Hindcasting bathymetric change in San Pablo Bay, 1856-1983: A step towards assessing likely geomorphic change in response to climate change

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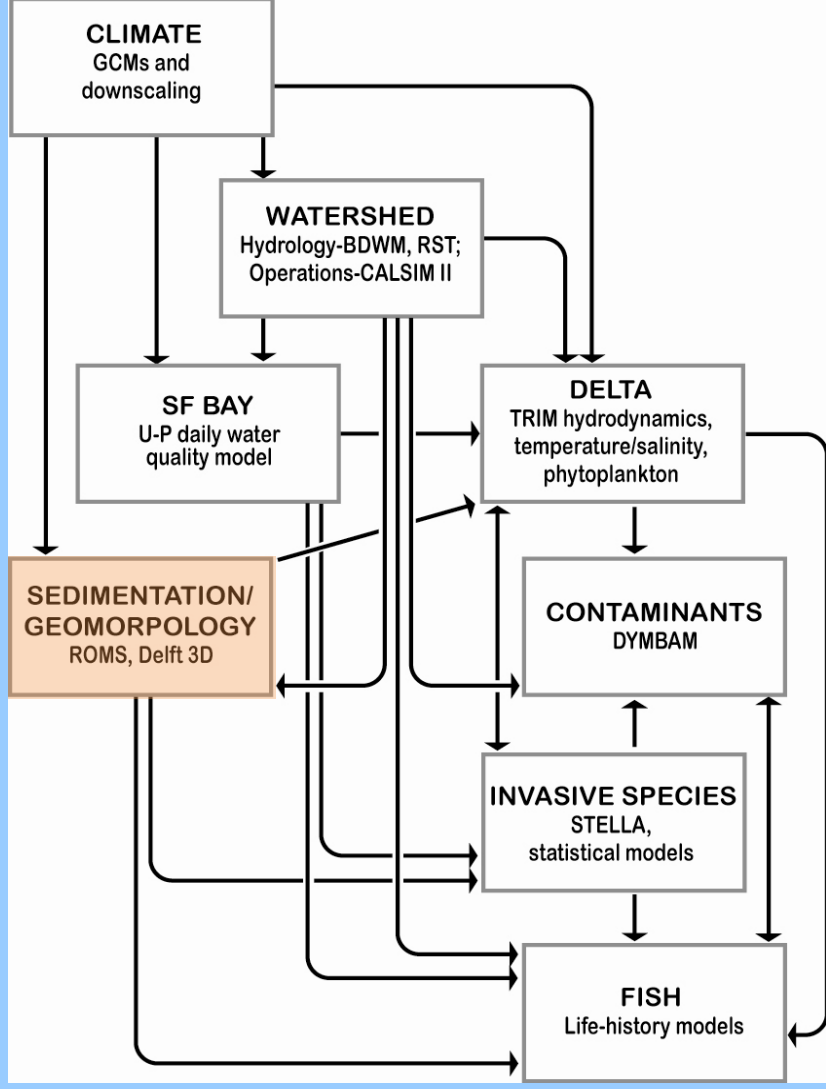
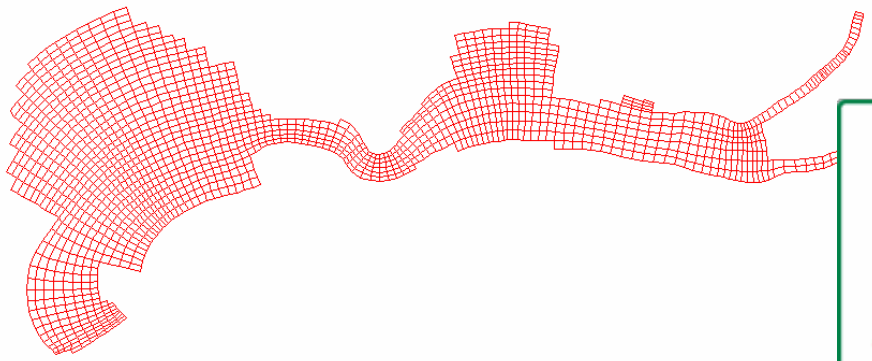
2 U.S. Geological Survey





Three characteristic periods

- Excess sediment supply due to ***hydraulic mining*** about 150 years ago – *measured deposition*.
- Dramatic decrease in sediment supply after stop in hydraulic mining and ***dam construction*** in the last century – *measured erosion*.
- ***Climate change*** will further perturb the morphodynamics as sea level rises and the river discharge regimes are altered by warming and precipitation changes – further erosion?.

Focus on 1856-1887 hydraulic mining period (extreme sediment supply)

Deposition = function of

river discharge *(estimated)*, tidal energy, wave energy, bathymetry, sediment supply *(estimated)*, sediment characteristics *(estimated)*

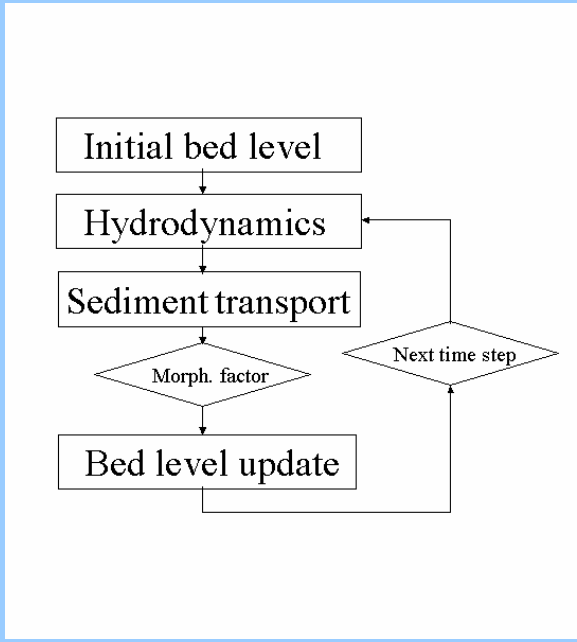
Subquestions:

Can process-based, 3D, numerical model reproduce sedimentation patterns?

How sensitive are model results to model parameter settings?

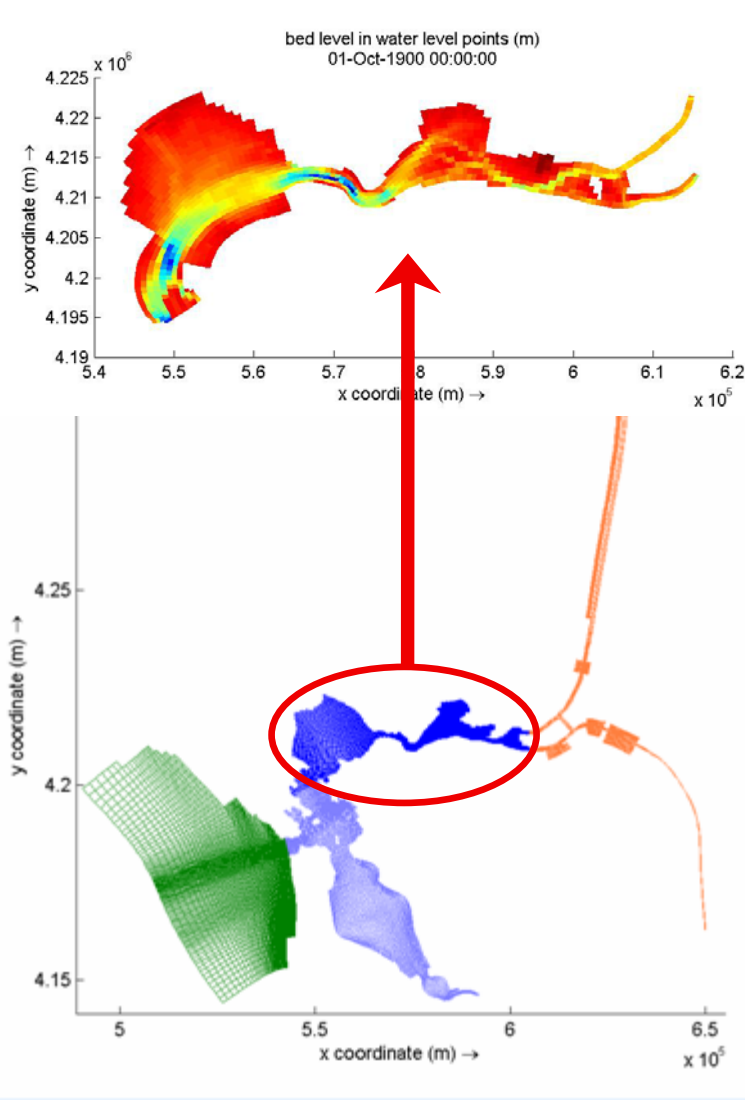
Delft 3D

- Process-based 3D numerical model
- Shallow water equations
- Multiple transport formulations
- Multiple sediment fractions
- Bed slope effects
- Bed level update every time step
- Waves

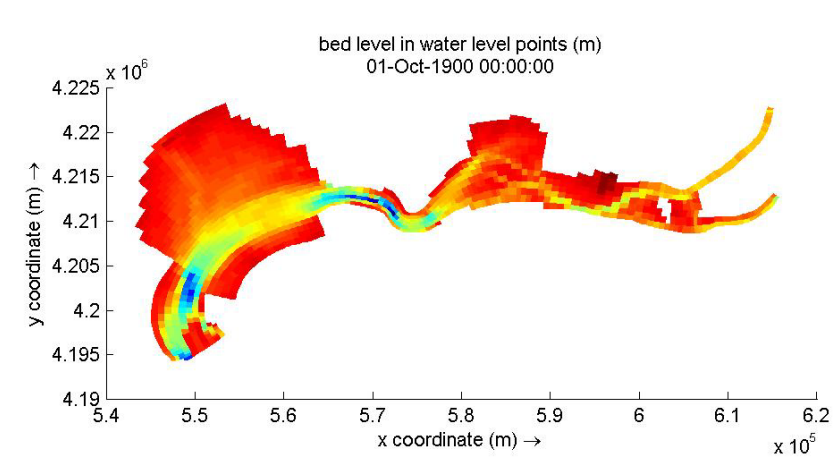


Model schematization

- Only SPB and SSB area (fast runs)
- Boundaries generated by big model
  - Boundary conditions by main harmonic constituents: M2, M4 and C1 (comb. of K1 and O1!)
  - River discharge (Qr)=10,000 m3/s for 1 month
  - River discharge (Qr)= 0 for 11 months
  - Sediment supply via $Qs = \alpha\ Qr^{\beta}$ (historic proxy by Ganju et al (2008))



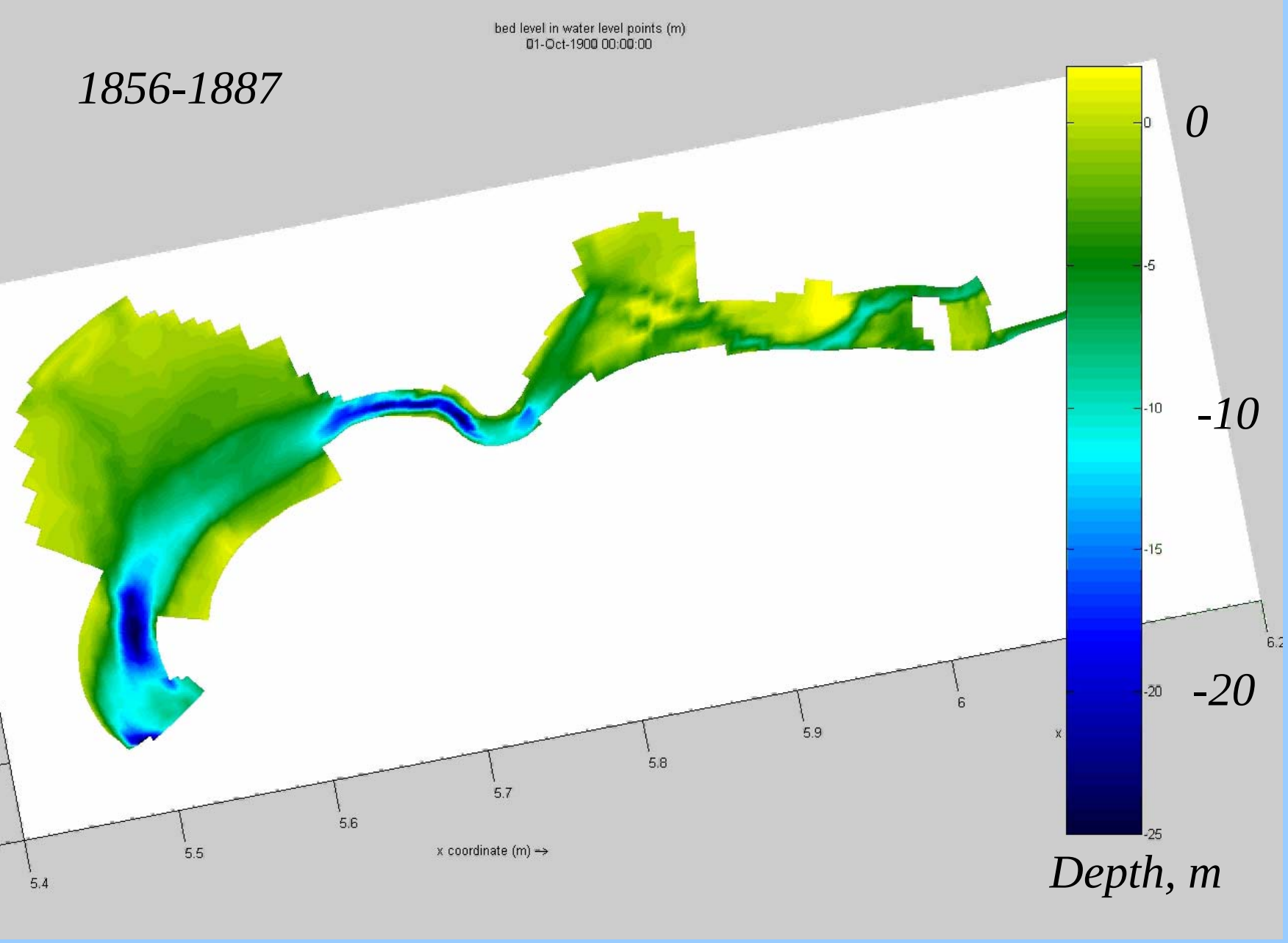
Model schematization



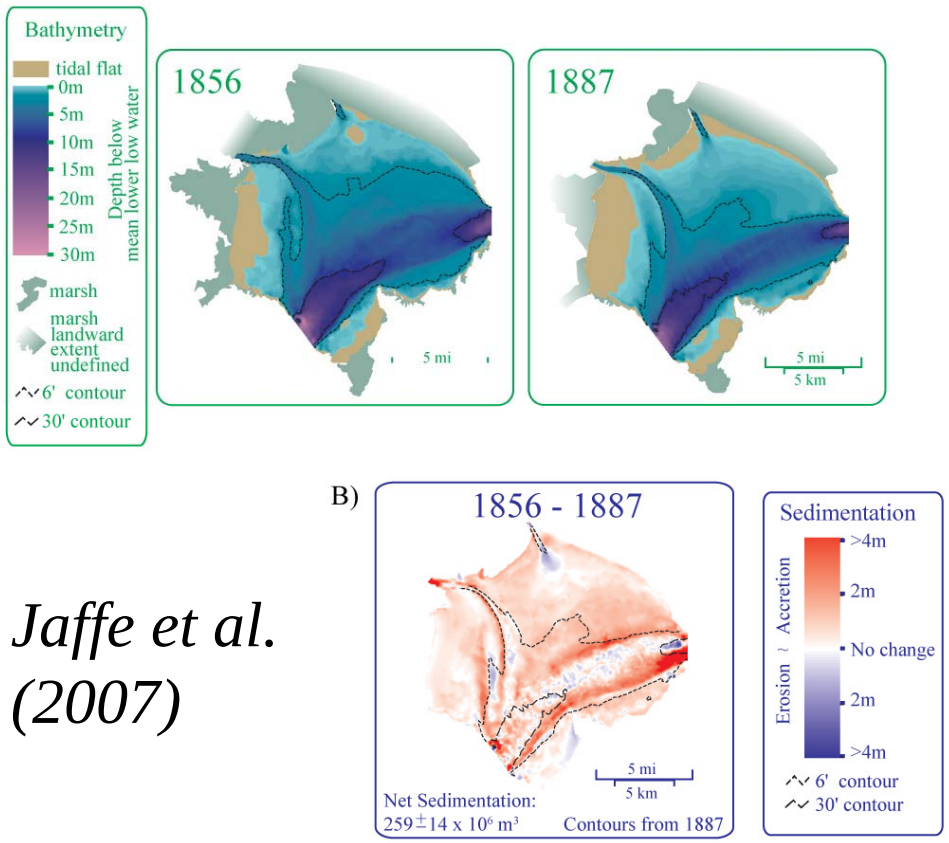
- 1856 measured bathymetry
- Wind diurnal with 7 m/s around noon
  - 6 months from the west
  - 5 months from south east
- Sediment transport formulae
  - Van Rijn for sand, 3 fractions
  - Krone/Partheniades for mud, 5 fractions

Model parameter settings

1		***Standard***
2	850 mg/l	1000 mg/l
3	1150 mg/l	1000 mg/l
4	Erosion factor = 0.00005	M= 0.0001
5	Erosion factor = 0.0002	M= 0.0001
6	2D	3D
7	D=10	D=1
8	D=0.1	D=1
9	Qr= 15000 m3/s	Qr=10000 m3/s
10	Qr= 5000 m3/s	Qr=10000 m3/s
11	90% of tidal amplitude	
12	110% of tidal amplitude	


bed level in water level points (m)
01-Oct-1900 00:00:00
1856-1887
0
-10
-20
Depth, m
0
-5
-10
-15
-20
-25
5.4
5.5
5.6
5.7
5.8
5.9
6
x
x coordinate (m) →

Sediment volume change in San Pablo Bay from 1856 to 1887



Jaffe et al. (2007)

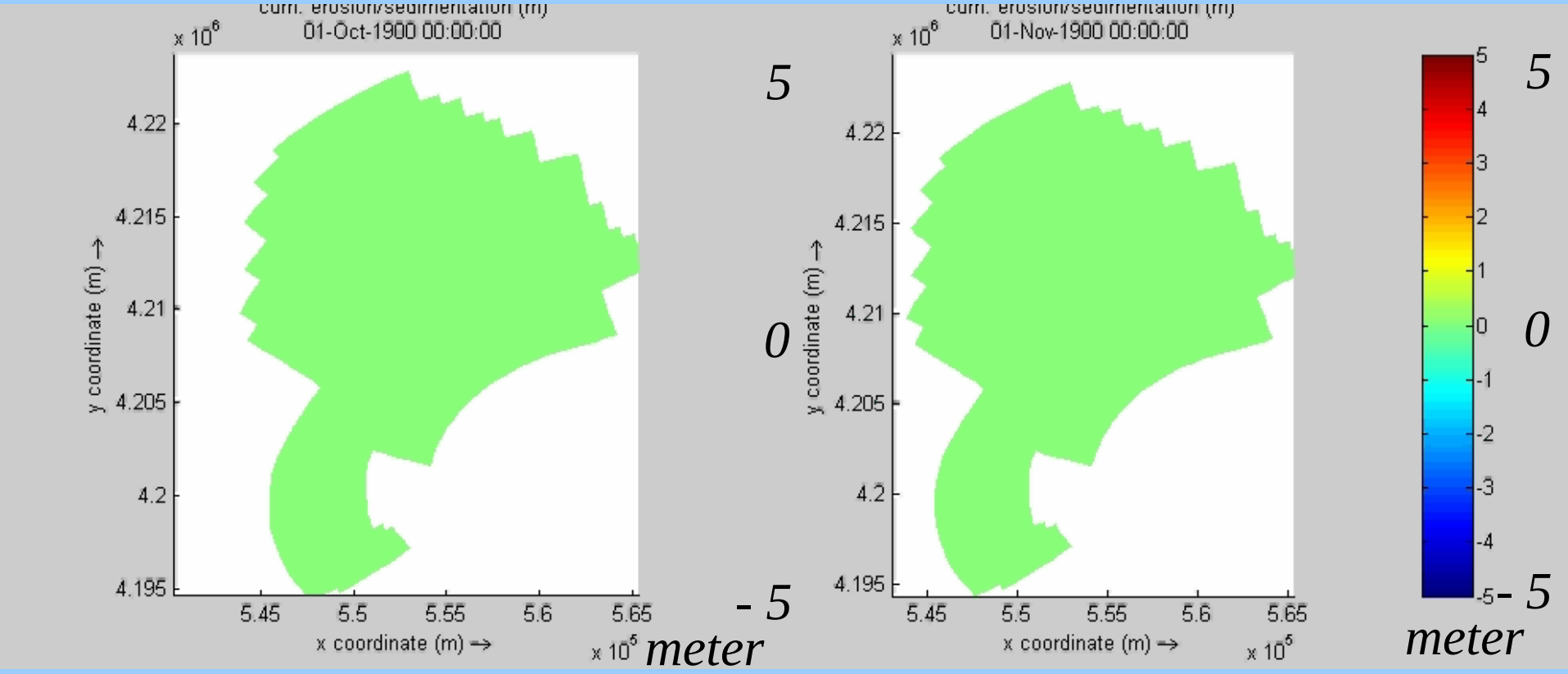
Average net sediment ***deposition*** was

~ 8 million m3/yr

Current conditions show ***erosion*** of

~ 0.8 million m3/yr

Typical erosion/deposition characteristics 1856-1887



1 month Wet

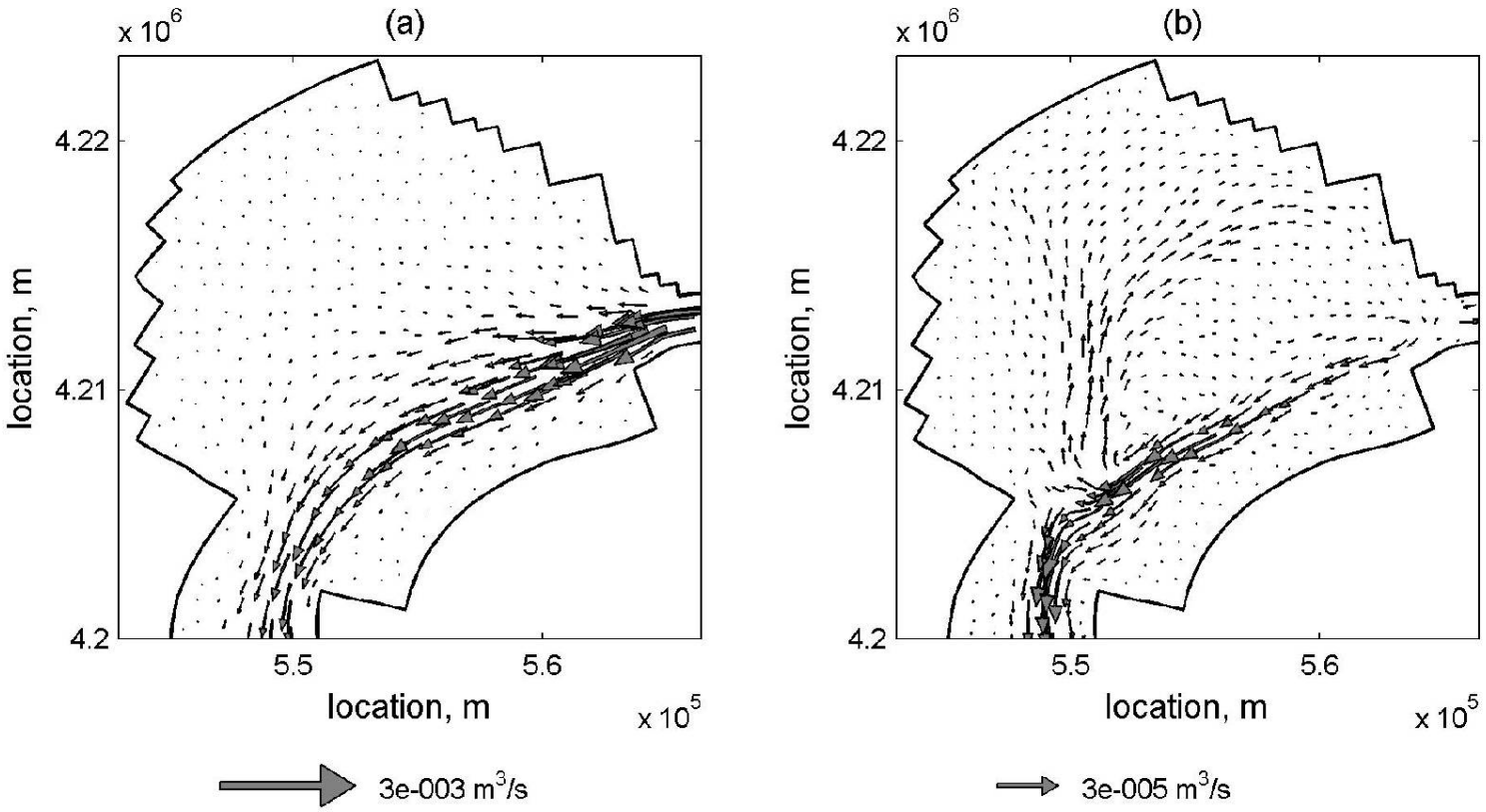
(30 times exaggerated!)

11 month Dry

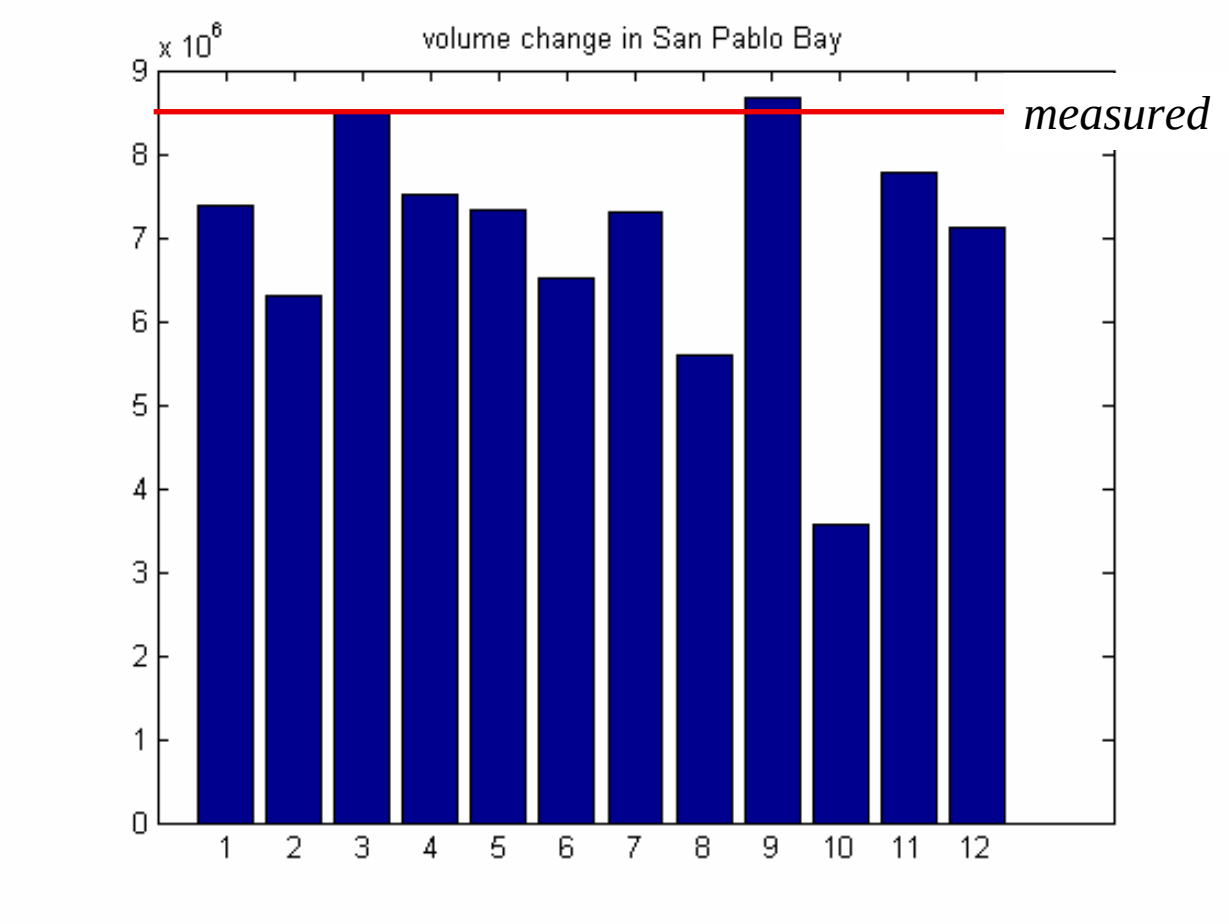
(30 times exaggerated!)

Mean transport patterns during 1856-1887 period

Wet Dry



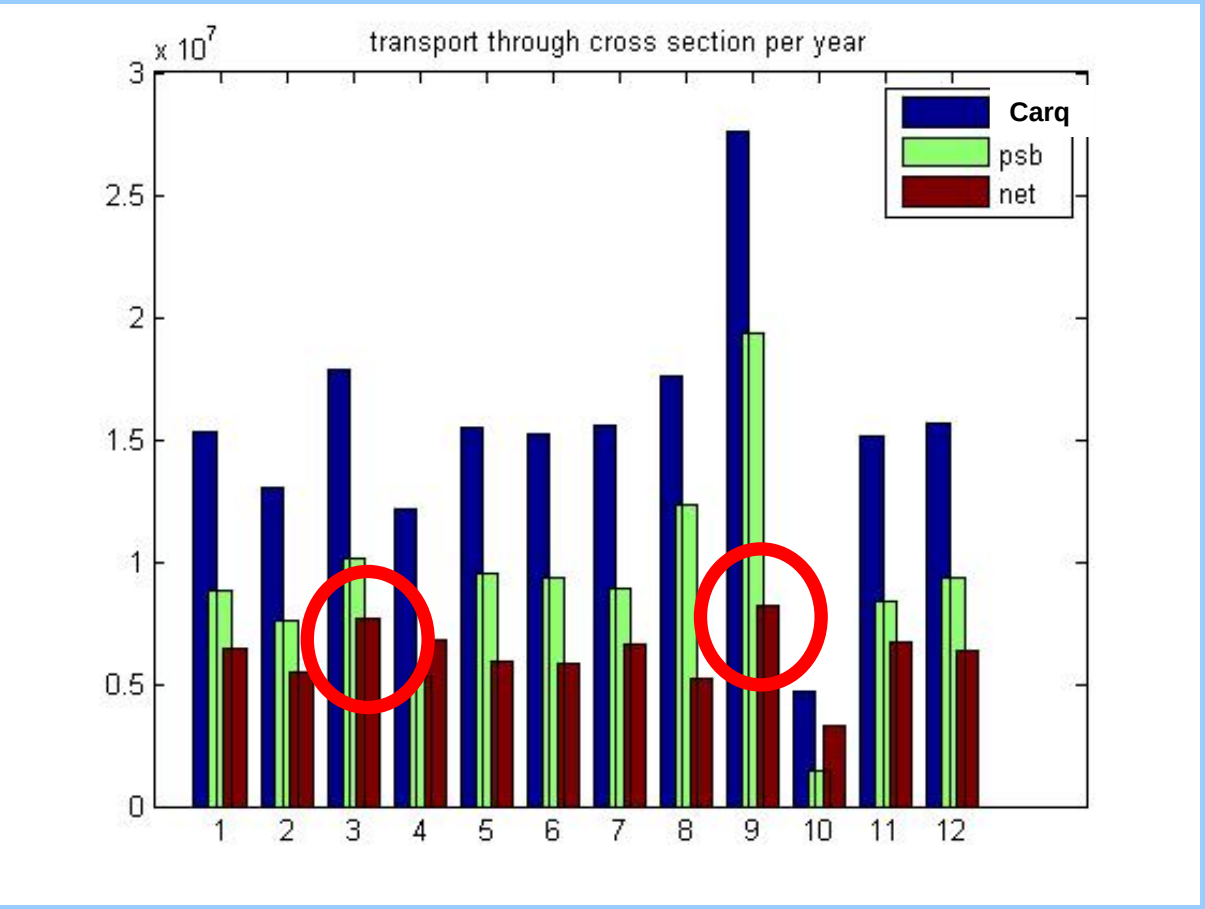
Sediment deposition is most sensitive to changes in ***sediment supply*** by means of River discharge (9,10) Sediment concentration (2, 3)



1 *standard case*
2/3 *Sediment concentration variation by 15%*
4/5 *Erosion factor variation by 50%*
6 *2D*
7/8 *Diffusion coefficient variation by O(1)*
9/10 *River discharge variation by 50%*
11/12 *Tidal forcing variation by 10%*

Transport per year (in m3/yr)

- *Sediment transport through Carquinez Strait (in)*
- *Sediment transport through Point San Pablo (out)*
- *Net deposition*



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Transport (in m3)

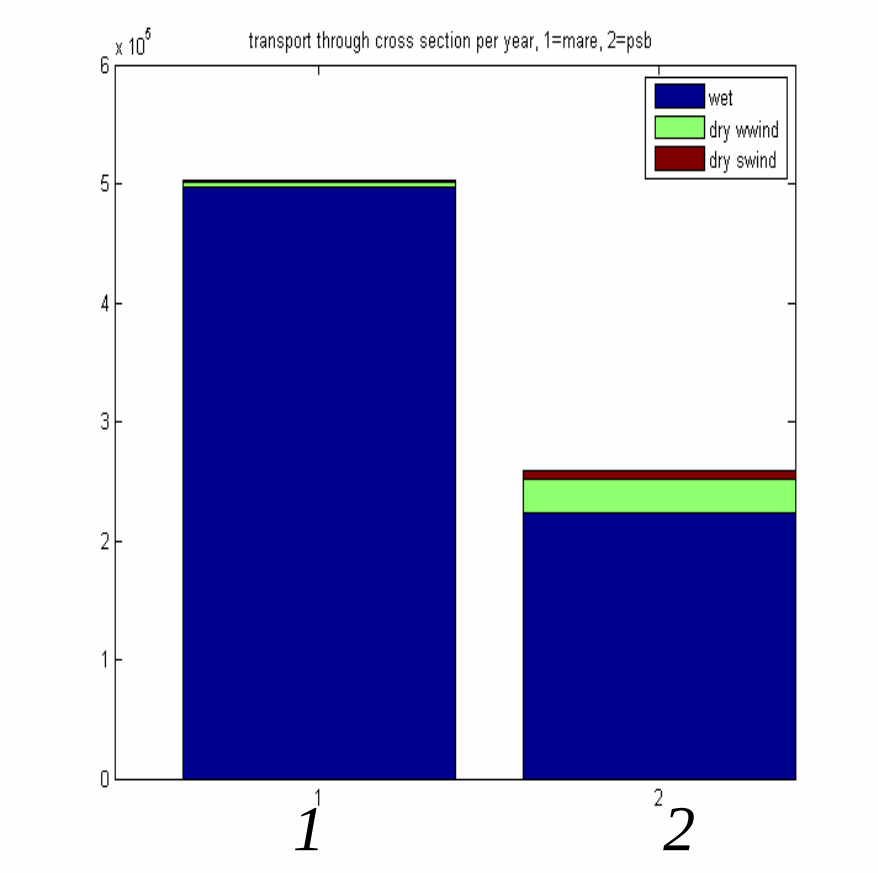
1- inflow at Carquinez Strait;

2- outflow at Point San Pablo;

During wet month

During 6 dry months – western wind

During 5 dry months – southern wind wind

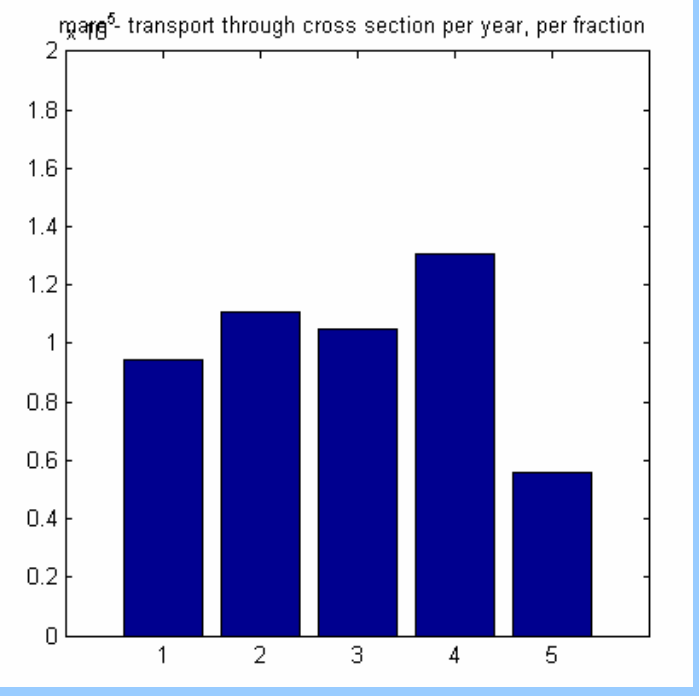


- ~15% of the sediment deposited during the wet month is transported out during dry months to Central Bay;
- in case of lower wet month sediment supply, the dry month erosion will probably become more important

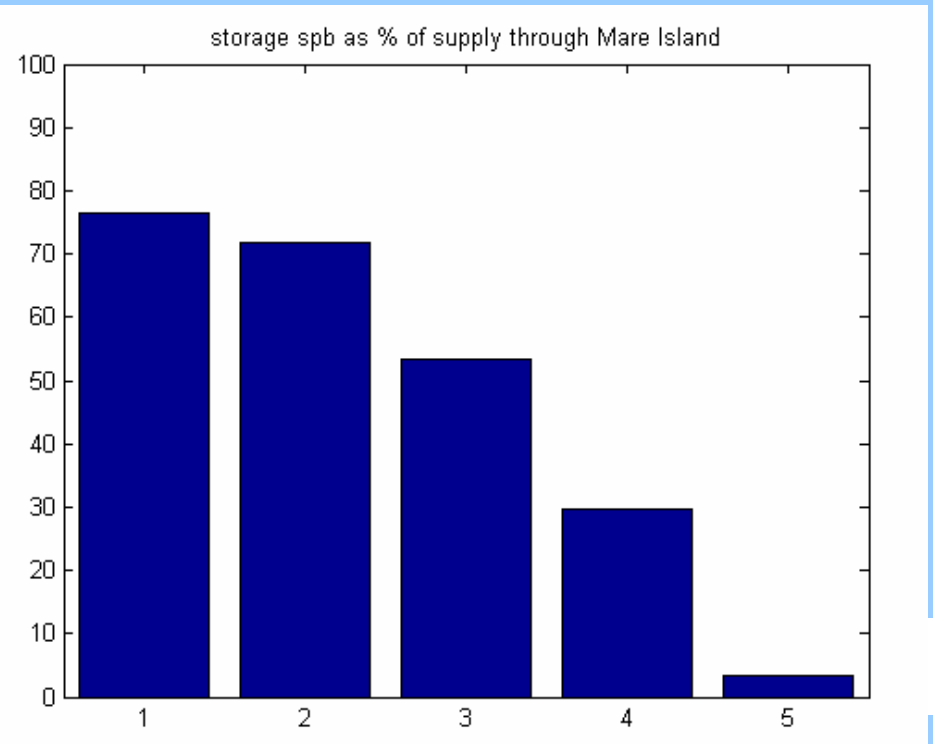
Sediment input at boundary

sed1	dia	1000
sed2	dia	400
sed3	dia	150
Mud 1	fall	0.5
	tau_cr	0.5
Mud 2	fall	0.4
	tau_cr	0.4
Mud 3	fall	0.25
	tau_cr	0.25
Mud 4	fall	0.15
	tau_cr	0.15
Mud 5	fall	0.05
	tau_cr	0.05

- *Sand concentration is 10% of mud concentration ;*
- *Equal mud concentrations with a total of about 1000 mg/l*
- *No flocculation processes included*



Yearly inflow of 5 mud fractions through Carquinez Strait



Yearly storage of 5 mud fractions as % of inflow at Carquinez Strait:

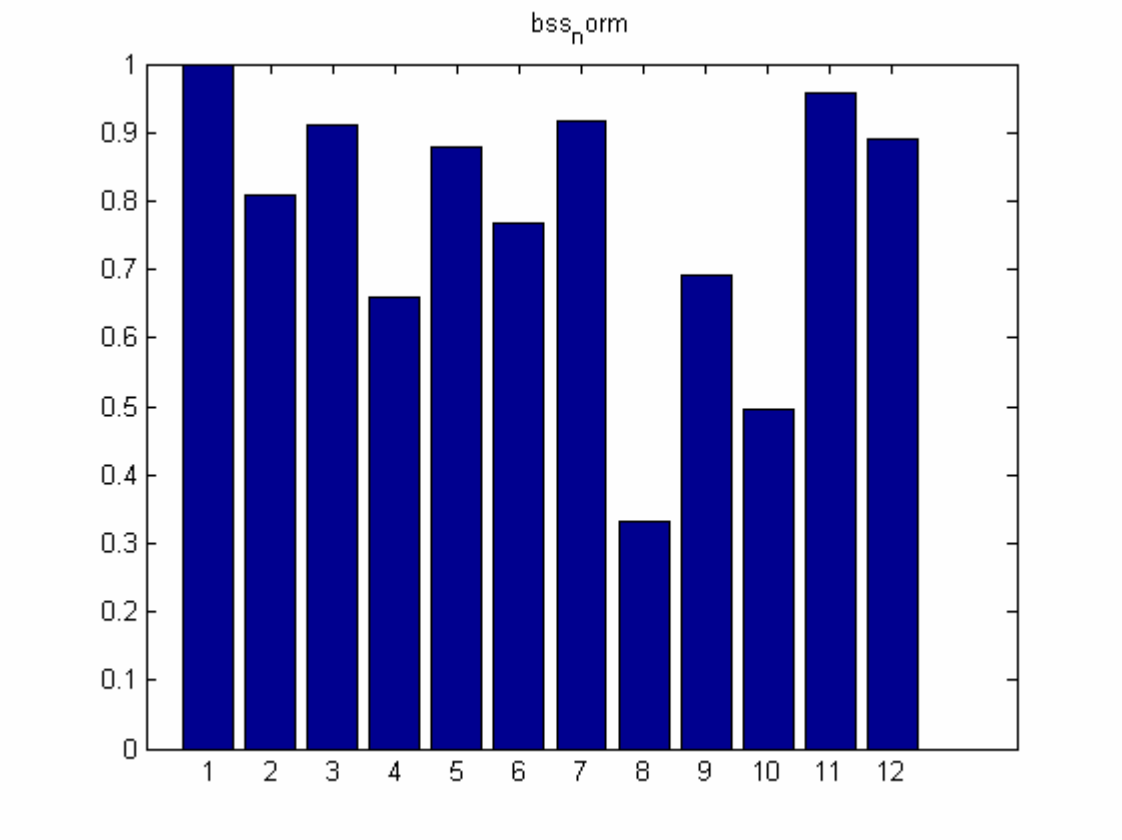
Finest mud does not deposit;

Brier skill score BSS

- Reflects to what extent modelled results compare well with measured bathymetries.
- 1=perfect, 0.3= poor correlation, (-2 has been determined for similar cases)
- Reflects quantity as well as distribution.

Brier skill score compared to ***standard case***

Changes in Diffusion and River discharge have most impact on sediment allocation in SPB.



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Conclusions

1) Process-based numerical model ***is able to reproduce adequately volumetric changes*** in San Pablo Bay for the 1856-1887 period under reasonable assumptions of model parameter settings.
2) Model results are

   - ***most sensitive to the sediment supply*** at the Delta boundary, and

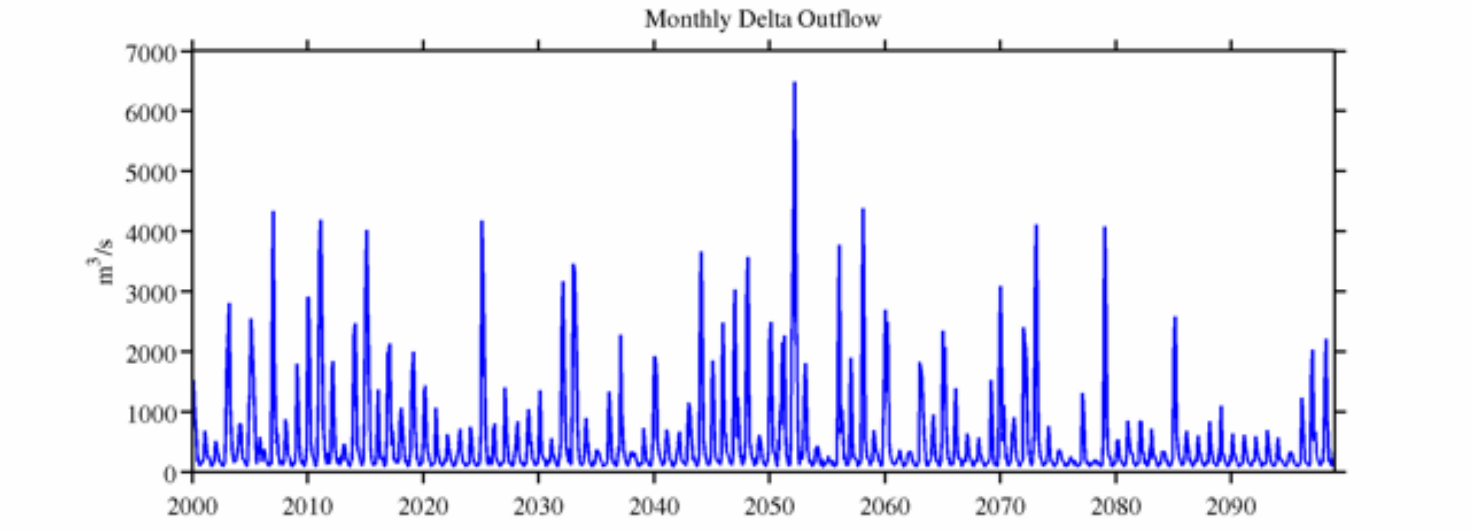
   - less sensitive to the definition of mud characteristics.
3) Results confirm similar modelling efforts in Cascade by Ganju and Schoellhamer focussing on Suisun Bay which increases ***confidence in modeling efforts***.

Future work

Similar exercises

- for erosional period (1950-1983);
- for future scenarios with changing

river discharge, ***sea level***, sediment supply, wind regime.



Major anthropogenic influences include ***hydraulic mining*** about 150 years ago and ***dam construction*** in the last century. These activities impacted sediment supply and the river hydrograph and continue to have an impact today. ***Climate change*** will further perturb the morphodynamics as sea level rises and the river discharge regimes are altered by warming and precipitation changes.

- The objectives of the study are to address long-term morphodynamic developments in the northern part of San Francisco Estuary and to assess likely geomorphic response to climate change.