Annual Conference 2020

Meteorological Society of NZ

November 25-27, 2020

Presentation abstracts

Keynote Presentations

Opening remarks and tribute to Brett Mullan

25 Nov
8:45am

James Renwick
Victoria University of Wellington

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26 Nov
8:30am

Norway comes to New Zealand: Edward Kidson, Jørgen Holmboe and the Modernisation of Australasian Meteorology

Ciaran Doolin
MetService

Edward Kidson, Director of the Meteorological Service of New Zealand from 1927 until his death in 1939, was an instrumental figure in modernising Australasian meteorology. Throughout the 1920s, Kidson promoted the methods of synoptic analysis emanating from the Bergen School of Meteorology. However, it was not until the 1930s that he began in earnest to apply these methods to weather charts for the Australasian region. This development was aided by two visits he made to Bergen and by a personal correspondence he maintained with Jacob Bjerknes during the 1930s. In 1932, Kidson presented the first Norwegian-style analysis conducted for a Southern Hemisphere region, promptly following this with a more extensive study. However, these analyses were not of a sufficient standard at that stage to be adopted in forecasting practice.

It was the fortuitous visit to New Zealand of Norwegian meteorologist Jørgen Holmboe, in 1934, that finally facilitated the transition. Holmboe was attached to the Lincoln Ellsworth Antarctic Expedition, but damage to their aircraft caused them to spend the winter of 1934 in New Zealand. Holmboe was engaged at the Meteorological Service in Wellington during this period, working with Kidson to apply Norwegian methods to the region. Kidson had hoped to further embed this practice by employing Tor Bergeron in New Zealand during 1938. Bergeron had accepted an offer from Kidson but cancelled at the last minute after contracting rheumatic fever. Nevertheless, shortly after Holmboe's visit, daily analyses were being conducted along Norwegian lines, bringing Australasian meteorology into the 20th century.

The Meaning of Air Quality!?

27 Nov
8:30am

Sarah Brand
Marlborough District Council

The Covid-19 crisis has led to many changes to our lives and for many the realisation of the significant role that the natural environment has on our personal wellbeing. Air quality was highlighted like never before with reports of "clear" air for the first time in many of our world's cities and a seemingly worldwide engagement from the general public with the air we breathe. So what does air quality mean? Sarah will explore this question and share some of her experiences of what air quality means from a Council perspective.

Sarah Brand
Environmental Scientist – Contaminants, Marlborough District Council
Sarah originally hailed from the UK where she graduated with an Environmental Science degree from the University of East Anglia before gaining her doctorate from the University of Southampton which focused on the investigation of high resolution climate change. Sarah emigrated to New Zealand over 20 years ago and has worked in a variety of industries including shipping, law, property, large format retail and is now on the science team for the Marlborough District Council. Her present role with the Council involves two core areas of air quality and contaminated land undertaking both district and regional functions relating to these areas.

Oral Presentations

Changing characteristics of New Zealand droughts in the 21st century

25 Nov
9:30am

Abha Sood
NIWA

Recent drought events of 2012-13 and 2019-20 have exposed New Zealand's vulnerability to dry extremes. Global warming can regionally become a potent driver of greater aridity with higher temperature extremes and lower soil moisture conditions resulting to more frequent, longer and more severe droughts. Earlier focus on droughts and their impacts on the lack of precipitation is now augmented to include the growing role of warming temperatures. The frequency and intensity of atmospheric aridity are likely to be greatly underestimated without the feedback of soil moisture to atmospheric temperature and humidity, and the critical role of land–atmosphere feedbacks in driving concurrent soil drought and atmospheric aridity under climate change is increasingly becoming more apparent. In this analysis, improved soil moisture estimates using revised soil models for New Zealand conditions and regional soil data are presented. The merged New Zealand Drought Index (NZDI) applicable from daily to multi-decadal scale is derived and the relative change in the role of precipitation and soil moisture deficits in projected droughts of the 21st century to historic droughts is discussed.

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25 Nov
9:50am

Surface temperature trends in New Zealand and surrounding oceans: 1870 - 2019

Jim Salinger

University of Tasmania

Homogenized series of maximum, minimum, and mean air temperature averaged over NZ for the period 1871-2019 are compared with marine temperature data measured over the surrounding ocean surface. Temperatures over the region (the New Zealand Exclusive Economic Zone) exhibit an increase (linear trend) of 0.66°C from 1871-2019. As well as the anthropogenic warming signal (identified by CMIP5 simulations), internal variability is also examined. Significant volcanic eruptions have caused temporary cooling and the positive trend in the Southern Annular Mode (SAM) is linked to warming over NZ. The influences of the Interdecadal Pacific Oscillation and the El Niño/Southern Oscillation (ENSO) are also evident in the temperature series. All but one of the seven warm years (>+0.45°C above the 1981-2010 normal) occur after 1998, and all the nine cold years (<-0.84°C below the 1981-2010 normal) occur prior to 1933. Climate teleconnections that cause interannual to decadal variability (ENSO and IPO) are key factors in these results, beyond the anthropogenic warming signal as well as the positive trend in the SAM.

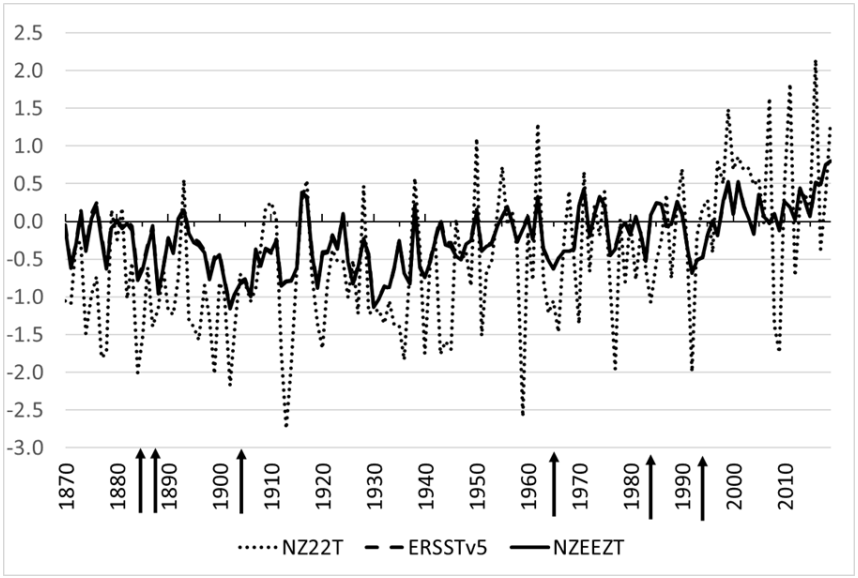

Figure 1: New Zealand temperature 1870-2019 (°C). Values are expressed as anomalies in mean annual temperatures from the 1980-2010 climatological period, for New Zealand land surface temperatures using 22 station series (NZ22T) (dotted), Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5) (dashed) and combined land and sea surface temperatures covering the Exclusive Economic Zone (NZEEZT) (solid). ERSSTv5 is very similar to NZEEZT. The arrows indicate dates of major volcanic eruptions that affected New Zealand climate.

An update on Earth's energy imbalance

25 Nov
10:40am

Kevin Trenberth
NCAR

Global Earth Energy Imbalance (EEI) is a fundamental metric of climate change, and the local distribution of the imbalance has implications for regional climate variations. It has been a major challenge to reign in the uncertainties and reasonably establish the EEI. The atmosphere and oceans are dynamically active, and many phenomena attempt to move heat to where it can best be lost in some sense, such as by radiation to space, or buried deep in the ocean. Although there is somewhat constrained effectiveness in many phenomena, such as hurricanes or ENSO, in redistributing heat and keeping regions cooler than they otherwise would be, these aspects are often not replicated well in climate models. Hence it is vital to understand the net heat gain of the Earth system and how much and where the heat is distributed in the Earth system. How much heat might be readily purged and serve as a negative feedback to warming? This paper provides new estimates of the vital flows of energy in the climate system and where energy is sequestered.

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25 Nov
11:00am

Reappraisal of the climate impacts of ozone-depleting substances

Olaf Morgenstern
NIWA

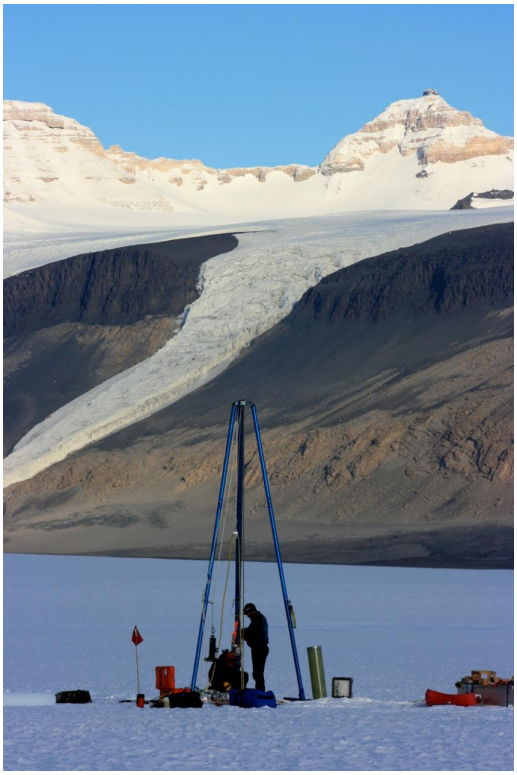
We assess the effective radiative forcing due to ozone-depleting substances using models participating in the Aerosols and Chemistry and Radiative Forcing Model Intercomparison Projects (AerChemMIP, RFMIP). A large inter-model spread in this globally averaged quantity necessitates an "emergent constraint" approach whereby we link the radiative forcing to the amount of ozone depletion measured and simulated during 1979-2000, excluding two volcanically perturbed periods. During this period ozone-depleting substances were increasing, and several merged satellite-based climatologies document the ensuing decline of total-column ozone. We use these analyses to come up with effective radiative forcing magnitudes. For an average of these satellite climatologies we obtain a best-estimate effective radiative forcing on the edge of the previously published "likely" range given by the 5th Assessment Report of IPCC, implying a likely offsetting effect of ozone depletion and/or other atmospheric feedbacks of -0.39 to -0.21 Wm^{-2}, which in absolute terms is larger than the previous best estimate of -0.15 (-0.3 to 0) Wm^{-2}, but is consistent with other literature results.

Pre-industrial $^{14}CH_4$ indicates that anthropogenic fossil CH_4 emissions are underestimated

25 Nov
11:20am

Tony Bromley
NIWA

Atmospheric methane (CH_4) concentrations have more than doubled since the pre-industrial era. Methane has a greenhouse effect that is about 80 times more potent than carbon dioxide over a 20 year period, and is responsible for at least 25% of global warming. There has been uncertainty about whether the source was biological - from agriculture, livestock, landfills - or from fossil fuels. There were also doubts about what share of fossil methane was naturally released and what share was from industry. Carbon-14 in methane ($^{14}CH_4$) can distinguish between fossil (i.e. carbon-14 free) emissions and modern biogenic sources. However $^{14}CH_4$ emissions from nuclear reactors have complicated the issue from the mid-20th century. It is also a matter of debate as to how total fossil emissions are divided between anthropogenic and natural geological sources e.g. seeps, volcanoes, wetlands. Current emission inventories suggest that the natural sources account for around 40 – 60 Tg CH_4/year.



A new collaborative study by researchers from the United States, Australia, New Zealand, Switzerland and France and recently published in Nature journal used pre-industrial era ice-core $^{14}CH_4$ measurements to show that natural geological CH_4 emissions into the atmosphere were an order of magnitude smaller than currently used estimates. This indicates that anthropogenic fossil emissions are under-estimated by around 25 – 40%, highlighting the human impact on the atmosphere and climate. This talk will briefly describe the techniques used to extract the trapped air from the ice cores, measurement of the isotopic signatures of the methane from that air and our atmospheric $^{14}CH_4$ reconstruction, and highlight the human impact on the atmosphere and climate.

25 Nov
11:40am

Changes to the tropopause transition layer in a warmer climate

Roger Davies
University of Auckland

The increase of surface temperature due to increased carbon dioxide is fundamentally important to the theory of climate change. An idealized model of one dimensional radiative-convective equilibrium is used to further explain this mechanism, with an emphasis on tropopause control, contrasting the understanding obtained by a simple grey model with that from a fully spectral treatment.

In the grey model, which has traditional pedagogical value, the top of the convective layer and the cold point temperature coincide to provide a clearly defined tropopause and clearly explicable tropopause control of surface temperature. In the spectral model, the top of the convective layer and the cold point temperature separate, creating what is often called a tropopause transition layer. This layer is a common feature of tropical atmospheres and is also a better representation of the global average.

Increasing carbon dioxide affects the temperature and pressure of both the cold point temperature and the top of convection. The increased surface temperatures resulting from these changes will be presented, together with the complications introduced by the presence of upper tropospheric clouds.

Machine Learning approaches to seasonal climate forecasting

25 Nov
1:00pm

Nicolas Fachereau

NIWA

The accuracy and local relevance of seasonal climate forecasts that are currently available for New Zealand are hampered by the relatively coarse spatial resolution of present climate prediction models (General Circulation Models, GCMs), which do not account for important orographic effects highly relevant to New Zealand/Aotearoa. In this presentation we report results of a research project that aims at using Machine Learning approaches to alleviate this issue. Features (predictors) derived from the outputs from multiple GCM ensembles are used as inputs to several Machine Learning algorithms, then ensemble learning (bagging, boosting, stacking) methods are used to derive single probabilistic forecasts for the NZ '6 regions'. We demonstrate significant improvements (10 – 20% improvement in accuracy) on the 'raw' outputs from the GCMs, and performance on par or exceeding revised estimates for NIWA's Seasonal Climate Outlook (SCO) accuracy. We also present results from experiments using stacked convolutional auto-encoders (a type of deep neural network) showing their potential for deriving compact embeddings of both the predictor fields (GCM outputs) and gridded predictor fields derived from the Virtual Station Climate Network (VCSN) dataset.

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25 Nov
1:20pm

Simulations of seasonal snow accumulation and melt across New Zealand

Jono Conway
NIWA

The growth and recession of the seasonal snowpack dramatically changes surface-atmosphere exchanges of heat and moisture, particularly in the South Island of New Zealand where snow regularly covers 25% of the land surface in mid-winter. Despite this, simulations of the distribution and seasonality of snow across New Zealand are lacking. The lack of simulations partly relates to the lack of in-situ climate observations in high elevations to use as model input and/or to produce interpolated climate products. Output from numerical weather prediction (NWP) models has shown promise as an alternative source of input data in mountainous areas lacking observations. In this presentation, I will present and discuss simulations of seasonal snow across New Zealand over the period April 2014 to April 2020 using output from the New Zealand Convective Scale Model (NZCSM) as model input. The NZCSM is an operational NWP model based on the UK MetOffice Unified model that provides 48-hour forecasts for the New Zealand domain at 1.5 km grid spacing. Six hours of surface climate and precipitation output from successive 6-hour forecast cycles have been joined to create a continuous time series of surface climate for the period April 2014 to March 2020. Snow simulations are performed using the physically-based snow model FSM2. Simulated snow cover is compared to fractional snow-covered area derived from satellite-based MODIS observations. Improved simulations of seasonal snow in New Zealand have many applications, including improving the lower boundary conditions in NWP forecasts and reanalyses, quantifying the distribution snow storage for down-stream river users as well as risks from rain-on-snow flooding.

Jono Conway, NIWA, Lauder
Trevor Carey-Smith, NIWA, Wellington
Céline Cattoën, NIWA, Christchurch
Stuart Moore, NIWA, Wellington
Pascal Sirguey, School of Surveying, University of Otago, Dunedin
Penny Smale, NIWA, Lauder
Christian Zammit, NIWA, Christchurch

Digitization and analysis of historic dew-point temperature records in Lower North Island

25 Nov
1:40pm

Richard Turner
NIWA

In the past year NIWA has digitised daily wet and dry bulb temperature data for both Kelburn and Masterton sites back to 1929 and undertaken an analysis of these records. This presentation aims to reflect on the challenges of accounting for site moves, changes in time of observation, and the methods for observing/estimating the dew-point temperatures. We also present key results of the analysis.

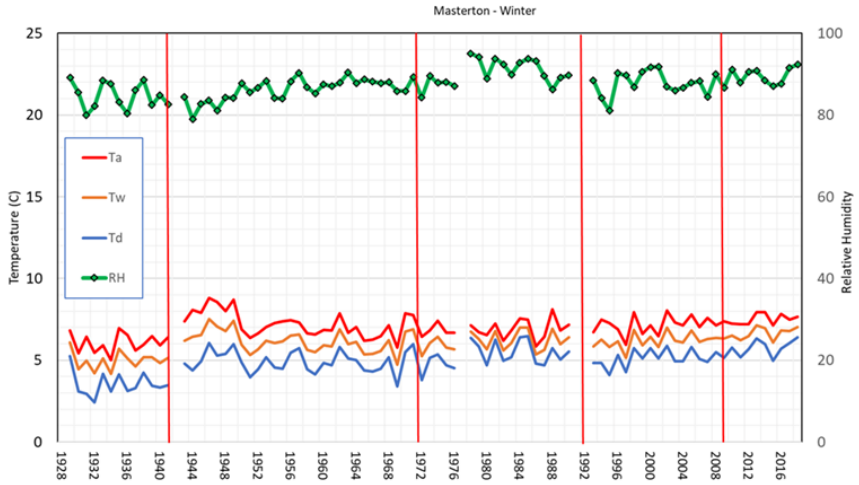

Figure 2: Time series of winter averages for dry bulb air temperature (T_a; red-line), wet-bulb air-temperature (T_w; orange line), dew-point temperature (T_d; blue line) and Relative Humidity (RH; green line) for the Masterton, Wairarapa site for the period 1928 to 2020.The red vertical lines mark station moves and the red line at 1972 marks the switch from earlier records recently digitized from meteorological charts to records retrieved from the national Climate Database (CliDB).

Overall, there was a 0.7°C increase in dew point temperature (T_d) averaged over all seasons. The strongest trend for an increase was in winter, amounting to +1.7°C over 90 years at Kelburn, and +1.8°C at Masterton over the same period. Autumn also saw increasing trends at both locations, whereas summer and spring saw smaller increases. January 2018 had the highest average T_d values of any month in both the Kelburn and Wairarapa records, while February 1998 was ranked third in the Kelburn record. Both 1998 and 2018 are tied for 2nd warmest years on record for New Zealand (dry bulb air temperature). Despite the long-term upward trend, average T_d values for February 1938 and February 1935 are ranked 2nd and 10th highest respectively in the Kelburn record. February 1935 is also ranked 8th highest in the Wairarapa record. Extreme high summer and autumn values of T_d occurred in the 1930s where there seems to be considerable year to year variability. Of the ten months with lowest average T_d values, seven occurred in the 1930s and 1940s for Wellington. At Masterton, six were in the 1930s and all ten had occurred by 1972.

Richard Turner, John-Mark Wooley, Katie Baddock, Petra Pearce

Climate and viticulture in the Waipara region: current and future potential

25 Nov
2:00pm

Hervé Quénol
CNRS, University of Rennes 2

This paper describes an international investigation into the climate variability within the Waipara region of Canterbury, New Zealand and its importance to viticulture. The complex terrain of the region results in intricate patterns of climate variability, which can create significant spatial variability in the optimal conditions needed for high quality wine production. Grape varieties are adapted to specific climate parameters (especially temperature), which determines the synchrony in the development of primary and secondary metabolites and hence wine quality. The viability of wine production therefore depends on ensuring that each variety is grown in the most climatically optimal locations. This research uses advanced techniques to map some key climate parameters at high spatial resolution with a combination of field measurement, remote sensing, and climate and phenological modelling techniques. This information can then be used to select optimal locations for specific grape varieties and for evaluating the future potential for grape production across the Waipara region under changing climate conditions. The new knowledge generated therefore provides the basis for rational decision-making in support of future development of viticulture in the region. The outputs also provide a framework within which to evaluate adaptation of viticulture to future climate change in other vineyard regions of New Zealand and elsewhere.

Sturman, A.[1], Quénol, H.[2], Parker, A.[3], Morin, G.[2], Dale, A.[1] and Trought, M.[4]

[1]University of Canterbury
[2]CNRS, University of Rennes 2, France
[3]Lincoln University
[4]Plant & Food Research

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25 Nov
2:20pm

Track characteristics of east coast lows in eastern Australia (1950-2019)

Jessie Gray
Central Queensland University

East coast lows (ECLs) are a significant cause of damage to crucial revenues (environmental, economic and social) and a vital water resource for communities along the east coast of Australia. An ongoing challenge for scientists is to improve the knowledge of ECL tracks along the east coast to aid in future mitigation and forecasting practices. Unfortunately, ECL track studies are not as extensive as those for tropical cyclones (TCs) and are limited by study-based definitions and parameters. Here, the spatial and temporal distribution of ECL tracks are explored from 1950-2019. The identification of key pathways used cluster analysis to group ECL events based on geographical characteristics (latitude and longitude) with respect to time. The relationship of storm intensification and sub-daily rainfall was investigated through the use of superimposed epoch analysis. The results from this study aim to build understanding and knowledge of ECL tracks and storm intensification in relation to rainfall, along the east coast of Australia.

Atmospheric rivers drive warming and ice loss on the Antarctic Peninsula

25 Nov
3:10pm

Kyle Clem

Victoria University of Wellington

On 6 February 2020, strong Foehn warming associated with an atmospheric river resulted in a record temperature of 18.3°C on the northeastern tip of the Antarctic Peninsula - the highest temperature ever recorded on the Antarctic continent. The synoptic circulation during this record consisted of a broad, northeastward elongated cyclone in the high-latitude South Pacific associated with the Amundsen Sea Low and a strong anticyclone over the southern tip of South America. We find that strong atmospheric rivers that occur under this synoptic pattern are key drivers of intense Foehn warming on the northeastern Antarctic Peninsula, and are associated with the positive phase of the Southern Annular Mode coupled with La Niña conditions. Farther to the south on the Larsen Ice Shelf, atmospheric rivers also play a key role in the occurrence of strong Foehn warming and surface melting that contributes to ice loss, but here the synoptic circulation that drives the atmospheric river consists of a strong anticyclone located over the Antarctic Peninsula, which is caused by El Niño conditions. There is little association between atmospheric rivers/Foehn-driven warming on the Larsen Ice Shelf and the Southern Annular Mode. Therefore the expected positive tendency of the Southern Annular Mode over the remainder of this century due to increasing greenhouse gases will likely lead to more extreme warm events on the northeast Antarctic Peninsula, but the fate of the Larsen C ice shelf is more tied to future variability in El Niño.

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25 Nov
3:30pm

Spatial distribution of wintertime Foehn intrusions in the McMurdo Dry Valleys of Antarctica

Rajasweta Datta
University of Canterbury

The sudden adiabatic warming of the atmospheric boundary-layer in the McMurdo Dry Valleys (MDV) of Antarctica is one of the most impressive meteorological phenomena in Antarctica. When the Ross Sea Region is under the influence of deep low-pressure systems, synoptic scale pressure gradient forces strong winds along the Transantarctic Mountains leading to adiabatically warmed air mass intrusions in the Dry Valleys. The annual frequency of Foehn intrusions can influence the average annual temperatures. We hypothesize that the variable geometry, orientation, and topographic features of the valleys in relation to the synoptic scale pressure gradient causes spatial variation in the characteristics of the Foehn intrusions.

To date, research of Foehn climatology in the Dry Valleys has relied on the extensive surface-based observational network of the Long Term Ecological Research program and mesoscale atmospheric modelling techniques that attempt to simulate dynamics of the valley flow systems as they interact with the synoptic scale winds.

Although mesoscale models can simulate airflow at high grid spacing (1km), the topographic features are not adequately resolved to capture within valley boundary-layer dynamics. Our paper presents results from using a synthesis of remote sensing and in-situ weather data to capture the spatial distribution of Foehn in the MDV; we rely on two datasets, AntAir and MODIS to detect rapid Land Surface Temperature (LST) warming events during winter and validate against LTER stations. During winter, the absence of diabatic heating of the surface by solar radiation results in high correlation between LST and air temperature in the MDV. Therefore LST can be used as a proxy for the temperature of lowest level of the atmospheric boundary-layer, allowing for the detection of locations under the influence of the Foehn. We show that AntAir and MODIS can capture the frequency, spatial extent, and duration of Foehn intrusion into the MDV providing a more complete picture of its influence over the within valley boundary-layer features.

Rajasweta Datta[1], Marwan Katurji[1], Peyman Zawar-Reza1, Hanna Meyer[2], Maite Lezama Valdes[2]

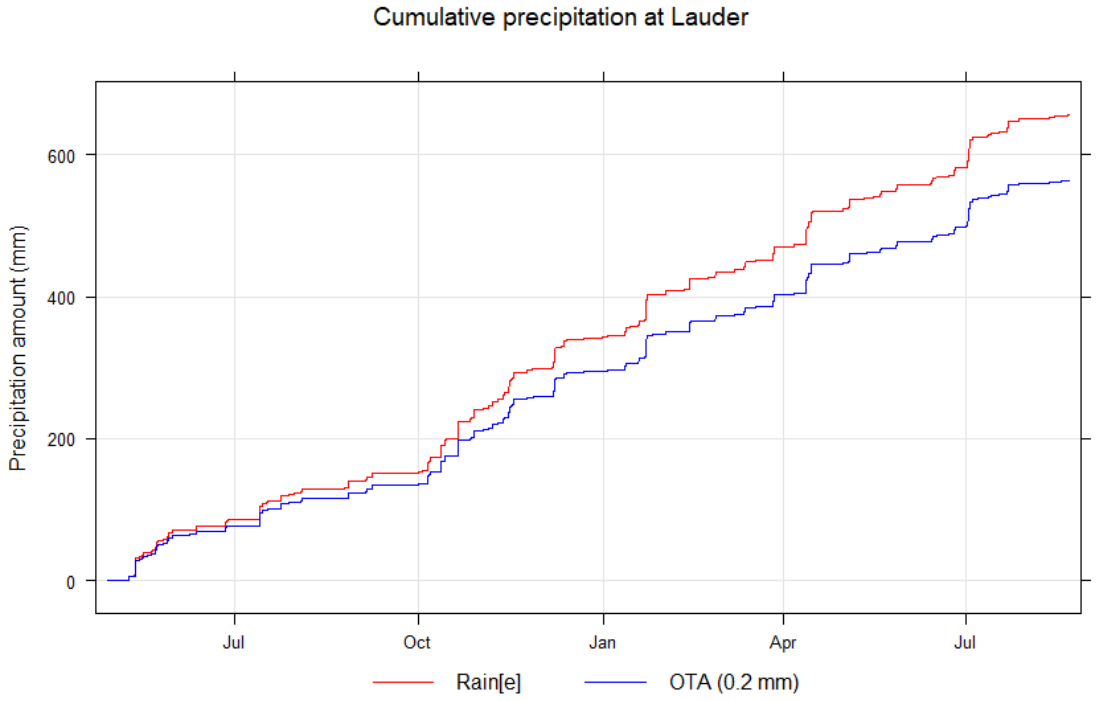
[1]Centre for Atmospheric Research, University of Canterbury, Christchurch, New Zealand
[2]Institute of Landscape Ecology, Westfälische Wilhelms-Universität Münster, 48149 Münster, Germany

Evaluation of the Lambrecht Rain[e] weighing precipitation instrument for high resolution precipitation measurements

25 Nov
3:50pm

Sam Edwards
NIWA

NIWA has been trialling the Lambrecht Rain[e] weighing precipitation instrument's suitability for precipitation measurements with high temporal resolution. The Rain[e] incorporates a tipping bucket mounted on a load cell. The sensitivity of the load cell allows the Rain[e] to resolve much smaller amounts than a conventional tipping bucket raingauge, with a specified resolution of 0.001mm.



The results of field testing at four sites in the South Island, representing locations with low and high rainfall rates, showed that the Rain[e] recorded significantly more precipitation than conventional tipping bucket raingauges and that the difference was location and event dependent. The high temporal resolution of the Rain[e] gives a more precise indication of the start and end of events. A heated Rain[e] was installed at two of the test sites to evaluate the measurement of solid precipitation. The heated Rain[e] produced a much better temporal description of the precipitation events than adjacent (unheated) tipping bucket raingauges. The challenge from here is how to transition these instruments into the national climate network and ensure homogeneity of the long-term record.

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25 Nov
4:10pm

Wildfire flaming zone dynamics at the immediate fire and atmospheric turbulence interface

Marwan Katurji
University of Canterbury

Novel observations and analysis methods applied to New Zealand experimental wildfire burns reveal new insights into the interaction of the wildfire flaming zone with the overlying wind turbulent dynamics for a rapidly moving stubble wheat fire. The in-situ and remotely sensed (via high-speed longwave infrared camera) flaming zone hot air parcel temperatures highlight spatial and spectral information of coherent turbulent structures that are responsible for fire front fuel heating patterns, and fire behavior resulting from the interaction with the overlying wind flow structure. Thermal image velocimetry was carried out on spatially observed brightness temperature of the hot air parcels located 0.85m above ground level and in the flaming zone. Turbulence spectral characteristics of the hot air parcels are similar to the overlying wind speeds at 10m above ground level. The spatial scales of our results (derived from fuel heights, observed flame lengths, and integral length scales associated with mean wind speed and decomposed turbulence frequency) were approximately 0.3 to 3m for the fuel-flame environment and approximately 1.6 to 80m for the flame-atmospheric surface layer environment. While other studies focused on laboratory scale experiments and numerical simulations of fire spread and interactions with atmospheric boundary layer scales, our new methods and results provided the first observations of wildfire flaming zone kinematics and the first verification of the application of time sequential thermography to wildfire-atmospheric turbulence interactions. In particular, the overhead oblique vantage point allow us to analyze for the first time in field-scale fires the coherent parcel motions responsible for flame advection and non-steady heating in fire spread in relation to turbulence perturbations of the overlying atmosphere.

Comparison of two spill-over heavy rain events in Canterbury, November 2018 and December 2019

26 Nov
9:15am

Fulong Lu
MetService

Severe weather always has significant impact, potentially causing loss of life, damaging property, infrastructure and crops, and disrupting travel and power supplies.

In New Zealand, broad-scale heavy rain events often occur with active mid-latitude systems in a blocked weather situation. In a strong northwesterly flow, heavy rainfall on the West Coast of the South Island can spill over onto the headwaters of Canterbury and Otago lakes and rivers. If the airmass is unstable, the rain is more likely to spread further east. For example, frequent thunderstorms accompanied a flooding event in December 2019 that affected the headwaters of the Rangitata River.

In this paper, two heavy rain events will be reviewed from the perspective of severe weather forecasting:

- A storm of 7-8 November 2018, which brought extremely heavy rain to southern NZ. The ranges of Westland had 400 to 650mm rain in 30 hours, and 300 to 400mm about the headwaters of Canterbury lakes and rivers. It was a classic event, as an active front moved up the South Island.

- The event of December 2019 produced heavy rain from the 1st to the 4th, and the 6th to the 7th. The most significant rain fell over the Canterbury headwaters on the 4th, which pre-conditioned the Rangitata River to flood on the 7th. Late on the 6th, frequent thunderstorms spread across South Canterbury and as far as the coast. This event was unique with several factors worthy of further study.

The performance of NWP guidance and the warnings issued by MetService during these events will be discussed. For both cases, the heavy rain that fell in the headwaters had a major downstream effect outside of the area of the heavy rain warnings. A new spill-over conceptual model will be introduced, and the processes that triggered the thunderstorms accompanying the December 2019 event will be elaborated on.

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26 Nov
9:35am

Modelling the spatial variability of high intensity rainfall

Trevor Carey-Smith
NIWA

Regional frequency analysis is a common method used to model extreme rainfall when observational records are too short to allow reliable estimation of long recurrence intervals. Typically, a region of influence is chosen, comprised of a collection of rain gauge sites with similar extreme rainfall properties, and a distribution (e.g. Generalised Extreme Value, GEV) is fitted to each site separately before parameters are averaged to create a dimensionless regional growth curve. This can lead to poorly estimated parameters from short rainfall records negatively impacting the regional result. In the Auckland region, a long-term radar derived rainfall record is available as an alternative data set. At 12 years, this radar data set is of shorter duration than the gauge records, many of which are over 40 years long, but it is spatially complete.

Here a non-stationary GEV distribution has been applied to multiple gauge sites simultaneously allowing the distribution parameters to be fixed for all sites, to vary based on an appropriate covariate or to be completely independent for all sites. Different covariates have been assessed for their ability to describe the spatial variability of the GEV parameters. These include location and terrain-based parameters and also several rainfall statistics, such as median annual maximum, derived from NIWA's high-resolution numerical weather prediction systems. For results in the Auckland region, the rain radar record is employed to validate both the NWP derived rainfall statistics and the skill of the other covariates to explain the spatial variability of the GEV parameters.

Trevor Carey-Smith[1], Beatriz Reboredo[2]
[1]NIWA, Wellington
[2]WRNZ, Auckland

The need for accurate turbulence inflow conditions for ultra-fine LES simulations

26 Nov
9:55am

Jiawei Zhang
University of Canterbury

In the recent decade, the use of large eddy simulations to study realistic cases in local scale rural and urban environments has been done mainly through coupling mesoscale models to large eddy simulation models. However, mesoscale models usually use Reynolds Averaged Navier-Stokes Equations (RANS) which parameterize the influence of turbulence on the mean flow. Due to the inadequate turbulence representation in mesoscale models, the turbulence information that passes from mesoscale model to the coupled LES model needs to be added using methods like statistical synthetic turbulence generators, or turbulence recycling method which uses the LES model itself to generate a quasi-steady stage background turbulence as inflow conditions.

The impact of the inflow turbulence information generated at the boundary of the LES domain on the internally (within domain) produced mechanical and thermal turbulence is unknown. To compare the two main methods (synthetic turbulence generator and turbulence recycling) that are widely used, this study investigated the weather conditions in the 2017 Port Hill Fire event. Two simulations with nested LES domains down to 1m grid resolution will be presented using different turbulent inflow initialization methods: one with turbulence recycling (PortRec) and the other one with synthetic turbulence generator (PortSyn) which can represent the performance of the coupled RANS-LES model. Both simulations use an initial vertical profile that represents the large scale meteorological conditions during the simulation period. The terrain and plant canopy information are also included by using the terrestrial LIDAR data from Land Information New Zealand. The inflow velocity fields from both simulations are compared to the Christchurch airport automatic weather station for verification. The work will also use turbulent energy frequency decomposition and gust maps to assess the produced turbulence of these two simulations. The outcome of this study can be used to evaluate the accuracy of the coupled RANS-LES model simulation. With the availability of a new WRF4PALM driver, we can now carry out more real weather driven ultra-high resolution simulations for future work, and the need to assess the performance of PALM becomes inevitable.

Jiawei Zhang, Marwan Katurji, Peyman Zawar-Reza, Dongqi Lin

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26 Nov
11:30am

A progress update of the Extreme Weather Event Real-time Attribution Machine (EWERAM) project

Jordis Tradowsky
Bodeker Scientific

The Extreme Weather Event Real-time Attribution Machine (EWERAM) project, currently underway in New Zealand, aims to develop a capability that can provide the information needed to attribute the effects of anthropogenic climate change on the severity and likelihood of specific extreme weather events (EWEs) within days following an event. An overview of the goals and objectives of the EWERAM project were presented at the MetSoc conference in 2019.

This presentation will provide an update on the developments within the project. Over the last year, several EWEs have been internally analysed by the EWERAM team. The methodology was refined and the estimation of uncertainties was enhanced while working towards the publication of a seminal paper describing the EWERAM approach to EWE attribution. The presentation will also outline remaining challenges which have to be addressed prior to making public statements in the immediate aftermath of an EWE.

Identifying the Data Needs for Severe Weather Impact-based Forecasting and Warning Systems in New Zealand

26 Nov
11:50am

Sara Harrison

Joint Centre for Disaster Research, Massey University

The World Meteorological Organization (WMO) is pushing for the implementation of impact-based forecasting and warning (IBFW) systems, with the goal of improving the communication of hazardous weather. There is a growing need for the standardised collection and storage of impact and risk data to support the implementation of IBFW systems. Methods for collecting impact data differ by country and region, making standardised collection and sharing difficult.

This exploratory PhD research, funded by the Resilience to Nature's Challenges 2 Weather & Wildfire Theme and supported by the HIWeather Project within the WMO's World Weather Research Programme, aims to identify the data needs for IBFWs, and map out existing and potential impact data sources in New Zealand that suit these needs. By interviewing officials from meteorological services and civil defence and emergency management agencies both within and outside of New Zealand, we found that impact data is needed for defining impact-based thresholds for the new warning system and for verifying the warnings. Several data sources were identified; however, finding both timely and trustworthy data and integrating the various datasets for warning purposes remain key challenges and are areas for future research.

The objective of this research is to help stakeholders understand what is available to them, and how they can access and contribute impact information. This will contribute to the implementation of IBFWs in New Zealand while also supporting efforts towards meeting the requirements of the Sendai Framework to build a national impacts and losses database.

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26 Nov
12:10pm

A stocktake of resources and understanding for extreme event attribution

Dáithí Stone
NIWA

Anthropogenic emissions have affected extreme weather events around the world. How has extreme weather in Aotearoa New Zealand been affected? There are now several related "event attribution" research efforts assessing this role, including the Whakahura and EWERAM projects. While EWERAM is developing capability for near-real-time assessments, Whakahura is discerning the time-evolving nature as we progress from the past, through the present, and into the future. In this talk we will present a stocktake of the current status of observational products, modelling tools, and understanding of how humans are affecting multiple different types of extreme weather events. This stocktake has been developed through a survey of experts involved in the Whakahura and EWERAM projects. This talk will discuss how this survey has highlighted areas in which current data and/or understanding preclude confident event attribution conclusions, with a particular focus on when there is disagreement between experts and how this disagreement arises.

Human influence on New Zealand's extreme weather: case studies of hot, cold and wet extreme weather events

26 Nov
1:40pm

Suzanne Rosier
NIWA

Climate change 'attribution' studies seek to understand how, and to what extent, any particular climate forcing acts within the climate system. Model simulations forced both with and without the forcing of interest are compared to isolate, and quantify, the effects. This study is concerned with the effects of human interference in the climate system, in particular its effect on weather extremes. Four attribution studies are described, which investigate how recent hot, cold and wet extremes in New Zealand were affected by human activity. A human influence was clearly apparent in making hot extremes much more likely and cold extremes less so; in the case of rainfall, changes due to human influence were apparent but somewhat more modest. The results align clearly with current understanding about temperature, as against rainfall, attribution. They also highlight the complex nature of the dynamic, as well as thermodynamic, changes that impinge upon rainfall extremes in the New Zealand region.

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26 Nov
2:00pm

Extracting interpretative value from ensembles through clustering

Thomas Adams
MetService

Ensemble NWP model data is numerically dense and there is little value in a human forecaster 'looking at it all'. Instead methods exist to compress this data into usable formats. These methods can be divided into two classes: statistical, which combine members to show ensemble probabilities, exceedances, averages and variance; and causal, which aim to preserve narratives as prescribed by the model physics, such as clustering.

Statistical methods are the more common of the two and, with experience, patterns that correspond to familiar weather scenarios can be recognised. However, as statistical methods combine all members together the result may be non-physical and the scenarios lost. For example, if members are equally split into one of two options, statistical methods may lead a forecaster to believe that both options could occur concurrently.

Causal methods – which preserve causality – facilitate a clearer narrative in terms of the underlying physics and increase interpretive value through expression of familiar scenarios. In this talk we will discuss efforts at MetService to apply clustering to the ECMWF medium and extended range atmospheric model ensembles.

The ECMWF medium-range ensemble extends to 15 days, and MetService has parameterised the members through a Principle Component Analysis (PCA) trained on the members at each timestep, permitting small differences to become apparent. In the interest of choosing a narrative that avoids statistically unlikely severe weather at longer prognosis times (e.g. a tropical cyclone seven days out), each ensemble member was rated by its distance from other members in the parameter space. The most central member was referred to as the most 'normal' member, and an average normality score over days 3-10 was assessed. This 'most-normal' member should avoid the more unlikely scenarios. It was found that this most-normal member was the low-resolution control in around 33% of runs for the ECMWF medium range ensemble, and for the GFS ensemble (GEFS) this increased to around 50%. These numbers were similar in both a New Zealand domain and a larger domain extending over eastern Australia. This is a strong indication that ensemble perturbations can detract value from the original control, and caution should be used when treating ensemble members as individual models. However, in the interest of a consistent narrative this trade-off may be worthwhile.

The ECMWF extended ensemble extends to 46 days. A sliding window averaging method was used on each member, increasing from a 3-day window in week 2 to 7-day window in week 4. At these timescales an unconstrained parameterisation was unpredictable, so the PCA was trained on either the 12 Kidson Types (Kidson, 2000), or a coarser taxonomy of Trough, Zonal and Blocking. Useful information could then be observed showing the movement of groups of ensemble members through different synoptic regimes, which provide a greater level of insight than simple ensemble averages.

A novel approach to tropical cyclone impact modelling

26 Nov
2:20pm

Ian Boutle
NIWA / Met Office

High-impact weather has significant direct and indirect adverse effects for New Zealand, and the weather theme of the Resilience to Nature's Challenges (RNC2) program aims to create physical datasets of extreme weather events not previously available to researchers and end-users in New Zealand. This paper focusses on the potential scenario of a major ex-Tropical Cyclone (ex-TC) hitting Auckland and the north of New Zealand. Highly-detailed, meteorologically consistent data of such an event is produced by relocating the New Zealand land mass into the path of historical ex-TC cases, using convection permitting simulations of the Unified Model. We illustrate the applicability of this method over simpler (non-consistent) methods, and show for ex-TC Cook what wind strength and precipitation totals would have been for a track just slightly to the west of reality. Finally, we illustrate how sub-kilometre simulations nested within the main simulation can add significant additional detail at the city scale, and show how simple modifications, for example raising the sea-surface temperature, can illustrate how events may change in future. This data may prove invaluable in designing future infrastructure and planning for such a scenario.

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26 Nov
2:40pm

Superposition of the sub-tropical jet and the polar front jet in the southwest Pacific

Yang Yang
NIWA

Between about 9 and 13 km height above sea level, two different jet streams exist with wind speeds up to 120 ms^{-1}, the subtropical jet (STJ) and the polar front jet (PFJ). Both occur due to different mechanisms. They are key components of the climate system and their tendencies are potential indicators of climate change. In the southwest Pacific, sometimes only a single meandering jet-stream can be found at ∼30°S, often during winter. A specific example was one that occurred during the end of June 2014. This kind of jet is usually treated as an STJ due to its low latitude. However, over the Tasman Sea immediately to the south of this jet, a cold low-pressure system (or cyclonic eddy) was found along with an associated cold front. These features seem to question the assumption that these jets are subtropical jets because eddies and cold fronts are the key features for the occurrence of the PFJ, not the STJ. Using simulations from the New Zealand limited area model (NZLAM) we have applied criteria used in previous studies for identifying the cores of the Northern Hemisphere STJ and PFJ and have identified the STJ and PFJ cores for this case. This analysis suggests that this meandering jet-stream at 30°S was a merging of the STJ and PFJ, or even a superposition of the two jets with the STJ at a higher altitude. Investigation of the eddy momentum flux divergence further supports this result. To our knowledge, this is the first time that a case of superposition of the STJ and PFJ has been described for the Southern Hemisphere.

Radiation and clouds relationship: Brewster Glacier in the Southern Alps of New Zealand

26 Nov
3:30pm

Nariefa Abrahim
University of Otago

Radiation data collected from an automatic weather station located adjacent to Brewster Glacier in the Southern Alps is analysed. The relationship between incoming radiation fluxes and changes in cloud properties at a high elevation site is examined. Less than half of the top of the atmosphere radiation reaches the surface; 21% is attenuated by the clear-sky atmosphere and a further 31% by clouds. Partly cloudy conditions are most frequent (43%) at a daily time scale, followed by overcast (34%) and clear-sky conditions (23%). A distinct diurnal and seasonal cycle of cloud cover is observed, with clouds most frequent in the afternoon during spring. Daily clear-sky conditions are most common in winter, in particular in June, while the atmospheric transmission of shortwave radiation is lowest in summer. For four months of the year (May to August), the increase in incoming longwave radiation by clouds exceeds the decrease in incoming shortwave radiation. To fully understand how this radiative forcing impacts mountain meteorology, including providing additional energy for glacier melt, further insights about the diurnal and seasonal variability of convective clouds is required.

B.N. Abrahim[1], N.J. Cullen[1] and J.P. Conway[2]

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[2]National Institute of Water and Atmospheric Research, Lauder, New Zealand

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26 Nov
3:50pm

Investigation into real-time correction of radar data to account for enhancement at the bright band

Lydia Watson
Weather Radar New Zealand

Scanning rain radars offer an efficient way to monitor the spatial and temporal distribution of rainfall. However, radar does not measure rainfall directly but rather the radar reflectivity from which rainfall estimates are derived. A critical source of bias is the enhancement in radar reflectivity at the freezing level, the so-called "bright-band". When radar measurements sample melting hydrometeors, the large slow-falling water-coated particles lead to much higher radar reflectivities than would be recorded from an equivalent quantity of liquid rain at the surface and result in the overestimation of rainfall rates. The spatial and temporal variability in the height and intensity of the bright band makes it challenging to reliably correct scanning radar data to account for this effect.

The bright band at a single location can be measured precisely by vertically profiling radar systems and corrections can then be applied regionally. However, vertically profiling data sets have only become available in Auckland in the last few years, so it is not possible to use these direct observations to correct all of the Auckland radar record, or moreover other radar records from around New Zealand. In this talk we present progress on estimating the effect of the bright band directly from the scanning rain radar measurements themselves. By fitting a model of the bright band to regions across the Auckland scanning radar's domain, we were able to apply a correction to radar measurements from past data and improve the accuracy of rainfall accumulation estimates. This method was then validated by comparing the derived profiles with the directly observed profiles from a calibrated vertically pointing radar.

Lydia Watson, John Nicol, Luke Sutherland-Stacey
WRNZ, Auckland

Doppler radar spectral retrieval of drop size distributions and vertical air motion

26 Nov
4:10pm

John Nicol

Weather Radar New Zealand

Vertical pointing radars can be used to estimate profiles of drop size distributions based on the measured Doppler spectrum. This is based on the relationship between drop diameter and terminal fall speed, assuming no significant vertical air motion. Such measurements can be used to derive simultaneous profiles of radar reflectivity and rainfall rate. The quality of these observations can be directly assessed using collocated rain gauge measurements. The radar reflectivity profiles provide the most direct means of evaluating the overall calibration of scanning meteorological radars and of quantifying the accuracy of corrections such as for attenuation. These are necessary steps when deriving high quality rainfall maps from scanning radar measurements. The profiling observations are also relevant for studies of the evolution of drop size distributions (e.g. due to drop accretion or evaporation).

However, the assumption of negligible vertical air motion is often broken. Even relatively modest updrafts or downdrafts of $1 ms^{-1}$ can result in an approximate doubling or halving of inferred rainfall rates respectively. This can bias long term profiling radar rainfall estimates as the errors are skewed towards overestimates. A method has been developed to estimate the vertical air motion and correct for its effect. This has been applied to observations from a 24-GHz Metek Micro Rain Radar. The validation of this method is presented and applications including the correction of regional radar measurements and detailed studies of orographic enhancement are discussed.

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26 Nov
4:30pm

A new rainfall dataset for the Auckland Region

Beatriz Reboredo Viso
Weather Radar New Zealand

Radar derived quantitative precipitation estimation (QPE) is used by a range of stakeholders within Auckland Council Healthy Waters department for activities such as flood and bathing water quality forecasting, post event stormwater investigations, and catchment development planning. Typically radar QPEs are prepared with approaches that adjust the radar measurement to match with rain gauges, in order to constrain the uncertainties that result from radar calibration, drop size distribution, vertical profile and path integrated attenuation uncertainties, among others. However, the success of such approaches depends on careful data treatment and rigorous quality control.

In this talk we report on the results of applying an improved analysis method to a 12-year record of historical rainfall radar data from the MetService Auckland radar. The updated decadal analysis employs an Ordinary Kriging of Radar Errors (OKRE) approach, utilising regional rain gauge observations. Inherent to the methodology is a requirement to eliminate erroneous rain gauge measurement in order to avoid "contamination" of the radar analysis. Once those gauge results identified as erroneous are ruled out from the archive dataset the radar retrievals may be optimally prepared. To test the end-to-end system, a "leave one out" cross-validation is performed. We show that the spatial QPE derived from OKRE substantially outperforms conventional gauge-alone interpolation methods. At short distances to the radar, the radar analysis alone outperforms the gauge-alone interpolation, without the need to gauge adjustment at all. Potential benefits of using radar data for different catchment-scale applications will also be discussed.

Offshore Rainfall Climatology from Space-borne Rain Radar

26 Nov
4:50pm

Tim Kerr
Rainfall.NZ

Observations of rainfall radar-reflectivity have been collected systematically across the mid-latitudes since 2014 from the Global Precipitation Mission core observatory satellite. Active rain radar is capable of directly sensing the near-surface rainfall field. This is not possible from the more-common satellite rainfall estimate techniques of passive microwave or infrared sensing. This difference should enable reduced uncertainty of returned rainfall intensity values. In theory, the radar observations should enable the generation of rainfall intensity probability distributions for any location between 65°N and 65°S.

Comparison of rainfall intensity distributions from the space-borne rain radar were compared to the distributions obtained from rain intensity gauges. The distributions show close agreement below the 90^{th} percentile at locations with low relief terrain. The findings indicate that the distributions offshore (where no gauge data are available) are likely to be reasonable. This would fill a large gap in our knowledge of the precipitation distribution in the New Zealand region.

An obvious application is to use this off-shore data to help validate/calibrate weather models. Currently validation of rainfall output from weather models is limited to land areas. Inclusion of offshore rainfall observations quadruples the area that could be validated within a New Zealand model domain. The addition of offshore validation also enables checking whether model process deficiencies are land related, thereby focusing efforts in model improvement.

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27 Nov
9:15am

Urban greenhouse gas emission response to COVID-19 shutdowns in New Zealand and North America

Jocelyn Turnbull
GNS Science

COVID-related shutdowns resulted in dramatic reductions in traffic and to a lesser extent other anthropogenic emission sources. Globally the change in emissions, although substantial, will be challenging to distinguish from the large and varying greenhouse gas background signal. In contrast, greenhouse gas emission changes are expected to be more readily detectable in urban areas, due to the concentration of emissions from cities.

Here we present results from greenhouse gas observation networks across Auckland, Wellington and six North American cities. The North American cities have all been instrumented for greenhouse gas measurements for several years including through the COVID shutdown period, with each city having similar but slightly different experimental configurations. We examine multiple observational analysis methods to evaluate the timing and magnitude of emission changes. The ratio of CO_2:CH_4 indicates a 10-20% drop in CO_2 emissions in most cities. Cumulative enhancement analysis allows us to detect the timing of the abrupt emission decline, and our results are consistent with traffic data and government directives.

In New Zealand, our long-term network was not yet installed and travel was very limited during Level 4 lockdown, so we used novel techniques to detect emission changes. We initiated a citizen scientist project, the Great Greenhouse Gas Grassoff, in which grass samples were collected at sites all around New Zealand throughout the lockdown. Radiocarbon (^{14}C) analysis allowed us to determine the daytime weekly mean fossil fuel CO_2 mole fraction at each site. Urban roadsides show emission reductions of $\sim$80% during Level 4 lockdown at most locations.

Implications for air quality management of changes in air quality during lockdown in Auckland (New Zealand) in response to the 2020 SARS-CoV-2 epidemic

27 Nov
9:35am

Hamesh Patel

The University of Auckland

The current changes in vehicle movement due to 'lockdown' conditions (imposed in cities worldwide in response to the COVID-19 epidemic) provide opportunities to quantify the local impact of 'controlled interventions' on air quality and establish baseline pollution concentrations in cities. Here, we present a case study from Auckland, New Zealand, an isolated Southern Hemisphere city, which is largely unaffected by long-range pollution transport or industrial sources of air pollution. In this city, traffic flows reduced by 60–80% as a result of a government-led initiative to contain the virus by limiting all transport to only essential services. In this paper, ambient pollutant concentrations of NO_2, O_3, BC, PM2.5, and PM10 are compared between the lockdown period and comparable periods in the historical air pollution record, while taking into account changes in the local meteorology. We show that this 'natural experiment' in source emission reductions had significant but non-linear impacts on air quality. While emission inventories and receptor modelling approaches confirm the dominance of traffic sources for NO_x (86%), and BC (72%) across the city, observations suggest a consequent reduction in NO_2 of only 34–57% and a reduction in BC of 55–75%. The observed reductions in PM2.5 (still likely to be dominated by traffic emissions), and PM10 (dominated by sea salt, traffic emissions to a lesser extent, and affected by seasonality) were found to be significantly less (8–17% for PM2.5 and 7–20% for PM10). The impact of this unplanned controlled intervention shows the importance of establishing accurate, local-scale emission inventories, and the potential of the local atmospheric chemistry and meteorology in limiting their accuracy.

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27 Nov
9:55am

Monitoring Auckland Emissions and Air Pollution in 2020

Jamie Halla

Defence Technology Agency

During the COVID lockdown there was an unprecedented period of low emissions in the Auckland region, and New Zealand as whole. The Defence Technology Agency (DTA) has collected a large data set of various pollutants measured during all levels of the COVID-19 lockdown. These include NO_2, SO_2, HCHO, O_3, PM10, and PM2.5. Measurements were performed using ground-based point source instruments such as electrochemical cells and laser particle counters. However, the largest data set consists of data collected using Multiple AXis Differential Optical Absorption Spectroscopy (DOAS). The MAX-DOAS technique used makes use of absorptions in scattered light to simultaneously identify several trace gases in one measurement scan. Also, by varying the elevation pointing angle of the instrument vertical profiling of the gases may also be performed. This offers a distinct advantage over the other point source techniques. This talk will examine preliminary results from the entire data set and look at trends in the Auckland region before and after the COVID lockdown.

Mapping Air Pollution eMissions (MAPM): The winter 2019 air pollution (PM2.5) measurement campaign in Christchurch

27 Nov
12:45pm

Ethan Dale
Bodeker Scientific

MAPM (Mapping Air Pollution eMissions) is a project whose goal is to develop a method to infer particulate matter (PM) emissions maps from in situ PM concentration measurements. In support of MAPM, a winter field campaign was conducted in Christchurch in 2019 (June to September) to obtain the measurements required to test and validate the MAPM methodology. Two different types of instruments measuring PM were deployed: ES-642s (17 instruments) and outdoor dust information nodes (ODINs; 50 instruments). The measurement campaign was bracketed by two intercomparisons where all instruments were co-located, with a permanently installed tapered element oscillating membrane (TEOM) instrument, to determine any instrument biases. Changes in biases between the intercomparisons were used to determine instrument drift over the campaign period. In addition to the PM measurements, meteorological variables (temperature, pressure, wind speed and wind direction) were measured at three AWS (automatic weather station) sites established as part of the campaign.

Here we present the data collected during the campaign and discuss the correction of the various PM instruments used, including the calculation of measurement uncertainties. We find that for low-cost ODINs, a correction based on environmental conditions is beneficial, while for the more sophisticated ES-642s this results in over-fitting, increasing the uncertainties on the corrected data. We also compare PM2.5 and PM10 measured by ODINs which, in some cases, allows us to identify PM from natural and anthropogenic sources. All measurements presented here are publicly available from the MAPM website (`www.mapm.co.nz`).

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27 Nov
1:05pm

WRF4PALM: A Mesoscale Dynamic Driver for the Urban-Scale PALM Model System 6.0

Dongqi Lin
University of Canterbury

We present the new WRF4PALM dynamic driver for the urban-scale PALM model to read mesoscale data from the Weather Research and Forecasting (WRF) model. The WRF mesoscale modelling system is widely used across the atmospheric science community for a broad range of multidisciplinary applications. For accurate and representative urban environmental modelling, the need to understand the microscale meteorological dynamics becomes important and requires development of new dynamical downscaling methods from the mesoscale to microscale. The PALM model system 6.0, which has a turbulent-resolving large-eddy simulation (LES) model at its core, has proven useful for microscale complex urban meteorological applications. PALM is able to resolve surface structures explicitly on a fine Cartesian grid. While it is possible to process the regional scale Consortium for Small-scale Modelling (COSMO) atmospheric prediction model outputs using software embedded in PALM, it is not yet possible to use COSMO outputs with PALM in most regions outside Europe. The WRF4PALM tools allow PALM to read space- and time-varying mesoscale data from WRF simulations. WRF4PALM was developed for the Ministry of Business, Innovation and Employment project Particulate Matter Emissions Maps for Cities (MAPM). Here, we present two case studies for Christchurch, New Zealand that demonstrate successful PALM simulations driven by synoptic forcing from WRF outputs using WRF4PALM. The WF4PALM dynamic driver tools developed in this study can potentially be used for micro- and mesoscale studies worldwide, for example in understanding air pollution events, wildfire emissions and spread, urban weather forecasting and agricultural meteorology.

Long-lived smoke clouds from the Australian megafires measured over Lauder, New Zealand

27 Nov
1:25pm

Richard Querel
NIWA

During January and February 2020, smoke from the Australian megafires drifted over Lauder, New Zealand. Some of the smoke was measured at Lauder within days, while other pyrocumulus smoke clouds continued over and back across the Pacific before passing over Lauder again weeks after leaving Australia. We present: in situ trace gas data from the early smoke periods; ozonesonde profiles from balloons launched directly into a 50-day-old smoke cloud, then lofted to 25-30 km altitude by radiative heating of absorbing aerosol (reporting extremely low ozone in the cloud and a temperature dipole across it); stratospheric water vapour retrievals from a microwave radiometer (showing high abundance); N_2O and CO from FTIR measurements (both showing high abundance); and aerosol LIDAR retrievals (confirming the vertical position of the smoke cloud). These ground-based measurements agree with the space-based aerosol, temperature and trace gas estimates from MLS, CALIPSO, GOME-2 and TROPOMI.

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27 Nov
1:45pm

Could airborne microplastics play a role in climate change?

Laura Revell

University of Canterbury

Approximately 5 billion tons of plastic waste have accumulated in landfills or the natural environment to date. This will increase to 12 billion tons by 2050 if current trends continue. The breakdown of larger plastics produces microplastics, which are ubiquitous contaminants in waterways, oceans and on land. In the last 3 years several studies have identified microplastics in atmospheric fallout over a range of urban and remote regions from the Arctic to Antarctica. Particulate matter in the atmosphere modifies atmospheric temperature by absorbing and scattering solar and terrestrial radiation, but exactly how it behaves depends on particle size, shape and composition. We calculated the optical properties of microplastics and implemented microplastics as a class of atmospheric aerosol in a general circulation model. Simulations were performed to calculate the radiative forcing of airborne microplastics. Concentrations of airborne microplastics, and the radiative forcing associated with them, are expected to increase in future as plastics continue to accumulate in the environment.

Marine biological influence on cloud properties - Overview of the Sea2Cloud voyage 2020

27 Nov
2:05pm

Mike Harvey
NIWA

The Sea2Cloud voyage took place between 16 March and 27 March 2020 on R/V Tangaroa in the Chatham Rise region to the east of New Zealand. This joint NZ/European Research Council funded project focused on the question of whether marine living microorganisms influence clouds. This question was originally posed as the CLAW hypothesis in 1987 but definitive demonstration of the entire hypothesis process chain remains elusive. In situ observations were made in the surface ocean and atmosphere of precursor gases and aerosol properties as well as remotely sensing the atmosphere and cloud above the vessel. Two on-board (mesocosm) air-sea interaction tanks (ASITS) with 1 cubic metre of sea-water provided a facility for following the evolving impact of biology in seawater and headspace air of the tank over periods of a couple of days.

In Sea2Cloud two process chains were investigated:

1. via the emission of short-lived gases that may be oxidized to extremely low volatility chemical compounds and form nanoparticles in the marine boundary layer (MBL). These nanoparticles and longer lived gas-phase species such as DMS can be transported to higher altitudes where they encounter conditions favourable to further oxidation, nucleation and early growth: with high UV radiation, low temperatures and low pre-existing particle concentrations. Once they reach CCN-relevant sizes (between 50 and 100nm), they may form cloud droplets and modify cloud properties.

2. via direct emission of microorganisms, fragments and organic components into the atmosphere by bubble bursting during wave breaking. These particles are much less numerous than the newly nucleated ones, but some of them have excellent ice nucleation properties and form ice crystals before other particles. The experiment looked at the efficiency of sea-spray aerosol for ice nucleation and the implication for clouds in the region. The presence of ice is significant for affecting cloud radiative properties and lifetime.

We present an overview of the voyage, and some of its preliminary findings in comparison to other measurements made in the region.

Mike Harvey, Cliff Law, Karine Sellegri, Fred Peyrin, Maija Peltola, Jon Trueblood, and S2C science team

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27 Nov
2:25pm

Using Air-Sea Interaction Tanks to Study the Effect of Marine Biology to Aerosol Formation

Maija Peltola

CNRS/ French National Research Centre

Marine micro-organisms such as phytoplankton can emit chemical vapours into the air and once these vapours react in the atmosphere they can nucleate and form secondary aerosol particles. Aerosol particles are important for the climate because of their radiative effects and ability to affect the formation and properties of clouds. While a connection of marine biology and climate through aerosol formation was first proposed already in the late 1980s, the processes related to this connection are still uncertain.

In order to study secondary aerosol production from marine biological emissions directly, we used self-built Air-Sea Interaction Tanks (ASIT). The bottom part of the tanks contained 1000 litres of real seawater which was sampled daily to obtain an image of the composition of the biological community and chemical properties of the seawater. The headspace above the water contained 1000 litres of air and it was continuously sampled and replaced with clean air. The air was monitored for aerosol number concentrations in different size ranges, chemical composition of molecular clusters and gas phase chemical species. By monitoring both the air and seawater simultaneously, we can identify which biological species are responsible for aerosol formation.

The tanks were used during the Sea2Cloud research voyage in March 2020 in the South Pacific Ocean. This way we could collect seawater from various locations with varying biological activity.To further expand our knowledge from the voyage, we performed additional experiments with coastal New Zealand seawater during winter 2020.

The preliminary results of the ASIT experiments show formation of particles in the smallest observable size range of 1-3nm and the concentrations of these particles varied depending on where the seawater was taken from. This shows that aerosols can be formed from seawater chemical emissions and that the formation depends on the biological properties of the seawater. In this presentation I will give a more detailed overview of the preliminary results of the experiments.

Pecha-Kucha Presentations

Climate sensitivity and radiator fins

Nick Edkins
The University of Auckland

The tropical warm pool, if isolated, would experience a runaway greenhouse effect and a very large temperature increase. The reason that this doesn't happen is because energy is transported both zonally, to cold pools, and meridionally, to the subtropics and poles. Because these regions are clearer and drier, energy can escape them more easily without requiring a large temperature increase. These regions are analogous to the fins that cool a radiator. The presence of these climatic radiator fins decreases the sensitivity (or increases the stability) of the system as a whole. The effectiveness of a region as a radiator fin depends on both its local sensitivity relative to the rest of the planet and the strength of the heat transport into the region.

We have devised a simple analytical model to quantify the effectiveness of a radiator fin, which gives the reduction in the sensitivity of the whole system caused by transport into the fin. Using a 2D radiative convective model, we then identify the regions of the planet with the greatest radiator fin effectiveness, which therefore contribute the most to overall climate stability. Of particular interest are the tropical cold pools, the subtropical dry zones, and the poles.

The effect of atmospheric forcing on glacial mass balance in the Ross Sea Region of Antarctica

Tamara Pletzer
University of Otago

The 2°C global warming target of the Paris Agreement, as well as a variety of climate change scenarios, are hypothesized to impact the distribution of water in the Ross Sea Region (RSR) with consequences on ecosystems. This recently commenced PhD (which is funded by the Antarctic Science Platform and the University of Otago) aims to adapt a coupled atmosphere and glacier dynamics model to the McMurdo Dry Valleys, one of the most ecologically studied terrestrial regions in Antarctica, also known to be the driest place on Earth. The expected outcome will be a better understanding of how glacier melt rates and subsequent hydrological routing will respond to changes in the climate by the end of this century. I will discuss challenges and present our methodology.

T.O. Pletzer[1], N.J. Cullen[1], M. H. Katurji[2], and J.P. Conway[3]

[1]University of Otago, New Zealand
[2]University of Canterbury, New Zealand
[3]NIWA, New Zealand

Revisiting the 'Kidson' synoptic types over Aotearoa New Zealand

Jonny Williams
NIWA

Clustering of dominant geopotential height patterns over Aotearoa New Zealand has a history stretching back more than 25 years and was epitomised in 2000 in Kidson's seminal paper on the topic (Kidson, Int J. Climatol., 20 (3), 2000). In this work, the Kidson types are reformulated from scratch and show broadly similar results but with some interesting differences too, most notably with respect to blocking. These differences are, in part, attributed to the more numerically rigorous treatment given here. This is possible due to the vast improvements in computational power since the mid 1990s. As well as using the NCEP/NCAR reanalysis (as Kidson did), we will also present equivalent types found using the new ERA-5 reanalysis, which has 10 times the spatial resolution in both longitude and latitude, making for 100 times better spatial coverage. This hugely improved resolution allows examination of orographic features which are absent in previous work.

Development of an objective once-daily and two-tiered synoptic type classification for New Zealand

Neelesh Rampal
NIWA

This research objectively identified an optimal number of once-daily synoptic types (also known as atmospheric regimes) within the New Zealand region, and linked their occurrence to large-scale modes of variability. An optimal number of naturally-occurring once-daily synoptic types was initially determined using Affinity Propagation. From this objective position, we applied k-means clustering to the z1000 geopotential height in several reanalysis products to identify eight basic atmospheric regimes for New Zealand. Each regime is characterised by spatial heterogeneity in the z1000 field that lend to different directions and intensity of atmospheric flow over the country. All of the eight atmospheric regime archetypes have a unique spatial pattern for temperature and precipitation anomalies, which varies significantly at a regional and sub-regional level. Frequency changes for the occurrence of once-daily synoptic types are strongly correlated with annual and seasonal anomalies in rainfall and temperature. Our analysis also further interrogated the once-daily atmospheric regime classification using a Euclidean distance score partitioning approach, which re-classified a subset of each initial regime categorisation in order to examine geopotential patterns associated with extreme weather. Unsurprisingly, the subsidiary set of once-daily synoptic types appears to be more significantly associated with stronger daily rainfall and temperature anomalies relative to the archetypes they were previously categorised with. This approach reveals an improvement on previous work that used k-means to analyse extreme weather. Associations between large-scale circulation (IPO, SOI, SAM) and fluctuations in the occurrence of once-daily synoptic types and their effects on regional climate is also quantified, particularly for events such as flooding and drought.

Analysis of trends in extremes from NIWA's climate rankings

Raghav Srinivasan
NIWA

NIWA routinely produces monthly, seasonal and annual climate summaries based on station observations within the National Climate Database (CliDB). These summaries provide historical context for contemporary observations of temperature, rainfall, sunshine and gust speed throughout the country. This routine process involves ranking the observations of selected climate variables based on station groupings, where historic data from nearby closed stations is used to provide a historic context for climate observations from recently established stations. From 2008 onwards, the top and bottom 4 rankings for individual station groupings have been calculated on a monthly basis. Here we investigate trends in the occurrence of high or low rankings for selected variables (mean temperature, max temperature, min temperature, total rainfall) from 2008 till 2019. The method applied to analyze the ranking data will be described, including discussion on how record length impacts upon the occurrence probability of new extreme rankings.

Life-cycle and societal impacts of atmospheric rivers in New Zealand and the West Coast of the USA

Hamish Prince
University of Otago

The occurrence of extreme precipitation events in New Zealand regularly results in devastating impacts to the local society and environment. In order to examine the occurrence of extreme precipitation in New Zealand, extreme horizontal atmospheric moisture fluxes are considered through an application of the emerging concept of atmospheric rivers (ARs). ARs account for 76% of total precipitation and up to 93% of extreme precipitation on the West Coast of the South Island, suggesting that ARs are the dominant synoptic feature producing orographic precipitation in the central part of the West Coast of New Zealand. Precipitation totals during AR events on the West Coast of the South Island exceed 1000mm within 3 days, possibly the most intense documented AR precipitation globally. A distinct seasonality exists in AR occurrence aligning with seasonal variations in the mid-latitude jet streams and consequently, mid-latitude cyclone tracks. The formation of the Southern Hemisphere winter split jet enables AR occurrence to persist through all seasons in northern regions of New Zealand, while southern regions of the country exhibit a substantial (50%) reduction in AR occurrence as the polar jet shifts southward during the cold season. ARs making landfall on the western coast of New Zealand (90% of all events) are characterised by a dominant north-westerly moisture flux associated with a distinct dipole pressure anomaly: low pressure to the south-west and high pressure to the north-east of New Zealand. The synoptic- and meso-scale atmospheric controls of AR-related extreme precipitation along the central West Coast of the South Island of New Zealand should remain a priority to comprehend the role of ARs on local hydrological extremes. The societal impacts of ARs are also explored, providing an example using flood insurance losses from the West Coast of the USA while considering how similar weather systems impact society in New Zealand.

A prognostic dust approach to test the role of ice nucleating particles in a climate model

Vidya Varma
NIWA

We have modified cloud micro-physics in a recent version of the Met Office's Unified Model (i.e., the atmosphere component of the New Zealand Earth System Model) and show that choosing a more realistic value for the shape parameter of atmospheric ice crystals, in better agreement with theory and observations, benefits the simulation of short-wave radiation over the Southern Ocean (SO) region. However, this approach to modify the cloud phase by directly adjusting micro-physics process rates tend to affect both hemispheres symmetrically, which improves the southern high-latitudes radiation bias but leads to some deterioration elsewhere. One way of achieving an asymmetric response is by making the ice-nucleating temperature dependent on the amount of dust in each grid box, thus mimicking the role of ice nucleating particles (INPs) in the atmosphere. By activating this prognostic dust approach, the nucleation temperature is here defined as to vary three dimensionally globally as a function of the mineral dust distribution in the model. This delays the heterogeneous nucleation in regions with lower dust number density (thus targets cleaner environments like the SO where INPs are relatively scarce) by lowering cloud freezing temperatures relative to other regions.

Night-time cloud properties over Lauder from ceilometers and all-sky cameras

Alexander Geddes
NIWA

At the Lauder atmospheric research station we have a multi-decade record of all-sky camera images and estimates of cloud fraction based on them. Night-time conditions are challenging for cameras designed for day-time operation. Some algorithms use star counting to estimate night-time cloud cover, but that technique requires extremely dark skies and will not function if any background city glow is illuminating the sky. Ceilometers are autonomous instruments that actively measure cloud base height and profiles using reflected laser light. While only a pencil-beam of light as opposed to the all-sky coverage of a fish-eye lensed camera, the ceilometers can operate daytime and night-time. We present some estimates of Lauder night-time cloud cover and sky conditions based on a comparison made between the daytime all-sky camera cloud estimates and daytime ceilometer estimates, and then applying that relationship to the night-time ceilometer data.

Improved Real-Time Quantitative Precipitation Estimation for Bangkok

Luke Sutherland-Stacey
Weather Radar New Zealand

The Bangkok Metropolitan Area is set in the alluvial plains of the Chao Phraya River system and home to some 15M residents spread over about 7000km^2. The region is subject to frequent flooding, from localised sub-km flash flooding due to afternoon convection to much more widespread flooding driven by drainage of monsoon rains. The localised rain patterns which are responsible for flash flooding are very difficult to observe with the metropolitan rain gauge network, and still more difficult to accurately forecast even with modern NWP systems. The city is well served by two Doppler weather radars operated by the Bangkok Metropolitan Authority, but to date no effort has been made to prepare Quantitative Precipitation Estimates or Nowcasts from the radar observations. In this talk we report on progress in preparing the radar data for real-time dissemination to regional stakeholders, coupling with urban stormwater models, and provide some examples of the rainfall accumulation maps now available to the city authorities.

MAPM: An overview of the Mapping Air Pollution eMissions project

Greg Bodeker
NIWA

MAPM (Mapping Air Pollution eMissions) is a 2.5-year project whose goal is to develop a method to infer particulate matter (PM) emissions maps from in situ PM concentration measurements. There are health concerns associated with airborne PM as, when inhaled, PM elevates the risk of developing heart-related illnesses and lung-related diseases. As the negative health impacts of airborne PM have become more obvious, the pressure on city officials to implement PM emissions mitigation strategies has increased. Establishing an effective air quality management strategy requires tools that can correctly identify the sources of air pollution. The MAPM project seeks to provide a tool where, given in situ measurements from a range of sensors (potentially of varying cost and quality) over the domain of a city and meteorological fields that describe the flow of air through that domain, an inverse model can be used to infer PM emissions maps for the city over some prescribed period (e.g. a daily mean emissions map) and the uncertainty on those maps. This presentation will provide an overview of MAPM, the key components of MAPM, and what has been achieved to date in advancing the development of those components. Presentations on specific aspects of MAPM will be presented elsewhere through the conference.

Posters

Global climate model simulations of natural aerosols over the Southern Ocean

Yusuf Bhatti
University of Canterbury

We studied Southern Ocean aerosols in an Atmospheric Global Climate Model (AGCM) that contributed to the sixth phase of the Climate Model Intercomparison Project (CMIP6), which will inform the forthcoming assessment by the Intergovernmental Panel on Climate Change. The AGCM contains significant errors over the Southern Ocean, which cascade to errors in climate change projections for New Zealand. Large sources of uncertainty include simulated clouds over the Southern Ocean, along with aerosols, which seed cloud formation. Aerosols over the Southern Ocean are primarily natural in origin, such as sea spray aerosol and sulfate aerosol formed by photoplankton-produced dimethyl sulfide. We evaluated aerosols over the Southern Ocean in the model against satellite and in-situ observations. Simulations were performed to compare sulfate aerosols using the AGCM biogeochemistry scheme versus the seawater DMS climatology used by the previous version of the model. The results show the impact of seawater DMS on sulfate aerosols and their influence on cloud formation.

Mapping Air Pollution eMissions (MAPM): FLEXPART-PALM, a Lagrangian dispersion particle model driven by meteorological fields obtained from PALM

Leroy Bird
Bodeker Scientific

Lagrangian particle dispersion models (LPDMs) are a powerful tool for modelling atmospheric transport. A LPDM tracks the dispersion of all particles from their sources/sinks to receptors, i.e. measurement sites, when running forward in time, or from receptors to their sources/sinks when running backwards in time. Within the MAPM project, we use a LPDM FLEXPART (FLEXible PARTicle dispersion model) to derive the source-receptor relationships that will be used in the inversion model framework to infer air pollution sources on city scale. Required input for FLEXPART is to provide meteorological fields, which can be obtained from, for example, mesoscale model output such as the Weather Research and Forecasting model (WRF).

Here we present the development of a different branch where output from a high resolution Parallelized Large-eddy Simulation Model (PALM) can be used to drive the motion of particles within FLEXPART, hereafter referred to as FLEXPART-PALM. FLEXPART-PALM is an offline, city scale, stochastic LPDM, developed on top of the FLEXPART-WRF model version 3.3. Unlike the built in LPDM in PALM, FLEXPART-PALM is capable of running backwards in time. Backwards simulations are much more efficient for developing source-receptor relationships, when the number of receptors is smaller than the number of sources. As a result, FLEXPART-PALM's backward capabilities can effectively derive emission footprints, i.e. the contribution of an emissions map to air pollution at a particular location. We will showcase the FLEXPART-PALM model, results of the performed validation and a comparison between footprints derived from FLEXPART-PALM and FLEXPART-WRF.

Leroy Bird, Matthias Sühring, Massimo Cassiani, Stefanie Kremser, Helge Knoop, Katrin Gehrke, and Dongqi Lin

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Development of A Full Carbon Budget for Auckland, New Zealand

Lucas Domingues
GNS Science

New Zealand has committed to ambitious greenhouse gas emission reductions. Yet key questions surrounding forest, grassland and urban carbon exchange remain unanswered. Recent studies hypothesize that urban ecosystems could absorb twice as much carbon as natural forest, but no direct evidence has yet been presented for any city. We will establish the first full urban-scale carbon exchange estimation for Auckland, incorporating both fossil emissions and carbon uptake by the urban ecosystem.

Being an island, the biggest city of New Zealand has a strategic geographical position, which facilitates the measurements of incoming background gases and the urban atmospheric contribution (Figure 1). We will perform measurements of CO, CO_2 and CH_4 using a Cavity Ring-Down Spectroscopy monitor at four sites which will provide the upwind background constraint and the urban plume information. In addition, an automatic flask sampler will collect weekly one-hour time-integrated air samples for analysis of CO_2, CO, CH_4, N_2O and COS concentrations, and the isotopes ^{13}C, ^{18}O and ^{14}C in CO_2. The measurements collected in this study will be used in city scale Atmospheric Inverse Modelling. Comprehensive assessment of NZ's carbon balance will enable emission mitigation strategies to be developed that optimise environmental, social and economic benefits.

L. Domingues[1], J. Turnbull[1],[2], L. Keller[1], J. Thompson[1], J. Collins[1], S. M. Fletcher[3], G. Brailsford[3], S. Xie[4], N. Goubiewski[5], K. Gurney[6] and L. Hutyra[7].

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Evaluating Regional Methane Emission in New Zealand Using Inverse Modelling

Alexander Geddes
NIWA

Agriculture accounts for nearly half of New Zealand's greenhouse gas emissions, primarily from enteric fermentation. Knowing this and that the farming sector must make progress in reducing emissions at the farm scale before joining the emissions trading scheme by 2025, it is vitally important to be able to monitor emissions rather than relying solely on bottom-up estimates. In this paper we present early results of a study into regional methane emissions of New Zealand using in-situ measurements of methane at NIWA's world class observations sites, the NAME dispersion model and a Bayesian regional inversion scheme. The early inversion results for 2017-2019 show that quantifying sub-national methane emissions is possible with strong error reduction and high degrees of freedom, particularly for strongly emitting, observation adjacent regions. We will also show the extent to which these results are dependent on the baseline, inter-site biases and the dispersion and meteorological modelling used in order to provide a robust and policy relevant quantification of sub national methane emissions.

New* UV Irradiance Measurements at Lauder

Alexander Geddes
NIWA

The spectral UV measurements made at Lauder are world class and provide an invaluable long-term dataset. Here we introduce two 'new' instruments that add significant value to our existing measurements. Firstly we present the UV-2 system which shares the same design as our existing spectrometer series, but crucially alternates between direct and global measurements. This allows us to explore Dobson-like measurements of ozone, diffuse irradiance and aerosol properties as well as our typical UV measurements. We present the first processing of a near ten year time series. We also present early data from a brand new, array based spectrometer, the Gigahertz UV Spectroradiometer. The Gigahertz is able to make measurements of the UV spectrum in a few seconds compared to the several minutes typical spectrometers need. This allows us to explore rapidly varying effects, such as cloud enhancement, at an unprecedented temporal resolution.

Discovering the climate of Antarctica and Southern Ocean

Alexandra Gossart

Anatrctic Research Centre, Victoria University of Wellington

The Antarctic continent which is almost fully covered by snow and ice, is not only the highest, windiest, coldest, and driest, but also the most remote land mass on Earth, entirely surrounded by the Southern Ocean. Owing to the remote location and harsh climate conditions, especially outside austral summer, we know relatively little about the Antarctic continent.

Studying the Antarctic climate is not trivial, as changes in the amount of incoming mass (precipitation) and mass losses (surface sublimation, erosion, meltwater runoff and iceberg calving) determine the contribution of the Antarctic ice sheet to sea level rise and changes in the atmospheric and oceanic circulation. In that aim, we apply the Polar-WRF regional climate model on Antarctica and simulate the year 2013 in order to assess its performance regarding meteorological surface variables, but also radiation parameters and surface mass balance, or accumulation.

The Long and Winding Path from a Sketch to Rainfall Data

Sally Gray
NIWA

A lovely hand drawn and coloured sketch was sent to the Meteorological Office in January 1909. It resurfaced at NIWA in 2020.

This presentation follows the path we have taken to learn about the early rainfall readings from the Mt Peel area of South Canterbury. What has changed over the last 120 years? ...which station is it actually from? ...and are any of these locations still recording rainfall?

Measuring Shipping Emissions via MAX-DOAS in Auckland

Jamie Halla
Defence Technology Agency

Multiple-AXis Differential Optical Spectroscopy (MAX-DOAS) measurements were taken recently from Defence Technology Agency field stations within the New Zealand Defence Force at Army Bay Whangaparaoa and HMNZS Philomel 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 poster will discuss preliminary results from these measurements.

HIWeather Citizen Science Project: a 2020 update

David Johnston
Massey University

High Impact Weather Project (HIWeather), a 10-year research project, was established in 2016 by the WMO (World Meteorology Organization) WWRP (World Weather Research Program). HIWeather is aimed at achieving dramatic improvements in the effectiveness of weather-related hazard warnings, following recent advancements in numerical weather prediction at km-scale and in disaster risk reduction. This poster describes the HIWeather Citizen Science Project. With many new and ongoing citizen projects planned or underway within the High Impact Weather community, this project is designed to share information and to provide tools to help groups and agencies develop new activities.

David Johnston, Marion Tan, Julia Becker, Lisa McLaren, Lauren Vinnell, Sara Harrison, Ben Payne, Emily Campbell
Massey University, Wellington

The good, the bad and the fast – comparing three agricultural pile burning techniques

Jessica Kerr

Scion

Agricultural burning is a large contributor to particulate matter air pollution that exceeds the National Environmental Standards in the Tasman District. To improve understanding of the agricultural burning challenge, the Tasman District Council, working in partnership with Scion, undertook a field-based research trial to monitor the effectiveness of current best practice for outdoor wood burning of orchard wood during winter. The experiment assessed three different burning practices,

1. standard practice,
2. current best practice, and
3. new technique,

for the overall effectiveness in fuel consumption, combustion efficiency, and smoke generation. The results show that consumption values in Burn 3 (new technique), were the highest, as were the fire intensity values indicating the best combustion efficiency. Smoke plume rise was very high and at times almost invisible, due to the efficiency of the burn and the lack of particles in the plume. PM2.5 concentrations were the lowest during quarters 1 and 2, but also the highest during quarters 3 and 4. We conclude that the new technique is suitable for when burning needs to happen as fast as possible in a limited amount of time, as when avoiding a morning and evening inversion, and it is possible to use it at midday when atmospheric dispersion potential is at its highest. The new technique, with modifications as recommended, offers the best potential to reduce pollutant gases and particle emissions during green wood burning of orchard wood in the winter months.

Mapping Air Pollution eMissions (MAPM): The MAPM inversion System to infer PM2.5 emissions maps on city scale

Stefanie Kremser
Bodeker Scientific

MAPM (Mapping Air Pollution eMissions) is a two-year project whose goal is to develop a method to infer particulate matter (PM) emissions maps from in situ PM concentration measurements. Central to the functionality of MAPM is an inverse model that takes as input a prior emissions field and time series of PM measurements from instruments distributed across the domain for which emissions maps are desired. Here we present the construction and results of the Bayesian-based inverse model system which uses

1. PM2.5 measurements obtained during a dedicated MAPM field campaign in Christchurch, New Zealand, and

2. a best estimate of PM2.5 emissions derived from 2018 census data,

to infer optimal daily PM2.5 emissions maps for Christchurch, including uncertainties.

High concentration of nonspherical particles and depleted ozone at 24-31km over New Zealand

Ben Liley
NIWA

High concentrations of nonspherical particles and low concentration of ozone have been observed at 24-31 km altitude over Lauder, New Zealand from 16 February 2020. They are attributable to Australian bushfire smoke injected into the stratosphere in late 2019 and then lofted by diabatic heating. In ozonesonde data, we observe depleted ozone at the same altitude. We report the detail of observations and discuss possible influences on the radiation balance and atmospheric chemistry as well as on XCO_2 retrieval of GOSAT satellite data.

Comparing satellite and ground-based observations of cloud occurrence over high southern latitudes

Cameron McErlich
University of Canterbury

The 2B-CLDCLASS-LIDAR R05 (2BCL5) and the raDAR/liDAR (DARDAR) satellite retrievals of cloud occurrence are compared as a function of altitude and latitude. The largest disparities are observed at low altitudes over high southern latitudes. These datasets are cross referenced to ground-based measurements from the Atmospheric Radiation Measurement (ARM) West Antarctic Radiation Experiment (AWARE) campaign at McMurdo Station, Antarctica. Compared to AWARE observations, both 2BCL5 and DARDAR underestimate cloud occurrence below 1.5km, with 2BCL5 and DARDAR distinguishing roughly one third of cloud occurrences observed by AWARE at 0.5km. While DARDAR identifies greater cloud occurrences than 2BCL5 below 1.5km, cloud occurrence values for the two datasets have similar differences relative to ground-based measurements. Therefore, the DARDAR retrievals of greater cloud occurrence at low altitudes are likely due to a larger quantity of false positives associated with radar ground clutter or attenuated lidar retrievals. DARDAR cloud occurrences match better with AWARE than 2BCL5 above 5km. However, the likely underestimation of ground-based measurements at higher altitudes suggests DARDAR may underestimate high level cloud occurrence. Finally, both datasets indicate the presence of liquid containing clouds at temperatures within the homogeneous freezing regime, despite the fact that the ECMWF-AUX dataset implemented in their processing clearly indicates temperatures below -38°C. Using AWARE radiosonde (ECMWF-AUX) temperature data, we find that 2BCL5 detects 13.3% (13.8%) of mixed phase clouds below -38°C, while DARDAR detects 5.7% (6.6%) of mixed phase and 1.1% (1.3%) of liquid phase clouds below -38°C.

Harnessing the Potential of Low Cost Particle Sensors for Use in Hierarchical Air Quality Networks

Hamesh Patel
The University of Auckland

Poor air quality is responsible for an extra 8 million premature deaths worldwide, with 92% of the world's population living in regions where air quality fails to meet recommended guidelines. Particulate matter is a toxic air pollutant that is detrimental to human health and has a degrading effect on the environment. Particulate matter comes in many different shapes, sizes and chemical compositions making it extremely complex to measure. Councils and regulators use specialized instrumentation to measure particulate matter which is very expensive to acquire, set-up and maintain. As a consequence regulatory networks have a limited temporal and spatial resolution which can impede an accurate assessment particulate matter on human health and the environment; it is already thought that current levels of particulate matter are significantly underestimated. Improvements in technology have seen cheap particulate sensors entering the market. However, questions have been raised regarding their reliability, accuracy and long term performance. This work characterized low and medium-cost particulate instruments alongside regulatory instruments deployed under real-world environmental settings to gain a better understanding of instrument performance and the impact of changes in environmental variables in order to successfully correct data and reduce error. The results demonstrate a reduction in data quality as the notional quality of the instrument decreases. An addition of a mini-cyclone to a low-cost instrument improved data quality. Instruments are affected by environmental factors such as specific humidity and temperature with varying results across different instruments and particle size ranges. A range of empirical correction factors were calculated and utilized to successfully correct data and reduce error for all bar one instrument.

Greenhouse gas columns over Antarctica in summer

David Pollard
NIWA

We present an overview and analysis of column averaged dry-air mole fractions of carbon dioxide, methane and carbon monoxide measured using an EM27/SUN portable solar absorption near infrared Fourier transform spectrometer which was deployed to the Arrival Heights laboratory in Antarctica during the 2019/20 summer season.

This dataset will be discussed in the context of the hemispherical latitudinal gradient by comparison with similar measurements made in NZ and from satellites.

Climate change emergence in CMIP6 models

Laura Revell
University of Canterbury

We explored the role that greenhouse gases, stratospheric ozone and aerosols play in the emergence of climate change in the Southern Hemisphere. Simulations performed by Earth system models participating in the sixth phase of the Coupled Model Intercomparison Project (CMIP6) were analysed to obtain the signal-to-noise ratio in near-surface air temperature through the 21st century. Simulations were based on the Shared Socioeconomic Pathway SSP2-4.5, and isolate individual forcings due to greenhouse gases, stratospheric ozone and aerosols. While greenhouse gas forcing primarily drives climate change emergence through the 21st century, the Antarctic ozone hole plays a small role in the Southern Hemisphere via coupling with the Southern Annular Mode.

Instantaneous spatio-temporal rate of spread of fast spreading wildfires - a new approach from visible and thermal image processing

Benjamin Schumacher
University of Canterbury

The rate of spread (ROS) of wildfires is an important parameter for understanding fire-atmospheric interactions and developing fire-spread models, but it is also vital for firefighting operations to ensure the safety of firefighters (Plucinski 2017, Stow 2019). Spatial ROS observations are usually carried out by using visible and thermal satellite imagery of wildfires estimating the ROS on a time scale of hours to days for large fires (>100 ha) or repeated passing with an airborne thermal infrared imager for higher spatial and temporal resolution (Viedma et al. 2015, Stow 2014). For fire experiments in highly controlled conditions like laboratory fires or during light fuel prescribed burns, ROS estimation usually involves lag-correlation of temperature point measurements (Finney 2010, Johnston 2018). However, these methodologies are not applicable to fast-spreading grass or bush fires because of their temporal and spatial limitations. Instantaneous spatial ROS of these fires is needed to understand rapid changes in connection with the three major drivers of the fire: fuel, topography and atmospheric forcings.

We are presenting a new approach towards a spatial ROS product which includes newly developed image tracking methods based on thermal and visible imagery collected from unmanned aerial vehicles to estimate instantaneous, spatial ROS of fast spreading grass or bush fires. These techniques were developed using imagery from prescribed wheat-stubble burns carried out in Darfield, New Zealand in March 2018 (Finney 2018). Results show that both the visible and thermal tracking techniques produce similar mean ROS; however they differ in limitations and advantages. The visible-spectrum tracking method clearly identifies the flaming zone and provides accurate ROS measurements especially at the fire front. The thermal tracking technique is superior when resolving dynamics and ROS within the flaming zone because it resolves smaller scale structures within the imagery.

Benjamin Schumacher[1], Katharine Melnik[2], Marwan Katurji[1], Veronica Clifford[2], Jiawei Zhang[1] and Grant Pearce[2]

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Mapping Air Pollution eMissions (MAPM): Investigating the effects of instrument uncertainties on Bayesian inverse estimation of urban PM2.5 emissions - an Observing System Simulation Experiment approach

Daisuke Seto

Bodeker Scientific

Two observing system simulation experiments (OSSEs) have been performed to investigate:

1. How different types of particulate matter (PM) measuring instruments (ES-642 and ODIN) affect the quality of PM emissions maps inferred using Mapping Air Pollution eMissions (MAPM) inverse model; and

2. How the number of instruments populating a PM measurement network affects the quality of the inferred emissions maps.

The OSSEs were performed by taking output from a Lagrangian particle dispersion model (FLEXPART), driven by a local numerical weather prediction model (WRF) and a 'true' emissions map, to generate 'true' PM concentration time series at 49 sites over Christchurch. For OSSE #1, those 'true' measurement time series were perturbed using statistically realistic measurement uncertainty characteristics derived from the two different types of instruments to generate synthetic concentration measurement time series at the 49 sites. These were then provided as input to the inverse model used to infer PM emissions maps at 1km x 1km spatial resolution. For OSSE #2, synthetic measurement time series from a subset of the 49 sites were used as input to the inverse model. Metrics quantifying the degree of agreement between the true emissions map and the inferred emissions maps were used to draw conclusions about the type and number of instruments required to achieve different levels of robustness of the inferred emissions maps.

An assessment of the topographic and atmospheric controls on terrestrial meltwater occurrence in the Ross Sea Region identified in the Geological Mapping Update of Antarctica (GeoMAP)

Matt Shepherd
University of Otago

Climate change has a widely known impact across the Antarctic region. The understanding of the complex interactions between the different branches of earth science is key to understanding how the region will respond to the environmental challenges associated with global climate change (+2°C) under the Paris Agreement Scenario. This study focuses on the topographic and atmospheric controls of terrestrial meltwater, displayed in GeoMAP, across the Ross Sea Region (RSR). Using both GeoMAP and REMA, the large scale spatial and geophysical characteristics of meltwater polygons will be presented and the residual differences between the meltwater characteristics of four regions within the RSR will be analysed. This will better define meltwater occurrence relationships with albedo (non-transport focused) verses those that don't (transport focused). Identifying more localised areas of transport focused meltwater and areas where meltwater is not present or identifiable, such as west of the Ross Ice Shelf, creates inquiry into the characteristics of air masses and its relationship with the cryosphere. Layers of atmospheric data including air temperature, humidity and wind speed/direction will be used to identify potential relationships between these localised areas and meltwater occurrence.

Convolution Neural Networks (CNN) for understanding mesoscale warming anomalies in Antarctica

Sagar Soni
Orbica Ltd/University of Canterbury

Rapid and intense warming events that are driven by intra-seasonal mesoscale weather variability cause seasonal streams to flood in the Dry Valleys and lead to ice shelf melting in the Antarctic Peninsula. To date, detailed analysis of the impact of these adiabatic warm air intrusions has focused mostly on the Antarctic Peninsula and the McMurdo Dry Valleys, but evidence is emerging that this warming mechanism is also at play in other regions, mostly undetected by the coarse resolution of numerical climate models. We have developed and validated an Antarctic-wide near-surface air temperature dataset (AntAIR) at a daily and 1km resolution, which was based on statistical learning from satellite and in-situ observations suitable for mesoscale climatological analyses. AntAIR was used successfully to detect some of the Dry Valley Foehn cases that were independently verified with regional climate model outputs.

Mesoscale forcing associated with Foehn winds, katabatic winds, and valley-wide cold air pool erosions can all influence the spatial and temporal cycles of positive temperature anomalies. We will extract temporal trends of positive temperature anomaly patches from trained convolution neural network models and will feed the extracted features to a clustering algorithm to find out spatial-temporal patterns inside each cluster emerging from AntAIR data. To understand the meteorological context of these emerging clusters we will introduce new variables like wind, velocity, and larger scale pressure gradients to understand how those variables correlate with clusters and their evolution. This work is based on non-supervised neural network classifications of complex mesoscale dynamics, and future work will focus on understanding how these complex models can help us statistically downscale regional climate projections.

Are CMIP6 models able to better represent New Zealand climate than the earlier CMIP models?

Abha Sood
NIWA

Even as the latest "CMIP6" global climate models are becoming increasingly complex by including more (e.g. biogeochemistry, atmospheric chemistry) processes and resolving finer features, their reliability depends on validation against observation-based data. In the following, we first apply the 62-element validation metric developed at NIWA (Mullan et al., 2013[1]) to evaluate how well the models represent the 'current' New Zealand climate. For this study, only the historical simulations are needed: the climate variables of primary interest are mean sea-level pressure, precipitation, and near-surface air temperature. The current model evaluation metric focuses on the New Zealand and southwest Pacific region, and assesses a number of circulation and climatic features in terms of their annual climatology and seasonal variation: the position and intensity of the westerly wind maximum and the subtropical high pressure belt; spatial patterns in the key climate variables and ENSO teleconnections; and annual cycles in regional circulation indices such as the Trenberth Z1 and M1 indices. In addition, the modelled regional temperature and rainfall trends in the recent historic period will be evaluated against observed trends and model climate sensitivity will be considered in the model evaluation metric. Finally, the results will be compared with previously evaluated CMIP3 and CMIP5 models to assess the "added-value" of the CMIP6 multi-model suite.

[1]Mullan, B., S. Dean and S. Stuart (2013). Validation of 5th assessment global climate models in the New Zealand region. Abstract and presentation for Joint Conference of the NZ Hydrological Society and Meteorological Society of NZ, 19-22 November 2013, Palmerston North. (Conference Handbook, p. 152-153).

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
NIWA

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.

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 50-100km. While measurements of CO_2 mole fractions indicate CO_2 level changes directly, measurements of δ^{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 $\sim$100km scales. Moreover, we will use COS (carbonyl sulfide) as an independent tracer for photosynthetic CO_2 uptake, and Δ^{14}C-CO_2 to examine ecosystem respiration and residence times.

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 detection and attribution of regional anthropogenic climate change relevant for assessing impacts

Dáithí Stone
NIWA

The international research community has documented a large number of impacts from multi-decadal climate trends on natural, managed, and human systems in mountainous areas. Are the relevant climate trends anthropogenic in nature, thus identifying documented impacts of anthropogenic climate change? In this talk we update a largely automated system for assessing the human role in regional climate trends. This update includes the adoption of simulation output from the newest generation of climate models, the newest observational data products, and a more detailed consideration of a priori confidence in climate models' ability to reproduce processes responsible for climate variations at small spatial scales. Using this updated system, we will assess the role of anthropogenic climate change in observed trends in mountainous regions around the world that have been documented as part of the IPCC Sixth Assessment Report's assessment concerning mountainous regions.

Atmospheric Carbon Dioxide uptake in New Zealand's North Island: Analysis of five years of atmospheric data from Maunga Kakaramea

Tegan Stone
NIWA

New Zealand's forests have estimated an approximate offset of 30% of greenhouse gases (MfE, 2019). CarbonWatch focuses on analysing forest uptake through atmospheric measurements with the aim to understand carbon on a national scale. A pilot study completed using techniques found that the South Island absorbed more CO_2 than expected (Steinkamp, 2017). While the South Island appeared to have carbon sinks, the North Island had not yet been observed. The eagerness to understand the story behind CO_2 and potential carbon sinks in the northern ends of New Zealand led to the introduction of another site located in the central North Island. The addition of the site Maunga Kākaramea to NIWA's CO_2 monitoring stations has resulted in new CO_2 data for the past five years. This addition has given NIWA the opportunity to extend their knowledge of potential carbon sinks beyond the South Island. With the past five years of data, we have been able to analyse CO_2 and begin to understand the carbon sinks present in the North Island.

A convection-permitting regional climate model for New Zealand

Stephen Stuart
NIWA

The climate of New Zealand is strongly influenced by the interaction between atmospheric circulation and complex local topography across a continuum of spatial scales. A Convection-Permitting regional climate Model (CPM) has here been configured for the whole of New Zealand at a horizontal grid length of 2.2km. This CPM uses the HadREM3-RA11M configuration the UK Met Office Unified Model. The CPM was run for a short historical simulation taking lateral boundary conditions from a 12km regional climate model (RCM), which was forced by ERA-Interim reanalyses. The performance of the CPM and 12km RCM over New Zealand is here assessed against observations, including precipitation, near-surface air temperature and wind speed. The CPM requires huge computational resources, but can in future be used to investigate changes in New Zealand climate in response to increased greenhouse gases.

Identifying extreme temperature events over New Zealand using self-organizing map

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Over the past few decades, human-induced warming of the climate and associated weather extremes have increased. The frequency of particular weather patterns and the intensity of extreme temperature and precipitation events are also showing changes. This study focuses on identifying and thereby classifying the extreme temperature events in New Zealand for simulations which include both natural and anthropogenic forces from the weather@home system and we have applied the Self Organizing Map technique to this model output. A self-organizing map (SOM) is an artificial neural network which performs unsupervised clustering of data. Using SOM cluster analysis large scale meteorological weather patterns are generated, which are associated with the physical mechanisms which result in weather extremes. The synoptic weather patterns derived from the SOM analysis are critically evaluated using various statistical techniques like pattern correlation to identify ideal SOM parameters and node configurations. These optimum SOM node patterns are further used to identify their relationship to extreme temperature and precipitation events that co-occur with the circulation represented in the pattern, for both pre-industrial conditions (also known as counterfactual or natural simulations) and post-industrial conditions (factual or anthropogenic simulations) from the weather@home model. This identification and classification of extreme temperature events along with the estimation of changes in frequency, persistence, and duration of occurrence of these circulation patterns in both the natural and anthropogenic induced cases provide a first-order understanding of how human influences have increased the risk of more extreme temperature days. It also further acts as a platform for attribution studies of extreme weather events in New Zealand, in particular to support efforts around near real time attribution of extreme events to human induced forcings.

Soil CO_2 and Nocturnal N_2O Fluxes in Lauder, Central Otago, NZ

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NIWA

Agriculture is New Zealand's biggest industrial sector. Therefore, a large amount of the country's greenhouse gas emissions profile consists of N_2O, CO_2 and CH_4. Due to New Zealand's large contribution to these greenhouse gases, it is vital to be able to estimate N_2O flux emissions. This can be done by using N_2O measurements in conjunction with CO_2 measurements. Knowing that our instrumentation and methods work allows us to confidently estimate N_2O flux emissions for the future and in regions where data is lacking.

The Fourier transform infrared spectrometer (FTIR) at NIWA's Lauder atmospheric research station produced a 10-year timeseries of continuous in situ N_2O and CO_2 measurements, in which the N_2O measurements from a period of December 2012 to April 2013 was extracted for this research. Along with this, soil carbon dioxide flux (FCO_2) measurements from an automated soil respiration chamber, Li-8100 was used. The FCO_2 was gap-filled by interpolation and regression methods (with soil moisture content and soil temperature as the predictor variables, R^2=0.7). The gap-filled FCO_2 was then used to calculate FN_2O by using Laubach's (2016) gas-gradient ratio method.

Enhancing VCSN rainfall estimates for hydrological modelling

Christian Zammit
NIWA

Accurate estimates of spatially- and temporally-complete rainfall are fundamental for hydrological modelling, particularly in ungauged catchments. The Virtual Climate Station Network (VCSN) daily rainfall estimates provide this input for NIWA's New Zealand Water Model (NZWaM). However, it is well known that these rainfall estimates in areas of high elevation of New Zealand have a relatively low accuracy. Since many catchments have their headwaters in these same areas, the resultant NZWaM flow estimations often have large bias, compared with observed flows, requiring bias correction.

The major source of VCSN rainfall estimation error is associated with the sparsity of observations in the high elevation areas. And yet, there are many hundreds of Regional Council-owned rainfall observation sites located in the hills and mountains that are not used for the VCSN simply because the data are not entered into NIWA's national climate database. Through a programme of bulk collection of these Regional Council data, we test the level of error reduction (measured as a function of the bias in modelled flows) associated with:

1. Augmenting the daily rainfall data stored in the NIWA climate database sites with all the Regional Council daily rainfalls, then re-running the VCSN interpolations;

2. Enhancing the spatial resolution of the VCSN from ∼5km to ∼500m; and

3. Performing interpolations of hourly rainfall.

The results of these tests will be presented and a plan for the ongoing enhancement of the VCSN rainfall estimates will be discussed.

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