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The integrated on-bottom stability analysis of offshore pipelines

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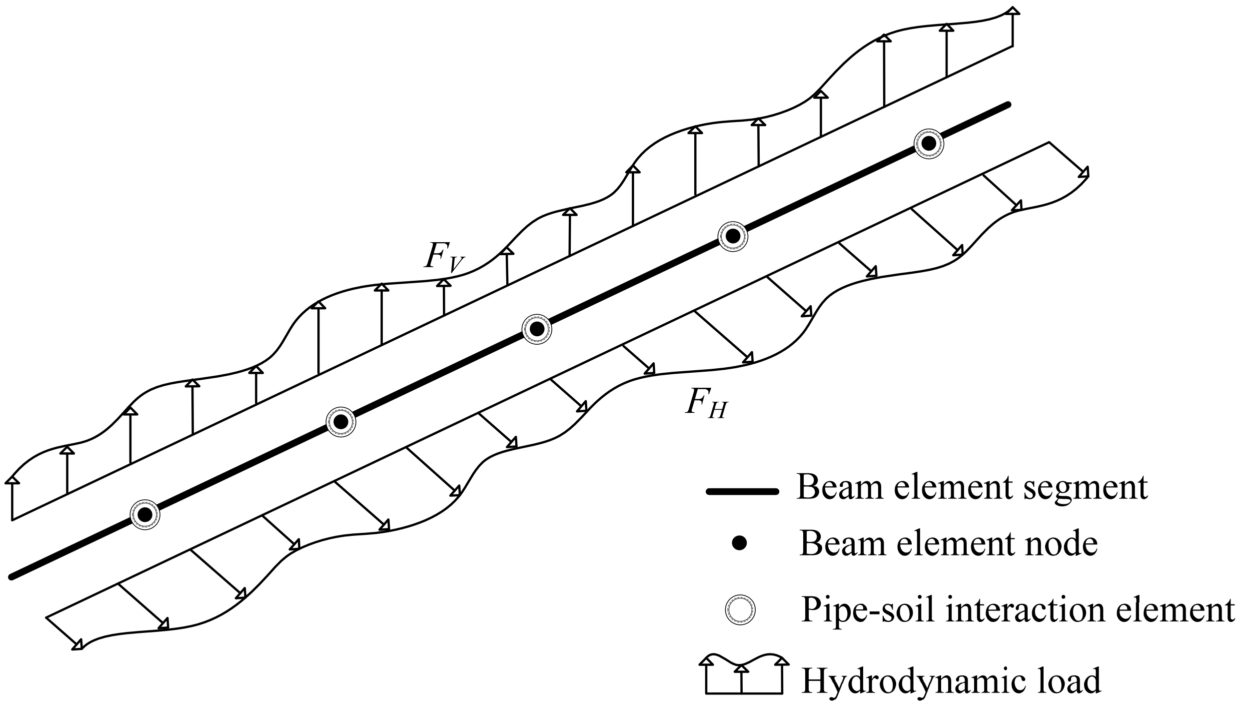
Integrated on-bottom pipeline simulation program

- Hydrodynamic load modeling *UWAHYDRO*
- Pipe-soil interaction modeling *UWAPIPE*
- Finite element analysis program *ABAQUS*

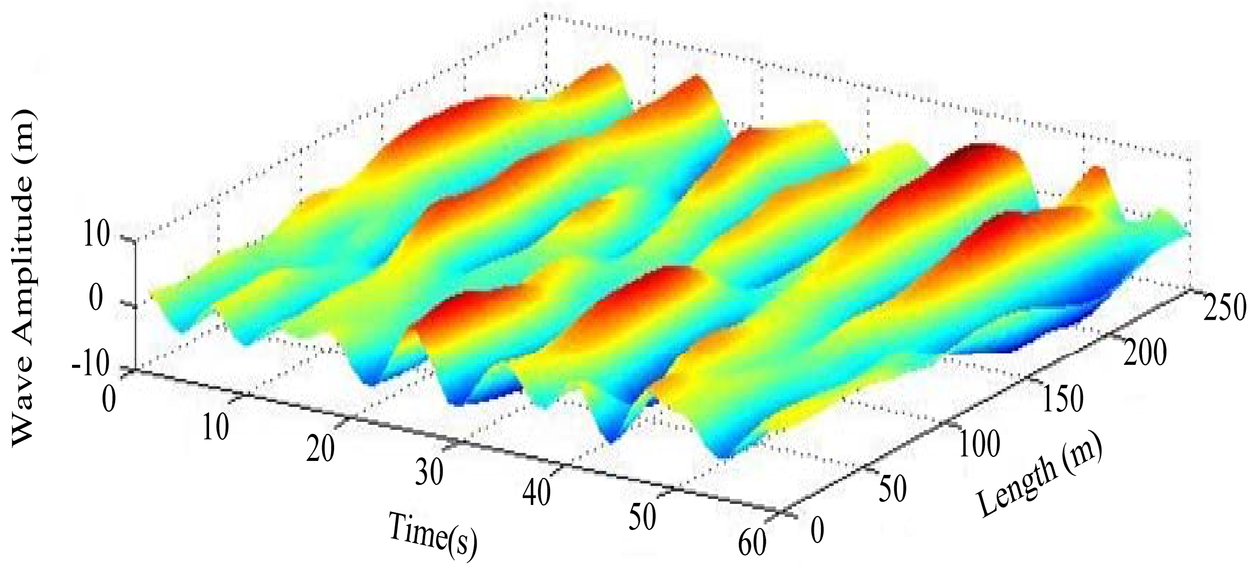


Hydrodynamic load modeling program *UWAHYDRO*

- ***(I) At the beginning of the simulation:***

1 - Developing the ocean surface

- Wave spectrum **(JONSWAP)**
- Spreading function **(ISO 19910-1)**
- Linear wave theory

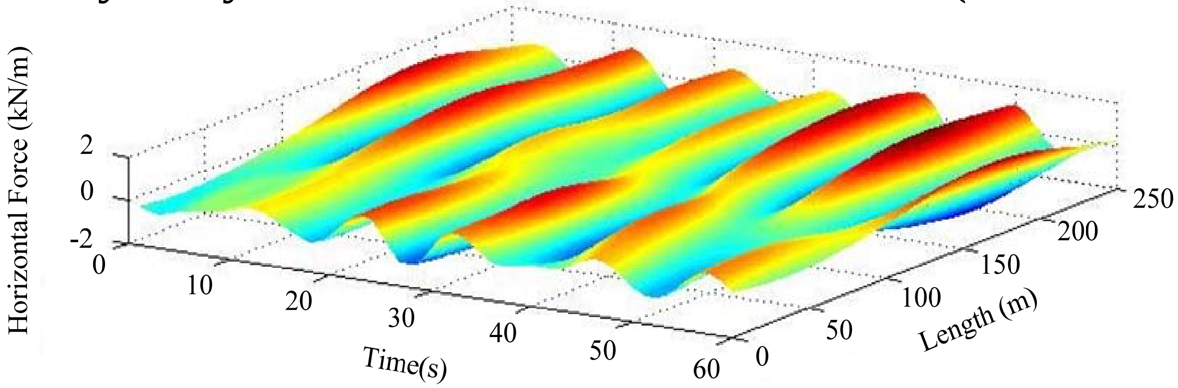


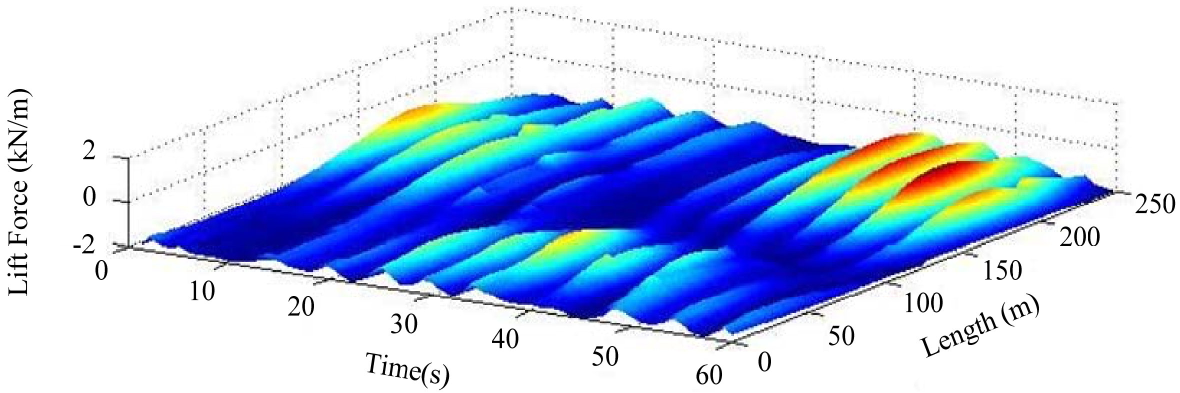
Hydrodynamic load modeling program *UWAHYDRO*

- ***(I) At the beginning of the simulation:***

  2 - Estimating the hydrodynamic forces

  - Wave kinematics at the pipeline level **(Linear wave theory)**
  - Hydrodynamic forces **(Fourier Method)**





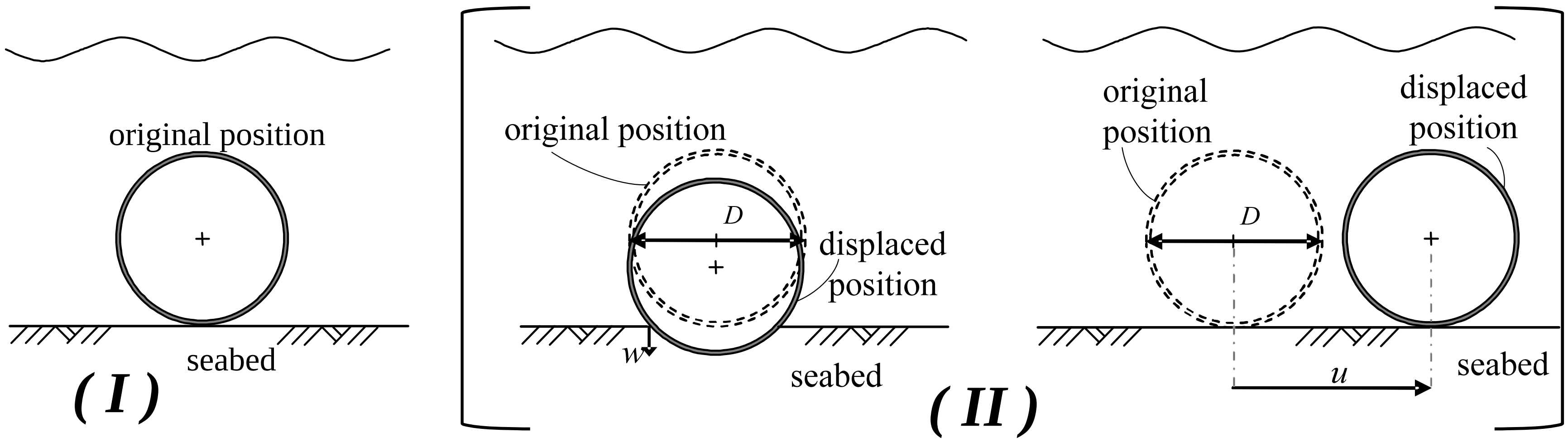
Hydrodynamic load modeling program *UWAHYDRO*

- ***(I) At the beginning of the simulation:***

  1 - Developing the ocean surface
  2 - Estimating the hydrodynamic forces

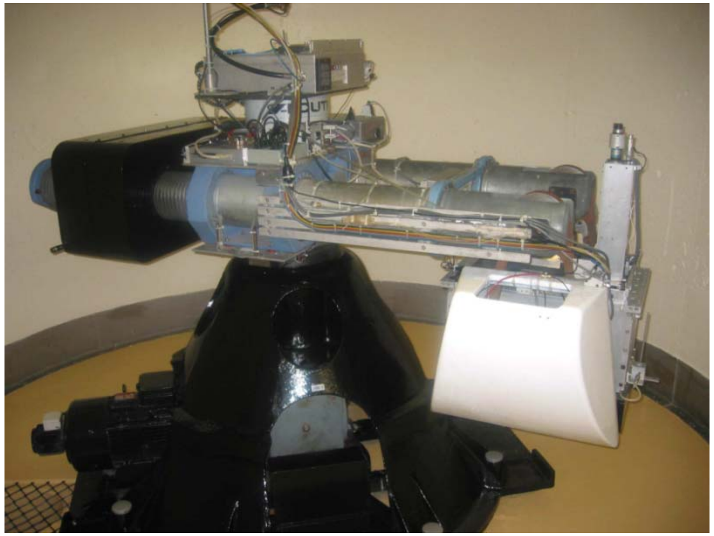
  Hydrodynamic loads will be develop the for each pipe node and will be saved as "***DataBase***" for the rest of the simulation

- ***(II) During the simulation :***
  - Update the "***DataBase***" according to the pipe displacements!!



Pipe-soil interaction modeling program *UWAPIPE*

State-of-the-art pipe-soil interaction model is developed by Zhang (2001). The model is based on centrifuge experiments of an element of prototype pipeline dimensions 1m in diameter and 8 m in length.

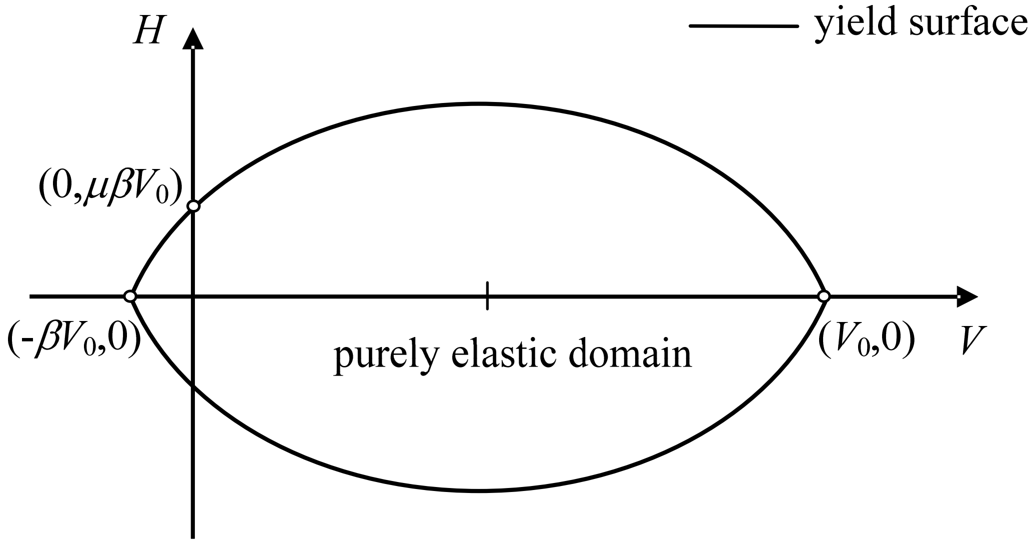


The beam centrifuge at UWA

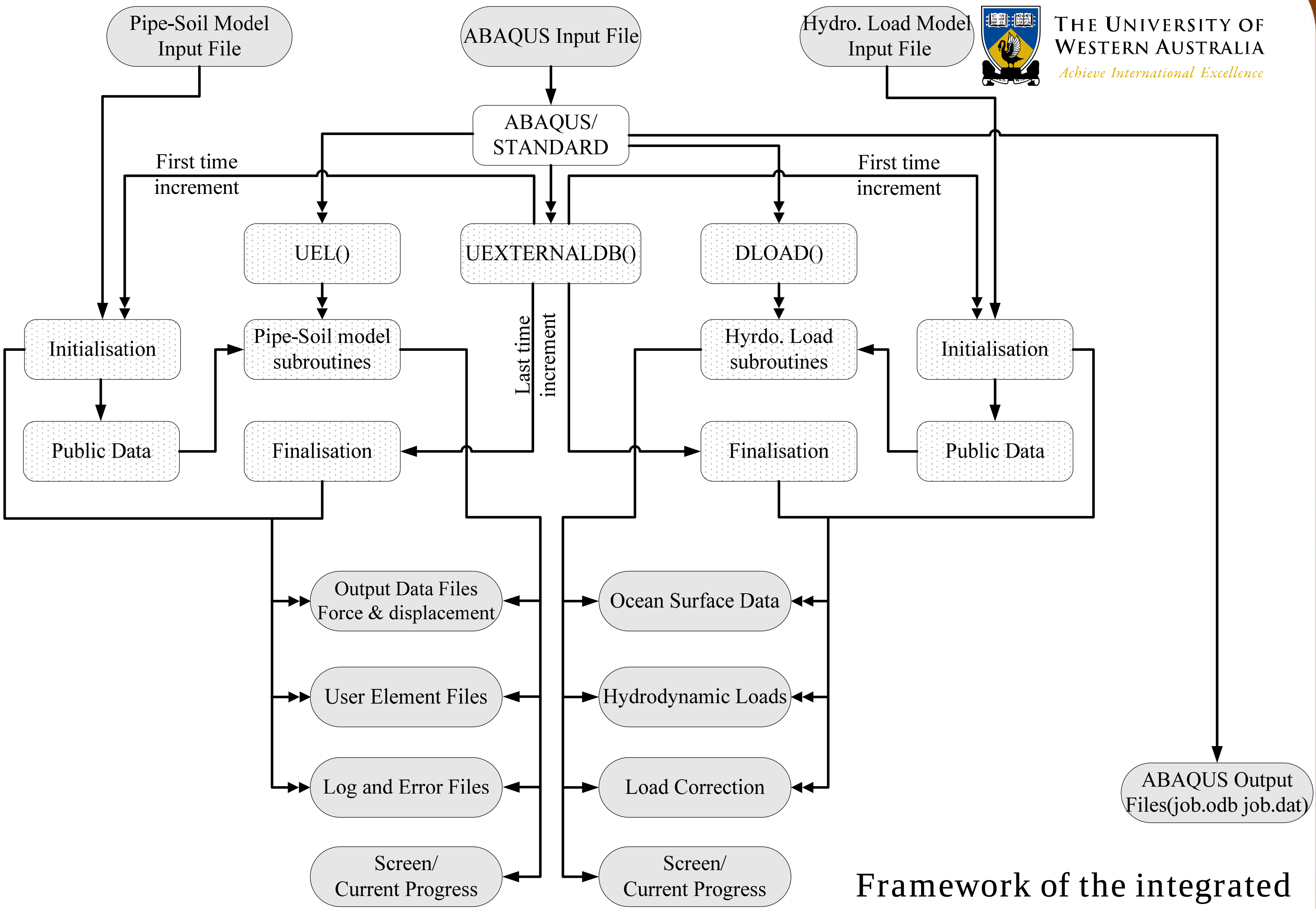
Pipe model during testing

Pipe-soil interaction modeling program *UWAPIPE*

The model uses the plasticity framework to directly relate the resultant force on a segment of pipe to the corresponding displacement.



The model formulations are coded in a computer program named UWAPIPE by Tian and Cassidy in 2008.



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Framework of the integrated pipeline simulation program

Illustrative Example

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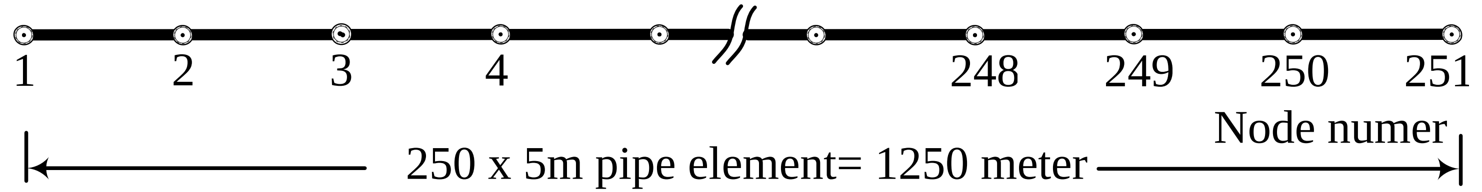
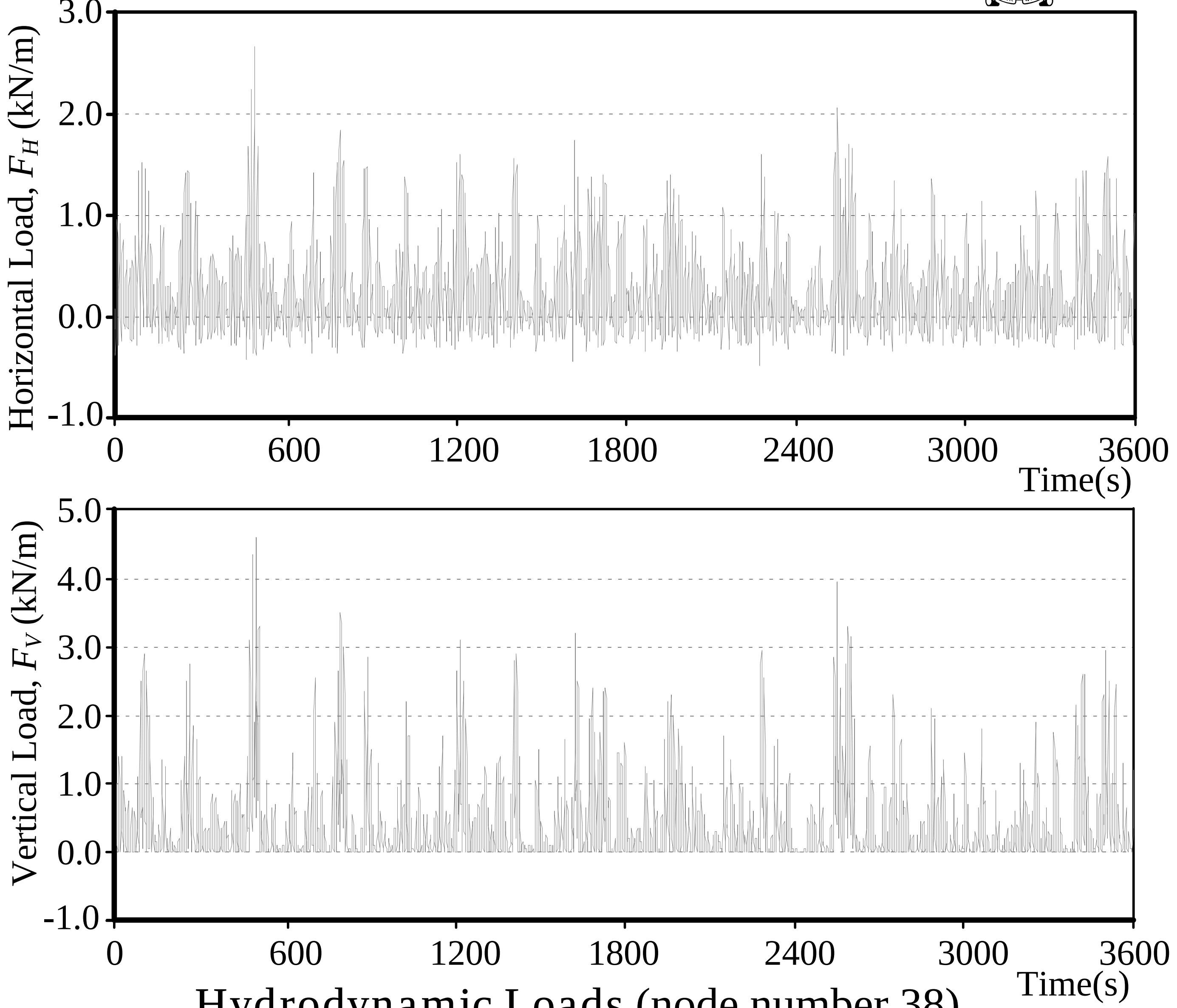
An example of pipeline simulation under 1 hour storm loading.



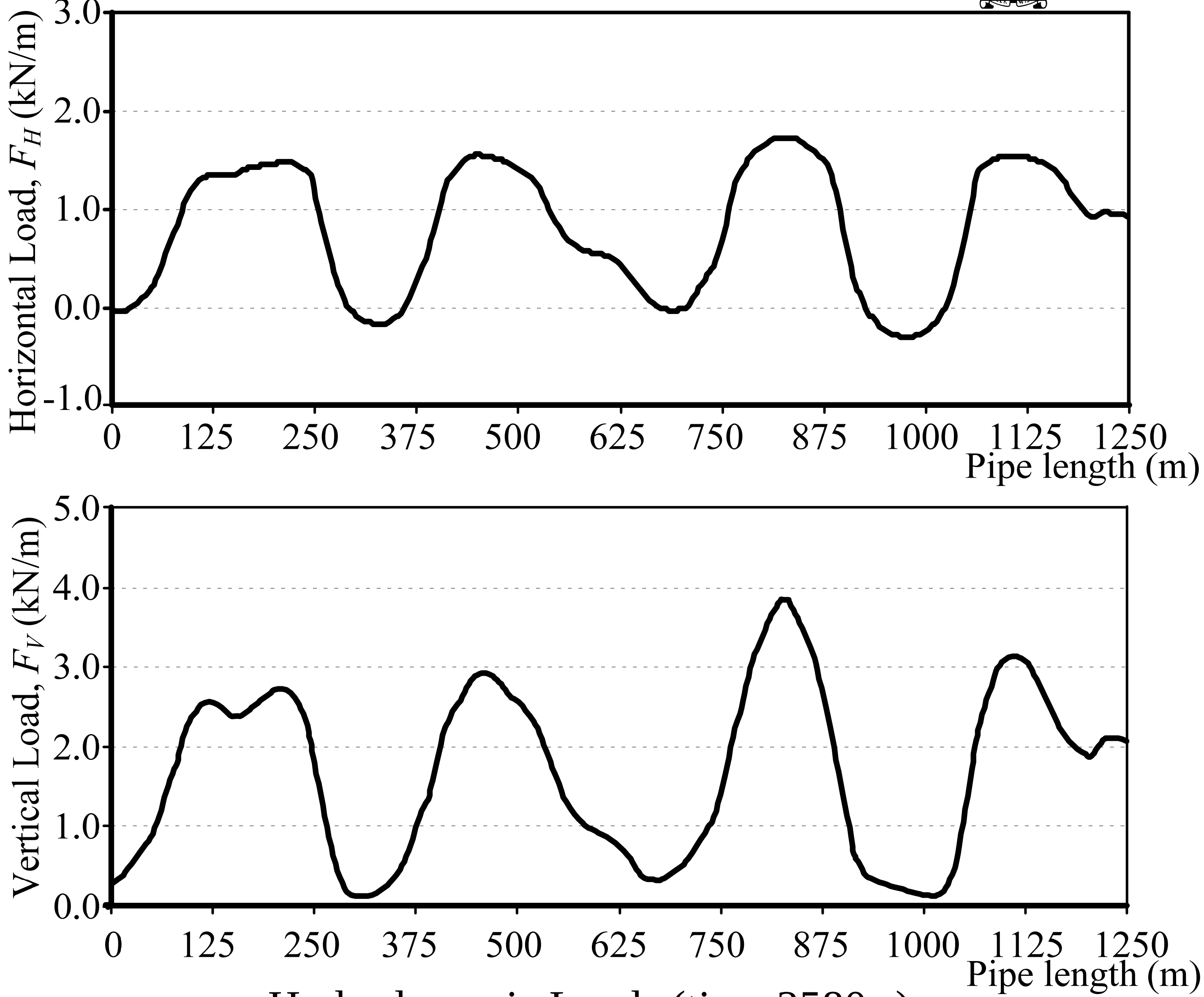
Category	Symbol	Value	Description
UWAHYDRO	H_s	12 m	Significant wave height
	T_p	10 s	Peak spectral period
	U_c	1 m/s	Current velocity
	Φ	5.43	Spreading constant
UWAPIPE	μ_o	0.40	Yield surface shape parameter
	β	0.06	Yield surface shape parameter
	m_t	0.65	Plastic potential surface shape parameter
	k_{vp}	400 kN/m/m	Plastic vertical stiffness
	k_{ve} & k_{he}	8000 kN/m/m	Elastic vertical & horizontal stiffness
Pipe	E	2.1E11 kN/m2	Young's modulus
	D	1.0 m	Pipe diameter
	t_s	0.03 m	Pipe thickness
	Ws	5.06 kN/m	Pipe self-weight

Hydrodynamic loads



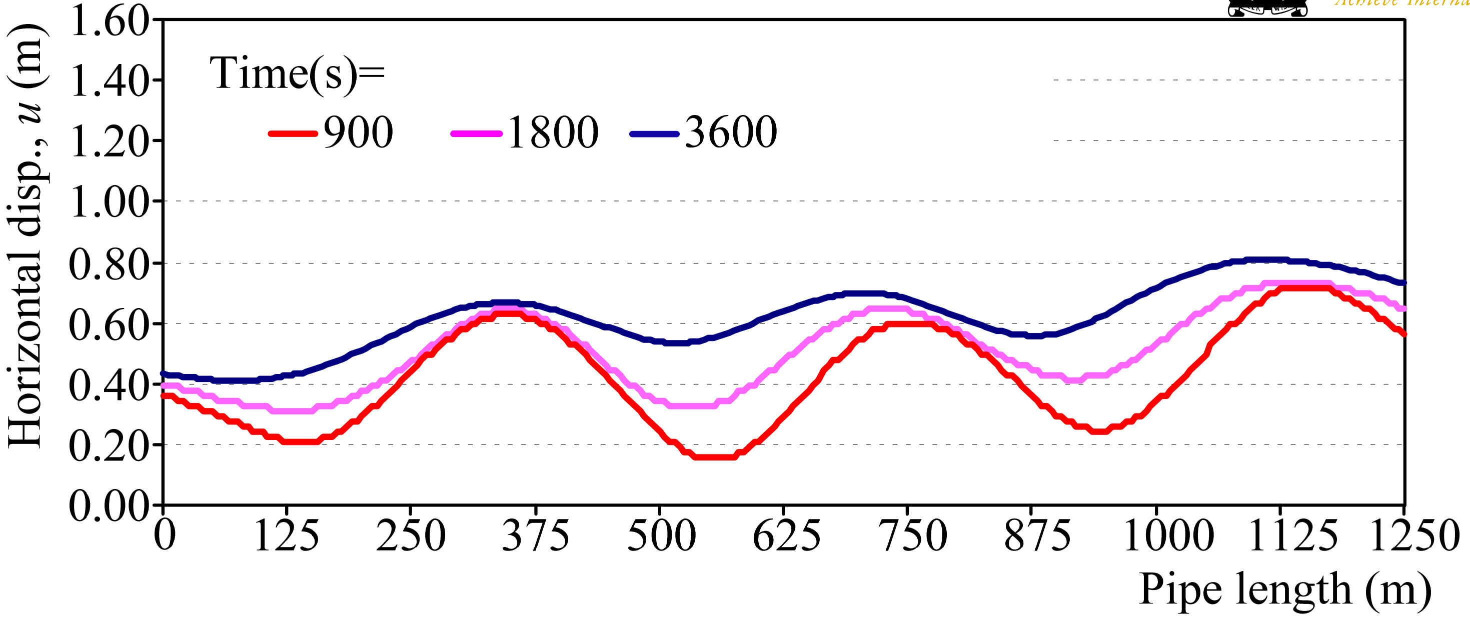
Hydrodynamic Loads (node number 38)

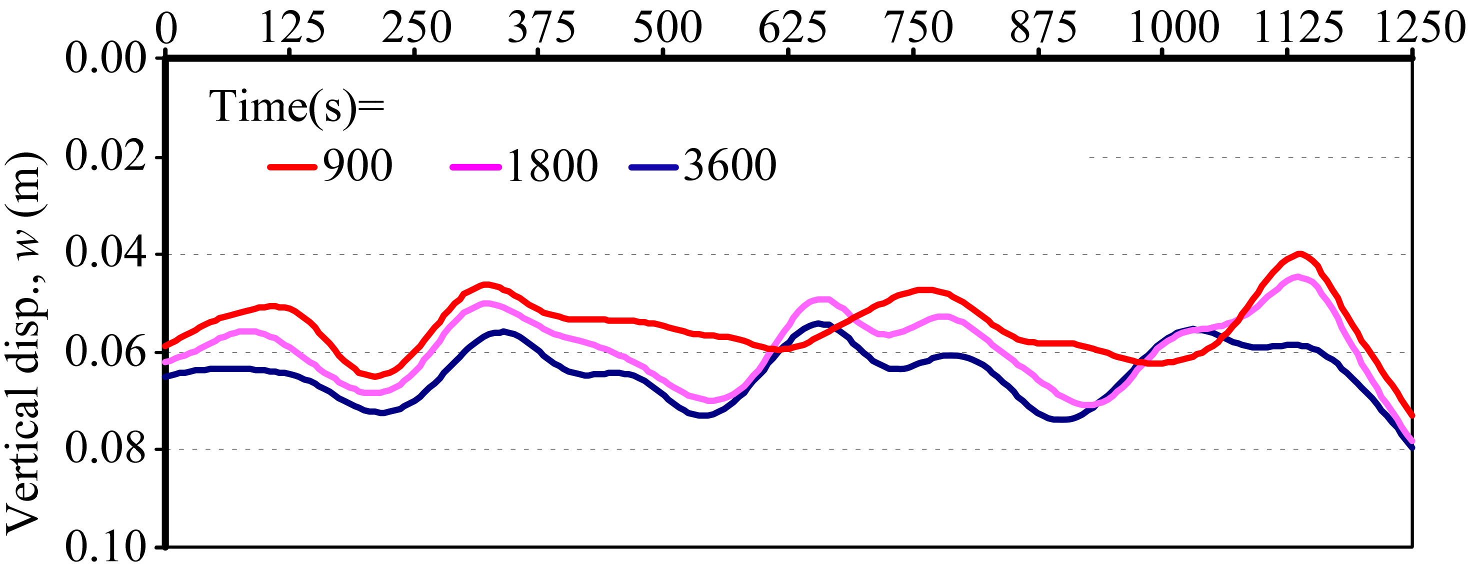
Hydrodynamic loads, cont.



Hydrodynamic Loads (time 2580 s)

Pipeline displacement results





Comparing the results with/without PME with/without updating the "***DataBase***"

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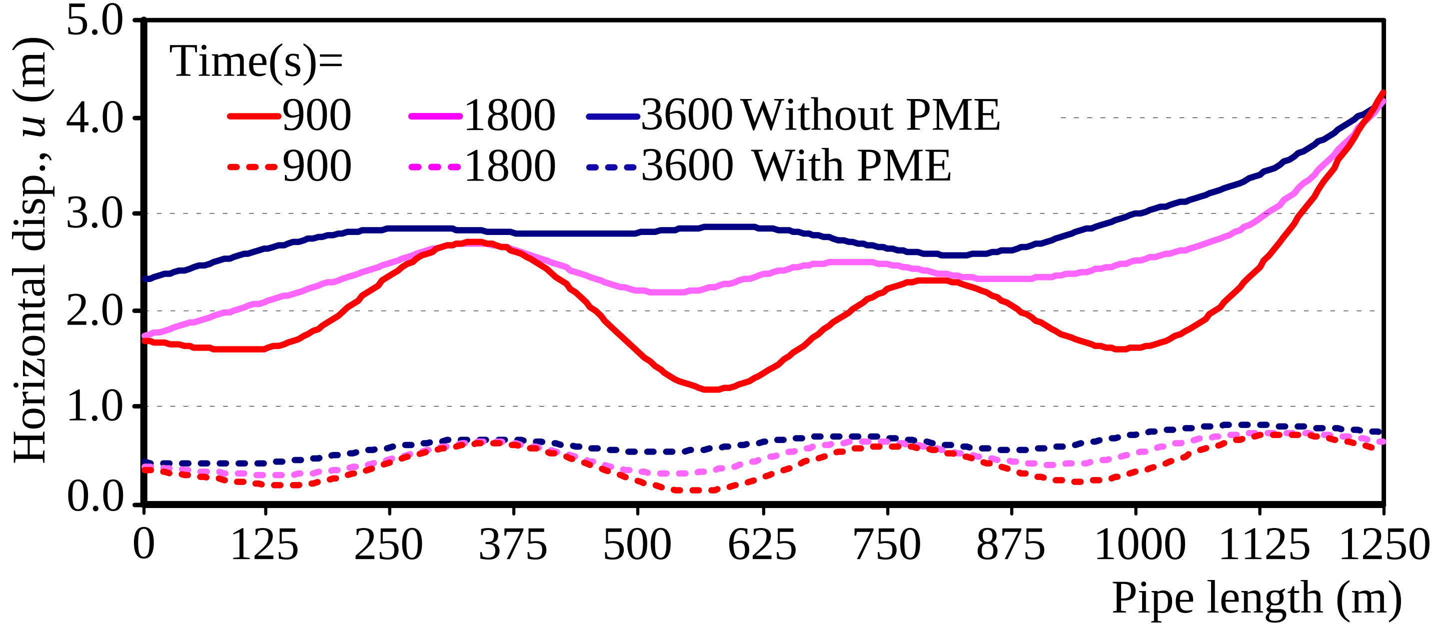

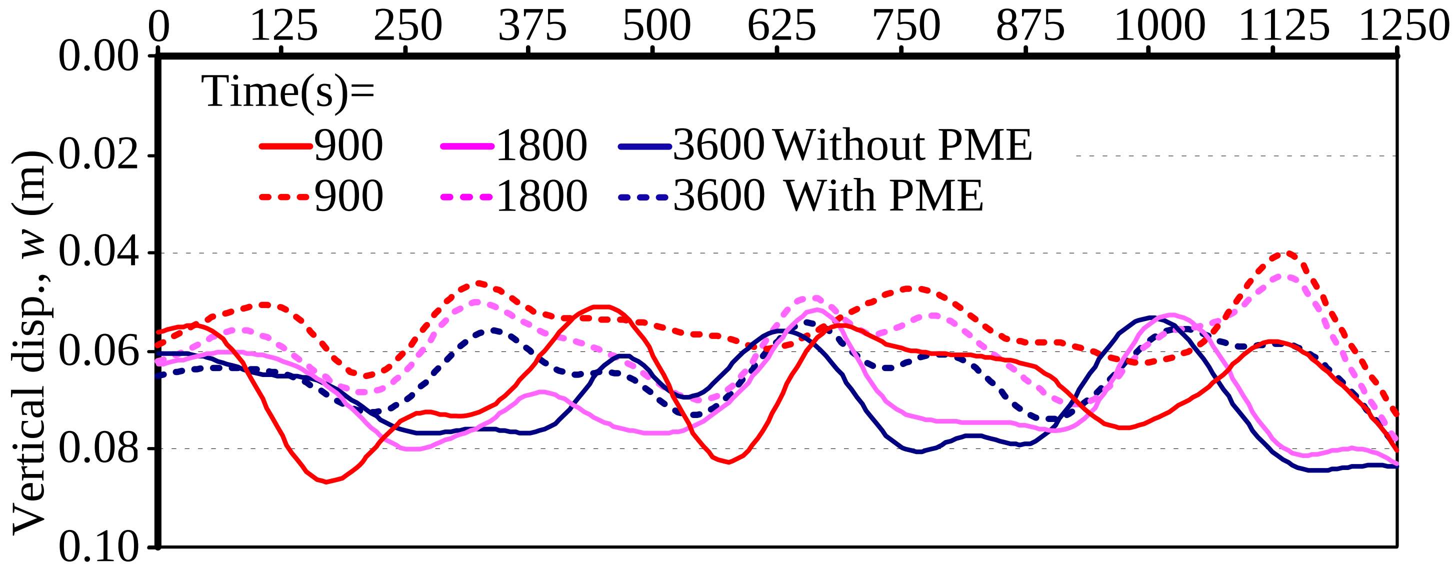

Illustration of the hydrodynamic reduction

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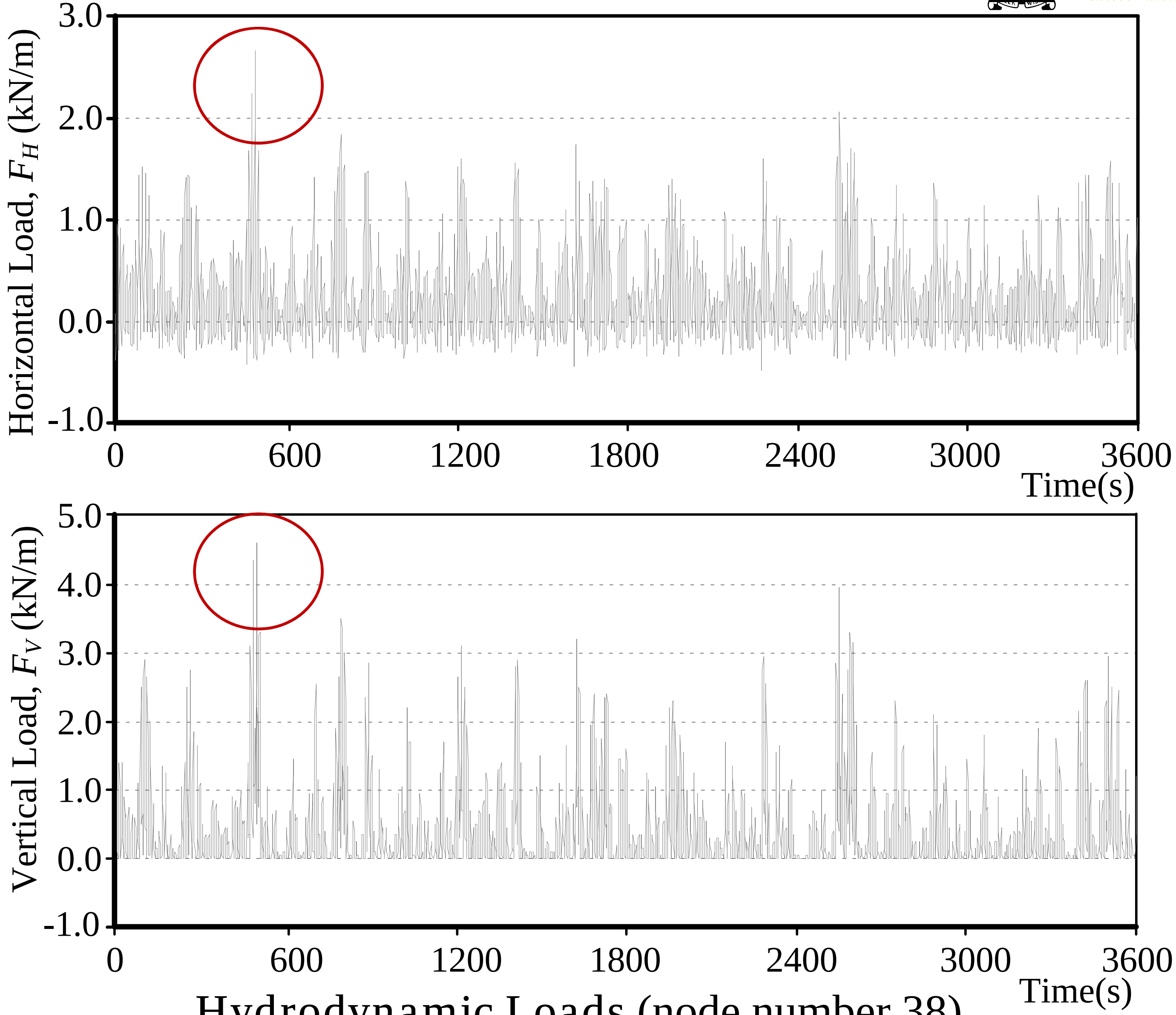
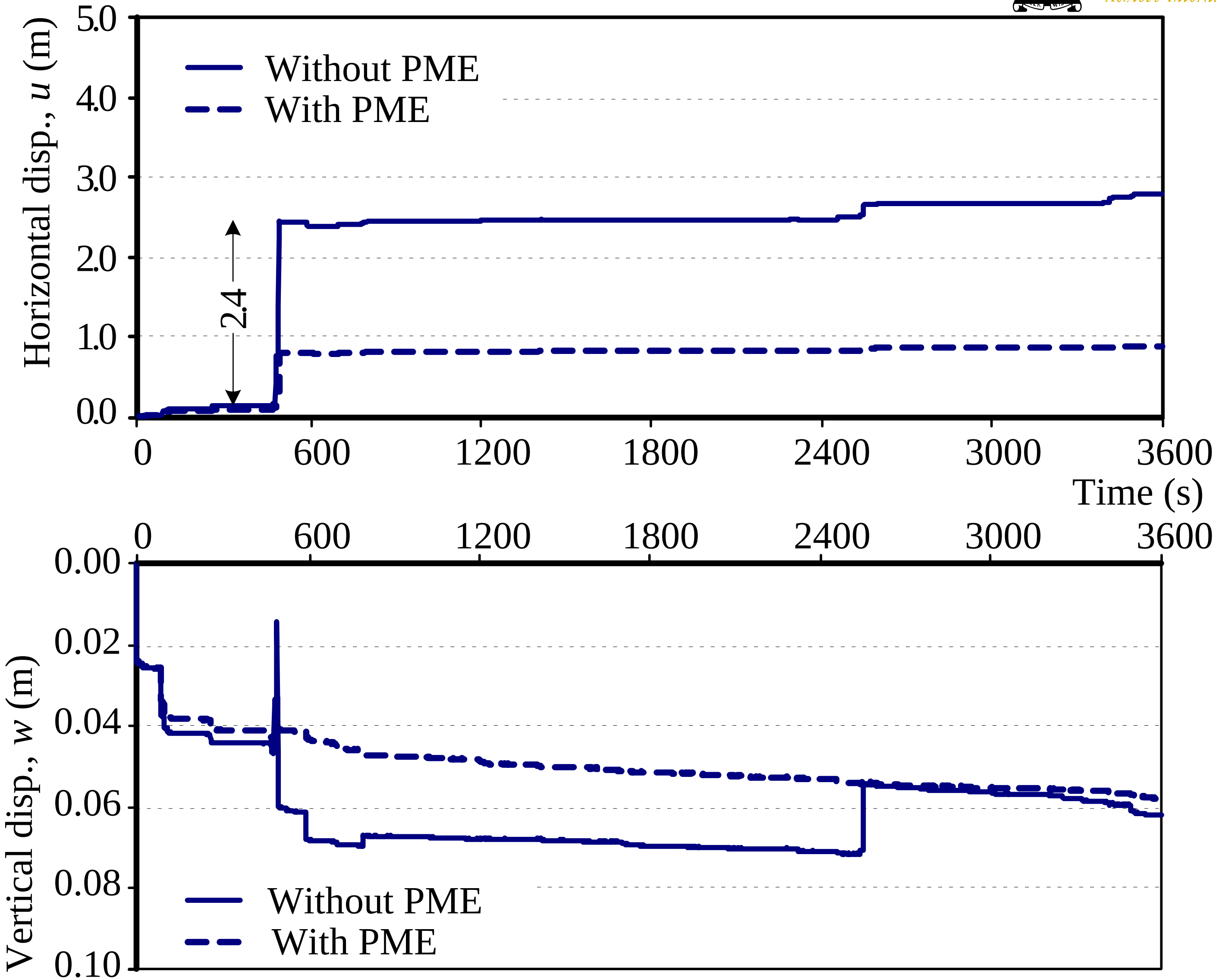


Hydrodynamic Loads (node number 38)

Pipeline displacements of node number 38



Conclusions

- The developed pipeline simulation program accounts for
  - An accurate hydrodynamic modeling
  - An advanced pipe-soil interaction modeling
  - The coupling effect between the hydrodynamic load model and the pipe-soil interaction model

Future studies

- Parametric study of the input parameters used in the pipeline simulations
- Deterministic and statistical analysis of pipeline stability in the NWS region
- Assessment of a displaced pipeline in the GOM after hurricane IVAN 2004

References

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The hydrodynamic model

[1] Sorenson, T., Bryndum, M., and Jacobsen, V. (1986). "Hydrodynamic Forces on Pipelines- Model Tests." Danish hydraulic Institute (DHI), Contract PR-170-185. Pipeline Research Council.

[2] Youssef, B. S., Cassidy, M. J., and Tian, Y. (2009a). "Implementing 3D Hydrodynamic Forces into Integrated Pipeline Analysis–UWAHYDRO." Research Report No. C:2521, COFS, University of Western Australia, Perth.

[3] Youssef, B. S., Cassidy, M. J., and Tian, Y. (2009b). "Numerical Modelling of Hydrodynamic Forces." Research Report No. C:2520, COFS, University of Western Australia, Perth.

The pipe-soil model

[1] Tian, Y., and Cassidy, M. J. (2008). "Modelling of Pipe-Soil Interaction and Its Application in Numerical Simulation." The International Journal of Geomechanics, 8(4), 213-229.

[2] Tian, Y., and Cassidy, M. J. (2009). "UWAPIPE Verification Example Manual." Centre for Offshore Foundation System, University of Western Australia, Perth.

[3] Zhang, J. (2001). "Geotechnical stability of offshore pipelines in calcareous sand." Thesis (Ph.D.), University of Western Australia.

The developed program and further studies

[1] Tian, Y., Cassidy, M. J., and Youssef, B. S. (2010). "Consideration for on-bottom stability of unburied pipelines using force-resultant models." Proc. 20th International Offshore (Ocean) and Polar Engineering Conference, Beijing, China.

[2] Youssef, B. S., Cassidy, M. J., and Tian, Y. (2010). "Balanced Three-Dimensional Modelling of the Fluid-Structure-Soil Interaction of an Untrenched Pipeline." Proc. 20th International Offshore (Ocean) and Polar Engineering Conference, Beijing, China.

[3] Youssef, B. S., Cassidy, M. J., and Tian, Y. (2011). "Probabilistic Model Application in the Integrated Stability Analysis of Offshore On-Bottom Pipeline." Proceedings of the 30th International Conference on Ocean, Offshore and Arctic Engineering, Rotterdam, The Netherlands.