OPTICAL CURRENTS

Sean McGill[1], Spicer Bak[1], Dylan Anderson[1], Maile McCann[2], and Brittany Bruder[1]

[1]Coastal and Hydraulics Lab

[2]University of Southern California

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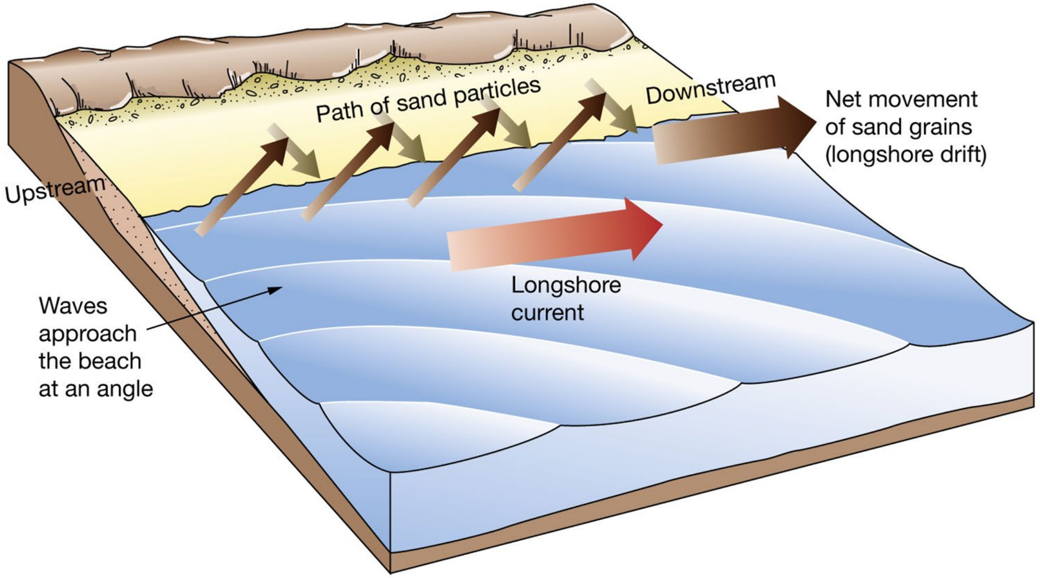
ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

DISCOVER | DEVELOP | DELIVER

Surfzone Currents

- Driver of sediment transport in coastal environments
- Driven by wave energy
- Longshore currents
- Rip currents
- Have implications to sediment management, structural integrity, water quality, and swimmer safety
- In-situ instrumentation traditionally used
  - Leaves questions about spatial variability
  - Unable to sustain long-term measurements



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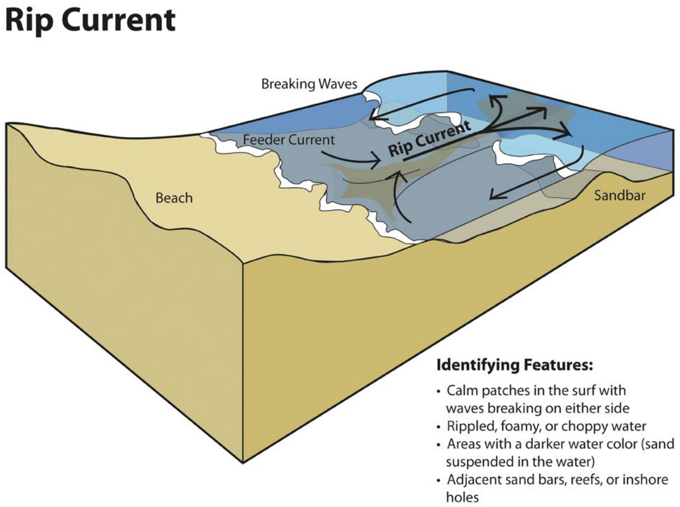
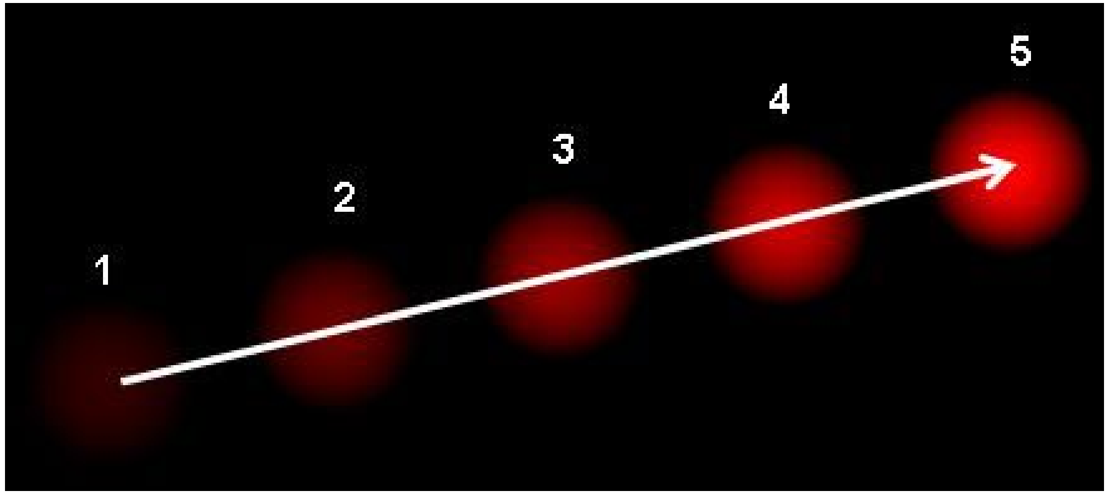


Optical Flow

- Apparent motion between two images
- Calculated based on movement of pixel intensities
  - Assumes pixel intensity is consistent between images with spatial and temporal differences
- Sparse Algorithms
  - Manually or automatically detects X points of interest, tracks between images
  - Fast, but coarse resolution
  - Lucas-Kande (1981), Shi and Tomasi (1994)
- Dense Algorithms
  - All pixels are considered between images
  - Slower, but fine resolution
  - Farnebäck (2003)

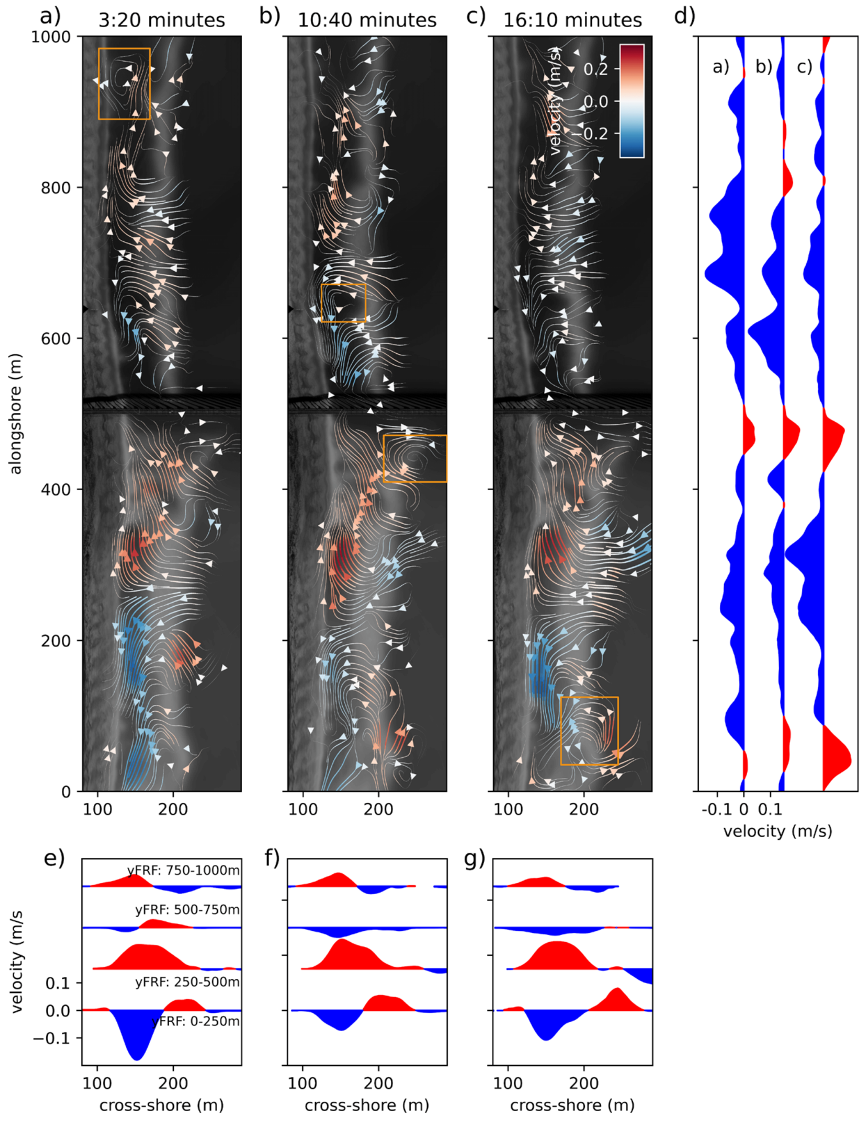
$$\frac{dI}{dx}u + \frac{dI}{dy}v + \frac{dI}{dt} = 0$$



Optical Currents (Background)

- Previous efforts developed novel method for measuring currents tracking foam mats
  - CIRP/CODS efforts

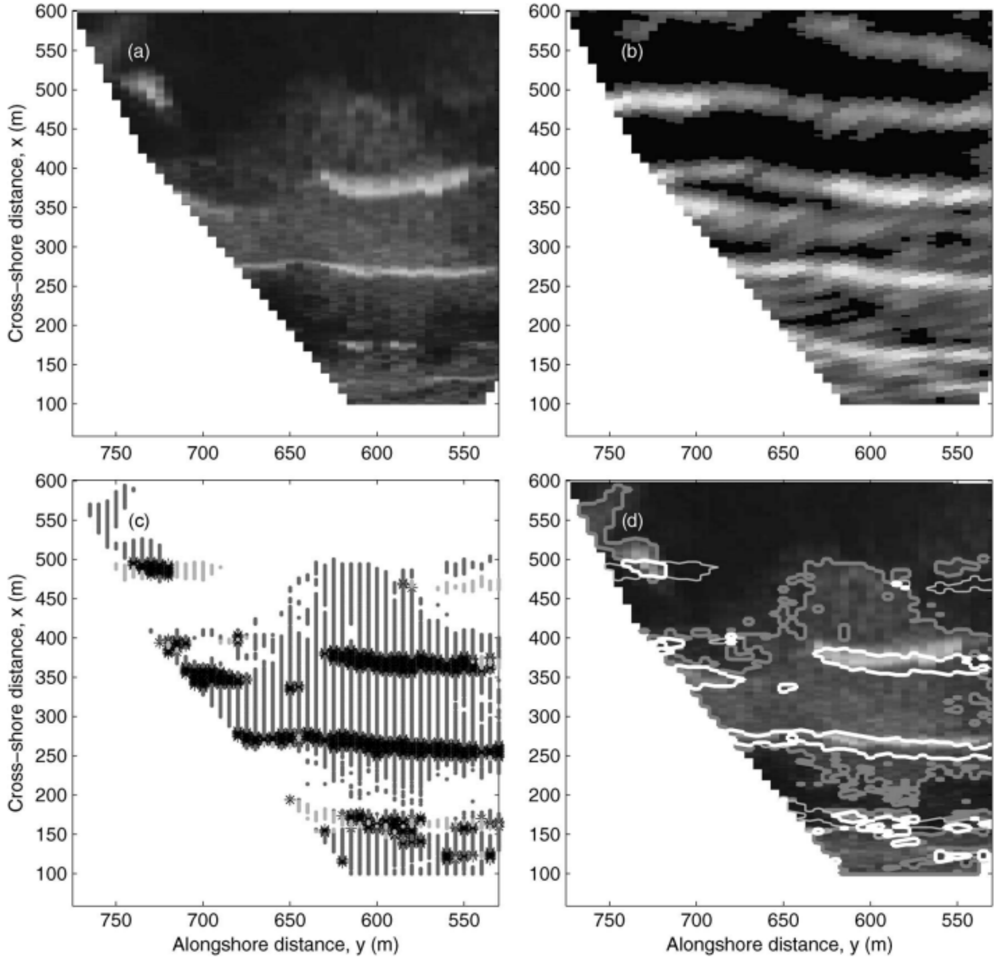
- Creation of Wave Average Movies (WAMs)
- Comparisons with in-situ drifters
- Results were similar to drifter results with some caveats
  - Highest errors near shoreline and offshore of breakpoint
  - Onshore bias due to breaking wave detection
  - Minimal detection outside of surfzone
- Foam is essential



(Anderson et al. 2021)

Catalán Method (Background)

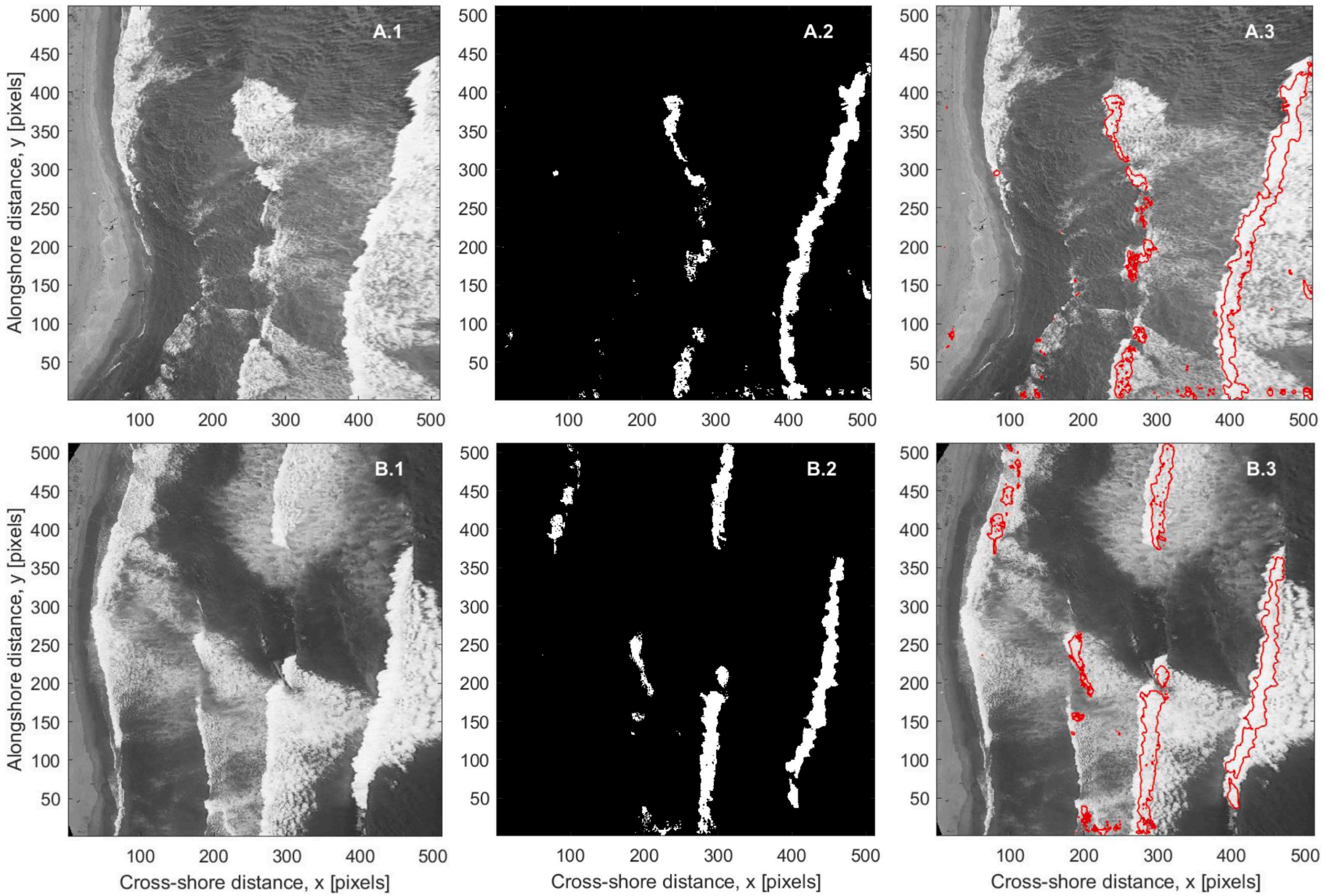
- Argus imagery and marine radar collected during April and May 2008
- Imagery and radar was synchronized
- Comparisons were made between the optical signal and radar scatter
  - Radar "sees" wave crests and breaking waves
  - EO "sees" breaking waves and relic foam
- Able to designate active breaking waves, remnant foam, and steepening waves
  - Brightness intensity of pixels relative to the rest of the image
  - Radar inclusion refined (i.e., bright due to foam or breaking wave)



(Catalán et al. 2011)

Machine Learning (Background)

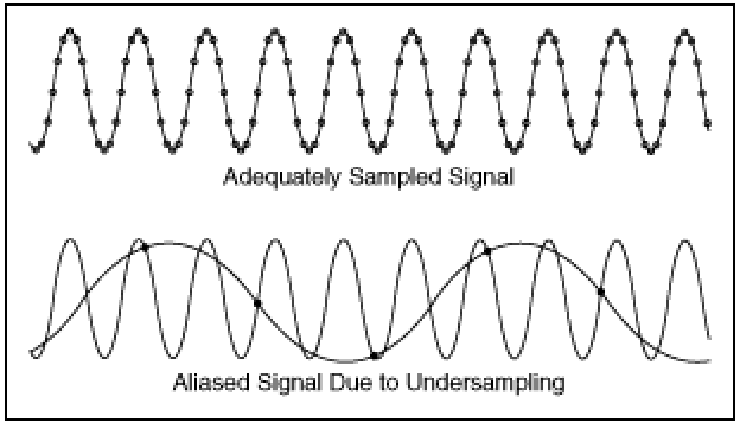
- Saez 2021 developed surrogate of Catalan method using EO.
- Identify breaking wave rollers
- Convolutional Neural Network (CNN) U-Net
- Builds on methods from Catalán et al. 2011
  - Used radar and imagery to train, does not consider radar for application
  - Trained on data from Surf Zone Optics (SZO) in September 2010
- Separate active breaking from steepening waves, unbroken waves, and remnant foam
- Operates with a 512x512 pixel area of interest



(Saez et al. 2021)

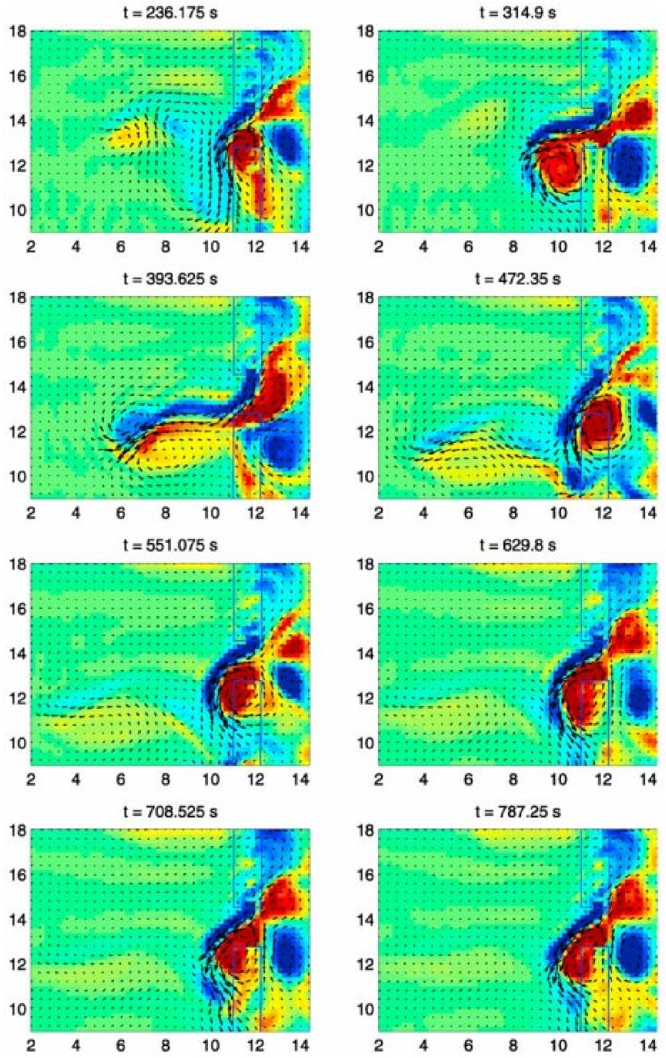
Concept

- Running averages cause aliasing in wave conditions with wide spectral spread
  - Current methods consider twice the dominant wave period
- Current methods have potential for onshore bias due to propagating bores



Why Optical Currents

- Sediment transport pathways and morphology
- Long duration flow measurements in surfzones using in-situ instrumentation is unsustainable
  - Acoustic transponders get buried by moving sandbars or are too high in the water column
- Single point measurements provide little insight into model performance
  - Wrong location vs non-existent



(Haas et al. 2003)

Hypothesis

If we can identify breakers using existing methods (Catalán et al. 2011, Saez 2021) to remove the bores before averaging, then the residual foam left behind can be used to more accurately track nearshore currents.

DUNEX

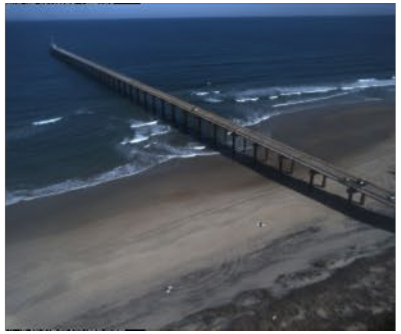
- DUring Nearshore Event eXperiment
- US Coastal Research Program
- Multi-agency, academia, and stakeholder collaborative experiment focused on studying nearshore processes during coastal storms
- Outer Banks of North Carolina
- Fall 2021 through Winter 2022
- Goal: Collaborate and leverage research efforts from various groups to collect and analyze data from the same region before, during, and after a storm event

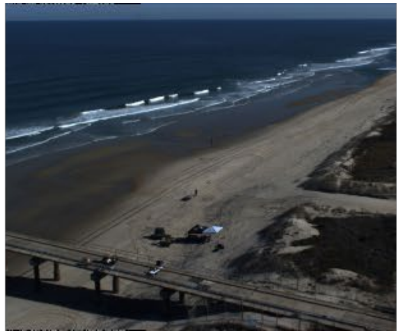
DUNEX
During Nearshore Event Experiment

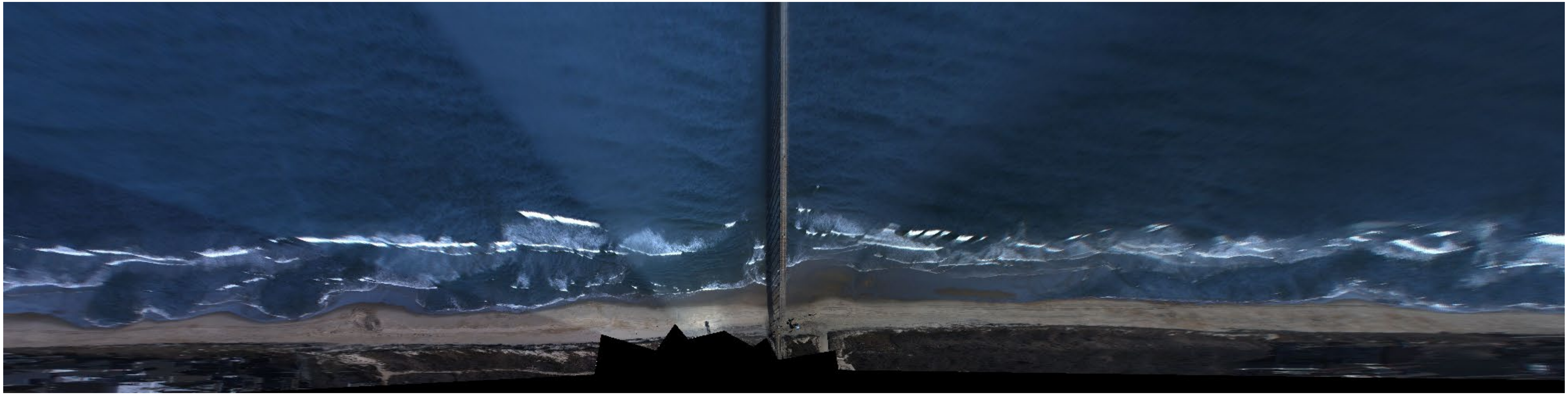
Methods

1. Process Argus imagery
2. Apply machine learning
3. Manually QA/QC'd results
4. Identify good masks
5. Run wamflow on masked and unmasked imagery
6. Compare detected optical flow

Argus Imagery

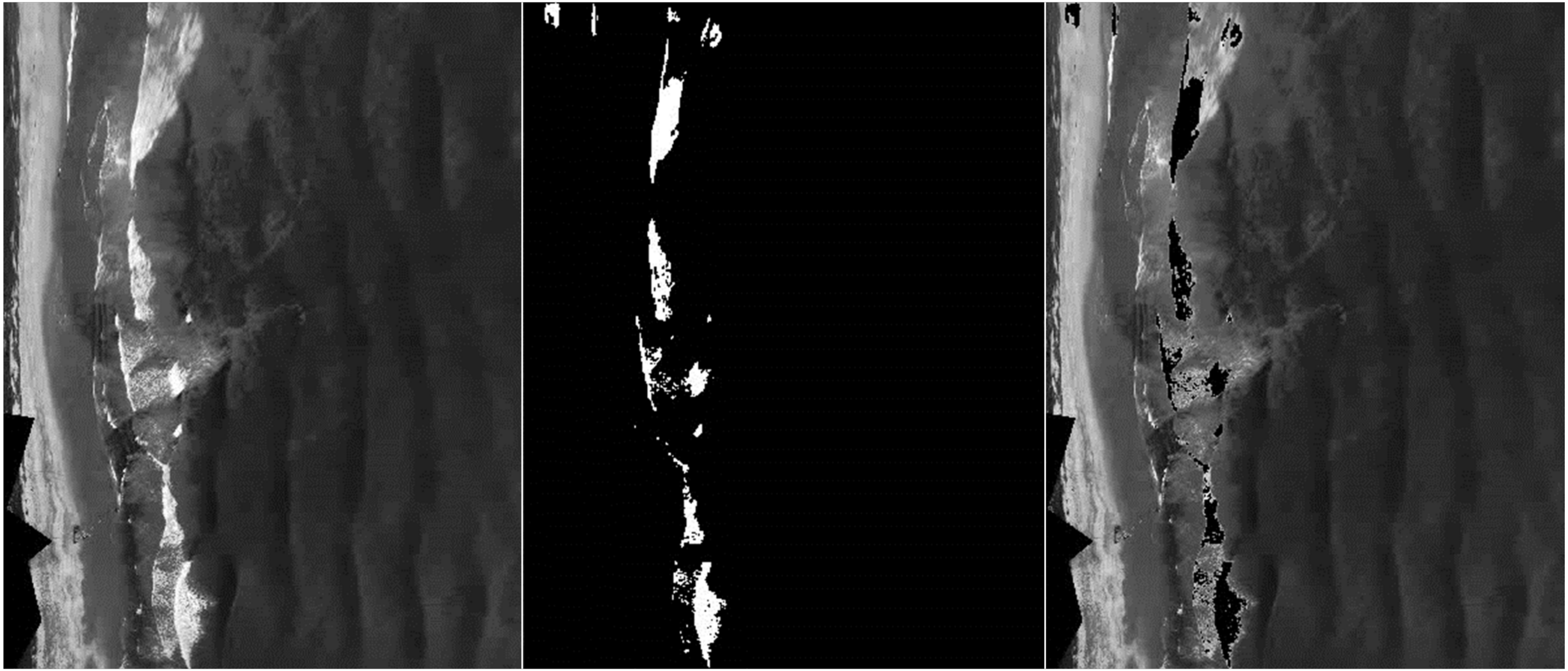




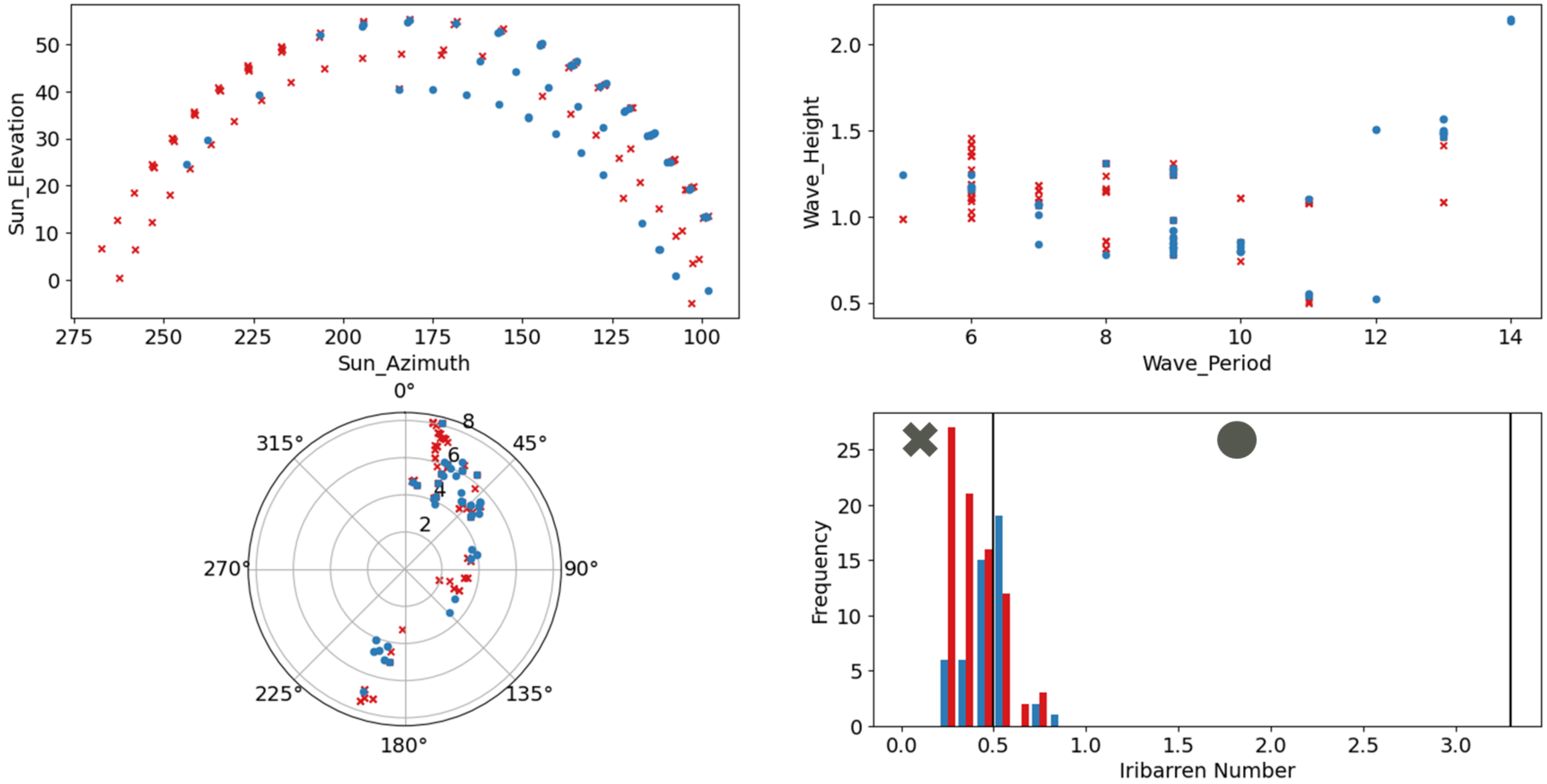


Apply Machine Learning

Raw → Machine Learning → Masked

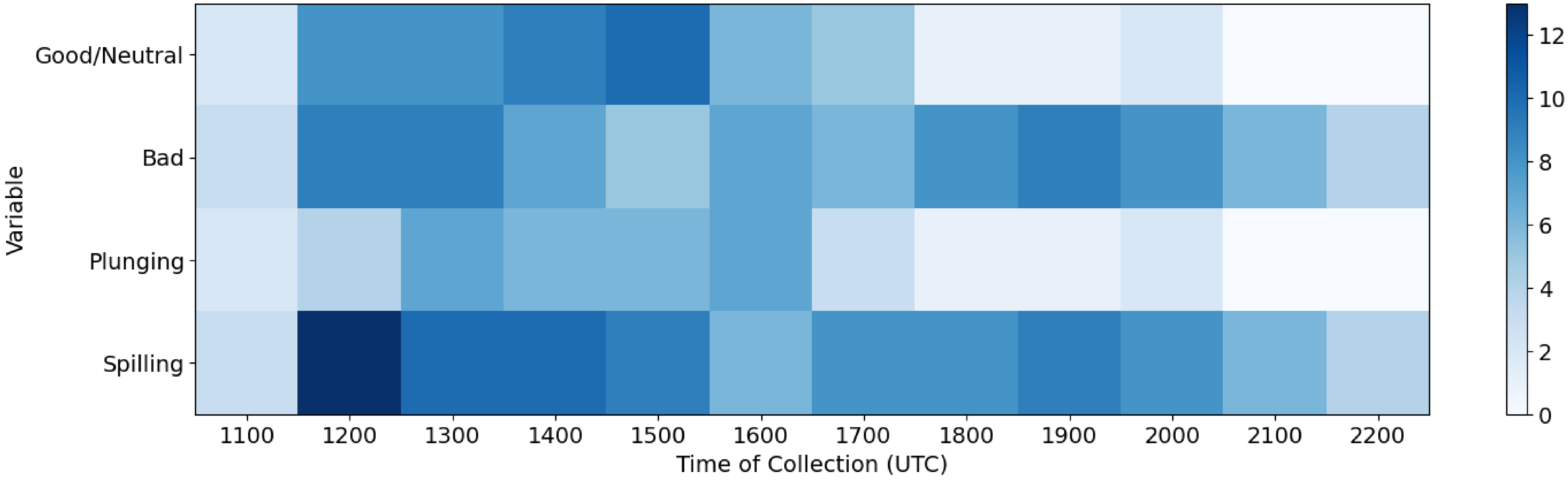


Results



Sun_Elevation
Sun_Azimuth
Wave_Height
Wave_Period
0°
45°
90°
135°
180°
225°
270°
315°
Frequency
Iribarren Number

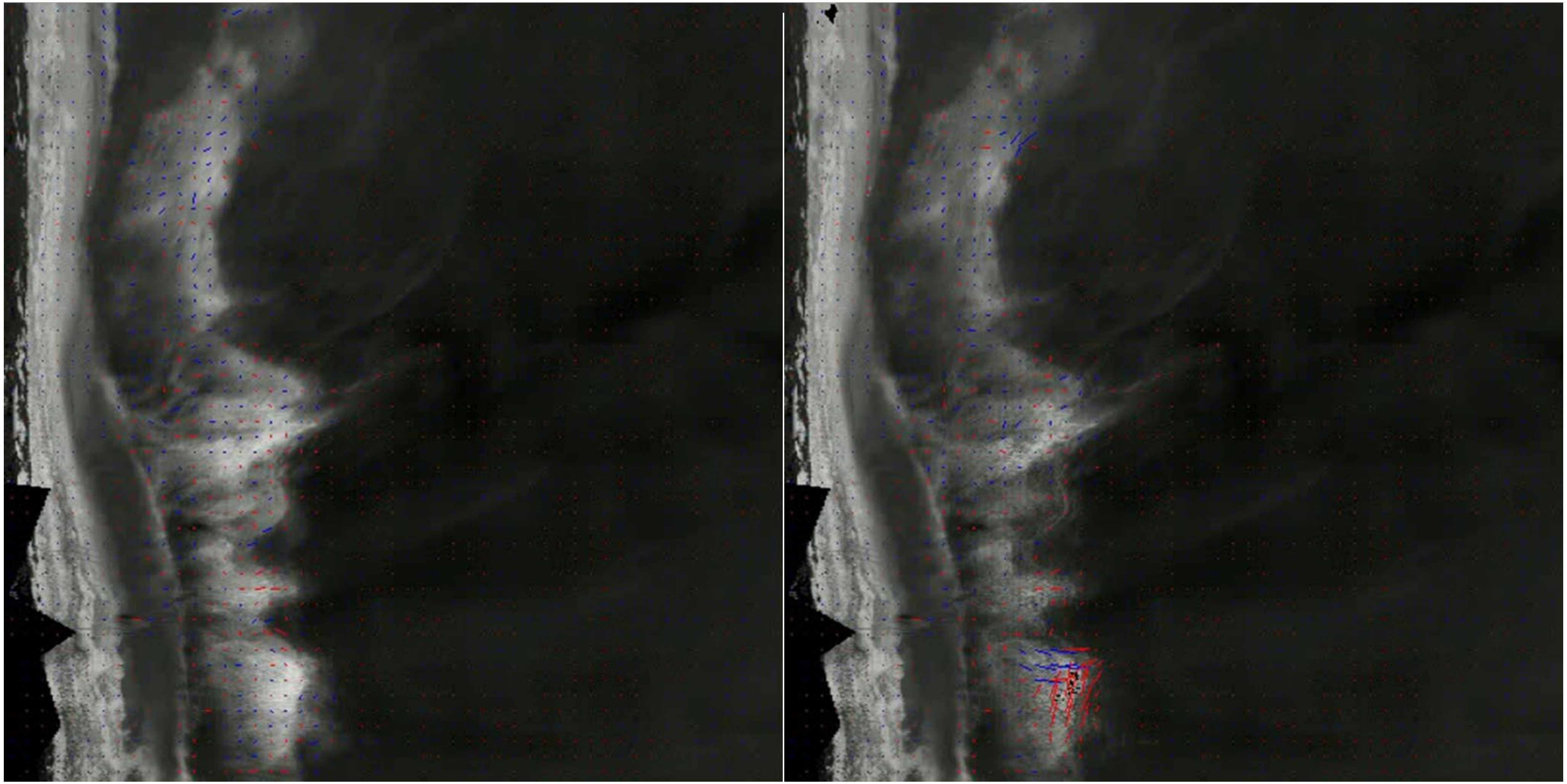
Results (Continued)



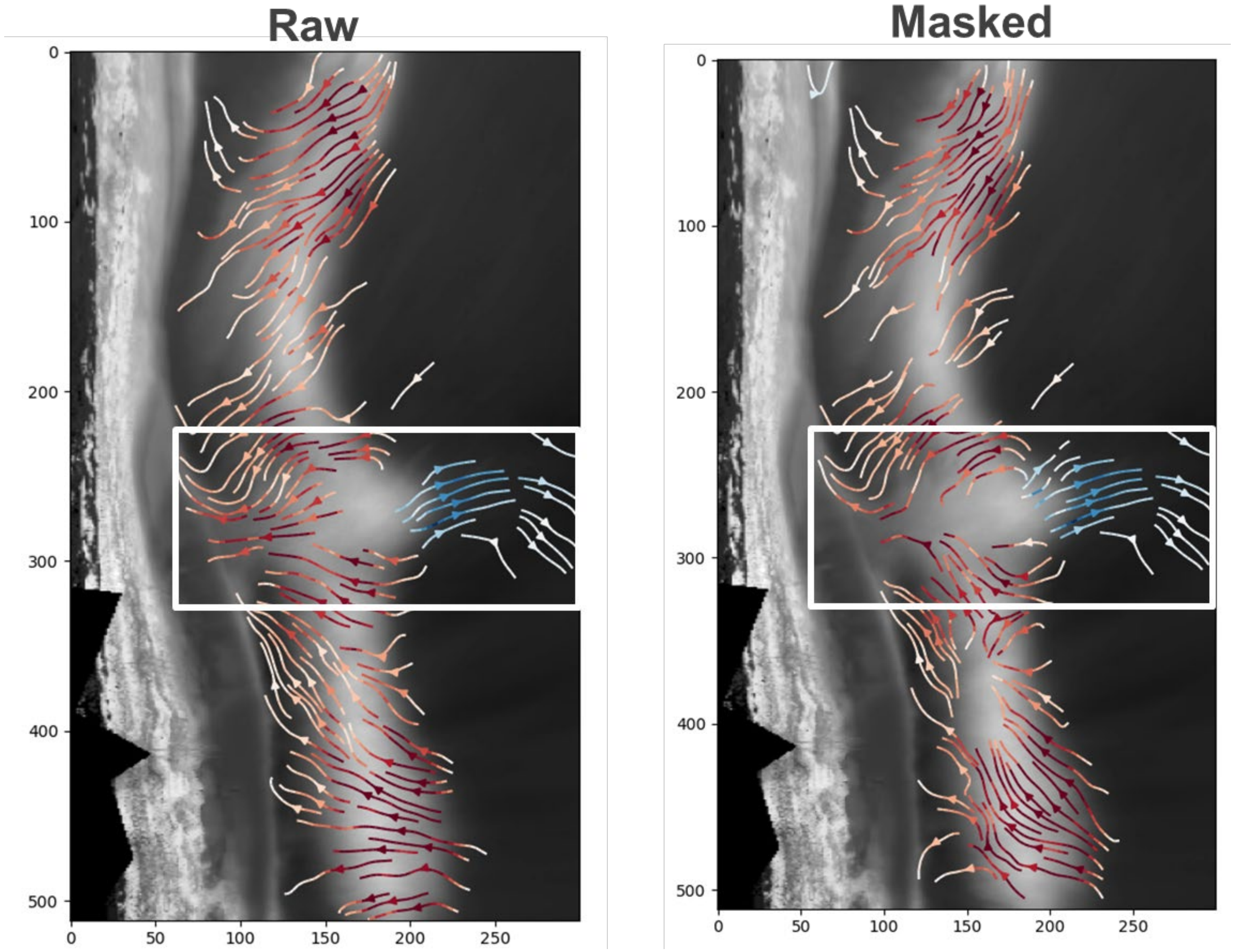
Impacts to Optical Currents (WAMs)

Raw

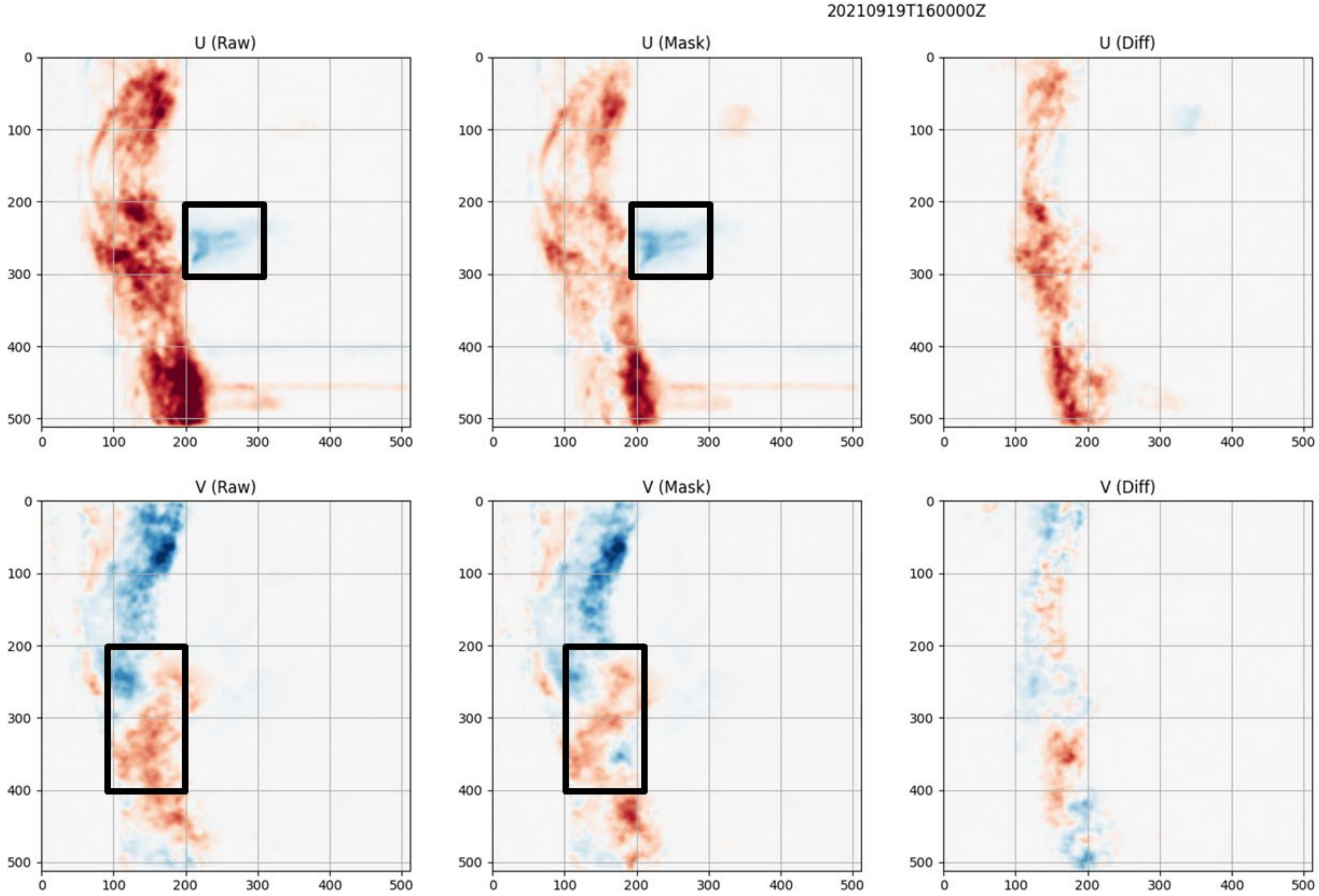
Masked

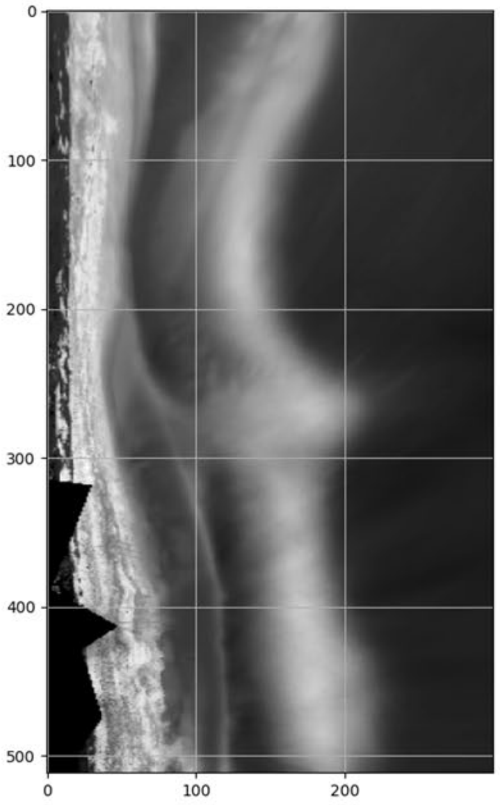


Impacts to Optical Currents (Stream Plots)

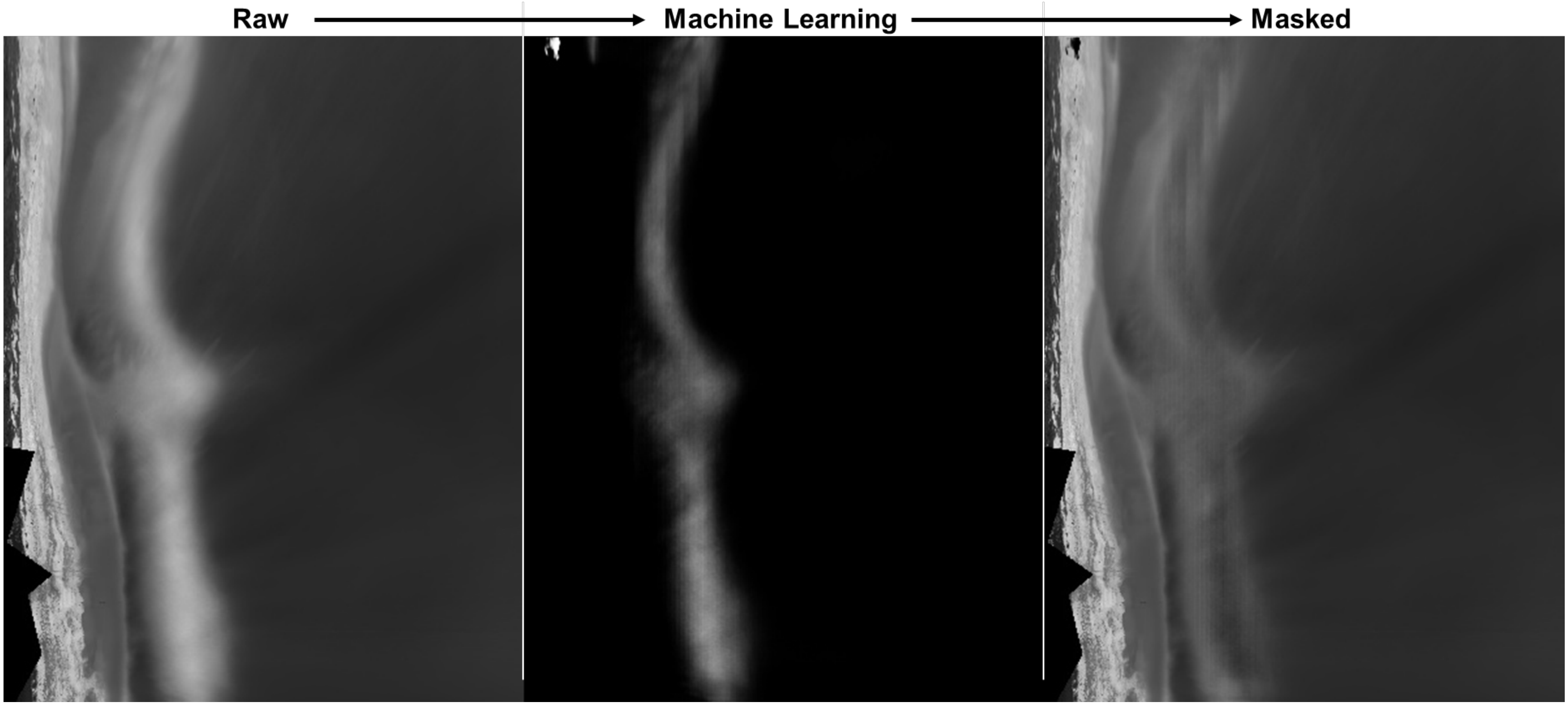


Impacts to Optical Currents (Averaged)

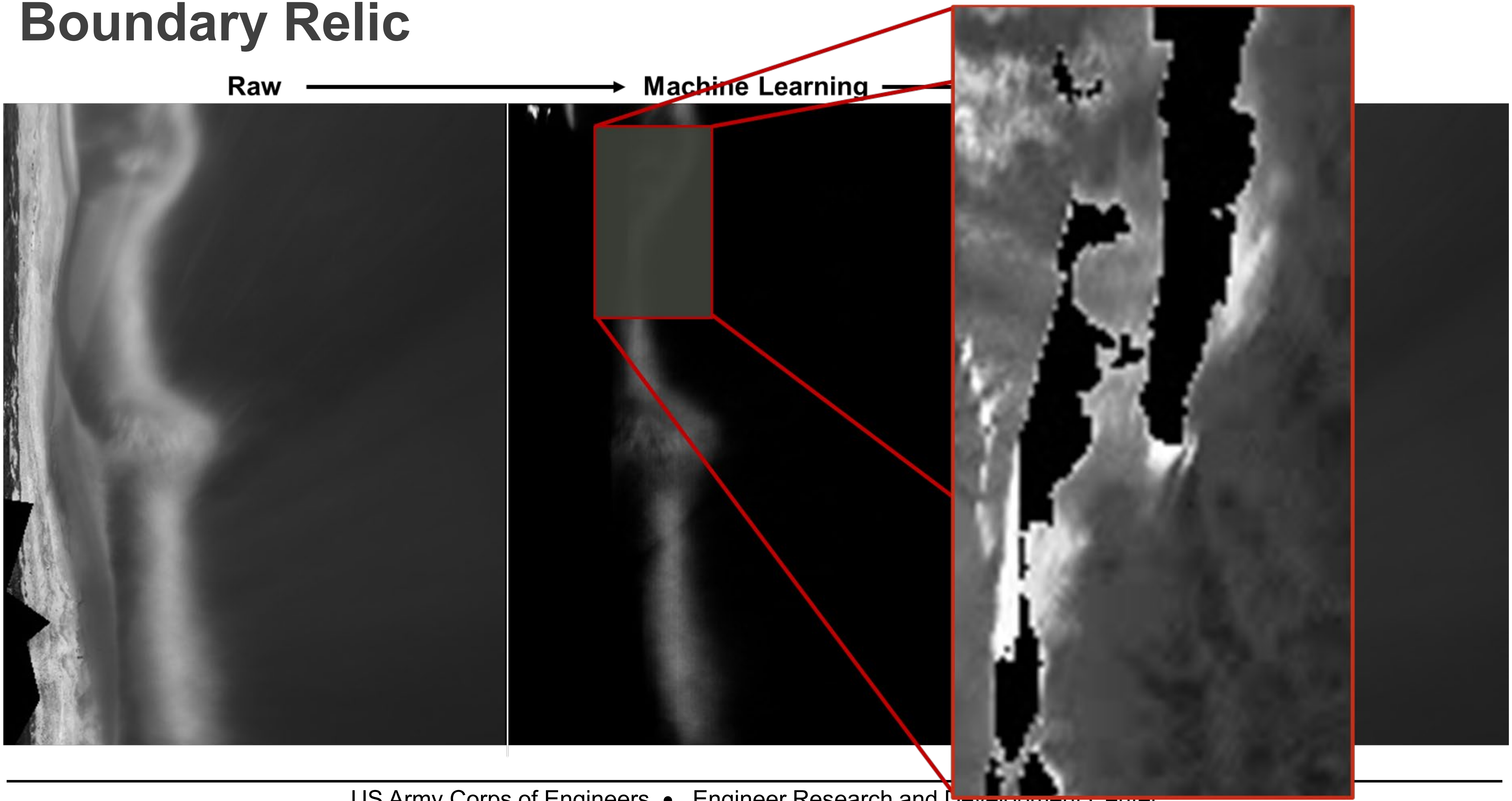




Impacts to Optical Currents (Timex)



Boundary Relic



Conclusion and Next Steps

- Mask impacts to nearshore current detection
  - ~40% decrease in detected onshore current velocity
  - ~15% decrease in detected alongshore current velocity
  - Removes onshore directed velocities, an issue in Anderson et al. 2021

- Potential for filtering out wave bores, allowing for shorter averaging windows and tracking shorter temporal flow features (transient rips)

- Lower mask accuracy then anticipated (60%)
  - Analysis of oceanographic conditions and brightness values did not provide conclusive success metrics, but provided possible causes
  - False detection of foam, non-detection of waves as clouds passed

- Continue process DUNEX imagery, host on ERDC library when completed
- Validate currents we are detecting using drifter data
- Filter wave rollers with radar, similar to Catalán et al. 2011
- Tech Note on the effort

Questions?

sean.p.mcgill@usace.army.mil
spicer.bak@erdc.dren.mil