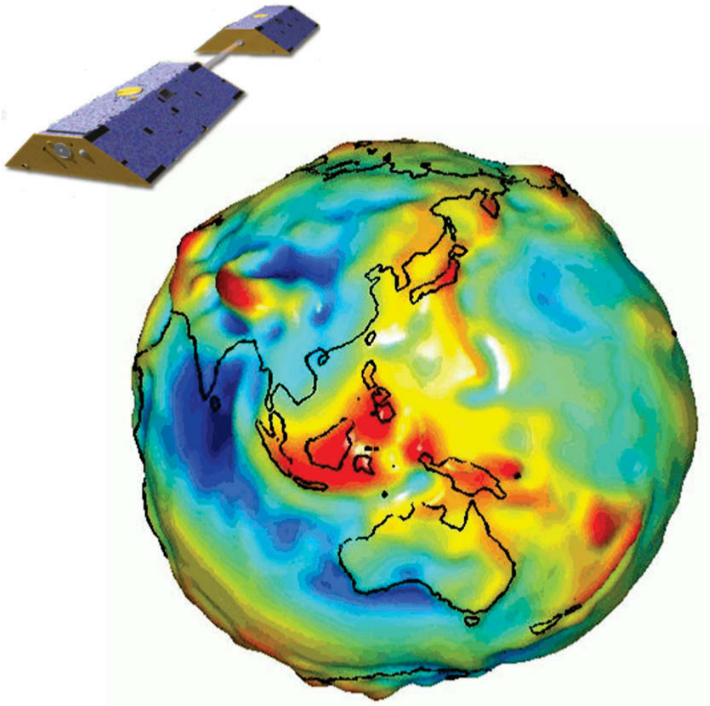
Ecohydrological interactions and landscape response to recent hydroclimatic events in Australia



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Certificate of original authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of student:

Date: 13-04-2017

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Publications

Peer reviewed journal articles arising directly from this thesis

<u>Journal publications</u>

1. **Xie, Z.**, Huete, A., Restrepo-Coupe, N., Ma, X., Devadas, R., & Caprarelli, G. (2016). Spatial partitioning and temporal evolution of Australia's total water storage under extreme hydroclimatic impacts. *Remote Sensing of Environment, 183*, 43-52.

2. **Xie, Z.**, Huete, A., Ma, X., Restrepo-Coupe, N., Devadas, R., Clarke, K., & Lewis, M. (2016). Landsat and GRACE observations of arid wetland dynamics in central Australia under multi-decadal hydroclimatic extremes. *Journal of Hydrology, 543*,818-831.

<u>Conference Proceedings</u>

Xie, Z., Huete, A., Restrepo-Coupe, N., Devadas, R., Davies, K., & Waston C. (2015). Terrestrial total water storage dynamics of Australia's recent dry and wet events. *Proceeding of 2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, 992-995, Milan, Italy; 07/2015

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Abbreviations

AOES	Advanced Orbital Ephemeris System
AVHRR	Advanced Very High Resolution Radiometer
AWAP	Australian Water Availability Project
BOM	Bureau of Meteorology
CAMS	Climate Anomaly Monitoring System
CDR	Climate Data Record
CI	Confidence Interval
CLM	Community Land Model
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	University of Texas Centre for Space Research
DEM	Digital Elevation Model
DLCD	Dynamic Land Cover Dataset
DSWE	Dynamic Surface Water Extent
ENSO	El Niño-Southern Oscillation
EROS	Earth Resources Observation and Science Centre
ESA	European Space Agency
ET	Evapotranspiration
ETM+	Enhanced Thematic Mapper Plus
EVI	Enhanced Vegetation Index

fPAR	Fraction of Photosynthetically Active Radiation
GDEs	Groundwater Dependent Ecosystems
GFZ	GeoForschungsZentrum
GLDAS	Global Land Data Assimilation System
GRACE	Gravity Recovery and Climate Experiment
HadISST	Hadley Centre Sea Ice and Sea Surface Temperature
IOD	Indian Ocean Dipole
IPCC	Intergovernmental Panel on Climate Change
JAXA	Japan's National Space Development Agency
JPL	Jet Propulsion Laboratory
MDB	Murray-Darling Basin
MEI	Multivariate ENSO Index
MNDWI	Modified Normalized Difference Wetness Index
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIR	Near-infrared
NLWRA	National Land and Water Resources Audit
NOAA	National Oceanic and Atmospheric Administration
OLI	Operational Land Imager
OLS	Ordinary Least Squares
PCCA	Partial Cross-Correlation Analysis
QA	Quality assessment

SAM	Southern Annular Mode
SEACI	South Eastern Australian Climate Initiative
SPCCA	Semi Partial Cross-Correlation Analysis
SRTM	Shuttle Radar Topography Mission
SST	Sea Surface Temperature
STL	Seasonal Decomposition of Time Series by LOESS
TRMM	Tropical Rainfall Measuring Mission
TW	Landsat Thematic Mapper
TWSA	Total Water Storage Anomaly
USCCGRP	United States Climate Change Global Research Program
USGS	United States Geological Survey

Abstract

Amplification of the water cycle as a consequence of climate change is predicted to increase the climate variability as well as the frequency and severity of droughts and wet extremes over continents such as Australia. Australia has recently experienced three large-scale hydroclimatic extremes, including a decadal millennium drought from 2001 to 2009 (termed the 'big dry'), followed by a short wet pulse during 2010 and 2011 (termed the 'big wet'), and another continent-wide dry condition in 2015. These dry and wet events exerted pronounced negative impacts on water resources, natural ecosystems and agriculture over large areas of Australia. Despite these extreme hydroclimatic impacts, the fate of ecohydrological resources such as the loss and recovery of water storage and vegetation remain largely unknown.

The overall goal of this thesis is to study the ecohydrological interactions and landscape response to Australia's early 21st century hydroclimatic extremes. To achieve thesis objectives, I (1) firstly investigated the spatial partitioning and temporal evolution of water resources across Australia under extreme hydroclimatic impacts, (2) then assessed the associations between the climate variability and dynamics in water resources and vegetation productivity, (3) furthermore examined the resilience of regional arid ecosystems to the highly variable water regimes and large-scale hydrological fluctuations, and (4) conducted a synthesized assessment of ecohydrological variations and interactions under these dry and wet events at continental, regional and biome scales, respectively.

Results show that highly variable continental patterns were observed in water resources and vegetation, involving differences in the direction, magnitude, and duration of total water storage and surface greenness responses to drought and wet periods. These responses clustered into three distinct geographic zones that correlated well with the influences from three large-scale climate modes: the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Southern Annular Mode (SAM). At regional scale, ecosystems such as arid wetlands exhibit strong ecological resilience to

hydroclimatic extremes, and are presumably sensitive to future altered water regimes due to climate change. In addition, Total Water Storage Anomaly (TWSA) data derived from Gravity Recovery And Climate Experiment (GRACE) satellites was found to be a valuable indicator for ecohydrological system performances and effectively linking the extreme climate variability with Australia's ecosystems.

This thesis highlights the value of Remote Sensing techniques (e.g. GRACE satellites) as important tools for improved assessments and management of water resources and associated ecosystems in Australia, particularly in the face of future increasing hydroclimatic extremes.