

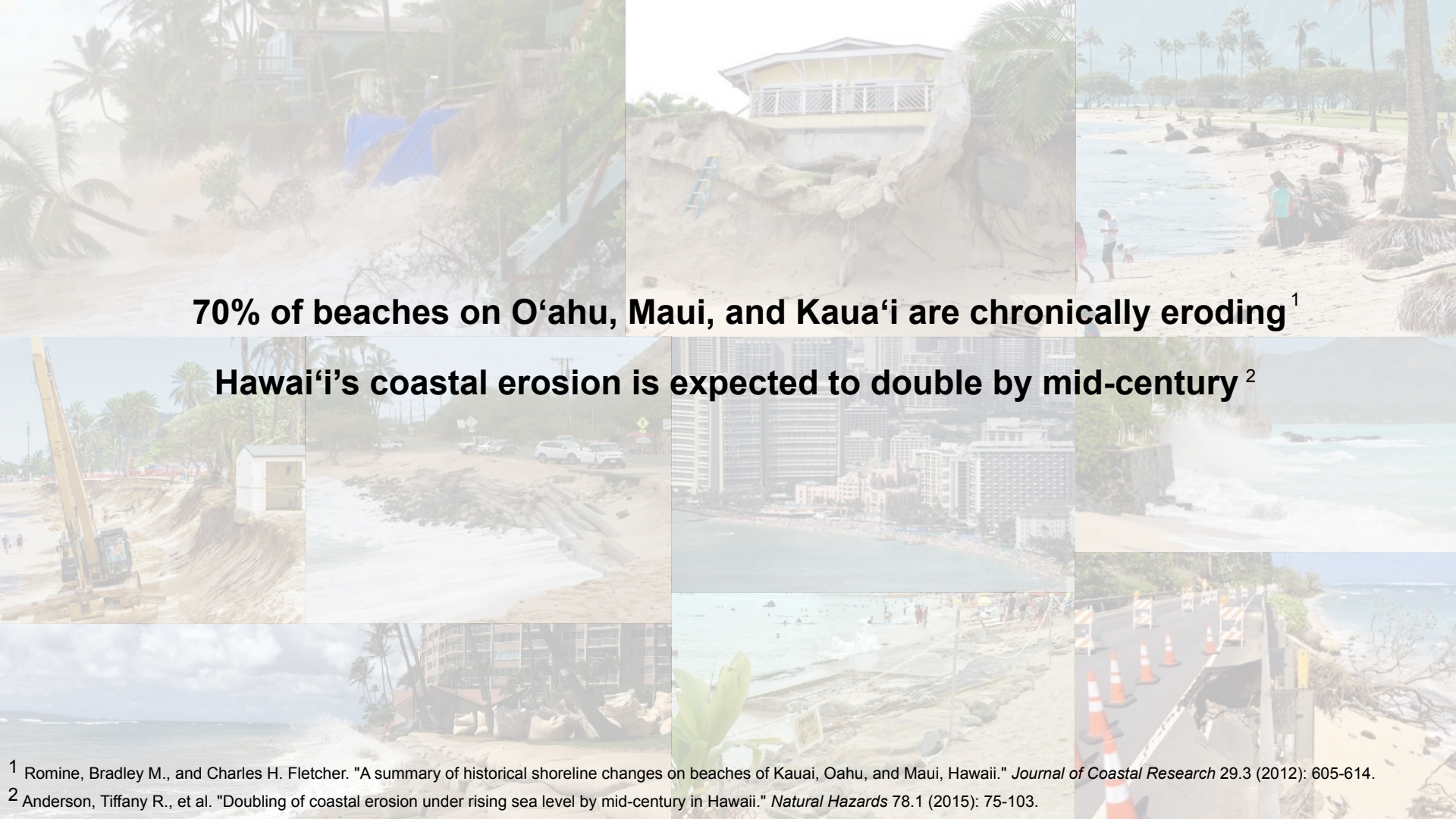
Coastal monitoring using UAS to track changes in beach morphology: Waikīkī, Hawai'i

Kristian McDonald, Chip Fletcher,
Tiffany Anderson, & Korey Wong

University of Hawai'i at Mānoa
Department of Earth Sciences
Coastal Geology Group





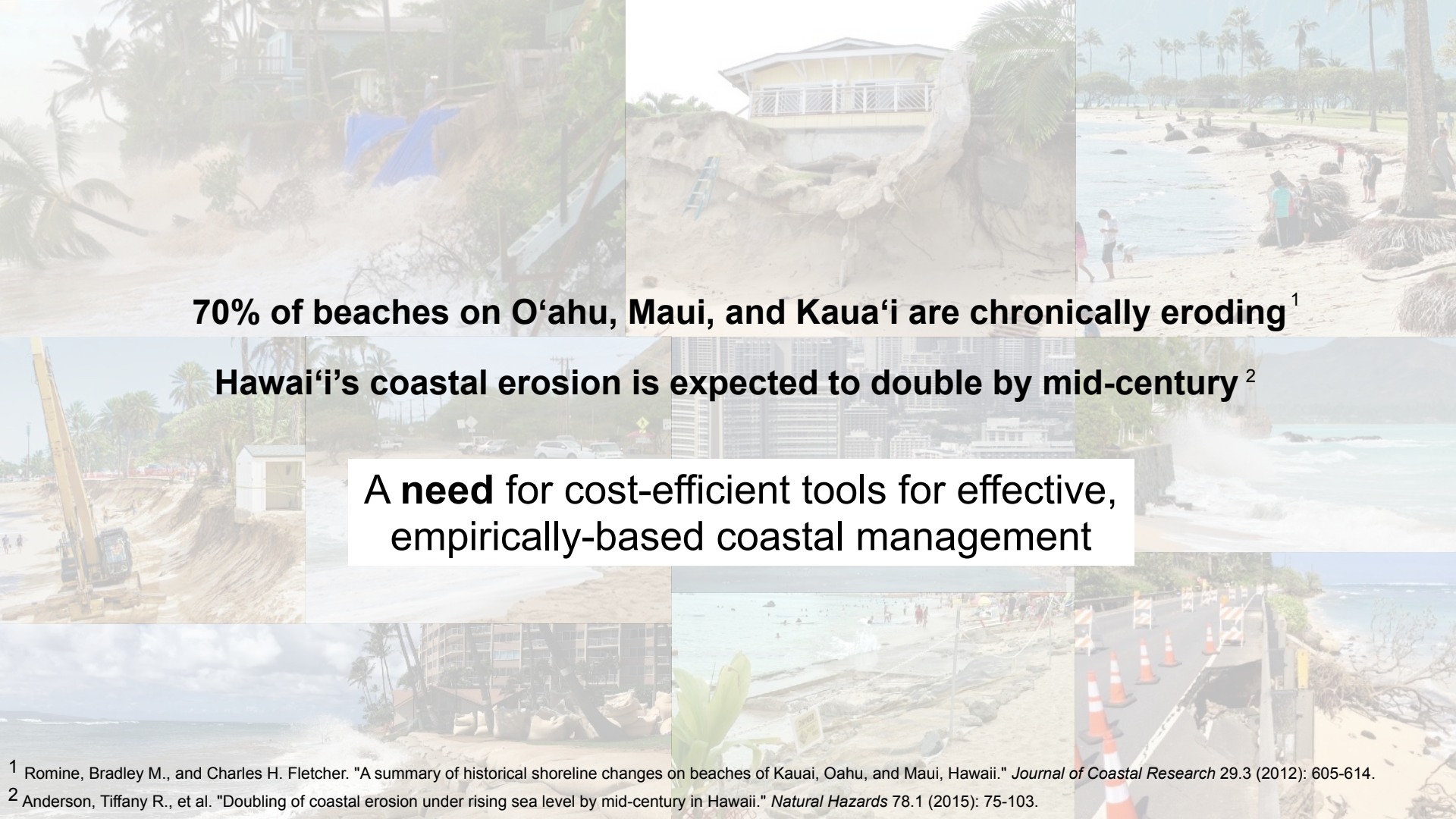


70% of beaches on O'ahu, Maui, and Kaua'i are chronically eroding¹

Hawai'i's coastal erosion is expected to double by mid-century²

¹ Romine, Bradley M., and Charles H. Fletcher. "A summary of historical shoreline changes on beaches of Kauai, Oahu, and Maui, Hawaii." *Journal of Coastal Research* 29.3 (2012): 605-614.

² Anderson, Tiffany R., et al. "Doubling of coastal erosion under rising sea level by mid-century in Hawaii." *Natural Hazards* 78.1 (2015): 75-103.



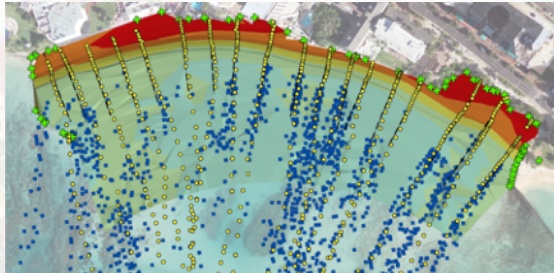
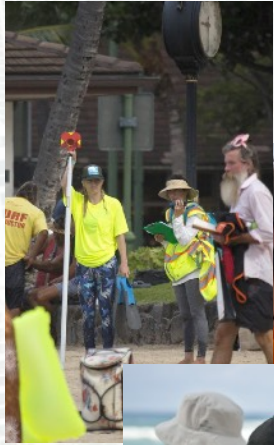
70% of beaches on O'ahu, Maui, and Kaua'i are chronically eroding¹

Hawai'i's coastal erosion is expected to double by mid-century²

A **need** for cost-efficient tools for effective,
empirically-based coastal management

¹ Romine, Bradley M., and Charles H. Fletcher. "A summary of historical shoreline changes on beaches of Kauai, Oahu, and Maui, Hawaii." *Journal of Coastal Research* 29.3 (2012): 605-614.

² Anderson, Tiffany R., et al. "Doubling of coastal erosion under rising sea level by mid-century in Hawaii." *Natural Hazards* 78.1 (2015): 75-103.



Total Station and Rod

~8 hours in the field

Difficult in crowded conditions, relies on line of sight

Undersampled

Nearshore data

Unmanned Aerial Systems

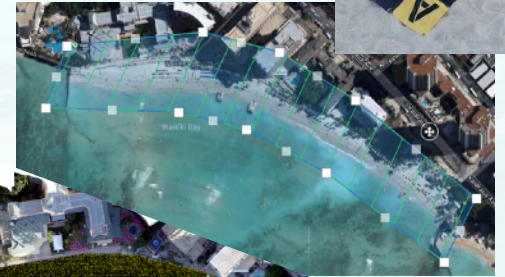
~1 hour in the field

Bird's eye view

Very high resolution (~3 cm/pix)

Limited to subaerial beach

Relatively cheap, readily available, easy to use, variety of data products





Study Area: Waikiki Beach



- Completely human-engineered system
- Economic importance - \$2.2 billion/year
- Culturally significant





- Compartmentalized littoral cell



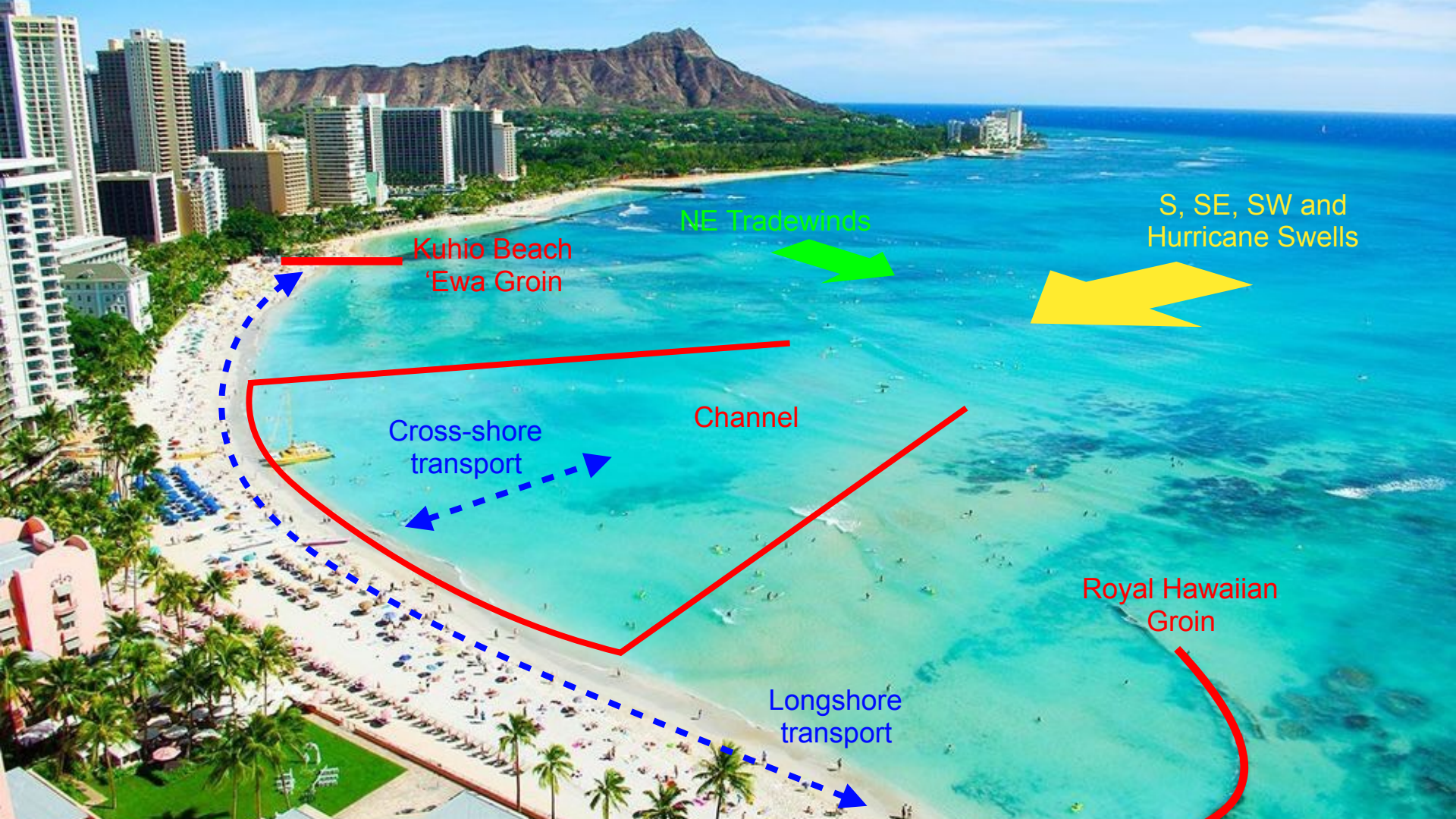
- Compartmentalized littoral cell
- Chronically eroding - consistent loss of subaerial beach year to year



- Compartmentalized littoral cell
- Chronically eroding - consistent loss of subaerial beach year to year
- Primarily influenced by summer south swells and the occasional storm or hurricane



- Compartmentalized littoral cell
- Chronically eroding - consistent loss of subaerial beach year to year
- Primarily influenced by summer south swells and the occasional storm or hurricane
- Weekly surveys for 8 months (April - November 2018)



NE Tradewinds

S, SE, SW and
Hurricane Swells

Kuhio Beach
'Ewa Groin

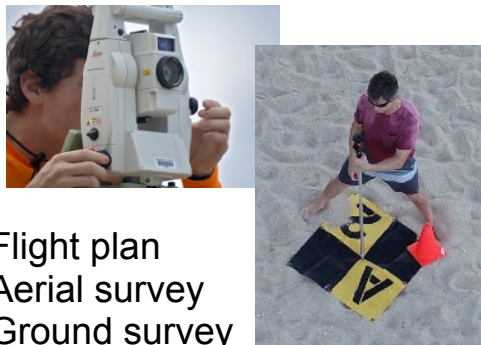
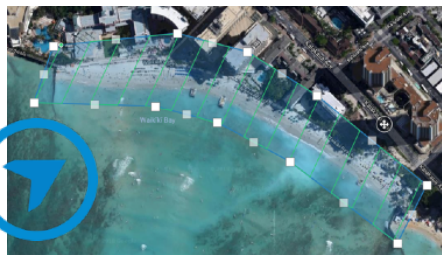
Cross-shore
transport

Channel

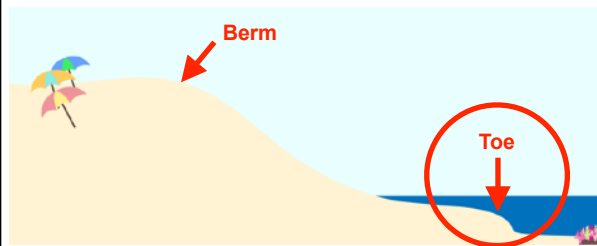
Royal Hawaiian
Groyne

Longshore
transport

Data Collection - - - - -> Post-Processing - - - - -> Data Analysis



- Flight plan
- Aerial survey
- Ground survey



- Error reduction
- Point cloud and orthomosaic generation



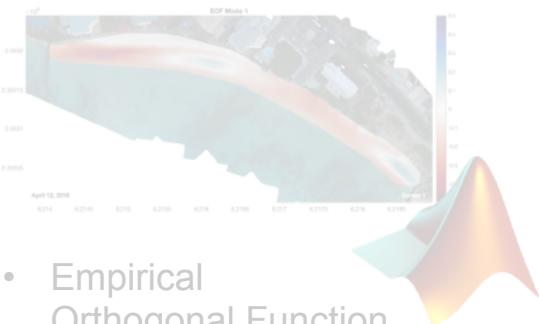
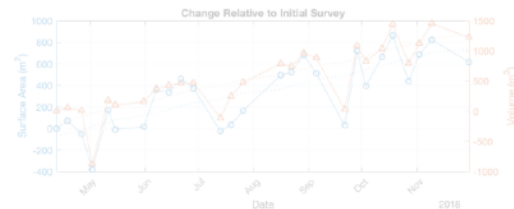
- Noise reduction
- "Bare earth" extraction



- Digital elevation model (DEM)
- Masking, smoothing, organizing

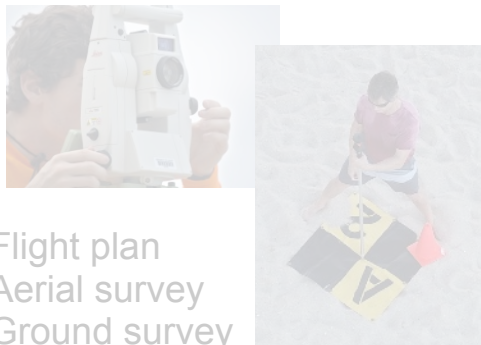


- Surface area and volume analysis (broader beach response)

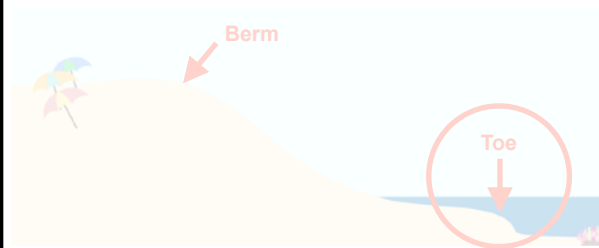


- Empirical Orthogonal Function analysis (sediment transport processes)

Data Collection - - - - ➔ Post-Processing - - - - ➔ Data Analysis



- Flight plan
- Aerial survey
- Ground survey



- Error reduction
- Point cloud and orthomosaic generation



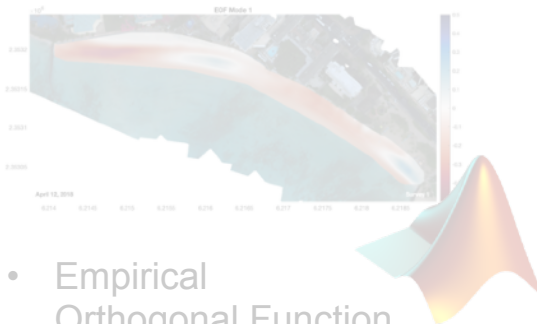
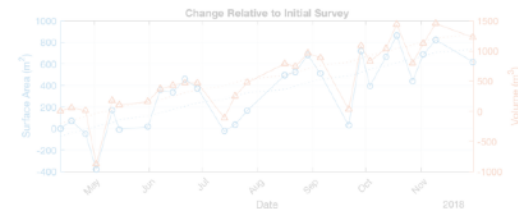
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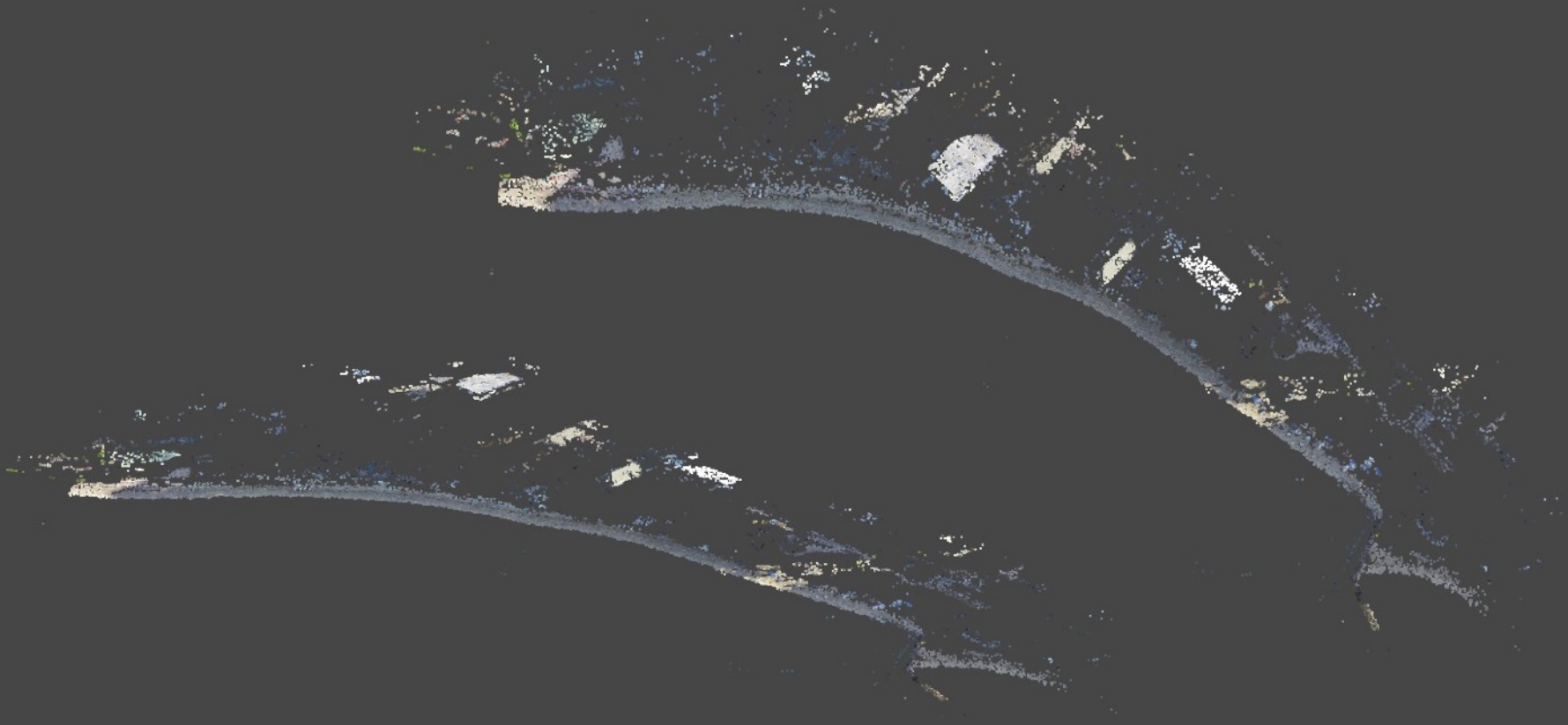
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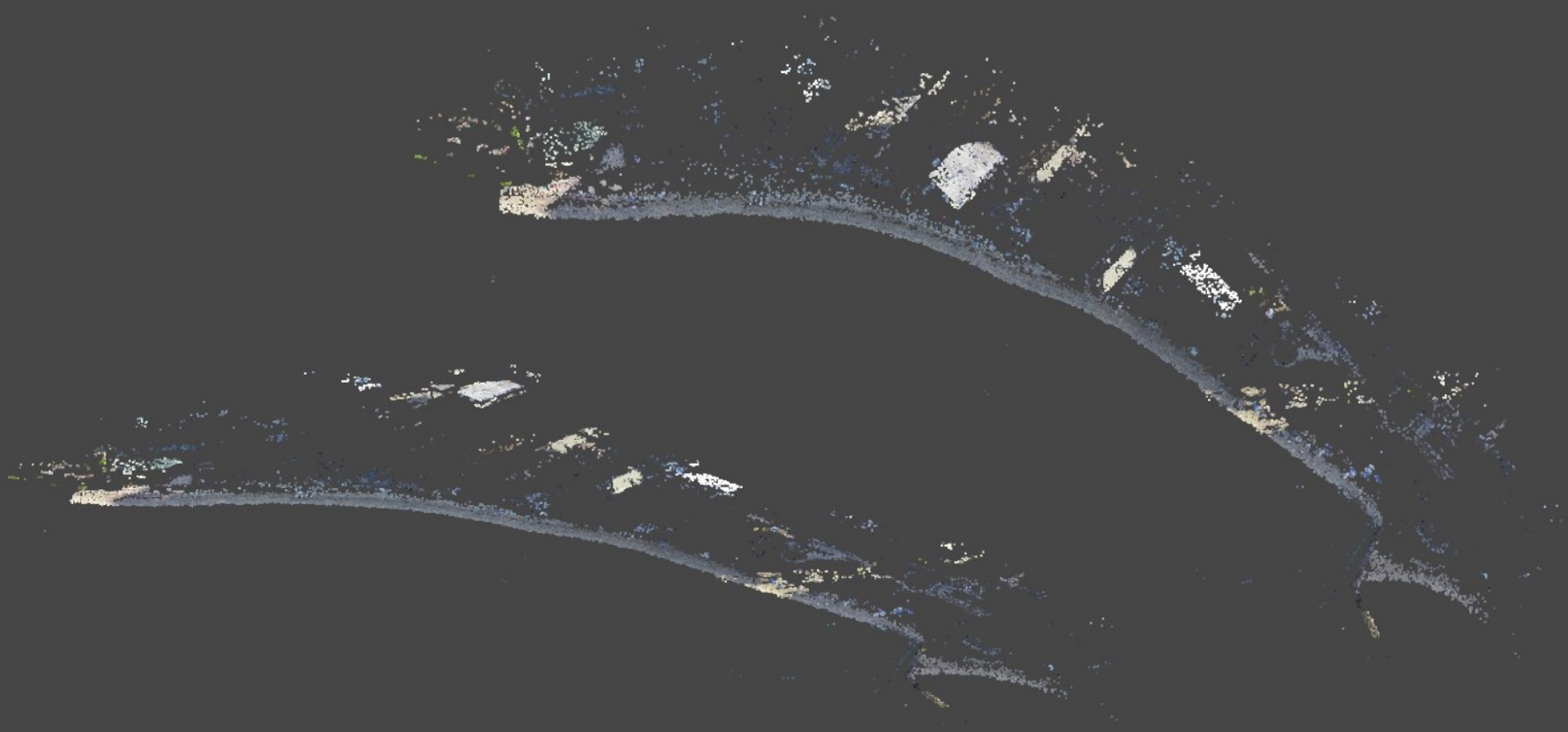
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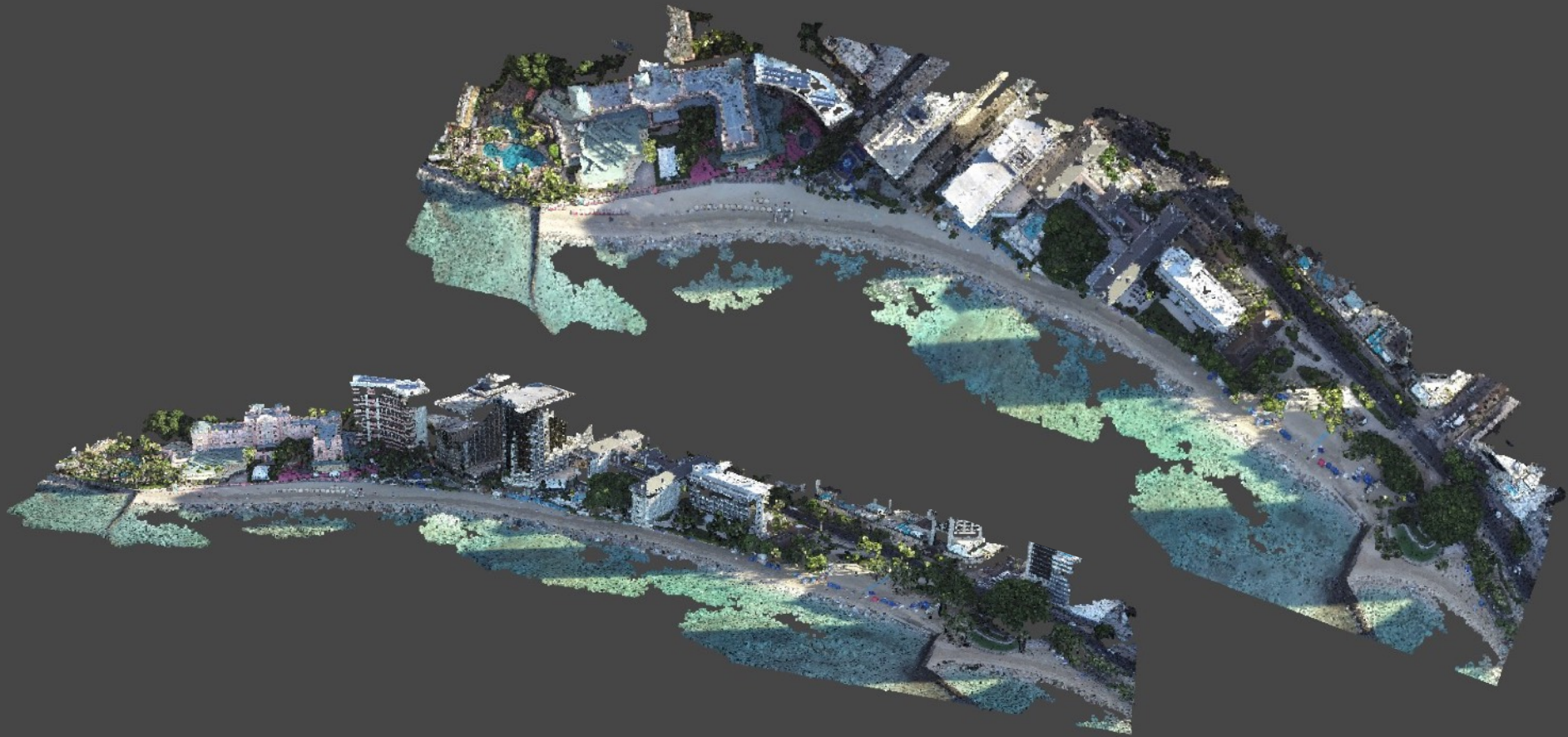
- Empirical Orthogonal Function analysis (sediment transport processes)



Sparse Cloud - Rudimentary 3-D model based off of common points across photos



Iterative error analysis to delete the worst of the points based on uncertainty parameters



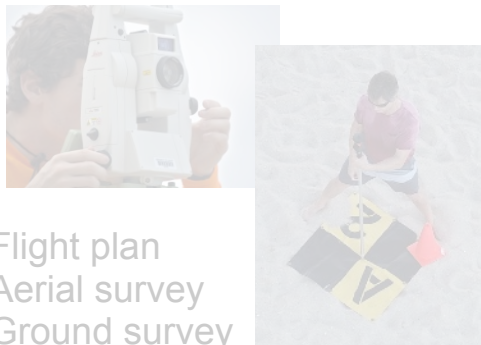
Dense Cloud - Robust point cloud based off most accurate points of the sparse cloud



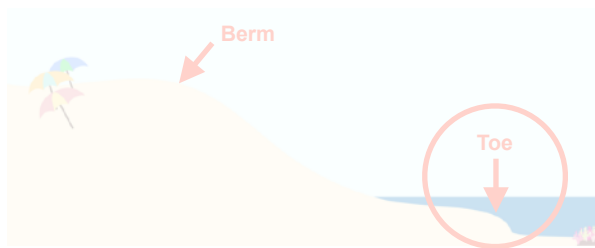
Orthomosaic - Geometrically
corrected mosaic of photos

04/12/2018

Data Collection - - - -> Post-Processing - - - -> Data Analysis



- Flight plan
- Aerial survey
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- Error reduction
- Point cloud and orthomosaic generation



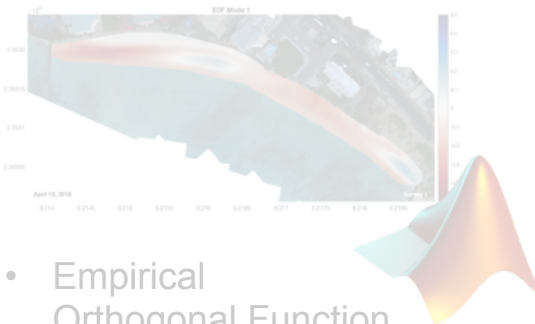
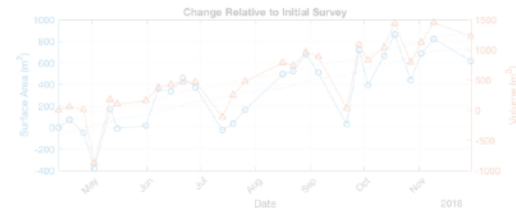
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- “Bare earth” extraction



- Digital elevation model (DEM)
- Masking, smoothing, organizing



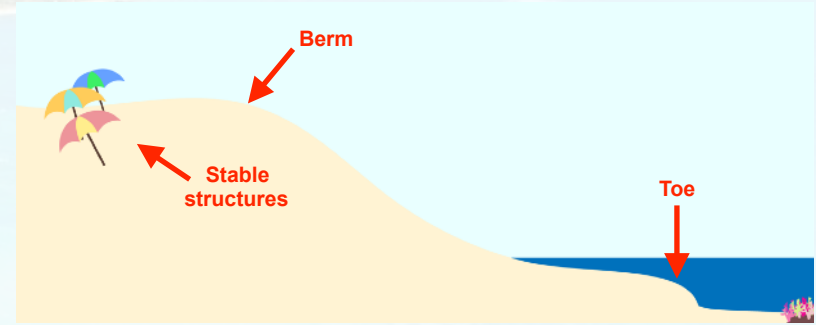
- Surface area and volume analysis (broader beach response)



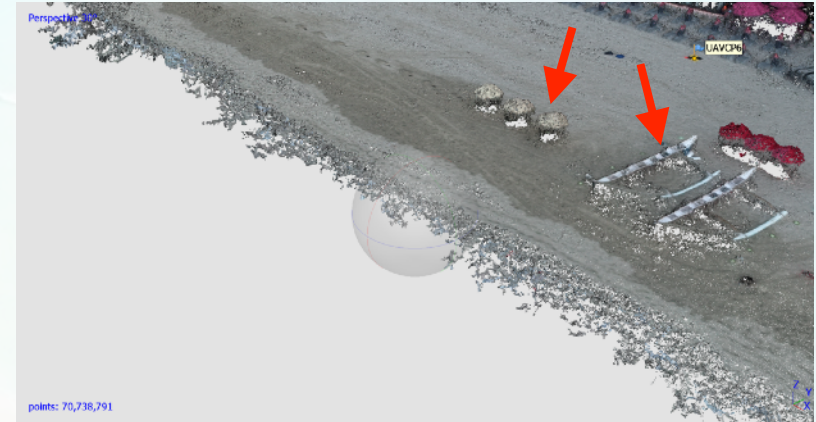
- Empirical Orthogonal Function analysis (sediment transport processes)

Dense Cloud Processing: LAStools

- Stable structures on the beach require removal

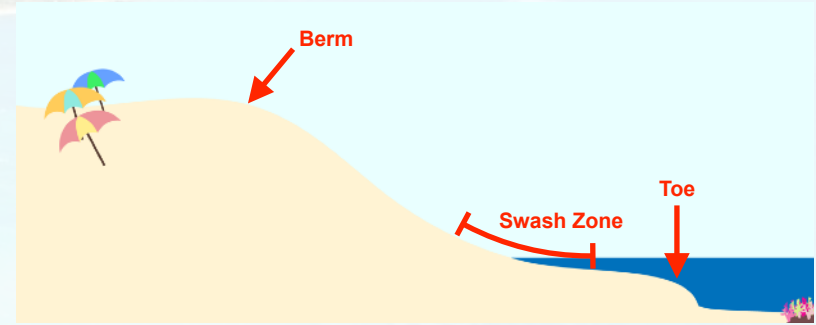


```
for /d %%i in (%IN_DIR%\*) do (  
  
  cd "%%i"  
  echo Current directory: %%i  
  
  IF EXIST "%IN_DIR%\mask_Beach.shp" (  
    lasclip -i *.laz ^  
      -poly %IN_DIR%\mask_Beach.shp ^  
      -odix _clip -olaz ^  
      -cores %NUM_CORES%  
  ) ELSE (  
    ECHO Polygon for clipping not found. No clipping  
  )  
  
  rmdir temp /s /q  
  mkdir temp  
  
  rmdir temp\tiles_raw /s /q  
  mkdir temp\tiles_raw  
  echo Created clean tiles_raw folder in temporary di  
  
  IF EXIST "*_clip.laz" (  
    lastile -i *_clip.laz ^
```

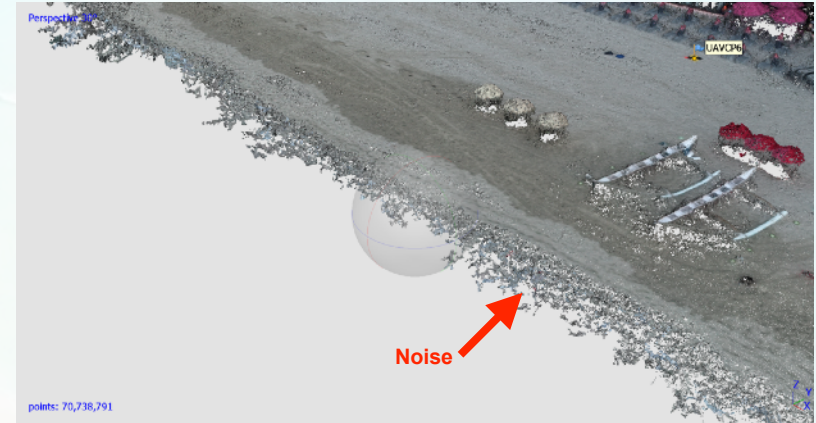


Dense Cloud Processing: LAStools

- Stable structures on the beach require removal
- Wave run-up at the foreshore results in noise - unable to resolve surface due to movement



```
for /d %%i in (%IN_DIR%\*) do (  
  
  cd "%%i"  
  echo Current directory: %%i  
  
  IF EXIST "%IN_DIR%\mask_Beach.shp" (  
    lasclip -i *.laz ^  
      -poly %IN_DIR%\mask_Beach.shp ^  
      -odix _clip -olaz ^  
      -cores %NUM_CORES%  
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  )  
  
  rmdir temp /s /q  
  mkdir temp  
  
  rmdir temp\tiles_raw /s /q  
  mkdir temp\tiles_raw  
  echo Created clean tiles_raw folder in temporary di  
  
  IF EXIST "*_clip.laz" (  
    lastile -i *_clip.laz ^
```





Objects

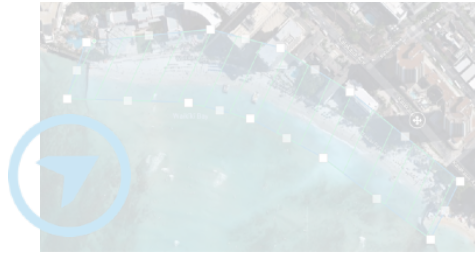
Low noise

Beach

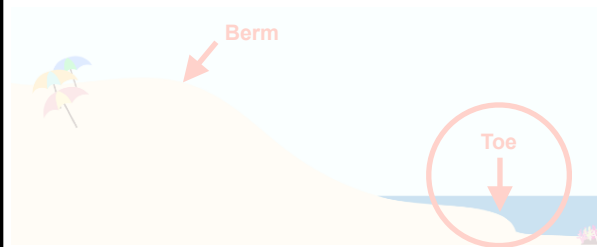


Digital Terrain/“Bare Earth” Model

Data Collection - - - -> Post-Processing - - - -> Data Analysis



- Flight plan
- Aerial survey
- Ground survey



- Error reduction
- Point cloud and orthomosaic generation



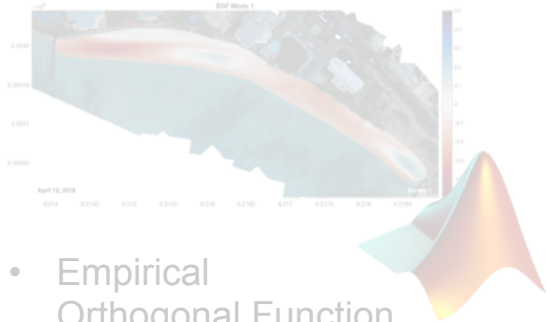
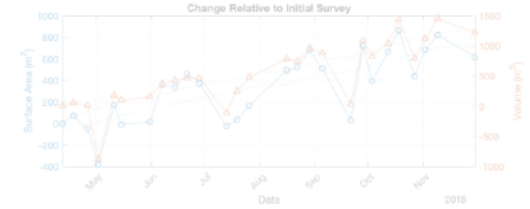
- Noise reduction
- "Bare earth" extraction



- Digital elevation model (DEM)
- Masking, smoothing, organizing

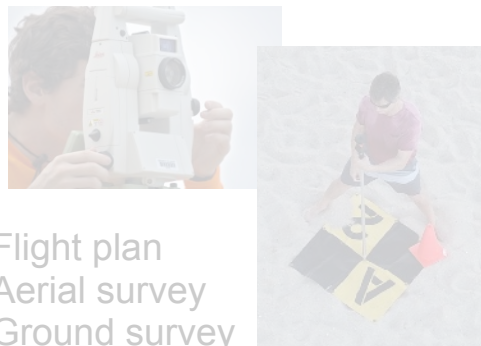


- Surface area and volume analysis (broader beach response)

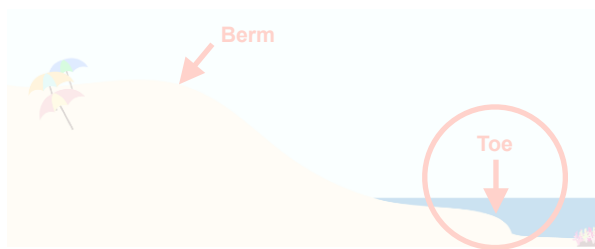


- Empirical Orthogonal Function analysis (sediment transport processes)

Data Collection - - - -> Post-Processing - - - -> Data Analysis



- Flight plan
- Aerial survey
- Ground survey



- Error reduction
- Point cloud and orthomosaic generation



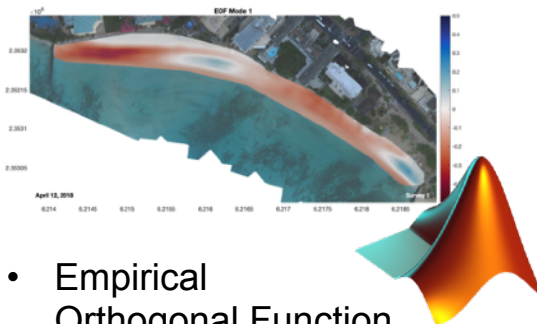
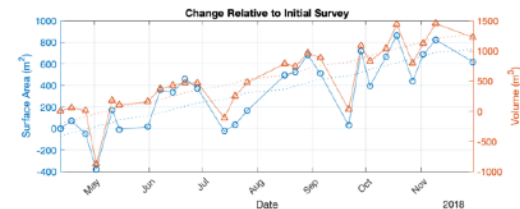
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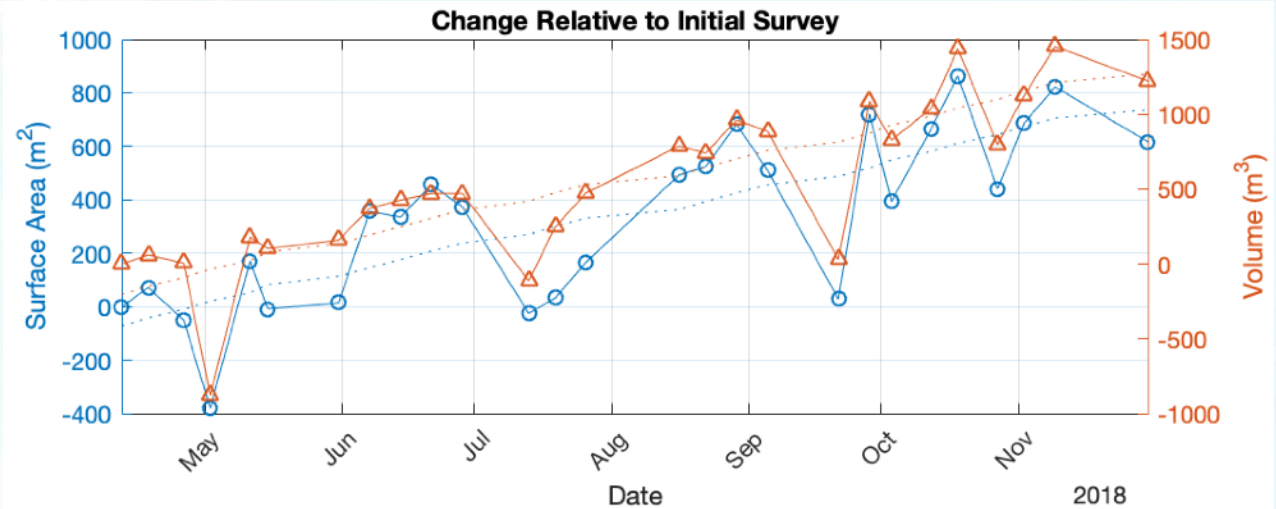
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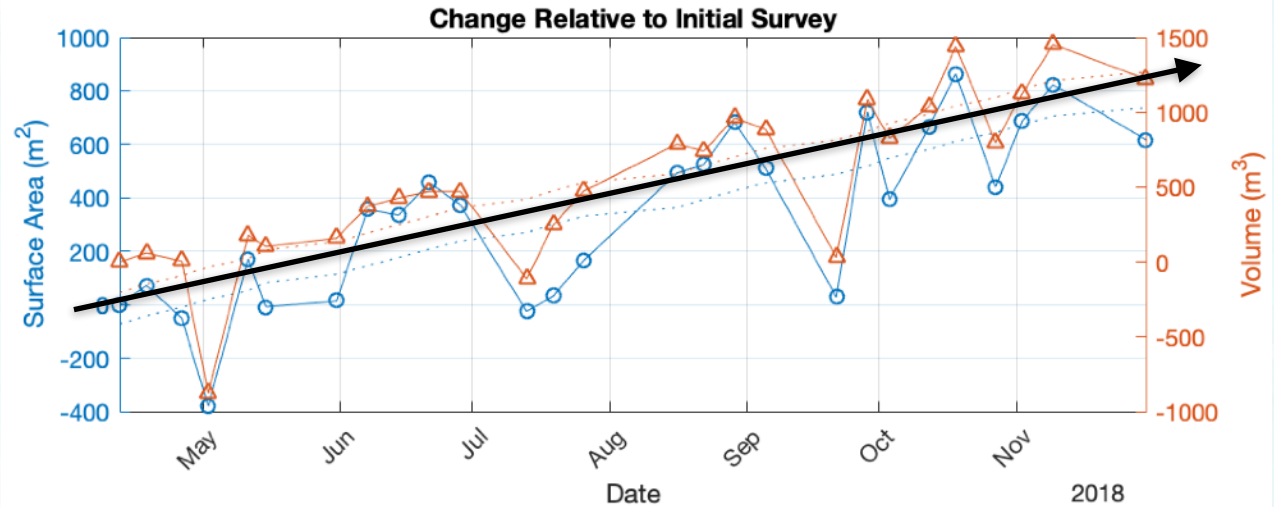
Results & Discussion

- Correlate variations in surface area and volume with conditions



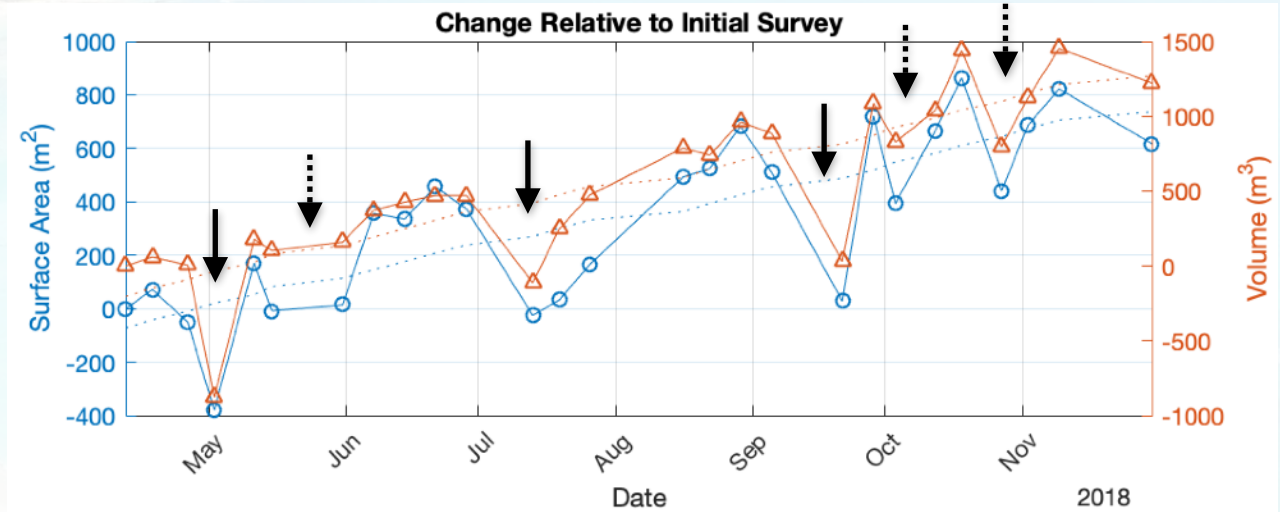
Results & Discussion

- Correlate variations in surface area and volume with conditions
- Overall increase in both surface area and volume



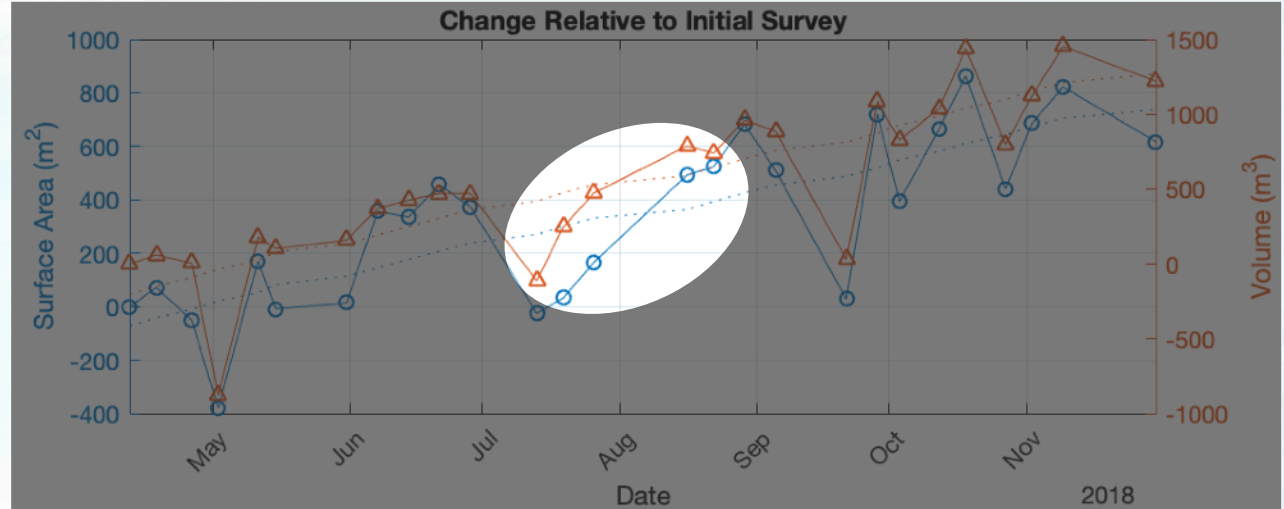
Results & Discussion

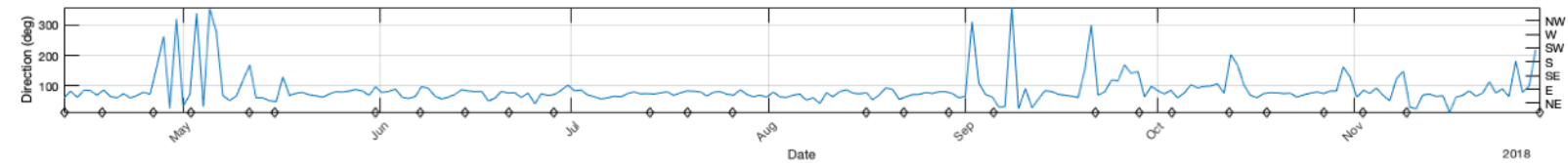
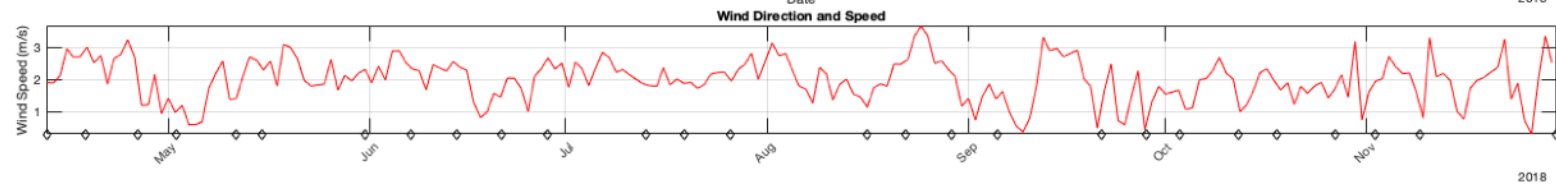
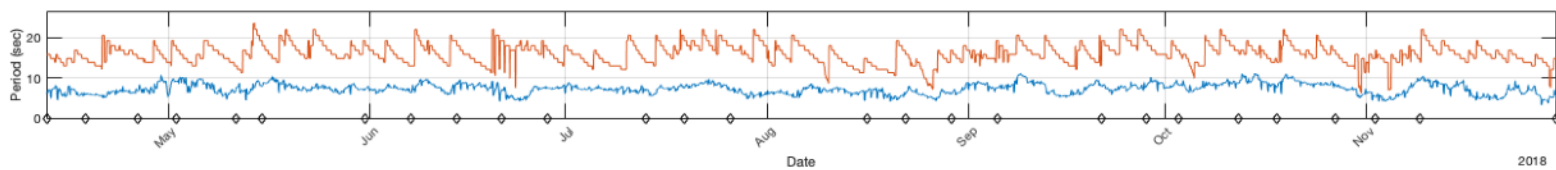
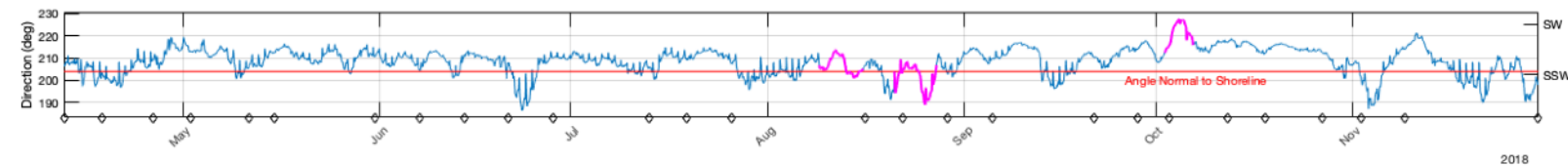
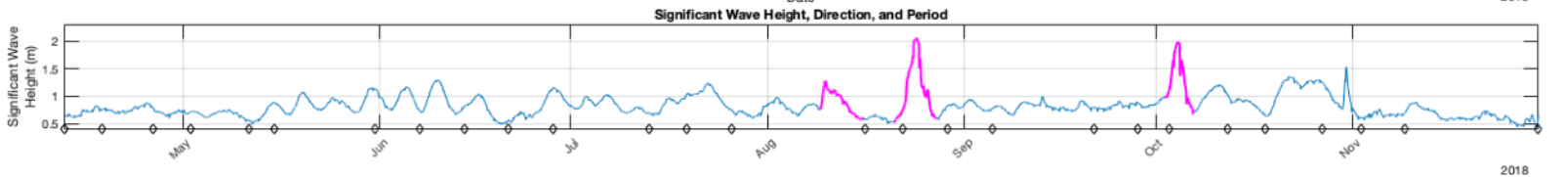
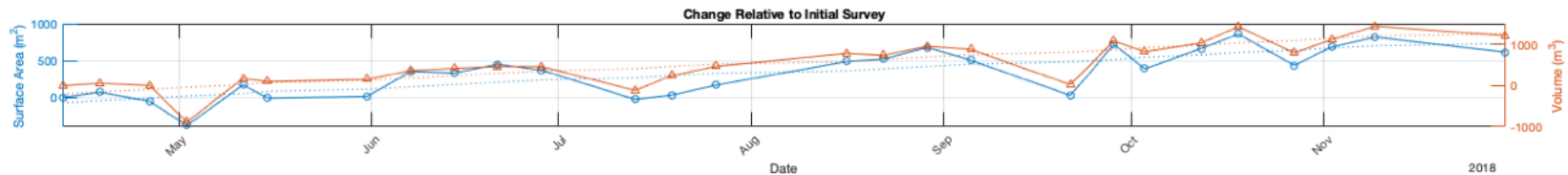
- Correlate variations in surface area and volume with conditions
- Overall increase in both surface area and volume
- Several erosion/recovery events



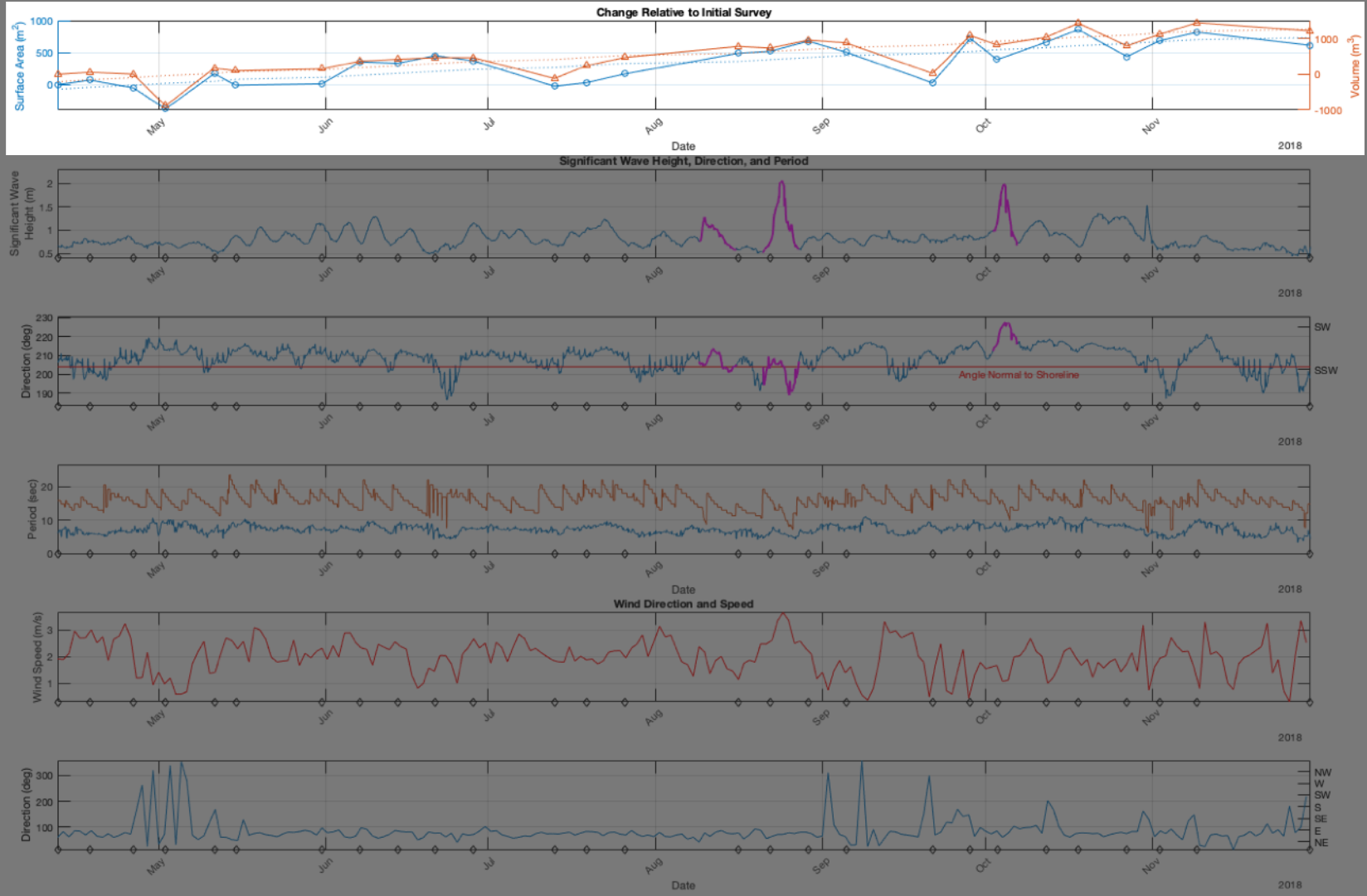
Results & Discussion

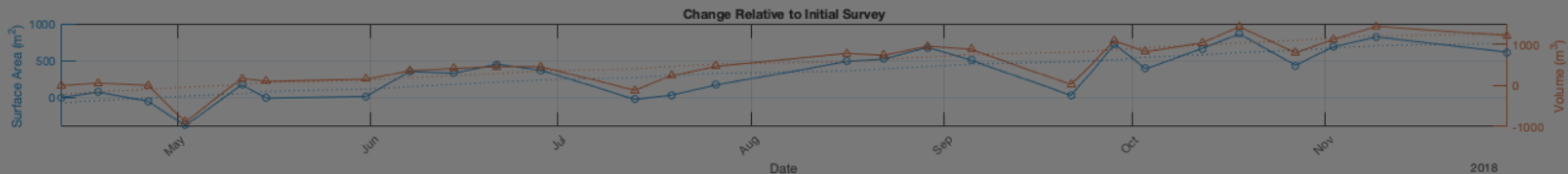
- Correlate variations in surface area and volume with conditions
- Overall increase in both surface area and volume
- Several erosion/recovery events
- Beach volume behavior relative to surface area



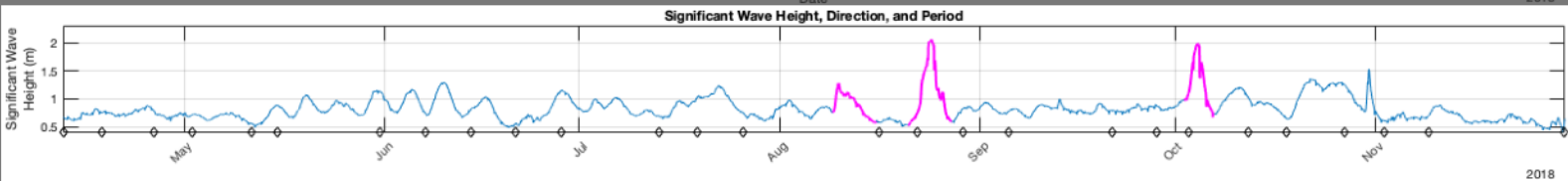


Surface
Area (m²)/
Volume (m³)

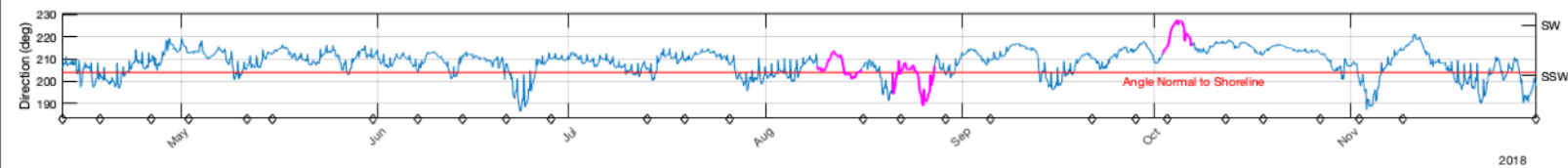




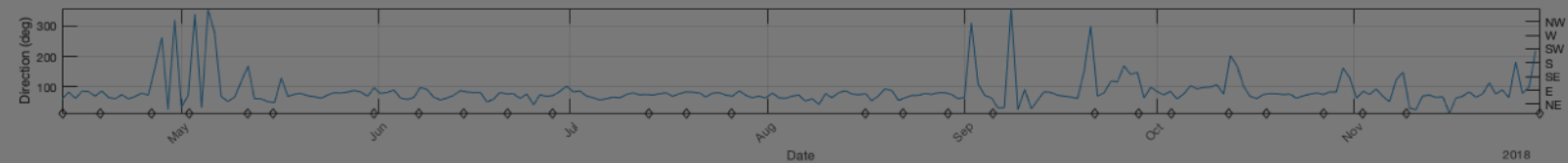
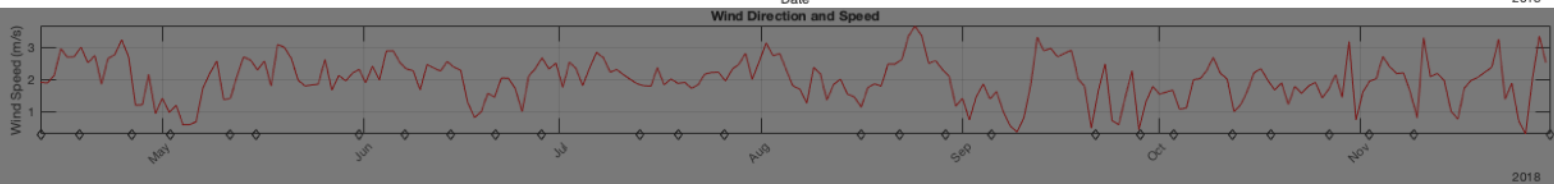
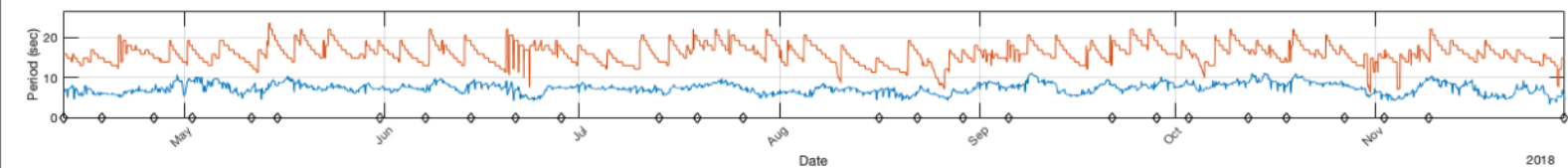
Significant
Wave Height
(m)

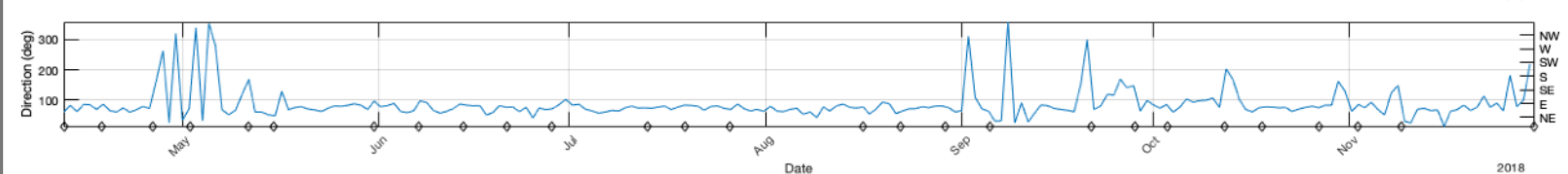
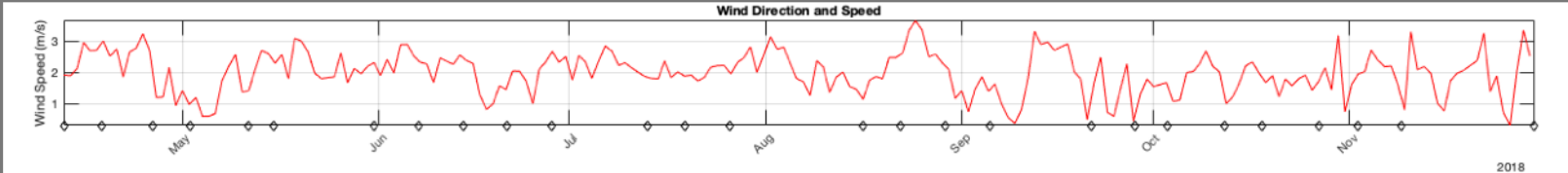
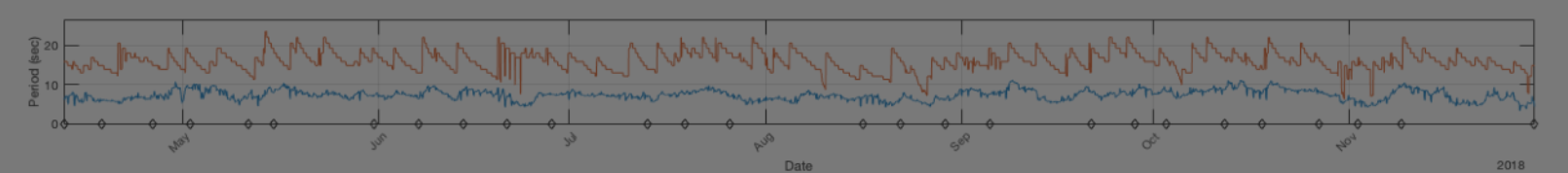
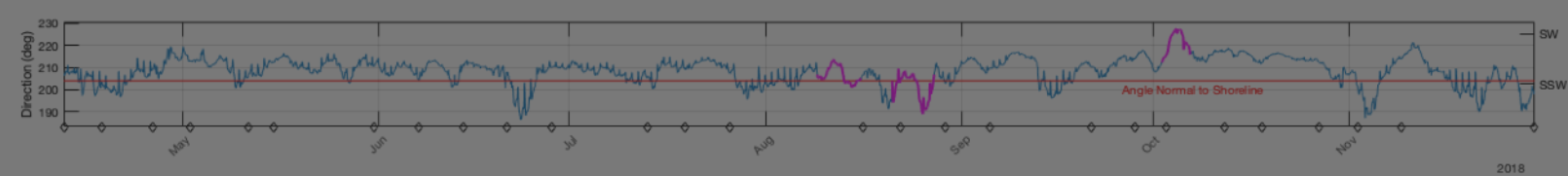
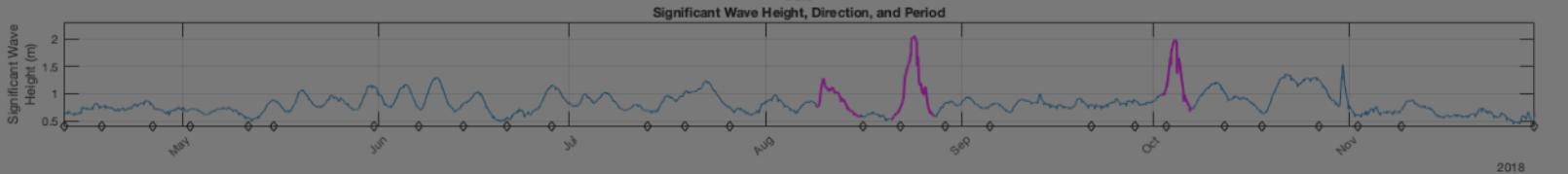
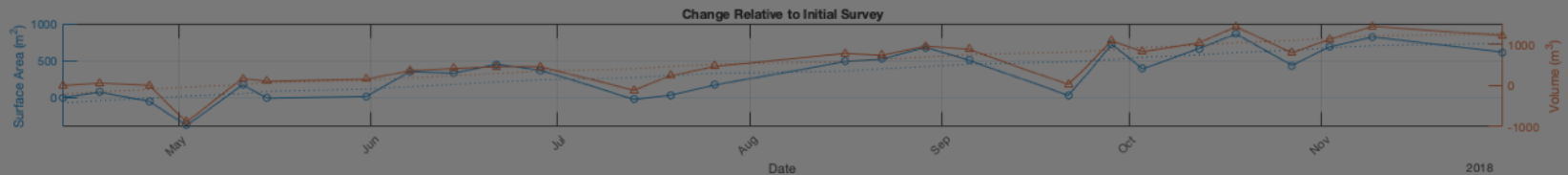


Direction (deg)



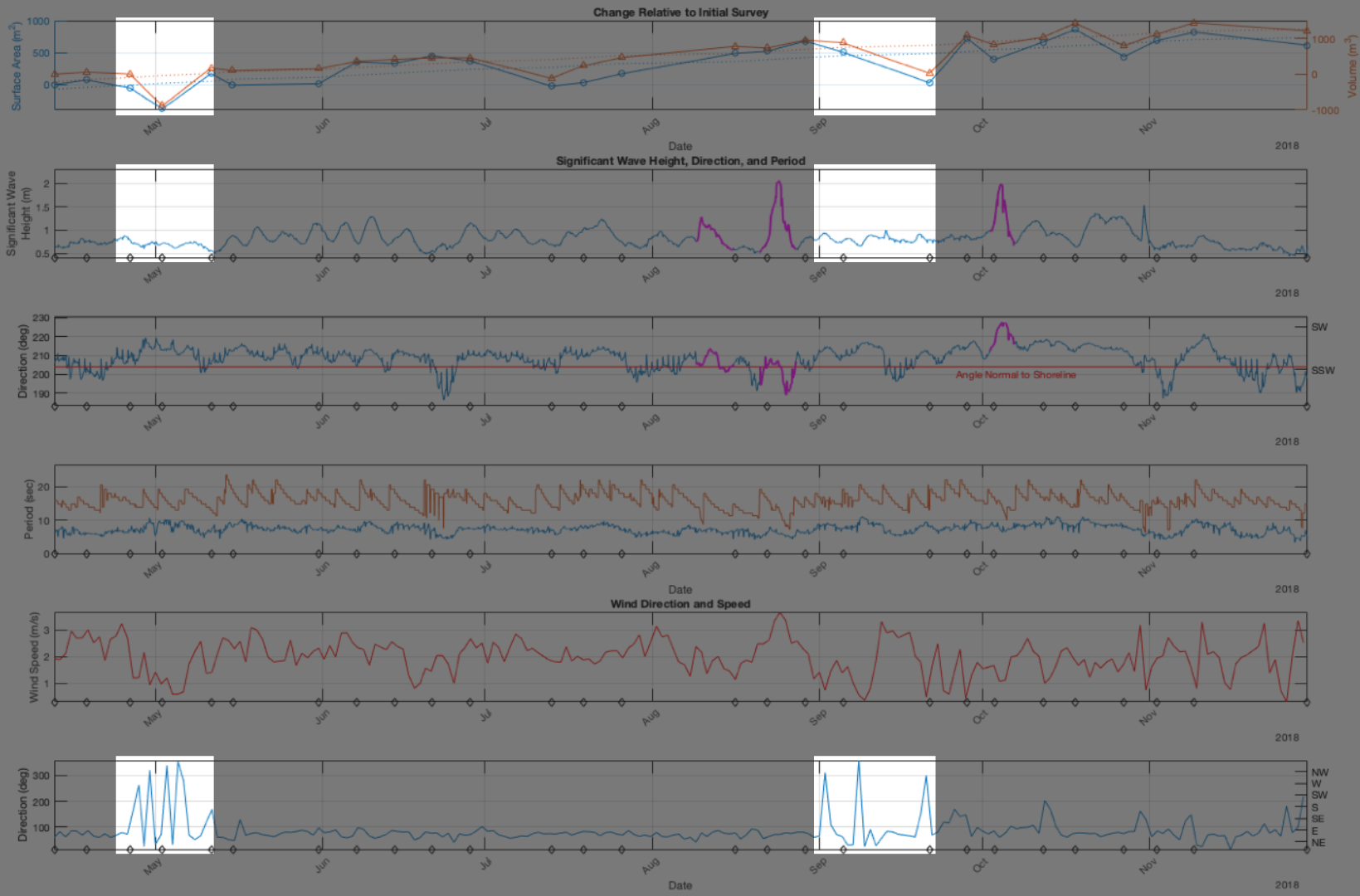
Period (sec)





Speed (m/s)

Direction (deg)

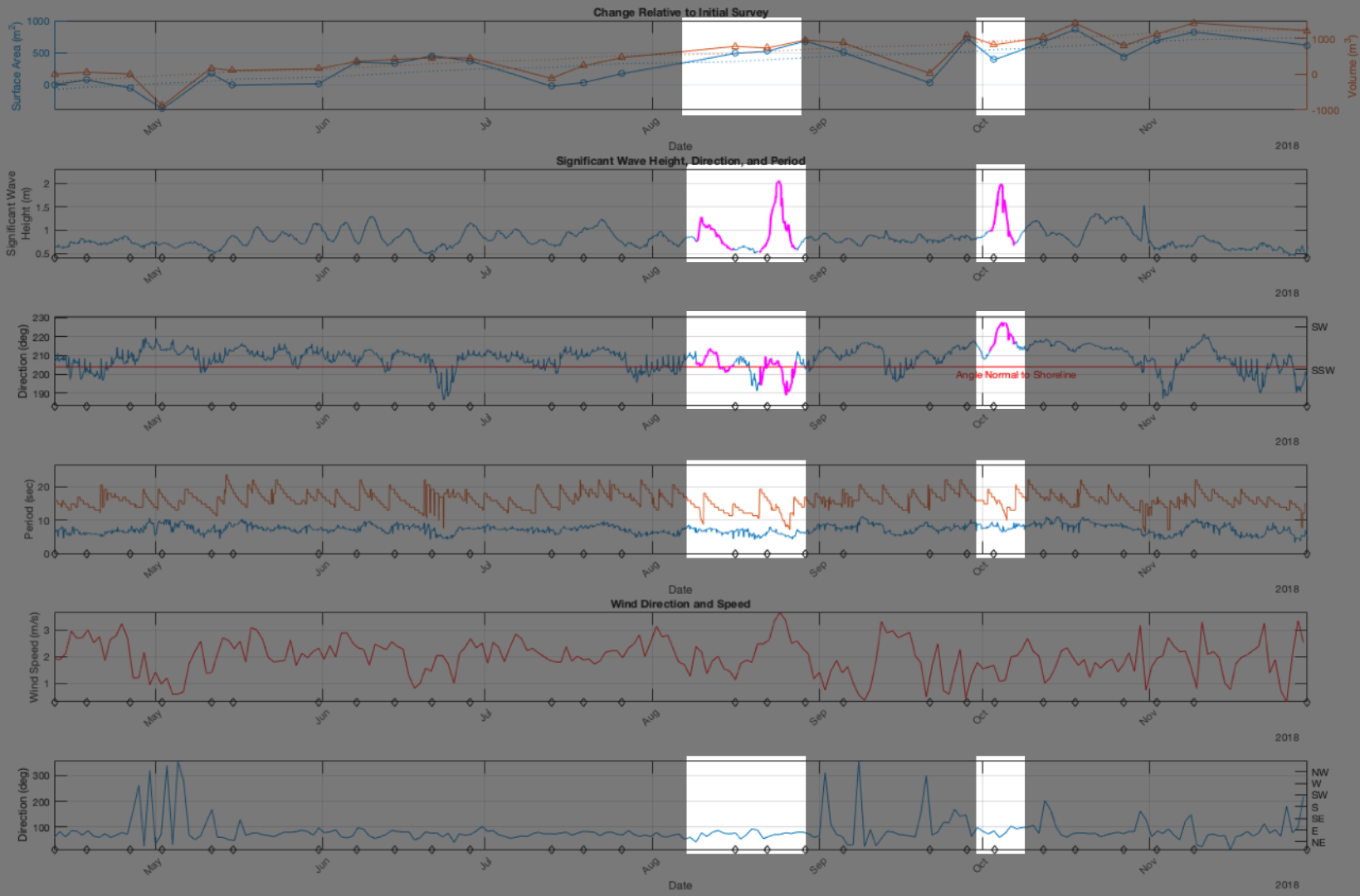


These erosion events seem to correlate with periods of little wave energy and a slackening/reversal of the tradewinds

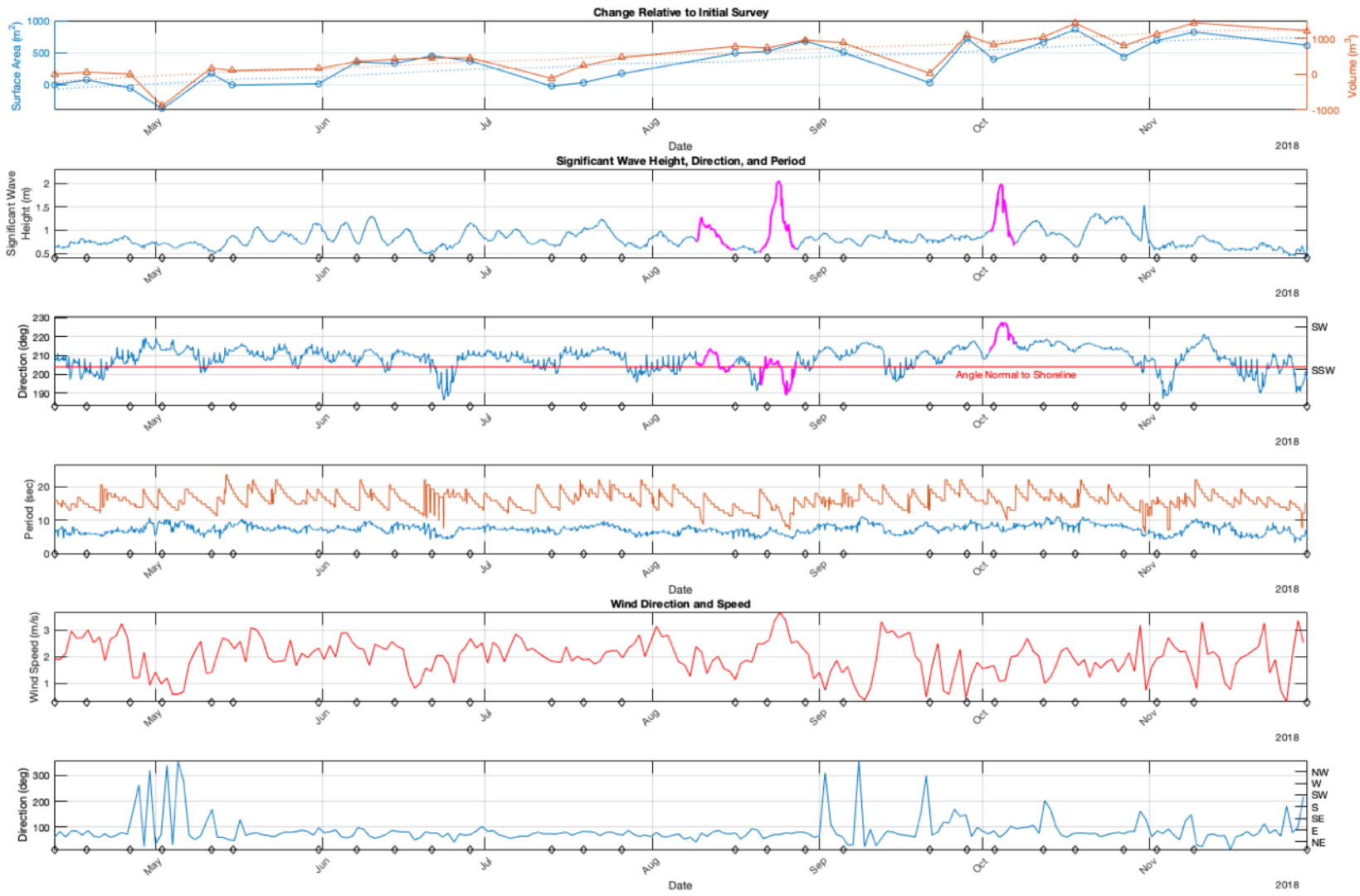


This erosion event seems to correlate with a weak south swell followed by more energetic SSW swells and a regular NE tradewind pattern

Hurricanes
generating
short period
swell of varying
directions
along with
typical
tradewind
patterns result
in accretion



A complex system that is directionally sensitive to wind and waves



Results & Discussion

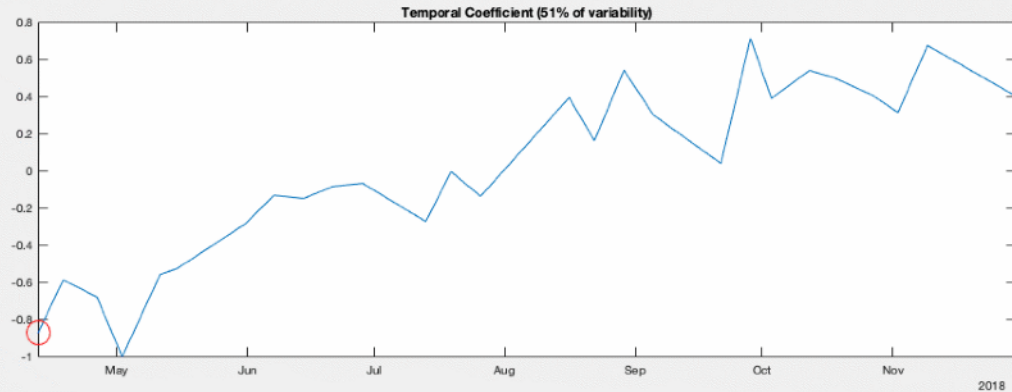
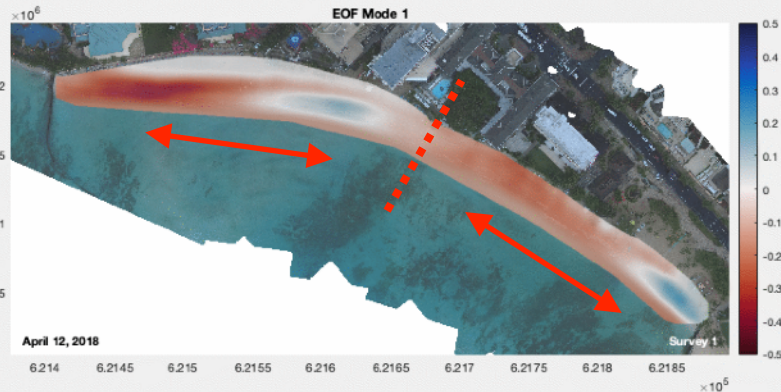
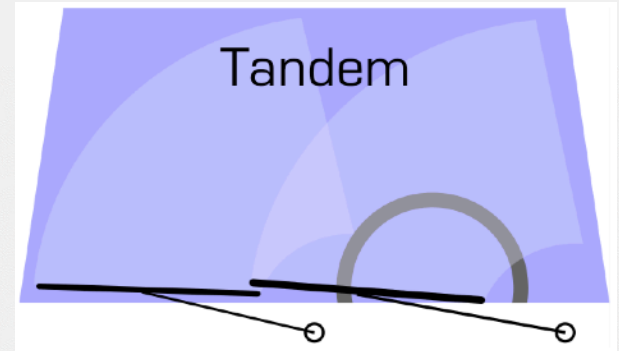
- Empirical Orthogonal Function (EOF) analysis used for spatiotemporal data analysis of a single field (i.e. elevation)
 - Useful where data representing a snapshot in time is linked to spatial dimensions (northing and easting, latitude and longitude, etc)
 - Finds “spatial patterns of variability, their time variation, and gives a measure of the ‘importance’ of each pattern”
- These patterns can be correlated to specific wave conditions and events
- Gives insight into sediment transport mechanisms related to these conditions or events

Mode 1 (51% variability): Congruent Transport, 2 Cells

Closed system? Cross-shore exchange?

2 subcells

Directionality of sand transport is consistent in both cells

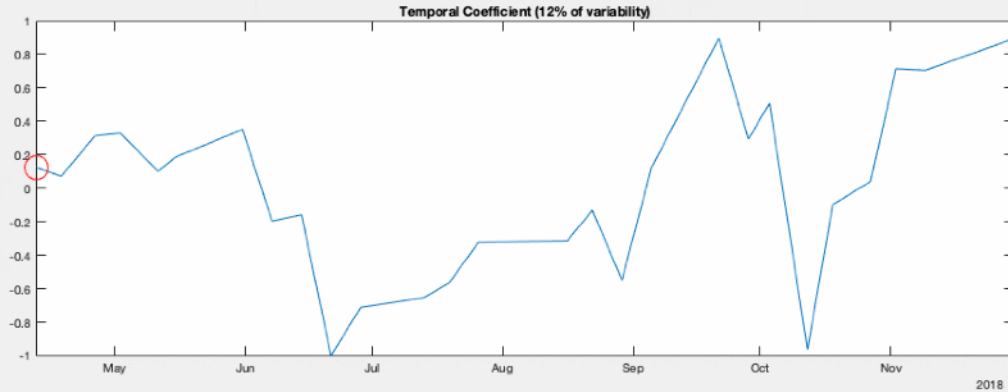
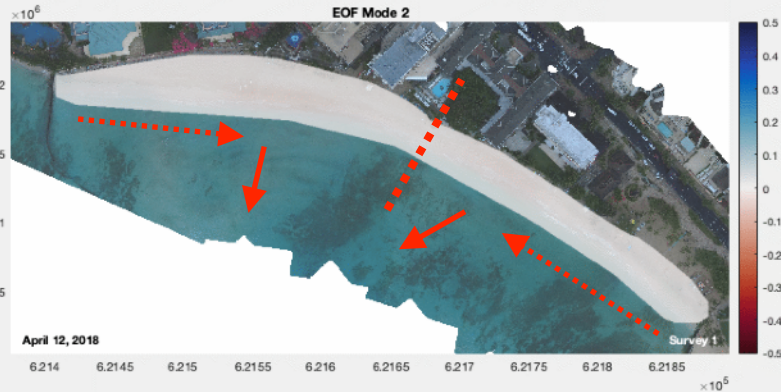
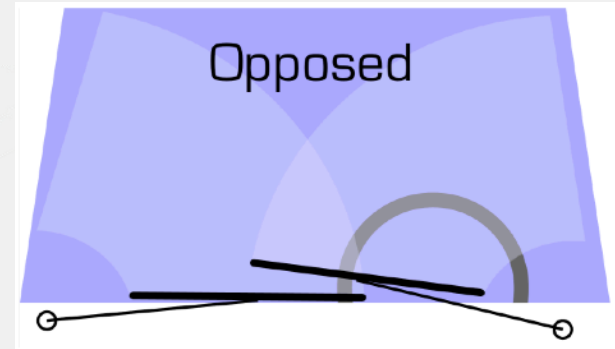


Mode 2 (12% variability): Non-congruent Transport, 2 cells

Open system, channel accretion? (Habel et al., 2012)

Again, 2 subcells within greater system

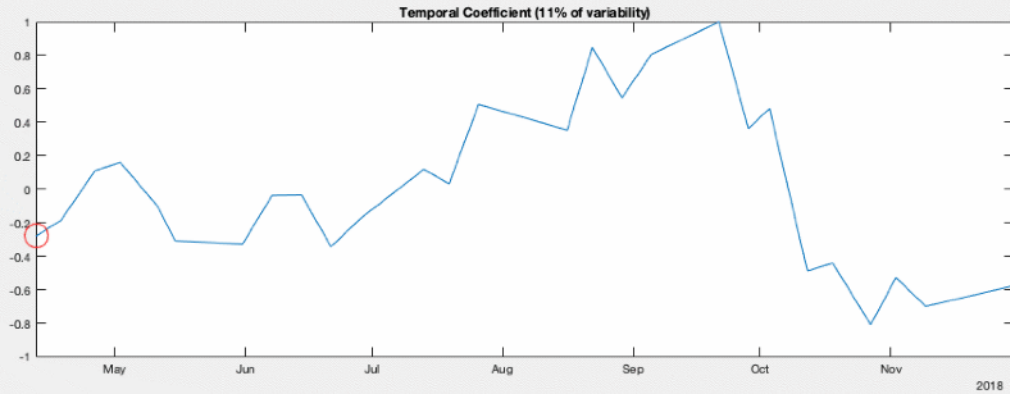
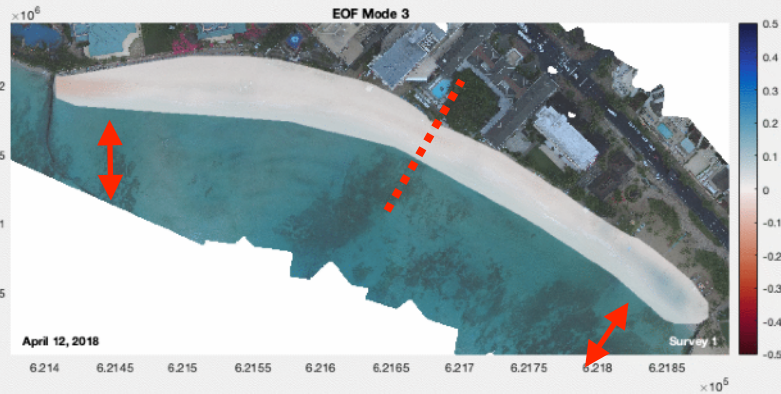
Directionality of sand transport is opposite in both cells



Mode 3 (11% variability): Cross-shore Transport Mode

Opposing cross-shore transport at ends of the beach

Central beach remains constant

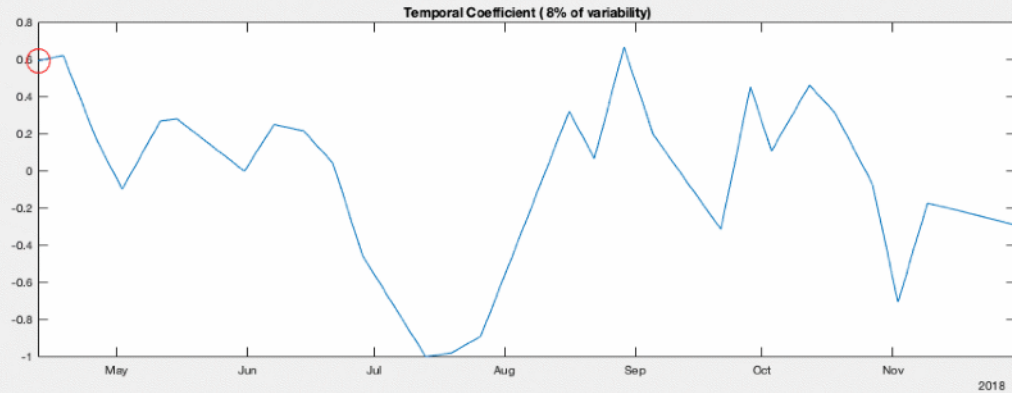
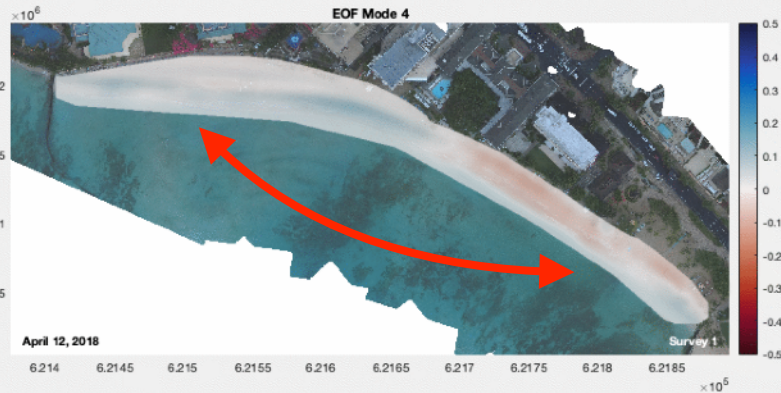


Tidally driven transport?

Mode 4 (8% variability): Seasonal Inflation/Deflation

Entire system operates as a single cell

Inflation of west end of the beach, deflation of east end of beach during summer season



Uncertainty

- Currently engaged in uncertainty analysis
- Validating the accuracy of UAS generated point cloud/DEM
 - Post-processed DTM vertical variation < 3 cm
- Validating cross shore profile assumptions
 - Interpolation area from seaward-most UAS generated point and toe measurement



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Takeaways

- **Waikīkī Beach**

- Overall increase in surface area and volume over study period
- Clear association between beach response and wind/waves
- West end of beach generally accretes, east end erodes
- Lack of offshore information a limitation

- **UAS and Coastal Monitoring**

- UAS capable of providing high-resolution, near-real time, actionable results
- Capture smaller scale beach dynamics
- Efficient - reduces hours in the field



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