Royal Meteorological Society

Student and Early Career Conference

University of Manchester

4th to 5th July 2022

BOOK OF ABSTRACTS

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Decadal Variability of the Extratropical Response to the Madden-Julian Oscillation

Daniel Skinner, PhD Student, Centre for Ocean and Atmospheric Sciences, School of Mathematics, University of East Anglia

Session 1: Tropics, Subtropics and Teleconnections

It is known that the Madden-Julian Oscillation (MJO) excites a response in the behaviour of many extratropical weather regimes at lag times of one to two weeks, acting as a key predictor in weather forecasting. Less well understood, however, is the robustness of these responses over long time scales. We begin by taking a statistical approach to assess the boreal winter response of a selection of key extratropical systems (e.g. North Atlantic Oscillation (NAO), Pacific North American (PNA) pattern) to the MJO, over two non-overlapping time periods (1974-1997 and 1997-2019). It is shown that there is significant change in both the magnitude and structure of the extratropical response signal, as a function of lag, between the two periods.

This is followed by a similar analysis applied to the 1100 year pre-industrial control run of the UKESM-1-0 coupled climate model. By breaking this period into separate 20 year segments and comparing the extratropical responses to the MJO in each segment, we show that although there is a predictable mean signal, it is overwhelmed by the internal variability in the system. Repeating this methodology with segments between 10 and 40 years in length allows us to assess sampling errors and identify the key timescales for the variability. A robust mean signal justifies the current use of the MJO as a predictor in the extratropics, although the variability casts doubt on the reliability of these predictors for the future.

Recent process based analysis has shown that El Niño Southern Oscillation (ENSO) can act to modulate the Rossby wave source associated with the MJO. We investigate this using our statistical approach to assess the impact of ENSO on the MJO teleconnection patterns. In addition to this, we consider lower-frequency modes, for example Atlantic Multidecadal Variability (AMV) and the Pacific Decadal Oscillation (PDO).

Deep Learning for Tropical Cyclone Nowcasting: Experiments with Generative Adversarial and Recurrent Neural Networks

Theo Xirouchaki, Foundation Scientist, Met Office

Session 1: Tropics, Subtropics and Teleconnections

Virtual Presentation

Tropical Cyclones (TCs) are deadly but rare events that cause considerable loss of life and property damage every year. Traditional TC forecasting and tracking methods focus on numerical forecasting models, synoptic forecasting and statistical methods. However, in recent years there have been several studies investigating applications of Deep Learning (DL) methods for weather forecasting with encouraging results.

We aim to test the efficacy of several DL methods for TC nowcasting, particularly focusing on Generative Adversarial Neural Networks (GANs) and Recurrent Neural Networks (RNNs). The strengths of these network types align well with the given problem: GANs are particularly apt to learn the form of a dataset, such as the typical shape and intensity of a TC, and RNNs are useful for learning timeseries data, enabling a prediction to be made based on the past several timesteps.

The goal is to produce a DL based pipeline to predict the future state of a developing cyclone with accuracy that measures up to current methods. We demonstrate our approach based on learning from high-resolution numerical simulations of TCs from the Indian and Pacific oceans and discuss the challenges and advantages of applying these DL approaches to large high-resolution numerical weather data.

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Non-Linearity in the Extratropical Teleconnection to ENSO and the QBO

Amber Walsh, PhD Researcher, University of Exeter

Session 1: Tropics, Subtropics and Teleconnections

Modes of climate variability that remotely alter the northern hemisphere stratospheric polar vortex state are explored using the Hadley Centre Climate Model (HadGEM3). Experiments are performed that sample combinations of El Niño—Southern Oscillation (ENSO) and quasi-biennial oscillation (QBO) states. These modes were chosen as El Niño and QBO easterly phases are known to weaken the polar vortex.

The El Niño induced weakening of the polar vortex is found to be more pronounced during QBO easterly than QBO westerly. Likewise, the polar vortex weakening caused by QBO easterly is stronger during El Niño than during neutral ENSO conditions.

It is also found that El Niño induces a change to the QBO itself, namely an increase in the descent rate of the QBO, but this is not large enough to explain the nonlinear response of the polar vortex. Other possible mechanisms are investigated, such as whether the QBO and ENSO teleconnections to the polar vortex are sensitive to the prior state of the polar vortex.

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Regional Climate Models: Assessing the Representation of the ENSO Cycle and its Impacts on Coffee Production and Climate in Colombia.

Katie Hodge, Foundation Applied Scientist, Met Office

Session 1: Tropics, Subtropics and Teleconnections

Virtual Presentation

Colombia is the world’s third largest coffee exporter. The high altitude and rich soils of Colombia’s mountains and valleys create ideal conditions for growing coffee plants. The coffee industry in Colombia mostly consists of small, family-owned farms, and provides many hundreds of thousands of jobs in rural areas. Climatic conditions, such as temperature, rainfall and the impact of the El Nino Southern Oscillation (ENSO) phase and strength, during the growing season strongly influence the quality and overall yields of coffee beans. Additionally, coffee crops in Colombia face a variety of threats originating from climate change, including loss of quality and increased prevalence of pests and diseases. High resolution climate data is needed to assess how the climate of the coffee growing areas could change in the future and assist growers to adapt to these changes. The ability of three regional climate models (RCA4, RegCM4.3 and CRCM5) to reproduce observed teleconnections between the ENSO cycle and climate in coffee-growing areas of Colombia will be assessed to determine if the models can be used for climate impact assessments for coffee production in Colombia. These regional climate model simulations were produced for the Coordinated Regional Dynamical Experiment (CORDEX) for the Central America, Caribbean, and Mexico (CAM) domain. As global models drive regional climate models, first an assessment of the representation of the ENSO phase and strength in global CMIP5 models will be investigated. Then high-resolution regional climate models simulations will be used to compare the influence of ENSO on rainfall and temperature signals over Colombia to observations. This is believed to be the first study to explicitly use the CAM-CORDEX results for Colombia.

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Hail Accumulation Events in Europe

Faye Hulton, Postgraduate Research Student, The University of Manchester

Session 2: Observations

On 31 May 2010, up to 100cm of hail accumulation was reported from a single 45-minute storm in the town of Badajoz in the southwest of Spain. At 1300 UTC 31 May 2003, a storm producing almost 50cm of hail accumulation hit the 18th and 19th districts of Paris. These two studies are extreme examples of convective storms that produce large depths of hail accumulation. However, the literature has little to say about what conditions these accumulating hailstorms form in, as well as why they produce accumulating hail. The aim of the study is to use a case-study approach to investigate the meteorological conditions that have produced hail accumulation in Europe. The European Severe Weather Database (ESWD) has a record of hail accumulation depth and was used to identify 17 events. Media reports were then used to supplement the information on the events. Events were initially categorised based on 500-hPa reanalysis charts from the NOAA Physical Science Laboratory's 6-hour reanalysis data composites into 5 groups: slow-moving troughs, cut-offs, ridges, omega blocks, and high-over-low patterns. Cut-offs accounted for 8/17 events, and slow-moving troughs 6/17 events. Satellite imagery, weather charts, and radar data were also used to investigate the storm structures.

Estimating the Impact of Historical Thermometer Exposures on Early Instrumental Temperature Data

Emily Wallis, Postgraduate Research Student, Climatic Research Unit, University of East Anglia

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Session 2: Observations

Long observational records of land surface air temperature are vital to our understanding of climate variability and change. However, of the relatively few long observational series which exist, many contain non-climatic changes (inhomogeneities) resulting from alterations to instrumentation, station location and/or observing practises, which impede their use for climate analysis. One such inhomogeneity is the exposure bias. Prior to the widespread adoption of Stevenson-type screens, various approaches were used to shield thermometers. Each approach exposed the thermometer to differing levels of solar radiation, thus introducing inhomogeneities (or biases across regions) when the transition to Stevenson-type screens was made. Despite a number of studies documenting the presence of the exposure bias in early instrumental data, relatively few corrections have been applied and the error associated with the bias is not sufficiently represented in gridded temperature datasets.

In this piece of work we analyse historical metadata, series with a known Stevenson-type screen introduction date, and parallel measurements from differentially-shielded thermometers, in order to better define the characteristics of the exposure bias. We focus particularly on how the bias differs between four categories of historical exposure (Open, Wall Mounted, Intermediate and Closed), the seasonal nature of the bias, and how it varies geographically. These characteristics are then used, along with historical metadata, to estimate the monthly mean exposure bias at stations within the CRUTEM5 station database. This work forms part of the NERC-funded GloSAT project which is developing a global surface air temperature dataset starting in 1781. The ultimate aim of the work reported here is to improve the representation of the exposure bias in error models used for gridded instrumental temperature datasets. It is also hoped the work will help inform the identification of exposure biases in early instrumental data in future.

Comparing Gravity Waves in a High Resolution Model to AIRS Satellite Observations

Emily Lear, PhD Student, University of Bath

Session 2: Observations

Gravity waves are small-scale atmospheric waves which transport energy and momentum. These waves impact the large scale circulation, and increasing our understanding of them is important to improve weather and climate models. This presentation focuses on gravity waves in the stratosphere using data from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 reanalysis, the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua satellite and a high resolution run of the ECMWF IFS operated at a km-scale spatial resolution. Data was examined during the first 2 weeks of November, as the high resolution model was initialised on the 1st of this month. Asia and surrounding regions are investigated, because preliminary studies of AIRS data suggested strong gravity wave activity in this region during this time period. Waves can also be seen in the ERA5 data at the same times and locations. The high resolution model also shows significant gravity wave activity in similar areas to where it is seen in the AIRS data, particularly over Russia. The 2D+1 S-Transform was used to find wave amplitudes, horizontal and vertical wavelengths and momentum flux for all three datasets. Weather models are advancing rapidly and km scales such as the experimental IFS run could become operational in next decade. At these grid scales, gravity waves must be resolved instead of parameterized, so the models need to be tested to see if they do this correctly. This work provides information on how a cutting edge model resolves gravity waves compared to observations.

Towards Homogenisation of Manual Snow Depth Series

Moritz Buchmann, PhD Student, WSL Institute for Snow and Avalanche Research SLF, Davos and Oeschger Centre for Climate Change Research, University of Bern, Switzerland

Session 2: Observations

Snow has important implications for a wide range of areas like ecology, economy and society: ranging from flora and fauna over winter tourism, hydro power, and fresh water availability to floods and avalanches.

Measurements of snow depth can vary dramatically over small distances, and as with any other meteorological variable, snow depth time series are affected by inhomogeneities or break points. Such inhomogeneities can arise due to e.g.; changes of instrumentation, changes to station location and observer practices, or changes in the local environment such as urbanisation or plant growth.

In order to analyse and monitor variation in snow depth time series accurately, homogenised snow data series are required. In deriving such homogenised series it is essential to understand the characteristics and impacts of inhomogeneities. Having applied some pre-selection criteria to identify candidate series, time series homogenization for 184 of the available manual Swiss snow depth series was performed using ACMANT, Climatol, and HOMER, three state-of-the-art break detection algorithms.

By evaluating the network using multiple methods, there is more confidence that the results can be applied to snow time series with insufficient metadata or no immediately nearby reference stations in order to include them in future homogenisation efforts.

Furthermore, the knowledge about inhomogeneities and break points paves the way for new applications such as the reliable combination of multiple parallel series into one single series for long-term climatological analyses.

Downscaling UK rainfall using machine-learning emulation of a convection-permitting model

Henry Addison, PhD Student, University of Bristol

Session 3: Convection and Modelling

Virtual Presentation

Climate change is causing the intensification of rainfall extremes in the UK. Physics-based numerical simulations for creating precipitation projections are computationally expensive and must be run many times to quantify the natural variability of precipitation. Local-scale projections such as those from the Met Office's 2.2km convection-permitting model are possible but the computational expense of these simulations requires trade-offs in the duration, domain size, ensemble size and emission scenarios for which to produce projections.

Here, we apply state-of-the-art machine learning methods to predict precipitation from the 2.2km model given large-scale predictors that are represented in general circulation models/global climate models (GCMs). By conditioning on outputs from a physical model, rainfall can be downscaled in both past and future climates. We test the extent these methods can reproduce the complex spatial and temporal structure of rainfall, with which past statistical approaches struggle. We are interested in the methods' ability to capture the distribution of extreme rainfall and to reproduce extreme events. Our methods are neural-network-based and explore generative approaches for representing the stochastic component of high-resolution precipitation. Compared to physical models, these approaches are computationally much cheaper and have a simple interface allowing them to be used to downscale other large GCM datasets.

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Improving Moist Thermodynamics in Weather and Climate Models

Paul Bowen, PhD Student, University of Exeter

Session 3: Convection and Modelling

Approximations in the moist thermodynamics of atmospheric models can often be inconsistent. Different parts of numerical models may handle the thermodynamics in different ways, or the approximations may disagree with the laws of thermodynamics. To address these problems all relevant thermodynamic quantities may be derived from a defined thermodynamic potential; approximations are then instead made to the potential itself - this guarantees self-consistency, as well as flexibility. Previous work showed that this concept is viable for vapour and liquid water mixtures in a moist atmospheric system using the Gibbs potential. However, on extension to include the ice phase an ambiguity is encountered at the triple-point. To resolve this ambiguity, here the internal energy potential is used instead. Constrained maximisation methods on the entropy can be used to solve for the system equilibrium state. However, a further extension is necessary for atmospheric systems. In the Earth's atmosphere many important non-equilibrium processes take place; for example, freezing of super-cooled water, and evaporation into subsaturated air. To fully capture processes such as these, the equilibrium method must be reformulated to involve finite rates of approach towards equilibrium. Here the principles of non-equilibrium thermodynamics are used, beginning with a set of phenomenological equations, to show how non-equilibrium moist processes may be coupled to a semi-implicit semi-Lagrangian dynamical core. A standard bubble test case and simulations of cloudy thermals are presented to demonstrate the viability of the approach for equilibrium thermodynamics, as well as the more complex non-equilibrium regime.

Analysis of Spectral Nudging Methods to Improve Skill in Convective-scale Ensembles

Adam Gainford, PhD Student, University of Reading

Session 3: Convection and Modelling

Convection-permitting ensemble forecasts are now widely used throughout meteorological centres around the world to assess the uncertainty associated with both day-to-day and severe weather events. However, these forecasts are frequently reported by operational meteorologists to be underspread, such that the perturbed members follow the control member too closely and lead to overconfidence in the predicted outcome. Recent work at the Met Office has improved forecast spread in its convective-scale ensemble prediction system, MOGREPS-UK, by implementing staggered, hourly data assimilation cycles centered around the deterministic UKV model. Here, the impact of using a novel spectral nudging method, termed large-scale blending, to improve ensemble spread is assessed. This approach has previously been demonstrated to improve predictability in the UKV model. The method blends spectrally filtered increments obtained from downscaling the global model into the background fields, and these incremented fields are then used in the UKV data assimilation cycles. The new configuration of MOGREPS-UK, set to become operational in 2022, will adopt this large-scale blending technique, and it is currently not known how this addition will affect the ensemble spread for convective cases, given the tighter dependence on its global forcing. Analysis of summer and winter forecast trials designed to assess the impacts of the large-scale blending on the ensemble skill, as measured by the Fractions Skill Score, will be presented.

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Far Flung Influences on North Atlantic Winter Climate Affect Predictability

Ned Williams, PhD Researcher, University of Exeter

Session 4: Climate

Seasonal forecasts cover part of the timescale gap between weather forecasts and climate change projections by aiming to predict climate anomalies a few months ahead of time. They aim to answer questions such as ‘Will the upcoming winter be colder or warmer than usual’? Whilst far from perfect, contemporary operational forecasts do demonstrate a useful level skill in predicting winter climate in the extratropics. However, a 'signal-to-noise paradox' has been observed in seasonal forecasts and predictions further ahead, where the sign of anomalies (e.g. positive/negative North Atlantic Oscillation) is correctly predicted despite large ensemble spread, but the magnitude of the modelled anomalous signal is inconsistently weak given the correlation with observations. The paradox may be caused by overestimation of unpredictable internal noise, or by underestimation of the strength of predictable signals. The predictable component of extratropical winter climate is strongly influenced by tropical drivers such as the El Niño-Southern Oscillation (ENSO). Modelled teleconnections have errors in their phase and amplitude – either or both of which could contribute to the signal-to-noise paradox. We find that the amplitude of the tropospheric ENSO-North Atlantic teleconnection is weaker in the Met Office GloSea5 forecasting system than in observations. This leads to a smaller predictable signal and may therefore contribute to the signal-to-noise paradox. A method of amplitude correction is applied to GloSea5 hindcast data and reduces the signal-to-noise problem for geopotential height predictions in the North Atlantic and North Pacific. A similar method to correct phase errors has little effect.

The Atmospheric Response to the Weddell Sea Polynya

Dr Holly Ayres, Postdoctoral Research Assistant, University of Reading

Session 4: Climate

The Weddell Sea Polynya is a large opening within the sea ice cover of the Weddell sea sector, typically found sitting over the Maud Rise in its largest occurrences. It has been a rare event in the satellite period, appearing throughout the 1970s and again in 2016/17. Many mechanisms have been suggested to cause the onset of the Weddell Sea Polynya, from deep convection of the ocean and upwelling at the Maud Rise, in addition to increased cyclone activity and the influence of atmospheric rivers. It is thought that with increasing atmospheric greenhouse gasses, the Weddell Sea Polynya will be even less frequent, due to an intensification of the haline stratification within the polynya region. The opening of the polynya creates an ocean to air heat flux in the cooler months, with the potential to influence atmospheric dynamics. The atmospheric response to the polynya and regional ice loss may be observed locally within the low-pressure region of the Weddell Sea or further afield climate. Here, we use high and low resolution AGCM experiments with the HadGEM3 UK Met Office model, alongside PRIMAVERA high-resolution analysis of the polynya, to evaluate the atmospheric response to the polynya and associated features, in addition to the role of model resolution in resolving the polynya and its associated features.

Global Impacts of the Pacific Decadal Variability

Melissa Seabrook, Climate Scientist, Met Office

Session 4: Climate

The Pacific Decadal Variability (PDV) is characterised by a pattern similar to the interannual El Niño oscillation with anomalously warm sea surface temperatures (SSTs) in the tropical Pacific surrounded by a horseshoe of cool SSTs. PDV affects global temperatures and contributed to the ‘slowdown’ at the beginning of the 21st century, but other climate impacts are more uncertain.

Here, the global impacts of PDV are assessed using experiments from the CMIP6 Decadal Climate Prediction Project (DCPP) which impose the PDV pattern in a coupled climate model. We compare model simulations using the Met Office model (HadGEM3.1) with the impacts of PDV diagnosed from observations, and find good agreement in general. Both model and observations show a decreased Pacific Walker circulation and an increased Hadley response which combine to generate large scale Rossby waves, impacting global atmospheric circulation and precipitation patterns. Differences between interannual impacts associated with El Niño and decadal impacts of PDV will also be explored.

Climate Change Impacts on the European Energy Balance

Emma Patmore, Meteorologist, Lake Street Consulting Ltd

Session 4: Climate

As climate changes, the ‘normal’, or climatology, also changes. Whilst many realise this is the case, how often are results quantifying the implications for industry communicated? We look at climate changes over the last 20 years for Europe in the context of the energy balance. First, we look at how temperature, wind and solar normals have evolved over time. We then consider part of the energy (electricity/power) supply demand balance, using temperature to estimate demand, and assessing the offset of renewable power generation. Finally, we look at extremes, which provide a challenge for the energy sector: mild temperatures (low energy demand) with high renewable output, and cold/hot temperatures (high energy demand- people start to turn on their heating/air con) coupled with low renewable outputs.

Changes in Ambient Air Quality and Atmospheric Composition and Reactivity in the South East of the UK as a Result of the COVID-19 Lockdown

Mark Nichols, Principal Air Quality Consultant, Hydrock / University of Brighton / IAQM

Session 5: Aerosols, Composition and Air Quality

The COVID-19 pandemic forced governments around the world to impose restrictions on daily life to prevent the spread of the virus. This resulted in unprecedented reductions in anthropogenic activity, and reduced emissions of certain air pollutants, namely oxides of nitrogen. The UK ‘lockdown’ was enforced on 23/03/2020, which led to restrictions on movement, social interaction, and ‘non-essential’ businesses and services. This study employed an ensemble of measurement and modelling techniques to investigate changes in air quality, atmospheric composition and boundary layer reactivity in the South East of the UK post-lockdown. The techniques employed included in-situ gas- and particle-phase monitoring within central and local authority air quality monitoring networks, remote sensing by long path Differential Optical Absorption Spectroscopy and Sentinel-5P's TROPOMI, and detailed 0-D chemical box modelling. Findings showed that de-trended NO2 concentrations decreased by an average of 14–38% when compared to the mean of the same period over the preceding 5-years. We found that de-trended particulate matter concentrations had been influenced by interregional pollution episodes, and de-trended ozone concentrations had increased across most sites, by up to 15%, such that total Ox levels were roughly preserved. 0-D chemical box model simulations showed the observed increases in ozone concentrations during lockdown under the hydrocarbon-limited ozone production regime, where total NOx decreased proportionally greater than total non-methane hydrocarbons, which led to an increase in total hydroxyl, peroxy and organic peroxy radicals. These findings suggest a more complex scenario in terms of changes in air quality owing to the COVID-19 lockdown than originally reported and provide a window into the future to illustrate potential outcomes of policy interventions seeking large-scale NOx emissions reductions without due consideration of other reactive trace species.

Street Canyon NO2 "Hotspots" and Regulatory "Wiggle Room": The Interacting Effects of Free-Radical Chemistry, Canyon Geometry, Primary NO2, and Emissions

Yuqing Dai, PhD Student, University of Birmingham

Session 5: Aerosols, Composition and Air Quality

The extent to which nitrogen dioxide (NO2) undergoes complex chemical-transport processes near strong nitrogen-oxide sources in street canyons is not fully understood. A multi-box framework with volatile organic compound (VOC) chemistry has been evaluated against large-eddy simulation (LES) data and observations, and then used to simulate NO2 at street-canyon “hotspots”. 42,000 sensitivity studies — varying nitrogen oxides (NOx) and VOC emission strength, and primary NO2 fraction (fNO2) emitted within each of five streetscape cases — show the importance of detailed VOC chemistry, rather than the simple NOx-O3-only cycle, even in a regular canyon (i.e., aspect ratio, AR = 1). For a midsummer central London scenario, the inclusion of chemistry moves the canyon from compliance to out-of-compliance with the 1-hour NO2 standard. Ignoring street-canyon chemistry can lead, therefore, to false positives in regulatory air quality modelling. Neglecting VOC chemistry can underestimate NO2 by 6%-22% in regular canyons, and even more (-51%-31%) in deep canyons (AR = 2), particularly with lower fNO2 values resulting from gasoline-dominated vehicle fleets or by tighter control of primary NO2 from diesels. The very significant changes in regulatory “wiggle room” across sensitivity studies demonstrate the utility of this kind of chemistry-transport modelling for identifying efficient and effective regulatory pathways.

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Inter-annual Variations in the Siberian Carbon Uptake and Carbon Release Periods

Dieu Anh Tran, PhD Researcher, Max Planck Institute for Biogeochemistry

Session 5: Aerosols, Composition and Air Quality

Along with spring and summer temperatures rising, warming is also noticeable during the winter. Increasing temperature in the winters could have a significant influence on the terrestrial carbon balance. Plant and soil respiration are one of the key processes during the winter months that are responsible for the variations in atmospheric CO2. Winters with higher temperatures are expected to increase both microbial and plant respiration enhancing the respiratory release of CO2 and thereby weakening the annual net terrestrial carbon sink. If warm winters occur at an increasing rate as predicted, the amount of winter respiratory release of CO2 could be significantly enhanced thus potentially shifting northern hemisphere ecosystems from net carbon sinks to net carbon sources. Despite the potential impacts of warm winters on the carbon balance, however, ecosystem responses during cold months have received less attention than during early spring and summer. Here we will look at the inter-annual variations of Siberian carbon release period (CRP) during the cold months and whether this process is compensated by the carbon uptake period (CUP) during the later warm months from 2009 to 2020. By using the detrended long-term record of atmospheric CO2 concentrations from the Zotino Tall Tower Observatory (ZOTTO) located at 60◦48′ N, 89◦21′ with the simultaneous use of multiple satellite-derived products, eddy covariance data and simulations with an atmospheric inversion model, we found that the CRP length and amplitude indeed increased from 2009 to 2020. This increase indicates accelerating net CO2 respiratory release. However, the CUP length and amplitude showed no positive trend since 2009, indicating that enhanced net CO2 release during cold months cancelled out the lower uptake during the later season. Our results demonstrate that a warming climate does not necessarily lead to higher CO2 uptake, even in high-latitude ecosystems that are considered to be temperature limited.

Investigating Aerosol Radiative Adjustment Mechanisms with Model Nudging

Max R. Coleman, PhD Student, Department of Meteorology, University of Reading

Session 5: Aerosols, Composition and Air Quality

We investigate a novel use of model nudging to isolate radiative adjustment mechanisms and their magnitudes in response to aerosol emission perturbations in an earth system model. The radiative effects of a forcing agent can be quantified using the effective radiative forcing (ERF). ERF is the sum of the instantaneous radiative forcing, and radiative adjustments – changes in the atmosphere's state in response to the initial forcing agent that cause a further radiative forcing. Radiative adjustments are particularly important for aerosols, which affect clouds both via microphysical interactions and changes in circulation, stratification and convection. Understanding different adjustment mechanisms and their contribution to the total ERF of different aerosol emissions is necessary to better understand how their ERF may change in future. In this work we investigate using nudging to isolate radiative adjustments resulting from changes in atmospheric temperature (affecting stratification and convection) and horizontal winds (affecting circulation) from anthropogenic sulphate and black carbon aerosol forcing.

We conducted multiple global atmosphere-only time-slice experiments using the UK Earth System Model (UKESM1). Each experiment has either control, black carbon perturbed, or sulphur dioxide perturbed emissions; and either no nudging, nudged horizontal winds (uv), or nudged horizontal winds and potential temperature (uvθ). The difference between nudged uvθ minus nudged uv simulation pairs isolates the atmospheric temperature related adjustments; and difference between nudged uv and fre simulation pairs isolates circulation mediated adjustments. We repeated each simulation to test sensitivity to different nudging parameters.

We find that nudging horizontal winds affects the resulting ERF very little, whereas nudging potential temperature as well causes significant difference from the non-nudged experiments, primarily in the cloud radiative effect. However, the full suppression of potential temperature is hard to achieve and dependent on the nudging setup - w identify best case settings and potential improvements.

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Improving Understanding of Mineral Dust Transport and Deposition Using Aircraft Observations and Modelling

Natalie Ratcliffe, PhD Student, University of Reading

Session 5: Aerosols, Composition and Air Quality

Mineral dust plays a vital role in the Earth system, altering radiative balance, hydrological and carbon cycles, and impacting human health. Recent field campaigns reveal unexpected long-range transport of coarse (d>2.5 µm) and giant (d>20 µm) dust particles from the Sahara across the Atlantic. Current understanding of dust transport and deposition processes suggest these particles should be subject to swift gravitational deposition. Climate models tend to feature a fine particle bias whereby coarse particles are underestimated, and giant particles are rarely simulated; this results in a further bias of the impacts of dust on the Earth system.

Three aircraft campaigns, providing vertically resolved particle size distributions over the Sahara, East Atlantic and West Atlantic, are analysed to demonstrate the change in size distribution from the source, at the Sahara, to the Caribbean along the track of the summertime Saharan dust plume. Additionally, the aerosol scheme currently used in the Met Office Unified Model is evaluated using the campaign data, to assess its representation of the size distribution evolution and identify areas for improvement.

Initial findings show that the deposition rate of coarse particles in the model is too rapid compared to the observations, resulting in an underestimation of dust mass transported from the Sahara. Results from this project will provide a better understanding of the processes involved in transport and deposition of mineral dust particles.

A New Post Processing Capability for Forecasting Surface Transport Hazards

Joe Eyles, Scientist, Met Office

Session 6: Communications, Industry and Applications

Forecasting the state of the road, for example if there is ice on the road at a given time, is of vital importance to the national transport infrastructure. Accurate and timely forecasts save lives, money, and the environment by enabling gritting services to operate efficiently and effectively. At the Met Office we are re-building our surface transport forecasting post processing capability (that is, processing that happens after the main Numerical Weather Prediction has completed) to improve the forecast and support future capabilities and requirements. At the heart of the post processing capability is the open-source physical model JULES (the Joint UK Land Environment Simulator). To use JULES, the physics that it simulates must be augmented to include the processes specific to a road surface (such as the impacts of traffic). JULES is supported by several other steps, including machine learning models for bias correction and initial condition generation. The new forecast can then be delivered via up-to-date techniques, such as an API (or Application Programming Interface). Once completed, this surface transport forecasting capability aims to improve on the current system, delivering accurate forecasts that support the future of mobility.

The Role of Partnership in Global-Coupled Model Science Configuration Development

Luke Roberts, UM Partnership Foundation Scientist, Met Office

Session 6: Communications, Industry and Applications

Developing a seamless modelling system is a challenge, requiring both scientific and technical collaboration with multiple institutes. The Met Office's Unified Model (UM) Partnership is an example of the importance partnership plays in accelerating scientific development far beyond what is possible from a single organisation.

The UM goes through cycles of development, testing and assessment. The current Global Coupled (GC) model science configuration under the development cycle is GC5 which will enter the final assessment stage in March 2022. We present case study examples of successes and lessons learnt from how partners have contributed to the development of GC5.

Highlight contributions have included cloud microphysics developments from NIWA (New Zealand); the addition of an E.Asian monsoon validation tool for model assessment from KMA (South Korea) as well as having all UM Partners involved in the analysis of assessment runs. We also present challenges faced when balancing differing interests and resources.

It is concluded that Partner contribution is overall beneficial for all involved and accelerates model development. It draws on areas of expertise from other Met services, as well as research institutes, and allows the sharing of scientific and technical knowledge.

Modelling weather dependent household water usage

Isabel Rushby, Foundation Scientist, Met Office

Session 6: Communications, Industry and Applications

As part of the Met Office collaboration with industry, we work with users – such as those in the water sector – to enable them to understand the impact of weather and climate on their businesses and to improve their meteorological-dependent decision-making.

An application of this is in modelling household water usage where, for example, if there has been a string of hot, dry days then it is expected that the typical household will use more water whilst watering their garden than they would on cool wet days – or if it is very cold there can be an increase in pipes bursting leading to rises in water demand. One approach to generating a predictive demand model to capture these relationships between meteorological variables on a given day (or days leading up to it) and the daily water usage across a region is to calibrate using Generalised Additive Models (GAMs).

The demand model development process is inherently collaborative, with water companies providing their recorded water usage over past years and insights into the behaviour of their customers, which are incorporated into the modelling through temporal variables to enable the effective separation of weather and non-weather dependent demand.

Here we demonstrate the application of GAMs for the prediction of regional water usage to replicate the weather dependent demand, as used to support the UK water sector. Results show that these demand models can explain a high proportion of the variation in daily water usage, leading to improved understanding of the drivers of high usage and better resilience planning. Using GAMs in the context of demand models can further extend beyond use in the water sector to plan for weather dependent customer demand in other sectors, for example retail and events.

From Showers to Sheep Chill: Forecasting for the Met Office

Sophie Bland, Senior Operational Meteorologist, Met Office

Session 6: Communications, Industry and Applications

Most people have their first encounter with operational meteorology as that familiar face in the morning on the TV delivering a public weather forecast. This feeds into the misconception that a meteorologist’s only job is on the television (how many times have you been asked if you’re on the TV when you say you’re a meteorologist?), or perhaps in academia. But there is a whole world of operational meteorology beyond this binary: From marine and offshore forecasting, to public advice and warnings, to flooding, to civil aviation, commercial, energy, space weather, sporting events to defence.

This presentation will introduce you to the world of operational meteorology within the Met Office, from the perspective of a Senior Operational Meteorologist specialising in defence aviation. Training begins in the college, covering basic meteorology and learning how to apply the science to create a weather forecast, and then honing skills with on the job training on an RAF or Army Air Corps base to qualify as a weather observer and operational meteorologist. Once qualified, daily tailored forecasts and briefs are delivered to a variety of customers: from delivering a daily met brief to fighter jets before their missions, to advising the safest time and routing of passenger or freight flights to avoid significant weather events, to briefing helicopters putting out forest fires, to providing forecasts for large scale search and recovery efforts.

With opportunities to travel overseas to Cyprus, The Falkland Islands, Ascension, Gibraltar, and further afield for those who become a sponsored reserve in the RAF; there is so much more to being a weather forecaster than being stood in front of a green screen.

From Black Boxes to Modifiable Codes: Improving Seasonal Forecasts in East Africa with Remote Technical Training

Alexander Chamberlain-Clay, Foundation Scientific Software Engineer, Met Office

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Session 6: Communications, Industry and Applications

As climate change drives an escalating risk of extreme events such as flooding and drought over East Africa, the importance of providing weather and climate services to this climate-vulnerable region increases. The ability to provide timely and accurate seasonal forecasts has become a key priority for East African states, as it allows for forward planning across key sectors such as food security and disaster reduction.

The WMO Regional Climate Centre for East Africa (ICPAC) provides capability support to National Meteorological and Hydrological Services (NMHS) across the Greater Horn of Africa, such as regular training courses and workshops, to upskill forecasters in seasonal prediction and to co-produce objective forecasts with them via a central supercomputer hosted at ICPAC in Nairobi. The Horizon 2020 CONFER project found that, due to wildly varying levels of technical backgrounds, training was not always being absorbed as effectively as possible.

Methods and Results

In response, we produced a set of blended, interactive training materials and exercises, tightly focused on what these forecasters would need to confidently contribute to the production of the ICPAC seasonal forecast. This involved building sufficient supercomputer fluency to use it confidently, as well as building capacity within R code development, to produce bespoke co-produced services for better engagement with national stakeholders.

Self-reported feedback from the trainers and trainees reported a greater widely applicable technical ability and increased confidence in contributing to future forecast production workshops. In this presentation, we will outline how we developed training tightly tied to forecasters needs, and show examples of exercises to build technical competence.

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Analysis of the Impacts of Aircraft Observations on Global NWP

Matthew Fry, Foundation Scientist - Observation Network Design, Met Office

Poster Board Number: 1
In Person

The forecast sensitivity to observation impact (FSOI) method is used with global numerical weather prediction (NWP) to calculate the sensitivity of the forecast error to each assimilated observation. In this study, FSOI for global Aircraft Meteorological Data Relay (AMDAR) and Air Report (AIREP) observations on the Met Office’s global T+24 forecast were analysed for the year of 2020. This is of particular interest currently, as winds and temperatures derived from Mode-S broadcasts are becoming widely available. The regional distribution of the impacts was investigated by averaging the observation impacts over 10- by 10-degree grid squares. Furthermore, the variation of impact by altitude and measured variable was investigated. Overall, the combined AMDAR/AIREP network was found to provide a significant beneficial impact per observation in almost every region, with the greatest beneficial impacts located in in the tropical belt between 10° N/S. Wind and temperature measurements had the greatest beneficial impacts on average; relative humidity measurements, which are largely restricted to Europe and the USA, were found to have a significantly lower average impact. Characteristics particular to the temporal and spatial scales of the global model’s T+24 forecast were identified as likely factors in the significantly lower beneficial impacts. Observations from the planetary boundary layer (PBL) and free troposphere (FT) had the greatest beneficial impact on average, primarily due to the lower density of observations within the PBL and the highly dynamical nature of the FT. The results of this analysis will help to inform the configuration of AMDAR and AIREP services in the future to optimise their impact.

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Analysis of Netatmo Data Quality within the London Local Area Model Domain

Matthew Fry, Foundation Scientist - Observation Network Design, Met Office

Poster Board Number: 2
In Person

Increasing the spatial and temporal density of observations is a critical milestone on the road to 100m-scale modelling. The advent of the “smart home” has brought the capability for weather observations into the homes and gardens of individuals. The resulting observations, primarily located in urban and suburban environments, may offer the necessary spatial density of observations for such high-resolution modelling. Nevertheless, these observations must be of a suitable quality for use in NWP. In this study, observational weather data made available from Netatmo home weather stations for the year of 2020 will be analysed, focusing on an evaluation of the data quality. Within the domain of the Met Office’s 300m-resolution London local area model, the data will be compared with existing Met Office automatic weather stations, Observation - Analysis statistics derived from the 1.5km UKV model analyses, and neighbouring sites from the Met Office Weather Observations Website (WOW) network. Furthermore, the inter-site variability of the Netatmo sites will be examined. The results of this investigation will help to quantify the quality of Netatmo weather station data and identify variables and locations that can best supplement existing observations in the urban environment.

Australian Precipitation Extremes Over the Last Millenia: How do Ephemeral Lake Records Compare Against Climate Models?

Sophie Grunau, PhD Student, University of Wollongong

Poster Board Number: 3

The United Nations Framework Convention on Climate Change recognised climate change as an urgent threat in the Paris Agreement, calling for mitigation and adaptation measures. To successfully implement such measures, accurate predictions of future climates by climate models, especially climate extremes, and their landscape responses are essential. However, climate models for Australia still involve high uncertainty, attributed to the limited palaeo data available for the Southern Hemisphere. This uncertainty makes it difficult to predict climate extremes and landscape responses Australia might face due to global warming. This project tackles the gap in scientific knowledge on the spatial and temporal scale of climate extremes by utilising palaeoenvironmental evidence collected from various ephemeral lakes across the country. The episodic filling and dry out events of ephemeral lakes are strongly linked to rainfall regimes and thereby Australia's high susceptibility to extreme climate variability. While previous studies have focused on high temporal resolution at specific locations the large spatial scale of this project enables the analysis of spatial variability of exceptionally wet periods and their timing, magnitude, and trend over the last thousand years. This timeframe allows the comparison of frequency and magnitude to inter-annual and spatial variability and thus will improve the understanding of climate patterns across Australia. The palaeoenvironmental record in combination with model simulations further enables analysis of landscape responses to identify climate thresholds and the impact of local and global drivers on extremes. Ultimately, by comparing the collected data against global climate simulations and other proxy data, model uncertainty can be reduced through observational constraint and future predictions of climate extremes and landscape responses can be improved.

Satellite Observations and Modelling of Hydrogen Cyanide Emissions During Indonesia 2015 Peat Fire Season

Antonio Giovanni Bruno, PhD Student, University of Leicester, NCEO

Poster Board Number: 4
Virtual

Atmospheric hydrogen cyanide (HCN) has a lifetime of 2–5 months in the troposphere and several years in the stratosphere. The key processes driving its tropospheric variability are biomass burning, as the main source, and ocean uptake, as the main tropospheric sink. In the upper troposphere and stratosphere, the main HCN loss mechanisms are oxidation by hydroxyl radicals (OH) and by reaction with O(1D). Despite its importance as an atmospheric tracer of many biomass burning events like peat fires, the mechanisms driving HCN variability are still not completely understood.

Indonesian peatlands are seasonally cleared to prepare the carbon rich soil for agriculture, enhancing the fire risk. Once burned, peats emit a large quantity of trace gases, including HCN. During 2015, one of the most intense fire seasons in recent decades was observed in Indonesia due to the drought conditions by the abnormally strong 2015/2016 El Niño event.

Here, we use the TOMCAT three-dimensional global chemical transport model to investigate the atmospheric response to the Indonesia 2015 peat fire season focusing on HCN. The HCN concentrations over the region have been modelled at a 2.8° × 2.8° spatial resolution from the surface to ~60 km and compared with the HCN observations of the Infrared Atmospheric Sounding Interferometer (IASI). Retrievals of HCN columns from IASI measured radiances were made using the optimal estimation method University of Leicester IASI Retrieval Scheme (ULIRS).

Using IASI measurements, we investigate the HCN plume propagation over the region during the 2015 wildfire season, observing a large peak of HCN at the end of October. We find that TOMCAT is able to simulate the magnitude of the HCN emissions observed by IASI instrument over Indonesia and the Indian Ocean. The implications of our results for understanding the HCN biomass burning emissions and its variability are then discussed.

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Understanding the Stratospheric Response to Arctic Amplification

Regan Mudhar, PhD Student, University of Exeter

Poster Board Number: 5
In Person

The Arctic is dramatically changing with rising greenhouse gas concentrations; without significant action, a sea-ice-free summer is projected to occur within the next century. Consequently, the lower Arctic atmosphere is warming at an accelerated rate compared to the global average, known as Arctic Amplification. Such changes at high latitudes have been proposed to produce more frequent and persistent weather extremes over mid-latitudes. The stratosphere's role in this potential teleconnection is not well understood, particularly the "stratospheric pathway" linking Arctic variability to mid-latitude extremes. One hypothesis is that sea-ice loss can enhance propagation of planetary waves into the stratosphere, weakening the winter stratospheric polar vortex, and potentially increasing the likelihood of the breakdown of the vortex in a sudden stratospheric warming. Then, through stratosphere-troposphere coupling, this may perturb the winter jet stream and affect surface climate. However, the simulated response of the stratosphere to Arctic warming has recently been shown to significantly vary among state-of-the-art climate models, even so far as the sign of the response.

In this study, the fundamental mechanisms behind the remote influence of polar heating on the structure of the stratospheric polar vortex will be investigated using Isca, an idealised 3-D general circulation modelling framework. This allows us to study both the impact of the structure of polar warming on the stratosphere, and the importance of the climatological stratospheric state. We will also be able to investigate the influence of phenomena such as the Quasi-Biennial Oscillation. We aim to use our results to understand and reduce biases among comprehensive climate model simulations.

Quantifying the Impact of Heat and Climate Change on the London Underground Infrastructure

Sarah Greenham, PhD Student, University of Birmingham

Poster Board Number: 6
In Person

The London Underground (LU) network is the world's oldest underground railway, comprised of surface, sub-surface and deep tube sections. The LU network can reach high temperatures that may result in passenger thermal discomfort, as well as asset failures that may lead to delays in operation. As the climate changes and temperatures increase across London, there are likely to be implications for future operational performance across the LU network. This study undertakes a quantitative examination of LU network temperature (2006-2018), LU performance data, called work orders (WOs) on point, crossing and train stop assets (2006-2018) and UK climate projections (2030s, 2050s and 2080s) for selected emissions scenarios. This paper presents results from the study to date on LU network thermal trends including the estimation of tunnel temperatures from surface temperature, the relationship between temperature variables and asset faults, and estimates of surface temperature in future. Different sections of the LU network have varying thermal characteristics. Days with extreme high or low temperatures lead to a greater frequency in WOs on the surface, but relationships are more complicated across the tunnel sections of the LU network. Climate projections indicate that temperatures will increase in future, with implications on future WO trends and decision-making points in developing climate change adaptation pathways for a more climate-resilient LU network.

Marine Cloud Brightening Geoengineering

William Smith, PhD Student, University of Cambridge

Poster Board Number: 7
In Person

Geoengineering is the name given to a collection of climate intervention strategies that aim to cool the Earth's climate on a large enough scale to counteract anthropogenic warming. One such strategy is marine cloud brightening (MCB), wherein the albedo of stratocumulus clouds is modified to increase the amount of sunlight they reflect with the aim to produce a net negative change in effective radiative forcing. This is achieved by increasing the number of cloud condensation nuclei in existing clouds, causing the water droplets to be spread over a larger number of nuclei and hence be smaller, increasing the albedo of the cloud. Understanding whether MCB is an effective geoengineering strategy requires many different levels of investigation. There are the global climate models; these are used to study the global effects of MCB, such as if it has the desired cooling effect and if there are any unintended side effects. Meteorological models are used to resolve aerosol-cloud interactions, these model areas on the order of 10s-100s of kilometres and are useful for determining the meteorological conditions under which MCB can be most effective. Micro-scale models can be used to understand the micro-physical processes that determine the macro-scale properties of clouds, this is useful for determining the salt particle radii that are most effective for MCB. On top of understanding the climate science questions around MCB, another important step is solving the engineering problems. These involve developing an effective way of spraying sea salt of the right size at the right rates and developing autonomous boats to deploy MCB around the world.

Quantifying the Influence of Climate Change on UK Winter Extreme Rainfall

Daniel Cotterill, Climate Scientist/PhD Student, Met Office and University of Bristol

Poster Board Number: 8
In Person

In the last decade there have been a large number of impactful flooding events in winter over the UK, with the winters of 2013-14, 2015-16 and 2019-20 leading to more than 2.7-billion-pounds of insurance loses from flooding alone. Whereas previous attribution studies have tended to focus on one event, this attribution study looks at the climate signal of multiple recent extreme rainfall events using the same method. This work produces results on whether and how much the probability of 1-in-3 up to 1-in-80-year rainfall events have already changed in different UK regions in Winter, providing useful information for flood risk predictions. The main resource used in this study is the very large UNprecedented Simulated Extreme Ensemble (UNSEEN) dataset, which enables us to isolate the climate signal for extreme events. Initial results show that 1-in-30 to 1-in-80-year rainfall events over a 1–3-day period in winter are generally around 2-3 times more likely in 2020 due to climate change, and 1-in-3 to 1-in-15-year events 1.3-1.6 times more likely. Future work will look at how this signal in the hazard (extreme rainfall) will translate into impacts (flooding) using flood inundation models.

Atmospheric forcing of the Northeast Water Polynya

Miriam Bennett, PhD Student, University of East Anglia

Poster Board Number: 9
In Person

Due to its high elevation, mountainous terrain and cold ice-covered surface, Greenland has a significant impact on atmospheric circulation in the Northern Hemisphere, over a variety of spatial and temporal scales. Strong tip jets, katabatic winds and barrier flows are known to develop in the region, impacting local meteorology as well as larger-scale climatology. Numerous studies have shown that orographic flows in Greenland can influence atmospheric, oceanic and cryospheric processes and dynamics, in addition to air-sea-ice interactions. The understanding of these Arctic systems, and how they interact, is crucial for meteorological forecasting and accurate modelling of the quickly changing global climate system, particularly with anthropogenic forcing. In this project, I am especially interested in the impact of northeast Greenland's orography on the larger-scale atmospheric flow field and how this is linked to local sea ice variability. Here, I focus on the Northeast Water Polynya, a relatively stable recurring polynya with significant influence on oceanic and bio-ecological processes. I am investigating the physical mechanisms that drive its formation and variability, hypothesising that the thermodynamic effect of the near-surface wind regime plays an important role. I also consider the possible link to larger-scale modes of climatological variability and cyclone activity. As there are few (especially in-situ) observations for such an isolated region, climatological reanalysis products are currently heavily relied upon for research in this field. Today, these products are generally thought to be of decent accuracy and detail, but it has also been shown that there can exist small biases when it comes to some specific variables, such as surface wind speed in areas of complex terrain.

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Marine Biomass Regeneration at Scale - A Natural Carbon Capture Technique

Elisavet Baltas, PhD Student, Centre for Climate Repair at Cambridge, Department of Engineering, University of Cambridge

Poster Board Number: 10
In Person

Marine Biomass Regeneration (MBR), otherwise known as Ocean Iron Fertilisation (OIF) has potential to capture atmospheric CO2 at scale. Effective and large-scale atmospheric carbon capture is essential in limiting global warming to within 1.5 degrees Celsius as outlined by the Paris Agreement. In order to do this, we require effective, reliable, scalable and, most importantly, safe techniques for carbon capture and storage. Due to humans over-fishing and whaling in the past few centuries, we have experienced a huge decline in fish stocks and marine mammal populations, which are essential for the oceans' productivity.

There is evidence that introducing certain key nutrients to nutrient depleted areas of the ocean can regenerate the biomass, which then acts as a carbon sink – this is the principle behind MBR. The ocean's ability to circulate nutrients has been hindered by the over-exploitation of whales, which naturally regulate oceanic nutrient levels by feeding at a depth of 150-200m and defecating at the ocean surface through the whale cycle. Their faeces are rich in nutrients such as nitrates, phosphates and iron, and act as a natural fertiliser. It will take decades to restore the whale population to pre-whaling numbers, therefore, to catalyse the biomass regeneration of oceans, artificial whale faeces must be deployed in order to mimic the whale cycle. A large-scale implementation of MBR would not only be crucial in restoring the ocean's ability to sequester carbon but would also be a natural solution in reaching net zero emissions.

This paper examines the rate-limiting steps of MBR and its potential for implementation at scale.

Atmospheric Dynamics of Daily 100-Year Precipitation Events Over Central Europe and the Difference to More Moderate Extreme Events

Florian Ruff, PhD Student, Freie Universität Berlin, Germany

Poster Board Number: 11
In Person

Extreme, large-scale precipitation events can lead to extreme river floodings which are one of the most dangerous weather events for society when occurring in highly populated areas. However, the largest impacts are caused by very rare events with return periods on the order of 100 years. To do a quantitative and robust analysis of daily 100-year precipitation events, observational time series are typically too short. Therefore, an approach is applied here in which operational ensemble prediction data from the ECMWF are used to generate a large pool of simulated, but realistic daily precipitation events (corresponding to 1200 years of data) from which several 100-year events can be analysed. For five different major Central European river catchments, composite analyses show that 100-year precipitation events in all catchments are typically associated with an upper-level trough moving into Central Europe 24h to 48h before the occurrence of the events. During the 24h before the events, details in the progression of the trough and the location of the associated surface cyclone determine in which catchment extreme precipitation occurs. A comparison to composite analyses of less extreme precipitation events shows that dynamical mechanisms such as an amplified mid-tropospheric trough/cut off are more important for an intensification of precipitation events in the Danube and Oder catchments while in the Elbe, Rhine and Weser/Ems catchments thermodynamical mechanisms such as a larger moisture flux are more important. The question how a warmer climate will affect the dynamical processes of such extreme precipitation events will be investigated in a follow-up study.

Investigation of the Production of Trifluoroacetic Acid from Two Halocarbons, HFC-134a and HFO-1234yf, and Its Fates Using a Global Three-Dimensional Chemical Transport Model

Rayne Holland, Postgraduate Research Student, University of Bristol

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Poster Board Number: 12
In Person

Trifluoroacetic acid (TFA), a highly soluble and stable organic acid, is photochemically produced by certain anthropogenically emitted halocarbons such as HFC-134a and HFO-1234yf. Both these halocarbons are used as refrigerants in the automobile industry, and the high global warming potential of HFC-134a has promoted regulation of its use. Industries are transitioning to the use of HFO-1234yf as a more environmentally friendly alternative. We investigated the environmental effects of this change and found a 33-fold increase in the global burden of TFA from an annual value of 65 tonnes formed from the 2015 emissions of HFC-134a to a value of 2220 tonnes formed from an equivalent emission of HFO-1234yf. The percentage increase in surface TFA concentrations resulting from the switch from HFC-134a to HFO-1234yf remains substantial with an increase of up to 250-fold across Europe. The increase in emissions greater than the current emission scenario of HFO-1234yf is likely to result in significant TFA burden as the atmosphere is not able to disperse and deposit relevant oxidation products. The Criegee intermediate initiated loss process of TFA reduces the surface level atmospheric lifetime of TFA by up to 5 days (from 7 days to 2 days) in tropical forested regions.

Climatology and simulations of precipitation bands associated with extratropical cyclones over the British Isles

Tianhang Zhang, PhD Student, University of Manchester

Poster Board Number: 13
Virtual

Precipitation bands are lines of heavy precipitation as seen on weather radar. Therefore, understanding how bands form, intensify, and evolve becomes important to understand heavy rain, snow, and flooding. Climatologies and simulations using a mesoscale numerical model are helpful approaches to achieve this goal.

First, a four-year climatology of precipitation bands associated with extratropical cyclones over the British Isles from April 2017 to March 2021 is constructed, including 167 single bands in association with 118 extratropical cyclones. Of these 167 bands, 65% formed over the water near the coasts, whereas 35% formed over land. At their formation time, most bands were prevalent west of Scotland in spring, west of Ireland in autumn and summer, and southwest of Great Britain in winter. Bands were most common in the late autumn and early winter, with a minimum in late spring and early summer. The average length of bands at their formation time and maximum length were about 310 and 480 km, respectively, showing that bands were lengthening. The number of bands decreased with increasing lifetime, with 42% of bands lasting for the minimum 2–3 h, although some bands lasted for more than 8 h. Bands were classified into six categories: occluded-frontal bands (38%), warm-frontal bands (20%), cold-frontal bands (18%), postfrontal bands (10%), warm-sector bands (7%), and other bands (8%).

Second, to understand why most bands formed over the water and to determine how the synoptic and mesoscale environments change during landfall, we pick three archetypal cases from the 4-year climatology and simulate them using the Weather Research and Forecasting (WRF) Model.

This study will address the following questions:

1. How did the synoptic-scale environment change during the landfalling?

2. How did the low-level frontogenesis change?

3. Was instability (symmetrical, conditional, and inertial instability) important for the enhancement of precipitation?

4. How did the moisture change?

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Analysis of the Temporal Distribution of PM2.5 Concentrations Before and After Lockdown in London, U.K.

Balendra V.S. Chauhan, PhD Scholar, University of Brighton

Poster Board Number: 14
Virtual

Several studies have associated PM10, PM2.5, and PM0.1 particles with a range of severe human health effects. Results have shown that fine and ultrafine particles can impact the cardiovascular system and the respiratory system, and that acute and chronic exposures may also lead to fatalities. It has been observed that during the formation of particulate matter, black carbon present at the surface of the nascent cluster can take-up biological and chemical components. Hence particulate matter may become an eligible vector to carry viruses for a protracted -time period compared to when they exist in isolation or in other forms; from this has followed the hypothesis PM being involved in the more effective transmission of coronavirus (SARS-CoV-2).

The U.K. government imposed a national ‘lockdown’ on the 23rd March 2022 owing to the spread of COVID-19, which in-turn halted anthropogenic activities and hence many sources of air pollution for months. This study focuses on the analysis of concentrations of PM at 9 locations in the London area before, during and after the COVID-19 pandemic. The analysis conducted here includes the comparison of PM2.5 concentrations at these 9 locations, 365 days before lockdown (from 23rd March 2019 to 22nd March 2020) and 365 days from the announcement of lockdown (23rd March 2020 to 23rd March 2021). Particle composition was also investigated. It was observed that the PM2.5 mass concentrations were reduced at most of the locations during lockdown, but for some locations, they remained approximately the same; this may have been due to an increase in domestic combustion and greater use of, for example wood burners. As such in some locations, concentrations of PM may have remained significant during the COVID-19 lockdown, adversely affecting local air quality, contrary to many media reports.

Analysis of Different Types of Precipitation over China using Machine Learning Algorithms

Yi Wang, PhD Student, University of Exeter

Poster Board Number: 15
In Person

In the context of global warming, changes in extreme weather disasters can pose great threats to human society. It is important to improve our understanding of the climatology of high-impact precipitation types (PTs) and their simulations, especially in regions of developing countries that are influenced by hazards related to different PTs. In this study, we first use historical climate reanalysis data (ERA5) to construct and evaluate three different machine learning (ML) models. Then combined with high-resolution climate models to test their ability to capture different types of precipitation climate in China. The result shows that the three different ML algorithms based on decision trees exhibit some capability of representing the historical pattern of different PTs in China when they are compared to the ERA5 climate reanalysis data. However, the Histogram-based Gradient Boosting method shows apparent overestimation of the PTs of a relatively low frequency of occurrences, such as freezing rain, mixed rain and snow, and ice pellets. All the ML algorithms show a poor performance in detecting mixed rain and snow and ice pellets. For the combination of different ML algorithms and the HadGEM3-GC3.1 climate model, the result shows some realism in the simulated distribution of liquid rain, snow, and freezing rain compared to ERA5, however, poor performance is shown for mixed rain and snow and ice pellets. This study implies the importance of further use of ML techniques to the detection of PTs, especially for the use of more sophisticated ML methods and the further analysis of multi-model uncertainties in simulating the different high-impact PTs in China.

A Numerical Model of Frazil Ice in Meltwater Plumes

Amelia Adcroft, Masters Student, University of Oxford

Poster Board Number: 16
In Person

Formation of frazil ice crystals in meltwater plumes due to the pressure dependence of freezing has been observed in a number of ice shelf cavities in Antarctica. This frazil ice precipitates onto the base of ice shelves, an input to ice shelf mass balance which is currently poorly constrained. Numerical models simulating this process exist, but describing the nucleation and growth of crystals of different size classes within a plume is computationally expensive. We propose a modified plume model in which frazil growth is characterised entirely by the fraction of water in the plume in the frozen state. This simplifies the number of differential equations used to describe the system and eliminates the need to account for nucleation. The thickness of precipitated marine ice predicted by our model is similar to the results of more complicated models, and is not sensitive to the choice of ice crystal radius or the assumed form of the ice crystal rise velocity relative to the plume. These findings support the use of simplified frazil plume models to predict ice shelf mass balances and suggest such a model could be usefully integrated into larger coupled ice-ocean simulations.

Extratropical Cyclone Characteristics and the Signal-to-Noise Paradox

Eswyn Chen, Postgraduate Researcher/PhD Student, University of Leeds

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Poster Board Number: 17
In Person

Much of the day-to-day weather variability in the North Atlantic region is governed by the storm track where extratropical cyclones (ETCs) develop to transport energy and momentum poleward and downstream within the atmosphere. As such, ETCs are a key component of the general circulation in mid-latitudes. Operational prediction systems now show predictive skill for the North Atlantic region on seasonal-to-decadal timescales, but the models are underconfident. This has been coined a ‘signal-to-noise paradox’. Tentative results have shown the representation of bulk eddy fluxes in the North Atlantic may be more realistically simulated at mesoscale resolution (~10 km) and this could improve predictions. However, it is not known which physical processes are affected by increasing resolution and how these relate to the large-scale flow. Here, I adopt a synoptic view of the signal-to-noise paradox, by comparing North Atlantic ETC characteristics in high- and lower-resolution models with a focus on how surface fluxes and interaction between the atmosphere and ocean change with resolution. Initial simulations are used from the Met Office Hadley Centre global model performed as part of a high-resolution climate modelling project, PRIMAVERA. ETCs are tracked using a feature-detection software package, TempestExtremes, and then composited to compare their structures. I will discuss plans for future work including analysing ETCs in global mesoscale simulations.

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Measuring Mesoscale Gradients at High Latitudes During HALO-(AC)3 to Force and Evaluate LES-Simulations

Fiona Paulus, PhD Student, Institute for Geophysics and Meteorology, University of Cologne

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Poster Board Number: 18
In Person

Moisture and aerosol exchange between the Arctic and the mid-latitudes plays a crucial role in the ongoing rapid warming of the Arctic climate. In particular the downward longwave radiation associated with liquid clouds as embedded in warm-air intrusions has been found to contribute significantly to enhanced melting of the ice sheet. The observed persistence of liquid clouds at high latitudes is not yet fully understood, but the transitions between cloud and cloud-free states are likely to be linked to large-scale dynamics. Recent Lagrangian Large-Eddy-Simulations (LES) following air masses into the Arctic have shown that the evolution of the mixed-layer depth is predominantly controlled by large-scale subsidence, and that relatively abrupt changes in subsidence rates can cause cloud collapse. This subsequently causes a drastic change in the surface energy budget. In order to support this modeling result with observations, simultaneous measurements of the large-scale subsidence and the mixed-phase cloud properties are necessary. During the recent HALO-(AC)^3 field campaign we used dropsondes to measure divergence and other gradients across mesoscale areas. In combination with in-situ measurements of clouds, radiation and water vapor we aim to use these data to force and evaluate LES simulations completely with observational data, for the first time ever. The simulations also allow us to gain new insights into the role of resolved small-scale processes in controlling air mass evolution, under observed large-scale meteorological conditions.

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Utilising Remote Engagement to Collaborate and Co-Produce Climate Services with Partners Across the World

Dr Stacey New, Climate Services Scientist, Met Office

Poster Board Number: 19
In Person

The development of climate services that informs decision making requires the active contributions of stakeholders. Stakeholder engagement and collaboration are critical components of effective co-production, and the onward communication and dissemination of climate information. This engagement has historically been conducted via in-person meetings, conferences, workshops, and interviews between climate service users and providers. The COVID-19 pandemic prevented travel, and therefore restricted in-person engagement from late 2019 into 2022. This has given rise to the new norm of remote engagement and has required the development of approaches with which to deliver engagement activities. Here, we present the most successful approaches developed through projects in China, South Asia, Southeast Asia, and Eastern Europe. This encompasses discussion on the tools used such as online whiteboards, video conferencing and digital breakout rooms; focussing on the remote engagement approaches used and the subsequent products created. Examples of products developed include top-level infographics highlighting project findings, briefing notes for policymakers, and comic book storylines sharing the process of co-creating climate services. The approaches to remote engagement include interactive elements during events, and being mindful of accessibility, cultural differences, and personal preferences. Through this work we have discovered quantifiable benefits to remote engagement such as reduced travel time and carbon footprints. However, there are also some difficult to quantify but important disadvantages, for example loss of in-person networking and chance conversations, technological limitations, and time-zone issues. We offer recommendations for future ways of remotely engaging with stakeholders, for example active participation was key to the success of many of our workshops, whilst events such as networking proved to be difficult to replicate remotely. The benefits of remote engagement mean it will continue to be part of our toolkit, and the lessons learned should be built on to ensure that engagement is as inclusive and accessible as possible.

Atmospheric Gravity Waves in Aeolus Wind Lidar Observations

Timothy Banyard, PhD Student, University of Bath

Poster Board Number: 20
In Person

As the first Doppler wind lidar in space, ESA's flagship Aeolus satellite provides us with a unique opportunity to study the propagation of gravity waves (GWs) from near the surface to the tropopause and UTLS. Existing space-based measurements of GWs in this altitude range are spatially limited and, where available, use temperature as a proxy for wind perturbations. Recent research confirms Aeolus' ability to measure GWs, and so this and future spaceborne wind lidars have the potential to transform our understanding of these critically-important dynamical processes.

Here, we present results from a special campaign onboard Aeolus, involving a change to the satellite's range-bin settings designed to allow better observations of orographic GWs over the Southern Andes during winter 2021. This campaign is still operating at the time of writing, but we expect to see GW wind structures extending down to near the wave sources, enabling detailed measurements of vertical and horizontal wavelength, pseudo-momentum flux and wave intermittency. Such parameters will feed into the next generation of numerical weather prediction and global circulation models, which will resolve waves at higher resolutions and employ more advanced parameterisation schemes.

The Potential of Urban Trees to Remove Air Pollutants, Carbon and Heat: A Large-Scale Analysis Based on Google Street View

Yanzhi Lu, PhD Student, University of Birmingham

Poster Board Number: 21
Virtual

Quantitative research on the distribution of the ecosystem services of green infrastructures (GIs) is important for urban sustainable development and exploring environmental inequality in urban areas. Street trees are an important GI in urban areas. It is easy to be planted and does not need large spaces compared with other GIs like green spaces, which has significant potential to be promoted. At present, there are many studies exploring different environmental benefits of trees and other GIs but there are few city-scale studies that focus on ecosystem services of street trees and their spatial distribution. This project will mainly focus on three major environmental benefits (air pollutant removal, carbon sequestration, and cooling). It is underpinned by large-scale tree investigations derived from Google Street View. Using data derived from this approach, pollutant removal and carbon sequestration are planned to be estimated and mapped with the help of i-Tree Eco, whereas the cooling ability of trees will be modeled and mapped by using ENVI-met or similar tools. This project will conclude by quantifying the three major ecosystem services provided by street trees in Birmingham and their spatial distribution, as well as examining any inequalities through a socio-economic lens. For urban planners and local authorities, this project can help understand the environmental benefits provided by street trees in their cities and their increasing potential from planting and the growth of street trees, as well as whether measures should be taken to reduce or prevent environmental inequalities.

A new framework for understanding multi-peril dependency: the correlation between wind and rain aggregate losses due to European windstorms.

Toby Jones, PhD Student, University of Exeter

Poster Board Number: 22
Virtual

Storm damages lead to substantial losses over the European region and so there is a need to better understand the nature of storm occurrence and intensity, both historically and in the future. The aggregate losses over a whole season, also called collective risk, can be decomposed into the aggregate risk attributed to different storm severity measures (such as maximum wind speed or rainfall). While links between wind speed and rainfall have been investigated for individual events, less is known about the correlation between aggregate losses.

A new statistical framework to quantify this relationship has been derived, which shows that increased clustering generally leads to increased correlation between aggregate losses. The framework can able to used to understand the special case of the correlation between storm counts and aggregate loss. The framework is applied to historical storm track data to estimate the correlation between the aggregate risk faced from wind and rainfall.

Should Global Climate Model Forecasts Be Used to Calculate Localised Extreme Climate Risk Indices?

Mala Virdee, PhD Student, University of Cambridge

Poster Board Number: 23
In Person

Adaptation to future impacts of climate change requires information about climate extremes over scales at which institutions have capacity to act. General circulation models (GCMs), while successfully predicting large-scale climate averages, lack forecasting ability for these tasks. A growing body of ‘climate services’ employ a range of post-processing methods aiming to extract localised statistics of future climate extremes from an ensemble of GCM forecasts to inform adaptive decision-making. Here, the sensitivity of an extreme heat risk index calculated from a Coupled Model Intercomparison Project 6 (CMIP6) GCM ensemble on the choice of post-processing methods is analysed, including choice of downscaling, bias correction and multi-model ensemble aggregation method. Furthermore, we evaluate the utility of GCMs for predicting the annual statistics of historical daily heat extremes.

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Atmospheric gravity wave observations over the Andes and Antarctic Peninsula

Phoebe Noble, PhD Student, University of Bath

Poster Board Number: 24
In Person

The mesosphere at heights of ~50-90km above the surface of the earth, has dynamics that are dominantly influenced by gravity waves. Gravity waves generated at lower heights propagate upwards into the mesosphere, growing in amplitude before breaking and depositing their momentum and changing the flow of the winds. Secondary gravity waves can also be formed where a gravity wave breaks. Despite the large influence of these waves, the physics governing their breaking and the generation of secondary gravity waves is not well understood. Gravity waves are small-scale processes and are therefore parametrised in General Circulation Models (GCMs), holding back the ability of GCMs to simulate the whole atmosphere well. A better understanding of gravity wave processes is needed to improve these parametrisations.

One of the largest sources of gravity waves is the Andes and the Antarctic Peninsula mountain ranges. Here, strong surface winds are forced upwards due to the topography, generating orographic gravity waves with large momentum fluxes that propagate upwards in the atmosphere. One of the limitations of gravity wave understanding is that different instruments are able to observe different parts of the gravity wave spectrum. The aim of this study is to combine observations of the middle atmosphere dynamics from satellites, meteor radar and ground based lidar to quantify gravity wave momentum deposition and generation.

The relationship between atmospheric heat transport and monsoonal precipitation variability

MD Rabiul Awal, PhD Student, Department of Meteorology, University of Reading

Poster Board Number: 25
In Person

During the boreal summer monsoon, the temperature gradient between land and ocean in the Northern Hemisphere (NH) facilitates large transports of moist air masses towards the land regions, where their convergence causes precipitation. This is associated with an export of net energy (internal, potential, and latent energy) away from the land. On a global scale, there is a tight relationship between the location of the intertropical convergence zone (ITCZ) and the cross-equatorial atmospheric heat transport (AHT) on seasonal, interannual and climate time scales: a more northward cross-equatorial AHT is associated with a displacement of the ITCZ (as defined by precipitation) toward the equator. We further analyse the relationships between cross-equatorial AHT and common streamfunction-based measures of the ITCZ position and width found in the literature. However, it remains unclear whether links between energy transport and the monsoonal precipitation exist at the scale of monsoon regions.

To address this question, we combine data from the European Centre for Medium-Range Weather Forecast (ECMWF) reanalysis ERA5 and Global Precipitation Climatology Project (GPCP-version 2.3) rainfall data. In the annual cycle, the cross-equatorial northward AHT transport peaks in July and the annual net northward cross-equatorial AHT is -0.34 PW (negative sign denotes southward). A regression analysis confirms that the global ITCZ shifts southward when the cross-equatorial AHT is anomalously large, although we demonstrate this mainly happens over the Pacific Ocean. Outside of the Pacific sector, the relationship between cross-equatorial AHT and JJA precipitation is complex. For the West African monsoon region, greater northward cross-equatorial AHT is related to weaker rainfall along the Gulf of Guinea coast, while there is stronger rainfall in the Atlantic Ocean ITCZ. In the Indian sector, anomalous northward AHT is associated with a weak monsoon, marked by strong decreases in precipitation on the Western coast of India and the southern flank of the Himalayas.

In future work, the CMIP6 multi-model dataset will be analysed to examine future projection of AHT and its impact on monsoonal precipitation. The characteristics of the ITCZ will be explored using the same datasets.

Influence of Dynamical Factors on Seasonal Forecast of Winter Windstorms Over Europe

Lisa Degenhardt, PhD Student, University of Birmingham

Poster Board Number: 26
In Person

Seasonal forecasts of extratropical storms are of interest to the scientific community and the general public.

In previous studies, seasonal forecasts of winter windstorm events over Europe from the Met Office GloSea5 model have shown significant skill especially over north-west Europe for windstorm frequency and were connected to large-scale patterns, i.e., the NAO. Recent investigations, which has been presented in last year's RMetS ECS conference, show links between windstorm intensities and the three dominant large-scale patterns over Europe (NAO, SCA and EA) which explain up to 80% of interannual windstorm variability.

Further investigation quantifies the role of additional, dynamical forcing factors as Eady-Growth-Rate (EGR) or 200hPa jet speed and location, which are known as influencing cyclone development. Or forcing factors that transport predictability as a proxy for Rossby wave source (RWS), and one factor related to tropical precipitation. The seasonal forecast skill of the factors themselves shows positive and significant skill in regions they are expected to be most influential or dominant, like for the RWS around its dipole over the south-west of the North Atlantic or for the EGR east of North America.

The links between these dynamical forcing factors to windstorm impact-relevant regions in the model and reanalysis data will be presented and the explanatory power of these factors for the overall model skill is discussed.

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Using Machine Learning to Predict Road Surface Conditions

Alice Lake, Foundation Scientist, Met Office

Poster Board Number: 27
In Person

The Met Office is currently developing a new surface transport forecasting system, which will be used to produce forecasts of road conditions. This new system is based on a community land surface model called the Joint UK Land Environment System (JULES). The current road surface transport forecasting system continuously produces site-specific forecasts at hourly intervals for lists of predefined locations such as roads, bridges, car parks and runways. Forecasting road surface conditions for a new location requires a long initialisation period; as we do not know the current (initial) road conditions at the new location, we must run the model for several hours before it produces accurate results. With the new surface transport forecasting system, one of the aims is the ability to forecast for new locations near-instantly, and to do this, we must have a method of generating accurate initial road surface conditions. This work describes the methods we have developed, using historical weather observation data and numerical weather prediction (NWP) data, to train machine learning models which can predict initial road surface conditions such as surface temperature, depth of water and depth of snow. These models will allow rapid forecasting at arbitrary locations, enabling future capabilities such as the ability to provide road condition forecasts to connected autonomous vehicles throughout the road network.

Atmospheric variability in the Northern Hemisphere winter in a warm past and a future climate

Arthur Oldeman, PhD Candidate, Institute for Marine and Atmospheric Research, Utrecht University, the Netherlands

Poster Board Number: 28
In Person

The Northern Annular Mode (NAM) is the leading mode of atmospheric climate variability in the middle and high Northern latitudes in the present-day climate. Its most prominent regional expression is the North Atlantic Oscillation (NAO), which has a strong influence on North Atlantic weather patterns. According to the IPCC AR6 WGI report, the current generation of climate models are skillful in simulating the spatial features and variance of the historical and present-day NAM/NAO. However, what kind of NAM or NAO patterns can we expect in a warm future climate, and why?

To answer this question, we have performed equilibrium climate simulations of a warm future as well as a warm past climate, using a global coupled climate model (CESM1.0.5). We have performed sensitivity studies using pre-industrial and mid-Pliocene boundary conditions (3Ma ago, a.o. changes in geography, vegetation, and ice sheet cover), as well as multiple levels of atmospheric pCO2. The zonal mean temperature response is similar when applying mid-Pliocene boundary conditions, or with a CO2 doubling. However, underlying processes such as meridional heat transport and cloud feedbacks show great differences, especially over the higher latitudes.

Looking at Northern hemisphere winter (DJF) sea-level pressure data, we find that the annular belts of action move poleward partially due to increase in CO2, but mainly due to the mid-Pliocene boundary conditions. Over the North Pacific Ocean, sea-level pressure variability slightly increases with CO2, but greatly reduces due to the mid-Pliocene geography. We will focus on the mechanisms that explain the differences between the past and future simulations, such as changes to the atmospheric circulation, especially regarding the residual circulation of mass.

An Approach for Targeting the Resolution of Weather and Climate Models to Where They Will be Most Effective

Alex Brown, Foundation Scientist, Met Office

Poster Board Number: 29
Virtual

Numerical models of the atmosphere for weather and climate prediction are typically composed of a dynamical core, which describes the resolved large-scale atmospheric flow, and the physical parametrisations, which represent unresolved processes and non-fluid dynamics processes that are important to the evolution of the atmosphere. Additionally, many models include a component describing the transport and reactions of various chemical species – this can be very expensive to run if a large number of species are included. These components are typically referred to as “dynamics”, “physics” and “chemistry”.

Conventionally, all these components have been on the same mesh. In this poster, I will present a new approach in which the dynamics, physics and chemistry can be run on meshes of different horizontal resolutions to another. By running different model components at different resolutions, we will be able to target computational resources where they will be most effective, allowing for improvement in model performance. Furthermore, by running some parts of the model at coarser resolutions we may in fact reduce errors by preventing the amplification of noise.

I will demonstrate this new approach through some idealised tests in LFRic, the next generation Met Office atmospheric model. Moreover, a method for mapping fields between meshes will be presented, which preserves important mathematical properties. Finally, I will also discuss ongoing challenges, such as the treatment of moisture and orography.

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Understanding the Mechanism of MSA formation in the Atmosphere

Lorrie S.D. Jacob, PhD Student, University of Cambridge

Poster Board Number: 30
In Person

Dimethyl sulfide (DMS), which originates from phytoplankton, is the major natural source of sulfur compounds in the atmosphere. The oxidation products of DMS can form aerosols which contribute to the formation of clouds, making them important for rain and the planet's radiative balance. Additionally, due to DMS naturally occurring above oceans, an oxidation product of DMS, methanesulfonic acid (MSA), has been used to determine sea ice extent in ice cores up to 300 years in the past. However, due to gaps in the oxidation pathway of DMS, there are large uncertainties in the modelling of MSA formation. The addition of aqueous phase and halogen reactions has improved the modelling of MSA concentration, but cloud formation of MSA is still lacking from atmospheric models. By using BOXMOX, a box model extension to the Kinetic PreProcessor, the effect of the additional reactions on temperature and aerosol size on MSA can be explored, and their impact on ice core modelling assessed. Understanding the reactions of DMS in the atmosphere is essential to both accurately modelling cloud formation processes and evaluating the reliability of ice core measurements.

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Moisture with Gusto: Towards Moist Shallow Water Test Cases Using the Gusto Dynamical Core Toolkit

Nell Hartney, PhD Student, University of Exeter

Poster Board Number: 31
In Person

The shallow water equations are widely used in the development of weather and climate models. As a simpler equation set than the full three-dimensional atmospheric equations, the shallow water equations allow efficient and computationally cheap numerical simulations, while retaining a reasonable degree of accuracy and most of the most pertinent dynamical features of the full equations. A suite of test cases in shallow water and spherical geometry have become the standard tests that any numerical model should pass before being applied to a full atmospheric model. The traditional shallow water equations, however, have no provision for moisture, and so model a ‘dry’ atmosphere. In reality, moisture plays a key role in the weather and climate system, and the usefulness of modelling with the shallow water equations can be significantly extended by including moisture. Here we present some shallow water test cases in a moist shallow water framework, using the Gusto dynamical core toolkit.

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An investigation of shipping sulphur emissions following changes to UN regulations using the FAAM Airborne Laboratory research aircraft

Stephanie Batten, Student, NCAS

Poster Board Number: 32
In Person

The combustion of sulphur containing fuels produces sulphur dioxide, an air pollutant that effects both air quality and climate. Sulphuric acid forms on reaction with water, the deposition of which is detrimental to marine and terrestrial ecosystems. Sulphur dioxide acts as a respiratory irritant and is a precursor of sulphate aerosol, which impacts climate through increasing planetary albedo due to its high reflectivity and effect on cloud properties. Ships traditionally use high sulphur content fuels, however recent changes to UN international ship emission regulations introduced in 2020 aimed to reduce this. The FAAM Airborne Laboratory aircraft was recently deployed to investigate the atmospheric changes resulting from these new UN regulations, by measuring ship exhaust plumes in 2019 and 2021 in the English Channel and South West Approaches. We present high resolution enhancements in sulphur dioxide and carbon dioxide from the ship plumes, and the plume identification and integration method. Derived emission ratios of SO2/CO2 and sulphur fuel content are then used to verify compliance of the identified ships sailing in the Sulphur Emission Control Areas defined by the International Maritime Organisation. We draw conclusions from airborne observations made using selected mission case studies offered by this unique sampling methodology.

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Multi-model attribution of extremes in fire weather intensity and duration using CMIP6 ensembles

Zhongwei Liu, PhD Researcher, University of Coventry

Poster Board Number: 33
In Person

In response to the occurrence of a number of large wildfire events across the world in recent years, the question of the extent to which climate change may be altering the meteorological conditions conducive to wildfires has become a hot topic of debate. Despite the development of attribution methodologies for extreme events in the last decade, attribution studies dedicated explicitly to wildfire, or otherwise extreme ‘fire weather’, are still relatively few. In turn, there is a lack of consensus on how to define fire risk in a meteorological context, posing a challenge for research in this subfield. Recent work has offered clarification on uncertainties associated with the choice of meteorological indicator to represent fire weather in the context of extreme event attribution but there are additional sensitivities that are still not fully understood.

Here, using established statistical methodologies applied to six large (>10-member) CMIP6 model ensembles, we conduct probabilistic attribution of extremes in fire weather intensity and duration across the world’s fire-prone regions. We assess trends in extremes in the Canadian Fire Weather Index (FWI) using extreme value distributions, fitted with annual maxima in 7-day averaged FWI (FWIx7day) and the number of consecutive days for which FWI is above the 90th percentile (FWIxCD90), scaled to global mean surface temperature. At each grid point, a probability ratio (PR) is calculated to express how the likelihood of extreme fire weather conditions has changed between 1880-1884 and 2010-2014 as result of global warming. Subsequently, attribution results across all six models are combined to generate a multi-model synthesis, following a model evaluation step. The results show that extremes in fire weather intensity and duration have become up to 4 times more likely since the pre-industrial era as a result of globally warming temperature in the majority of the world’s fire-prone regions.

The Influence of Mid-Level Dry Air Intrusions on Maritime Continent Rainfall

Ashar Aslam, PhD Student, University of Leeds

Poster Board Number: 34
In Person

The Maritime Continent in Southeast Asia experiences extreme rainfall all year round. Deep convection is regulated by multiple processes, from internal modes of climate variability to the diurnal cycle. Convection is also affected by synoptic-scale events – one example is that of mid-level dry air intrusions, emanating from extratropical disturbances. The presence of this dry air is a key driver in causing breaks in the monsoon across the tropics.

However, over the Maritime Continent, the link between periods of reduced rainfall and mid-level dry air intrusions has not been studied extensively. Current ability to predict and model regional meteorology is limited by our knowledge of the multi-scale variability of weather here. While communities experience serious floods and landslides as a result of extreme rainfall, breaks in the monsoon can result in crop failure and water scarcity. Therefore, bettering our understanding will help to improve forecasting potential, ensure socioeconomic security and alleviate vulnerability to disaster and loss.

Here, initial analysis on the influence of mid-level dry air intrusions on Maritime Continent rainfall is presented for 42 DJFs (December-February). Normalised mid-level specific humidity anomalies, relative to the mean seasonal cycle, are used to identify dry events southwest of Java and Sumatra. These dry events are characterised by amplification of upper-level disturbances along the subtropical jet around 5 days prior to the event. Lagrangian back trajectory analysis further highlights this extratropical source. Descending dry air is later advected by anomalous mid-level cyclonic circulation over Australia, directing the air towards the Maritime Continent. Forward trajectory analysis shows dry air continues to descend for up to 10 days after the dry event, leading to a gradual increase in the number of locations experiencing significant reductions in rainfall. Areas of interest include Java, South Sumatra, South Borneo and Sulawesi.

Future work will aim to better understand the influence of mid-level dry air on rainfall on an event-by-event basis and during other seasons. Scale interactions with other processes influencing rainfall patterns over the Maritime Continent will also be investigated.

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Tropical Cyclone Activity in Southeast Asia

Haider Ali, Research Associate, Newcastle University

Poster Board Number: 35
In Person

Tropical Cyclones (hereafter TCs) are one of the most devastating natural hazards associated with heavy rainfall, flood and storm surge leading to loss of human lives, economic losses and severe health problems. On the other hand, TCs have positive hydro-climatic effects on the ecosystem in providing a freshwater resource for agriculture and breaking heatwave and drought conditions in the summer months in the Ganga-Brahmaputra-Meghna basin, Mekong river basin and Red river basin (hereafter Living Deltas). Therefore, it is important to study the characteristics of TCs that make landfall in the Deltas. Our work focus on in-depth research on the potential influence of the TCs and TCs associated with rainfall in the Living Deltas. For this, we use TC tracks data from the PRIMAVERA-HighResMIP (total 13) multimodel ensembles based on the tracking algorithm TRACK (based on vorticity). We show that the frequency of TC making landfall in the Living Deltas is declining in the future (by 2050) while the intensity and strength (available cyclone energy; ACE) of TCs is projected to increase in the future. We plan to use precipitation data from the HighResMIP models to study characteristics like the contribution of TC associated rainfall (TCR) to the annual total precipitation in the Living Deltas etc. Our results have implications for a better understanding of the TCs activity and the mechanisms (like ocean-atmosphere interactions) that drives TCs.

Black Summer: A retrospective analysis of bushfire incidence in New South Wales, Australia.

Amy Duffy, Operational Meteorologist Technician, Met Office

Poster Board Number: 36
In Person

Australia is a drought-prone continent that has a long history of extreme bushfire events, caused in combination by natural and anthropogenic factors. Due to the dramatic events and the anomalous scale of disaster that dominated Australia during 2019/2020, the bushfire season was infamously deemed the ‘Black Summer’. This period was statistically and graphically analysed using SPSS and Excel to understand high level relationships between the contributing meteorological variables, climate drivers and resultant fire danger ratings. Focussed solely on the state of New South Wales to address a gap in the literature, results concluded that 2019 was the hottest and driest year recorded, and fire danger ratings increased significantly for 55% of the state in 2019/2020 compared to 2000-2019 averages. Furthermore, the Indian Ocean Dipole was found to have a highly significant correlation to 17 out of 20 fire areas that were identified for this study. However, when looking at historical patterns, El Nino Southern Oscillation events were found to occur more frequently during years where large bushfires occurred. This is a preliminary investigation and therefore further insights are required, including the influence of Climate Change and the consideration of other physical factors such as topography.

Hydrological Coherence of Flood-Prone Agricultural Soils

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CNRS – IRD – CONICET – UBA, Instituto Franco-Argentino

Poster Board Number: 37
Virtual

The Argentine Pampas is one of the most agriculturally-productive regions in South America, but its potential and yields are affected by episodic and non periodic flooding and waterlogging. The increase in the frequency and extent of these phenomena in recent years may be explained by a combination of anthropogenic environmental changes, such as an increase in mean annual rainfall attributable to climate change that, in combination with land use changes and agricultural management, has caused a rising mean water table. In this sense, it is essential to understand and evaluate the mechanisms that cause floods, to develop tools for their monitoring, to implement efficient agricultural practices, and to make decisions for conservation of the ecosystem. In this work, we attempt to integrate emerging satellite tools to observe water content in different compartments as well as water fluxes to analyse the mechanisms involved in producing flooding and waterlogging. For this objective, we use surface soil moisture, evapotranspiration, precipitation, and groundwater storage products, together with surface water estimates obtained from spectral information and in situ water table data, focusing on the study period 2017-2021.

Deep learning techniques for trapped lee wave detection and characterisation in NWP model output

Jonathan Coney, University of Leeds

Poster Board Number: 38
In Person

Trapped lee waves and turbulent rotor activity are a hazard for aviation, so forecasters must take into account the likelihood of lee wave activity when advising aviation personnel. The UK Met Office's operational high resolution Numerical Weather Prediction model, UKV, resolves lee wave activity. However, there is currently no automated operational way to recognise such regions directly from the high resolution UKV data, short of a forecaster looking at the data themselves. If lee waves can be identified from the UKV data, we can use this output to gain a better understanding of lee waves and their impact over the UK. For example, over which regions are lee waves likely to form? Which atmospheric conditions are the most conducive to lee wave propagation?

We present a machine learning based method for the automatic detection of lee waves from UKV model output, utilising recent developments in machine learning. A U-Net (a neural network originally used for medical scan images and commonly used for segmentation problems) was trained on a small dataset of 335 instances of UKV vertical velocity model output to segment vertical velocity data into regions of lee waves and no wave activity. This model achieved pixel accuracy greater than 90% on unseen test data, and even identified lee waves which were missed during the labelling of the training data.

It is hypothesised that during the process of recognising lee waves from the data, the model has learned wave characteristics. Transfer learning, where a pre-trained model is fine-tuned to perform a new task (here we predict wave characteristics) is being explored to judge whether machine learning can be used to provide insight to the characteristics of lee waves over the UK and beyond.