Waveform Simulations
Transmit Pulse/FOV Offset Effects
In Vegetated Surfaces

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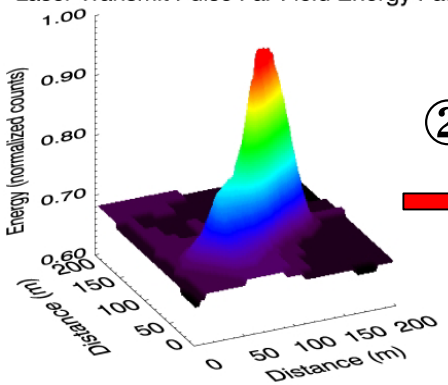
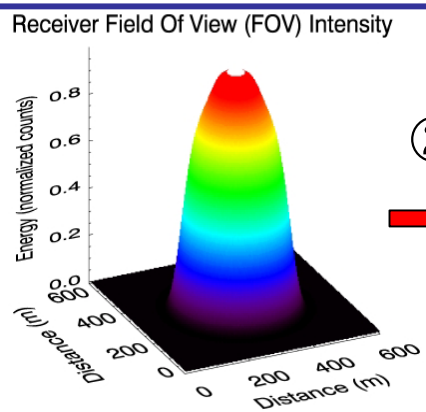
NASA Goddard Space Flight Center

GRID-BASED SIMULATOR COMPONENTS



②



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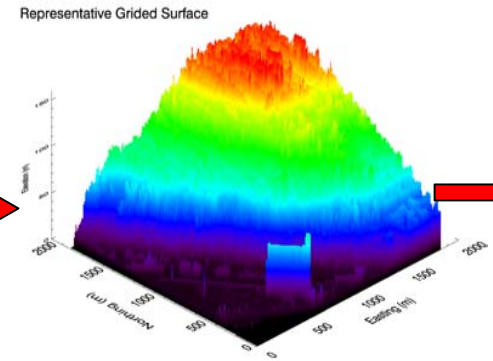
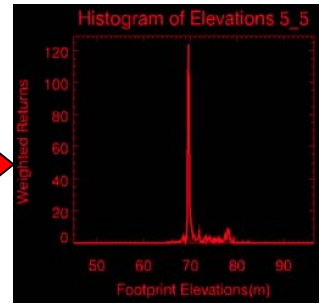




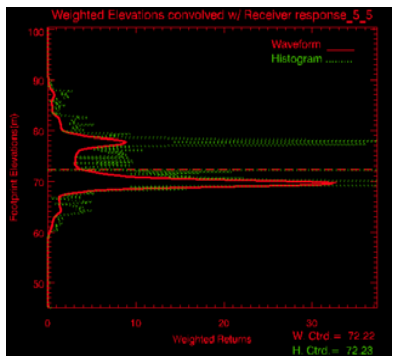
GLAS Transmit Pulse Energy Representation

1064nm Receiver GLAS FOV Representation

Grided Highest Surface Elevations for an urban/vegetated scene

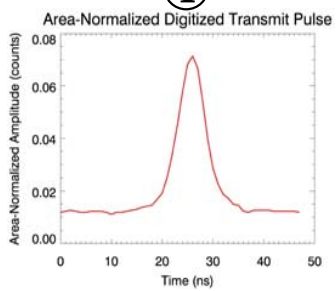
Elevation distribution weighted by the combined spatial effects of transmit pulse energy and receiver FOV for a simulated ICESat footprint centered at around 900m Easting and 900m Northing (vertical bin size = 0.15m).

Laser Profiling Array (LPA) Image Showing Far-field Spatial Distribution of Laser Pulse Energy



Simulated Waveform

④



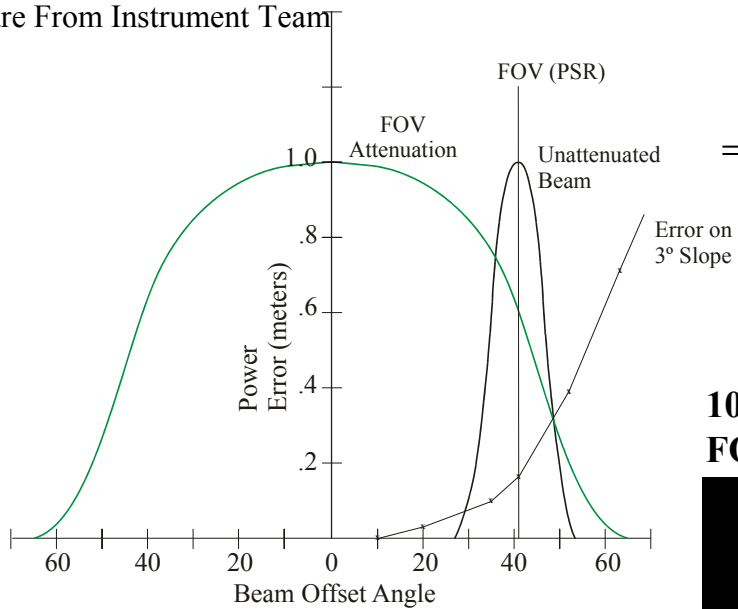
Transmit Pulse Impulse Response *6.1ns Gaussian (full width at half maximum)

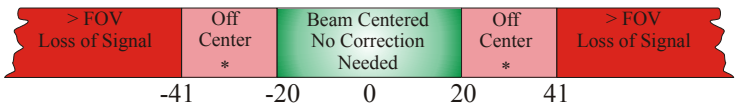
②Spatial convolution

④Temporal convolution

FOV Alignment Offsets Effects
Error Analysis from Simulations

Figure From Instrument Team

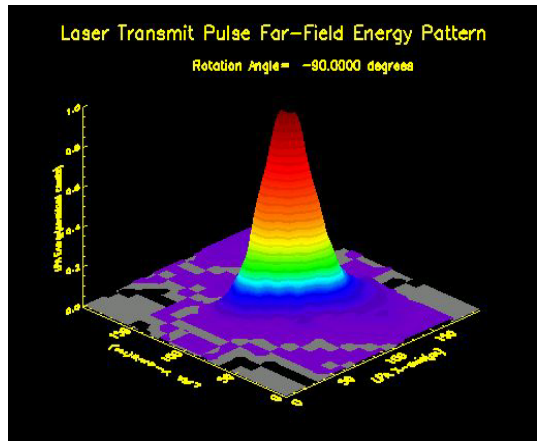




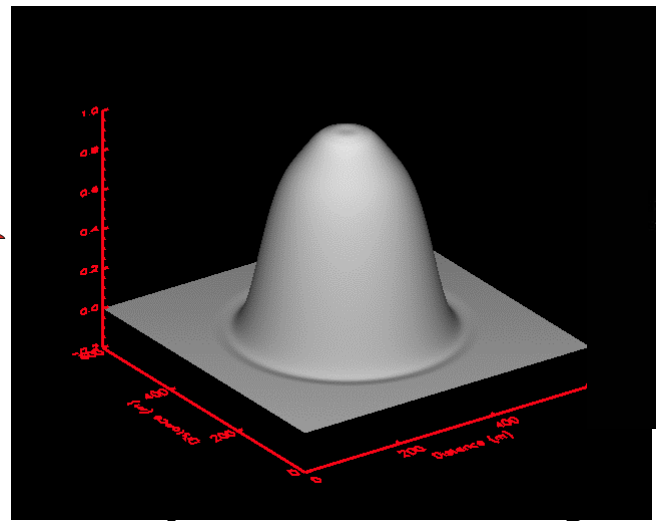
* Elevation Correction Requires:
- Misalignment offset angle & azimuth
- Local slope & azimuth

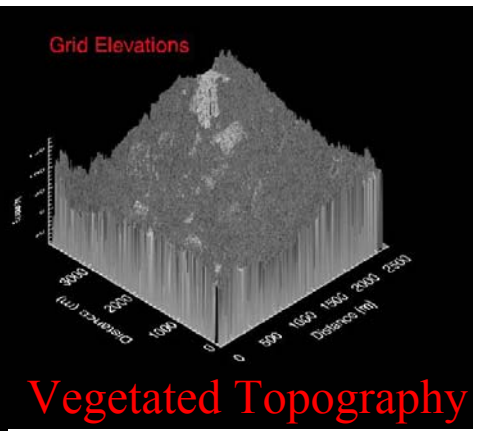
=>LPA representation

GLAS Transmit Pulse Energy Representation



1064nm Receiver GLAS FOV Representation





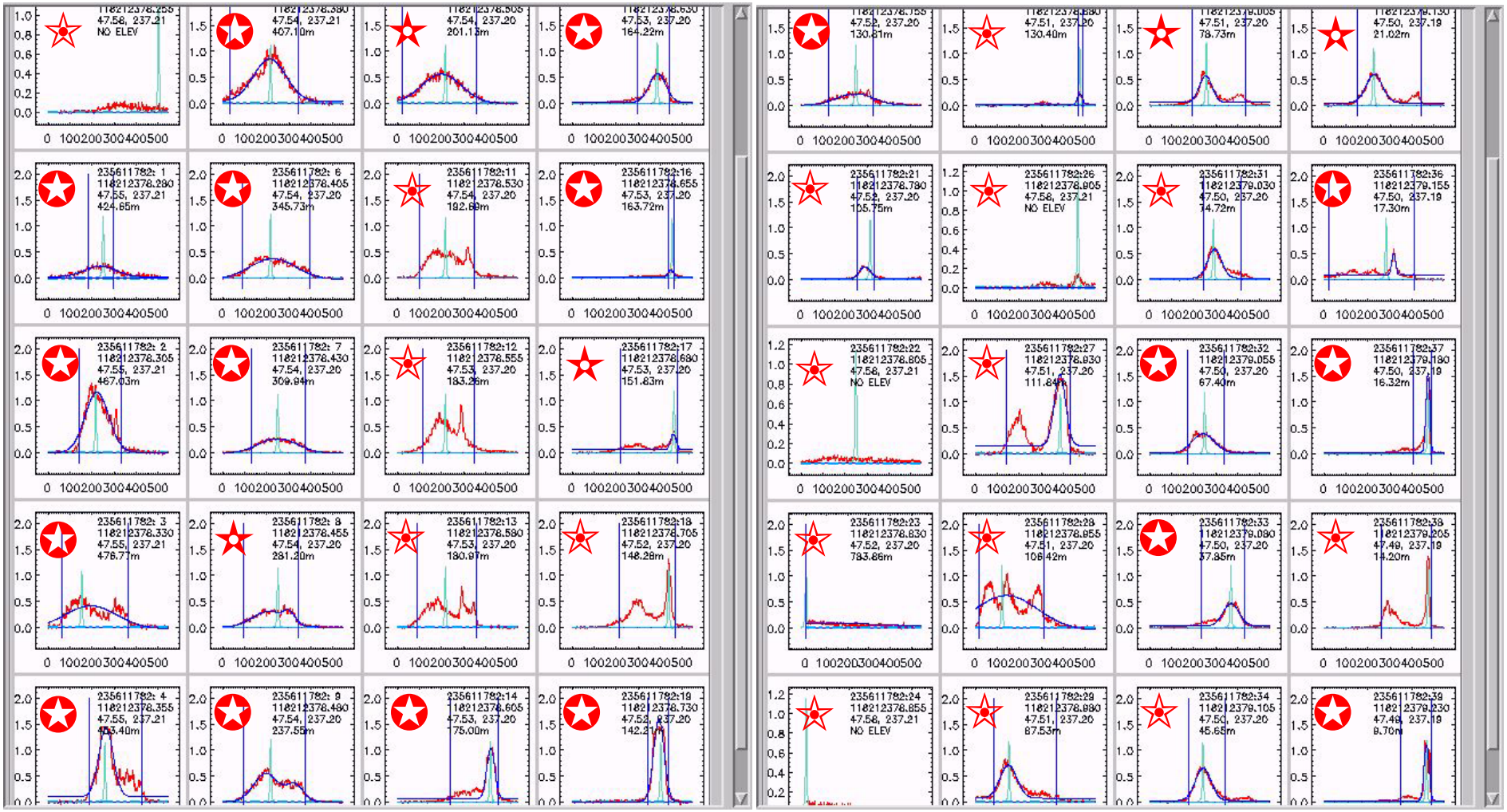
Vegetated Topography
(6ft resolution)

No Surface Reflectivity

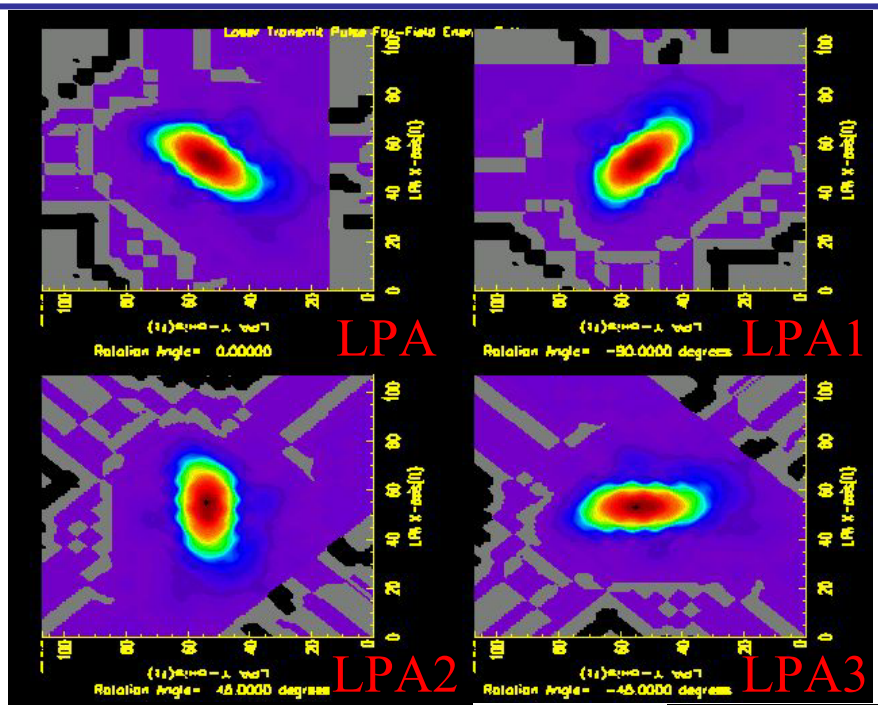
Shift down-slope ← → Shift up-slope

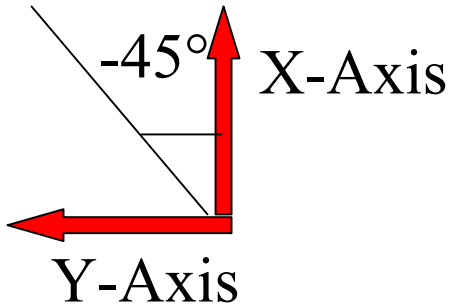
Waveforms Simulated in the Pacific NW

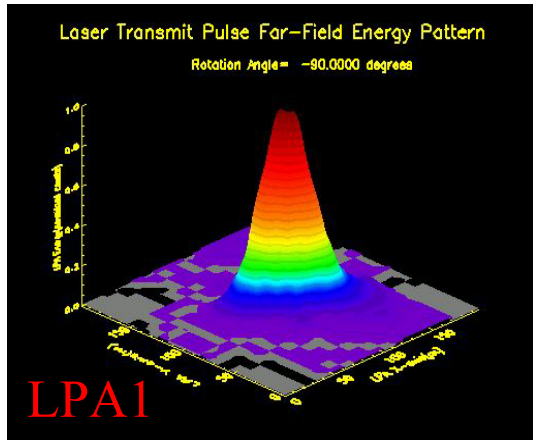
Release 14 - Record=235611782 - ✪=18 ★=5 ☆ =17



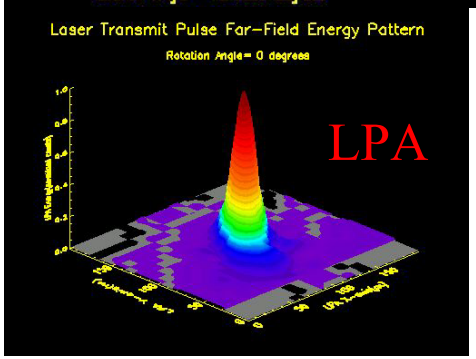
L2-Different LPA orientations

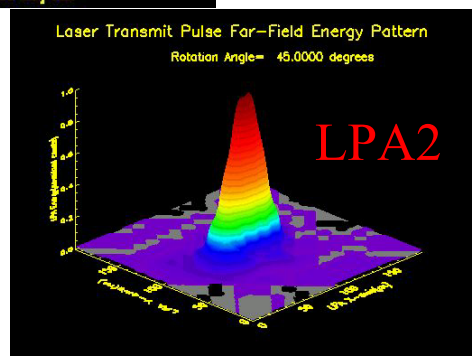


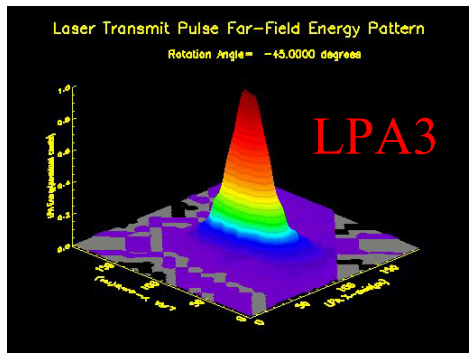




Will show results using LPA1 orientation at the center of FOV



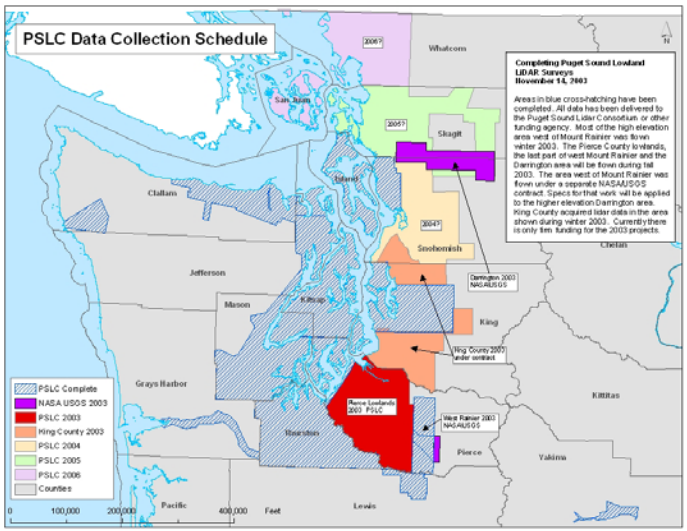


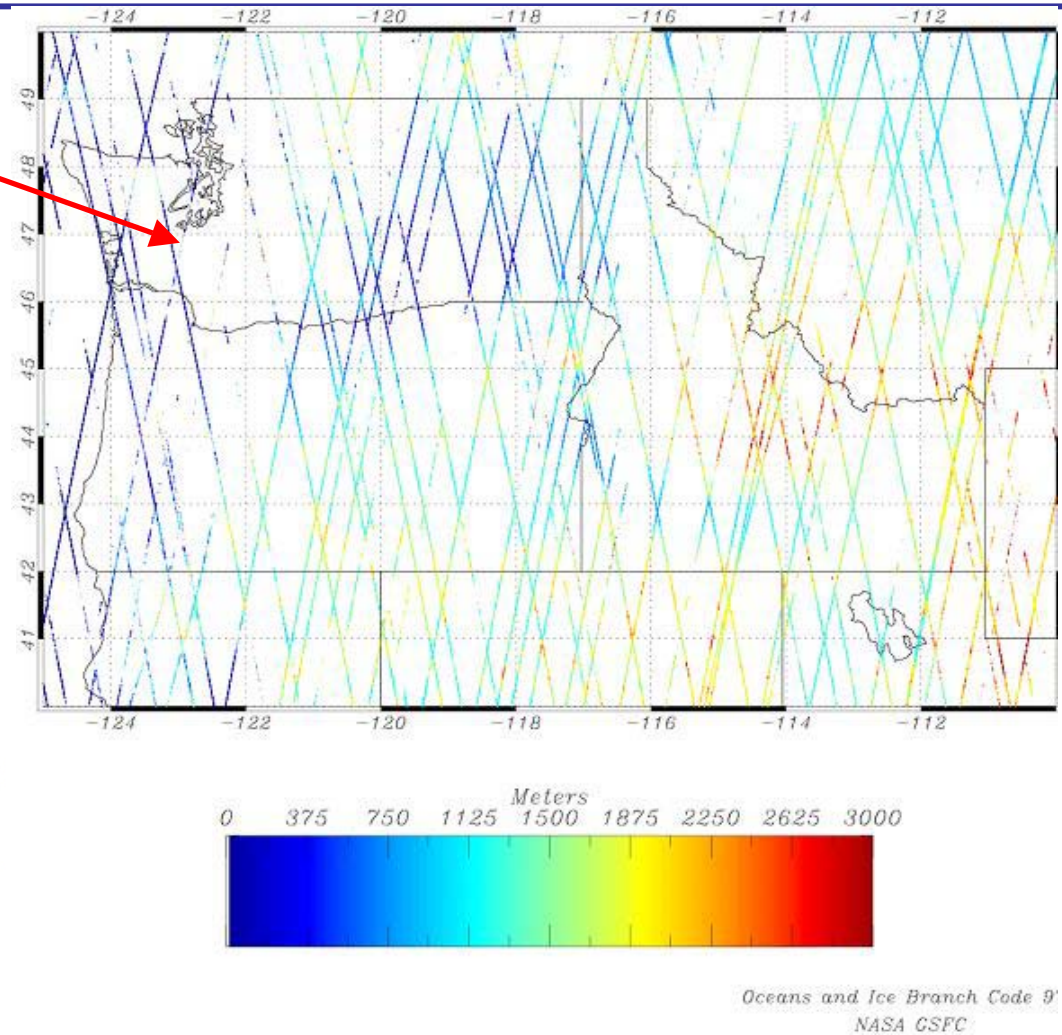


ICESat Surface Return Coverage for Sept. 25 to Nov. 18, 2003

Track43-Cycle29

ICESat Elevations
Pacific North West
Laser 2 – Release12



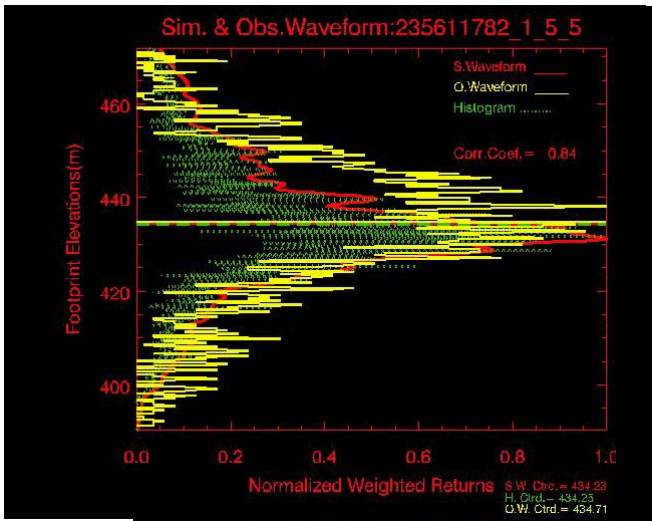


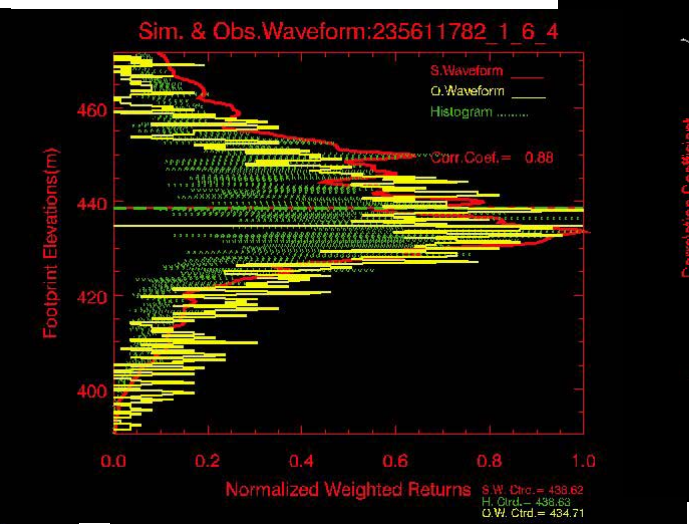
PUGET SOUND SIMULATIONS-Laser 2-LPA1

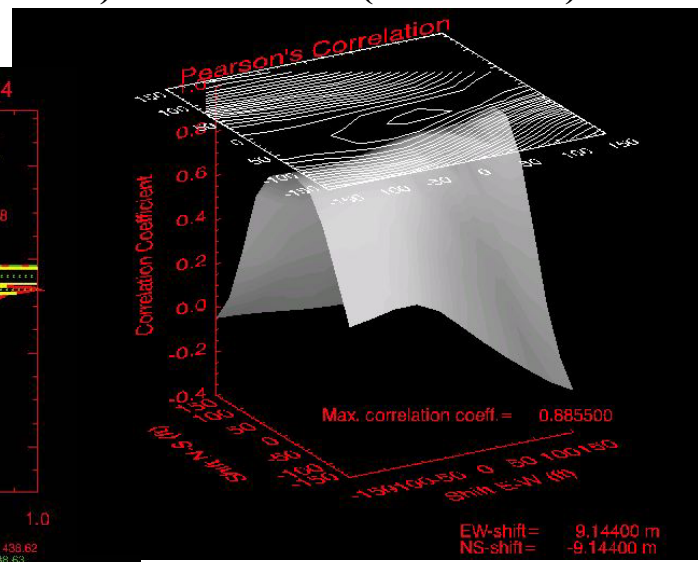
Observed (yellow) – Computed (red)

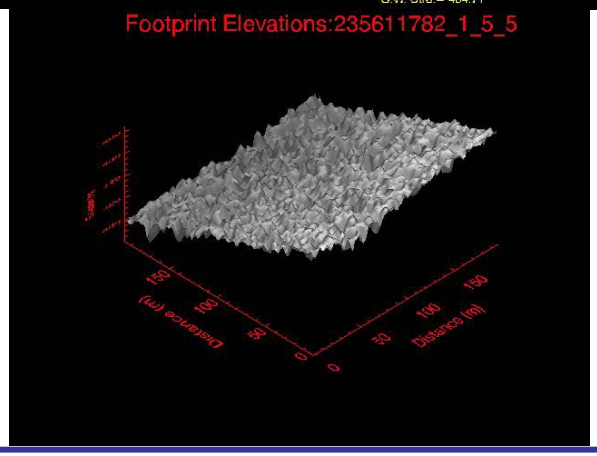
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

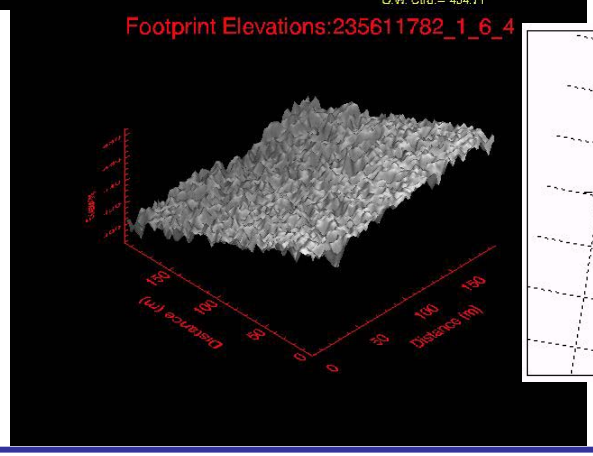
Shot 1 – No FOV Offset

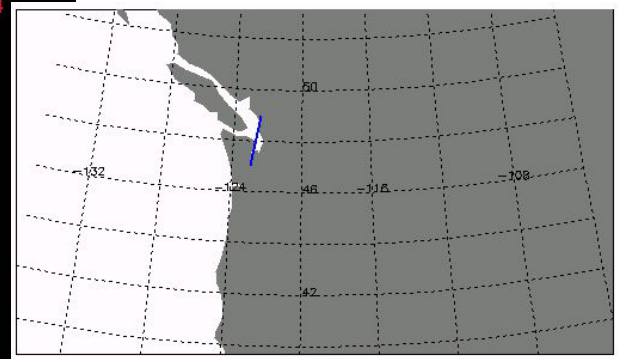












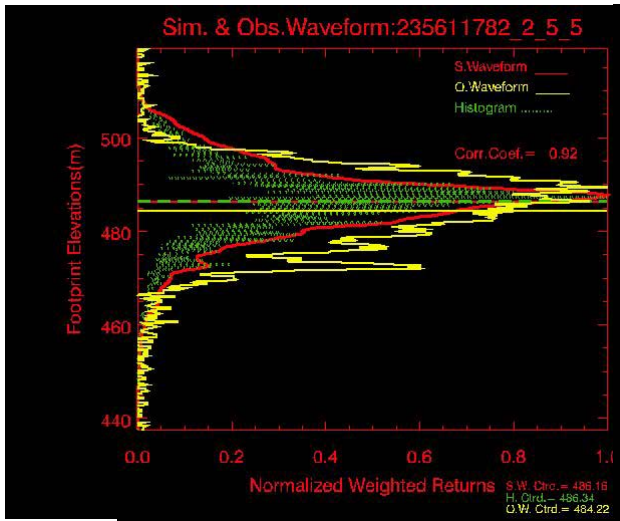
FOV Offset = 0urad
Corr.Coeff. = 0.989666

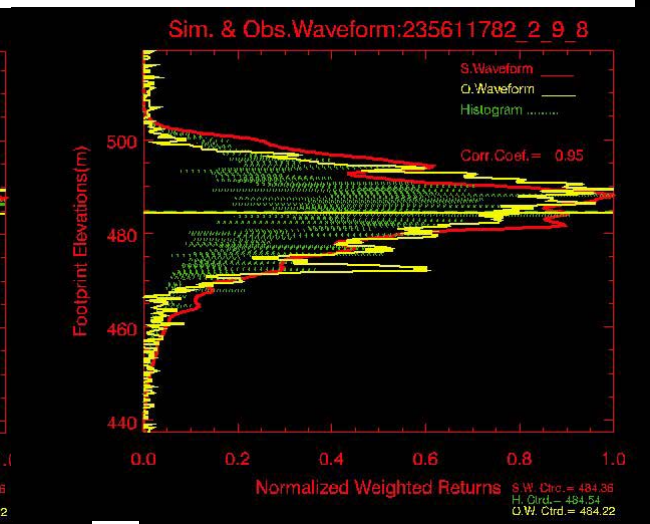
PUGET SOUND SIMULATIONS-Laser 2-LPA1

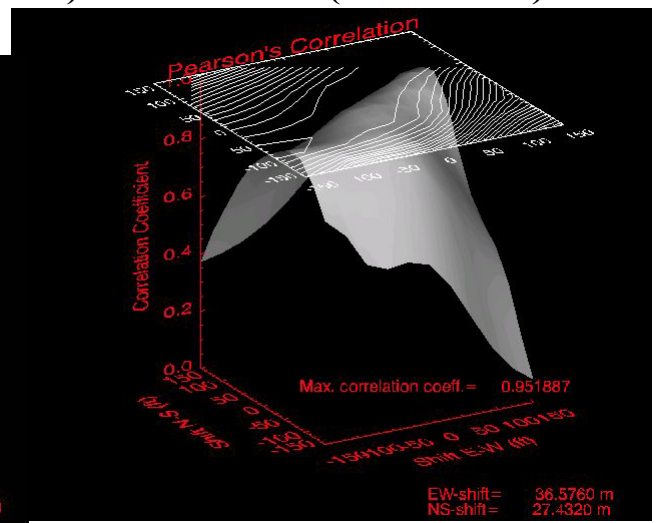
Observed (yellow) – Computed (red)

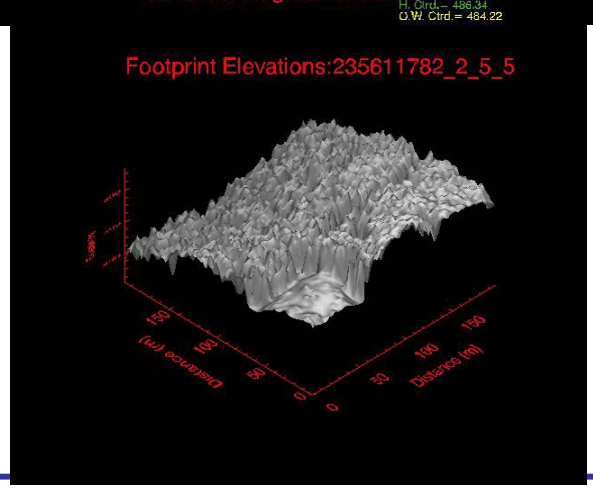
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

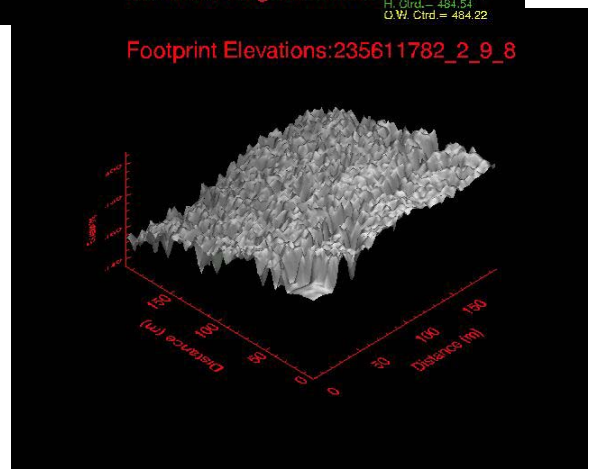
Shot 2 – No FOV Offset

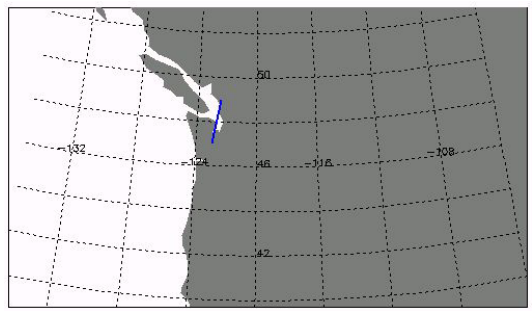










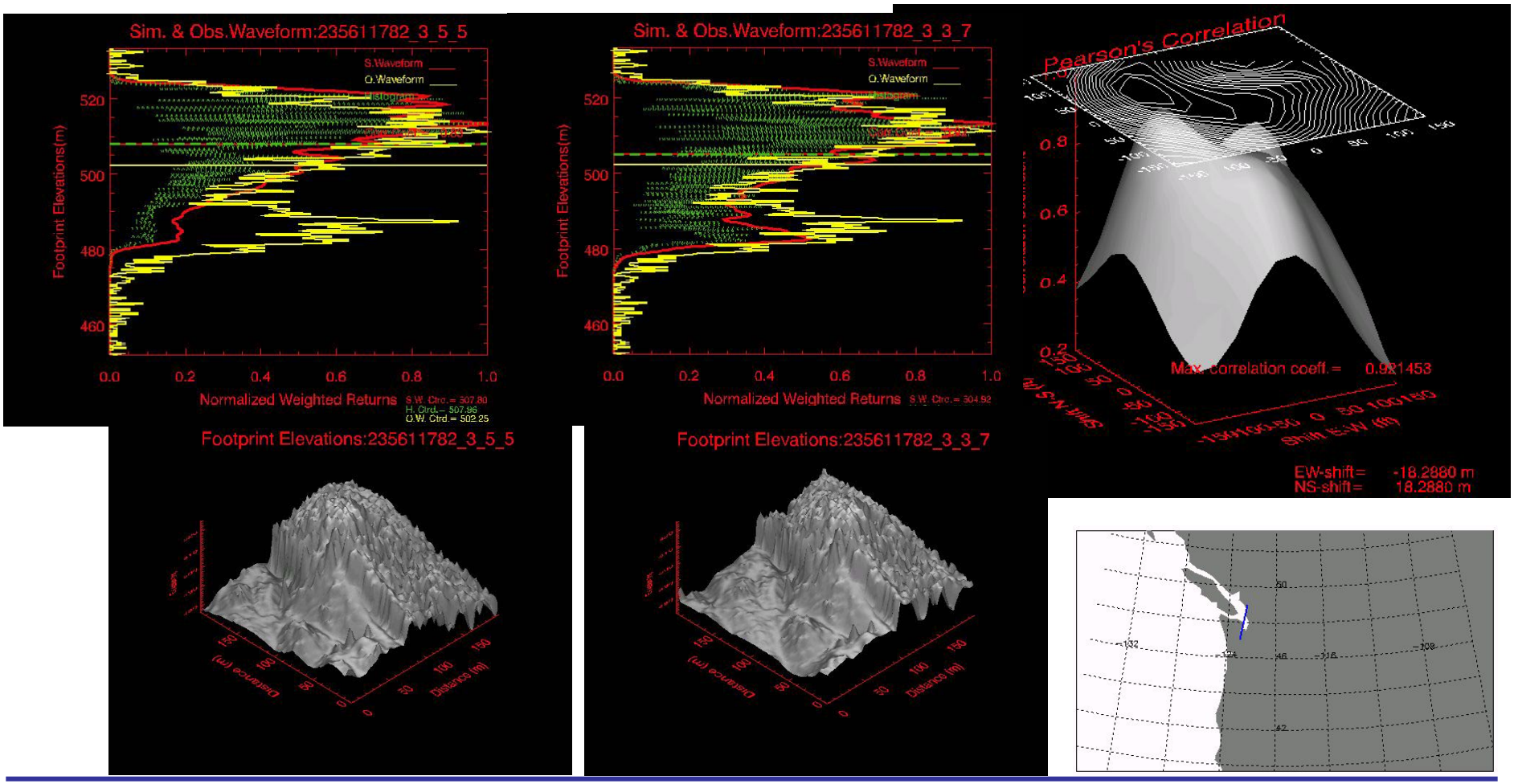


PUGET SOUND SIMULATIONS-Laser 2-LPA1

Observed (yellow) – Computed (red)

Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

Shot 3 – No FOV Offset

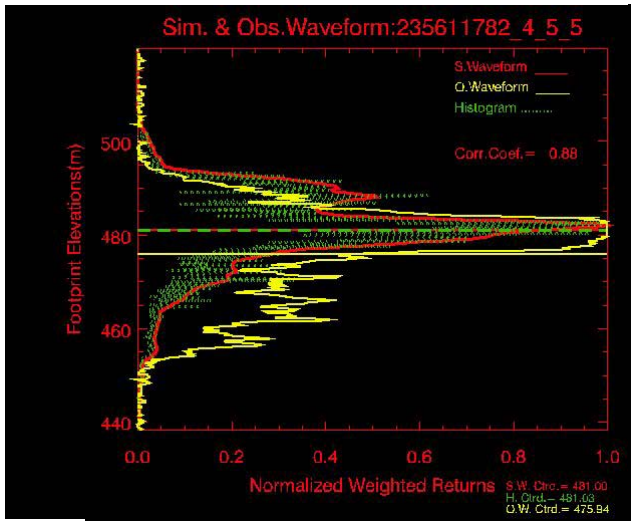


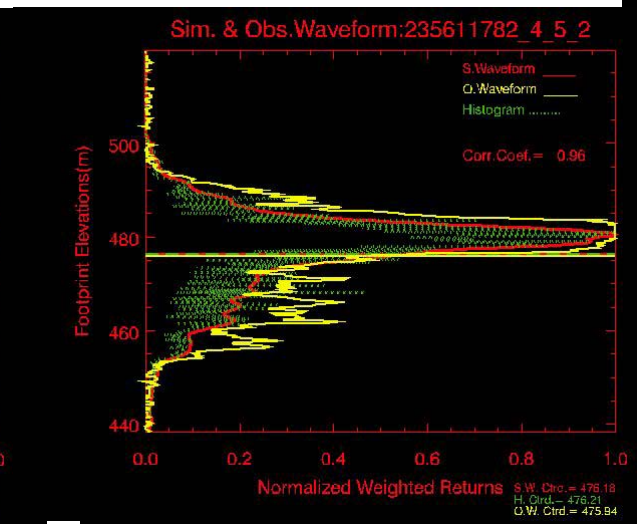
PUGET SOUND SIMULATIONS-Laser 2-LPA1

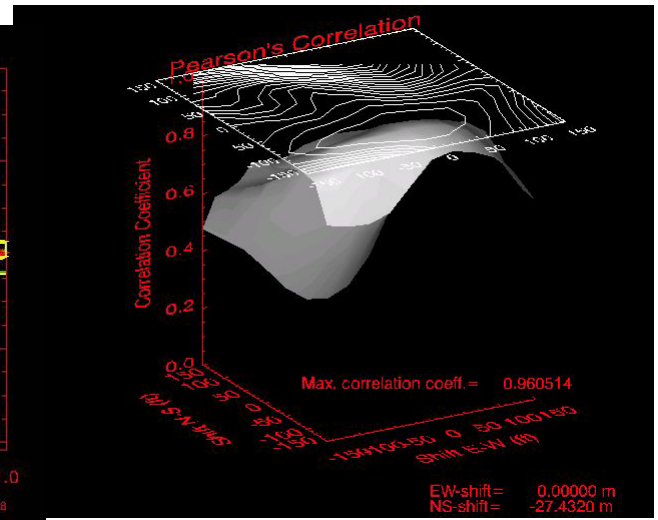
Observed (yellow) – Computed (red)

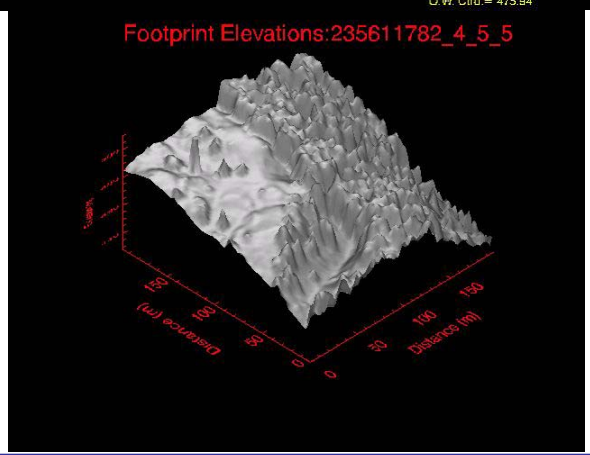
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

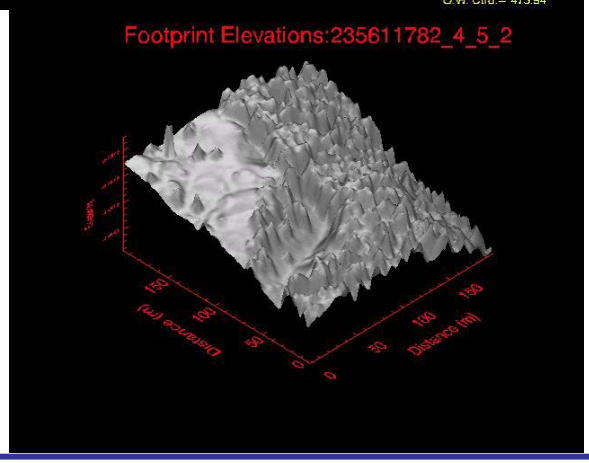
Shot 4 – No FOV Offset

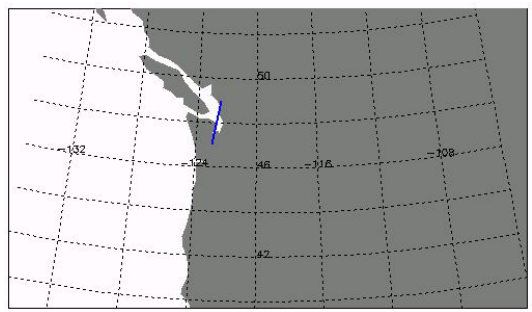








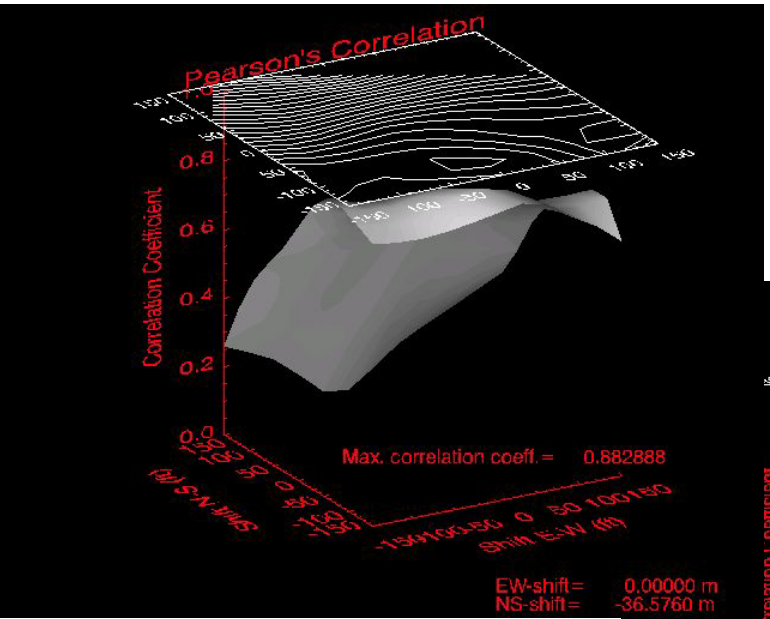




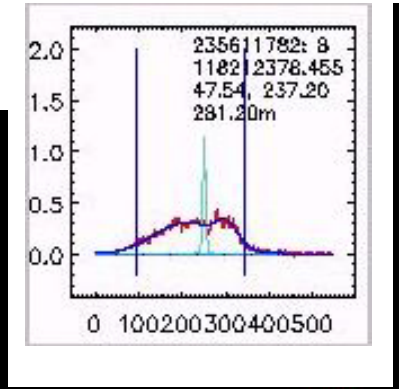
PUGET SOUND SIMULATIONS-Laser 2-LPA1

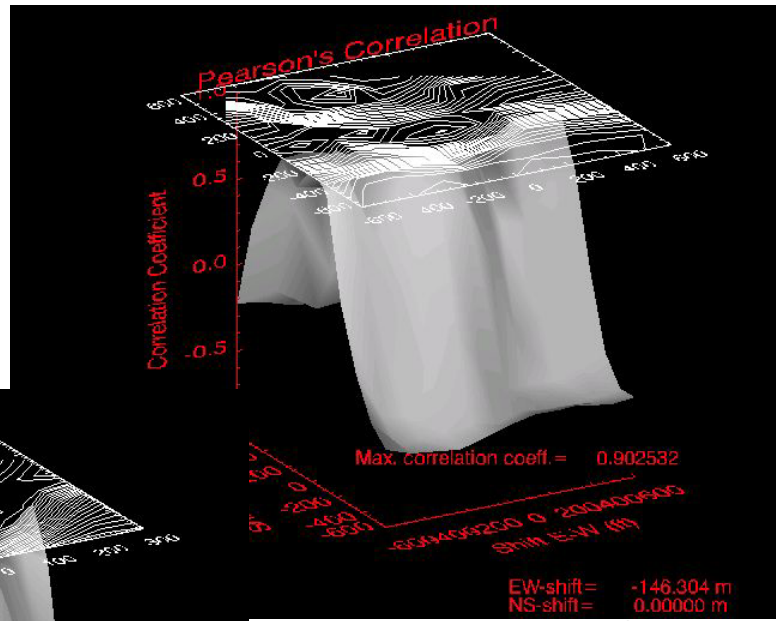
Shot8 – No FOV Offset

Shifts Not Solved

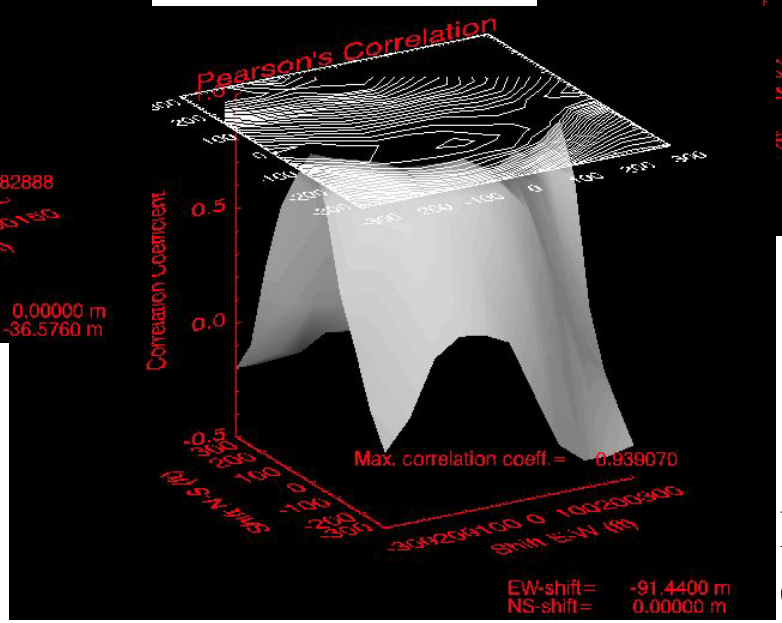


Increment=30ft
Corr. Coeff.=0.88288





Increment=120ft
Corr.Coeff.=0.902532



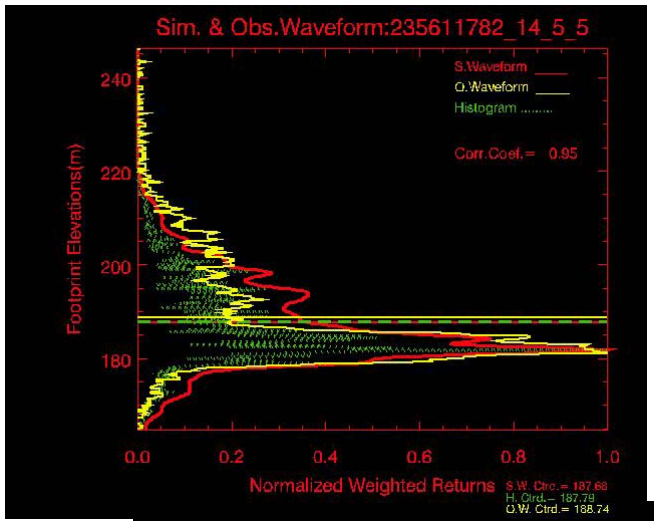
Increment=60ft
Corr.Coeff.=0.939070

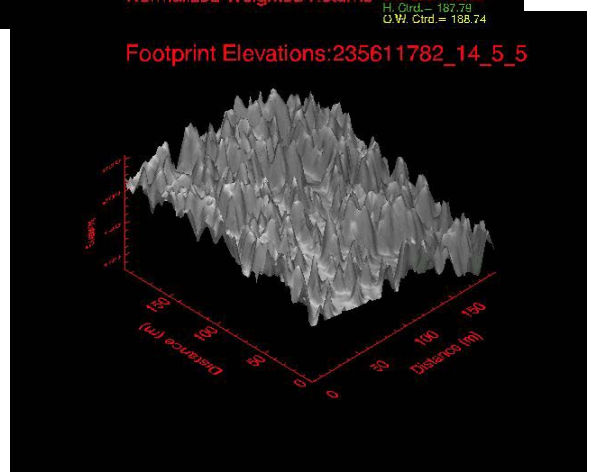
PUGET SOUND SIMULATIONS-Laser 2-LPA1

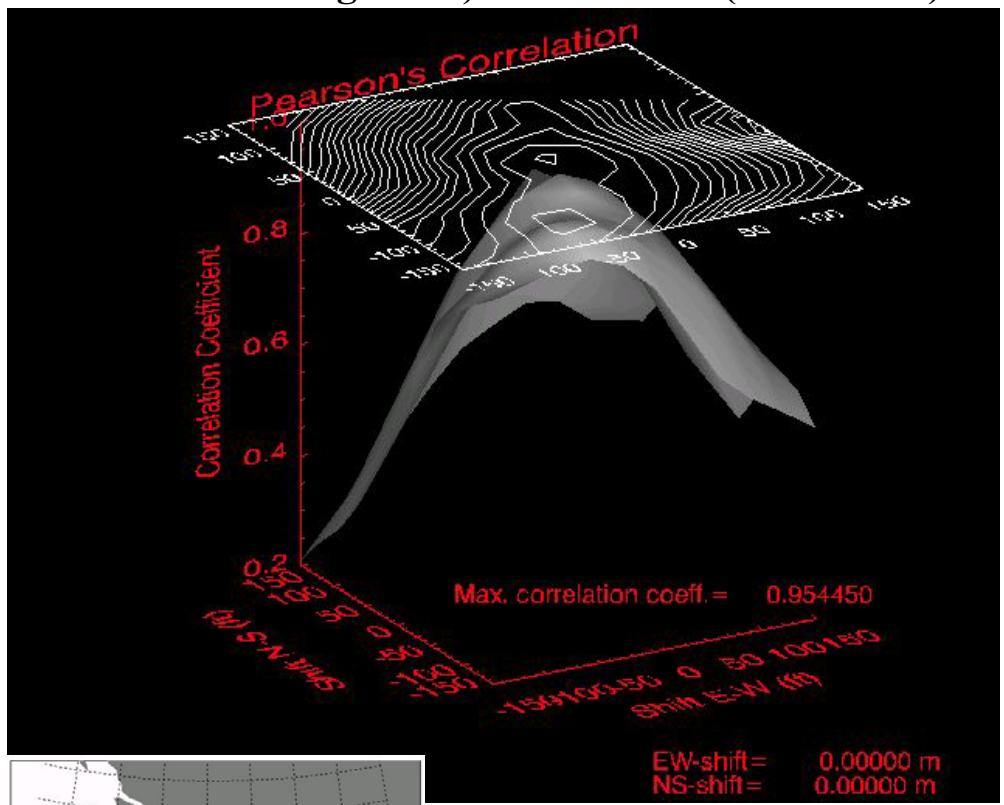
Observed (yellow) – Computed (red)

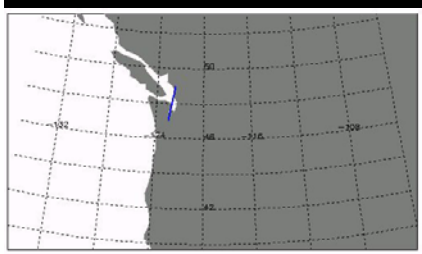
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

Shot14 – No FOV Offset







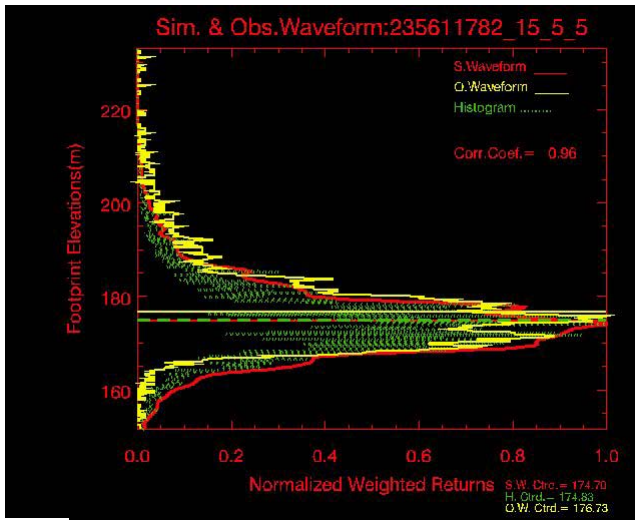


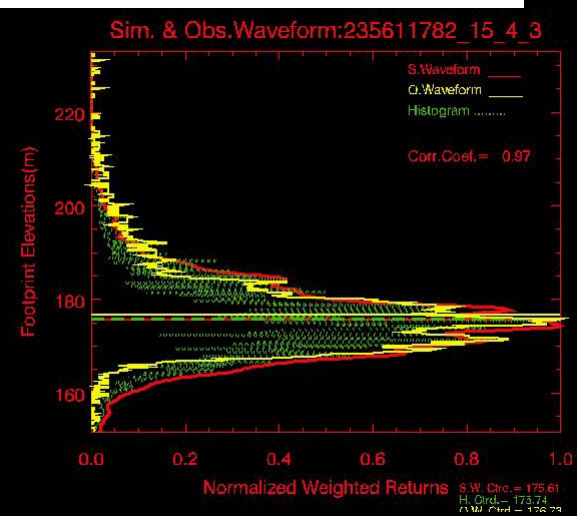
PUGET SOUND SIMULATIONS-Laser 2-LPA1

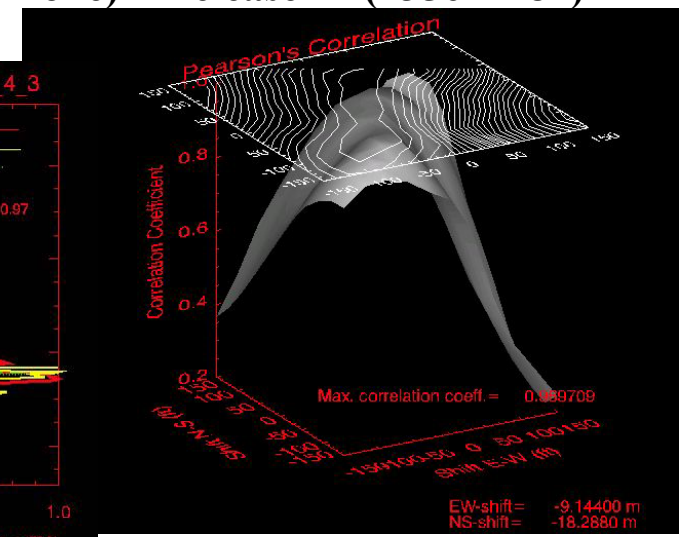
Observed (yellow) – Computed (red)

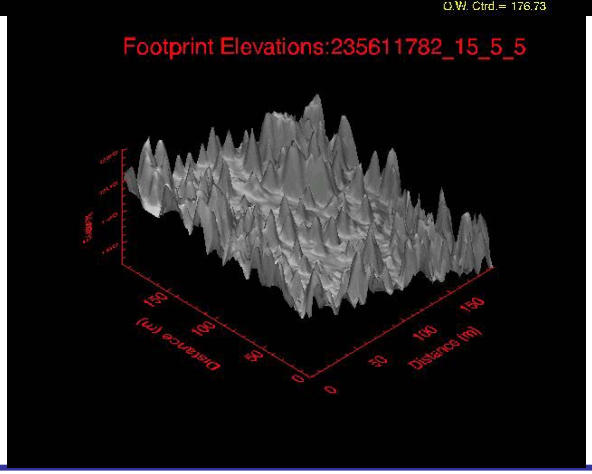
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

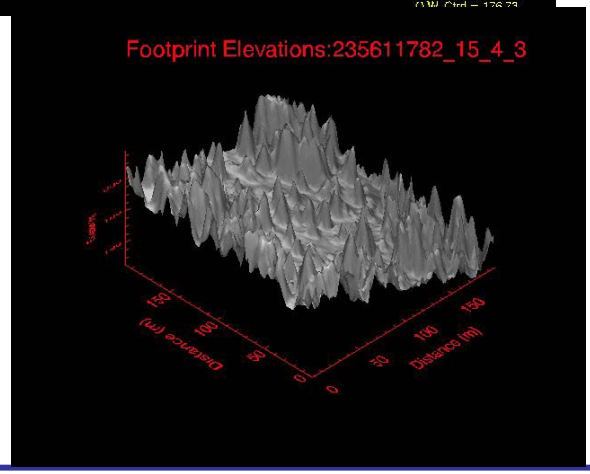
Shot15 – No FOV Offset

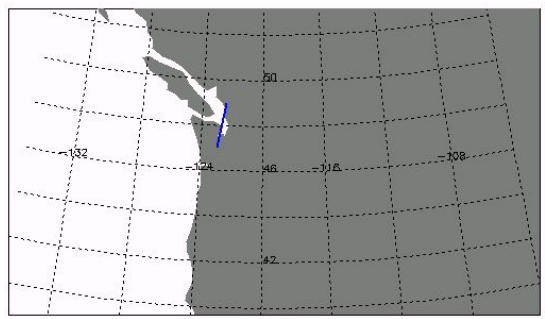










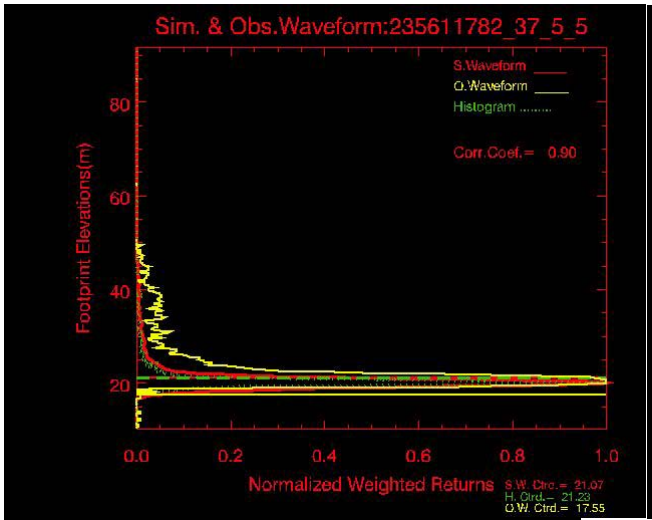


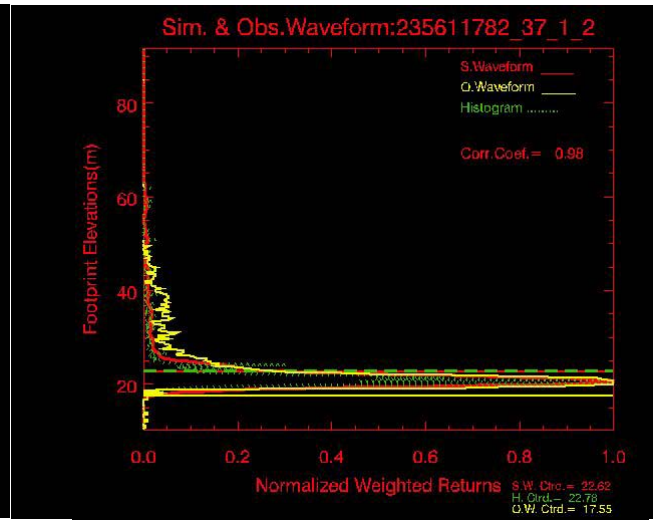
PUGET SOUND SIMULATIONS-Laser 2-LPA1

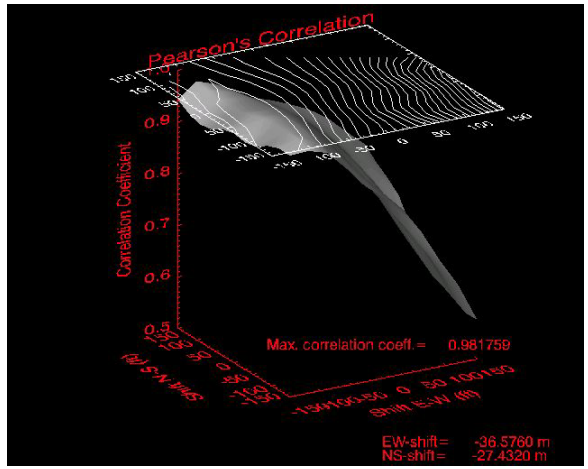
Observed (yellow) – Computed (red)

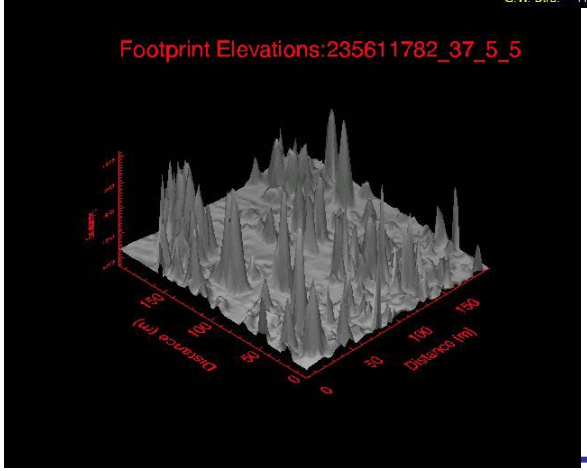
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

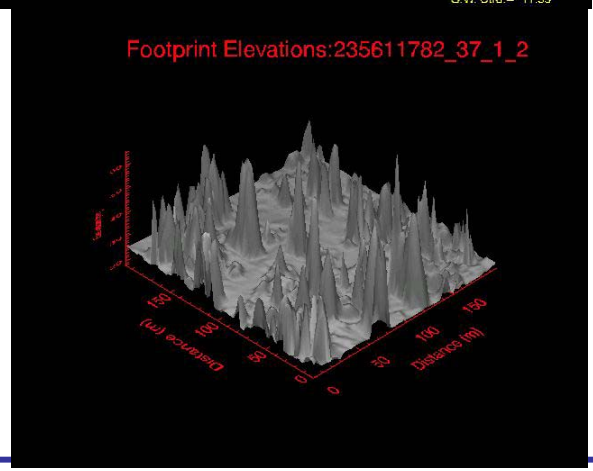
Shot37 – No FOV Offset

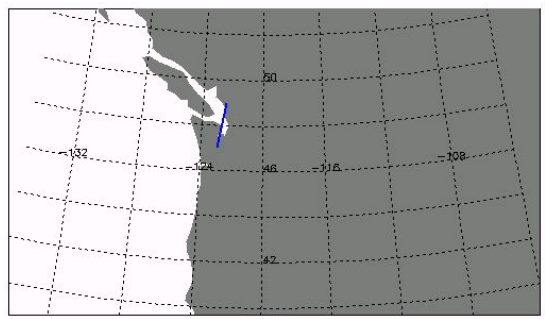










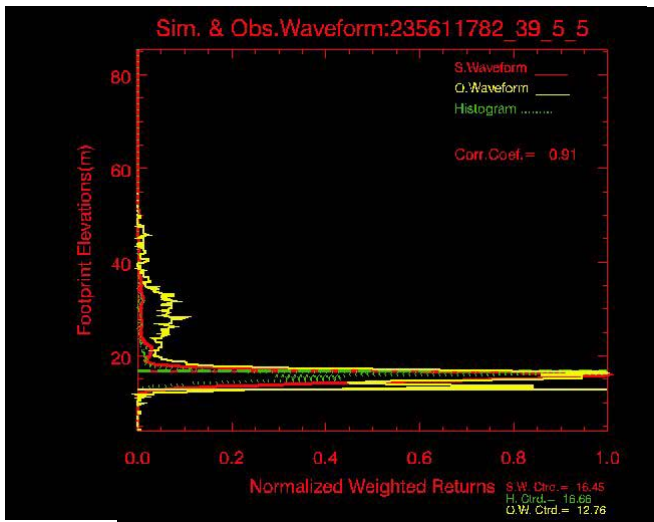


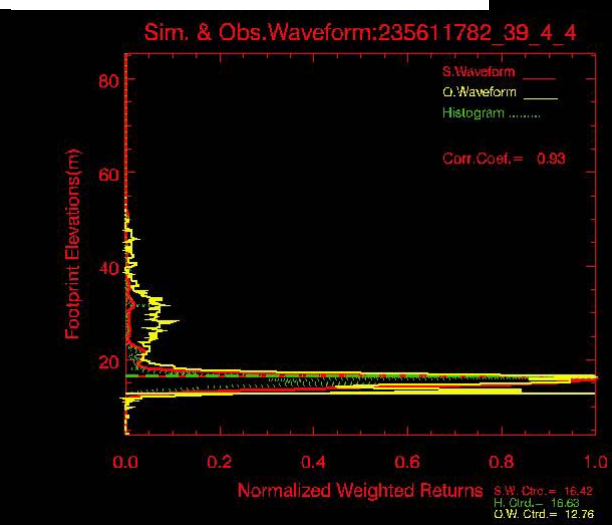
PUGET SOUND SIMULATIONS-Laser 2-LPA1

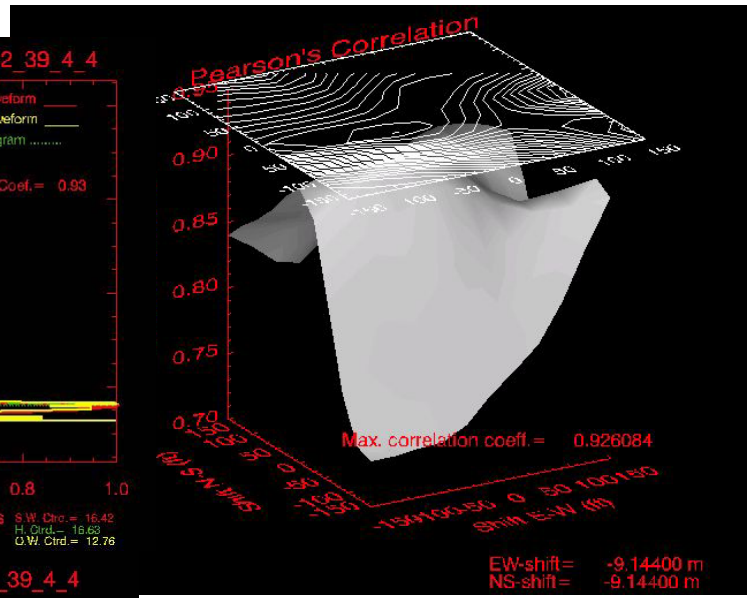
Observed (yellow) – Computed (red)

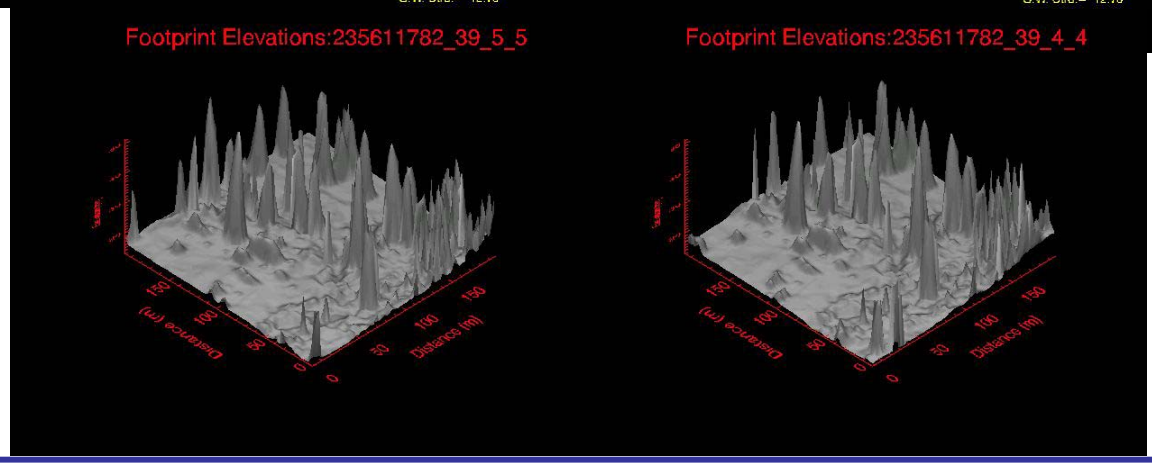
Footprint at Mission d_lat and d_lon (Not Profile Matching Done) – Release 14 (235611782)

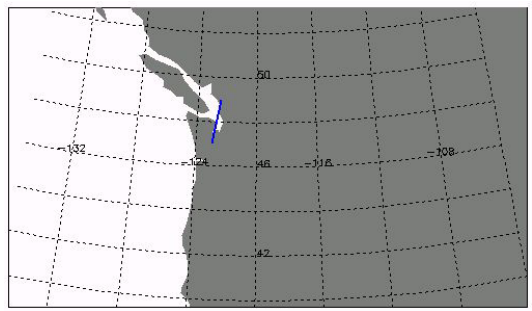
Shot39 – No FOV Offset







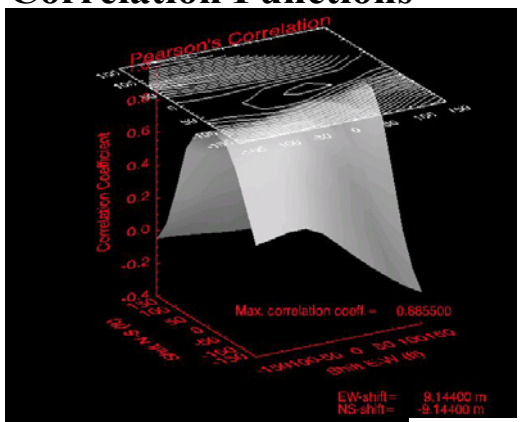




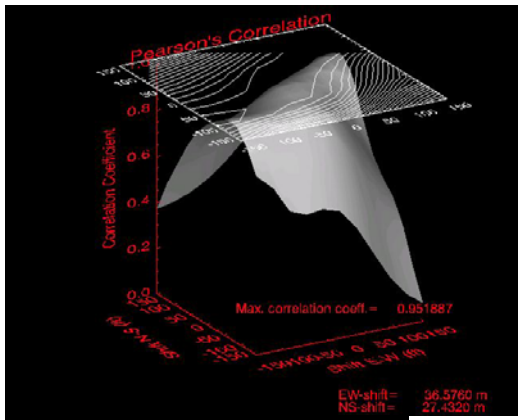
PUGET SOUND SIMULATIONS-Laser 2-LPA1

Waveform Matching Results – Correlation Functions

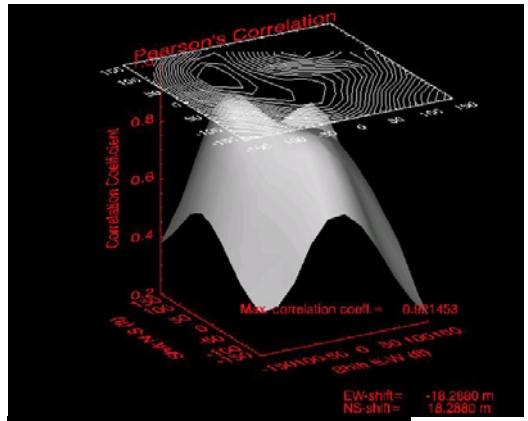
Correlation Functions



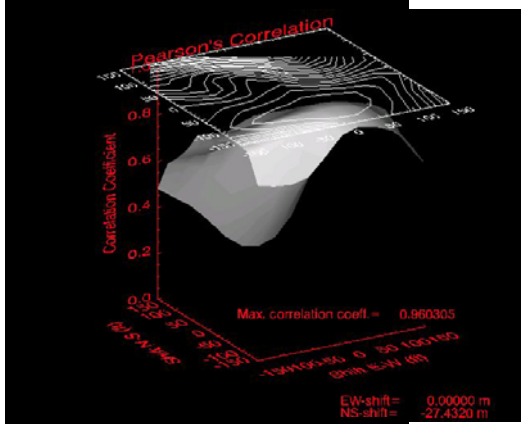
Shot 1
Corr.Coeff. = 0.989666



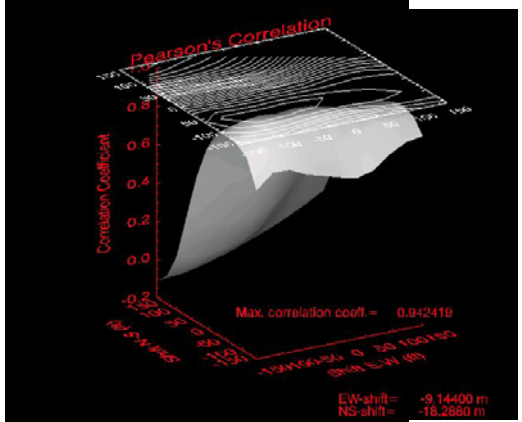
Shot 2
Corr.Coeff. = 0.951887



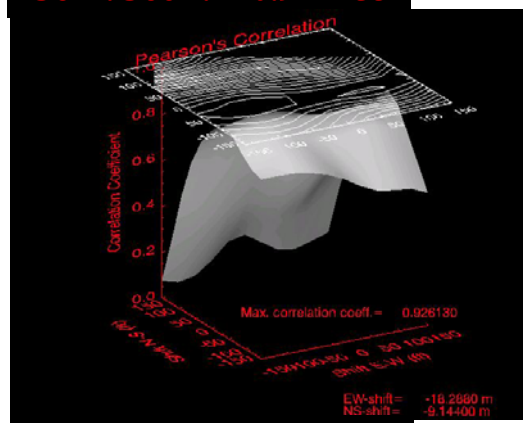
Shot 3
Corr.Coeff. = 0.921453



Shot 4
Corr.Coeff. = 0.960514



Shot 5
Corr.Coeff. = 0.942419

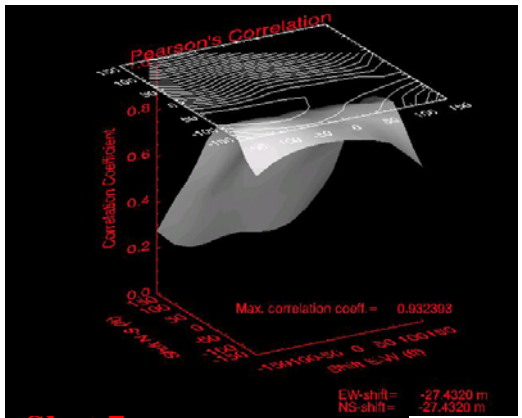


Shot 6
Corr.Coeff. = 0.942419

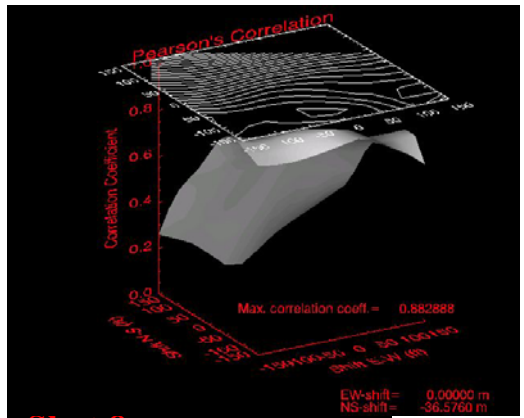
PUGET SOUND SIMULATIONS-Laser 2-LPA1

Waveform Matching Results – Correlation Functions

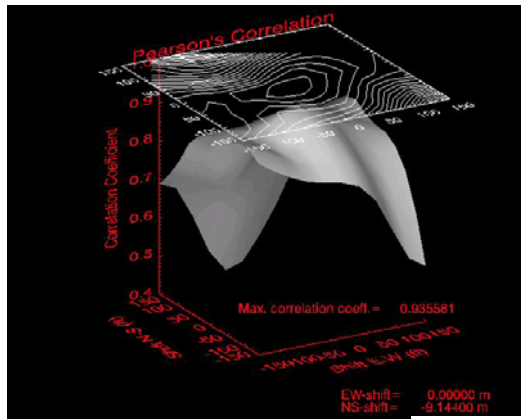
Correlation Functions



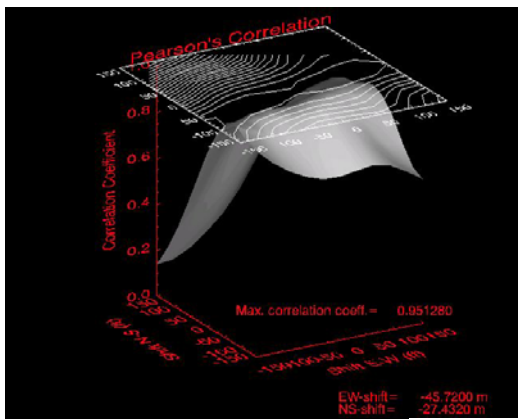
Shot 7
Corr.Coeff. = 0.932393



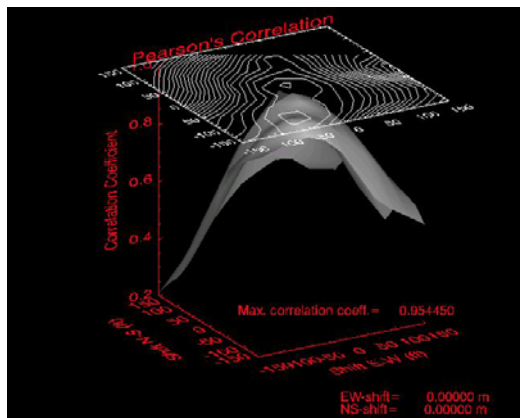
Shot 8
Corr.Coeff. = 0.88288



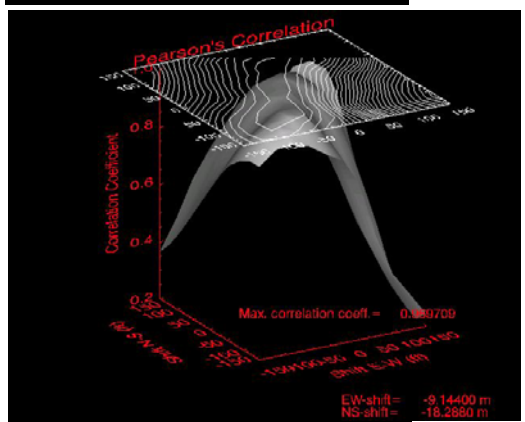
Shot 9
Corr.Coeff. = 0.935581



Shot 10
Corr.Coeff. = 0.951280



Shot 14
Corr.Coeff. = 0.954450

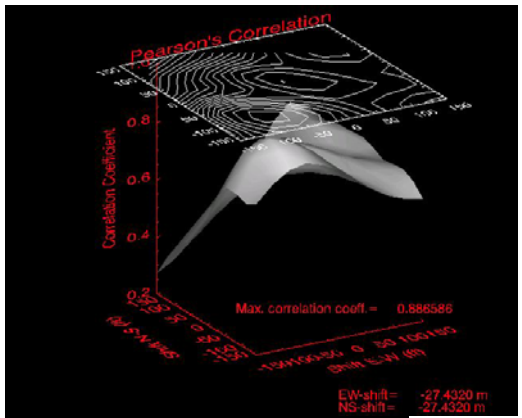


Shot 15
Corr.Coeff. = 0.969709

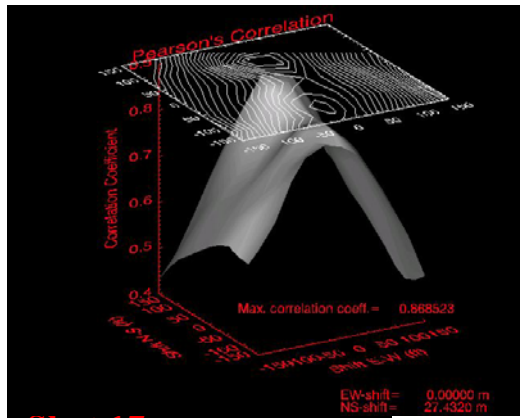
PUGET SOUND SIMULATIONS-Laser 2-LPA1

Waveform Matching Results – Correlation Functions

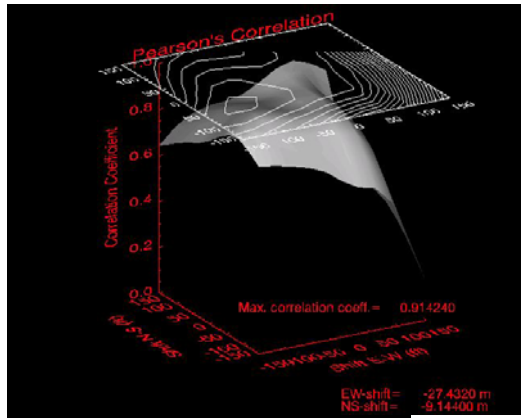
Correlation Functions



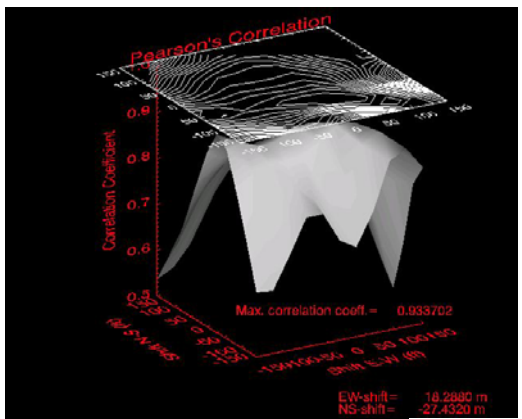
Shot 16
Corr.Coeff. = 0.932393



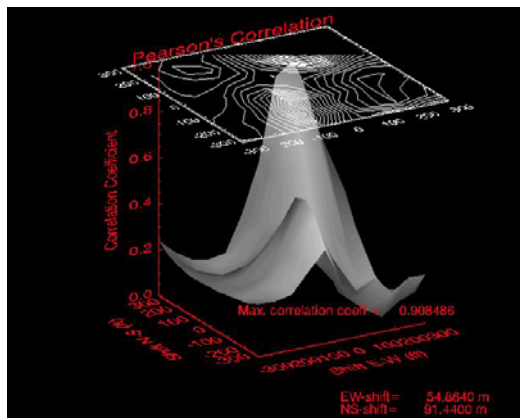
Shot 17
Corr.Coeff. = 0.88288



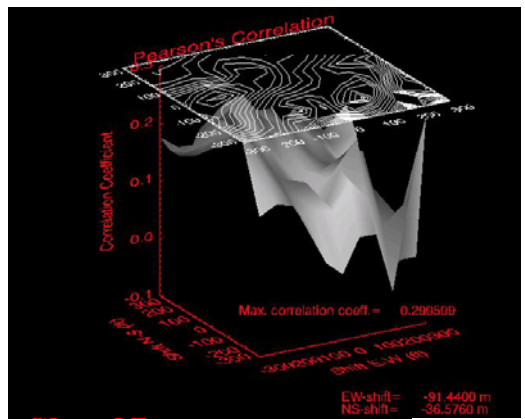
Shot 19
Corr.Coeff. = 0.914240



Shot 20
Corr.Coeff. = 0.933702



Shot 25
Corr.Coeff. = 0.719390



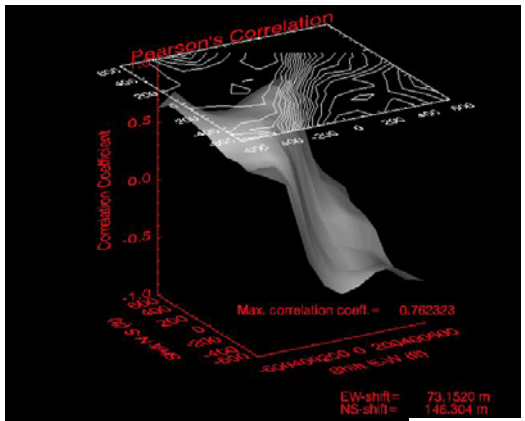
Shot 27
Corr.Coeff. = 0.275771

PUGET SOUND SIMULATIONS-Laser 2-LPA1

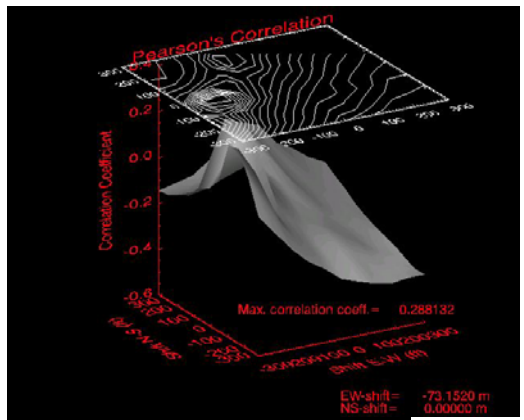
Waveform Matching Results – Correlation Functions

Correlation Functions

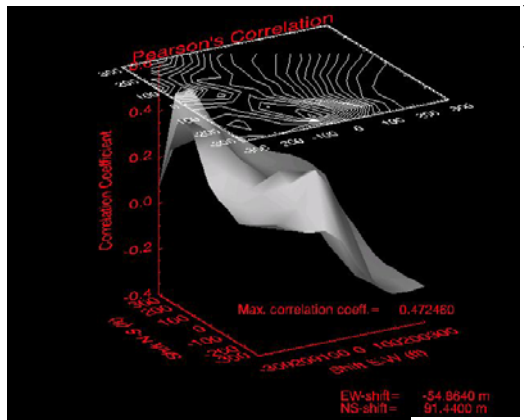
Inc.=10



Shot 28
Corr.Coeff. = 0.683471

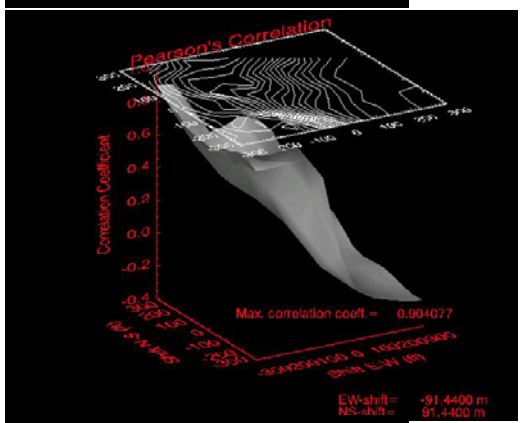


Shot 29
Corr.Coeff. = 0.748870

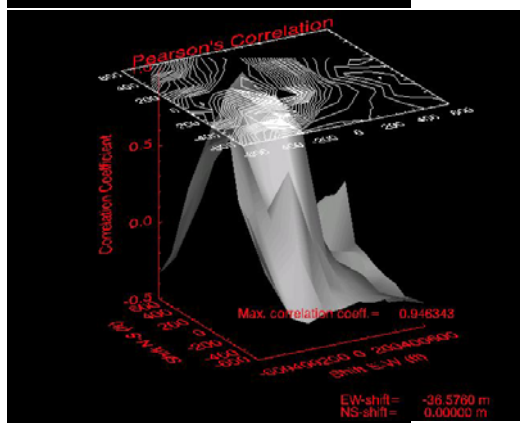


Shot 30
Corr.Coeff. = 0.472460

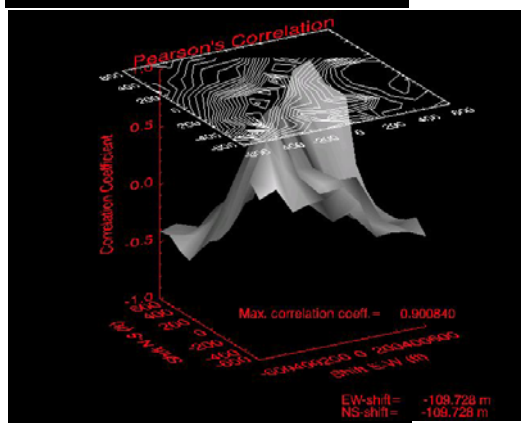
Inc.=20



Shot 31
Corr.Coeff. = 0.904077



Shot 32
Corr.Coeff. = 0.946343



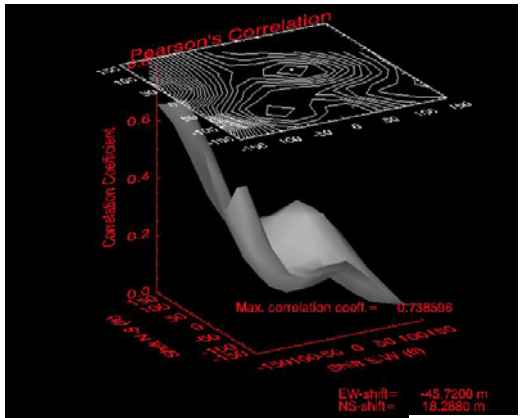
Shot 33
Corr.Coeff. = 0.900840

PUGET SOUND SIMULATIONS-Laser 2-LPA1

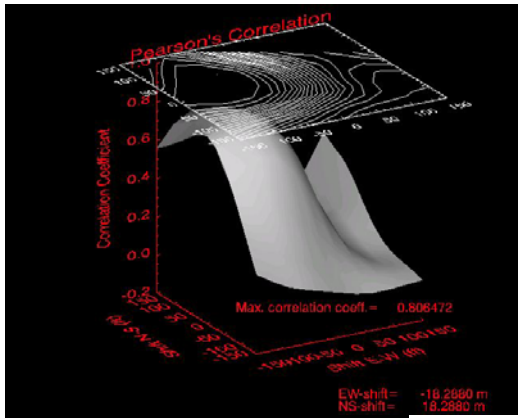
Waveform Matching Results – Correlation Functions

Correlation Functions

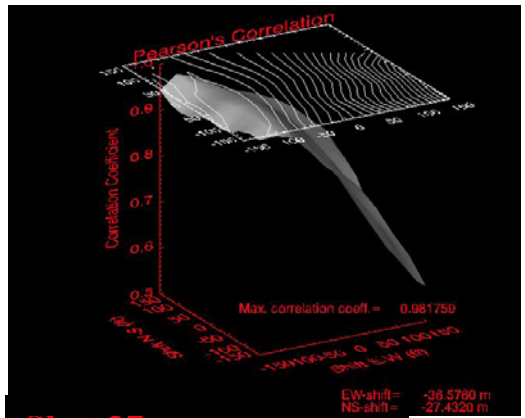
Inc.=5



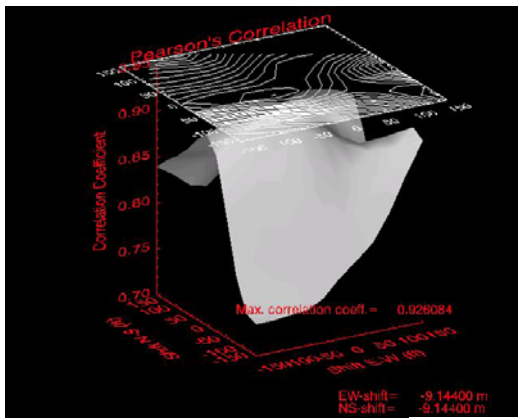
Shot 35
Corr.Coeff. = 0.738596



Shot 36
Corr.Coeff. = 0.806472



Shot 37
Corr.Coeff. = 0.981754



Shot 39
Corr.Coeff. = 0.904077

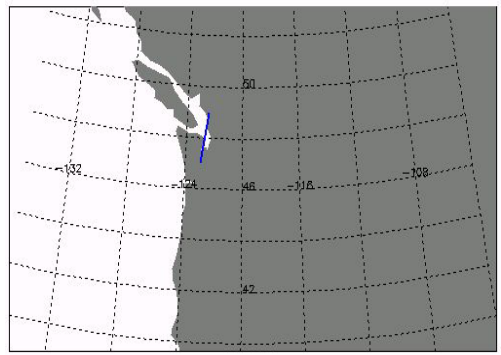
PUGET SOUND SIMULATIONS-Laser 2-LPA1

Mission Geolocation - Waveform Matching Results

Release 14 (235611782) –Geolocation Offsets

EW-Shift	NS-Shift	Corr	shot
9.144	-9.144	0.8855	1
36.576	27.432	0.951887	2
-18.28	18.28	0.921453	3
0	-27.432	0.960514	4
-9.144	-18.288	0.942419	5
-18.288	-9.144	0.92613	6
-27.432	-27.432	0.932393	7
0	-36.576	0.88288	8
0	-9.144	0.935581	9
-45.72	-27.432	0.95128	10
0	0	0.95445	14
-9.144	-18.288	0.969709	15
-27.432	-27.432	0.886586	16
0	27.432	0.868523	17
-27.432	-9.144	0.91424	19
18.2288	-27.432	0.933702	20

EW-Shift	NS-Shift	Corr	shot
45.72	45.72	0.71939	25
-45.72	36.576	0.683471	28
-73.152	0	0.288132	29
-54.864	91.44	0.47246	30
-91.44	-91.44	0.904077	31
-36	0	0.946343	32
-109.728	-109.728	0.90084	33
-45.72	18.28	0.738596	35
-18.288	18.288	0.806472	36
-36.576	-27.432	0.981754	37
-9.144	-9.144	0.926084	39

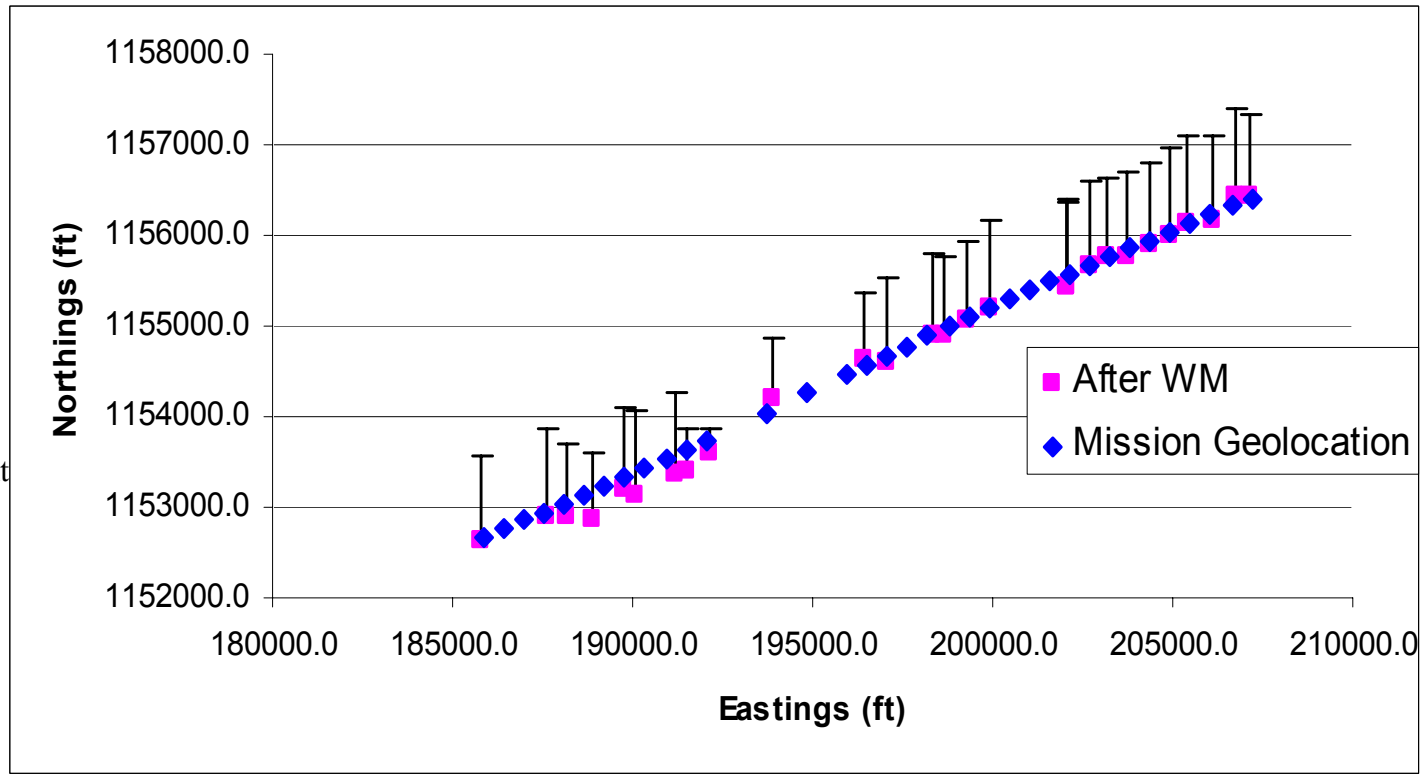


PUGET SOUND SIMULATIONS-Laser 2-LPA1

Mission Geolocation vs. Waveform Matching Results

Release 14 (235611782)
Geolocation Offsets

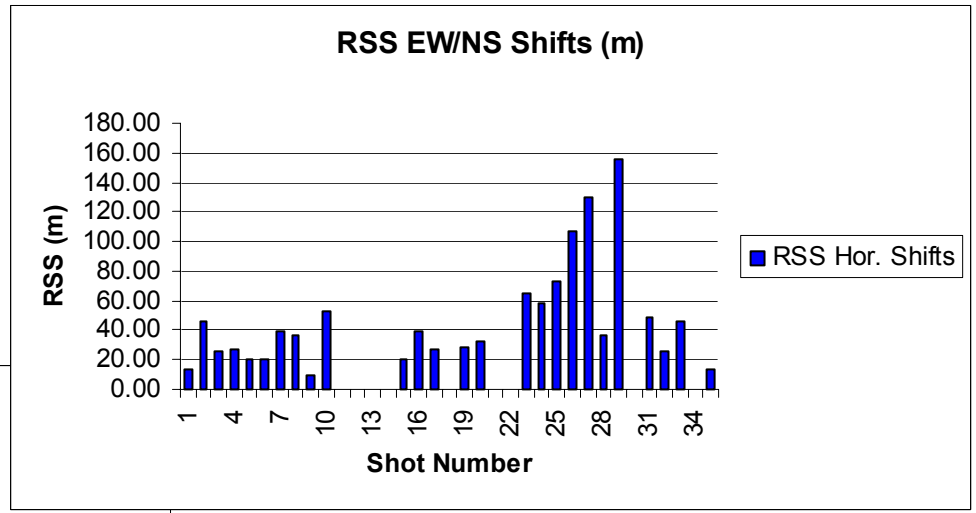
Correlation Coefficient
Indicated by bar size

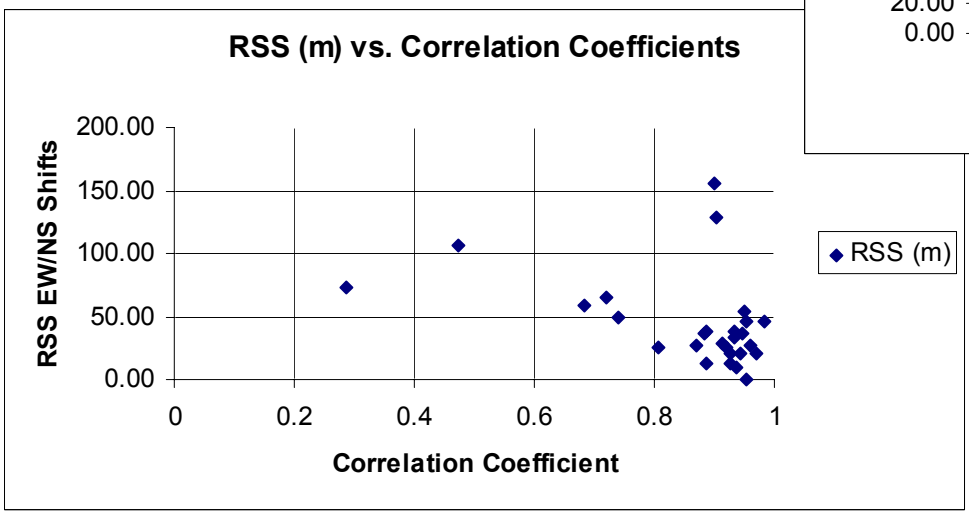


PUGET SOUND SIMULATIONS-Laser 2-LPA1

Mission Geolocation vs. Waveform Matching Results

Release 14 (235611782)
Geolocation Offsets





PUGET SOUND SIMULATIONS-Laser 2-LPA1
No Offset from FOV Center

•For the first part of the 40 shots record, correlations are higher and offsets are smaller

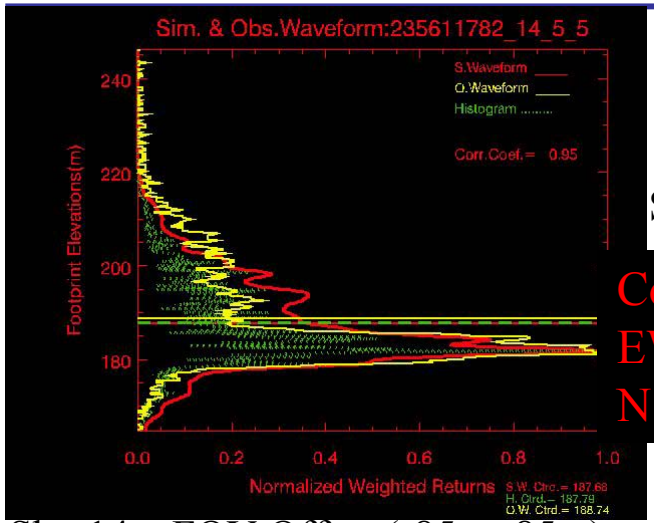
(the topography for the latter part of record did not offer sufficient variation for correlations to be robust while footprint was offset)

•Peaks of the Correlation functions are not always well defined (low resolution in a particular direction)

•Shot to shot geolocation offsets vary, but are less than ~45 m for waveforms with higher correlation coefficients

PUGET SOUND SIMULATIONS-Laser 2-LPA1

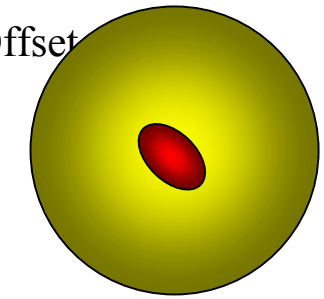
Observed (yellow) – Computed (red)

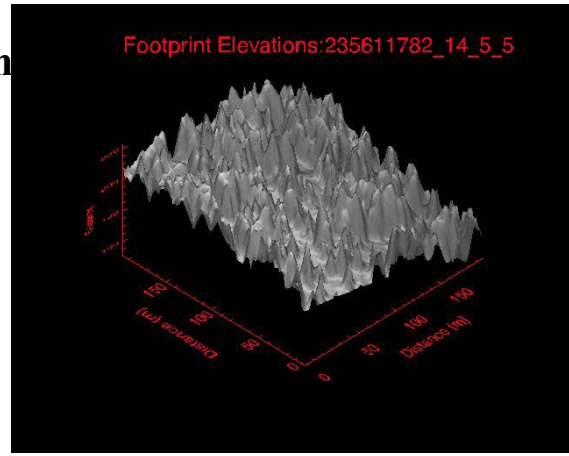


Release 14 (235611782)
Footprint at Mission d_lat and d_lon
(Not Profile Matching Done)

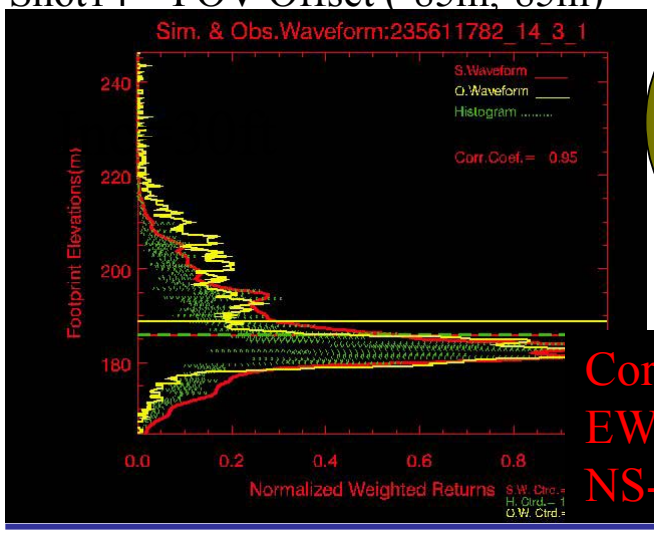
Shot14 – No FOV Offset

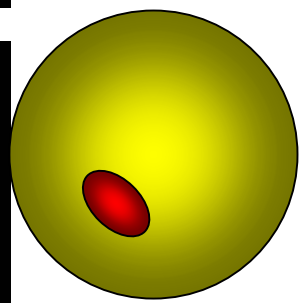
Corr.= 0.967868
EW-Shift=0m
NS-Shift=0m





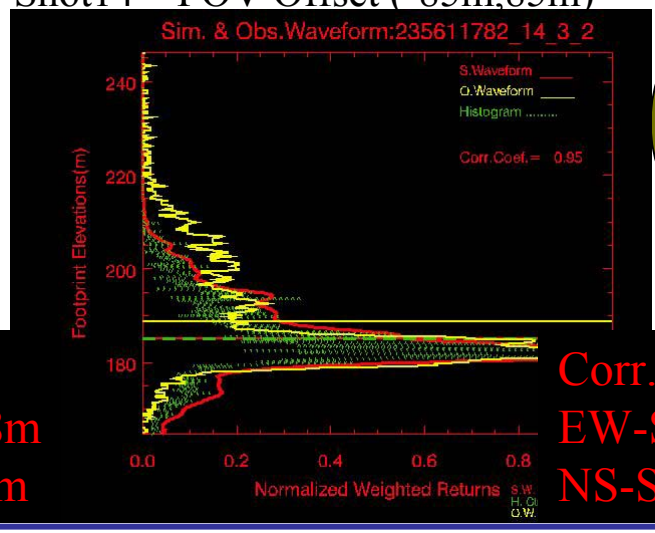
Shot14 – FOV Offset (-85m,-85m)

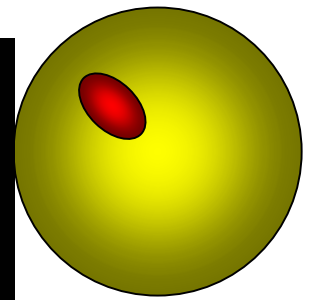




Corr.= 0.967868
EW-Shift=-18.288m
NS-Shift=-36.576m

Shot14 – FOV Offset (-85m,85m)

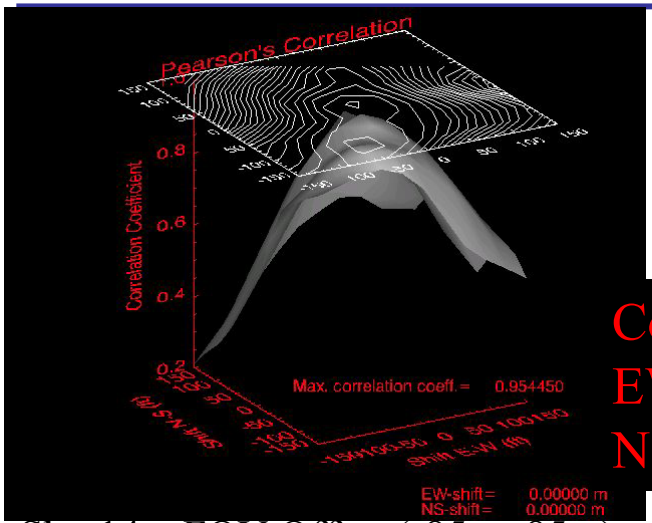




Corr.= 0.967868
EW-Shift=-18.288m
NS-Shift=-27.432m

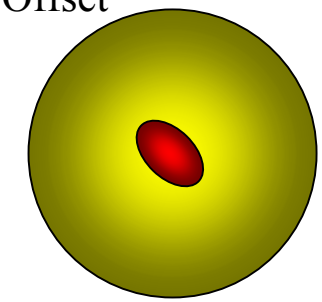
PUGET SOUND SIMULATIONS-Laser 2-LPA1

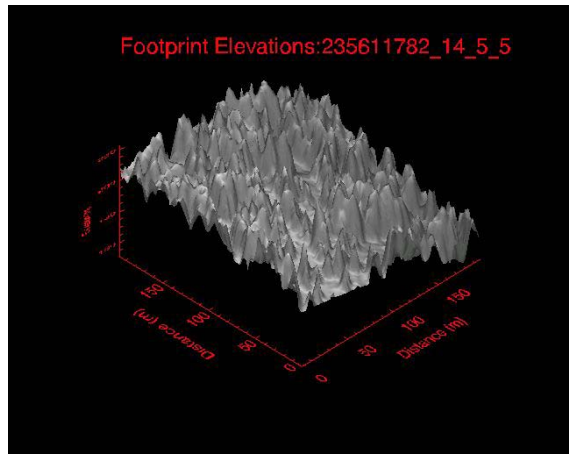
Correlation Functions



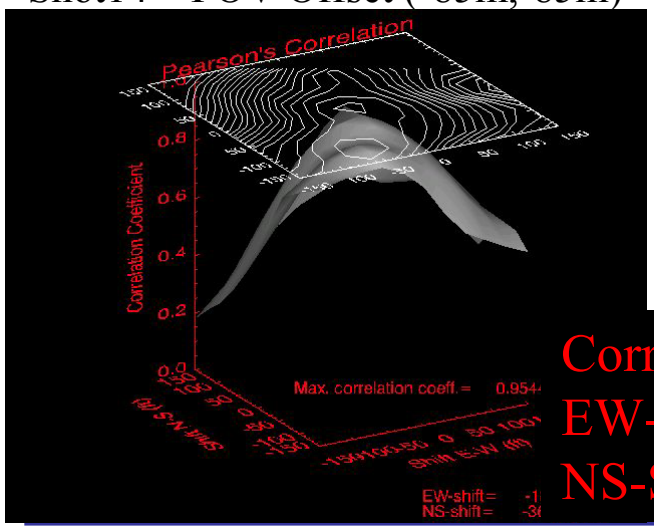
Footprint at Mission d_lat and d_lon
(Not Profile Matching Done)
Shot14 – No FOV Offset

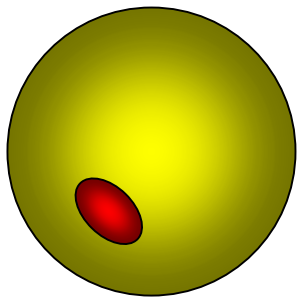
Corr.=0.954450
EW-Shift=0m
NS-Shift=0m





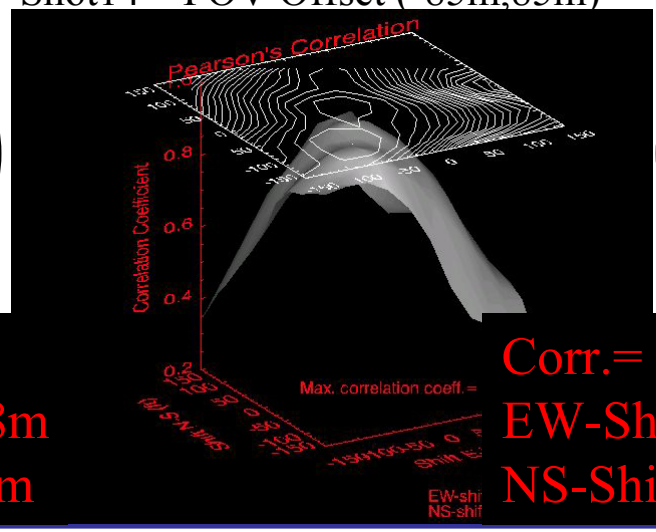
Shot14 – FOV Offset (-85m,-85m)

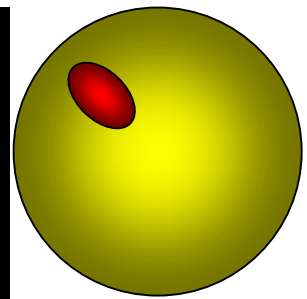




Corr.= 0.954438
EW-Shift=-18.288m
NS-Shift=-36.576m

Shot14 – FOV Offset (-85m,85m)

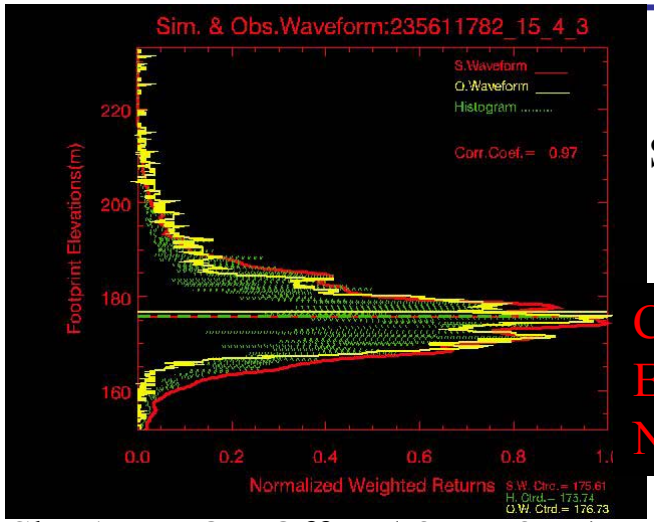




Corr.= 0.948502
EW-Shift=-18.288m
NS-Shift=-27.432m

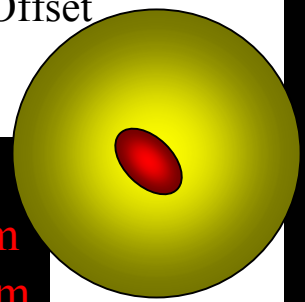
PUGET SOUND SIMULATIONS-Laser 2-LPA1

Observed (yellow) – Computed (red)

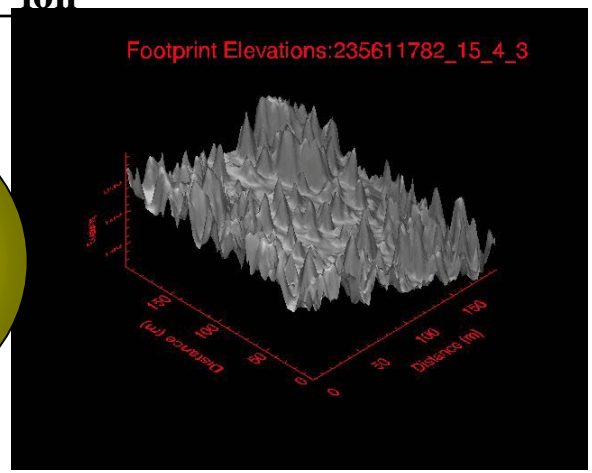


Footprint at Mission d_lat and d_lon
(Not Profile Matching Done)

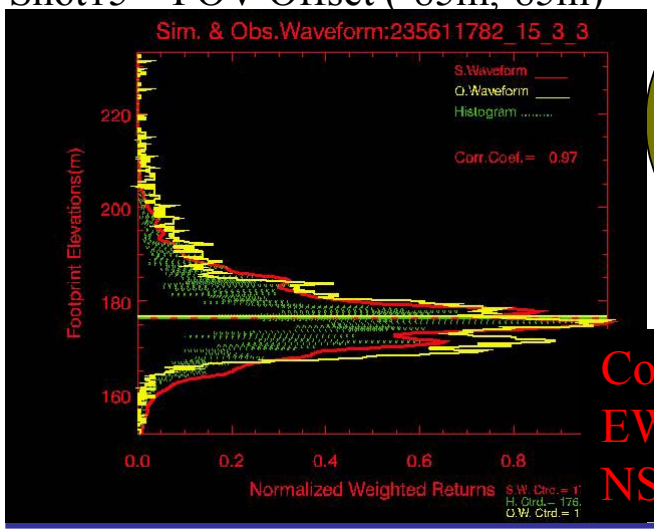
Shot15 – No FOV Offset

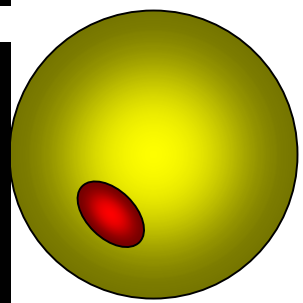


Corr.=0.948502
EW-Shift=-9.144m
NS-Shift=-18.288m



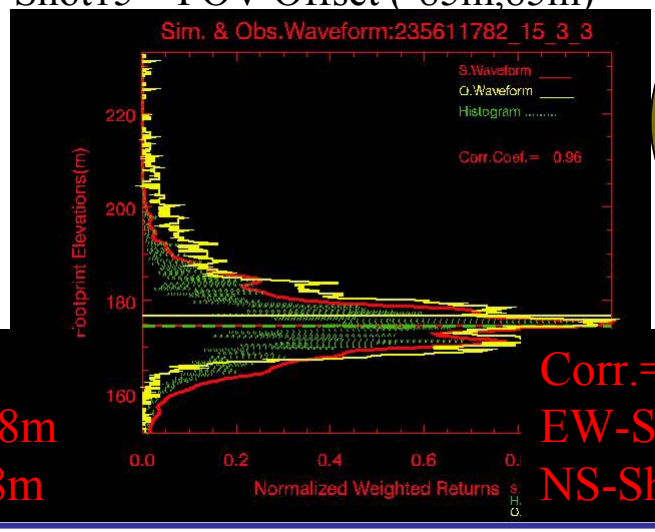
Shot15 – FOV Offset (-85m,-85m)

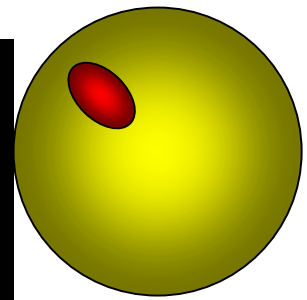




Corr.= 0.967868
EW-Shift=-18.288m
NS-Shift=-18.288m

Shot15 – FOV Offset (-85m,85m)

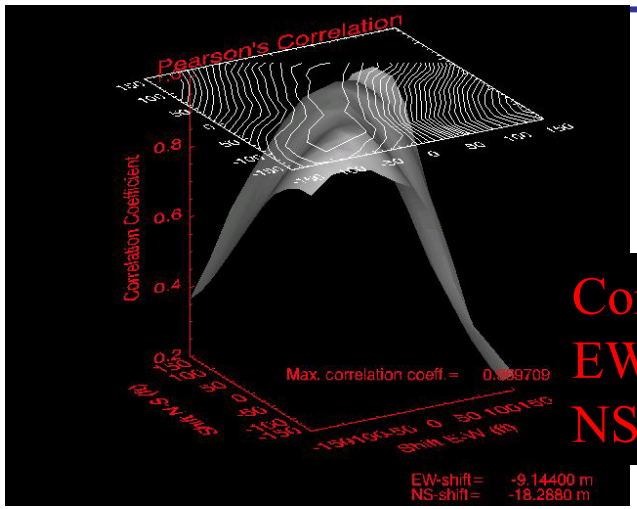




Corr.= 0.96035
EW-Shift=-18.288m
NS-Shift=-18.288m

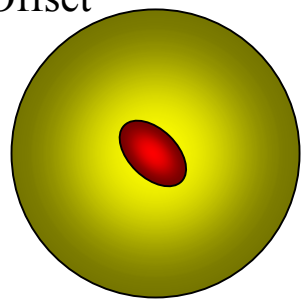
PUGET SOUND SIMULATIONS-Laser 2-LPA1

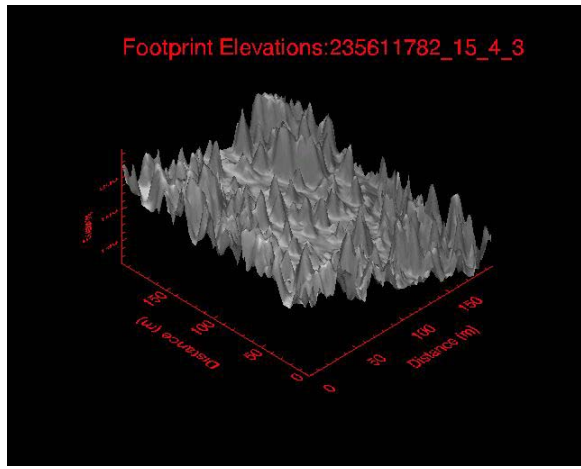
Correlation Functions



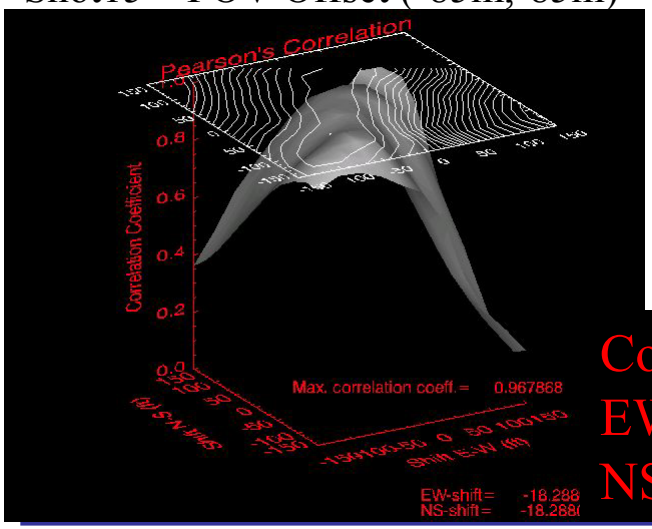
Footprint at Mission d_lat and d_lon
(Not Profile Matching Done)
Shot15 – No FOV Offset

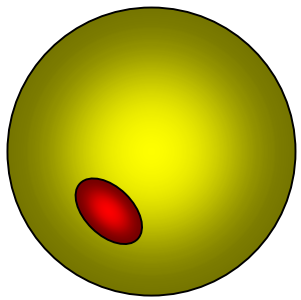
Corr.=0.948502
EW-Shift=-9.144m
NS-Shift=-18.288m





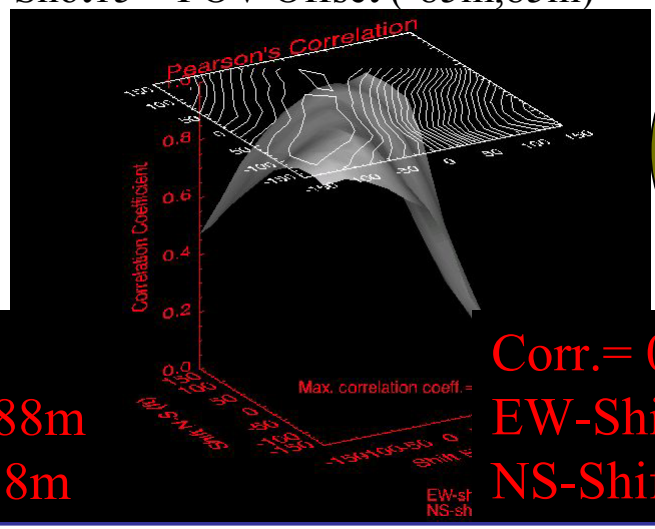
Shot15 – FOV Offset (-85m,-85m)

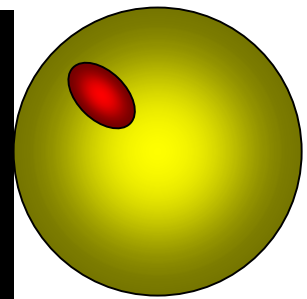




Corr.= 0.967868
EW-Shift=-18.288m
NS-Shift=-18.288m

Shot15 – FOV Offset (-85m,85m)





Corr.= 0.96035
EW-Shift=-18.288m
NS-Shift=-18.288m

PUGET SOUND SIMULATIONS-Laser 2-LPA1

- FOV effects translate into geolocation offsets
- Waveform matching should be used as a validation (rather than a calibration) tool for FOV offsets determined from other techniques
- Offsets from the center of the FOV have to be larger than 250urad (~50arcsec) for the effects to be significantly discernable from geolocation errors
- Complex building landscapes may provide greater sensitivity (Urban Seattle is being targeted on track 296 in two weeks)