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San Francisco Bay Sand Transport Study Ring Analysis

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Contents

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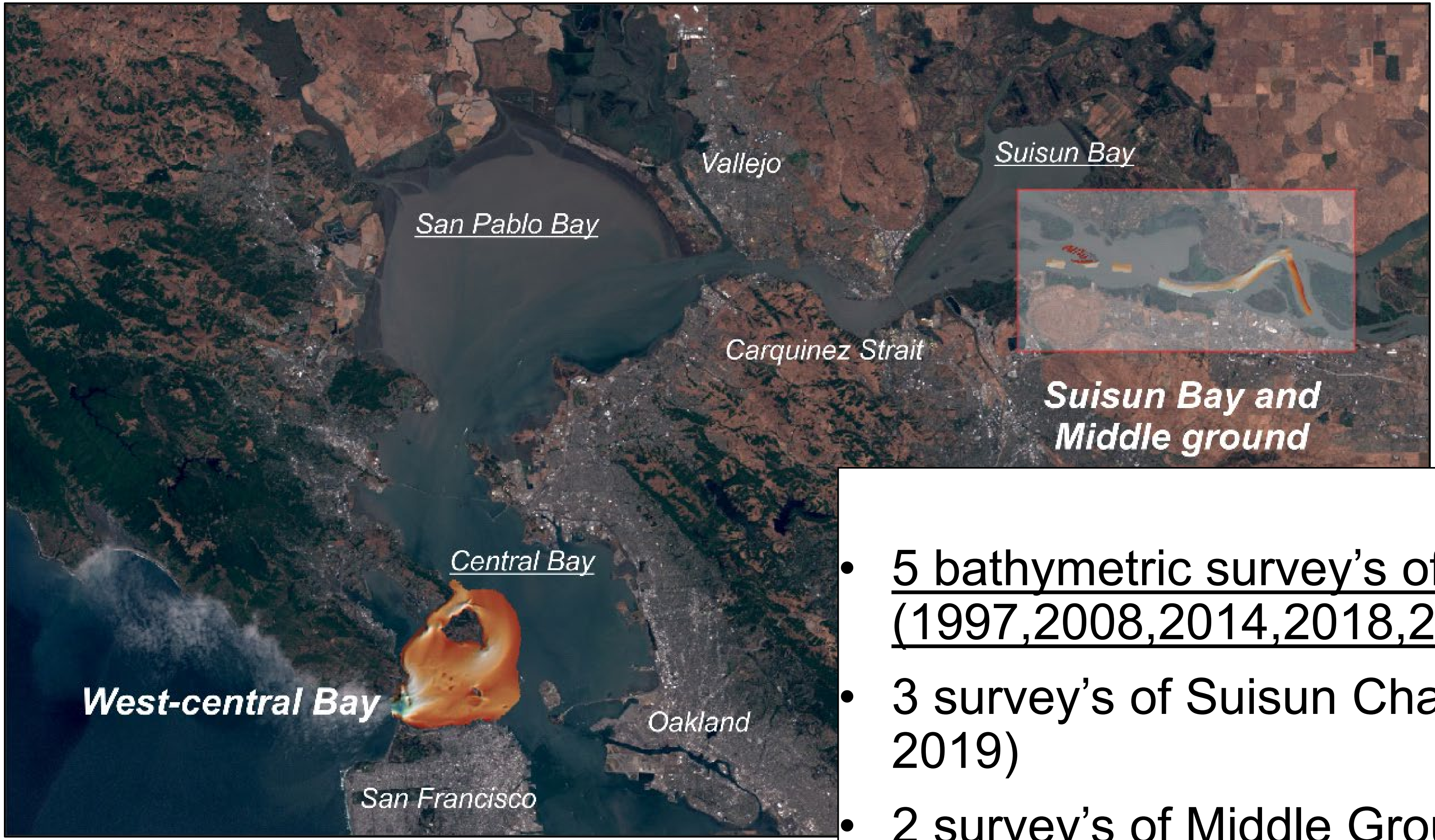
Investigate the impact of sand mining on bedforms and sediment transport in SF Bay

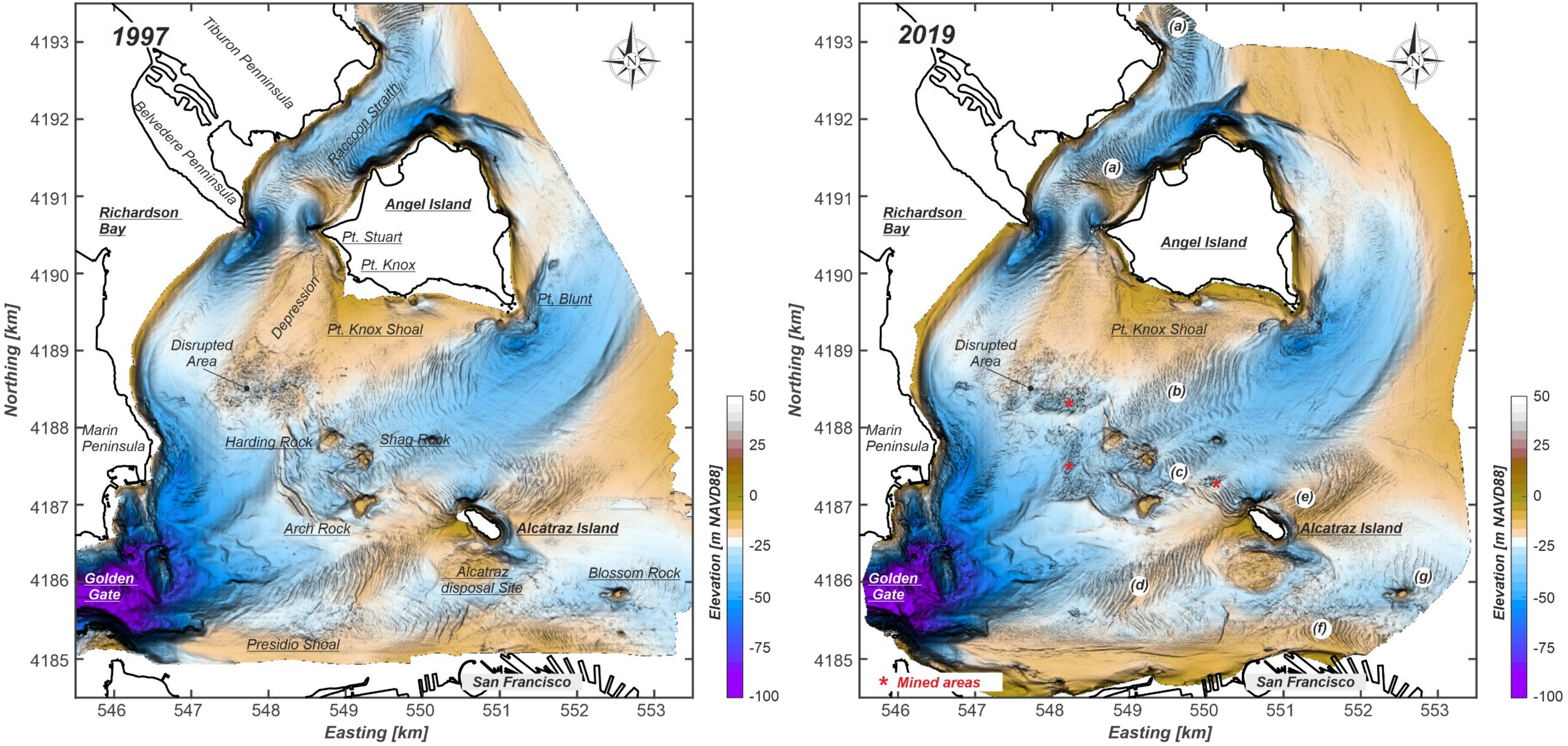
- Detailed volumetric analysis of mining areas (Ring analysis)
- Quantifying bedforms and bedform mobility in and around the mining sites
- Understanding bay-scale morphodynamic change
- Investigations of (bay-scale) sediment transport pathways (in collaboration with USGS)

Analyzing bathymetric change



- 5 bathymetric survey's of West-Central Bay (1997,2008,2014,2018,2019)
- 3 survey's of Suisun Channel (2014, 2018, 2019)
- 2 survey's of Middle Ground Shoal (2018, 2019)

High-resolution maps provide valuable information and insights



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Part 1: Quantification of local mining impact in West-central Bay

Mining volume area analysis or *Ring analysis*

- Impact is assessed through Ring Analysis, method outlined by e-trac (2018)
- Six bounding polygons were defined
- For each bounding box, compute :
    1. the dredged volumes (dredge records)
    2. the bathymetric change
    3. the recovery factor (ratio between 1 and 2)

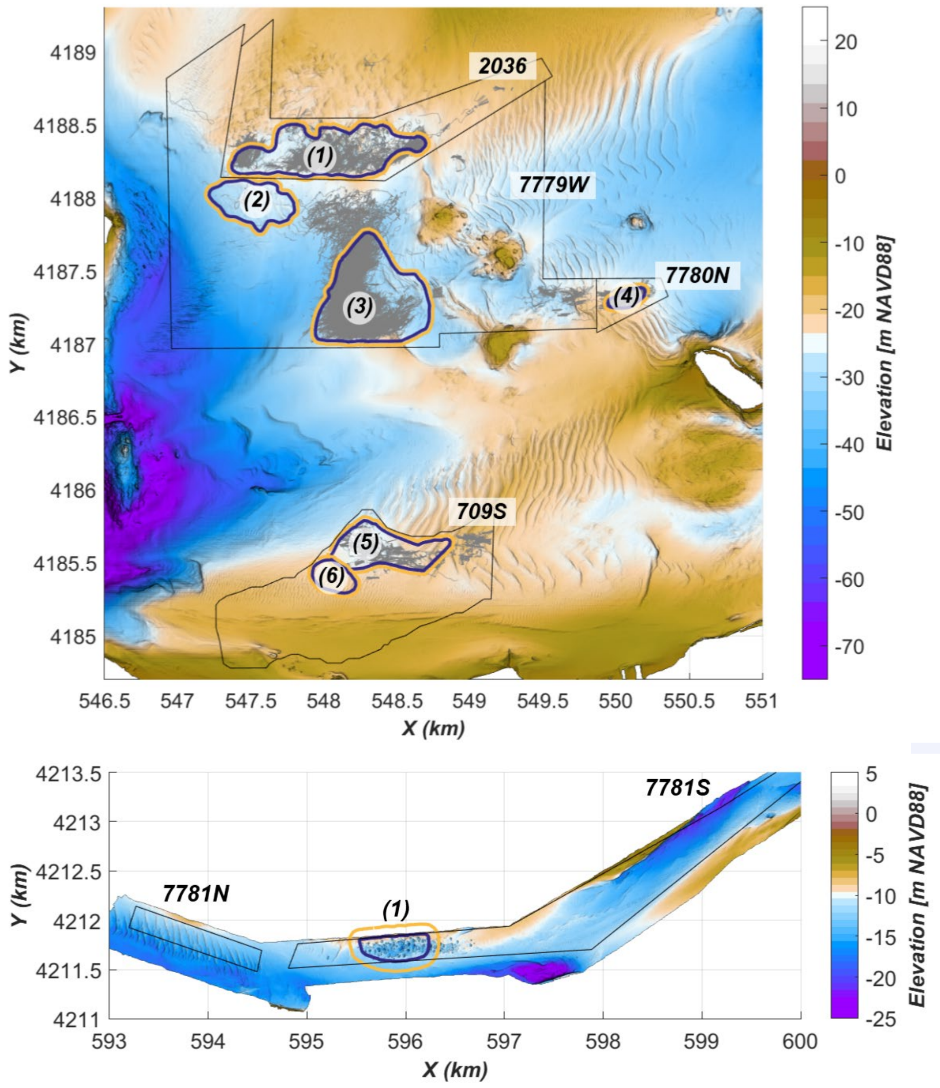

Illustration of measured bed level and location of the mining areas (ring polygons) .

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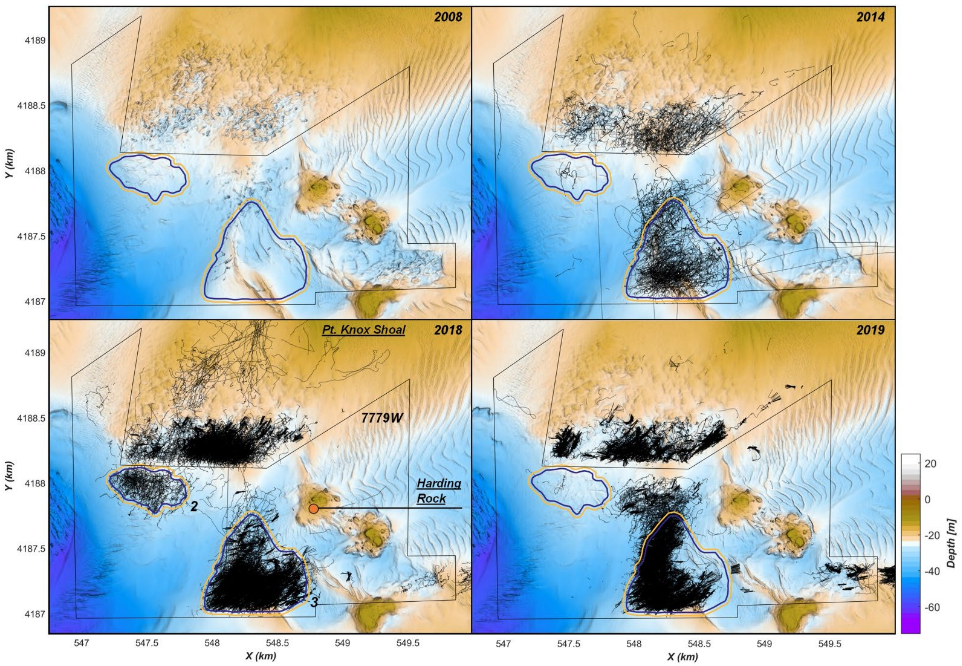
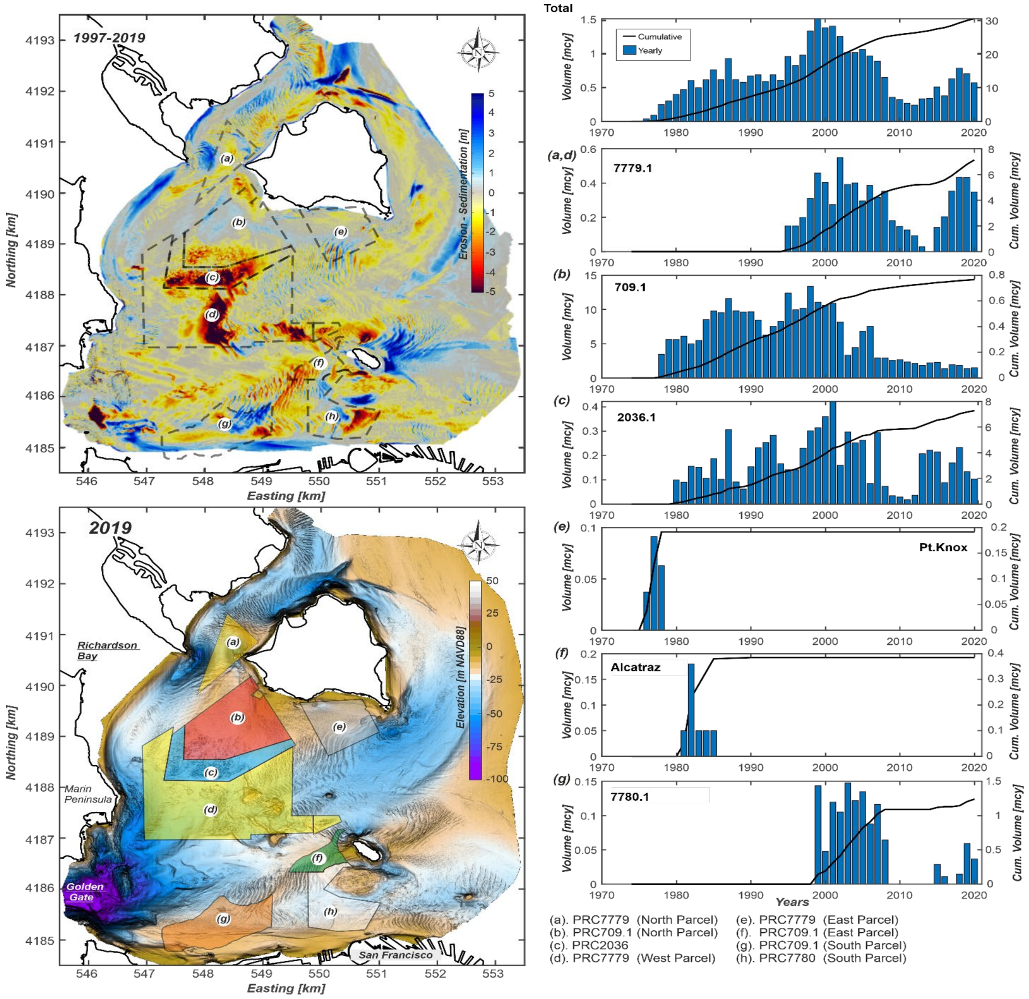
Mined volumes

- Dredged volumes from (dredge records)
    - 5.5 Mcy mined in the lease areas
    - 4.4 Mcy mined in the ring polygons





	2008-2014		2014-2018		2018-2019		Total	
	Mcy	[%]	Mcy	[%]	Mcy	[%]	Mcy	[%]
Lease 2036	-0.62	25	-0.47	31	-0.37	25	-1.46	27
Lease 7779W	-0.93	37	-0.7	46	-0.87	59	-2.49	45
Lease 7780N	-0.06	3	-0.04	3	-0.07	5	-0.18	3
Lease 709S	-0.89	36	-0.30	20	-0.17	12	-1.36	25
Total	-2.51		-1.51		-1.48		-5.50	

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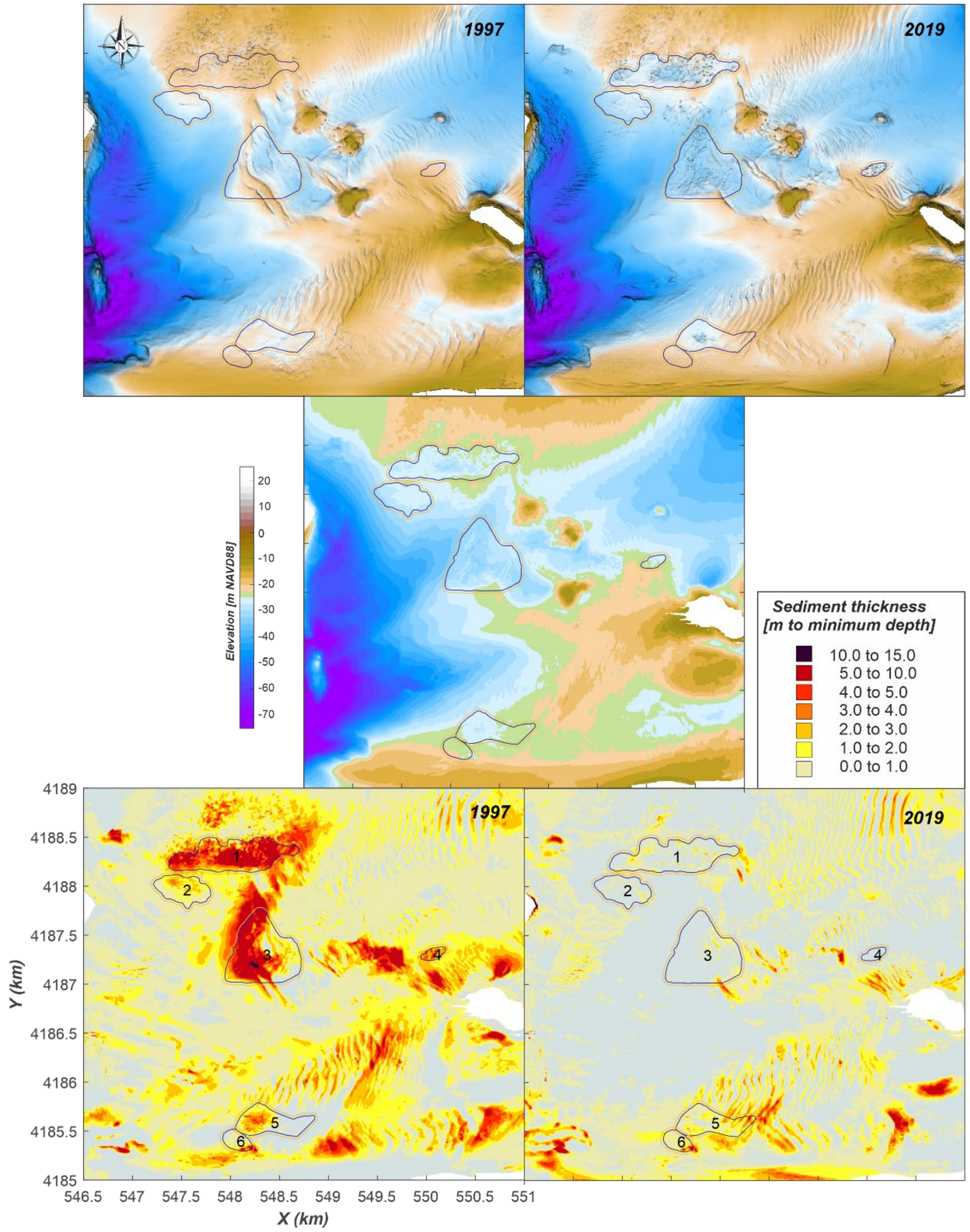
Measured volume change

- 5 multi-beam survey's available in West Central Bay
- Impact is assessed through Ring Analysis, method outlined by e-trac (2018)
  - 6 ring polygons in West central Bay
  - Inner and an outer ring
  - Compute the bathymetric change for each ring polygon
- Volumetric change can be computed from the change in bed-level, or as a change in sediment thickness in relation to a reference level (the minimum depth)
- Volumetric change was computed for each of the lease areas and ring polygons
- Diffusion of mining impact was determined with an "extended" buffer analysis.



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Mining volume area analysis or *Ring analysis*

- Analysis of dredge records
  - 5.5 Mcy mined in the lease areas
  - 4.4 Mcy mined in the ring polygons

- Analysis of the bathymetric change
  - -2.3 Mcy of volume change in ring polygons

- Partial recovery of the mining areas
  - Recovery rates vary between 14 and 141%
  - A different response is observed between the Northern and Southern lease areas; low versus high recovery rates

Mined volumes

		2008-2014		2014-2018		2018-2019		Total	Total Ring / Lease
		Mcy	Mcy/yr	Mcy	Mcy/yr	Mcy	Mcy/yr	Mcy	%
Lease 2036	Ring 1	0.32	0.05	0.77[1]	0.22	0.27	0.17	1.36	93
Lease 7779W	Ring 2	0	0	0.15	0.04	0	0	0.15	6
	Ring 3	0.39	0.06	0.82	0.23	0.63	0.39	1.84	74
Lease 7780N	Ring 4	0	0	0.04	0.01	0.07	0.04	0.11	63
Lease 709S	Ring 5	0.27	0.04	0.36	0.10	0.11	0.07	0.74	55
	Ring 6	0.09	0.01	0.01	0.00	0	0	0.10	7
Total		1.08		2.15		1.20		4.43	

Measured volumetric change

		2008-2014		2014-2018		2018-2019		Total	
		VC [Mcy]	Rc [%]	VC [Mcy]	Rc [%]	VC [Mcy]	Rc [%]	Total VC [Mcy]	Average Rc [%]
Lease 2036	Ring 1	0.01	105	-0.43	45	-0.20	26	-0.61	55
Lease 7779W	Ring 2	0.04	-	-0.11	27	-0.04	-	-0.10	28
	Ring 3	-0.35	11	-0.59	28	-0.53	15	-1.48	20
Lease 7780N	Ring 4	-0.01	-	-0.03	40	-0.06	15	-0.10	14
Lease 709S	Ring 5	-0.07	73	-0.06	84	0.07	163	-0.06	91
	Ring 6	-0.01	91	0.03	351	0.02	-	0.04	141
Total		-0.39		-1.18		-0.74		-2.31	

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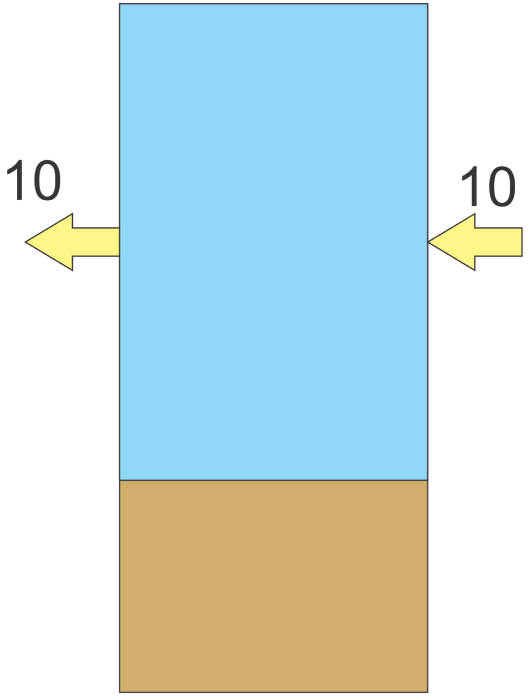
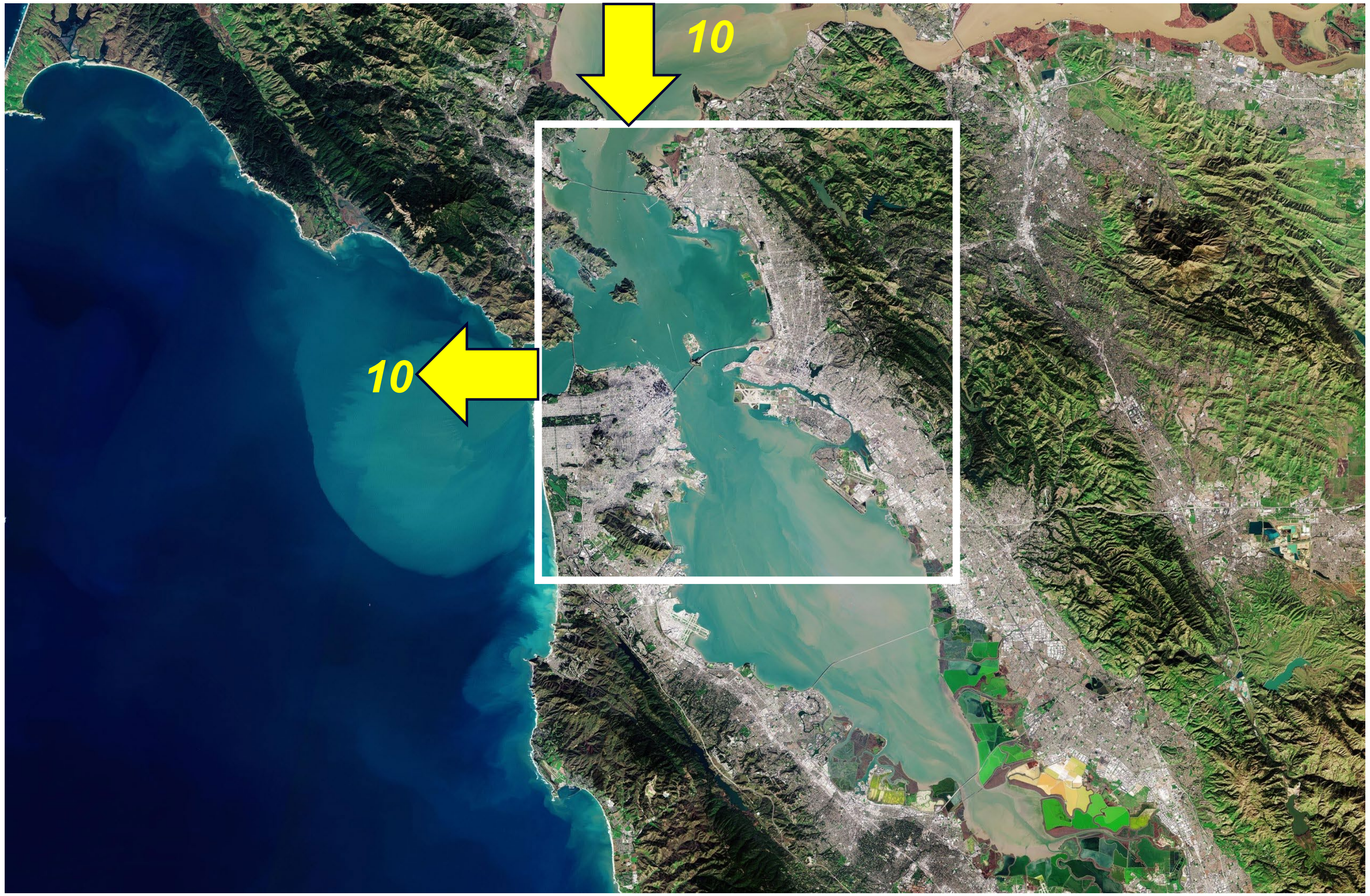
Low versus high recovery rate



equilibrium state
No mining



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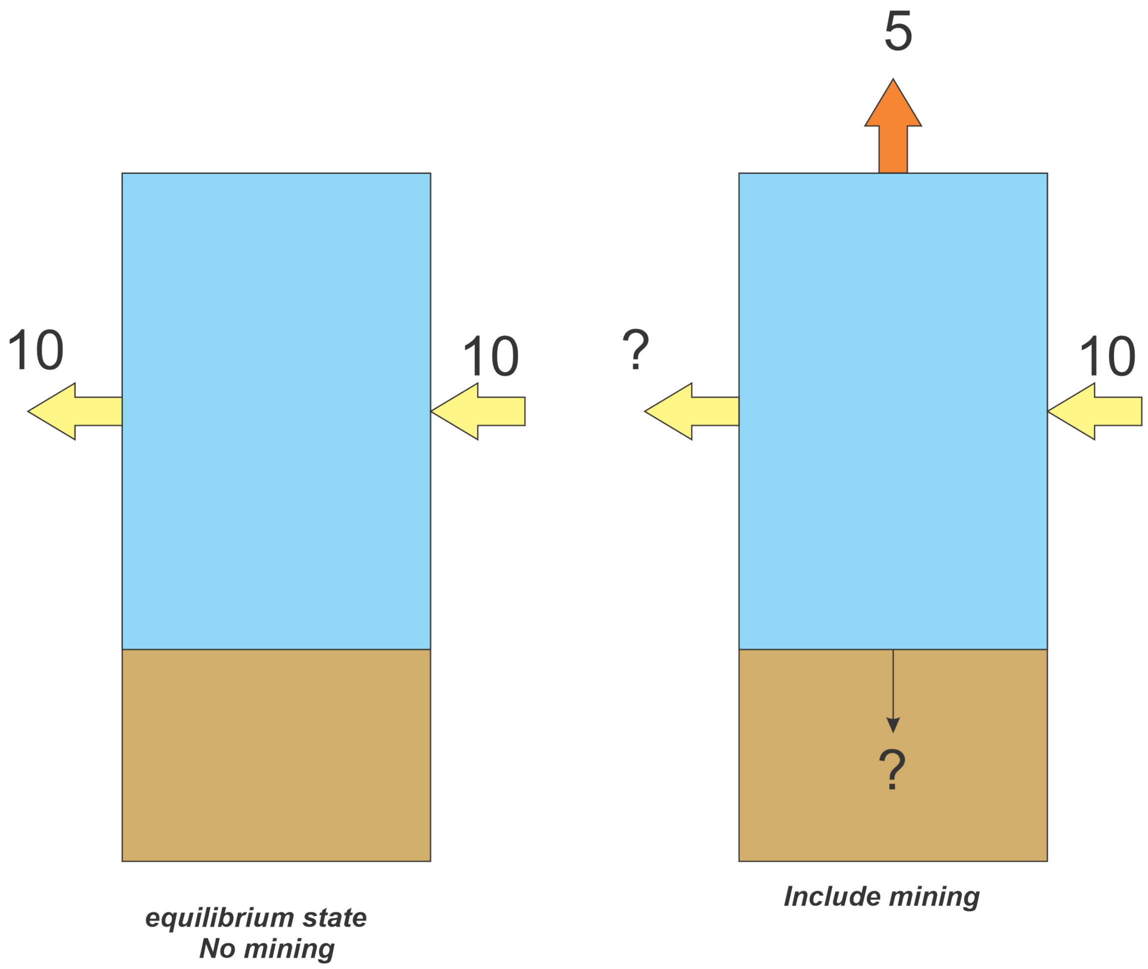
Low versus high recovery rate



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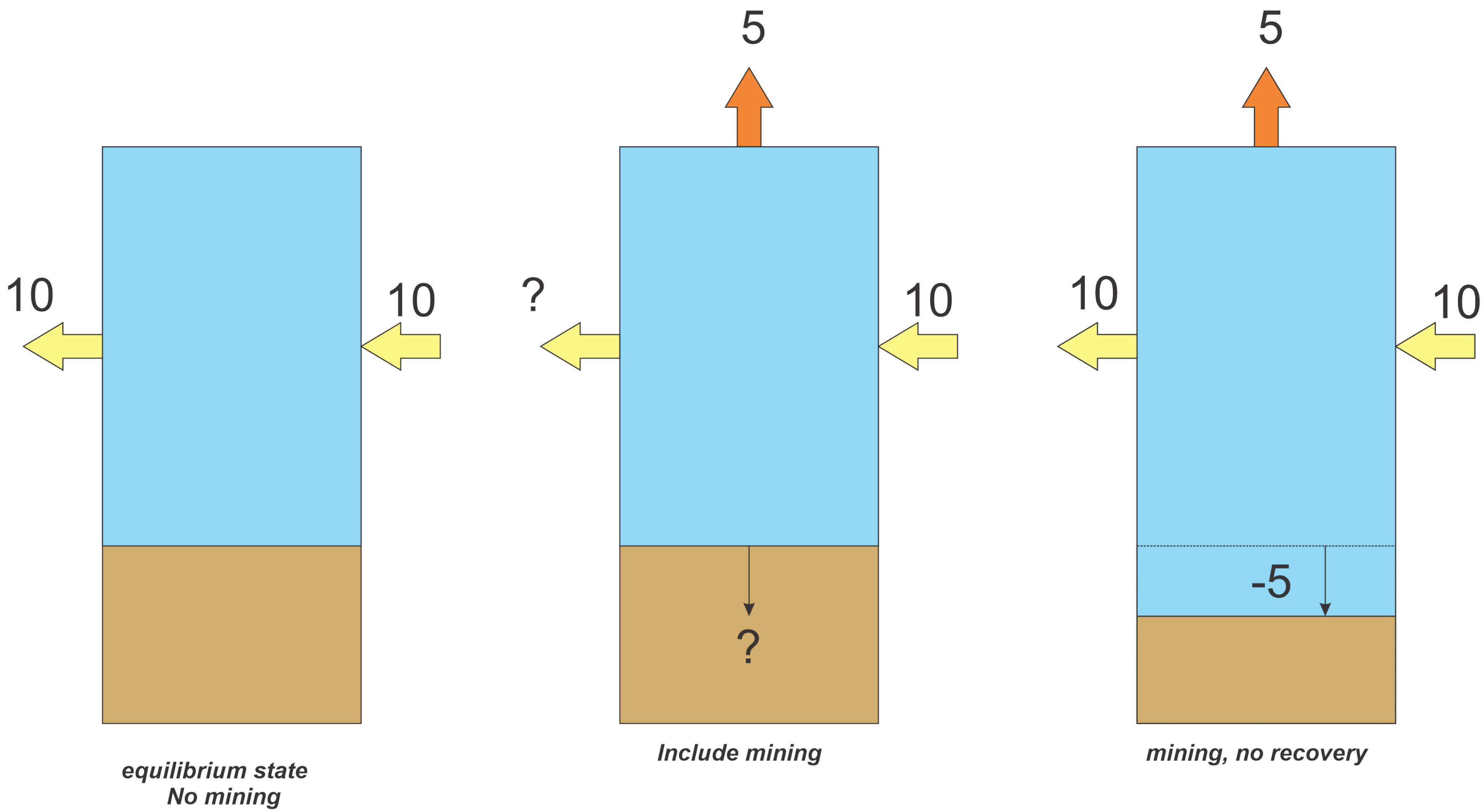
Low versus high recovery rate



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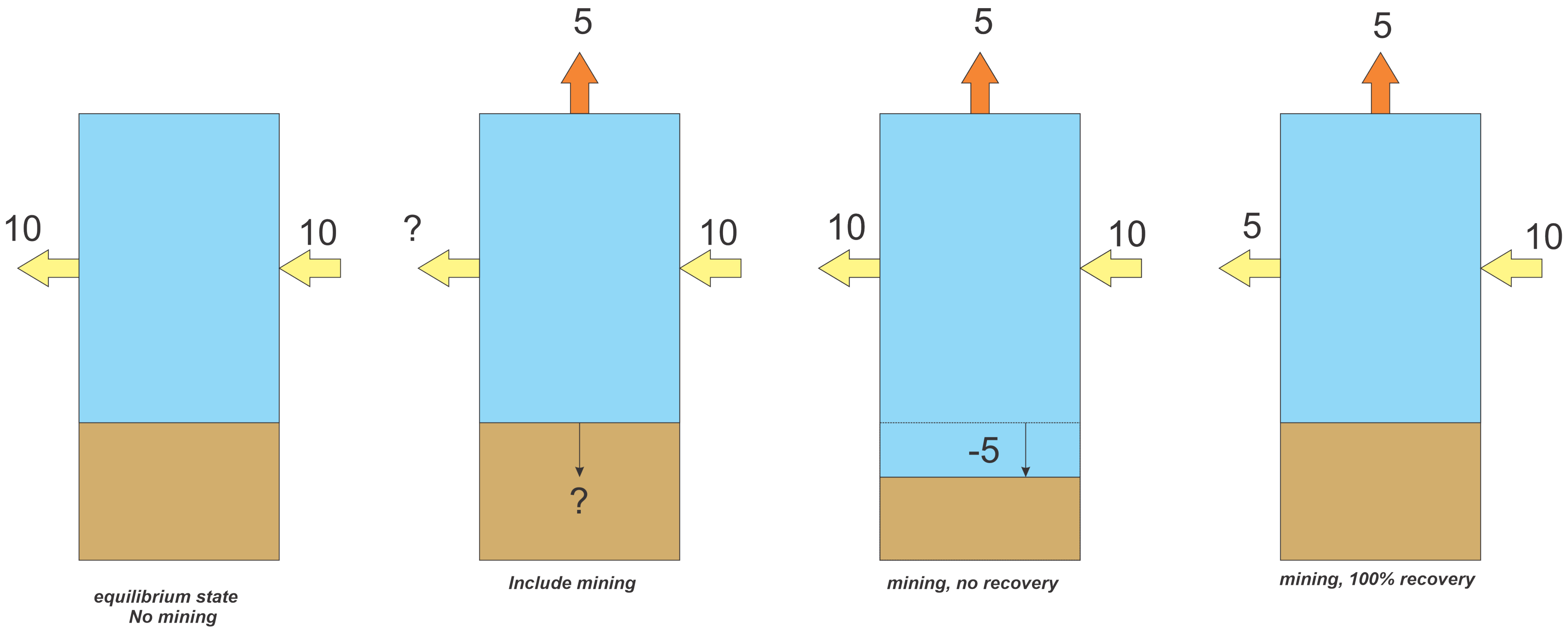
Low versus high recovery rate



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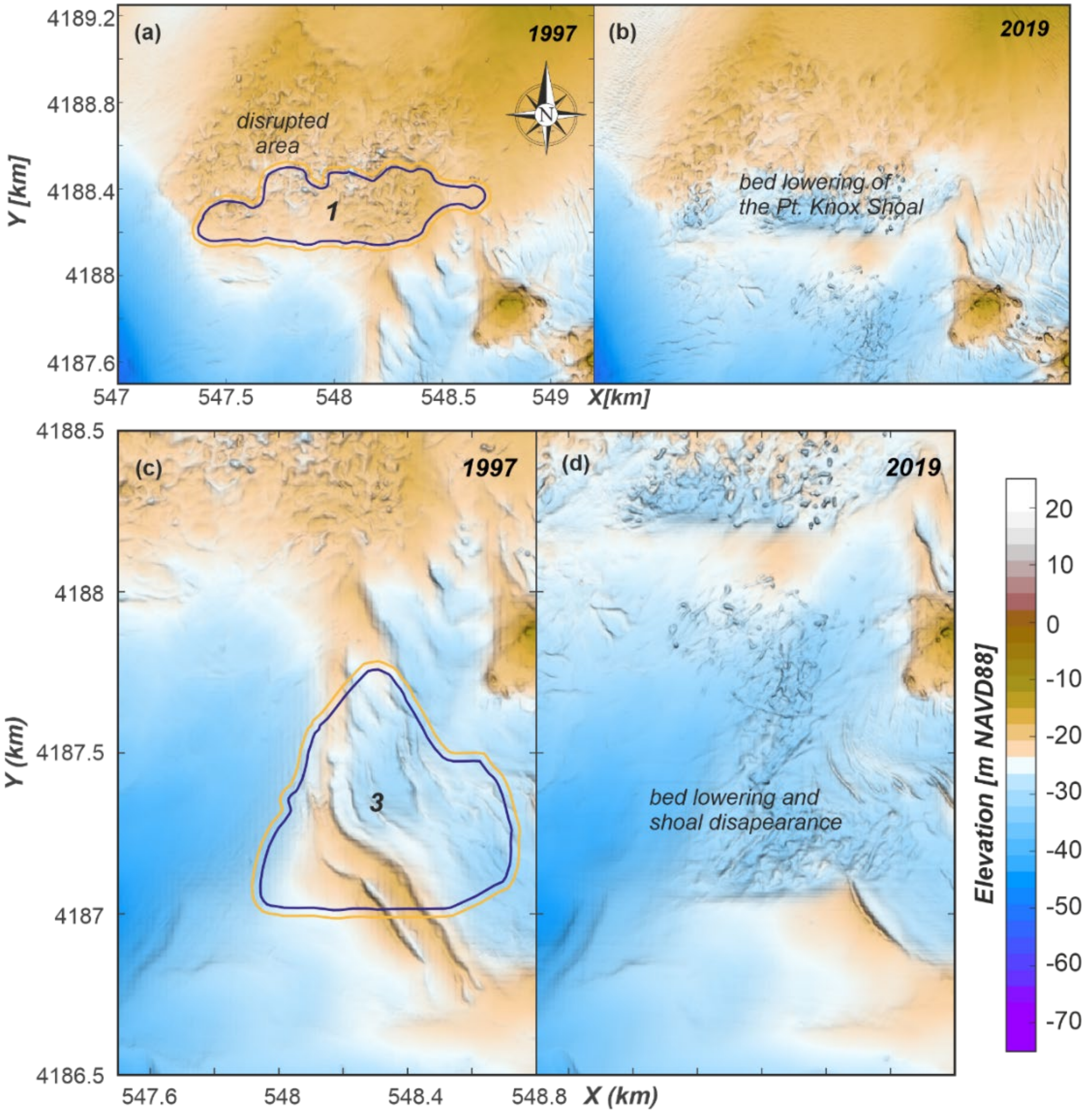
Mining volume area analysis or *Ring analysis*

- Lowest recovery in ring 2 and 3
- Distorted bed and bed lowering in lease 2036 (Ring 1) and lease 7779W (Ring 3)

<u>Large local impact (bed lowering and shoal disappearance), but low impact on the bay-scale sediment budget</u>



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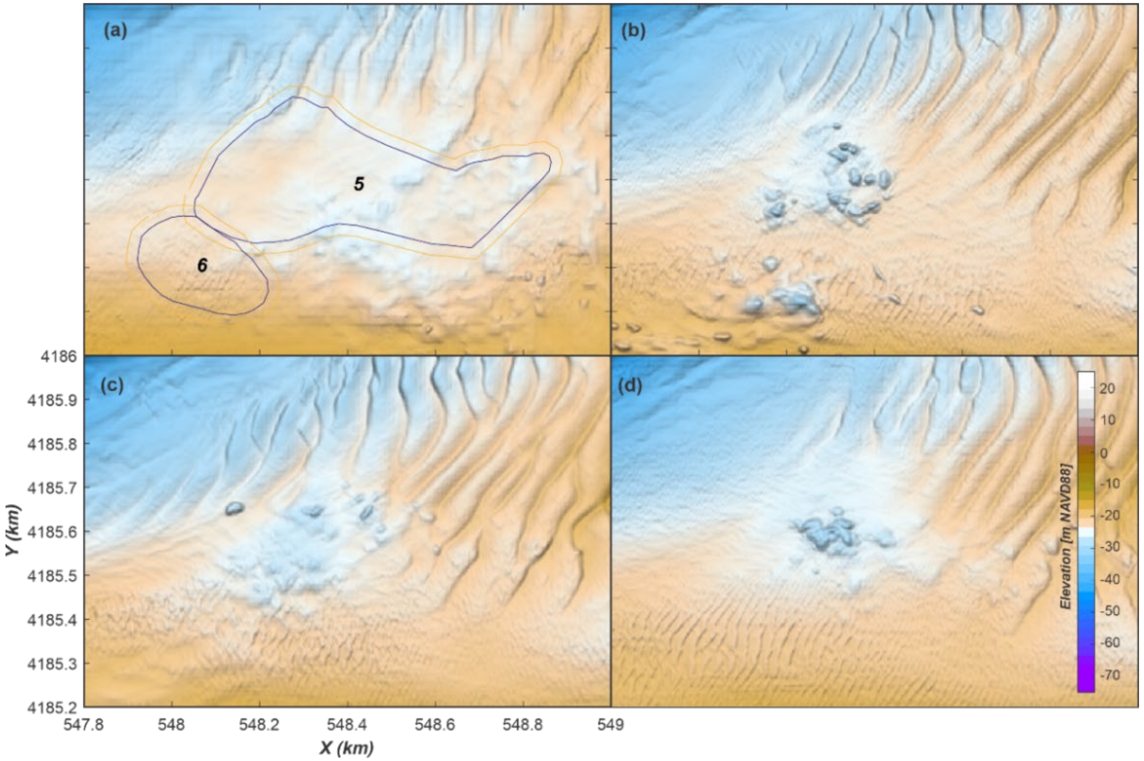
Mining volume area analysis or *Ring analysis*

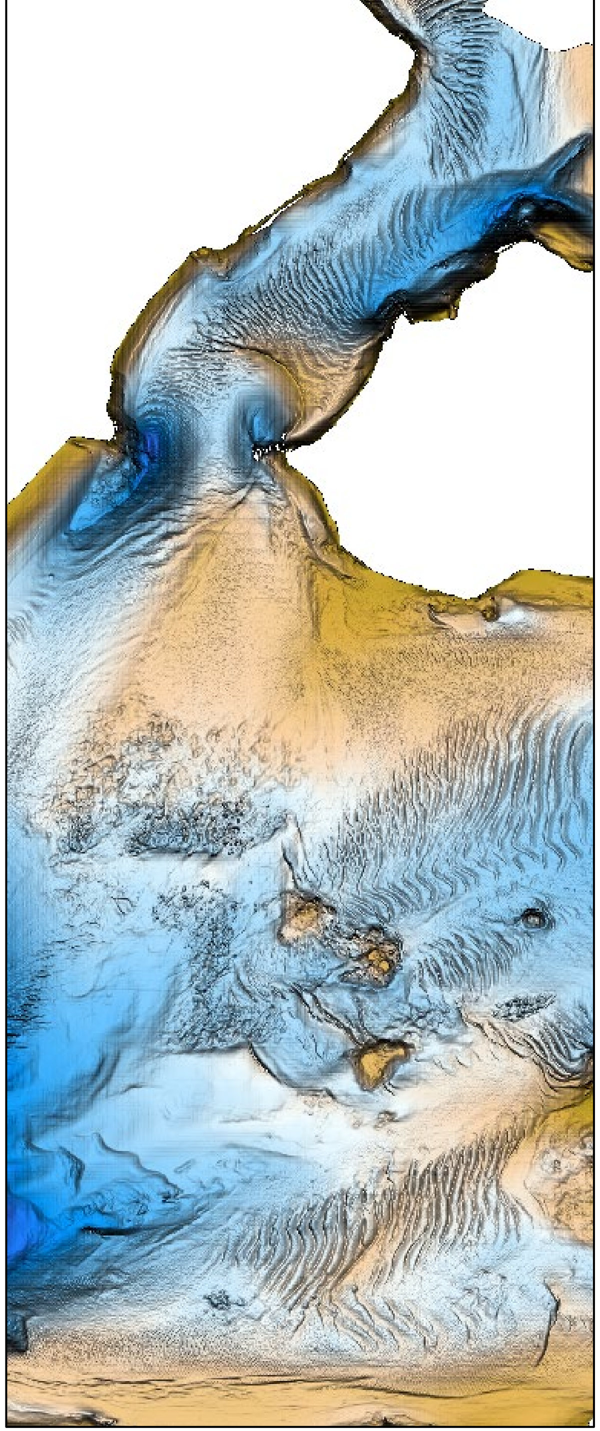
- Lease area 709S (Ring areas 5 and 6) exhibits (near) complete recovery and continuation of "natural" morphodynamics.



__Low local impact (limited bed lowering), but larger impact on sediment budget.__

Part 2: Quantification of mining impact on West-central Bay

- Extended ring analysis (impact in the direct vicinity of the mining area)
- Quantifying bedforms and bedform mobility in and around the mining sites (impact on sediment transport patterns)
- Understanding bay-scale morphodynamic change



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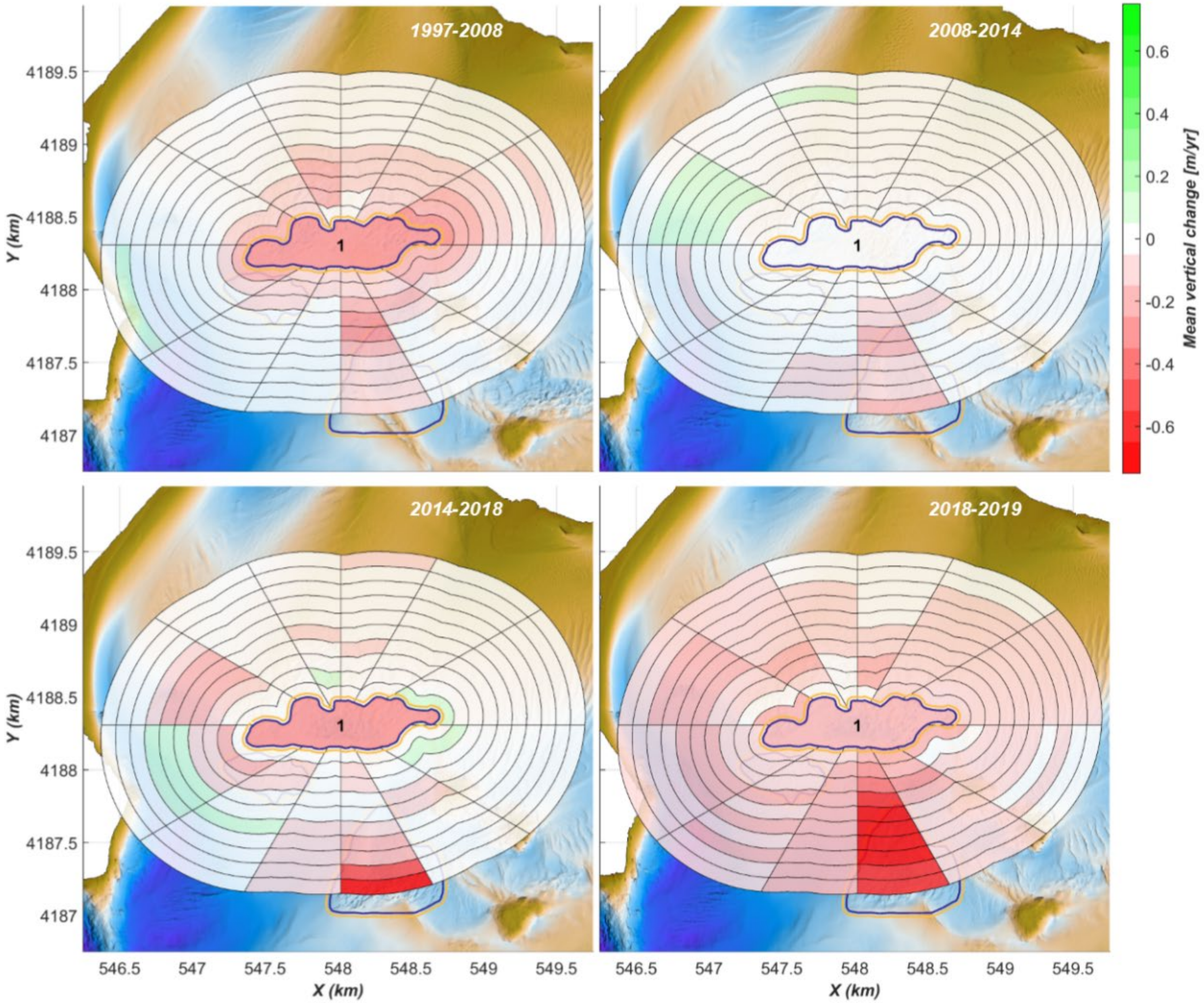
Extended ring analysis

- The ring polygons and original buffer areas were insufficient to perform a diffusion analysis.
- The extended ring buffer analysis suggests that mining has caused a spread of bathymetric changes in a 200-500 meter radius around ring area 1 for the period 1997-2008.
- No diffusion effects can be observed in the measurements for the other ring areas.
- More frequent measurements are needed for a more accurate evaluation of the diffusion of mining activities.



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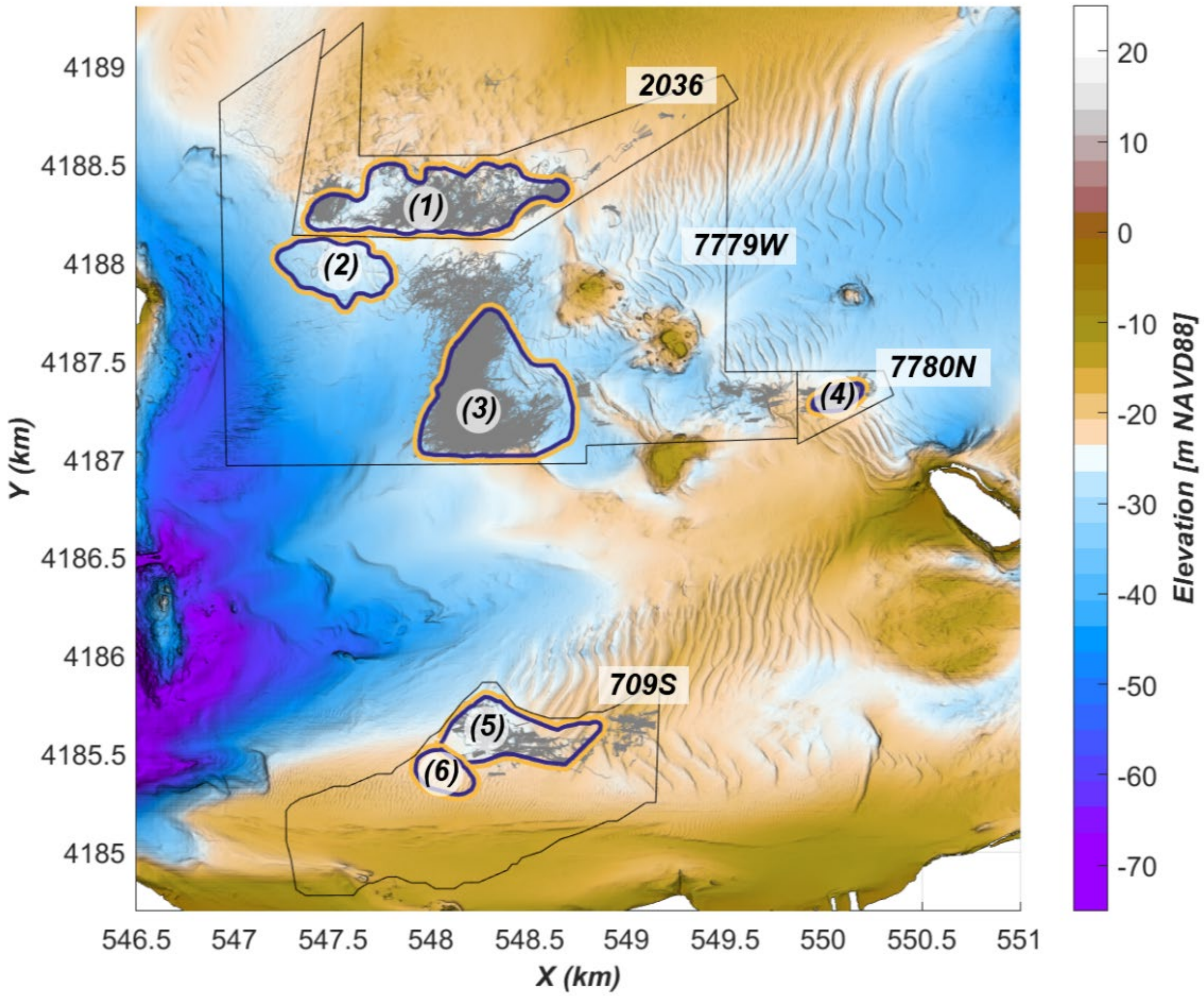
Mining impact on larger-scale

Bedform analysis of nearby sandwave fields

- Bedforms characteristics provide indications of regional scale sediment transport patterns and rates.
- Major bedforms cannot be observed in the areas of intensive mining. Bed lowering and potholing dominate the bed floor.
- Transport rates and migration rates can be determined from the 2018-2019 datasets.
- Longer intervals do not provide a statistical meaningful correlation. You can still compute bedform characteristics



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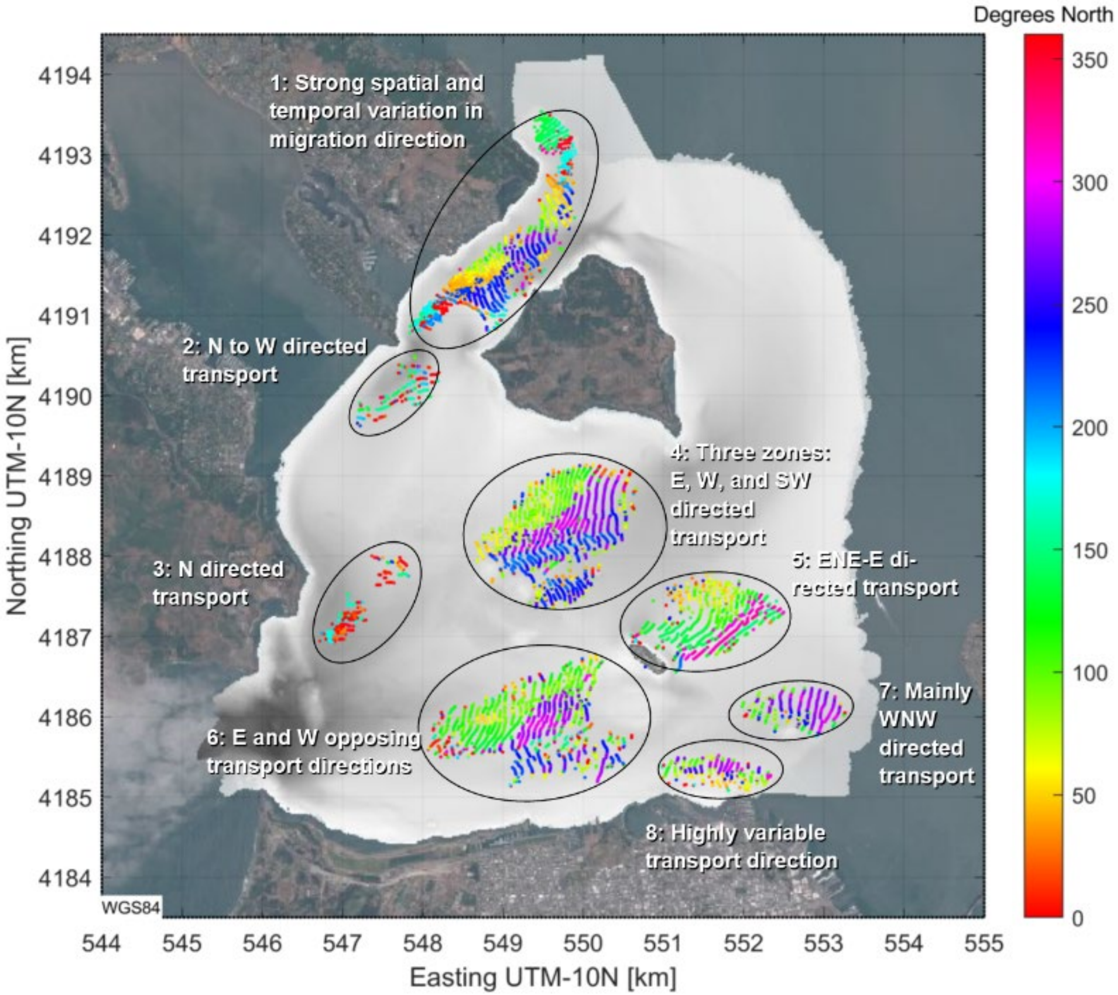
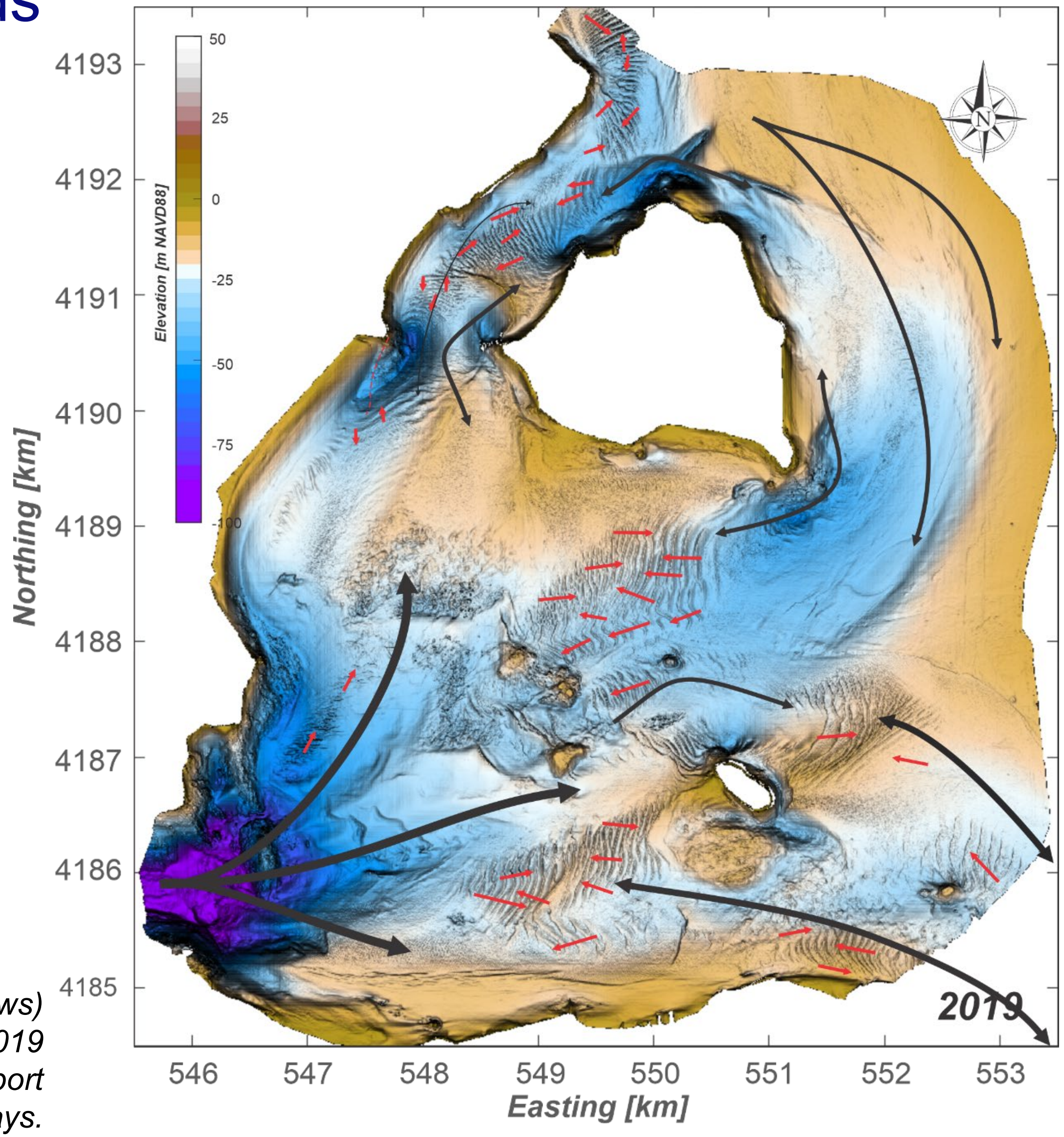


Mining impact on larger-scale

Bedform analysis of nearby sandwave fields

- Bedforms characteristics provide indications of regional scale sediment transport patterns and rates.
- Major bedforms cannot be observed in the areas of intensive mining. Bed lowering and potholing dominate the bed floor.
- Opposing bedform asymmetries and migration can be used to identify sediment transport convergence zones with preferential sediment accumulation. Such zones have higher recovery rates (for example ring areas 5 and 6).



Estimates of sediment transport direction (red arrows) based on sandwave asymmetry derived from 2019 multibeam data. Black arrows indicate the main transport pathways.

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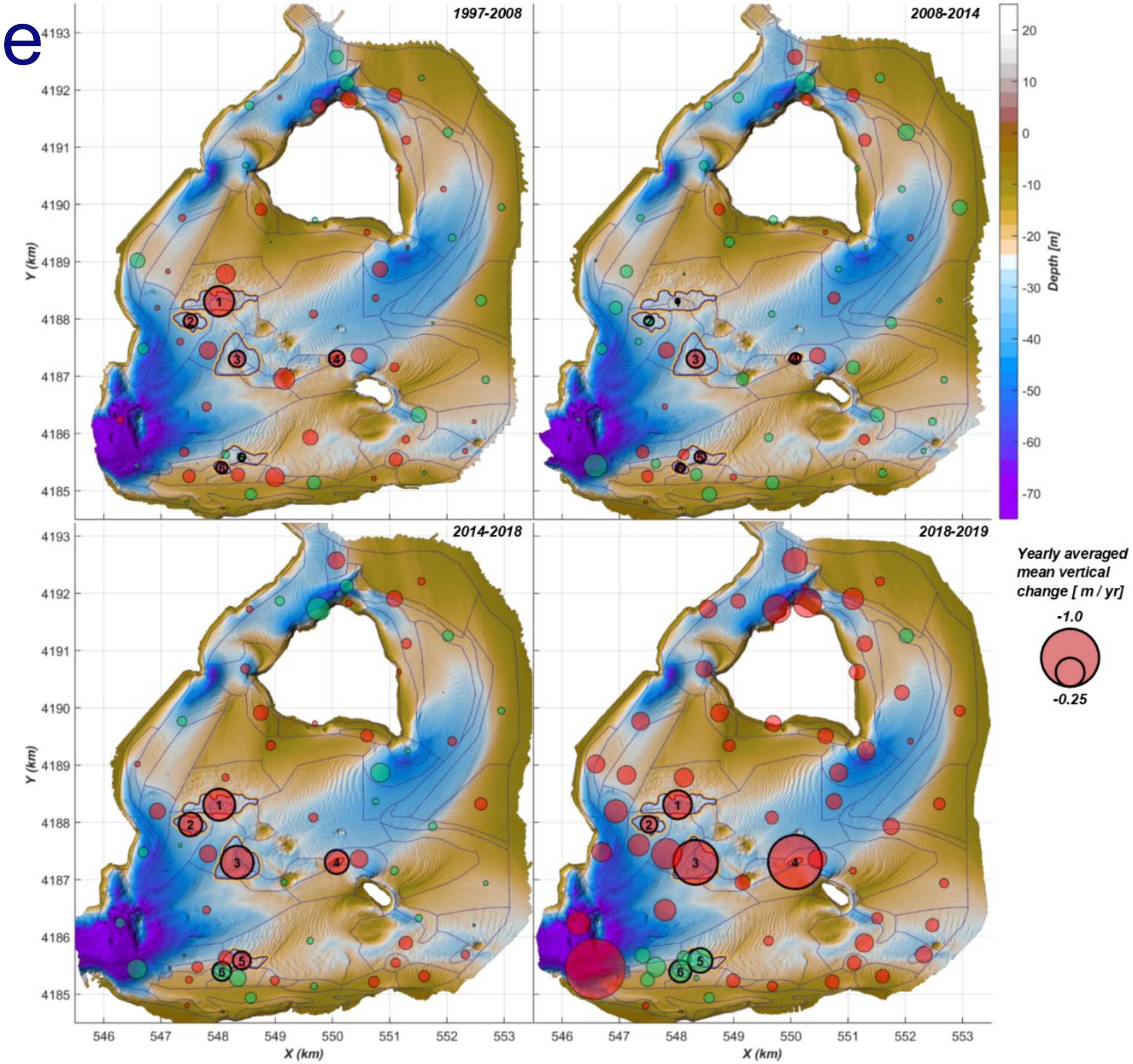
Mining impact on larger-scale

Bathymetric change analysis

- During the period of low mining intensity (2008-2014), most regions show net accretion.
- During the period of high mining intensity (2018-2019), most regions show net erosion. The net erosion is, however, likely caused by natural variations in sediment supply.

<u>We cannot conclude that bay scale erosion or sedimentation is correlated to the mining intensity based on this data.</u>



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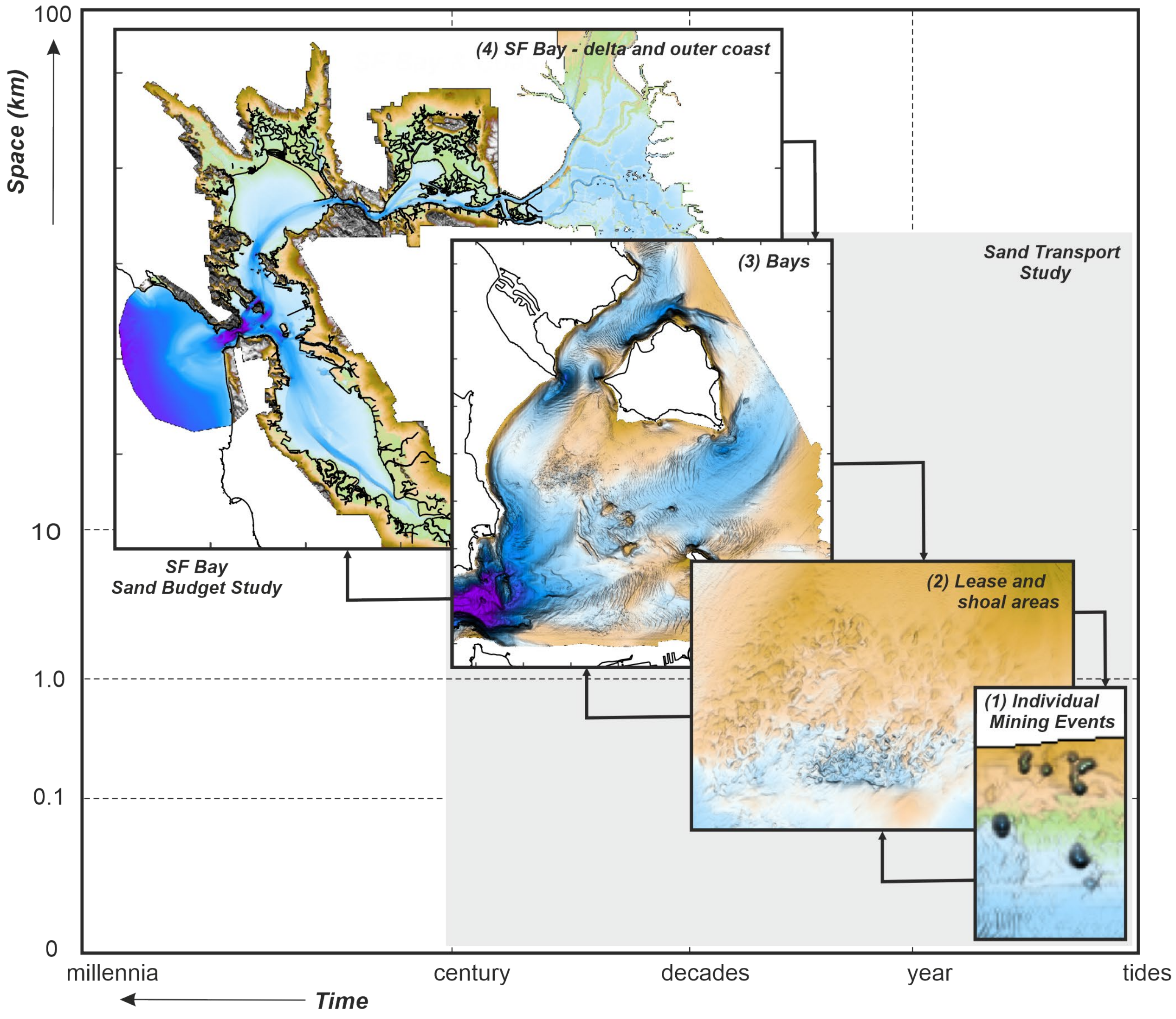
Part 3: Synthesis of results
Scale 1 and 2 (Local effects)

- Potholing dominates the small-scale, local morphodynamic response.
- Mining caused the disappearance of a large shoal (Ring area 3) and disruption and bed lowering of the area south of Pt. Knox Shoal (Ring area 1). Ring area 4 also shows major bed lowering between 2008 and 2019.
- Lease area 709S (Ring areas 5 and 6) exhibits (near) complete recovery and continuation of “natural” morphodynamics. Other lease areas show marginal recovery.



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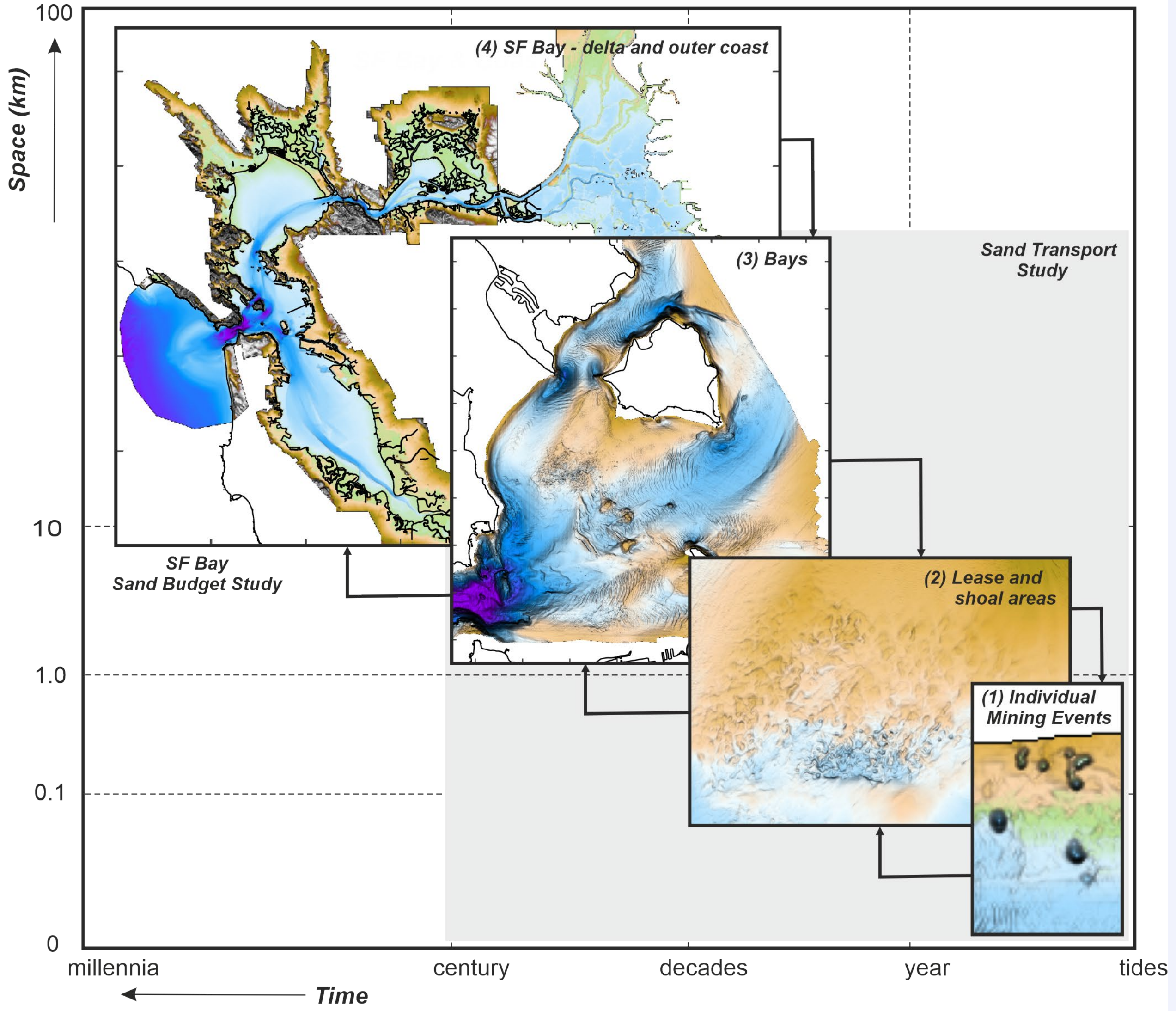
Part 3: Synthesis of results
Regional to Bay scale (Scale 3 and 4)

- Mining can have a long-term impact on the local Bay floor if recovery rates are low. If these changes do not significantly alter net transport patterns, it will probably not affect the larger scale system, unless tipping points are reached.
- High recovery rates result in limited long-term effects on the local Bay floor. However, the sediment sink might cause a sediment deficit elsewhere in the Bay or might reduce sediment supply to the outer coast.
- Sand removal may cause little change in the Bay budget, if accommodation space is filled with fines deposition



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Questions?

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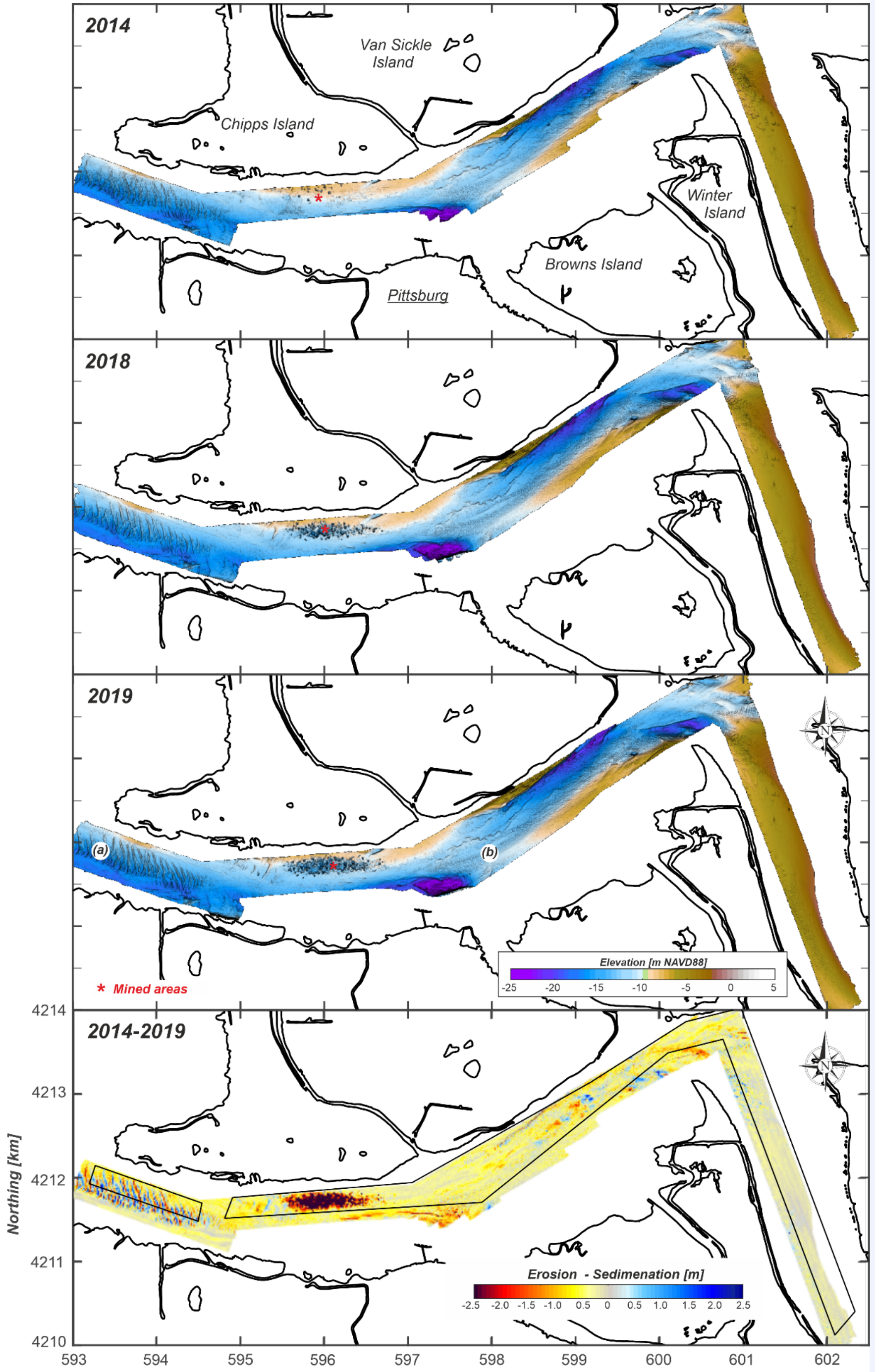
Available data; Suisun Bay and Middle ground shoal

Table 2-2: Overview of available datasets for **Suisun Bay** and **Middle Ground Shoal** (see Appendix A, Figure A-2 and A-3).

	Source	Resolution	Measuring device	Date
2014	Seafloor Mapping Lab (SFML) of California State University Monterey Bay	2 m	Reson 8101 multibeam sonar system	10/04/2014 - 12/15/2014
2018	eTRAC Inc (eTrac Inc, 2018)	2 m	R2Sonic	2018
2019	eTRAC Inc	2 m	R2Sonic	2019

- Detailed bathymetric data is available and suitable for analysis.
- Data reveals that mining has an impact on the bed
- In the timeframe of observations mining areas do not (fully) recover
- In general an overall deepening of the entire channel, including the mining area



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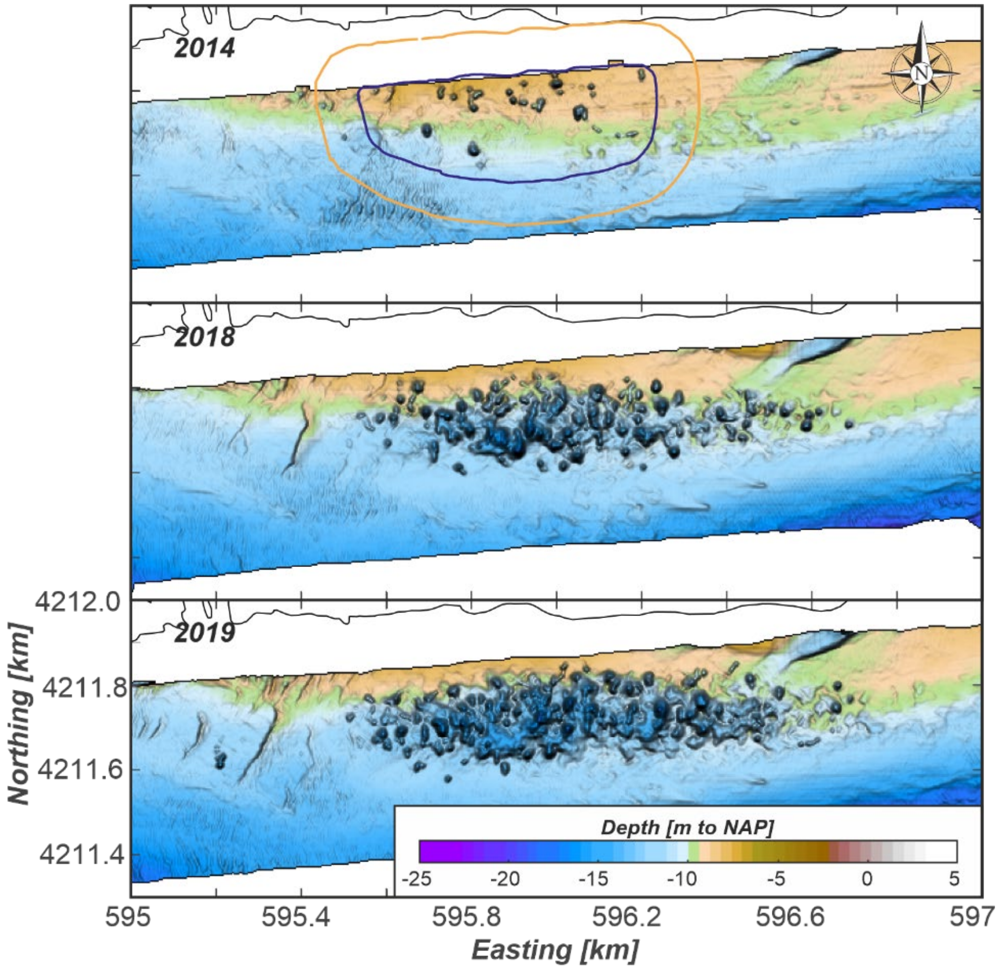
Summary of research results; Suisun Bay

- Potholing and bed lowering dominates the small-scale, local morphodynamic response.
- In total 0.62 Mcy mined volume
- Low recovery rates (1% between 2014 and 2019)
- Mean vertical change = -2.48 m between 2014 and 2019
- No bedform fields can be identified in the mining area.
- Bedform asymmetry (outside the mining area) is variable in time and space. Just west of the ring area transport is eastward directed.



	2014-2018	2018-2019	2014-2019
Mined Volume [Mcy]	**0.37**	**0.25**	**0.62**
Yearly Mined volume (Mcy/yr)	**0.10**	**0.16**	**0.12**
Survey Volume [cy]	**-0.33**	**-0.17**	**-0.50**
Recovery [%]	**-5**	**10**	**1**
Mean Vertical Change [m]	**-1.62**	**-0.86**	**-2.48**
Yearly Mean Vertical Change [m/yr]	**-0.46**	**-0.53**	**-0.48**

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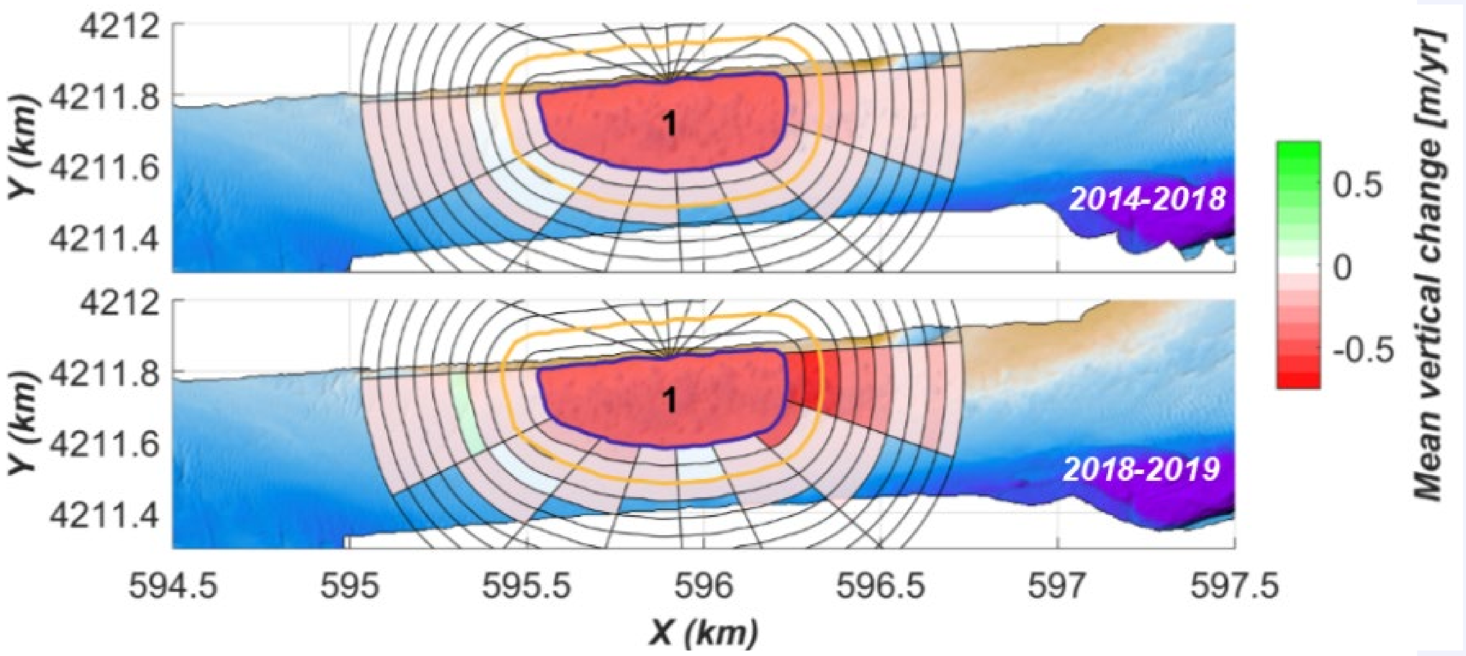
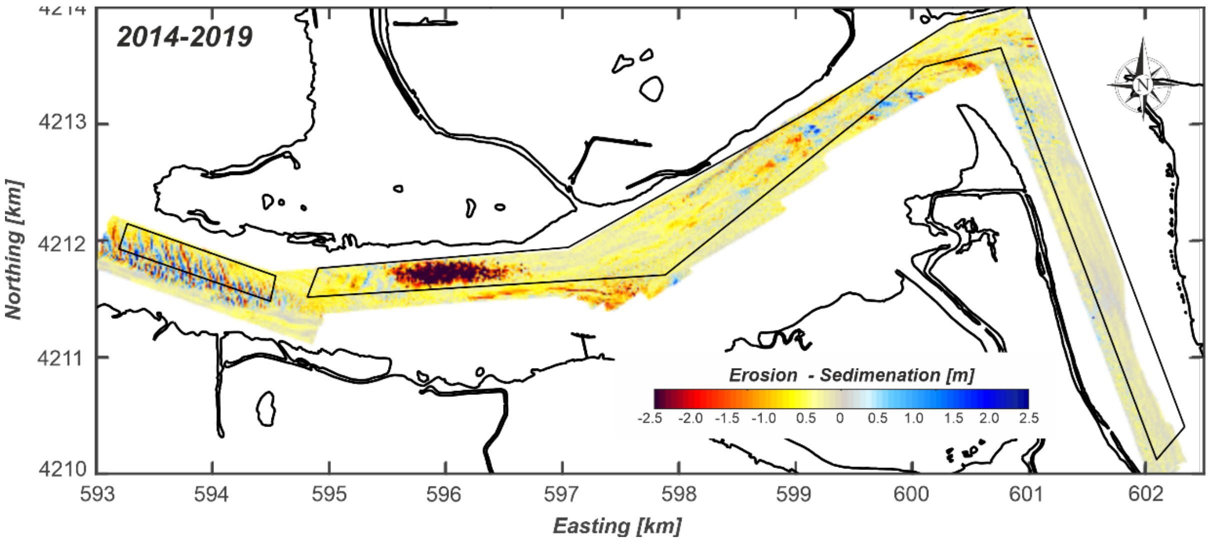
Summary of research results; Suisun Bay

- Diffusion of impacts from mining activities cannot be discerned from natural erosive patterns.





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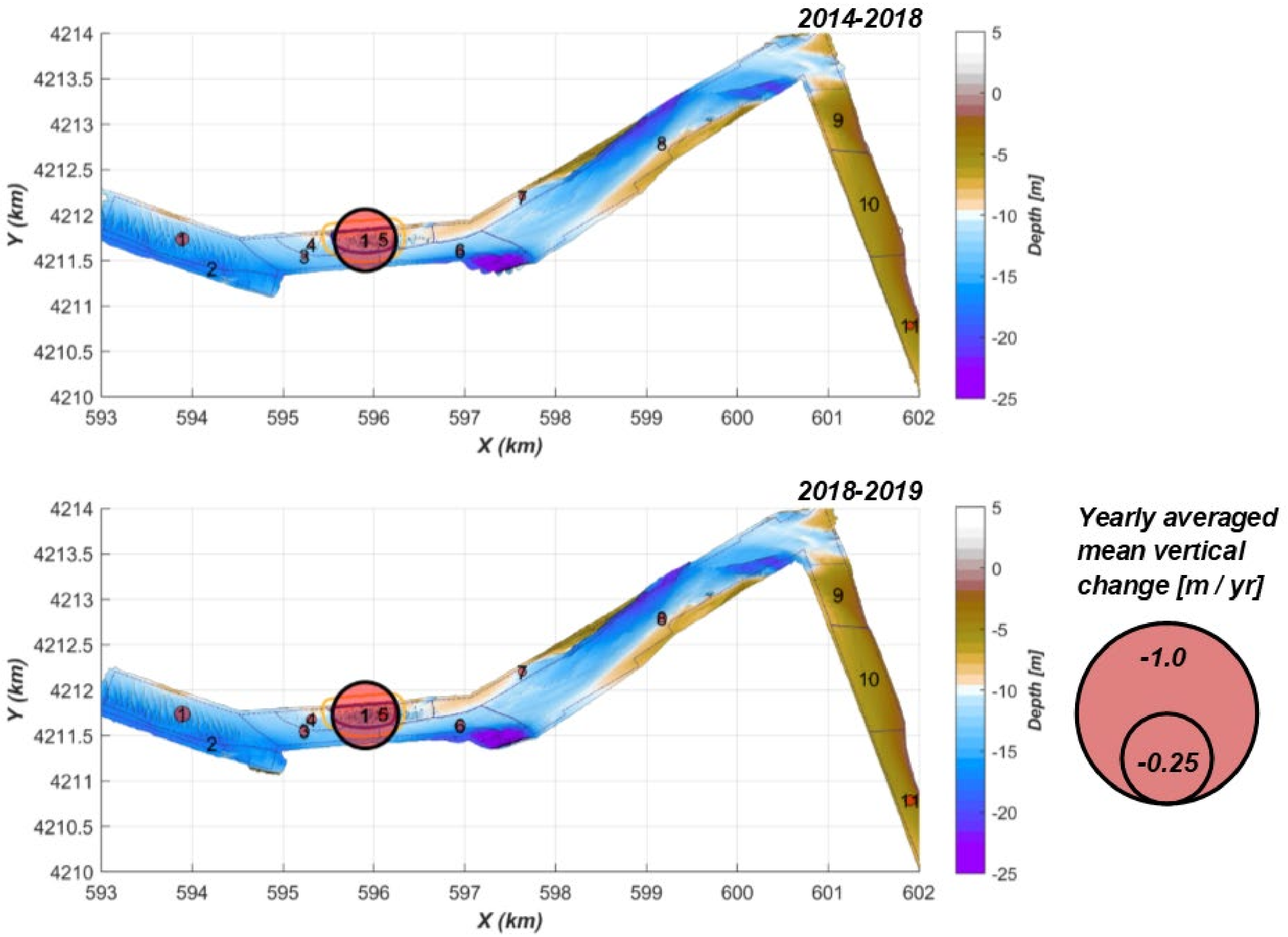
Summary of research results; Suisun Bay

- Volume loss and bed lowering at the mining area significantly exceeds the upstream and downstream morphodynamic changes.
- A correlation between mining and morphodynamic changes in the region cannot be discerned based on the limited available data.
- Low recovery rates in Suisun Channel suggest that sediment supply to San Pablo Bay is hardly affected by the mining or low sediment transport during the observations



Questions?

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