DrSPNeill

PRIFYSGOL BANGOR UNIVERSITY

The role of tidal asymmetry in characterizing the tidal energy resource of Orkney

Simon Neill*, Reza Hashemi, Matt Lewis
Ocean Physics Group,
School of Ocean Sciences,
Bangor University, UK
*s.p.neill@bangor.ac.uk

FUJITSU

HPC WALES · CYMRU

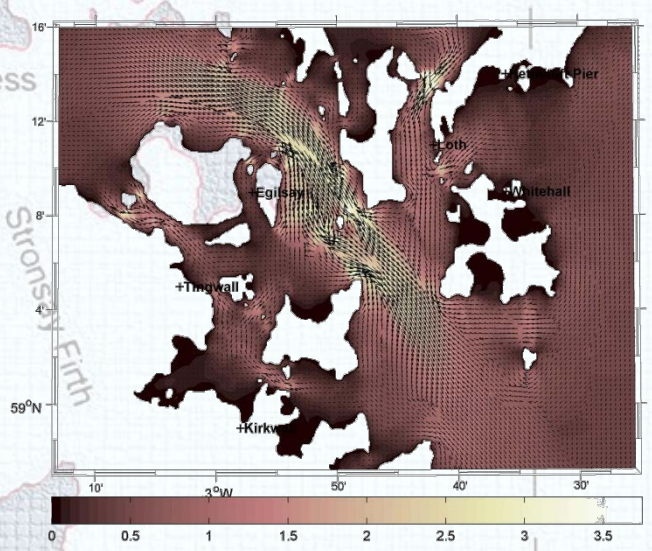
LCRI LOW CARBON RESEARCH INSTITUTE

SUPERGEN

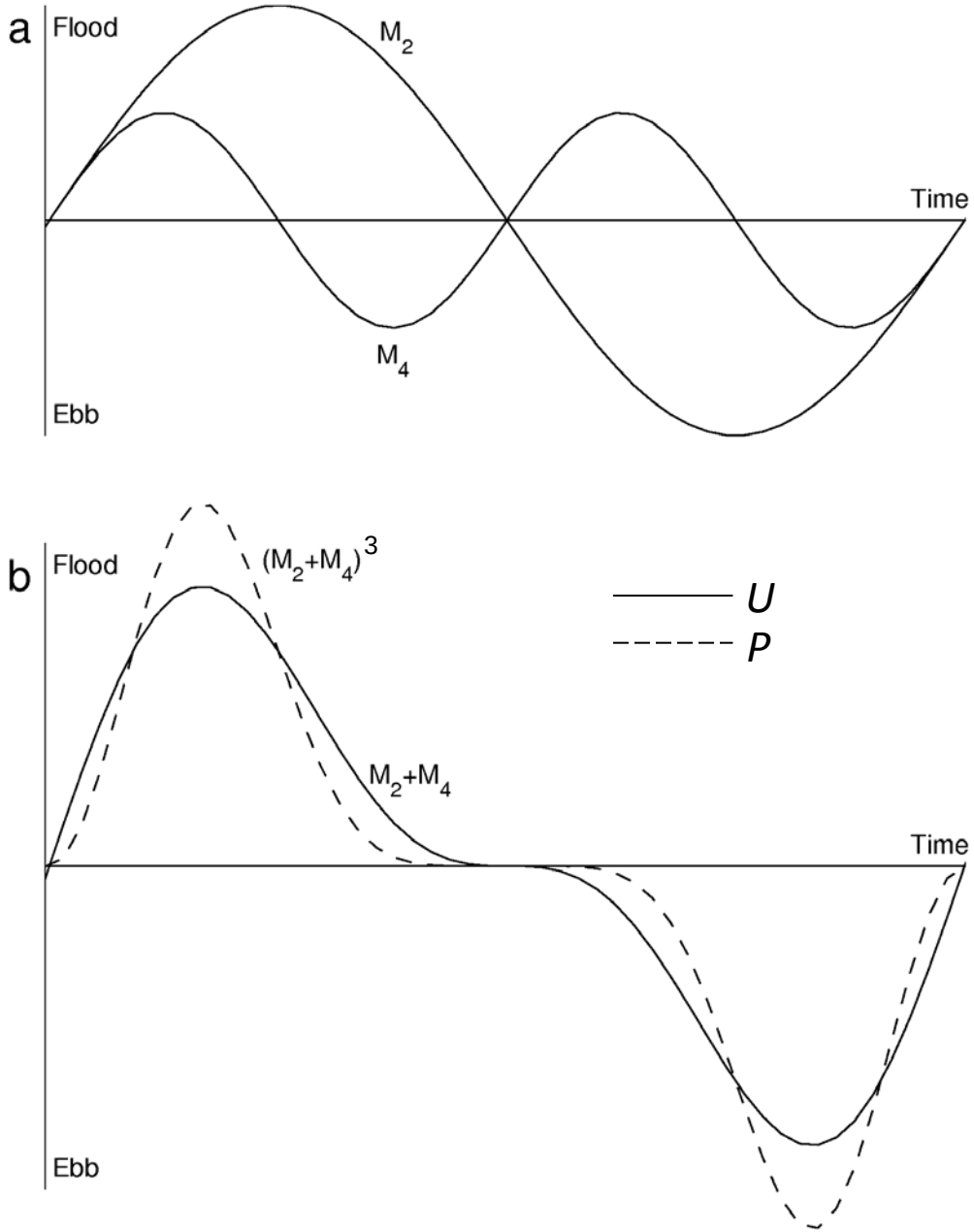
EPSRC Engineering and Physical Sciences Research Council

Presentation outline

- Tidal asymmetry – theory
- Case study – Orkney
- 3D ROMS modelling
- Simulated asymmetry
  - Current speed (and fit with theory)
  - Practical resource
  - Hub height
- Conclusions and further work



Overtides and tidal symmetry



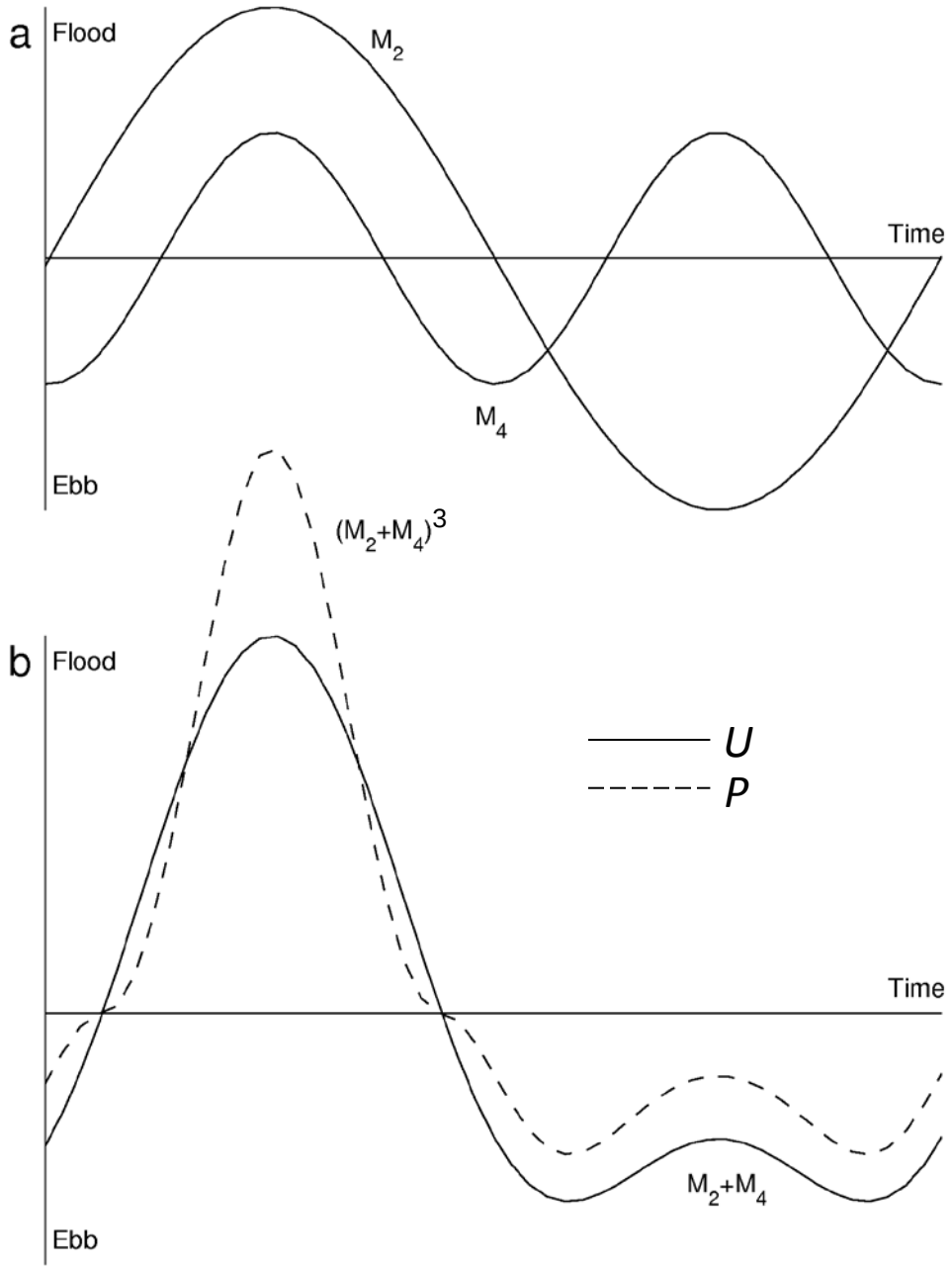
M_2 = principal lunar semidiurnal constituent (represents rotation of the Earth with respect to the moon).
T=12.42 h

M_4 = shallow water overtide.
T=6.21 h

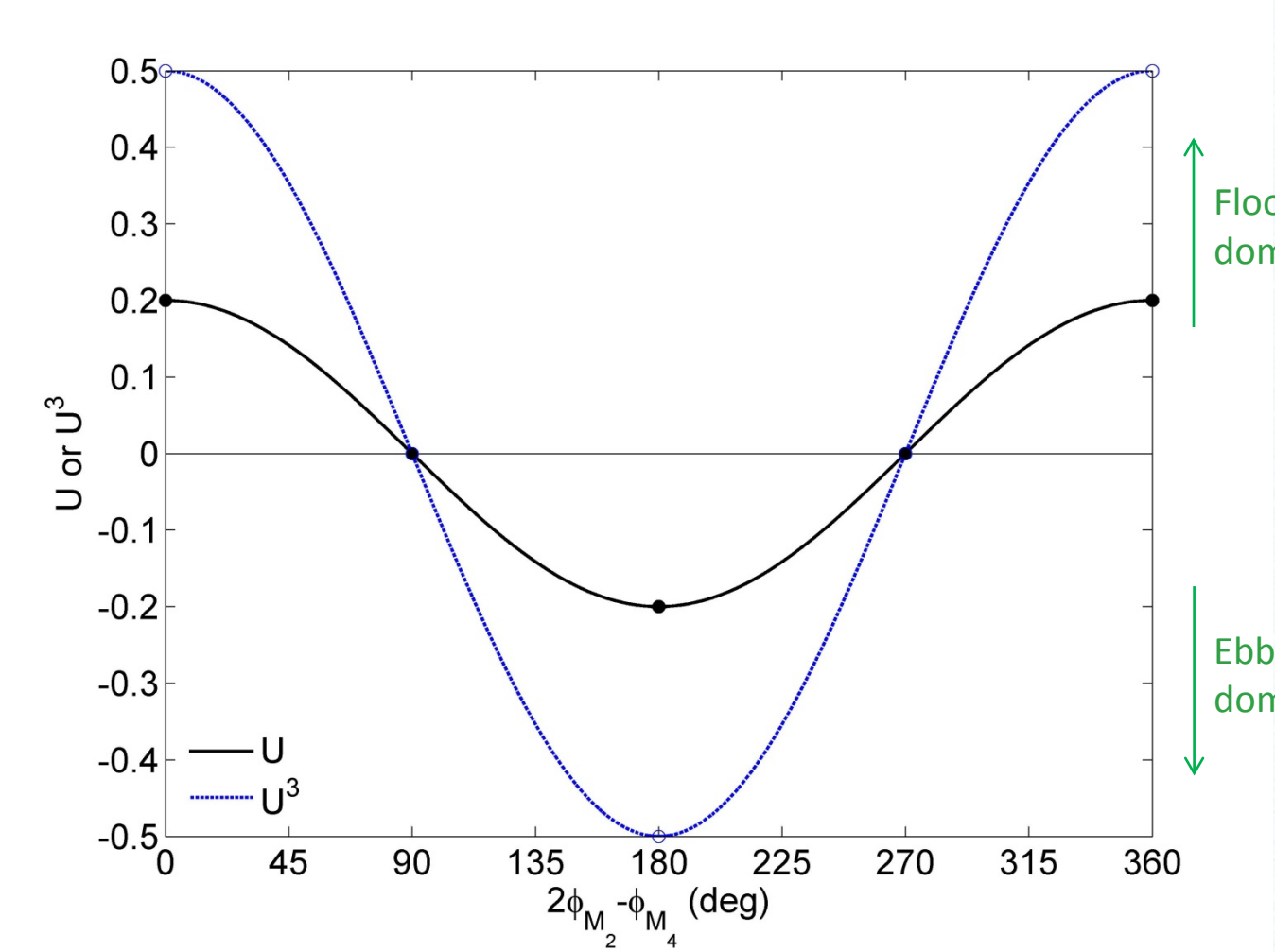
$$P = \frac{1}{2}\rho U^3$$

Pingree and Griffiths (1979) | Neill et al. (2009)

Tidal asymmetry



Phase relationship between M_2 and M_4



Neill et al. (2009)

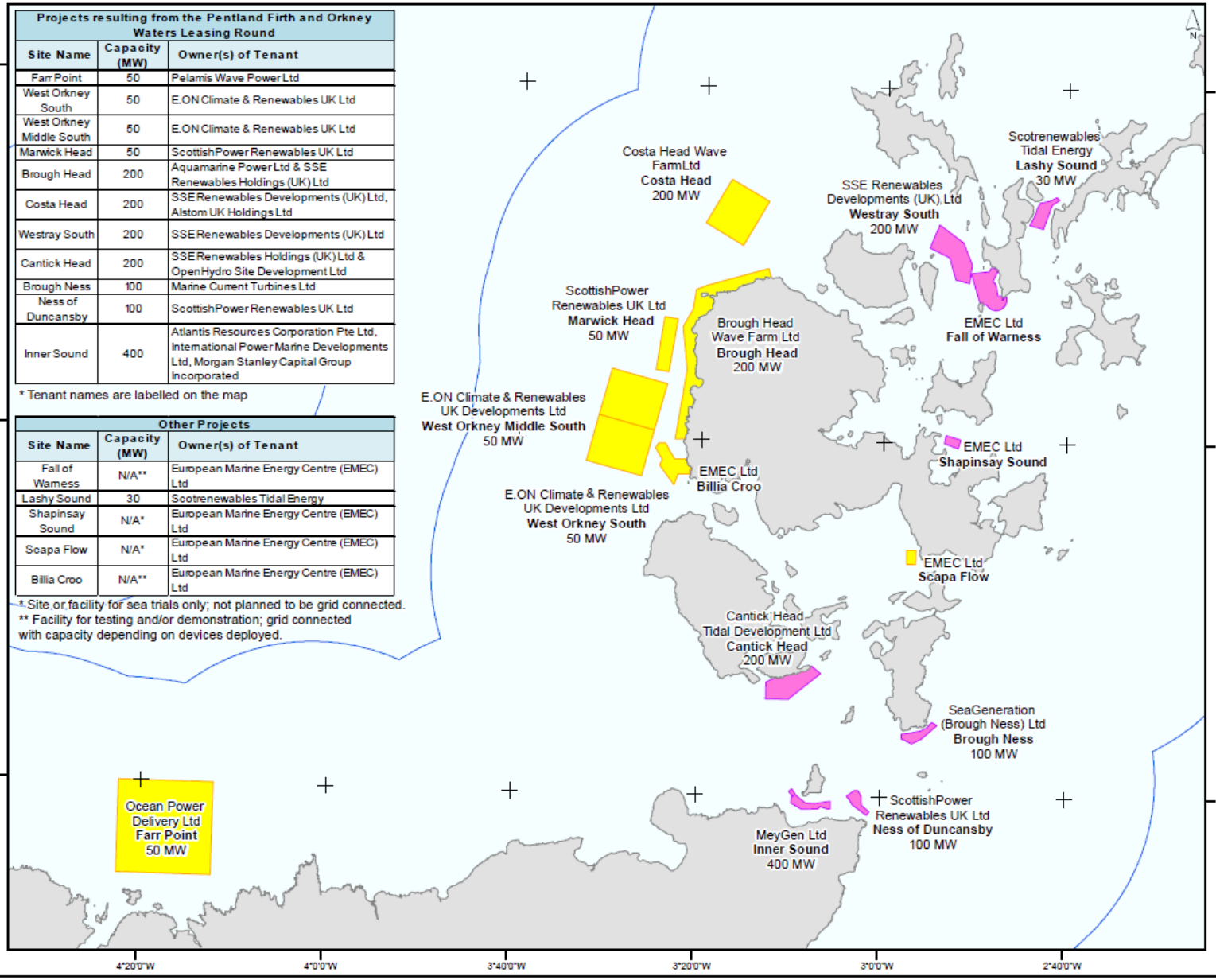
Wave and Tidal (Pentland Firth and Orkney Waters)

Projects resulting from the Pentland Firth and Orkney Waters Leasing Round		
Site Name	**Capacity (MW)**	**Owner(s) of Tenant**
Farr Point	50	Pelamis Wave Power Ltd
West Orkney South	50	E.ON Climate & Renewables UK Ltd
West Orkney Middle South	50	E.ON Climate & Renewables UK Ltd
Marwick Head	50	ScottishPower Renewables UK Ltd
Brough Head	200	Aquamarine Power Ltd & SSE Renewables Holdings (UK) Ltd
Costa Head	200	SSE Renewables Developments (UK) Ltd, Alstom UK Holdings Ltd
Westray South	200	SSE Renewables Developments (UK) Ltd
Cantick Head	200	SSE Renewables Holdings (UK) Ltd & OpenHydro Site Development Ltd
Brough Ness	100	Marine Current Turbines Ltd
Ness of Duncansby	100	ScottishPower Renewables UK Ltd
Inner Sound	400	Atlantis Resources Corporation Pte Ltd, International Power Marine Developments Ltd, Morgan Stanley Capital Group Incorporated

* Tenant names are labelled on the map

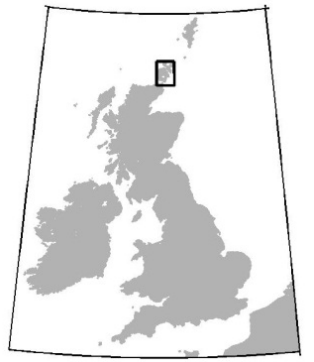
Other Projects		
Site Name	**Capacity (MW)**	**Owner(s) of Tenant**
Fall of Warness	N/A**	European Marine Energy Centre (EMEC) Ltd
Lashy Sound	30	Scotrenewables Tidal Energy
Shapinsay Sound	N/A*	European Marine Energy Centre (EMEC) Ltd
Scapa Flow	N/A*	European Marine Energy Centre (EMEC) Ltd
Billia Croo	N/A**	European Marine Energy Centre (EMEC) Ltd

* Site or facility for sea trials only; not planned to be grid connected.
** Facility for testing and/or demonstration; grid connected with capacity depending on devices deployed.



Wave and Tidal Activity
- Wave Site
- Tidal Site

Base Map
- Territorial Waters Limit
- United Kingdom



0 10 20 km

MaRS
Marine Resource System

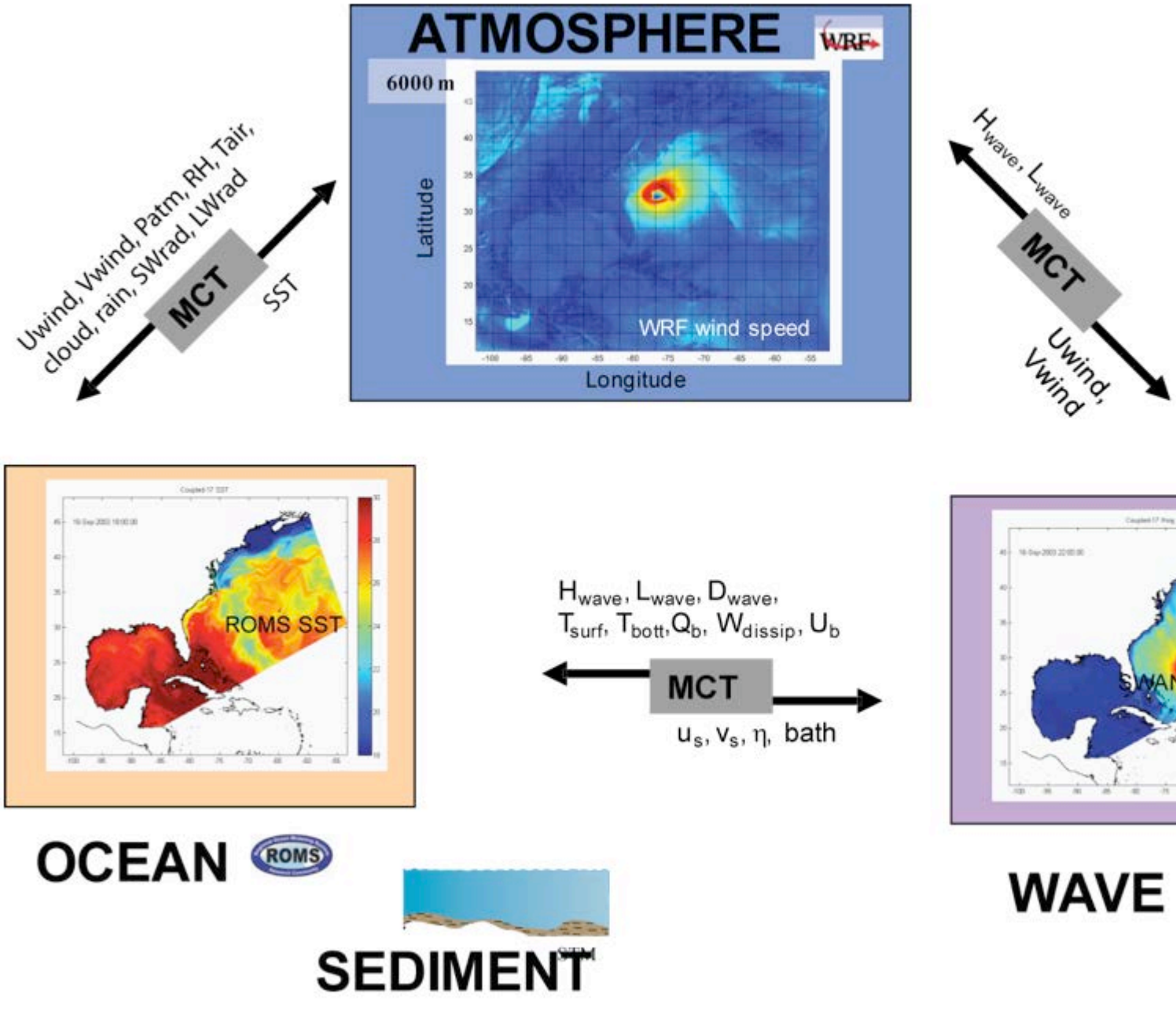
MAP/1301/007	
01 Mar 2013	
Author : KW	
QA : DM	
Size: A4	
1:550,000	

6 Bell's Brae
Edinburgh EH4 3BJ
Tel: 0131 260 6070

16 New Burlington Place
London W1S 2HX
Tel: 020 7851 5080

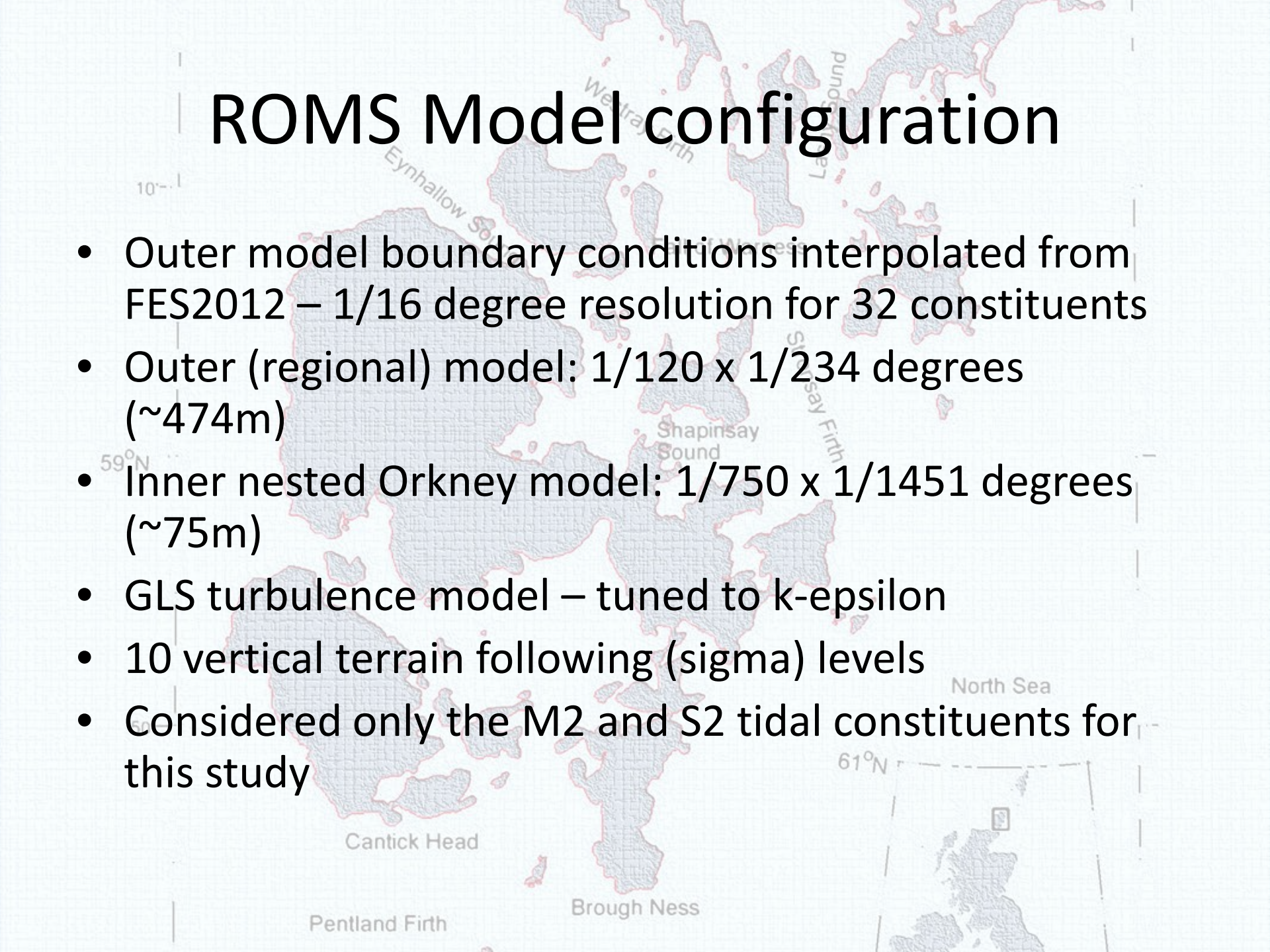
www.thecrownestate.co.uk

THE CROWN ESTATE

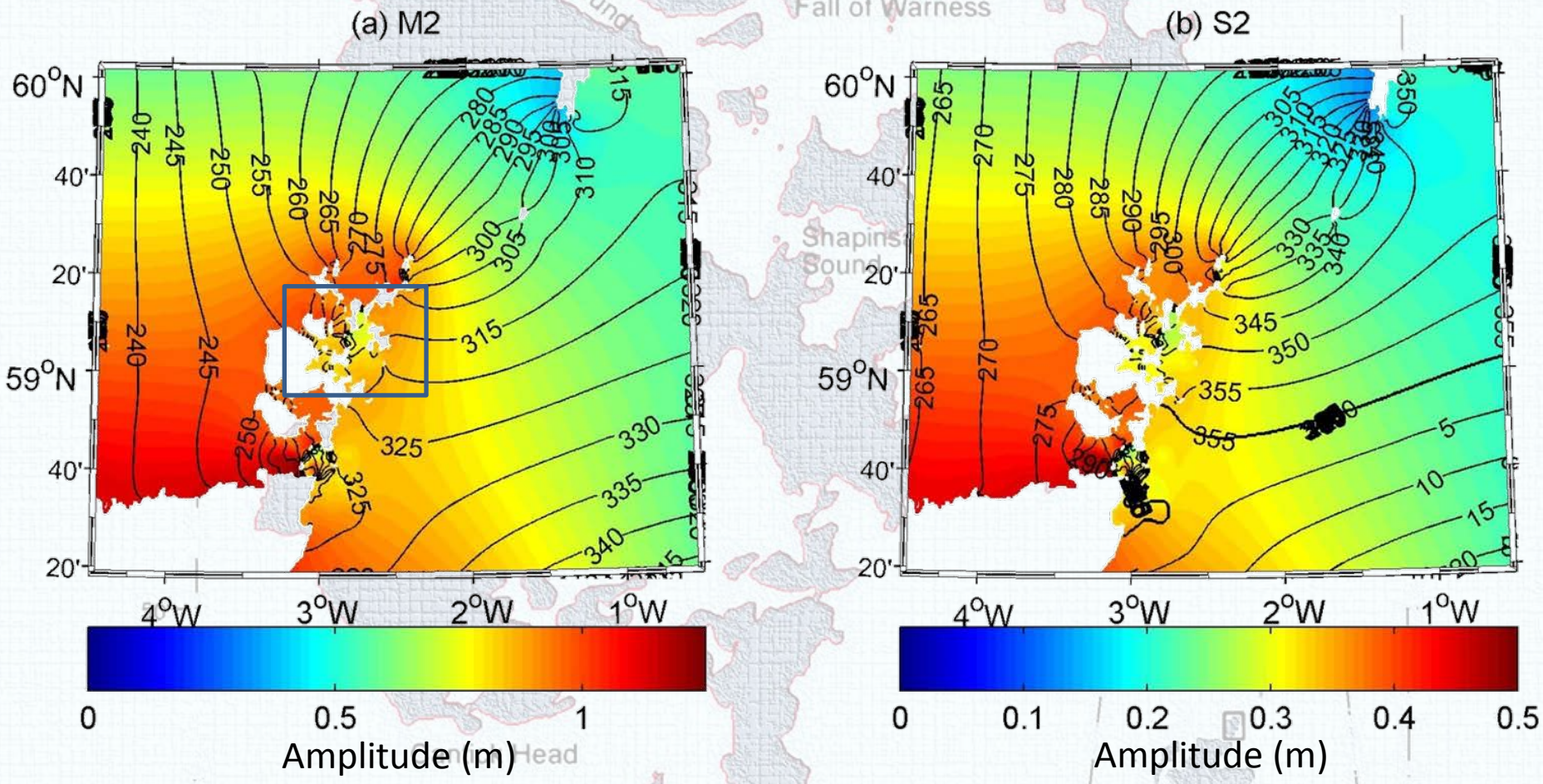

ATMOSPHERE
WRF
6000 m
Latitude
Longitude
WRF wind speed
Uwind, Vwind, Patm, RH, Tair,
cloud, rain, SWrad, LWrad
MCT
SST
Hwave, Lwave
MCT
Uwind,
Vwind
ROMS SST
OCEAN
ROMS
Hwave, Lwave, Dwave,
Tsurf, Tbott, Qb, Wdissip, Ub
MCT
us, vs, η, bath
SWAN Hsig
WAVE
SWAN
SEDIMENT

ROMS Model configuration

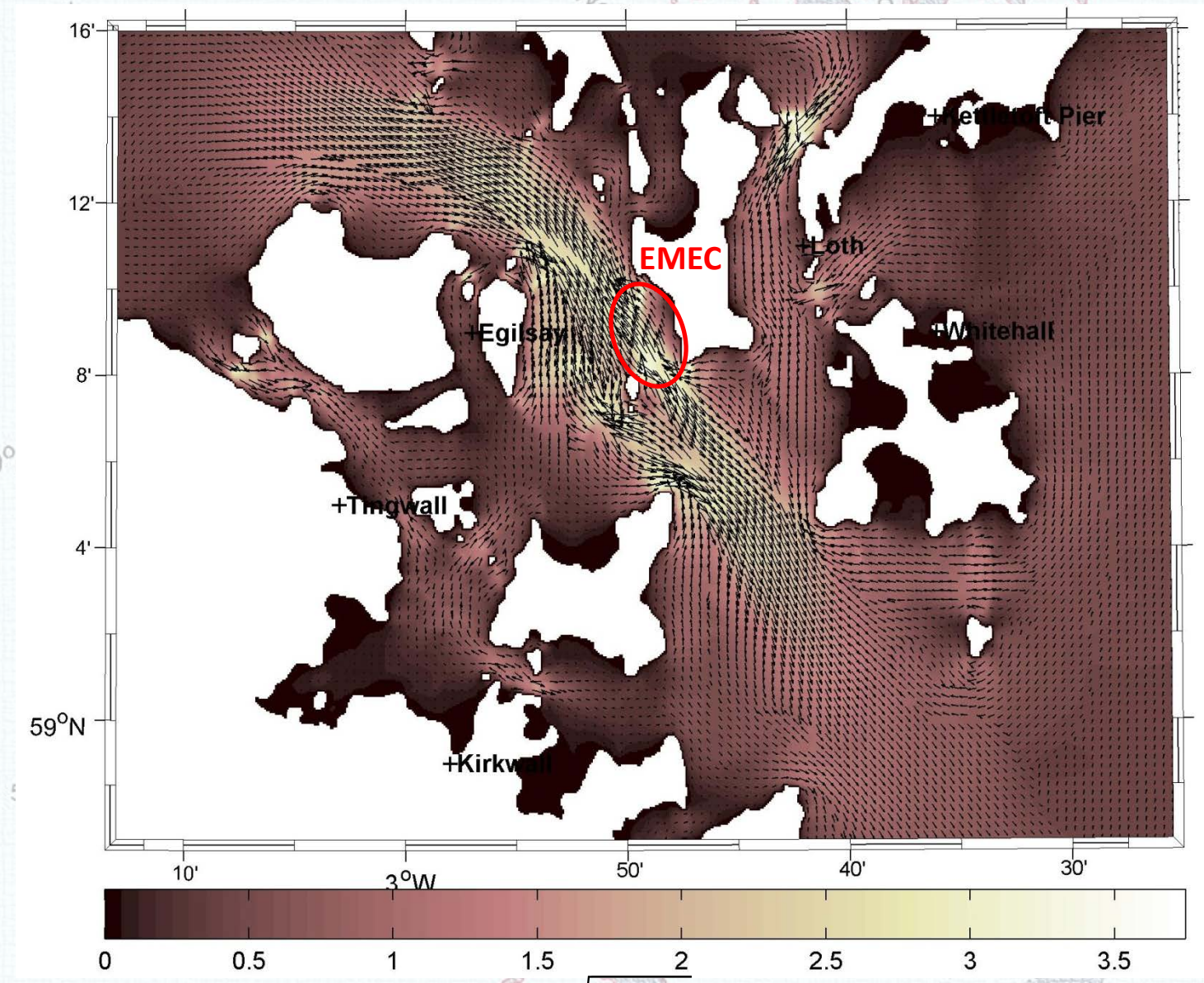
- Outer model boundary conditions interpolated from FES2012 – 1/16 degree resolution for 32 constituents
- Outer (regional) model: 1/120 x 1/234 degrees (~474m)
- Inner nested Orkney model: 1/750 x 1/1451 degrees (~75m)
- GLS turbulence model – tuned to k-epsilon
- 10 vertical terrain following (sigma) levels
- Considered only the M2 and S2 tidal constituents for this study



M2 and S2 co-tidal charts from regional model



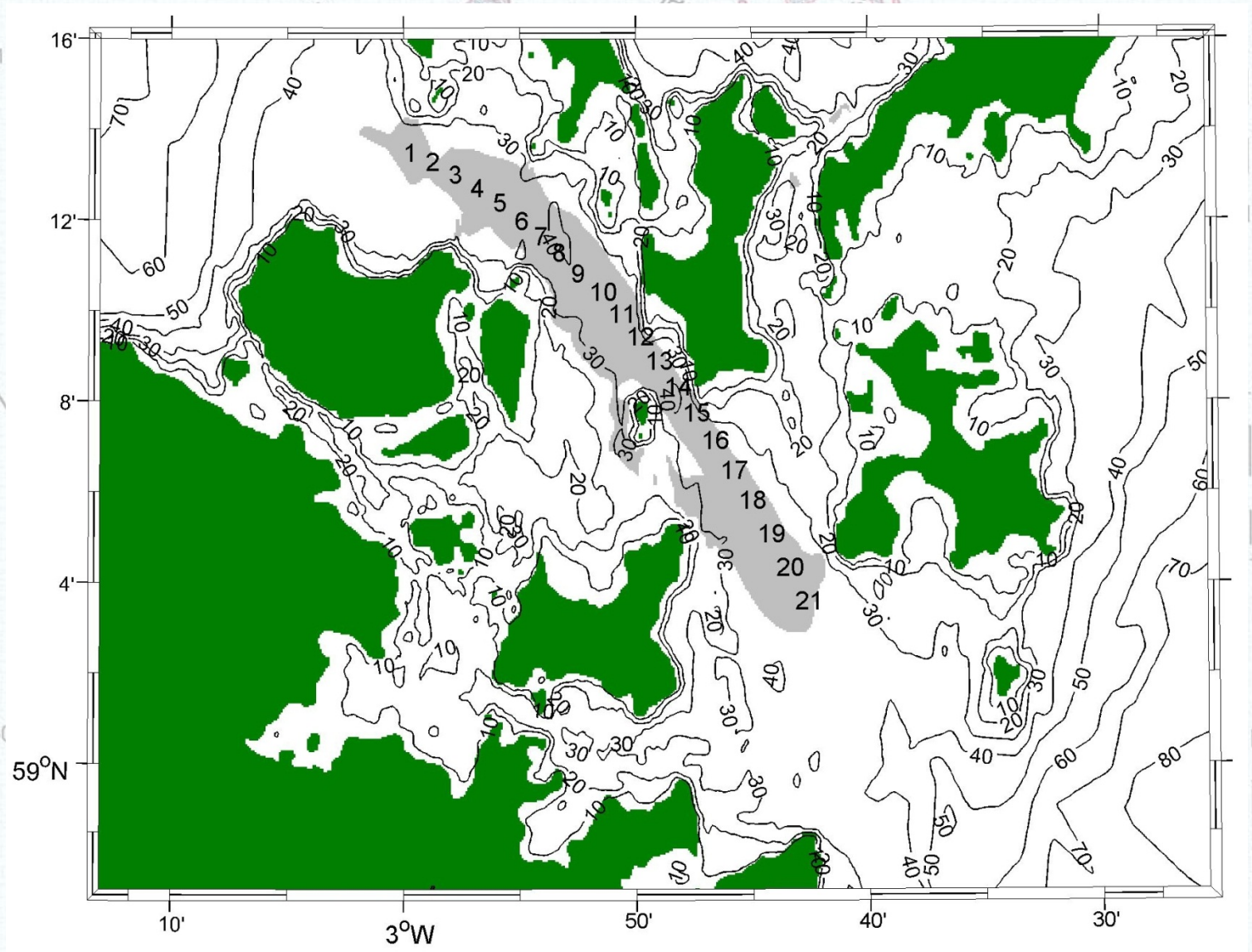
Peak (spring) tidal currents



Masked region

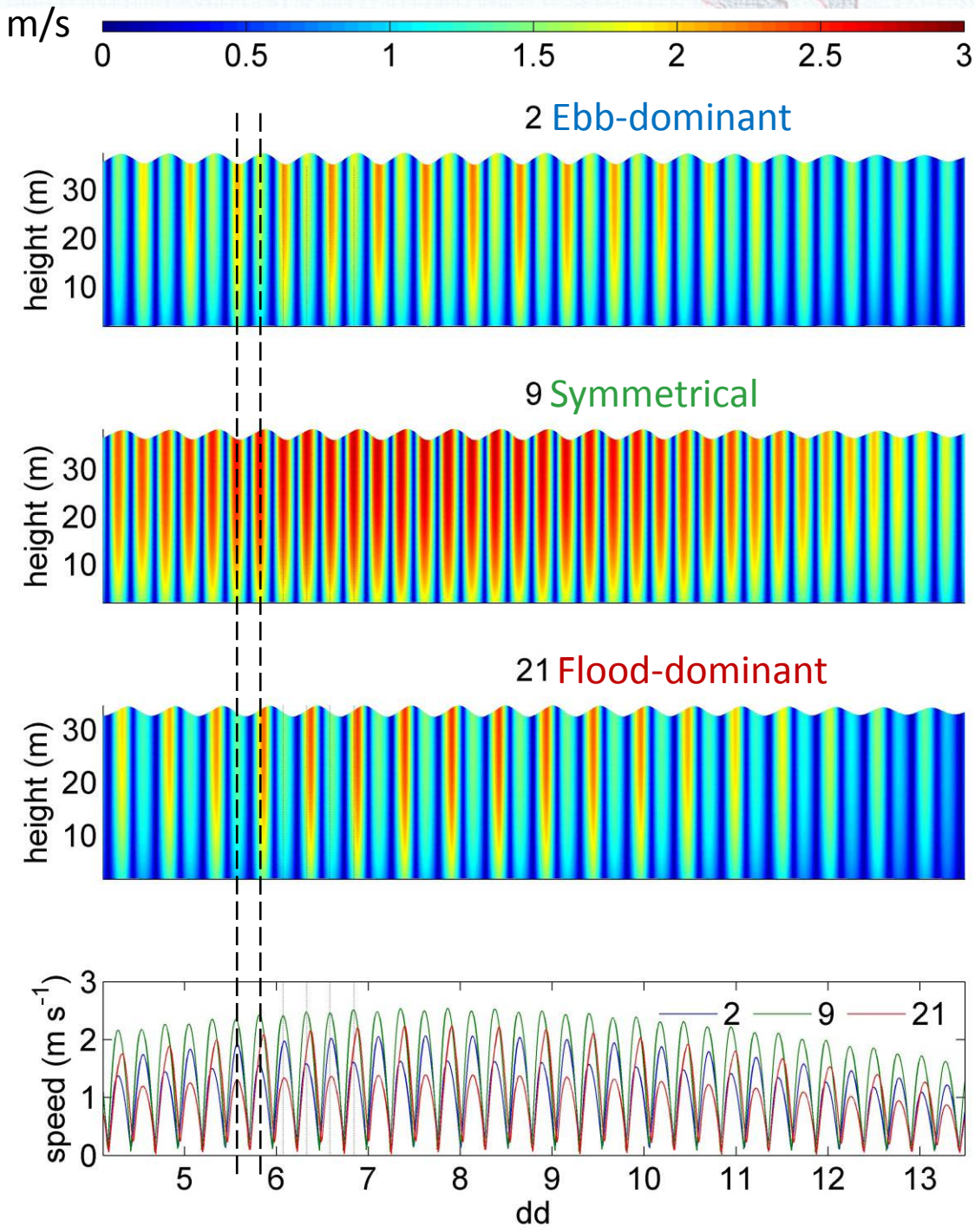
$V_{spring} > 2$ m/s

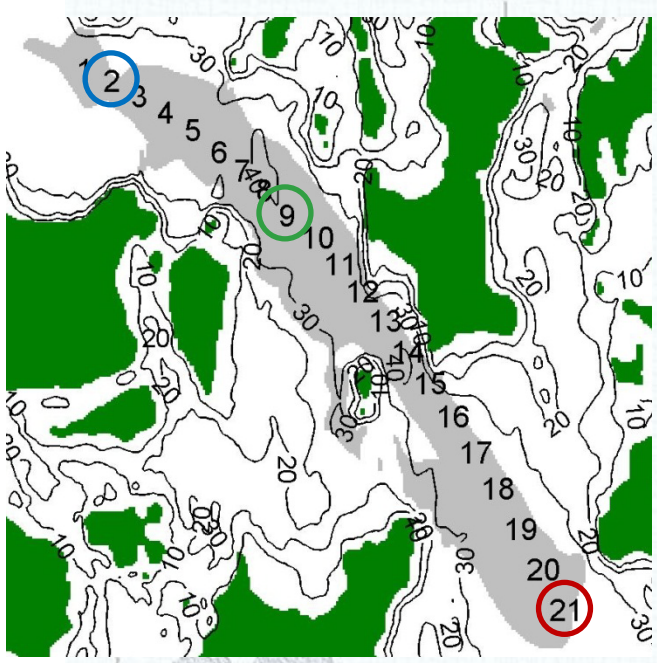
$25 < h < 50$ m

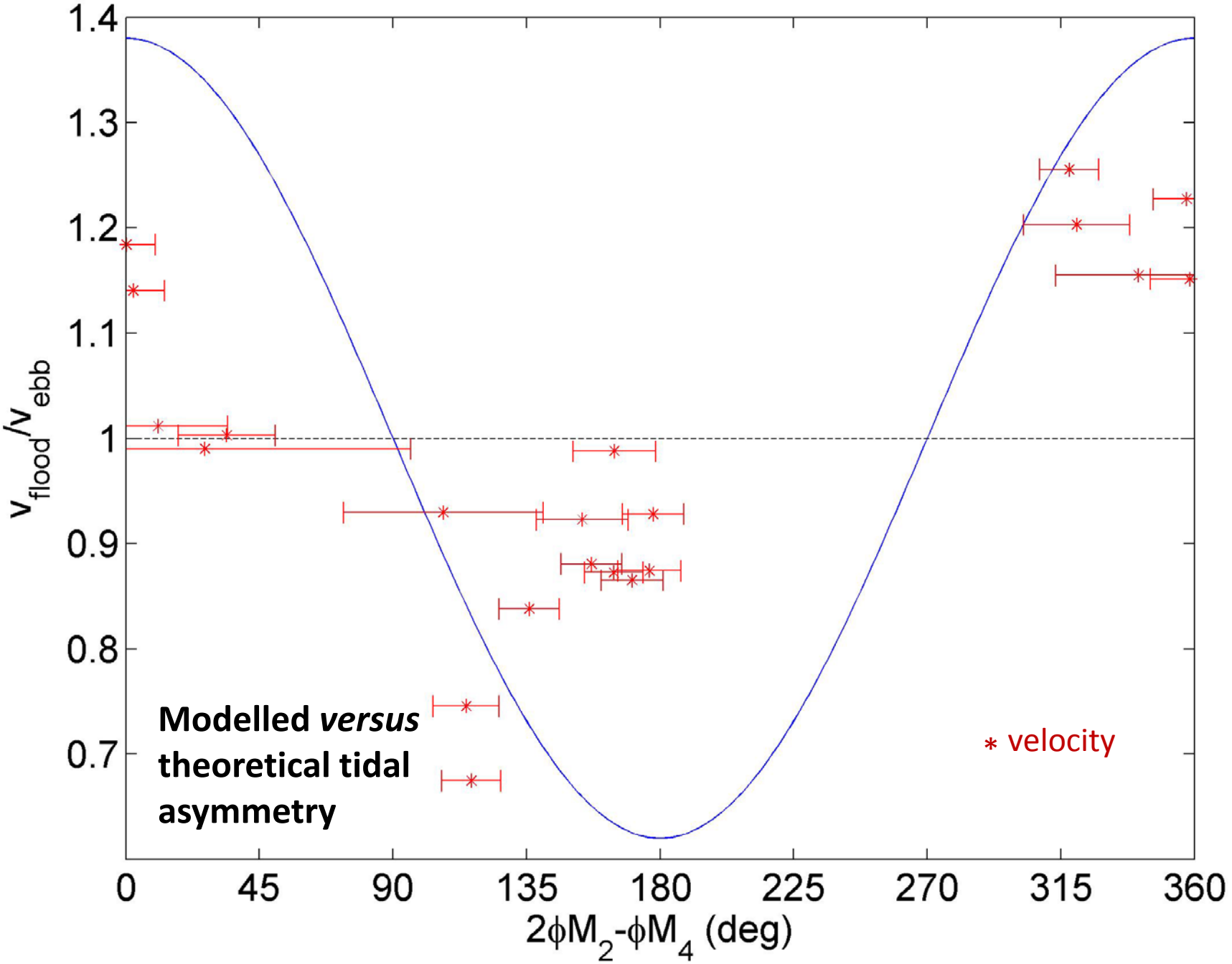


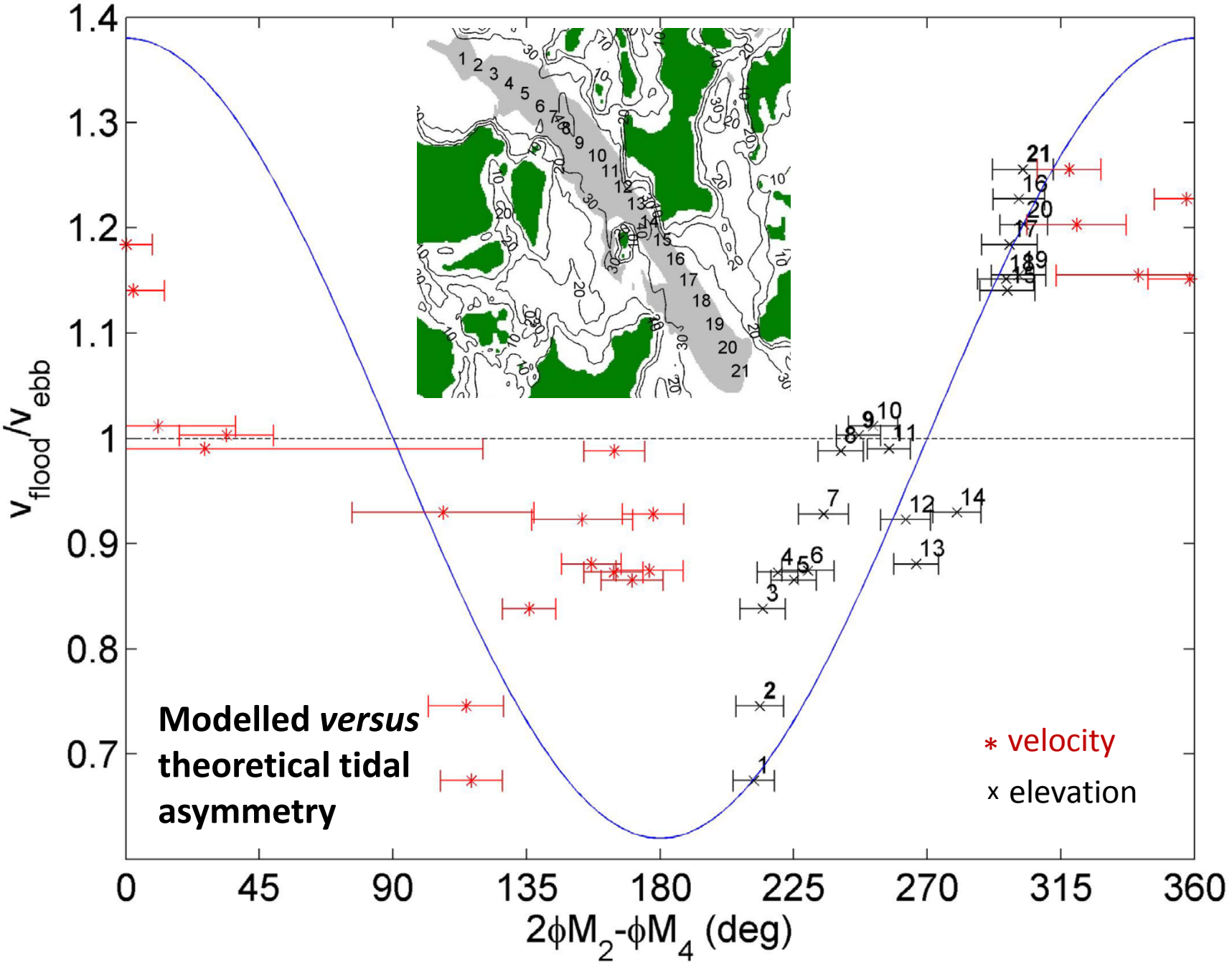
Pentland Firth

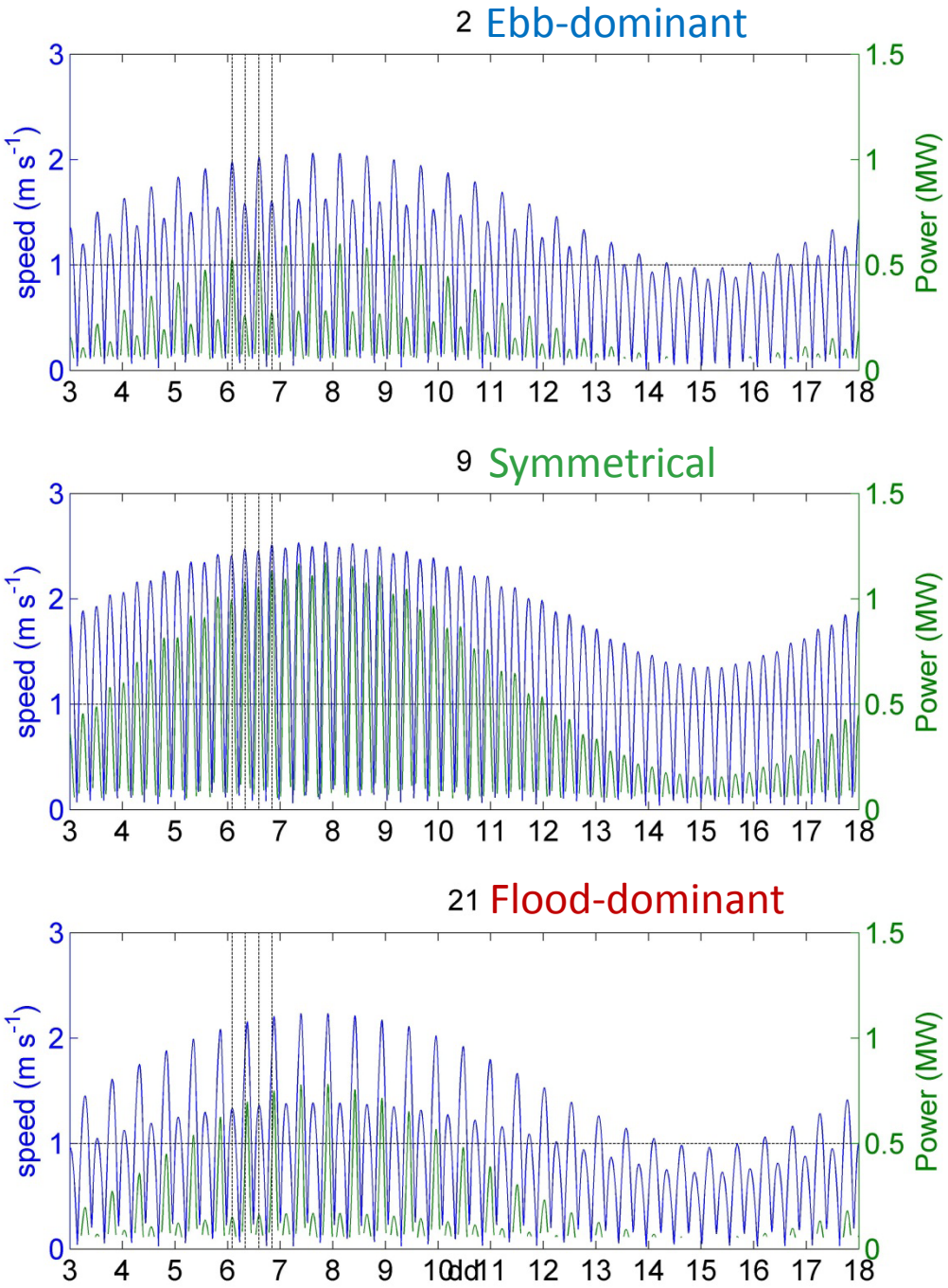
Time series of current speed at 3 contrasting sites



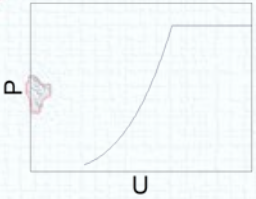


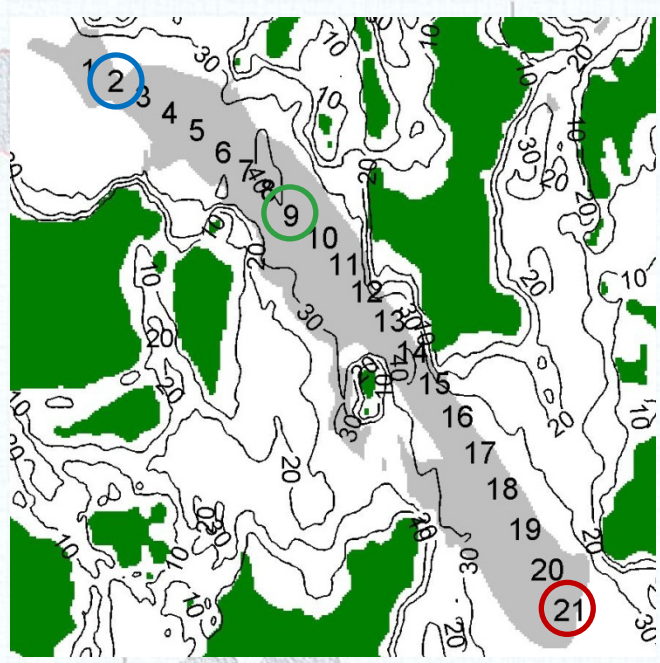

1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
v_{flood}/v_{ebb}
0
45
90
135
180
225
270
315
360
$2\phi M_2-\phi M_4$ (deg)
Modelled *versus* theoretical tidal asymmetry
velocity


1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
v_{flood}/v_{ebb}
0
45
90
135
180
225
270
315
360
$2\phi M_2-\phi M_4$ (deg)
Modelled *versus* theoretical tidal asymmetry
velocity
elevation

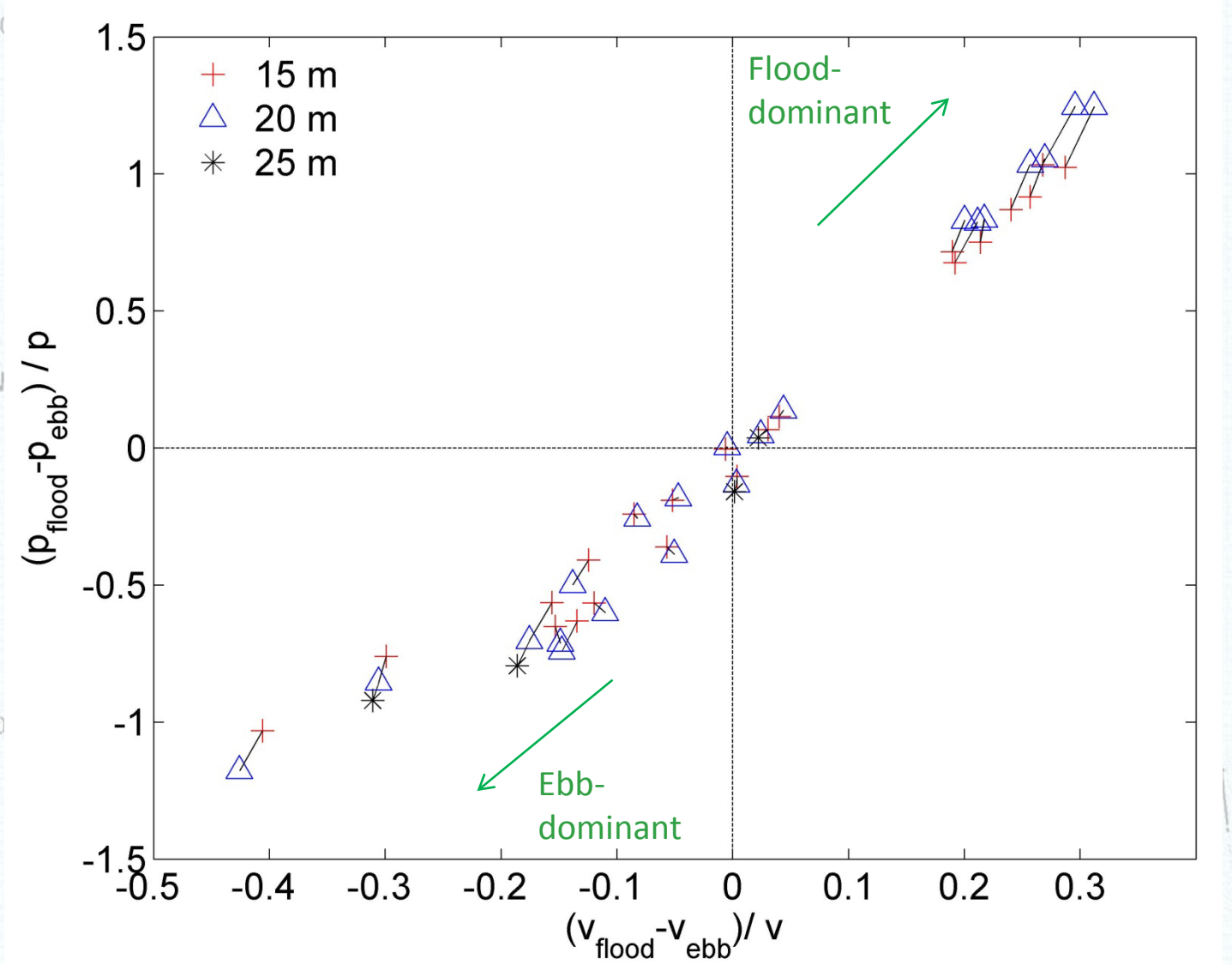


Power generated by a hypothetical SeaGen S 1.2 MW device





Velocity and power asymmetry at different hub heights



Conclusions

DrSPNeill

- 30% velocity asymmetry translates into 100% power asymmetry
- Our 3D model of an energetic tidal channel fits tidal asymmetry theory
- There is stronger asymmetry higher in the water column – implications for technology selection
- Aggregating regions of flood- *versus* ebb-dominant asymmetry provides balanced power output between flood and ebb phases of the tidal cycle
- Other 3D variables output – e.g. turbulent kinetic energy
- Impact of wind-driven currents on power asymmetry ~14% at the surface during a SE gale coinciding with neaps
- Wave/current interaction
- Sediment dynamics
- Lagrangian transport

Stuff in the paper
Stuff we're working on

Neill, S.P., Hashemi, M.R. & Lewis, M.J. (2014) The role of tidal asymmetry in characterizing the tidal energy resource of Orkney. *Renewable Energy* 68, 337-350