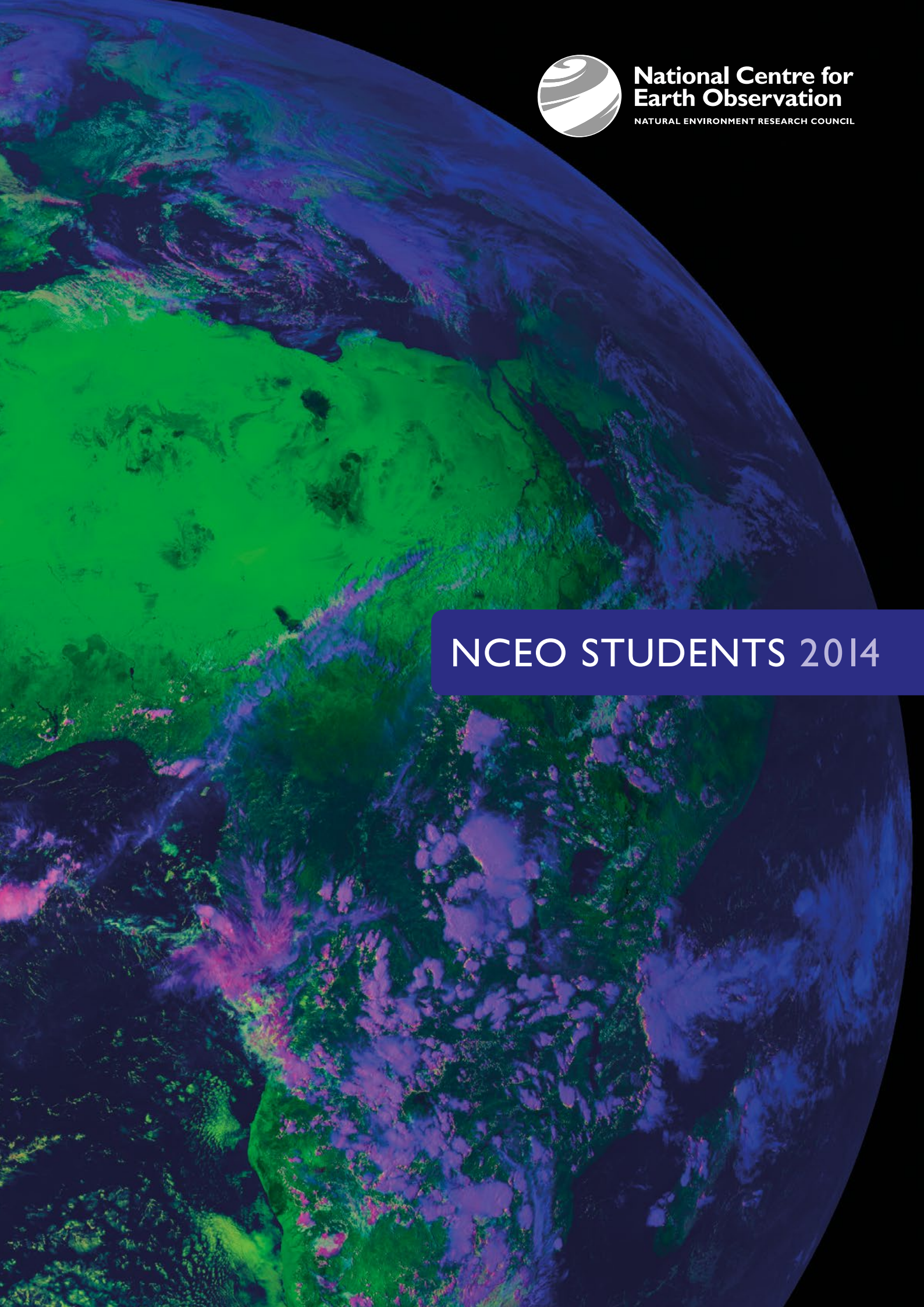


National Centre for Earth Observation

NATURAL ENVIRONMENT RESEARCH COUNCIL

NCEO STUDENTS 2014

CONTENTS

Cover: Acknowledgement Bethan Perkins, Assimila Limited and EUMETSAT

FOREWORD

The National Centre for Earth Observation (NCEO) is an established NERC research centre that provides NERC with national capability in Earth observation science. Our core activity is the challenge of understanding and predicting the behaviour of planet Earth as a complex, multi-component coupled system using observations from space and mathematical models.

This publication emphasises the excellent work of our postgraduate students over the first 6 years of NCEO, told in their own words. Their work spans the complete range of NCEO science: climate, carbon cycle and land based processes, atmospheric composition, natural hazards, cryosphere, ocean biogeochemistry and data assimilation.

Training has been a key element of the NCEO since its foundation in 2008. The NCEO runs a coordinated multi-disciplinary training programme to help remedy the skills shortage limiting the exploitation of EO in environmental science, in government and in commerce.

As part of our programme, students and other early career scientists in NCEO are brought together for their own NCEO conference once a year where they are offered the opportunity to discuss their science and also receive training in areas such as data assimilation, outreach, talking to the media and communicating science through popular publications. Speakers from public sector and commercial organisations are also invited to show how EO is exploited beyond academia.This brochure shows how excellent this has all been, and presents you with the strong cohort of leading scientists of the future.

Peter Jan van Leeuwen
Interim Director NCEO

BRENDAN MCCORMICK *University of Cambridge*

Supervisors: Marie Edmonds, Tamsin Mather, Simon Carn

MONITORING VOLCANIC SO_2 EMISSIONS FROM SPACE

OVERVIEW

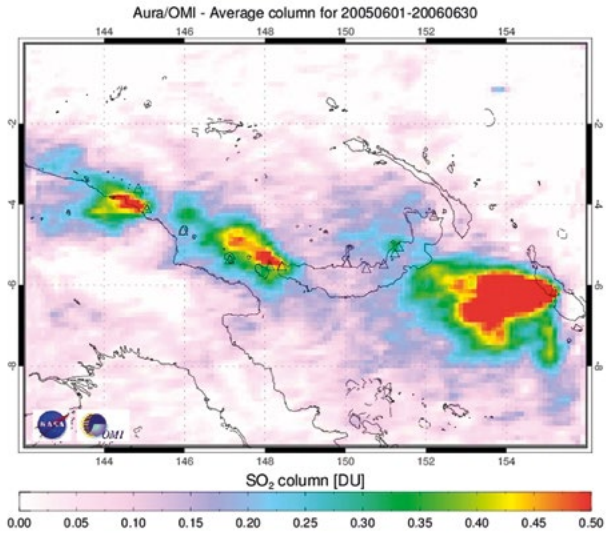
My research uses data from a satellite-based ultraviolet (UV) spectrometer called the Ozone Monitoring Instrument (OMI) to study volcanic sulphur dioxide (SO_2) degassing over a range of spatial and temporal scales. The application of Earth Observation to studies of volcanic emissions has traditionally focussed on large SO_2 releases during major explosive eruptions. Instruments like OMI, with unprecedented sensitivity to atmospheric SO_2, have enabled an extension of capability to the continuous monitoring of persistent volcanic degassing.

FINDINGS

My work has resulted in the first synoptic analysis of SO_2 degassing from the volcanoes of Papua New Guinea [McCormick et al., 2012a]. Whilst the satellite data agrees well with observed volcanic activity in the region, agreement with available ground-based measurements of SO_2 emission is harder to achieve. A range of factors which may limit the application of OMI data to volcano monitoring are discussed in a second paper [McCormick et al., 2012b] which also contains new case studies from volcanoes in Italy, Siberia, Central America and Mexico. My current work is an attempt to further understand the specific role played by local meteorological and atmospheric conditions on satellite retrievals, specifically the impact of meteorological cloud, and rapid chemical processing of SO_2 leading to its removal from the plume. The target volcano is Tungurahua, Ecuador, and the principal aim is to improve agreement between ground- and satellite-based datasets of its SO_2 emissions, using newly gained understanding of potential sources of interference.

IMPORTANCE OF THE WORK

The use of satellites to monitor volcanic degassing has the potential to greatly extend the scope of present volatile emissions inventories. This is important in understanding the environmental and atmospheric impacts of volcanic degassing, as well as the role of volcanoes in cycling volatiles through various Earth reservoirs. Additionally, the long-term and continuous datasets offered by satellite instruments could prove to be crucial for monitoring volcanoes from a hazard mitigation perspective: certain notable eruptions have been preceded by observable changes in gas emission shortly prior to their onset. In order to accomplish these aims however, further work focussed on improving data quality and our understanding of sources of uncertainty or error is crucial.



Monthly mean plot of SO_2 column concentrations [scale in Dobson Units] over Papua New Guinea, June 2005. Plumes of SO_2 are evident at a number of volcanoes. Plots like these demonstrate the relative SO_2 emission from each volcano.

Find out more
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McCormick, B.T., M. Edmonds, T.A. Mather and S. A. Carn. 2012a. First synoptic analysis of volcanic degassing in Papua New Guinea. Geochemistry, Geophyics, Geosystems, 13, Q03008.

McCormick, B.T., M. Edmonds, T.A. Mather, C.S.L. Hayer, R. Campion, H.E. Thomas and S.A. Carn. 2012b. Volcano monitoring applications of the Ozone Monitoring Instrument (OMI). Submitted to Geological Society of London Special Publication "Remote sensing of volcanism".

SUSANNA EBMEIER *University of Oxford*

Supervisors: Juliet Biggs, Tamsin Mather, Don Grainger

InSAR MEASUREMENTS OF VOLCANO DEFORMATION IN CENTRAL AMERICA

OVERVIEW

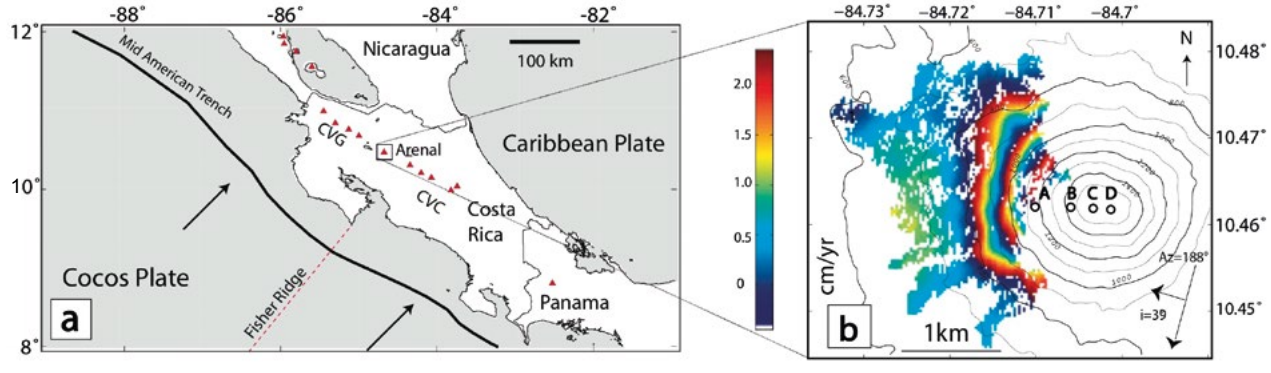
Volcano deformation can illuminate a range of volcanic processes from the emptying or recharge of a chamber during eruption to the slow gravity-driven collapse of a volcano's edifice itself. Interferometric synthetic aperture radar (InSAR) uses time separated radar images to measure the movement of the ground on the scale on millimetres to centimetres. I have made InSAR measurements of volcano deformation along the Central American Volcanic Arc between 2007–2010 and compared my results to literature measurements to put volcano deformation in Central America into a global context.

FINDINGS

My measurements of deformation at Arenal volcano, Costa Rica, show for the first time that a large section of the western flank of the volcano is sliding downslope at a rate of about 6 cm/yr. I have also used InSAR to measure the changes to the shape of lava flows (10 -200 m) at Santiaguito volcano, Guatemala. This novel approach has allowed the first measurements of extrusion rate at this volcano for the period between 2000-2010. The most striking result from my PhD is actually the lack of measurable deformation caused by magma movement in Central America, which may be due to particular features of its tectonic setting.

IMPORTANCE OF THE WORK

Remote measurements of deformation are crucial for assessing the hazard posed by volcanoes in parts of the world where ground-based measurements are not made routinely, either because they would be too dangerous or are unfunded. My measurements of flank collapse at Arenal are of immediate importance to the Costa Rican volcano observatory (OVSICORI). I expect other aspects of my PhD research to be useful to the wider volcanological and natural hazards research community as well as to volcano observatories and eventually policy makers concerned with volcanic hazard. For example, extracting volcano extrusion rate from InSAR has the potential to allow the level of activity of some remote, inaccessible volcanoes to be assessed from space. The lack of measureable magmatic deformation in Central America also has broad implications for the use of InSAR as a tool in volcano monitoring and hazard assessment.



a) Map showing the location of Arenal Volcano, Costa Rica. b) An interferogram of Arenal. Each complete colour cycle represents ~2.5cm/yr of downslope motion. The letters A, B, C and D show the location of craters. C is the current summit.

Find out more
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Ebmeier, S.K., Biggs, J., Mather, T.A., Elliott., J.R., Wadge, G., and Amelung, F. (2012) Measuring large topographic change with InSAR: lava thicknesses, extrusion rate and subsidence rate at Santiaguito Volcano, Guatemala, Earth and Planetary Science Letters, doi:10.1016/j.epsl.2012.04.027.

Ebmeier, S.K., Biggs, J., Mather, T.A., Wadge, G., and Amelung, F. (2010) Steady downslope movement on the western flank of Arenal Volcano, Costa Rica, Geochemistry, Geophysics, Geosystems, doi:10.1029/2010GC003263

RICHARD WALTERS *University Of Oxford*

Supervisors: Barry Parsons, Phil England and Tim Wright

CONTINENTAL DEFORMATION AND SEISMIC HAZARD IN THE ALPINE-HIMALAYAN BELT USING InSAR

OVERVIEW

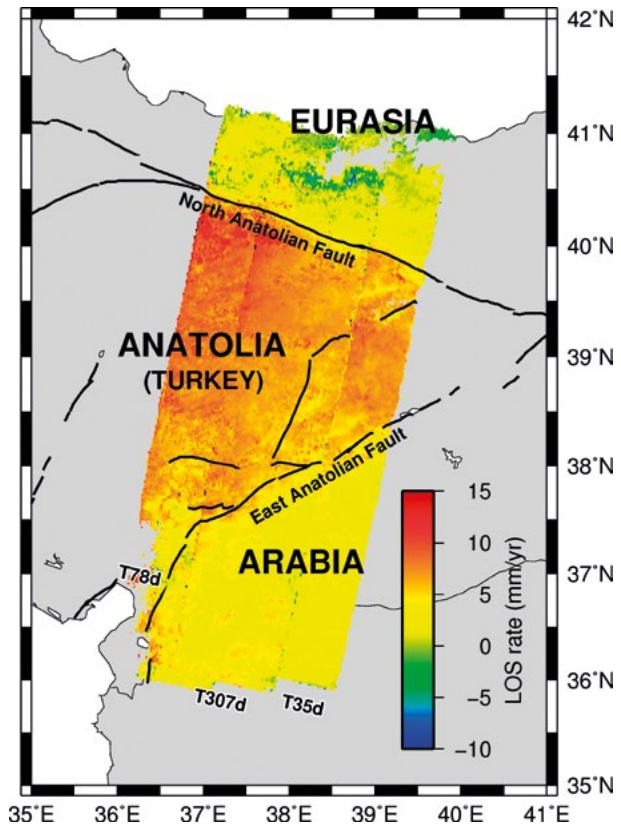
My research focuses on using satellite radar measurements in order to measure millimetric-scale tectonic ground motion. This radar technique, known as InSAR, can be used in two main ways to study earthquake hazard. Firstly it can be used to conduct a 'post-mortem' of an earthquake, determining its size, type and location, in a complementary way to traditional seismology. This is often vital for assessing further risk within an earthquake region. Secondly, InSAR can be used to measure how fast strain is building up on faults between earthquakes, which enables calculation of the likelihood and frequency of future seismic events. During my PhD I have used InSAR for both purposes, and have studied a number of recent earthquakes as well as measuring strain accumulation across large faults in the Middle East.

FINDINGS

I used InSAR to study the L'Aquila earthquake that struck central Italy in 2009, and made several important findings relating to local earthquake risk, including how stress had brought other nearby faults closer to failure. I have used InSAR to measure long-term strain accumulation, and therefore characterise earthquake hazard, across the North Anatolian Fault and East Anatolian Faults in Eastern Turkey, and across the little-understood Ashkabad Fault in NE Iran. As part of this research, I have investigated and developed different methods of correcting for atmospheric effects in InSAR data, which are one of the largest sources of error when trying to measure small ground motions with this technique.

IMPORTANCE OF THE WORK

This work helps us to understand the regional tectonics of the Middle East, and also helps evaluate the seismic hazard in this area. This is of interest to local and national government, and also to the insurance and reinsurance industries. My research on correction of atmospheric effects is important for other geophysicists using InSAR to measure small ground motions, and will become even more useful in future as we attempt to measure increasingly small deformations.



InSAR "ratemap" showing slow westwards movement (red colour) of Anatolia, facilitated by the North and East Anatolian Faults.

Find out more

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Walters et al., 2009, The 2009 L'Aquila Earthquake (Central Italy): an InSAR source mechanism and implications for seismic hazard, GRL, V.36, L17312

Walters et al., 2011, Interseismic strain accumulation across the North Anatolian Fault from Envisat InSAR measurements, GRL, V.38, L05303

MICHELLE PARKS *University of Oxford*

VOLCANIC DEFORMATION IN THE COLOMBIAN ANDES AND THE SOUTH AEGEAN ARC: A COMBINATION OF InSAR AND FIELD BASED TECHNIQUES FOR MONITORING ACTIVE VOLCANOES

Supervisors: Juliet Biggs, Tamsin A Mather, David M Pyle

OVERVIEW

My research is concerned with understanding the characteristic behaviour of volcanoes during both eruptive phases and periods of quiescence. My project incorporates both remote sensing and field based techniques, utilising Interferometric Synthetic Aperture Radar (InSAR) to measure volcanic deformation and soil gas monitoring to determine rates of degassing. I am currently working on active volcanoes in the Colombian Andes and the South Aegean Arc.

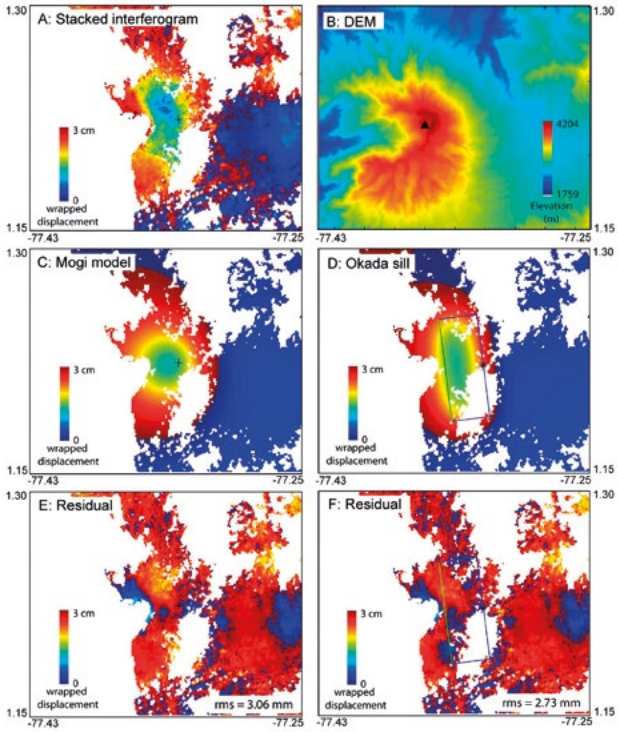
FINDINGS

Analysis of 3 years of satellite images covering the Colombian segment of the Northern Volcanic Zone (NVZ) showed that the majority of Colombian volcanoes were not deforming. However, independent interferograms spanning June 2007-September 2008 displayed a subsidence signal on the northeast flank of Galeras volcano. By combining InSAR, field measurements and source modelling we were able to determine the origin, size and location of the source of deflation at Galeras. The deformation period coincided with the January 2008 eruption and it is proposed that this signal was caused by deflation of the magma chamber associated with this explosive event.

InSAR observations at Santorini volcano from 1993–2010 using ERS and Envisat satellite data show subsidence on the central volcanic island of Nea Kameni which can be interpreted as loading by recent lava flows or degassing of a shallow magma body. In January 2011, the volcano entered a period of unrest, characterised by the onset of detectable seismicity and caldera-wide uplift. We have used Envisat and TerraSAR-X interferograms to measure ground deformation since March 2011 and 6 soil CO_2 flux surveys have been undertaken on the summit of Nea Kameni to measure variations in diffuse soil degassing between September 2010 and May 2012. The results of these studies will be published shortly.

IMPORTANCE OF THE WORK

It is important to study volcanoes during both eruptive phases and periods of quiescence. Volcanic deformation and degassing occur during both episodes; understanding the characteristic behaviour of volcanoes during these periods can help identify the transition from one state to another and modelling deformation measurements can provide an improved understanding of the complex subsurface structure of active volcanoes.



Galeras volcano 2D source modelling. A) Stacked interferogram. B) DEM. C) Modelled interferogram using Mogi point source. D) Best-fit model (Okada sill). E) Difference between stack and modelled interferogram in Figure c. F) Difference between stack and modelled interferogram in Figure D. The location of the Mogi point source is displayed as the cross in Figures A and E. The outline of the Okada sill is displayed as the rectangle in Figures D and F.

Find out more
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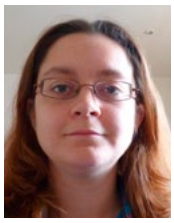
Parks M M, Biggs J, England P, Mather T A, Nomikou P, Palamartchouk K, Papanikolaou X, Paradissis D, Parsons B, Pyle D M, Raptakis C and Zacharis V, Evolution of Santorini Volcano dominated by episodic and rapid fluxes of magma from depth. Nature Geoscience (in press).

Parks M M, Biggs J, Mather T A, Pyle D M, Amelung F, Monsalve M L and Narváez Medina L (2011), Co-eruptive subsidence at Galeras identified during an InSAR survey of Colombian volcanoes (2006-2009). Journal of Volcanology and Geothermal Research, 202, 228-240. doi:10.1016/j.jvolgeores.2011.02.007.

CAT HAYER *University of Reading*

Supervisor: Geoff Wadge and Marie Edmonds

THE VARIABILITY OF SO_2 EMISSION FROM SOUFRIÈRE HILLS VOLCANO, MONTSERRAT, USING SATELLITE AND GROUND OBSERVATIONS



OVERVIEW

I am investigating sulphur dioxide (SO_2) emission from the Soufrière Hills Volcano (SHV), Montserrat, using remote sensing data – both from satellites and from ground-based systems. I am exploring the way in which SO_2 is stored in, and released from, the magmatic system. I have been using the Ozone Monitoring Instrument (OMI), a UV backscatter imager onboard NASA's Aura satellite, to observe the SO_2 emission from space, and the Differential Optical Absorption Spectrometer (DOAS) array on Montserrat to observe the emission from the ground. I have also used the Infrared Atmospheric Sounding Interferometer (IASI) and the Spinning Enhanced Visible and Infrared Imager (SEVIRI).

FINDINGS

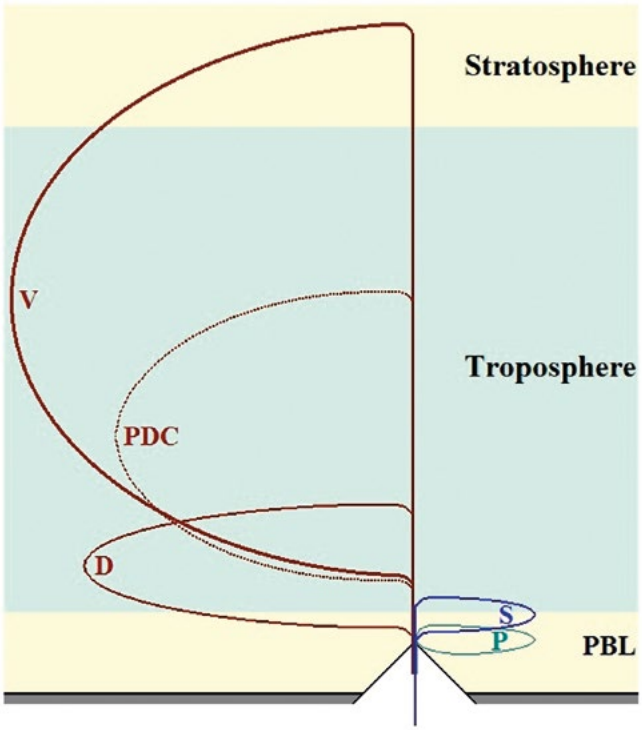
During periods of higher activity and lava emission, more plumes are observed by OMI than during periods of reduced activity. The main reason to explain this difference is the variation in the altitude at which the SO_2 is emplaced in the atmosphere, rather than a significant increase in the amount of SO_2 emitted (see figure, S). If the plume is higher in the atmosphere, as is the case during activity, then satellites are able to observe it more easily as the path length is shorter as there is less of the atmosphere for the radiation to travel through and vice versa.

During high activity there are 3 main mechanisms which emplace the plume at a greater altitude than the passive degassing which occurs during low activity (P). The first is large explosive eruptions which emplace the SO_2 at very high altitudes, up to ~15 km at SHV (V); the second is buoyant plumes which rise off of pyroclastic density currents moving down the flank of the volcano, reaching ~10 km (PDC); the third is due to the hot lava dome. This increases the temperature of the surrounding air which is entrained into the continuously released plume from SHV, and increases the plume height up to ~4 km (D).

I will be comparing the findings from OMI to those from IASI and SEVIRI for the most recent periods of high activity at the volcano, and looking at the largest events seen at SHV to try to understand the gas release mechanisms that occur only during large explosive eruptions.

IMPORTANCE OF THE WORK

Since volcanic gases are one of the main drivers of explosive eruptions, understanding the movement of gas through the system is crucial to improving our understanding of volcanic eruptions and the hazards associated with them. If we can improve our understanding of the processes behind these explosive events, it will help volcano observatories, both on Montserrat and around the world, to forecast when they may happen and so reduce the risk posed by volcanoes to the people who live nearby.



Physical mechanisms which would lead to a change in height of the volcanic SO_2 plume. P: Passive degassing; S: Increased SO_2 emission (no significant change in altitude); V: Vulcanian explosion; PDC: Co-pyroclastic density current plume; D: Hot lava dome plume.

Find out more
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ANDREW TAYLOR *University of Bristol*

Supervisor: Tony Payne

MODELS OF ICEBERG CALVING IN GREENLAND

OVERVIEW

1. To develop and adapt the BISICLES Ice Sheet model to simulate the calving of icebergs. This will be validated by testing of the methods, using, amongst other techniques, idealised geometries to test our calving parameterisation.

2. To test the changes to the BISICLES ice sheet model using 1 km-resolution topography, ice thickness, velocity and temperature data from the Greenland Ice Sheet.

3. To compare numerical simulations to available remote sensing data, particularly regarding the changes in front position, grounding line and velocity structure, in order to validate the approach to the modelling of calving.

4. To be able to produce a complete Greenland ice sheet model using the improved calving model in order to better understand ice dynamic changes across the Greenland Ice Sheet, and therefore to better predict its future response to climate change

FINDINGS

The research completed to date suggests that BISICLES performs well on both hypothetical and real data. A crevasse-depth calculation based on stress calculations used by Benn et al. (2007) and Nick et al. (2010) has been successfully tested offline using BISICLES output. The next stage of the process involves implementing crevasse depth calculations into real-time BISICLES simulations to create calving events based on calving occurring when crevasses penetrate to the waterline. Oceanic and atmospheric forcing will then be included and BISICLES tested against available remote sensing data.

IMPORTANCE OF THE WORK

Accurate projections of the future dynamics of Greenland are vital because they will allow better quantification of its impact on sea level change. The Greenland ice sheet contains 2.9 x 106 km3 of ice, which is a eustatic sea-level equivalent of 7 m. Much of the ice sheet is drained through large tidewater terminating glaciers that deliver substantial quantities of ice to the ocean through iceberg calving. Theoretical analyses and numerical predictions of iceberg calving are therefore important.

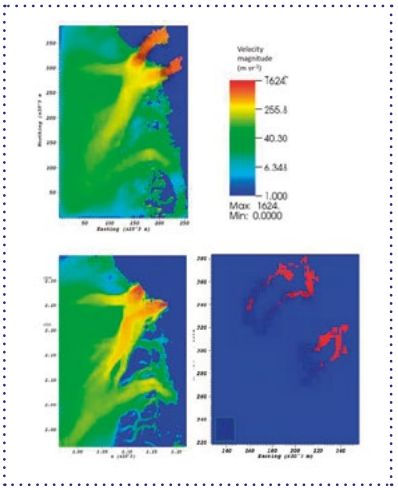


Fig 1: Simulations of North East Greenland using BISICLES. (a): Predicted velocities based on 50-year simulation. (b): Observed velocities (note absence of data for floating tongue). (c): predicted calving; red areas signify parts of the north-east of the domain that had crevasse depths that extended below the waterline. Velocities are in m yr^{-1}.

Find out more

Benn et al. (2007), Annals of Glaciology

Nick et al. (2010), Journal of Glaciology

AMBER LEESON *University of Leeds*

Supervisor: Andrew Shepherd

SIMULATING THE EVOLUTION OF SUPRA-GLACIAL LAKES ON THE GREENLAND ICE SHEET

OVERVIEW

In the IPCC AR4, a lack of understanding concerning the processes which contribute to changes in ice dynamics was highlighted as a concern. This work aims to help address this uncertainty by providing a new insight into the behaviour of supra-glacial lakes, which promote melting by lowering the area-averaged surface albedo of the ice sheet and they are also believed to influence ice sheet dynamics when they drain.

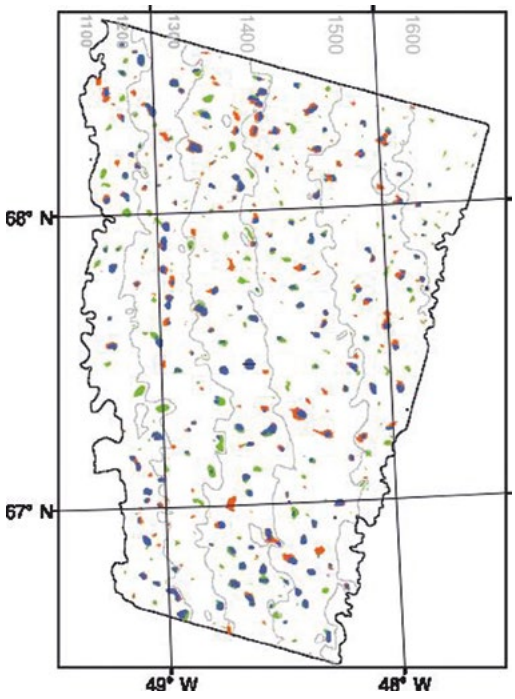
During this PhD, a transient 2D hydrology model of supra-glacial lake evolution has been developed which employs elevation measurements recorded using interferometric synthetic aperture radar data along with equations for open channel flow and flow through a porous medium to determine the course of water routing and ponding across the ice sheet surface. Ice sheet run-off is determined at 25 km resolution using the Modèle Atmosphéric Régionale (MAR) regional climate model output.

FINDINGS

When compared to MODIS derived observations for 2003 the model is found to simulate 64% of lakes in coincident locations with the observations. A correlation co-efficient of 0.83 is calculated between simulated and observed onset dates for these lakes. Maximum cumulative fractional lake area coverage is overestimated by 9% which we attributed to the absence of drainage in the model. We are currently using the model to investigate inter-annual variability in supra-glacial lake behaviour using the model and MODIS observations across the period 2001-2010. Preliminary forward predictions have also been made which suggest that we can expect lakes to appear sooner in the year and grow quicker in 2100.

IMPORTANCE OF THE WORK

The mass balance of the Greenland ice sheet has been negative for a number of years; the presence of supra-glacial lakes promotes ice mass loss by reducing ice sheet surface albedo and also potentially through lubrication of ice flow if they drain. This may cause additional mass loss through discharge and also perturb the surface mass balance budget through a net lowering of the surface. Greenland currently contributes 0.46 mm per year to global sea level rise (van den Broeke et al., 2009). However uncertainty estimates on these data are large. It is hoped that this work will inform the treatment of supra-glacial lakes in climate and ice sheet models and contribute to reducing the uncertainty in predictions of future contribution of Greenland to global sea level rise.



Simulated (green), observed (red) and both simulated and observed (blues) supra-glacial lakes in 2003

Find out more

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Leeson, A. A., A. Shepherd, S. Palmer, A. Sundal, and X. Fettweis: Simulating the growth of supra-glacial lakes at the western margin of the Greenland ice sheet, The Cryosphere Discuss. 2012

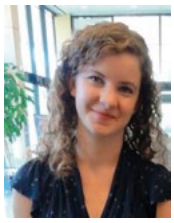
Graversen, R. G., Drijfhout, S., Hazeleger, W., van de Wal, R., Bintanja, R., and Helsen, M.: Greenland's contribution to global sea-level rise by the end of the 21st century, Clim. Dyn., 37, 1427-1442, 10.1007/s00382-010-0918-8, 2011.

van den Broeke, M., Bamber, J., Ettema, J., Rignot, E., Schrama, E., van de Berg, W. J., van Meijgaard, E., Velicogna, I., and Wouters, B.: Partitioning Recent Greenland Mass Loss, Science, 326, 984-986, 10.1126/science.1178176, 2009.

ANNA HOGG *University of Leeds*

MAPPING GROUNDING LINES FROM SATELLITE OBSERVATIONS

Supervisor: Andrew Shepherd



OVERVIEW

The aim of this PhD thesis is to map change in the location of ice sheet Grounding Lines (GL's) using satellite Earth Observation (EO) techniques, at an annual temporal sampling frequency, for the 20 year EO data archive. The aim of this PhD thesis will be achieved by accomplishing the following objectives:

- Map GL locations using the Differential Interferometric Synthetic Aperture (DInSAR) technique to determine the Hinge Line (HL) location at a high spatial but coarse temporal resolution.
- Adapt the laser altimeter technique for determining GL location to use radar altimeter data.
- Map GL locations using the new radar altimeter technique to determine the HL location at a low spatial but high temporal resolution.
- Evaluate the accuracy of the radar altimeter GL location technique through a comparison with the DInSAR GL location technique, when permitted by overlap of suitable EO data acquisitions.
- Apply the radar altimeter GL location technique to a EO time series over one or more ice streams with a floating ice tongue to determine the change in GL location, at an annual sampling frequency, over a 20 year time period.

FINDINGS

Due to the fact that I am currently in the first year of my PhD, I do not have any final results yet. In order to develop the skills required to locate a GL using DInSAR it was first necessary to gain knowledge of the InSAR processing chain. As a short term goal this capability was also utilised as part of a Coherence and Feature Tracking Study (CaFTS). Figure 1 illustrates ice velocity at the Petermann Glacier study area processed during CaFTS using the intensity offset tracking method (Strozzi et al, 2002). The results of CaFTS indicate that over ice land surfaces the 6-day repeat period of S-1 results in significantly higher levels of coherence in comparison with the 12-day repeat period. Future work will include locating the GL at Petermann using DInSAR and applying the laser altimeter GL technique to ERS and ENVISAT radar altimeter data.

IMPORTANCE OF THE WORK

Grounding Line (GL) migration is a key indicator of change in mass balance and internal instability in marine terminating ice masses (IPCC, 2010). Flux in GL location has been observed on a short, sub-decadal timescale as exemplified by the rapid retreat of Pine Island Glacier GL between 1992 and 2011 (Park et al, 2012). The majority of the West Antarctic Ice Sheet's (WAIS's) subglacial bedrock lies below current sea level and is therefore particularly susceptible to a dynamic response caused by GL retreat as hypothesised by Hughes (1973). The WAIS contains enough ice to raise global sea levels by approximately five meters if total melt occurs and therefore even small fluctuations in GL location have potentially large global effects (Shepherd et al 2001). Current predictions of the Antarctic Ice Sheet contribution to Sea Level Rise over the next 100 years are principally limited by a lack of understanding about the ice sheet response to GL retreat, in conjunction with the effect of additional ice ocean interactions (IPCC, 2010). As a result of this it is important to regularly measure the change in GL location to determine the mass loss of the most rapidly changing regions of the ice sheets and thus their contribution to global sea level rise.

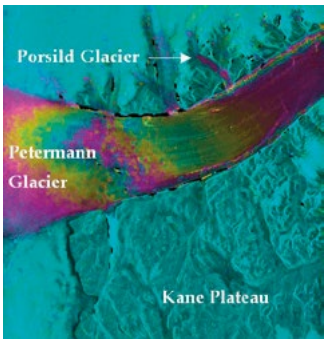


Fig 1. Ice velocity of Petermann Glacier, North West Greenland, determined using SAR offset tracking. Coloured fringes on Petermann Glacier each represent 10m of ice velocity.

MARK RICHARDSON *ESSC Reading*

Supervisor: Robert Gurney

SNOW OBSERVATIONS AND MODELLING

OVERVIEW

Light that passes through snow is strongly affected by the snow's structural properties, such as the size of snow grains which scatter radiation. We ultimately want to 'weigh' the Earth's snow to know about water supplies, flood risks and climate change but satellite methods use microwaves that are sensitive to snow's optical grain size. Grain growth depends on the weather, so in principle we can simulate it to improve measurements of snow mass from space. The albedo of snow also depends on grain size, and new work suggests that a combination of clear skies and warming summer temperatures over Greenland have led to larger grains, increasing the amount of sunlight absorbed by the ice sheet and raising the chances of surface melt which contributes to sea level rise.

Knowing more about the snow grains is therefore very important, and with new methods we can determine how they interact with radiation and what we need to do to improve our measurements of snow from space. My work tries to link traditional and modern measurement methods to test our expectations of how they relate and to allow us to translate the huge quantity of traditional measurements into a modern format that will be relevant to satellite measurements.

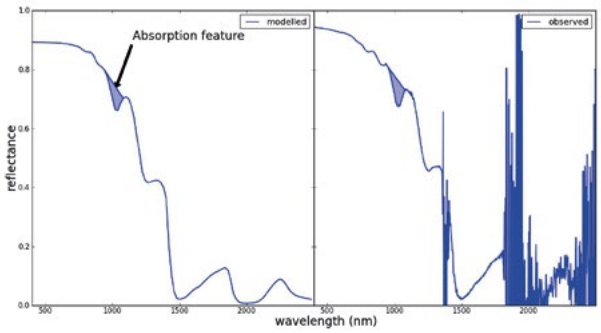
FINDINGS

In a fieldwork campaign in Sodankylä, Finland, snow grain size measurements were taken in snow pits using both traditional microscope and spectroradiometer measurements in the near-infrared. These data will provide a 'bridge' between the two methods. Preliminary results have confirmed the reliability of computer simulations of how radiation interacts with snow (see figure). This is important as these simulations make some simplifications to reduce processing time.

In warmer weather the snow grains clump into 'conglomerates', an effect ignored by large climate models. The Sodankylä results suggest that this clumping does not affect the radiation interactions at these wavelengths, supporting the use of more streamlined snow models.

IMPORTANCE OF THE WORK

Linking modern spectroradiometry measurements to traditional measurements that have been performed for decades would allow us to translate large quantities of old data into a form that's useful for satellite measurements. This would retrospectively improve estimates of snow mass and the cause of changes in snow reflectivity, helping to identify climate trends in the past. Additionally, by identifying how we can simplify computer simulations, processing time and cost can be reduced when interpreting measurements from modern satellites to provide knowledge of the climate change, water availability and flood risks of the future.



Reflectance spectra of snow from a computer simulation (left) and as measured by a spectroradiometer in Abisko, Sweden (right). The size of the shaded area informs us about how big the snow grains are, which is important for other measurements. The big spikes on the right are caused by atmospheric absorption.

Find out more
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HARRY HEORTON *UCL CPOM*

Supervisors: Daniel Feltham (UCL CPOM), Ann Keen (Met Office Hadley Centre)

JET FORMATION AT THE SEA ICE EDGE

OVERVIEW

Sea ice components of Global Climate Models crudely parameterise processes at the edge of the sea ice cover leading to inaccuracies in calculating the location of the sea ice edge and thus the extent of the cover. Atmospheric jets are bands of modified wind velocity that form parallel to coastlines during on-land winds. A similar formation is expected over the sea ice edge and in the ocean underneath the sea ice. We have modeled the formation of these jets and the effect they have upon the sea ice.

We present a study of a reduced 1 dimensional model of the sea ice momentum balance, introducing atmospheric and oceanic jets. We present the application of jets to an idealised sea ice edge using the Los Alamos Sea Ice Model (CICE). The simulations are run on an idealised domain and show the formation of an ice jet.

Areas of likely jet formation are found by analysing ice concentration data from the NSICD and the Met office Hadley Centres HadGEM2 model.

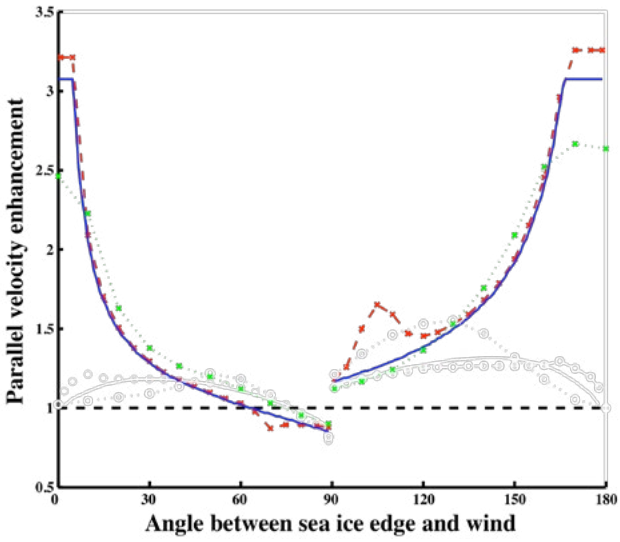
FINDINGS

Atmospheric jets can form at the sea ice edge due to the sharp change in surface roughness between the open ocean and the broken ice floes of the marginal ice zone. Atmospheric jet formation increases the wind speed parallel to the ice edge. This increase in wind speed is transferred to the sea ice drift for all on ice winds (see figure). An increase in ice drift speed changes the transport of sea ice along the sea ice edge and the compaction or dispersion of the sea ice. Due to the similarity of ice and ocean drift speed, ocean jets are unlikely to form at the sea ice edge.

IMPORTANCE OF THE WORK

Atmospheric jets are likely to form over the sea ice edge in both the Arctic and Antarctic. Of particular interest is the Fram Strait, where the sea ice edge allows for atmospheric jet throughout the year. The ice transport increase associated with atmospheric jet formation could contribute for a quarter of the ice transport through the Fram Strait. Current global climate models do not accurately model the ice transport through the Fram strait.

The sea ice transport through the Fram Strait is responsible for 90% of the sea ice export out of the Arctic Ocean. This export is a major factor in the Arctic sea ice extent. The Arctic sea ice extent is observed to be reducing with a record low in 2007, which was not predicted by most current global climate models. The reduction in Arctic sea ice could have major repercussions for the global climate. Also as Arctic becomes ice free in the summer months, opportunities for shipping and industry arise. Accurate predictions of sea extent are essential for the safety of these operations.



Velocity enhancement (jet speed/no-jet speed) parallel to the sea ice edge due to atmospheric jet formation. Wind speed – Blue, Ice drift speed (analytical model) – Red, (CICE model) – Green.

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THERESA MEACHAM *The University of Edinburgh*

Supervisors: Mathew Williams, Andreas Heinemeyer.

IMPROVING THE REPRESENTATION OF BELOWGROUND C PROCESSES IN ECOSYSTEM MODELS.

OVERVIEW

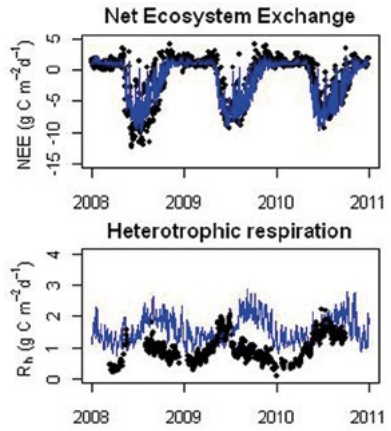
Models based on eddy flux data have poorly constrained parameters because there is limited information on how C is processed within ecosystems and its residence times. In particular, belowground parameters (i.e. fine root biomass turnover and soil carbon fluxes) are poorly understood and constrained because few datasets of them have been collected. Our objective has been to improve the representation of belowground processes in ecosystem models by collecting novel datasets of fine root turnover and partitioned soil respiration fluxes (i.e. from roots, mycorrhizae and microbes). The uncertainty and spatial variability of these measurements has also been characterised at larger spatial scales. We are now comparing the results from these experiments with outputs from the Soil-Plant-Atmosphere (SPA) model.

FINDINGS

The initial comparisons of modelled and measured Net Ecosystem Exchange (NEE) have indicated that SPA is well parameterised above-ground. However, comparisons of modelled heterotrophic respiration with measurements taken using the automated soil respiration (R_s) chambers indicate that belowground processes are poorly parameterised (Figure 1), supporting the findings of previous studies (Richardson et al. 2010, Fox et al. 2009). To characterise potential biases between the model outputs and data, field surveys characterising landscape variability have been conducted. These field surveys indicate that biases may occur from 'hotspots' of R_s which persist seasonally. The biomass measurements of fine root turnover are also being used to constrain SPA further.

IMPORTANCE OF THE WORK

These model-data comparisons are helping to provide critical parameters for C cycle models that relate to fine root allocation and turnover, and to the contribution of plant, mycorrhizae and microbes to soil respiration. Current data assimilation work taking place at The University of Edinburgh is constraining C cycle models using remote sensing. The outputs from this study will feed into these efforts, by providing fundamental ecological information on belowground processes, alongside their associated uncertainties.



Top – modelled (blue line) and measured (black dots) NEE (g C m^{-2} d^{-1}). Bottom – modelled (blue line) and measured (black dots) heterotrophic respiration (g C m^{-2} d^{-1}) in a south east England oak forest.

Find out more

Email: theresa.meacham@ed.ac.uk
www.geos.ed.ac.uk/homes/s0897919/

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In preparation

Meacham et al. Linking spatial and seasonal variability of soil respiration to its key drivers in a temperate deciduous forest.

Meacham et al. How precise are estimates of net fine root biomass change in temperate woodlands?

JENNIFER PRICE *University of Reading*

CONSTRAINING A GLOBAL VEGETATION MODEL WITH EARTH OBSERVATION DATA

Supervisor: Tristan Quaife

OVERVIEW

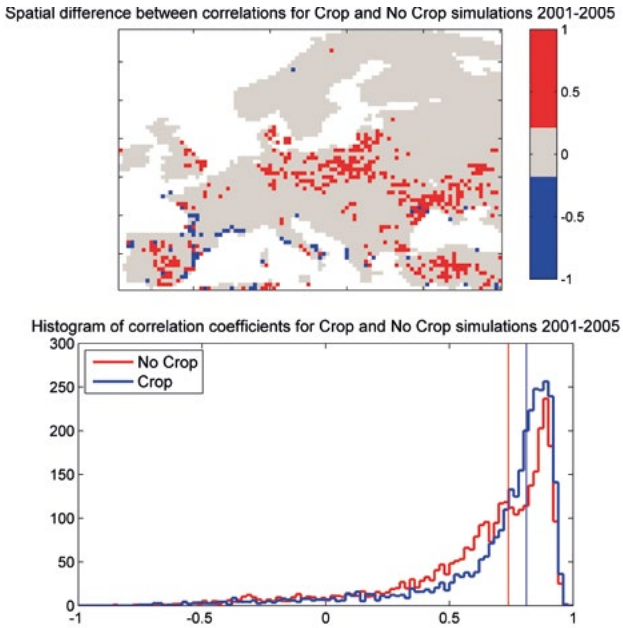
Global vegetation models (GVMs) are useful tools for understanding the exchanges of water and carbon between the atmosphere and the terrestrial biosphere and the associated feedback effects. This is of particular importance with increased atmospheric CO_2 concentrations and associated climate changes. The overall aim of this research project is to improve the performance of the Sheffield Dynamic Global Vegetation Model (SDGVM) using Earth observation data to validate model outputs and constrain model processes and parameters. The primary aim is to improve the representation of global vegetation types in SDGVM in order to reduce some of the uncertainties associated with modelling vegetation activity.

FINDINGS

Two simulations were run in order to test the performance on the crop module in SDGVM. These used the land cover data from the GLC2000 product to specify fractional vegetation coverage across Europe. The first simulation assumed equal cover between crops and grasses for the land cover classes containing crops, the second simulation removed the crop fraction and replaced it with grass. SDGVM was run for a 5 year period across Europe and the monthly outputs of fPAR were correlated against monthly MODIS NDVI data. The figure shows the differences between the correlations for each simulation (map was calculated as Crop correlations minus No Crop correlations) and there is a clear positive shift in the correlations when crops are included as a separate functional type. There are however regions around the Mediterranean where model performance is weaker when crops are included. This is a region where fruit trees and vines comprise a large proportion of crop area and the current harvesting controls do not appear to be appropriate for this crop type. Further work will address this issue by modifying the representation of different crop types in SDGVM. Additional work is aiming to further test the structural representation of vegetation in SDGVM by utilising an observation operator in order to simulate canopy reflectance from SDGVM outputs of LAI; this will then be validated against MODIS data. The aim is to identify regions where the current turbid medium representation of vegetation is inappropriate and to improve this.

IMPORTANCE OF THE WORK

This work will be of relevance to the vegetation and land surface model development community. This could also be of benefit to policy makers as the improved representation of vegetation in models will reduce the uncertainties associated with simulating continental scale carbon fluxes.



The map shows the differences in correlation strength between Crop and No Crop simulations of fPAR and MODIS NDVI. Red indicates positive correlations with crops and blue indicates positive correlations without crops. The vertical lines on the histogram show the median correlation coefficients.

Find out more
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ANTHONY WALKER *University of Sheffield*

PLANT PRODUCTIVITY AND PHOTOSYNTHESIS ON EARTH IN THE HIGH CO_2 21ST CENTURY: INFORMING SIMULATIONS WITH DATA

Supervisors: Ian Woodward, Chris Huntingford

OVERVIEW

The objective of the PhD was to inform and develop global carbon cycle models with data from Free Air CO_2 Enrichment (FACE) experiments.

The PhD starts with a meta-analysis of plant and ecosystem responses to elevated CO_2 under FACE to generalise key CO_2 responses that models should capture. To determine experimental accuracy an artefact of the FACE experiments – oscillating CO_2 – was tested on Poplar and Oak seedlings.

Using FACE data to inform model development began by simulating the Oak Ridge and Duke FACE experiments using the Sheffield Dynamic Global Vegetation Model (SDGVM) and the Joint UK Land Environment Simulator (JULES). Model development progresses using mixed-model multiple regression to determine novel relationships of photosynthetic parameters (Vcmax and Jmax) with leaf nitrogen phosphorus and Specific Leaf Area (SLA).

Findings were integrated into SDGVM to determine the impact of more accurate parameterisation of Vcmax on the simulation of the global carbon cycle by SDGVM.

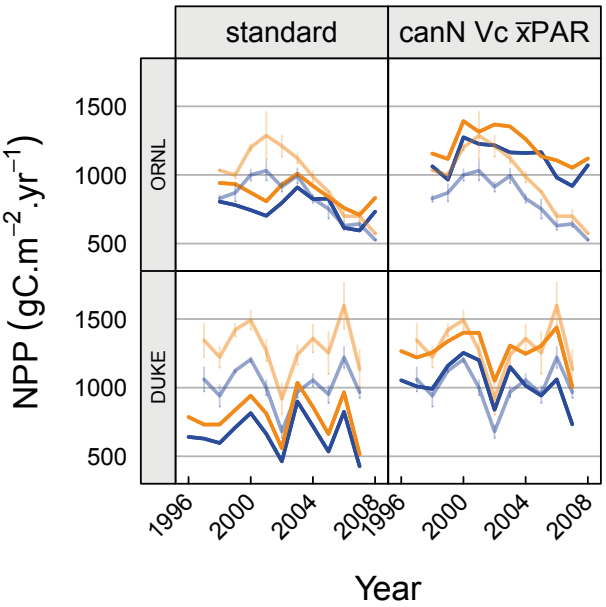
FINDINGS

Models have biases which are often compensated by biases of an opposite sign. For example, SDGVM over-predicts photosynthetically active radiation compensated for by under-prediction of Vcmax; JULES over-predicts carbon assimilation, which is compensated by high levels of soil water limitation. Fixing these biases in SDGVM led to over-prediction of carbon assimilation and plant biomass highlighting the need for improved simulation of nitrogen limitation and tree mortality. Phosphorus was shown to be an important determinant of Vcmax, necessary for inclusion in a global relationship of Vcmax to leaf traits.

IMPORTANCE OF THE WORK

Bias and compensating factors are key features of models and areas for development in SDGVM and JULES were highlighted and improved.

Global carbon cycle models are fundamental to understanding global change yet we still do not understand key questions such as: for how long will terrestrial plant productivity respond to elevated CO_2 or to what extent does soil water limitation impact plant productivity?



Net Primary Productivity under ambient (blue lines) and elevated (orange) CO_2 observed (faded lines) at Duke and Oak Ridge FACE experiments and simulated (solid lines) by SDGVM. SDGVM was run in two configurations – in its standard set up (standard) and parameterised with observed canopy nitrogen, the Vcmax relationship to leaf nitrogen and mean observed photosynthetically active radiation (canN Vc xPAR).

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Please contact for details of papers in preparation

LAIMONAS ZUBAS *University of Leicester*

ATTRIBUTION OF SPATIO-TEMPORAL ANOMALY PATTERNS OF ATMOSPHERIC METHANE TO EMISSIONS FROM WETLANDS AND PADDIES

Supervisors: P. Monks, H. Boesch

OVERVIEW

The goal of this project is to exploit optimally the synergy between remote sensing and surface properties in combination with atmospheric transport modelling to advance our understanding of the highly uncertain biogenic sources of methane. It is assumed that any deviation in GOSAT measured atmospheric concentrations of methane (CH_4) from the 'baseline' background can be attributed to the emissions in the local region.

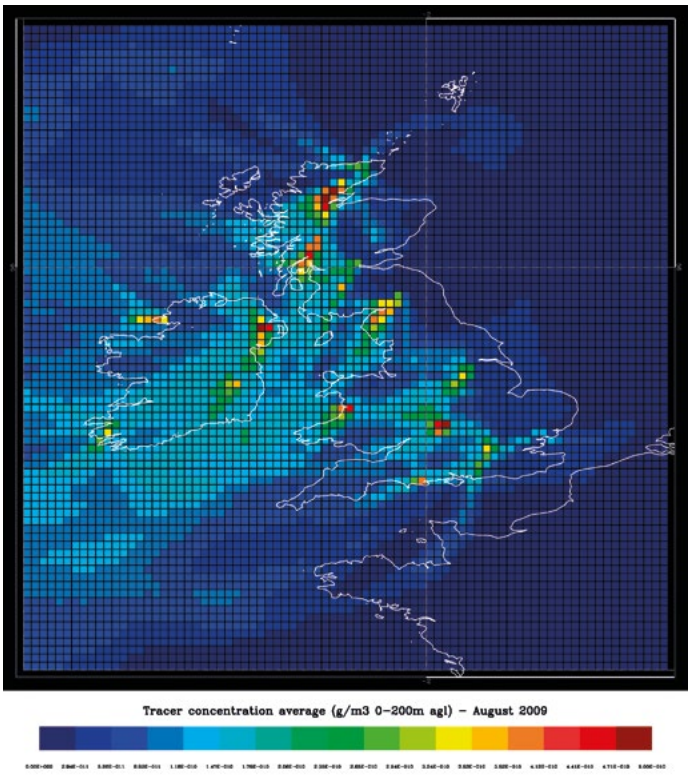
The areas responsible for the enhancement of atmospheric concentrations of CH_4 are identified using a lagrangian dispersion model. The UK atmospheric dispersion model NAME (Numerical Atmospheric Modelling Environment) is used here to calculate the so-called source-receptor relationships for each satellite measurement. Tracer particles are released into the model atmosphere at the location and time of the measurement and the model runs in backwards mode. Statistical analysis of the tracer concentration (source-receptor) maps and the corresponding satellite measurements allows us to calculate the surface emissions in the region of interest.

FINDINGS

The combination of NAME with GOSAT can help constrain methane emissions. Whilst measurements from the ground measurements stations are very sensitive to local sources, GOSAT is influenced by emissions from a larger area. The inversion algorithm will be used with measurements over high emitting regions (South East Asia, South America) and potentially other areas in the near future, once testing over the UK is complete.

IMPORTANCE OF THE WORK

Atmospheric methane (CH_4) plays a significant role in global warming and has a radiative forcing efficiency 21 times greater than that of CO_2. The quantification of individual methane sources and sinks is still, however, largely uncertain. These uncertainties are particularly large for the various biogenic CH_4 sources, such as wetland emissions or emissions from rice paddies due to their large spatial and temporal variation. Having a good understanding of methane emissions is therefore essential for modelling climate change as well as the running of global chemistry transport models.



The average footprint of GOSAT measurements over the UK in August 2009. The emissions from the highlighted areas will have the greatest influence over the measured column concentration.

Find out more
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ROSEMARIE GRAVES *The University of Leicester*

Supervisor: Paul Monks

CAN A HSI-DOAS TECHNIQUE BE USED TO IMPROVE UNDERSTANDING OF THE EMISSIONS, DYNAMICS AND CHEMISTRY OF NITROGEN DIOXIDE IN THE URBAN BOUNDARY LAYER?

OVERVIEW

The main objectives of this PhD are to demonstrate the use of the novel Hemispherical Scanning Imaging Differential Optical Absorption Spectroscopy (HSI-DOAS) technique as a tool to monitor concentrations of nitrogen dioxide within the urban boundary layer. The HSI-DOAS instrument, CityScan, has been designed and built at the University of Leicester. CityScan is capable of measuring concentrations of nitrogen dioxide along specific lines of sight over a full hemisphere every six minutes. This field of view allows measurements to be taken on an urban wide scale. These instruments aim to bridge the gap in spatial scales between point source measurements of air quality and satellite measurements of air quality offering additional information on emissions, transport and the chemistry of nitrogen dioxide.

CityScan instruments have been deployed in London and Bologna, Italy. Data collected will offer valuable new information on the air quality in these two cities.

FINDINGS

The use of the HSI-DOAS technique has been demonstrated as a valuable tool for monitoring the air quality in urban environments; particularly adding extra knowledge on the spatial variability of nitrogen dioxide concentrations and the transport of emissions downwind.

More work needs to be completed to isolate near-field emissions from urban background concentrations and to compare these results to those collected by in-situ monitors and satellite instruments.

IMPORTANCE OF THE WORK

Differential Optical Absorption Spectroscopy is now commonly used as an air quality measuring system, primarily through the measurements of nitrogen dioxide (NO_2) both as a ground-based and satellite technique. In the UK, the main sources of air pollutants such as nitrogen containing compounds are motor vehicles and power generation. With more emphasis being applied to meeting air quality regulations it is becoming increasingly important to measure changes in these air pollutants particularly in urban environments where they can be at highly elevated concentrations.

The ability to isolate specific emission sources will be especially useful to policy makers and local councils.

Figure showing a CityScan instrument deployed on a roof in North Kensington, overlooking south west London.

Find out more

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Roscoe, H.K. (50 authors), M. Van Roozendael, ...R. Graves, R. Leigh, et al. "Intercomparison of slant column measurements of NO_2 and O4 by MaxD0AS and zenith-sky UV and visible spectrometers", Atm. Meas. Tech. 3, 1629-1646 (2010).

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LUCY VENTRESS *University of Oxford*

Supervisors: Anu Dudhia (U. of Oxford) and John Eyre (Met Office)

ATMOSPHERIC SOUNDING USING IASI

OVERVIEW

The Infrared Atmospheric Sounding Interferometer (IASI) is a nadir viewing infrared Fourier transform spectrometer onboard the METOP-A satellite, which has become a key instrument in providing data for both Numerical Weather Prediction (NWP) systems and trace gas retrievals. Due to my CASE studentship with the Met Office, methods to improve the accuracy of such retrievals are investigated with the primary focus on improvements to the NWP model inputs.

FINDINGS

Each IASI spectrum contains 8461 wavenumber channels, which results in a large quantity of data that can cause problems for both retrievals and data assimilation. Choosing an optimal subset of the channels is an established method to reduce the amount of data, whilst maintaining the information it contains. A method to select the best IASI channels for use in an NWP context was investigated and compared to the selection currently in wide use (Collard, 2007).

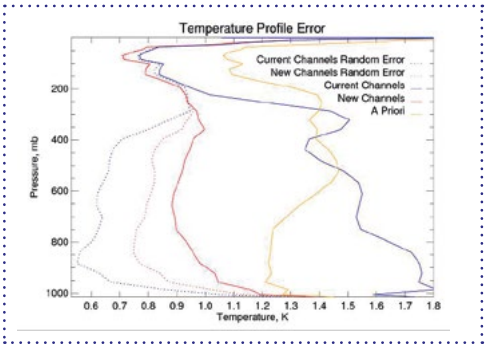
Channels are chosen by evaluating their impact upon the Degrees of Freedom for Signal (DFS), a quantity that characterises performance. Whilst the current channel set only considers the impact of the random measurement error on the DFS, the new method also includes potential 'systematic' errors.

These errors are caused by the lack of knowledge of a parameter, or the misspecification of absorbing gases within the spectrum in the initial problem. It can be shown that the new channel set maintains the same amount of information as that previously used but is less sensitive to unknown errors in the initial problem, as displayed in Figure 1.

Although established for an NWP framework, the method can also be used in trace gas retrievals, selecting the channels least affected by interfering species.

IMPORTANCE OF THE WORK

The ability to accurately simulate IASI spectra using Radiative Transfer Models is essential within the data assimilation process and in continuing to produce accurate retrievals. Widely used radiative transfer models, which simulate observations, are being examined and comparisons with both each other and real IASI data are being carried out to discover where any discrepancies occur and their causes.



Comparing the error in the temperature profile for channels selected using the new method (red) against the channels currently used (blue). The impact of considering solely the random error (dotted) or all 'systematic' errors (solid) is also shown for both sets of channels.

Find out more
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TIM TRENT *University of Leicester*

Supervisor: John Remedios

CLIMATE AND VARIABILITY OF WATER VAPOUR IN THE TROPOSPHERE

OVERVIEW

The launch of NASA's Aqua Platform in May 2002 heralded the beginning of the use of next generation hyperspectral infrared sounders for meteorological and climate applications with the Atmospheric Infrared Sounder (AIRS). These new thermal infrared sounders will provide profiles of tropospheric water vapour with a much higher resolution than before providing us new knowledge of atmospheric concentration and variability. With the launch of new operational instruments such as the Infrared Atmospheric Sounding Interferomter (IASI) in October 2006 and the Cross-track Infrared Sounder (CrIS) in October 2011 we will have datasets spanning between 30-50 years into the future. My PhD focuses on utilising data from these sounders in order to develop a new more accurate water vapour climatology which will provide improved estimates of seasonal and interannual variability. A major part of my work uses corrected humidity measurements from radiosondes in order to understand and characterise the instrumental biases in the water vapour measurements.

FINDINGS

Measurements made by radiosondes are prone to multiple sources of error. Therefore in order to use them in climate studies these errors need to be accounted for and corrected. Work done by Miloshevich et al. 2004 & 2009 provides details how these errors can be corrected. Once corrected, coincident AIRS/IASI overpasses of these radiosonde launches (within a 50km drift radius and 45 minutes of launch) can be used to investigate AIRS/IASI water vapour profile biases in profile as well radiance space. These biases vary with latitude, however, due to the inhomogeneous distribution of radiosonde sites; this only breaks down into three broad latitude bands (90S to 30S, 30S to 30N and 30N to 90N) for which robust estimates of instrumental bias are calculated. Furthermore additional instruments aboard the Aqua/MetOp platforms are used to provide sub pixel cloud information and its effect on bias.

IMPORTANCE OF THE WORK

Water vapour is the most important non-anthropogenic greenhouse gas in the atmosphere. Crucial in regulating climate it affects all key global atmospheric processes, either by directly affecting the Earth's radiative balance through the storage of longwave radiation as latent heat or indirectly by reflecting shortwave radiation effecting surface fluxes and soil moisture. Yet it is sufficiently abundant and short lived that it is essentially under natural control (Sherwood et al. 2010). However, this control means water vapour has a dominant positive feedback, variable making it critical for climate studies (Trenberth et al. 2005) as well as for improved weather forecasting. Therefore it is important to provide consistent water vapour estimates with increased accuracy and well defined errors.

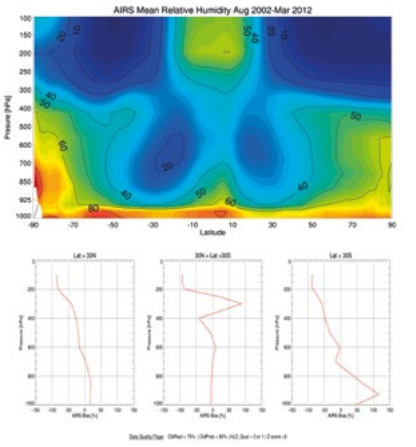

Figure 1: Mean distribution of humidity as seen from AIRS (August 2002 to March 2012) and regional profile biases for 2007–2012.

Find out more

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CLAIRE BARBER *University of Reading*

OBSERVATIONS AND MODELLING OF TROPICAL MARINE BOUNDARY LAYER CLOUDS

Supervisor: Richard P. Allan

OVERVIEW

This thesis exploits the existence of the long-term satellite record of clouds and cloud properties provided by the ISCCP dataset to evaluate the HadGEM2 GCM in terms of its ability to represent Marine Boundary Layer cloud. Issues representing in-cloud liquid water are identified, and a detailed study of visible- and microwave-spectrum satellite retrievals of cloud liquid water is presented, together with an analysis of thermodynamic factors which control cloud liquid water.

FINDINGS

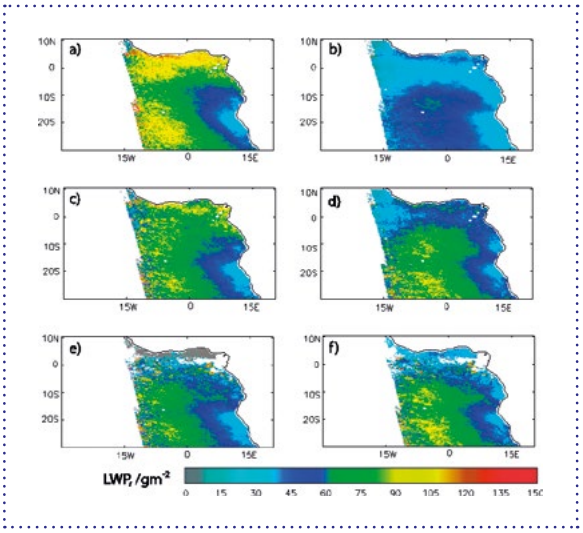
The importance of using multiple independent datasets is highlighted and systematic biases in observed albedo fields of 10-15 % between ISCCP, CERES and ERBS are found. In line with previous studies a strong dependence of cloud fraction on LTS was found, although this ranged from 3 $\%K^{-1}$ to 5 $\%K^{-1}$ depending on the data and reanalysis used. The HadGEM2-A model is able to capture the major features of tropical marine boundary layer cloud, although there is a systematic high bias of 10 % low cloud fraction in the central stratocumulus regions. Furthermore, the model underestimates mean liquid water path by over 50 % in all regions.

Analysis of different methods of retrieving liquid water showed systematic biases of 20 gm^{-2} between microwave and visible methods even for completely overcast cloud. A simple atmospheric model shows agreement of LWP retrievals with TOA albedo is best for completely overcast conditions. A decrease in liquid water path of 3 gm^{-2} per degree K increase in LTS and an increase of 10 gm^{-2} per $10^6 Jm^{-2}$ LHF is also found.

IMPORTANCE OF THE WORK

Understanding of the processes governing Marine Boundary Layer (MBL) clouds is essential both for the understanding of the Earth's current climate and for predicting its future. Small changes in MBL properties have the potential to substantially affect the global water and energy budgets. Model development can be limited by a lack of available validation data, caused in part by difficulties associated with the accurate measurement on global scales of the liquid water content of clouds.

Understanding the source of observational biases can help to improve the reliability of our observations. This thesis aims to improve our understanding of processes that control and affect liquid water content in boundary layer cloud.



In-Cloud liquid water path under different conditions using independent retrievals from (left) AMSR-E; right, MODIS. a)b), all scenes; c),d),overcast cloud only; e),f), overcast cloud for low water vapour scenes.

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ADRIAN CHAMPION *University of Reading*

Supervisor: Kevin Hodges

EXTREME PRECIPITATION AND EXTRA-TROPICAL CYCLONES: A DYNAMICAL DOWNSCALING STUDY

OVERVIEW

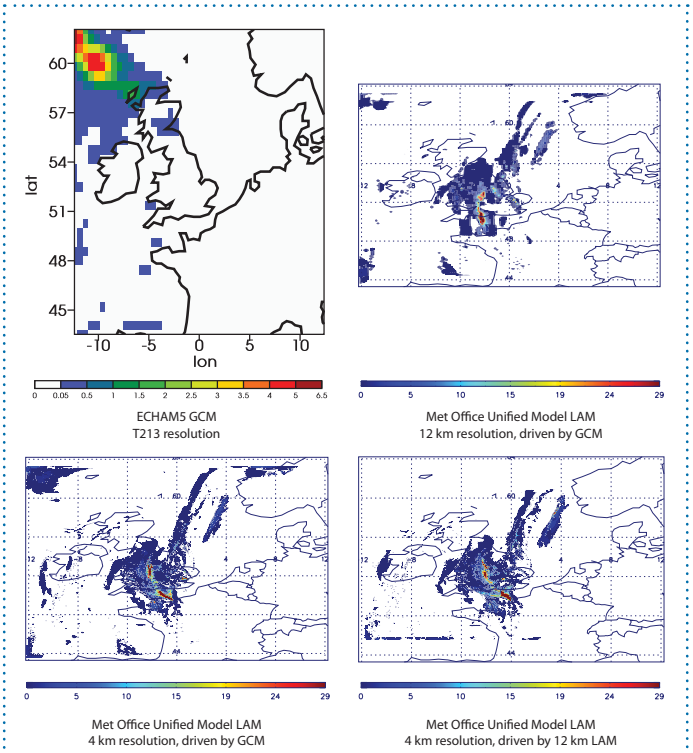
My PhD looked at how to gain high spatial and temporal information on precipitation associated with extra-tropical cyclones to be potentially used in hydrology models, so that the effect of a warmer climate on events that may be flood producing can be investigated. The use of a Limited Area Model (LAM) to dynamically downscale precipitation associated with extra-tropical cyclones, identified in a high resolution Global Climate Model (GCM), is assessed with the aim of gaining more realistic extreme precipitation associated with the cyclones. The effect of a warmer climate and the impact of an increase in horizontal resolution on the GCM precipitation from extra-tropical cyclones are also investigated.

FINDINGS

The results from the GCM study show an increase in the intensity and frequency of extreme precipitation events associated with extra-tropical cyclones, due both to a warming climate and also to an increase in horizontal resolution of the GCM, highlighting the need to downscale this information. The LAM evaluation shows that the model is capable of producing realistic precipitation estimates of intense precipitation events, under certain simulation criteria. The downscaling assessment highlighted some issues with the selection criteria but showed that it was a suitable method for downscaling precipitation from extra-tropical cyclones to obtain more realistic precipitation intensities that can be used as the inputs to hydrological models.

IMPORTANCE OF THE WORK

Extra-tropical cyclones have caused widespread disruption to the UK and Western Europe in recent years, with numerous examples of precipitation associated with these events leading to pluvial and fluvial flooding. The prediction of these events, and any possible changes to their intensity and/or frequency, is extremely important to those who may be affected by such events. To predict the location accurately, and to gain realistic intensities, very high resolution models are required.



An example of the precipitation (mm/hr) from an extra-tropical cyclone from the year 2099 in a GCM (top left), and as simulated by the LAM.

Find out more

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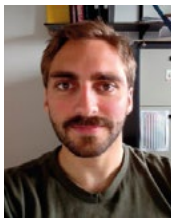
Champion, A.J., Hodges, K.I., Bengtsson, L.O., Keenlyside, N., Esch, M. (2011). Impact of increasing resolution and a warmer climate on extreme weather from northern hemisphere extra-tropical cyclones. Tellus. 63A, 893-905.

TOM PHILP *University of Reading*

Supervisor: Kevin Hodges

VERIFICATION OF EXTRA-TROPICAL CYCLONE WIND-SPEED STRUCTURE FROM SATELLITE OBSERVATIONS



OVERVIEW

This study aims to assess whether climate reanalyses and high resolution global climate models are our best guess in extreme windspeed environments, given that we now have relatively long (>10 years) windspeed records with global oceanic coverage from satellite scatterometers and radiometers.

- Datasets Investigated: ECMWF ERA Interim Reanalysis, ECMWF IFS Operational Model, NASA MERRA Reanalysis, QuikSCAT RSS v1, QuikSCAT RSS v4, WindSAT RSS v7.
- Data Processing Methods: Daily satellite data are converted into seasonal files consisting of global windspeed data split into 2 hourly windows (0000, 0600, 12000 and 1800z +/- 1hour) in order to minimise temporal differences. Interpolations of lower resolution data are made so that data can be compared on the same grid. Model/Reanalysis data are masked in regions where satellites are unable to retrieve windspeeds.
- Extra-Tropical Cyclones (ETCs) are detected in model vorticity fields at a smoothed T42 spectral resolution, and tracked using an objective feature tracking technique (Hodges 1994; 1995; 1999).
- Composites of ETCs are produced using the methodology described in Bengtsson et al. (2009) and Catto et al. (2010).

FINDINGS

- In the ECMWF Operational Model and ERA Interim, no ETCs are found with windspeeds exceeding 35ms^{-1}. However, both versions of QuikSCAT data continue to observe ETCs with windspeeds in excess of 40ms^{-1}.
- Composite plots of ETCs indicate that across the region of an ETC, windspeeds are generally comparable (within 1-2ms^{-1}) in both satellite and modelled/reanalyses datasets.
- However, the model and reanalysis do a relatively poor job of resolving small-scale wind structures in the sting jet region of ETCs. Conversely, satellite observations pick up much higher windspeeds in these regions. This suggests that the small-scale wind structure of the inner core regions is poorly resolved in climate models and reanalyses.

IMPORTANCE OF THE WORK

- Climate reanalyses are routinely used to verify the structure of meteorological phenomena in contemporary climate model integrations. This is especially true in regions where historically we have poor observation coverage.
- Results suggest that in extreme and thus highly uncertain regions, observations can be much more useful for verification purposes.

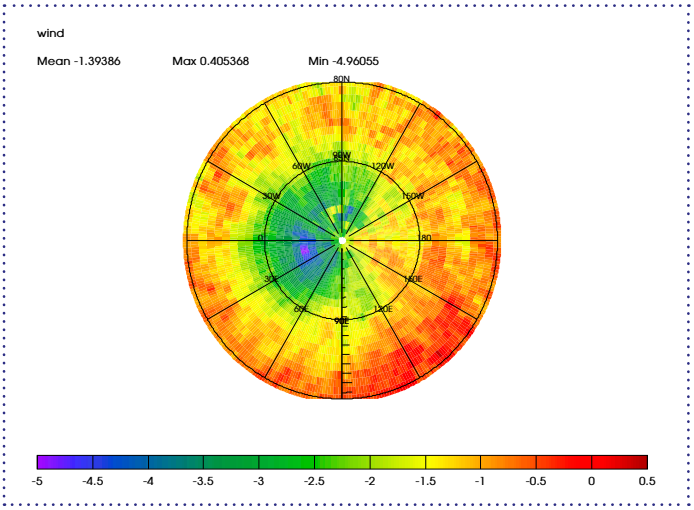


Figure: Composite plot of the windspeed difference (ERA Interim – QuikSCAT) of approximately 50 Northern Hemisphere Winter (DJF) ETCs. Negative windspeed regions show where QuikSCAT is more intense, and positive windspeed regions show where ERA Interim is more intense.

Find out more
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Bengtsson, L., K. I. Hodges, and N. Keenlyside, 2009: Will Extratropical Storms Intensify in a Warmer Climate? J. Clim., 22, 2276-2301.

Catto, J. L., L. C. Shaffrey and K. I. Hodges, 2010: Can Climate Models Capture the Structure of Extratropical Cyclones? J. Clim., 23, 1621-1635.

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Hodges, K. I., 1995: Feature tracking on the unit sphere. Mon. Wea. Rev., 123, 3458-3465.

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DANIEL FISHER *University College London*

Supervisors: Jan-Peter Muller, Caroline Poulsen

NEW CLOUD PRODUCTS FROM (A)ATSR(-1,-2)

OVERVIEW

The primary aim of my work is to generate a new cloud top height product from the Along Track Scanning Radiometer instruments through application of stereo photogrammetric methods. This new product will be used as an input to the Oxford RAL Aerosol Cloud (ORAC) algorithm to improve the robustness of cloud retrievals in more challenging retrieval situations. I am also investigating the impacts of cloud height and fraction over Greenland, searching for correlations between these two parameters and snow and ice melt volume. Lastly, I was also part of the ESA Alanis project, in which stereo methods were applied to derive smoke plume injection heights for the Boreal fire seasons of 2008 through 2011 from AATSR.

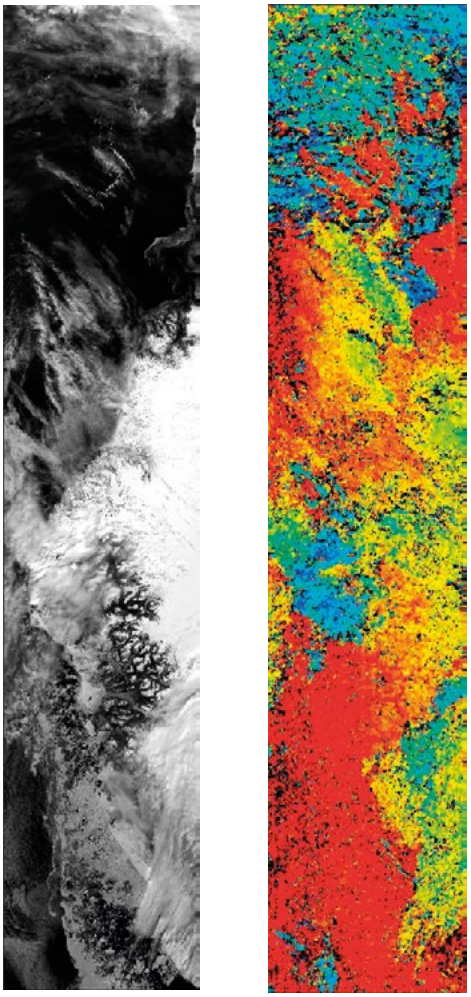
FINDINGS

To date my work has been focussed on developing a new stereo matching algorithm, the output of which can be seen in the inset figure. This stereo matching algorithm is currently being applied to the entire AATSR data time series over Greenland, to develop a new cloud top height and fraction climatology. Once derived the dataset will be used for scientific study to search for relationships between clouds and seasonal melting.

To facilitate accurate stereo height retrievals from the ATSR instruments work has been undertaken to improve the co-registration between the forward and the nadir views. An automated tie pointing and warping algorithm was developed and used to improve the co-registration to pixel level accuracy. The derived warping coefficients are in press for use within the scientific community.

IMPORTANCE OF THE WORK

Clouds effectively control the Earth's radiation budget. One of the main drivers behind whether a cloud leads to a cooling or warming effect is its type, which is typically dependent upon its elevation. Therefore knowledge of cloud height is of vital importance for effectively understanding the impact of clouds on climate. Retrieval of cloud height and other parameters over polar regions and in multi-layer cloud situations is challenging for typical radiance based algorithms. Stereo methods perform effectively in such situations as they rely on scene texture rather than radiance, and so can provide an important contribution to understanding.



This figure shows the raw output of the stereo processing chain applied to a scene over Greenland (greyscale image). The applied colour look up table sets sea level elevations as red through to high clouds at around 8km elevation as blue.

Find out more

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Fisher, D. and J.-P. Muller, in press, Global warping coefficients for improving ATSR co-registration. Remote Sensing Letters.

Fisher, D., J.-P. Muller, V. Yershov, submitted, Automated Retrieval of Smoke Plume Injection Heights (SPIH) and Smoke-Plume Masks (SPM) from AATSR stereo for mapping aerosol and trace gas injection into the free troposphere.

SARAH KEMP *University of Bristol*

PARAMETER ESTIMATION WITHIN A CARBON CYCLE DATA ASSIMILATION SYSTEM (CCDAS)

Supervisor: Marko Scholze

OVERVIEW

This PhD focuses on how to quantitatively estimate terrestrial carbon cycle model parameters through observational data assimilation and thus reduce uncertainties associated with model parameters and model predictions. The Carbon Cycle Data Assimilation System (CCDAS) is used to seek optimal model parameters that are physically meaningful, in order to generate the space-time distribution of terrestrial carbon fluxes consistent with, among others, assimilated CO_2 concentrations. Optimal solutions sometimes contain non-physical parameter values so different methods have been used to bound parameters to their physically meaningful values. Parameter transformations, constrained optimisation and penalty term optimisation have all been trialled. The use of parameter transformations means the optimisation is performed in a transformed parameter space and can search everywhere, whilst the other two restrict or aim to restrict the optimisation to searching only physically reasonable values.

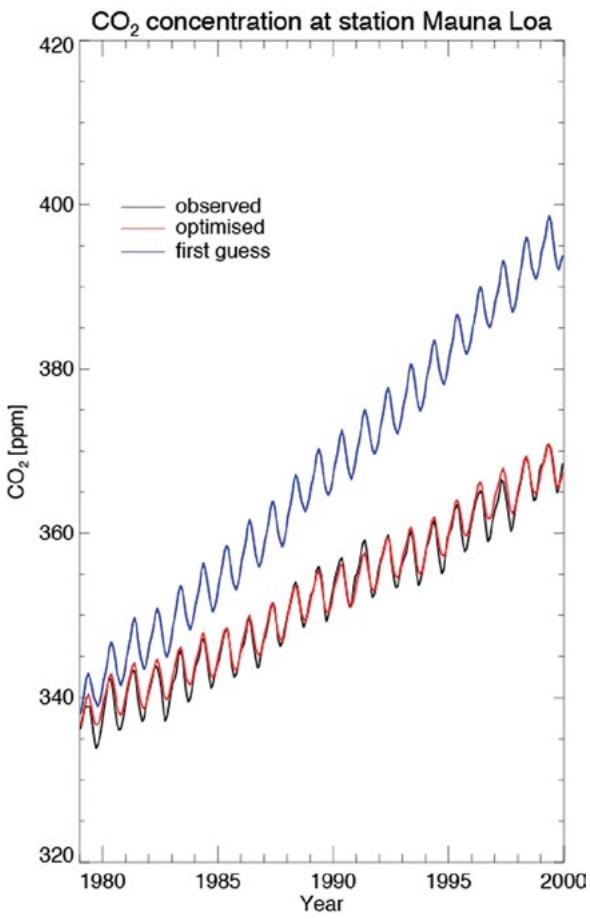
FINDINGS

Results from the parameter transformation studies were highly successful and are likely to have located a global minimum. Results from the other two methods were not successful; the constrained optimisation did not converge at all and adding a penalty term to the optimisation did not produce the desired effect of guiding the optimiser to search for solutions in the physically meaningful parameter space, indicating that these methods are not good solutions to this kind of problem.

Future work will focus on employing the Particle Filter methodology to carbon cycle model parameter estimation.

IMPORTANCE OF THE WORK

More accurate estimates of the net exchange of carbon dioxide between the terrestrial biosphere and the atmosphere are crucial in improving predictions of future atmospheric CO_2 levels. Better modelling of the carbon cycle strongly depends on improving the parameterisation of the underlying processes. Because of the project's application on the global carbon cycle, it is of wide interest to Earth observation and climate change institutions.



Atmospheric CO_2 concentration before and after an optimisation. The "first guess" shows the model output with the prior model parameters and "optimised" shows the output post optimisation.

Find out more
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Rayner, P. J., Scholze, M., Knorr, W., Kaminski, T., Giering, R., & Widmann, H. (2005). Two decades of terrestrial carbon fluxes from a carbon cycle data assimilation system (CCDAS). Global Biogeochem. Cycles, 19(2), GB2026. AGU. doi:10.1029/2004GB002254

RUTH PETRIE *University of Reading*

Supervisors: Ross Bannister (University of Reading), Mike Cullen (Met Office), Sue Ballard (Met Office)

BACKGROUND ERROR COVARIANCE MODELLING FOR CONVECTIVE-SCALE VARIATIONAL DATA ASSIMILATION

OVERVIEW

A modern numerical weather prediction (NWP) forecast starts from a best guess of the current state of the atmosphere. Data assimilation is a vital component of NWP, it is a procedure which estimates the current state of the atmosphere by combining observational information, a prior estimate (usually a previous forecast) together with estimates of their uncertainty to produce the best guess of the current atmospheric conditions.

The NWP problem has over 10 million pieces of information which need to be known. The variational (VAR) approach to data assimilation provides a framework within which the large dimensionality of the problem can be handled efficiently, thus making 3D and 4D VAR popular choices for operational implementation. One vital component of the data assimilation scheme is the specification of the forecast error covariance matrix P^f which describes the degree of confidence in the prior state through variances and multivariate relationships through covariances. The P^f matrix is too large to be computed explicitly and in variational assimilation it is replaced by an approximation known as the background error covariance matrix, B . This matrix is usually a climatological estimate of the error statistics and captures only large scale covariances. It is essentially a static approximation, i.e at the start of each assimilation cycle the same B matrix is used. The B matrix is represented using a Control Variable Transform (CVT) which projects between model variables and 'control variables'. The latter variables are assumed to be uncorrelated by using balance relationships such as hydrostatic and geostrophic balance; this forms a representation of the problem which is greatly simplified.

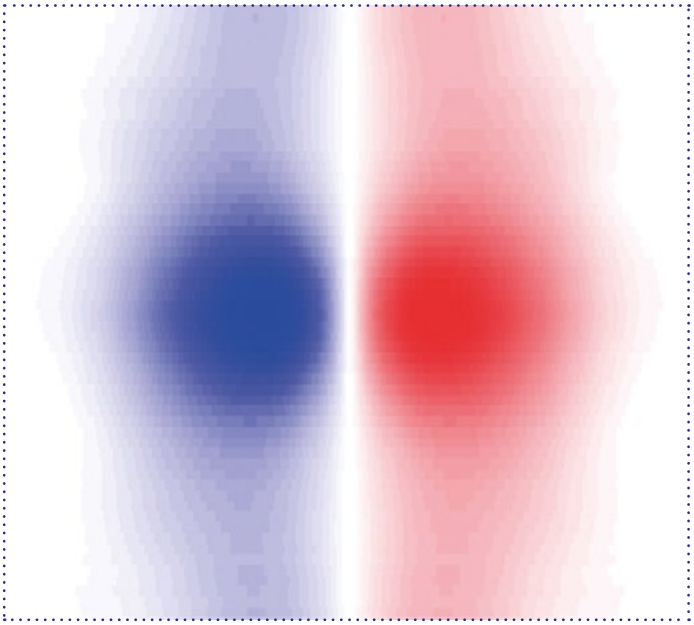
FINDINGS

A control variable transform (CVT) approach to modelling the B-matrix where the control variables are taken to be the normal modes (NM) of the linearized model was investigated. This approach is attractive for convective-scale covariance modelling as it allows for unbalanced as well as appropriately balanced relationships. The NM-CVT approach is shown to be a viable approach to convective-scale covariance modelling.

A new mathematically rigorous method to incorporate flow-dependent error covariances with the otherwise static B-matrix estimate is also proposed. This is an extension to the reduced rank Kalman filter (RRKF) where a Hessian singular vector calculation is replaced by an ensemble estimate of the covariances, this new method is known as the ensemble RRKF (EnRRKF).

IMPORTANCE OF THE WORK

Ultimately it is hoped that together the NM-CVT and the EnRRKF would improve the predictability of small-scale features in convective-scale weather forecasting through the relaxation of inappropriate balance and the inclusion of flow-dependent covariances.



A non-geostrophic covariance structure in the meridional wind with pressure in convective flow.

Find out more

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http://www.met.reading.ac.uk/~wx019276/index.html

Petrie, R. and Bannister, R. N.; A method for merging flow-dependent forecast error statistics from an ensemble with static statistics for use in high resolution variational data assimilation. Comput. Fluids, 2011, 46, 387-391

JOANNE POCOCK *University of Reading*

USING OBSERVATIONS AT DIFFERENT SPATIAL SCALES IN DATA ASSIMILATION FOR ENVIRONMENTAL PREDICTION

Supervisors: Amos Lawless, Sarah Dance, Nancy Nichols, John Eyre

OVERVIEW

Data assimilation combines observations with a model prediction to find the best estimate, known as the 'analysis', of the true state. The observations used in assimilation can contain information at smaller scales than the model can resolve. Errors of representativity are the result of the small scale observation information being incorrectly represented in the model. We seek to understand the structure of representativity error and understand how to use it in the data assimilation process.

FINDINGS

- As model resolution increases representativity error decreases.
- Observations with larger length scales have lower representativity error.
- The representativity error is not dependent on the number of observations, only the distance between them.
- The errors are state and time dependent.
- Representativity error is more significant for humidity than temperature.
- Representativity error varies throughout the atmosphere

IMPORTANCE OF THE WORK

Accurate estimates of error statistics are required for data assimilation schemes to produce optimal analyses. Currently representativity errors are not explicitly included in data assimilation schemes. A better understanding of these errors would allow them to be incorporated into the observation error statistics to provide more accurate analyses and also would allow us to make better use of the available observations. In turn it is hoped that this could improve the analysis, which would provide better initial conditions for weather forecasting.

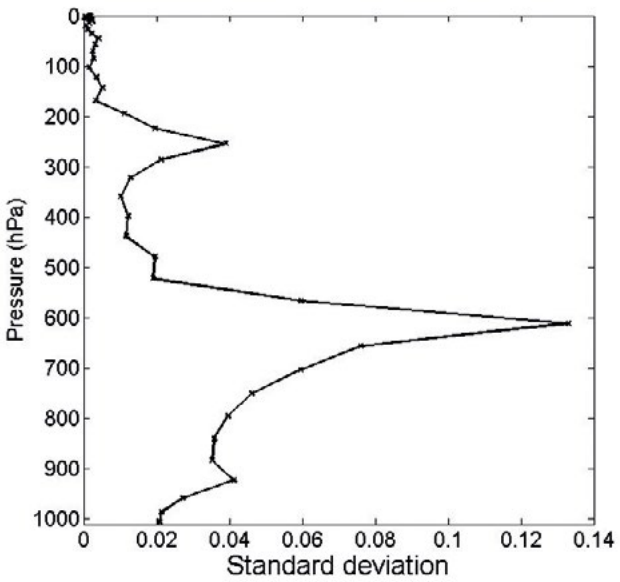

Figure 1: Change in standard deviation of log(specific humidity) representativity error (kg/kg) with model level height.

Find out more
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Z.-Q. Liu and F. Rabier. The interaction between model resolution observation resolution and observation density in data assimilation: A one dimensional study. Quarterly Journal of the Royal Meteorological Society, 128:1367–1386, 2002.

J. A. Pocock, S. L. Dance, A. S. Lawless, N. K. Nichols and J. R. Eyre. Representativity error for temperature and humidity using the Met Office UKV model. University of Reading, Department of Mathematics, Preprint, 2012.

DALE PARTRIDGE *University of Reading*

Supervisors: MJ Baines and NK Nichols

MOVING MESH ICE SHEET MODELLING WITH DATA ASSIMILATION

OVERVIEW

The aims for the project can be split into two primary streams; in one we use a moving mesh method based on mass conservation to simulate dynamical ice flow models. This means the numerical mesh that is used to approximate the ice flow is updated each time to adapt to the flow of the ice and change in domain.

The second stream of the project assesses the compatibility of data assimilation with the moving mesh approach. Data assimilation combines a prediction from a numerical model with any observations that are taken to produce a best representation of the true state of the system, in this case an ice sheet. We determine if standard assimilation techniques can be applied within a moving mesh environment in both one and two dimensions. Additionally we aim to improve the numerical models representation of the changing domain and positional features by including observations of key locations into the simulation.

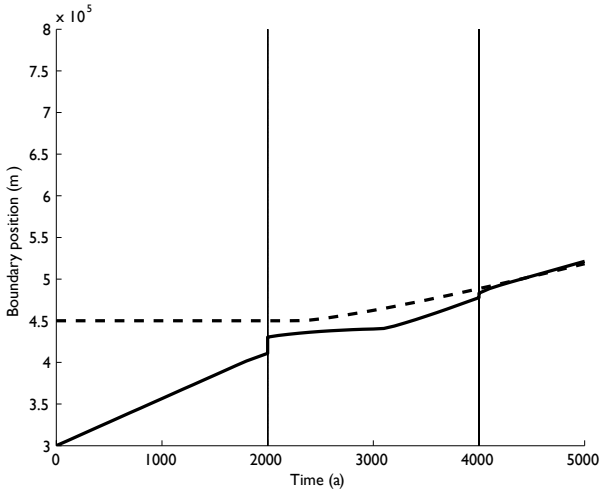
FINDINGS

The moving mesh approach has a number of key benefits over traditional fixed grid methods. One is it naturally moves to allow higher resolution in the areas where there is more activity. A second benefit is the key feature such as the boundary can be tracked directly giving greater accuracy.

Data assimilation can also be used effectively on the moving mesh, combining observations of ice thickness with the numerical model to give a greater representation of the truth. Because the moving method directly tracks key features we can adapt the scheme to include observations of these features. As a test we include observations of the boundary in one-dimension which, as you can see from figure 1, works nicely by pulling the boundary towards its true location.

IMPORTANCE OF THE WORK

Modelling of any physical process always contains inaccuracies from many sources: incorrect initial information, lack of understanding of the underlying physics or simplifications made to gain a computational solution. Different processes also require varying techniques to give the best predictions. By applying a method to ice sheet modelling that has not been done before we are determining the best approach to gain the best representation. By applying the assimilation we can further improve the predictions that are made for future forecasts of ice sheet flow.



Convergence of the predicted boundary location (solid) towards the true location (dashed). Taking observations at t=2000 and t=4000 acts to correct the prediction giving greater accuracy.

Find out more
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ANNA CHUTER *University of Surrey*

Supervisors: P.J. Aston, A.C. Skeldon, I. Roulstone

A QUALITATIVE ANALYSIS OF THE DALEC MODEL

OVERVIEW

The Data Assimilation Linked Ecosystem Carbon, DALEC, is a very simple dynamic vegetation model, which simulates the key processes of the carbon cycle of a forest and is typical of that which underpins more complex systems such as global climate models. Uncertainties in observations and parameters can influence the outcome of a simulation of a complex system, such as a GCM, as a consequence of changes in the dynamics of the core model. Better understanding of the behaviour of different models could help to reduce some of the uncertainty. In order to begin studying the issues that arise in more complex systems we study the qualitative behavior of DALEC, applying methods such as fixed point analysis, using continuation software and the method of averaging.

FINDINGS

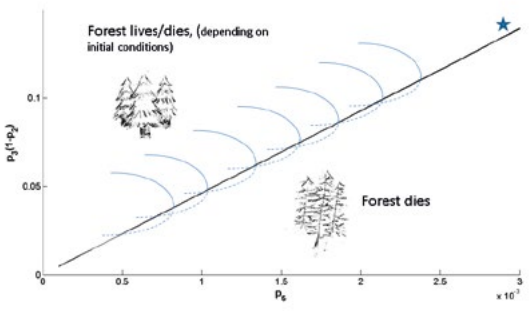
We have shown that the dynamics of an evergreen forest according to the DALEC EV model fundamentally depend on the behaviour of the needle pool (C_f) and the parameters involved in this pool, $p_3(1\text{-}p_2)$ (fraction of Gross Primary Production, GPP, daily allocated to foliage) and p_5 (daily turnover rate of foliage). The dynamics of the foliar carbon pool show a tipping point, which is dependent on the value of these parameters and explains how, for certain values of the parameters according to the model, a forest is expected to die out, without any chance of coming back to life. Likewise, for other values and depending on the initial conditions of the foliar pool, a forest grows to an annual cycle and lives, see figure. This does not only apply to the DALEC Evergreen model, we found a similar tipping point structure for the DALEC Deciduous model. Additionally we have shown that it may not be necessary in the DALEC model, for a forest that is living in a steady climate, to use daily driver data, but that it is sufficient to represent the drivers by a smooth cosine wave, where all that is needed is to measure the amplitude, mean and phase of the annual cycle. Although forests respond to high frequency variability of climate drivers, this has already been taken out by using daily observations, rather than 30 minute observations.

The photosynthesis function, called the Gross Primary Production (GPP), is a complicated combination of functions collectively called the Aggregated Canopy Model (ACM). We simplified the GPP and, using an annual map for the foliar pool rather than a daily map, created a mechanism which is suitable for experimenting with shocks, such as droughts, by varying certain constants in the model.

To examine what the model can tell us about its sensitivity to certain parameters, based on certain inputs, we applied a numerical and analytical sensitivity analysis to the foliar pool, C_f, and the Net Ecosystem Exchange, NEE, the results of which were mostly in agreement with the REFLEX project.

IMPORTANCE OF THE WORK

- A startling finding is that the parameter values of the real data used in our research seem to lie close to the limit point, something we were able to repeat with data from a different forest. It would be interesting to explore this in more detail, using data of various forests throughout the world.
- We have shown that in DALEC it is not important to use daily climate drivers, which will simplify and possibly cut the time for running of the model.
- The model equations can tell us a lot about its sensitivity to certain parameters, based on the input the model receives. The sensitivity analysis also gives information about which parameters it is possible to fit using data assimilation methods.
- This research can help users of the DALEC models to set and find sensible values for the parameters.
- It would be interesting to compare the findings of our research with other vegetation models. Although many models are more complex than the DALEC models, one should also expect a similar bifurcation structure to occur.



Schematic diagram showing how the limit points (tipping points) divide the parameter plane into two different regions. Note the star near the line of tipping points, which represents the real parameter values used in the REFLEX project.

Find out more
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DAMON MCDOUGALL *University of Warwick*

Supervisors: Andrew Stuart, Chris Jones

EULERIAN AND LAGRANGIAN DATA ASSIMILATION

OVERVIEW

We wish to understand the effect on flow uncertainty through utilising a 'control' for ocean drifters. We explore a testbed kinematic travelling wave model with two recirculation regimes (eddies). Toy ocean drifters are placed in one of the eddies and various different control strategies are used to determine which is 'better'. The efficacy of each control strategy is determined by analysing the effect on the posterior variance. A smaller variance implies greater knowledge about the flow and hence a better control strategy.

We use a random walk Metropolis-Hastings algorithm to probe the posterior distribution on the underlying flow given observations of the location of ocean drifters. The model for the drifter evolution in the flow is highly nonlinear. As a consequence, the resulting posterior distribution is non-Gaussian.

FINDINGS

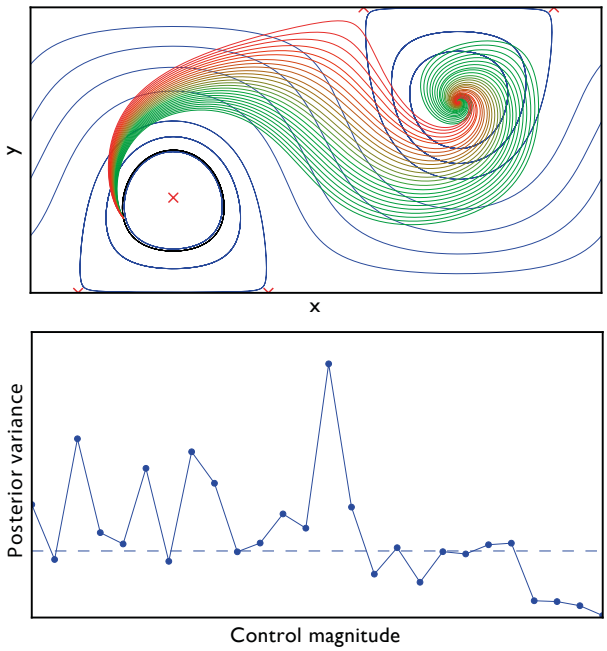
When we utilise a control strategy that allows the drifter to escape the eddy, or navigate towards an 'interesting' flow structure, we observe a marked decrease in posterior variance. We try two basic types of control. A purely horizontal control, a control with equal magnitude in the both coordinate directions. We also utilise an 'a posteriori' control which is constructed using information from a previous assimilation cycle (see figure).

We also extend these findings to the case where a time-periodic perturbation is added to flow. Using the same three controls mentioned above we see that some effects on the posterior variance are in some sense robust to these perturbations. This means that some of the strategies in the time-independent case carry over to the time-periodic case.

IMPORTANCE OF THE WORK

Understanding uncertainty in ocean flows is of clear direct interest to the oceanographic and weather forecasting community. It is often the case the ocean drifters may become 'stuck' in specific flow regimes, like eddies or loop currents. In this situation, the use of a control to explore uncharted parts of the flow with the view of making fresh observations must be done in a way that adds value to the posterior distribution. What we have done for the kinematic travelling wave model is quantify some of these uncertainties as a function of control strategy.

Further work is certainly needed in this area, especially with regard to flow models that are more badly behaved than time-periodic. The quintessential flow model, the ultimate goal, is to apply this to the fully nonlinear Navier-Stokes equations.



Posterior variance as a function of control magnitude. The control pushes the drifter along against streamlines. Notice the variance decreases as the drifter navigates closer to the top fixed point.

Find out more
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DAVID TALMY *PML*

A THEORETICAL INVESTIGATION OF PHYTOPLANKTON RESOURCE ALLOCATION IN VARIABLE ENVIRONMENTS

Supervisors: Jerry Blackford, Nick Hardman-Mountford, Luca Polimeneand Richard Geider

OVERVIEW

Overarching objective: to develop quantitative representations of phytoplankton growth for large scale models of ocean biogeochemistry and remote sensing based estimates of carbon fixation.

Methods: I have used a coarse-grained model of a phytoplankton cell (figure 1) in combination with idealised descriptions of abiotic variables such as light, temperature and nutrients, to predict important phytoplankton traits. The results of the model can be used to parameterise ecosystem models and remote sensing based estimates of primary productivity.

FINDINGS

By optimising allocation to different cell constituents (figure 1), I have found categorical differences in resource partitioning between environments characterised by low environmental variability, and those characterised by high environmental variability.

IMPORTANCE OF THE WORK

Quantitative representations of biological processes are essential components of large scale representations of ocean biogeochemistry. The oceans are difficult places to sample and perform experiments, so there are often large uncertainties involved in the parameterisation of biological processes. My work has attempted to get around this by forming a theoretical basis with which to predict biological parameters of biogeochemical significance. My results should help to guide future experiments, since I have successfully identified a range of hypotheses concerning the types of environmental variability that regulate subcellular processes and consequently organism function.

Anyone interested in assessment of climate change on ocean productivity may be interested in my work. This is likely to primarily concern those in research, but may also be of interest to policy makers and government departments. The ideas could also be useful to companies concerned with optimisation of algal biofuel production.

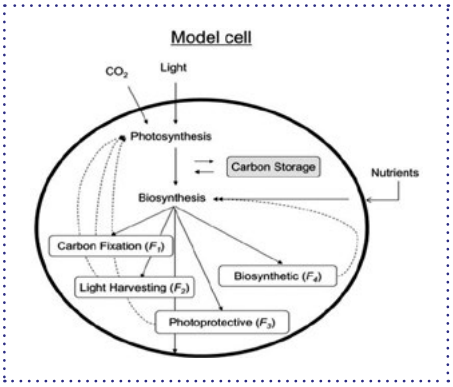

Figure 1: schematic of main cellular constituents that influence growth and photosynthesis in a phytoplankton cell.

Find out more
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JUSTIN KRIJNEN *University of East Anglia*

Supervisors: Andrew Watson, Ute Schuster, Samantha Lavender

KEY MECHANISMS OF SURFACE WATER PCO_2 VARIABILITY IN THE NORTH ATLANTIC

OVERVIEW

The world oceans are currently taking up about 25 % of anthropogenic CO_2, with the North Atlantic being one of the most important sink regions. The North Atlantic sea surface partial pressure of CO_2 (pCO_2) shows substantial seasonal to inter-annual variability in the surface partial pressure of CO_2 (pCO_2) as well as the uptake of atmospheric CO_2, both spatially and temporally. Additionally, observations point towards a decrease in the sink for CO_2 between the mid 1990s to mid 2000s in the mid-latitude North Atlantic.

The PhD aims to establish the key drivers of the seasonal and inter-annual variability of the observed surface pCO_2. To achieve this, parameters which are likely to affect the surface pCO_2 were cross-correlated with one another to ascertain statistically significant relationships. For example satellite altimetry (TOPEX-Poseidon/Jason-1) was used to elucidate the gyre circulation strength, satellite chlorophyll-a (SeaWIFS), the biological drawdown of CO_2 and sea-surface temperature (SST) the solubility effects on the pCO_2. Model output from the NEMO-Planktom-5 model was used to compare with the observational results.

FINDINGS

We find that the gyre circulation strength imparts a significant contribution to both the seasonal and inter-annual variability of the surface pCO_2 in the North Atlantic. On seasonal timescales, in the subtropics this is mainly through SST decreasing the pCO_2 in winter through vertical mixing, whereas in the temperate regions (north of 40°N), carbon entrainment of subsurface waters through vertical mixing reduces the degree of pCO_2 decrease. On inter-annual timescales, in the subtropics, an enhanced gyre circulation increases the SST, thereby increasing the pCO_2. In the temperate zone, in response to the gyre circulation strength, the interplay between carbon entrainment and biological drawdown dominates, dampening the inter-annual pCO_2 variability.

IMPORTANCE OF THE WORK

Understanding how the marine carbon cycle will respond under future climate change is vital. This research provides important insights into the key factors (e.g. ocean circulation and SST) that are likely to be significantly affected by and thus significantly affect the marine carbon cycle, specifically oceanic CO_2 uptake.

The results of this PhD will help modellers to better predict the response of the marine carbon cycle under certain climate change scenarios and thus aid the government in setting new greenhouse gas targets.

Further work is certainly needed in this area, especially with regard to flow models that are more badly behaved than time-periodic. The quintessential flow model, the ultimate goal, is to apply this to the fully nonlinear Navier-Stokes equations.

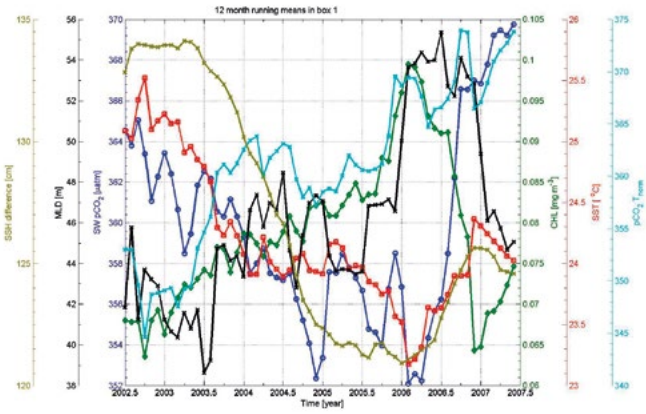

Figure 1: Inter-annual variability of the SSH differences [cm] (proxy for ocean circulation) (brown), surface water pCO_2 T_{norm} (an index of carbon content of water, excluding SST effects) [µatm] (light blue), surface water pCO_2 [µatm] (dark blue), SST [°C] (red), MLD [m] (black), CHL [mg m-3] (green) for the observations in the subtropics. Note the close co-variability of the SSH differences (brown line) with the SST (red line) and surface pCO_2 (dark blue line), indicative of the ocean circulation driving changes in the SST and hence surface pCO_2.

Find out more
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SAMMIE BUZZARD *University of Reading*

Supervisors:
Professor Daniel Feltham (Reading),
Dr Daniela Flocco (Reading),
Professor Peter Sammonds (UCL)

MODELLING THE ROLE OF SURFACE MELT IN THE RETREAT AND DISINTEGRATION OF ANTARCTIC ICE SHELVES

OVERVIEW

Lakes of melted ice have been observed on the Larsen C ice shelf in Antarctica, an area which has warmed over five times the global average over the last century. This project involves creating a mathematical model of this melting, following three key aims:

1 To develop a mathematical model of the surface melt of an ice shelf, particularly accounting for the effect of meltwater on the surface radiative balance (lake-covered ice has a lower albedo than bare ice, which will enhance surface melt) and the role of snow densification;

2 To calculate explicitly meltwater volume and flow paths for a given surface topography so that we can see where there is sufficient meltwater to cause hydrofracture; and

3 To examine the mechanism of hydrofracture, and in particular evaluate the relative role of horizontal fracture versus vertical fracture since horizontal fracture would increase crevasse volume and decrease the impact of a given meltwater volume on vertical cracking.

FINDINGS

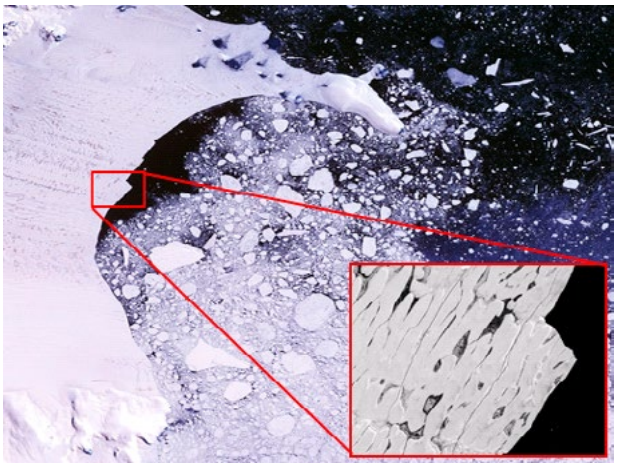
I am currently using automatic weather station data collected from Larsen C to force a one dimensional model of heat transfer through the surface of an ice shelf in order to investigate the mechanism through which these melt lakes are forming. I plan to use this information to go on to look at lateral meltwater transport and investigate the role of meltwater in the expansion of surface crevasses.

IMPORTANCE OF THE WORK

In 2002 the Larsen B ice shelf on Antarctica spectacularly collapsed. 3250km^2 of ice, twice the surface area of Greater London, was lost. Before the collapse, lakes of melted water of up to 4km long were observed on the ice shelf (see figure) and are thought to have played a role in its collapse. Therefore, gaining an understanding of the lakes on Larsen C (which is situated next to the remnants of Larsen B) is key to understanding the future of this ice shelf.

Ice shelves are floating on the ocean so their break up does not directly contribute to sea level rise. However, glaciers that feed ice shelves can speed up after collapse, which does contribute to sea level rise as this water is coming from on the land. In addition, ice shelf collapse can affect the ocean heat budget, water currents and biological habitat.

The project work will lead to new insights into the role of meltwater in triggering ice shelf collapse and, through a more explicit treatment of the thermal budget, to future improvements of ice shelf and climate models.



The collapse of the Larsen B ice shelf, February 2002, with observed melt lakes shown in the zoomed in area (red box). *(copyright NASA)*

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JACQUES MALAPRADE *University College London*

Supervisor: Dr Matthias Disney

LAND SURFACE GPP AND LAND-ATMOSPHERE INTERACTIONS FROM GOSAT FLUORESCENCE

OVERVIEW

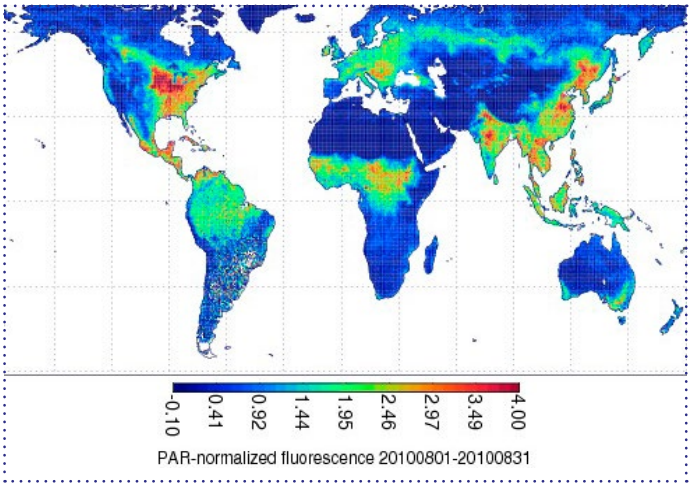
The major constraint on vegetation growth and ultimately land surface carbon is the Gross Primary Production (GPP) of vegetation. Other than losses due to disturbance (such as fire), respiration and fluxes from soils, it also controls the exchange of carbon between the land surface and the atmosphere. At present, our information on this comes from extrapolated flux tower measurements and models, the latter being partially constrained by satellite observation of vegetation state. In the last year, it has been shown that it is feasible to measure canopy fluorescence from satellite instruments, namely the Japanese GOSAT instrument, by measuring in filling in solar Fraunhofer lines, but we not have data for more than two years, globally. There are plans for future instruments that would be able to continue such measurements and hopefully improve on them, such as the ESA EE8 candidates. This presents exciting new opportunities for science and monitoring of GPP. Fluorescence is the closest we can hope for to a direct measurement of vegetation process (rather than state).

FINDINGS

There are several complicating factors that have limited current explorations of the fluorescence signal to coarse scale (in space and time) estimates by averaging observations. These include the spatial and temporal sampling characteristics of GOSAT and the inherently high noise in the fluorescence estimates (the instrument was never designed for such things). Further complication arises because GPP is most useful as a time integral quantity whereas the measurement is instantaneous. Furthermore, to understand fully leaf scale processes, we need to account for vegetation amount and structure. For surface atmosphere flux considerations, we must also be able to include respiration, disturbance and soil fluxes. The exploitation of fluorescence then, needs both models and measurements and this is best achieved in a data assimilation framework. We have access to GOSAT, GOME2, TROPOMI and HyPlant data through existing collaborations. Field data collected in collaboration with partners will allow for the direct retrieval of solar induced fluorescence from field data for comparison with satellite methods. This data can then be compared to models of fluorescence currently being implemented.

IMPORTANCE OF THE WORK

The production of GPP estimates at higher spatial and temporal resolutions than the current coarse averages will be used to test land surface process models and help constrain atmospheric CO_2 inversions. It will also be future looking in better positioning the community for future exploitation of data from forthcoming instruments. Improved estimates of GPP are valuable as constraints to Land Surface Models which ultimately provide input to Global Climate Models.



Solar Induced Fluorescence as retrieved through the method of Joiner et al (2013).

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EDWARD MALINA *University College London*

GLOBAL ISOTOPIC RATIOS OF FUGITIVE GAS EMISSIONS FROM NATURAL AND ANTHROPOGENIC SOURCES FROM EO

Supervisors: Professor Jan-Peter Muller and Dr David Walton

OVERVIEW

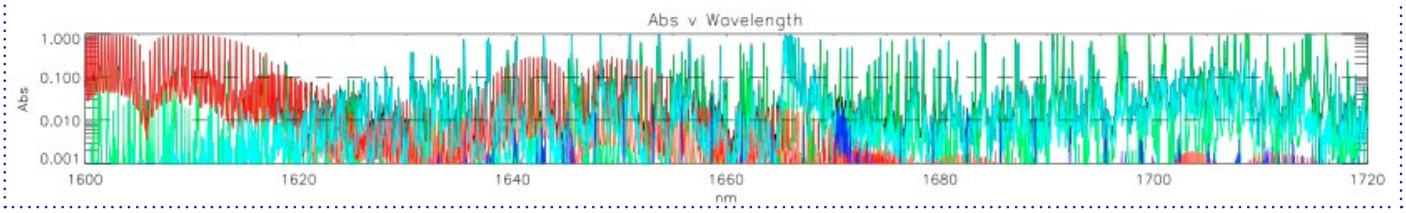
This project aims to develop suitable methods for the retrieval of methane isotopologue ratios (C12/C13) in methane, ethane and propane using the extremely fine spectral resolution of the Canadian ACE (Atmospheric Chemistry Experiment) and JAXA GOSAT instruments. Starting from recent spectral measurements and HiTRAN 2012 simulations, retrieval methods will be developed to measure isotopologues of these 3 gases using ACE & GOSAT applying the methods being developed for the ESA Trace Gas Orbiter 2016 which will orbit around Mars to make these kind of measurements with a similar instrument (NOMAD). Particular emphasis of this project will focus on natural thermogenic and abiogenic sources such as over known gas seeps as well as known areas of extensive fracking and gas flare burn-off.

FINDINGS

This project is in very early stages. Nevertheless, we plan to use the following methods. Using HiTran2012 simulations, we have shown that it is possible to distinguish between methane isotopologues using the FTS based instruments on ACE and GOSAT, and retrieve the abundances in the Short Wave Infra-red (SWIR) 1.65µm (GOSAT only), 2.3µm, 3.3um, 3.7um and Thermal IR, 7.8µm wavebands. Initially we use the spectral line database HITRAN to determine the most appropriate spectral waveband to retrieve methane isotopologues and to minimise water vapour, CO_2 and NO_2 contamination. We then plan to apply the atmospheric simulation tool MODTRAN, to determine the barriers in retrieving methane isotopologues in both the ACE (limb profile) and GOSAT (nadir measurements) satellites, and investigate the effects of clouds, aerosols, surface reflectance and turbulence within the Planetary Boundary Layer (PBL) on the retrieval of methane isotopologues. The effects of these disturbing effects on the instrumental data and thence onto the retrieval are key in this process, and are investigated in some detail using optical modeling tools.

IMPORTANCE OF THE WORK

The importance of methane as an anthropogenic Green House Gas (GHG) is well recognized in the scientific community, and is second only to carbon dioxide in terms of influence on the Earth's radiative budget (Parker., et al, 2011) suggesting that the ability to apportion the source of the methane (whether it is biogenic, abiogenic or thermogenic) has never been more important. It has been proposed (Etiope 2009) that it is possible to distinguish between a thermogenic (e.g. mud volcanoes), biogenic (e.g. bacteria fermentation) and an abiogenic methane source (complex hydrocarbons) via the retrieval of the abundances of methane isotopologues ($12CH_4$ and $13CH_4$) from the gas sources. This work will provide a significant improvement to our knowledge of fugitive gas emissions at the global level and the contribution of thermogenic and abiogenic sources.



Example atmospheric absorption spectrum (extracted from HITRAN) between 1600nm and 1720nm, where green is H_2O, red is CO_2, cyan is $^{12}CH_4$ and blue is $^{13}CH_4$.

Find out more
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Supervisors:
Professor Martyn Chipperfield,
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Professor Manuel Gloor

JOEY MCNORTON *University of Leeds*

USING SATELLITE OBSERVATIONS OF GREENHOUSE GASES TO AID THE DEVELOPMENT OF UK LAND SURFACE MODELLING

OVERVIEW

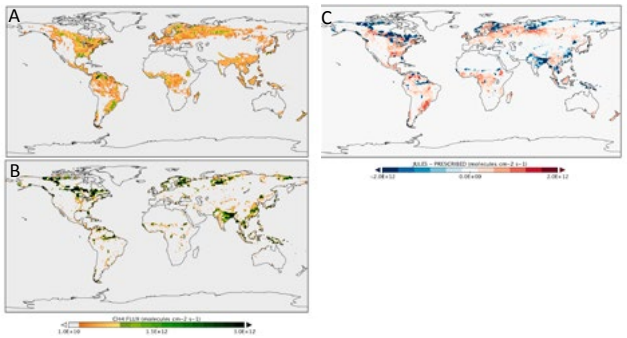
The overall objective of the PhD is to improve the description of greenhouse gas emissions from natural sources, such as wetlands, in the leading UK land surface model by linking the bottom-up process description in the model to atmospheric observations. Information on key parameters, such as soil temperature, wetland fraction and soil carbon can be taken from wetland research and used to inform the Joint UK Land Environment Simulator (JULES). JULES will be used to generate wetland CH_4 fluxes which will be used to drive the atmospheric chemical transport model (TOMCAT). Model comparisons will be made with satellite observations such as GOSAT and, through the use of statistical analysis, model accuracy will be assessed.

FINDINGS

Initial results suggest that different current emission estimates capture wetland emission fluxes well in either tropical regions or boreal regions but never both. The uncertainty in wetland model emissions comes from a lack of understanding of the governing processes and a poor representation of the key parameters, mainly wetland extent. Future work will assess the use of prescribed parameter values and the addition of a more complex wetland process scheme.

IMPORTANCE OF THE WORK

Global CH_4 accounts for approximately 20% of the total direct radiative forcing by long-lived greenhouse gases, with wetlands accounting for approximately 30% of total CH_4 emissions. Wetlands remain the area of largest uncertainty in global CH_4 emissions, suggesting that our process understanding of wetlands is limiting estimates of CH_4 emissions. This work aims to improve the representation of wetland emissions in models, which can inform future predictions and improve understanding of past variations in atmospheric CH_4. It is hoped that development in this field will reduce uncertainty in future climate change predictions.



CH_4 wetland emission fluxes for August 1993 from two wetland models. A) CH_4 fluxes calculated using JULES variables. B) CH_4 fluxes calculated using observations. C) Difference between emissions using JULES variables (A) and observations (B).

Find out more
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RICHARD POPE *University of Leeds*

Supervisors:
Professor Martyn Chipperfield,
Dr Nick Savage

IMPROVING UK AIR QUALITY MODELLING THROUGH EXPLOITATION OF SATELLITE OBSERVATIONS

OVERVIEW

The aim of this project is to test and improve the accuracy of the chemical forecasts from the Met Office regional Air Quality in the Unified Model (AQUM) by using satellite observations. This involves:

1) Using available satellite retrievals (e.g. SCIAMACHY (NO_2), OMI (NO_2, HCHO), TES (O_3), and model transfer functions (which modifies the model output so it is directly comparable to retrievals) previously developed, to analyse the skill of the regional air quality model. We focus primarily on the summer and winter of 2006 looking at AQUM tropospheric column NO_2 vs. OMI NO_2.

2) Identify possible model improvements and run sensitivity tests. This has included sensitivity experiments of NO_x emission datasets (including free running tracers) and lateral boundary conditions from the global model and the introduction of basic heterogeneous chemistry into the AQUM.

3) Using insight gained through these comparisons to improve the Met Offices operational air quality forecast system.

FINDINGS

In the summer (Apr–Sept) of 2006, the AQUM significantly overestimates column NO_2 over northern England. By perturbing the NO_x emissions and the use of a free running tracer we show the representation of NO_x point sources (power stations) in the model are the cause.

In the winter (Jan–Mar, Oct–Dec), the AQUM overestimates column NO_2 across the whole domain. Therefore, by introducing basic heterogeneous chemistry, hydrolysis of N_2O_5 on aerosol, we achieve better AQUM winter representation of column NO_2.

We also investigate the links between UK synoptic weather and atmospheric chemistry. By using the Lamb Weather Type data, an objective method using pressure and wind shear/direction to classify the daily synoptic weather type, we composite the OMI column NO_2, 2005–2011 under different synoptic conditions. Under anticyclonic conditions, stable conditions lead to the accumulation of NO_2 over the source regions. While, cyclonic conditions lead to the transport of NO_2 away from source regions. Also, looking at wind direction, OMI can detect the leewards transport of NO_2 from the sources.

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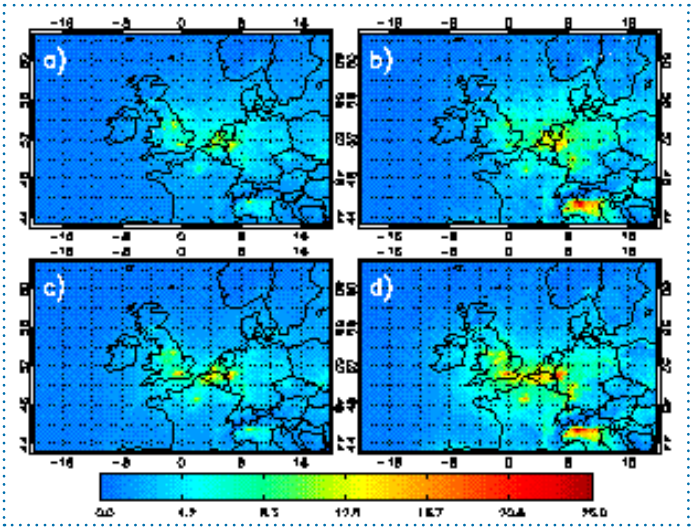
IMPORTANCE OF THE WORK

By validating the AQUM against satellite observations, we are taking advantage of information to look at the AQUM skill in untested regions (e.g. the vertical domain). Also, by investigating the link between weather and chemistry, we can see which conditions lead to extended poor air quality episodes and pose a threat to human health.



Composites of OMI column NO_2 ($x10^{15}$ molecules/cm^2) for (a) summer cyclonic, (b) winter cyclonic, (c) summer anticyclonic and (d) winter anticyclonic conditions.

Find out more
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Pope, R.J., N.H. Savage, M.P. Chipperfield, S.R. Arnold and T.J. Osborn, *The influence of synoptic weather regimes on UK air quality: Analysis of satellite column NO_2*, Atmos. Sci. Letts., doi:10.1002/asl2.492, 2014.

NINA RAOULT *University of Exeter*

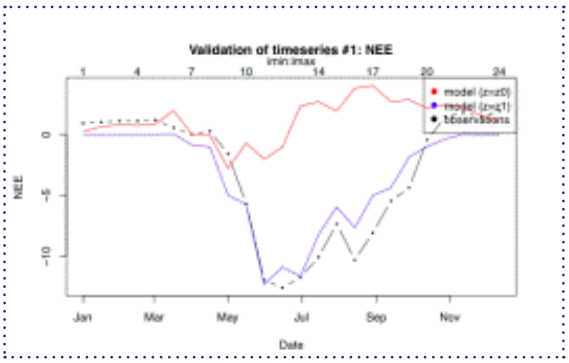
CONSTRAINING FUTURE LAND CARBON CYCLE FEEDBACKS WITH IN SITU AND EO OBSERVATIONS USING ADJULES

Supervisor: Tim Jupp

OVERVIEW

This PhD aims to improve the fit of the JULES land surface model against in situ and EO observations.

The ADJULES data assimilation system provides an efficient way to calibrate uncertain internal JULES parameters (e.g. leaf nitrogen concentration, and parameters affecting the soil moisture and temperature-sensitivity of photosynthesis) against latent, sensible and CO_2 eddy-fluxes measured at FluxNet sites and vegetation greenness trends from EO. It uses information from the adjoint of JULES to search for a (locally) optimum parameter set. Furthermore, using the second derivative of the cost function, ADJULES provides estimates of uncertainties in the best-fit parameters.



Observed (black), original (red) and optimised (blue) monthly net ecosystem exchange (NEE) fluxes.

FINDINGS

ADJULES has been shown to improve significantly the fit of the JULES model against the observed data at certain FluxNet sites.

The optimal parameter sets are site specific so the next step is to generalise over plant functional types.

IMPORTANCE OF THE WORK

There is a need to reduce the uncertainty in the evolution of the land carbon sink, which is a key unknown in future climate projections.

This project will enable observationally-constrained probabilistic statements to be made about the possibility of key transitions and tipping-points in the land biosphere, such as Amazon forest dieback, a global carbon sink to source transition, and greening of the boreal forests.

Find out more

A version of ADJULES can be downloaded from www.adjules.ex.ac.uk

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RACHEL TILLING *University College London*

SATELLITE RADAR ALTIMETER ESTIMATES OF ARCTIC SEA ICE THICKNESS AND VOLUME, AND AN INVESTIGATION INTO SEA ICE DYNAMICS

Supervisor: Professor Duncan Wingham

OVERVIEW

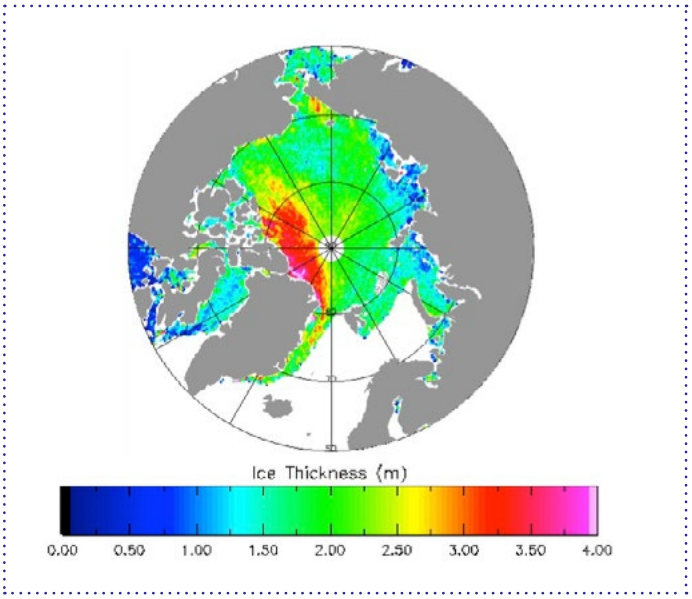
Radar altimeter data from the European Space Agency CryoSat-2 mission is used to investigate on-going changes in Arctic sea ice thickness and volume. This project also aims to improve our understanding of how Arctic sea ice behaves in terms of its dynamics, with particular emphasis on the factors that drive regional differences in ice thickness, and interannual variations in thickness and volume.

FINDINGS

We have developed monthly thickness maps of Arctic sea ice, extending across the entire Arctic Ocean for the CryoSat-2 period (October 2010–present). The spatial distribution of Arctic sea ice thickness varies throughout the year, as the ice grows and melts. Our maps of winter sea ice thickness suggest that the transport of thick ice down the coast of eastern Greenland has decreased over the period 2011–2013.

From monthly thickness maps we have produced a time series of sea ice volume. Autumn sea ice volume significantly increased in 2013 compared to the previous two years, which could be due to an increase in the amount of thick ice around northern Greenland and the Canadian archipelago surviving the summer melt.

Future work will investigate the driving forces behind sea ice thickness and volume variations in the Arctic. For this, CryoSat-2 data will be combined with reanalysis data to assess the importance of potential influences such as the summer melt season length, snow fall, and Arctic wind patterns.



Arctic sea ice thickness estimates for March 2013, computed using CryoSat-2 radar altimeter data. Credit: CPOM, UCL

IMPORTANCE OF THE WORK

Changes in Arctic sea ice volume impact the heat and freshwater budgets of the Arctic and have wider implications for the global climate, making observations of the ice volume critical. September 2012 marked the lowest Arctic sea ice extent on modern satellite record, with a decline documented since the late 1970s. However, thickness observations have been spatially and temporally sporadic making it difficult to reliably estimate volume trends. This project aims to estimate thickness and volume changes accurately over the CryoSat-2 period, which will aid model validation and improve model simulations of volume trends, to assess their global impact further.

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EMMA BRAMHAM

Leeds (T Wright & C Pagli)

THE ROLE OF MAGMATISM IN ACTIVE RIFTING IN ETHIOPIA AND ICELAND

Tectonics and magmatism interact in rift environments, their relative roles depending on where, in the progression from initial continental rifting to fully-developed mid-ocean ridge, the rift lies. The processes at work in their formation can be understood by examining active rifts currently above sea-level spanning different stages of rift evolution.

In order to answer such questions as:

- what are the roles of magmatism and tectonics in accommodating strain in rift zones?
- where does magma accumulate within a rift zone, and how does it migrate?
- how do magma supply rates and strain accumulation vary within and between rift segments?

This project will compare results from two key areas:

1. Afar (Ethiopia): where the 2005 Dabbahu rifting episode provides a spectacular example of the transition from late stage continental rifting to seafloor spreading.

2. Iceland: Where GPS and InSAR data show a range of complex, time-varying behaviours at central volcanoes within the rift segments, with recharge and discharge often occuring at a variety of depths.

ED COMYN PLATT

Leicester (J Remedios)

OBSERVING THE DAILY CYCLE OF LAND SURFACE TEMPERATURE USING GEOSTATIONARY AND POLAR ORBITING SATELLITE INSTRUMENTS

A very important aspect of climate monitoring is the observation of both mean temperatures and the extremes of daily temperature. This CASE studentship investigates the potential for combining geostationary and polar orbiting infra-red data in order to achieve an improved accuracy for the diurnal land surface temperature (LST) cycle; diurnal refers to the variation through a 24 hour period. In particular, the project aims to develop consistent methods for retrieving LST from the geostationary SEVIRI instrument and the polar-orbiting AATSR instrument with the eventual aim of extending to other sensors. The project also examines how longer term seasonality is represented in the data sets.

MATTHEW WALDRAM

Leicester (Sue Page)

MONITORING THE DEGRADATION OF TROPICAL PEAT SWAMP FORESTS USING SATELLITE BORNE RADAR

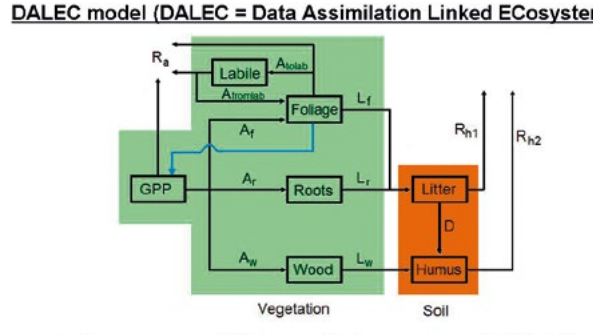
This project is investigating use of high resolution remote sensing for monitoring and assessing deforestation and degradation in the tropical peat swamp forests of Indonesia as a contribution to the REDD carbon trading initiative. Specific objectives include: assessing the use of high resolution ALOS-PALSAR radar data, in combination with other radar and optical data, to deliver information on the location and rates of deforestation and forest degradation, and the types and rates of forest regrowth, and their contribution to the tropical carbon cycle (this component in collaboration with scientists at the University of Sheffield); carrying out ground data collection at case study areas in Indonesia that are representative of a range of peat swamp forest loss and forest degradation scenarios; deriving emission estimates by integrating EO measurements with ground data; and, based on results, investigating uncertainties and exploring the potential for up-scaling to national and regional scales.

EDMUND RYAN

Sheffield (S Quegan)

IMPROVING THE PREDICTIONS OF ECOLOGICAL MODELS BY ASSIMILATING SATELLITE MEASUREMENTS OF WATER AND BIOMASS

This PhD project concentrates on assimilating new satellite measurements of forest biomass and hydrological variables in ecological models. Biomass has an obvious link to carbon, since it represents carbon stored by plants. However, a plant's ability to take up carbon is highly dependent on water availability, so carbon and water variables are highly interlinked. The overall aim of the project is to make much better use of available data than occurs at present in ecological model calculations, and in so doing make significant contributions to our quantitative understanding of the carbon and water cycles, as well as developing the methodology and application of data assimilation.



JAMIE WILLIAMS

Swansea (S Los)

EFFECTS OF CHANGES IN PLANT WATER USE EFFICIENCY ON THE HYDROLOGY OF A WATERSHED

Increased atmospheric CO_2 levels over the 21st century are likely to affect vegetation and may change the leaf density, the rate of photosynthesis, and plant transpiration. Climate models indicate that these changes can increase global warming by about 25 % in some areas. However, estimates of vegetation response vary widely between models and their impact on future climate is therefore largely uncertain.

The study measures changes in water use efficiency from tree ring carbon isotope data. These data, in combination with satellite vegetation data and climate data are used to model the energy and water budget of a catchment. The study is testing if changes in the hydrological regime can be attributed to changes in water use efficiency.

LUKE SMALLMAN

Edinburgh (M Williams)

ATMOSPHERIC PROFILES OF CO_2 AND CH_4 AS INTEGRATORS OF LANDSCAPE EXCHANGE AT THE MESOSCALE

This project explores how concentrations of greenhouse gases in the lower atmosphere are forced by the land surface; observations and modelling are combined at the regional scale using the university's research aircraft.

ALEX BROWN

York (P Bernath)

TRENDS IN HALOCARBONS FROM ACE SATELLITE DATA, AND NEW METHANE SPECTRA IN THE 3 MICRON REGION

The Atmospheric Chemistry Experiment (ACE) is a Canadian satellite used for the remote sensing of trace gases in the Earth's atmosphere from a low circular orbit. The primary instrument upon the ACE satellite is a high-resolution Fourier transform spectrometer (FTS) with spectral coverage of the 750 to 4400 cm^{-1} region at a resolution of 0.02 cm^{-1}. The ACE-FTS records spectra by solar occultation technique (a set of spectra are taken through the limb of the Earth's atmosphere during sunrise and sunset). Over 30 trace species are retrieved from ACE-FTS spectra with near-global sampling.

WILL HEWSON

Leicester (H Bosch)

IMPROVING SATELLITE RETRIEVALS OF FORMALDEHYDE AND GLYOXAL FROM GOME-2 TO IMPROVE TROPICAL BIOGENIC EMISSION ESTIMATES

The main objective of this studentship is to develop a novel approach for the retrieval of HCHO and CHOCHO columns over the tropics by exploiting synergies between satellite observations from UV/vis spectrometers and from collocated or assimilated observations from multispectral imagers to minimise the dominant errors introduced by aerosols, cirrus and water clouds.

ROBYN BUTLER

Edinburgh (NCEO/NCAS joint studentship Paul Palmer)

SHORT-LIVED HALOCARBONS AND THEIR SUBSEQUENT ATMOSPHERIC CHEMISTRY AND TRANSPORT

This PhD is associated with the CAST project (Co-ordinated Airborne Studies in the Tropics) looking at atmospheric chemistry associated with very short-lived halocarbons and their impact on tropospheric and lower stratospheric ozone. The CAST project has two overall goals. The first is to improve understanding of the tropical atmosphere and how gases move from the surface to the stratosphere. The second is to develop the UK capability to use UAVs (Unmanned Aerial Vehicles) for atmospheric research.

CRAIG MAHONEY

Swansea (N Kljun, P North, S Los)

IMPROVED ESTIMATES OF MASS AND ENERGY BUDGETS AT THE LAND-ATMOSPHERE INTERFACE USING SATELLITE LIDAR AND OPTICAL DATA FROM POLAR ORBITING SATELLITES

Atmospheric CO_2 is a key driver of global warming. However, key processes of the land carbon cycle are difficult to measure and the closure of the carbon budget is elusive as a result. Better understanding is essential, especially in view of the fact that some models predict that the land carbon sink may convert to a source in the next decades as a result of global warming. This project brings together a number of datasets to examine land carbon budgets including data collected at the former BOREAS sites in collaboration with the Canadian Carbon Program and the Applied Geomatics Research Group, Community College Nova Scotia, the NASA ICESAT Geoscience Laser Altimeter System (GLAS) instrument, and from aircraft LIDAR. Optical remotely sensed data from SeaWiFS, MODIS, ATSR and AVHRR provide information on the amount of leaves and the fraction of visible light absorbed by vegetation at 8 day to monthly intervals. Additional data on topographic height and land-cover type are available as well. Data have been collected for both undisturbed sites as well as sites disturbed by fire.

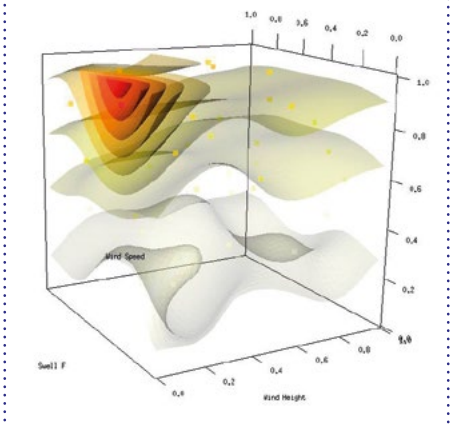
This systematic analysis of a range of data sources has the potential to lead to substantial improvements in the representation of the carbon cycle in land-surface models and ecological models.

BEN TIMMERMANS

NOCS (P Challenor & PJ van Leeuwen)

UNCERTAINTY AND SENSITIVITY IN OCEAN SURFACE WAVE MODELLING

The modelling of ocean waves is now carried out routinely at meteorological centres around the world. However little is known about the source of the uncertainty in the predictions of waves produced. Ben is taking new statistical methods for the analysis of computer experiments and applying them to the state of the art wave model Wavewatch III to see how uncertainty propagates through the model both from uncertain wind fields and from uncertainty parameters in the model.



SAMUEL THOMAS

UCL/Bristol (R Bingham)

ARCTIC OCEAN MEAN DYNAMIC TOPOGRAPHY FROM SATELLITE ALTIMETRY AND GRAVITY MEASUREMENTS

The project takes advantage of the high latitude, high quality data available from CryoSat 2 and the recent advances in space borne gravity modelling from GOCE. By combining the new altimetry with gravity data, we can calculate the dynamic topography of the Arctic and from that derive the macro- and mesoscale features of its circulation. This is some of the very first data of its kind for the Arctic. The original brief for this project was focused only on CryoSat 2, but we are also bringing in data from Envisat, ICESat and (hopefully) SARL-Altika to improve the temporal coverage of the mean sea surfaces produced from the altimetry. We are also interested in bringing in gravimetry from NASA/NOAA's Operation IceBridge campaign for diagnosing errors arising from the gravity model. Once this data product is validated with in-situ data (drifters, etc.), we can then investigate changes to the Arctic Ocean's circulation in recent times. Of particular interest are changes to freshwater flux, which has implications for global ocean circulation, spin-up of the Beaufort Gyre, and changes to currents in the region of the Alaskan/Canadian coast. The data can also be used to validate models (cf. AOMIP/FAMOS).

TIMOTHY KESLAKE

Leeds (M Chipperfield, Dr Brian Kerridge (RAL))

4-D VARIATIONAL ASSIMILATION OF SHORT-LIVED GASES AND METHANE IN THE ECMWF MACC SYSTEM

The ECMWF is coordinating the MACC project, which will provide analyses for chemical species relevant to both Air Quality and Climate. MACC is ambitious and "all encompassing" and aims to produce analysed fields and short-lived chemical species, aerosols and greenhouse gases. The very wide and operational scope of MACC means there are a wide number of areas where research collaborations with university partners is essential.

Within the framework of the TOMCAT CTM, the University of Leeds has developed a DA and 4D-var inverse modelling (IM) system.

This studentship builds on links between NCEO, ECMWF and RAL

The programme of work is:

- Developing the TOMCAT CTM DA/IM system for O_3 and shorter lived species, as a computationally cheap test bed for MACC system. It will test the impact of the assimilation of precursors and sinks on the modelled O_3 and fast chemistry and determine the information content and benefit of assimilating trace species such as HCHO, NOs (e.g. OMI) compared to direct O_3 assimilation. It will also test the impact of the assimilation of new MetOP (RAL combined retrieval scheme) and Sentinel-5 Precursor data.
- Testing assimilation of new IASI and MetOP CH_4 data into the TOMCAT model and then ECMWF system and quantifying how well this data can be used to constrain surface flux estimates.

TO BE APPOINTED

ADVANCING MARINE ECO-SYSTEM UNDERSTANDING

Plymouth Marine Laboratory and University of Reading (S Ciavatta and R Torres (PML), PJ van Leeuwen (Reading))

INVESTIGATING THE VARIABILITY OF THE OCEAN BIOLOGICAL CARBON PUMP BY MEANS OF NOVEL OBSERVATION-BASED 3D BIOGEOCHEMICAL FIELDS.

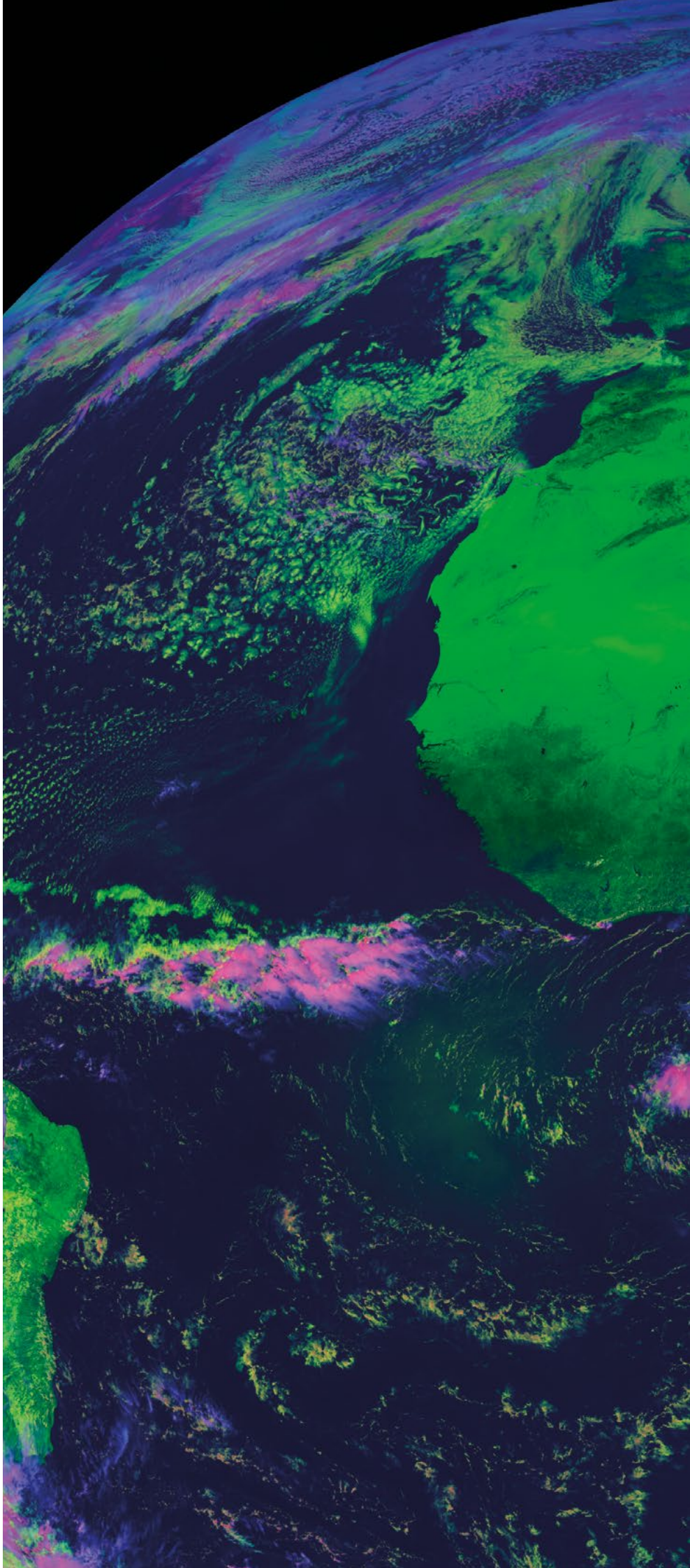
Plymouth Marine Laboratory and University of Reading (G Dall'Olmo (PML), K Haines (Reading))

ISOPRENE PHOTOSYNTHETIC EMISSION MECHANISMS

Leicester (J Remedios)

OXIDANT CHEMISTRY OVER MEGACITIES AND THEIR IMPACT ON LARGER SPATIAL SCALES.

Edinburgh (P Palmer)



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