Sub-meter commercial satellite stereo imagery for snow

David Shean
dshean@uw.edu

University of Washington
Civil and Environmental Engineering

SnowEx Workshop, Baltimore, MD
September 17, 2019

CIVIL & ENVIRONMENTAL ENGINEERING
UNIVERSITY of WASHINGTON

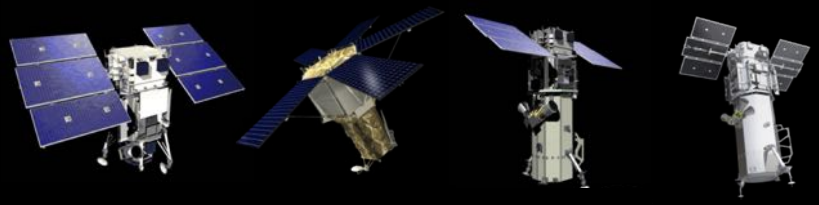
NASA

Satellite stereo DSMs:

Not LiDAR, but close

Available submeter imagers

DigitalGlobe
A MAXAR COMPANY



0.3-0.5 m PAN
~1.2-2.0 m 8-band MS
(~3.4 m 8-band SWIR)

Two-image stereo
~200-2000 km2 each collect
<20-50 cm vertical accuracy*

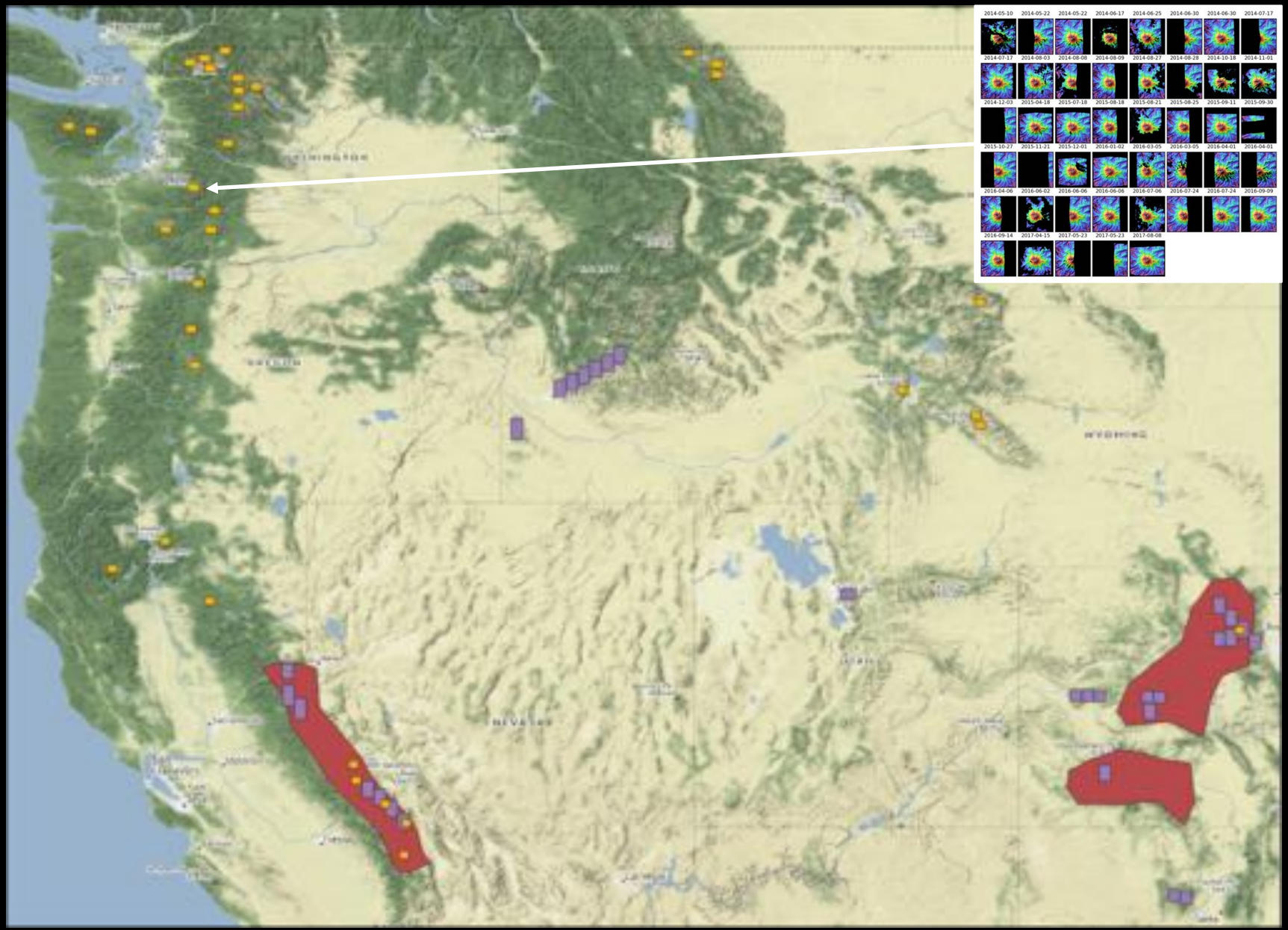
planet.

~0.7-0.9 m PAN
~0.7-0.9 m 4-band MS

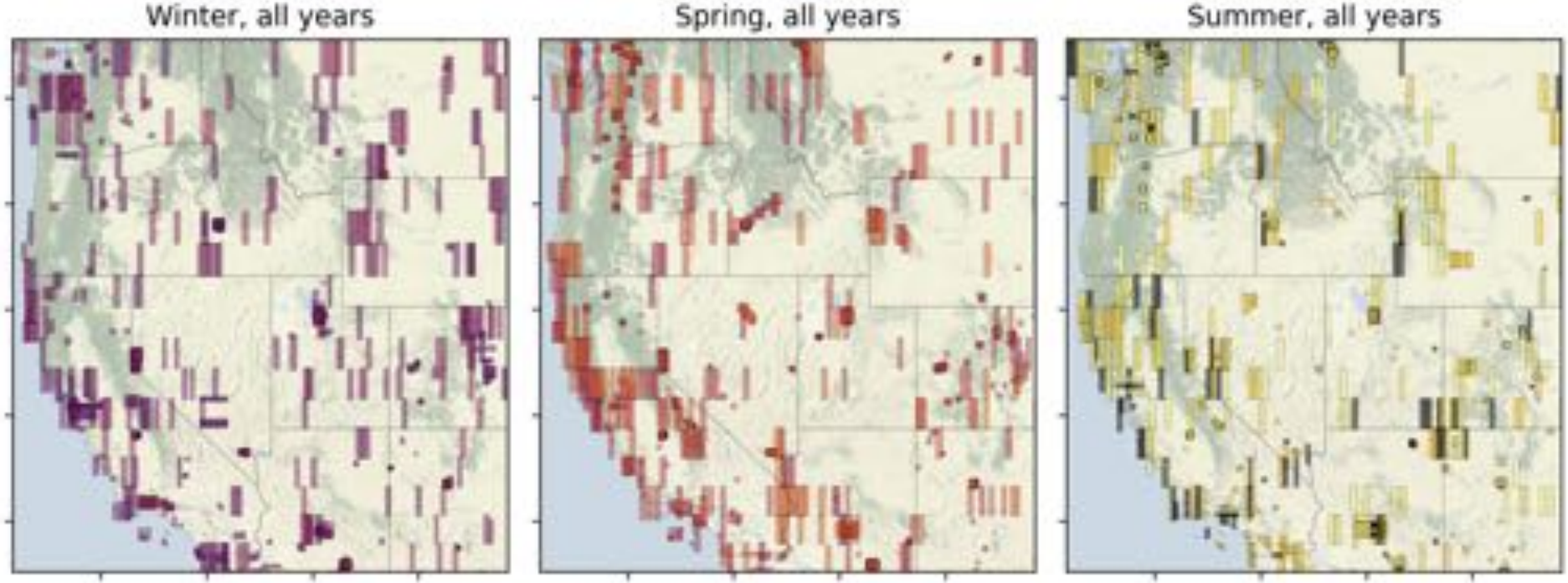
Triplet (3-image) and Video (3600 image)
~60-70 km2 each collect
<1 m vertical accuracy**

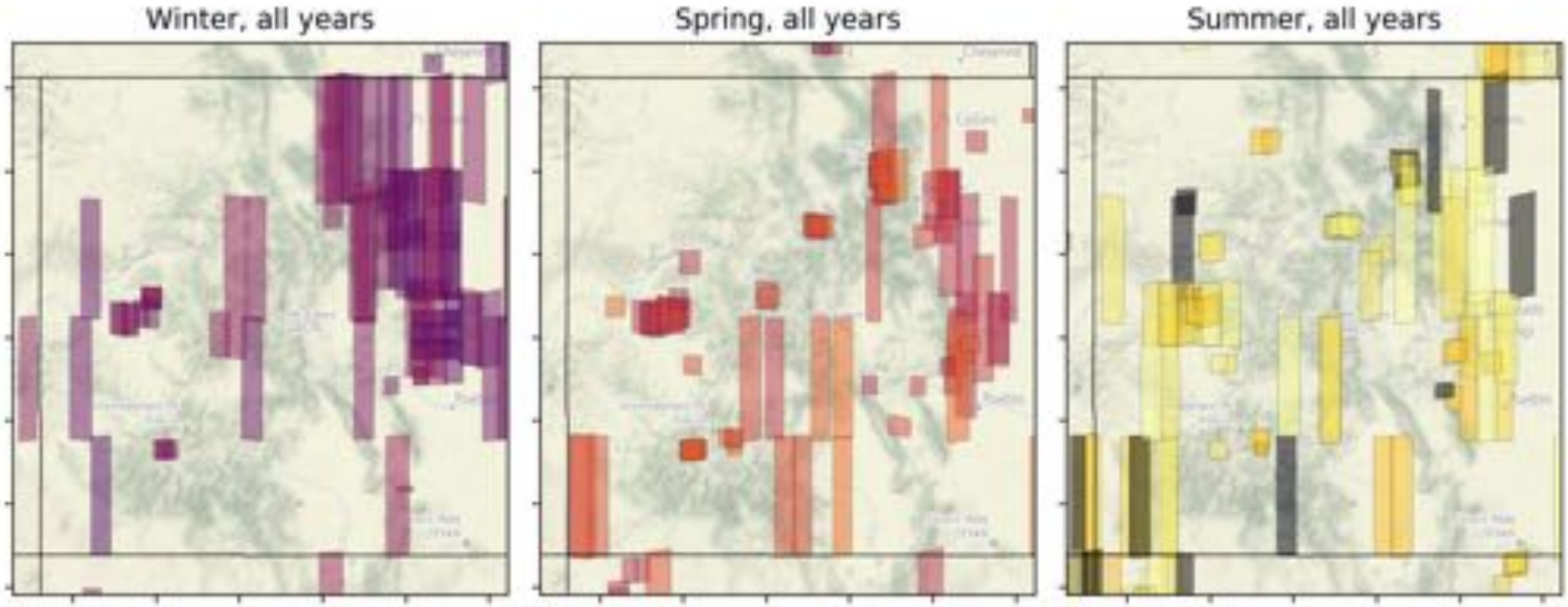
Platform	Coverage for single collection (km^2)	Image Resolution (m)	Image bands	Number of multi-view stereo images	DSM Relative Vertical Accuracy* (m) *for surface slope <10°	Tasking capabilities for repeat or on-DSMand coverage	Cost (0 = existing federal or research access)
DigitalGlobe WorldView-1/2/3	170-1870	0.3-0.5 1.2 3.4	Panchromatic 8-band MS SWIR option	2	<0.5	Fair-Good	0
Planet SkySat video	2-4	1.0	Panchromatic	900-3600	<0.5-1.0	Good	$$$$
Planet Skysat triplet stereo	60-70	0.7 1.0	Panchromatic 4-band MS	3	<1-3, TBD	Good	$$
Planet PlanetScope (Dove)	400 (spatially continuous)	3-4	4-band MS	2-9+	>3 m, TBD	Temporally continuous	0/$

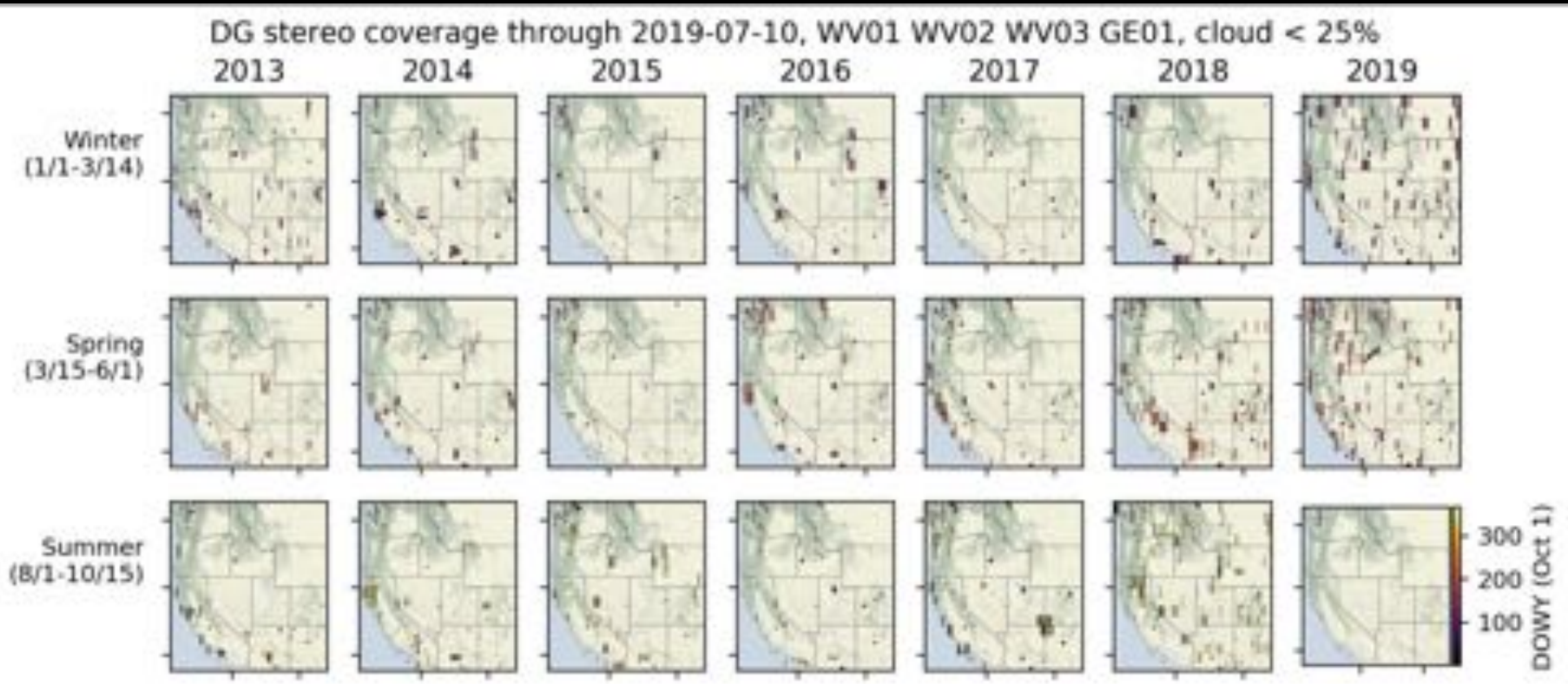
2019/2020 DG Stereo Tasking

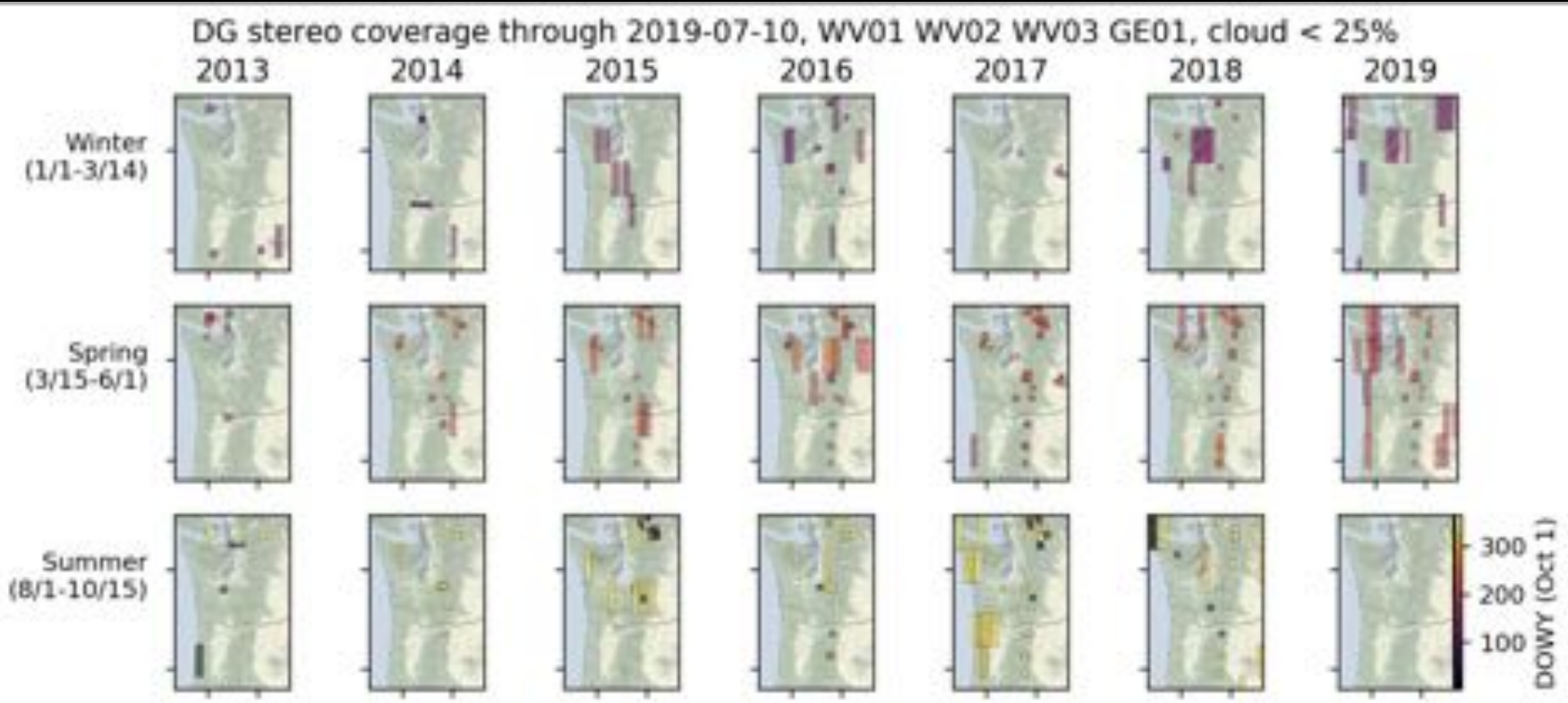


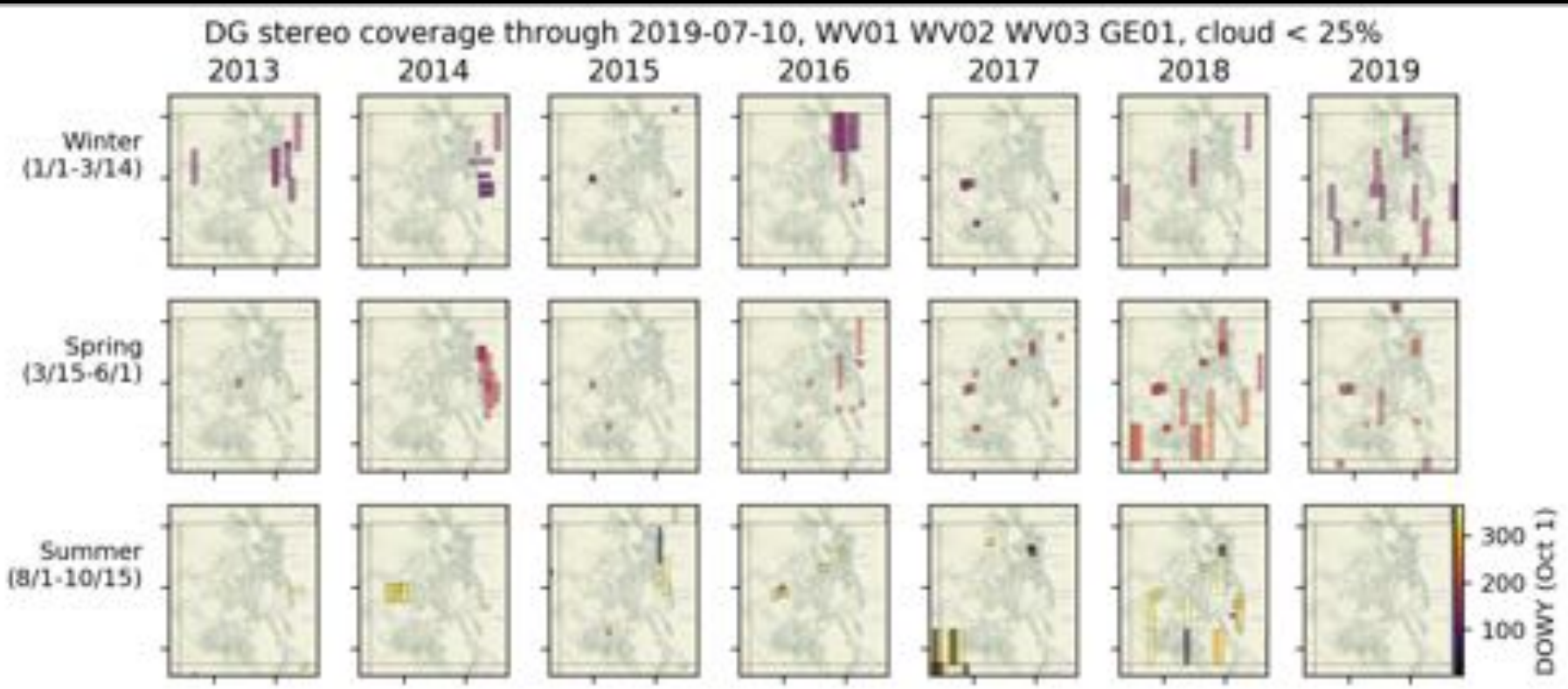
DG stereo coverage through 2019-07-10, WV01 WV02 WV03 GE01, cloud < 25%



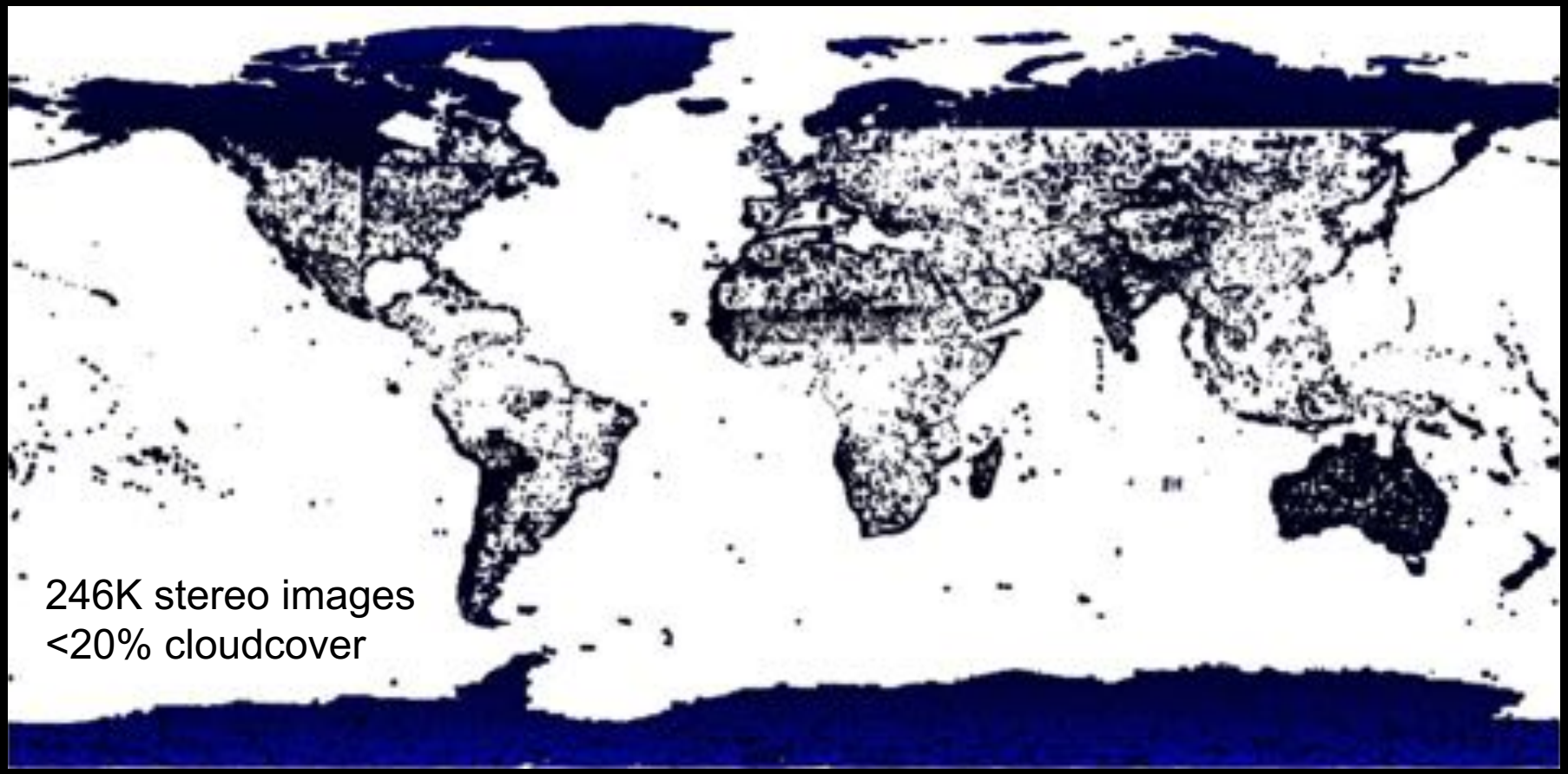

Winter, all years
Spring, all years
Summer, all years


DG stereo coverage through 2019-07-10, WV01 WV02 WV03 GE01, cloud < 25%
2013
2014
2015
2016
2017
2018
2019
Winter
(1/1-3/14)
Spring
(3/15-6/1)
Summer
(8/1-10/15)
300
200
100
DOWY (Oct 1)

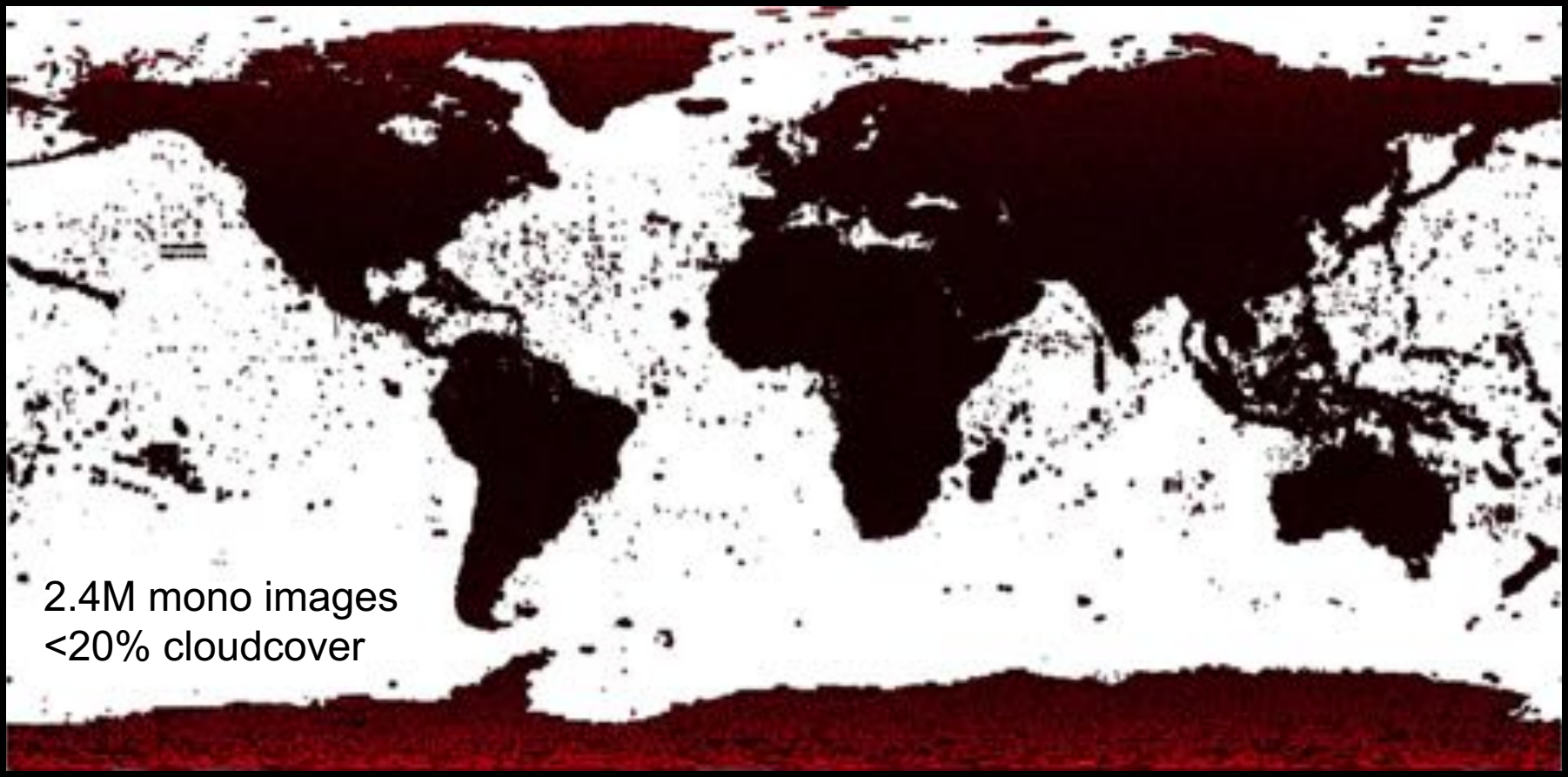

DG stereo coverage through 2019-07-10, WV01 WV02 WV03 GE01, cloud < 25%
2013
2014
2015
2016
2017
2018
2019
Winter
(1/1-3/14)
Spring
(3/15-6/1)
Summer
(8/1-10/15)
300
200
100
DOWY (Oct 1)

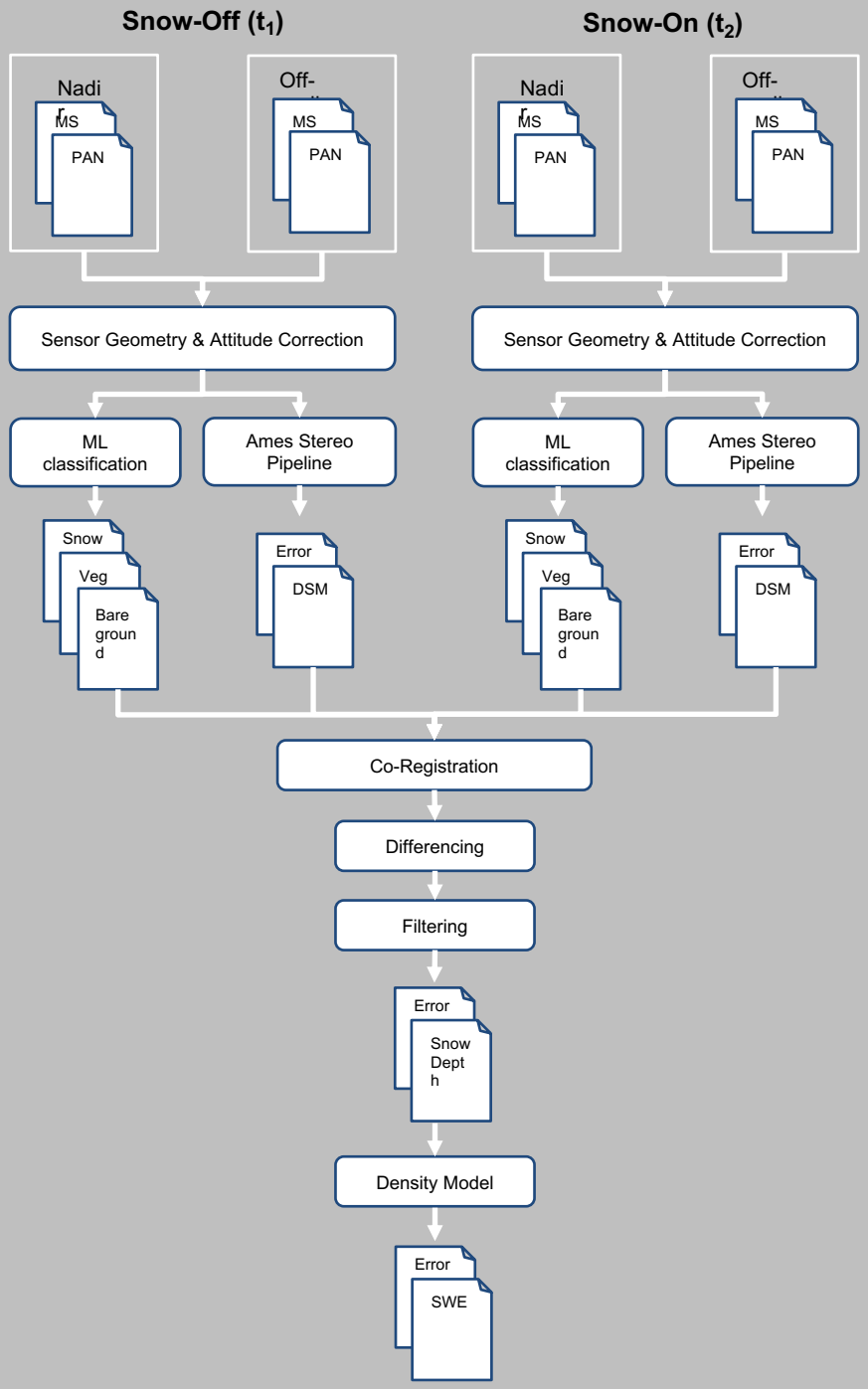

DG stereo coverage through 2019-07-10, WV01 WV02 WV03 GE01, cloud < 25%
2013
2014
2015
2016
2017
2018
2019
Winter
(1/1-3/14)
Spring
(3/15-6/1)
Summer
(8/1-10/15)
300
200
100
DOWY (Oct 1)

DigitalGlobe Stereo Archive (April 5, 2017)



DigitalGlobe Mono Archive (April 5, 2017)

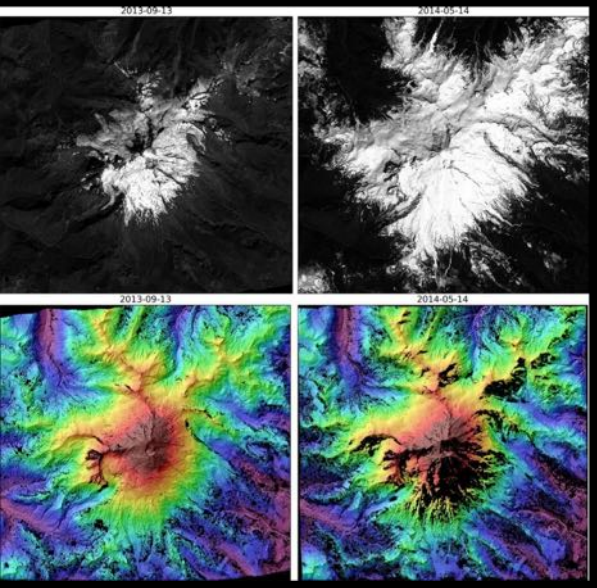



Snow-Off (t_1)
Snow-On (t_2)
Nadi r
MS
PAN
Off-
MS
PAN
Nadi r
MS
PAN
Off-
MS
PAN
Sensor Geometry & Attitude Correction
Sensor Geometry & Attitude Correction
ML classification
Ames Stereo Pipeline
ML classification
Ames Stereo Pipeline
Snow
Veg
Bare groun d
Error
DSM
Snow
Veg
Bare groun d
Error
DSM
Co-Registration
Differencing
Filtering
Error
Snow Dept h
Density Model
Error
SWE

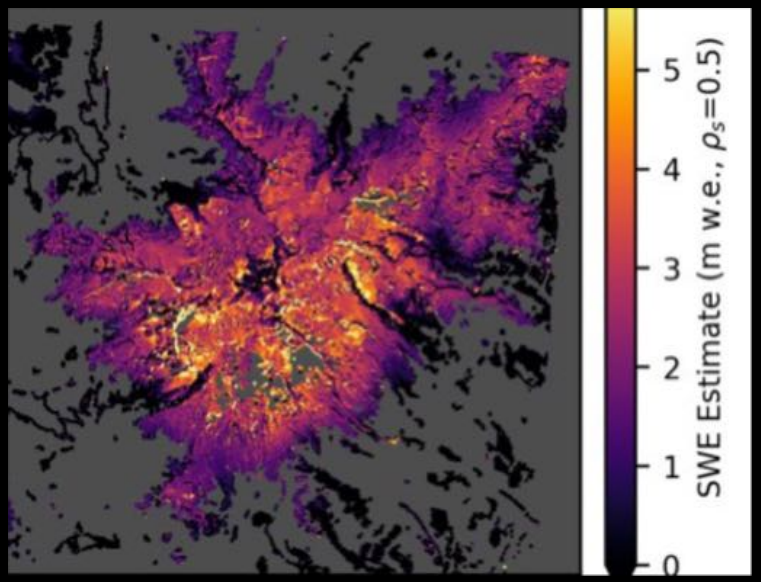
Stereo2SWE: Regional snow depth from space

Snow-off

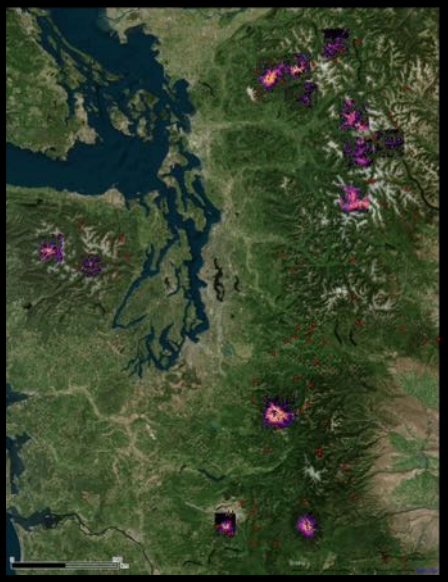
Snow-on



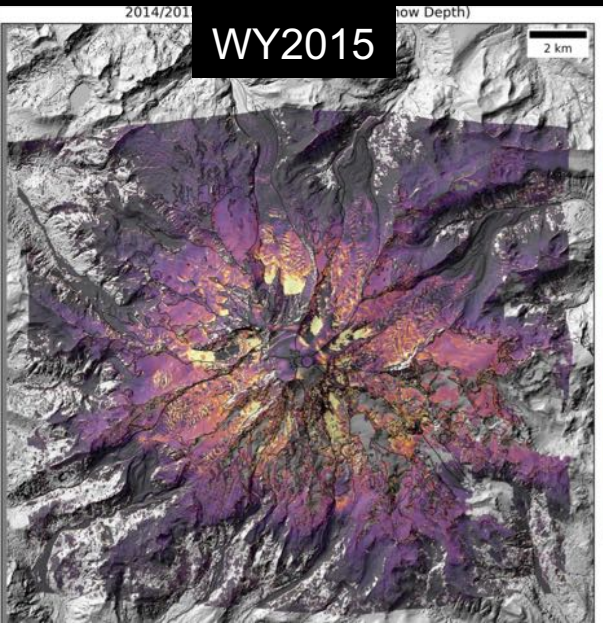
Snow depth



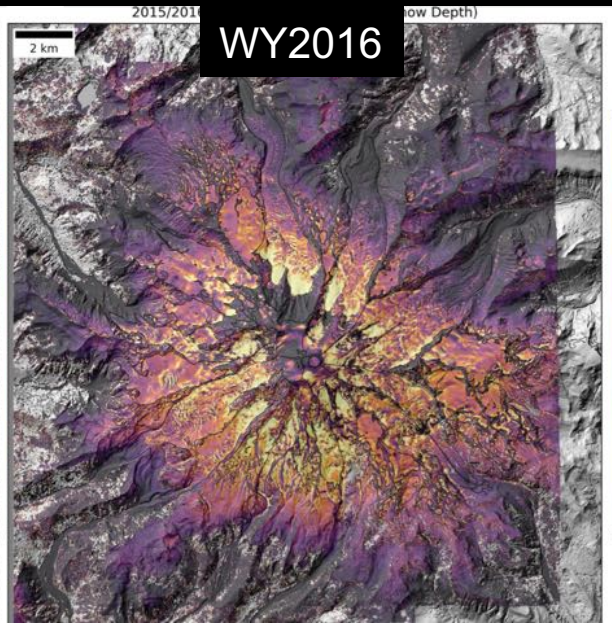
WY2016 Peak SWE



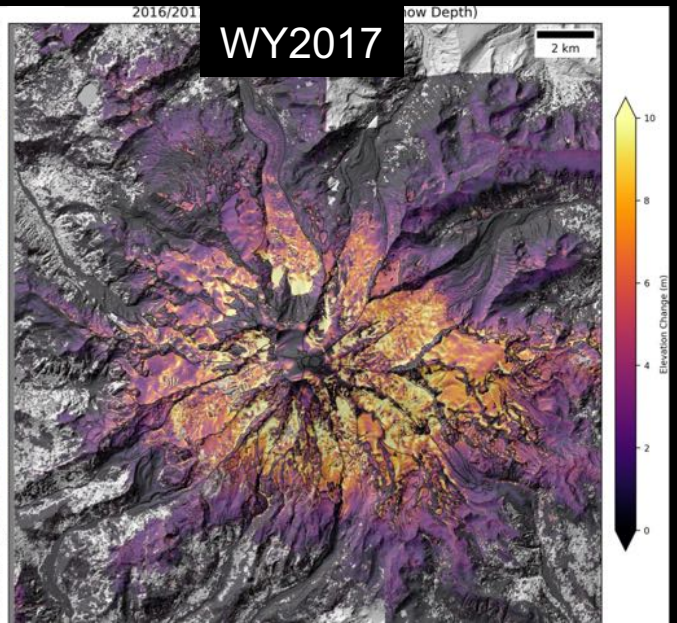
WY2015



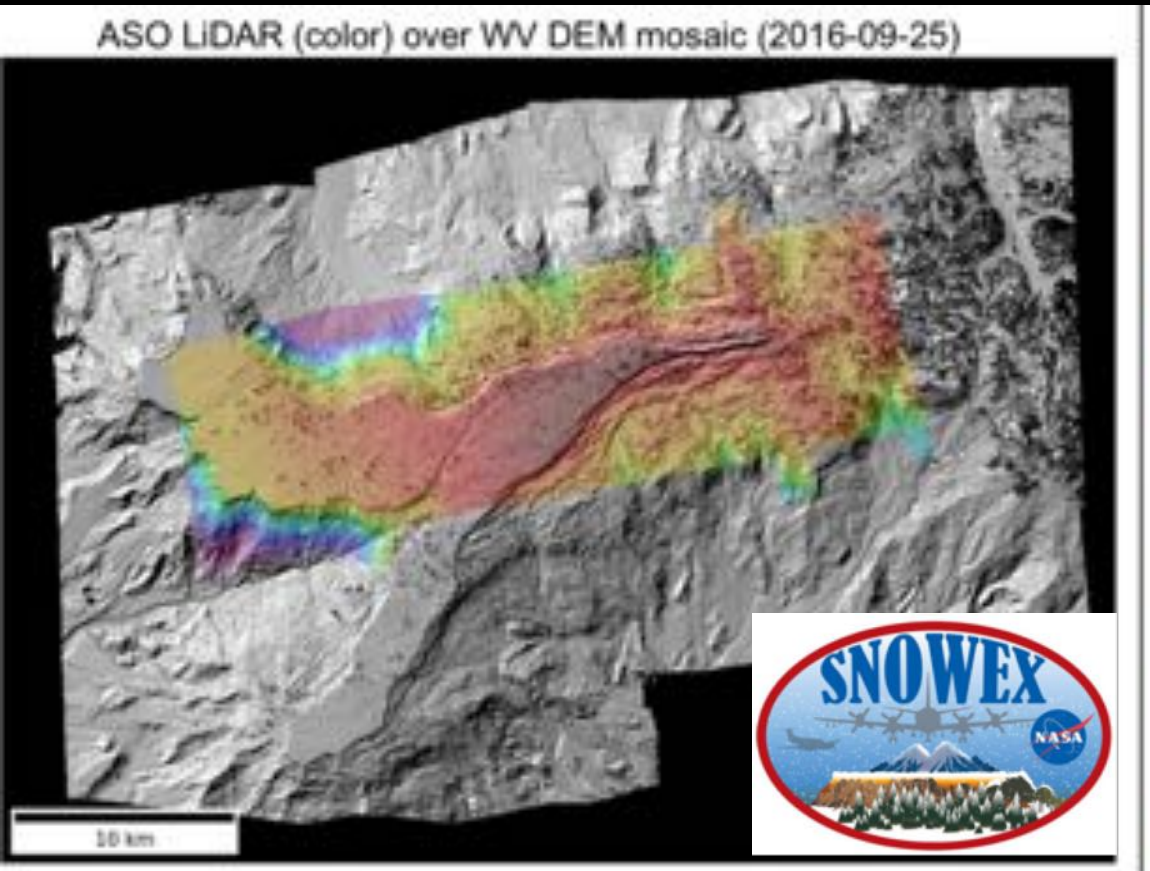
WY2016

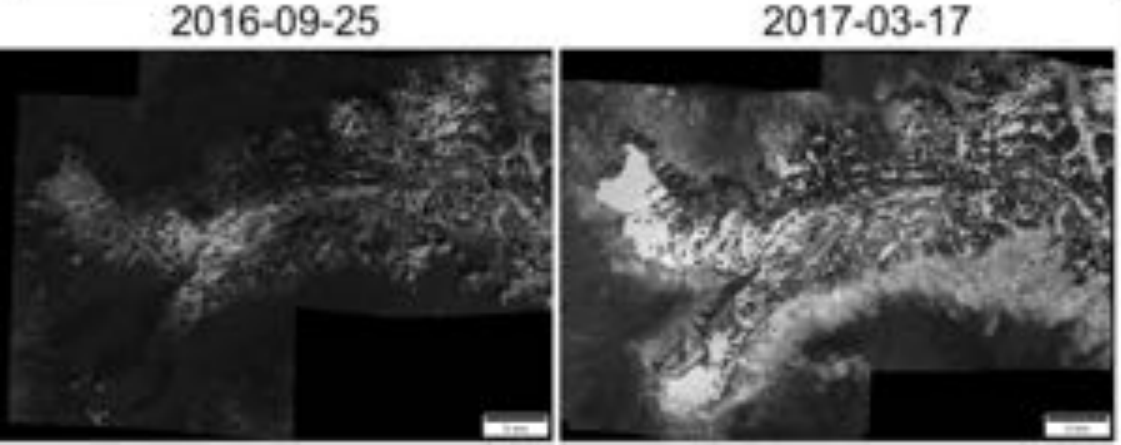


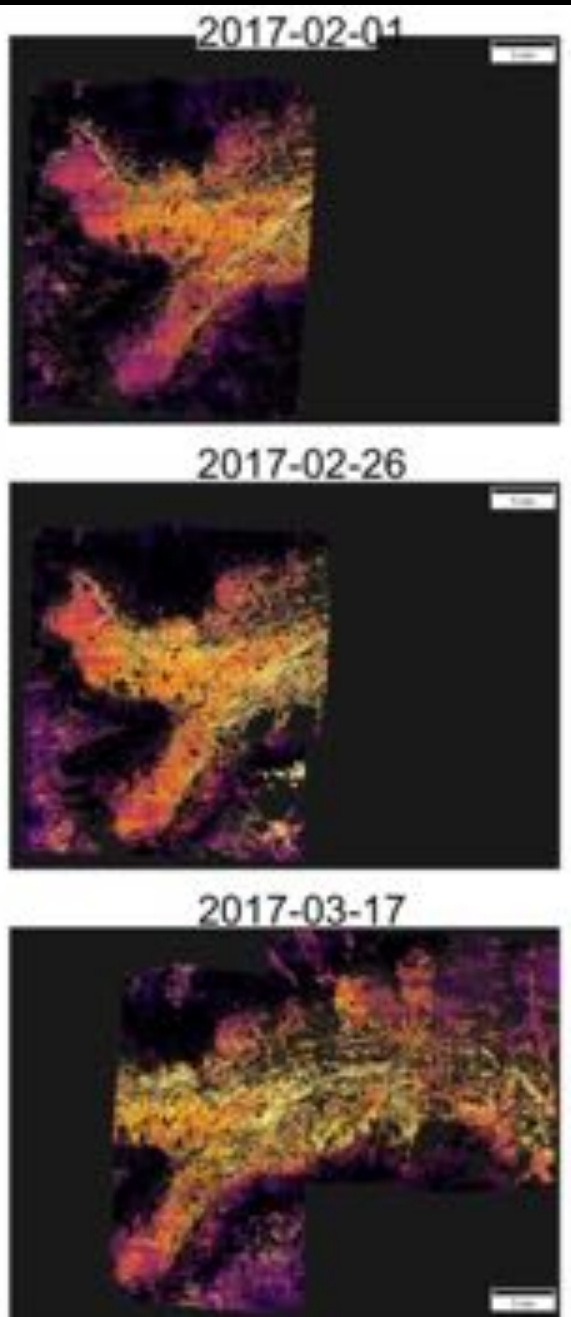
WY2017



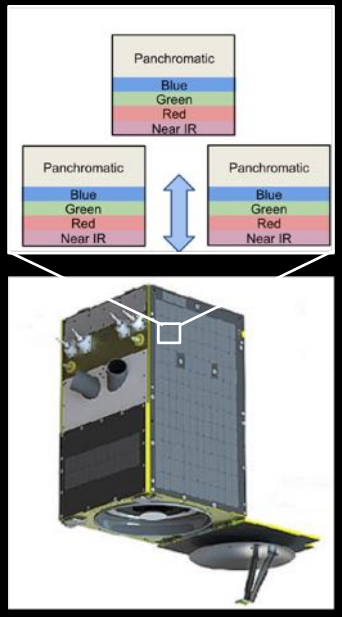
NASA SnowEx: Grand Mesa, CO

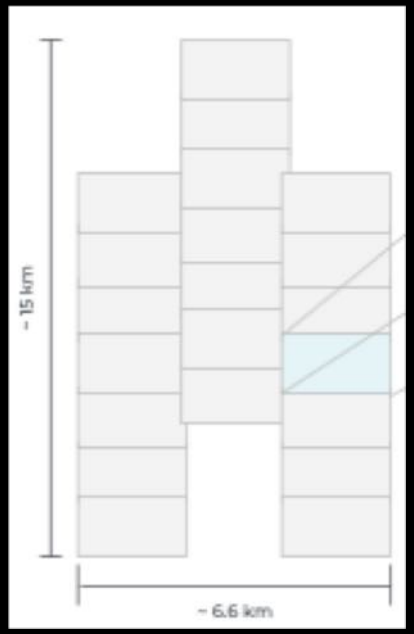


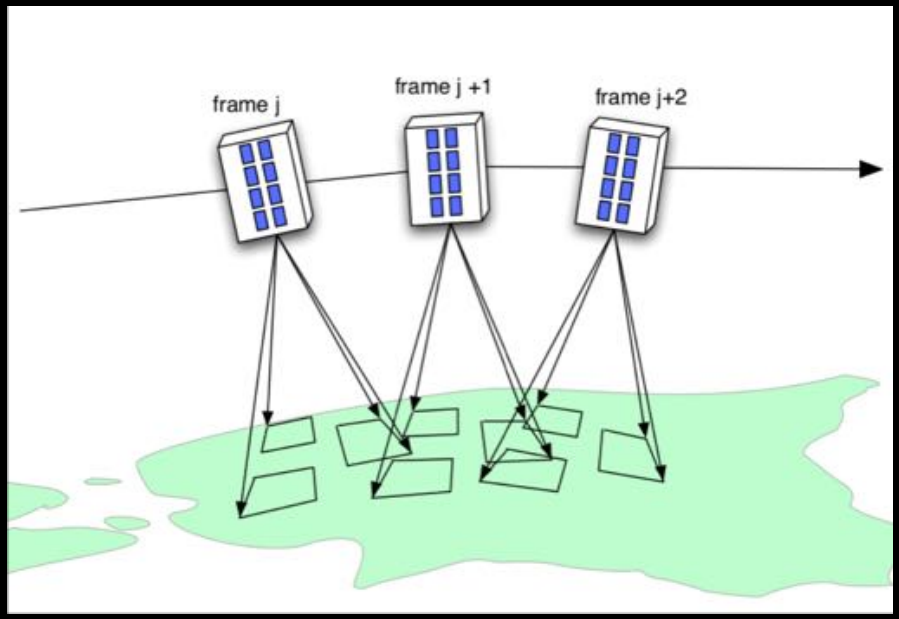




SkySat Triplet Stereo





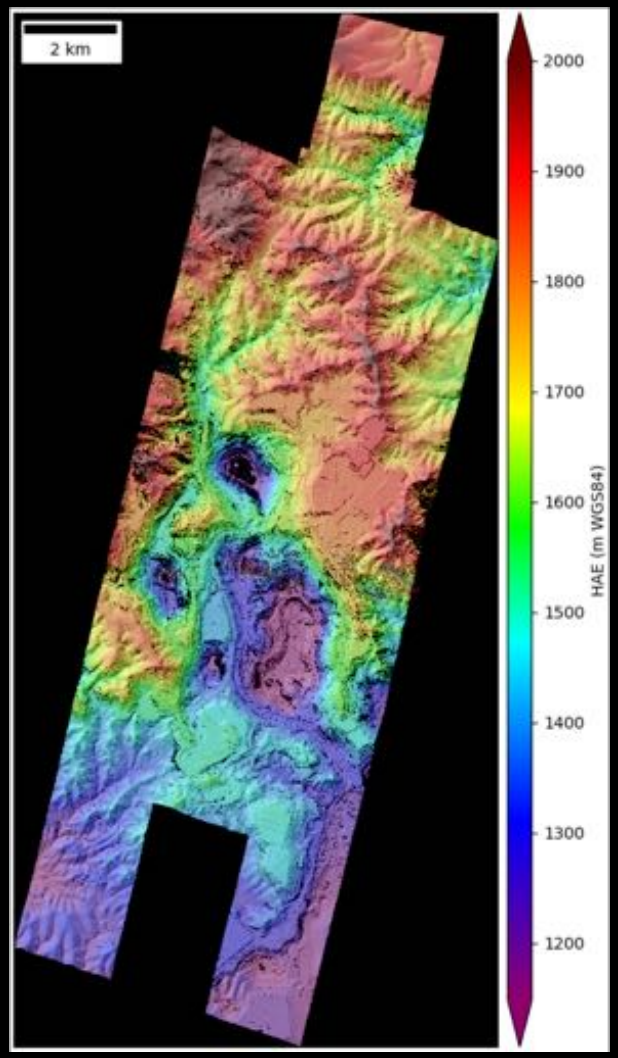


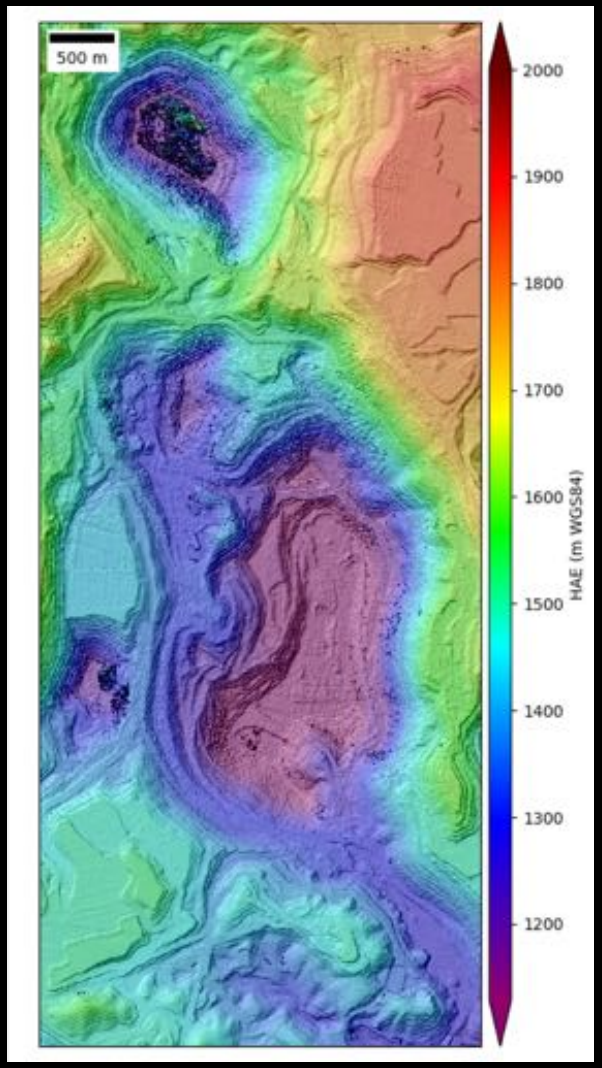
SkySat Triplet Stereo: Morenci, AZ

2019-01-28

Off-nadir angles:
204710: 27.1°
204744: 8.1°
204819: 26.9°

0.7 m GSD
© Planet, 2019

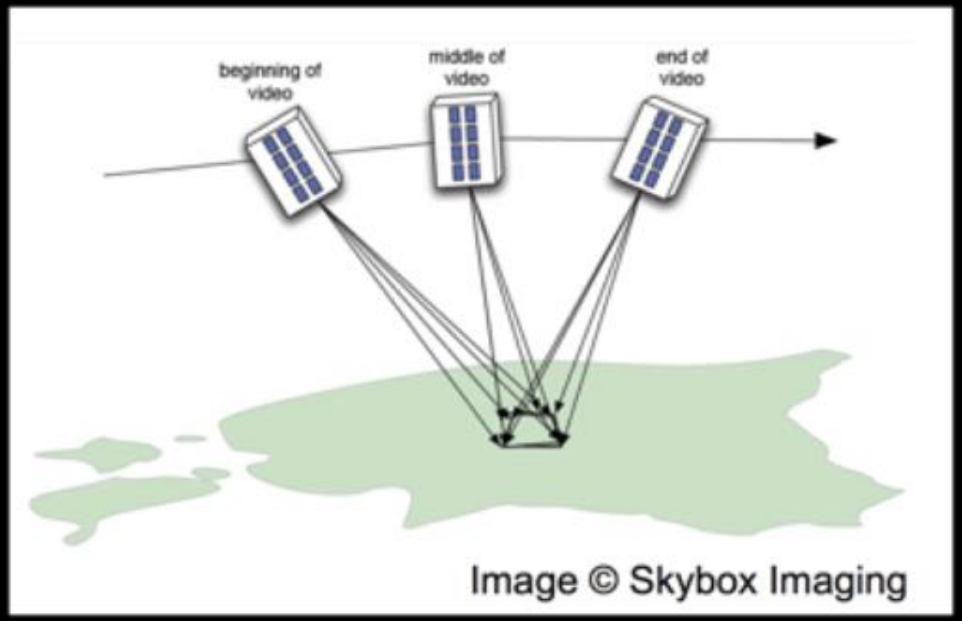




S. Bhushan

SkySat Video

- Single CCD
- 2560 x 1080 px (HD)
- ~1 meter GSD
- 30,60,90,120 seconds

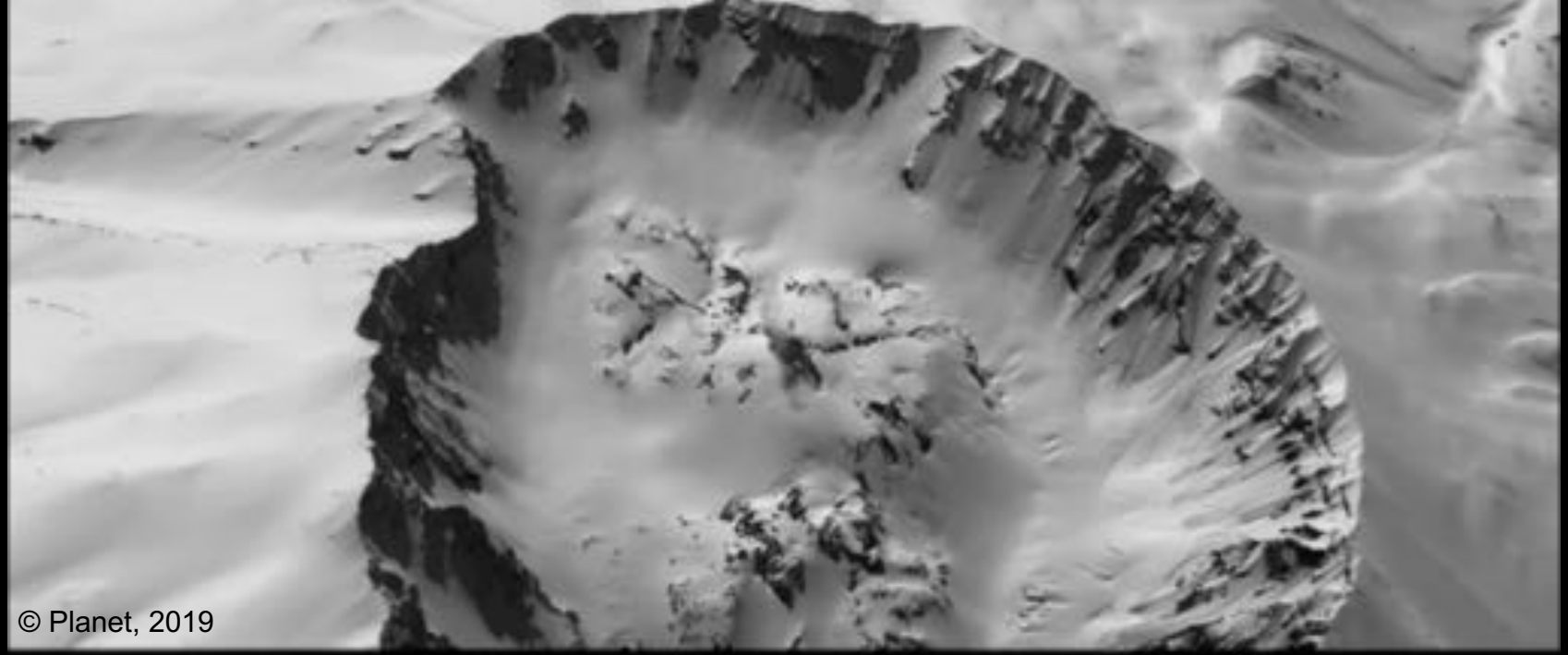


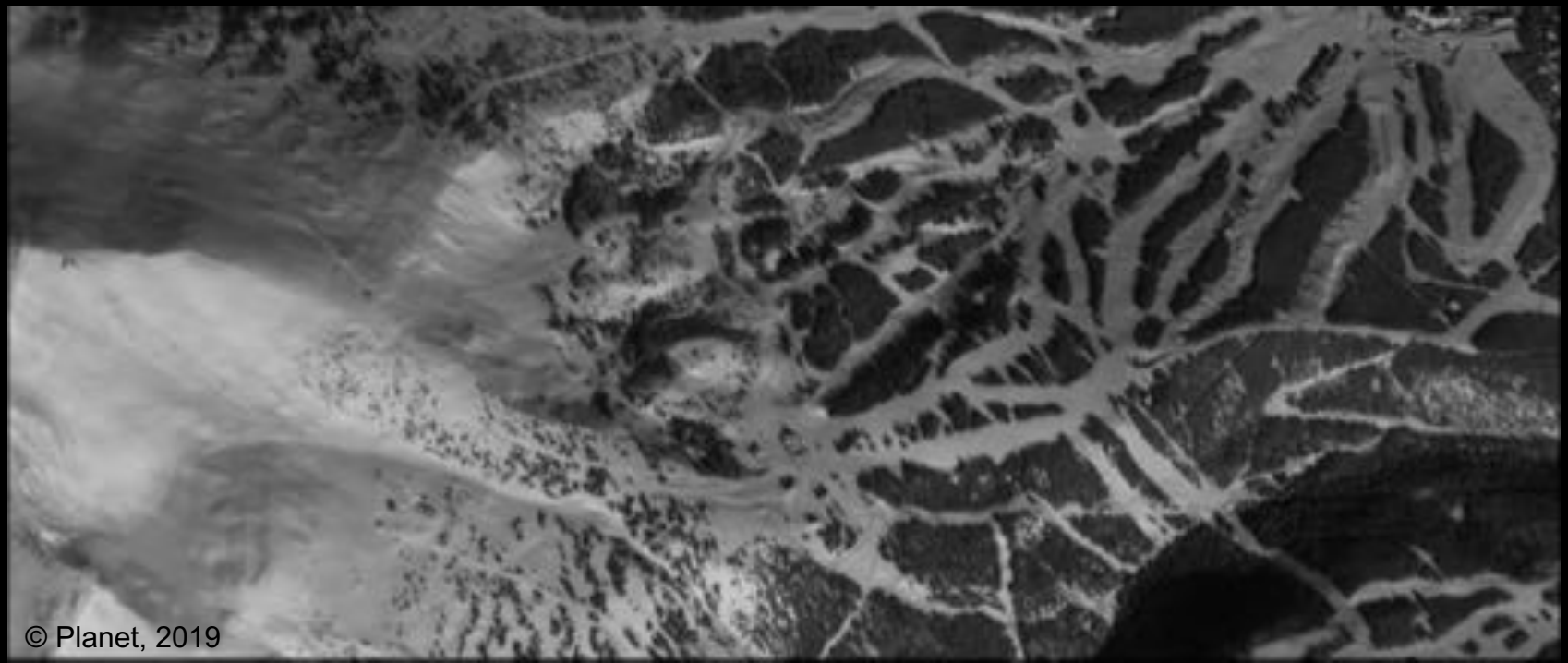
Samples (next slide):

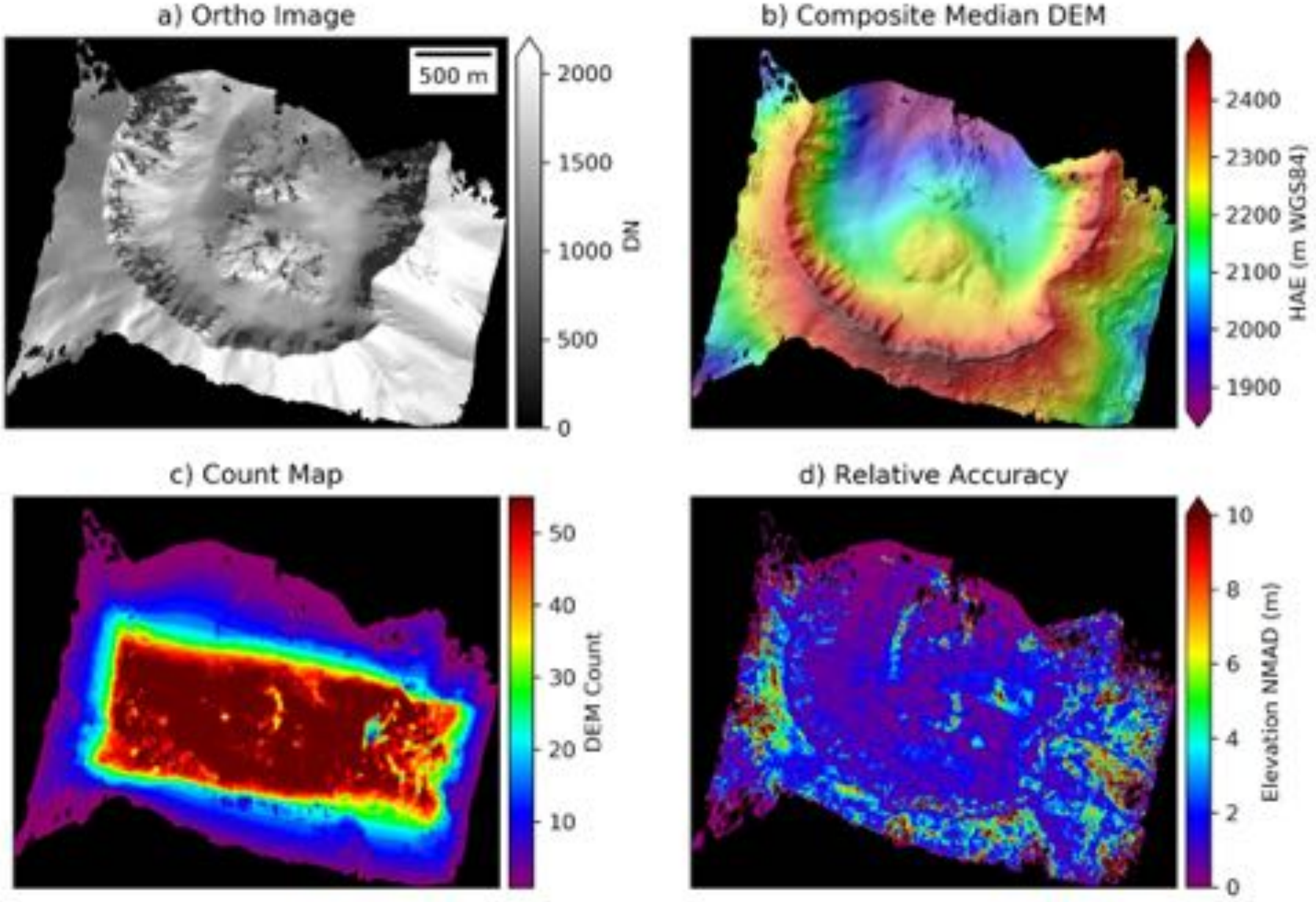
Mt. St. Helen's, WA
April 20, 2019
Planet SkySat-C video (120 seconds)

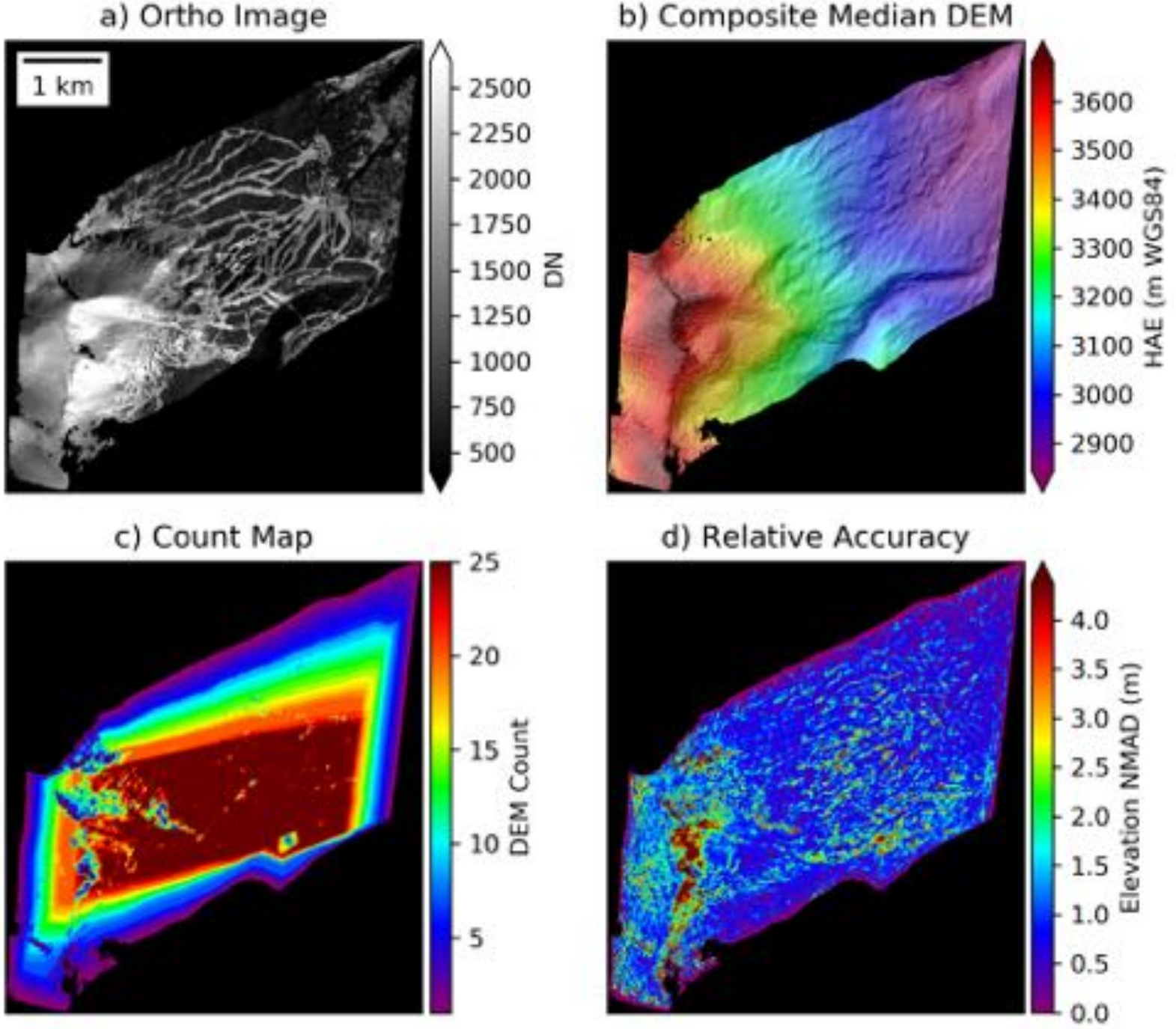
Breckenridge, CO
November 7, 2018
Planet SkySat-C video (72 seconds)

Reduced size, sped up by factor of 5 (from 30 fps to 6 fps)


© Planet, 2019


© Planet, 2019


a) Ortho Image
500 m
2000
1500
1000
500
0
DN
b) Composite Median DEM
2400
2300
2200
2100
2000
1900
HAE (m WGS84)
c) Count Map
50
40
30
20
10
DEM Count
d) Relative Accuracy
10
8
6
4
2
0
Elevation NMAD (m)


a) Ortho Image
1 km
2500
2250
2000
1750
1500
1250
1000
750
500
DN
b) Composite Median DEM
3600
3500
3400
3300
3200
3100
3000
2900
HAE (m WGS84)
c) Count Map
25
20
15
10
5
DEM Count
d) Relative Accuracy
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Elevation NMAD (m)

WV/GE Stereo

Pros:

- Large footprint
- High-resolution
- Good sensor geometry calibration
- DEM relative accuracy <0.2-0.5 m (slope-dependent)
- Rigorous and RPC models

Cons:

- Only 4 sensors available through NextView
  - Competition, limited time of day
- Only two looks (occlusions)
- Image artifacts: ~0.5 m DEM error
- Synthetic linescan model, proprietary sensors