Australian Academy of Science
Elizabeth and Frederick White Research Conference on
Atmospheric Dynamics

20 - 22 August 2024

Melbourne, Australia

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Proudly supported by:

Attendee Information

Philosophy, aims and objectives of the conference

This workshop aims to bring together and coalesce a community of experts in atmospheric dynamics with the ultimate goal of increasing our confidence in forecasts and future projections by understanding the processes underpinning them. It will assess current knowledge and identify important knowledge gaps, to guide and support research in atmospheric dynamics. The large cohort of Early Career Researchers both attending and presenting their work aims to highlight and inspire the future of process-based atmospheric research in Australia.

Despite a large oral presentation component, the intent of the conference is to be highly interactive and discussion-based. The work and ideas that speakers present aims to inspire and initiate thought and debate amongst attendees which we hope will provide a path and strategy going forward for atmospheric dynamics research in the years and decades to come. As such, we provide time at the end of each talk, day and at the end of the conference that we hope will be used by attendees to discuss and debate the work presented during the conference. Although opinions may be strong and robust debate is encouraged, we ask that attendees be respectful of each other and the work being presented at all times.

Conference venue

The Australian Academy of Science Elizabeth and Frederick White Research Conference on Atmospheric Dynamics will be held at the Monash Conference Centre on 30 Collins Street in the ***Melbourne CBD***. The exact location of the venue can be found here or by searching for "Monash Conference Centre" on your preferred navigation app.

Dinner venue

There will be a free conference dinner organised on the evening of Wednesday 21 August at Melbourne Cellar Door. We plan to walk to the venue as a group (40 min walk through the city). However, the venue can also be accessed by public transport by taking the Route 12 tram leaving outside the workshop venue to the Melbourne Convention and Exhibition Centre. Dietary requirements are considered as per registration form.

Acknowledgement of Country

The organisers acknowledge the Traditional Owners of the land on which the conference takes place, the Wurundjeri People. We pay our respects to Elders past and present.

Speaker Information

Timing

In order to manage the timing of the conference, we ask speakers to please keep presentations to a maximum of 15 minutes, unless otherwise specified and discussed with the organisers. 5 minutes will be given for questions, answers and discussion after every presentation. Session chairs will be asked to keep timing strict. Plenty of time will be made available to discuss presentations and issues that are highlighted in more detail at the end of each day and at the end of the conference.

Presentation format

Speakers are requested to upload their presentation to the Google Drive Folder the day before their presentation. Please use the filename convention *surname_name_speakernumber*. For example: Smith_John_Speaker1.ppt or Smith_John_InvitedSpeaker.ppt. Powerpoint is the preferred format for all presentations.

Session chairs

Sessions chairs are largely an Early Career Researcher cohort who have volunteered to assist by chairing sessions. The job of our session chairs will be to introduce speakers, manage time and prompt questions, debate and discussion after each talk. We ask our session chairs to be relatively strict on times for talks and discussion to keep the conference running smoothly and on time. Plenty of time provided at the end of each day and at the end of the workshop if discussion needs to continue. Our session chairs will play a vital role in the success of these discussions and of the success of the conference as a whole. The organisers would thank our session chairs for taking on this task.

Conference Program

Day 1 - Tuesday 20 August

Time	Activity	Person	Title
08h30	Registration		
09h00	Welcome	Martin Jucker	
09h15	Keynote Address	Juliane Schwendike	Local Hadley and Walker circulations
10h15	Tea		
11h00	Session 1	Chair: Corey Robinson	Dynamics of the tropics
11h00	Speaker 1	Sugata Narsey	Do we really understand the dynamics of the Australian Monsoon on any timescale?
11h20	Speaker 2	Hanh Nguyen	Dynamical and ML global model skill in predicting convectively coupled equatorial waves
11h40	Speaker 3	Yi-Xian Li	A new diagnostic for the evolution of tropical convection based on large-scale vertical motion: The Top-Heaviness Plane
12h00	Lunch		
13h00	Session 2:	Chair: Kim Reid	Tropical-extratropical interactions
13h00	Invited Speaker	Michael Reeder	The Australian Summertime Washing Machine
14h00	Speaker 4	Corey Robinson	Synoptic dynamics of tropical moist margin perturbations
14h20	Speaker 5	Lara Richards	The meteorology of Great Barrier Reef coral bleaching events
14h40	Tea		
15h10	Session 3:	Chair: Yi-Xian Li	Idealised dynamics
15h10	Speaker 6	Kial Stewart	Atmospheric Dynamics in the Large Rotating Annulus
15h30	Speaker 7	Vassili Kitsios	Physics-constrained data-driven model of a hydrostatic atmosphere
15h50	Speaker 8	Thomas Valentini	Stratospheric Mountain waves over the South Andes: ERA5 Reanalysis and simple 2D models
16h10	Discussion		
16h50	Wrap-up Day 1	Martin Jucker	

Day 2 - Wednesday 21 August

Time	Activity	Person	Title
08h30	Registration		
09h00	Welcome	Martin Jucker	
09h15	Keynote Address	Isla Simpson	Missing dynamical connections and trends in Earth System Models: how does increasing resolution help?
10h15	Tea		
11h00	Session 4:	Chair: Aditya Sengupta	Climate dynamics
11h00	Speaker 11	Julie Arblaster	Detected climate change signals in atmospheric circulation: mechanisms, puzzles and opportunities
11h20	Speaker 12	Eun-Pa Lim	CMIP6 evaluation on the dynamical evolution of the SH polar vortex anomalies
11h40	Speaker 13	Callum Shakespeare	The probability distribution of lower tropospheric water vapour
12h00	Lunch		
13h00	Session 5:	Chair: Dongqi Lin	Teleconnections
13h00	Invited Speaker	David Karoly	What was missing/wrong with Hoskins and Karoly (1981)?
14h00	Speaker 14	James Risbey	Remote driver or drivel?: Influences of rainfall variability on Australia
14h20	Speaker 15	Aditya Sengupta	Changes in ENSO variability and teleconnection post net-zero in ACCESS-ESM-1.5
14h40	Tea		
15h10	Session 6:	Chair: Tess Parker	Drought and heatwaves
15h10	Speaker 16	Chenhui Jin	A synoptic-dynamic view of the Millennium Drought (2001-2009) in southeastern Australia
15h30	Speaker 17	Irina Rudeva	The Tinderbox Drought in observations and ACCESS-S2
15h50	Speaker 18	Qinuo Huang	Quantify the contributions of the physical processes to heatwaves in Victoria, Australia
16h10	Discussion		
16h50	Wrap-up Day 2	Martin Jucker	
17h30-21h00	Conference dinner	Martin Jucker	Melbourne Cellar Door

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21st Century Weather ARC Centre of Excellence; climate extremes ARC centre of excellence; Australian Academy of Science; ACCESS Australian Earth System Simulator National Research Infrastructure; Australian Meteorological & Oceanographic Society

Day 3 - Thursday 22 August

Time	Activity	Person	Title
08h30	Registration		
09h00	Welcome	Martin Jucker	
09h15	Keynote Address	Kai Kornhuber	Understanding the dynamics of record breaking, concurrent and sequential extremes.
10h15	Tea		
11h00	Session 7:	Chair: Chenhui Jin	Dynamics of the extratropics
11h00	Speaker 21	Tess Parker	Blocking and Extreme Weather
11h20	Speaker 22	Stacey Osbrough	Tipping points of Australian climate extremes and changes in Southern Hemisphere explosive storms.
11h40	Speaker 23	Valentina Ortiz	The Dynamics of Stalling Cyclones: A Global Perspective
12h00	Lunch		
13h00	Session 8:	Chair: Valentina Ortiz	High-resolution modelling and small-scale processes
13h00	Invited Speaker	Christan Jakob	Connecting Atmospheric Dynamics, Climate Models and Society
14h00	Speaker 24	Thi Lan Dao	Joint modulation of coastal rainfall in Northeast Australia by local and large-scale forcings: Observations versus AUS2200 simulations
14h20	Speaker 25	Todd Lane	Dynamical aspects of organised convection in Australia - recent progress and opportunities
14h40	Tea		
15h10	Discussion		
16h50	Wrap-up Workshop	Martin Jucker	

Abstracts

Invited Talks

Isla Simpson, National Center for Atmospheric Research, Boulder, Co, USA

Missing dynamical connections and trends in Earth System Models: how does increasing resolution help?

At a time when the global warming signal is emerging from the noise in many aspects of the climate system, it is critical that our Earth System Models (ESMs) that are used for predictions on seasonal to multi-decadal timescales are accurately representing dynamical connections and long-term trends. A number of areas have been identified in recent years in which there is an apparent mis-match between ESMs and observations, either in their representation of dynamical connections within natural variability or in their representation of longer term trends. These highlight dynamical connections that have yet to be fully understood and their mis-representation in ESMs raises concerns for our ability to predict the future of the climate system. This presentation will highlight three such features where models have been found to mis-represent dynamical connections. These are: (1) the missing connection between the Quasi-Biennial Oscillation and the Madden-Julian Oscillation; (2) the signal-to-noise paradox and missing multi-decadal variability in the North Atlantic; and, (3) long-term trends in the Tropical Pacific and Southern Ocean sea surface temperatures and their connection. For each case, the state of the science and the outstanding issues will be summarized, and the potential for increasing model resolution to resolve the problems will be discussed.

Kai Kornhuber, Columbia University, New York, USA, and International Institute for Applied Systems Analysis, Austria

Understanding the dynamics of record breaking, concurrent and sequential extremes

Record-breaking, simultaneous, sequential and more persistent weather extremes such as multiple heatwaves within a year, or around the globe are an expected outcome of the increasing magnitude and frequency of many climate impact drivers due to anthropogenic activities. Next to a purely stochastically driven compounding, increased impacts from interacting extremes can also have causal roots. Feedbacks, preconditioning and changes in the dynamics of the atmospheric and ocean circulation can have a pronounced impact on extreme event statistics. State-of-the art climate models still struggle to accurately reproduce some of these phenomena, which can lead to a systematic underestimation of high impact extremes.

Understanding and modelling newly emerging physical climate risks to natural and societal systems, such as global supply chains, the global food system and critical infrastructures is essential for adequate preparedness and honest discussions about consequences from rising greenhouse gas emissions. In this talk I will discuss compounding physical mechanisms that have led to recent record breaking extreme weather and climate events and will provide an overview of recent advances in benchmarking climate models in reproducing observed trends.

Juliane Schwendike, University of Leeds, Leeds, UK

Local Hadley and Walker circulations

Conceptually, it is useful to partition the three-dimensional tropical circulation into meridional and zonal components, namely, the Hadley and Walker circulations. The averaging involved in their definitions can introduce ambiguities. These problems can be circumvented by first partitioning the total vertical mass flux into components associated with overturning in the meridional and zonal directions, respectively, called here the local Hadley and local Walker circulations. Defining the local Hadley and local Walker circulations this way ensures the pair of two-dimensional overturning circulations can be added to give the original three-dimensional circulation, even when the averages are taken over limited domains.

David Karoly, University of Melbourne, Melbourne, Australia

What was missing/wrong with Hoskins and Karoly (1981)?

The paper Hoskins and Karoly (1981) was published more than 40 years ago and is one of the most highly cited papers in atmospheric dynamics. Preliminary versions of the results were presented at an NCAR Summer Colloquium on ``The General Circulation: Theory, Modelling and Observations'' in 1978.
Our paper was motivated by observational studies at that time of large-scale teleconnection patterns of seasonal geopotential height anomalies across the Northern Hemisphere, that resembled the propagation of quasi-stationary Rossby waves in a barotropic atmosphere. It used a steady-state linearized baroclinic model and the theory analysis to consider the response of a spherical atmosphere to thermal and orographic forcing and the propagation of barotropic Rossby waves on the sphere.
In this presentation, I will revisit the background to the paper and some of the simplifications that were made in the different parts of the model approach and theoretical analysis. I will focus on the response to low latitude thermal forcing, as that is the topic that has gained the most attention.
I will describe some aspects of the paper that were missing or limited its interpretation. These were identified in subsequent research (summarized in Trenberth et al. (1998). These include the role of zonal variations of the basic state, and the importance of the divergent response to tropical thermal forcing and of transient baroclinic systems in mid-latitudes affecting the Rossby wave source and propagation.

Michael Reeder, Monash University, Melbourne, Australia

The Australian Summertime Washing Machine

During summer, southeastern Australia lies at the end of the midlatitude jet, which can be thought of as the termination point for the Rossby wave guide. Rossby waves propagate along the midlatitude jet stream and on occasion overturn in the Australian region, producing isolated cyclonic potential vorticity (PV) streamers and anomalies. This PV debris is transported equatorwards. More PV debris is transported along the Australian east coast than anywhere else in the world and is the origin of most heavy rainfall on the east coast. Some of the PV debris is entrained into the tropics where they can, at times, organise deep convection. Some tropical cyclones in the Australian region can be traced back to this PV debris, as can around half of all rain in the Australian monsoon. The upper-level divergent outflow from wet season convection in the north of the continent perturbs the midlatitude jet, affecting Rossby wave breaking and the further production of PV debris. The effect of the midlatitudes on tropical precipitation and the back reaction of tropical precipitation on the midlatitudes is explained and an analogy with a washing machine is drawn.

Christian Jakob, Monash University, Melbourne, Australia

Connecting Atmospheric Dynamics, Climate Models and Society

One of today's most urgent societal challenges is to meaningfully mitigate climate change and to prepare communities for the changes already locked in. As both the mitigation responses and adaptation require us to understand changes in local weather, this creates a new challenge, but also opportunities, for the atmospheric dynamics community.In this presentation we will identify potential avenues to better connect science to climate services. We will show that atmospheric dynamics is a key link in the science to services chain. Furthermore, we will describe how the interplay of better process understanding, improved high-resolution modelling, and the application of new techniques in big data analysis may enable a transformation in how we interpret and apply climate change information in societal decision making.

Submitted Talks

Sugata Narsey, Bureau of Meteorology

Do we really understand the dynamics of the Australian Monsoon on any timescale?

The Australian Monsoon region constitutes a large fraction of the Australian continent, and moderates many aspects of life in Northern Australia. While the natural resources associated with the seasonal abundance of rainfall in the north is tantalising for future development, fundamental uncertainties associated with the dynamics of the monsoon remain a barrier to decision-making. On what timescales do we not understand the Australian monsoon? In this talk I will describe some key problems that we can try to address to unpick the uncertainty of Australian monsoon dynamics. These problems range from very fine spatial scales to hemispheric scale processes, and drivers of uncertainty from daily to multi-decadal scales. I will contrast some features of the Australian Monsoon with other regional monsoons to make the case that we need further investigation with potentially highly idealised experiments to verify the ways in which Australian Monsoon dynamics can and cannot be generalised with other more extensively studied regional monsoon systems. This will have implications for how we consider lines of evidence for planning at all time horizons.

Hanh Nguyen, Bureau of Meteorology

Dynamical and ML global model skill in predicting convectively coupled equatorial waves

This work aims to assess the UKMO GC5 model and a ML Global multiweek model skill in predicting convectively coupled equatorial waves and how they affect the representation of precipitation extremes over the Maritime Continent and tropical Australia.

Yi-Xian Li, Monash University

A new diagnostic for the evolution of tropical convection based on large-scale vertical motion: The Top-Heaviness Plane

Previous studies indicate that the evolution of tropical convection typically progresses through stages of shallow convection, deep convection, stratiform, and no convection, and this evolution occurs both at the individual cloud level and for cloud ensembles. This study introduces a novel methodology for analyzing the evolution of tropical convection at hourly resolution, employing a diagnostic phase diagram called the "top-heaviness plane." This plane utilizes two simple sinusoidal basis functions of vertical velocity to track the phases of convection development based on the shape and intensity of vertical velocity profiles. Composite analysis of intense convective events reveals a consistent life cycle that evolves from bottom- to top-heavy as the event progresses, but with regional variations; the west Pacific region demonstrates a propensity towards top-heaviness, while the east Pacific demonstrates a propensity towards bottom-heaviness. In both cases, the event composites are characterized by rapid intensification and decay in close proximity to the deep-convective phase. Further investigations will explore differences in thermodynamic variables between top-heavy and bottom-heavy convection development.

Corey Robinson, Monash University

Synoptic dynamics of tropical moist margin perturbations

The tropical moist margin, defined through column water vapour, acts as a boundary that contains most of the rainfall in the tropics, and its movement on synoptic scales is tightly linked to rainfall. Here we examine the tropical and extratropical dynamical causes for shifts in the moist margin. In the tropics, we demonstrate a strong connection with the Madden-Julian oscillation, equatorial waves, tropical lows, and cyclones. Meanwhile, the extratropical interaction can be characterised by upper-level potential vorticity anomalies, which can substantially influence the moist margin under certain conditions. In all cases, the horizontal advection of mid-level moisture is a key process controlling perturbations in the moist margin.

Lara Richards, Monash University

The meteorology of Great Barrier Reef coral bleaching events

Great Barrier Reef coral bleaching events (CBEs) are becoming ever more frequent with climate change as 5 of the last 8 recent events have occurred since 2015. The local meteorology is known to contribute to the development of CBEs as periods of weak winds and reduced cloud cover, brought about by the disruption of the trade winds, creates ideal conditions for ocean heating. Once the trade winds are re-established, rapid ocean cooling soon follows. While the peak of the CBE is well understood, many questions remain on the development and termination of a CBE. In particular, what forces the breakdown and re-establishment of the trade winds?

Using a combination of ERA5 and observational data, we employ a cluster analysis performed on atmospheric soundings from Davies Reef (located in the central GBR), and synoptic composites to further understand the weather related to coral bleaching.
Our results highlight a non-trade wind regime that dominates the last 8 CBEs, and the role of Rossby wave breaking and coastal ridging in the disruption and re-establishment of the trade winds.

Kial Stewart, Australian National University

Atmospheric Dynamics in the Large Rotating Annulus

The Large Rotating Annulus (LRA) in the Climate and Fluid Physics Laboratory offers a novel approach to investigate a wide range of atmospheric dynamics, and reflects the ongoing renaissance of laboratory experiments that has been spawned by modern technologies and analysis techniques. Recent experiments have explored the processes associated with rotating stratified flows forced through constrictions in the presence of a strong background potential vorticity gradient. Despite their relatively simple configuration, these circulations exhibit a rich set of dynamics that are characterised by zonal jets, block flows, geostrophic turbulence, and Rossby waves. There is a clear distinction between eastward and westward forced flows, indicative of the role that Rossby waves play in guiding the circulation. A governing parameter of the system is the maximum Rossby wave frequency; the general circulations of configurations with forcings that exceed this frequency are fundamentally different. The transitions between these states are explored and their geophysical implications discussed.

Vassili Kitsios, CSIRO

Physics-constrained data-driven model of a hydrostatic atmosphere

A reduced-order model of the global atmosphere is developed by symbolically projecting the hydrostatic equations of motion onto a set of empirical orthogonal functions (EOF). This approach transforms a system of partial differential equations dependent upon time and space, into a system of ordinary differential equations dependent upon time and EOF mode index. As such, one instead solves for the coupled temporal evolution of each principal component, as opposed to the spatio-temporal evolution of the field variables. This represents a massive dimension reduction. The required three-dimensional EOF modes are calculated from the atmospheric fields of the ensemble climate reanalysis dataset, CAFE60, which comprises of 96 realisations of the Earth every day from 1960 to near present day. The reduced-order model coefficients will be calculated using a regression approach. We have previously developed such models for the global oceans, which reproduced the large-scale statistics at a fraction of the computational cost required to numerically simulate the flow..

Thomas Valentini, University of Melbourne

Stratospheric Mountain waves over the South Andes: ERA5 Reanalysis and simple 2D models

The South Andes is a hotspot for stratospheric gravity wave activity, with mountain waves propagating thousands of kilometres downstream. These waves are resolved, visualised, and analysed using data from the ERA5 reanalysis. It is shown that the core properties of these mountain waves can be replicated through the simple linear equation for internal waves in a stratified medium -- the Taylor Goldstein equation. The solutions to this equation depend on the “Scorer parameter”, which is a function height dictated by the flow velocity and stability profiles. Several different scorer parameters, such as a constant, exponentially decaying, and exponential above a constant layer, are used to explain salient features of the flow over the Andes.

Julie Arblaster, Monash University

Detected climate change signals in atmospheric circulation: mechanisms, puzzles and opportunities

The circulation response to climate change shapes regional climate and extremes. We have moved into a new era where circulation signals have been detected across many regions and seasons. The detected circulation signals represent an exciting opportunity for improving our understanding of dynamical mechanisms, testing our theories and reducing uncertainties. They have also presented some puzzles that represent an opportunity for better understanding the circulation response, its contribution to climate extremes, interactions with cloud feedbacks, and connection to thermodynamic discrepancies. The next decade or so is likely to be a golden age for dynamics with many advances possible.

Eun-Pa Lim, Bureau of Meteorology

CMIP6 evaluation on the dynamical evolution of the SH polar vortex anomalies

The springtime stratospheric polar vortex variability over Antarctica provides long-lead predictability to the southern annular mode (SAM) and associated southern hemisphere (SH) regional climate in austral spring-summer seasons. The Antarctic spring vortex anomalies are often instigated by the poleward and downward progression of the meridional dipole anomalies of the SH winter stratospheric jet, accompanied by subsequent wave-mean flow feedback. This dynamical process is conveniently captured by the anti-correlation of the zonal mean zonal wind anomalies at 60°S in the upper stratosphere between winter and spring. In this study, we evaluate the ability of CMIP6 models to simulate these dynamical connections from the winter stratospheric jet to the spring polar vortex to its downward coupling to the surface SAM. We examine zonal winds from 44 models and the eddy heat fluxes, computed with the models' daily winds and temperature data with the historical forcings and the future forcings following the Shared Socioeconomic Pathway5-8.5.

Our results show that the dominant majority of the models do not simulate the observed anti-correlation between the winter and spring westerlies, which is largely linked to the models' biases in the mean position of the winter stratospheric jet jet. Furthermore, the relationship of the winter vortex winds at 60°S, 10 hPa and surface SAM tends to be overestimated compared to the observed. In contrast, CMIP6 models skilfully simulate the relationship between the spring polar vortex and the SAM. We further show that the identified winter polar night jet-spring vortex biases can affect the models' future projections of the Antarctic stratospheric vortex with increasing greenhouse gases for the end of the 21st century.

Callum Shakespeare, Australian National University

The probability distribution of lower tropospheric water vapour

Water vapour in the lower troposphere plays a major role in energy balance at the Earth's surface through modifying radiative and latent heat fluxes. A key question is how and why this distribution might change under global warming. Here I will address this question through a probabilistic approach by developing Probability Density Functions for the relative humidity with altitude in the lower troposphere, building on the classic advection-condensation model. The advantage of such an approach compared to "mean" theories is that it also describes the variability, allowing a more fulsome characterisation of water vapour and the probability of extreme wet/dry. The theoretical PDFs depend only on the water vapour scale height, surface relative humidity and synoptic lifting/sinking at a given location, and agree well with those extracted from the ERA5 reanalysis. As such, these results provide a basis to better understand changes in tropospheric water vapour (including extremes) in future climates.

James Risbey, CSIRO

Remote driver or drivel?: Influences of rainfall variability on Australia

Our understanding of the remote drivers of rainfall variability is predicated on a range of simplifying assumptions or methods, including time means, composites, and simplified dynamical models or experiments. These methods have implied a range of remote drivers and teleconnection mechanisms, which are now commonly invoked to explain rainfall anomalies. In practice, these drivers explain only the minor component of variability. This talk revisits some of the evidence for these drivers and some alternative processes.

Aditya Sengupta, University of Melbourne

Changes in ENSO variability and teleconnection post net-zero in ACCESS-ESM-1.5

El Niño Southern Oscillation (ENSO) is a prominent climate phenomenon affecting the variability of global precipitation and temperature patterns. Past studies have highlighted that, under rapid anthropogenic warming, ENSO variability is likely to increase and its teleconnections with regional rainfall and temperature patterns are also likely to intensify. These changes are often attributed to the dynamical changes in the tropical Pacific Ocean and air-sea coupling processes, because of the warming caused by anthropogenic emissions. In this study, both ENSO variability and teleconnection changes are analysed following emission cessation using a new set of net-zero experiments with ACCESS-ESM-1.5. These results are then compared against the rapid warming SSP5-8.5 scenario to assess the impacts of rate of warming and cessation of emissions. We find that both ENSO variability and frequency of ENSO events increases under rapid warming in the 21st century but declines post net-zero. Temperature and rainfall teleconnection changes are regionally consistent across the rapid warming and net-zero runs; however, the impacts are more pronounced under the rapid warming scenario. Further analysis at different warming levels indicates that stabilising at higher warming levels causes stronger amplification in teleconnection strength. This research will provide insights into the long-term changes in ENSO and its effects on regional climate even after we achieve net-zero and will highlight the dynamical mechanisms driving such changes.

Chenhui Jin, Monash University

A synoptic-dynamic view of the Millennium Drought (2001-2009) in southeastern Australia

Australia has had several severe droughts in its recent history. Most studies have linked these droughts to large-scale modes of variability, whereas few studies have investigated droughts from the perspective of weather systems. The current study examines a wide range of weather systems focusing especially on heavy rainfall events, which are important to meteorological drought. Two distinct phases (development and recovery) are identified for the Millennium Drought based on the cumulative Standardized Precipitation Index. A pronounced reduction in precipitation from autumn heavy rainfall events during the development phase is due to fewer, less intense, faster-moving warm conveyor belts. In contrast, increased precipitation from autumn heavy rainfall events in the recovery phase is explained by an interaction between warm conveyor belts and upper-level anticyclonic potential vorticity, with persistent anticyclonic circulation over the Tasman Sea acting to slow the eastward propagation of rainfall-producing weather systems. For summer, the changes in precipitation from heavy rainfall events between the two drought phases are, however, due to changed moisture content within warm conveyor belts. In the recovery phase, high moisture content is due to enhanced moisture transport over the Tasman Sea between Australia and New Zealand.

Irina Rudeva, Bureau of Meteorology

The Tinderbox Drought in observations and ACCESS-S2

The rainfall decline during the three years of the Tinderbox drought 2017-2019 was unprecedented - making it one of the most severe droughts in Australia's history. However, none of the three drought years was the driest on record. More importantly, a comparison of the large-scale circulation anomalies shows that the anomalous patterns are very different across the drought years and cannot be explained by a single cause, e.g., the Hadley cell expansion. Regression analysis between rainfall and the large-scale drivers shows that they can, at best, explain the rainfall anomalies only in 2019, but not in the first two years of drought. In this presentation, we will explore the observed large-scale circulation patterns along with ACCESS-S2 simulations and discuss potential reasons for the dry conditions in each of the three years.

Qinuo Huang, Monash University

Quantify the contributions of the physical processes to heatwaves in Victoria, Australia

Heatwaves cause more deaths than other natural hazards in Australia. The physical processes and their contribution to the extreme high temperatures in Victoria are investigated using a single column model. Given that heatwaves (consecutive hot days) and single hot days are dynamically similar, we show that the temperature of the air before entering the boundary layer and the duration of the upper level anticyclone can determine whether or not the event will be a heatwave.

Tess Parker, CSIRO

Blocking and Extreme Weather

Atmospheric blocking is associated with many high-impact weather extremes, such as heat waves/cold air outbreaks, droughts/floods, and extreme winds/wind droughts. However, there is still no agreement on the definition of blocking, and the physical processes responsible for the formation, reinforcement, and decay of blocks are not fully understood. While short-term forecast skill has improved, blocking is still responsible for occasional forecasts busts in the midlatitudes. Furthermore, the prediction of blocking on timescales from subseasonal to decadal and beyond is problematic, and the effect of climate change on the location, frequency, and duration of blocking is uncertain. This in turn reduces confidence in the projections of changes to associated weather extremes under global heating. A recent workshop in the USA highlighted some of the questions and latest research on blocking and extreme weather, which I'll talk about here.

Stacey Osbrough, CSIRO

Tipping points of Australian climate extremes and changes in Southern Hemisphere explosive storms.

In their report discussing the risks to Australia in a 3°C warming world, The Australian Academy of Science recommend further action be taken to “improve our understanding of climate impacts, including tipping points and their consequences to the Australian human and natural systems.”

This presentation will give evidence of regime transitions having already occurred during the 20th and early 21st century over Southern Australia in rainfall, temperatures and extremes, including some particularly dramatic shifts in streamflow into Perth dams.

The shift in annual surface temperatures over SWWA and SEA, and indeed for Australia as a whole, has occurred primarily over the last 20 years with the percentage area experiencing extreme maximum temperatures in decile-10 increasing to an average of more than 45% since the start of the 21st century. South-west Western Australia (SWWA) experienced the most dramatic drying trend with average streamflow into Perth dams in the last decade just 20% of that before the 1960s, and extreme decile-10 rainfall reduced to near zero. In south-eastern Australia (SEA) systematic decreases in average and extreme cool season rainfall became evident in the late 1990s with a halving of the area experiencing average decile-10 rainfall in the early 21st century.

The mechanisms causing the shift of southern hemisphere circulation and prolonged periods of drought although extensively studied are not fully understood. A new data driven method developed for determining the growth rates and statistical structures of growing and decaying weather systems has been used to improve understanding of the relationships between the SH jet streams and storm tracks based on lower tropospheric circulation anomalies through high-pass (periods < 4 days) and band-pass (periods between 4 and 8 days) filtering of 6-hourly reanalysis data. Here, leading Empirical Orthogonal Functions (EOFs) and storm tracks based on all disturbances are determined. As well, the structure and standard deviations of streamfunction fluctuations are determined separately in three growth rate and three decay rate bins focusing on explosive growth. Storm tracks based on separate growing and decaying disturbances are more informative than standard compositing methods and show new insight into fast propagating extratropical storms and slower propagating weather systems such as dipole blocking and NWCB systems that are associated with extreme rainfall.

Valentina Ortiz, University of New South Wales

The Dynamics of Stalling Cyclones: A Global Perspective

Extratropical cyclones are a primary driver of extreme weather in the mid- to high latitudes, responsible for the majority of extreme precipitation events. Among these, stalling cyclones, defined here as slow-moving and rainy cyclone systems, represent a particularly severe hazard, due to their prolonged influence, often associated with flooding. Existing studies, mostly focused on the Northern Hemisphere (NH), usually only consider the slow-speed cyclone feature and identify two major hot spots at the eastern coasts of the NH continents, while storm tracks in the Southern Hemisphere (SH) have been perceived as zonally symmetric. In this work, we study stalling cyclone systems across the globe, first looking at the planet's spatial pattern. Using cyclone tracking data, we find that the global distribution of stalling cyclones is remarkably similar between the hemispheres. Contrary to previous perceptions, the SH does not exhibit a zonally symmetric organisation but instead shows three distinct spots located at the eastern coasts of each continent, mirroring the pattern observed in the NH. Initial results further indicate that these high-impact cyclones are often embedded within a global wave train, suggesting a broader interconnectedness. Our research suggests that SH storm tracks should not be treated as something zonally symmetric and encourages us to examine how these cyclones are connected and how models depict their distribution compared to reanalysis products.

Thi Lan Dao, University of Melbourne

Joint modulation of coastal rainfall in Northeast Australia by local and large-scale forcings: Observations versus AUS2200 simulations

This study investigates the interaction between large-scale and local-scale forcings in regulating precipitation and its diurnal variation over coastal areas in Northeast (NE) Australia using the convection-permitting UK Met-Office Unified Model simulations with a horizontal grid-spacing of 2.2 km (AUS2200). The AUS2200 simulates well the spatial distribution of rainfall and its variation with large-scale variabilities such as El Niño-Southern Oscillation (ENSO) and the Madden Julian Oscillation (MJO) over Northeast Australia during a total 180 simulations days. Over the coastal areas, inhomogeneous rainfall patterns are evident in both radar observations and model simulations. By classifying the characteristics of offshore and onshore rainfall propagation, we found that the rainfall propagation modulates the average rainfall patterns. Modelling results suggest that the large-scale background wind and local-scale land-sea breeze circulations are two important factors driving rainfall propagation. For offshore rainfall propagation, a dominant propagation type over NE Australia, rainfall is triggered during the afternoon by strong sea breezes, and then propagates offshore during the nighttime with the strong upper-level westerly wind. In contrast, onshore rainfall propagation occurs during days with strong background easterlies from the surface to the upper levels. Rainfall tends to occur and stay over the land during days with strong sea breezes and weak background upper-level westerlies. On days with strong low-level easterly winds and strong upper-level westerly winds, rainfall is mainly concentrated over the ocean. We test the hypothesis that the background wind regimes associated with different phases of the MJO modulate the direction and strength of rainfall propagation, leading to different coastal rainfall patterns. In some cases, this may dominate the thermodynamic influence of the convective phases of the MJO.

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Dynamical aspects of organised convection in Australia - recent progress and opportunities

Organized convective systems have a variety of archetypes that are ultimately related to dynamical interactions between the background environment and circulations created by the storms, which helps maintain them and/or grow upscale. Such archetypes range from the canonical front-fed, upshear tilted and downshear propagating model, which is common for long-lived and linear systems, through to a large set of combinations of mesoscale tilts and propagation directions relative to the mean flow and shear. Ultimately, the dynamical aspects of organized systems control their longevity, propagation, and the severity of hazards like damaging surface wind gusts and extreme precipitation. Previous studies have characterised the occurrence and longevity of the range of dynamical archetypes over the midlatitudes (e.g., in the USA). There has been comparatively little work on this topic in Australia. Here we discuss recent progress on understanding dynamical aspects of organized convection in Australia, the value of such concepts for weather and climate model evaluation, and future opportunities in this area.

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