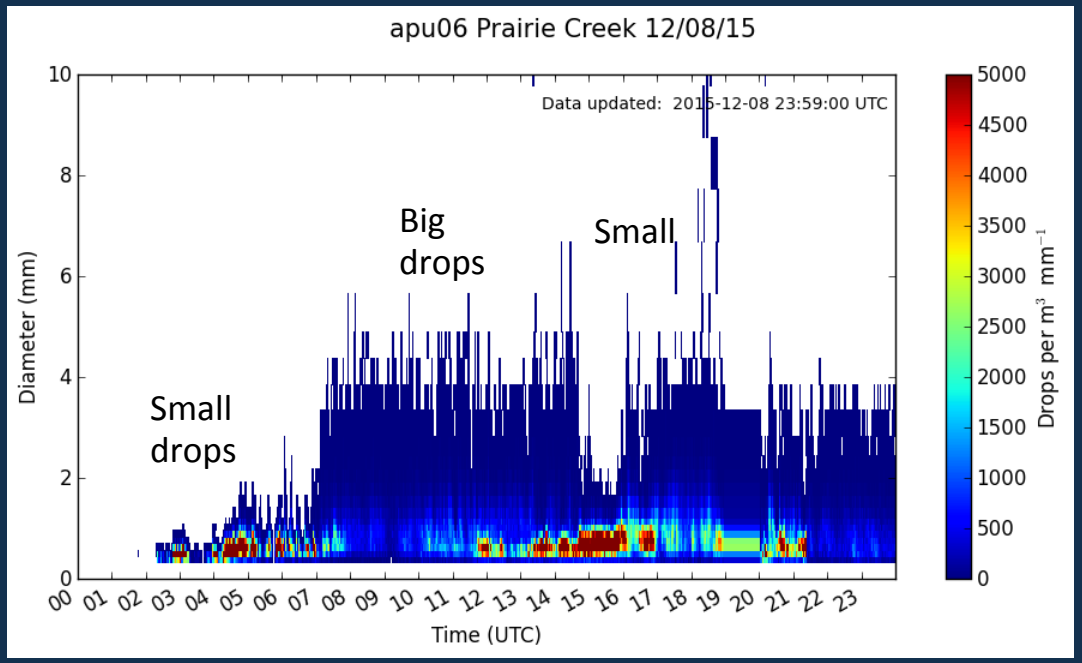
Transition from rain to snow

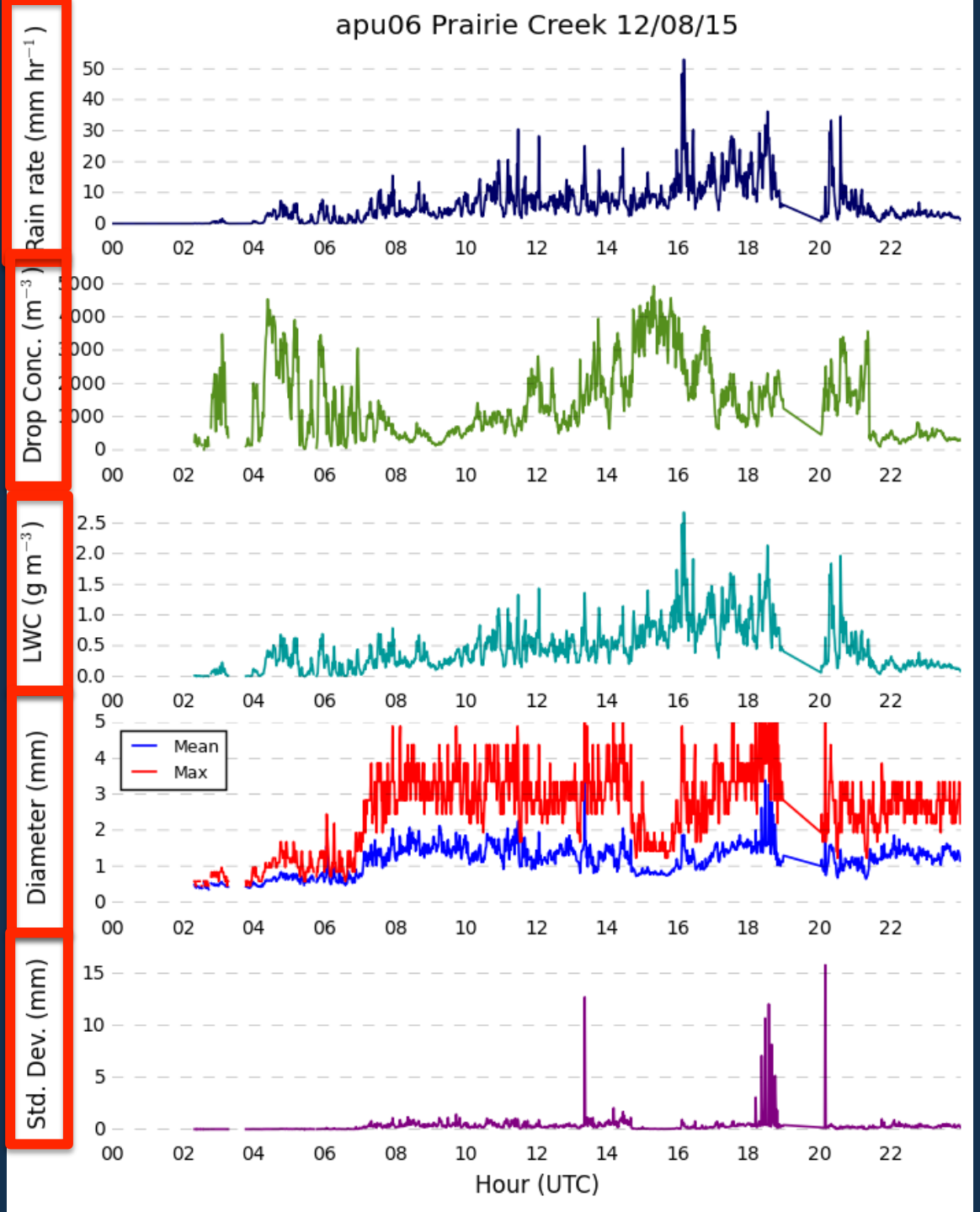


Parsivel (PARticle SIze and VELocity)

- **Size and fall speed**
- Measures reduction in the voltage and duration of signal loss



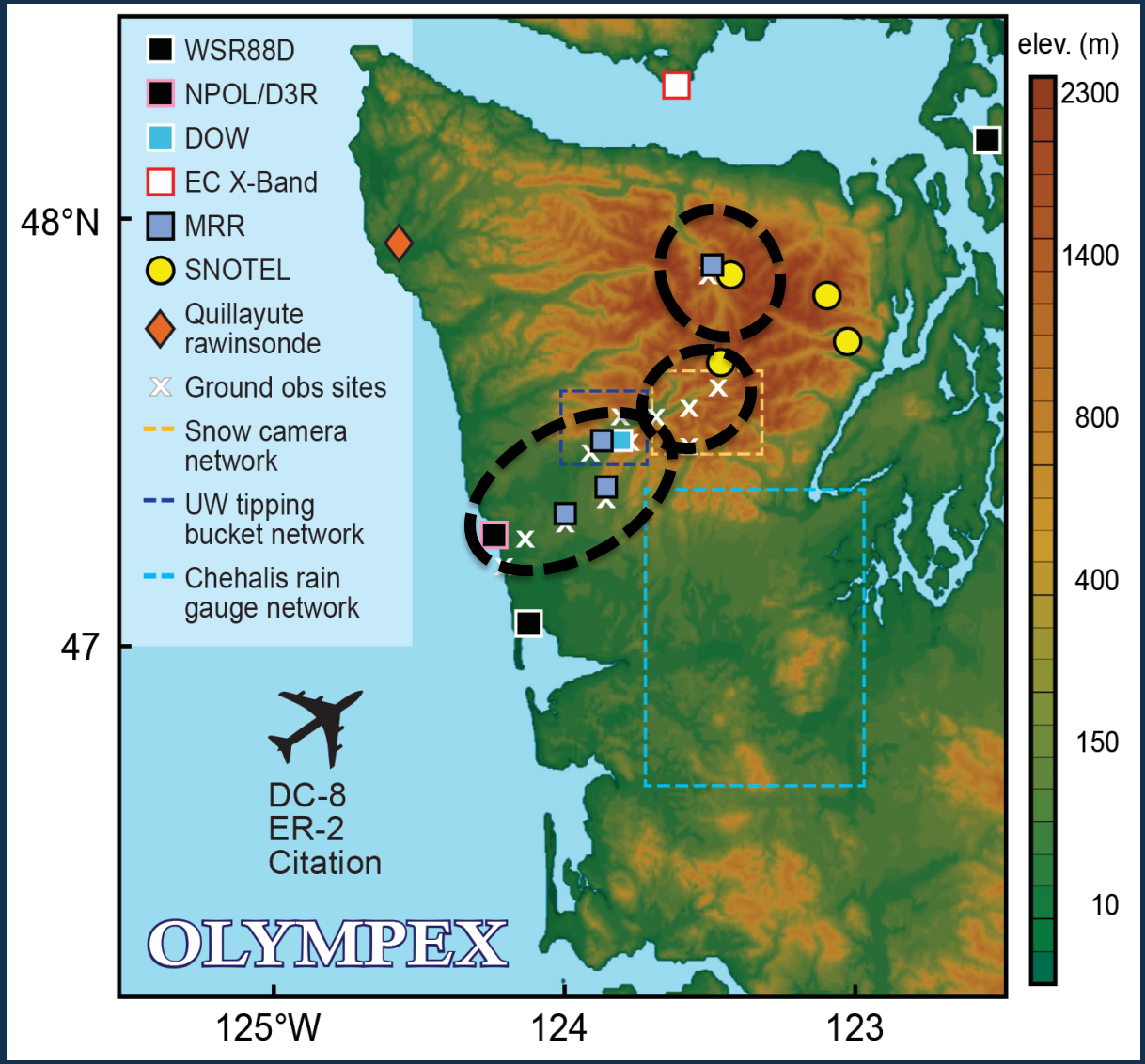



apu06 Prairie Creek 12/08/15
Rain rate (mm hr^{-1})
Drop Conc. (m^{-3})
LWC (g m^{-3})
Diameter (mm)
Mean
Max
Std. Dev. (mm)
Hour (UTC)

Ground instruments

Tipping (single and dual) bucket rain gauges

Ground Instrument Network

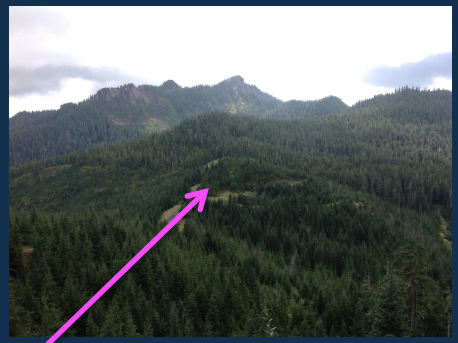


Ground instruments

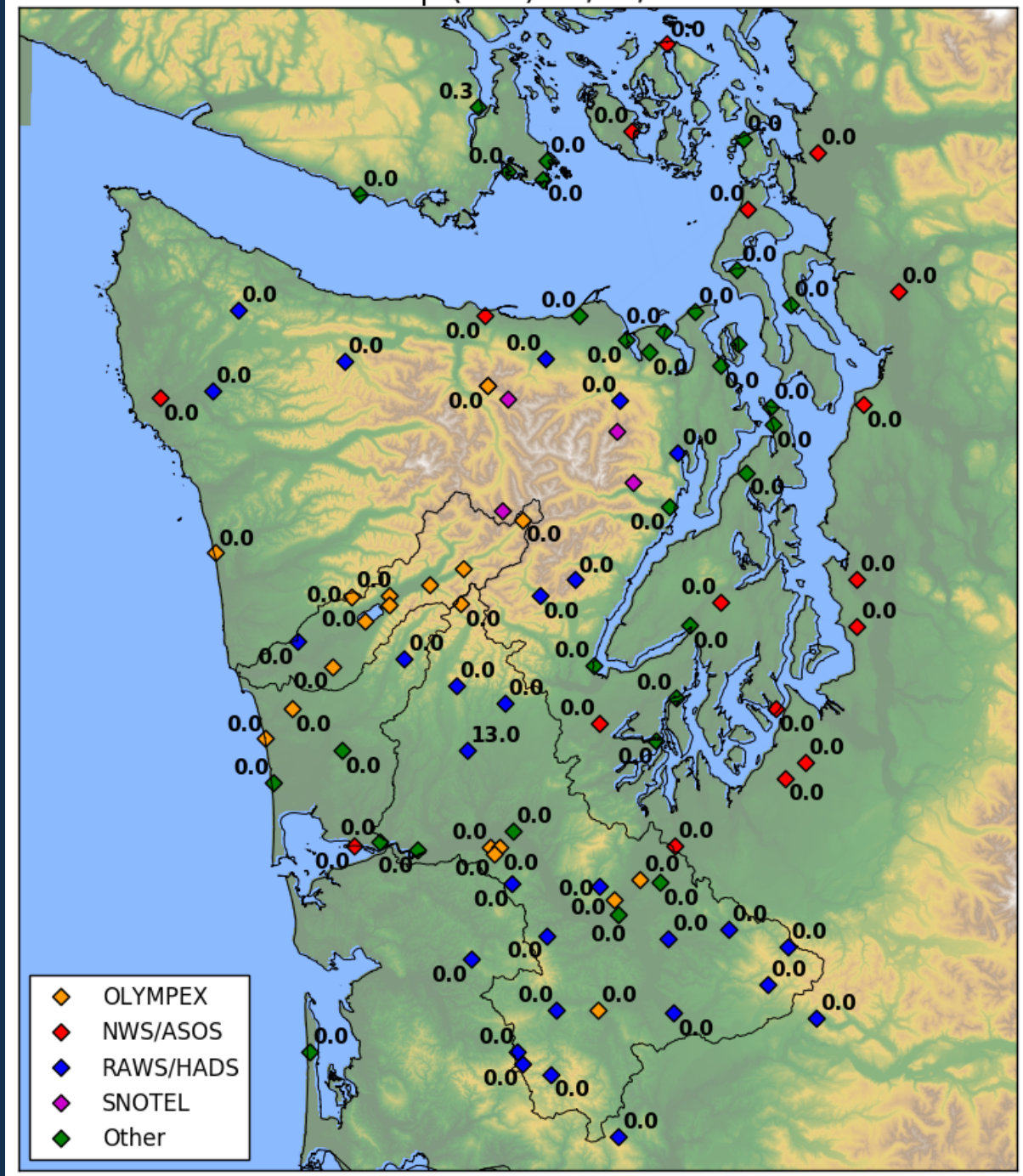
Pluvio – Weighing rain gauge for rain/snow

Parsivel – measures rain/ snow characteristics

Powered by 8 batteries and solar panels



Placed instrumented trailer at high elevation location (>3000') through spring


OLYMPEX 24-hour Precip (mm) 04/17/16 00:00 - 23:59 UTC
OLYMPEX
NWS/ASOS
RAWS/HADS
SNOTEL
Other

Summary

- Multi-frequency, dual-polarization, Doppler **radar**
  - Windward, leeward
  - Microphysical processes (dynamical context)
  - Rainfall estimation
- Ground instrument network
  - Drop size distribution, rain rate
  - Snow particle size, fallspeed
  - Rain totals
- Snow measurements…


Thank you!
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