Using a micro-UAV as a Portable Turbulence Profiler

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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
Introduction: scale bridging

Turbulence profiles between 2 m and 200 m altitude bridges the scales from towers to larger piloted aircraft. Area surveys \((10-1000 \text{ m})^2\) 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**
Introduction: marine focus at SAMS

Scottish Marine Robotics Facility:

combining a range of marine robotic platforms for air/sea interaction and spectral (optical) characteristics.
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:
“I could do science with this tomorrow!”


The boundary layer turbulence community are becoming now aware of the possibilities of RPAS platforms.
Let the technology loose on hobby engineers who want to make flying robots (“DIYDrones” web site and blog)
Engineering background: UAV avionics from the crowd

Result is *PixHawk*, an open-source avionics package for < £100.
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.
Case study: evening transition, 26th August 2013

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.

17:40 BST

21:00 BST
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.
Case study: Afternoon, vertical acceleration
Case study: Afternoon, vertical acceleration

Measured spectra (vertical acceleration)  Theoretical spectra (vertical wind)

Assumed spectral gap due to motor response…
Case study: Afternoon, vertical acceleration

Measured Motor spectra not as expected: also, each motor has quite different control behaviour…
Case study: Afternoon, 3-axis acceleration

- $a_{cx}$
- $a_{cy}$
- $a_{cz}$

$S(f)$

17:40

Frequency / Hz

100 m
50 m
25 m
12 m
6 m
Case study: Afternoon, rotational acceleration: x-axis
Case study: Afternoon – Evening comparison
Case study: Afternoon – Evening comparison, horizontal acceleration
Case study: Afternoon – Evening comparison, vertical acceleration
‘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!
Questions?