The OLYMPEX Ground Validation Campaign: Perspectives from a Graduate Student in the Field

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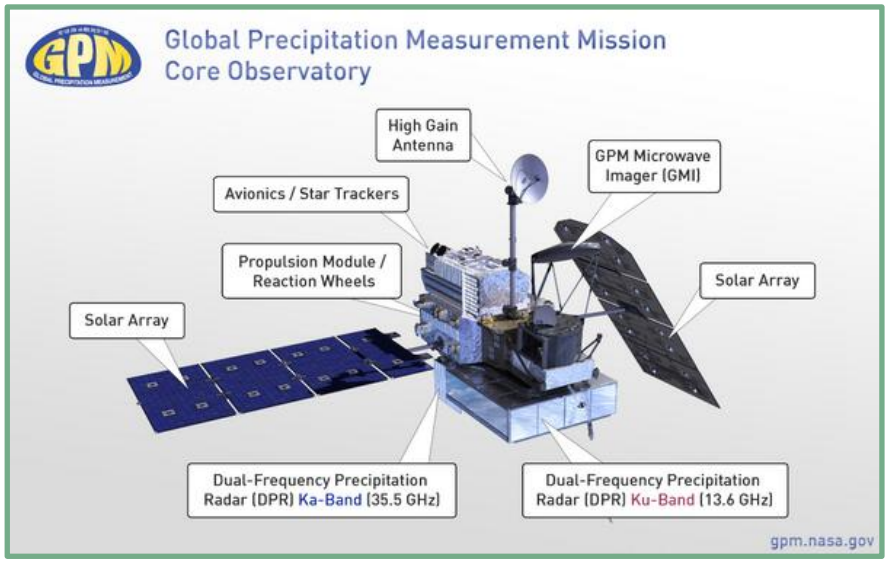
ATM 220

2 May 2016

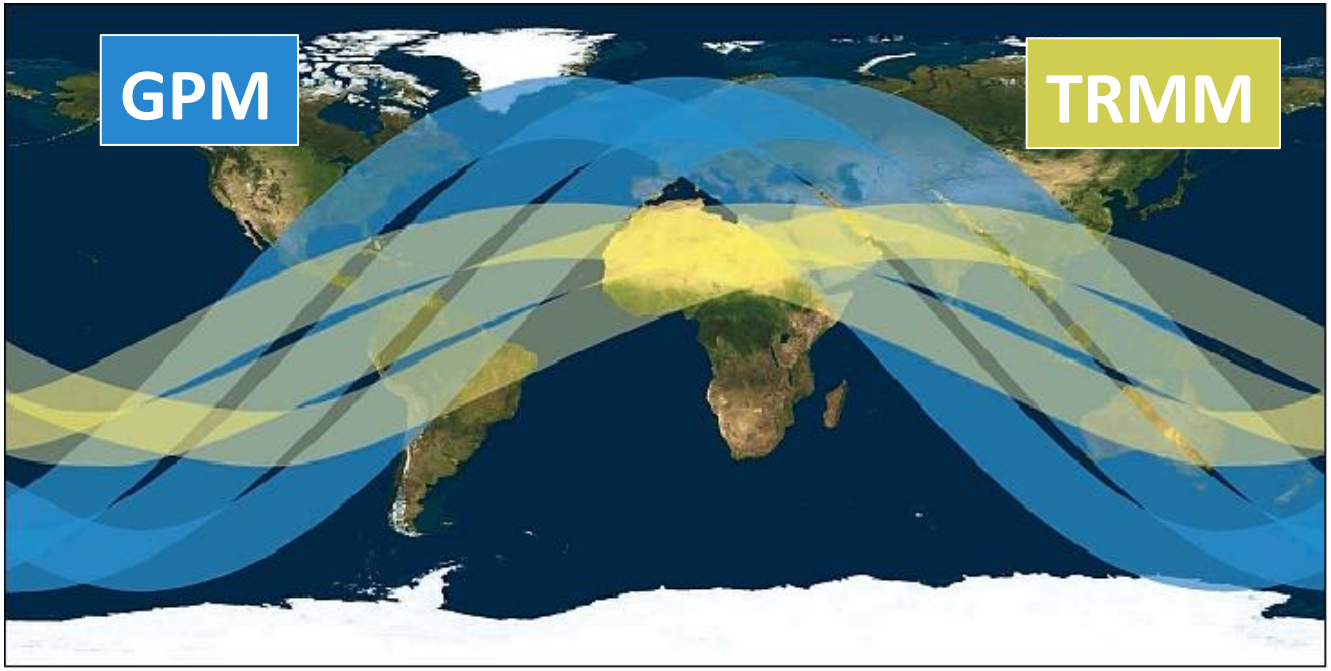
What is OLYMPEX?

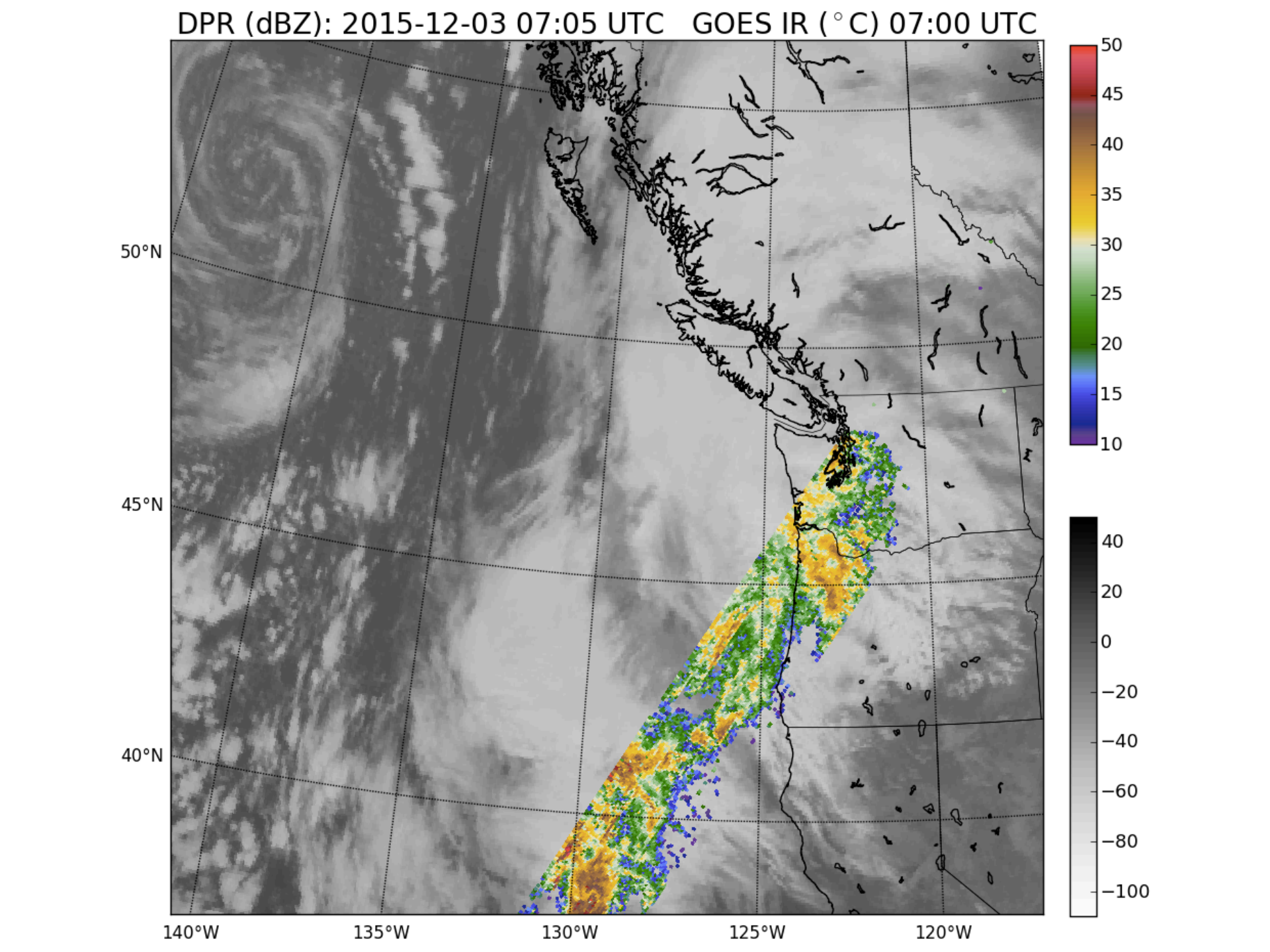
- Funded by NASA to validate measurements from the GPM satellite (launched Feb 2014)
- Last in a series of 6 campaigns taking place across the world (Iowa, North Carolina, Oklahoma, Ontario, Finland)
- Tools for ground validation include aircraft measurements, radars, and ground instruments



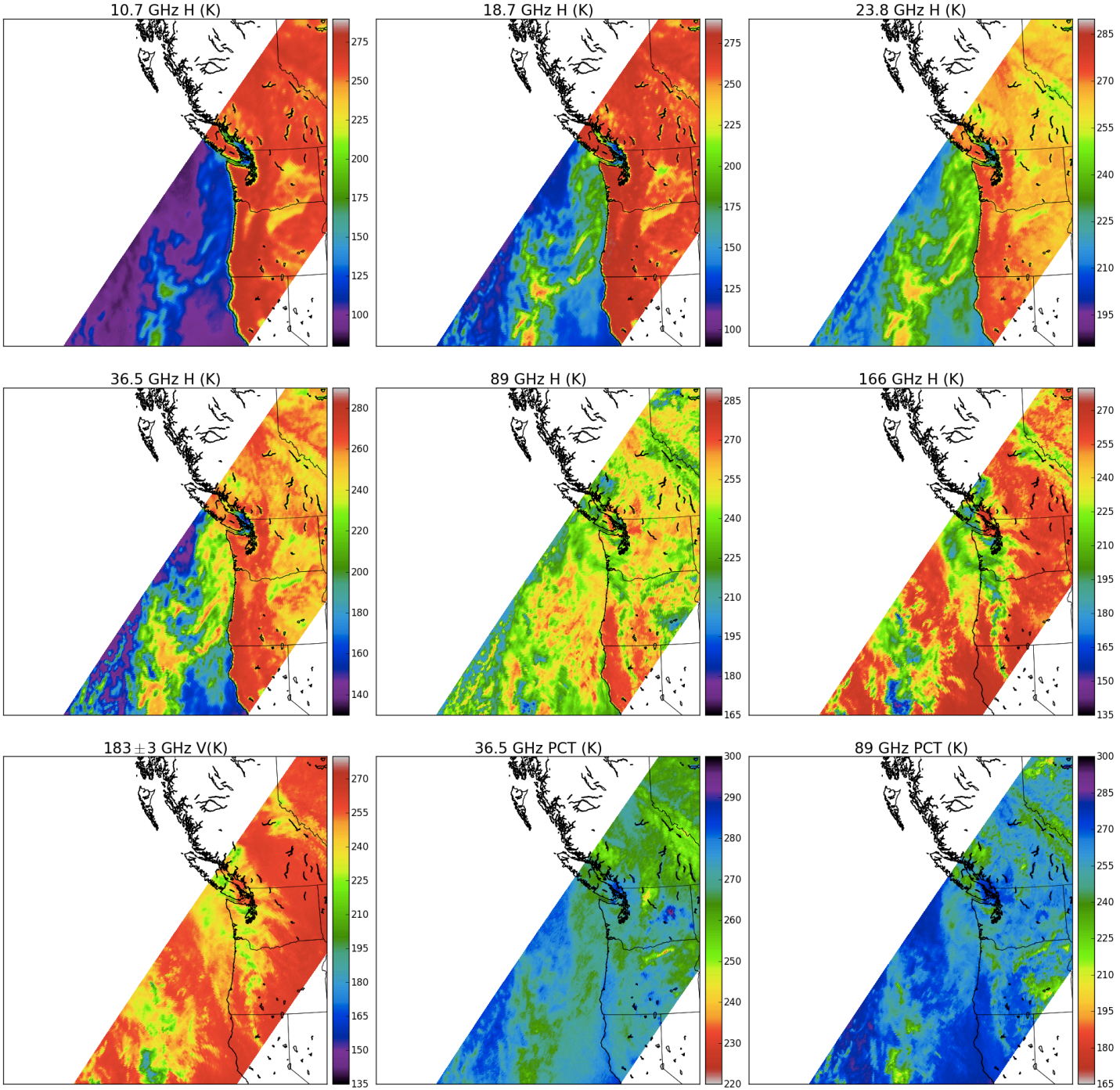
Why in the Pacific NW?

- Unlike its predecessor (TRMM), GPM's orbit extends into mid and high latitudes. This introduces new challenges for measuring precipitation (e.g. frontal cyclones, snow)



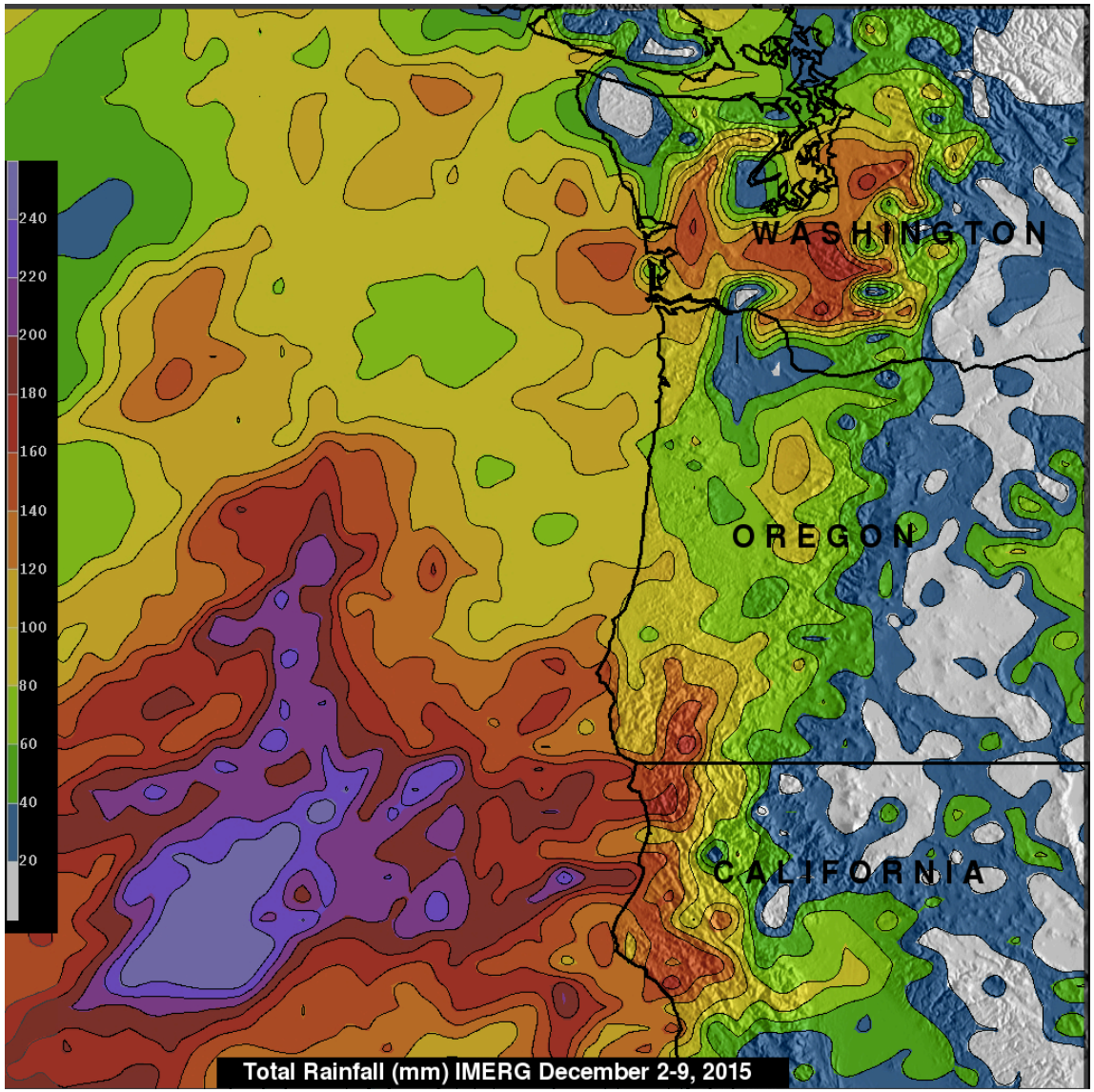

DPR (dBZ): 2015-12-03 07:05 UTC
GOES IR (°C) 07:00 UTC
50°N
45°N
40°N
140°W
135°W
130°W
125°W
120°W
50
45
40
35
30
25
20
15
10
40
20
0
−20
−40
−60
−80
−100

OLYMPEX GMI Tb 2015-12-03 07:08 UTC



GPM's most used product is called IMERG

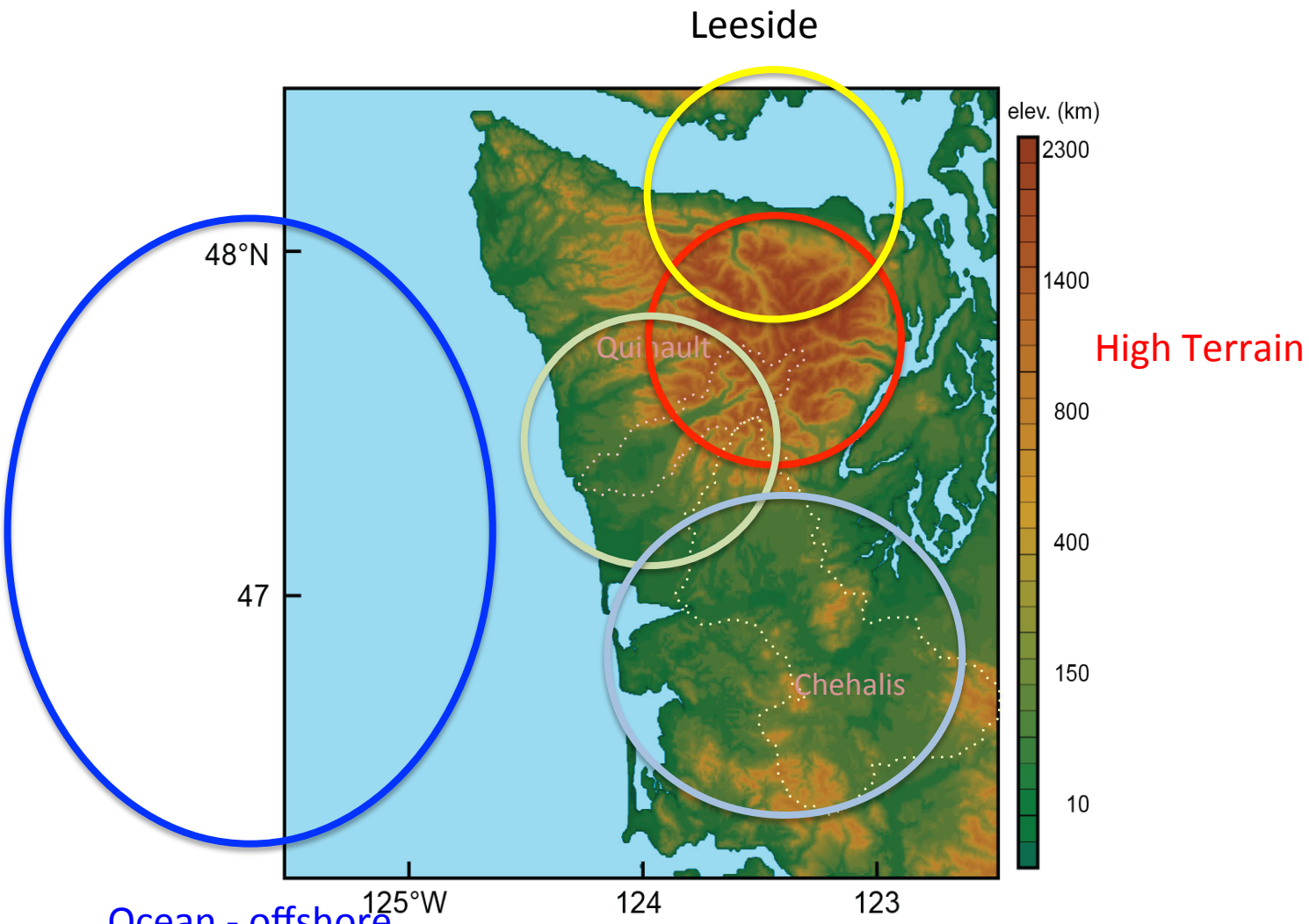
- Combination of rainfall estimates from all available satellites and rain gauges
- Really bad over mountains!!!



OLYMPEX Goals

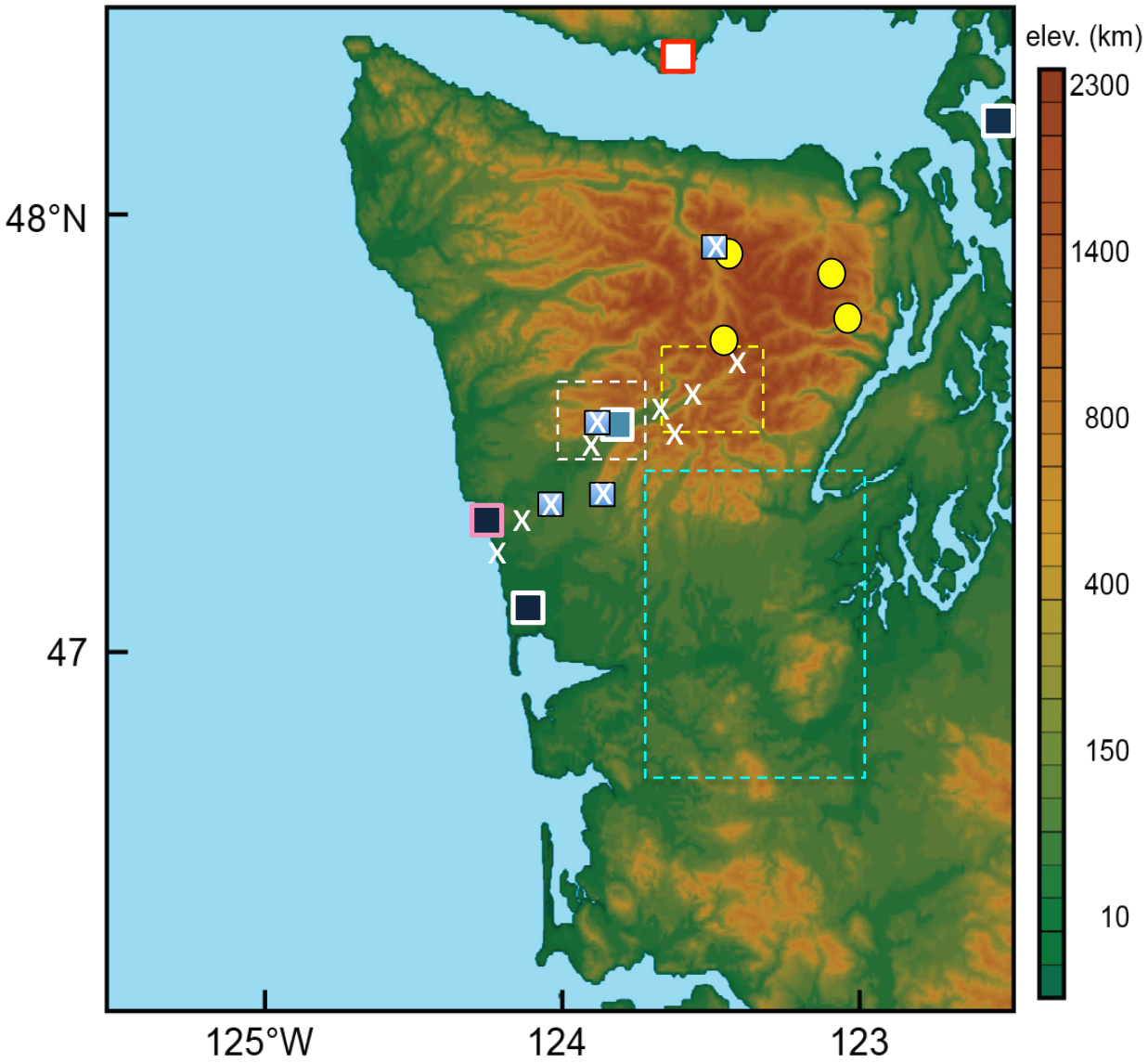
- **Physical validation** of the precipitation (rain and snow) algorithms for both the GMI and DPR.
- How precipitation mechanisms in **all sectors of midlatitude frontal systems** and their **modification by terrain** affect GPM rainfall estimation uncertainties.
- Quantifying the accuracy and uncertainty 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.

Geographical Regions



High Terrain

Site Locations



Radars

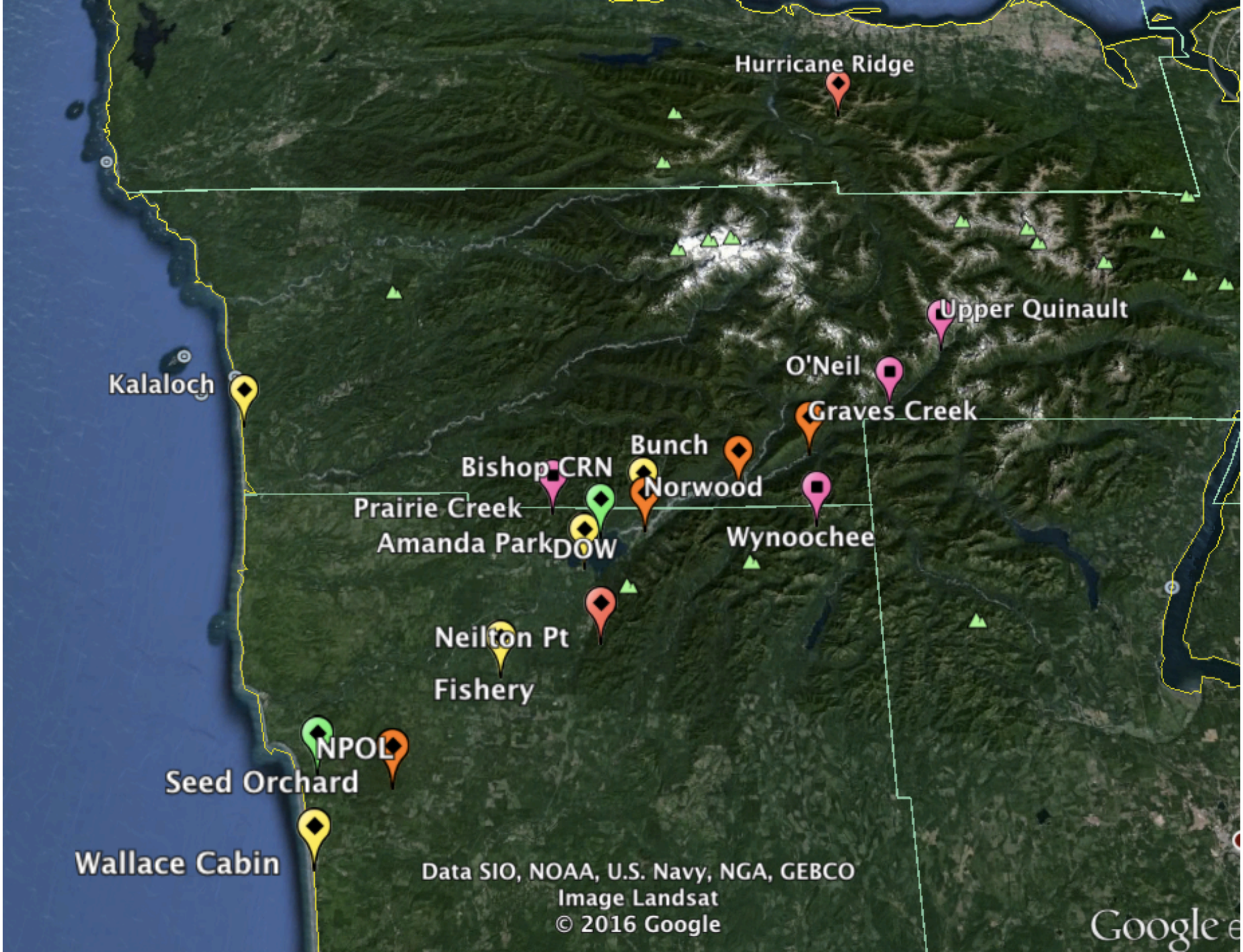
NPOL (above):
Vertical (RHI) scans over ocean and up Quinault valley

DOW (right)
Positioned on Lake Quinault, sees higher-resolution and under lowest NPOL scan

Environment Canada also had a radar on Vancouver Island

Choosing ground sites

- 12-15 ground sites ranging from the coast to interior, both low and high elevation
- Preferred locations should have:
  - Easy access
  - Grid power (for certain instruments)
  - Cell communications for real-time monitoring
  - Open field but not too exposed to wind
  - Within range of ground radars
  - Permission from site owners (USFS, NPS, WSDOT, Quinault Indian Nation, State Patrol, Fish/Wildlife Service, private owners)

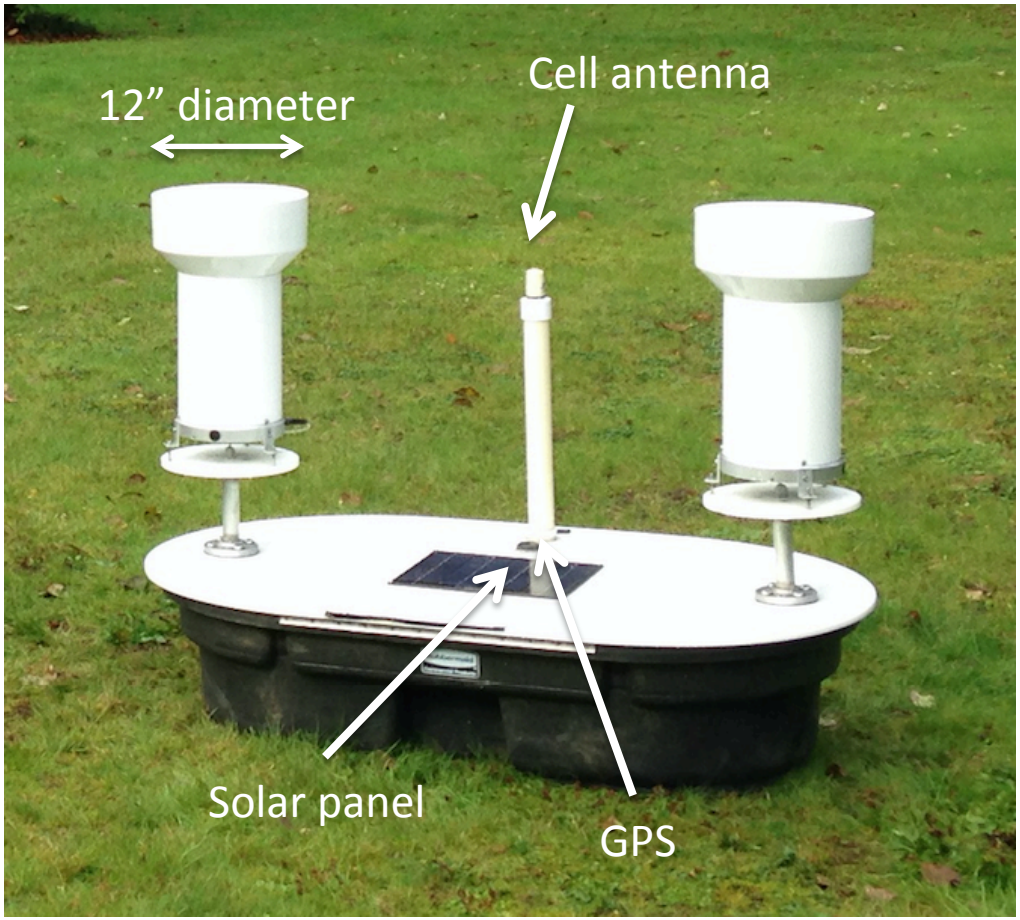

Hurricane Ridge
Upper Quinault
O'Neil
Kalaloch
Graves Creek
Bunch
Bishop
CRN
Norwood
Prairie Creek
Amanda Park
DOW
Wynoochee
Neilton Pt
Fishery
NPOL
Seed Orchard
Wallace Cabin
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
© 2016 Google
Google

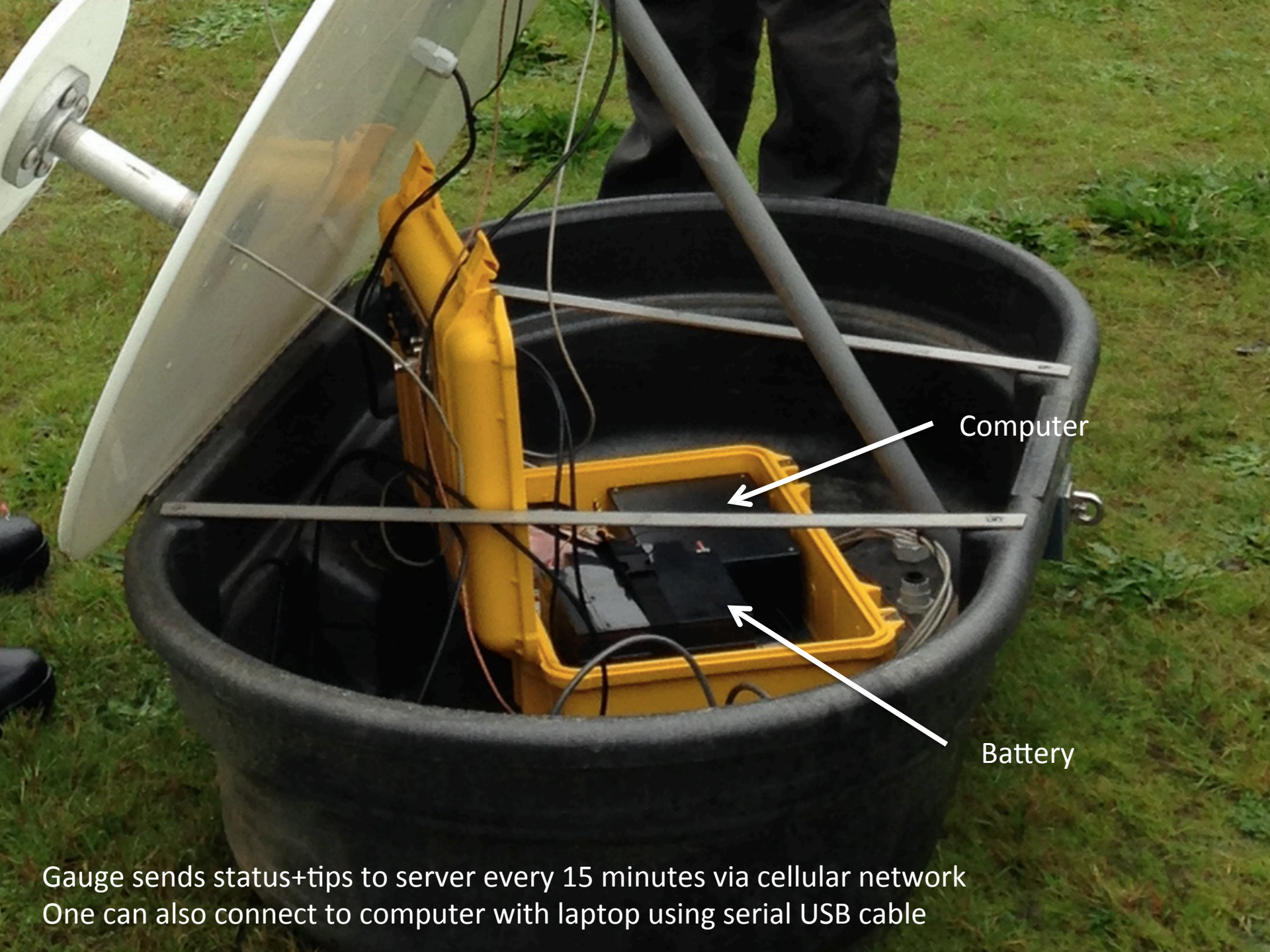
Precipitation measuring instruments (not including radars)

- Tipping buckets
- Weighing buckets (Pluvio)
- Snow poles + time lapse cameras
- Three types of disdrometers:
  - 2D-Video disdrometer
  - Parsivel
  - PIP

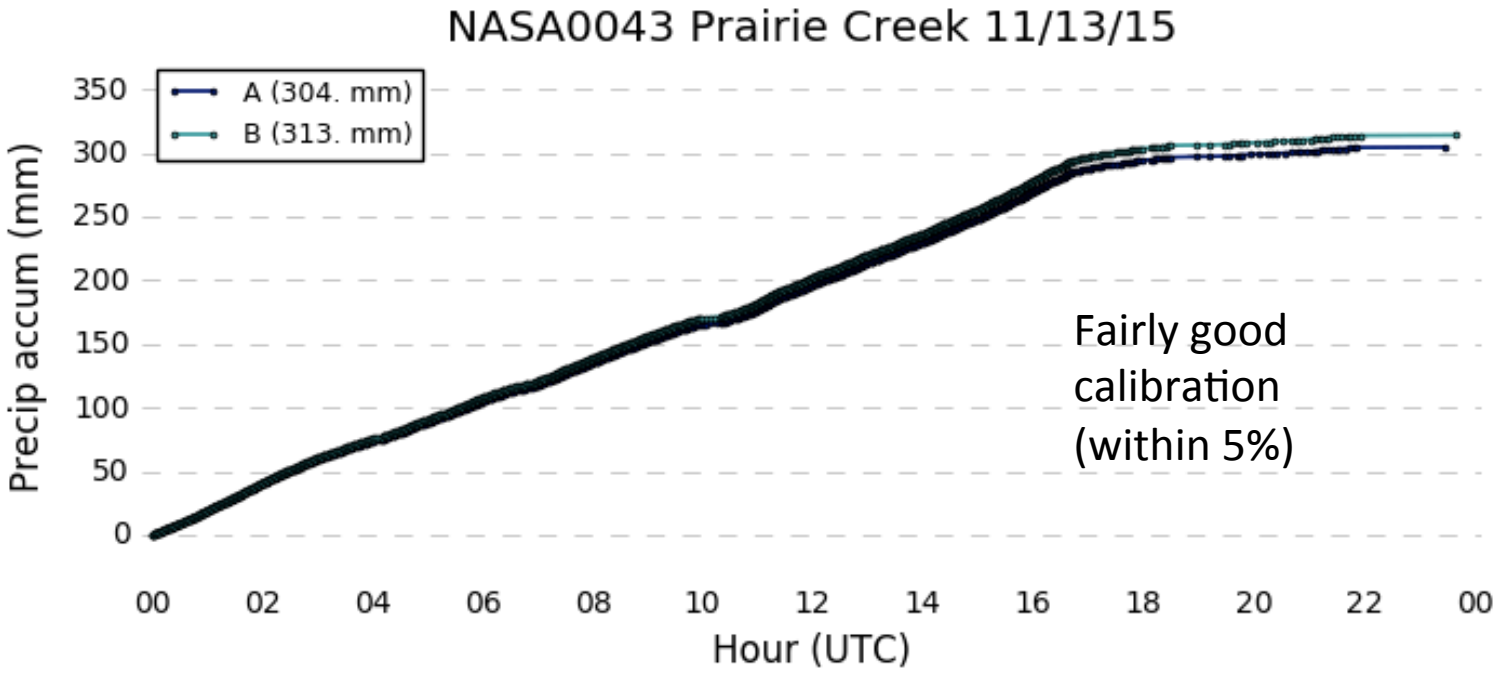
“Iowa” Dual Tipping Buckets

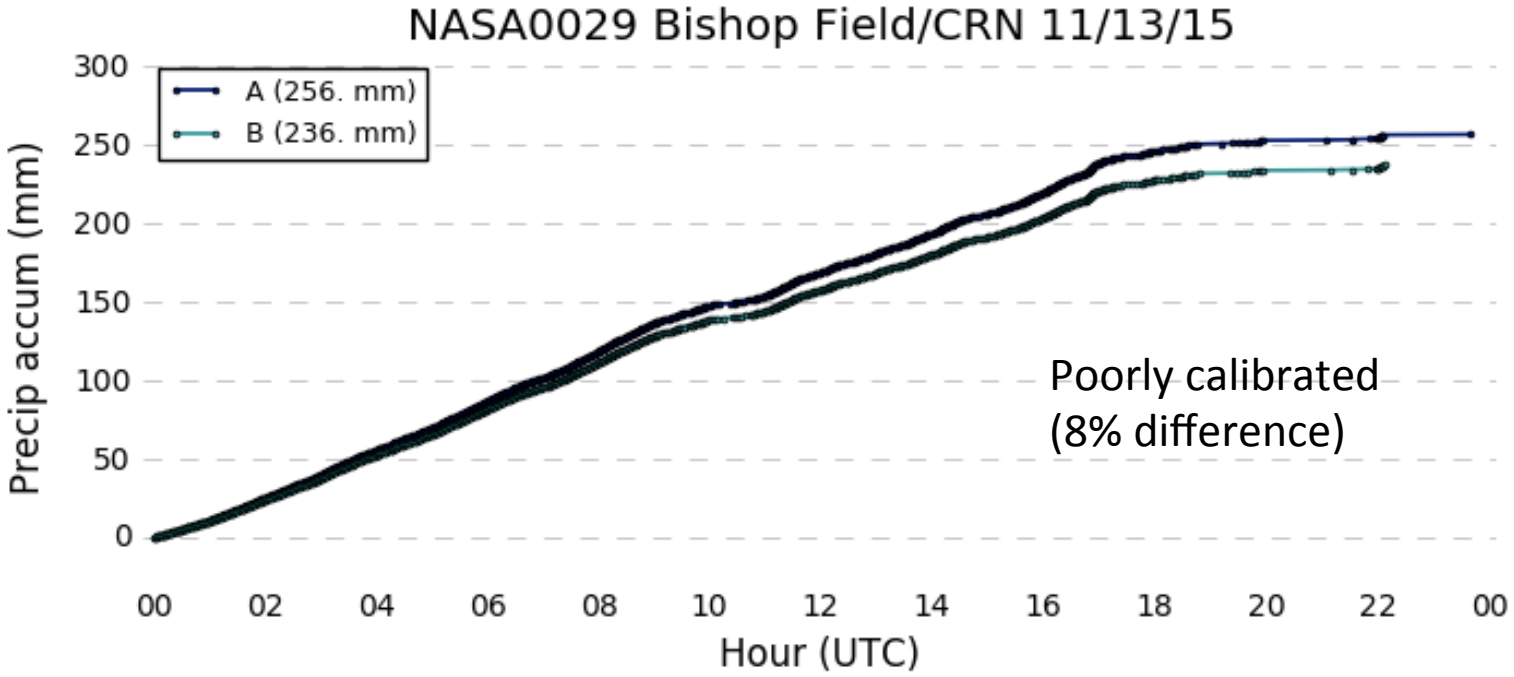
20 deployed:
10 in Quinault basin, 10 in Chehalis





Gauge sends status+tips to server every 15 minutes via cellular network
One can also connect to computer with laptop using serial USB cable


NASA0043 Prairie Creek 11/13/15
A (304. mm)
B (313. mm)
Precip accum (mm)
350
300
250
200
150
100
50
0
00
02
04
06
08
10
12
14
16
18
20
22
00
Hour (UTC)
Fairly good
calibration
(within 5%)


NASA0029 Bishop Field/CRN 11/13/15
A (256. mm)
B (236. mm)
Precip accum (mm)
300
250
200
150
100
50
0
00
02
04
06
08
10
12
14
16
18
20
22
00
Hour (UTC)
Poorly calibrated
(8% difference)

Standard tipping bucket gauges

- For areas without cell coverage
- Cheaper, easier to deploy than Iowa platforms
- Deployed in sets of 2

What about snow?

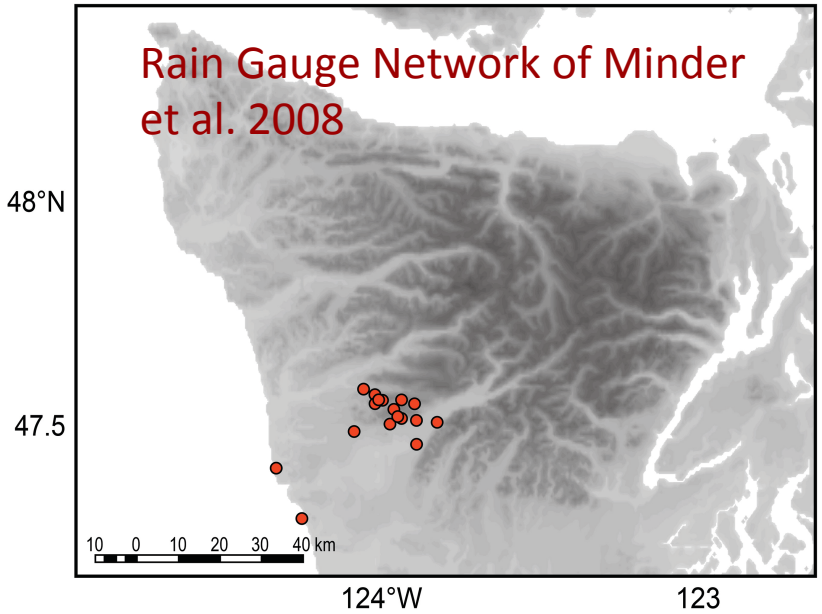
Low-elevation snow in late December

Could just let this tip out as it melts, but then future events will be overestimated

We also don't know how much snow missed the gauge

Thaw/refreeze cycle can knock gauge off calibration

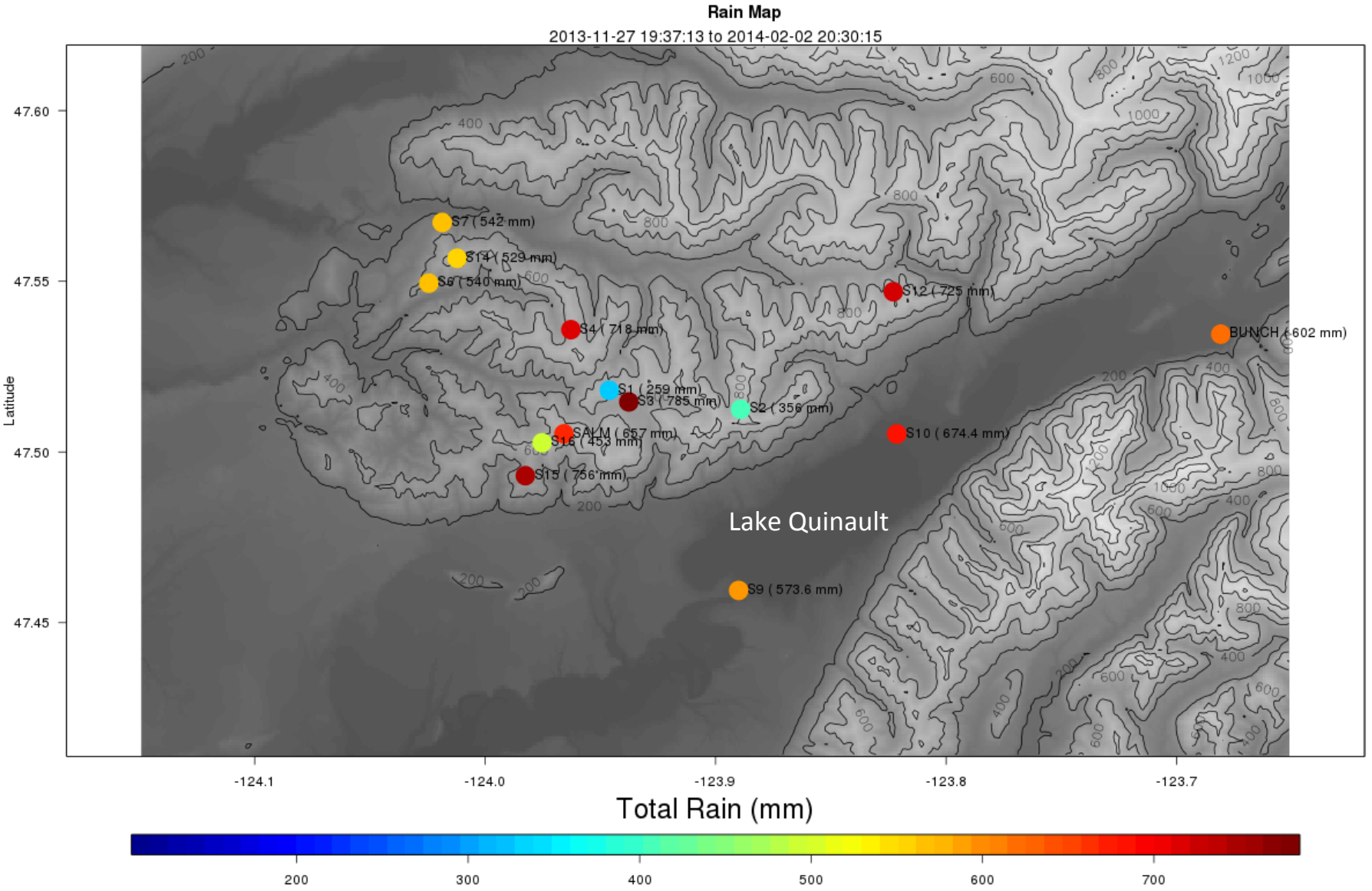
“Snow” tipping buckets



Tall bucket made from giant PVC pipe

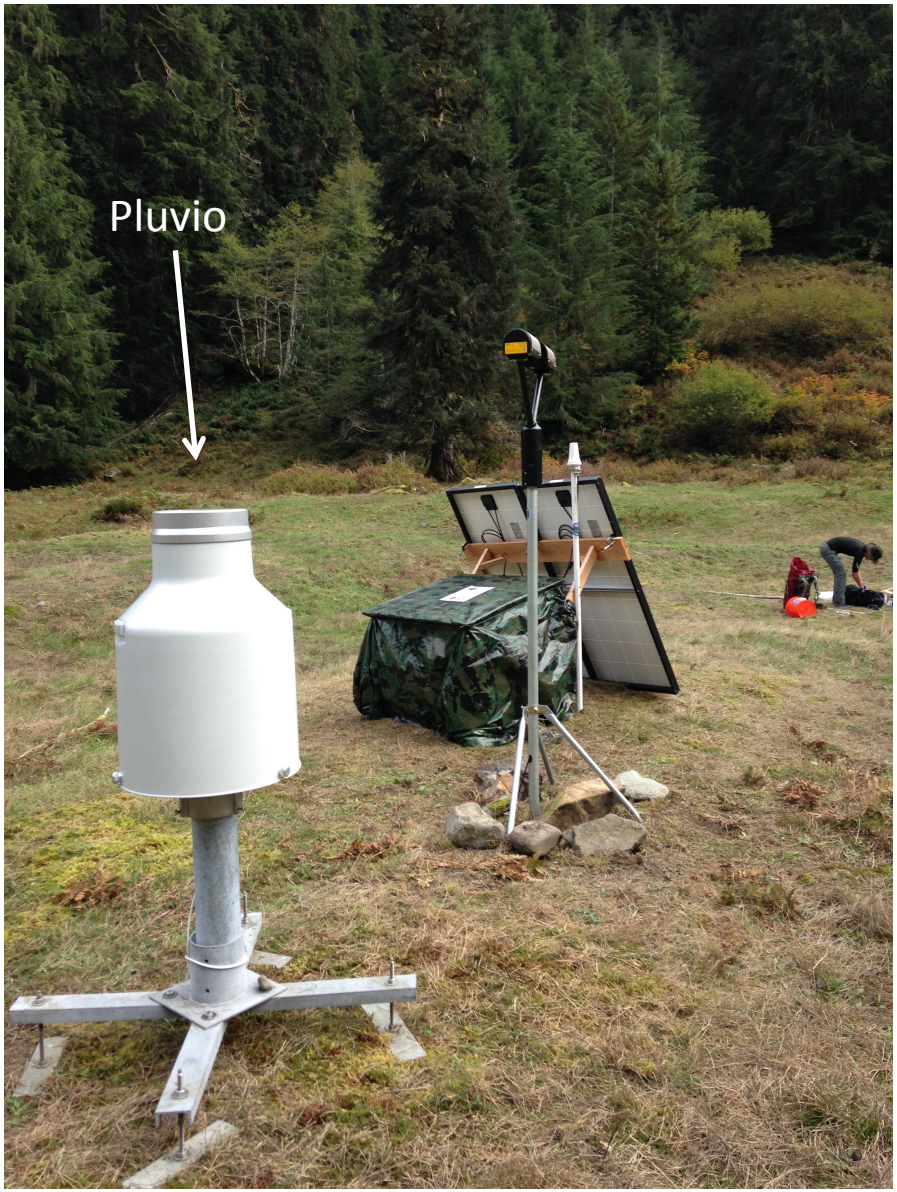
Tube connects to tipping bucket in side panel

Bucket collects up to 4 feet of snow and tips it out when it gets warmer



- Questionable accuracy, sometimes knocked over by wildlife, sometimes damaged by freeze/thaw cycle
- Others have disappeared (lots of bored locals driving around the logging roads)
- One killed a bird last year

Pluvio (weighted bucket)

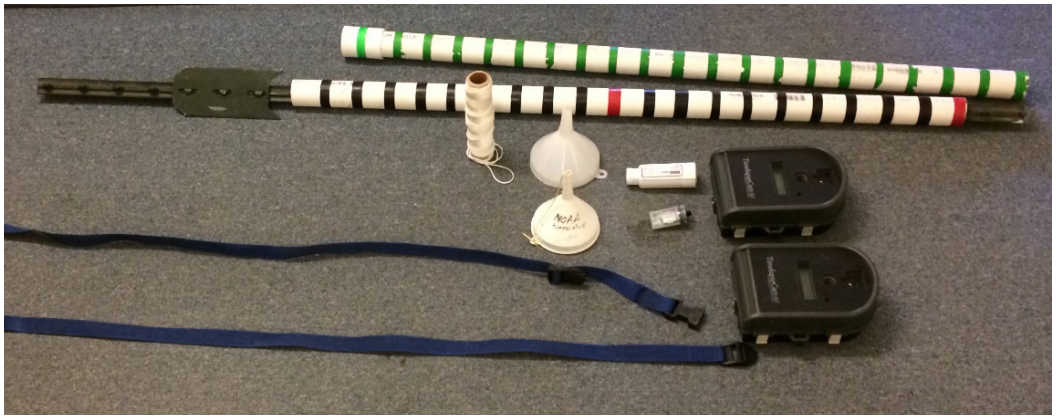


- Bucket on an extremely sensitive scale
- Accurate to 0.001 mm
- Heated rim
- Antifreeze solution melts snow

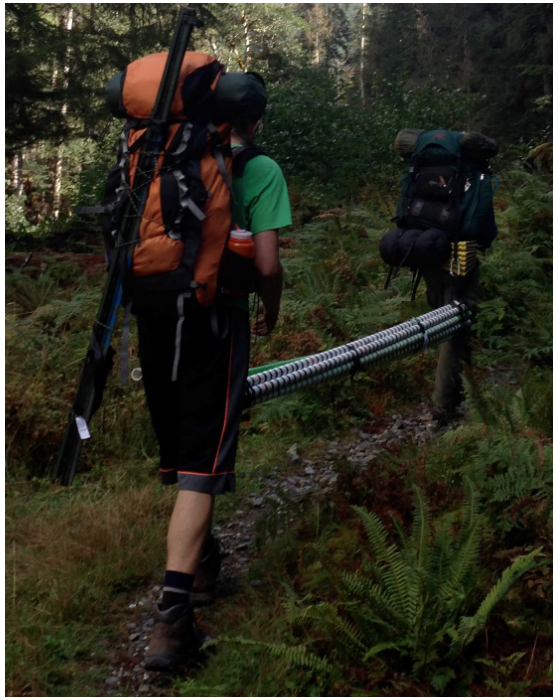
- Antifreeze mix is nontoxic but needs to be packed out of wilderness
- Requires someone to empty the bucket every 20-25” of precip

- Heater must be turned off when using battery power. Snow sometimes accumulates on rim and drops into bucket in chunks

Snow Cameras



- Designed by Jessica Lundquist (UW hydrology)
- PVC pipes with duct tape lines
- Wildlife cameras take photo of poles every hour
- Great for snow depth, liquid equivalent has to be estimated

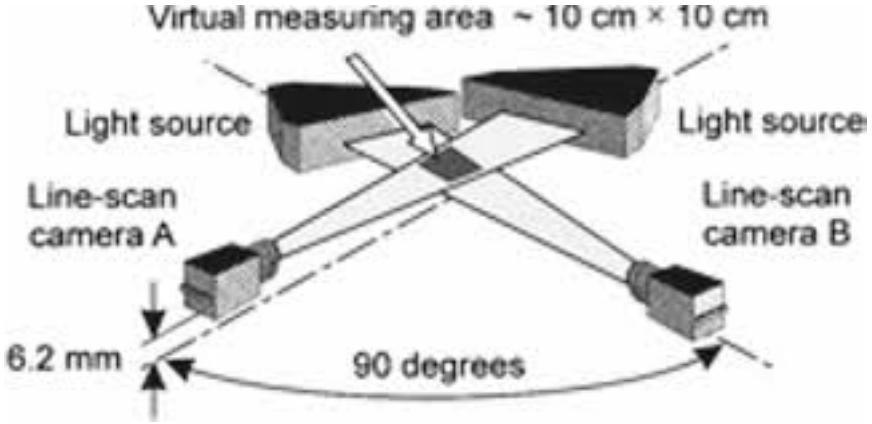


Vandals caught on camera…

What is a Disdrometer?

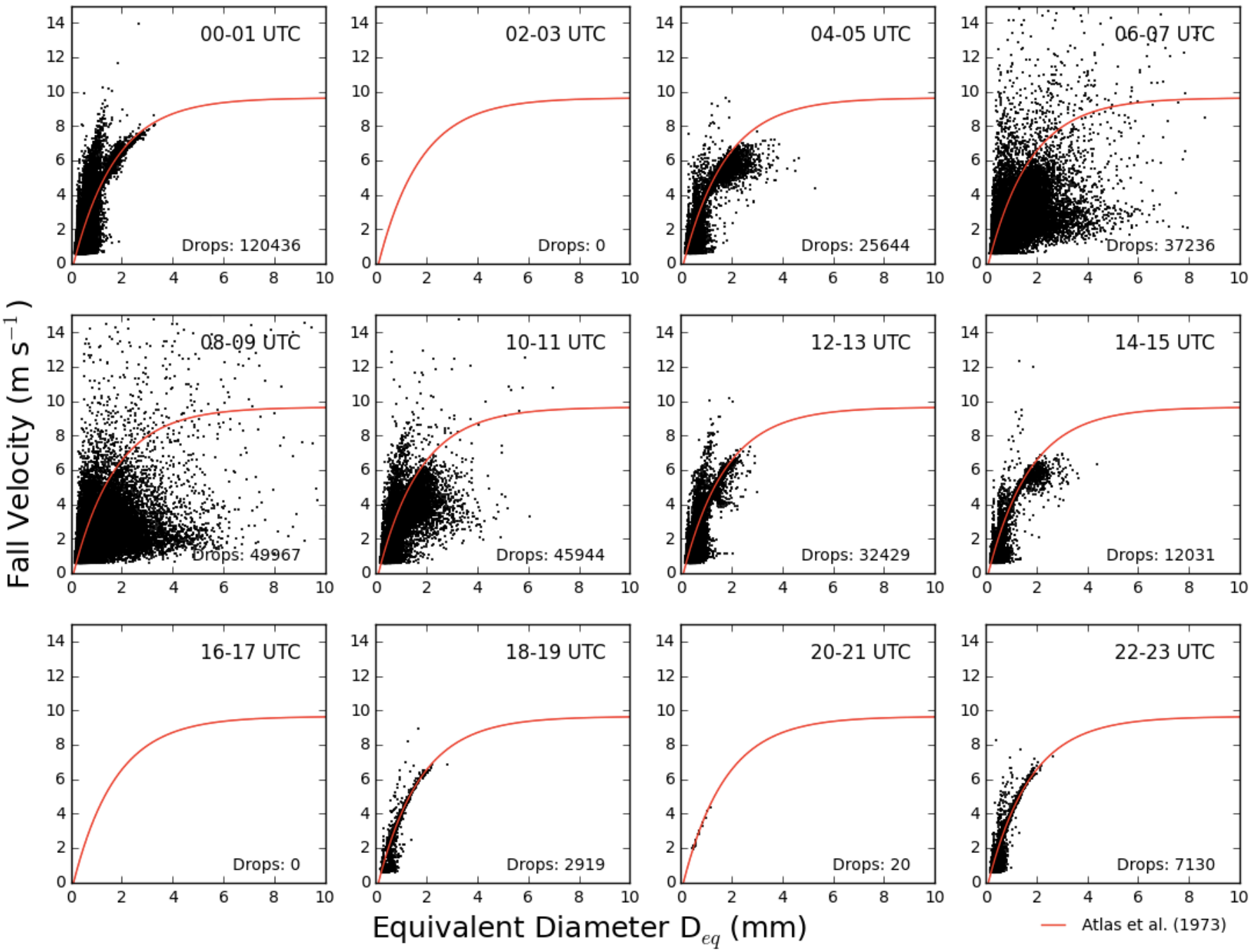
- Device that measures individual rain drops size and fall velocity
- Also can infer rain/snow accumulation, but not as accurately as other methods
- Disdrometer data is valuable because radars measure reflectivity (Z) which is proportional to the 6^{th} power of drop diameter (D). If we know the drop size distribution (DSD), we can calculate rain rate from weather radar or GPM's radar using a Z-R relationship
- The drop size distribution is influenced by the larger synoptic-scale weather, cloud microphysics, and mountains

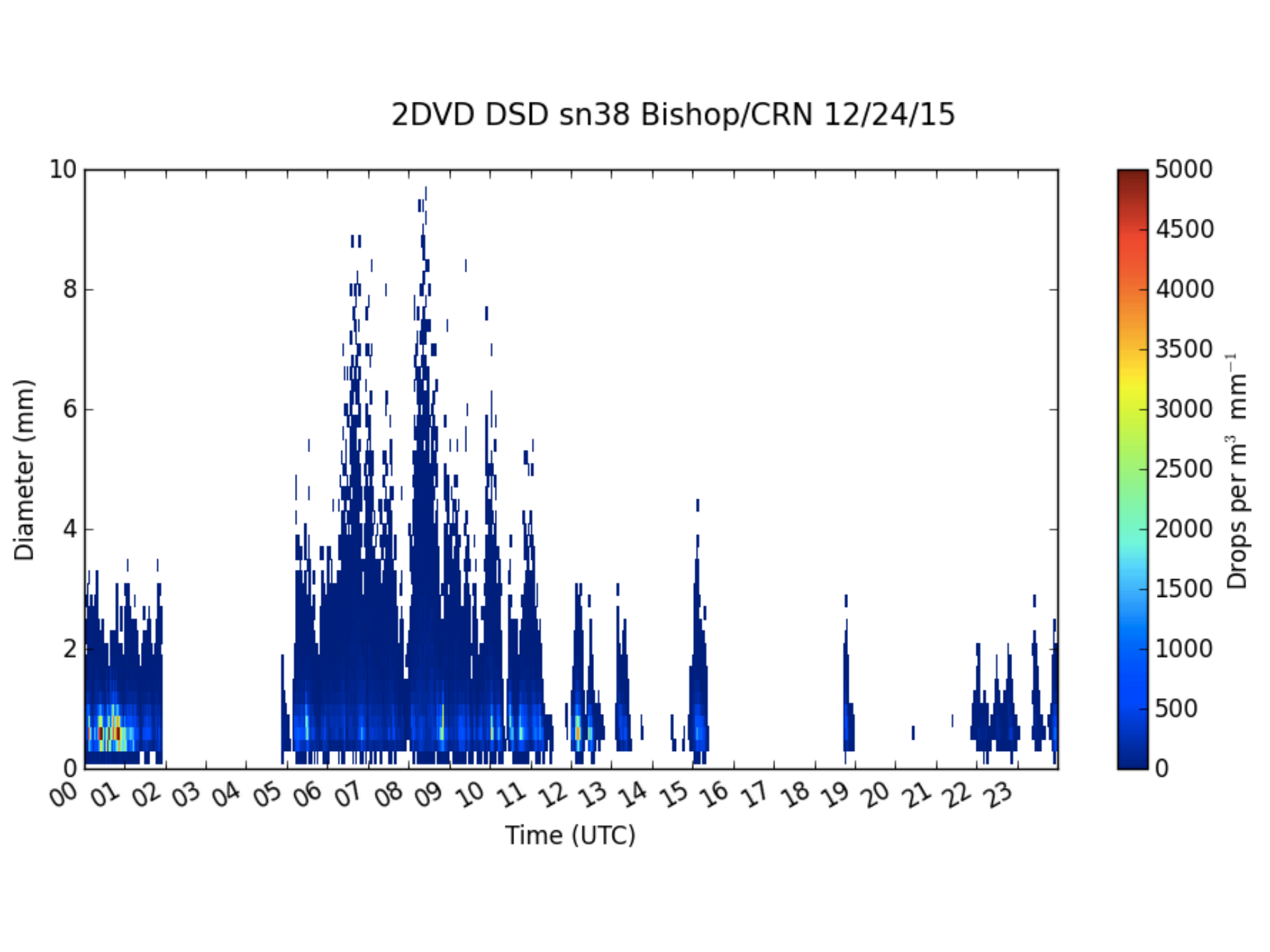
2D-Video Disdrometer (2DVD)

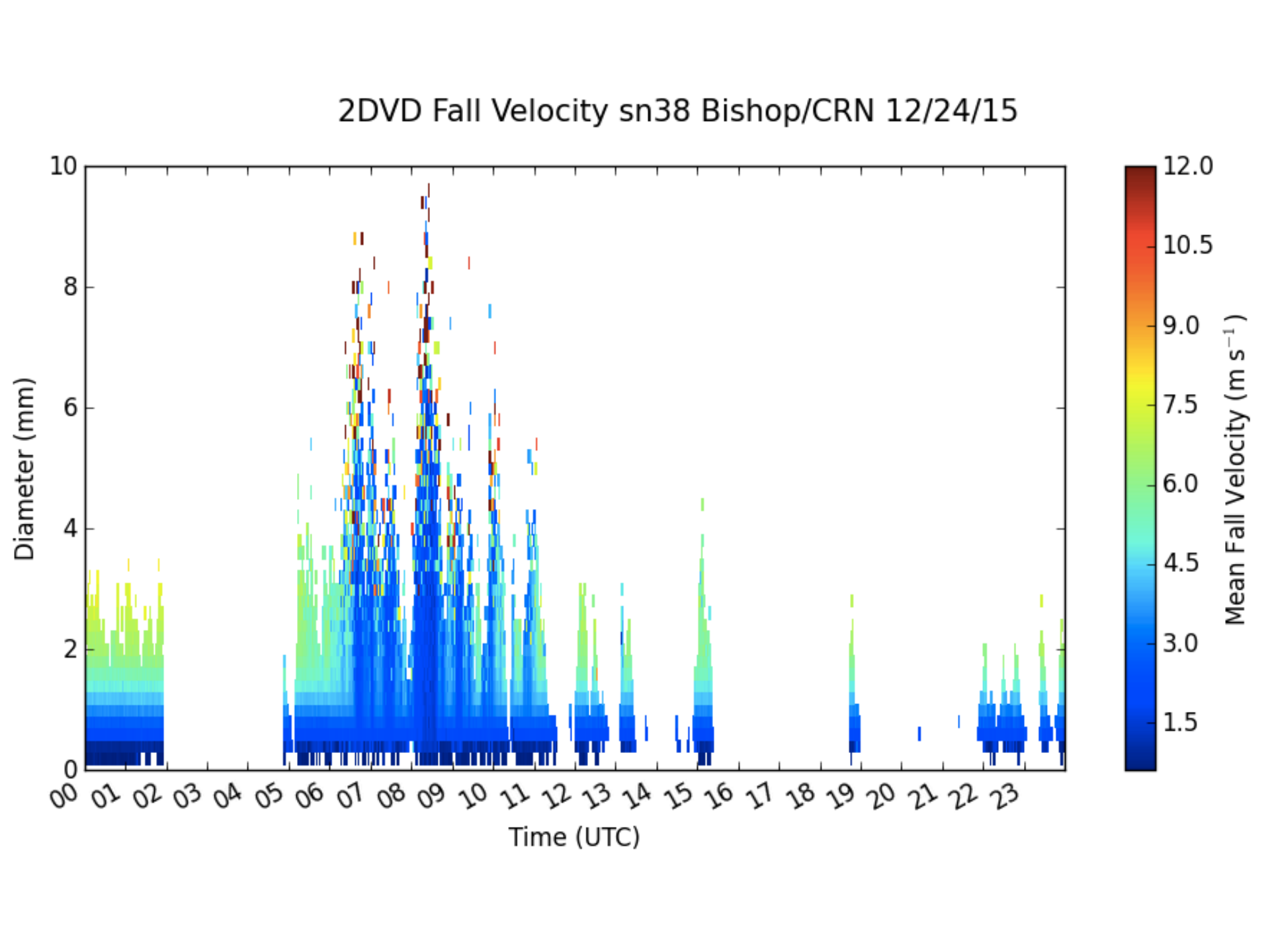


- Two high-speed line cameras offset by 90° and 6.2 mm
- Accurate to D=0.2 mm
- Cost: $100,000
- Requires lots of electricity and babysitting
- 4 deployed in OLYMPEX

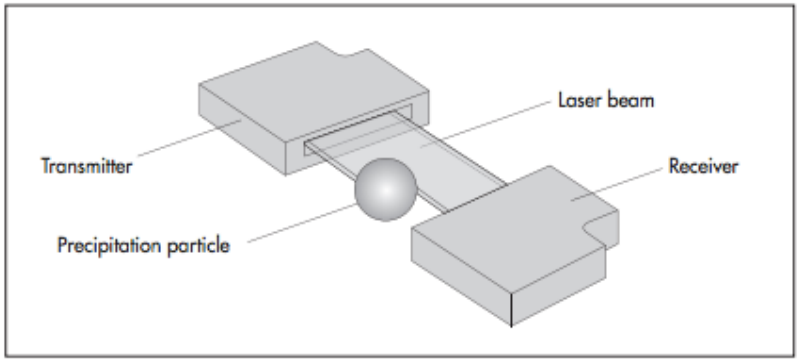
2DVD is calibrated using metal spheres of known diameter


2DVD sn38 Bishop/CRN 12/24/15
00-01 UTC
Drops: 120436
02-03 UTC
Drops: 0
04-05 UTC
Drops: 25644
06-07 UTC
Drops: 37236
08-09 UTC
Drops: 49967
10-11 UTC
Drops: 45944
12-13 UTC
Drops: 32429
14-15 UTC
Drops: 12031
16-17 UTC
Drops: 0
18-19 UTC
Drops: 2919
20-21 UTC
Drops: 20
22-23 UTC
Drops: 7130
Fall Velocity (m s^{-1})
Equivalent Diameter D_{eq} (mm)
Atlas et al. (1973)


2DVD DSD sn38 Bishop/CRN 12/24/15
Diameter (mm)
0
2
4
6
8
10
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Time (UTC)
Drops per m^3 mm^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


2DVD Fall Velocity sn38 Bishop/CRN 12/24/15
Diameter (mm)
0
2
4
6
8
10
00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Time (UTC)
Mean Fall Velocity (m s^{-1})
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0

Parsivel Disdrometer



- Particles pass through sheet laser, fall speed inferred based on time in laser path
- Assumptions:
  - Terminal velocity
  - Spherical drops
  - Drops falling straight down (no wind)
  - Only one drop in laser path at a time
- Measurements are only 1D (bad for snow)
- Cost: $2,000
- Runs on battery + solar power = huge plus for OLYMPEX
- Deployed at 14 ground sites

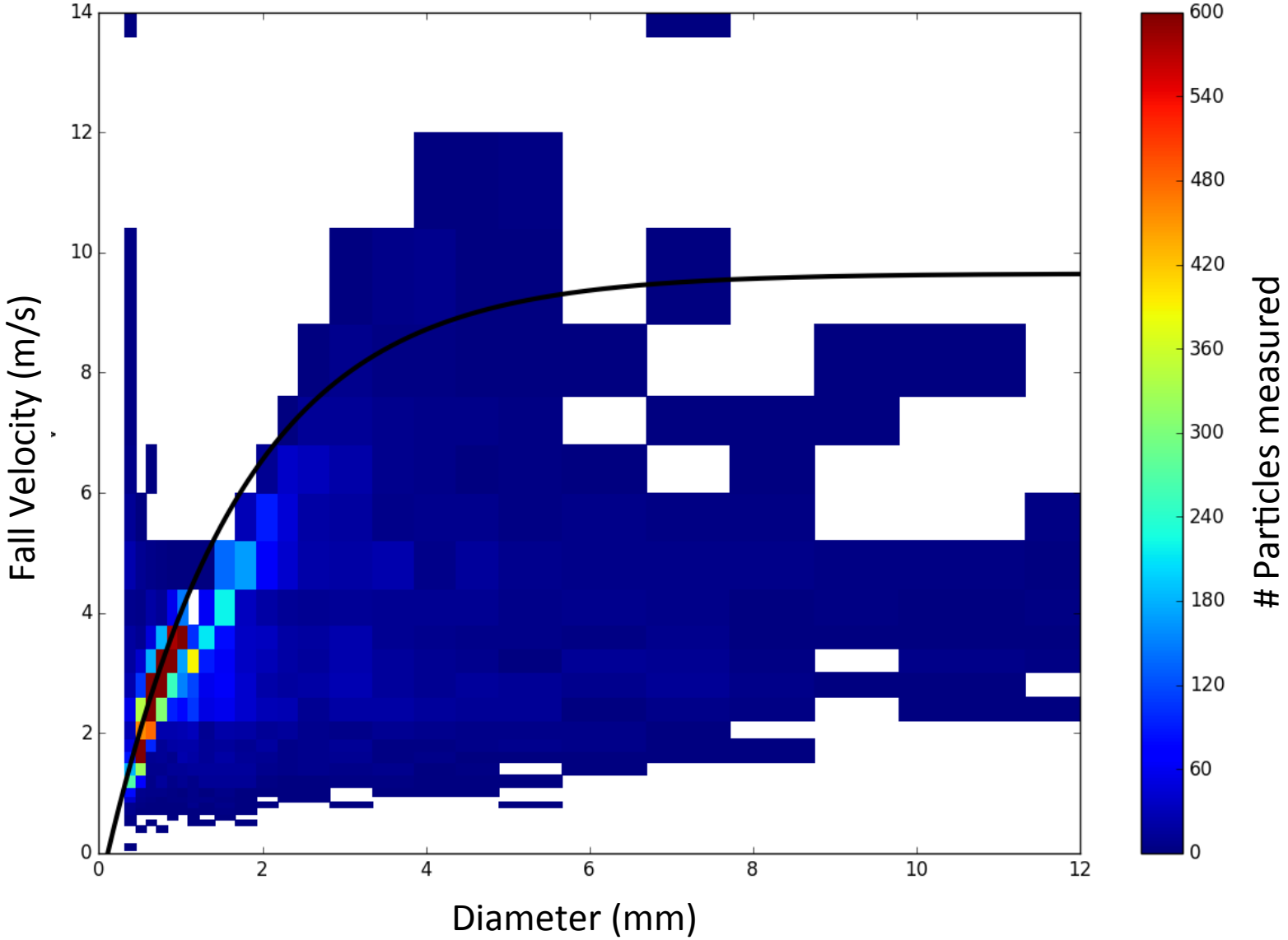
Condensation/splashing: major issue with Parsivels, especially those on battery power

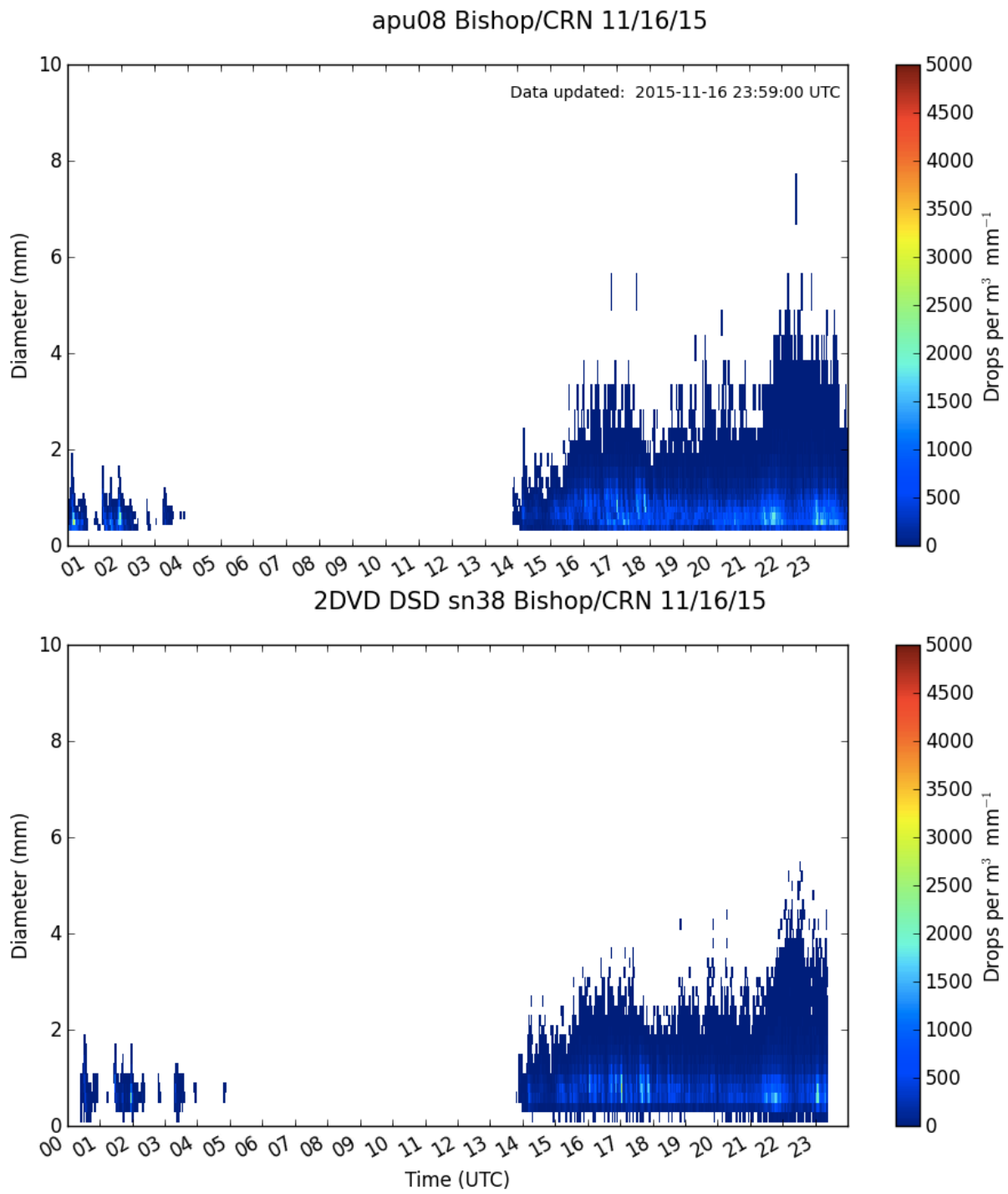
In this image, the condensation is on the INSIDE of the instrument!!!

We were able to mitigate this using silica desiccant packets and waxing the windows, but it remains the #1 problem with Parsivels

Parsivel Diameter vs. Velocity

(precipitation was mixed at this time)





Parsivel DSD

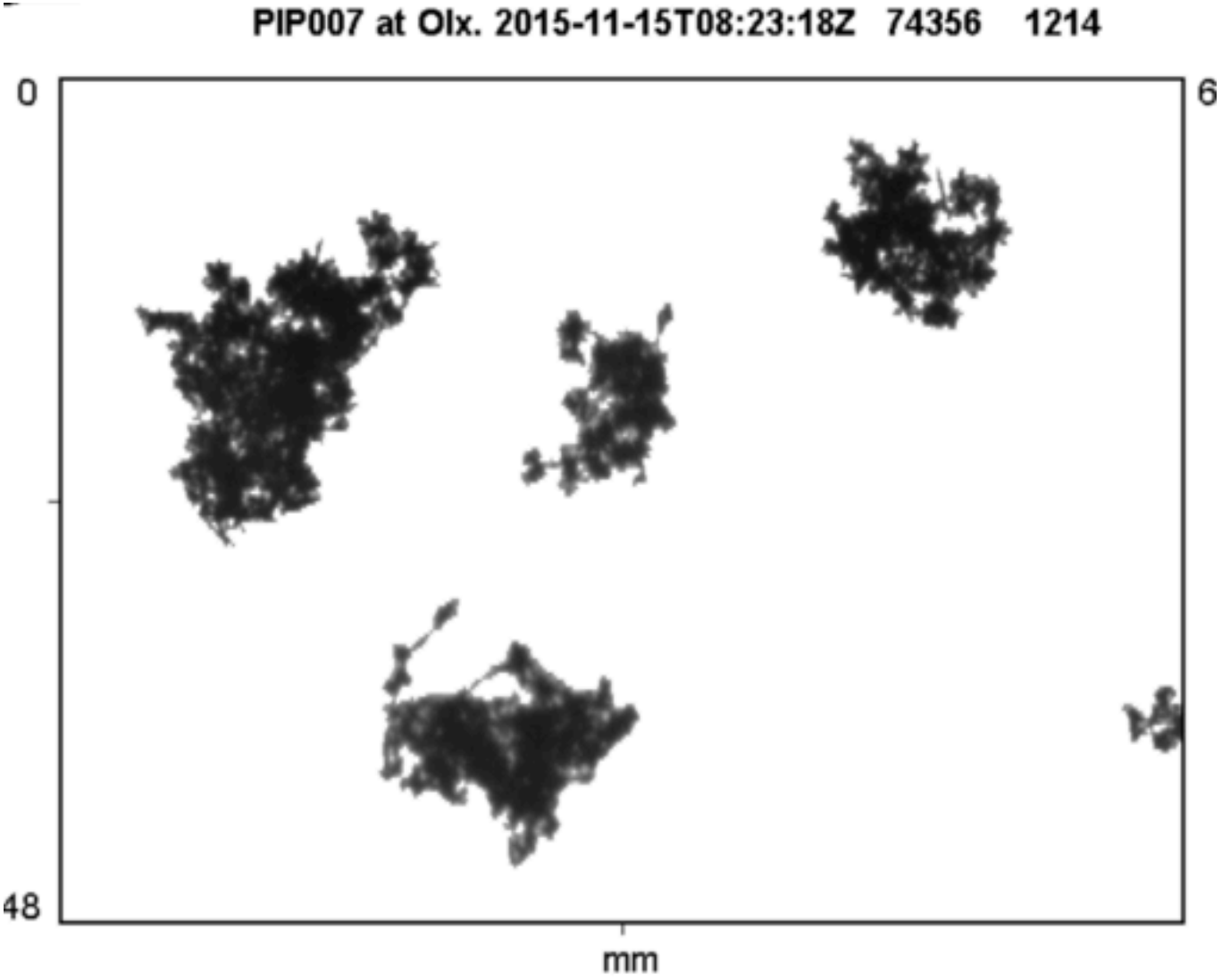
-Overall good agreement
-Parsvel less certain above 2 mm diameter

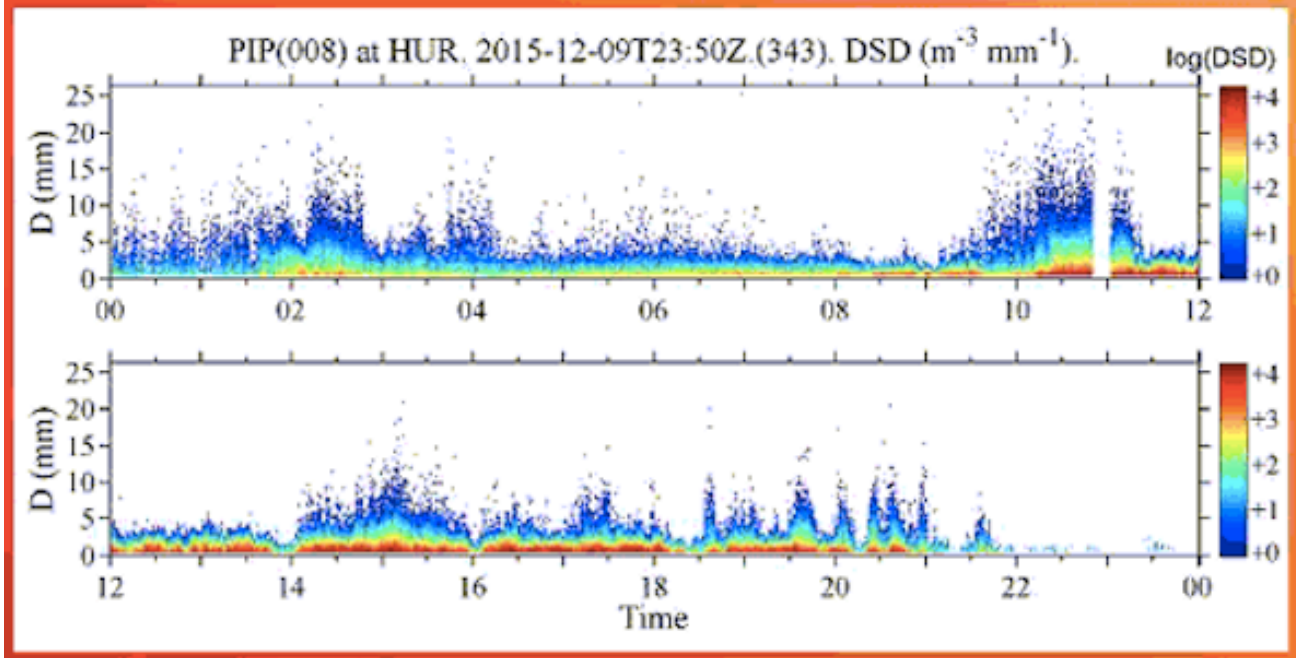
2DVD DSD

PIP Disdrometer

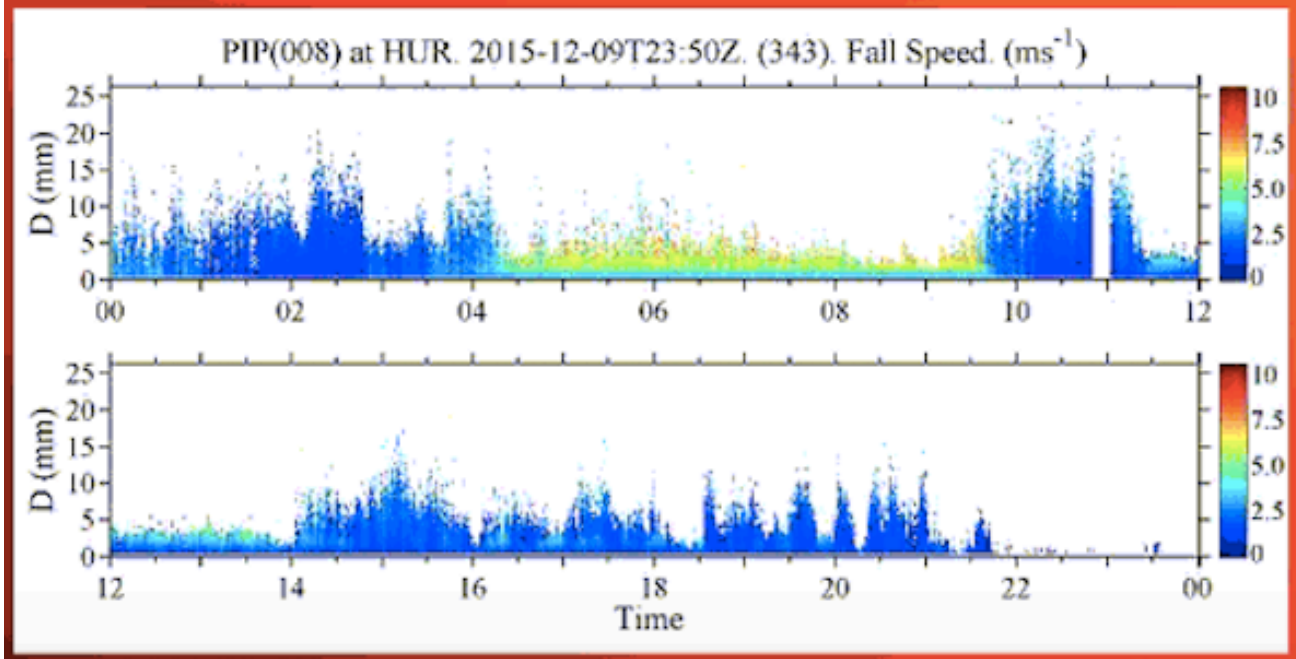
- Invented by Larry Bliven at NASA
- Camera taking 380 FPS video pointed at halogen lamp
- Software detects particles and differentiates between rain/snow
- Not affected by wind—deployed at Hurricane Ridge

Aggregates captured by PIP





DSD



Fall speed

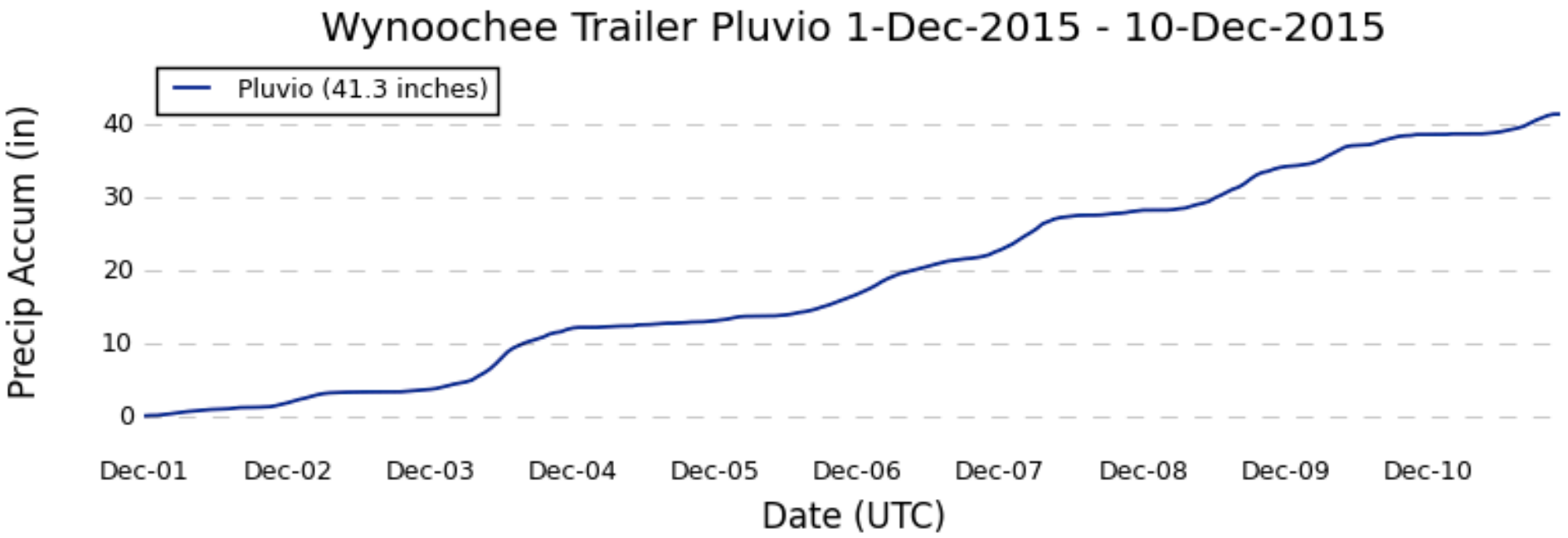
Wynoochee Trailer Deployment (Sept 2015)

- 3,400 ft site on Forest Service Road near Wynoochee Pass
- Difficult to maintain (deep snow)

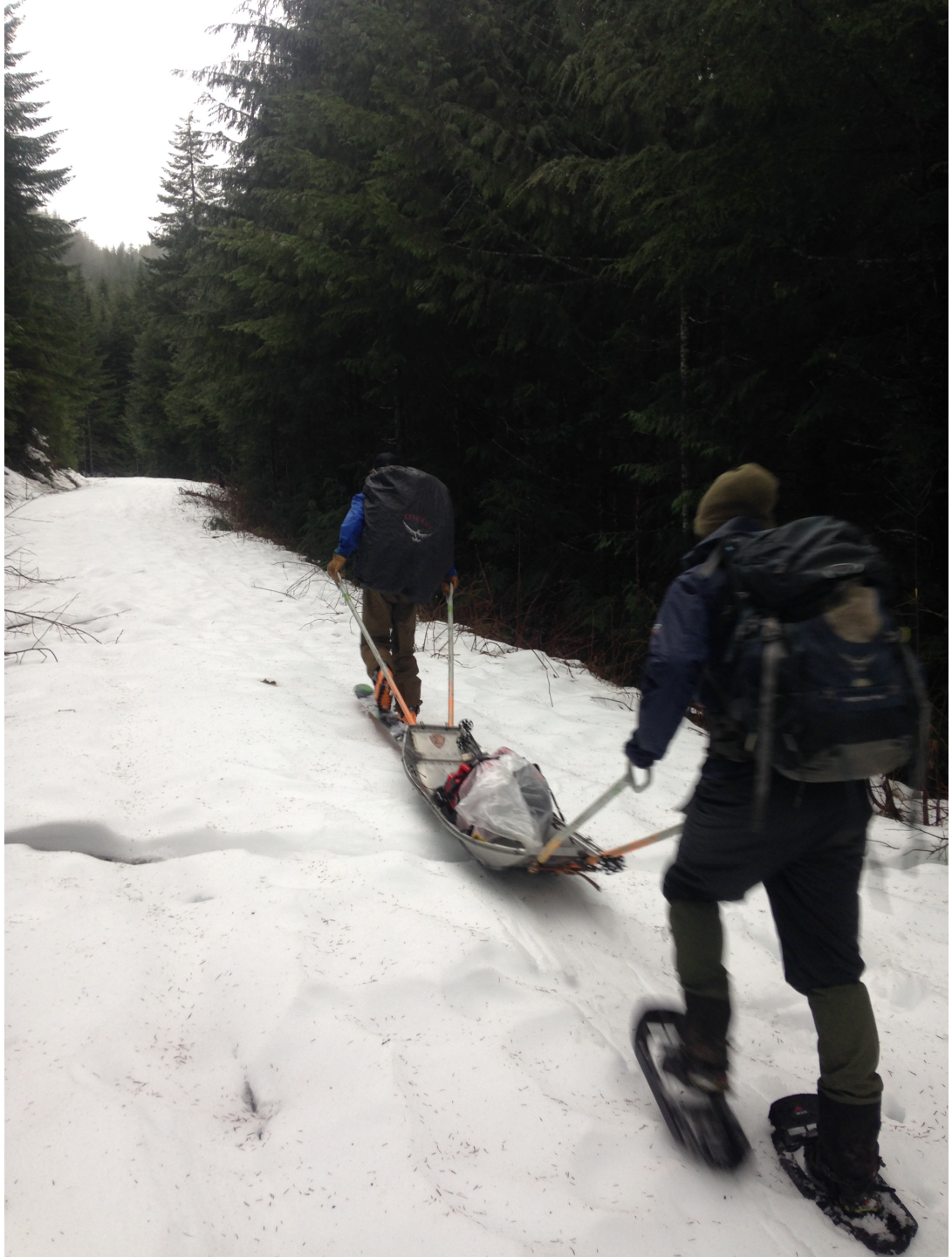

Wynoochee trailer: 3,400 ft
WINGSCAPES
TIMELAPSECAM
01 OCT 2015 02:00 pm


This is bad
WINGSCAPES
TIMELAPSECAM
25 DEC 2015 01:15 pm

41 inches of precipitation in 10 days!!!



Not sure of seasonal total because of missing data, probably around 150-170 inches so far



Snow covered the solar panels, causing batteries to run out in January

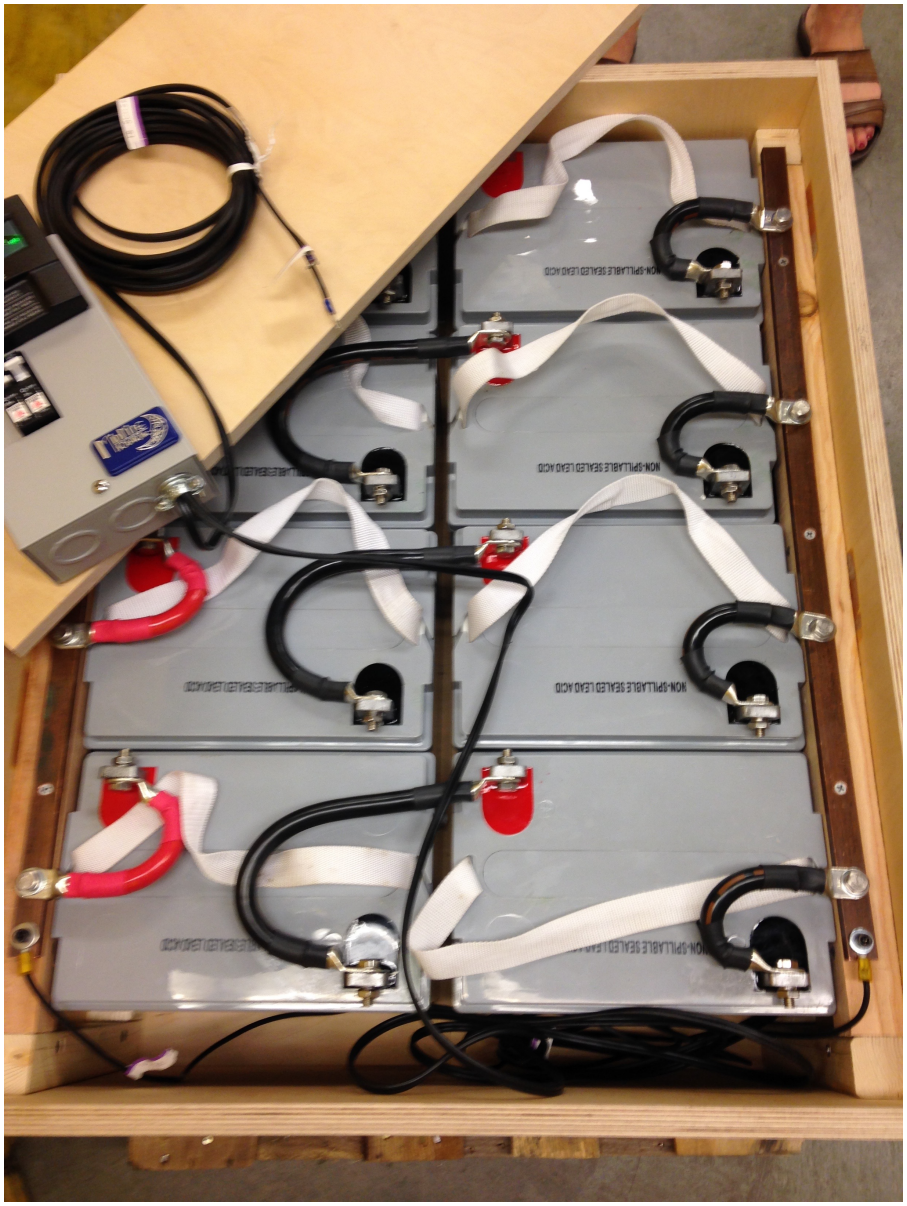
Solution: bring a generator to recharge batteries

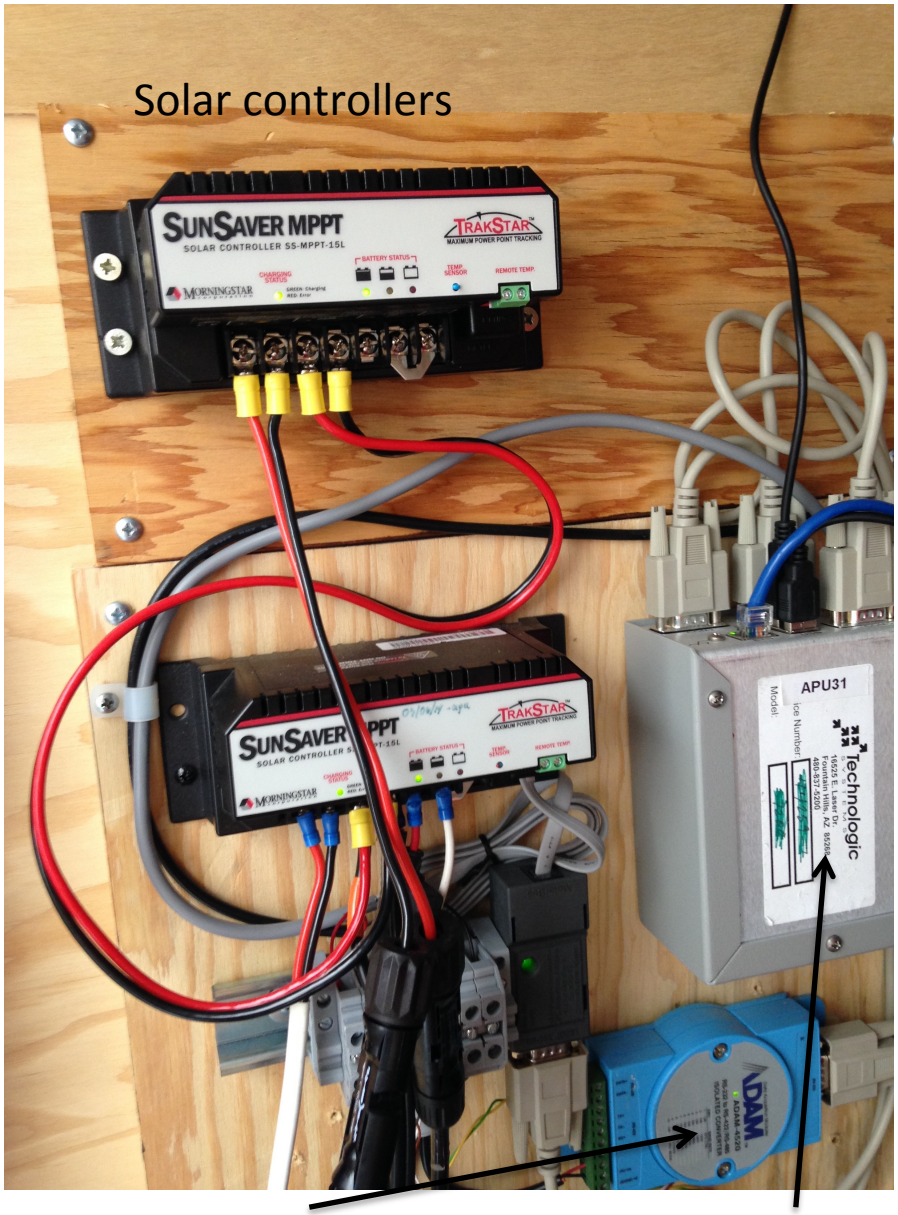
Hurricane Ridge deployment (Oct 2014)

Upper Quinault deployment

14 miles up the East Fork Quinault trail in Olympic National Park

Battery box (12V system)

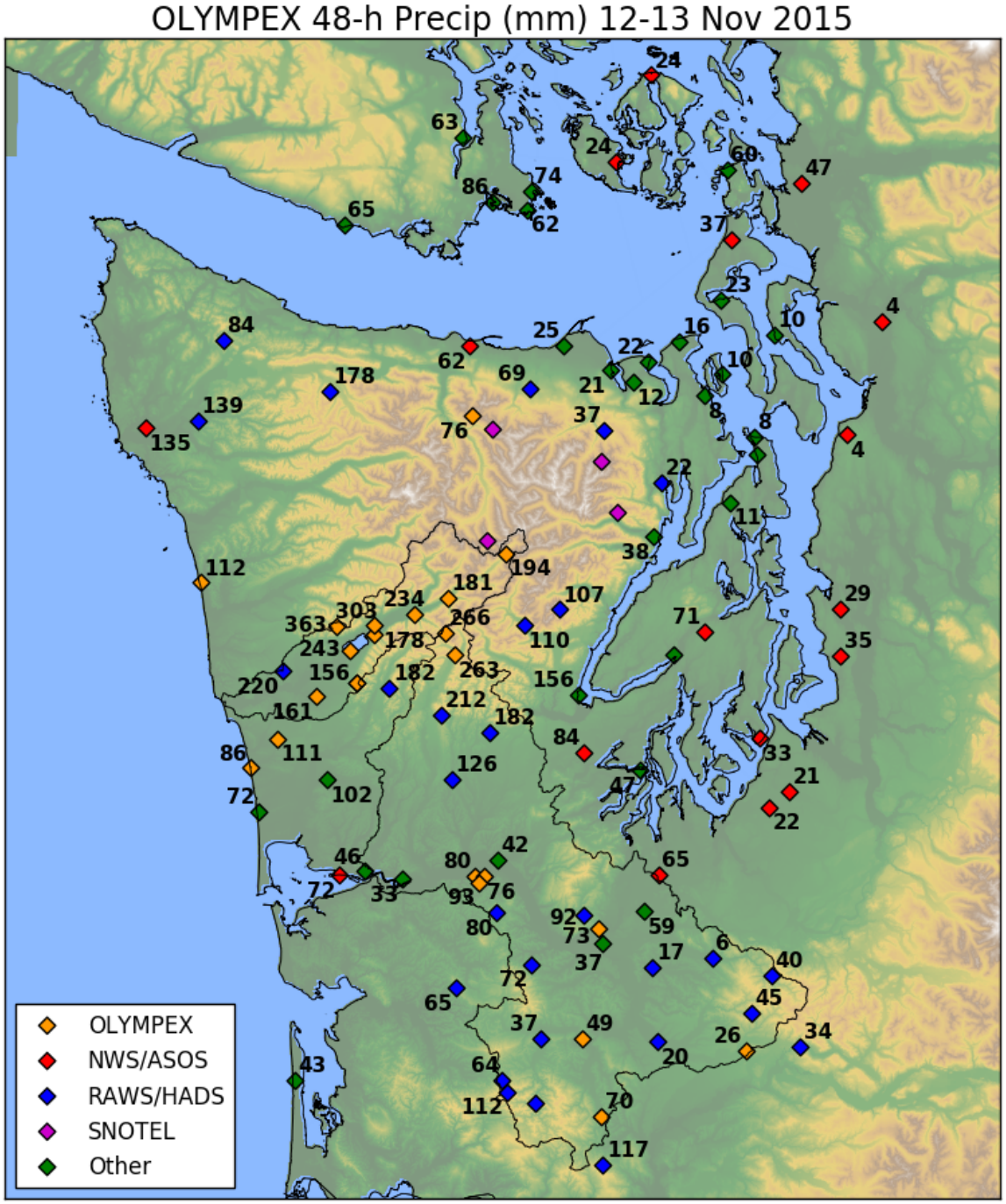





45°F
10/22/2015
07:08AM
UQ


41°F
01/07/2016
03:34AM
GRAVES

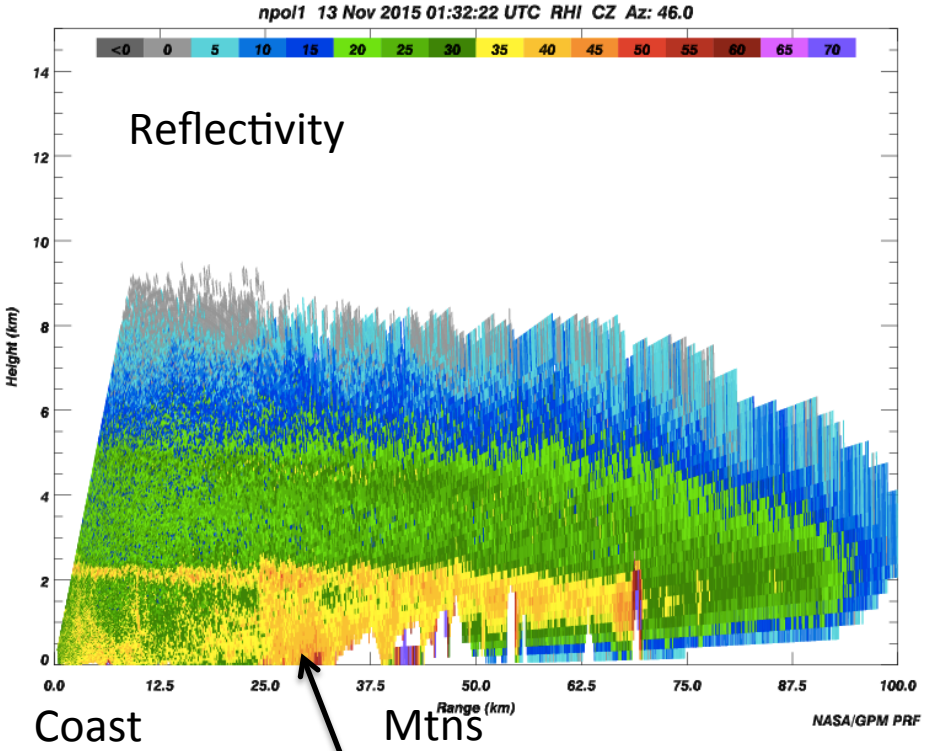

29°F
11/02/2015
10:32PM
UQ

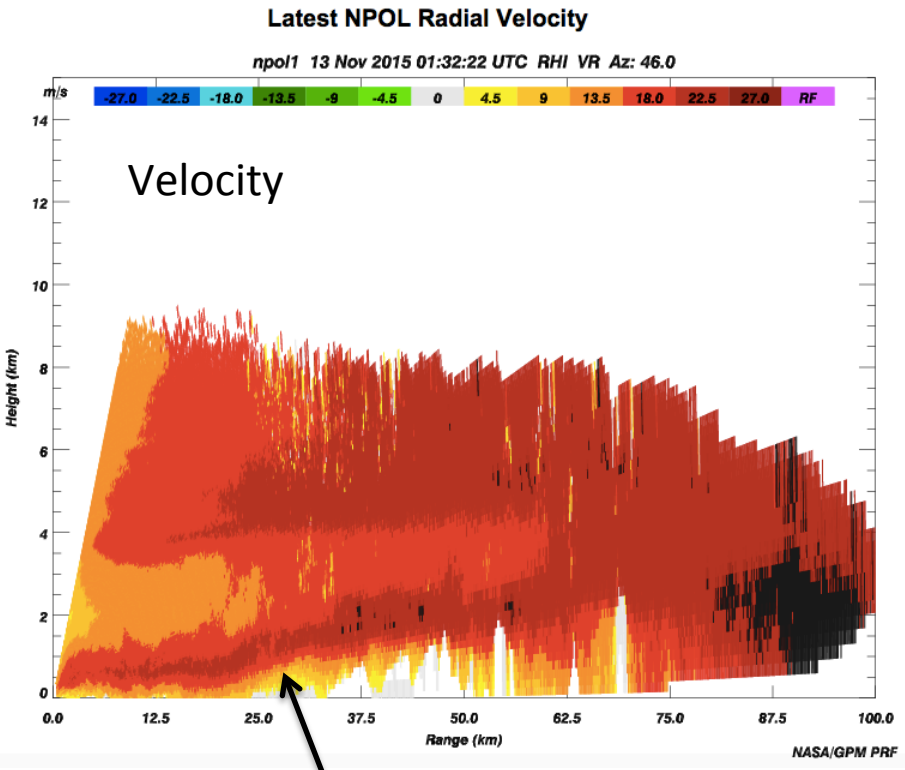


Nov 12-13 "Atmospheric River" on the first day of the IOP

Widespread 8-14 inches

Another 8-10 inches fell 4 days later





Coast

Mtns

-Low-level jet lifts over terrain

-Higher precipitation rates in region of jet lifting

NPOL RHIs 01:32 UTC 13-Nov


O’Neil Creek deployment…looks like a nice field


After Nov 13 storm…narrowly avoided flood

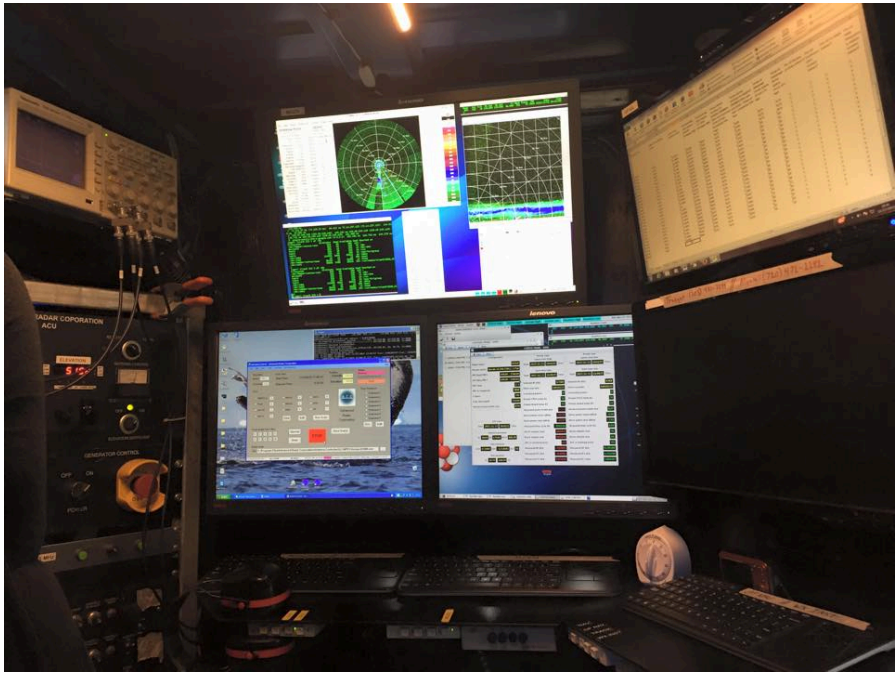
After Nov 17 storm…one was knocked over, other was full of debris

More trail damage

Landslide damage

Nov 17: Quinault River flooding (~10 year flood)

Doppler on Wheels




DOW 6


DOW 6


Center for Severe Weather Research

December—too much snow to hike, use helicopter instead!


HONDA
EU2000i

Video of return flight

Radiosonde Launch Video

Concluding thoughts…

- Despite all of the challenges mentioned, we still collected 80-90% of possible ground data
- Testing in 2014-15 was critical to mitigating potential issues
- One site that we thought would be great turned out to be problematic, another that we added at the last minute turned out to be one of the best
- Difficult to make conclusions based on one measurement. Much easier when multiple locations/platforms can be weaved into a single narrative.