ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018
The State of the Art and Science of Coastal Engineering

Coastal Flooding-Induced Debris Motion

Ioan Nistor, Professor, Ph.D., P.Eng.

Department of Civil Engineering, University of Ottawa, Ottawa, Canada

uOttawa

Technische Universität Braunschweig

Co-authors:

Nils Goseberg, Professor, TU Braunschweig

Jacob Stolle, PhD Student, University of Ottawa

Tomoya Shibayama, Professor Waseda University

Takahito Mikami, Assistant Prof. Tokyo City University




ForoTV (2015)

Motivation

- Debris impact and damming forces have been identified as a significant loading condition in extreme hydrodynamic events (Robertson et al., 2007; Palmero et al., 2009; Chock et al., 2013).

- Focus of research has primarily been on the impact forces.

- Less emphasis on the risk associated with debris motion.
  - ASCE 7 Chapter 6 first document that explicitly addressed debris motion.

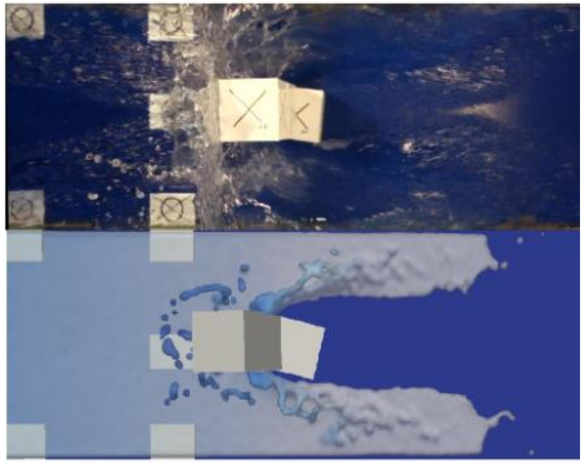
2011 Tohoku Tsunami (Nistor, 2011)

2010 Chilean Tsunami (Nistor and Palmero, 2014)

Motivation

- Difficult to quantify debris motion:
    - Tsunami forensic field surveys
        - Tsunami are rare events
        - Difficult to assess debris sources
    - Numerical
        - Computationally expensive
        - Lack of sufficient benchmarking
    - Physical modelling
        - Time-consuming
        - Scaling issues

Khao Lak, Thailand (Nistor and Saatcioglu, 2005)



SPH-DEM Model (Canelas et al., 2013)

Objectives

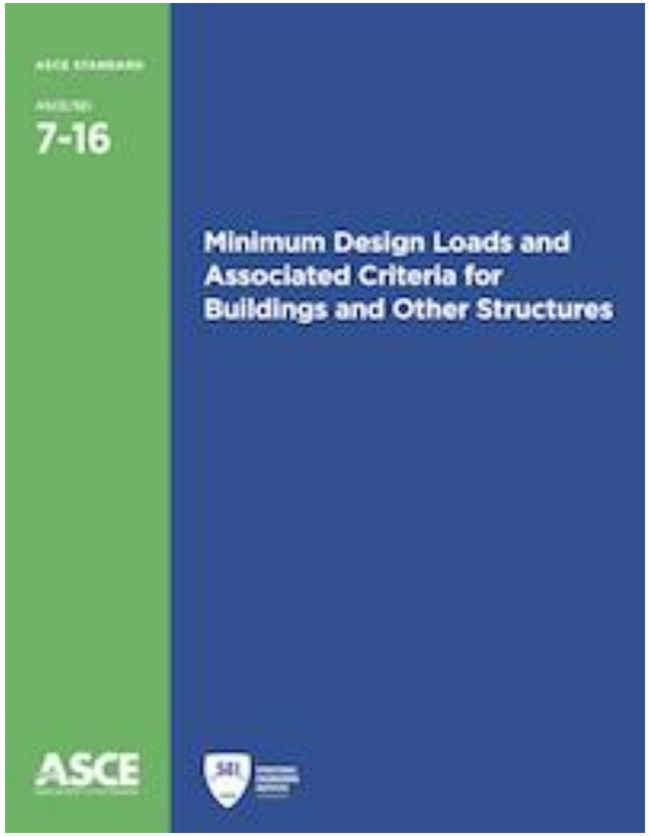
Develop a **quick** and **accurate** method to **track debris** in energetic flow conditions.

Validate the current provisions of the ASCE7 Chapter 6 standard for debris hazard assessment.

ASCE7 Chapter 6:
Tsunami Loads and Effects

Chock, Gary YK. "Design for tsunami loads and effects in the ASCE 7-16 standard." Journal of Structural Engineering 142.11 (2016): 04016093.

- First standard, written in **mandatory language**, for tsunami loading on structures in North America.
- Addresses tsunami loading from a **probabilistic** perspective.
- Touches on three aspects related to debris loading:
  - Debris Loading Potential
  - Debris Impact Loading
  - Debris Damming (to a lesser extent)

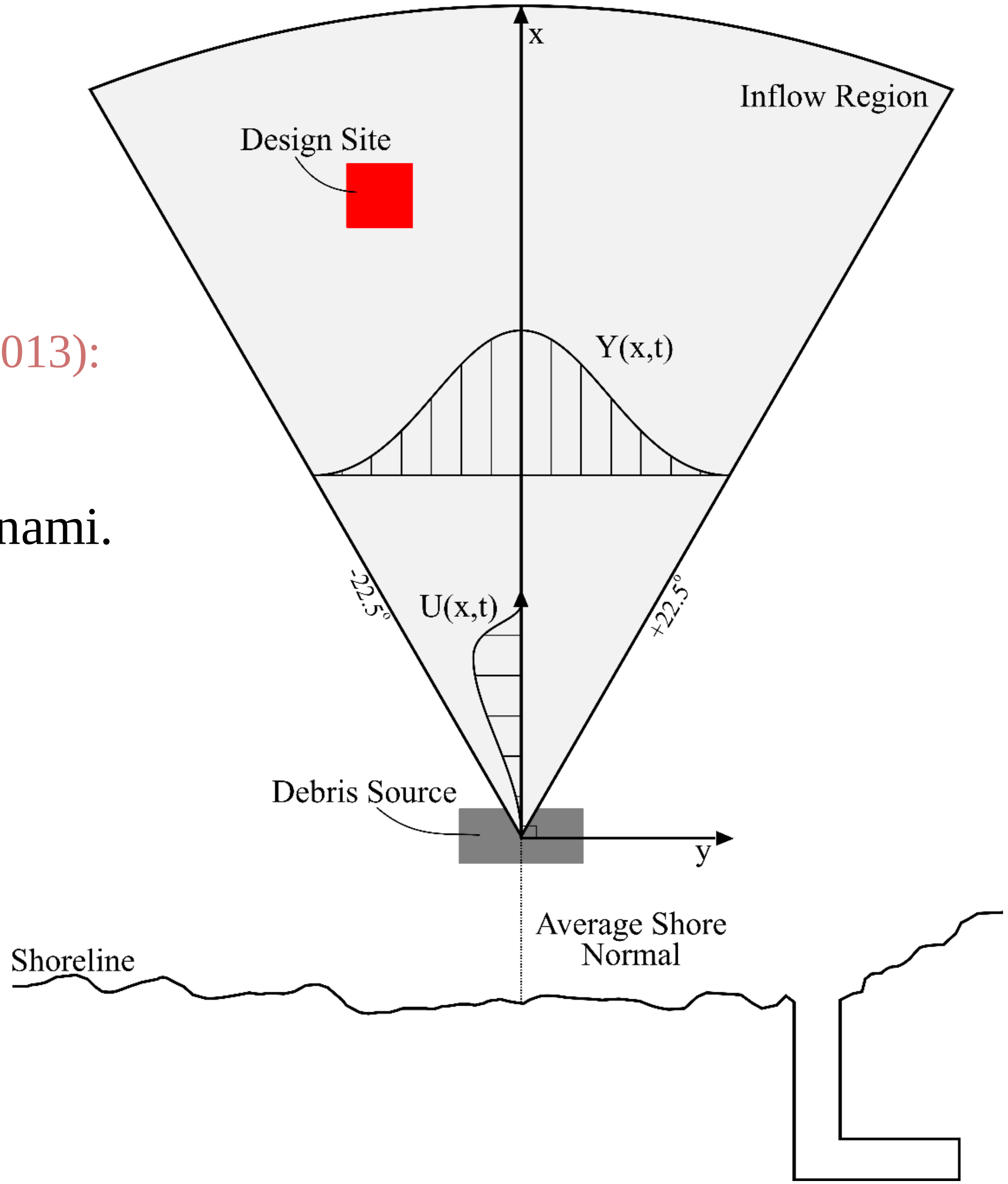


Debris Hazard Assessment

- Naito et al. (2014)
  - Naito, Clay, et al. "Procedure for site assessment of the potential for tsunami debris impact." *JWPOCE* 140.2 (2013): 223-232.
- Based on a site assessment after the 2011 Tohoku Tsunami.
- Focused on debris with a defined source.
  - Shipping vessels.

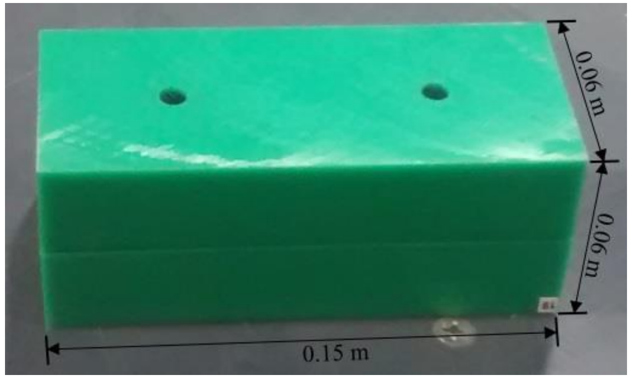
Limitations

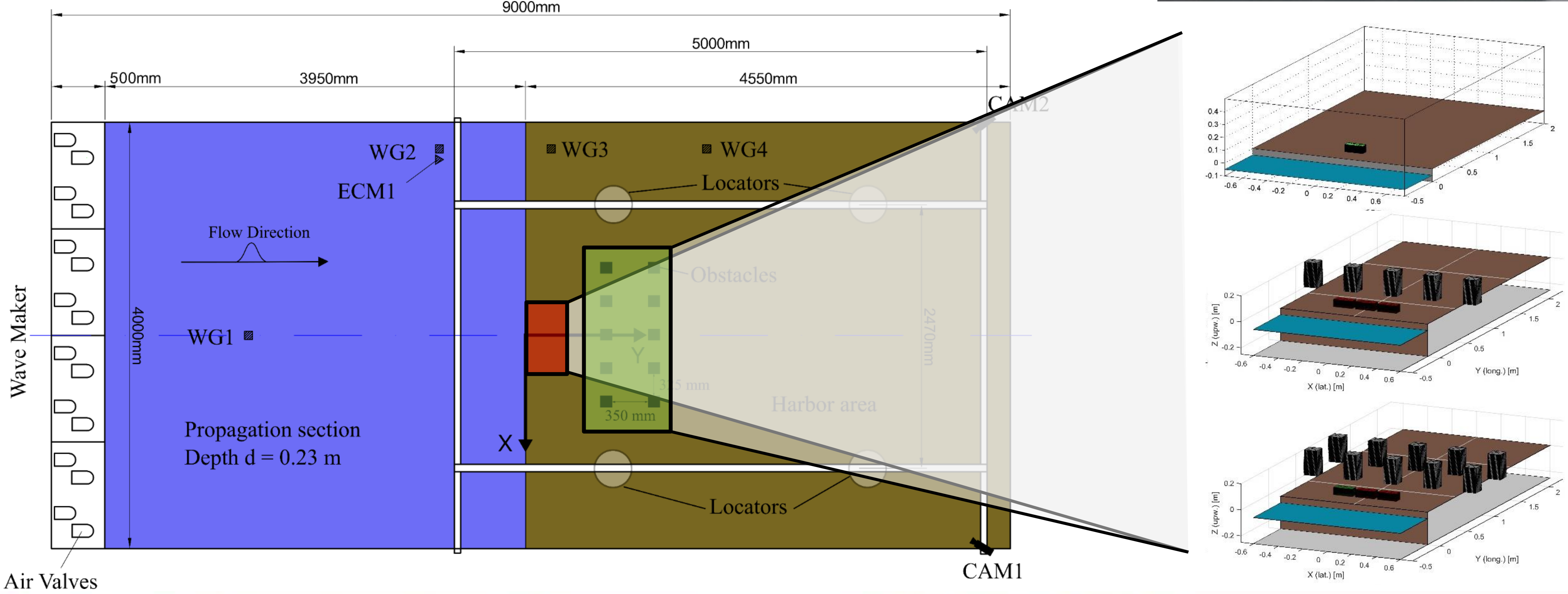
- Limited data set.
- Could only be performed in the aftermath.
- Unclear debris source.



Experimental Setup

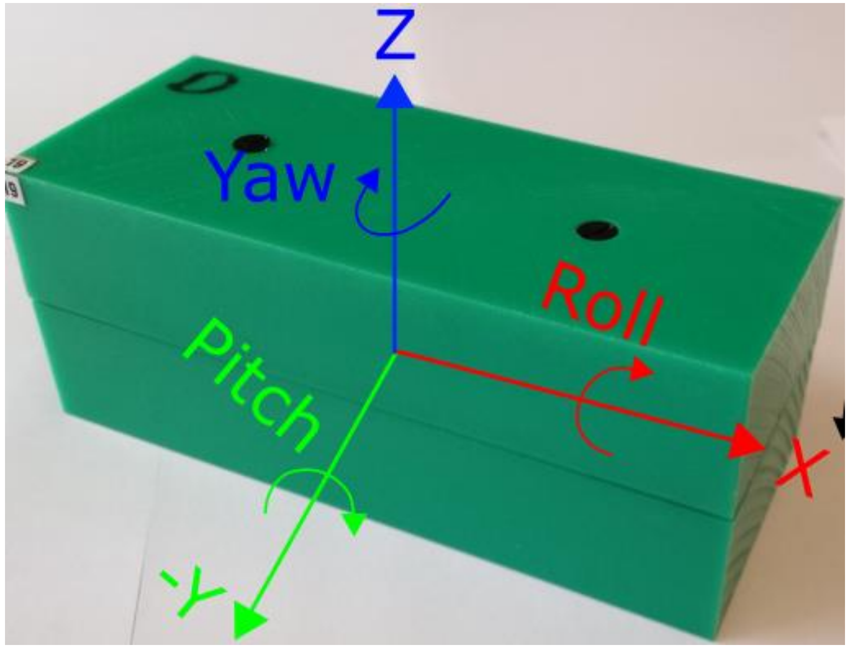
- Experiments were performed in new Tsunami Wave Basin at Waseda University (Tokyo, Japan).



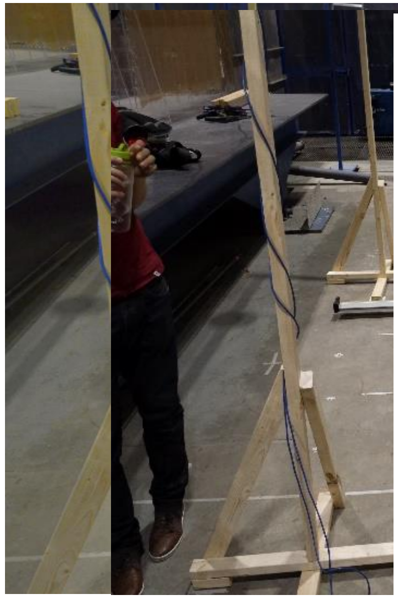


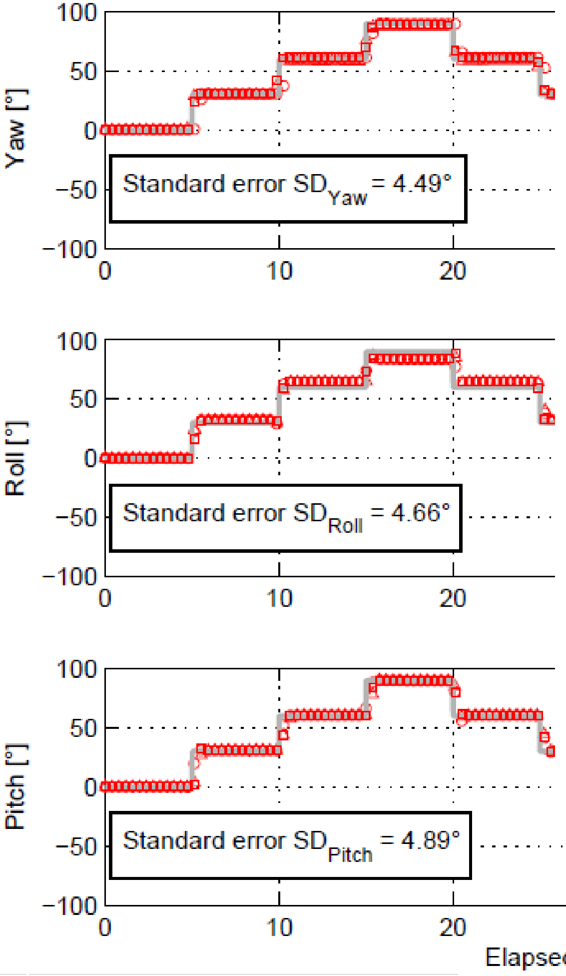
Experimental Setup

- 1:40 geometric scaling
- Ability to track the debris with 6 degrees-of-freedom.
- Bluetooth Low Energy (BLE) Tags for debris tracking
- Inertial Measurement Units (IMU) for debris acceleration and rotation

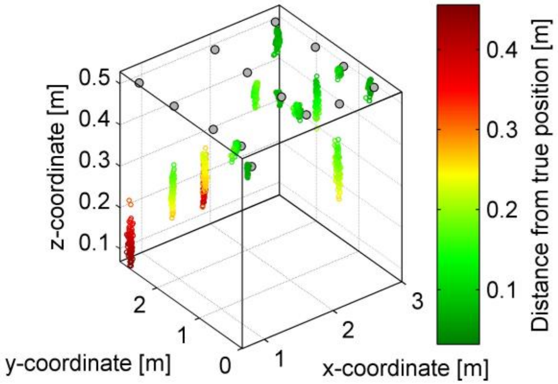


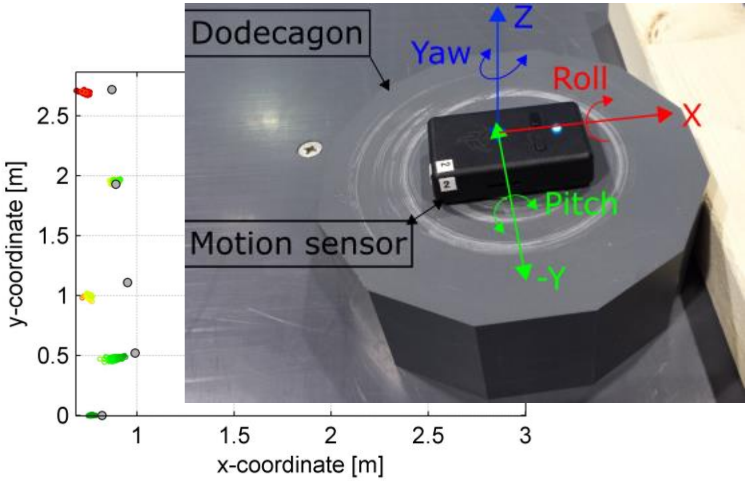
"Smart" Debris Testing

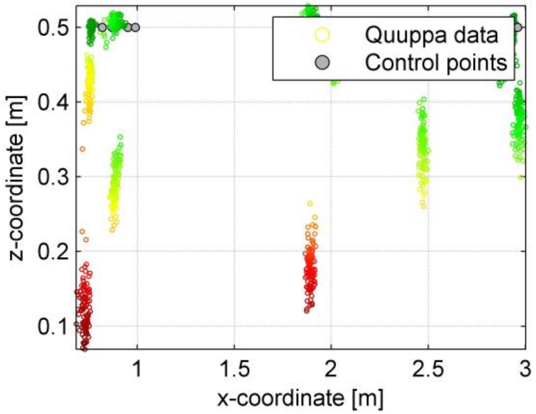


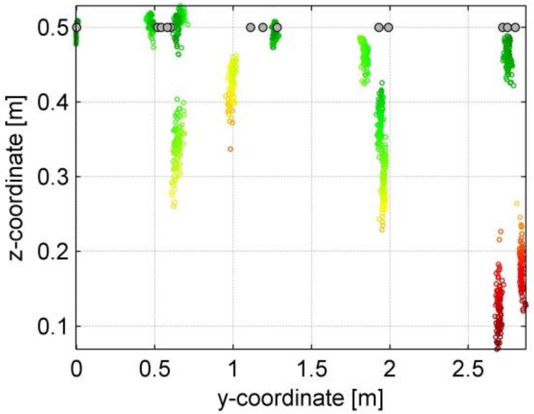


Direction
X
Y
Z









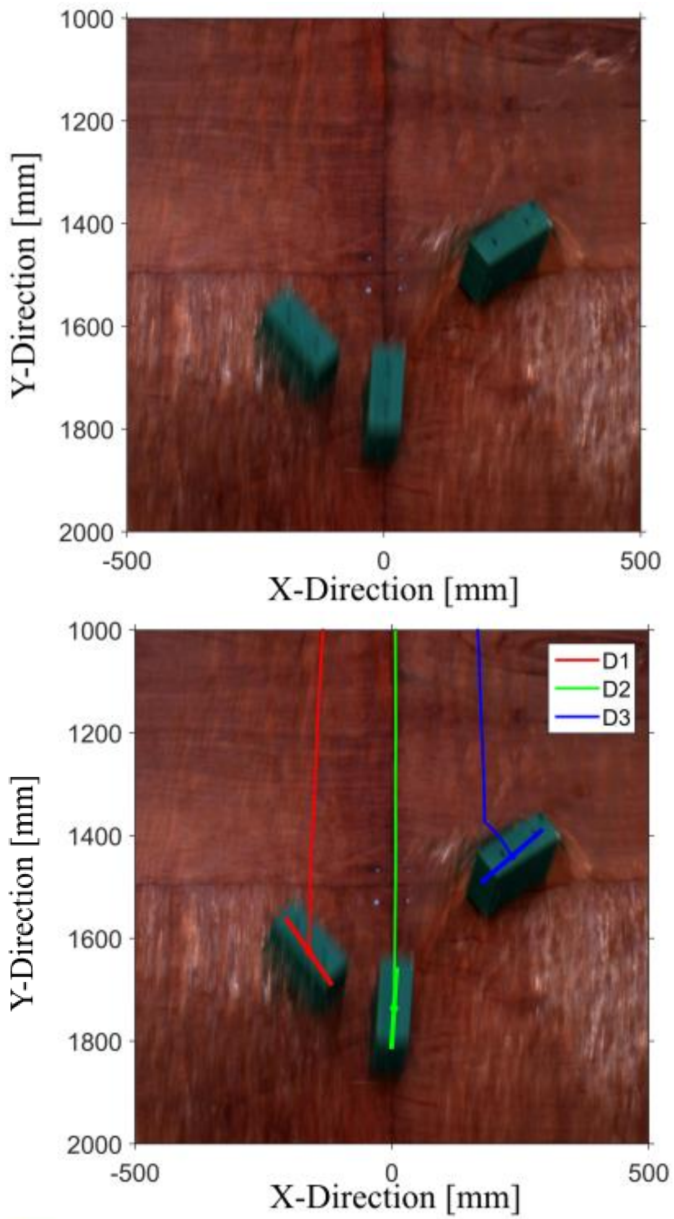
Goseberg, N., Nistor, I., Mikami, T., Shibayama, T., & Stolle, J. (2016). Nonintrusive Spatiotemporal Smart Debris Tracking in Turbulent Flows with Application to Debris-Laden Tsunami Inundation. *Journal of Hydraulic Engineering*, IAHR, 04016058.

Optical Tracking Algorithm

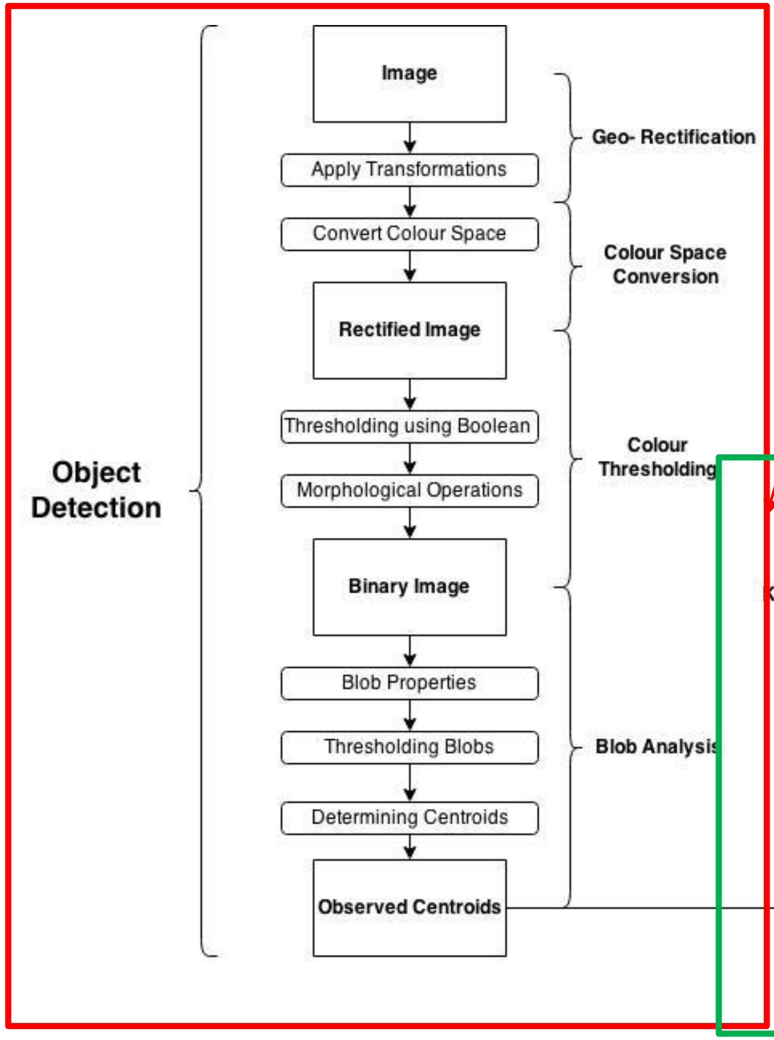
- Algorithm was implemented using open-source software:
  - Matlab
  - OpenCV (Bradski et al., 2000)

- Required to quickly and accurately (+/- 0.03 m) track the **2D (plan) position** and **orientation** of the debris throughout the AOI.

- Methods:
  - Kalman Filter
  - Hungarian Algorithm



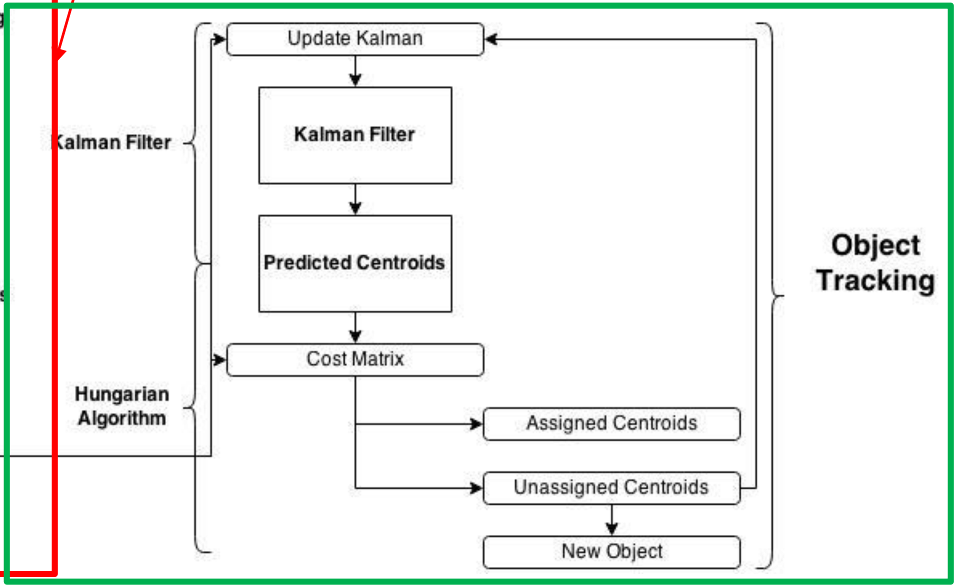
Optical Tracking Algorithm

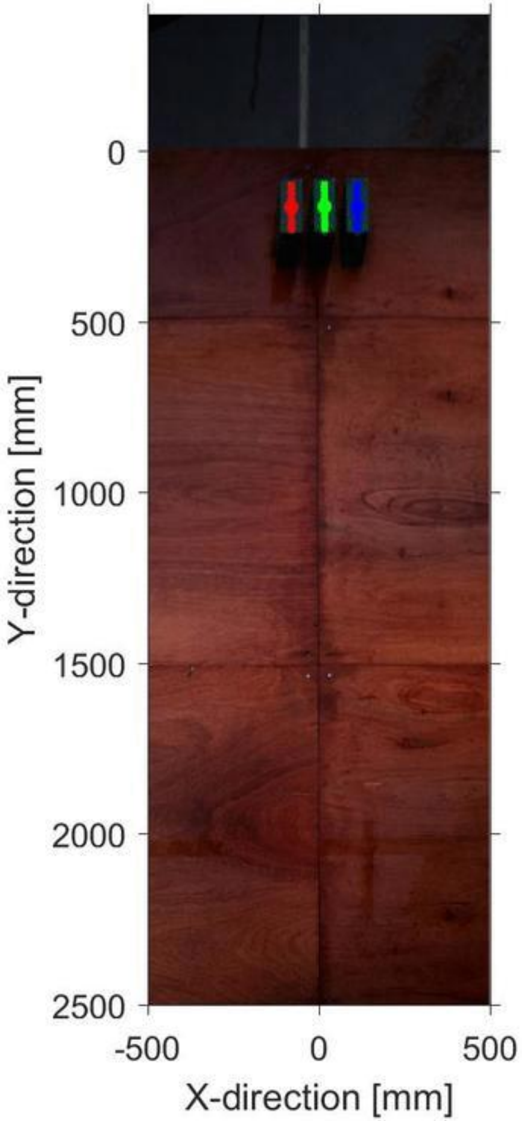


For tracking debris in the individual frame.

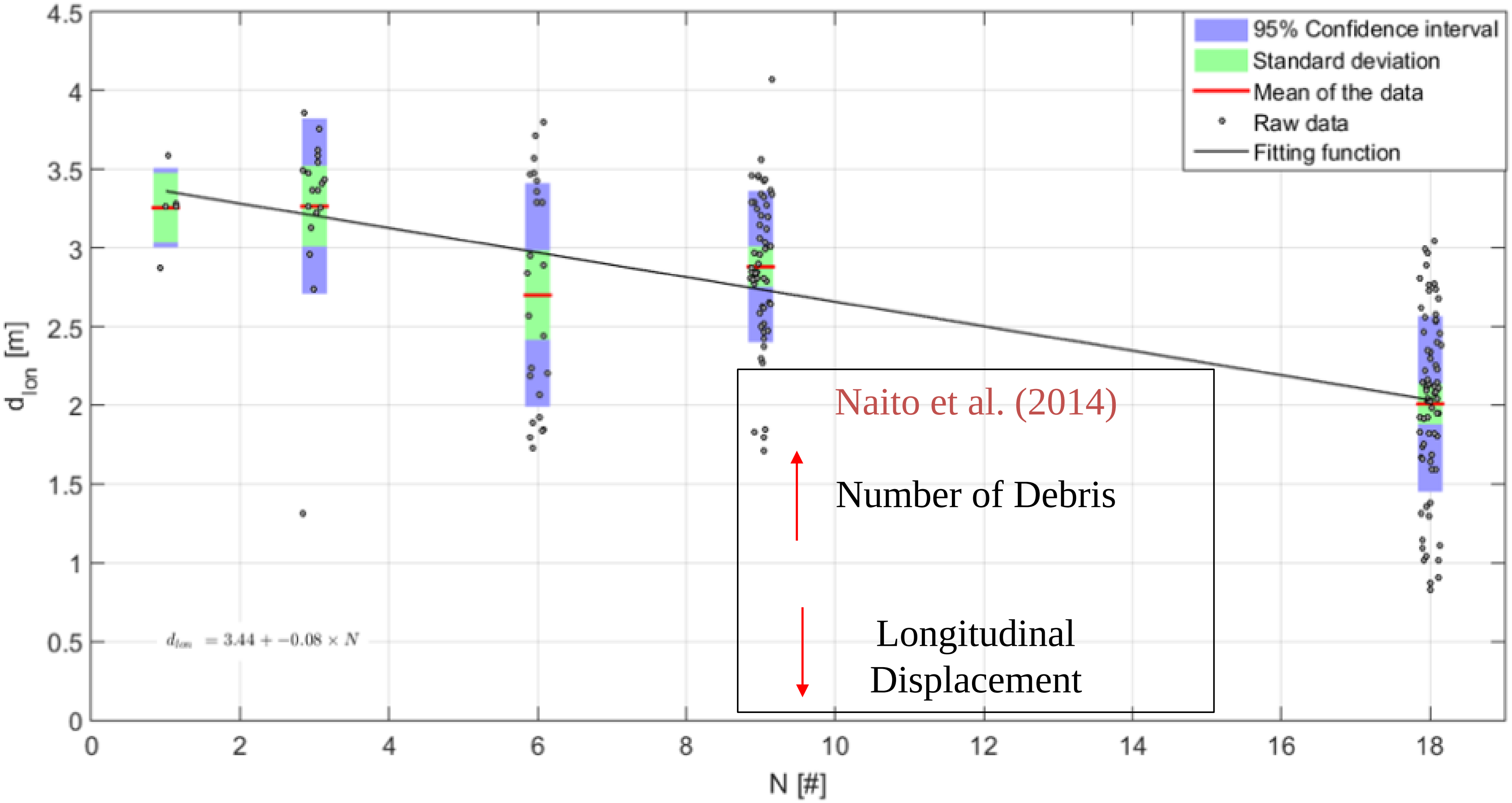
Stolle, J., Nistor, I., & Goseberg, N. (2016). Optical Tracking of Floating Shipping Containers in a High-Velocity Flow. *Coastal Engineering Journal*, JSCE 1650005.

Maintaining debris identity.

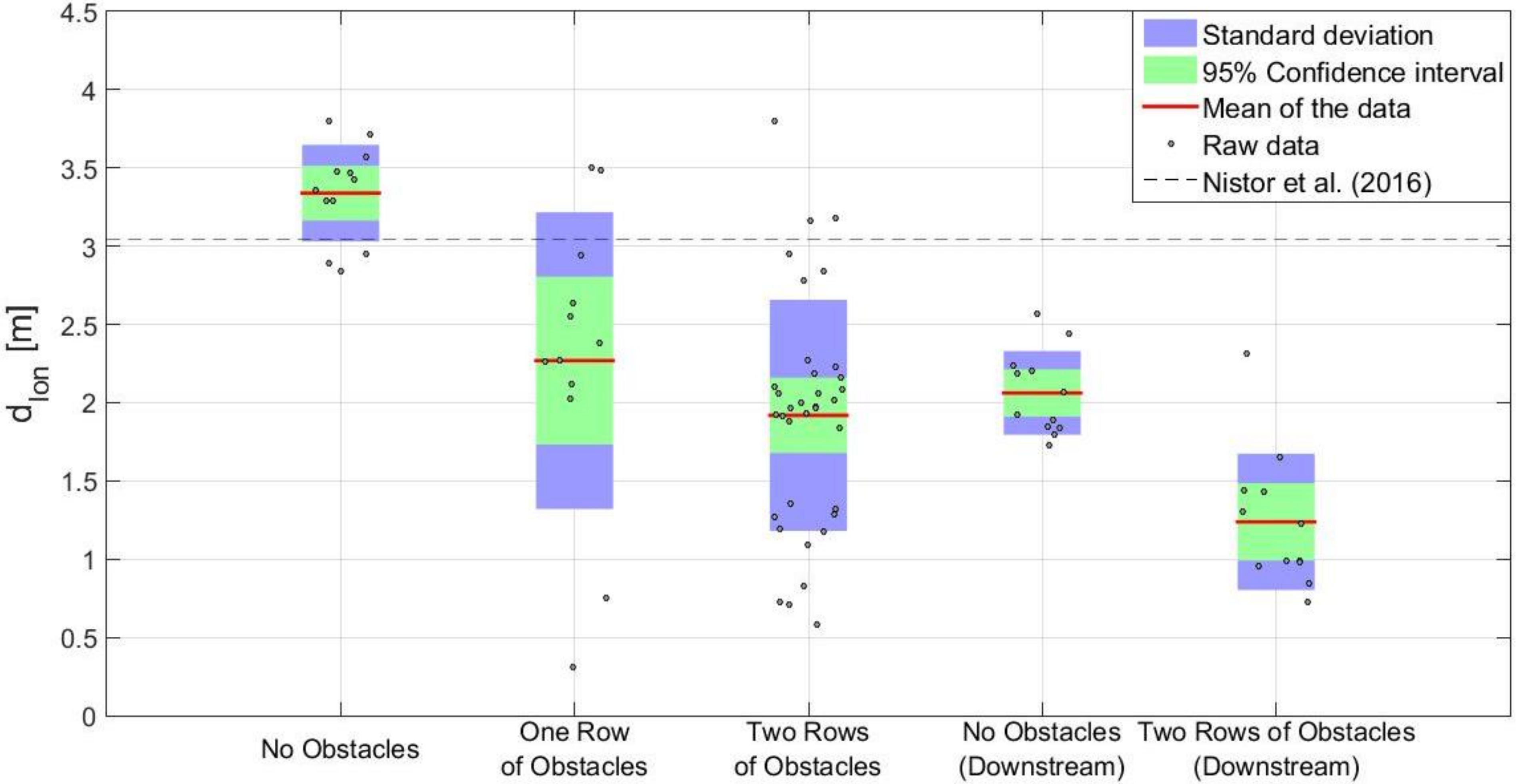




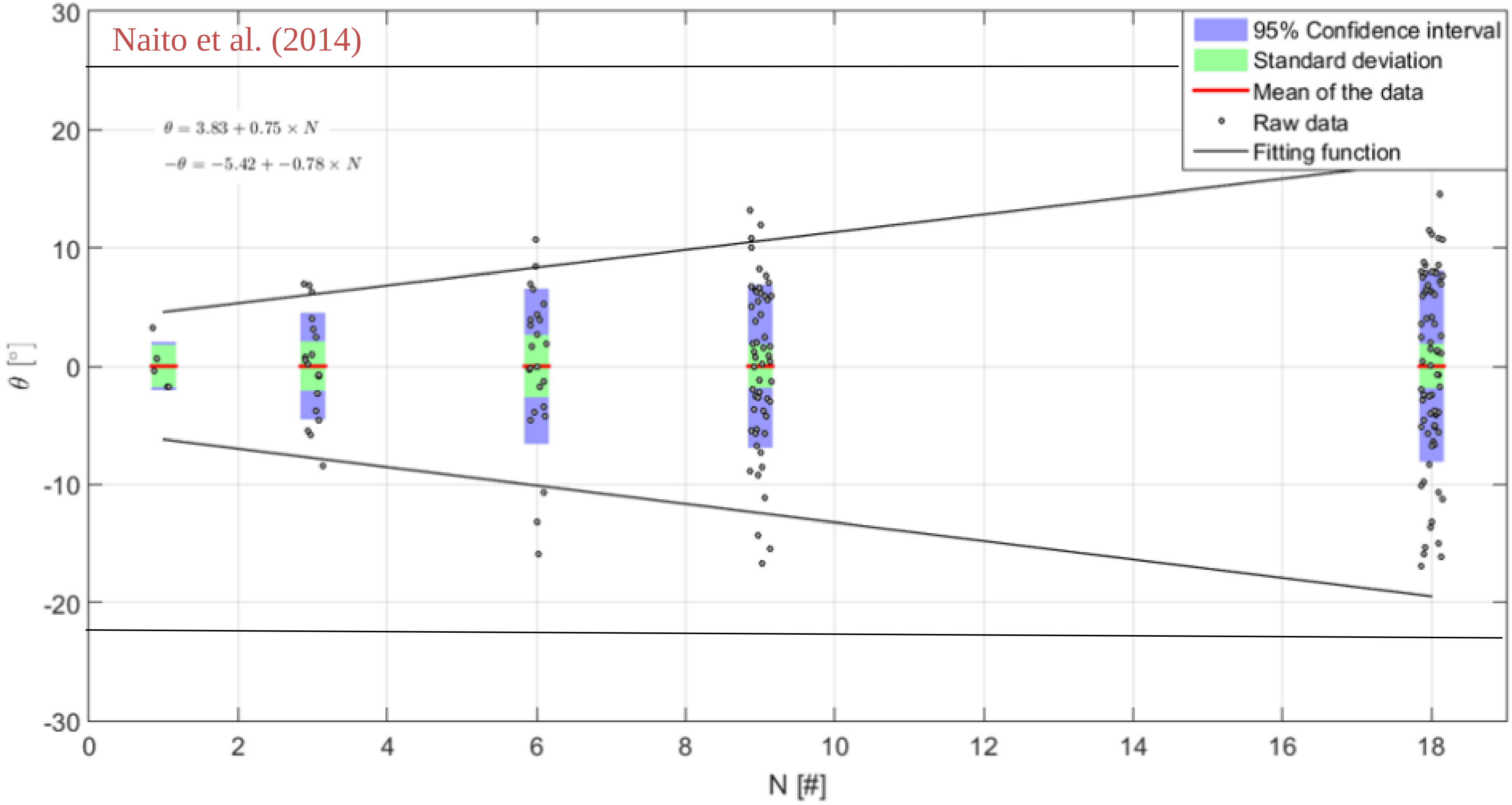
Debris Displacement



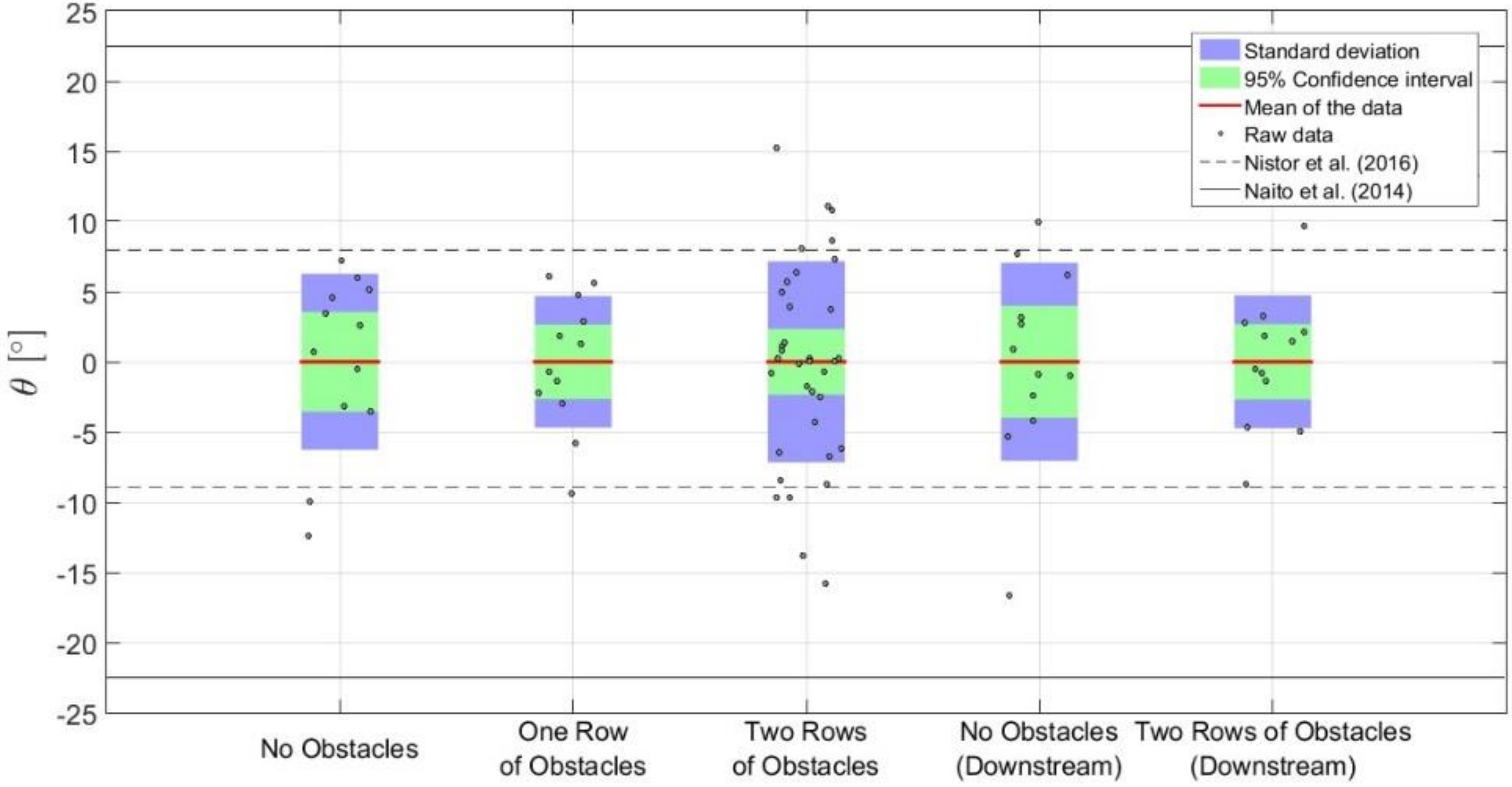
Debris Displacement



Debris Spreading



Debris Spreading



Conclusions

- Developed two methods of capturing debris motion in energetic flow conditions.
    - Video tracking algorithm had superior accuracy and fewer limitations than the sensor-based technology.

- Longitudinal displacement a function of the energy dissipation in the wave.
    - Caused by debris-debris interactions as well as flow resistance from obstacles.

- Debris spreading angle well within the ASCE7 Chapter 6 provisions.
    - Presence of obstacles had no significant influence on spreading angle.

Next Steps

- Develop a **probabilistic framework** for assessing debris transport in extreme flooding conditions.

- Improve upon current tracking techniques to expand application to the wider fields of coastal and hydraulic engineering.

- Investigate **scale effects** related to solid body transport under hydraulic forcing.

Thank you for your attention!

Ioan Nistor
University of Ottawa, Ottawa, Canada
Email: inistor@uottawa.ca

References

Chock, G.Y., (2016). Design for tsunami loads and effects in the ASCE 7-16 standard. *Journal of Structural Engineering* 04016093.

Goseberg, N., Nistor, I., Mikami, T., Shibayama, T., & Stolle, J. (2016). Nonintrusive Spatiotemporal Smart Debris Tracking in Turbulent Flows with Application to Debris-Laden Tsunami Inundation. *Journal of Hydraulic Engineering*, 04016058.

Goseberg, N., Stolle, J., Nistor, I., and Shibayama, T. (2016). Experimental Analysis of Debris Motion due the Obstruction from Fixed Obstacles. *Coastal Engineering*, 18, 35-49.

Naito, C., Cercone, C., Riggs, H. R., & Cox, D. (2014). Procedure for site assessment of the potential for tsunami debris impact. *Journal of Waterway, Port, Coastal and Ocean Engineering*, 140(2), 223–232.

Nistor, I., Goseberg, N., Mikami, T., Shibayama, T., Stolle, J., Nakamura, R., and Matsuba, S. (2016). Hydraulic Experiments on Debris Dynamics over a Horizontal Plane. *Journal of Waterway, Port, Coastal and Ocean Engineering*, 04016022.

Palermo, D., Nistor, I., Nouri, Y., Cornett, A., (2009). Tsunami loading of near-shoreline structures: a primer. *Canadian Journal of Civil Engineering* 36, 1804–1815.

Rueben, M., Cox, D., Holman, R., Shin, S., & Stanley, J. (2014). Optical Measurements of Tsunami Inundation and Debris Movement in a Large-Scale Wave Basin. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 141(1).

Stolle, J., Nistor, I., & Goseberg, N. (2016). Optical Tracking of Floating Shipping Containers in a High-Velocity Flow. *Coastal Engineering Journal*, 1650005.