Question on notice no. 3

Portfolio question number: SI-3

2017-18 Supplementary budget estimates

Economics Committee, Industry, Innovation and Science Portfolio

Senator the Hon. Kim Carr: asked the Commonwealth Scientific and Industrial Research Organisation on 26 October 2017—

Senator KIM CARR: Dr Marshall, CSIRO participated with the Academy of Science in the Australian climate science capability reviewthat's correct, isn't it? Dr Marshall: I'm aware of the academy's review. I'm not exactly sure which parts of our organisation participated, but perhaps, if it is important, Dr Mayfield can answer that. I'm aware of the reviewif that serves the purpose of the question. Dr Mayfield: I am also aware of the review. In terms of our participation, I would have to take that on notice, but it would have been an opportunity for some of our scientists to participate as individuals, as well as to make other representations. Can I say, our chief scientist, Dr Anita Hill, was made a fellow of the Academy of Science this year, so we are very proud of her. Senator KIM CARR: Congratulations. So, are you telling me you're not certain of CSIRO's involvement? Is that what you're saying to meyou're not certain of what the involvement was? Dr Mayfield: In terms of formal CSIRO involvement, at this point in time, I would have to take that on notice. Senator KIM CARR: Did you write a submission? Dr Mayfield: I can just check. Dr Marshall: We'll get Dr Jack Steel to answer these questions. Dr Steele: I believe there was a formal submission from the CSIRO. I make the observation, as well, that a number of our scientists would have participated in the academy's deliberations in relation to this, and we have an expectation that those scientists, as they do that, do that as individual scientists as well as keeping in mind the CSIRO. Senator KIM CARR: But you did write a submission. Dr Steele: There was a submission, I believe. Senator KIM CARR: Can I have a copy of it? Dr Steele: Sure, no problem at all.

Answer —

See attachment.

Economics Legislation Committee
ANSWERS TO QUESTIONS ON NOTICE
Industry, Innovation and Science Portfolio
2017 – 2018 Supplementary Budget Estimates
26 October 2017

AGENCY/DEPARTMENT: CSIRO

TOPIC: CSIRO submission to the Australia Climate Science Capability Review

REFERENCE: Question on Notice (Hansard, 26 October 2017, 61-62)

QUESTION No.: SI-3

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ANSWER

A copy of CSIRO's written input to the Australian Academy of Sciences "Australian Climate Science Capability Review" is attached.

Australian Academy of Science
Ian Potter House, Gordon Street, Canberra ACT 2601

AUSTRALIAN CLIMATE SCIENCE CAPABILITY REVIEW

CONSULTATION PAPER FOR ORGANISATIONS

INTRODUCTION

The Australian Academy of Science is conducting a review of Australian climate science capability and future requirements to better understand the capabilities (including expertise and infrastructure) that are needed in Australia. The arrangements for conducting climate science in Australia are currently undergoing significant change, and this review will provide information and advice to help the climate science community and government manage that change and plan for future requirements.

The review is being overseen by a steering committee, headed by Professor Trevor McDougall FAA. The committee will conduct extensive consultations with the climate science community focusing primarily on basic climate-related science, including observations, fundamental processes and modelling – approximately those areas that would fall into the IPCC Working Group I report. This review is being completed independently of government.

The committee would like your organisation's input into the review to help gain a complete picture of the current climate science capabilities in Australia.

Information provided in responses will be used only for the purposes of completing this work. In general, the committee may quote or otherwise represent responses in the report, however please indicate if any material provided is subject to particular sensitivities (copyright restrictions, security implications etc.)

The committee would greatly appreciate any assistance your organisation is able to give, and would appreciate responses being emailed to science.policy@science.org.au, by **24 June 2016**. Queries may be directed to Dr Alex St John, Senior Policy Officer at the Australian Academy of Science on (02) 6201 9465 or science.policy@science.org.au.

BASIC INFORMATION

1) Contact details of responsible person:
    - Dr Andreas Schiller
    - Science and Deputy Director
    - CSIRO Oceans and Atmosphere
    - (03) 6232 5300
    - Andreas.Schiller@csiro.au

2) Is any of the material represented in this response sensitive in any way?

    Due to the Government's current care taker convention, the material contained in this submission must be considered confidential and used strictly for AAS internal purposes. Post the election on 2 July 2016, it may be treated as non sensitive material.

    Note also that at the time of writing this submission (June 2016) some business units in CSIRO are undergoing a reshaping of their capabilities. This includes climate research capability. Hobart will become the HQ of the new CSIRO Climate Science Centre (CSC), which will provide a long-term foundation for climate monitoring, modelling, adaptation and mitigation research in CSIRO. The scoping and establishment of the Centre are

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work-in-progress. Based on these changes, some of the material presented in this document with a reference date of 31 March 2016 will be out-of-date.

Information provided herein has been provided by

- CSIRO Oceans and Atmosphere
- CSIRO Agriculture
- CSIRO Land and Water
- CSIRO Energy

INFORMATION ABOUT YOUR ORGANISATION'S CLIMATE SCIENCE ACTIVITIES

3) The Committee would like to know about the climate science/research activities that your organisation undertakes. For your organisation, please list the activities undertaken in the following areas, and indicate :
   - number of FTE undertaking the activity/research
   - types of position (e.g. technician, research student, junior researcher, researcher, senior researcher, manager), undertaking the activity/research
   - Level of funding supporting the activity
   - Duration of funding/commitment
   - Infrastructure associated with activity
   - Maintenance tasks associated with the activity

To ensure that data provided by all organisations are comparable, it would be helpful for responses to these questions to reflect the situation at 31 March 2016, as far as possible.

Comment: Please see separate table provided as part of this submission.

Area 1: Climate observations

- Monitoring of temperature, precipitation and run-off
- Records of CO_2, other greenhouse gas and aerosols from the Cape Grim base-line station or other monitoring stations
- Ice core records and other paleoclimate

Area 2: Climate processes

- Atmospheric, e.g. convection, clouds, aerosols
- Oceanic, e.g. changes in ocean salinity, temperature, acidity, sea level and Southern Ocean sea ice extent and thickness
- Surface-atmosphere, e.g. measurement of the fluxes of carbon, water and energy between the Earth's surface and the atmosphere
- Natural and anthropogenic radiative forcing

Area 3: Climate understanding

- Modes of variability e.g. MJO, ENSO
- Detection/attribution
- Extreme weather events, such as the frequency and intensity of tropical cyclones, heat waves, droughts, thunderstorms, heavy rain and hail
- Interpretation and analysis of climate observations
- Greenhouse gas emissions estimation

Area 4: Climate model development, prediction and projections (global and regional)

- Development of the Australian Community Climate and Earth System Simulator (ACCESS)
- Climate simulation and projection, including modelling contribution to IPCC Assessment Reports.
- Carbon cycle modelling, including lead development of the ACCESS land surface and ocean biogeochemistry components, CABLE and WOMBAT, respectively.
- Atmospheric chemistry modelling

- Models and output data made accessible broadly via CWSLabs and the Earth System Grid (ESG), respectively.
- Regional climate modelling and climate change downscaling
- Decadal prediction (experimental)
- Development of global greenhouse gases budgets.

Area 5: Linking climate with social and economic systems (e.g. users of climate information)

CSIRO provides information and services to local, state and federal governments, industry and the service and research sector. This serves to link climate science to social and economic systems, and through an emphasis on collaboration and partnership ensures that information and products are fit for purpose.

Area 6: Any other climate science activities not specified elsewhere

4) In terms of climate science activities, what has changed in the last ten years in your organisation? Does your organisation focus on different areas of climate science to ten years ago? What factors have driven this change?

   Overall, CSIRO climate science experienced about a one third reduction in its climate science effort within CSIRO Oceans & Atmosphere. Two fundamental factors have driven this change.

   Firstly, CSIRO has experienced a significant reduction in government funding for climate research. The end of major climate programs with CSIRO participation like PCCSP/PACCSAP and ACCSP are examples. Furthermore, the new NESP Earth System and Climate Change Hub does not financially compensate for this loss in funding.

   The second but comparatively smaller but still notable change is associated with the new CSIRO Strategy 2020: Australia's Innovation Catalyst. Organisational budget constraints and additional strategic investment priorities mean a reduced internal appropriation investment into climate science in CSIRO.

   That said, CSIRO has made a decadal commitment to 40 FTE to maintain a core climate capability. CSIRO has announced a Climate Science Centre to provide a sound foundation for rebuilding the capability.

INFORMATION ABOUT DEPENDENCIES

The review would like to capture information about the climate science networks in Australia. Climate science is a particularly collaborative effort and many researchers and organisations are dependent on expertise, infrastructure or information from other researchers or organisations.

5) Please tell us about any **dependencies** associated with your organisation's work in climate science. Does your organisation rely on any of the following inputs from external sources? Please specify the organisation/person that provides the input (both Australian and internationally)

   - Data sets
     - IPCC/AR climate simulations
     - Satellite data sets, incl. altimetry, SST, ocean colour from, e.g. NASA, NOAA, ESA, …
     - Access to data from the Global Ocean Observing System (GOOS)
   - Models/computer programs
     - UKMO Unified (atmospheric) model
     - GFDL MOM ocean model
     - CABLE (Community Atmosphere Land Exchange Model): collaboration with Australian universities
     - CICE, Los Alamos sea-ice model

- OASIS Couple, CERFACS, Toulouse

- Infrastructure or specialised equipment
  - National Computational Infrastructure (NCI), Canberra, including the NCI ESG node
  - Many observing platforms, e.g.
    - TERN/Ozflux (carbon dioxide, water vapour and energy transfer between the terrestrial ecosystem and atmosphere)
    - AEROSPAN (Aerosols)
    - Cape Grim Baseline Station
    - MNF/RV INVESTIGATOR
    - RSV Aurora Australis
    - IMOS:
      - Argo profiling floats
      - Ship of opportunity (SOOP) (XBT, air-sea fluxes, biogeochemistry)
      - Deep water and shelf-scale mooring arrays, including physical and biogeochemical observations
      - Satellite remote sensing
      - Satellite-tracked animal tags
    - Instrumentation for oceanographic and atmospheric field campaigns and process studies (e.g. Deep Argo floats, EM-APEX floats, turbulence profilers, moorings)

- Support or expertise, including:
  i. Technical support on data sets, computer programs, models

     Technical support for data sets, computer programming and modelling provided by in-house capability. However, strong collaboration is required and exists domestically and internationally at the individual and organisational level (see below) for the mutual benefit in areas such as QC of data sets, and oceanic, atmospheric and land surface development and calibration.

  ii. Expertise on particular subjects, processes, observations
     See above.

  iii. Logistical support

     We depend on logistical support for work on research vessels like the RSV Aurora Australis operated by the Australian Antarctic Division, smaller vessels operated by partner agencies like AIMS, and vessels operated by overseas partners.

  iv. Other support or expertise – please specify
     Support from AAD & BoM for greenhouse gas monitoring and ice core drilling

6) Do other organisations or researchers have dependencies on any of the climate science activities undertaken by your organisation, both within Australia and internationally? If so, please specify
   - The dependent organisation
   - The activities, outputs, infrastructure or support and expertise provided by your organisation that are relied upon
   - The nature of these dependencies (e.g. formalised in a contract, informal collaboration, no specific links)

   1. DoE:
      - NESP Earth System and Climate Change Hub (led by CSIRO with BoM and universities as partners)
      - Addresses a variety of priority and capability areas, incl.

- Earth systems modelling and assessment
- atmospheric dynamics
- climate variability and extremes
- regional climate projections and impacts
- carbon-climate dynamics and feedbacks
- global and regional sea-level changes
- coastal extremes, storm surge and inundation modelling, and
- ocean, land and air observations and modelling.

- DoE-CSIRO contract.
- In addition, other smaller DoE-CSIRO contracts.

2. DoET (NCRIS)/IMOS and DoET(NCRIS)/TERN:
   - CSIRO provides infrastructure (facilities), performs QC of data sets and provides ocean and atmospheric climate data to the Australian and international research community.
   - IMOS-CSIRO and TERN-CSIRO contracts.

3. BoM:
   - Assist BoM in mandated responsibilities associated with climate projections.
   - ACCESS climate model
   - Undertake observations at Cape Grim
   - Assist BoM in representation on WMO committees
   - Heads of agreement

4. ARC Centre of Excellence for Climate System Science (ARCCSS):
   - ARCCSS bases its climate modelling on the ACCESS model, and relies on CSIRO for the model development and maintenance.

5. Melbourne University:
   - User of the ACCESS atmospheric chemistry model, and relies on CSIRO for the model development and maintenance.

6. Australian Antarctic Division:
   - CSIRO provides oceanography and climate science to the Australian Antarctic Division to meet the government goal of understanding the role of Antarctica in the global climate system

7) Does your organisation collaborate formally (at an organisational level) with other organisations on climate science activities? If so:
   - Which organisations and/or individuals does your organisation mainly collaborate with?
   - On which areas of climate science does your organisation collaborate?
   - Can you describe the nature of your organisation's formal collaboration? For example, does it involve sharing information or ideas, exchanging data, working on a common climate model, using collaborator's facilities or infrastructure, co-supervision of research students, or something else?

1. BoM: Heads of Agreement
   - ACCESS climate model; climate projections
   - Sharing of information, ideas, exchanging data, working on common climate and weather model, sharing infrastructure (NCI), co-supervision of research students.

2. NOAA and JAMSTEC: MOUs

Joint work on ocean acidification, ocean observing system. Exchange of data. Cooperative flask network (greenhouse gases).

3. UTas/IMAS: Contract
   Quantitative Marine Science Program: joint supervision of postgraduate students in climate science.

4. Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) (CSIRO, UTas, BoM, AAD, DoE plus international partners): UJV
   Integrated research program on oceans, atmosphere, cryosphere and ecosystems of the Southern Ocean and Antarctica, including observations, modelling, student supervision and research delivery.

5. UTas/IMAS, AAD, CSIRO O&A: Agreement
   ARC SRI GATEWAY Partnership: research cruises in Southern Ocean to measure climate change and investigate ocean-ice ice shelf interactions, joint supervision of postgraduate students and PDFs. Measurement of greenhouse gases in Antarctica.

6. Atmospheric Unified Model (UM) Consortium (UK Met Office, Bureau-CSIRO, KMA, NCMRWF and NIWA).

7. ARC Centre of Excellence for Climate System Science (ARC CSS): CSIRO contributes 4 Partner Investigators.

8) Does your organisation provide support directly to organisations in Australia or overseas that are responsible for shaping or implementing the national or international response to climate change (e.g. Department of the Environment, UNFCCC and subsidiary bodies, Climate Change Authority, WMO, international observing networks, international climate research programs)? If so, please outline the nature of that arrangement

1. DoE: NESP ESCC Hub – see comments under (6) above. Also: top-down synthetic greenhouse gas emissions estimates, subsequently submitted by DoE to UNFCCC reporting along with bottom-up estimates.
2. WMO (through BoM): CSIRO contributes to Cape Grim observations, especially through the associated science program. Cape Grim is one of the premier WMO GAW global stations.
3. WMO – World Climate Research Programme (WCRP): CSIRO contributes expertise (through committee participation) and model projections (using ACCESS, for the WCRP's Coupled Model Intercomparison Project (CMIP)).
4. GOOS: CSIRO contributes through IMOS to the GOOS, e.g. Argo data, and through non-IMOS observational programs (e.g. repeat hydrography).
5. Global Carbon Project (GCP), sponsored by: the International Geosphere-Biosphere Programme (IGBP), the International Human Dimension Programme (IHDP), the World Climate Research Programme (WCRP), and Diversitas. CSIRO hosts Executive Office.
6. IPCC: sponsored by United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO). CSIRO contributes Lead Authors, model projections (ACCESS), greenhouse gas observational data, and science that informs IPCC assessments
7. Advanced Global Atmospheric Gases Experiment – Cape Grim is one of the core stations in this observational network that is funded by NASA/MIT.

9) Does your organisation consider some or all of its work **critical** to the understanding of Australian and regional climate, for responding to climate change, or otherwise essential to the national interest? If so, why?

All of the climate work in CSIRO is work critical to the understanding of Australian and regional climate and for responding to climate change. However, climate research in CSIRO can only be sustained with sufficient

external funding (which has been declining in recent years, see answers to Question 10).

Why:

- improve our understanding of Australia's future hydroclimate, to inform planning, infrastructure and investment for Australia's future water resources management;
- track, understand and predict future changes in greenhouse gases and Australia's carbon budget, to support and inform Australia's emissions mitigation policy responses;
- improve our understanding of current and future climate variability and extremes in the Southern Hemisphere, and improve the quality and delivery of this information, to enable greater resilience to extreme weather and climate events;
- provide access to nationally coordinated and refined knowledge, information and data on how Australia's coastal climate will change in the future, to inform coastal planning, investment and development, and
- develop and deliver improved climate change and climate variability information relevant to ecosystem function and food production, to inform agency and sector decision-making and planning.

CSIRO's specific contributions to the national effort to address these goals include:

- Leading the development, improvement and maintenance of the ACCESS earth system model, including the CABLE land surface model developed by CSIRO.
- Lead agency for the collection and interpretation of ocean observations in Australia, including physical and biogeochemical observations.
- Lead agency for measurements of greenhouse gases in the atmosphere and ice cores.
- Lead agency for delivery of climate change information to end users, including projections and scenarios.
- Lead agency for global carbon cycle research and for ocean carbon and acidification.
- Australia's contributions to IPCC (models, lead authors, greenhouse gas measurements and science on oceans, sea level, greenhouse gases, impacts, etc).
- Significant contributor to the national research effort on climate variability and its impacts on Australian climate, the impact of climate change on modes of variability, delivery of climate knowledge to inform mitigation and adaptation strategies, ice - ocean – atmosphere – land interactions, detection and attribution of climate change, and analysis of pathways to a low carbon future.

THE CLIMATE SCIENCE RESEARCH ENVIRONMENT

This section asks about how climate science in Australia is supported and workforce issues.

10) Please tell us about the **nature** of the **resourcing** that supports your organisation's climate science activities (both funding and in-kind support).

- How are your organisation's climate science activities funded– please select all that apply and indicate funding amounts provided in in the last 5 years:
  i. Competitive grants – ARC Discovery/Linkage
  ii. Internal university grant scheme
  iii. General university funds
  iv. ARC Fellowship (DECRA/Future/Laureate)
  v. ARC Centre of Excellence
  vi. Other competitive grant – please specify
  vii. Other grant type or contract – Government
  viii. Other grant type or contract – Defence
  ix. Other grant type or contract - international
  x. Organisational internal funding
  xi. Private sector funding
  xii. Philanthropic grant/award
  xiii. Other – please specify

Oceans and Atmosphere:

External revenue ($m)

Funding Category	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016 (to May)
ACE CRC	1.75	0.81	0.62	0.61	0.86	0.99
ARC Fellowship	0.00	0.00	0.21	0.19	0.19	0.15
General University funds	0.01	0.01	0.00	0.24	0.24	0.06
Other grant type or contract - Government	19.21	18.32	15.39	10.61	9.86	7.51
Other grant type or contract - International	4.87	0.57	1.22	0.70	0.61	0.34
Private sector funding	0.85	0.24	0.38	0.62	0.62	0.22
Grand Total	**26.68**	**19.94**	**17.81**	**12.97**	**12.37**	**9.28**

- Do the climate science activities in your organisation receive support in other ways, such as in-kind support or in-house expertise? If so, please specify.

  Most of the climate activities in CSIRO are co-invested with external customers. CSIRO usually covers a significant fraction of the direct costs and overheads.

  In addition, CSIRO Oceans and Atmosphere has supported fully appropriation-funded climate projects that are aligned with its strategy.

  High performance scientific computing for CSIRO is provided by NCI as a share based pro rata on CSIRO funding contribution to total NCI budget. CSIRO climate science uses a portion (typically order 25-30%) of the total CSIRO share of NCI resources.

11) Please tell us about the **adequacy of** the **resourcing** that supports your organisation's work:

- Is the resourcing that supports your organisation research adequate? If not, does it suffer from a lack of a **specific capability**?

  Reductions in appropriation and external funding in recent years have led to a significant decline in resources supporting climate science in CSIRO. Support for the fundamental science that underpins delivery of climate information to users is particularly at risk, as funders focus on delivery and use of end products rather than the science advances that support them. The decrease in resources has reduced CSIRO's ability to deliver research, observations and models that other research providers and research users in Australia depend on.

- If your organisation received 30% less support, what would be the likely impact?

  Given recent reductions in internal and external funding, a further cut of 30% would mean that CSIRO could no longer make a significant contribution to climate science. CSIRO would likely no longer be able to support a national climate model, large-scale observations of the ocean, long-term observational programs such as Cape Grim, or contributions to IPCC. The organization would need to focus on one or two areas where it was possible to contribute.

- If your organisation received 30% more support, how would this enhance your organisation's research?

  An increase of 30% would be sufficient to restore CSIRO's research effort in climate science to the level of six months ago, still significantly below funding levels of a few years ago.

12) Does your organisation have to reapply for resourcing and/or employment on a regular basis, or is resourcing generally continuing (or a combination)? Does the level of security of resourcing affect your organisation's work, and if so, how?

    CSIRO operates on a 4-year rolling budget cycle. Combined with fluctuations in the external funding environment and changing strategic priorities, this dependency creates some fluctuations in resourcing and employment. To secure internal and external funding, climate researchers need to frequently reapply for resourcing. Also see answer to question 4 regarding external revenue streams.

13) Are there functions or capabilities resident in your organisation that your organisation is uniquely placed to house or undertake? For example, is there something that another organisation would find very difficult to replicate due to current funding models or other institutional or capability barriers? If so, please explain why.

    - CSIRO is the key developer of the ACCESS climate model, which no other Australian agency and university can easily replicate.
    - Long-term measurement programs requiring an enduring commitment.
    - Atmospheric and ice core measurement capability (Ozflux, AeroSpan, Cape Grim (science program)): Aspendale GASLAB and ICELab infrastructure and capability and calibration standards.
    - Ocean observing and analysis capability, including both IMOS facilities (moorings, Argo, SOOP and satellites) and non-IMOS measurements (e.g. deep hydrography, process studies).

14) Please tell us about the state of the climate science workforce in Australia.
    a. Is the workforce currently adequately equipped to provide an appropriate level of information to the government and community on climate science and climate change?

       There are a large number of science questions still unresolved, especially regarding the local and regional implications of a changing climate on Australia. At current resourcing levels, although Australia retains capability to address most or all of the important scientific questions, our ability to respond quickly or with deep knowledge may be compromised.

b. Is there a critical mass of scientists for the effective conduct of climate science in Australia? Is Australia significantly below or above that level currently?

   Australia is likely below critical mass. For example, the effort devoted to the Australian climate model is a small fraction of that deployed by other nations.

c. Where do you think the major gaps are in current capabilities to maintain an appropriate climate science workforce in Australia? e.g. PhD, postdoc, early or mid career?

   Early and mid-career researchers due to limited job (and funding) opportunities in Australia.

OTHER MATTERS

15) Are there any other matters that your organisation wishes to raise?

CSIRO believes that climate science has great potential to deliver national benefit by preparing Australia to respond effectively to the challenges of a variable and changing climate. To deliver on this potential, the national climate science effort needs to be better integrated, collaborate more effectively and be adequately resourced. CSIRO sees the CSIRO Climate Science Centre as a stepping stone towards this goal.

The Committee thanks you for your time and effort in replying to this consultation. Your contribution will help draw a complete picture of climate science in Australia.

Australian Climate Science Capability Review – Organisational Consultation Paper: Question 3 (information provided in this table is only approximate)

	Number of FTE undertaking the activity/research (as of 31 March 2016) – does not include students	Types of position (e.g. technician, research student, junior researcher, researcher, senior researcher, manager), undertaking the activity/research	Level of funding supporting the activity (indicative)	Duration of funding/commitment	Infrastructure associated with activity	Maintenance tasks associated with the activity
1. Climate Observations a) Monitoring of temperature, precipitation and run-off b) Records of CO_2, other greenhouse gas and aerosols from the Cape Grim base-line station or other monitoring stations c) Ice core records and other paleoclimate	O&A: 26	O&A: all of these. Teams (approx. size: 5-10 staff) are typically led by one or two senior researchers and include mid and junior researchers. Due to reduction in Government funding in recent years and associated reduced recruitment the age profile is shifting towards more senior staff. Students are part of some teams (co-supervised by CSIRO staff).	O&A: most of the activities are supported by Government, e.g. DoET, DoE, DIIS (see table under Q 10). Mostly through ACCSP, ACE-CRC, IMOS, TERN, PCCSP, PACCSAP, NESP ESCC Hub etc. plus international funding agencies (e.g. ADB)	O&A: projects are typically 1-5 years.	O&A: Mooring workshop, Argo lab, electronics lab, RV Investigator (operated by MNF), Cape Grim (operated by BoM), TERN flux towers, gas lab, ice lab, …	O&A: IMOS and TERN facilities operated by CSIRO
2. Climate Processes a) Atmospheric, e.g. convection, clouds, aerosols b) Oceanic, eg. changes in ocean salinity, temperature, acidity, sea level and Southern Ocean sea ice extent and thickness c) Surface-atmosphere, eg. measurement of the fluxes of carbon, water and energy between the Earth's surface and the atmosphere d) Natural and anthropogenic radiative forcing	O&A: 29				O&A: As above	O&A: As above

3. Climate Understanding a) Modes of variability e.g. MJO, ENSO b) Detection/attribution c) Extreme weather events, such as the frequency and intensity of tropical cyclones, heat waves, droughts, thunderstorms, heavy rain and hail d) Interpretation and analysis of climate observations e) Greenhouse gas emissions estimation	O&A: 19				O&A: N/A	O&A: N/A
4. Climate model development, prediction and projections (global and regional) a) Development of the Australian Community Climate and Earth System Simulator (ACCESS) b) Climate simulation and projection, including modelling contribution to IPCC Assessment Reports. c) Carbon cycle modelling, including lead development of the ACCESS land surface and ocean biogeochemistry components, CABLE and WOMBAT, respectively. d) Atmospheric chemistry modelling e) Models and output data made accessible broadly via CWSLabs and the Earth System Grid (ESG), respectively. f) Regional climate modelling and climate change downscaling	O&A: 36				O&A: NCI Supercomputer plus numerous high-end workstations, NCI storage capacity	O&A: N/A

g) Decadal prediction (experimental) h) Development of global greenhouse gases budgets.						
5. Linking climate with social and economic systems (e.g. users of climate information)	Agriculture: 5[1] O&A: 21 L&W: 20 Energy: 4	Agriculture: all of these O&A: all of these L&W: all of these Energy:	Agriculture: all of the activity is supported by industry. Mostly rural research and development corporations (grains, meat, dairy, wool, cotton) and also the Department of Agriculture under its various climate change schemes in recent years O&A: see O&A comments above L&W: Government (e.g. DFAT) and international/ philanthropic (e.g. Gates Foundation) Energy: ~250K (~1 FTE)	Agriculture: projects are typically 3-5 years. The 5 FTE is an average annual level of support from industry and government O&A: see O&A comments above L&W: projects are typically 1-5 years. Energy: Ongoing projects incorporating	Agriculture: None. Work is predominantly desktop-based O&A: see O&A comments above L&W: N/A Energy: N/A	Agriculture: N/A O&A: N/A L&W: N/A Energy: N/A

[1] The activities conducted by CSIRO Agriculture are largely able to be categorised as follows: (1) integration of climate forecasts into predictive models, (2) assessment of climate impacts, (3) assessment of adaptation options to climate change and variability, (4) assessment of spatial and temporal patterns in key climate variables across agricultural regions, (5) development of predictive relationships between key climate variables and production variables.

		(Principal Research Scientist x 1, Senior Research Scientist x 2, Research Scientist x 1)		climate information into forecasting		
6. Any other climate science activities not specified elsewhere	N/A					