INTRODUCTION TO
CLIMATE CHANGE SCIENCE

Leanne Webb, representing the Stream 2, Element 1 team

TUESDAY 15TH APRIL 2014
Record of observations

State of the Climate 2014 draws on an extensive record of observations and analysis from CSIRO, the Bureau of Meteorology, and other sources.

Source: Bureau of Meteorology and CSIRO
WHAT HAS BEEN OBSERVED?
The picture of a warming world

Indicators of a world experiencing a consistent pattern of warming.

1 With regional variation (almost all glaciers worldwide losing mass but some gaining) but overall net loss.

2 With regional variation (large loss in the Arctic, small net gain in the Antarctic) but overall net loss.
Global temperatures have increased
Global temperatures have increased

Each of the last three decades has been successively warmer at the Earth’s surface than any preceding decade since 1850.
The picture of a warming world

The oceans are warming
Sea level is rising
Arctic sea ice is declining
Australian temperatures have risen since 1910, especially since 1950, with the trend occurring against a background of year-to-year climate variability.

Warming over Australia has been consistent with warming in the surrounding oceans.

Time series of anomalies in sea-surface temperature and temperature over land in the Australian region. Anomalies are the departures from the 1961–1990 average climatological period. Sea-surface temperature values are provided for a region around Australia (from 4°S to 46°S and from 94°E to 174°E).
2013 - Australia’s hottest year so far

2013 hottest year on record
0.17°C warmer than 2005

and hottest summer (2012/13) and warmest spring 2013 on record

January heatwave:
Hottest day on record for Australia:
40.3°C on 7 Jan 2013

Highest recorded temperature:
49.6°C on 12 Jan 2013 in Moomba
Australian Heatwaves

Number of days each year where the Australian area-averaged daily mean temperature is above the 99th percentile for the period 1910–2013. The data are calculated from the number of days above the climatological 99th percentile for each month and then aggregated over the year. This metric reflects the spatial extent of extreme heat across the continent and its frequency. Half of these events have occurred in the past twenty years.
UNDERSTANDING
CLIMATE VARIABILITY and CHANGE
Climate change - the science is NOT new

1859
John Tyndall measures heat absorption of greenhouse gases

1896
Svante Arrhenius predicted that doubling CO2 would lead to 5-6 degree warming
What are greenhouse gases?
Without heat trapping gases in our atmosphere, the Earth’s surface temperature would be, on average, -18°C rather than the +15°C we currently experience.
Atmospheric carbon dioxide (CO₂)

The atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years.
Climate variability is influenced by various processes

Internal variability

External forcing mechanisms
Understanding climate - climate modelling
Causes of global warming

Observed warming is reproduced by models with both natural and human forcing mechanisms (e.g. Greenhouse gases).

Models with solar and volcanic forcing only predict a cooling over the last 50 years.
Attribution

[Diagram of the greenhouse effect]

[Graph of global average temperature anomaly over time]

[Graph of atmospheric CO₂ at Mauna Loa Observatory]

[Graph of temperature anomaly and volcanic eruptions]
WHAT ABOUT THE FUTURE?
Representative concentration pathways

Concentrations of most greenhouse gases are expected to rise further in the future
The world will keep warming

Global average surface temperature change

IPCC (2013)
More warming on land and high latitudes
Days over 35°C are expected to increase

<table>
<thead>
<tr>
<th>City</th>
<th>Current number of days</th>
<th>Mid-range emissions (2030)</th>
<th>High emissions (2070)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perth</td>
<td>28</td>
<td>36-43</td>
<td>48-76</td>
</tr>
<tr>
<td>Alice Springs</td>
<td>90</td>
<td>102-118</td>
<td>132-182</td>
</tr>
<tr>
<td>Dubbo</td>
<td>25</td>
<td>31-39</td>
<td>44-87</td>
</tr>
<tr>
<td>Mildura</td>
<td>32</td>
<td>36-43</td>
<td>48-76</td>
</tr>
<tr>
<td>St George</td>
<td>47</td>
<td>56-72</td>
<td>80-135</td>
</tr>
<tr>
<td>Canberra</td>
<td>5</td>
<td>7-10</td>
<td>12-26</td>
</tr>
<tr>
<td>Adelaide</td>
<td>17</td>
<td>21-26</td>
<td>29-47</td>
</tr>
<tr>
<td>Hobart</td>
<td>1.4</td>
<td>1.6-1.8</td>
<td>2.0-3.4</td>
</tr>
</tbody>
</table>

CSIRO (2007)
Sea level rise of up to 1m by 2100

IPCC (2013)
Projections indicate higher rates of warming being anticipated in the central regions, and lower rates in the coastal and southern regions. This confirms findings from the earlier studies (CMIP3).

On average, the median of temperature projections indicate that by 2090 with the highest emissions, Australia’s annual temperature is projected to be about 4.2°C higher than the 1986-2005 period.
Expected future rainfall change varies spatially

Hatch = small change (agreement) stipple = large change (agreement)

IPCC (2013)
At all points, except in the far south west, there is a wide range of change, from drying (top) through to a wetter future climate (bottom).

Median of projections indicate decreases for much of the continent, but there is little change in part of the north and also NSW.

Decreases remain large in the southwest.
Cyclone frequency may decrease, but proportion of severe cyclones could increase
Fire weather risk is likely to increase

Percent changes in the number of days with very high and extreme fire weather: 2020 and 2050, relative to 1990

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low global warming (0.4°C)</td>
<td>High global warming (1°C)</td>
</tr>
<tr>
<td>Very High</td>
<td>+2-13%</td>
<td>+10-30%</td>
</tr>
<tr>
<td>Extreme</td>
<td>+5-25%</td>
<td>+15-65%</td>
</tr>
<tr>
<td></td>
<td>Low global warming (0.7°C)</td>
<td>High global warming (2.9°C)</td>
</tr>
<tr>
<td></td>
<td>+5-23%</td>
<td>+20-100%</td>
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<tr>
<td></td>
<td>+10-50%</td>
<td>+100-300%</td>
</tr>
</tbody>
</table>

Map of study region, Lucas et al (2007)

2009 Victorian Bushfires Royal Commission report made 67 recommendations for adaptation
Availability of data and information
Climate change in Australia website
Website with user-friendly functionality

Decision tree to aid navigation around the web-site.

Lots of support and guidance material will be included.
Representing the range of climate projections

- Users of climate projections are strongly advised to represent a range of climate model results in their studies and reports.

- CSIRO’s Climate Futures approach has been developed to help capture the range of projection results relevant to their region.
Climate analogue tool
Two data types

- Projected climate changes (relative to the IPCC reference period 1986–2005), based on CMIP5 global climate models judged to perform well over Australia, plus dynamic and statistical downscaling where appropriate;

- Application-ready future climate data, where projected climate change data are applied to 30 year average climatology of observed data (1981–2010).
Spatial scale

Super-cluster cluster, sub-cluster

Gridded data

Cities and towns (limited to HQ datasets)

Wind Speed (month)

Rainfall (month)
### Projected change data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Annual (Gridded)</th>
<th>Annual (Area Avg.)</th>
<th>Seasonal (Gridded)</th>
<th>Seasonal (Area Avg.)</th>
<th>Monthly (Gridded)</th>
<th>Monthly (Area Avg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Temperature</td>
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<tr>
<td>Maximum Daily Temperature</td>
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<tr>
<td>Minimum Daily Temperature</td>
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<tr>
<td>Rainfall</td>
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<tr>
<td>Relative Humidity</td>
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<tr>
<td>Wet Areal Evapotranspiration</td>
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<tr>
<td>Solar Radiation</td>
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<tr>
<td>Wind-Speed</td>
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<tr>
<td>Extreme Rainfall (Intensity of 1 in 20 yr event)</td>
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<tr>
<td>Extreme Wind (Intensity of 1 in 20 yr event)</td>
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<td>Severe Thunderstorm Frequency</td>
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<tr>
<td>Drought (SPI-based, Duration, Frequency, Intensity, % Time)</td>
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<tr>
<td>Fire</td>
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<tr>
<td>Sea Level Rise (Mean and Extreme)</td>
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<tr>
<td>Sea Surface Temperature</td>
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<tr>
<td>Sea Surface Salinity</td>
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<tr>
<td>Ocean Acidification (Aragonite Saturation)</td>
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<tr>
<td>Tropical Cyclone Frequency/Location</td>
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<tr>
<td>Tropical Cyclone Intensity</td>
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<tr>
<td>Snow</td>
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<tr>
<td>Run-off</td>
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</tbody>
</table>

*Footnotes:

- Data for Extreme Rainfall and Extreme Wind refer to the intensity of 1 in 20 year events, determined using ARCCS-2020, and are reported in the Australian rainfall and runoff (ARR) study.
- Information on locations and specific events will be provided in the final report.
- Fire data are supplied at 30 sites (See Appendix 2).

Note: This table provides a summary of projected change data for various climate-related parameters. Further details and specific data are available in the comprehensive report.
## Application-ready data: Baseline climate + projected change

<table>
<thead>
<tr>
<th>CLIMATE VARIABLE</th>
<th>DAILY*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean temperature (°C)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Maximum daily temperature</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Minimum daily temperature</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Days above/below/between temperature thresholds</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Frequency above/below/between rainfall thresholds</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Wet areal evapotranspiration (mm)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Mean wind-speed (ms⁻¹)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Solar radiation (Wm⁻²)</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Fire weather</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Fire weather days above/below/between thresholds</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
<tr>
<td>Extreme sea level</td>
<td>TIMESERIES, AVERAGES</td>
</tr>
</tbody>
</table>

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K. ERA Interim reanalysis (10°-25° grid), but daily humidity data at cities/towns have quality control problems.
L. ERA Interim reanalysis (0.75° grid), but daily solar radiation data at cities/towns have quality control problems.
Finally...
In Australia, climate change will have a significant impact...
What can we do?

1. Prepare for and adapt to current weather risk and near-term climate change

2. Reduce greenhouse gas emissions and thereby long-term climate change
Understanding climate change - observations

- ENSO
- Volcanic aerosols
- Solar irradiance
- Anthropogenic influence

Lean et al. (2010)
Discernible human influences
The contribution of different forcing mechanisms

<table>
<thead>
<tr>
<th>Emitted compound</th>
<th>Resulting atmospheric drivers</th>
<th>Radiative forcing by emissions and drivers</th>
<th>Level of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>CO₂</td>
<td>1.68 [1.33 to 2.03]</td>
<td>VH</td>
</tr>
<tr>
<td>CH₄</td>
<td>CO₂, H₂O, O₃, CH₄</td>
<td>0.97 [0.74 to 1.20]</td>
<td>H</td>
</tr>
<tr>
<td>Halocarbons</td>
<td>O₃, CFCs, HCFCs</td>
<td>0.18 [0.01 to 0.36]</td>
<td>H</td>
</tr>
<tr>
<td>N₂O</td>
<td>N₂O</td>
<td>0.17 [0.13 to 0.21]</td>
<td>VH</td>
</tr>
<tr>
<td>Anthropogenic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>CO₂, CH₄, O₃</td>
<td>0.23 [0.16 to 0.30]</td>
<td>M</td>
</tr>
<tr>
<td>NMVOC</td>
<td>CO₂, CH₄, O₃</td>
<td>0.10 [0.05 to 0.15]</td>
<td>M</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Nitrate, CH₂, O₃</td>
<td>-0.15 [-0.34 to 0.03]</td>
<td>M</td>
</tr>
<tr>
<td>Aerosols and precursors</td>
<td>Mineral dust, Sulphate, Nitrate, Organic carbon, Black carbon</td>
<td>-0.27 [-0.77 to -0.23]</td>
<td>H</td>
</tr>
<tr>
<td>Short-lived gases and aerosols (Mineral dust, SO₄, NH₄, Organic carbon and Black carbon)</td>
<td>Cloud adjustments due to aerosols</td>
<td>-0.55 [-1.33 to -0.06]</td>
<td>L</td>
</tr>
<tr>
<td>Albedo change due to land use</td>
<td></td>
<td>-0.15 [-0.25 to -0.06]</td>
<td>H</td>
</tr>
<tr>
<td>Natural</td>
<td>Changes in solar irradiance</td>
<td>0.05 [0.00 to 0.10]</td>
<td>M</td>
</tr>
</tbody>
</table>

Total anthropogenic RF relative to 1750

- 2011: 2.29 [1.13 to 3.33] (H)
- 1980: 1.25 [0.64 to 1.86] (H)
- 1950: 0.57 [0.29 to 0.85] (M)
The global warming hiatus I

This graph of average global temperatures is generated using 42 different climate simulators, assuming 'medium' (RCP4.5) future emissions of greenhouse gases, and compares their projections to observations from the HadCRUT4 dataset. A common reference period of 1961–1990 is used, but the temperatures are presented relative to the 'pre-industrial' era.
The global warming hiatus II
Climate change will be super-imposed on natural variability

Jones (2008)
Global emission pathways for the period 2010–2050

The figure shows variants of a global emissions trend with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, annual reduction rates of 3.7% (green), 5.3% (blue) or 9.0% (red) would be required in the early 2030s (relative to 2008).

Source: WBGU
The peer-review process

Cartoon by Nick D Kim, strange-matter.net. Used by permission.
Conclusions

• Navigating the maze of information about climate change science is challenging.
• There are many robust findings about the science. These provide a basis for action through adaptation and reducing emissions.
• Understanding the range of projected future change will inform prudent adaptation actions.

By Richard Gifford
All greenhouse gases

Global mean greenhouse gas concentrations (‘ppm’ is parts per million, while ‘ppb’ is parts per billion) determined from continuous monitoring by CSIRO, the Bureau of Meteorology and the CSIRO/Advanced Global Atmospheric Gases Experiment at Cape Grim since 1976, in Antarctic firm air samples since the mid-1970s, and globally by CSIRO since the mid-1980s.