Remotely sensed nearshore currents:
wave-averaged movies & surf zone drifter deployments

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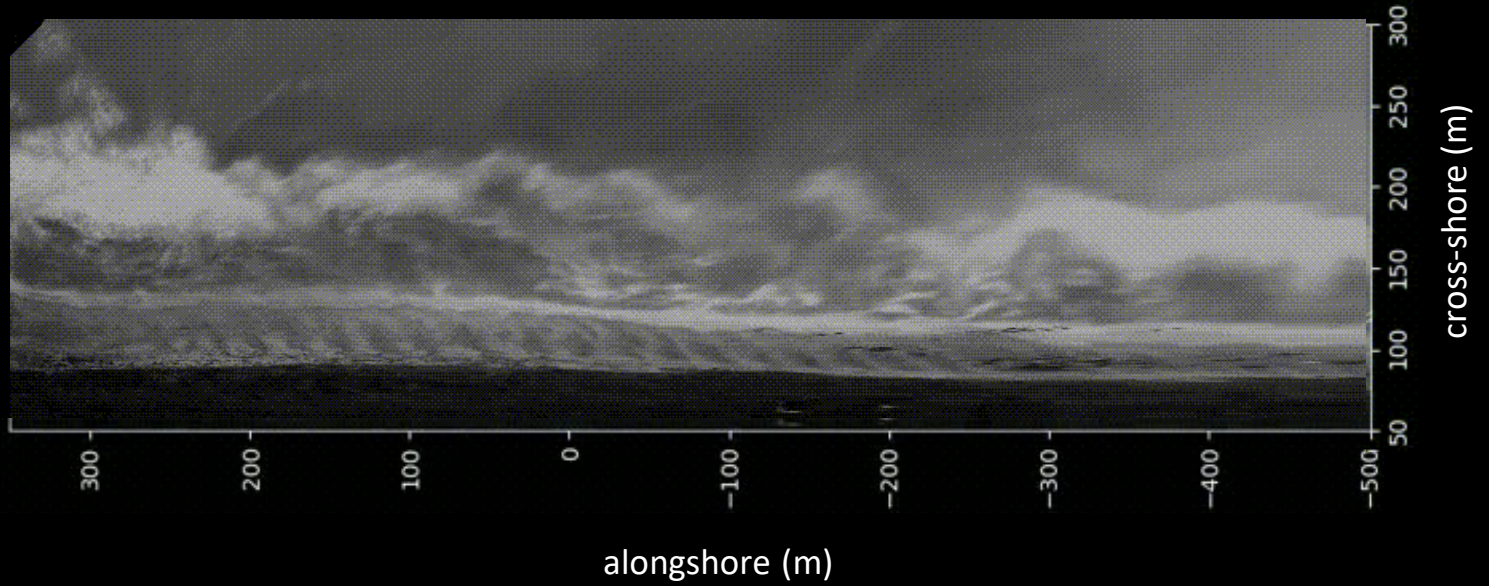
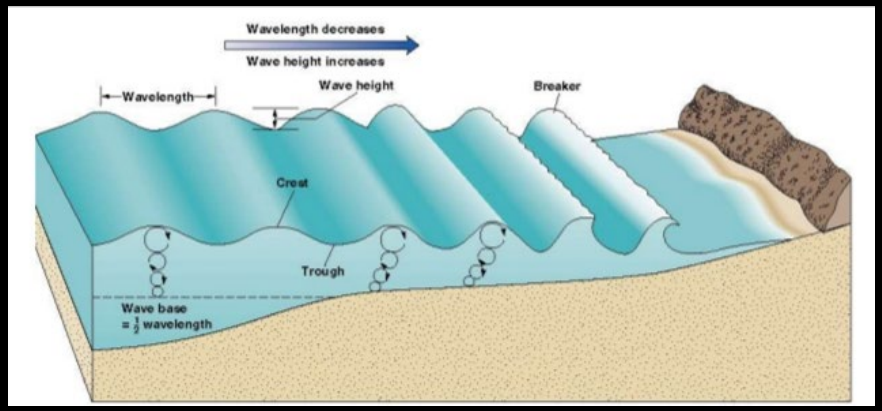
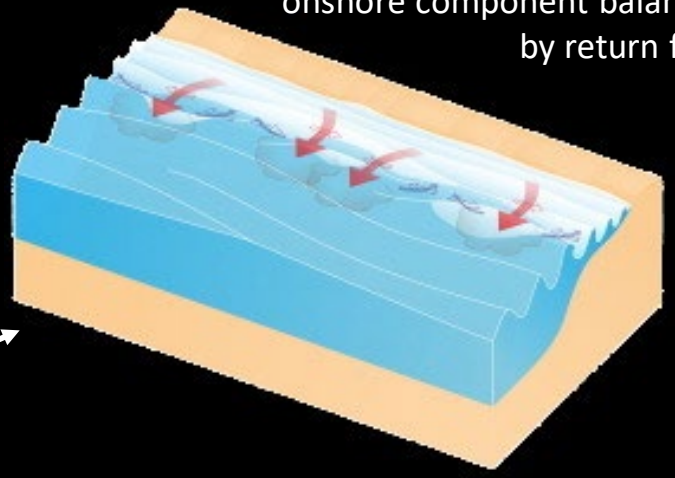


Nearshore circulation is mainly forced by excess momentum resulting from wave breaking

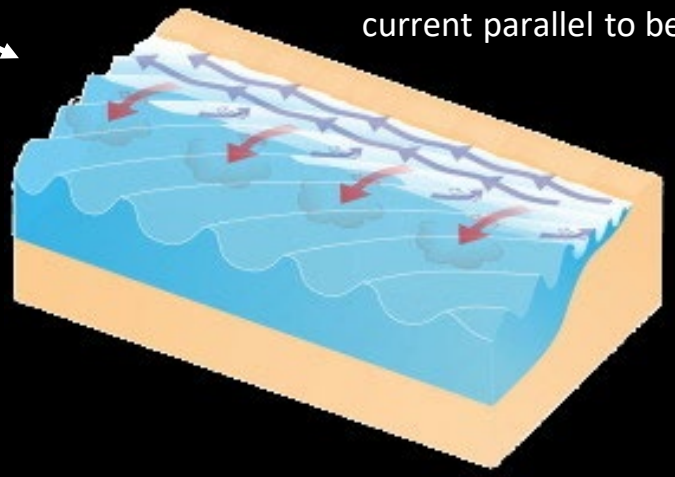
Wave energy is “released” at the break point



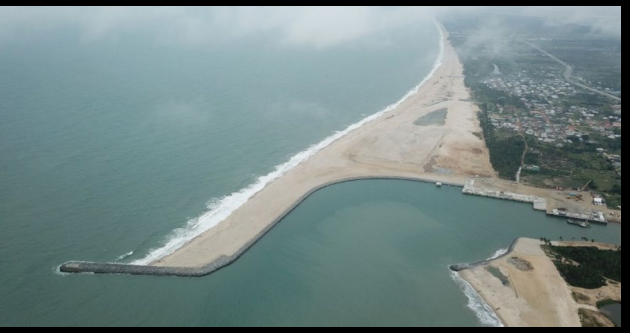
onshore component balanced by return flow



alongshore component becomes current parallel to beach

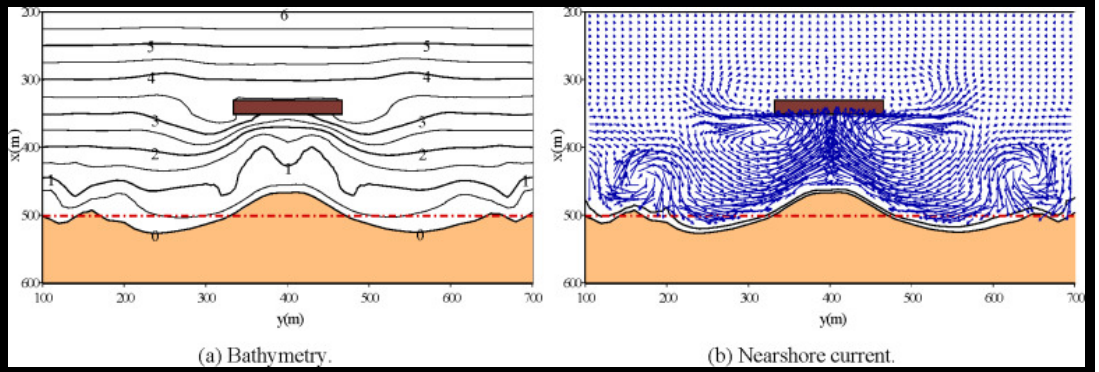


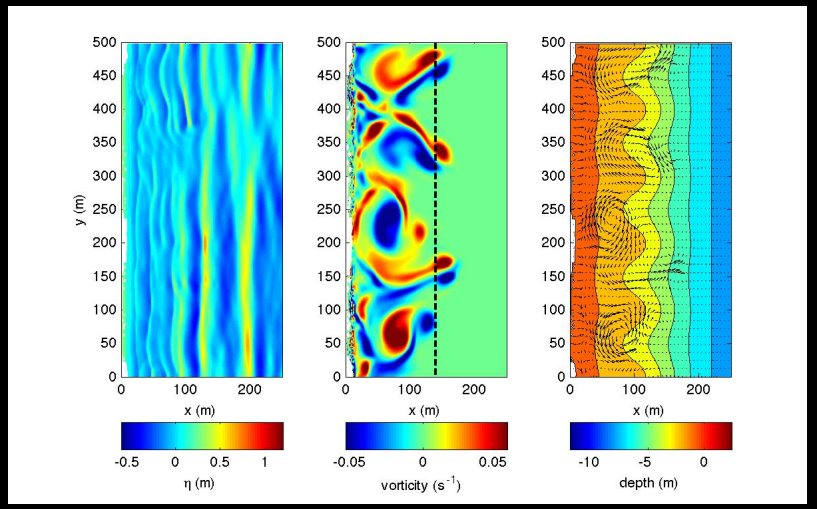
Resulting currents are relevant to a broad range of disciplines



- Swimmer safety
- Coastal structure interaction
- Transport and mixing of sediment, nutrients and pollutants

Considerable model development in the coastal community



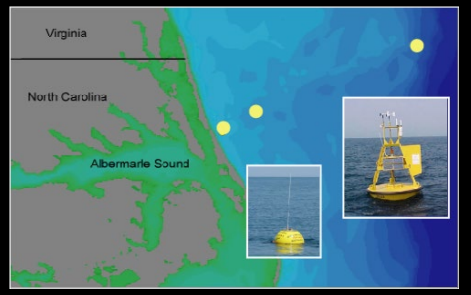


But considerable problems obtaining validation data...

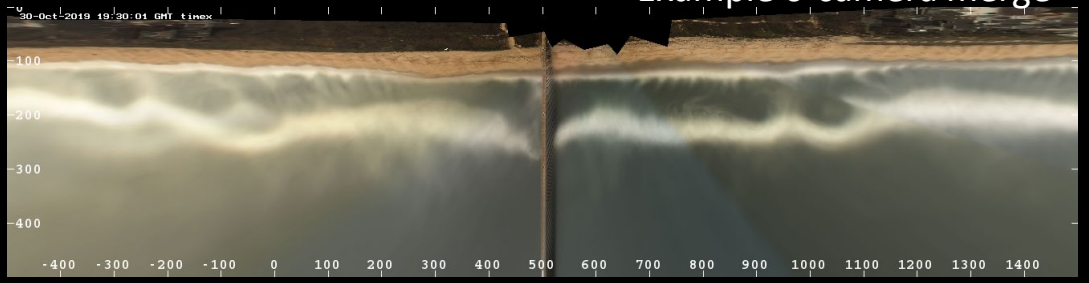
USACE Field Research Facility

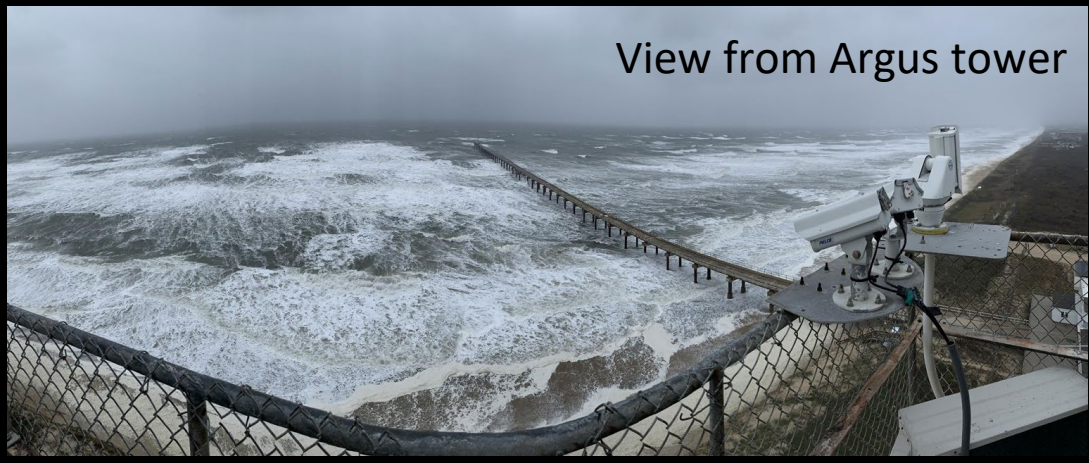
- How can we quantify/asses model predictive capability to spatially/temporally variable circulation patterns?
- Goal: develop remotely-sensed product built on existing coastal imagery technology.

North Carolina, USA



Example 6-camera merge

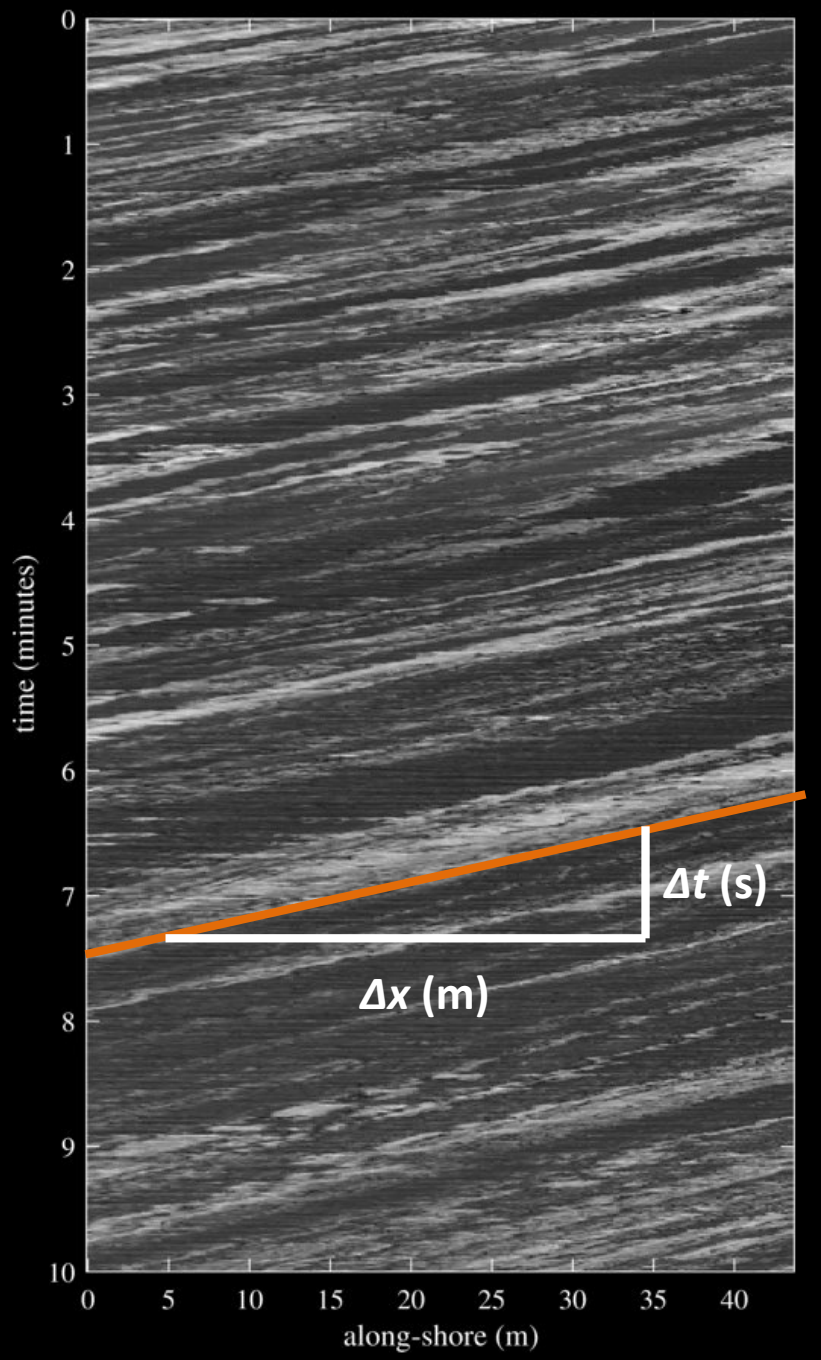




Optical currents can be obtained by tracking foam

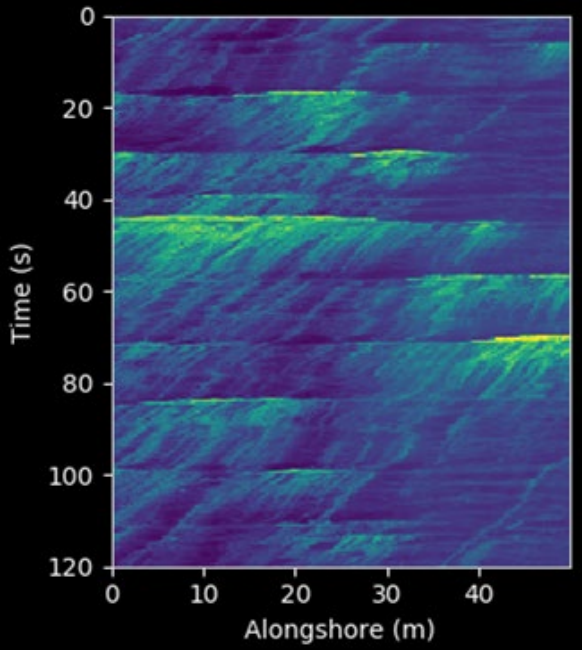
Alongshore timestack:

extract line of pixels from every frame in the 17 minute recording

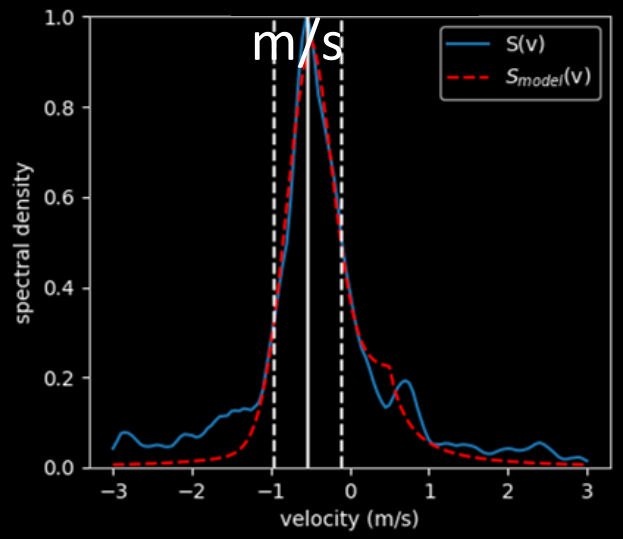


Optical currents can be obtained by tracking foam

Fourier Transformation – “vBar” (Chickadel et al. 2003)
Radon Transformation (Almar et al. 2016)



0.53 m/s



Oysterville, WA: SEDEX2 (Sandbar Aeolian Dune Exchange Experiment)

10 second loop from a UAV's 30 minute movie of the surfzone (2 Hz images)

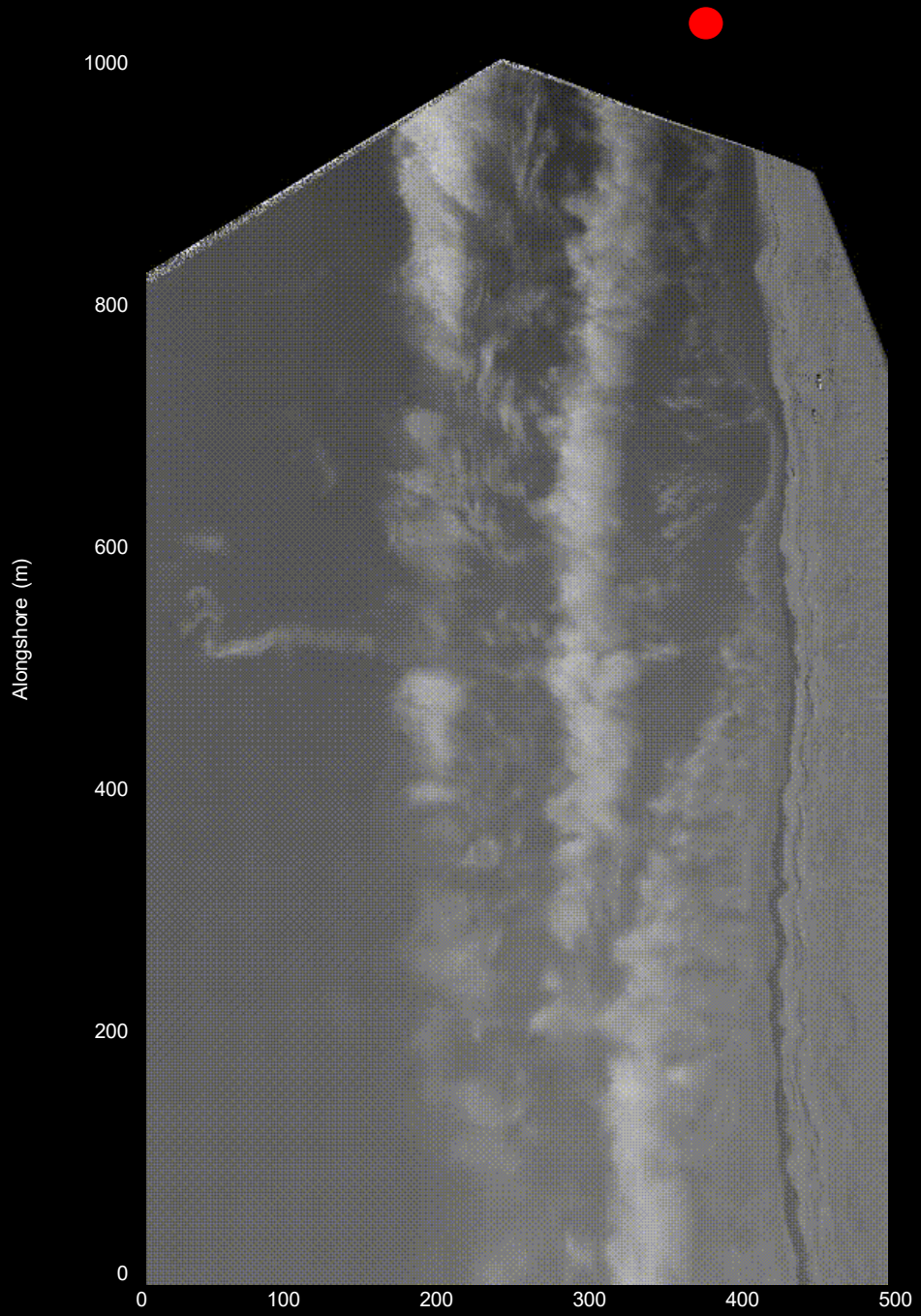
Dominant signal is incident wave energy

Oysterville, WA: SEDEX2 (Sandbar Aeolian Dune Exchange Experiment)

Temporal average of images (20 second averages with 10 second time step)

Reduce this signal by considering it “noise”

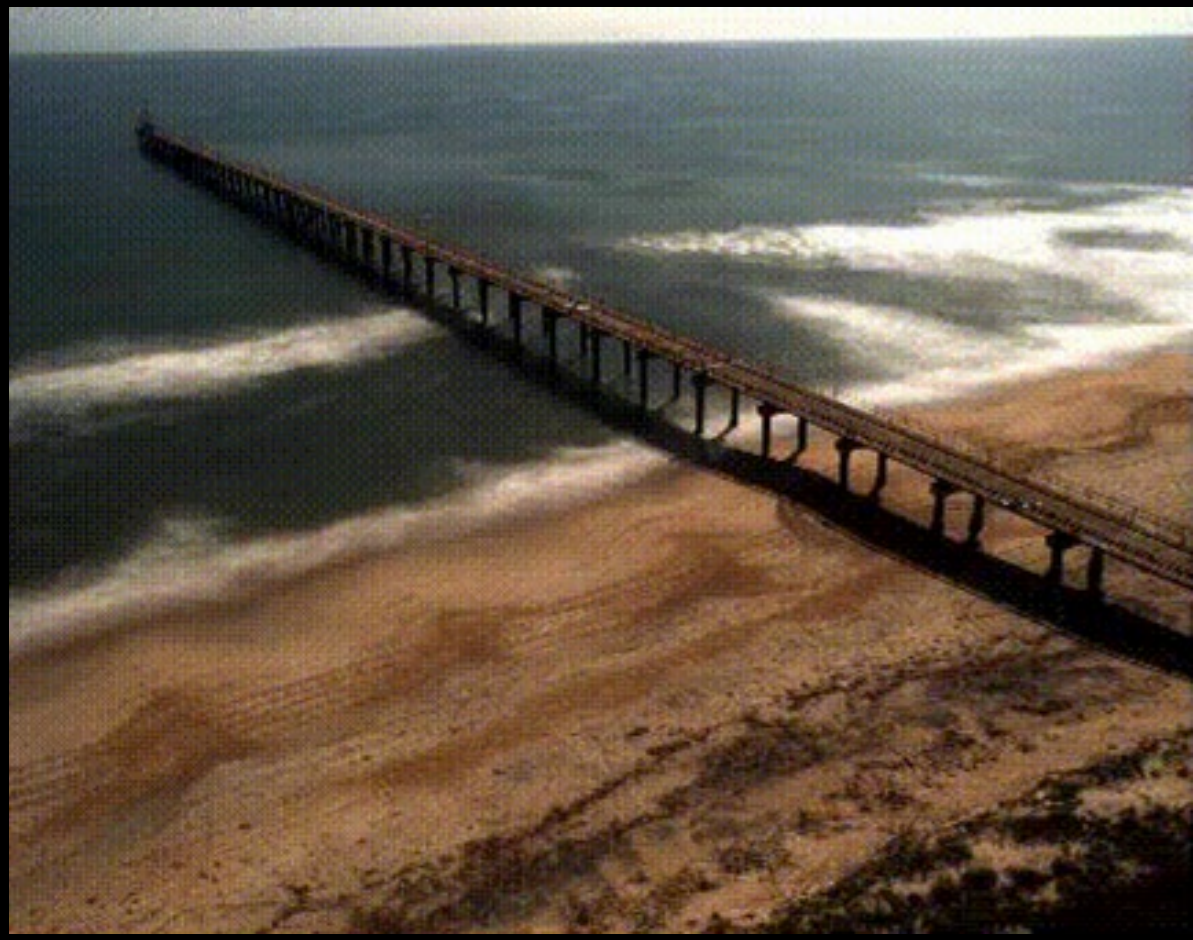
Stabilized and Rectified with CIRN Toolbox



Wave-Averaged Movie (WAM)

- 20s averages, with a 10s step (50% overlap)
- 1m x 1m rectified grid
- New Argus product saved every 2 hours at FRF

- Argus tower: 43 m tall, 6 cameras observing a longshore distance of several kilometers
- 2 Hz for 17 minutes



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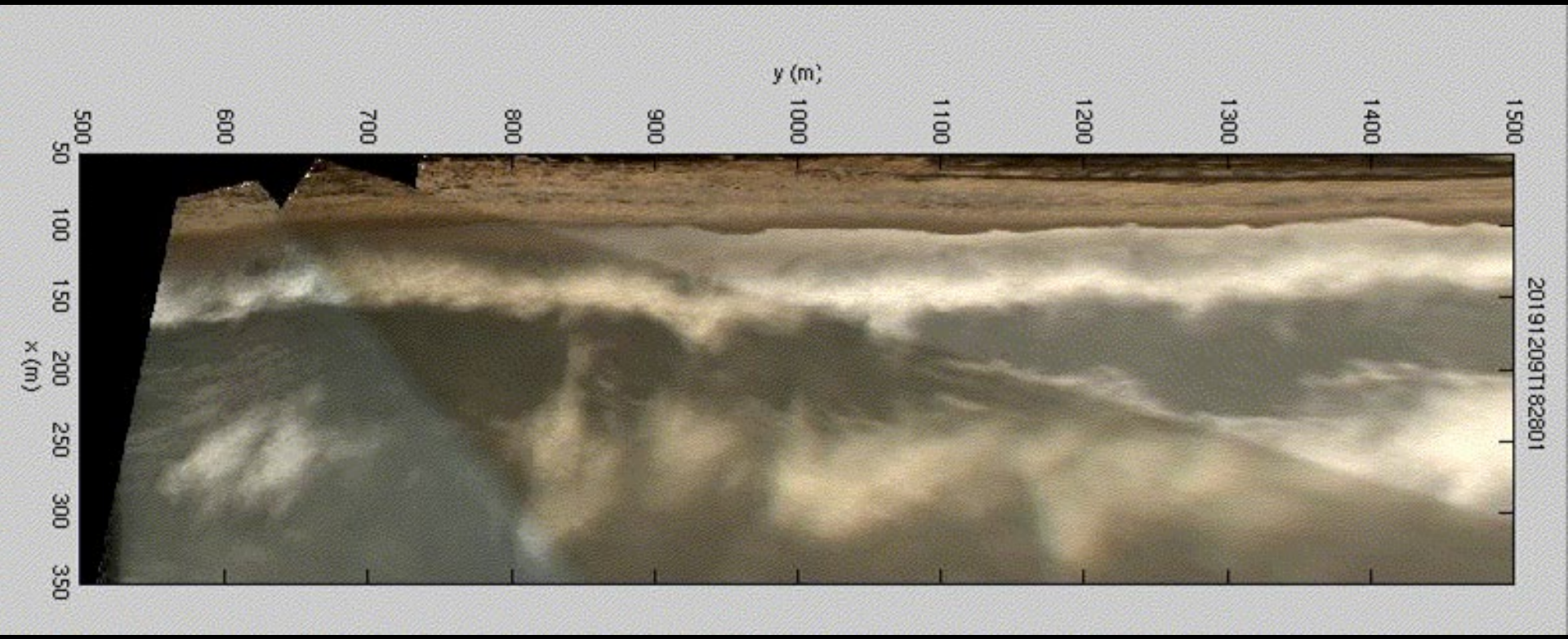

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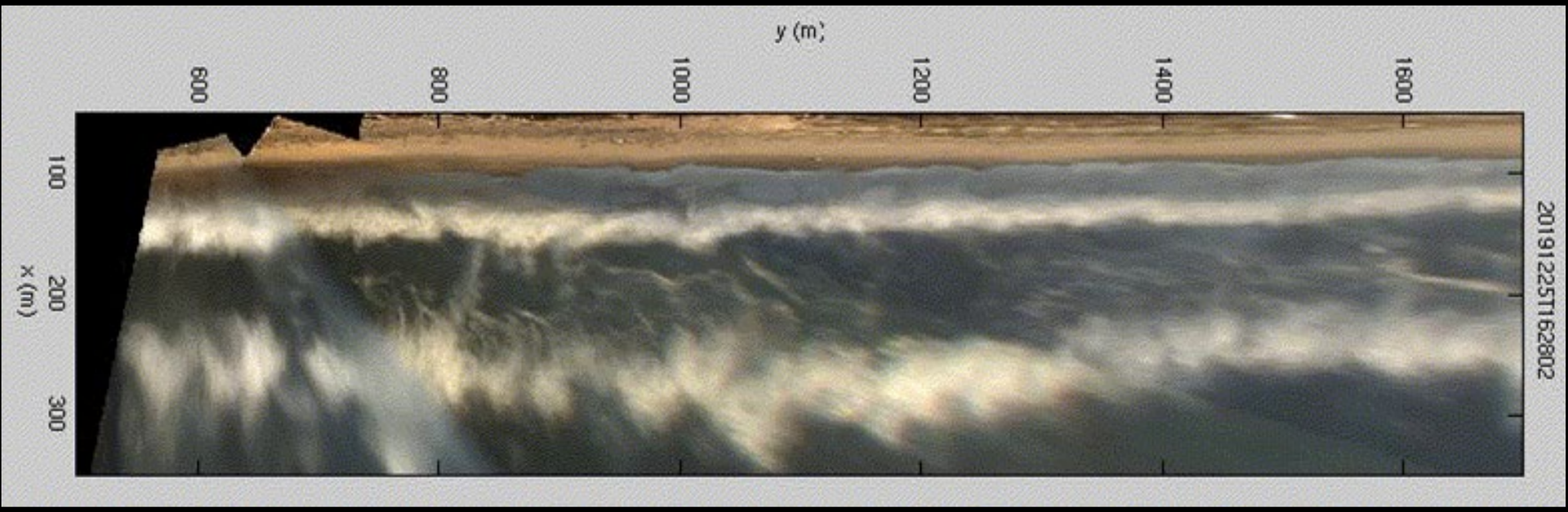

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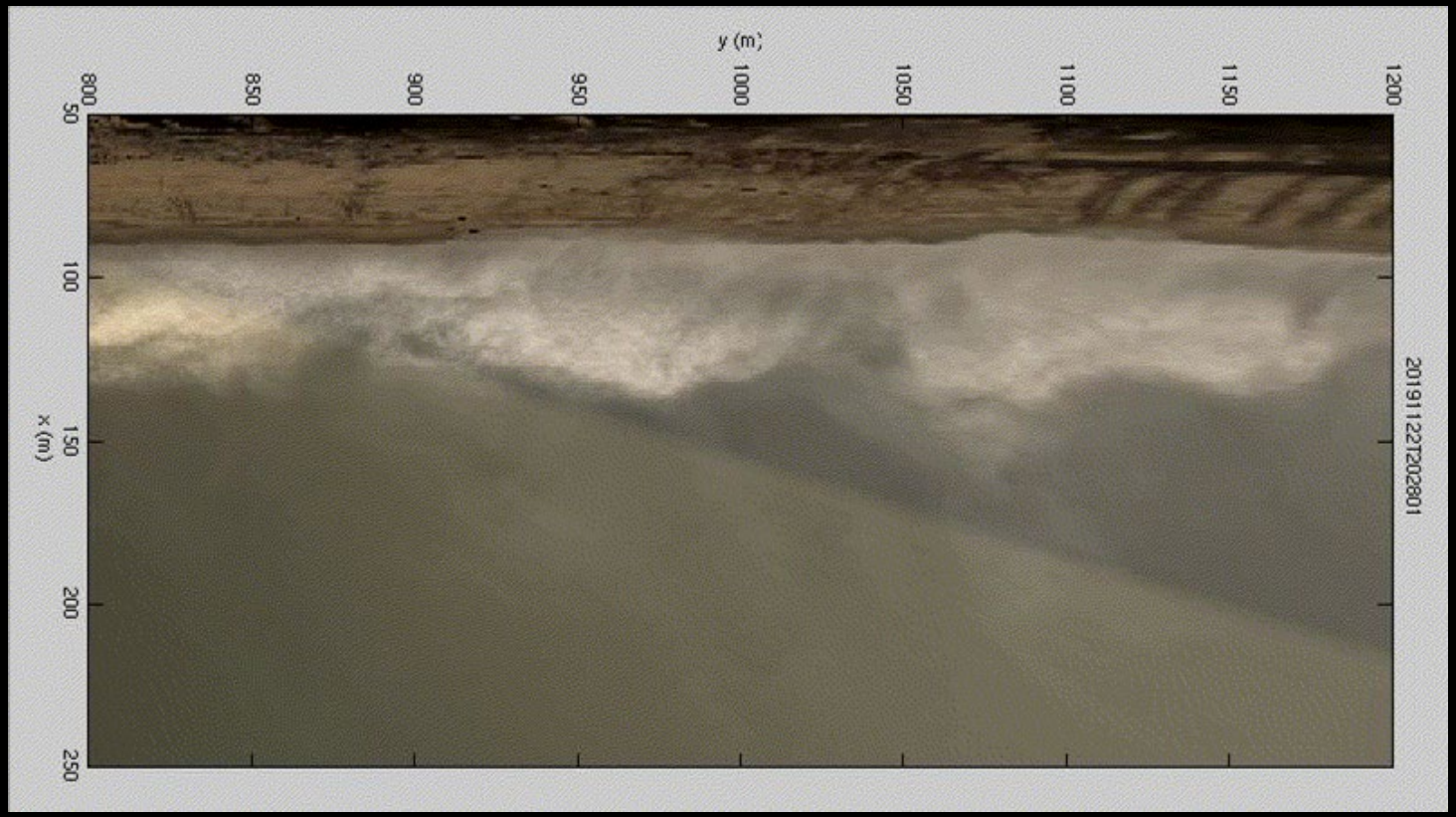

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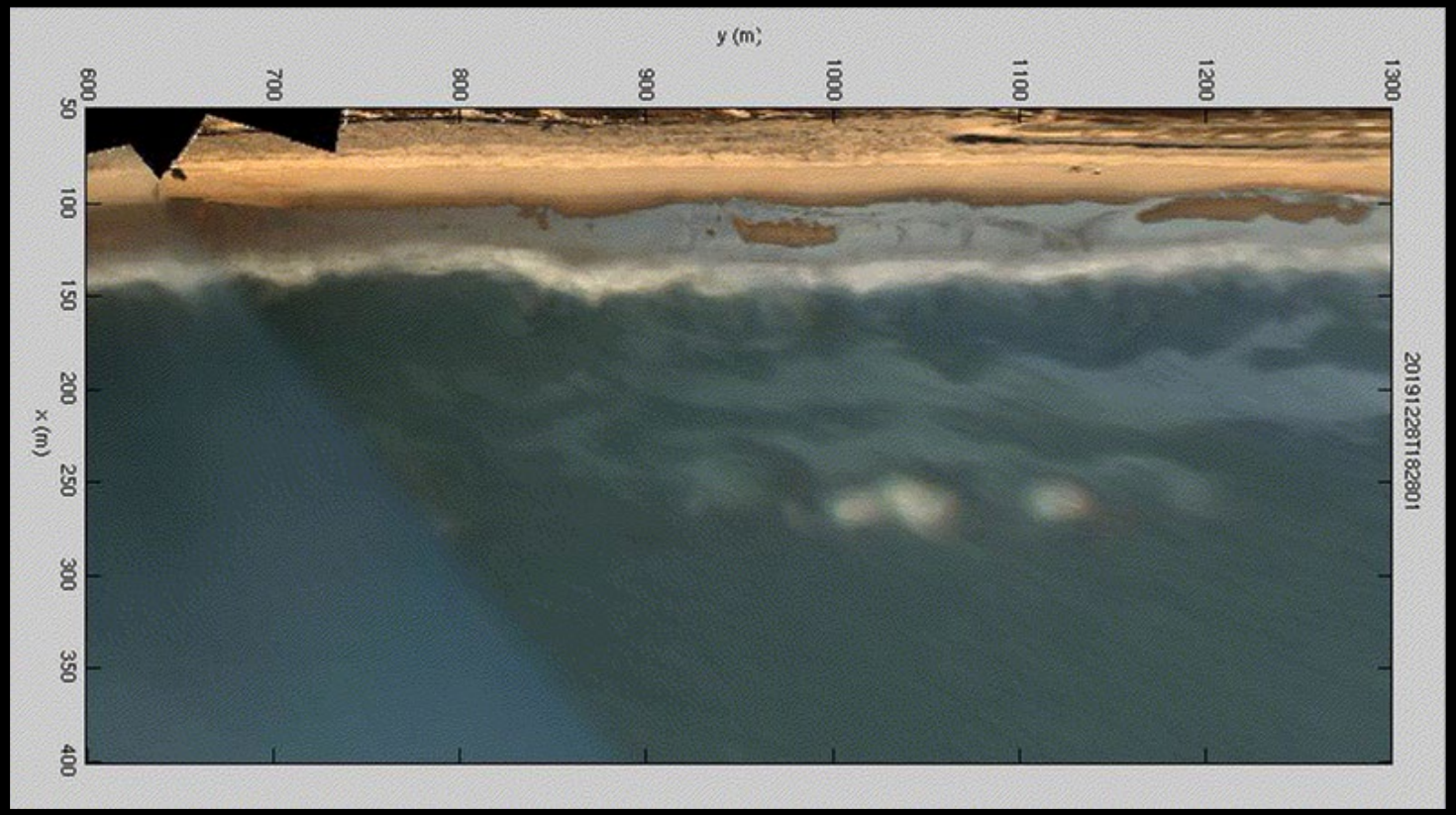

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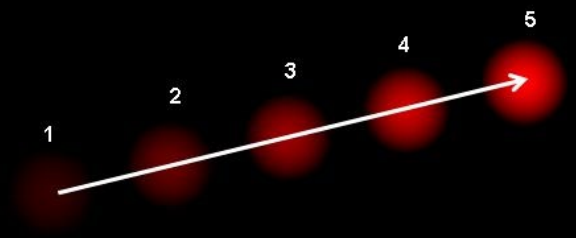
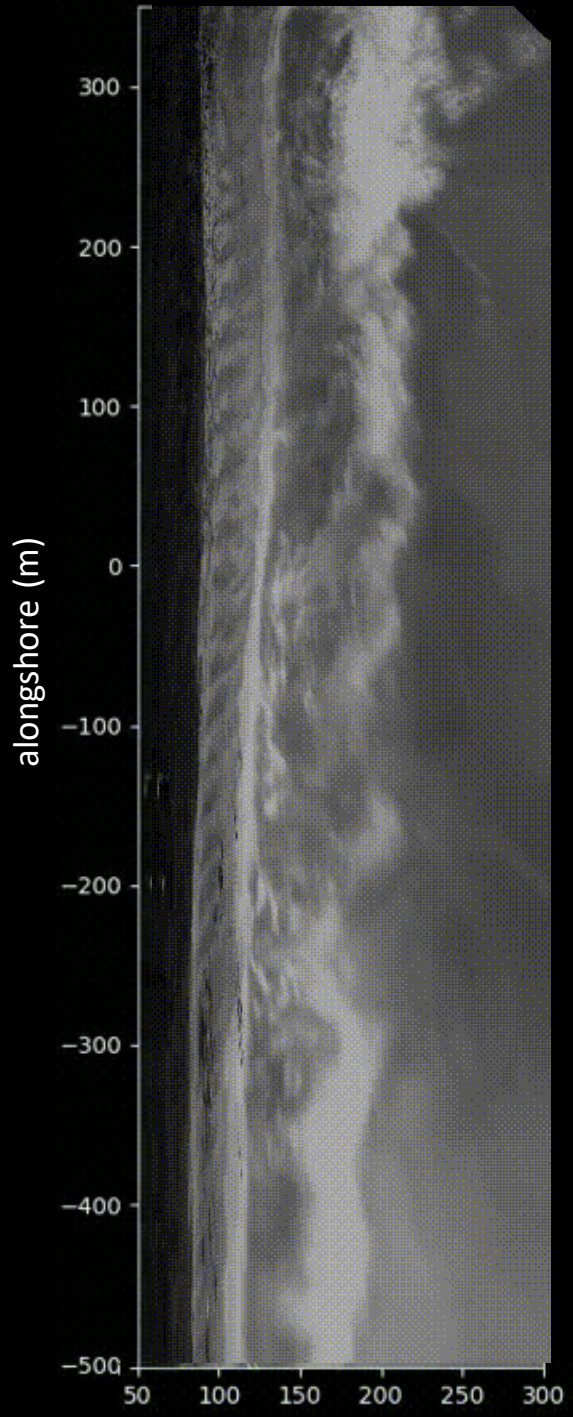
Optical Flow



Solves for gradients of image intensity in both space and time (Farneback 2003)

$$\frac{\partial I}{\partial x}u + \frac{\partial I}{\partial y}v + \frac{\partial I}{\partial t} = 0$$

Gives a direction and magnitude at every pixel between every frame in the video



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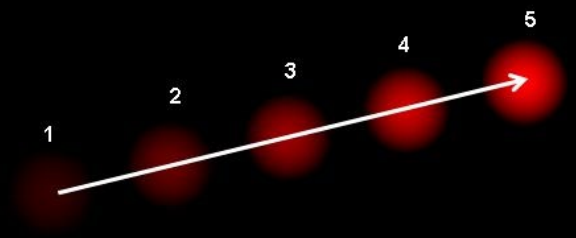

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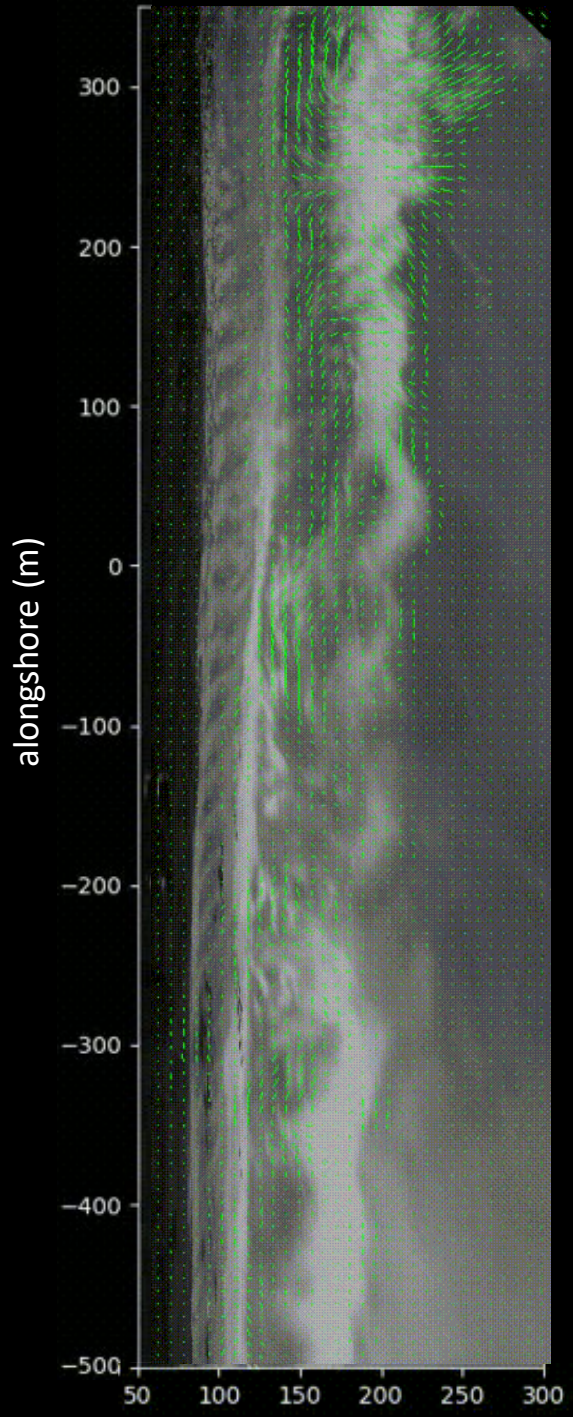
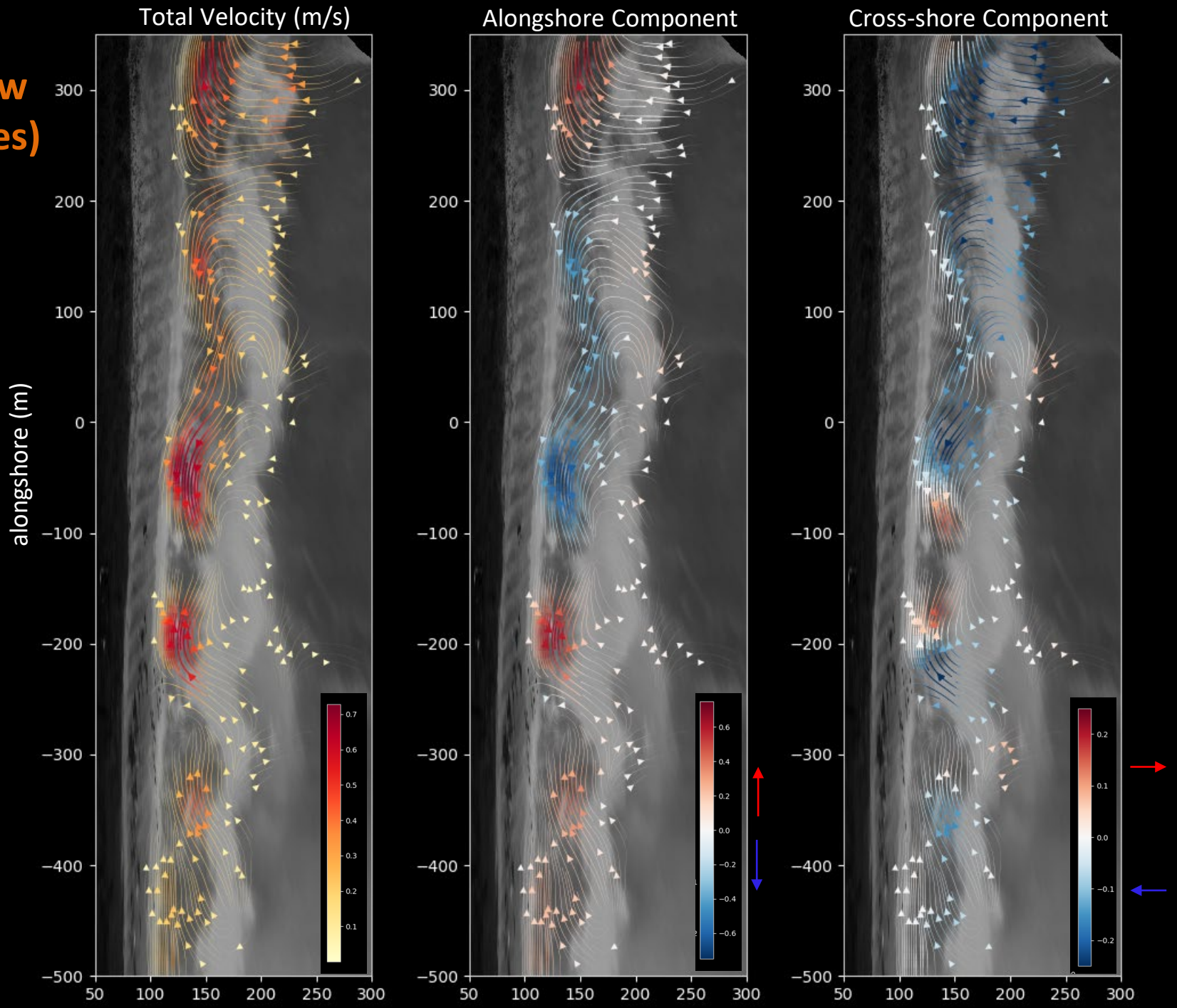


Mean Flow (180 frames)



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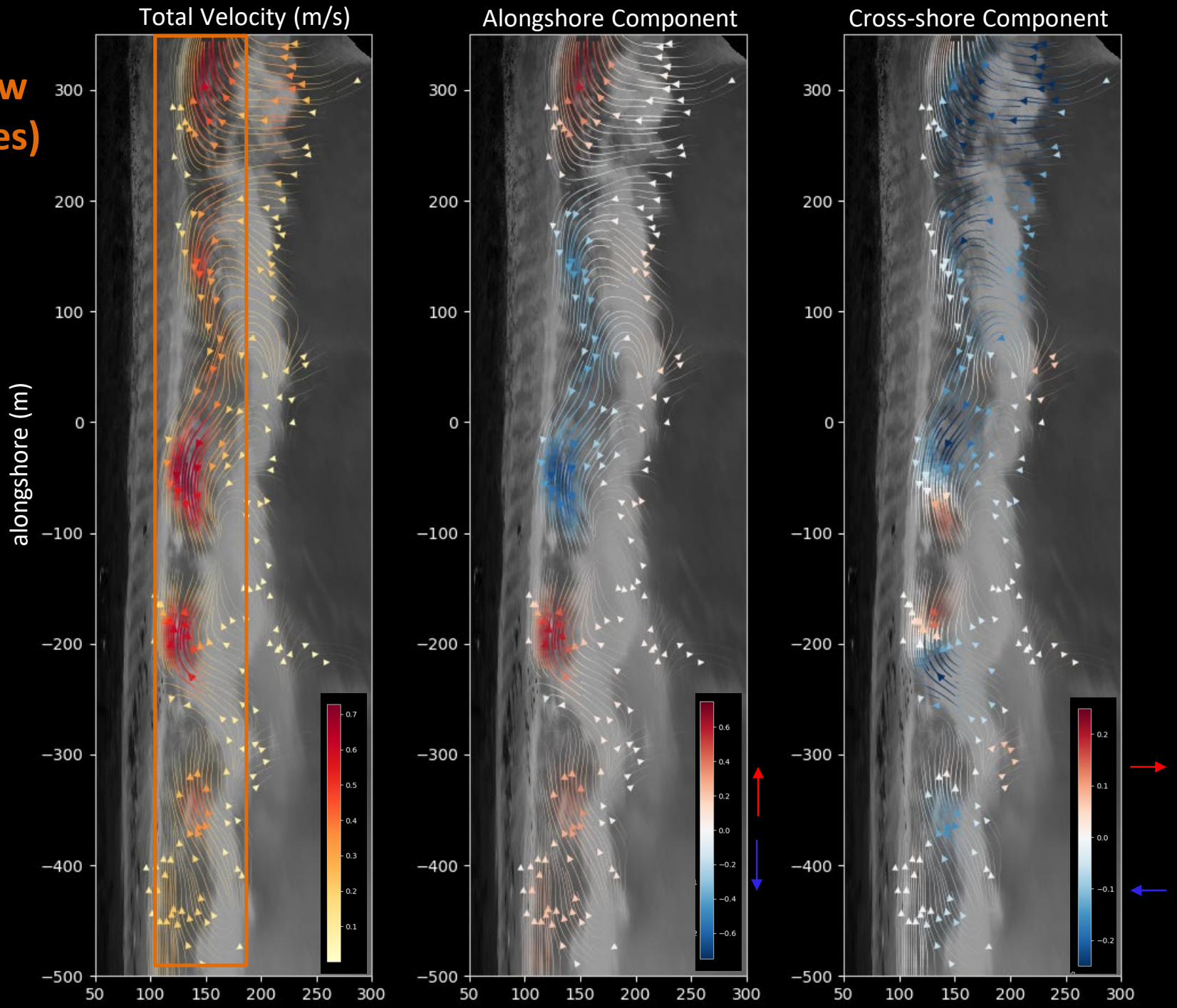

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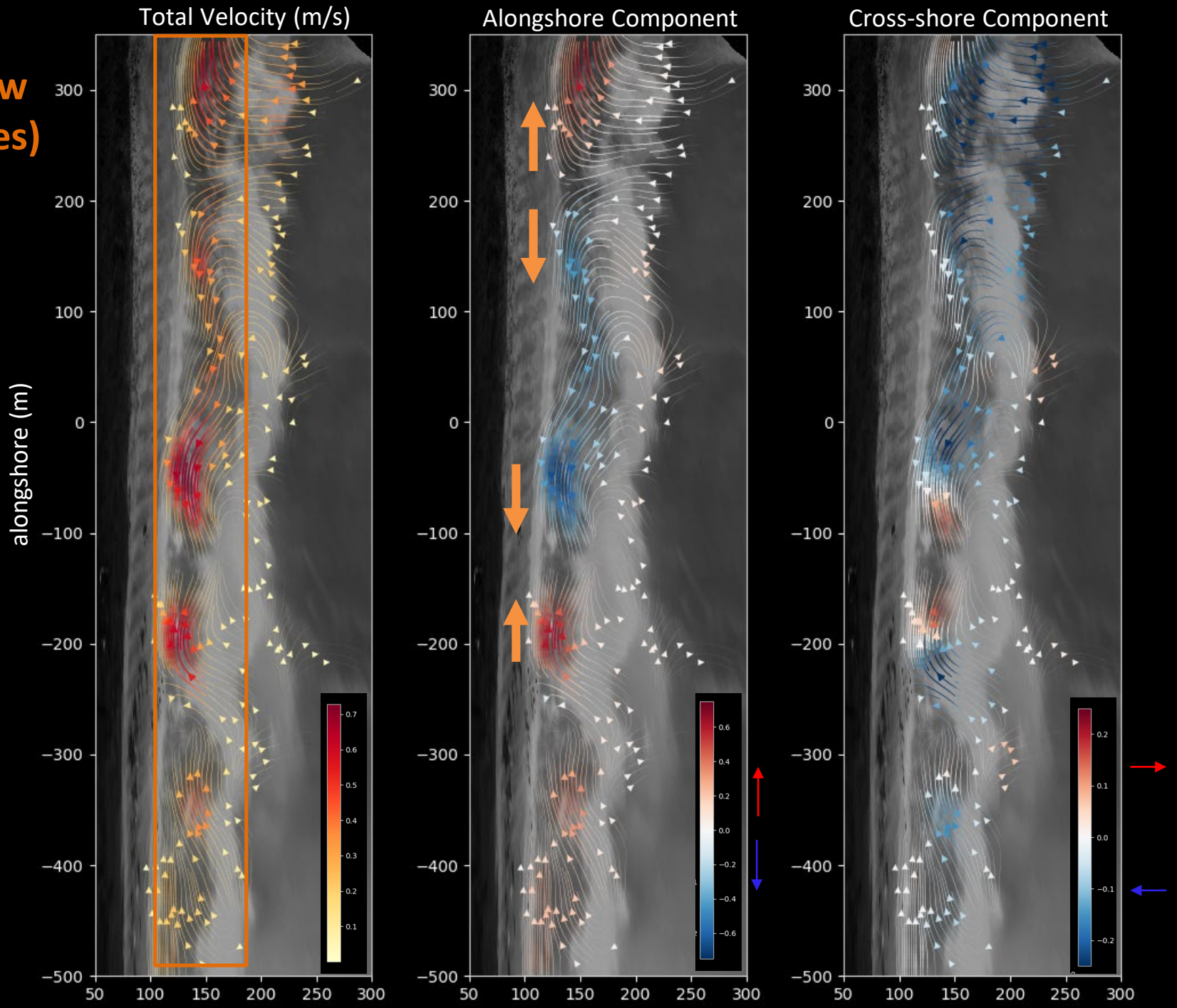

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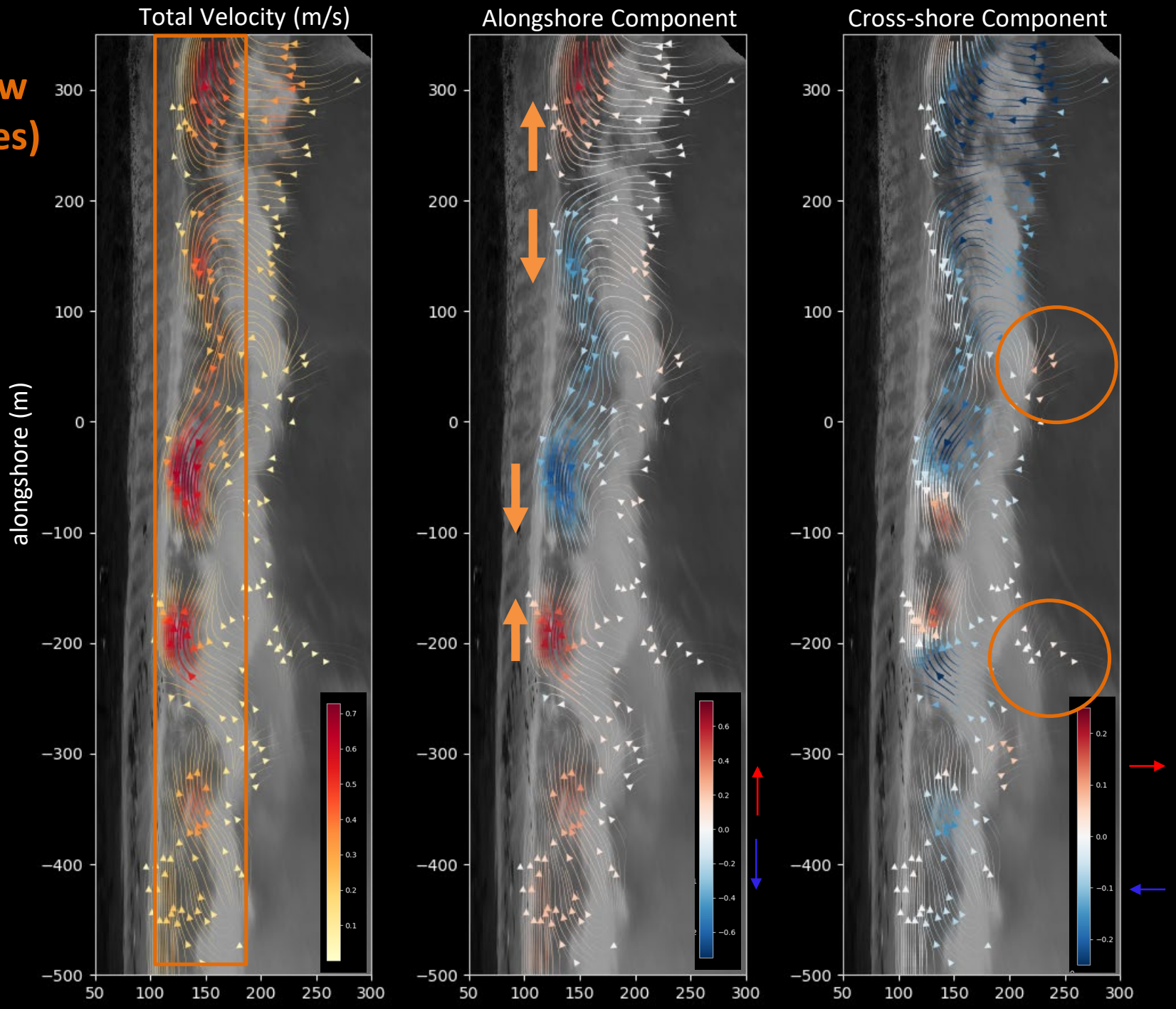
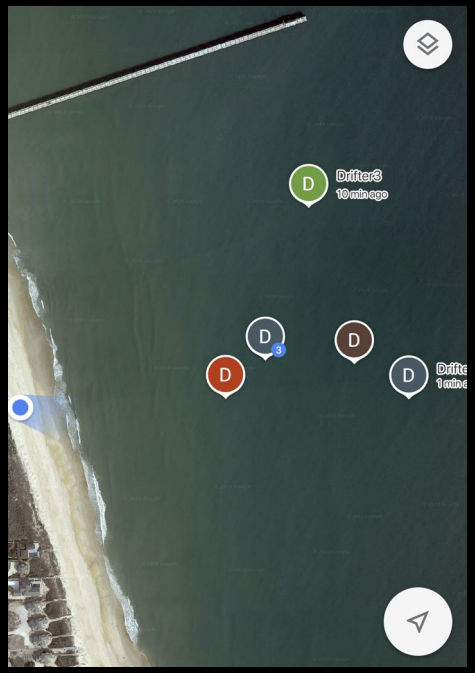
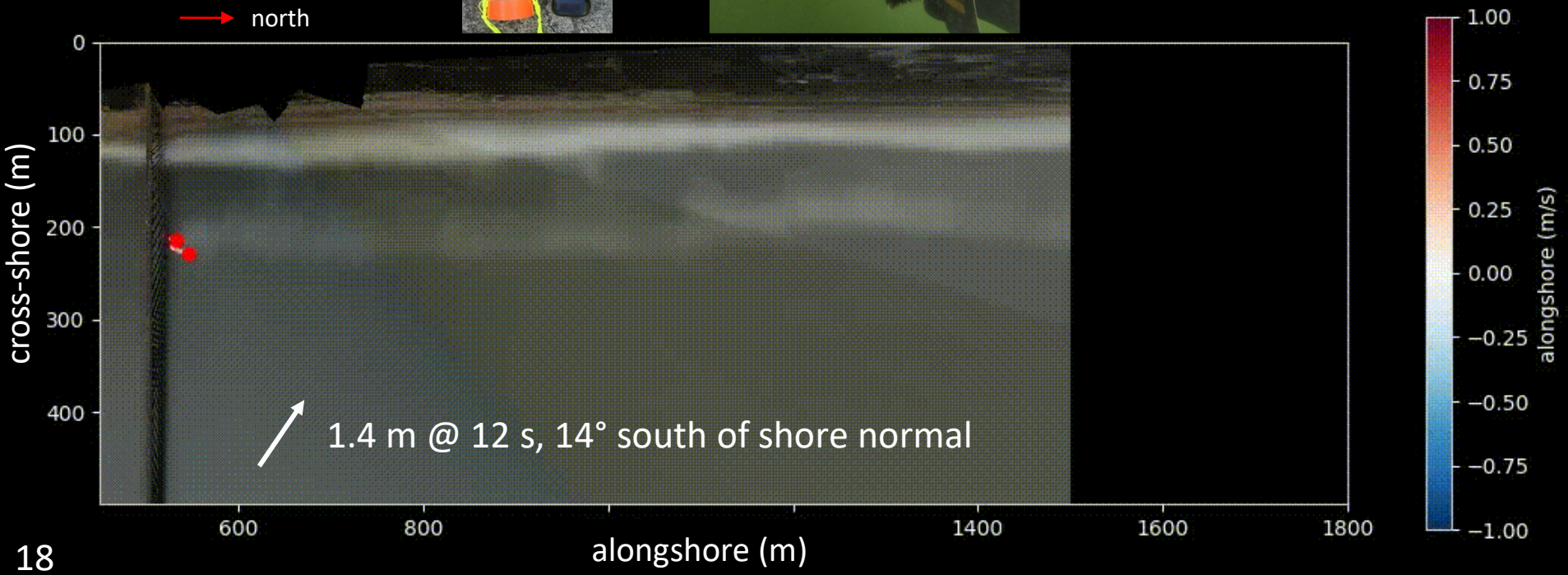


Drifter deployments at the FRF

- Dropped drifters off the pier at varying cross-shore distances during DUNEX pilot
- Tracked in live time with mobile devices
- Spit out by the shore-break (typically)





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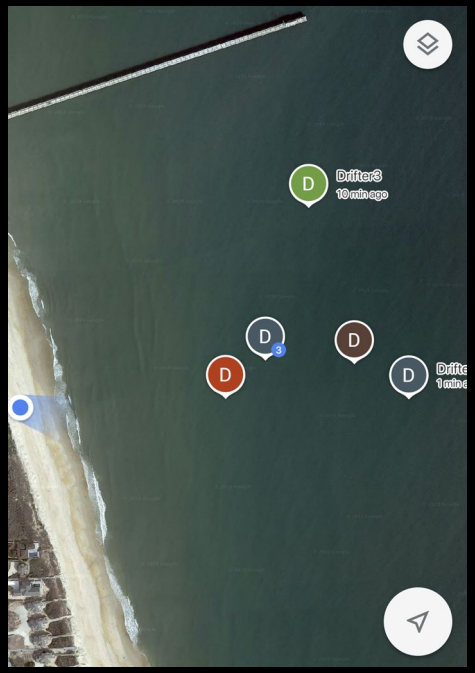
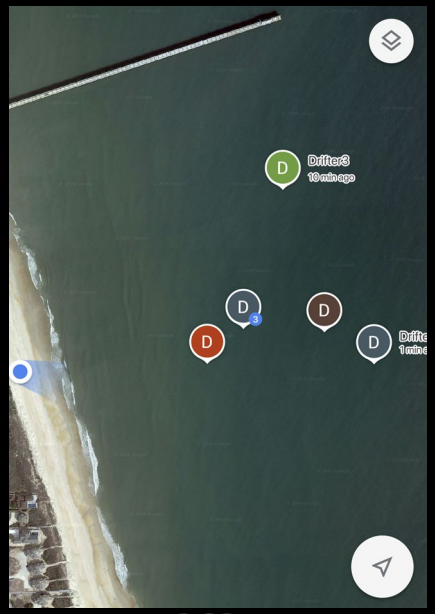
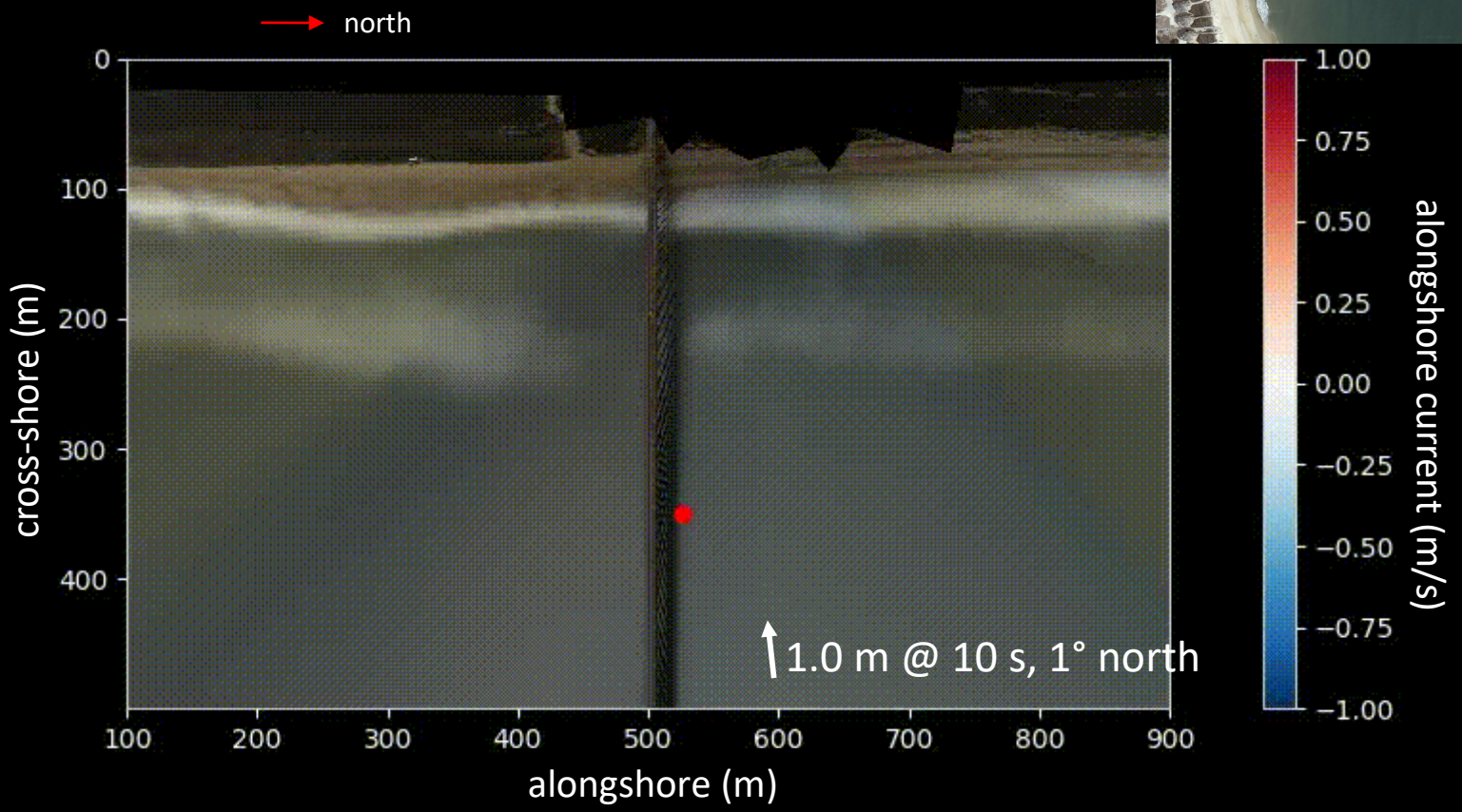
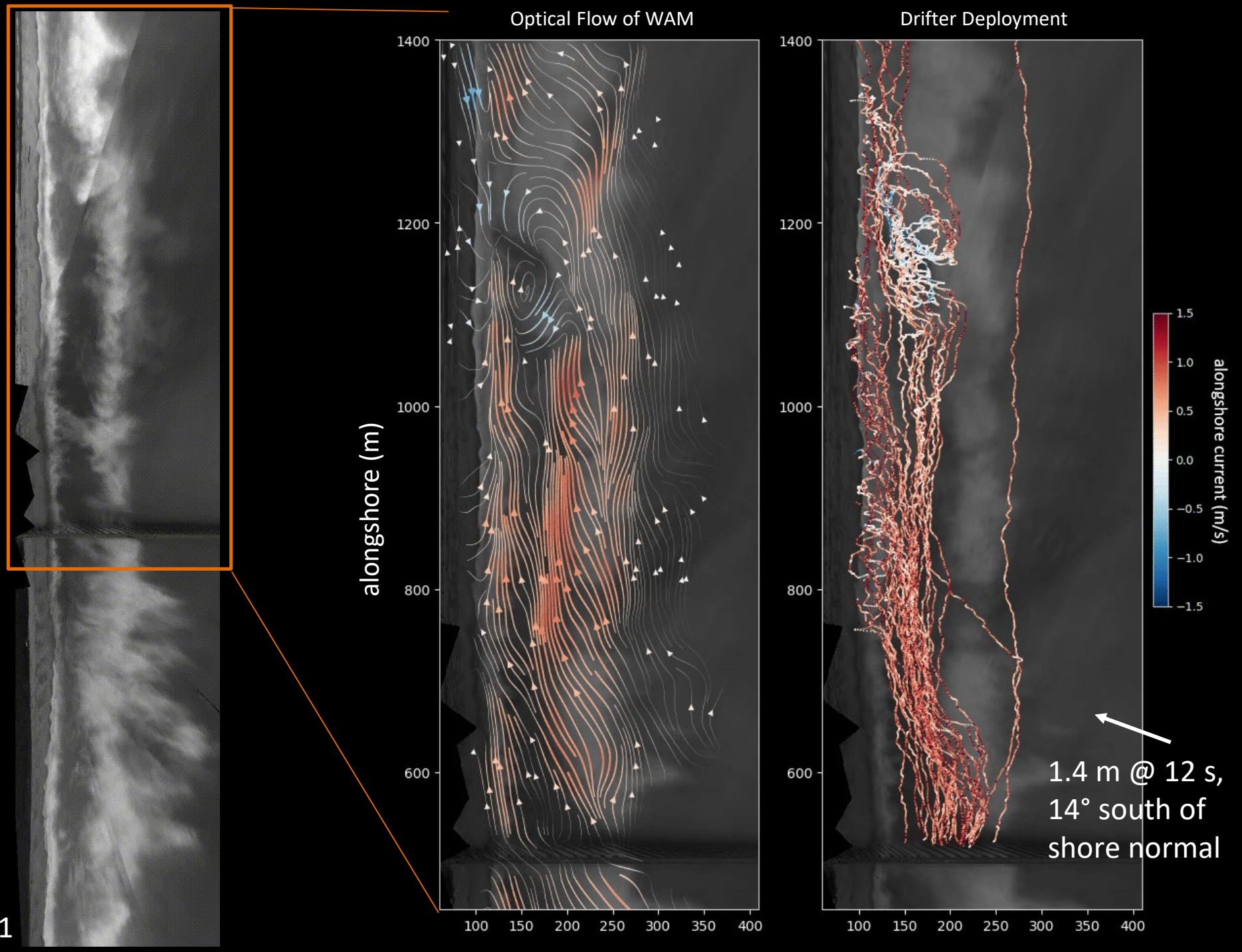


Drifter deployments at the FRF

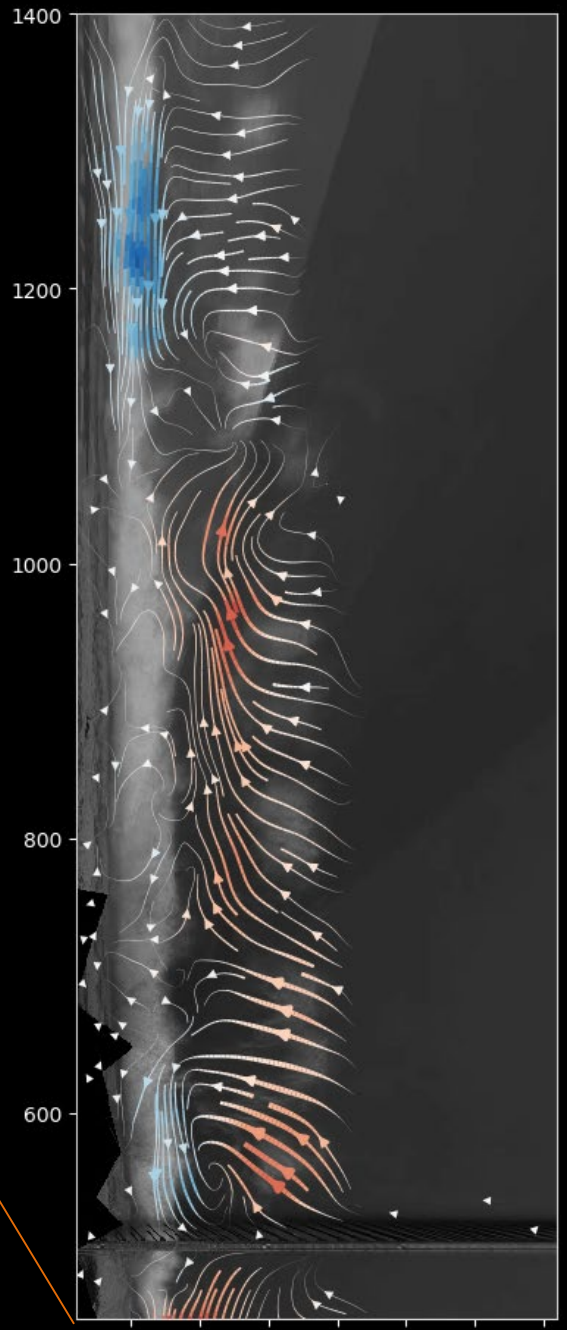
- Dropped drifters off the pier at varying cross-shore distances during DUNEX Pilot
- Tracked in live time with mobile devices
- Allowed to freely float alongshore & onshore
- Spit out by the shore-break (typically)



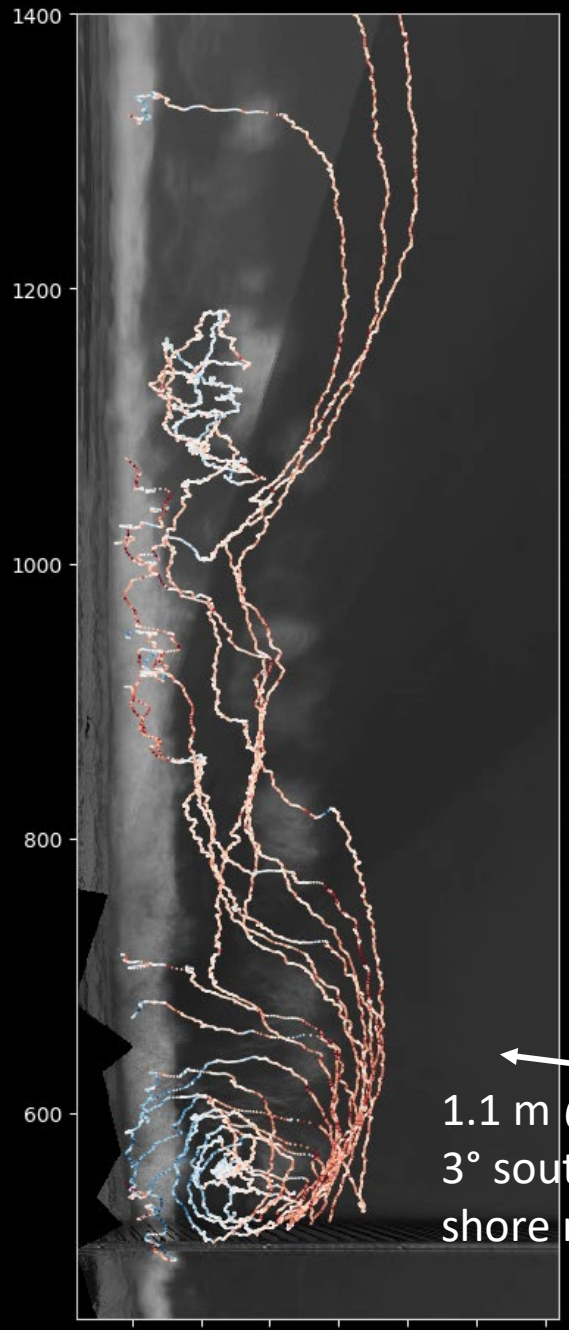



Optical Flow of WAM
Drifter Deployment
alongshore (m)
1400
1200
1000
800
600
100
150
200
250
300
350
400
alongshore current (m/s)
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
1.4 m @ 12 s,
14° south of
shore normal

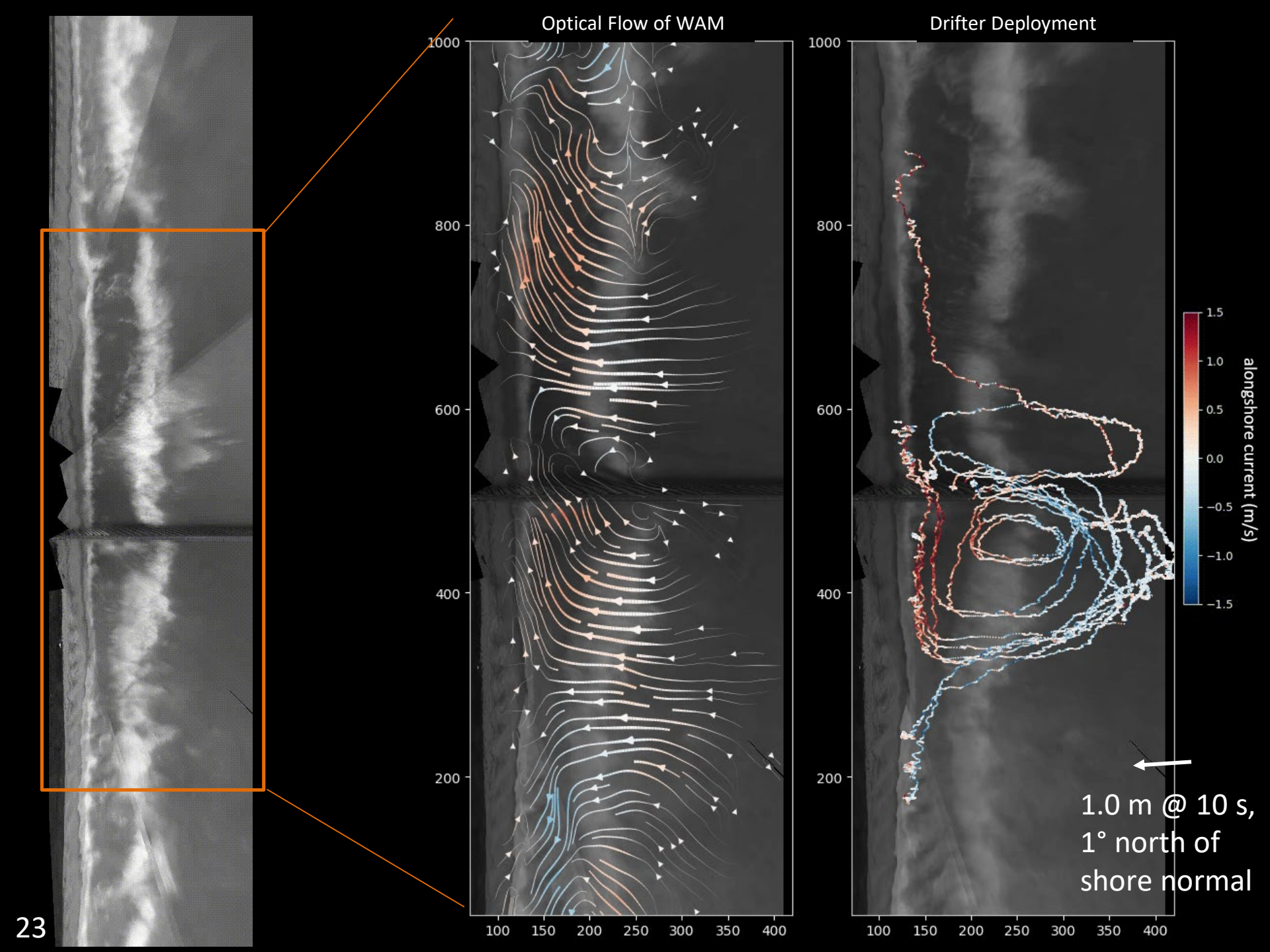
Optical Flow of WAM

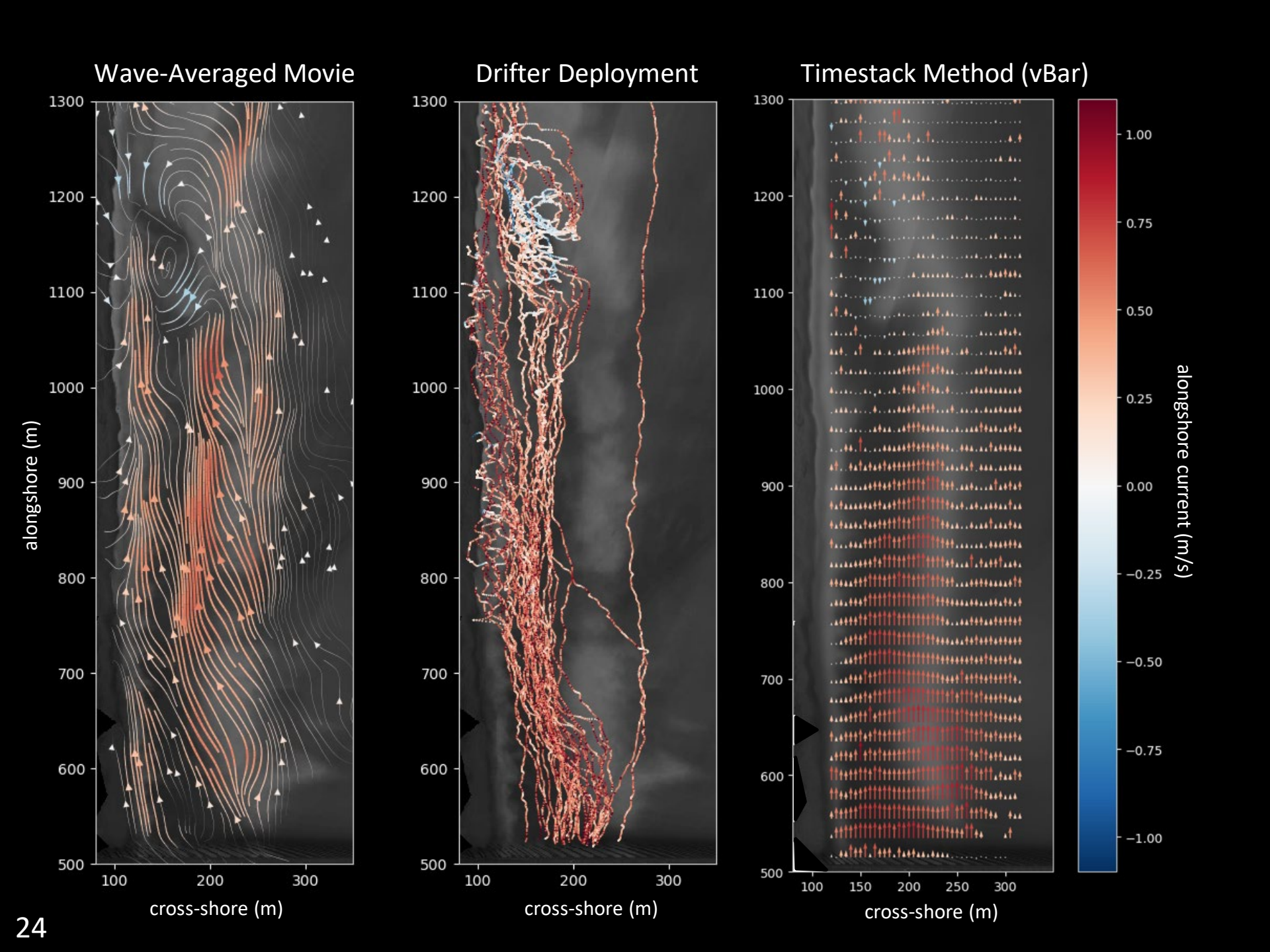


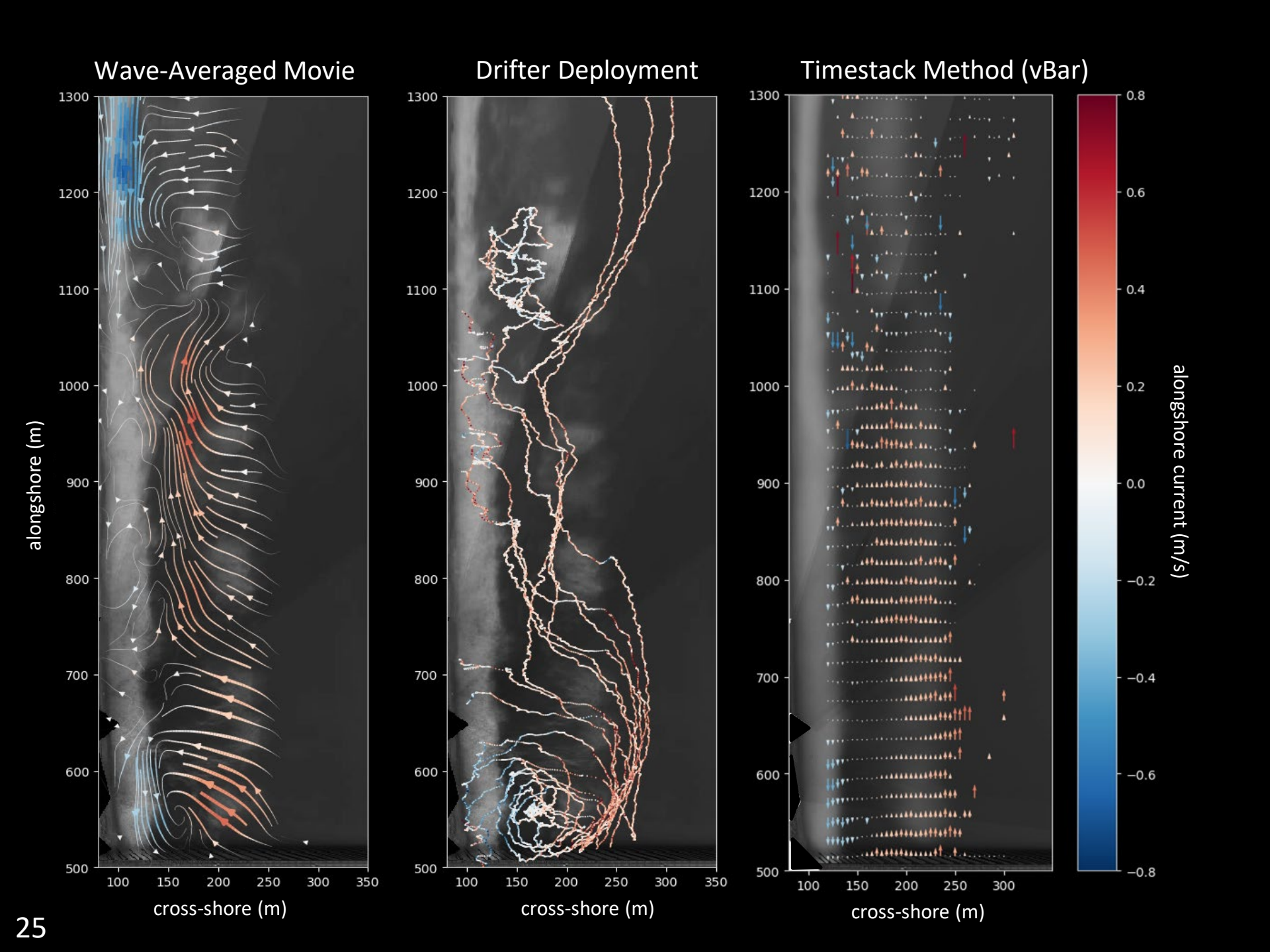
Drifter Deployment

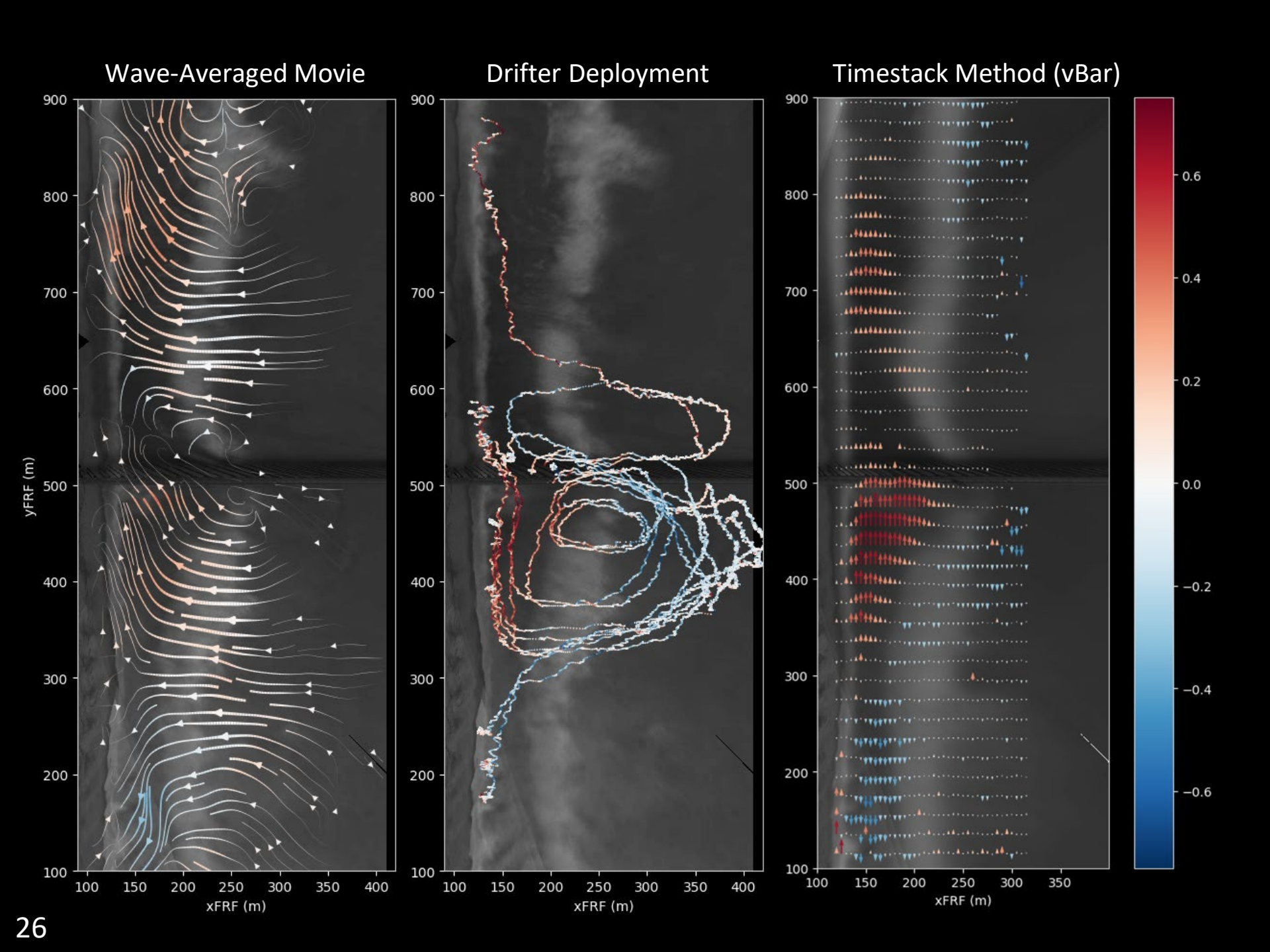


1.1 m @ 8 s,
3° south of
shore normal


Optical Flow of WAM
Drifter Deployment
1000
800
600
400
200
100
150
200
250
300
350
400
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
alongshore current (m/s)
1.0 m @ 10 s,
1° north of
shore normal

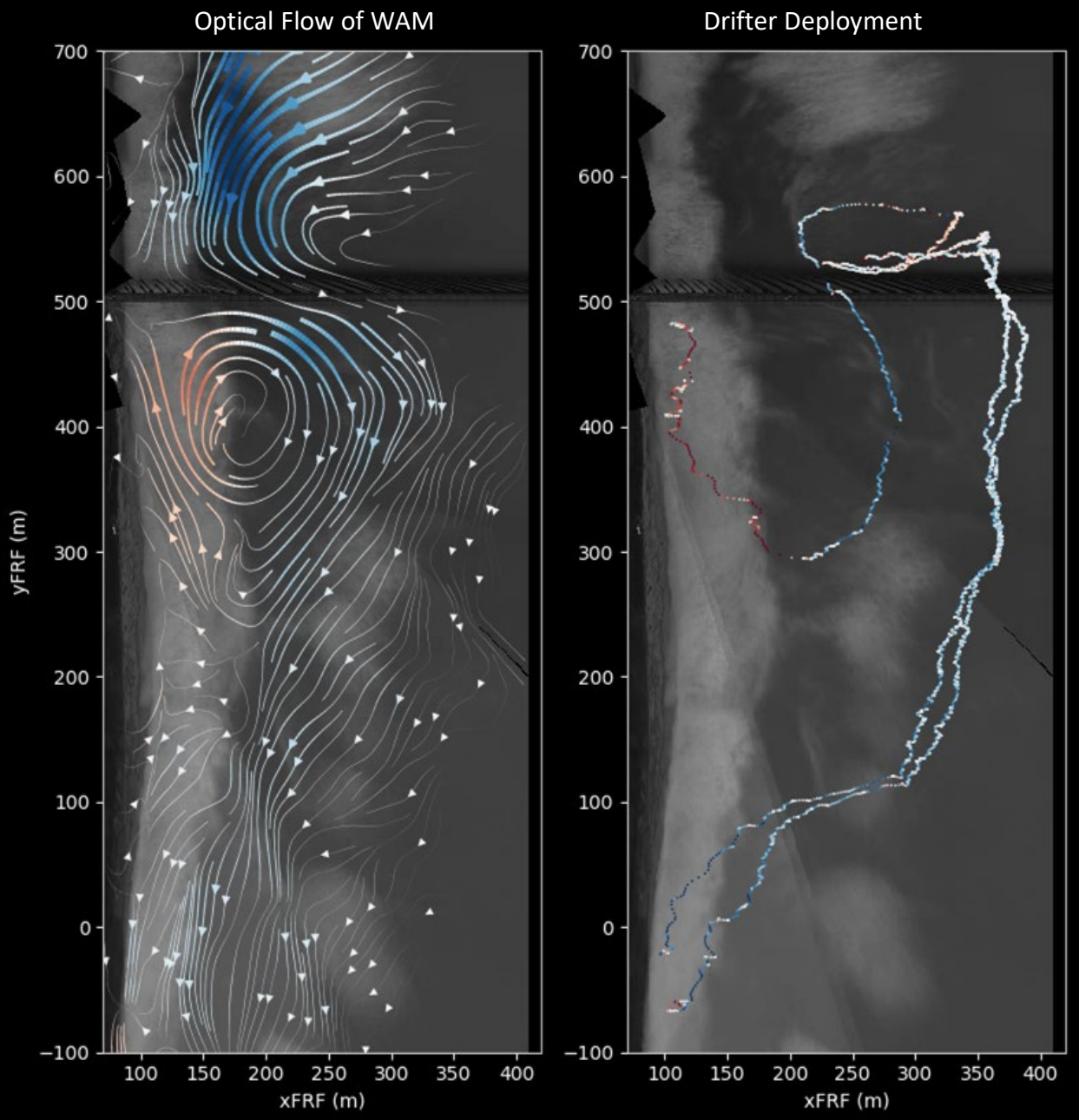

Wave-Averaged Movie
Drifter Deployment
Timestack Method (vBar)
alongshore (m)
cross-shore (m)
cross-shore (m)
cross-shore (m)
alongshore current (m/s)
1300
1200
1100
1000
900
800
700
600
500
100
150
200
250
300
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


Wave-Averaged Movie
Drifter Deployment
Timestack Method (vBar)
alongshore (m)
cross-shore (m)
cross-shore (m)
cross-shore (m)
alongshore current (m/s)
1300
1200
1100
1000
900
800
700
600
500
100
150
200
250
300
350
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8

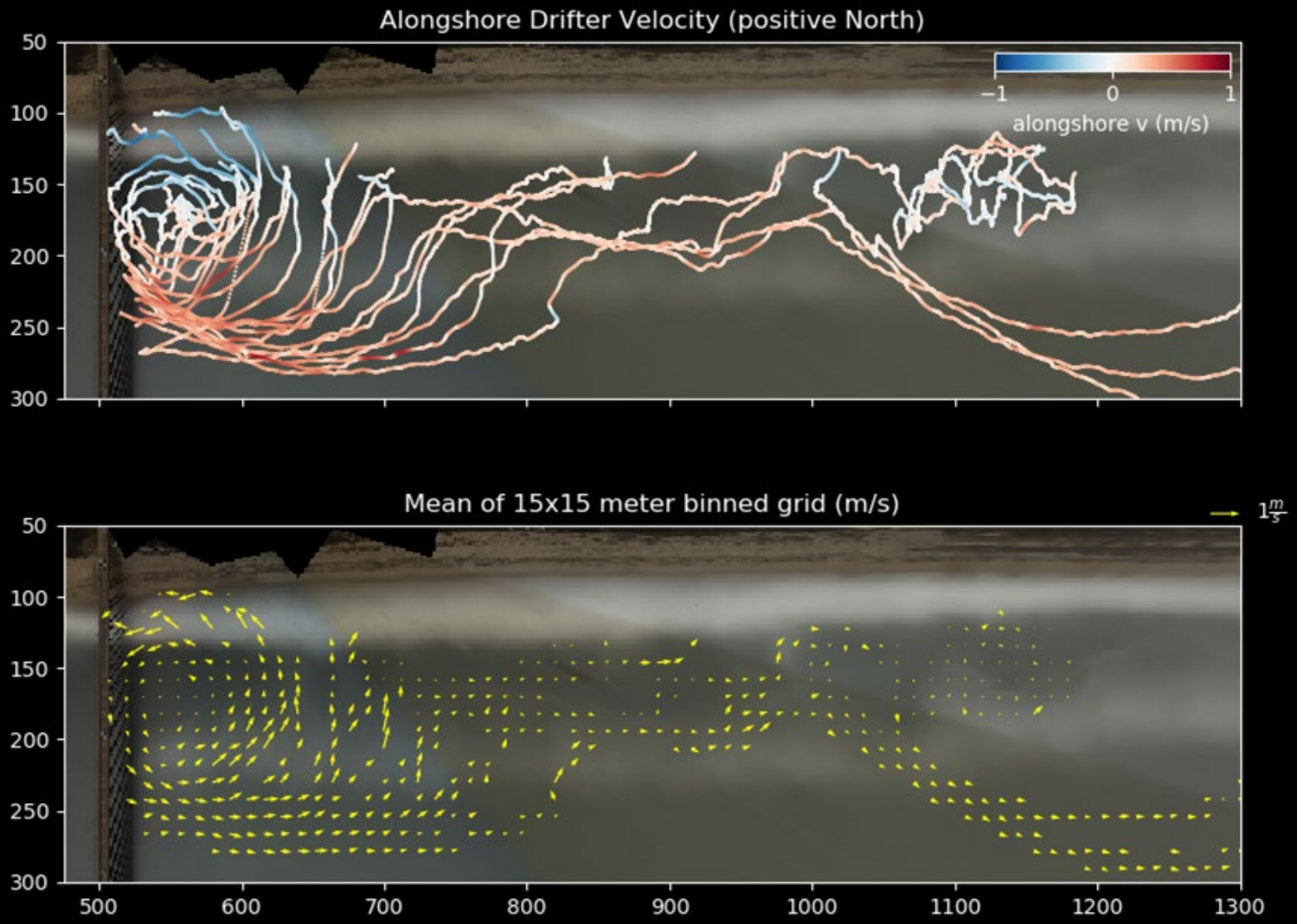

Wave-Averaged Movie
Drifter Deployment
Timestack Method (vBar)
yFRF (m)
xFRF (m)
xFRF (m)
xFRF (m)
900
800
700
600
500
400
300
200
100
100
150
200
250
300
350
400
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

Even a limited number of drifters can provide confidence in the flow pattern derived from the wave-averaged movies.

But ultimately, even the best drifter design is feeling both the mean current and the individual wave components… And its moving through the domain such that 1-to-1 drifter to WAM comparisons are not measuring the same process.

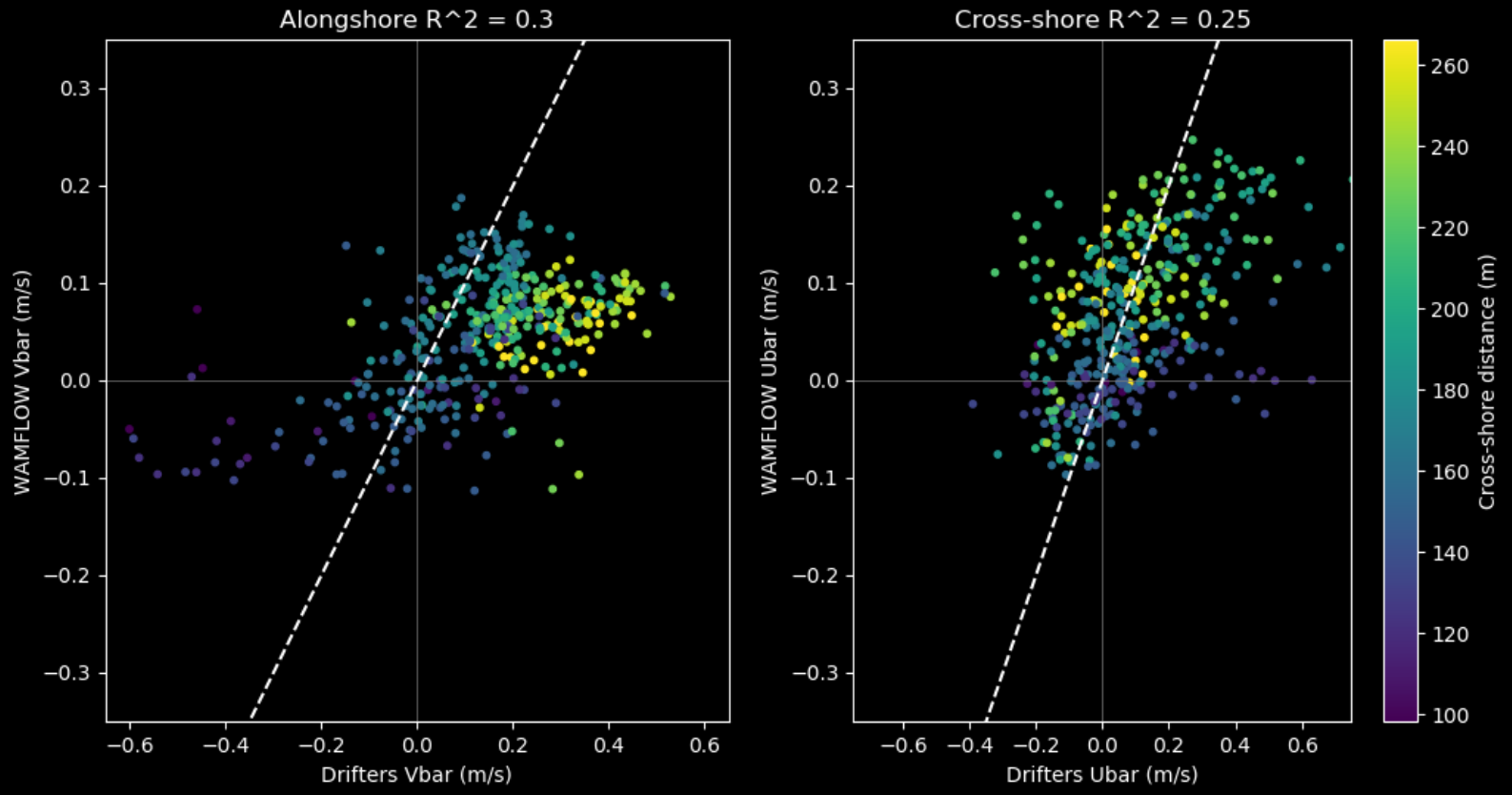


One technique for comparing eulerian and lagrangian measurements: Collapsing lagrangian observations to look at all measurements in an dx,dy spatial bin regardless of time.



Decent amount of scatter:

- Underpredict in swash zone, where depths are shallow, shore-breaking waves dominate and drifters “surf” quickly to shore
- Underpredict outside of the surf zone, where foam is intermittent and an “average” current includes zeros due to there being no foam on the surface



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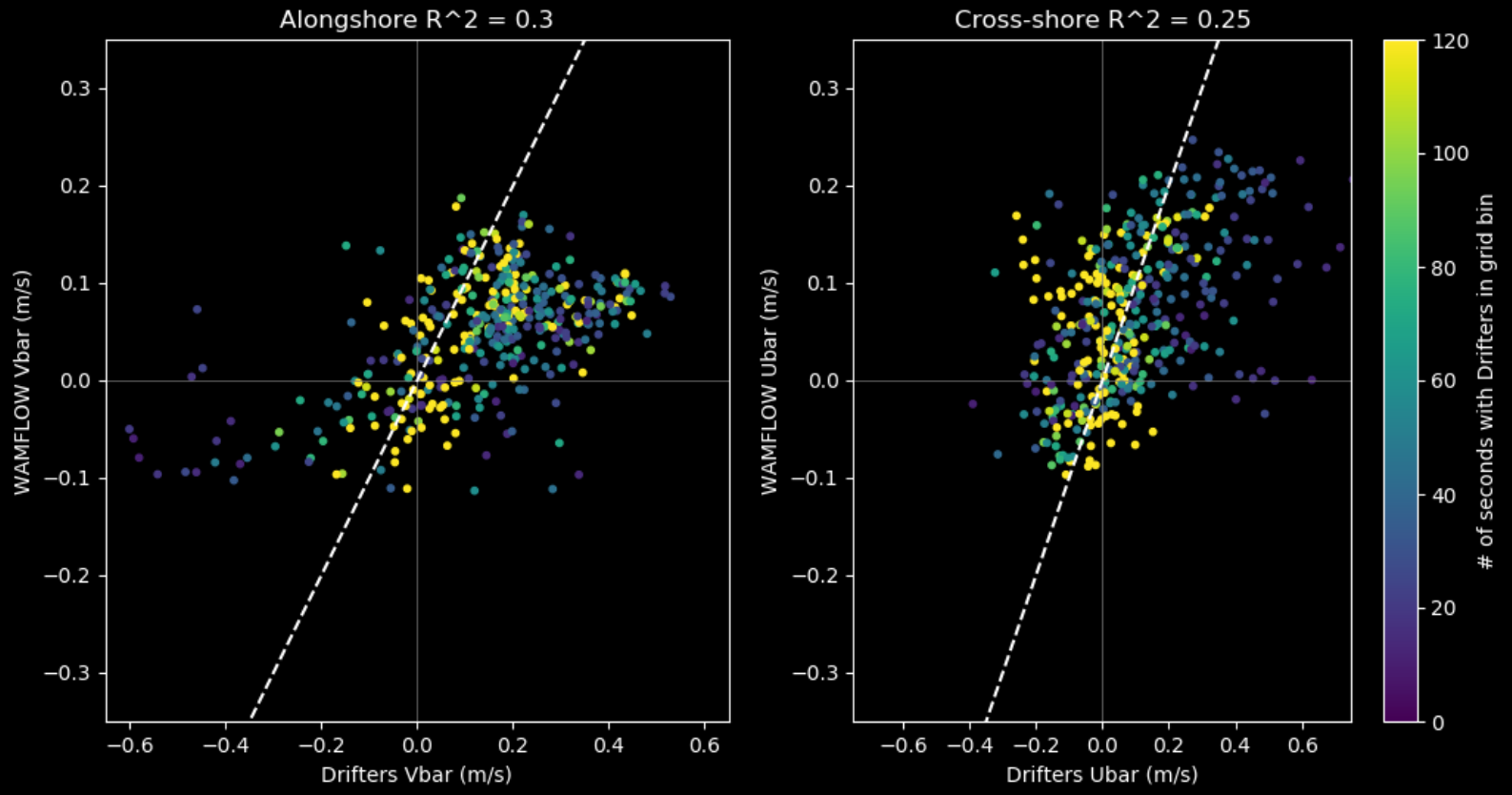
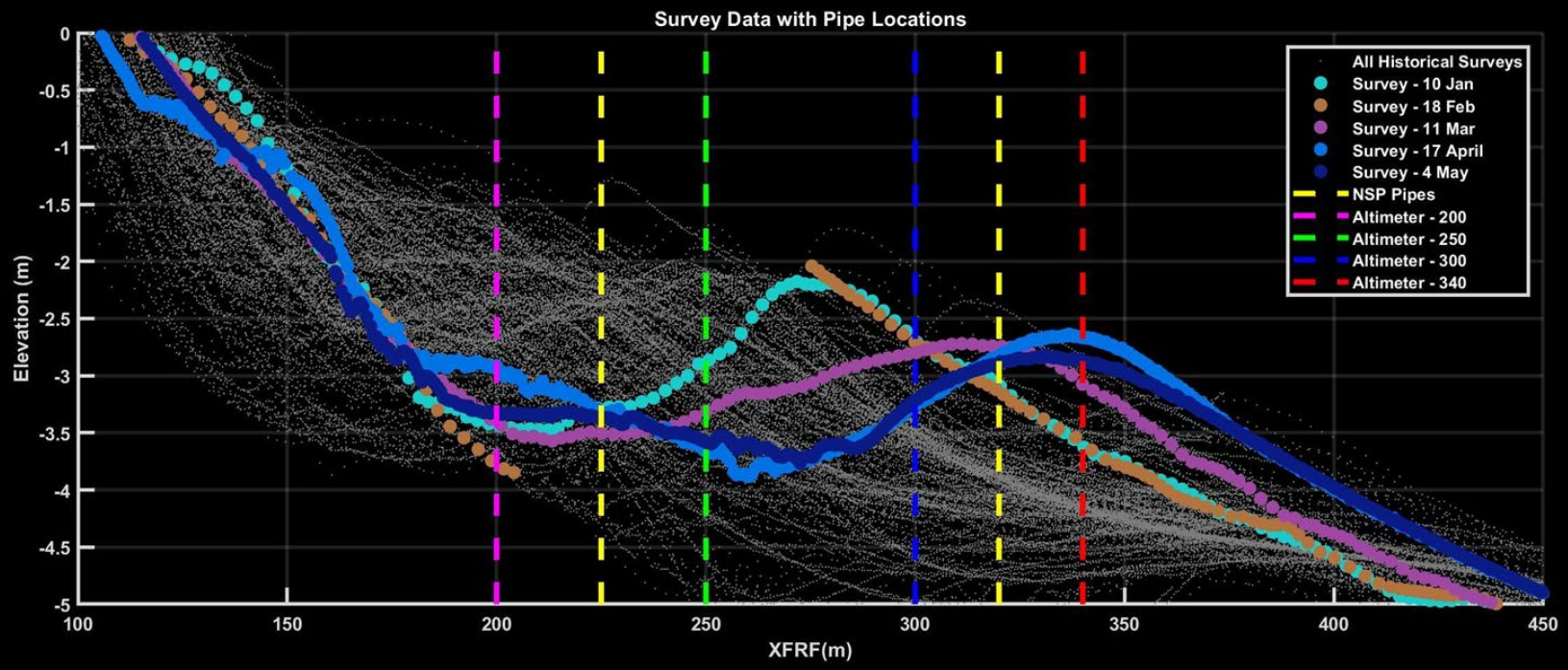
- Underpredict outside of the surf zone, where foam is intermittent and an “average” current includes zeros due to there being no foam on the surface
- Ultimately, the scatter is also a consequence of the number of observations, fewer observations = more wave-by-wave velocity, more observations = more mean flow



Future Validation & Development

Plan to leverage stationary current profile data collected this spring at the FRF by the Nearshore Processes Research project

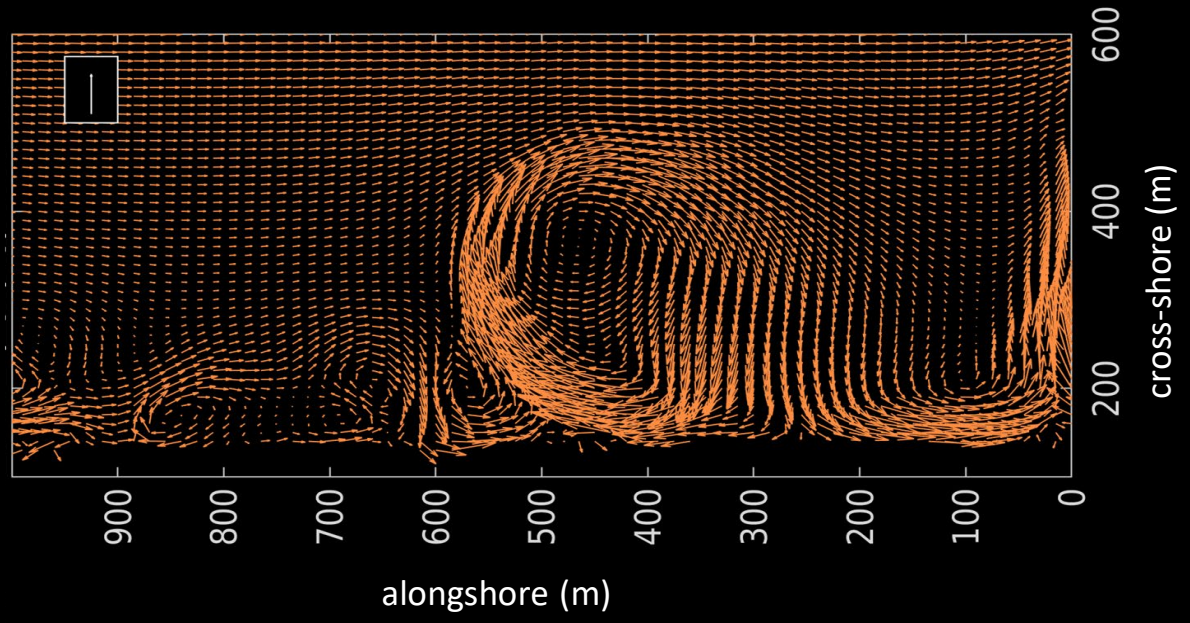
- Will provide a range of wave, water level, and wind conditions
- Frequent bathymetric surveys



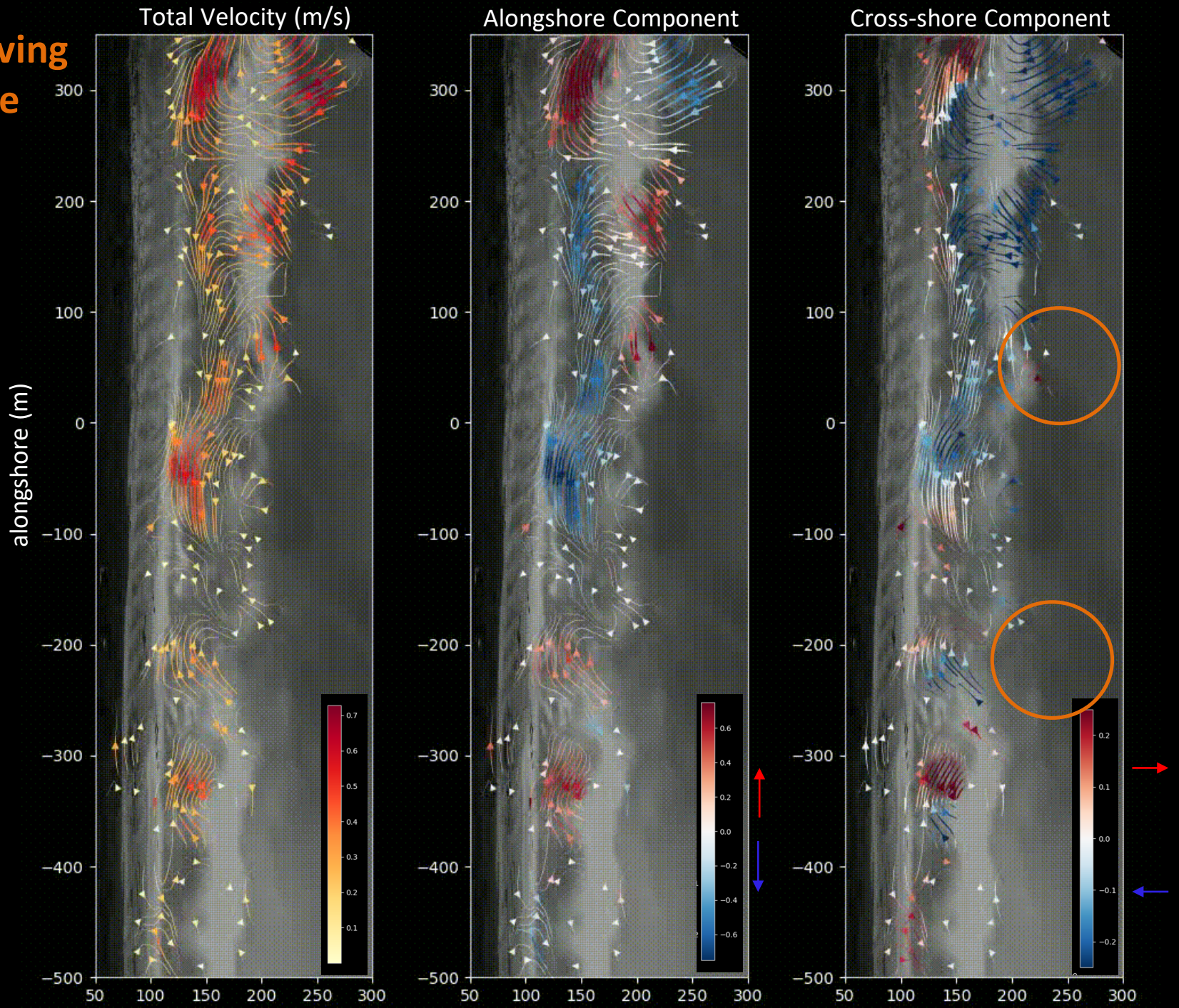
Nearshore Processes Research: Brad Johnson, Nick Cohn, Patrick Dickhudt, Kate Brodie, Spicer Bak

Future Validation & Development

- Plan to deploy drifters again in DUNEX
  - Targeting the circulation patterns from a large wave event
- Data assimilation techniques
- Model/data comparisons
- Standardized Argus product (POH mini-argus pilot)

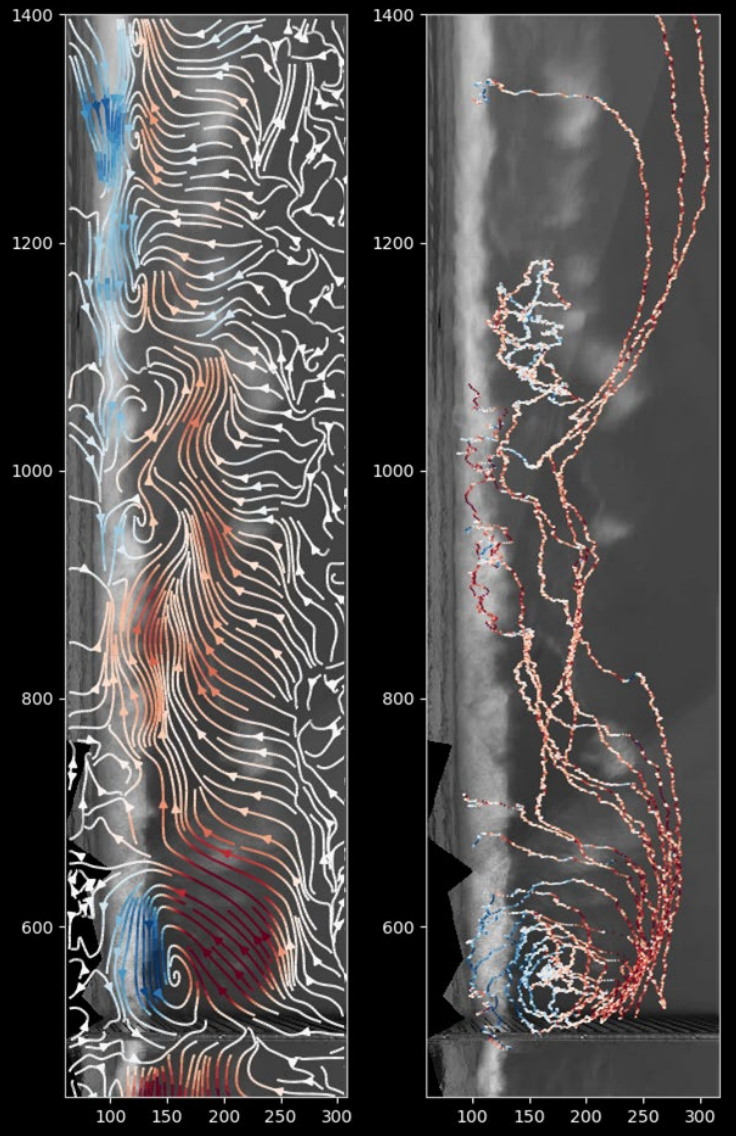


2 min moving average



New approach, with intriguing potential

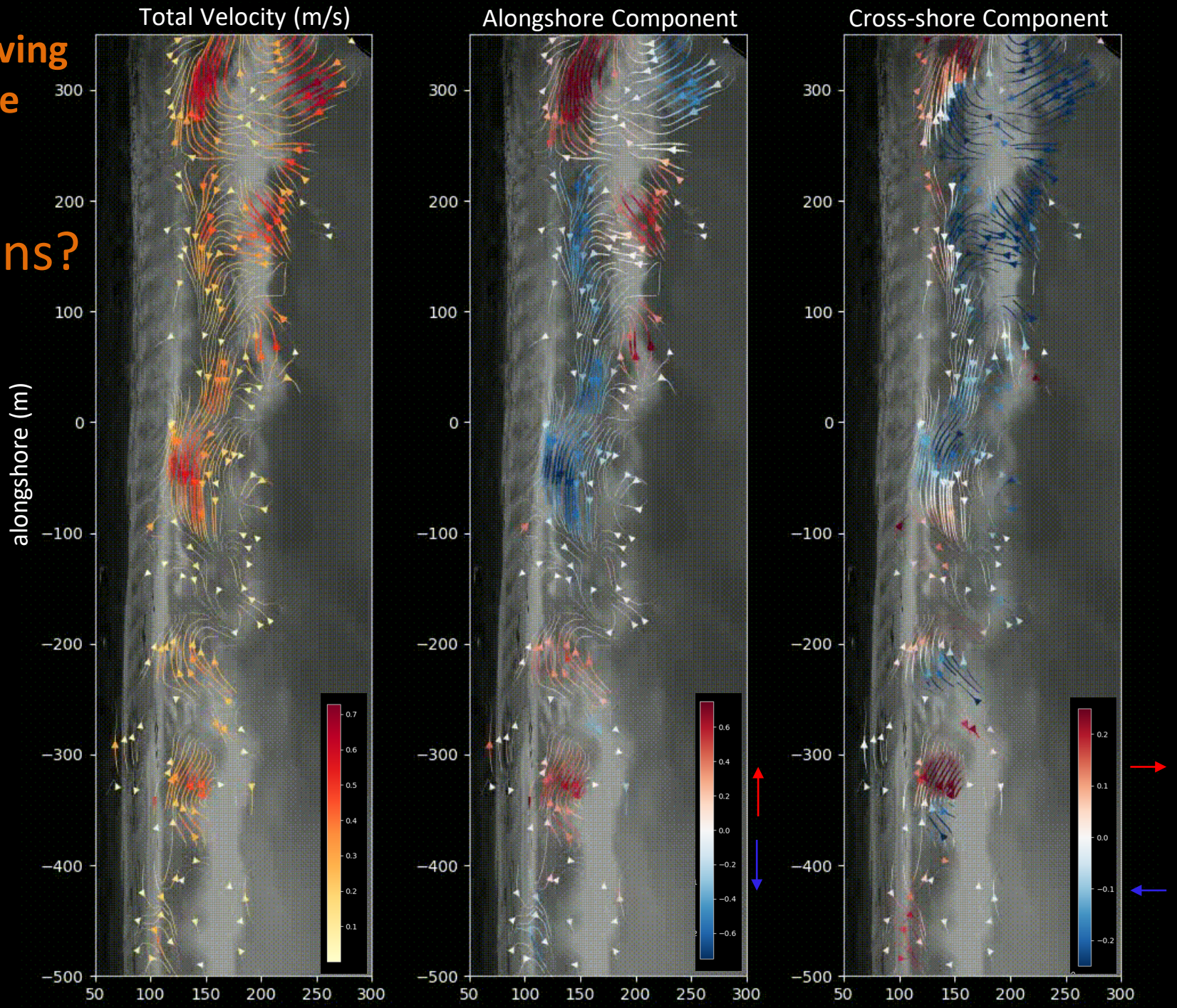
- Can use time-averaged imagery to resolve 2-D flow patterns at scales of 10 to 100s of meters within the surf zone
- Initial results qualitatively similar to drifter patterns and quantitatively similar to other optical methods
- Considerable work still to be done… sensitivities to conditions, image quality, averaging windows, optical flow parameters

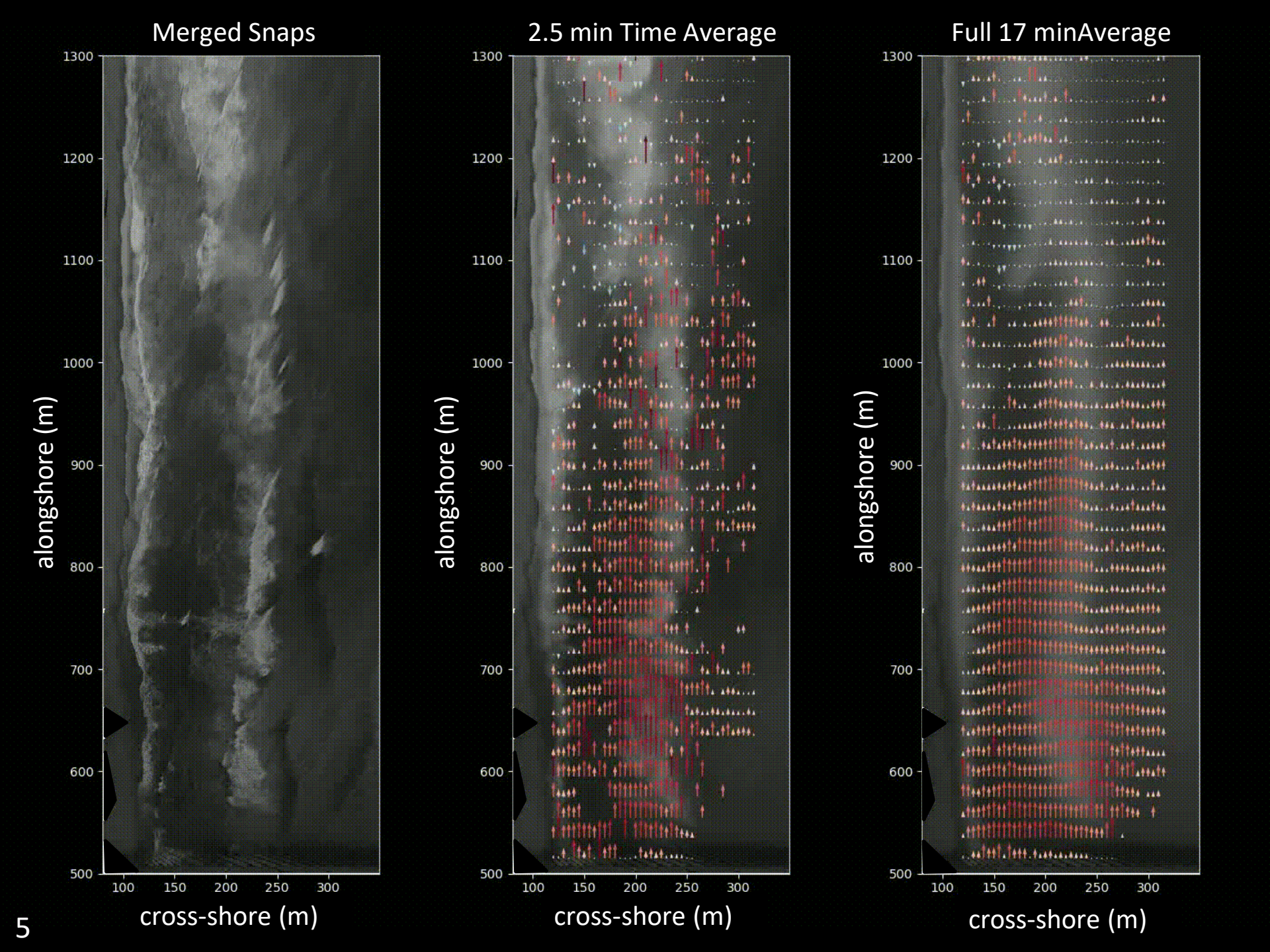


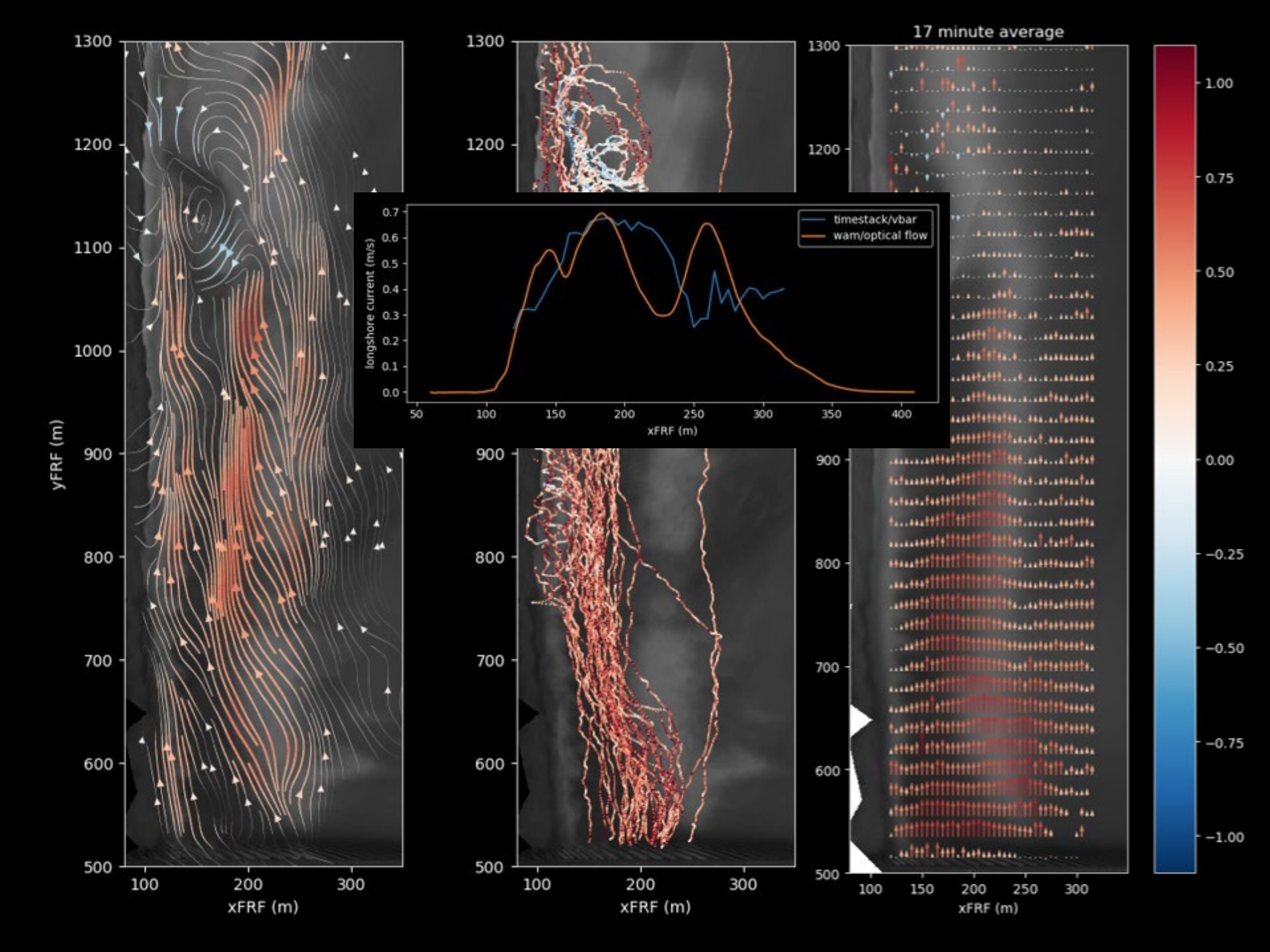
2 min moving average

Questions?

Thanks to the FRF crew!




Merged Snaps
2.5 min Time Average
Full 17 minAverage
alongshore (m)
cross-shore (m)
1300
1200
1100
1000
900
800
700
600
500
100
150
200
250
300


17 minute average
yFRF (m)
xFRF (m)
longshore current (m/s)
timestack/vbar
wam/optical flow