OzEWEX

The Australian Energy and Water Exchanges
Regional Hydroclimate Project

Science Plan

2014– 2019

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Foreword

In October 2012, researchers and research managers representing several universities, government research organisations and government-funded research programs established the Initiation Phase of an Australian RHP (OzEWEX). In November 2013, the OzEWEX steering group decided to apply with GEWEX for formal project status. This document provides a five-year Science Plan (2014–2019) as part of the application process.

We would like to acknowledge the in-kind support from all of its members as well as the financial and moral support from the Australian National University and other universities in Australia, the Australian Research Council (ARC) Centre of Excellence for Climate System Science, the Terrestrial Ecosystem Research Network (TERN), the Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation (CSIRO), including through their joint Centre of Australian Weather and Climate Research (CAWCR) and Water Information Research and Development Alliance (WIRADA).

We also acknowledge the contributions and guidance of Jason Evans, co-chair of the GEWEX Hydroclimatology Panel.

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Executive summary

OzEWEX is the Australian Energy and Water Exchanges initiative. It aims to be recognised as a Regional Hydroclimate Project (RHP) under GEWEX. GEWEX is an international science volunteer organisation focusing on the energy and water cycles and is the largest of its kind. RHPs provide a regional mechanism for GEWEX activities. This document provides the Science Plan for OzEWEX for the period 2014-2019.

The overarching science question that drives OzEWEX is to *understand and predict Australia's fresh water resources and water security into the future given Australia's many climate zones, relatively large climate variability and future climate change.*

OzEWEX aims to help address this overarching question by promoting and facilitating data sharing, collaboration and engagement between researchers, data providers, research users, resource managers and research managers.

This science plan identifies and describes the following six science priority areas:

1. Observational Data
2. Model Evaluation and Benchmarking
3. Data Assimilation
4. Trends and Extremes
5. Vegetation Processes
6. Hydrological Prediction.

Working groups have formed around each of these thematic areas. Working Group activities include organising workshops, data collection, collation and hosting, and collaborative experiments and development.

1. Background

1.1. Introduction

The Global and regional Energy and Water Exchanges (GEWEX[1]) program is an internationally coordinated effort to integrate research and observations that has been a core component of the World Climate Research Programme (WCRP) since 1990. It is the largest initiative of its kind, focusing on the observation, understanding and prediction of the global and regional water and energy budgets and the way they are affected by interactions between land and atmosphere.

GEWEX is a bottom-up initiative that thrives with enthusiasm from, and benefit for the participants. It does not provide any funding for research, though it can help by endorsing funding bids. Many Australian water and climate researchers are already active in GEWEX.

Various Regional Hydroclimate Projects (RHPs) exist under GEWEX auspices. These RHPs provide a regional mechanism and justification for coordinated joint activities among researchers, and between researchers and research users. The key requirement for a RHP to be established is that it actively contributes to the overall GEWEX goals with a regional focus, and the main costs of coordinating regional research through a GEWEX RHP are a (relatively modest) commitment to participate in and report to higher level coordination activities. Some of the benefits include:

- incorporation in an international forum for fostering cross-collaboration between RHPs in terms of expertise, instrumentation development, modelling exercises, observational data exchange etc.
- increased visibility of RHP research at GEWEX-initiated sessions at international meetings and conferences.
- promotion of the RHP research at the programmatic level, such as within the WCRP and with its international sponsors; through the web, regular electronic and paper newsletters, mailing lists, etc.

Some RHPs have been highly successful in galvanising and supporting activities that contribute to GEWEX goals[2]. Example activities have included collation, merging and analysis of long-term data records; field experiments and campaigns for model or product validation and process understanding; Data Assimilation and re-analyses experiments; multi-model studies (e.g., sensitivity studies, scenarios and benchmarking); and so on. Frequently these have led to high-impact multi-author publications, edited books, widely used data sets, influence on the science strategies, and other rewarding outcomes.

1.2. Project origins

OzEWEX was established after a meeting on 9 October 2012 at Bureau of Meteorology (BoM) offices involving 29 researchers or representatives from BoM, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), several universities[3] and initiatives including the Water Information R&D Alliance (WIRADA), Centre for Australian Weather and Climate Research (CAWCR), Centre of Excellence for Climate System Science (CECSS) and Terrestrial Ecosystem Research Network (TERN). The participants overwhelmingly supported the development of an Australian RHP. The name arrived upon was Australian Energy and Water Exchanges RHP, or OzEWEX. Based on the discussion, interim coordinator Albert van Dijk wrote the present draft project development plan, to be circulated for further comment. Van Dijk was subsequently elected as chair.

2. Goal and Science Questions

The general objective of RHPs is to 'provide regional level science and implementation that yields results and tools and make scientific conclusions, products and tools openly available'[4] This objective provides a good overall description of the objective of OzEWEX.

The overarching science challenge that drives OzEWEX is to:

> ***Understand and predict Australia's fresh water resources and water security into the future given Australia's many climate zones, relatively large climate variability and future climate change.***

This can be translated into derived objectives; importantly, to promote and increase the measurement, understanding and prediction of the water and energy cycles and related variables over Australia. Examples of important related variables include vegetation dynamics and ecosystem carbon, energy and water fluxes. OzEWEX aims to achieve its goal by promoting and facilitating data collection and sharing; collaborative research activities across organisations, and engagement between researchers, research users and research managers. Data brokering, collaborative research experiments, and workshops are considered important means.

2.1. Science Questions

In line with the overarching OzEWEX science challenge and GEWEX Science Questions, the key science questions are as follows:

1) How can we better understand and predict precipitation variability and changes?

This will be pursued by the sharing and analysis of improved data sets of precipitation (as well as related variables such as soil moisture) over Australia. Improved data are available from ongoing and planned satellite missions as well as greater use and availability of in situ observations. Past work has identified the inter-annual variability of precipitation over Australia to be sensitive to several large scale climate modes such as ENSO. How this variability might alter in the future remains an unresolved question.

2) How do changes in land surface and hydrology influence past and future changes in water availability and security?

This will be addressed by better closing the water budget over land through exploitation of new and existing satellite and in situ data sets, data assimilation, and improved physical understanding and modelling skill across scales, from catchments to regions and involving the entire hydrological cycle, including ground water and river systems. Of particular interest is vegetation response to climate change and variability.

3) How does a warming world affect climate extremes, especially droughts, floods, and heat waves, and how do land area processes, in particular, contribute?

This will be addressed by analysing new, improved and updated data sets that properly characterize droughts as well as high intensity rainfall events and distributions. These will be used to analyse long-term climate change and variability, to evaluate and improve models, and to project the changing character of extreme events into the future.

4) How can the understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

This will be addressed by evaluating the consistency between observations, estimates and predictions of sensible and latent heat fluxes at the surface. Of particular interest are feedbacks between climate variability, large scale natural and man-made changes in vegetation function, and the energy and water

balances, for example through changes in the partitioning and timing of evapotranspiration, surface roughness and soil water dynamics. Consideration of vegetation function changes in a changing climate requires the examination of Carbon cycle changes, along with the water and energy cycles.

3. Geographical scope

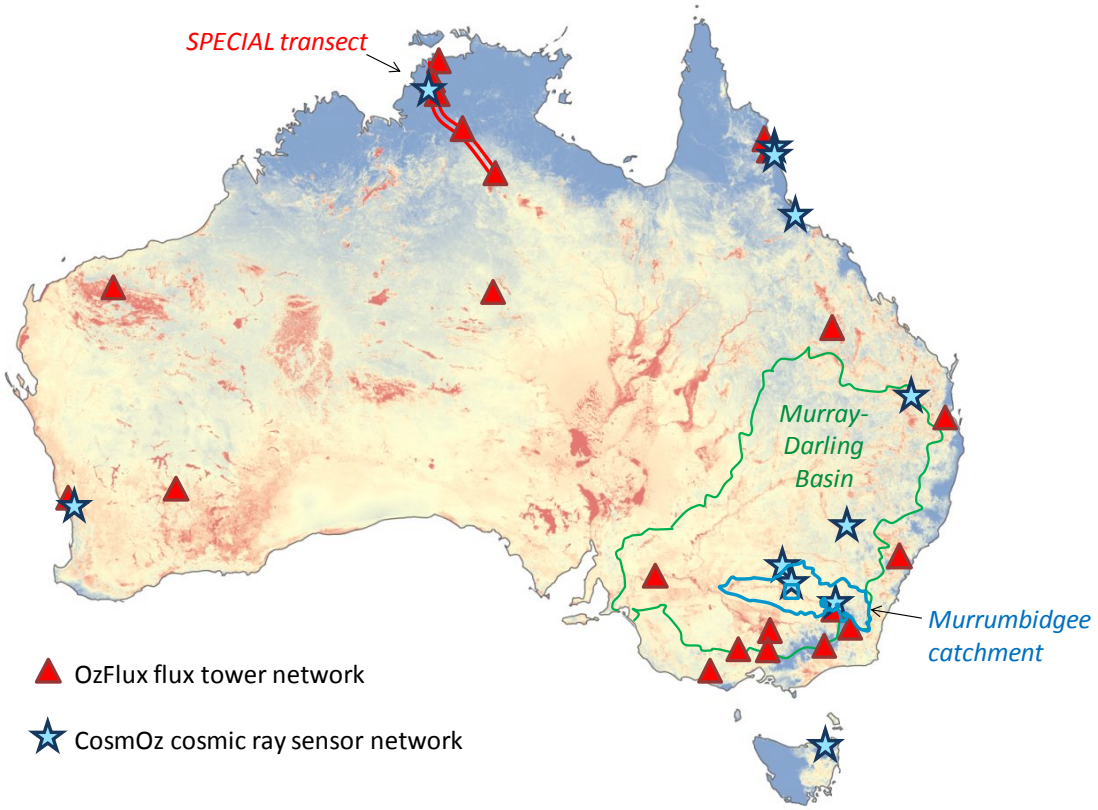
The first GEWEX regional experiments tended to focus on coordinated field measurement campaigns and subsequent analysis efforts. The scope of OzEWEX has been extended to Australia, for the following reasons:

- Constraining project scope to the Murray-Darling Basin (or a similarly limited region) would narrow the research activities and interests that could be encouraged and coordinated through OzEWEX and would probably not achieve the critical mass needed for a successful RHP.
- Constraining project scope to a single region would be less likely to achieve the coordination and strengthening of an Australia-wide water and energy research community.
- With gradually more open access to government-collected data and with research technology becoming more routine, robust and coordinated through existing research networks, the need for coordinated field campaigns as the primary means for collaboration has receded somewhat. A perhaps greater challenge for OzEWEX now is to help researchers find and access these existing observation data and to provide support to collaborate in interpreting and using the data in research.
- Many research activities central to OzEWEX are carried out at continental scale. This includes much of the climate, water and carbon modelling and remote sensing-based research. Limiting project scope to a single region would unnecessarily limit the opportunities for inter-comparison and evaluation, and not make optimal use of national measurement networks.

For these reasons, the RHP will have national scope. This however does not mean that all research can or should occur at national scale and OzEWEX encourages regionally or locally focused research activities where appropriate.

Examples include:

- *Intensive regional field measurement campaigns*. These allow a far greater richness and density of observations to be used in research. In particular, the Murrumbidgee catchment[5] and the SPECIAL savannah transect in Northern Australia[6] have been the focus of extensive field and airborne data collection targeting, respectively, the development and validation of soil moisture remote sensing products, and the understanding of landscape scale water and carbon fluxes.
- *Reference stations and catchments*. Some of the research does not have full national cover but uses a selected set of locations or catchments. For example, the BoM uses subsets of reference catchments without regulation and high-quality streamflow observations for the benchmarking of its water balance estimation system (the Australian Water Resources Assessment system, AWRA) and streamflow forecasting systems. It also uses a subset of Reference Climate Stations[7] for climate analysis. Where research has relevance to these operational uses, OzEWEX will encourage the same measurement network be used in research.



Some examples of Australia's research and monitoring infrastructure, which includes national and regional networks as well as full spatial satellite observations and data products. Background shows net land surface-atmosphere water fluxes estimated from remote sensing: blue colours indicate that rainfall exceeds evapotranspiration, red colours the reverse (after Guerschman et al., 2009[8])

OzEWEX will formally support these regional studies and reference networks and recommend that they be the focus of research activities where a narrower geographical scope is necessary or advantageous. Additional regions and networks may be nominated by WGs at any time and can be formally recognised and supported by OzEWEX where they provide an exceptionally suitable research context, facilitate collaborative research experiments, or enhance the usefulness of research to stakeholders.

4. Activities

OzEWEX is a volunteer organisation that has only minimal funding to support a small project office. The main purpose of OzEWEX is to provide a coordinated environment to encourage collaboration among researchers and research users that achieves benefits for the individuals involved, while at the same time working towards the OzEWEX goal. An important pathway to our goal is by increasing data sharing, communication, discussion and collaboration within the water and energy research community.

A selection of typical activities that participants have contributed to RHPs in Australia and elsewhere include:

- collation and sharing of observation and model data;
- organising workshops, courses and summer schools;

- joint scientific experiments and their publication;
- joint synthesis, statements, and reports (e.g., on climate change or its impacts);
- endorsement, advocacy and support for funded proposals;
- web-based research infrastructure, dissemination and brokering (e.g. a data portal).

It is anticipated that activities in these categories will also form the main part of OzEWEX. Members and WGs are expected to organise these activities without additional funding, or to apply for additional support where necessary.

Where beneficial, there is no impediment for OzEWEX activities to be organised under the primary or additional auspices of more than once science organisation or program, or be formally recognised as a contribution to these. This can include participating organisations and initiatives in Australia, projects within international science programs (e.g., WCRP, International Geosphere-Biosphere Programme[9] or International Association of Hydrological Sciences[10]) or professional membership associations (e.g. Australian Meteorological and Oceanographic Society[11], Engineers Australia and Australian Water Association[12]).

5. Thematic priority areas

Based on discussions to date, a number of thematic priority areas have been identified. Brief initial descriptions of these are provided below. It is envisaged that a working group (WG) will be formed around each priority area to revise the WG goal and scope as deemed necessary and to plan concrete WG activities.

5.1. Observational Data

Goal: *To promote awareness, access and continuity of existing observation data sources that are critical for research of the energy and water cycle, and to evaluate new observations.*

The data of interest derive both from operational and research monitoring networks and programs as well as from occasional field and airborne data collection activities. Where data are deemed particularly valuable for research but are not easily accessible or future availability is not secure, OzEWEX will in addition aim to advocate for their (continued) provision. Where research data are not yet readily available, OzEWEX will encourage data owners to make the data publicly available or allow OzEWEX members to do so on their behalf. OzEWEX will also encourage the use of data standards and the provision of uncertainty information.

Existing data types of interest include, but are not limited to:

- *In situ* observations: precipitation and other meteorological observations at climate stations and flux towers, eddy covariance water and carbon flux data, hydrometric monitoring data (e.g., streamflow, groundwater level), soil moisture measurements.
- Remote sensing observations: atmospherically corrected Landsat imagery; optical, thermal, passive microwave and radar land surface remote sensing time series; airborne and satellite soil moisture data at various spatial resolutions.
- Derived data products: national-scale dynamic or static land cover or use, elevation, physical soil properties (e.g., water holding capacity), physical vegetation properties (e.g., albedo, canopy conductance).

To assist the research community in discovering existing data sources, an anticipated WG activity will survey and web-publish hyperlinked summary of currently available data and data portals. An illustrative but incomplete listing includes: various climate and water data services provided by the BoM, water data provided by state agencies or departments, flux tower observations and remote sensing data products currently coordinated through TERN (OzFlux[13] and AusCover[14], respectively), the MoistureMap[15], SMAPEx[16] and OzNet[17] soil moisture data portals and gridded data provided through CSIRO's Earth Observation Services portal (EOS[18]), including the CosmOz cosmic ray sensor soil moisture network[19].

New observational data sources of particular interest will include the Global Precipitation Mission[20] and the Soil Moisture Active Passive mission[21]. Activities are anticipated to evaluate the accuracy of and utility of these new observations once available.

5.2. Model Evaluation and Benchmarking

Goal: *To use observations to evaluate and compare biophysical models and data products describing energy and water cycle components and related variables.*

Biophysical models of particular interest include those of particular importance to the Australian research community or BoM: the Community Atmosphere Biosphere Land Exchange (CABLE), the Australian Water Resources Assessment system (AWRA), the UK Met Office land surface models (MOSES and JULES). However other existing or newly developed models will also be included where deemed of interest by WG members, in particular where it is anticipated that they will overcome model weaknesses.

This WG will build on past experiments and existing infrastructure, code and data to develop new opportunities for model evaluation and benchmarking. These will be focused through further development of the Protocol for the Analysis of Land Surface Models (PALS[22]) - a web-based infrastructure for model evaluation and benchmarking that is under development with resources from CECSS and TERN under the auspices of GEWEX and the International Land Model Benchmarking project (ILAMB[23]). It will build on experience and technologies developed through WIRADA, including the AWRA benchmarking infrastructure, gridded Evapotranspiration product Inter-Comparison and Evaluation experiment (ET-ICE[24]) and Near-real time blended precipitation product comparison[25]. It may also build on related inter-comparison experiments, e.g. the REgional Carbon Cycle Assessment and Processes (RECCAP)[26] initiative. It will seek to reuse the infrastructure used in these experiments, but also make the observation data publicly accessible to the OzEWEX community where possible.

This WG will develop appropriate specifications for the inter-comparison or evaluation of estimates and predictions. It will address such questions as: What observations should be used in model evaluation? How should differences between estimates and observations be interpreted? How does performance vary regionally across Australia and what does it mean for the driving processes? How do evaluation metrics translate into estimation uncertainty? It will use the infrastructure to carry out and publish new evaluation and benchmarking experiments using estimates or predictions provided by WG members.

5.3. Data Assimilation

Goal: *To develop successful new approaches to assimilate observations into energy and/or water balance models.*

The assimilation of a range in situ and satellite observations of atmosphere, ocean and land is a critical factor in the success of weather forecasting. Statistical climate and streamflow predictions also entrain current observations. Retrospective climate analysis (re-analysis) and water balance estimation through the

AWRA system also rely on data assimilation techniques. Flood forecasting currently relies on the implicit assimilation of weather and streamflow observations in the mind of the forecaster, but formal data assimilation procedures are being developed. Finally, climate and water scenario prediction models are informed by observations in a range of ways (e.g. for calibration, evaluation), some of which can be considered forms of data assimilation.

Data assimilation is a highly complex challenge, as it requires understanding across a range of areas: observation characteristics and errors; the relationship between observed and modelled quantities; the conceptual structure and equations of the biophysical model; the mathematical assimilation techniques available; and the constraints imposed by the computational software and hardware. As a consequence, the Australian data assimilation community tends to be highly specialised towards specific applications in terms of each of these aspects. While necessary, this has been an obstacle to the exchange of expertise and to increasing the efficiency of research through collaboration.

This WG will strengthen and grow the Australian data assimilation community in the area of climate and water modelling. In particular, it will provide a forum to exchange expertise and collaborate on topics of common interest in the areas mentioned. The WB has already commenced work on installing data assimilation software tools and collating key remote sensing data sets on collaborative research computing infrastructure (NCI) to promote collaboration amongst WG members, the wider OzEWEX community (WG's 2 and 5 in particular), and across government institutions and universities. This will aid in the development and execution of experiments aimed at addressing questions of common interest, such as the error in particular observations (e.g., remotely sensed soil moisture) or the effectiveness and efficiency of alternative assimilation techniques (e.g., ensemble versus variational techniques). The experiment may be tiered, e.g., be partly continental and partially focused on the Murrumbidgee catchment.

5.4. Trends and Extremes

Goal: To describe, analyse and attribute observed variability and change in averages and extremes of water- and energy-related variables.

Detection and attribution of changes to the averages and extremes of climate variables such as rainfall, temperature, evapotranspiration, winds, streamflow, and storm tides is fundamental to support efforts to adapt to future climate change. However, progress has been hampered in many cases because of the limited availability of high-quality, long observational data records, and the complexity and spatiotemporal range of the underlying processes.

This WG will analyse observational and modelling data to improve understanding of change in societally-relevant climate variables. Anticipated activities include (1) coordinating with WG1 to develop and make available enhanced observational datasets and derived indices with suitable characteristics (e.g., record length, measurement frequency, quality) for assessment of long-term change in societally-important climate variables; (2) bringing together experts from a diversity of disciplines including meteorology and climate science, hydrology, and statistics, to develop methods for the detection and attribution of changes to extremes; (3) developing and disseminating rigorous statistical methods to support the detection and attribution of changes to climate variables; (4) developing rapid-response assessment methods to enable fraction-of-attributable risk calculations of recent extreme climate events; and (5) improving links between fundamental climate science, impacts science and risk-based decision makers, to ensure that existing and new scientific discoveries are rapidly made available for use in management and policy development.

5.5. Vegetation Processes

Goal: *To better understand the role of different vegetation types and functioning in coupling the energy, water and carbon cycles through field experimentation, analysis of field data and modelling.*

This WG will analyse observational data and use models to investigate the role of vegetation in modulating and coupling the energy, water and carbon cycles. Of particular interest is the role of native dryland ecosystems and land cover change, for example through changes in partitioning and timing of evapotranspiration, surface roughness and soil water dynamics.

Anticipated WG activities include the collation of data sets to answer specific questions about vegetation functioning. This may include research data (e.g. from flux towers, vegetation sampling for mass, biochemistry, isotopes, etc) as well as land cover information derived from remote sensing (e.g., leaf area index, cover fraction, greenness, biomass and land use). These data will be used to test hypotheses about the way vegetation interacts with the water and energy cycles, and to improve models representing vegetation function. Example questions include: How does land cover change affect precipitation? What is the net warming or cooling impact of vegetation change? What are the trade-offs between carbon, water and energy fluxes involved in land cover change? Can vegetation dynamics and function be predicted from optimality in resource use? How will vegetation function change due to global changes in climate and biogeochemical cycles?

Examples of research in this area include the representation of vegetation groundwater use, the partitioning of evapotranspiration into transpiration and wet canopy and soil evaporation, and predicting stomatal behaviour. An example data collation activity is the Stomatal Behaviour Synthesis project[27] that collates gas exchange data (including variations in stomatal conductance and corresponding assimilation rates and environmental data) to test the hypothesis of vegetation optimality. Synthesis and review activities may occur as initiated by researchers or in response to priorities expressed by management and policy organisation staff.

5.6. Hydrological Prediction

Goal: *To improve and provide hydrological predictions over time scales of hours to decades.*

This WG will aim to test existing and develop improved methods of hydrological prediction at a wide range of time scales. Of particular interest are streamflow forecasts at daily, seasonal and decadal time scales. Topics of particular interest include forecast initialisation, using meteorological forecasts and predictions, and determining prediction skill.

Forecast initialisation refers to the initialisation of hydrological models. This can involve assimilation of hydrometric and hydrological remote sensing data and deal with data latency and lead time, for example by combining historic data and short-term forecasts to 'now-cast' recent conditions.

Using weather forecasts and climate predictions involves mechanisms for researchers to access weather forecasts and climate predictions, research to evaluate the skill of alternative forecast and prediction sources, and the development of ensemble, downscaling and bias-correction procedures for hydrological application. Anticipated activities could facilitate near-real time research access to forecasts from the BoM's numerical weather prediction and seasonal prediction systems, and original or post-processed climate predictions produced in support of the Intergovernmental Panel on Climate Change's 5th Assessment Report (e.g., the COordinated Regional climate Downscaling Experiment [28]).

Several techniques and approaches to hydrological forecast exist, and include simple as well as complex

methods that may use meteorological forecasts, hydrological models, multi-variate statistical techniques, ensemble methods or a combination of these. There is a need to measure and compare their respective skill. This will require the design of benchmarking experiments and infrastructure to test improvements. Performance needs to consider accuracy as well as reliability in the forecasts, and consider unavoidable operational constraints. The BoM will be a key participant in this WG as the organisation responsible for operational forecasting.

It is anticipated that this WG will design and carry out hind-cast experiments to compare the skill of alternative statistical and/or dynamic prediction techniques. This will build on the hind-cast and verification experiments that have occurred in WIRADA and the BoM Extended Hydrological Prediction section, and likely involve the same or a similar set of experiment catchments.

6. Relation to GEWEX Objectives

Recognition as GEWEX RHP requires a science plan that details how the RHP contributes to the GEWEX 'Science Imperatives' [29] and 'Science Questions' [30]. These imperatives and challenges are summarised below based on the original documents, and the contribution OzEWEX will make is outlined.

6.1. GEWEX Science Imperatives

The GEWEX Science Imperatives will be addressed as follows:

1) Data sets: *foster development of climate data records of atmosphere, water, land, and energy-related quantities, including metadata and uncertainty estimates.* OzEWEX will address this explicitly through a dedicated WG. In addition, WGs around Model Benchmarking and Evaluation and Data Assimilation will analyse the observational records to understand and account for their uncertainty.

2) Analysis*: describe and analyse observed variations, trends, and extremes (such as heat waves, floods, and droughts) in water- and energy-related quantities*. OzEWEX will address this explicitly through a dedicated WG.

3) Processes*: Develop approaches to improve process-level understanding of energy and water cycles in support of improved land and atmosphere models*. OzEWEX will address this as part of many of its WGs. Model inter-comparisons and evaluation against observations and comparing open- and closed-loop model runs in Data Assimilation experiments will provide insight into the importance of process assumptions and the uncertainties or errors in the way that processes are represented. This will lead to suggestions for improvement in the models involved.

4) Modelling*: Improve global and regional simulations and predictions of precipitation, clouds, and land hydrology, and thus the entire climate system, through accelerated development of models of the land and atmosphere.* OzEWEX will address this implicitly through the model development efforts by researchers involved. Of particular relevance to OzEWEX is the further development of CABLE as the intended climate land surface model of choice for many in the Australian climate research community.

5) Applications*: Attribute causes of variability, trends, and extremes, and determine the predictability of energy and water cycles on global and regional bases in collaboration with the wider WCRP community.* OzEWEX will address hydrological predictability directly through a WG on hydrological prediction, which will address prediction from hourly via seasonal to decadal time scale. Activities in another WG will include research into the causes of variability, trends and extremes.

6) Technology transfer*: Develop new observations, models, diagnostic tools and methods, data*

management, and other research products for multiple uses and transition to operational applications in partnership with climate and hydro-meteorological service providers. In Australia the BoM is the sole climate and hydro-climatological data custodian. OzEWEX addresses technology transfer through the involvement of BoM participants in several of its WGs: by encouraging the provision of monitoring and model data by BoM, as well as the use of research observations in support of BoM's operational and evaluation activities; by developing techniques to help BoM meet its requirements in benchmarking and evaluation (e.g., of AWRA and hydrological forecasts); by developing Data Assimilation techniques applied to models of strategic importance (CABLE and AWRA); and by the gradual transfer of forecasting techniques developed by research into operational use.

7) Capacity building*: Promote and foster capacity building through training of scientists and outreach to the user community.* OzEWEX will build research capacity as part of all its activities, by supporting researchers and students to increase their knowledge and skills through information exchange, training and collaborative research activities. It is anticipated that research users will be approached to identify what outreach activities would be of particular benefit to them, which may include knowledge synthesis reviews or other customised information.

6.2. GEWEX Science Questions

The GEWEX Science Questions will be addressed as follows (more details can be found in section 2):

1) Observations and Predictions of Precipitation. This is addressed by OzEWEX science question: *How can we better understand and predict precipitation variability and changes?*

2) Global Water Resource Systems. This is addressed by OzEWEX science question: *How do changes in land surface and hydrology influence past and future changes in water availability and security?*

3) Changes in Extremes. This is addressed by OzEWEX science question: *How does a warming world affect climate extremes, especially droughts, floods, and heat waves, and how do land area processes, in particular, contribute?*

4) Water and Energy Cycle. This is addressed by OzEWEX science question: *How can understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?*

7. Organisation

7.1. Membership

OzEWEX membership to the RHP is open to all individuals with an interest in its objectives or a subset thereof. Membership is particularly encouraged for:

1) *Researchers and students* in universities and in government or private research organisations.
2) *Research users* in private or government organisations that require knowledge, data or technology in support of climate or water information services (e.g., BoM), policy development and implementation, operational water management, or other purposes.
3) *Research managers* in organisations, programs or initiatives that carry out, manage, commission, fund or coordinate relevant research and development activities.

7.2. Organisation structure

OzEWEX is organized into working groups (WGs) around its main themes. Membership can be as general observer or active WG participant. There are few differences but in some cases, registration and active participation in WGs may be required to access selected information (data, code, models) or be part of WG discussion, publications, or other activities. This is to be decided by majority of the WG participants and/or information owner as applicable.

OzEWEX has deliberately chosen a flat, self-organizing coordination mechanism. The key measure of success will be the degree to which there is a working and active organization structure.

The steering group is comprised of the OzEWEX chair, the WG chairs, and is open to OzEWEX members that fulfil a role higher up in the GEWEX organisations.

The role of the chair is as follows:

- maintain the OzEWEX secretariat and web presence;
- draft and revise strategic documents (such as the current);
- encourage WGs to nominate leadership and progress activities;
- seek a brief progress report from each WG when requested by GEWEX; and
- represent OzEWEX to stakeholders and in the GEWEX organisation.

The role of the WG chairs is to:

- initiate or support WG meetings and activities;
- encourage new WG participants;
- support effective WG decision making;
- provide brief progress reports per quarter, showing evidence of concrete activity and progress; and
- represent the WG members in the Steering Group.

7.3. Reporting

A brief annual report on progress to GEWEX will be produced by the chair based on input from the WGs. It will detail progress on the planned activities as detailed in the RHPs science and implementation plan. It will also measure these against the GEWEX imperatives. It will be published on an OzEWEX web presence.

7.4. End date and Exit Plan

This science plan if for the period June 2014 to June 2019. Before the end date, a plenary meeting will be called to review progress and prospects, and a majority decision made to continue or discontinue the RHP.

Regardless, a summary report will be produced and a hand-over arrangement will be pursued to ensure the continued availability of any data sets made available or developed. Any such data sets are expected to be of small number and volume (see ‘Data management’ below).

7.5. Data management

It is not the intention to duplicate existing data management arrangements hence OzEWEX data management will be pursued largely through three existing mechanisms. The BoM maintains responsibility for the collection and dissemination of water and climate related data, TERN maintains responsibility for

ecosystem and land surface flux related data, and the national Research Data Storage Infrastructure (RDSI) network of sites holds responsibility for storing and disseminating research data of national significance. RDSI will be the primary mechanism for storing and disseminating data outside the BoM and TERN responsibilities. For example, RDSI is responsible for the regional climate model data over Australia as part of the CORDEX initiative. Minor data management in support of an OzEWEX web presence will be supported by the OzEWEX project office. Where such efforts are required, OzEWEX will advocate with appropriate organisations to contribute or resource these activities.

8. Resourcing

OzEWEX will initially be fully resourced through in-kind contributions from its members. At secretarial level, the Australian National University will resource coordination and communication, including an OzEWEX web presence and discussion forum. Contributing organisations and individuals will be encouraged to resource the organisation of workshops and data hosting in support of OzEWEX, typically within the context of existing, already funded projects and initiatives. Significant funded relevant programs and initiatives that have agreed to contribute to OzEWEX include:

- The CECSS[31] funded by the Australian Research Council and involving several partner organisations.
- The CABLE model development community[32], part of the Australian Community Climate and Earth-System Simulator (ACCESS), a joint initiative of the BoM and CSIRO in cooperation with the university community in Australia.
- The AWRA system development projects funded through the WIRADA between the BoM Water and Climate Division and CSIRO Water for a Healthy Country Flagship[33].
- Several projects executed through TERN, funded by the Australian Federal Government and involving several partner organisations[34]. Projects include :
    - the AusCover facility [35] for the provision of biophysical remote sensing data time-series, continental-scale map products and selected high-resolution datasets;
    - the OzFlux network[36] that provides nationally consistent observations of energy, carbon and water exchanges between the atmosphere and key Australian ecosystems;
    - the Ecosystem Modelling and Scaling Infrastructure facility (e-MAST) that supports Data Assimilation and integration by assembling data sets and developing software.
- A number of projects supported through the Australian Research Council.

OzEWEX welcomes moral, in-kind or financial support from any other relevant program or initiative. Furthermore, where deemed beneficial, OzEWEX will offer advocacy and statements of support to WG members applying for new resources.

List of Acronyms

ACCESS	Australian Community Climate and Earth-System Simulator
AWRA	Australian Water Resources Assessment system
BoM	Bureau of Meteorology
CABLE	Community Atmosphere Biosphere Land Exchange
CAWCR	Centre for Australian Weather and Climate Research
CECSS	Centre of Excellence for Climate System Science
CSIRO	Commonwealth Scientific and Industrial Research Organisation
e-MAST	TERN Ecosystem Modelling and Scaling Infrastructure facility
EOS	CSIRO Earth Observation Services
GEWEX	Global and regional Energy and Water Exchanges
ILAMB	International Land Model Benchmarking project
OzEWEX	Australian Energy and Water Exchanges Regional Hydroclimate Project
NCI	National Computing Infrastructure
PALS	Protocol for the Analysis of Land Surface Models
RECCAP	REgional Carbon Cycle Assessment and Processes
RHP	Regional Hydroclimate Project
SPECIAL	Savanna Patterns of Energy and Carbon Integrated across the Landscape
TERN	Terrestrial Ecosystem Research Network
WCRP	World Climate Research Programme
WG	working group
WIRADA	Water Information Research and Development Alliance

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