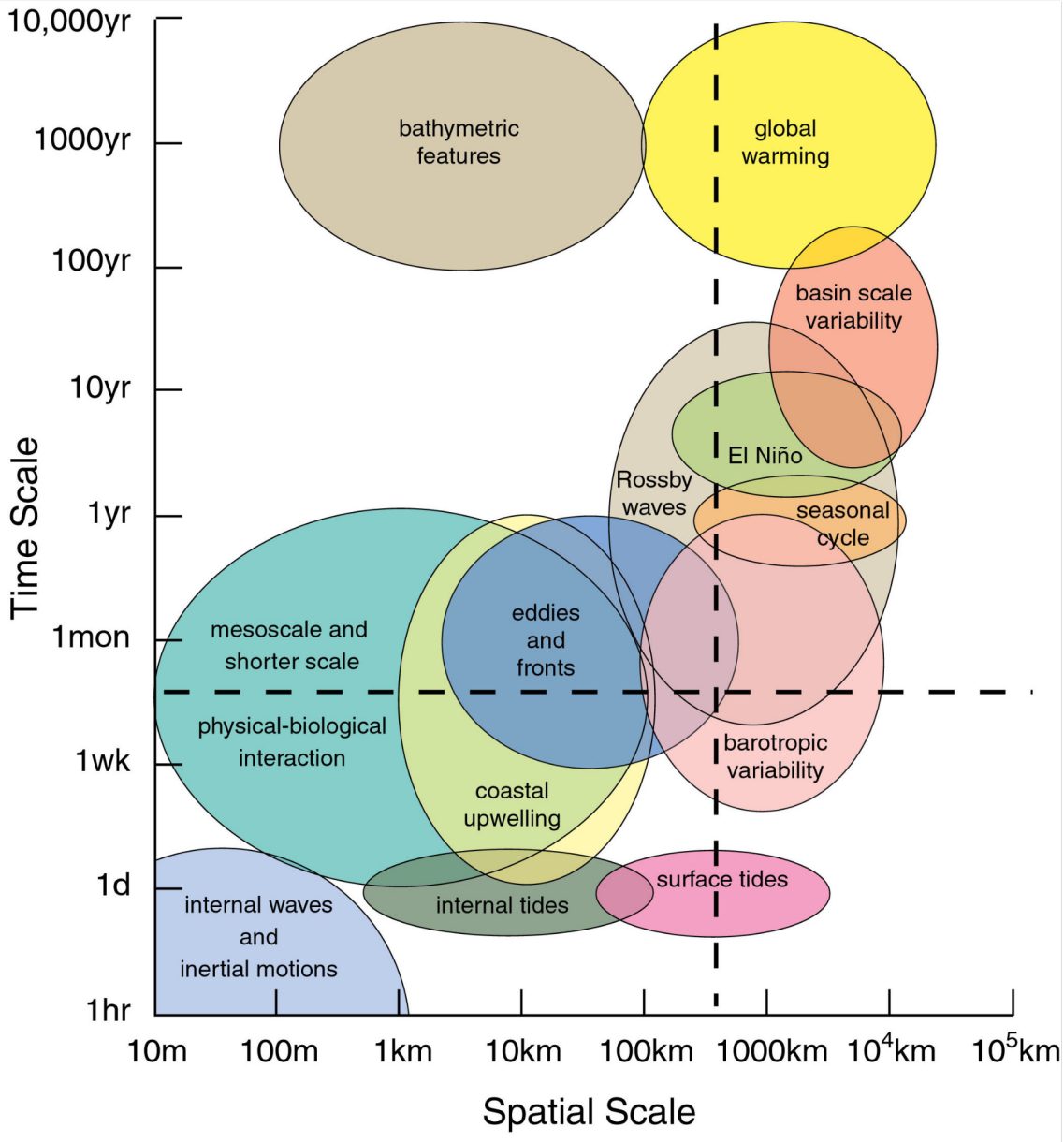
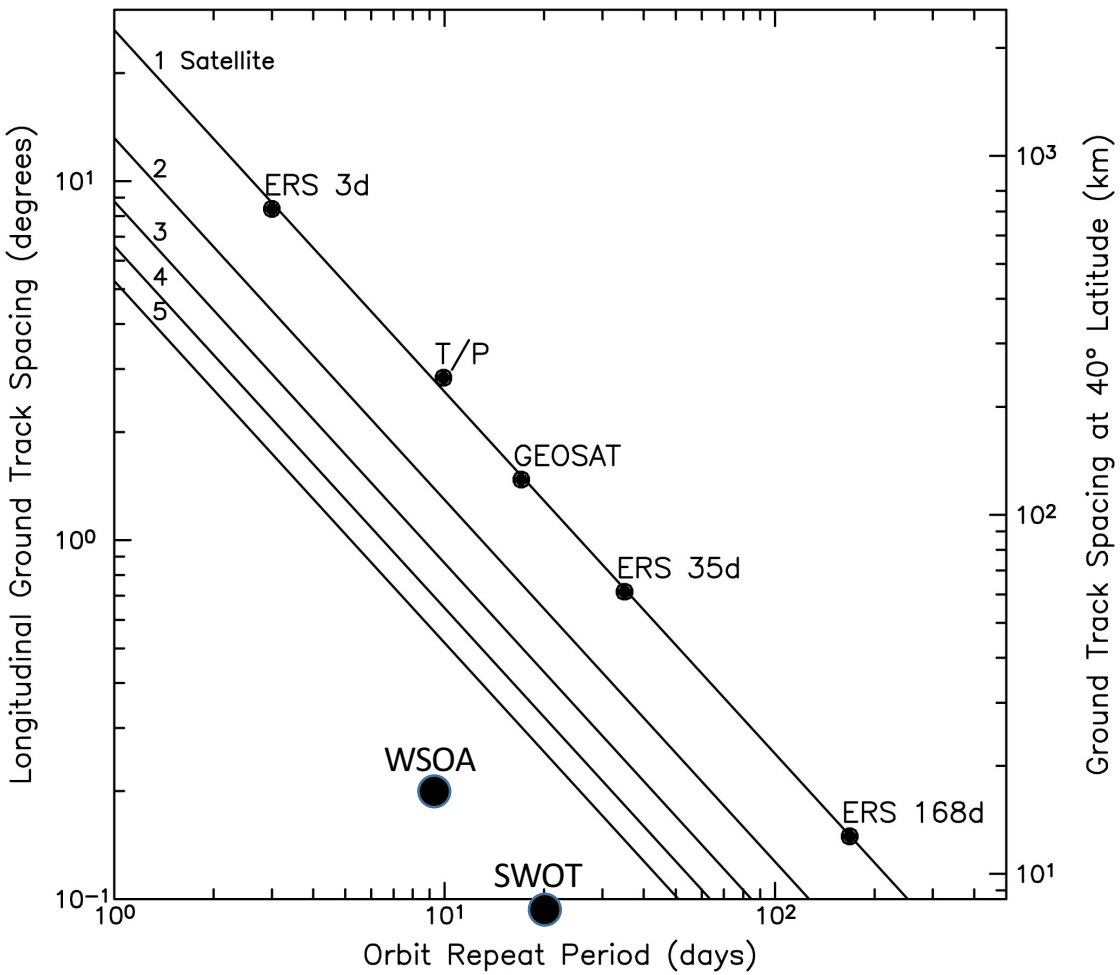
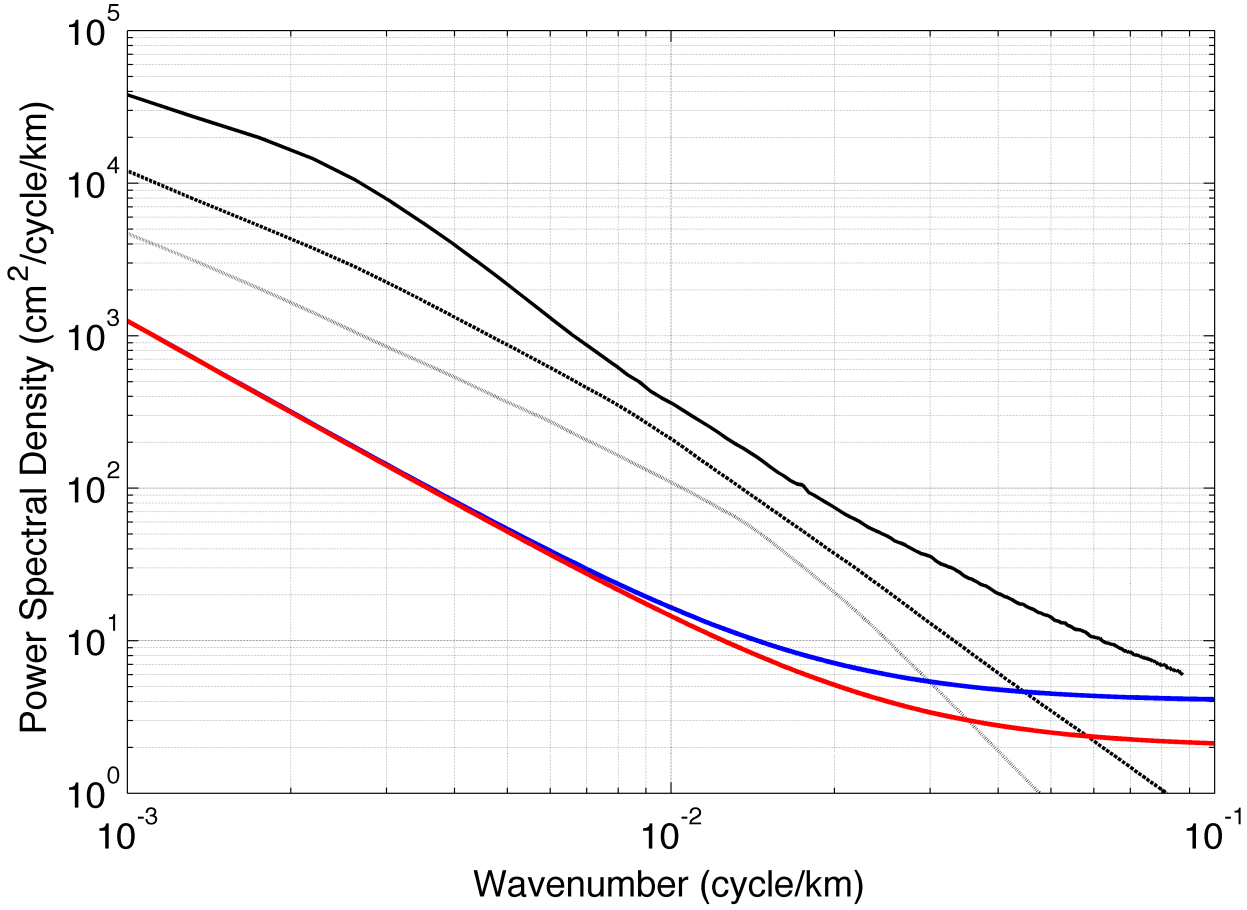
Wide-Swath Altimetry: A Review

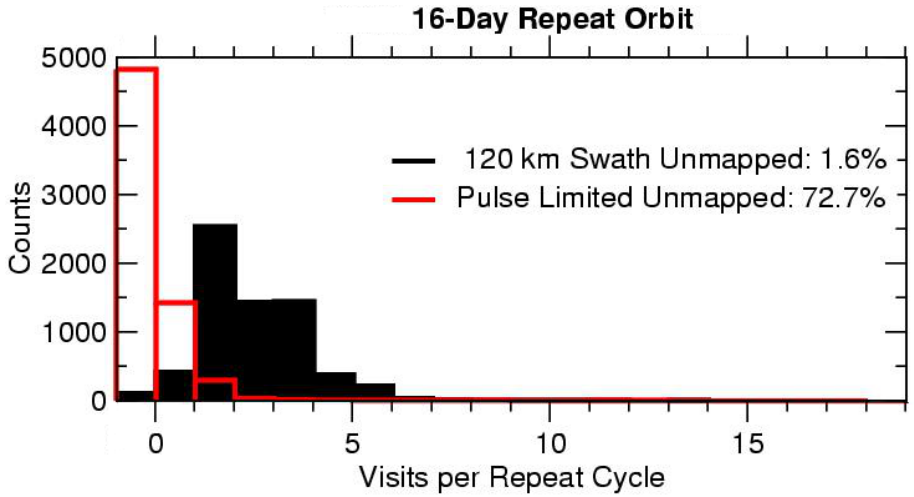
Ernesto Rodriguez, Daniel Esteban Fernandez, Eva Peral, Curtis W. Chen, Jan-Willem De Bleser, Brent Williams

Jet Propulsion Laboratory, California Institute of Technology

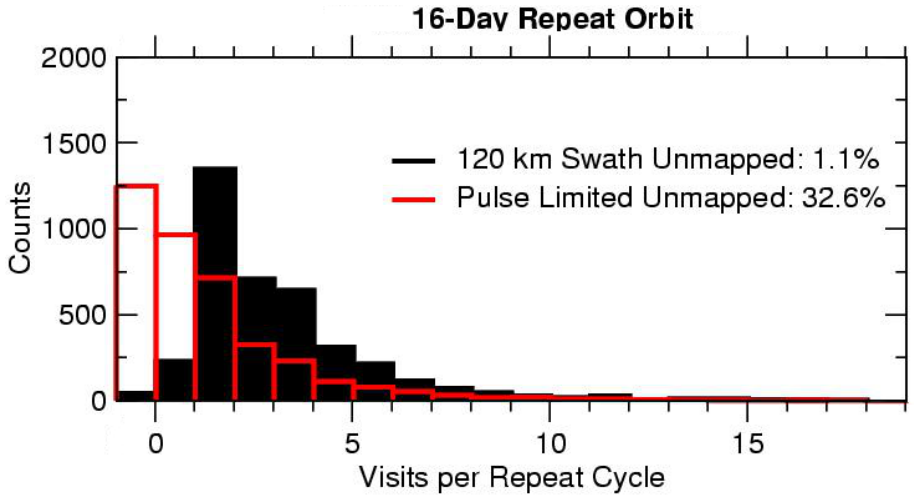

10,000yr
1000yr
100yr
10yr
1yr
1mon
1wk
1d
1hr
Time Scale
10m
100m
1km
10km
100km
1000km
10^4km
10^5km
Spatial Scale
bathymetric features
global warming
basin scale variability
El Niño
Rossby waves
seasonal cycle
mesoscale and shorter scale
eddies and fronts
physical-biological interaction
barotropic variability
coastal upwelling
internal waves and inertial motions
internal tides
surface tides


1 Satellite
2
3
4
5
ERS 3d
T/P
GEOSAT
ERS 35d
ERS 168d
WSOA
SWOT
10^1
10^0
10^{-1}
10^0
10^1
10^2
10^3
10^2
10^1
Longitudinal Ground Track Spacing (degrees)
Ground Track Spacing at 40° Latitude (km)
Orbit Repeat Period (days)

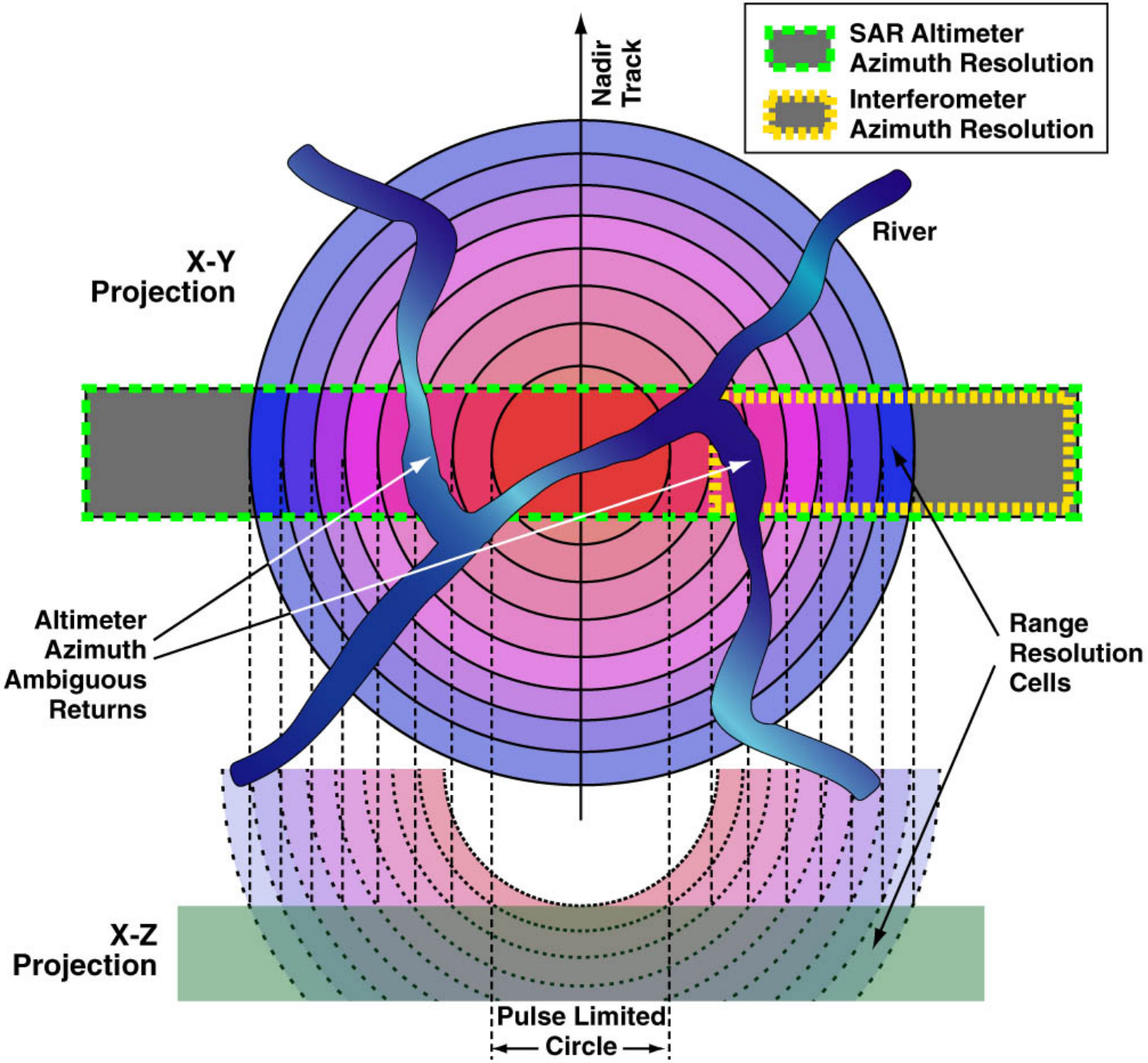

Power Spectral Density (cm^2/cycle/km)
Wavenumber (cycle/km)
10^5
10^4
10^3
10^2
10^1
10^0
10^{-3}
10^{-2}
10^{-1}

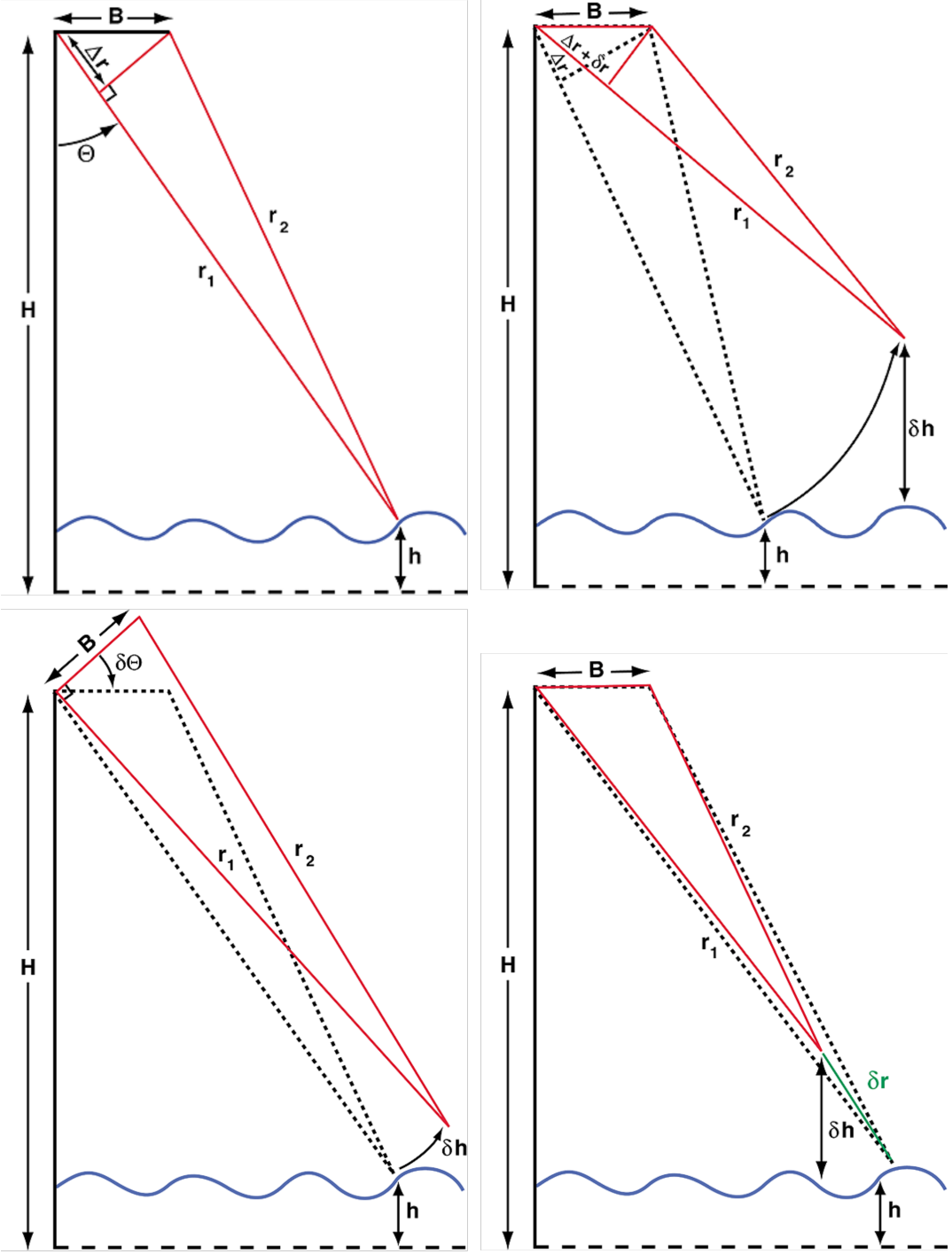

16-Day Repeat Orbit
Counts
Visits per Repeat Cycle
120 km Swath Unmapped: 1.6%
Pulse Limited Unmapped: 72.7%
5000
4000
3000
2000
1000
0
0
5
10
15

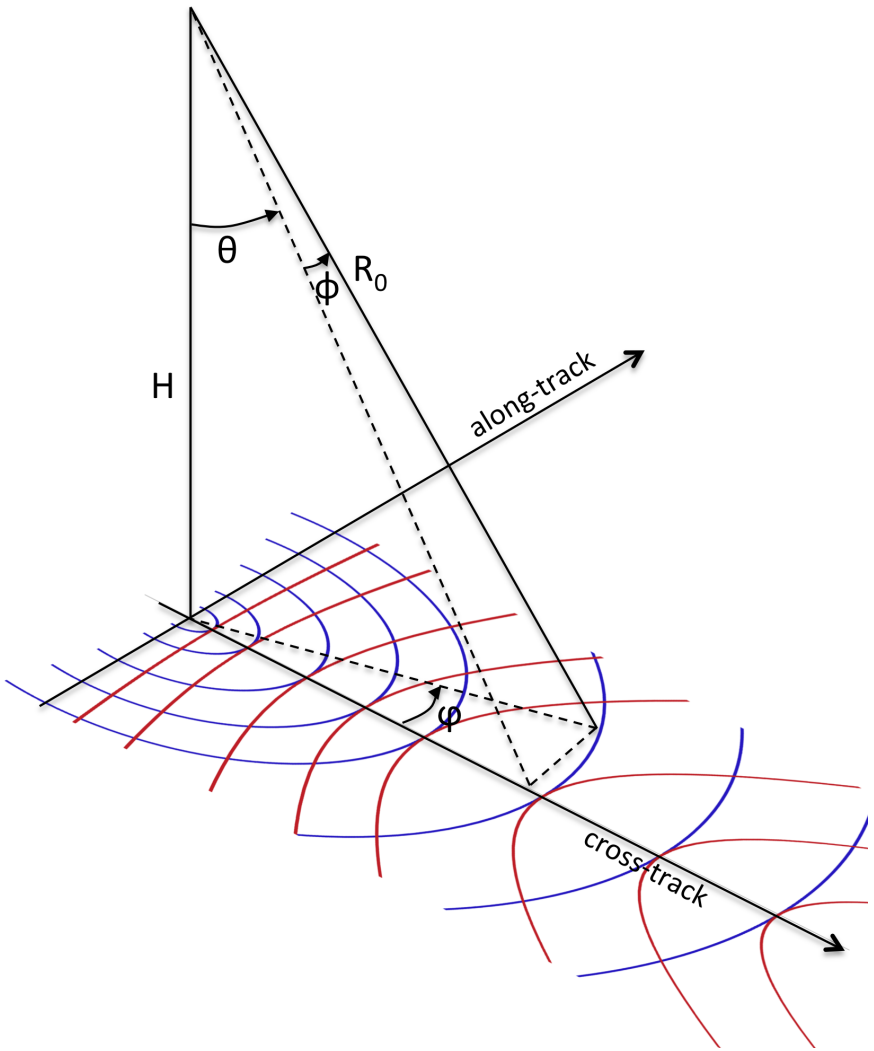
(a)

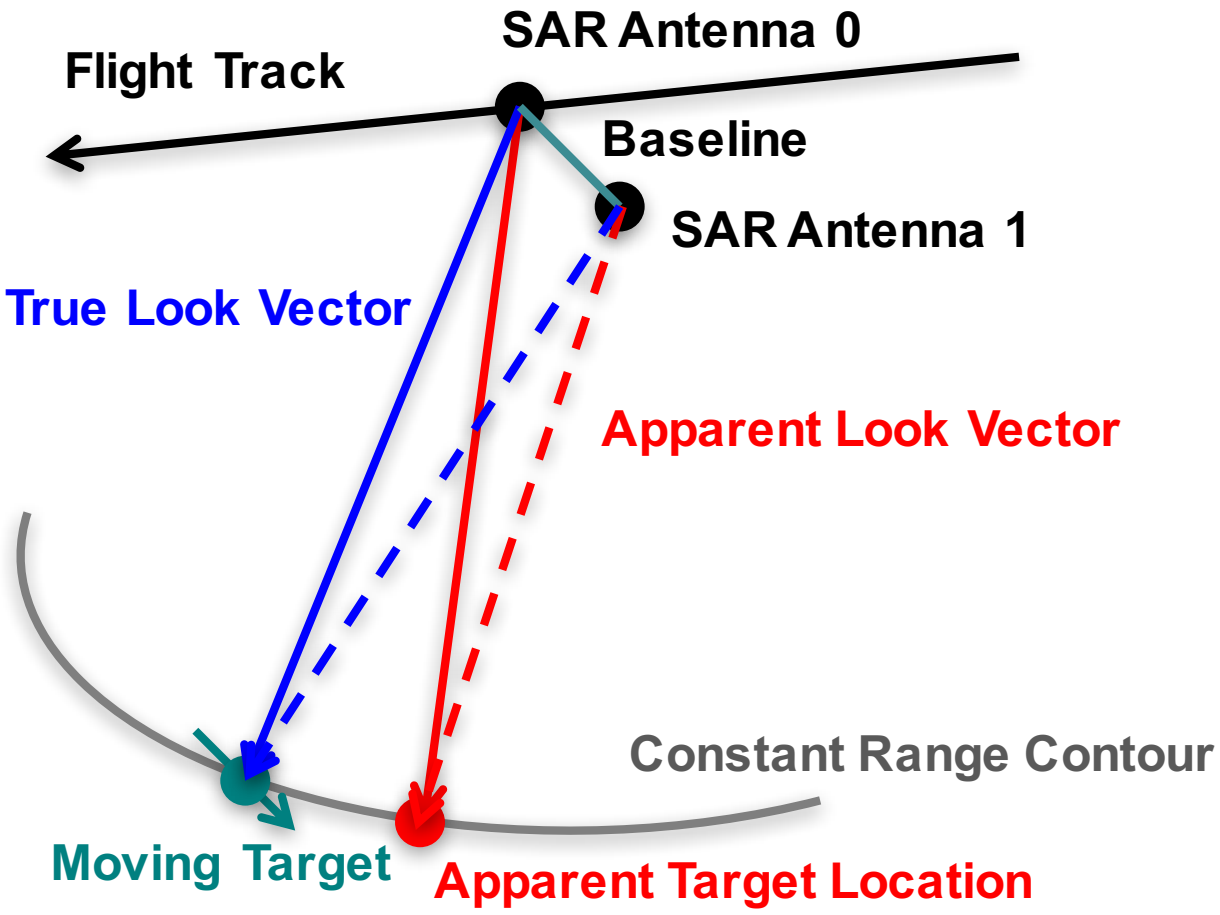

16-Day Repeat Orbit
Counts
Visits per Repeat Cycle
120 km Swath Unmapped: 1.1%
Pulse Limited Unmapped: 32.6%
2000
1500
1000
500
0
0
5
10
15

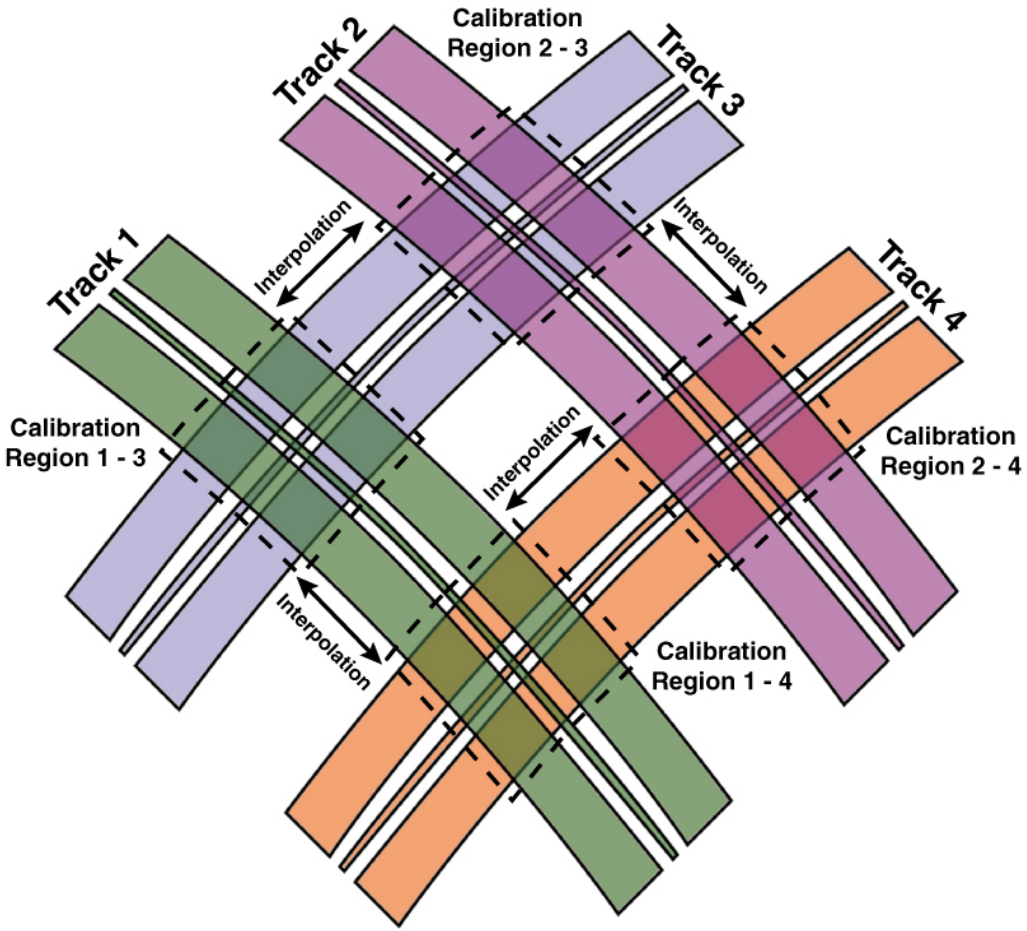
(b)

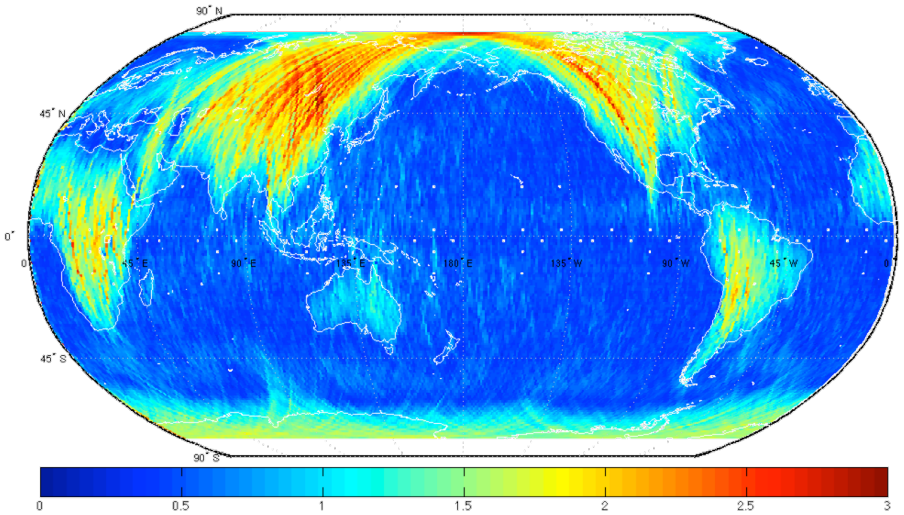

Nadir Track
SAR Altimeter Azimuth Resolution
Interferometer Azimuth Resolution
River
X-Y Projection
Altimeter Azimuth Ambiguous Returns
Range Resolution Cells
X-Z Projection
Pulse Limited Circle

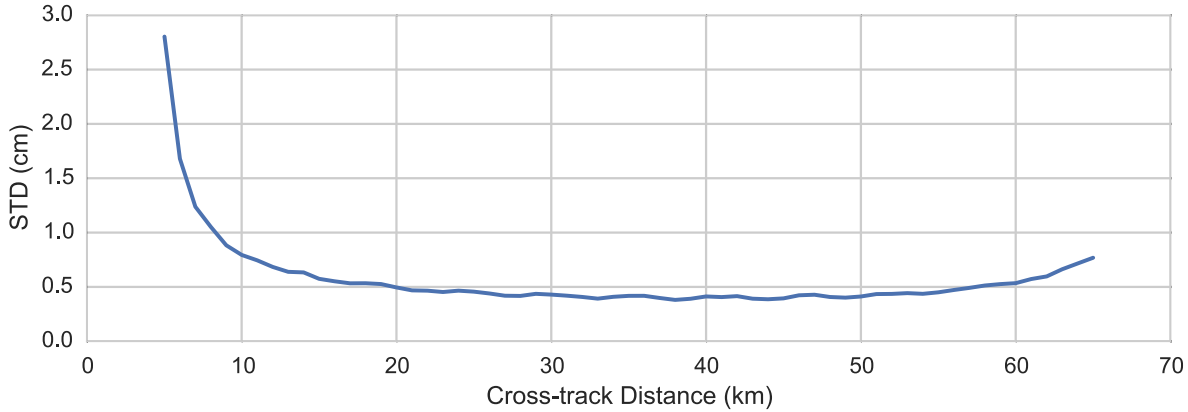

B
Δr
Θ
r 2
r 1
H
h
B
Δr + δr
Δr
r 2
r 1
H
δh
h
B
δΘ
r 1
r 2
H
δh
h
B
r 2
r 1
H
δr
δh
h

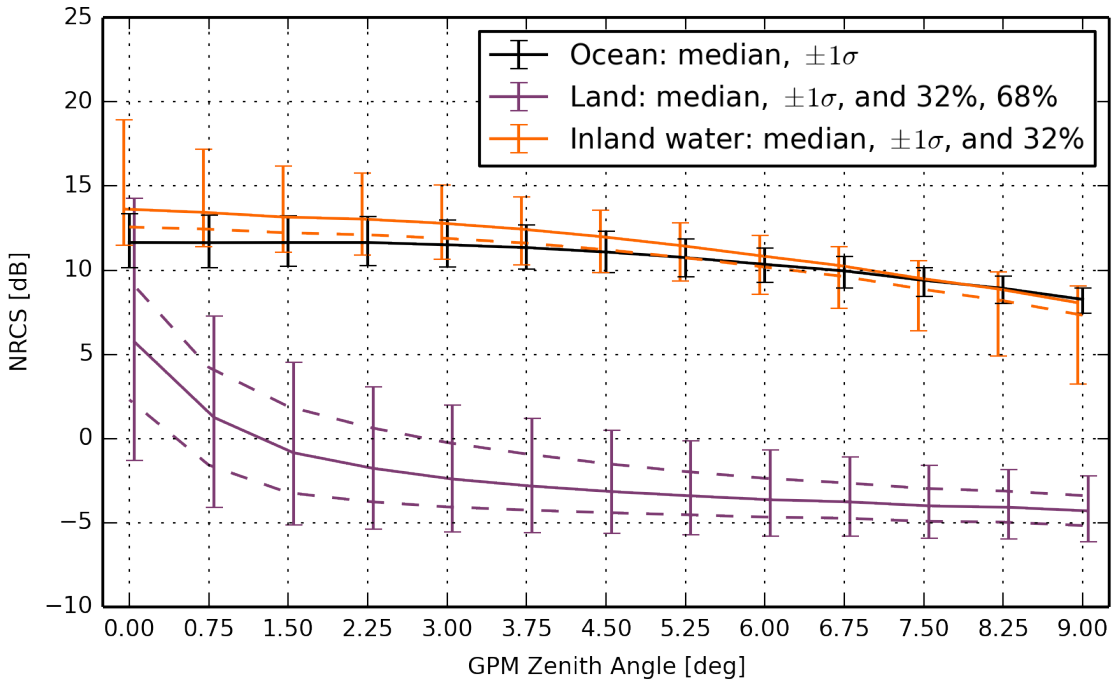

θ
ϕ
R_0
H
along-track
φ
cross-track

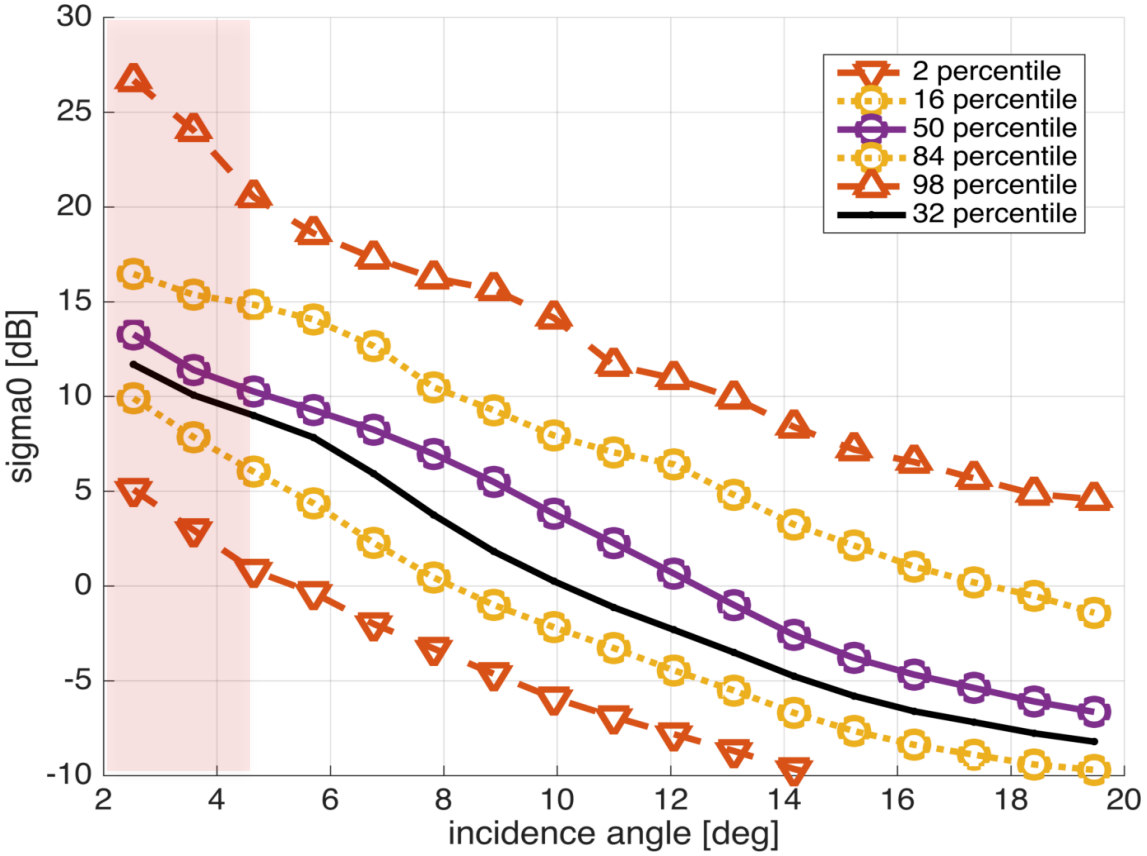

Flight Track
SAR Antenna 0
Baseline
SAR Antenna 1
True Look Vector
Apparent Look Vector
Constant Range Contour
Moving Target
Apparent Target Location

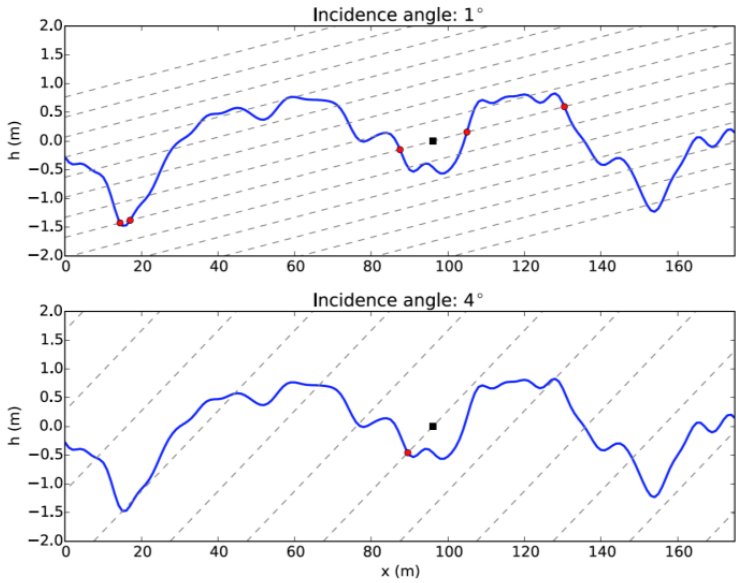

Track 1
Track 2
Track 3
Track 4
Calibration Region 2 - 3
Calibration Region 1 - 3
Calibration Region 2 - 4
Calibration Region 1 - 4
Interpolation
Interpolation
Interpolation
Interpolation


90° N
45° N
0°
45° S
90° S
45° E
90° E
135° E
180° E
135° W
90° W
45° W
0
0.5
1
1.5
2
2.5
3

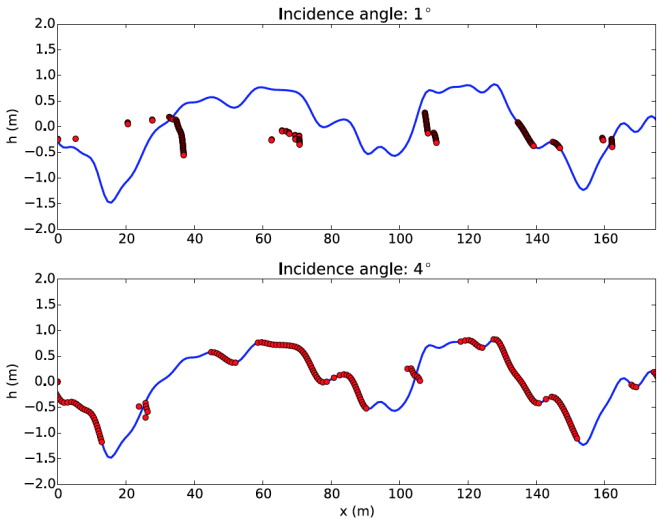

STD (cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Cross-track Distance (km)

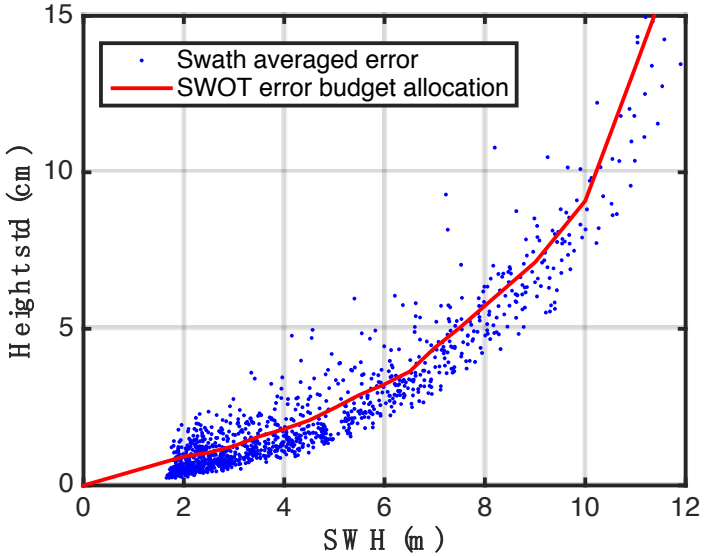

Ocean: median, $\pm 1\sigma$
Land: median, $\pm 1\sigma$, and 32%, 68%
Inland water: median, $\pm 1\sigma$, and 32%
NRCS [dB]
GPM Zenith Angle [deg]
25
20
15
10
5
0
−5
−10
0.00
0.75
1.50
2.25
3.00
3.75
4.50
5.25
6.00
6.75
7.50
8.25
9.00


2 percentile
16 percentile
50 percentile
84 percentile
98 percentile
32 percentile
sigma0 [dB]
incidence angle [deg]
30
25
20
15
10
5
0
-5
-10
2
4
6
8
10
12
14
16
18
20

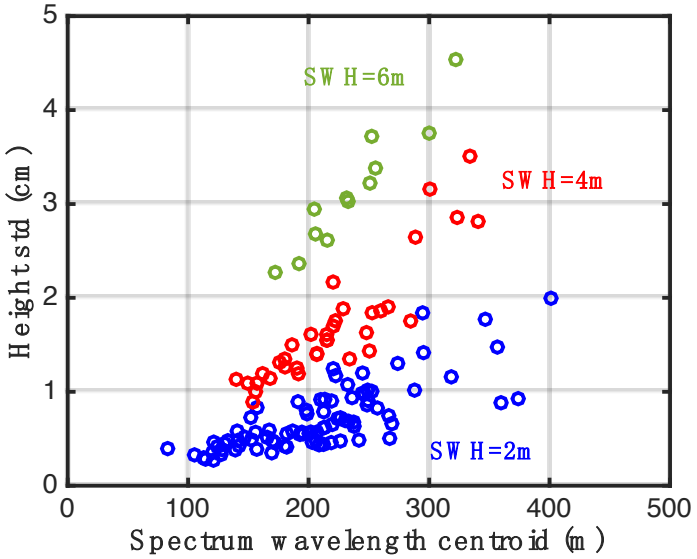

Incidence angle: 1°
Incidence angle: 4°
h (m)
x (m)

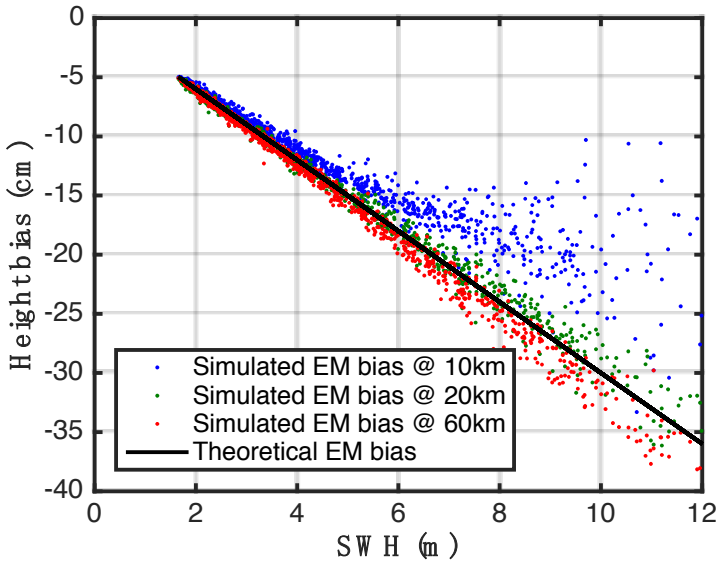
(a)

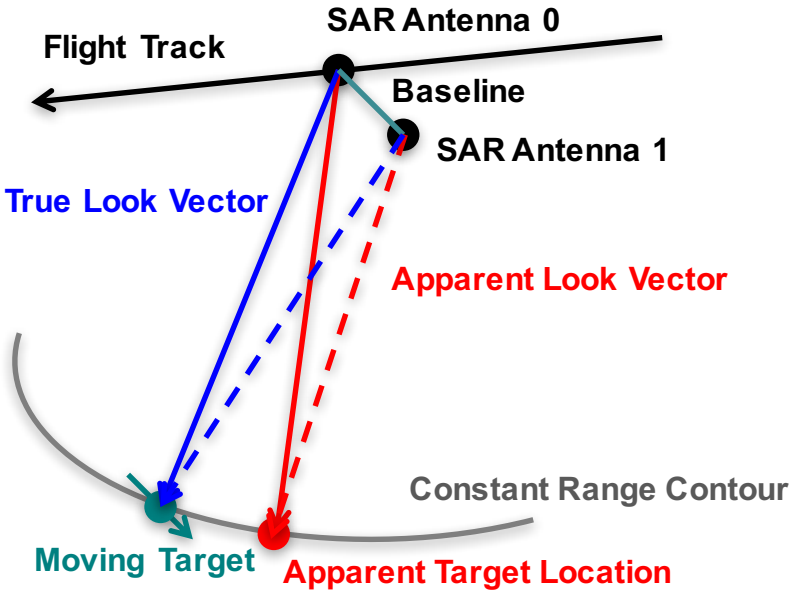

Incidence angle: 1°
Incidence angle: 4°
h (m)
x (m)

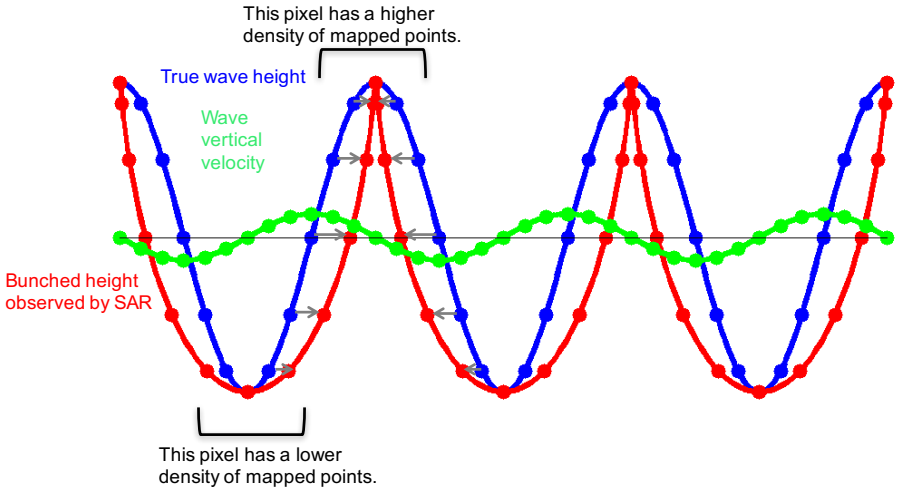

Swath averaged error
SWOT error budget allocation
Height std (cm)
SWH (m)

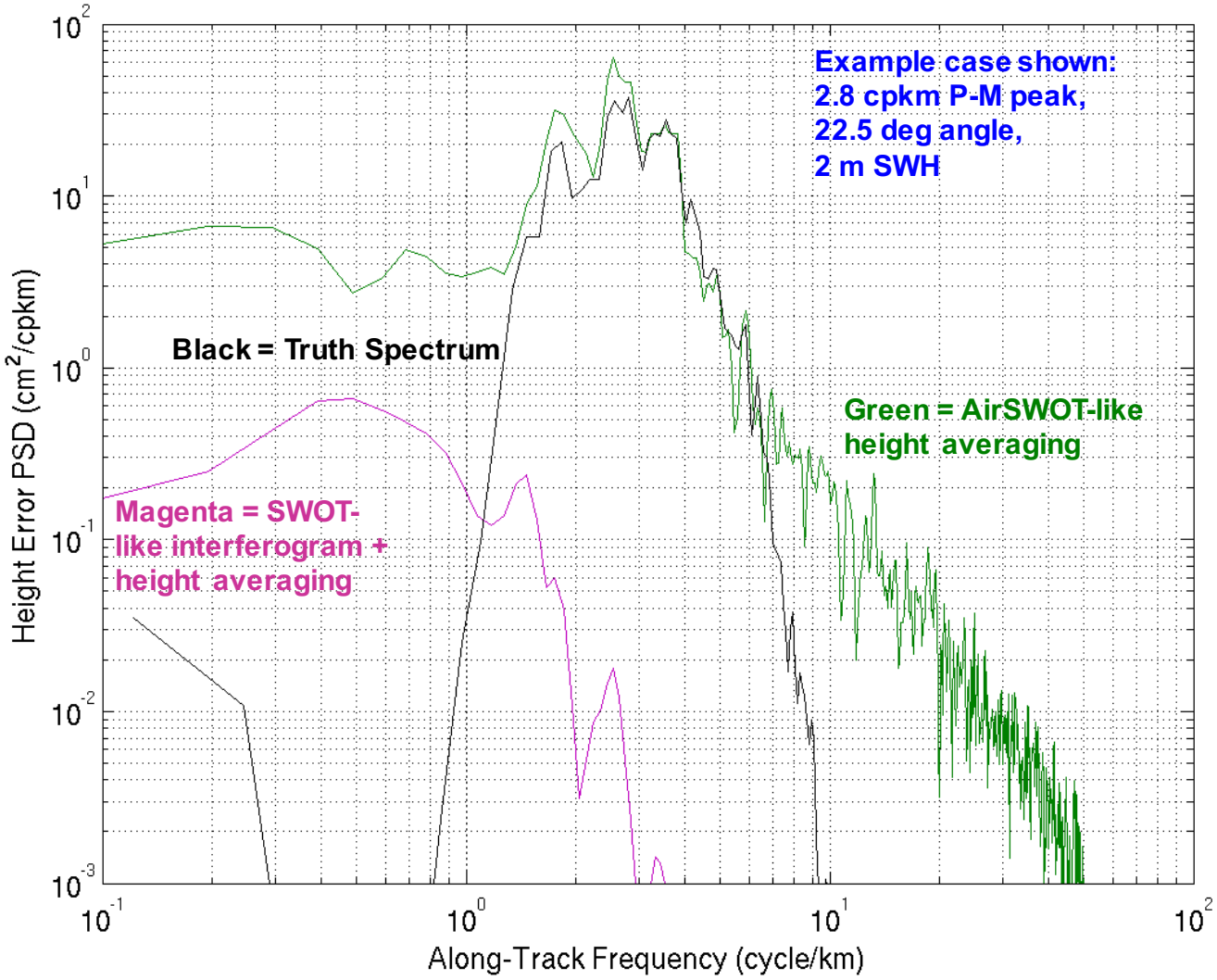
(a)

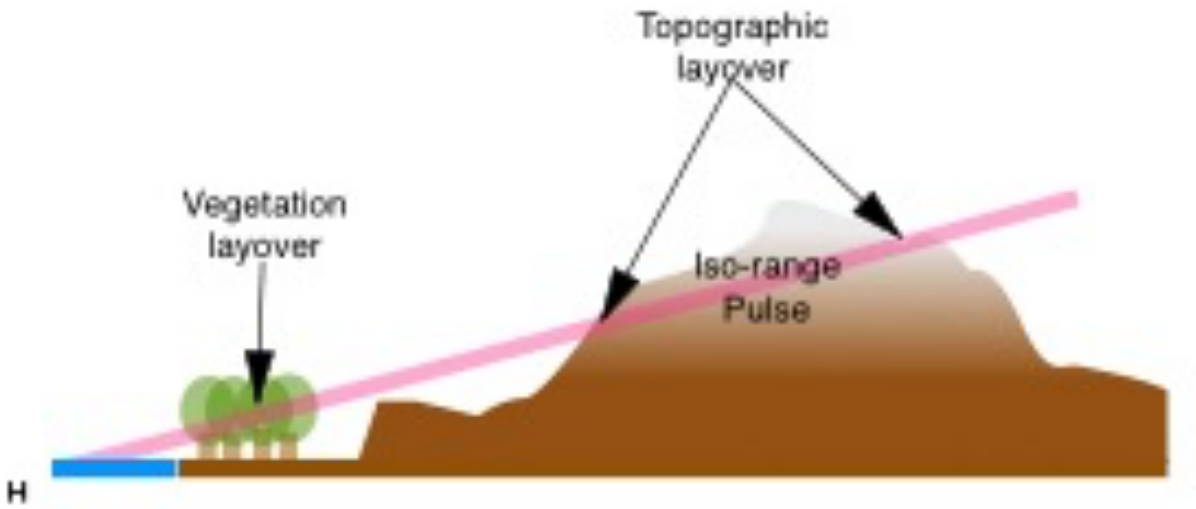

SWH=6m
SWH=4m
SWH=2m
Height std (cm)
Spectrum wavelength centroid (m)

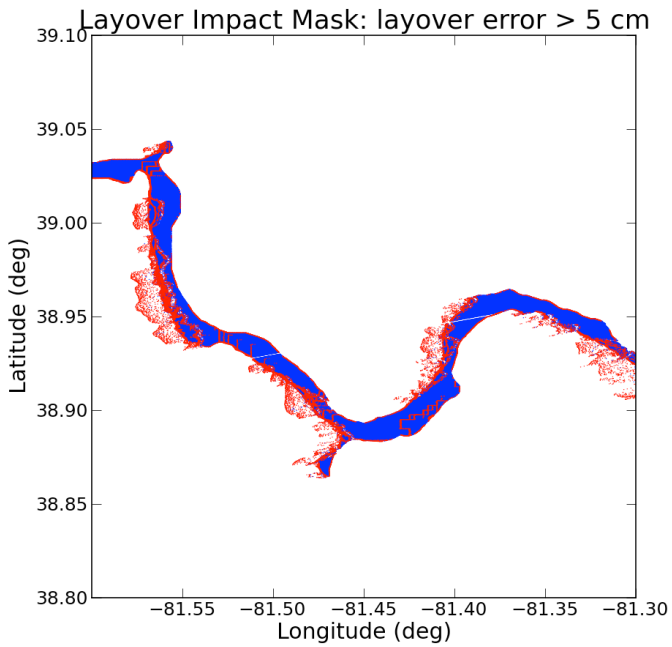

Simulated EM bias @ 10km
Simulated EM bias @ 20km
Simulated EM bias @ 60km
Theoretical EM bias
Height bias (cm)
SWH (m)

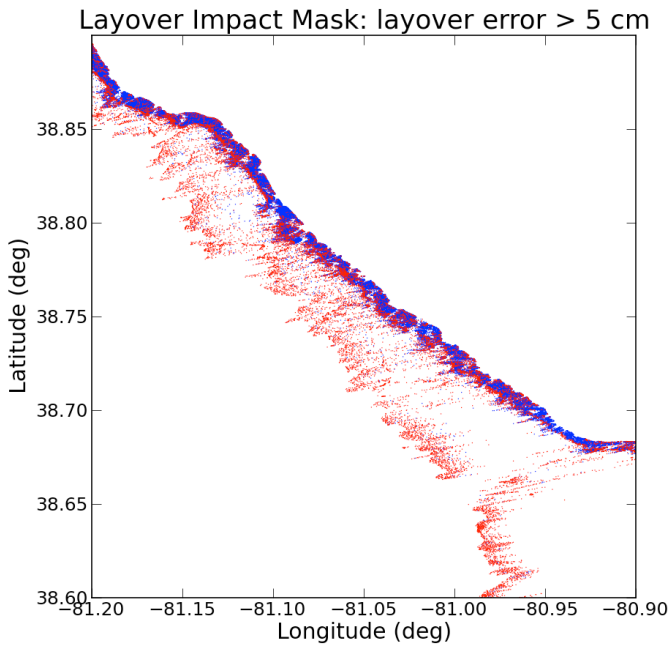

Flight Track
SAR Antenna 0
Baseline
SAR Antenna 1
True Look Vector
Apparent Look Vector
Constant Range Contour
Moving Target
Apparent Target Location

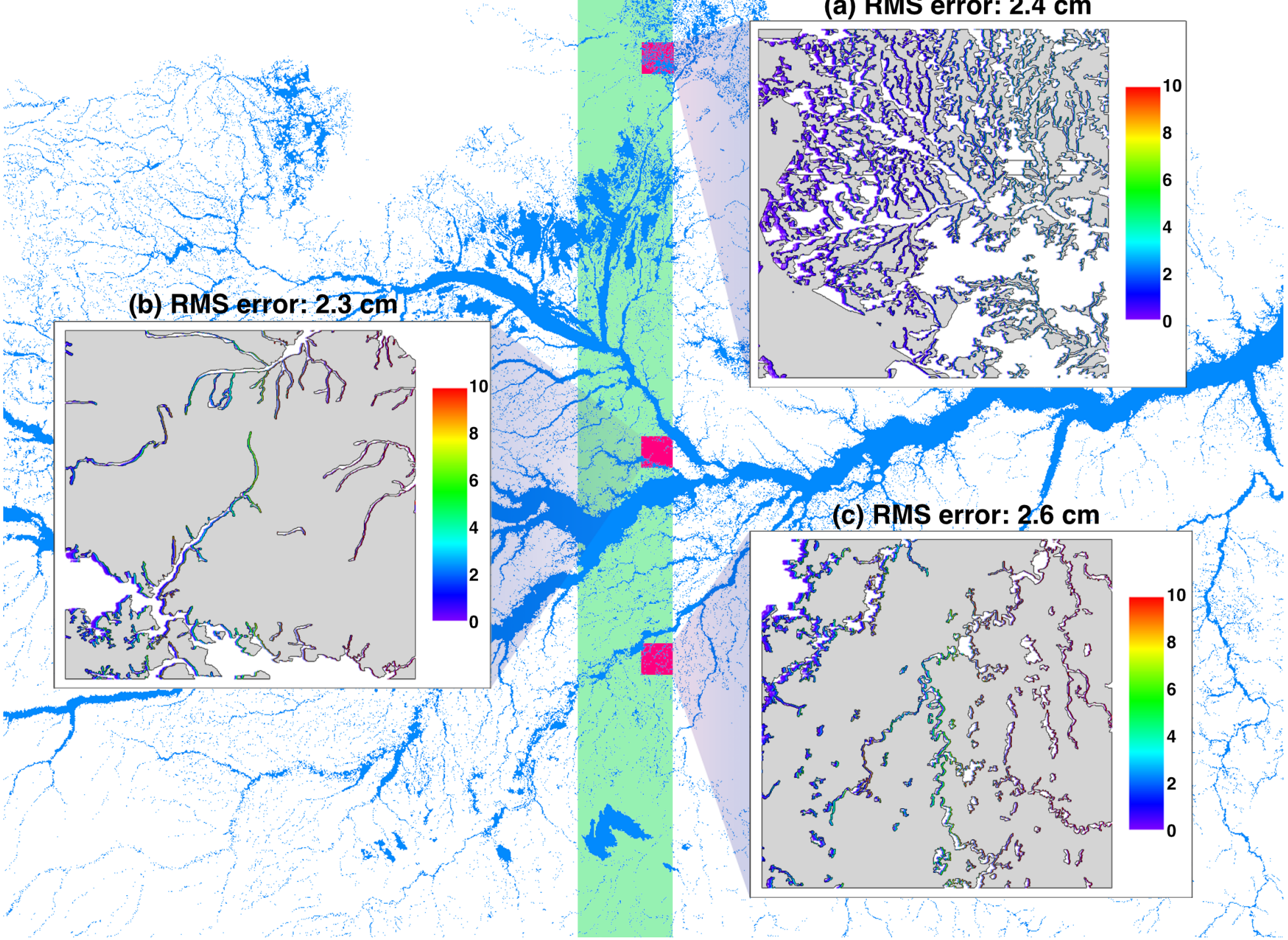

This pixel has a higher density of mapped points.
True wave height
Wave vertical velocity
Bunched height observed by SAR
This pixel has a lower density of mapped points.

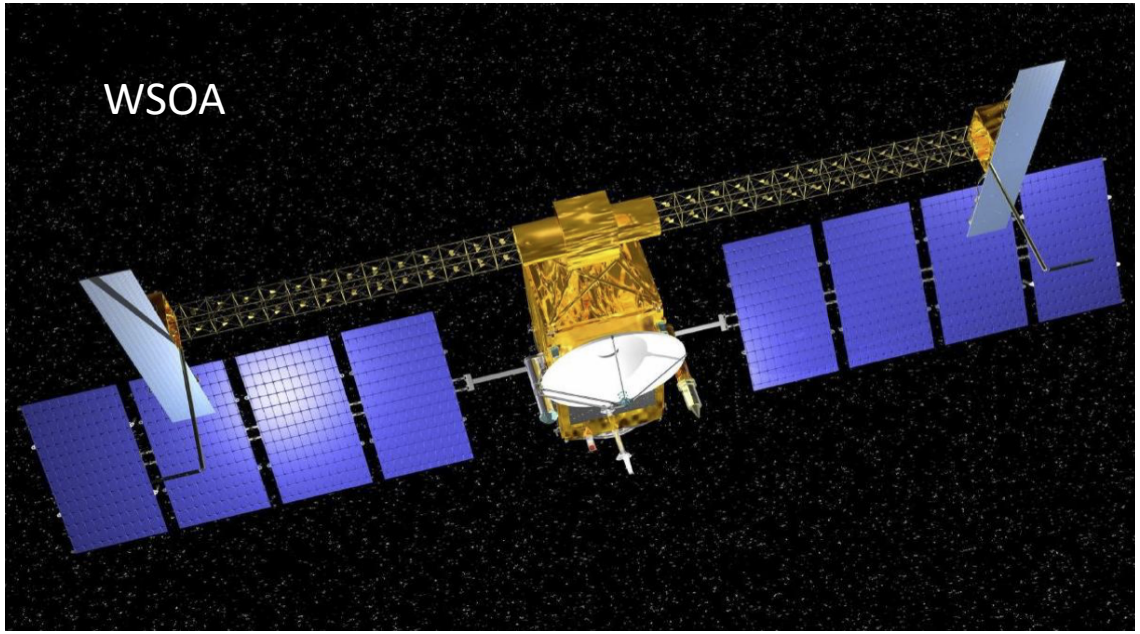

Example case shown:
2.8 cpkm P-M peak,
22.5 deg angle,
2 m SWH
Black = Truth Spectrum
Green = AirSWOT-like height averaging
Magenta = SWOT-like interferogram + height averaging
Height Error PSD (cm²/cpkm)
Along-Track Frequency (cycle/km)


Topographic
layover
Vegetation
layover
Iso-range
Pulse
H


Layover Impact Mask: layover error > 5 cm
Latitude (deg)
Longitude (deg)
39.10
39.05
39.00
38.95
38.90
38.85
38.80
−81.55
−81.50
−81.45
−81.40
−81.35
−81.30

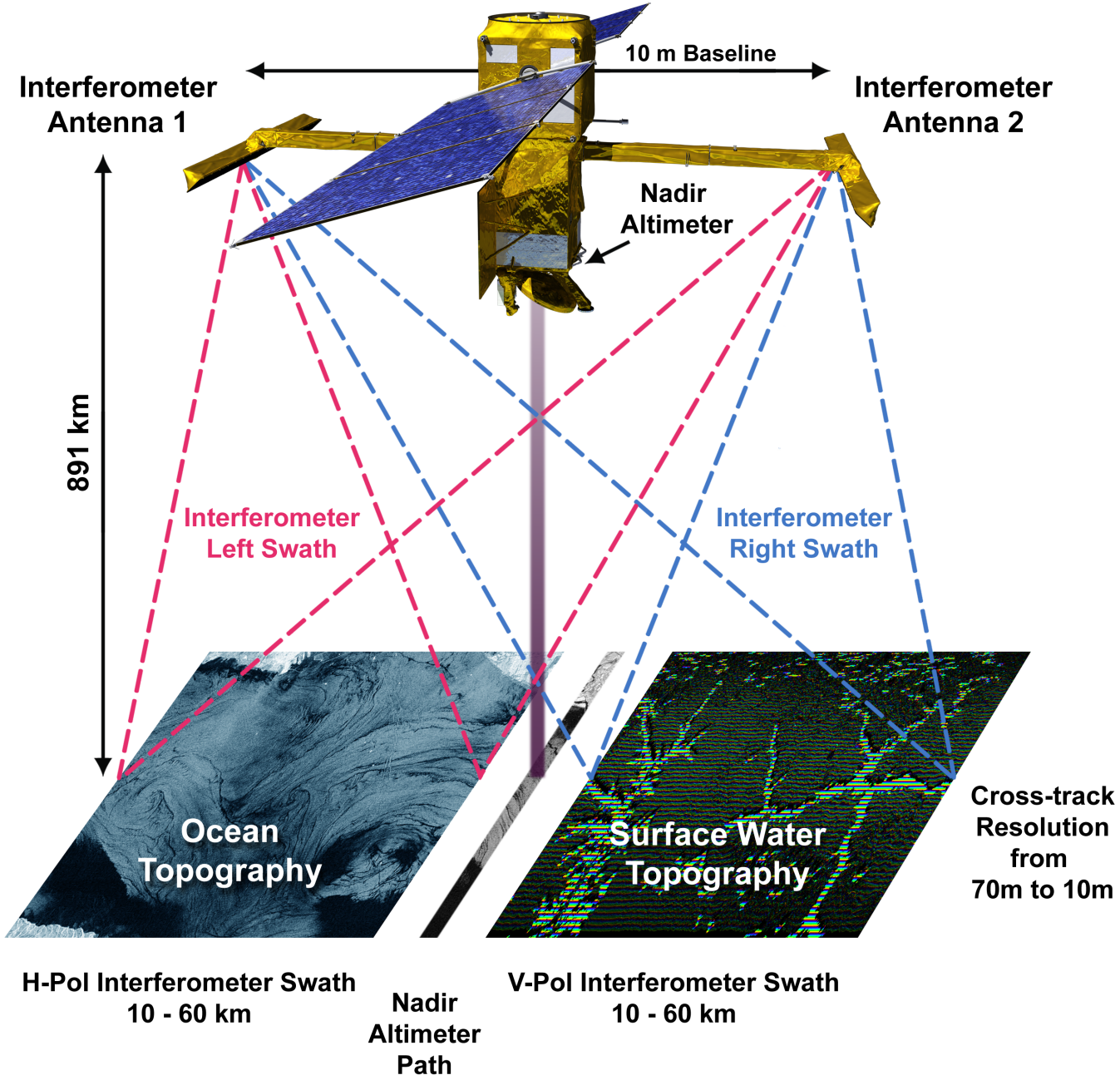

Layover Impact Mask: layover error > 5 cm
Latitude (deg)
Longitude (deg)
38.85
38.80
38.75
38.70
38.65
38.60
−81.20
−81.15
−81.10
−81.05
−81.00
−80.95
−80.90


(a) RMS error: 2.4 cm
10
8
6
4
2
0
(b) RMS error: 2.3 cm
10
8
6
4
2
0
(c) RMS error: 2.6 cm
10
8
6
4
2
0



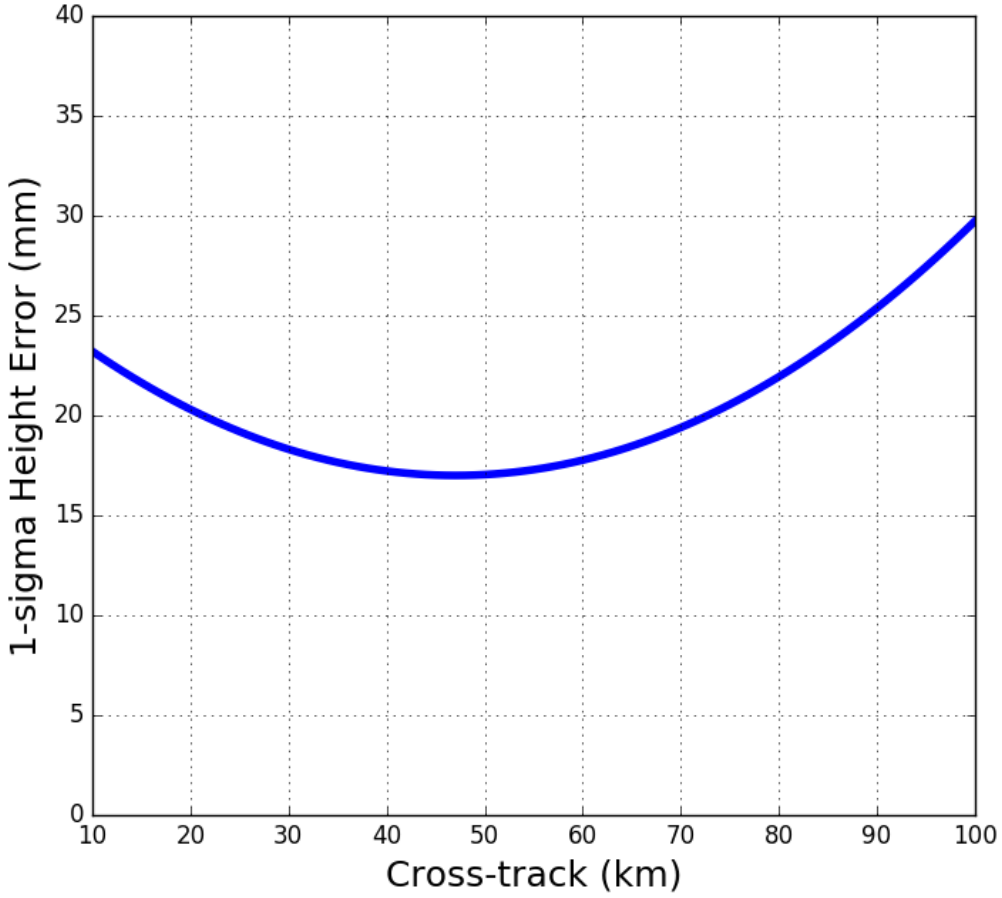
Parameter	WSOA	WaTER	SWOT
Orbit height	1334 km	834 km	981 km
Orbit Inclination	66°	93.7°	77.6°
Orbit Repeat Period	10 days	16 days	20.86 days
Average Revisit Period	5 days	8 days	11 days
Total swath	200 km	120 km	120 km
Spatial Resolution	15 km	500 m (ocean) ~ 50 m(land)	500 m (ocean) ~ 50 m(land)
Wavelength	2.2 cm	0.8 cm	0.8 cm
Baseline length	6.4 m	10 m	10 m
Peak transmit power	100 W	1.5 kW	1.5 kW
Altimeter	Ku/C Jason	AltiKa	Ku/C Jason
Radiometer	Nadir WVR	Nadir WVR	2-beam WVR

Tab. 1: Comparison of WSOA, WaTER and SWOT parameters.

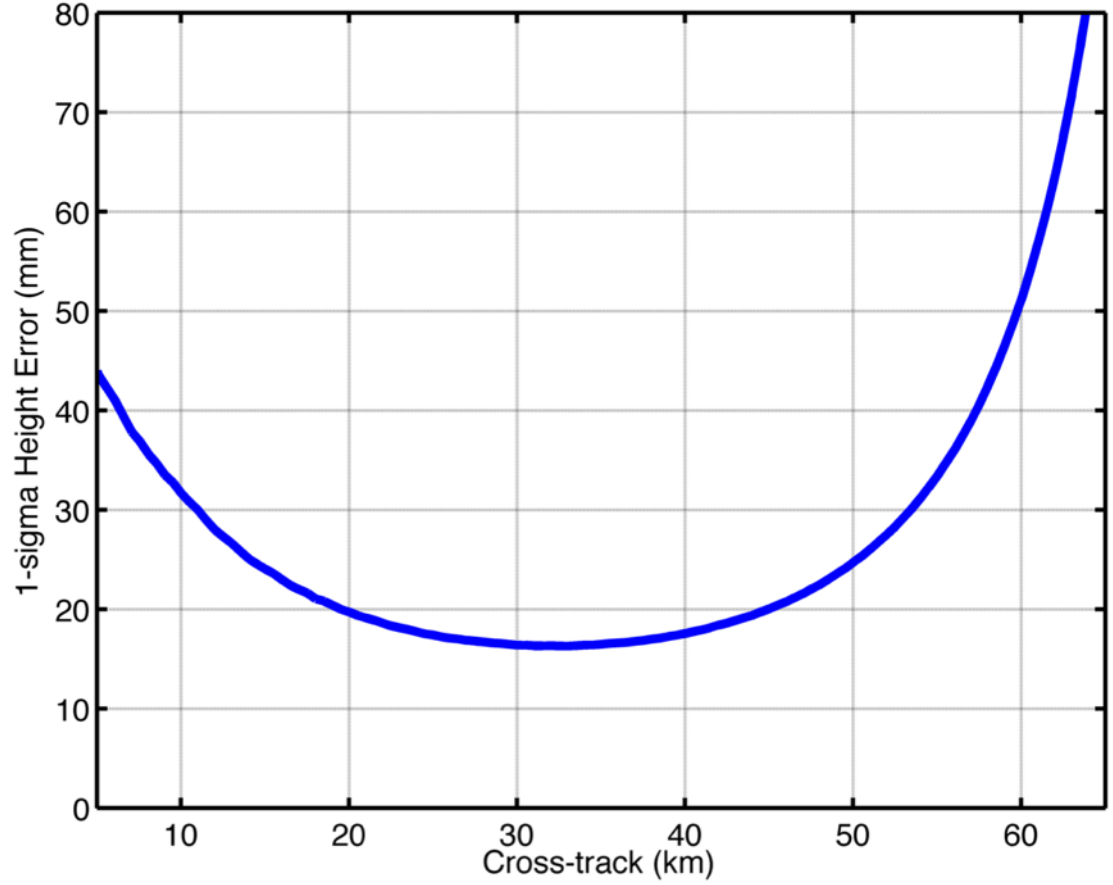


SWOT

WSOA


1-sigma Height Error (mm)
Cross-track (km)
0
5
10
15
20
25
30
35
40
10
20
30
40
50
60
70
80
90
100

SWOT


1-sigma Height Error (mm)
Cross-track (km)
0
10
20
30
40
50
60
70
80
10
20
30
40
50
60