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

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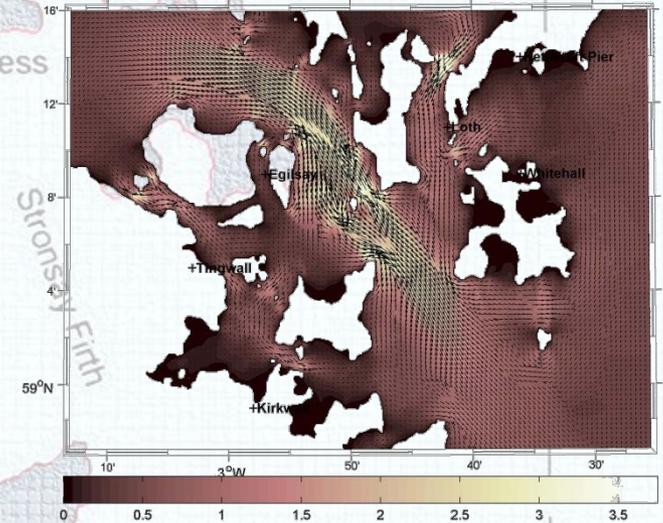


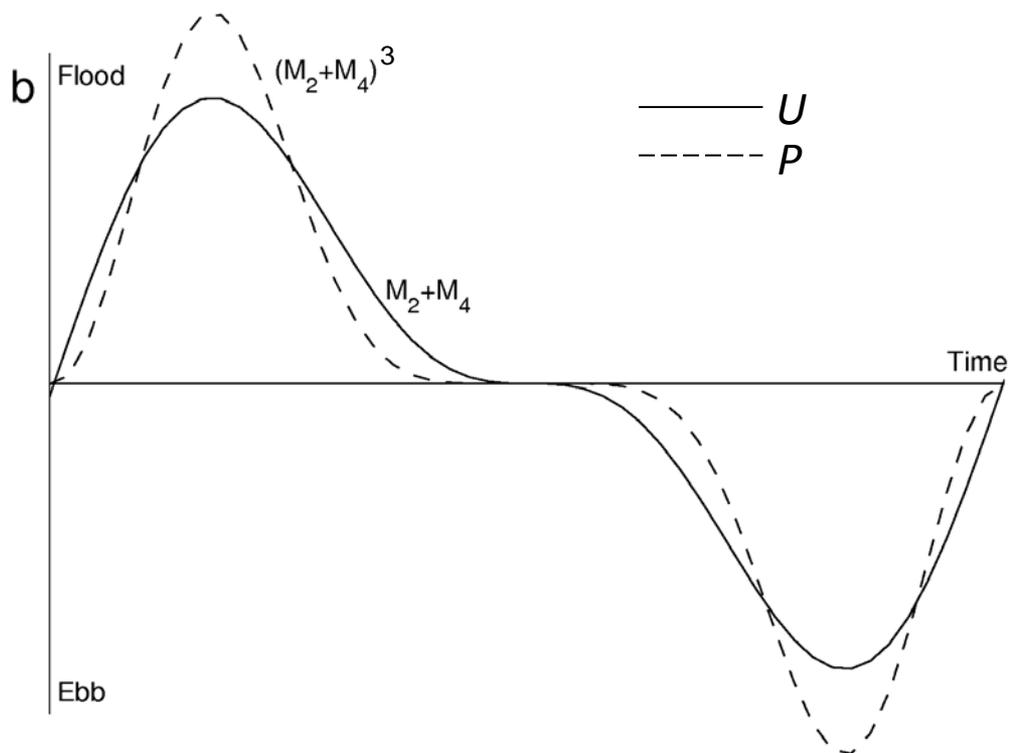
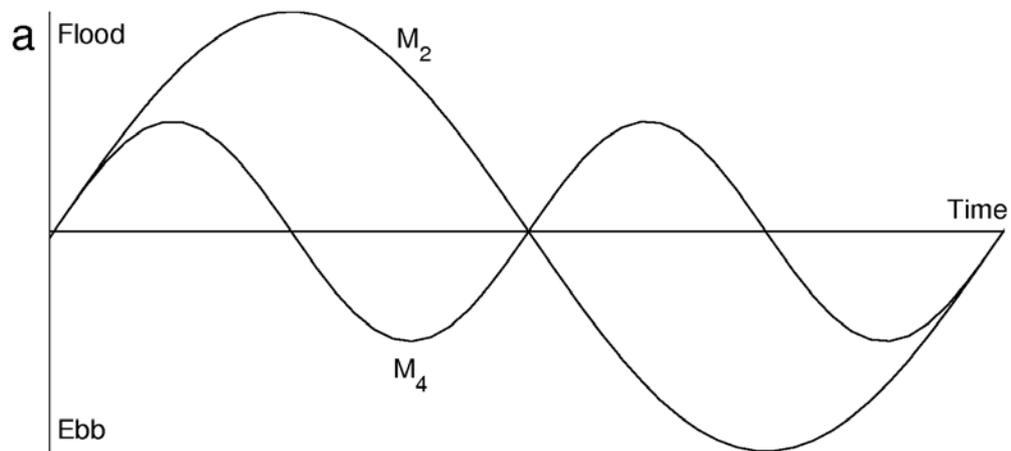
EPSRC

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).

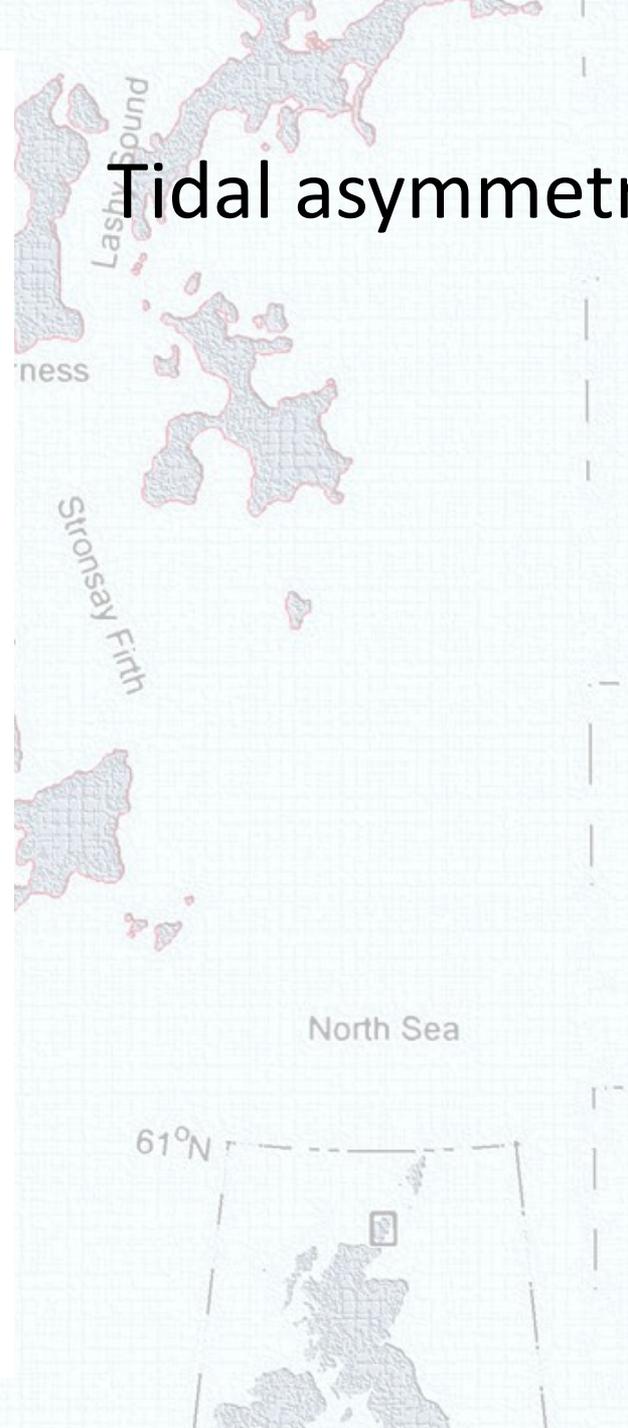
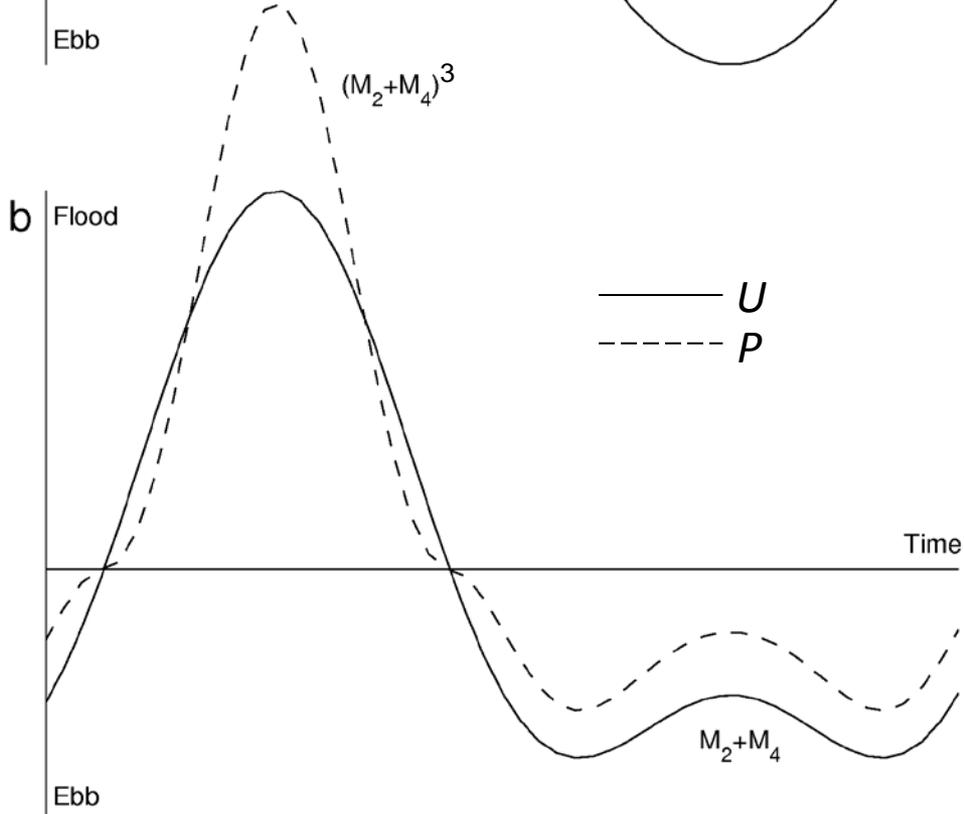
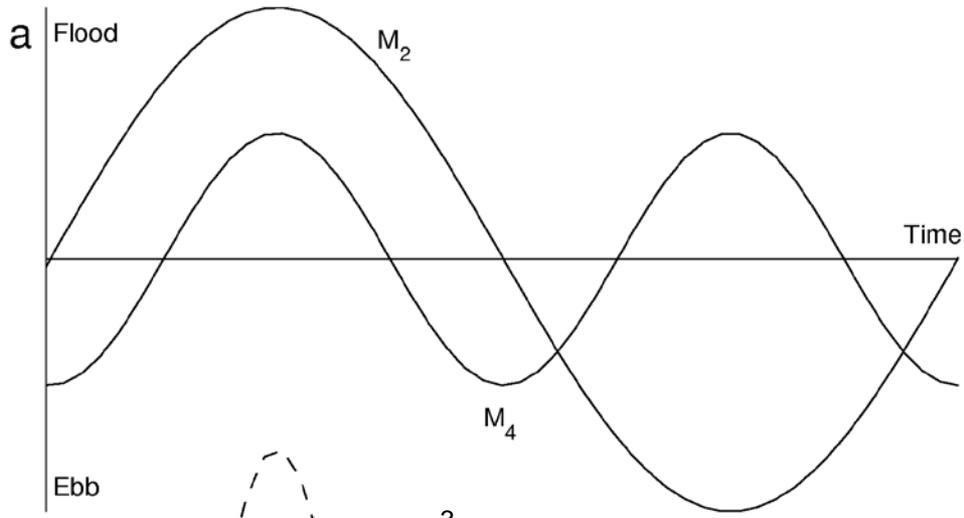
$T=12.42$ h

M_4 = shallow water overtide.

$T=6.21$ h

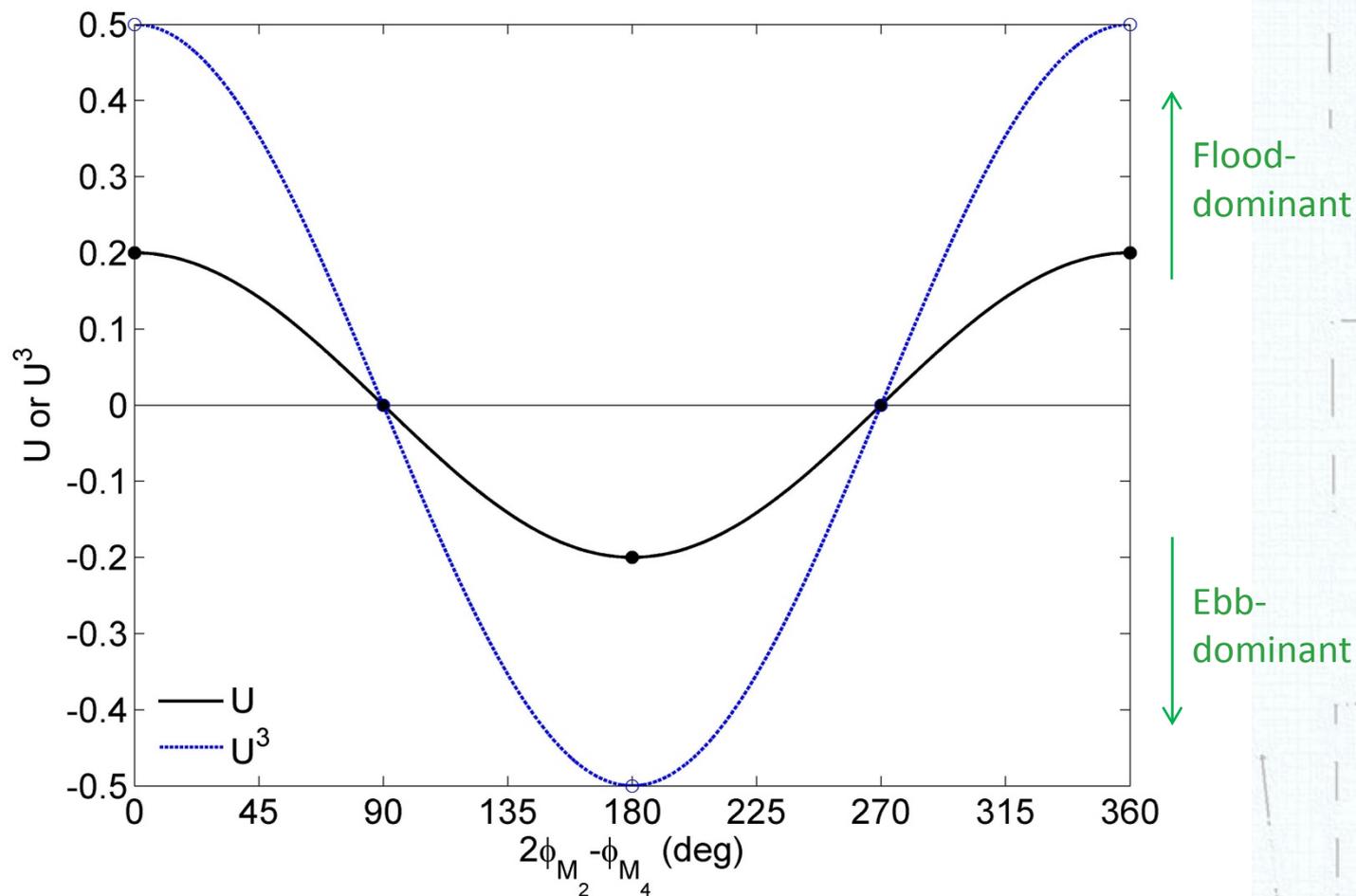
$$P = \frac{1}{2}\rho U^3$$

Tidal asymmetry



Pentland Firth

Phase relationship between M_2 and M_4



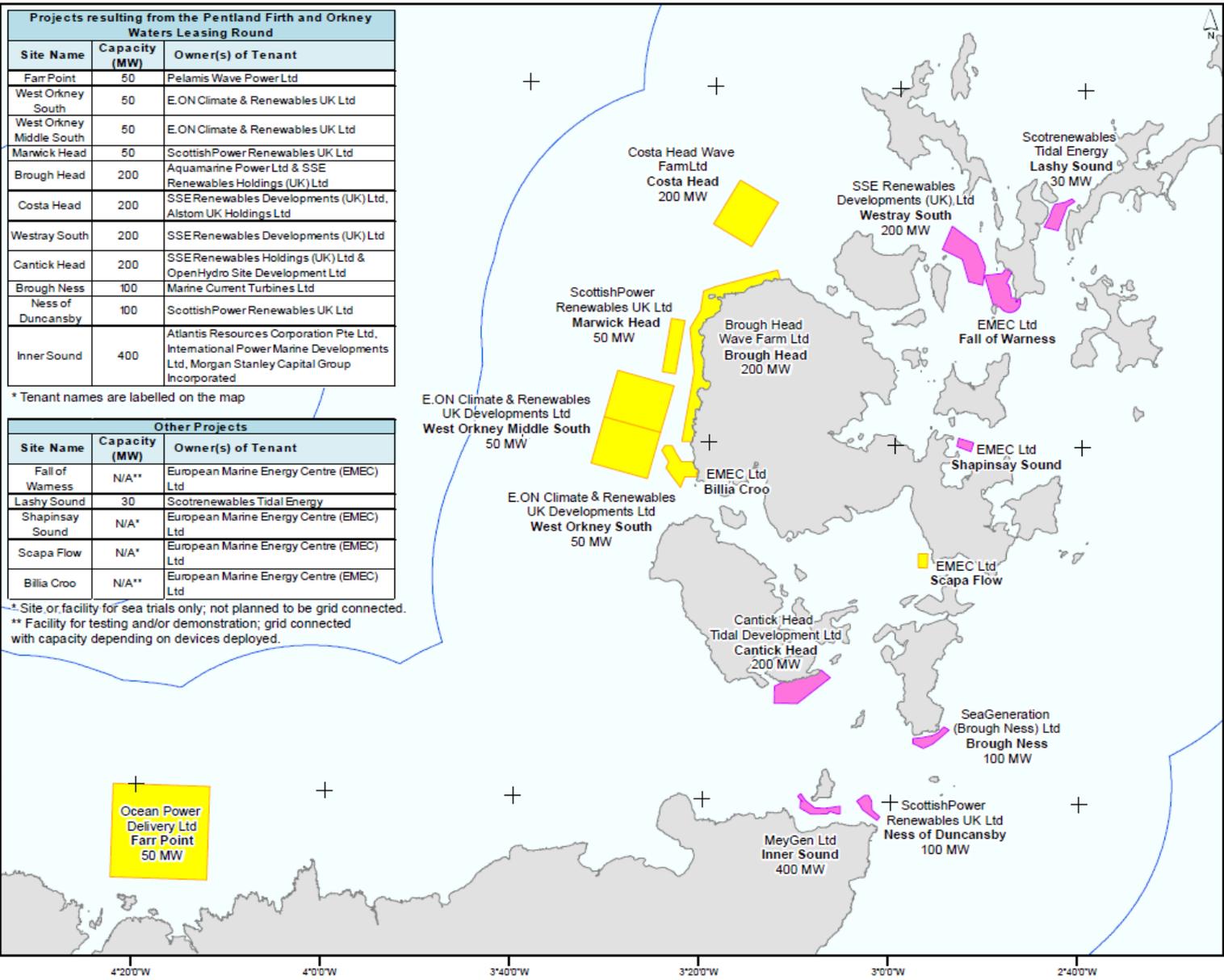
Wave and Tidal (Pentland Firth and Orkney Waters)

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

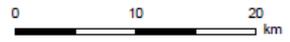
* Tenant names are labelled on the map

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



MaRS
 Marine Resource System

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



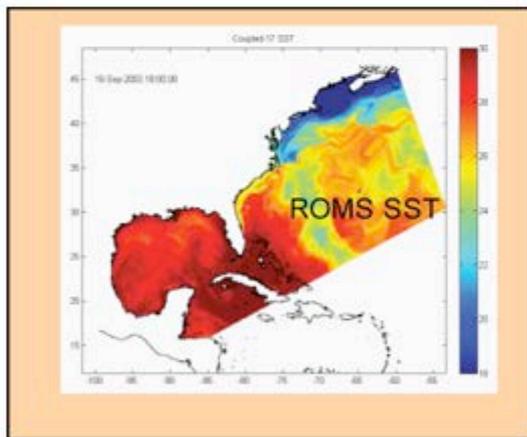
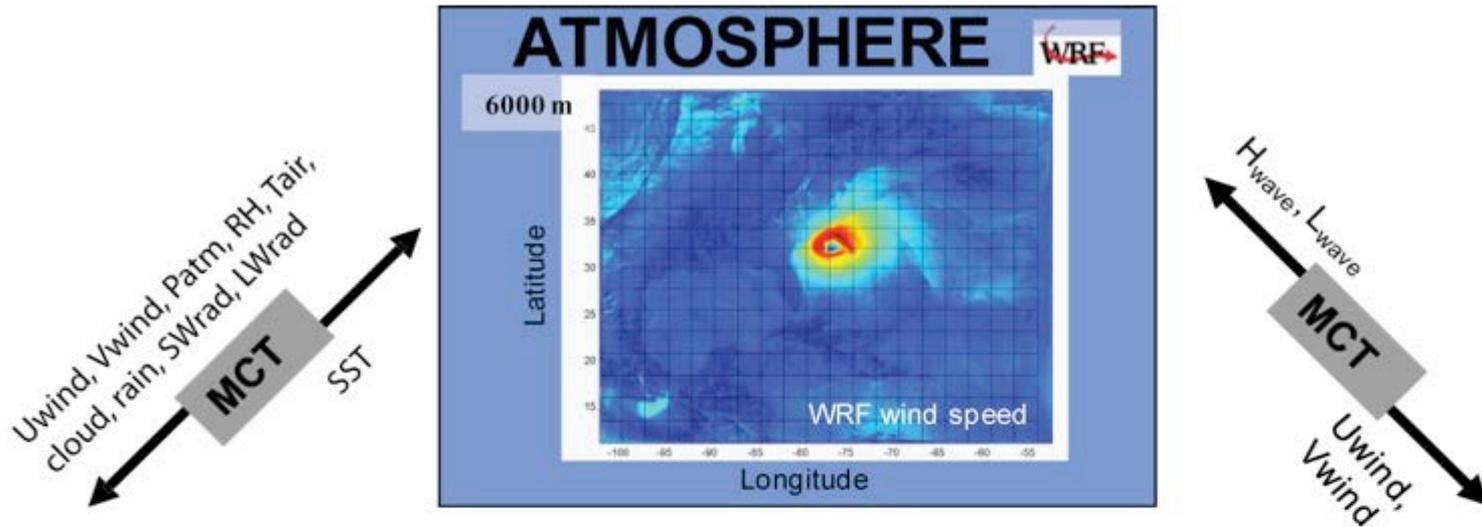
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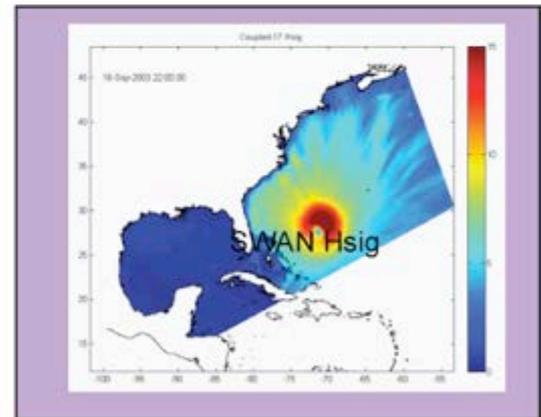
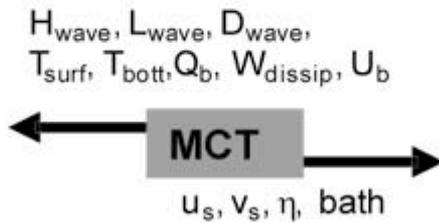




OCEAN



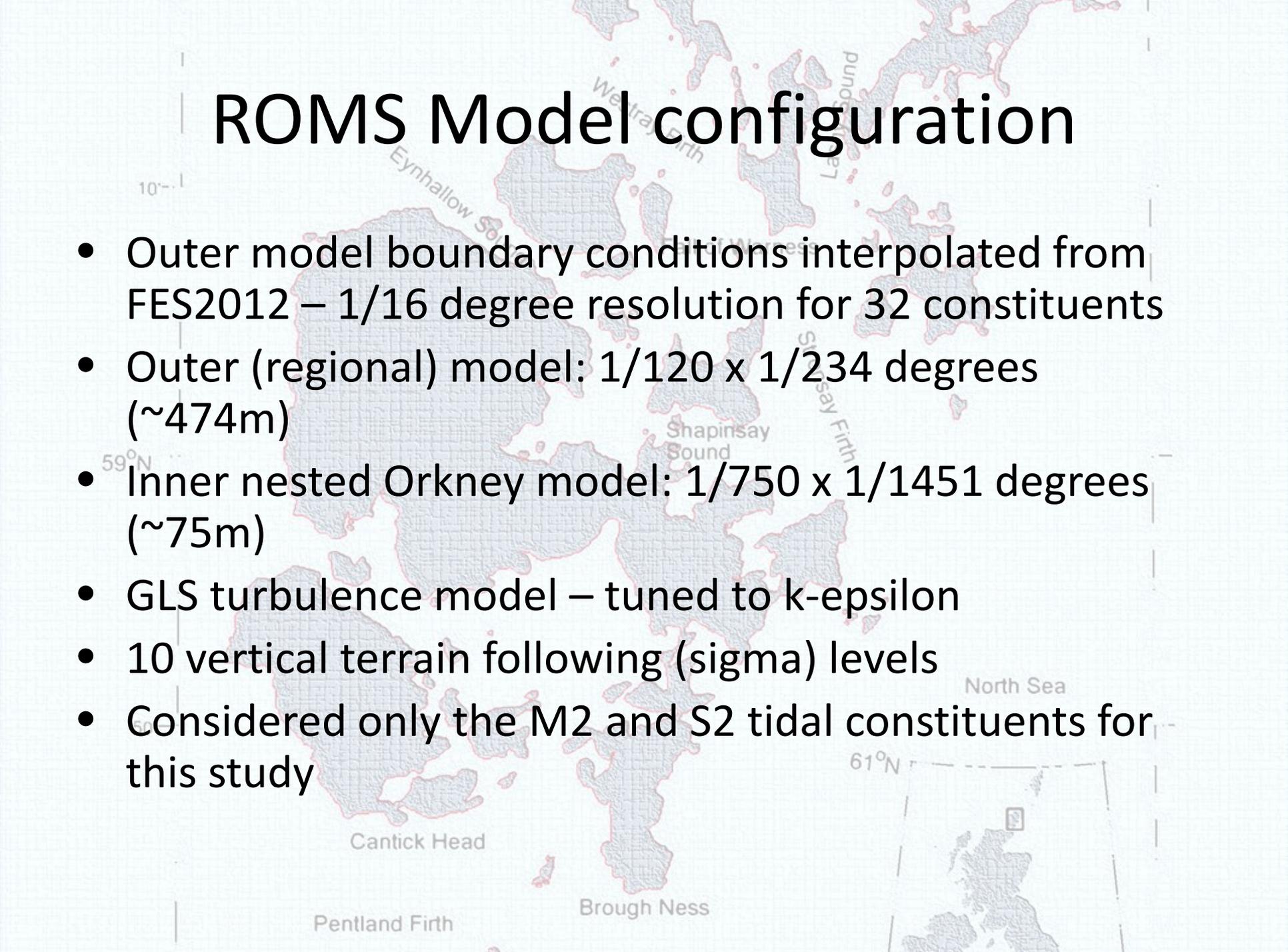
SEDIMENT



WAVE

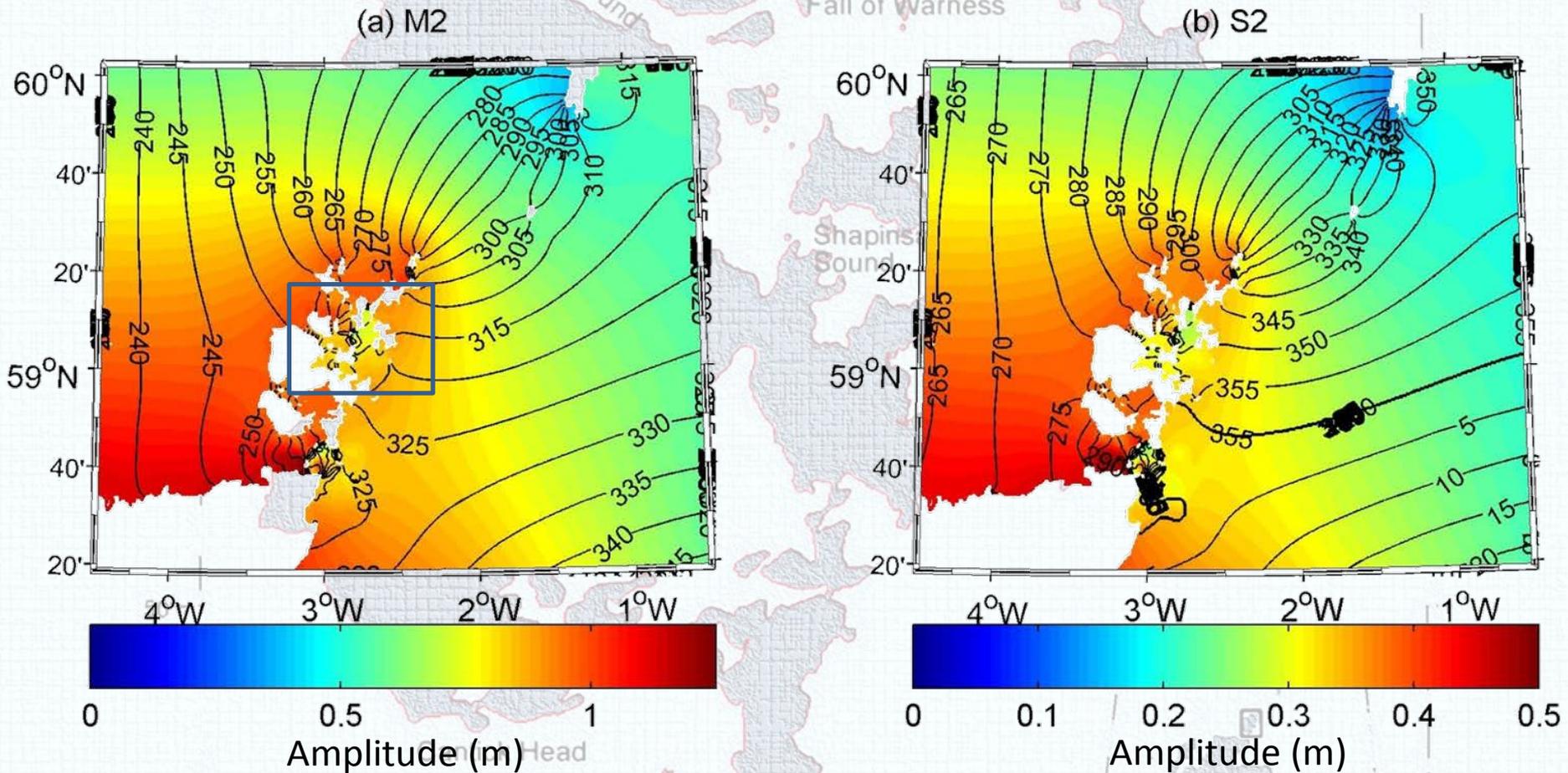


ROMS Model configuration

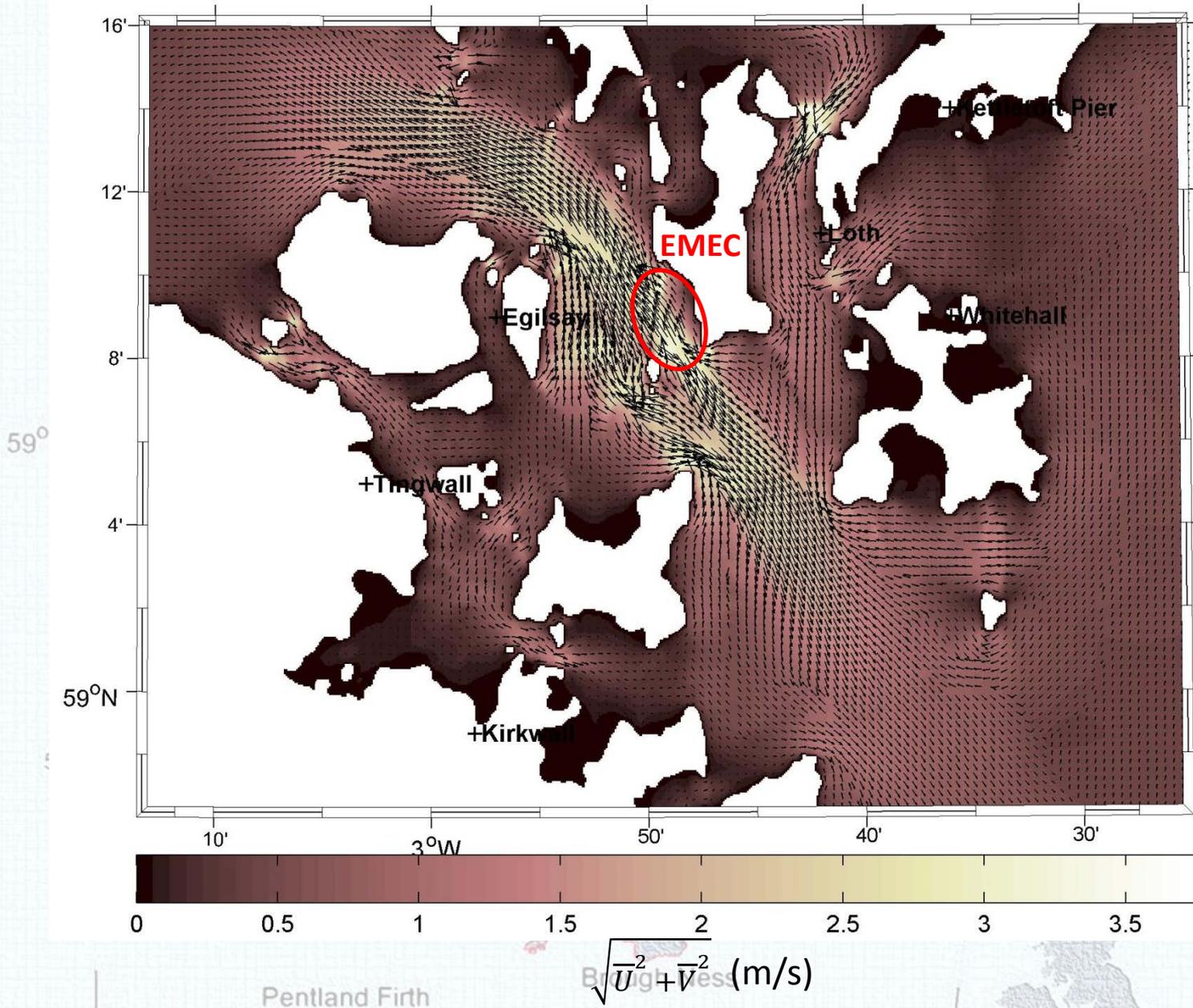


- Outer model boundary conditions interpolated from FES2012 – 1/16 degree resolution for 32 constituents
- Outer (regional) model: 1/120 x 1/234 degrees (~474m)
- Inner nested Orkney model: 1/750 x 1/1451 degrees (~75m)
- GLS turbulence model – tuned to k-epsilon
- 10 vertical terrain following (sigma)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

M2 and S2 co-tidal charts from regional model



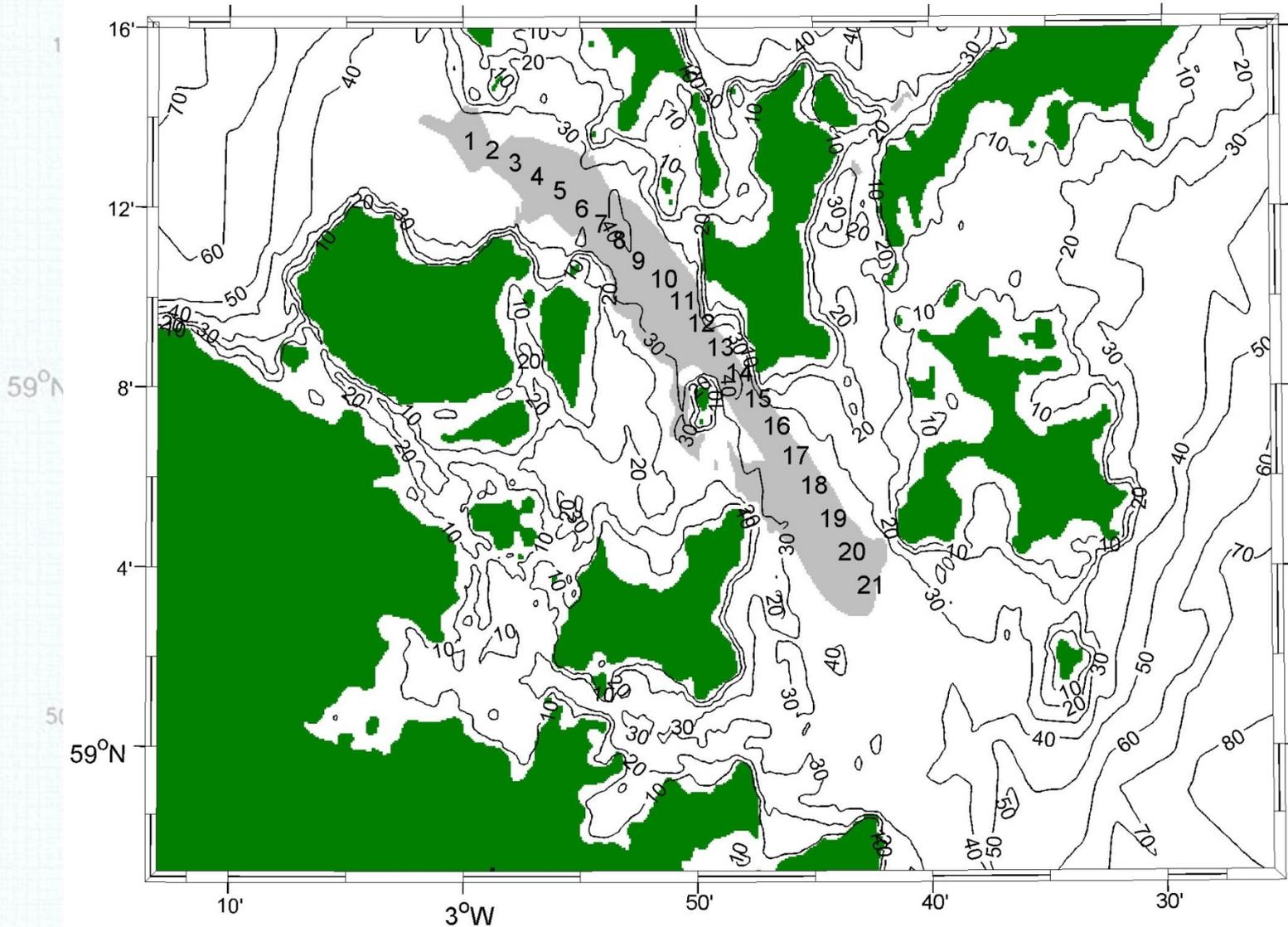
Peak (spring) tidal currents



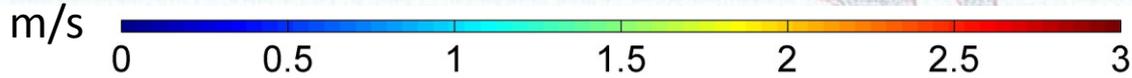
Masked region

$$V_{spring} > 2 \text{ m/s}$$

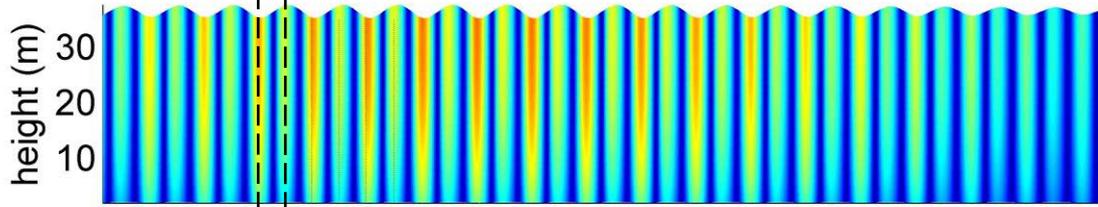
$$25 < h < 50 \text{ m}$$



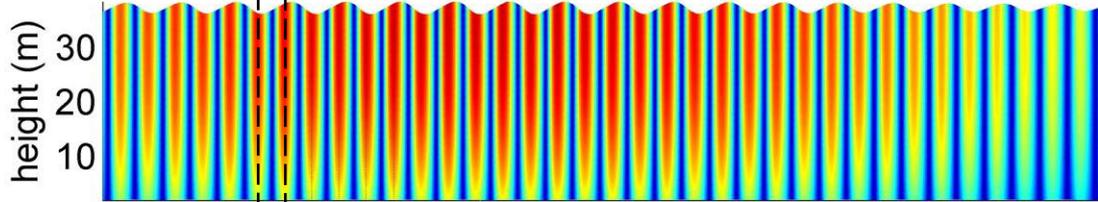
Pentland Firth



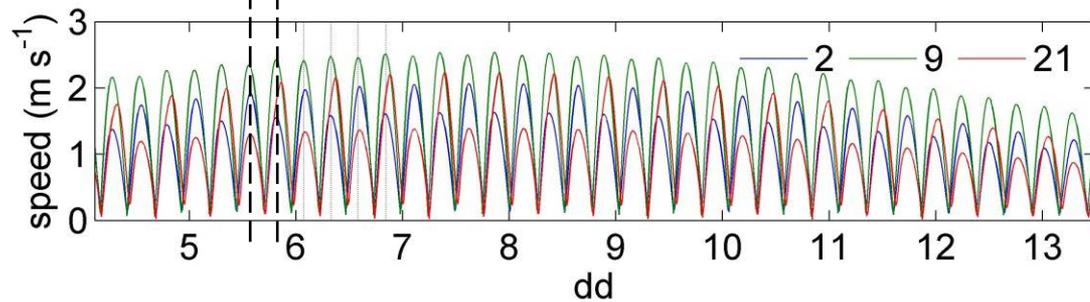
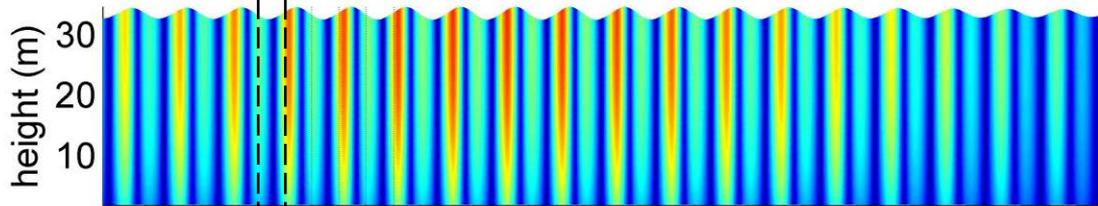
2 Ebb-dominant



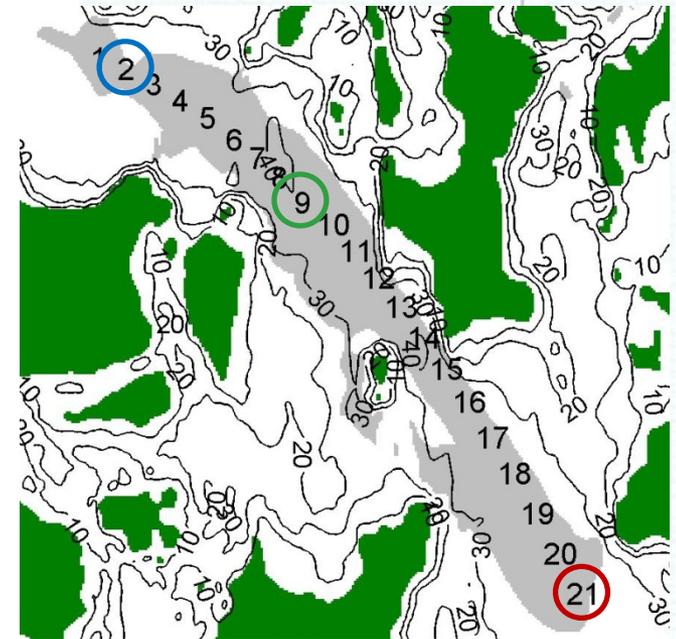
9 Symmetrical

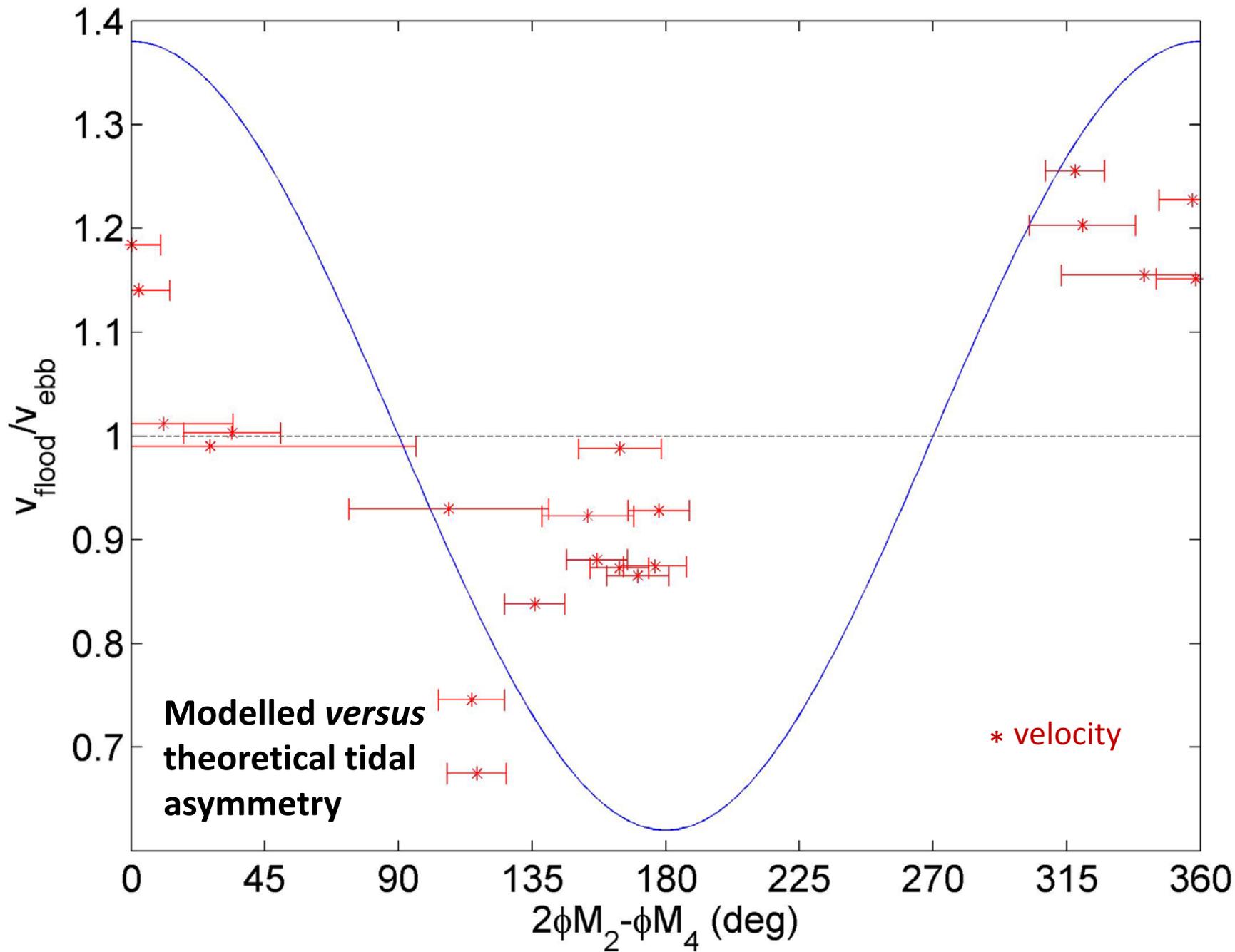


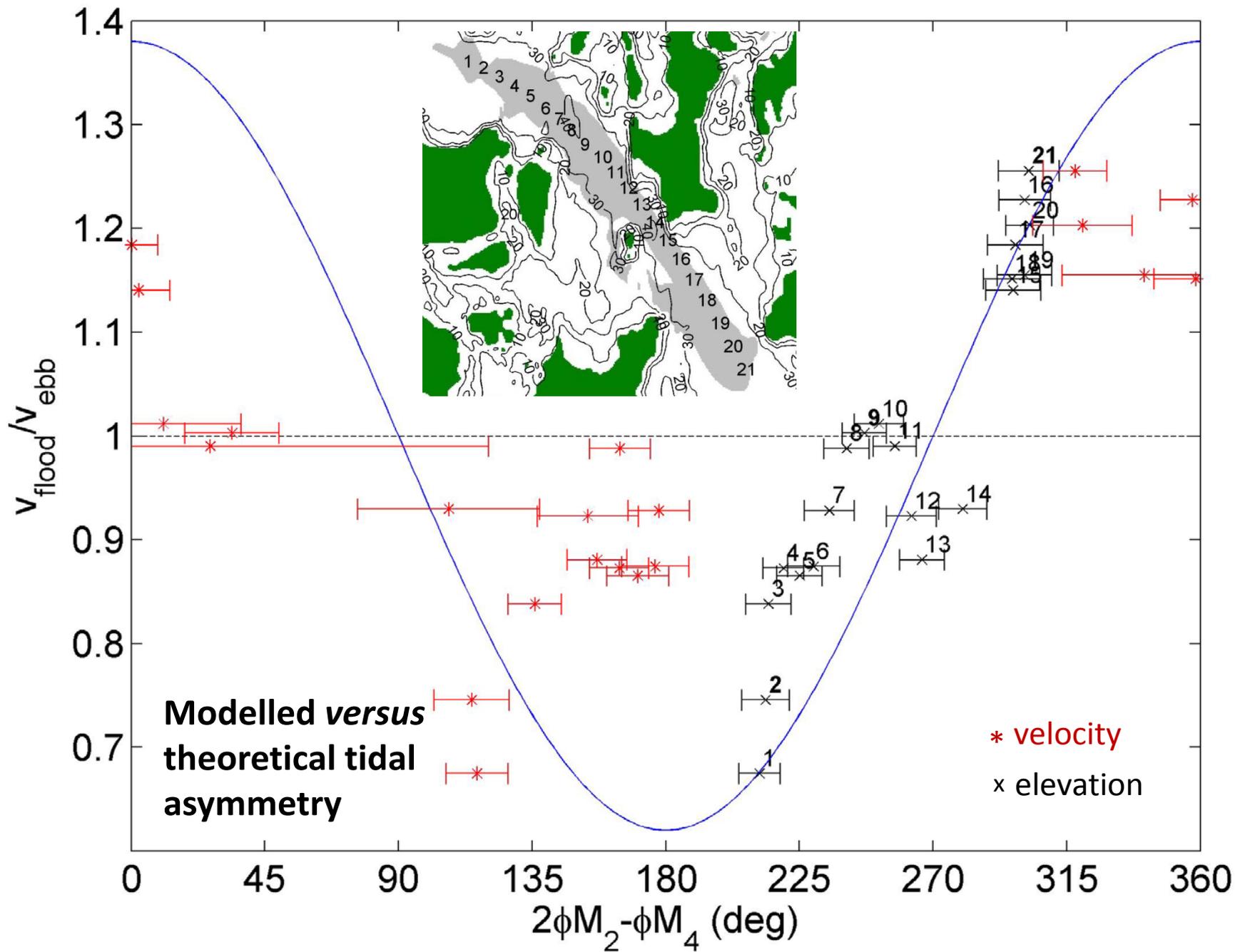
21 Flood-dominant



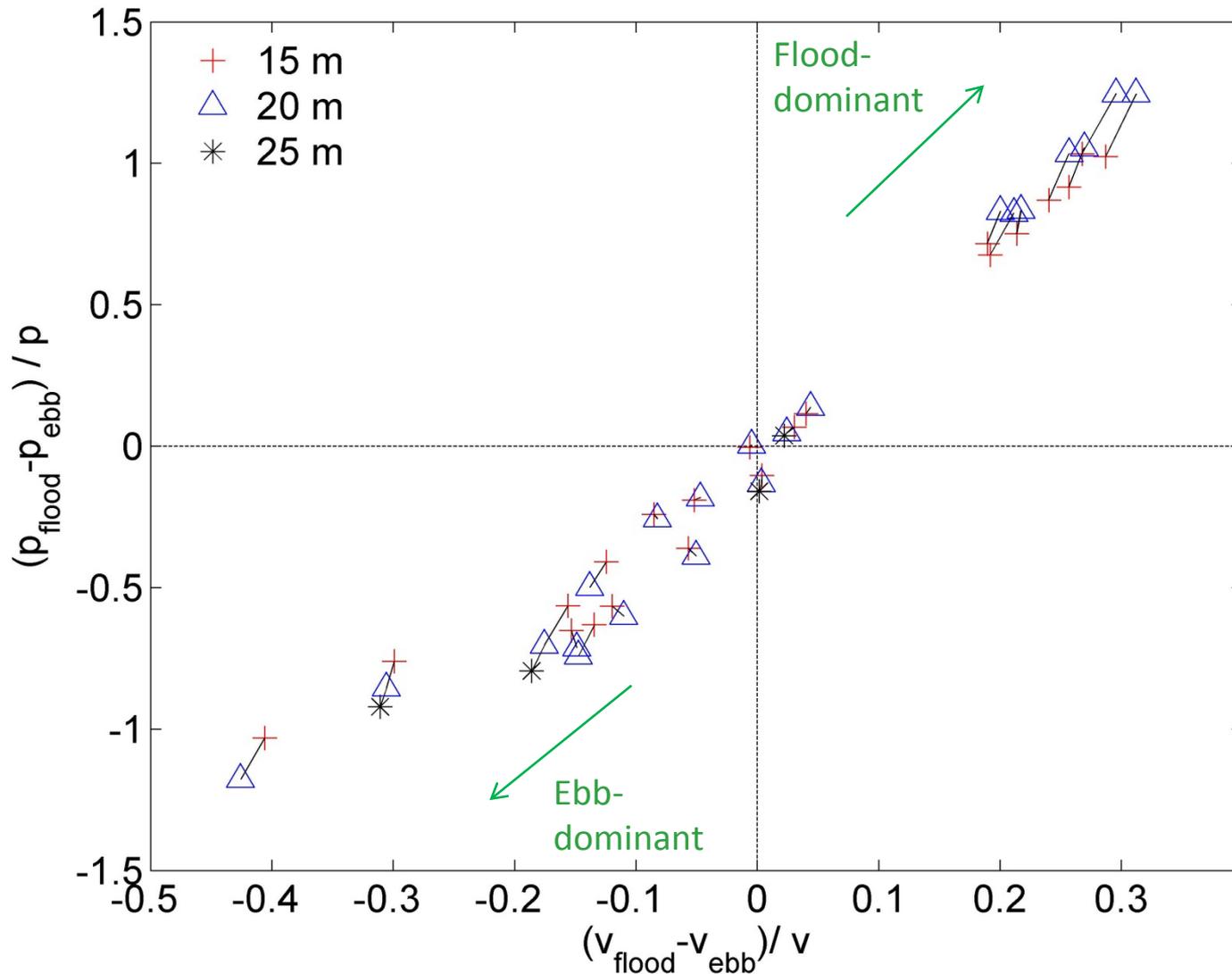
Time series of current speed at 3 contrasting sites







Velocity and power asymmetry at different hub heights



Conclusions



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- 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