Impact of Tidal-stream Energy Converter (TEC) arrays in relation to the natural variability of sedimentary processes

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Case study: Northwest Anglesey, UK

- One of 7 UK regions of interest for ‘first generation’ energy extraction
- Skerries leased from the Crown Estate for commercial development by MCT

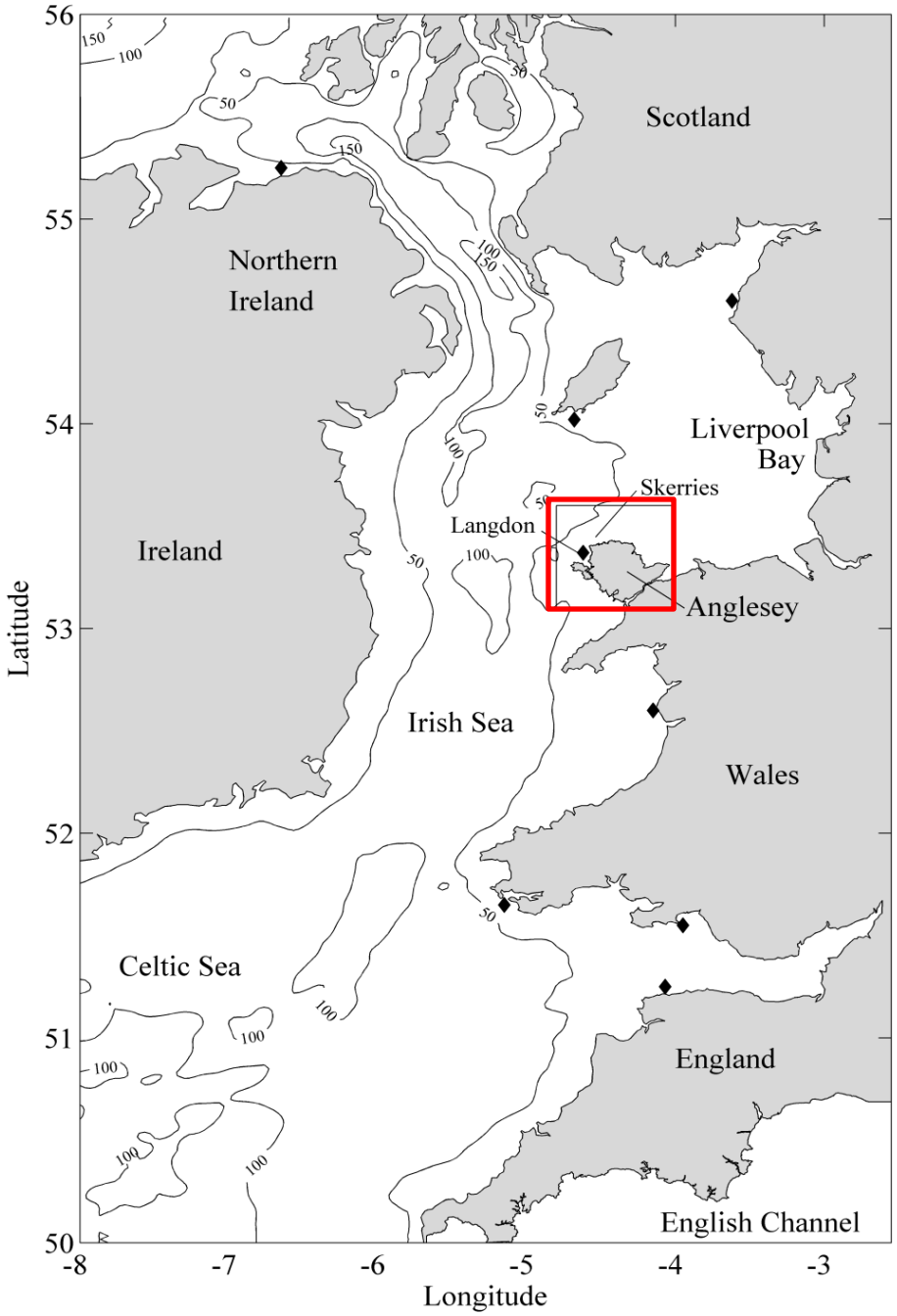
Why?

- Tidal velocities > 2.5 m/s
- Water depths = 30 m
- Distance to shore < 5 km
- Holyhead harbour nearby
- National grid connection

Sedimentary impacts:

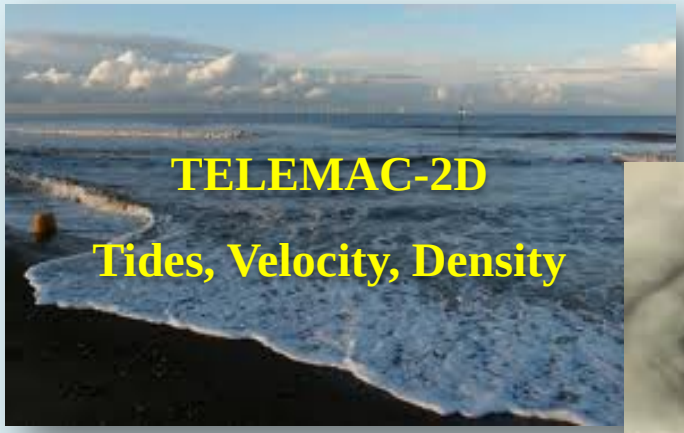
Suspended sediment
- Turbidity maxima

bedload sediment
- Sand bank formation
- Net sediment transport fluxes



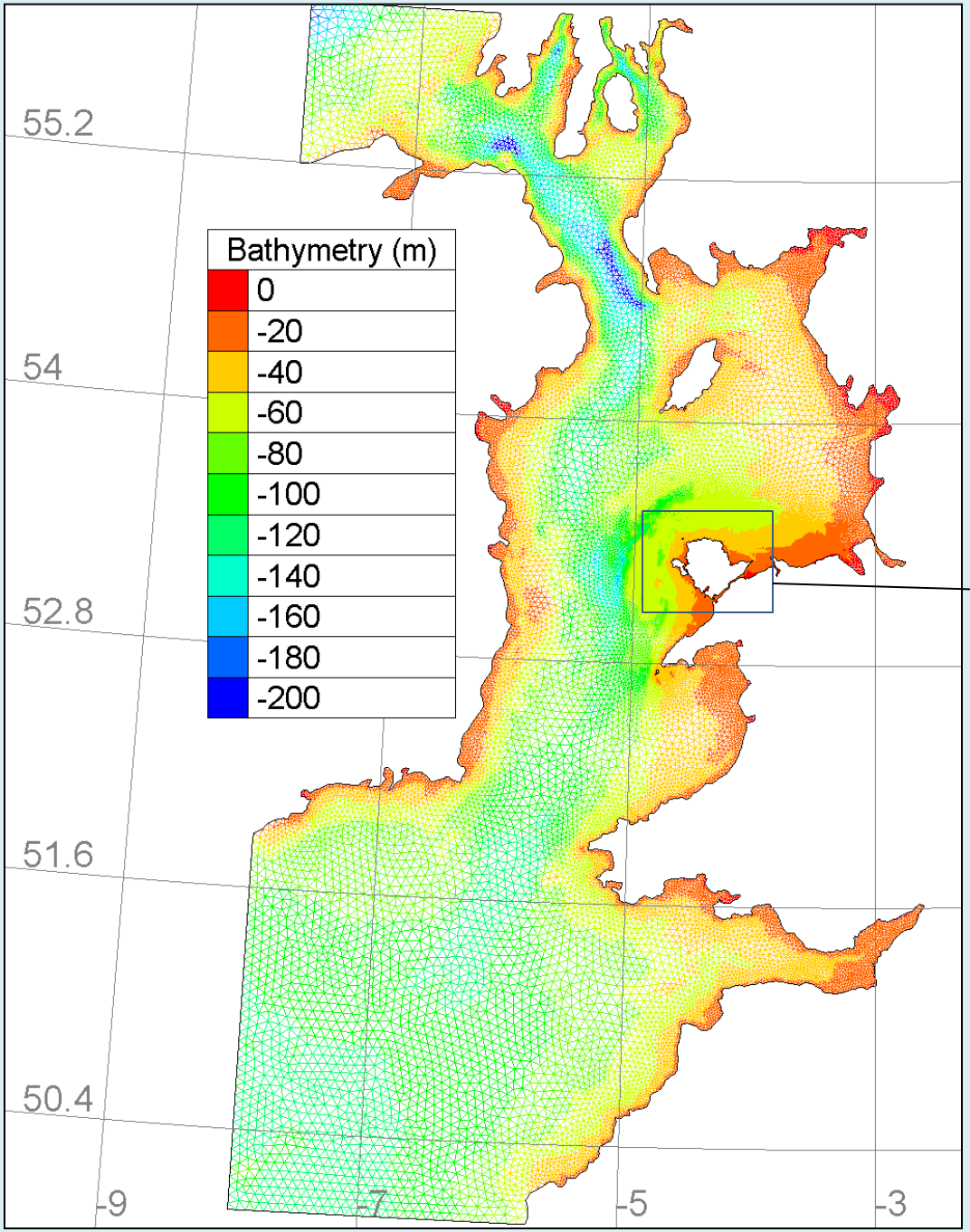
open TELEMAC-MASCARET

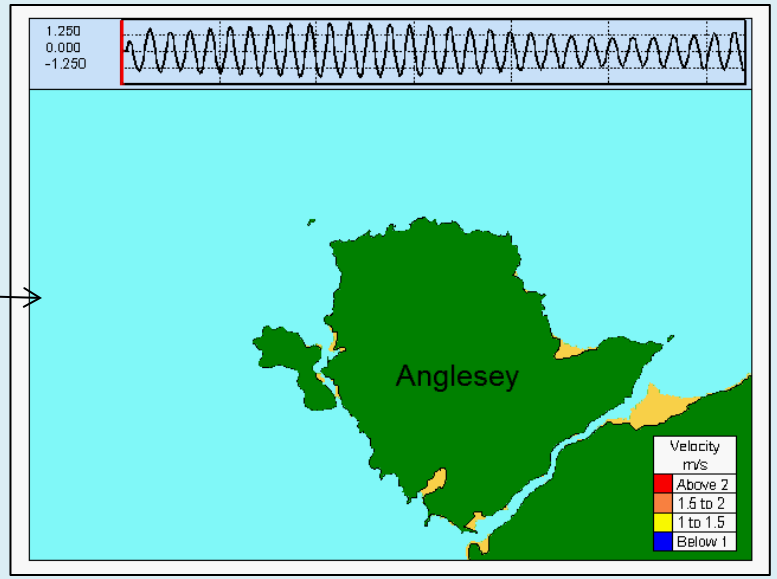
The mathematically superior suite of solvers

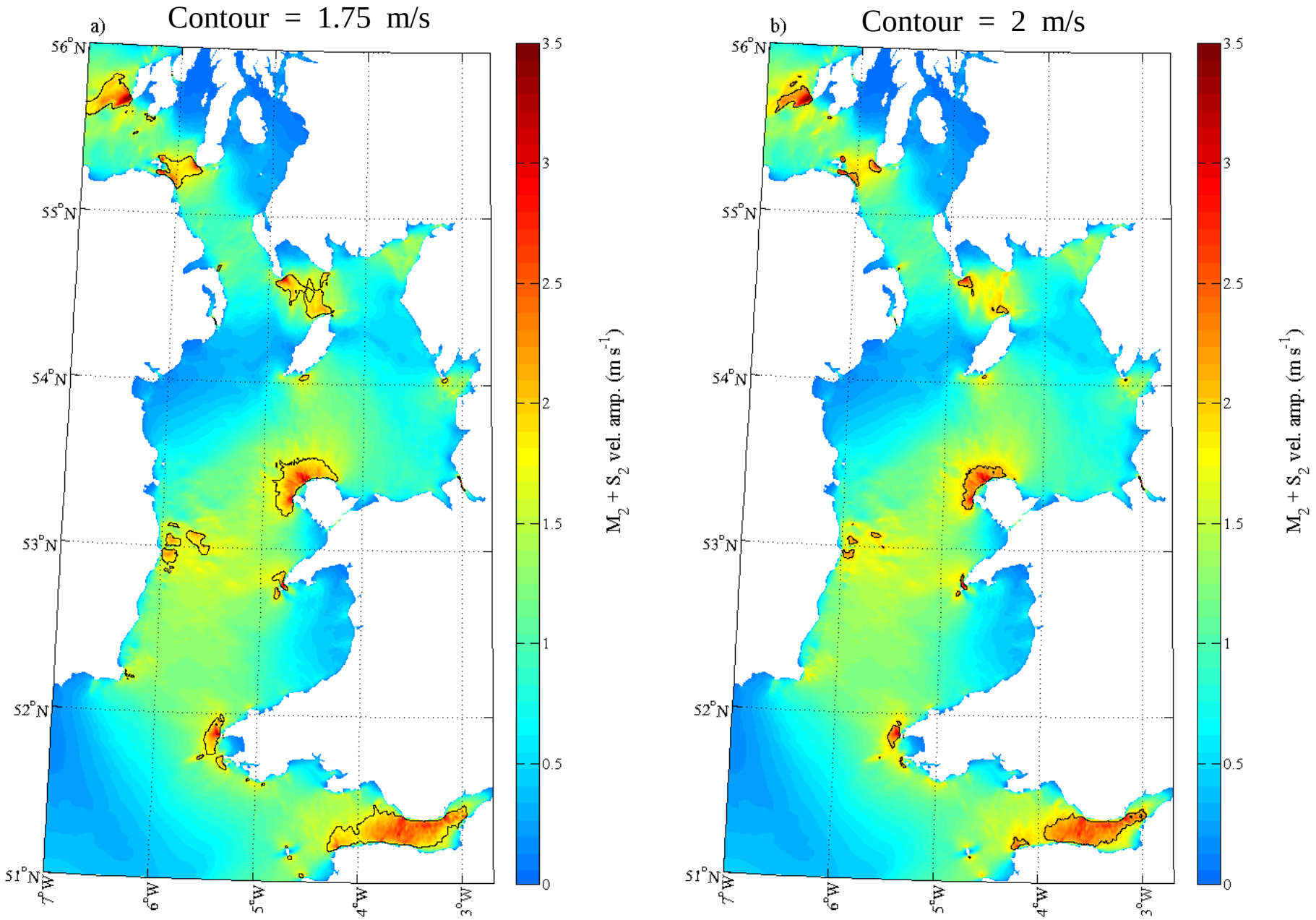


HPC WALES · CYMRU

FUJITSU


Bathymetry (m)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
55.2
54
52.8
51.6
50.4
-9
-7
-5
-3

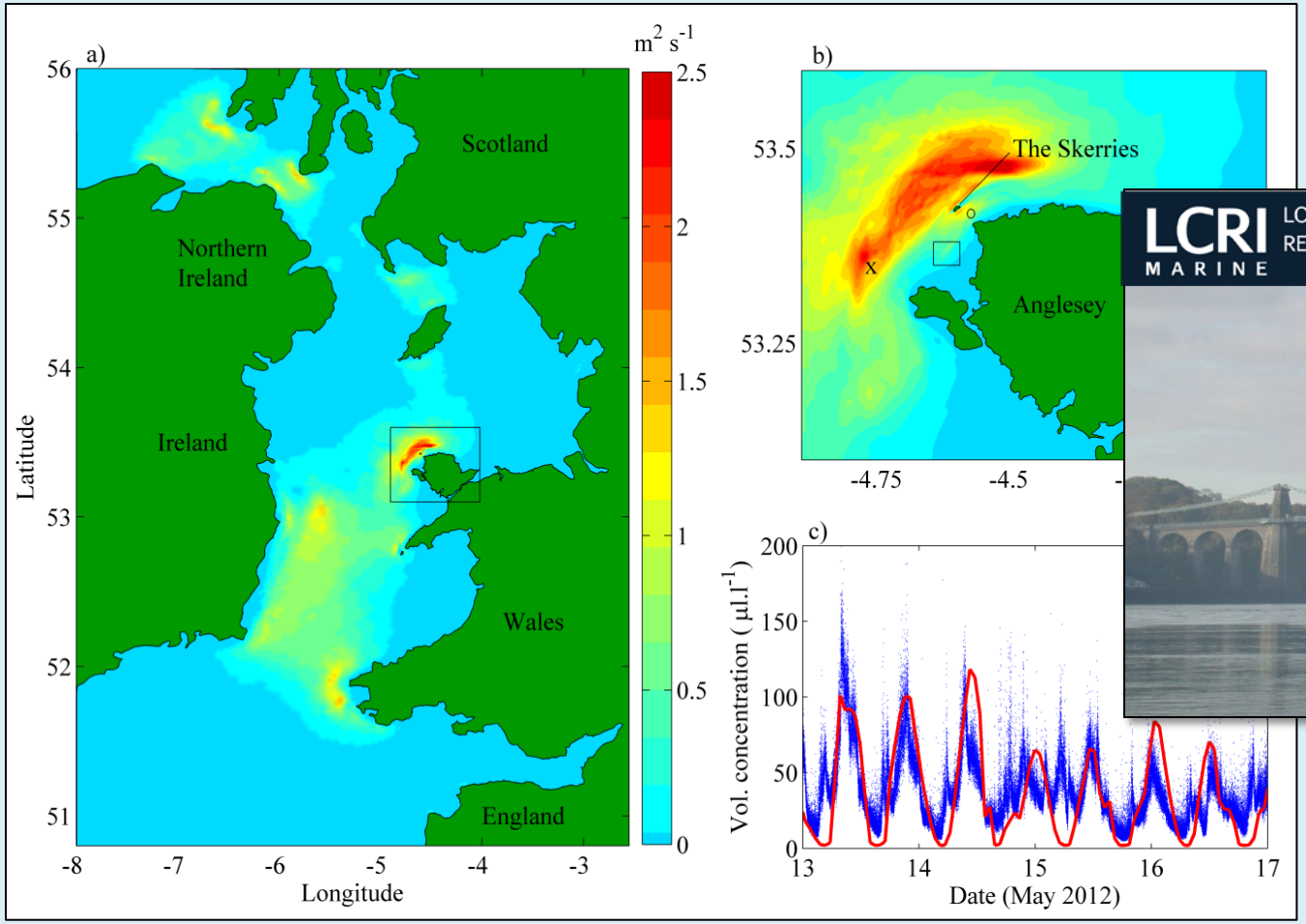

1.250
0.000
-1.250
Anglesey
Velocity
m/s
Above 2
1.5 to 2
1 to 1.5
Below 1

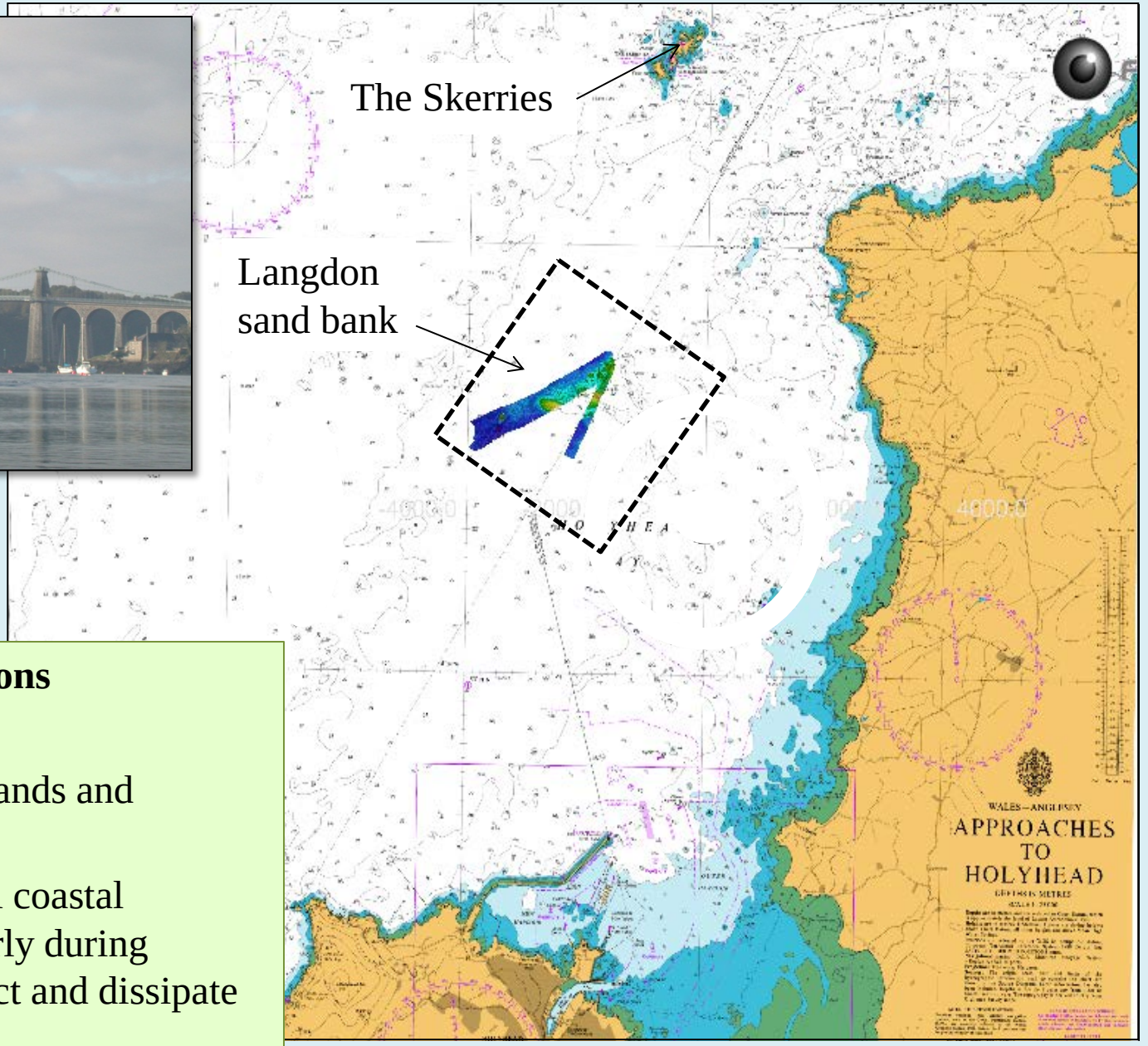

a)
Contour = 1.75 m/s
b)
Contour = 2 m/s
56°N
55°N
54°N
53°N
52°N
51°N
7°W
6°W
5°W
4°W
3°W
0
0.5
1
1.5
2
2.5
3
3.5
$M_2 + S_2$ vel. amp. (m s^{-1})

Why are sediment dynamics important?

1) **High tidal dissipation** ⇨ **Suspended sediment**: Anglesey turbidity maximum

- Enhance nutrient supply for marine species
- Increase secondary production
- Serve as critical nursery areas for economically important species

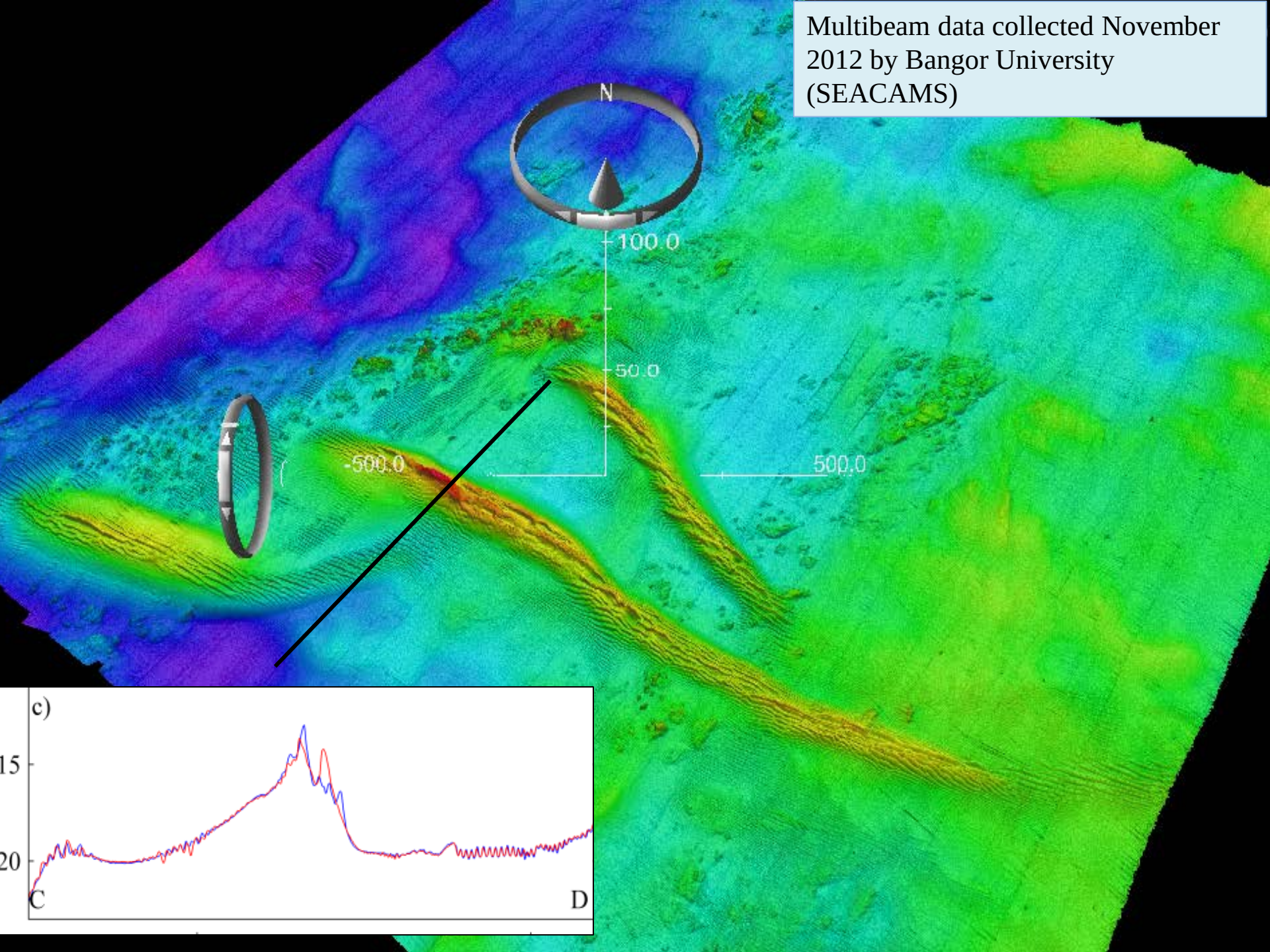


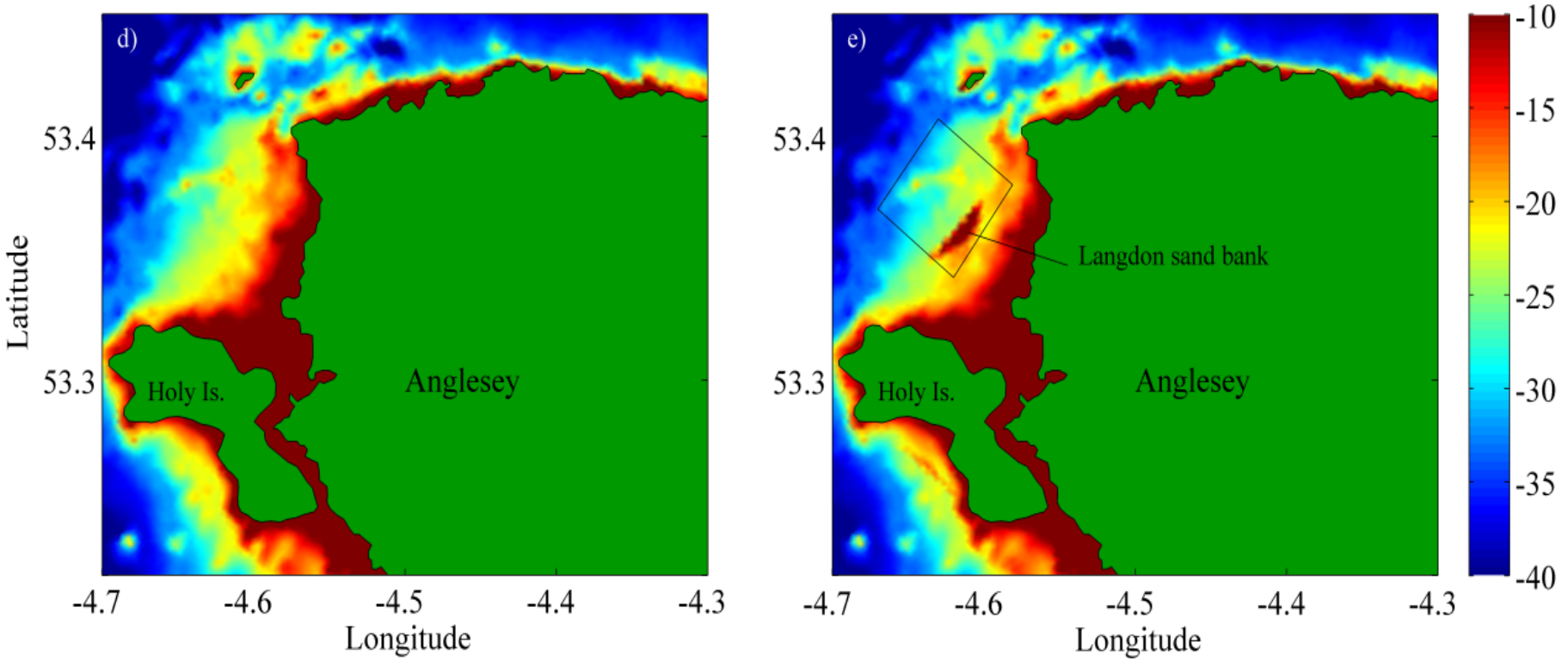


2) Sand bank formations

- form in the lee of islands and headlands
- Important for natural coastal protection, particularly during storms, as they refract and dissipate wave energy

Multibeam data collected May 2012 by Bangor University (SEACAMS)


Multibeam data collected November 2012 by Bangor University (SEACAMS)
N
100.0
50.0
-500.0
500.0
c)
15
20
C
D


d)
e)
53.4
53.3
Latitude
Holy Is.
Anglesey
Langdon sand bank
-4.7
-4.6
-4.5
-4.4
-4.3
Longitude
-10
-15
-20
-25
-30
-35
-40

3) Net bed load transport

Pingree and Griffiths (1979):

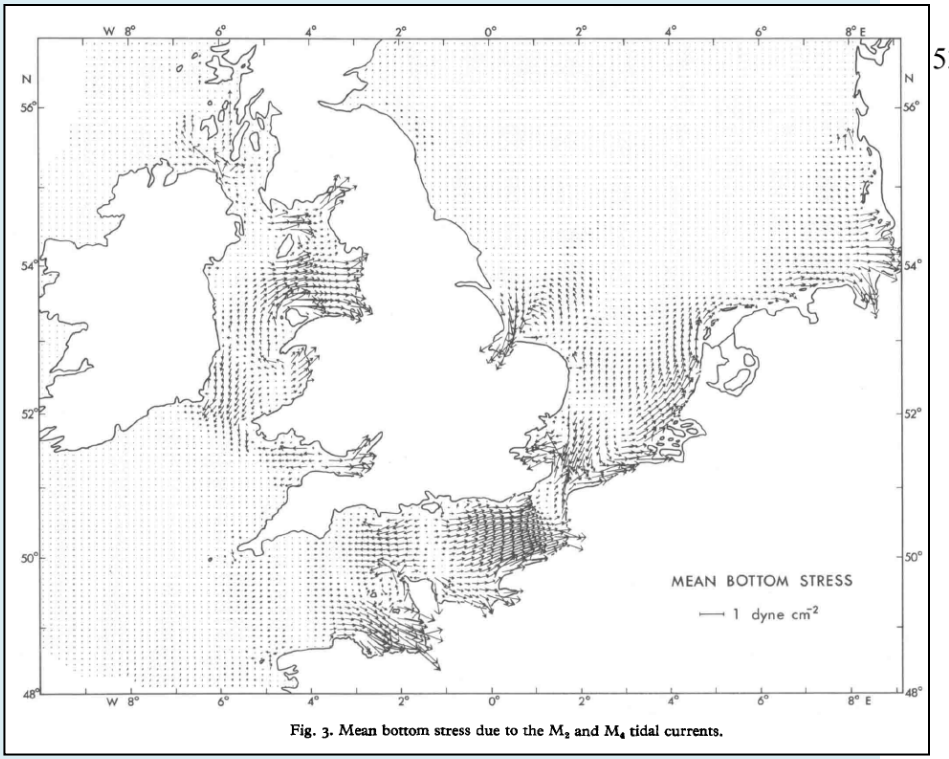
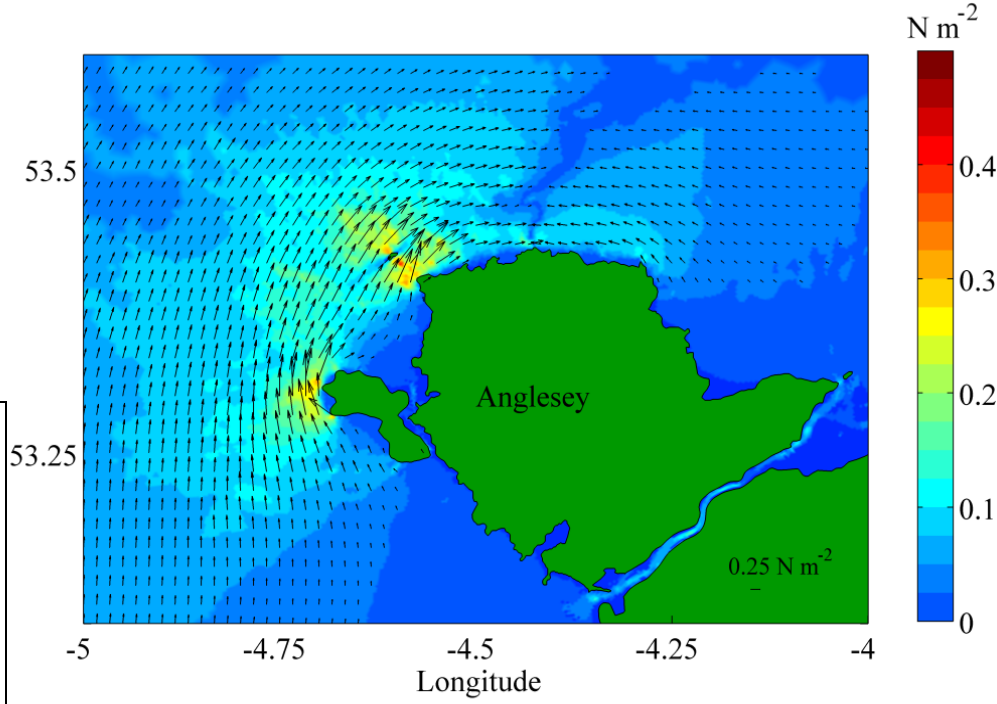
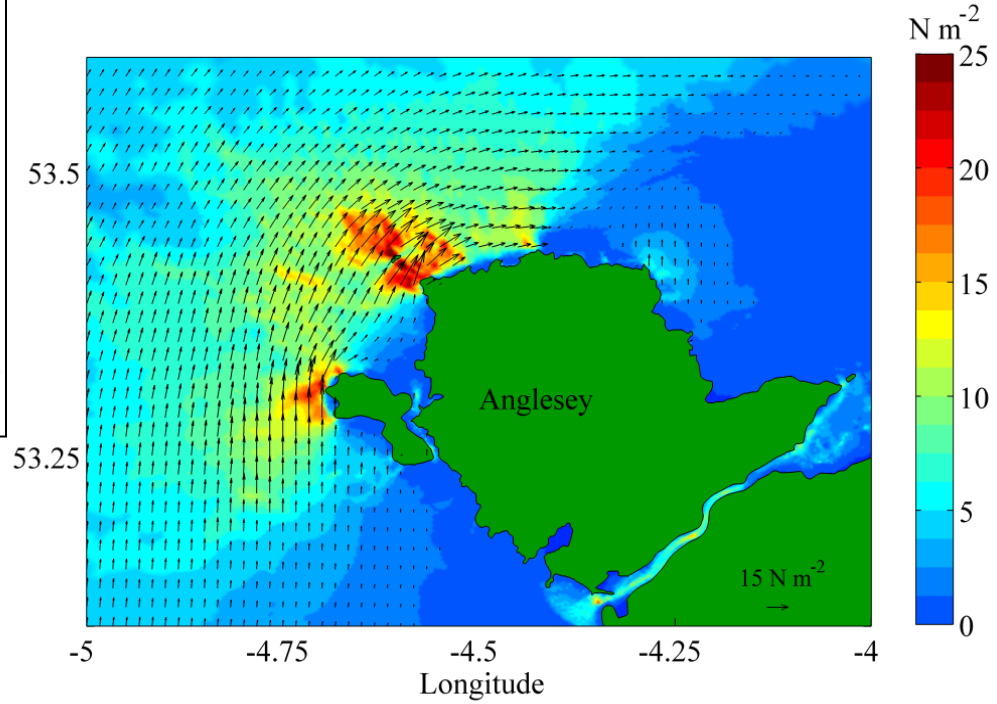


Fig. 3. Mean bottom stress due to the M_2 and M_4 tidal currents.





Natural variability: wave-induced bed shear stress

$$\tau_{wave} = \frac{1}{2}\,\rho\, f_w\, UW_{RMS}{}^2$$

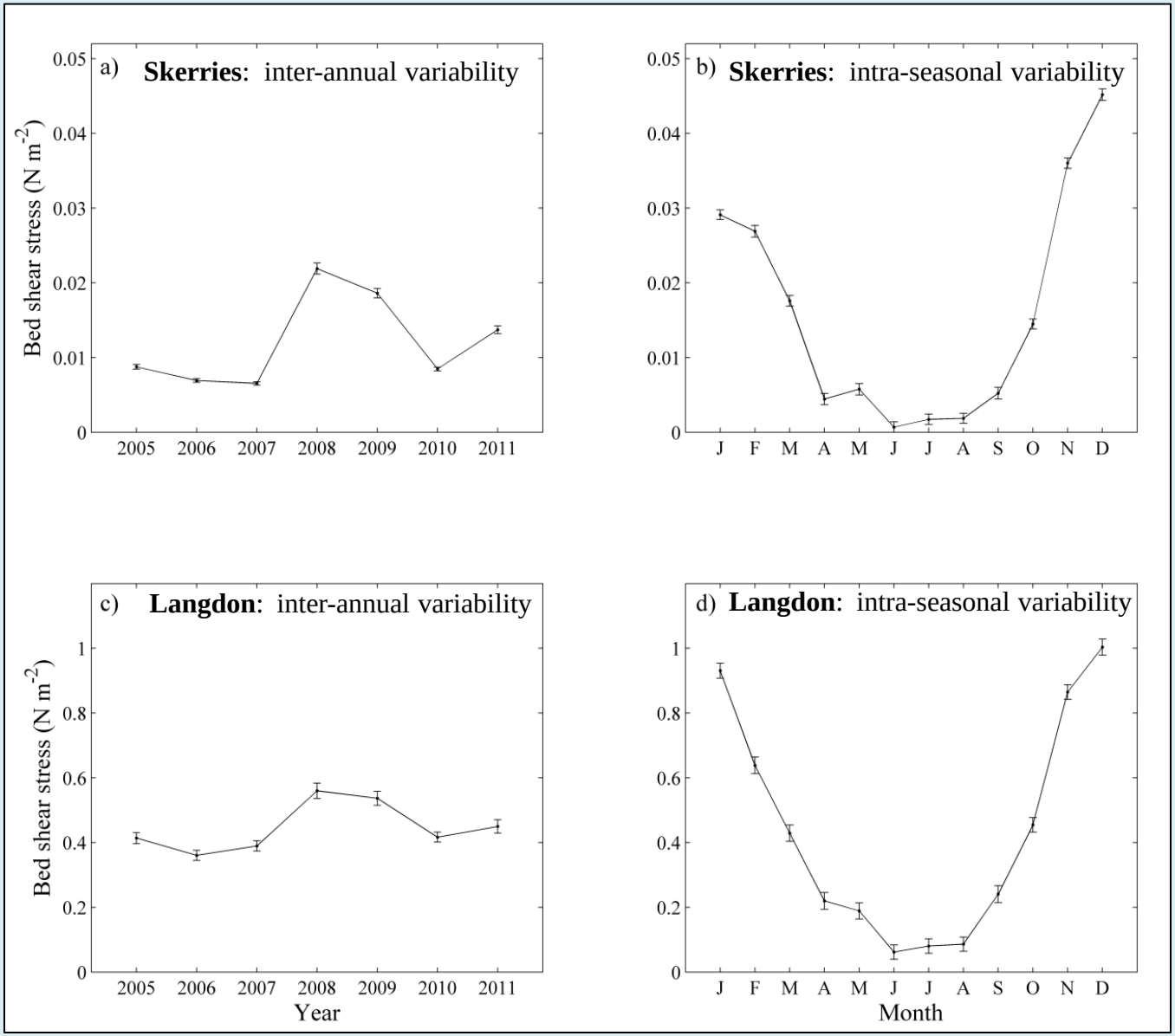
SWAN

- Spectral wave model
- NW European shelf
- 1/24° resolution
- Neill & Hashemi (2013)

RESULTS

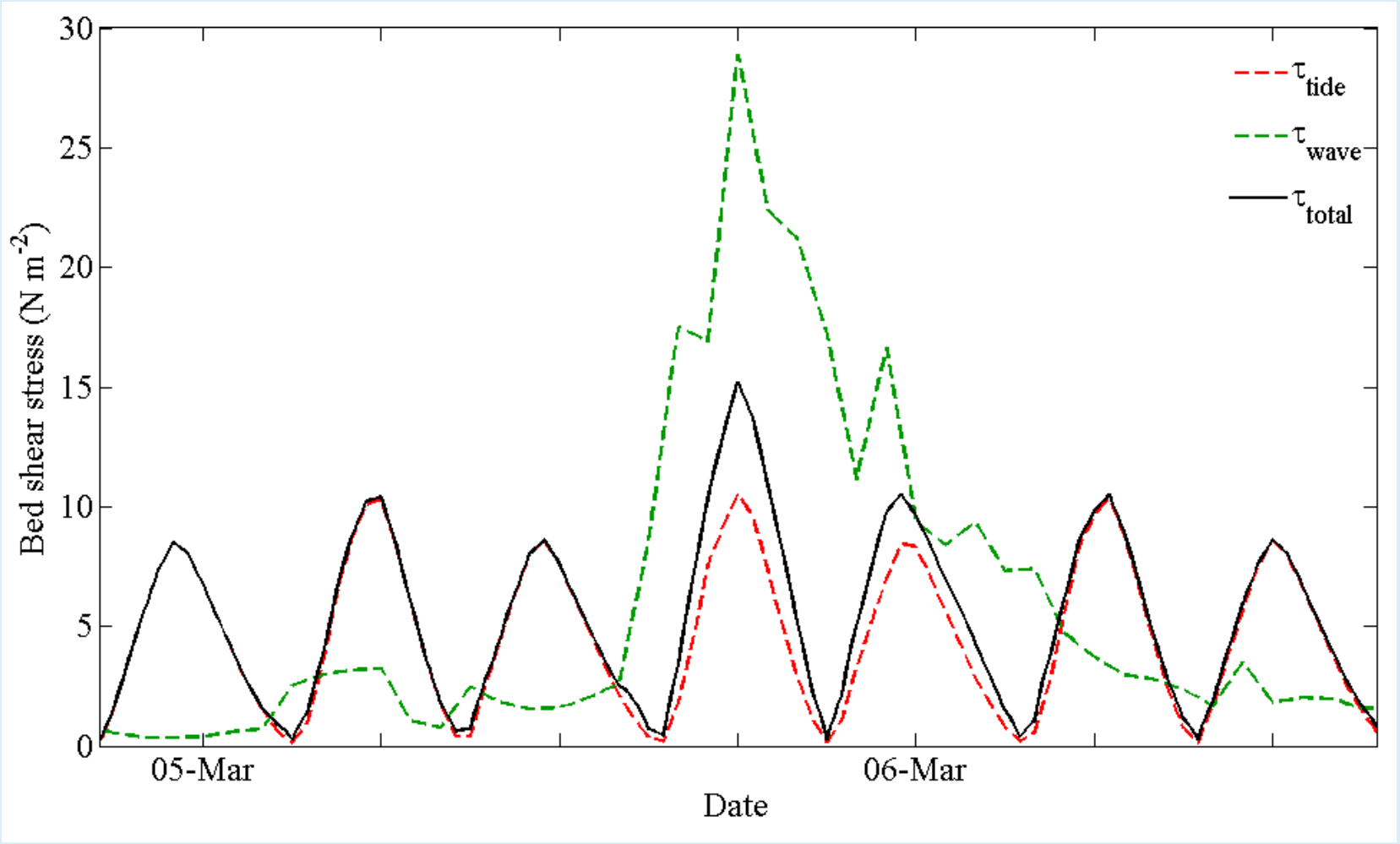
Skerries:
inter-annual: 0.012 ± 0.005
Intra-seasonal:
-Summer: 0.004 ± 0.002
-Winter: 0.03 ± 0.01

Langdon sand bank:
inter-annual: 0.45 ± 0.05
Intra-seasonal:
-Summer: 0.15 ± 0.06
-Winter: 0.72 ± 0.2



Combined stress: waves + tides

Soulsby (1997): $$\tau_{total} = \tau_{tide}\left[1 + 1.2\left(\frac{\tau_{wave}}{\tau_{tide} + \tau_{wave}}\right)^{3.2}\right]$$



Tidal-stream energy extraction

How do TEC arrays affect:

- Suspended sediment?
- Formation of sand banks?
- Net sediment fluxes?

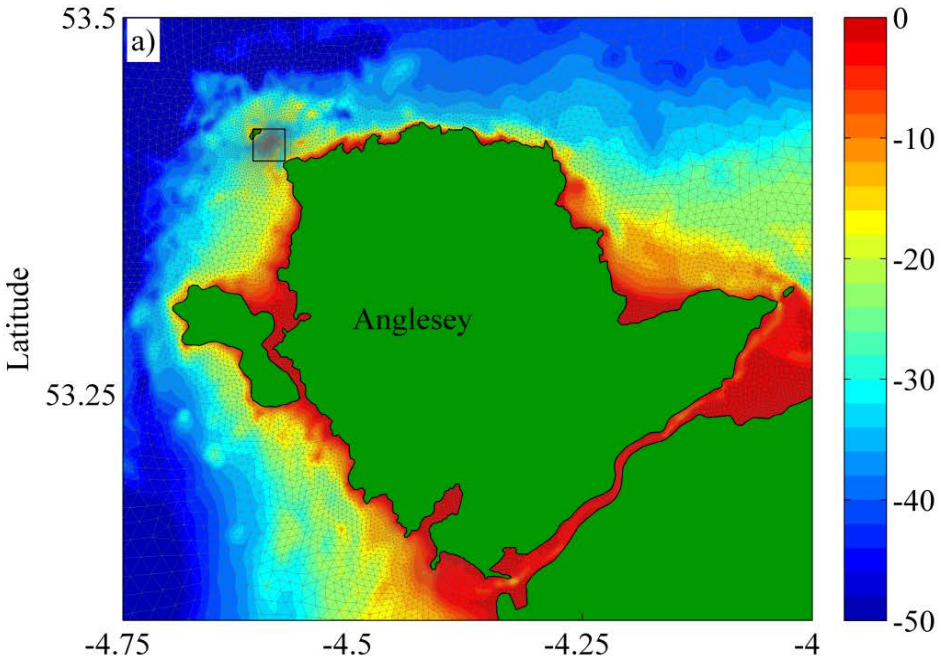
Is the impact significant relative to natural intra-seasonal and inter-annual variations?

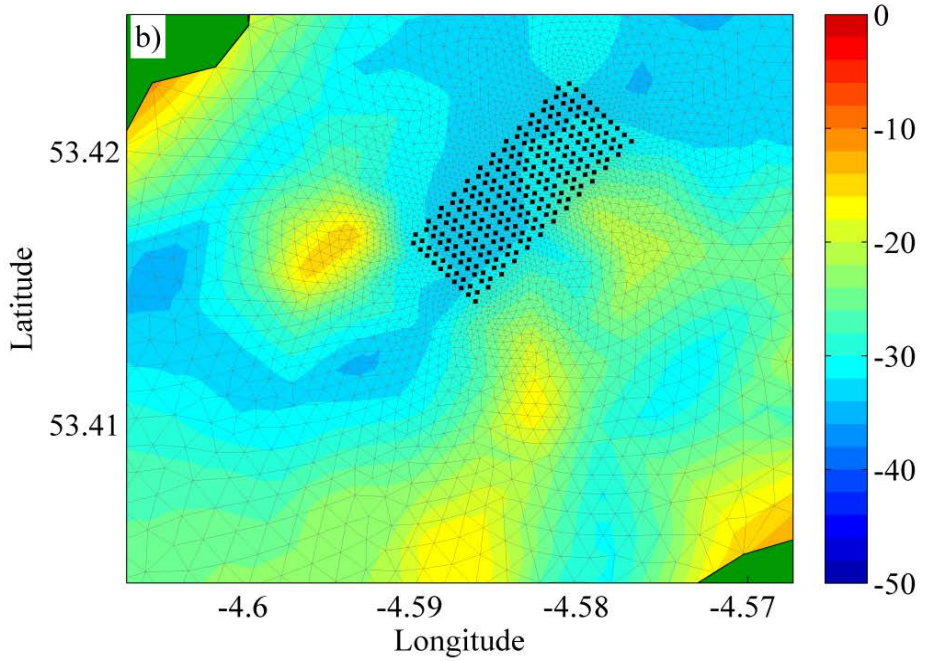
TEC array simulations:

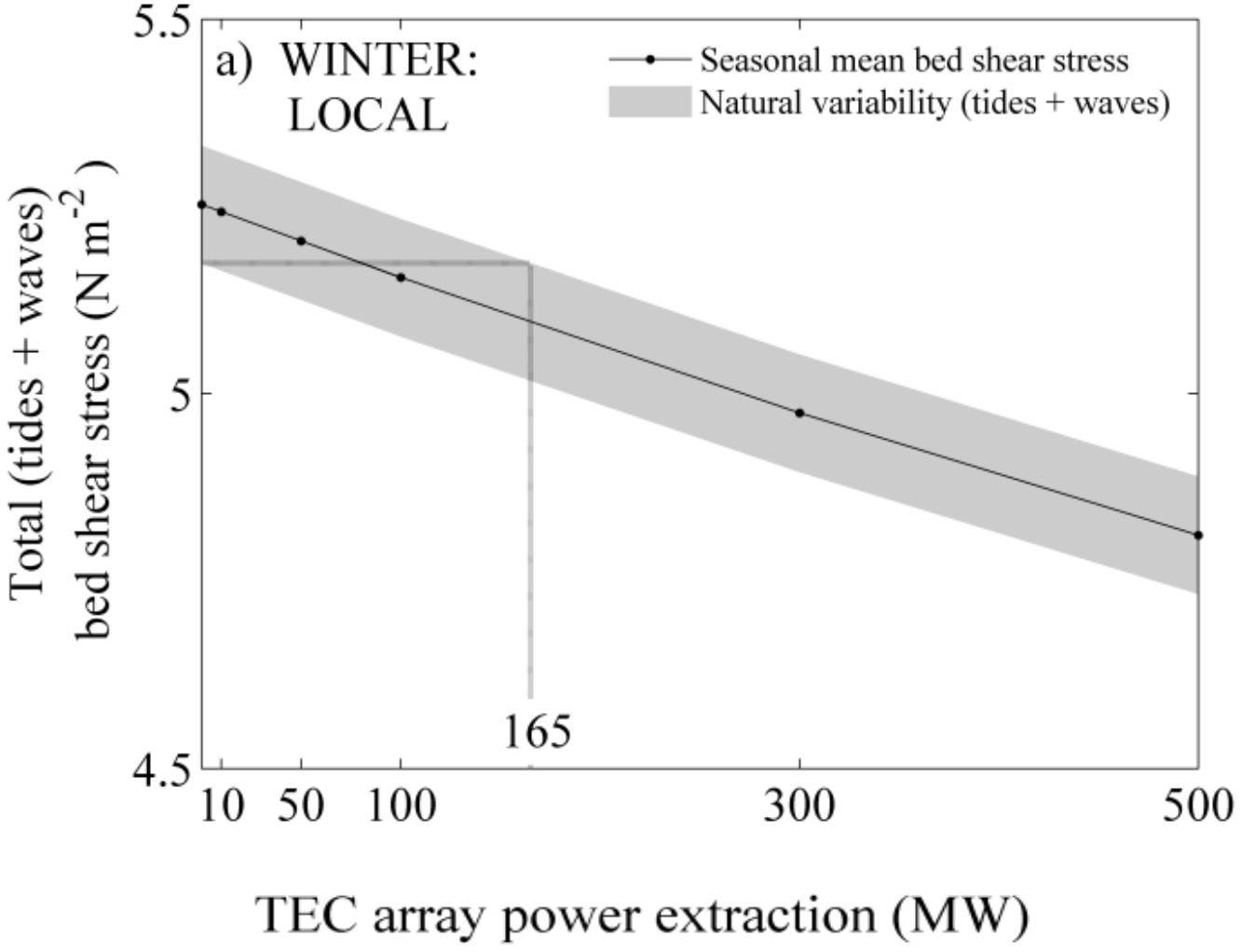
- Turbines induce drag force on flow

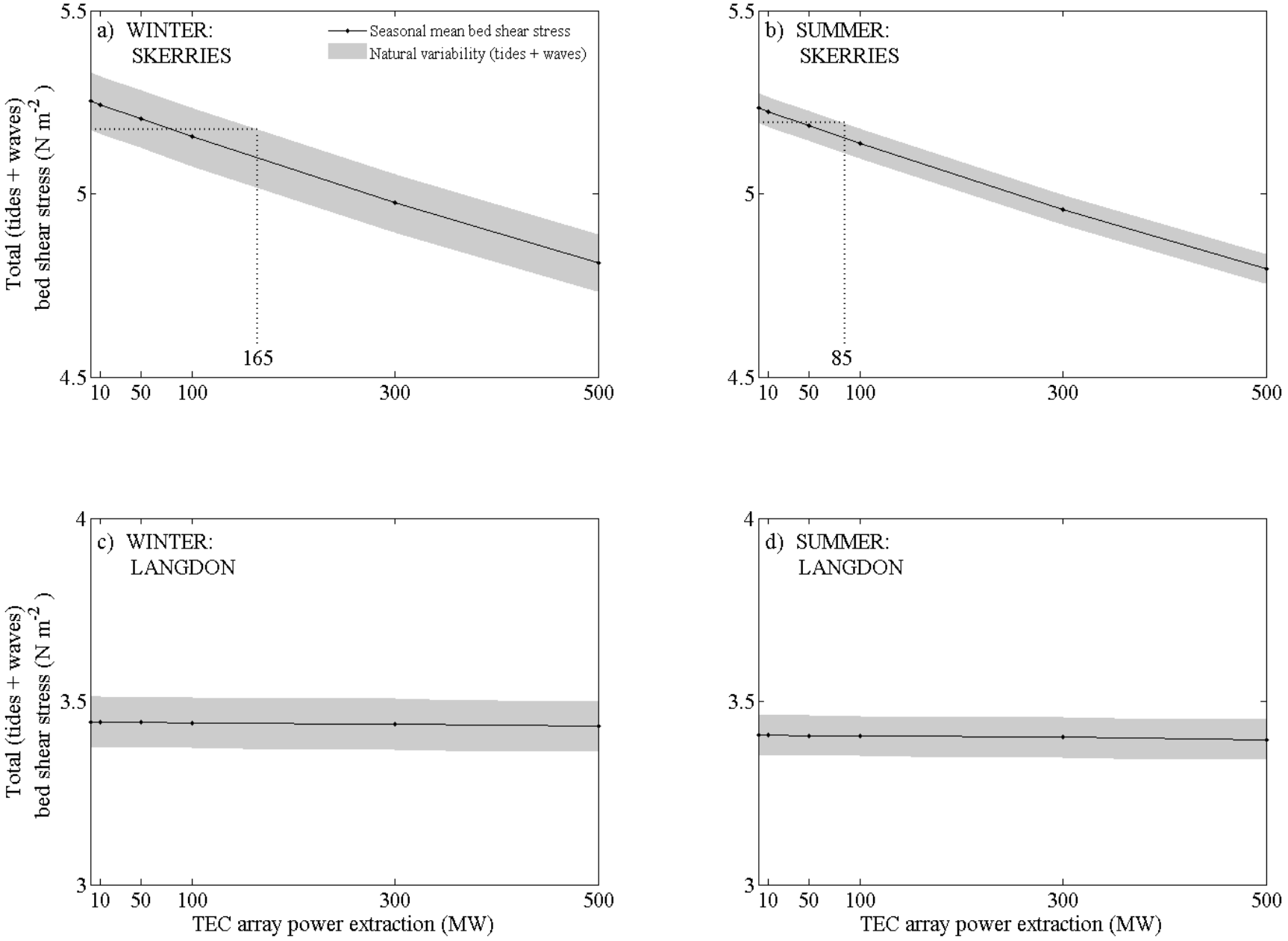
$$F_x = -C_p \frac{P}{\rho U A D} cos(\theta)$$

- TEC array rated power modelled:
- 10, 50, 100, 300, 500 MW






a) WINTER:
LOCAL
Seasonal mean bed shear stress
Natural variability (tides + waves)
Total (tides + waves)
bed shear stress (N m-2)
5.5
5
4.5
165
10
50
100
300
500
TEC array power extraction (MW)


a) WINTER:
SKERRIES
Seasonal mean bed shear stress
Natural variability (tides + waves)
Total (tides + waves) bed shear stress (N m-2)
5.5
5
4.5
165
10
50
100
300
500
b) SUMMER:
SKERRIES
85
c) WINTER:
LANGDON
4
3.5
3
d) SUMMER:
LANGDON
TEC array power extraction (MW)

Conclusions

- Telemac-2D Model simulated:
  - Anglesey turbidity maximum
  - net bed shear stress
  - sand banks formation

- First generation TEC arrays (10-50 MW) reduce velocities and bed shear stress by a few per cent, which could be considered insignificant compared to the natural variability.

- Further afield (10 km away), energy extraction did not exceed natural levels of variability in bed shear stress. However, this impact will always be site-specific.

- Sedimentary impacts of energy extraction should be considered at site selection stage.