Integration of Regional Lidar to Expand Shoaling Rate Analytics Beyond Navigation Channels

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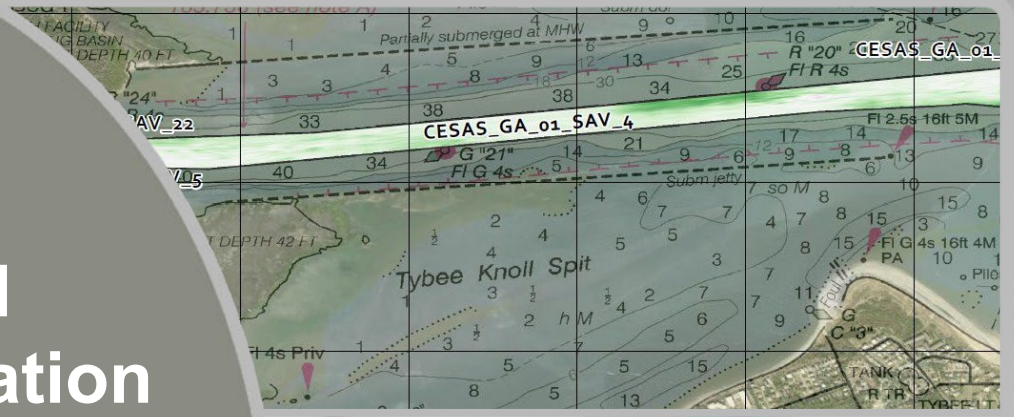
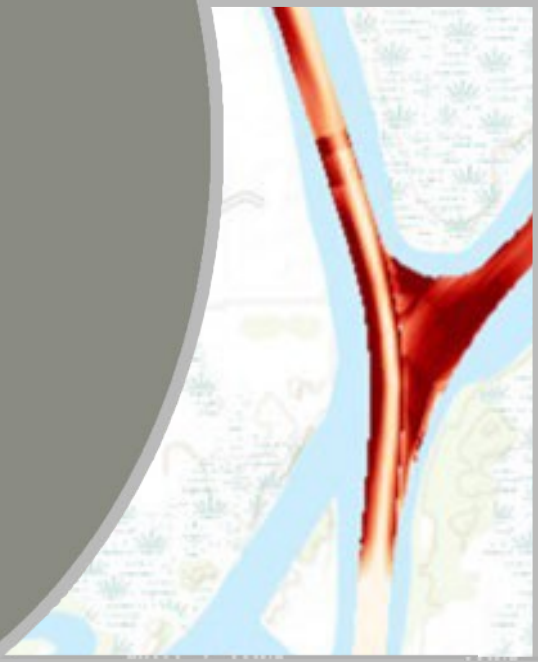
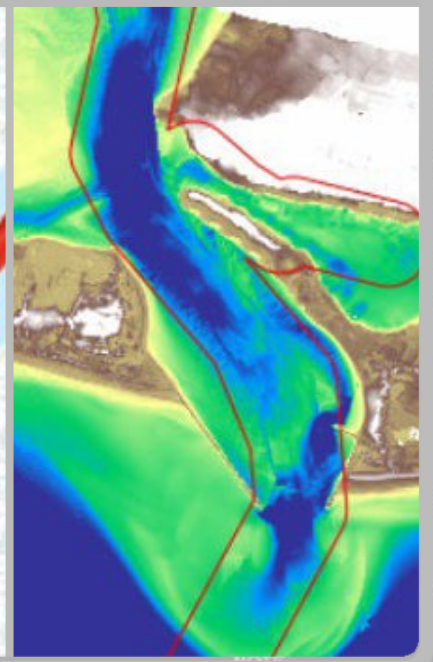
Coastal Sediments '23







COASTAL INLETS RESEARCH PROGRAM

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CHL COASTAL & HYDRAULICS LABORATORY

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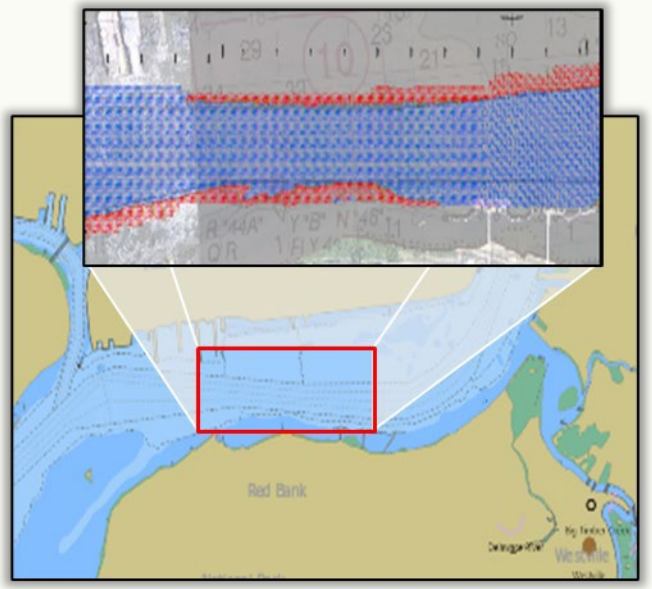
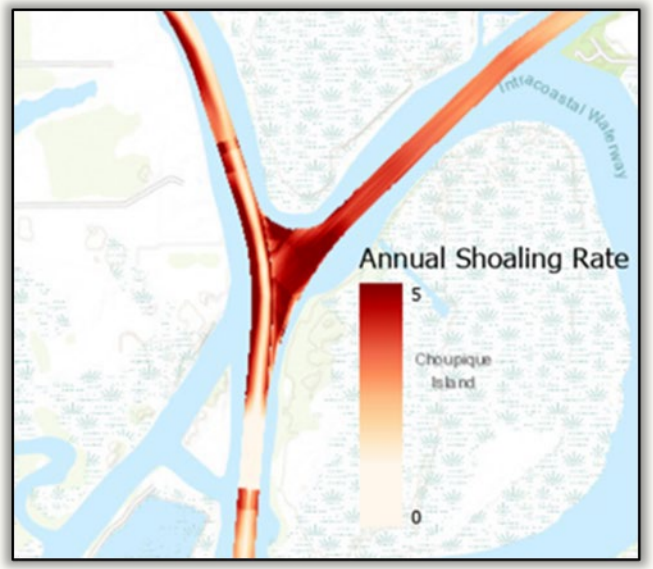
Problem

- Quantitative analysis of navigation channel conditions is critically important to supporting the USACE Navigation Mission area.
- Accurate shoaling estimation is critical for designing various aspects of navigation projects:
  - Advanced maintenance depth selections
  - Dredged material management plan development
  - Erosion control and sediment training structure designs.
- Current shoaling estimates limited to Federally authorized navigation channel dimensions





Sample report providing volumes at different depth/time intervals and shoaling rates

Oakland Harbor (12990)

RelativeDepth	0_Months	6_Months	12_Months	18_Months	24_Months	30_Months	36_Months
VA_s5	170	268	17011	110995	256638	439863	651617
VA_s4	380	629	37849	160493	333984	543181	777208
VA_s3	822	1848	73338	230601	435783	671386	928089
VA_s2	1760	10408	131878	330139	568150	830209	1107008
VA_s1	8097	46367	228386	470456	739993	1024519	1318239
VA_p0	22591	131827	382466	663121	956930	1258243	1564307
VA_p1	69944	325969	618266	919374	1226110	1536123	1848464
VA_p2	352952	646087	948645	1257045	1568686	1882661	2198080
VA_p3	699612	1002390	1312029	1625199	1940585	2257072	2574207
VA_p4	1076911	1386917	1701263	2017559	2334818	2652699	2970999
VA_p5	1476264	1791251	2108145	2425936	2744281	3062973	3381847

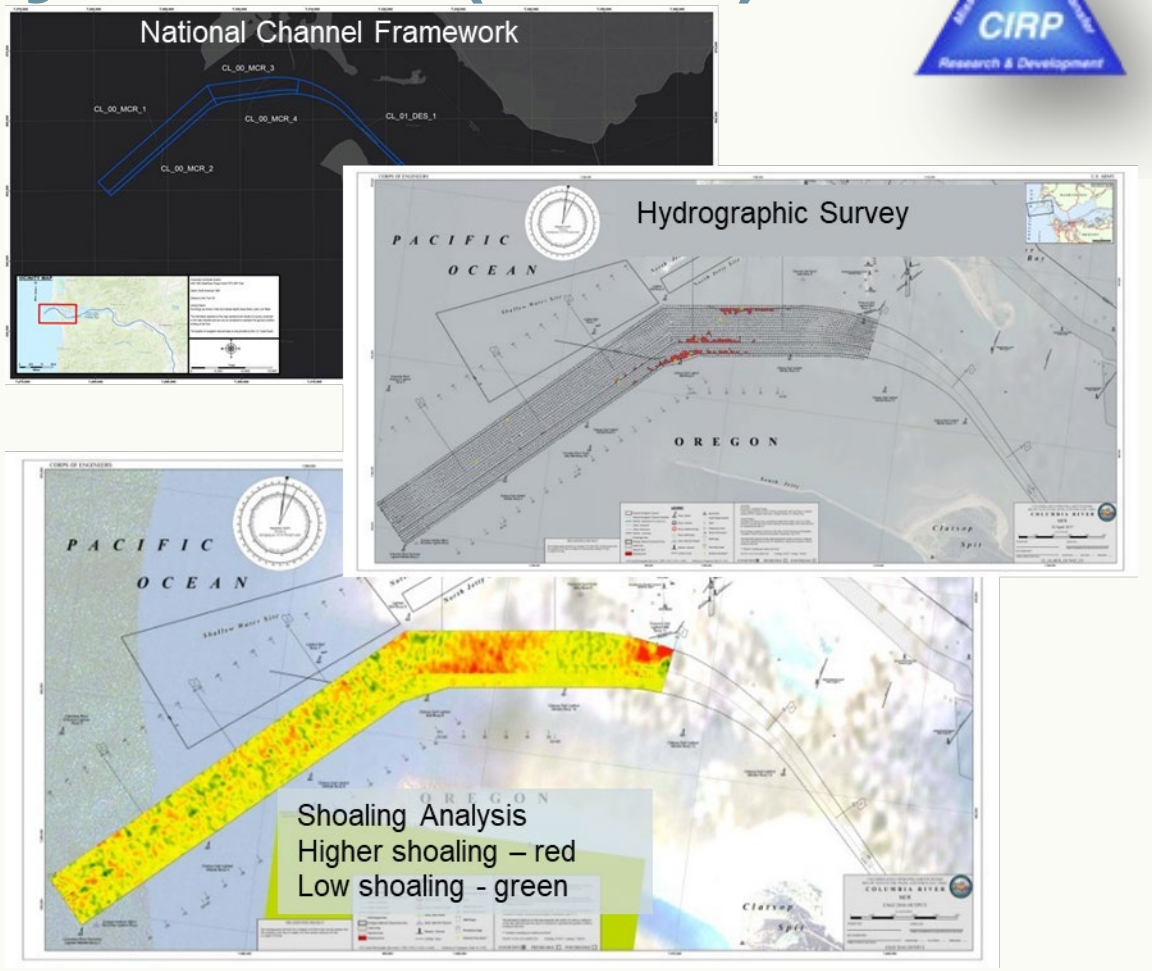
0_months column is equivalent to Summary Planning Quantities (SPQs)

Corps Shoaling Analysis Tool (CSAT)

Description

- CSAT estimates shoaling rates using hydrographic surveys within the boundary of the National Channel Framework.
- CSAT uses the historical shoaling rates to predict future dredging volumes at various channel depth intervals.
- Where are shoaling 'hot spots' within the navigation channel?
- How has shoaling changed as a result of meteorological events (extratropical storm, rainfall or drought periods), dredge schedule change or dredge type change?

https://cirp.usace.army.mil/products/csat.php



National Channel Framework, hydrographic survey map sheet from eHydro, and the shoaling rate prediction for Columbia River, OR.

Capability and Strategic Impact Statement

Shoaling rates can be used to identify hot spots or areas of increased sedimentation, ***allowing engineers and scientists to evaluate environmental and human-induced changes on the Navigation portfolio***. Additionally, CSAT shoaling rates and channel navigability supports decision makers efforts to ***maximize the use of Operations and Maintenance (O&M) funding*** in the Navigation Business Line.

Expanding CSAT Capabilities beyond the NCF

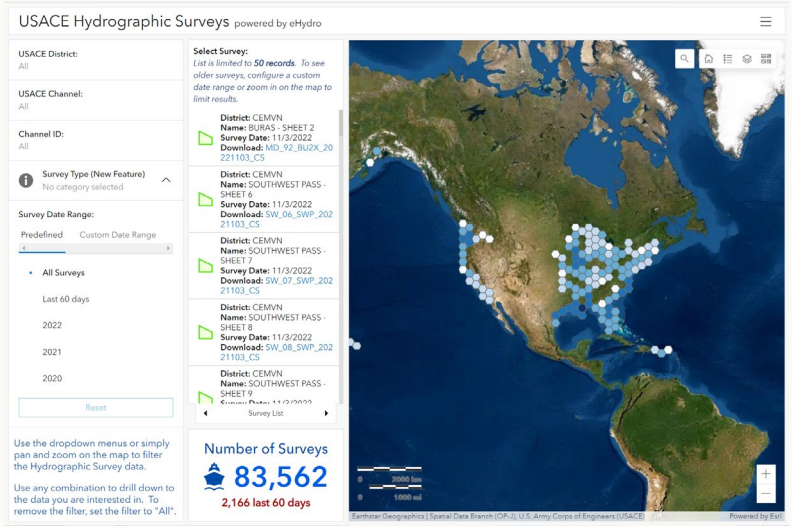
- CSAT currently estimates shoaling rates using hydrographic surveys within the boundary of the National Channel Framework.
- Sediment migration patterns within the vicinity of the NCF are important to understand.
- Availability of high-resolution regional topobathy lidar datasets provides opportunity to expand CSAT capabilities.

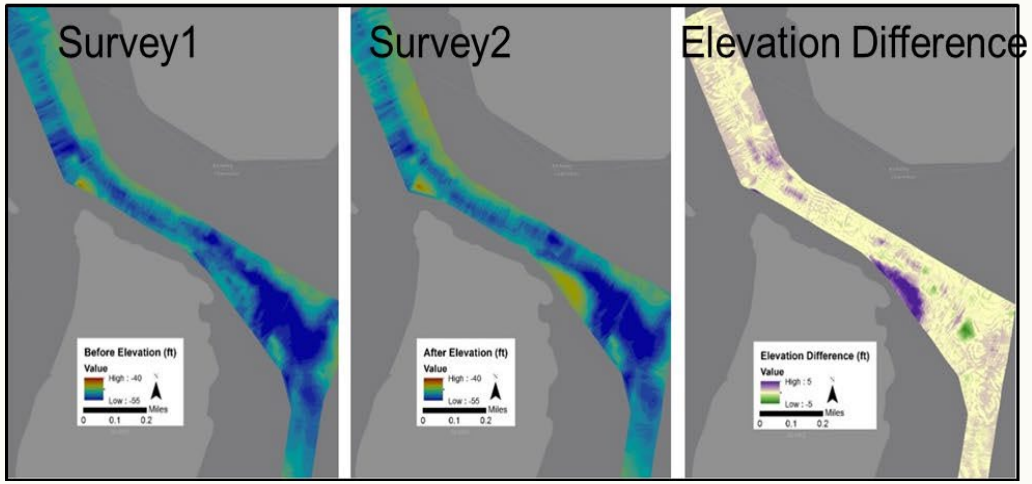
National Coastal Mapping Program

- Develops regional, repetitive, high-resolution, high-accuracy elevation and imagery data
- To build an understanding of how the coastal zone is changing
- Facilitates management of sediment and projects at a regional, or watershed scale

CSAT Input Generation Routine

- Survey Type (After-dredge, Before dredge, Condition)
- Partial coverage
- Duplicate surveys
- User Classification (Use/Do Not Use)



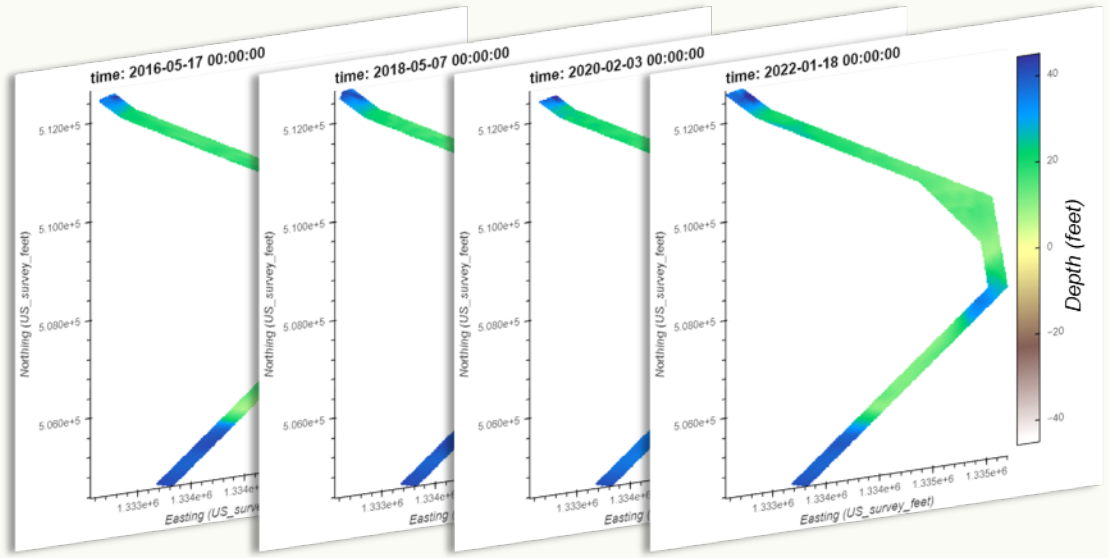


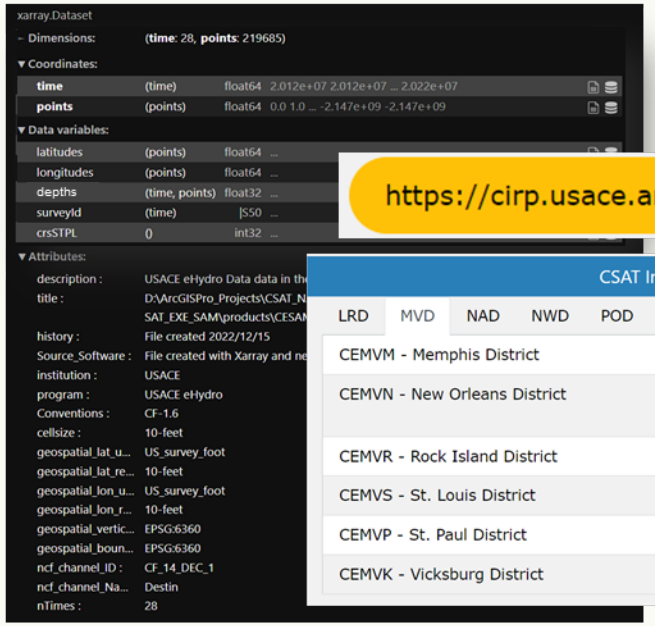
python ArcGIS

CSAT Input Generation

eHydro Viewer - https://www.arcgis.com/apps/dashboards/4b8f2ba307684cf597617bf1b6d2f85d

CSAT Inputs and Formats





eHydro Survey Data

NetCDF

https://cirp.usace.army.mil/products/csat_districts.php

CSAT Input/Output Files (by Division)

LRD | MVD | NAD | NWD | POD | SAD | SPD | SWD

CEMVM - Memphis District	Input	Output
CEMVN - New Orleans District	Input	Output - SW Pass Output - All others
CEMVR - Rock Island District	Input	Output
CEMVS - St. Louis District	Input	Output
CEMVP - St. Paul District	Input	Output
CEMVK - Vicksburg District	Input	Output

Latest survey data inputs

Reach_ID	Sheet_Name	Reach_Name	Depth	Depth_Proj	Name	Projection	CCR_group	CCR_line_1	CCR_line_2	raster_cel
CF_01_PEC_1	Pensacola Civil Entrance Channel	Reach_1	35.0	35.0	CF_01_PEC	Florida North	PENSACOLA	Pensacola Civil Entrance Channel	Reach_1	10
CF_01_PEC_2	Pensacola Civil Entrance Channel	Reach_2	35.0	35.0	CF_01_PEC	Florida North	PENSACOLA	Pensacola Civil Entrance Channel	Reach_2	10
CF_01_PEC_3	Pensacola Civil Entrance Channel	Reach_3	35.0	35.0	CF_01_PEC	Florida North	PENSACOLA	Pensacola Civil Entrance Channel	Reach_3	10

Channel Reach Table

CSV

	SurveyDateStamp	SurveyID	Reach_Name	Reach_ID	Cell_Size	Use	% Coverage
0	20120430	CF_14_DEC_20120430_CS	Destin Entrance	CF_14_DEC_1	10.0	1.0	2.01
1	20120628	CF_14_DEC_20120628_CS	Destin Entrance	CF_14_DEC_1	10.0	1.0	57.32
2	20120910	CF_14_DEC_20120910_CS	Destin Entrance	CF_14_DEC_1	10.0	1.0	40.91
3	20130823	CF_14_DEC_20130823_CS	Destin Entrance	CF_14_DEC_1	10.0	1.0	58.51

Survey Information Table

CSV

JALBTCX NCMP Topobathy Integration

- Workflow to format NCMP topobathy lidar for integration with CSAT's eHydro input.
- Jupyter Lab notebooks leveraging custom CSAT Python environment and the ESRI REST API.

(1) Transform eHydro input from 2D to 3D NetCDF

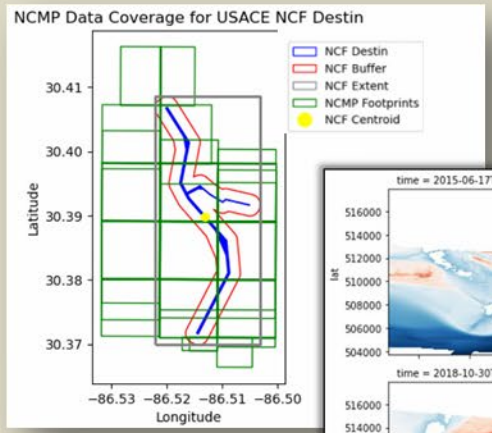
2D eHydro NetCDF

```
Dimensions:        (time: 28, points: 219685)
Coordinates:
  time             (time)          float64  2.012e+07 2.012e+07 ... 2.022e+07
  points           (points)        float64  0.0 1.0 ... -2.147e+09 -2.147e+09
Data variables:
  latitudes        (points)        float64  ...
  longitudes       (points)        float64  ...
  elevations       (time, points)  float32  ...
  surveyId         (time)          |S50     ...
  crsSTPL          ()              int32    ...
```

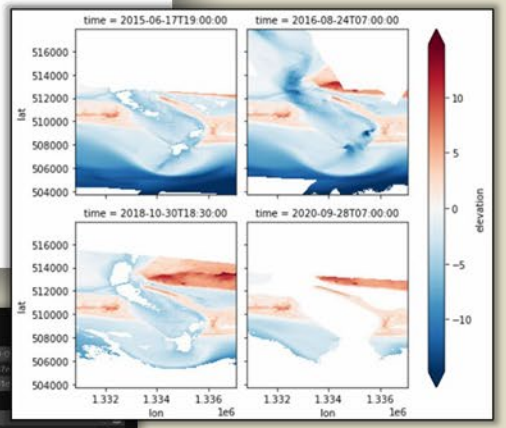
3D eHydro NetCDF

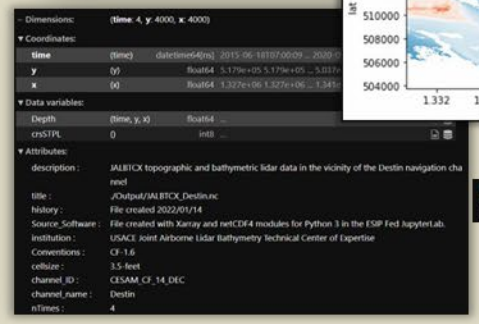
```
Dimensions:        (time: 28, latitude: 829, longitude: 265)
Coordinates:
  time             (time)                    float64  2.012e+07 2.012e+07 ... 2.022e+07
  latitude         (latitude)                float64  5.127e+05 5.126e+05 ... 5.044e+05
  longitude        (longitude)               float64  1.333e+06 1.333e+06 ... 1.335e+06
Data variables:
  elevations       (time, latitude, longitude)  float64  ...
  surveyId         (time)                    |S50     ...
  crsSTPL          ()                        int8     ...
```

(2) Query and extract NCMP topobathy and write to 3D NetCDF



NCMP footprints and images from REST Image Service





3D NCMP NetCDF

(3) Combine eHydro and NCMP 3D NetCDFs → 2D

3D eHydro + NCMP NetCDF

```
xarray.Dataset
Dimensions:        (time: 32, y: 829, x: 265, latitude: 829, longitude: 265)
Coordinates:
  time             (time)          datetime64[ns]  2012-04-30 ... 2022-07-06
  y                (y)             float64  5.127e+05 5.126e+05 ... 5.044e+05
  x                (x)             float64  1.333e+06 1.333e+06 ... 1.335e+06
  spatial_ref      ()              int32    0
  latitude         (latitude)      float64  5.127e+05 5.126e+05 ... 5.044e+05
  longitude        (longitude)     float64  1.333e+06 1.333e+06 ... 1.335e+06
Data variables:
  Depth            (time, y, x)    float64  nan nan nan nan ... nan nan nan nan
  elevations       (time, latitude, longitude)  float64  nan nan nan nan ... nan nan nan nan
  surveyId         (time)          object   b'CF_14_DEC_20120430_CS' ... b'C...
  crsSTPL          ()              int8     -127
Attributes:  (10)
```

2D CSAT Input NetCDF

```
xarray.Dataset
Dimensions:        (time: 32, points: 219685)
Coordinates:
  time             (time)          int32  20120430 20120628 ... 20220706
  points           (points)        int32  0 1 2 3 ... 219682 219683 219684
Data variables:
  elevations       (time, points)  float64  nan nan nan nan ... nan nan nan nan
  latitudes        (points)        float64  5.044e+05 5.044e+05 ... 5.127e+05
  longitudes       (points)        float64  1.333e+06 1.333e+06 ... 1.335e+06
  surveyId         (time)          |S29    b'CF_14_DEC_20120430_CS' ... b'C...
Attributes:
  description :    CSAT 2D Input
```

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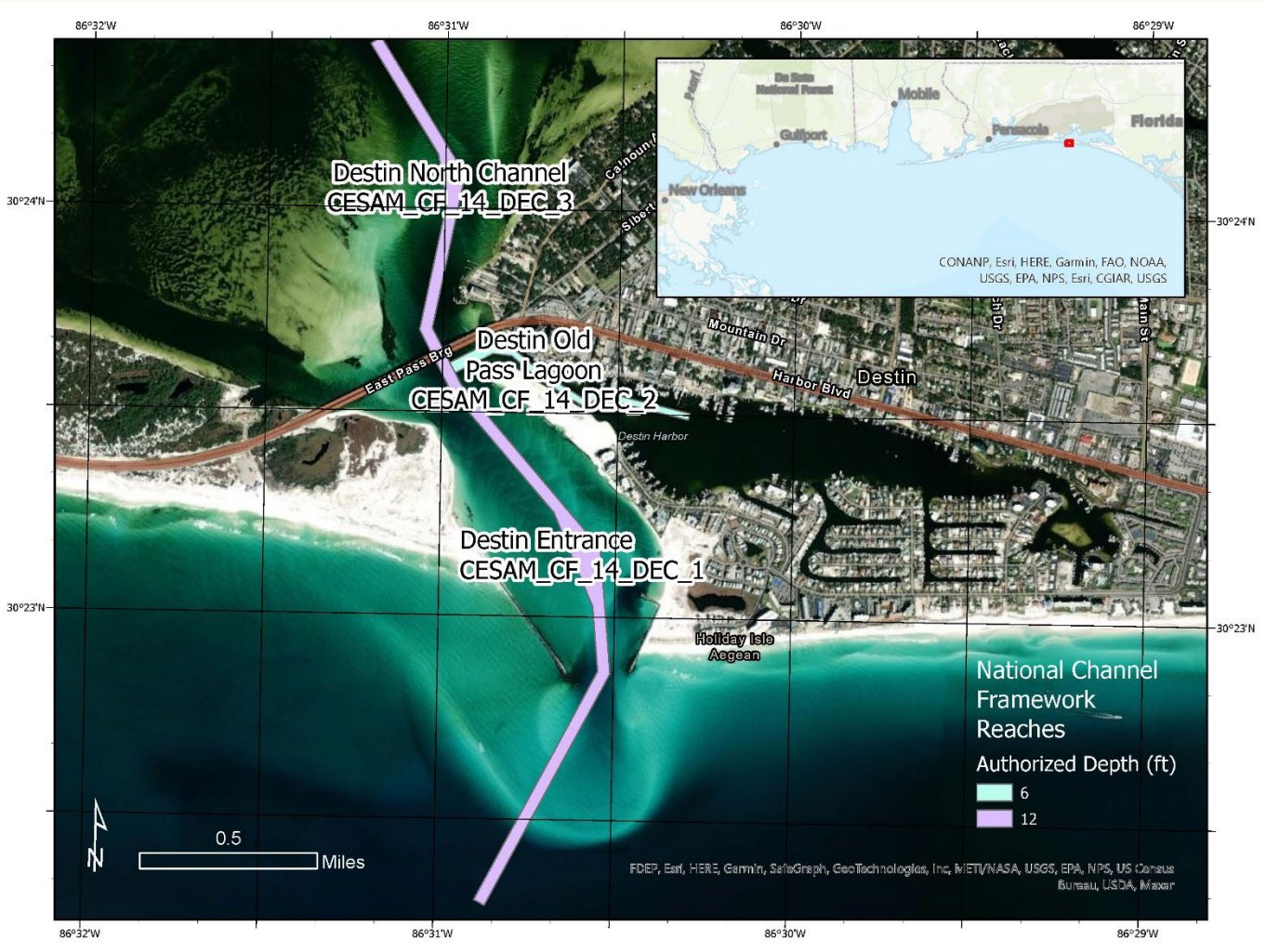
Case Study from East Pass Inlet (Destin, FL)

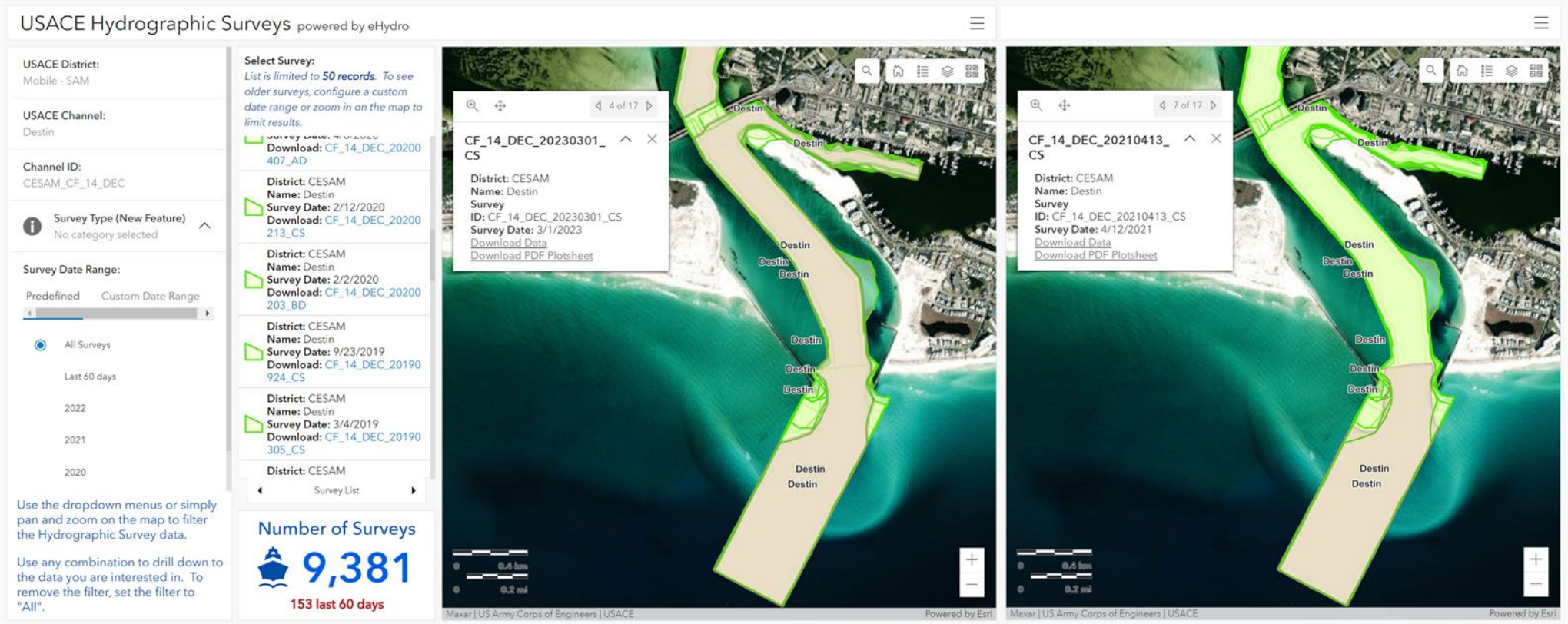
Overview

- Tidal connection between Gulf of Mexico and Choctawatchee Bay
- Authorized as Federal navigation channel in 1930 and re-authorized in 1951
- Dredged materials beneficially used for nourishment of beaches
- Develop understanding of broader shoaling patterns to inform dredging and nourishments
- Compare shoaling rates derived from combined eHydro + NCMP input vs. eHydro input alone



Case Study from East Pass Inlet (Destin, FL)

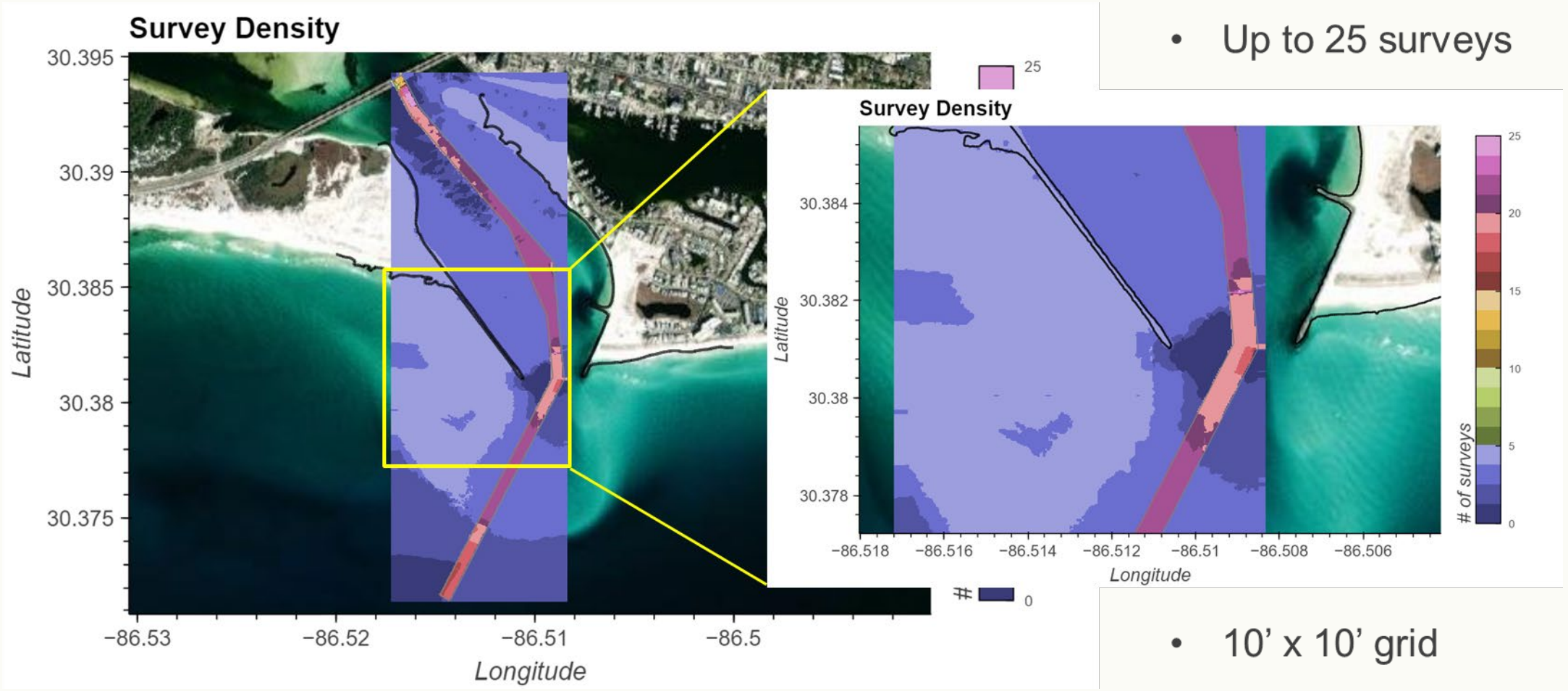
Spatial distribution of survey coverage



- Survey coverage can be complete or partial

Case Study from East Pass Inlet (Destin, FL)

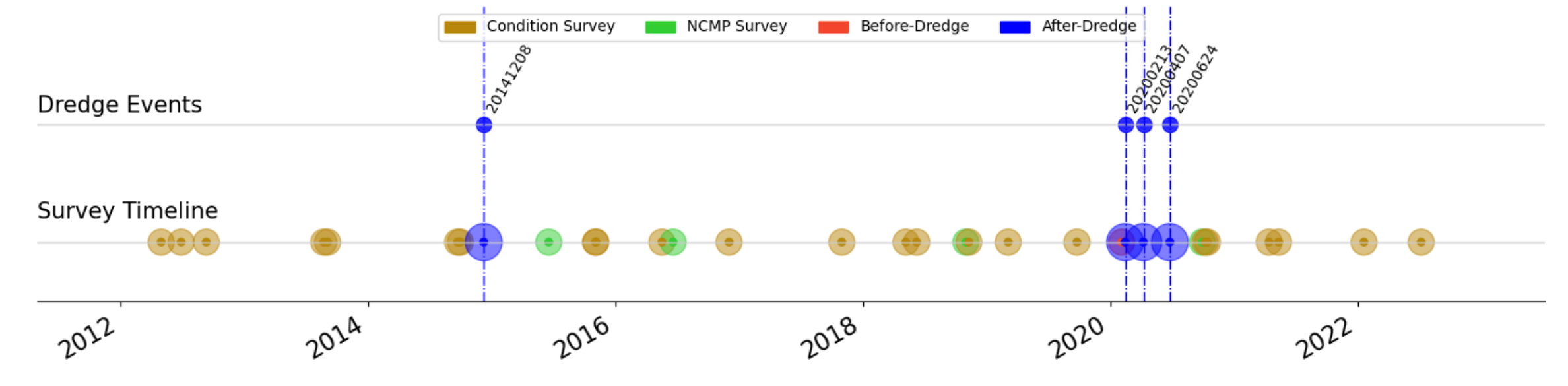
Spatial distribution of survey coverage



- Up to 25 surveys
- 10’ x 10’ grid

Case Study from East Pass Inlet (Destin, FL)

Temporal distribution of surveys and dredge events



- Dredge events define the aggregation of survey pairs
- NCMP survey dates represent the mid-point of data acquisition operations
- CSAT mosaics surveys within 10-day window by default, can override

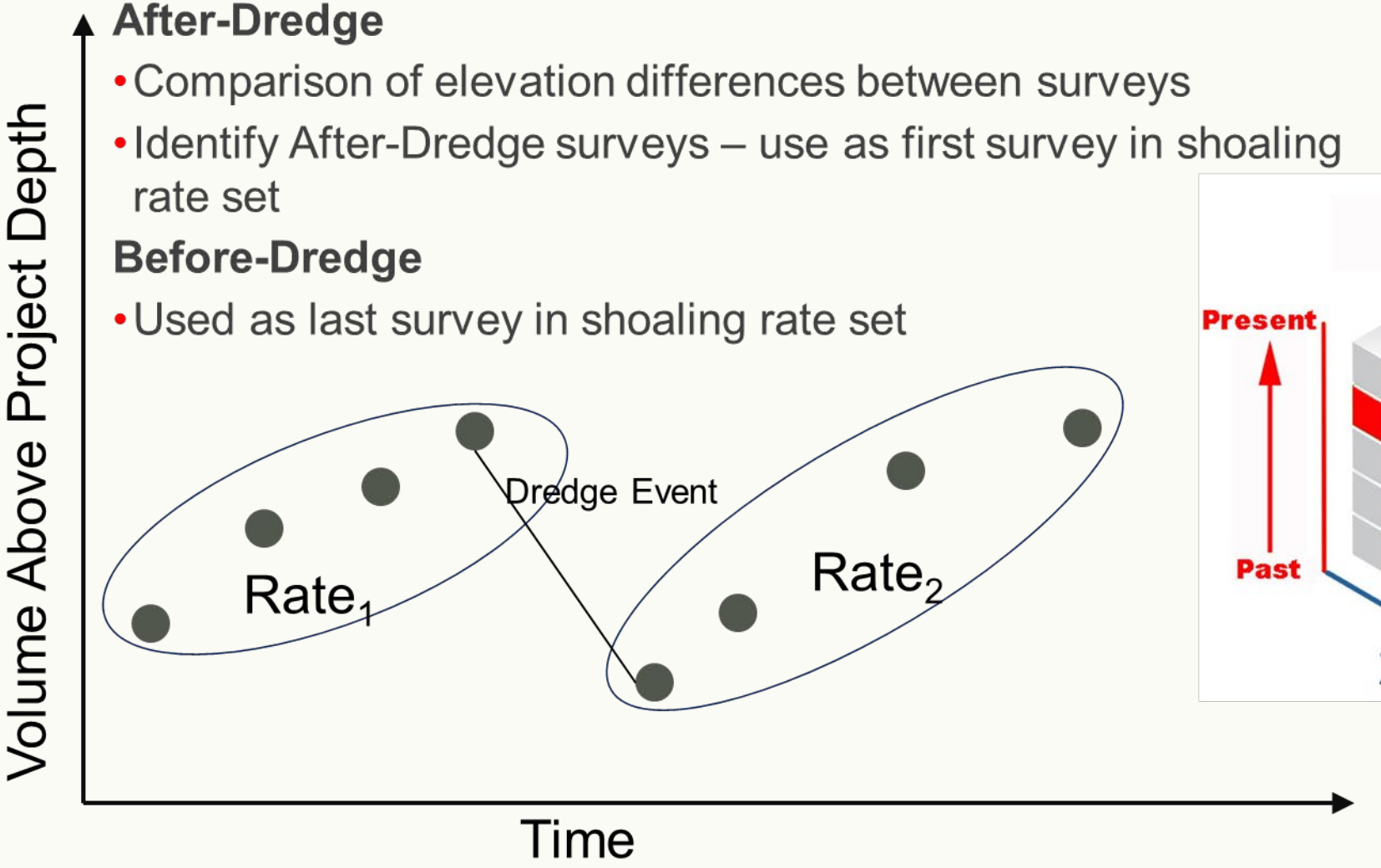
CSAT Workflow – Survey Type

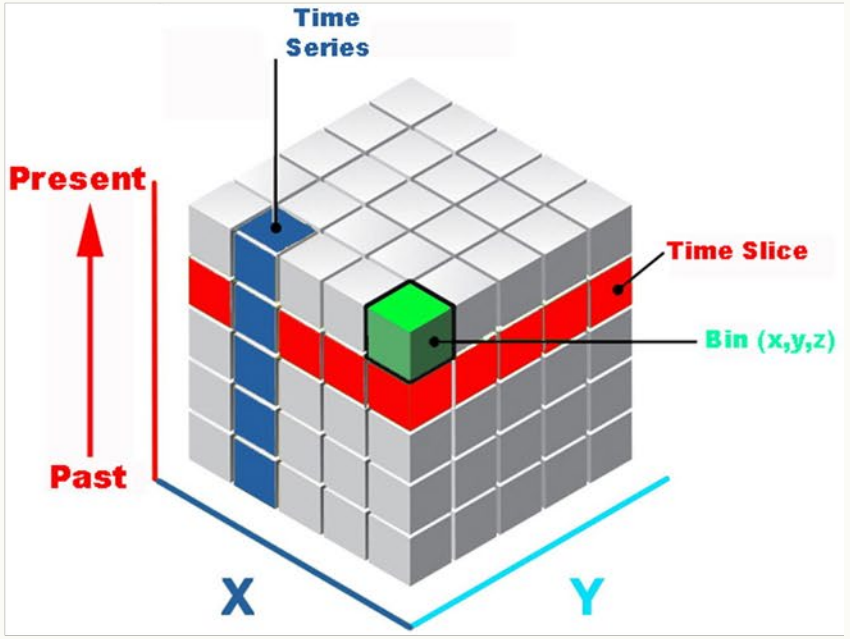
After-Dredge

- Comparison of elevation differences between surveys
- Identify After-Dredge surveys – use as first survey in shoaling rate set

Before-Dredge

- Used as last survey in shoaling rate set



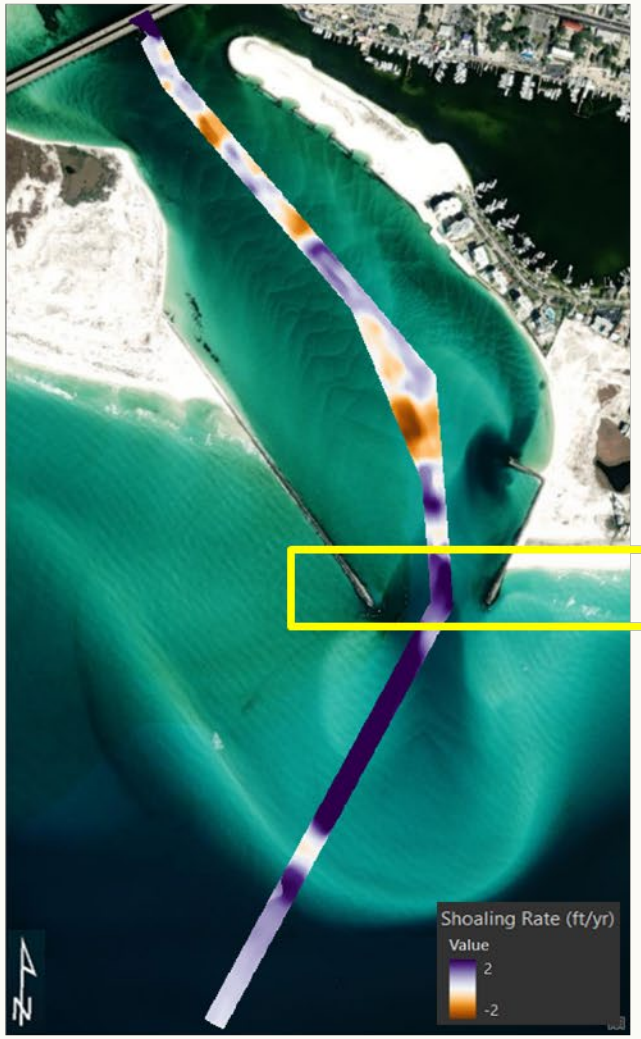


$$\bar{m} = \frac{\sum(w_i \Delta z_i)}{\sum w_i}$$

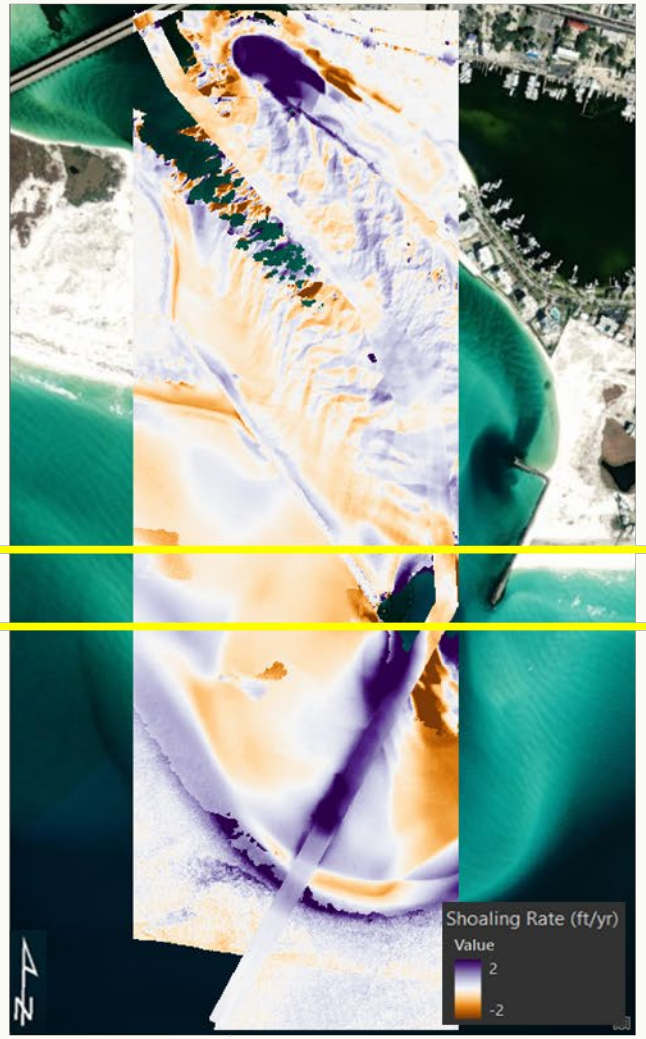
$$\bar{m} = \text{mean}(m_{14}, m_{58})$$

CSAT Results – Shoaling Rates

eHydro Survey Input Alone



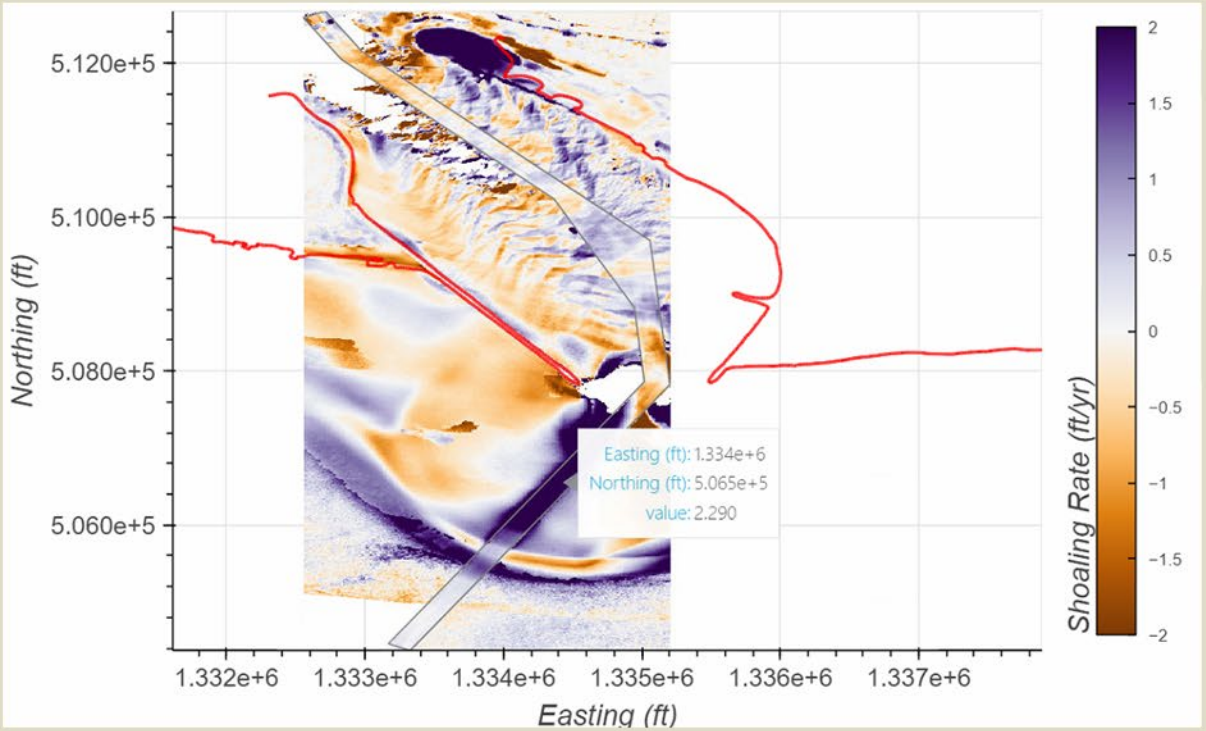
eHydro & NCMP Survey Input



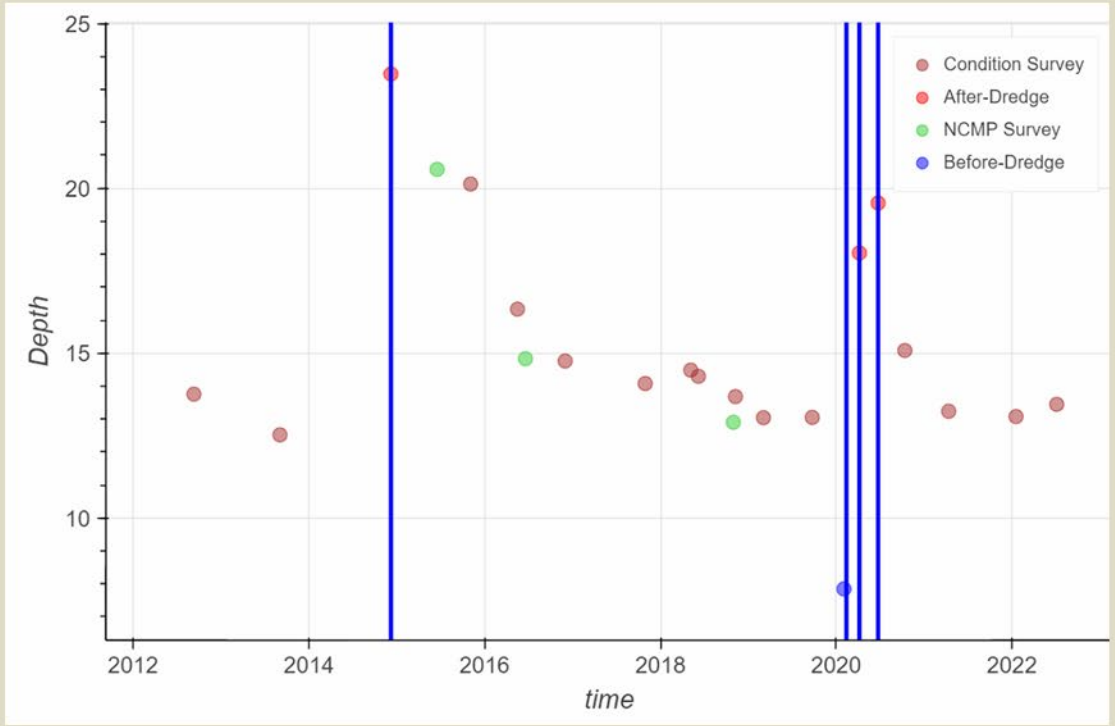
Difference

CSAT Results – Shoaling Rates

Shoaling Rate Map



Depth Timeseries



+ Shoaling Rate: Shoaling
- Shoaling Rate: Deepening

CSAT Results – Reach-level Volume Tables

- Report volumes at different depth/time intervals and shoaling rates

TimeToDredge	VA_p5	VA_p4	VA_p3	VA_p2	VA_p1	VA_p0	VA_s1	VA_s2	VA_s3	VA_s4	VA_s5
0 months	5,277,326	4,709,810	4,161,942	3,637,607	3,143,820	2,685,010	2,267,012	1,900,817	1,611,541	1,414,314	1,264,837
6 months	5,377,743	4,807,305	4,256,127	3,727,511	3,227,841	2,760,954	2,332,280	1,956,409	1,656,259	1,450,644	1,295,512
12 months	5,481,160	4,907,247	4,352,916	3,820,777	3,315,999	2,843,267	2,406,436	2,019,254	1,707,176	1,491,756	1,330,476
18 months	5,587,514	5,010,668	4,452,785	3,916,886	3,407,575	2,929,596	2,486,705	2,090,484	1,766,414	1,538,328	1,369,736
24 months	5,695,672	5,116,441	4,555,766	4,016,596	3,502,759	3,019,377	2,571,062	2,167,815	1,834,612	1,592,922	1,414,221
30 months	5,805,431	5,223,905	4,660,757	4,118,769	3,601,437	3,113,169	2,659,079	2,249,659	1,908,714	1,656,348	1,465,723
36 months	5,916,642	5,332,968	4,767,489	4,222,800	3,702,391	3,210,065	2,750,819	2,335,663	1,987,463	1,726,626	1,524,763
42 months	6,029,186	5,443,500	4,875,794	4,328,618	3,805,313	3,309,294	2,845,555	2,425,053	2,070,282	1,802,202	1,590,258
48 months	6,142,960	5,555,394	4,985,523	4,435,985	3,909,987	3,410,762	2,942,680	2,517,291	2,156,354	1,881,611	1,661,307
54 months	6,257,877	5,668,471	5,096,614	4,544,815	4,016,213	3,514,097	3,042,170	2,612,088	2,245,415	1,964,139	1,736,753
60 months	6,373,870	5,782,732	5,208,877	4,654,943	4,123,891	3,618,999	3,143,705	2,709,253	2,337,389	2,049,595	1,815,615

0_months row is equivalent to Summary Planning Quantities (SPQs)

Summary and Future Work

Summary

- Quantitative analysis of navigation channels is critically important to supporting the USACE Navigation Mission Area
- The Corps Shoaling Analysis Tool (CSAT) provides shoaling rates within the boundary of the National Channel Framework (NCF) and predictions for future dredging volumes
- CSAT capabilities show potential for expansion beyond the NCF and opportunities for linkages with other tools to support Navigation O&M
- Semi-automated production of consistent data analytics for the Corps' coastal navigation portfolio ensures limited financial resources are rationally allocated according to channel maintenance needs

FY23 Advances in Capability

- **Extending CSAT capabilities beyond the NCF**
  - Formalizing workflow for integrating JALBTCX topobathy lidar data into CSAT's Input Generation routine
  - Adding capability for shoaling rate computations with user-supplied polygons
- **Improved QA/QC Tools**
  - Jupyter Notebooks with interactive widgets to explore input surveys, dredging events and intervals, and shoaling rates
- **Documentation**
  - Verification and validation of NavPortal Integration
  - Streamline installation and update the User Guide

Planned Outyear Products/Advances

- Improved Datum Transformation Support
- Continued integration with USACE NavPortal web interface
- Implementation of additional shoaling rates

CSAT
Corps Shoaling Analysis Tool

Team

- Dr. Michael Hartman (PI)
- Dr. Jack Cadigan
- Dr. Rachel Bain
- Charlene Sylvester
- Mark Cowan
- Lauren Dunkin

Contact

- Michael.A.Hartman@erdc.dren.mil
- Charlene.S.Sylvester@usace.army.mil

Website

- https://cirp.usace.army.mil/products/csat.php

Thank You!