

Framework for optimal met-ocean sensor placement in offshore wind farms

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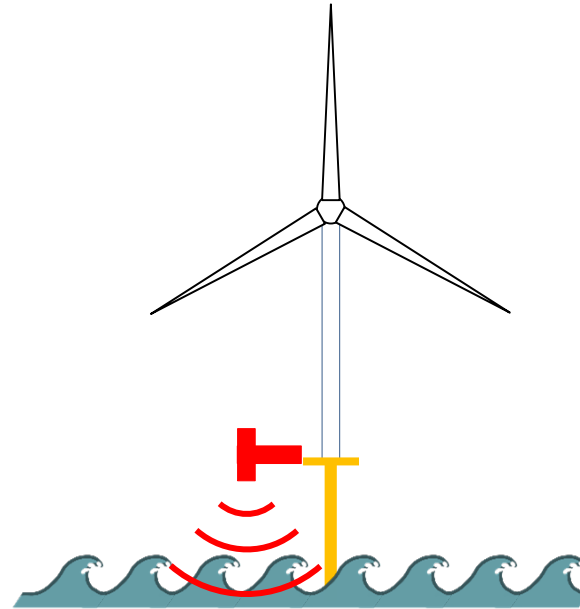
Project partners



Innovate UK

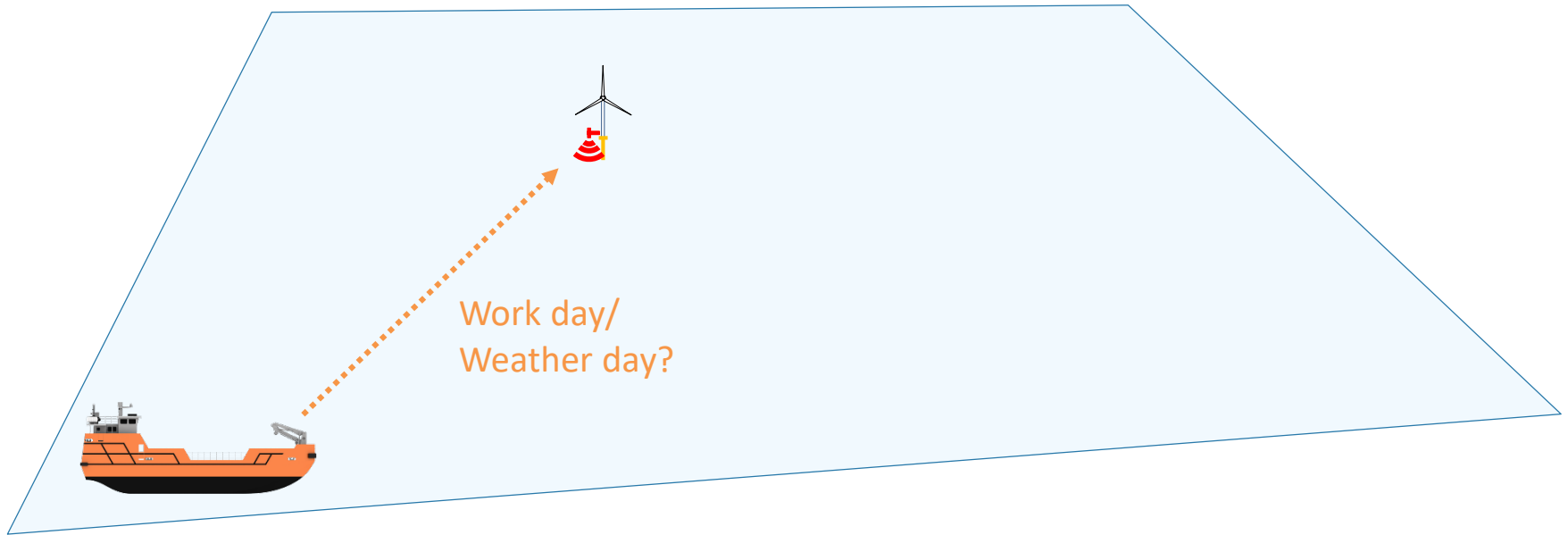
Point measurement of wave height

- Downward-facing wave radar
- Real-time data
- $H_s \approx$ turbine access
- Where best to place sensors?
- What are the conditions at other, sensorless turbines?



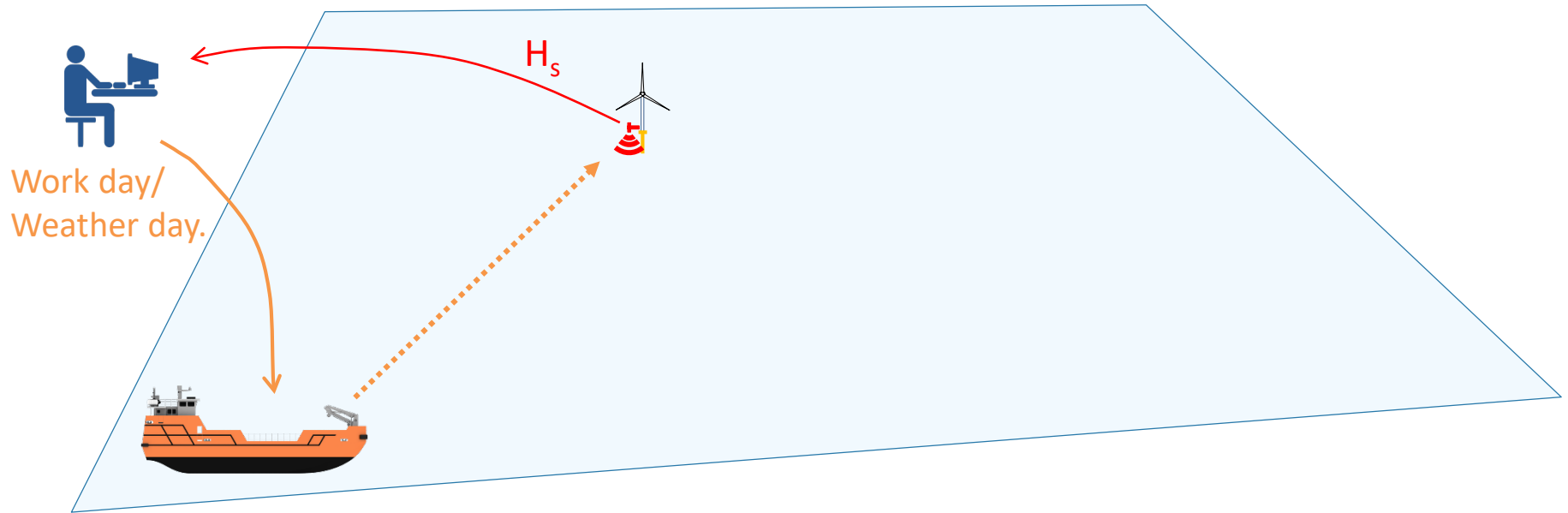
Vessel dispatch decisions

Sensor data - local conditions



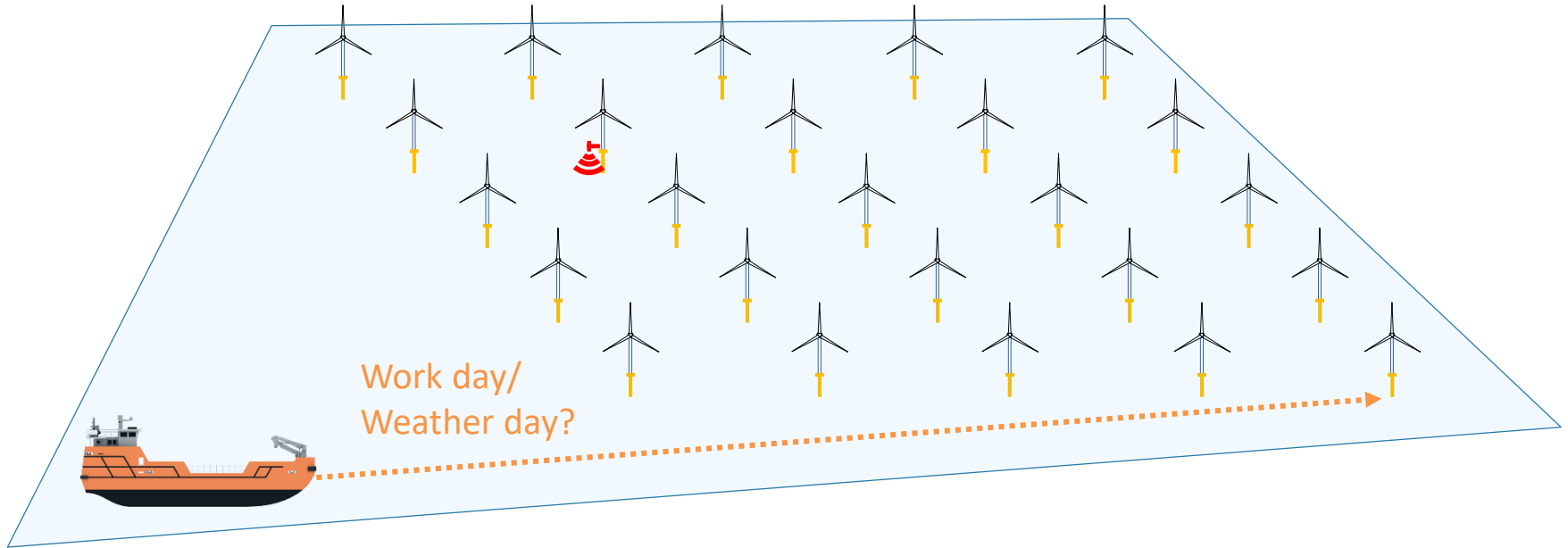
Vessel dispatch decisions

Marine coordinator uses sensor data directly



Vessel dispatch decisions

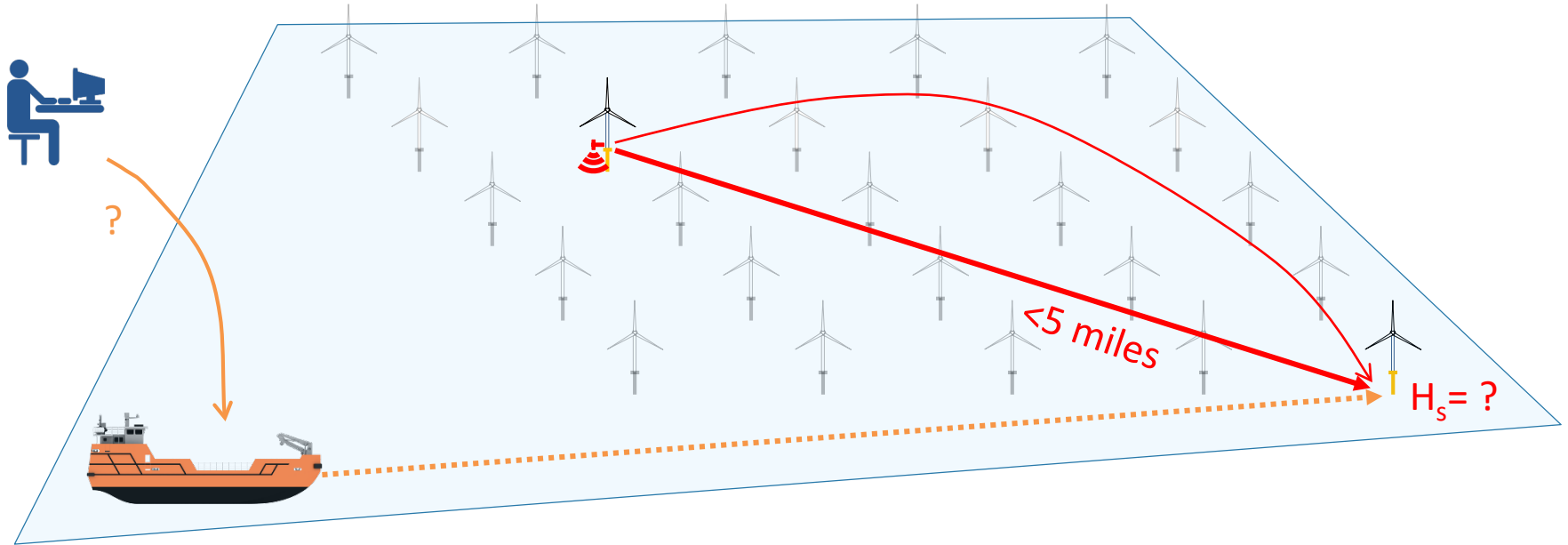
Without local sensor data



Vessel dispatch decisions

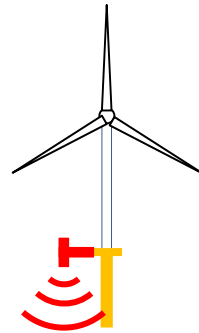
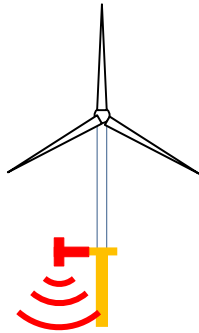
How to assess the conditions 'out there'?

Forecast is often inaccurate on a very local scale



Spatial sensor coverage

How far from a point measurement can we extrapolate?

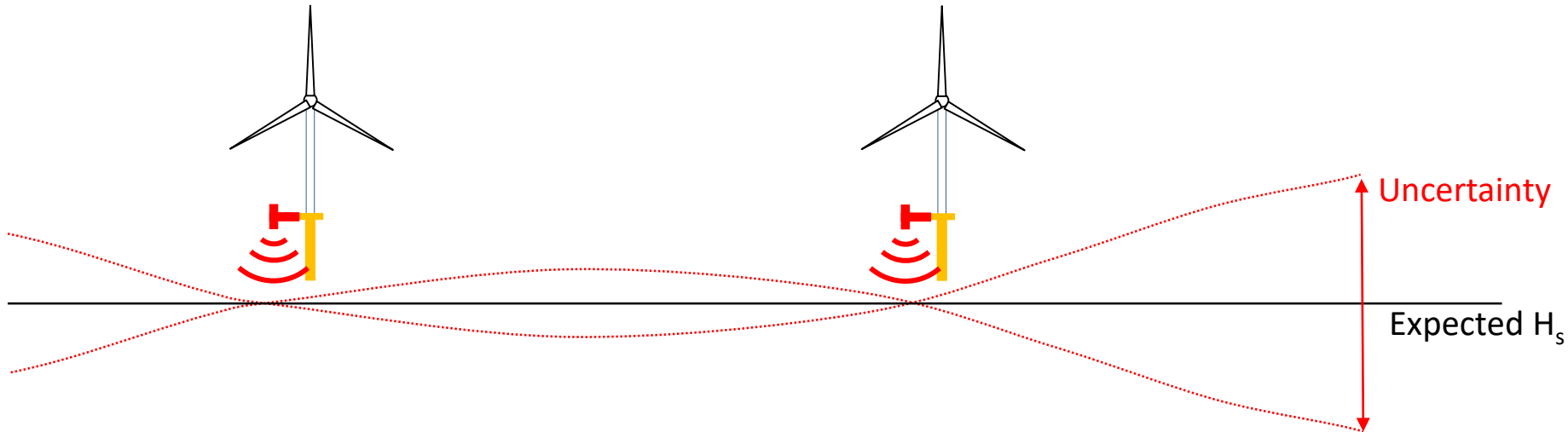


Expected H_s

Spatial sensor coverage

How far from a point measurement can we extrapolate?

Uncertainty estimated using a Gaussian process

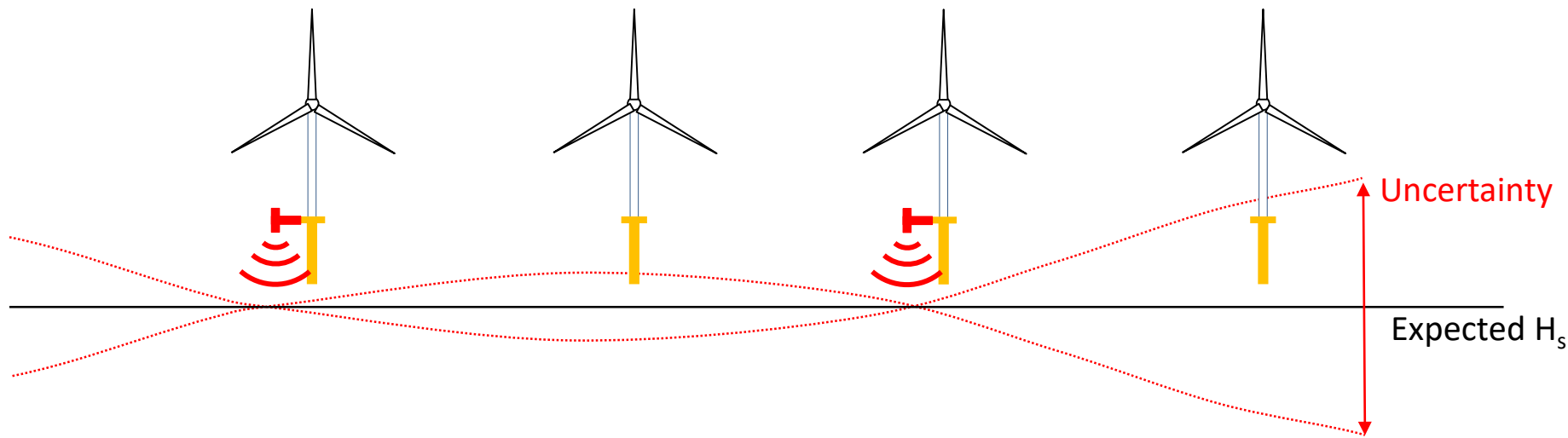


Spatial sensor coverage

How far from a point measurement can we extrapolate?

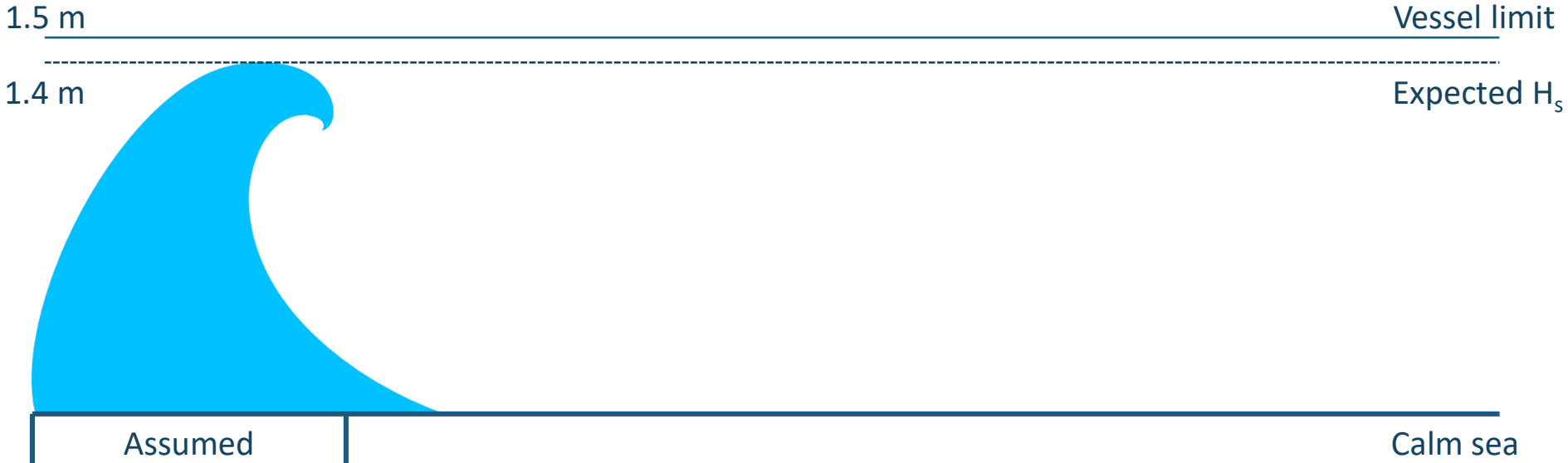
Uncertainty estimated using a Gaussian process:

- Low at turbine locations
- Higher as distance increases



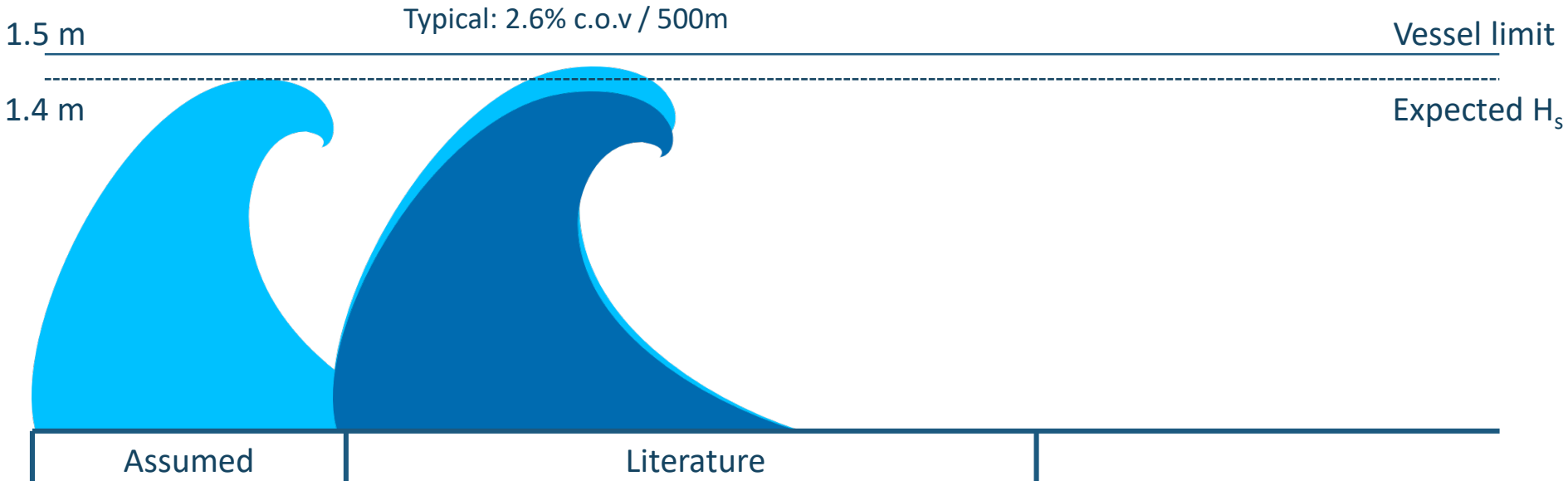
Scale of uncertainty

Wave height estimates in marginal conditions
(95% confidence)



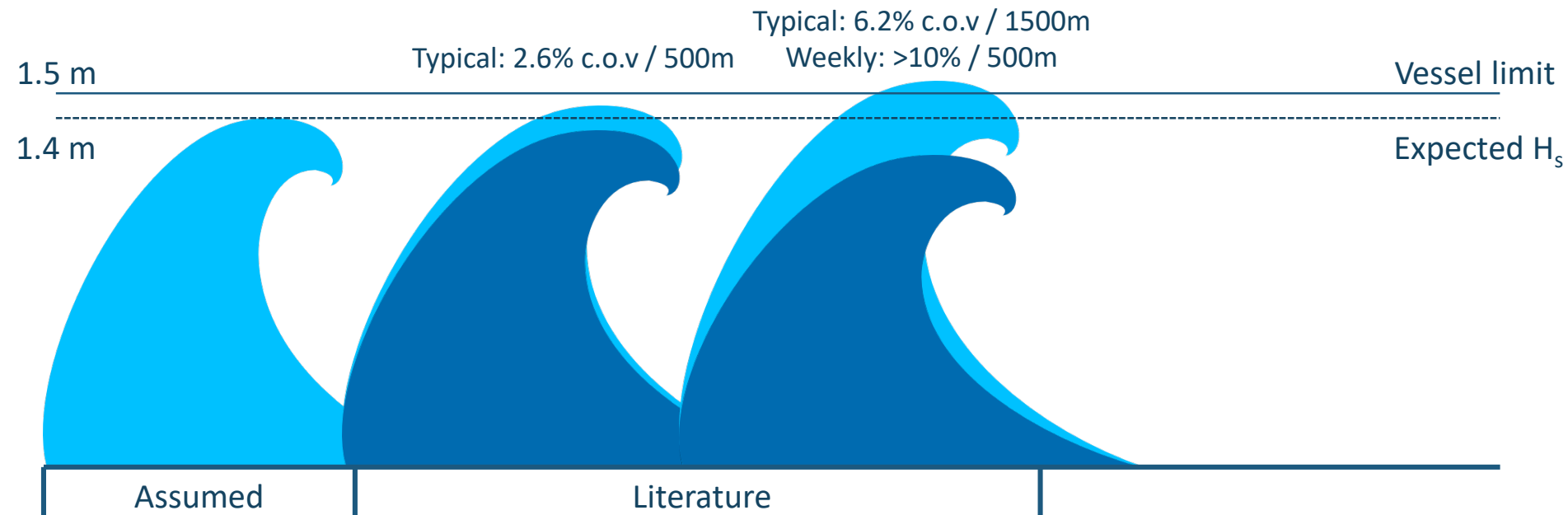
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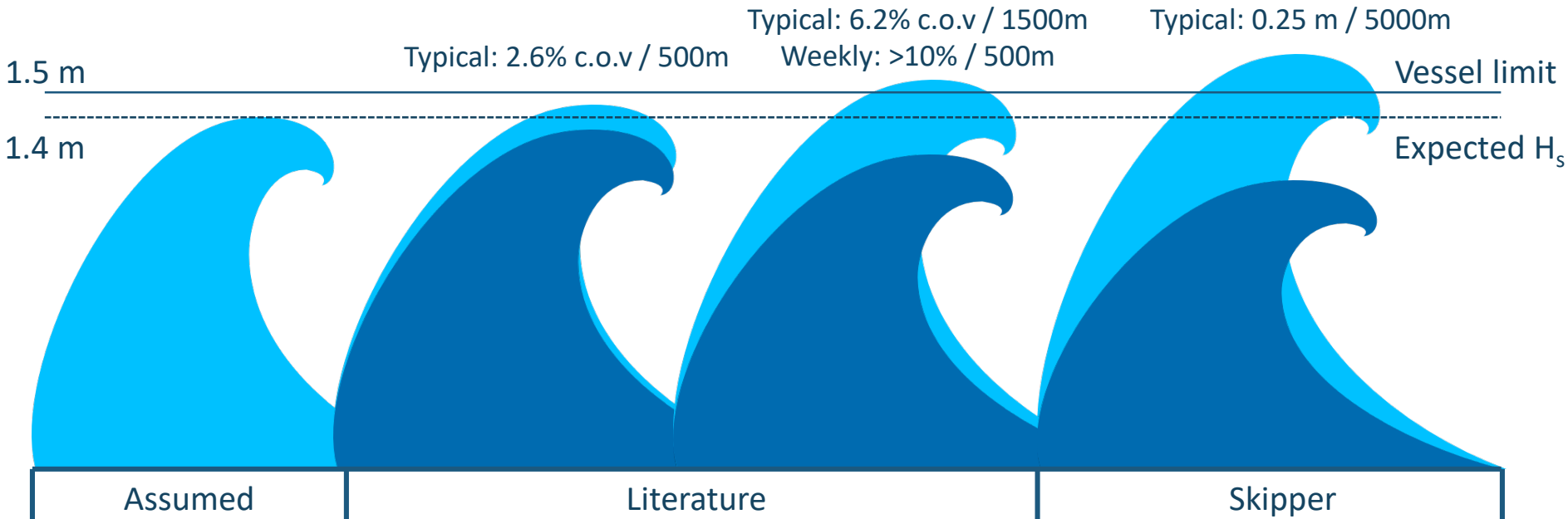
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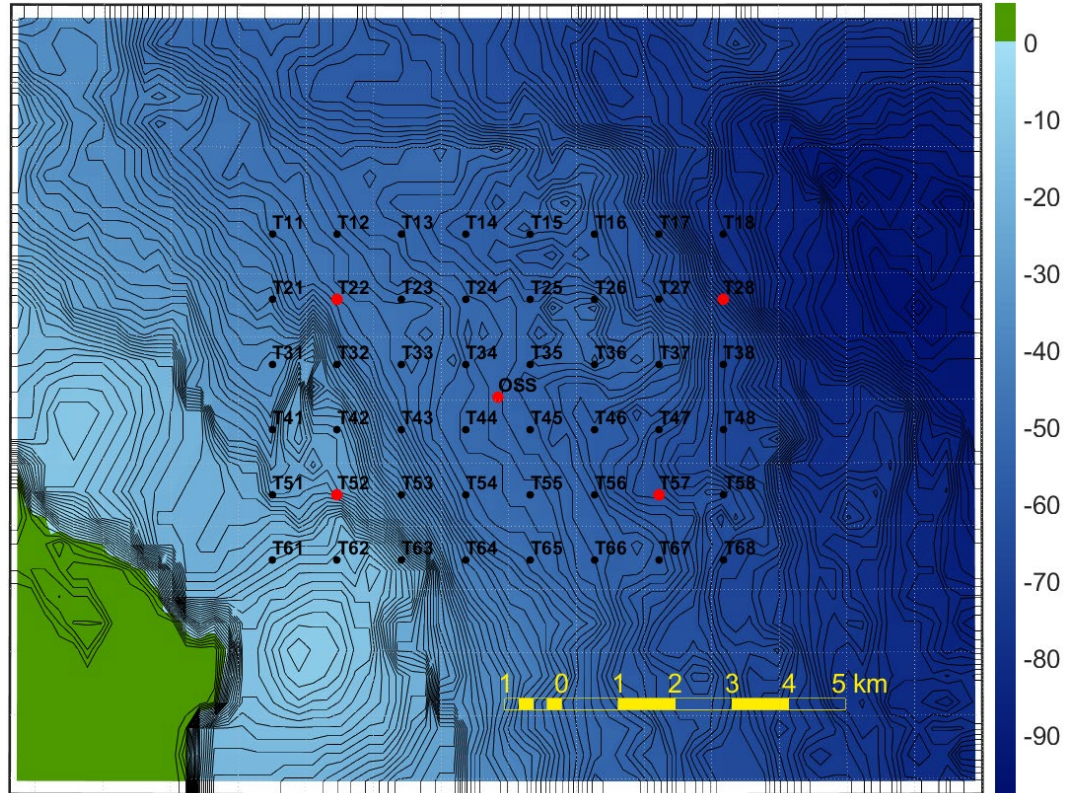
Scale of uncertainty

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Example case

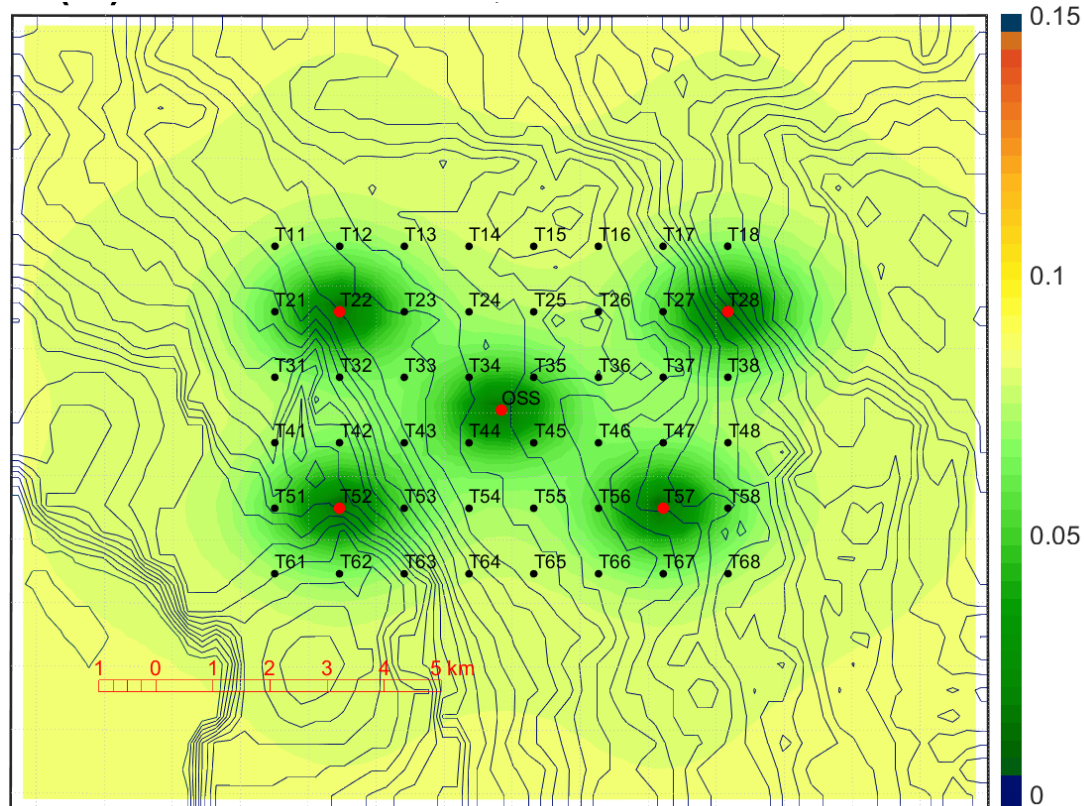
Hypothetical site in UK waters



Hypothetical site in
Scotland.
GEBCO 2019 bathymetry.
Red dots represent
turbines with Hs sensors.

Example case

Uncertainty modelled using Gaussian process

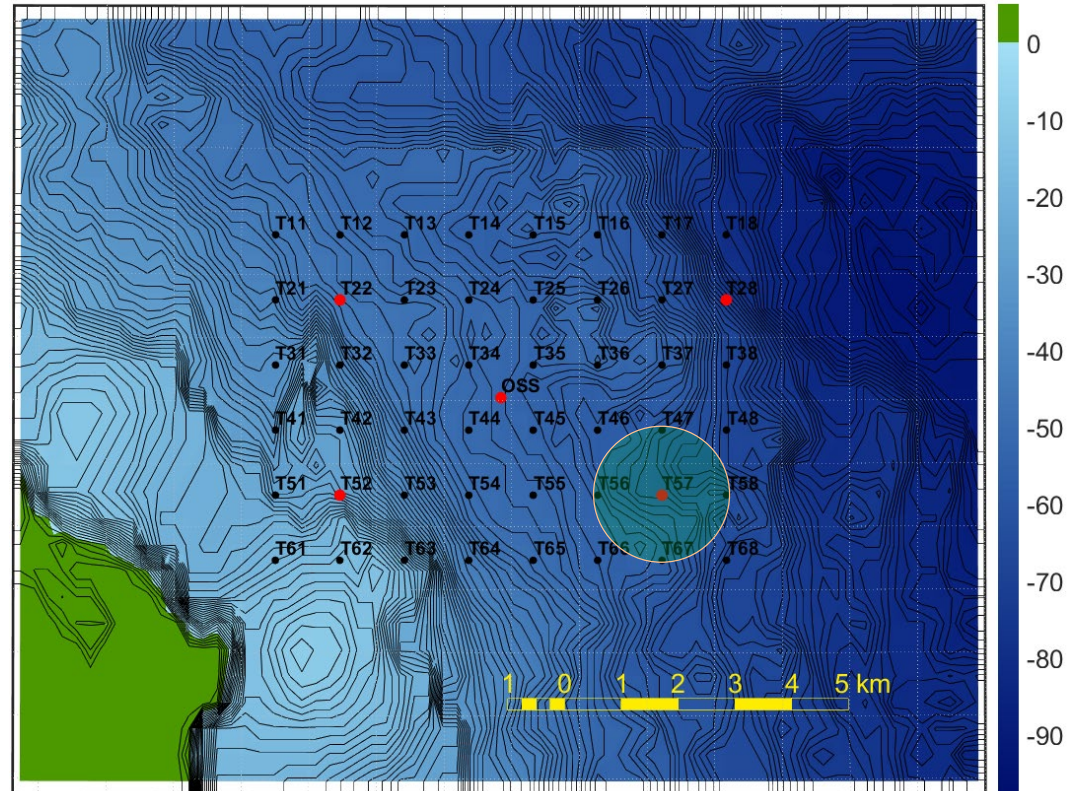


Hypothetical site in
Scotland.
GEBCO 2019 bathymetry.
Red dots represent
turbines with Hs sensors.
6% c.o.v across site.
Average of 10 model runs.

Variations in spatial scales

Local variations not always captured by Gaussian process

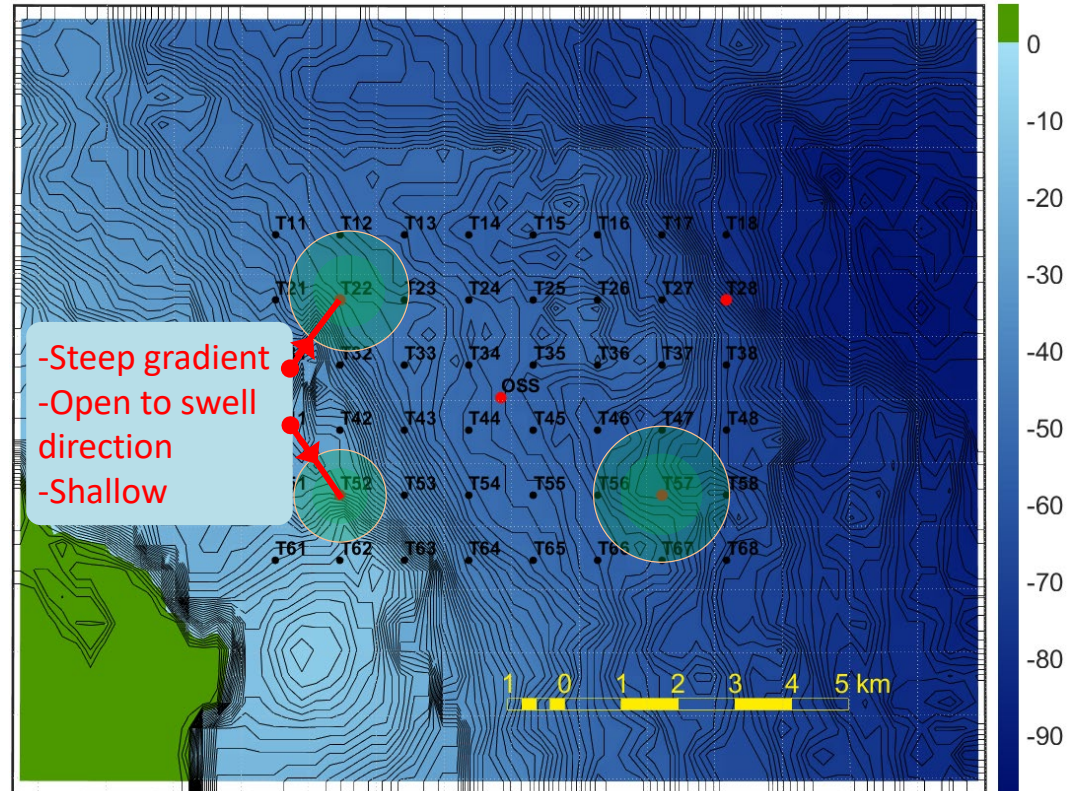
- Hs
- Swell
- Tide
- Current
- Wind
- Bathymetry



Variations in spatial scales

Local variations not always captured by Gaussian process

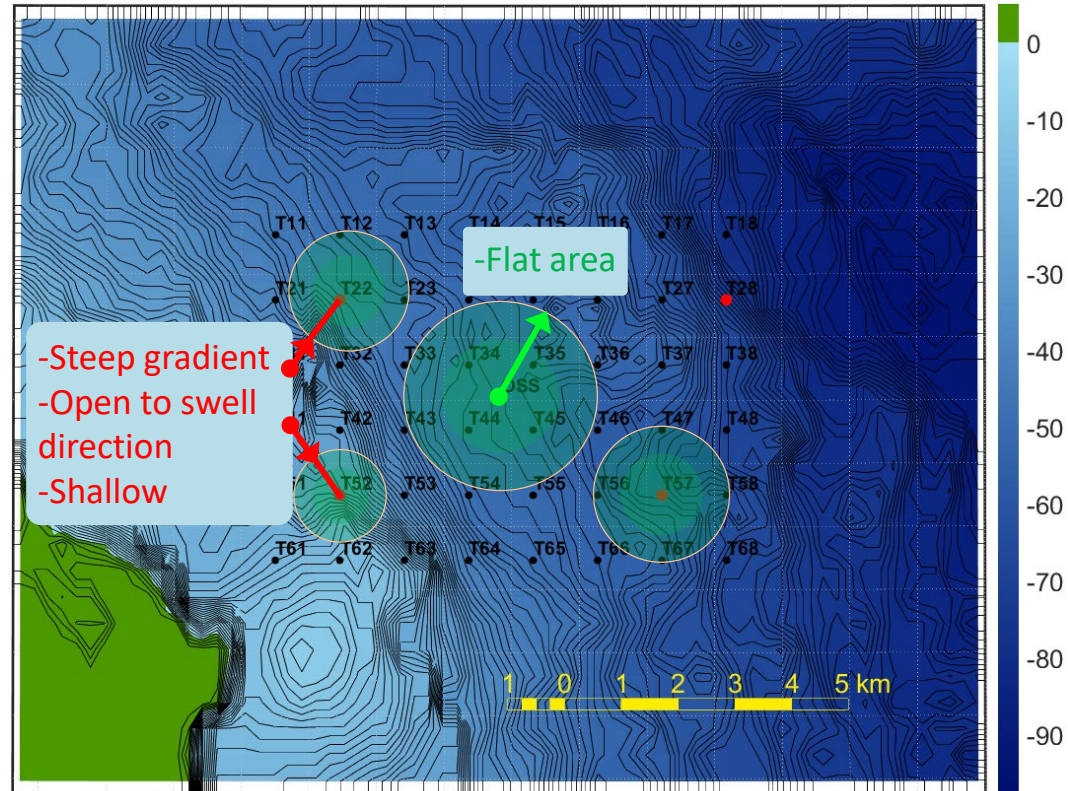
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Variations in spatial scales

Local variations not always captured by Gaussian process

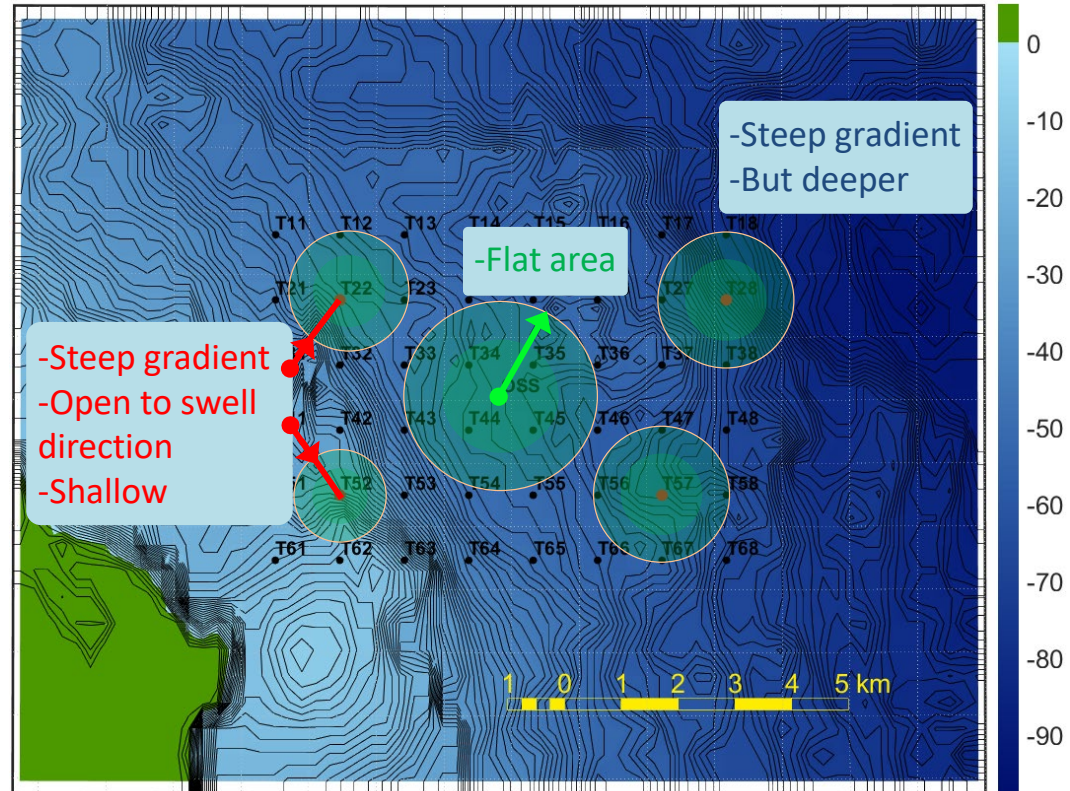
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Variations in spatial scales

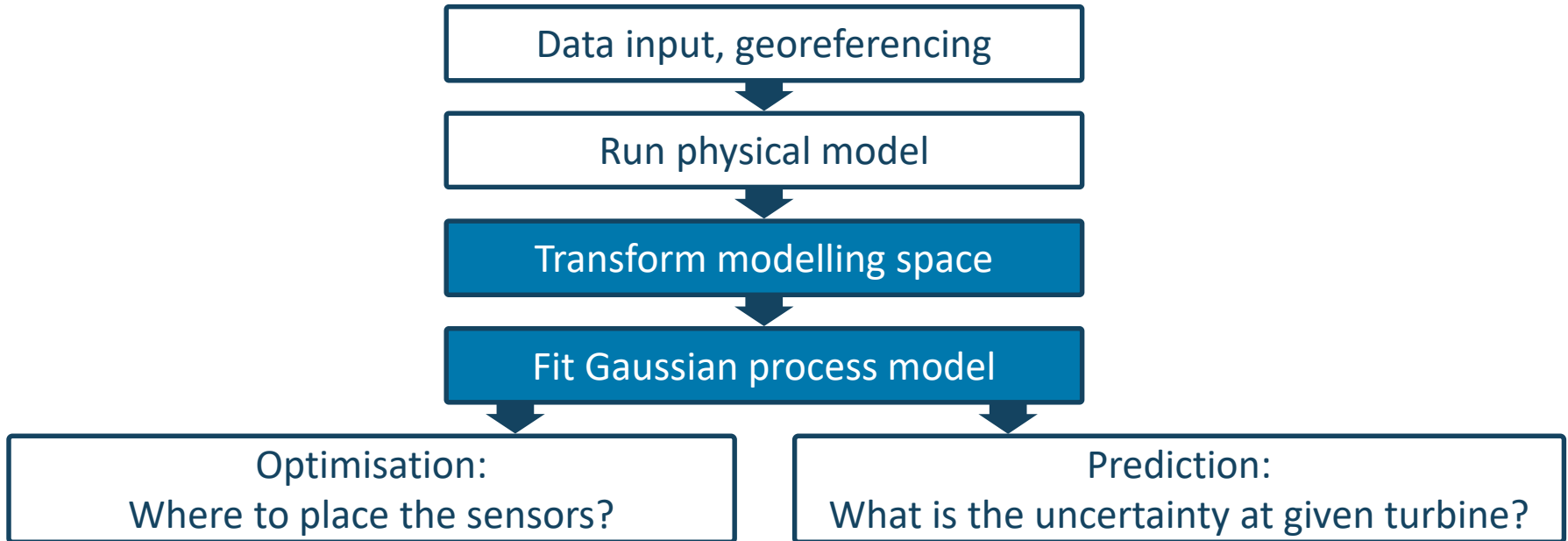
Local variations not always captured by Gaussian process

- Hs
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- Current
- Wind
- Bathymetry



Proposed framework

To include spatial uncertainty in decision-making



Conclusions

- We propose a framework to maximise the decision value of Hs point measurements
- 3-5 point measurements seen as optimum
 - Bathymetry mainly determines placement
- Value of uncertainty quantification in O&M decisions:
 - <£1 M per year per site
- Ongoing work:
 - Trials at two UK sites
 - Transformations
 - Validation

Thank you for your attention!

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