Investigation of the Southern Methane Anomaly using Unmanned Octocopters

Dr Rick Thomas[1], Dr Colin Greatwood[2], Dr Tom Richardson[2], Prof. Jim Freer[2], Prof. Rob MacKenzie[1], Rebecca Brownlow[3],
David Lowry[3], Rebecca E. Fisher[3], James France[4], Euan G. Nisbet[3]

1.The University of Birmingham, UK; 2.University of Bristol, Bristol, UK; 3.Royal Holloway, University of London, Egham, UK; 4.Univ. of East Anglia, Norwich, UK

Global Methane Emissions

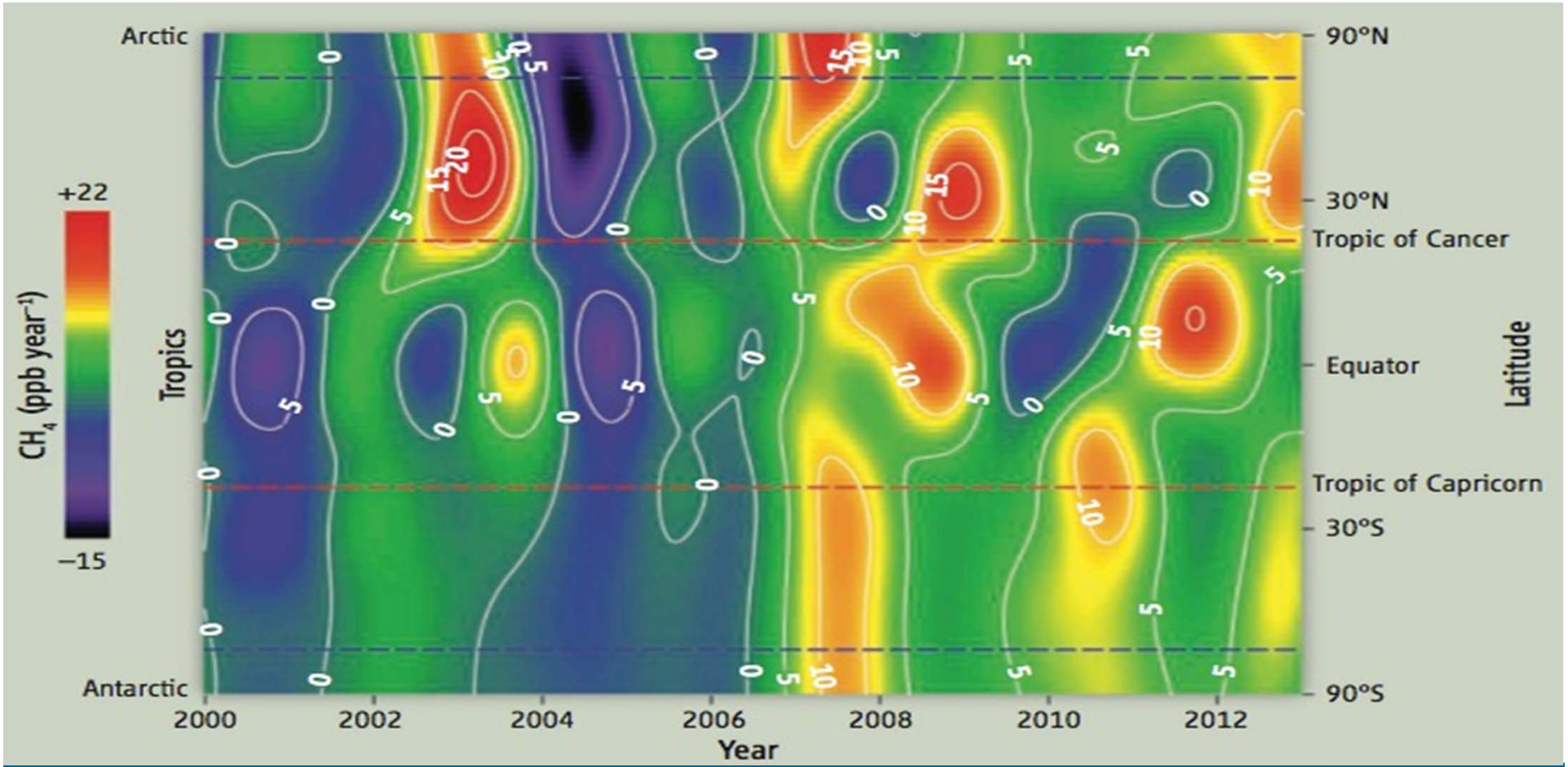
- Methane is a significant greenhouse gas connected with sudden shifts in climate.
- Wetlands are the largest source of methane emissions.
- Tropical methane sources and sinks are a significant component of the global methane budget.

Source of CH_4 emissions	CH_4 (Tg yr^{-1})
Fossil Fuels	96 [85–105]
Ruminants	**89 [87–94]**
Rice agriculture	36 [33–40]
Biomass Burning	**35 [32–39]**
Landfills & Waste	75 [67–90]
Wetlands	**217 [177–284]**
Termites	11 [2–22]
Geological (incl. Oceans)	54 [33–75]
Tropical Sources	**~200**
Total	678 [542–852]

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.*



Nisbet et al., Science 2014

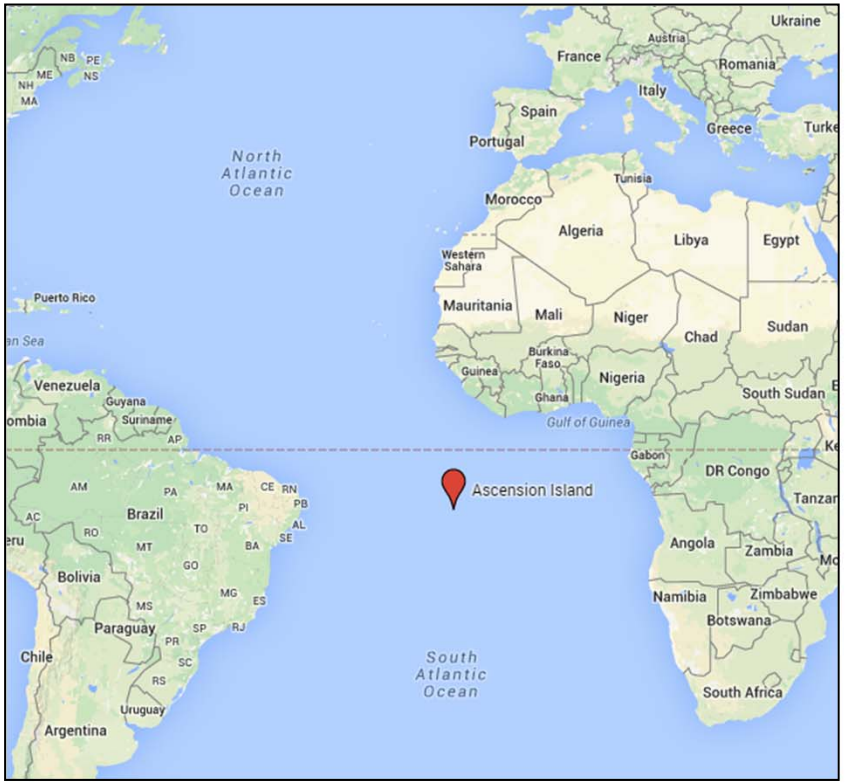
Isotopic Source Signatures

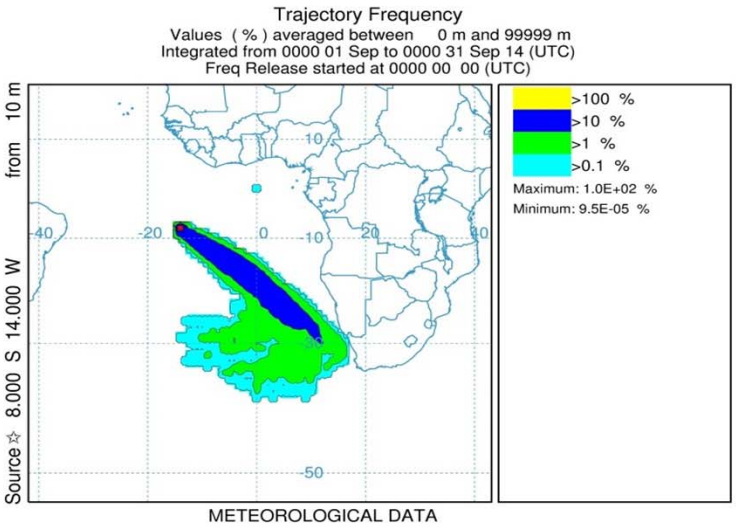
- Different methane sources have different $\delta^{13}C$ source signatures.
- Relative to background ambient air which is −47‰ they are either enriched or depleted in ^{13}C.
- Ratio of isotopes are mainly temperature related.

Source	$\delta^{13}C_{CH4}$ ‰
Biomass burning C4 vegetation	-17 ±3
Biomass burning C3 vegetation	-26 ±3
Gas North sea	-34 ±3
Coal and industry	-35 ±3
Ruminants C4 diet	-49 ±4
Landfills	-53 ±2
Wetlands: swamps	-55 ±3
Rice Agriculture	-62 ±3
Wetlands: bogs & tundra	-65 ±5
Ruminants C3 diet	-70 ±4

Dlugokencky et al., 2011

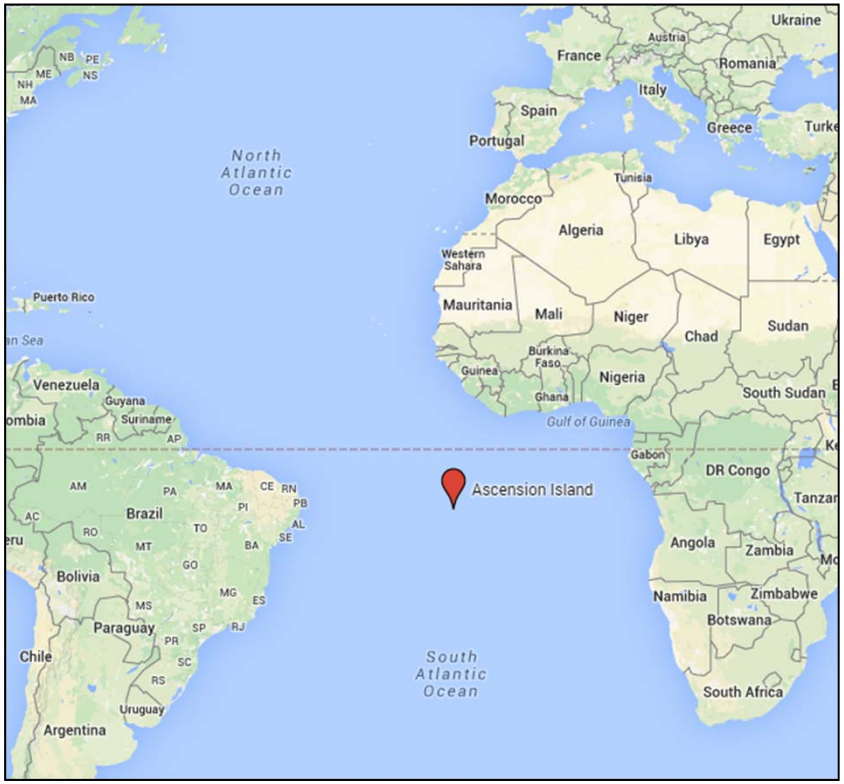
Ascension Island

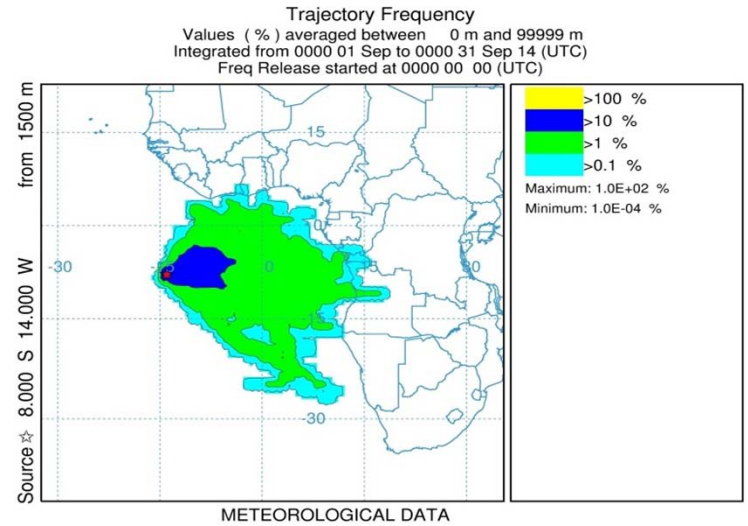




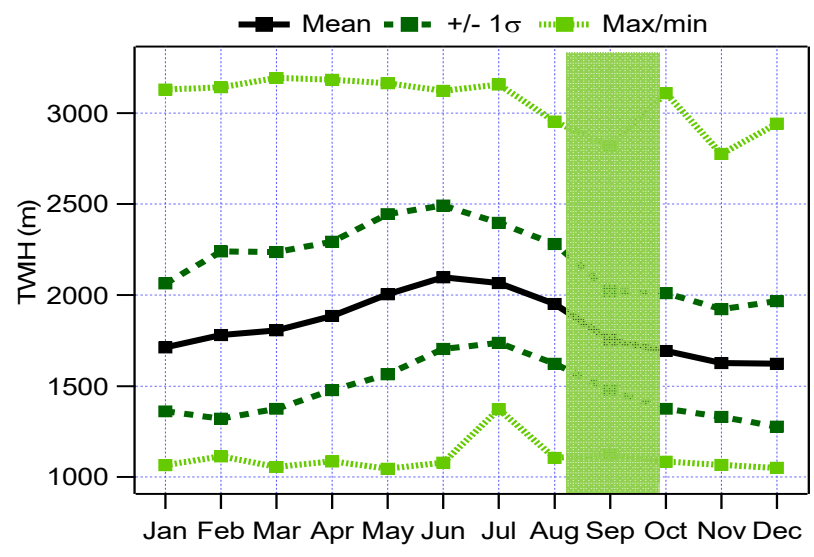
- UK Royal Airforce & United States Airforce Base
- Controlled Airspace with few unannounced visitors…
- Royal Holloway (with UK Met Office) has well-established high-precision continuous greenhouse gas monitoring and flask sampling on Ascension Island

Ascension Island





TWI Height: Monthly averages for years 1996 - 2010



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- Controlled Airspace with few unannounced visitors…
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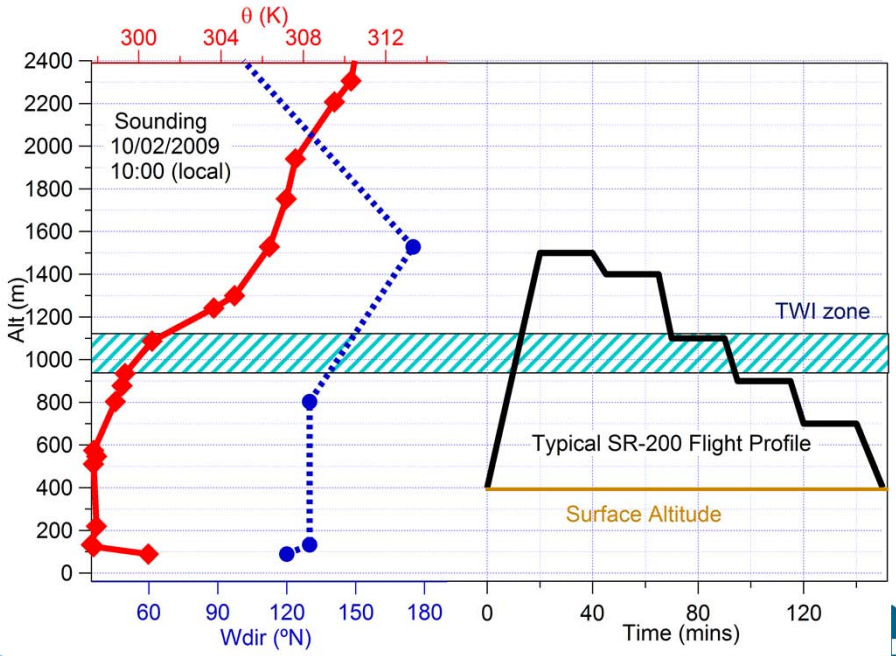
Proposed Platform

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

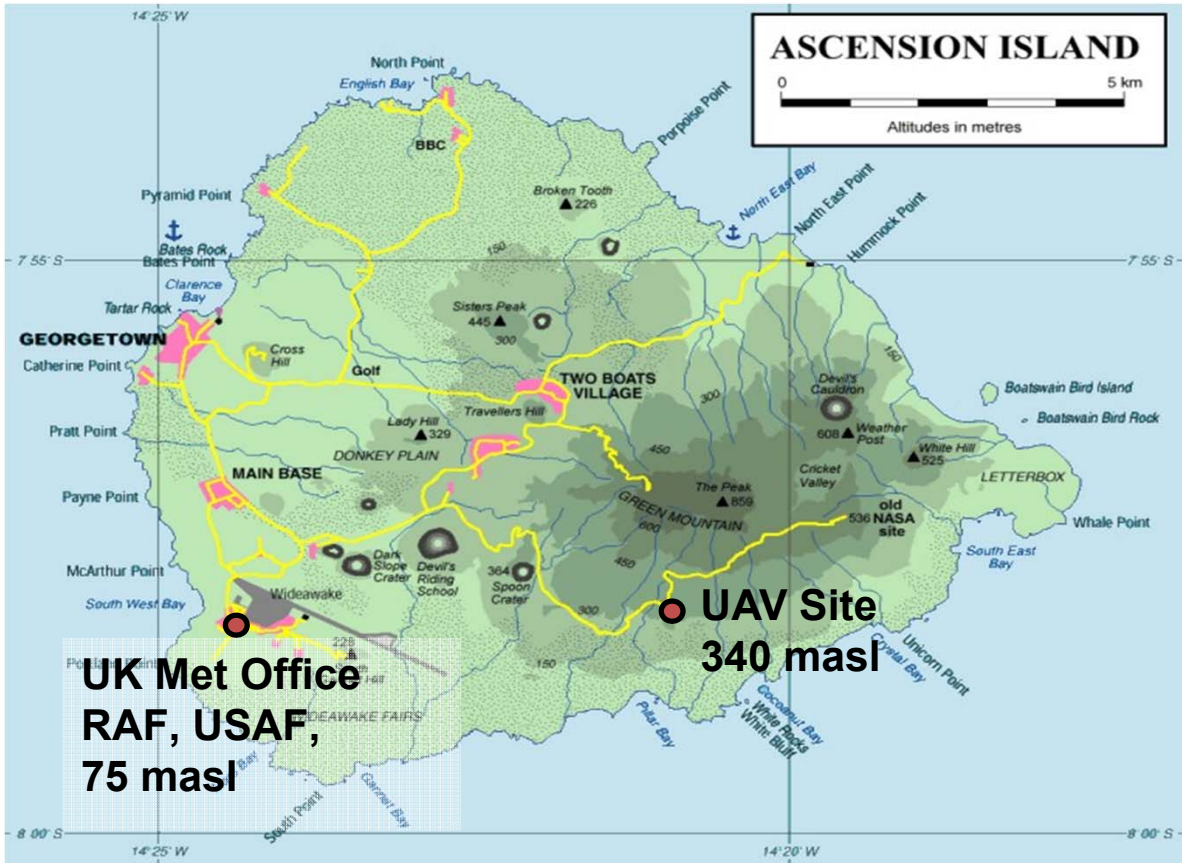


Development of Octocopter and Payload

Development of Octocopter and Payload

Maximum Take Off Weight (inc. batteries)	10kg
Diagonal rotor-rotor distance	1.07m
Maximum battery capacity	32,000mAh 6 cell Lithium Polymer
Motors	T-Motor MN3515 400KV
Propellers	T-Motor 16x5.4”
Autopilot	Pixhawk by 3DRobotics
Autopilot software	ArduCopter v3.1.5
Safety pilot control link	FrSky L9R 2.4GHz
Ground Control Station link	Ubiquiti 5GHz directional
Onboard computing	BeagleBone Black

Ascension Island Map and Launch Site

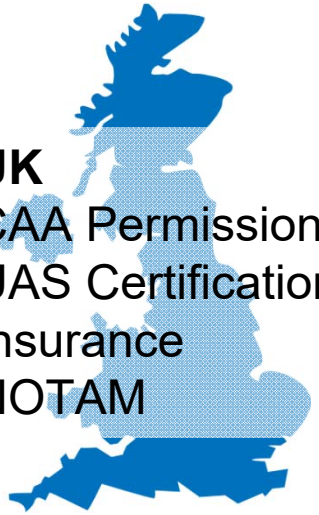


Measurement Periods:

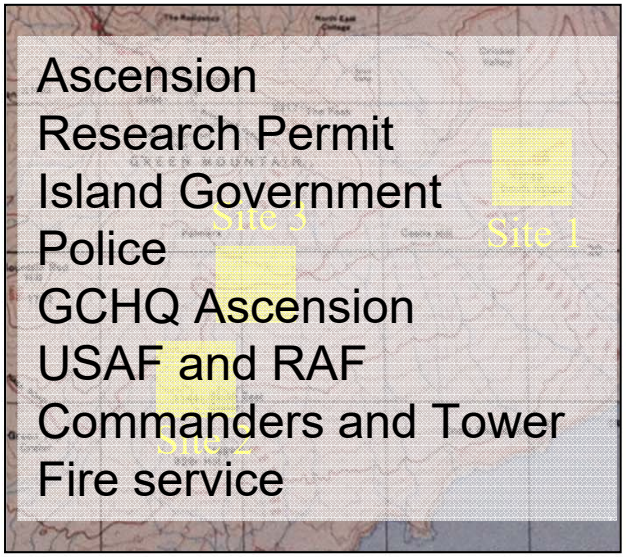
10th -19th Sept 2014

4th -16th July 2015

UAV Permissions



UK
CAA Permissions
UAS Certification
Insurance
NOTAM



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

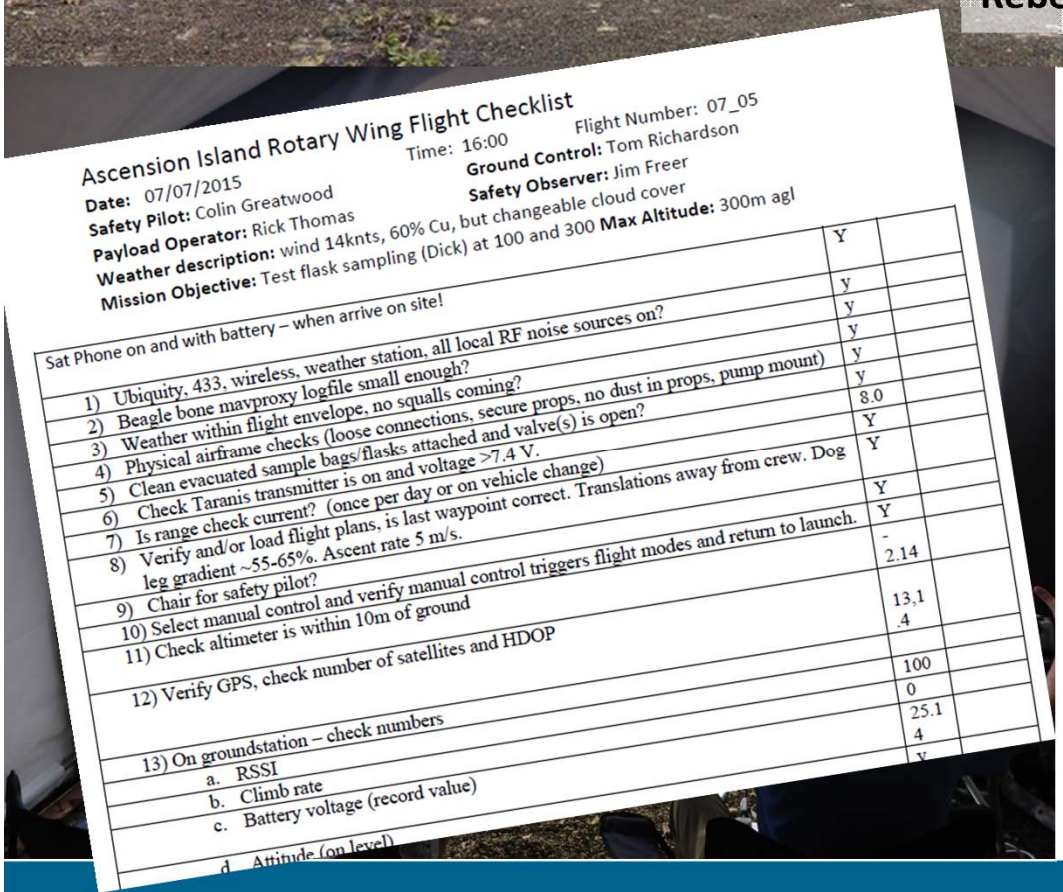
Ascension Island
Air Safety Support International
USAF UAS range safety permit
Insurance
NOTAM

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



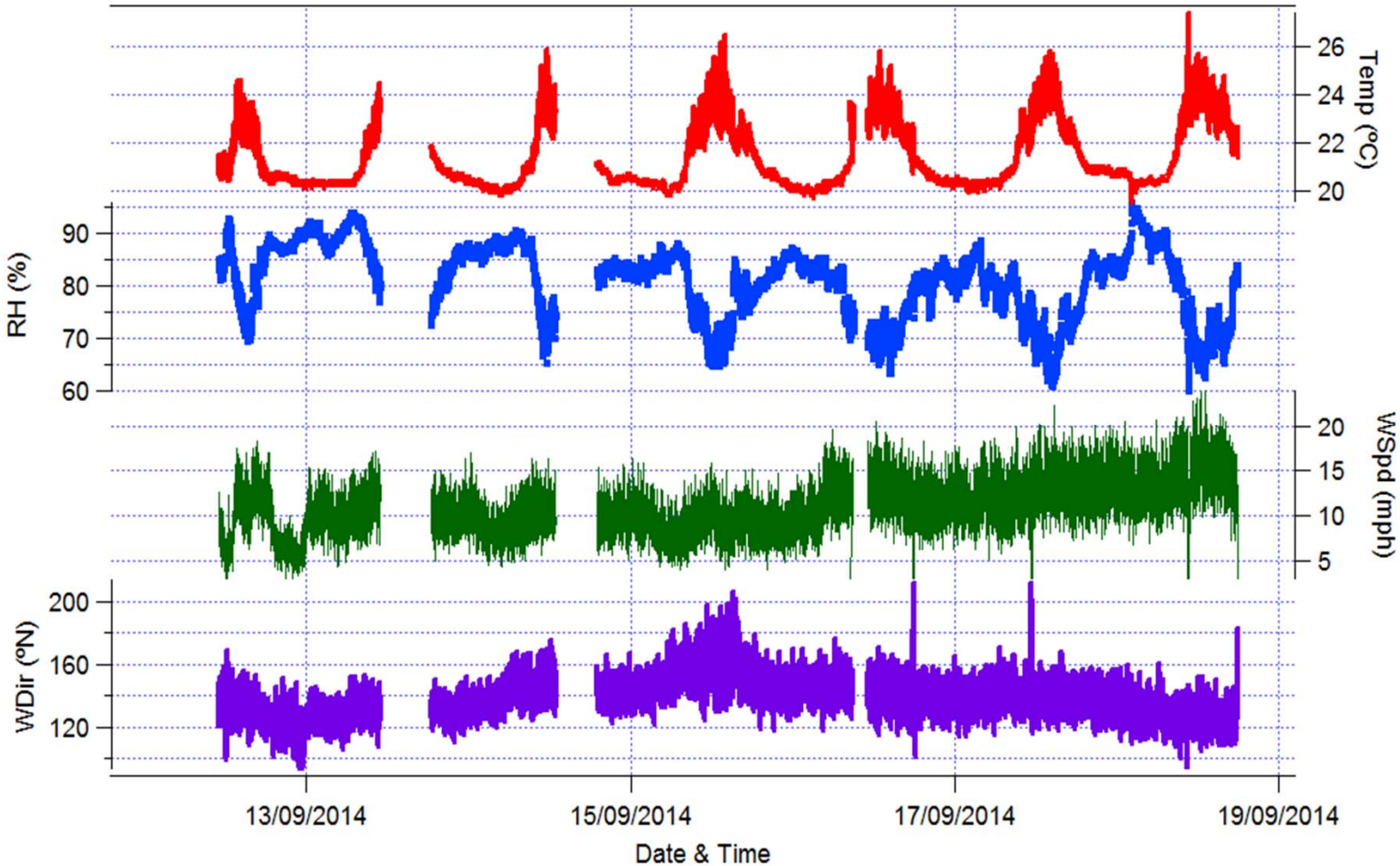
Ascension Island Rotary Wing Flight Checklist

Date: 07/07/2015 Time: 16:00 Flight Number: 07_05
Safety Pilot: Colin Greatwood **Ground Control:** Tom Richardson
Payload Operator: Rick Thomas **Safety Observer:** Jim Freer
Weather description: wind 14knts, 60% Cu, but changeable cloud cover
Mission Objective: Test flask sampling (Dick) at 100 and 300 **Max Altitude:** 300m agl

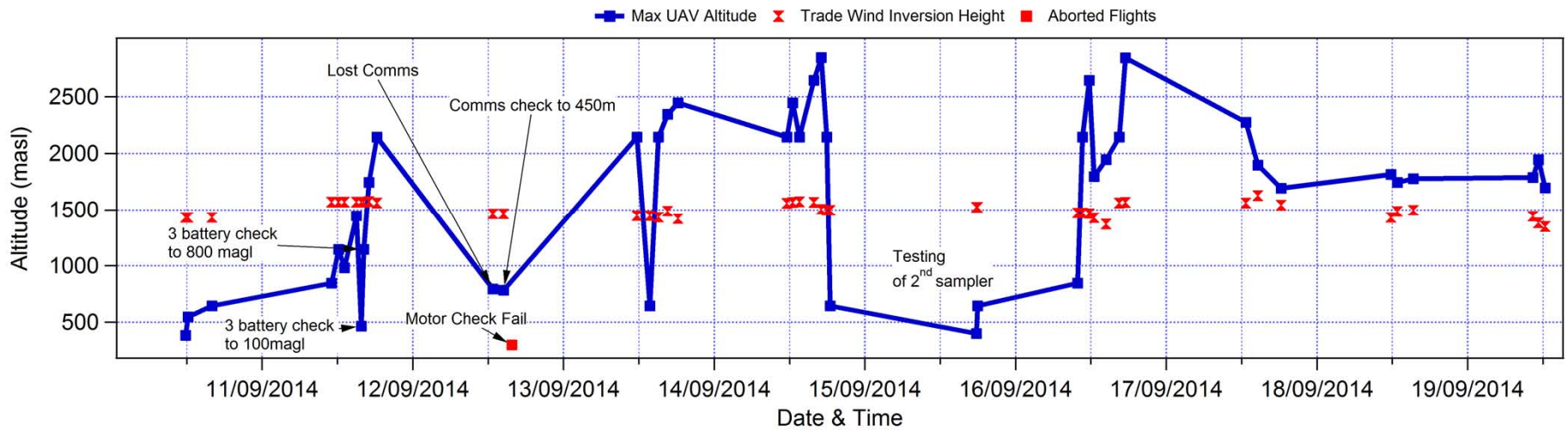
Sat Phone on and with battery – when arrive on site!	Y	
1) Ubiquity, 433, wireless, weather station, all local RF noise sources on?	y	
2) Beagle bone mavproxy logfile small enough?	y	
3) Weather within flight envelope, no squalls coming?	y	
4) Physical airframe checks (loose connections, secure props, no dust in props, pump mount)	y	
5) Clean evacuated sample bags/flasks attached and valve(s) is open?	8.0	
6) Check Taranis transmitter is on and voltage >7.4 V.	Y	
7) Is range check current? (once per day or on vehicle change)	Y	
8) Verify and/or load flight plans, is last waypoint correct. Translations away from crew. Dog leg gradient ~55-65%. Ascent rate 5 m/s.	Y	
9) Chair for safety pilot?	Y	
10) Select manual control and verify manual control triggers flight modes and return to launch.	-	
11) Check altimeter is within 10m of ground	2.14	
12) Verify GPS, check number of satellites and HDOP	13,1 .4	
13) On groundstation – check numbers	100	
a. RSSI	0	
b. Climb rate	25.1	
c. Battery voltage (record value)	4	
d. Attitude (on level)	y	

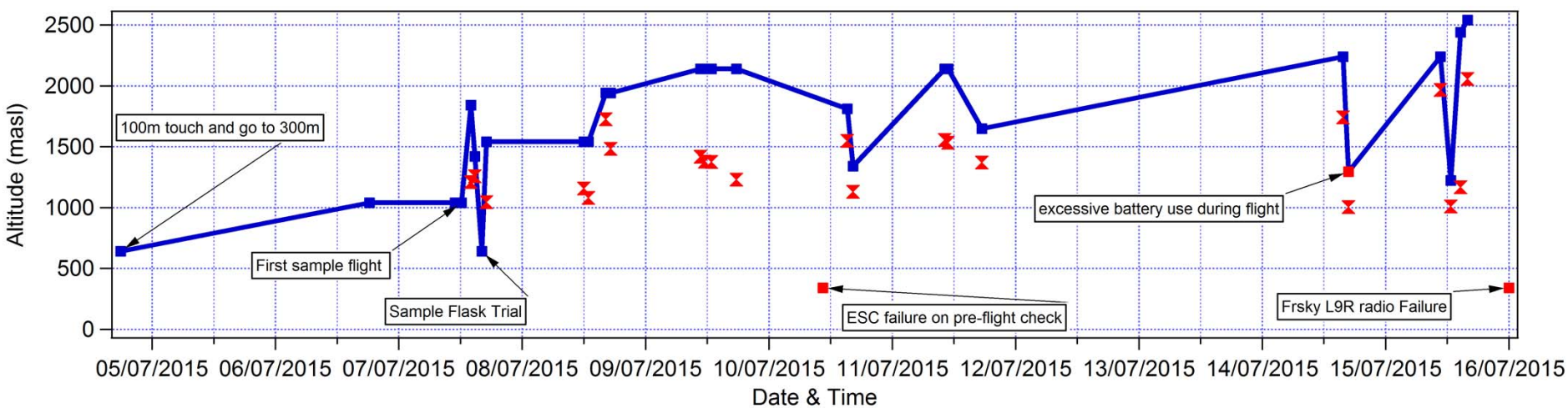
- **Daily Flight Routine**
- **Check Met Office weather e-mail**
- **Collect Radios from US Fire Department**
- **Check-in with air traffic control on RAF base**
- **Optional discussion with met office**
- **Plan initial flight and day strategy**
- **Prepare aircraft/sample bags**
- **Run though UAV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

Site Surface Meteorology

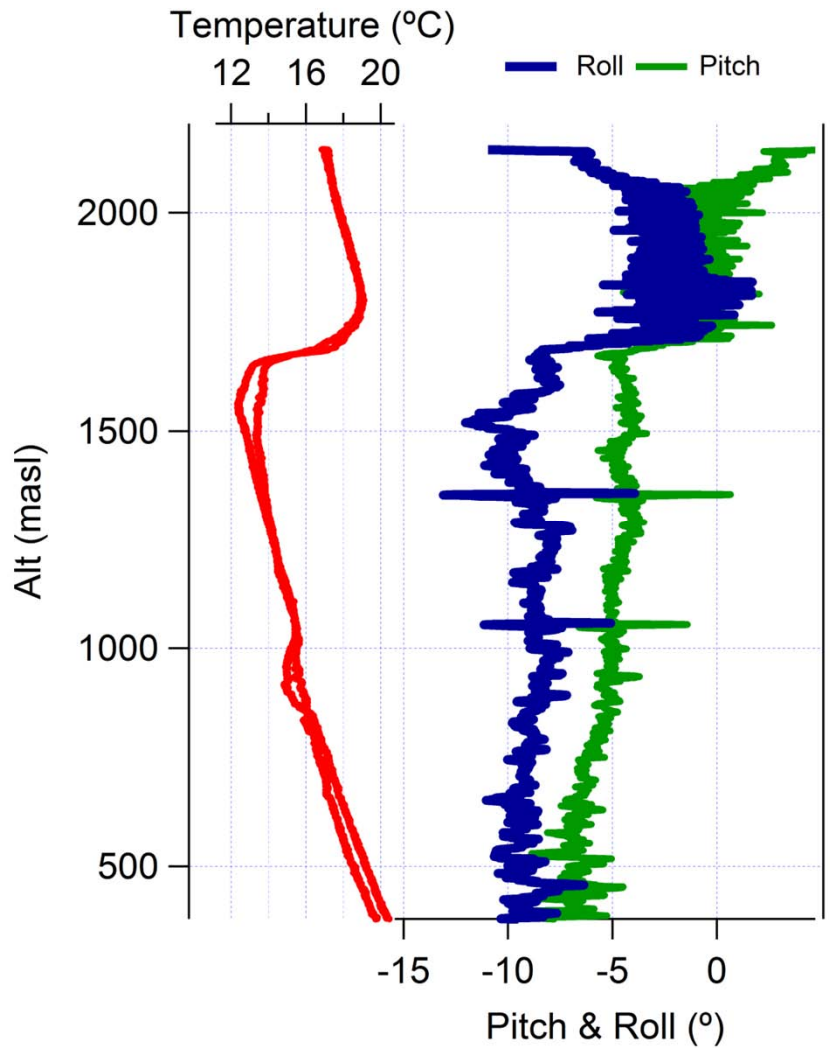


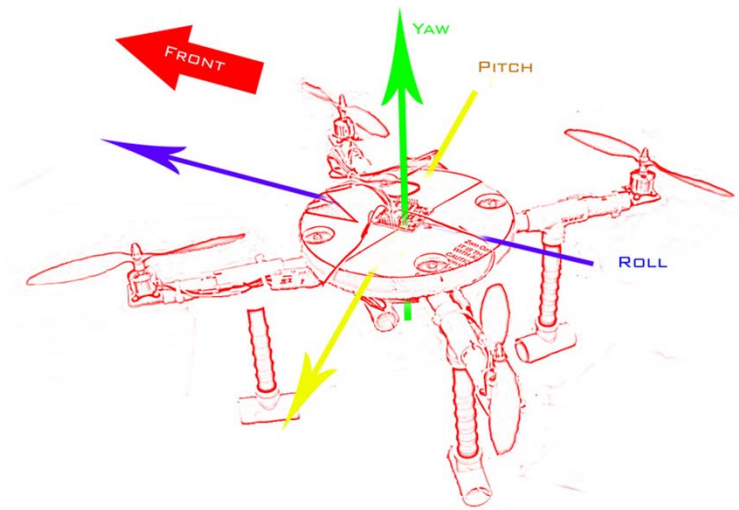
Max Alt Flight Profiles

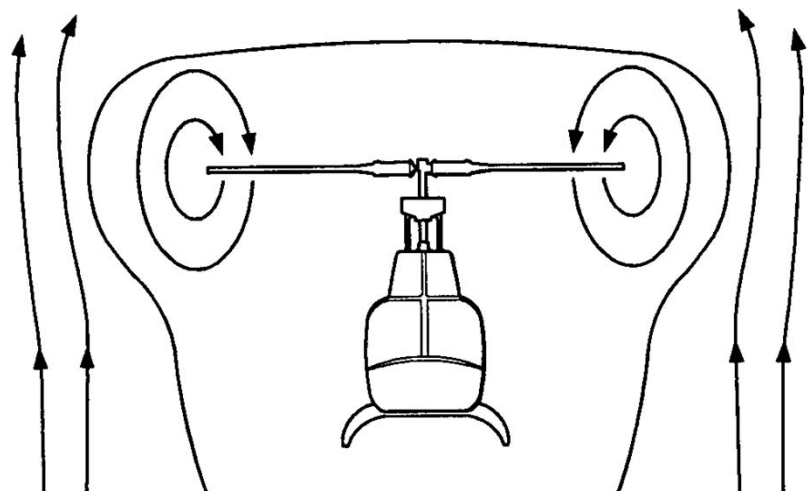




Flight Operations: Descent in low wind speeds

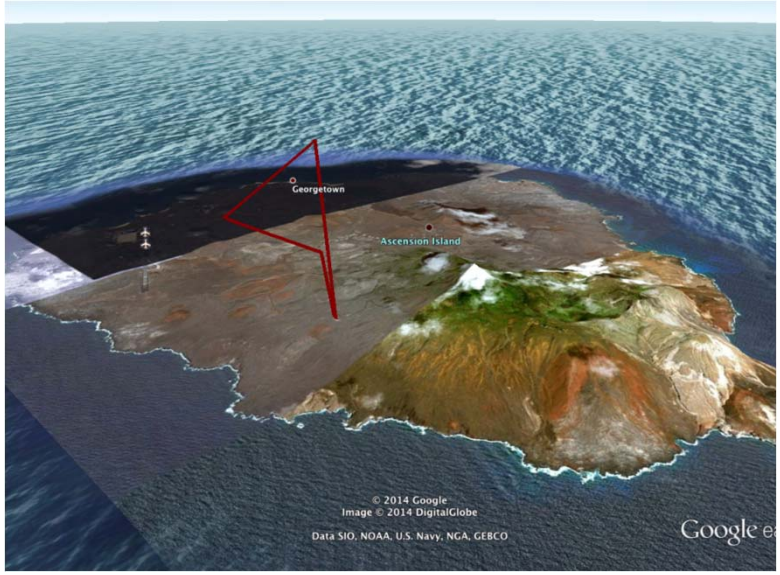






Vortex ring state

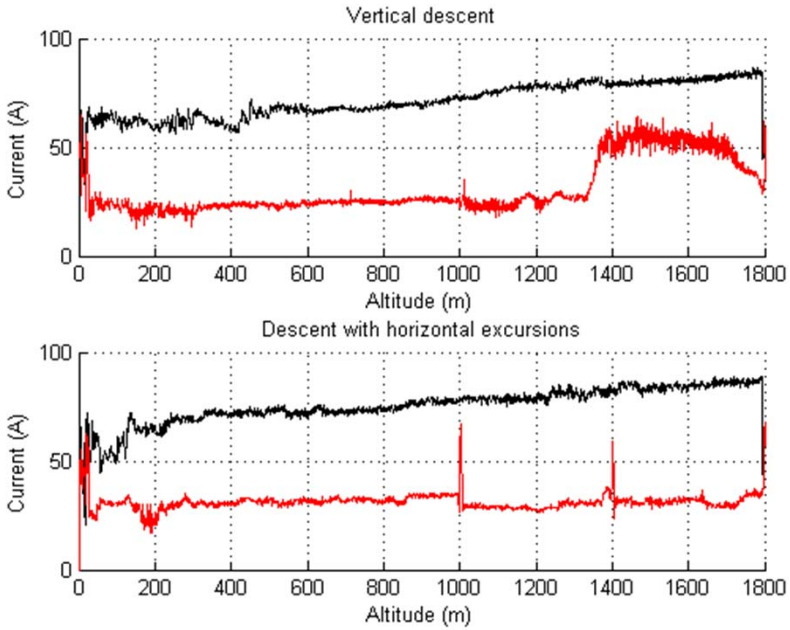
Flight Operations: Descent in low wind speeds: Solution



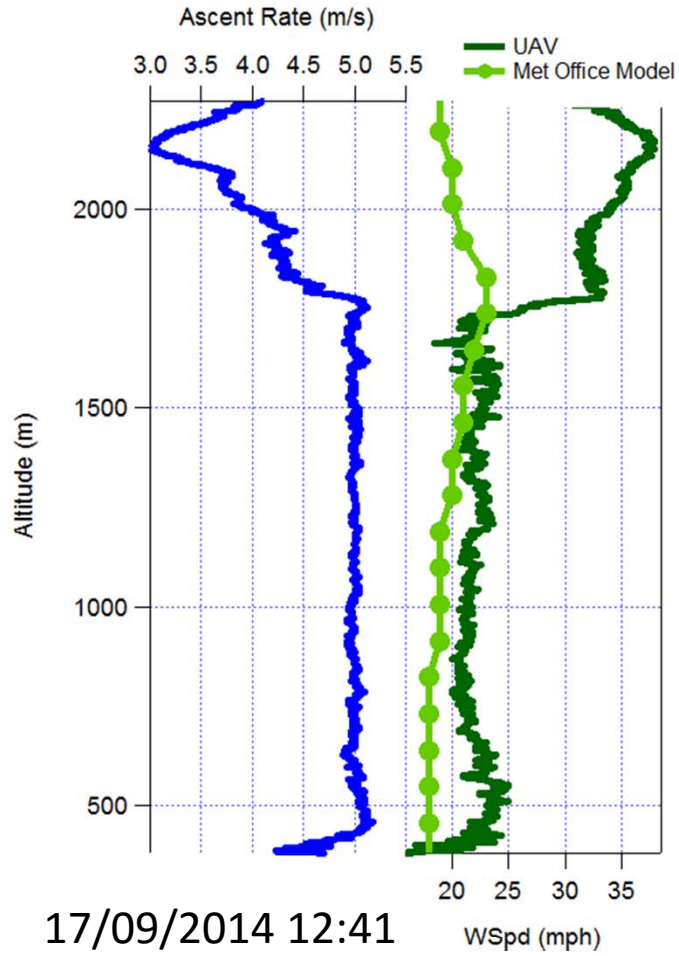
Implementing the Solution

- 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

- 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



Flight Operations: Ascent into high Wind Speeds



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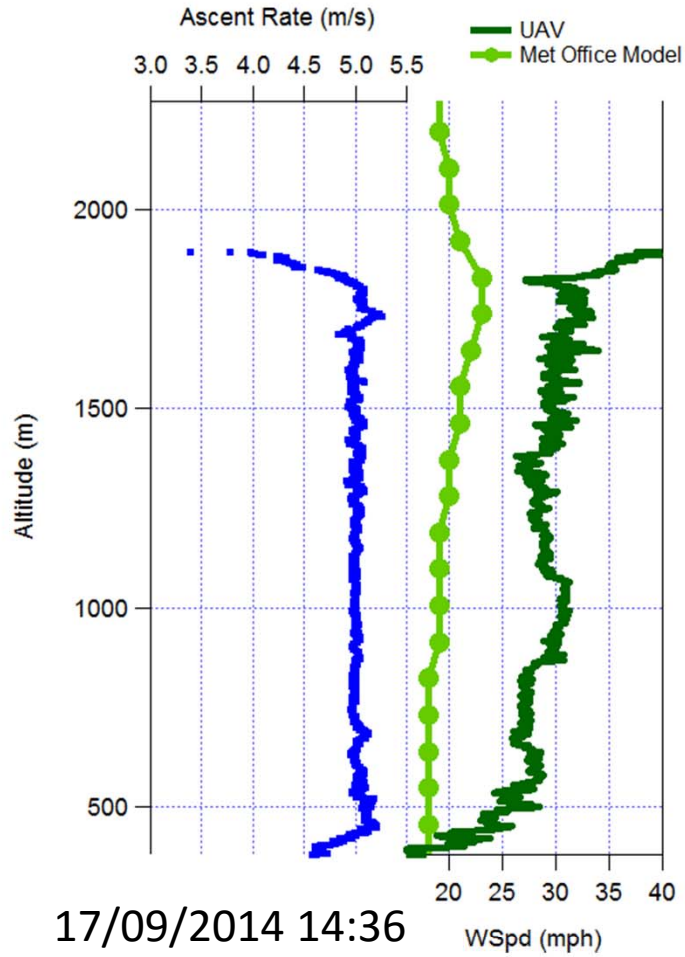


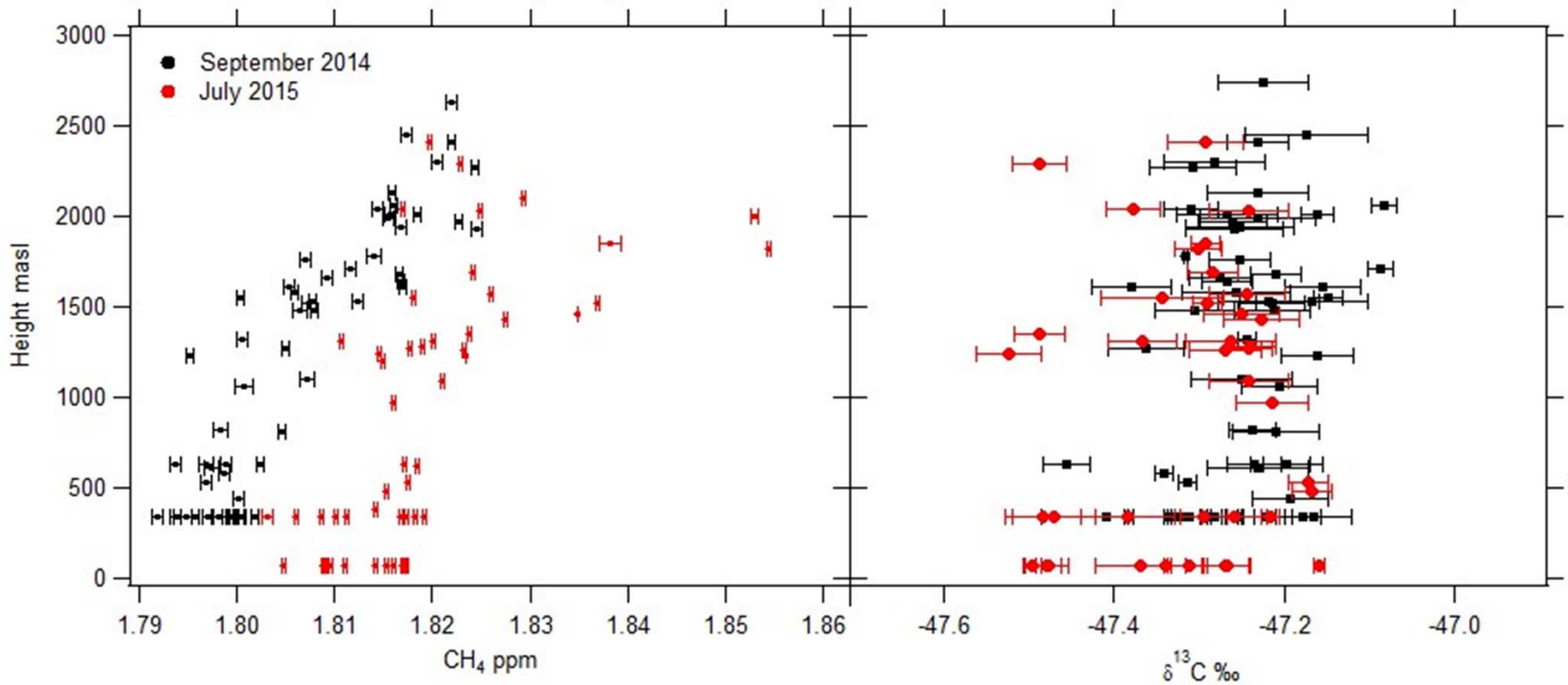
17/09/2014 14:36

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

"Automatic Path Generation for Multirotor Descents Through Varying Air Masses above Ascension Island", AIAA Atmospheric Flight Mechanics Conference, AIAA SciTech, (AIAA 2016-1532). http://dx.doi.org/10.2514/6.2016-1532

AI Results: Quick Video

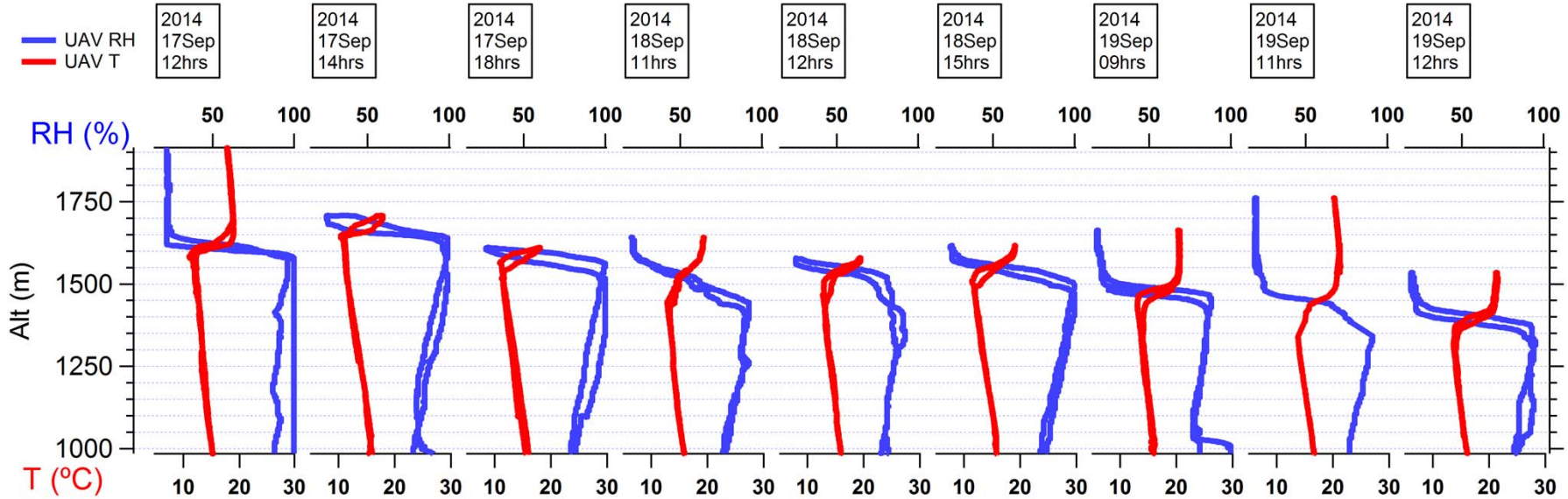
AI Results: CH_4 Conc and Isotope data

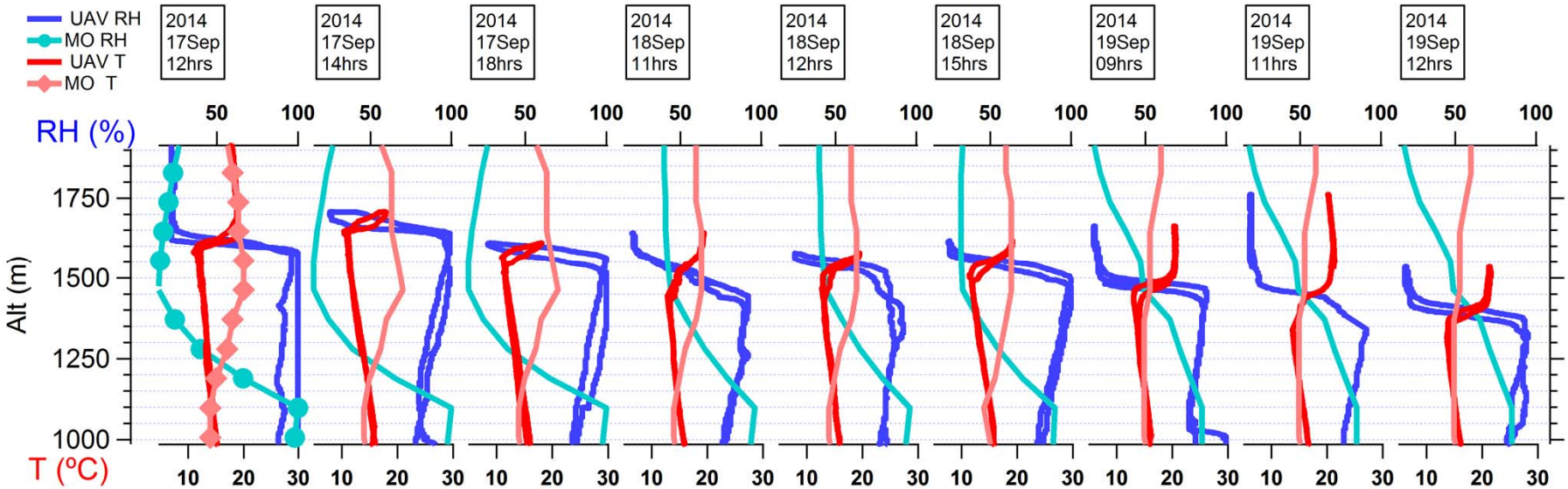


a) Comparison of CH_4 mole fraction variation with altitude for two field campaigns in September 2014 and July 2015. b) Comparison of $\delta^{13}C_{CH4}$ variation with altitude between the two field campaigns in September 2014 and July 2015.

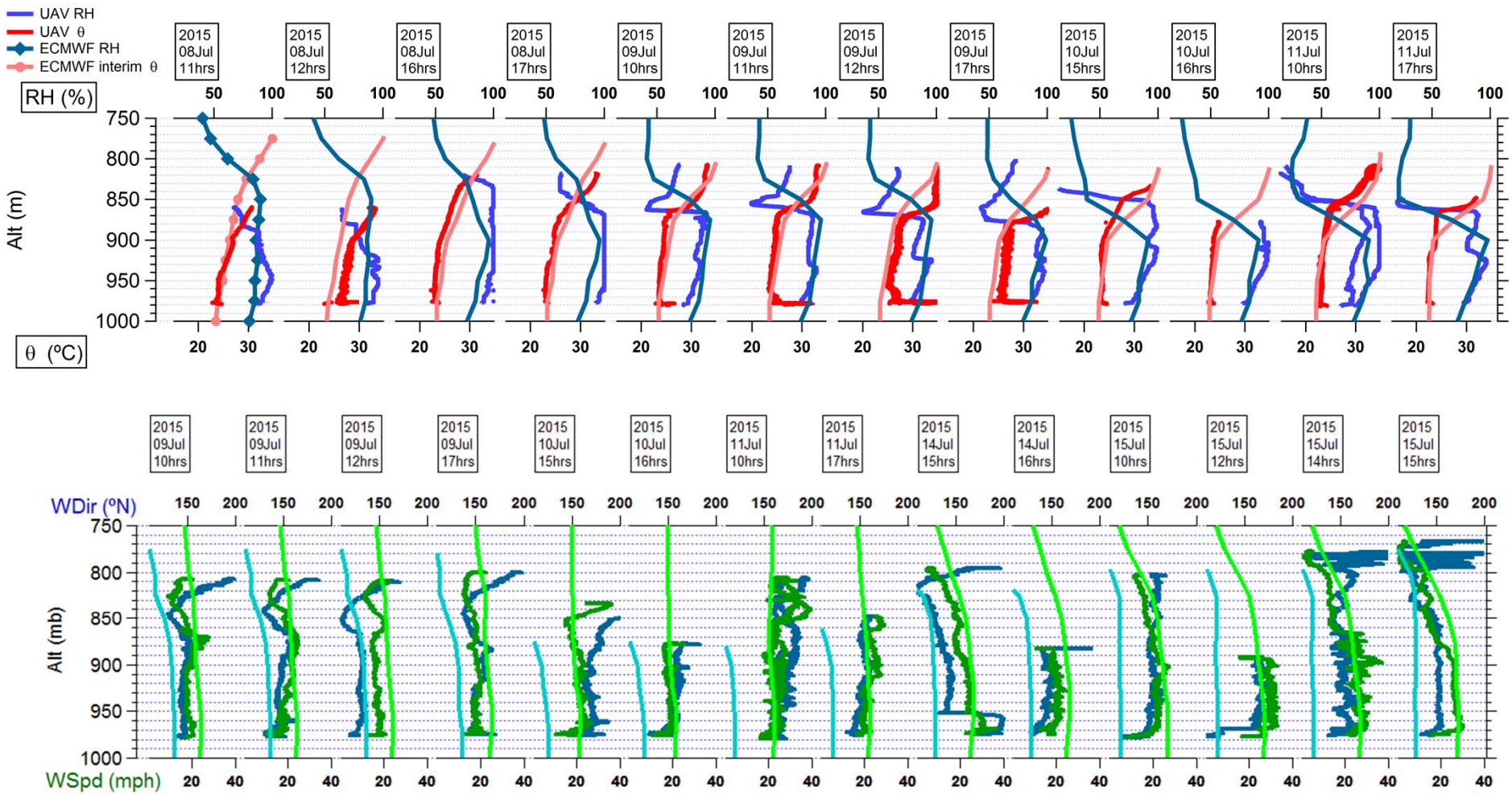
- **Biomass burning and wetland influence from Africa in July?**

Results: Profiles Sept 2014





Results: Profiles July 2015



Conclusions

Successful campaigns – Yes!

Challenge	Solution
Low wind Speeds	Change flight plan
High Wind Speeds	Calculate wind profiles on the fly
Difficult communications on high	Build a UAV tracker antenna
Need to collect other gases	Develop flask collection system

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

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NERC SCIENCE OF THE ENVIRONMENT

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**

NEW PAPER: Pistone, K., Praveen, P. S., Thomas, R. M., Ramanathan, V., Wilcox, E. M., and Bender, F. A.-M.
Observed correlations between aerosol and cloud properties in an Indian Ocean trade cumulus regime
Atmos. Chem. Phys., 16, 5203-5227, doi:10.5194/acp-16-5203-2016, 2016.

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