Martin Singh,
Monash University, Australia

The interaction between tropical convection and the large-scale atmosphere: implications for current and future climate

Understanding how the behaviour of moist convection will change in response to global warming is challenging because of the small spatial scales relevant to convective clouds. In the tropics, moist convection is intimately coupled to large-scale circulations making such understanding critical for climate projection at regional and even global scales. In this talk, I will present a conceptual model linking mixing and microphysical processes in moist convection to the large-scale thermodynamic and dynamic structure of the atmosphere. According to this model, convective entrainment affects the vertical structure of overturning circulations, with implications for energy transport within and out of the tropics. Furthermore, as the climate warms, the effects of entrainment on the thermal structure become larger, providing an explanation for GCM-projected increases in tropical convective available potential energy and providing evidence for future increases in the intensity of tropical thunderstorms.

Eun-Pa Lim,
Bureau of Meteorology, Australia

Eun-Pa Lim [1], Debra Hudson [1], Matthew C. Wheeler [1], Andrew Marshall [1], Andrew King [2], Hongyan Zhu [1], Harry H. Hendon [1], Catherine de Burgh-Day [1], Blair Trewin [1], Morwenna Griffiths [1], Avijeet Ramchrn [1], and Griffith Young [1]
[1] Bureau of Meteorology, Melbourne, VIC, Australia
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Why was Australia not wet during spring 2020 despite La Niña?

The climate of 2020 was characterised by the occurrence of La Niña. Consistent with the typical impacts of La Niña on Australian rainfall, the Bureau of Meteorology's dynamical sub-seasonal to seasonal forecast system, ACCESS-S1, confidently predicted wetter-than-normal conditions over most of Australia for spring when forecasts were initialised in July 2020 and thereafter. However, many areas of eastern Australia received near average to very much below average rainfall, particularly during November. In this study, we have investigated some major causes of the deviation of rainfall from its canonical response to La Niña and causes of the forecast errors, using observational and reanalysis data for the period 1979-2020 and real-time forecasts of ACCESS-S1 initialised in July to November 2020. Our results show that while the ocean surface to the north of Australia was warmer than normal, which would have acted to promote northern Australian rainfall, it was not as warm as anticipated from its historical relationship with La Niña and its long-term warming trend. Besides, a negative phase of the Indian Ocean Dipole, which typically promotes spring rainfall in southern Australia, decayed earlier than normal in October. Furthermore, Madden-Julian Oscillation (MJO) activity over the equatorial Indian Ocean appeared to have suppressed rainfall across northern and eastern Australia during November. Although ACCESS-S1 accurately predicted the strength of La Niña and its spatial features, it over-predicted the ocean warming to the north of Australia and under-predicted the strength of the November MJO event, leading to an over-prediction of the Australian spring rainfall and especially the November rainfall.

Charmaine Franklin,
Bureau of Meteorology, Australia

Assessment of prototype km-scale atmospheric model configurations (RAL3) in the tropics

Convection-permitting models (km-scale) have delivered benefits for weather and climate forecasting due to their ability to better represent convective systems, high impact and topographically driven weather. Delivering improved configurations of the km-scale model is one of the underpinning activities of the Met Office's Regional Model Evaluation and Development program. With UM partners running the km-scale model in many regions of the world, the testing of prototype configurations relies on UM partners to assess new configurations in their regions of interest.

A major challenge of km-scale atmospheric modelling is dealing with the impacts of partially resolved convection. In the midlatitudes, convection can be very under-resolved in km-scale models and this has led to the regional model having two configurations, one for the midlatitudes and one for the tropics. The main difference between the configurations is that the midlatitude configuration has relatively weak turbulent mixing and stochastic perturbations to help initiate convection. With recent model developments, we are now at the ideal stage of having a prototype configuration of the regional model that may produce good performance across the globe. This presentation will show an assessment of the prototype km-scale RAL3 configurations in the tropics, which includes evaluation of the new cloud microphysics scheme CASIM (Cloud AeroSol Interacting Microphysics) and the new bimodal statistical cloud scheme.

Ali Tamizi,
University of Melbourne, Australia

Observed waves within Tropical Cyclones

Adam Conroy,
Bureau of Meteorology, Australia

The use of Ensemble Prediction Systems to quantify risk of tropical cyclogenesis

The Tropical Cyclogenesis Forecaster is responsible for producing daily outlooks which quantify the risk of tropical cyclone formation over parts of the Australian region for the next seven days. The use of Ensemble Prediction Systems is fast becoming one of the most important components in the forecast process. Adam will discuss how the Tropical Cyclogenesis Forecaster incorporates this information into the determination of the daily risk of tropical cyclone formation, and look at ways this can be improved in the future."

Stefan Zieger,
Bureau of Meteorology, Australia

Variable-resolution nearshore wave modelling

Over 80 percent of the Australian population lives in close proximity to the coast. The Australian coastline is fragile and at risk of coastal erosion and inundation, when exposed to large waves, that often occur in combination with elevated coastal sea levels. Accurate predictions of wave conditions in the nearshore are essential for the development of reliable coastal forecasting systems including coastal impacts. Such a system will support the real time activities and planning for all users of the marine environment and will deliver a range of short, mid and long-term benefits needed to de-risk, reduce costs and assist in growth of the fisheries and aquaculture sector, whilst supporting government planning and policy making.

The Bureau of Meteorology's operational wave forecast system (AUSWAVE) is relatively coarse in spatial resolution with 1/8° to 1/16° around Australia. This is generally insufficient to provide the level of detail required for predicting coastal impacts. To close this gap, a new high-resolution wave hindcast and forecast system has been developed to provide detailed wave information at the coast.

The Bureau Research Program has been trialling a few of pilot systems with variable resolution of up to 250 m in the coastal zone. The coastal wave models are nested within a global configuration of AUSWAVE G3 with a focus on a couple of regions around Australia. This talk will provide highlights of these systems and plans to extend the operational capabilities in form of a national wave forecast system.

Mark Doubell,
South Australian Research and Development Institute, Australia

Mark Doubell[1], Charles James[1] and Frank Colberg[2]
[1] South Australian Research and development Institute (SARDI)
[2] Bureau of Meteorology (BoM)

eSA-Marine: short-term forecasting for decision support in South Australian fisheries and aquaculture

Ocean models are an essential component of operational oceanography systems and can provide a range of services to a variety of marine users including industries, managers, and policy makers. SARDI and BoM have jointly developed a now-cast/forecast ocean modelling system for shelf and coastal waters of southern Australia. Presently, eSA-Marine system is one of only two high-resolution, data assimilating, nowcast-forecast models configured for a specific Australian region. The eSA-Marine systems fills an important ocean forecasting gap by providing short-term predictions of ocean circulation and properties on synoptic timescales (1 to 6 days) with high spatial (500 to 2500 m) resolution. This presentation will demonstrate applications of eSA-Marine system to date, with a focus on the needs of the South Australian fisheries and aquaculture sector. Specific examples will show how model 'hind-cast', 'nowcast' and 'forecasts' are being used to assist fishing operations and safeguard sectors from potentially harmful biosecurity events as well as developing disease surveillance and emergency response programs and policy.

Rabi Rivett,
Bureau of Meteorology, Australia

Downscaling swell in GFE

Julian O'Grady,
Commonwealth Scientific and Industrial Research Organisation, Australia

Mapping the hazards of high seas and dangerous surf conditions

Cherie O'Sullivan,
University of Southern Queensland, Australia

Cherie M. O'Sullivan[1], Afshin Ghahramani[1], Ravinesh C. Deo[1,2], Keith Pembleton[1,3], Urooj Khan[4], Narendra Tuteja[4]*
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Simulating nutrients flowing from ungauged catchments to the Great Barrier Reef

Classifying Catchments for Nitrogen using spatial data and pattern recognition

Hydrological modelling for ungauged catchments uses classification to overcome data deficits. Classification often applies physical drivers of the landscape to inform catchments with similar streamflow responses. However, water quality, such as Dissolved Inorganic Nitrogen (DIN) is also driven by biological and anthropogenic drivers, which is not only physical. Drivers of the nitrogen cycle are represented in other ways such as by vegetative responses to regions and land zones including soil types or land uses. While land use has been investigated for its suitability for classification, results for the same land uses are inconsistent and attributed to an unknown heterogeneity in the landscape. Effective classification for DIN in catchments that drain to The Great Barrier Reef has not yet been explored to date. This research, therefore, evaluates spatial data extracted from maps that are ubiquitously available across Queensland for original ecosystems and land use considered suitable proxies for observed DIN releases to The Great Barrier Reef. Together these maps are applied as eco units to consider heterogeneity in the same land use as a result of different ecological processes. The suitability of the data is evaluated using a new application of the Artificial Neural Network based Pattern Recognition (ANN-PR) technique to directly compare the classification result of the spatial data with the observed DIN releases. Kruskal-Wallis test for independence found that corroboration between the observed water data compared to classification results using proxy spatial data was independent of each other for streamflow responses, but, were not independent for DIN responses. This finding supported the hypothesis that the drivers of streamflow differ from drivers of DIN, and so, catchment classification should differ for these also. The results also indicate that inclusion of original ecosystem spatial data facilitated for corroboration of classification results with observed DIN, where land use classification on its own was not corroborated. These findings have implications to demonstrate a new application of ANN-PR to inform classification, as well as the importance of applying relevant drivers of the water quality constituent in the classification.

Chelle Gentemann,
Farallon Institute, USA

Science storms the cloud

Chelle Leigh Gentemann(1,2), Chris Holdgraf(3,4), Ryan Abernathey(3,5), Daniel Crichton(6), James Colliander(3,7,8), Edward Joseph Kearns(9), Yuvi Panda(3), Richard P. Signell(10)
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The core tools of science (data, software, and computers) are undergoing a rapid and historic evolution, changing what questions scientists ask and how they find answers. Earth science data are being transformed into new formats optimized for cloud storage that enable rapid analysis of multi-petabyte datasets. Datasets are moving from archive centers to vast cloud data storage, adjacent to massive server farms. Open source cloud-based data science platforms, accessed through a web-browser window, are enabling advanced, collaborative, interdisciplinary science to be performed wherever scientists can connect to the internet. Specialized software and hardware for machine learning and artificial intelligence (AI/ML) are being integrated into data science platforms, making them more accessible to average scientists. Increasing amounts of data and computational power in the cloud are unlocking new approaches for data-driven discovery. For the first time, it is truly feasible for scientists to bring their analysis to data in the cloud without specialized cloud computing knowledge. This shift in paradigm has the potential to lower the threshold for entry, expand the science community, and increase opportunities for collaboration while promoting scientific innovation, transparency, and reproducibility. Yet, we have all witnessed promising new tools which seem harmless and beneficial at the outset become damaging or limiting. What do we need to consider as this new way of doing science is evolving?

Salman Khan,
Commonwealth Scientific and Industrial Research Organisation, Australia

Sustained satellite observations of ocean surface waves and wind

Wei Han,
China Meteorological Administration, China

Wei Han[1] , Ruoying Yin[1] and Robert Knuteson[2]

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Assimilation of GEO Hyperspectral Infrared Sounders (GeoHIS) - progress and perspectives

Hyperspectral infrared (IR) sounders feature thousands of channels, which collectively provide high vertical resolution and the capability to accurately measure atmospheric temperature and humidity vertical structure information . The assimilation of high spectral resolution infrared sounder observations from polar orbit satellites has been widely used in global and regional numerical weather prediction (NWP) models and has large positive impact on NWP. However, Polar hyperspectral IR sounders have inadequate temporal coverage which limits their capability on rapid evolving weather systems analyses and forecasts. High temporal geostationary (Geo) hyperspectral IR sounder (GeoHIS) radiance measurements enable continuous sounding of the atmospheric temperature and moisture, and thus capture the temporal and spatial variability for high impact weather or rapid changing weather events.

On 10 December 2016, the successful launch of China's Fengyung FY-4A satellite into geostationary orbit initiated a new era in Earth observation by providing the first time-continuous observations of the upwelling thermal infrared at high spectral resolution with the Geostationary Interferometric Infrared Sounder (GIIRS). GIIRS is a Michelson interferometer that measures the atmospheric infrared radiation in a spectral range 700-2250cm-1 at a spectral resolution of 0.625cm-1. It has 1650 spectral channels covering longwave infrared (LWIR) (700-1130cm-1, 689channels) and middle-wave infrared (MWIR) (1650-2250cm-1, 961channels) bands. A subset of GIIRS longwave temperature sounding channels has been assimilated in China's global NWP system GRAPES (Global/Regional Assimilation and PrEdiction System) since December 2018 and improve the forecast over East Asia , especially for high impact weather forecasting, such as Typhoons. FY-4B was successfully launched on June 3, 2021 with a modified GIIRS featured by a 16×8 sensor array plane. The European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) is developing an operational advanced GEO hyperspectral IR sounder (IRS) as a part of Meteosat Third Generation (MTG-3) in the mid 2020's. The Japan Meteorological Agency (JMA) also has started discussions of a follow-on program for the operational geostationary satellites Himawari-8 and -9, which are scheduled to operate until 2029. NOAA recently has evaluated a range of space architecture options to select one that will provide the highest priority observations effectively and efficiently for a future Geosynchronous and Extended Orbit (GEO-XO) program considering infrared hyperspectral sounder onboard two spacecraft near the current GOES-East and GOES-West positions.Based on the assessments and assimilation of GIIRS, this talk will discuss the recent progresses and future perspectives of GeoHIS assimilation.

Jane Warne and Viriginia Mazzini,
Bureau of Meteorology, Australia

When is an observation not an observation?

Rachael Quill,
Weatherzone, Australia

Integrating multiple data streams to improve wind generation forecasts

At various stages of their development and operation, the latest predictive frameworks for wind generation rely on high-quality observations in conjunction with numerical weather prediction (NWP). Here, we explore two such perspectives on incorporating observations in forecast development.

Firstly, quality-control (QC) of multiple incoming data streams plays a significant role in producing accurate and timely wind generation forecasts. The robust QC engine developed here is designed to incorporate and leverage layers of available observed information. As an example, on their own, the statistical properties of historic wind generation can be derived and used in many ways to accurately identify suspicious observations, such as unexplained periods of reduced power output. However, when appropriate and high-quality metadata is available, such as turbine availability, these statistical properties can be complemented by physically-informed outlier detection, and in turn can further improve forecast accuracy. Combining the use of observed meteorology and operational metadata, alongside high-quality NWP, enables the development of a robust and dynamic QC engine, the principles and structure of which can be generalised across multiple forecasting systems.

Further to operational forecast improvements, observational sources allow for the validation of NWP in the context of significant weather events and understanding their impact of downstream outputs. The impact of phenomena such as low-level jets (LLJs) on wind power production has been reported and analysed in a number of regions around the world. However, little is known of the phenomenon and its impact of wind energy in Australia. The second part of this presentation will highlight a preliminary case study on the use of lidar observations in understanding the occurrence of LLJs in SE Australia, their presence in high resolution NWP and their impact on wind power generation.

Luigi Renzullo,
Australian National University, Australia

Land Surface Temperature and other non-meteorological Himawari-8 products for Terrestrial Ecosystem Science

Estel Cardellach,
Institute of Space Sciences (ICE-CSIC) and Institute of Space Studies of Catalonia (IEEC), Spain

Portfolio of GNSS reflectometry: a broad catalogue of products beyond ocean winds

GNSS reflectometry (GNSS-R) is an opportunistic technique: it operates as an active radar, but the signals are emitted by satellites intended for other uses (in this case, for navigation and positioning purposes). This makes GNSS-R payloads small, light and cheap, facilitating their assembly in a diversity of spaceborne platforms, including cubesats, and enabling cost-effective constellations and meta-constellations that provide GNSS-R measurements.

Measurements of the ocean winds and waves are the most known GNSS-R product, as this was the objective of NASA's CyGNSS constellation mission. Nevertheless, GNSS signals reflected off land surfaces, lakes and rivers, wetlands, sea ice and ice shelves also carry geophysical information, unfolding potential for a sustainable earth observation program. This talk will present, at a very high level, the basic principles of the technique and how they are used to retrieve a large variety of meteorology, hydrology, cryosphere and climate variables. Discussions on their spatio-temporal resolution, coverage, as well as the drawbacks derived by its opportunistic nature shall give a balanced picture of what can be expected from GNSS-R. The presentation will also provide an overview of the spaceborne GNSS-R missions currently orbiting and those planned for launch in the near future.

Stephen English,
European Centre for Medium-range Weather Forecasting, UK

Future challenges in data assimilation for NWP

NWP underpins the major advances in weather forecast accuracy achieved in recent decades. It is also expanding into climate monitoring through reanalysis and into new areas such as environmental prediction. This means the socioeconomic importance of NWP has never been higher. ECMWF's strategy and indeed the strategy of WMO and many other places recognises that an Earth System approach is important for future improvements. Data assimilation systems for the atmosphere have advanced remarkably in recent decades, but the demands of an Earth System approach, as well as applications needing ever higher spatial resolution, mean this evolution must continue, which in turn changes the requirement for observations. There are major evolutions taking place both for space and surface-based observations to try to meet this evolving requirement. There are also major advances needed and taking place in the science to ensure effective use of these observations. In this presentation some aspects of this changing landscape will be explored. When we look at observation data coverage maps we sometimes see good coverage and sometimes we see gaps. However the reality is much more complex, because coverage is only really good if the observations are being assimilated in an optimal way. This depends very much on the maturity of the system (both the assimilation system itself, but also critically the model of the physical processes). For most Earth System components neither the data coverage nor the maturity of use comes close to what we have for the atmosphere. We lack key observations and there is still much to do to bring the model and data assimilation up to the same standard as decades of research and development has achieved for the atmosphere. For example, microwave imagers have sensitivity to the earth's surface (snow, temperature, soil moisture, waves) that are yet to be fully exploited in operational systems. This can make it more difficult to judge where there are really observation gaps and where there are science developments needed. To illustrate this consider scatterometer observations: these drive the low level wind field; in a strongly coupled data assimilation system this drives the sea surface temperature analysis in persistently cloud areas, where we lack thermal observations of the ocean's surface. In particular this has been shown to be important in the cold wake of a tropical cyclone. Existing observations therefore play a very different role in coupled data assimilation systems, meaning some gaps could be addressed with existing observations. It is also important to recognise gaps remain even for the atmosphere, with the challenge to use observations with a more non-linear relationship to the state space, to extract higher vertical resolution, and to gain wind information where feature tracing can’t (either through AMVs or through the direct tracer effect in 4D-Var). Some elements of new data assimilation developments at ECMWF will be briefly mentioned, to show how they address elements of this (OOPS, Continuous DA, soft-centred ensemble DA, outer-loop coupled DA, model error estimation). Finally the talk will attempt to address the question whether is it even possible to assess future requirements.

Blair Trewin,
Bureau of Meteorology, Australia

The IPCC Sixth Assessment Report: what does it tell us about the climate risks facing Australia?

Australia has a high level of vulnerability to a wide variety of climate risks. Many of these risks are linked to short-period extreme events, such as heatwaves (land and ocean), floods, storms and tropical cyclones, and dangerous fire weather. Others are linked to issues which manifest over longer timeframes, including drought and water availability, and sea level rise and associated coastal risks. Changes in mean climate have the potential to affect land and marine biodiversity, and shift viable zones for types of agriculture. In this presentation, I will discuss what the recently released IPCC Sixth Assessment report says about how these risks have changed in the past and are expected to change into the future, including low-likelihood, high-impact scenario. Also considered are how human activity will influence key drivers which affect Australian climate variability, such as the El Niño-Southern Oscillation; the variables for which we do not have a clear-cut signal for past or future change; and where key uncertainties still lie.

Tanya Fiedler,
University of Sydney, Australia

Climate impacts on company accounts

The Financial Stability Board's Taskforce on Climate-related Financial Disclosures (TCFD) published recommendations in 2017 for organisations to disclose in their annual financial reports' information pertaining to risks arising from climate change. TCFD and investors recommend such information should be presented in financial statements, for example in a company's balance sheet or profit and loss (income) statement. To account for physical climate risks in this way requires, however, a chain of knowledge translation from climate science to accounting that is complicated by the languages, standards, cultures and practices of two very diverse disciplinary domains. I will unpick some of the points where this translation breaks down from the perspective of accounting.

Fran Moore,
University of California, Davis, USA

Applications of Social Media Data for Understanding Human Exposure and Responses to Extreme Weather

Social media data, with its wide spatial scope, high temporal resolution, and embedded information about impacts and responses, has the potential to complement more traditional environmental monitoring tools. Here I present two studies using social media data to better understand both the exposure and social response to changing environmental conditions. The first study uses social media posts about weather to quantify the rate at which extreme temperatures are socially normalized. The second uses posts about flooding to better characterize tidal flood thresholds along the US east and gulf coasts.

Julia Mindlin,
Universidad de Buenos Aires, Argentina

Implications of model uncertainty in regional climate change in the Southern Hemisphere: a storyline approach

Regardless of the latest advances in global climate modelling, understanding and predicting regional climate change is still challenging due to the fact that regional precipitation is under the control of both thermodynamics and dynamics (i.e. atmospheric circulation). There is high confidence on the thermodynamic aspects of climate change, but changes in dynamics remain to a high degree uncertain. This is due to the chaotic nature of the atmosphere, which makes it difficult to distinguish the atmospheric circulation response to global warming from natural chaotic variability of the atmosphere. In this talk I will explain how this uncertainty can be addressed with a storyline approach, in order to provide climate change information at a regional level in the Southern Hemisphere.

Julie Demuth,
National Centre for Atmospheric Research, USA

Risk Communication, Perceptions, and Responses to Tropical Cyclones

Kim Klockow-McClain,
University of Oklahoma, USA

Exploring Connections Between Probabilistic Hazard Information and Warnings

A major research program in the United States, FACETs (Forecasting a Continuum of Environmental Threats) aims to revolutionize the country's weather hazards communication system with more continuous, probabilistic forecast information. A key question of this program is how to mesh forecast uncertainty information with the existing watch/warning system, or potentially to replace it. This presentation will discuss this issue from the perspective of warnings in severe weather contexts: in experiments with users in the Hazardous Weather Testbed, various methods for blending the two concepts were attempted, with various drawbacks to each approach. This led to a need to more deeply understand the functions of the existing warning system, and to situate the attribute of forecast uncertainty within it. A survey of NWS forecasters reveals the prevalence of various philosophies about warnings within the NWS, and offers broader insight into what factors forecasters consider when they make warning decisions. The study informs decisions about how, if at all, warnings should be linked to probabilistic hazard information during latter stages of FACETs implementation.

Deryn Griffiths
Bureau of Meteorology, Australia

Communicating Probabilistic Rainfall Information in Public Forecasts

We will take a journey through historical and future communication of probabilistic rainfall forecasts within the Bureau of Meteorology. We will see how different areas of the Bureau are working together to overcome difficulties we have faced. We will touch on communication of probabilistic forecasts of other weather parameters.

Sally Potter,
GNS Science, New Zealand

Impact-based forecasts and warnings – how effective are they?

Carla Mooney and Brenda Mackie,
Bureau of Meteorology, Australia

Challenges and opportunities in redesigning a warning service

The Bureau is committed to developing warning services that are timely, targeted and well communicated. It is critical to respond to the challenges and changing demands of weather and society in order to ensure public safety into the future. This presentation will describe the Future Warnings Services Roadmap 2021-26 and how it embraces the insights of social science and the experience of the broader warning community.

Kozo Okamoto,
Japan Meteorological Agency, Japan

Kozo Okamoto[1], Toshiyuki Ishibashi[1], Izumi Okabe[1], Masahiro Hayashi[1], Tempei Hashino[2], Masayuki Nakagawa[1], Arata Okuyama[3]

[1] Meteorological Research Institute, Japan Meteorological Agency (JMA), Tsukuba, Japan.
[2] School of Environmental Science and Engineering, Kochi University of Technology, Kami, Japan
[3] Meteorological Satellite Center, JMA, Kiyose, Japan.

All-sky infrared radiance assimilation of Himawari-8 in the JMA global system

All-sky infrared radiance (ASR) assimilation has been developed for Himawari-8 in the global data assimilation system of JMA. The representation of ASR simulations from the global forecast model and radiative transfer model were carefully examined. The systematic differences between observations and simulations were caused by considerable deficit of high cloud in the forecast model of JMA and overestimated absorption of thin ice cloud in radiative transfer calculation. This examination results helped to develop quality control (QC) procedures and cloud-dependent observation error model and bias correction in all-sky conditions. We recently accounted for cloud-dependent inter-band observation error correlation that rapidly increases with cloud effect.

Data assimilation cycle experiments showed that the ASR assimilation significantly improved background fit and forecasts in comparison with experiments without Hiwamari-8 radiances. Accounting for observation error correlation brought slightly better fit to IASI temperature channels. However, the clear-sky radiance (CSR) assimilation of Hiwamari-8 brought greater improvement in forecast despite worse fit to IASI temperature channels. This suggests the need to more careful comparison of response from ASR and CSR and to enhance ASR processings.

Thomas Deppisch,
Deutsche Wetterdienst, Germany

Use of visible reflectances in an ensemble data assimilation system for high-resolution NWP

Philippe Chambon,
Météo-France, France

Philippe Chambon, Marylis Barreyat, Jean-François Mahfouf and Ghislain Faure

Improving precipitation forecasts in the Tropics through data assimilation of microwave observations

Microwave observations are becoming more and more useful for numerical weather prediction (NWP); in particular in an all-sky context within which they can bring highly relevant information content on the vertical distribution of water vapor and hydrometeors.

The method used at Météo-France for assimilating the cloudy and rainy observations is called the '1D-Bay+4D-Var' (Duruisseau et al., 2019) and corresponds to a two step process: (i) a Bayesian inversion to retrieve atmospheric profiles from microwave radiances, (ii) the 4D- Var assimilation of these retrieved profiles. Cloudy and rainy observations from 3 MHS and 2 ATMS instruments are now assimilated using this method within the 2021 parallel suite of the ARPEGE global model; this parallel suite will become operational early 2022.

In the first part of the presentation, the forecast impacts of all-sky assimilation of those 5 sounders will be summarized, with a particular focus on precipitation.

In its current implementation, the 1D-Bay+4Dvar method uses the RTTOV-SCATT V12 forward model with a single set of radiative properties for hydrometeors. This means that the same properties are used for all weather situations over the globe. This rather common assumption in the NWP context is somewhat unsatisfactory when considering the variability of hydrometeors habits in nature. The '1D-Bay+4D-Var' methodology offers an interesting test-bed in order to examine how this variability can be taken into account and propagated to the analysis through the inversion. In this presentation, results from using this unique feature of the 1D-Bay and consisting of using several different radiative properties together within the inversion step will be shown and discussed.

Andreas Becker,
Deutsche Wetterdienst, Germany

Global land-surface precipitation going extreme with global warming? What do we know, what's up for further research?

Alison Stirling,
Met Office, UK

The ParaCon programme: improving the representation of convection across model scales

Atmospheric convection responds locally to instability, but it also transfers heat upscale such that conditions on the planetary-scale depend, organise, and interact with it. It is the simultaneous need to represent the small length-scales of the buoyant transport, with its reach to global scales that makes it a long-standing problem for atmospheric modelling, and recognised as of such significance that it is central to four grand challenges of the World Climate Research Programme.

The ParaCon programme was set up to improve the representation of convection in weather and climate models, and three different conceptual approaches have been explored. In this seminar I will talk about some of the advances that have been made, and the nature of some of the key challenges that remain, most notably in the representation of moist-turbulent behaviour on the smallest scales.

Simon Dadson and the Hydro-JULES Team
Center for Ecology and Hydrology, UK

Hydro-JULES: Next generation Land-surface and Hydrological Predictions

This presentation will give highlights from the Hydro-JULES, a five-year research programme funded by NERC National Capability and delivered by the UK Centre for Ecology and Hydrology (UKCEH) in partnership with the British Geological Survey (BGS) and National Centre for Atmospheric Science (NCAS). The Hydro-JULES project covers topics in land-surface science and hydrology including: quantification of hydro-meteorological risks, using high-resolution climate predictions for hydrological applications, calculation the impacts of environmental change on evaporation, transpiration, and soil moisture, modelling flood inundation over large areas, representing anthropogenic interventions in the water cycle, and application of new techniques including Earth observation and data assimilation. The presentation will explore the scientific drivers for integrated land surface and hydrological modelling and give highlights from the main elements of the programme.

Ryan Sobash,
National Centre for Atmospheric Research, USA

Ryan Sobash, David John Gagne, Dave Ahijevych, Craig Schwartz, Charlie Becker, Gabrielle Gantos
NCAR, Boulder, CO, USA

Improving convective hazard forecasts by post-processing convection-allowing model forecasts with machine learning techniques

This presentation will summarize two ongoing projects that are exploring the potential of machine learning (ML) to improve predictions of severe convective storms in the United States. The first project uses convection-allowing model (CAM) output and neural networks to produce gridded probabilistic guidance for convective hazards (e.g., tornadoes and hail storms). Output from this system has been objectively and subjectively evaluated over multiple years, and this presentation will summarize the performance of the forecasts, with an emphasis on understanding the situations when the ML systems improve upon conventional forecasting techniques. The second project applies ML techniques to objectively classify the convective mode within CAM predictions. Given that convective mode is strongly related to the likelihood of specific convective hazards (i.e., intense tornadoes are most likely to occur within supercells), objective techniques and guidance products developed to summarize CAM mode information may improve hazard predictions. The presentation will summarize the development of the mode classification system, including the collection of expert-derived mode labels, training of ML models such as convolutional neural networks, and subjective evaluations of the guidance products by forecasters. The presentation will close with a discussion of future research directions and challenges encountered when applying ML techniques to improve convective hazard predictions.

Joshua Soderholm, Alain Protat, Valentin Louf,
Bureau of Meteorology, Australia

Transforming radar-based nowcasting - hail and wind guidance for operations

Radar-based analysis and nowcasting of severe weather provides critical guidance for informing warnings. Currently, operational nowcasting tools are agnostic to the hazards of wind and hail, which limits the capacity to incorporate this information into cell-based warnings. Further work is also required to effectively utilise Doppler-radar information for wind analysis and polarimetric-radar information for hail sizing. With the ongoing expansion of the Doppler and polarimetric radar coverage, these new capabilities are now possible over much of Australia's populations. The following talk provides an overview of current work to deliver wind and hail analysis and nowcasting tools into operations by mid 2022. This includes the use of 3D wind retrievals and polarimetric information to assess hail size and accumulation depth.

Christian Jakob,
Monash University, Australia

Interactions of convection with the larger scale atmosphere - an observational perspective

The faithful representation of tropical convection in weather and climate models remains one of most difficult tasks in atmospheric science. This is so, because the complex interactions of small-, meso- and large-scale processes that occur in convection need to be parametrised in those models.

Since the 1990s, a research radar network operated by the Bureau of Meteorology around Darwin has been instrumental in significantly improving our understanding of the scale interactions associated with tropical convection. Its use has culminated in a unique, 16-year long data set for atmospheric convection research developed in joint research between the Bureau and Monash University. We use this data set to examine the key ingredients of tropical convective cloud ensembles, such as cloud number, size, depth and in-cloud vertical motion and their relationship to the large-scale state of the atmosphere.

We show that convective heating in an area is largely dominated by the fraction of the area that experiences convection. We show that the most intense convection is associated with large clouds that occur in a dry and often descending atmosphere, while the largest area-average rain results from a moderate number of moderate size clouds embedded in a humid and ascending atmosphere. Combining cloud-structure information with radar-based estimates of in-cloud vertical velocity, enables us to estimate convective mass-fluxes over long periods of time and large areas. Finally, we present some early examples how the work can be carried forward to other locations in Australia through the use of the Australian Unified Radar Archive (AURA).

In addition to presenting ground-breaking science results achieved over a long period of time, the talk highlights how a successful partnership between the Bureau of Meteorology and the Universities can significantly enhance national capabilities in frontier areas of atmospheric science.

Carlos Velasco and Jayaram Pudashine,
Bureau of Meteorology, Australia

Multi-scale evaluation of NWP rainfall predictions across Australia

In this talk, a multi-scale scheme was used to evaluate the skill of rainfall forecasts from two NWP models (ACCESS-G3 and ECMWF-HRES) across Australia for lead times from 1 hour up to 8 days. High-resolution gridded radar-based rainfall fields were used as 'truth'. Results show substantial variability of skill due to the diurnal cycle that, in some tropical and subtropical regions, may be more extreme than the expected reduction with the lead time of the forecast. Also, ACCESS-G3 seems to have better initial skill than ECMWF for larger scales indicating a better Data Assimilation process in the former. However, ECMWF-HRES shows a smaller reduction of the skill with lead time that seems to indicate a better evolution of the model core than ACCESS-G3 one.

Francisco Doblas Reyes,
Barcelona Supercomputing Centre, Spain

Climate prediction for climate services: uses in agriculture and energy

Doerte Jakob,
Bureau of Meteorology, Australia

D. Jones[1], R. Matear[2], K. Braganza[1], D. Jakob[1] and J. Landsberg[1]
[1] Bureau of Meteorology, Melbourne, Australia
[2]CSIRO, Hobart, Australia

A new national approach to assist Australians build resilience to climate hazards

Australia is well known for its climate extremes, exacerbated by its location in the tropics/subtropics, and affected by multiple modes of climate variability including the El Niño-Southern Oscillation and the Indian Ocean Dipole. This variability now occurs against a background of climate change, which has well documented impacts increasing some climate hazards including heatwaves, fire weather, intense rainfall, drought (southern areas in particular) and coastal inundation.

In response to recent climate extremes including Black Summer 2019/20, the Australian Government has established a new multi-agency partnership called the Australian Climate Service (ACS, https://www.acs.gov.au/). The ACS is a partnership between the Bureau of Meteorology, CSIRO, Geoscience Australia, and the Australian Bureau of Statistics and will help its customers to better understand the threats posed by a changing climate and physical hazards, to limit the impacts now and in the future. ACS will draw on exposure, vulnerability, and hazard data to provide an integrated picture of hazard impacts and future risk.

This presentation will give a high-level overview of the approach being taken to develop seamless hazards services as part of the ACS, covering the past, present and future. This includes enhanced historical datasets, hazard seasonal outlooks and future hazard projections.

Mike Davidson,
Australian Energy Market Operator, Australia

Emerging meterological issues in the energy industry

Warwick Grace,
Grace Research, Australia

The COtL Mesonets: R&D Opportunities

Grace Research Network

(on behalf of COtL)

Mesonets are operating in South Australia in the Midnorth and the Riverland and Mallee regions. These mesonets comprise over 70 Automatic Weather Stations (AWS) with typical nearest neighbour distances of 10 to 15 km over complex topography and 20 to 25 km over undulating countryside.

The primary purpose of these mesonets is to reduce off-target spray drift of agricultural pesticides and herbicides. This has been demonstrably successful. Perhaps counter-intuitively, inversions are conducive to long distance off-target spray drift and it is illegal to spray when an inversion exists. The AWS measure and provide inversion information and growers can avoid spraying in inversion conditions. The AWS report the usual weather variables as well as inversion and stability information. Data quality assurance is rigorous.

The mesonets are a commercial enterprise of COtL (Conditions Over the Landscape - see https://cotl.com.au/ or https://midnorthmesonet.com.au/).

R&D opportunities, current and potential, exist around the investigation of the basic datasets and operation of client-specified instrumentation.

Al Hawksford,
Bureau of Meteorology, Australia

Trusted Private Automatic Weather Stations – Tapping the value of 10,000 privately owned automatic weather stations through automated quality control.

Farmers frequently complain that their nearest automatic weather station (AWS) is too far away and doesn't represent their conditions; "How can you forecast for my place if you don't know what happens here?" This has led to a surge in the installation of privately owned AWS', with owners now expecting their data to be used for high value decision making and services such as parametric weather index insurance policies. However, service providers are resistant to using privately managed data; "How do I know if I can trust it?"

The Trusted Private Automatic Weather Stations (TPAWS) project is addressing this market failure by creating an automated quality control service that provides a measure of the confidence end users can place in any daily observation created by a privately owned AWS. The project has brought together internationally praised geo-statisticians from Data61, 16 Managers and Operators of Observation Networks (MOONs) and 12 insurers to co-design the service.

In fact, if all MOONs subscribe to the service, the Bureau and its customers could have access to quality controlled data from over 10,000 extra AWS' to compliment the Bureau's 2,000 strong network.

Caroline Poulsen,
Bureau of Meteorology, Australia

Surface solar irradiance measurements from satellite

Tim Cowan,
Bureau of Meteorology, Australia

Tim Cowan[1,2], Matthew C. Wheeler[2], Hanh Nguyen[2], Catherine de Burgh-Day[2], and David Cobon[1]
[1] Centre of Applied Climate Science, University of Southern Queensland, Toowoomba, Australia
[2] Bureau of Meteorology, Melbourne, Australia.

Livestock chill conditions associated with the February 2019 Queensland floods

The compound extreme weather event that impacted northern Queensland in February 2019 featured record-breaking rainfall, persistent high wind gusts and relatively low day-time temperatures. The event caused more than half million livestock deaths across six northwest Queensland Gulf country shires. In this talk, I examine the livestock chill conditions associated with this week-long weather event and its potential for prediction from eleven world-leading sub-seasonal to seasonal (S2S) forecast systems. The livestock chill index, used for sheep grazier warnings, combines daily rainfall, wind and surface temperature data. Averaged over the event week, the potential heat loss of livestock fell in the moderate to high category, with severe conditions on the day of peak rainfall on 5 February. Using calibrated forecasts from the Bureau of Meteorology's S2S forecast system, ACCESS-S1, a one-week lead prediction showed a 20 to 30% probability of extreme livestock chill conditions over the northwest Queensland Gulf region, however the highest probabilities were located to the west of where the greatest livestock impacts were observed. Of the other ten S2S systems, around half suggested greater than a 20% chance of extreme conditions, more than twice the climatological probability. Despite a clear association between the observed extreme weather conditions and an active Madden-Julian Oscillation (MJO) event stalling in the western Pacific (Cowan et al. 2019), the majority of one week lead S2S forecasts did not predict an extended slow-down in the MJO. In this talk, I will discuss the need for tailored diagnostics that better represent the cold effects of summer tropical cyclones and quasi-stationary lows on northern Australian livestock, particularly cattle.

Sam Emmerson,
University of Oklahoma, USA

Demonstrating the Capabilities of a Low-Cost Passive Multistatic Weather Radar System through Observations and Simulations

Multistatic radar architectures have the potential to provide a cost-effective source of 3D wind information from both operational and research radars, owing to a system design of one transmitter and several receivers. A prototype multistatic network consisting of two passive receivers and the KTLX WSR-88D has been constructed in the Oklahoma City metropolitan area. To achieve sufficiently precise Doppler frequency estimates while reducing cost, transmitter/receiver synchronization is done through measurements of the WSR-88D's sidelobe radiation, rather than an expensive GPS-based system. Weather observations of stratiform rain using KTLX as a transmitter of opportunity are used to validate the accuracy of velocity measurements obtained through this technique.

Additional convective weather cases collected with the passive radar network demonstrate its benefits and weaknesses, as the simultaneity of the observations negates the need for interpolation in time, but the low directivity of the antennae can lead to significant sidelobe contamination. Using a multistatic radar simulator and NWP model data, simulations of the system show that additional receiver systems can improve the network's coverage and robustness at little additional cost. If a phased-array weather radar (PAWR) is used as a transmitter of opportunity, then techniques like sidelobe whitening could be used to greatly reduce sidelobe contamination, while improved PAWR scanning techniques could provide 3D wind retrievals with temporal resolution of 60 s or less, yielding a promising future for this type of weather radar system. In addition, a receiver upgrade to dual polarimetry is being considered, which could allow for novel hydrometeor classification and retrieval techniques. Preliminary simulations of such a network will be presented.

Martin Cope,
Commonwealth Scientific and Industrial Research Organisation, Australia (CSIRO)

Martin Cope, Fabienne Reisen, Julie Noonan

Forecasting urban air quality during bushfire smoke impacts. Learning the lessons of the black summer fires.

Smoke emissions during the 2019/20 black summer bushfires caused extreme levels of air pollution over populated urban and rural cities along the eastern seaboard of Australia for periods extending from days to weeks. During black summer, the Bureau of Meteorology (BOM), with support from CSIRO operated AQFx, a regional air pollution forecasting system which was originally set up to forecast smoke transport from prescribed burning in Victoria, and, more recently, in NSW.

Following the Royal Commission into Natural Disasters, CSIRO, BOM, university partners, and fire agency, health and environment department stakeholders have embarked on a project (AQFx national prototype project; funded by the National Recovery and Resilience Agency) to extend the focus of AQFx to include all states and territories, and to increase the robustness of AQFx for forecasting population smoke exposure from large, long-lived bushfires. In this presentation, we will outline the goals of the national prototype project, and will highlight some of the early project outputs as we progress towards project delivery in June 2022.

Vinod Kumar,
Bureau of Meteorology, Australia

Vinod Kumar[1], Charmaine Franklin[1], Sylvia Bohnenstengel[2], Kirsty Hanley[2] and Humphrey Lean[2]
[1]Bureau of Meteorology, Melbourne
[2]UK Met Office, Exeter

Development of an urban-scale model for the Paris Olympics Research Demonstration Project

The Bureau, in partnership with the Met Office, is developing an urban-scale modelling system for Paris in the context of the 2024 Paris Olympics Research Demonstration Project (RDP). The RDP is a platform to bring international agencies together to advance the research on future weather forecasting systems for urban areas and is supported by the World Meteorological Organization. Participation in the RDP provides an opportunity to understand the capability of the Unified Model (UM) and its urban scheme, called the Met Office Reading Urban Surface Exchange Scheme (MORUSES), at ~100m resolution. The present study will give an overview of the Paris RDP and some of the specific modelling research questions that will be addressed. We will also discuss the development of the modelling system and some of the associated challenges. Specifically, the study will focus on the urban morphological datasets required by the urban scheme MORUSES. The accurate representation of these parameters is found to be critical for the model performance. Some preliminary work done to incorporate third-party urban datasets to estimate the required morphological parameters will be presented.

Song Chen,
National Environment Agency, Singapore

Song Chen[1] and Anurag Dipankar[2]
1. Centre for Climate Research Singapore, 537054, Singapore
2. ETH Zurich, 8092 Zurich, Switzerland

On the applicability of urban canopy parameterization in building grey zone

With increasing interest in urban meteorology and related services, there is a growing need to appropriately represent urban environment in climate/weather models. These regional weather/climate models typically use a km-scale horizontal grid, which is not sufficient to resolve the flows around buildings. Effects of the urban environment on the atmosphere above are represented through a bulk approach using the Urban Canopy Parameterization (UCP) schemes. All existing UCPs use the repeating canyon-roof representation that assumes homogeneous distribution of building within the grid box. It is commonly accepted that the assumption of homogeneity holds at km scales, however, it is doubtful when regional models are gradually approaching towards city-scale modelling employing sub-km grids. The building grey-zone ranges from a few hundred meters to tens of meters (i.e. building resolving-scales), where the use of existing UCPs can be questionable. In this work, we show that the assumption of homogeneity indeed does not hold at the urban grey zone for the city-sate Singapore. To understand the possible influences of the use of UCPs at scales from the building grey zone to the conventional mesoscale, we propose an urban-grid method that allows to estimate the parameterized fluxes from a typical UCP at different urban morphology resolutions while keeping the same atmospheric model grid. Numerical results show variations of near-surface temperature and wind, and the impacts of different resolutions on boundary layer above the surface will also be discussed.

Melissa Hart,
University of New South Wales, Australia

Urban climate research at the ARC Centre of Excellence for Climate Extremes (CLEX): multi-scale observational and modelling approaches

Karl Monnik
Bureau of Meteorology, Australia

A roadmap to access third party observations for urban applications

Australia's climate is changing, and weather extremes are occurring more frequently and with greater intensity. Urbanisation and population growth mean our customers and their assets are increasingly exposed to extreme events, bringing greater demand for the Bureau's services, as identified in the Bureau's Observations Ecosystem Roadmap (OER). In spite of infrastructure investment orders of magnitude greater than in rural areas, investment in real-time environmental data to underpin forecasts and warnings in urban areas is dismally lacking.

The OER highlights the benefit to the Bureau gained through unlocking access to all the data available in the Australian observations ecosystem. Initiatives such as creating value from the world of data, deployment of adaptive monitoring capability to characterise conditions at high spatiotemporal scale will contribute to unlocking value. These benefits can depend on a significant investment in relationships, standards, analytics, systems and a deep understanding of the characteristics of the data. Once this is in hand, then the benefits can be measured and prioritised.

Using recent examples of access to third party data, the presentation will illustrate the roadmap.

Hartmut Bösch,
University of Leicester, UK

Observing greenhouse gases from space - from climate applications towards monitoring of emissions from cities and point sources

We have now a 20-year record of global space-based observations of atmospheric CO2 and CH4 thanks to missions such as SCIAMACHY, GOSAT and OCO-2. These missions provide us with the data needed to better constrain and understand the exchange of carbon between the surface and the atmosphere from natural ecosystems, especially for regions poorly monitored from the ground.

In recent years, we have seen a shift in focus towards observations that can inform on anthropogenic emission and their response to emission reduction policies. Although not designed for this purpose, the OCO-2 mission has given us a first glimpse into atmospheric signals from anthropogenic emission sources which has improved with the launch of new satellite missions with better mapping capabilities (OCO-3 and TROPOMI). This is accompanied by an emerging fleet of hyperspectral satellites that allow to observe emission plumes on a much finer (meter) scale but limited to the strongest sources. Further progress in monitoring anthropogenic emissions can be expected with the launch of Copernicus Carbon Dioxide Monitoring mission CO2M which will form the space component of the European integrated monitoring and verification support capacity (MVS)

In this presentation, I will introduce space-based observations of atmospheric CO2 and CH4 and discuss measurements of CO2 and CH4 over cities and for emission hotspots. I will also describe a new network of ground-based column instrument that we have setup in London and show how we use it to evaluate satellite observations over cities. The presentation will conclude with an outlook towards future mission

Richard Engelen,
European Centre for Medium-range Weather Forecasting, UK

Monitoring and forecasting air quality in times of Corona

The Copernicus Atmosphere Monitoring Service (CAMS) is one of six services that form Copernicus, the European Union's Earth observation programme. Copernicus offers information services based on satellite Earth observation, in situ (non-satellite) data and modelling. CAMS provides consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing, at global and European scales. CAMS is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission, working with many service providers around Europe. By doing so, CAMS combines the expertise and infrastructure that exist in Europe to provide a range of services that are among the best in the world.

CAMS is continually monitoring air quality in Europe and around the world using satellite and ground-based observations and advanced numerical models. In the context of the worldwide COVID-19 crisis, there has been increased interest in changing air quality. The main reasons are:

- Air quality, being partly determined by emissions of pollutants from human activities (and partly by changes in weather), is an indicator of the level of these activities. In situations of prolonged lockdown and over time, the expectation is that average levels of air pollution will go down.
- COVID-19 is an infectious respiratory disease and air quality (including pollen) affects respiratory health. Therefore, air quality information is especially important during this period.
- Through what mechanisms might SARS-CoV-2 transmission or COVID-19 spread and severity (e.g., severe cases, deaths) be influenced by meteorological and air quality conditions? CAMS data can support this research by providing information about the distribution and evolution of fine particulate matter just above the surface.

The significantly changed emissions due to lockdown situations in many countries around the world have also affected the quality of the CAMS forecasts themselves. To inform our users, CAMS has assessed the reduction in air pollutant emissions over Europe and produced hindcasts to estimate the impact of these reduced emissions on the CAMS operational forecasts.

This presentation will illustrate how CAMS has been monitoring the impact of COVID-19 induced lockdowns on air quality and the quality of the CAMS air quality forecasts. It also addresses how CAMS has been supporting the three research topics above.

Sue Grimmond,
University of Reading, UK

Sue Grimmond, Professor of Urban Meteorology, Department of Meteorology, University of Reading, UK + many others listed on the talk

Modelling Weather and Climate in Urban Environments

Rapid urbanisation (over 6.3 billion urban residents are expected by 2050), combined with more frequent and more extreme climatic conditions, make cities places where most people are exposed to high impact weather (e.g. typhoons, heat stress, poor air quality events). Cities are centres of creativity and economic progress, but polluted air, flooding and other climate impacts mean urban residents also face significant weather, climate and environment-related challenges. Moreover, increasingly dense, complex and interdependent urban systems make cities particularly vulnerable: a single extreme event can lead to a widespread breakdown of a city's infrastructure through inter-linked ‘domino’ effects.

The complexity of urbanised environments presents enormous challenges to modelling atmosphere exchanges in urban areas, this is further complicated by the lack of measurement at appropriate scales in urban environments. This presentation will provide an overview of recent research in urban hydrometeorology and climatology undertaken to meet the special needs of cities.

John Abatzoglou,
University of California, Merced, USA

Climate driven fire hazards: Knowledge and Limitations

Marta Yebra,
Australian National University, Australia

Changing fuel moisture dynamics, the influence in bushfire impacts and management

Sujay Kumar
National Aeronautics and Space Administration/Goddard Space Flight Centre, USA

Land data assimilation for characterizing fire-hydrology interactions

Andrew Marshall,
Bureau of Meteorology, Australia

Andrew G Marshall[1], Paul A Gregory[2], Catherine O de Burgh-Day[2], and Morwenna Griffiths[2]
[1.] Research, Bureau of Meteorology, Hobart, Tasmania, Australia
[2.] Research, Bureau of Meteorology, Docklands, Victoria, Australia

Subseasonal drivers of extreme fire weather in Australia and its prediction in ACCESS-S1 during spring and summer

Australia has experienced an increase in extreme fire weather over the last few decades. The widespread and devastating impacts of the recent 2018-2019 and 2019-2020 Australian bushfire seasons highlight the importance of understanding climatic factors that contribute to extreme fire danger, including large-scale climate driver activity. We present, for the first time, a subseasonal analysis of the impacts of six important drivers of Australian extreme fire weather in spring and summer, and its representation in the Bureau of Meteorology's ACCESS-S1 dynamical forecast system. The observed likelihood of extreme fire weather increases over most of Australia in association with El Niño, the positive Indian Ocean Dipole, negative Southern Annular Mode, and low split-flow blocking activity. These increases are most pronounced in SON over the southeast where extreme fire weather is up to three times more likely. Large increases in the likelihood of extreme fire weather also occur over south-eastern Australia when the Madden-Julian Oscillation is active over the eastern tropical Indian Ocean. Using retrospective forecasts at lead times of 2-3 weeks for the period 1990-2012, we show that ACCESS-S1 simulates reasonably well the observed modulation of extreme weekly-mean fire weather by each climate driver. Each driver also plays an important role in providing more accurate predictions for regions where ACCESS-S1 captures the observed connection to extreme fire weather. Our results highlight forecast opportunities that will help with predicting the fire potential across Australia every year and will be very useful to many sectors including fire management, health, and emergency services.

Sarah Harris
Country Fire Authority, Australia

Fire agencies and research: embedding scientists within fire agencies and collaboration

Ashkan Shokri,
Bureau of Meteorology, Australia

The new Australian Water Outlook - applications in bushfire risk assessments

Hanh Nguyen, Matthew Wheeler, Catherine de Burgh-Day, Morwenna Griffiths,
Bureau of Meteorology, Australia

Flash drought: Historical climatology, realtime monitoring and prediction

This study describes the climatology of objectively identified flash drought occurrence over Australia, identifying flash drought using rapid changes of the Evaporative Stress Index (ESI). The ESI is computed from the actual and potential evapotranspiration outputs from the Bureau of Meteorology's high resolution land surface water balance model AWRA-L version v6. During the 46-year period 1975-2020, the flash drought occurrence at 5km gridscale ranges between 0 events per decade in the central desertic regions to 10 per decade in the regions toward the coasts. The normally wetter regions nearer the coasts have greater ability to experience flash drought since they can experience more anomalously low actual evapotranspiration and anomalously high evaporative demand (i.e. potential evapotranspiration). These flash droughts tend to occur during the growing season when both water supply and evaporative demand are climatologically high. Between the time leading to and following flash drought onset, composite analysis suggests that evaporative demand starts increasing first as a response to rainfall deficit leading to clearer skies and subsequently higher temperatures and reaches peak value at the onset. Evapotranspiration starts decreasing about two weeks after due the delayed response of soil moisture to rainfall and reaches a minimum coinciding with the minimum ESI which corresponds to flash drought peak intensity.

Realtime monitoring of flash drought potential development and onset is updated daily in step with the daily operational output of AWRA-L. Trial multiweek forecasts of the ESI are computed from the ACCESS-S1 calibrated output and updated daily.

Greg McFarquhar,
University of Oklahoma, USA

[1]Cooperative Institute for Severe and High-Impact Weather Research and Operations (CIWRO), University of Oklahoma, Norman, OK
[2]School of Meteorology, University of Oklahoma, Norman, OK

Lessons learned from Southern Ocean Cloud-Aerosol-Precipitation-Radiation Field Campaigns in 2017-2018 and Needs for Future Observations

Field campaigns conducted over the Australasia sector of the Southern Ocean (SO) between 2016 and 2018 were motivated by the fact that Earth system models absorb too much surface shortwave radiation, especially over summer in cold dry sectors of cyclones traversing the SO. Air, ship and surface data collected during SOCRATES, MICRE, MARCUS and CAPRICORN synergistically provide measurements of boundary layer and free troposphere structure, vertical and distributions of liquid and mixed-phase clouds and aerosols over cold waters where supercooled and mixed-phase boundary layer clouds are frequent. Data analysis combined with satellite and modeling studies has provided information about processes acting over the SO. Key findings include: ubiquitous thin supercooled clouds occur in multiple layers with large liquid water contents; the SO has very few ice nucleating particles; new aerosol particle formation is observed in pockets in the free troposphere; small-scale generating cells near cloud top in produce liquid water; cloud droplet concentrations and cloud condensation nuclei vary considerably depending on meteorological and aerosol concentrations, and coupling of the surface to cloud; ice crystals occasionally appear at temperatures up to -5 Celsius; secondary ice crystal production is important for cloud glaciation. Despite these findings, much is unknown about SO clouds. More observations should be acquired over the SO to resolve. Future aircraft campaigns should concentrate on seasons with greater variability in phytoplankton blooms, use Lagrangian sampling to measure clouds before and after encountering blooms, include observations closer to the Antarctic, and collect more comprehensive data on aerosol chemical properties.

David Bromwich,
The Ohio State University, USA

Year of Polar Prediction in the Southern Hemisphere (YOPP-SH)

Petra Heil,
Australian Antarctic Division, Australia

Exploring the East Antarctic Marginal Ice Zone

The Marginal Ice Zone [MIZ]defines the transition from open water to the pack ice.

It is a highly dynamic region susceptible to atmospheric and oceanic forcing mechanisms and a key area for energy, momentum and gas exchanges between ocean and atmosphere. The location of the MIZ is a function of several balances, not least the radiation budget and heat fluxes at the ocean-atmosphere interface.

Autumn expansion of the MIZ depends on the cooling of surface waters and lower ocean heat fluxes. This may be aided by equatorward transport of sea ice. During spring the MIZ retreats to balance the thermal energy budget and due to the lack of equatorward transport of sea ice. Short-term (hours to many days) deviations are driven by external forcing including oceanic meanders, atmospheric low-pressure systems, or persistent wave and/or swell action. In recent decades observations have shown that the ice in the MIZ is generally thinner and more diffuse than seen in earlier observations. This allows for extended momentum transfer, and is reflected in the deeper penetration of waves into the pack. As the ocean-ice- atmosphere systems responds to changing environmental conditions, we turn our attention to better understand relevant processes, such as the propogation and attenuation of waves in the ice pack, the absorption of short-wave radiation and its transport within the ice pack and the underlying ocean, the response of the oceanic mixed layer, mixing processes and gas transports, as well as embedded biogeochemical processes and associated ecosystems. Our near-term focus is on the East Antractic marginal ice zone, to improve our knowledge of its physical and chemical processes, how these change and how this affects the ecosystem functions.

Sonya Fiddes,
University of Tasmania, Australia

Evaluating ACCESS-AM2 cloud-radiative biases in the Southern Ocean using machine learning

A persistent bias in surface shortwave cloud radiative effect continues to hamper the Australian Community Climate and Earth System Simulator (ACCESS) – Atmosphere only Model (AM2) across the Southern Ocean. This bias has been attributed to how well climate models simulate low cloud frequency and super-cooled liquid water clouds, and is related to the availability of ice-nucleating aerosol. Here, we present an evaluation of the model against satellite products and campaign-based observations. The ACCESS-AM2 model has been nudged to reanalysis, with global daily output over four years, 2015-2018.

We first evaluate ACCESS-AM2 using a satellite simulator and k-means clustering to individually quantify the radiative biases associated with different cloud regimes. We confirm that the ACCESS model struggles to simulate low-level clouds, often miss-identifying them as mid-level clouds. We then take a new evaluation approach, using machine learning methods to better understand what cloud features drive the cloud radiative bias. Using an XGBoost model, approximately 55% of the variance in the cloud radiative effect bias can be explained. The biases in cloud ice fraction, ice cloud optical depth and liquid water path are the most important over-all predictors of the cloud radiative effect bias. However, each predictor shows spatially varying importance, reflective of the structure of cloud properties across the Southern Ocean.

Finally, initial evaluation of ACCESS-AM2 against campaign observations with respect to aerosol number concentrations has been performed. We find ACCESS-AM2 underpredicts the number of aerosol over the Southern Ocean sector, forming a particular concern for subsequent aerosol-cloud interaction processes included in the model.

Marc Mallet,
University of Tasmania, Australia

Marc D. Mallet[1], Simon Alexander[2,1], Alain Protat[3,1],
[1] Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania, Australia
[2] Australian Antarctic Division, Kingston, Tasmania, Australia
[3] Australian Bureau of Meteorology, Melbourne, Victoria, Australia

Reducing Southern Ocean shortwave radiation errors in the ERA5 reanalysis with machine learning and 25 years of surface observations

Correspondence to: Marc D. Mallet (marc.mallet@utas.edu.au)

Clouds and their radiative effects are difficult to simulate and are prone to large biases over the Southern Ocean. We collated measurements of downwelling shortwave radiation, SW_{down}, spanning 25 years from 1995 to 2019 in the Southern Ocean collected on the *RSV Aurora Australis*, the *RV Investigator*, and at Macquarie Island. During the October - March months when most of the measurements were collected, the ERA5 simulation of SW_{down} exhibited large errors (root mean squared error = 120 ± 7 Wm^{-2}, R^2 = 0.75 ± 0.03). We bypassed ERA5's simulation of SW_{down} by using the surface measurements from the ships and Macquarie Island and tuned, trained, and tested machine learning based predictive models for SW_{down} using a small number of meteorological and cloud variables from ERA5 as predictor variables. Models built using the random forest algorithm had the best performance relative to ERA5 with a mean decrease in the root mean squared error by 25% ± 3% and an increase in the R^2 value of 4% ± 1%. Most of the improvement occurred at higher latitudes of the Southern Ocean, which is where ERA5 also performed the most poorly and most climate models tend to have a positive bias in the net surface shortwave cloud radiative effect. The robust performance of the random-forest-based model over a significant portion of the Southern Ocean and 25 summer seasons indicates that data-driven models built using machine learning techniques could have a role in improving the simulation of surface radiation fluxes.

Andy Hogg,
Australian National University, Australia

A new, high-resolution circum-Antarctic ocean-sea ice model

Current state-of-the-art global ocean models are now able to resolve the ocean mesoscale over much of the globe. It is likely that the next-generation model will progress one step further: to resolve submesoscale features such as small-scale fronts, although global submesoscale-resolving models are prohibitively expense with today's computers. To progress towards this goal the Consortium for Ocean-Sea Ice Modelling in Australia (COSIMA) is testing regional high-resolution configurations.

A new, regional, high-resolution (1/20°, 75-layer) model of the Southern Ocean and Antarctic margin is presented. The model uses MOM6-SIS2 configured with a northern boundary at 37°S, where boundary conditions are prescribed using daily output from a single year of an ACCESS-OM2-01 simulation. The simulation is forced at the surface by the JRA55-do repeat-year forcing (1990-91) strategy. We use this model to demonstrate the utility and effectiveness of hybrid vertical coordinates in better representing fine-scale processes, particularly in the ocean waters that fringe the Antarctic ice sheets.

Irina Rudeva,
Bureau of Meteorology, Australia

Irina Rudeva, Ghyslaine Boschat, Chris Lukas, Pandora Hope

Low stratospheric anomalies linked to circulation regimes in the troposphere. From large-scale circulation to Victorian climate and from short-term anomalies to long-term trends.

The Southern Hemisphere (SH) circulation has experienced a lot of changes in recent decades. In this work we explore these changes in the isentropic framework and focus on long term trends in the frequency of the daily patterns of the mean meridional circulation (MMC) using ERA-Interim dataset for 1979-2017. We identified six clusters in the standardized MMC, smoothed by 5-day running mean. Standardisation is an important step as raw streamfunction values in the upper troposphere/low stratosphere are relatively small due to the low air mass; thus, standardisation helps to increase the weight of changes in the upper troposhere and implies that those levels play an important role in the global atmospheric circulation.

We show that in both winter and summer the clusters that represent weaker MMC have become more frequent in 1979-1997. After the year 1997, the trends in clusters' frequency have paused. These trends are in close agreement with the change in the low-stratospheric ozone concentration over Antarctica in spring, and based on earlier studies, spring ozone trends can be responsible for MMC changes in austral summer. In this talk we will present MMC clusters and show differences in the tropospheric circulation between weaker and stronger MMC circulations. We will then discuss possible reasons behind the observed MMC changes and their associated trends in atmospheric variables during winter. Interestingly, we find that long-term MMC trends are made up by changes in frequency of short-term patterns, rather than represent a gradual transition from one state to another.

Ilene Carpenter
Hewlett Packard Enterprise, USA

On the path to Exascale for weather and climate

Peter Steinle,
Bureau of Meteorology, Australia

M. Krysta, P.J. Steinle, J. Finch, S.J. Rennie, J.T. Lee
Bureau of Meteorology

National Analysis System

In support of more advanced automated forecast generation, the Bureau of Meteorology is introducing the National Analysis System (NAS) to replace the Mesoscale Surface Analysis System (MSAS, Glowacki et al. 2012). The primary goal of this system is to provide a national overview of the atmosphere to support both statistical downscaling and verification. The current MSAS uses forecasts from the Bureau's Numerical Weather Prediction (NWP) systems that can be up to 8 hours old in some areas. In addition, MSAS is only able to use near-surface observations (2m temperatures and dewpoints, 10m winds and air pressure), and only produce analyses of these variables. By using the software systems of the Bureau's latest NWP systems, the NAS is able to use a much broader range of observations including data from aircraft, wind profilers, satellites and radars (both Doppler wind and estimated rainfall) to provide analyses of a much broader range of variables.

Whereas MSAS uses grids from the Bureau's standard NWP systems (a patchwork of ~12km and 1.5km grids updated every 6 hours) as a starting point, the NAS is supported by a cycling NWP system using a 2.2km forecast grid and 6.6km 4D-variational assimilation, producing grids about two hours behind real time. On top of this there are also a pair of 3D-variational analyses to provide lower latency products (30-40 minutes) with a tighter fit to the observations. The latter analysis is purely to provide situational awareness rather than initialize an NWP model.

This presentation will provide an overview of progress and performance of the NAS.

References:

Glowacki, T.J., Y. Xiao, P.Steinle, 2012, "Mesoscale Surface Analysis Systems for the Australian Domain: Design Issues, Development Status and System Validation", Weather & Forecasting, 27, pp. 141-157, DOI: https://doi.org/10.1175/WAF-D-10-05063.1

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Added Value of Regional Climate Projections for Australia

Australia's climate is highly variable and extreme weather events range from extreme precipitation to drought, heatwaves, cyclones, thunderstorms and bushfires. With many types of extreme events projected to become more pronounced with climate change including in Australia, there is an increasing need for robust fine-scale projections of key climate variables. Spatial and temporal fine-resolution climate model output is needed in climate change impact and adaptation studies particularly when conducted on regional and local scales.

The Bureau of Meteorology Atmospheric Regional Projections for Australia (BARPA) is a new regional climate modelling framework developed for the Australian region. BARPA dynamically downscales global climate information to fine temporal and spatial resolutions using the atmosphere and land model components from the Australian Community Climate and Earth-System Simulator (ACCESS): the UK Met Office Unified Model (UM) and the Joint UK Land Environment Simulator (JULES). Here we report the moderate resolution framework of BARPA – BARPA-R – with a horizontal grid length in the order of 10 km which covers the Australasian CORDEX domain. The added value of BARPA is evaluated for the historical period by comparing the model outputs against observation-based data and the potential for added value in future projections is assessed by measuring how much the RCM climate change signal differs from its host GCM. This work demonstrates that BARPA yields stable and realistic simulations of near-surface meteorological parameters and provides added regional information to the host global data for the past and future periods, especially over areas with complex terrain.

Using the ACCESS model provides the benefit of similarities to other weather and climate products provided by the Bureau of Meteorology including historical reanalysis, operational weather forecasting, and seasonal prediction. The consistency of climate products is part of broader goals towards providing seamless and consistent services across a range of time scales. It is intended that BARPA-R will contribute to a broader set of regional climate models (CCAM and WRF) in the NextGen Climate Projections for understanding future changes in climate extremes, particularly near features of topography, urban areas, and coasts.

The initial set of BARPA projections have been developed and tested for the Electricity Sector Climate Information (ESCI) project and will be extended to support the Australian Climate Service (ACS).

Debbie Hudson
Bureau of Meteorology, Australia

ACCESS-S2 and beyond: What's next for global coupled modelling

ACCESS-S is the Bureau's coupled model seasonal prediction system, which underpins the seasonal climate outlook (http://www.bom.gov.au/climate/ahead), provides inputs to downstream modelling systems (e.g., the Bureau's seasonal water outlook) and provides forecast data to several external customers. ACCESS-S Version 2 replaced ACCESS-S1 in October 2021.

The key difference between ACCESS-S2 and ACCESS-S1 is in the data assimilation and thus the initial conditions of the forecasts. ACCESS-S1 used ocean initial conditions from the UK Met Office, whereas ACCESS-S2 uses a weakly-coupled data assimilation system developed at the Bureau. In ACCESS-S2 sea surface temperature is strongly relaxed to the daily observational analysis and ocean in-situ temperature and salinity profiles are assimilated every day using ensemble optimal interpolation with a seasonally varying background error covariance. The atmospheric component is nudged towards a pre-exiting atmospheric analysis (ERA-Interim for the historical period, and ACCESS-G3 for real-time) and the land surface responds to the atmospheric forcing. The latter is advantageous since it means that the initial conditions for soil moisture are realistic - in contrast to ACCESS-S1, where the soil moisture was initialized using climatological fields.

Having an in-house assimilation system enables the real-time system to be run timelier, especially the multi-week forecasts, to meet our customer needs. It also reduces the Bureau's dependence on the provision of UK Met Office ocean initial conditions. Importantly, it will be shown that the new data assimilation impacts positively on forecast performance compared to ACCESS-S1.

Beyond ACCESS-S2, the focus for global coupled modelling lies in the development (jointly with the UK Met Office) of a seamless coupled earth system modelling framework that brings together the current set of disparate modelling systems (global NWP, global ocean and seasonal) into a common coupled model framework. Our research with ACCESS-S has shown that customers want forecasts that are seamless and consistent in time from days (weather forecast) to weeks to seasons. In early 2022, the UK Met Office will upgrade its global weather forecast model to a coupled model, bringing several of these elements together to provide more accurate and consistent predictions. There has been growing evidence that ocean-atmosphere interactions are important on shorter timescales, for both weather and ocean prediction, as well as the longer multi-week/seasonal timescales. Bureau plans for delivering seamless and consistent earth system forecasts across timescales and domains including weather, ocean, multi-week and seasonal will be presented.

Ulrike Bende-Michl,
Bureau of Meteorology, Australia

Ulrike Bende-Mich [1], Louise Wilson[2], Elisabeth Vogel[1], Justin Peter[1], Wendy Sharples[1], Pandora Hope[1], Vjekoslav Matic[1], Sri Srikanthan[1], Margot Turner[1], Alison Oke[1], Zaved Khan[1], Jake Roussis[1], Vi Co Duong[1], Andrew Frost[1], Elisabetta Carrara[1]
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Australian Water Outlook: innovation in serving water-sensitive customers

Australia's water-sensitive industries and eco-systems depend on the availability of already scarce and vulnerable surface and groundwater resources, such that there is an emerging need to develop mitigation strategies to adjust for a drier future. Thus, understanding changes in water availability due to climate change and associated impacts viewed through a lens of the historical context, is a priority for Australia.

Australia's water management and infrastructure decision making needs detailed high-resolution climate and water forecasts and projections to serve water-sensitive customer needs, raise awareness and understand future risks and to mitigate negative impacts of a changing climate. In Australia, currently, hydrologic change information exists in a fragmented form preventing a nationally consistent impact assessment across multiple spatial and temporal scales. Typically, information is available for multiple state based regional downscaling efforts, across limited timescales and using different interpretation methods for hydrologic impact assessment.

The Bureau of Meteorology is soon to release an innovative, seamless national landscape water service called the Australian Water Outlook (AWO). This service provides historical data on water availability with forecast products, as well as hydrological impact projections, using the Bureau's operational Australian Water Landscape Water Balance model (AWRA-L) (Frost and Wright 2018). The service also combined many challenging aspects: i) state-of-the-art hydrologic research, and the journey into operations, ii) a user centred design approach gathering critical user requirements and converting this into a public user interface, iii) novel ways of communicating situational awareness of plausible impacts from climate change on Australia's water resources through storylines (Shepherd et al. 2018), and, iv) working with early adopters and priority customers to demonstrate the application of the service to water management.

The innovative science underpinning the service include nationally consistent downscaling and bias-correction approaches using three statistical methods for the hydrologic projections in the operational framework to produce a future projections dataset including climate inputs (rainfall, solar radiation, temperature, and wind) and hydrological outputs (soil moisture, evapotranspiration, and runoff). This presentation will focus on and share an overview of the National Hydrological Projections project and its deliverables.

References

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Rachel Law,
Commonwealth Scientific and Industrial Research Organisation, Australia

Rachel Law, Chloe Mackallah, Matthew Chamberlain, Harun Rashid, Tilo Ziehn, Martin Dix, Dave Bi, Peter Dobrohotoff, Arnold Sullivan, Siobhan O'Farrell, Ian Harman, Andrew Lenton, Simon Marsland

Modelling climate and carbon: the ACCESS submissions to the Coupled Model Intercomparison Project Phase 6

The World Climate Research Programme Coupled Model Intercomparison Project Phase 6 (CMIP6) brings together international climate modelling groups to perform standardised climate model simulations. The simulations include idealised, historical and future scenario simulations. Two versions of the Australian Community Climate and Earth System Simulator (ACCESS) have contributed to CMIP6, one of which, ACCESS-ESM1.5, includes the capability of running an interactive carbon cycle. Additionally, the two versions differ mostly in their atmospheric component with ACCESS-CM2 using the GA7.1 configuration of the Unified Model (UM vn10.6), while ACCESS-ESM1.5 uses a configuration close to GA1 (UM vn7.3). While the horizontal resolution is the same (N96: 1.875^o longitude x 1.25^o latitude), ACCESS-CM2 uses 85 vertical levels with a model top at 85 km compared with 38 levels and a model top of 40 km for ACCESS-ESM1.5. Both versions include CABLE (2.5 or 2.4) as the land component, MOM5 for the ocean and different versions of CICE (5.1.2 or 4.1) for the sea-ice.

The different atmosphere configurations lead to different climate sensitivities and compute needs. ACCESS-CM2 has a higher equilibrium climate sensitivity for doubled CO_2 (4.7K) compared with ACCESS-ESM1.5 (3.9K). ACCESS-ESM1.5 is around seven times cheaper to run than ACCESS-CM2, allowing for a larger ensemble of historical and scenario simulations, with a 40-member ensemble completed for ACCESS-ESM1.5 and a 5-member ensemble currently available for ACCESS-CM2. On the other hand, ACCESS-CM2 incorporates more recent developments in atmospheric process parameterisations.

The talk will present a selection of climate and carbon cycle results from the ACCESS CMIP6 experiments, including both global and Australian perspectives.

Antje Weisheimer,
European Centre for Medium-range Weather Forecasting, and University of Oxford, UK

Seasonal forecasts of the 20th Century

The large-scale fluctuations of the equatorial atmosphere and ocean over the tropical Pacific known as El Niño - Southern Oscillation (ENSO), play an important role in the climate system. Forecasting ENSO is at the very heart of seasonal predictions because it provides the largest source of predictability on time scales of months and seasons ahead and is of great relevance to society.

Forecasts of seasonal climate anomalies using physically based global circulation models are routinely made at operational meteorological centres around the world. A crucial component of any seasonal forecast system is the set of retrospective forecasts, or hindcasts, from past years that are used to estimate future forecast skill and to calibrate the forecasts for biases. Hindcasts of seasonal predictions are usually produced over a period of around 20–30 years. With an average frequency of 4-5 years, there is only a very limited number of ENSO cases available in the operational reforecast records and sampling the wide spectrum of ENSO flavours is not possible. In the presence of considerable variations in the coupled ocean-atmosphere system, good skill in predicting the most recent ENSO events cannot guarantee that future events will have similar predictability.

In this talk, I will introduce new historical retrospective research forecasting datasets created with a reduced-resolution version of the ECMWF forecasting model that cover all of the 20th Century and extends the forecast lead times to 2 years. The reforecasts show substantial decadal modulations of forecast skill. In particular, skill to predict ENSO is very high during recent decades, but it is markedly reduced during the 1930s–1950s. ENSO skill at the beginning of the century is, however, as high as for recent high-skill periods suggesting that the loss of skill in the mid-century period is not related to the lack of good observational data. Alternative hypotheses related to intrinsic predictability and the role of the observing system will be discussed. Extratropical modes of variability such as the North Atlantic Oscillation also show distinct multi-decadal fluctuations of forecast skill during the 20th Century, with implications for the so-called signal-to-noise paradox. Our results imply that relatively short hindcasts are not adequate for reliably testing seasonal forecasts and that small hindcast sample sizes can potentially lead to skill estimates that are not robust.

Tim Graham,
Met Office, UK

Developing coupled atmosphere-ocean NWP at the Met Office

The Met Office will implement global operational coupled NWP for all weather forecast activities in early 2022. Getting to this point has taken several years of research and planning. In this talk I will give an overview of the Met Office journey towards implementing coupled NWP picking out some of the research highlights. Finally, I will discuss some of the challenges coupled NWP may pose for future model development.