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Cable scour from fluid-seabed interactions in regions of mobile sedimentary bedforms

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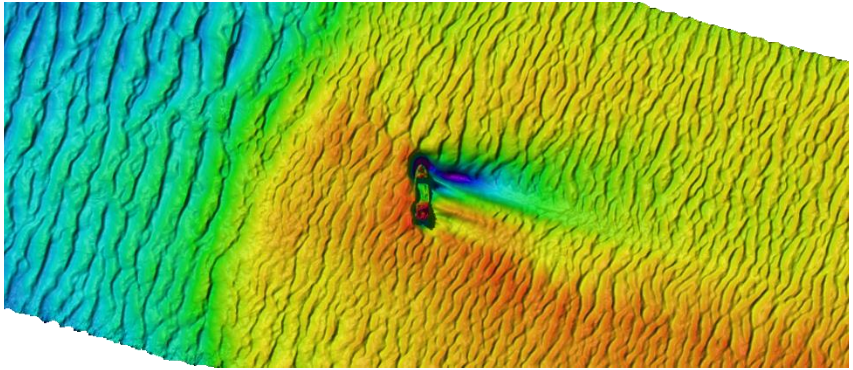
Supergen Offshore Renewable Energy | HR Wallingford | JDR Providing the Vital Connection | Nortek | RWE

MOBILE SEDIMENTARY BEDFORMS, WAKES & SUB-SEA CABLES



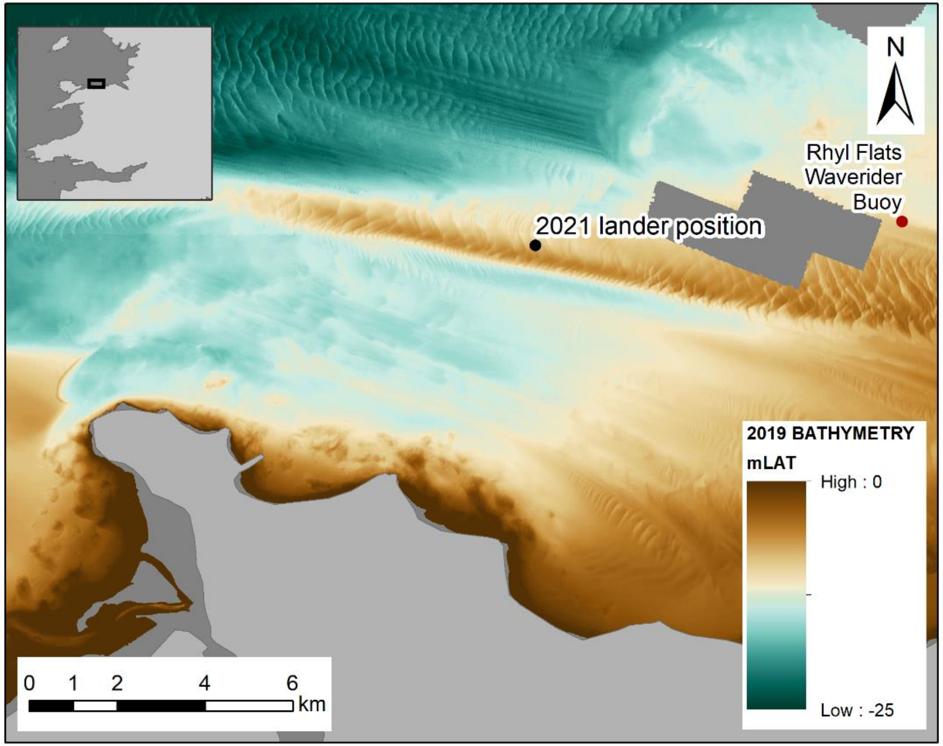
Premise:

- Mobility of sedimentary bedforms → seabed lowering, cable free spans and surface exposed cables.
- Resultant turbulent cable wake scours seabed → cable free-spanning within days.
- Cable exposed to mechanical stress damage and physical impacts.

- ORE infrastructure creates turbulent wake modifying the flow field.
- Strong gradients in dissipative turbulent wake motions alter fluid-seabed equilibrium changing bedform dynamics.
- Increased cable exposure downstream of ORE infrastructure.

Field deployment in an area of future wind farm developments

- **North Wales (UK) Field site**
- Active bedform migration
- 8 - 16 m water depth
- Tides 0.6 – 1 m s^{-1}
- D_{50} ~ 210 µm
- Sand and some shell fragments



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PROVIDING THE VITAL CONNECTION

NORTEK

RWE

METHODS

2 x 6-day offshore programmes over spring tides (Sep 2020, Jul 2021)

Benthic Boundary Layer (BBL)

- seabed lander deployed with section of real HV cable.
- cable span perpendicular to reversing tidal current.
- rectilinear tide provides “natural” turbulence on flood tide and “enhanced” wake turbulence on ebb.

- multiple high resolution acoustic measurements within the BBL:
  - mean flows
  - turbulent metrics
  - suspended sediment concentration

Local Scale

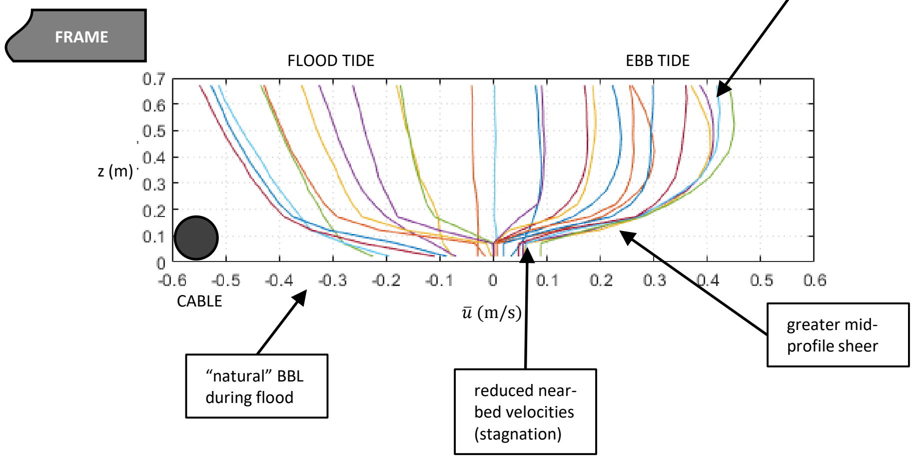
- vessel mount MBES at $\mathcal{O}(10^{-1} – 10^{2}\text{ m})$ scales
- vessel mount ADCP

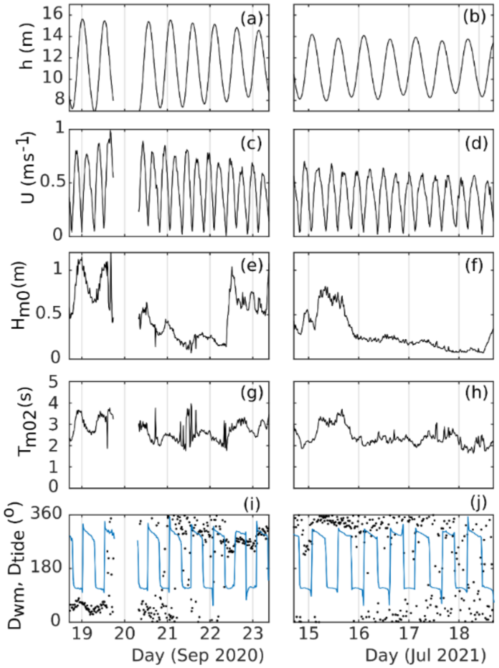
BENTHIC BOUNDARY LAYER (EXAMPLE)

Flood upstream flow: natural flow conditions

Ebb downstream of cable/frame: contaminated flow

- 5-min burst-averaged streamwise velocity profiles

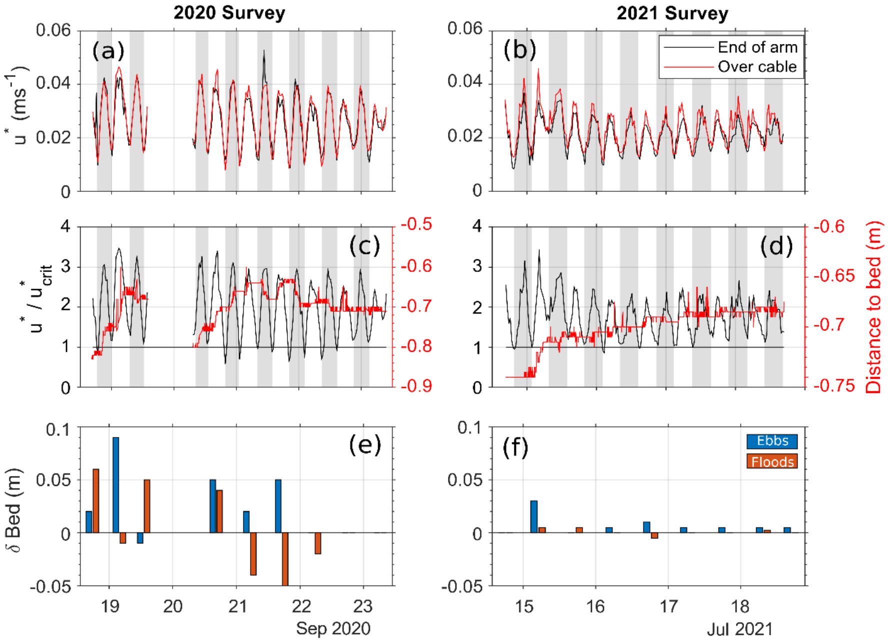




Hydrodynamic forcing recorded by the AWAC during the field observations, September 2020 left panels, July 2021 right panels. (a, b) Water depth h; (c, d) mean tidal current speed U; (e, f) significant wave height H_{m0}; (g, h) mean wave period T_{m02}; and (i, j) mean wave direction D_{wm} (black dots) and tidal directions (blue line).

Benthic boundary layer structure fundamentally altered by the presence of the cable and lander:

- Clear flood-ebb differences
- Significant implications for sediment transport



(a,b) u* derived from the TKE method Aquadopps. Shaded areas indicate flood tides. (c,d), bed levels plotted with u* scaled by the initiation of motion for the bed sediments, (e,f) change in bed level over individual flood and ebb tides, positive values indicate deposition, negative is erosion.

KEY IMPACT 1:

Seabed level changes indicate net cable burial rather than scour

- u* almost identical over cable and clean bed during floods
- Enhanced u* during (most) ebbs driven by wake-effects

- Almost all shear observations exceed threshold of motion
- Bed-level changes occur at peak excess stress

- Expect during first 1 - 2 tides of deployment, if bed-level changes occur, floods typically erode, and ebbs accrete

- Cable self-burial processes occurred during both deployments
- Rapid changes during initial dis-equilibrium conditions

- What governs longer-term response? And is it consistent burial or scour

Problem:

Development on the sea bed changes the topography and the hydrodynamics

Leads to a breakdown in the assumptions usually used to estimate bed shear stress

So should you estimate sediment transport in this kind of environment?

1. Standard 2D model (with a Chezy)

2. Law of the wall methods

3. Near bed turbulence measurements

Used to drive 5 different sediment transport models predicting near bed concentration

1. Einstein 1950
2. Smith & McLean 1977
3. van Rijn (1984)
4. Garcia & Parker (1992)
5. de Leeuw *et al.,* (2020)

Measured near bed suspended sediment concentrations

Multifrequency acoustic backscatter system

Question:

Where is the uncertainty coming from?

The driver of sediment transport?

Or the representation of sediment transport?

2D method (van den Berg & van Gelder 1992)

Law of the Wall (most of the water column- upward facing ADCP)

Law of the Wall (near bed flow - downward facing ADP)

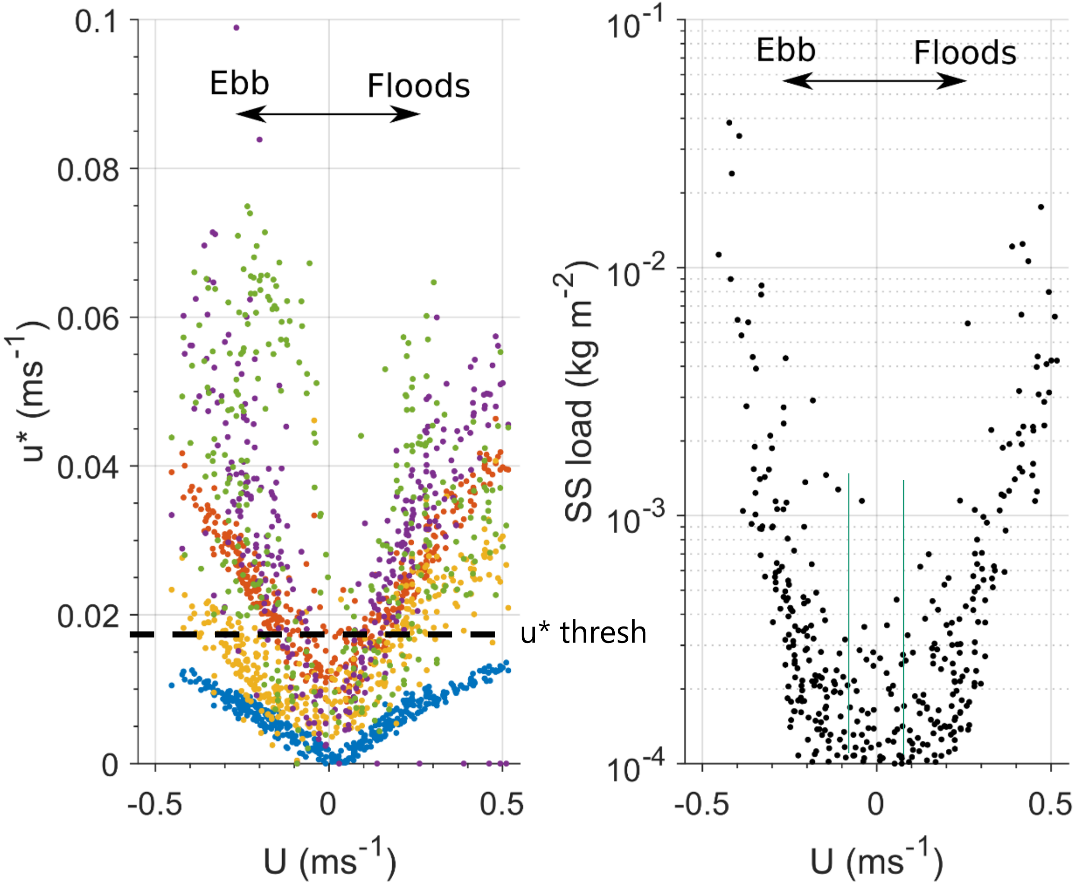
TKE method $0.19(0.5\rho(u'^2 + v'^2 + w'^2))$

TKE Klipp (2016) method – from Aqaudopp

Huge variation in u* depending on method used.

Standard 2D method appears to significantly underpredict, but low scatter

LoW on measurements show big scatter



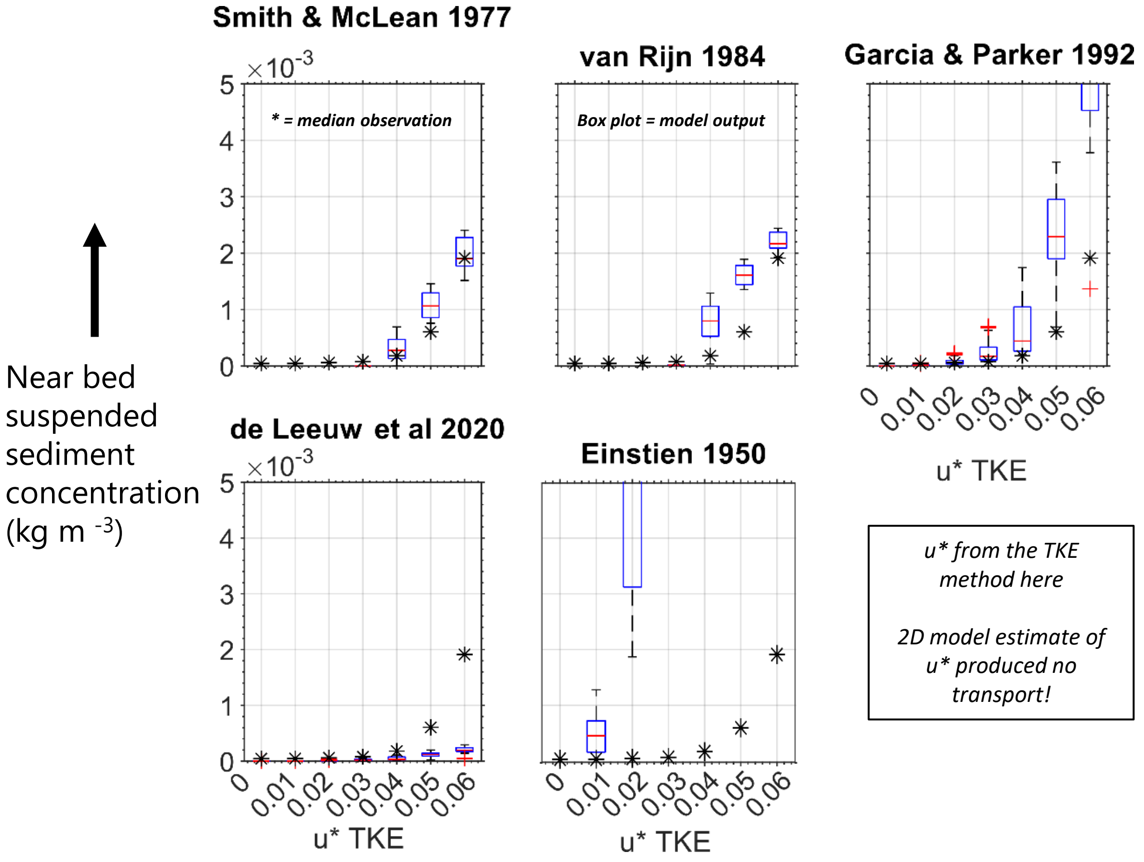
Depth average velocity

Distribution (with u*) correct:

- **Mclean and Smith 1977** – magnitudes also good
- **Garcia and Parker 1992** But magnitudes off

- **de Leeuw et al 2020 & Einstein 1950** Distribution correct but magnitude way off

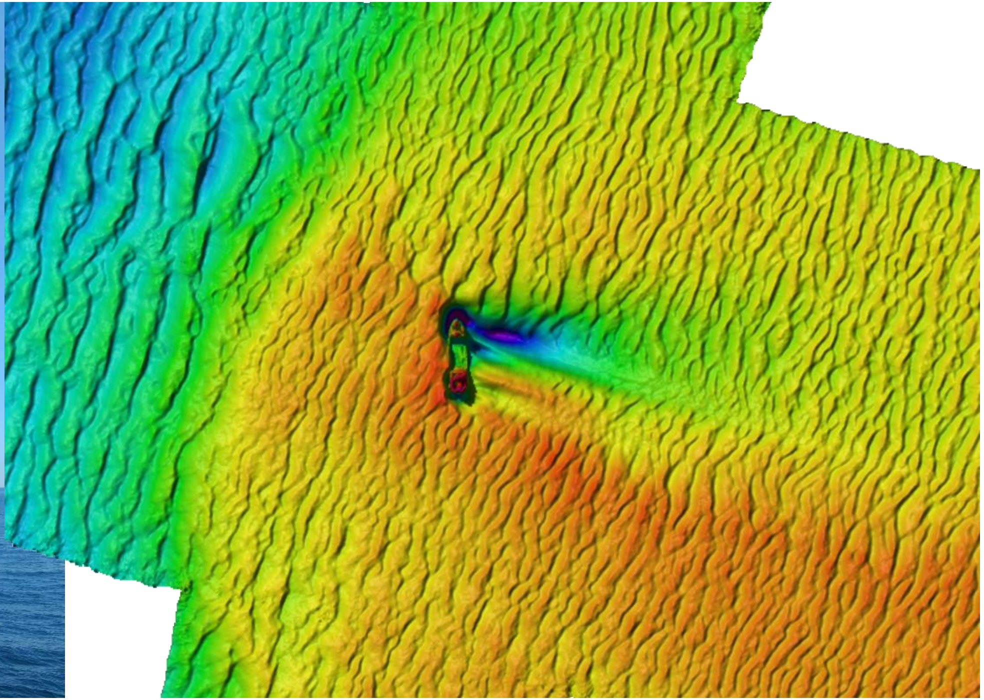
- **Van Rijn 1984** Distribution ok, Magnitudes good at high u*, poor at low u*



Data binned in increments of u*

u from the TKE method here*

2D model estimate of u produced no transport!*



KEY IMPACT 2:

1) Crucial to get ‘local’ bed shear stress correct – even Law of the wall on good field data is **risky**

2) **Try many sediment transport models!** Even with the good estimates of bed shear stress there’s a lot of variation

Legacy & Follow on work:

£2.5M NERC ECOWind-ACCELERATE project funded on the back of this Supergen ORE project

- PI Van Landeghem
- Co-I Austin
- PDRA Unsworth

£2M NERC HT Enhanced mixing of stratified seas by floating offshore wind

- PDRA Lincoln

Industry-focused report & data

- HR Wallingford led
- optimisation/standardisation for cable survey/installation
- inform risks in mobile seabeds
- testable estimates of additional scour due to flow interaction

Peer-reviewed publications

- Unsworth, Austin, Van Landeghem, Couldrey, Whitehouse (submission Nov 2022). Field measurements of cable self-burial in a sandy marine environment. Coastal Engineering.
- Unsworth, Austin, Van Landeghem, Couldrey, Whitehouse (submission Mar 2023). Parameterisation of wake-effected sediment suspension into a 2D model.

Conferences Presentations

- Unsworth, Austin & Van Landeghem (2022). Using a natural laboratory to quantify sediment mobility in the turbulent wake of instrument frames and offshore infrastructure. EGU Conference, EGU22-8006
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- Van Landeghem, Unsworth, Austin & Waggitt (2022). Flow changes in the wake of a large sediment wave: helping to understand geological and ecological impacts of seabed infrastructure. EGU Conference, EGU22-6349.
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- Austin, Lincoln & Van Landeghem (2021). Non-equilibrium turbulence dissipation: wake affects in an energetic tidal boundary layer. Non-equilibrium Bedforms and Turbulence Workshop, British Society of Geomorphologists, May 2021.