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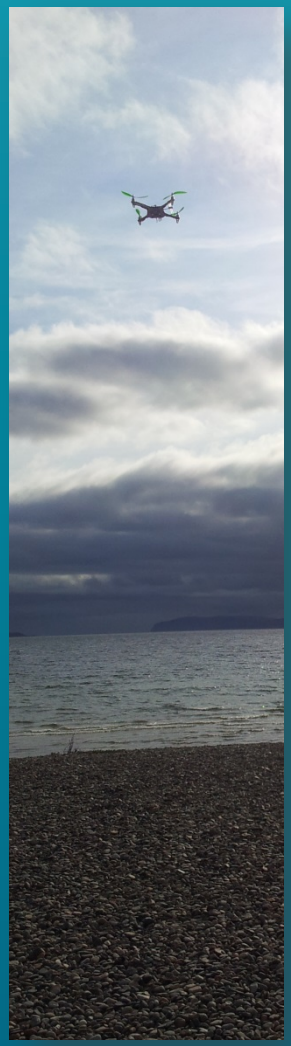
3rd ISARRA Conference,
Norman, Ok, U.S.
20-22 May 2015

Using a micro-UAV *as* a Portable Turbulence Profiler



Phil Anderson
Scottish Association for Marine Science, Oban, Scotland

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Talk overview

Introduction: measuring turbulence with aircraft.
- Scale bridging,
- Marine focus at SAMS
- the need for a portable turbulence profiler (PTP)

Engineering background: UAV avionics from the crowd:
- grass roots drivers and deliverers
- State of the Engineering and Kalman filters
- The multi-copter in “Loiter” mode

Case study: evening transition, 26th August 2013
- Conceptual model of the turbulence profile
- Spectra profiles

Future work

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Introduction: scale bridging

Turbulence profiles between 2 m and 200 m altitude bridges the scales from towers to larger piloted aircraft. Area surveys (10 – 1000 m)^2 necessary to assess advective terms. RPAS platforms augment field / aircraft campaigns, rather than replace them.

Some possible science applications:

- Model validation (notably LES)
- Model constraint (mesoscale)
- Process studies (flux / profile relationships)
- Discovery science: fine scale structure, biogeochem
- **Air/sea interaction, especially thermal, momentum and tracer flux**

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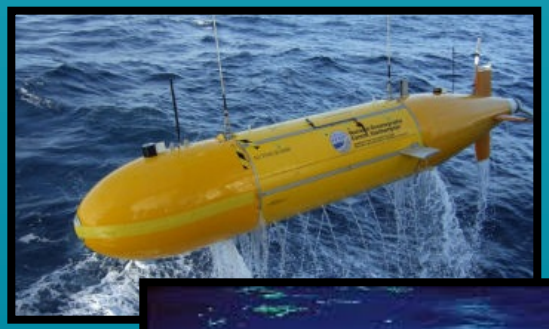
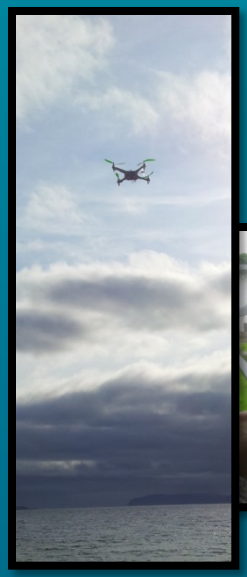
Introduction: marine focus at SAMS

Scot - MRF
The Scottish Marine Robotics Facility



Scottish Marine Robotics Facility :

combining a range of marine robotic platforms for air/sea interaction and spectral (optical) characteristics.



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Introduction: measuring turbulence with aircraft

Turbulence measurement from RPAS platforms often focuses on miniaturisation of the 5/multi-hole pitot tube techniques, i.e. miniaturisation of existing research aircraft sensors:

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Engineering background

"I could do science with this tomorrow!"

Prof. Rod Jones (Chemistry dept., University Cambridge) at Cardington Demonstration Flying Day, 2010, co-hosted by ES0802, Met Office and Royal Met. Soc.

The boundary layer turbulence community are ~~becoming~~ now aware of the possibilities of RPAS platforms.

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Engineering background: RPAS avionics from the crowd

Let the technology loose on hobby engineers who want to make flying robots ("DIYDrones" web site and blog)

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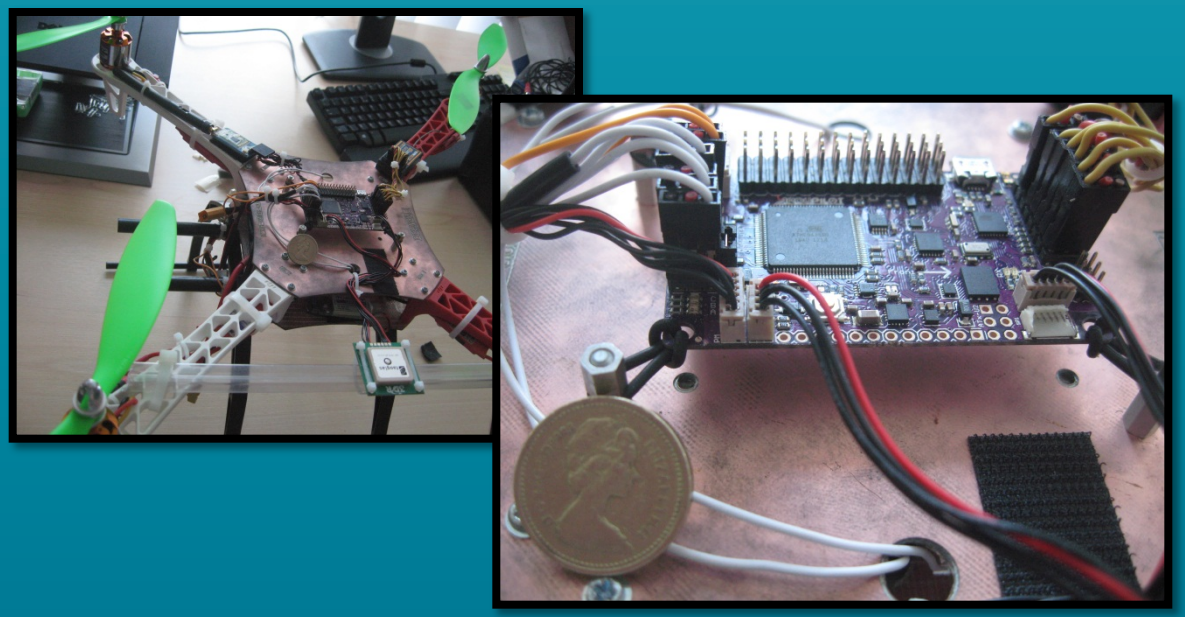
Engineering background: UAV avionics from the crowd



Result is *PixHawk*, an open-source avionics package for < £100.

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Engineering background: UAV avionics: loiter mode

The Quad-copter ***as*** a turbulence sensor: concept

PixHawk, like most RPAS avionics, has a "Loiter Mode", a function to get the aircraft to maintain a fixed position: either absolute to earth coordinates or relative to the ground station.

To maintain station, the avionics responds to mean winds and variable turbulence. The Portable Turbulence Profiler uses the avionic's diagnostic logs to estimates the TKE. Signature is implicit in the accelerometer and the motor command data.

There are no pitot tubes involved, only the platform and the avionics.

This results is an inexpensive (~ $1000) and robust (no delicate instruments to damage) sensor platform.

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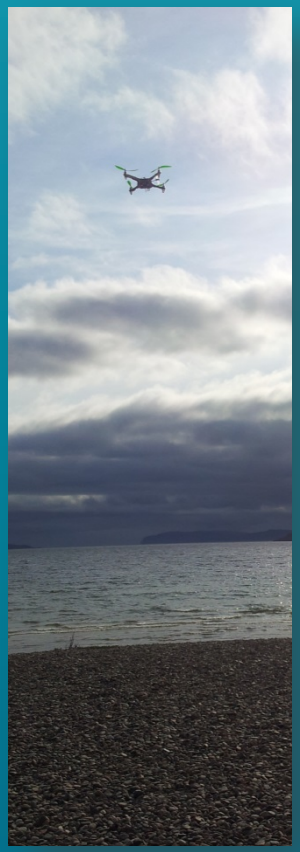
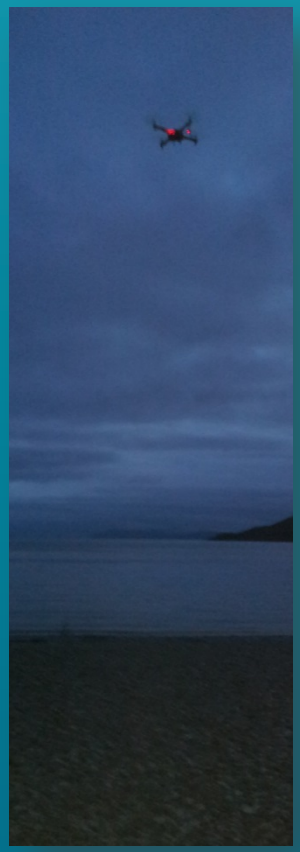
Case study: evening transition, 26th August 2013



17:40 BST

Two flights, on-shore breeze of ~ 6ms^{-1} in late afternoon, dropping to 2-3 ms^{-1} in late evening.

Flight profiles of one minute loiter at:
6, 12, 25, 50 and 100 m agl.



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Case study: evening transition, 26th August 2013

Present analysis from preliminary flights

3-axis linear acceleration
(3-axis rotational acceleration available)
(4 motor command values available)

Platform DJI F450
Pixhawk flight controller
Arducopter v3.

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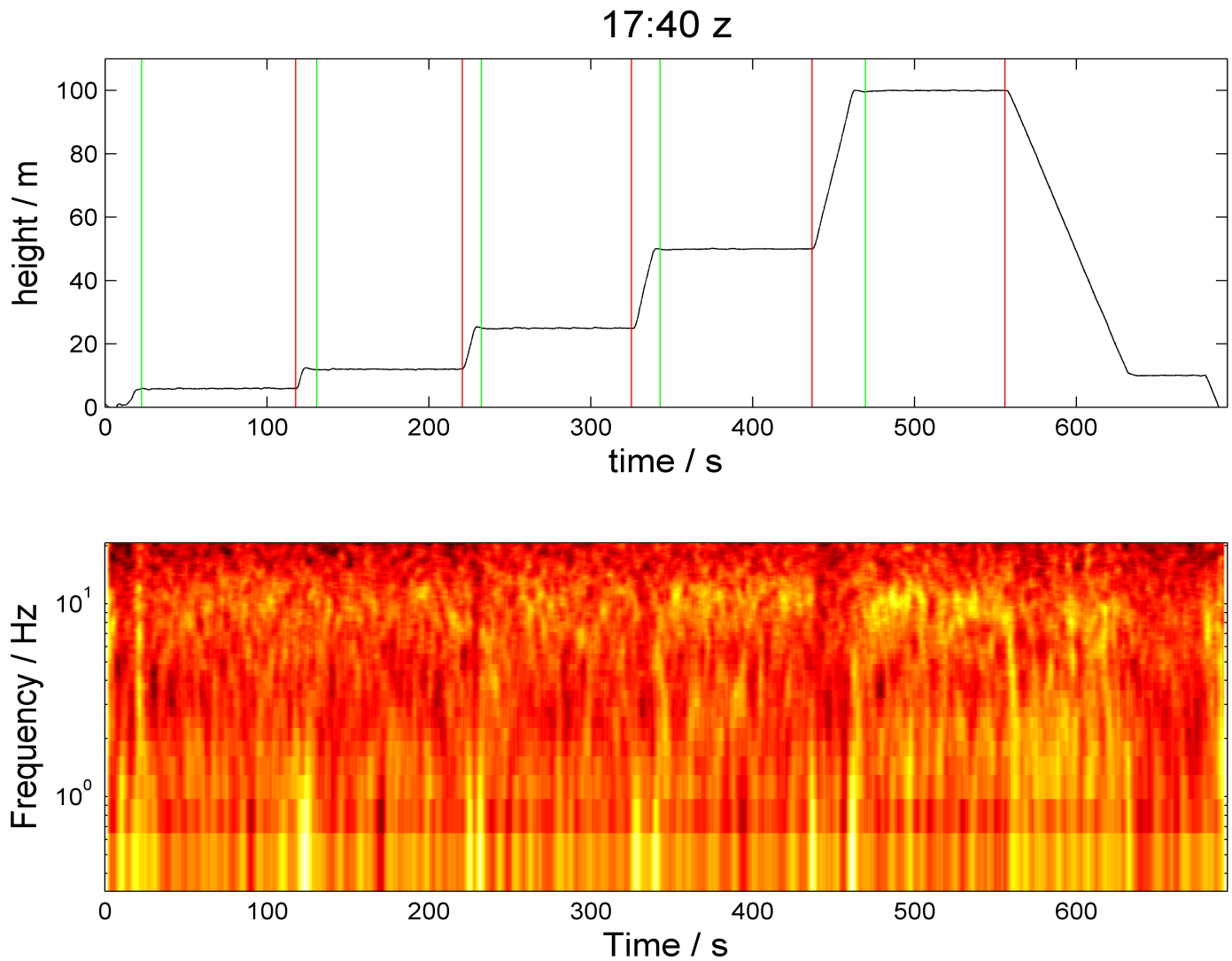
Case study: Afternoon, vertical acceleration



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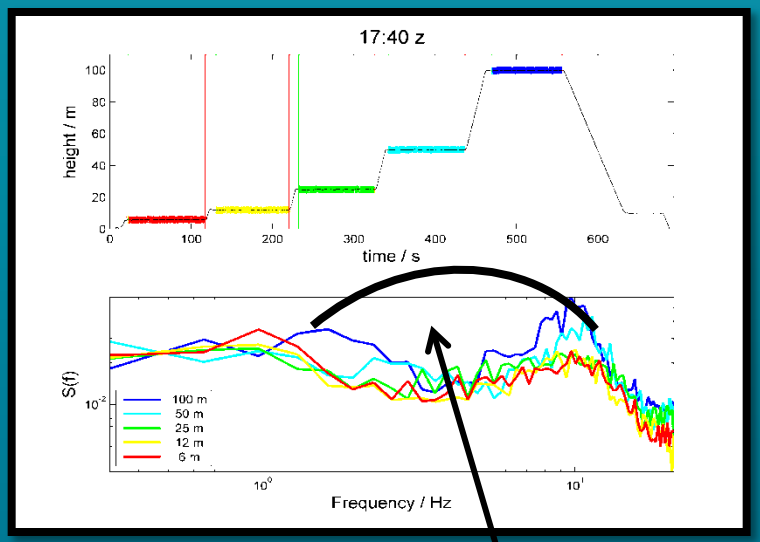
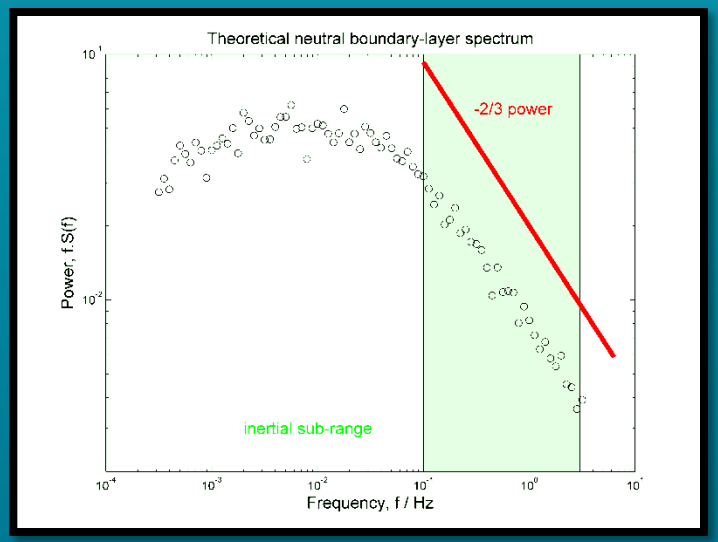
Case study: Afternoon, vertical acceleration

Measured spectra (vertical acceleration)



Theoretical spectra (vertical wind)



Assumed spectral gap due to motor response…

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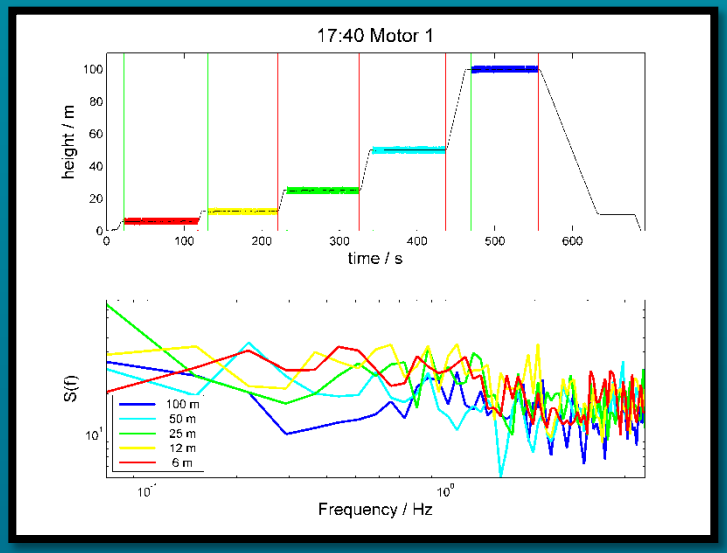
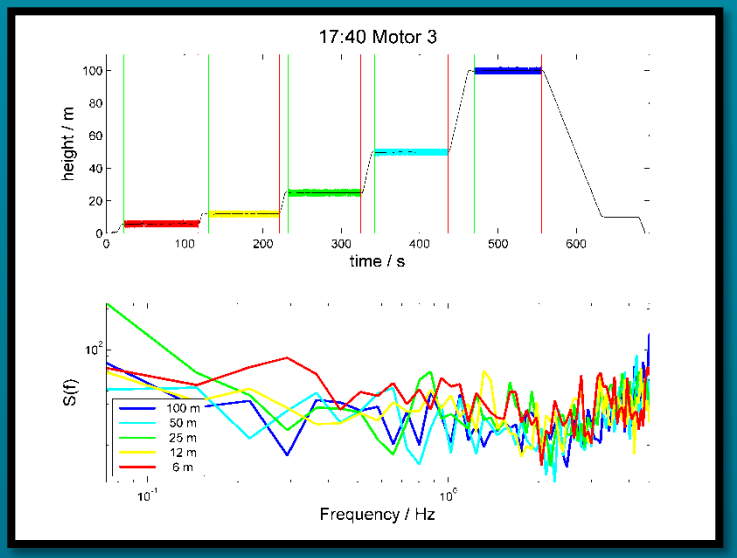
Case study: Afternoon, vertical acceleration

Measured Motor spectra not as expected: also, each motor has quite different control behaviour…





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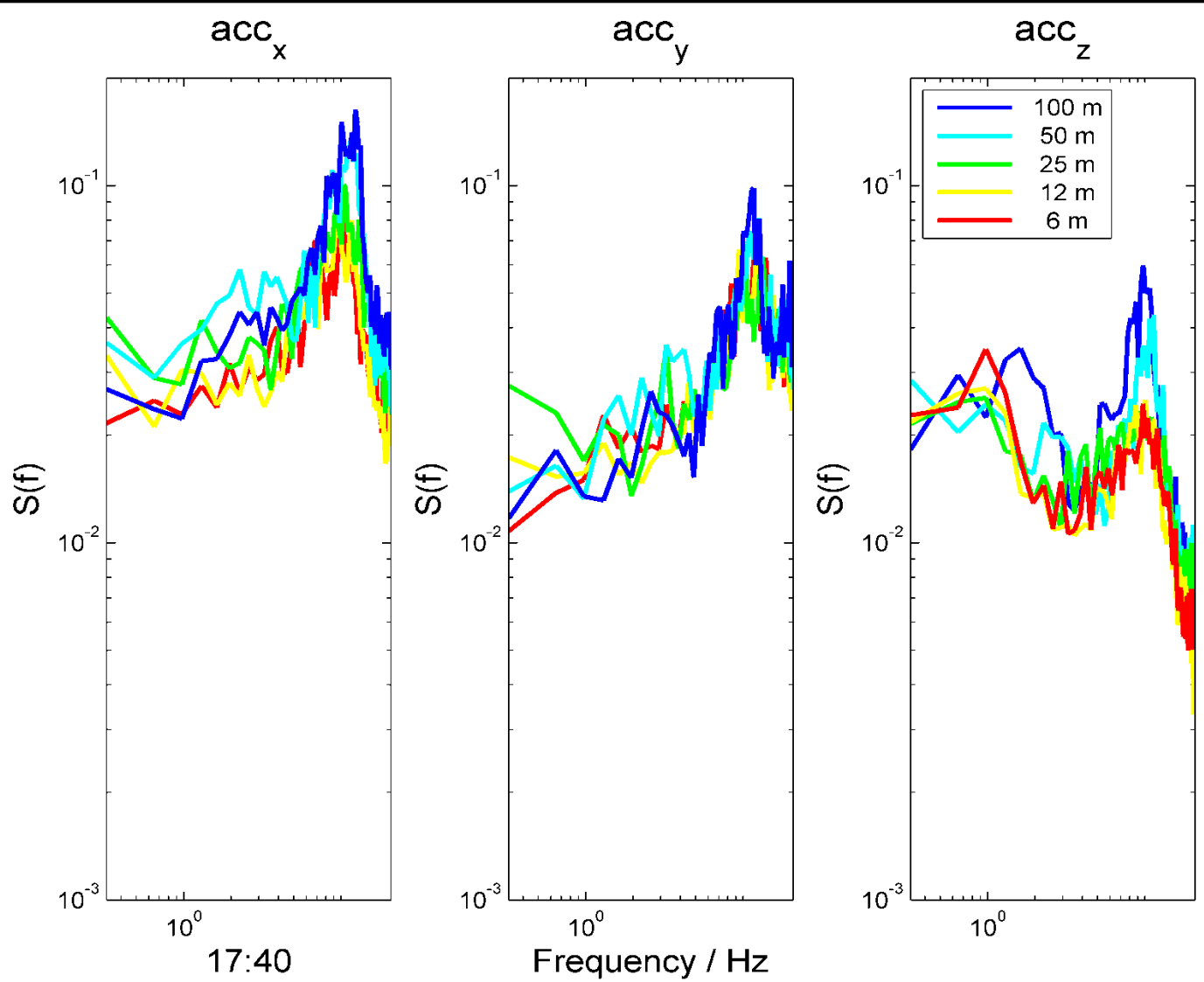
Case study: Afternoon, 3-axis acceleration



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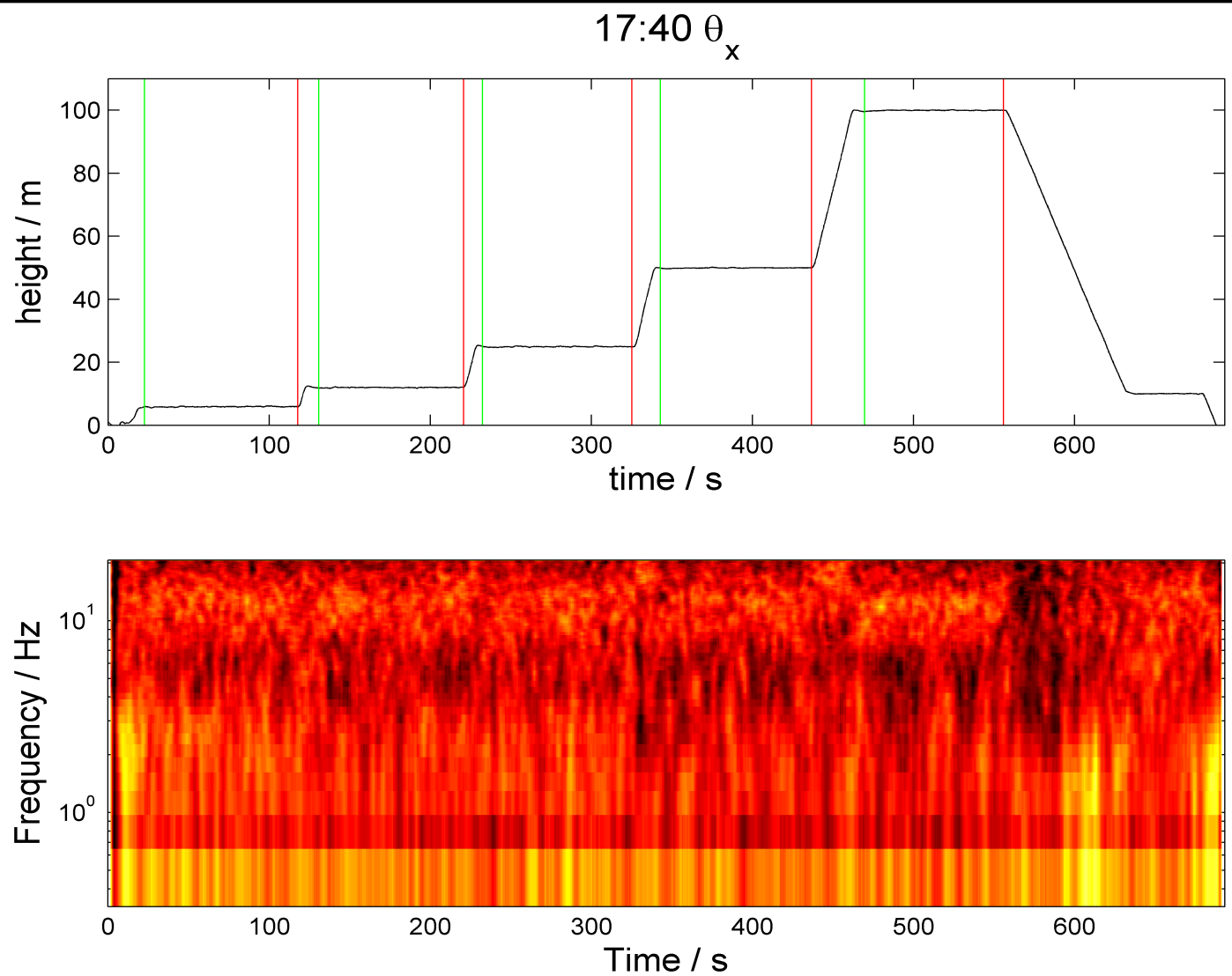
Case study: Afternoon, rotational acceleration: x-axis



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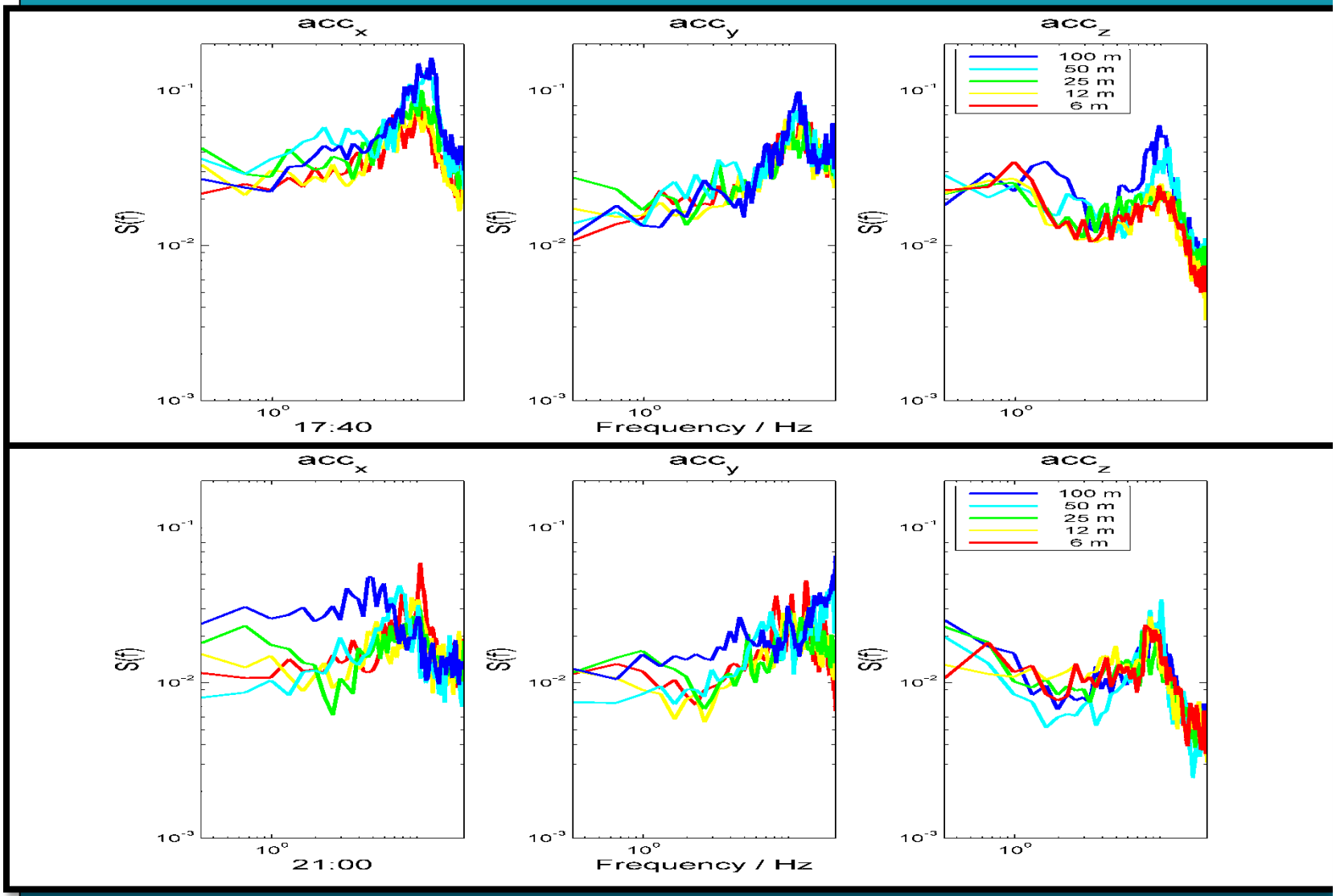
Case study: Afternoon – Evening comparison



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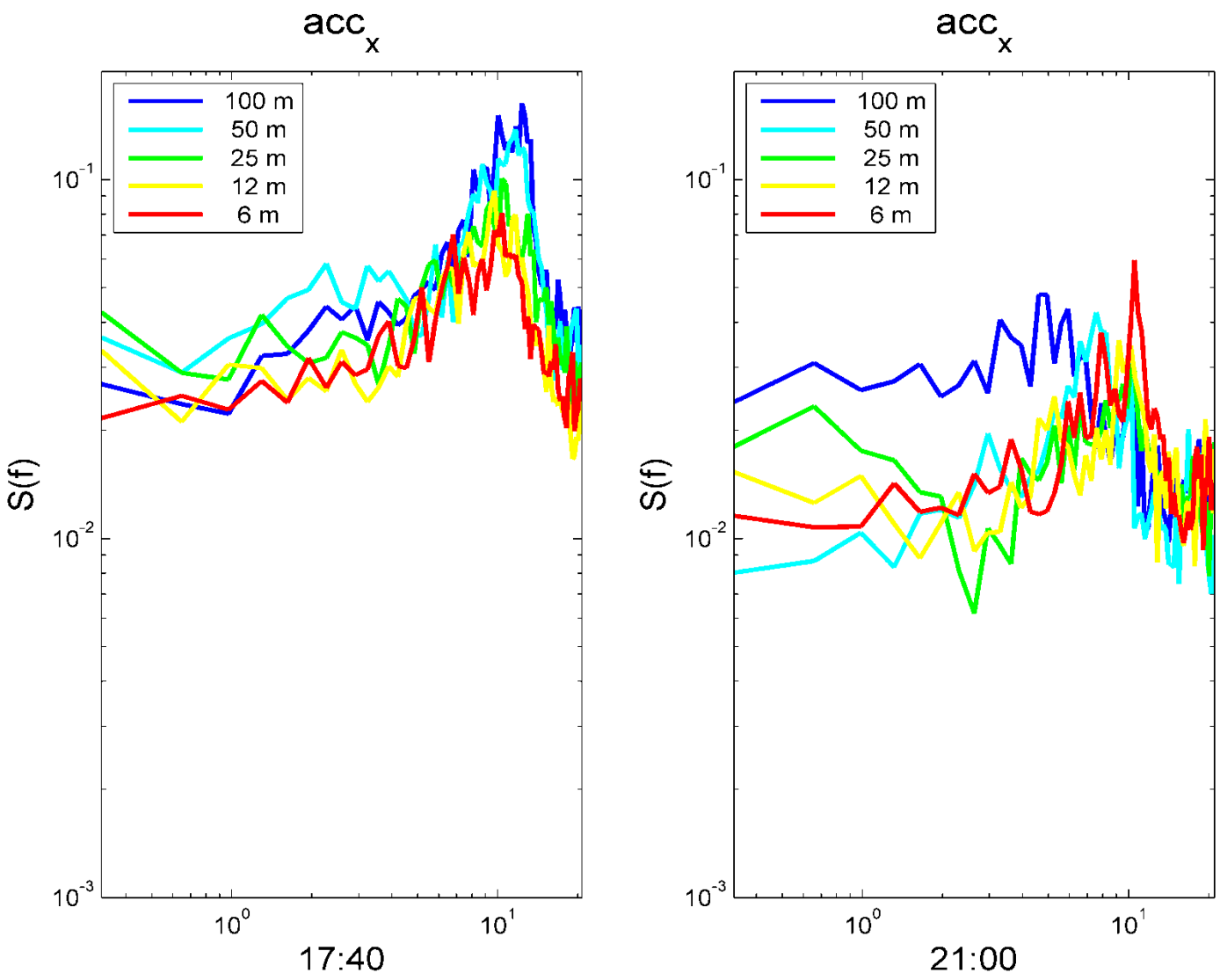
Case study: Afternoon – Evening comparison, horizontal acceleration



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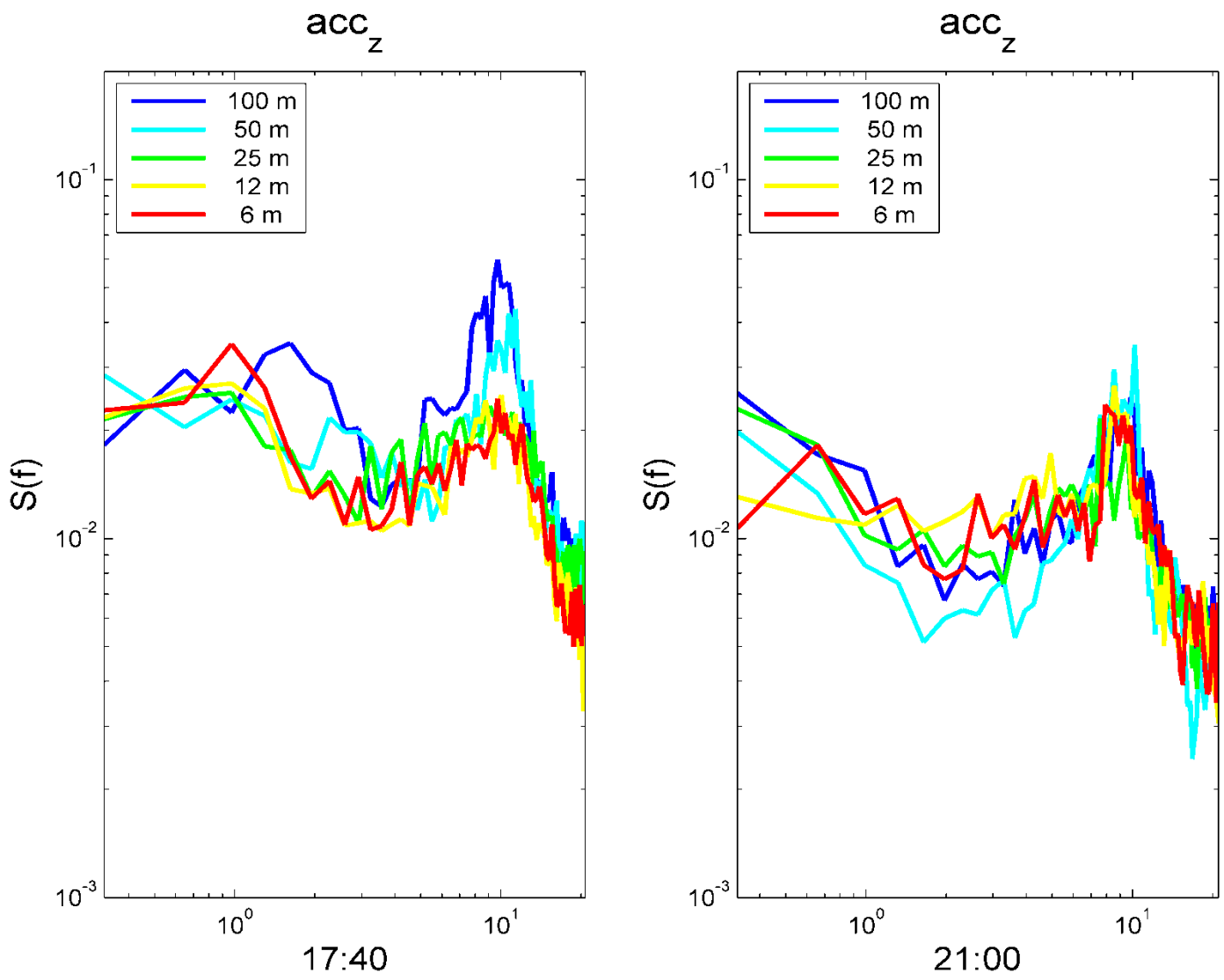
Case study: Afternoon – Evening comparison, vertical acceleration



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‘Conclusions’

Tentative conclusion that there is signal present that is ‘related’ to turbulence, but now need a more systematic and quantitative approach.

Need to assess whether further miniaturisation is necessary or even desirable.

Offers for a collaborative / MSc project!

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Questions?

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