ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018
The State of the Art and Science of Coastal Engineering

Vessel-Induced Surge Model Validation Using High-Resolution AIS Data and Field Measurements in a Complex Harbor

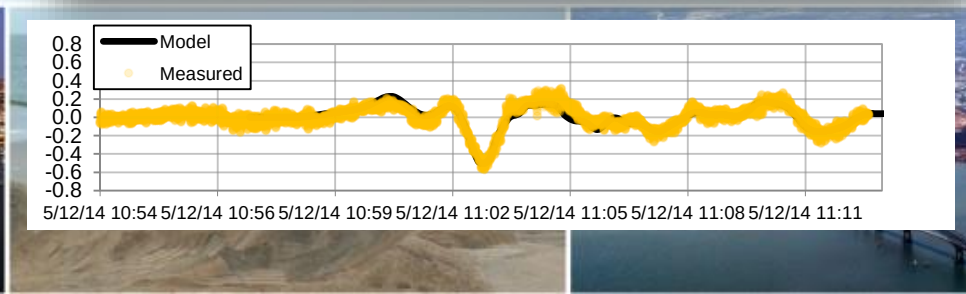
Francis Salcedo, PE - Mott MacDonald

Scott Fenical, PE, D.CE, D.PE - Mott MacDonald

Abhishek Sharma, PhD - Mott MacDonald

Gary Ledford - Ch2M/Jacobs

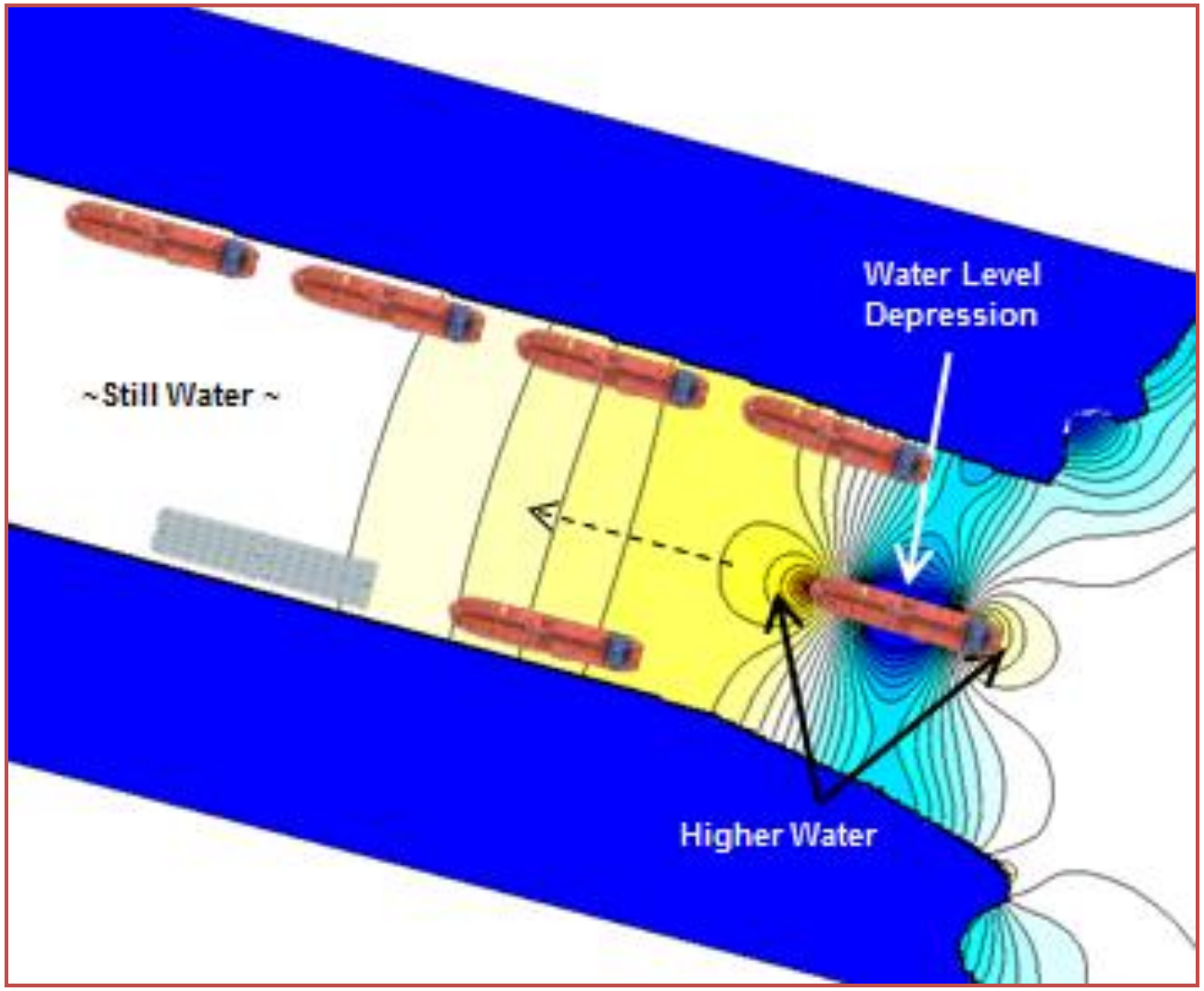
Bill Crowe - Canaveral Port Authority



Presentation Outline

1. General Passing Ship Effects
2. Description of the Modeling System – VHLU
3. Port Canaveral and Passing Cruise Ships
4. Full-Scale Validations at Port Canaveral Harbor using AIS data and pressure sensors
5. Applying VHLU to calculate mooring loads at Port Canaveral
6. Summary

General Passing Ship Effects

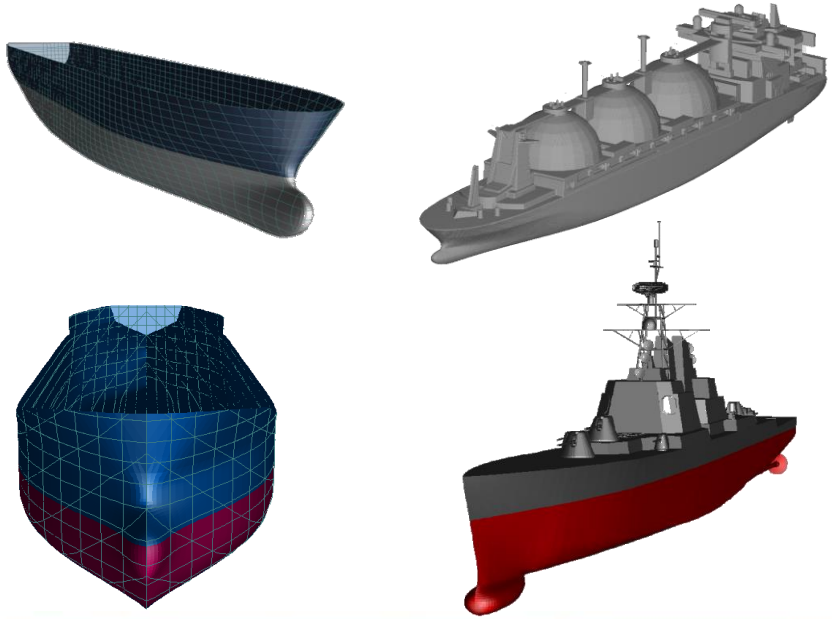


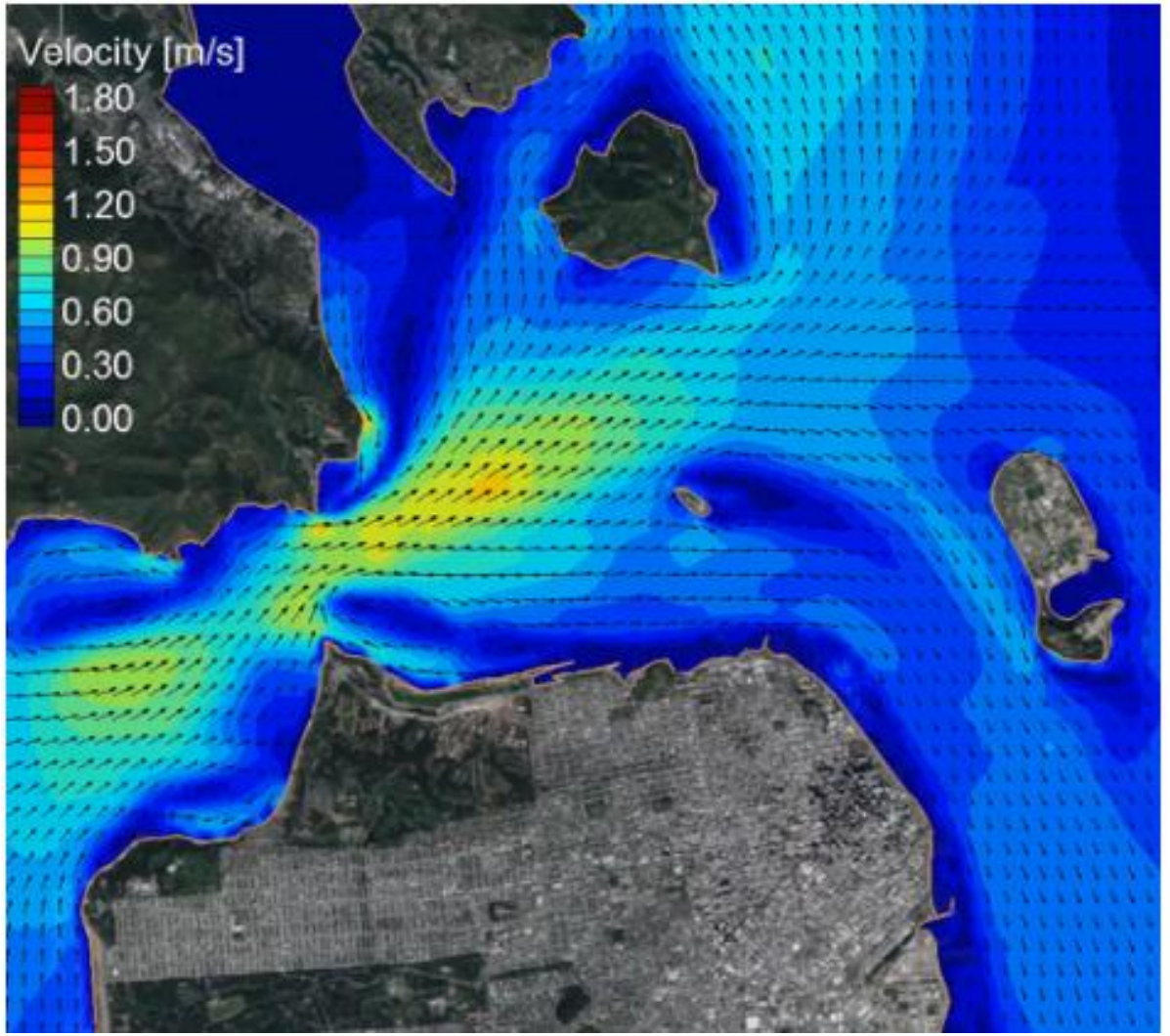
General Passing Ship Effects

6x Real Time

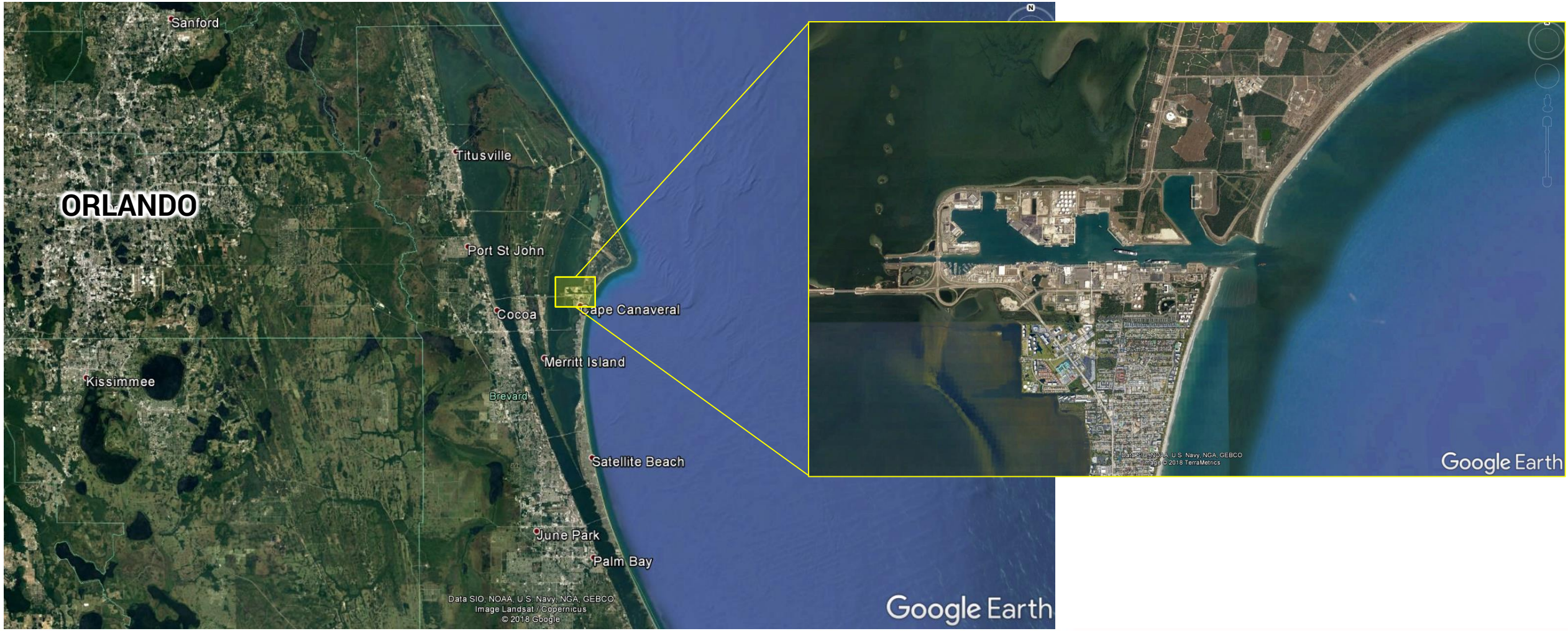
Model System Overview - VHLU

- 2-D Hydrodynamic model generated from MM's coastal processes modeling system.
- Finite Volume Model
- Incorporates ambient currents, waves, winds, tide.
- Expanded to include multiple moving/berthed vessels (unlimited). Model is called Vessel Hydrodynamics Longwave Unsteady (VHLU)





Port Canaveral, Florida, USA






ICCE 2018

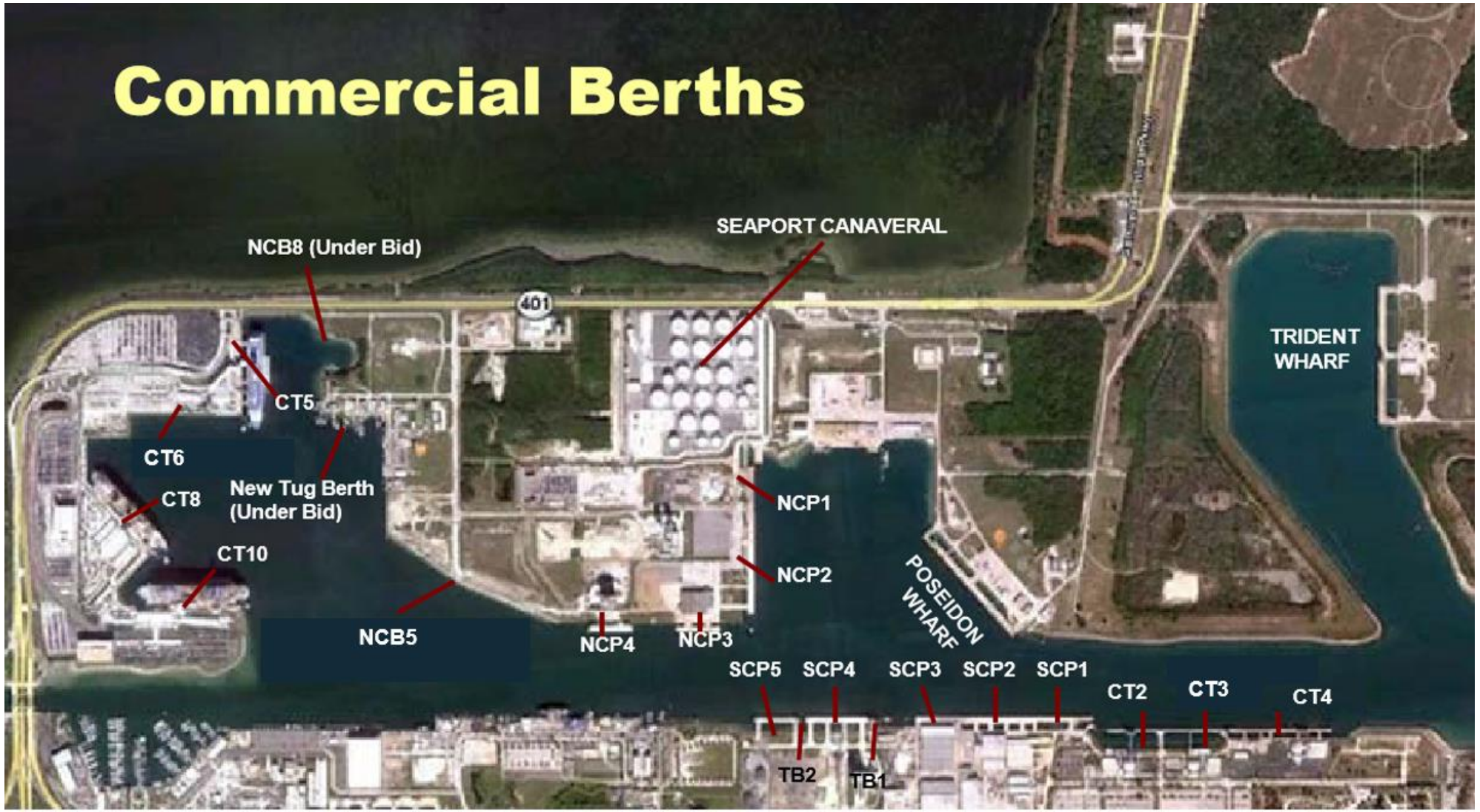
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

Baltimore, Maryland | July 30 – August 3, 2018

Port Canaveral, Florida, USA



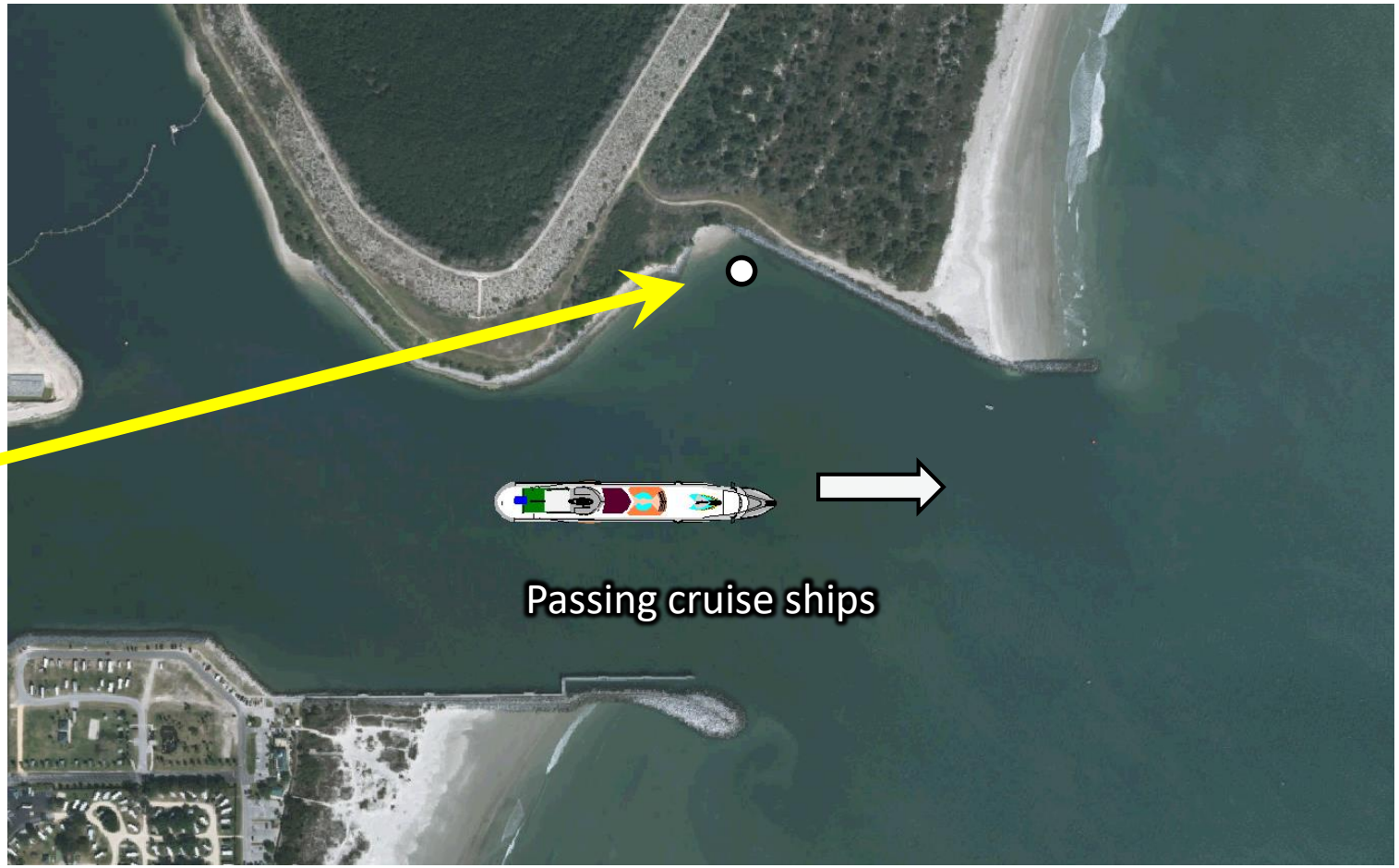

Port Canaveral, Florida, USA





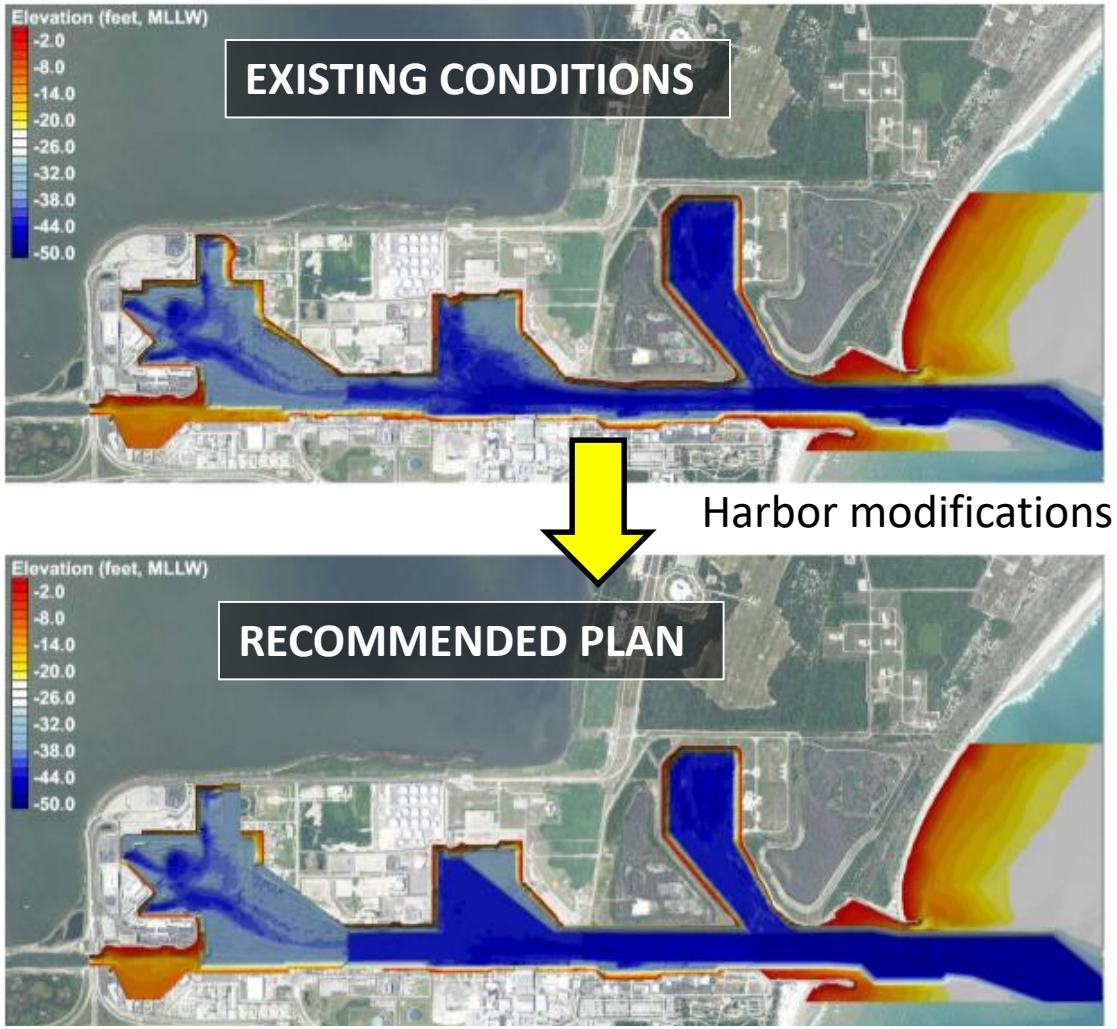

Port Canaveral and Passing Cruise Ships

Example:
Oasis of the Seas
LOA = ~1190 ft
Beam = ~160 ft
Draft = ~30.6 ft






Passing Ships and Mooring Safety Questions

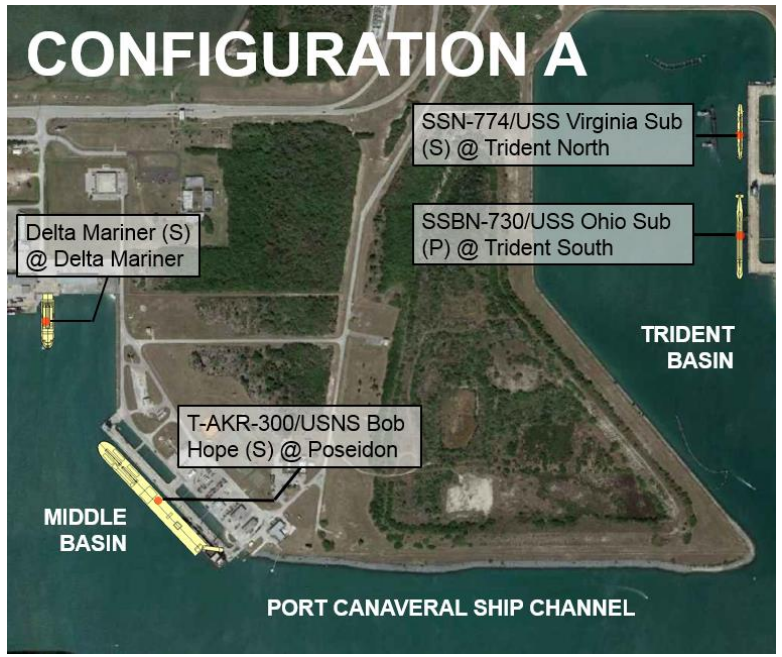


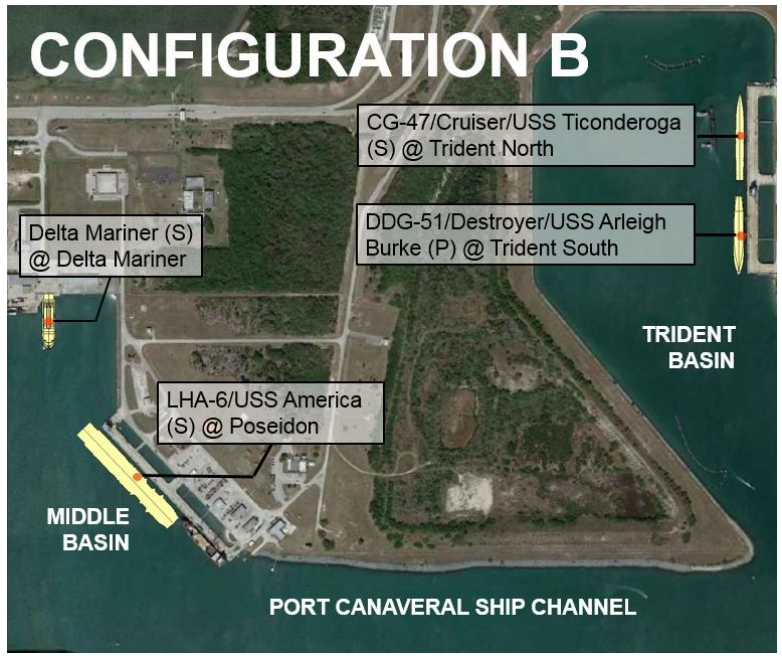



Passing Ships and Mooring Safety Questions

(a) Investigate mooring safety at Middle Basin and Trident Basin due to passing cruise ships (five configurations) in 2011

(a) Mission Partner Vessels
Channel Deepening



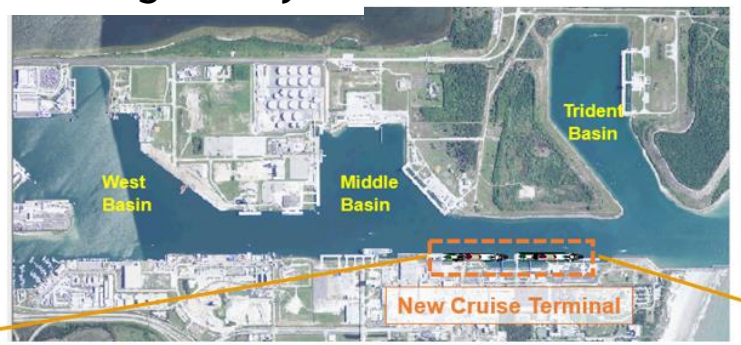


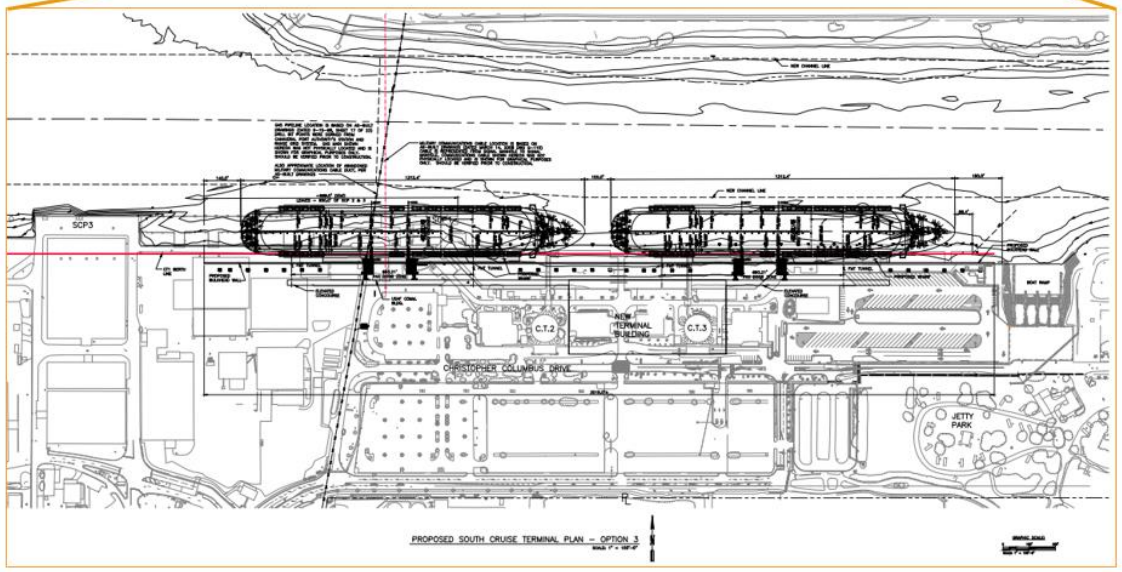
Vessel Configuration	Berth	Ship Name/Class or Type	Length [ft]	Beam [ft]	Draft [ft]
A	Trident S	SSBN-730/USS Ohio Sub (P)	559	42	35.4
A	Trident N	SSN-774/USS Virginia Sub (S)	337	34	30.5
A	Poseidon	T-AKR-300/USNS Bob Hope (S)	951.4	105.7	27.6
B	Trident S	DDG-51/Destroyer/USS Arleigh Burke (P)	505	59	20.3
B	Trident N	CG-47/Cruiser/USS Ticonderoga (S)	568	55	23.2
B	Poseidon	LHA-6/USS America (S)	844	106	29
C	Trident S	T-AGS 45/USNS Waters (P)	442	69	20
C	Poseidon W	CG-47/Cruiser/USS Ticonderoga (P)	568	55	23.2
C	Poseidon E	DDG-51/Destroyer/USS Arleigh Burke (P)	505	59	20.3
D	Poseidon W	SSN-774/USS Virginia Sub (P)	377	34	30.5
D	Poseidon E	T-AGS 45/USNS Waters (P)	442	69	20
E	Poseidon W	T-AGS 60/USNS Pathfinder (P)	328.5	58	19
E	Poseidon E	LCS-2/USS Independence (S)	418	104	13
A-E	Delta Mariner	Delta Mariner (S)	312.6	82	12

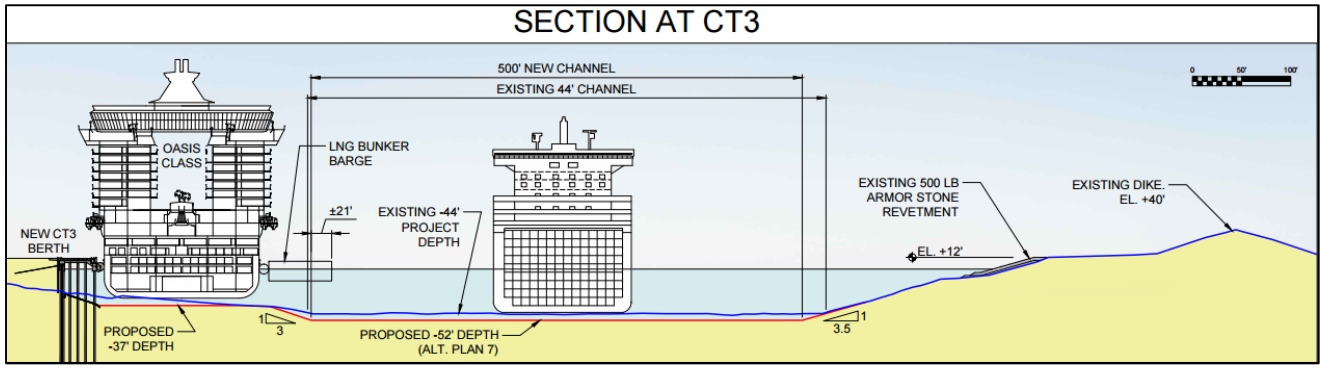
Passing Ships and Mooring Safety Questions

(b) Investigate mooring safety at New Cruise Terminal due to passing ships in 2017

(b) South side Surge Study







Presentation Outline

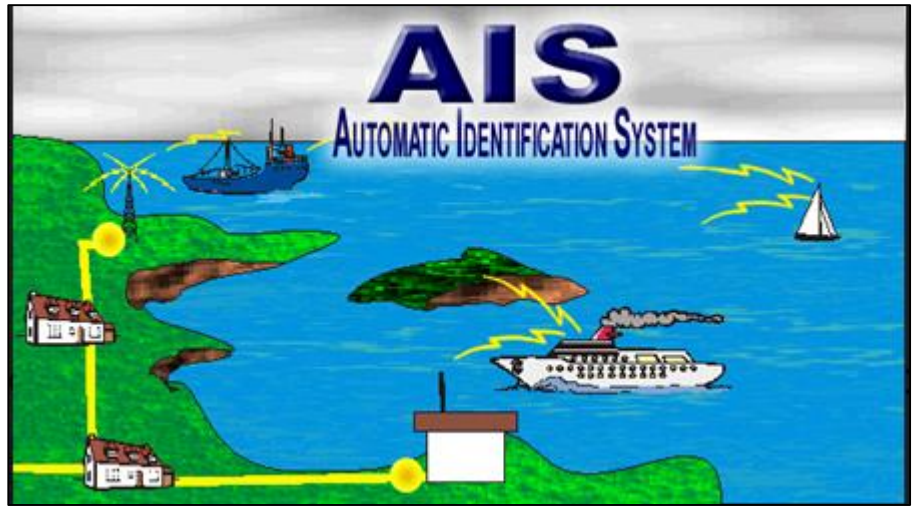
1. General Passing Ship Effects
2. Description of the Modeling System – VHLU
3. Port Canaveral and Passing Cruise Ships
4. Full-Scale Validations at Port Canaveral Harbor using AIS data and pressure sensors
5. Applying VHLU to calculate mooring loads at Port Canaveral
6. Summary

Validating VHLU Model

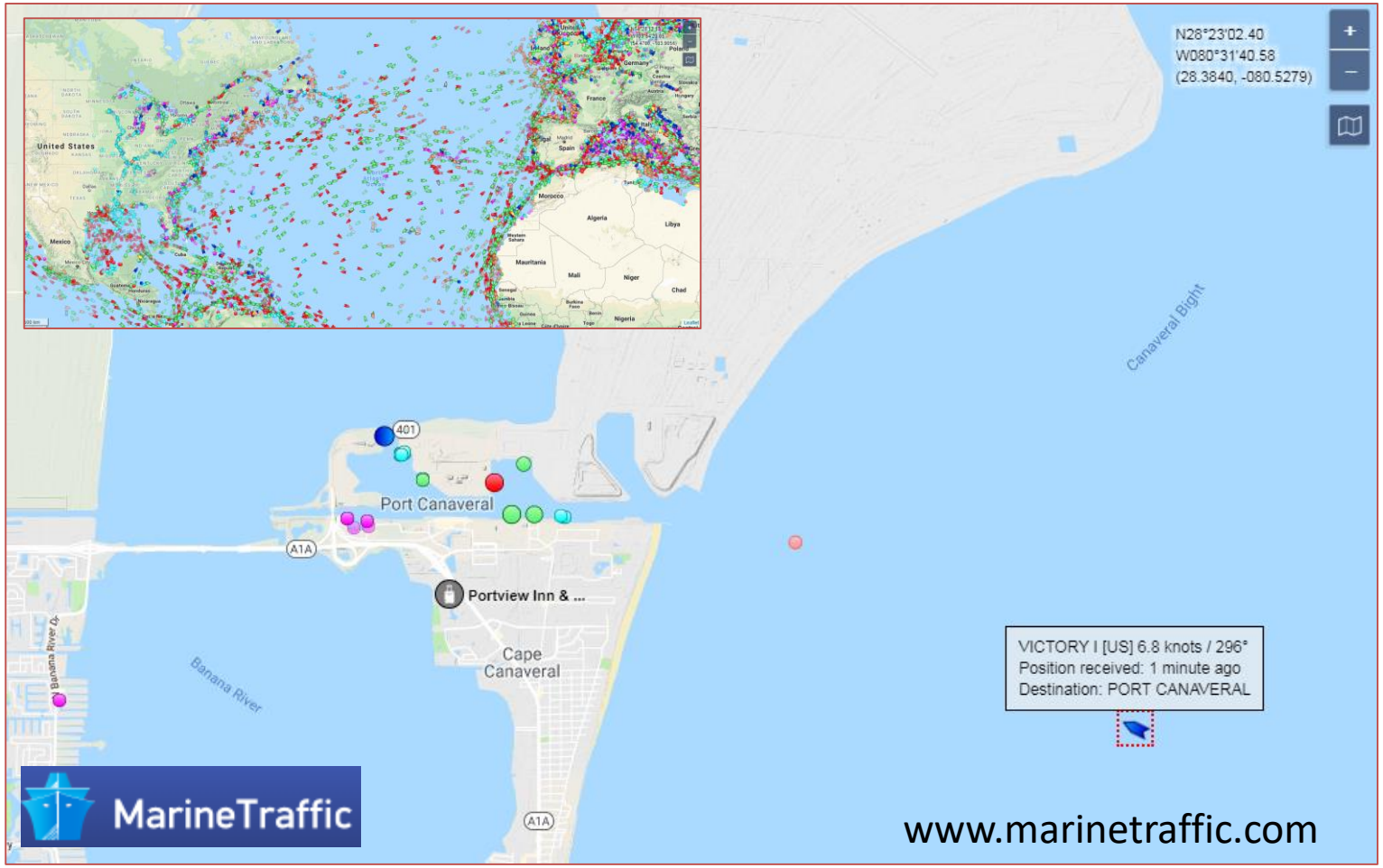
Place Pressure Sensors near Passing Ships

Validating VHLU with Automatic Identification System

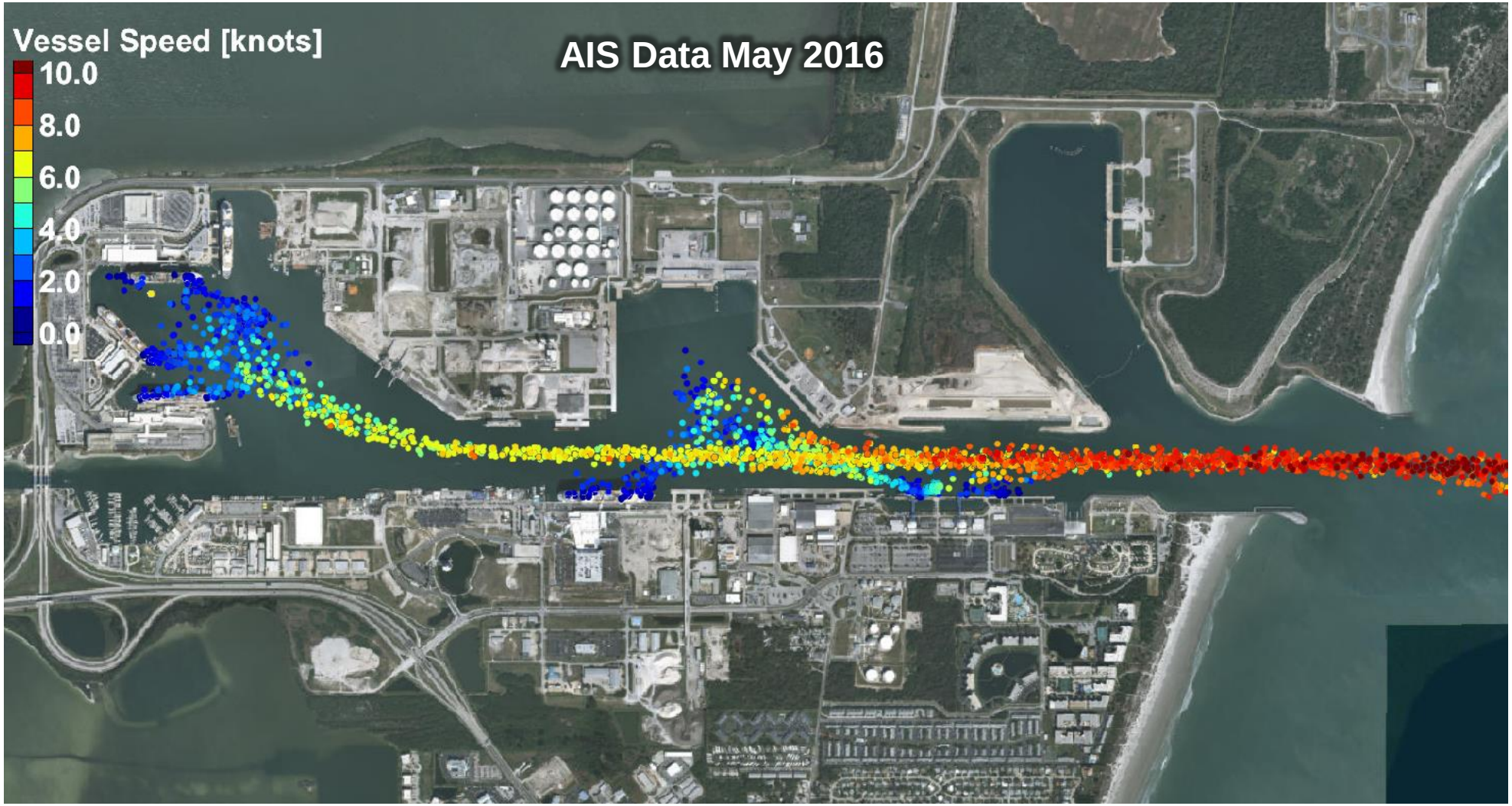
- Vessel position, heading, course over ground, speed over ground particulars, etc.



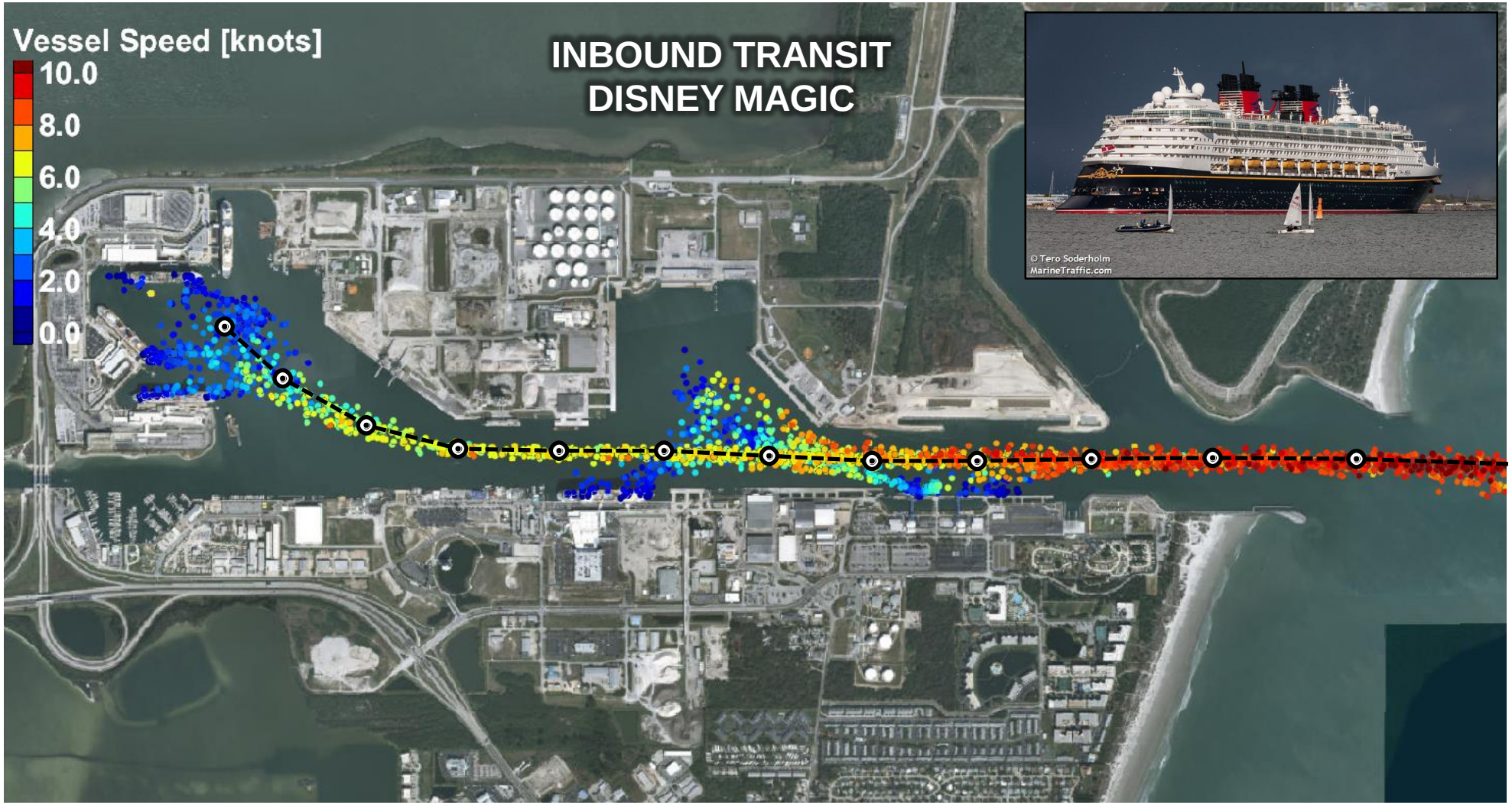
Snapshot at 07/26/2018 07:18 PM UTC



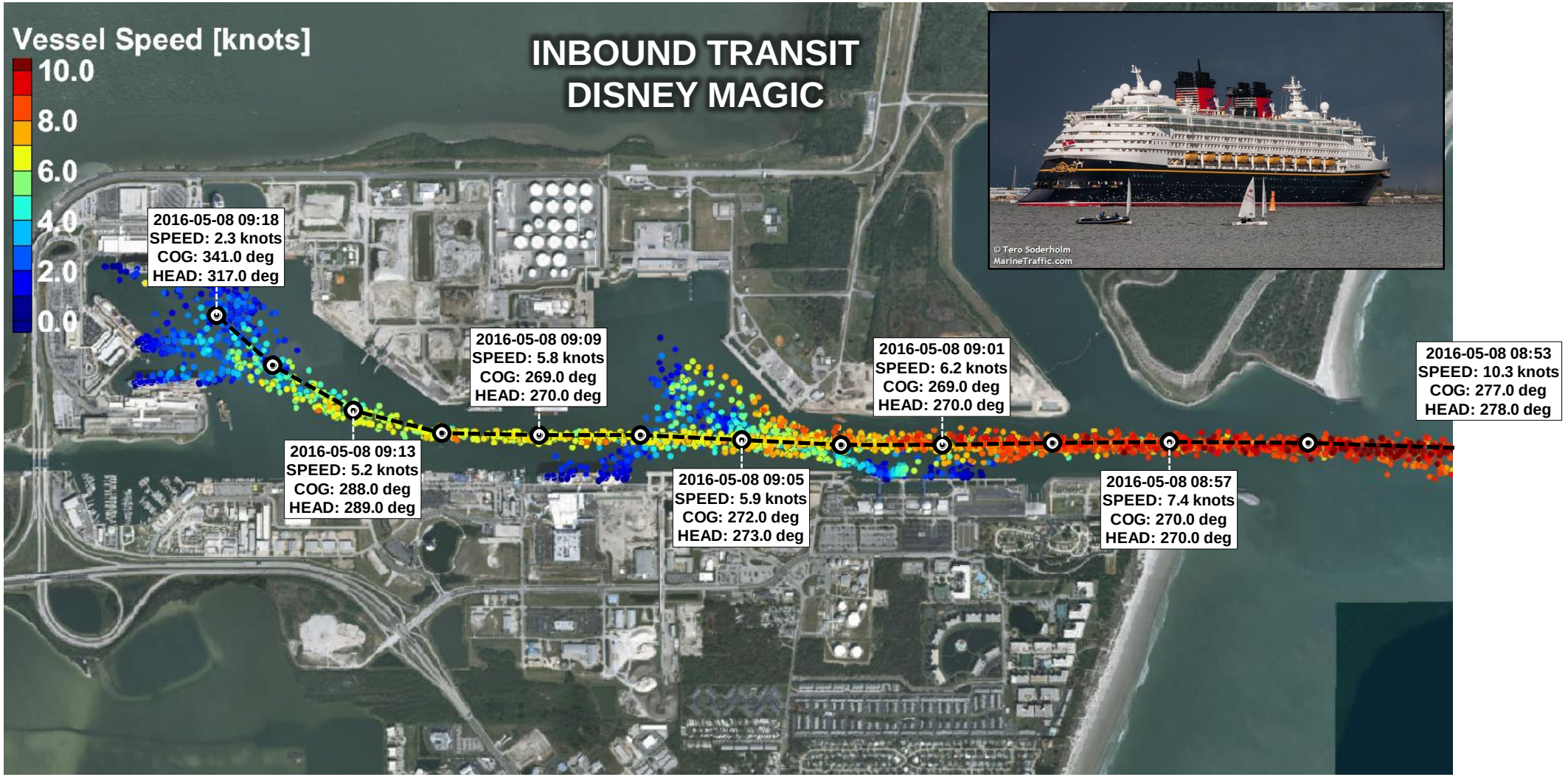
Validating VHLU with Automatic Identification System



Validating VHLU with Automatic Identification System



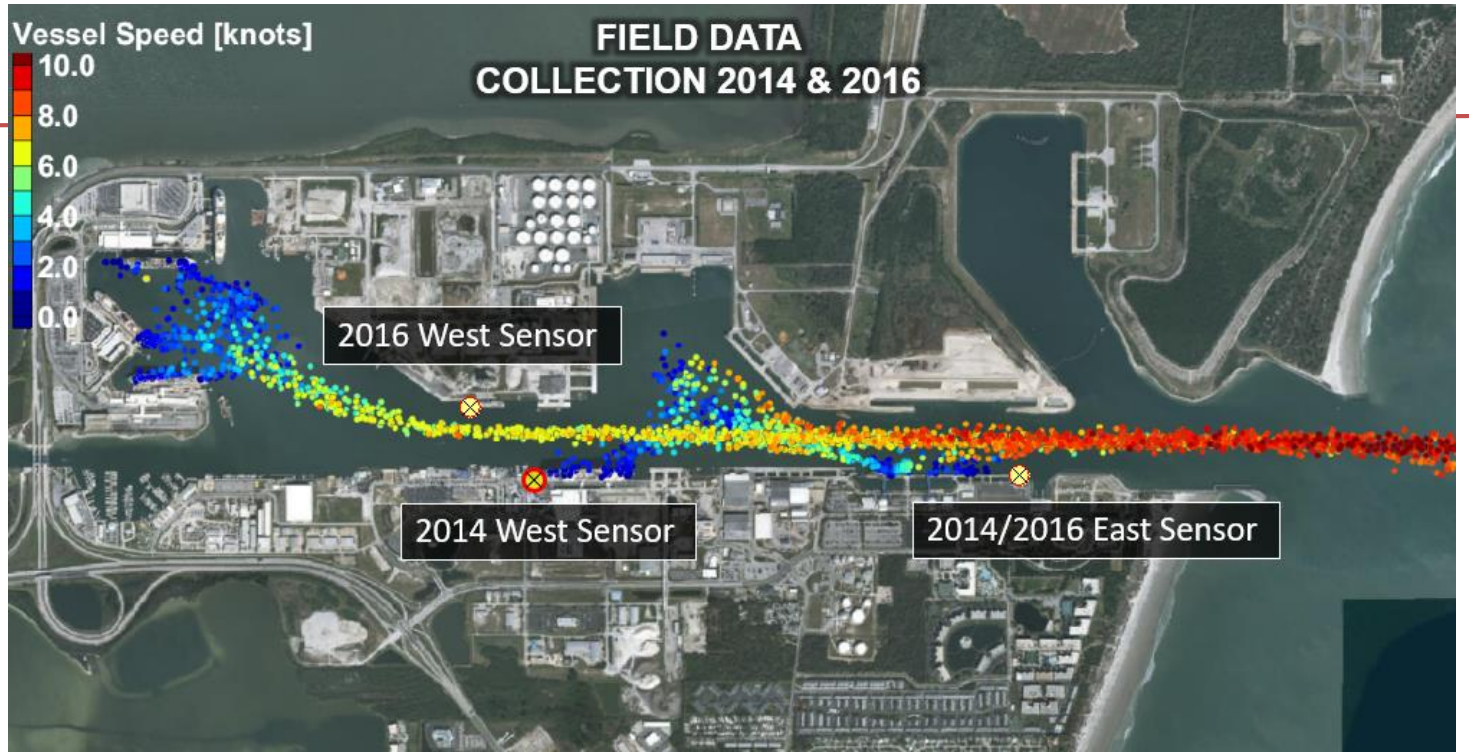
Validating VHLU with Automatic Identification System

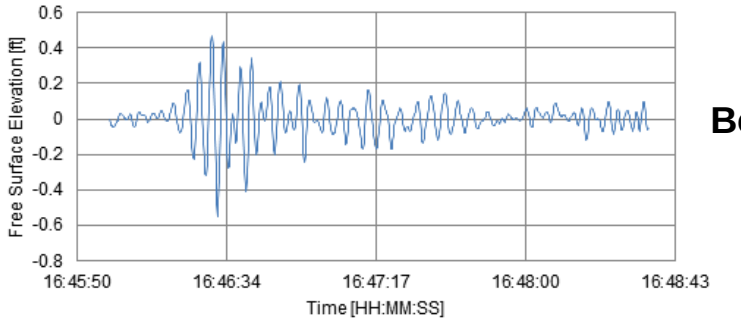




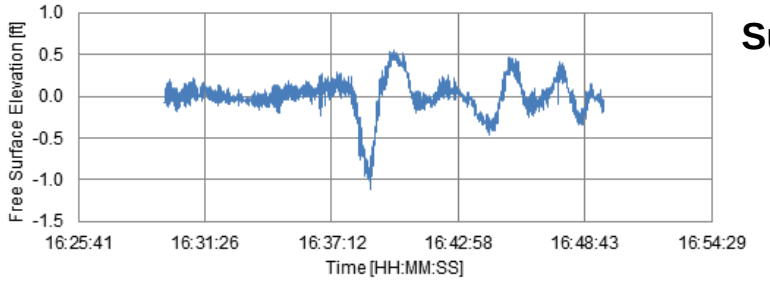

Field Measurements

- Pile-mounted non-directional pressure gages.
- Measured boat wakes, wind-waves/swell, cruise ship surge effects.
- Cruise ship maneuvering data obtained from terrestrial AIS data.





Boat wakes



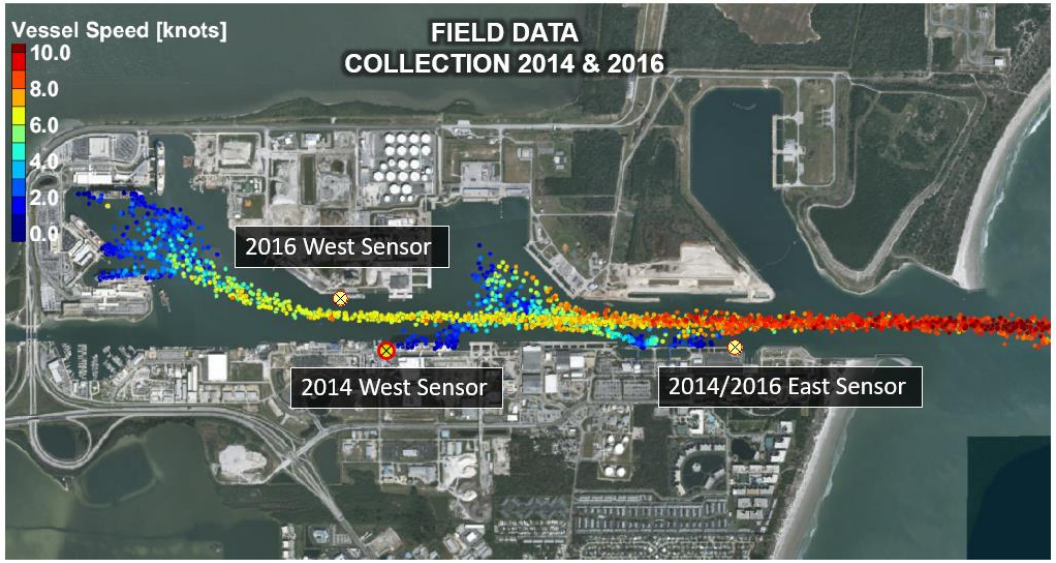
Surge effects

Passing Cruise Ships from AIS Data in May 2014 and May 2016

2014

Ship Name	Transit Direction	Date & Time [EST]
Norwegian Breakaway	outbound	4/29/2014 21:08
Carnival Pride	inbound	4/30/2014 6:09
Carnival Pride/Regatta	outbound	4/30/2014 18:19
Disney Dream	inbound	5/1/2014 5:13
Carnival Sensation	outbound	5/1/2014 16:51
Carnival Sunshine	outbound	5/2/2014 16:26
Disney Fantasy	inbound	5/3/2014 5:09
Disney Dream	inbound	5/5/2014 5:18
Enchantment of the Seas	outbound	5/5/2014 16:41
Norwegian Gem	outbound	5/5/2014 21:43
Disney Dream	inbound	5/8/2014 5:02
Carnival Sensation	outbound	5/8/2014 16:39
Disney Magic	inbound	5/9/2014 5:11
Disney Fantasy	inbound	5/10/2014 5:09
Carnival Sunshine	outbound	5/10/2014 16:29
Disney Magic	inbound	5/12/2014 5:18
Norwegian Gem	inbound	5/12/2014 11:13
Norwegian Gem	outbound	5/12/2014 21:51

Total: 18 passing events



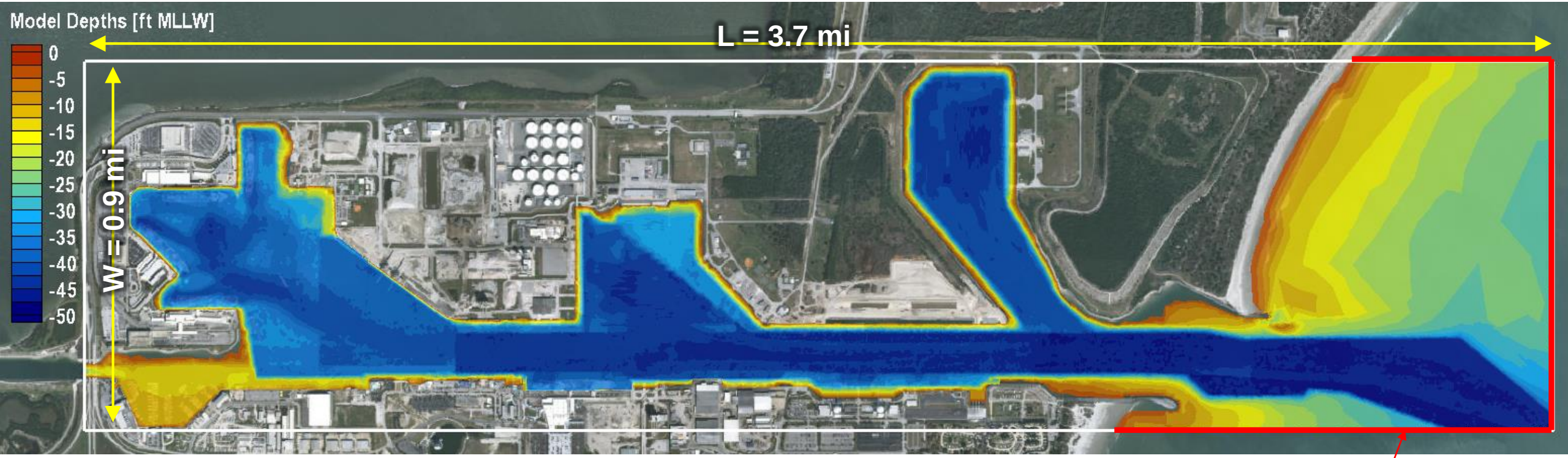
2016

Ship Name	Transit Direction	Date & Time [EST]
Carnival Pride	Outbound	4/22/2016 22:09
Disney Fantasy	Inbound	4/23/2016 9:06
Disney Dream	Inbound	4/29/2016 9:04
Carnival Sunshine	Inbound	4/29/2016 9:52
Disney Dream	Outbound	4/29/2016 20:35
Carnival Sunshine	Outbound	4/29/2016 23:16
Carnival Pride	Inbound	5/4/2016 9:53
Disney Fantasy	Inbound	5/7/2016 9:14
Disney Magic	Inbound	5/8/2016 8:49
Norwegian gem	Outbound	5/10/2016 1:22
Disney Dream	Inbound	5/16/2016 8:59
Norwegian gem	Inbound	5/16/2016 15:45
Disney Dream	Outbound	5/16/2016 20:15

Total: 13 passing events

Model Grid for VHLU

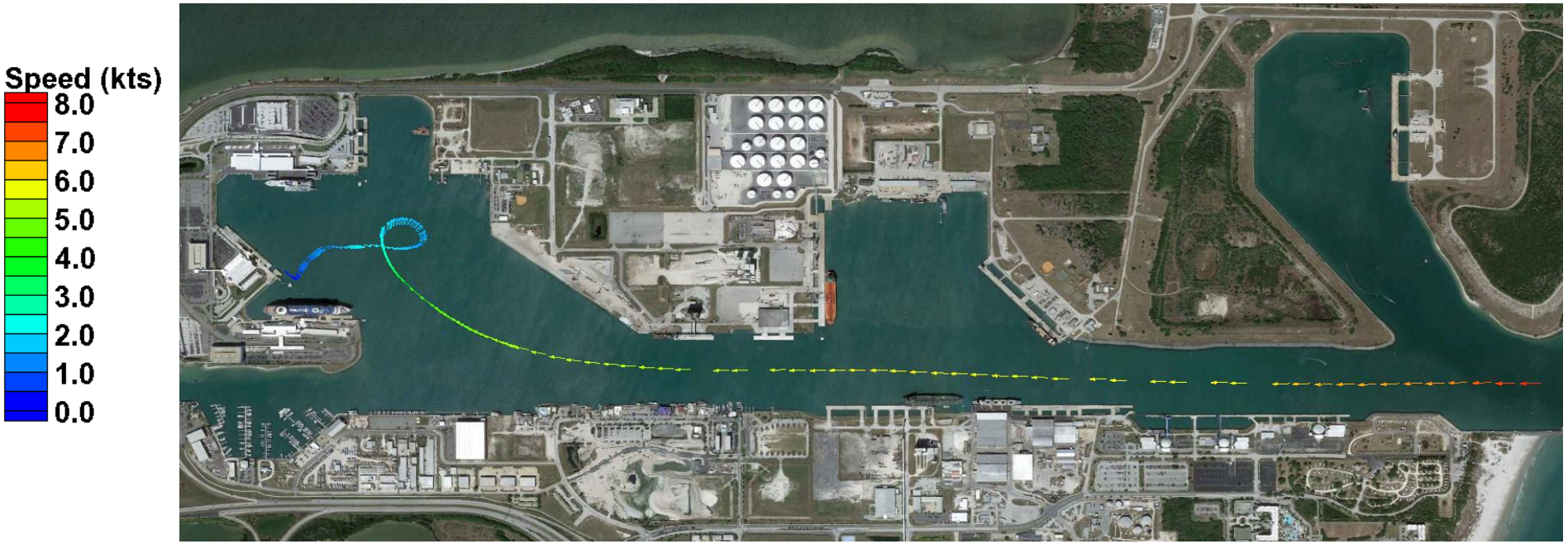
- Computational Rectilinear Grid 2 meter Cells
- Approximately 1.2 million active wet nodes
- Domain Length = 3.7 mi, Domain Width = 0.9 mi



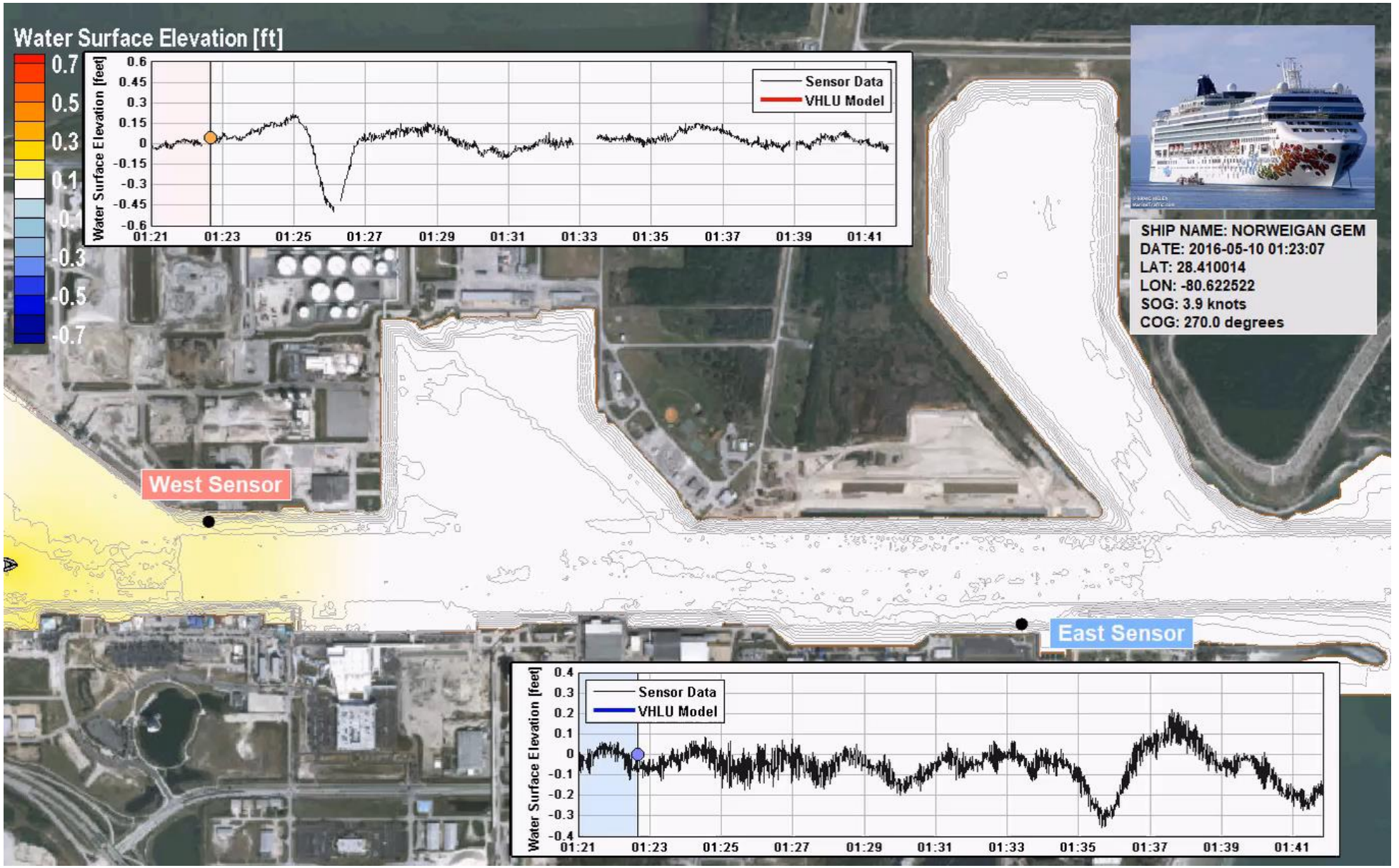
- Saint Venant Equations
- Courant Number = 0.3
- Varying Timestep Magnitude 1e-3 to 1e-4 seconds




Maneuvering extracted from AIS Data



Disney Dream
5/1/2015
05:30 Arrival





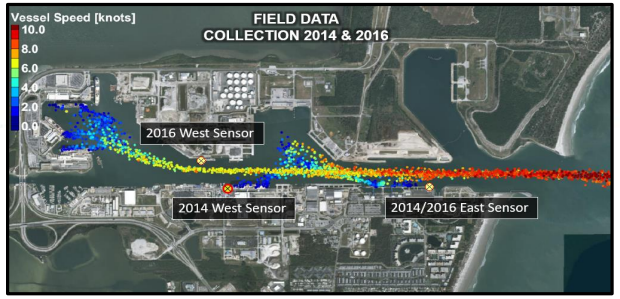

ICCE 2018

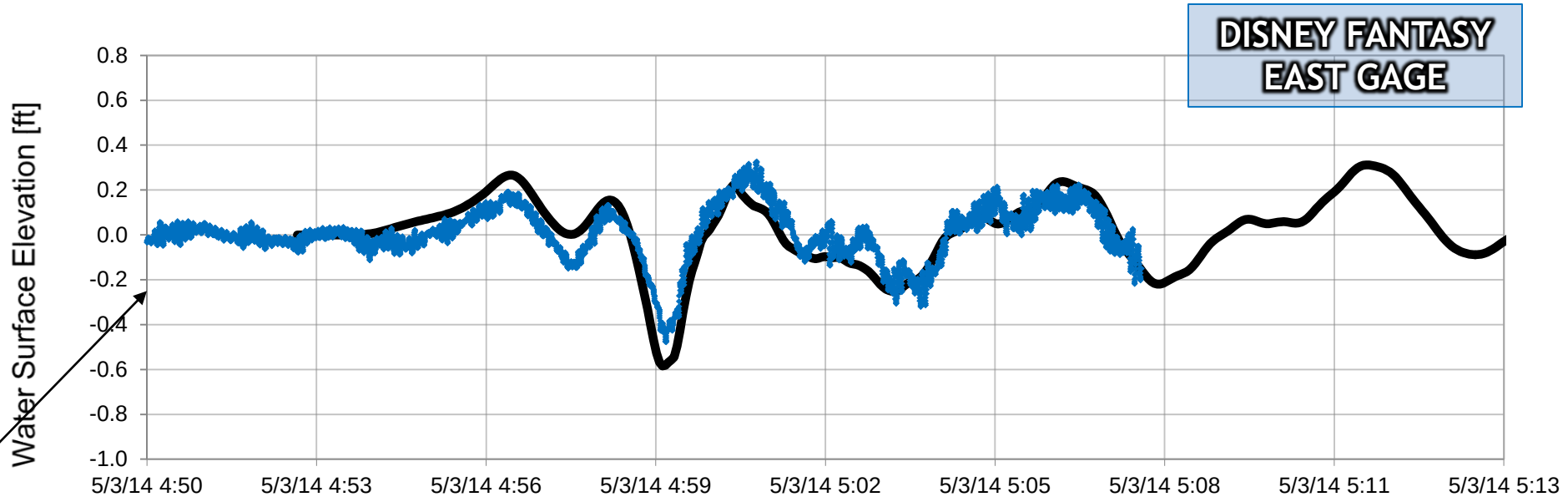
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018

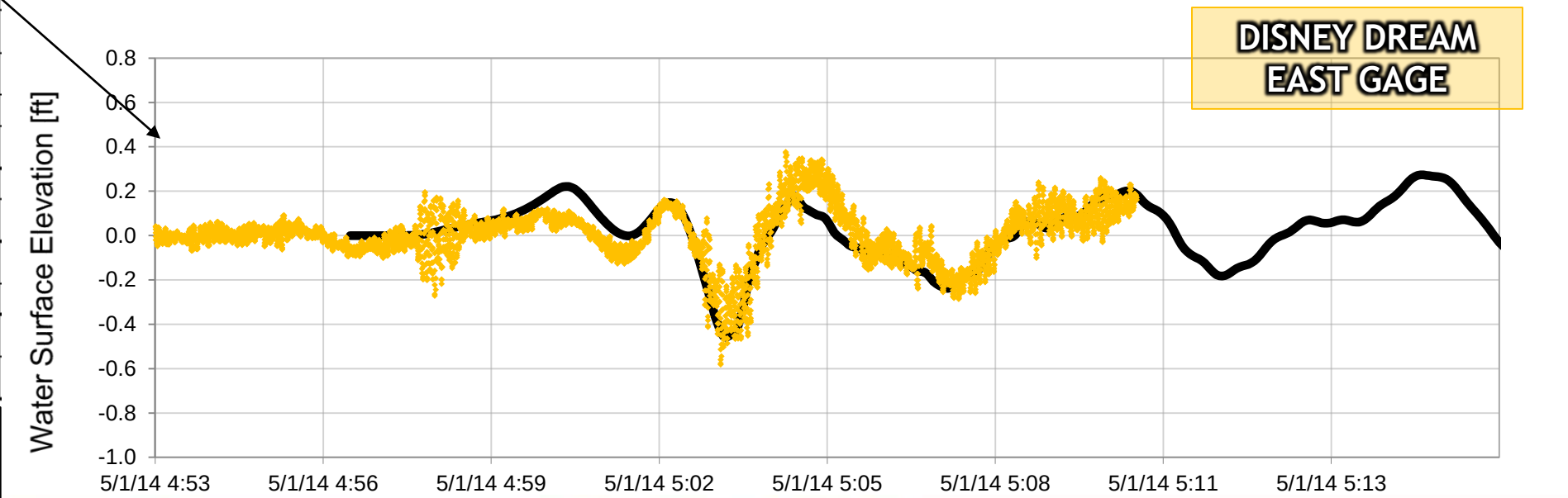
Baltimore, Maryland | July 30 – August 3, 2018

FIELD VALIDATION 2014

Ship Name	Transit Direction	Date & Time [EST]
Norwegian Breakaway	outbound	4/29/2014 21:08
Carnival Pride	inbound	4/30/2014 6:09
Carnival Pride/Regatta	outbound	4/30/2014 18:19
Disney Dream	inbound	5/1/2014 5:13
Carnival Sensation	outbound	5/1/2014 16:51
Carnival Sunshine	outbound	5/2/2014 16:26
Disney Fantasy	inbound	5/3/2014 5:09
Disney Dream	inbound	5/5/2014 5:18
Enchantment of the Seas	outbound	5/5/2014 16:41
Norwegian Gem	outbound	5/5/2014 21:43
Disney Dream	inbound	5/8/2014 5:02
Carnival Sensation	outbound	5/8/2014 16:39
Disney Magic	inbound	5/9/2014 5:11
Disney Fantasy	inbound	5/10/2014 5:09
Carnival Sunshine	outbound	5/10/2014 16:29
Disney Magic	inbound	5/12/2014 5:18
Norwegian Gem	inbound	5/12/2014 11:13
Norwegian Gem	outbound	5/12/2014 21:51

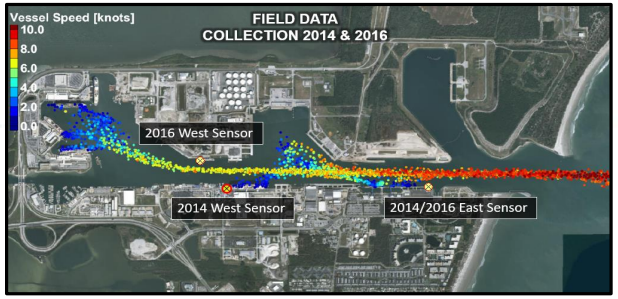




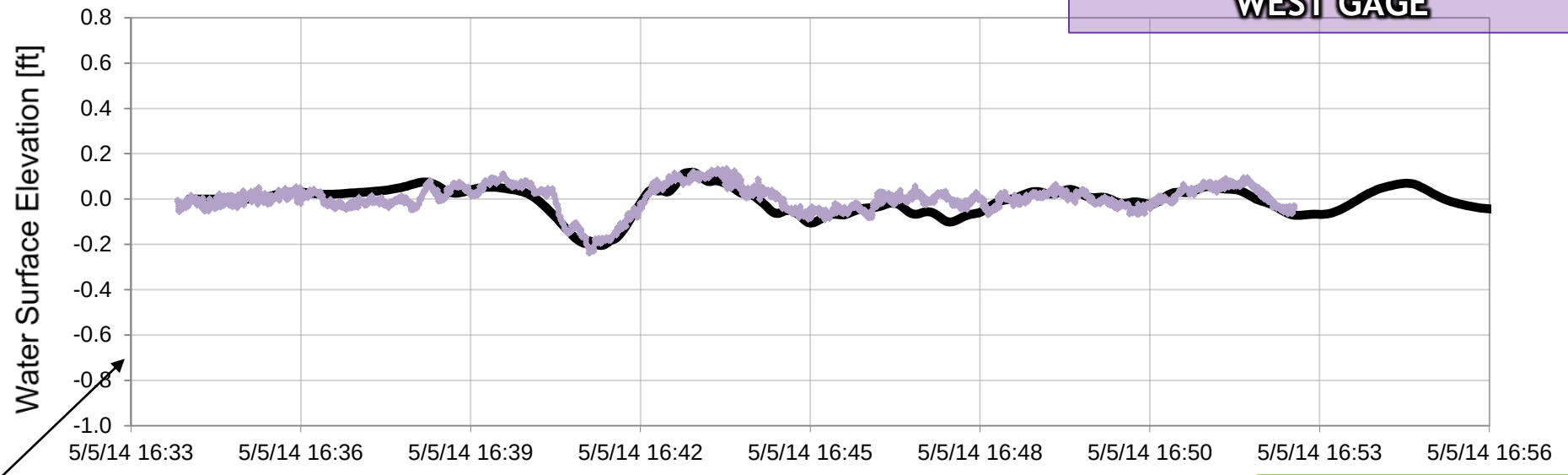


FIELD VALIDATION 2014

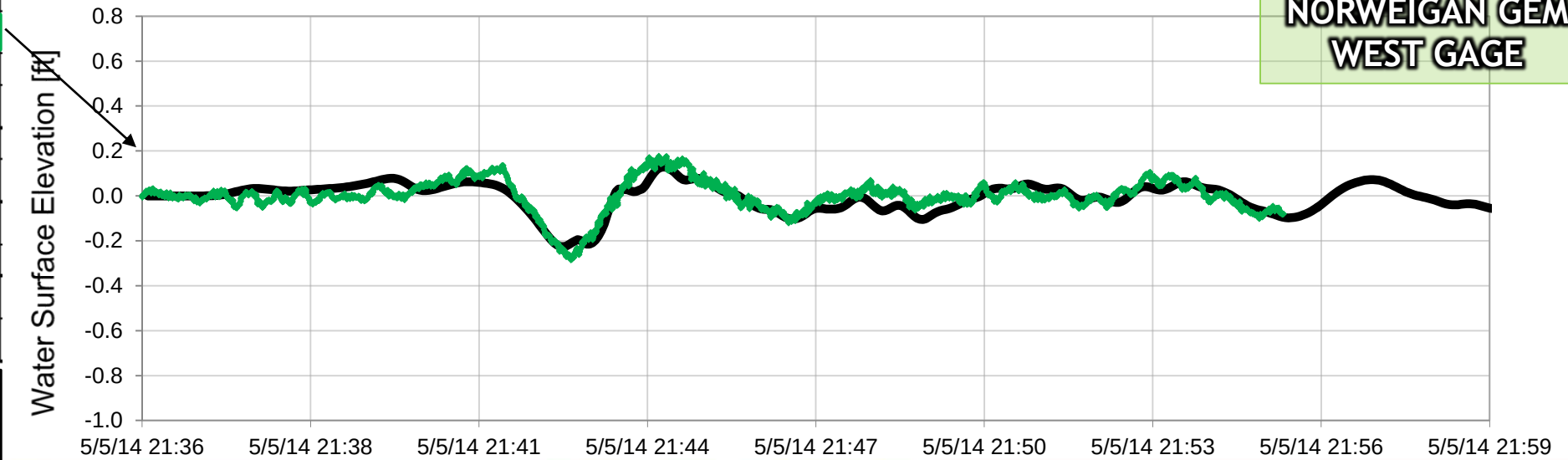
Ship Name	Transit Direction	Date & Time [EST]
Norwegian Breakaway	outbound	4/29/2014 21:08
Carnival Pride	inbound	4/30/2014 6:09
Carnival Pride/Regatta	outbound	4/30/2014 18:19
Disney Dream	inbound	5/1/2014 5:13
Carnival Sensation	outbound	5/1/2014 16:51
Carnival Sunshine	outbound	5/2/2014 16:26
Disney Fantasy	inbound	5/3/2014 5:09
Disney Dream	inbound	5/5/2014 5:18
Enchantment of the Seas	outbound	5/5/2014 16:41
Norwegian Gem	outbound	5/5/2014 21:43
Disney Dream	inbound	5/8/2014 5:02
Carnival Sensation	outbound	5/8/2014 16:39
Disney Magic	inbound	5/9/2014 5:11
Disney Fantasy	inbound	5/10/2014 5:09
Carnival Sunshine	outbound	5/10/2014 16:29
Disney Magic	inbound	5/12/2014 5:18
Norwegian Gem	inbound	5/12/2014 11:13
Norwegian Gem	outbound	5/12/2014 21:51



ENCHANTMENT OF THE SEAS WEST GAGE



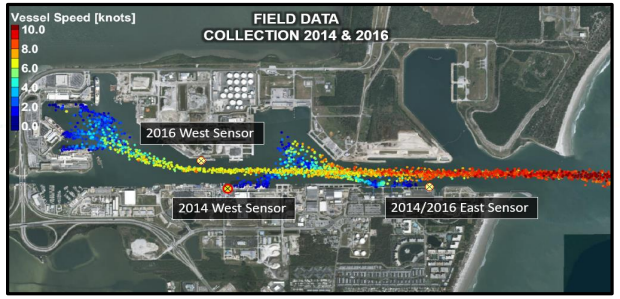
NORWEIGAN GEM WEST GAGE



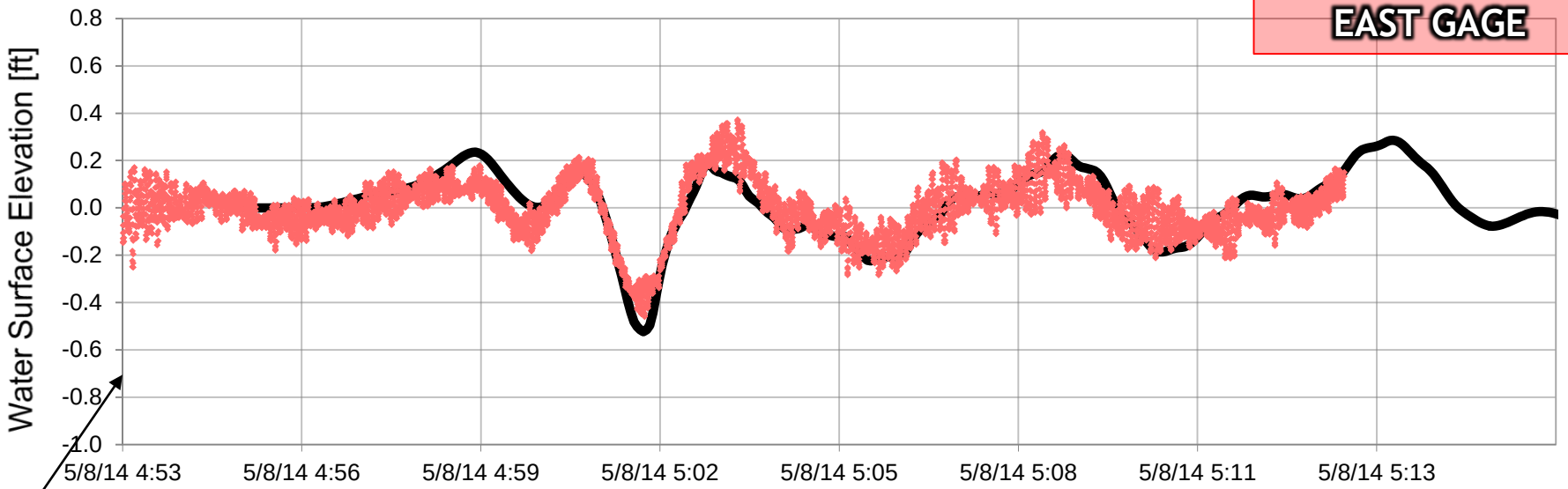
ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018

FIELD VALIDATION 2014

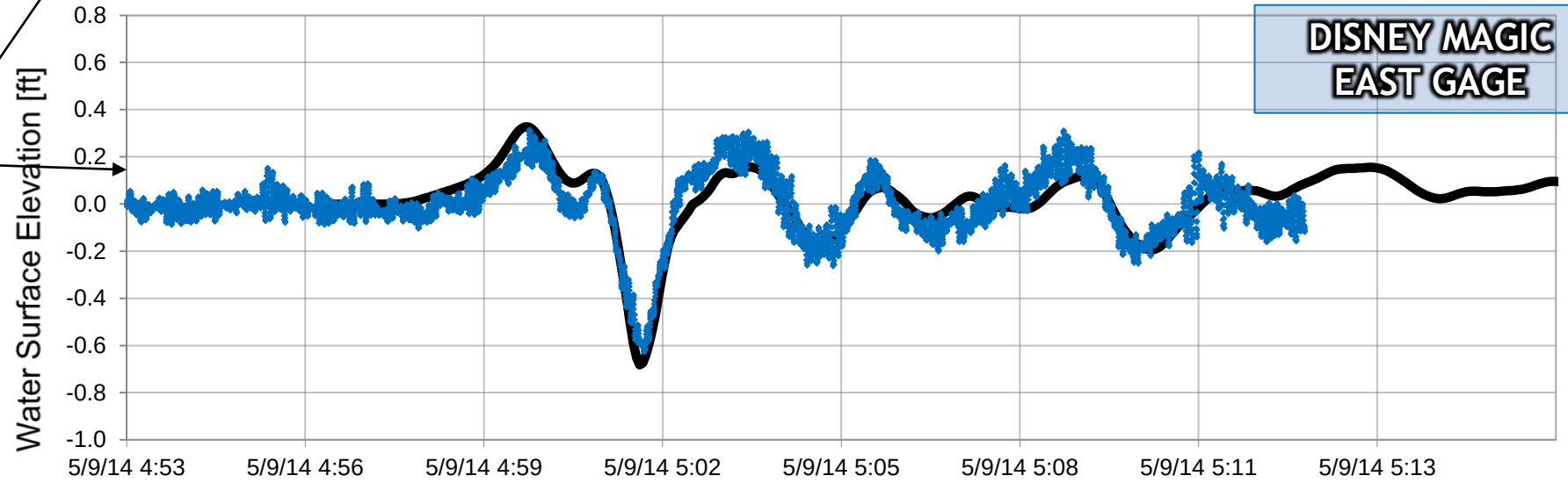
Ship Name	Transit Direction	Date & Time [EST]
Norwegian Breakaway	outbound	4/29/2014 21:08
Carnival Pride	inbound	4/30/2014 6:09
Carnival Pride/Regatta	outbound	4/30/2014 18:19
Disney Dream	inbound	5/1/2014 5:13
Carnival Sensation	outbound	5/1/2014 16:51
Carnival Sunshine	outbound	5/2/2014 16:26
Disney Fantasy	inbound	5/3/2014 5:09
Disney Dream	inbound	5/5/2014 5:18
Enchantment of the Seas	outbound	5/5/2014 16:41
Norwegian Gem	outbound	5/5/2014 21:43
Disney Dream	inbound	5/8/2014 5:02
Carnival Sensation	outbound	5/8/2014 16:39
Disney Magic	inbound	5/9/2014 5:11
Disney Fantasy	inbound	5/10/2014 5:09
Carnival Sunshine	outbound	5/10/2014 16:29
Disney Magic	inbound	5/12/2014 5:18
Norwegian Gem	inbound	5/12/2014 11:13
Norwegian Gem	outbound	5/12/2014 21:51



DISNEY DREAM
EAST GAGE

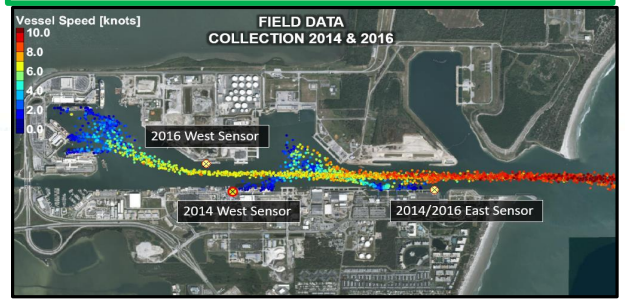


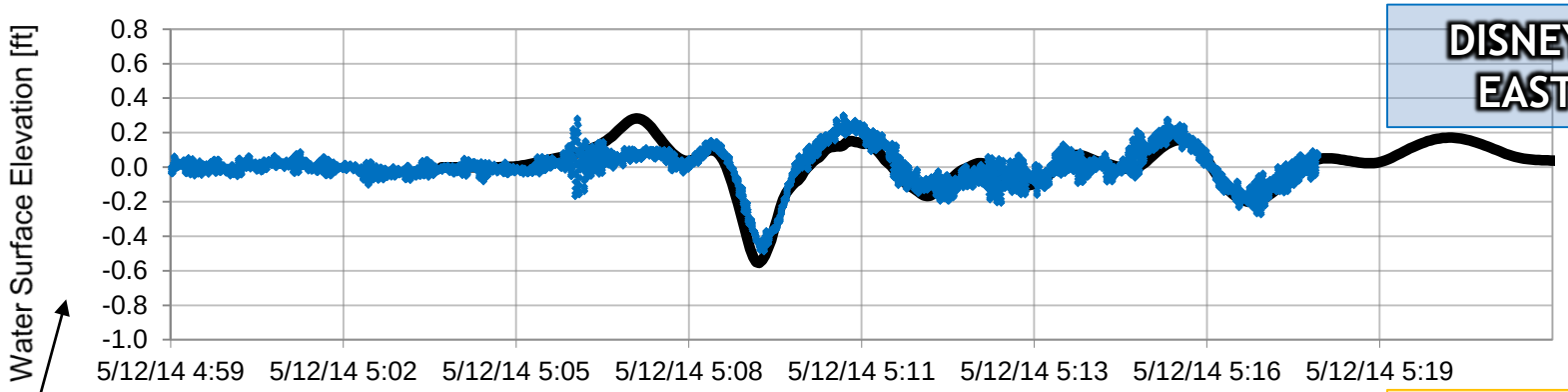
DISNEY MAGIC
EAST GAGE



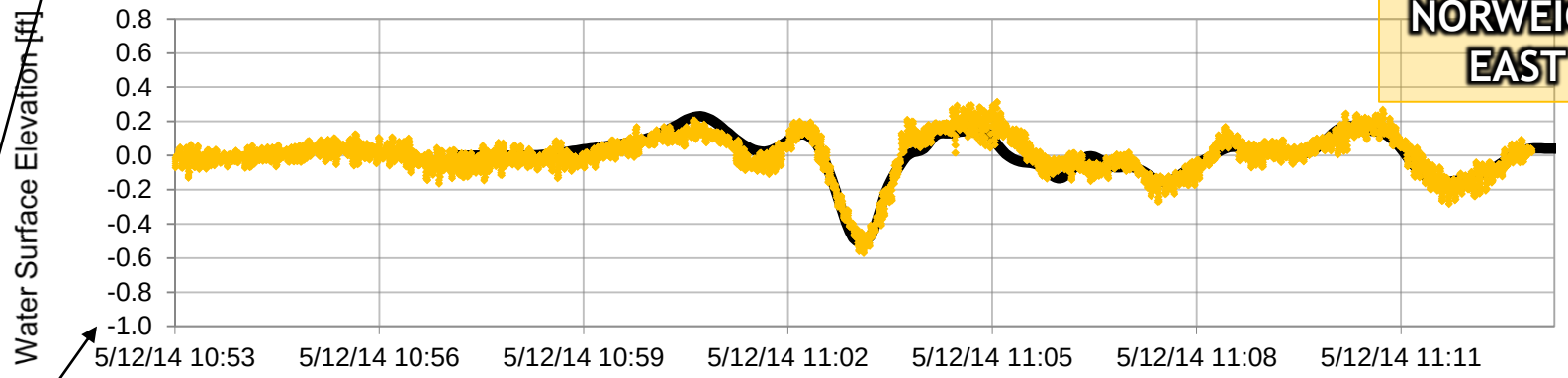
FIELD VALIDATION 2014

Ship Name	Transit Direction	Date & Time [EST]
Norwegian Breakaway	outbound	4/29/2014 21:08
Carnival Pride	inbound	4/30/2014 6:09
Carnival Pride/Regatta	outbound	4/30/2014 18:19
Disney Dream	inbound	5/1/2014 5:13
Carnival Sensation	outbound	5/1/2014 16:51
Carnival Sunshine	outbound	5/2/2014 16:26
Disney Fantasy	inbound	5/3/2014 5:09
Disney Dream	inbound	5/5/2014 5:18
Enchantment of the Seas	outbound	5/5/2014 16:41
Norwegian Gem	outbound	5/5/2014 21:43
Disney Dream	inbound	5/8/2014 5:02
Carnival Sensation	outbound	5/8/2014 16:39
Disney Magic	inbound	5/9/2014 5:11
Disney Fantasy	inbound	5/10/2014 5:09
Carnival Sunshine	outbound	5/10/2014 16:29
Disney Magic	inbound	5/12/2014 5:18
Norwegian Gem	inbound	5/12/2014 11:13
Norwegian Gem	outbound	5/12/2014 21:51

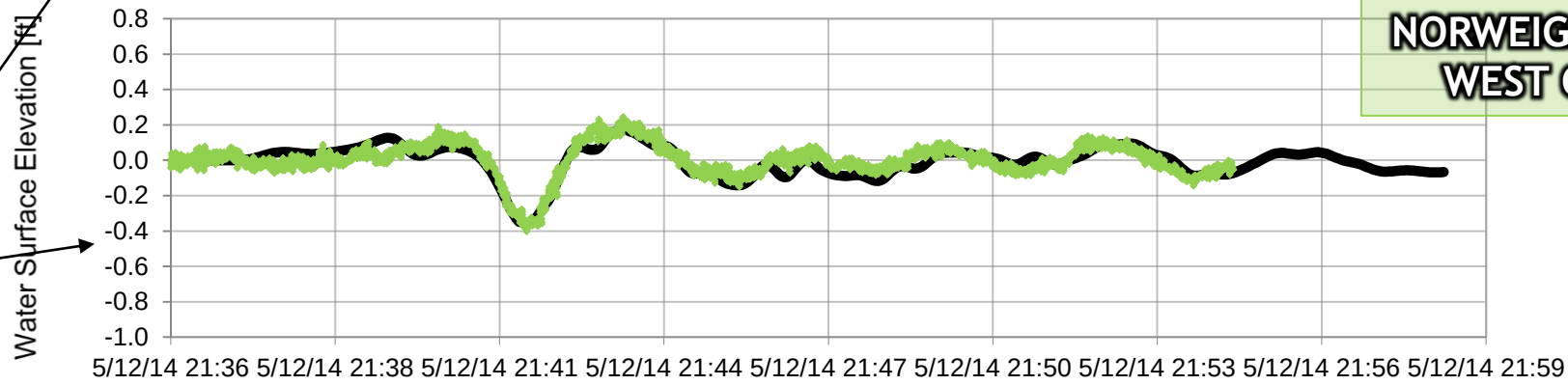




DISNEY MAGIC EAST GAGE



NORWEIGAN GEM EAST GAGE

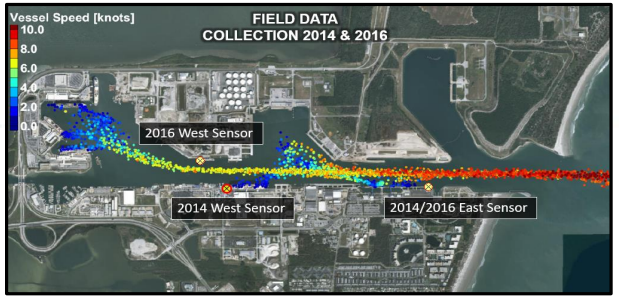


NORWEIGAN GEM WEST GAGE

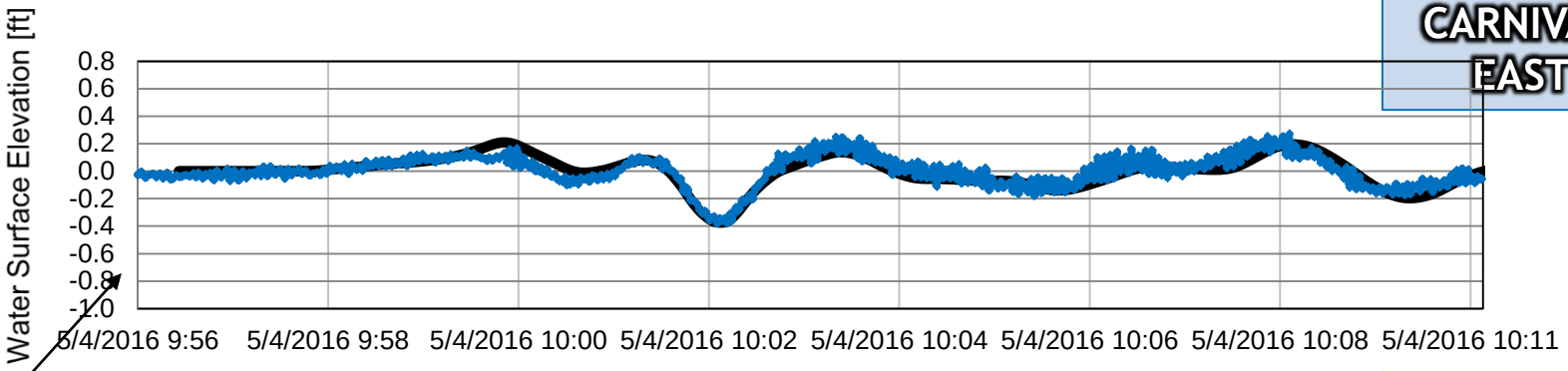
ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018

FIELD VALIDATION 2016

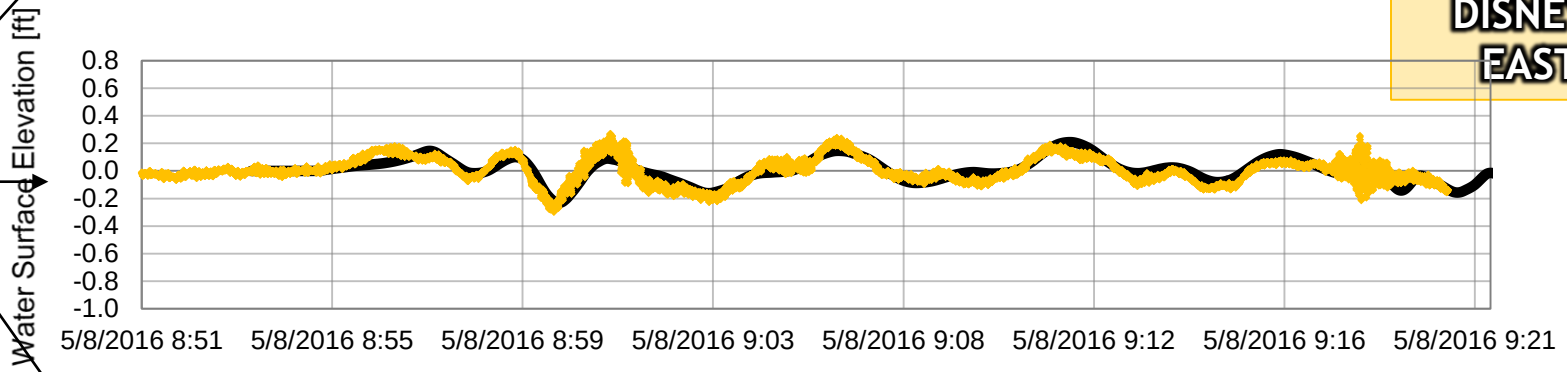
Ship Name	Transit Direction	Date & Time [UTC]
Carnival Pride	Outbound	4/22/2016 22:09
Disney Fantasy	Inbound	4/23/2016 9:06
Disney Dream	Inbound	4/29/2016 9:04
Carnival Sunshine	Inbound	4/29/2016 9:52
Disney Dream	Outbound	4/29/2016 20:35
Carnival Sunshine	Outbound	4/29/2016 23:16
Carnival Pride	Inbound	5/4/2016 9:53
Disney Fantasy	Inbound	5/7/2016 9:14
Disney Magic	Inbound	5/8/2016 8:49
Norwegian gem	Outbound	5/10/2016 1:22
Disney Dream	Inbound	5/16/2016 8:59
Norwegian gem	Inbound	5/16/2016 15:45
Disney Dream	Outbound	5/16/2016 20:15



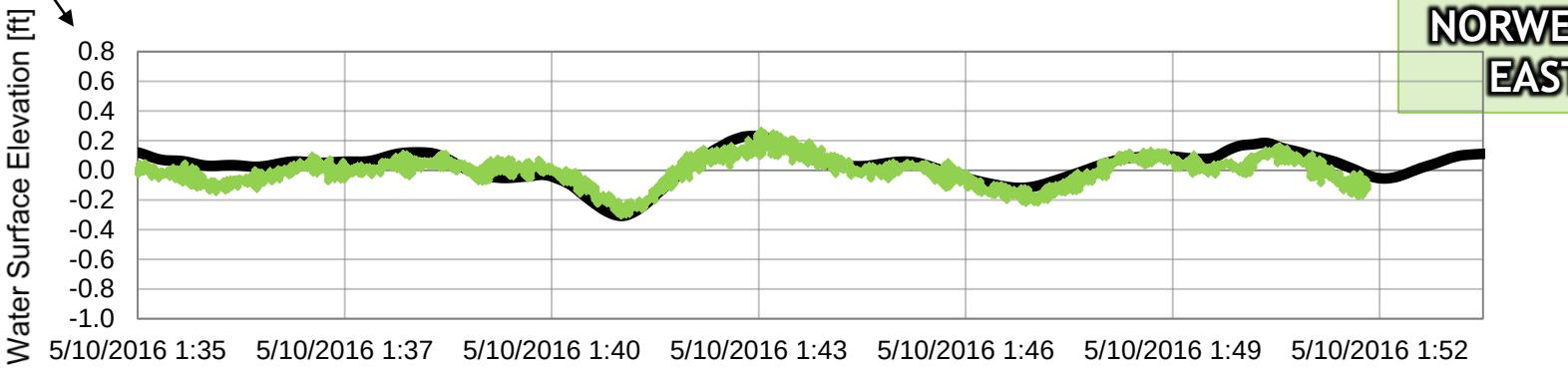
CARNIVAL PRIDE EAST GAGE



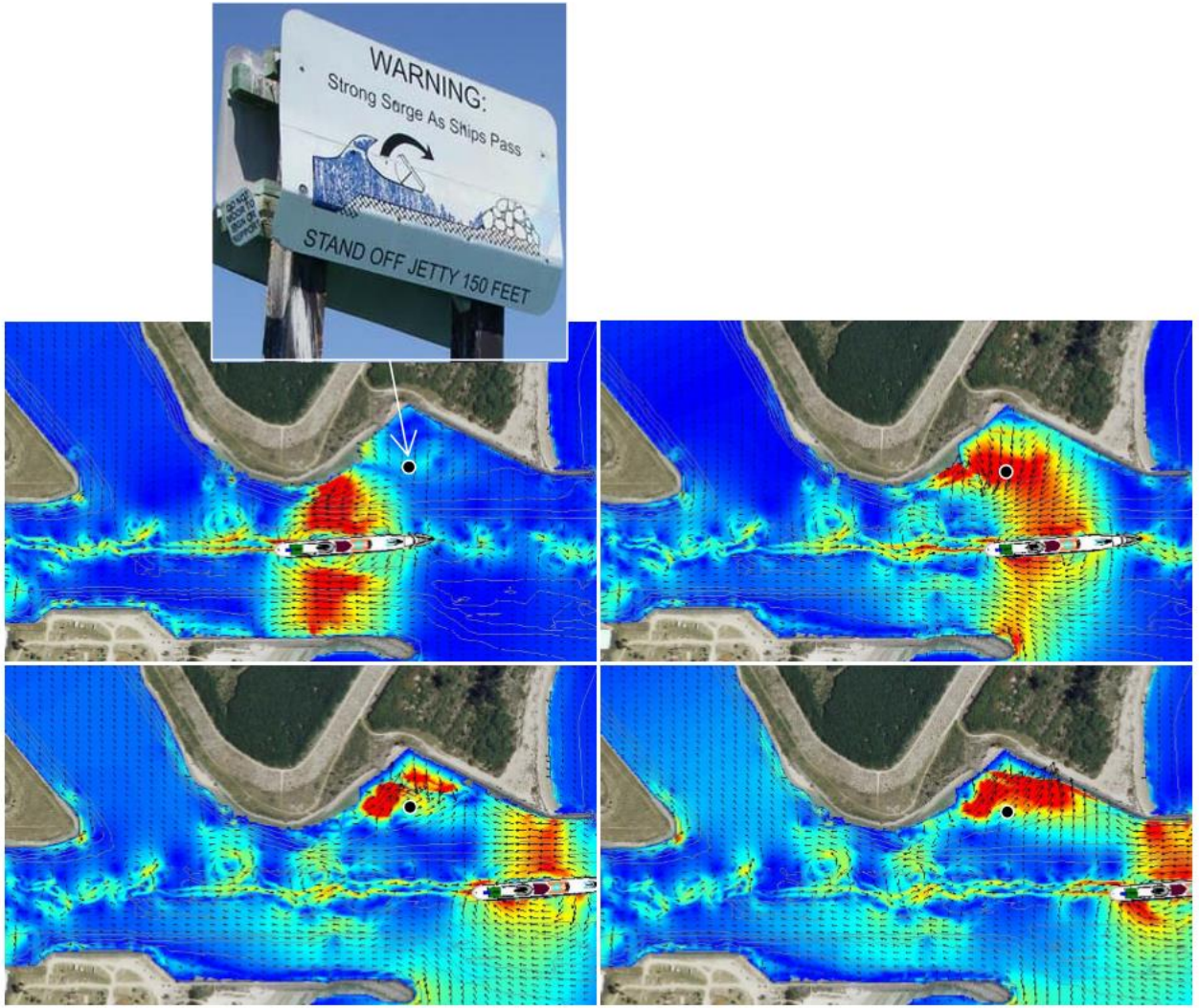
DISNEY MAGIC EAST GAGE



NORWEIGAN GEM EAST GAGE



Validating VHLU with Automatic Identification System



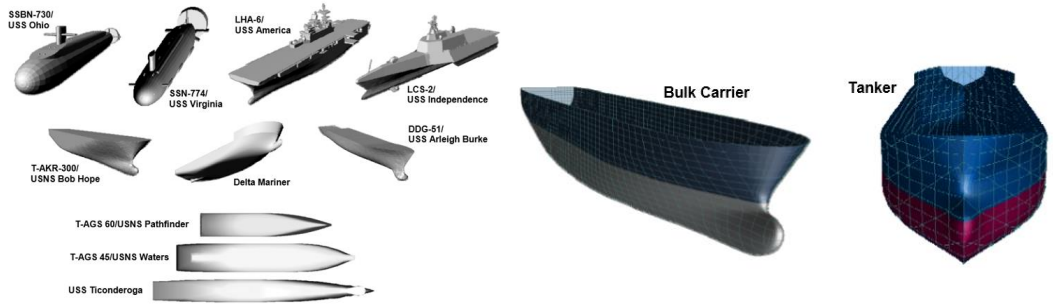


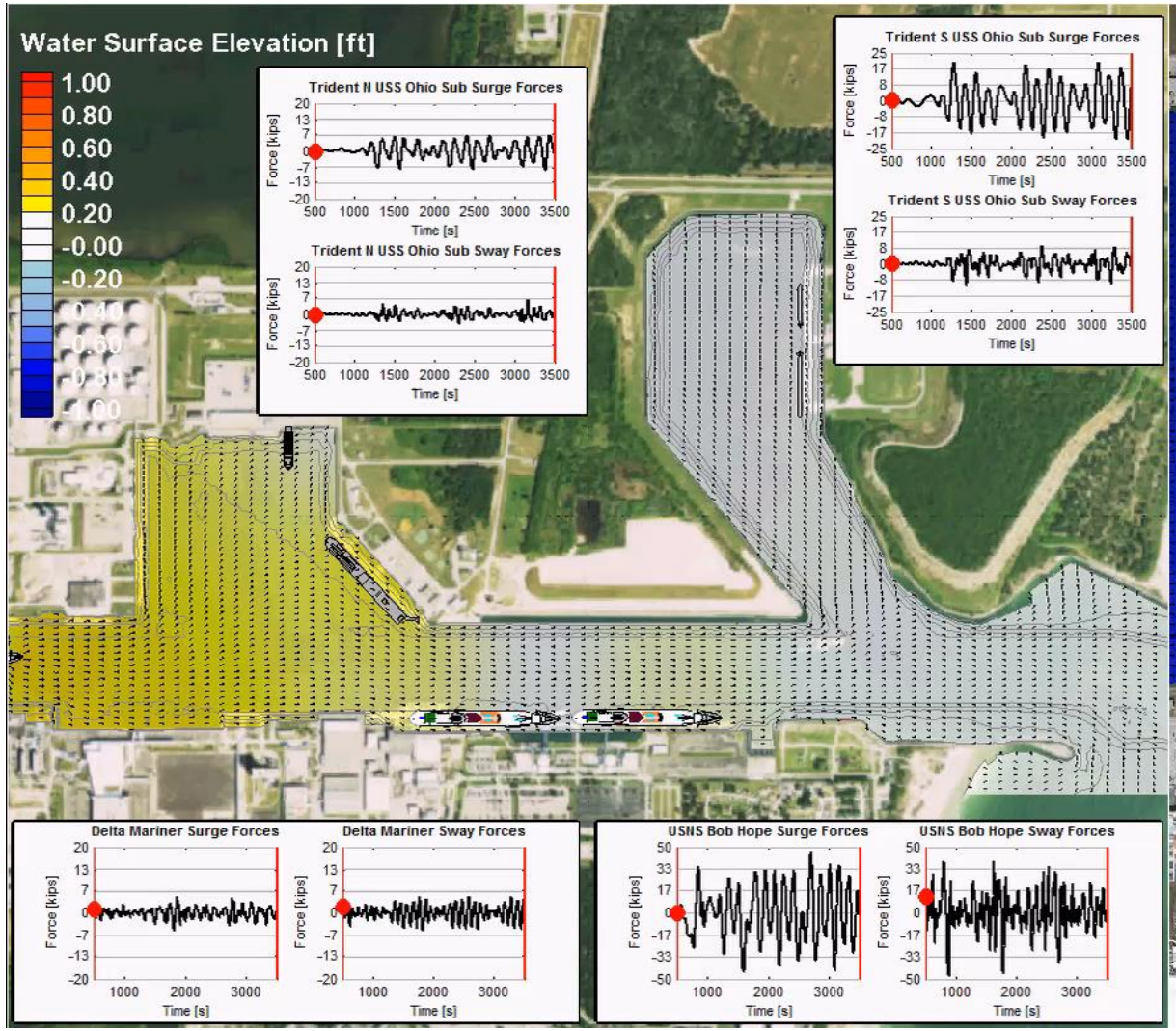

Presentation Outline

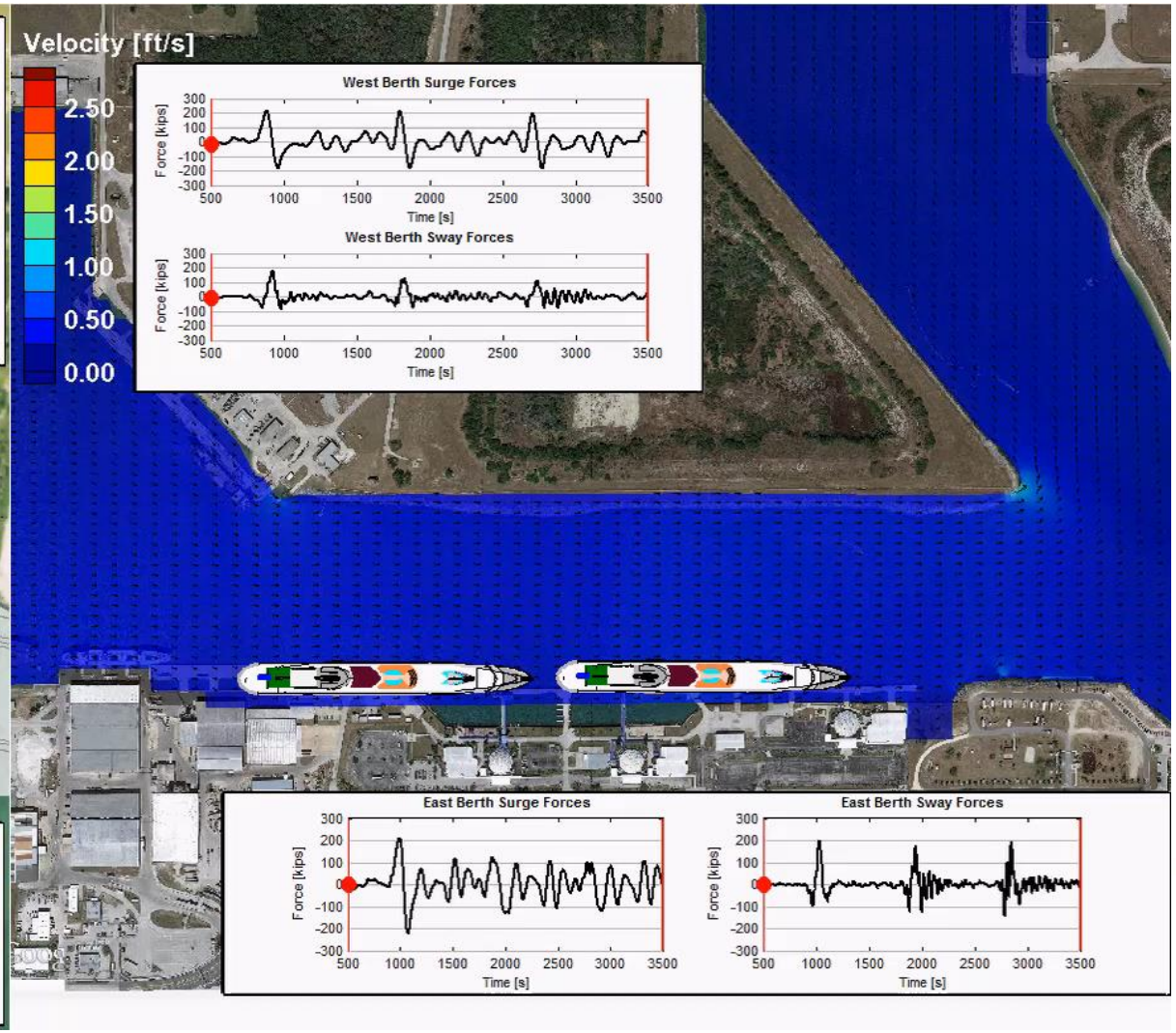
1. General Passing Ship Effects
2. Description of the Modeling System – VHLU
3. Port Canaveral and Passing Cruise Ships
4. Full-Scale Validations at Port Canaveral Harbor using AIS data and pressure sensors
5. Applying VHLU to calculate mooring loads at Port Canaveral
6. Summary

Applications of the Surge Model

Surge/Sway Loads calculated using pressure forces normal to ship hull and integrated throughout entire ship surface

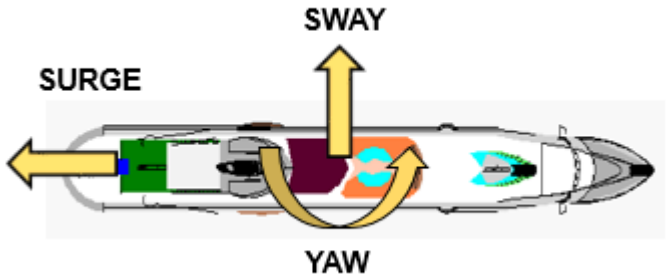


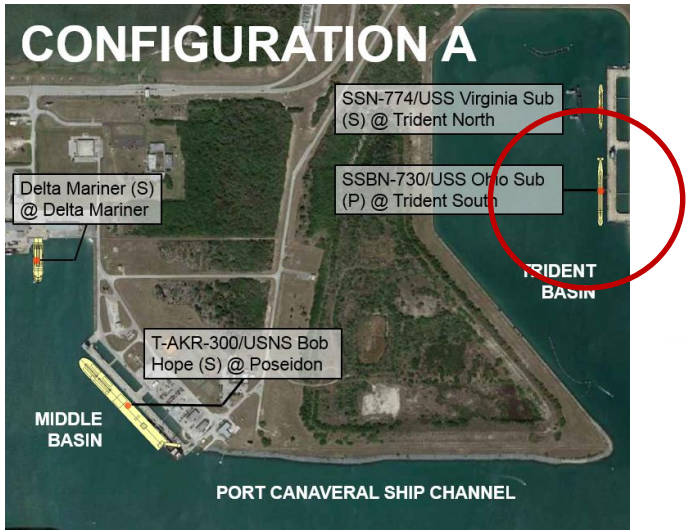


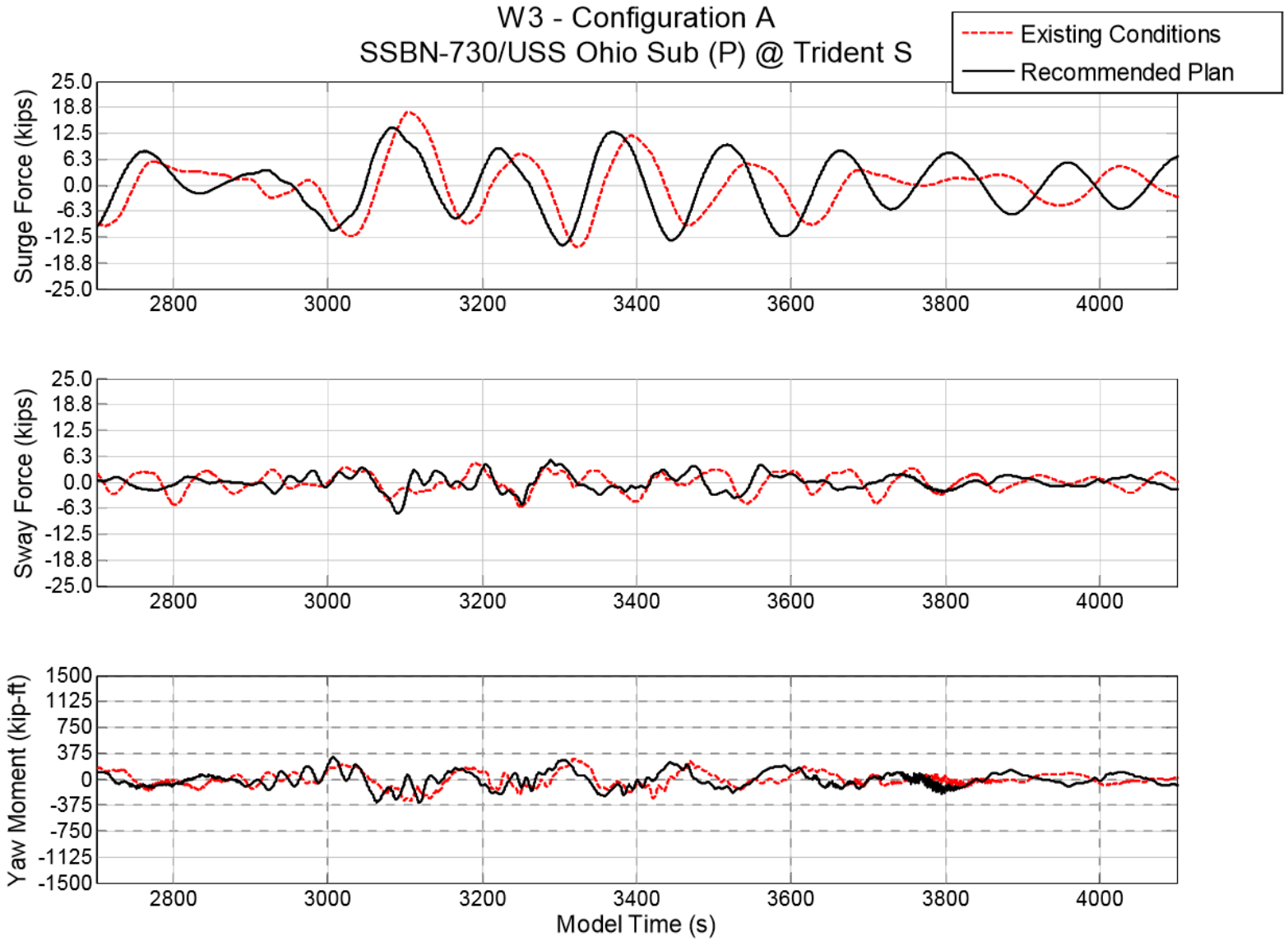


Load Comparison

SSBN-730
USS Ohio Sub (P)
@ Trident South
W3 Passing Configuration
A Berth/Vessel Configuration

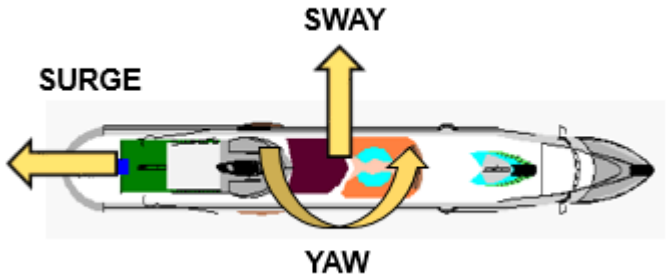


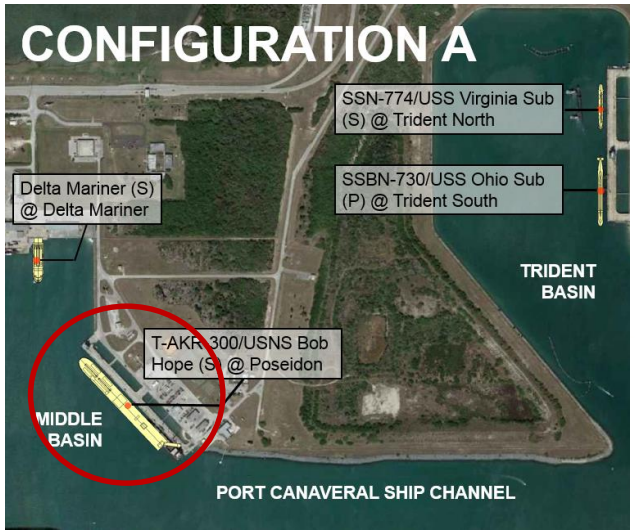


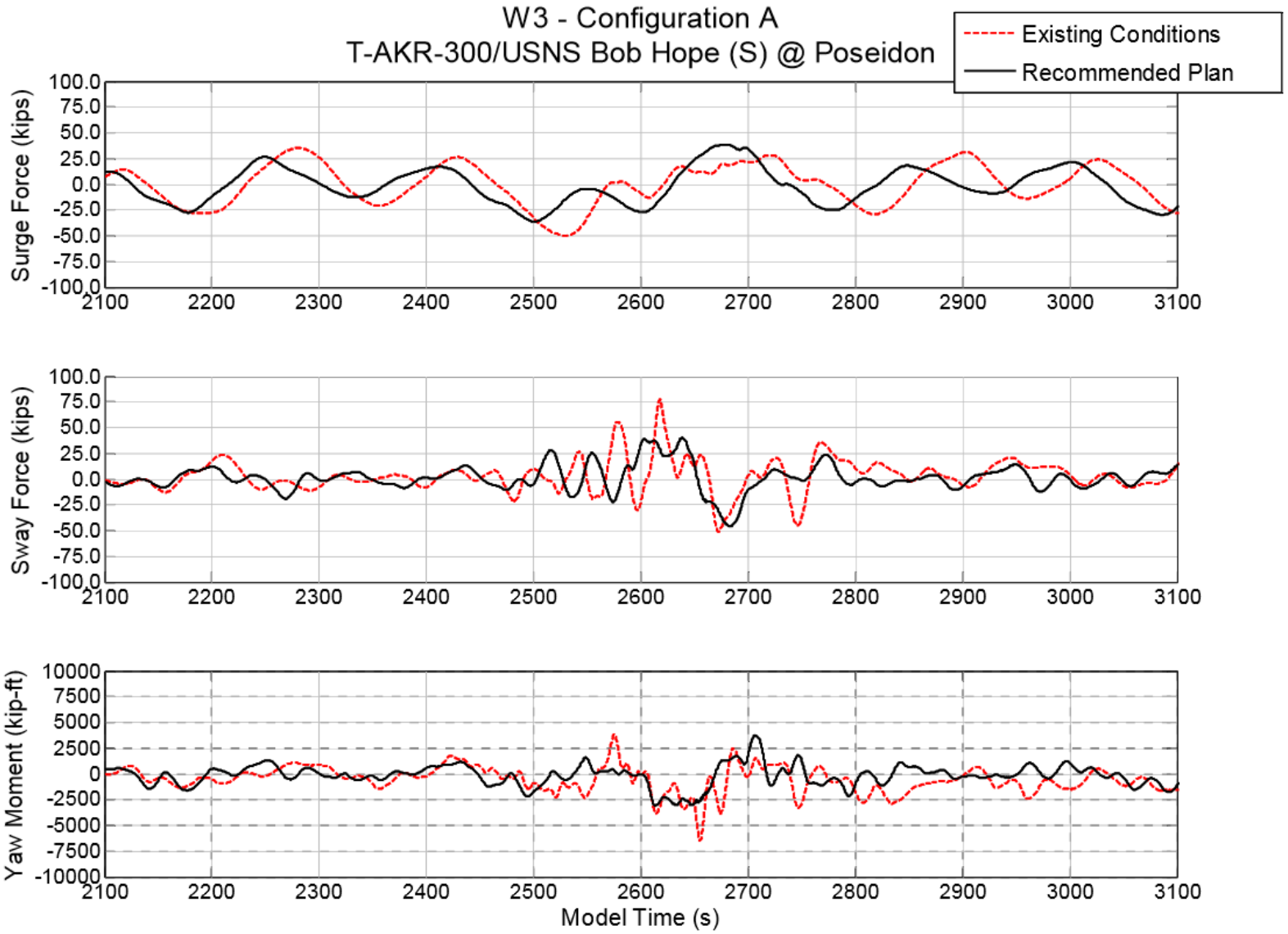


Load Comparison

T-AKR-300
USNS Bob Hope (S)
@ Poseidon
W3 Passing Configuration
A Berth/Vessel Configuration

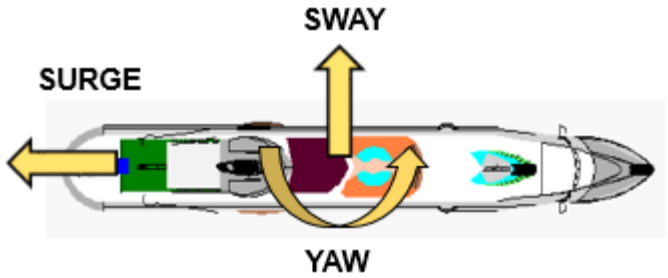


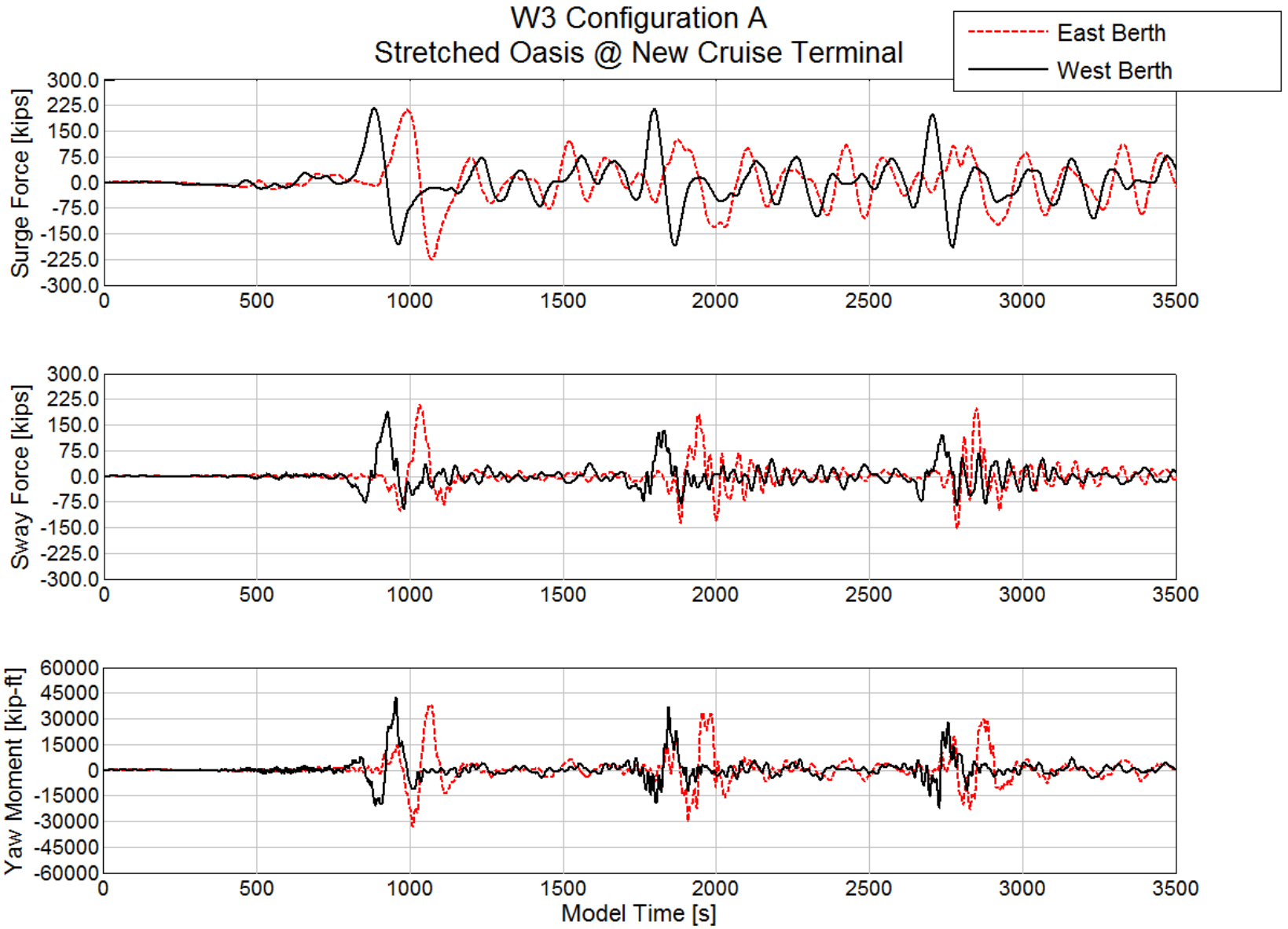




Load Comparison

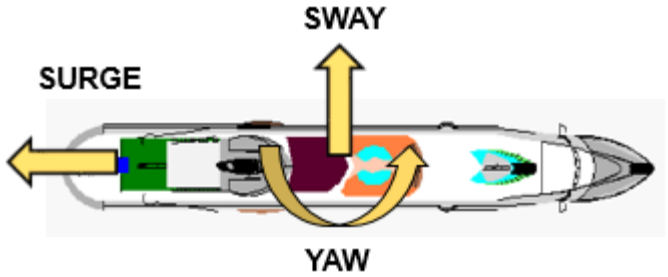
West Berth vs East Berth
W3 Configuration

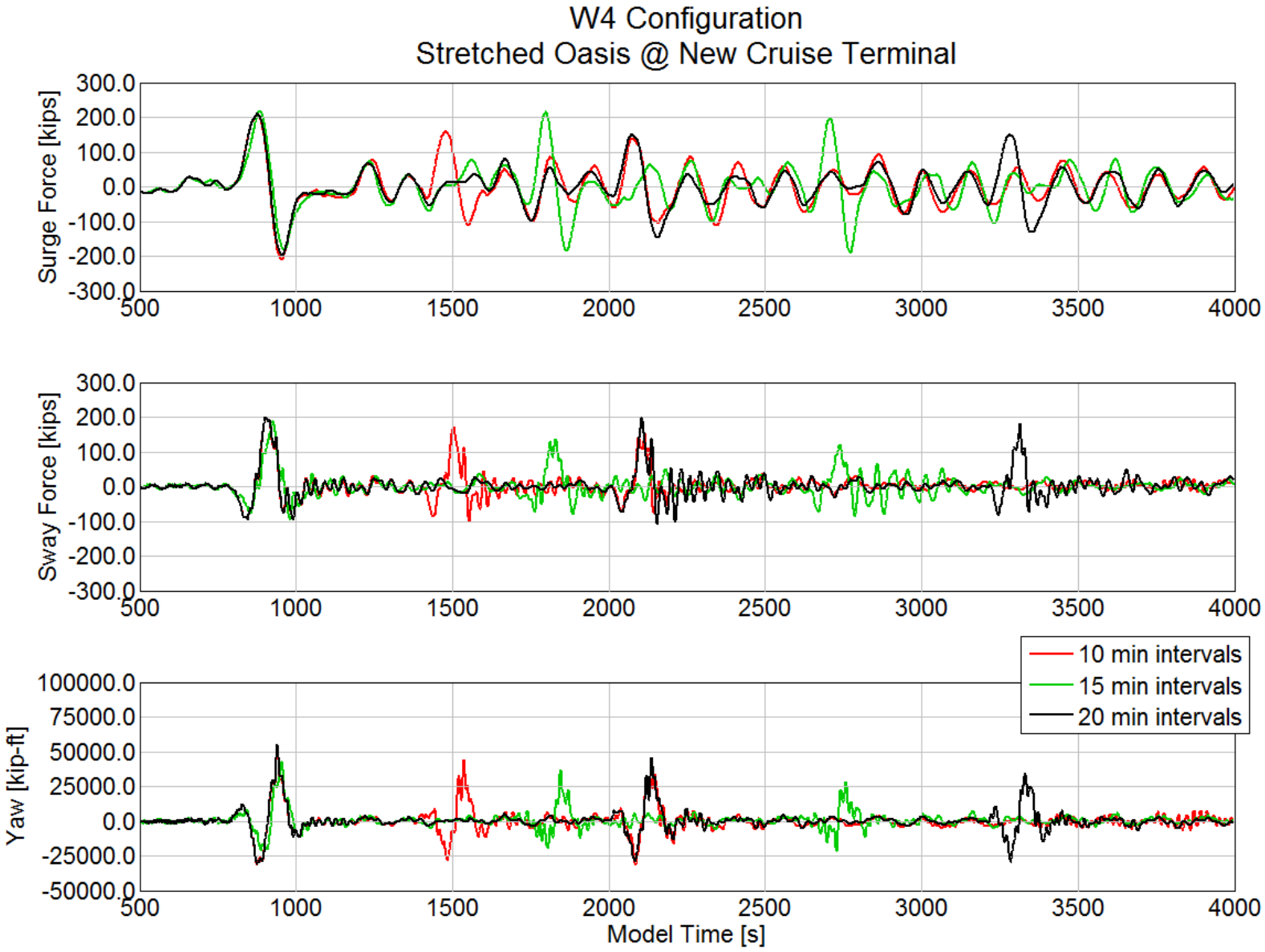




Load Comparison

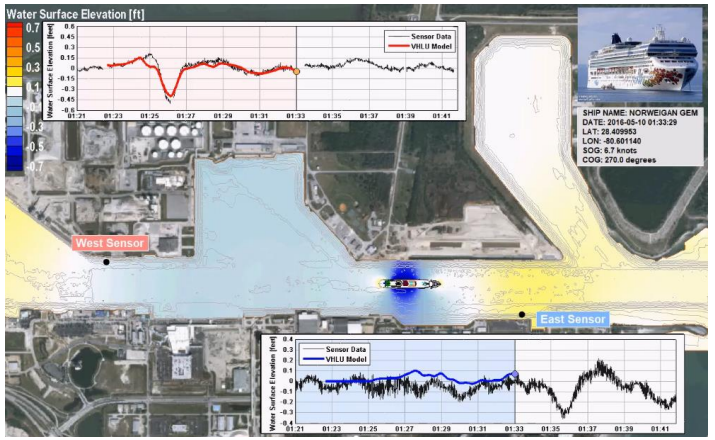
Departure Interval Sensitivity
West Berth
W4 Configuration

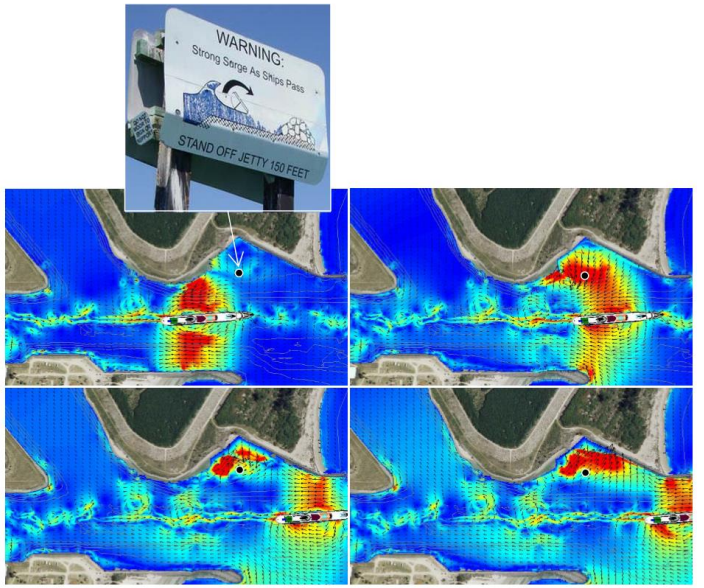




SUMMARY

- VHLU Modeling system developed which has proven capability to simulate many common - yet complex - passing ship problems.
- Full-scale field validations successful in complex, real-world harbor – system shows high level of accuracy.
- System proven critical for mitigating the impacts of passing ship effects.
    - ✓ Terminal siting/configuration development
    - ✓ Berth/channel modifications
    - ✓ Mooring system improvements
    - ✓ Traffic management





THANK YOU

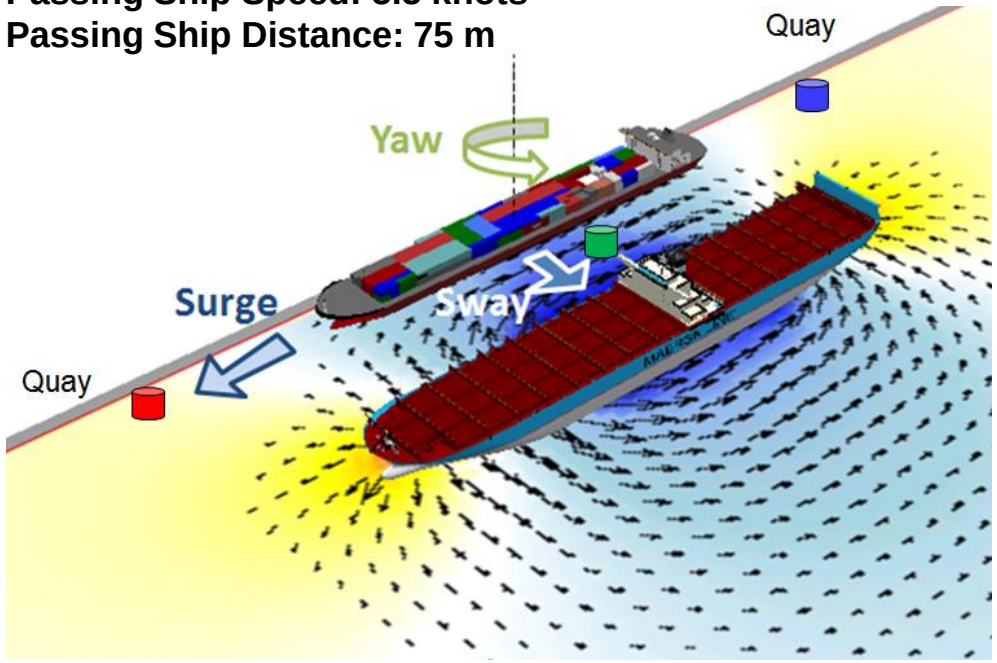
- Any Questions?

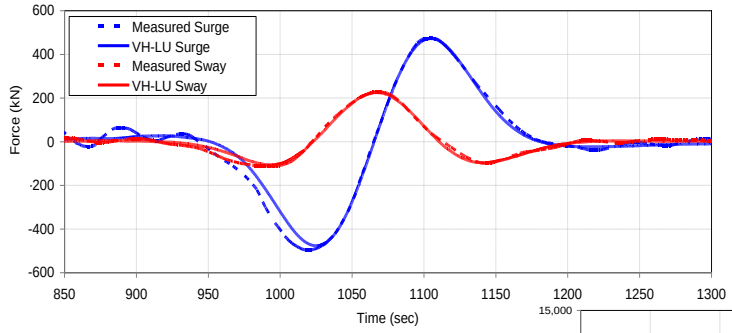
Validation - Laboratory Passing Vessel Forces

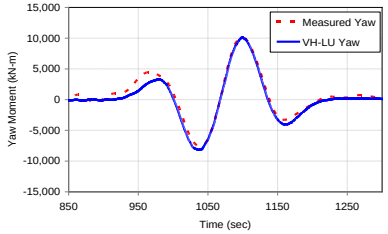
MARIN (2008)

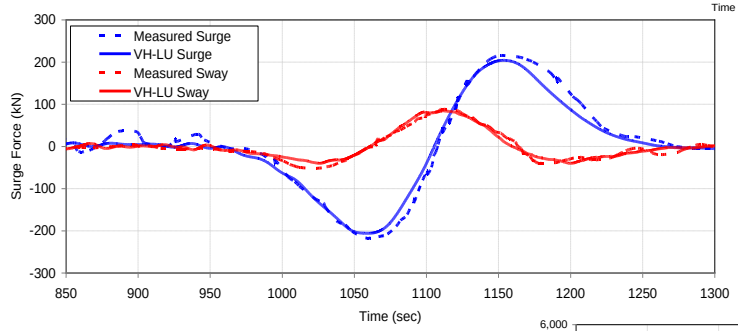
- MARIN tests with 38:1 scale containerships.
- Vertical quay.
- Parallel-passing situation only.

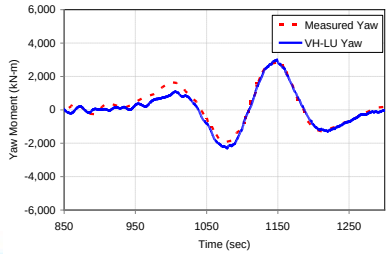
Passing Ship Speed: 5.5 knots
Passing Ship Distance: 75 m









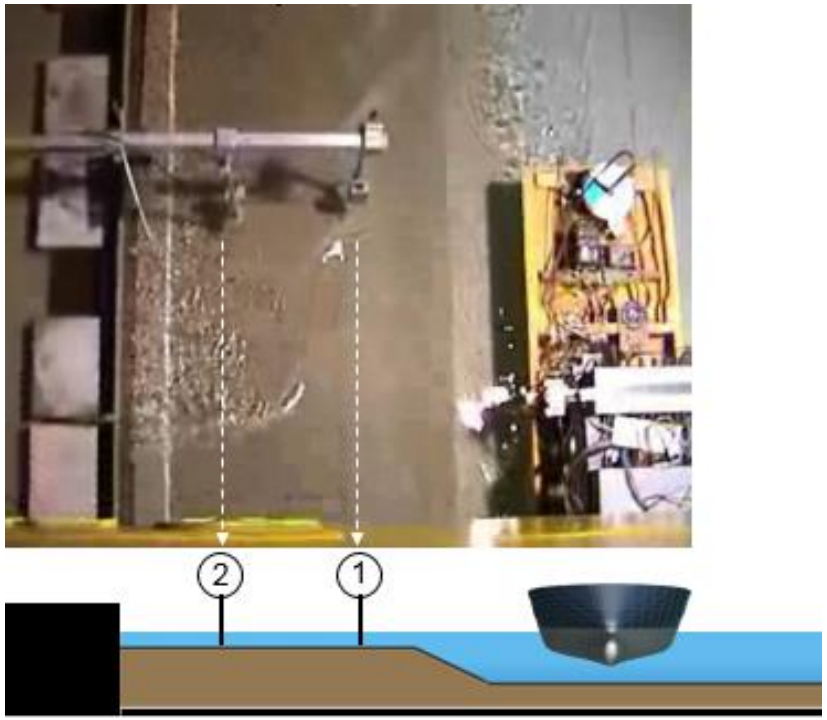


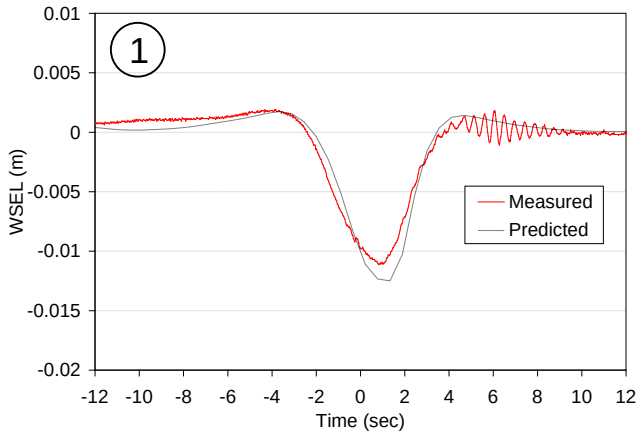
Data from van Wijhe et al. (2008)

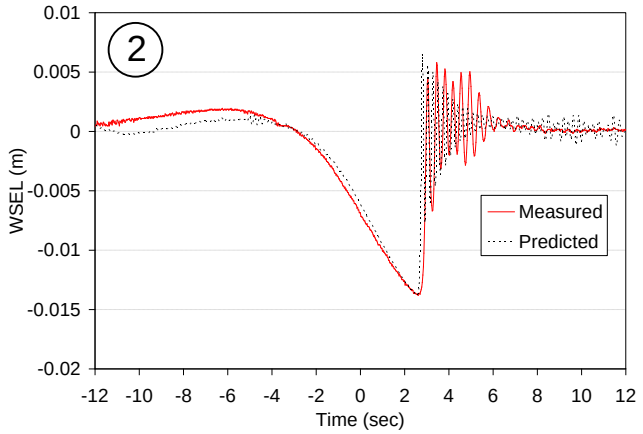
Validation – Laboratory Passing Vessel Hydrodynamics

Flanders Hydraulics (2009)

- Flanders Hydraulics tests with 80:1 scale containerships.
- Submerged bank, vertical wall.







Data from Lataire et al (2009)