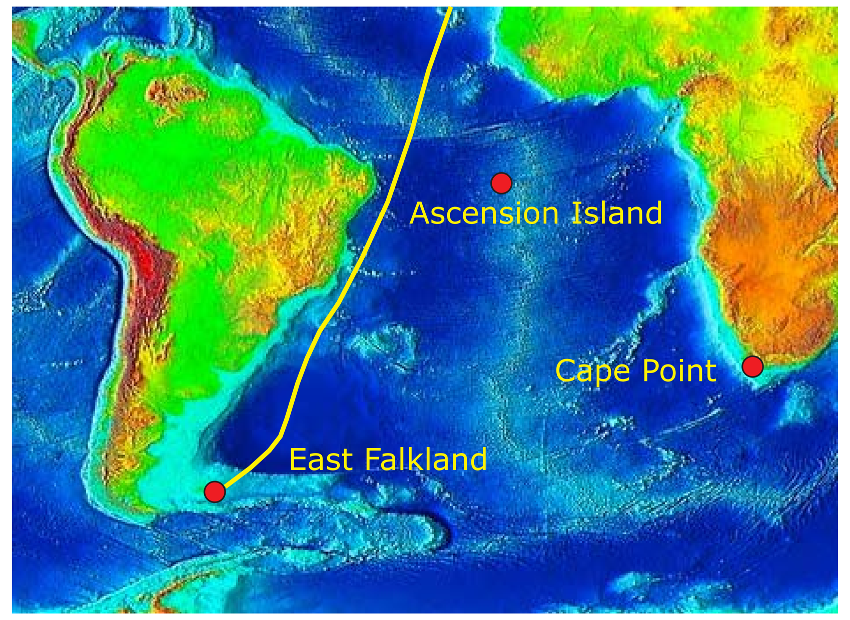
Greenhouse gases in the South Atlantic Ocean: recent trends and anomalies from continuous island and shipboard measurements (AS3.8-12035)

Dave Lowry (d.lowry@es.rhul.ac.uk), Rebecca Fisher, Mathias Lanoisellé, James France and Euan Nisbet
Greenhouse Gas Laboratory, Department of Earth Sciences, Royal Holloway, University of London, Egham, Surrey TW20 0EX, UK
Ernst Brunke, South African Weather Service, Stellenbosch, SA, Ed Dlugokencky, NOAA ESRL GMD, Boulder, US,
Zoe Fleming, University of Leicester, UK, Karl Shepherdson, Meteorological Office, Exeter, UK

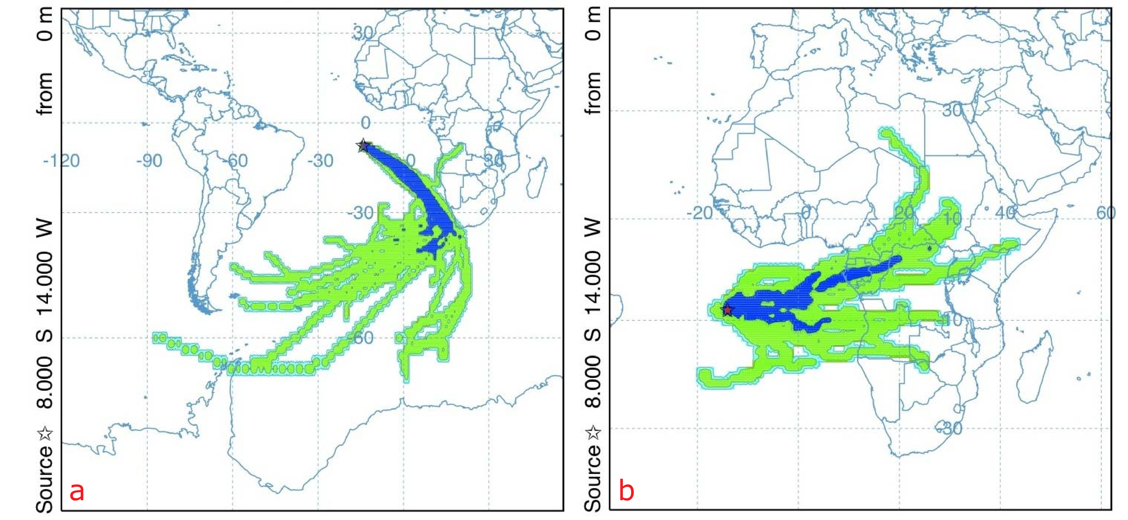
1. Introduction

In-situ observation of tropical and southern Atlantic greenhouse gases is still very limited. To address key problems in the region such as CO_2 uptake by the Southern Ocean and South Atlantic, or the causes of the 2009-2011 southern tropical methane anomaly, requires that more continuous measurement of these gases are made in the region, at sites which have a big geographical footprint and a well-defined oceanic background sector.

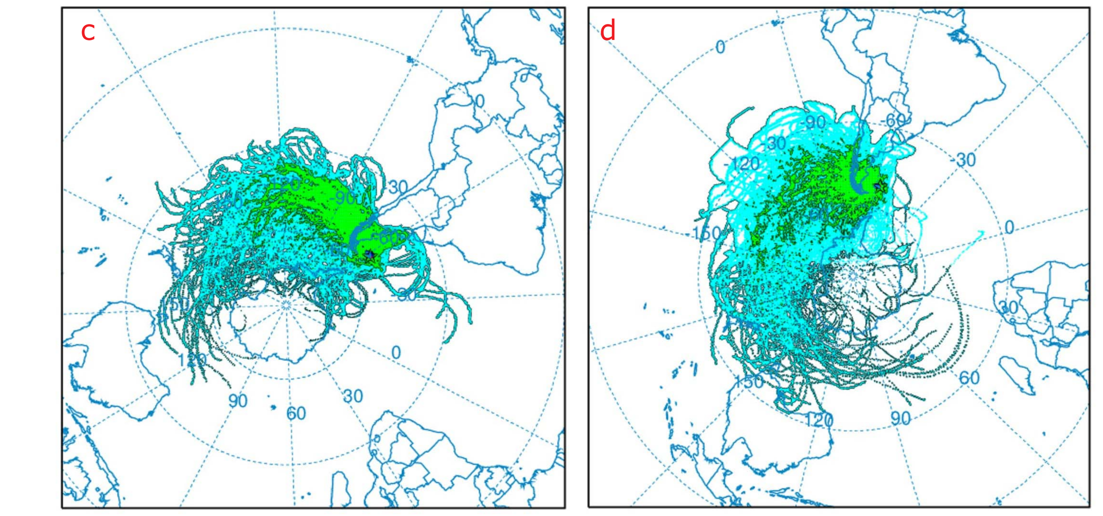
Continuous high-precision greenhouse gas measurement by CRDS in the South Atlantic started in 2010 on Ascension Island (8°S) and near Stanley on East Falkland Island (52°S), and in 2012 on the British Antarctic Survey ship RRS James Clark Ross, which sails annually from the UK to Antarctica and back.



Map of the South Atlantic region showing current sites with both continuous measurement of CO_2 and CH_4 by CRDS and collection of samples for methane isotopic measurement. Also shown is the ship track of the RRS James Clark Ross when sailing directly from the UK to Port Stanley during October 2010 and October 2012.



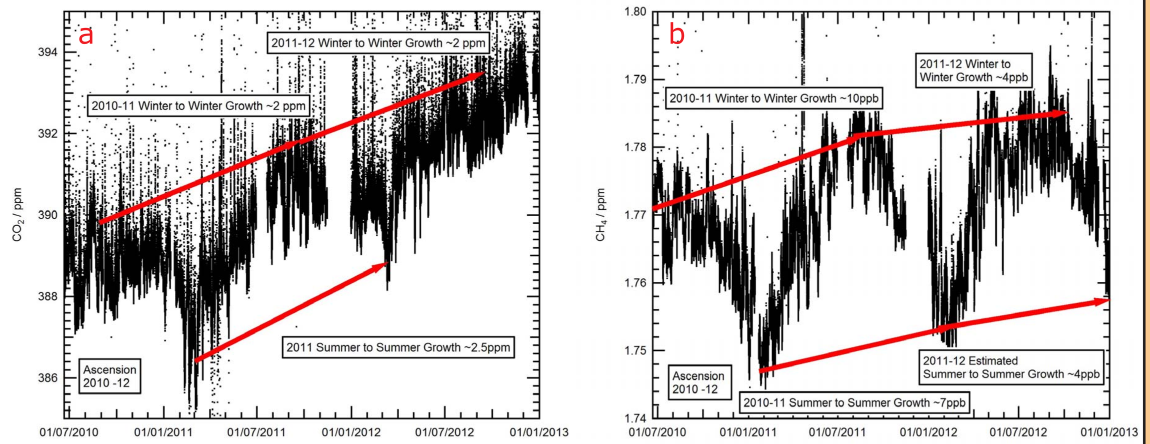
Trajectory maps for Ascension Island for April 2010, showing the dominant SE trade winds at surface level (a) and dominant African air (with associated emissions) at 2000m altitude above the island (b).

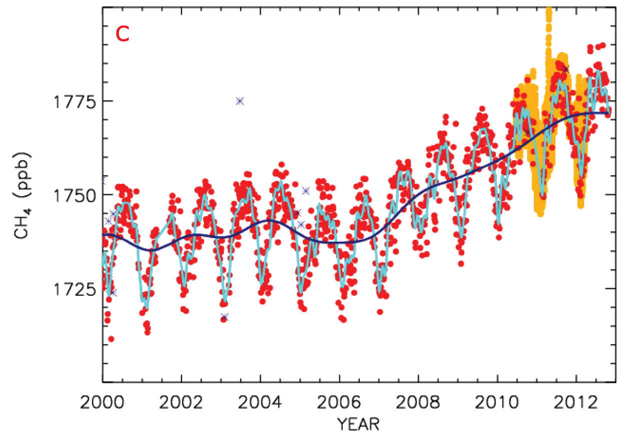


Ten-day back trajectory maps for 100m arrival height on East Falkland showing the dominant W and NW winds during summer 2011 (c) compared to winter 2011 (d) which has more air from S and SW sectors.

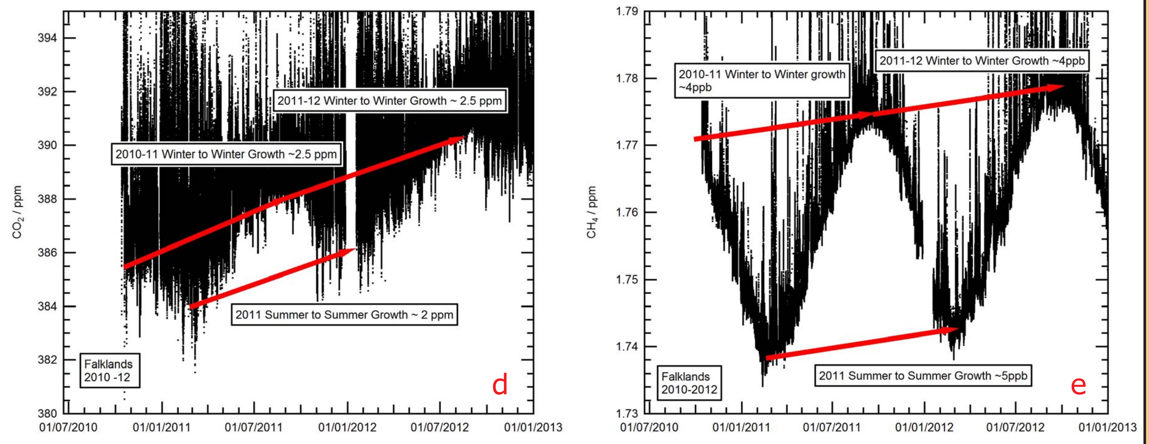
2. Continuous Time-Series from Ascension and East Falkland

Both the Ascension and East Falkland records show sustained inter-annual growth in both CO_2 and CH_4. NOAA data from a small number of stations indicate that Southern Tropical Methane has been increasing since 2007 but that growth is now slowing. Strong CH_4 growth of 11 ppb was observed on Ascension between July 2010 and July 2011 (winter to winter), 7 ppb/yr from Jan 2011 to Jan 2012 (summer-to-summer) and decreased further to 4 ppb from July 2011 to July 2012. This compares with a fairly constant growth of 4-5 ppb/yr for the Falklands site. CO_2 has grown by 2-2.5 ppm/yr at both sites since 2010, similar to global averages.

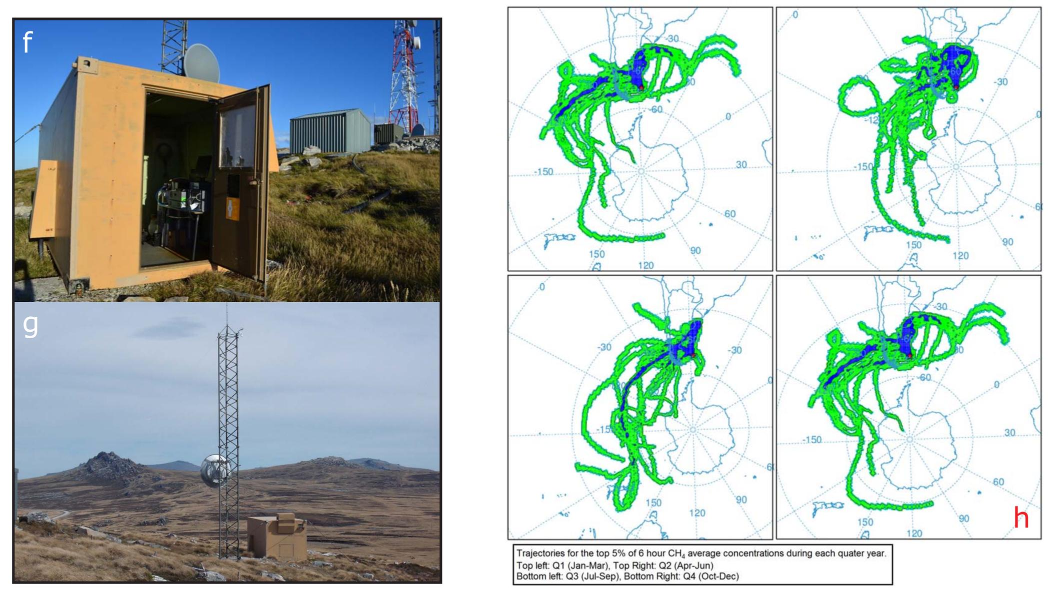




Time-series of continuous measurement of CO_2 (a) and CH_4 (b) on Ascension Island, highlighting the growth rate of both gases since 2010 and the Southern Tropical Methane Anomaly that led to higher than normal growth rate from 2009-2011. The first 2 years of continuous CH_4 data have been plotted against the NOAA flask record (c) with very good agreement, although flask sampling missed the April 2011 event (see Section 6).



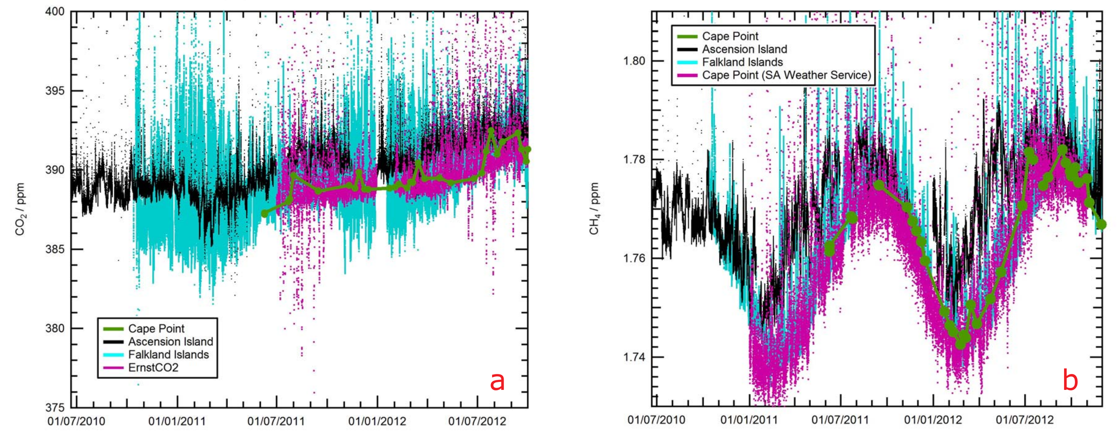
Time-series of continuous measurement of CO_2 (d) and CH_4 (e) on East Falkland Island, highlighting the steady growth rate of both gases since 2010.



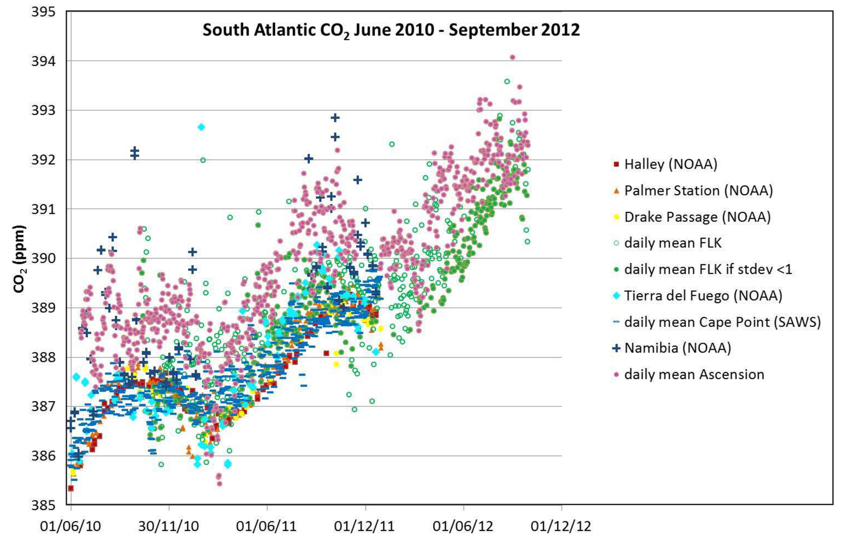
Sapper Hill installation (f,g) in a hut with a 12m mast and WiFi link to coastal receiver. Analysis of the top 5% of methane mixing ratios based on 6-hour averages (h) suggests that these are emissions from Argentina and Uruguay.

3. Comparison of South Atlantic Region Measurements

Ascension and Falkland time-series have been directly compared with Cape Point time-series data and Cape Point flask samples measured at RHUL. Cape Point and Ascension records show strong agreement for CO_2 whereas the Falklands has a strong influence of the biological cycle of the dominant pampas grassland, particularly during the spring growing season and summer. For CH_4 the strong similarity is between Cape Point and the Falklands, which show a strong seasonal cycle of more than 40 ppb.



Comparison of time-series at Ascension, Cape Point and East Falkland for CO_2 (a) and CH_4 (b).

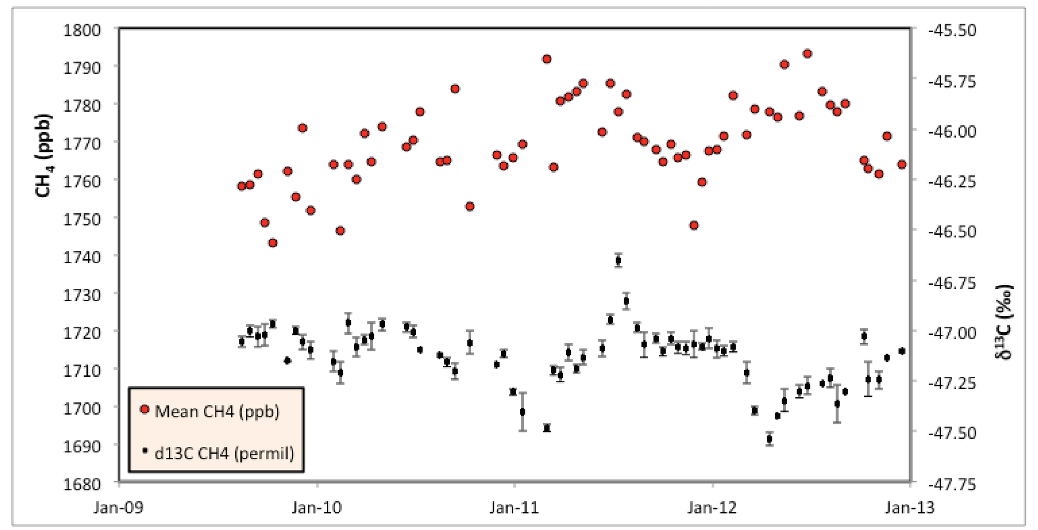


Comparison of CO_2 continuous and flask records for stations in and around the South Atlantic and Southern Oceans. Least variability is observed for the Antarctica stations with more noise in the signal and higher mixing ratios as seasonal sources become important further north.

4. Isotopic Records

Samples are now being collected every 2 weeks on Ascension Island, East Falkland and at Cape Point. The longest of these records is from Ascension Island where data comparisons are made with the INSTAAR record from NOAA flask samples collected at the same site.

Isotopic evidence for the causes of the 2009-11 southern hemisphere sub-tropical methane anomaly is inconclusive. A slight depletion in ^{13}C on Ascension might indicate that wetland emissions are the dominant cause of the anomaly, fitting with much higher than average sub-tropical rainfall during recent years, but there is no clear evidence that any tropical African air was sampled. A much longer isotopic data set is required to isolate anomalies from the long-term trend.

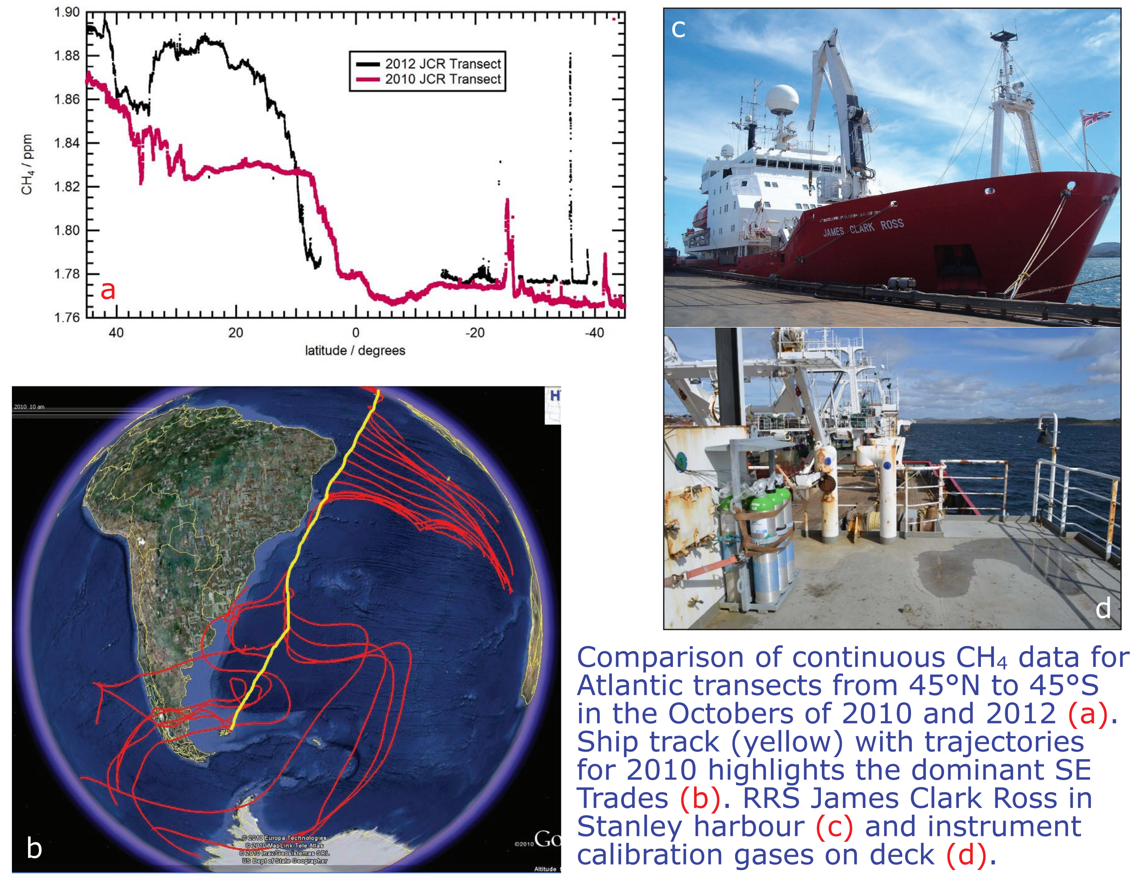


Seasonality of $\delta^{13}C$ in methane at background stations in the southern hemisphere is very small, normally less than 0.3‰, requiring high-precision analysis to detect. Ascension rarely sees inputs of source emissions beyond minor influence of local sources, unless there is a rare break-up of the inversion between the SE trades and higher African air allowing emissions to mix.

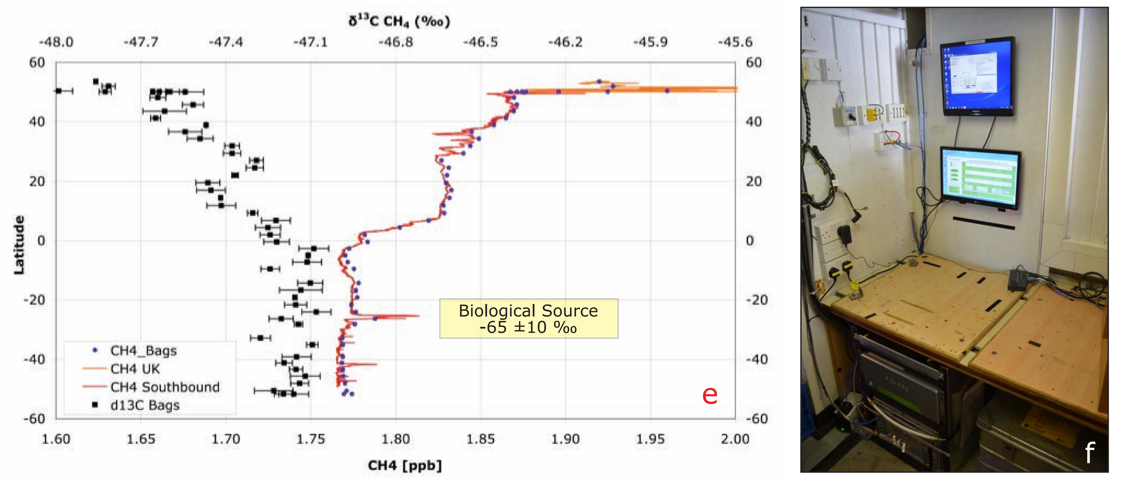
5. Atlantic Ship Transects

A Picarro G1301 CRDS instrument was installed 17-18 Sept 2010 on the RRS James Clark Ross (JCR), operated by the British Antarctic Survey. The ship sailed from Immingham, UK (53°N) to Port Stanley, Falkland Islands (51°S) between Sept 28 and Oct 24, where the equipment was installed for long-term measurement (see Section 2). A shift of 55 ppb (1825 to 1770 ppb) was observed during continuous measurement as the ship crossed the ITCZ from 8°N to 8°S during this transect.

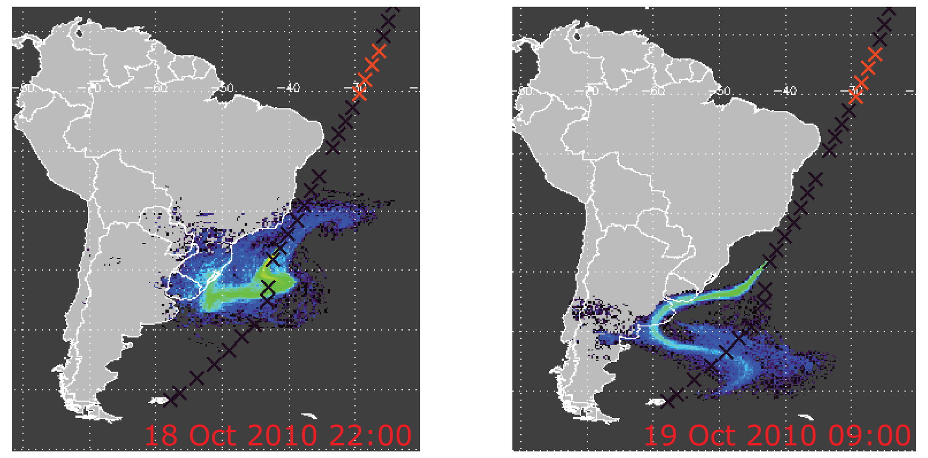
A Picarro G2301 CRDS instrument with auto-calibration was installed on the JCR in October 2012 for long-term measurement in the South Atlantic and Southern Ocean and will transect the Atlantic back to the UK in May-June 2013. During the October 2012 crossing of the ITCZ a drop of 75 ppb was recorded between 12 and 8°N.



Comparison of continuous CH_4 data for Atlantic transects from 45°N to 45°S in the Octobers of 2010 and 2012 (a). Ship track (yellow) with trajectories for 2010 highlights the dominant SE Trades (b). RRS James Clark Ross in Stanley harbour (c) and instrument calibration gases on deck (d).



Tedlar bag samples were collected twice daily on the RRS James Clark Ross during October 2010 following the ship transect shown on the maps. These were later analysed for $\delta^{13}C$ of CH_4 at RHUL and the mixing ratios compared with the continuous record (e). Current ship installation (f).



Five-day back trajectories for particles arriving at 0-100m using the NAME model confirm that air (and emissions of CH_4) from the East coast of South America reached the ship on 18-19 Oct, 2010.

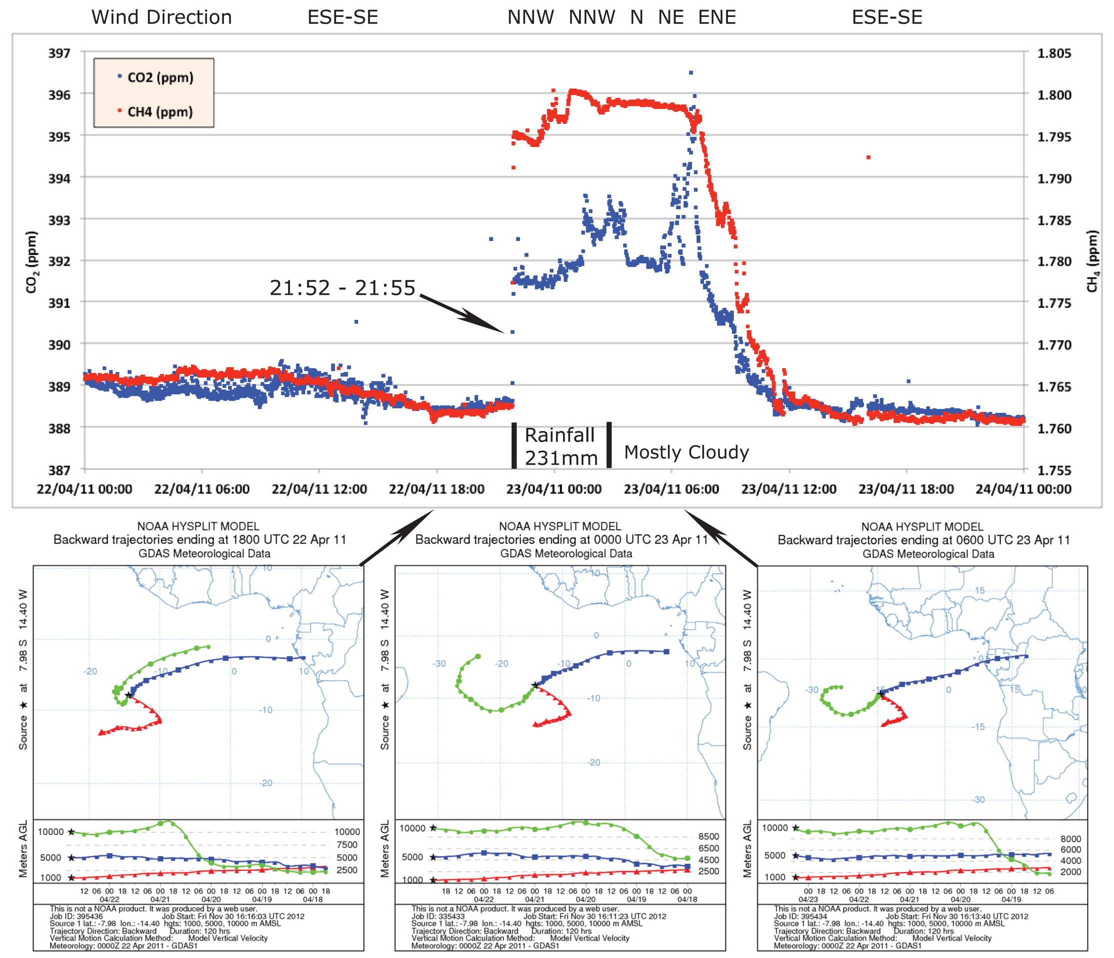
6. A Decadal Meteorological Event on Ascension Island

On 22-23 April 2011, Ascension experienced a decadal event when the ITCZ moved far south of its normal position. In very clean marine air, in the space of 3 minutes the CH_4 jumped from a normal autumn southern hemisphere level of 1763 ppb to 1795 ppb, closer to the concentrations of northern hemisphere spring, settling near to 1800 ppb for six hours, after which it rapidly fell back to 1760 ppb. Simultaneously CO_2 rose from 389 to about 392 ppm, then to 396 ppm before falling back to 388 ppm.

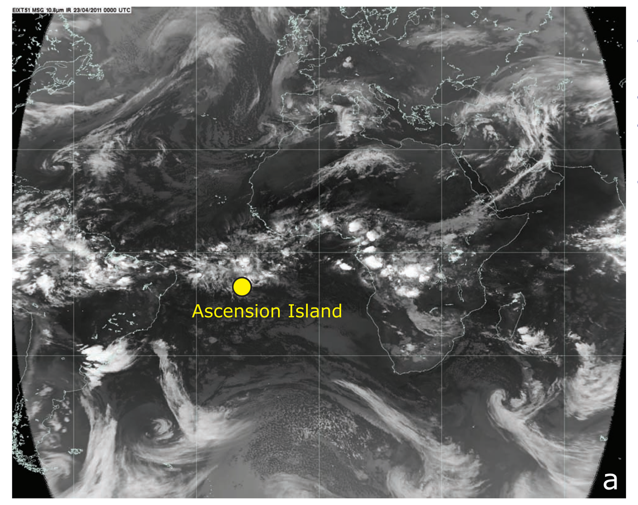
During this period there was very heavy rainfall, with nearly 300 mm on the slopes of Green Mountain and more than 100 mm in surrounding desert areas, making it the wettest April since a similar event in 1985. In the 2011 event, high altitude Northern hemisphere air was moving SE over NW moving trade winds until the storm brought high level air to ground level. The 35 ppb magnitude of this CH_4 switch compares with a magnitude of 55 ppb (1825 to 1770 ppb) observed by continuous measurement on-board the James Clark Ross when crossing the ITCZ from 8°N to 8°S in October 2010 (see Section 5).

The normal well-defined inversion layer between the SE trades and higher African air broke up and allowed development of thunder clouds up to the tropopause. It is thought that this permitted downdrafts of high level air although this has not yet been revealed by analysis of the air masses involved.

The observations highlight the usefulness of continuous measurement at such a site and demonstrate that the meteorological boundary between the hemispheres can on occasion be very sharp.



The meteorological event of April 22 and 23, 2011 lasted 12 hours. Hysplit 4 120-hour back trajectories show 3 distinct air masses at different heights above Ascension island.



Satellite image of cloud cover over the Tropics at 00:00 on 23 April 2011 clearly shows the large thunder cloud cells had reached the latitude of Ascension Island (a). The heavy rainfall caused flooding and badly damaged some roads on the island (b).

References: Dlugokencky, E.J., Nisbet, E.G., Fisher, R., and Lowry, D. (2011) Global atmospheric methane in 2010: Budget, changes and dangers. Phil. Trans. R. Soc. A., 369, 2058-2072.
Nisbet, E.G. and Weiss, R. (2010) Top-down vs. Bottom-up. Science, 328, 1241-1243.

Acknowledgements: Sampling at the sites presented here would not have been possible without logistal assistance from: Picarro (CRDS), British Antarctic Survey (James Clark Ross measurement), Meteorological Office UK (Ascension Island measurement and sampling), Louise Taylor and Mario Zuvic (East Falkland Island measurement and sampling).