Investigation of the Southern Methane Anomaly using Unmanned Octocopters

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Global Methane Emissions

- Methane is a significant greenhouse gas connected with sudden shifts in climate.
- Wetlands are the largest source of methane emissions.
- Tropical methane sources and sinks are a significant component of the global methane budget.

<table>
<thead>
<tr>
<th>Source of CH₄ emissions</th>
<th>CH₄ (Tg yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil Fuels</td>
<td>96 [85–105]</td>
</tr>
<tr>
<td><strong>Ruminants</strong></td>
<td>89 [87–94]</td>
</tr>
<tr>
<td>Rice agriculture</td>
<td>36 [33–40]</td>
</tr>
<tr>
<td><strong>Biomass Burning</strong></td>
<td>35 [32–39]</td>
</tr>
<tr>
<td>Landfills &amp; Waste</td>
<td>75 [67–90]</td>
</tr>
<tr>
<td><strong>Wetlands</strong></td>
<td>217 [177–284]</td>
</tr>
<tr>
<td>Termites</td>
<td>11 [2–22]</td>
</tr>
<tr>
<td>Geological (incl. Oceans)</td>
<td>54 [33–75]</td>
</tr>
<tr>
<td><strong>Tropical Sources</strong></td>
<td>~200</td>
</tr>
<tr>
<td>Total</td>
<td>678 [542–852]</td>
</tr>
</tbody>
</table>

IPCC, 2014; Bousquet et al., 2006
The Southern Methane Anomaly

• Recently been a major anomaly in tropical methane growth – but little study into it.
• The figure shows **Growth rate** in ground-level methane, in ppb per year, 2000-2013, plotted against the sine of latitude *based on NOAA measurements.*
Different methane sources have different $\delta^{13}$C source signatures.

Relative to background ambient air which is $-47\%$ they are either enriched or depleted in $^{13}$C.

Ratio of isotopes are mainly temperature related.

<table>
<thead>
<tr>
<th>Source</th>
<th>$\delta^{13}$C$_{CH_4}$ %o</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass burning C4 vegetation</td>
<td>-17 ± 3</td>
</tr>
<tr>
<td>Biomass burning C3 vegetation</td>
<td>-26 ± 3</td>
</tr>
<tr>
<td>Gas North sea</td>
<td>-34 ± 3</td>
</tr>
<tr>
<td>Coal and industry</td>
<td>-35 ± 3</td>
</tr>
<tr>
<td>Ruminants C4 diet</td>
<td>-49 ± 4</td>
</tr>
<tr>
<td>Landfills</td>
<td>-53 ± 2</td>
</tr>
<tr>
<td>Wetlands: swamps</td>
<td>-55 ± 3</td>
</tr>
<tr>
<td>Rice Agriculture</td>
<td>-62 ± 3</td>
</tr>
<tr>
<td>Wetlands: bogs &amp; tundra</td>
<td>-65 ± 5</td>
</tr>
<tr>
<td>Ruminants C3 diet</td>
<td>-70 ± 4</td>
</tr>
</tbody>
</table>

Dlugokencky et al., 2011
Ascension Island

- UK Royal Airforce & United States Airforce Base
- Controlled Airspace with few unannounced visitors...
- Royal Holloway (with UK Met Office) has well-established high-precision continuous greenhouse gas monitoring and flask sampling on Ascension Island
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TWI Height: Monthly averages for years 1996 - 2010
# Proposed Platform

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Rotor Diameter</td>
<td>3.0 metres</td>
</tr>
<tr>
<td>Engine</td>
<td>150cc, 16 HP, 2-stroke gasoline engine</td>
</tr>
<tr>
<td>Batteries</td>
<td>Lithium Polymer for Avionics</td>
</tr>
<tr>
<td>Endurance</td>
<td>Up to 5+ hours</td>
</tr>
<tr>
<td>Climb Rate</td>
<td>400 fpm</td>
</tr>
<tr>
<td>Ceiling</td>
<td>1,500 m (2,000 m)</td>
</tr>
</tbody>
</table>

![Diagram of flight profile](image)

- **Sounding**
  - 10/02/2009
  - 10:00 (local)

- **TWI zone**

- **Surface Altitude**

- **Typical SR-200 Flight Profile**
Development of Octocopter and Payload

Fast (<1s) Thermistor

Capacitive humidity sensor
## Development of Octocopter and Payload

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Take Off Weight (inc. batteries)</td>
<td>10kg</td>
</tr>
<tr>
<td>Diagonal rotor-rotor distance</td>
<td>1.07m</td>
</tr>
<tr>
<td>Maximum battery capacity</td>
<td>32,000mAh 6 cell Lithium Polymer</td>
</tr>
<tr>
<td>Motors</td>
<td>T-Motor MN3515 400KV</td>
</tr>
<tr>
<td>Propellers</td>
<td>T-Motor 16x5.4”</td>
</tr>
<tr>
<td>Autopilot</td>
<td>Pixhawk by 3D Robotics</td>
</tr>
<tr>
<td>Autopilot software</td>
<td>ArduCopter v3.1.5</td>
</tr>
<tr>
<td>Safety pilot control link</td>
<td>FrSky L9R 2.4GHz</td>
</tr>
<tr>
<td>Ground Control Station link</td>
<td>Ubiquiti 5GHz directional</td>
</tr>
<tr>
<td>Onboard computing</td>
<td>BeagleBone Black</td>
</tr>
</tbody>
</table>
Ascension Island Map and Launch Site

Measurement Periods:
10th - 19th Sept 2014
4th - 16th July 2015
UAV Permissions

Ascension
Research Permit
Island Government
Police
GCHQ Ascension
USAF and RAF
Commanders and Tower
Fire service

UK
CAA Permissions
UAS Certification
Insurance
NOTAM

Ascension Island
Air Safety Support International
USAF UAS range safety permit
Insurance
NOTAM

Operating in a remote place does not necessarily make the permissions to fly any easier!
Flight Operations: On site

Crew:
- Rick Thomas – Mission Director and Scientist
- Tom Richardson – Ground pilot/Aeronautical Engineer
- Colin Greatwood – Manual Pilot/Engineer
- Jim Freer – Flight and campaign Logistics
- Rebecca Brownlow/Dave Lowry: Sample analysis

- Daily Flight Routine
- Check Met Office weather e-mail
- Collect Radios from US Fire Department
- Check-in with air traffic control on RAF base
- Optional discussion with met office
- Plan initial flight and day strategy
- Prepare aircraft/sample bags
- Run through UAV checklist and fly
Site Surface Meteorology
Max Alt Flight Profiles

![Graph showing flight profiles over time with specific events and markers.](image-url)
Flight Operations: Descent in low wind speeds

![Graph showing temperature and pitch & roll angles against altitude.]

Vortex ring state
Flight Operations: Descent in low wind speeds: Solution

- Low air speed above 1350m
- Include horizontal excursion (dogleg) - Increase apparent horizontal airspeed ‘Cleaner’ air
- Used pitch and roll to calculate WS
- Aim to improve stability

Implementing the Solution

- Two flights on same day - Similar conditions
- Second flight includes dogleg
- 41% less power used descending through still air
- Same flight time, much more stable platform
Flight Operations: Ascent into high Wind Speeds

17/09/2014 12:41

17/09/2014 14:36

Colin M. Greatwood, Thomas S. Richardson, Jim Freer, Rick Thomas, and Euan Nisbet.

AI Results: Quick Video
AI Results: CH$_4$ Conc and Isotope data

a) Comparison of CH$_4$ mole fraction variation with altitude for two field campaigns in September 2014 and July 2015. b) Comparison of $\delta^{13}$C$_{CH_4}$ variation with altitude between the two field campaigns in September 2014 and July 2015.

Biomass burning and wetland influence from Africa in July?
Results: Profiles Sept 2014
Results: Profiles July 2015
Conclusions

Successful campaigns – Yes!

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low wind Speeds</td>
<td>Change flight plan</td>
</tr>
<tr>
<td>High Wind Speeds</td>
<td>Calculate wind profiles on the fly</td>
</tr>
<tr>
<td>Difficult communications on high</td>
<td>Build a UAV tracker antenna</td>
</tr>
<tr>
<td>Need to collect other gases</td>
<td>Develop flask collection system</td>
</tr>
</tbody>
</table>

Take home messages
- Keep things simple and build up to full capability
- This is not easy – needs a skilled team with clear defined roles
- Real time information essential for safe flight operations
THANK YOU FOR YOUR ATTENTION!

Dr Rick Thomas, r.thomas@bham.ac.uk

And to:
- NERC - Grant: NE/K005979/1
- Ascension Island Government
- RAF and USAF
- Ascension Island Police Force
- People of Ascension Island


Practical use of mini- and micro-Unmanned Aerial Vehicles for the Environmental Sciences - See more at: http://www.sams.ac.uk/education/short-courses/unmanned-aerial-vehicles#sthash.6SWr9wsj.dpuf