Mine Impact Burial Prediction Experimental (MIBEX)

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Modeling Mine Impact Burial Depth

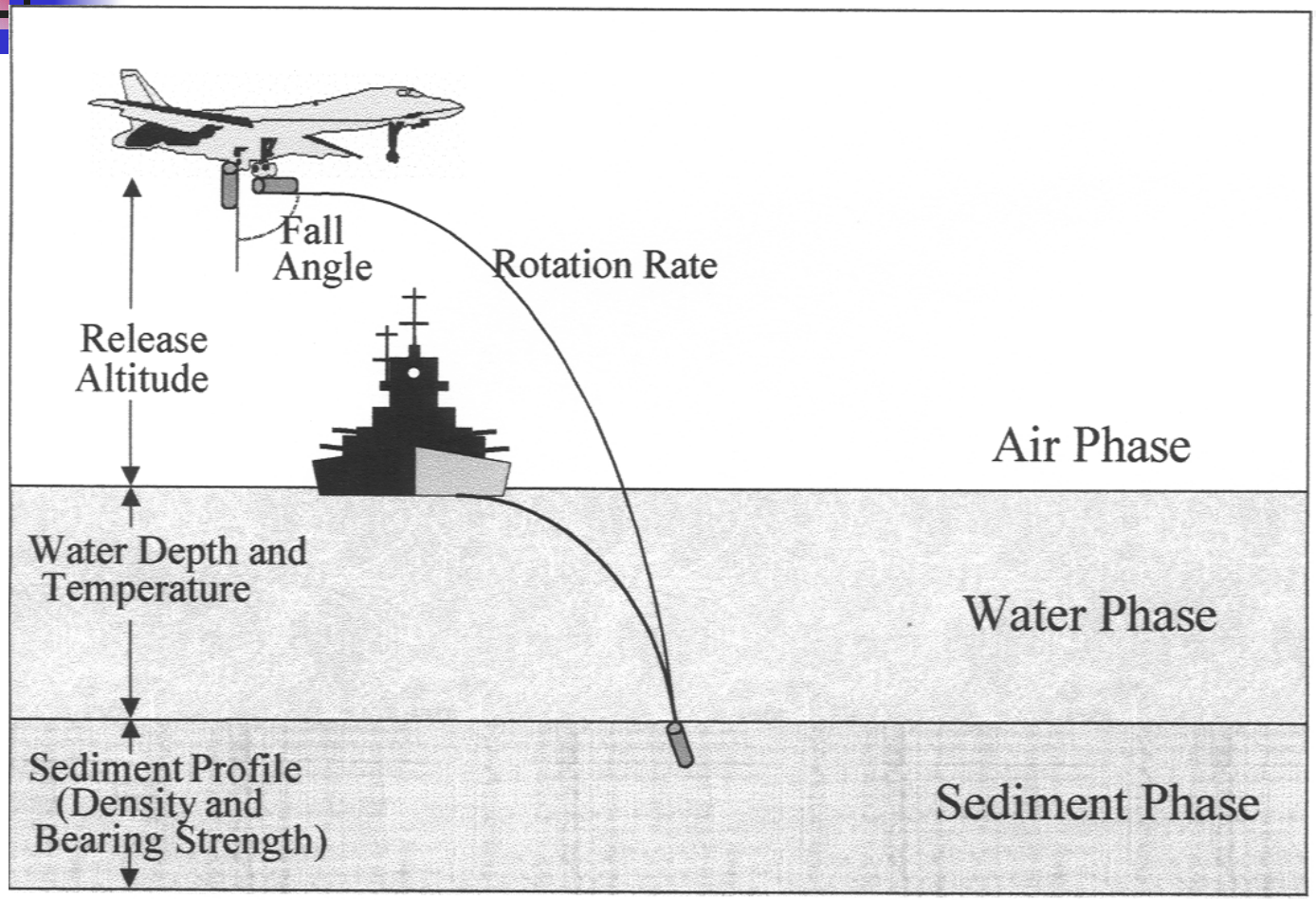
- Modeling is first step in planning mine sweeping mission
- Determining depth of burial, and height, area and volume protruding upon impact is first step in modeling the mine's situation

Purpose of the Study

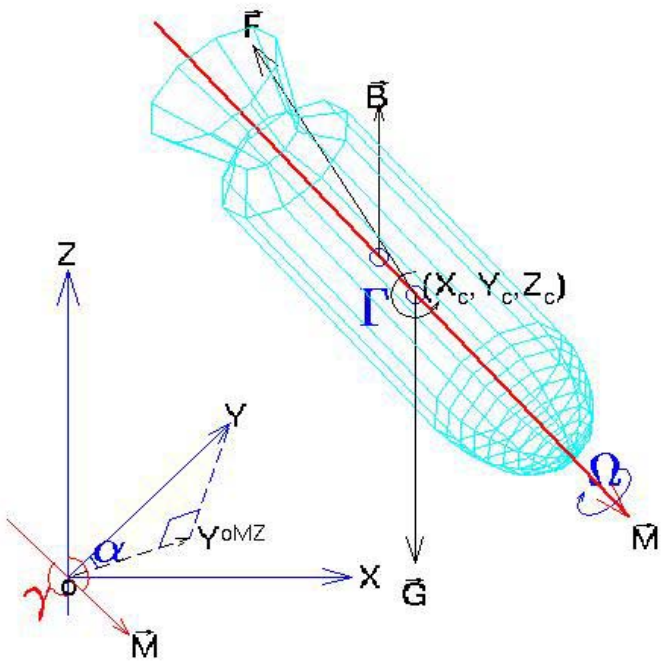
- To obtain simultaneous sediment input parameters while the impact experiment was being conducted.

- To validate the IMPACT25/28 Mine Burial Prediction Model with Real-Time Synchronous Mine Impact Burial and Environmental Data

Typical Mine Insertion Profile



Six Parameters for Determination of Mine Position



Six Parameters for Determination of Mine Position

- Coordinate of Center of Gravity (x_c y_c z_c)
- Direction Angles with Cartesian Coordinate

Development of Navy's Impact Burial Prediction Model (IBPM)

- Arnone & Bowen Model (1980) – Without Rotation
- Modified Impact Burial Model (Satkowiak, 1987-88) – With Rotation
- IMPACT25/28 (Hurst, 1992) –
- Environmental Impact on IMPACT25 (Chu et al., 1999, 2000, Taber 1999, Smith 2000)

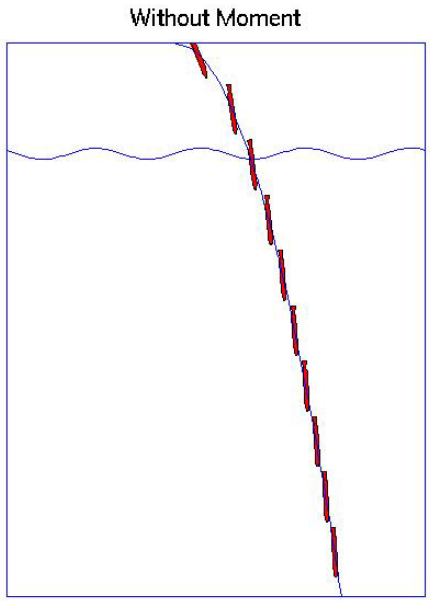
Basic Assumption in theIMPACT25/28

2D model with artificial rotation

rate (user input).

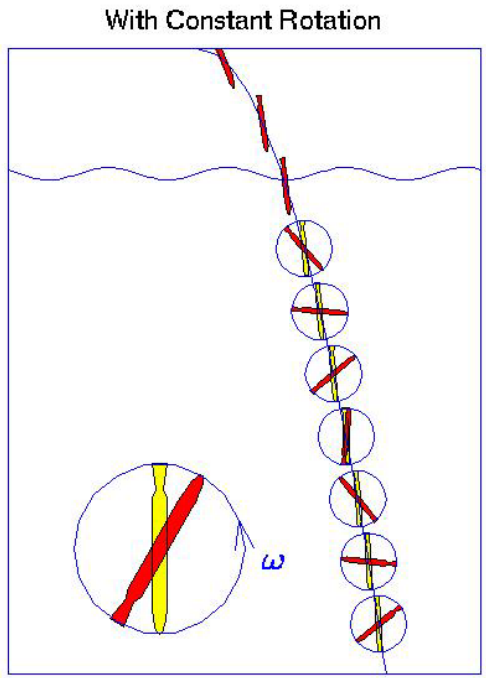
Current IBPM Without Rotation

- Arnone & Bowen Model (1980)
- Mine is dynamically treated as a point

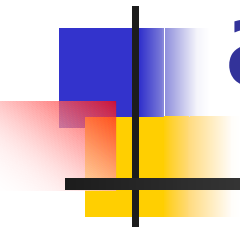


Current IBPM With Artificial Rotation

- Satkowiak (1987-88) – With Artificial Rotation



Is this mine uniformity assumption realistic?



No, both cases are not realistic.

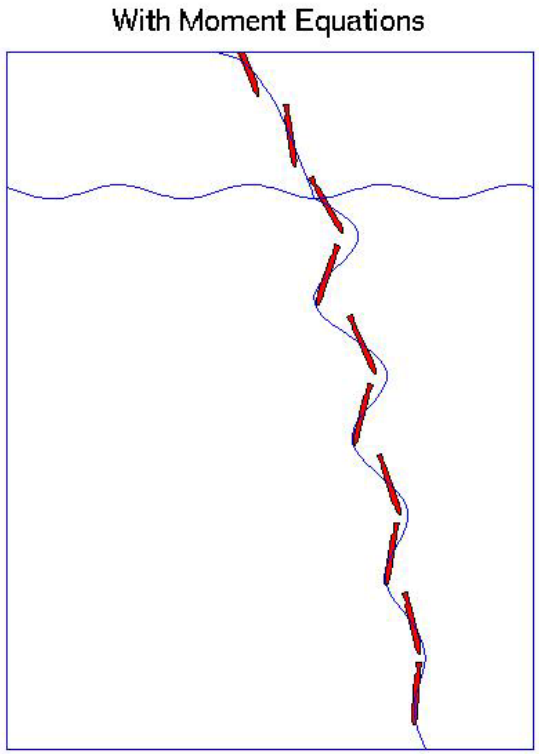
What is the Problem ?

Mass is not uniformly distributed inside mine. The center of gravity does not coincides with the center of buoyancy.

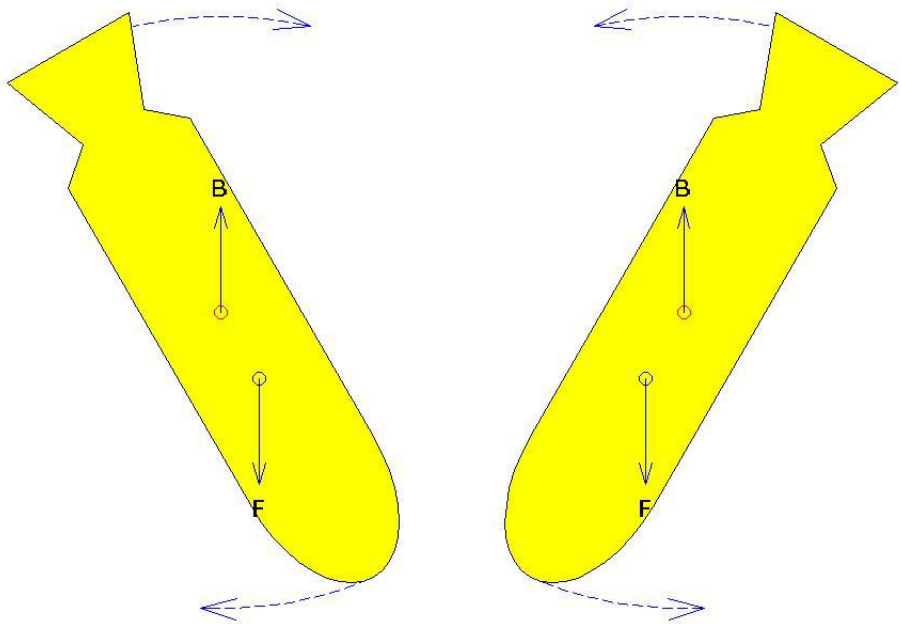
Problems of Current IBPM-Motion of Gravitational Center

- Three Parameters (x_G y_G z_G)
- Momentum Balance Only
  - $m\, d\mathbf{V}/dt = \Sigma \mathbf{F} + \mathbf{W}$
- No Helicoidal Motion

Spiral-Type Motion of Mine



Spiral-type motion of mine



Hydrodynamic Theory

- Solid Body Falling Through Fluid Should Obey 2 Physical Principles:

1. Momentum Balance

$$\int (dV^* / dt^*) dm^* = W^* + F_b^* + F_d^*$$

2. Moment of Momentum Balance

$$\int [r^* \times (dV^* / dt^*)] dm^* = M^*$$

* Denotes dimensional variables

V^* → Velocity

W^* → gravity

F_b^* → buoyancy force

F_d^* → drag force

M^* → resultant moment

Sensitivity Studies on IMPACT25/28

- Chu et al. (1999), Taber (1999)
- Environmental Sensitivity Study
- Chu et al. (2000), Smith (2000)
- Mine Impact Burial Experiment (MIBEX) at Monterey Bay

Environmental Sensitivity Study (Chu et al. 1999)

- Hydrodynamics and sedimentation are key factors to affect the mine impact burial.

IBPM Model Input Parameters

- Mine Parameters
  - Mass in Air
  - Mass in Water
  - Length
  - Diameter
  - Maximum diameter
  - CM displacement
- Altitude when released
- Angle when released
- Initial horizontal and vertical velocity
- Initial Rotation rate
- Water depth
- Water Temperature
- Sediment Parameters
  - Density
  - Shear Strength

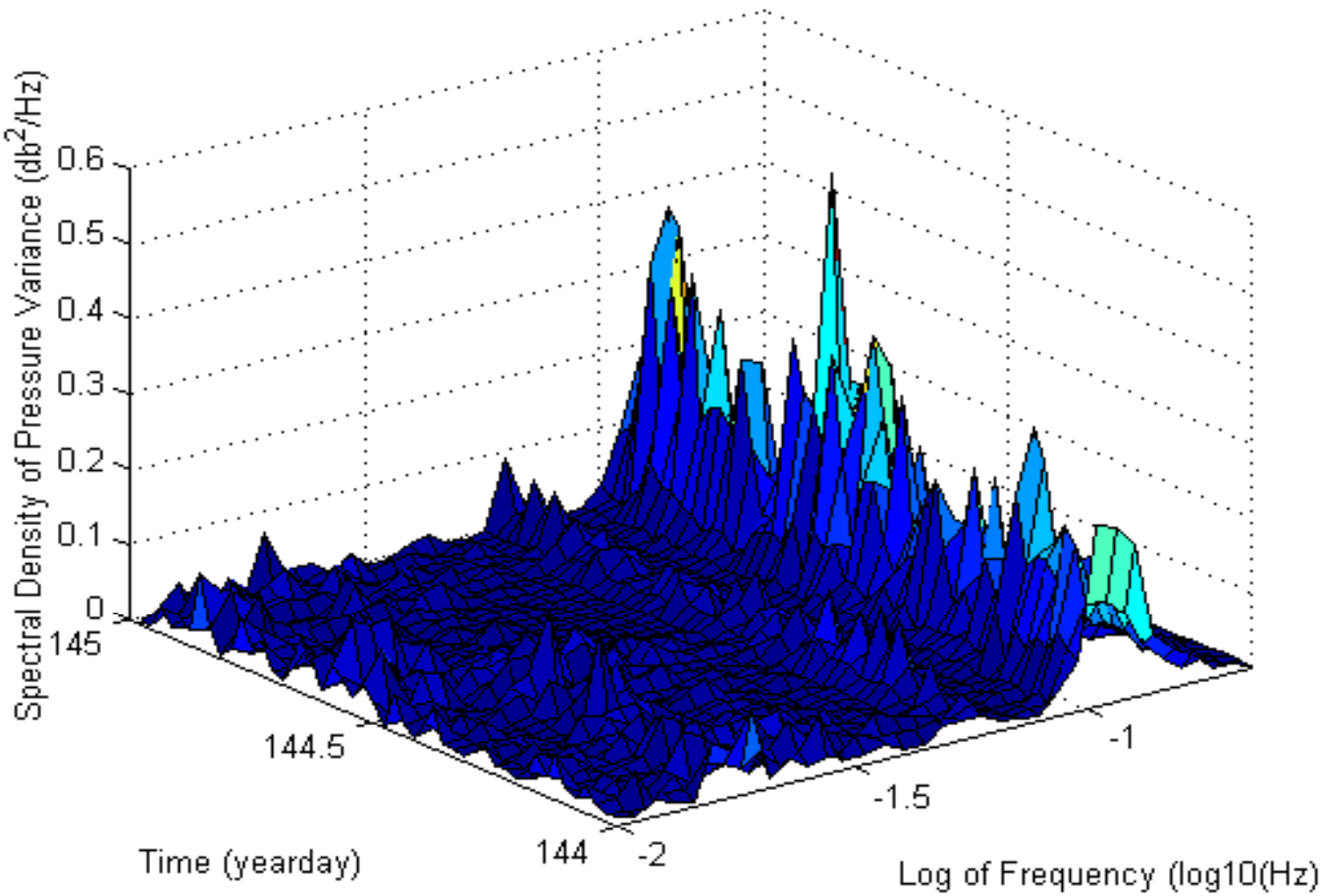
MIBEX at Monterey Bay (May 3, 2000)

- Proposal was to conduct several controlled “mine” drops in real world environment while simultaneously gathering sediment data and oceanographic data to determine effect on code output.
- Synchronized environmental and mine burial data

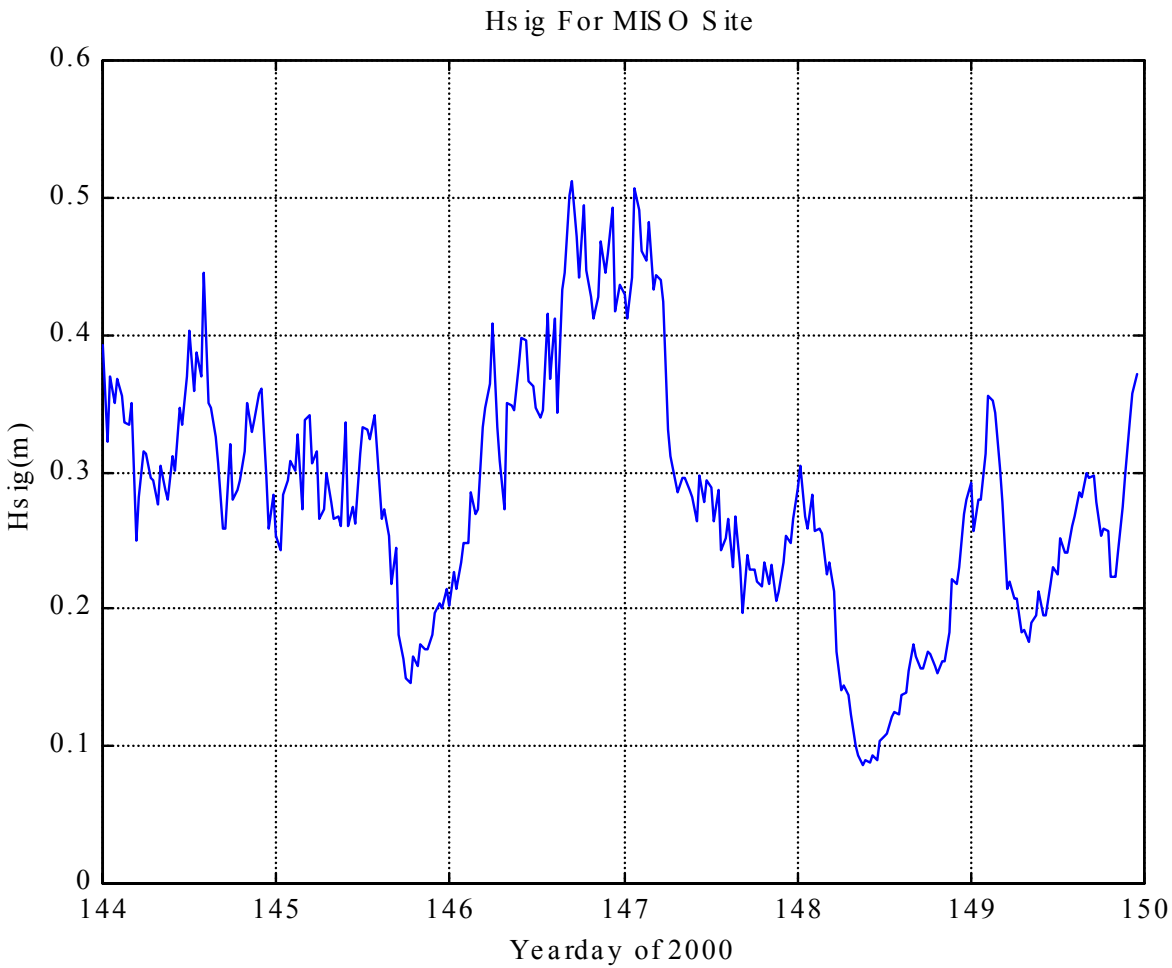
Environment

- Experiment was conducted off Del Monte Beach in Monterey in the vicinity of the Monterey Inner Shelf Observatory (MISO) which is a component of the Rapid environmental Assessment Laboratory (REAL)

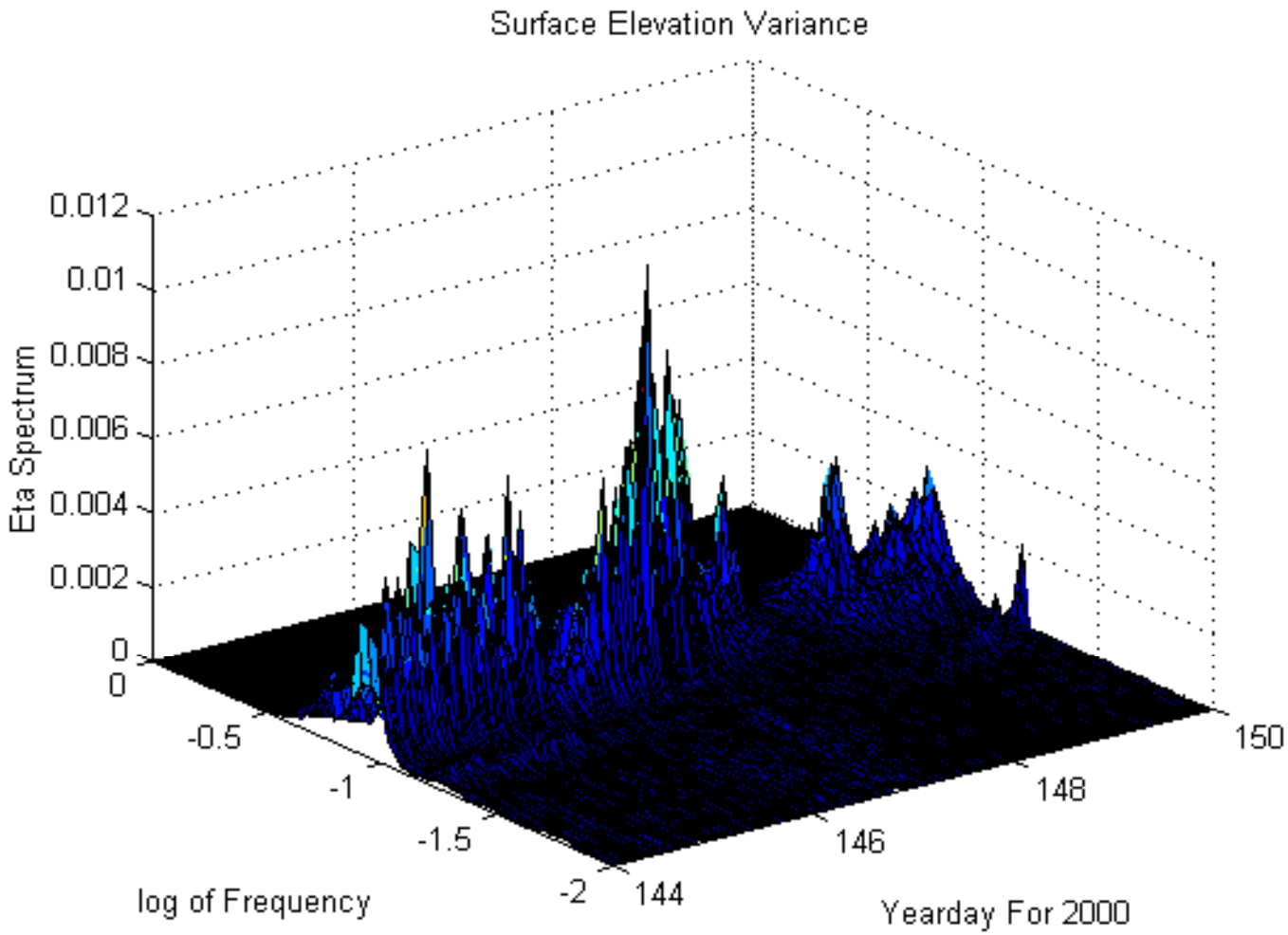
Wave Turbulence



Temporal Variability of H_{sig}



Surface Elevation Variance



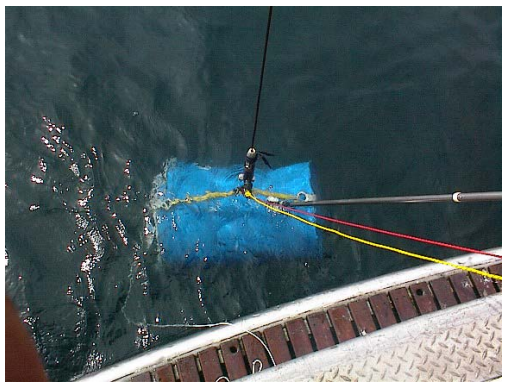
R/V John Martin

Sequence of Events

The “Mine”

The “Mine” and Gravity Cores

Loading onto the John Martin



Retrieving the Mine

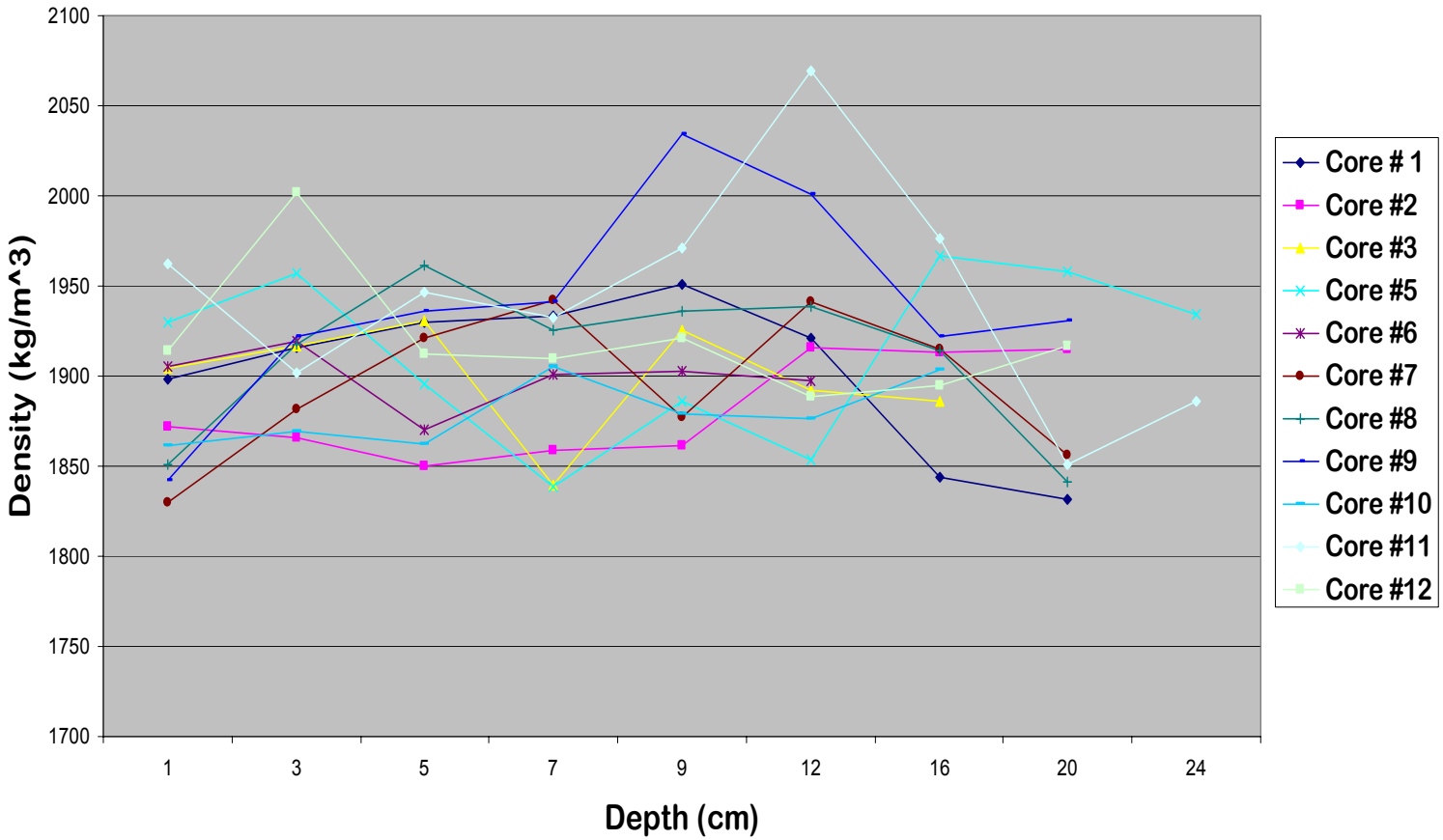
In the water

Taking measurements

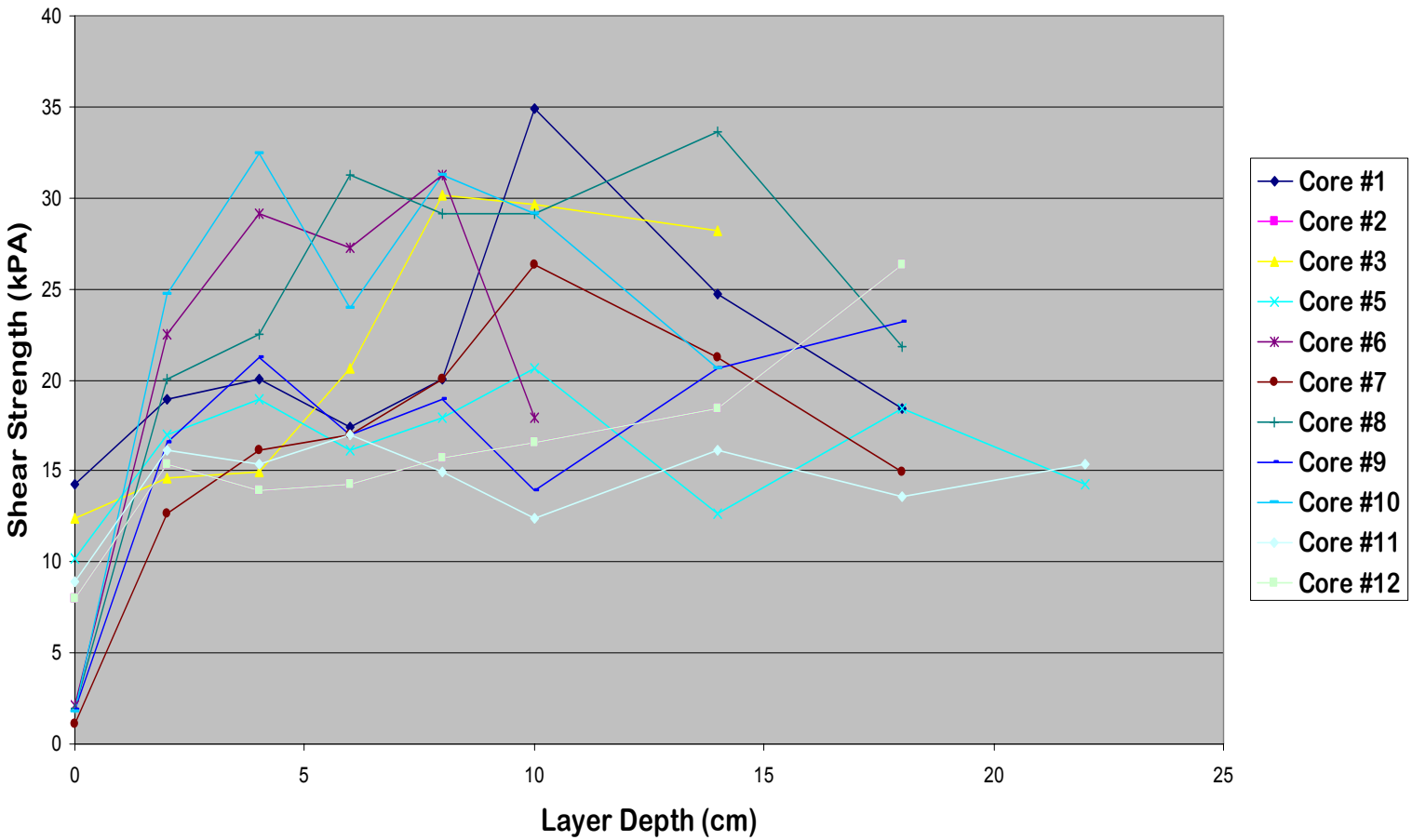
Sequence of Events

- Underway:
  - Conduct drops
  - Take gravity cores
  - Gather MIBEX and REAL Data
  - Analyze Gravity Cores
  - Run Model

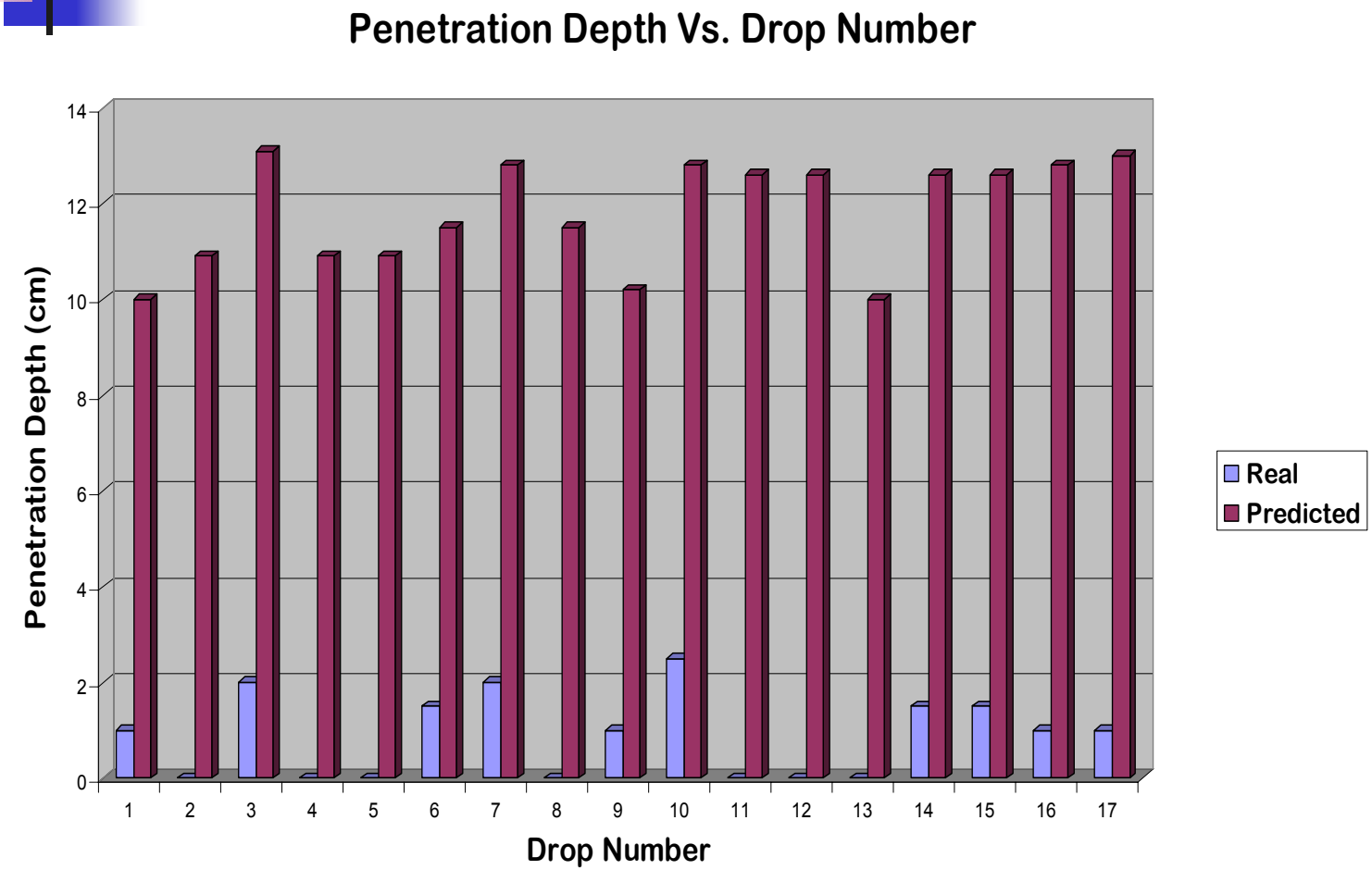
Density


Sediment Density Vs. Depth
Density (kg/m^3)
2100
2050
2000
1950
1900
1850
1800
1750
1700
1
3
5
7
9
12
16
20
24
Depth (cm)
Core # 1
Core #2
Core #3
Core #5
Core #6
Core #7
Core #8
Core #9
Core #10
Core #11
Core #12

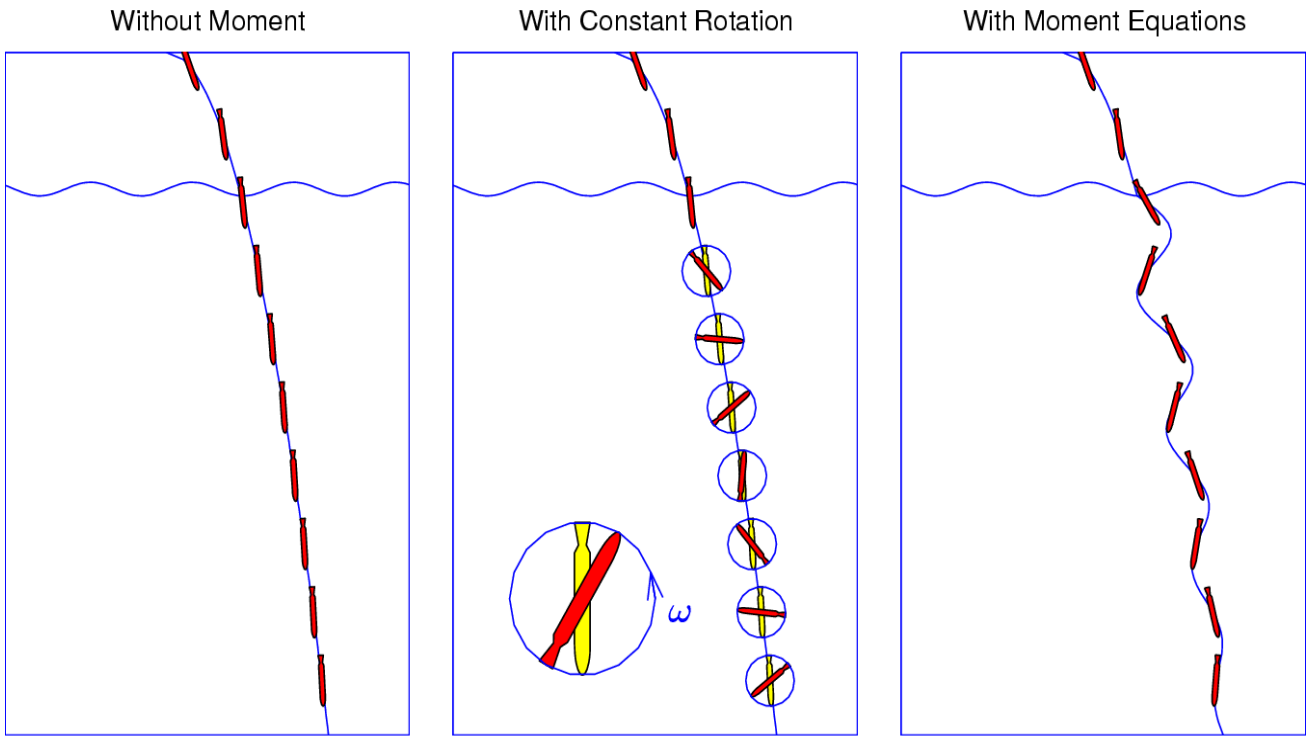
Shear Strength



Results


Penetration Depth Vs. Drop Number
Penetration Depth (cm)
0
2
4
6
8
10
12
14
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Drop Number
Real
Predicted

Difference Between Three and Six Parameter Mine Models



/s4/raid0/paper/project/mine.dir/mine 24–Aug–2000

Conclusions

- The IMPACT25 over predicts penetration depth by an order of magnitude
- Overestimation is due to inadequate modeling of hydrodynamic effects in the water column
- This causes slowing of the mine as it travels through the medium with spiral-type motion.

Recommendations

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- We should get rid of the uniformity assumption for mines and build up a correct version (6 parameters) for IBPM.