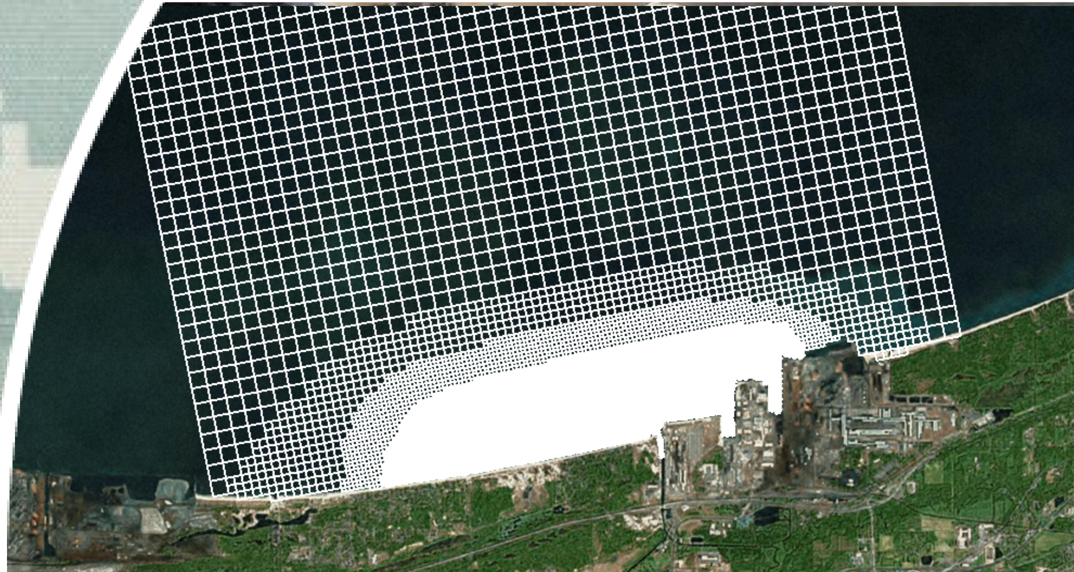
Performance of CMS with Cross-shore Processes in a Field Study

Honghai Li

CIRP TD
17 December, 2019



US Army Corps of Engineers
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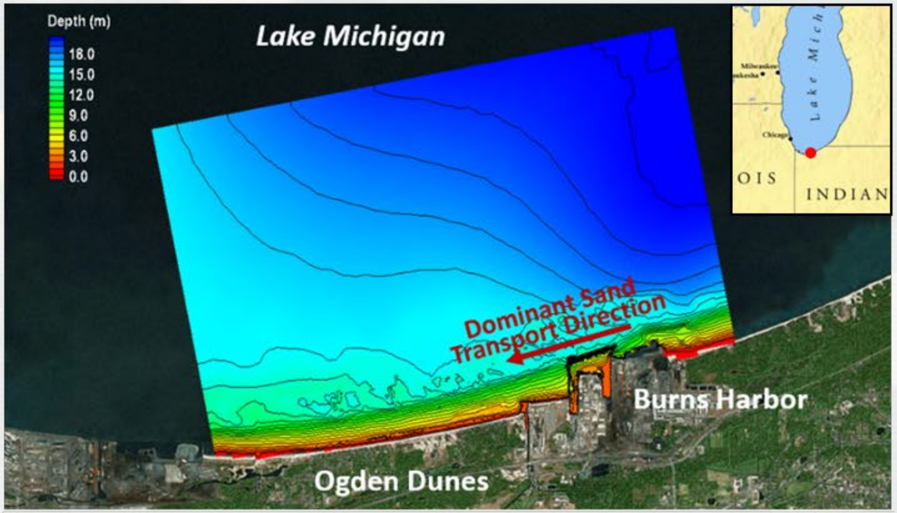
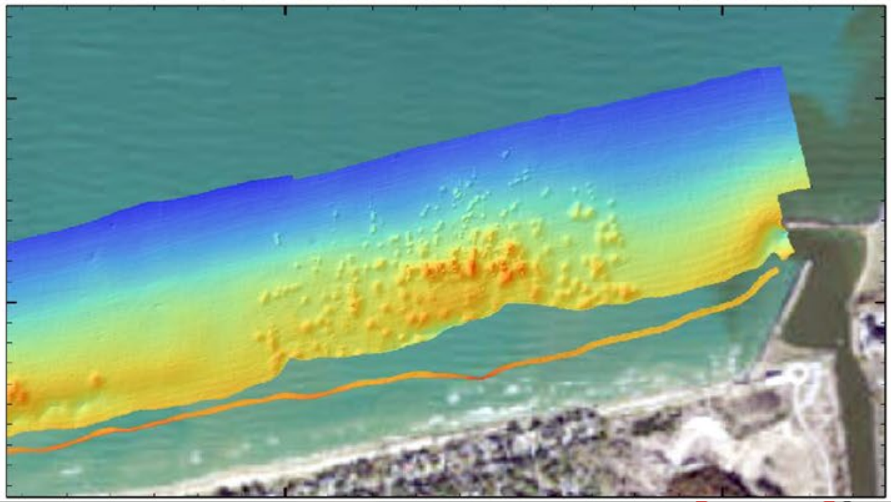
Outline

- Study site
- Data
- Numerical Model
- Results
- Summary

Study Site

- Harbor/port complex and coastal structure interrupt natural littoral movement of sand
- Sand accretion/erosion pattern around the complex leaves Ogden Dunes little to no beach along the shoreline
- To protect the natural habitat and shoreline residences, USACE has placed dredged sand in the nearshore area as beach nourishment effort since 2006
- RSM study (field/numerical modeling) was launched to examine the sediment transport of nearshore placed material under various hydrodynamic and wave conditions
- CSHORE and LUND-CIRP routines in CMS were applied to calculate wave induced cross-shore transport and changes in beach profile





Data

Waves and Hydrodynamics

NOAA WL Gage (Calumet Harbor)

NOAA Buoy (#45007)

Waves spectrum

Wind

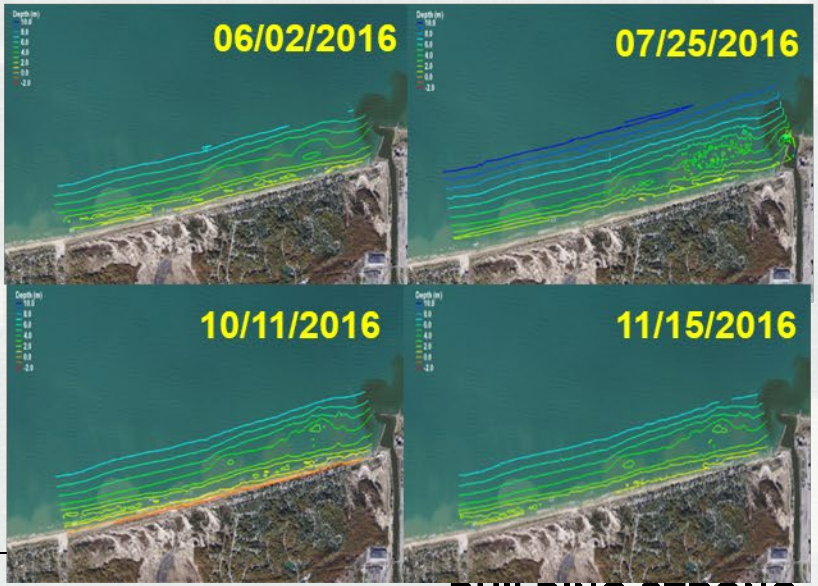
Nearshore ADCP gage (BHSH001)

Multibeam echosounder (MBES)

Bathymetric and beach topographic surveys

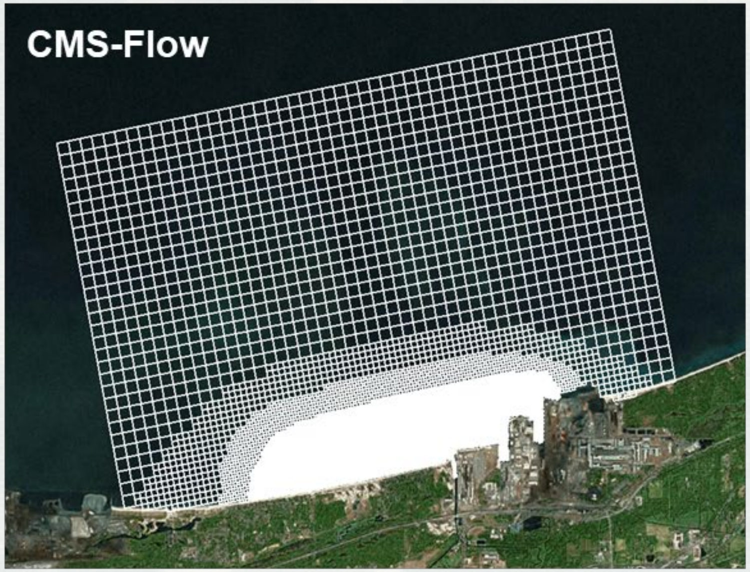
Survey Periods

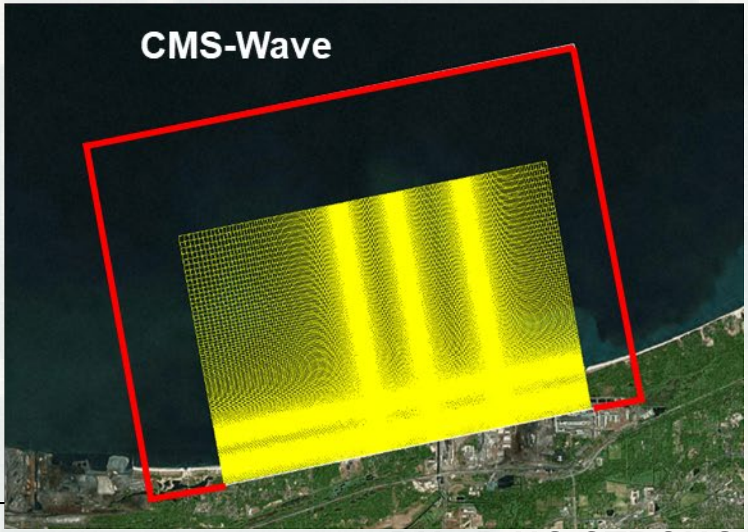
June-November 2016



Model Setup

- Model domain
  15 x 10 km / 11 x 7 km
- No of cells
  ~ 80,000 / 67,000
- Cell size
  10 ~ 300 m/ 10 ~ 180 m
- Water depth (LWD):
  -2 ~ 20 m
- Open lake boundary
- Simulation Periods
  ~ Oct 10 – Nov 20, 2016





CSHORE Calculation
(Johnson et al. 2012)

- Suspended sediment volume

$$V_s = P_s \frac{e_B D_r + e_f D_f}{\rho g (s-1) w_f} (1 + S_{bx}^2)^{0.5} (1 + S_{by}^2)^{0.5}$$

- Cross-shore suspended sediment transport rate

$$q_{sx} = a_x \overline{U} V_s$$

$$a_x = [a + (S_{bx} / tan\varphi)^{0.5}]$$

- Bed load sediment transport rate

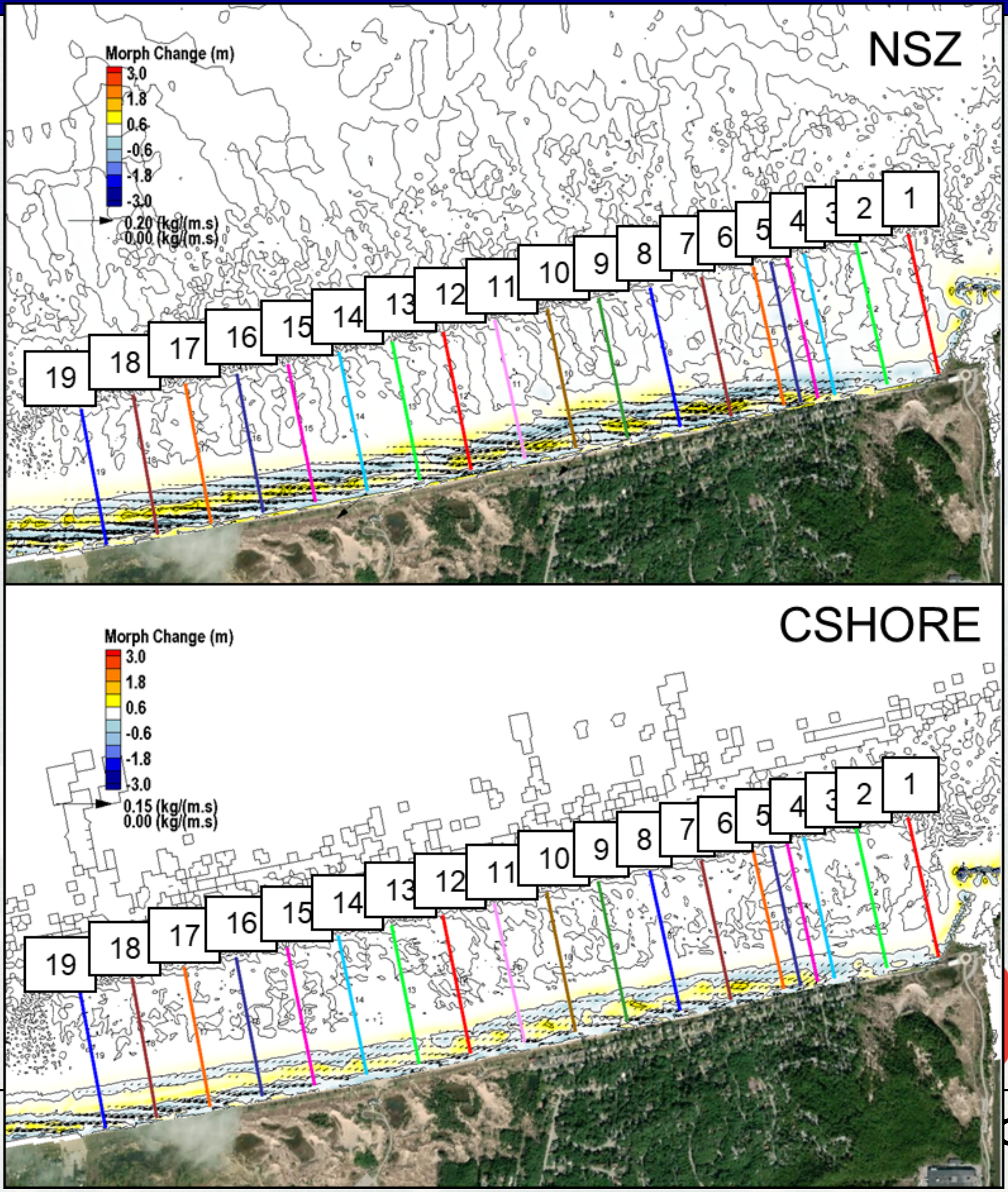
$$q_b = \frac{b P_b}{g(s-1)} \sigma_T^3$$

D_r	=	energy dissipation rate due to wave breaking
D_f	=	energy dissipation rate due to bottom friction
e_B	=	suspension efficiency for D_r
e_f	=	suspension efficiency for D_f
a	=	empirical suspended load parameter
b	=	empirical bed load parameter

Model Results

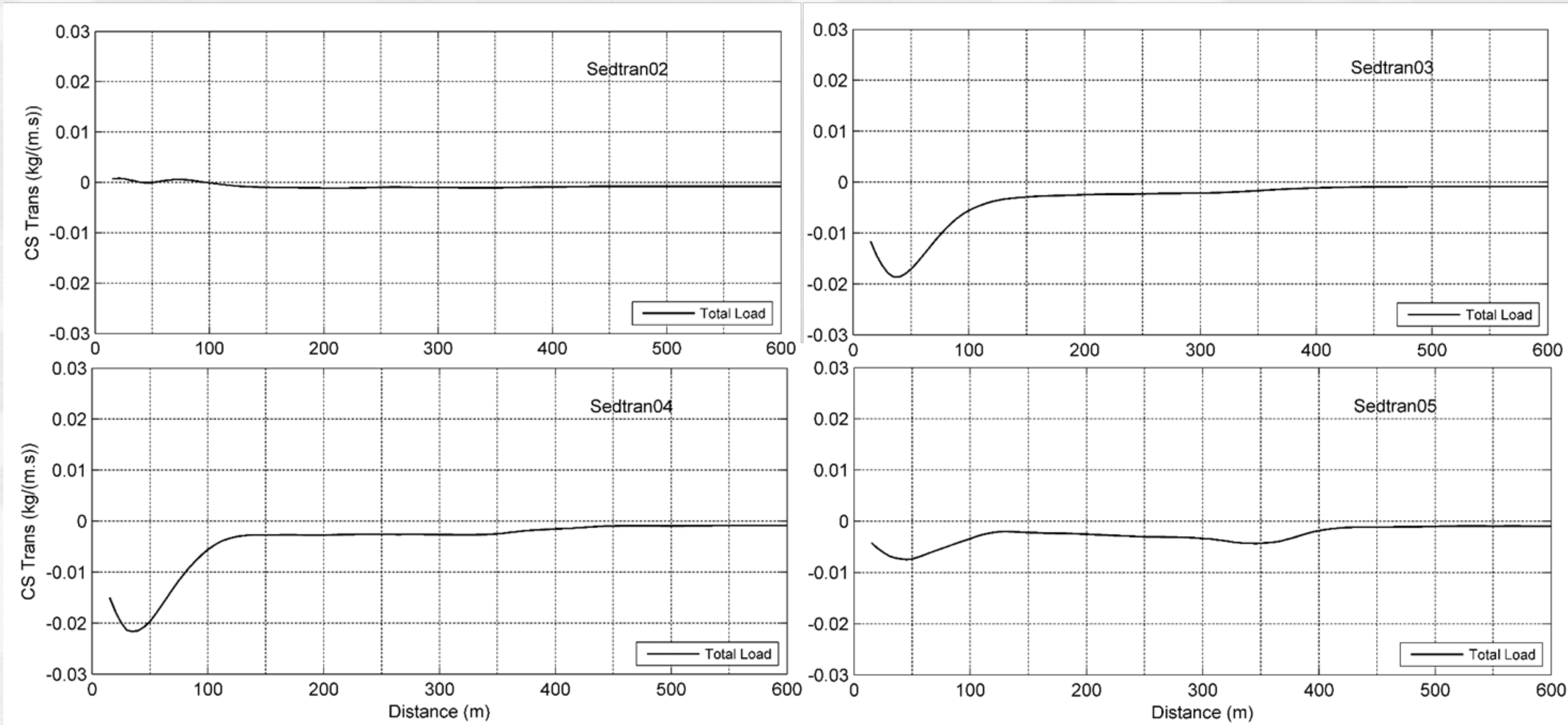
Sediment transport rates and morphology changes

- Oct 10 - Nov 15, 2016



Cross-shore Sediment Transport

LUND-CIRP (NSZ)



Cross-shore Sediment Transport

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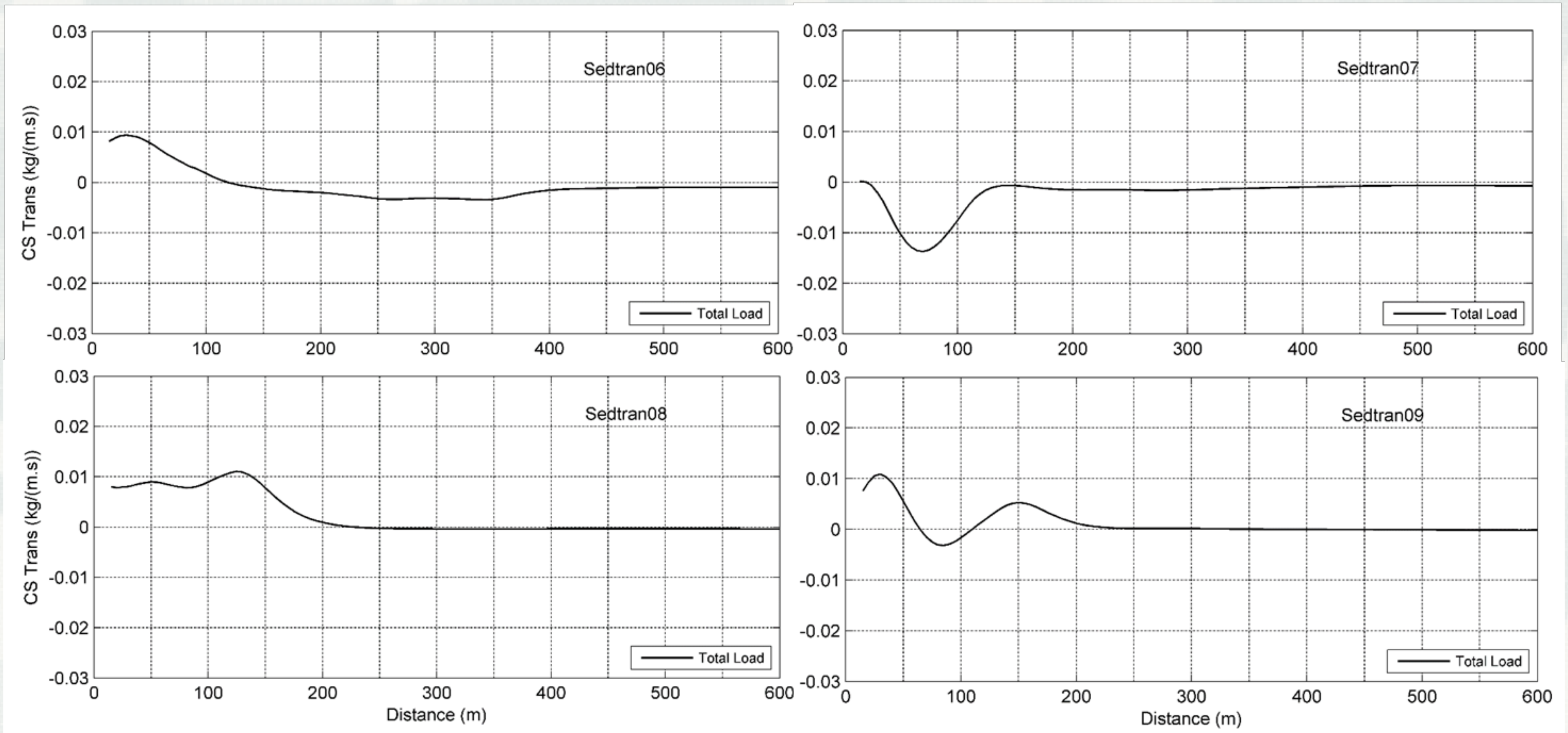

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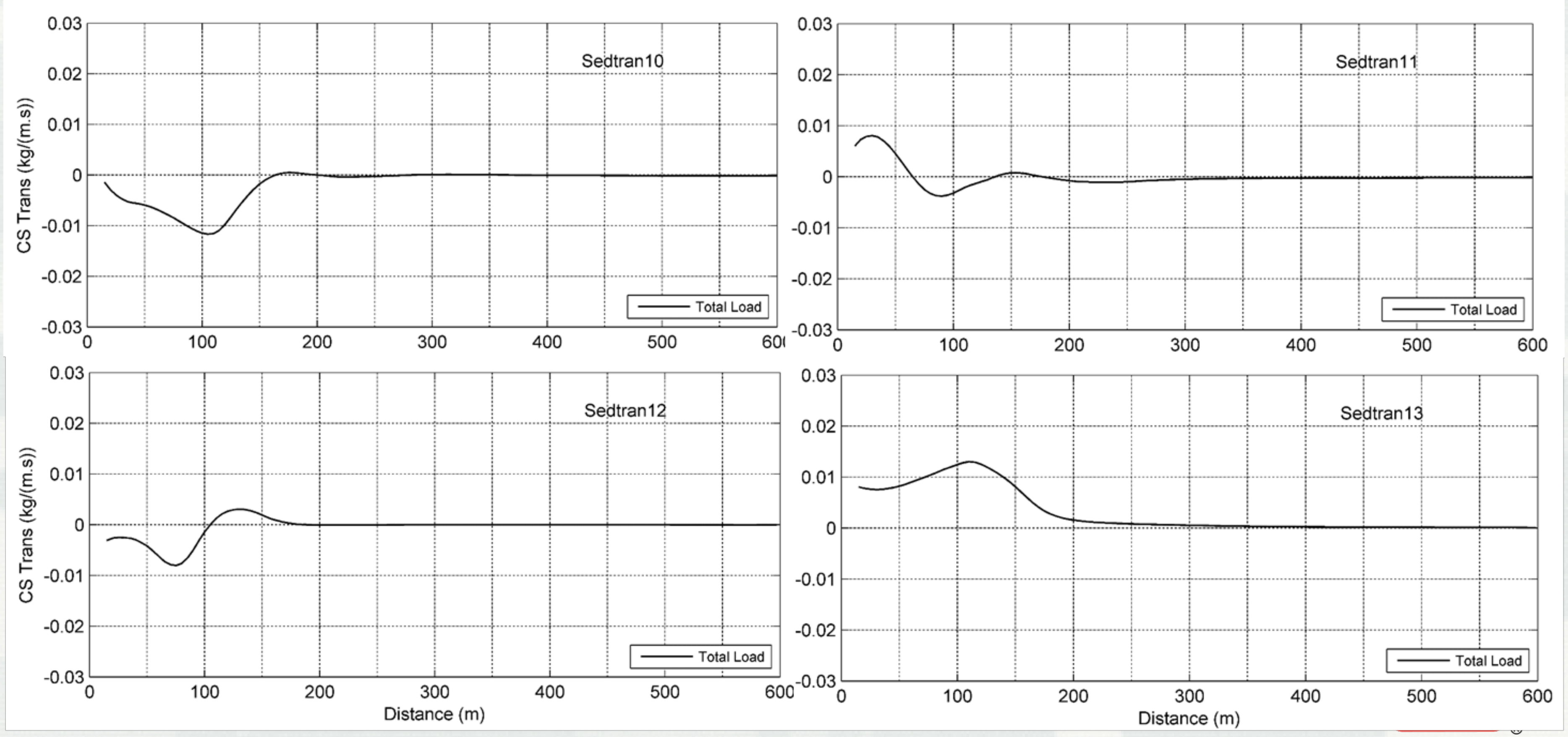

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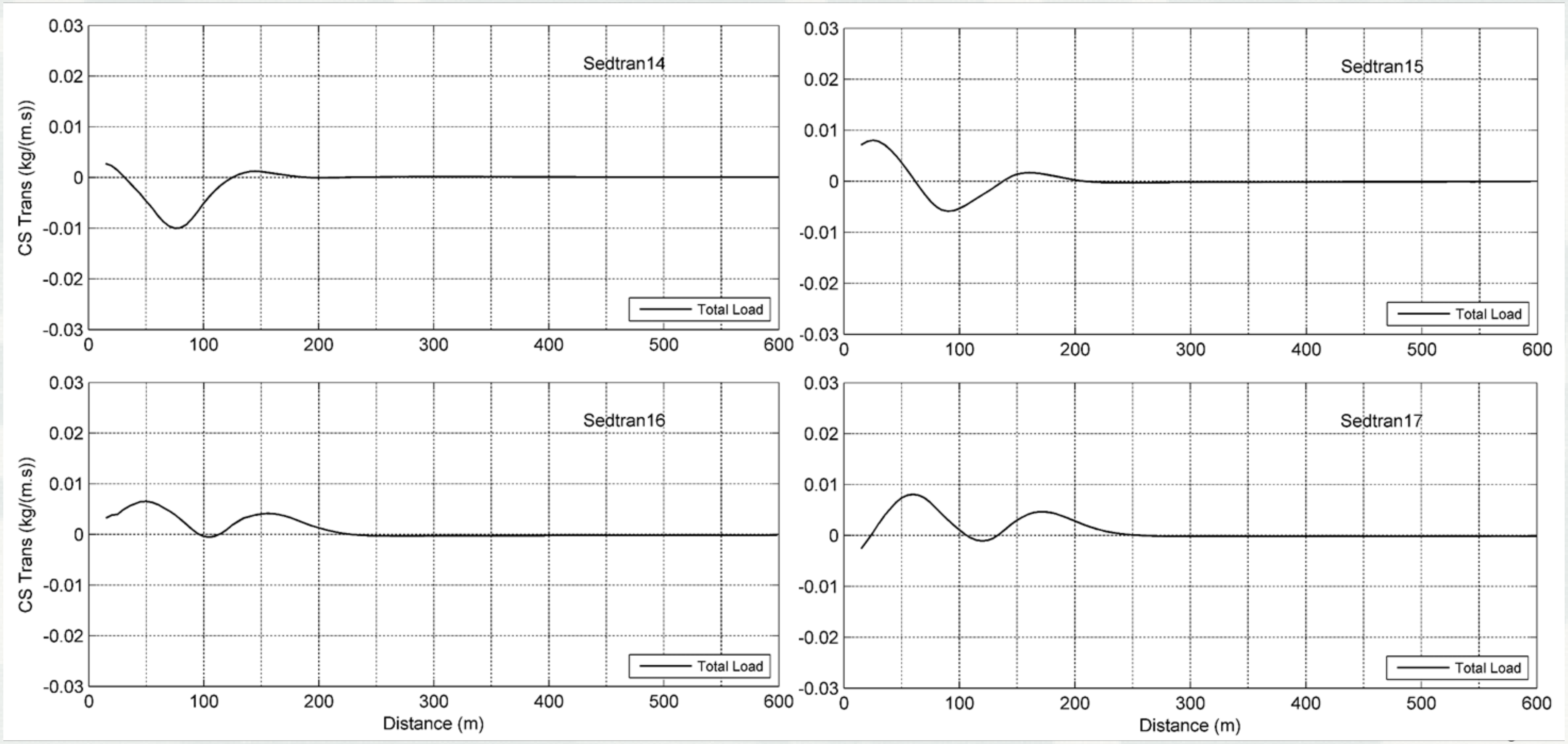

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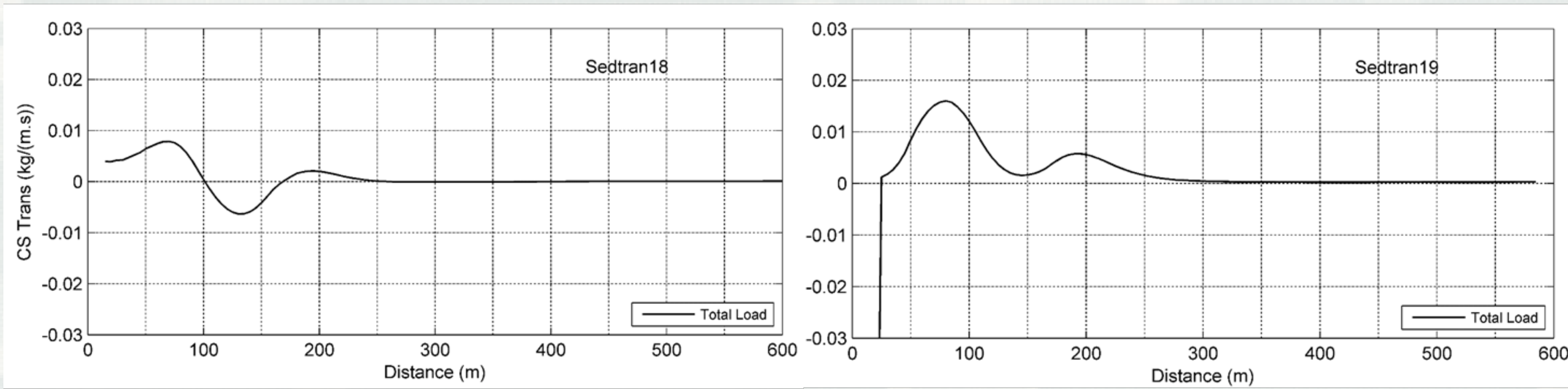
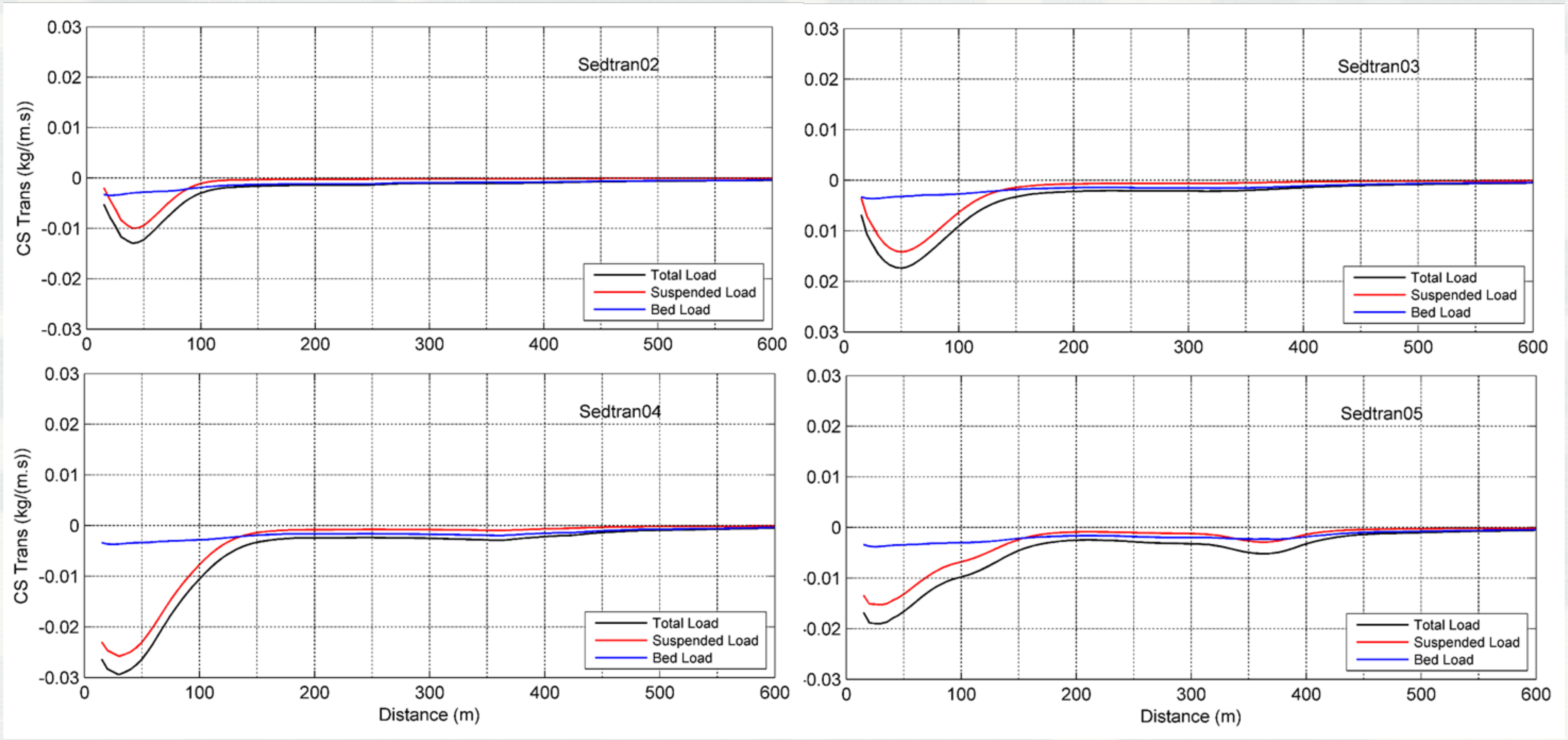


Cross-shore Sediment Transport

Large suspension coefficients

$$e_B = \quad 0.015$$
$$e_f = \quad 0.02$$



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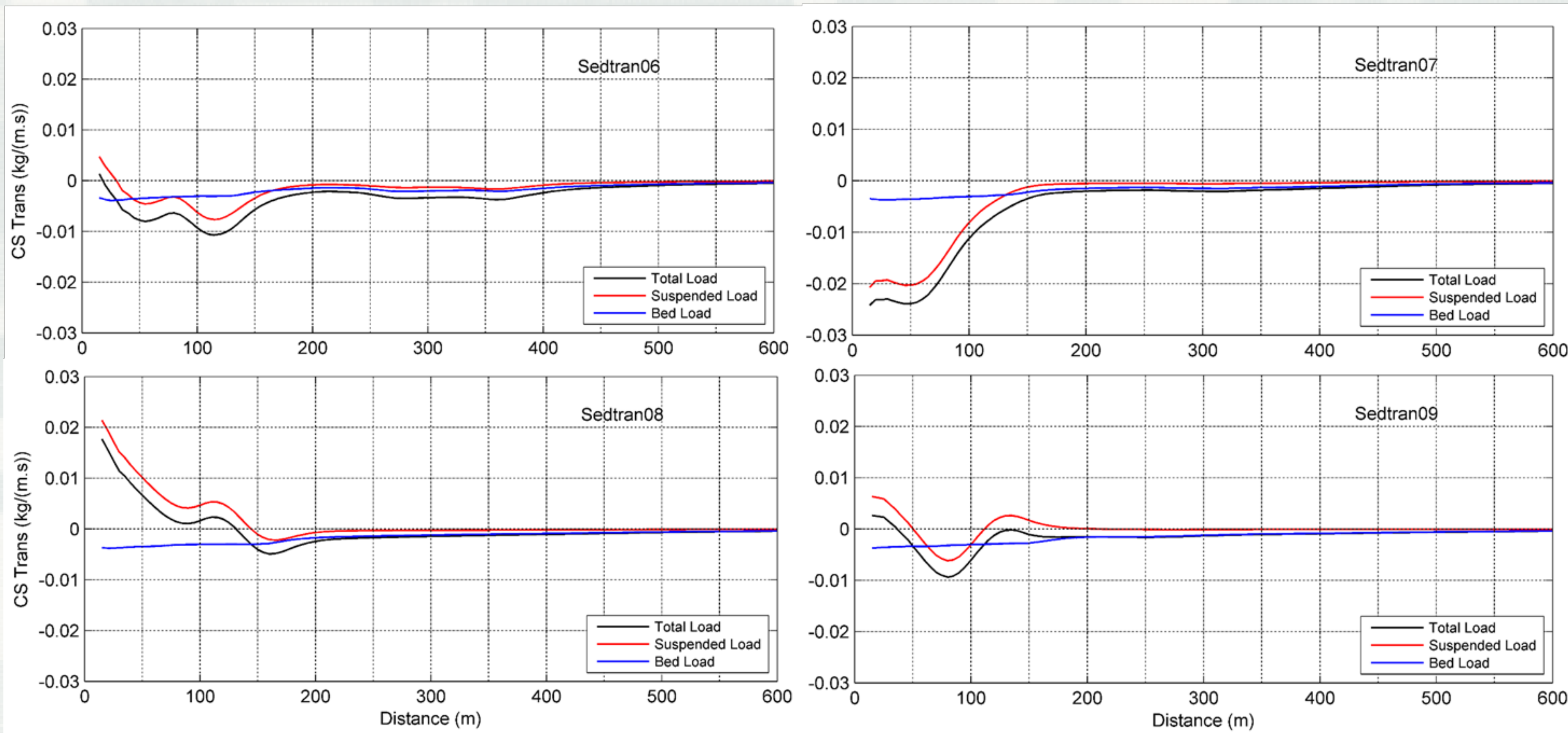

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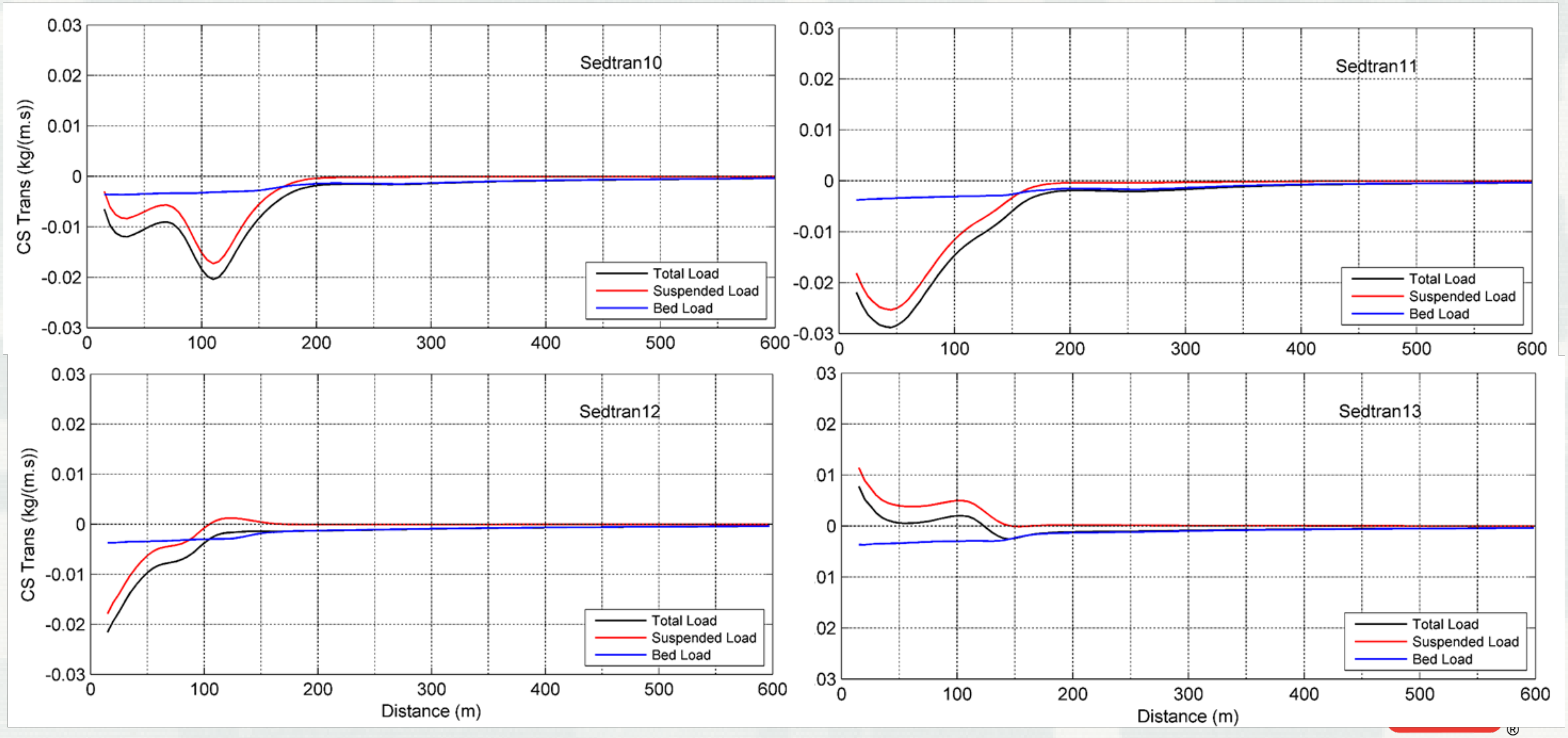

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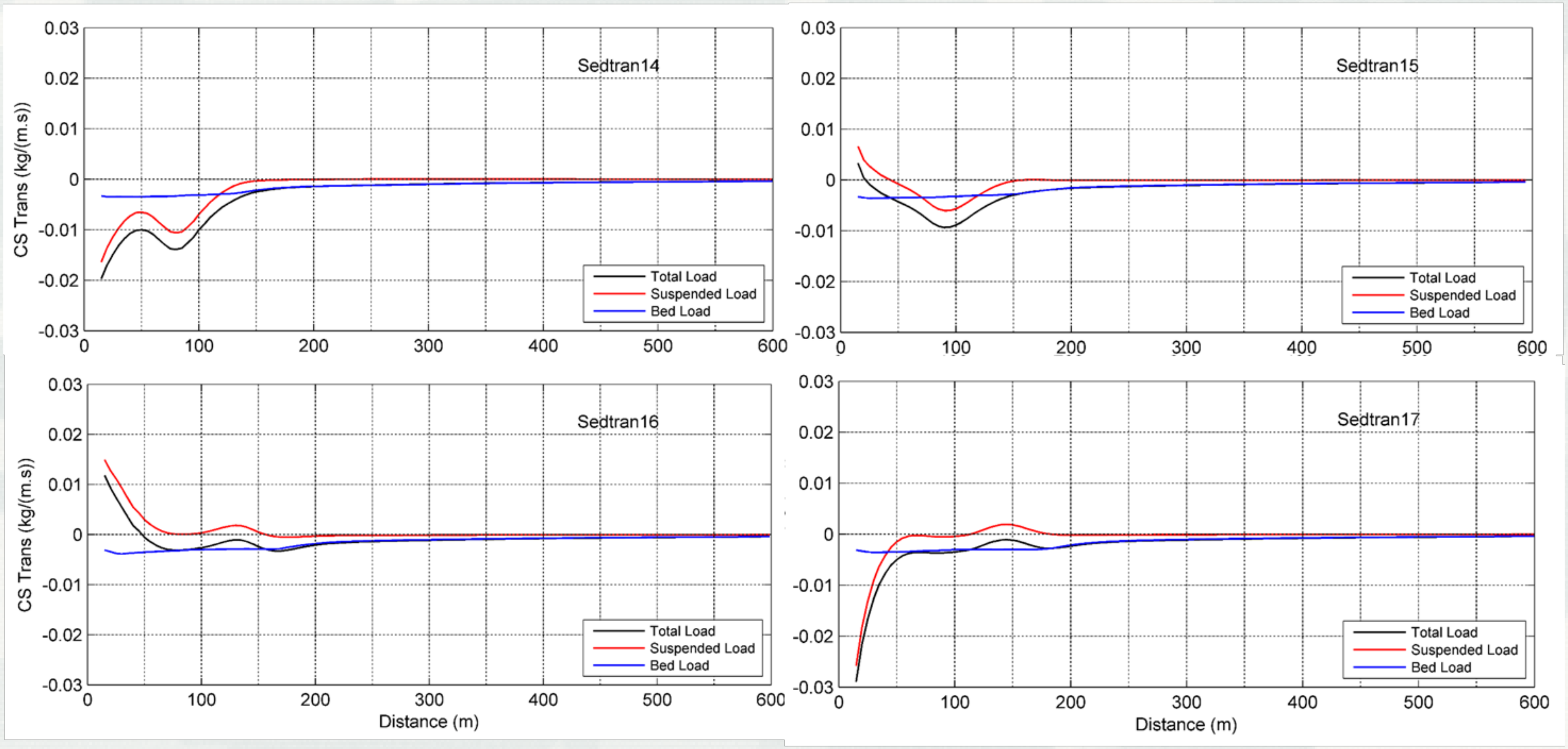

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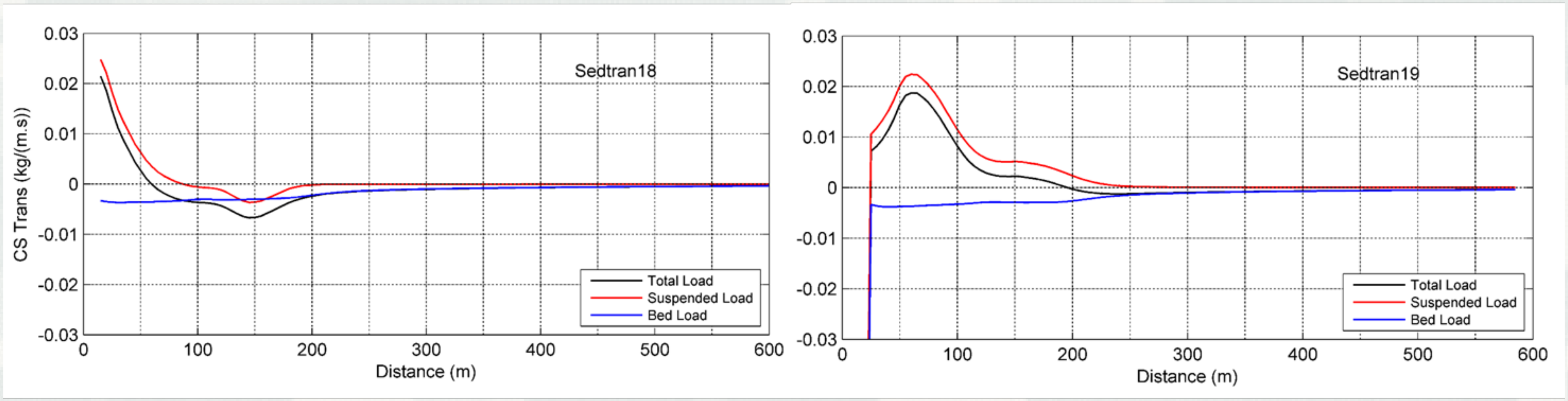
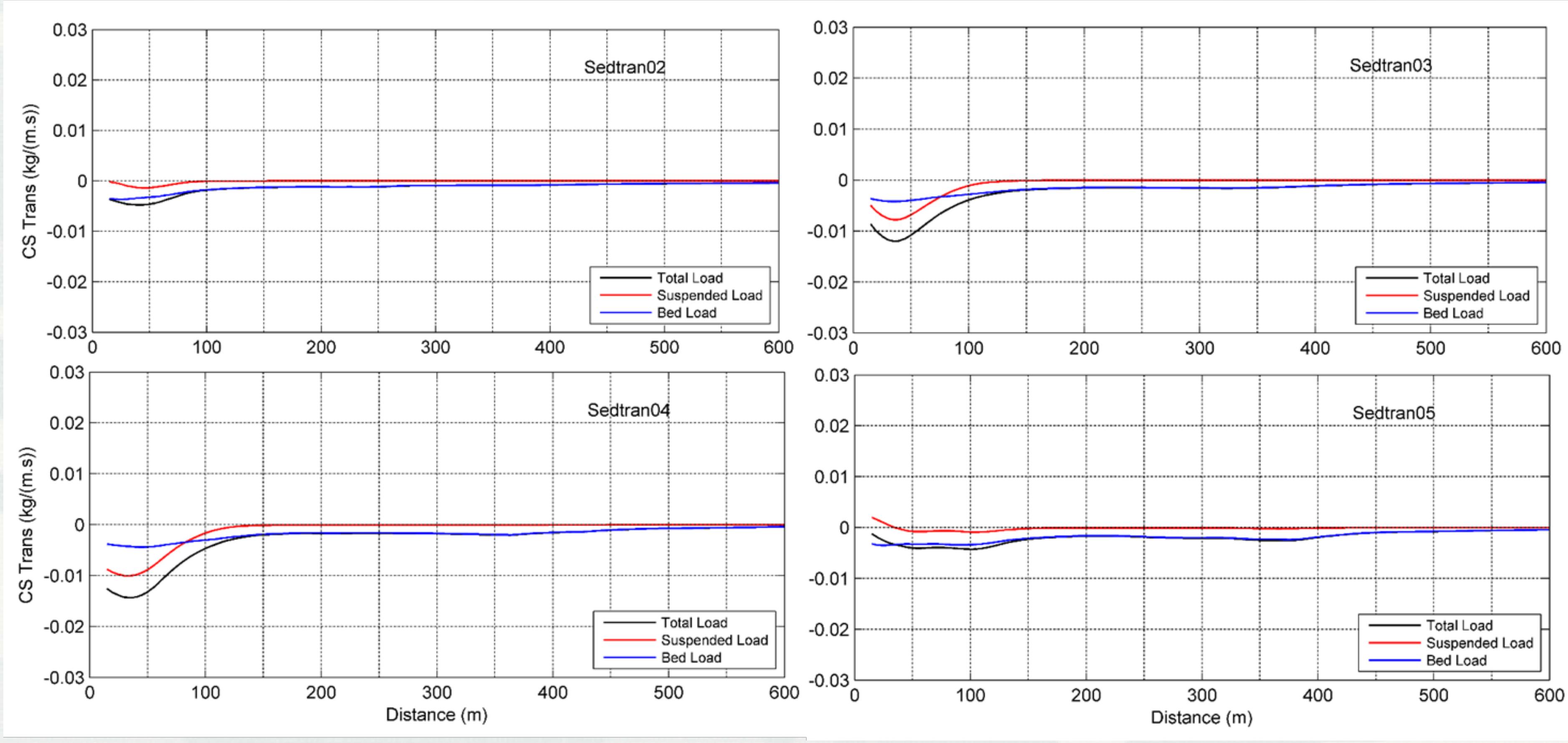


Cross-shore Sediment Transport

Smaller suspension coefficients

$$e_B = 0.0015$$

$$e_f = 0.001$$



Cross-shore Sediment Transport

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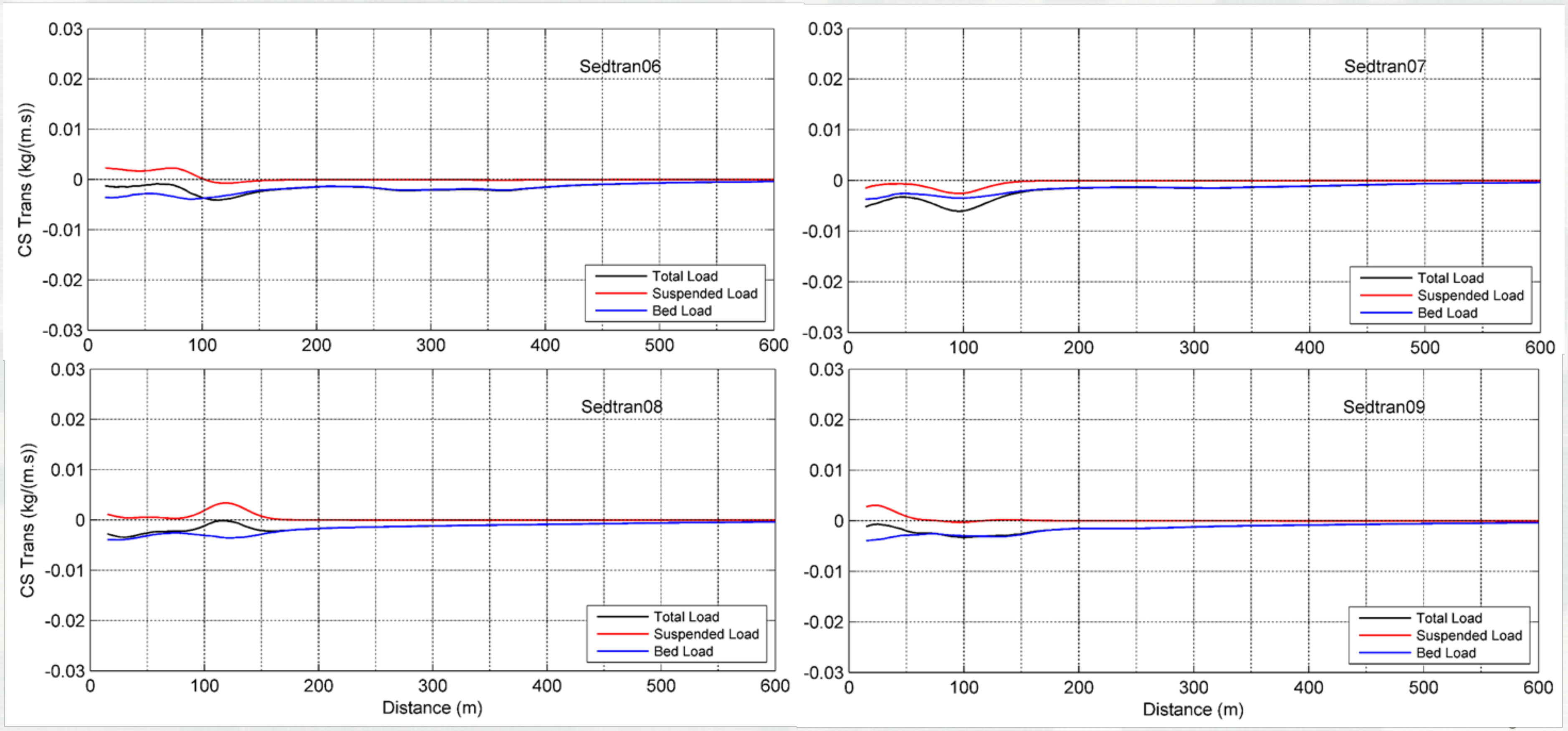

Cross-shore Sediment Transport

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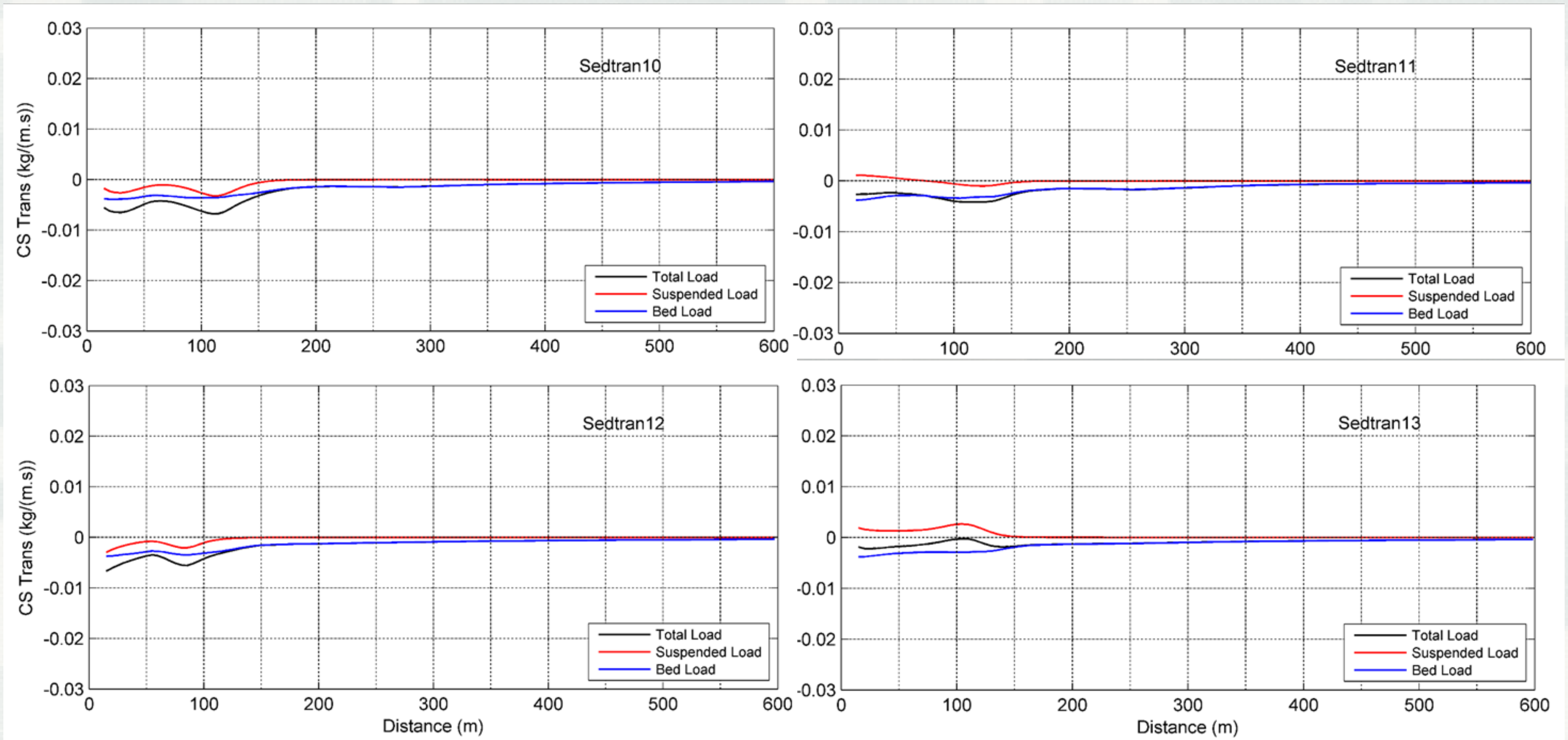

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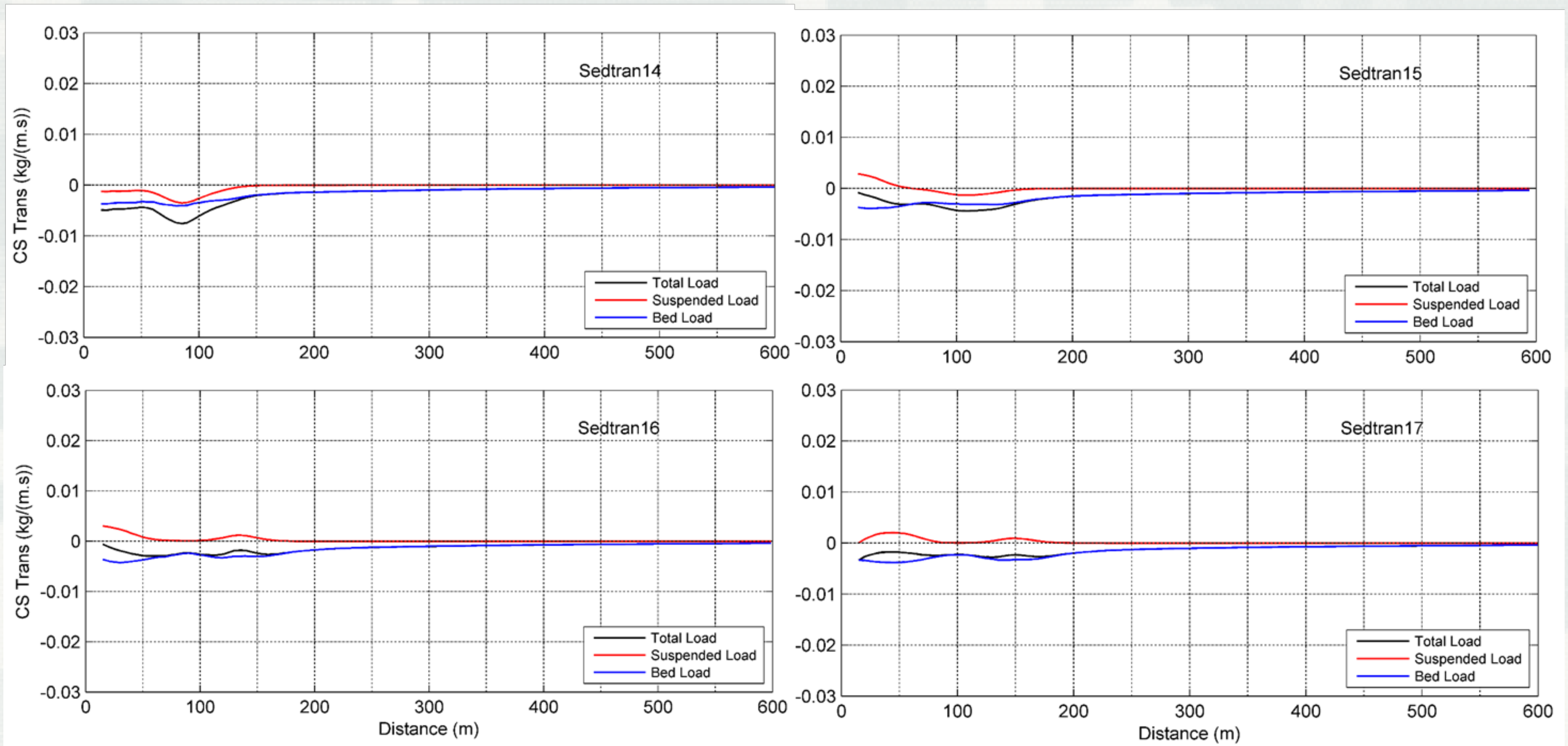

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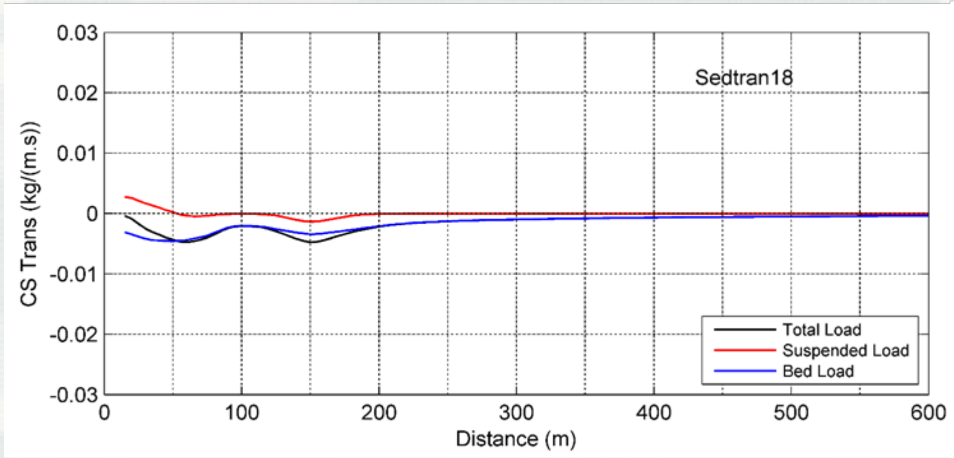
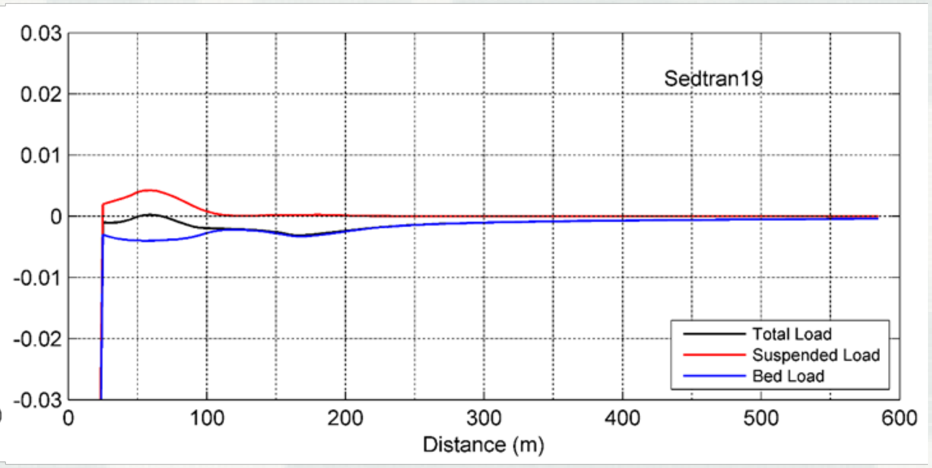
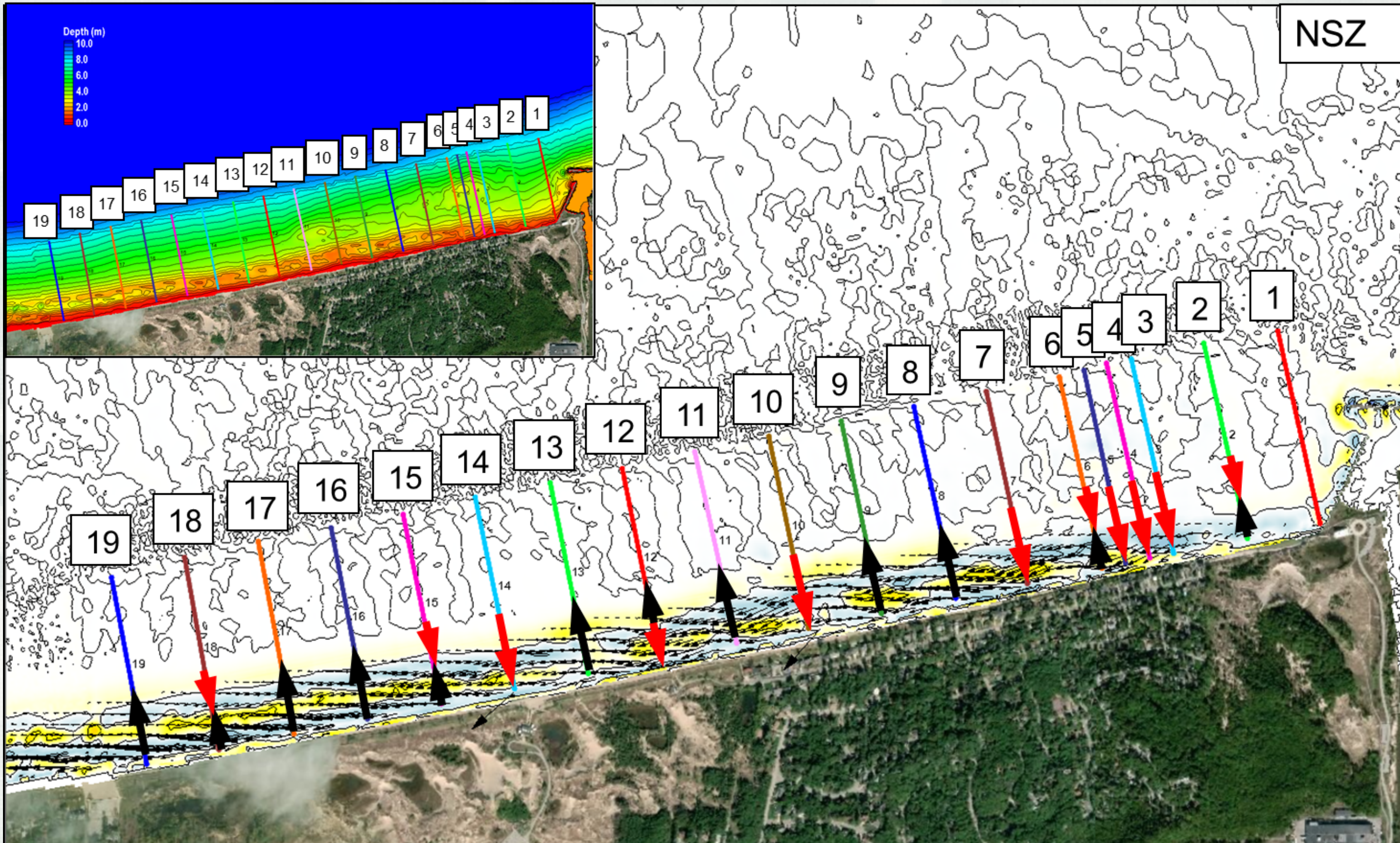
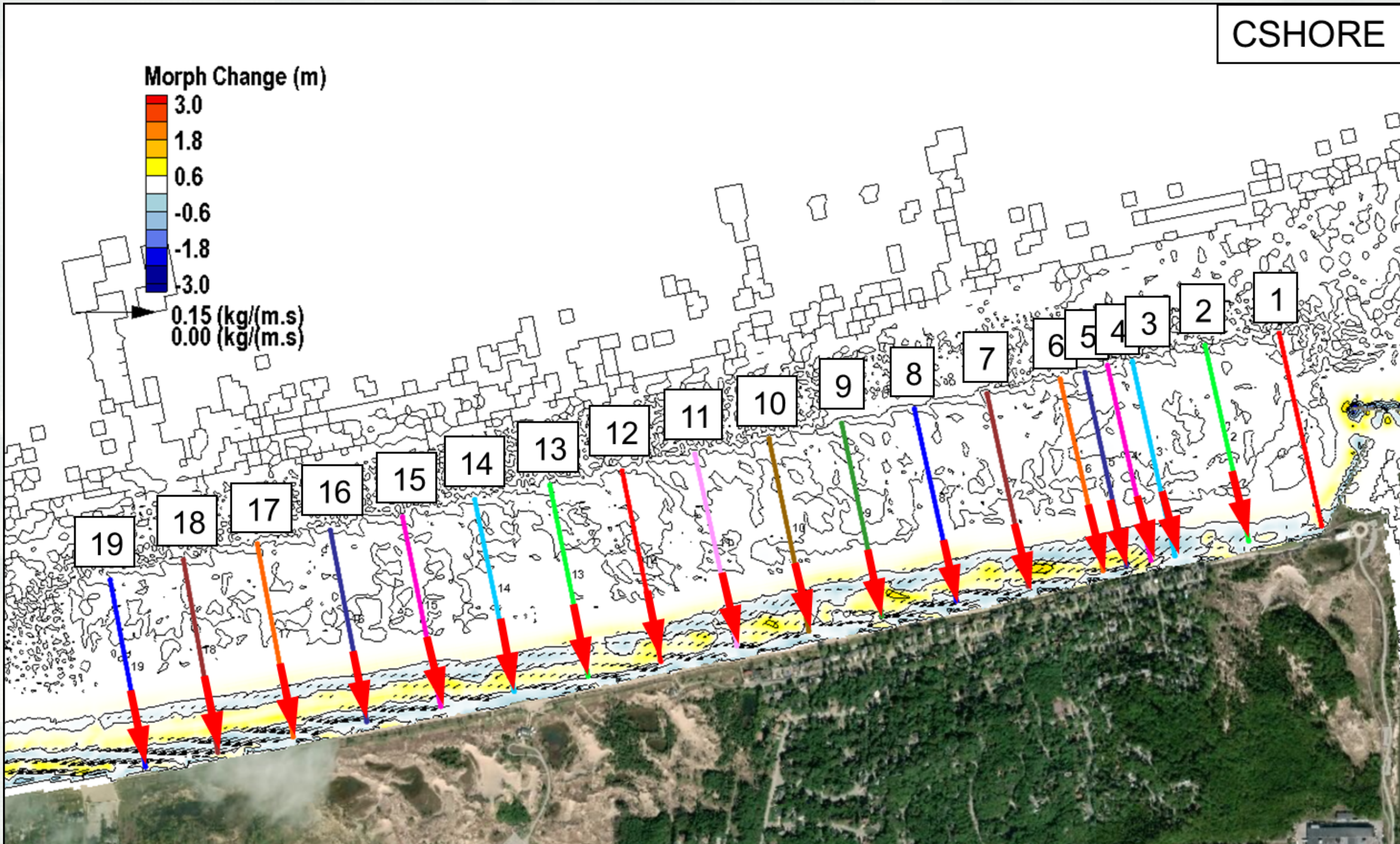




LUND-CIRP


NSZ
Depth (m)
10.0
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

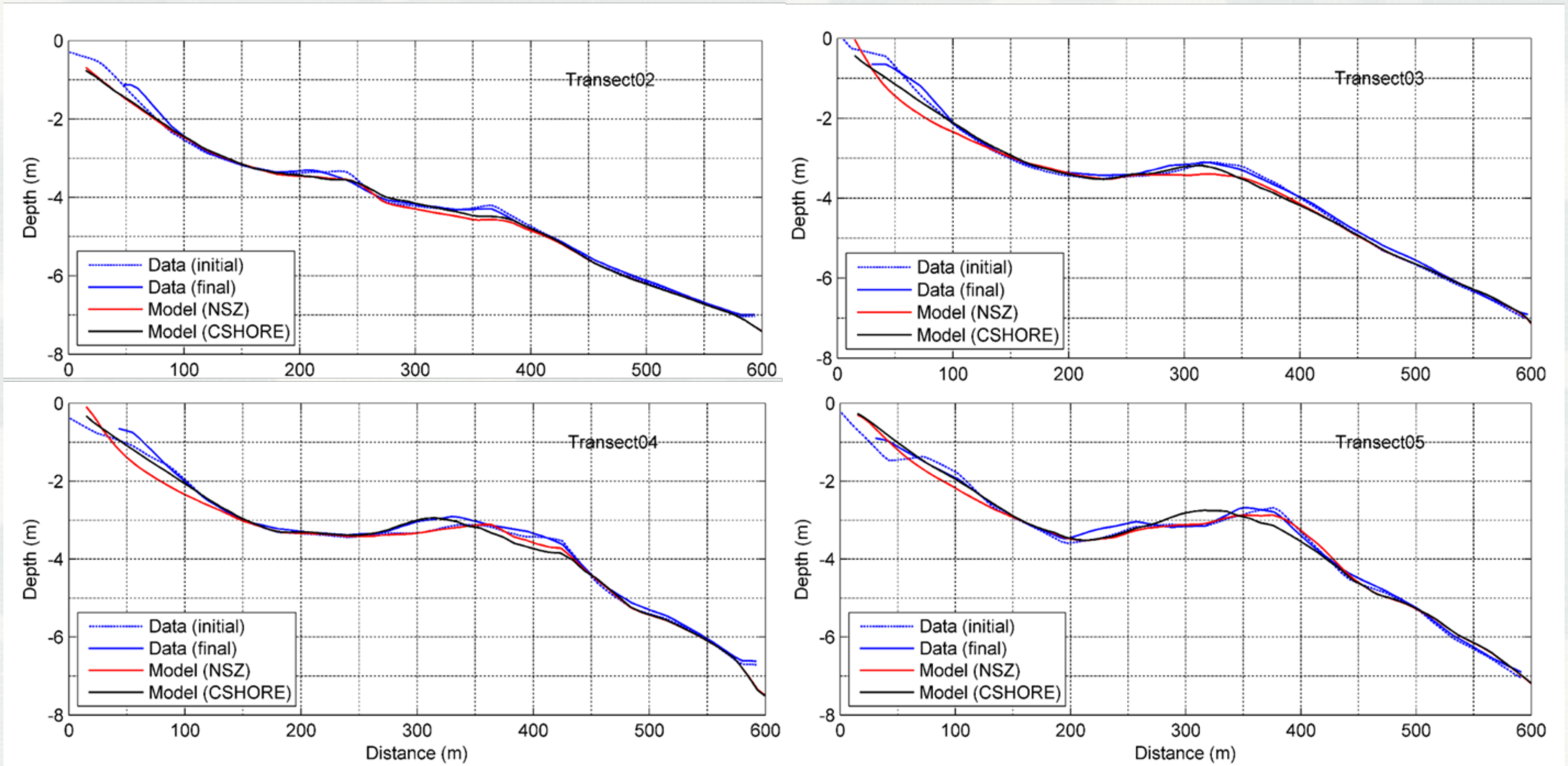
CSHORE



CSHORE
Morph Change (m)
3.0
1.8
0.6
-0.6
-1.8
-3.0
0.15 (kg/(m.s)
0.00 (kg/(m.s)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

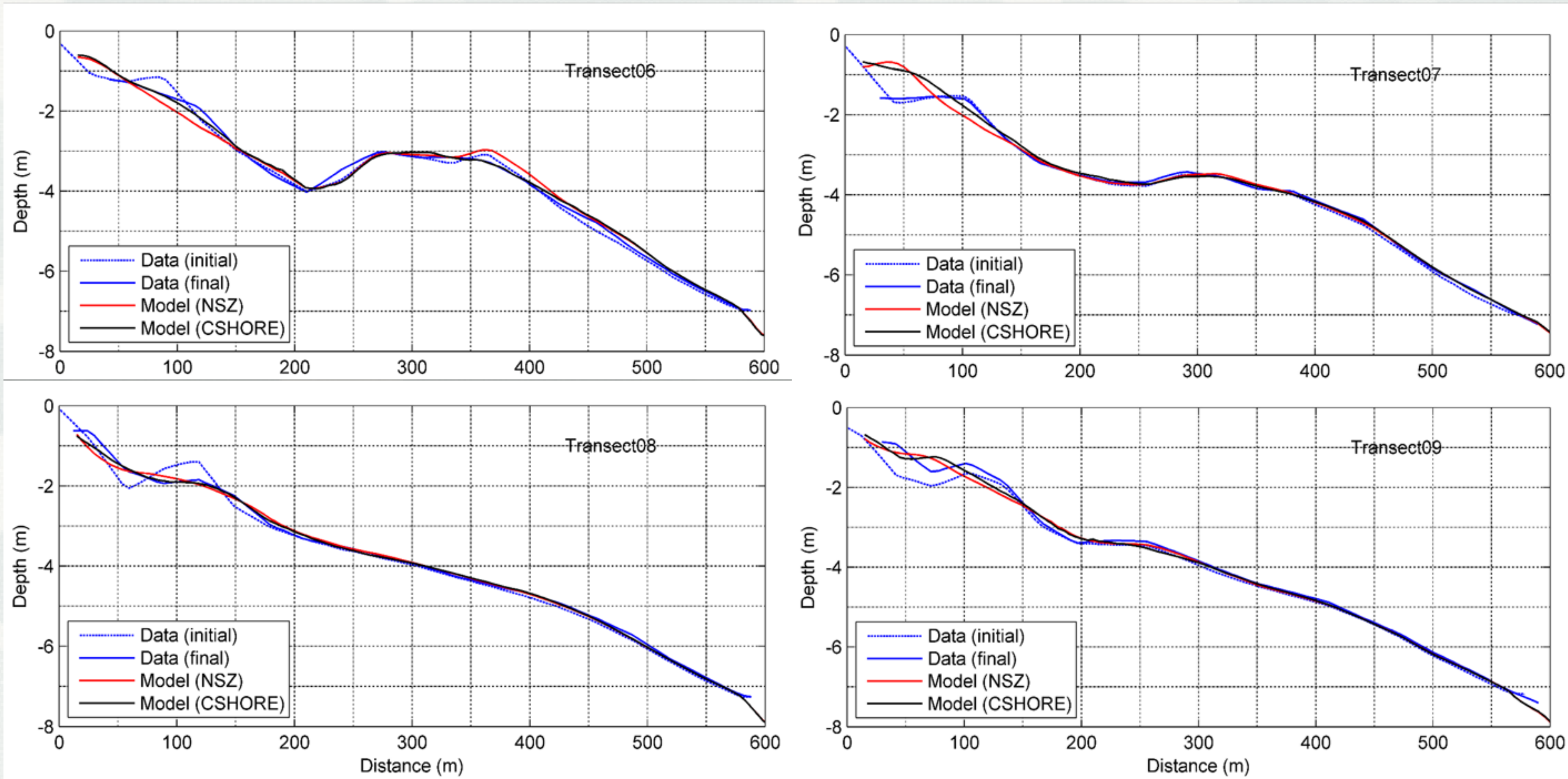
Profile Changes

- Transects 02-05



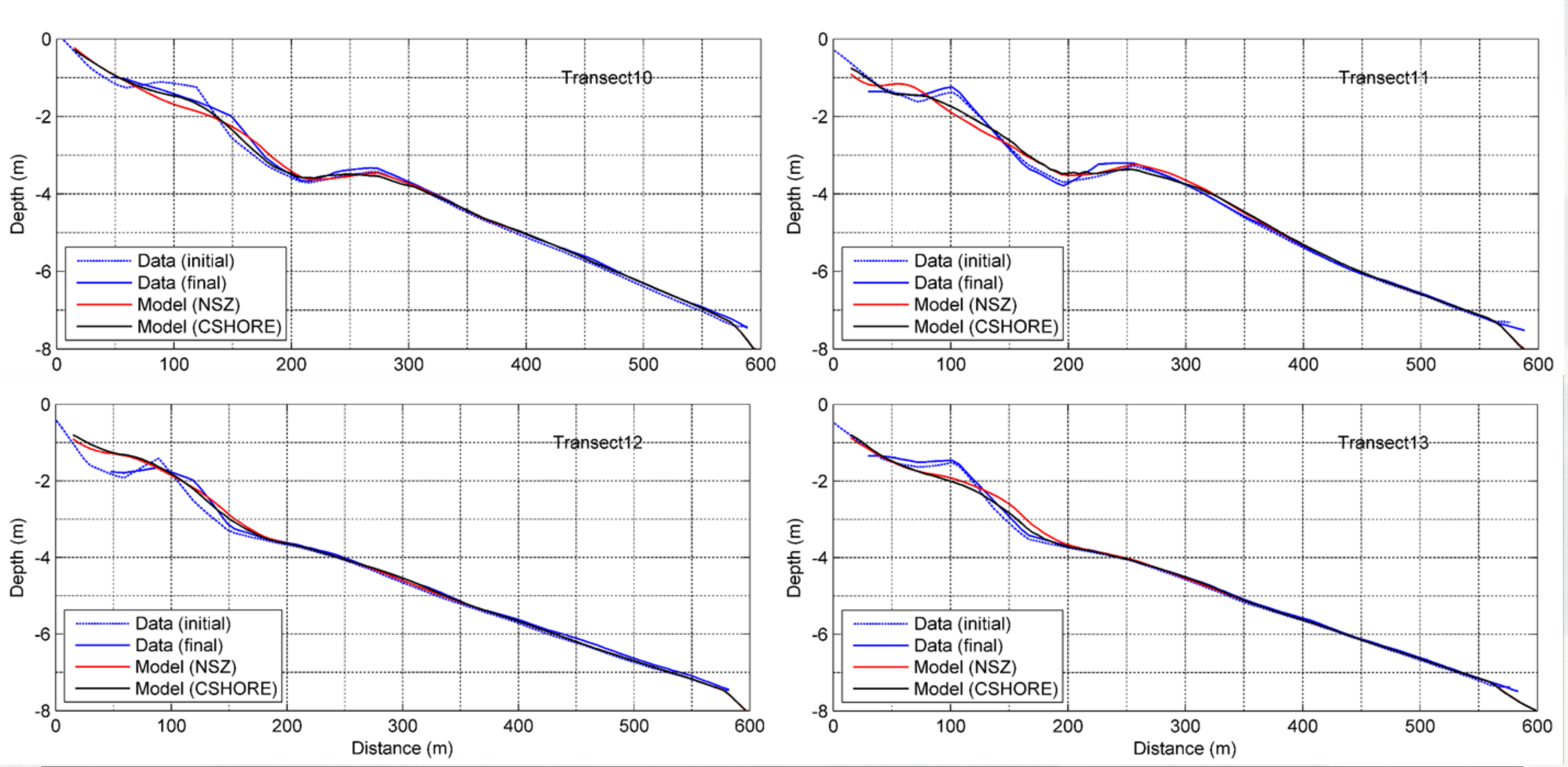
Profile Changes

- Transects 06-09



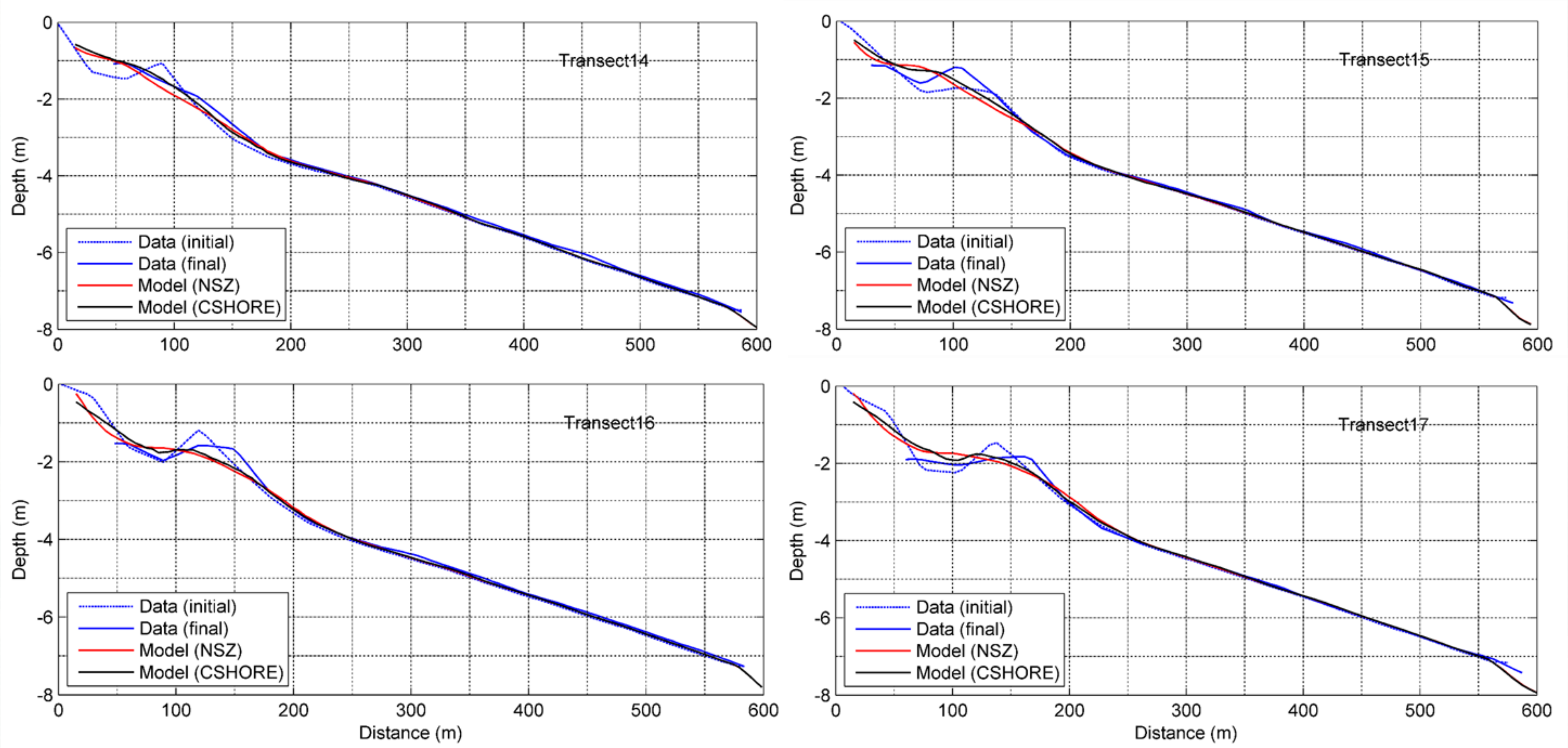
Profile Changes

- Transects 10-13



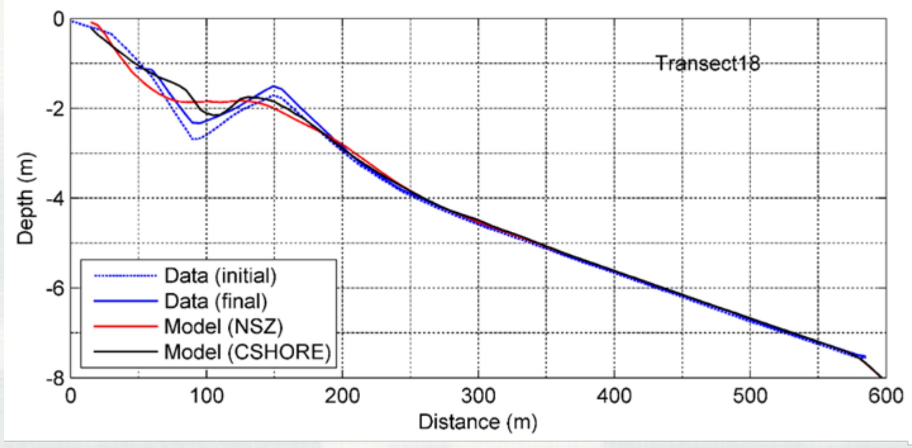
Profile Changes

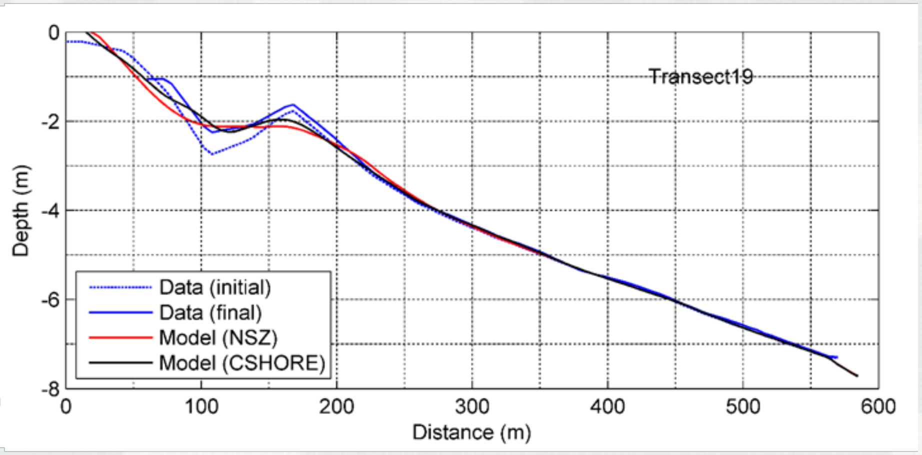
- Transects 14-17



Profile Changes

- Transects 18-19





Goodness of Fit Statistics

(measured and calculated bed elevations)

Transect	Scenario	RMSE (m)	RRMSE (%)	R^2	Transect	Scenario	RMSE (m)	RRMSE (%)	R^2
2	NSZ	0.147	1.99	0.995	11	NSZ	0.199	2.69	0.989
	CSHORE	0.124	1.68	0.995		CSHORE	0.177	2.39	0.992
3	NSZ	0.237	3.21	0.991	12	NSZ	0.129	1.74	0.996
	CSHORE	0.148	2.00	0.996		CSHORE	0.128	1.73	0.996
4	NSZ	0.252	3.41	0.985	13	NSZ	0.150	2.02	0.994
	CSHORE	0.183	2.48	0.989		CSHORE	0.144	1.95	0.995
5	NSZ	0.139	1.88	0.993	14	NSZ	0.098	1.32	0.999
	CSHORE	0.167	2.25	0.988		CSHORE	0.080	1.09	0.999
6	NSZ	0.177	2.39	0.987	15	NSZ	0.167	2.25	0.993
	CSHORE	0.121	1.64	0.994		CSHORE	0.131	1.77	0.995
7	NSZ	0.229	3.10	0.981	16	NSZ	0.148	1.99	0.994
	CSHORE	0.203	2.74	0.988		CSHORE	0.132	1.79	0.995
8	NSZ	0.108	1.46	0.996	17	NSZ	0.144	1.95	0.994
	CSHORE	0.078	1.05	0.998		CSHORE	0.135	1.82	0.995
9	NSZ	0.138	1.86	0.995	18	NSZ	0.167	2.25	0.993
	CSHORE	0.123	1.67	0.996		CSHORE	0.130	1.75	0.996
10	NSZ	0.121	1.64	0.997	19	NSZ	0.170	2.30	0.995
	CSHORE	0.104	1.40	0.998		CSHORE	0.114	1.54	0.998

Summary

- Average nearshore sediment transport has a predominant longshore direction from east to west.
- Waves in surf zone induce consistent onshore sediment movement, which primarily corresponds to bed load transport direction.
- Surf zone processes and wave induced cross-shore sediment transport improve model performance in simulating beach profile changes.
- LUND-CIRP + Surf Zone Processes

Thank You!