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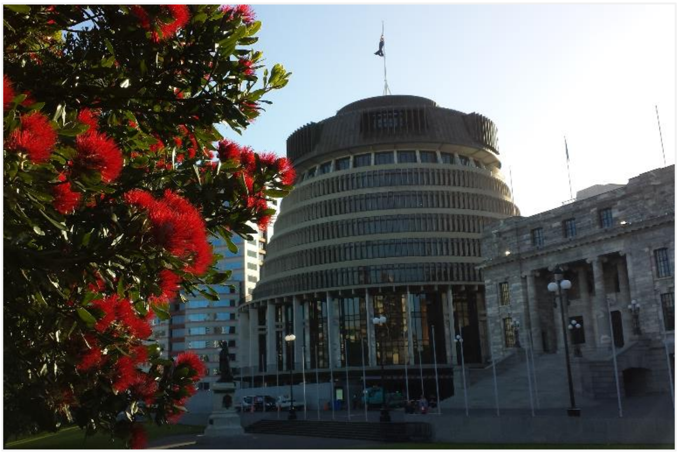
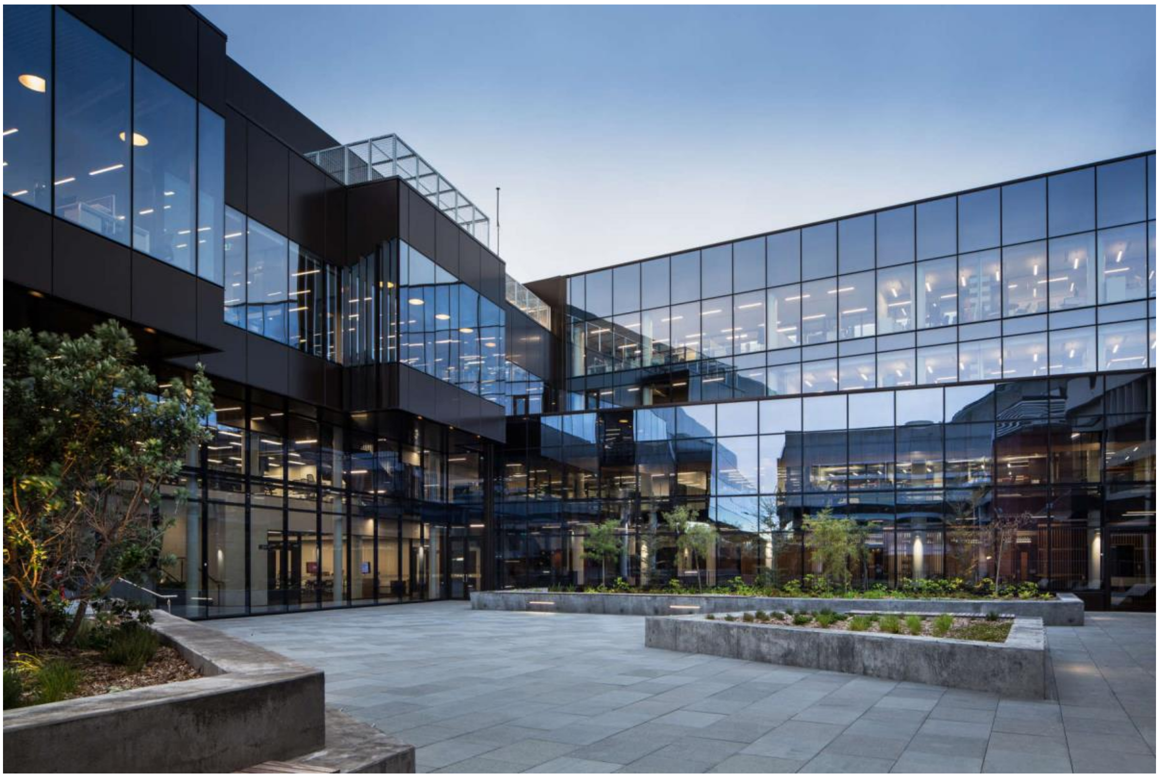
The Meteorological Society of New Zealand



Presentation Abstracts

Contents

Note: Abstracts are ordered alphabetically based on the presenting author's surname.



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Poster Presentation Abstracts

A machine learning approach to inferring the existence of extreme events in meteorological fields

Leroy Bird[1], Greg Bodeker[1] and Jordis Tradowsky[1]

[1]Bodeker Scientific

Automated detection of extreme weather events (EWEs) in meteorological fields is challenging for several reasons: (i) events of similar dynamical nature can have very different outcomes regarding extremes, (ii) some extremes result from features that are smaller than the spatial scale of the fields that are being analysed (e.g. thunderstorms), and (iii) the use of threshold exceedances does not always unambiguously identify EWEs (e.g. sustained non-extreme rainfall over a large catchment leading to flooding). Here we present a new approach to detecting EWEs whereby a machine-learning approach, in the form of a deep neural network, is trained on extreme weather databases (e.g. the NZ Historic Weather Events (HWE) catalogue) to infer the 'rules' that underlie EWEs in medium resolution meteorological fields (e.g. ERA-5; 0.25°x0.25°). Once trained, and provided with vertically resolved meteorological fields (e.g. temperature and humidity on pressure levels, amongst others) at time T and T+1, the neural network can then infer the likelihood of an EWE having occurred between T and T+1. More specifically, in this application, we use a U-Net, a form of deep convolutional neural net, which is trained on 40 years of ERA-5 data. This presentation will describe how a U-Net can be used for such an application, how the U-Net was trained, and present the capabilities of this U-Net for detecting and classifying EWEs in meteorological fields.

Picton Air Quality Study 2019-2020: current status

Tony Bromley[1] and Sally Gray[1]

[1]NIWA

In collaboration with the Marlborough District Council, NIWA have commenced a study of Picton's air quality. The study is a result of Picton residents petitioning the council to carry out measurements and also a desire by the council gather air quality data over at least a one year period to help understand the current issues; the data will also be used to help select a pertinent site in Picton to install a long-term quality air quality monitoring site.

The imprint of ENSO on total column greenhouse gas measurements

Beata Bukosa[1], Nicholas Deutscher[1], Jenny Fisher[1], David Griffith[1], Voltaire Velazco[1], Paul Wennberg[2], Geoffrey Toon[2], Dave Pollard[3], Dietrich Feist[4], Mahesh Kumar Sha[5] and Martine de Maziere[5]

[1]University of Wollongong [2]California Institute of Technology [3]NIWA [4]Max Planck Institute for Biogeochemistry [5]Royal Belgian Institute for Space Aeronomy

The El Niño–Southern Oscillation (ENSO) is a natural variability of the climate system and it is known to have significant effects on the climate of different regions. However, there are still large uncertainties about its impact on future climate and the global carbon cycle. In this study we use column average CO_2, CH_4 and CO mole fractions from the Total Carbon Column Observing Network (TCCON), combined with simulations from the GEOS-Chem model to identify the impact of different ENSO phases on the carbon cycle.

The aim of our study is to identify (1) the correlation between different ENSO phases and observed inter-annual variability (IAV) of the carbon greenhouse gases, (2) its latitudinal change and regional dependence and (3) the processes driving this correlation, in order to better understand climate variability and carbon cycle feedback. We also examine the lagged correlation between ENSO and the anomalies to identify the optimal time needed for the manifestation of the different drivers.

Our results show that 5-45% of the CO_2 variability, 6-16% of the CH_4 and 1-49% of the CO variability can be explained by ENSO; however, only after a time lag was applied to the response of all three gases. The correlation between ENSO and the CO_2, CH_4 and CO IAV was generally stronger in the tropics, and decreasing towards higher latitudes. The CO_2 IAV was mainly driven by changes in the biosphere, ocean and biomass burning, for CH_4 by wetlands, while for CO biomass burning and secondary production changes in the meteorology were the processes mostly impacted by ENSO.

On-board cloud radar project to characterize the role of marine micro-organisms emissions on the atmospheric properties of clouds

Mike Harvey[1], F. Peyrin[2], C. Le Gac[3], T. Latchimy[2], C. Hervier[2], F. Bertrand[3] , C. Caudoux[3], J.P. Vinson[3], A. Protat[4], J. Delanoe[3], F. Donnadieu[5] and K. Sellegri[6]

[1]NIWA [2]OPGC CNRS France [3]LATMOS CNRS France [4]BOM, Australia [5]LMC CNRS France [6]LaMP CNRS France

VOLDORAD-3 is a W-band (3.2 mm) radar dedicated to the study of volcanic plumes for ash load and dynamic processes assessment. Funded through the "Interdisciplinary Mission of CNRS" (DEFI-Instrumentation aux limites) and LabEx ClerVolc, this radar has been based on the cloud radar BASTA (Delanoë and al., 2016). The instrument will be deployed on R.V. Tangaroa for cloud characterization as part of the suite of aerosol and cloud sensing instrumentation planned for the Sea2Cloud voyage in March 2020 to the east of New Zealand over the Chatham Rise. The project aims to characterize the role of microorganisms on the atmospheric properties of clouds which is poorly represented in climate models in this region of the world.

Initially, with clouds, the radar was used to obtain vertical profiles of reflectivity and radial velocity to characterize the density of fine and foggy clouds as well as the associated hydrometeors. In order to reconstruct velocity fields at sea, the radar has been equipped with an active positioning system for scanning the atmosphere in azimuth and elevation. The scans allow reconstruction of both 3D fields of volcanic plumes and also clouds, fog and weak precipitation (in the form of Range Height Map, or Planar Position Map) with ability to reconstruct cloud dynamics (with a Velocity Azimuth Display). The design has undergone marinization for ship deployment and motion correction allows reconstitution of vector fields accounting for ship position and velocity with yaw, roll, pitch and heave. Each full mapping rotation will take 1.5 minutes.

Communicating Weather Uncertainty

David Johnston[1], Emma Hudson-Doyle[1] and Douglas Paton[1]

[1]Massey University

Weather models are vital for all phases of risk assessment and disaster management. However, the high number of uncertainties inherent to these models is highly challenging for crisis communication. The non-communication of these is problematic as interdependencies between them, especially for multi-model approaches and cascading hazards, can result in much larger uncertainties. The recent upsurge in research into uncertainty communication makes it important to identify key lessons, to inform future development and future research. A recently published literature review assessed methods for effective communication of model uncertainty. Themes identified include a) the need for clear uncertainty typologies, b) the need for effective engagement with users to identify which uncertainties to focus on, c) managing ensembles, confidence, bias, consensus and dissension, d) methods for communicating specific uncertainties (e.g., maps, graphs, and time), and e) the lack of evaluation of many approaches currently in use. Finally, we identify lessons and areas for future investigation, and propose a framework to manage the communication of model related uncertainty with decision-makers, by integrating typology components that help identify and prioritise uncertainties. We conclude that scientists must first understand decision-maker needs, and then concentrate efforts on evaluating and communicating the decision-relevant uncertainties. Developing a shared uncertainty management scheme with users facilitates the management of different epistemological perspectives, accommodates the different values that underpin model assumptions and the judgements they prompt, and increases uncertainty tolerance. This is vital, as uncertainties will only increase as our model (and event) complexities increase.

HIWeather Citizen Science Initiative

David Johnston[1], Julia Becker[1], Lisa McLaren[1], Emma Hudson-Doyle[1], Hugo Remaury[2], Paolo Ruti[2] and Qinghong Zhang[3]

[1]Massey University [2]WMO Geneva [3]Peking University

Citizen science is a broad term, which encompasses a variety of different types of projects where the public (citizens) work with agencies and academic researchers to undertake scientific research. Citizen science has its beginnings in the physical sciences but has expanded to other areas, including natural hazard research. The motivations, design, and outputs of citizen science projects vary widely. Some projects are highly participatory, where the citizens are involved in the project design, data collection and analysis. In others, citizens only contribute data to projects designed and coordinated solely by the science agencies. Both ends of this spectrum are effective for creating new scientific outputs and enhancing citizen involvement in science. With many new and ongoing Citizen Projects planned or underway within the High Impact Weather community this project is designed to share information and provide tools to help groups and agencies development new activities.

Severe Weather Forecasting and Disaster Risk Reduction Demonstration Project (SWFDDP) of the South Pacific

James Lunny[1]

[1]MetService

The Severe Weather Forecasting and Disaster Risk Reduction Demonstration Project (SWFDDP) is a World Meteorological Organization (WMO) initiative aiming to improve severe weather forecasting and build closer relations between meteorological offices, disaster risk reduction (DRR) services and other interested stakeholders in the South Pacific.

MetService has created a password-protected website, MetConnect Pacific; a website which makes available guidance, numerical weather prediction (NWP) products and observations central to forecasting severe weather in the region. The Project commenced in 2009 and now involves nine Pacific Island Countries (Fiji, Samoa, Vanuatu, Solomon Islands, Kiribati, Tuvalu, Tonga, Niue and the Cook Islands).

Financial assistance has been provided by the New Zealand Ministry for the Environment, the Government of Canada, and the National Weather Service of the US National Oceanic and Atmospheric Administration (NOAA), amongst others, to conduct in-country training and undertake maintenance/upgrades of the Project website. However, on-going success of moving the project from the demonstration phase into operations depends on the guarantee of long-term support.

Communicating daily CO_2 measurements made at NIWA's Clean Air Station at Baring Head.

Sylvia Nichol[1], Gordon Brailsford[1] and Stacy Mohan[1]

[1]NIWA

Carbon dioxide (CO_2) has been measured at NIWA's clean air station at Baring Head (near Wellington) since 1972. This makes it the longest running continuous CO_2 data record in the Southern Hemisphere, and the second longest globally.

Our primary Baring Head CO_2 dataset is the baseline dataset. These baseline data meet the strict criteria: (i) the CO_2 mole fraction (over a minimum length of 6 hours) has a maximum standard deviation of 0.1 ppm, (ii) the wind at the time was from the south, (iii) it is unlikely that the air has passed over the South Island. These baseline conditions, which are representative of large relatively homogeneous Southern Ocean air masses, occur on average about 7% of the time.

With increasing public interest in climate change, we were approached to see if we could make daily values of Baring Head CO_2 data publicly available in "real-time". We have developed a method to create a larger dataset than the baseline dataset, but with values reasonably close to the baseline data. We filter the hourly data based on the CO_2 mole fraction standard deviation and a wind speed criteria. These filtered hourly data are then averaged to get a daily value. We get a filtered daily value about 67% of the time. Yesterday's daily value and the value from 1-year and 10-years ago can be found on the CarbonWatchNZ website (https://niwa.co.nz/climate/research-projects/carbonwatchnz/dailyco2measurements) and on Stuff's environment page (https://www.stuff.co.nz/environment/climate-news).

Clouds over the Southern Ocean in the CMIP6 AMIP model outputs

Tristan O'Hanlon[1], Tra Dinh[1]

[1]University of Auckland

The cloud bias over the Southern Ocean has been well documented in the outputs of the CMIP5 generation of climate models when compared to satellite data. Studies have also concluded that the low clouds over the Southern Ocean in these models do not contain enough supercooled liquid water. With the new generation of CMIP6 models coming out, we analyse any improvements to the Southern Ocean cloud bias in available models and make comparisons with satellite data products. We also investigate the physical parameters that have been adjusted in each successive model generation and evaluate their combined effectiveness.

Preliminary results show that, in general, there is improvement in total cloud cover over the Southern Ocean in the CMIP6 models from their CMIP5 counterparts. Cloud liquid fraction is however overestimated at high altitude over the Southern Ocean in 4 of the 6 CMIP6 models studied. The CMIP6 CESM2-CAM6 model in particular has the highest degree of overestimation. We hypothesise that, in this model, the ice nucleation temperature threshold is set too low or that the function describing the dependence of liquid clouds on temperature does not diminish rapidly enough at low temperatures.

The amount of supercooled liquid water in most models over the Southern Ocean has been increased from CMIP5 to CMIP6. A notable finding is that the GFDL-AM4 model runs closest to all satellite products and reanalysis data studied. This was true for both its CMIP5 and CMIP6 versions.

A New Method for Assessing Floods' Economic Risk using Insurance Claim Data

Jacob Pastor[1], Ilan Noy[1], Isabelle Sin[2]

[1]Victoria University of Wellington [2]MOTU

The standard framework for undertaking a risk assessment of a natural hazard involves analysing the interaction of three components: Hazard data (in the form of maps), the elements exposed to the hazard (exposure), and measures of these elements' vulnerability (understood as the susceptibility to harm or damage). In New Zealand, national flood risk remains unquantified due to the absence of national flood inundation hazard map coverage. In this paper, we develop a methodology that aims to fill this gap by estimating instead the likelihood of a flood insurance claim for a stock of residential buildings. We estimate a non-linear limited-dependent variable model and using a set of fragility functions (also known as damage curves), we calculate the expected monetary losses under plausible flood depth scenarios. The outcome of this research could inform insurers of their potential liabilities and threats to their financial sustainability in the face of flooding events and storms

Why do people respond in different ways to weather warnings?

Sally Potter[1]

[1]GNS Science

When an agency issues a warning, people respond in a variety of ways, and often not in the way that is recommended. This presentation will outline the influences on people's behavioural response to a warning, and what a warning message can include in order to be as effective as possible.

A warning should empower people to respond to hazards in a timely and appropriate manner, in order to reduce the risk of death, injury, and damage. Research has shown that there are many influences on people's responses to warnings. This includes receiver characteristics, environmental and social cues, the content and format of the warning message, the channel that the warning uses, and characteristics of the information sources. The warning should include information on the source (agency), hazard, impacts, guidance on actions to take, the location at risk, time of issue and time to have responded by, and a link to further information. The length of a message, and even the order of these elements, can influence people's responses. The message should be specific, clear, effective, and accurate, which can be a challenge when the warning is issued by a national agency to a large geographic area. Impact-based warnings are increasingly being used world-wide to help prompt an appropriate response. This presentation will include an overview of impact-based severe weather warnings, and recent related research we are conducting in New Zealand.

Droughts and Farms' Financial Performance: A Farm-Level Study in New Zealand

Farnaz Pourzand[1], Ilan Noy[1] and Yiğit Sağlam[1]

[1] Victoria University of Wellington

We quantify the impacts of droughts in New Zealand on the profitability of dairy, sheep, and beef farms using a comprehensive administrative database of all farms in New Zealand. For dairy farms, we found that drought events have positive impacts on dairy farms' revenue and profit in the year of the drought. This effect is most likely attributable to drought-induced increases in the export price of milk solids; New Zealand is the market maker in this global market and almost all dairy products are exported. There is, however, a negative relationship between the occurrence of droughts two years earlier and farms' revenue, profit and consequently their return on capital. All of these quantified impacts, however, are not very large suggesting that at this point in time, droughts have a fairly moderate impact on New Zealand dairy and sheep-beef businesses.

Scientific Data: a journal for your scientific data?

Hinrich Schaefer[1]

[1]NIWA

Readily accessible, high quality data sets are enabling increasingly integrative research. Scientific Data is a journal in the Nature family that publishes data descriptors, thus providing access to data sets and detailed information on the methods underlying the record. This opens the data for subsequent use by the scientific community. Publication in Scientific Data provides the authors with a citable, peer-reviewed and archived record of their work, enhances visibility of the research and facilitates further use of the data by other scientists. The publication does not include a scientific interpretation of the data; examples include long-term measurements and data that underlie previously published studies.

An analysis of precipitation extremes in New Zealand using two case studies: Auckland and Whataroa

Matt Shepherd[1]

[1]University of Otago

Extreme precipitation events (EPEs) are the primary cause of flooding in New Zealand. Although rare, these events generate the highest level of critical impacts to people, the economy and our environment. The weather and climate of New Zealand is driven by a range of multi-scalar climatic drivers. The aim of this study is to analyse the climatic drivers of the 5 most extreme events at Auckland and Whataroa over the last 25 years (March 1994 – March 2019). Two sites were selected due to distinct regional climatic variations and contrasting risk factors (human, economic and environmental). Kidson weather types were evaluated as a tool for characterising the synoptic-scale drivers of EPEs. An analysis of 24-hour rainfall totals and vertically integrated water vapour flux (IVT), determined using ERA-interim reanalysis data, was undertaken to assess the role of IVT in precipitation outcomes. The role of atmospheric rivers as the transport mechanism for the poleward moisture flux was evaluated. Globally, it has been established that there is a strong relationship between atmospheric water vapour content and precipitation outcomes. The large-scale drivers, El Niño Southern Oscillation (ENSO), Southern Annular Mode (SAM) and the Inter-decadal Pacific Oscillation (IPO) are well understood as having an influence on the frequency and magnitude of EPEs. However, the individual effect of each driver presents distinct regional variation.

Drought intensification in regional climate projection over New Zealand

Abha Sood[1] and Brett Mullan[1]

[1]NIWA

Significant changes in regional drought frequency, spatial distribution and intensity are expected and linked to overall climate change over New Zealand. Droughts are complex phenomena exacerbated by increased drying of soil moisture caused by the lack of rainfall or increased evapotranspiration or both combined. Thus, quantifying drought intensity is as multifaceted as the underlying causes. Recently, NIWA applied a merged drought indicator, the New Zealand Drought Index (NZDI), based on four commonly-used drought indicators: the Standardised Precipitation Index (SPI), the Soil Moisture Deficit (SMD), the Soil Moisture Deficit Anomaly (SMDA), and the Potential Evapotranspiration Deficit (PED). Computing these indicators for the past climate and the future projections requires high quality simulated rainfall and evapotranspiration data which to date remains a challenge. We present the NZDI as well as the related indices using bias corrected climate model data for New Zealand downscaled on 5 km grid for regional analysis. Furthermore, the past observed and simulated drought conditions are presented and expected changes in frequency and intensity of droughts for several drought prone regions are discussed. This information can be used to identify hot spots and for example to anticipate the future bottlenecks in water resource availability for drinking water or irrigation. Results vary regionally to some extent, but a general finding is for droughts to intensify (larger NZDI), occur earlier in the July-June water year, and not reduce as much in winter leading to an increased likelihood of 'back-to-back' droughts.

Rainfall Changes over New Zealand

Waren Soriano[1], Tra Dinh, Gilles Bellon

[1]University of Auckland

My research focuses on extreme climate phenomena, specifically extreme (heavy) rainfall and extreme temperature events over New Zealand (NZ). The goal is to identify whether the changes in mean and extreme temperature and rainfall over NZ are consistent with global warming.

Observational data of rainfall and temperature with at-least 30 years' worth of data, collected at over 800 weather stations over NZ, are available for the period 1910-2018 and are archived at NZ's climate database (CliFlo/NIWA).

Our analysis of these observational data shows that changes in extreme temperature show a general increase throughout most of NZ, for the time periods of 1990-2018 and 1910-2018, which is consistent with the expectation of global warming.

However, changes in extreme rainfall, exhibit a larger degree of natural variability. There is generally a decreasing trend in the frequency of extreme rainfall events over NZ for the period 1990-2018 but an apparent opposite behaviour (frequency of extreme rainfall is increasing) on the West Coast of the South Island in NZ for the period 1910-2018.

In future work, we will analyse other model-simulated dataset, particularly BARRA, which is a reanalysis of our current Climate (1990-present), from the Australian Bureau of Meteorology. We will also analyse a projection of the future, which predicts Earth's climate change in a 2.0K global warming scenario (generated by the weather@home project). We will therefore identify whether the past changes of NZ rainfall seen in CliFlo, are consistent signals of a warming world.

Where is the missing CO_2? A regional multi-species approach to trace the fate of atmospheric CO_2 in Fiordland National Park, New Zealand.

Peter Sperlich[1], Tony Bromley[1], Sara Mikaloff-Fletcher[1], Gordon Brailsford[1], Rowena Moss[1], Sally Gray[1], Jocelyn Turnbull[2,3], Liz Keller[2], Steve Montzka[4] and Mao-Chang Liang[5]

[1]NIWA [2]GNS Science [3]University of Colorado [4]NOAA [5]Institute of Earth Sciences, Academia Sinica, Taipei

A robust understanding of CO_2 fluxes is vital for accurate estimates of future atmospheric carbon dioxide (CO_2) levels. However, current estimation techniques show large disagreement on terrestrial CO_2 fluxes. In particular, atmospheric data suggests a larger net CO_2 sink than previously thought for New Zealand's Fiordland region, one of our largest indigenous, temperate rainforests with an area of 12,600 km^2 and a mean annual precipitation of up to 15 m.

We will test the hypothesis that Fiordland's forest is more productive than previously thought with flask samples in air parcels before and after the air has passed over Fiordland's forests. We present our first results of a multi-tracer ensemble to determine biogeochemical trace-gas exchange on spatial scales of 50-100 km. While measurements of CO_2 mole fractions indicate CO_2 level changes directly, measurements of $\delta^{13}C$-CO_2 distinguish the forest's net CO_2 uptake due to the characteristic isotope fractionation during photosynthesis. A modified Keeling-Plot-Analysis of existing CO_2 mixing and isotope ratio data from a coastal site (Baring Head) and inland site (Lauder) suggests this approach is suitable to resolve atmospheric gradients on ~100 km scales. Moreover, we will use COS (carbonyl sulfide) as an independent tracer for photosynthetic CO_2 uptake, and $\Delta^{14}C$-CO_2 to examine ecosystem respiration and residence times. We plan to analyse $\delta^{18}O$, $\Delta^{17}O$ and clumped isotopes in CO_2 and assess the suitability of these tracers to further constrain Fiordland's CO_2 fluxes. Our measurement results will be interpreted using state-of-the-art bottom-up and top-down models.

This study will help to better understand regional CO_2 fluxes on process levels and assess the most suitable tracers for regional carbon cycle observations in comparable ecosystems.

Progress in the International CLIVAR C20C+ Detection and Attribution Project

Dáithí Stone[1,6,10], Nikolaos Christidis[2], Chris Folland[2], Sarah Perkins-Kirkpatrick[3], Judith Perlwitz[4], Hideo Shiogama[5], Michael Wehner[6], Piotr Wolski[7], Shreyas Cholia[6], Harinarayan Krishnan[6], Donald Murray[4], Oliver Angélil[3], Urs Beyerle[8], Andrew Ciavarella[2], Andrea Dittus[9], Xiao-Wei Quan[4] and Mark Tadross[7]

[1]NIWA, New Zealand [2]Met Office Hadley Centre, U.K. [3]University of New South Wales [4]NOAA [5]National Institute for Environmental Studies, Japan [6]Lawrence Berkeley National Laboratory [7]University of Cape Town [8]ETH Zürich [9]University of Melbourne [10]GCAP, U.K.

Assessment of changes in extreme weather under a changing climate is hindered by the paucity of data relative to what is required to characterise rare events. Observationally-based products are fundamentally limited by the length of record, while publicly available coupled atmosphere-ocean climate model products are both limited in sample size and have important biases arising from deficiencies in the coupling between the atmosphere and ocean. The International CLIVAR Climate of the 20th Century Plus Detection and Attribution (C20C+ D&A) Project aims to fill this gap for extreme weather over terrestrial areas by producing large ensembles of simulations with multiple atmospheric climate models, under recent observed boundary conditions and under various estimates of boundary conditions that might have been experienced in the absence of human interference.

This presentation describes the experiment design, reports on the current status of climate simulation production, and highlights some recent studies that have taken advantage of unique characteristics of the data product. As the project moves into its next phase, the authors invite discussions on future product requirements.

A convection-permitting regional climate model for the Southern Alps of New Zealand

Stephen Stuart[1], Stuart Moore[1] and Jonny Williams[1]

[1]NIWA

To adapt to a changing climate, New Zealanders require the best possible information about what changes in climate are likely to occur under different future emissions scenarios. Future projections from global climate models, such as the New Zealand Earth System Model (NZESM), can be dynamically downscaled to high spatial and temporal resolution using a limited-area regional climate model (RCM). An RCM has here been set up for the Southern Alps of New Zealand at a horizontal resolution of 1.5 km, using the HadREM3-RA11M configuration of the UK Met Office Unified Model. At this resolution, the steep, complex terrain is well represented and some atmospheric convection can be explicitly resolved; the model is therefore referred to as a Convection-Permitting regional climate model (CPM). However, this also requires huge computational resources which limit the domain extents and simulation lengths that are feasible. The Southern Alps CPM has been run for a short historical simulation and its performance is being assessed against observations, initially focusing on precipitation. Precipitation in the Southern Alps is particularly important because it affects key economic industries such as hydroelectricity generation, agriculture and tourism. In future, the CPM will be used to investigate climatic changes in spill-over of precipitation into eastern catchments, sub-daily rainfall intensities and extreme winds.

Bias correction for simulated soil moisture using MOS: linear regression vs. CDF matching

Yang Yang[1] and Trevor Carey-Smith[1]

[1]NIWA

Soil moisture is vital for vegetation growth, greatly affects bushfire, river flow, and water resource management. Soil moisture also affects local winds, convection and precipitation. Using surface meteorological observations/predictions to drive a land surface model is a common way to obtain soil moisture "data". However, due to the errors in the model physics schemes and in the soil parameters, the predicted soil moisture may have large errors and biases.

We introduced two model output statistics (MOS) approaches, linear regression MOS (MOS_SN) and cumulative distribution function (CDF) matching (MOS_CDF) to bias-correct the predicted soil moisture by the Joint UK Land Environment Simulator (JULES) at 10 New Zealand sites with soil moisture observations. MOS_SN combines four 3-month linear regression models that were created for different seasons and are used to correct the predicted soil moisture for the corresponding time periods. MOS_CDF is to match the CDF of the simulated soil moisture by JULES to the in-situ soil moisture observations.

Pecha Kucha Presentation Abstracts

A simple approach to identifying the surface meteorological fields associated with extreme weather events through thresholding against the HWE Catalogue

Greg Bodeker[1] and Jordis Tradowsky[1]

[1]Bodeker Scientific

Extreme weather events (EWEs) are at the sharp end of climate change and the purpose of the EWERAM (Extreme Weather Event Realtime Attribution Machine) project is to develop a near real-time EWE attribution capability i.e. to generate quantitative statements about the effects of climate change in the frequency and/or severity of the event. A requirement of EWERAM is algorithms to identify EWEs in surface meteorological fields.

NIWA maintains the New Zealand Historic Weather Events (HWE) catalogue that collates information from newspaper reports, journals, books and databases on historically newsworthy events. For each event, the regions affected, the hazards types associated with the event, and the resulting impacts are identified. In this work, we have used the information contained in the HWE catalogue to define thresholds (in terms of statistical likelihoods of events occurring) in surface climate variables that lead to ‘newsworthy’ events. Spatial interpolation between those thresholds creates maps such that, given any appropriate surface climate variable field (e.g. precipitation), the likelihood of that field representing an extreme/newsworthy event can be quantified. This algorithm can then be used, for example, to scan meteorological fields from the weather@home archive to identify and count extreme/newsworthy events. The presentation will give an overview of the development of the algorithm, its performance, and its utility in the EWERAM project.

1D vs. 2D Radiative-Convective Equilibrium

Nick Edkins[1] and Roger Davies[1]

[1]University of Auckland

Radiative-convective equilibrium models are useful for understanding changes in the global average vertical temperature profile. However, there are situations in which the 1D approach can be insufficient. An example is when temperature is a non-linear function of a variable and that variable takes a wide range of values over different latitudes. In this case, a 2D model is appropriate. The most commonly used relative humidity parameterisation is a linear function of pressure that approximately fits the observed global vertical profile. The 2D model reveals that this is a result of large compensating errors near the tropopause, with the predicted relative humidity being much too high at the poles and too low in the tropics. The surface temperature is very sensitive to relative humidity near the tropical tropopause. Similarly, surface temperature is a non-linear function of lapse rate. The lapse rate varies widely with latitude, even changing signs at the poles, and the lapse rate at a given latitude determines the strength of the greenhouse effect. We compare 1D and 2D radiative-convective equilibrium results to demonstrate the errors that the 1D approach can produce.

Monitoring Shipping Emissions using DOAS

Jamie Halla[1]

[1]DTA

Multiple-AXis Differential Optical Spectroscopy (MAX-DOAS) measurements were taken recently from DTA ground stations in Whangaparaoa and Devonport. The goal was to examine the pollutant emissions from ships in the vicinity, namely large container ships as well as the occasional cruise liner. MAX-DOAS measurements have the potential to remotely sense several trace gases simultaneously such as NO_2, HCHO and SO_2. In particular, if signatures of NO_2 and SO_2 are detected, the NO_2/SO_2 ratio can provide an indication of the type of fuels being used by individual ships. Finally, when coupling MAX-DOAS measurements of the O_2-O_2 collisional dimer (O_4) with radiative transfer modelling, aerosol information, in particular aerosol optical depth (AOD) and aerosol layer height may be found. This talk will discuss preliminary results from these measurements.

Data Needs for Impact-based Forecasting and Warning Systems in New Zealand: Exploring the production, sharing and management of impact data from severe weather events

Sara Harrison[1], Sally Potter[1], Raj Prasanna[2], Emma Hudson-Doyle[2] and David Johnston[2]

[1]GNS Science [2]Massey University

There is a growing need for the standardised collection and storage of impact data. The importance of systematically recording, sharing, and publicly accounting for disaster losses and impacts is threaded throughout the Sendai Framework for Disaster Risk Reduction from 2015-2030. Moreover, the World Meteorological Organization (WMO) has pushed for the implementation of impact-based forecasting and warning systems, furthering the need to systematically collect, store, and share impact data. However, methods for collecting the required impact data differ by country and region, making standardised collection and sharing difficult.

This exploratory PhD research, supported by the HIWeather Project within the WMO's World Weather Research Programme and funded by the RNC2 Weather & Wildfire Theme, aims to map out existing and potential impact data sources from severe weather events in New Zealand. The expected outcome of this research is a framework outlining the process of getting impact data from the source (e.g. the public) to the end-users (e.g. Civil Defence groups, the MetService, impact/risk modellers, etc.) for impact-based forecasts and warnings. This will involve identifying challenges and opportunities in doing so. The objective is to help stakeholders understand what is available to them, and how they can access it and contribute to it. This will contribute to the implementation of impact-based forecasts and warnings in New Zealand while also supporting efforts towards meeting the requirements of the Sendai Framework to build a national impacts and losses database.

Spatial patterns of changes in Antarctic sea ice extent

Hamish Jelleyman[1], Tra Dinh, Evan Weller and Dion O'Neale

[1]University of Auckland

Understanding both the temporal and spatial changes of sea ice in Antarctica is essential for better understanding our changing global climate. Previous research shows that sea ice has a significant influence on many atmospheric and oceanic systems. For example, changes in sea ice can affect the albedo of our planet, the amount of CO_2 in our atmosphere, the salinity of the ocean and the heat exchange between the atmosphere and the ocean. Using sea ice concentration data from Nimbus-7 SMMR and DMSP SSM/I-SSMIS Passive Microwave Data, Version 1, provided by NSIDC, we aim to explore the changes of sea ice extent in Antarctica from 1978 to 2018. Using linear regression methods, we identify regions of sea ice in Antarctica where there are statistically significant trends in the temporal behaviour of the sea ice. Doing this helps us to understand spatial patterns in the behaviour of sea ice around the continent. Overall, the temporal and spatial patterns combined have the potential to highlight important processes that drive fluctuations (i.e., melting, freezing or extent) of sea ice in this region and subsequent impacts on our global climate.

Success of Montreal Protocol demonstrated by comparing UV measurements with "World Avoided" from chemistry-climate models

Ben Liley[1], Richard McKenzie[2], Olaf Morgenstern[1], Germar Bernhard[3] and Alkis Bais[4]

[1]NIWA [2]NIWA emeritus [3]Biophysical Instruments [4]University of Thessaloniki

The Montreal Protocol on protection of the ozone layer has been hailed as the most successful environmental treaty ever. Yet, although our main concern about ozone is in protecting us from harmful solar UV radiation, no studies prior to our recently published analysis have demonstrated its effectiveness in that regard. We use long-term UV Index (UVI) data derived from high-quality UV spectroradiometer measurements to demonstrate its success in curbing increases in UV radiation. Without this landmark agreement signed in 1987, UVI values would have increased at mid-latitude locations by approximately 20% between the early 1990s and today and would approximately treble by 2065. In contrast, an analysis of UVI data from multiple clean-air sites that are archived in the NDACC database show that maximum daily UVI values have remained essentially constant over the last ~20 years in all seasons. Reconstructions of the UVI from total ozone data show evidence of increasing UVI levels in the 1980s, but unfortunately, there are no high-quality UV measurements available prior to the early 1990s to confirm these increases with direct observations.

The provision of Maritime Safety Information for New Zealand waters

Elke Louw[1]

[1]MetService

How do mariners access our weather information and what goes on behind the scenes to produce a marine forecast? The Worldwide Met-Ocean Information and Warning Service (WWMIWS) provides Maritime Safety Information (MSI) to mariners in the form of marine forecast and warning products. The MSI is distributed via various means; HF Radio, websites and satellites to name a few. The world's oceans are divided into 21 defined areas, called METAREAs. New Zealand falls under METAREA XIV, and each METAREA has a Coordinator who is assigned to coordinate the provision of the marine services for each area. This presentation will cover how the need for MSI came about, the governing agencies, examples of warnings and forecasts within METAREA XIV including New Zealand coastal waters, as well as the challenges that we face.

World Meteorological Organization (WMO) Reform

James Lunny[1]

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The World Meteorological Organization (WMO) is a specialised agency of the United Nations. It is dedicated to international cooperation and coordination on the state and behaviour of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate it produces, and the resulting distribution of water resources. The World Meteorological Congress (the supreme body of WMO) meets every four years and, in 2015, decided to review WMO governance. The aim was to reform WMO so that it remains fit-for-purpose and becomes more agile and cost-effective. In June 2019, Congress decided to begin this reform by disestablishing the current eight technical commissions of WMO and establishing:

- two technical commissions (on Infrastructure and on Services);
- the Joint WMO-International Oceanographic Commission (IOC) Collaborative Board;
- the Research Board on Weather, Climate, Water and the Environment; and
- the Scientific Advisory Panel.

The first stage of the reform will be important to many experts within New Zealand, including those from public, private and academic sectors, as they engage globally with the scientific community through WMO. Over the next two years it will be important that New Zealand be involved in the transition to the new structure, in order to make it a success.

The Ashburton Tornado of 18 November 2018

Tui McInnes[1]

[1]MetService

On 18 November 2018, atmospheric conditions were suitable for supporting vigorous convection over the east of South Island. A series of severe thunderstorms subsequently developed during the afternoon on the Canterbury Plains. Synoptic conditions encouraged strong instability and provided adequate convective initiation in the area. These conditions are examined, followed by a detailed investigation of the severe event that occurred at Ashburton. High resolution radar imagery and cross-sections provide an objective analysis of the primary mesoscale circulation and thunderstorm. The radar analysis uncovers a number of interesting features, and evidence overwhelmingly indicates supercellular development and therefore a tornado. The case is not entirely conclusive, given a number of factors, but nonetheless presents an insightful case of severe convection in New Zealand.

Towards a convection-permitting ensemble forecasting system for New Zealand

Stuart Moore[1], Trevor Carey-Smith[1], Chris Brandolino[1], Ben Noll[1], Nava Fedaeff[1], Seth Carrier[1], Maria Augutis[1] and Douglas Boyd[2]

[1]NIWA [2]Met Office

Numerical Weather Prediction (NWP) has traditionally seen improvements in forecast skill come about from increases to the horizontal resolution of the models used. Today, operational regional or limited area forecast models are typically running with horizontal resolutions approaching the order of 1km, at what is termed the "convective scale", where the models will usually forgo use of a convection parameterisation scheme used in coarser resolution model configurations and attempt to resolve convective processes explicitly. An alternative approach is to embrace a probabilistic approach to NWP forecasting and run an ensemble of coarser resolution models, substituting high resolution for statistical spread and looking to capture more information about likely forecast scenarios.

Since early 2019, NIWA has been running, once a day, an 18 member ensemble forecast system with a horizontal resolution of ~4.5km over the New Zealand and Tasman Sea region. Each member is initialised from a member of the UK Met Office-run MOGREPS-G ensemble forecast system and forecasts out to 5 days ahead. In this presentation, we describe the system and some of the early product development work, give an overview of how our forecasters are harnessing this new tool and outline what lies ahead in its development path.

Travels with an EM27, total column GHG measurements below 45 degrees south.

Dave Pollard[1], Dan Smale[1], John Robinson[1], Frank Hase[2], Thomas Blumenstock[2], Darko Dubravika[2], David Griffith[3] and Nicholas Deutscher[3]

[1]NIWA [2]KIT [3]UoW

Measurements of greenhouses gases (CO_2, CH_4 and CO) are important as inputs for, and verification of climate models and for satellite validation. The Total Column Carbon observing Network (TCCON) provides high precision, column averaged GHG measurements from near-infrared solar absorption spectra from a network of around twenty stations globally. The TCCON instrumentation is expensive, large and requires significant infrastructure. The Bruker EM27 instrument provides a portable low-cost complementary measurement and is the basis of the Collaborative Carbon Column Observing Network (COCCON).

In this presentation we describe the adventures of an EM27 that has been loaned to NIWA by the Karlsruhe Institute of Technology, which have included side-by-side inter-comparisons with the TCCON site at Lauder, a side-by-side inter-comparison with another EM27 from the University of Wollongong, a deployment to Fiordland and installation at Arrival Heights, Antarctica for the 2019/20 summer season to provide validation data for ESA's Sentinel 5-precursor satellite. We report provisional results of the side-by-side inter-comparisons and the latitudinal gradients of CO_2, CH_4 and CO between 45 and 78 degrees south, and provide a summary of future scientific endeavours with the EM27.

Radiocarbon clues on fossil methane emissions

Hinrich Schaefer[1], Tony Bromley[1] and Keith Lassey[2]

[1]NIWA [2]Lassey Research

The amount of methane in the atmosphere is currently increasing, contributing to climate change. It is important to identify the cause of the increase, which could be rising emissions from agriculture or fossil fuel use. The radiocarbon content of atmospheric methane ($^{14}CH_4$) will decline with rising fossil fuel methane, but the interpretation of trends is complicated by $^{14}CH_4$ production in nuclear power generation. Here we examine 30 years of $^{14}CH_4$ data measured in New Zealand using a technique that simultaneously resolves trends in the fossil fuel fraction of the methane budget and nuclear $^{14}CH_4$.

Diagnostic and Predictability Assessments of Absolutely Unstable Heavy Rainfall Events

Mark Schwarz[1]

[1]MetService

Moist absolute instability is an atmospheric condition in which a saturated layer of air has a lapse rate that is more unstable than the saturated adiabatic lapse rate. Such layers can form when an initially unsaturated, conditionally unstable layer is lifted bodily. In this paper, cases of heavy rainfall and associated severe flooding in the Greater Wellington Region are examined as possible examples of Moist Absolutely Unstable Layer (MAUL)-driven convection. The synoptic and mesoscale environments of each case are investigated, and assessments made of the likely predictability of the events on corresponding spatial and temporal scales. These predictability considerations, along with typical rainfall characteristics, are then used to suggest possible forecasting and warning strategies for similar events.

Advanced satellite products at MetService: GEOCAT and VOLCAT

Rosa Trancoso[1], Wim Vandijk and Cory Davis

[1]MetService

Real-time satellite imagery can greatly improve weather forecasts by providing real and detailed guidance in the short-range and at scales typically not resolved by mesoscale models. MetService has developed an automated system to generate real-time derived Level-2 products that can be used as visual guidance by forecasters as well as being ingested in numerical weather prediction models. For example, the products help improve volcanic ash dispersion forecasts, which fall under MetService's responsibilities as the Volcanic Ash Advisory Centre for the South Pacific (VAAC Wellington).

The system is based on the open-source GEOstationary Cloud Algorithm Testbed (GEOCAT). This platform offers a collection of state-of-the-art algorithms to produce higher-level geophysical products (including cloud and low cloud/fog products) from sensors such as Himawari-8's AHI and GOES-W ABI, covering the whole of VAAC Wellington. GEOCAT has an associated VOLolcanic Cloud Analysis Toolkit (VOLCAT) that generates alerts when volcanic unrest or an eruption is detected by the algorithms, and automatically tracks and characterizes volcanic clouds. At MetService, this information is ingested automatically and triggers volcanic ash dispersion models, based on HYSPLIT model, that are initialized with the characteristics detected by VOLCAT as well as historical volcanic activity. This combination of systems provides the best possible guidance to the VAAC forecasters, particularly for aviation and emergency procedures.

Improving the simulation of clouds and related radiation biases in a global climate model

Vidya Varma[1], Olaf Morgenstern[1], Jonny Willliams[1], Kalli Furtado[2] and Paul Field[2]

[1]NIWA [2]UK Met Office

Most of the present-day global climate models is are identified by insufficient reflection of short-wave radiation over the Southern Ocean due to a misrepresentation of clouds. In this study, we present the results from a recent version of the Met Office's Unified Model (the base model for the atmospheric component of the New Zealand Earth System Model). By modifying the cloud micro-physics parametrisation and choosing a more realistic value for the shape parameter of atmospheric ice-crystals, in agreement with theory and observations, we suggest that the simulation of short-wave radiation is significantly improved. In the model, for calculating the growth rate of ice crystals through deposition, the default assumption is that all ice particles are spherical in shape. We modify this assumption to effectively allow for oblique shapes or aggregates of ice crystals. We also examine the impact of changing other temperature thresholds in the cloud micro-physics scheme for the onset of heterogeneous ice production. As a result, we achieved a reduction in the annual-mean short-wave cloud radiative effect over the Southern Ocean by up to 4 W/m^2, and much larger seasonal reductions as well. The base model had an excess of atmospheric ice. Thus, by slowing the growth of the ice phase, the model simulates substantially more super-cooled-liquid cloud. We hypothesize that such abundant super-cooled-liquid cloud is the result of a paucity of ice nucleating particles in this part of the atmosphere.

Rolls, Streets, Waves and More… 2-D Structures in the Planetary Boundary Layer

Chris Webster[1]

[1]MetService

2-D cloud structures are a common feature in the planetary boundary layer during moderately windy conditions. Sometimes dubbed "cloud streets", there have been many observational and modelling studies of these linear forms during the 1980s and 1990s, all overseas. But they are also common over New Zealand in conditionally unstable environments, in all seasons, wherever there are moderate onshore winds over flat or undulating terrain. Narrow rolls are typically one thermal wide, a thermal being a 3-D convective plume, usually of the order of hundreds of metres across, rising from the Earth's surface to a capping inversion. Fair-weather cumulus clouds result from condensation within individual thermals. The rolls and embedded thermals that generate the cumulus can lead to a "string of pearls" appearance. 2-D structures contribute significantly to the vertical fluxes of momentum, heat, and humidity in the planetary boundary layer.

Extreme climate modelling; delivering climate projections out to 2100

Jonny Williams[1], Erik Behrens[1] and Olaf Morgenstern[1]

[1]NIWA

With the availability of our new supercomputer, I will present results from our new climate model. The model is complex to say the least, having a stratosphere-resolving atmosphere, global ocean, dynamic sea ice, atmospheric chemistry and ocean biology. This model is closely related to the one developed in the UK - the UKESM - but with the addition of a nested high resolution ocean model surrounding the New Zealand region. I will present results for the historical period 1950-2015 and show how they compare to the parent model and also observations and reanalyses. I will also discuss our scenario simulations which will show a range of possible future worlds, informed by different future greenhouse gas emissions scenarios. I will also detail how the results of this global model are feeding in to local meteorological and hydrological models for New Zealand.

Oral Presentation Abstracts

Understanding the atmospheric controls on the recent and unprecedented retreat of glaciers in the Southern Alps

Nariefa Abrahim[1], Nicolas Cullen[1], Jonathan Conway[2] and Ralf Ohlemuller[1]

[1]University of Otago [2]NIWA

Marine heatwaves in the south-west Pacific region are strongly impacting local and regional climates in New Zealand. Over the past two years, New Zealand has recorded the most intense heatwaves as well as the greatest loss of glacial ice observed in the Southern Alps. Understanding the behaviour of glaciers in the Southern Alps is crucial to improving our knowledge of the influence of climatic variability in the Southern Hemisphere. A recent geodetic study has indicated that Brewster Glacier has experienced a significant negative shift in mass balance since 2006. Interestingly, the change in the mass balance gradient has been found to be most significant at the highest elevations on Brewster Glacier as opposed to the lower ablation area. The full causality chain of the controlling physical processes and environmental significance of this drastic change in glacier mass balance is unresolved. The aim of this research therefore is to determine the multi-scale atmospheric processes governing the significant mass loss on Brewster Glacier over the period 2006-2018. To achieve this aim, a distributed mass balance model will be used to understand the local atmospheric processes governing glacier mass balance, while time slice simulations using a mesoscale atmospheric model will provide insights into how large-scale atmospheric circulation is impacting high-mountain climate. A key focus of this work will be to better understand the impacts of recent ocean and atmospheric warming on accumulation processes at high elevations, which until this time has not been examined in as much detail as the atmospheric controls on ablation in summer.

Meridional Oceanic Heat Transport Influences Marine Heatwaves in the Tasman Sea on Interannual to Decadal Timescales

Erik Behrens[1], Denise Fernandez[1] and Phil Sutton[1]

[1]NIWA

Marine heatwaves (MHWs) pose an increasing threat to the ocean's wellbeing as global warming progresses. Forecasting MHWs is challenging due to the various factors that affect their occurrence, including large variability in the atmospheric state. In this study we demonstrate a causal link between ocean heat content and the area and intensity of MHWs in the Tasman Sea on interannual to decadal time scales. Ocean heat content variations are more persistent than 'weather-related' atmospheric drivers (e.g., blocking high pressure systems) for MHWs and thus provide better predictive skill on timescales longer than weeks. Using data from a forced global ocean sea-ice model, we show that ocean heat content fluctuations in the Tasman Sea are predominantly controlled by oceanic meridional heat transport from the subtropics, which in turn is mainly characterized by the interplay of the East Australian Current and the Tasman Front. Variability in these currents is impacted by wind stress curl anomalies north of this region, following Sverdrup's and Godfrey's 'Island Rule' theories. Data from models and observations show that periods with positive upper (2000 m) ocean heat content anomalies or rapid increases in ocean heat content are characterized by more frequent, larger, longer and more intense MHWs on interannual to decadal timescales. Thus, the oceanic heat content in the Tasman Sea acts as a preconditioner and has a prolonged predictive skill compared to the atmospheric state (e.g., surface heat fluxes), making ocean heat content a useful indicator and measure of the likelihood of MHWs.

The anatomy of past and future extreme storm-tide events for Aotearoa-NZ coastal areas

Rob Bell[1] and Scott Stephens[1]

[1]NIWA

Coastal flooding is emerging as a major hazard for low-lying areas of Aotearoa-NZ on the back of rising sea level and will become a more extensive risk than coastal erosion. Thirty coastal sea-level records of varying lengths have been analysed, quantifying extreme sea level and skew-surge frequency and magnitude. We identified the relative magnitudes of sea-level components contributing to extreme sea level events recorded in NZ and clustered these events with typical weather types. Most extreme sea levels historically were driven by moderate skew-surges combined with high perigean-spring tides. The seasonal distribution of both extreme sea-level and skew-surge events closely follows the seasonal and associated inter-annual pattern of mean sea-level anomaly (MSLA)—MSLA was positive in 92% of all extreme sea-level events. There was no discernible correlation of extreme storm-tide events with climate indices (e.g. SOI, AAO, zonal and meridional pressure gradients), which confirms the dominant role perigean-spring tides play in setting up extreme events. However, the important secondary influence of low-amplitude (−0.06 to 0.28 m) MSLA on the timing of extreme events shows that mean sea-level rise (SLR) of similarly small heights will drive rapid increases in the frequency of presently rare events. For example, the historic extreme centennial event will become a frequent once a year event in NZ with SLR of only 30-40 cm (by ~2040-2060). These findings have important implications for setting adaptation thresholds and the urgency to develop dynamic adaptive plans and in the meantime cope with more frequent “sunny-day”, nuisance and extreme flooding.

Climatology of vapour transport associated with New Zealand droughts

Morgan Bennet[1] and Daniel Kingston[1]

[1]University of Otago

Droughts are widely recognised as one of the most costly environmental hazards, impacting an area socially, economically and ecologically (Mishra and Singh, 2010). The exact definition of a drought remains an area of research which is as yet unanswered, although in general terms it can be thought of as the absence of moisture. Moisture transport has been shown to follow seasonal patterns over numerous study areas, with directional changes linked to the dominant synoptic pattern during the seasonal cycle (Liu et al., 2017). Throughout New Zealand, the wider synoptic conditions associated with drought development are well understood (Salinger and Porteous, 2014). However, the climatology of moisture transport remains an area which is under-researched. The aim of the study is to investigate the transport of vapour across the wider New Zealand region, with a particular focus on investigating this movement during drought events across the country.

The standardised index of precipitation and evapotranspiration (SPEI) over New Zealand for the period July 1979 to December 2010 was used to examine drought events across the country. A three-month rolling time step was chosen. Vapour transport data were obtained from ERA Interim for the period July 1979 to December 2010 (IVT).
Initial results illustrate unique characteristics of IVT for drought events across New Zealand, with composite analysis revealing a weakening of the westerly movement of moisture across New Zealand associated with drought across New Zealand. Decreases in moisture fluxes were greatest over the west coast and north of the North Island.

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The dynamics of marginal snow cover: Observations and implications for water resource management in a warmer world

Shane Bilish[1], Nik Callow[2], Gavan McGrath[3] and Hamish McGowan[4]

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Seasonal snowpacks in marginal snow environments are typically warm and nearly isothermal. They exhibit high inter- and intra-annual variability yet make an important contribution to regional water supplies. Fully characterising snow cover requires a consideration of both its distribution across the catchment and its dynamics - that is, the changes to snow water equivalent through the season, and how these vary spatially. Regular surveys of a small (1.4 km^2) subalpine catchment in the Australian Alps were made over two snow seasons, showing that snowpack variability was driven by upwind terrain, vegetation, solar radiation, slope and elevation. A new conceptual model for marginal snowpack dynamics is presented, consisting of a dynamically unstable accumulation state and a stable ablation state, and it is shown that ablation processes have an effect on the distribution of the snowpack even early in the season. Methods used to quantify snowpack water storage and forecast snowmelt are frequently derived from research into colder and more persistent snow, and the inherent assumptions are not always consistent with snowpack behaviour in warmer climates. In particular, the features of snowpack dynamics described in this presentation mean that increased care is required when applying point measurements of the snowpack at the catchment scale. These findings suggest that different methods are needed to study and manage water resources in marginal snow regions, and these considerations will extend to regions not previously considered marginal as global warming continues.

What the Historians Say

Erick Brenstrum[1]

[1]Retired, ex MetService

In his landmark book, Climate History and the Modern World, published in1982 the climatologist H.H. Lamb outlined the effects of climate change on the last 20,000 years of human history. Since then more abundant proxy-climate data and historical evidence has emerged and a new generation of historians are ascribing climate change a major role in shaping human history. This talk will discuss Geoffrey Parker's Global Crisis: War, Climate Change & Catastrophe in the Seventeenth Century; Kyle Harper's The Fate of Rome: Climate, Disease & the End of an Empire; Sam White's A Cold Welcome: The Little Ice Age and Europe's Encounter with North America among others.

What's happening in the New Zealand atmosphere?

Tony Bromley[1] and Sally Gray[1]

[1]NIWA

In New Zealand, the Climate Change Response (zero carbon) Amendment Bill includes an aim to set new greenhouse gas emission reduction targets to:

- reduce all greenhouse gases except biogenic methane to net zero by 2050.
- reduce biogenic methane within the range of 24–47% below 2017 levels by 2050, and a target of 10% below 2017 levels by 2030.

This bill is to be introduced into parliament during the latter part of 2019. So how have the main greenhouse gas components been tracking over the years? This presentation shows the changes in these components as measured at the NIWA Clean Air Station at Baring Head near the entrance to Wellington Harbour.

Record warming at the South Pole consistent with natural variability

Kyle Clem[1], James Renwick[1], Ryan Fogt[2], Benjamin Lintner[3], John Turner[4] and Gareth Marshall[4]

[1]Victoria University of Wellington [2]Ohio University [3]Rutgers University [4]British Antarctic Survey

In 2018, the South Pole recorded its warmest year on record. A closer look reveals that the South Pole has been warming at an increasing rate since the 1980s, and in the most recent 30-year period of 1989-2018 it experienced its strongest annual-mean warming trend on record at a rate of +0.6 C/decade, more than three times the global average rate. In this talk I will describe the local and large-scale mechanisms that caused the recent warming, and explore how "unprecedented" this warming is using CMIP5 models run with and without anthropogenic radiative forcing. Based on these findings, I will discuss possible future trajectories of South Pole temperatures in the coming decades with continued increases in greenhouse gas concentrations, recovery of the Antarctic ozone hole, and likely shift of the Interdecadal Pacific Oscillation to its positive phase.

Atmospheric radiocarbon Southern Hemisphere latitudinal gradient over recent decades

Rachel Corran[1,2], Jocelyn Turnbull[1,3] and Sara Mikaloff-Fletcher[4]

[1]GNS Science [2]Victoria University of Wellington [3]CIRES, University of Colorado [4]NIWA

The net carbon uptake of the Southern Ocean is characterised by the combination of outgassing of CO_2 from carbon-rich deep waters and sequestration of anthropogenic carbon into surface waters. Atmospheric radiocarbon dioxide ($^{14}CO_2$) in the Southern Hemisphere is sensitive to release of CO_2 from the upwelling of 'old' ^{14}C-free carbon-rich deep waters at high southern latitudes, but is insensitive to CO_2 uptake into the ocean. Thus $^{14}CO_2$ can be used as a tracer of the upwelling observed to isolate the outgassing carbon component.

The Southern Ocean region is under-sampled for $^{14}CO_2$ measurements, with sparse long-term atmospheric sampling sites and a few shipboard flask measurements. We therefore exploit tree rings, which faithfully record the ^{14}C content of atmospheric CO_2 with annual resolution, to reconstruct $^{14}CO_2$ back in time. Our tree ring derived $^{14}CO_2$ results have comparable measurement accuracy to atmospheric $^{14}CO_2$ measurements.

We present new ^{14}C measurements of tree rings from eight coastal sites in New Zealand and Chile, spanning a latitudinal range of 41°S to 55°S. These allow us to reconstruct the atmospheric $^{14}CO_2$ Southern Hemisphere latitudinal gradient over recent decades. We consider our results in context of other regional ^{14}C data and atmospheric transport model output, to investigate the temporal and spatial variability of atmospheric $^{14}CO_2$ data in the Southern Ocean region.

The 2019 Christchurch MAPM (Mapping Air Pollution eMissions) air quality monitoring field campaign

Ethan Dale[1], Stefanie Kremser[1], Jordis Tradowsky[1], Greg Bodeker[1], Adrian McDonald[2], Shaun Lowis[1], Nariefa Abrahim[3], Jan-Niklas Schmidt[4] and Jonathan Barte[5]

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MAPM (Mapping Air Pollution eMissions) is a project funded through the MBIE Smart Ideas programme. Its goal is to develop a new way of deriving maps of particulate matter (PM) sources in cities. The project runs from 1 October 2018 to 30 September 2020 after which we intend to deploy the method as a service to officials in highly polluted offshore cities.
From June to September 2019, a field campaign was conducted in Christchurch to collect a wide variety of data to test and validate the MAPM method. Fifty ODIN (Outdoor Dust Information Node) instruments and 17 Dust-Mote sensors were distributed around the city, measuring PM levels in the air every minute. Temperature, pressure, humidity, wind speed and direction were also measured at several automatic weather stations. Vertical profiles of meteorological variables were measured during two intense radiosonde campaigns, as well as using micropulse lidar and ceilometer instruments operated at the University of Canterbury. The purpose of the campaign was to collect the air quality and meteorological data required to demonstrate the utility of the MAPM inverse model in inferring emissions maps from concentration fields and prescribed meteorology. A key question that will be addressed using these campaign data is: how does the spatial and temporal resolution of the measurements affect the uncertainties in the retrieved PM emissions maps? This presentation will give an overview of the campaign, summarize the data collected, and present some preliminary results from the analysis of the data.

The tropopause perspective in climate modelling: why cloud heights really matter

Roger Davies[1] and Nick Edkins

[1]University of Auckland

The MISR instrument on the Terra satellite has been measuring cloud heights since early 2000, creating a unique climate data record of over 19 years duration that is useful for a variety of regional climate studies. But how are cloud heights relevant to studies of global climate or climate change? We answer this question with results from a state-of-the-art radiative-convective equilibrium model developed in our Climate Laboratory at the University of Auckland. This model agrees with simple cloud cases in the global simulations by others but can also handle cases with complex vertical distributions.

In explaining these more complex results we have been struck by the importance of the vertical distribution of longwave opacity. This importance is missing from the traditional explanation of the greenhouse effect that has a surface perspective and focuses on total longwave opacity (which is not dependent on cloud height). If we invert the conventional approach to adopt a tropospheric perspective, the importance of vertical distribution becomes more apparent, and this can even be illustrated using a much simpler model that has a strong pedagogical value. Both perspectives are similar when dealing with a well-mixed gas such as carbon dioxide, but for clouds, water vapour, and perhaps methane, the tropopause perspective is far more enlightening. We find for example that changes in lower tropospheric opacity can be inconsequential compared to changes in the upper troposphere.

Assessing the Impact of Climate Change on Flood Risk

Sam Dean[1], Cyprien Bosserelli[1], Trevor Carey-Smith[1] and Emily Lane[1]

[1]NIWA

Flooding is New Zealand's most consistently damaging natural hazard and given expected changes in rainfall with climate change is likely to increase into the future. Here we present our work on developing new methodologies for assessing flood risk by combining a design storm approach to rainfall changes with a rapid GPGPU-based open source inundation model. This has become feasible with technological change in computing performance. This method compares with previous approaches outlined in MfE guidance for local government and engineers based entirely on scaling the amount of rainfall that fell in an historically observed event by a climate change factor of up to 8% per degree of warming. Recent work for the High Intensity Rainfall System has suggested that such factors should be dependent on both the return period and the duration of the rainfall. In particular, short duration high return period events are expected to increase by more than the 8% limit. Initial results are presented for the Waikanae catchment. To scale this work up to a nationally consistent risk assessment for all catchments in the country we are preparing an Endeavour Programme proposal for submission in March in partnership with local and central government agencies. The research plan will be outlined and opportunities to participate highlighted.

On the Causal Relationship between the Moist Diabatic Circulation and Cloud Rapid Adjustment to Increasing CO2

Tra Dinh[1] and Stephan Fueglistaler[2]

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General Circulation Models (GCMs) predict that clouds in the atmosphere rapidly adjust to the radiative perturbation of an abrupt increase in atmospheric CO_2 concentration on a short time scale of about 10 days. This rapid adjustment consists of an increase of clouds in the boundary layer and a decrease of clouds in the free troposphere. Our focus is the mechanism for the decrease of clouds in the free troposphere, which is the dominating component of cloud rapid adjustment in most GCMs. We propose that the decrease in clouds in the free troposphere arises from the causal relationship between the moist diabatic circulation and the production of condensates that forms clouds in moist processes. As CO_2 concentration increases, tropospheric radiative cooling is reduced, resulting in weakening of the moist diabatic circulation and a decrease in precipitation. As the hydrologic cycle weakens and the moist processes involving phase change of water vapour to form the condensates in the atmosphere lessen, the mass of cloud condensates decreases. This decrease in cloud condensates can be predicted from the decrease in the radiative subsidence mass flux, which is a metric for the strength of the moist diabatic circulation in the free troposphere.

Arsenic in hair as a marker of exposure to smoke from the burning of treated wood in domestic fireplaces

Kim Dirks[1], Alana Chester, Jennifer A. Salmond, Nicholas Talbot, Simon Thornley and Perry Davy

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Treated timber is used extensively in the New Zealand building and agricultural industries. While illegal, the burning of treated timber is commonplace due to its abundance as a free building by-product. However, the burning of treated timber results in an increased risk of lung cancer due to the inhalation of arsenic (As). Moreover, the outdoor ambient monitoring of arsenic in airborne particulate matter has identified levels in exceedance of the maximum acceptable standards of 5.5 ng m-3 (annual average) at some urban locations. In this study, two-week-old beard hair samples were collected during the winter months to establish individual exposure to arsenic and compared with questionnaire data about wood burner use during the two weeks prior to sampling, and spatial trends in As from ambient monitoring. Analysis of As content was carried out using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Results suggest that the burning of construction timber is associated with a higher level of arsenic in hair than those who burn logs or coal exclusively. There is no association between the area-level density of wood burners and As levels but a correlation with individual household behaviour with respect to the choice of fuel as well as the smell of wood smoke in the community, suggesting very localised influences. The burning of treated timber and the resulting exposure to arsenic may be a consequence of economic pressures. Strategies are needed to raise awareness of the risks of the burning of treated timber, to minimise the behaviour and to provide economically viable alternatives.

How to deal with a climate change sceptic

Pierre Foucaud[1]

[1]MetService

The motto of the Royal Society, one of the oldest scientific institutions, is “nullius in verba” or “take nobody’s word for it”. In other words, it says that scepticism is one of the characteristics of the scientific process. However, it must have two imperatives: The first one is the imperative to doubt and the second is the imperative to follow the evidence. This means you can ask questions, but it also implies that you must listen to the answers and the evidence. This paper will attempt to address why climate change sceptics are continuing to challenge the overwhelming evidences of Global Warming, and whether we can change their minds.

Emergence, Attribution and Extremes Programme

Dave Frame[1], Belinda Storey[1], Greg Bodeker[2], Suzanne Rosier[3], Dáithí Stone[3], Shaun Awatere[4] and Sally Owen[1]

[1]Victoria University of Wellington [2]Bodeker Scientific [3]NIWA [4]Landcare

Extreme weather events continue to be the primary manifestation of climate change. The Extreme Weather Events and the Emergence of Climate Change Programme ("Emergence") team has recently estimated the current costs to New Zealand of climate change attributable EWEs to be well in excess of several hundred million dollars per decade. However, to date, we have only studied a small number of events. This talk/research poster will outline our programme. We will be: identifying how extremes have previously damaged New Zealand's environmental, social and economic systems, and compiling a comprehensive database of these losses; detecting how climate change signals have emerged above natural variability in extreme events from the recent past (i.e., the problem of attribution); elaborating on how climate change signals will emerge above variability in the future (known as climate change emergence); estimating damages and losses, for New Zealand, from future extreme events; and creating better tools for near real-time modelling of extreme events, and incorporating these into national weather forecasting.

The World Meteorology Organisation's HIWeather Programme: an overview

David Johnston[1], Sally Potter[2], Richard Turner[3], James Lunny[4], Peter Kreft[4], Chris Noble[4], Jane Rovins[5], Julia Becker[5], Sara Harrison[5], Emily Campbell[5], Lisa McLaren[5] and Emma Hudson-Doyle[5]

[1]Massey University [2]GNS Science [3]NIWA [4]MetService [5]Massey University

Despite advances in forecasting and emergency preparedness, weather-related disasters continue to cost many lives, to displace populations and to cause wide-spread damage. Therefore, High Impact Weather Project (HIWeather), a 10-year research project, was established in 2016 by WMO (World Meteorology Organisation) WWRP (World Weather Research Program). HIWeather is aimed at achieving dramatic improvements in the effectiveness of weather-related hazard warnings, following recent advancement in numerical weather prediction at km-scale and in disaster risk reduction. The implementation plan was developed under the concept of warning chain, which comprises all components and the connections between a successful weather-hazards warning: observations, weather forecast, hazard forecast, impact forecast, the generation of warnings and decision making. A successful warning relies on information produced by the meteorological and related physical sciences, thus its effectiveness of delivery depends on applications of social, behavioural and economic sciences. This paper will present an overview of current activities within the programme and how New Zealand researchers can get involved.

Solar energy - how much is in Aotearoa's zero-carbon future?

Ben Liley[1]

[1]NIWA

New Zealand's commitment to 'zero-carbon' by 2050 requires major reorganisation of our economy. Agricultural emissions remain difficult, but the required course for other sectors has a clear target. We need to completely eliminate use of fossil fuels for electricity generation, transport, manufacturing, heating, and primary industries, as soon as possible. In this respect we are like all other developed countries, and several international studies have suggested how it is possible. For most countries they suggest that solar energy will be the largest single source for future energy needs, but New Zealand has been a laggard, and several reports have suggested that solar energy is less suitable for NZ. Solar energy has been a focus for many countries, either through very favourable feed-in tariffs, or through regulation or direct government action. Germany was a leader, and it now has rooftop solar generation capacity of over 40 GW, more than four times NZ's total grid-connected capacity. Nowhere in Germany receives more solar energy per year on a horizontal surface than does Invercargill, and every population centre in NZ receives more. Solar energy is the most abundant source of renewable energy, and can provide more than enough energy for electric transport and electrification of industry. Issues arise with continuity of supply, but hydroelectricity is the perfect complement, and EV batteries will provide enough storage to power the country for several days. A hydrogen economy could also work to provide interseasonal storage, energy for shipping, and export.

Extreme Heavy Rain in Westland, Nov 2018 and Mar 2019

Fulong Lu[1]

[1]MetService

Extreme heavy rain always has significant impact, potentially causing loss of life, damaging property and infrastructure, and disrupting travel and power supplies. In New Zealand, broad-scale extreme heavy rain events have occurred with ex-tropical cyclones. They can also occur with mid-latitude systems, e.g. the heavy rainfall events on the West Coast of the South Island in November 2018 and March 2019. The storm of 7-8 November 2018 brought extremely heavy rain, strong winds and high elevation snow to southern NZ. In a 24-hour period, Cropp River recorded 636.5mm at Waterfall and 518.5mm at the Base. The storm of 25-26 March 2019 caused major flooding in Westland and destroyed the Waiho River bridge. In a 48-hour period, Cropp River Waterfall recorded 1086mm; Haast River at Roaring Billy recorded 469mm in 24 hours.

MetService introduced a "Colour-Coded Severe Weather Warning System" in May 2019. Had these two events occurred after this time, they would have been categorized as "Red Warnings" based on their impacts and severity. In this paper, these extreme heavy rain events will be reviewed from the perspective of severe weather forecasting. The Extreme Forecast Index and Shift of Tails indices, and other NWP guidance, will be discussed along with the concept of a "warm conveyor belt" (WCB). The WCB acted like an atmospheric river, directing warm moist air with an 850hPa wet-bulb potential temperature of 18 to 19°C onto the West Coast. The orographic effects and strong dynamic processes combined to make these events extreme.

The 2018 Tolaga Bay Queen's Birthday Flood: A Meteorological Analysis

Nathanael Meila[1]

[1]SCION

On 4-5 June 2018, torrential rain fell on the East Cape area, causing significant flooding and slips in the area. Many roads were closed, and some properties lost power. The Tolaga Bay area was particularly adversely affected by debris flows caused by forestry slash and debris following harvesting of steep catchments. Sixty-one bridges in the Tolaga Bay catchment were closed due to flooding, and one bridge had twisted and moved at least 30 cm after the flash floods. This project's scope was to ascertain the extreme nature of the rainfall that led to this event by use of weather radar and expert meteorological analysis combined with land-use factors.

CarbonWatch-NZ: A bird's eye view of New Zealand's Greenhouse Gas Emissions and Uptake

Sara Mikaloff-Fletcher[1], Beata Bukosa, Gordon Brailsford, Mike Harvey, Jocelyn Turnbull, Zoe Buxton, Scott Graham, John Hunt, Elizabeth D. Keller, Miko Kirschbaum, Rowena Moss, Louis Schipper, Dan Smale and Peter Sperlich

[1]NIWA

New Zealand's carbon uptake by forests and other land areas currently offset 30% of our total greenhouse gas emissions, and forest carbon offsets are expected to play a major role in achieving our ambitious Carbon Zero target. Yet, the amount of carbon exchanged between the atmosphere and the terrestrial biosphere is the most uncertain component of our carbon budget. We will present first results from CarbonWatchNZ, a five-year project to improve our understanding of carbon exchange in New Zealand's forests, pastures, and urban environments using atmospheric greenhouse gas measurements and models.

As air passes over a region, the amount of carbon in the air increases or decreases due to carbon exchange. Atmospheric inverse modelling infers net air–sea and air–land CO_2 fluxes from measurement records at a network of sites and atmospheric model simulations that describe how air travelled prior to arriving at the site. Preliminary work from a pilot study using only two observing sites suggested that New Zealand's land carbon uptake has been under-estimated, with much of this carbon uptake occurring in Fiordland. Here, we update this work with additional measurements and a tenfold improvement in our atmospheric model resolution. Our new results confirm the Fiordland carbon sink, and suggest the carbon uptake in the North Island is also under-estimated. In addition to presenting these results, we will outline the five-year plan to expand our observing network to eleven sites and answer key carbon science questions in New Zealand's forest, pasture, and urban environments.

South Island West Coast Rainfall – insights from radar and high resolution NWP

Stuart Moore[1], Trevor Carey-Smith[1] and John Crouch[2]

[1]NIWA [2]MetService

Regions such as New Zealand's Southern Alps, where orographic rainfall processes are significantly enhanced due to the steep slopes and high altitude mountain peaks in close proximity to the coastline, provide a stern challenge to Numerical Weather Prediction (NWP). To overcome this, very high resolution NWP has in recent times become a mainstay of current research practice, enabling investigations into atmospheric processes that previously relied solely on intensive (and expensive) observation campaigns. With increases to High Performance Computing (HPC) capabilities, NWP models can be run with horizontal resolutions <1km. At these scales, the model can begin to explicitly resolve a number of the atmospheric processes that will hopefully lead to improved forecast skill.

In this presentation we report on early work into the use of very high resolution (<1km) configurations of the Unified Model, the NWP modelling system used in NIWA's NWP workflow, to conduct case study simulations of a South Island West Coast heavy stratiform rainfall event. Observations from MetService radar indicate the presence of a melting layer and dendritic growth zone over the Southern Alps and significant atmospheric turbulence during this event. We investigate what impact changes in the model's horizontal resolution has on its ability to capture not only the observed rainfall totals on the ground, but also the significant atmospheric processes and features, such as these observed layers, associated with this rain event.

New Zealand climate projections: Where do we come from, where do we go?

Olaf Morgenstern[1], Jonny Williams[1], Erik Behrens[1], Abha Sood[1], Brett Mullan[1], Stephen Stuart[1], Christian Zammit[1] and Mike Williams[1]

[1]NIWA

The New Zealand Earth System Model is now operational and is being used for producing new global climate simulations. These simulations will drive the next generation of downscaled climate and hydrological projections for this country. We will review how the previous set of regional climate simulations was produced, successes and weaknesses of that approach, and how we are planning to proceed with the new set of simulations. We will discuss the rationale for having our own global climate model, as opposed to relying solely on international models. We will also present some early results of the NZESM simulations.

Future Heavy-Rainfall Events in Bay of Plenty and changes in associated Storm Tracks

Brett Mullan[1] and Stephen Stuart[1]

[1]NIWA

This case study describes how future changes in storm tracks affect heavy-rainfall events in the Bay of Plenty (BoP). The analysis draws on archived daily mean sea-level pressure (psl) and rainfall data as simulated with a global atmospheric model (HadAM3P) forced by bias-corrected sea-surface temperatures from six CMIP5 global coupled models under two forcing scenarios (RCPs 4.5 and 8.5).

Heavy-rainfall events in the BoP region are defined as periods ("Wet Spells"), typically lasting 3-5 days, starting with a daily rainfall accumulation over the region of at least 25mm. Low-pressure centres and vorticity centres are first diagnosed over the Tasman Sea-New Zealand domain for the period 1971-2100 from the six models and two RCPs, where the centres are identified from the Laplacian of the psl field. Then, working backwards from the first day of heavy-rainfall in BoP, cyclone tracks associated with the rainfall events are generated and their statistics evaluated.

Wet Spell historical climatologies agree well between modelled rainfall and VCSN observations, in terms of frequency, length and accumulated rainfall. In the future scenarios, Wet Spells increase in frequency in all seasons, in spite of a general decrease in the number of cyclone centres to the northwest of the North Island. Over the tropical cyclone season (November-April), there is a consistent pattern of fewer storms coming out of the tropics but the storms being stronger as they get close to New Zealand. Some comment will also be made on changes in the all-centre distribution, irrespective of BoP Wet Spells.

WIVERN: A New Satellite-borne Radar Concept to Provide Global In-Cloud Winds

John Nicol[1], A. J. Illingworth[2], et al.

[1]Weather Radar New Zealand [2]University of Reading, UK

This presentation concerns the development of a ground-based prototype radar system intended for a conically scanning spaceborne Dopplerized 94-GHz radar Earth science mission concept: Wind Velocity Radar Nephoscope (WIVERN). WIVERN aims to provide global measurements of in-cloud winds using the Doppler-shifted radar returns from hydrometeors. The conically scanning radar could provide wind data with daily revisits poleward of 50°, 50-km horizontal resolution, and approximately 1-km vertical resolution. The measured winds, when assimilated into global weather forecast models, should lead to further improvements in the accuracy and effectiveness of forecasts of severe weather and better focusing of activities to limit damage and loss of life. Polarization diversity allows high wind speeds to be unambiguously observed; analysis indicates that artefacts associated with polarization diversity are rare and can be identified. Winds should be measurable down to 1 km above the ocean surface and 2 km over land. The potential impact of the WIVERN winds on reducing forecast errors is estimated by comparison with the known positive impact of cloud motion and aircraft winds. The main thrust of WIVERN is observing in-cloud winds, but WIVERN should also provide global estimates of ice water content, cloud cover, and vertical distribution, continuing the data series started by CloudSat, with the conical scan giving increased coverage. As with CloudSat, estimates of rainfall and snowfall rates should be possible. These non-wind products may also have a positive impact when assimilated into global forecast models.

An Investigation into Severe Aircraft Icing, East Coast of South Island, 27 April 2019

Neal Osborne[1]

[1]MetService

On 27 April an aircraft travelling from Dunedin to Christchurch encountered severe airframe icing between 15,000 and 17,000ft, just off the North Otago coast at 1329 NZST. Airframe icing occurs when an aircraft travels through clouds predominantly composed of Super-cooled Liquid Water Droplets (SLWDs) rather than ice crystals. When an aircraft comes into contact with SLWDs, they spontaneously freeze, causing a layer of ice to form on the skin of the aircraft. Commercial aircraft are fitted with de-icing equipment that is normally able to remove this accretion of ice.

During 27 April 2019, a cold front moved northeast over the South Island, and an associated upper jetstream contributed to a broad area of upward motion ahead of the front. Additionally, a standing wave generated by the Southern Alps created downward motion immediately east of the Alps (evident by a 'dry slot' on satellite imagery) and an area of enhanced upward motion further east near the coast. It was within this region of upward motion that the aircraft encountered severe icing. It is concluded that a combination of the dry slot upstream and the enhanced upward motion resulted in an abundance of SLWDs in the region of the incident. Ice crystals are an important ingredient in the natural glaciation of SLWDs. In this case, the supply of ice crystals falling through the SLWD zone was limited due to the dry slot upstream.

Future liabilities of insurance and climate change: a quantification case study from New Zealand

Jacob Pastor[1], Ilan Noy[1], Isabelle Sin[2] and Abha Sood[3]

[1]Victoria University of Wellington [2]MOTU [3]NIWA

New Zealand's public insurer, the Earthquake Commission (EQC), provides residential insurance for weather-risk, specifically for floods and rainfall-induced landslides (with only partial cover for the former). Here, we estimate the empirical relationship between extreme precipitation events and the EQC's weather-related insurance claims based on a complete dataset of all claims from 2000 to 2018. We then use these estimated relationships, together with climate projections, based on future emission scenarios, to predict the impact of future extreme events on the value of insurance claims under different climate change scenarios. We quantify the predicted total future liability of the EQC to weather-extremes for different time horizons and different future greenhouse gasses emission scenarios known as Representative Concentration Pathways (RCPs). Results show that climate change impacts are heterogenous over time and space, and range between -0.4% up to 7.2%, on average.

Overview of the Resilience to Nature's Challenges: Weather & Wildfire theme research plan

Sally Potter[1] and Richard Turner[2]

[1]GNS Science [2]NIWA

The Resilience to Nature's Challenges (RNC) National Science Challenge is a five-year research programme funded by the Ministry of Business, Innovation and Employment to enhance resilience to extreme events in New Zealand. High impact weather, plus associated risks such as wildfire, flooding and landslides, has significant adverse impacts on Aotearoa New Zealand, and is the focus of the High Impact Weather and Wildfire theme.

Our multidisciplinary research team is from five organisations, and in conjunction with stakeholders and Māori partners, will create new fine-scaled datasets of extreme weather, and a more comprehensive understanding of the impacts on communities, infrastructure and economic activity. We will investigate practical, cost effective and socially acceptable mitigation methods, including improving communication of information, and developing a tool to assist a highly impacted Māori community to strengthen levels of resilience. We will use three scenarios as a focus of our research: an ex-tropical cyclone impacting the Northland, Auckland and Waikato regions; a severe winter storm in Otago, and a Rural-Urban Interface wildfire.

We will present an overview of our research plan and discuss our engagement strategy to invite stakeholders and researchers to give feedback and co-design the research. We will also highlight the intended leadership role that the RNC will have in New Zealand. This will be by facilitating connections between researchers, and to guide other researchers to align their work with RNC and leverage off it to increase their chances of being funded from separate funding pools as well as a small RNC contestable fund.

The Impact of Climate Change and Drought Persistence on Farmland Values in New Zealand

Farnaz Pourzand[1], Ilan Noy[1] and Kendon Bell[2]

[1]Victoria University of Wellington [2]Manaaki Whenua

Changing climate and extreme weather conditions will affect agricultural production, and consequently will increase the risk of food insecurity in New Zealand. This project aims to obtain a quantitative understanding of the potential impacts and implications of climate change on New Zealand's agriculture, especially through the impacts of drought events on farmland values. We do so by implementing the Ricardian approach of land climate-pricing using QV data (which is sourced from Quotable Value New Zealand (QVNZ) and historical and projected climate scenarios (CCII/NZESM). The baseline model measures the average effect of linear and nonlinear climate variables on farmland values while controlling for socio-economic and topographical-geographical features. Furthermore, we explore the importance of lagged impacts of climate in our models. Autoregressive (AR) coefficients of daily weather variables are applied to measure the degree of persistence of drought events. Finally, we take the estimated relationships using historical data to simulate agricultural land values forward under climate change. Preliminary results using historical data show the heterogeneity in which rural land values are affected by climate depending on the land use category. In general, we see that the value of rural land decreases with summer temperature among all land uses, while it increases with spring temperature. The cumulative impacts of drought reduce farmland values. This knowledge allows New Zealand to make better target drought adaption efforts and understand which agricultural sub-sectors and areas are the most at risk from future climate change.

Spatial Sampling Scale Implications for Rainfall Induced Landslide Forecasting

Kate Prebble[1], John Nicol[1] and Luke Sutherland-Stacey[1]

[1]Weather Radar New Zealand

Accurate prediction of the location and timing of landslides is essential for mitigating physical, social and economic risk. Rainfall (alongside earthquakes) is one of the most significant triggers for landslides, thus more detailed spatial and temporal rainfall data could help improve current landslide prediction models. This study contrasts the spatial characteristics of rain-radar observations to conventional rain gauge approaches within the context of Rainfall Induced Landslide Hazard Models (RILHM). An empirical RILHM based on underlying terrain slope and rainfall accumulation has been implemented and the response when driven with high resolution radar rainfall accumulations or a hypothetical sparse gauge network has been investigated. The skill of the conceptual model for identifying the landslide risks showed a False Alarm Rate of 0.67 and a Probability of Detection of 0.42 when compared with the rain-radar driven model. This implies that the significant spatial sampling uncertainties associated with sparse rain gauge measurements are likely to be an important source of forecast error in any operational RILHM.

40-years of Atmospheric Rivers in New Zealand

Hamish Prince[1] and Nicolas Cullen[1]

[1]University of Otago

Atmospheric Rivers (ARs) are filamentary regions of enhanced atmospheric water vapour transport, responsible for over 90% of the horizontal moisture flux through the midlatitudes. A vast amount of research has been conducted on ARs experienced on the West Coast USA linking these features to extreme precipitation, flooding, drought and snowfall. Comparatively, little work has been conducted on these features in other mid-latitude locations around the world. In the Southern Hemisphere, New Zealand has been recognized as a location where Atmospheric Rivers may be just as influential as they are in the USA, however, research is yet to fully substantiate this connection. The main objective of this research is to study the occurrence of Atmospheric Rivers in New Zealand and how well tracking algorithms can detect and track these events over the last 40 hydrological years. The role of ARs in New Zealand surface water hydrology is also to be addressed by examining precipitation and discharge records during landfalling AR events at different locations within New Zealand. A new event characterization is tested for New Zealand based on the intensity of duration of events to assess the connection between these properties and the damage produced from such an event. A key case study is of the landfalling AR in March 2019 which caused catastrophic damages. This event only registered as a '1 in 5-year' storm based on the historical analysis of moisture fluxes indicating that the link between moisture flux and precipitation is non-trivial.

The projected impacts of climate changes to lake inflows and wind on electricity supply and demand in NZ

Jen Purdie[1] and Grant Telfar[1]

[1]Meridian Energy

Rainfall is projected to get higher in the largest New Zealand hydro-electricity catchments over coming decades, and the wind to get stronger over much of the country. The government is advocating 100% renewable electricity generation (or close to it) by 2035. What are the likely impacts of these changing conditions on the electricity system, and will we be able to continue to balance the energy trilemma of security of supply, sustainability, and moderate pricing? We use a complex, multi-nodal two phase optimisation and simulation model of the entire NZ power system to model the impact of various climate change scenarios on electricity supply and demand in NZ. In particular, we examine the impact of increases in the volume and volatility of hydro lake inflows, the changing seasonality of these inflows, and changes to the wind regime in New Zealand, on electricity supply and demand.

On the factors controlling boundary layer cloud albedo

Neelesh Rampal[1] and Roger Davies[1]

[1]University of Auckland

This study develops an Artificial Neural Network (ANN) to classify satellite imagery from Multi-angle Imaging SpectroRadiometer (MISR) in domains of 200 km^2 into four categories of marine low-clouds based on their type of Mesoscale Cellular Convection (MCC). These categories are (i) closed-celled MCC, (ii) open-celled MCC, (iii) disorganised MCC, and (iv) no MCC. These different types of MCC are usefully defined as low-clouds of different morphologies.

These classifications are used to investigate the large-scale meteorological controls on MCC. The large-scale meteorological variables that were used in this study are sea-surface temperature (SST) and Lower-Tropospheric Stability (LTS). Changes in large-scale meteorology are found to impact the occurrence of each MCC type disproportionately. We also investigated relationships between the El Niño Southern Oscillation (ENSO) and MCC. MCC is found to be strongly influenced by the SST anomaly patterns that arise during El Niño and La Niña. Changes in the coverage of MCC during ENSO phases are found to have significant impacts on the Top-Of-Atmosphere albedo.

Classifications from the ANN are also combined with satellite observations of MISR to develop relationships between cloud morphology, domain albedo, cloud fraction and a cloud heterogeneity. Cloud morphology is found to play an essential role in modulating these relationships. The cloud fraction-albedo relationships are found to be directly a function of cloud morphology. Relationships between domain albedo and cloud heterogeneity are also found to be a function of MCC type. Our results strongly indicate that the albedo has a strong dependence on cloud morphology and cloud heterogeneity. Understanding both the physical properties and the meteorological controls on MCC has important implications for understanding low-cloud behaviour and improving their representation in General Circulation Models.

Communicating severe weather information via MetService digital channels

Stephanie Raill[1]

[1]MetService

MetService is New Zealand's "Official Alerting Authority" for severe weather watches and warnings. In April 2019, MetService introduced a new approach to communicating watches and warnings, including an official colour code and consistent iconography across consumer-facing digital channels. A multidisciplinary team with expertise in communication, product development, severe weather forecasting, and design worked together to develop and implement this new approach. This presentation will address some of the successes and challenges of our approach and its implementation. It will include an overview of the user research that informed our product design, a discussion of the tensions among the needs of various audiences for severe weather warnings (for example, MCDEM, Councils, and the general public), strategies for overcoming constraints introduced by systems used to produce various warnings, and the design challenge of creating a consistent and clear iconography for severe weather in New Zealand.

Scale sensitivity of the Gill circulation

Beatriz Reboredo[1,2] and Gilles Bellon[1]

[1]University of Auckland [2]Weather Radar New Zealand

In this talk, I will overview the Gill circulation and its relationship with a renowned tropical disturbance, the Madden-Julian Oscillation (MJO). I will go through our investigation of the steady dynamical response of the atmosphere on the equatorial β-plane to a steady, localised, mid-tropospheric heating source at the equator. Studies of the dynamical pattern associated with the MJO showed how this pattern is essentially a Gill (1980) equatorially symmetric solution. Expanding Gill's seminal work, we vary the latitudinal and longitudinal scales of the diabatic heating pattern while keeping the total amount of diabatic heating fixed. The focus will be on characteristics of the response that would be particularly important if the circulation interacted with the hydrologic and energy cycles. The intensity of the overturning circulation decreases with increasing longitudinal or latitudinal scale of the diabatic heating. The low-level westerly jet decreases in maximum velocity and spatial extent relative to the spatial extent of the diabatic heating with increasing longitudinal or latitudinal scale of the diabatic heating, and the associated low-level eastward mass transport decreases with increasing longitudinal scale. The results of our analysis suggest that moisture-convection feedbacks will favour small-scale disturbances, and surface heat-flux feedbacks will favour small-scale disturbances in mean westerlies and large-scale disturbances in mean easterlies.

Emerging patterns of change in New Zealand's extreme rainfall with anthropogenic climate influence: projections from the 'weather@home ANZ' modelling system.

Suzanne Rosier[1], Trevor Carey-Smith[1], Luke Harrington[2] and Sarah Sparrow[3]

[1]NIWA [2]University of Oxford [3]Oxford eResearch Centre

New Zealand is vulnerable to the effects of climate change, perhaps most acutely via extreme rainfall and its potential to cause significant flooding and landslide. The warming atmosphere can hold more moisture, potentially delivering more intense rainfall extremes; however, New Zealand's situation as a steep isolated landmass in the path of strong winds means the effects of circulation changes are also important, and they can sometimes counteract the intensification signal. Significant geographical variation exists in rainfall and its extremes. The 'weather@home ANZ' model (HadRM3P nested in HadAM3P) is shown to be capable of reproducing these variations with a good degree of accuracy, and is evaluated here by comparison with observations from 'HIRDS' (High Intensity Rainfall Design System), New Zealand's foremost tool for infrastructure planning related to heavy rainfall. Strong W-E contrasts in extreme rainfall, particularly across the Southern Alps, are modelled well, as are regions of high rainfall associated with high elevation elsewhere. Similar geographical patterns are also evident in projections of future changes in extreme rainfall from the same model, although the patterns indicate wetter extremes in the west and drier in the east. Expressed as percentage changes from current conditions, the projected reductions in extreme rainfall in the east are often larger than the projected increases in the west. The joint picture of attributable changes to date and projections for the future should be of value for those planning for adaptation to New Zealand's coming climate changes.

WMO Coastal Inundation Forecasting Demonstration Projects

Graeme Smart[1]

[1]NIWA

The UN World Meteorological Organisation Commission for Hydrology and WMO Commission for Oceanography and Marine Meteorology have initiated Coastal Inundation Forecasting Demonstration Projects to improve community safety and socio-economic sustainability at selected locations around the world. Prediction of inundation events is particularly challenging in low-lying, coastal areas where meteorological, hydrological and oceanographic influences can all interact. This talk describes the mechanics of coastal inundation forecasting projects developed under WMO auspices for the Dominican Republic, Indonesia and more particularly, Fiji. These countries have different inundation drivers and widely differing levels of technical capability. In Fiji three programs are in place: flash flood guidance, ocean inundation forecasts, and a coastal inundation alert support system (CIA SS). Fiji's size and location means there is high uncertainty in predictions based on global numerical weather models and there is limited historical data to calibrate and verify models. Basing inundation warnings on telemetered data overcomes some of the significant uncertainties associated with inundation prediction but warning lead time can be short, particularly for small catchments. The CIASS - Fiji incorporates information from rainfall, river and sea level gauges and from tide forecasts. Three types of alert are issued: "AWARE", "WARN" or "CRITICAL". Alert triggers are based on thresholds derived from previous events, antecedent rainfall and the elevation heights of key infrastructure such as roads. Data are updated every five minutes. Alerts can be issued with up to 12 hours lead time.

The impact of greenhouse gas emissions on recent low pasture supply events

Dáithí Stone[1], Trevor Carey-Smith[1], Sam Dean[1], Luke Harrington[2] and Belinda Storey[3]

[1]NIWA [2]University of Oxford [3]Victoria University of Wellington

The New Zealand Pasture Growth Index (NZPGI) is used by the New Zealand Stock Exchange as a signalling tool for fluctuations in pasture supply that may affect the dairy industry. In this presentation, we will examine the NZPGI as a tool for understanding the effects of extreme seasonal weather, such as occurred during summer 2012-13 and late 2017, on pasture supply and dairy productivity. We will then use the NZPGI to diagnose the effect of long-term climate change on pasture supply, with a specific focus on extreme low supply events, and how that effect may cascade to dairy production.

Progress in Regional Radar Quantitative Precipitation Estimation in New Zealand

Luke Sutherland-Stacey[1], Geoff Austin, John Nicol, Nick Brown, Beatriz Reboredo Viso, Nava Fedaeff and Nathanael Melia

[1]Weather Radar New Zealand

Accurate and timely quantitative precipitation estimates are fast becoming essential for operation of 3-waters assets, catchment management and warning vulnerable communities about unfolding rainfall and flooding events. Rain radar is arguably the only viable observation system for obtaining representative rainfall estimates at the spatial and temporal scales required for proper characterisation of rainfall hazards in New Zealand's varied urban and natural catchments. In this talk we review progress in establishing operational regional radar QPE in New Zealand and report on how both real-time and retrospective QPE has been integrated onto end-user operational ("warning and informing") and planning. We also introduce current research directions which are anticipated to significantly improve the accuracy of radar derived QPE. Finally, we discuss the barriers to implementation of improved QPE which are currently being experienced by end- and next-users in the current NZ organisational landscape and the implications of these road-blocks for best engineering and science practice.

The Extreme Weather Event Real-time Attribution Machine (EWERAM) – An Overview

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As greenhouse gases continue to accumulate in Earth's atmosphere, the nature of extreme weather events (EWEs) has been changing and is expected to change in the future. EWEs have contributions from anthropogenic climate change as well as from natural variability, which complicates attribution statements. EWERAM is a project that has been funded through the MBIE Smart Ideas programme to develop the capability to provide, within days of an EWE having occurred over New Zealand, and while public interest is still high, scientifically defensible statements about the role of climate change in both the severity and frequency of that event. This is expected to raise public awareness and understanding of the effects of climate change on EWEs.

Researchers from five institutions across New Zealand are participating in EWERAM. EWE attribution is a multi-faceted problem and different approaches are required to address different research aims. Although robustly assessing the contribution of changes in the thermodynamic state to an observed event can be more tractable than including changes in the dynamics of weather systems, for New Zealand, changes in dynamics have had a large impact on the frequency and location of EWEs. As such, we have initiated several lines of research to deliver metrics on EWE attribution, tailored to meet the needs of various stakeholders, that encompass the effects of both dynamical and thermodynamical changes in the atmosphere. This presentation will give an overview of EWERAM and present the methodologies and tools used in the project.

Marine heat wave in the Tasman Sea and meridional ocean heat transports

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New and improved methods and datasets enable the Earth's energy balance to be closed locally on annual time-scales. Earth's energy imbalance is not uniformly distributed and has consequences for subsequent climate variability regionally as well as globally. The net surface energy flux is computed as a residual of the energy budget using top-of-atmosphere radiation combined with the divergence of the column-integrated atmospheric energy transports, and then used with the vertically-integrated ocean heat content tendencies to compute the ocean meridional heat transports (MHTs). The mean annual cycles, and 12-month running mean MHTs as a function of latitude will be presented for 2000-2016. Effects from the Indonesian Throughflow (ITF), associated with a net volume flow around Australia accompanied by a heat transport are fully included. Because the ITF-related flow necessitates a return current northward in the Tasman Sea that relaxes during El Niño, the reduced ITF during El Niño may contribute to warming in the south Tasman Sea by allowing the East Australian current to push farther south even as it gains volume from the tropical waters not flowing through the ITF. Although evident in 2015-16, when a major marine heat wave occurred, these effects can be overwhelmed by changes in the atmospheric circulation.

Development of A Full Carbon Budget for Auckland

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City governments are often leading the way in CO_2 emission mitigation efforts, both to address the climate challenge and the many associated co-benefits. Cities want to assess the potential of carbon mitigation strategies and planning decisions as well as evaluate the success of such strategies. In Auckland city, total fossil fuel emissions have been estimated following existing international protocols. Getting these city-scale inventories right is challenging, with international studies showing that biases of 50-100% are common in reported city emissions. Even more critically, no reliable estimates of urban land carbon exchange (uptake) are available for Auckland, nor do protocols exist to do so.

In collaboration with Auckland Council and iwi groups, we aim to provide robust scientific information that can be used by these stakeholders to evaluate emissions and mitigation strategies. We present results from a pilot study that has now been incorporated into CarbonWatch-NZ, developing spatially and temporally resolved fossil fuel and biogenic carbon flux maps for Auckland. We then evaluate these products using urban atmospheric observations of CO_2, CO, and $^{14}CO_2$, from which fossil fuel and biogenic CO_2 can be determined. We demonstrate that Auckland's fossil fuel CO_2 emissions are dominated by traffic sources. The urban biosphere is active year-round with little apparent seasonality and initial results suggest that the urban biosphere may be a modest net sink.

Participation in CMIP6 AerChemMIP project – modelling composition changes and their associated radiative effects

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AerChemMIP activity is an international multi-model comparison project feeding into the 6th Assessment Report of the IPCC, aiming to assess atmospheric composition changes and associated radiative forcing (RF) from preindustrial (1850) to present-day (2014) and into the future (2100) under various Shared Socio-economic Pathways (SSP) scenarios. We are contributing to this activity through the collaboration between the Unified Model Partners led by the UK Met Office using the United Kingdom Earth System Model (UKESM). In this presentation, we will show selected model results showing past to present changes in main atmospheric constituents and associated RF through perturbation simulations. We particularly look at changes in composition and RF associated with changes in ozone depletion substances (ODS) which the Southern Hemisphere climate is most sensitive to. A notable difference versus previous evaluations of RF is the transition from "instantaneous" to "effective" RF, with effective RF providing a more holistic and, in some cases, qualitatively different view on the role of anthropogenic climate forcers than instantaneous RF widely used in previous assessments.

New Zealand High-Resolution Rapid-Refresh Forecasting System

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[1]MetService

The need for effective updated weather information to improve the situational awareness of forecasters and assist related decision making has been increasing for many weather-related applications (e.g. transportation, severe weather and energy). MetService is developing a New Zealand High-Resolution Rapid-Refresh Forecasting System (NZH3R), which is an hourly updating convection-allowing atmospheric forecasting system that provides real-time high resolution information.

The Weather Research and Forecasting Model (WRF) is used as the dynamical forecasting model with a Three-Dimensional Variational (3DVar) data assimilation approach that incorporates the latest observations, including radar data, and provides forecasts out to 12 hours. Initial evaluations have been carried out by comparing NZH3R with other models running at MetService. In general, NZH3R produces improved forecasts over the short-range, especially for high impact mesoscale weather.