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Observing, Estimating and Forecasting Rainfall: From Science to Applications - abstracts of the seventh CAWCR Workshop 21 October - 23 October 2013, Melbourne, Australia

Keith A. Day and Shoni Maguire (editors)

CAWCR Technical Report No. 066

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FOREWORD

The Centre for Australian Weather and Climate Research (CAWCR) is a partnership between Australia's leading atmosphere and ocean research agencies – CSIRO and the Bureau of Meteorology. CAWCR was first established in 2007 and is now entering a second five year term. CAWCR jointly manages science capability across the Bureau and CSIRO Marine and Atmospheric Research and provides a major national centre for research excellence with a focus on Earth system science. The CAWCR Workshop is an annual event and brings together national and international expertise to highlight latest development in research relevant to CAWCR and its stakeholders. It provides an opportunity to identify gaps, opportunities, build relationships and enhance the quality, breadth and depth of our research efforts.

This year the theme for the workshop is *Observing, Estimating and Forecasting Rainfall: From Science to Applications.* This is in recognition of the importance of precipitation to the well-being, safety and productivity of the nation. Increasing the accuracy and utility of precipitation information remains a significant challenge. This workshop will consider the science associated with observing and estimating precipitation, the physics of precipitation, its predictability, the modelling and forecasting of precipitation over a range of time and space scales, and developments associated with applications that employ such information e.g., hydrological prediction. Importantly the workshop brings together not only scientists with diverse expertise, but also computer and observing system specialists and key practitioners that depend upon our science in their activities.

The workshop is organised around topics related to:

- Precipitation Physics
- Precipitation Observations and Estimations (rain gauge, satellite, radar)
- Precipitation Modelling (nowcasting, NWP, seasonal, climate)
- Precipitation Statistics and Climatology
- Precipitation and Applications

A number of prominent scientists and experts from overseas, Australian research agencies and universities have been invited to give presentations. International keynote speakers include:

- Dr Richard Carbone – National Center for Atmospheric Research
- Prof V. Chandrasekar – Colorado State University
- Dr Julie Demargne – HYDRIS Hydrologie
- Prof Brian Golding – UK Met Office
- Dr Marianne König – European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
- Dr Humphrey Lean – UK Met Office
- Dr Frederic Vitart – European Centre for Medium Range Weather Forecasts (ECMWF)

National keynote experts include:

- Dr Lisa Alexander – Centre of Excellence Climate System Science
- Dr John Le Marshall – CAWCR
- Dr Alain Protat – CAWCR
- Dr Alan Seed - CAWCR
- Dr Peter Steinle – CAWCR
- Dr QJ Wang – CSIRO
- Dr Matthew Wheeler – CAWCR

The workshop is hosted by the Bureau of Meteorology and CSIRO and is sponsored by the Selex, Fujitsu, the Department of the Environment and Primary Industries (Victoria), Centre of Excellence Climate System Science and Intel. I would like to thank these sponsors for their generous support of the workshop.

Finally, we would like to thank the members of the organising committee, comprising: Alan Seed and Shaun Cooper (Co Chairs), Wenju Cai, Beth Ebert, Val Jemmeson, Sally Lavender, Eun-Pa Lim, Shoni Maguire, Jeff Perkins, Peter Steinle and the excellent support provided by Liz Adams, James Allen, Anu Arora, Angela Artiaga, Mark Bervanakis, Keith Day, Julie Sortino and Meryl Wiseman.

Tom Keenan

Director
Centre for Australian Weather and Climate Research:
A partnership between the Australian Bureau of Meteorology and CSIRO

October 2013

THE POTENTIAL VALUE OF RAINFALL FORECASTS

Brian Golding

UK Met Office, UK

Abstract

Recent advances in convective scale NWP have enabled direct coupling of NWP with hydrological and inundation models leading to a revolution in flood forecasting.

At the same time, the impacts of flooding on all parts of society are growing at an unprecedented rate due to population growth, climate change, economic and cultural development. Impacts are seen in loss of life – often from flood-related landslides – and in damage to buildings, loss of power, water and transport infrastructure, disease from contaminated water and sediment; all leading to economic loss and personal distress.

Flood forecasts and warnings provide the key to flood management actions that can save life and mitigate loss and distress, but they only have value if they lead to people taking actions that improve the resilience of their communities. In recent years improvements in rainfall forecasting capability have not been matched by corresponding increases in confidence of forecast users in taking critical flood management decisions. To reverse this trend requires a broader view of the flood forecasting enterprise, coupled with a re-focussing of scientific research onto key user requirements. In particular, it requires that the skills of social scientists are mobilised to contribute to defining and solving this problem.

For weather services this might mean focussing on improved accuracy at very short range rather than extending the forecast range; on verification for public education rather than for scientific understanding; on designing products that convey information that is needed, rather than that which is available; on delivering the message through combinations of channels that reinforce each other, rather than choosing the medium that is most efficient.

Weather scientists will need to carry out their research seamlessly with hydrologists and behavioural psychologists, amongst others, while continuing to produce the required advances in forecast accuracy: e.g. the need to produce a convincing message requires that the initial stages of the rainfall forecast are in much better agreement with observed reality than is currently achievable; forecasts of uncertainty and skill need to be presented in a way that clearly conveys what aspects of each forecast can be relied on and why.

THE DALLAS-FORT WORTH URBAN DEMONSTRATION NETWORK

V. Chandrasekar[1], Brenda Philips[2], Haonan Chen[1], Dong-jun Seo[3], Eric Lyons[2], Francesc Junyent[1], Apoorva Bajaj[2], Jerry Brotzge[4], Delbert Willie[1], Amy Cannon[5], Arezoo Nasib[3] and David Westbrook[2]

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[2]*University of Massachusetts Amherst*
[3]*The University of Texas at Arlington*
[4]*University of Oklahoma*
[5]*Department of Transportation and Public Works, the City of Fort Worth, Texas.*

Abstract

Since spring 2012, the Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) has been transformed from a research to operational demonstration emphasis, and has started the development of Dallas-Fort worth (DFW) urban remote sensing network. The main goal of this network is to demonstrate the operational feasibility of the dense radar network in a metropolitan environment. The DFW network consists of 8 dual-polarization X-band weather radars covering the greater DFW metropolitan region, designed to provide real time high-spatial and temporal radar and other data to diverse user community for urban flood mitigation and severe weather warning operations. The major goals include urban flash flood mitigation, severe weather warning and demonstration of network-of-network concept (NRC, 2009). It is also expected to be an ideal development platform for multi-Doppler wind retrieval, quantitative precipitation estimation (QPE), quantitative precipitation forecast (QPE), and accurate hydrologic response. In addition, multi-sensor products will be generated as well from combining the existing remote sensors such as KFWS radar (a WSR-88D radar), TDWR, and local rainfall gauges.

This paper will first present a brief overview of the development of DFW radar network. The current installation status and recent field observations will then be described in depth. Sample data and products from different applications will be shown to demonstrate the capability of the Urban demonstration radar network.

THE ERROR STRUCTURE OF RADAR RAINFALL ACCUMULATIONS

Sandy Dance[1] and Alan Seed[2]

[1] *The Centre for Australian Weather and Climate Research, Melbourne, Australia,* *s.dance@bom.gov.au*:
[2] *The Centre for Australian Weather and Climate Research, Melbourne, Australia*

Abstract

In this study we compare radar derived rainfall from the Rainfields QPE system with gauge derived rainfall in order to elucidate the error structure of radar derived rainfall estimates for each point under the radar. The error structure is useful in the assimilation of radar derived rainfall accumulations into an NWP model, and in the upscaling of radar rainfall rates into merged products such as a national rainfall map. Here we describe our efforts to understand the rainfall error structure and to find potential correlations between error variance and any factors available at the time of rainfall data delivery, such as radar range, altitude and topography, that would enable the error variance to be predicted. Initially, we compared the rate of data acquisition with the data required to reliably calculate variance, finding that it would take about 3 years, longer than the average time between changes to the radar configuration. We then searched for predictors of variance, but found none except for the case of one low quality radar, Marburg, whose variance correlated with range. We conclude that the variance of radar rainfall errors is best modelled using a single value defined for each radar type.

SPATIO-TEMPORAL CHARACTERISTICS OF BLENDED RADAR/GAUGE DATA AND THE ESTIMATION OF DESIGN RAINFALLS

Dörte Jakob[1] and Alan Seed[2]

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Abstract

Radar data provide consistent spatial and temporal information that cannot be readily gleaned from gauge information alone. As part of the revision of Australian Rainfall and Runoff, and under the auspices of Engineers Australia, the Bureau of Meteorology is currently undertaking a project to evaluate the realism of downscaled rainfall extremes for the Greater Sydney region. This evaluation is based on spatio-temporal characteristics derived from blended radar and gauge rainfall accumulations (Rainfields).

Information about the spatio-temporal characteristics of precipitation – especially for large events – is desirable for a multitude of other activities related to the analysis of design rainfall estimates and potential changes in these estimates under climate change. These applications include the choice of realistic parametrisation schemes in the downscaling of rainfall extremes from Global Climate Models, the choice of spatial parameters in the statistical modelling of extremes and in assessing the realism of areal reduction factors depending on the choice of gridding technique.

This presentation outlines algorithms used in blending radar and gauge data, the analyses undertaken to remove artefacts, and the analysis of errors in the resulting product of radar rainfall accumulations to provide information to users on the quality of these products. We discuss spatio-temporal characteristics of radar data suitable for the analysis of rainfall extremes.

TURBULENCE EFFECTS ON DROPLET COLLISION-COALESCENCE AND PRECIPITATION FORMATION

Charmaine Franklin[1,2]

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Abstract

In clouds where the temperature does not reach freezing, cloud droplets initially grow through the process of condensation. However, as the rate of increase of drop radius by condensation decreases with increasing radius, it is the process of collision and coalescence that enables drops to grow into larger drizzle and raindrops. When the equations governing these two modes of droplet growth are applied to describe observed warm cloud precipitation formation, there is a discrepancy between the observed and theoretical growth rates with observations showing a faster onset of precipitation. Several physical mechanisms have been suggested to play an important role in accelerating precipitation formation including entrainment, giant cloud condensation nuclei and turbulence. A double moment warm rain parameterisation has been developed that includes the effects of turbulence on cloud droplet collision and coalescence rates (Franklin 2008, JAS). This parameterisation has been implemented in a large-eddy model to investigate the effects of turbulence on precipitation formation, cloud microstructure and morphology.

Simulations of shallow cumulus convection and stratocumulus demonstrate that the turbulence effects on the microphysical processes produce an increase in precipitation due to a more rapid conversion of cloud water to rain. Turbulence has a greater effect on the simulated precipitation rates in the shallow convection case, where the higher turbulent kinetic energy dissipation rates contribute to surface rain water amounts that are almost 5 times greater in the simulation with the turbulent microphysics. The results show that different precipitation-dynamical feedbacks occur in these two cloud regimes when the effects of turbulence are considered. In the shallow convection case, the turbulent microphysics simulation shows enhanced latent heating associated with the increased cloud and rain water. This has the effect of reducing the entrainment and buoyancy production of turbulent kinetic energy. The stratocumulus case on the other hand shows a positive precipitation feedback. In this cloud regime the enhanced rainwater in the turbulent case produces greater turbulent kinetic energy due to more subcloud evaporation driving stronger circulations and variability. Sensitivity tests show that by including the turbulence effects on cloud microphysical processes overcomes the need to artificially reduce aerosol loading to obtain realistic precipitation rates.

THE RELATIONSHIP BETWEEN PRECIPITATION AND LARGE-SCALE CIRCULATIONS IN SOUTH EAST QUEENSLAND

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Abstract

Statistics of radar-retrievals of precipitation are presented. A K-means clustering algorithm is applied to an historical record of radiosonde measurements which identified three major synoptic regimes; a dry, stable regime with mainly westerly winds prevalent during winter, a moist south easterly trade wind regime and a moist northerly regime both prevalent during summer. These are referred to as westerly, trade wind and northerly regimes, respectively. Cell statistics are calculated using an objective cell identification and tracking methodology on data obtained from a nearby S-band radar. Cell statistics are investigated for the entire radar observational period and also during sub-periods corresponding to the three major synoptic regimes. The statistics investigated are cell initiation location, area, rainrate, volume, height, height of the maximum reflectivity, volume greater than 40 dBZ and storm speed and direction. Cells are found predominantly along the elevated topography. The cell statistics reveal that storms which form in the dry, stable westerly regime are of comparable size to the deep cells which form in the northerly regime, larger than those in the trade regime and, furthermore, have the largest rainrate. However, they occur less frequently and have shorter lifetimes than cells in the other regimes. Diurnal statistics of precipitation area and rainrate exhibit early morning and mid-afternoon peaks, although the areal coverage lags the rainrate by several hours indicative of a transition from convective to stratiform precipitation. The probability distributions of cell area, rainrate, volume, height and height of the maximum reflectivity are found to follow lognormal distributions.

WEATHER RADAR APPLICATIONS. INNOVATION, CHALLENGE AND OBJECTIVITY

André Weipert

SELEX SI GmbH, Gematronik Weather Radar Systems

Abstract

It is beyond doubt that dual polarization weather radar systems enable a better weather monitoring, short term and long term weather forecasting. The usage of modern weather radars is manifold. The market demands as well. Who is the driver for "Innovation" ? The product supplier/manufacturer) or the application (customer) ? Who defines "Trends ?" Who responses with trend-setting solutions ? Do we already use the full potential of given technologies ? And finally how to find the balance between customer expectations and smart weather radar system architectures and concepts ? This presentation addresses different perspectives with respect to hydrological/meteorological as well as aviation meteorological weather radar applications. Special focus will be done on "open" concepts, weather radar network management, modern and open data standards and IT architecture.

SHORT TERM ENSEMBLE PREDICTION SYSTEM (STEPS): MODELLING THE UNCERTAINTY IN RAINFALL RADAR ESTIMATION AND PREDICTION

Alan Seed[1] and Clive Pierce[2]

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Abstract

The spatial and temporal statistical structure of rainfall can be modelled using multiplicative cascade models that were developed to describe turbulence. The main advantage of these cascade models is that the temporal evolution of the field can be modelled in a way that depends on the scale, with large scale features evolving more slowly than small scale features. This paper describes the Short Term Ensemble Prediction System (STEPS) that has been developed as a joint project between the Australian Government Bureau of Meteorology and the Met Office (U.K.) that exploits these models to generate ensembles of rainfall fields for a range of applications.

Urban flash flood models require high-resolution forecasts of rainfall with a lead time of several hours, called rainfall nowcasts. These nowcasts are generated by advecting fields of radar rainfall estimates forwards in time. Errors in radar rainfall estimates are correlated over time and space scales that are similar to scales of interest in flash flood forecasting, and forecasting errors due to the development of the rainfall field after the observation become significant after 30 to 60 minutes. The skill of a nowcast that is based on advecting a radar rainfall field forwards in time increases with scale and decreases with lead-time. STEPS generates an ensemble nowcast by perturbing the radar rainfall analysis using a space-time model for radar estimation error and then generating a forecast where the evolution of the field is provided by a stochastic model of rainfall evolution.

The skill of a radar advection nowcast deceases rapidly with lead time and generally falls below the skill of a high-resolution NWP model after about 3 hours. The skill of the NWP forecast can be assumed to be independent of lead time if this is limited to 24 hours, but decreases with scale. STEPS generates ensembles of rainfall forecasts that are based on a blend of a nowcast and a NWP rainfall forecast which is then perturbed by a stochastic error model that takes into account the relative skills of the NWP and nowcasts at that scale and lead time so as to generate the ensemble members.

The response times for river catchments depends on the scale of the catchment, but hydrologists require rainfall forecasts out to at least 5 days. High-resolution NWP models are run over limited areas and cannot generate forecasts beyond a couple of days, and therefore global NWP models are required to generate forecasts beyond this lead time. Hydrological prediction systems need rainfall forecasts that have a consistent resolution over the entire lead time of the forecast, and require that the rainfall forecasts respect the statistical structure of rainfall. STEPS can be used to downscale global NWP models and blend with high-resolution NWP so as to generate an ensemble of seamless rainfall forecasts.

SEAMLESS RAINFALL FORECASTS FOR 0-10 DAYS

Shaun Cooper[1] and Alan Seed[1]

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Abstract

The Bureau uses a number of Numerical Weather Prediction (NWP) models to generate rainfall forecasts over a range of lead-times, each with a different resolution in space and time and forecast domain. Many users require a seamless forecast system that is able to blend the various NWP forecasts into a single forecast with a uniform resolution over the entire forecast period. The magnitude of the forecast error for each NWP model depends on spatial scale and lead time. The idea, therefore, is to blend the NWP models in such a way that recognises the skill of the NWP at a particular scale and lead time. A stochastic model of forecast errors can then be used to perturb the blended forecast so as to generate an ensemble.

The NWP uncertainties are scale and forecast lead time dependent, especially at long forecast lead times, and are characteristic to each model. By blending the models scale by scale it is possible to recognise the increased skill of the models at larger spatial scales and shorter lead times. The stochastic model is applied at each scale, adding increasingly more variability at smaller spatial scales, while preserving the space-time structure of rain.

The NWP models also contain biases. By comparing the NWP forecasts (accumulated to daily rainfall totals) with AWAP analyses biases can be calculated and corrected for. Bias corrected high resolution ACCESS-A and coarser resolution ACCESS-G forecasts have been blended to generate forecasts over two 1000 km x 1000 km domains. A 50 member ensemble of hourly, downscaled precipitation forecasts out to 10 days has been generated with an output resolution of 2 km x 2 km. A year of these ensemble forecasts (accumulated to daily rainfall totals) have been verified against the daily AWAP analyses and show the system is able to produce bias corrected, reliable forecasts out to 5 days over these domains.

COMPARING THE SKILL OF PRECIPITATION FORECASTS FROM HIGH RESOLUTION SIMULATIONS AND STATISTICALLY DOWNSCALED PRODUCTS IN THE AUSTRALIAN SNOWY MOUNTAINS

Thomas Chubb, Jingru Dai, Michael Manton and Steven Siems

Monash University

Abstract

Statistically significant improvements to a “Poor Man's Ensemble” (PME) of coarse-resolution numeral precipitation forecast for the Australian Snowy Mountains can be achieved using a clustering algorithm. Daily upwind soundings are classified according to one of four clusters, which are employed to adjust the precipitation forecasts using a linear regression. This approach is a type of “statistical downscaling”, in that it relies on a historical relationship between observed and forecast precipitation amounts, and is a computationally cheap and fast way to improve forecast skill. For the “wettest” class, the root-mean-square error for the one-day forecast was reduced from 26.98 to 17.08 mm, and for the second “wet” class the improvement was from 8.43 to 5.57 mm. Regressions performed for the two “dry” classes were not shown to significantly improve the forecast. Statistical measures of the probability of precipitation and the quantitative precipitation forecast were evaluated for the whole of the 2011 winter (May-September). With a “hit rate” (fraction of correctly-forecast rain days) of 0.9, and a “false alarm rate” (fraction of forecast rain days which did not occur) of 0.16 the PME forecast performs well in identifying rain days. The precipitation amount is, however systematically under-predicted, with a mean bias of -5.76 mm and RMSE of 12.86 mm for rain days during the 2011 winter.

To compare the statistically downscaled results with the capabilities of a state of the art numerical prediction system, the WRF model was run at 4 km resolution over the Australian Alpine region for the same period, and precipitation forecasts analysed in a similar manner. It had a hit rate of 0.955 and RMSE of 5.16 mm for rain days. The main reason for the improved performance relative to the PME is that the high resolution of the simulations better captures the orographic forcing due to the terrain, and consequently resolves the precipitation processes more realistically, but case studies of individual events also showed that the choice microphysical parameterisation was very important to precipitation amounts. The WRF model is capable of reasonably good forecasts of the sounding “class” for Wagga Wagga, with an accuracy of 80% for the first day and 65% for the third day of the forecast, facilitating the use of the PME downscaling for a number of forecast days instead of only the day of the sounding.

METEOSAT PRECIPITATION AND RELATED NOWCASTING PRODUCTS

Marianne König

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Abstract

The talk will focus on the products derived from EUMETSAT's geostationary satellites of the Meteosat Second Generation (MSG) series. There are currently three MSG satellites in orbit with their operational names Meteosat-8, Meteosat-9 and Meteosat-10. Meteosat-10 serves the zero degree mission, providing full earth scans at 15 minute intervals, in 12 spectral channels covering the solar, near-infrared and thermal infrared parts of the spectrum. Meteosat-9 provides the Rapid Scan Service from its position at 9.5 E, covering the northern third of the globe every 15 minutes, while Meteosat-8 at 3.4 E serves as backup satellite for either mission.
An operationally available precipitation product for both the full disk and the rapid scan missions is the MPE product, the Multi-Sensor Precipitation Estimate, which relates measured IR temperatures at ~11 µm wavelength to precipitation measurements of recent SSM/I overpasses, thus providing a continuous "re-calibration" of the IR brightness temperatures with respect to precipitation.

Recent developments have focussed on the use of a newly available MSG product to derive a precipitation estimate. This new product, knows as the "Optimal Cloud Analysis" (OCA) product, derives a number of cloud bulk and microphysical parameters in an optimal estimation approach, using the entire spectral information provided by MSG. First results of these developments will be shown.

Finally, the presentation will show examples of other nowcasting applications of MSG, mainly in the area of convection and severe weather nowcasting and short-term forecasting, covering issues like strong rain and hail and where the satellite observations can help in providing timely warning

LOWER BOUNDARY INFLUENCES ON THE OCCURRENCE AND PREDICTABILITY OF PRECIPITATION

Richard Carbone

National Center for Atmospheric Research, Boulder, Colorado USA

Abstract

Terrestrial and oceanic surfaces are known to have profound effects on the occurrence of precipitation and, oftentimes, precipitation predictability as well. Such effects can be particularly strong when the atmosphere is vulnerable to relatively weak forcings, e.g. in the absence of fronts and cyclones. A surprisingly large fraction of precipitation occurs under such circumstances; circumstances that often prove problematic for global models.

Skill in numerical prediction of precipitation is often derived from knowledge of geostrophy, baroclinic instability, partially resolved orography and large scale sea breeze circulations. Systematic errors in prediction of precipitation are often associated with organized convection, including mid-latitude mesoscale convective systems, tropical superclusters, the MJO active phase in its entirety, real and imagined ITCZs, and insufficiently resolved orographic precipitation.

Topics to be discussed include warm season continental convection; cool season orographic precipitation; and tropical oceanic precipitation, including the MJO active phase. A common theme is the effect of lower boundary gradients, which can induce convergence, vertical air motion, and lead to modulation of the amount and distribution of precipitation. The characteristic temporal-spatial coherence of precipitation events, together with characteristics of lower boundary forcings, may also infer practicable limits of predictability in some circumstances.

RESEARCH AND OPERATIONAL COMPUTING

Tim Pugh

The Centre for Australian Weather and Climate Research

Abstract

The talk is to discuss the advances in end-to-end simulation infrastructure and computing facilities in support of the Australian weather and climate research community and the Bureau's operational facility. And to highlight the next challenges and steps to advance numerical weather prediction and earth system simulation in future computing facilities.

TO INFINITY AND BEYOND!

Peter Kerney and Malcolm Cowe

Senior HPC Specialist and SystemsEngineer from the Intel High Performance Data Division
Intel Australia

Shaped by their experiences with commodity-based, clustered compute systems, end-user expectations of performance, scale and ease of management have extended to include storage and the entire software stack. Fully integrated and rigorously tested end-to-end solutions have quickly become required for HPC and data intensive computing workloads of all sizes. Intel is a leading provider of server hardware, advanced interconnect fabrics and parallel development tools – and a key contributor to open source software vital to HPC.

This session will describe Intel's comprehensive hardware and software vision for HPC systems moving forward – from the Silicon and Fabric, Lustre and Hadoop to advanced data center management tools — to create an integrated software suite that will accelerate the return on investment for HPC technologies by making them easier to deploy, simpler to manage and more productive.

PROGRESS WITH FORECASTING RAINFALL AT THE MET OFFICE

Humphrey W Lean

UK MetOffice, Reading, UK

Abstract

Recent progress and research at the Met Office in NWP forecasting of short range rainfall will be described.

The current status and verification of the UKV (1.5km UK) model and MOGREPS-UK will be briefly summarised. Outcomes from the Nowcasting Demonstration Project (NDP) which ran a small domain, hourly cycling, 4D-Var system over the southern UK from March 2012 until March 2013 will also be presented.

An important aspect of research is to improve understanding of the representation of convection in high resolution models which explicitly represent convection. DYMECS (DYnamical and Microphysical Evolution of Convective Storms) is a collaborative project between MetOffice@Reading and University of Reading radar and cloud physics scientists. This project has used the Chilbolton research radar in southern England to make 3D scans of clouds and gather statistical data on a large number of convective storms. The resulting observational data has been compared to the Unified Model (UM) in the 1.5km UKV configuration as well as a number of higher resolution versions. It is shown that the characteristics of the model representation of convection are strongly dependent on the model resolution. As might be expected the UKV usually under-resolves convection. However going to higher resolution, although beneficial in some ways, does not improve all aspects of the representation. A particular problem is that the highest resolution models (order 100m) tend to incorrectly represent convection on very small scales. The representation also depends strongly on the subgrid mixing scheme employed and this will be the subject of future research. Some novel work as part of this project to estimate the vertical velocities in convective clouds and compare it to the models will be presented.

The paper will also include some results of UM modelling of tropical convection in the Singapore region. This will include discussion of the impact of changing to the new UM dynamical core (ENDGAME) which is expected to be implemented in the operational UKV next year.

MOISTURE PRECIPITATION AND EARTH OBSERVATIONS FROM SPACE

John Le Marshall[1,3], Jin Lee[1], Paul Gregory[1] Jim Jung[2], Robert Norman[3], Chris Tingwell [1]and Rolf Seecamp[1].

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Abstract

Earth observations from space (EOS), from current and future space missions are increasingly providing larger volumes of data related to current and future Earth System State. We articulate key benefits from assimilating these Earth observations, particularly in relation to moisture, precipitation and NWP generally from a southern hemisphere perspective. The benefits described are in the atmospheric and severe weather area. Instruments providing these benefits include the Atmospheric Infrared Sounder, those carried by the COSMIC Constellation and the GOES and MTSAT imager. Examples of the beneficial impact of these data are provided. Many examples are Observing System Experiments, based on the application of these data to the operational forecast systems at NCEP and at the Australian Bureau of Meteorology. It is found in an era where populations are increasing in areas subjected to severe weather and while extreme weather events remain a considerable problem, that EOS significantly extend the life of numerical forecasts. For example in a study using both the NCEP and the Australian operational forecast system ACCESS the life of a high quality numerical forecast is extended by a factor of four over the southern hemisphere by using EOS. The study also shows the great benefit of using EOS data in the southern hemisphere when predicting heavy rain. The examples shown in this study underline the great importance and great benefit of EOS for those in both the southern and the northern hemisphere.

EVALUATION OF ACCESS-TC PRECIPITATION FORECASTS USING CRA

Yingjun Chen,[1] Elizabeth E. Ebert,[2] Noel Davidson,[2] and Kevin Walsh[3]

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Abstract

The Australian Community Climate and Earth-System Simulator – Tropical Cyclone version (ACCESS-TC) has been operational since 2011. How does it perform on tropical cyclone (TC) rainfall forecasts? Does it have system bias on rainfall location error? What is the error contribution from different components, such as volume, pattern and location? To answer these three questions, we use Contiguous Rain Areas (CRA) methods to verify ACCESS-TC rainfall forecasts, against TRMM 3B42 satellites estimates.

Under the CRA methodology, a rainfall forecast will be shifted to a location where the forecast has the best match with satellite estimates. By comparing the statistics between the original and shifted forecasts, we can calculate the displacement error of the original model forecast. The total precipitation error can also be decomposed into four components: displacement, rotation, volume and pattern. For the limited cases considered, pattern error and displacement error were found to be major error contributors.

This validation study can identify ACCESS-TC rainfall forecasting biases and limitations, and guide future efforts towards model development and improvement of TC rainfall forecasts.

RAINFALL PROPERTIES: THEIR VARIABILITY AS A FUNCTION OF LARGE-SCALE ENVIRONMENT, AND THEIR REPRESENTATION IN NWP MODELS USING DUAL-POLARIZATION RADAR OBSERVATIONS

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Abstract

The representation of precipitation properties in global and high-resolution models is an essential step towards accurate quantitative precipitation forecasts. It has been recently demonstrated that global models tend to produce a reasonably good estimate of the rainfall accumulation, but for wrong reasons (rain is too light in models, but produced too often). This calls for a better understanding of precipitation processes and their variability as a function of the large-scale environment. In this talk we will describe results obtained using a research C-band dual-polarization radar located around Darwin, Australia and collocated model outputs from the limited-area version of the ACCESS model (ACCESS-A). This talk will highlight (i) the variability of the statistical properties of convective clouds as a function of large-scale atmospheric "regimes" as derived from the Darwin radiosoundings and different phases of the Madden-Julian Oscillation (MJO), (ii) the diurnal cycle of convection and its variability as a function of those regimes, (iii) the mechanisms involved in the transition from shallow to deep convection, with some focus on the role of the congestus stage, and (iv) how well those processes are reproduced by the model.

DYNAMICS AND PREDICTABILITY OF A SPRINGTIME PRECIPITATION EVENT IN THE AUSTRALIAN ALPS

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Abstract

Precipitation in southeast Australia is strongly influenced by the Australian Alps, with the terrain playing an important role in the initiation and enhancement of precipitation. Orographic precipitation events in the region are often associated with frontal systems, with enhanced precipitation on the northwestern slopes before and during a frontal passage. However, the mesoscale aspects of precipitation events in the region have received relatively little attention. Moreover, with ongoing improvements in numerical weather prediction models, which enable complex terrain features and moist processes to be explicitly resolved, the dynamics and predictability of such events warrants increased attention. In this study the Weather Research and Forecasting model is used to simulate a springtime precipitation event in the Australian Alps using a domain with 1.1 km grid spacing to investigate the mesoscale components of the event. We also examine results from a 3.3 km grid spacing 30-member ensemble, created from perturbed initial conditions, to elucidate aspects of the predictability of the event, and compare all of these results to surface and radar observations.

The event occurred on 29 October 2010; the synoptic setting was characterized by the passage of a cold front and associated cloud band that extended from the tropics to the southeast corner of the Australian continent. Observations showed a relatively short-lived prefrontal rainfall event whereby precipitating convection was triggered upstream and subsequently enhanced over the Alps. This was followed by a more prominent orographically enhanced frontal system. It is the prefrontal event that is the focus of this study. Using the observations and simulations, it is shown that the initiation of the prefrontal convection is coincident with the passage of surface disturbance (an undular bore) that propagates ahead of a prefrontal trough. The convection is triggered near the upstream extent of the mountains and is subsequently advected towards and enhanced by the mountain range. To appreciate the predictability of this prefrontal event, results from the ensemble are also presented. Interrogation of the ensemble elucidates the important components of the flow necessary for initiation and maintenance of the convective system.

EVALUATION AND COMPARISON OF PRECIPITATION FORECASTS OVER AUSTRALIAN SNOWY MOUNTAINS REGION WITH ACCESS AND NWP MODELS

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Abstract

Orography is known to enhance precipitation in mountainous regions through a variety of mechanisms. For example, Houze identifies seven such mechanisms in his textbook Cloud Dynamics. While there have been a number of studies examining the nature of wintertime precipitation across Southeast Australia, they commonly examine the role of fronts and cut-off lows crossing the Murray Darling Basin. Little work has been done in exploring the nature of orographic precipitation across the Great Dividing Range.

Two wintertime storms have been examined to assess the skill in precipitation forecasts employing both the Australian Community Climate Earth-System Simulator (ACCESS) and Weather Research and Forecasting (WRF) Numerical Weather Prediction (NWP) models under an operational environment. The first storm in July 2011 is featured by a decaying cut-off low that brought substantial precipitation to the Snowy Mountains Region. The second storm in late September was associated with a complex set of low pressure centres over the Bight, producing the largest daily precipitation amount of the whole winter of 2011.

An evaluation of the precipitation forecasts is performed against the high-elevation rain gauge network across the Snowy Mountains and the simultaneous satellite observations. The probability of precipitation and quantitative precipitation forecast (QPF) are assessed and compared between the models. The forecasts of synoptic conditions, structures of the orographic clouds, as well as the skill of prediction of supercooled liquid water and isotherm heights are also examined. High-resolution simulations are then undertaken to better understand the dynamical mechanisms that lead to the orographic enhancement observed across the Snowy Mountains.

PROBABILISTIC RAINFALL FORECASTS FROM POST-PROCESSING OF NWP OUTPUT

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Abstract

Probability of Precipitation (PoP) forecasts are produced by the Gridded Operational Consensus Forecasting System (GOCF) of the Australian Bureau of Meteorology using forecasts of rainfall amount from a Poor Man's Ensemble of Numerical Weather Prediction output from a number of international centres. The PoP forecasts are created using historical data to relate the observed frequency of rainfall above various thresholds to the ensemble mean forecast rainfall amount, using an adaptation of the method of Sloughter et al., 2007. Functions giving the probability of rain above a minimum threshold, and the probability distribution function for the amount of rainfall given that the minimum threshold was exceeded, are produced. A byproduct of the system is the calibration of the forecast rainfall amount.

Calibration of probabilities requires much data, and though the method produces reliable and skillful PoP forecasts with a relatively small training data set, it still needs at least several weeks' data over a large fraction of Australia to be stable. The original implementation of the method produced forecasts for SE Australia only with a single calibration for the whole area and a year of past data. This approach is not suitable for forecasts for the whole of the continent. Methods for allocating forecast grid points to one of several calibration categories have been developed. The calibration of each category is based on data from the past 14 months and the same season as the forecast. This allows for both geographical and seasonal variations in the calibration parameters.

This paper describes the calibration method, including the method for allocating forecast grid points to calibration categories. The performance of the system is illustrated using verification statistics for different areas of Australia, seasons and forecast lead times. For lower rainfall thresholds (up to 10mm) the system has skill significantly above climatology to forecast lead times of five or six days.

MAKING PRECIPITATION FORECASTS WITH THE GFE

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Abstract

The Bureau of Meteorology is greatly enlarging the suite of quantitative precipitation forecasts it provides. This encompasses data on 3 hourly and daily timescales, including probabilities and mean and percentile rainfall amounts, on 3 or 6 km grids being extended across the Australian landmass.

The vehicle for producing these forecasts is the Graphical Forecast Editor (GFE) software, which is being rolled out in the Bureau's Regional Forecasting Centres. Forecasters can take raw and post-processed model guidance in the GFE as the basis for the forecasts, and have a variety of editing techniques available by which they may add value to the guidance.

It was expected that the Gridded Objective Consensus Forecast System (GOCF) would be the mainstay of the precipitation forecast process. In practice, alternative guidance strategies using manual blends of direct model outputs have been heavily used by forecasters, for reasons which will be discussed. Verification products from the National Meteorological and Oceanographic Centre provide comparisons of the quality of the GOCF guidance with the forecasts produced using the GFE. Implications for future improvements in guidance and forecast process within the GFE are considered.

REPRESENTING THE PRECIPITATION PROBABILITY DISTRIBUTION IN THE GFE

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Abstract

Official forecasts from the Bureau of Meteorology's Regional Forecasting Centres are increasingly being produced using the Graphical Forecast Editor (GFE) software. These forecasts include quantitative information about rainfall on 3 or 6 km resolution grids.

Over the 7 days of the forecast, there are forecasts of probabilities of precipitation for a range of thresholds, the expected value of precipitation amount, and various percentile amounts. These are on daily and three-hourly timescales. That is a large number of forecast grids for the forecaster to oversee. To manage this, the GFE provides tools which assume a functional form for the cumulative conditional probability distribution for rainfall amount. By adjusting the parameters associated with this distribution, the forecaster can derive the full set of probability and amount grids from the distribution.

The function which has been adopted is the Weibull distribution. One attraction of the Weibull distribution is its simple form which allows for analytic solutions rather than needing more expensive numerical-fitting approaches. Another advantage of this function of two parameters ('shape' and 'scale'), is that a good representation of climatological rainfall frequencies can be obtained with a constant value of the shape parameter. This has previously been shown for United States data, and similar results will be shown for Australian at daily and 3 hourly timescales. This allows the forecaster to concentrate their forecasting consideration on the probability of any rain and on one or two quantities related to rainfall amount, which are sufficient to specify the distribution.

ACCESS CONVECTIVE SCALE DATA ASSIMILATION

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Abstract

Over the past 3 years, the Australian Bureau of Meteorology has been assessing the potential of a convective scale numerical weather prediction (NWP) system capable of assimilating radar data – both Doppler radial winds and precipitation data. The aim is for the new NWP system to bridge the gap between purely observation based precipitation nowcasting and existing regional scale NWP systems. The system is being developed as part of the broader modeling effort of the Australian Community Climate and Earth System Simulator (ACCESS, [1]). The NWP components of the system are based on the UK Met Office Unified Model and variational assimilation system – specifically the 1.5km UKV system [2].

An important part of this system is the ability to provide a rapid update to forecasts by using a short (hourly or 3-hourly) assimilation cycle. Extensive trials have been carried out from September 2011 to July 2012, as well as for specific periods over 2010-11. Despite the differences in observation networks and weather conditions between Australian and the UK, the system is providing guidance far superior to existing global and regional NWP systems. This presentation will discuss some of the challenges in applying this system to semi-tropical conditions as well as an overview of the performance of the 1.5km system relative to other systems. These issues cover various aspects of data assimilation: from quality control, error covariances, dealing with large scale errors from the host model and the limitations imposed by model errors, particularly as they impact on short term prediction of intense rainfall events.

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SPATIAL VERIFICATION OF HIGH-RESOLUTION MODELS OF PRECIPITATION

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Abstract

Numerical weather prediction is continually improving with respect to both skill and spatial resolution. In particular, high-resolution models of precipitation are capable of representing fine scale structure, location and temporal placement more accurately than ever before. However, classical model verification approaches do not help to quantify such properties. The aim of this work is to objectively measure the quality of high resolution forecasts of precipitation using spatial verification metrics with the hypothesis that spatial verification of high-resolution models is on-average better than downscaling lower resolution models and more accurate at defining complex precipitation structure.

In this study we make use of two popular, and complimentary, spatial verification metrics to compare three versions of the ACCESS NWP systems. The first is the operational APS0 12km (ACCESS-A) that includes 6 hourly 4dVAR assimilation. The second is the operational 5.5km city system centred over Sydney, a downscaling of the operational 40km regional system. The final system is the experimental 1.5km system that includes 3hourly 3dVAR.

Firstly, the Fraction Skill Score (FSS) is used to determine the scale at which models have appreciable skill. Secondly, the Structure Amplitude Location (SAL) score is used to quantify fine structure, location and amplitude errors of the precipitation. Using time period with significant precipitation events we compute the aggregate of SAL and FSS.

Initial results suggest that the high resolution models have greater skill at equivalent scale, and better represent the structure of estimated precipitation and have comparable location accuracy to lower resolution models.

QUANTITATIVE PRECIPITATION FORECAST WITH CONVECTION-PERMITTING ACCESS MODEL: ENSEMBLE SENSITIVITIES TO PRECIPITATION ASSIMILATION, HORIZONTAL RESOLUTION AND DOMAIN SIZE

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Abstract

The ACCESS model with different horizontal grid distances and domain sizes has been tested in a series of high resolution ensemble simulations of heavy precipitation cases. The ensemble simulations are initialized at 06UTC and cover forecast lead time up to 36h. Rainfall rate from radar and rain gauges is assimilated through the Latent Heat Nudging (LHN) method. The Bias Score, bias adjusted Threat Score, Correlation Function and Fraction Skill Score against observation are calculated for quantitative precipitation forecasting (QPF) verification. The verification shows that both domain size and model resolution have remarkable influences on the skill of QPF. Although the influences may change from case to case, the bigger domain represents larger scale background better, while the higher resolution runs reveal more detail about smaller scale precipitation structure. As the domain size and resolution are fixed, the LHN during the early stage of convection development can shorten the spin-up time of the mesoscale weather systems and improve the QPF slightly. However, the positive impact of the LHN on the QPF only persists in the first few hours.

Ensemble sensitivity tests to small random errors in initial fields are undertaken for demonstration of the intrinsic predictability of small scale heavy precipitation cells. The skill scores with control run used as truth are taken to measure the predictability of precipitation. The quick decrease of skill scores with increase of precipitation intensity confirms that the predictability of precipitation is scale sensitive and that the predictability of individual heavy convection precipitation cells is very limited.

The ensemble experiments confirm that the ensemble mean has better skill than individual deterministic forecasts, but the skill score of smaller scale heavy precipitation cores are not improved by the ensemble. The implications of these results for data assimilation and precipitation forecasting are also discussed.

PRECIPITATION CHANGES DUE TO THE INTRODUCTION OF EDDY-RESOLVING SEA SURFACE TEMPERATURES INTO SIMULATIONS OF EAST COAST LOWS

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Abstract

Weather Research and Forecast model (WRF) simulations are used to investigate how the distribution of precipitation is related to the distribution of sea surface temperatures (SST) during the life cycle of four east coast lows. Focus is placed on investigating changes caused by the introduction of complex eddy and filament structures present in the Bluelink reanalysis SST dataset. Past research on the effect of SST gradients on surface winds has shown that convergence occurs when air flows from a warm to a cold sea surface. In an unstable environment, such as that associated with a cold core upper-level low, this convergence may help to trigger thunderstorms and consequently affect precipitation. In the simulations enhancement/suppression of rainfall is found over and downwind of warmer/cooler SSTs. Warm eddies are at times associated with a pronounced enhancement of rainfall along their downwind flank where a strong SST gradient exists. These relationships are dependent on atmospheric conditions and the location of storm features like rainbands and fronts. An ensemble of simulations is used to test the statistical robustness of these findings. In addition to WRF simulations, Global Position and Tracking System (GPATS) lightning data are overlaid on maps of SST and sea level height anomalies to look for relationships between thunderstorms and upper ocean heat content. A complex picture emerges of a correspondence between the distribution of upper-ocean temperature gradients and that of lightning strikes. The WRF simulations are used to establish what atmospheric changes contribute to the observed distributions of thunderstorms and how this changes are related to the SST distribution.

INFLUENCE OF VERTICAL ADIABATIC HEATING PROFILE ON THE TROPICAL RAINFALL SIMULATION

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Abstract

Convective heating tendencies shows that the UM has a large cooling spike at the freezing level due to all the snow in the downdraught being melted in the layer where the environmental temperature reaches the freezing level. Looking at downdraughts in a few CRM simulations suggests that there is a mix of frozen and liquid precipitation over a layer several km deep from the freezing level downwards. A simple way to alter the convection downdraught code to approximate this behaviour is to allow a mix of liquid and frozen precipitation from the freezing level to the freezing level plus 10 degrees. This change allows a mix of snow and rain between the freezing level and 10K above this with the proportion of rain increasing linearly from zero at the freezing level to one at the freezing level plus 10K.

A four year simulation with the above changes shows that the improved vertical adiabatic heating profile helps to reduce the divergence associated with the cooling at the melting levels, so that the convection is more efficient in moistening the grid column in the vertical. As a result, the precipitation has been improved in the region of the central Indian Ocean and Maritime continent. This improvement leads to a better simulation of eastwards propagating waves.

FLOODZOOM – EMPOWERING INTELLIGENT FLOOD PLANNING AND RESPONSE

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Abstract

Victoria experienced significant flooding in 2010, 2011 and 2012. Several post flood reviews highlighted the importance of timely and reliable flood warning to assist community planning and response. The Victorian Government announced the FloodZoom initiative in May 2011. This initiative aims to improve access and sharing of flood information to empower planning and response by communities and agencies. The initiative has three primary components:

- Flood warning arrangements and upgrades: Clarifying total flood warning arrangements and improving flood warning gauge infrastructure
- Flood risk assessment and mapping: Investigating and mapping flood behaviour for mitigation measure assessment and flood intelligence preparation
- Flood intelligence platform: Developing a web based platform to access and share flood information and intelligence for planning and response.

This presentation updates progress on these three components and outlines the next steps. Further the benefits of this integrated approach are discussed.

SHORT-TO-LONG RANGE HYDROLOGIC ENSEMBLE FORECAST SERVICE IN THE U.S. NATIONAL WEATHER SERVICE

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Abstract

NOAA's National Weather Service (NWS) is implementing a short- to long-range Hydrologic Ensemble Forecast Service (HEFS). Ensembles are an effective means to quantify uncertainty in support of risk-based decision making for a wide range of practical applications (e.g. flood risk management, water supply management, streamflow regulation, and recreation planning). HEFS extends the existing hydrologic ensemble services to provide reliable and skillful ensemble forecasts over multiple spatio-temporal scales at forecast horizons ranging from 6 hours to about a year.

Based on separate modeling of the input and hydrologic uncertainties, HEFS includes: 1) the Meteorological Ensemble Forecast Processor, which ingests weather and climate forecasts from various numerical weather prediction models to produce bias-corrected forcing ensembles at the hydrologic basin scales; 2) the Hydrologic Ensemble Processor, which uses the forcing ensembles with hydrologic, hydraulic, and reservoir models to generate streamflow ensembles; 3) the Ensemble Post-processor, which adjusts the streamflow ensembles to account for the collective hydrologic uncertainty and correct for systematic hydrologic biases; 4) the Ensemble Verification Service, which verifies the forcing and streamflow ensembles to help identify the main sources of skill and error in the forecasts and guide decision making; and 5) the Graphics Generator, which enables forecasters to create configurable plots for analysis and delivery to the public.

Since the beginning of the phased implementation in 2011, five NWS River Forecast Centers (RFC) have been testing the HEFS in real-time over a large number of basins. The New York City Department of Environmental Protection is currently transitioning its water supply system to make use of HEFS ensembles for more efficient and effective water and water quality management while avoiding large costs associated with new construction. This presentation describes recent verification results using multi-year hindcasting based on precipitation and temperature forecasts from RFC operational, single-valued, forecast systems, as well as the NWS Global Forecast System, Global Ensemble Forecast System, and Climate Forecast

System. The functional capabilities of HEFS are also briefly compared to two operational mid-range hydrometeorological ensemble prediction systems used for flood risk preparedness in France: the Joint Research Centre's European Flood Alert System and Meteo-France's SIM Ensemble Prediction System.

POST-PROCESSING GCM OUTPUTS TO IMPROVE SEASONAL RAINFALL FORECASTS

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Abstract

Seasonal rainfall forecasts are critical inputs to hydrological models for forecasting seasonal streamflows. Coupled general circulation models (GCMs) are increasingly being used to forecast seasonal rainfall, but forecast skill is still low for many regions. GCM forecasts suffer from systematic biases, and forecast probabilities derived from ensemble members are often statistically unreliable. For hydrological modelling applications, there is often a mismatch between GCM grid and catchment spatial scales. Therefore, it is necessary to post-process GCM forecasts to improve skill and statistical reliability and to downscale to catchment scales.
We present a Bayesian method for post-processing GCM forecasts to produce rainfall forecasts. Statistical calibration models are used to convert GCM raw rainfall forecasts into unbiased and statistically reliable forecasts. To improve forecast skill, climate indices based on GCM forecasts of the sea surface temperature field are used as predictors in statistical bridging models to also produce rainfall forecasts. The calibration and bridging forecasts are then merged to take advantage of their unique strengths.

The Bayesian method is applied to post-process forecasts from the Predictive Ocean Atmosphere Model for Australia (POAMA), across Australia. Forecast attributes including skill, sharpness and reliability are assessed through a rigorous leave-three-years-out cross validation procedure. The calibration forecasts are more skillful for JFM - JJA. The bridging forecasts are more skillful for JAS - DJF. Overall, the merged calibration and bridging forecasts are the most skillful across all seasons.

The method is also applied to post-process POAMA forecasts to produce catchment scale monthly rainfall forecasts. To form ensemble monthly time series forecasts, ensemble members of individual months are connected through the Schaake Shuffle. The method is shown to produce well-calibrated ensemble forecasts that source skill from both the atmospheric and ocean modules of the GCM. Although skill is generally low, moderate skill scores are observed in some catchments for lead times of up to 6 months. In months and catchments where there is limited skill, the forecasts revert to climatology.

In future work, the ensemble monthly time series forecasts will be used to drive a monthly water balance model to produce ensemble streamflow forecasts.

SUB-SEASONAL TO SEASONAL PREDICTION OF RAINFALL AT ECMWF

Frederic Vitart

Dr Frederic Vitart, European Centre for Medium Range Weather Forecasts (ECMWF)

Abstract

The ECMWF ensemble prediction system (EPS) and System 4 are used operationally to produce respectively 32-day forecasts of rainfall twice a week and seasonal forecasts of rainfall (up to month 7) once a month. The forecasting systems have skill to predict the Madden Julian Oscillation (MJO), ENSO and the Indian Ocean Dipole (IOD) and their impact on rainfall in the Tropics and Extratropics. This presentation will discuss the skill of the ECMWF forecasting systems to predict rainfall in the Tropics and Extratropics in the sub-seasonal to seasonal time ranges. During the first 10 days, the model displays higher skill in the Extratropics. After 10 days, the forecast skill is higher in the tropical regions than in the Extratropics. The skill to predict rainfall has improved significantly over the past 10 years with a gain of about a week of predictive skill in the extended range.

A new technique for calibrating sub-seasonal and seasonal rainfall based on EOF projections has been tested for African rainfall. Results suggest a significant improvement in the forecast skill scores of African rainfall with this technique. Finally, a WWRP-THORPEX-WCRP project on sub-seasonal to seasonal prediction has been set up. A deliverable of this project will be a database of near real-time sub-seasonal to seasonal forecasts which will be useful to evaluate the benefit of multi-model prediction of rainfall.

SEAMLESS PRECIPITATION PREDICTION SKILL IN THE TROPICS AND EXTRATROPICS FROM A GLOBAL MODEL

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Abstract

The skill with which a coupled ocean-atmosphere model is able to predict precipitation over a range of time scales (days to months) is analysed. For a fair comparison across a seamless range of scales, the verification is performed using data averaged over time windows equal in length to the forecast lead time. At a lead time of one day, skill is greatest in the extratropics around 40-60º latitude, lowest around 20º, and has a secondary local maximum close to the equator. The extratropical skill at this short range is highest in the winter hemisphere presumably due to the higher predictability of winter baroclinic systems. The equatorial skill comes mostly from the Pacific, and thus appears to be associated with the El Niño-Southern Oscillation. As both lead time and averaging window are simultaneously increased, the extratropical skill drops rapidly with lead time, while the equatorial remains approximately constant, resulting in the equatorial skill exceeding the extratropical at leads ≥ 4 days in austral summer and ≥ 7 days in boreal summer. At longer lead times, the extratropical skill eventually flattens out or increases, but does not approach the equatorial values. Comparisons with persistence confirm that the model beats persistence for most leads and latitudes, including for the equatorial Pacific where persistence is high. The results are consistent with the view that extratropical predictability is mostly derived from synoptic-scale atmospheric dynamics, while tropical predictability is primarily derived from the response of moist convection to slowly-varying forcing such as from sea surface temperature.

INTRA-SEASONAL SIMULATION AND PREDICTION OF RAINFALL IN ASSOCIATION WITH THE MJO, SAM AND BLOCKING USING POAMA-2

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Abstract

We assess the ability of the Predictive Ocean Atmosphere Model for Australia version 2 (POAMA-2) to simulate and predict precipitation anomalies on intra-seasonal timescales in association with three key climate drivers: the Madden-Julian Oscillation (MJO), the Southern Annular Mode (SAM), and blocking in the Australian region. POAMA-2 simulates well the weekly-mean rainfall variation associated with the evolution of the MJO over the tropical Indo-Pacific. Weekly rainfall anomalies associated with the SAM and blocking are also simulated reasonably well over the Australian region. Skilful prediction is achieved beyond 3 weeks for the MJO index and out to about 2 weeks for the SAM and blocking indices, with POAMA-2 outperforming its predecessor POAMA-1.5 in its ability to predict all 3 climate drivers. These results translate to enhanced predictability of rainfall in weeks 2 and 3 over much of the tropical Indo-Pacific and eastern Australia when the MJO is present in the initial conditions compared to when the MJO is not present in the initial conditions, and over much of the Australian continent in association with the SAM and blocking. POAMA-2 is thus capable of providing useful forecast skill for rainfall on the intra-seasonal timescale to meet the needs of Australian farming communities, whose management practices often rely upon decisions being made a few weeks ahead.

DYNAMICAL FORECAST OF EXTREME WET CONDITION OVER AUSTRALIA IN 2010 SPRING

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Abstract

2010 spring hosted a near-record strong La Nina and a record-breaking positive SAM, which played key roles in the extreme wet condition in eastern Australia. In this study, we assess the prediction skill of the Australian Bureau of Meteorology's dynamical seasonal forecast system (POAMA2) for the 2010 spring extraordinary climate conditions.

POAMA2 skilfully predicted the spatial pattern and magnitude of the tropical ocean temperatures associated with the La Niña event at lead times of at least 4 months. Importantly, POAMA2 also predicted the key variations of atmospheric circulation during spring 2010 associated with the positive swing in the Southern Oscillation as well as the strong positive excursions of the SAM out to a lead time of 3-4 months. Consequently, the wet conditions over eastern Australia in 2010 spring were skilfully anticipated from the preceding early winter.

We also conducted model experiments to investigate the forecast sensitivity to atmosphere and land surface initial conditions. The results suggest that POAMA's ability to predict the 2010 strong La Niña and its teleconnection to Australia was the key component for the success of the prediction for 2010 spring rainfall at up to a season lead time. On the other hand, realistic atmospheric conditions played an important role in predicting the extremity of the rainfall event at short lead time.

POAMA CLIMATE FORECASTS FOR SEASONAL STREAMFLOW FORECASTING

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Abstract

In 2010, the Australian Bureau of Meteorology (the Bureau) launched a seasonal streamflow forecast (SSF) service. Since then, the Bureau provides SSF products every month using a statistical modelling method called Bayesian Joint Probability (BJP). In parallel, the Bureau produced experimental forecasts using a dynamic modelling approach. Rather than using statistical relationships between streamflow and climate indices, the new modelling approach was designed to use climate forecasts directly for the seasonal streamflow forecasts. In this approach, ensemble streamflow forecasts are developed using: 1. Downscaled regional rainfall forecasts from the Predictive Ocean Atmosphere Model for Australia (POAMA) to the catchment scale; 2. Calibrated rainfall-runoff model with a heteroscedastic residual error model using the Bayesian Total Error Analysis framework (BATEA); and 3. A post-processing method for reducing the bias and inflating the variance in streamflow forecasts.

Compared with the statistical approach, the dynamic approach results in more accurate and/or precise forecasts at several locations across different seasons. However, overall forecast performance of the dynamic approach is lower than that of the statistical approach on the basis of currently available approaches. The dynamic approach tends to overestimate streamflow volumes from catchments in drier regions, which results in lower reliability. Without any form of post-processing, the approach tends to generate emphatic forecasts with narrow uncertainty bands. We found additional efforts to improve forecast quality in both climate modelling and hydrological modelling are required to produce more accurate and reliable operational seasonal streamflow forecasts with the dynamic approach.

In this paper, we introduce details of the dynamic modelling approach, evaluate the modelling outcome, and explain the value of POAMA climate forecasts for water information services.

Keywords: Streamflow, rainfall, forecast, model, season, water, POAMA, Bureau of Meteorology

GENERATING REALISTIC ENSEMBLE RAINFALL FORECASTS FOR FLOOD AND SHORT-TERM STREAMFLOW FORECASTING APPLICATIONS.

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Abstract

Ensemble streamflow forecasts can support risk-based decision processes to optimally manage water resources and prepare for impending floods. Rainfall forecasts produced with Numerical Weather Prediction (NWP) models are potentially highly valuable for generating streamflow forecasts. However, available rainfall forecasts from Australian NWP models are deterministic and have different statistical characteristics from rainfall observations used by flood and streamflow forecasters. In particular, rainfall forecasts over small catchments can be strongly biased because of the coarse NWP model resolution.

In this presentation, we will describe and evaluate a method of post-processing rainfall forecasts from the latest generation of Australian NWP models. We use a Bayesian joint probability (BJP) method to correct the statistical properties and quantify the uncertainty of the forecast rainfall. As we apply the BJP method discretely to forecasts at each lead time and location, the corrected rainfall forecast ensembles do not yet have realistic spatial and temporal correlation structures that are necessary for streamflow forecasting. Statistical post processing methods that explicitly model spatial and temporal correlations structures are typically computationally expensive and are yet to be widely adopted for operational streamflow forecasting applications. To overcome these computational challenges, we use a simple yet effective method called the "Schaake Shuffle", which produces multi-day ensemble rainfall forecasts by linking samples from discretely post-processed forecasts. These forecasts follow historically observed spatial and temporal correlation patterns. The method is applied to NWP rainfall forecasts for 10 catchments across Australia. The results demonstrate that the ensemble rainfall forecasts are consistent with the observed rainfall used for real-time streamflow forecasting and retain the spatial and temporal correlation pattern of the observations. The method is well suited for operational flood and short-term streamflow forecasting applications.

A NEW SERVICE TO DELIVER SHORT TERM STREAMFLOW FORECASTS FOR AUSTRALIA.

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Abstract

As part of its responsibility to deliver water forecasts for Australia the Australian Bureau of Meteorology (the Bureau), in collaboration with CSIRO and CAWCR, is developing a service to deliver short term (up to 10 days) streamflow forecasts at key forecast locations around the country.

Short term streamflow forecasts can support optimal management of water resources in areas such as urban supply and irrigated farming as well as environmental flows.

The forecasting system that is being developed combines real-time observations of rainfall and streamflows with rainfall forecasts and continuous hydrological modelling to produce streamflow forecasts at hourly time intervals. The real time data network consists of telemetered rainfall and streamflow gauges that submit data to the Bureau's forecasting data management system AIFS. Rainfall forecasts are extracted from the Bureau's global Numerical Weather Prediction (NWP) model ACCESS APS1 G. This model delivers gridded 10 day weather forecasts including precipitation at a spatial resolution of approximately 40km. Continuous hydrological modelling is undertaken using the SWIFT modelling system which utilises the GR4H conceptual model developed by Cemagref.

In this paper, we provide an overview of the methods used to generate streamflow forecasts and describe the verification of those forecasts for 10 catchments covering a range of Australian climatic and hydrological conditions. Future work on ensemble short term streamflow forecasting will make use of seamless rainfall forecasts from CAWCR and will also account for rainfall uncertainty at the catchment scale.

QPF FOR FLOOD WARNING SERVICES – CURRENT AND FUTURE APPLICATIONS

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Abstract

The continuous improvement in QPF has been reflected in the increasingly accurate detection of potential flooding with the Flood Watch product. Flood Watches are typically issued 2 to 4 days ahead of an event and provide the emergency services and community an opportunity to plan for a flood threat. In New South Wales, based on the Flood Watch, the State Emergency Service routinely deploy personnel, aircraft and other assets to areas threatened by major flooding. Such operations can cost several hundred thousand dollars so such actions reflect their confidence in reliability of the Flood Watch product.

QPF has also been successfully used in NSW to extend warning lead times in quantitative flood warnings for a number of major floods requiring the evacuation of communities. To date the incorporation of QPF values in hydrological models used for flood forecasting and warning has been a manual process. This manual approach relies on operational meteorologists to provide regional QPF values for 12 or 24 hours. These are translated by hydrologists to a catchment scale and the temporal patterns from a specific NWP model, typically the Bureau's ACCESS model, are then applied to these QPF totals.

A next generation flood modeling system, HyFS, is being developed by the Bureau which will allow for automatic ingestion of gridded time series QPF values directly from a range of numerical weather prediction models and ensembles. This will allow hydrologists to fully utilize the improvement in precipitation forecasting, particularly with higher resolution models, that should more accurately define rainfall on a catchment scale for which flood warnings are issued. In NSW such catchment areas are as small as 12 sq. km.

The paper will also discuss QPF guidance for the recent ex-TC Oswald event in NSW as a case study of current practice and also look at how future needs to provide more targeted advice for smaller urban areas as well as for overland flooding can be met.

CONDITIONAL WEATHER RESAMPLING PROCEDURE FOR SEASONAL WATER RESOURCES FORECASTING

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Abstract

Seasonal streamflow forecasts are used by operational hydrologic agencies and hydropower companies around the world for water resources planning. The Ensemble Streamflow Prediction (ESP) is a common procedure to provide these seasonal forecasts. The ESP procedure uses a hydrological model starting from the current initial state and driven by historical meteorological time series to generate an ensemble of future streamflows, assuming that historical records from the same date in past years form an ensemble that represents the probability distribution of future weather. A clear advantage of this approach is that spatial and temporal correlations in the weather patterns are automatically conserved. A disadvantage of the ESP is that it relies on the availability of long records of historical weather. Moreover, the ESP in its original implementation does not accommodate for any additional information that the forecaster may have about expected deviations from climatology in the near future. More specifically, climatic modes such as El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) are known to persist for several months and will affect the future weather in many regions around the globe. Therefore, as an alternative to the use of an ensemble of historical years to represent climatology, we propose a conditional weather resampling method to generate synthetic meteorological time series. A resampler algorithm was developed that assembles meteorological time series by randomly selecting monthly periods from past years based on ENSO and/or PDO climate index values and on logical follow-up. The effectiveness of the method was investigated using non-operational hindcasts and observational data from a Delft-FEWS real-time hydrologic seasonal forecasts system for the Columbia River basin that is operated by the Bonneville Power Administration (BPA). The forecast skill of the resampler method was tested against the original ESP for three subcatchments in the Columbia River basin at the long-range seasonal time scale. The Brier skill score (BSS) and Continuous Ranked Probability Skill Score (CRPSS) were used to compare the forecast skills. Results from non-operational hindcasts will be presented.

APPLYING PRECIPITATION TO DESIGN

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Abstract

Engineers, hydrologists and planners require estimates of rainfall quantiles for probabilities from one Exceedance per Year to 1% Annual Exceedance Probability (previously referred to as one year and100 year average recurrence intervals).

The sparseness of the available rainfall data – both temporally and spatially – in Australia means that estimation of rainfall quantiles of these probabilities directly from at-site rainfall frequency analysis is not appropriate. Instead estimates of Intensity-Frequency-Duration (IFD) design rainfalls provided by the Bureau of Meteorology (the Bureau) are used for the design of infrastructure including gutters, roofs, culverts, storm water drains, flood mitigation levees and retarding basins. The previous IFD estimates were derived in 1987 using techniques for the statistical analysis of the data that were considered appropriate at the time.

The Bureau has recently finalised a revision of the previous IFD estimates, with the new IFDs released in July 2013. The revision of the IFDs was based on a greatly expanded rainfall database incorporating not only nearly 30 years of additional data collected at the Bureau's gauges but also data from networks operated by other organisations across Australia. In particular, the inclusion of continuous rainfall data collected by urban water utilities such as Melbourne Water has more than doubled the data base available for estimating IFDs for sub-daily durations. All the data were subject to rigorous and consistent quality controlling to ensure that the data were accurate.

In addition to the expanded data base, the revision adopted more statistically rigorous analysis techniques, such as: the Generalised Extreme Value (GEV) distribution, which was fitted to the extreme value series using the technique of L-moments for rainfall frequency analysis; Bayesian Generalised Least Squares Regression for deriving sub-daily rainfall statistics from daily rainfall values and thereby expanding the sub-daily rainfall database; an 'index rainfall procedure' for regionalisation of point data in order to remove bias incorporated through short period of records; and objective GIS based methods for gridding the GEV parameters to enable IFDs to be obtained at any point in Australia;. Adopting these techniques has provided engineers with more accurate IFD estimates for the design of infrastructure.

THE DEVELOPMENT OF GLOBAL LAND-BASED DATASETS OF PRECIPITATION EXTREMES

Lisa Alexander

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Abstract

For over a decade the World Meteorological Organisation (WMO) Commission for Climatology (CCl)/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) has been developing a suite of indices based on daily temperature and precipitation data that focus on more extreme aspects of climate. Of the 27 indices recommended by the ETCCDI, 11 relate to precipitation extremes. Indices are calculated at station locations using quality controlled data from international datasets, with data sparse regions of the globe supplemented with data from targeted regional workshops. In order to account for the uneven global distribution of stations and in order to easily compare with the output from climate models, indices were gridded onto a 3.75 longitude x 2.5 latitude grid to create the dataset HadEX. While HadEX made significant advances to our understanding of global changes in these types of extremes and allowed evaluation of modelled extremes for the first time using state-of-the-art global climate models, it still suffers from a lack of coverage over large areas (particularly for precipitation extremes), only covers the period 1951-2003 and does not contain the measures of uncertainty required to fully assess the trends and variability in extremes.

This presentation will introduce the "next generation" of global gridded extremes products (the CLIMDEX project) which aim to improve our understanding of the variability of extremes, enhance detection and attribution studies and provide the highest quality observations for model evaluation. Advances over previous datasets include longer-term data availability, delivery via a web interface (www.climdex.org) including near-real time updates, and an assessment of the uncertainty in the gridded products. However, the production of these datasets has not been easy and analyses are still affected by a number of uncertainties related to data quality and availability, homogenisation, sampling, gridding techniques, and time period considered.

Despite these uncertainties, results show that globally the number of heavy precipitation days and precipitation intensity has likely increased and that this increase is related to anthropogenic forcings. Changes in extreme dryness are less coherent although with some regions indicating likely increases (e.g. the Mediterranean) and others likely decreases (e.g. north-west Australia).

MODELLING AND ANALYSIS OF RAINFALL EXTREMES IN THE GREATER SYDNEY REGION

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Abstract

How extreme rainfall events may change under future climate scenarios is of great interest to a large section of the community. As part of the revision of *Australian Rainfall and Runoff*, possible changes in rainfall intensity-frequency-duration (IFD) curves due to anthropogenic climate change will be quantified. These will be used to provide advice to practitioners on how these changes can be included into design and planning decisions.

Concentrating on the Greater Sydney region, two different limited area models will be used to downscale reanalysis data as well as global climate model data under both the current climate and a future climate scenario. Biases associated with the modelling approach will be assessed by comparing the spatial and temporal patterns of modelled extreme rainfall from the reanalysis-based simulations with radar observations. For the current climate, IFD curves will be calculated from the downscaled reanalysis and climate model data. These results will be compared with the updated IFD curves under the current climate which have recently been prepared by the Bureau of Meteorology. If the results differ, a method of correcting the downscaled results will be identified.

Future changes to rainfall IFD curves will be assessed relative to the current climate case. If necessary, the dynamically downscaled results for the future climate will be adjusted using the approach identified and applied to those for the current climate. This will ensure that any advice on climate change will be relevant to the baseline revised IFDs prepared by the BoM and will be able to be adopted by users.

This presentation will give an overview of the modelling being carried out in this project.

SPATIAL DISTRIBUTION OF SEVERE THUNDERSTORM RAINFALL EVENTS THROUGHOUT THE GMSTWA & ADJACENT TASMAN SEA

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Abstract

Severe thunderstorms are previously found to be the second most costly climatic factor in Australia on the basis of strict damages caused and high insurance payouts. Severe convective outcomes, such as tornados, winds, hails and intense rains are responsible for billions of dollars in damage each year around the New South Wales (NSW). They form an important part of the climate system by redistributing heat, moisture, and trace gases, as well as producing large quantities of precipitation. The policy of observation and reporting of severe thunderstorms varies from country to country, however, so that determining their temporal and spatial distributions from the reports alone has been complicated, at best even throughout the NSW. Numerous research evidences, found in the Australian literature, do exist that the modelling of different aspects of such events, particularly torrential rainfalls, has been faced with diverse sorts of complexities.

To respond the previous unsolved research questions, we will review a few on demand subjects associated to Severe Thunderstorm Rainfall Events (STRE) with a multi-purpose and composite-scale approaches. Accordingly, in this stage of the research, some of the major Severe Thunderstorm Rainfall Events (STRE) - observed from 1998 to 2012 - were analysed to illustrate the tempo-spatial changes in the context of the Greater Metropolitan Severe Thunderstorm Warning Area (GMSTWA). To purchase such aims, a "climatologically oriented GIS" was intently applied in examining and mapping of the prevalent major STREs throughout the study area and vicinity of the Tasman Sea, when a flash flooding was reported. The concluding outcomes may well highlight the catastrophic and significant expensively effects of such storms upon the environment and social community of GMSTWA, specifically Sydney Metropolitan's highly populated areas, in the current climate change circumstance.

Key words: *STRE, GMSTWA, Tempo-Spatial Distributions, Flash Flooding.*

Invited Research Professor

VORTEX ROSSBY WAVES AND MESOSCALE ORGANISATION OF INTENSE RAINFALL IN HIGH-RESOLUTION SIMULATIONS OF TYPHOON MORAKOT (2009)

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Abstract

Typhoon Morakot was a very large, moderate intensity tropical cyclone which made landfall over Taiwan during August 2009, and produced enormous destruction in that nation. Morakot's main impact was caused by the extreme rainfall it produced, reaching 1404 mm in 24 hours at Weiliao Mountain, and a three day total of 2777 mm at Alishan, both of which are records for Taiwan and relatively close to world record values. The subsequent flooding and landslides caused about 700 deaths, and were responsible for economic losses estimated at around NT$110 billion (US$3.3 billion).

Morakot featured an extremely large wind field, an asymmetric structure of its deep convection, and strong mesoscale waves (or mesovortices) near the radius of maximum winds. These features, along with strong topographic forcing due to upslope flow over the central mountain range of Taiwan, were critical factors involved in the enormous rainfall. Important questions surround the impact of these mesoscale asymmetries on the placement and timing of the intense rainfall, and this case emphasises the need to better understand, and eventually improve predictions of, the structure of landfalling tropical cyclones in complex terrain.

Here, the results of simulations of Morakot utilising a high resolution mesoscale model, the Advanced Regional Forecast System (ARPS), with finest grid scale of 3 km, will be presented. Following a very simple initialization procedure, the simulations closely reproduced the track and intensity of Morakot during the 48 hour period encompassing its passage over Taiwan. Satellite and ground-based radar imagery from Taiwan showed that the model also captured important aspects of the mesoscale structure and evolution as well. The mesoscale wave motions were identified as Vortex Rossby Waves, and were found to play a significant role in the development and organisation of deep convective banding, which in turn influenced the placement and timing of the extreme rainfall over Taiwan. Importantly, numerical models run with coarser horizontal grid scale could not properly capture the structure of these Vortex Rossby Waves, and produced poorer forecasts of both the placement and quantity of the heaviest rainfall.

THE REPRESENTATION OF FRONT-RELATED PRECIPITATION IN CLIMATE MODELS

Jennifer Catto

Monash University

Abstract

The global importance of precipitation and how it will change in the future means that it is vital that climate models are able to adequately simulate the characteristics of precipitation and the relationship between precipitation and the dynamical systems in which it falls. Atmospheric fronts play an important role in providing precipitation and frontal precipitation can be associated with heavy rain and flooding.

Here an objective front identification method is applied to reanalysis data and the CMIP5 models and the fronts linked with the corresponding daily precipitation. The
Total precipitation error in the models can be decomposed into components associated with the frequency and intensity of both frontal and non-frontal precipitation. The total precipitation error decomposition shows that while the models have small biases, there are compensating errors. Most models capture the distribution and magnitude of the frequency of fronts, but the frontal precipitation occurs too often. This is found to be not only related to the well-known “drizzle” problem.

The Centre for Australian Weather and
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