Met Office Wildfire Workshop 2014: Workshop Summary

The second Met Office Wildfire Workshop was held on 3rd-4th December 2014 at the Met Office, Exeter. The workshop was themed 'Weather and Climate, Modelling and Services' and it aimed to build relationships across the national community of providers and users of wildfire information relating to weather and climate, providing opportunities for collaboration, knowledge exchange, and ultimately building the research capacity of the community. As with the previous workshop another important aim was to increase engagement with the user community and to help identify potential areas for development of services and products.

The workshop was well attended by academics and practitioners from across the UK, as well as overseas colleagues from Singapore and Australia. It was opened by **Richard Betts (Met Office)** with some introductory comments on the state of our knowledge of future wildfire risk projections. Several questions were raised in the face of projections shown in the IPCC AR5, which showed an incoherent picture of changes in fire danger. This provoked lively discussion around the use of weather-based fire danger indices for longer-term prediction, and ultimately the need to consider changes to other factors such as vegetation in order to gain a better understanding of future fire regimes.

This introduction was followed by a talk by **Sandy Harrison (Reading University)** titled **'Enhanced carbon sink despite increased wildfire during the 21st Century: an Australian Case Study'**. This emphasized the need to have a more holistic examination of fire regimes and the importance of understanding changes to the biosphere. Discussion following this talk included the importance of getting carbon fertilisation correct in models and concluded it would be useful to look at carbon fertilisation in models without climate change. With a low climate sensitivity model carbon fertilisation could still have large impact, particularly where fire is fuel limited. Further comments included the fact that feedbacks from fires are still not included in earth system models. The model intercomparison project FireMIP was discussed, along with the intention for more grid point experiments with varying levels of fire activity, and also repetitions of the world without fire experiments.

Colin Prentice {Grantham Institute) presented **'The controls of fire frequency: evidence from the contemporary data.'** This work considers the comparative influence of different controls on global fire frequency, such as climatic, land use and population factors, with some counter-intuitive results, such as a negative relationship between population density and fire frequency. Also there was found to be no relationship between ignition sources and burnt area (both lightning and population density). This work highlighted the need for greater regional analysis where conditions will be different, rather than using existing assumptions about fire controls.

Understanding fire emissions

Several talks were given on the estimation of wildfire emissions. The first of these was given by **Cristina Santin (Swansea University)** on **'Improving carbon accounting for wildfires: incorporation of charcoal production as a carbon sink.'** The main conclusion from this work was that charcoal is a more significant carbon sink than currently estimated, and the new data from this study could be incorporated easily into fire carbon emissions models. This talk also highlighted the need for better fire observations, a theme repeated throughout the workshop.

Stephane Mangeon (Imperial College London) gave an overview of **'Interactive Fire and Emission algorithm for Natural envirOnments (INFERO)'**; a project aimed at improving the accuracy of the emissions and burnt area parameterisations used in models. This work raised questions about how to approximate human interaction in fire models, and highlights the need to feed in other work from the fire research community. **Tianran Zhang (Kings College London)** gave an overview of work on **'Emission measurements of trace gases and aerosols from agricultural biomass burning in Easten China'.** This field-based work shows how estimating emissions from fires using direct field measurements can help to consider impacts on air quality. There is the potential to combine the measurements from this work with satellite information to create a new dataset. **Alex Archibald (NCAS)** spoke **'On the influence of biomass burning and biogenic emissions on measurements of methane, benzene and methyl chloride at Ragged Point, Barbados.'** Using the long time series of atmospheric measurements from this location this work used the NAME atmospheric dispersion model to assess the role of biomass burning on air quality in downstream locations.

Modelling of fire dynamics

A further theme of the workshop was considering the high resolution modelling of fire behaviour and our understanding of fire processes at this scale. **Will Thurston (Bureau of Meteorology, Australia)** presented **'The effects of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting.'** This work concentrates on modelling smoke plumes and the transport of particles including ember using high-resolution simulations. The eventual aim is to parameterise spotting distance and fire spread. Will also presented work on a specific case study: **'Modelling the fire weather of the Coonabarabran (NSW) fire of 13 January 2013.'** This work considers the capability of ACCESS to simulate severe weather conditions at high resolution and using this model to better understand the evolution of the fire in this case study. The model is able to demonstrate the complex wind structures that would affect fire spread and fire management on the ground. It clearly shows the elevation of fire danger that occurred after the cold change went through, as winds picked up. This is part of on-going work with the fire services to develop better information for activity on the ground at fire sites.

Ronan Paugam (KCL) also presented work on a **'Fire Radiative Transfer Model: Modelling the FRP product.'** This fine scale modelling simulates fuel energy output from the flame, and models evolution of temperature during a burn.

Fire data services

Following points raised about the need for better quality fire observation datasets a couple of talks were given on this theme. Firstly **Martin Wooster (KCL)** introduced **'The Global Fire Assimilation System of the Prototype Copernicus Atmosphere Service'.** This new system aims to improve the global observation data currently available from MODIS. The GFAS dataset is able to pick up smaller fires due to higher resolution, improving on representation of small fires, repeated fires in a single location, agricultural burns and prescribed burns. **Gareth Roberts (Southampton University)** also presented **'A temporal active fire detection algorithm applied to geostationary satellite observations.'** This work makes use of an active fires dataset to represent global fire occurrence, using bias correction.

From research to services

A final theme of the workshop considered the use of wildfire research to develop operational and one-off weather and climate services for the fire management community. **Denise Hertwig (Met Office)** presented on **'Smoke-haze dispersion predictions with NAME using wildfire emission data for South East Asia.'** This work presented case studies of haze events in Singapore 2013 and Thailand 2013 and 2014. A real-time bias correction approach is used and varied for event, season and location. This is now operational but with further improvements to be made.

Mark de Jong (KCL) presented work on **'Calibration of the Canadian Fire weather Index System for Operational use in the UK and its relationship to fire occurrence.'** This is part of on-going development of the Met Office Fire Severity Index (MOFSI). This work presented limitations of applying the FWI to UK environments both in terms of validation and the communication of index thresholds or bandings for land management. Different components of the FWI were considered to have varying relevance for the UK in different seasons and vegetation types, but in general it was concluded that the FWI (whole) and FFMC perform well.

Rob Gazzard (Forestry Commission) gave a useful user perspective of wildfire information and services entitled **'Wildfire statistics and prevention practices.'** This talk introduced the dataset of wildfires attended by the Fire and Rescue Services, which provide details on number and burnt area, and the impact on designated areas of natural conservation. The way impact is measured is an important consideration, which needs further development. Rob also presented the Forestry Commission Practice Guide, which outlines the importance of adaptation considerations in forest management, and some of the information needs for this task. Again, the need for better UK data was highlighted, both in mapping areas and assets at risk, and in capturing fire occurrence. Ideas discussed included crowd sourced data, such as in WOW, and an app currently in development to allow the public to record wildfire instances.

Julia McMorrow (Manchester University) presented some collaborative work on **'Wildfire Threat Analysis in a UK Forest-Urban Interface.'** The Wildfire Threat Analysis has been applied at a national scale elsewhere but has useful employment at a local level in the UK for risk assessment. Julia presented a case study of the Swinley Forest Area, due to its critical infrastructure and vulnerabilities, and previous severe fire occurrence. This work focuses on capturing expert knowledge to identify important factors in fire risk such as land cover and distance from roads, and to weight relative importance. Values at risk were also identified and mapped with stakeholders. Hazard assessment of fire propagation was then added using the PROMETHEUS model. This work has shown great value in calculating avoided costs for the case study fire in Swinley Forest and has valuable transferability to other locations for fire risk assessment.

Finally Tom Smith (KCL) presented work on **'How can aerial sensing and computer simulation modelling enhance understanding of wildfire preparedness and prevention in northern European landscapes?'** Using field measurements to understand fire emissions, and then combining this with aerial measurement and fire modelling this work has already proved a useful training tool for Fire and Rescue Services. Currently there is limited confidence in how robust this method is with different vegetation types, and work is on-going to evaluate and customise the fuel model. Development is now moving toward ensemble fire spread modelling, the potential being to simulate multiple potential weather and fire scenarios for a single location. This can then be used to evaluate different management options with regard to cost and losses.

Interactive Session: Development of fire weather and climate services.

As part of the workshop a session was held to discuss potential development of user-focused services based on the research capacity and information needs of the community present. This session was in the form of 4 break-out groups, each of which discussed a user problem or question. Each group then addressed this question, identifying the following:

1. What further research is required to answer this question?
2. What information or data does the user require?
3. What would the service look like in practice?

These notes capture just some of the key points from each of the groups.

Group 1: What does an H++ (high end) scenario for fire risk in the UK look like?

- It was clearly expressed by users present in this group that the situation already exists in the UK for a 'worst case' fire scenario. The right fuels are present in locations that would threaten significant infrastructure and assets (as shown by the Swinley Forest assessment), all it needs is the right weather at the right time. Essential timescales are irrelevant here as it could happen next year.

- Moreover it was highlighted that for fire risk the variable of most importance was where the fire took place – i.e. close to critical national infrastructure.

- In addition it is the capacity of the fire service that would determine the impact of the fire – should multiple large fire events happen in two critical locations the capacity of the fire service to respond adequately would be challenged.

- Further research that would aid the development of this information includes using PROMETHEUS fire model to conduct risk assessments for locations where critical infrastructure has been identified. A similar model for heathland is essential. This research is also necessary to highlight priority areas for fire fighting.

- Conducting analogue studies in this context may have limited use – particularly temporal analogues as the vegetation in previous warmer periods was significantly different, and in both temporal and spatial analogues the interaction with populations is likely to be incomparable.

- Considering changes to seasonality of fire risk is useful for resource planning, mostly on shorter timescales.

- Evidence of the impact of an H++ scenario would be needed to make changes to fire management, for instance imposing fire management on landowners which is currently not in place, or increasing education of land owners.

- From an ecological point of view it is necessary to better understand the tolerances of local vegetation to increasing incidence of fire, and to highlight any thresholds relevant to ecology. It would also be useful to consider the adaptive capacity of vegetation to new fire regimes. It was suggested that the forestry community could usefully identify a list of questions for academic biologists to prioritise research.

- In considering changing fire risk related to climate change it is important to also consider impacts on vegetation and soils from drought, pests, flooding…

Group 2: What is the seasonal outlook for wildfires in the UK?

- Who might care about having access to a seasonal outlook?
  - Fire & Rescue services
  - Reinsurance sector
  - Forestry
  - Land managers

Of these, it was felt that land managers would be the main primary stakeholder, with other secondary stakeholders using the same information to influence the behaviour of land managers that are less well engaged with wildfire.

- What does 'seasonal' mean?
  - 3 months ahead. Such products would need to be in comparison to climatology. Do we even know what the climatology is?!
  - 1 month ahead
  - 1 week

This cuts to an important point. What timescales are important for making what decisions? The discussion from this point on tacitly assumed that seasonal meant longer timescales than currently available products such as MOFSI.

- What might stakeholders (particularly land managers) do in response to some seasonal product?
  - Preparative, not reactive actions- the latter is already catered for with MOFSI
  - Refresh training for fire & rescue service personnel
  - Increase public awareness well ahead of CROW-type situations
  - Manage resources by raising or lowering the emphasis on wildfire as appropriate
  - Plan ahead for good winter prescribed-burn days
  - Plan for increased surveillance
  - Re-position resources
  - Whatever the products are, they must have a demonstrative ability
  - Communication and action upon probabilistic information will be key

- – Reinsurance industry can use such information as part of balancing their risk portfolio

- What product do stakeholders want? Nobody knows! There is a chicken and egg scenario at present
  - – Show/tell and regional trials of different possibilities would be valuable
  - – Important to do this via the various UK fire fora to reach as many of the right people as possible
  - – Need to stop agreeing that doing something is important and actually do something- try things and learn!
  - – "Just a number" is too complicated for some stakeholders to work with
  - – Interpreting any numbers into a more easily acted-upon product would be welcome by stakeholders, eg traffic light system
  - – Who and how to we perform than interpretation
  - – Products would probably need to be a deviation from climatology.
  - – Usual fire metrics (FWI etc)
  - – Output from vegetation model and observations, pushing towards fuel load
  - – Fuel moisture. Soil moisture an adequate proxy to get started?
  - – There is a crucial link between the last two points- to be able to generate a useful traffic light product, we need the understanding and systems to allow us to model/measure the complex climatology information

- Who's going to fund all of this?
  - – Funding from individual stakeholders won't work. Will result in piecemeal bits and bobs of work that will be conservative, fragmented and incremental.
  - – The Public Weather Service or Natural Hazard Partnership are intuitively offer the greatest chance of realising the products and services we (the UK) want/need
  - – Proof of concept is needed before the community can make a persuasive case for funding to realise an operational system.
  - – Pre-engagement with stakeholders and feedback on operational and trial services
  - – Cost-benefit analysis
  - – Case studies
  - – NERC PURE?
  - A summer student/intern somewhere with in-kind assistance from the community?

Group 3: Can we use models to manage wildfire with relation to carbon budgets?

- The discussion focussed around undertaking a project such as REDD but specifically for the UK (or other country).

- Discussed that if you want to do this we need to first know a lot more about wildfire contributions to carbon budgets
  - Including charcoal in models
  - Impacts of prescribed vs natural burns
  - Timing of bunrs
  - Carbon stocks to begin with

- There is a strong need here to have a good observations record to base this research on. GFED is not considered good enough as it is too low a resolution.

- Source – receptor relationships could be investigated further in models

- Useful services products could include:
  - Quantifying the carbon budget through an activity similar to REDD plus.
  - Air quality modelling, for instance using NAME to assess sources of poor air quality and therefore give some evidence to accountability.
  - Assess specific regions to be protected, for instance a risk map of carbon stores, vulnerability and different climate scenarios.
  - Guidelines for prescribed burning relating to carbon stores and seasonality of impacts

Group 4: Are there thresholds, tipping points or large-scale shifts associated with wildfire and climate change on a global or regional scale?

- An examination of the palaeo record would be useful to identify any of these features.

- Further development of earth system models to include fully interactive fire is necessary before addressing this question.

- Are tipping points useful for the discussion of wildfires? For the users present a discussion of extreme fire events was more useful. Tipping points was seen as more of a research question.

- This question could be relevant however regarding a change in policy for forestry – it could be an ecological service tipping point where beyond a point of exploitation the system is unable to recover.

- Of most relevance would be identifying a level of climate change beyond which fire regime changes could be unrecoverable. i.e. levels of climate change to avoid.

- The conversation turned to discussion of risk and vulnerability which does need further work. A change in fire regime would create new areas of risk and may encounter changing vulnerabilities.

- This could be developed as a combination of parameters e.g. days of extreme heat, drought, wind, vulnerable assets and population, management practices which would feed into a decision support tool.

Development of a national dialogue for wildfire research and management

This workshop has shown, as did the previous workshop, the importance of providing opportunities for engagement between members of the wildfire research community. As a multi-disciplinary research area, the community is scattered and lacks the automatic cohesiveness of some disciplines. The breadth of research presented and discussed at this workshop demonstrates the wealth of potential for this community and particularly for collaboration and sharing of expertise and knowledge. As such, the continuation of dialogue amongst members of this community is essential.

In addition it is increasingly necessary for there to be strong engagement between the research community and the wildfire management community. This is essential for knowledge transfer, effective and efficient data capture, and the prioritisation of research. The workshop in 2013 was particularly effective in this respect, attracting a useful balance of both communities. This workshop in 2014 attracted fewer 'users' of wildfire information and therefore had more of an underpinning research focus, however the interactive sessions in particular benefited from the fire management participants present, and highlighted many opportunities for collaborative research that would feed directly into practical application.

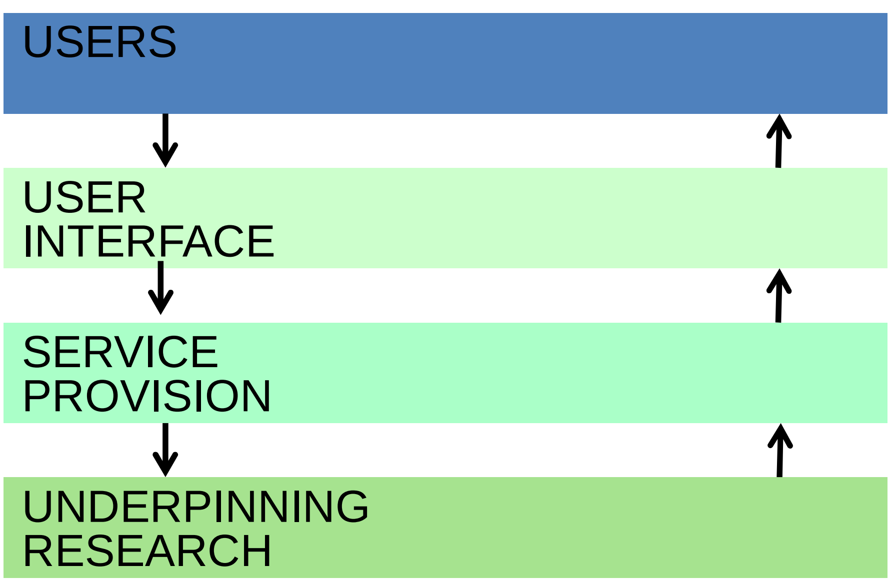

Figure 1: components of a successful research-to-services dialogue

The arrows in figure 1 demonstrate key interactions that are necessary for a sustained and productive dialogue. A number of actions were discussed with the aim of retaining the engagement of the workshop and improving these interactions. These include:

1. Expanding the use of existing infrastructure from the Knowledge For Wildfire initiative to create a conduit for knowledge exchange, advertisement of events, and collaboration opportunities.
2. Encouraging the involvement of the research community in events such as Wildfire, a conference occurring biannually.
3. Encouraging the involvement of the management community in research projects as advisory stakeholders, contributors of data and knowledge, or active research partners.
4. Establishing the wildfire workshop as a regular opportunity to share research and engage with users of the information provided. Also prioritise this as an opportunity to develop research proposals that focus on both collaboration and application.

The continued success of this dialogue is dependent on the enthusiasm and commitment of the community involved. Many thanks to the input of all those presenting and participating in this year's workshop:

Nicola Golding	Met Office (organiser)
Karl Kitchen	Met Office (organiser)
Richard Gilham	Met Office (organiser)
Rowena Jeremy	Met Office (organiser)
Inika Taylor	Met Office
Rob Gazzard	Forestry Commission (speaker)
Colin Prentice	Grantham Institute (speaker)
Sandy Harrison	Reading University (speaker)
Julia McMorrow	Manchester University (speaker)
Jodie Davis	Climate Southwest
Dom Letham	Met Office
Noel Nelson	Met Office
Richard Betts	Met Office (speaker)
Mariana Adam	Met Office
Will Thurston	Bureau of Meteorology (speaker)
Laura Burgin	Met Office
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Christopher Gan	Meteorological Service Singapore (Skype)
Joanne Robbins	Met Office
Helen Titley	Met Office
Andrew Jones	Met Office
Denise Hertwig	Met Office (speaker)
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Gareth Roberts	Southampton University (speaker)
Ronan Paugam	Kings College London (speaker)
Martin Wooster	Kings College London (speaker)
Mark de Jong	Kings College London (speaker)
Tom Smith	Kings College London (speaker)
Charlotte Hewitt	Kings College London
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Sarah Monks	Leeds University
Nicholas Walding	Exeter University (speaker)
Claire Belcher	Exeter University
Cristina Santin	Swansea University (speaker)
Stefan Doerr	Swansea University (speaker)
Alex Archibald	NCAS (speaker)
George Peet	Regional Head Forester
Stephane Mangeon	Imperial College (speaker)
Vicky Hudspith	Exeter University
Claire Witham	Met Office
Matthew Hort	Met Office
Franco Marenco	Met Office

Appendix: Workshop abstracts

1. Enhanced carbon sink despite increased wildfire during the 21st century: an Australian case study

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Significant warming, coupled with reduced precipitation, is a feature of 21st century projections for many mid-latitude and subtropical regions and is conventionally considered to increase wildfires leading to reduced carbon storage. Using Australia as a case study, and a new vegetation-fire model incorporating realistic post-fire plant-recovery strategies, we show that the projected increase in fire is small (0.72-1.31% of land area, depending on the climate scenario) and accompanied by an increase in carbon storage by 3.7-5.6 Pg C. Increased fire promotes a shift to more fire-adapted trees in wooded areas and tree encroachment into grasslands, with an overall increase in forested area of 3.9-11.9%. Both changes increase carbon uptake and storage. The increase in woody vegetation increases the amount of coarse litter, which decays more slowly than fine litter leading to a relative reduction in overall heterotrophic respiration, further reducing carbon losses. Direct CO_2 effects increase woody cover, water-use efficiency and productivity, such that carbon storage is increased by 8.5-14.8 Pg C compared to simulations in which CO_2 is held at modern values. CO_2 effects tend to increase burnt area, fire fluxes and therefore carbon losses in arid areas, but increase vegetation density and reduce burnt area in wooded areas.

2. The controls of fire frequency: evidence from the contemporary data

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Burnt area is an appropriate measure of fire frequency because it is equivalent to the probability of fire occurring at a point. We used the Global Fire Emissions Database (GFED) to test the dependence of burnt area on a set of quantitative predictors representing potential ignitions, land use, vegetation and climate, with a generalized linear model (Bistinas *et al*., 2014). The data to be predicted were 0.5° gridded monthly values during 2000-2005. The key findings, also supported in a parallel analysis of annual values, were as follows:

- Fire frequency is negatively related to human population density across its entire range.
- Fire frequency does not increase with potential ignitions, natural or human.
- Dry day frequency, maximum daily temperature and diurnal range all independently tend to increase fire frequency.
- Fire frequency increases with net primary production (NPP) and decreases with cropland area.
- Published *unimodal* relationships to precipitation, human population and gross domestic product are statistical artefacts.

The data support a strong relationship of fire frequency to both fuel accumulation (indexed by NPP) and those aspects of climate that are captured in fire danger indices used operationally and in models. But the human dimension of fire that has been misunderstood, and modelled incorrectly.

Bistinas, I., S.P. Harrison, I.C. Prentice and J.M.C. Pereira (2014) Causal relationships versus emergent patterns in the global controls of fire frequency. *Biogeosciences Discussions* 11: 3865-3892. [Accepted for publication in *Biogeosciences*].

3. Improving carbon accounting for wildfires: incorporation of charcoal production as a carbon sink

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Wildfires emit 2.5 Pg yr^{-1} of carbon (C) to the atmosphere, with future emissions expected to increase under a warming climate. Critically, however, part of the biomass C is not emitted during burning, but converted into charcoal, which is very resistant to degradation and, thus, contributes to long-term C sequestration.

The magnitude of charcoal production from wildfires as a long-term C sink remains essentially unknown and, to the date, it has not been included in wildfire emission and C budget models. Here we *i)* provide evidence that previous charcoal inventories are based on incomplete dataset; *ii)* present the first complete quantification of charcoal production during a wildfire (FireSmart, Canada 2012), and find that it accounts for over a fourth of the C affected by fire; and *iii)* suggest an initial approach to include charcoal production in C emission models, by using our case study of a boreal forest fire and the Canadian Fire Effects Model (CanFIRE).

Based on our findings, charcoal production from wildfires might represent globally a major and currently unaccounted error in the estimation of the effects of wildfires in the C balance. This could explain, in part, the terrestrial 'missing C sink' of ~1.5 Pg C yr^{-1}.

4. INteractive Fire and Emission algorithm for Natural envirOnments (INFERNO)

Stéphane Mangeon[1,2*], Gerd Folberth[2], Apostolos Voulgarakis[1]
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Global estimates of fire emissions have greatly improved over the last decade, mainly through the developments in satellite observations. However, such estimates remain constrained to the recent satellite observational period. Forest fires remain a crucial element of the Earth system, affecting and affected by the biosphere and the atmosphere through a variety of interactions. Yet these influences are sporadic, justifying the need to interactively model fires in a global climate model. In this talk we will present the INteractive Fire and Emission algorithm for Natural envirOnments (INFERNO) scheme. Starting from simulating fire counts we create a parameterisation to predict burnt area, burnt biomass and subsequent emissions. The performance of this scheme is assessed against the predictions of the Global Fire Emissions Database (GFED).

5. Emissions measurements of trace gases and aerosols from agricultural biomass burning in Eastern China

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King's College London

Smoke from the burning of agricultural residues represents a significant source of emissions to the atmosphere. Though the individual agricultural fires maybe quite small compared to many open grassland and forest fires, in a regions burning season they can be present simultaneously in extremely large numbers, and have increasingly been identified as significant contributor to global scale emissions. In densely populated Eastern China such agricultural burning results in annual air pollution problems, public health impacts and traffic accidents. Fieldwork in two cities of Eastern China was performed in June, 2014 to qualify the emission characteristics of trace gases and aerosols from this open agricultural biomass burning. A series of major crop residue types, including wheat, rice, oil plant, were burnt in the open field. With the purpose of parallel instantaneous gas and aerosol measurements, a new box was designed assembling TSI Dusttrak, micro Aethalometer, filter holder and gas sensors (CO, CO_2, H_2) inside. Weight and volume of the box was minimized in order to provide good portability and handling in the field with self-supplied power. The box was deployed alongside an open path FTIR to measure a wider range of trace gases. The final output of the box, together with FTIR output, provided us with the data to estimate the emission factors of PM2.5, black carbon and trace gases, which can be used for the future regional emission estimation procedures that are being developed by combining active fire and burned area detection data from satellite remote sensing.

6. On the influence of biomass burning and biogenic emissions on measurements of ethane, benzene and methyl chloride at Ragged Point, Barbados.

A.T. Archibald[1,2], C.S. Witham[3], M.J. Ashfold[1*], A.J. Manning[3], S.J. O'Dohertey[4], B.R. Greally[4†], D. Young[4] and D.E. Shallcross[4].

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Periodic episodes of high concentrations of ethane and benzene and methyl chloride have been observed at the costal monitoring station at Ragged Point, Barbados, from 2005-2007. Here we analyse an exemplar episode during September 2007 to assess if measurements made at this location are impacted by long-range transport of biomass burning and biogenic emissions from South America. We use the Met Office Lagrangian Particle Dispersion model, NAME, run both forwards and backwards in time to identify and characterize the air history related to these observations. Air history simulations highlight that the air arriving at Ragged Point during these events is associated with cross-equator advection from the Southern Hemisphere, heavily influenced by the North East of Brazil. To assess whether biomass burning was the cause of these events we used the time and location of hot spots detected using the Moderate Resolution Imaging Spectroradiometer (MODIS) to act as point sources for simulating the release of biomass burning plumes. Excellent agreement was found between the arrival time of the simulated biomass burning plumes and the observations of enhancements in the trace gases at Ragged Point, indicating that biomass burning strongly influenced these measurements. The modelling data were then used to perform atmospheric inversion calculations to determine the magnitude of emissions required to match the observations. These inversion-modelling results were compared with bottom up estimates (based on burnt area and literature emission factors). Good agreement was found between the two techniques for estimates of benzene emissions. However, for methyl chloride and ethane the NAME inversions suggested much stronger emission sources (factors of 3 and 5 respectively) than the bottom up estimates. In part the lower estimation in methyl chloride from the bottom up method could be caused by non-biomass burning emissions effecting the NAME inversions. However, further analysis was performed which suggests that there is only a small role for biogenic emissions of methyl chloride from South America impacting measurements made at Ragged Point.

We therefore conclude that increases in the literature emission factors of ethane and benzene are needed in order to reconcile the NAME inversions based on the atmospheric observations made during these events of enhanced mixing ratios.

These results, when scaled up to the global level, suggest that the emissions of ethane and methyl chloride calculated using current emission factors from tropical biomass burning may be significantly underestimating the role of biomass burning as a source of these two compounds to the atmosphere.

7. The effects of fire-plume dynamics on the lateral and longitudinal spread of long-range spotting

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The lofting of firebrands from bushfires into a background flow can lead to spotting downwind of the fire front. Spotting is a hazardous phenomenon because it leads to both unpredictable and accelerated fire spread, as winds aloft are often in a different direction from and faster than the near-surface winds. Here we use a two-stage modelling system to address some of the uncertainty associated with spotting.

Firstly, we present high resolution, three-dimensional numerical simulations of bushfire plumes using the UK Met Office Large Eddy Model (LEM). Plumes are simulated under a range of background wind conditions and the behaviour of the resulting plumes is examined. Secondly, we use a Lagrangian particle transport model to calculate the trajectories of particles released near the base of each plume. Particles are assigned fall velocities representative of common firebrands and then advected by the three-dimensional velocity fields from the LEM simulations. By calculating the trajectories of many potential firebrands for each plume, distributions of landing position are constructed. We find that: (i) interaction between the plume updraft and background wind determines the distance travelled by firebrands, and (ii) the morphology of the plume determines the lateral and longitudinal spread of landing positions. These variations need to be properly accounted for in predictive models of fire spread and systematic studies such as these form the building blocks of better empirical spotting models.

8. Modelling the fire weather of the Coonabarabran (NSW) fire of 13 January 2013

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We will present high-resolution numerical weather prediction simulations for Sunday 13 January 2013, with a specific focus on the region of the Coonabarabran fire which started at around 1600 EDT on Saturday 12 January in the Warrumbungle National Park of New South Wales, Australia. The simulations show a complicated range of meteorology including weather features that affect fire behaviour critical for fire-fighter safety.

Features such as thunderstorm outflow gust fronts are displayed in the simulations in the north-westerly wind ahead of the main wind change, together with boundary-layer rolls, mountain waves and sea-breeze-like wind changes proceeding inland from the coast. In addition, small-scale vortices are modelled on the main change: these lead to hazardous local spikes in the modelled forest fire danger index. Exceptionally strong north/south temperature gradients were observed over inland New South Wales on the Sunday and these are also seen in the simulations.

Sunday 13 January brought difficult conditions for fire fighting and exceptionally strong north/south temperature gradients across inland New South Wales. When the fire was declared “out” on 24 January, it had burnt an area of 55,210 ha west of Coonabarabran, including 95% of the Warrumbungle National Park. The Siding Spring Astronomical Observatory (which includes the Anglo-Australian Telescope) suffered damage from the fire, although the telescopes survived.

The simulation has been performed using a research version of the Bureau of Meteorology's operational NWP system (ACCESS), which incorporates the UK Met Office Unified Model.

9. Wildfire Emission and injection height: Development and Optimization for global Scale.

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Evaluation of wildfire emissions in global chemistry transport model is a subject of debate in the atmospheric community, and few approaches are currently providing information on injection height. In this work we aim to set-up a 3-dimensional wildfire emission inventory. Our approach is based on the Fire Radiative Power product (FRP) evaluated at a cluster and the plume rise model (PRM) of Freitas et al 2007. PRM was developed to take into account effects of atmospheric stability and latent heat in plume updraft. Here, the original version is modified: (i) the input data of convective heat flux and Active Fire area are directly force from FRP data derived from a modified version of the Dozier algorithm applied to the MOD12 product, (ii) and the dynamical core of the plume model is modified with a new entrainment scheme inspired from latest results in shallow convection parameterization. The new parameters introduced are then defined via an optimization procedure based on characteristics of single fire events extracted from the official MISR plume height project. The current work presents a calibration of the new input parameter of PRM for North America several run for some dedicated year of the MODIS archive.

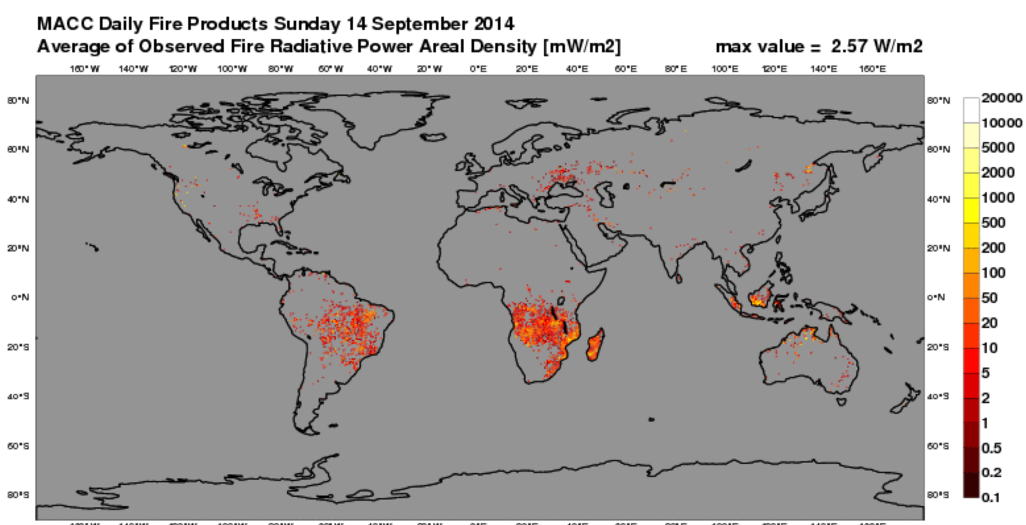
Freitas, S. R., Longo, K. M., Chatfield, R., Latham, D., Silva Dias, M. A. F., Andreae, M. O., Prins, E., Santos, J. C., Gielow, R., and Carvalho Jr., J. A.: Including the sub-grid scale plume rise of vegetation fires in low resolution atmospheric transport models, Atmospheric Chemistry and Physics, 7, 3385–3398, 2007

10. The Global Fire Assimilation System of the Prototype Copernicus Atmosphere Service

Angelika Heil, Guido van der Werf, Johannes Kaiser, Martin Wooster*, Martin Schultz, Guido van der Werf, Rob Detmers, Ronan Paugam, Isabel Trigo and Samuel Remy.

The map below shows the amount of thermal energy radiated from open vegetation fires and detected from space-borne sensors. It is expressed as the daily average of the fire radiative power (FRP) observations, in the units of [mW/m2]. The rate of release of thermal radiative power by a fire is related to the rate at which fuel is being consumed and smoke produced.

Thus these daily averaged FRP data are used for estimating the release of trace gas and particulate emissions from global fires within the prototype Copernicus Atmosphere Service developed by the MACC series of project. These emissions estimates are then passed onto the other MACC services for incorporation as model source terms. This talk will cover the theory and practicalities of the GFAS system and how it is expected to develop into the future using information from new sensors such as NPP VIIRS and Sentinel-3 SLSTR.



11. A temporal active fire detection algorithm applied to geostationary satellite observations

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Geostationary fire detection algorithms are typically contextual and as a result fail to exploit the high temporal frequency of geostationary observations. A fire detection algorithm is presented which makes use of high frequency observations to model the diurnal temperature cycle (DTC) in the MIR waveband. The modelled DTC is then used to characterise the pixel brightness temperature temporal dynamics which is blended with observations using a Kalman filter. The multi-temporal algorithm is applied to one month of SEVIRI data over southern Africa and the fire detections compared against those from a contextual fire detection algorithm applied to the same data. The multi-temporal fire detection algorithm detects ~1 million more fire affected observations than the contextual approach. Many of these are low intensity fires (fire radiative power (FRP) <30MW) which are more difficult to detect due to SEVIRIs coarse spatial resolution. However, since they are predominantly low intensity fires, the fire radiative energy (FRE) -derived fuel consumption estimate is only ~20% greater than that of the contextual approach. When compared to MODIS fire detections, the multi-temporal algorithm detects a greater number than of them the contextual algorithm but does so at the expense of a higher false alarm rate (16%).

12. Smoke-haze dispersion predictions with NAME using wildfire emission data for South East Asia

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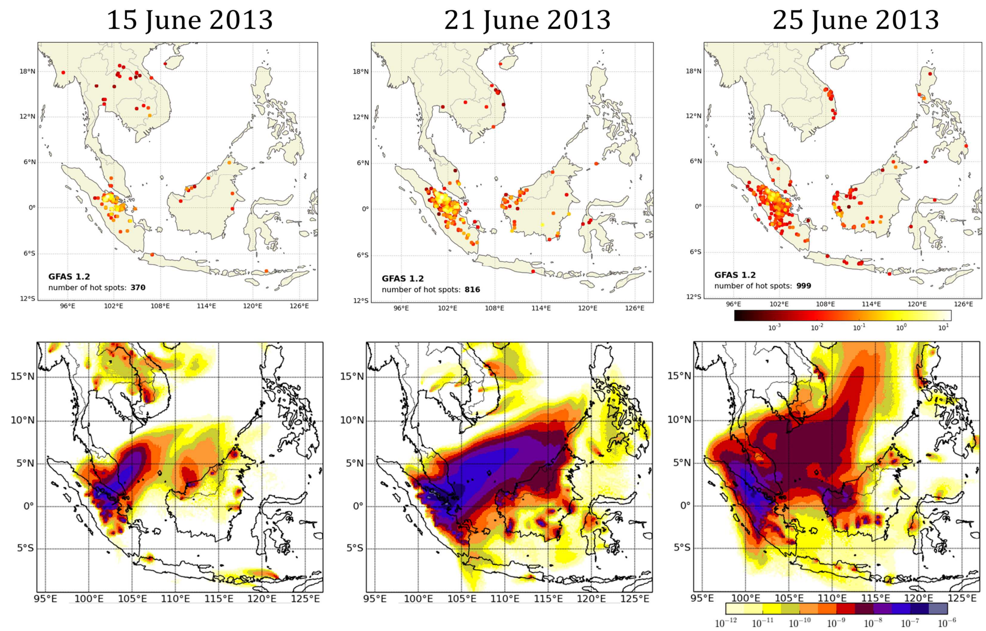
Biomass burning periodically deteriorates air quality in many South East Asian megacities due to the transboundary transport of smoke-haze. Over more than two weeks in June 2013, Singapore experienced the worst wildfire related air-pollution event on record following from the escalation of fires in Sumatra.

Reacting to this event, the Met Office and the Meteorological Service Singapore (MSS) have explored how to adequately simulate haze-pollution dispersion, with the aim of providing a reliable operational forecast for Singapore. Simulations with the Lagrangian particle model NAME (Numerical Atmospheric-dispersion Modelling Environment) are running on numerical weather prediction data from the Unified Model and on emission data derived from satellite observations of fire radiative power. Two forecast versions are produced, each using different emissions data.

Comparisons of simulated concentrations with hourly averages of PM_{10} measurements in Singapore show that the model captures the severe event in June 2013 and a minor episode in March 2014 using both sources. A strong level of quantitative agreement could be achieved by further scaling the satellite-derived emissions from one of the sources by a factor of 2. Confidence in the skill of the model system has been substantiated by further comparisons with monitoring sites in Malaysia, Brunei and Thailand.



GFAS v1.2 hotspot locations and corresponding source strengths (kg/s) *(top)* together with 24hr averaged boundary-layer PM_{10} concentrations (kg/m^3) from NAME simulation and *(bottom)* during the onset and peak of the Singapore haze episode in 2013.

13. Calibration of the Canadian Fire Weather Index System for operational use in the UK and its relationship to fire occurrence

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The UK Met Office currently produces wildfire danger forecasts for England and Wales in the form of the Fire Severity Index (FSI), based upon the Canadian Fire Weather Index System (CFWIS). The CFWIS forms the basis of many fire danger rating systems around the world, however its relationship with fuel properties and fire behaviour in the UK is poorly understood, making interpretation of the FSI output challenging. To build upon the FSI, long-term (~20-30 year) meteorological observations have been used in conjunction with numerical weather prediction data to construct a nationwide 'fire weather climatology' of CFWIS indices. Percentiles from these climatology data were used to create a series of new spatially varying FSI bandings (Figure 1). Combined with mapping of other landscape parameters conducive to fire spread (land cover type, aspect and slope angle), these bandings allow improved interpretation of fire severity forecasts in a historically and locally relevant context. A comparison of historical fire weather with UK wildfire events indicates that this approach successfully identifies periods of exceptional fire danger. Evidence of variations in performance of the CFWIS indices by season and vegetation type is also observed.

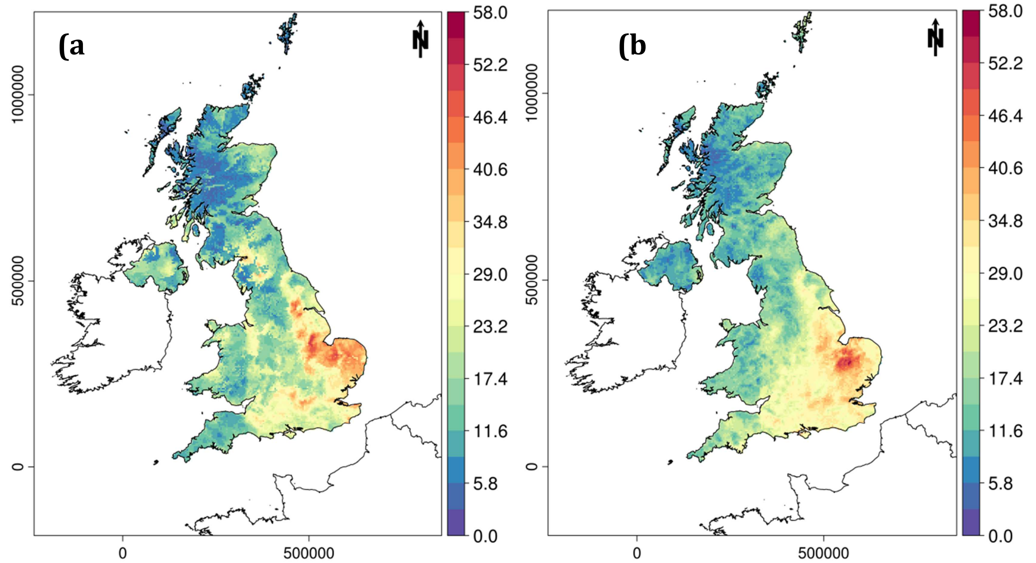


Figure 1. 99th percentile threshold values of the FWI Index for (a) Spring (Mar/Apr/May) and (b) Summer (Jun/Jul/Aug). These values reflect extreme wildfire severity conditions for the season, and form the basis of the 'exceptional' fire severity bandings. Threshold values vary greatly both seasonally and spatially, ranging from less than 1 to 58.

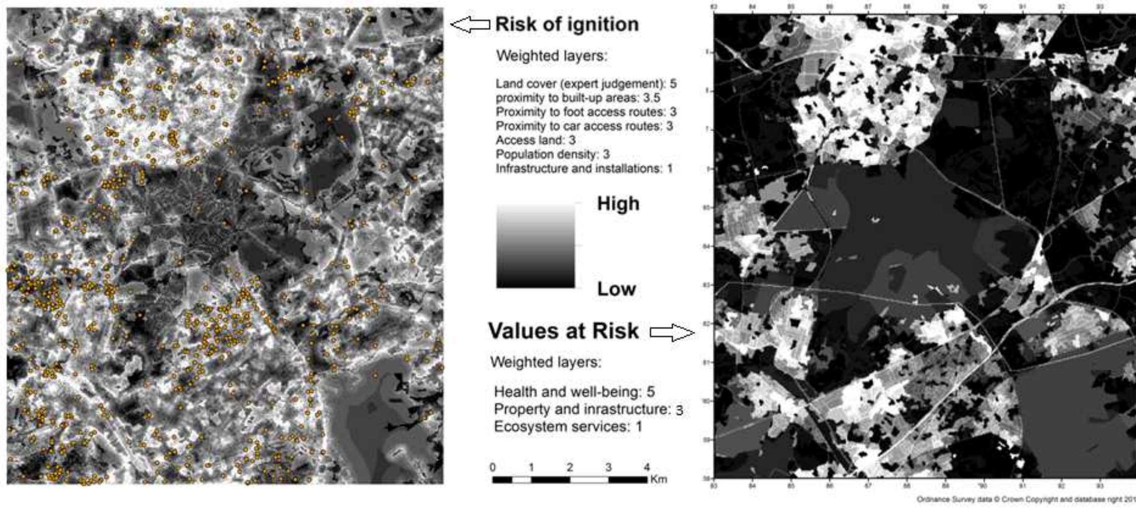
14. Wildfire Threat Analysis in a UK Forest-Urban Interface

Julia McMorrow (Geography, School of Environment Education and Development, University of Manchester), Jonathan Aylen (Manchester Business School, University of Manchester, Aleksandra Kazmierczak (School of Planning and Geography, Cardiff University), Rob Gazzard (Forestry Commission), James Morison (Forest Research), Andy Moffat (Forest Research)

We undertook a 6-month, NERC-funded scoping study of Wildfire Threat Analysis (WTA) to test its suitability for a UK forest-urban interface. Threat here is a cumulative combination of three GIS modules: Risk of Ignition (RoI); Hazard (head fire intensity, rate of spread); and Values at Risk (VaR).

RoI and VaR modules were successfully developed for a 11x12 km area around Crowthorne/Swinley Forest, where a major fire occurred in May 2011. Guided by expert knowledge at two stakeholder workshops, we adapted the New Zealand WTA framework, producing a data catalogue of > 90 GIS layers. RoI scores were assigned to public access and land cover layers using geo-locations of Incident Recording System vegetation fires and expert elicitation. Lack of suitable fire climate data prevented a Hazard module from being developed. Using stakeholder knowledge, a 25m cell size RoI map and three VaR maps (infrastructure/property, ecosystem services and social vulnerability) were produced from weighted combinations of layers. Taken together, hotspots requiring management were identified.

The WTA framework should be tested for other types of UK rural-urban interface, and at coarser scales up to the 2km grid at which probabilistic fire severity data is available. Fine Fuel Moisture Code could be included as a scaling factor within a national RoI model to give spatially-distributed estimates for probability of sustained ignition.



15. How can aerial sensing and computer simulation modelling enhance understanding of wildfire preparedness and prevention in northern European landscapes?

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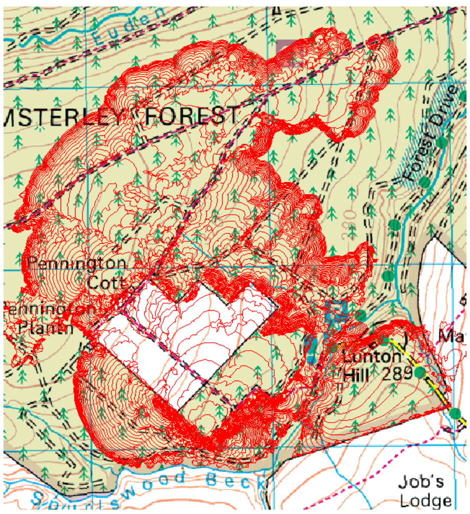
We present recent use of airborne infrared imaging from low-cost unmanned aerial vehicles (UAVs) to record and replay moorland 'training fires' (Figure 1). This imagery can be used to support future training of Fire & Rescue Service personnel, but also provides valuable research-quality fire intensity and rate-of-spread data. The improved knowledge of fire intensity and rate-of-spread through UK fuel types gained through these aerial measurements will help evaluate existing freely available fire spread models (e.g. FARSITE, see Figure 1).

Here we will outline a pilot project with the Mourne Heritage Trust and Northern Ireland Fire & Rescue Service, where fire spread modelling has been used to identify at-risk areas and suitable management solutions in the Mourne Mountains. We explore implications for both wildfire preparedness (identifying at-risk areas, evaluating the effectiveness of different firefighting strategies) and prevention (identifying areas for fuel modification). We also explain how simulating multiple fires in landscapes that are under different management strategies can be used to explore spatially explicit tradeoffs between stakeholder values and wildfire land management options.

Figure 1 (left) Near-infrared imaging of a heathland fire in Dorset; (right) Simulated fire 'perimeters' using FARSITE wildfire spread modelling software for a moorland/forested site in County Durham.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