

COASTAL MODELING SYSTEM: ADVANCED TOPICS USING CMS 5.1 AND SMS 13.0

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DAY 3: MULTIPLE-SIZED SEDIMENT TRANSPORT

Honghai Li, Mitchell Brown









Outline

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- Sediment transport in CMS
- Multiple-sized sediment transport calculation
 - Transport grain sizes
 - Bed layering
 - Bed composition
 - Other parameters
- Export CMS files

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Multiple-sized Sediment Transport Calculation (Ft. Pierce, Florida)





Sediment Transport in CMS (Non-equilibrium Transport, NET)



$\frac{\partial}{\partial t} \left[\frac{DC_{tk}}{\beta_{tk}} \right] + \frac{\partial (DuC_{tk})}{\partial x} + \frac{\partial (DvC_{tk})}{\partial y} = \frac{\partial}{\partial x} \left[\varepsilon_s D \frac{\partial (r_{sk}C_{tk})}{\partial x} \right] + \frac{\partial}{\partial y} \left[\varepsilon_s D \frac{\partial (r_{sk}C_{tk})}{\partial y} \right] + \frac{U_c D}{L_t} (C_{t^*k} - C_{tk})$

- *c*_{*tk*}: depth-averaged sediment concentration
- *k*: sediment size class
- c_{t^*k} : depth-averaged total load concentration at the equilibrium state
- β_{tk} : correction factor as the ratio of depth-averaged sediment and flow velocities
- U_c : resultant velocity of current
- \mathcal{E}_S : sediment diffusion coefficient
- r_{sk} : ratio of suspended load to total load
- L_t : total load adaptation length

or	mulation	_
	Formulation:	
	Nonequilibrium Total Load 🔹	
	Equilibrium Total Load	
	Equilibrium Bed load plus Nonequilibrium Susp Load Nonequilibrium Total Load	

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Sediment Transport Formulas (Non-equilibrium Transport, NET)

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 $\frac{\partial}{\partial t} \left| \frac{DC_{tk}}{\beta_{tk}} \right| + \frac{\partial (DuC_{tk})}{\partial x} + \frac{\partial (DvC_{tk})}{\partial y} = \frac{\partial}{\partial x} \left| \varepsilon_s D \frac{\partial (r_{sk}C_{tk})}{\partial x} \right| + \frac{\partial}{\partial y} \left| \varepsilon_s D \frac{\partial (r_{sk}C_{tk})}{\partial y} \right| + \frac{U_c D}{L_t} (C_{t^*k} - C_{tk})$

Sediment concentration and concentration capacity:

LUND-CIRP VAN RIJN SOULSBY-VAN RIJN WATANABE *CSHORE

Tra	ansport Formula
	Transport Formula:
	Lund-CIRP 🔫
	Lund-CIRP
	van Rijn
	Soulsby-van Rijn
	watanape



Bed Change

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Bed change due to the *k*th class of sediment:

$$(1 - p'_{m})\left(\frac{\partial z_{b}}{\partial t}\right)_{k} = \frac{U_{c}D}{L_{t}}(C_{tk} - C_{t^{*}k}) + \frac{\partial}{\partial x}\left[d_{s}U_{c}D(1 - r_{sk})C_{tk}\frac{\partial z_{b}}{\partial x}\right] + \frac{\partial}{\partial y}\left[d_{s}U_{c}D(1 - r_{sk})C_{tk}\frac{\partial z_{b}}{\partial y}\right] + \frac{\partial q_{twx}}{\partial x} + \frac{\partial q_{twy}}{\partial y}$$

- p'_m : porosity of bed material
- d_s : coefficient for bed slope effect
- q_{twx} : sediment transport rate due to wave asymmetry and undertow in x-direction
- q_{twy} : sediment transport rate due to wave asymmetry and undertow in y-direction

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Multiple-sized Sediment Transport Calculation

Geometric Standard Deviation

$$\sigma_g = exp_{\sqrt{\sum} p_k (lnd_k - lnd_g)^k}$$

 p_k : fraction d_k : size class diameter d_g : geometric mean

Geometric Standard Deviation	Sorting Classification					
<1.27	Very well sorted					
1.27-1.41	Well sorted					
1.41-1.62	Moderately well sorted					
1.62-2.00	Moderately sorted					
2.00-4.00	Poorly sorted					
4.00-16.00	Very poorly sorted					
>16.00	Extremely poorly sorted					

Geometric Standard Deviation greater than approximate 1.41 should be simulated with multiple grain sizes



Multiple-sized Sediment Transport Calculation (Transport Grain Sizes)



Transport Grain Sizes

- Transported sediment material is discretized into different groups each representing the sediments within a specific size range
- These groups are referred to as sediment size classes and have the following properties
 - Characteristic diameter
 - Fall velocity
 - Corey shape factor
 - Critical shear stress





Multiple-sized Sediment Transport Calculation

(Transport Grain Sizes)

Transport Grain Sizes

- Characteristic diameter
 - Related to the lower $d_{k-1/2}$ and upper $d_{k+1/2}$ bin limits by

$$d_k = \sqrt{d_{k-1/2}d_{k+1/2}}$$

 Estimate the grain size classes based only on the size limits of the distribution

$$d_k = exp\left[lnd_1 + ln(d_N/d_1)\frac{k-1}{N-1}\right]$$

- Fall velocity
 - Soulsby (1997)
 - Wu and Wang (2006)
 - User-specified
- Corey shape factor
 - Used in Wu and Wang (2006)
- Critical shear stress
 - Soulsby (1997)
 - Wu and Wang (1999)
 - User-specified

	Flow	Sediment Transport	Salinity/Tempe	erature Wave	Wind	Output		
	0.1							^
	Hiding	g and exposure coefficient	:					
	1.0							
A	daptat	ion						
	Total	load adaptation method:						
	Con	stant length		•				
	Total	load adaptation length:						
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s	ize Cla	sses						1
	Sedin	nent size class diameters:						
		Diameter	Fall	Velocity Method		Fall Velocity		
	1 0	.1	mm 🔻 Soulsb	vy (1997) 🔻	0		m/s	
	2 0	.21	mm 🔻 Soulsb	vy (1997) 🔹 🔻	0		m/s	
	3 0	.5	mm 🔻 Soulsb	vy (1997) 🔹 🔻	0		m/s	
	4 1	2	mm 🔻 Soulsb	vy (1997) 🔹 🔻	0		m/s	
	5 2	.7	mm 🔻 Soulsb	vy (1997) 🔹 🔻	0		m/s	
	6 6	i	mm 🔻 Soulsb	vy (1997) 🔹 🔻	0		m/s	
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	5	nam namber of bea layers						
	Minim	num bed laver thickness:						
	0.05	i	r	meters 🔻				
	Maxir	num bed layer thickness:						
	0.5		r	meters 🔻				
	Mixin	g Layer Thickness:						~
-	_							

Multiple-sized Sediment Transport Calculation (Bed Discretization)



Mixed Layer Thickness

- Sediment exchange
- Constant, Default: 0.05 m
 Typical range: 0.001 0.2 m
- Automatic (calculated)
 Median grain size
 Bed form size

• Lower Layers

- Specified
- Copied from the layer above
- Constant
- Spatially varying (dataset)



Multiple-sized Sediment Transport Calculation (Bed Composition)

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Bed Composition:

- d_{16} , d_{50} , d_{84} datasets
- d_{35}, d_{50}, d_{90} datasets
- Accumulative grain size distribution

Percentile diameters allowed in SMS are: 5, 10, 16, 20, 30, 35, 50, 65, 84, 90, and 95.

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- D50 dataset and constant geometric standard deviation
- Size class fractions

2 0 1	mm 🔻 Soulsby (19	97) 🔻 0		m/s		Sol	leby (1997)	V 0.2		1		
3 0.21	mm × Soulsby (19	97) 🔻 0		m/s	Y	Sou	ilsby (1997)	• 0.2		-		
4 0 21	mm × Soulsby (19	97) 🔻 0		m/s		Sol	ilehy (1997)	▼ 0.2		-		
5 0.5	mm Soulsby (19	97) 🔻 0		m/s	· · · · · · · · · · · · · · · · · · ·	Sou	ilsby (1997)	• 0.2		1		
6 1.2	mm Soulsby (19	97) 🔻 0		m/s	v	Sol	ilsby (1997)	• 0.2				
7 2.7	mm V Soulsby (19	97) 🔻 0		m/s	v	Sou	ılsby (1997)	▼ 0.2		1		
8 6	mm Soulsby (19	97) v 0		m/s	7	Sou	ilsby (1997)	• 0.2		1		
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Bed Composition												
Maximum number of bed laye	ers:											
5												
Minimum bed layer thickness												
0.05					meters 💌							
Maximum bed layer thickness												
0.5					meters 💌							
Mixing Layer Thickness:												
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Mixing Layer Thickness:												
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Layer ID	Thickness Dataset	D05	D10	D16	D20	D30	D35	D50	D65	D84	Dat	
1	Thickness Layer 1 (2)	(none selected)) (none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	D50 1 (2)	(none selected)	D84 1 (2)	(none sel	
2 2	Thickness Layer 2 (2)	(none selected)) (none selected)	D16 1 (2)	(none selected)	(none selected)	(none selected)	D50 1 (2)	(none selected)	D84 1 (2)	(none sel	
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Avalanching												
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Avalanching Options: Calculate Avalanching Critical bed slope: 32.0					deg							
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Avalanching Options: Calculate Avalanching Critical bed slope: 32.0 Maximum number of iteration	is (implicit only):				deg							
Avalanching Options: Calculate Avalanching Critical bed slope: 32.0 Maximum number of iteration 100	is (implicit only):]			deg							

Multiple-sized Sediment Transport Calculation (Other Parameters)



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Multiple-sized Sediment Transport Calculation (Adaptation Coefficient)

Adaptation coefficient (method and length)		Adaptation Total load adaptation method: Constant length Total load adaptation length: 10.0 meters •
Adaptation method	-	Adaptation Total load adaptation method: Constant length Constant length Constant time Maximum of bed and suspended adaptation lengths Weighted average of bed and suspended adaptation lengths
Bed and suspended adaptation lengths		Adaptation Total load adaptation method: Maximum of bed and suspended adaptation lengths Bed load adaptation method: Constant Length Bed load adaptation length: 10.0 meters Suspended load adaptation method: Constant length Suspended adaptation length: 10.0 meters Suspended adaptation length: 10.0 meters
Bed and suspended adaptation methods	-	Bed load adaptation method: Suspended load adaptation method: Constant Length Constant length Constant Time Constant length Depth Dependent Constant coefficient
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Multiple-sized Sediment Transport Calculation (Avalanching and Hard Bottom)

Avalanching

Angle of repose

Avalanching Options:		
Calculate Avalanching		
Critical bed slope:		
32.0		d
Maximum number of iterations (im	plicit only):	
100		
ardbottom		
Usedbatten danthe		
Hardbottom deput:		



References

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