Numerical studies on multiphase flow in tsunami with oil spill in Osaka bay

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Background

•In 2011, Tohoku earthquake, the tsunami induced run up and back wash water caused movement of oil tanks and oil spill in Kesennuma Port and Ofunato cement plant.

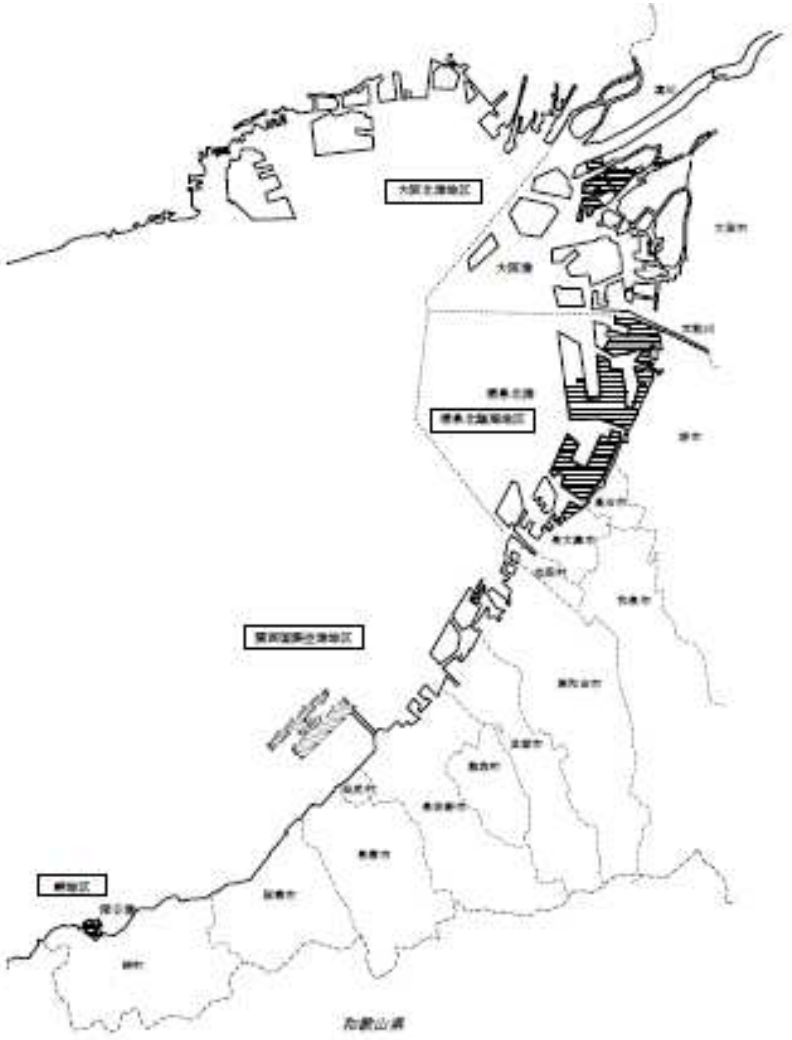
•11523 kiloliters of oil, mainly heavy oil as well as light oil and gasoline, was estimated

•It had been found that if the height of the tsunami inundation is between 2.5 to 5 meters, the pipes start to burst, and when the inundation rises above 5 meters, the main body of the tank suffers damage as well.

Risk management in Osaka Bay Area for Oil Spill

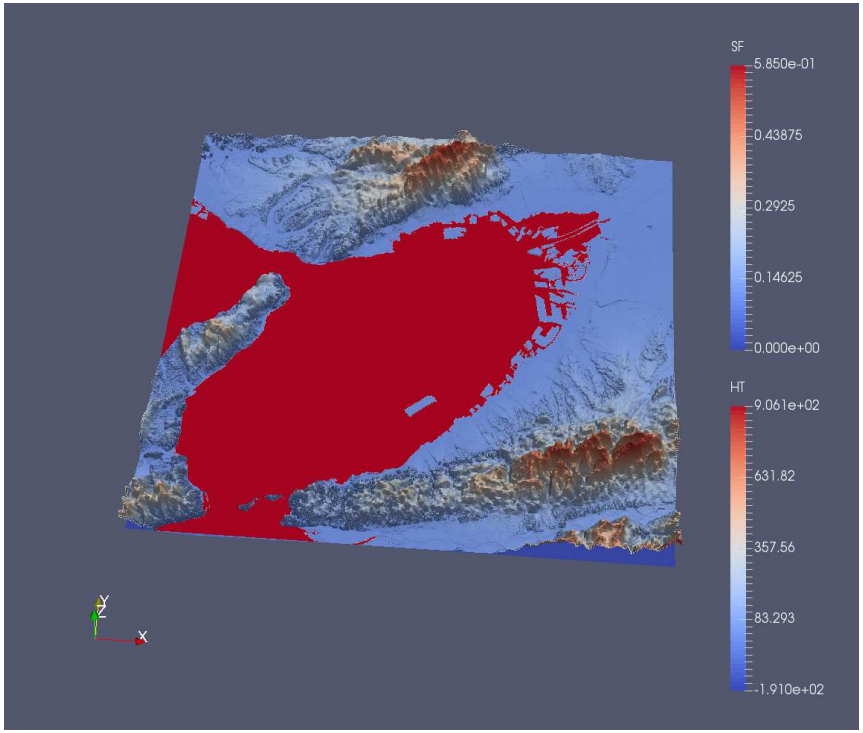
Risk analyses of earthquake-oriented and tsunami- oriented damages of oil and gas storages are needed in industrial parks along Osaka Bay.

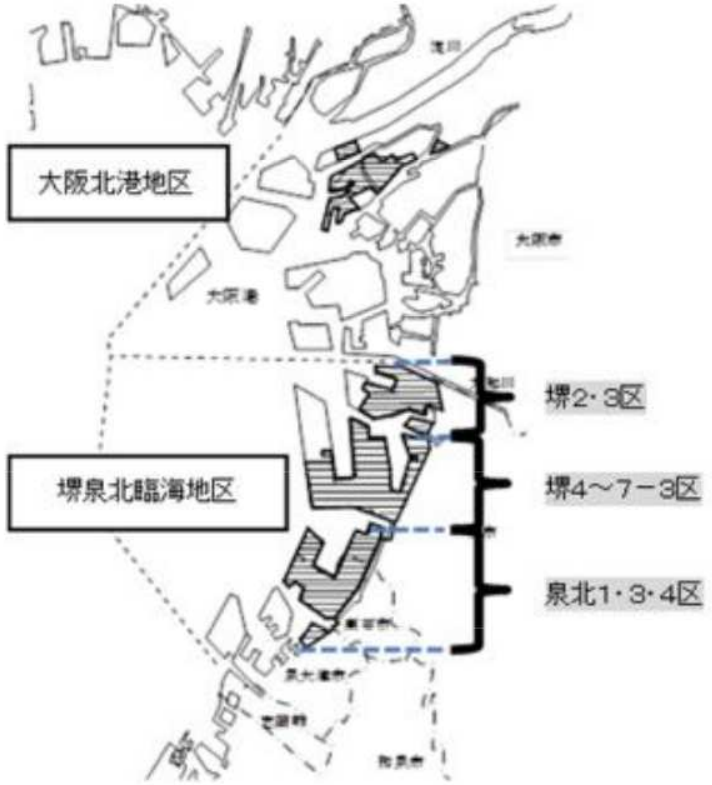
There also is a potential for Nankai Trough earthquake which can bare a seismic intensity of 6 or smaller at Osaka Prefecture and can promote a tsunami with maximum wave height of 6 meters along the coastal line of Osaka Bay



OBJECTIVE

The objective of this research is to investigate the distribution of oil spill along the shore if tsunami of high impact hits the industrial parks, which includes infrastructures for the storage of oil and gas, in Osaka Bay area. The extent of the distribution of oil spill will be estimated both inland and offshore, around the Sakai Senboku industrial park in Osaka Bay.





※ 堺泉北臨海地区については、上記の３地区に分割して資料を整理。

The amount of potential spill out oil in case of Tsunami estimated by

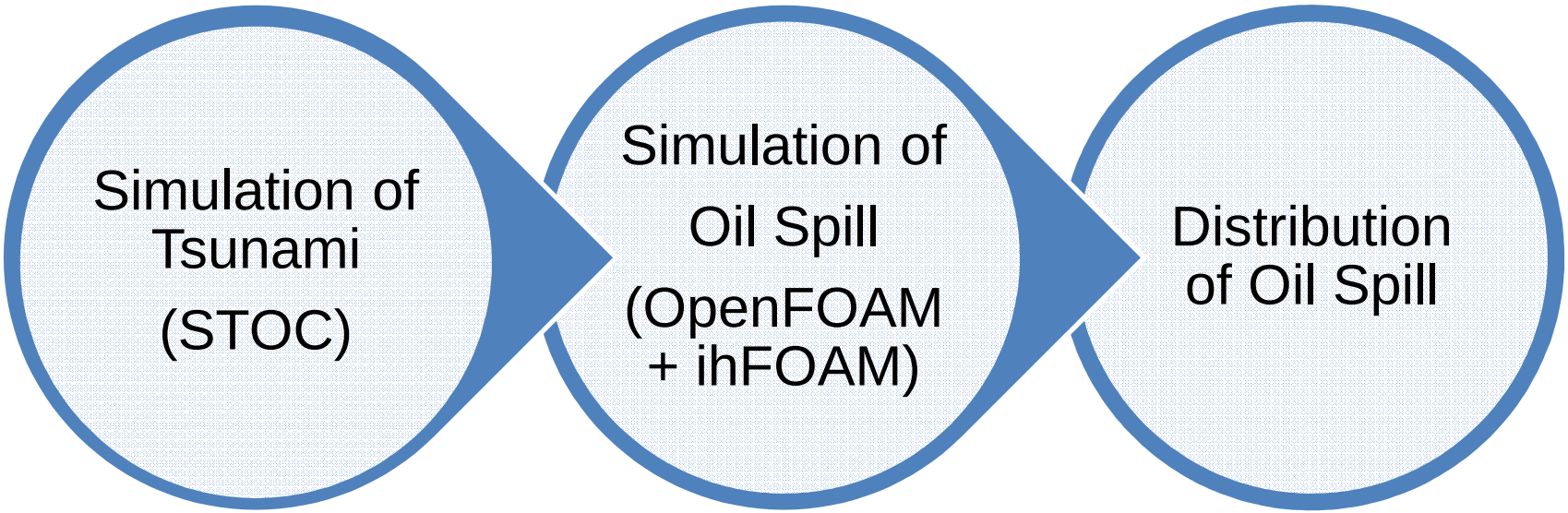
【石油類別の最大流出量】

特防区域名		浸水状況（m）	危険物第4類の区分	タンク数（基）割合（%）	最大流出量（kL）（割合（%））
大阪北港		0.3～5.0	第1石油類	85（40.4%）	4,823（17.7%）
			第2石油類	68（32.4%）	8,045（29.5%）
			第3・4石油類	57（27.2%）	14,359（52.7%）
			小計	210（100%）	27,227（100%）
堺泉北臨海	堺2、3区	0～2.0	第1石油類	0（0%）	0（-）
			第2石油類	2（100%）	23（100%）
			第3・4石油類	0（0%）	0（-）
			小計	2（100%）	23（100%）
	堺4～7－3区	0～2.0	第1石油類	15（22.7%）	440（27.0%）
			第2石油類	18（27.3%）	405（24.8%）
			第3・4石油類	33（50.0%）	786（48.2%）
			小計	66（100%）	1,631（100%）
	泉北1、3、4区	0～2.0	第1石油類	37（22.8%）	357（11.2%）
			第2石油類	32（19.8%）	327（10.3%）
			第3・4石油類	93（60.4%）	2,500（78.5%）
			小計	162（100%）	3,184（100%）
	堺泉北臨海中計		第1石油類	52（22.6%）	797（16.5%）
			第2石油類	52（22.6%）	755（15.6%）
			第3・4石油類	126（54.8%）	3,286（67.9%）
			小計	230（100%）	4,838（100%）
関西国際空港		0～0.3			
岬		浸水しない			
合　計			第1石油類	137（31.1%）	5,620（17.5%）
			第2石油類	120（27.3%）	8,800（27.4%）
			第3・4石油類	183（41.6%）	17,645（55.0%）
			小計	440（100%）	32,065（100%）

Reference: : The 1st Report of Working Group on Estimation of Damage by Earthquake and Tsunami issued by Osaka Prefecture in February, 2014

METHODS

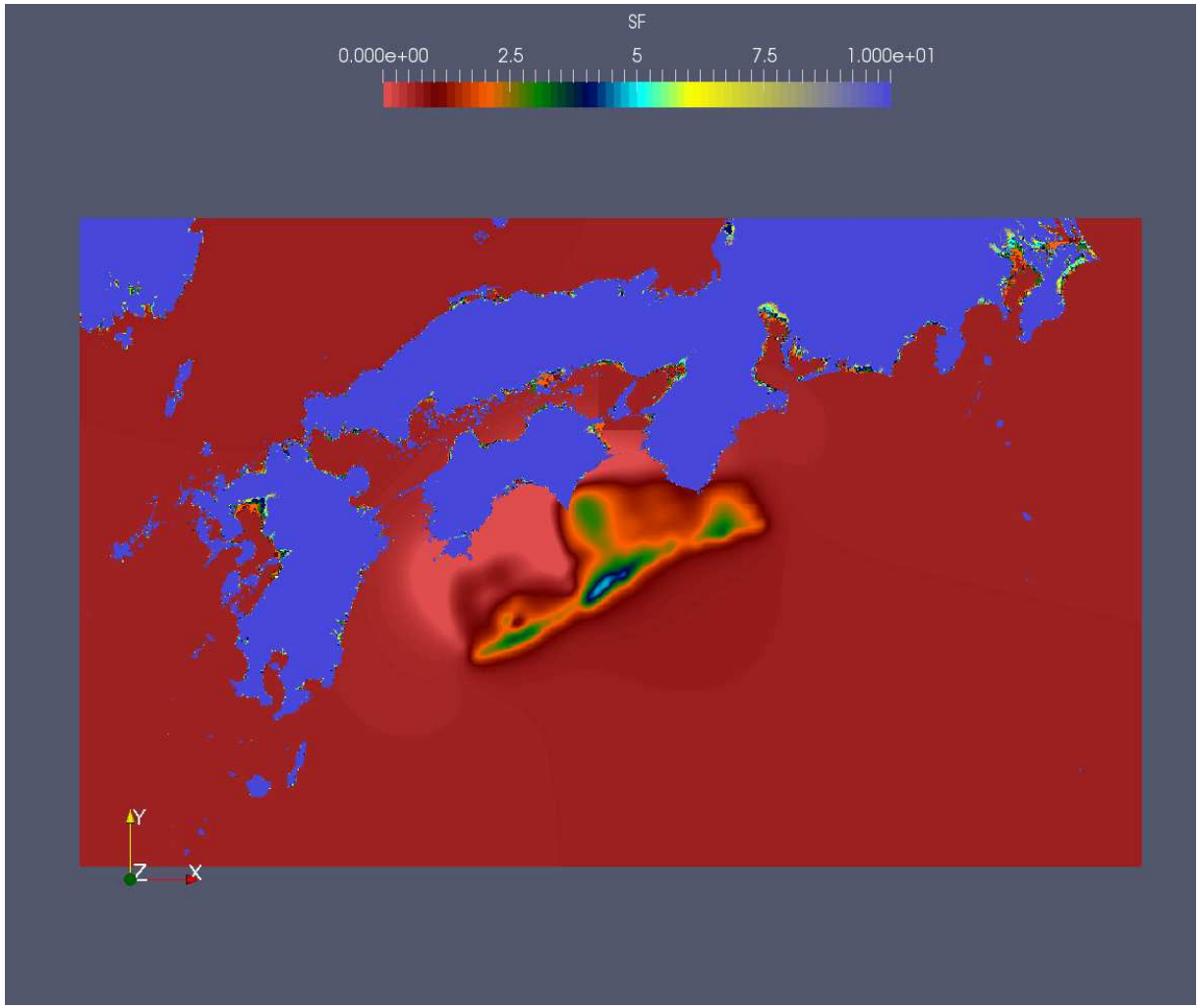
Overview of Simulation Procedure



METHODS

Simulation of Tsunami

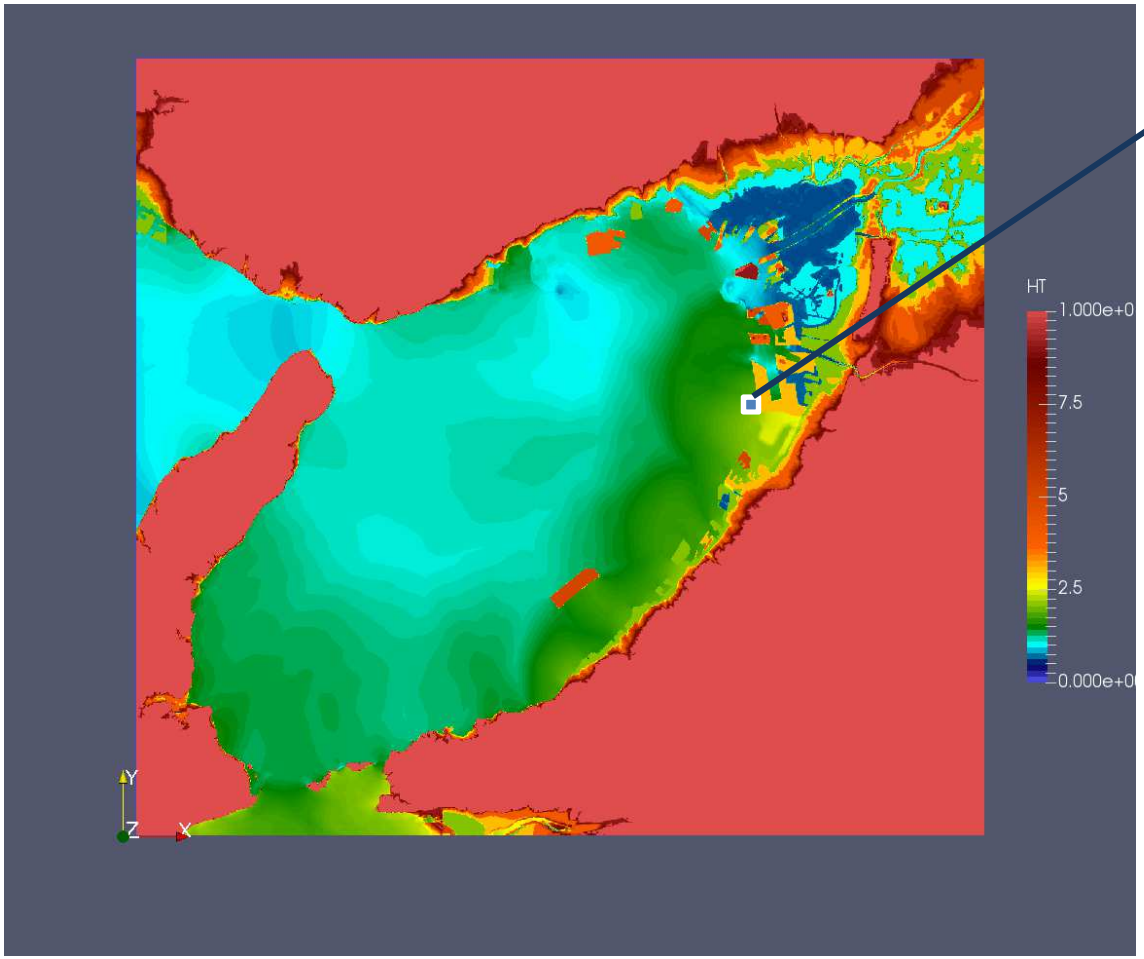
Storm Surge and Tsunami Simulator in Oceans and Coastal Areas (STOC) developed by Port and Airport Research Institute (PARI).



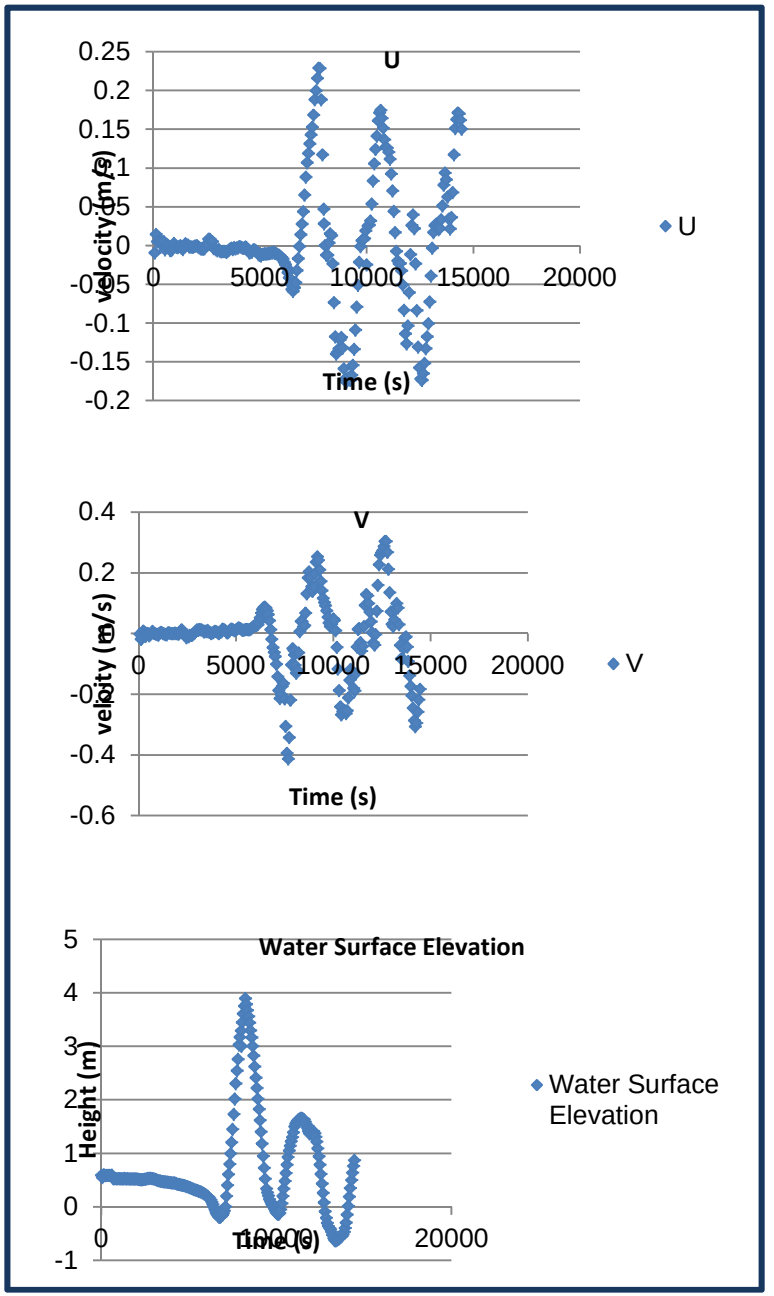
Nankai Fault is used to create initial water surface elevation.

All the input parameters for STOC including the fault parameters are derived from 内閣府公表の津波及び地震動解析　データ (Publication of Tsunami and Earthquake Analysis Cabinet Office)

METHODS



Maximum Water Surface Elevation

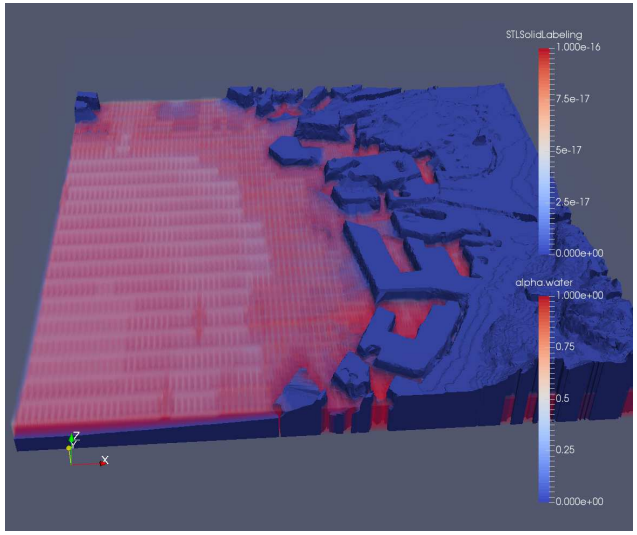


METHODS

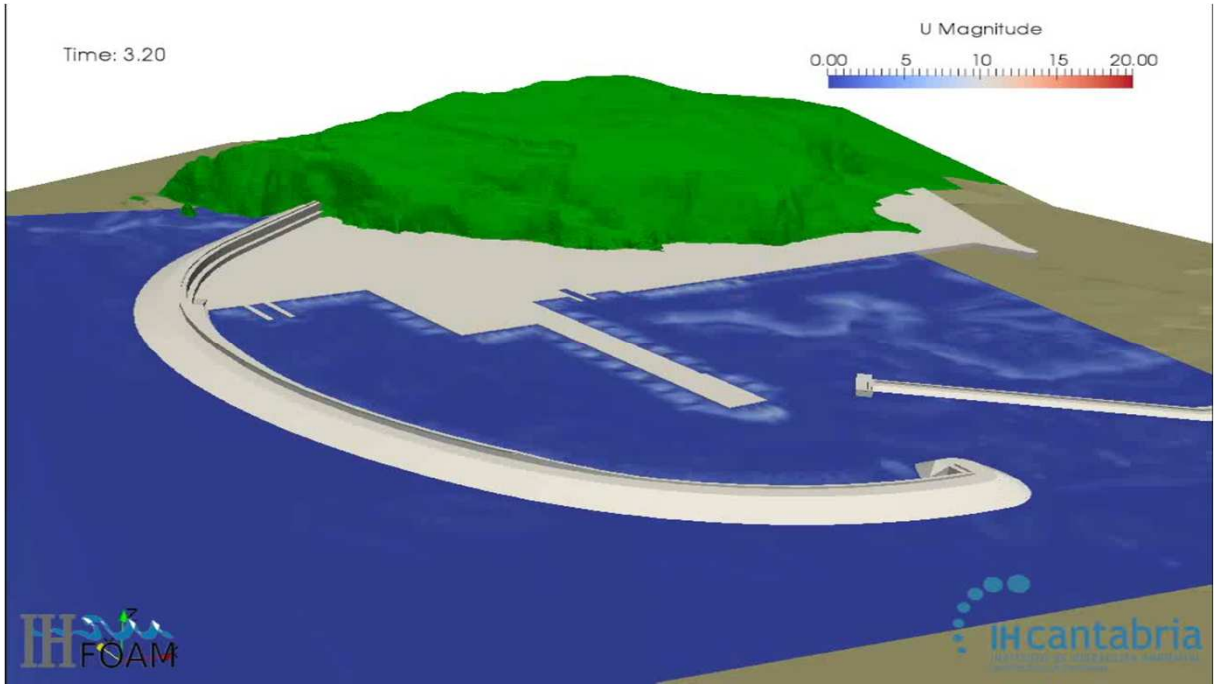
Simulation of Oil Spill

Open FOAM® – an open source CFD technique. Open FOAM® is free open source software mainly meant for Computational Fluid Dynamics (CFD) supported by OpenCFD Ltd.

IHFOAM is a newly developed three-dimensional numerical two-phase flow solver specially designed to simulate coastal, offshore and hydraulic engineering processes. Its core is based on OpenFOAM®



Domain used for oil spill simulation with OpenFOAM

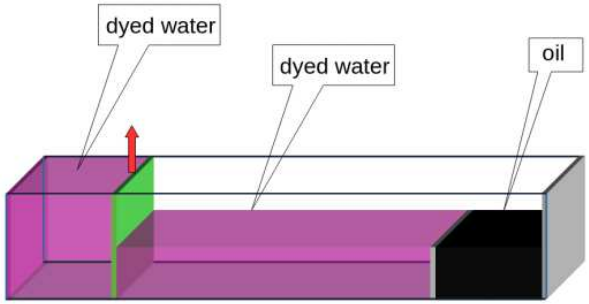


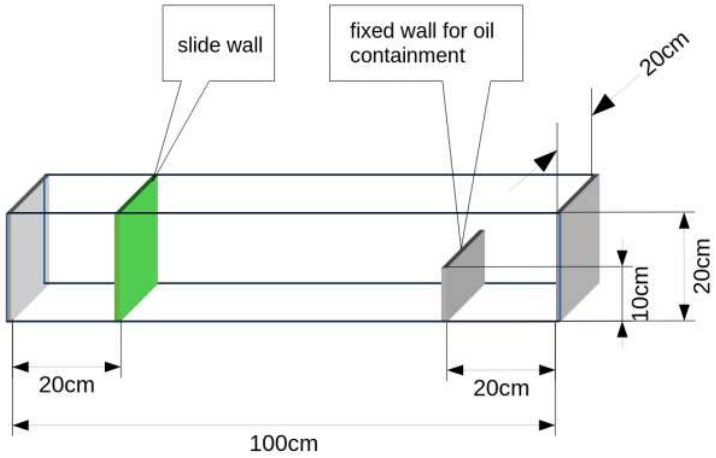
IHFOAM for wave boundary condition

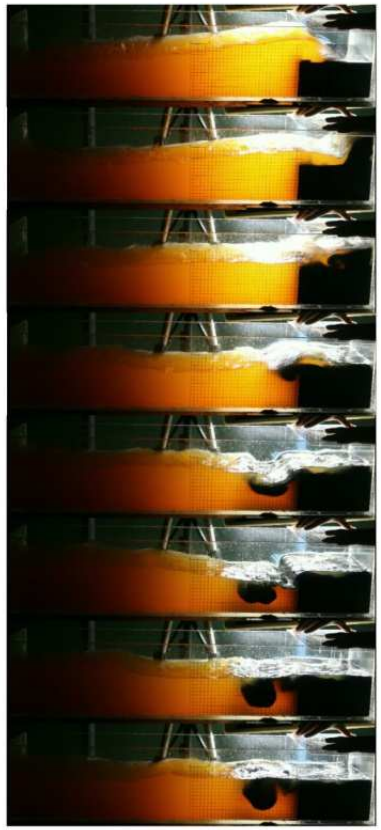
METHODS

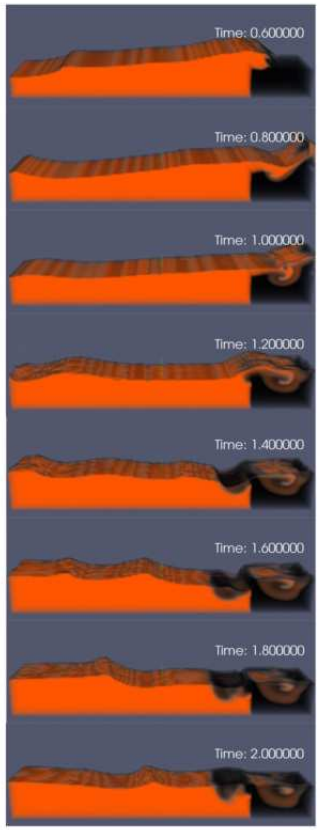
Evaluation of the code

Previously, experiment sand numerical simulations were conducted to evaluate Open FOAM® , multiphase simulation accuracy and applicability

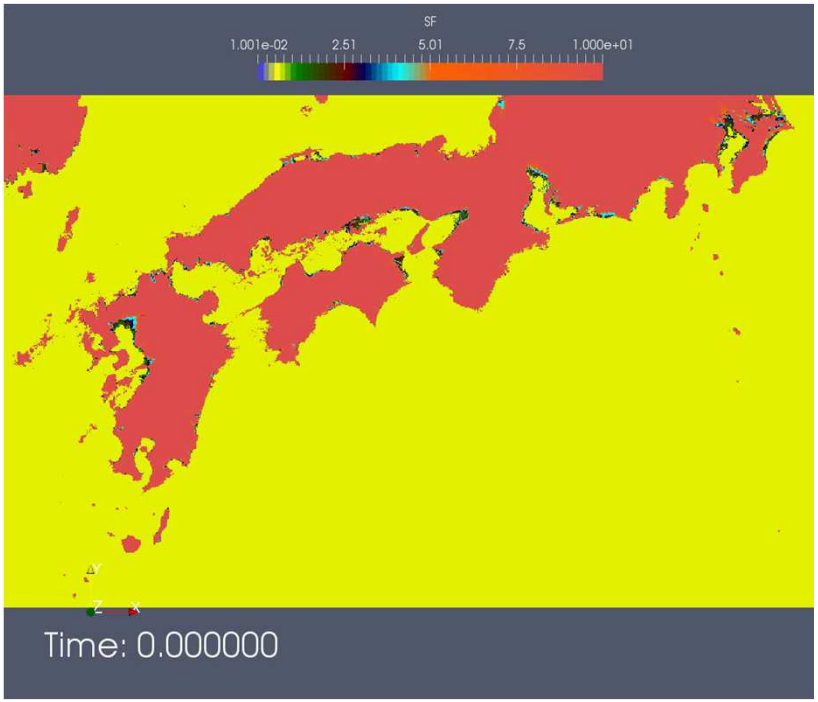




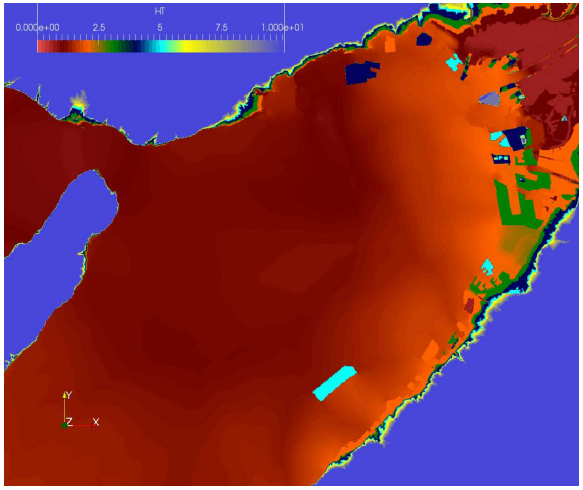




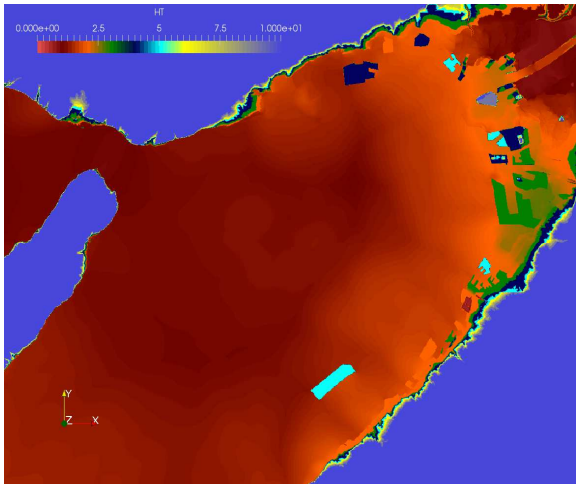
RESULTS



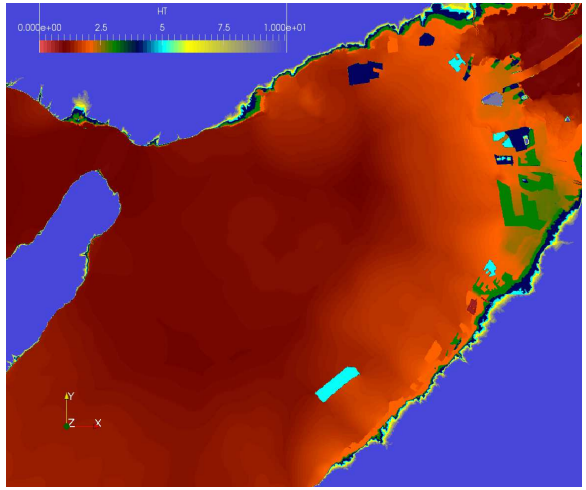
Maximum water surface elevation distribution



Time = 8000s (2hr 13min)



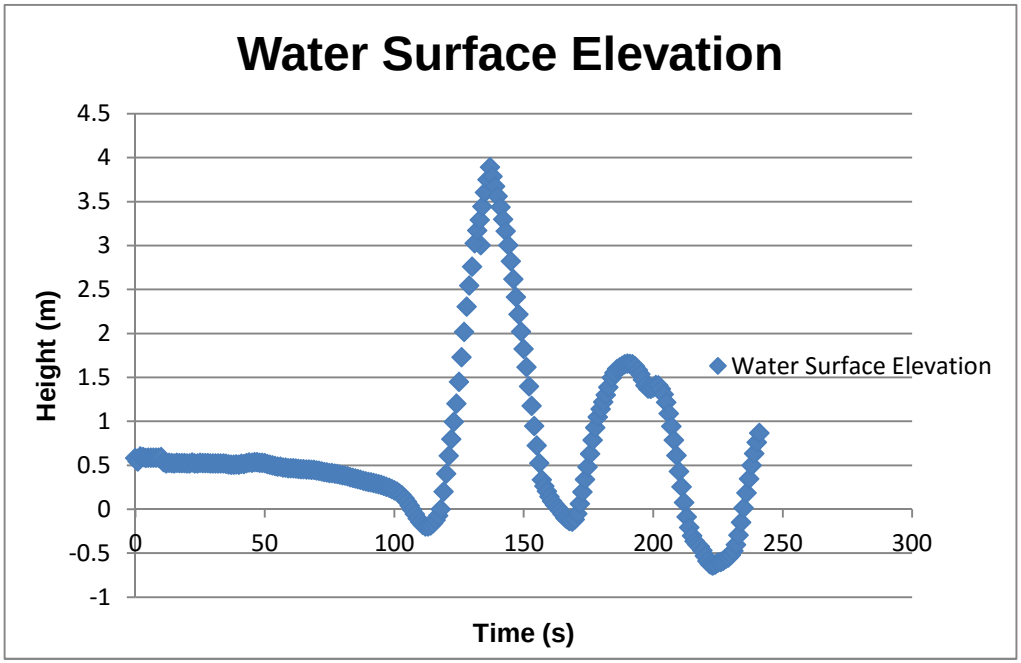
Time = 12000s (3hr 20min)

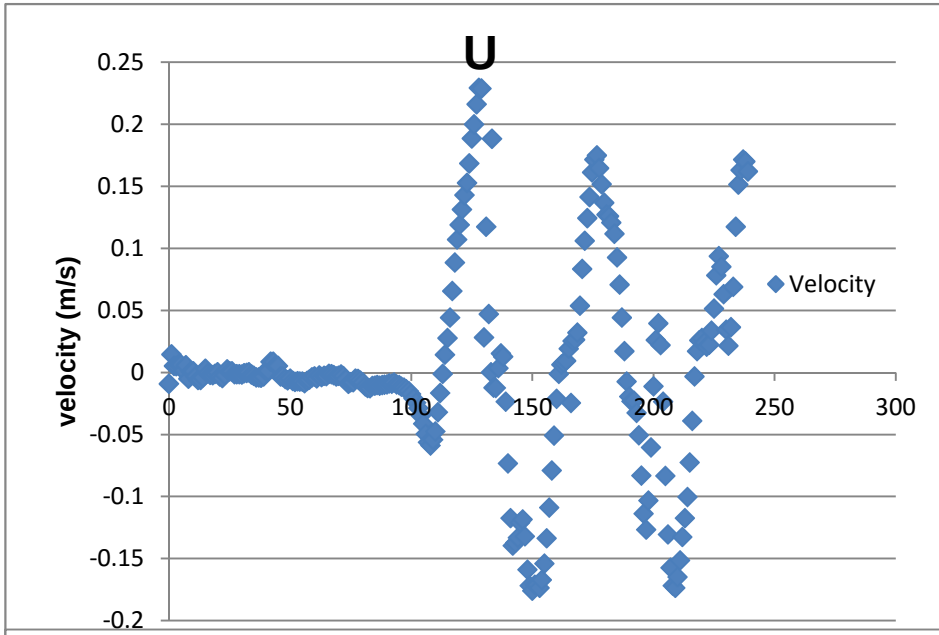


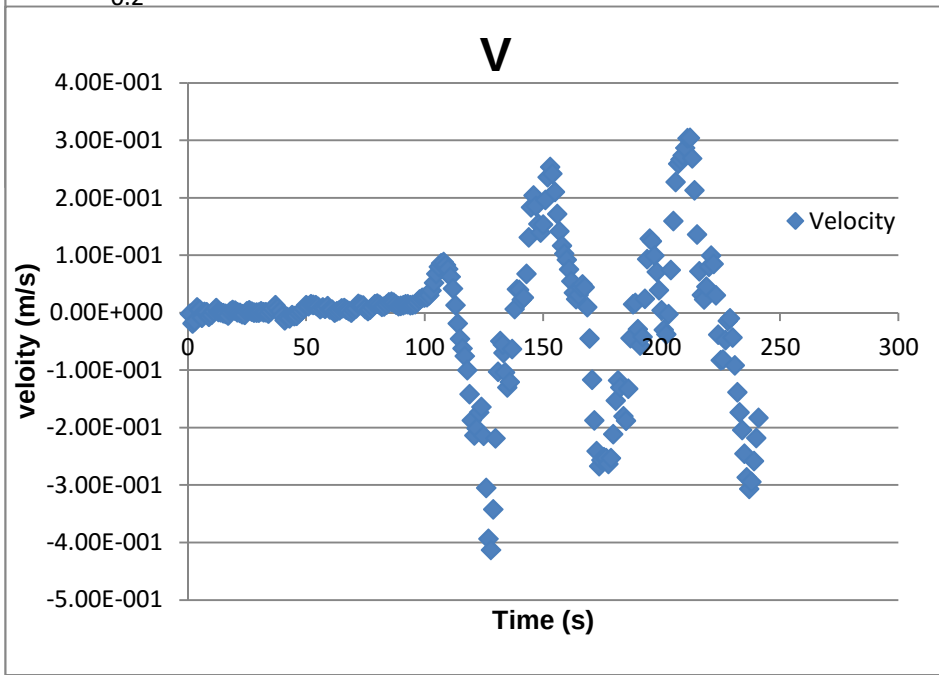
Time = 14040s (3hr 54min)

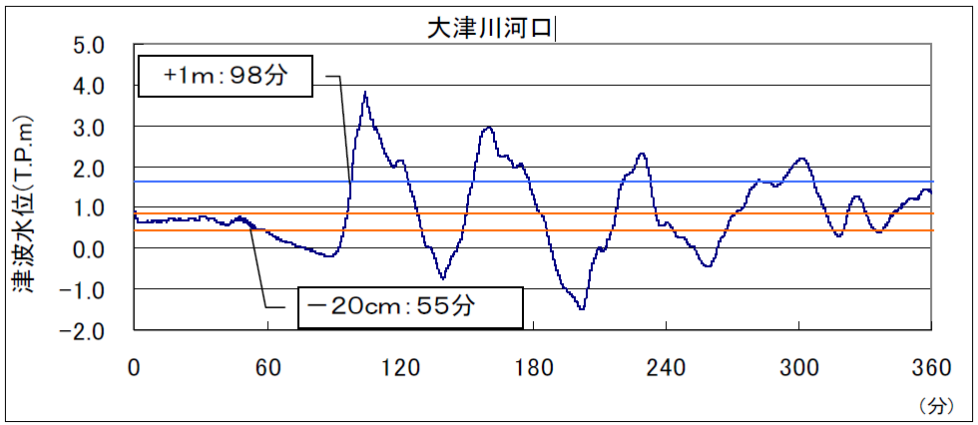
RESULTS

Water Surface Elevation and Velocity distribution near Sakai Senboku Industrial Park.



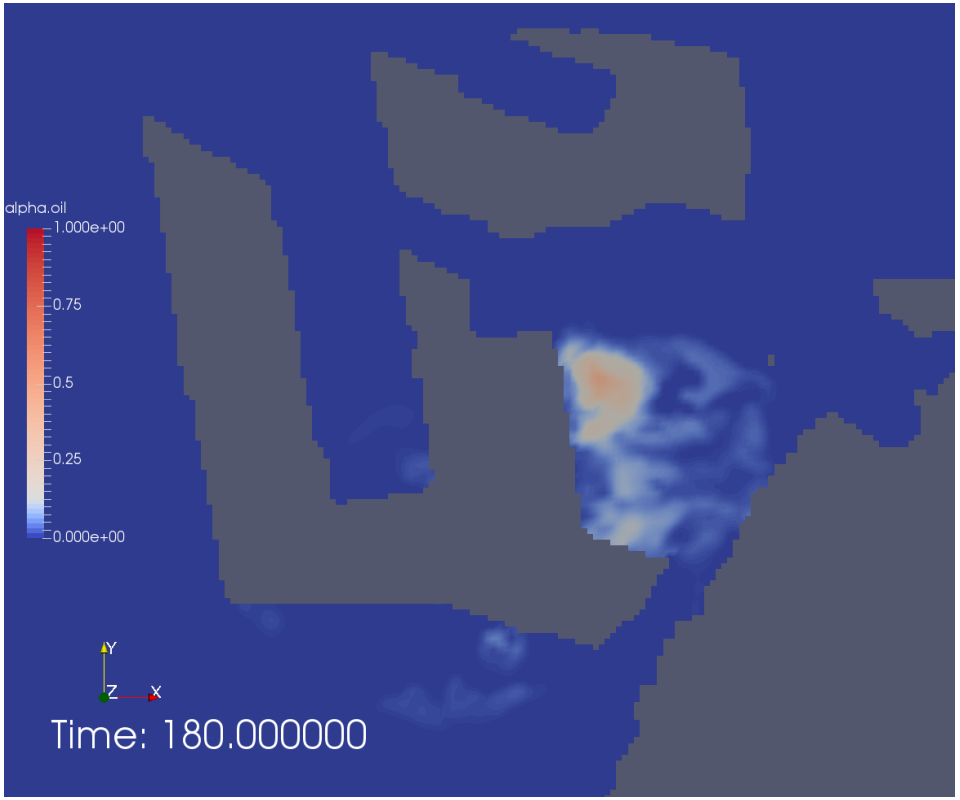


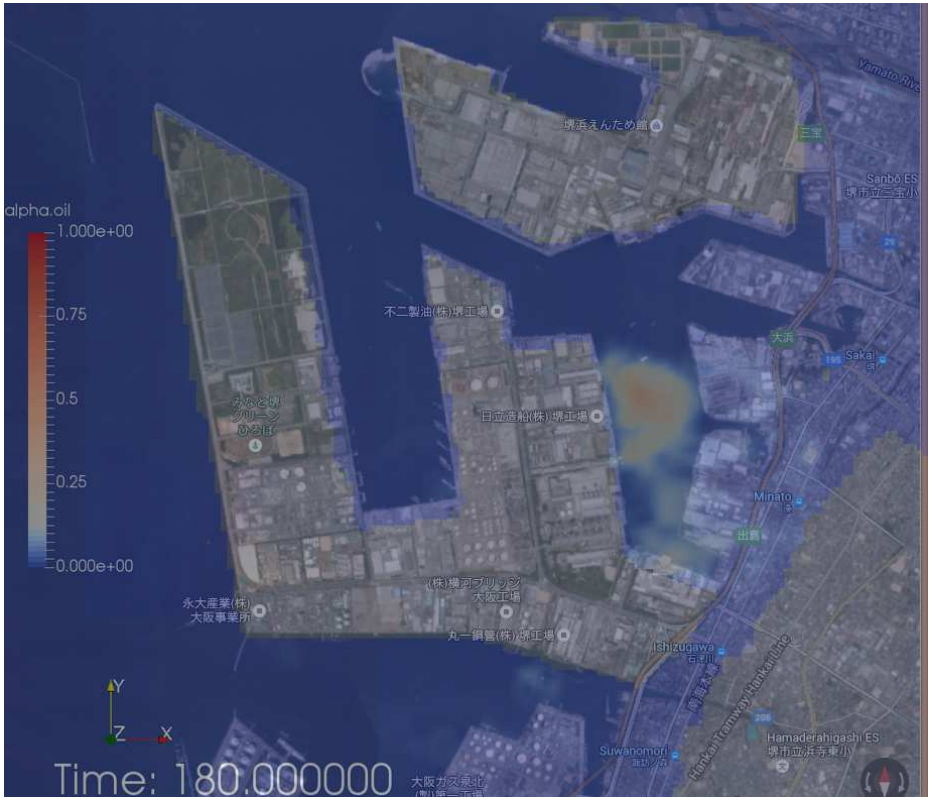




RESULTS

The distribution of oil spill in Osaka Bay after tsunami hits the Sakai Senboku industrial park.





CONCLUSION

Based on the results of this study, the risk assessment of Sakai Senboku industrial park area could be revised for the worst scenario of oil spill in case of high intensity tsunamis, and revised the residential areas which have the potentials of fire after the tsunami, and the bay areas for evading the ships avoiding the oil spill.

Also, these results would help the analysis of submarine oil pollution because the tsunami-triggered, high turbid seawater has a potential to mix with oil spill.

In addition, these results can help the development and implementation of the flexible pipe mechanism, which is currently developing in Kato Laboratory of Osaka University, to mitigate the tsunami impact and damage to the industrial parks.

FUTURE WORK

The same oil spill simulation procedure shall be conducted for the Osaka North Port, which is more vulnerable than Sakai Senboku, in case of Tsunami attack

Thank You So Much