Natural Drivers of Alongshore Varying Dune Evolution in Cape Lookout National Seashore, NC

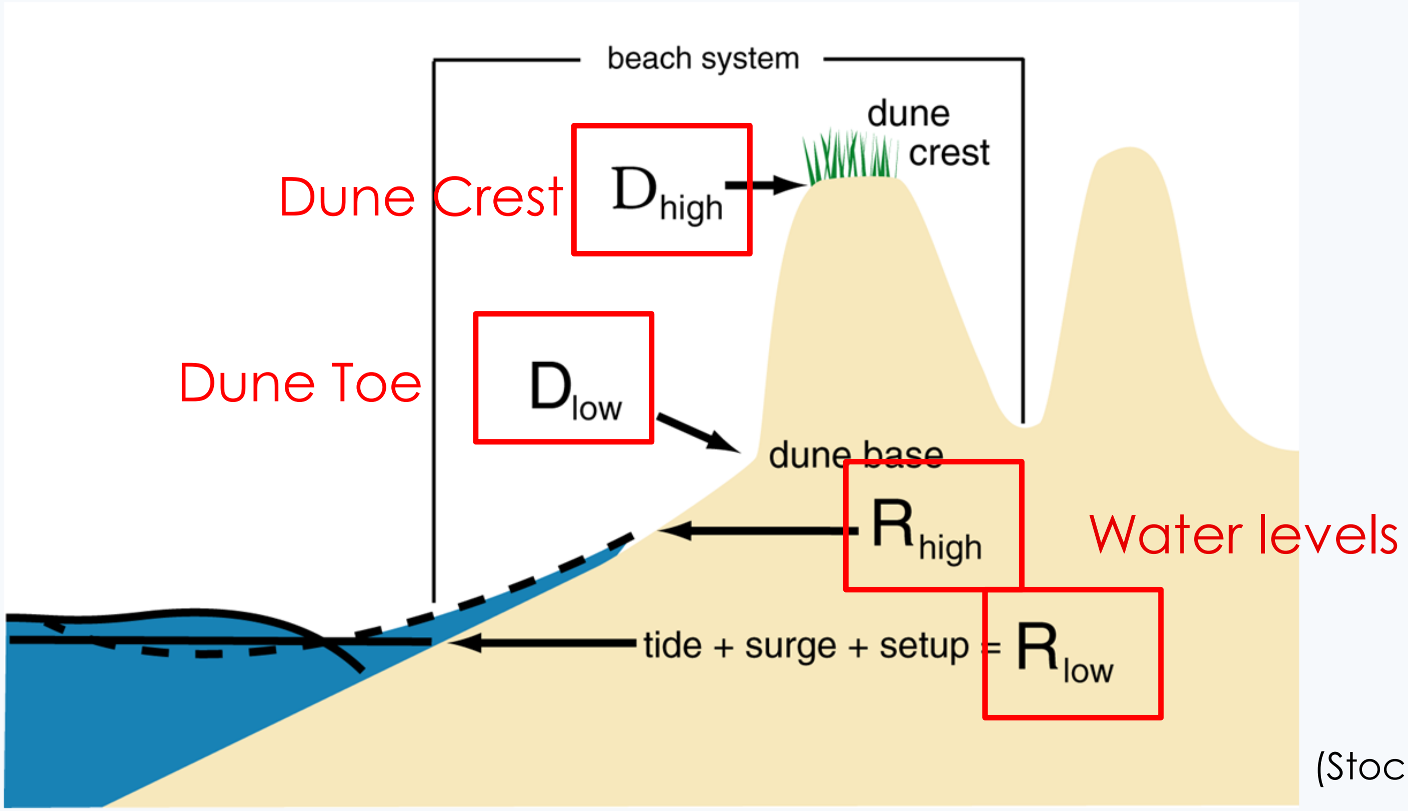
Paige A. Hovenga, Peter Ruggiero, Nick Cohn, Sally Hacker, Katya R. Jay, Laura Moore, Michael Itzkin

ICCE 2018

Baltimore, Maryland

Background

Coastal dunes are often the first and primary form of defense against destructive surge and waves that accompany storm events.

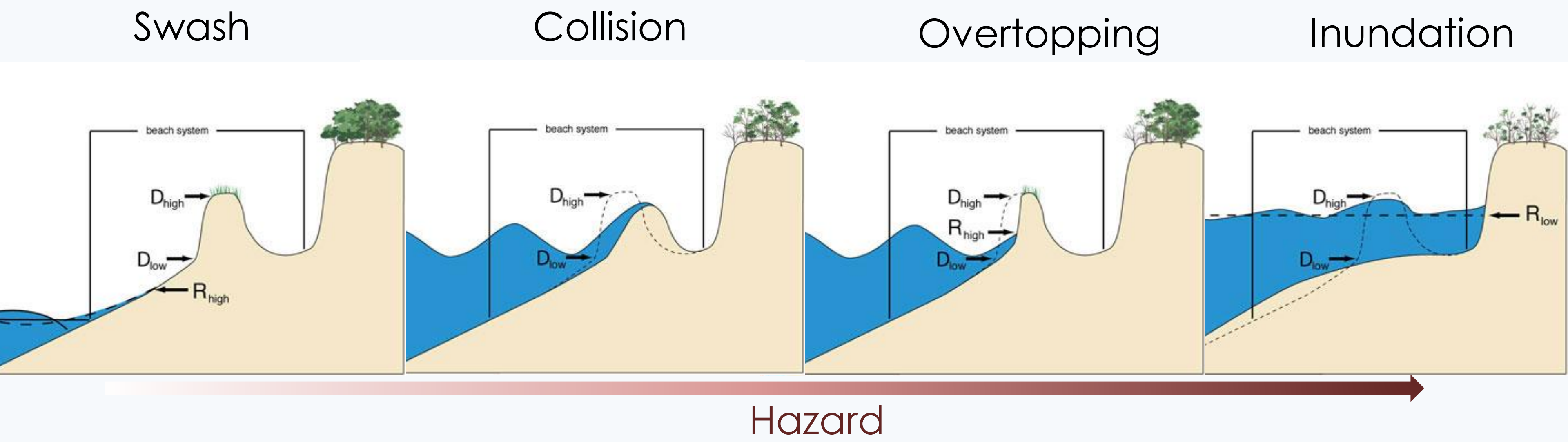


(Stockdon et al. 2007)

Background

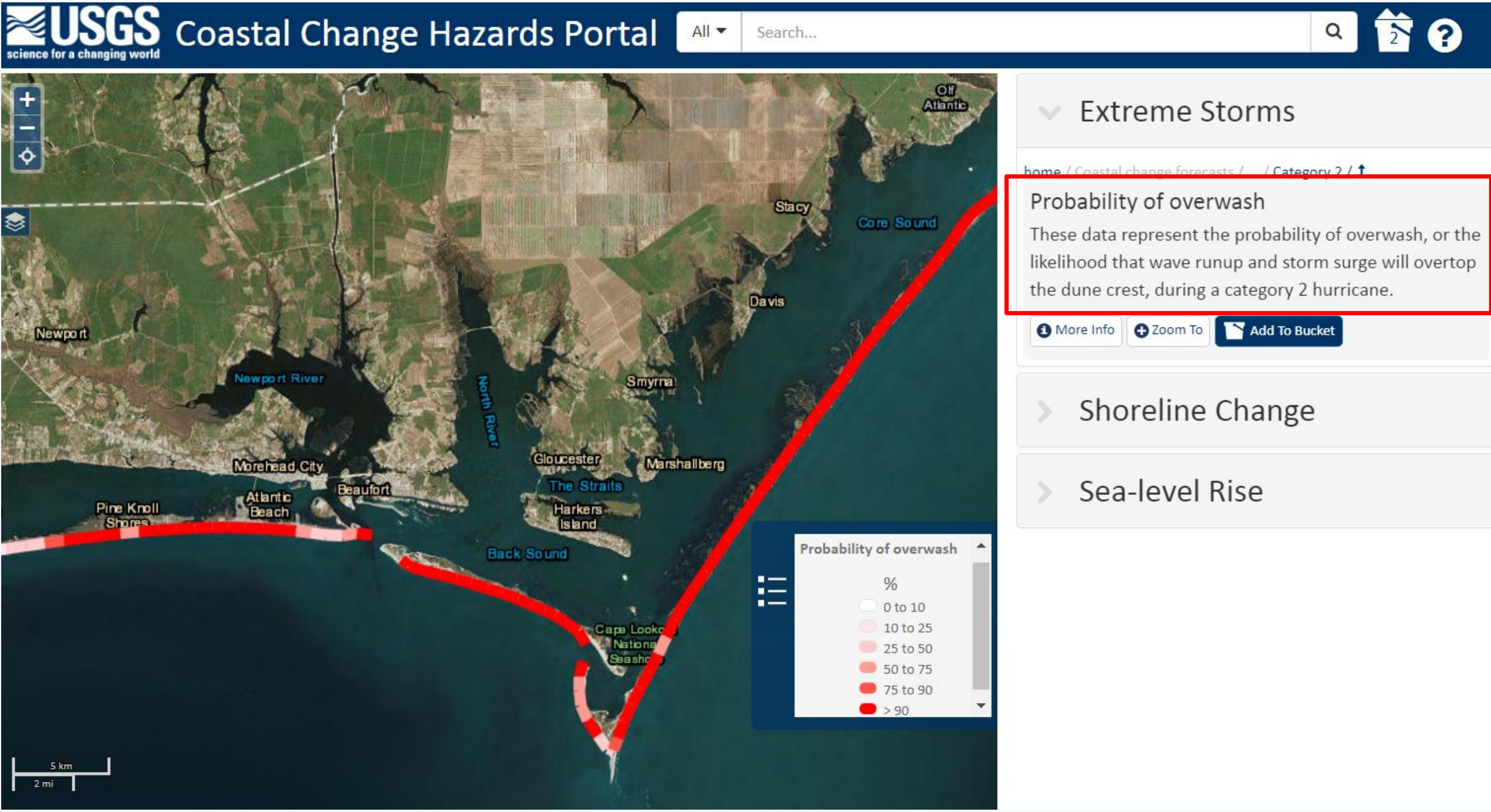
Coastal dunes are often the first and primary form of defense against destructive surge and waves that accompany storm events.

- Storm Impact Regime (Sallenger, 2000)



US Department of the Interior | USGS
http://coastal.er.usgs.gov/hurricanes/impact-scale/inundation.php

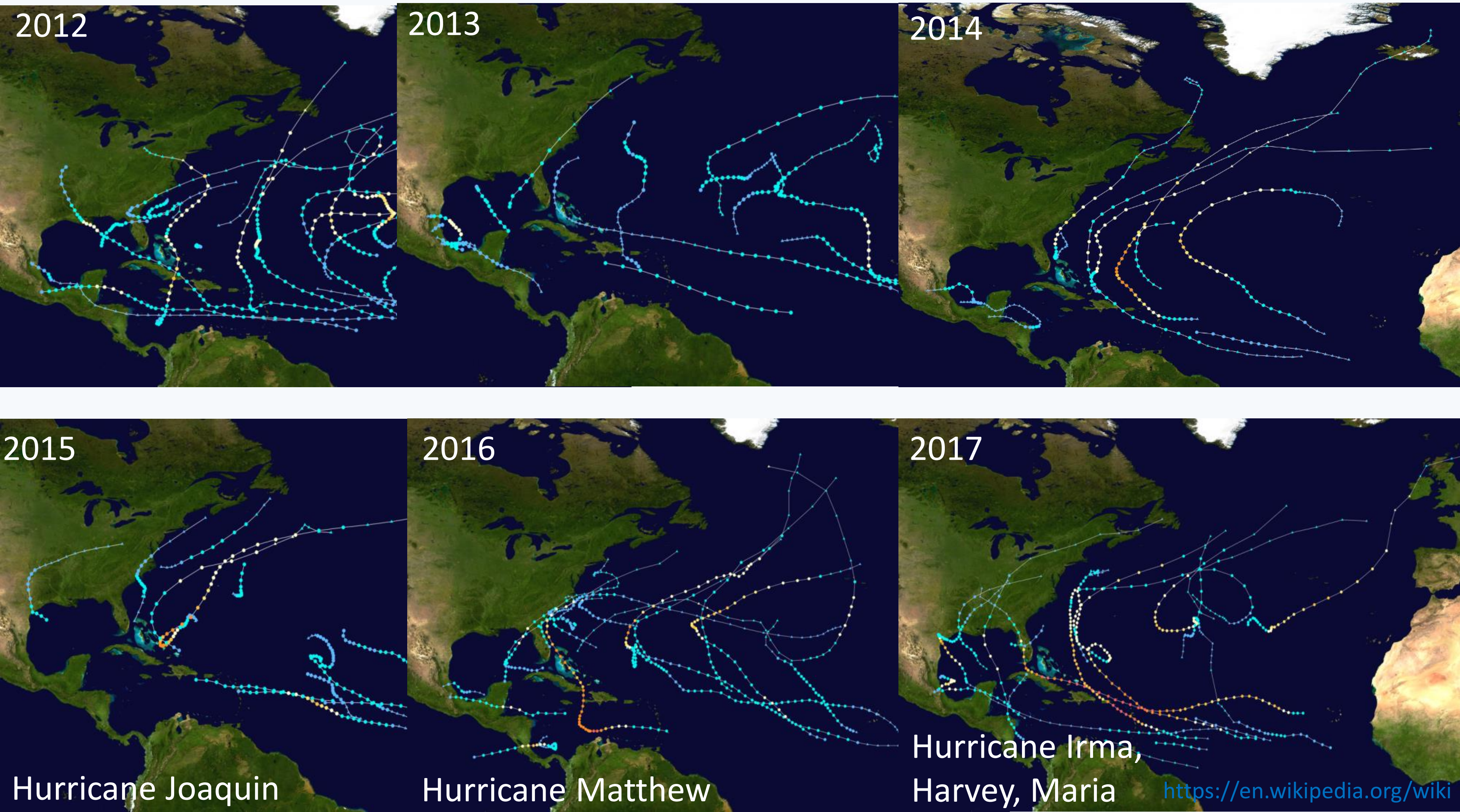
Background



https://marine.usgs.gov/coastalchangehazardsportal/

Background

The ability to predict coastal hazards are only as good as our latest dataset



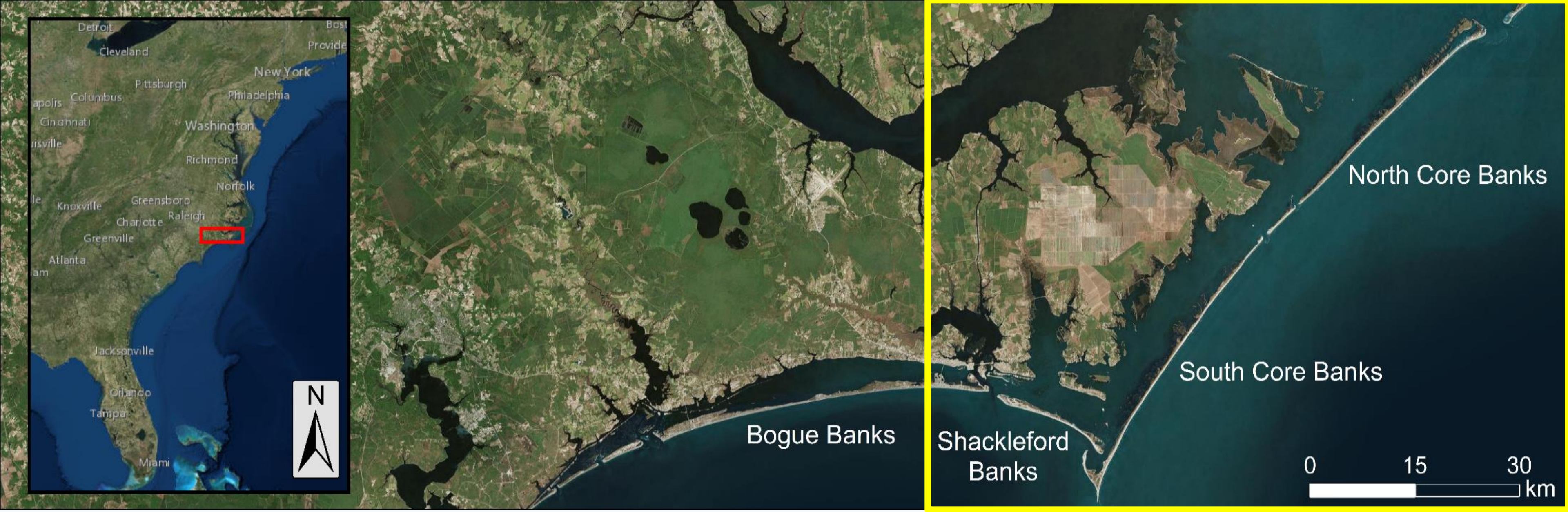
Objective

The objective of this interdisciplinary research is to quantify dune evolution on a natural coast and discern the relative importance of the dominant factors driving alongshore variability.

Drivers of Dune Growth

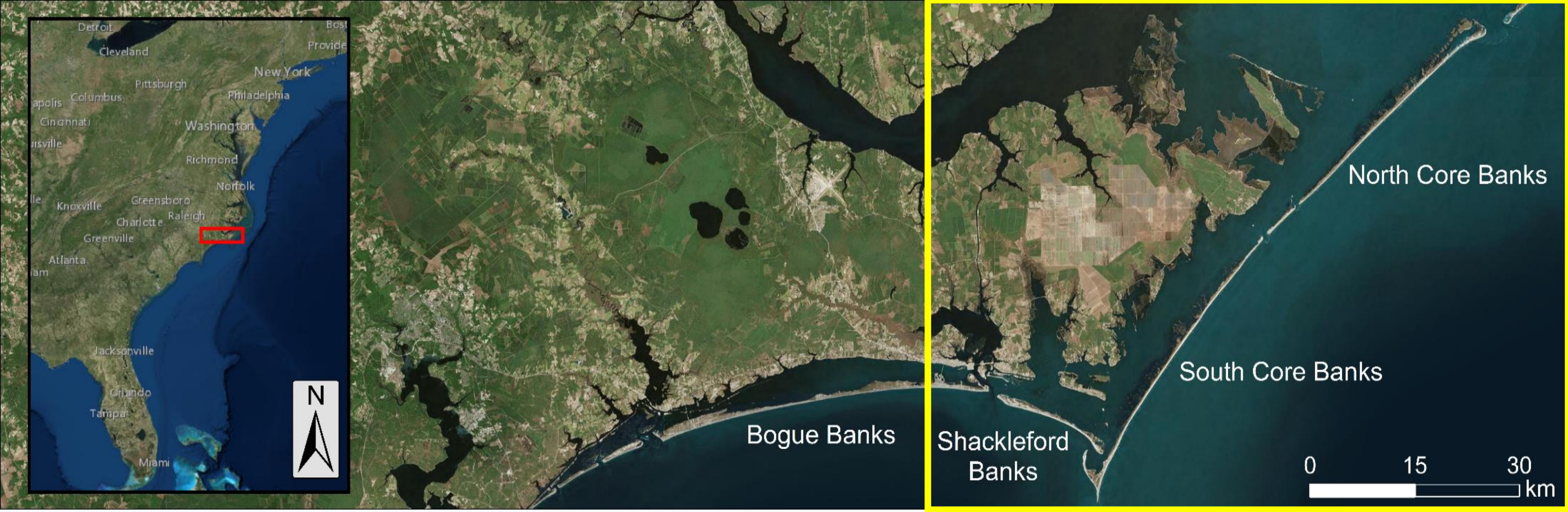
- Pre-existing morphology
- Environmental conditions (wave/wind climate, storm events)
- Ecomorphodynamic processes

Photo Credit: Laura Moore



Cape Lookout National Seashore (CALO)

- Spatial variability in:
  - coastal orientation, beach width and slope, beach grass species
- Multiple cycles of response and recovery
  - Hurricanes Bonnie (1998), Floyd (1999), Isabel (2003), Irene (2011), Joaquin / Nor'easter (2015), Matthew (2016), Tropical Storm Maria (2017)



Cape Lookout National Seashore (CALO)

- Techniques for quantifying dune evolution and the dominant drivers
  - Airborne lidar, field surveying techniques, and numerical modeling

Airborne Lidar Datasets

NOAA Data Access Viewer

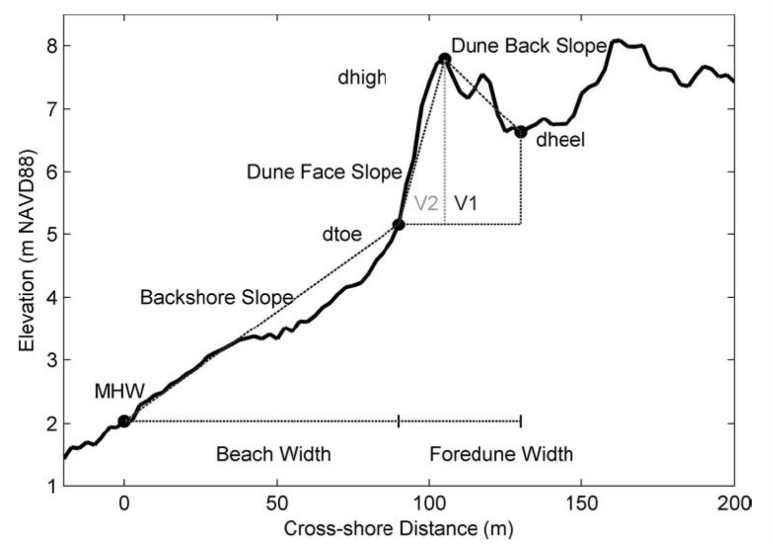
- 12 lidar datasets (1997-2016)

Available for CALO

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016

- 20 meter alongshore resolution
  - Shoreline position
  - Dune toe, dune crest, dune heel
  - Dune volume



Airborne Lidar Datasets

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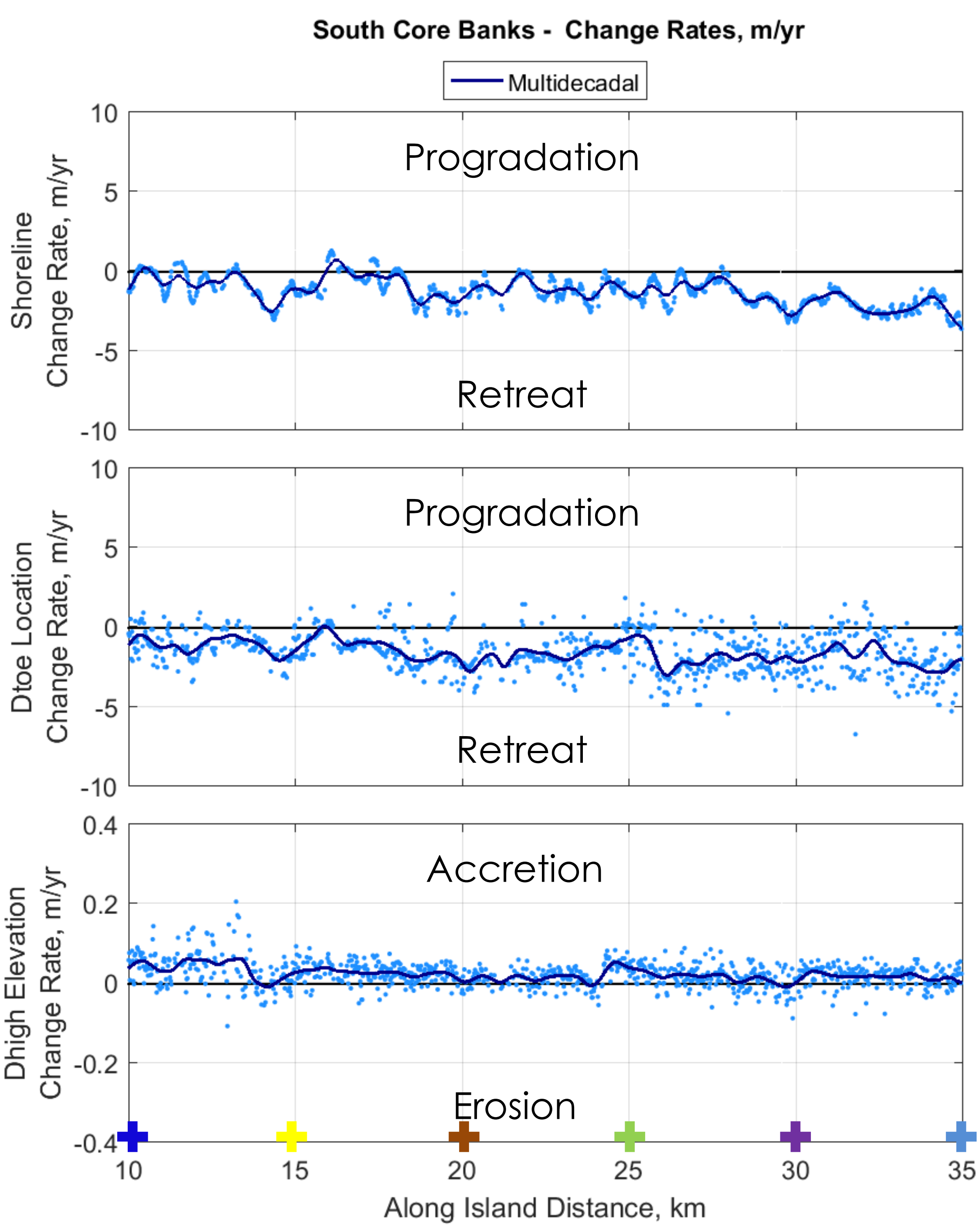
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
2007	2008	2009	2010	2011	2012	2013	**2014**	2015	**2016**

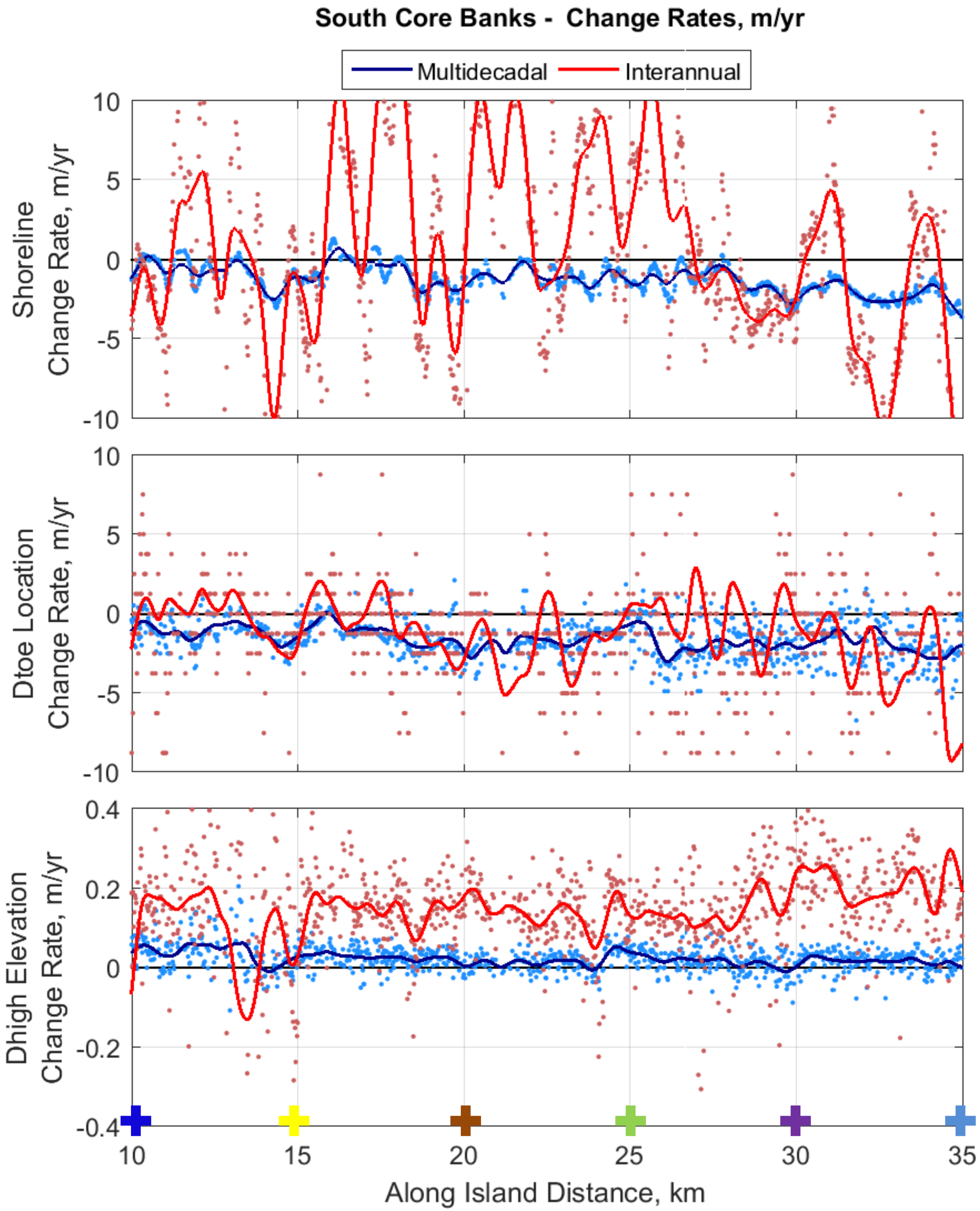
Multidecadal (1997 – 2016)

Interannual (2014 – 2016)



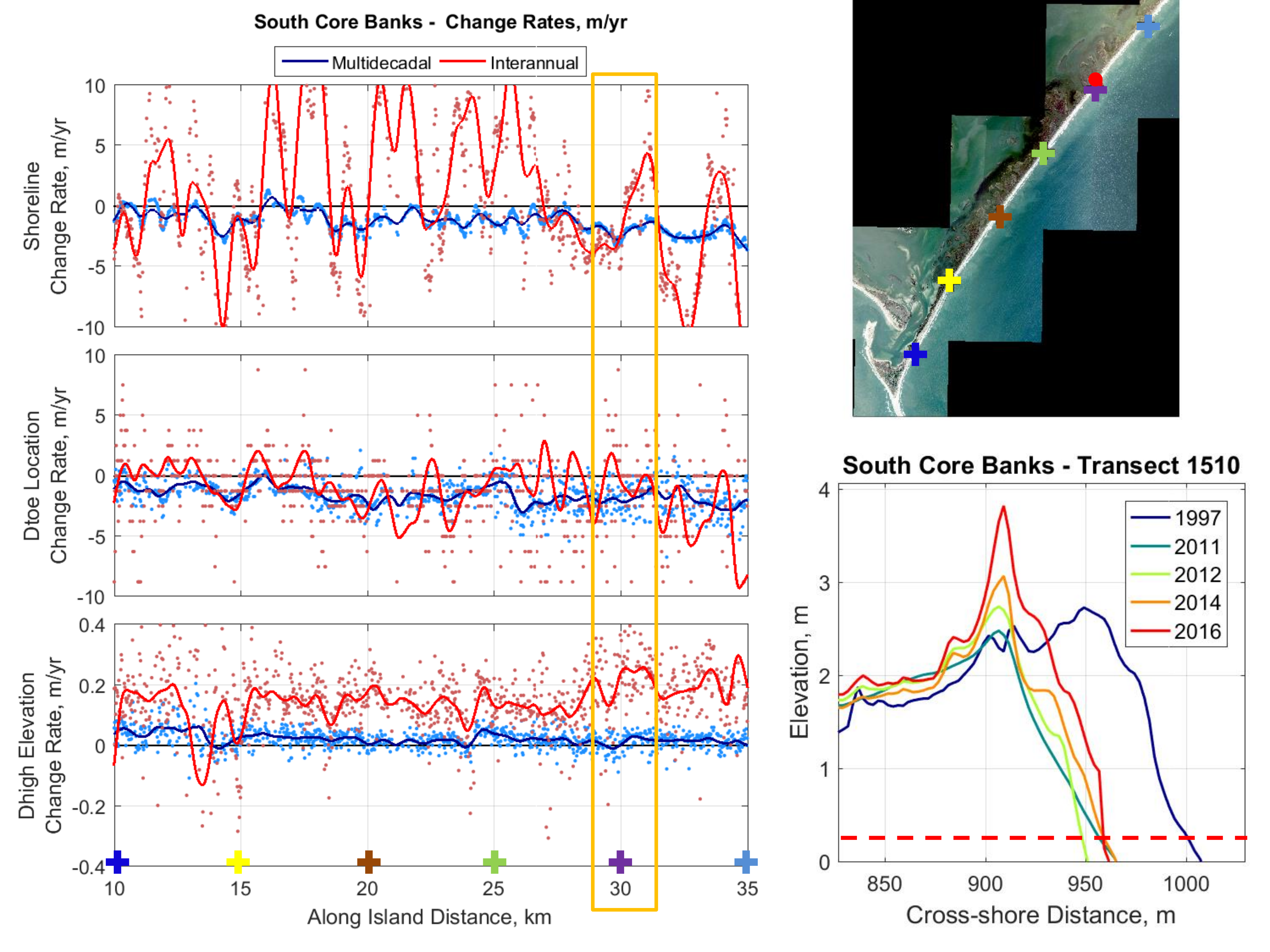
Average Dune Crest Change Rate

- Multidecadal = 2 cm/yr



Average Dune Crest Change Rate

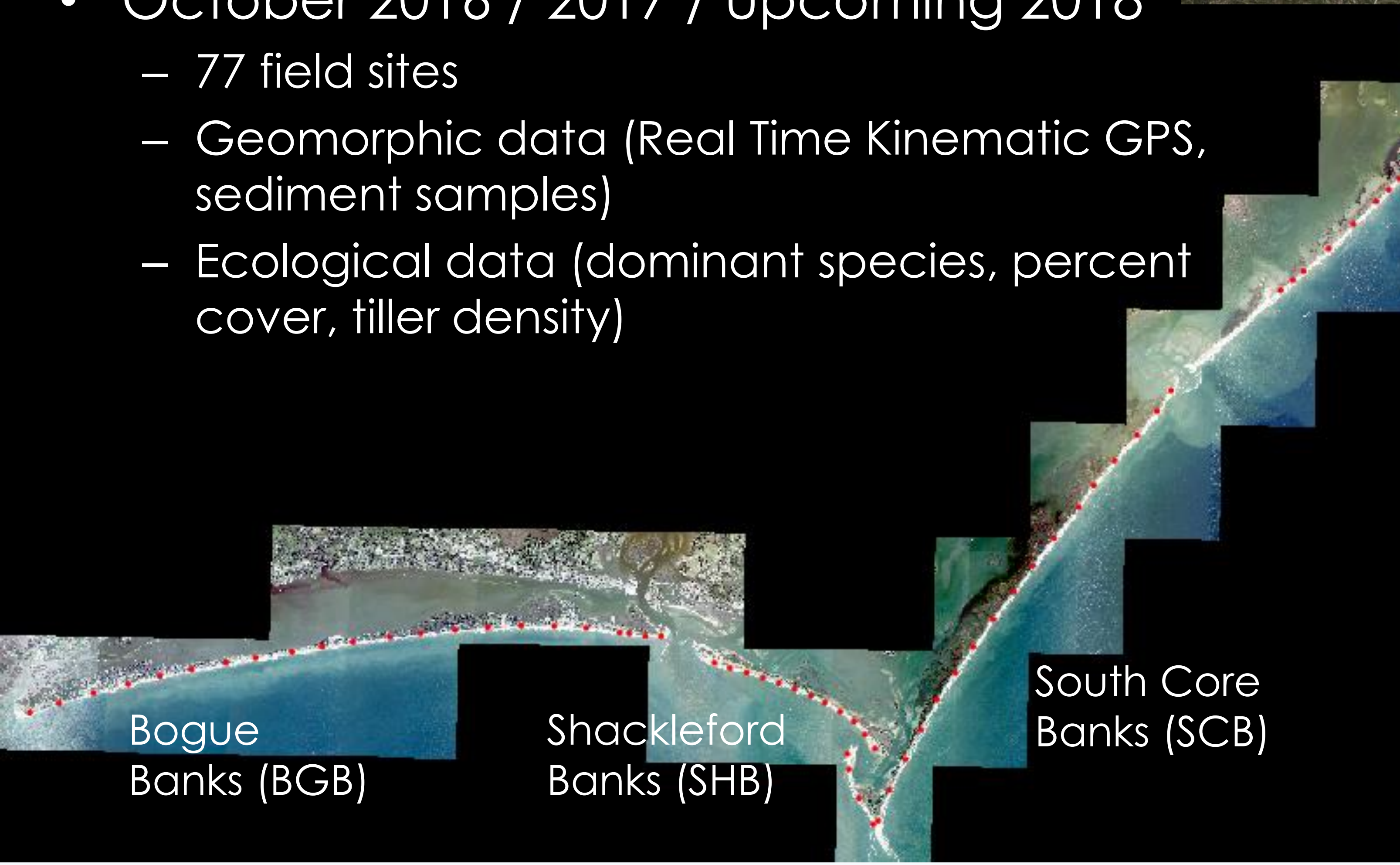
- Multidecadal = 2 cm/yr
- Interannual = 15 cm/yr



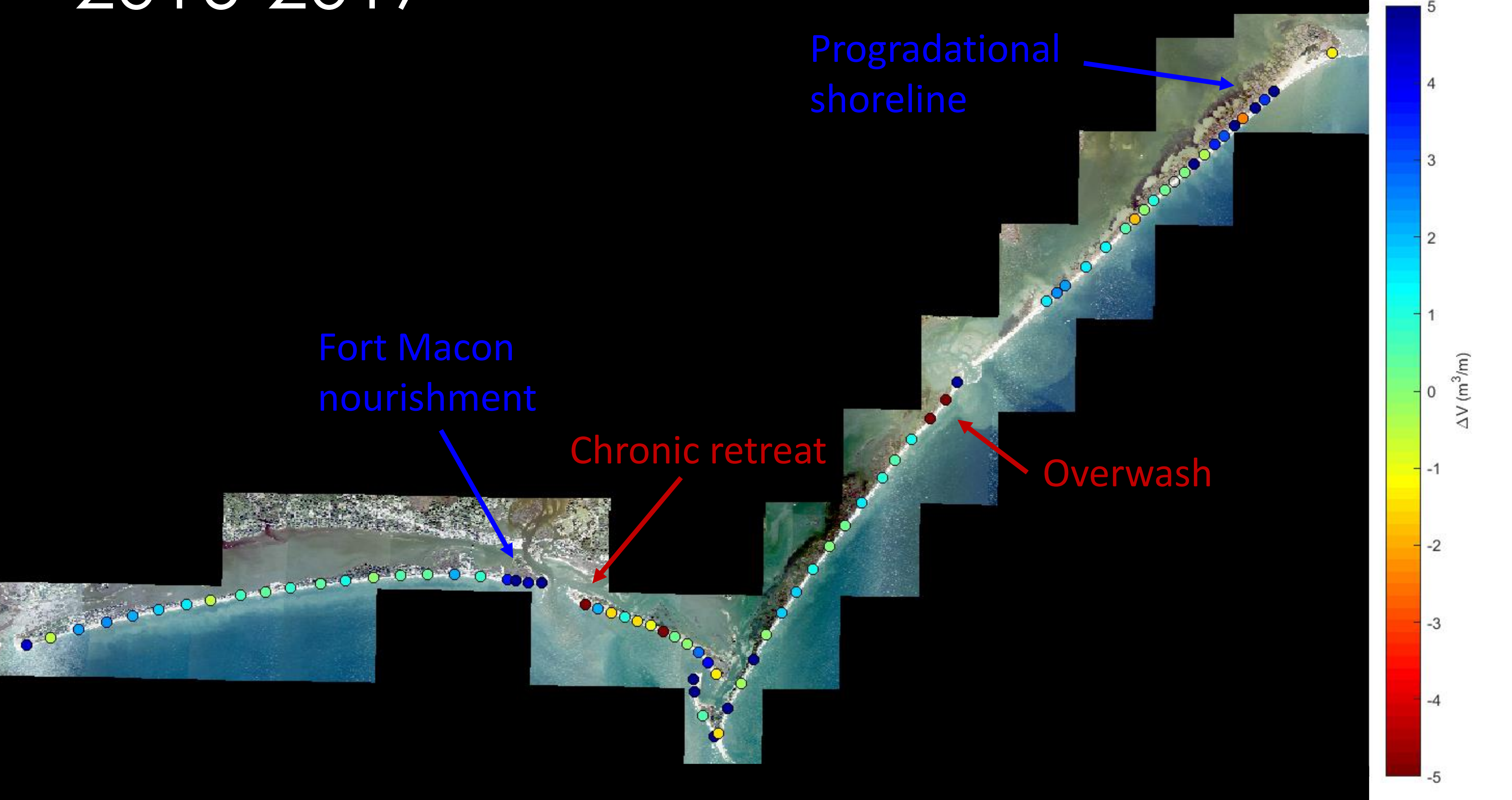
South Core Banks - Change Rates, m/yr
Multidecadal
Interannual
Shoreline Change Rate, m/yr
Dtoe Location Change Rate, m/yr
Dhigh Elevation Change Rate, m/yr
Along Island Distance, km
South Core Banks - Transect 1510
1997
2011
2012
2014
2016
Elevation, m
Cross-shore Distance, m

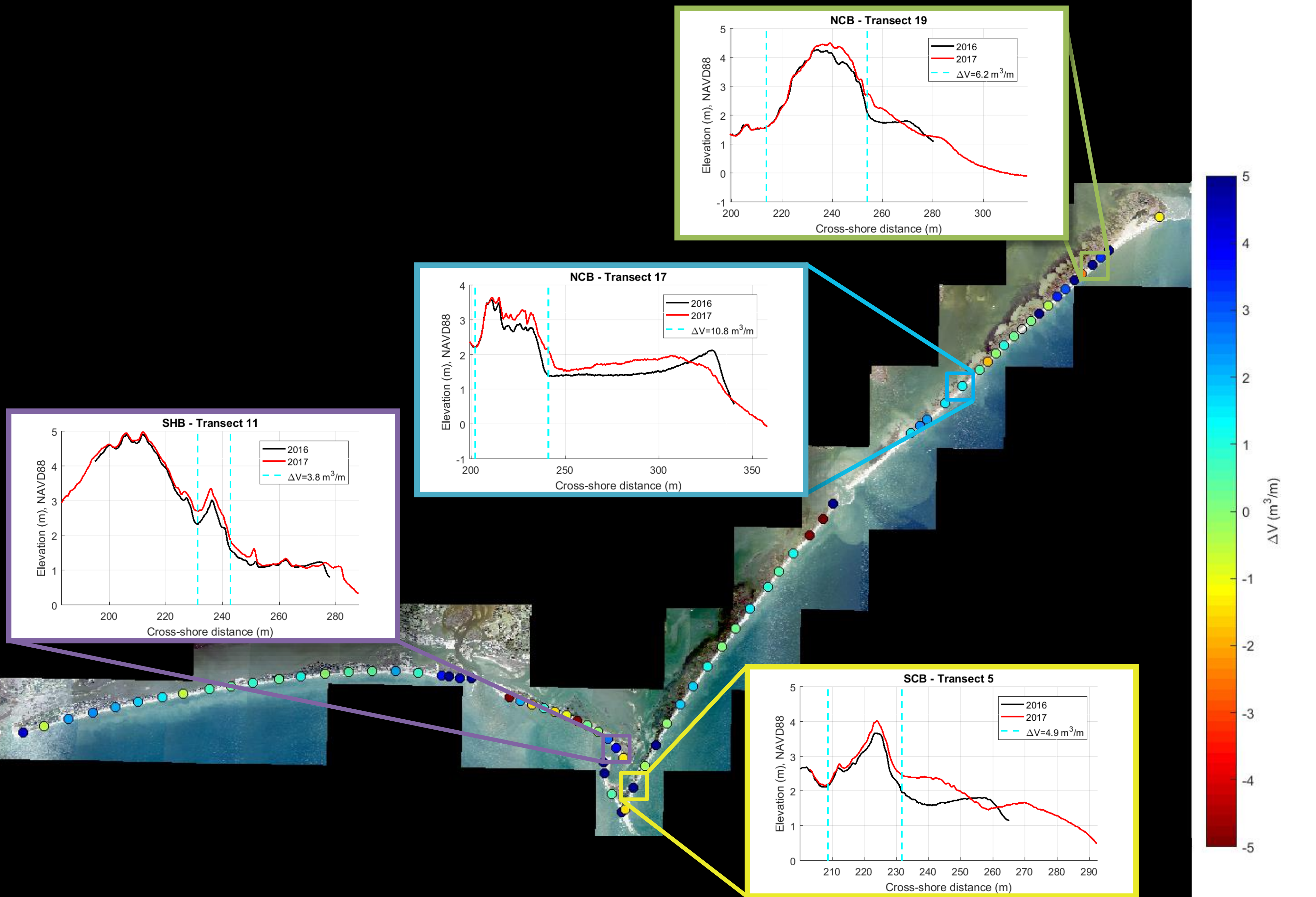
Field Campaigns

- October 2016 / 2017 / upcoming 2018
  - 77 field sites
  - Geomorphic data (Real Time Kinematic GPS, sediment samples)
  - Ecological data (dominant species, percent cover, tiller density)

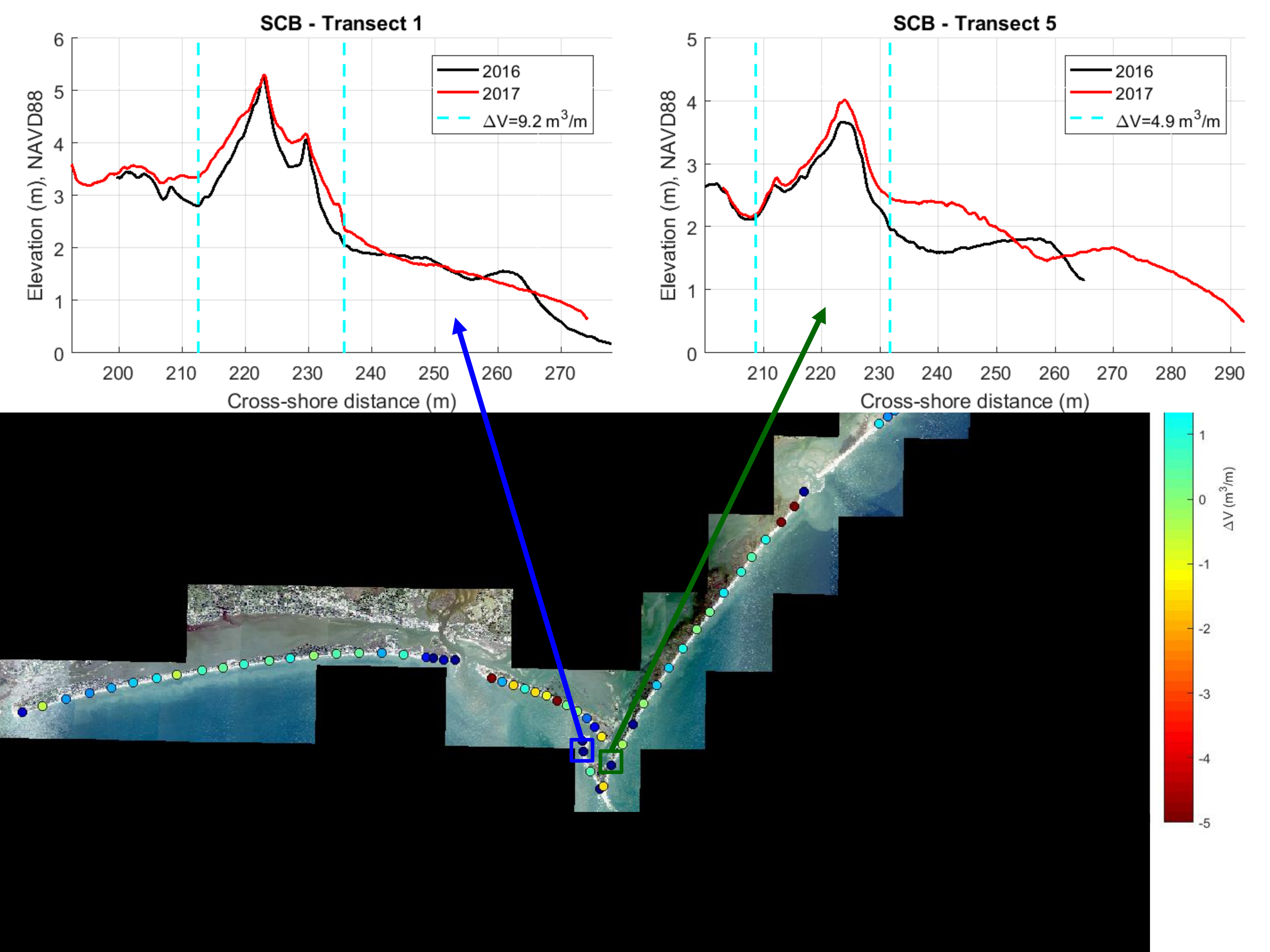


Dune Volume Change 2016-2017

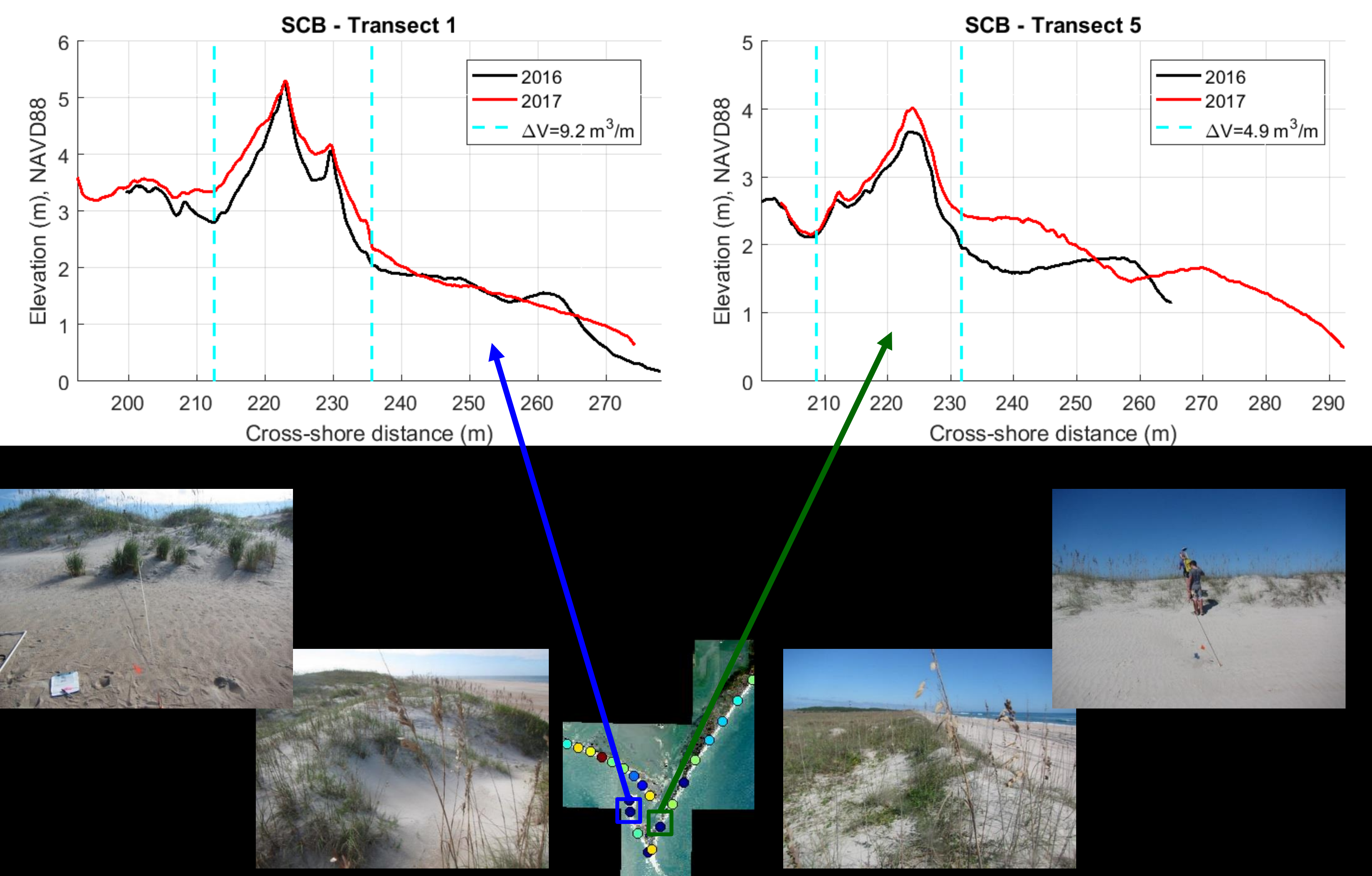


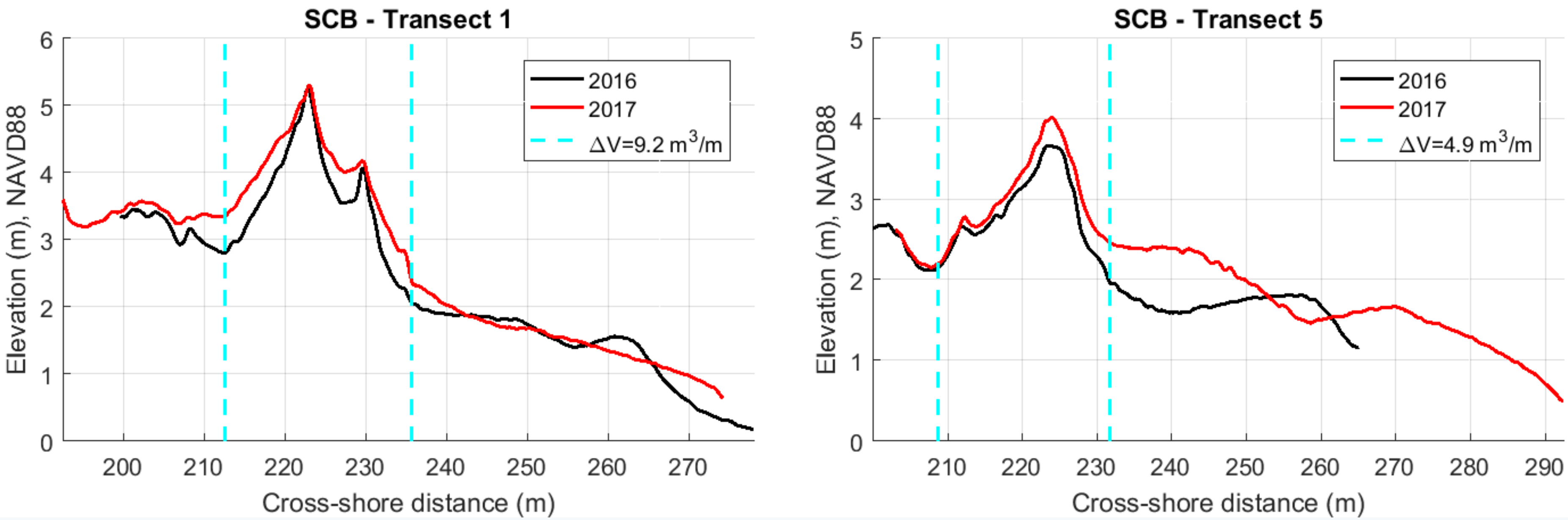


NCB - Transect 19
2016
2017
ΔV=6.2 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
NCB - Transect 17
2016
2017
ΔV=10.8 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
SHB - Transect 11
2016
2017
ΔV=3.8 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
SCB - Transect 5
2016
2017
ΔV=4.9 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
ΔV (m³/m)



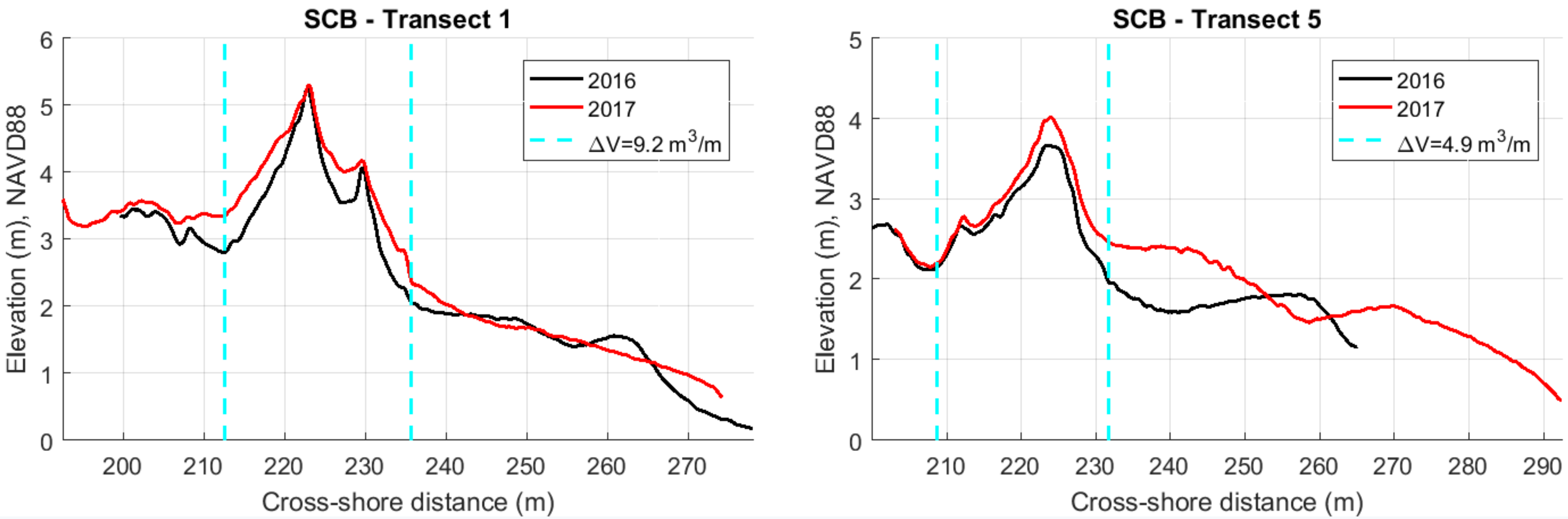
SCB - Transect 1
2016
2017
ΔV=9.2 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
SCB - Transect 5
2016
2017
ΔV=4.9 m³/m
Elevation (m), NAVD88
Cross-shore distance (m)
ΔV (m³/m)


SCB - Transect 1
Elevation (m), NAVD88
Cross-shore distance (m)
0
1
2
3
4
5
6
200
210
220
230
240
250
260
270
2016
2017
ΔV=9.2 m^3/m
SCB - Transect 5
Elevation (m), NAVD88
Cross-shore distance (m)
0
1
2
3
4
5
210
220
230
240
250
260
270
280
290
2016
2017
ΔV=4.9 m^3/m



Drivers of Dune Growth

- Subaqueous sediment transport
  - Sediment supply
  - Total water levels (sheltering effects, beach slope)
  - Impact hours per year
- Aeolian sediment transport
  - Cross-shore wind (orientation)
  - Grain size distribution (armoring)
- Sand trapping capacity
  - Beach grasses



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- Sand trapping capacity
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AeoLiS

- Process based numerical model that simulates aeolian sediment transport (Hoonhout and de Vries, 2016)

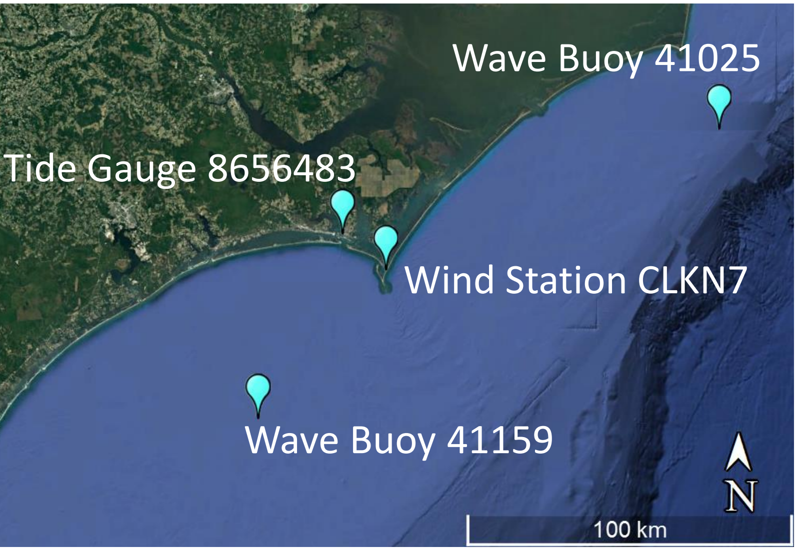
- Sediment availability is modeled rather than parameterized
  - Supply limiting effects due to variations in bed surface properties e.g. sediment sorting and armoring

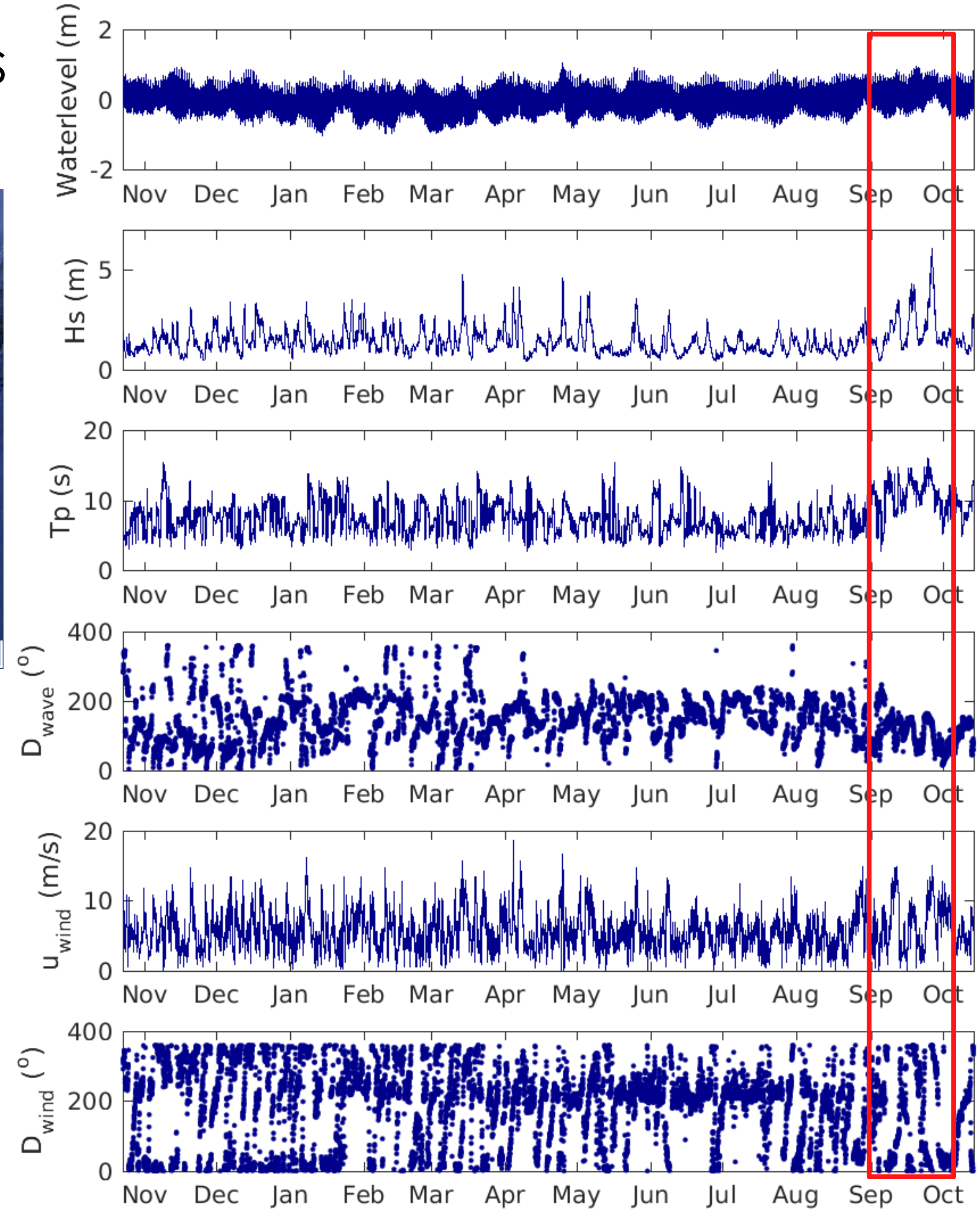
Application

- Simulate aeolian sediment transport for one year (2016-2017)
  - Modeled results are representative of observed dune accretion volumes?
- Explore parameter space (cross-shore wind and grain size distribution)

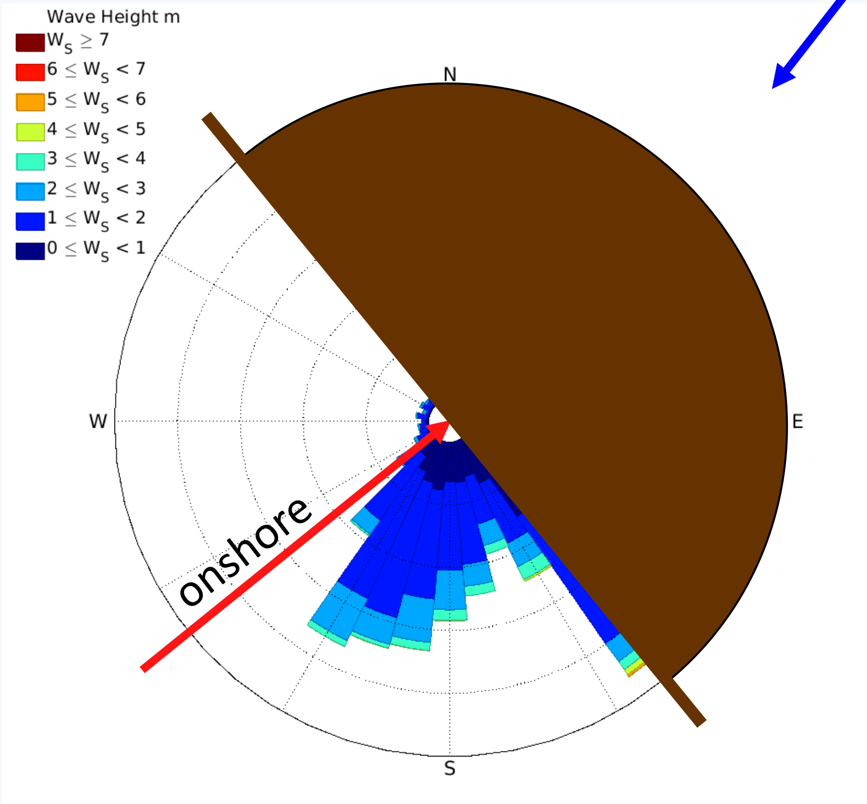
Hoonhout and de Vries (2016), "A process-based model for Aeolian sediment transport and spatiotemporal varying sediment availability", J. Geophysical Research Earth's Surface, 121, 1555-1575.

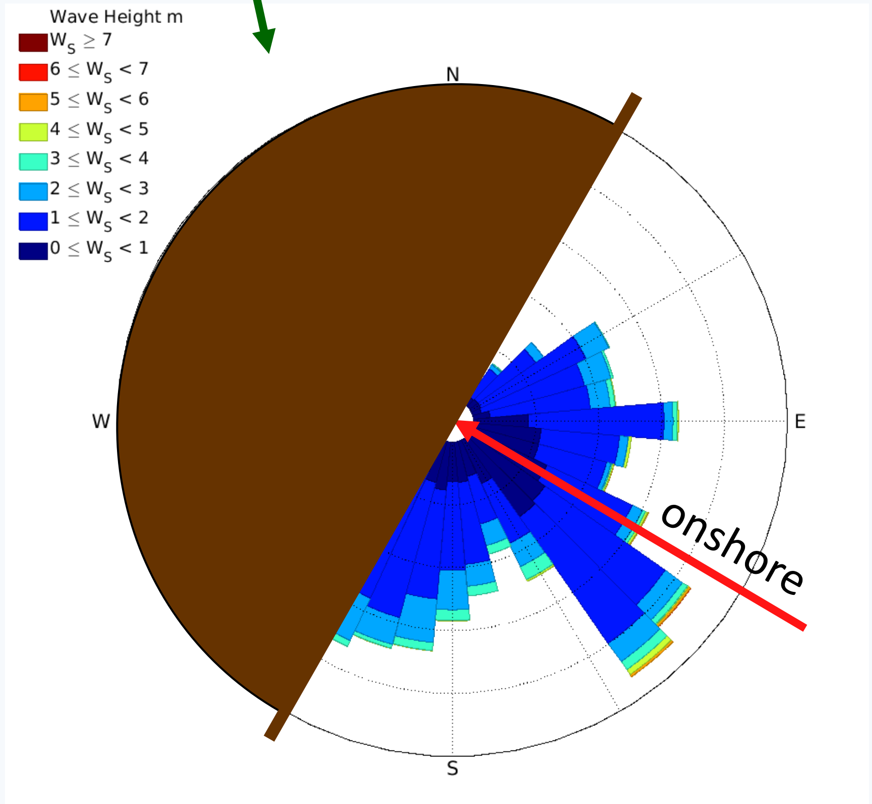
Environmental Variables 2016-2017



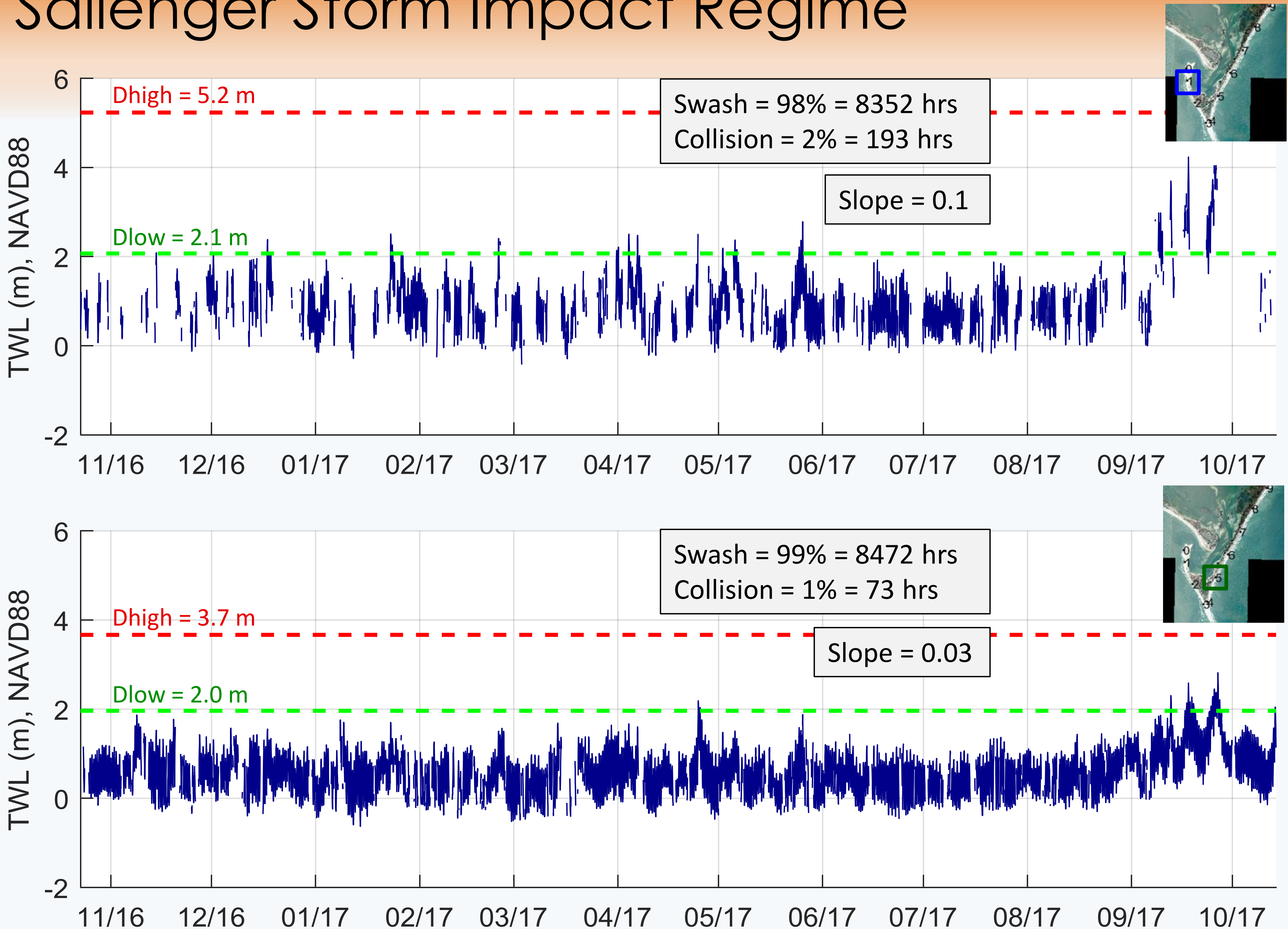


Sheltering Effects -Waves

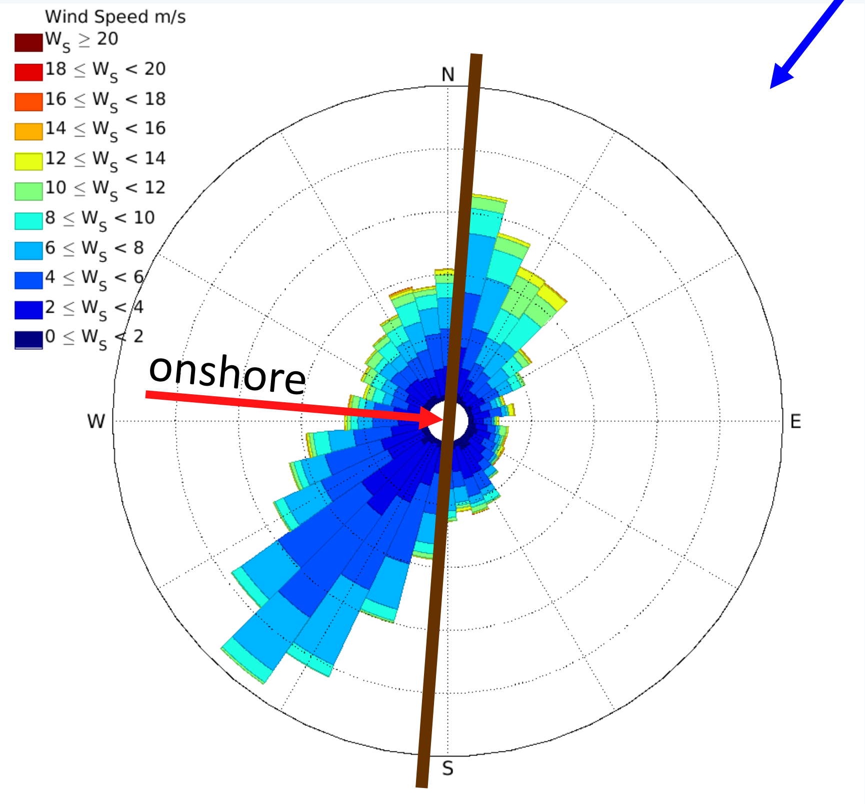


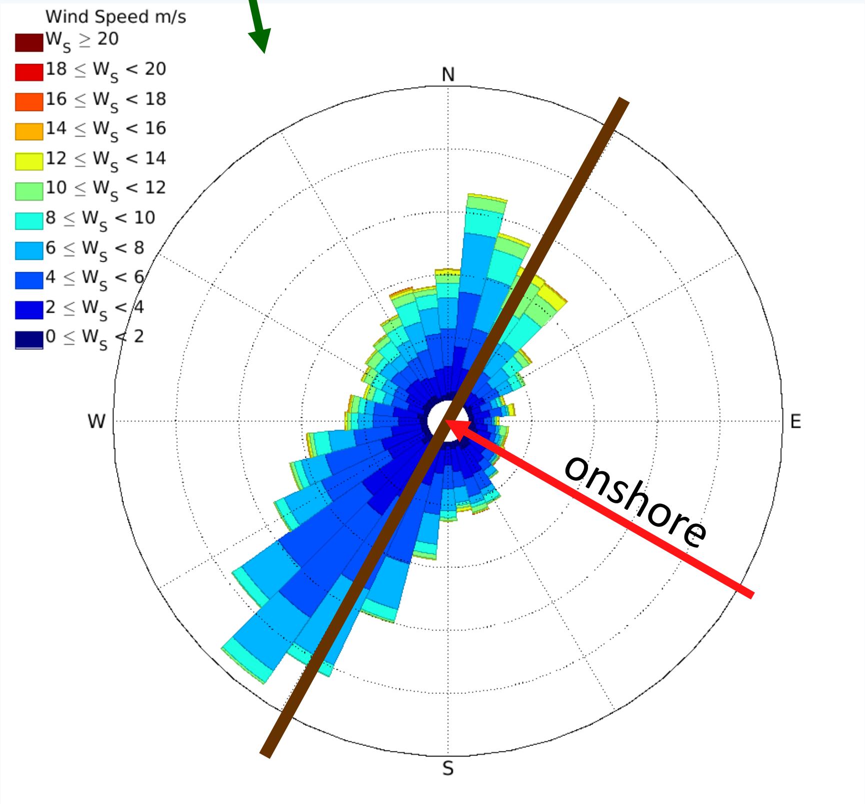


Sallenger Storm Impact Regime

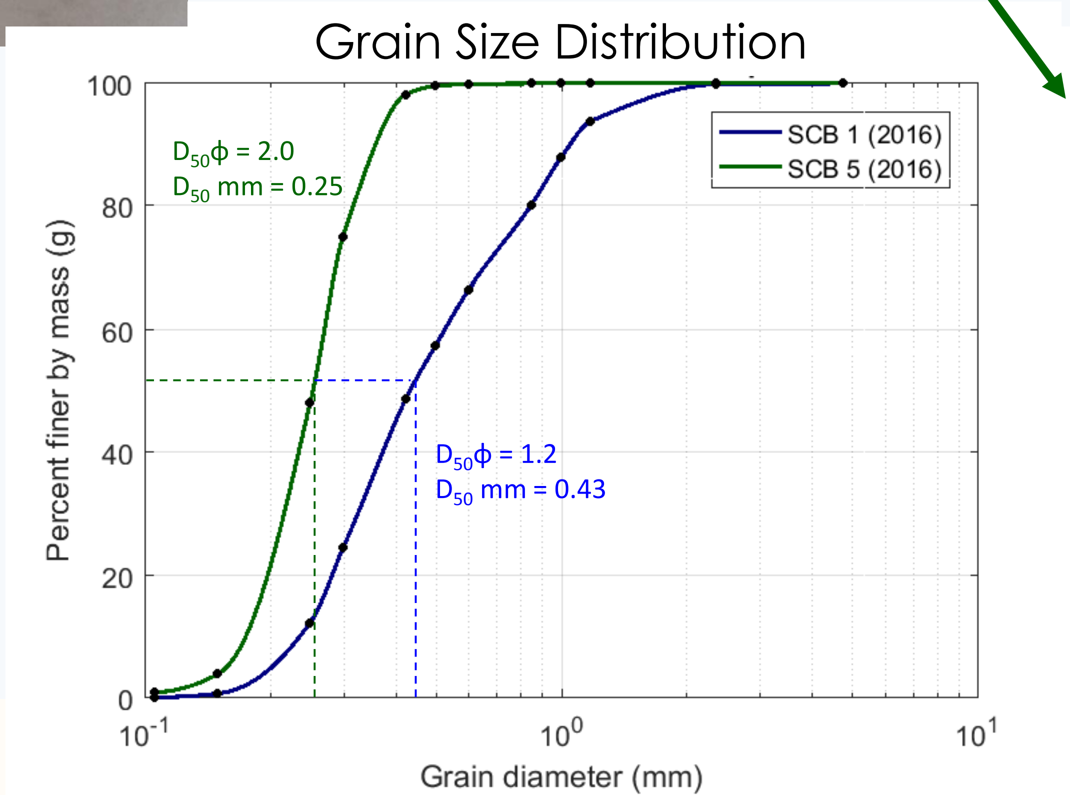


Coastline Orientation -Cross-shore Winds

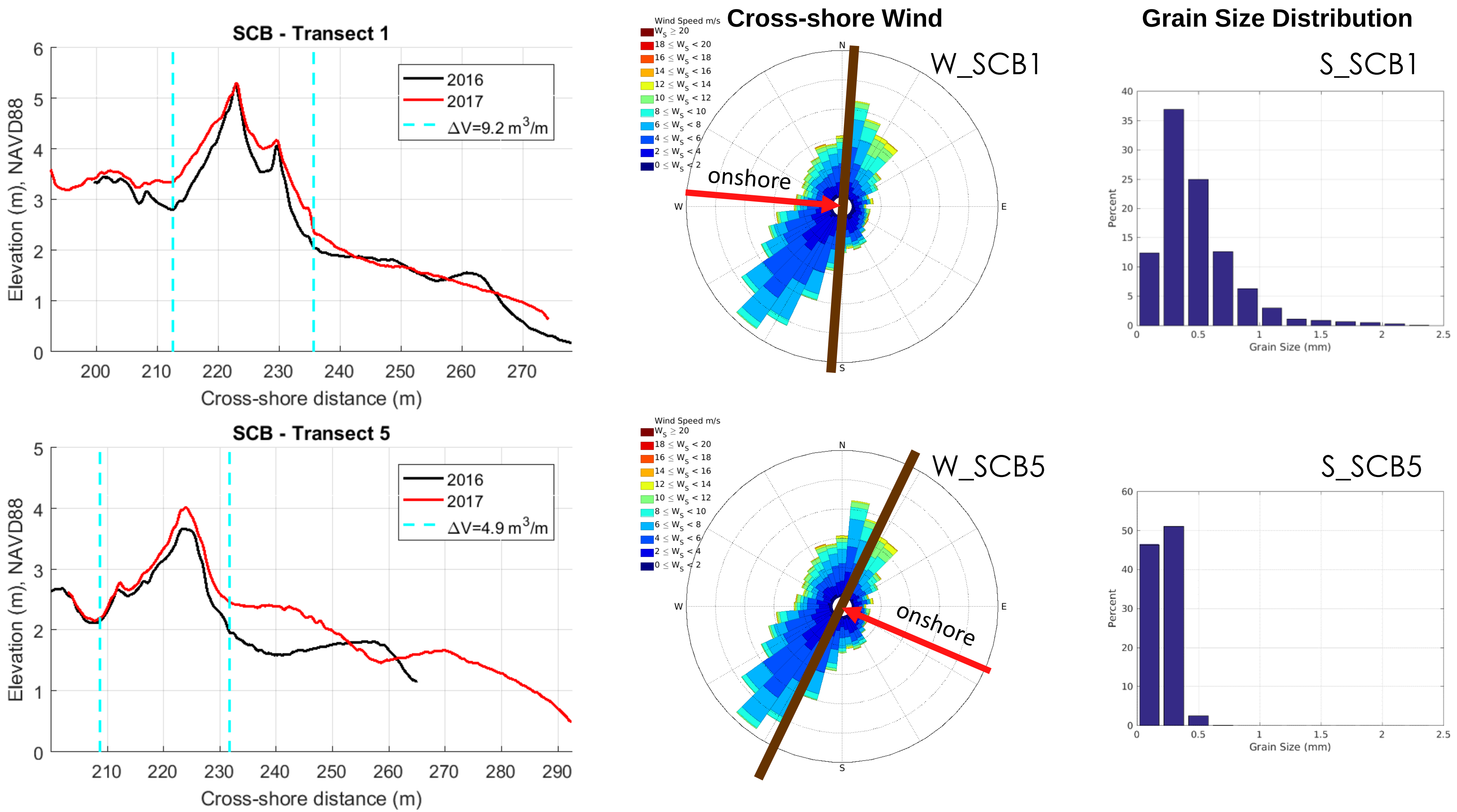




0
1
2
3
4
5
6
7
8
9
10
11
12



Grain Size Distribution
$D_{50}\phi = 2.0$
D_{50} mm = 0.25
$D_{50}\phi = 1.2$
D_{50} mm = 0.43
SCB 1 (2016)
SCB 5 (2016)
Percent finer by mass (g)
0
20
40
60
80
100
10^{-1}
10^{0}
10^{1}
Grain diameter (mm)

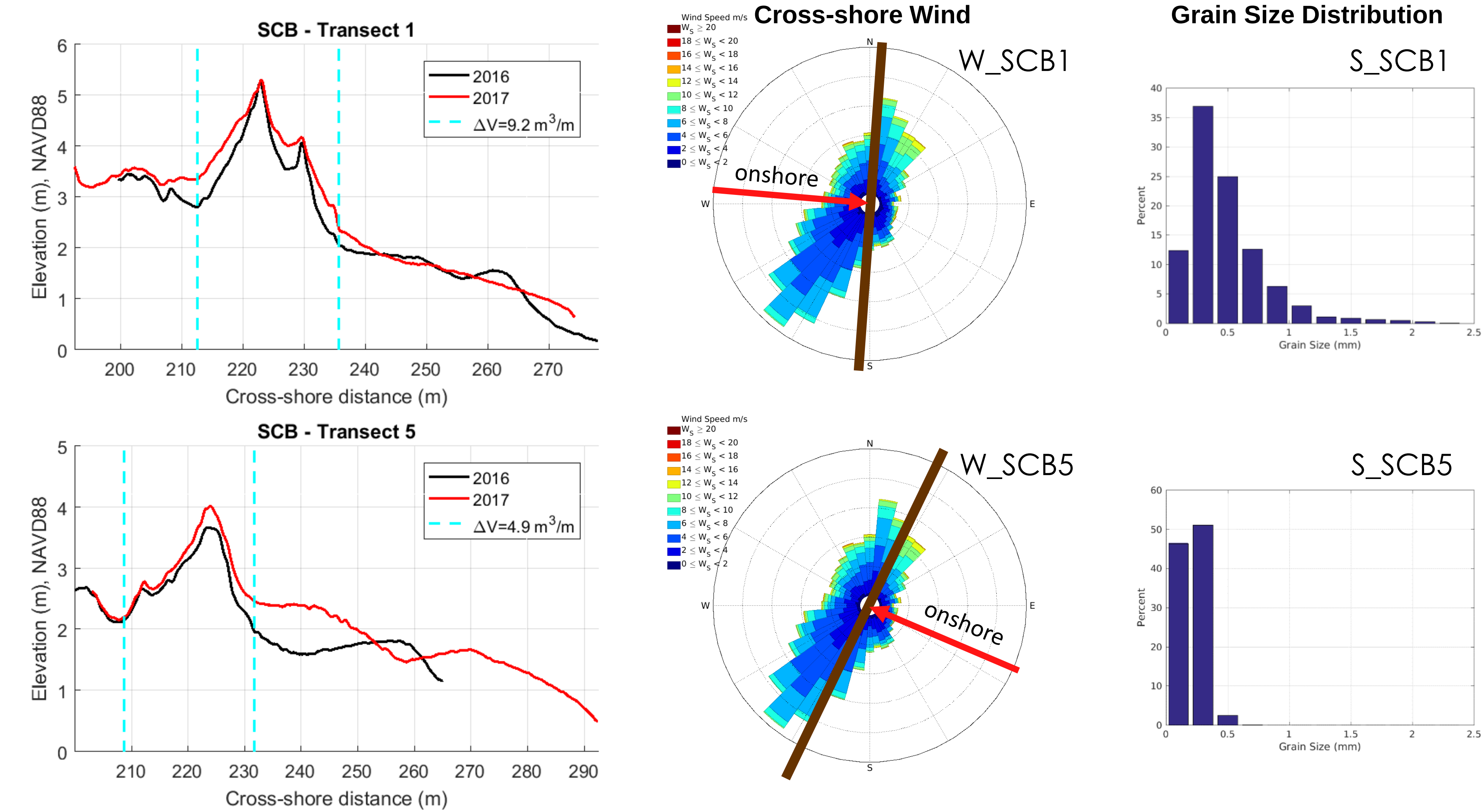


SCB1

Field = 9.2 m^3/m

SCB5

Field = 4.9 m^3/m



SCB1

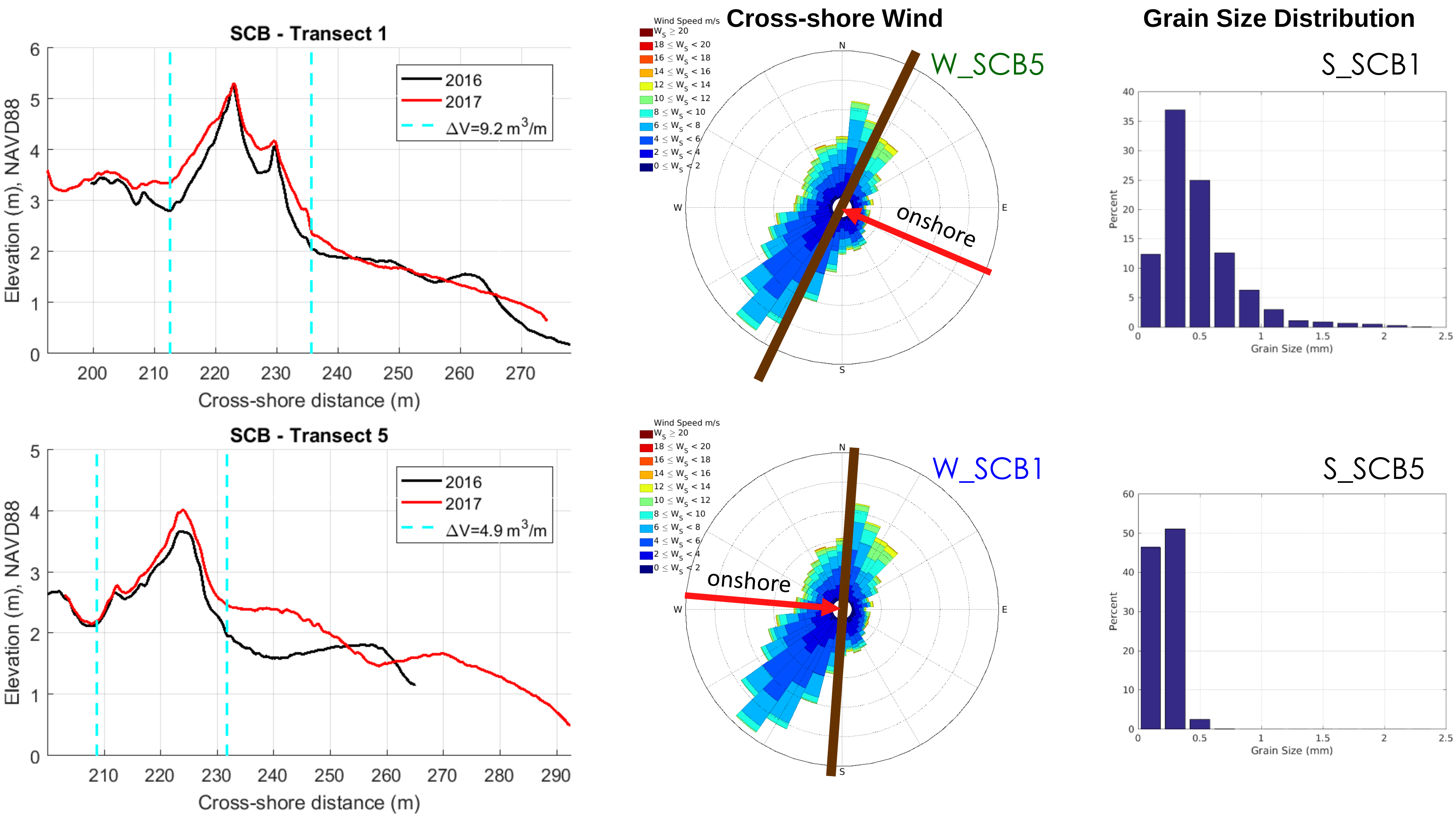
Field = 9.2 m³/m

AeoLiS (W_SCB1; S_SCB1) = 9.2 m³/m

SCB5

Field = 4.9 m³/m

AeoLiS (W_SCB5; S_SCB5) = 11.9 m³/m



SCB1

Field = 9.2 m³/m

AeoLiS (W_SCB1; S_SCB1) = 9.2 m³/m

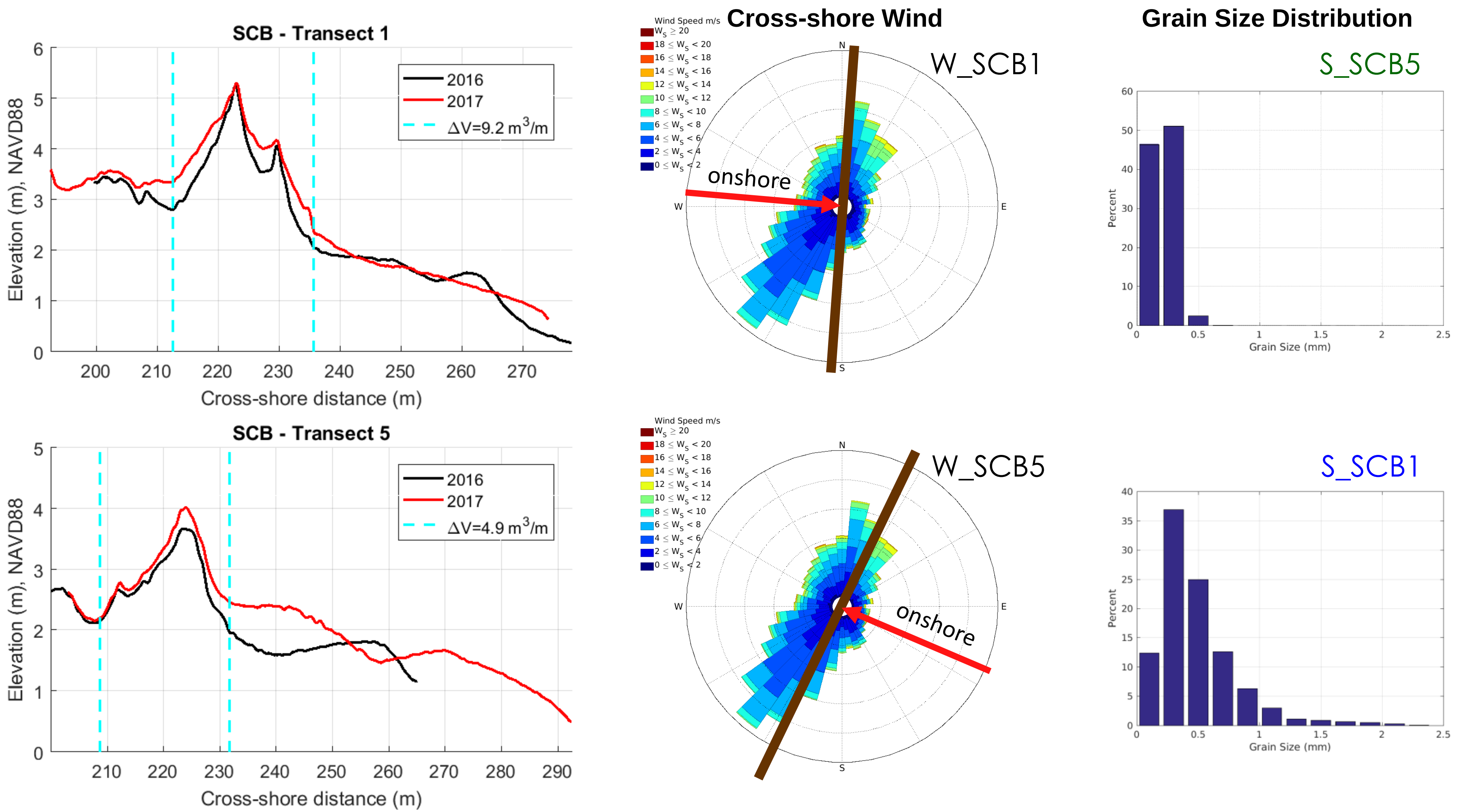
AeoLiS (W_SCB5; S_SCB1) = 7.5 m³/m (-18%)

SCB5

Field = 4.9 m³/m

AeoLiS (W_SCB5; S_SCB5) = 11.9 m³/m

AeoLiS (W_SCB1; S_SCB5) = 19.7 m³/m (+66%)



SCB1

Field = 9.2 m³/m

AeoLiS (W_SCB1; S_SCB1) = 9.2 m³/m

AeoLiS (W_SCB5; S_SCB1) = 7.5 m³/m (-18%)

AeoLiS (W_SCB1; S_SCB5) = 19.5 m³/m (+112%)

SCB5

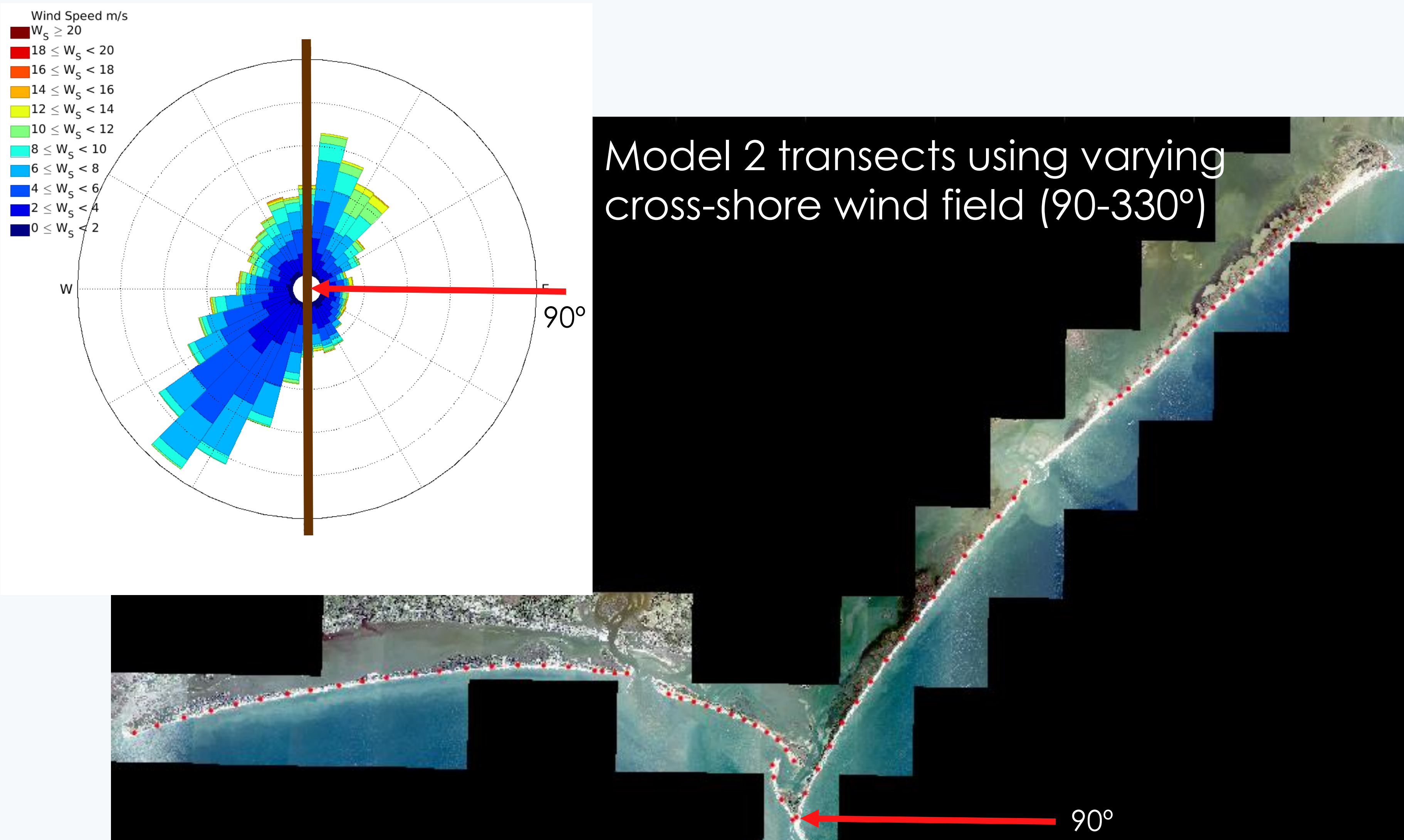
Field = 4.9 m³/m

AeoLiS (W_SCB5; S_SCB5) = 11.9 m³/m

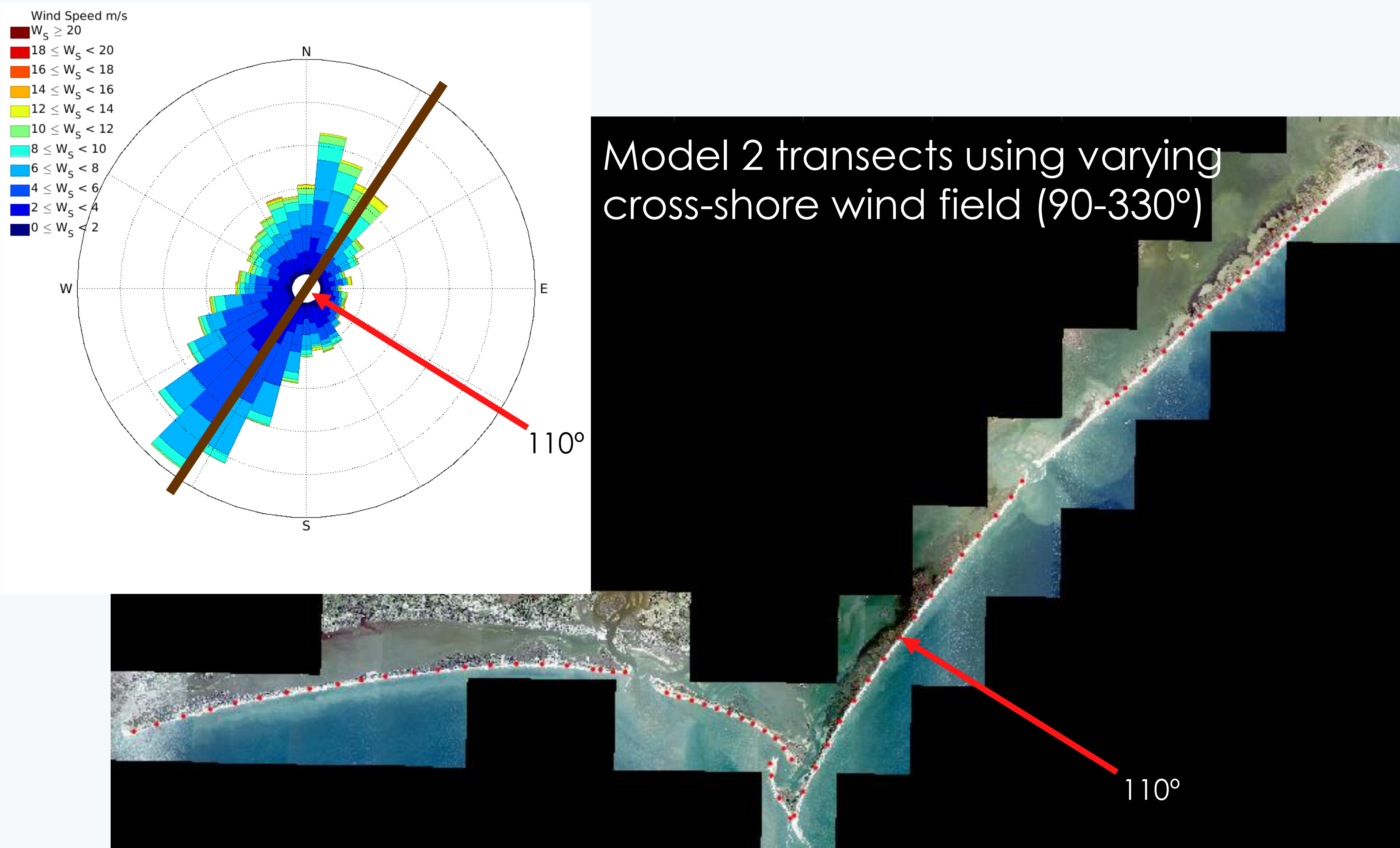
AeoLiS (W_SCB1; S_SCB5) = 19.7 m³/m (+66%)

AeoLiS (W_SCB5; S_SCB1) = 6.5 m³/m (-45%)

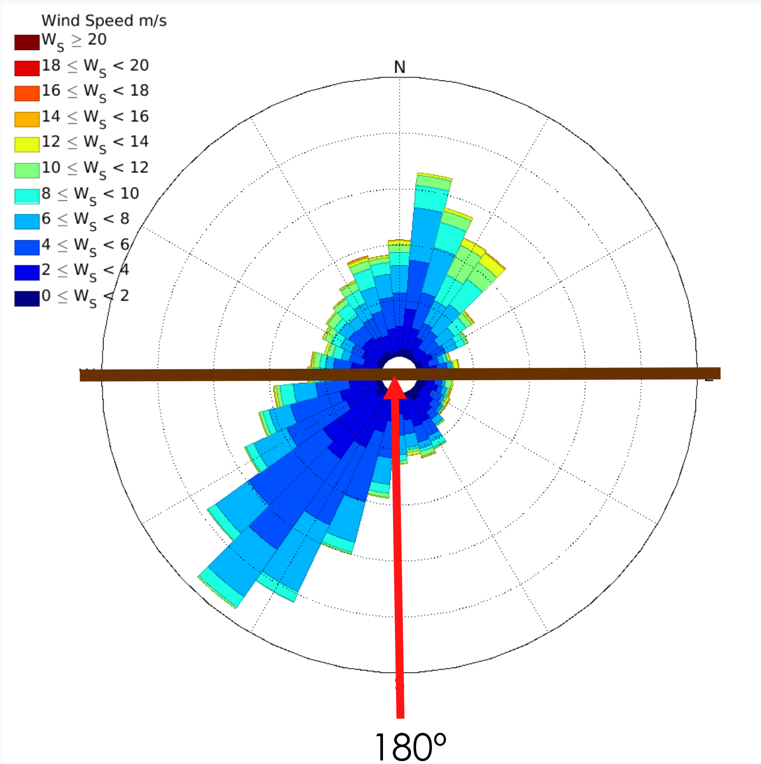
Cross-shore Wind Sensitivity



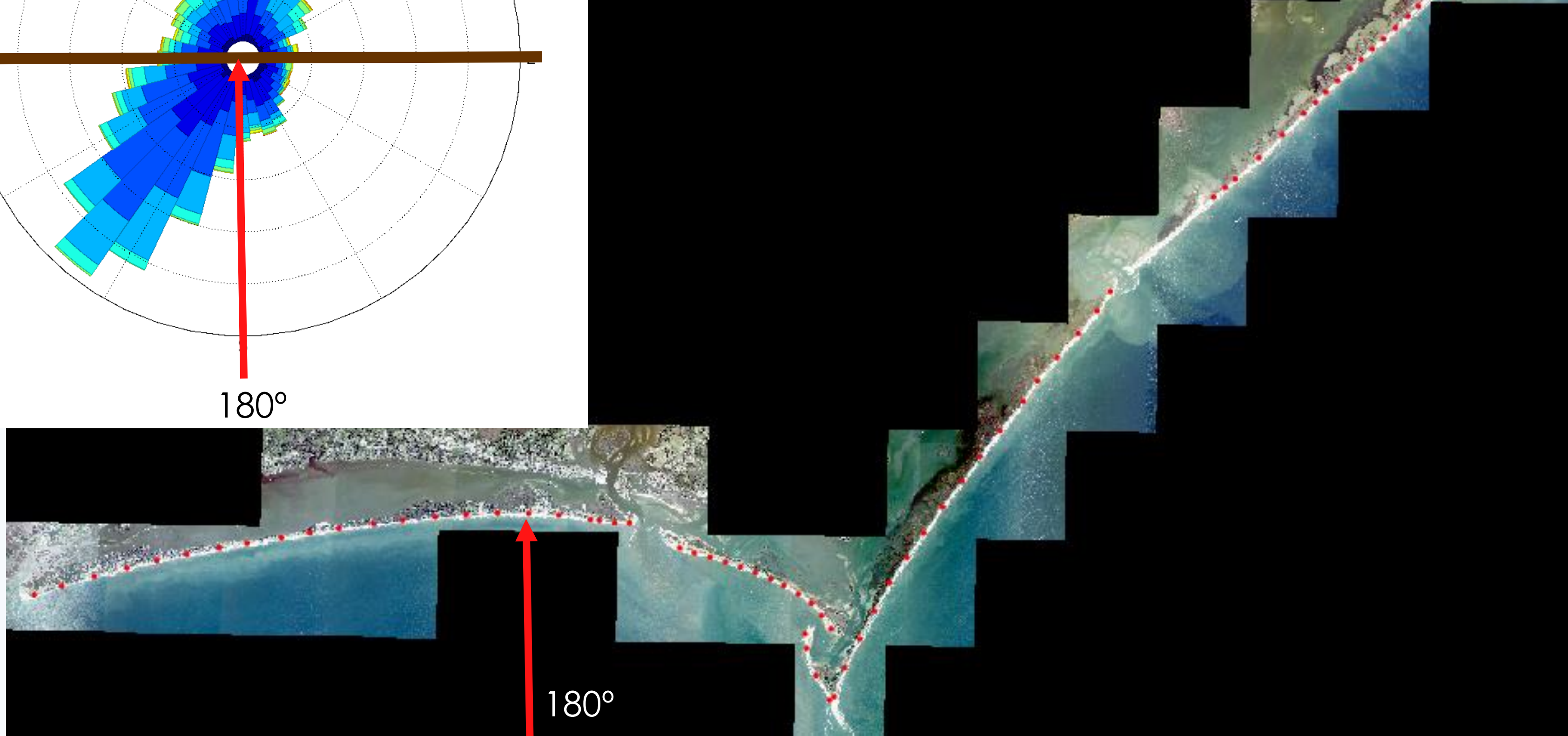
Cross-shore Wind Sensitivity



Cross-shore Wind Sensitivity



Model 2 transects using varying cross-shore wind field (90-330°)



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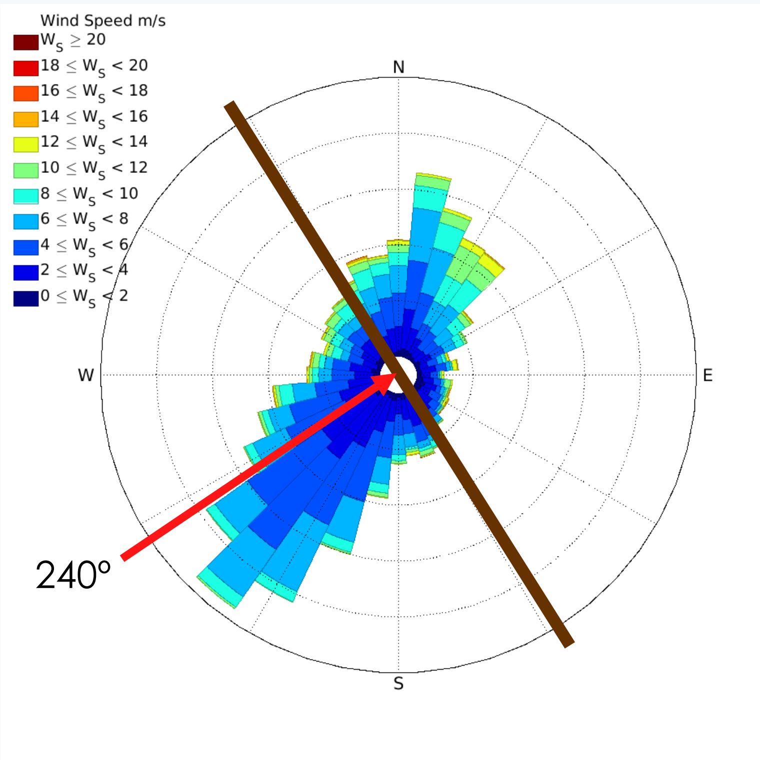
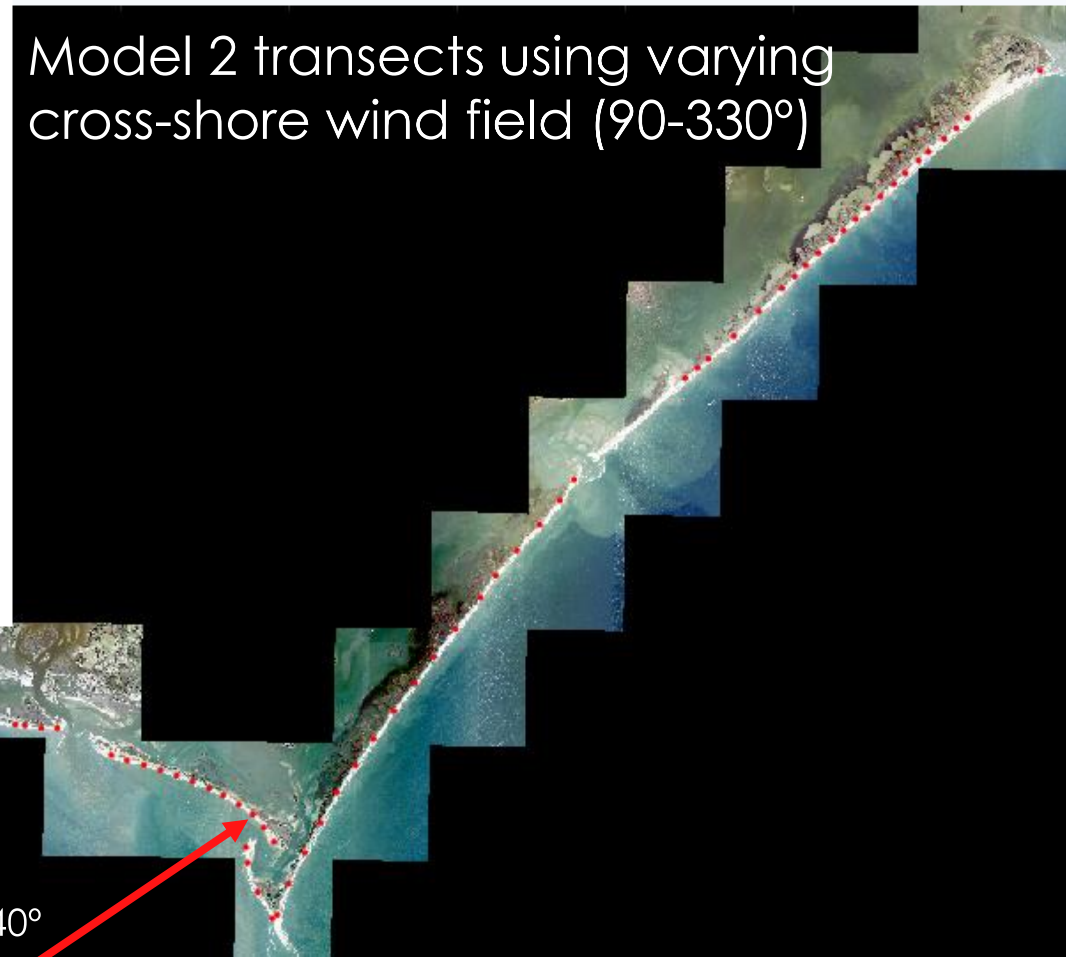
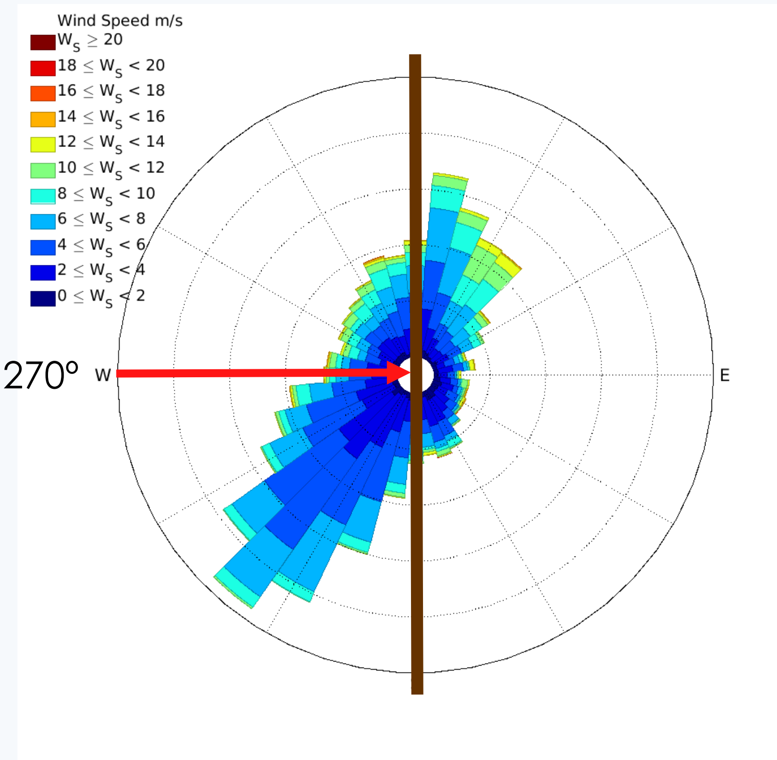




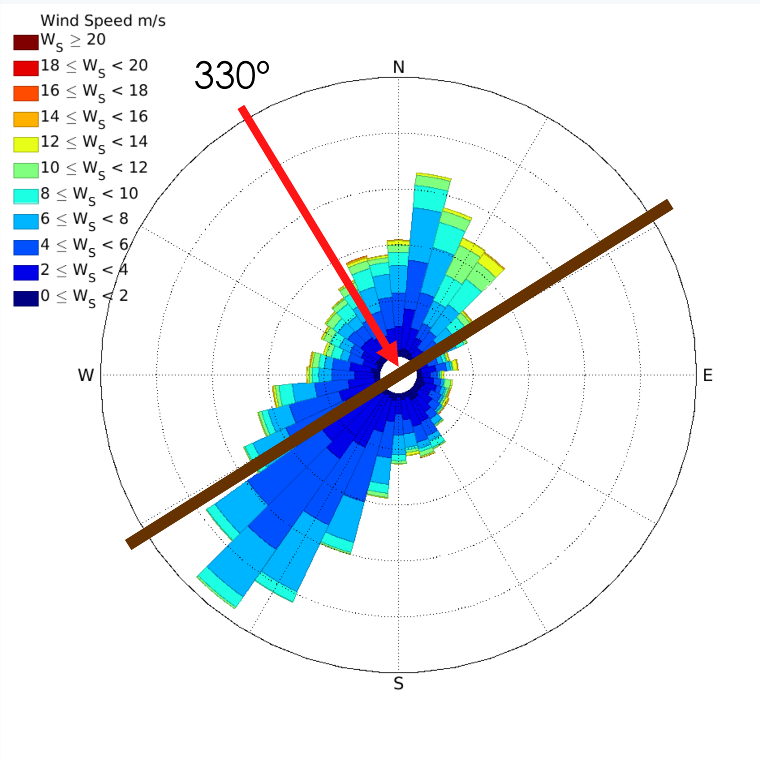
Cross-shore Wind Sensitivity

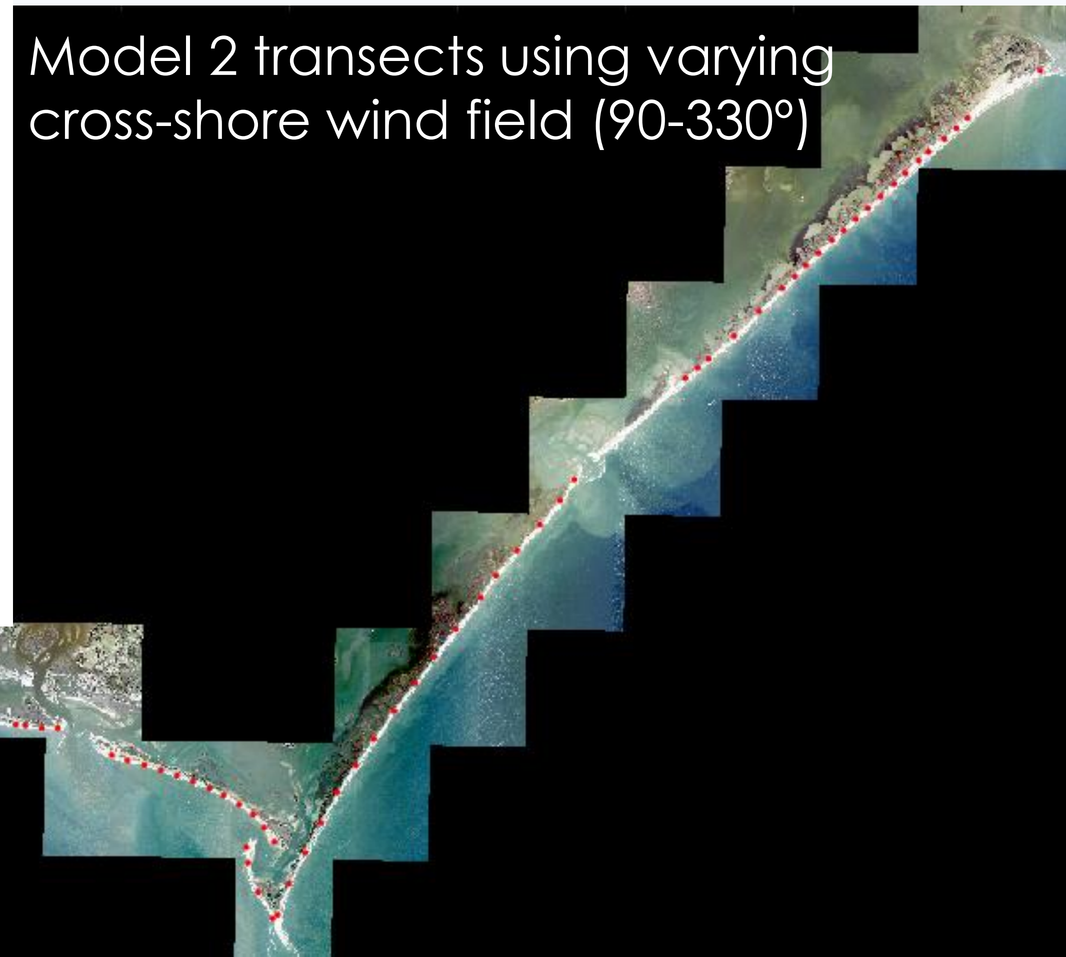
270°



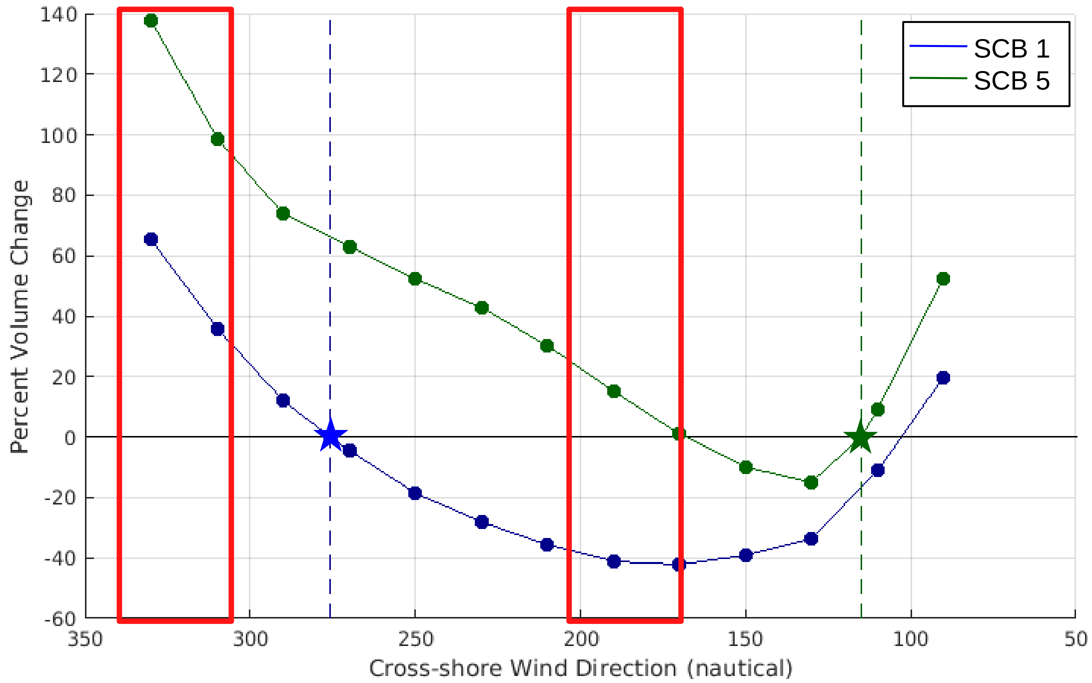
Model 2 transects using varying cross-shore wind field (90-330°)

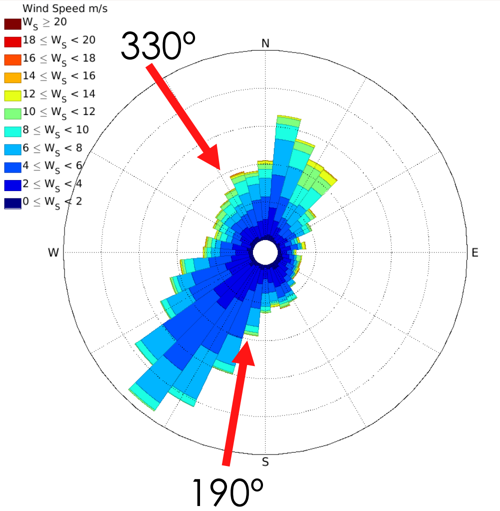
Cross-shore Wind Sensitivity

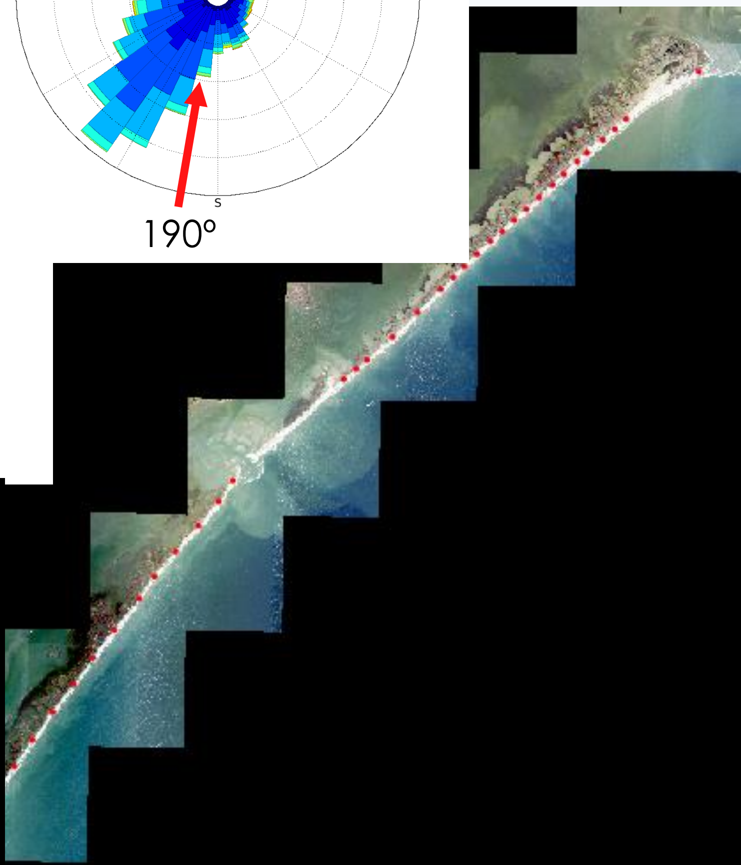




Cross-shore Wind Sensitivity



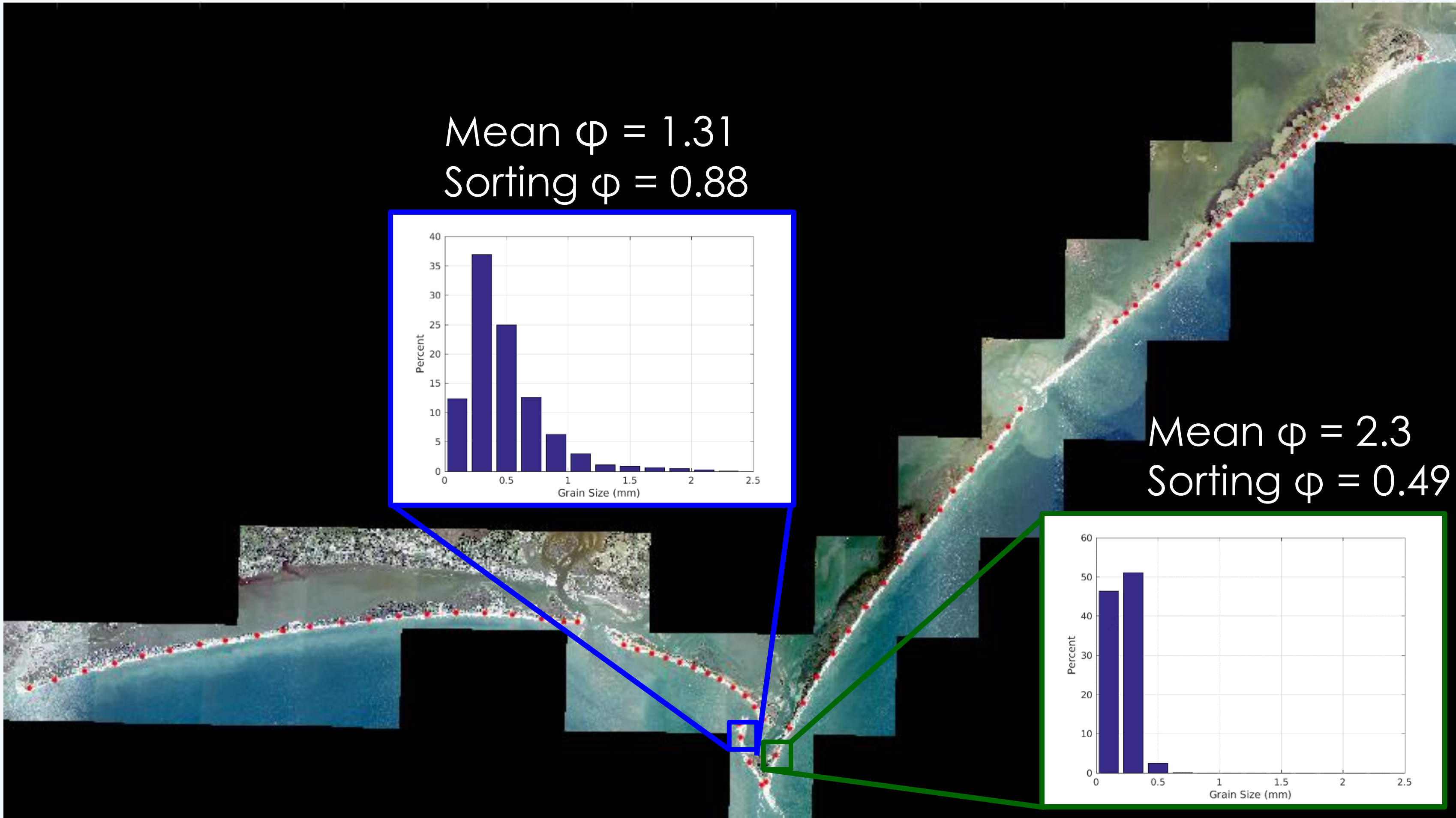




Largest sediment supply to the dune occurs for simulations with the wind field having the strongest cross-shore winds, not necessarily the most frequent.

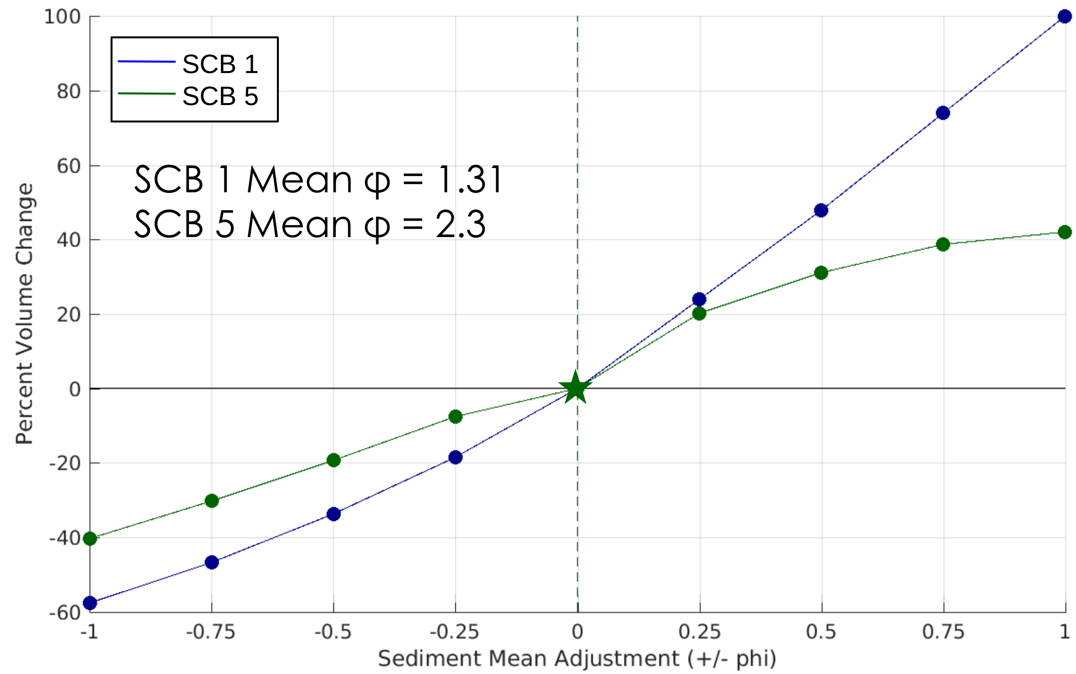
Sediment Distribution Sensitivity

- Mean (±1 phi)
- Sorting (25-200%)



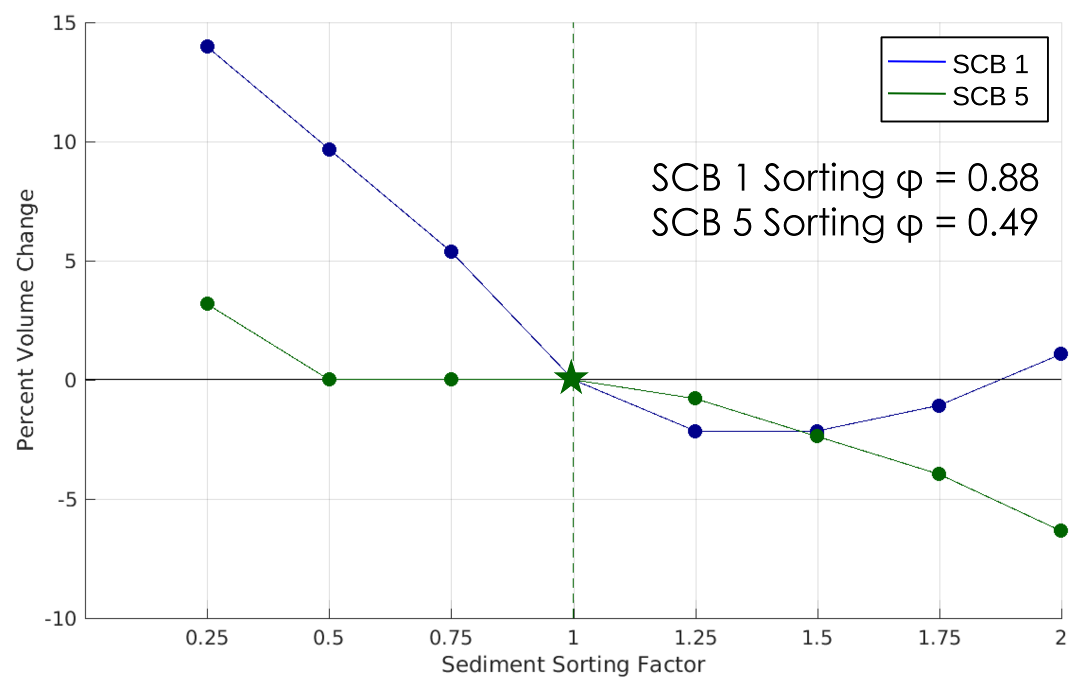
Mean (±1 phi)

- Decrease in grain size results in more volume change
- More sorted distribution (SCB 1) has more sensitivity to mean grain size



Sorting (25-200%)

- More sorted, coarse distribution (SCB 1) is more sensitive to narrowing the distribution
- Sorting has less effect than mean



Summary of Results

- Change rates of the shoreline position, dune toe location, and dune crest elevation vary at differing spatial and temporal scales
  - Dune recovery 2 cm/yr (multidecadal) and 15 cm/yr (interannual)
  - Types of recovery (vertical growth, deposition behind crest, etc.)
- Modeled dune accretion volumes are on the same order of magnitude captured in field dataset
- Largest volume change occurred for large cross-shore winds and fine sand on steep, sheltered beach
- Relative strength of controls on modeled sediment volume change
  - Strong cross-shore wind > grain size distribution
  - Wind magnitude > wind frequency
  - Mean grain size > sediment sorting

Ongoing Work - ecomorphodynamics

SCB1

- U. paniculata and A. breviligulata present
- A. breviligulata increased in density form 2016-2017

SCB5

- Only U. paniculata present
- Density consistent between 2016-2017

U. paniculata

A. breviligulata

Photo Credit: Katya Jay

Ongoing Work – data collection, analysis, and modeling

- October 2018 field work
- Finalize the 'natural' evolution of CALO: Processing remaining lidar datasets (topography & ecology)
- Simulate beach and dune evolution over a range of time scales using Windsurf:
  - Aeolis (Hoonhout and deVries, 2016)
  - XBeach (Roelvink et al., 2009)
  - Coastal Dune Model (Duran and Moore, 2013)