The Australian Energy and Water Exchange Initiative

OzEWEX 2014

1st national workshop | Canberra, ACT | 28-29 October

WORKSHOP SUMMARY REPORT

About this report

On 28 and 29 December, around 100 participants met at in Canberra for the first annual OzEWEX workshop. The theme of the workshop was '*Water and Climate Information for Tomorrow*". This report represents the organisation committee's best effort to summarise the workshop and discussions, and does not necessarily reflects the view of the authors[1]. Submitted abstracts as well as the individual presentations slides and posters, where permission was given, are all available via the via workshop web site www.ozewex.org/workshop.

Executive Summary

[1] Suggested reference when citing: *Van Dijk, A.I.J.M, J.P. Guerschman, G. Abramowitz, L. J. Renzullo, S. Westra, B. Evans, T. Pagano, F. Johnson (2014). OzEWEX 2014 Workshop Summary Report. In: Proceedings, OzEWEX, 'Water and Climate Information for the Future', 28-29 October, Canberra, 21 pp. Available at http://www.ozewex.org/*

Contents

Conference Theme: Water and Climate Information for Tomorrow

The first years of this century have been marked by drought, increased competition over dwindling water resources, and concerns about the impact of future climate change. While these issues are likely to remain, new demands for water and climate information have arisen. Examples are flood and fire management, the agricultural development of northern Australia, the impact of mineral resources extraction, and compound extreme events such as droughts/heat waves.

Objectives

The workshop examined the water and climate information needs for tomorrow and compared them to the current state and developments in information services, observation sources, scientific knowledge and model technology. The following topics were explored in workshop sessions, through facilitated debate around the following six questions:

1. Are we getting close to integrating water and climate prediction?
2. With ground networks in decline, can satellites meet our needs?
3. How well can we trust our models, and how can we be sure?
4. What new water and climate information should we be developing?
5. Is Australia's data and model infrastructure ready for the future?
6. Have we reached the limits of what can be forecast?

Organisation

This workshop was organised by the Australian Water and Energy Exchanges Initiative (OzEWEX) under the auspices of the Global Water and Energy Exchanges Project (GEWEX) and the Modelling and Simulation Society of Australia and New Zealand (MSSANZ).

The workshop was made possible by generous financial support from Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Fenner School for Society & Environment of The Australian National University, MSSANZ, the ARC Centre of Excellence for Climate System Science (ARCCSS) and the Bureau of Meteorology (BoM).

The organizing committee consisted of the OzEWEX chair and working group chairs:

- Albert van Dijk, The Australian National University (OzEWEX chair)
- Juan Pablo Guerschman, CSIRO
- Gab Abramowitz, University of New South Wales, ARCCSS
- Luigi Renzullo, CSIRO
- Seth Westra, University of Adelaide
- Brad Evans, Macquarie University, Terrestrial Ecosystem Research Network
- Tom Pagano, Bureau of Meteorology
- Fiona Johnson, University of New South Wales

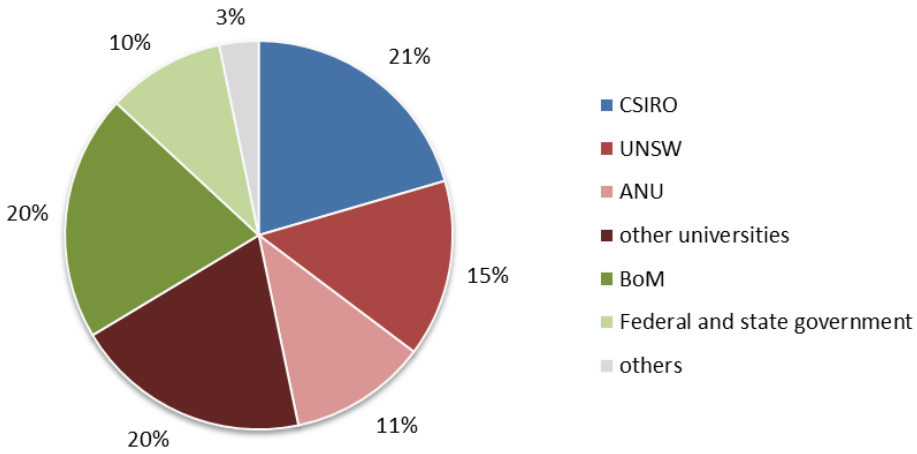
The advisory board consisted of:

- Ian Prosser, Bureau of Meteorology
- Warwick McDonald, CSIRO
- Andy Pitman, ARCCSS
- Stuart Phinn, Terrestrial Ecosystem Research Network
- Tony Jakeman, MSSANZ
- Jason Evans, Global Energy and Water Exchanges (GEWEX) project

Facts and Figures

Participants

- 132 people registered for the workshop, which was free to attend thanks to the workshop sponsors.
- Around 100 registered participants attended. An estimated 10 additional participants registered on the day, or attended without registering.
- The (approximate) distribution of participants across organisations was as follows:



Program

- There were oral 40 presentations in total, including
  - 2 plenary morning sessions, with 3 or 4 invited speakers each.
  - 6 discussion sessions, around an overarching question; each involving 3-7 introductory presentations followed by facilitated debate.
- 20 posters were presented during the poster session, including 9 presented by PhD students.
- There were catered breaks for tea and lunch and on the first day there was a cocktail function. These were provided for by the workshop sponsors.
- The $500 MSSANZ student poster prize was awarded by popular closed ballot. It was won by Anna Ukkola of Macquarie University, for her poster titled "CO_2-induced greening reduces streamflow in water-stressed climates in Australia"

Plenary sessions

Invited speakers offered their views in two plenary sessions. The presentations and discussion are summarised below.

Day 1: Information Needs for Tomorrow

This session hosted presentations by four invited presenters.

Rob Vertessy is Director and CEO of the Bureau of Meteorology, Australia's national weather, climate and water information service. Previously, he was Chief Executive of the CRC for Catchment Hydrology (2002–2004) and Chief of CSIRO Land and Water (2004–2007), and was seconded to the Department of Prime Minister and Cabinet to advise on the establishment of a national water information strategy (2006), which is now being implemented by the Bureau. In his presentation, Vertessy addressed the workshop questions through six propositions. First, judgements of adequacy are context sensitive – he outlined BOM's definition of environmental intelligence and the dimensions to it. Second, history proves we have poor foresight. Despite this discouraging conclusion, there are important positive exceptions. For example weather forecasts are still rapidly gaining in skill, and Vertessy addressed the factors that together have been forging progress: new observations, theoretical understanding, greater computational capacity, model technology, internet communication, and collaborative networks. Third, observations are key - as exemplified by the growing stream of new satellite observation platforms (e.g., Himawari) and novel sensing approaches. Fourth, advances in hydrology will continue to be dependent on improvements in meteorology – in terms of understanding and predicting weather events, e.g. leading to flooding or drought. Fifth, the last few years have been very productive – Vertessy outlined several advances in the production and dissemination of new information services by BoM and others (e.g., the Geosciences Australia data cube). Finally and sixth, we have great foundations and thus great opportunities. Vertessy stressed that collaboration is essential for future success.

Warwick McDonald leads the CSIRO's Water Resource Management Program, which undertakes water resource assessments and forecasts to inform the sustainable management of Australia's surface and groundwater resources. Previously, he led the Environmental Information Services Branch of the Bureau of Meteorology and was Director of the Water Information Research and Development Alliance (WIRADA, 2008-2011). In his presentation, McDonald identified the need, accessibility, timeliness, and usefulness as critical factors in developing new water and climate information types. He examined the applicability of the "Earth System Science for Global Sustainability: Grand Challenges" framework developed by the International Council for Science, which identifies Forecasting, Observing, Confining, Responding and Innovating as important components of a science strategy. He then gave examples of opportunities in each domain, including specific research activities to provide more certainty around the future (e.g. the development of Northern Australia and on-ground environmental watering actions); enhancing the discovery, access and reuse of observational data (e.g., the GA data cube project); identifying patterns and tipping points (e.g., whether the Millennium drought was foreseeable); sustaining essential institutions and services; and making connections with global issues such as food security, economic growth and greenhouse gas emissions.

Mike Makin is General Manager Water Resource Planning with the Murray-Darling Basin Authority. He has been with the MDBA since 2005 and was worked across many of the major program areas. In his current role he oversees a range of programs including Basin Plan Evaluation and Water Resource

Planning Policy, and is also the Chief Information Officer. In his presentation, Makin explained the different functions of the MDBA and the ways that water and climate data are used in each. These functions include operating the river system, implementing policy, monitoring outcomes, managing compliance, communicating with stakeholders, and developing future policy. He proceeded to illustrate these with worked examples. Makin stressed that MDBA's first priority is for information that helps to manage risk, rather than to necessarily maximise efficiency, benefits or opportunities. He discussed the resulting requirements in terms of quality, resolution, and the necessary integration between water, climate, ecology and socio-economic information.

Michael Roderick holds a joint appointment as a Professor in the Research School of Earth Sciences and in the Research School of Biology, both at The Australian National University. His research revolves around water at scales from cells to the globe, and he is also a Chief Investigator in the ARC Centre of Excellence for Climate System Science. In his presentation, Roderick challenged the now widespread perception that as a consequence of climate change, the "wet will become wetter and the dry become drier". Although a clear, simple and effective message, Roderick demonstrated that it is in fact misguided and too simplistic. He proceeded to define aridity in meteorological, agricultural/ecological, and hydrological terms, showing that there is no single index that will measure aridity from all these perspectives. He proposed that OzEWEX can play a critical role in bringing together the meteorological, hydrological, ecological/biological, and agronomy/forestry science perspectives that are together needed to understand future climate change impacts.

The presentations were followed by a discussion between the four speakers and audience. Some of the key points included:

- Future projections of climate are of limited use in decision making, because of the lack of skill of the current generation climate models in terms of rainfall, and because of the generally large divergence between projections by different models for most of Australia, with the exception of SW Western Australia. Researchers may want to avoid too much emphasis on downscaling efforts until this has demonstrably has been addressed.
- The importance of considering the importance of biological processes in the water and energy balance was widely supported. Examples include water use efficiency and vegetation density adjustment in response to it.

Day 2: Creating and environment for innovation

This session hosted presentations by three invited presenters.

Andy Pitman is a Professor in climate science at the University of New South Wales, and Director of the ARC Centre of Excellence for Climate System Science. He has broad interests extending across climate modeling, climate change, climate impacts and land cover change. He was appointed to the Australian Federal Government's science advisory panel to the Climate Commission in 2011. In his presentation, Pitman addressed what the community needs to do to compete internationally, solve important research problems, and delivery useful outcomes. He drew from his experience in climate system science and land surface science. He elaborated on the exponential increase in information technology challenges between each subsequent IPCC assessment and used the management of the ACCESS source code; the CMIP-5 process; and the shared National Computing Infrastructure (NCI) as examples where

the Australian community has come together and collaborates. Pitman proposed that an innovative environment requires shared science teams, shared technical teams, and shared development environments. He gave examples relating to the CABLE land surface model. Pitman proposed that the key requirements for an innovative environment are organisation, scale, collaboration, technical support, money, leadership, and a longer-term perspective. On the other hand, he addressed several impediments, including institutional competition; a tendency to fall back on familiar approaches ("it's easier for me if I.."); a reticence to accept the overheads of collaboration and coordination; difficulty in learning new ways to collaborate; money; Australian Research Council (ARC) rules around collaboration and software systems; and the profound differences in organisational cultures between universities, CSIRO, and BoM. Pitman put forward that individual groups can no longer sustain a capability and collaboration is imperative. He proposed that the Australian community needs to develop a strategic water science strategy to complement the existing climate science and Earth system science strategies.

Helen Owens is Assistant Secretary Data Policy in the Department of Communications. Previously, she was Director Geospatial Information at the Defence Imagery and Geospatial Organisation (DIGO) in the Department of Defence and held senior management roles in both the public and private sectors. In her presentation, Owens expanded on the important of geospatial data as the centre piece of the Federal Government's Open Data agenda, being pursued through ANZLIC. The ANZLIC framework covers ten themes, of which spatial water data is one. Aspects of special interest include supply chain improvements, data quality, data delivery improvements, and an open and at no-cost data policy. This represents a major shift from historical policies and requires many technical as well as institutional changes. Owens proceeded to report on progress so far. The initial focus has been on spatial administrative data, and she expanded on some of the challenges and successes. The intention is that the spatial water data theme will be actively pursued in 2015.

Brad Evans is the Director of Terrestrial Ecosystem Research Network (TERN) Ecological Modelling and Scaling Infrastructure Facility (e-MAST). His research interests extend from observations of plants and ecosystems to modelling the land surface and the impacts of ecosystem condition and land cover change on Australia's carbon and water cycles. On behalf of TERN, Evans aimed to provide an honest overview of the successes and challenges of TERN. The network has been funded to enable development of a sustainable network of people and data collection, discovery and sharing systems to advance ecosystem science and management in Australia. Evans introduced the different TERN projects, objectives and achievements, emphasising how they covered a wide range of spatial scales, from plots to continental data sets. He proceeded to discuss some of the main challenges encountered so far: dealing with large and extremely diverse data sets; engendering appreciation for the critical importance of metadata; acknowledgement of data collection by researchers; the tension between a national focus and international science impact that individual researchers need to reconcile; dealing with large egos and other familiar aspects of the human condition; and securing the long-term funding needed to provide research infrastructure.

The presentations were followed by a discussion between the three speakers and audience. Some discussion points were as follows:

- The need for a water science strategy was supported by a large majority of participants. Someone pointed out that a few such strategies have been developed in recent years. Others responded that this was too much end user driven and did not address science needs.

- In a vote on the impediments identified by Andy Pitman in his talk, a large majority found that the different cultures between universities, CSIRO and BoM were a major impediment for collaboration and progress (apart from the usual funding constraints).
- The research community has some modest use for data services that are visual only, but the large majority of users required access to the underlying GIS data. There was some discussion around the research value of having access to administrative GIS data coupled to data from the Australian Bureau of Statistics at higher granularity, particularly given the often expressed need to put biophysical information in a socio-economic context.
- There was discussion about the effectiveness of data object identifiers and other forms of data acknowledgement that may provide an alternative to publication citations. It was commented that these would need to become widely accepted in academia and become an integral part of important evaluation processes (e.g., promotion cases, research proposals, citation metrics) if they are to be an alternative to publication citations.

Discussion sessions

The six questions for each of the discussion sessions were used to derive a total of 58 propositions. These were discussed and voted on by show of hands in the discussion sessions. One of the session co-chairs facilitated discussion, while the other took notes and acted as rapporteur in the plenary session. A summary of each Discussion session is provided below.

Session 1: Are we getting close to integrating climate and water information?

Session organisers: Seth Westra and Tom Pagano

Propositions for debate:

1. Water and climate information are already sufficiently well integrated for the purpose of decision making.
2. Currently available water and climate information are inconsistent.
3. Integration of water and climate information is best left to the users.
4. Water and climate information cannot currently be interpreted together.
5. There is no real need to integrate water and climate information.
6. Water and climate information are too different to be integrated.
7. Climate information needs to be better integrated into hydrological models.
8. Climate models should be improved so they can replace hydrological models.
9. There are some major scientific challenges in integrating water and climate information.

Presentations:

- Mohsin Hafeez (BoM): Combining climate and water resources assessment information in decision making
- Imtiaz Dharssi (BoM): Are we improving weather forecasts through better initialisation of the land surface state?

- Dushmanta Dutta (CSIRO): Australian Water Resources Assessment (AWRA)
- Jason Evans (UNSW): Convection permitting regional climate modelling for short time scale precipitation extremes

Summary:

The focus of the debate was on modelling and the integration of climate and water modelling. For the state of the science, it was considered beneficial to have a "grand unified model of everything that does all for everybody". It was commented that "after all, there is only one atmosphere, one set of laws of physics". The question then was if Land Surface Models (LSM, like those typically used in Numerical Weather Prediction) and hydrology models (like those used to forecast floods) could ever merge? A likely candidate for such a merged model would be the BoM's Australian Community Climate and Earth-System Simulator (ACCESS) model. The current land surface model for ACCESS is the Joint UK Land Environment Simulator (JULES) but Australia has also invested significant resources in developing the Community Atmosphere Biosphere Land Exchange (CABLE) model.

In addition, the Bureau has also invested heavily in the Australian Water Resources Assessment (AWRA) hydrology model. Presenters showed comparisons of AWRA to other hydrology models (e.g GR4J), and to CABLE. Even though using a single parameter set for hundreds of catchments across the country, AWRA performed very well at simulating streamflow. GR4J was intended to be used with local calibration of the parameters and so it is unsurprising that its performance was poor. Those familiar with CABLE contended that it was not a fair comparison.

Despite the sense that there is only set of laws of physics, participants agreed that all models are necessarily simplifications of reality and the necessary simplifications will depend on the intended application, scale of interest, and available data. Also, given that NWP models require simulations of both the energy and water balance, a model such as AWRA (which only simulates the water balance) could never replace JULES or CABLE. Furthermore, participants questioned the goal of "physically realistic" models when even our target variables, such as soil moisture/wetness, can only be measured as a relative index. Satellite soil moisture measurements are not directly comparable to in situ point measurements and neither are directly comparable to the simulated model storages.

When the participants were asked what had and had not changed since 2000 in the field, the following were listed as greatly improved:

- awareness of drought;
- water availability (augmented by desalinisation)
- variety and accessibility of data and information, including satellite products;
- understanding of climate change forecast uncertainty - even if forecasts are now more uncertain than they used to be, that is preferable;
- ACCESS/NWP model skill and NWP data assimilation;
- AWRA process modelling.

Things that have not significantly improved since 2000 include

- policy action on climate change;
- flood risk estimation practices;
- fire danger index calculations;

- the over-abundance of models;
- flood forecasting techniques;
- availability of computing time.

Session 2: With ground networks in decline, can satellites meet our needs?

Session organisers: Brad Evans and Juan Guerschman

Propositions for debate:

1. All models are wrong. Satellite-derived information is essentially modelled, and therefore wrong.
2. Satellite data is only a valid observation if interpreted by experts.
3. Satellites need to be calibrated with ground observations to be more than pretty pictures.
4. Currently, satellite information is 'validated' by remote sensing scientists misinterpreting a handful of spatially inadequate samples.
5. Satellite data should only ever be used to interpolate ground measurements.
6. Satellite and ground data are only useful when both are available and carefully interpreted together.
7. Fusion of satellite data, ground data and models is the only way to achieve the best possible information.
8. Cheaper ground sensors, power supply and telemetry will reverse the decline in ground networks.
9. The attention to satellites is contributing to the decline of field measurement and needs to be stopped.

Presentations:

- Leo Lymburner (Geoscience Australia): Using a calibrated archive of Landsat data to characterise the distribution of water across the Australian continent between 1998 and 2012
- Geoff Podger (CSIRO): Ground and satellite observations in water resources management
- Belinda Medlyn (Macquarie Univ.): Making good use of satellite data: one modeller's perspective
- David Jones (BoM): Monitoring Australia's climate: current practices and some thoughts on future directions
- Eva van Gorsel (CSIRO): The role of flux tower observations in water and climate information

Summary:

When asked whether satellites can be considered to provide real climate and water observations, or rather use models to estimate them, it was agreed that currently they can indeed be considered to provide 'observations', however that we need to be careful about their limitations. It was pointed out that we already commonly use derived or modelled data, and need to understand the assumptions and uncertainties associated with the modelling process. It was recognised that there is a need to rely on experts. This was demonstrated in a comment from a user of eddy-covariance derived carbon flux

estimates to a producer of these data: "I don't want raw data, give me GPP but tell me about the assumptions".

It was proposed that we are entering an era of 'hyper-resolution' science. An increase in both spatial and temporal resolution will follow the unlocking of the Landsat archive by the Geosciences Australia Data Cube project. It was debated what this means for our assumptions in both the remote sensing and our models?

Leaf area index (LAI) products were discussed, including the issues with existing LAI products given their widespread use in ecosystem modelling. It was concluded that LAI is still an important quantity desired by ecosystem modellers, but that it is poorly estimated by remote sensing analysts and the models which they use to derive this quantity.

It was suggested that there are various levels of investment (i.e. growth) and decline across the observational networks. There appears to be some correlation with the capacity for remote sensing to fill gaps but there is no ubiquitous solution. As such, some gaps can be filled and replacement solutions likely are already being implemented, but we need to be strategic and pragmatic about the choices we make when re-allocating resources to observational networks.

Session 3: How well can we trust our models, and how can we be sure?

Session organisers: Gab Abramowitz and Fiona Johnson

Propositions for debate:

1. The simplest model that explains the observations is necessarily the best model.
2. All models are wrong, but some are still useful.
3. The models are not the main problem, it is the quality of the data and assumptions that go into them.
4. Much more effort is needed to objectively assess the performance of alternative models.
5. We need to stop calibrating our models, it leads to a false sense of security.
6. In circumstances where calibration is essential for a model to be useful, we should just use an empirical model (for example, based on data mining or Bayesian methods).
7. We cannot know whether to trust our models. Therefore multi-model ensembles should be standard operational practice, not just a research endeavour.
8. In the absence of quantitative knowledge of model inter-dependence, ensemble methods are meaningless.
9. Inappropriate values for unconstrained parameters (through calibration or assumption) should remove any trust in predictive ability.
10. Talking about 'physically-based' models is meaningless when there is not enough data to construct an empirical model.

Presentations:

- Gab Abramowitz (UNSW): Defining expectations: an approach to quantifying trust in modelling
- Beth Ebert (BoM): Verification of numerical models – what are the biggest challenges?

- Bellie Sivakumar (UNSW): Hydrologic systems as complex networks: structure, connections, and dynamics
- Dmitri Kavetski (Univ. Adelaide): Hydrological modelling at the catchment scale: Trusty Friend or Devious Foe?
- Andrew Frost (BoM): Evaluation of the Australian Water Resource Assessment Landscape (AWRA-L) model, WaterDyn and CABLE
- Lucy Marshall (UNSW): Balancing the realities of environmental observations, model uncertainty and model truthfulness
- Gift Dumedah (Monash Univ.): Diagnostic evaluation of land surface models from decision space –the hydrologic genome approach

Summary:

This session was designed to promote discussion on common modelling issues that can arise when we aim to represent climate, weather or hydrological systems and included speakers on numerical weather prediction, land surface modelling and hydrologic models. The list of discussion questions circulated prior to the event focused on the usefulness of calibration, the balance between model complexity and simplicity including the usefulness of empirical and physically-based models and finally the purpose of model ensembles. Discussion tended to be dominated by provocative or more contentious questions that were raised in talks rather than these pre-defined discussion questions.

Empirical models have a place in defining the lower limits for model acceptability – i.e. quantifying how much information is available in the driving data regarding prediction variables. If our models cannot match or improve on the empirical models them we know that they are not fully using the information in the data. The completeness of process representation was also discussed in this context. One potential complication mentioned was that empirical model might seem to be doing better but may not be consistent between different variables.

There was a tension identified between (a) evaluation and benchmarking of models needing to be application specific, and (b) that we tend to learn a great deal about of models from using them in new and different applications.

There is value in sharing model benchmarks and a standardised platform for comparison would be useful. However there was also a view that standard reference tests for the purposes of comparison between studies might stifle innovation and lead to a 'one size fits all' fallacy. In addition, there were suggestions that benchmarking needed to be industry specific and include applications (e.g. impact of weather prediction on flight time estimates) rather than just climate or hydrological variables. Benchmarking needs to consider a wide range of variables, not just one or two from a particular model. Models need to be considered as a means to an end, and one needs to consider the users' needs and the scales that they will be using the model at.

Everyone agreed that there should be more emphasis on publishing or otherwise making available poor results or known weaknesses of models as a way to understand the limitations of particular models. This would clearly help define model development priorities as well.

There also needs to be more emphasis on using "soft data" to verify model behaviour (e.g. ancillary information that may not be immediately digestible by a model but offers constraints on system

behaviour). This can be in the form of informative priors or qualitative model verification in terms of behaviours. This requires sharing of data in particular between modellers and those who are collecting data in the field. How can this be achieved amongst the community in general? Once soft data is quantified however it is no longer soft data, and so a careful approach is needed.

Session 4: What new water and climate information should we be developing?

Session organisers: Juan Guerschman and Seth Westra

Propositions for debate:

1. We do not need new information, just greater quality in existing information.
2. We understand the most important water and climate processes well enough.
3. Basic hydrological processes are still poorly understood and quantified.
4. Basic climate processes are still poorly understood and quantified.
5. We need more analysis of past records (e.g., historical and paleo-data) to interpret information.
6. We do not need more data or information, but share and communicate the existing data better.
7. We need better and faster access to information and data.
8. The focus should be on making satellite data easier and cheaper to use.
9. The main priority should be groundwater data, given the risk related to coal seam gas for example.
10. With all this focus on predicting the future, we are neglecting understanding the present and past.

Presentations:

- Paul Dalby (In Fusion Consulting): Overcoming the tyranny of climate: capturing the social and economic benefits of great climate research
- Peter Stone (CSIRO): Information needs for the development of Northern Australia
- Bertrand Timbal (BoM): Victorian Climate Initiative
- Seth Westra (Univ. Adelaide): Challenges in attributing change in Australian natural hazards
- Jorge Peña-Arancibia (CSIRO): Towards dynamic continental estimation of irrigated areas and water use
- Jay Larson (ANU): Not Your Average Visualisation Project

Summary:

This session was designed to promote discussion on the water and climate information needs from a wide range of potential end-users.

In its first half Paul Dalby argued that more and better information of natural hazards such as floods and bushfires is needed. He also showed an example of a US company providing agronomic advice for farmers using remote sensing and climate forecast data. This triggered a discussion about why a similar

information service is not available in Australia: is it a lack of demand, or because of poor communication and engagement between users and researchers?

Peter Stone then offered his views on the data demands for the development of Northern Australia. He emphasised the need of better surface and groundwater estimates both in space and time and their interactions (for example good quality, daily streamflow estimates). In his view, better climate data were not critical but improved spatial rainfall estimates would certainly be desirable.

Bertrand Timbal presented results of modelling experiments in Victorian catchments aimed at improving the representation of streamflow during the Millennium drought. The end goal was to improve the prediction and understanding of the climate system and its representation by climate models, as well as the linkages between climate and water availability.

In the second half of the session Seth Westra used the 2010 Australian floods to summarise the challenges in attributing change in natural hazards in Australia. He argued that the understanding and modelling capability is limited and encouraged a better community effort to tackle these issues.

Juan Guerschman (on behalf of Jorge Peña-Arancibia) argued that better information on the water use by irrigated agriculture is needed in Australia. He showed how remote sensing can provide such information on a relevant temporal scale (seasonally) and with an appropriate spatial resolution (~30 meters). MODIS and Landsat data can provide timely estimates of both the area occupied with irrigated crops and the water evapotranspired by them and this information can be incorporated in hydrological models to result in better water accounting.

Finally, Jay Larson showed an implementation of a toolbox which provides a visualisation framework for the Australian Carbon and Water Observatory (ACWO) and the Australian Water Availability Project (AWAP). The toolbox uses highly parallelised processes in a high performance computing environment at the National Computer Infrastructure. Such tool has the potential to extract new information regarding climate and water variability as he demostrated with an example from a long-term climate station.

In the last part of the session the following topics were discussed:

- If funds were really limited, what would be priority to invest in, more science or better science communication? The answer was “more science”.
- It was agreed that a water science plan as argued by Andy Pitman is indeed needed.
- It was noted that none of the presenters mentioned the use of increasingly cheap and more readily available in-situ sensors.

Session 5: Is Australia’s data and model infrastructure ready for the future?

Session organisers: Luigi Renzullo and Brad Evans

Propositions for debate:

1. Australia’s water and climate community data systems and models are out of date.
2. The NWP and Astronomy communities should share their computing infrastructure more.

3. Our challenges are rapidly being solved, provided we make use of global data sets and computing solutions, such as cloud computing, data services and the available infrastructure.
4. The research community already has ready access to high performance computing infrastructure, but many do not realise it.
5. The way operational and research data are shared in Australia is systematically biased and flawed.
6. There is a lot of data storage and computing infrastructure, but it does not have the characteristics we need.
7. We need better incentives for collaboration on large problems across institutions.

Presentations:

- Leo Luigi Renzullo (CSIRO): Towards a hyperresolution land data assimilation system for Australia
- Mike Hutchinson (ANU): Making the most of the ground based meteorological network using anomaly-based interpolation
- Adam Smith (BoM): The Australian Water Resources Assessment (AWRA) Modelling System Implementation Project: Getting Australia's data and model infrastructure ready for the future
- Tim Pugh (BoM): Sharing data and infrastructure
- Ben Evans (National Computing Infrastructure): National Computing Infrastructure

Summary:

The session was comprised of two parts: the first addressing computational needs as driven by application areas; the second about the current computation infrastructure, with an emphasis on near-future tools to make the high performance computing solution accessible to wider group of researchers.

We began with a round of introductions, and an impromptu request for a response to the question whether Australia's modelling and data infrastructure ready for the future. The vast majority of responses can be summarised as: "Not quite, but it is getting better." Some other responses include:

- The technology is world-class, but we should not become complacent.
- Better searchability is needed; often people do not know what data are available.
- There appears to be a lag in adopting leading edge software solution in Australia, when compared to the rest of the world.

In the first presentation following the introductory discussion, Luigi Renzullo used the example of 'hyper-resolution' modelling (1 km globally; 100 m continentally) as a potential driver for investment in computational infrastructure and to spur model development at finer scales. The presentation also discussed the trend in some of the EO data sets that is driving modelling towards higher resolution in space. It was commented that in climate modelling, it does not make sense to have high resolution modelling in space at daily or coarse time resolution.

Mike Hutchinson described the generation of new (1-km resolution) surfaces of interpolated meteorological data for Australia. This includes daily surfaces (1970 – 2011) for minimum and maximum temperature, vapour pressure and precipitation, and monthly surfaces (1970 – 2011) for the same variables as well as pan evaporation, rain days, solar radiation, and perhaps runoff. The data were

generated on NCI and are disseminated through a THREDDS server under the TERN eMAST facility. The presentation focused on method development and the robust quality check of the station-level data – needed to be implemented on top of the QC/QA checks that the BoM have in-house.

Adam Smith gave an introduction to the BoM's AWRA system and an overview of developments over the last couple of years. An emphasis of the presentation was on how the AWRA software has moved toward open-source solutions. The presentation showed a user-friendly, python-based interface to drive the AWRA model. This is a step closer towards sharing AWRA more widely across the research community, and promoting a community around the AWRA model.

Ben Evans presented on the NCI: the infrastructure, the partners, the links with Australian government initiatives, and (most importantly) the services provided to make high performance computing solution more accessible to a wider community of researchers. With regard to data collections, a great deal of effort goes into making the data more searchable. Greater support from NCI working with researchers is needed.

Tim Pugh described the BoM's strategic investments into high performance computing. The BoM has aspiration to provide 1-km scale NWP forecast for cities in Australia; 5-km continentally, and 12-km globally by 2020. Tim asked whether the community is ready to take on greater computing power, as it is a missed opportunity if not resourced. A question addressed the accessibility of NWP by the wider research community. Tim's response was the he believes they can be made available (perhaps with some lag). It was agreed that is would be worthwhile surveying who would find such data useful.

Some responses to the debating propositions were:

- Australia's water and climate community data systems and models are not out of date; the NCI is a good facilitator for cross institutional collaboration
- Our challenges are rapidly being solved, provided we make use of global data sets and computing solutions, such as cloud computing, data services and the available infrastructure. Some of these are already in place, others are being worked on.
- The research community already has ready access to high performance computing infrastructure, but many do not realise it. HPC solutions have become a lot more accessible than (for example 5 years ago). It is just that not many research know about what is available and how to access.
- There is a lot of data storage and computing infrastructure, and it has the characteristics we need. It was suspected that people held a different view, they are not sufficiently aware about what is available.

Session 6: Have we reached the limits of what can be forecast?

Session organisers: Fiona Johnson and Tom Pagano

Propositions for debate:

1. We are very close to the limits on predictability imposed by chaotic behaviour of the climate system.

2. We don't actually know how well we can forecast; past forecasts are not evaluated and forecasting methods change too fast.
3. High quality and frequency ground and satellite radar precipitation measurement capability will transform our short-term hydrological forecasting capacity.
4. There are still major gains and breakthroughs to be had in seasonal prediction.
5. Our current forecasting methods are too fragmented over time scales; resolving that will cause a leap in the accuracy and utility of forecasts.
6. We can't forecasts well at all timescales, so we should we just focus on those that are both feasible and useful.
7. The communication between the research and operational communities needs to be much better.
8. Improvements should we focused on the measurement infrastructure, not the models.
9. The priority should be on data quality control algorithms that synthesize data from different sources to identify outliers and infill missing values.
10. Forecasters cannot use new data until the record is long enough to know its properties and biases.
11. We need to transition from hydrograph mimicry to better representation of hydrologic processes.
12. Scientists need to field test new methods under the supervision and on the terms of operational agencies.
13. The influence of human interferences (farming, urbanization, deforestation) on forecasts cannot be predicted.

Presentations:

- Tom Pagano (BoM): Challenges of operational river forecasters
- Dongryeol Ryu (Melbourne Univ.): Leveraging ground and remotely sensed observations for short-term streamflow forecasting
- Fiona Johnson (UNSW): Driving through floodwaters: what's the point of flood forecasting?
- Oscar Alves (BoM): Improving seasonal climate forecasts
- Narendra Tuteja (BoM): Improving seasonal water forecasts

Summary:

This session was divided into two sub-sessions; the first was on flood forecasting and the second on seasonal climate and streamflow forecasting. The focus of most of the presentations was on operational concerns of forecasting although there was also discussion of research experiments.

In the flooding session, discussion ranged from the challenges of operational river forecasts to the usefulness of data assimilation in flood forecasts. There is limited understanding of what our true hydrologic forecasting skill is and how this has changed over time. If there are improvements in skill, are these due to better models, better data flow or better forecasts of rainfall? We are currently not in a position to answer these questions. The issue of how to integrate new research ideas into operational forecasting in a way that limits liability and works for the operational agency was also raised.

In the research space, data assimilation was shown to have some benefit when assimilating streamflow measurements in a gauged catchment but limited benefit when assimilating soil moisture in an

ungauged catchment. This research also showed that the benefits of a semi-distributed model are minimal if data assimilation is also implemented at least for the catchments tested in the work presented.

Finally the issue of the effectiveness of flood warning was raised. This is particularly an issue at flash flood time scales where there are currently limited specific forecasts. The effectiveness of flood warnings is related to the trust that the community has in the reliability of the warning – it requires good models, well trained staff and good data. How can we leverage new technologies to inform people of particular areas of risk? How can we educate drivers about the risks of entering flood waters? These are not traditional areas of research for hydrologists and engineers and they need multi-disciplinary research and applications.

One of the most interesting findings to come out of the session was the divide between what are perceived to be the biggest impediments to better forecasts, when compared to what people are researching and working on. Most of the attendees saw their work as related to models, while those same people considered that, in practice, improved data and institutions should have greater priority than better models.

In the seasonal forecasting session, the first topic of discussion was on improving seasonal climate forecasts using POAMA. Potential predictability can be quantified using an ensemble of model runs and treating one hind-cast run as the truth that the remaining ensemble members can be considered against. However if the model spread is too narrow than the predictability can be overestimated. Given that the models do not yet always agree, it is argued that we have not yet reached the limit of predictability. There is still work to do to understand when models provide poor forecasts.

The second topic in the seasonal forecasting session was on seasonal streamflow forecasts. The lessons learned from setting up this service in Australia are useful for thinking about forecasting in general. Some of the important lessons are the time it takes to properly quality control data. Automation would be useful in this context. It takes a lot of patience and communication to translate research methods into an operation system. This requires goodwill on the part of both researchers and operational staff. It is important to consider how forecasts are being used: is it the same as the way that forecasters expect? Technology choices are very important, particularly in ensuring platform independence.

Some research needs were identified:

- data quality control methods; through discussion between users, modellers and data/IT experts;
- quantifying forecast value;
- bridging the gap from seasonal forecasts to year or multi-year forecasts for water planning;
- How can scientists test experimental techniques under the supervision and on the tem of operational agencies, whilst avoiding liability associated with forecasts that affect lives and property?

Poster presentations

The following posters were presented in the poster presentation session (* denotes students in contention for MSSANZ Student Poster Award):

- Emetc, V. (ANU)*: Improving hydrological models focusing not on hydrology
- Gevaert, A. (VU Univ. Amsterdam)*: Evaluation of downscaled soil moisture and vegetation optical depth derived from the Land Parameter Retrieval Model
- Gharun, M. (Univ. Sydney): Spatio-temporal controls on catchment ecohydrology: lessons learnt from eucalypt forests
- Guerschman, J., J. Pena-Arancibia (CSIRO): Towards dynamic high resolution mapping of cropped areas in Australia
- Haughton, N., et al. (UNSW)*: Dissecting PLUMBER: Why are land surface models performing so poorly?
- Kala, J., M. De Kauwe (UNSW): Influence of an optimal stomatal conductance scheme in Australian Community Climate and Earth System Simulator (ACCESSv1.3)
- Kim, S. (UNSW)*: Improvement of soil moisture dataset combining AMSR2 soil moisture products
- Lievens, H., et al. (Ghent Univ.): Impact of different data assimilation strategies for SMOS observations on flood forecasting accuracy
- Lin, Y.-S. (Macquarie Univ.): A synthesis of a global stomatal conductance database under an optimal stomatal behaviour framework: patterns from leaf to ecosystem
- Liu, Y., et al. (UNSW): Observing water availability impacts on vegetation using an enhanced passive microwave remote sensing method
- Lopez Lopez, P., et al. (Utrecht Univ.)*: Alternative configurations of quantile regression for estimating predictive uncertainty in water level forecasts for the upper Severn River: a comparison
- Olson, R., et al. (UNSW): The NARCliM Project: Model Evaluation and Climate Projections for Temperature and Precipitation for South-East Australia
- Pathiraja, S., et al. (UNSW)*: Hydrologic Modelling in Non-Stationary Catchments:A Data Assimilation Approach
- Summers, D., A. van Dijk (ANU): Interpreting vegetation condition from satellite observations: accounting for the influence of water availability
- Bishop, T., A. Horta (Univ. Sydney): Space-time monitoring of (sub) soil moisture for agricultural management: a case study
- Tian, S., et al. (ANU)*: The potential for improving terrestrial water storage estimates through assimilation of GRACE data into a hydrological model
- Ukkola, A. et al. (Macquarie Univ.)*: CO_2-induced greening reduces streamflow in water-stressed climates in Australia. **Winner, MSSANZ Student Poster Award**
- Yebra, M., A. van Dijk (ANU): Coupling gross primary production and transpiration for a consistent estimate of apparent water use efficiency
- Hasan, M. (UNSW)*: An approach to estimate rainfall at ungauged location by merging the radar and gauge estimates

Annex: Workshop Program

TUESDAY, 28 October 2014

8:00	Registration		
9:00	Welcome and Introduction - Albert van Dijk		
9:30	Plenary session: **Information needs for Tomorrow** Keynote: Rob Vertessy, Bureau of Meteorology		
10:00	Warwick McDonald, CSIRO Land and Water		
10:30	Morning tea		
11:00	Mike Makin, Murray-Darling Basin Authority		
11:30	Mike Raupach, Australian National University		
12:00	Plenary discussion		
12:30	Lunch		
13:30	Session 1: **Are we getting close to integrating water and climate information?** chairs: Seth Westra, Tom Pagano	Session 2: **With ground networks in decline, can satellites meet our needs?** chairs: Brad Evans, Juan Guerschman	Session 3: **How well can we trust our models, and how can we be sure?** chairs: Gab Abramowitz, Fiona Johnson
	Session 1a	Session 2a	Session 3a
15:00	Afternoon tea		
15:30	Session 1b	Session 2b	Session 3b
17:00	Report back from the sessions		
17:30	Poster introductions		
18:00	Social drinks and poster session posters		

WEDNESDAY, 29 October 2014

8:30	Registration		
9:00	Opening and poster award – Albert van Dijk		
9:30	Plenary session: **Creating an environment for innovation** Keynote: Andy Pitman, ARC Centre of Excellence on Climate System Science, UNSW		
10:00	Helen Owens, Data Policy Branch, Dept. of Communications		
10:30	Morning tea		
11:00	Brad Evans, Terrestrial Ecosystem Research Network		
11:30	Plenary discussion		
12:00	Lunch		
13:00	Session 4: **What new water and climate information should we be developing?** chairs: Juan Guerschman, Seth Westra	Session 5: **Is Australia's data and model infrastructure ready for the future?** chairs: Luigi Renzullo, Brad Evans	Session 6: **Have we reached the limits of what can be forecast?** chairs: Fiona Johnson, Tom Pagano
	Session 4a	Session 5a: Applications	Session 6a: Flood forecasting
14:30	Afternoon tea		
15:00	Session 4b	Session 5b: Data and Infrastructure	Session 6b: Seasonal forecasting
16:30	Report back from the sessions		
16:50	Wrap up		
17:00	Workshop adjourns		