Numerical modeling of methane hydration and droplet transport for deepwater oil spill

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Keywords: Methane hydration, Oil/gas droplet transport, Numerical simulation

Project overview

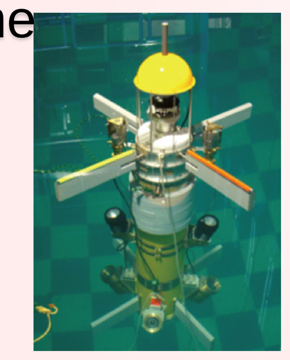
Innovative disaster prevention system for oil/gas spill

Numerical prediction of diffusion and drifting of spilled oil/gas
- Fluid dynamics, chemical process
- Multi-scale, multi-physics

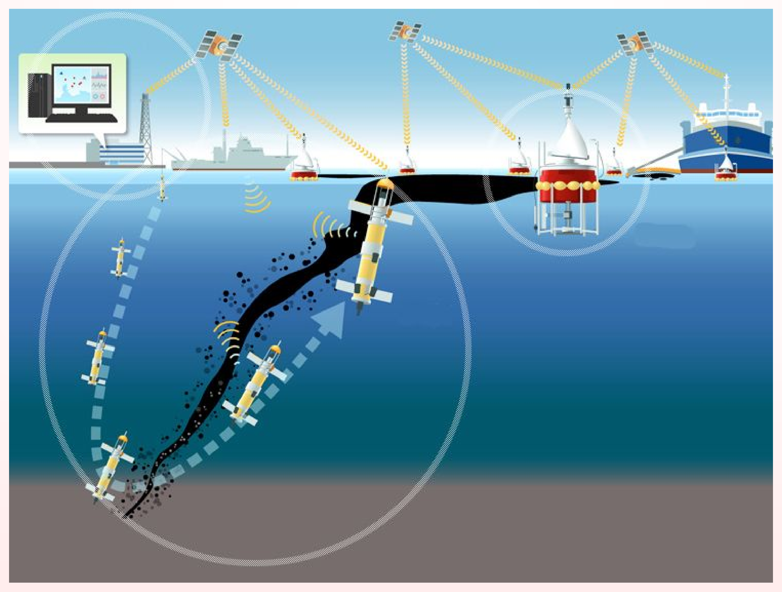
Data transfer

Data assimilation

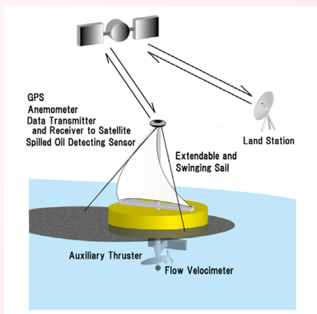
Autonomous tracking and monitoring oil/gas plume



SOTAB-I Robot



Autonomous tracking of spilled oil on sea surface



SOTAB-II Robot

Project Web: http://www.naoe.eng.osaka-u.ac.jp/~kato/project/en/

Objective of present study

- Numerical modeling of oil/gas spill in deep water.
- Implementation of methane hydration considering convective mass and heat transfer.
- Investigation of drop size effect on spilled region.

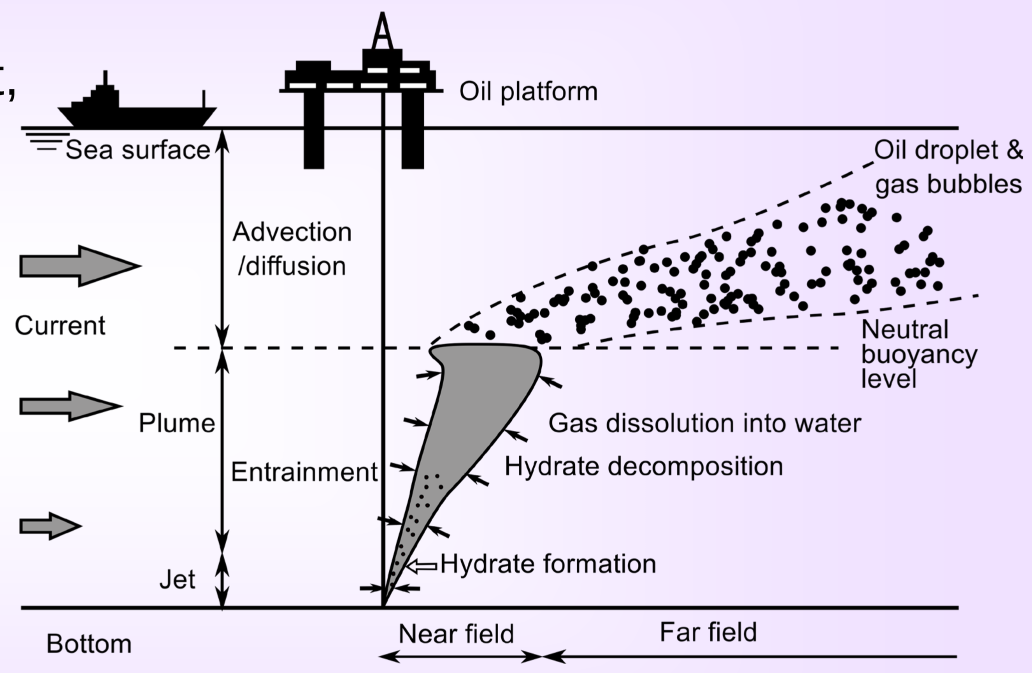
Numerical model

Methane gas

- Lagrangian control volume + Lagrangian particle tracking
- Conservations of momentum, heat, and mass
- Bubble size distribution
- Gas dissolution
- Gas separation from plume
- Bubble breakup and coalescene
- Hydrate formation, dissociation
- Hydrate dissolution

Crude oil

- Lagrangian particle tracking
- Conservation of momentum
- Droplet size distribution



Conclusions

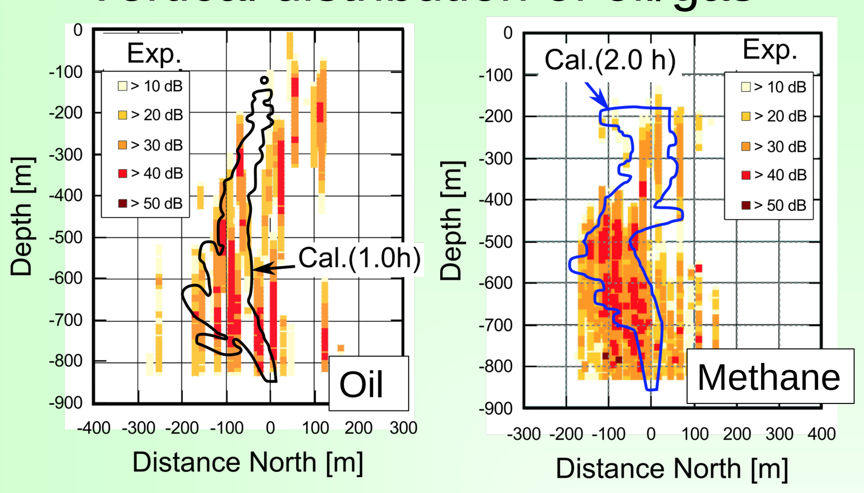
- Oil/gas spill behavior was simulated by using a Lagrangian approach.
- Effect of convective mass and heat transfer on methane hydration was successfully considered with Ranz-Marshall equation.
- Small oil drop raise slowly and diffused in horizontal direction by sea current.

Results and discussion

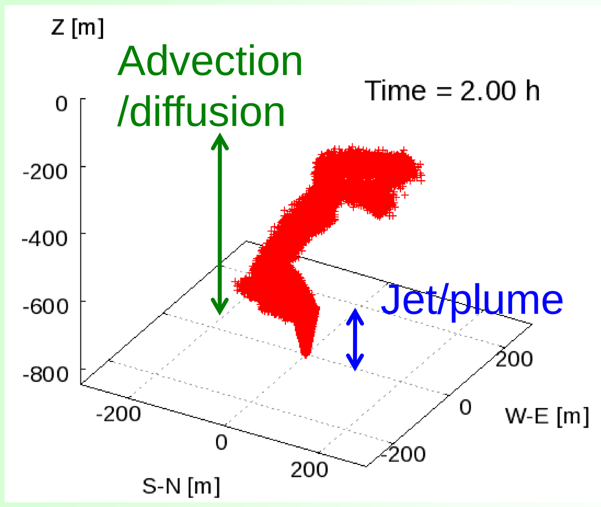
Validation of numerical code

"DeepSpill" exp. in Norwegian Sea (2000)

Vertical distribution of oil/gas

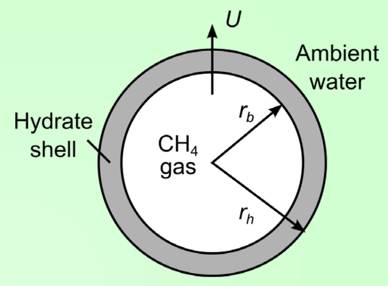


3D view of spilled methane



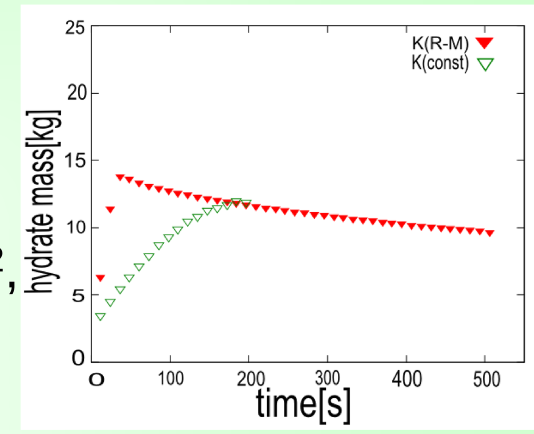
Kinetics of hydrate formation

$$\frac{dn}{dt} = K \cdot 4\pi r^2 \cdot \psi (f_{dis} - f_{eq})$$



Chen&Yapa(2002):
K = const., Ψ = 38

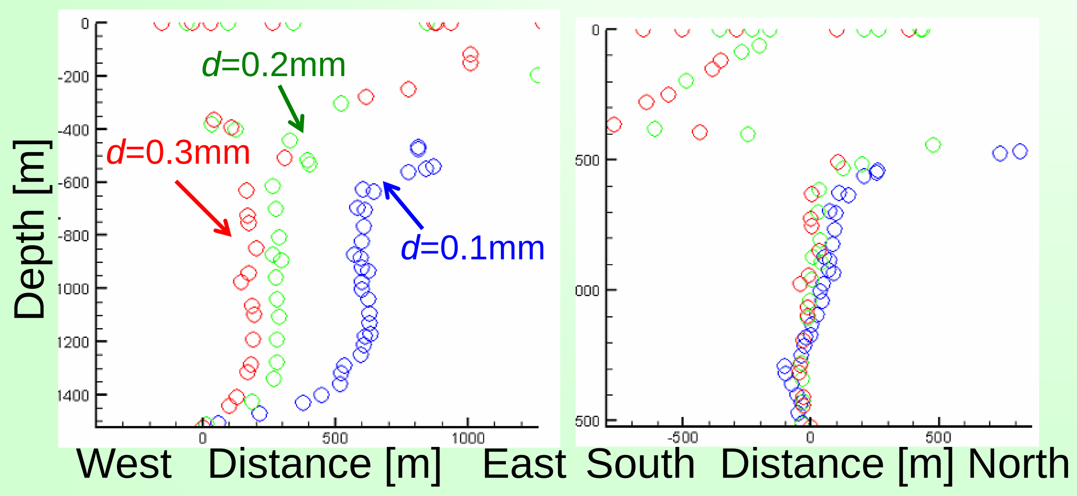
Present model:
Ranz-Marshall eq.
$Sh = 2+0.65Sc^{1/3}Re^{1/2}$,
$Nu = 2+0.6Pr^{1/3}Re^{1/2}$
$\Rightarrow K = f(Re)$, $\Psi = 1$



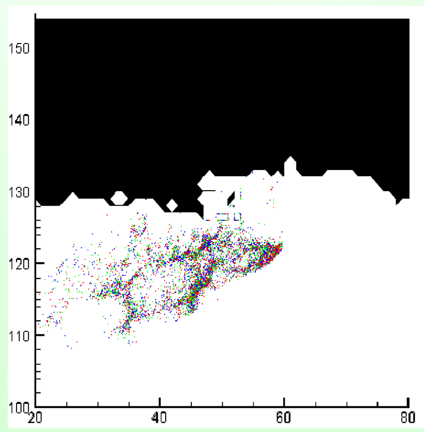
- Simulated extent of spilled oil/gas well agreed with experiment.
- Methane hydration decreased the rising velocity of methane.
- Convective mass and heat transfer affected methane hydration immediately after blowout.

Oil spill simulation in GOM with the Prinston Ocean model (POM)

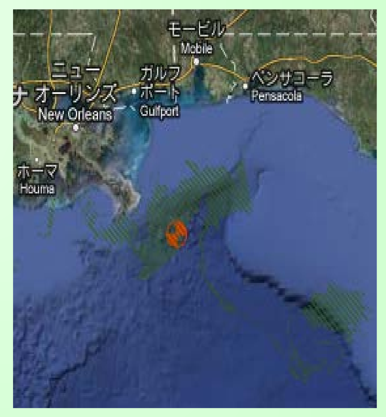
Vertical distribution of oil droplet (12 hours after)



Horizontal distribution of oil droplet on sea surface (30 days after)



Present result



ERMA Gulf Response

- Motion of small oil droplets was strongly affected by sea current.
- Around the the Macondo well, oil spilled in the east-west direction. High accuracy prediction requires a proper ocean model.