Earth Systems and Climate Change Hub

National Environmental Science Programme

Earth Systems and Climate Change Hub

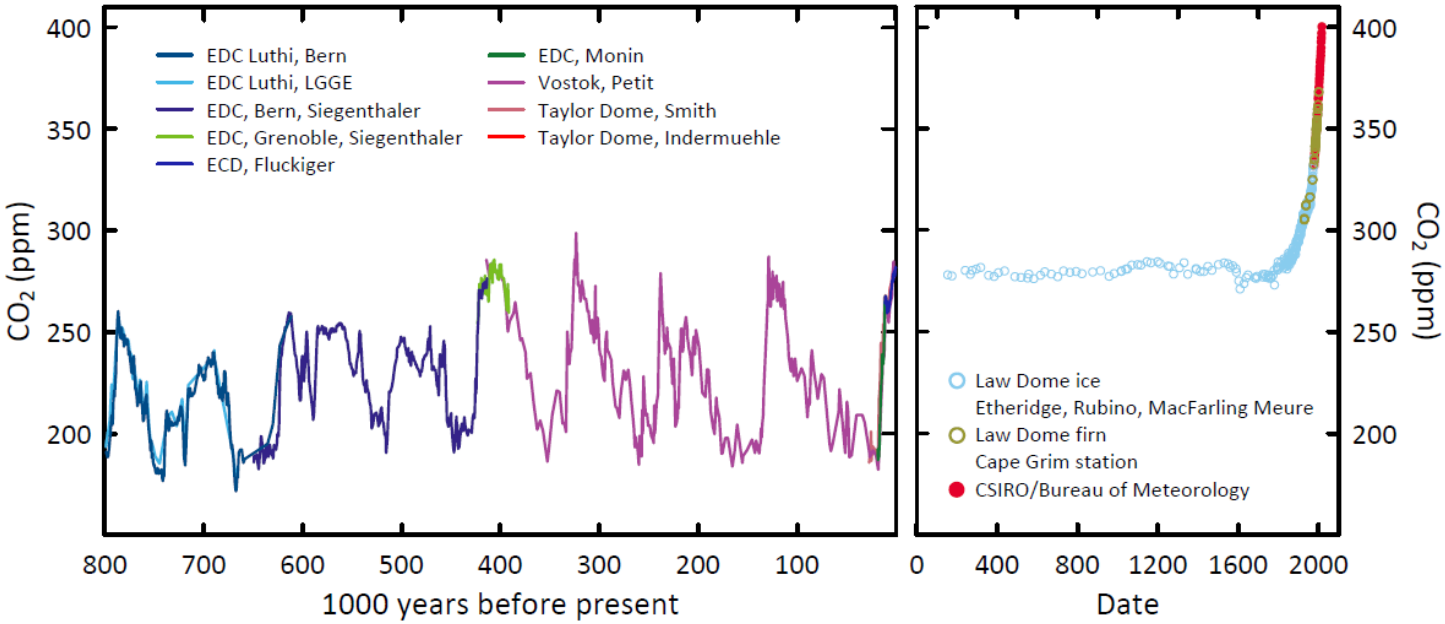
Earth System Science for a productive and resilient Australia

Helen Cleugh, CSIRO
Hub Leader

CSIRO · Climate Change Research Centre · Australian National University · University of Tasmania Australia · UNSW Australia · Monash University · The University of Melbourne · Australian Government Bureau of Meteorology

Greenhouse gases CO_2 observations

- Carbon dioxide (CO_2) levels steadily increasing since pre-industrial
- Global levels will exceed 400 ppm in 2016



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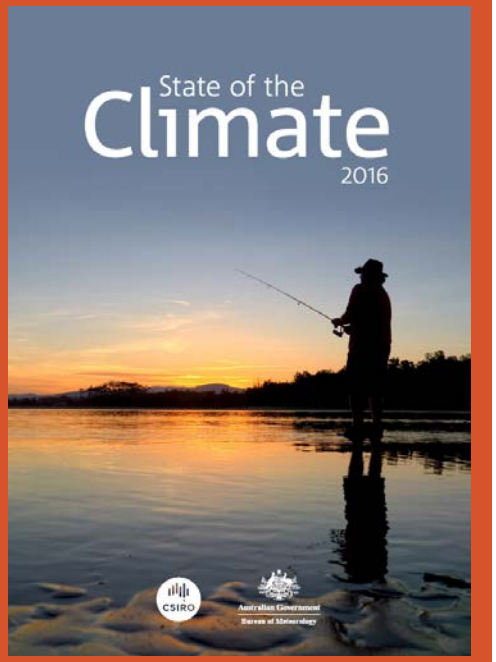
Source: Etheridge *pers comm*

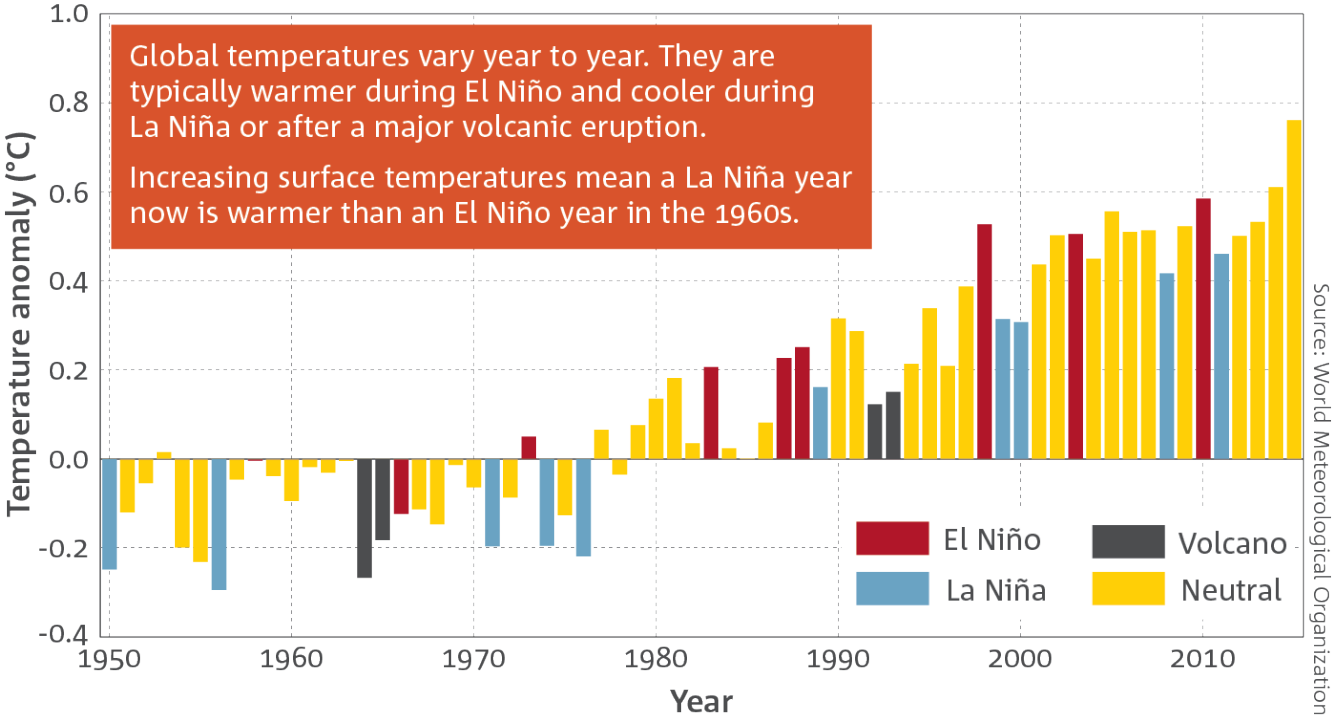


Key points

Global

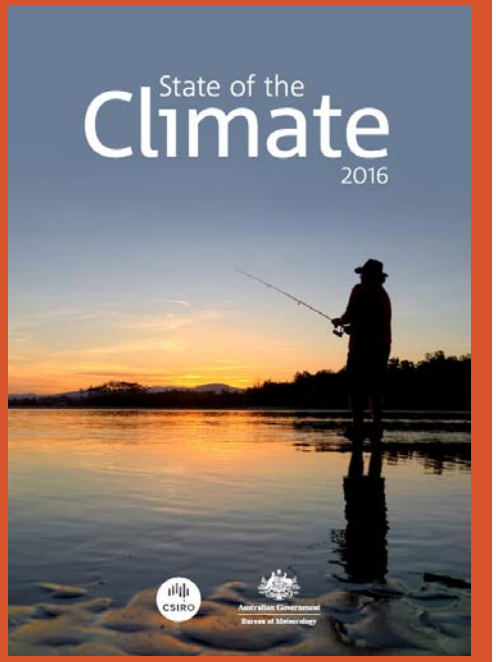
2015: warmest year on record since reliable global surface air temperature records began in 1880.

2016 will surpass 2015 to be the hottest year on record.



Australian Government
Bureau of Meteorology

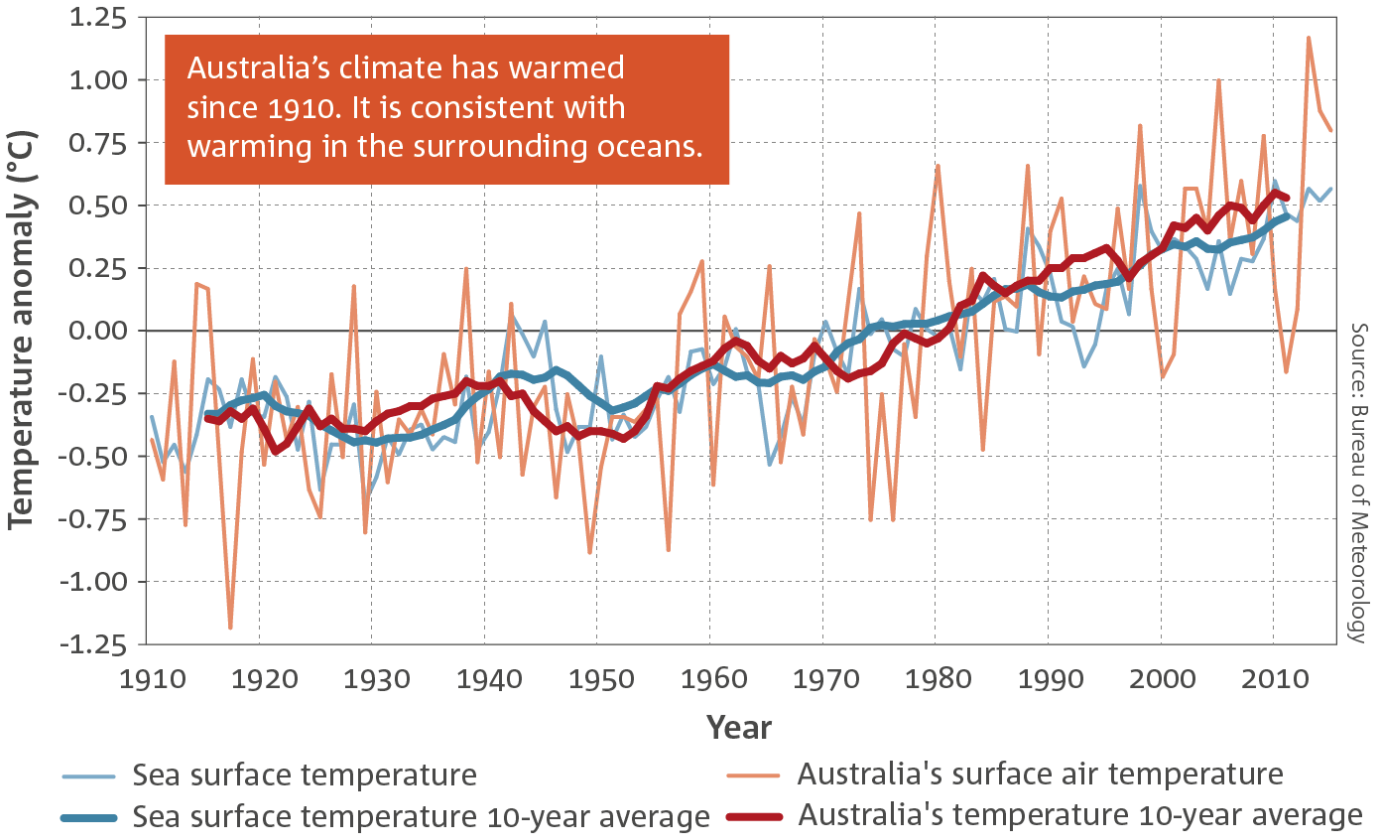
Temperature



Key points

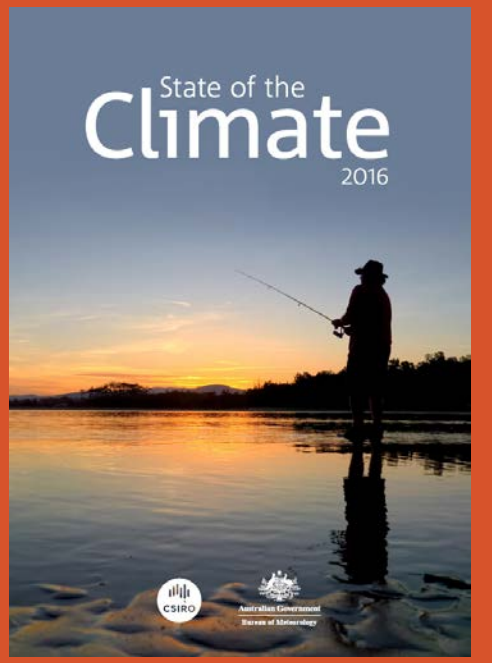
Australia

Australia's mean surface air and surrounding sea surface temperatures have increased by around 1 ºC since 1910.



Australian Government
Bureau of Meteorology

Temperature



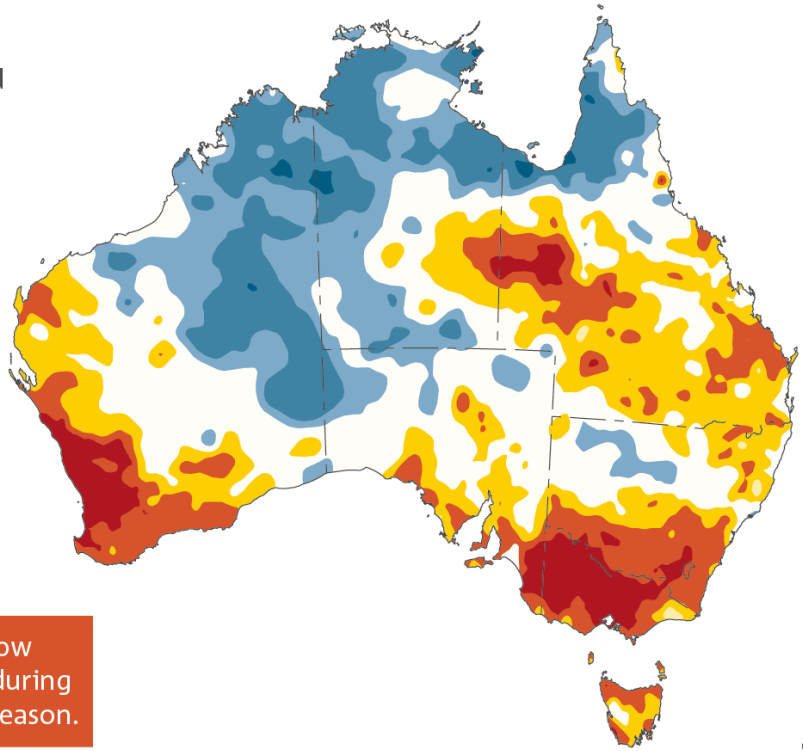
Key points

Australia

Southern growing season (April – October) 1996 - 2015

Rainfall decile ranges

	Highest on record
10	Very much above average
8–9	Above average
4–7	Average
2–3	Below average
1	Very much below average
	Lowest on record



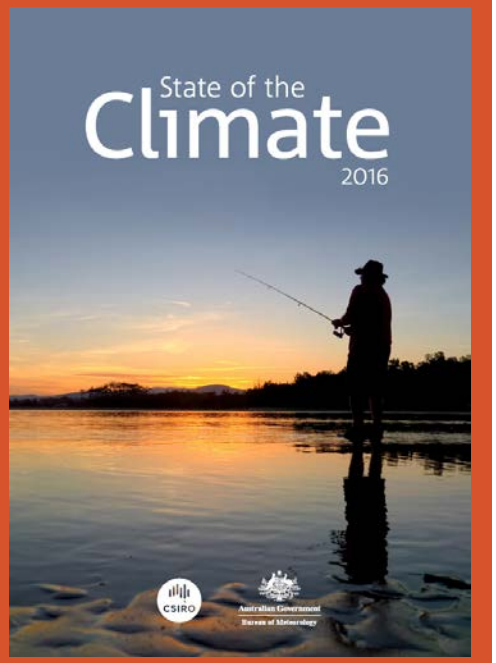
Source: Bureau of Meteorology

Rainfall has been very low over parts of Australia during the southern growing season.

CSIRO

Australian Government
Bureau of Meteorology

Rainfall



Key points

Australia

Northern wet season
(October – April)
1996 - 2015

Rainfall during the northern wet season has been very much above average.

Rainfall decile ranges

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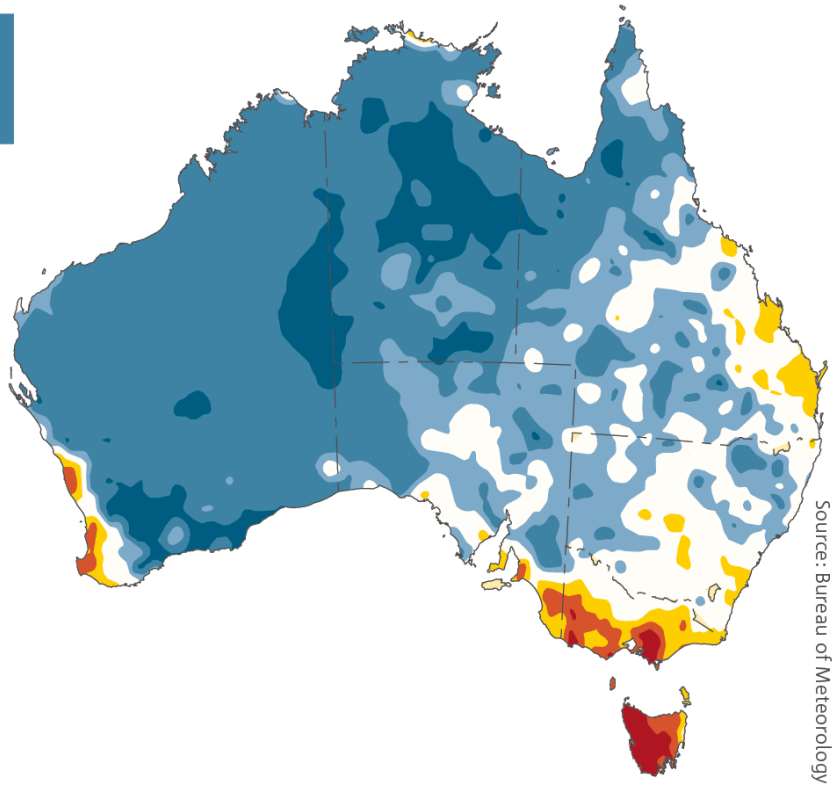

Source: Bureau of Meteorology

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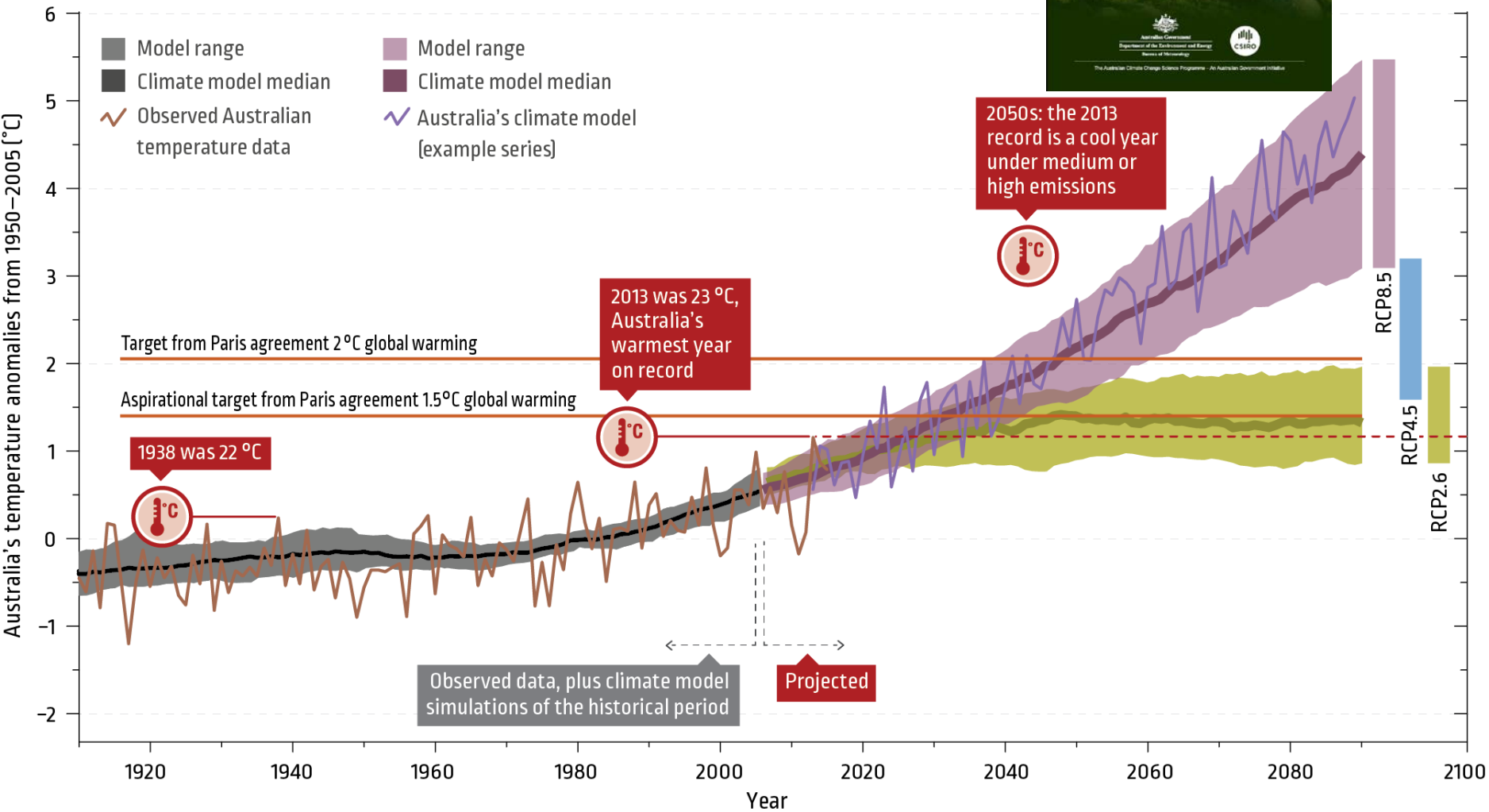
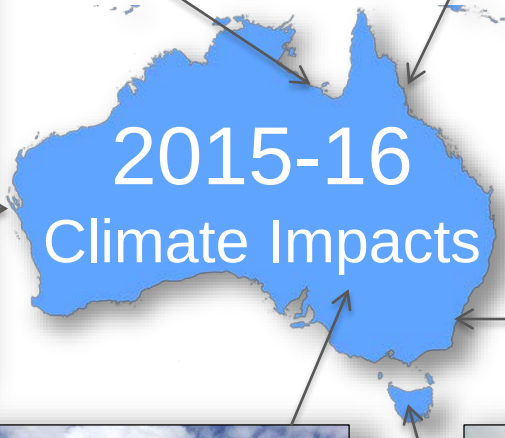
Australian Government
Bureau of Meteorology

Rainfall

Australia's climate observed and projected temperatures





From Pep Canadell, 2016

Earth System and Climate Science
climate-proofing Australia

A nation and region better prepared for, and resilient to, climate and environmental challenges:

- Adaptation and mitigation
- Sustainability and resilience
- Water resource management
- National security
- Well-being: ecosystems, biodiversity, people

National Environmental Science Programme NESP

An ongoing programme of applied environmental and climate research to improve understanding and inform Australian decision making

Earth Systems and Climate Change Hub
National Environmental Science Programme

Marine Biodiversity Hub
National Environmental Science Programme

Clean Air and Urban Landscapes Hub
National Environmental Science Programme

Northern Australia Environmental Resources Hub
National Environmental Science Programme

Threatened Species Recovery Hub
National Environmental Science Programme

Tropical Water Quality Hub
National Environmental Science Programme

Making a difference: Science to actions

Earth System and Climate Science

- How and why is the climate changing?
- What will it be like in the future?
- What are the impacts, consequences and risks?

What do we do about it?

- Adaptation and mitigation
- Locally, regionally and globally

Earth Systems and Climate Change Hub

ESCC Hub Outcomes

CLIMATE CHALLENGES FOR AUSTRALIA

Future hydroclimate and water resources

More effective water resources planning, management, infrastructure and investment

Food security, ecosystems and natural resource management

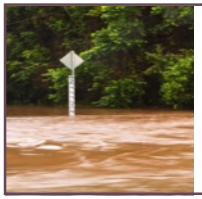
More effective decision making and planning through better climate information at multi-annual to multi-decadal timescales

Carbon cycle and Australia's future warming

Australia's emissions mitigation policy responses are informed by tracking past, and predicting future, changes in greenhouse gases

Changes in coastal climate

Coastal planning and development decisions are informed by nationally coordinated data and information on changing sea levels and climate in coastal regions



Extremes and disaster risk reduction

Greater resilience to extreme weather and climate events through improved knowledge and better quality, relevance and delivery of targeted information

ESCC Hub Goal

Building a national partnership in multi-disciplinary Earth system science and modelling capability

Earth system and climate information in support of a productive and resilient Australia

Ensuring Australia's policy and management decisions are effectively informed by Earth systems and climate change science, now and into the future

CSIRO

Climate Change Research Centre

Australian National University

UNIVERSITY of TASMANIA AUSTRALIA

UNSW AUSTRALIA

MONASH University

THE UNIVERSITY OF MELBOURNE

Australian Government Bureau of Meteorology

ESCC Hub Objectives

- **Through world-class research:**
  - Advance understanding of Australia's changing and variable climate (including extremes) and associated drivers
  - Lead the development of a national Earth system and climate simulator (ACCESS)
  - Develop and strengthen stakeholder relationships, and support informed management and evidence-based decision making
  - Facilitate outreach and communication of science, with products and services to end-users and the general public

Earth Systems and Climate Change Hub

ESCC Hub Research

- Understanding Australia's variable and changing climate
  - Tracking greenhouse gas levels and carbon budgets
  - Ocean change: heat content, salinity, sea levels
  - Climate variability and climate-related extremes
- ACCESS: Australia's weather and climate model
  - Globally benchmarked performance; with improved skill in Australasian region
  - Australian ecosystems and landscapes: carbon and water availability
- Projections of Australia's future climate, including extremes
  - Water availability and carbon sequestration
  - Ocean change, coastal hazards (storm surge, sea levels, waves)
  - Improved predictions and latest climate models
  - Targeted for end-user needs

Earth Systems and Climate Change Hub

ESCC Hub Research projects

INFORMATION PRODUCTS AND SERVICES FOR NEXT- AND END-USERS

2.8 Extreme weather projections

2.11 NCCC

2.9 Future carbon sources and sinks – risk assessment

2.7 Refining Australia's water futures

2.10 Coastal hazards

2.6 Regional climate projections, information and services

2.5 Improving Australia's climate model (ACCESS)

2.4 Changing oceans and Australia's future climate

2.3 Towards an ACCESS decadal prediction system

2.2 Enhancing Australia's capacity to manage climate variability & extremes in a changing climate

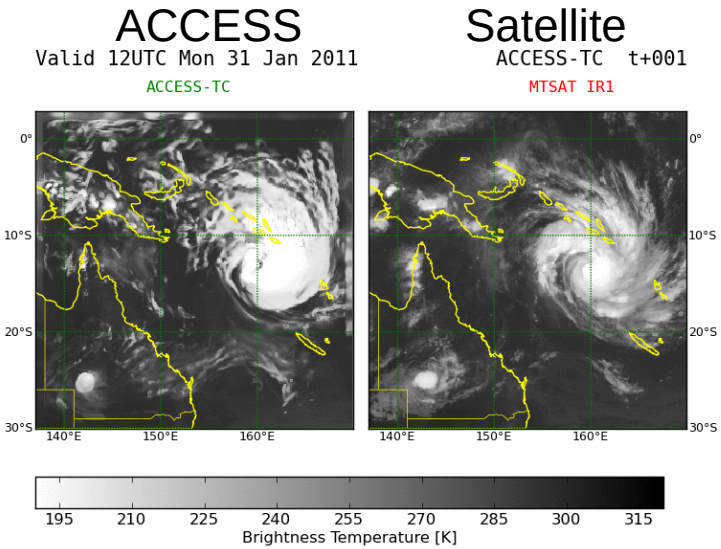
2.1 Preparing ACCESS for CMIP6

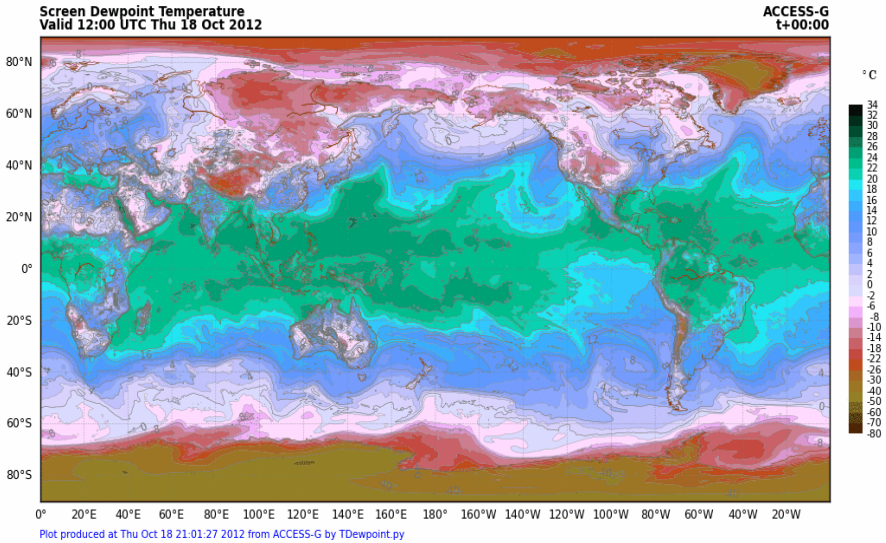
ACCESS a weather, climate and Earth System model for Australia

Weather forecasts for this week

Climate over next 30, 50 100 years (and more), including feedbacks

Coupler



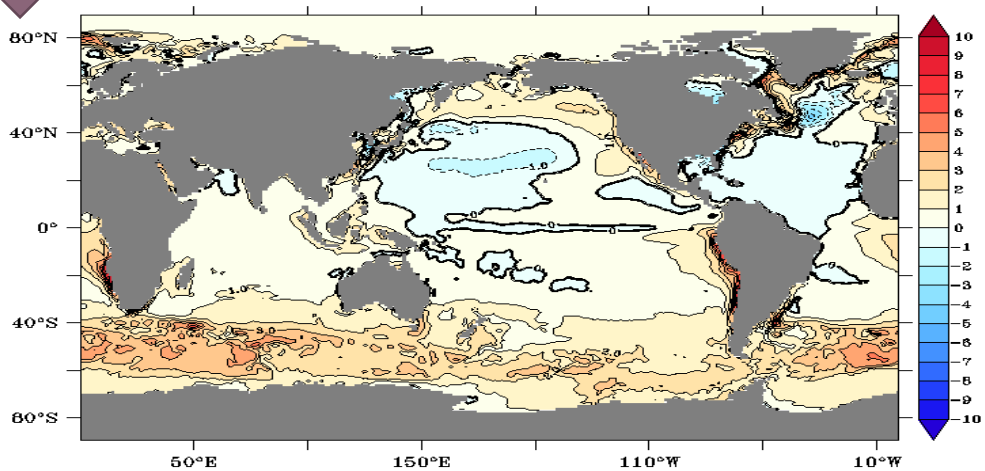


Benchmarking and Improving ACCESS

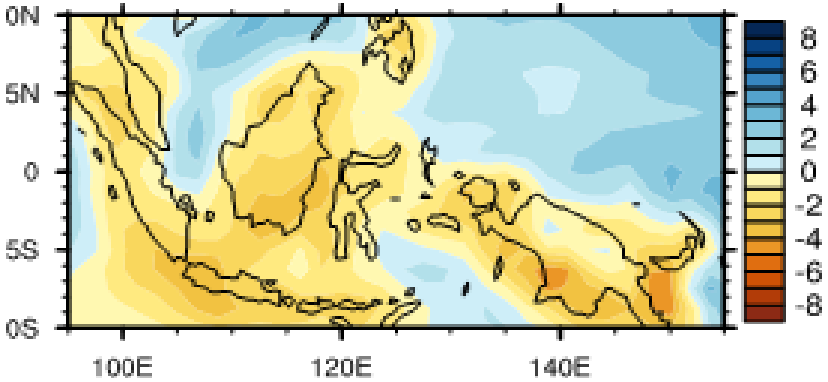
Address systematic errors and uncertainties that limit ACCESS predictive skill in Australian region

- Rainfall biases in the tropical Indo-Pacific region
- Systematic biases over the Southern Ocean
- Refine climate sensitivity (CO_2, clouds)

Sea surface temperature bias (°C)
ACCESS – observed [Annual]



Rainfall bias (mm/day)
ACCESS – observed [Annual]



Benchmarking and Improving ACCESS

- Deliver Australia's model simulations for AR6; participate in CMIP6 to benchmark performance
- More reliable model predictions → improved climate projections → better information for decisions and policies
- Deliver to the Australian research and end-user communities:
  - A new version of ACCESS: new parameterisations; higher resolution
  - Suite of diagnostic tools and model experimentation framework for studying and characterising systematic model errors
  - Communication and education tools - ACCESS and climate models

Australia's future climate Regional projections released in 2015

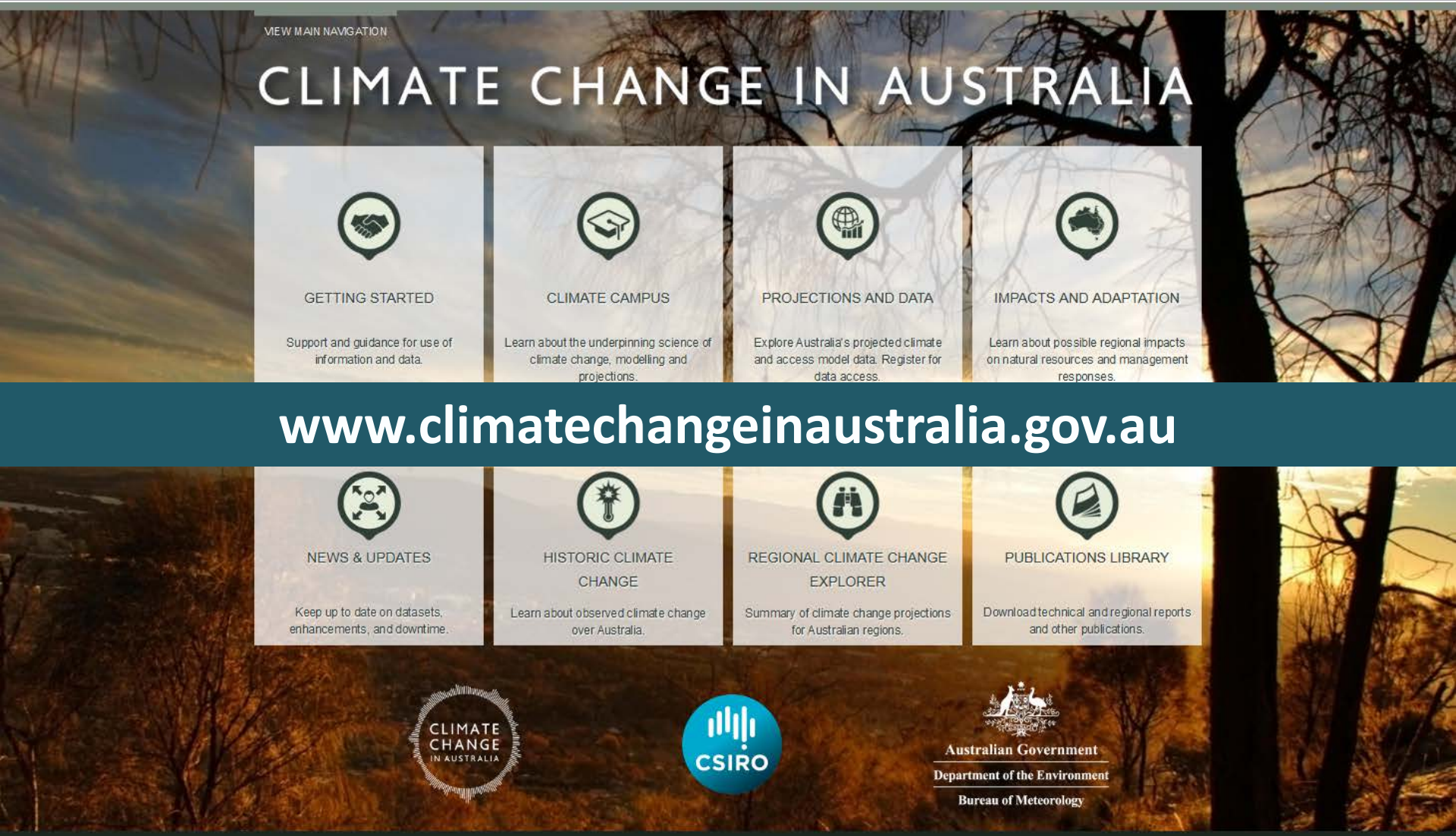
Four emission scenarios and four time periods

Ranges of change for 21 climate variables based on 40 climate models

Addressing a range of user needs and building user capacity

Providing users with data and information for decision making

Australia's future climate Regional projections released in 2015



Regional Climate Projections Science, Information and Services

- Enhance the uptake of existing projections (CCiA and others)
  - Products that **fill known gaps**
  - **Services** e.g. workshops, training, presentations.
  - Broad and sustained stakeholder engagement
- Better understanding of confidence and uncertainty
  - Consistency between GCM and **dynamically downscaled projections**
  - Improved understanding of climate feedbacks and key climate processes in northern/southern Australia to constrain uncertainties
- Preparing for the next generation of regional projections
  - **Review and re-assess** projection methods from here and overseas

User needs: future projections of hydroclimate information, e.g.:

Runoff

Soil moisture

Droughts

Problems:

1. What are the relevant hydroclimate metrics (not just averages)?
2. Range in projections – how to interpret and communicate?
3. Limitations of current modelling science

Existing hydroclimate knowledge & modelling:

- Climate models: global and regional
- Impact models: Hydrological models, land-surface models …
- Many ways to define a metric (e.g. drought indices)

Research required

1. Better understanding of user needs

1 & 2. Improved and consistent national projections across metrics/variables

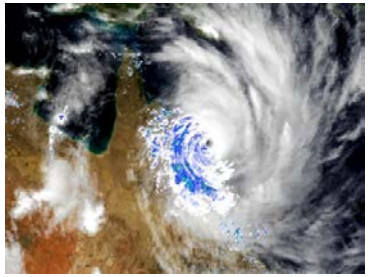
1. Improved delivery and communication of information

3. Improved modelling to supporting projection science and climate change adaptation

Projections of Extreme Weather

- Fill knowledge gaps for “weather extremes” in a variable and changing climate (Hub and university collaborations)

- Tropical Cyclones
- East coast lows (ECLs)
- Thunderstorms
- Bushfires



- Improved future projections of these extreme phenomena
  - An integrated approach
  - Focus on end-user information needs

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Climate Variability and Extremes in a Changing Climate

- Extreme weather and climate events profoundly affect Australian lives, health, infrastructure, productivity
  - TCs, droughts, floods, storms, bushfires
- How are these changing; now and into the future?
  - frequency, intensity and duration
- Understanding past trends and causes
  - attribution of anthropogenic forcing
- Outcome: Improved understanding → improved model simulations

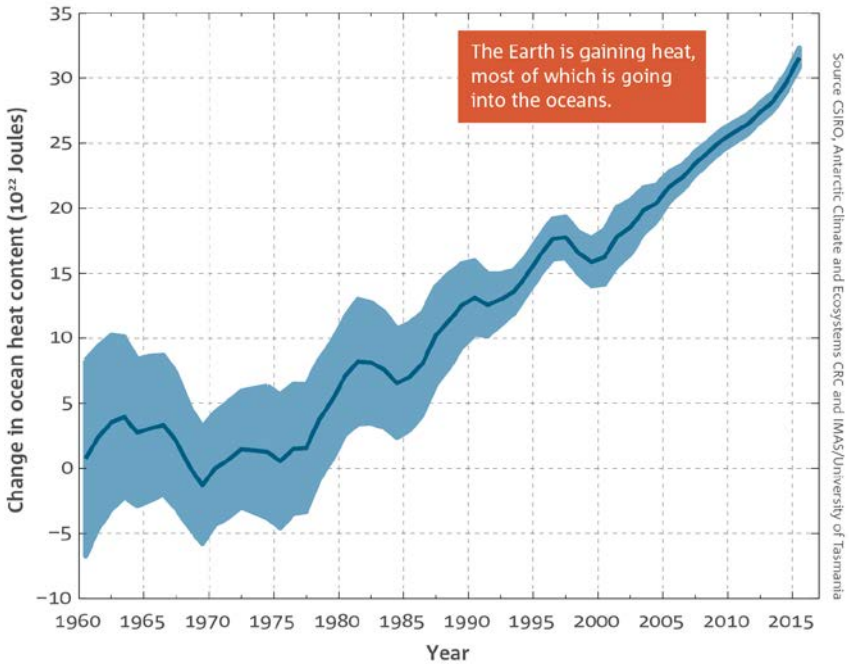
Ocean Change and Future Climates

Global warming is ocean warming

a) Ocean heat content

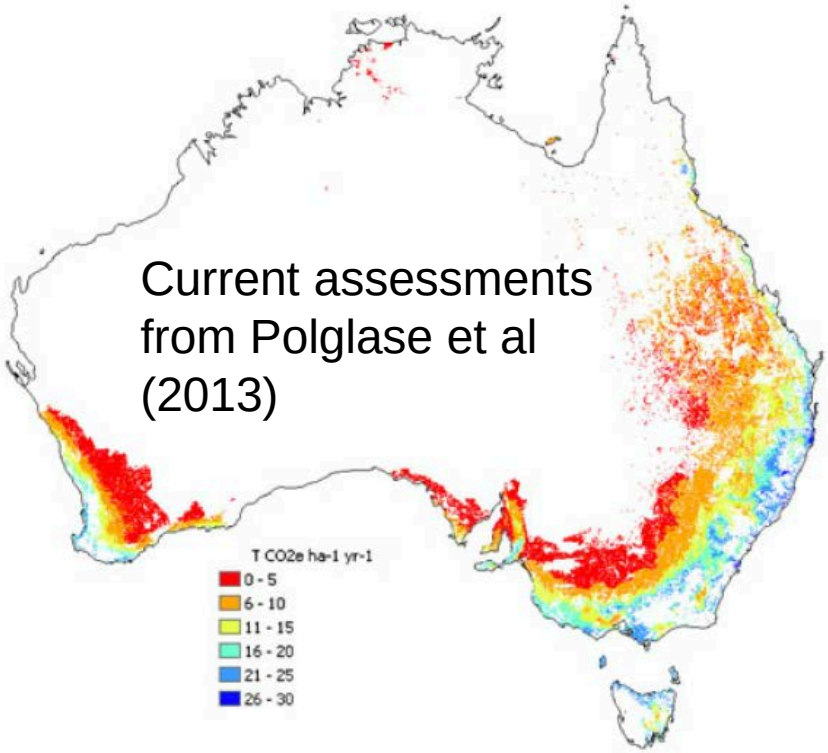
- Rate of planetary warming; tracked by ocean heat content
- What controls ocean heat uptake rates and patterns
- Improve heat uptake processes in climate models

b) Patterns of ocean heat and salinity change and regional climates, incl. the water cycle



Risk Assessment of Future Carbon Sources and Sinks

What is Australia's carbon sequestration potential?



Current assessments from Polglase et al (2013)

What's missing?

- Change in soil carbon stocks✓
- Coupling to water cycle✓
- Response to changing climate✓
- Response to CO_2✓
- Response to disturbance, incl. fire✓
- Drought-stress mortality✓

✓ BIOS2
✓ BIOS3

BIOS = Australia's community land surface model (CABLE) plus significant enhancements

Earth Systems and Climate Change Hub

Risk Assessment of Future Carbon Sources and Sinks

1. Assess vulnerability and carbon sequestration in Australia using CABLE enabled with land use change:
   - Future climate change and variability
   - Reforestation/deforestation avoidance scenarios
2. Global carbon-climate feedbacks
   - Including land use change
   - Historically and under future emissions scenarios
3. Contemporary Australian and global GHG budgets
   - Australian terrestrial ecosystems
   - Global carbon-CO_2 [annual] and carbon-CH_4 budget [biennial]
     - Includes support for the Global Carbon Project
   - Assess remaining carbon budgets to stabilization targets

Earth Systems and Climate Change Hub

ESCC Hub Outputs

RESEARCH PAPERS	• Journal and conference papers (peer review) • Technical reports
DATA AND MODELS	• Model data: hindcasts and future projections • Analyses of observations • Application-ready data sets • Model systems, models and parameterisations
COMMUNICATION & KNOWLEDGE PRODUCTS AND ENGAGEMENT ACTIVITIES	• Stakeholder network engagement • Briefings, workshops, seminars and newsletters • Science Informing Policy events • Targeted products, assessments and reports • Case studies
TRAINING	• End-user and stakeholder capacity building • Postgraduate students

Earth Systems and Climate Change Hub

ESCC Hub Stakeholders

- Any group or individual with an interest in, or use for, the best available climate science
  - Governments at all levels (local, state, federal)
  - Australian and global research community, including allied research programs (e.g. NCCARF, ACE CRC, ARCCSS)
  - Private sector: industry, resources, finance, insurance
  - Indigenous communities
  - NGOs
  - Farmers and water resources managers
  - Australian community

Earth Systems and Climate Change Hub

The capability building blocks: national climate programs and agencies

NESP Earth Systems and Climate Change Hub

Earth Systems and Climate Change Hub
National Environmental Science Programme

ACCSP ends in June 2016; ESCC Hub's research begins

NCCARF

ARC CoE Climate System Science (ARCCSS)

ACE CRC

Bureau of Meteorology

CSIRO

Australian universities

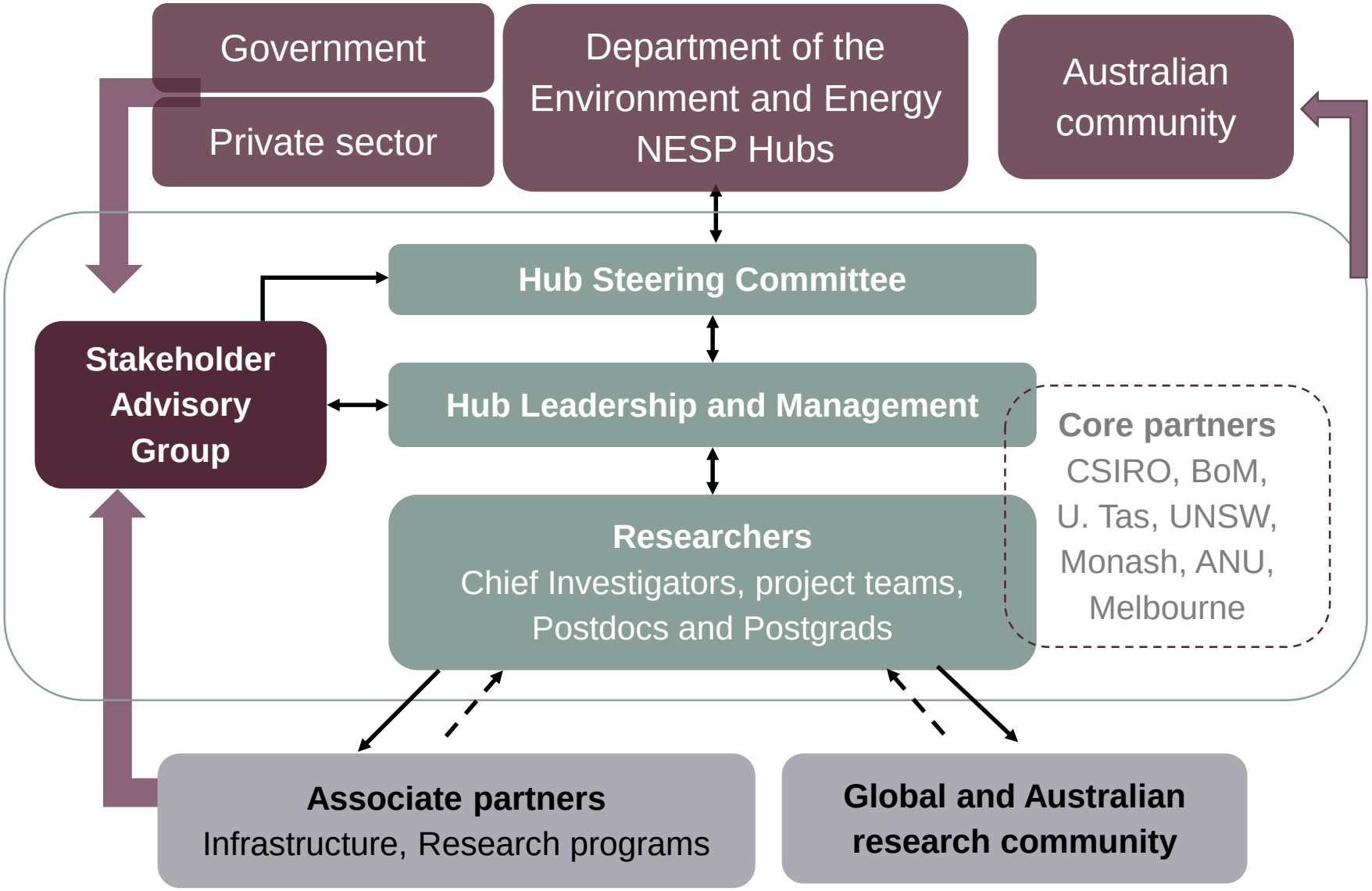
Antarctic Division

Terrestrial Ecosystem Observing Network (TERN)

Integrated Marine Observing System (IMOS)

NCI - Supercomputing

ESCC Hub Relationships



Earth Systems and Climate Change Hub

National Environmental Science Programme

Thank you for your interest - from the Climate Hub

FOR MORE INFORMATION

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The Earth Systems and Climate Change Hub is funded by the Australian Government's National Environmental Science Programme, with co-investment from the following partner agencies

CSIRO | Climate Change Research Centre | Australian National University | University of Tasmania Australia | Australian Government Bureau of Meteorology | UNSW Australia | Monash University | The University of Melbourne

ESCC Hub Research priorities

Improving understanding of past and current climate

Improving understanding of how the climate system may change in the future

Building the utility of Earth systems and climate change information

Ensuring Australia's policy and management decisions are effectively informed by Earth systems and climate change science, now and into the future

Earth Systems and Climate Change Hub

ESCC Hub Timeline

Dec 2014

- Successful hubs, lead agencies and partners announced

Feb 2015

- Department released research priorities for the Earth Systems and Climate Change Hub

Apr-Dec 2015

- Building Hub leadership and governance
- Research outcomes and proposals developed
- Departmental review, assessment, approval

Feb-Jul 2016

- Refine research activities and work plans
- Hub research begins (2016–19)

Ongoing stakeholder engagement

ESCC Hub Leadership & management

HUB LEADERSHIP TEAM

Dr Helen Cleugh
Hub Leader

Dr Aurel Moise
Deputy Hub Leader (BoM)

Mr Kevin Hennessy
Deputy Hub Leader (CSIRO)

Prof. Nathan Bindoff
Deputy Hub Leader (Universities)

HUB PROGRAMME MANAGEMENT TEAM

Ms Mandy Hopkins
Programme Officer

Dr Geoff Gooley
Programme Manager

Earth Systems and Climate Change Hub

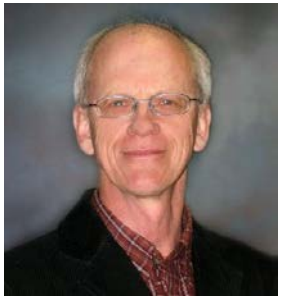
ESCC Hub Steering Committee

CHAIR; PARTNER REPRESENTATIVES; AND DEPARTMENT OF THE ENVIRONMENT

Wendy Craik
Chair

Peter May
(BoM)

Ken Lee
(CSIRO)



Neville Nicholls
(Universities)

Diana Wright
Science Partnerships
Beth Brunoro
Climate Policy

ALLIED PROGRAMS AND DOMAIN EXPERTS

Andy Pitman
ARCCSS

Tony Worby
ACE CRC

Jo Mummery
Univ. Canberra

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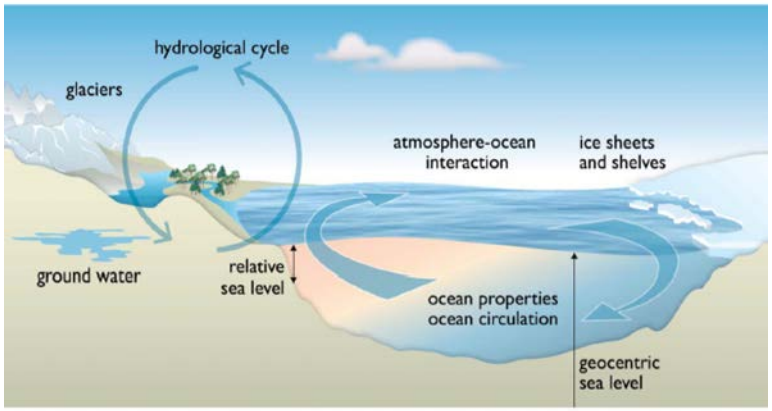
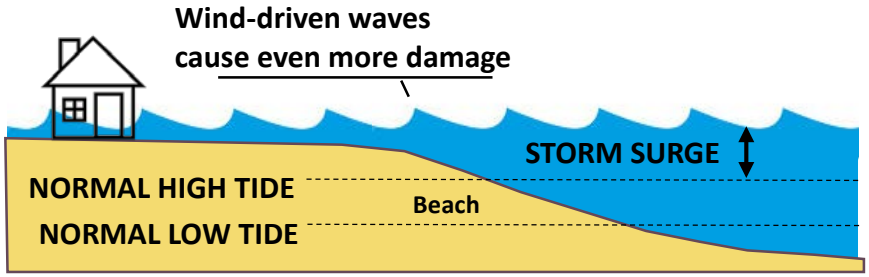
Coastal Hazards in a Variable and Changing Climate

Improved understanding of past and future changes in sea level, storm surges, waves and physical coastal impacts





Sea-Level

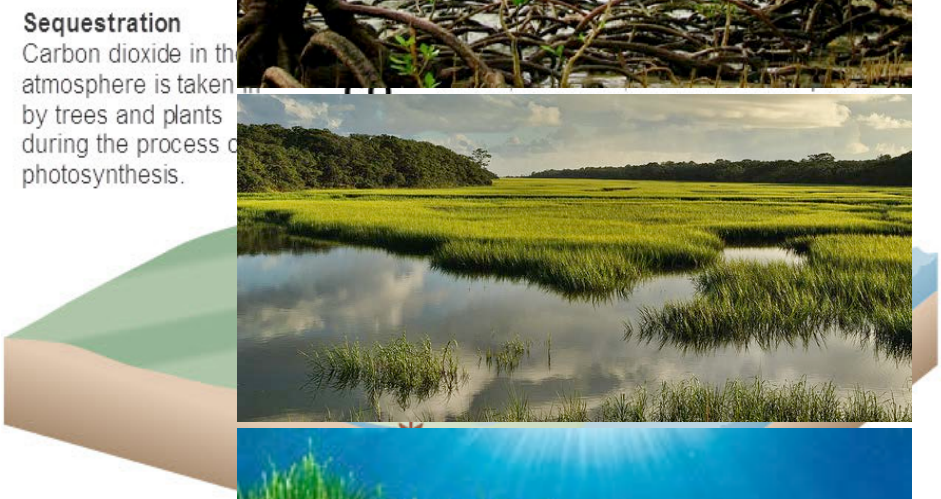
- Updated global and regional sea-level rise estimates with greater focus on regional variation and coastal sea level
- Mass loss from glaciers and icesheets using latest space gravity observations
- Sea-level projections for 21st and 22nd centuries

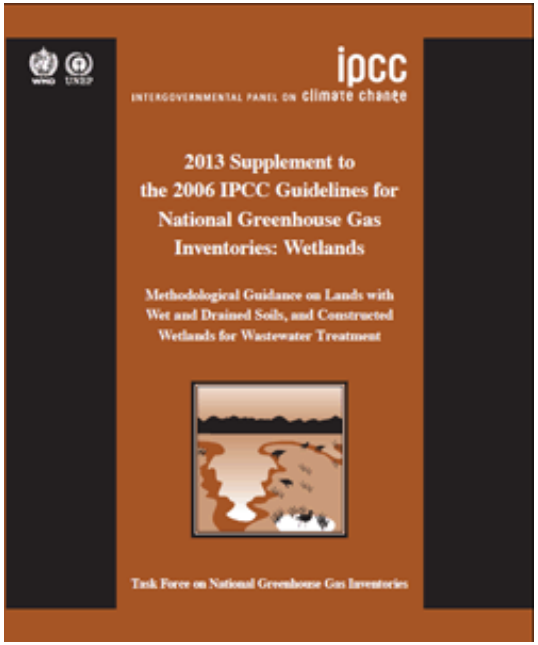
Coastal Sea-Level Extremes

- Improved knowledge of past changes (extend analysis of tide gauge records)
- Indices of geomorphological sensitivity to sea-level drivers
- Characterise historical extreme sea level and wave events
- Future changes to coastal sea-levels

Establishing the National Centre for Coasts and Climate

- Carbon sequestration potential of coastal vegetated ecosystems
  - Quantifying the climate mitigation potential
  - Filling regional data gaps
  - Carbon cycling and storage potential





NCCC
National Centre for Coasts and Climate

Towards a Decadal Prediction System

Component 1: Develop and apply a multiyear forecast system for Australia, based on ACCESS

- Linked to CSIRO's "Decadal Prediction project" and building on prior investments across CSIRO and the Bureau

Component 2: Ocean temperature extremes (OTEs) in Australian region:

- Identify and characterise decadal-scale predictability and trends (above natural variability and attributable to human forcing)

Outcomes: information for improved adaptation and resource management in marine, agriculture, energy, and water sectors

How are climate variability and extremes changing?

- Extreme weather and climate events profoundly affect Australian lives, health, infrastructure, productivity
  - TCs, droughts, floods, storms, bushfires

- Strong influence of “modes” of variability: a coherent system of coupled ocean-atmospheric phenomenon, including:
  - El Nino Southern Oscillation (ENSO)
  - Indian Ocean Dipole (IOD)
  - Southern Annular Mode (SAM)
  - Interdecadal Pacific Oscillation (IPO)

- How are these changing – now and into the future?

Project 2.2: Research

- Causes and predictability of decadal climate variability
- What factors precede extreme Indo-Pacific climate events?
- Evaluate climate model simulations of multi-year drought, El Niño and La Niña and decadal variability
  - How will their impact on Australian drought change?
- How is global warming interacting with El Niño to amplify extremes?
- Why do some years see more high impact weather systems?
- Attribution of individual climate-related extreme events

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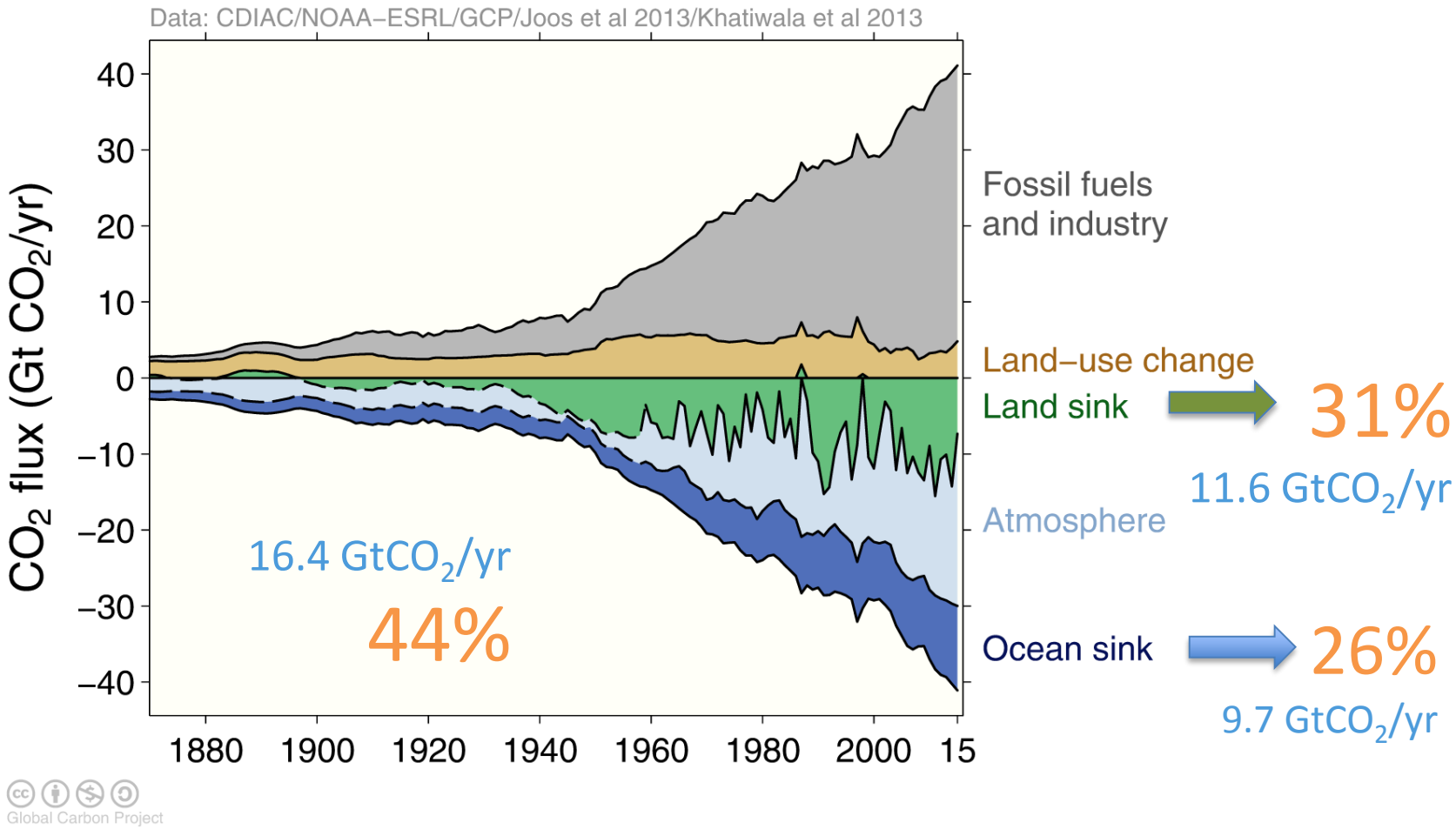
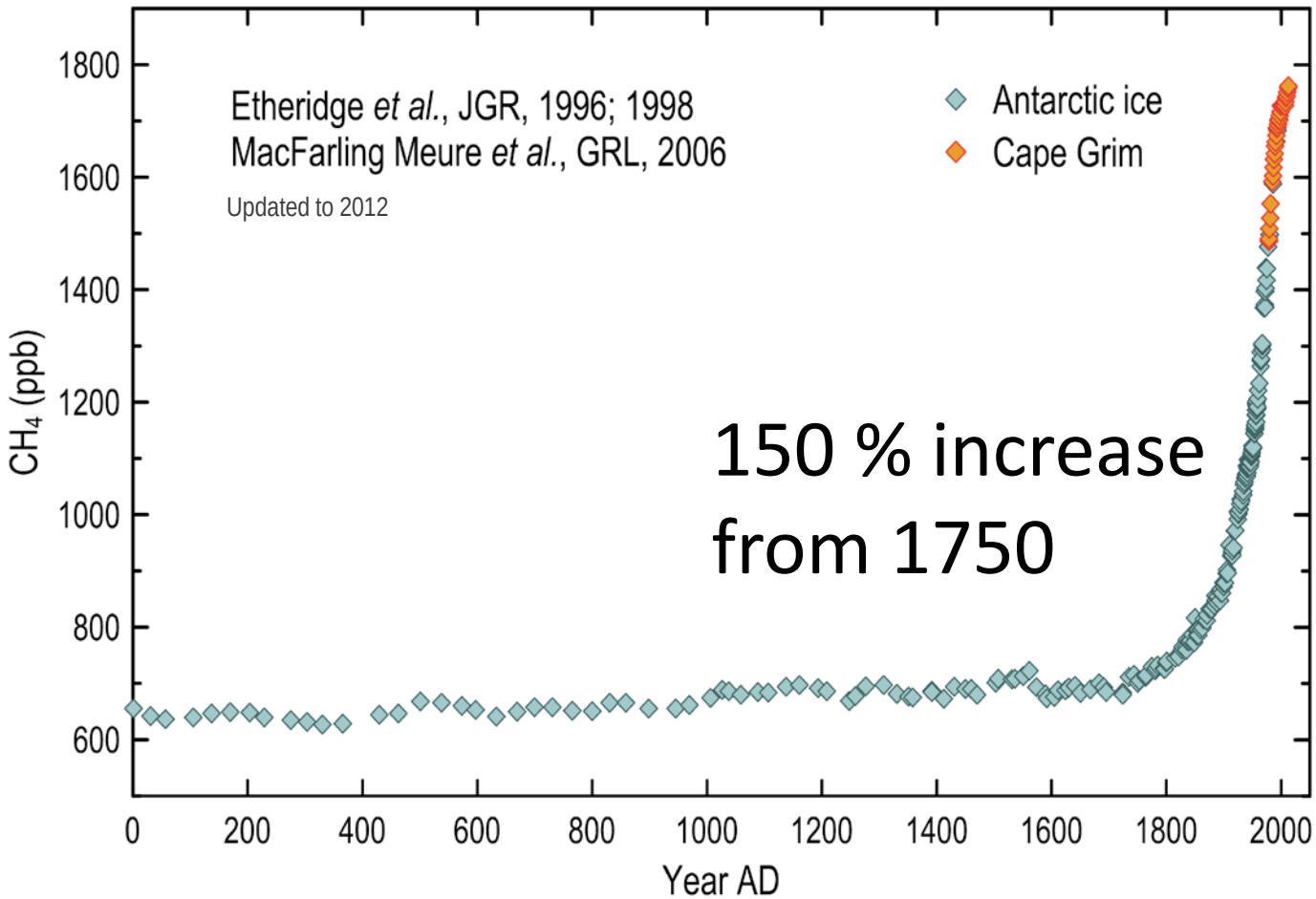
Global carbon budget

The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean



Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Joos et al 2013; Khatiwala et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

CH_4 Atmospheric Growth Rate, 1983-2012



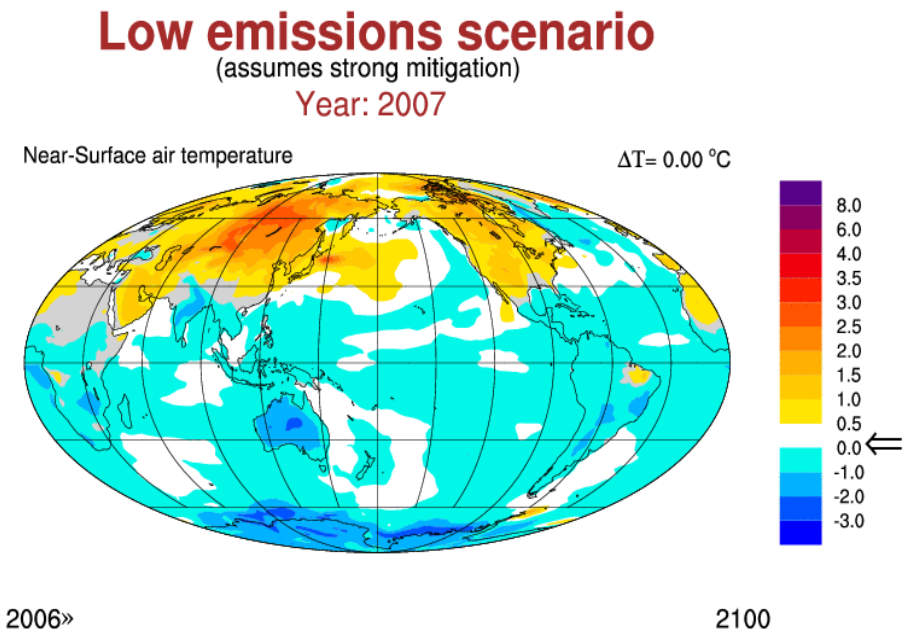
Atmospheric methane observations

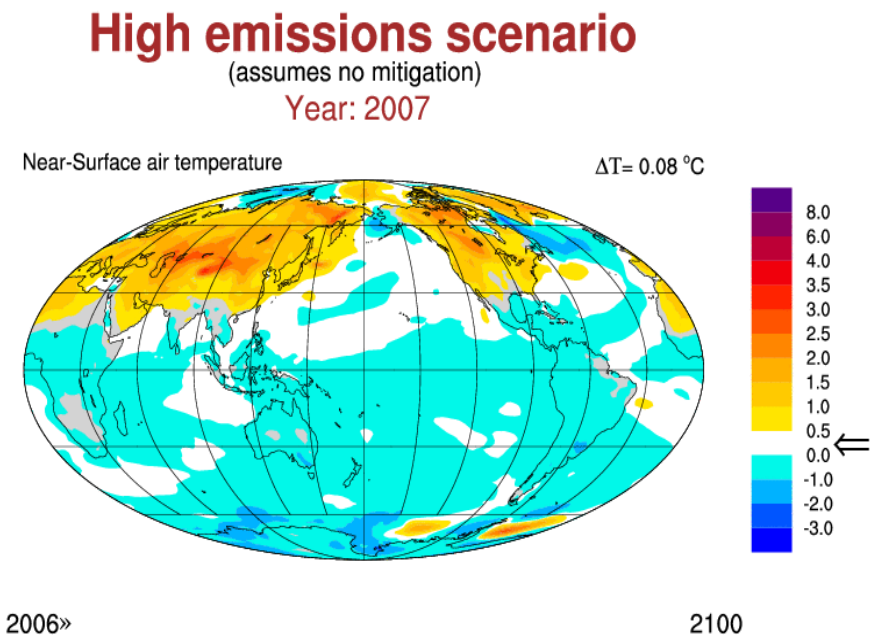
wdown of atmospheric
wth rate before 2006
umed increase after
06

Source: Saunois et al. 2016, ESSD (Fig. 1)

ACCESS simulates the global climate in the past, present and future

Information for adaptation and mitigation





Earth Systems and Climate Change Hub