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Programme Area: Marine

Project: ReDAPT

Title: 3D Modelling of Channel Flow in the Fall of Warness

Context:

One of the key developments of the marine energy industry in the UK is the demonstration of near commercial scale devices in real sea conditions and the collection of performance and environmental data to inform permitting and licensing processes. The ETI's ReDAPT (Reliable Data Acquisition Platform for Tidal) project saw an innovative 1MW buoyant tidal generator installed at the European Marine Energy Centre (EMEC) in Orkney in January 2013. With an ETI investment of £12.6m, the project involved Alstom, E.ON, EDF, DNV GL, Plymouth Marine Laboratory (PML), EMEC and the University of Edinburgh. The project demonstrated the performance of the tidal generator in different operational conditions, aiming to increase public and industry confidence in tidal turbine technologies by providing a wide range of environmental impact and performance information, as well as demonstrating a new, reliable turbine design.

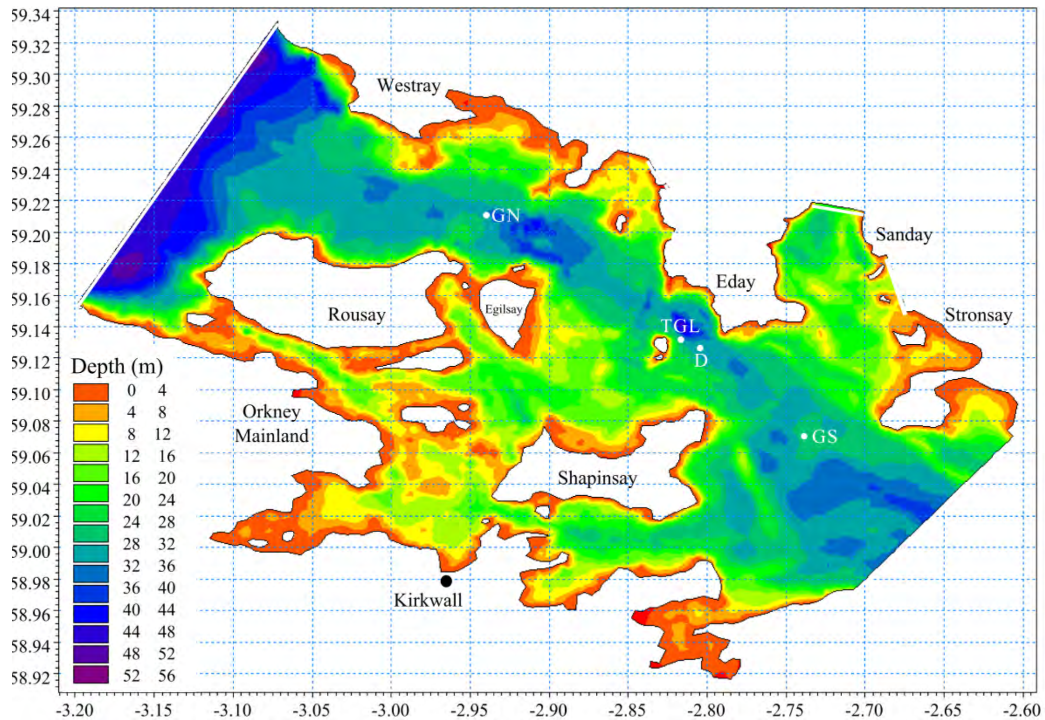
MD5.2 – 3D Modelling of Channel Flow in the Fall of Warness

Kester Gunn, OEE 2015

The Aim of MD 5.2

- Generate boundary conditions for CFD of the ReDAPT Turbine
- Using a MIKE3 model
- Forced by an existing larger scale 2D model
- Validated against ADP data
- The tasks:
  - Modelling by DHI
  - Validation by E.ON
- The conclusions:
  - The model was not able to produce representative inflow conditions for load assessment.
  - It can create a lot of other useful information and understanding

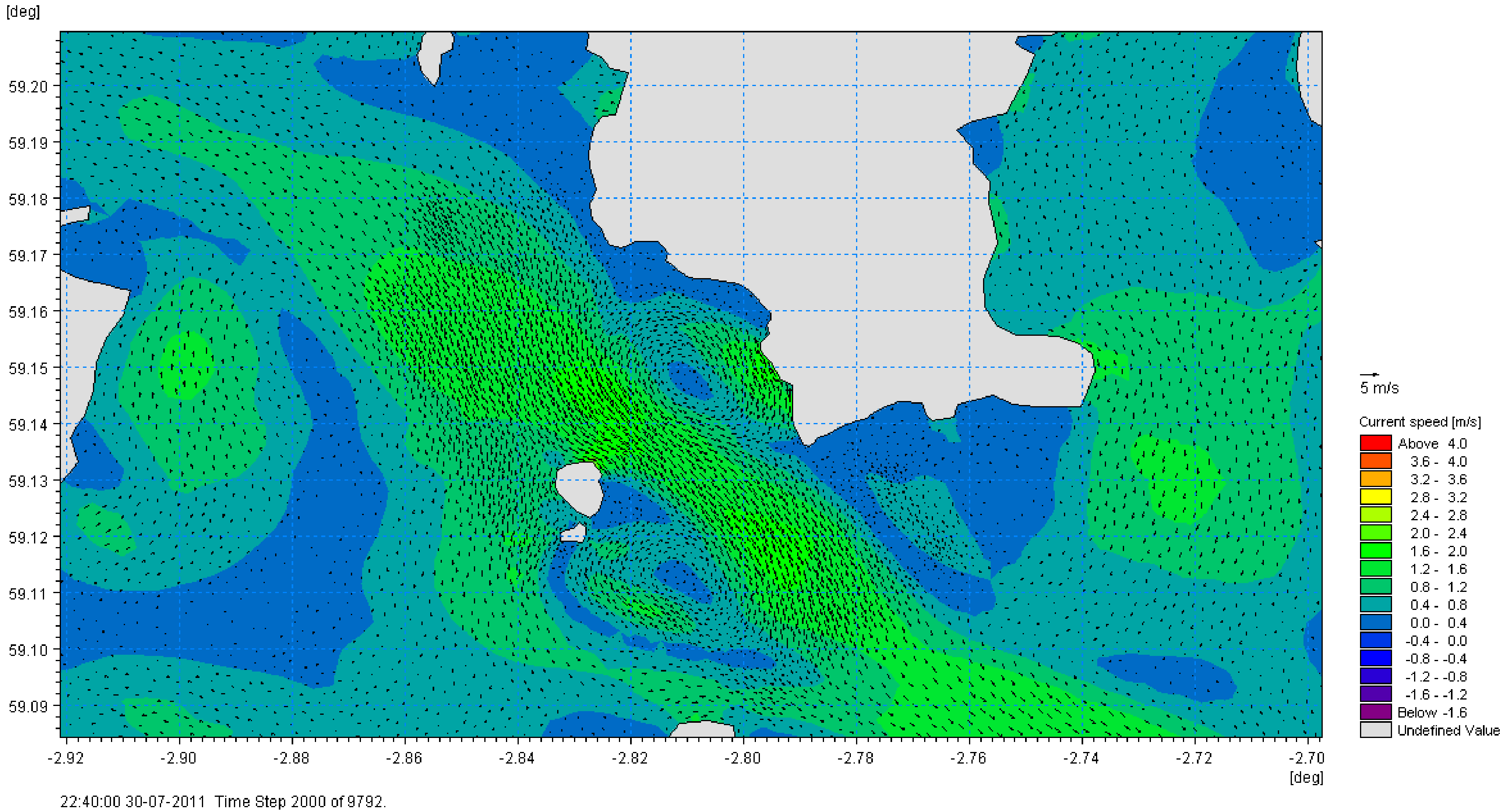
The Hydrodynamic Flow Model



- MIKE3 model
- Fall of Warness, Orkney Islands
- Built by DHI for the ETI ReDAPT project

Simulation Time	24/7/2011 00:00 to 27/8/2011 00:00
Output Timestep	30 minutes
Mesh size	11802 nodes, 22203 elements.
Vertical layers	10 equidistant sigma layers.
Boundary Conditions	Flather (velocities and heights) at all seven mesh boundaries – from larger 2D model. Constant domain roughness height (0.017m).
Initial Conditions	Soft-start (3600s sinus) on boundaries.

The Hydrodynamic Flow Model



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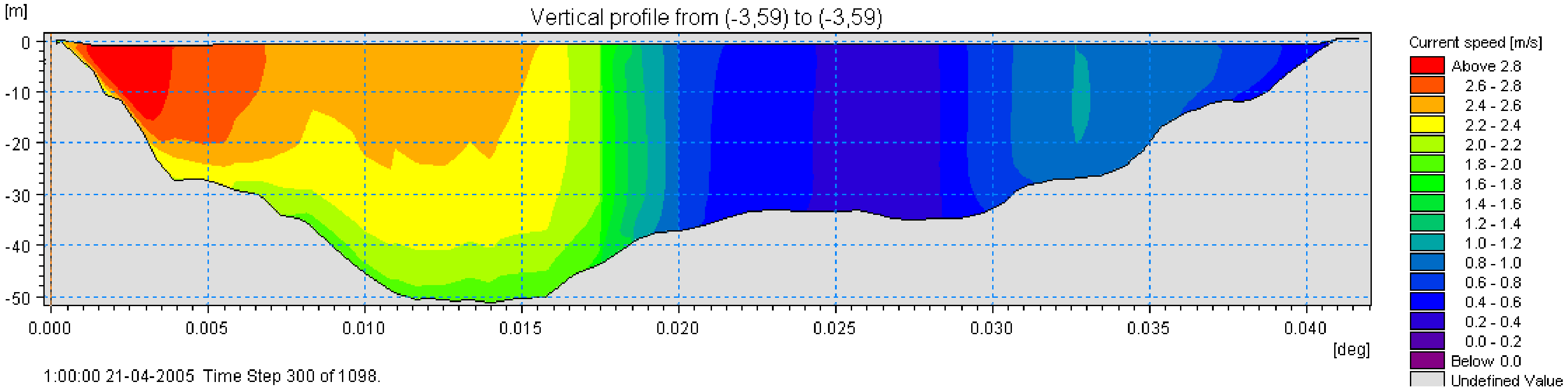


Calibration and Validation

"**Calibration** is the process of tuning a model to best fit calibration data.

It is a **comparative process**: "is this model better than that"

Statistics such as Skill Score or correlation coefficient are excellent for comparing models.

"**Validation** is the process of assessing the accuracy of a single model."

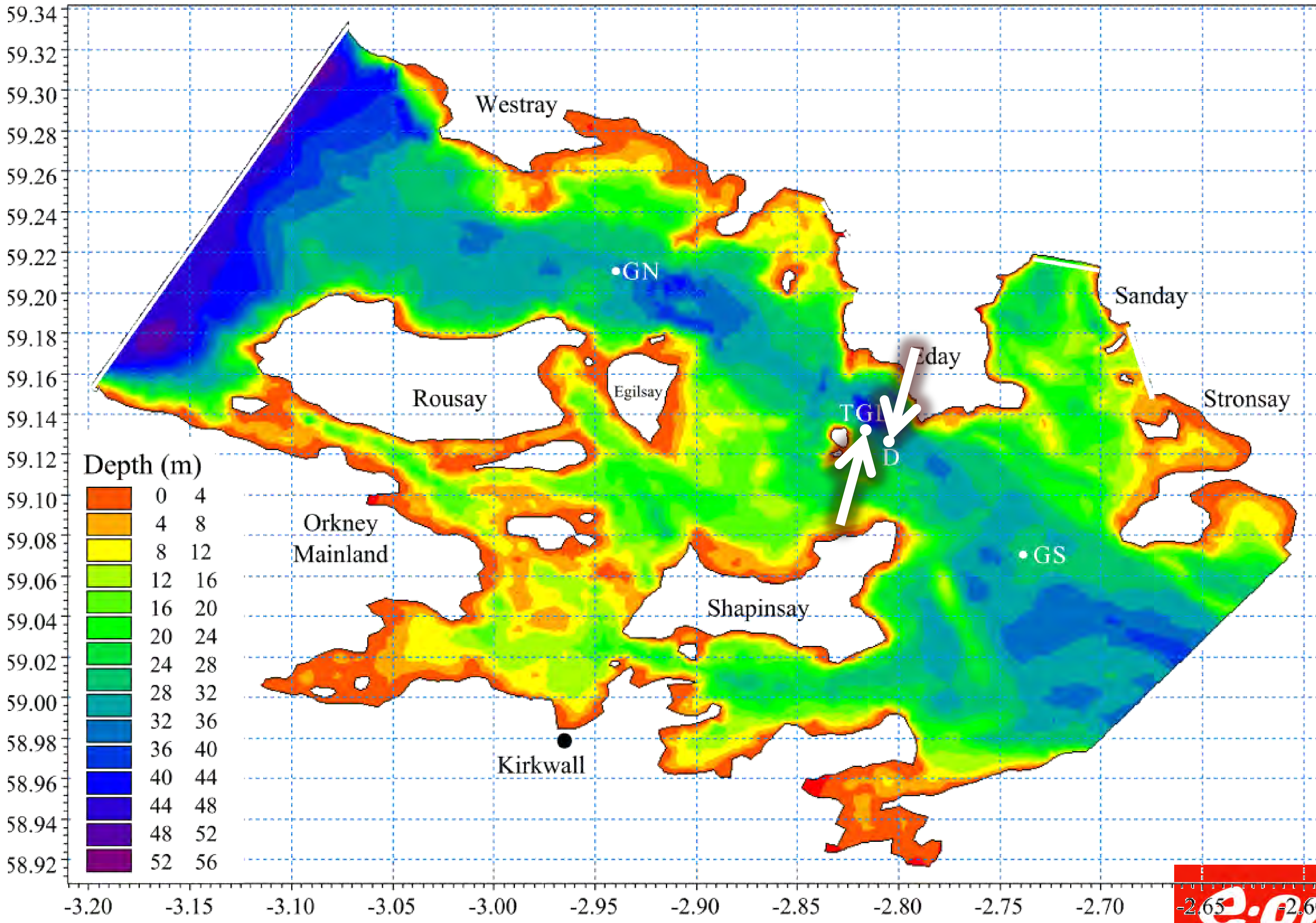
Results must be **absolute**: "is this model good enough?"

Validation requires an understanding of the physical meaning of the statistics in order to ***set criteria a priori***.

Calibration data must not be used for validation

One can say that a model is invalid.
But one can never state that a model is unconditionally "validated".

The Hydrodynamic Flow Model



Reason for validation:

To assess trends (e.g. farm layout design)	**To assess absolute results** (e.g. yield predictions, **loading calculations**)
Systematic errors are OK!	No type of errors are OK
Need to assess random errors	Assess systematic errors with, e.g. the confidence interval

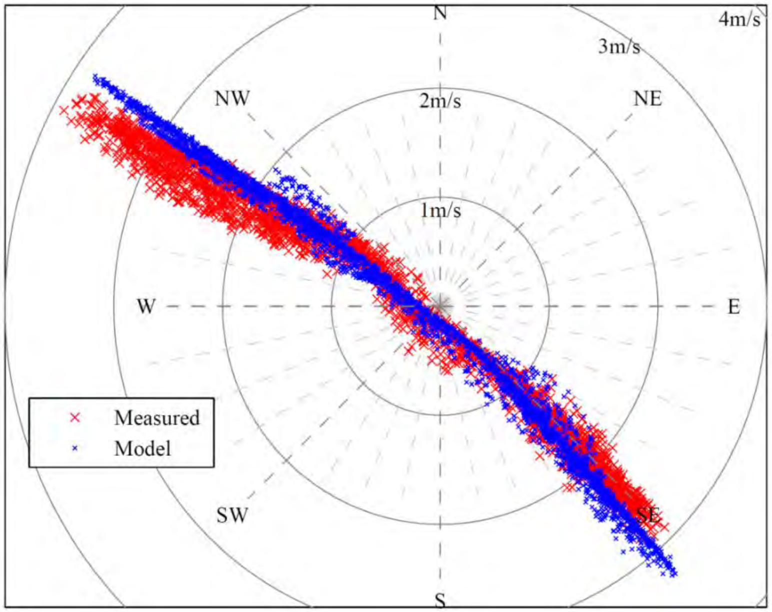
We started with validation of 2D statistics, then moved on to 3D

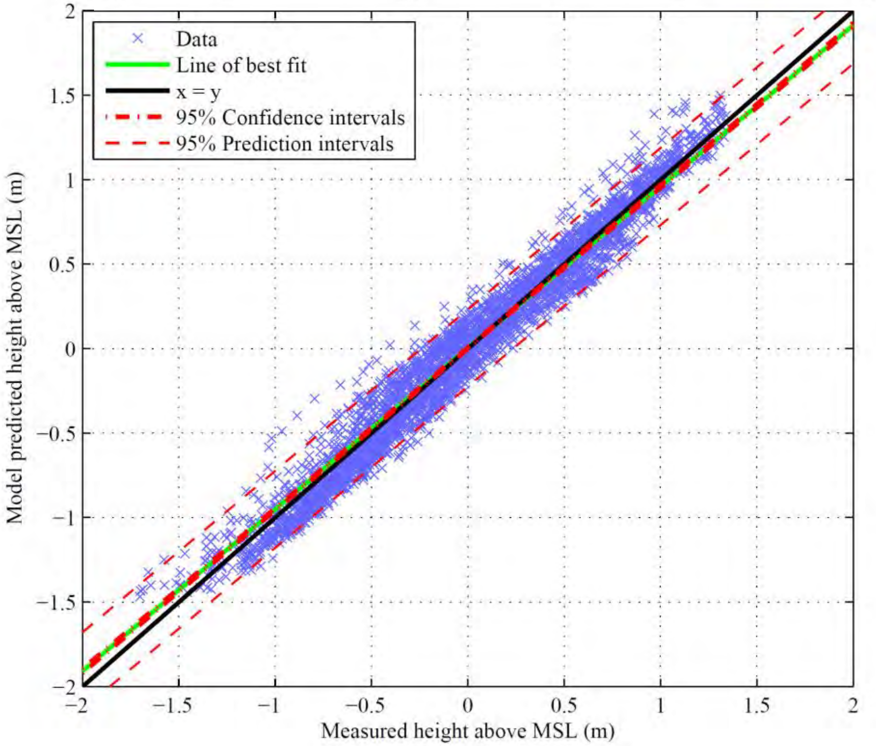
e·on

Validation 1: In the Time Domain

- Time series graphs etc. are only useful for highlighting special events or diagnosing model problems.

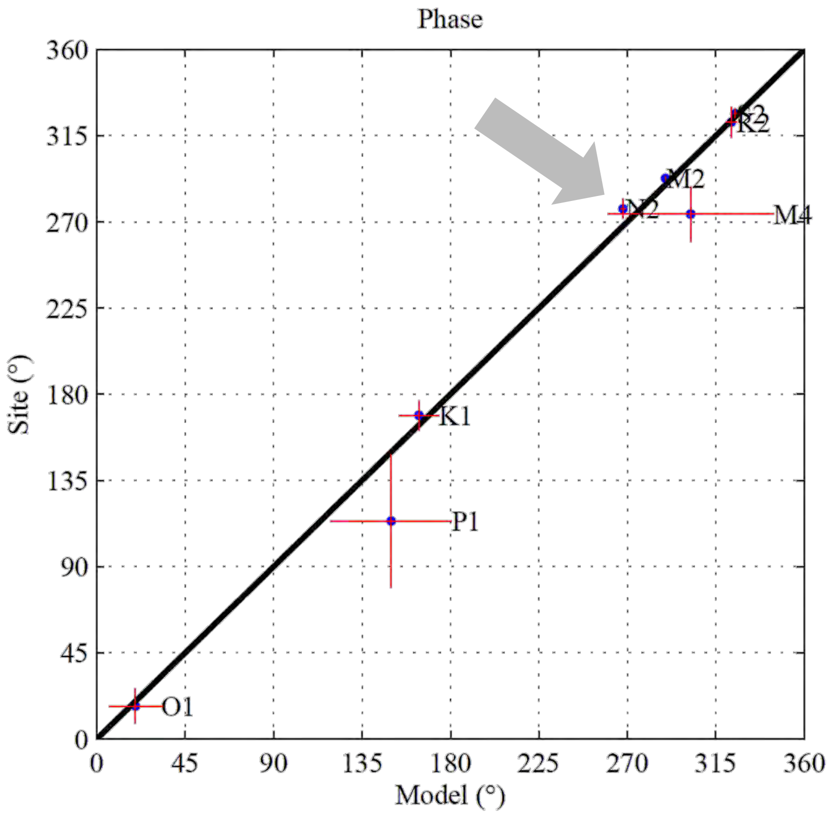
- Numerous statistics for validation of single-dimension data such as tidal height exist, e.g. NOS. Instead, ensure that:
  1. the statistics chosen have physical meaning for the parameter being validated;
  2. the statistics are the smallest set possible to uniquely examine the potential errors.

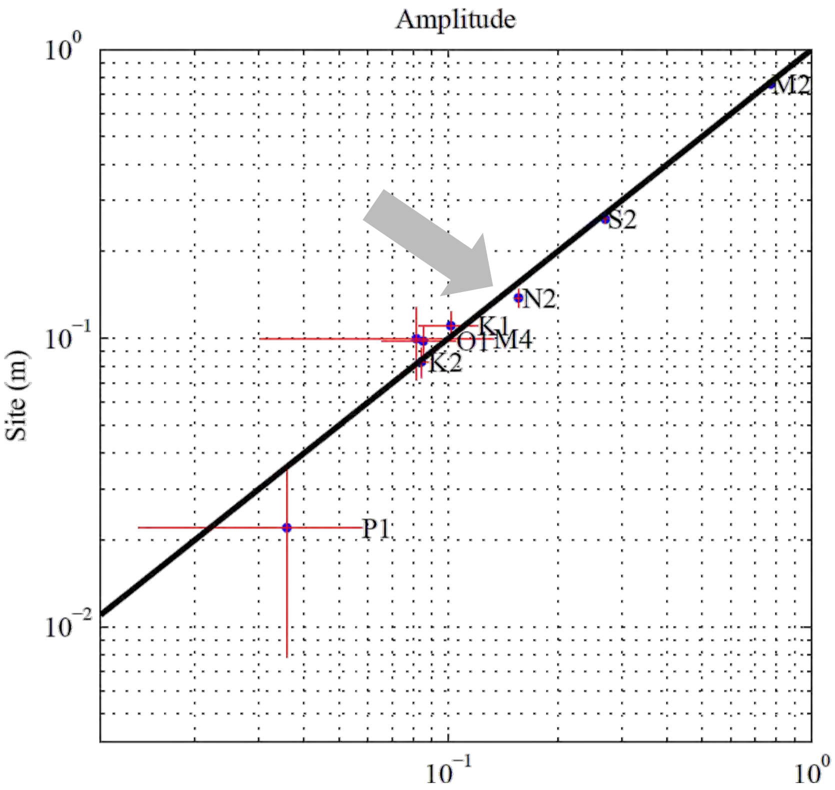




Validation 2: In the Frequency Domain

- Harmonic analysis for tidal data is a powerful tool to identify errors in models.





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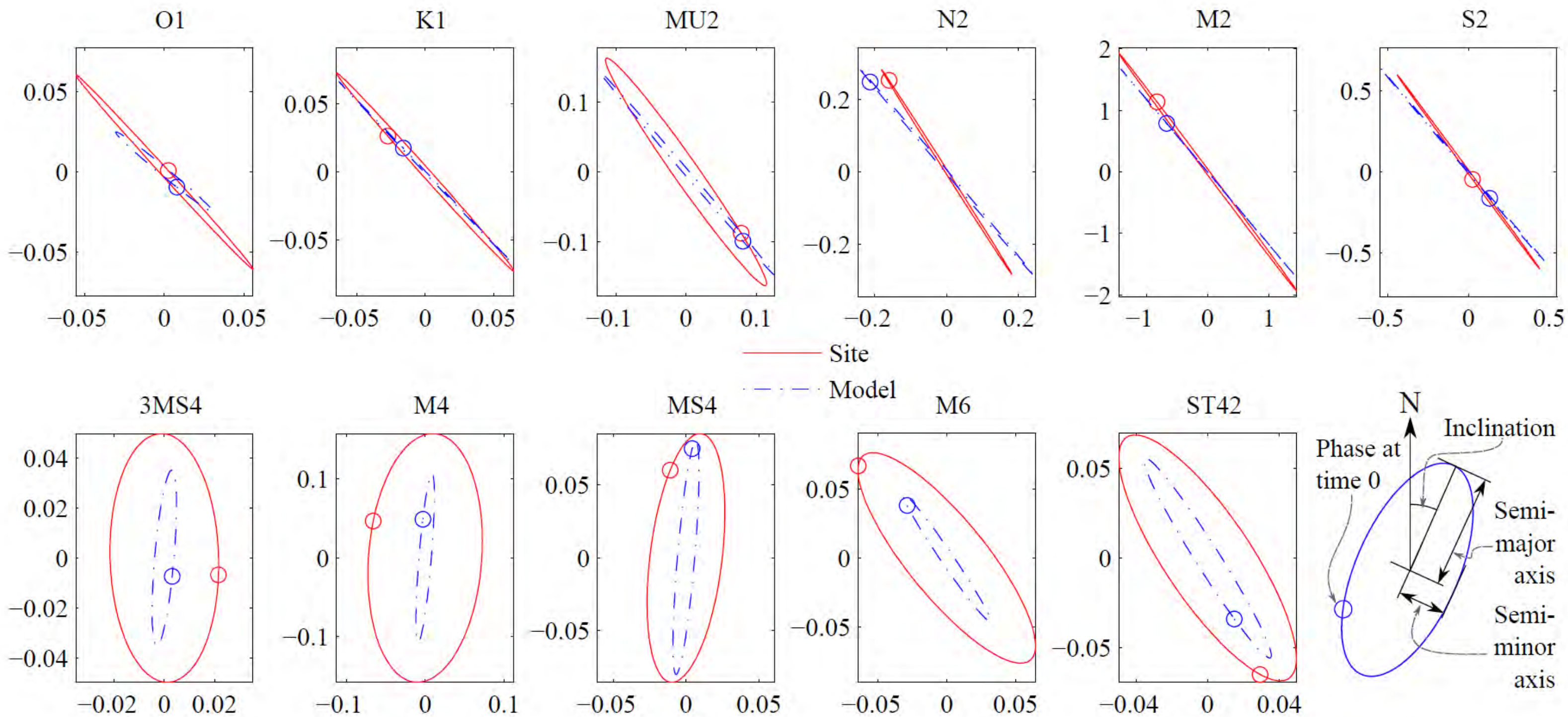
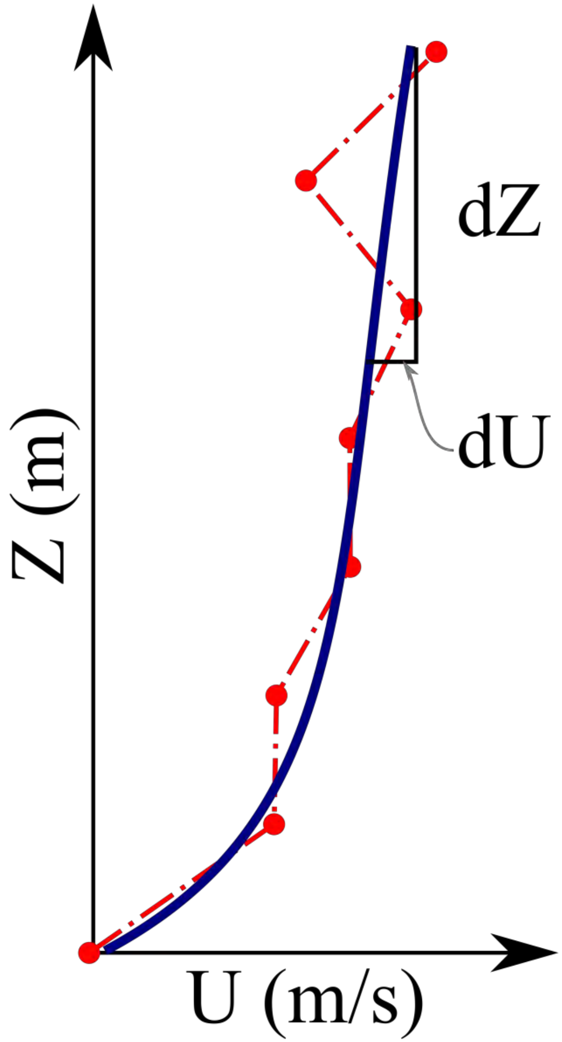


Conclusions from the 2D validation

- Systematic errors were small, but significant on some chosen statistics
- The model is representative enough to be used for layout design and early stage yield prediction

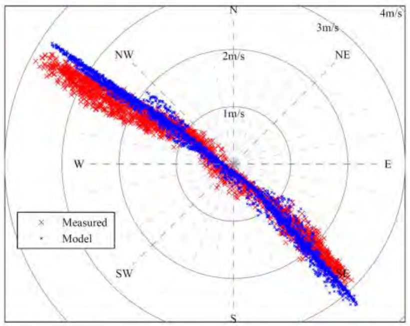
Moving on to 3D…

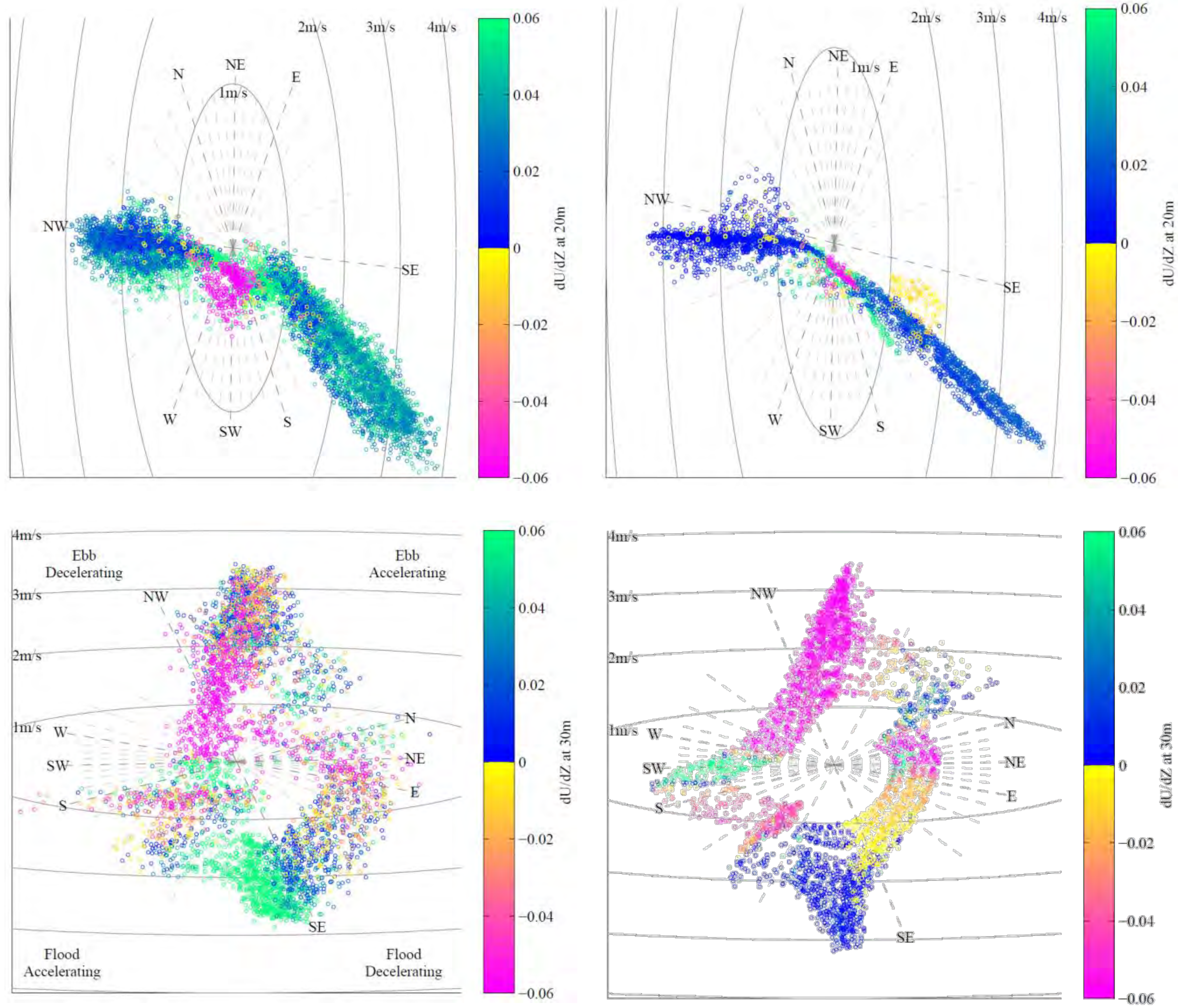
What statistic to use?



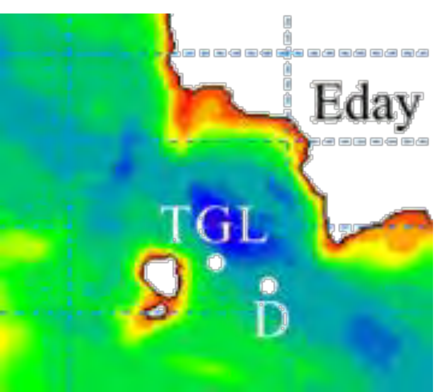
- Fit a curve to the ADCP and model shear profile
- Calculate the differential of the shear at a point of interest (we have used close to the surface)
- Validate the model's ability to reproduce this
- See Gunn and Stock-Williams 2013 for details.
- Conclusion: **It was not valid!**

Comparison in 3D

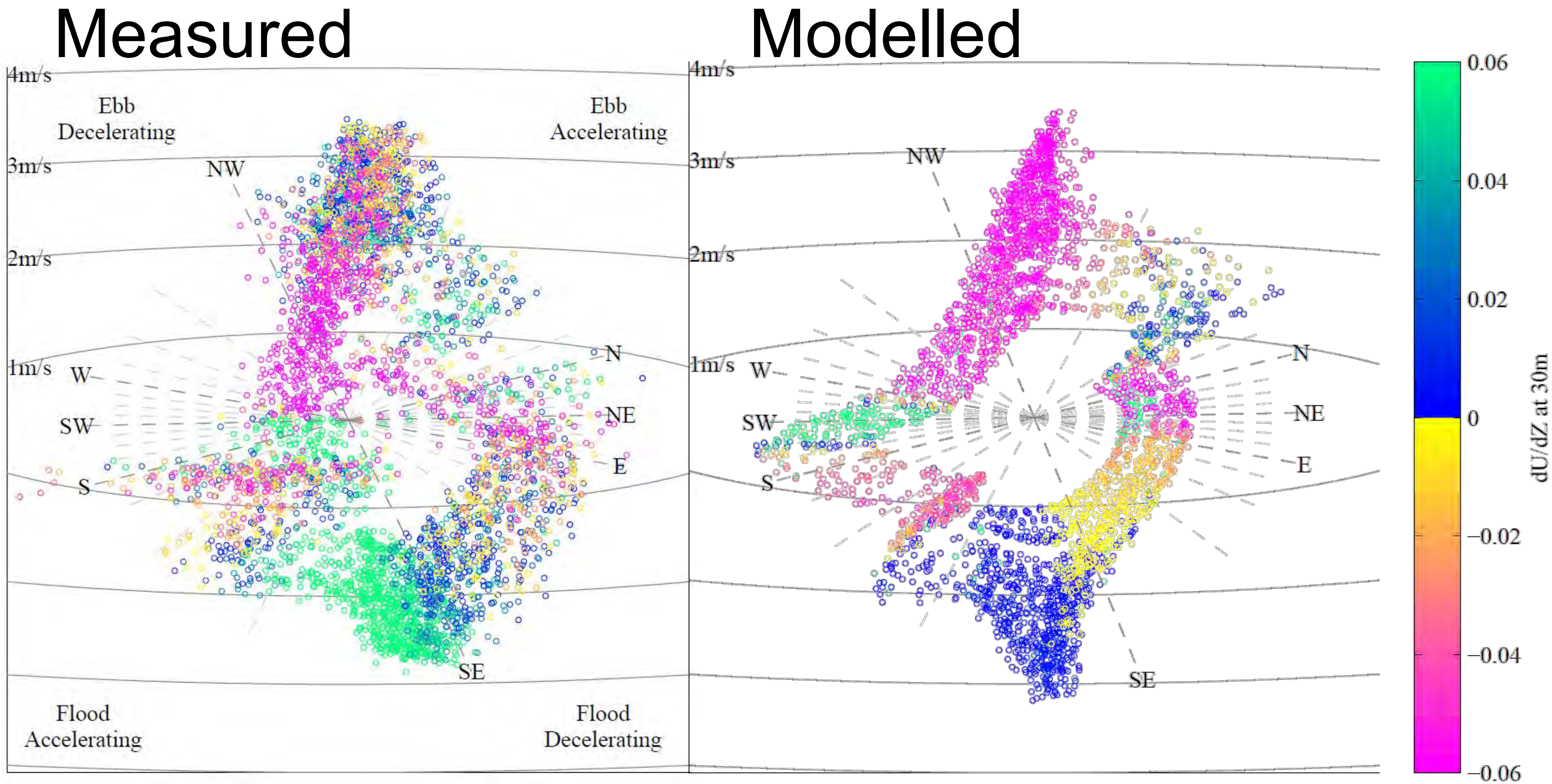




1. Good general agreement

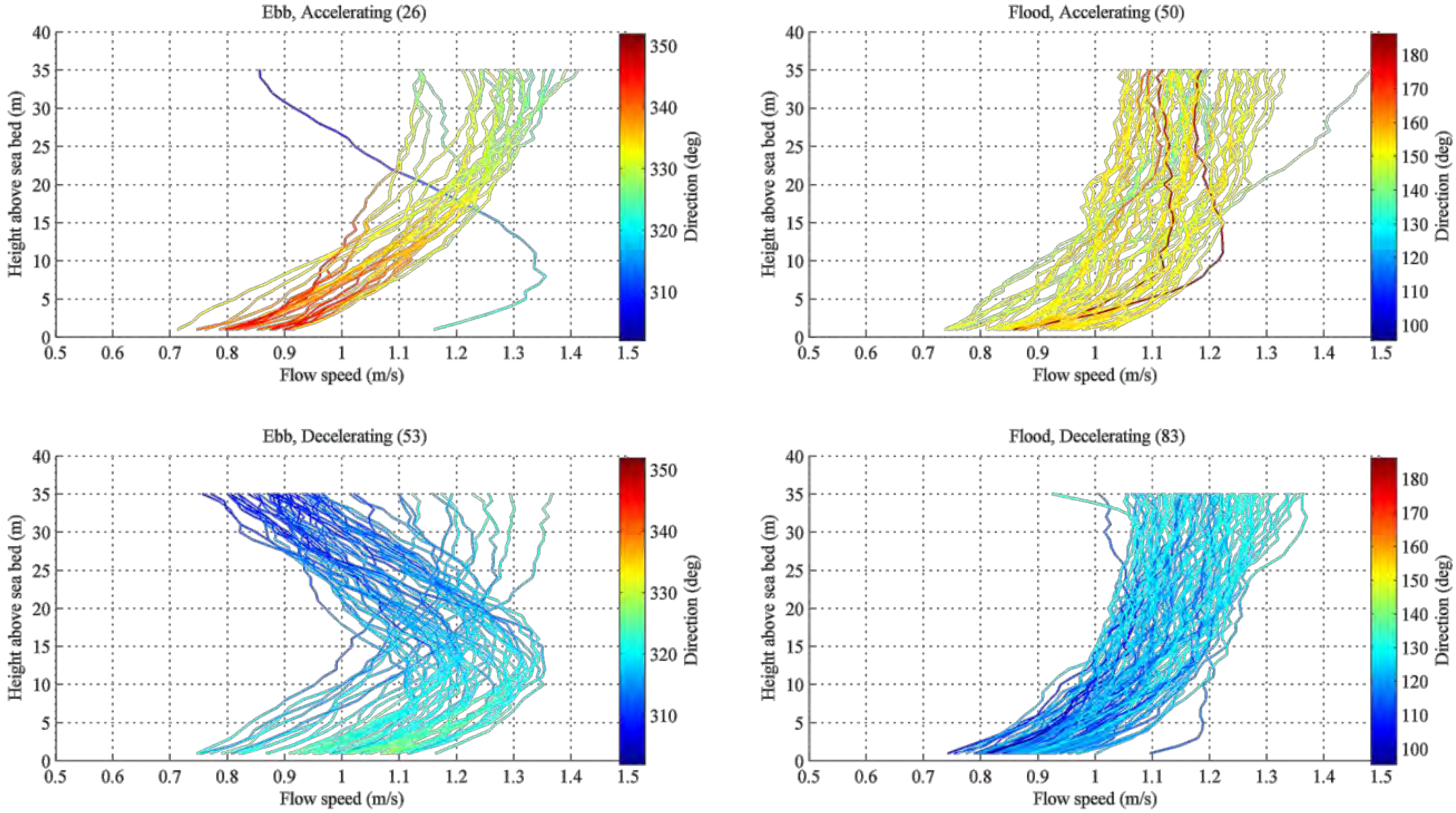


Comparison in 3D: TGL

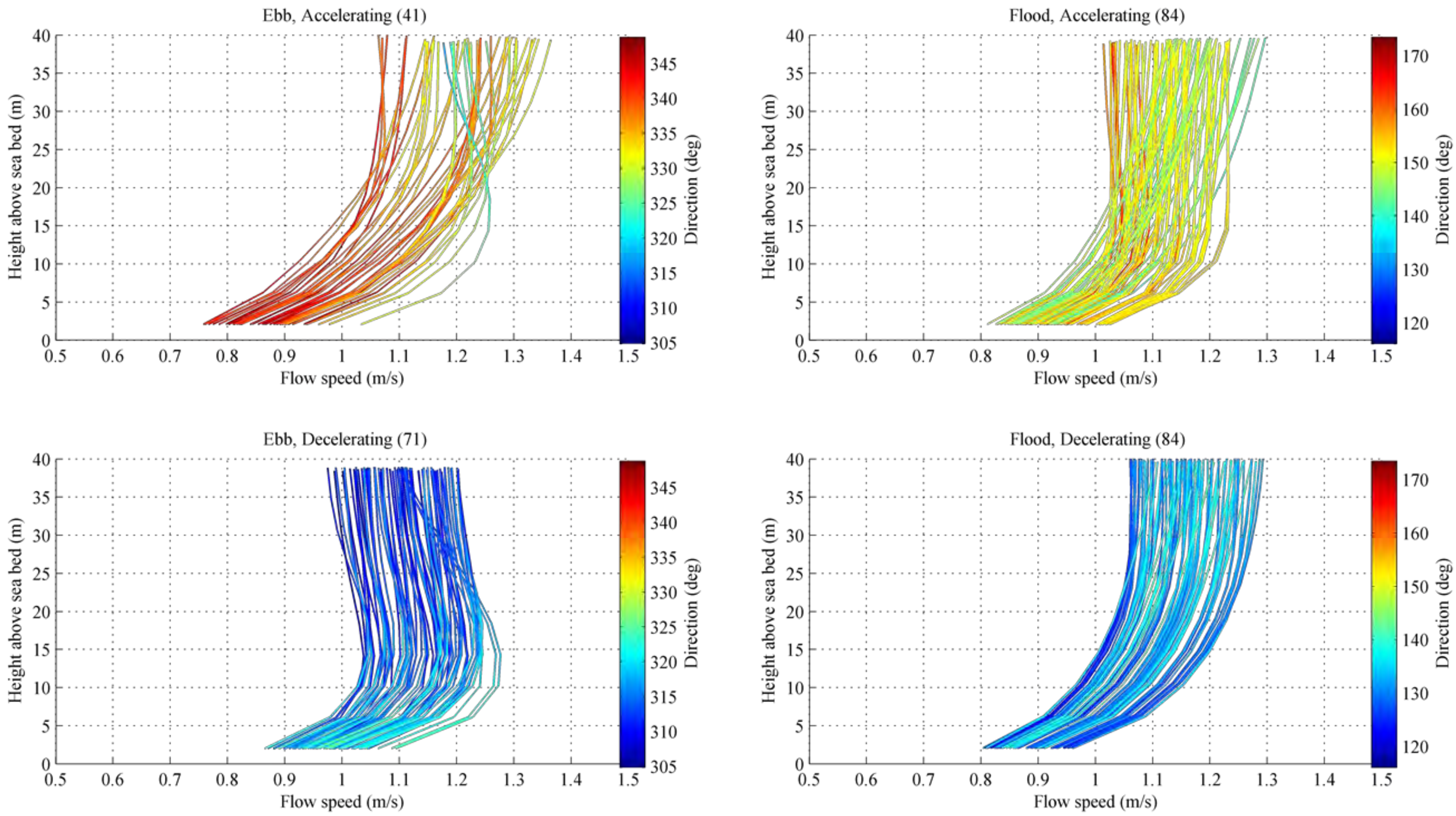


1. Good general agreement
2. Correct negative shear for NW, NE and S
3. Low gradients for E – SE (but wrong sign)
4. Failed to predict high positive gradients SE - SSE

ADP Shear Data: 1 – 1.2 m/s



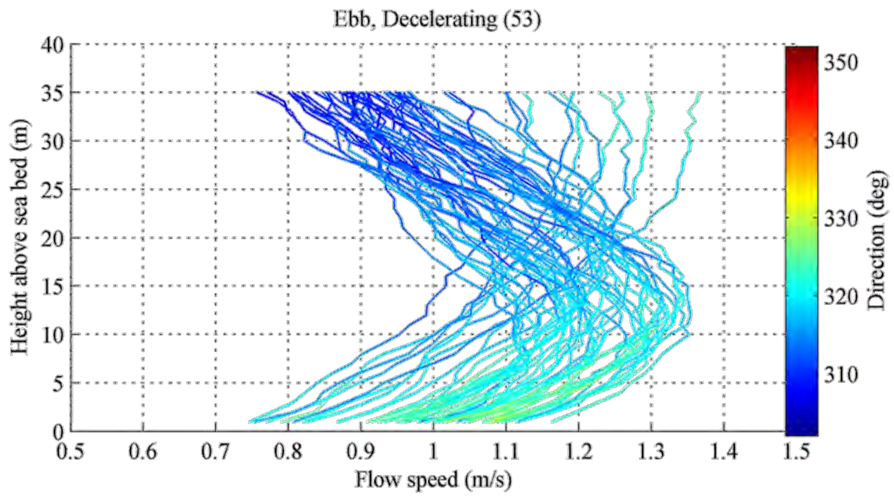
Model Shear Data: 1 – 1.2 m/s

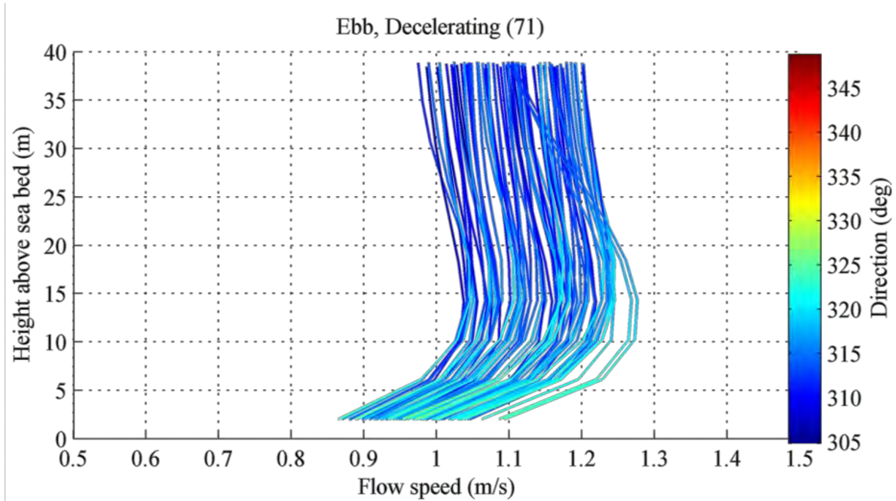


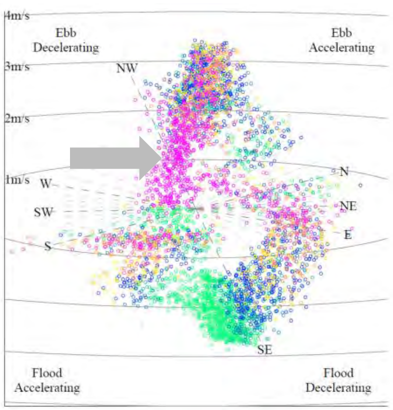
Direct comparison of Shear Profiles: 1 – 1.2 m/s

+ Correct general form

- Under predicted magnitude of reverse shear



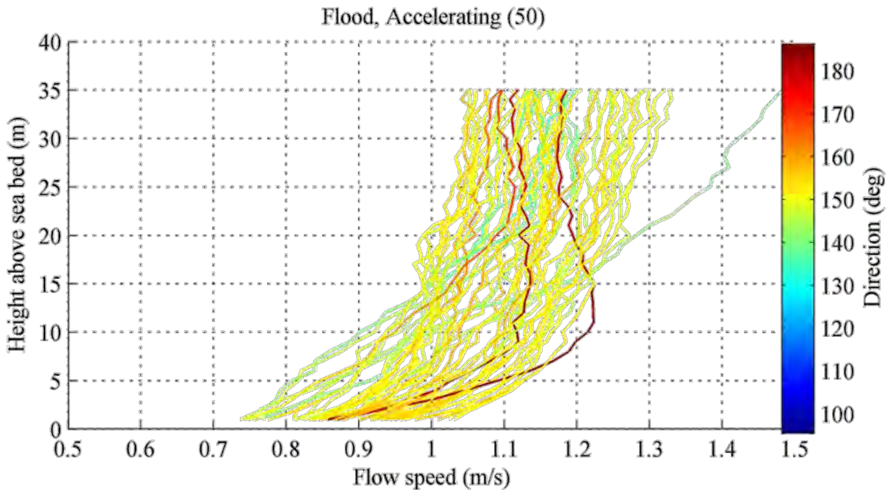


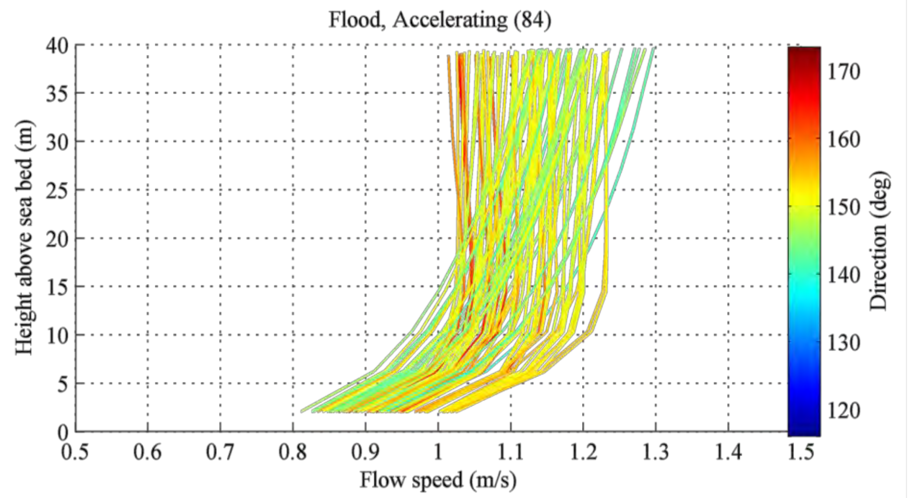


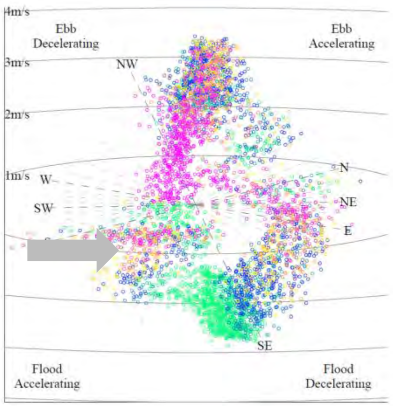
Direct comparison of Shear Profiles: 1 – 1.2 m/s

+ Identified multiple forms

- Predicts reverse shear



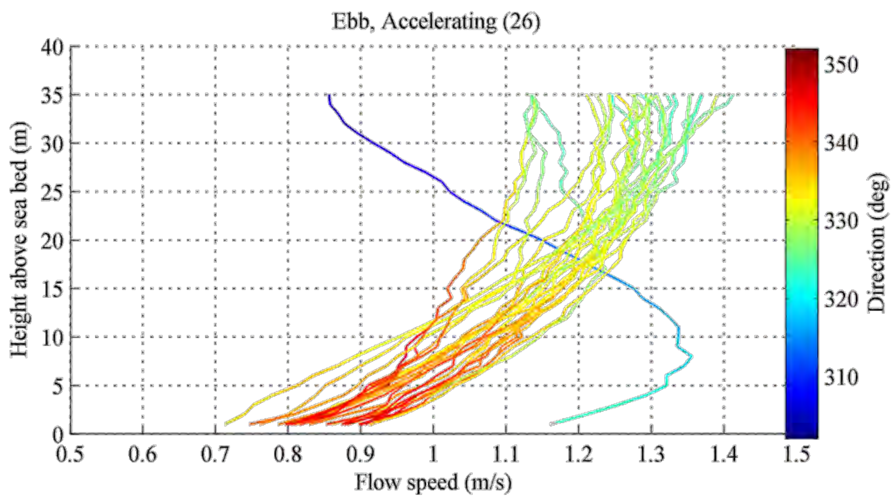


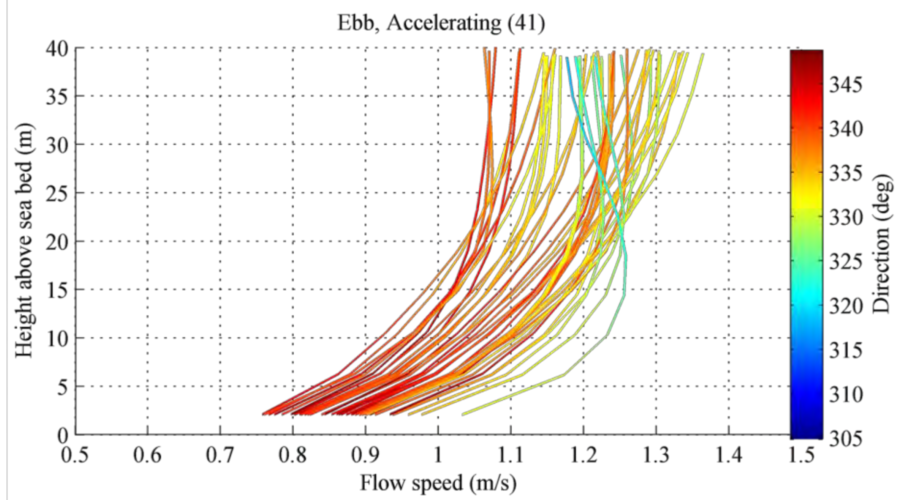


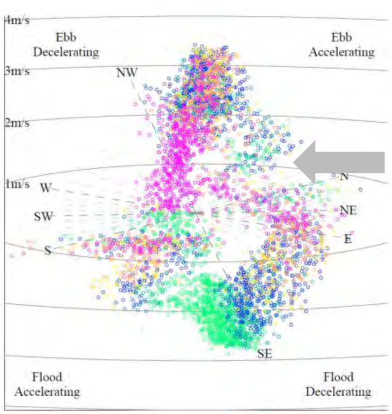
Direct comparison of Shear Profiles: 1 – 1.2 m/s

+ Predicts extreme veer

- Under predicts magnitude

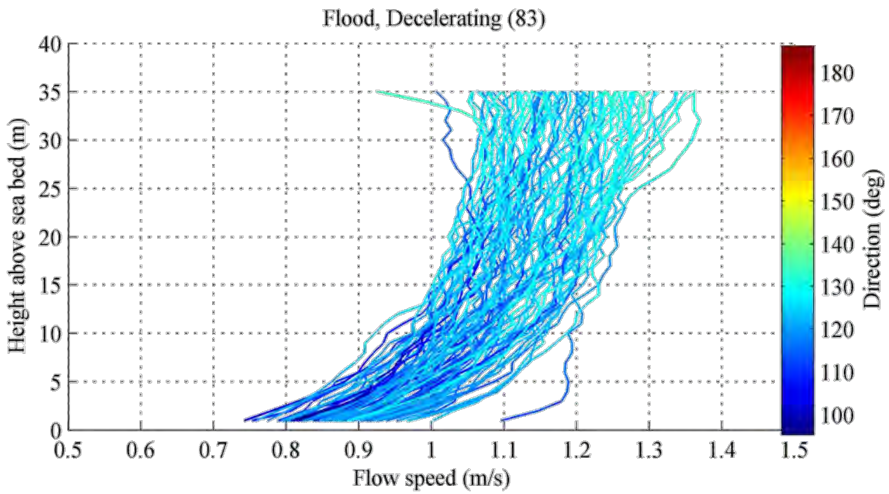


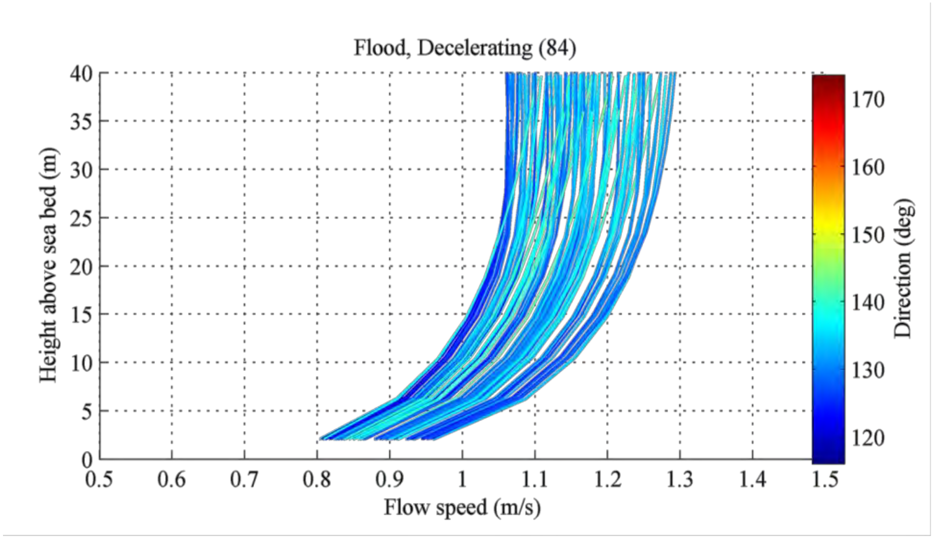


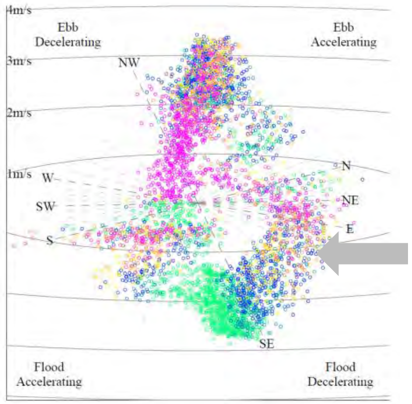


Direct comparison of Shear Profiles: 1 – 1.2 m/s

+ Excellent agreement in simple case







Key Points – 2D

- The model showed good agreement with the validation data

- There was (almost) no evidence for significant errors in the frequency domain (thus **no false resonant effects**)

- This type of model could be used for:
  - Farm layout
  - Early stage yield assessment
  - Measurement campaign design

- It could not be used for:
  - Load case identification
  - Late stage yield assessment

- **Validate for a purpose:**
  1. **Choose meaningful validation statistics.**
  2. **Choose acceptable values of validation statistics *before* performing the validation.**

Key points – 3D comparison

1. Even when a model is not "valid" – trends in results can be instructive

2. In this case, the model was able to show complex trends in the 3D flow field

3. 3D features should be analysed in **4 quadrants**

4. This sort of information is **invaluable for planning future measurement campaigns**

5. The 3D model data is not good enough to use for loading cases (or accurate yield estimates) – ADP deployments **are needed *at* potential turbine locations.**

6. **For details, see** Gunn and Stock-Williams, *On validating numerical hydrodynamic models of complex tidal flow,* International Journal of Marine Energy, 2013

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