The Use Of High–Resolution Space Imagery to Census Marine Mammals

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Introduction

- Aerial surveys are widely used for marine mammal population census. For example,
  - Mobley et al. (1993) survey humpback stock off Hawaii
  - Carretta et al. (2000) survey for Navy operations near San Clement Island
  - Early Warning System–north right whale monitoring off U.S. Atlantic seaboard
- Motivation for using satellite imagery
  - Faster, easier, cheaper coverage in remote areas
- Results reported in this study
  - A model for detectability of marine mammals from space
  - First results from IKONOS imagery

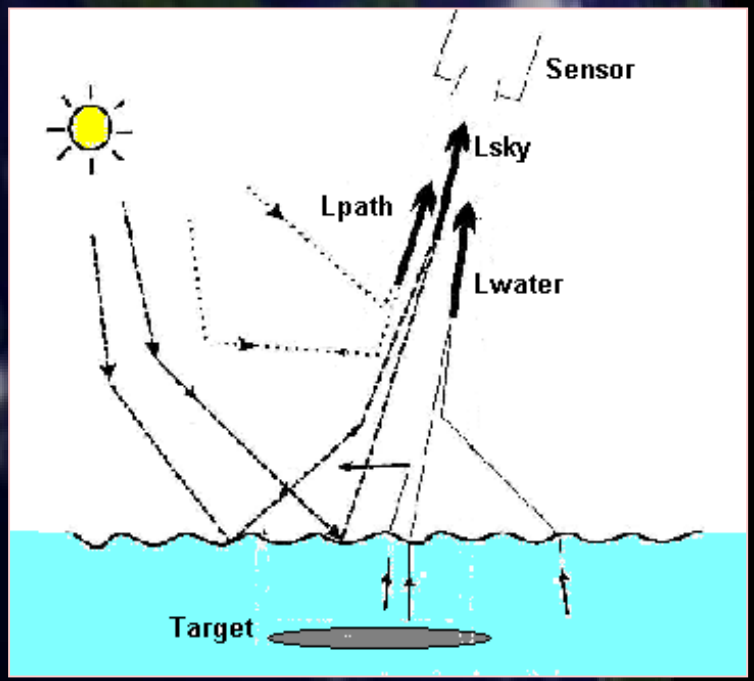
Commercial High Resolution Satellites

Satellite		Pan/MS resolution	
Operational			
IKONOS 2	Space Imaging	1 m/4 m	Launched 9/99
EROS A1	ImageSat	2 m/NA	Launched 12/00
QuickBird 2	DigitalGlobe	0.6 m/2.4 m	Launched 10/01
Future launches			
OrbView 3	OrbImage	1 m/4 m	
EROS B1,2	ImageSat	0.8 m/2.4 m	Launch 2003-4
IKONOS 3	Space Imaging	0.5 m/2 m	Launch 2003

IKONOS 2 Characteristics

Panchromatic	1 m resolution
Multispectral bands	4 m resolution
Blue (B)	481 nm
Green (G)	551 nm
Red (R)	665 nm
Near IR (NIR)	805 nm
Dynamic range	11 bits
Sun synchronous orbit	10:30 equator crossing
Image size	11 km x 11 km
Revisit rate	1–3 days

Model

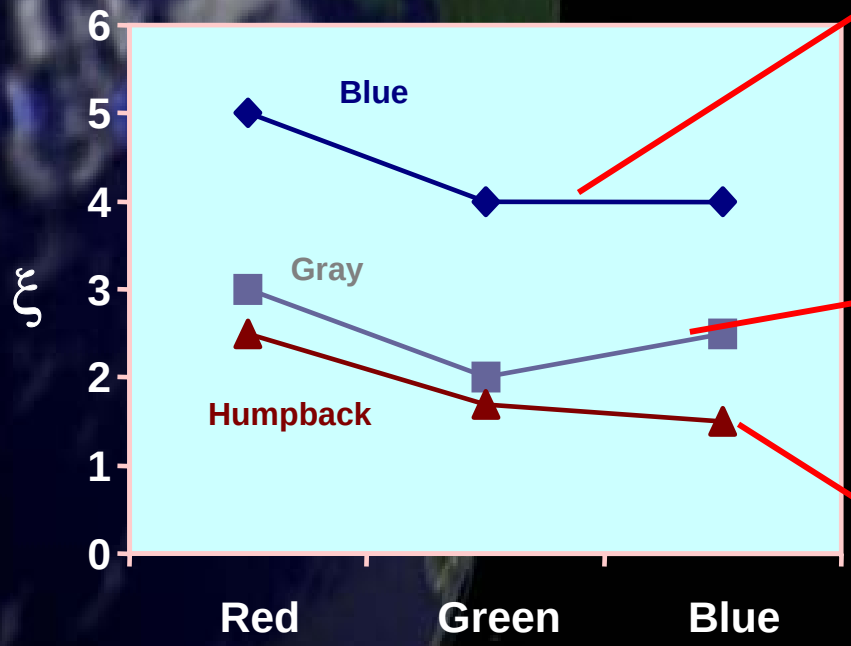


L_{sensor} = Radiance at sensor
L_{path} = Path radiance
L_{sky} = Surface sky reflection
L_{water} = Water volume scatter
k = Water attenuation
z = Target depth
τ = Atmosphere attenuation
ξ = L_{target}/L_{water} (Relative reflectivity)

$$L_{sensor} = L_{path} + \tau [L_{sky} + L_{water}(\xi - 1)e^{-2kz}]$$

Relative Reflectivity (ξ)

(estimated from photographs)

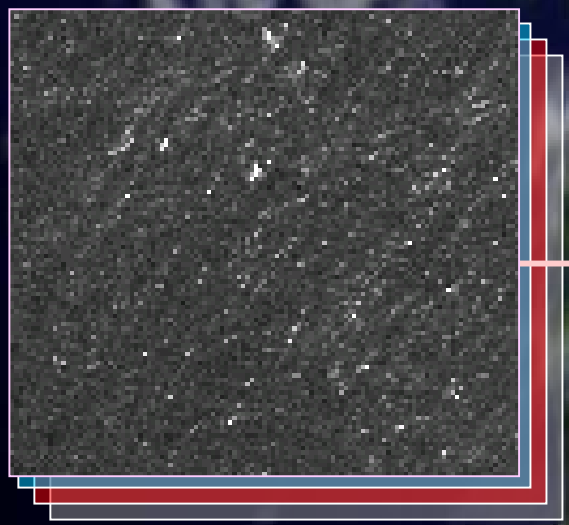


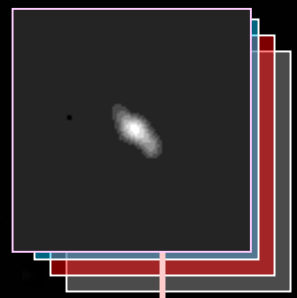
Detection Simulations

Detection Test

(Target injected into real data with wind wave and whitecaps)

IKONOS ocean image
(4 spectral bands)

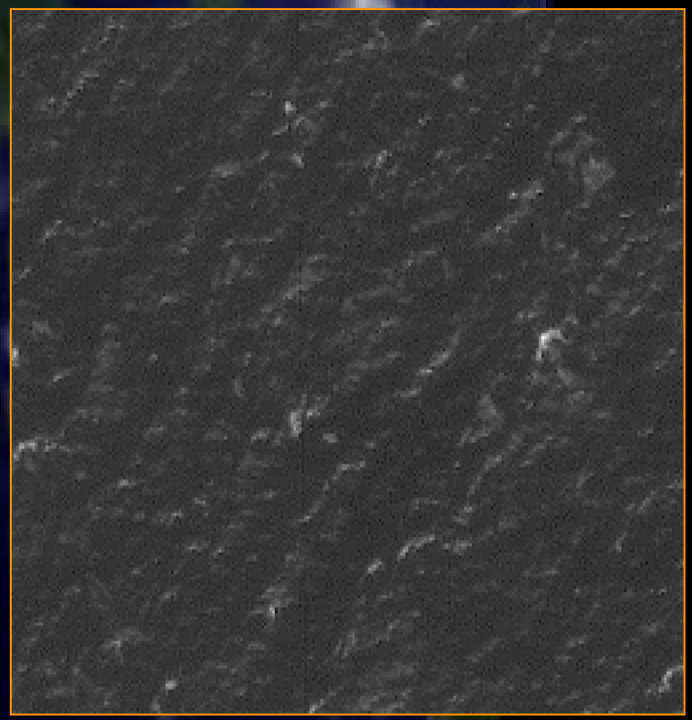


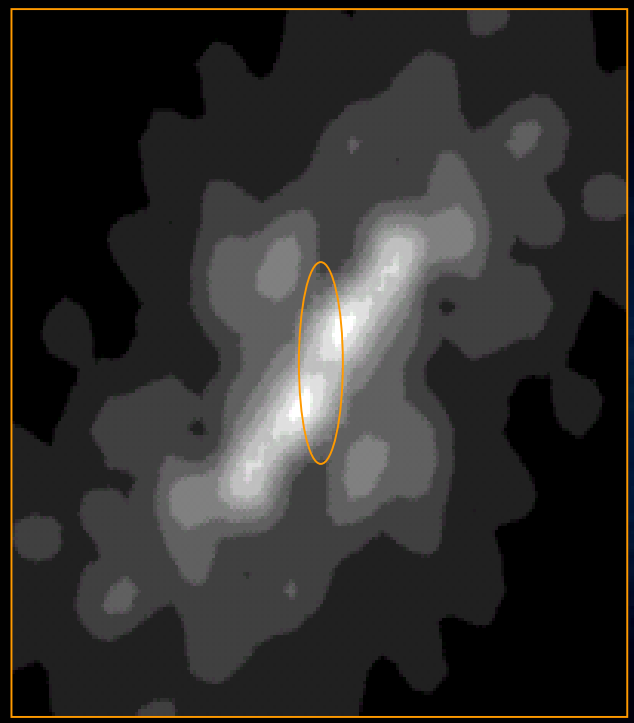


Simulated elliptical target, major axis = 14 m, minor axis = 3 m, downsampled to IKONOS MS resolution (4 m)

Detection algorithm

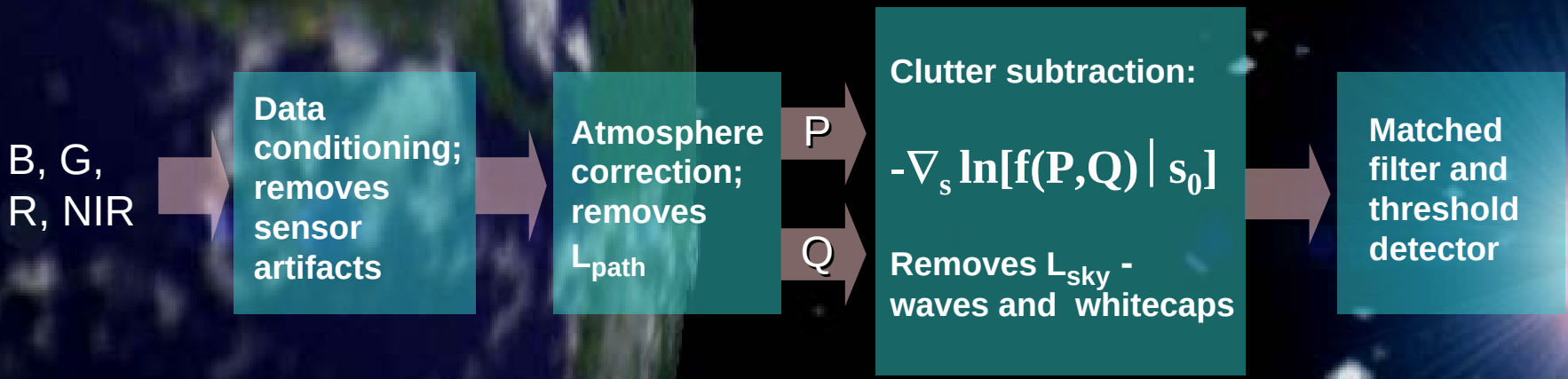
Wavenumber Spectrum





PQ Detection Algorithm

(for submerged targets)

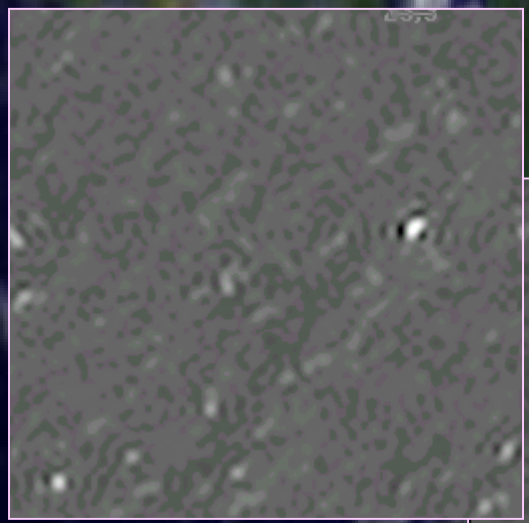


	Case I	Case II, III
P = Water penetrating image =	B	B+G
Q = Surface image =	R+NIR	NIR

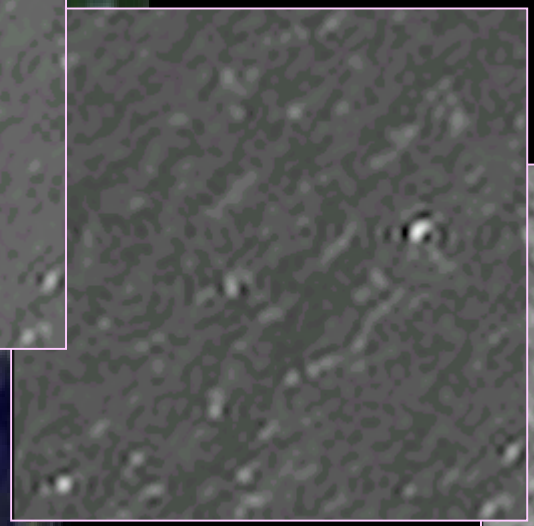
Detection Example

(Simulated targets, ξ = 2, depth = 10 m)

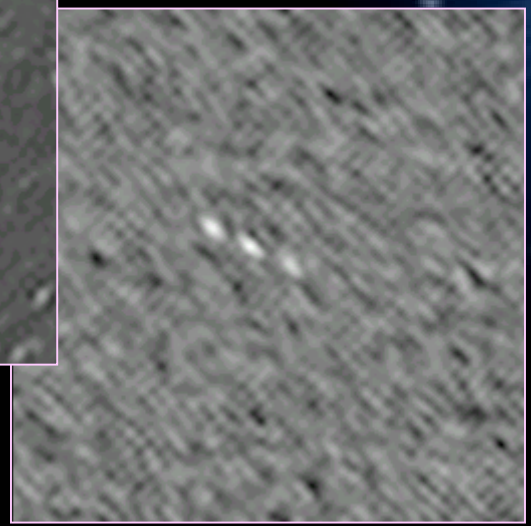
P



Q



PQ Detector output

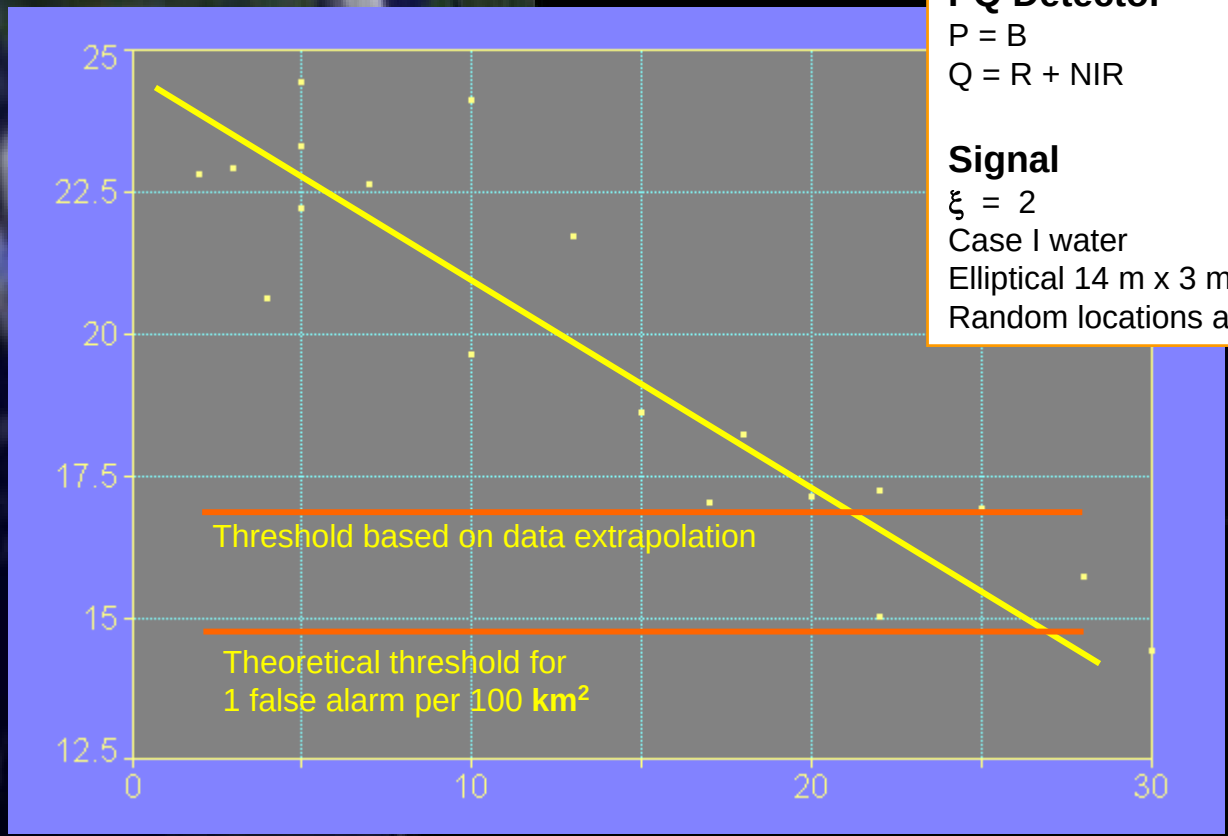


Detection SNR vs Depth

(simulated targets injected into IKONOS image)

PQ Detector
P = B
Q = R + NIR

Signal
ξ = 2
Case I water
Elliptical 14 m x 3 m
Random locations and orientations



First Images Of Whales From Space

Shamu Stadium

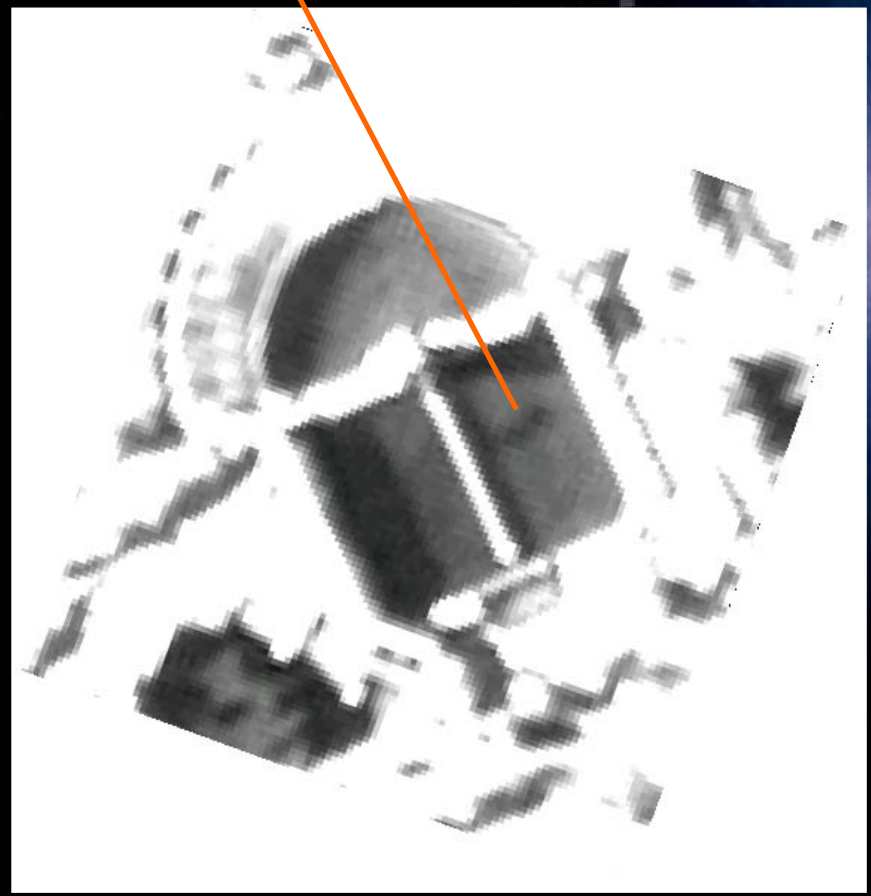
SeaWorld, San Diego

SpaceImaging

IKONOS
January 8, 2000

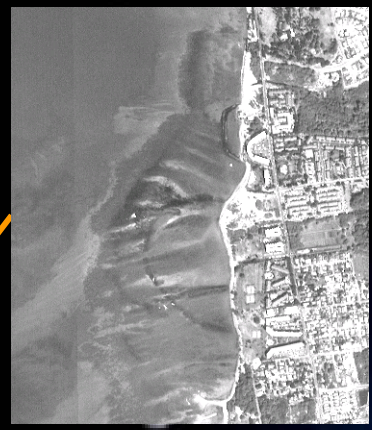
From Sky Tower
October 14, 2001

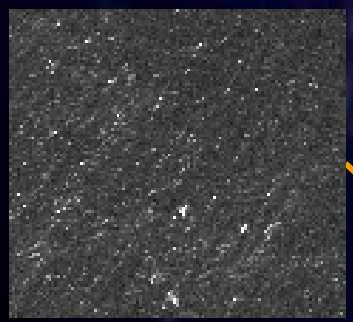
Whale in Holding Pool



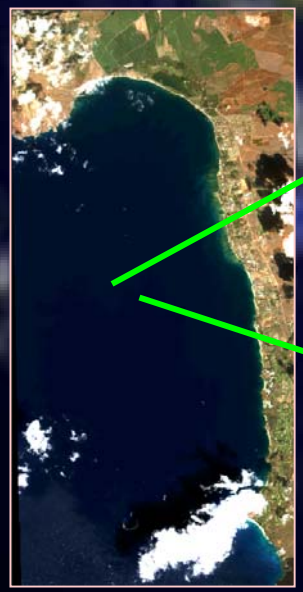
Maui Image Quick Tour

January 25, 2001

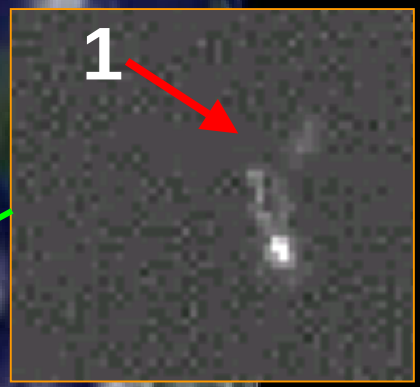


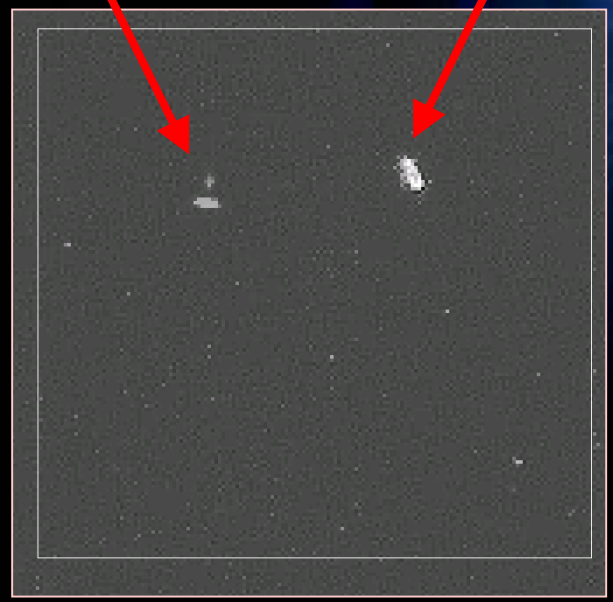


Marine Mammals In Maui Image



SpaceImaging





Future Plans

- Model improvements
  - Better spectral reflectivity measurements
- Processing improvements
  - SNR and FAR
- Validation
  - Simultaneous aircraft-satellite data collection

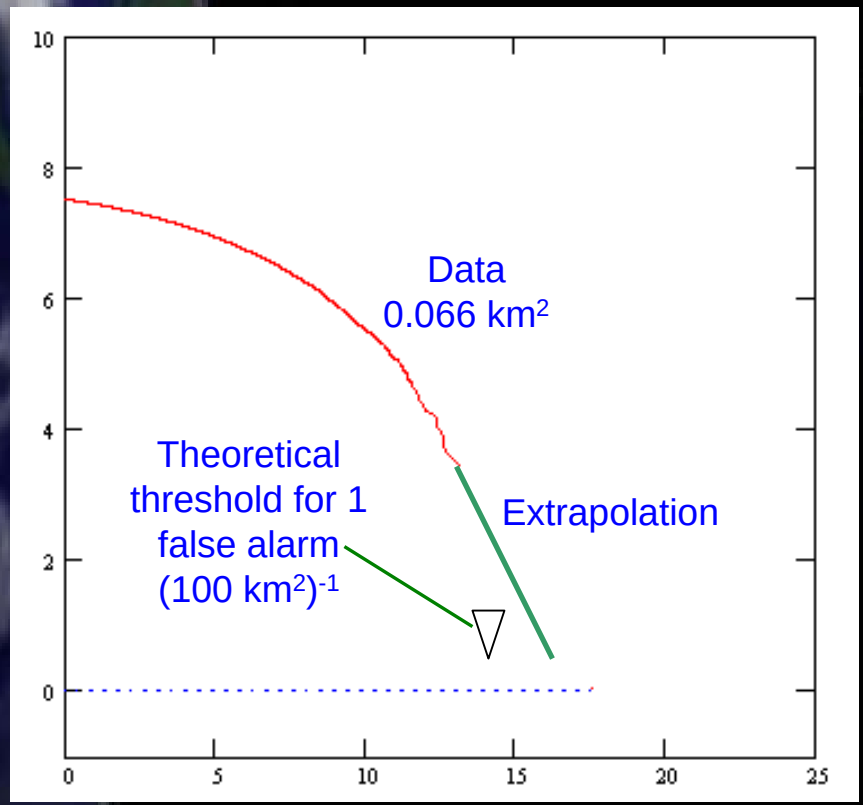
Acknowledgements

- Maui image provided by *Space Imaging, LLC*
- Research partially supported by *ONR*

Holding Pool

Detection False Alarms

Log Number of false alarms $(100\ km^2)^{-1}$



Threshold (dB)