15th International Coastal Symposium
May 13-18, 2018, Busan, Republic of Korea

Normandie Université

Bar migrations on a macrotidal ebb delta over a period of six-years using LiDAR survey

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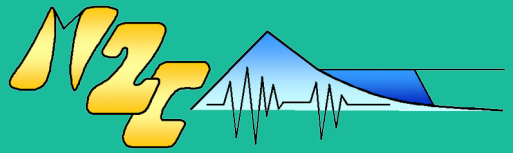

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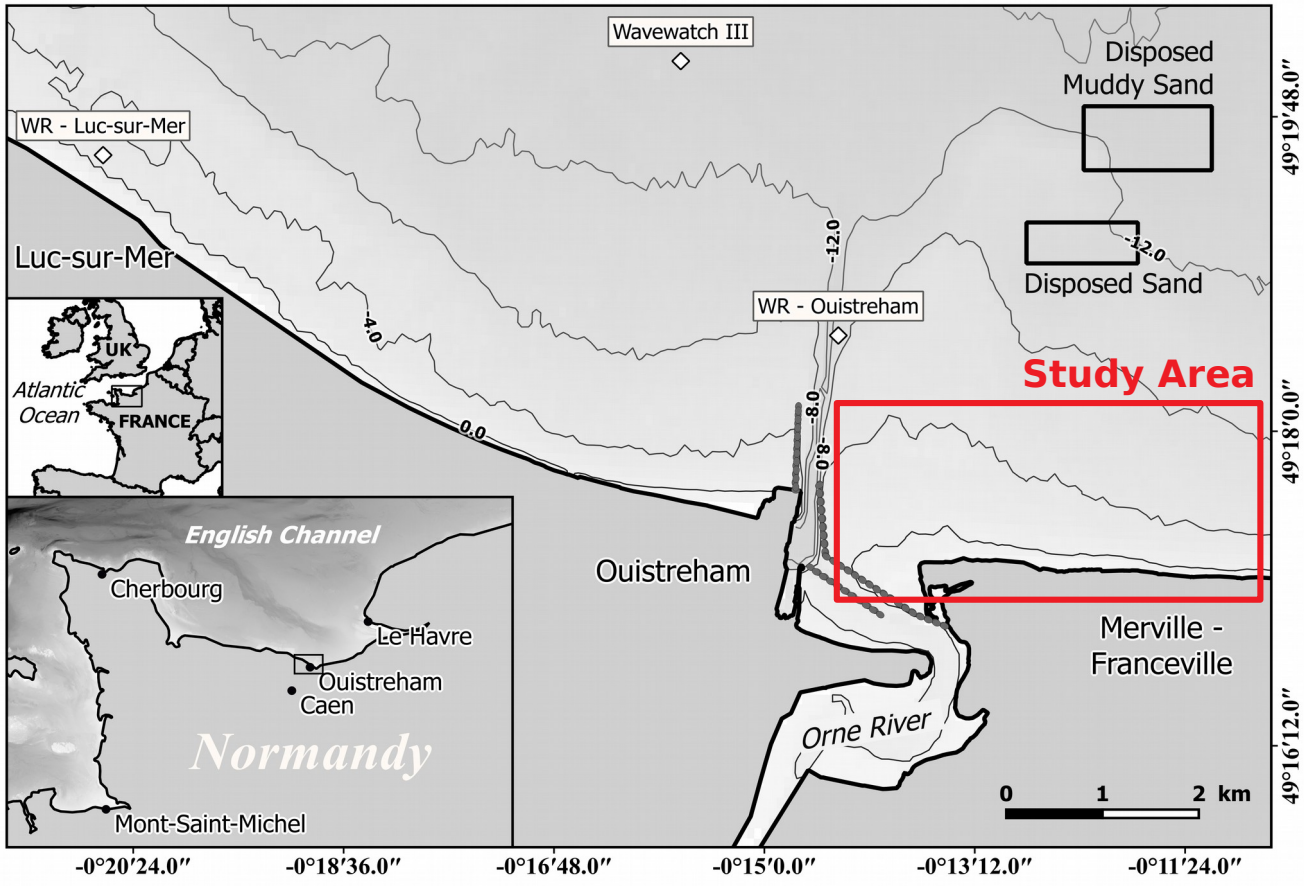
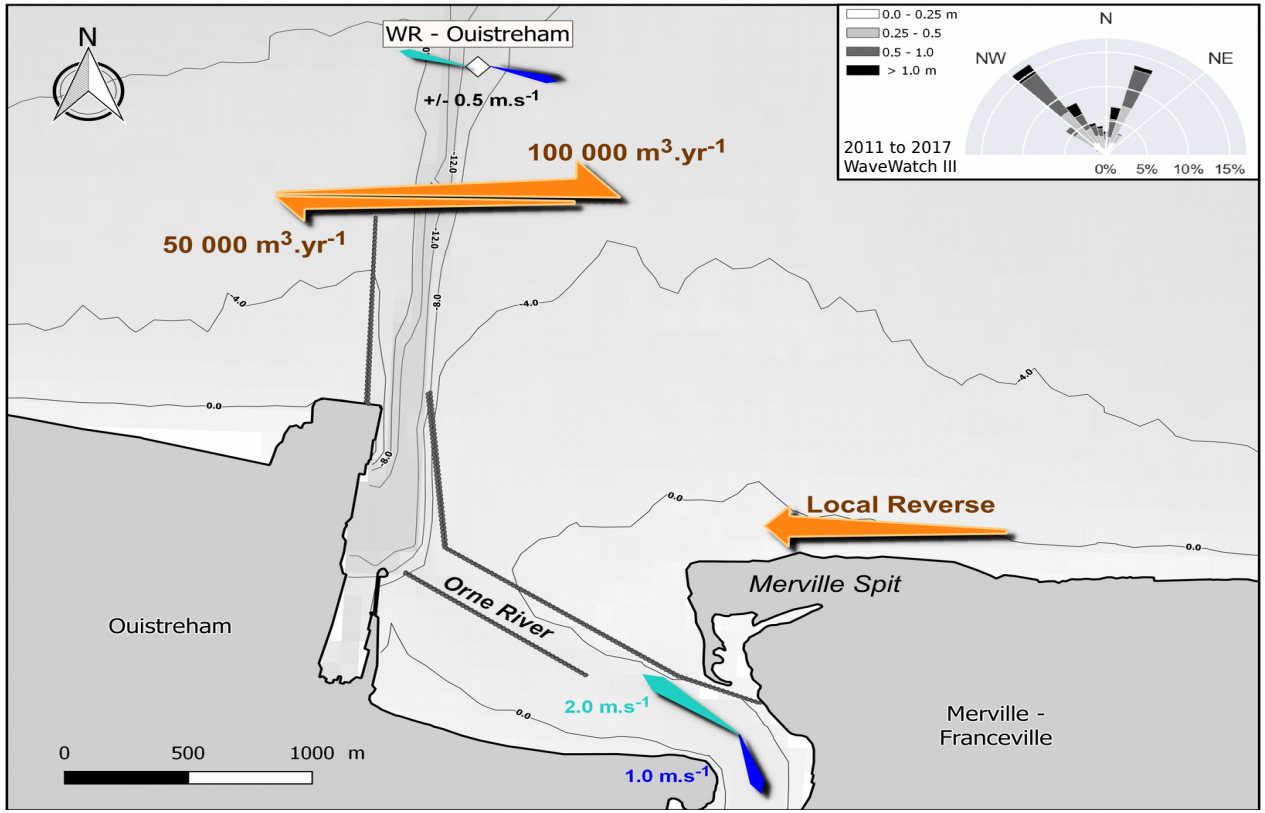
Study Area

- **Orne estuary, Normandie, France**
- **Ebb-tidal delta:**
  - **> 10 km²** – extends 2 km offshore
  - West side **2 km** wide
  - East side **4 km** wide
  - **Fine sand:** 0.125 to 0.250 mm
- **Anthropogenic delta:**
  - Ferry-boat harbour
  - North-south access channel (-12 m MSL)
  - Mean dredged volume of sand: **250 000 m³.yr⁻¹**
  - Dredged materials disposed: **4.5 km** toward **NE**



Hydrodynamics

- **Tides:**
  - Mean spring tides: **6.7 m**
  - High tides holding: 2 hours
  - Offshore currents: 0.5 m.s^{-1}
- **Waves:**
  - 90 % of **Hs** < 0.70 m
  - 4 s < **Tp** < 8 s
  - **Directions:** NW & NNE
- **Littoral Drift:**
  - **Net:** 50 000 m^3.yr^{-1} eastward
  - **Local reverse** along Merville Spit

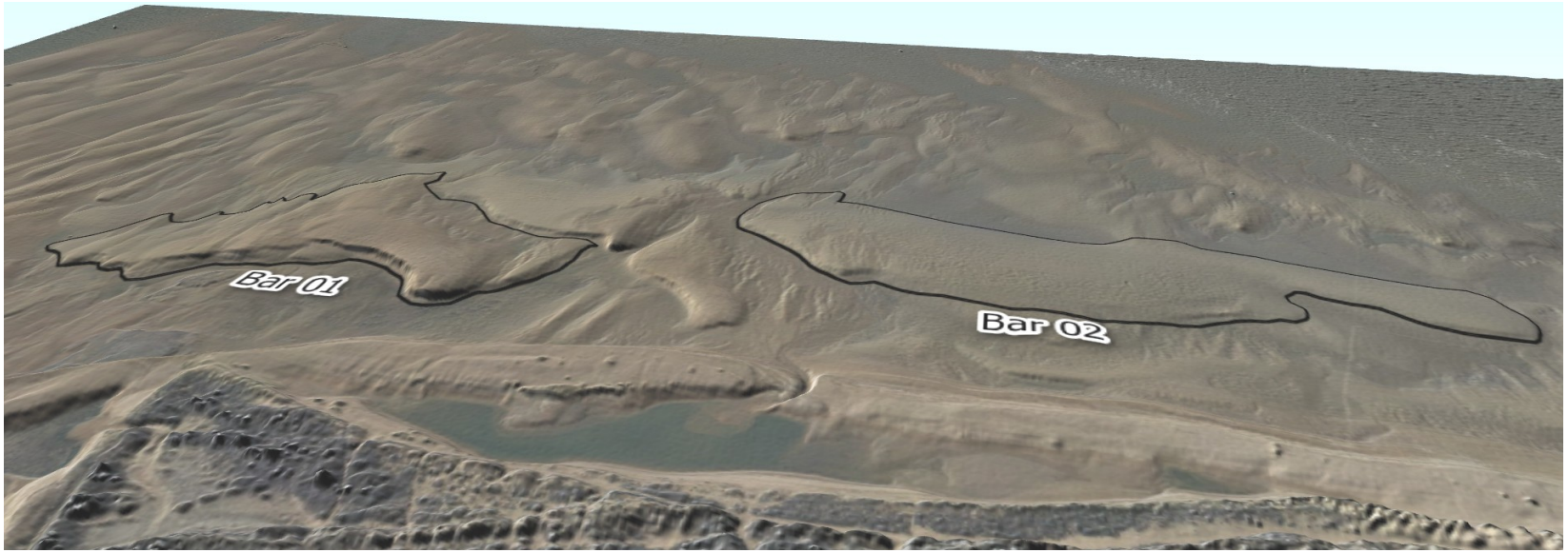


Studied Swash Bars

- **Why these swash bars ?**
  - Easily defined :
    Does not split
  - **Observable**
    over the 6-year period

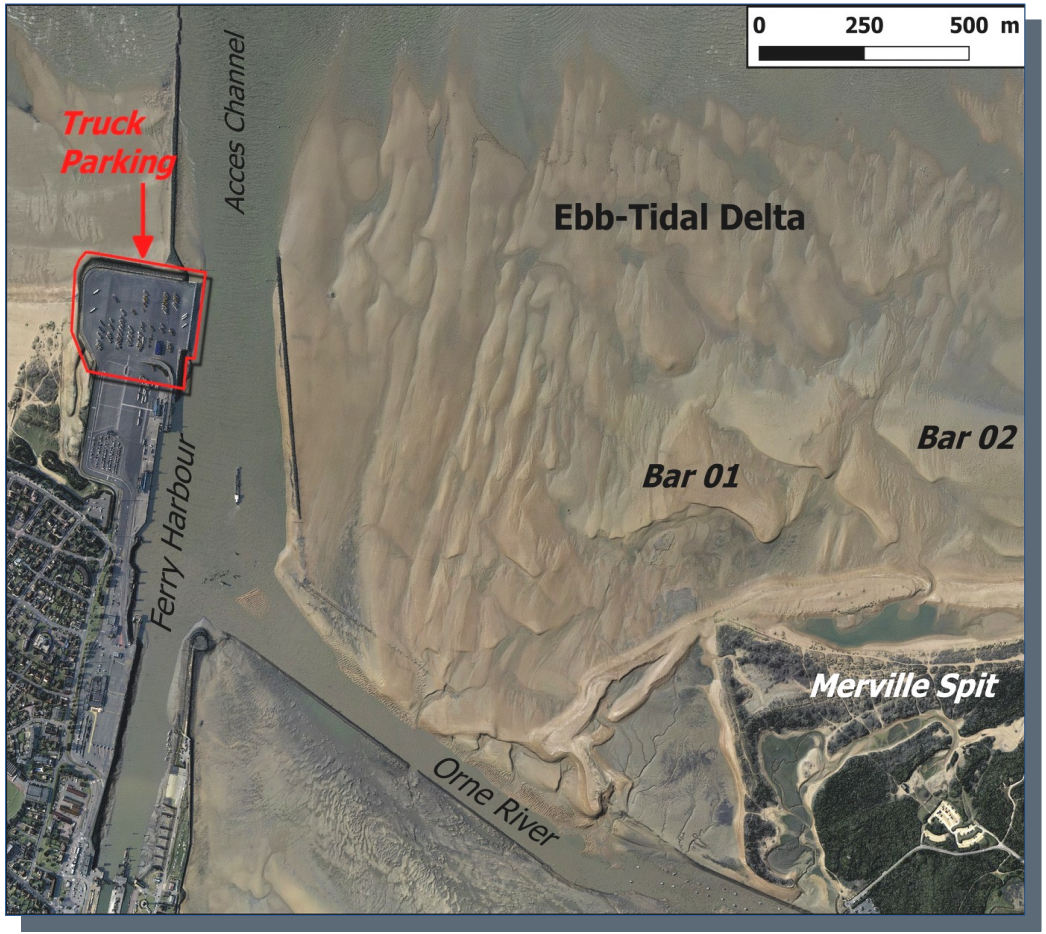
- **Bar 01:**
  - Feb-2011: **60 000 m³**
  - May-2017: **40 000 m³**

- **Bar 02:**
  - Nov-2011: **36 000 m³**
  - May-2017: **250 000 m³**



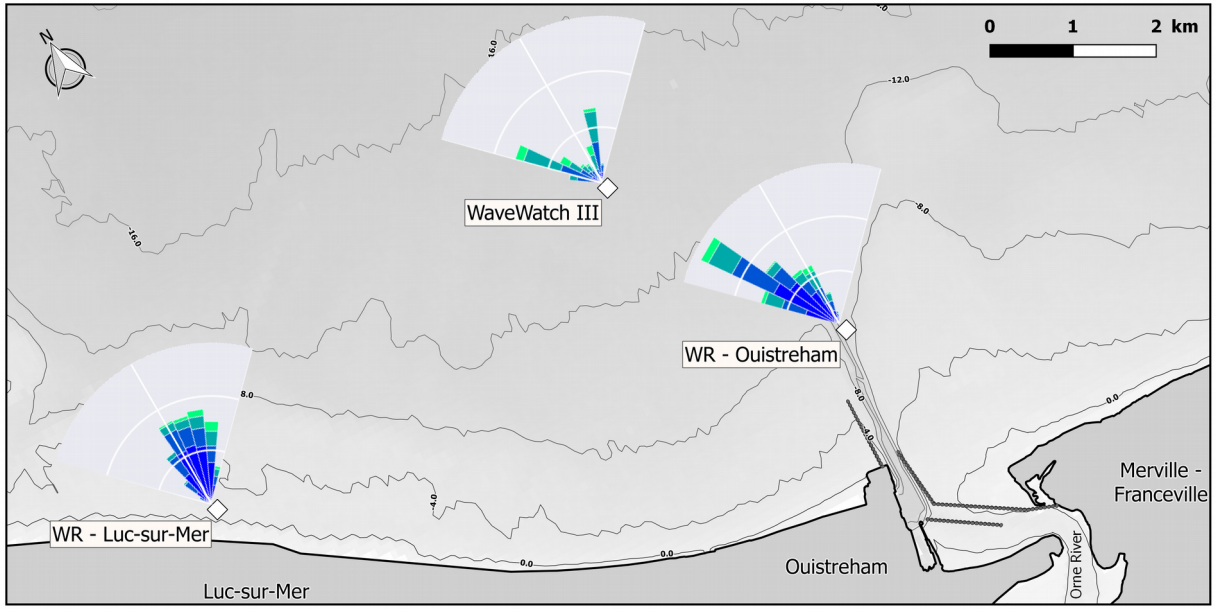
Methods - Topography

- **12 LiDAR surveys**
  February 2011 to May 2017
  (2 surveys/yr)
- **Computed Error:**
  - Over large flat & stable zone:
    55 000 m² (≈ 0.5 % of entire area)
  - Mean Z RMSE: **3.9 cm**
    (between 2.4 cm to 8.7 cm)
  - Mean X and Y RMSE:
    15.2 cm and **23.9 cm**
- **Digital Elevation Models:**
  - Compute volumes of bars
  - Bar Movement:
    Bar Crest (DSAS 4.3)



Methods - Hydrodynamic

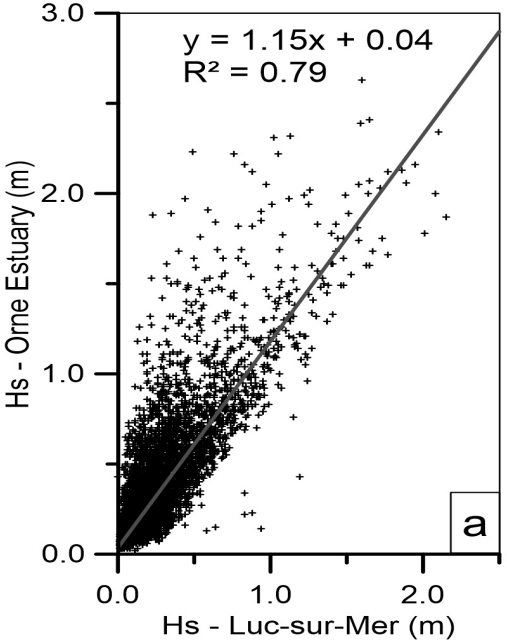
- **Luc-sur-Mer Wave Recorder**
  - From **2011** to **present**
  - **10 km west** of study area
  - Depth: **-3.0 m** below MSL
    Out of water during spring tides
  - **0.80 m** of water above sensor needed
- **WaveWatch III data**
  - From **November 2011** to **present**
  - **5 km offshore** of study area
  - Depth: **-14 m** below MSL
  - Fill lack of measurement
- **Ouistreham Wave Recorder**
  - From **March 2014** to **June 2017**
  - **2 km offshore** of study area
  - Distal part of Ebb delta
  - Depth: **-8.5 m** below MSL
  - Always under water



Results - Hydrodynamic

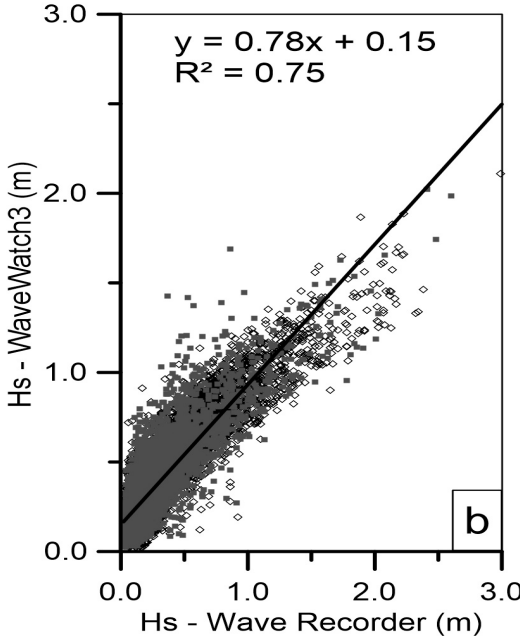
Hs Compare

2 Wave Recorders



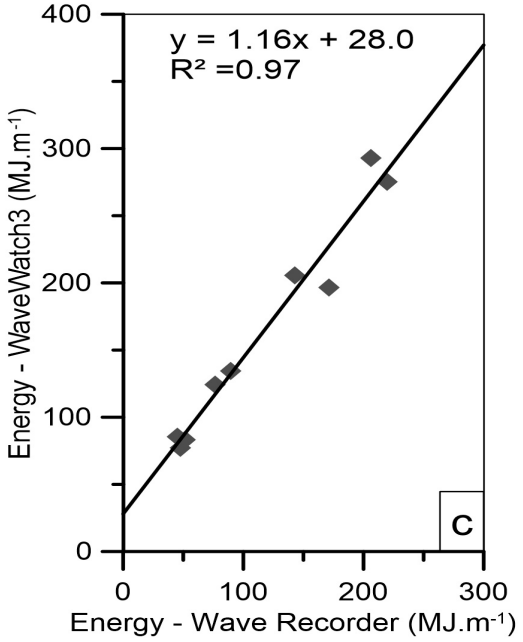
Hs Compare

WaveWatch III vs
2 Wave Recorders

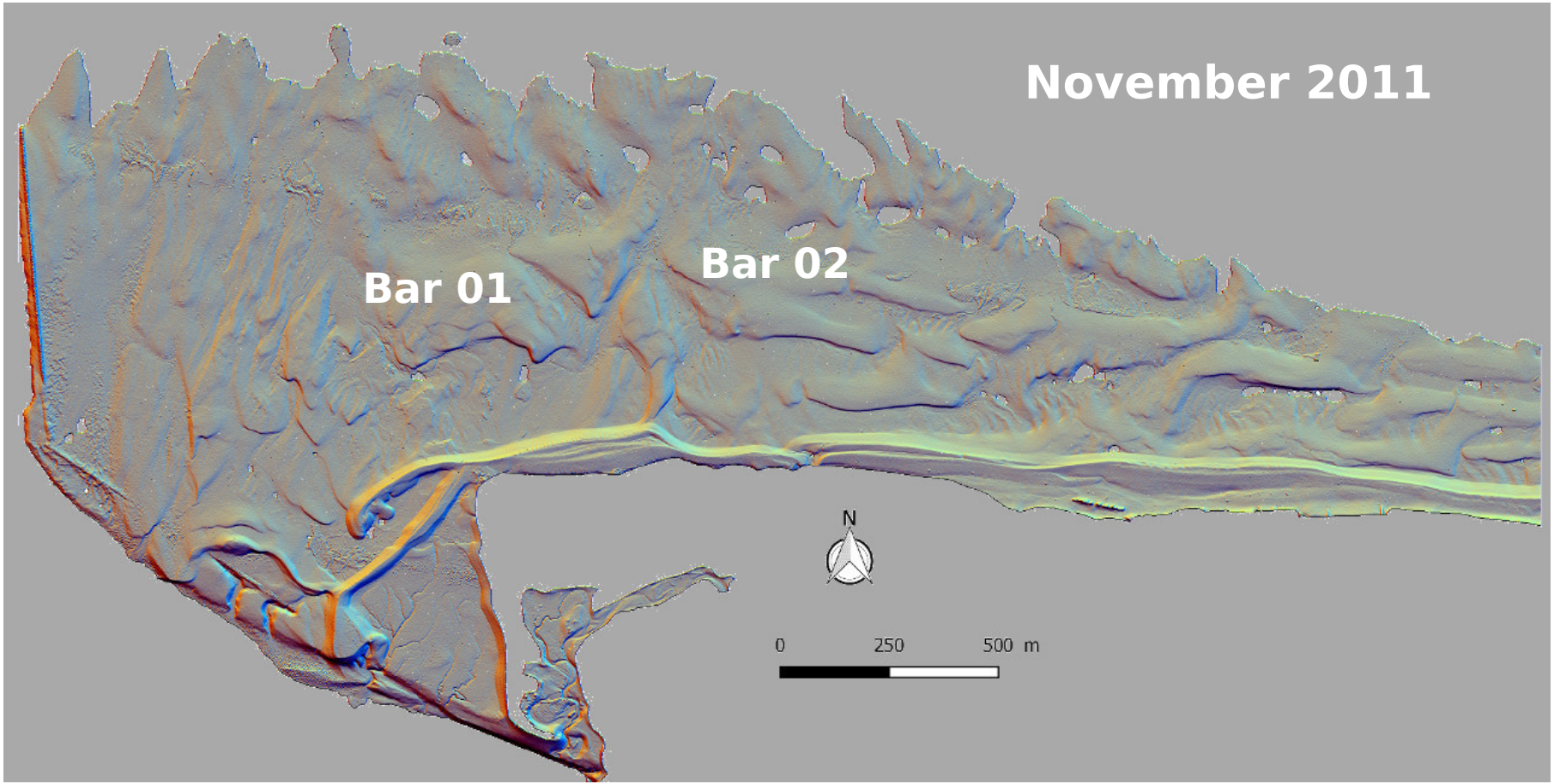


Energy Compare

WaveWatch III vs
2 Wave Recorders



Results – Bar Migrations



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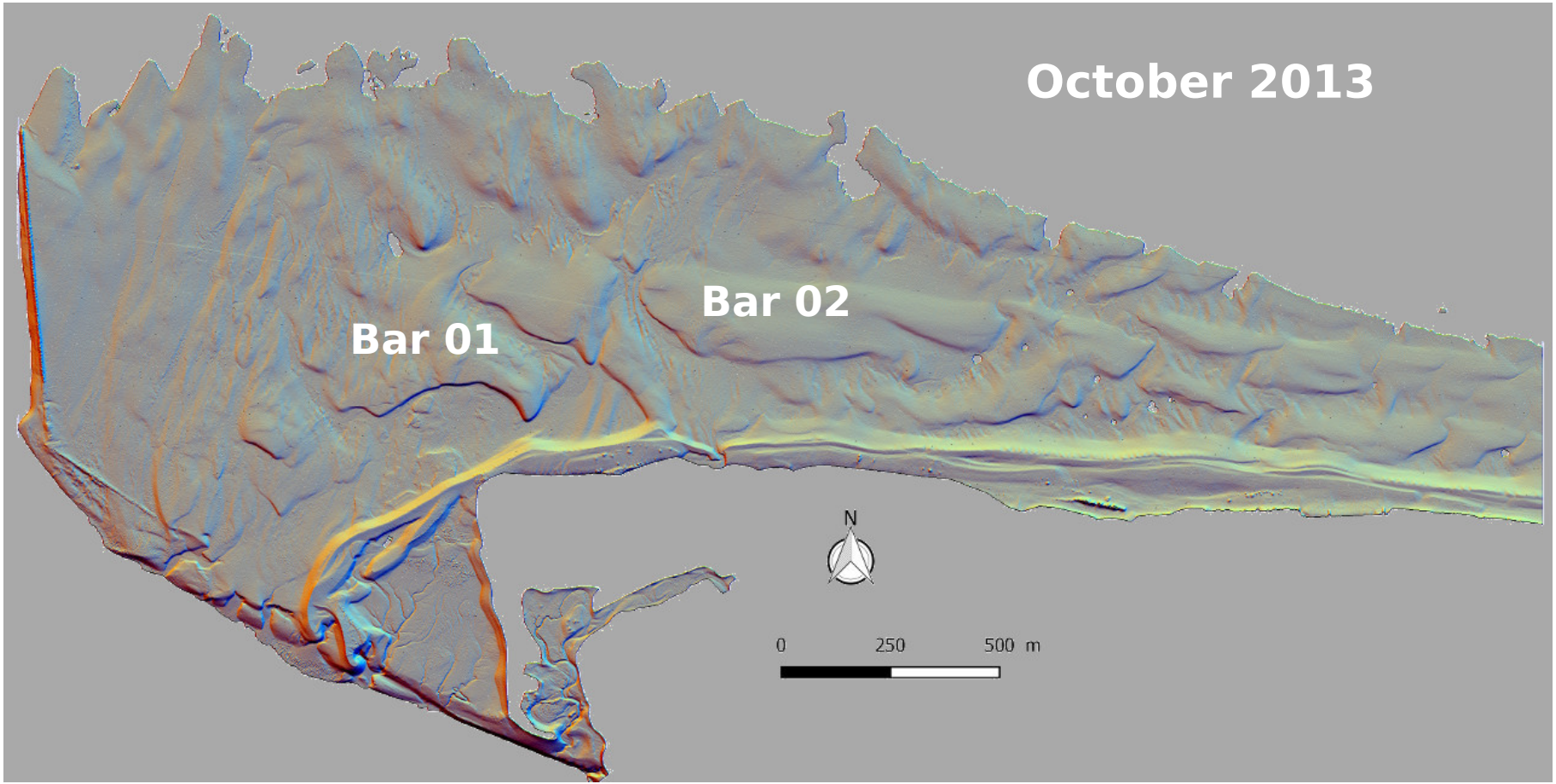

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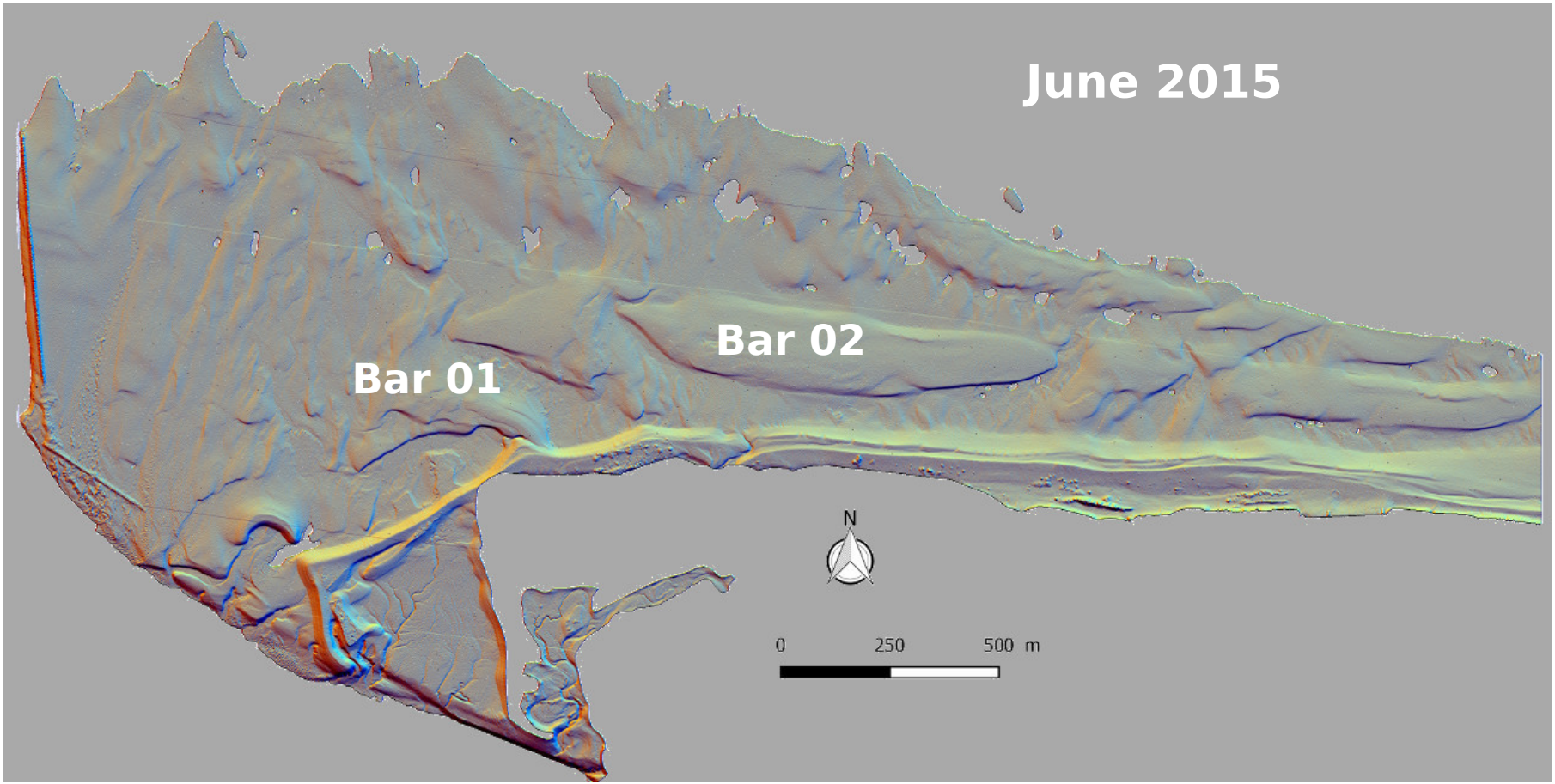

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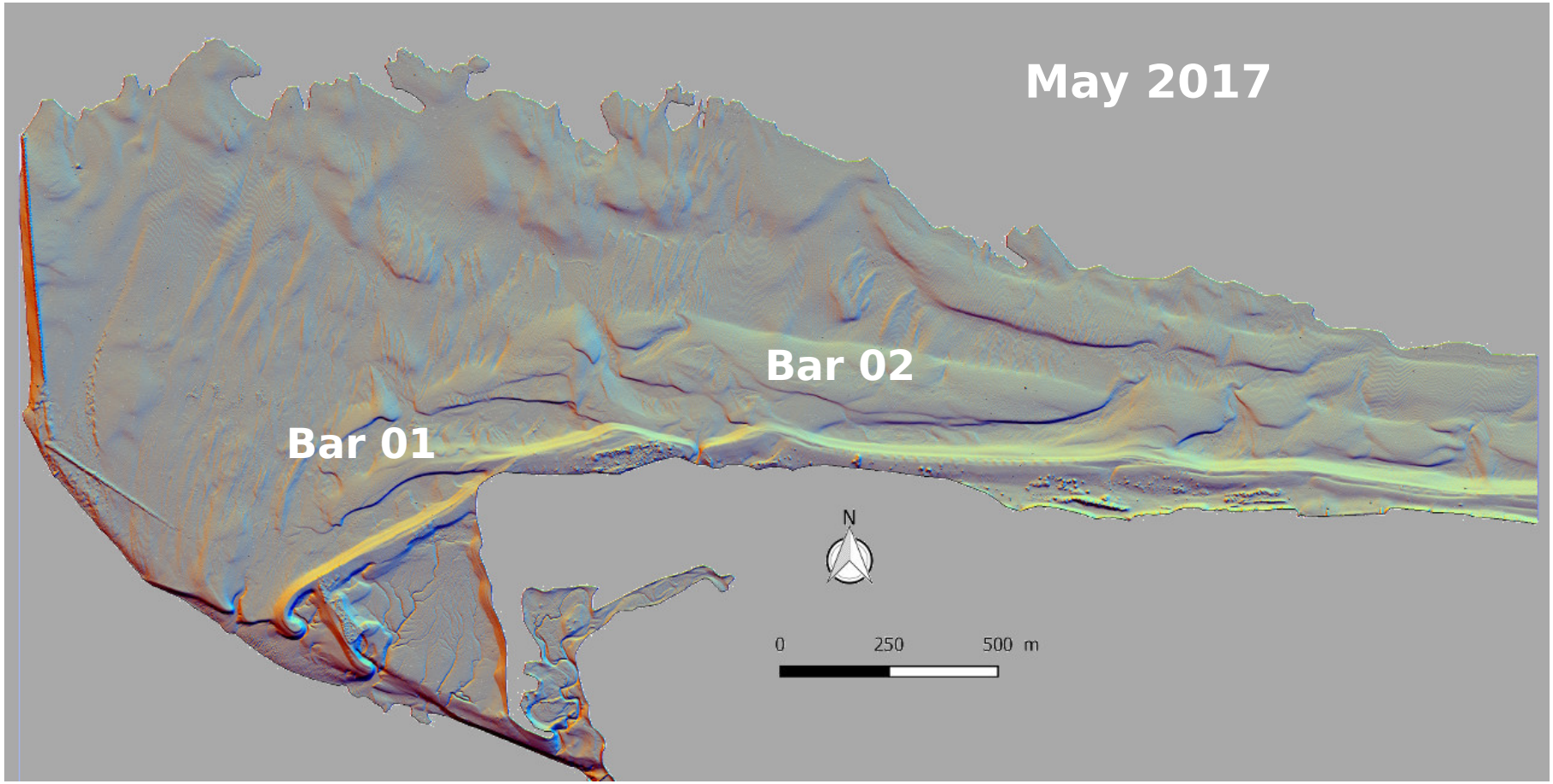


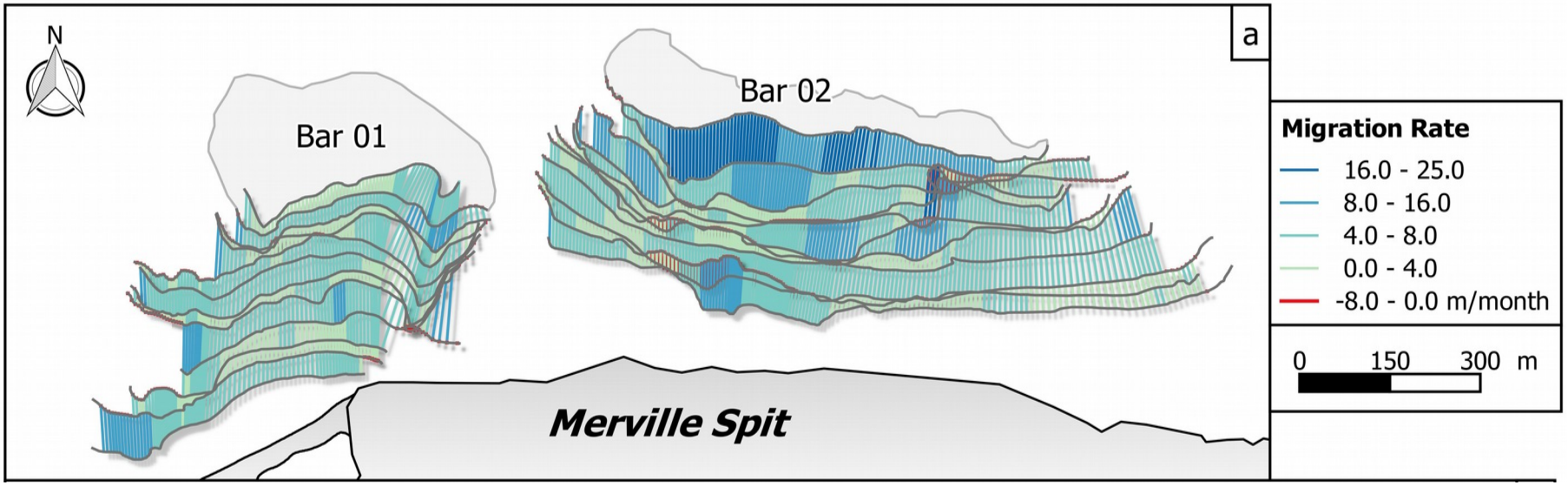
Results – Bar Migrations

Bar 01:

- Distance: **350 m**
  from February 2011 to May 2017
- Mean Migration Rate: **4.6 m/month**

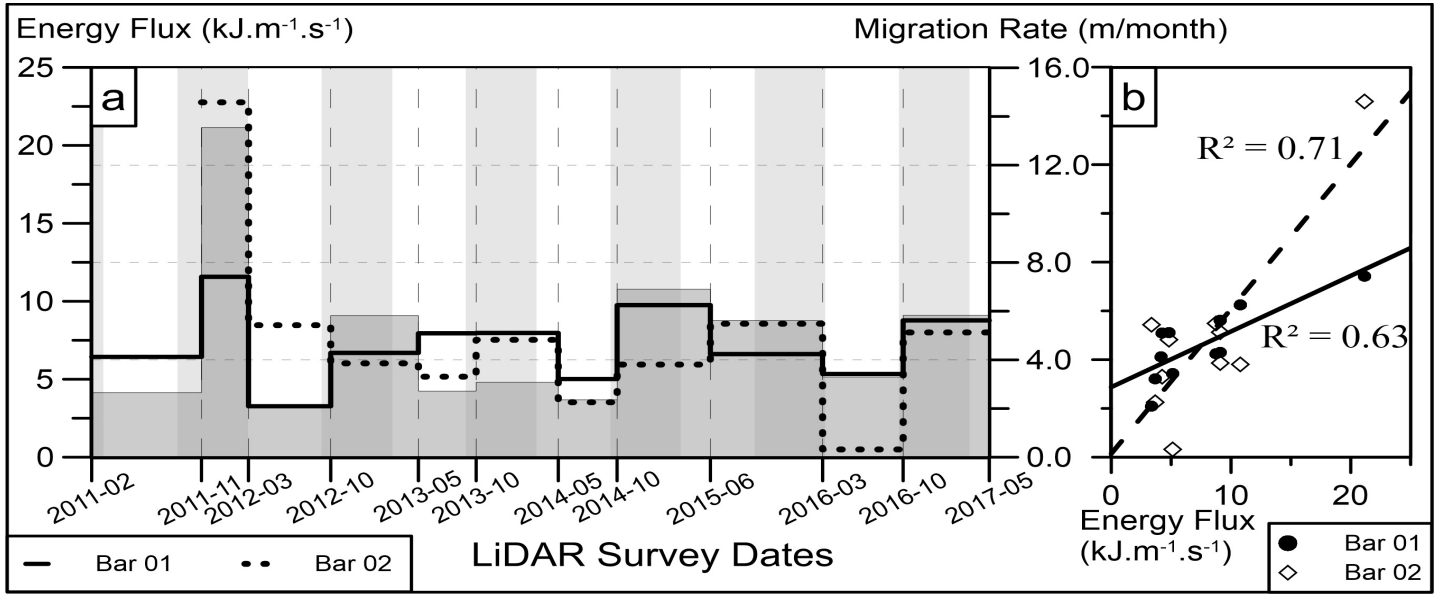
Bar 02:

- Distance: **325 m**
  from November 2011 to May 2017
- Mean Migration Rate: **4.9 m/month**



Migration Rate – Energy Flux

- **Bar 01**
  - R^2 without isolated point: **R^2 = 0.43**
  - **More Responsive** with **Energy Flux**
- **Bar 02**
  - R^2 without isolated point: **R^2 = 0.08**
  - **Less Responsive** with **Energy Flux**



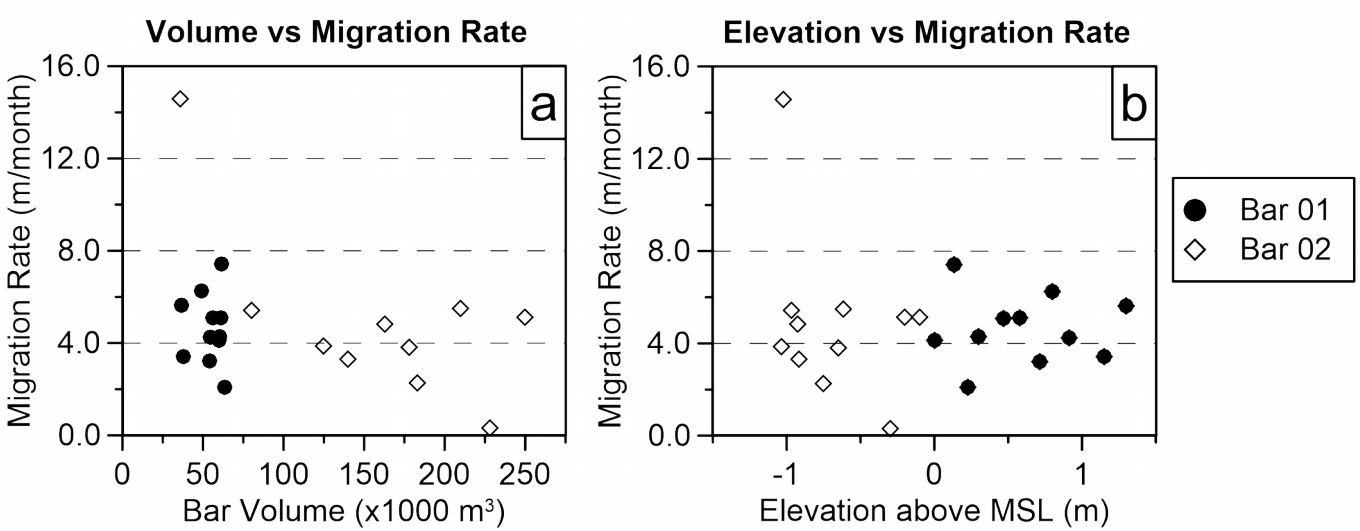
Mean bar migrations are **seasonal responsive**:
Winter ≈ 6-7 m/month
Summer ≈ 3-4 m/month

Migration Rate – Volume & Water Depth

- **Bar Volumes vs Bar Migrations**
  - **Bar 01:**
    Stable Volume: between 40 000 and 60 000 m^3
  - **Bar 02:**
    Increasing Volume: from 75 000 to 250 000 m^3

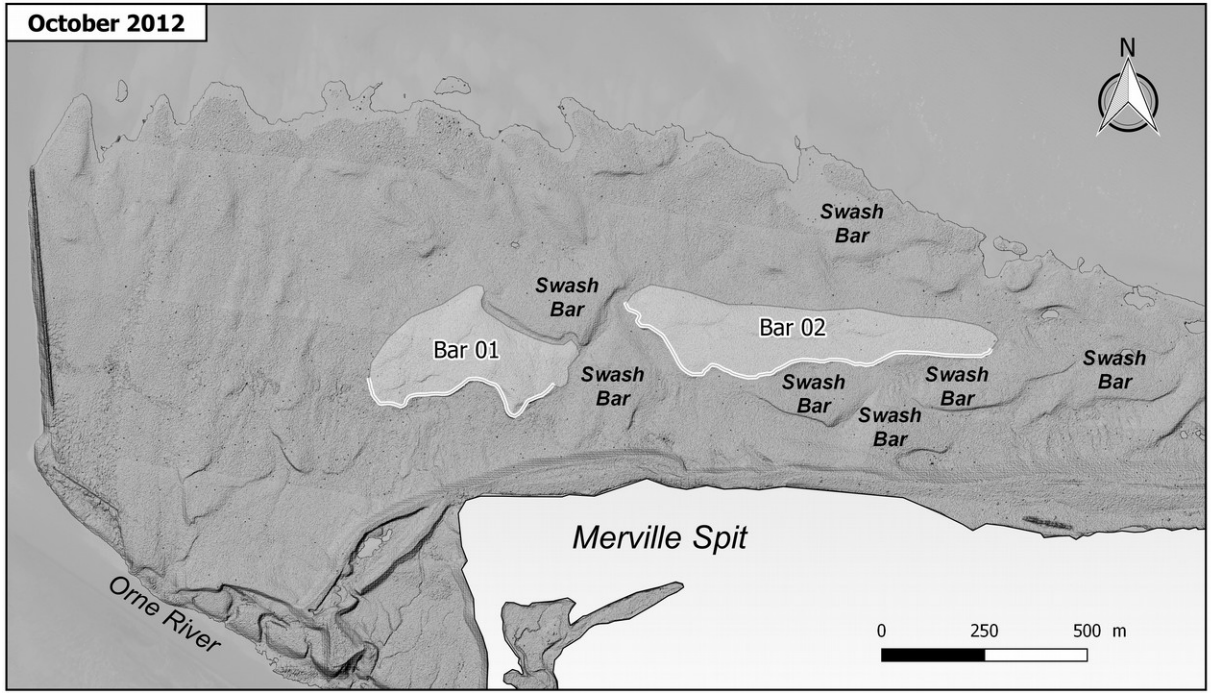
- **Bar Water Depth vs Bar Migrations**
  - **Bar 01:** Above MSL
  - **Bar 02**: Below MSL

Both bars have similar range of migration rates
with different volume evolution and water depth



Surrounding Swash Bars

- **Closed swash bars < 100 m**
- **Bar 01**
  - 2 swash bars around
  - **Free west part**
  - Migrates toward **SW**
- **Bar 02**
  - 5 to 7 swash bars around
  - Migrates toward **South**



Conclusion

Similar and Different Behaviours

Similarities

- **Mean migration rate** over six-year period (4.6 and 4.9 m/month)
- Mean **winter** rate **>** Mean **summer** rate

Differences

- **Volume evolution:**
  Bar 01: Stable | Bar 02: Increasing
- **Water depth:**
  Bar 01: Above MSL | Bar 02: Below MSL
- **Number** of surrounding swah bars

- Volume and Water depth do not seem to be the major factors to explain the bar behaviours
- **Number of surrounding swash bars** is a clue to explain the responsive or non-responsive behaviours of the bars:
  Bar 01 not surrounded by swash bars → more consistent with wave energy flux

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Thank you !

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