Grassfires problem

Company: ICMS

Facilitator: Ann Smith (University of Huddersfield)

Natural Resources Wales promotes the sustainable maintenance of natural resources in Wales. One of their managed regions, South Wales, is of particular interest due to concerns about the high number of grassfires and is the focus of this study.

This area is amongst the poorest regions nationwide and has a high population density. Most of the wildfires that occur in this area are believed to be deliberately lit. This means that to model the wildfire risk, different factors may need to be considered than those addressed in the wildfire modelling literature which usually focus on land usage and weather conditions.

The Welsh Government has joined the Wellbeing Economy Alliance and is working towards delivering human and ecological well-being. This integrated approach recognises that the well-being of both people and planet are intertwined and are central to solving the nature and climate emergencies.

As such the focus is on identifying the motivations for fire setting and to identify opportunities for intervention and education.

The Grassfires Excel dataset 2017-2021 South Wales lists grassfires that have occurred over this period with such information as location, timestamp, land use and motive.

Adsorption of environmental contaminants from a fluid stream

Company: ICMS

Facilitator: Tim Myers (Centre de Recerca Matemàtica, Campus de Bellaterra, Edifici C, Barcelona, Spain)

Perhaps the greatest danger currently facing mankind concerns environmental challenges and climate change. In the most recent IPCC (Intergovernmental Panel on Climate Change) report [IPCC2021] on climate change it is stated that “It is unequivocal that human influence has warmed the atmosphere, ocean and land. [...] Observed increases in well-mixed greenhouse gas concentrations since around 1750 are unequivocally caused by human activities”. The link between climate change and human activity has been apparent for many years, it is therefore all the more tragic that first world countries could easily reduce emissions and achieve green energy targets. The well-known goal of maintaining the global temperature rise between 1.5-2°C can now only be achieved through drastic emission cuts

combined with the active removal of greenhouse gases. Similarly the UN Sustainable Goal of a “toxic free environment” requires the removal of a multitude of ubiquitous pollutants.

One practical method of removing fluid based environmental contaminants is column sorption, either through absorption or adsorption. Column sorption involves passing a fluid through a tube filled with a material capable of capturing certain components of the fluid. The process is depicted in Figure 1 where a fluid enters at the inlet and contaminant components attach to the adsorbate. A standard laboratory experiment would involve a column of the order 20cm long and radius 5mm with a steady flow and contaminant escaping after around 15 minutes. Industrial columns are of the order 5m tall and may run continuously for months with a constantly varying fluid intake.

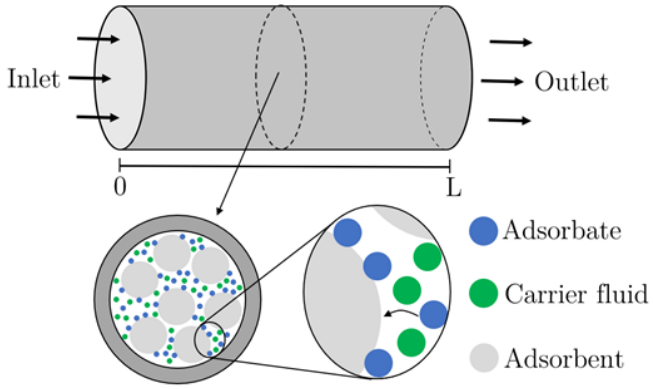

Figure 1: Adsorption process, where contaminant molecules attach to a solid adsorbent material.

Current adsorption models focus on the removal of a single contaminant, in which case the process is defined by an advection-diffusion equation linked to a sink model, typically an ODE, determined by the chemistry. The majority of studies involve numerical solutions. Mathematical analysis of single contaminant models is largely based on asymptotic reductions and travelling wave solutions [Myers 20,Myers 23].

Adsorption is particularly effective at the source of pollution, for example at a chimney outlet or exhaust, where concentrations are high, see Figure 2. Exhaust gases are usually composed of multiple components.

Figure 2: A rather unpleasant chimney emission, taken from https://www.tradeindia.com/products/stack-chimney-emission-and-flue-gas-treatment-from-aeolus-c4994396.html

Processes where more than one pollutant is removed require multiple concentration equations. Some pollutants may adsorb and then desorb due to competition with other components. In a study sponsored by the Ford Motor Company [Tef14] the simultaneous adsorption (and desorption) of eight volatile organic compounds is studied. COMSOL was used to solve their system of approximately 50 equations. In a reduced case, where only two components are adsorbed (n-decane and n-heptane), their numerical results show that heptane is first adsorbed but subsequently displaced by decane.

The goal of this study is to develop and analyse mathematical models for the simultaneous adsorption of a two contaminant fluid. The work will extend existing single contaminant models, using techniques such as non-dimensionalisation, asymptotics, travelling wave solutions and optimisation. Experimental data will be provided and it is hoped to match theoretical results to the data to provide information about ways to improve the process and, hopefully, make the environment a little better.

[Myer20] **T**.G. Myers, F. Font Martinez. Mass transfer from a fluid flowing through a porous media. *Int. J. Heat Mass Trans*., 2020.

[Myer23] T.G. Myers, A. Cabrera-Codony, A. Valverde. On the development of a consistent mathematical model for adsorption in a packed column (and why standard models fail) *Int. J. Heat Mass Trans*., 2023.

[Tef14] D.T. Tefera. Modeling competitive adsorption of mixtures of volatile organic... *Env. Science & Technology, 2014.*

Optimization of mouthguard-derived heart rate measures in combat sport athletes

Company: Sports and wellbeing analytics (Kieran and Chris)

Facilitator: Abdul-Lateef Haji-Ali (Heriot-Watt University)

Sport and Wellbeing Analytics (SWA) is a data analytics and sport technology company; utilizing multiple streams of data input to improve welfare, performance and entertainment within sport. Heart rate data is used within high level sport to measure the internal load placed on athletes during sporting performance. While many sports utilized chest-strap heart rate monitors, such systems are not permitted within combat sports due to safety concerns. SWA currently manufacture an instrumented mouthguard system that allows for the collection of in mouth heart rate data using photoplethysmography (PPG). PPG measures the volumetric variations in blood circulation via the absorption or reflection of visible or infrared light. Signals derived from the gum tend to be saturated with noise and require signal optimisation to appropriately estimate heart rate. This project aims to optimise data processing procedures for the valid and reliable detection of heart rate peaks from a mouthguard embedded sensor, in comparison with gold standard measures of PPG and ECG derived heart rate data.

The use of Earth Observation/Satellite data to understand soil and crop nutrient composition for improved application of bio-nutrient in food production

Company: IntelliDigest Ltd. (Ifey)

Facilitator: Cathal Cummins (Heriot-Watt University)

IntelliDigest Ltd has set up the World Food tracker Platform to help stakeholders across the food system in transitioning to a more sustainable food system through data insight.

For the farmers, data insight on crop and soil nutrient is essential in optimising the application of nutrients during food production enabling them to move away from intensive agricultural practices.

However, soil sampling is costly and time-consuming. The processing of each field sample costs around $24 without factoring in the expenses of personnel, storage and transportation cost.

Remote sensing and machine learning are useful techniques that can provide insight on crop and soil health. With Earth Observation (EO) data, large regions may be covered, negating the requirement for groundtruth data and greatly reducing the expense and duration of soil sensing.

Thus, the overall goal of this project is to access and study EO data and existing soil data to develop an algorithm to determine the crop health and soil health.

Modelling correlation for Economic Scenario Generation

HYMANS ROBERTSON

Company: Hymans Robertson (Joe and Mayukh)

Facilitator: Alfred Chong (Heriot-Watt University)

Correlation plays a pivotal role in modelling dependency between asset class returns (and economic variables) in Economic Scenario Generators (ESGs).

Typically, a correlation matrix encodes (linear) relationships between variables in our economic models. In many cases, these variables model shocks to the economic system and drive stochasticity in the simulation engine. As such, this correlation matrix is crucial to generating realistic economic scenarios. Nevertheless, the construction of this correlation matrix is often based on expert judgement and subject to several model and calibration risks.

For this project, we consider a joint model for nominal interest rates, inflation, and joint interest rates, calibrated to the UK economy. Stochasticity in this model is driven by a multivariate Brownian motion, which is conditioned on a static correlation matrix. Our goal is to develop a scalable model for this correlation matrix that accounts for either time-varying or market-stress effects.