Development and Verification of IMPACT35

Peter Chu, C. Fan, and NPS Students (U.S. Naval Officers)

Naval Postgraduate School

Peter Fleischer, Ron Betsch

Naval Oceanographic Office

Phil Valent, Paul Elmore, Andre Abelev, Mike Richardson

Naval Research Lab

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References

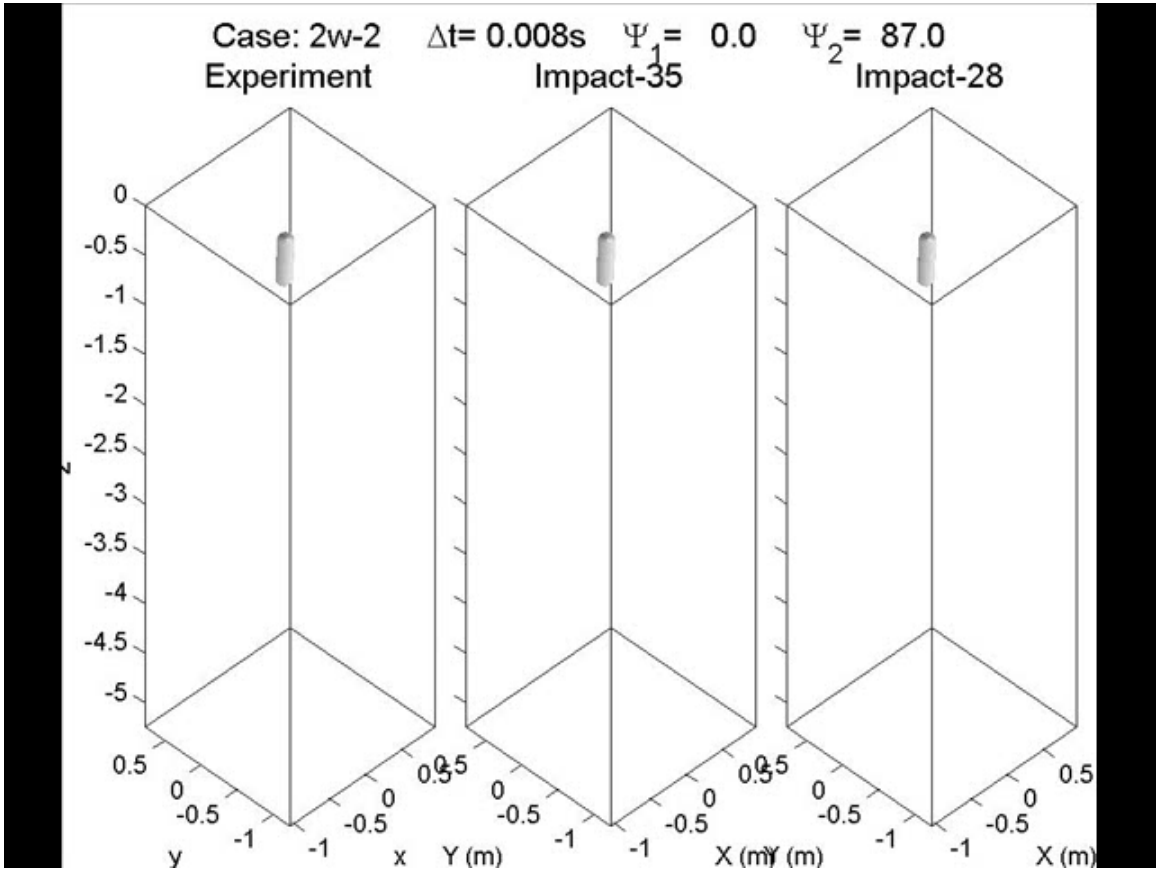
- Chu, P.C., C.W. Fan, A. D. Evans, and A. Gilles, 2004: Triple coordinate transforms for prediction of falling cylinder through the water column. Journal of Applied Mechanics, 71, 292-298.

- Chu, P.C., A. Gilles, and C.W. Fan, 2005: Experiment of falling cylinder through the water column. Experimental and Thermal Fluid Sciences, in press.

- Chu, P.C., and C.W. Fan, 2005: Prediction of falling cylinder through air-water-sediment columns. Journal of Applied Fluid Mechanics, in press.

- Chu, P.C., and C.W. Fan, 2005: Mine impact burial prediction. Journal of Fluids Engineering, in revision.

Comparison Between IMPACT28 and IMPACT35 Using Carderock Data



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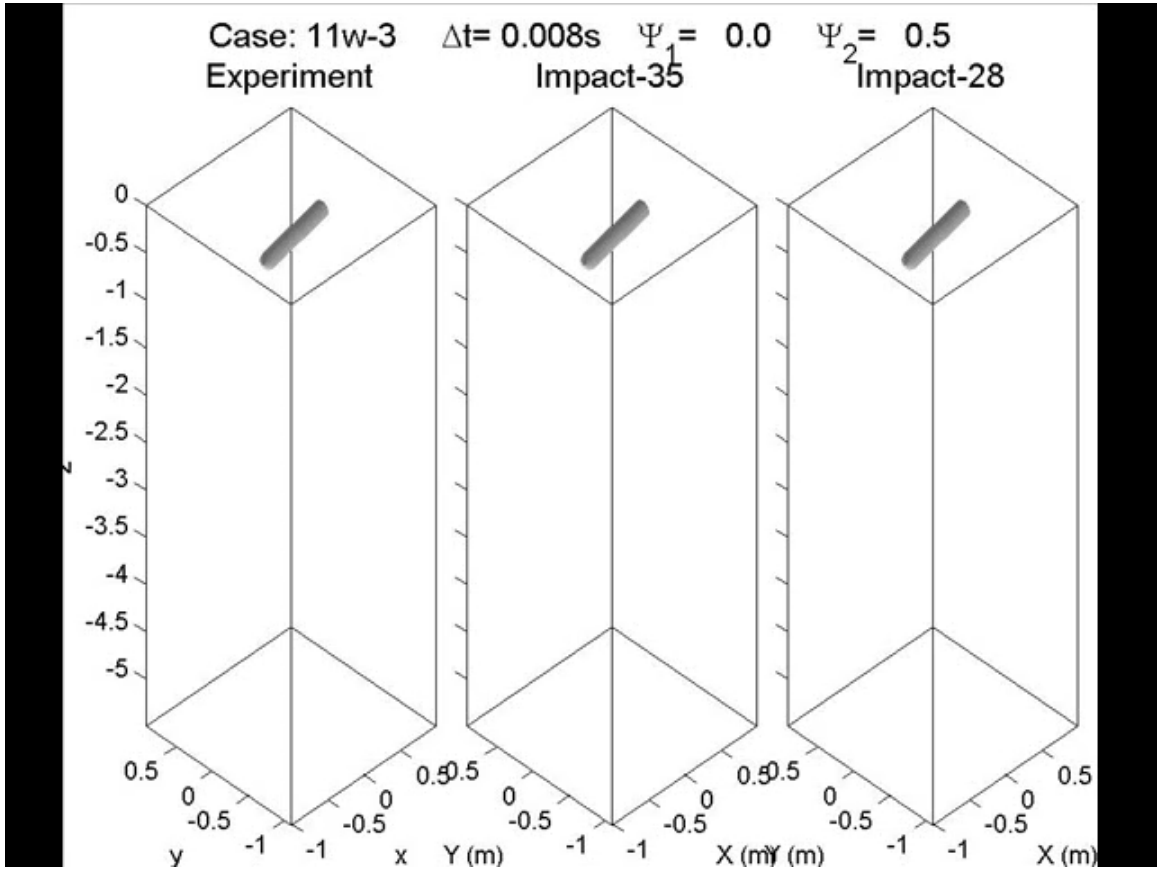

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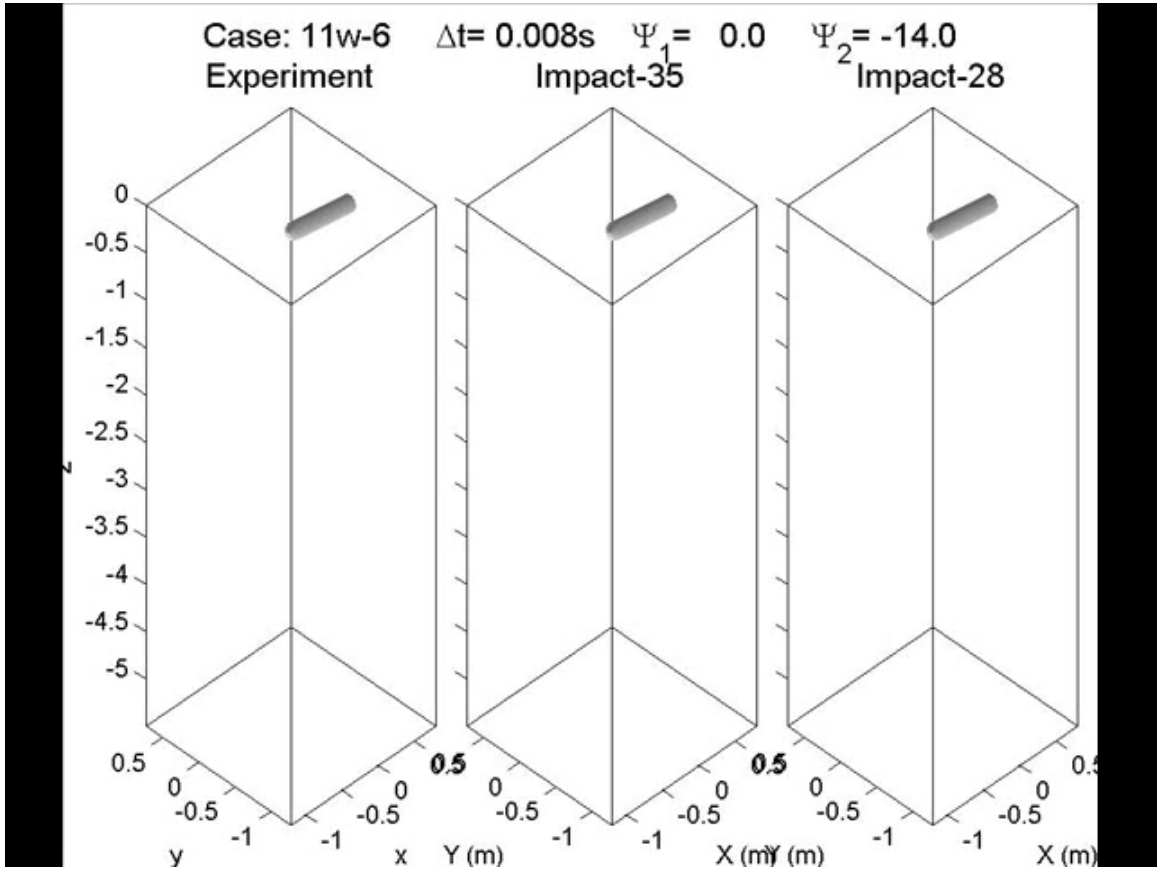

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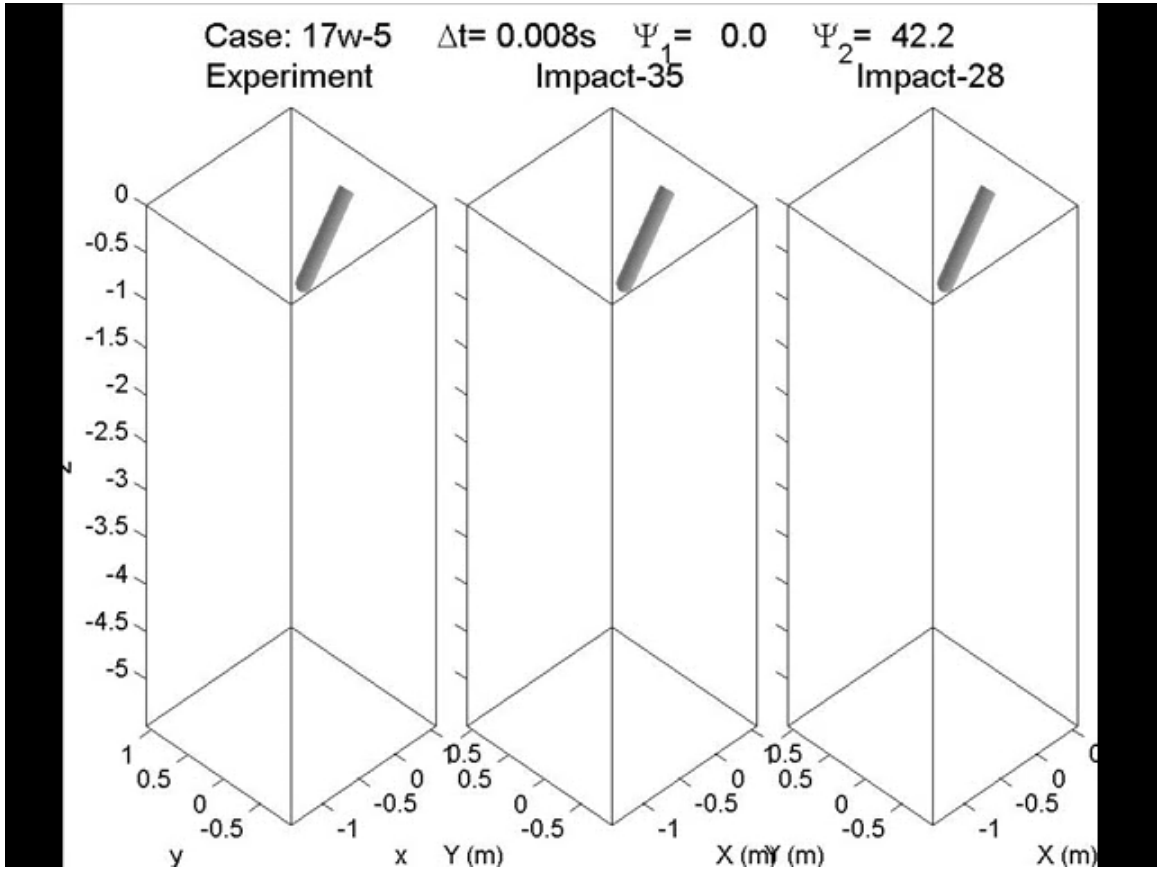


Major Features of IMPACT35

(1) Three-Dimensional, Full Physics

(2) Triple Coordinate Systems

E-Coordinate: Momentum Equations

M-Coordinate: Moment of Momentum Equations

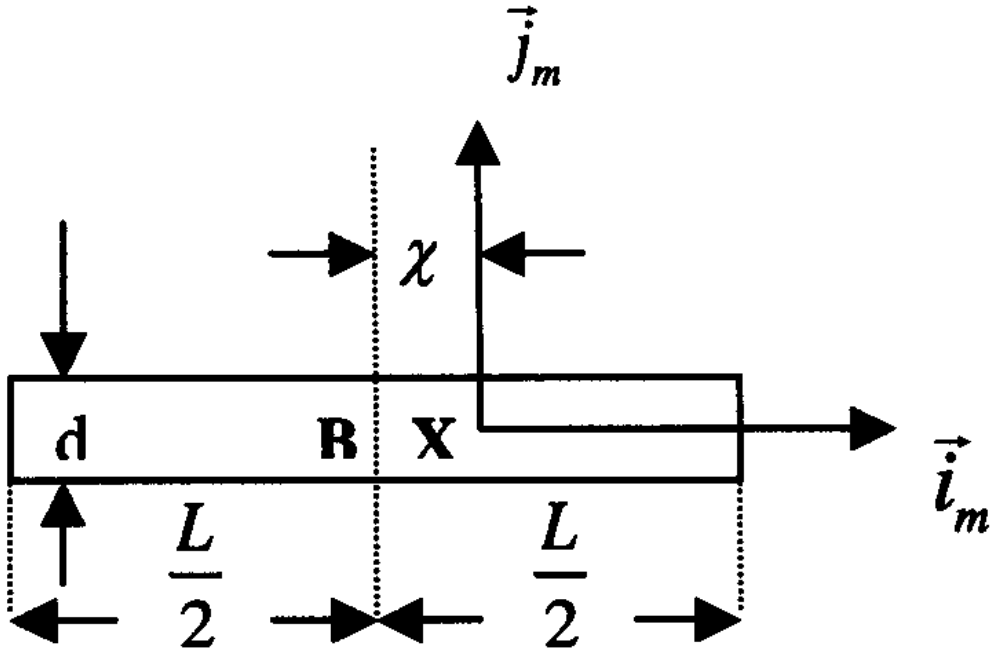
F-Coordinate: Hydrodynamic (drag/lift) Forces and Torques

(3) Drag/Lift Coefficients Depends on Reynolds Number and L/D ratio

(4) Cavitation

(5) Sediment Resistant Force (Bearing Strength and Pore-Water Pressure)

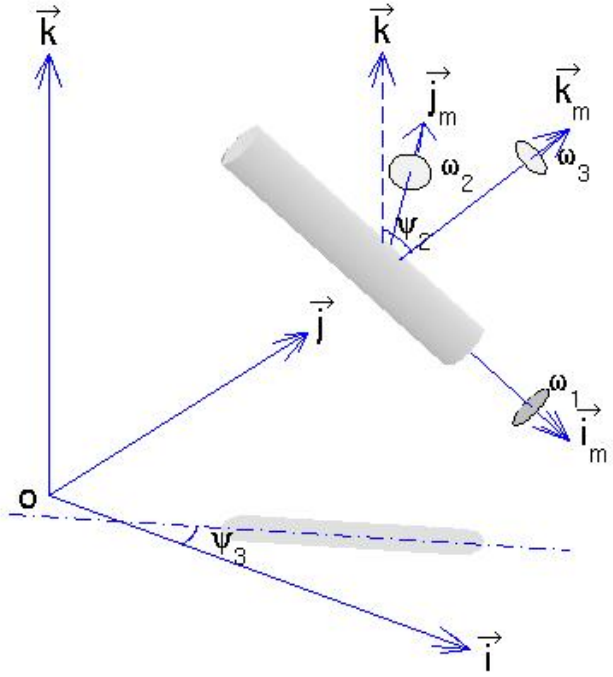
Mine Parameters



Triple Coordinate Transform

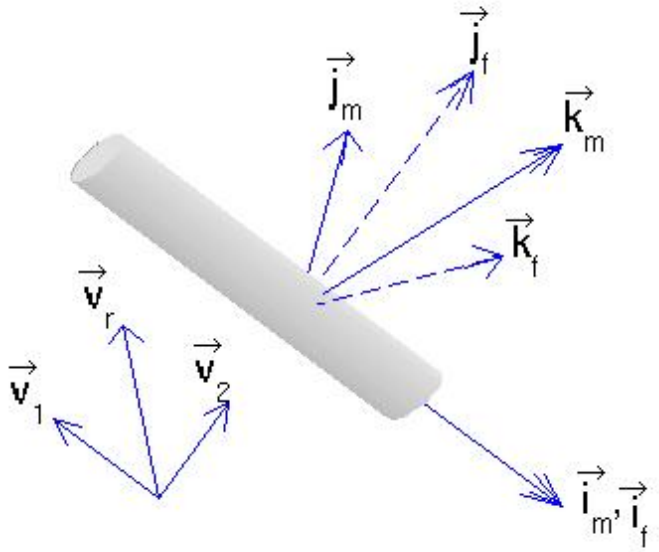
- Earth-fixed coordinate (E-coordinate)
- Cylinder's main-axis following coordinate (M-coordinate)
- Hydrodynamic force following coordinate (F-coordinate).

E and M Coordinate Systems



$$\mathbf{j}_M = \mathbf{k} \times \mathbf{i}_M, \qquad \mathbf{k}_M = \mathbf{i}_M \times \mathbf{j}_M$$

F-Coordinate System



Transform Between E- and M-Coordinate Systems

$$
{}^{E}_{M}\mathbf{R}(\psi_2,\psi_3) \equiv \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix};
$$

$$
= \begin{bmatrix} \cos\psi_3 & -\sin\psi_3 & 0 \\ \sin\psi_3 & \cos\psi_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\psi_2 & 0 & \sin\psi_2 \\ 0 & 1 & 0 \\ -\sin\psi_2 & 0 & \cos\psi_2 \end{bmatrix},
$$

E- and F-Coordinate Transform

$$\mathbf{i}_F = \mathbf{i}_M = \begin{bmatrix} r_{11} \\ r_{21} \\ r_{31} \end{bmatrix}, \qquad \mathbf{j}_F = \mathbf{V}_2 / |\mathbf{V}_2|, \qquad \mathbf{k}_F = \mathbf{i}_F \times \mathbf{j}_F.$$

$$\overset{E}{F}\mathbf{R}(\psi_2, \psi_3, \phi_{MF}) \equiv \begin{bmatrix} r_{11} & r'_{12} & r'_{13} \\ r_{21} & r'_{22} & r'_{23} \\ r_{31} & r'_{32} & r'_{33} \end{bmatrix},$$

Momentum Equation in E-Coordinate System

$$\frac{d}{dt}\begin{bmatrix} u \\ v \\ w \end{bmatrix} = -\begin{bmatrix} 0 \\ 0 \\ \left(1-\rho_w/\bar{\rho}\right)g \end{bmatrix} + \frac{1}{\bar{\rho}\Pi}\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix},$$

Moment of Momentum Equation in M-Coordinate System

$$\mathbf{J}\bullet\frac{d\boldsymbol{\omega}}{dt}=-2\mathbf{J}\bullet(\boldsymbol{\Omega}\times\boldsymbol{\omega})+\mathbf{M}_{nh}+\mathbf{M}_{h}$$

M-Coordinate

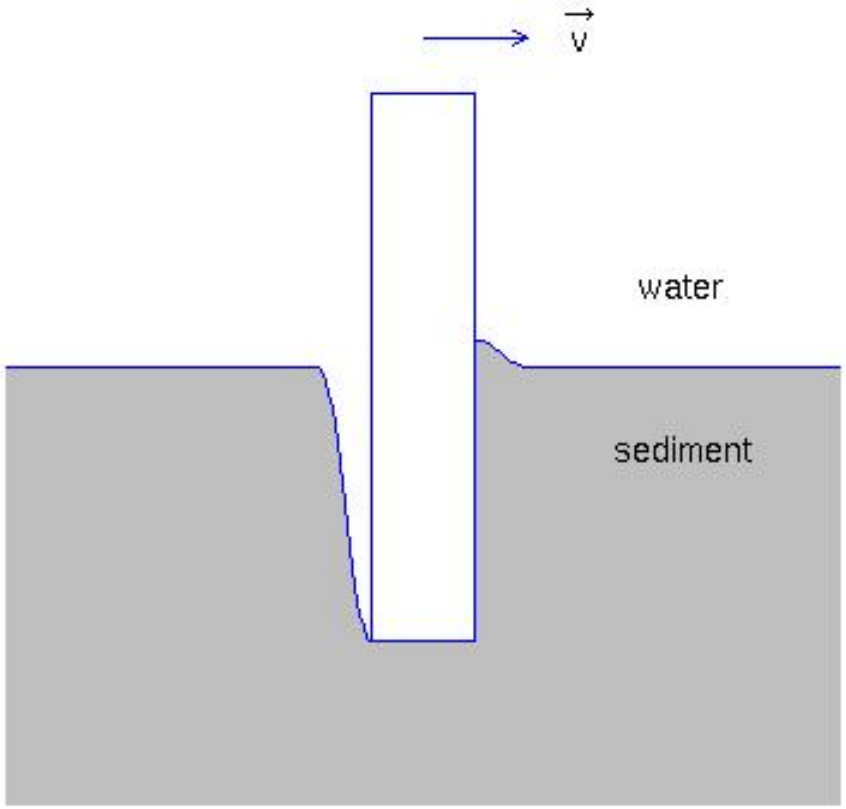
The moment of gyration tensor for the axially Symmetric cylinder is a diagonal matrix

$$\mathbf{J} = \begin{bmatrix} J_1 & 0 & 0 \\ 0 & J_2 & 0 \\ 0 & 0 & J_3 \end{bmatrix},$$

Moment of Momentum Equations

$$\frac{d\omega_1}{dt} = -a_1\omega_1 ,$$

$$\frac{d}{dt}\begin{bmatrix}\omega_2\\ \omega_3\end{bmatrix} = -\mathbf{B}\cdot\begin{bmatrix}\omega_2\\ \omega_3\end{bmatrix} + \boldsymbol{\alpha}_2 ,$$


v
water
sediment

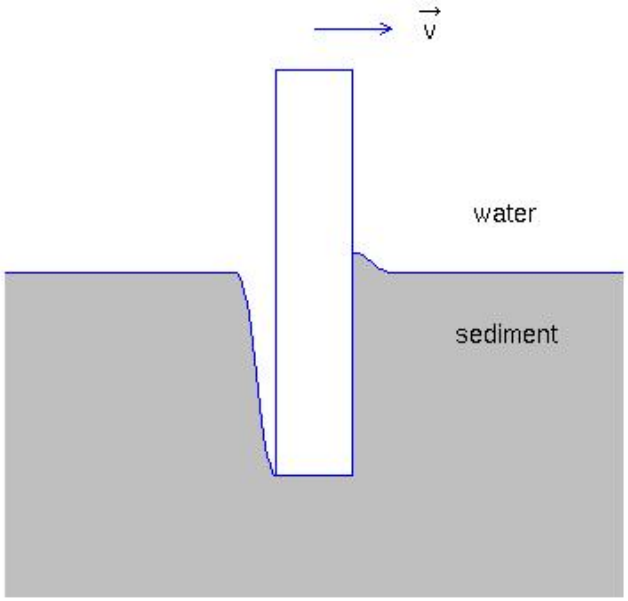
Sediment Resistant Forces (Bearing Strength and Pore-Water Pressure)

IMPACT28

Bearing Strength
= 10 X Shear Strength

IMPACT35

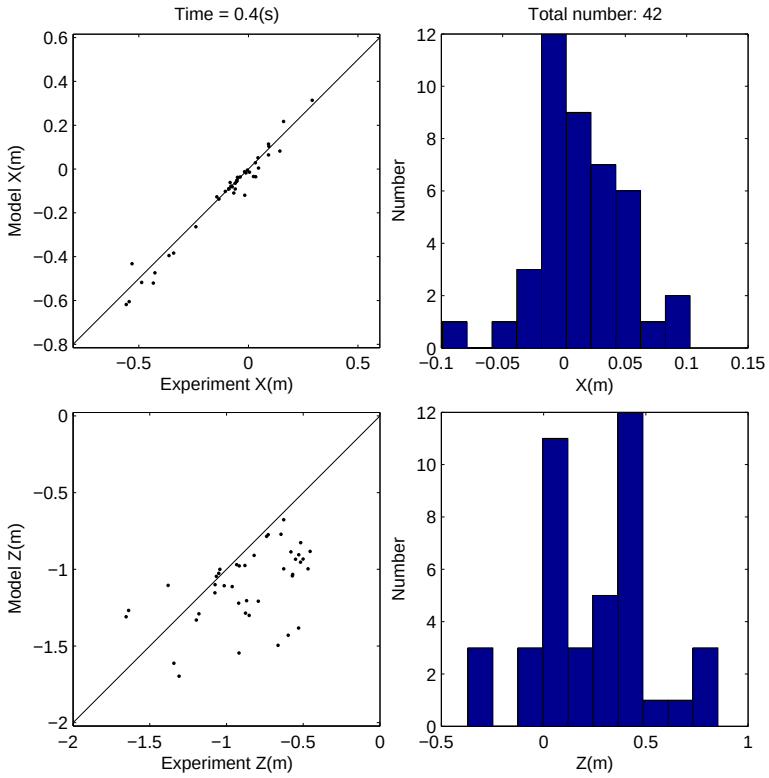
More Realistic



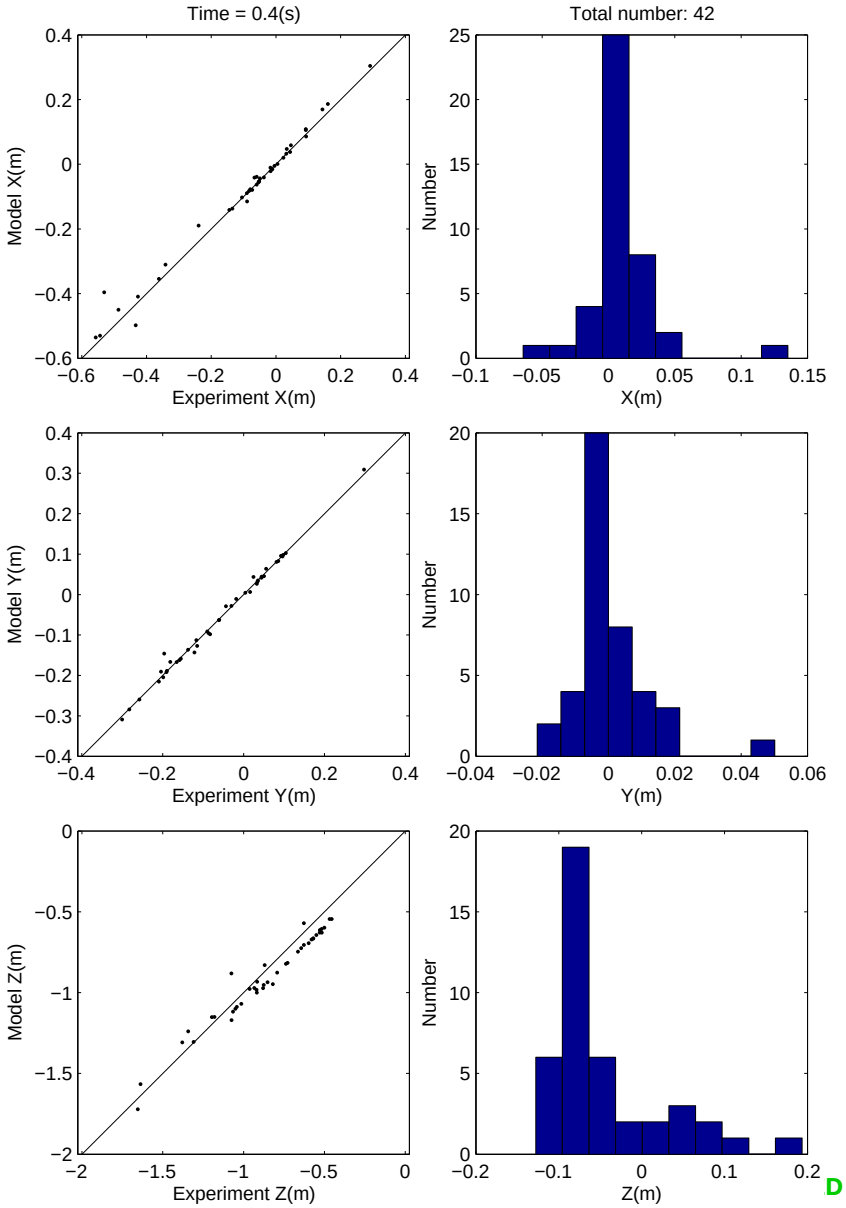
Model Verification Using Carderock Data

COM at t = 0.4 s

IMPACT28 (x, z)



IMPACT35 (x, y, z)

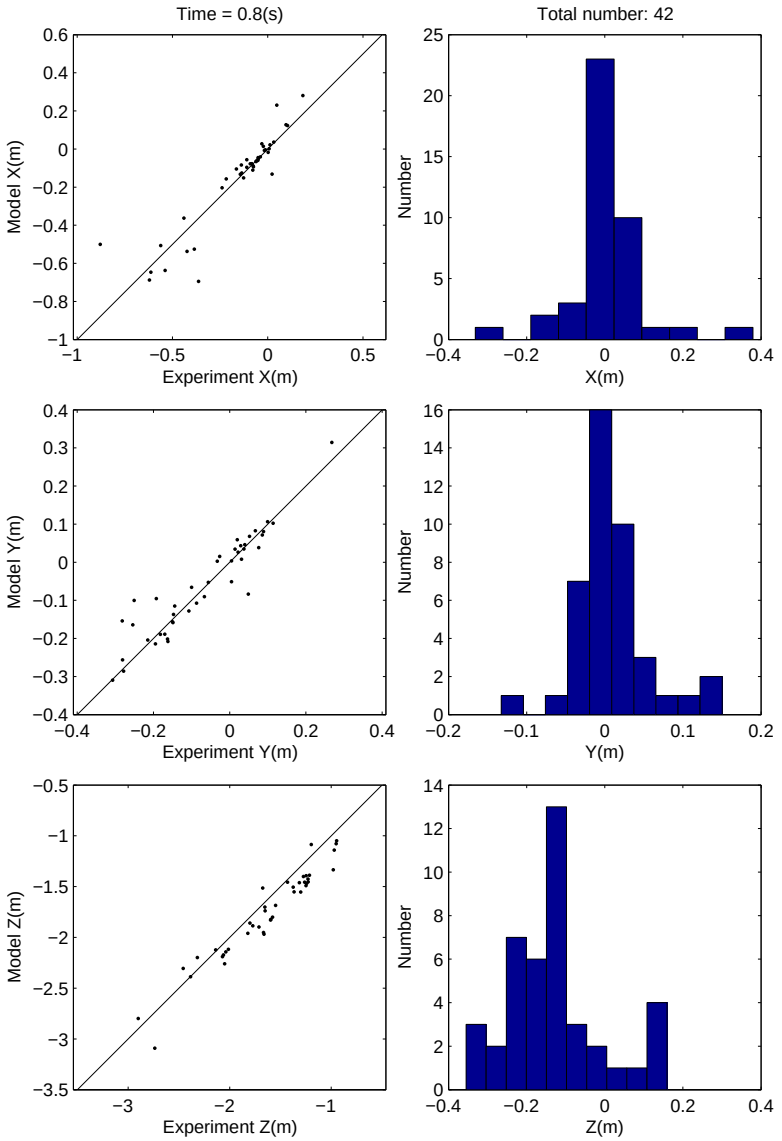


D

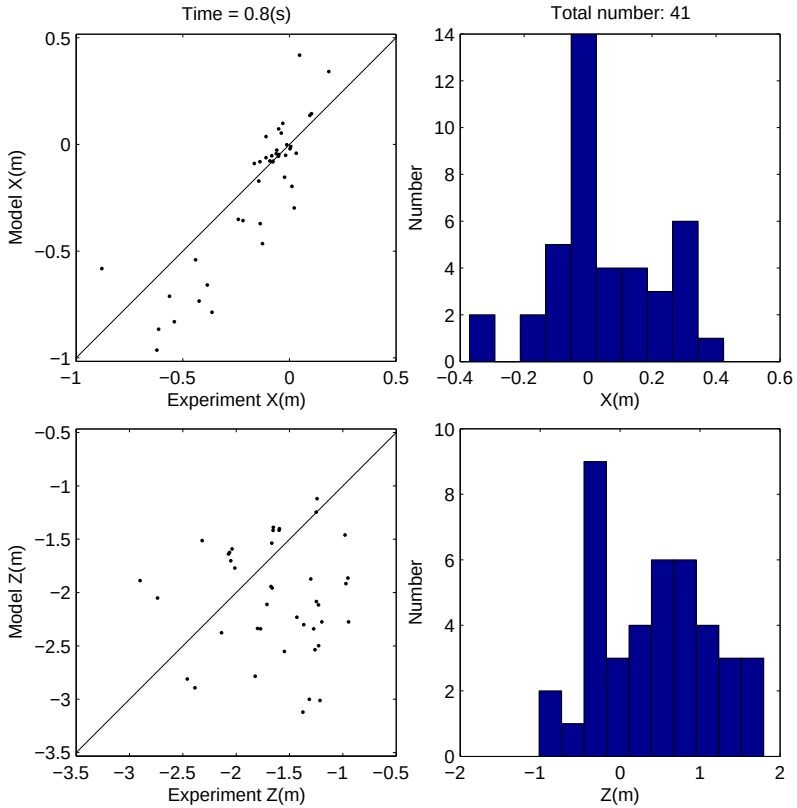
Model Verification Using Carderock Data

COM at t = 0.8 s

IMPACT35 (x, y, z)



IMPACT28 (x, z)

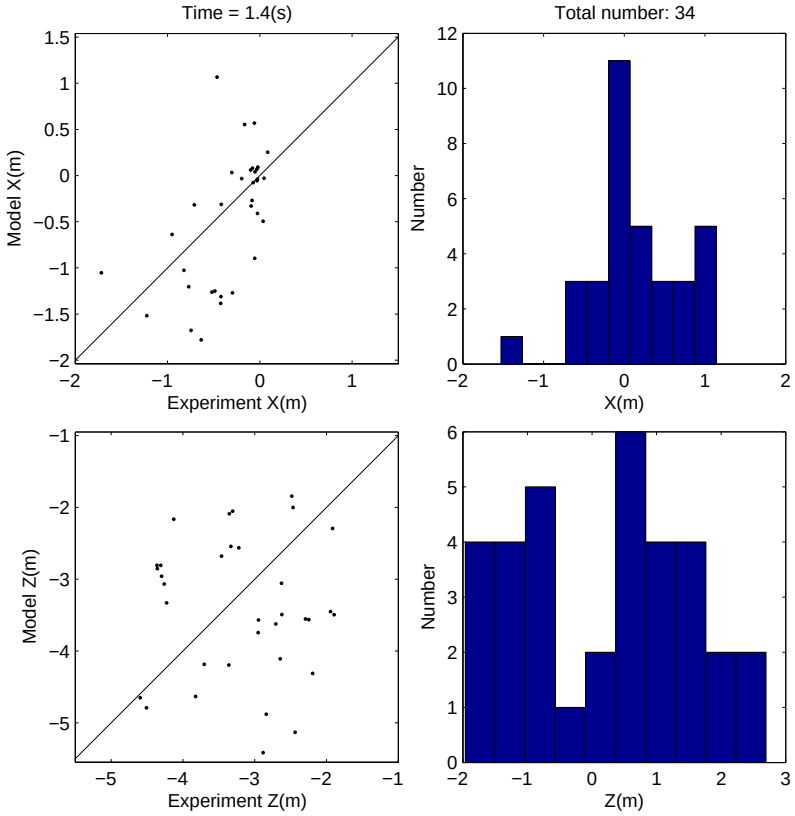


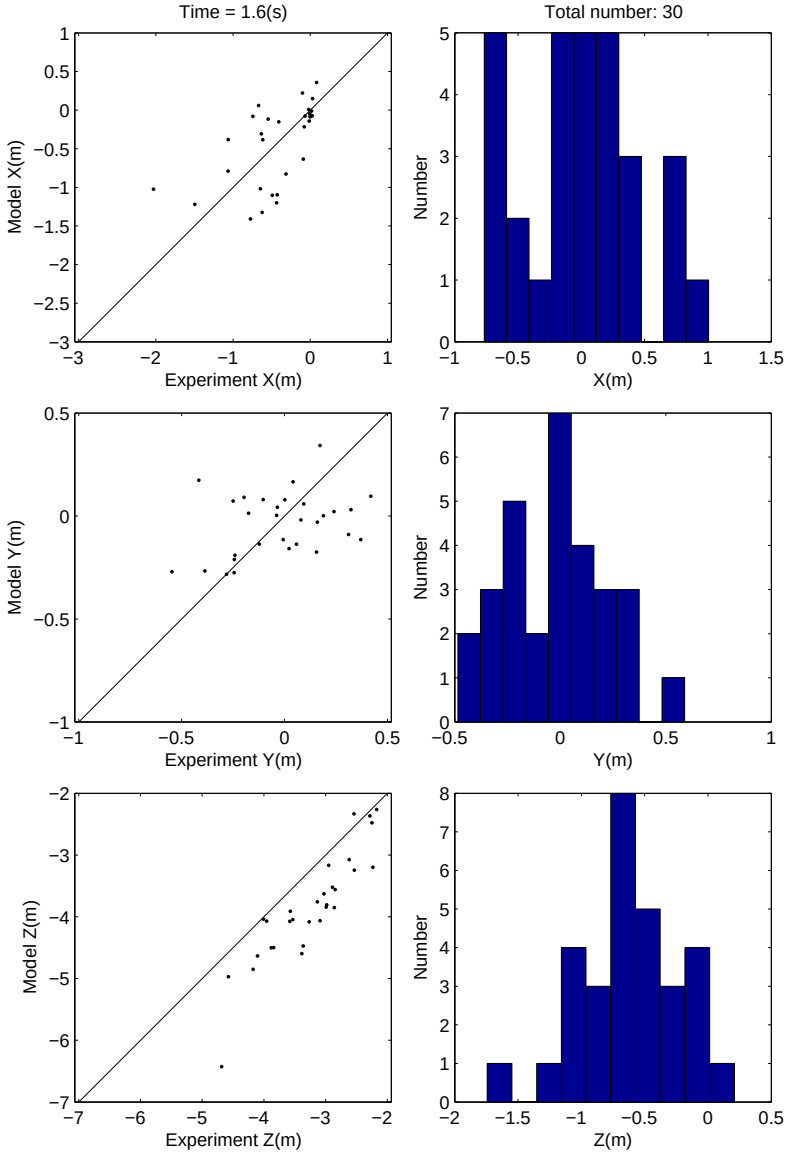
Model Verification Using Carderock Data

COM at t = 1.4 s

IMPACT35 (x, y, z)

IMPACT28 (x, z)

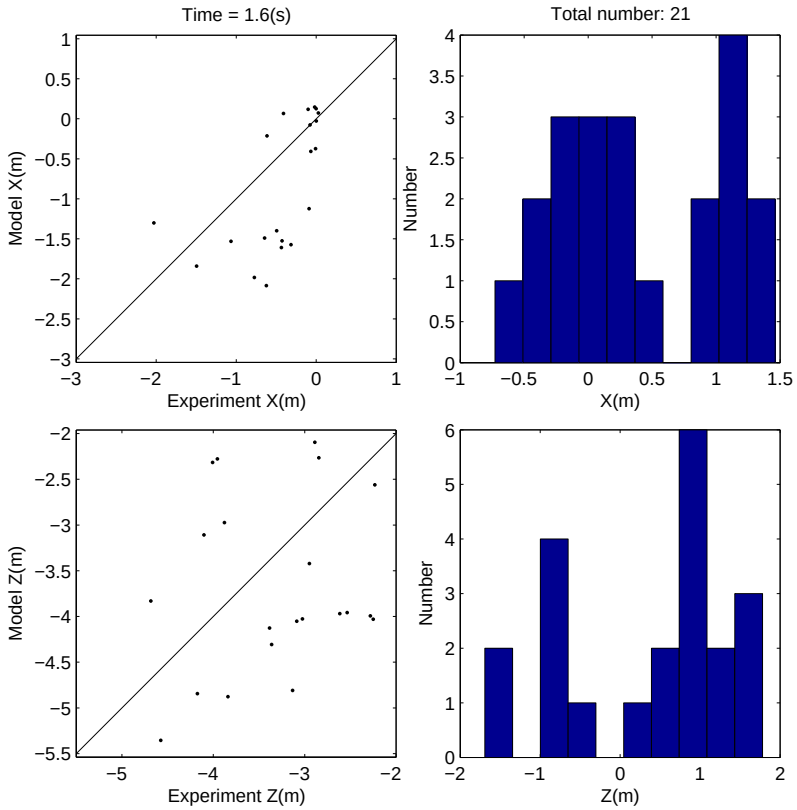




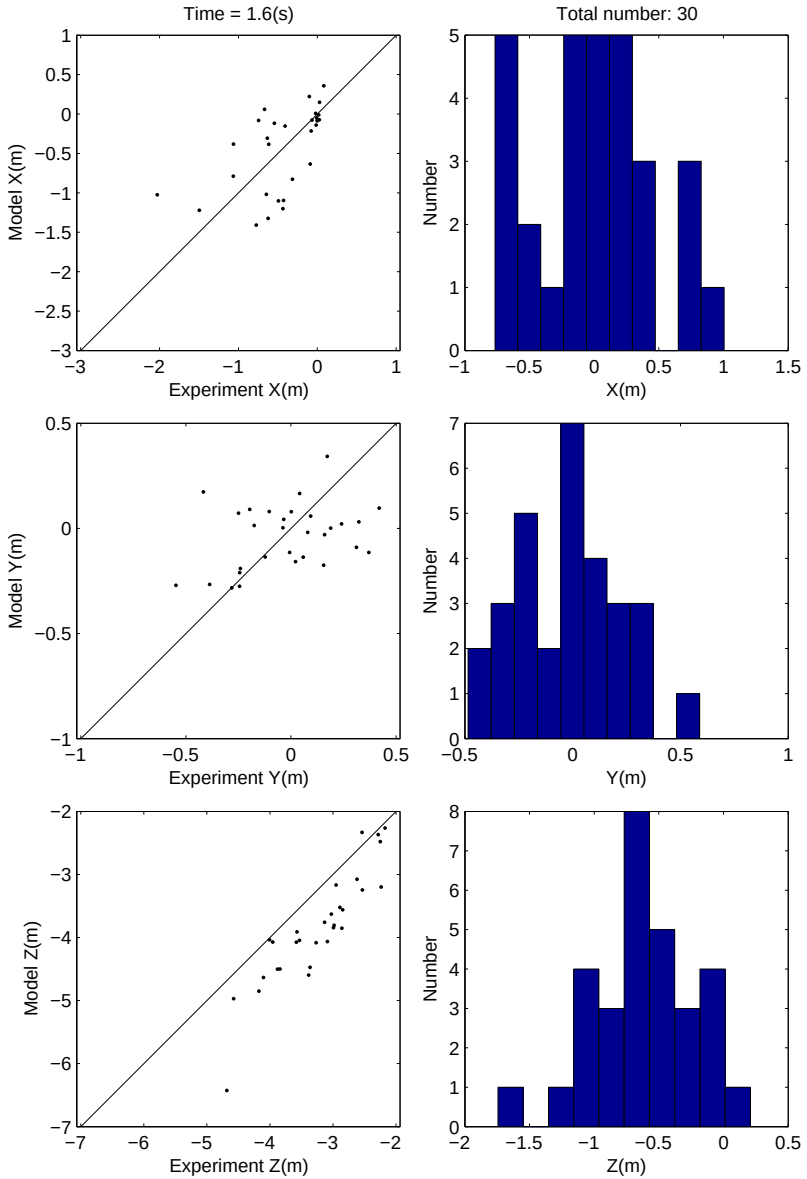
Model Verification Using Carderock Data

COM at t = 1.8 s

IMPACT28 (x, z)

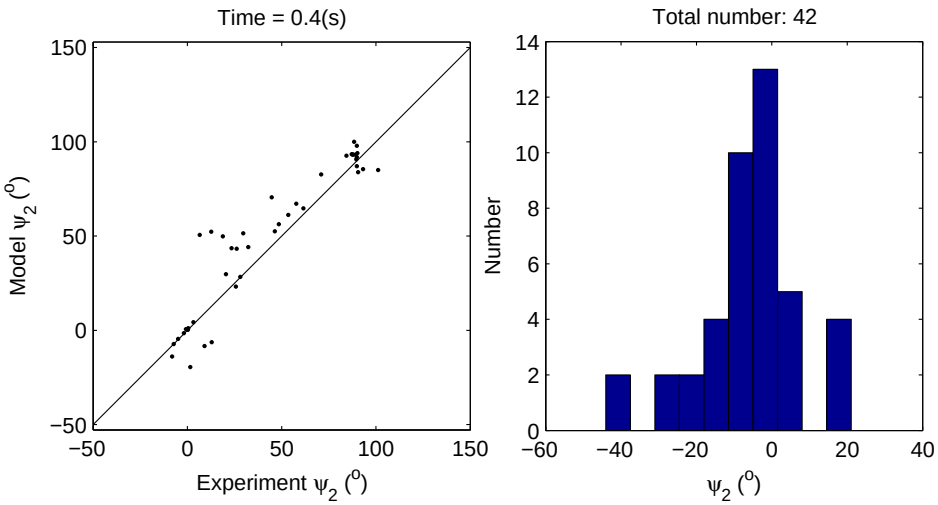


IMPACT35 (x, y, z)

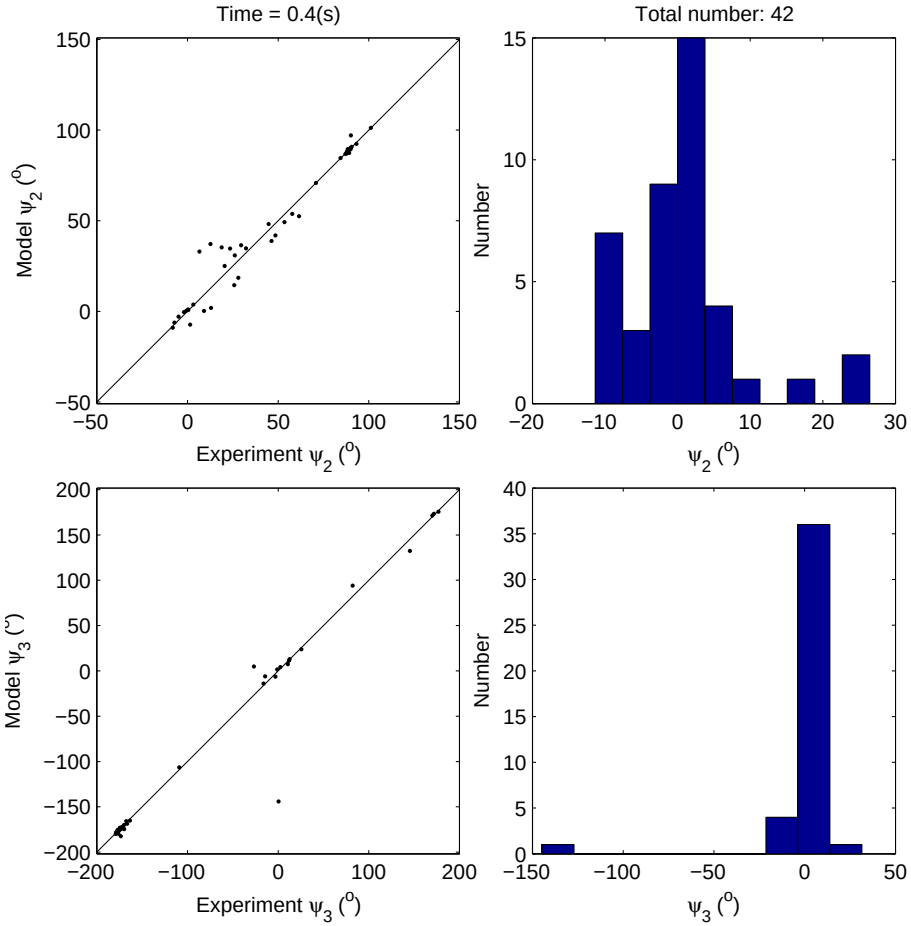


Model Verification Using Carderock Data Orientation t = 0.4 s

IMPACT28 (psi2)

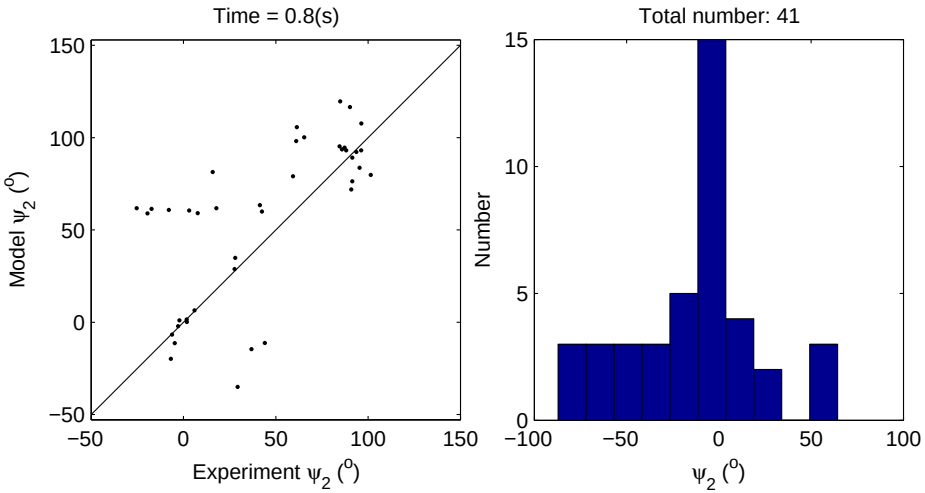


IMPACT35 (psi2, psi3)

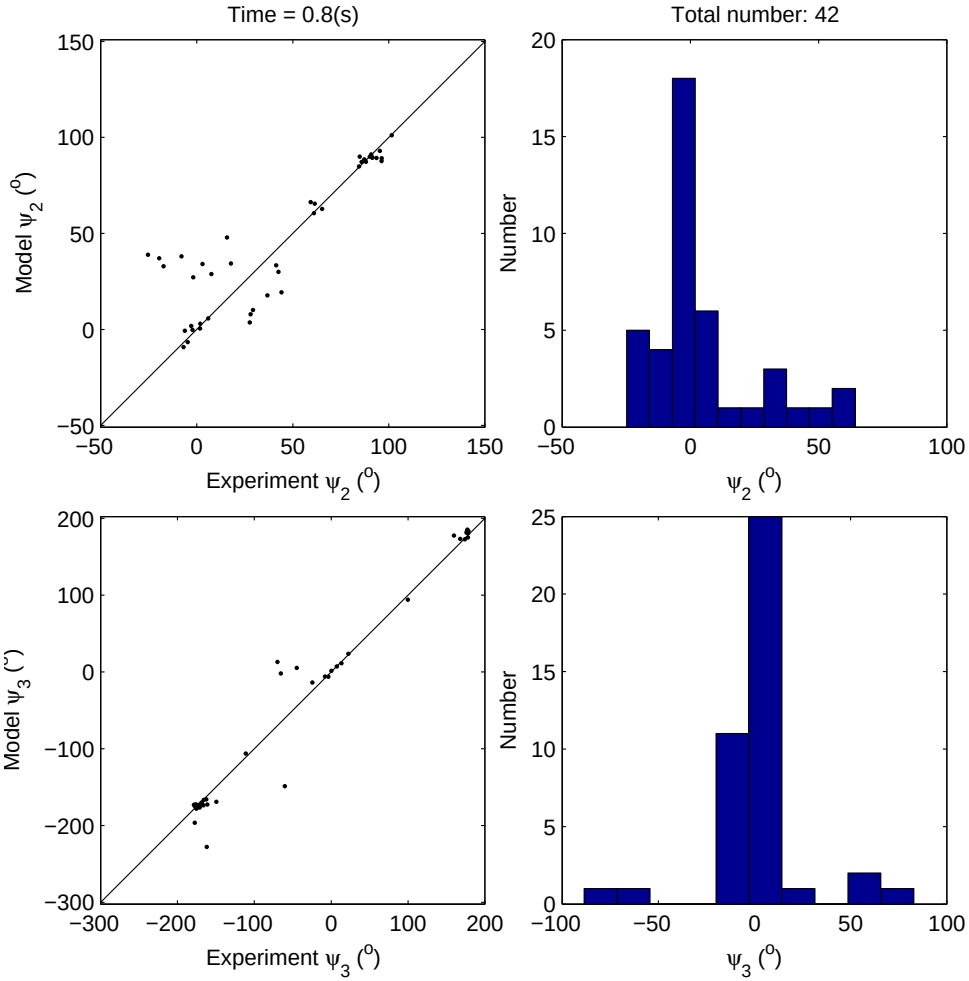


Model Verification Using Carderock Data
Orientation t = 0.8 s

IMPACT28 (psi2)

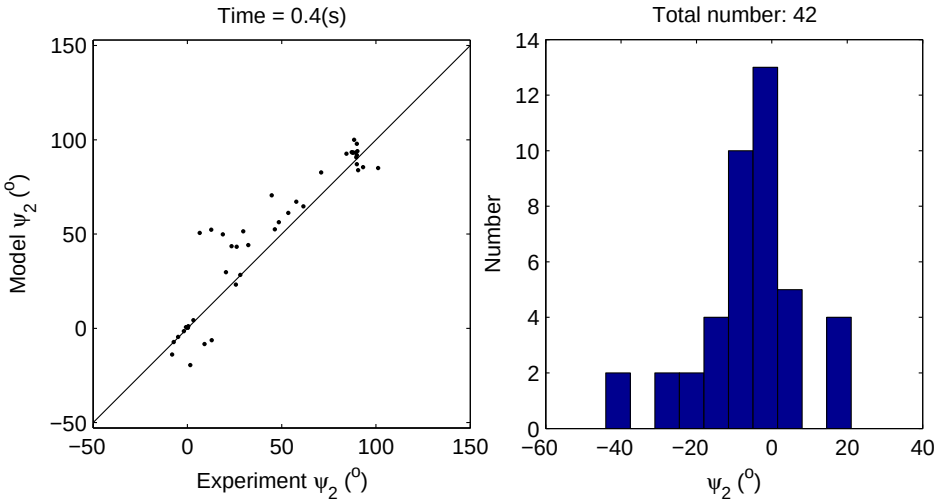


IMPACT35 (psi2, psi3)

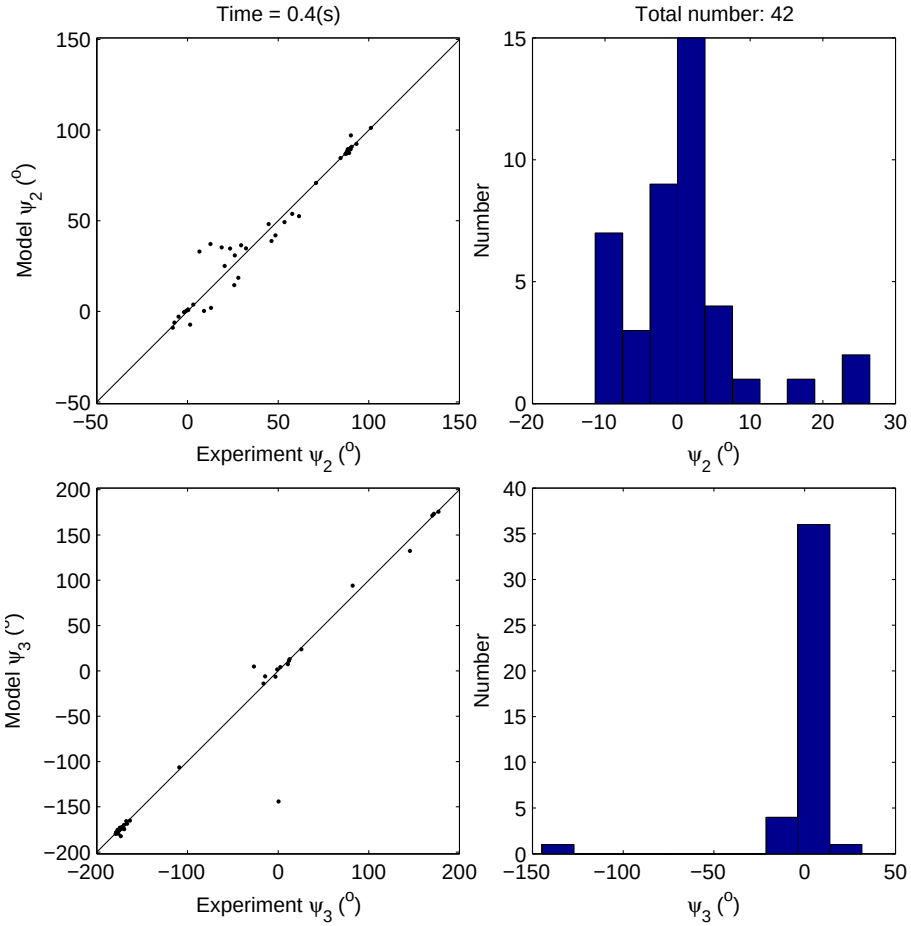


Model Verification Using Carderock Data Orientation t = 1.4 s

IMPACT28 (psi2)

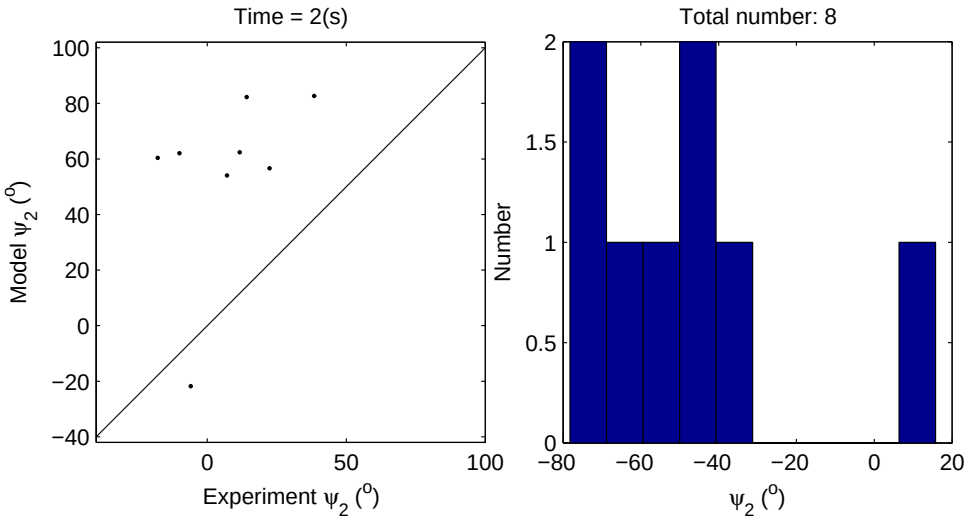


IMPACT35 (psi2, psi3)

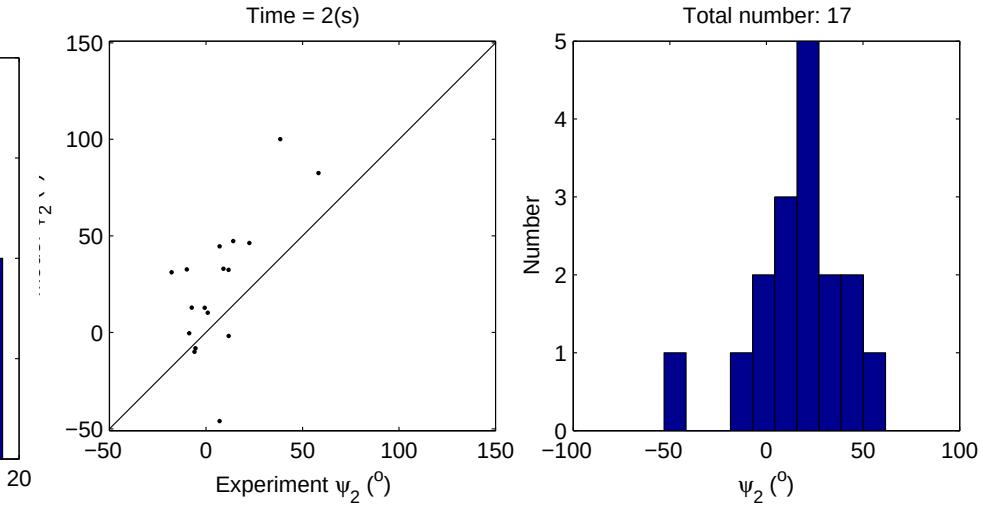


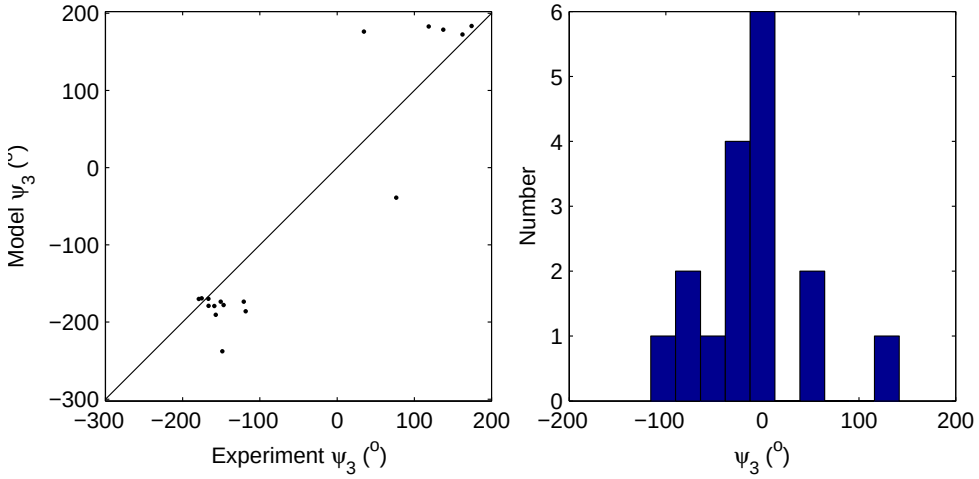
Model Verification Using Carderock Data Orientation t = 2 s

IMPACT28 (psi2)



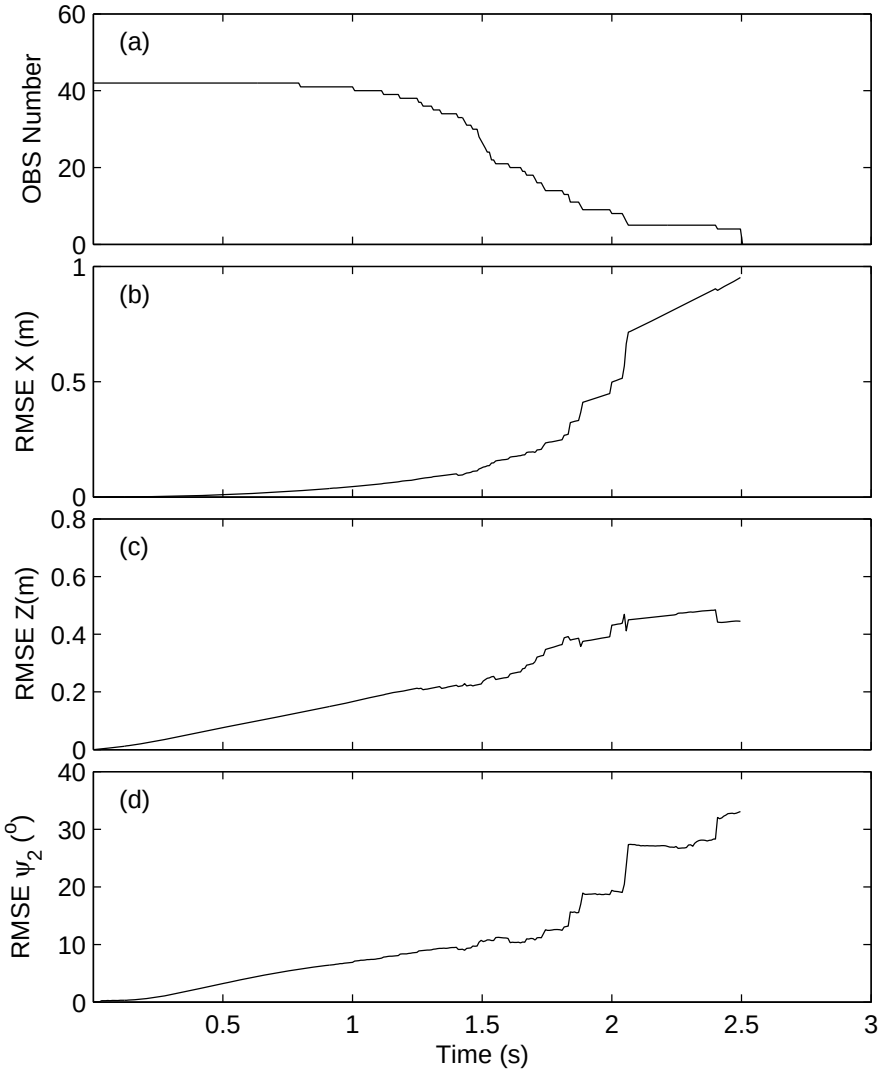
IMPACT35 (psi2, psi3)





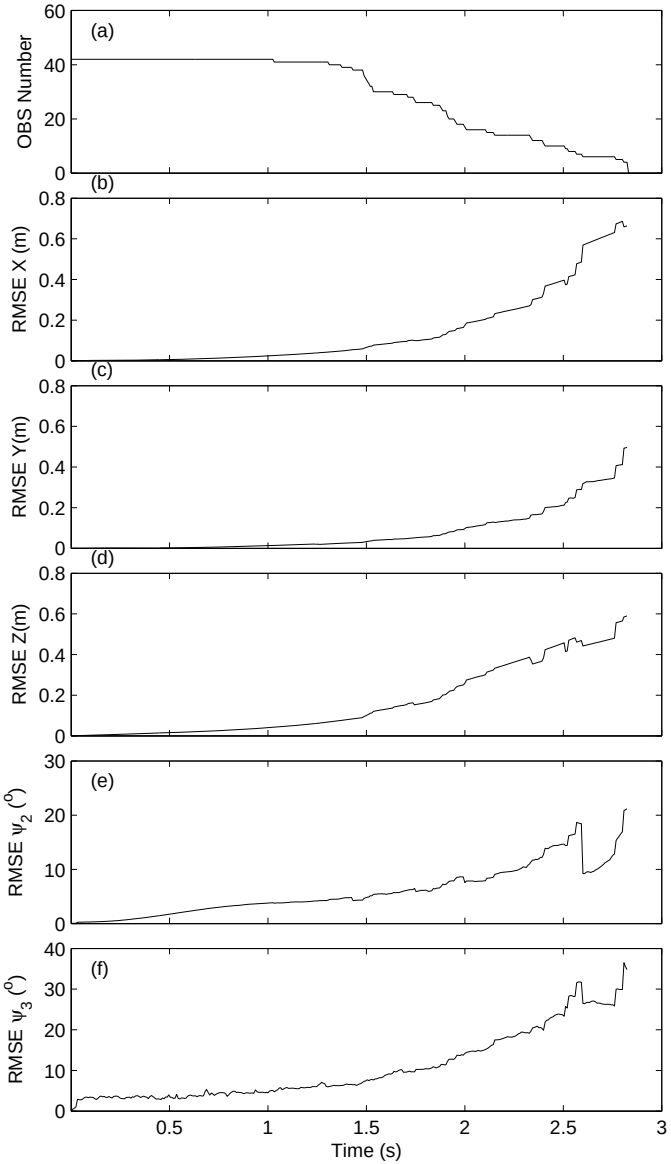
Temporally Varying RMSE IMPACT28

- Observation Number
- X
- Z
- PSI_2

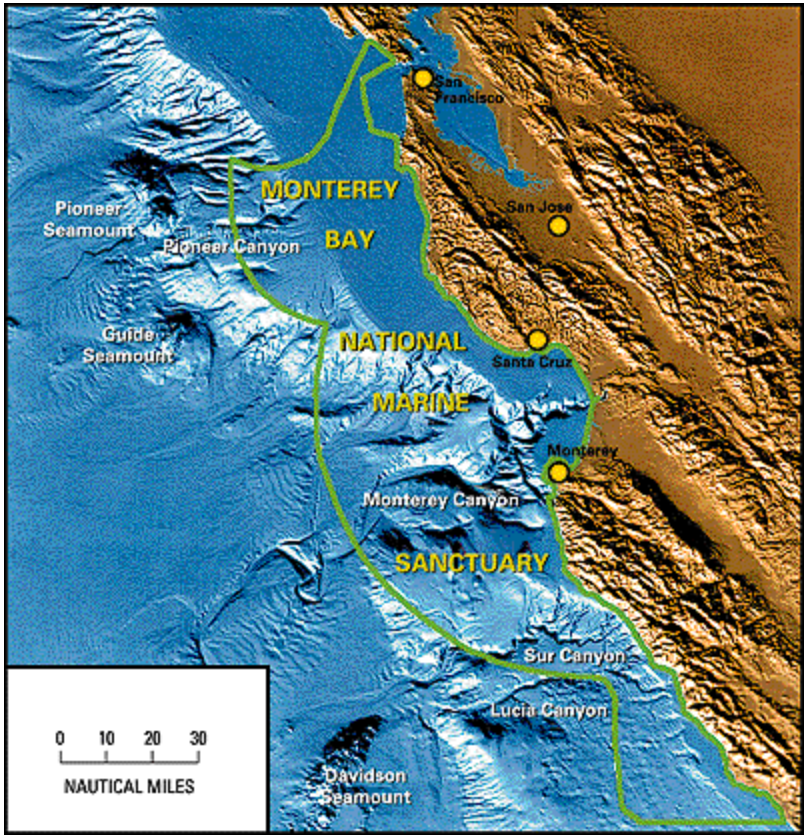


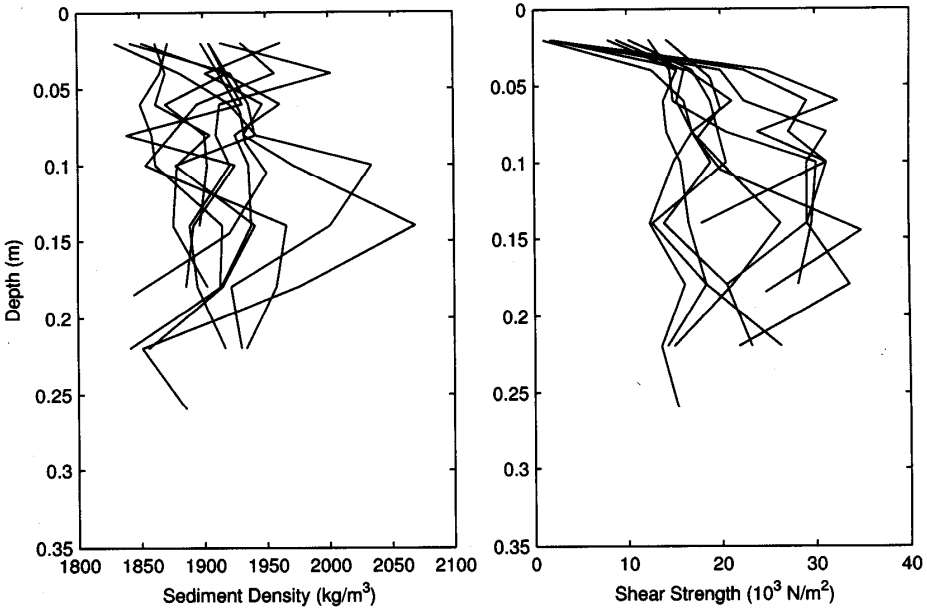
Temporally Varying RMSE IMPACT35

- Observation Number
- X
- Y
- Z
- PSI_2
- PSI_3

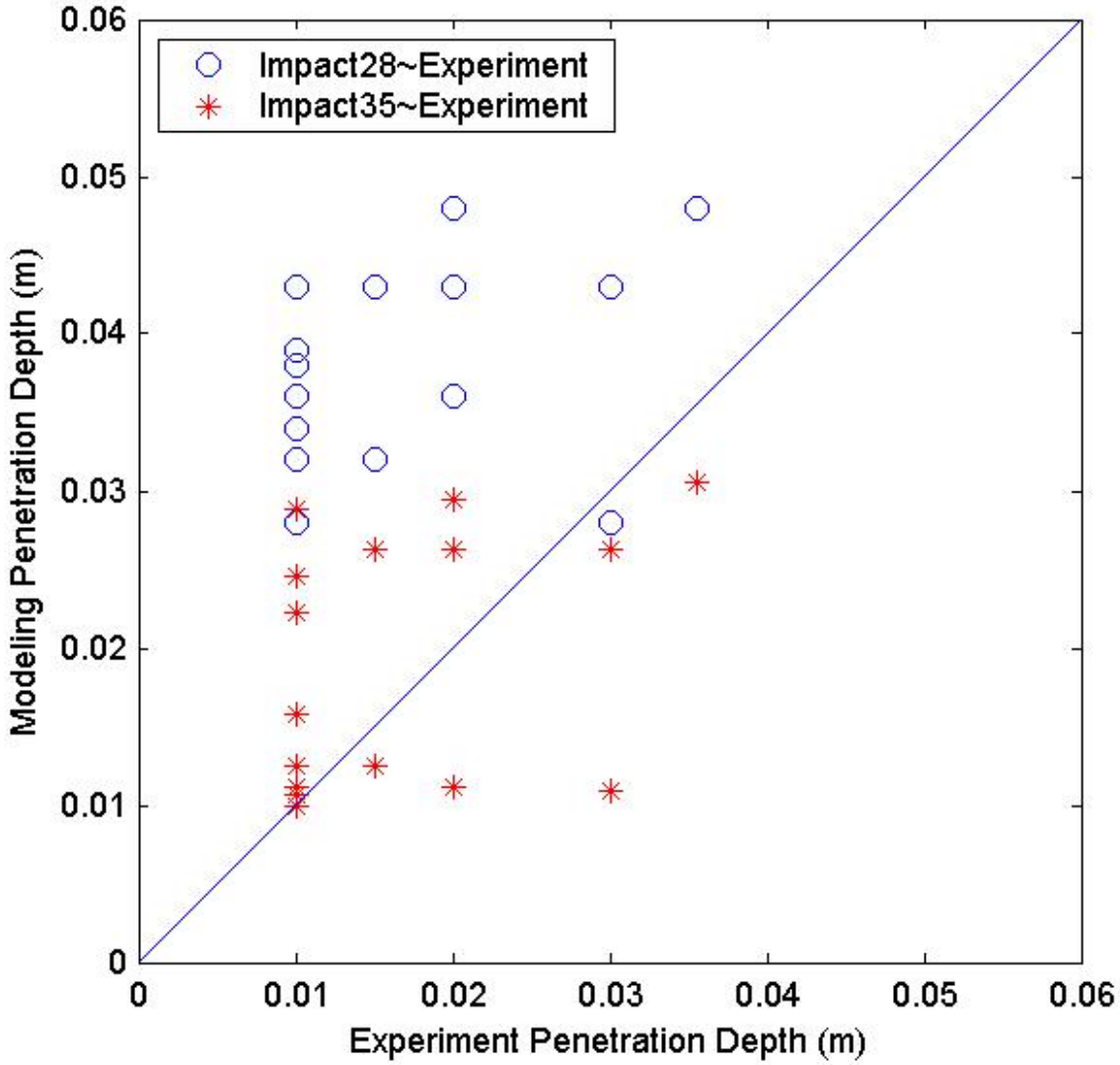


Gravity Cores During MIBEX (5/21/2000)





Predicted Burial Depth Comparison Using MIBEX Data



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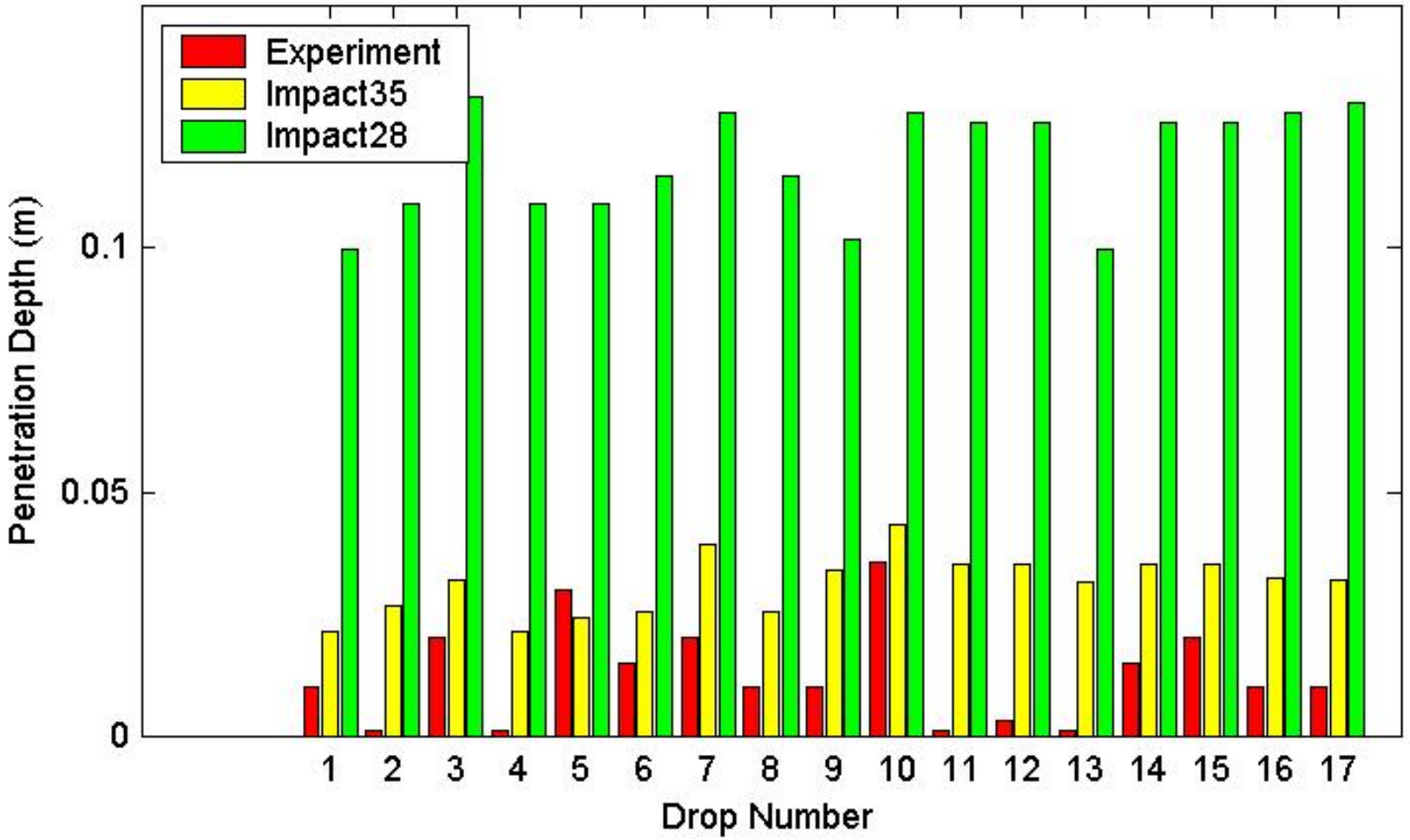

Conclusions

- IMPACT35 has capability to predict the COM position and mine orientation in the water column.
- The sediment part of IMPACT35 needs improvement

Future Work

- (1) Extensive Model Verification
  - NRL (Drs. Phil Valent, Paul Elmore, Andre Abelev)
  - JHU-APL (Drs. Alan Brandt, Sarah Rennie)
  - FWG (Dr. Thomas Wever)
- (2) Extension the IMPACT35 for Cylindrical Mines to Non-Cylindrical Mines for Naval Operational Mines
  - Manta, Rockan
  - Korean Mines, Bowen Mines, Psi Mines
  - KW36, KW52, KWDST, KWGE, KWIT
  - Mark36N, Mark52 …