Modeling Maritime Radar Scattering

WPI Major Qualifying Project

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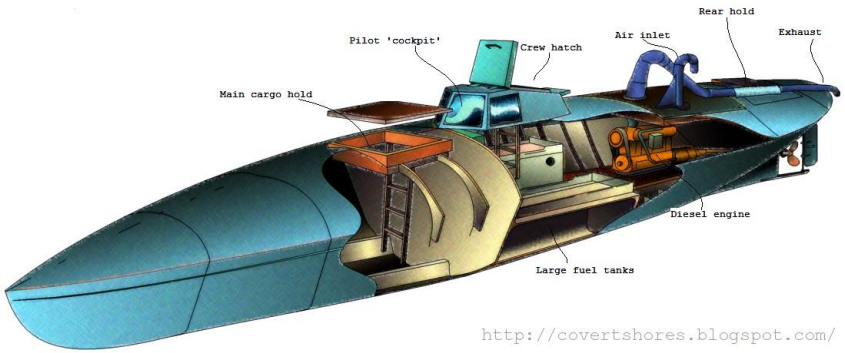
Outline

- **Introduction**
- **Ocean Scattering Simulation**
  - **1-D Model**
  - **2-D Model**
- **Phased Array Radar Simulation**
- **Parallelization**
- **Graphical User Interface**
- **Future Work**

Introduction

- **Small boats and semi-submersible boats are being used by drug-runners, smugglers, and pirates**
- **Small boats loaded with explosives present a threat to the security of our naval forces**
- **The first step to counter these threats is detection**
- **Currently, lack of data and understanding inhibits detection**

Semi-Submersible Sub



USS Cole

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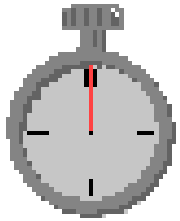
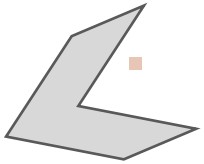
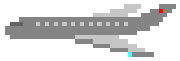
Radar

- **Single fixed antenna**
- **Determine range and velocity information of boats and ocean surface**
- **Time Delay→ Range**
- **Frequency Shift→ Velocity**



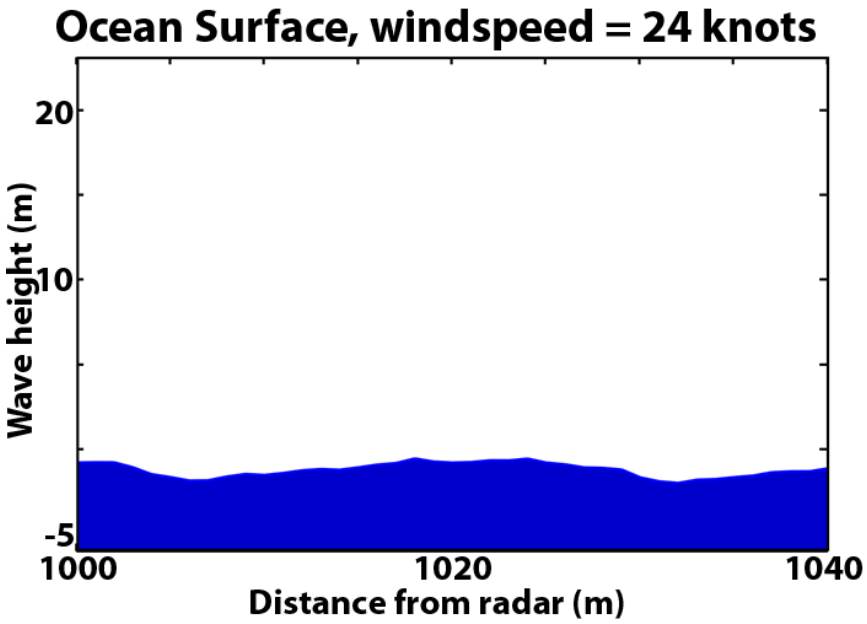




http://www.radartutorial.eu/01.basics/rb05.en.html

1-D Ocean Model

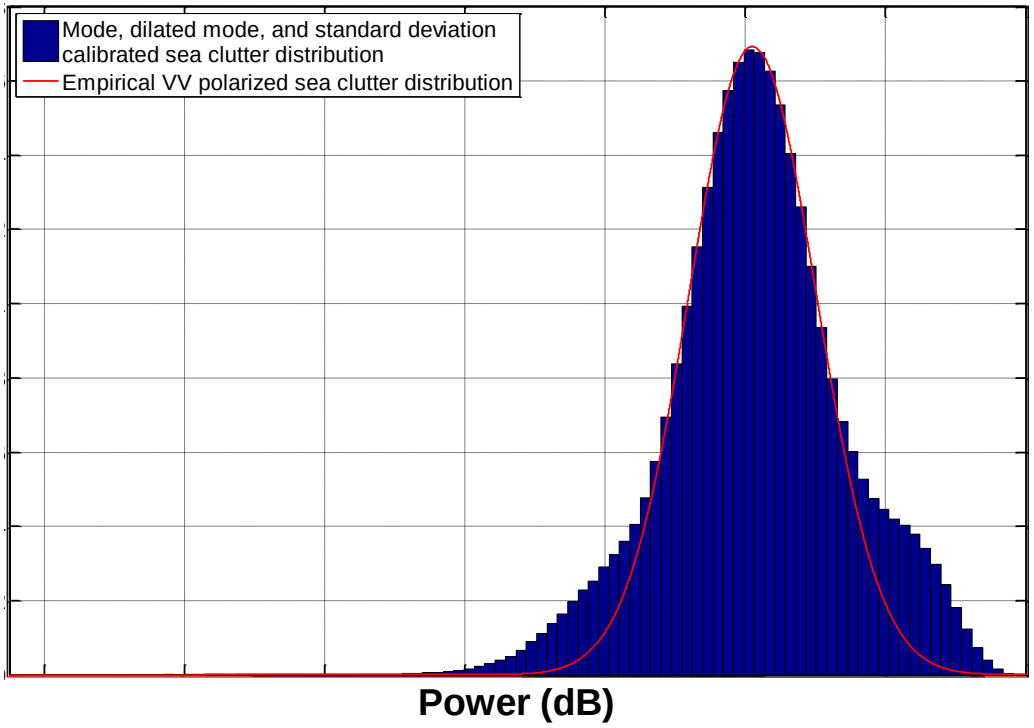
- Waves created by wind blowing over the ocean surface
- Modeled ocean surface height
  - Spectral composition based on wind speed (Pierson-Moskowitz spectra)
  - Significant wave height based on wind speed (Beaufort scale)

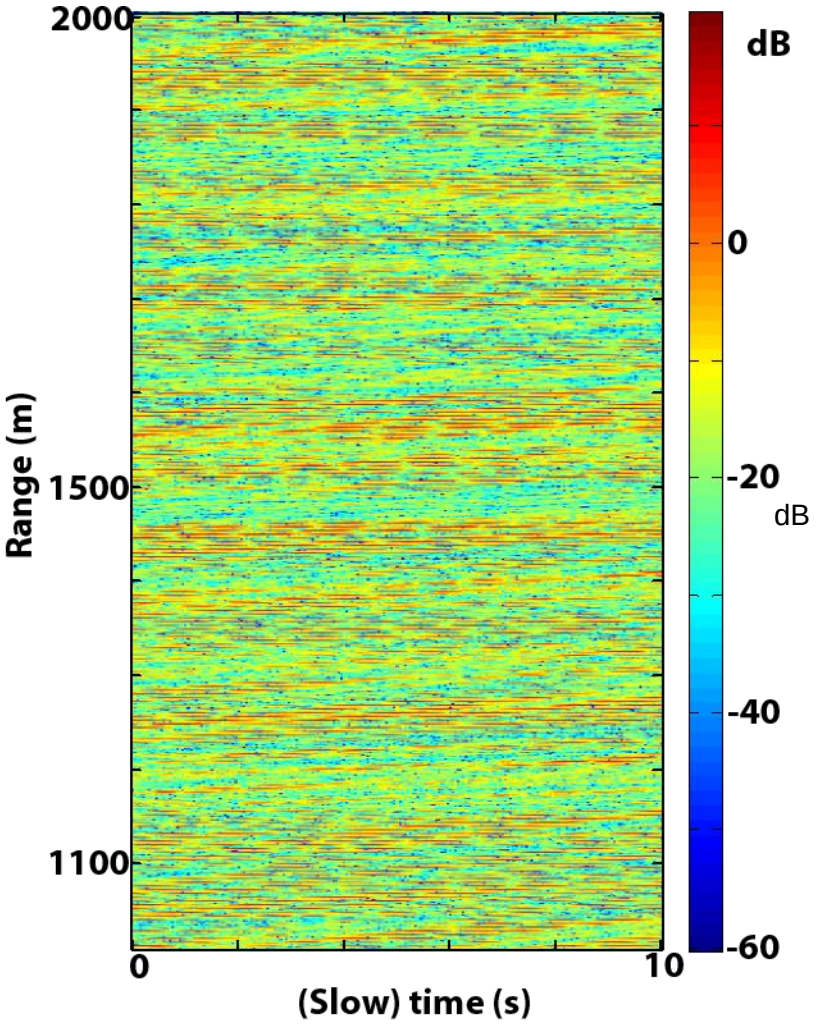


Ocean Radar Return:

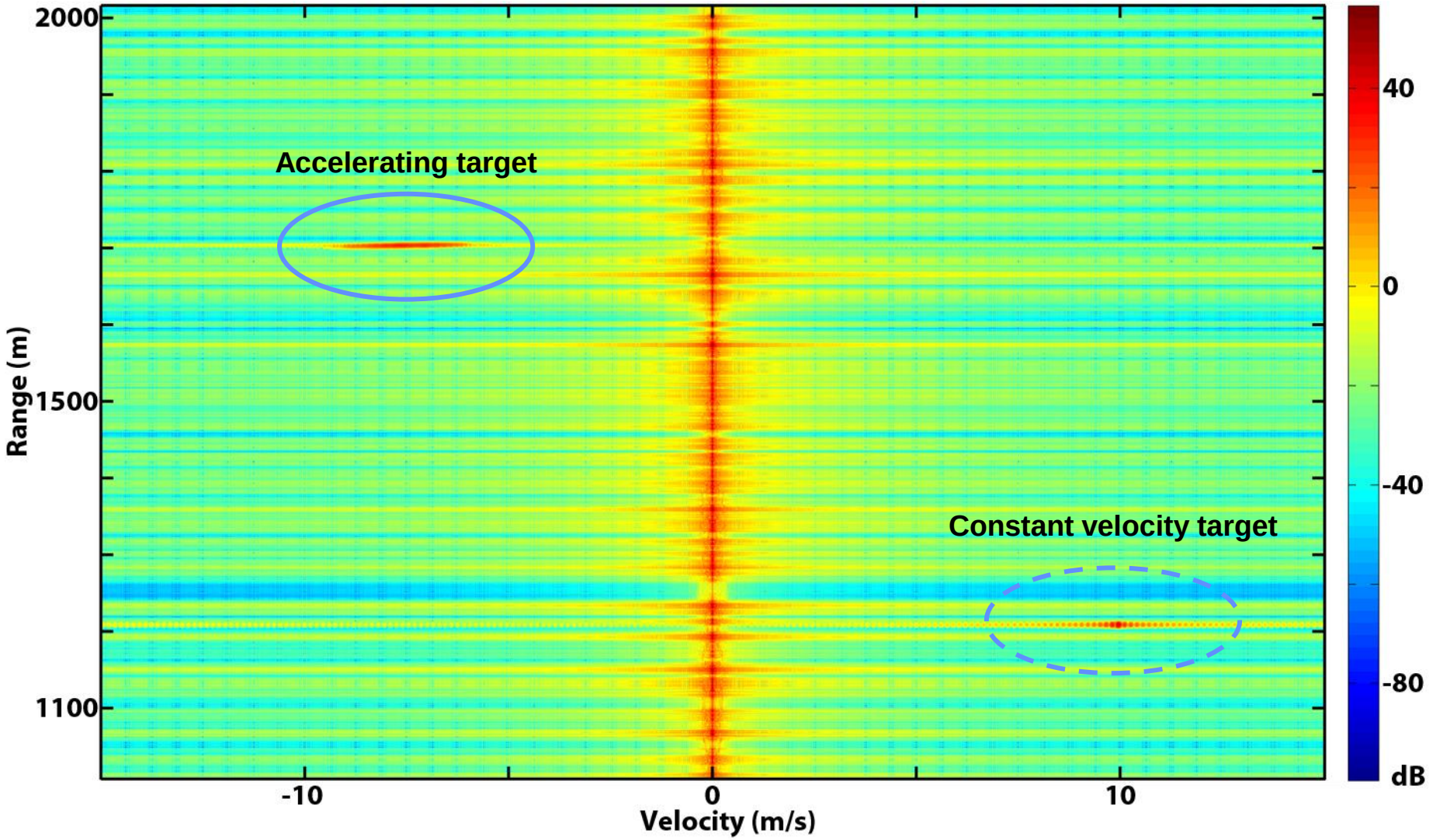
Wind Speed = 13 knots, VV polarization

- Radar return power dependent on ocean surface slope
- Used log-normal statistics to scale simulated radar data





Range Doppler Map



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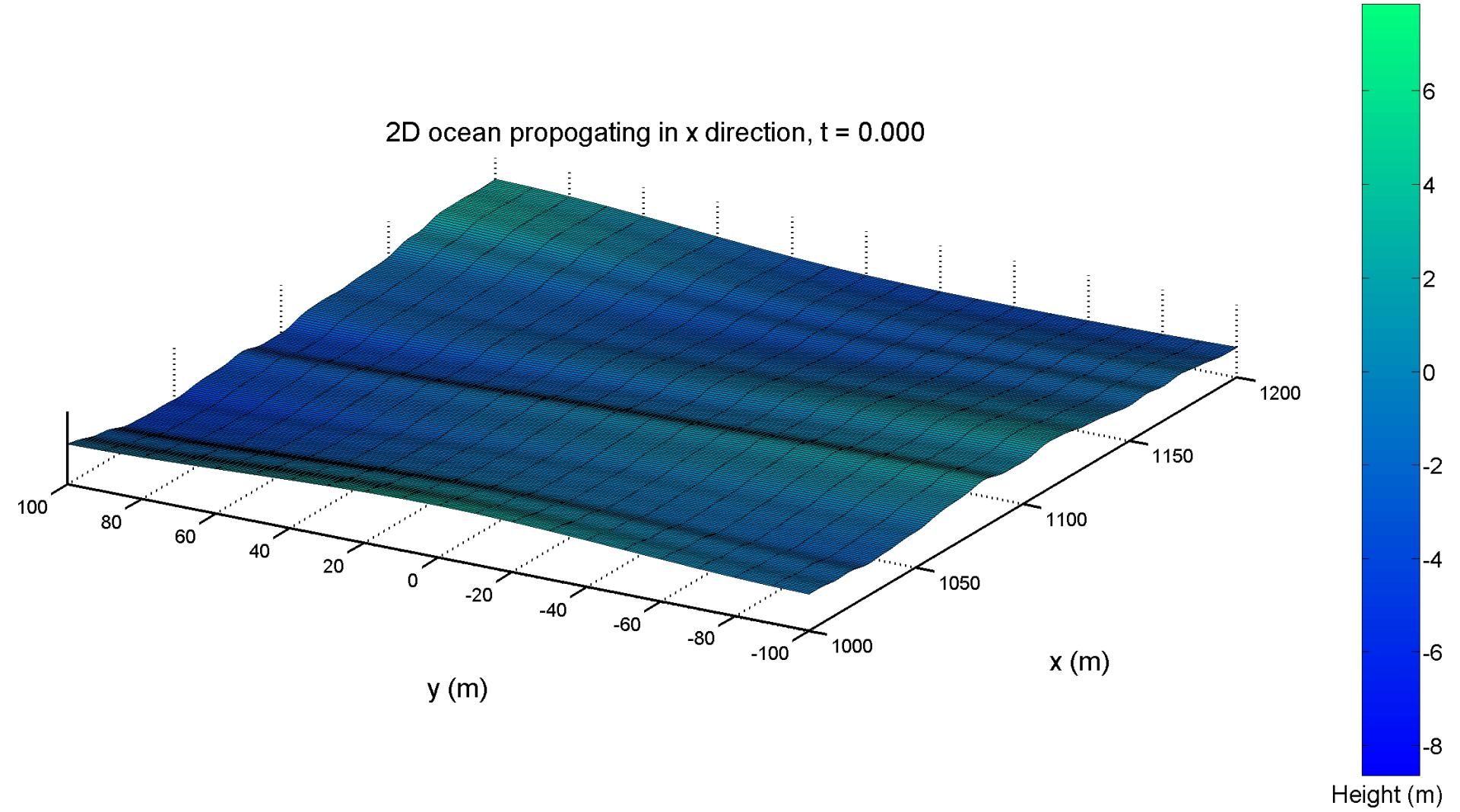
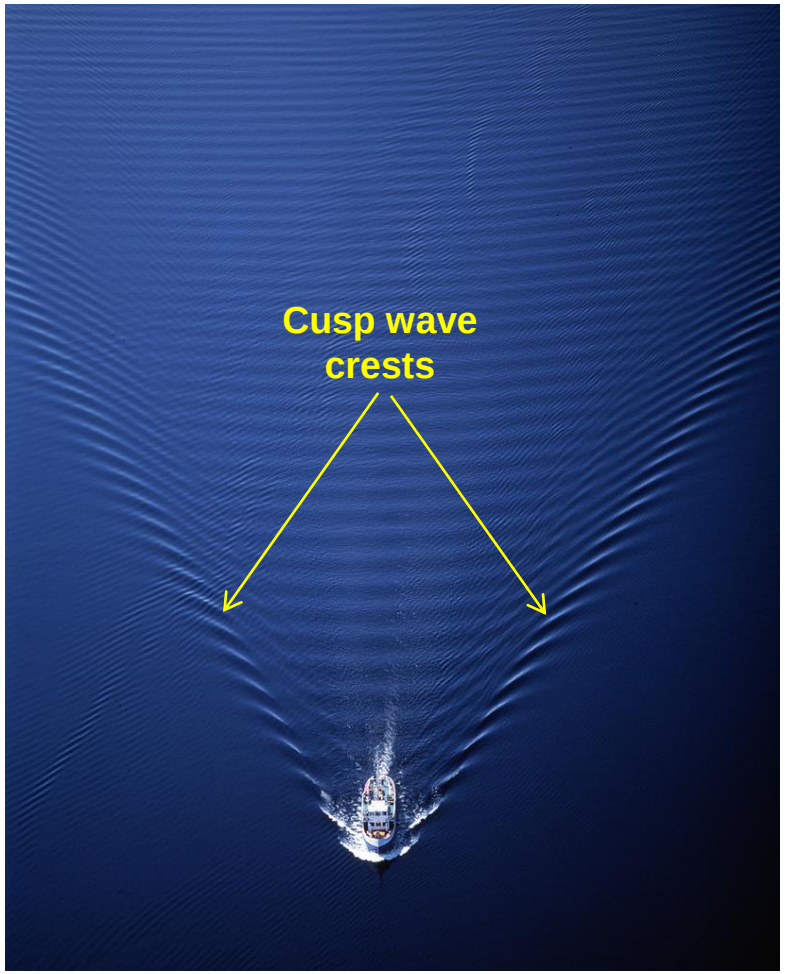
Quasi-Two-Dimensional Ocean



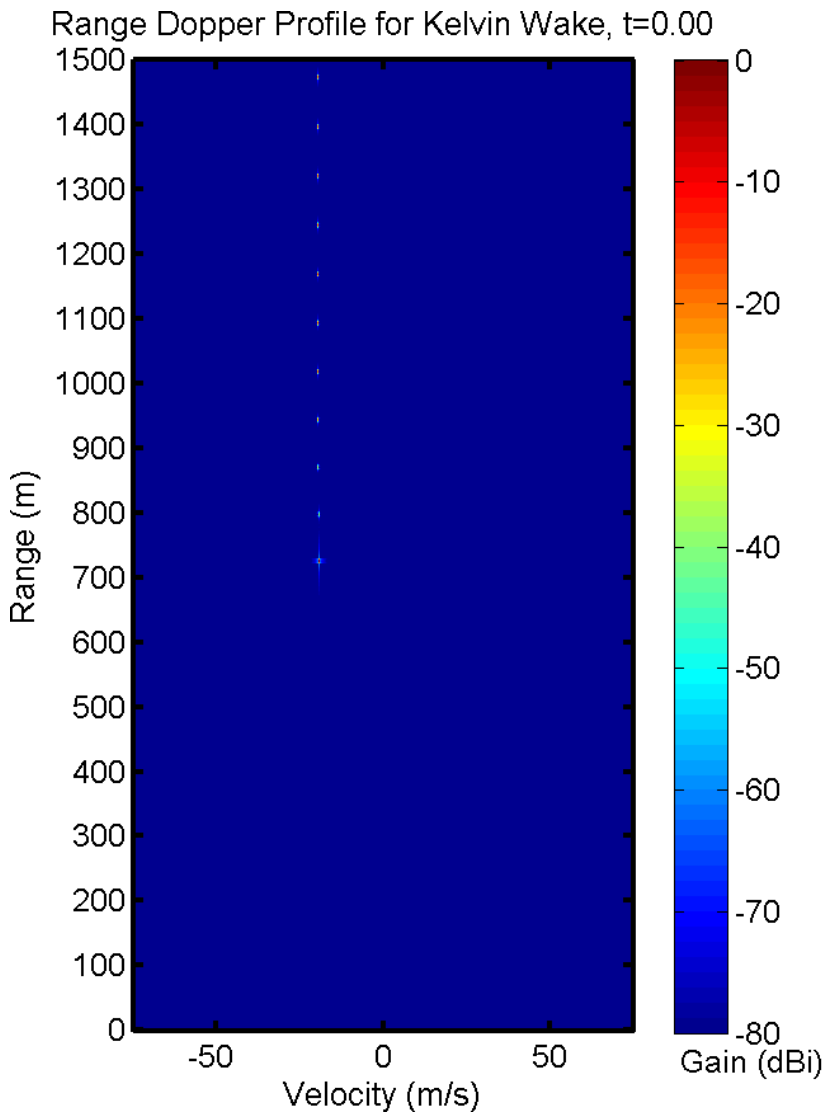
Boat and Wake Model

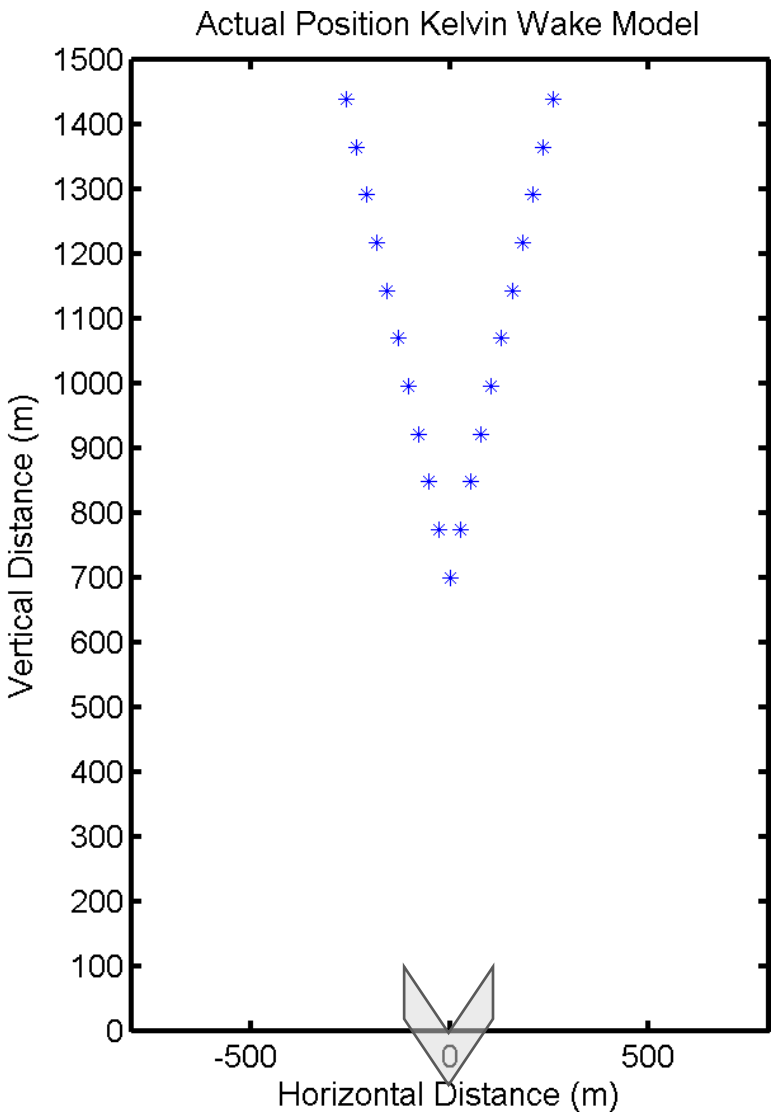
- **Boat modeled as a simple point target on the ocean**
- **Wake modeled as Kelvin wake**
  - **Cusp wave crests**
  - **Gives strongest radar returns**
  - **Amplitude decay**



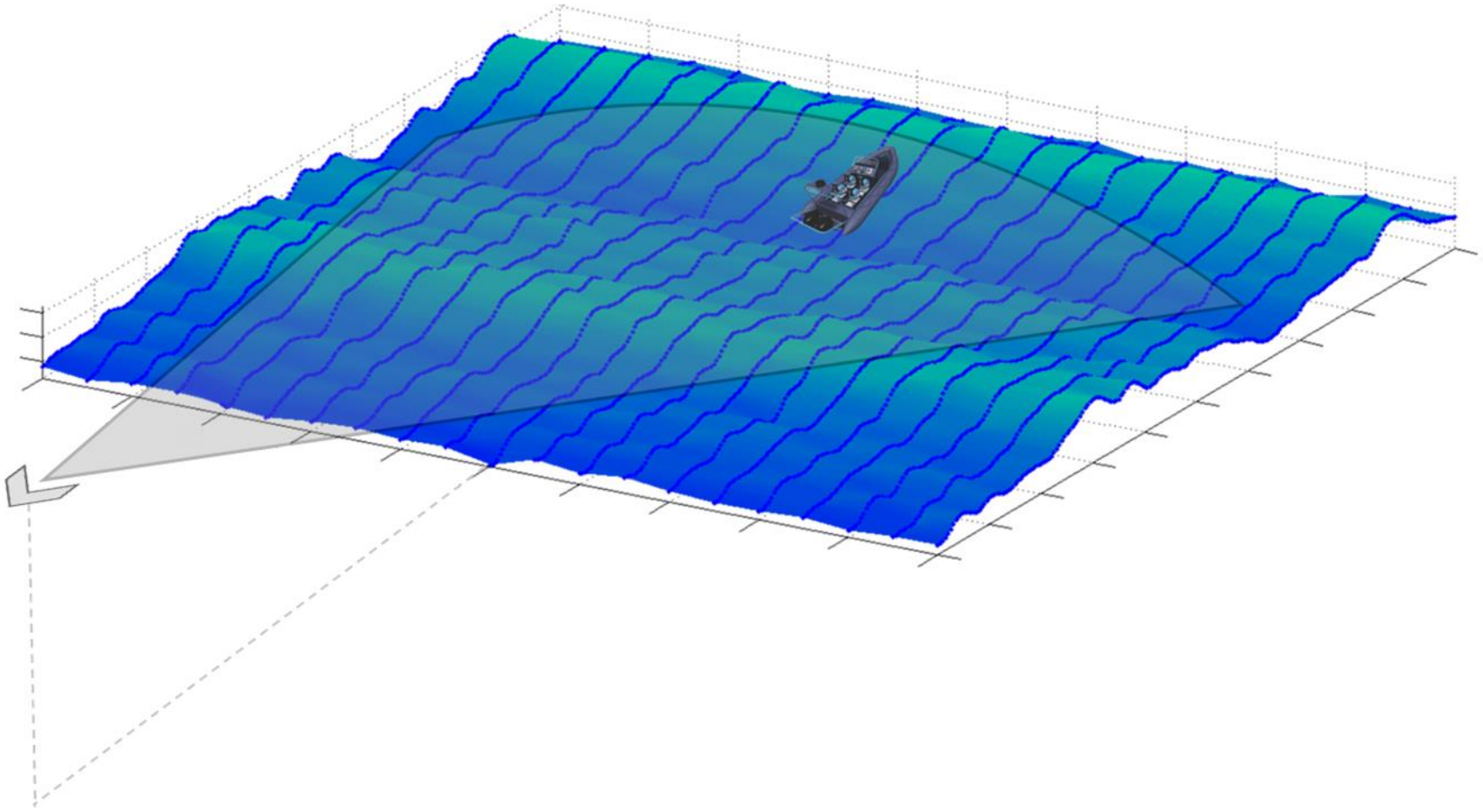
http://www.goshen.edu/physix/204/gco/2slit.php

Range-Doppler of Boat and Cusp Waves

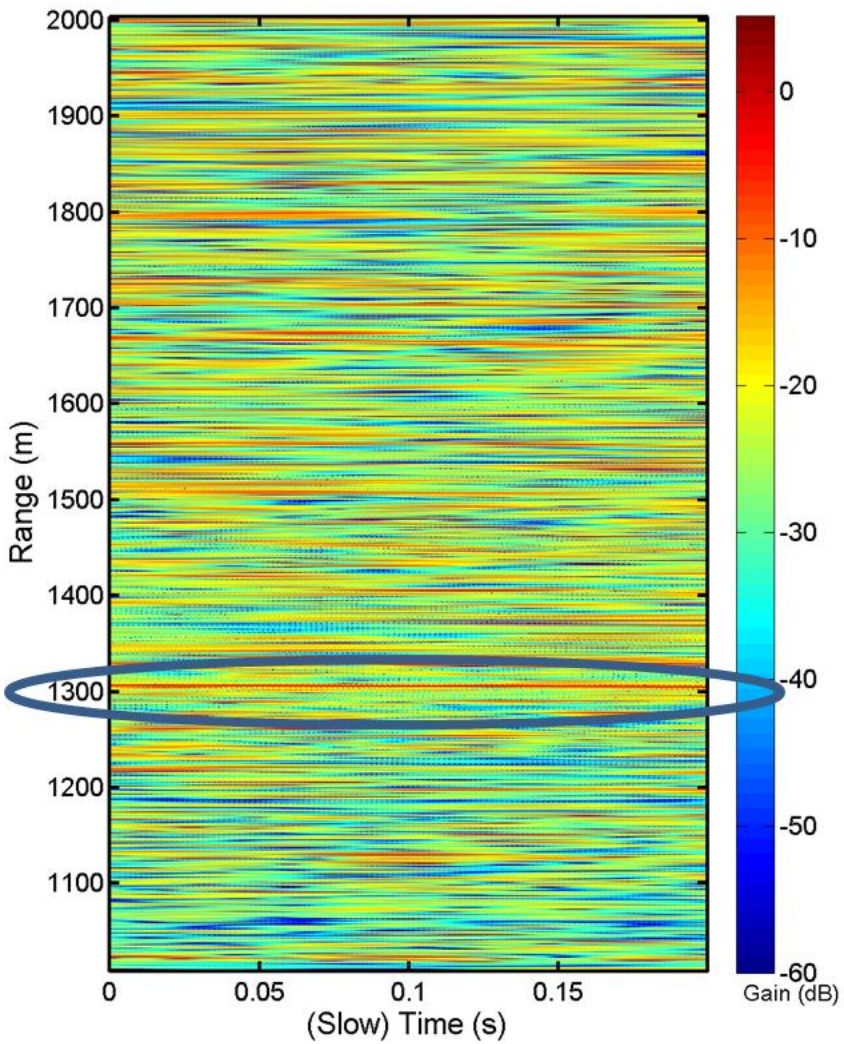


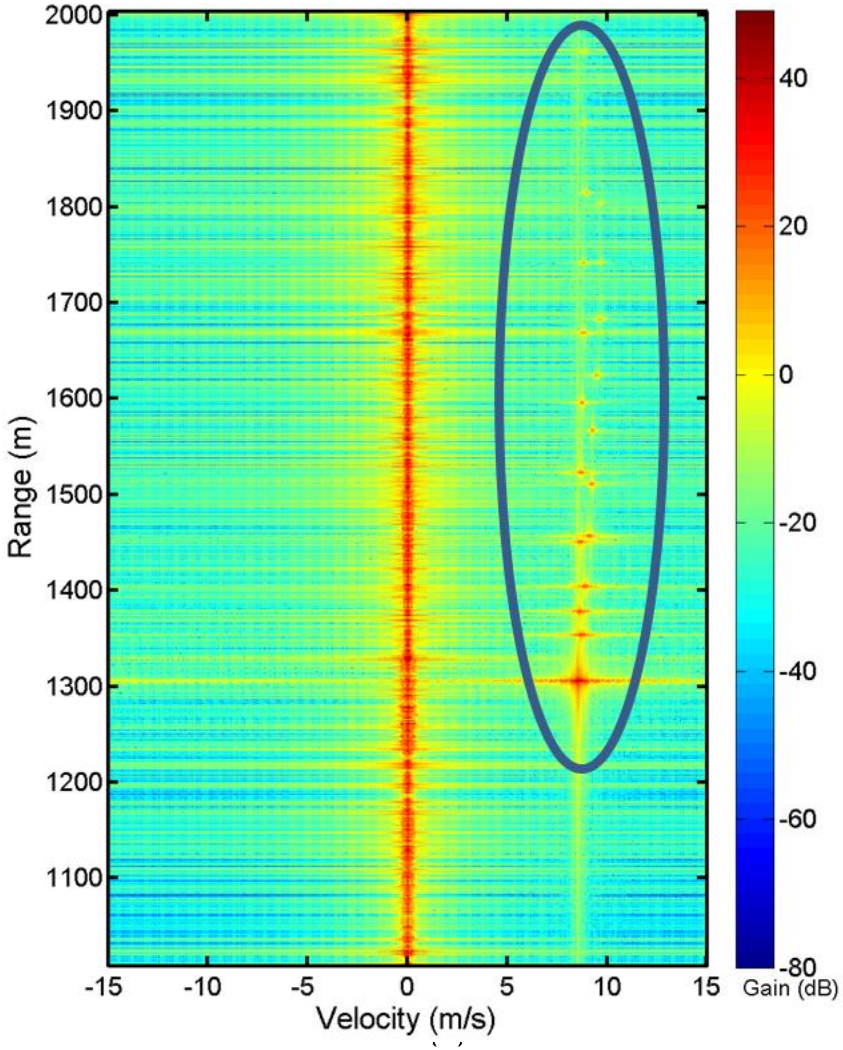


2-D Ocean Scattering Simulation



RTI and RDP for a Boat With Wake on the Ocean





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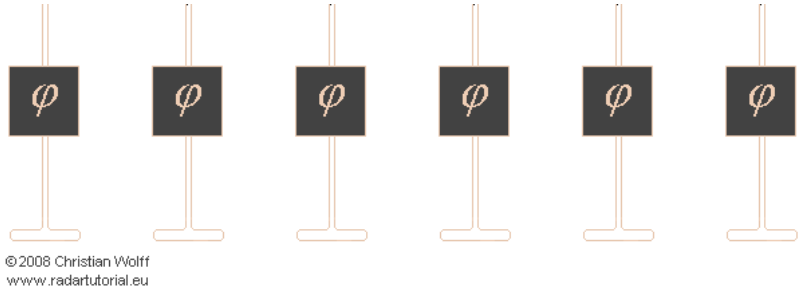
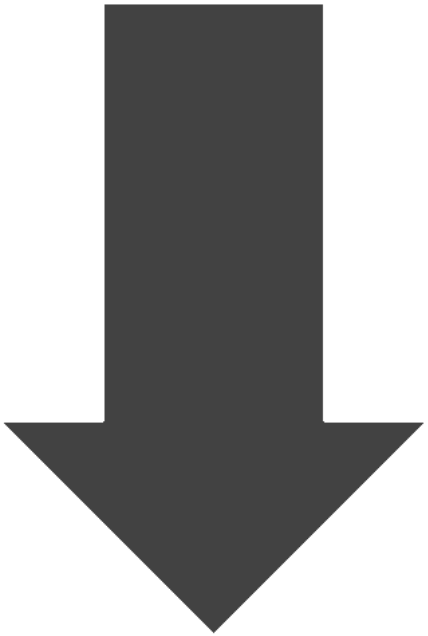
Background: Phased Array Radar

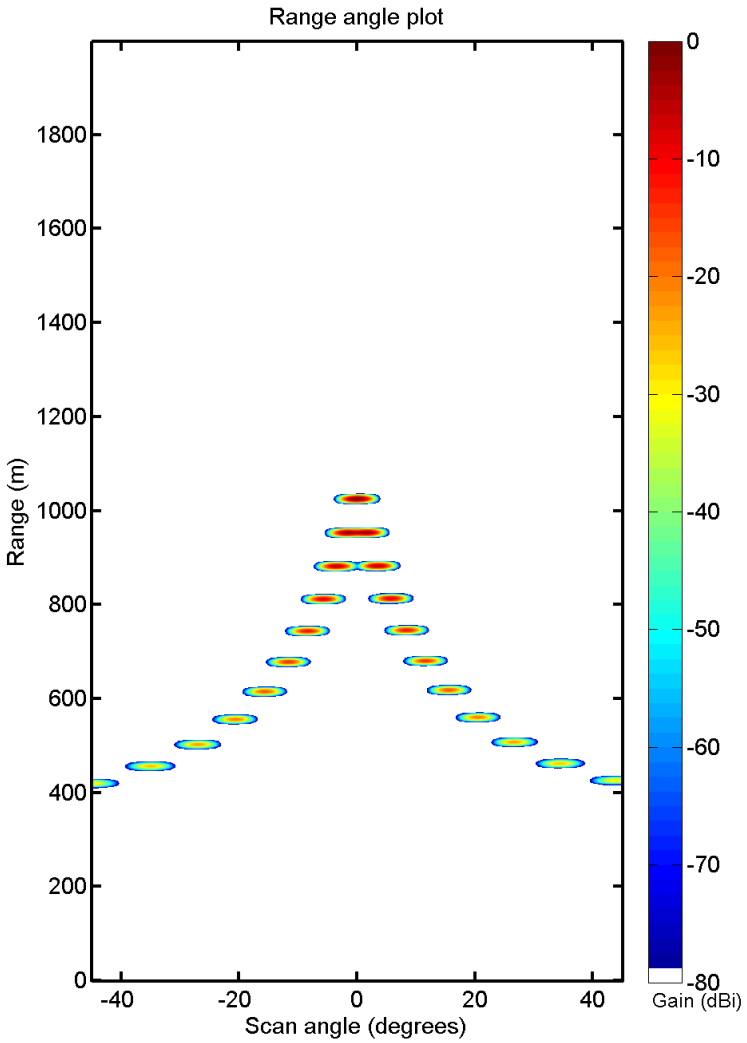
- **RF signals sent at *given scan angles* and return with time delay and Doppler shift**
- **Determine range, velocity, *and angle* information of boats and ocean waves**

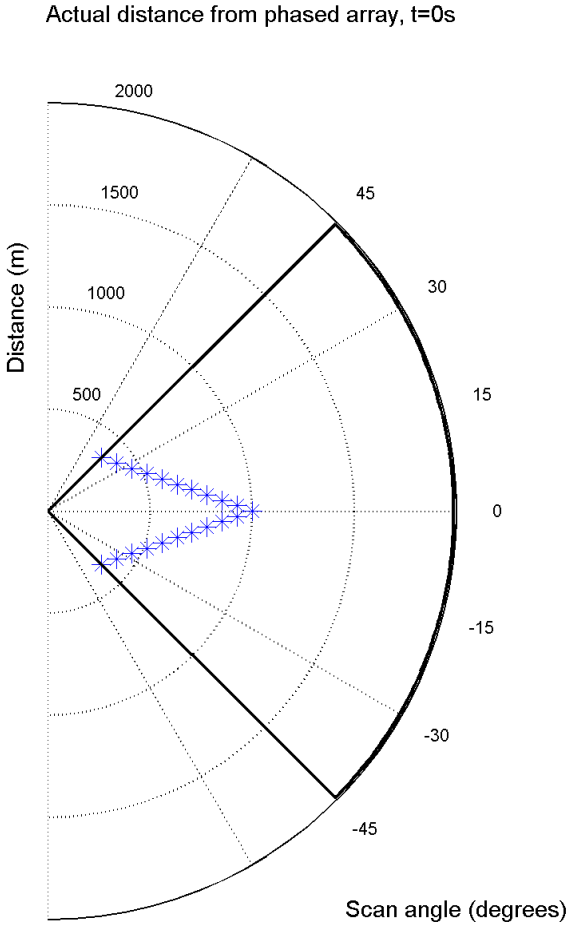




http://sitelife.aviationweek.com/ver1.0/Content/images/store/13/7/7d634054-f899-41a1-b7ca-552c8df19915.Full.jpg

Phased Array Range Intensity Profile





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Processing and Computation

Radar model contains trillions of computations for each second of data

Solution:

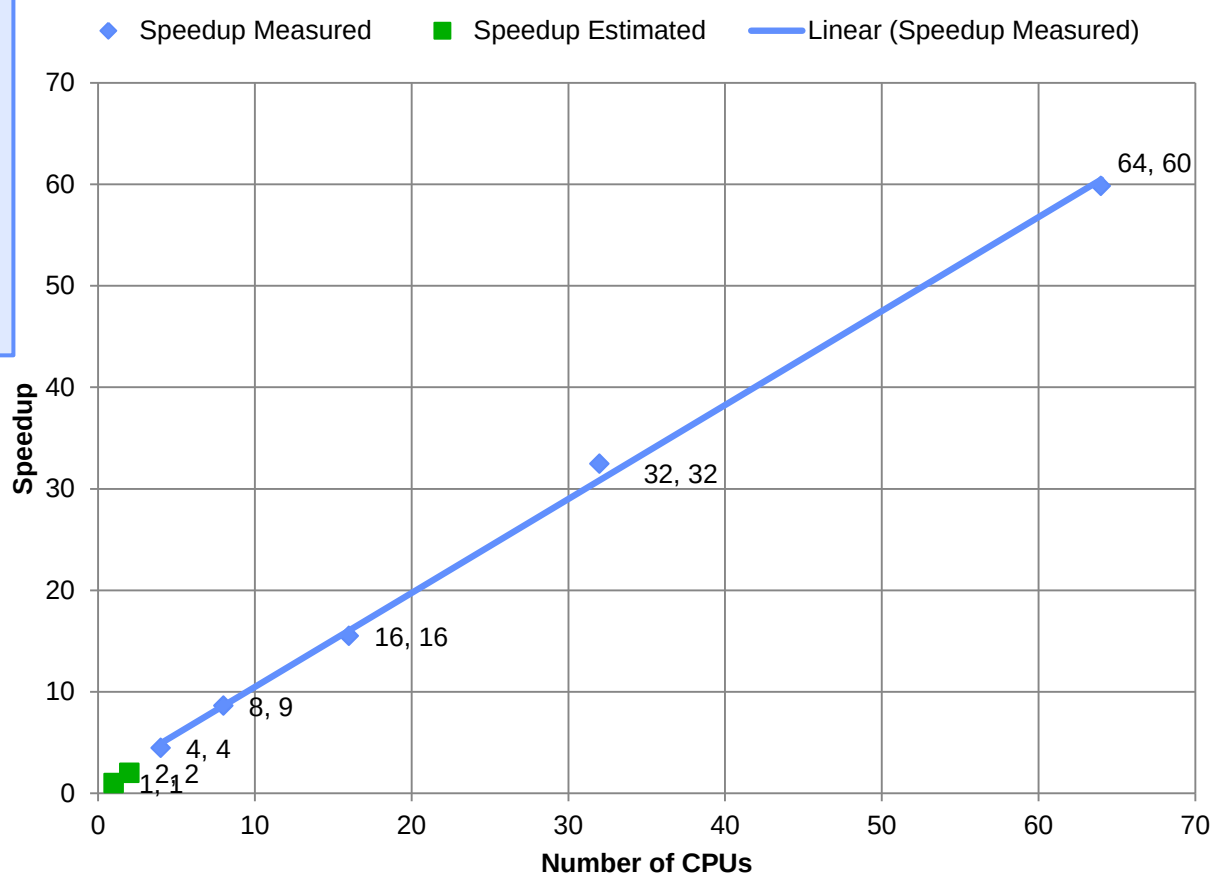
- **Algorithmic Efficiency**
  - **Simplifying equations (assumptions)**
  - **Use of more efficient functions or processes**
- **Parallelization**
  - **pMATLAB**
  - **Multiple cores**
  - **LLGrid**

http://en.wikipedia.org/wiki/File:IBM_Blue_Gene_P_supercomputer.jpg

```
Saving Ocean...
Ocean Saved.
Total Time: 99.45
Ocean Done.
Elapsed time is 99.607038 seconds.
Starting Range Time Intensity Processing...
03-Oct-2012 15:51:46
Loading Ocean Data Complete...
Node job size: 673
Saving Data...
Data Saved.
RTIP Done.
Elapsed time is 8980.005715 seconds.
Loading RTI Data...
RTI Data Loaded.
```

Parallelization

- **Algorithm highly parallelizable, Speedups of up to 60x**
- **Scales to compute clusters e.g. LLGrid**



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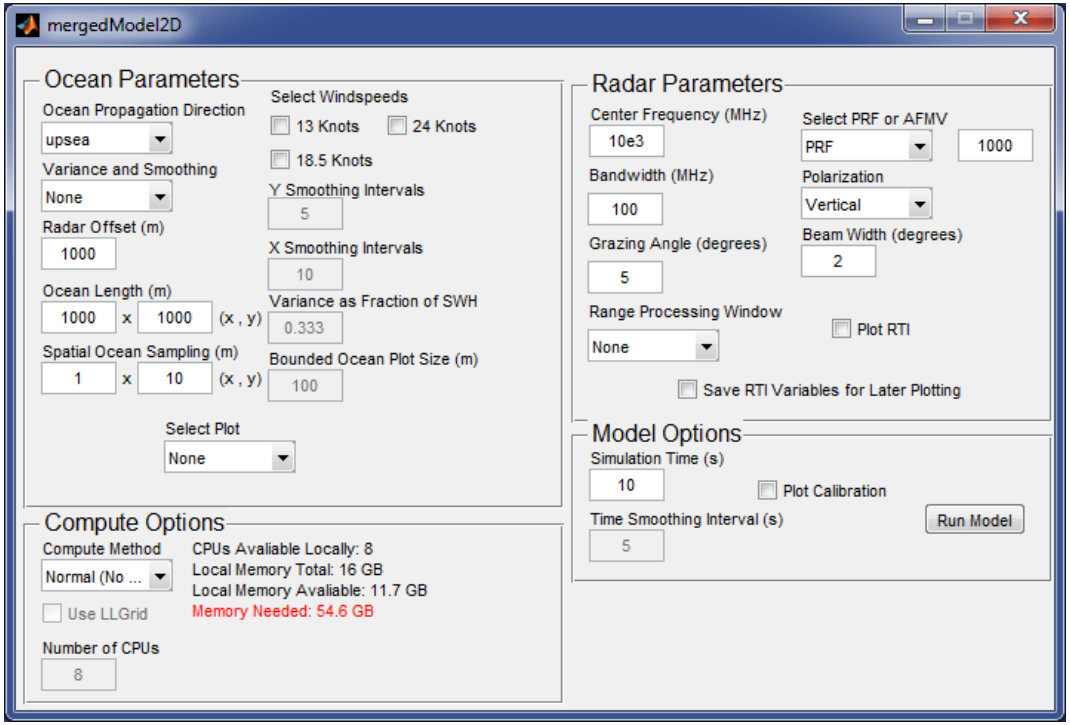
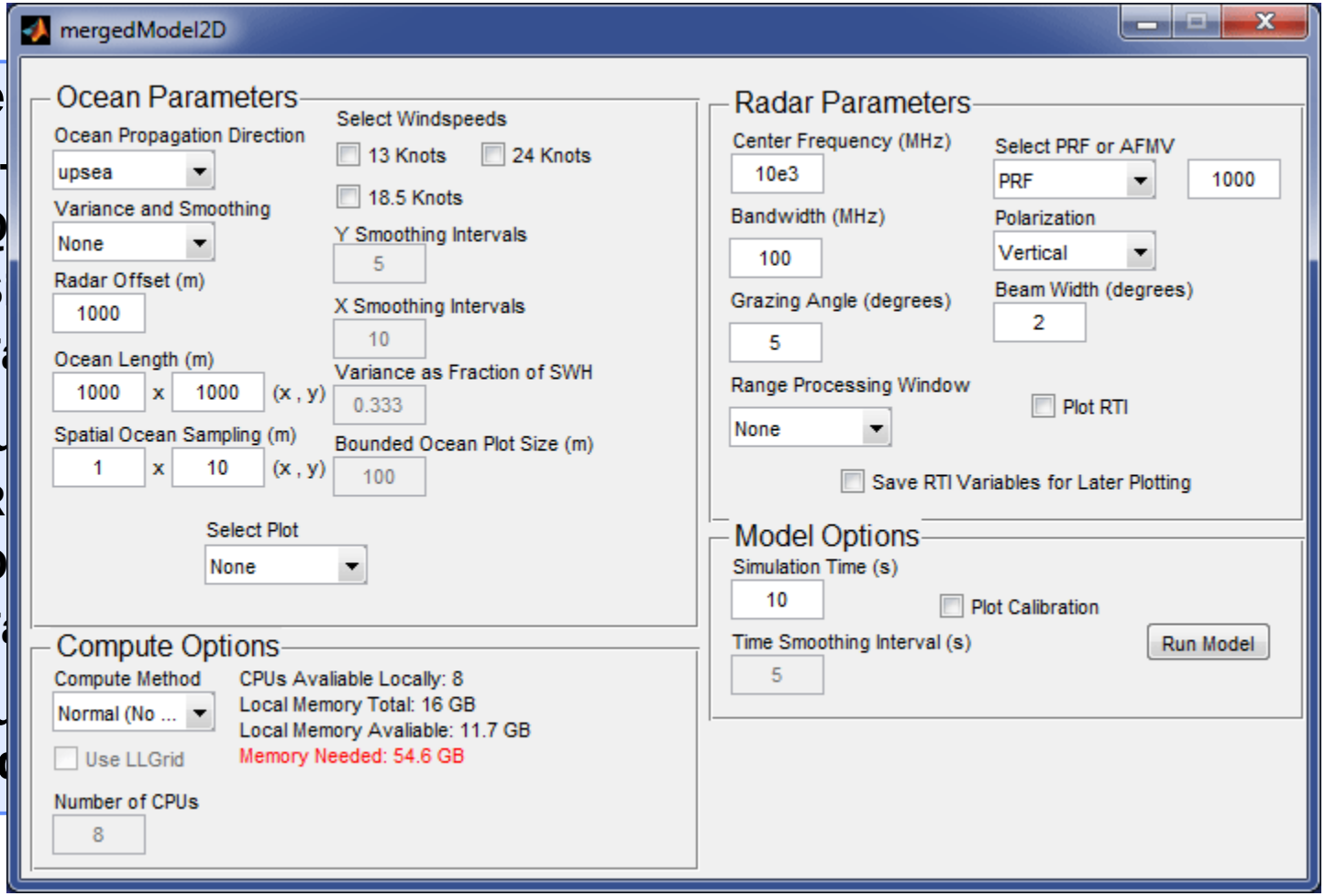
Graphical User Interface

- **User selected model**
  - **1-D ocean**
  - **Quasi-2-D ocean**
  - **Single antenna radar**
  - **Target generation**
- **Input parameters**
  - **Radar**
  - **Ocean**
  - **Target & wake**
- **Input parameter validation**



Graphical User Interface

- Use
  - 1-
  - Q
  - S
  - Ta
- Inpu
  - R
  - O
  - Ta
- Inpu
  valid



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Future Work

- **Improve Doppler estimation**
- **Implement phased array model**
- **Fluctuating target cross section (Swerling model)**
- **True 2-D ocean model**
- **Graphics core parallel processing**

Acknowledgements

- **Thank you to everyone that has helped our team progress with this project.**
  - **Dennis Blejer, Lincoln Laboratory Advisor**
  - **Edward Clancy, WPI Project Advisor**
  - **Emily Anesta & Seth Hunter, LL-WPI Coordinators**
  - **Jennifer Watson, Lincoln Laboratory Assistant Group Leader**
  - **Loretta Wesley, LL Secretary**
  - **Byun Chansup, LL Grid Support**
  - **Scott Ehrlich, Computer Hardware and IT Support**

Questions?

- Introduction
- 1-D Ocean Scattering Simulation
  - Radar Processing
  - 1-D Ocean Model
  - Radar scattering
- 2-D Ocean Scattering Simulation
  - Quasi-2-D Ocean Model
  - Boat Wake Model
  - Radar scattering
- Phased Array Radar Simulation
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