

An aerial satellite image of a coastal region. The top half of the image shows a large, deep blue bay or inlet. The bottom half shows a coastal plain with a grid-like pattern of agricultural fields, some in shades of red and brown. A road or canal runs diagonally across the fields. The text is overlaid on the left side of the image.

# MAPPING SHALLOW WATER DEPTH FROM SATELLITE

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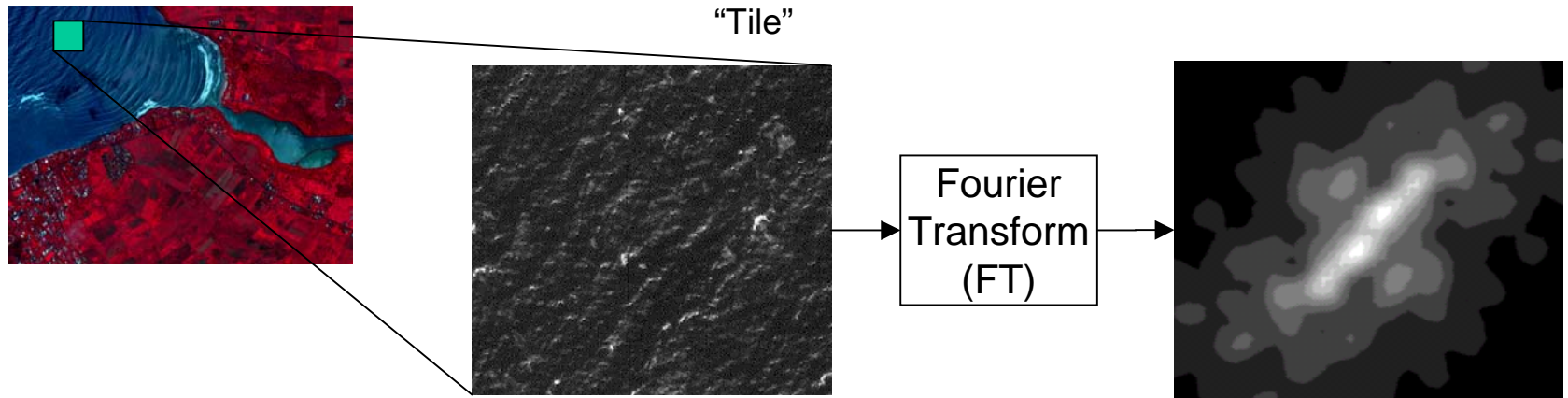
An aerial photograph of a coastline. The water is a deep blue, and the land is a vibrant red. The coastline is irregular, with a large bay on the right side. The water shows some wave patterns, particularly near the shore.

**Shoaling waves display four depth-related physical changes**

- 1. Steepening → breaking**
- 2. Wavenumber transformation**
- 3. Refraction**
- 4. Change in phase velocity**

} Remote sensing bathymetry  
using ocean waves  
kinematics (WK)

# Wave spectrum phase



$$S_t(k_x, k_y) = S_0(k_x, k_y) e^{-j\Omega(k)t}$$

$$j\Omega(k) = j(\underbrace{\sqrt{g|k|\tanh(|k|d)}}_{\text{Depth}} + \underbrace{[U_x, U_y]}_{\text{Ocean surface current}} \bullet [k_x, k_y])$$

Depth

Ocean surface current

# WK (Phase Velocity) Depth Estimation

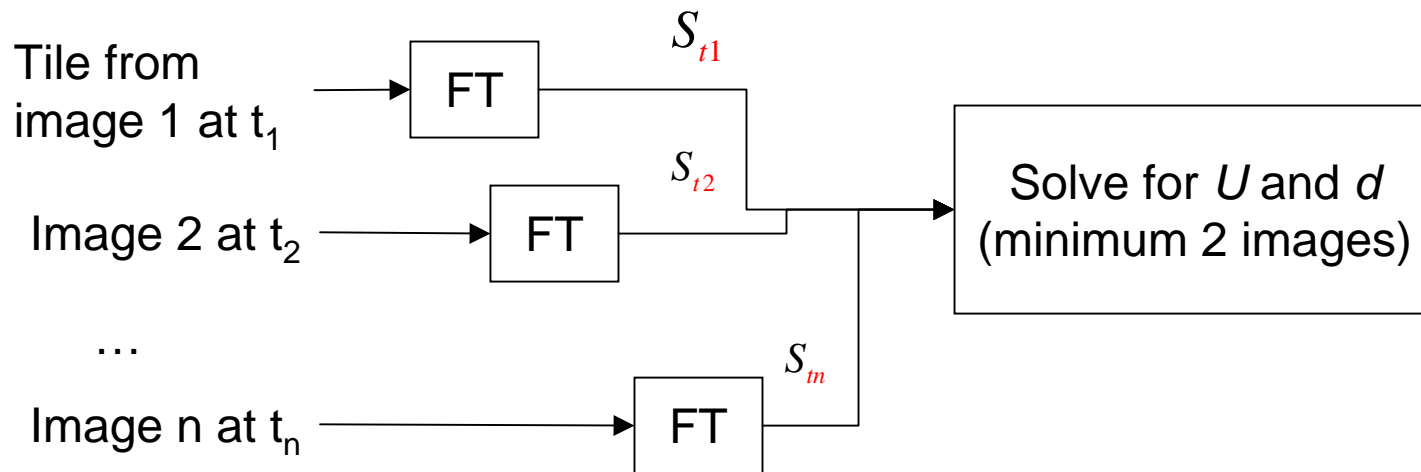
Wavenumber  
spectrum at  
time  $t$

$$S_t(k_x, k_y) = S_0(k_x, k_y) e^{-j\Omega(k)t}$$

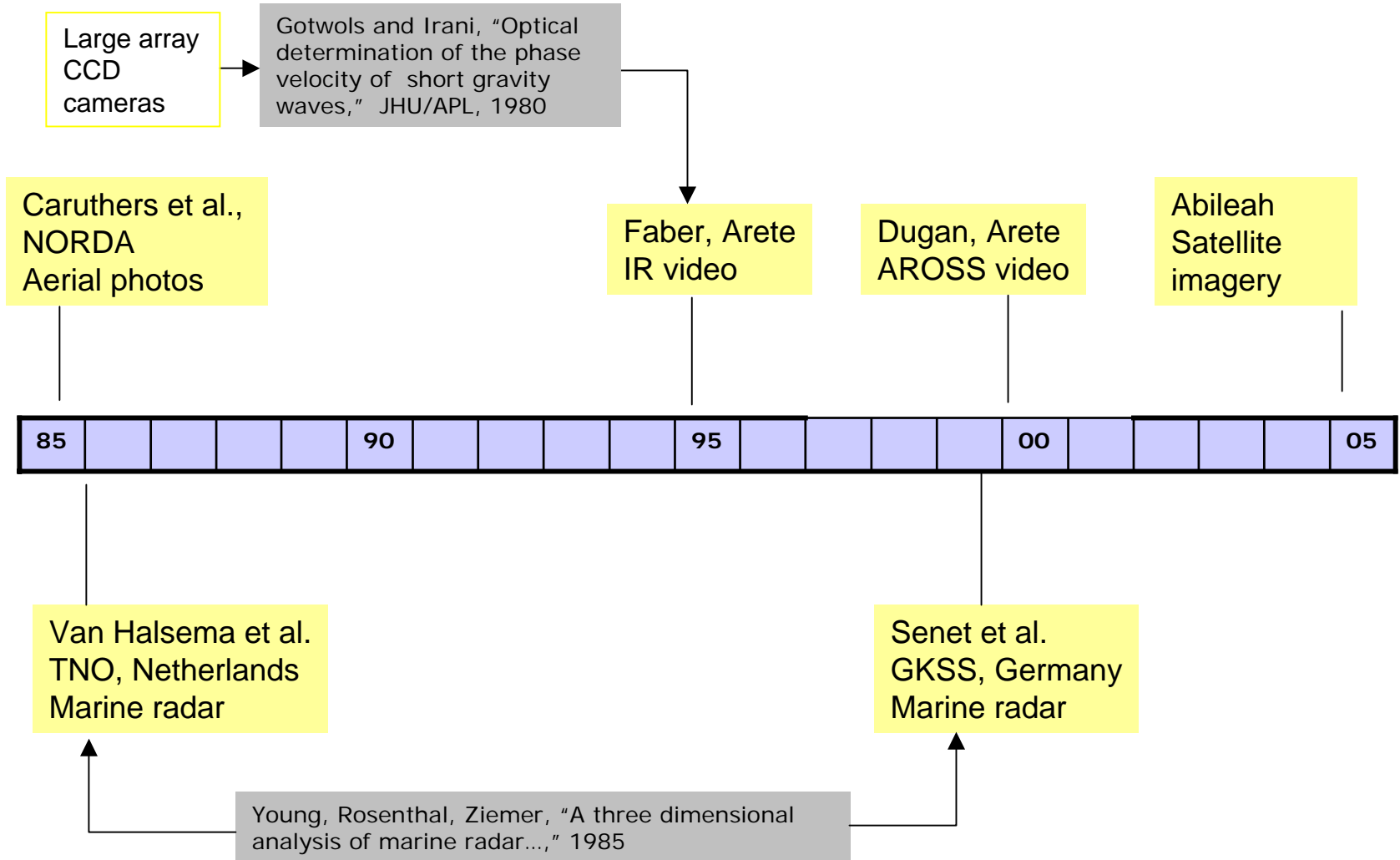
$$j\Omega(k) = j(\underbrace{\sqrt{g|k|\tanh(|k|d)}}_{\text{Depth}} + \underbrace{[U_x, U_y] \cdot [k_x, k_y]}_{\text{Ocean surface current}})$$

Depth

Ocean surface current

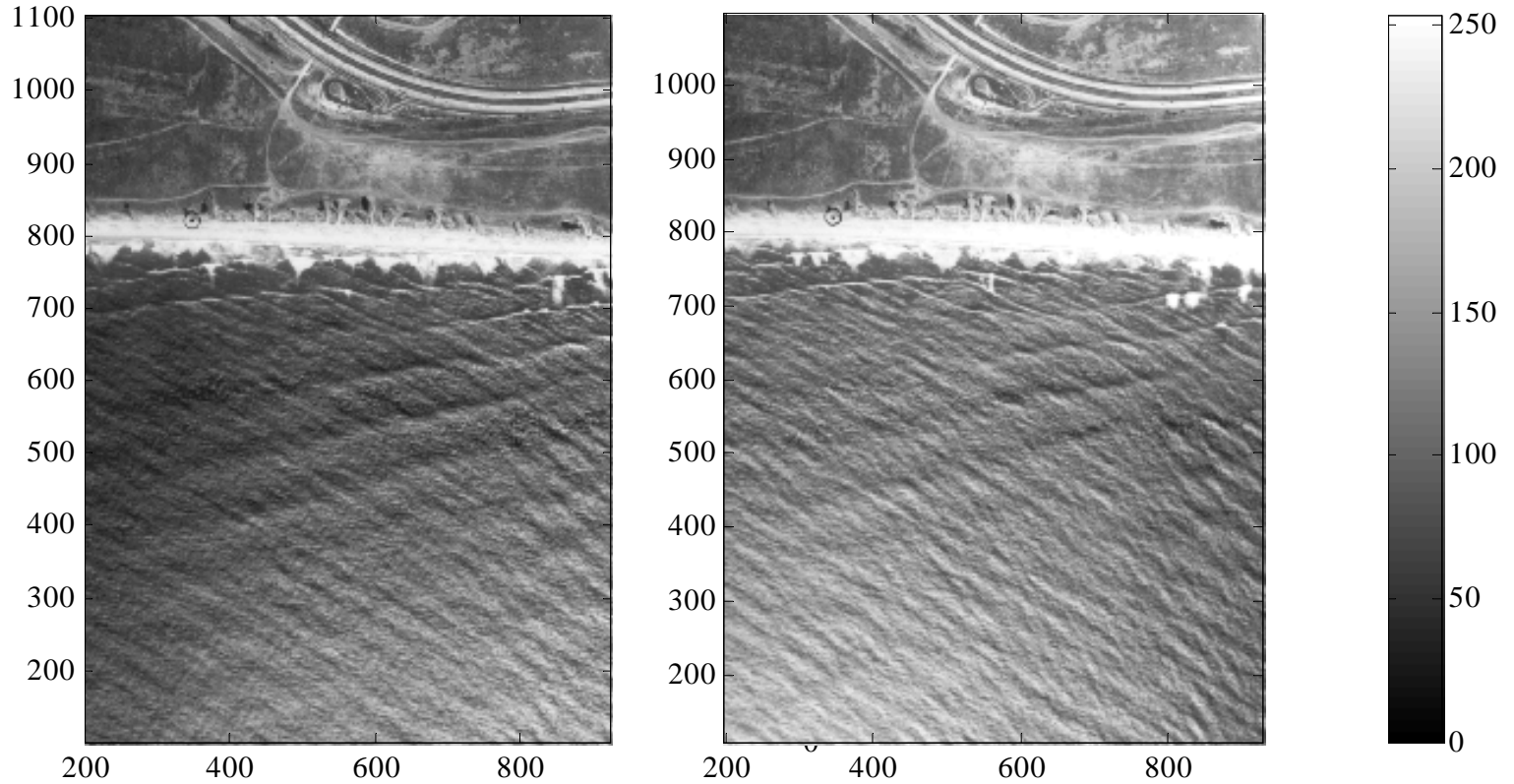


# 20 Year History

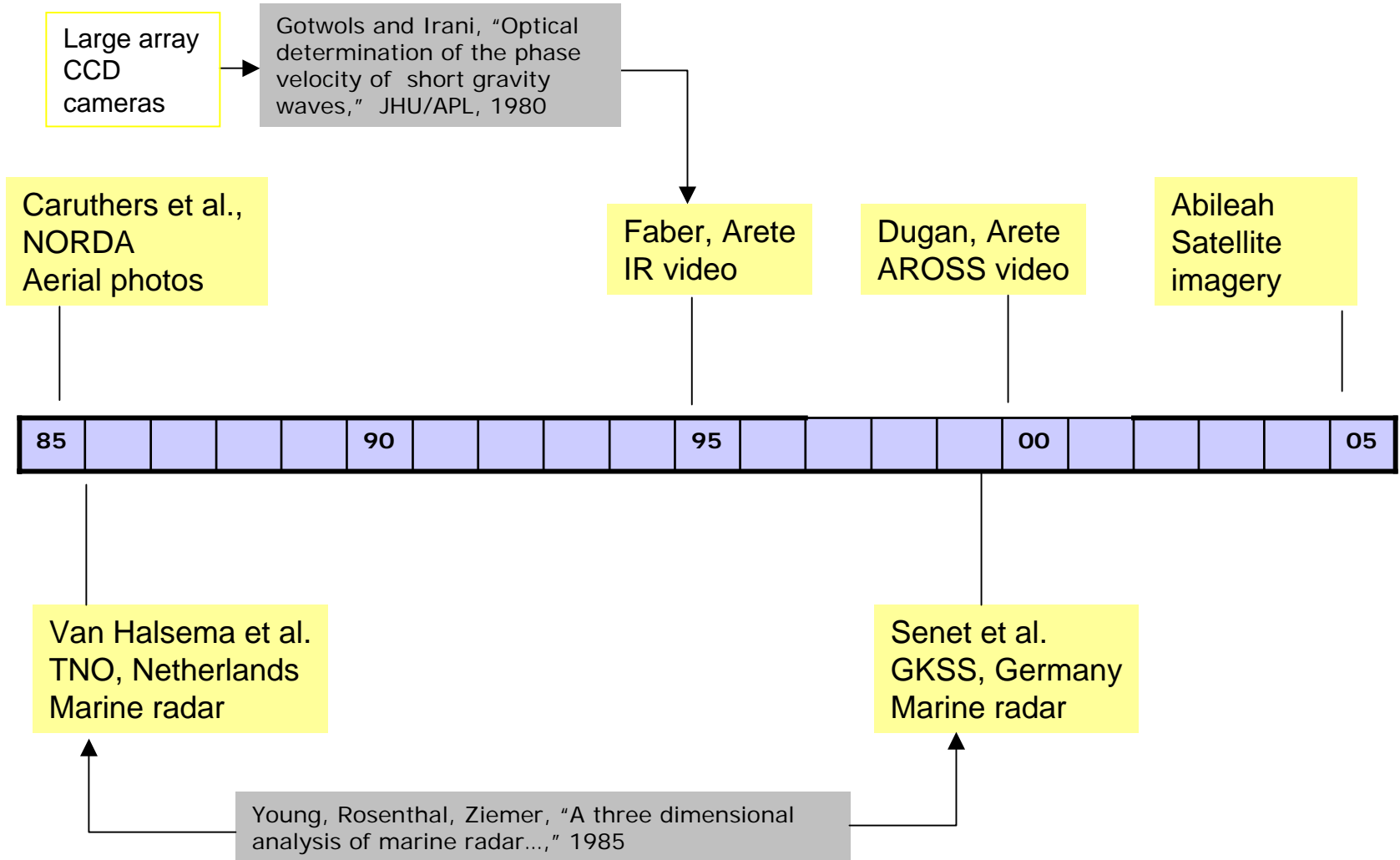


# Caruthers et al.

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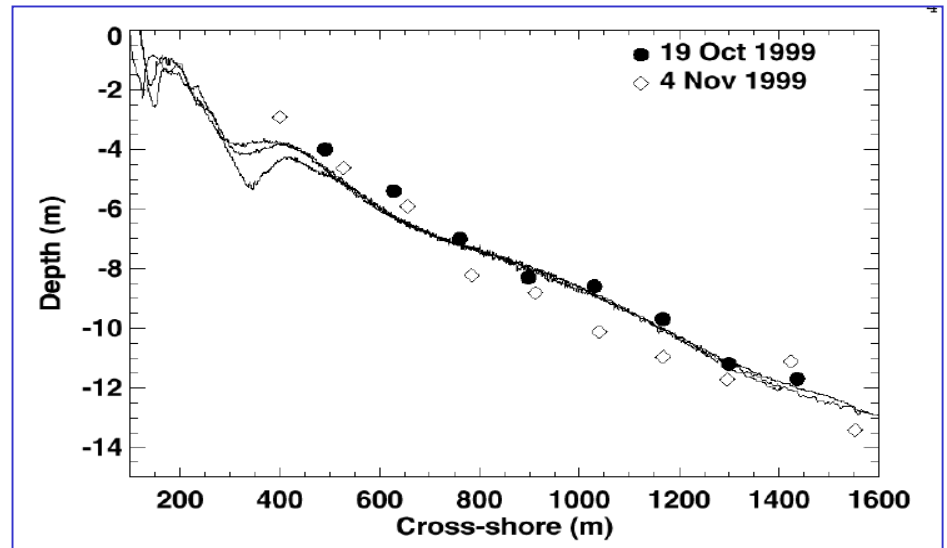
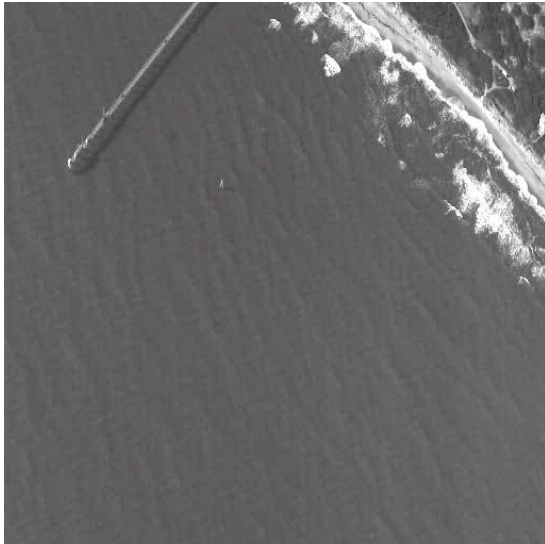


# 20 Year History



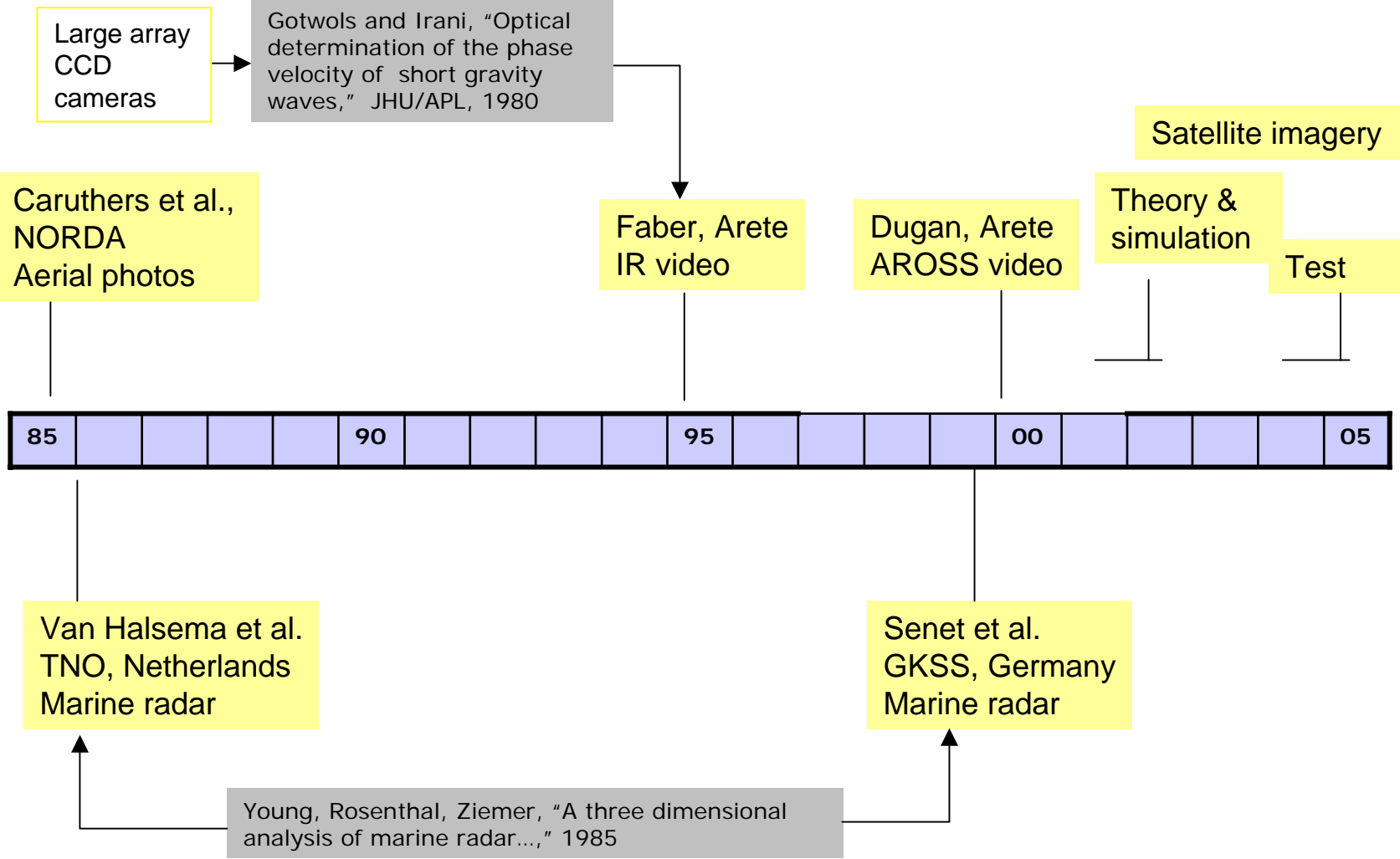
# Dugan

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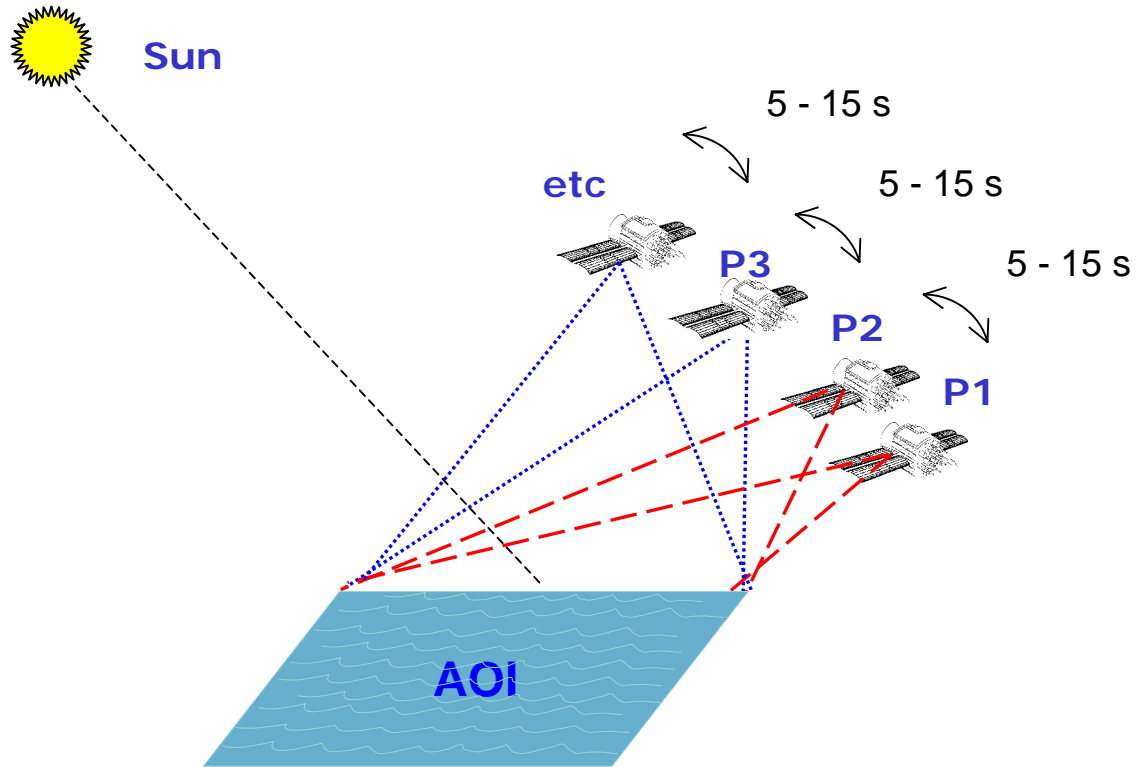


# 20 Year History



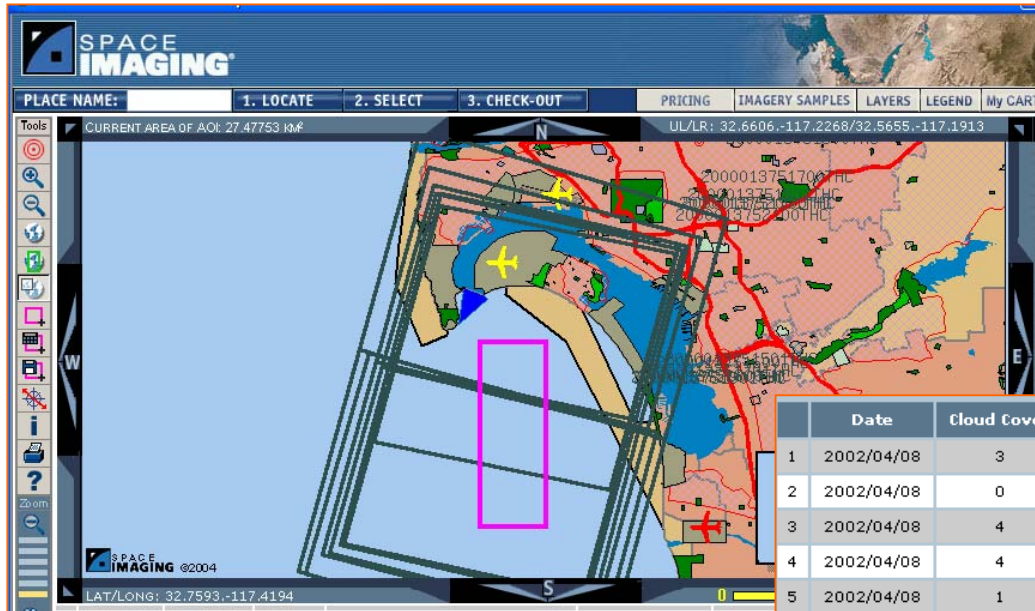
# Satellite image collection

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# IKONOS San Diego Set

## Footprints

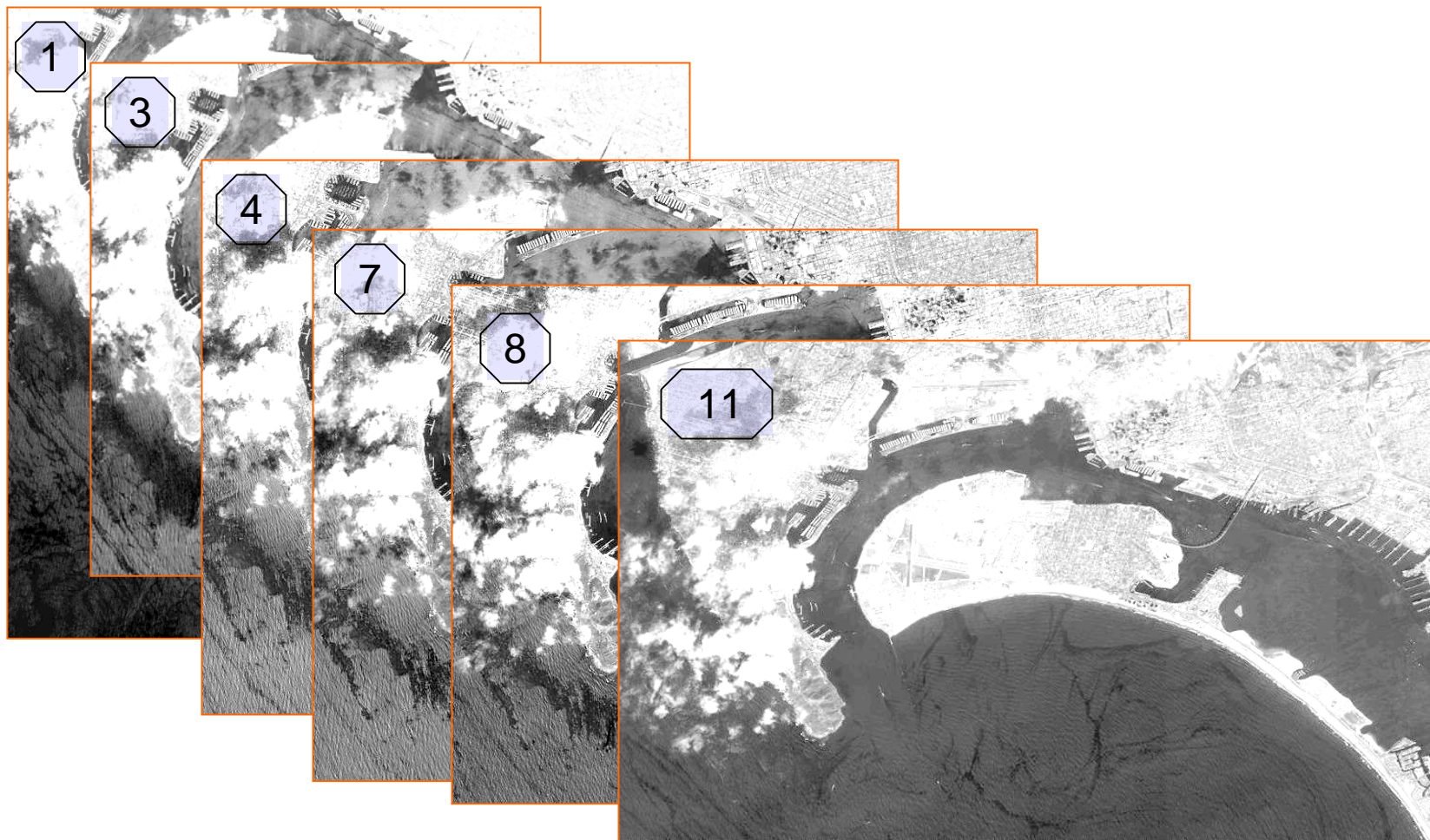


## Image IDs

	Date	Cloud Cover	Elevation	Source Image Id
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3	2002/04/08	4	76.9761	2002040818470270000011607270
4	2002/04/08	4	69.769	2002040818464940000011607269
5	2002/04/08	1	69.769	2002040818464940000011607269
6	2002/04/08	2	62.8147	2002040818463670000011607268
7	2002/04/08	6	62.8147	2002040818463670000011607268
8	2002/04/08	8	56.4435	2002040818462340000011607267
9	2002/04/08	4	56.4435	2002040818462340000011607267
10	2002/04/08	7	50.6926	2002040818461070000011607266
11	2002/04/08	13	45.8774	2002040818455810000011607265
12	2002/04/08	10	45.8774	2002040818455810000011607265

# IKONOS San Diego Images

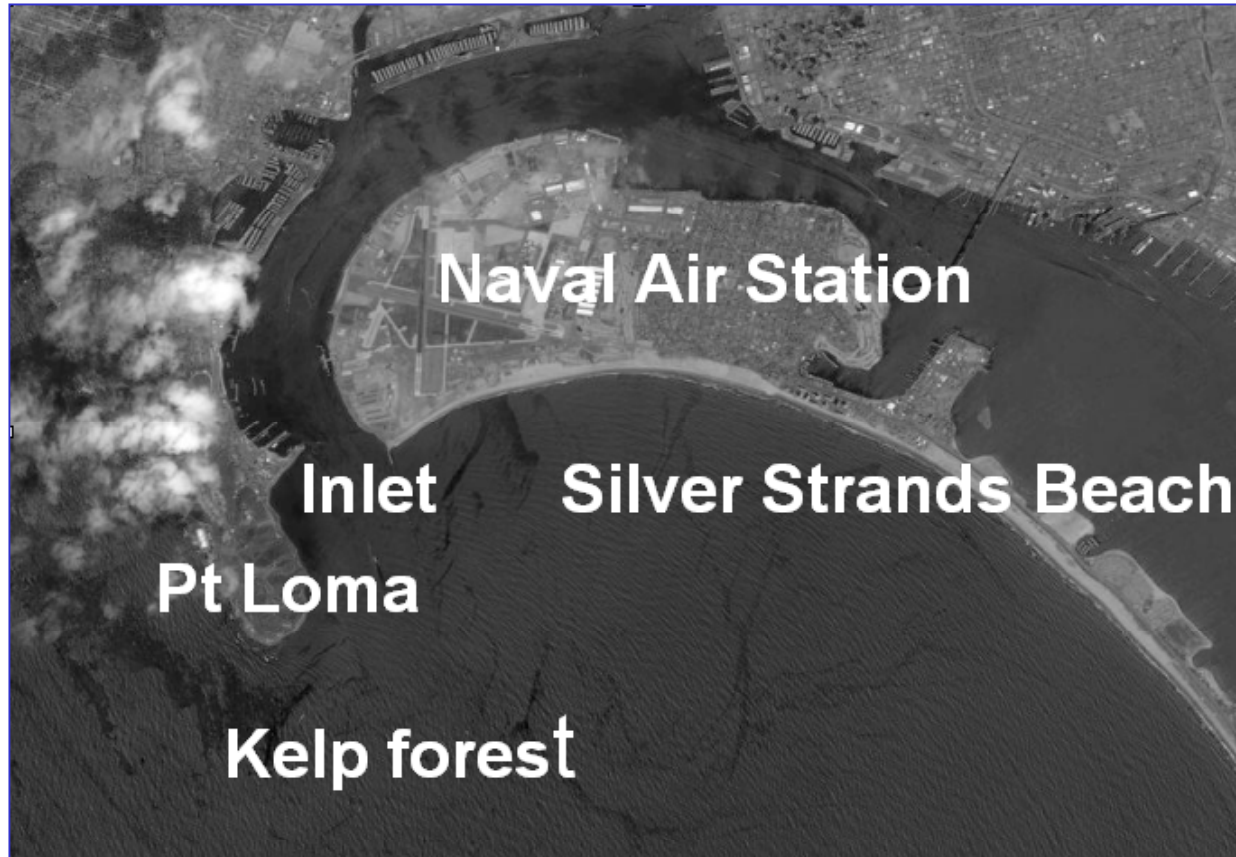
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SpacelMaging CARTERRA

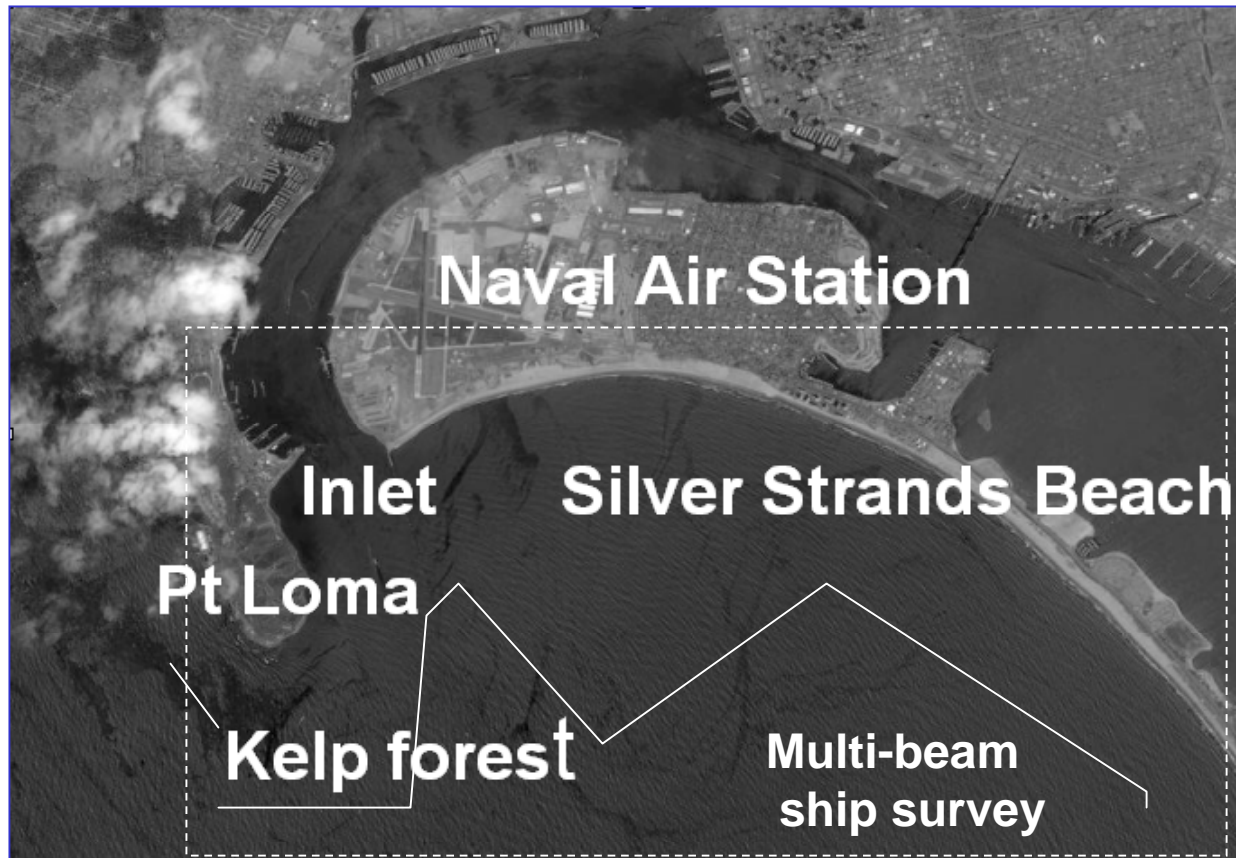
# San Diego Inlet

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# San Diego Inlet

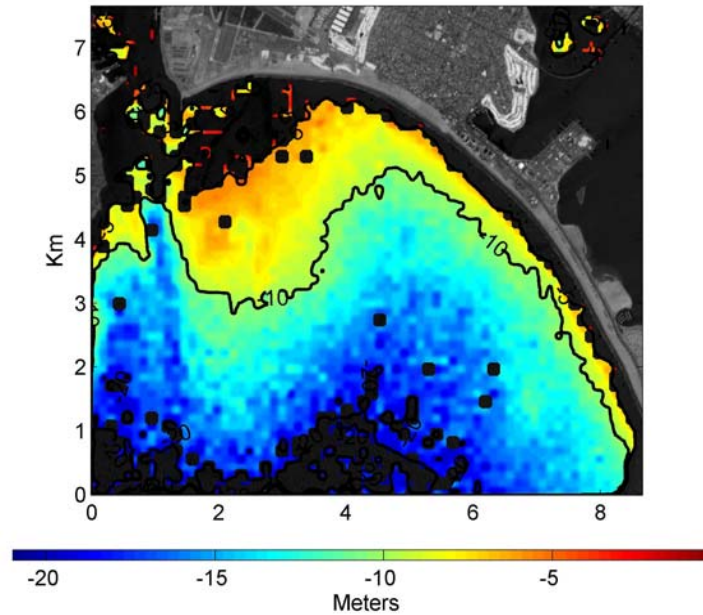
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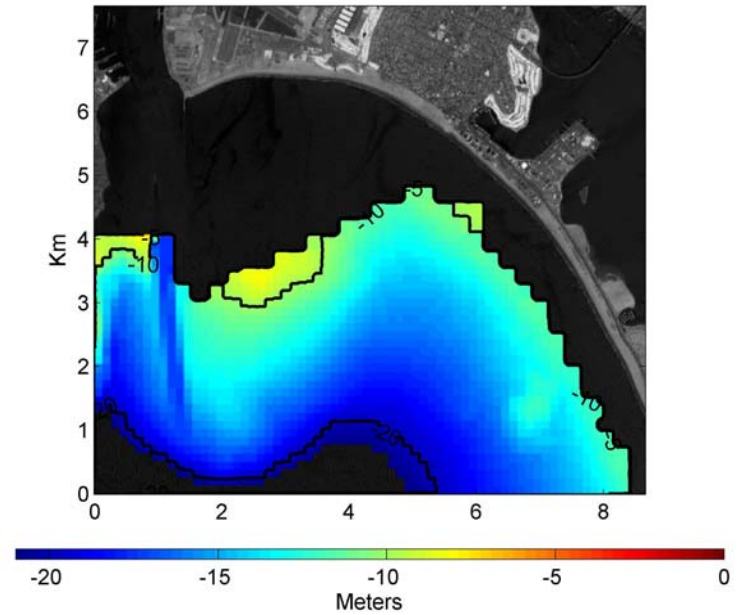
# WK with 2 images

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WK depths  
**128 m tiles**, 2 images

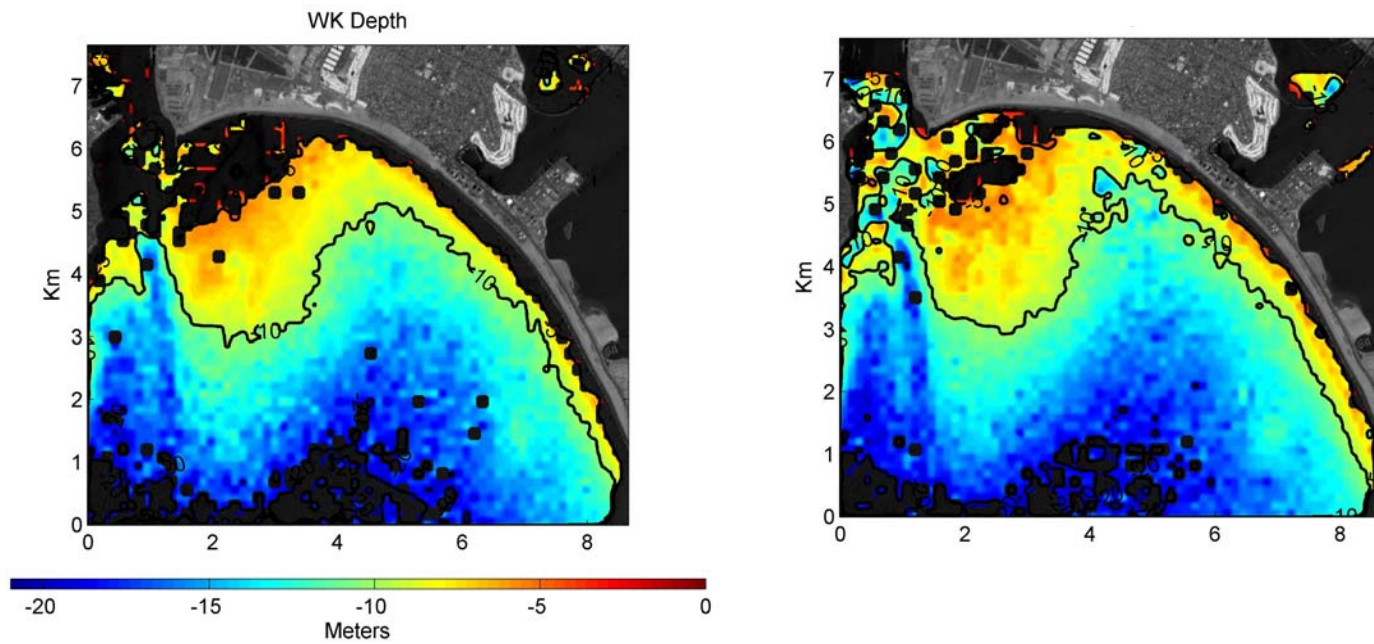


Fugro multibeam  
ship survey



# 2 vs 4 images

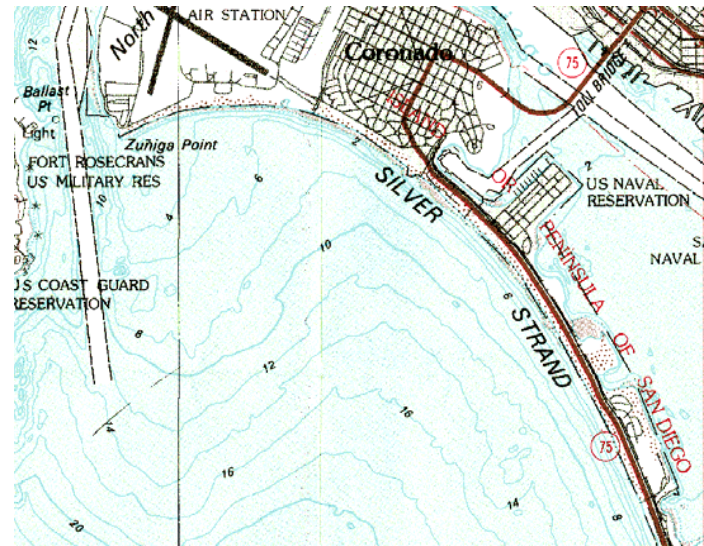
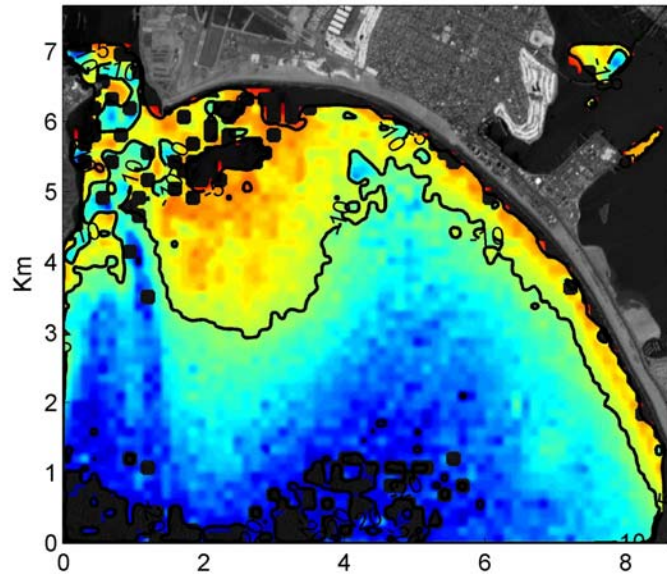
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# Comparison to USGS Chart

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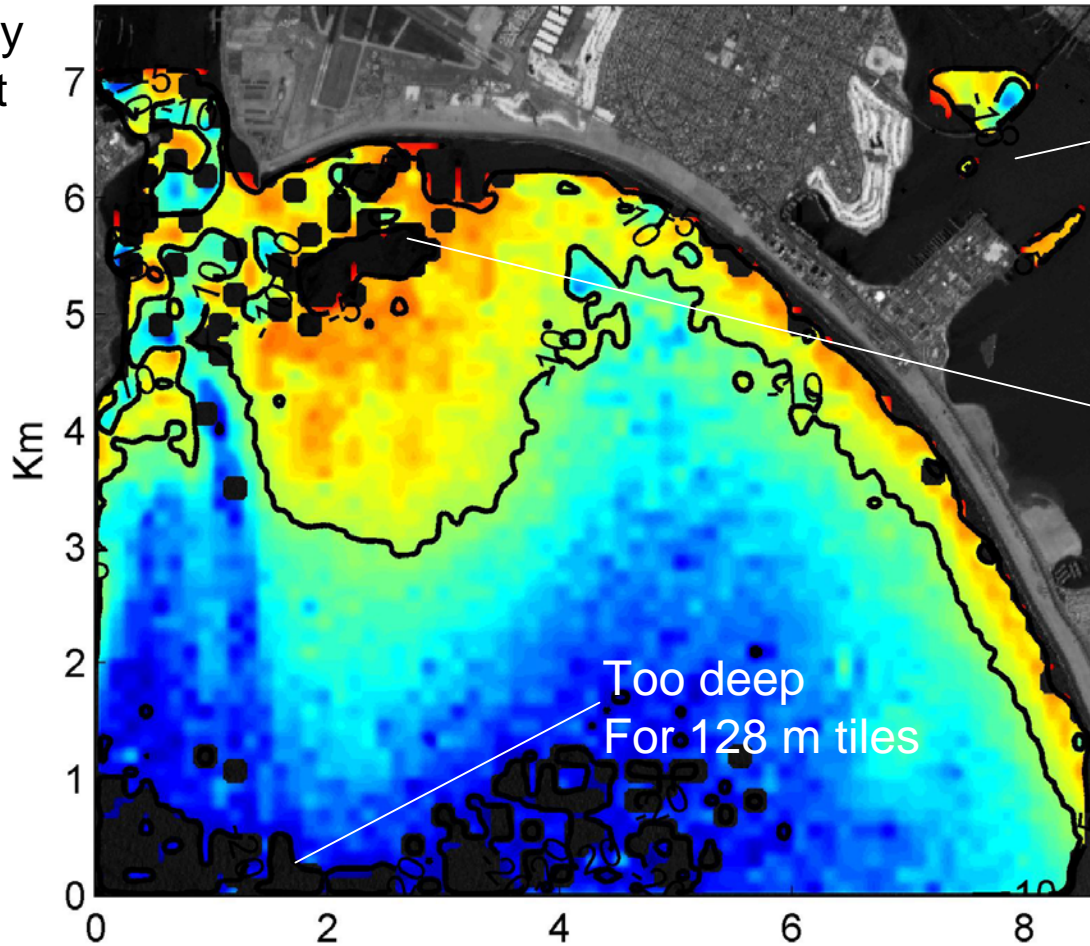
# Comparison of Satellite-Based Methods

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Method	Type of satellite	Depth accuracy	Horizontal resolution	Est. cost \$/km <sup>-2</sup>	Turbid waters
WK	Hi Res Pan or Multispectral	5-10%	50-200 m	50	Yes
Photo-bathymetry	Hi Resolution Multispectral	5% but biased	10-30m	50	No
Currents interaction	SAR	5%	5m	10	Yes
Wave refraction	SAR	30%	1 km	<10	Yes

# Gaps in WK Solutions

Wind waves  
damped by  
kelp forest  
(outside  
figure)



No waves

Waves blocked  
by jetty

Too deep  
For 128 m tiles

# Summary

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- **WK bathymetry resolution – depth accuracy**

<b>Resolution @ 10 m</b>	<b>Depth accuracy</b>
250 m	4 %
125 m	6 %
50 m	10 %

- resolution proportional to depth
- accuracy also depends on number of images

- **Special considerations**

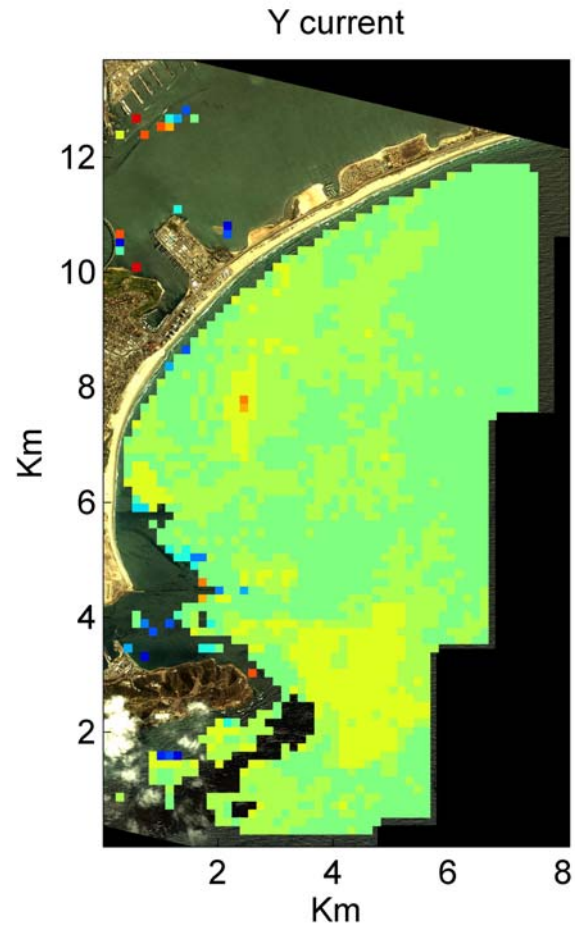
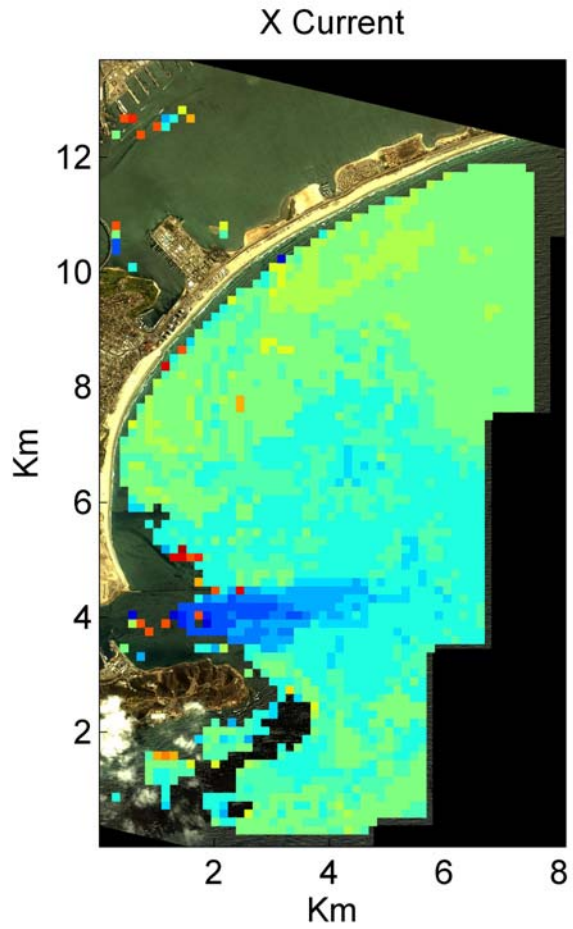
- requires wind waves
- no solution where waves are blocked or damped out
- currents, turbidity are not issues

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## **Extra Slides and Backups**

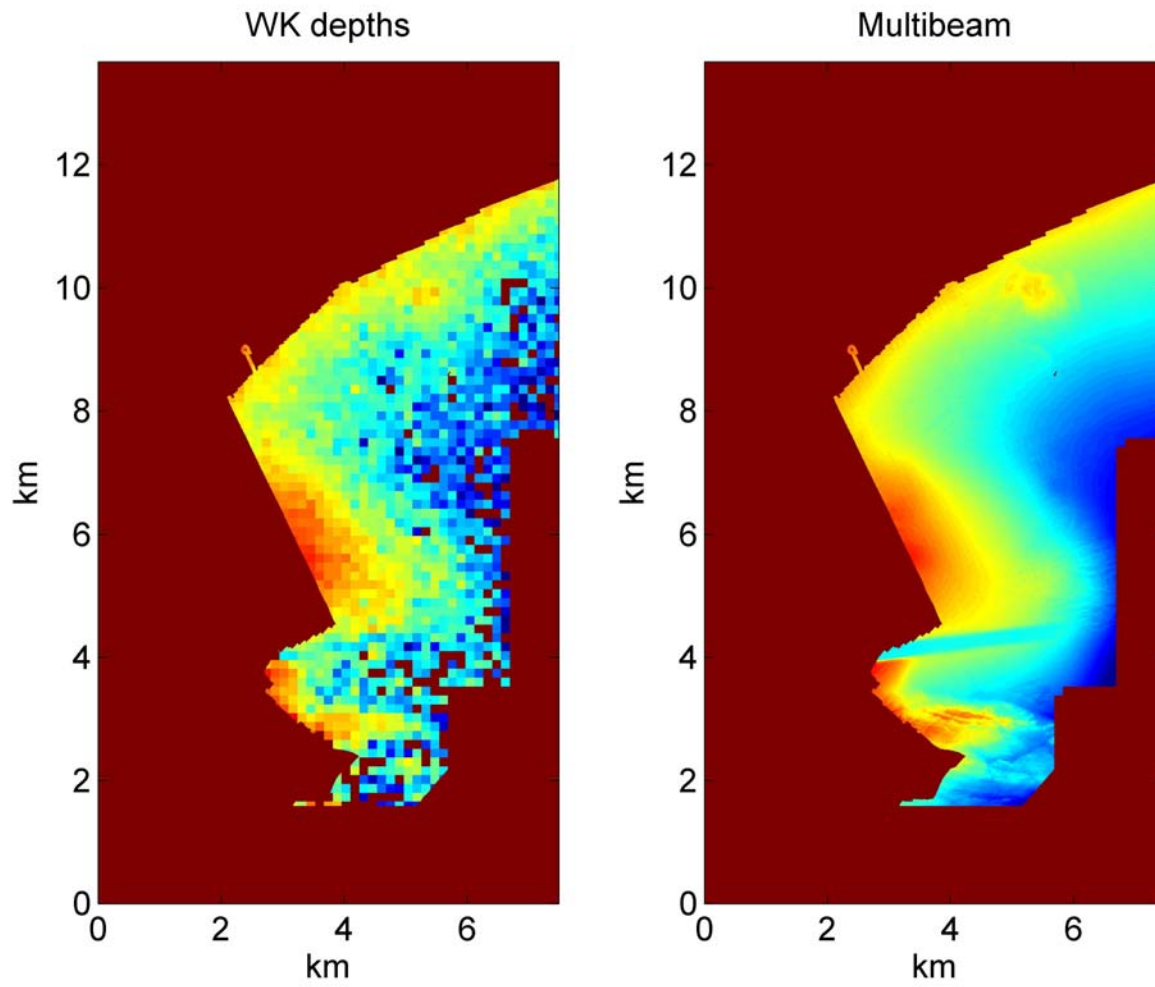
# Current

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# WK compared with multibeam

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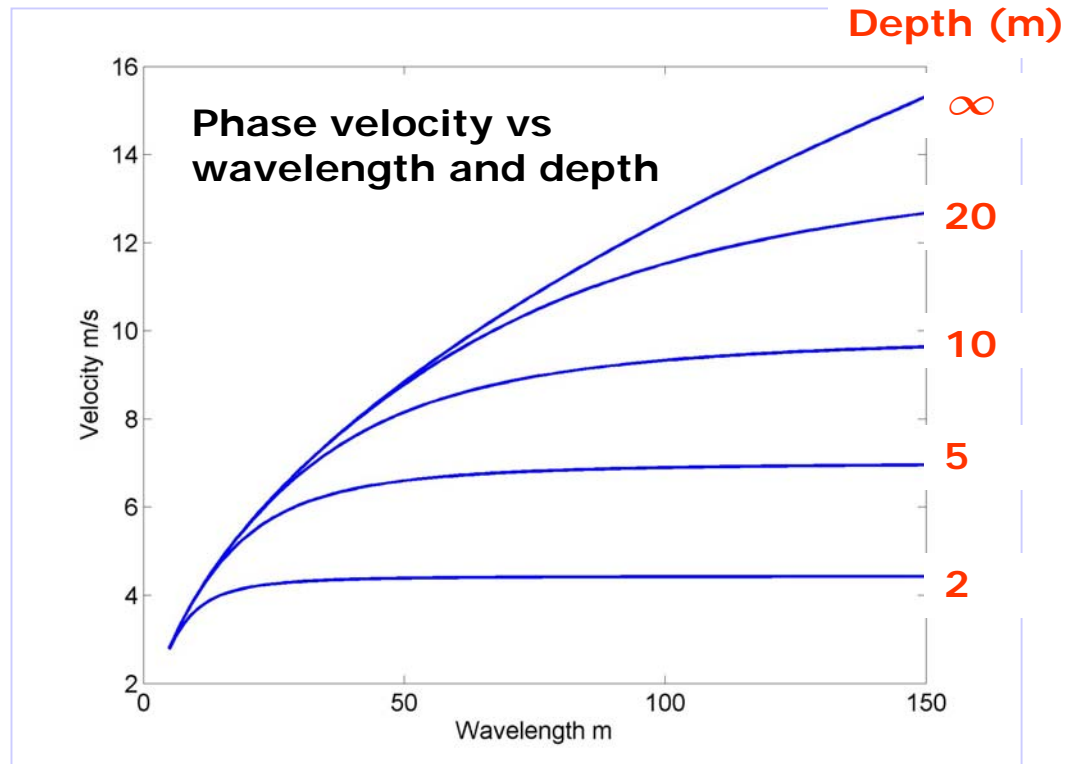
# Reconnaissance Aircraft Photos - Movie

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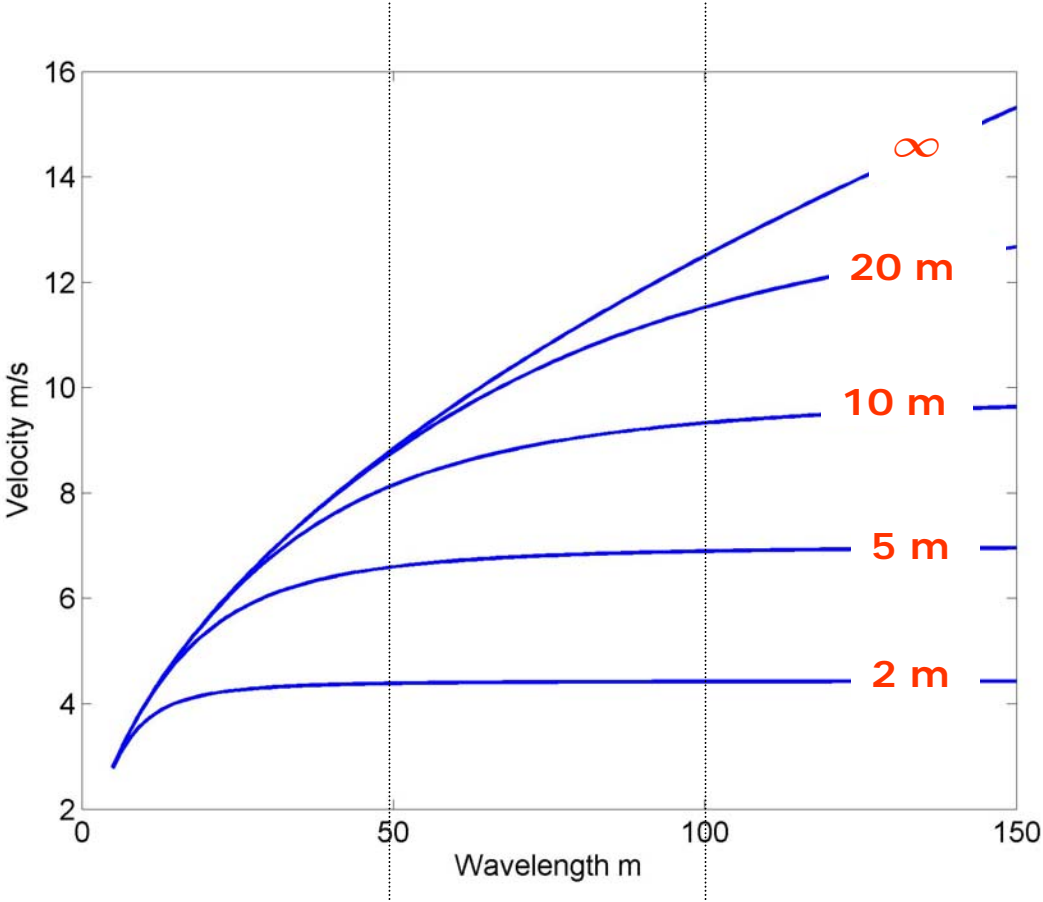




# Phase Velocity



# Wavelength-Depth-Speed Relationship



# San Diego Area



Depth Contours in m,  
10 m increments to  
200m

# Multispectral images for photobathymetry

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