The value of tidal-stream energy resource to off-grid communities

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Motivation:

- Renewables have vital role in improving access to electricity and energy

  >20M people on >1800 islands[3] are paying up to €2000/mwh[2]

- Concern about "quality" of non-thermal renewables (e.g. clouds and wind gusts)

  e.g. to balance supply and demand expensive storage and system controls needed (e.g. battery ~ $500/kw)[3]

- We hypothesize tidal-stream energy to be "higher quality" (persistent, controllable and predictable), making the comparatively higher cost worthwhile.

Example: ~50% Faroe Islands electricity met by renewables (installed capacity double that of peak demand) with a 2.3MW battery[4], due to variability of renewable energy sources (wind, solar and thermal) leading some authors to conclude tidal energy is needed for the target of 100% renewable by 2030[5]

[1] doi.org/10.1016/j.esd.2012.05.006
[2] doi.org/10.1016/S0301-4215(03)00047-8
[3] doi.org/10.1016/j.enpol.2016.03.043
[4] doi.org/10.1016/j.renene.2018.12.042
[5] Nielsen et al. 2018, IHSPW

Power & electricity from a 1 MW turbine measured. Fine-scale power variability and predictability investigated

- 1 MW turbine, deployed as part of the ReDAPT project, at EMEC in the Fall of Warness (Orkney Islands, UK)
- 50 Hz generator power (in nacelle) and 10 Hz shore-side voltage
- 0.5Hz tidal speed measured with hub height ADCP nearby

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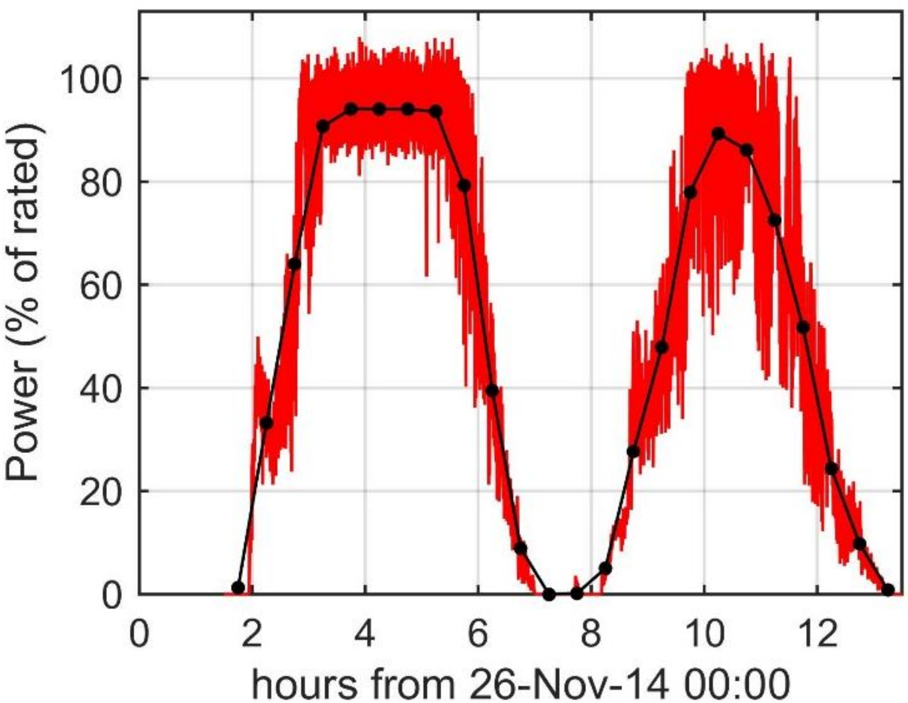
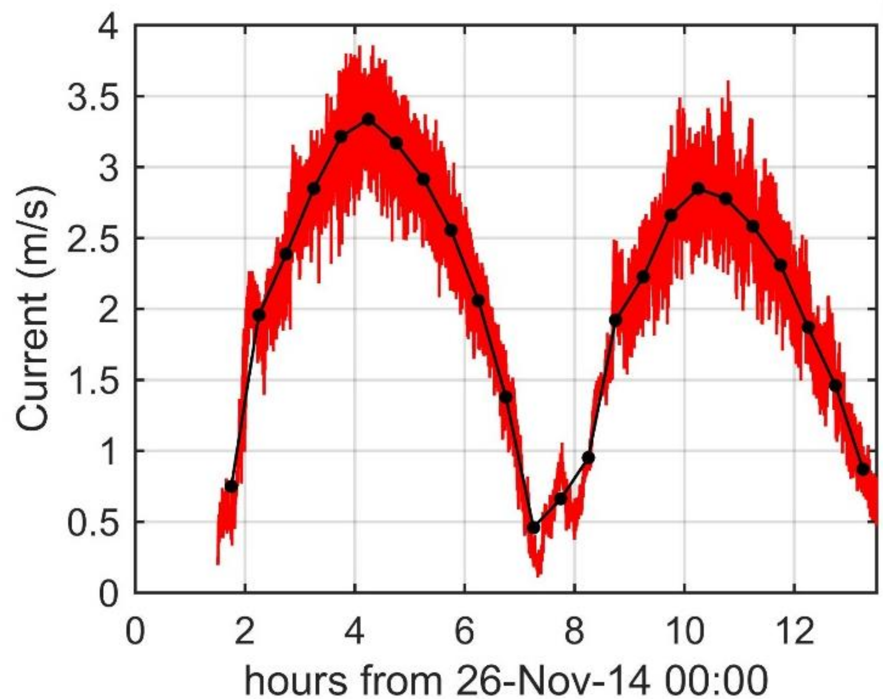
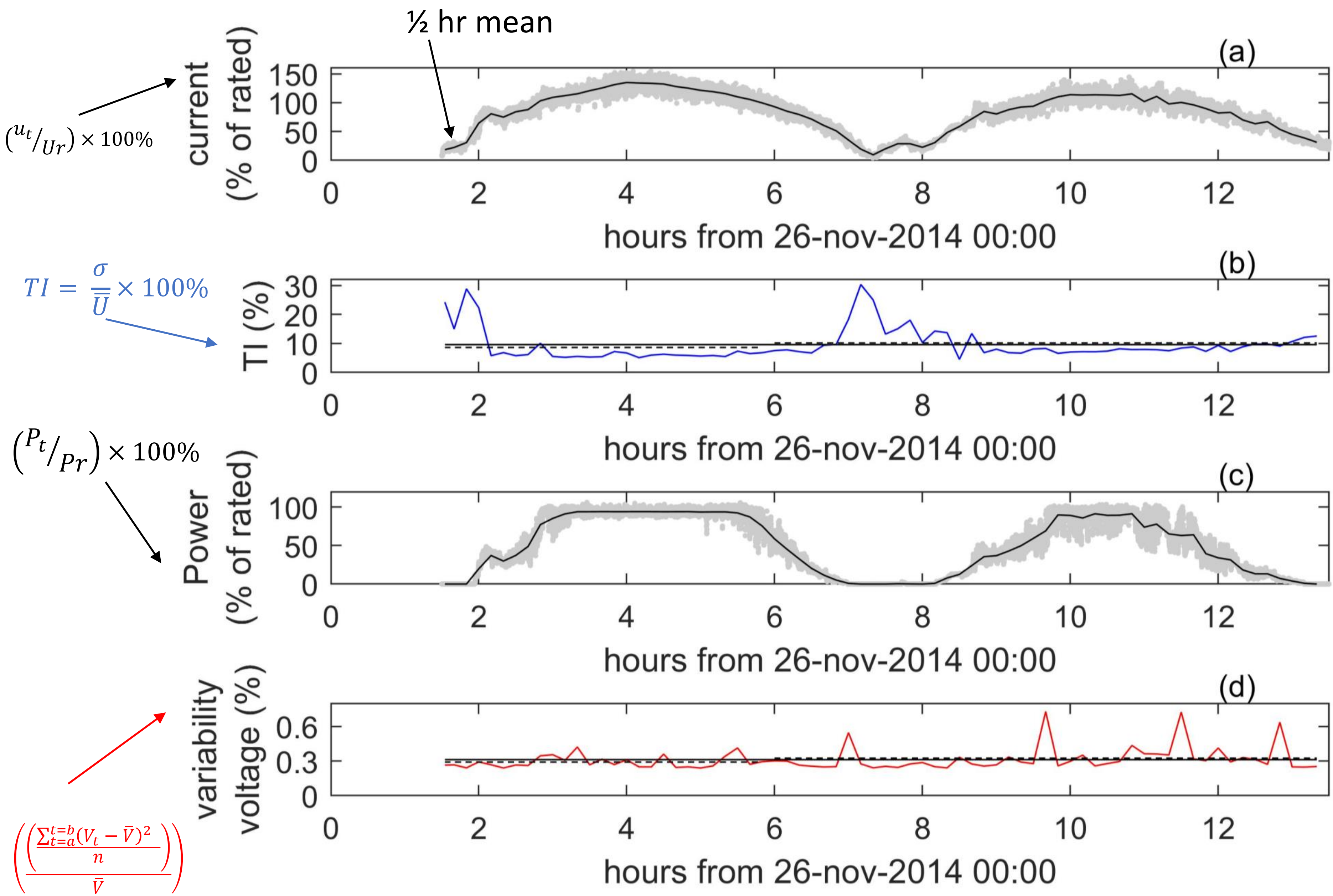
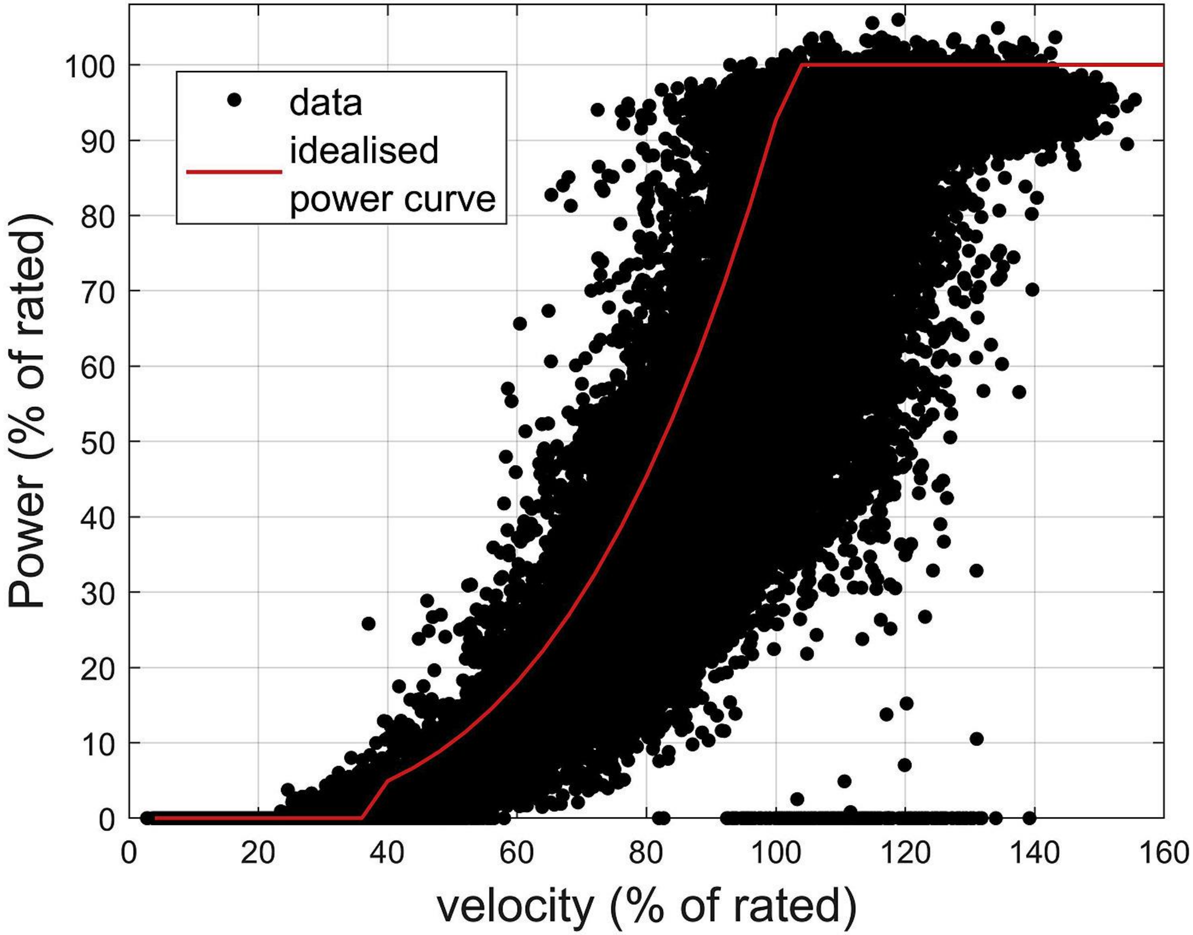




Data interpolated to common 0.5 Hz timeseries & normalised



- 2Hz measured power curve very different to "idealised" used in resource assessment
- Yet this fine-scale variability did not affect yield estimates (<1%)
- Observed variability of voltage was well within acceptable levels (~0.3% at 0.5Hz) & better than some other renewable energies

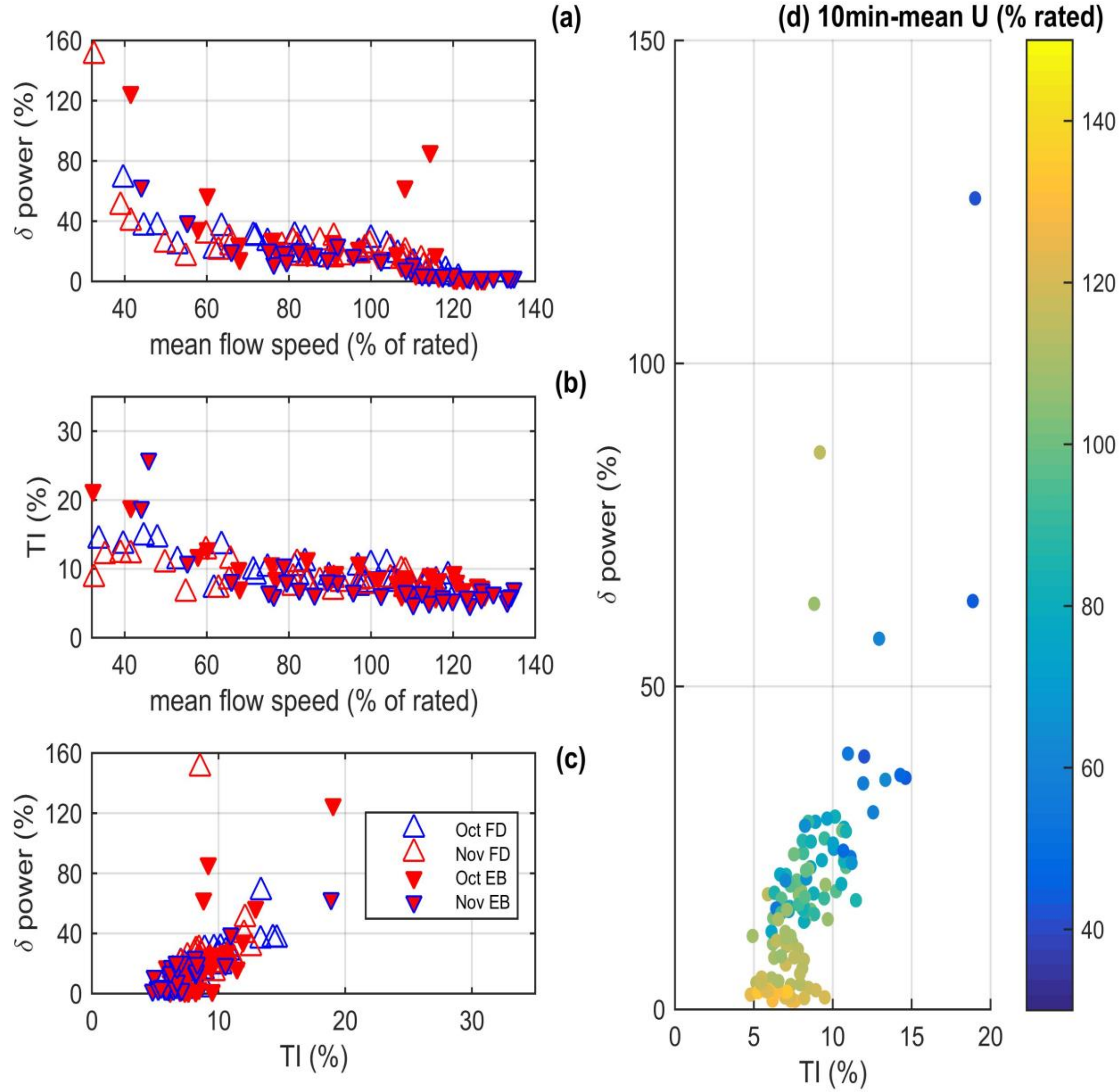


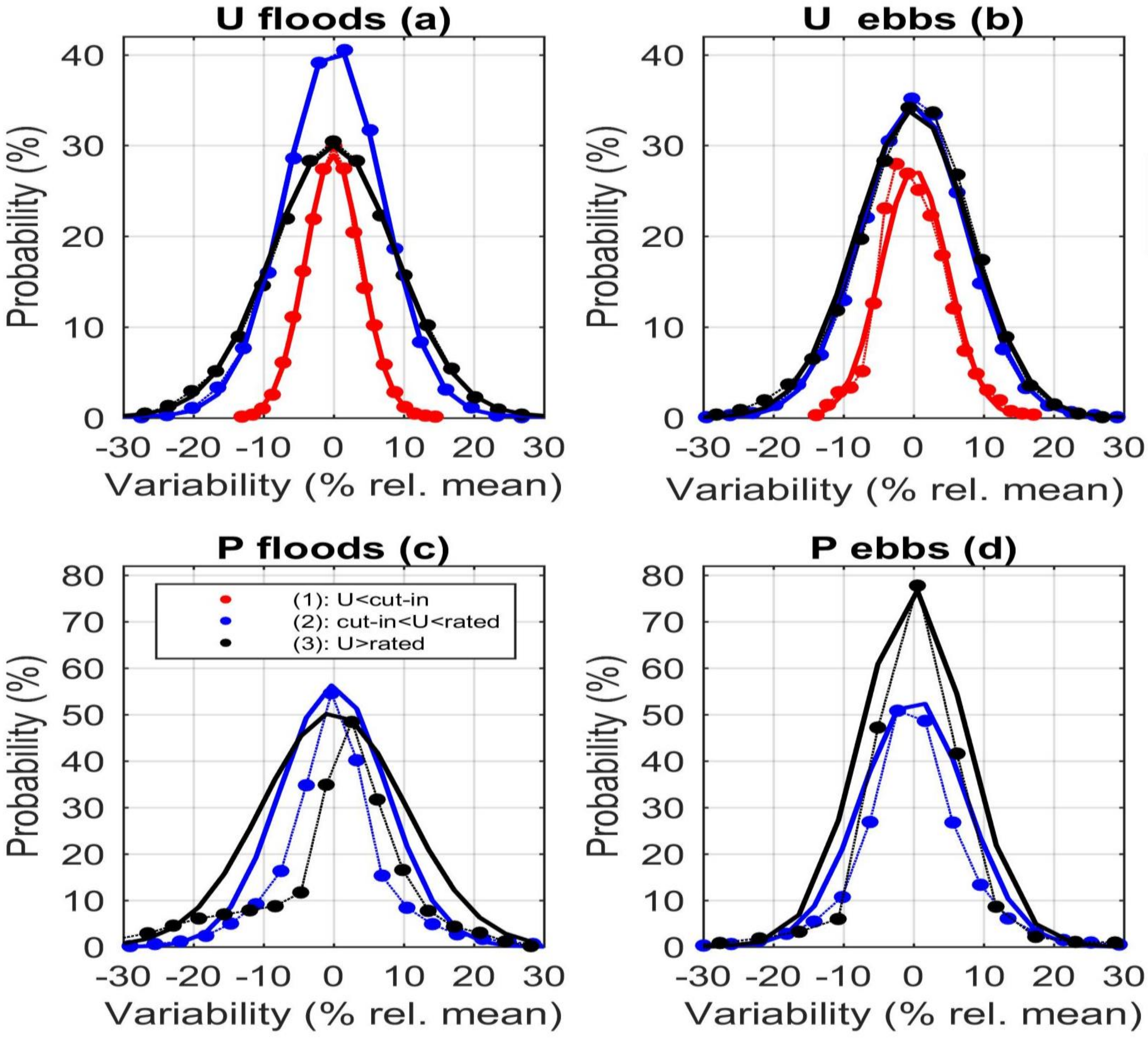
Overall 10min running-mean power variability was low (standard deviation 10–12% of rated power)

Power variability ($\delta power$) decreases with increasing flow speed *(U)*

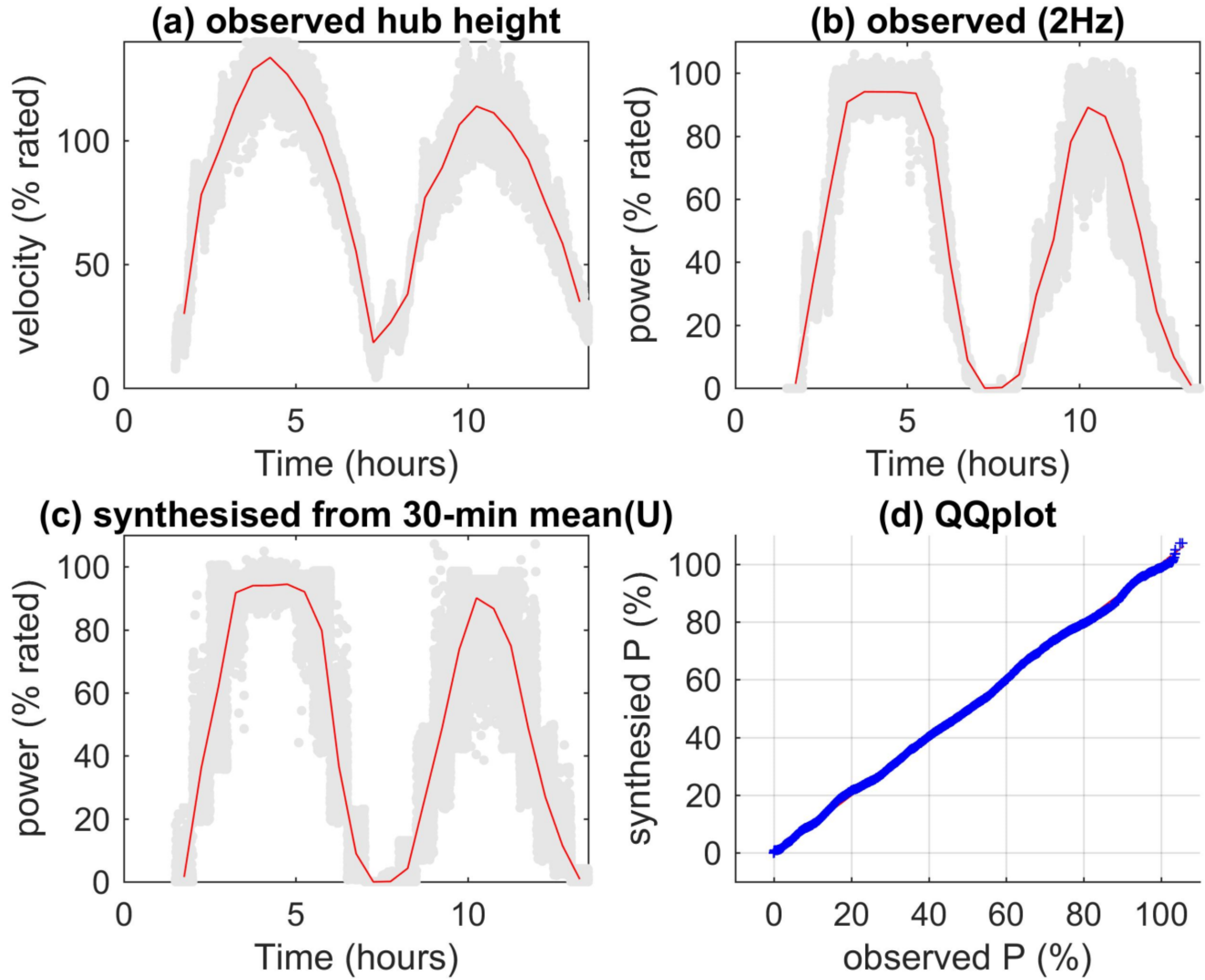
Turbulence Intensity (TI) decreases for increasing flow speed (U)

Power variability ($\delta power$) increases with Turbulence Intensity (*TI*)





- Variability of flow speed (U) normally distributed when grouped
- Variability of power (P) followed t-location distribution*
- Can use distribution to make synthetic noise



Synthetic power variability model reliably downscaled 30min modelled currents with standardized power curve to 0.5 Hz power (85% skill, 14% error & energy difference <0.7%)

Conclusions:

- Low variability (an order of magnitude lower than reported in wind)
- Synthetic power variability model downscaled 30-min ocean-model currents and "standardised" power curve to 0.5 Hz power
- **Tidal-stream energy may have a higher LCOE, but perhaps worth it?**

Future work and implications:

- Independence between data assumed

(synthetic model assumes turbulent fluctuation at *t* has no influence on *t+δt)*

- Apply analysis to battery size needed in off-grid communities?