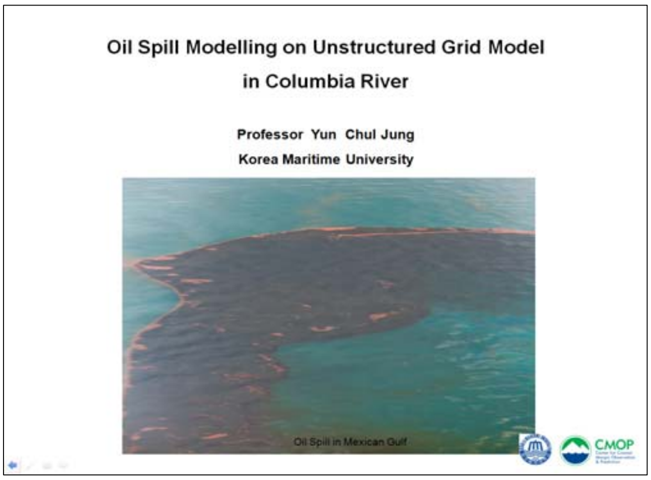
비정렬격자 모델에 기반한 콜럼비아 강에서의 유출유 모델링

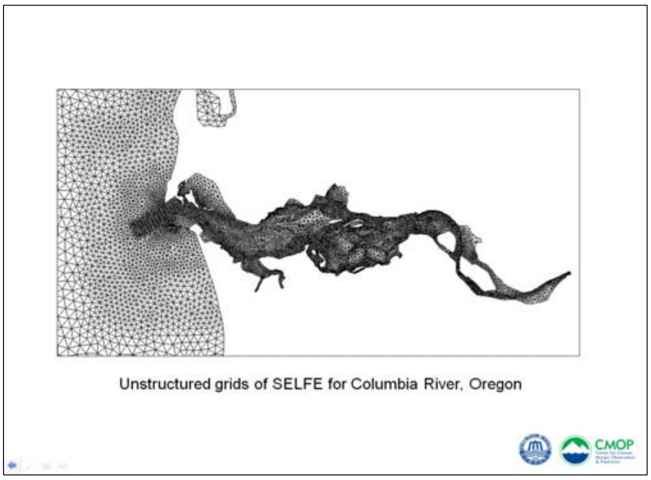
정 연철*

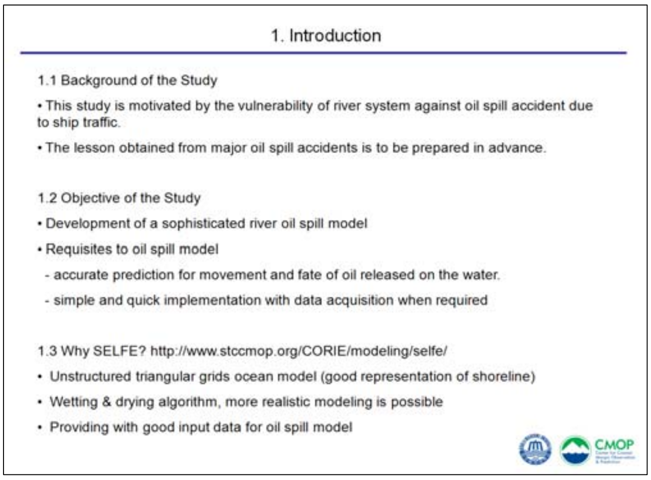
*한국해양대학교 항해학부 교수

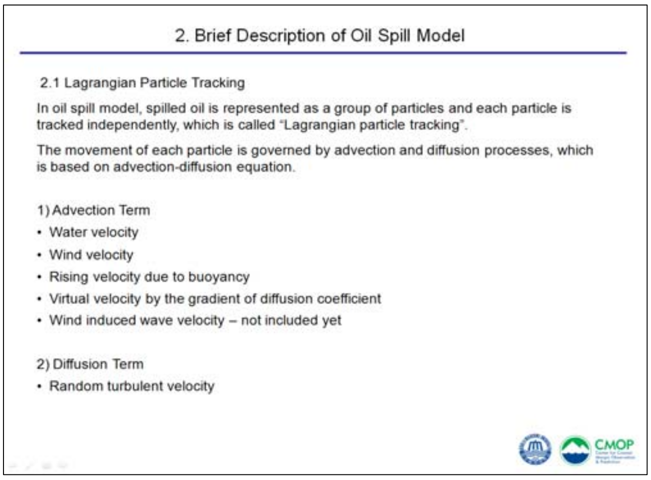
요 약 : 본 연구에서는 유한체적법과 함께 비정렬 격자(Unstructured Grid) 를 채택한 SELFE 모델을 기반으로 운영되는 유출유 확산 모델을 개발하였다. 모델의 적용성을 검토하기 위해 미국 오레건주 콜롬비아 강의 유출유 모델링에 적용하였으며 양호한 결과를 얻을 수 있었다. 앞으로 이 모델은 하천, 호수 및 해양을 포함한 다양한 수계에 적용이 가능할 것으로 기대된다.

핵심용어 : 비정렬격자, 유한체적법, SELFE 모델, 유출유 확산모델, 유출유 모델링









* 교신저자 종신회원) ycjung@hhu.ac.kr

2. Brief Description of Oil Spill Model

2.2 Random Displacement Model

The RDM is basically similar to random walk model, but it works more accurately in heterogeneous media(different turbulent diffusion coefficient in space).

1) Representation of Particle Movement in RDM

$$X^{n+1} = X^n + (U + W_x + \frac{\partial K_x}{\partial x})\Delta t + R\sqrt{6K_x^{*}\Delta t}$$

$$Y^{n+1} = Y^n + (V + W_y + \frac{\partial K_y}{\partial y})\Delta t + R\sqrt{6K_y^{*}\Delta t}$$

$$Z^{n+1} = Z^n + (W + V_r + \frac{\partial K_z}{\partial z})\Delta t + R\sqrt{6K_z^{*}\Delta t}$$

Where *U* ,*V* & *W* are x, y & z components of water velocity, respectively.

n is current time step, *n+1* is next time step, * denotes *n+½* time step.

Δt is time step interval. *R* is uniform random number [-1 1].

2. Brief Description of Oil Spill Model

K_x, K_y & K_z are turbulent diffusion coefficients in x, y, z direction, respectively.

W_x & W_y are wind dragging speeds in x, y direction. Where $W_i = c_d \times W\_vel_i^{10}$

c_d is dragging coefficient, normally 0.03.

V_r is rising velocity due to buoyancy, which is calculated from following empirical equation.

$$V_r = \left[\frac{3}{8} g d_i \left(1 - \frac{\rho_o}{\rho_w}\right)\right]^{\frac{1}{2}}$$

Where, *g* is the acceleration of gravity coefficient, d_i is oil droplet diameter, ρ_o & ρ_w are density of oil and water, respectively.

2) Weathering Processes

There are many weathering processes, such as evaporation, dispersion, emulsification, dissolution, bio-degradation, etc., but in this study, evaporation process is only considered because it is major process.

2. Brief Description of Oil Spill Model

3) Boundary Treatment

- At land boundary : It is assumed that 80% of particles are stranded when they get on shore. So, remaining 20% particles still move with reflecting to shoreline. Also, if drying land is rewetted, stranded particles will start to move again. We can put this stranded percentage arbitrarily as based on shoreline type.

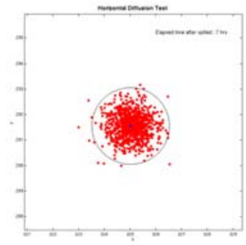
- At open boundary : It is assumed that particles which crossed the open boundary don't come back to computational region. Thus, modeling region must be sufficiently large as compared to the interest area.

3. Model Application and Results

3.1 Simple Test of Model

1) Horizontal Diffusion Test

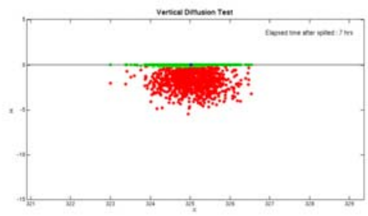
- Switched off advection term and 1,000 particles are released at same time.
- Black circle in picture represents 3 times standard deviation($\sqrt{2Kt}$) limit. It means that 99.7% of total particles should be located in circle statistically.



3. Model Application and Results

2) Vertical Diffusion Test

- Switched off advection term and 1000 particles are released at same time.
- With rising velocity (green particles in picture)
- Without rising velocity (red particles in picture)

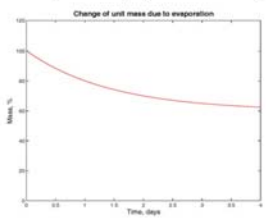


3. Model Application and Results

3.2 Model Application

1) Model Set Up

- At three different parts of Columbia river estuary, particles are released for 24 hours with 10 particles in every 15 minutes
- Turbulent diffusion coefficients : The vertical coefficient is taken from SELFE output, but the horizontal coefficient is set to constant value, 5.0 $m^2/_s$
- Evaporation is progressed as below graph.

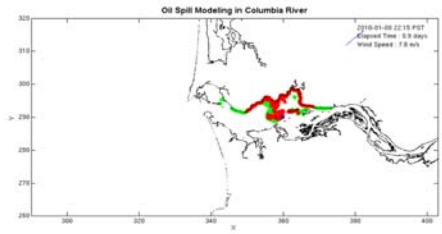


- The unit mass is reduced exponentially by evaporation from 100% to 60% with time.
- Half-life time is set to 1.5 days.

3. Model Application and Results

2) Modeling Case 1

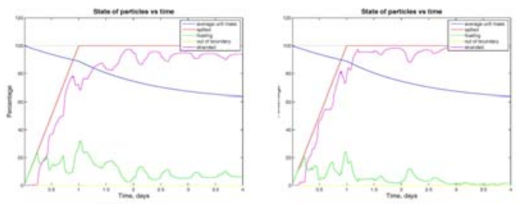
- Particles are released at middle part of Columbia river estuary.
- Model was run for 4 days with and without wind, respectively.



3. Model Application and Results

2) Modeling Case 1

- The change of particle state with time
- The wind makes the particles stranded more on shore.

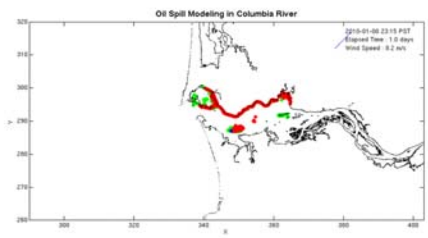


Without wind　　　With wind

3. Model Application and Results

3) Modeling Case 2

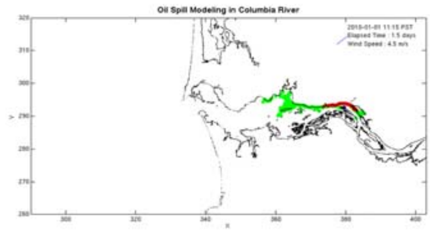
- Particles are released at middle part of Columbia river estuary.
- Model was run for 3 days with and without wind.



3. Model Application and Results

4) Modeling Case 3

- Particles are released at upper part of Columbia river estuary.
- Model was run for 5 days with and without wind.



4. Conclusion Remarks

- The study of oil spill modeling in Columbia river seems to be successful, but model still needs to be verified with observational data.
- If SELFE output is provided, oil spill modeling can be done anytime within few minutes. But the accuracy of SELFE output affects to modeling results inevitably.
- The oil spill modeling study in Columbia river estuary shows that wind plays an important role in moving the spilled oil. Thus accurate wind data is requisite to get good results of modeling.
- *For the further works,*

- It is necessary to run oil spill model with realistic horizontal diffusion coefficients and to check the results.

- Weathering processes except evaporation are to be considered.

Thanks for your attention !