GARRAD HASSAN

Tidal energy and turbulent flow

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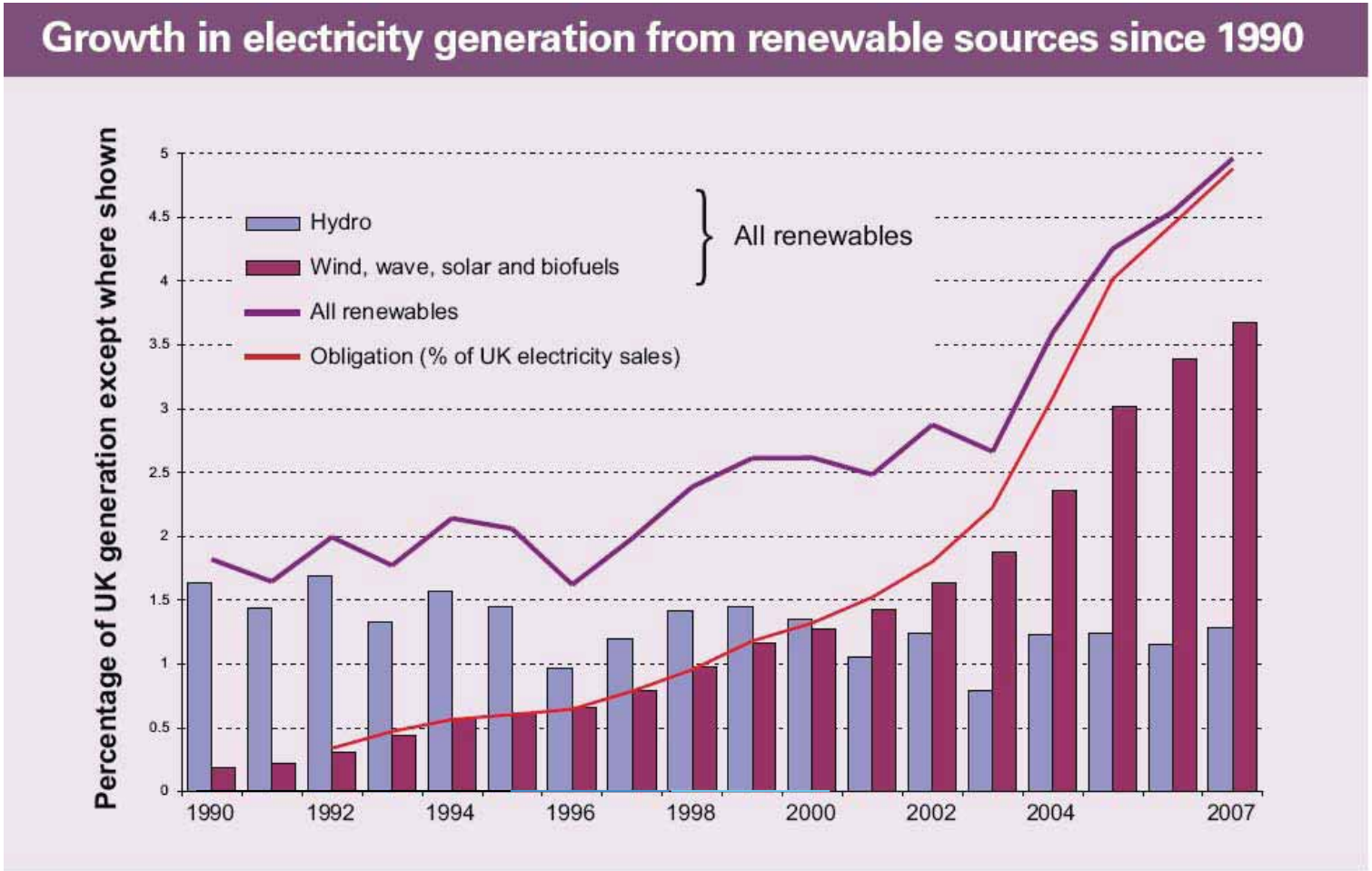
ICMS, Glasgow

Marine Energy Experts
worldwide

Motivation - UK plans for renewables

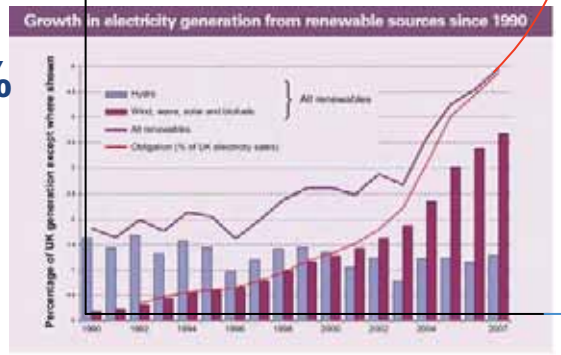


Source: Berr UK ENERGY IN BRIEF JULY 2008

Motivation - UK plans for renewables

35%

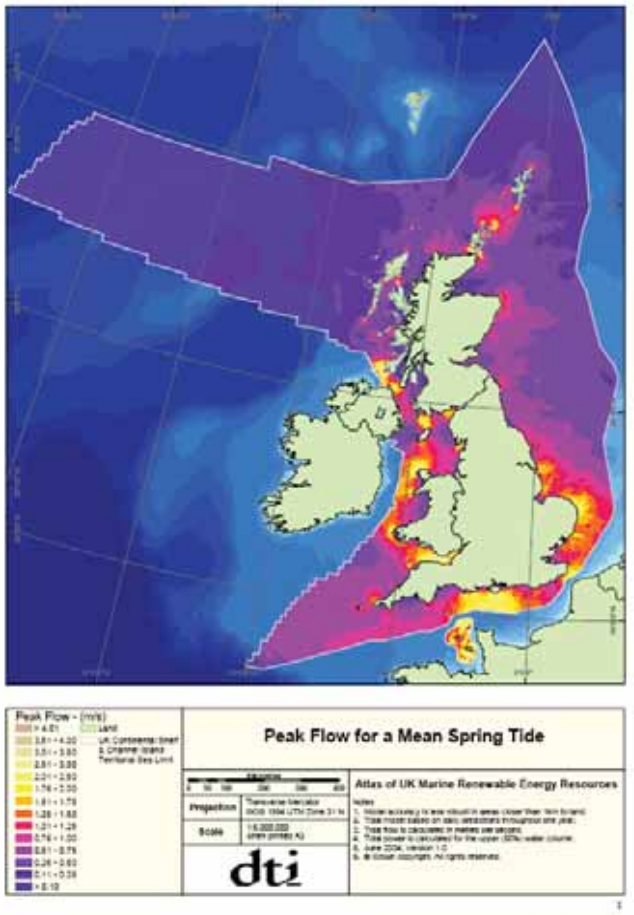
5%



2020

Tidal stream energy

- Why?
  - Tidal stream resource (UK): 18 TWh/y - 5% electricity demand
  - Target 2GW by 2020
- Worldwide Potential
  - UK Tidal stream resource = ½ European resource (limited potential to export technology)
  - IEA-OES (Tidal stream): 800+ TWh/y

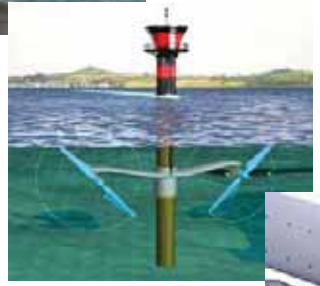


Tidal stream energy

- Headline benefits
  - Predictable source of renewable energy
    - Important for the renewable energy mix
  - Potential for GWs of useful power to the UK and the rest of the world
  - Not too far offshore

- Headline challenges
  - Installation and retrieval (significant part of CAPEX)
  - Complex flow environment (device and array scale)

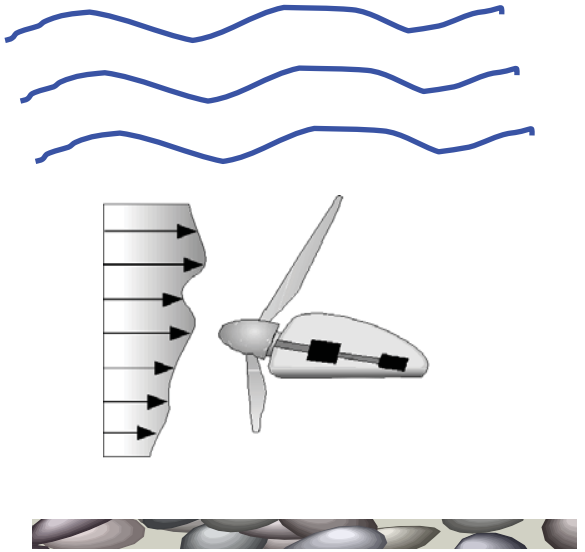
Tidal stream energy technology



Now over 70+ concepts…

…..tidal turbine behaviour is complicated

- Interaction of:
  - Currents
  - Waves
  - Hydrodynamics
  - Structural dynamics
  - Power train
  - Control systems



It has to operate safely and generate power economically over a wide range of environmental conditions

Requirements for a loading assessment

Loads analysis - as required for certification:

- Current, including vertical profile and turbulent fluctuations
- Wave kinematics, irregular sea-states and regular, non-linear waves
- Tidal sea levels
- Soil dynamics

site specific

- Rotor hydrodynamics, including stall and wake effects
- Hydroelastic coupling
- Operating behaviour, including control system pitch and rotor speed adjustment

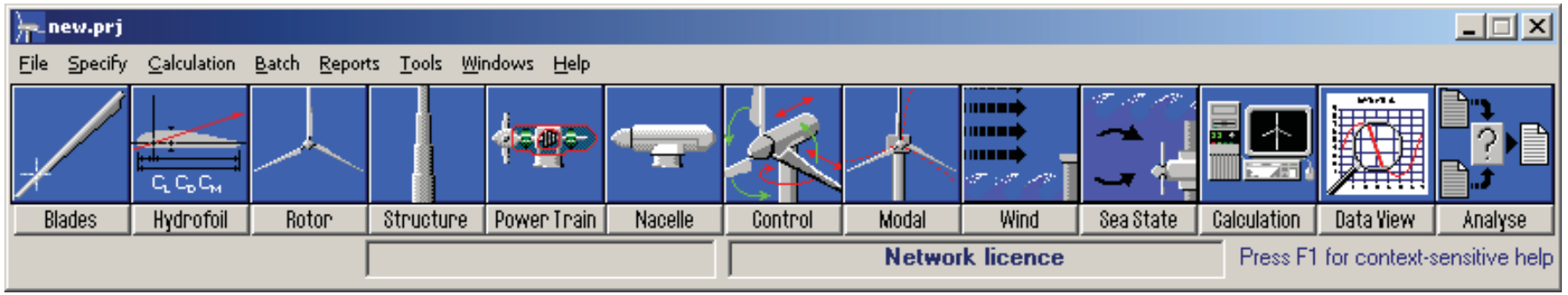
device specific

Time domain dynamic analysis required for nonlinear system

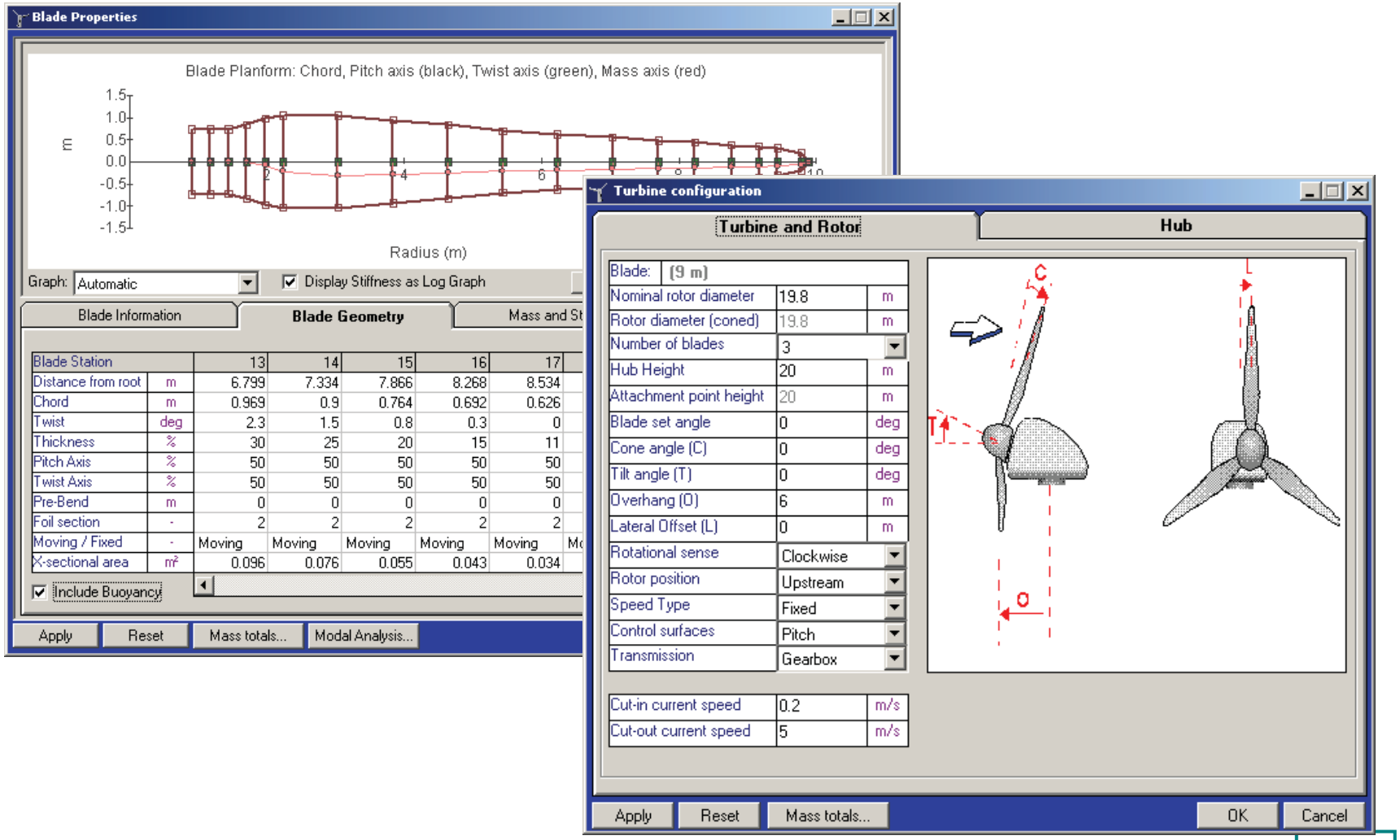
Requirements for a loading assessment

GH Tidal Bladed - generic design tool for tidal turbines incorporating:

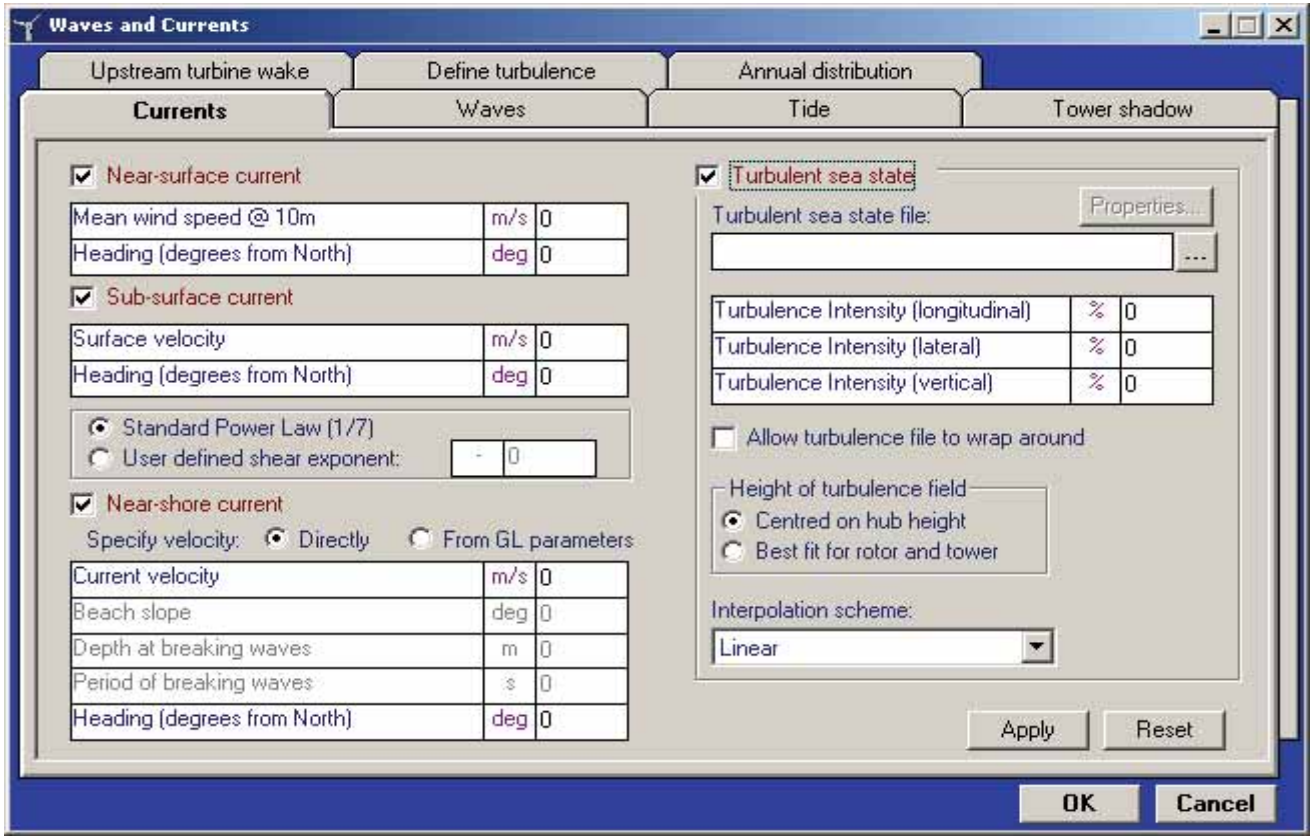
- A description of the turbine
  - Blades, rotor, nacelle, support structure, drive train, controller system
- A full description of the environment
  - Currents (near and sub surface, near-shore currents), waves, turbulence, wind



GH Tidal Bladed

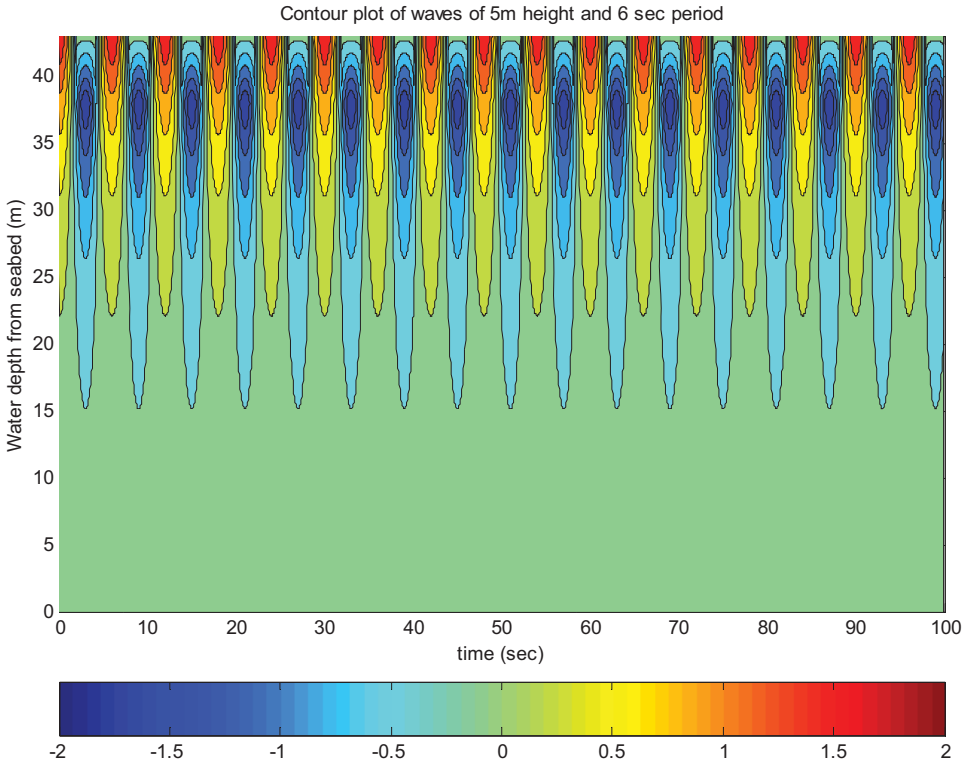


Description of the environment



Modelling waves

– Extreme wave:
  - Regular non-linear

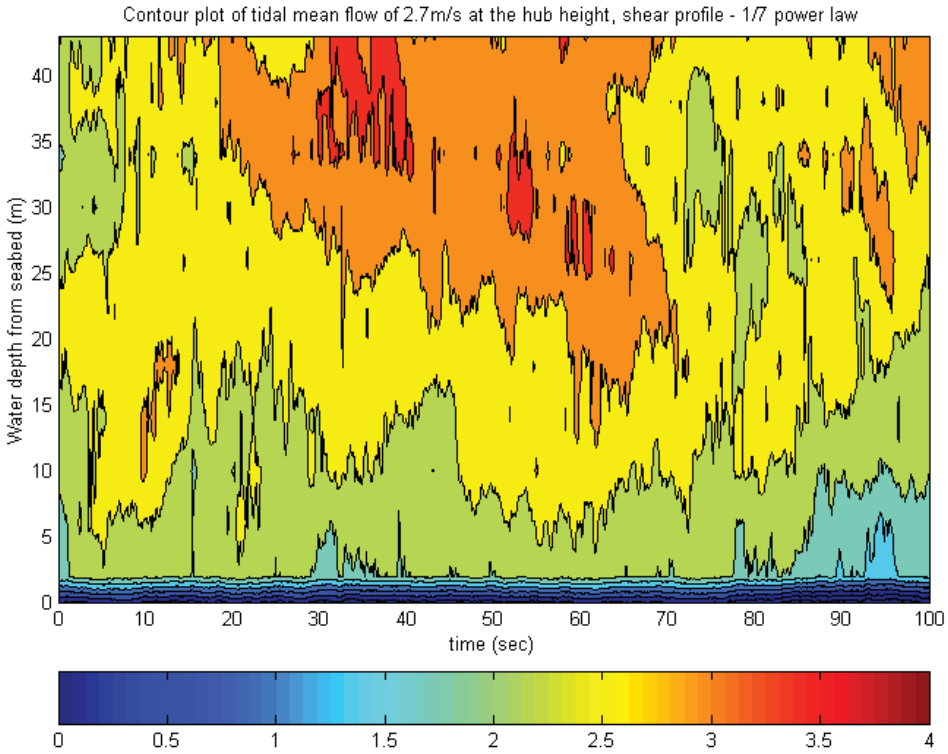


Modelling turbulent flow

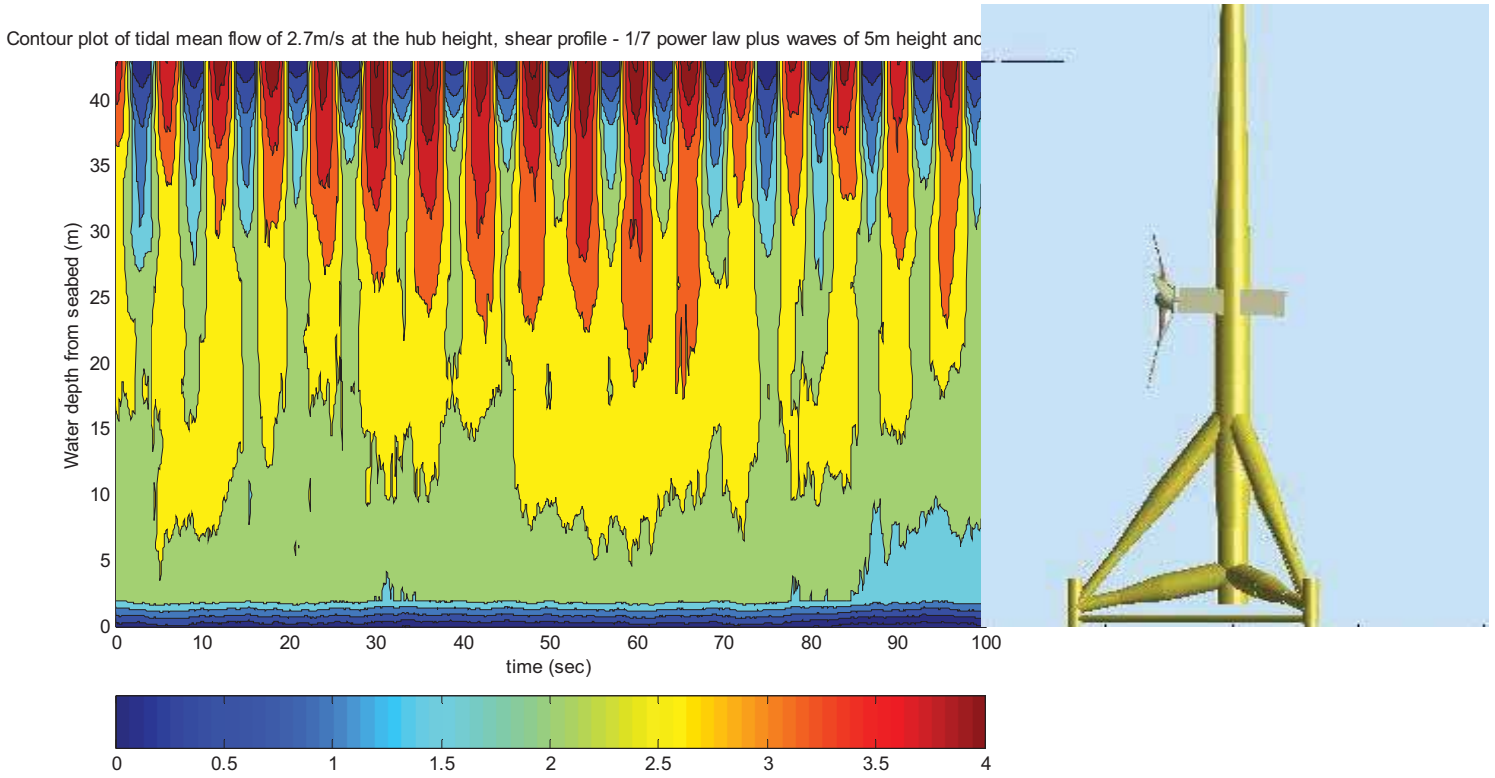
–Shear profile

–Turbulence

- Von Karman wind based model!

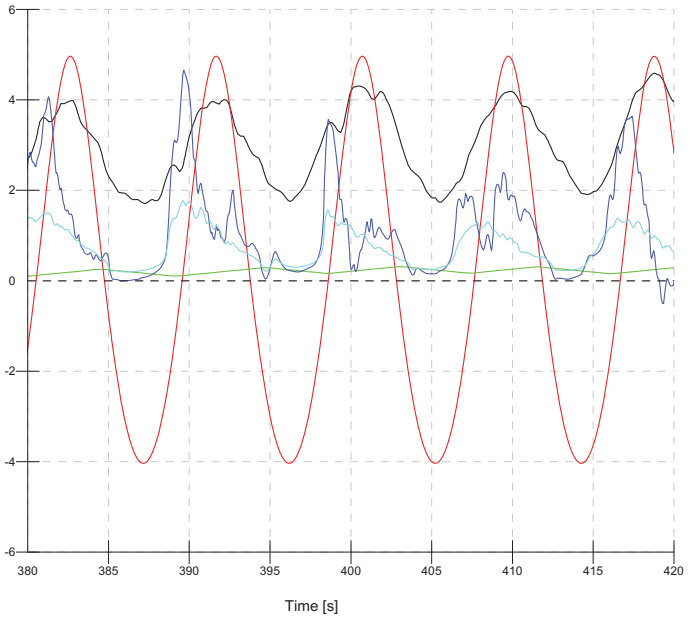


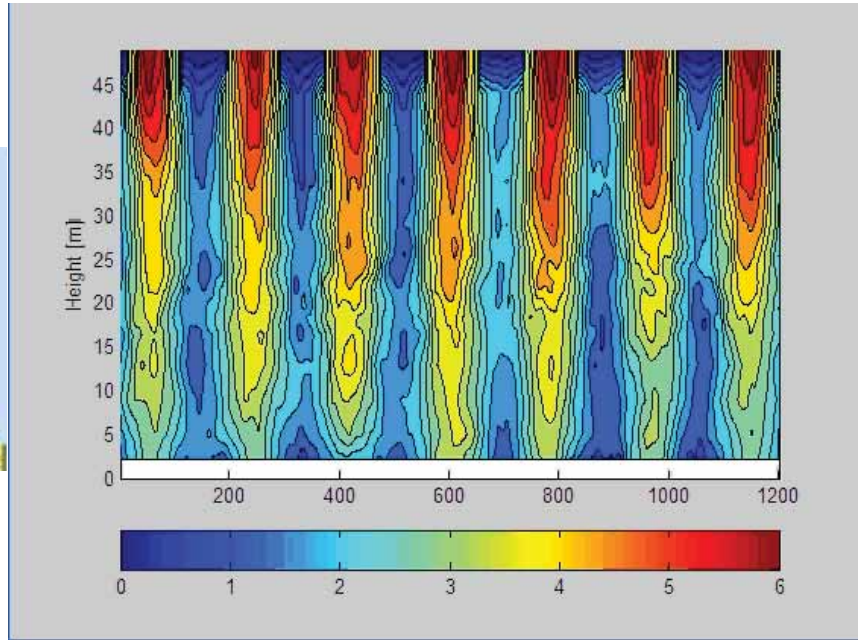
Combined effect



Extreme loads assessment

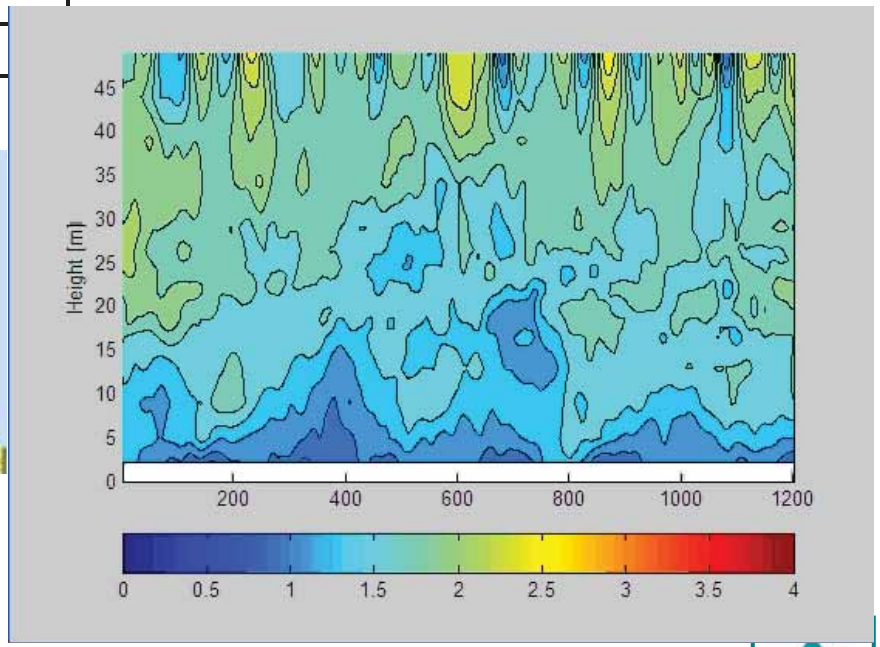
Rated flow speed [m/s]	3.5
Extreme flow turbulence [%]	10
Extreme stream fn wave H, T [m, s]	9, 9
Wave, current direction	In line
Wave current interaction	λ shift



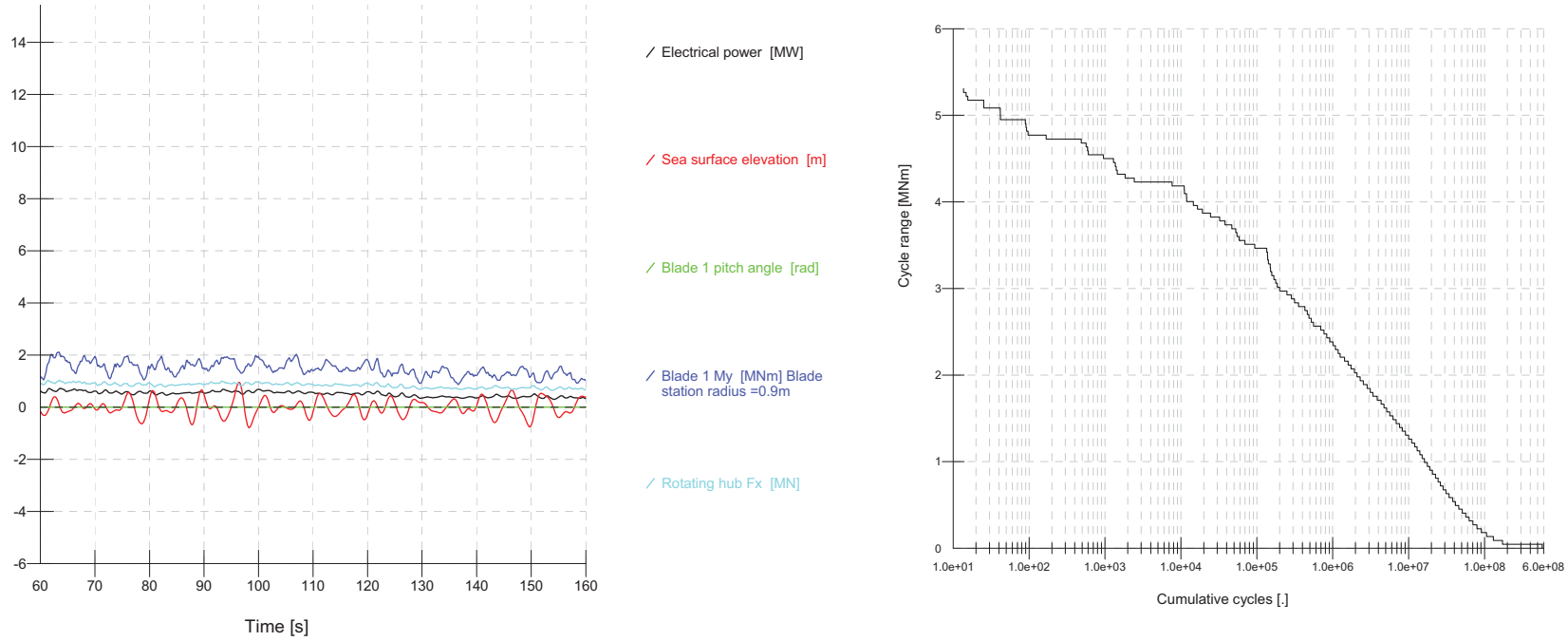


Fatigue loads assessment

		Head-on		In-line	
Current	Heading	North -10º	South +10 º	North -10º	South +10 º
	Probability (occurrence)	50%	50%	50%	50%
	No of bins	9		9	
Waves	Heading	South +10 º	North -10 º	North -10º	South +10 º
	Probability (occurrence)	37%	63%	63%	37%
	No of bins	28		28	
Total	Probability (occurrence)	19%	31%	31%	19%
	No of bins	252		252	



Fatigue loads assessment



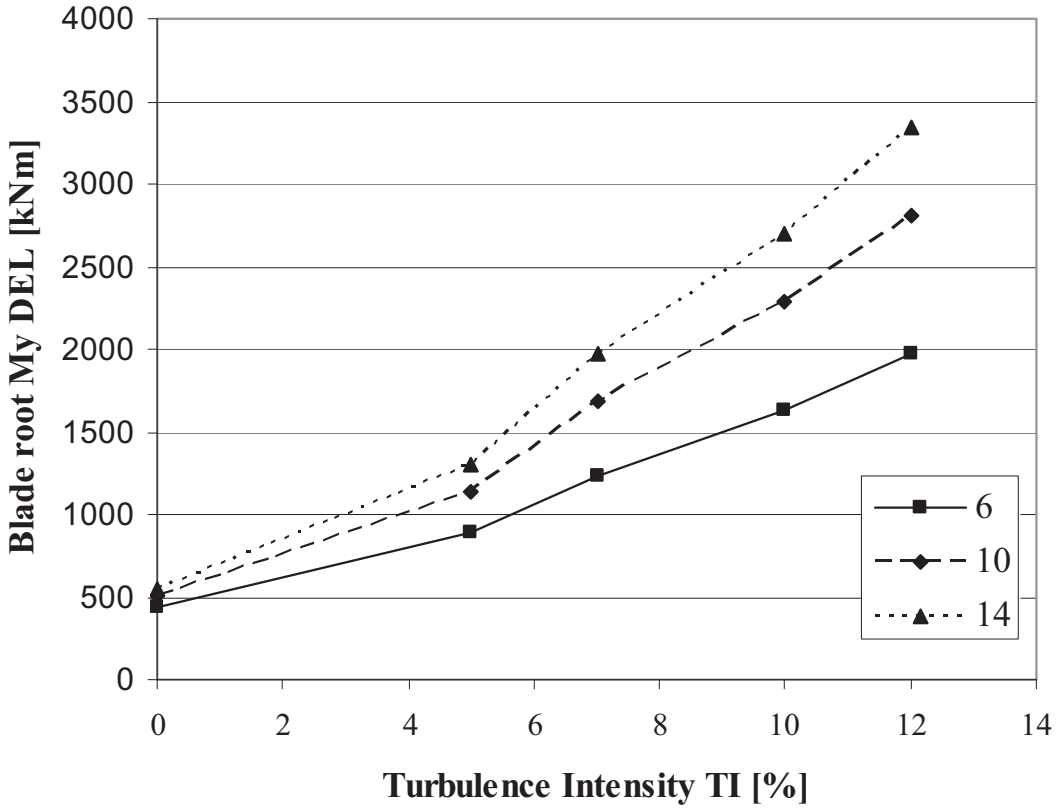
Time series → Rainflow counted → Design Equivalent load

→ Stress margin

(for given geometry)

The implications for design – an example

…resulting in 20 year lifetime fatigue damage equivalent loads



The implications for design – an example

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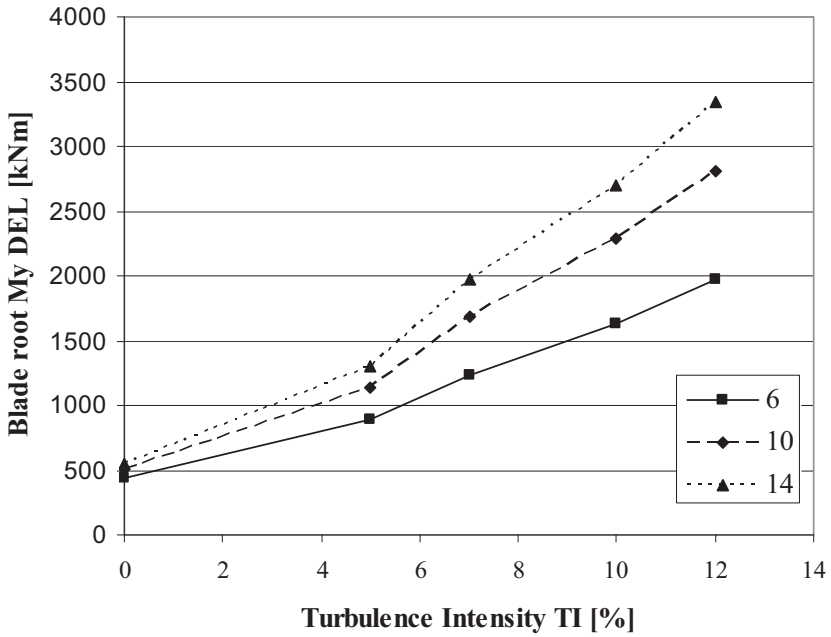
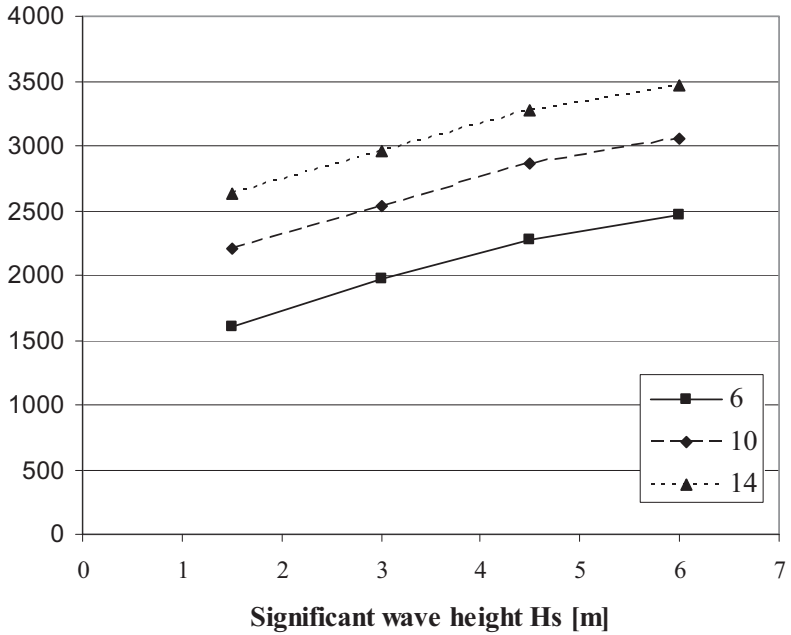




Design driven by fatigue?

BUT…

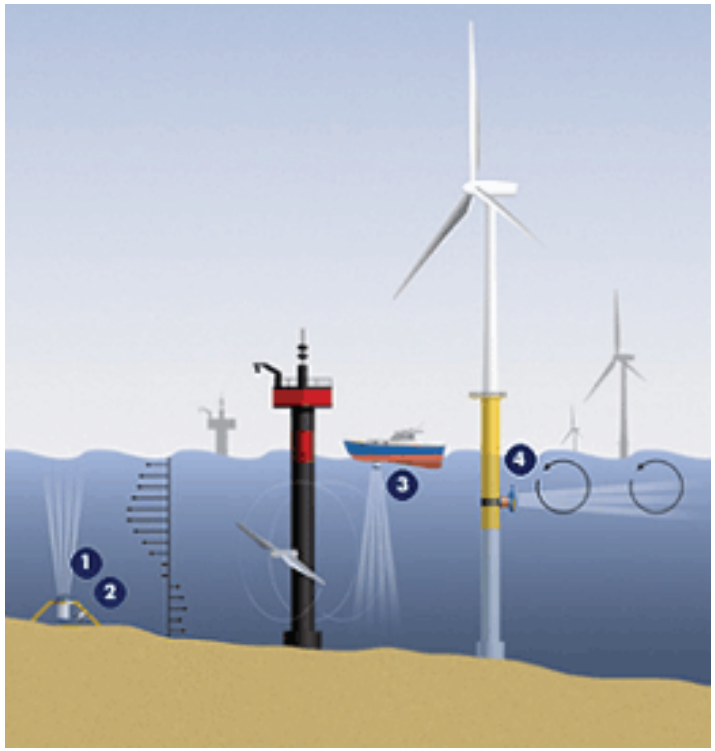
…all this is dependant on

- the structure of the turbulent flow
  - Intensity
  - length scales
  - frequency spectrum
  - spatial correlation characteristics
- wave current interaction
  - regular and irregular waves
  - current profile effects
  - shallow water effects

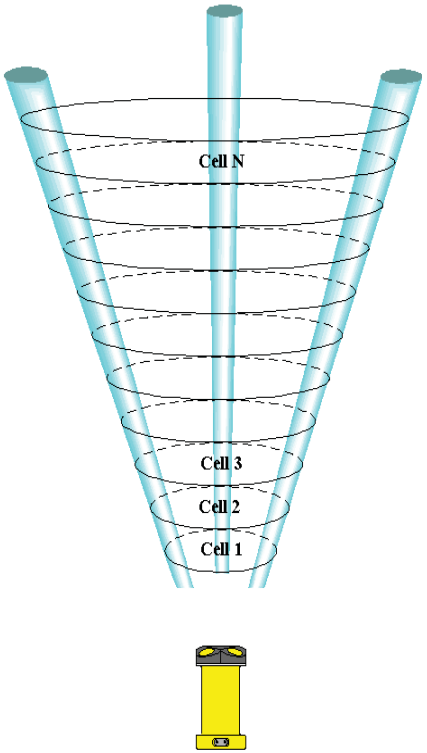
So the challenge is…

- To better understand the turbulent flow
  - Limited field data available
  - Flow measurements techniques limited

Flow measurements systems

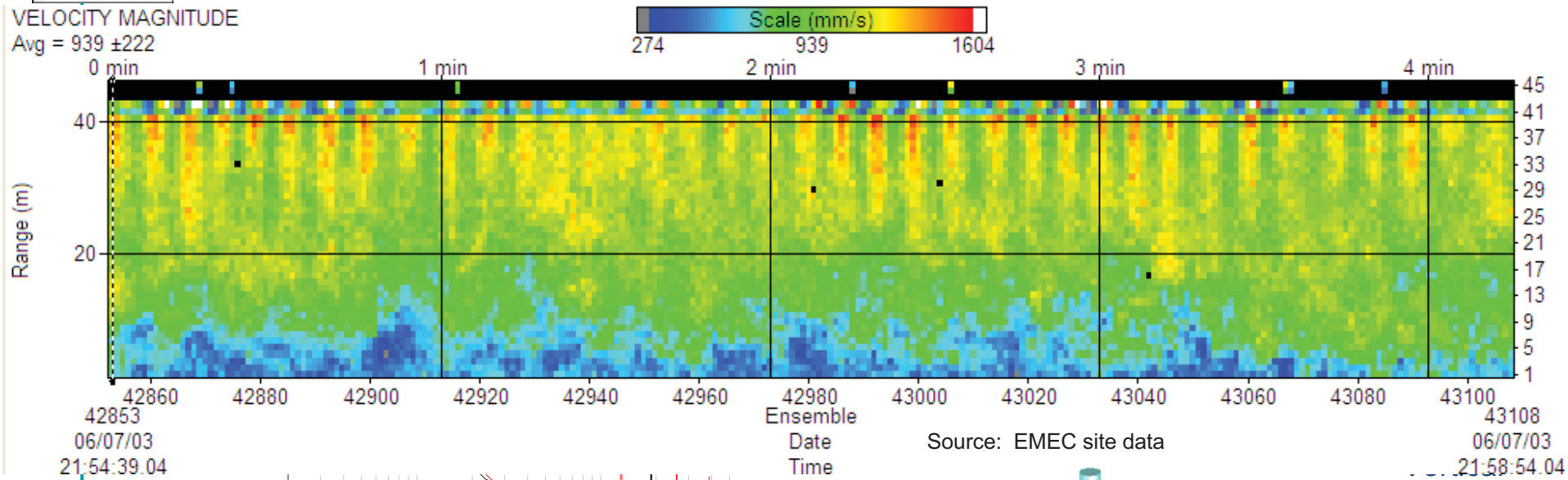


Source: Teledyne RD Instruments' ADCP Products

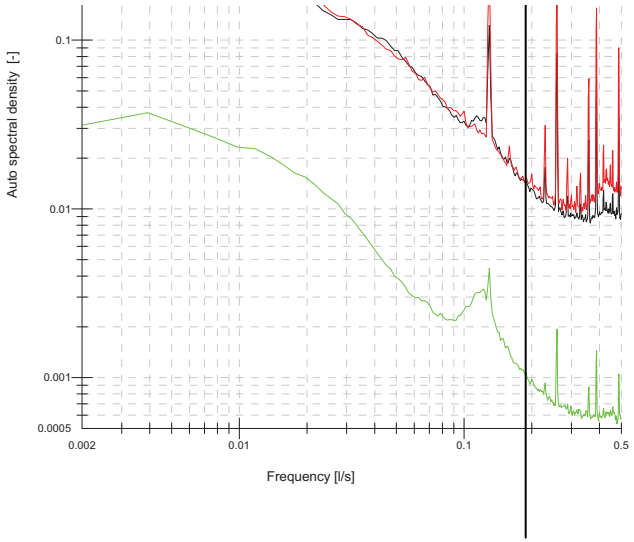


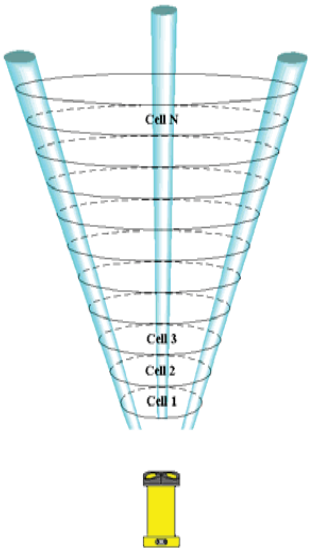
Source: http://www.sontek.com/product/adp/adpxd02.gif

ADCP data



Source: EMEC site data





So the challenge is…

- To better understand the turbulent flow
  - Limited field data
  - Flow measurements techniques limited

- And then develop better representations of the environment for loading analysis
  - Seabed roughness
  - Large bathymetry
  - Waves

In summary

- The drive
  - Understanding the flow is critical for fatigue analysis
- The challenge
  - To better understand the turbulent flow
  - And then develop better representations of the environment for loading analysis
- Moving forward
  - Reliant upon the input of expert knowledge from many different disciplines
  - Need for collaborative R&D

Thank you for your time

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