Abstracts and Posters

ABSTRACTS

Phil Andrews

(NIWA)

The NZENS-DA: NIWA's Future NWP Forecasting System

At NIWA we are developing a new forecasting system to replace our current NZLAM and NZCSM forecast models. Called the NZENS-DA, it will be based on a data assimilating ensemble forecasting workflow, which will give us the probability of particular weather events occurring during the five-day forecast period. The ensemble will be supplemented by sub-kilometre resolution models, run on either selected or on-demand smaller domains, and driven from NZENS-DA ensemble members, to give improved guidance over regions of particular interest, including extreme weather events affecting Aotearoa New Zealand. In this talk I will present the goals and design details of the NZENS-DA.

Geoff Austin

(Weather Radar New Zealand Limited)

Upgrades to the high resolution "Trailer Radar" platform

Mobile weather radar platforms are useful research tools for field campaigns because they can be deployed close to the location of interest, achieving exceptional time and space resolution. The presenting author has a history of building mobile radar systems based on marine radar hardware. The equipment, while relatively basic from a contemporary perspective, has been employed successfully in a variety of field studies since the 90s. The final radar system constructed at University of Auckland (in 2005) was designated the "Trailer Radar" and has recently been upgraded as part of an MBIE Smart Ideas project with a software defined radio receiver chain to achieve Doppler spectra processing capabilities. We briefly review some of the notable observations made with the various generations of mobile radars over the decades, describe the latest upgrades and demonstrate observations captured with the new platform.

Yusuf Bhatti

(University of Canterbury)

Aerosol and dimethyl sulfide sensitivity to global sulfate chemistry schemes

Dimethyl sulfide (DMS) is the largest natural contributor to the global sulfur cycle but remains highly uncertain due to the oceanic concentrations and emission parameterizations. Additionally, oxidation pathways for DMS are highly simplified in climate models, which are also poorly constrained, and remain an additional source of uncertainty to the global sulfur burden. We test four oceanic DMS concentrations and three flux parameterizations. We also implement seven sulfate chemistry schemes within the same oceanic DMS dataset and DMS emission, to quantify the associated variance across these configurations and to quantify the global sulfur burdens.

We also show the global sensitivity of DMS to its oxidation products, emissions, and oceanic DMS datasets. Changing the sulfate chemistry scheme produces much larger effects on the global AOD. The lifetime of DMS is 260% longer over the SH. The impacts on Shortwave radiation in the Northern Hemisphere are twice as sensitive to changes in the sulfate chemistry than in the Southern Hemisphere.

This study highlights the high levels of uncertainty for the processes of model DMS oxidation, which cascades to the confidence in aerosol forcing. To better constrain the aerosol forcing uncertainty, more work is needed to better represent DMS in sulfur chemistry.

Greg Bodeker

(Bodeker Scientific)

Inferring the sensitivity of extreme precipitation to climate change using artificial intelligence

Evaluating changes in extreme precipitation, and how those extremes change with climate, is challenged by the paucity, brevity and inhomogeneity of observational time series. Even when aggregating observations over large regions (obscuring potentially important spatial heterogeneity) and applying non-stationary Generalized Extreme Value (GEV) analyses to describe the statistics of extreme precipitation, statistical uncertainties arise that limit any practical application of the results. We will present a new approach that uses a convolutional neural network (CNN) to learn the spatial structure of GEV parameters and the sensitivity of those parameters to climate change. Using global precipitation measurements from 10,000 stations and an annual mean, global mean surface temperature time series as a climate covariate, we will show that the CNN successfully learns the non-stationarity of the GEV fit parameters. Once trained, the CNN is used to generate maps of the sensitivity of extreme precipitation to global temperature change on ~1.5km×1.5km grids over North America, Europe, Australia and New Zealand in a way that is robust against the limitations of the observational record. This observations-based method also avoids the short-comings of regional and global climate models in simulating expected changes in extreme precipitation.

Tony Bromley

(NIWA Wellington)

Climate trends at Campbell Island

The sub-Antarctic islands to the south of New Zealand lie ina narrow belt of latitude (48.5S - 55S): the southernmost island, Campbell, is at 52.6S. These latitudes are a region of strong and consistent westerly winds, and north of the latitudes usually traversed by cyclonic storms of the southern oceans, and south of the paths usually taken by the travelling anticyclones of the subtropical latitudes. The IPCC 2007 (AR4) report mentions a significant warming trend across the sub-Antarctic latitudes over all seasons.

This talk covers some preliminary study we have carried out on nearly 75 years of meteorological data recorded at Campbell Island; we are looking for evidence of climate change that has occurred in recent decades, in particular air temperature, rainfall and wind speed and direction. We are also looking at the general airflow over this sub-Antarctic region, and looking for associated linkages with any changes with SAM (Southern Annular Mode) and ENSO (El Niño-Southern Oscillation; reanalyses of meteorological patterns over the 75 year period will also be studied to view any changes to the general circulation.

Beata Bukosa

(NIWA)

How well can MethaneSAT detect and quantify pastoral agricultural emissions?

MethaneSAT is a joint American and New Zealand satellite mission, which involves a partnership between Environmental Defense Fund (EDF), MethaneSAT LLC and the New Zealand government. The satellite is scheduled for launch in early 2024 and it is designed to target specific 200 km x 200 km regions and map methane (CH_4) within those regions at 100 m x 400 m resolution with unprecedented precision (2 ppb precision). The core mission of the satellite is to support emissions reductions by detecting and quantifying CH_4 emissions from oil and gas leaks (i.e., point sources), globally. The Aotearoa New Zealand team's aim is to develop and test the capability to use the satellite to detect agricultural CH_4 emissions. New Zealand is an ideal place to detect this capability due its large CH_4 emissions, 85% of which are from agricultural sources. Here, we will present details of the research programme to develop and test this capability. We will present preliminary results of modelled atmospheric CH_4 values for the main agricultural targets across Aotearoa New Zealand and emission estimates from the selected agricultural targets.

Isaac Campbell

(NIWA)

Comparison of reanalysis-driven regional climate models over New Zealand: climatology and extreme events

Regional climate models (RCMs) are important tools for downscaling global models, generating fine-scale detail at the local level. Aotearoa/New Zealand (NZ) provides an excellent case study for assessing the added value of high-resolution models, with its

complex terrain and extensive coastlines. Dynamical downscaling driven by reanalysis (i.e., perfect boundary conditions) can be used to evaluate the biases within an RCM, relative to observations. Here, we compare the performance of three RCMs in reproducing precipitation, temperature, and surface wind climatologies and extremes over NZ. We find all RCMs generally perform well: precipitation and temperature climatologies are well captured but with more variable performance in extremes. The RCMs differ the most for surface wind climatologies and for capturing the diurnal cycle of temperature. We find observational uncertainty is also important; model biases largely fall within estimated observational uncertainty, often preventing firm conclusions about the best performing model.

Trevor Carey-Smith

(NIWA)

Estimating TC-Gabrielle rainfall using citizen science measurements and convective scale modelling

Accurate estimates of rainfall at high spatial and temporal resolution are critical for driving models to describe and understand impacts such as floods and landslides. Typically, this rainfall input comes from interpolating relatively sparse rain gauge observations using tools such as ANUSPLINE, for example NIWA's Virtual Climate Station Network (VCSN). However, without additional spatial and temporal information, such methods struggle to capture realistic rainfall patterns, especially during extreme events. Here we combine rain gauge observations from regional council networks and members of the public with high-resolution numerical weather prediction rainfall fields to produce hourly rainfall at 500m resolution over the Hawkes Bay and Tairawhiti regions during TC Gabrielle. Using ground truth gauge data reduces systematic biases often found in weather models, while the physically coherent spatial information from the model can be used to guide the interpolation process.

Bryce Chen

(NIWA)

Time series sensor anomaly detection at NIWA

Sensor data collected from climate stations has been used in a wide range of scientific applications and environmental monitoring. Maintaining data quality is essential to guarantee the reliability and accuracy of the science outputs, potentially impacting many critical decision making processes. Traditional sensor anomaly detection techniques rely mainly on statistical and domain knowledge, which are often manual and time-consuming. Another limitation is their inability to timely detect sensor drifts, a slow deviation in sensor reading from actual value as time progresses caused by hardware and environment. Moreover, existing approaches are usually designed targeting at particular types of sensors, lacking generalization. We present a new machine learning-based time series anomaly detection framework which automatically detects the anomaly along with generating the time series forecasts. This solves the data curation problem that is often challenging due to the lack of modelling in previous works. With the help of spatial-temporal modelling and anomaly detection mechanism, our framework significantly improves the sensor drift detection capability in a timely manner. Moreover, the proposed semi-supervised learning

approach helps to generalize the solution for various types of sensors and contextual anomalies. Our experiments using real-world dataset have demonstrated promising and competitive performance.

Jono Conway, Céline Cattoën, Rasool Porhemmat

(NIWA)

Modelling the effect of seasonal snow on streamflow: model sensitivity and rain-on-snow events.

Snow accumulation and melt plays an important role in modulating streamflow in the Southern Alps of Aotearoa New Zealand. During extreme rain-on-snow events, snowmelt significantly increases runoff above that expected from rainfall alone. This is especially the case in maritime regions like New Zealand where atmospheric rivers can deliver intense rain to alpine areas during winter and spring, when snow cover is extensive. Conversely, snowfall during heavy precipitation events can reduce event runoff and moderate stormflow. Despite this, the representation of snow in hydrological simulations is subject to uncertainties from meteorological input data as well as model structural and parameter choices. This uncertainty limits the quality of forecasts, historical simulations, and climate change projections made with hydrological models such Topnet. Here we use stream-flow observations and satellite remote sensing of snow to (i) test the sensitivity of Topnet simulated snow cover and streamflow to snow model uncertainties, and (ii) assess how snow modulates streamflow in different seasons and during recent flood events. We will also discuss emerging opportunities to combine satellite and in-situ snowpack observations with physics-based snowpack modelling to better understand and predict rain-on-snow events.

Nicolas Cullen

(University of Otago)

What have two decades of continuous meteorological observations from Brewster Glacier revealed about glacier-climate interactions in the Southern Alps?

It has now been two decades since meteorological observations were first obtained from an automatic weather station installed at the terminus of Brewster Glacier. Since that time the glacier has retreated rapidly, with the annual loss of ice over the last decade more than three times greater than in the decades preceding it. The meteorological data have been used in a range of studies focusing on the impacts of climate variability and change on glacier mass balance, with the standout observations being the high-quality 4-component radiation measurements, which have helped us untangle the impacts of cloud forcing on mass balance, and to dig deeper into the physical processes governing the exchanges of energy and mass at different spatial and temporal scales. The publicly available data set has become a sought-after benchmark for mountain research internationally and continues to be useful for mass balance modelling and supporting the remote sensing of glaciers in the Southern Alps. In a research environment where atmospheric modelling dominates our agenda, the value of the meteorological data obtained at Brewster Glacier demonstrates that the simple art of obtaining high-quality observations still deserves its place in our efforts to better understand mountain climate.

Kunal Dayal

(Fiji National University)

Mesoscale atmospheric modelling of the wind climate for mesoscale wind resource assessment of the small island state of Fiji

This study presents a recent decade (2009 – 2018) high-resolution (1 km x 1 km) mesoscale atmospheric modelling results of the wind climate useful for renewable power generation for the small island developing state of Fiji using the Weather Research and Forecasting (WRF) model. The wind climate (wind speed, direction and power density) is presented at appropriate wind turbine hub-heights on an annual, seasonal and monthly basis. The long-term mesoscale wind climate was also coupled with an industry standard linear microscale wind modelling tool, Wind Atlas Application and Analysis Program (WAsP) to evaluate the accuracy of the wind predictions for wind resource assessment. Other atmospheric/meteorological parameters from the 10-year mesoscale modelling results will be studied in future work which will include extreme winds/precipitation from tropical cyclones within the Fijian Waters. Other future research activities include rainfall prediction using Gamma Ray Spectroscopy at Lautoka Campus of the Fiji National University.

Kim De Vantier and Daniel G. Kingston

(School of Geography, University of Otago)

Using crowdsourced weather data to analyse hot temperature extremes in Dunedin, New Zealand

Knowledge of weather and climate becomes increasingly imperative alongside progressively severe socioeconomic and ecological impacts of growing population densities, climate change, and associated increases in the frequency and magnitude of extreme weather events. However, current weather observation systems possess limitations, particularly in terms of their spatial resolution. Crowdsourcing data from private weather stations (PWSs) can be a cost-effective, novel addition or alternative to traditional monitoring systems, particularly in urban environments where population parameters facilitate the formation of dense networks. This study uses crowdsourced data from PWSs in the Weather Underground network to investigate spatial variation in hot temperature extremes in Dunedin, New Zealand. Following a series of quality control procedures, PWSs indicate that temperature varies by as much as 4.1◦C above and 5.4◦C below the official Musselburgh weather station. Correspondingly, these findings shed new light on the magnitude of spatial variability in temperature extremes across Dunedin and demonstrate the potential of crowdsourced weather data in this respect.

Sam Dean

(NIWA Wellington)

An international rapid attribution study of extreme rainfall in Cyclone Gabrielle: lessons learned

From the 12th to the 14th of February 2023, northern and eastern regions of Aotearoa New Zealand's North Island were hit by extremely heavy rainfall associated with the passage of ex-tropical cyclone Gabrielle. To analyse whether and to what extent human-caused climate change altered the likelihood and intensity of this extreme rainfall, scientists from Aotearoa New Zealand, the Netherlands, Germany, the US and the UK used published, peer-reviewed methods to perform a rapid event attribution study. The results of this study suggested there was some evidence that such rainfall was 30% more intense and 4 times more likely, but with heavy caveats that required careful communication. There was significant global media coverage of the findings. In this presentation we will consider the results of this study again, how it was covered in the media, and summarise the significant lessons learned from taking part.

Arti Devi

(University of the South Pacific)

Mesoscale and microscale analysis for a wind park development in the northeast of Viti Levu

The research study was conducted for five sites using wind data acquired from Fiji Department of Energy, Clay energy and NASA data to find a feasible site for wind farm development in the Northeast of Viti Levu. The data was validated using range test, relational test, and trend test. A detailed statistical analysis was carried out. The wind speed analysis for the five sites included the daily variation, diurnal variation, monthly variation, and seasonal variation.

The wind shear and temperature and turbulence intensity graphs were plotted. WAsP analysis was carried out. An analysis was performed in WAsP climate analyst to identify the wind direction and Weibull parameters. The Vector maps and resource grids were generated. Resource grid maps such as mean wind speed, power density, annual energy production and RIX maps were generated. Four 275kW Vergnet wind turbines were placed at sites. WAsP annual energy production for the wind farm. Finally, a detailed economic analysis has been performed using the following tools: Simple Payback Period (SPP), Cost of Energy analysis (CoE), Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR) to determine if the proposed wind farm is economically feasible.

Ciaran Doolin

(MetService - Te Ratonga Tirorangi & School of Science in Society, Victoria University of Wellington - Te Herenga Waka)

Exploring meteorological thought in 19th century New Zealand through Transactions and Proceedings of the New Zealand Institute

For much of the 19th century, science in New Zealand was an activity undertaken by gentlemen of leisure; the New Zealand Institute was the primary vehicle for these early scientists to exchange views. Transactions and Proceedings of the New Zealand Institute (TPNZI) offers a fascinating window into these discussions. Meteorological topics feature sporadically on the pages of TPNZI. Debates included the relationship between forests and

the climate, the effects of climate on health, the origin of the "hot winds of Canterbury", James Croll's theory of ice ages, and typical pressure patterns in the New Zealand region. By the late 19th century New Zealand science was undergoing major changes, namely institutionalisation and professionalisation.

These reforms were simultaneously helped and hindered by changes in wider society following the Liberal victory of 1891. By following meteorological debates in TPNZI we can observe these structural changes in New Zealand science from a unique angle.

Nick Edkins

(NIWA)

Active sites and ice nucleation: Primary marine organic aerosol and beyond

Primary marine organic aerosol (PMOA) is an organic component of sea spray aerosol which has the ability to nucleate ice clouds. This is particularly important over the Southern Ocean because in this region there are few other sources of ice-nucleating particles (INPs) and the shortwave radiation bias is significant. To include this process in the NZESM, the active sites framework is employed. An active site is a preferred location for ice nucleation on an INP. Parameterisations of the active site density of various aerosol species have been developed based on cloud chamber experiments and atmospheric measurements. Representing the heterogeneous ice nucleation temperature in the model as a function of active sites means that the impact of any aerosol species on ice nucleation can be modelled. In the NZESM, this has been implemented for dust and PMOA, with the results presented here. Other potential influences on nucleation, including pollen, fungus, and bacteria, are also discussed.

Rochelle Fleming

(MetraWeather Australia)

Machine learning in extreme wind gust forecasting

Forecasting extreme wind gusts at any location is a challenging problem, particularly since these have a very low frequency of occurrence. Dynamic numerical weather prediction (NWP) models can substantially aid weather forecasters in predicting strong winds that persist for long periods (meanmwinds) and the corresponding wind gusts that are likely to accompany these. However, extreme wind gusts, are usually short-lived and rare. As such, these are more difficult to forecast since NWP models, by design, predict the most likely conditions in any given situation. Machine learning (ML) algorithms provide a valuable first guess for extreme/rare wind gusts when trained on features derived from NWP models. The solutions derived from these hybrid NWP-ML models, can further help forecasters in making more informed decisions in predicting the likelihood of extreme/rare wind gusts at certain locations within a given block of time.

Peter Gibson

(NIWA)

Storylines for future projections of precipitation over New Zealand in CMIP6 models

Considerable uncertainty still exists for how regional scale mean precipitation will respond to climate change. Here we explore this uncertainty for New Zealand in CMIP6, documenting the spread across models, the sources of uncertainty, and the relevant physical drivers. A storyline approach is adopted to characterize and explain the main precipitation change patterns across models. The spatial patterns of precipitation change are more robust in winter compared to summer. In winter, spatial patterns of precipitation change across models relate to inter-model differences in Hadley cell and jet changes. In contrast, in summer, most models show a spatially non-uniform precipitation change that is strongly impacted by internal variability. However, a small group of models in summer predict a robust wet signal across most of the country. For this group of models, changes to stationary Rossby waves appear to drive wetter conditions by increasing north-easterly flow over the country.

Peter Gibson

(NIWA)

NIWA CMIP6 downscaling project: Status and historical evaluation

The coarse resolution of Global Climate Model (GCM) output remains problematic for several climate change applications, especially in complex terrain settings like New Zealand. To address this, work is ongoing at NIWA to dynamically downscale the latest generation of GCMs from CMIP6. The downscaling involves a 2-step procedure where simulations from coarse-resolution GCMs are first dynamically downscaled to 12-km with the Conformal Cubic Atmospheric Model (CCAM) and then further empirically downscaled and bias-corrected to 5-km. CCAM is a non-hydrostatic global atmospheric model which employs a stretched grid and scale-aware physics. Six GCMs have been selected for downscaling based on a balance of: historical evaluation for the region, model independence, and warming rate. This poster will describe the current status of the downscaling project, the historical evaluation of the now complete simulations, bias correction procedures, as well as data availability and access.

Felix Goddard

(University of Canterbury)

Future projections of atmospheric rivers for New Zealand

Recent weather events have seen atmospheric rivers rise to the forefront of the minds of many New Zealanders, with these events bringing both beneficial rains and destructive floods. A natural question to ask, then, is how do we expect these events to change in a warming world? Using an ensemble of dynamically downscaled CMIP6 global climate models, we begin to answer this question for New Zealand in particular, showing that atmospheric rivers increase in both duration and intensity under the SSP370 emissions scenario. We break the change into components due to the thermodynamic and dynamic changes, and show a robust poleward shift in the tracks of atmospheric rivers, consistent

with a poleward shift in the position of the jet streams observed as part of the climate change signal.

Felix Goddard

(University of Canterbury)

Sea spray dehalogenation in the NZESM

Despite being the largest source of inorganic bromine to the atmosphere, dehalogenation of sea spray aerosol is a process not currently represented in the NZESM. In reality, by introducing reactive halogen species into the atmosphere, SSA dehalogenation places an important control on the concentrations and lifetimes of a number of chemical species in the atmosphere, such as ozone and dimethyl sulfide (DMS), that NZESM simulations at present do not model accurately. DMS in particular is an important source of sulfate aerosol globally, influencing the Earth's radiation budget both through direct radiative effects and indirect impacts on cloud properties. The IPCC has identified that clouds over the Southern Ocean are a significant problem area for state-of-the-art climate models, with this radiative bias placing major restrictions on the accuracy of future climate projections for New Zealand. By adding this source of reactive halogens to the model, we show improvements in the representation of these chemical species and hence the global sulfate budget in comparison to observations.

Neil Gordon

(Retired)

Automated text weather forecasts and large language models

Text weather forecasts retain their importance as a means of clearly and succinctly communicating weather information, complementing graphical presentations. This talk will first briefly cover the history of automated production of text weather forecasts, from simple templates through to sophisticated Natural Language Generation. It will then move to the implications of the current revolution in text generation using Large Language Models (LLMs). This was popularised by the introduction of ChatGPT in November 2022.

The author has successfully implemented an online system to produce automated text weather forecasts, based on open source model forecasts, currently (June 2023) using GPT-4 and a ChatGPT plugin. With the rapid pace of developments in AI and LLMs, this system is likely to have evolved further by the time of the Conference. The system will be explained and demonstrated, along with a discussion of future implications for weather forecasting.

Catherine Hardacre

(University of Canterbury)

Impact of cloud water pH on atmospheric composition over the Southern Ocean in UKESM1.1

UKESM1.1 is the latest generation Earth system model to be developed in the UK. It couples together component models of the atmosphere, ocean, land surface, ocean biogeochemistry, atmospheric composition and vegetation to capture key land-atmosphere-ocean interactions and feedbacks in the Earth system. An important, yet underdeveloped aspect of the atmospheric chemistry and aerosol component model, UKCA-Mode, is its representation of cloud water pH, key driver of aqueous phase chemistry, including the formation of sulphate aerosol from sulphur dioxide. Sulphate aerosol loading in turn impacts cloud formation, composition, and thus radiative balance. UKCAMode currently uses a fixed cloud water pH value of 5, which does not vary in space or time. A recent development introduces a simple parameterization that varies cloud water pH with atmospheric sulphur dioxide. In the atmosphere only configuration of UKESM1.1 this results in temporally and spatially cloud water pH values. However, initial results have shown impacts over the Southern Ocean are substantial; CDNC is reduced by a fraction of 0.05 – 0.2 and net TOA by +0.22. While this new scheme is an important step forward in sulphur cycle process representation, we highlight the need for further testing and new observational data sets to constrain the model.

Luke Harrington

(University of Waikato)

Maximising the value of observations to understand future drought risk: evidence from Aotearoa New Zealand

To understand the risks associated with climate extremes in a warming world, one of the most powerful sources of insight comes from observational data associated with past events. Yet, we know the relative rarity of historical weather events can be effectively random and heavily influenced by multiple sources of internal variability. In this study, we demonstrate a statistical framework to quantify the relative rarity of past meteorological drought events around Aotearoa, exploring an extensive range of drought onset periods, spatial footprints, and event durations. Using several case studies, we show which regions are statistically overdue for a record-breaking meteorological drought, which past events were statistically exceptional across multiple regions, and suggest pathways to quantify worst-plausible events under current and future warming scenarios at the local scale.

Timothy Hilton

(GNS Science)

Constraining Auckland's urban biogenic CO_2 fluxes using atmospheric flask observations

Understanding fossil fuel carbon dioxide emissions requires understanding the co-located biogenic CO_2 fluxes from photosynthesis and respiration. We present biogenic flux estimates for the Auckland Region (New Zealand) from the urbanVPRM (urban Vegetation Photosynthesis and Respiration Model). We also present these fluxes' ratio to fossil fuel CO_2 emissions estimates from our Mahuika Auckland bottom-up emissions inventory. We compare these ratios to the radiocarbon-derived biogenic :fossil fuel flux ratios from flask

samples we have measured around Auckland since 2017. We find that model parameterisation is crucial to producing results that reflect atmospheric observations.

Daemon Kennett

(NIWA)

CarbonWatch-NZ: Atmospheric inverse modelling of terrestrial carbon exchange in New Zealand's forests and grasslands

We will present new results from the CarbonWatch-NZ research project, which uses a national-scale atmospheric inverse modelling framework to investigate carbon exchange in New Zealand's forests and grasslands. Previous results, based on observations from two in-situ sites revealed a larger (30-60%) net sink compared to National Inventory Report (NIR) estimates. In particular, a large portion of this additional uptake was found to occur over the indigenous forests of Fiordland. We extend these results by incorporating observations from an additional site, Maunga Kakaramea, located in the Central North Island (near Rotorua). We assess whether forest sinks in the North Island are underestimated by the NIR overall, and resolve differences between indigenous and exotic forest uptake. This insight is critical, as the land use, land-use change and forestry sector offsets approximately 30% of New Zealand's gross emissions, thus New Zealand will continue to rely on forest offsets to meet future emissions targets.

Molly Leitch

(NIWA)

Evolution of foredune notch morphology

Due to urban development around coastlines and the introduction of exotic plant species, originally dynamic dune systems have become stabilised. Such a process increases the coasts vulnerability to the impacts of a changing climate. Artificial dune blowouts and notches cut into foredunes are used to re-establish these dynamic systems by providing channels for sand transport to the back of the foredune.

This project focussed on one of the previously constructed foredune notches along the St Kilda foredune in Dunedin, NZ. The primary aim was to characterise how the notch morphology evolved over roughly 6 years, as a result of the interaction between wind speed and direction through the notch morphology.

Hamish Lewis

(University of Auckland)

Upstream large-scale control of subtropical low-clouds

The atmospheric boundary layer (ABL) adjusts to largescale meteorological conditions on time scales from a few hours to a few days. Along the trade winds, the ABL air can travel thousands of kilometers during that time span. As a result, the ABL state depends on the large-scale meteorological conditions upstream (upstream controls). Previous work using

back-trajectories and machine-learning statistical models with feature selection capabilities found upstream controls are systematic enough to dominate the climatological signal of low-cloud coverage, with a unique interplay of upstream and local controls found for Stratocumulus (Sc) deck, Sc-to-cumulus transition, and trade-cumulus regimes. Here we extend this analysis to examine the sensitivity of a range of low-cloud properties to upstream controls over an extended marine domain, with unique upstream and local controls being found for different low-cloud properties. This analysis is then repeated for 11 present-climate GCM simulations. Upstream controls are poorly represented by the majority of the GCMs in this analysis, with some exceptions. These results indicate a promising avenue to improve climate model low-cloud fields through the inclusion of upstream controls or advecting more information on boundary-layer properties.

Harris (Deng) Liu

(The University of Auckland)

Direct numerical simulation in turbulent radiation fog

Fog is a natural atmospheric phenomenon, and radiation fog is the most common fog-type in New Zealand. The mechanisms that drive fog formation and dissipation are poorly understood, impeding our ability to forecast fog accurately, which has important implications for transportation, agriculture, and infrastructure. This study will investigate the early stages of radiation fog using Direct Numerical Simulation (DNS) techniques. DNS solves the governing equations of fluid dynamics without simplifying assumptions or turbulence parameterisations, ensuring a more comprehensive and precise analysis. We analyze the roles of turbulence in fog formation, and our findings reveal that turbulence does not inhibit fog formation but somewhat facilitates the aggregation of water vapor, contributing to the growth and development of fog at the early stage of fog formation. We will further study the interaction between turbulence and radiation during the fog lifecycle, providing insights into the underlying physical mechanisms. The simulation results will additionally enable us to assess the accuracy of existing fog-forecasting models, thereby bolstering resilience against fog-related challenges in New Zealand and beyond.

Fulong Lu

(Meteorological Service of New Zealand)

Forecasting Cyclone Gabrielle from a NZ severe weather perspective and beyond

Tropical cyclones are among the most dangerous weather hazards. After tropical cyclones transition into extratropical cyclones, they can still cause significant damage and disruption to mid-latitude countries like NZ. They often interact with mid-latitude weather systems, and can bring widespread heavy rain, gales and storm surges. In February 2023, Cyclone Gabrielle became one of the worst cyclones in NZ history when it affected the North Island.

This paper reviews Cyclone Gabrielle from the perspective of severe weather forecasting in NZ. The track of Gabrielle was very well forecast 48-72 hours ahead, along with associated heavy rain and gale-force winds that affected northern NZ. The mechanism of the heaviest

rain that fell on the coastal hills of Hawke's Bay will be investigated. A brief comparison will be made with cyclones Bola (1988) and Giselle (1968).

Tom Marsh

(University of Canterbury)

A quantitative overview of El Niño in New Zealand

La Niña years are believed to be quite bad news for parts of New Zealand as they typically set up conditions for extreme precipitation events. Most recently this could be observed in the dying breaths of the Severe Tropical Cyclone, Gabrielle back in February 2023 which devastated much of the upper North Island. As El Niño events are the reverse meteorological setup, the common opinion is that these events set up conditions instead for drought in parts of the country. From these assumptions, the coming El Niño years should give some respite from extreme precipitation events. This study aims to explore quantitatively these events over the last 30 years comparing data from both observed and simulated models to determine the likelihood of extreme weather events occurring across New Zealand in either regime.

Nathanael Melia

(Climate Prescience Ltd)

Our "perfect storm": charting Cyclone Gabrielle, from forecasting to devastation

Join me for a yarn about Cyclone Gabrielle. Climate Prescience Founding Director and Principal Scientist, Dr Nathanael Melia, will break down the story of Cyclone Gabrielle from forecast inception through to impact and aftermath.

In this self-admittedly rambling talk – where the weather takes centre stage, but a high chance of tangents are forecast – he'll share insights on:

• The Remarkable Forecasting Skill

• Storm Phenomena

• Working with the Media

• Visual Damage Impact

• The 'Land Use Inquiry'

Vanessa Monteiro

(Victoria University of Wellington/GNS Science)

Informing Auckland's greenhouse gas emissions through in-situ atmospheric measurements of CO2, CO, and CH_4 mole fractions

Auckland is responsible for about 23% of Aotearoa New Zealand's industry and household CO_2 (carbon dioxide) emissions. Therefore, quantifying its urban fluxes is crucial to support measures aimed for greenhouse gases (GHGs) emissions reduction. In 2021, a GHG network was established in Auckland as part of the CarbonWatch-NZ programme. The network

consists of three sites equipped with high-precision and high-resolution instruments (cavity ringdown spectrometers) that continuously record atmospheric mole fractions of CO_2, carbon monoxide (CO), and methane (CH_4), which will be used on atmospheric inversion modelling to estimate urban emissions. The atmospheric observations showed a seasonal and daily cycles that reveal the influence of anthropogenic emissions. Fossil fuel emissions from traffic dominate the city's emissions, as indicated by CO_2 and CO observations. CO also indicated the presence of wood burning during the winter, while CH4 observations have been used to test the influence of meteorology on the other gases. These findings are crucial for the next steps on emissions estimates.

Stuart Moore

(NIWA)

Climate change impacts on extreme wind gusts in Aotearoa New Zealand

The Aotearoa New Zealand government has recently passed legislation making climate-related disclosures mandatory for many organisations who are now undertaking assessment exercises to quantify projected climate change risks to their organisation. These assessments often include profiling their exposure of assets or operations to extreme wind gusts under climate change. In this presentation, results from a climate model downscaling analysis of extreme wind Annual Exceedance Probabilities (AEPs) for a local power distribution company in the Canterbury region are described. The assessment indicates possible increases in 99% wind speeds and, for inland locations of Canterbury, potentially large changes in design speeds of up to 10% later in the century for the worst-case Representative Concentration Pathways (RCPs). This later outcome could be the result of changes in lee-slope windstorm intensity, which may have implications on the built environment of the region.

Stuart Moore

(NIWA)

The New Zealand Reanalysis Project – an update

The New Zealand Reanalysis (NZRA) project has been created to provide an atmospheric reanalysis dataset better suited to NZ's complex terrain and the atmospheric processes that drive NZ's local weather and climate. In this presentation we provide an update on the production status of the NZRA dataset, the initial post-processing steps undertaken, and how users can begin to access it for research purposes. Secondly, a brief introduction to the nascent plans for NZRA2 will be given, highlighting the expected scientific and data assimilation updates that will be used.

Stuart Moore

(NIWA)

Putting New Zealand in harm's way

New Zealand has always been susceptible to ex-tropical cyclone (TC) systems and the impacts they unleash, be it from winds, rainfall or storm surges. The passage of ex-TC Gabrielle across northern New Zealand in February 2023 and the havoc it wrought on the Hawke's Bay region is the most damaging in recent history, displacing people from their homes and wiping out large swathes of agricultural land. Insurance costs alone are estimated to be in excess of NZ$1.6B.

In this presentation we make use of a modelling technique that allows us to shift NZ directly into the path of incoming ex-TC storms and assess the likely worst-case scenarios and impacts such a direct hit might entail. This is demonstrated for ex TC Gabrielle and ex TCs Lusi (March 2014) and Cook (April 2017).

Olaf Morgenstern

(NIWA)

Potholes, tugs-of-war, and mad drivers: What can be learned from simulations of historical global-mean temperature?

A leading topic surrounding the 6th Assessment Report (AR6) of IPCC is the presence of several well-established climate models informing the report that have much larger equilibrium climate sensitivities (ECSs) than found in the previous generation of models. AR6 recommends an ECS of the Earth system of 3K, much smaller than the ECSs exceeding 5K characterizing some of these models. These large climate sensitivities then relate to generally larger future simulated warming for any climate scenario than would be the case for a smaller ECS. AR6 stipulates that these models represent "low-probability, high-risk" outcomes. This judgement is partly based on how these models represent the "historical" (post-1850) past. I here assess the question of what can be learned from historical simulations of these and other present-generation models. I decompose the global-mean temperature signals simulated by 14 such models into warming due to greenhouse gases and offsets due to aerosols and discuss how the observational historical temperature record constrains the contributions of both drivers. This leads to a qualification of the realism of these simulations regarding both these drivers.

Stijn Naus

(NIWA)

Using high-resolution meteorological modelling to estimate Auckland's carbon emissions

Carbon dioxide (CO_2) is the single largest contributor to the increase in anthropogenic radiative forcing, and 70% of global CO_2 emissions originate from urban areas. New Zealand has set ambitious greenhouse gas emission reduction targets (net-zero emissions in 2050), and Auckland will play a key role in those reductions as New Zealand's largest city. To meet these targets, it is vital to understand current emissions and monitor the impact of implemented policies (e.g., planting trees). For this reason, we are developing the first observation-constrained, urban-scale emission estimation framework for Auckland. In this framework, we link urban measurements of CO_2 to emission inventories, with the use of

transport model simulations driven by meteorological data from the 333-m Auckland Numerical Weather Prediction model. Use of such high-resolution meteorological data is unique and helps interpret atmospheric measurements of CO_2 and related species (e.g., CO_2 isotopes) in the heterogeneous landscape of Auckland, especially when combined with the high-resolution emission inventories that have been developed specifically for Auckland (Mahuika- Auckland and UrbanVPRM). The resulting emission product will be a policy-relevant instrument that can help evaluate and meet New Zealand's emission reduction targets.

Sylvia Nichol

(NIWA)

Using Baring Head Radon-222 to identify CO_2 baseline conditions

NIWA's Baring Head Atmospheric Research Station (45.41◦ S, 174.87◦ E) has been in operation for over 50 years. A wide range of greenhouse gas and other trace gas measurements, including Radon-222 since 2015, are made at the station. Radon-222 is a naturally occurring radioactive gas originating exclusively from the rocks and soils of the earth's crust. It has a half-life of 3.8 days, and its oceanic source function is 2 to 3 orders of magnitude less than the terrestrial value. These features make Radon-222 a sensitive indicator of an air mass's recent contact with land, and so provide a way to identify baseline conditions i.e. when an airmass has had minimal recent influence from localised pollution sources.

Our current operational method to identify CO_2 baseline conditions requires meeting low CO_2 variability and southerly wind criteria. We investigate using Radon-222 as an additional criteria.

John Nicol

(Weather Radar NZ)

Evaluating convective rainfall processes in high-resolution Numerical Weather Prediction

The advent of supercomputing has allowed Numerical Weather Prediction (NWP) models to be routinely run at convection permitting resolutions. Despite this, grid length (among other factors) has a significant impact on the representation of rainfall processes and accurate forecasting of convective rainfall remains very challenging. Capturing the true spatial structure, weather radar provides a valuable means of evaluating rainfall in NWP. Based on four high impact case studies affecting the Auckland region, a detailed investigation of the representation of convective rainfall in the Unified Model with grid lengths of 1.5km and 333m was undertaken in collaboration between NIWA and Weather Radar NZ (WRNZ).

Over recent years, WRNZ (with Auckland Council's support) have developed a profiling radar network in the Auckland region. This network not only provides detailed observations of rainfall at selected locations, but also unique insight into vertical air motions, allowing the distribution and intensity of convective rainfall to be associated with the size and strength of updrafts at the heart of the processes. These novel observations allow the representation of

convective processes in NWP to be directly assessed. We report on the findings of this study and discuss potential directions for improved forecasting of extreme rainfall.

Emily O'Riordan

(Bodeker Scientific)

DeepWeather: using deep learning to produce high-resolution forecasts over New Zealand

New Zealand is vulnerable to extreme weather events due to its complex climate and terrain. The ability to forecast the weather at hyperlocal scales would better resolve many of these events, allowing for enhanced warnings and preparations. However, producing high-resolution forecasts using numerical weather prediction models, such as WRF, is prohibitively expensive. The DeepWeather project aims to produce a generative deep learning (DL) model, taking coarse-resolution WRF forecasts as inputs, and outputting a high-resolution forecast. The generative component produces an ensemble of forecasts and ensures the outputs are realistic. The DL model will be inexpensive to run, producing high-resolution forecasts at a fraction of current costs.

This project is partnered with MetService and, once trained, the DL model will be embedded into MetService's WRF implementation through two-way coupling. This will allow WRF outputs to be instantly fed into the DL model, generating high-resolution forecasts at minimal cost, which can then be used to nudge coarse-resolution WRF simulations. As the DL model will resolve sub-grid-scale processes and account for local terrain, the DeepWeather model (that fuses WRF and the DL model) should enhance the accuracy of weather forecasts over New Zealand.

Neal Osborne

(MetService)

Severe weather warning performance for the Auckland Anniversary storm and Cyclone Gabrielle

In early 2023 New Zealand experienced several devastating storms, including the Auckland Anniversary storm on 27 January followed by Cyclone Gabrielle between 12 and 14 February. The characteristics of these two storms was very different as was the sequence of warnings. The Auckland Anniversary storm was caused by local-scale convective structures, making the forecasting of this event exceptionally challenging. In contrast, Cyclone Gabrielle was a large-scale system that was well-predicted by the numerical weather prediction (NWP) models. The first media release for New Zealand was issued nearly a week in advance and the first warnings three days in advance.

This talk will present some of the work done following these two storms to understand the performance of the NWP models available to the forecasters and the severe weather warnings issued. This includes novel approaches that were developed to help summarize the events and review the performance of the various predictive components.

Hamesh Patel

(The University of Auckland/Mote)

Determining the chemical and elemental composition of ambient particulate in Auckland

Particulate matter (PM) is one of the greatest risks to human health and the environment. Emitted into the air via a series of different emission pathways, PM is comprised of various elements and compounds. Common optical and gravimetric methods fail to identify the elemental and chemical composition of PM. PM samples were collected onto PTFE substrates using a FilterMote across three Auckland sites. Samples were analysed using x-ray fluorescence (XRF), Raman spectroscopy (RS), light reflectance and gravimetric mass estimates. XRF mass reconstruction highlighted the presence of sea salt, soil and heavy metals. XRF results yielded similar results across the three sites. RS identified carbon black and diesel soot along with the presence of other chemicals. Fitting of RS identified multiple peak positions within the D and G bands, highlighting a variety of soot particle crystallinities between sites. RS proved powerful in complementing other commonly used techniques to identify the chemical composition of ambient particulate around Auckland Central. Such studies contribute to the complex field of understanding the composition of ambient particulate and its impact on human health and the environment.

Matt Pearce

(Early Warning Network)

How knowledge of past weather events can reduce insurance losses

Early Warning Network (EWN) has developed Climatics, Australia's most comprehensive database of historical weather events. "Perils" included are hail, thunderstorms, bushfires, flood, droughts, heatwave and tropical cyclones. This presentation will introduce the database and tool, and show how it can be used to assess risk trends at any location in Australia. The benefits and drawbacks of an historic database approach such as Climatics versus traditional climate models are explored. Case studies are presented, demonstrating how to use the database to understand trends in cyclone frequency, extreme temperatures and extreme rainfall. Finally, applications are briefly discussed, including use in development planning, insurance and reinsurance modelling, and extensions of the database to other regions, such as New Zealand.

David Pollard

(NIWA)

Measurements of tropospheric column average methane from a portable remote sensing instrument

For nearly two decades, measurements of the total column averaged dry-air mole fraction of methane (CH_4) and other greenhouse gases have been made at the Total Carbon Column Observing Network (TCCON) site at Lauder. In recent years these have been supplemented by measurements using portable EM27/SUN instruments. To improve the sensitivity of these data in the lower atmosphere, the relationship between CH_4 and hydrogen fluoride (HF) in the stratosphere can be exploited to remove the slowly varying stratospheric methane contribution from the total column to yield a tropospheric component.

HF is a species that is retrieved alongside CH_4 by the TCCON instruments, but is not measured by the lower spectral resolution EM27/SUN. Here, we apply the HF correction to EM27/SUN CH_4 columns made adjacent to the TCCON site, and – by exploiting the spatial homogeneity of trace gases in the stratosphere – when operated remotely. These retrievals provide estimates of CH_4 amounts in the lower atmosphere with greater precision and at multiple locations, which can be used to help infer regional fluxes.

Rasool Porhemmat

(NIWA)

Hydrometeorological characteristics of flooding events in Westport, New Zealand

Westport in New Zealand has a history of severe floods due to its exposure to northwesterly airflows causing heavy rainfall. Recent floods in 2021 and 2022 caused significant damage through landslides and overflowing rivers, particularly the notable storms in July 2021 and February 2022. In 72 hours, over 690 mm of rain fell in parts of the West Coast, leading to record flows in the Buller River, the highest in almost a century. Similarly, February 2022 experienced consecutive heavy rainfall events from the 2nd to the 11th, resulting in the region's wettest February on record. The aim of this study is to analyse the hydrometeorological and synoptic climatological characteristics during the days leading to the events and highlight how their complex interactions may lead to impact on the ground. This will provide insights that span from immediate disaster response and management to long-term planning and policy development.

Hamish Prince

(University of Wisconsin-Madison)

Polar thermal emission - emerging trends, spectral breakdown and the NASA PREFIRE mission

Satellite observations reveal that decreasing surface albedo in both polar regions is increasing the absorption of solar radiation, but the disposition of this absorbed energy is fundamentally different. This research explores the modern record of Earth's energy balance in the polar regions through the Clouds and Earth's Radiant Energy System (CERES) record over the last 21 years. Arctic solar absorption is increasing at about 1 Wm−2 dec−1, consistent with the anticipated response to sea ice loss. However, Arctic thermal emission is also increasing at the same rate, with two thirds of the annual variability being explained by solar absorption. Conversely, Antarctic thermal emission is not responding to the increasing (though not yet statistically significant) solar absorption of 0.5 Wm−2 dec−1, with less than a

third of the annual thermal variability explained by accumulated solar absorption. These results provide a key scientific benchmark for the upcoming NASA PREFIRE (Polar Radiant Energy in the Far InfraRed Experiment) mission, being launched from New Zealand in 2024. PREFIRE is a cubesat mission measuring the spectral breakdown across the far infrared (5-50 microns), revealing the spectral bands, and consequently geophysical processes, responsible for variable thermal emission.

Laura Queen

(Victoria University of Wellington)

Climate change detection and attribution of Aotearoa New Zealand hydrometeorology

Last year, we presented significant spatio-temporal trends in observed near-natural streamflow across Aotearoa New Zealand. Can we discern the Detection and Attribution (D&A) of a climate change signal in these observed patterns of change? Using an established D&A method (optimal fingerprinting) in a new context (large ensemble, atmosphere-only simulations), this study addresses the challenging problem of regional D&A in the context of NZ hydrometeorology. Testing this method using both a perfect-model setup and observations, we present D&A results for NZ runoff, temperature and precipitation.

Neelesh Rampal

(NIWA)

A deep-learning strategy to reliably downscale present-day relationships to future climates

A fundamental problem in climate science has been the unreliability of extrapolating present-day empirical relationships into future climates. To address this challenge, we propose a novel approach using Convolutional Neural Networks with pre-training. The distinctive two-step training process first trains the CNNs to learn patterns in the predictors via an unsupervised learning step, then fine-tunes them with high-resolution target observations. This approach is tested to downscale rainfall projections at a 5km resolution over New Zealand, where a standard CNN implementation fails to reliably predict expected future changes even though it is highly skilful on present-day data. In contrast, the pre-trained models robustly reproduce the future trends. Further exploration reveals that the pretrained CNN produces much more stable predictor saliency maps than the standard CNN, enabling its superior extrapolation properties to be established from present-day data. Therefore, this study demonstrates that pre-training CNNs can significantly enhance the generalization of the learnt relationships to unobserved climate scenarios, offering a promising avenue for improved future climate projections.

Beatriz Reboredo

(Weather Radar New Zealand)

Performance of the Auckland Council Rainfall Analysis System during the Anniversary Weekend storms

Tamaki Makaurau's subtropical climate and maritime influences mean that it is often subjected to convective rainfall which can lead to flash flooding. Unfortunately, this is something that Auckland communities are becoming increasingly familiar with. Auckland Council Healthy Waters Department (ACHW) is responsible for planning activities associated with community resilience, indeed the community expects proactive management of hazards. An important input into planning activities is a robust understanding of the spatiotemporal characteristics of extreme rainfall events. There is no national scale observation or model analysis which is suitable for these requirements. Therefore, ACHW and the authors, have developed a Regional Analysis System (RAS) which merges the available rainfall observations- the council gauge network, raw MetService radar and emerging, novel, vertically profiling radar information. We present RAS outputs from the Anniversary storms and discuss how the immediate availability of high quality rainfall information contributed to a rapid modelling study immediately post event.

James Renwick

(Victoria University of Wellington-Te Herenga Waka)

Is there a climate change signal in Antarctic sea ice yet?

Antarctic sea ice extent has dropped away recently, after decades of slow expansion. Is this a sign that climate change is finally catching up with Antarctic climate, or is it yet another blip of "natural variability"? I'll present an analysis of sea ice variability and trends, with a view to separating the two.

Suzanne Rosier

(NIWA)

A new higher-resolution climate modelling capability for New Zealand: providing very large ensembles to further understanding of climate and weather extremes

Extreme weather events are increasingly wreaking havoc as human interference with the climate system progresses. Understanding these extremes and projecting their expected changes requires modelling in sufficient spatial detail to capture the events adequately, but with enough realisations to capture their statistics adequately too – a big ask, even with today's supercomputing power. The 'weather@home' project – which utilises global distributed computing to run climate models many thousands of times – has recently taken a step forward in the New Zealand region by releasing a 25km version of the regional model which until now has only been run at 50km resolution. Thousands of simulations returned from public computation reveal that this new model configuration captures many aspects of New Zealand climate extremes with improved accuracy over the previous version and thus these datasets represent a valuable resource for furthering our understanding of the changing landscape of extreme events in this region.

Michael James Salinger

(Victoria University of Wellington)

Recent extreme warm seasons in the New Zealand Region (cor. version)

Four out of the five warmest summers (November to March) have occurred in the last six years (2017/18, 2018/19, 2021/22 and 2022/23), with only one other (1934/35) occurring back to 1870/71. For these warm seasons the New Zealand (NZ) region experienced the most intense coupled ocean/atmosphere (MHW/AHW) heatwaves on record. Average temperature anomalies over land and sea were +1.2 to 1.4◦C. Maximum sea surface temperature (SST) anomalies occurred to the west of the South Island of NZ. Atmospheric circulation anomalies showed a pattern of blocking high pressure over the Tasman Sea and Pacific Ocean to the south, and southeast of NZ. Hindcasts show positive temperature anomalies in for these areas. Under 1.5◦C of global warming the five events would have estimated recurrence intervals (ERIs) of 2-3 years, and under 2.0◦C of warming all would be considered cool years. Major loss of glacial ice occurred from Southern Alps glaciers.

Mark Schwarz

(MetService)

Diagnostic analysis of the Auckland Anniversary flood of Jan 2023, with a view to its predictability

Late January 2023 saw a relatively weak frontal system meander over northern Aotearoa/New Zealand for several days. During the afternoon of 27 January, near the onset of Auckland's Anniversary Weekend, torrential rainfall developed which led to severe flooding, particularly over Auckland City. A staggering 200mm or more of rain fell over much of the city within 12 hours, with more than 150mm being recorded in a 3-hour period by several stations. Insurance claims for the event are comparable to those for Cyclone Gabrielle which struck the North Island two weeks later. This talk examines the features which led to the intense rainfall over Auckland, from the climatological setup to the synoptic and mesoscale structures observed. The moisture availability and efficiency of rainfall processes are also investigated. For each aspect of the event, its relative role, its rarity and predictability are discussed.

Prasad Shelke

(Antarctic Research Centre, Victoria University of Wellington, New Zealand)

Representation of atmospheric blocking in Community Earth System Model Large Ensemble 2

Atmospheric blocking significantly impacts regional weather patterns, but current climate models struggle to accurately represent blocking. In this study, we assess the atmospheric blocking representation in the Community Earth System Model Large Ensemble 2 (CESM-LENS2). Results show substantial progress in representing the atmospheric blocking with improved fidelity and minimal bias in the model when compared with Reanalysis dataset. In the CESM-LENS2, a reduction in the underestimation of winter blocking frequency for the Northern Hemisphere was observed from 2% to 7%, excluding the ~4% overestimation observed in Euro-Atlantic blocks. Similarly, for summertime blocking, the underestimation has been decreased to ~14% in the North Pacific region. The overestimation seen in central North America and central Asia has been improved to 12% to 15%. Future simulations of

CESMLENS2 confirm a projected decrease of Northern Hemispheric atmospheric blocking by ~15% Annually, ~13% during winter, and ~10% in summer under the SSP370 emission scenario. Additionally, we explore the model's potential to capture southern hemispheric blocking patterns. Our findings highlight CESM-LENS2's advancements and provide valuable insights into weather pattern representation.

Abha Sood

(NIWA)

Transition from climate data to adaptation relevant climate information

In the face of the rapidly evolving global climate transition to a new transient climate "normal" with significant to severe impacts of climate change linked extreme events experienced globally and in New Zealand, it is imperative to reduce greenhouse gas emissions to limit the intensity of severe impacts. At this late stage, we must also accelerate the development of regional climate adaptation strategies to protect communities and ecosystems, minimize economic disruptions, and ensure a more resilient and sustainable future for all.

The fine resolution validated climate projection data from three generations climate simulations (CMIP3 2010; CMIP5 2016; CMIP6 2023) based on best performing models for New Zealand region are available to our stakeholders in government, industry and communities. The presentation will discuss the conversion of the climate data to relevant impact metrics that are directly related to the sectors and specified applications (e.g., crop yields, water availability, flood risk, human and livestock health, ecosystems, . . .). Along with these application specific climate indices, information regarding the uncertainty and speed of change required to optimize sector specific local climate adaptation measures will be discussed.

Abha Sood

(NIWA)

Role of soil moisture in adaptation to climate extremes in New Zealand

The impacts of more frequent and intense weather events due to climate change, such as more persistent droughts, heatwaves and floods caused by intense rainfall events, are directly modulated by the background soil moisture state. Improved soil moisture state is therefore crucial for adapting to climate extreme impacts and will help with better water resource management, agricultural planning, flood control, and ecosystem preservation. This involves combining observations from monitoring networks, remote sensing and ground-based sensors with validated modelling frameworks.

In this study we assess the impact of improved soil moisture representation on the severity of wet and dry climate extremes in the historic observed past and the projected past and future climate projections. Environmental indices are derived to represent the soil moisture state related impacts (e.g., soil saturation or drought indices) for application in early warning and decision support systems as well as for developing agricultural and water management strategies. By incorporating soil moisture assessment into climate adaptation strategies can

greatly enhance our ability to mitigate the impacts of climate extremes. By using a combination of monitoring technologies, modelling, and data integration, stakeholders can make informed decisions that promote sustainable resource management and resilience to changing climate conditions.

Raghav Srinivasan

(NIWA)

Machine learning-based approach to explore extreme temporal rainfall patterns in New Zealand

Design storms are often used in flood inundation modelling to incorporate rainfall in a realistic way. There are a variety of ways to disaggregate a total storm rainfall depth to simulate the temporal evolution of event. These include for example, a simple triangle shape, a parameterised functional form, or a nested design storm. In this study we use a novel machine learning approach to model historic storm shapes and explore the use of generative AI to derive design storm shapes that capture the key observed temporal properties. A database of approximately 6000 12-hour storms and 9000 48-hour storms has been assembled from historic rain rate observations distributed across New Zealand. A Variational Auto Encoder (VAE) model was trained on these storms and, based on return period classification of the observed storms using High Intensity Rainfall Design System (HIRDS), a relationship between storm type and the VAE model's latent space was found. This model has been used to generate representative and realistic design storm shapes with different temporal characteristics. Results have been compared against nested design storms generated from the same storm database using the average variability method.

Dáithí Stone

(NIWA)

The role of anthropogenic warming in Cyclone Gabrielle

The Extreme Weather Event Risk Attribution Machine (EWERAM) collaboration runs parallel Met Service weather forecasts under conditions of a world that might have been in the absence of human interference in the climate. Here we report on the comparison of these "natural-world" forecasts for the Cyclone Gabrielle event with the actual forecasts. This comparison can inform us of how Cyclone Gabrielle-like events differ because of human interference, but not on their likelihood of occurrence.

Dáithí Stone

(NIWA)

Detection and attribution of trends in extreme temperature and precipitation in Aotearoa

We present 10-member ensemble simulations of the CCAM atmospheric climate model run globally but with 12km resolution over New Zealand covering the 1982-2021 period, with

and without the inclusion of anthropogenic forcing. We use these simulations to diagnose the causes of interannual variability and multi-decadal trends in observed extremes of temperature and precipitation, in particular the role of anthropogenic forcing.

Stephen Stuart

(NIWA)

Precipitation over the Southern Alps of New Zealand in a convection-permitting regional climate model

A classic example of orographic precipitation is found in the steep terrain of the Southern Alps, which experience the highest magnitudes of rainfall in New Zealand (NZ). We compare observations by 572 rain gauges in the South Island against an extended historical (1982-2000) simulation by a regional climate model, based on the Met Office Unified Model, operating at a convection-permitting grid-scale of 2.2 km across all mainland NZ. Relative to the 12km model in which it is nested, the 2.2km model more accurately simulates spatial variations in gauge-observed annual mean rainfall across much of NZ, but too much precipitation spills over into lee regions of the South Island. The wettest events in the Southern Alps occur during strong northwesterly airflow, which greatly increases the cross-mountain flux of water vapour, upward velocity over windward mountain flanks and spillover of rainfall into leeside catchments.

Luke Sutherland-Stacey

(Weather Radar New Zealand Limited)

Estimating the Auckland radar tilt

Robust use of weather radar information requires the dish pointing be precise. Even pointing errors of less than a degree translate into significant errors in altitude and location at range. Verifying radar pointing can be accomplished in a variety of ways, including registering the radar's position encoder information based on solar interference against the known position of the sun. Such techniques have been operationally implemented in Europe to independently consider errors in azimuth and elevation, and have been extended to consider tilting of the radar platform at the Bureau of Meteorology, Australia. Here, we briefly report on experiences applying solar interference techniques to the Auckland radar. Results indicate significant tilting towards the west. We briefly demonstrate the impact of the tilting on radar rainfall estimates and that accounting for the tilt rectifies these errors.

Luke Sutherland-Stacey

(Weather Radar New Zealand Limited)

Assessment of the suitability of New Zealand's NWP products for Early Warning Systems in Auckland

The communities in Tamaki Makaurau have been sorely tested by extreme weather, not only this year during the Anniversary Weekend storm and Cyclone Gabrielle, but also in previous

years (e.g. Kumeu flooding 2022, New Lynn flooding 2017 and Piha flooding 2018). Observing and forecasting the extreme precipitation which can lead to flash flooding is well known to be a challenging task. Council engineers do not have sufficient, reliable, information about the level of uncertainty which should be anticipated from rainfall forecasts- a situation exacerbated by notable forecasting “busts". Auckland Council Healthy Waters have initiated a programme of work to become conversant with the limits of automated rainfall observations, nowcasting and numerical weather prediction. Here, we present results of an assessment of the probabilistic skill of New Zealand’s operational NWP, utilising rainfall observations from the Auckland Council Rainfall Analysis System. The analysis is undertaken at time, space and intensity scales relevant to the engineering practitioners. Unsurprisingly, we find that NWP must not be anticipated to provide actionable information in advance of all events. Therefore, practitioners will frequently need to be able to deal with emergency decision making processes at short lead times and in the presence of significant uncertainty.

Annick Terpstra

(MetService)

Improving gust forecasting through gust event classification

Forecasting wind gusts is vital for informed decision-making in industries like aviation, maritime operations, and construction. Yet, accurate gust forecasting remains challenging due to the intermittent, non-linear, and variable nature of gusts. Furthermore, gustiness, defined by the difference between sustained and maximum windspeed, is strongly dependent on interactions with the local orography and the timing and location of mesoscale weather features, both complicating accurate gust forecasting.

This study aims to improve gust forecasting by identifying and categorizing gust events. Periods of strong gustiness often persist for hours or even a day. These gust events are related to airmass changes induced by synoptic-scale forcing and diurnal effects, whereas individual gusts are related to convection, orography, and airmass properties (vertical shear, static stability). The underlying rationale of this work is that distinct mechanisms (convection, airmass properties, or orography) lead to distinct statistical gust-event distributions. Focusing on New Zealand, we identified gust events using observations and categorized them based on their statistical properties. We used this database of gust events to evaluate model performance during the different gust classes and utilize this information to guide our ML models to improve gust forecasting during strong gustiness.

Anjali Thomas

(School of Physical and Chemical Sciences, University of Canterbury)

Anthropogenic influence on extreme precipitation over New Zealand under differing circulation types

This study estimates the influences of anthropogenic forcing on precipitation over Aotearoa New Zealand (ANZ) and its connection to large-scale synoptic circulation features. Large ensembles of simulations from the weather@home regional climate model, under two scenarios, pre-industrial (natural ‘NAT’) and present-day (anthropogenic ‘ANT’) are analysed.

The influences of anthropogenic forcing on precipitation are disaggregated by large-scale weather patterns over ANZ derived using an existing synoptic classification system based on Self Organizing Maps. Under synoptic conditions characterised by low-pressure systems lying to the south and southwest of the country, precipitation differences between the ANT and NAT simulation exceed expectations from the Clausius-Clapeyron relationship indicating that both dynamics and thermodynamics play important roles in modulating the precipitation. A pronounced increase in the precipitation intensity is observed under these synoptic conditions when moving from the NAT to ANT. The wet day occurrence reduces in the ANT scenario, while the frequency of days with extreme precipitation rises. Therefore, as a result of human-induced climate change, while the number of rainy days decreases, a higher percentage of rainy days exhibit extreme precipitation events with an increased intensity, particularly over the west coast of the South Island.

Kevin Trenberth

(Auckland University and NCAR)

A more strategic approach to climate change issues in New Zealand

Climate change poses significant threats to New Zealand's environment, economy, and society. New Zealand is isolated and has a strong reliance on shipping, air travel, and tourism industries, all of which depend on fossil-fuelled transport. New Zealand exports many primary products some of which (e.g., rough wood) are bulky, and various goods are imported. As emissions are cut or a carbon tax is implemented, including tariffs on goods with carbon content, all of these are in jeopardy because of extra costs to export and import, and fewer tourists. Rising sea levels, extreme weather events, and disruptions in the natural environment can have severe impacts on the nation's economy, biodiversity, and quality of life. There is a great need to optimize renewable energy. In addition, trees and forests play a pivotal role in carbon sequestration, biodiversity conservation, and enhancing resilience against extreme weather events. Recommendations are discussed.

Mike Trought

(Innovative winegrowing)

Short- and long-term effects of temperature on Sauvignon blanc production in Marlborough

The Marlborough region produces approximately 70% of the $2.4B New Zealand wine exports. Climate warming is likely to affect vine phenology and flavour and aroma profile of the regions wine, in particular the flagship Sauvignon blanc. Phenological modelling indicates that budburst, flowering and harvest have advanced 0.22, 0.06 and 0.11 days per year respectively since 1945. Over the same period the date of the last frost has also progressively advanced since 1950 resulting in little change in the risk of a damaging spring frost. Short-term fluctuations in temperature at key phenological stages can have an unexpected effect on vine yield. For example, a 40% reduction in yield in 2021 can be attributed to six days cold days in mid-flowering that season, resulting in poor fruit set, reduced bunch weight and problems to the supply chain. The paper will discuss climate

factors determining wine grape production in Marlborough.

Jocelyn Turnbull

(GNS Science)

Radiocarbon as a tracer for Southern Ocean carbon exchange

The Southern Ocean is a key sink for anthropogenic carbon dioxide, yet the processes that govern the uptake rate remain only partly understood. We use observations of radiocarbon in carbon dioxide from shipboard transects across the Southern Ocean to develop latitudinal gradients of radiocarbon in the surface atmosphere. We present eight years of austral summer observations from ships of opportunity travelling between New Zealand and Antarctica, along with time series measurements from Baring Head, Macquarie Island, and Arrival Heights. We observe lower radiocarbon in the latitudes where upwelling occurs, consistent with upwelling of radiocarbon-depleted deep waters. We then combine NEMO model simulations of ocean carbon and radiocarbon with NAME atmospheric dispersion simulations to predict surface atmosphere radiocarbon and compare with the observations. Our model does a reasonable job of matching the observations, capturing the spatial pattern and day-to-day variability quite well. However, the model underestimates the magnitude of the observed radiocarbon gradient, particularly between 50 and 60◦S. The model-observation mismatch provides insights into our current understanding of Southern Ocean wind strength and deep water upwelling, and implications for the past the future strength of the Southern Ocean carbon sink.

Richard Turner

(NIWA)

NAME-III Simulations of Trans-Tasman and within Aotearoa/New Zealand dispersal of Fall Army Worm

NIWA operates the NAME-III (Numerical Atmospheric-dispersion Modelling Environment) dispersion for use in modelling long-range aerial dispersal of pathogens such as trans-Tasman movement of Myrtle Rust down to the potential farm-to-farm movement of Foot-and-mouth virus. In early 2022 Fall Army Worm (*Spodoptera frugiperda*) which had become established in Australia a few years ago was trapped in the North Island of New Zealand and in January 2023 trapped in the upper South Island. For this incursion, NIWA has deployed both "trans-Tasman" and "within-country" configurations of NAME-III to evaluate when Fall-Army Worm could have dispersed to different regions of New Zealand from various source regions in Australia and to also evaluate where moths may have dispersed from known (trap) locations within New Zealand. The 4 km grid-spaced trans-Tasman weather model (NZLAM4) and the 1.5 km New Zealand regional model were both used to provide detailed wind and weather analyses to NAME-III. Details and results of the NAME modelling will be presented in the talk.

Gokul Vishwanathan

(University of Canterbury)

Characteristics of regional extreme precipitation events over Aotearoa New Zealand

Regional mean characteristics of extreme precipitation events (EPEs) on an hourly scale have not been documented systematically over New Zealand. Using the recently created Extreme Weather Events (EWE) database, we examine the characteristics of EPEs recorded over different regions in NZ. Here, we focus on the rainfall ("R") and convective ("C") types of events. Using a spatiotemporal-based framework, several properties, such as the peak intensity, duration, and accumulation of individual events, are evaluated to quantify the characteristics of the EPEs across different regions. Our methodology effectively captures clear regional differences in the mean duration, accumulation, and peak intensity of "R" and "C" events. In particular, the "R" events have higher accumulations, especially over the West Coast and Southland, than the "C" events. Results also suggest that for "R" events, the higher accumulation is more strongly tied to the duration than the peak intensity, suggesting that the duration strongly controls EPEs across all regions over NZ. This emphasizes the importance of improving the skill of numerical weather forecast in simulating the duration of EPEs. Understanding an event's duration is particularly important in practice as EPEs with longer duration have more potential to cause severe floods over larger areas.

Jonny Williams

(NIWA)

Coupled atmosphere-ocean simulations of contemporary and future South Pacific tropical cyclones

Tropical cyclones – TCs – affecting the South Pacific region are studied using coupled atmosphere-ocean earth system models and (offline) storm tracking software which tracks the position of simulated pressure lows through time. The models used are the United Kingdom Earth System Model, version 1 – UKESM1 – and the related NZESM. The model pair considered here differ only in their treatment of the ocean and the NZESM has a nominal resolution of 0.2◦ in the region surrounding New Zealand and 1◦ elsewhere. After validating the storm tracking algorithm against cyclones Giselle and Gabrielle we use the Saffir-Simpson scale to split the tracked systems into categories based on their severity. For systems formed in the vicinity of New Zealand the overall number is overestimated but stronger storms are underestimated. We also see a general decrease in the total number of storms as radiative forcing, F, increases although there is some evidence of a small increase at extreme levels of warming. The power dissipation index, PDI, gives a first order measure of TC strength and we find that the average PDI per storm increases with F by up to 26 % under a 'fossil-fuelled development' scenario.

Yang Yang

(NIWA)

The role of jet-streak induced circulations on the heavy rainfall over New Zealand

Orographic and cold-front lifting play well documented roles in the occurrence of heavy rainfall in New Zealand (NZ). However, it is not well-known if jet-streak induced circulations similarly contribute to heavy rainfall occurrence in NZ, despite jet-streaks associated with the subtropical, polar front jet-streams often being found over the south-west Pacific. In this

study, the role of jet-streaks in three extremely heavy rainfall events are investigated. These are the February 2022 Westport, March 2022 Gisborne rain events and the February 2023 extreme rainfall associated with the passage of ex-TC Gabrielle over Napier and Gisborne. The jet-streak-induced circulations were isolated by applying a filter to the simulated ageostrophic winds and the vertical wind velocity forecast by NIWA's 4.4km horizontal resolution New Zealand Limited Area Model (NZLAM4). For the three events, the uprising branches associated with the jet-streak induced circulations were found over the heavy rainfall areas. Results suggest that the jet-streak induced circulations allow to provide favourable environmental conditions for existing rainfall mechanisms to persist, yielding greater rainfall amounts.

Hayden Young

(GNS Science)

Urban flask measurements of CO_2ff and CO to identify emission sources at different site types in Auckland, New Zealand

As climate action becomes increasingly more important, cities have become focal points for observing anthropogenic carbon emissions. As part of the CarbonWatch-NZ research programme, flask air samples were collected around Auckland and measured for their CO:CO_2ff ratio (RCO) at 28 sites. These sites were grouped by location to provide overall emission ratios for each site type, namely motorway, urban, suburban, and industrial sites. Since emission sources have unique RCO signatures, these results provided insight into the relative source compositions at each site type. By comparing flask and inventory data, we determined the traffic RCO in Auckland and showed its overestimation by Auckland's inventory. Similar comparisons were made in Los Angeles, Baltimore, Indianapolis, and Melbourne which showed varying degrees of agreement to inventory. We observed that on-road CO production is decreasing over time as vehicles become more advanced. This varies city to city and is influenced by local emission control laws.

Guang Zeng

(NIWA)

Impact of climate change on Southern midlatitudes ozone changes detected in the long-term Lauder ozonesonde record

Ozone plays a central role in atmospheric chemistry and the radiation budget. The stratospheric ozone layer prevents the harmful ultra-violet radiation from reaching the surface. Stratospheric ozone is also a natural source of tropospheric ozone, an air pollutant, via cross-tropopause transport. Since the 1980s, stratospheric ozone changes are dominated by Antarctic ozone depletion. From the late 1990s, due to the successful implementation of the Montreal Protocol (MP) in 1987 and its subsequent amendments, concentrations of ozone-depleting substances (ODSs) have been declining leading to recovery of stratospheric ozone now starting to become discernible. However, the stratospheric ozone recovery has been complicated by increasing greenhouse gases (GHGs) including CO2, methane, and nitrous oxide. Increases of these GHGs lead to both increasing and decreasing ozone at different levels of the stratosphere and troposphere. Here, we present the long-term newly

homogenised ozonesonde time series observed at Lauder, New Zealand, and show how ODSs and GHGs drive ozone changes at southern mid-latitudes throughout the lower and middle atmosphere. We stipulate that long-term vertically resolved ozone observations are critical for understanding the wide-ranging changes that the Earth System is currently undergoing.

POSTERS

Nick Edkins	Active Sites and Ice Nucleation: Primary Marine Organic Aerosol and Beyond
Peter Gibson	NIWA CMIP6 Downscaling Project: Status and historical evaluation
Felix Goddard	Sea spray dehalogenation in the NZESM
Daniel Morrish	A look at the long white clouds of Aotearoa
Sylvia Nichol	Using Baring Head Radon-222 to identify CO_2 baseline conditions
Daithi Stone	The role of anthropogenic warming in Cyclone Gabrielle
Daithi Stone	Detection and attribution of trends in extreme temperature and precipitation in Aotearoa

PANEL DISCUSSION

Jess Berentson-Shaw

(The Workshop)

Narratives for change: Communicating for effective climate change action

Most climate change specialists need to communicate publicly at some point to achieve a professional end – be that advising, advocating, or simply informing. The current communications landscape can make that extremely challenging. Climate communicators must negotiate a plethora of competing voices (some credible, many not), shifting media priorities, widespread scepticism, pseudo-science and outright misinformation, and a growing distrust of authority. The New Zealand public is also significantly 'doom fatigued' following the pandemic response. As climate change beds in, there is an increasingly urgent need for clear public understanding and well-informed policy that underpins adaptive and mitigative actions. However, in such a complex landscape, inaccurate or unhelpful narratives often prevail and become stuck in the public psyche. These narratives typically encourage inaction, diminishing the public and political will to take the urgent steps needed. So, can they be shifted? If so, what role do climate change communicators and others have to play?

Dr Jess Berentson-Shaw is Co-Director of The Workshop, a Wellington-based agency that uses research and evidence-based strategies and toolkits to help people communicate about complex issues. Dr Berentson-Shaw will outline one such strategy – Narratives for Change – which uses proven techniques to deepen understanding and adjust the mindsets that matter when making change. She will draw on examples from her extensive work in climate change

advocacy. Dr Berentson-Shaw's address will be followed by brief perspectives from a panel of specialists chosen from different points on the climate change communications chain:

- Eloise Gibson, Climate Change Editor, Radio New Zealand
- Lisa Murray, Head of Weather Communication, MetService
- Sam Dean, Principal Climate Scientist, NIWA

The session will conclude with an open-floor discussion.