



Australian Government

Bureau of Meteorology

An update on climate change

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Royal Hydrological Society SA – 21 June 2018



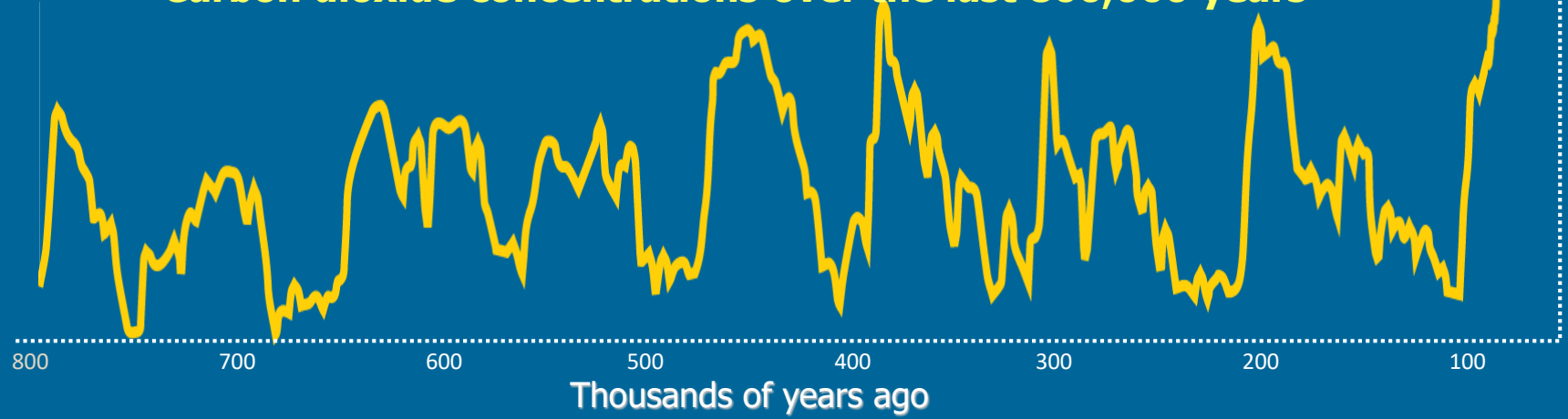
CO₂
(ppm)

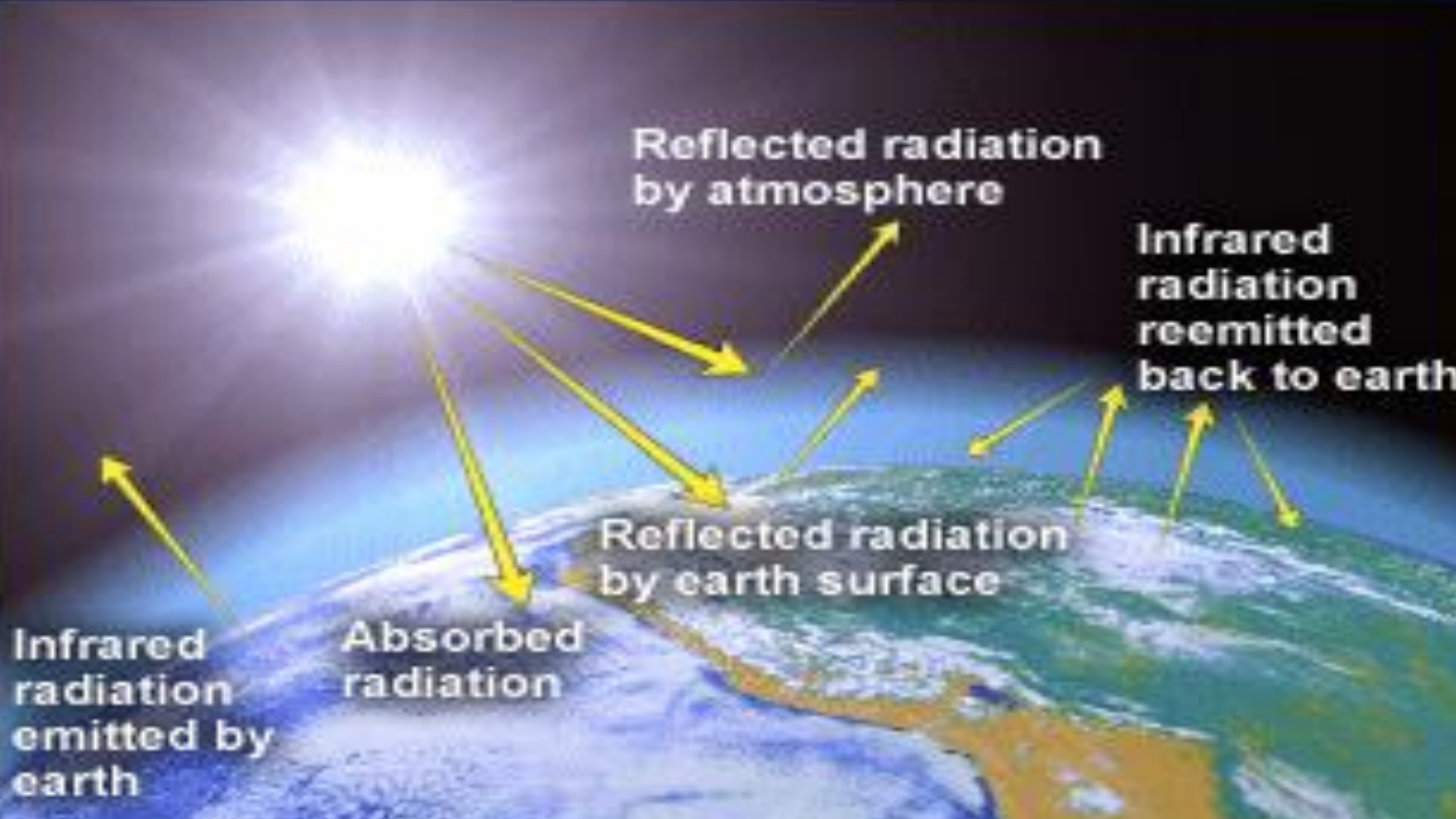
We have put a large pulse of greenhouse gases into the atmosphere over a short period

Atmospheric CO₂ concentrations currently 411ppm at Mauna Loa

1ppm increase per year now at 2-3ppm

Carbon dioxide concentrations over the last 800,000 years





Reflected radiation
by atmosphere

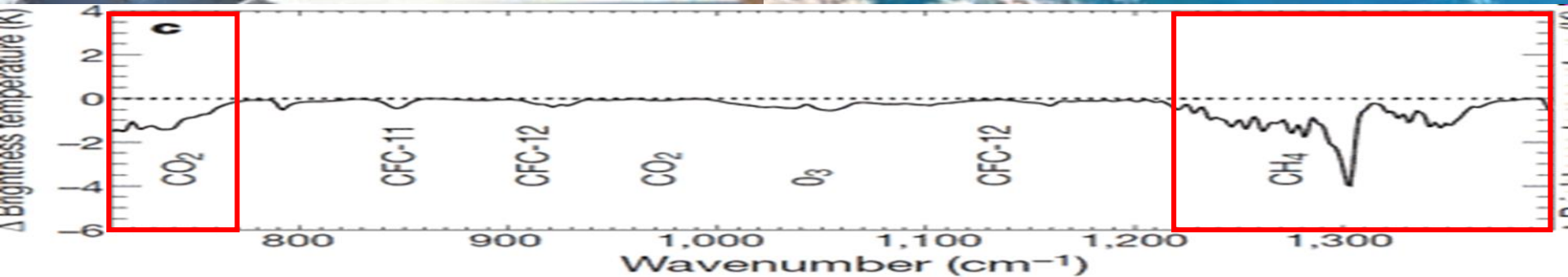
Infrared
radiation
reemitted
back to earth

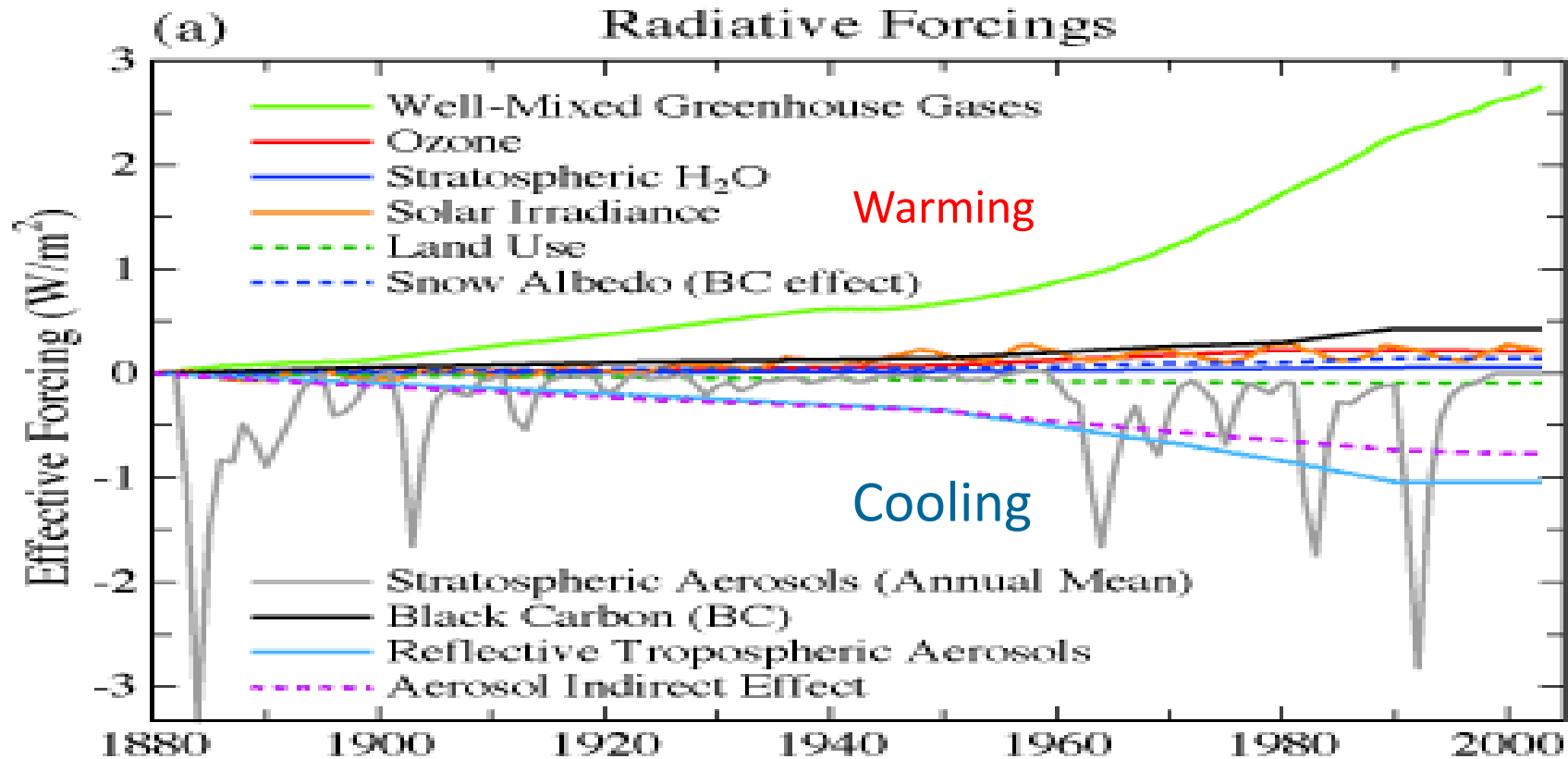
Reflected radiation
by earth surface

Absorbed
radiation

Infrared
radiation
emitted by
earth

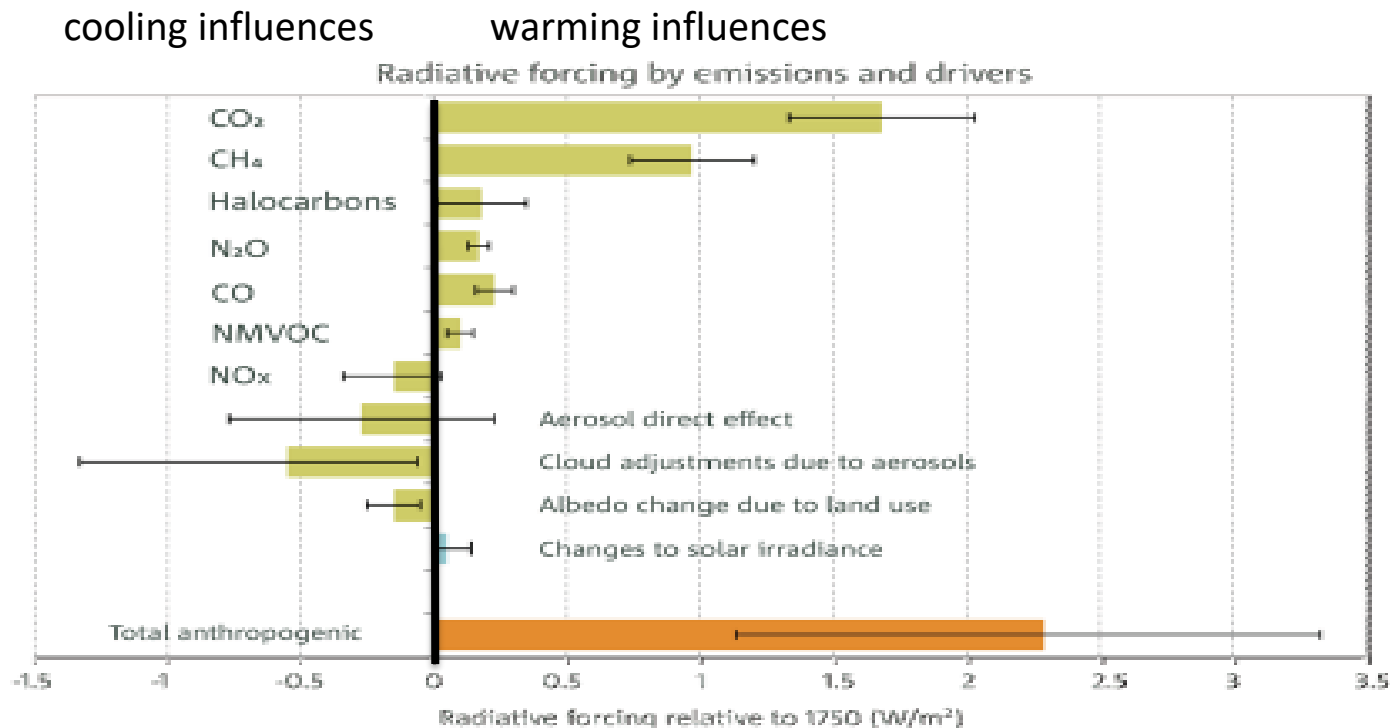
Enhancement of the greenhouse effect is being directly observed- less heat escaping to space and more measured coming back to the Earth surface. This is direct confirmation of climate science calculation and modelling [1] [2]





Greenhouse gases are not the only climate influence... but are starting to dominate

Overall extra warming is now \sim 2 Watts/square metre



Patterns of change

		Climate Drivers			
		Greenhouse Gases	Sun	Volcanoes	Internal Variability
Climate Patterns	Cooling upper atmosphere	✓	✗	✗	✗
	Less heat to space	✓	✗	✗	✗
	Rising tropopause	✓	✓	✓	✗
	Annual cycle	✓	✗	✗	✗
	Daily cycle	✓	✗	✗	✗
	Ocean warming	✓	✗	✗	✗
	More heat back to Earth	✓	✗	✗	✗
	Land warming faster than oceans	✓	✓	✗	✗

✓ Consistent with Climate Driver ✗ Rules out Climate Driver

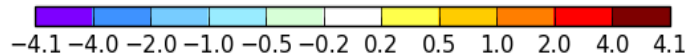
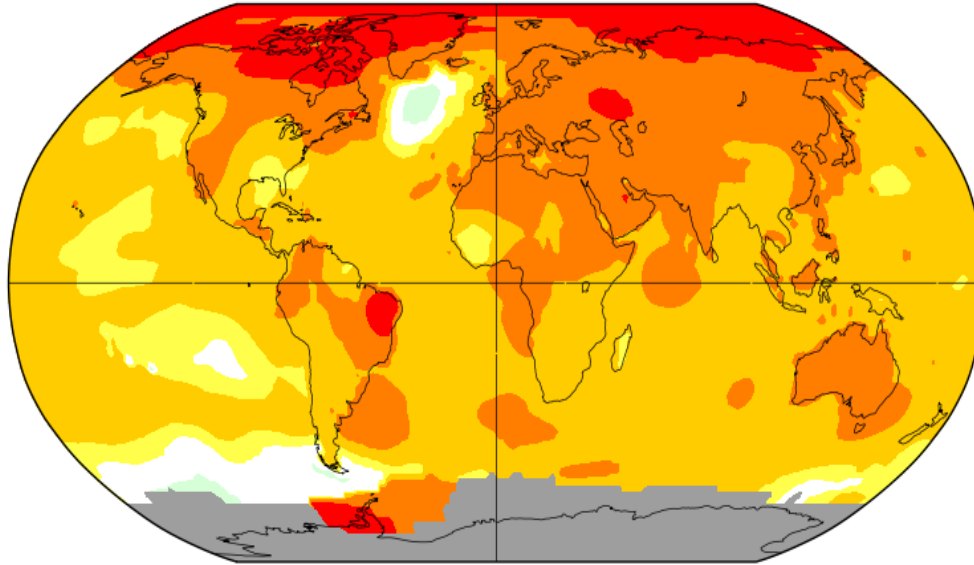
There are a range of changes being observed, all of which can only be explained by what is expected from increased greenhouse gases. No other influence explains all of these patterns of change

Warming around the globe

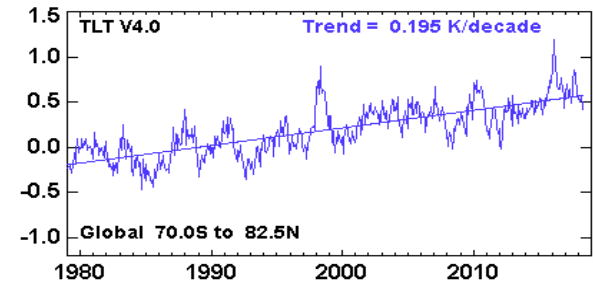
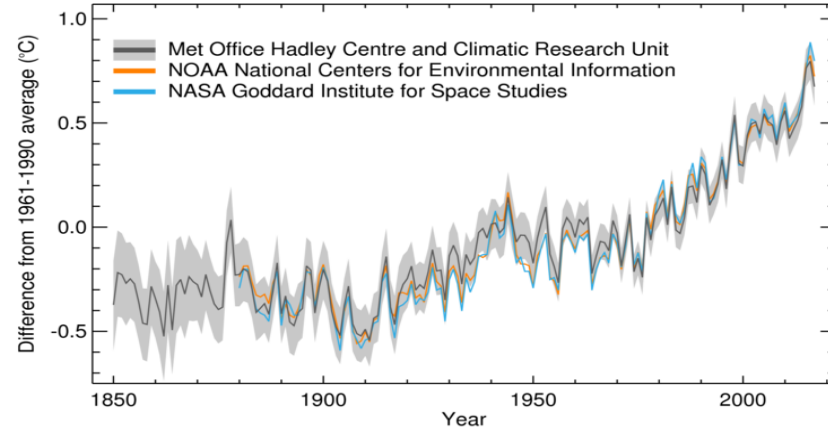
Annual J-D 2008-2017

L-OTI(°C) Anomaly vs 1880-1950

0.92



Met Office Global average temperature anomaly (1850-2017)

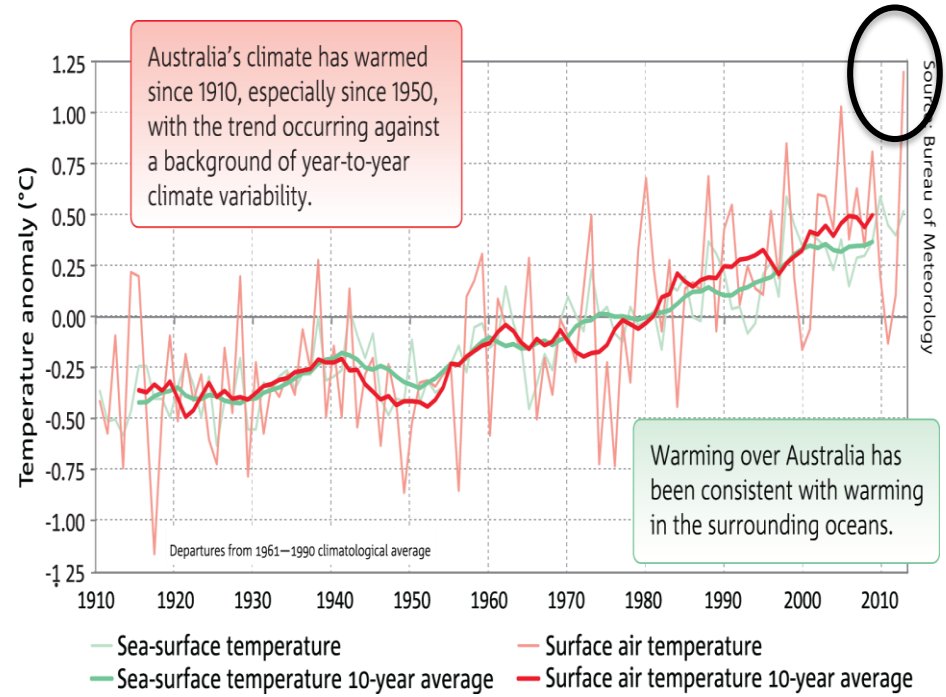
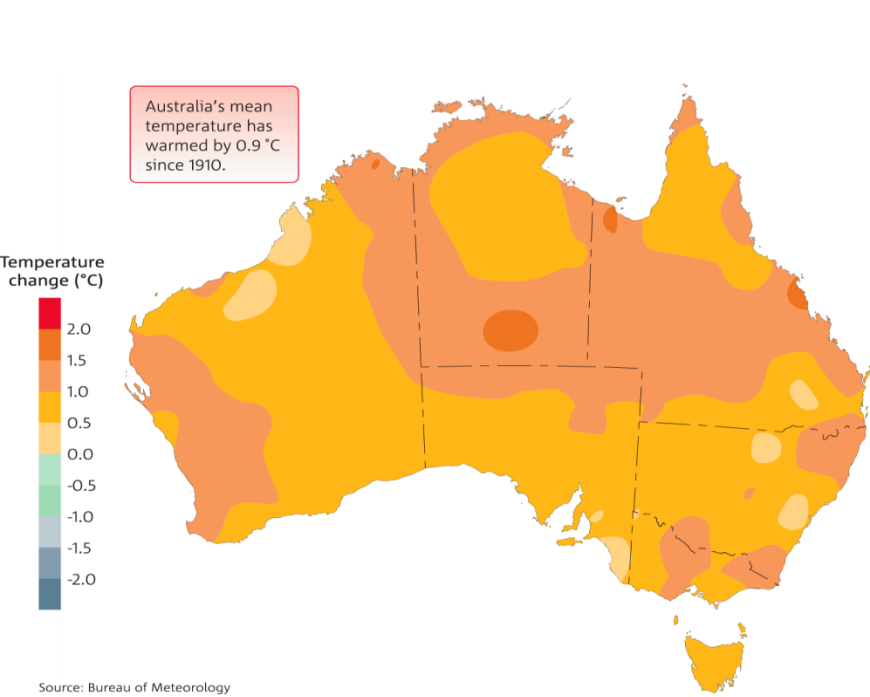


Lower tropospheric temperature from satellite

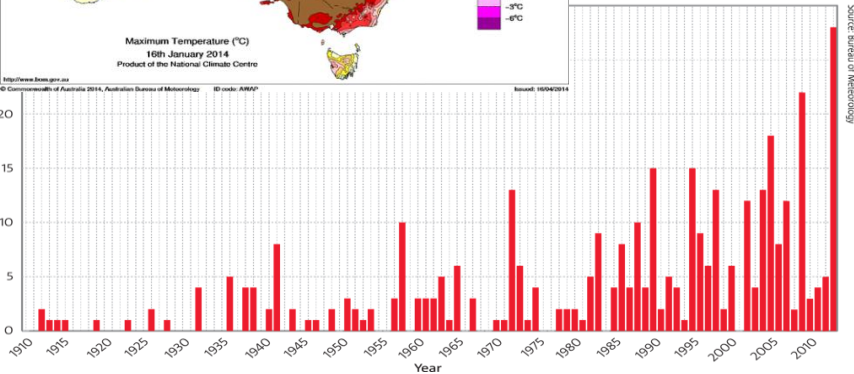
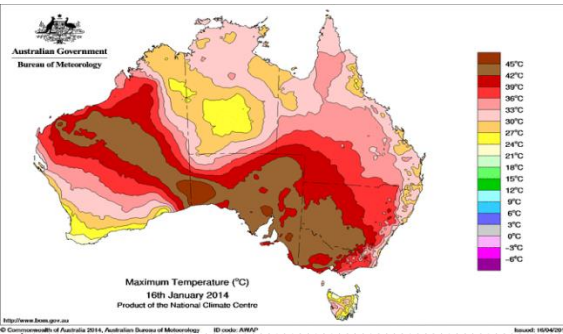
2016 was the hottest year on record globally. 2017 2nd hottest

https://data.giss.nasa.gov/gistemp/graphs_v3/ http://images.remss.com/msu/msu_time_series.html

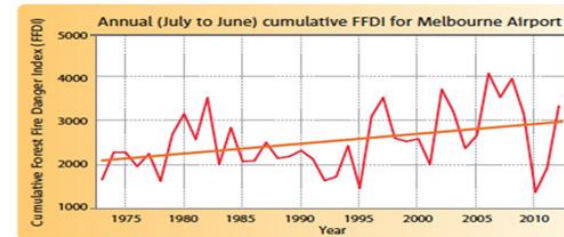
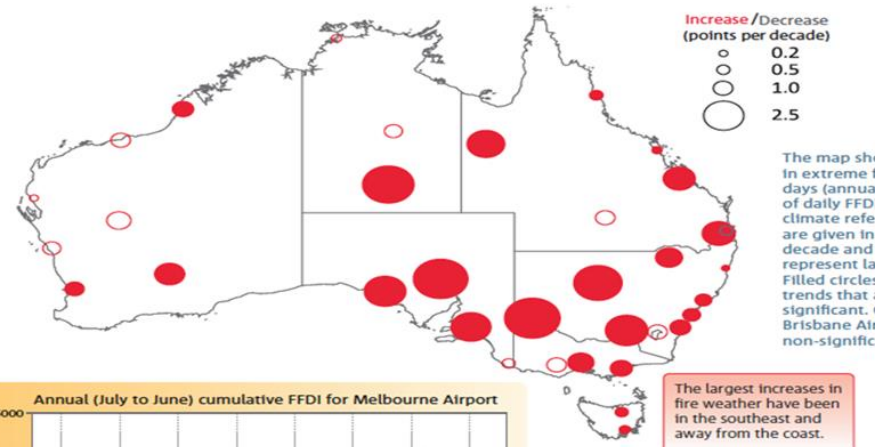
Australia is warming - on land and in the oceans



Increased heatwave intensity and increased bushfire risk



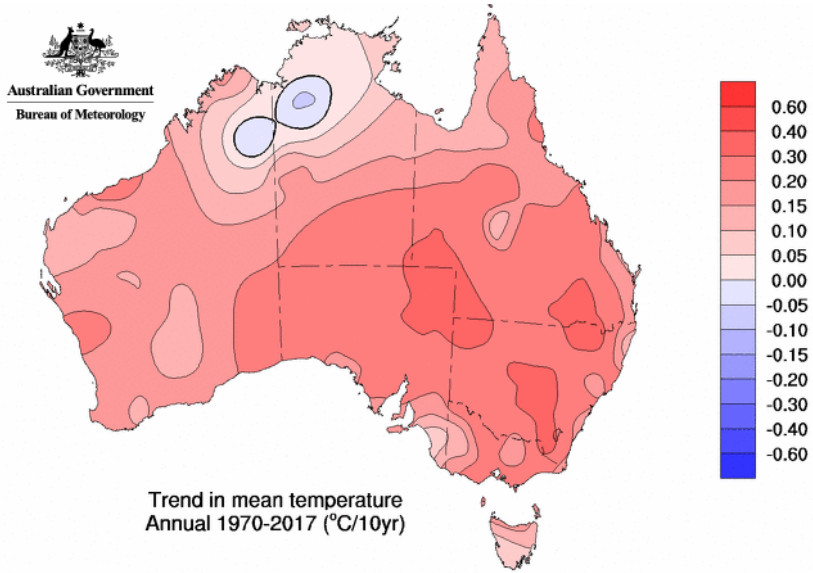
Source: Bureau of Meteorology, CSIRO and Office of Environment and Heritage (NSW)



The largest increases in fire weather have been in the southeast and away from the coast.

Time series showing the increasing trend in the annual cumulative Forest Fire Danger Index (FFDI) at Melbourne Airport. A long-term trend is discernible despite significant annual variability.

Seasonal temperatures



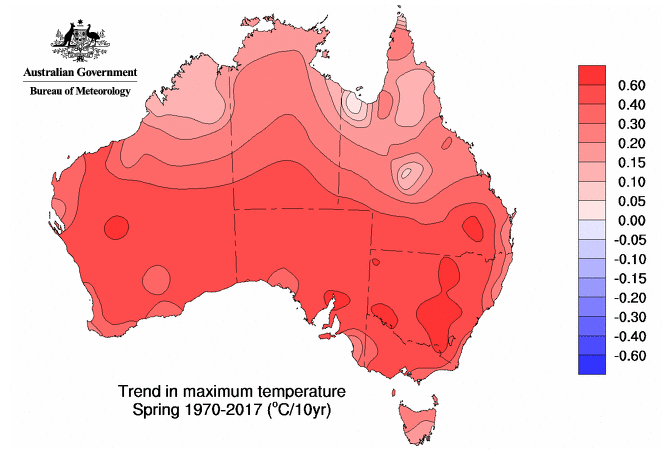
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Significant seasonal and regional variability exists in trends

Spring maximums are strongly warming

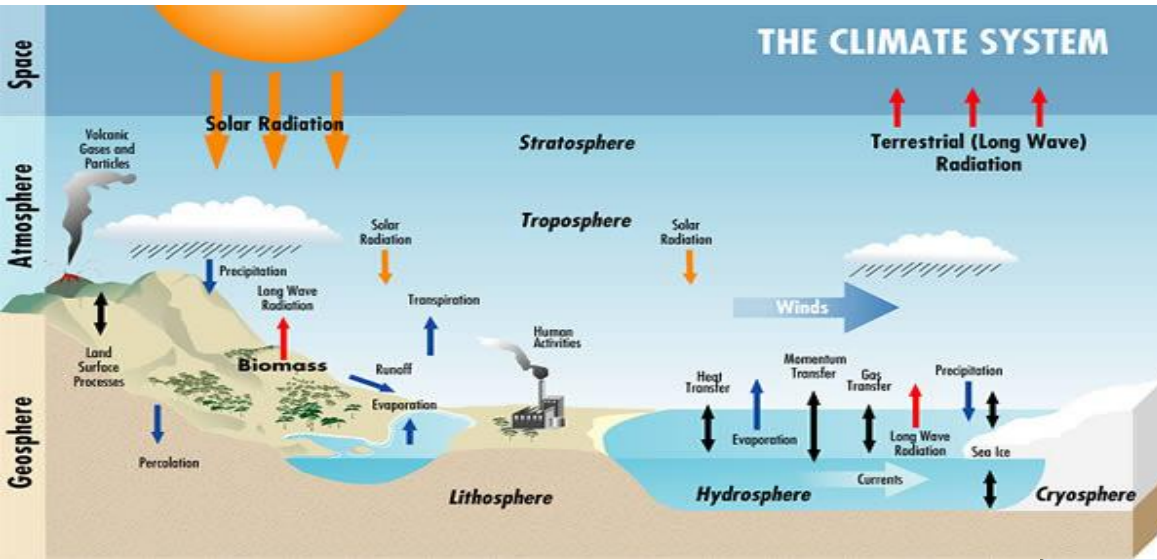
<http://www.bom.gov.au/climate/change/>



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Modelling Climate



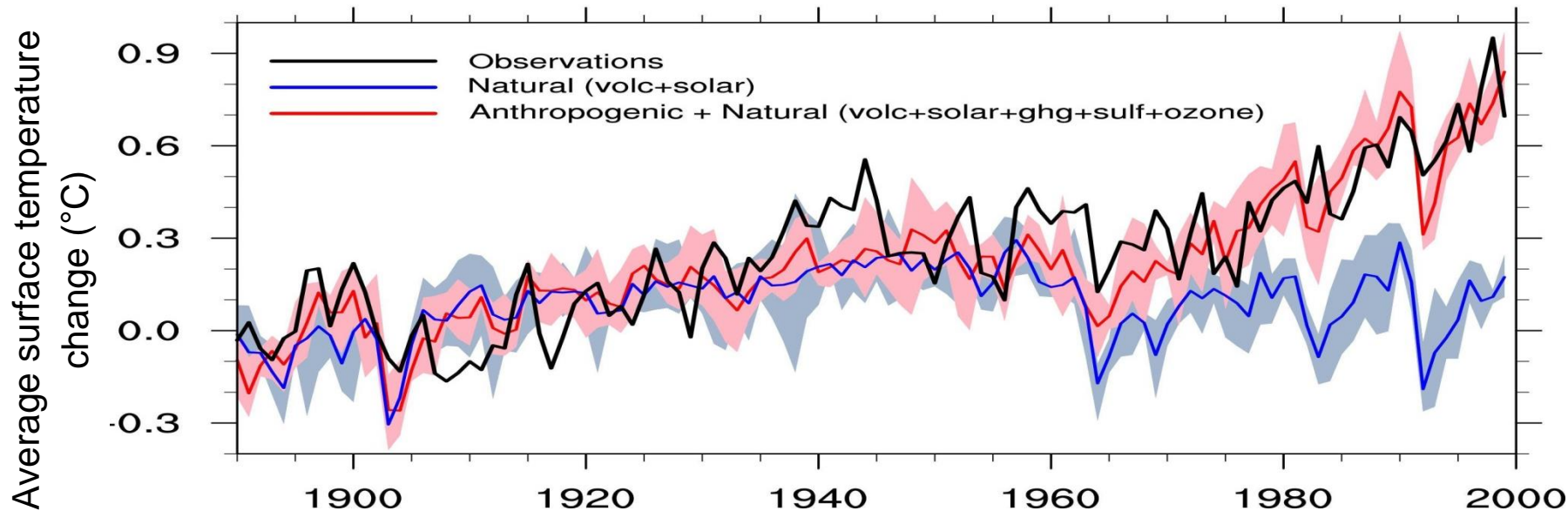
Global computer climate models are dynamical, being based on the laws of physics – calculations with conservation of energy, momentum & mass

Paleo-climate indicators provide some clues.

Global climate models are the only way to forecast future change in any detail.



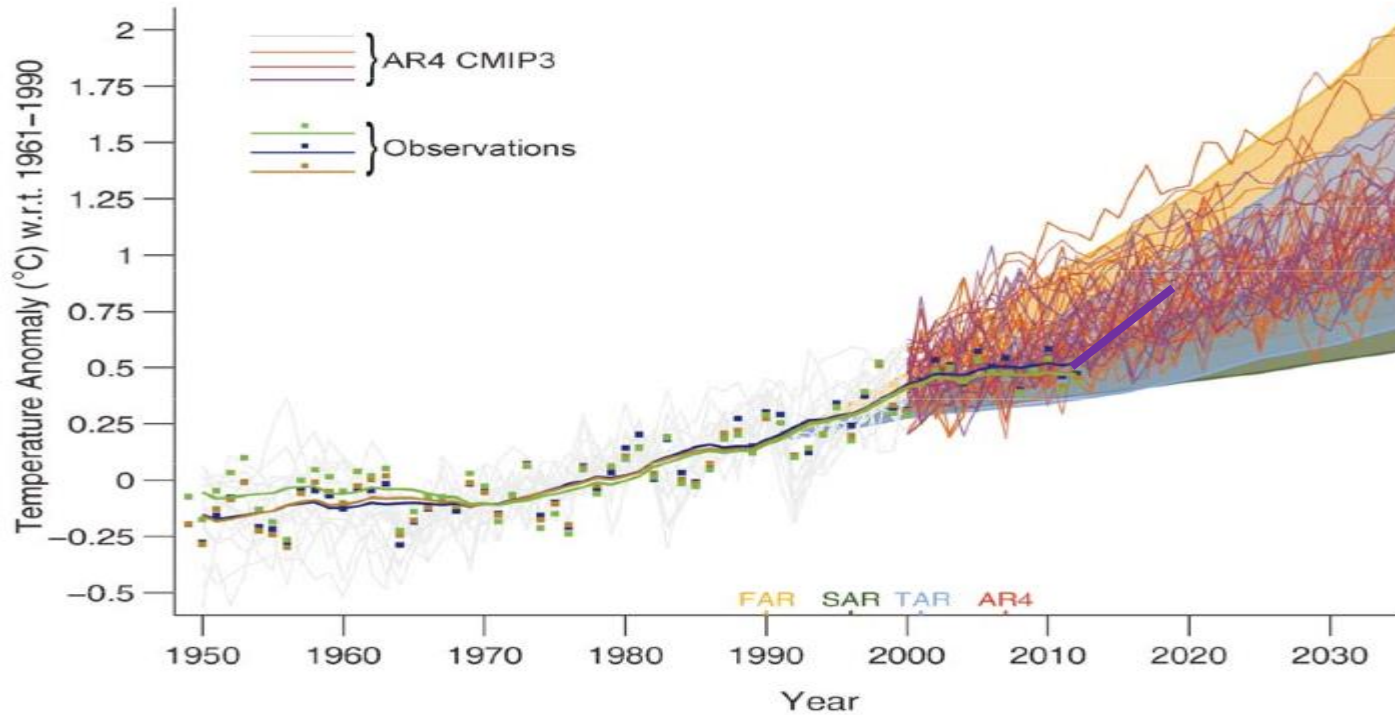
Models can perform the “control experiment” not possible in the real world



Global climate models run without increasing greenhouse gases (blue line) fail to represent actual observed temperature (black line) from the 1960's on – when greenhouse emissions strongly increased

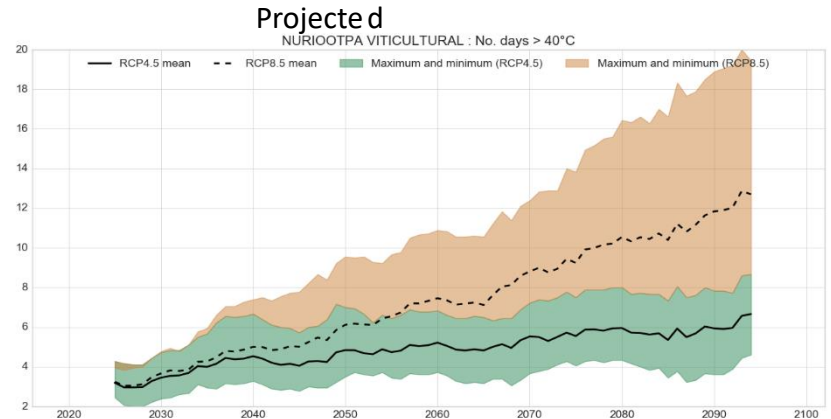
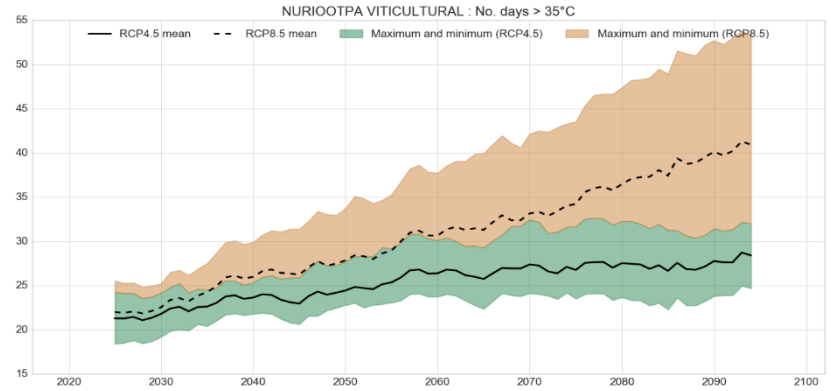
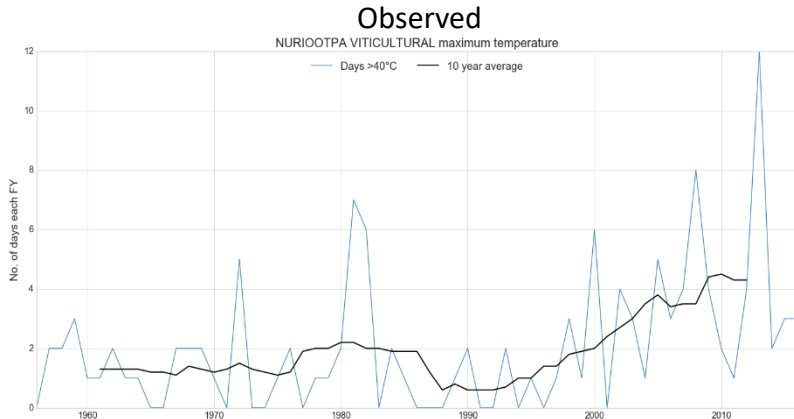
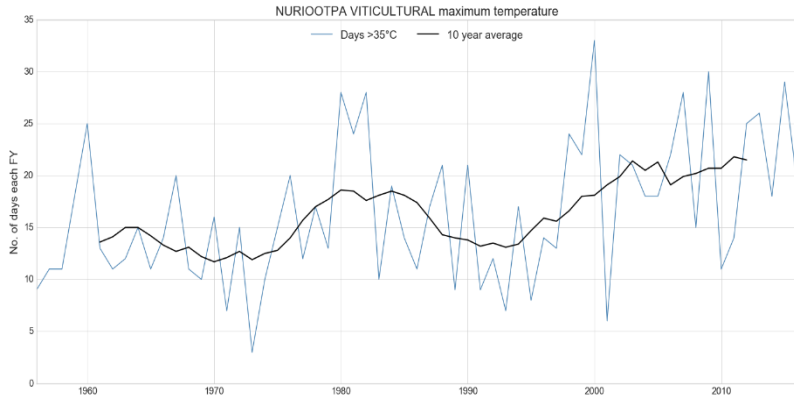
Models run with the observed greenhouse gas increase much better recreate the observed (black line) warming from 1960 on

How are the projections doing?

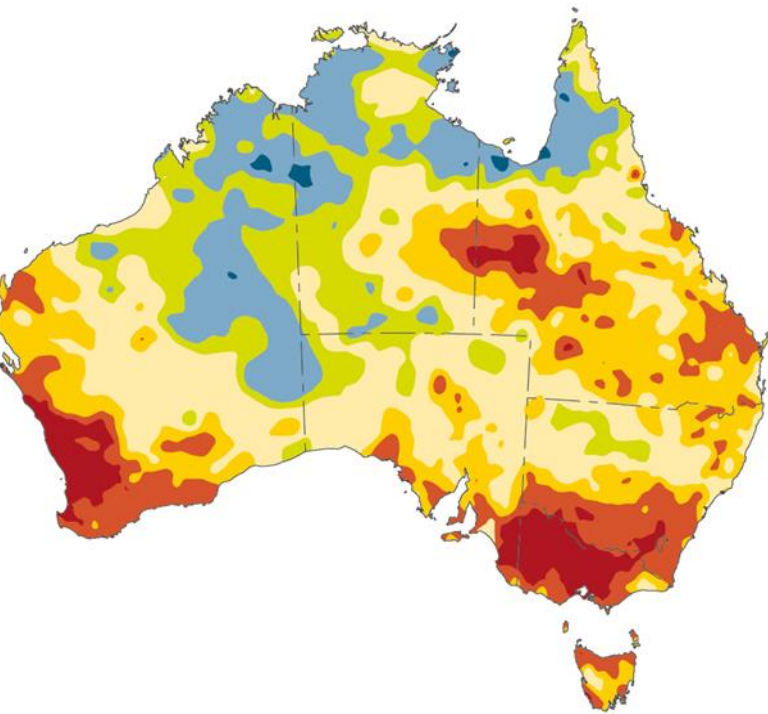


Earlier projections of warming from earlier IPCC reports (First Assessment Report – FAR and the Second and Third reports (SAR, TAR) are being seen in warming to date, after some slowdown in temperature rise through the period 2000-2013

Changes in heat extremes

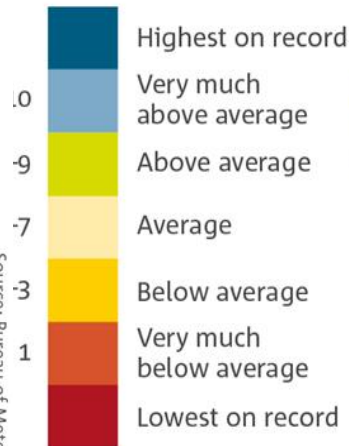


Rainfall trends

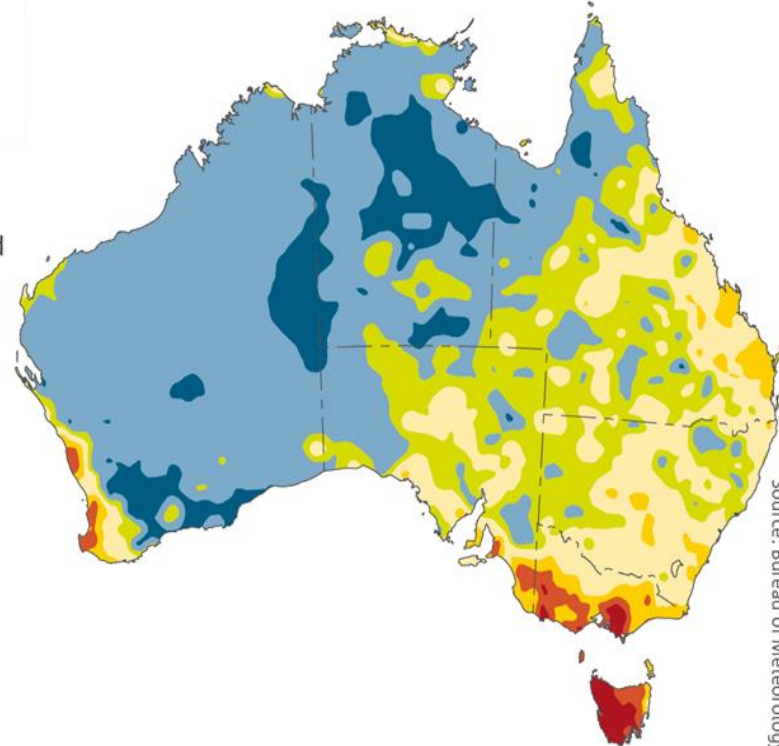


April – October

Rainfall decile ranges



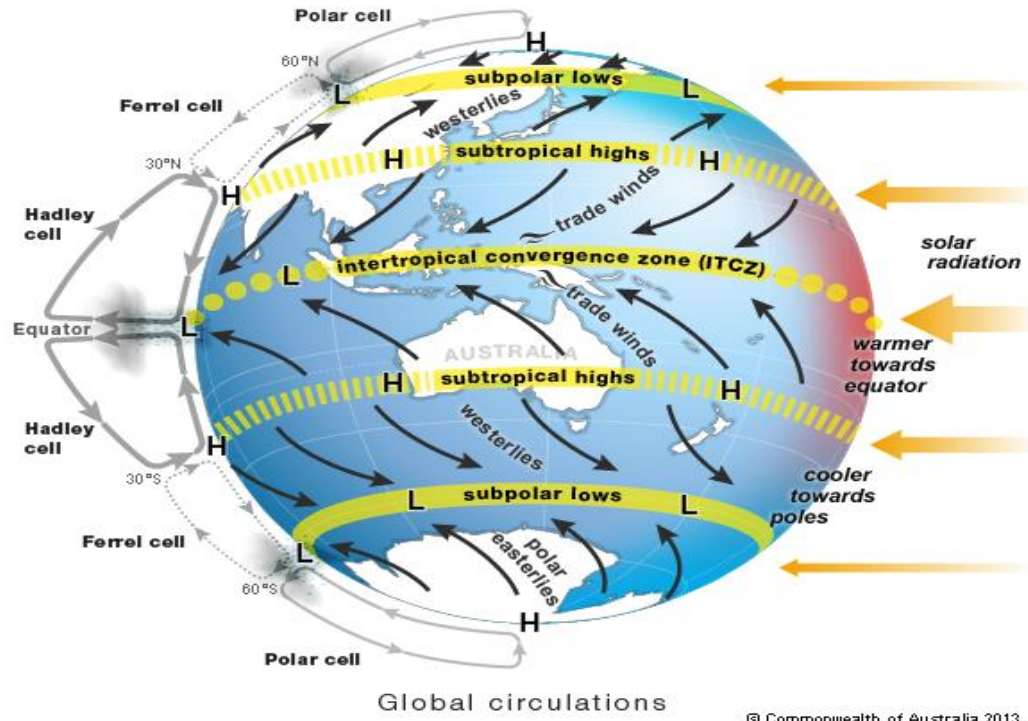
Source: Bureau of Meteorology



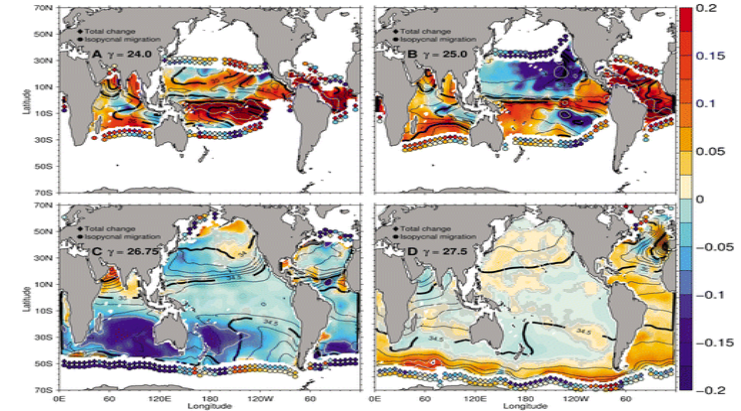
November-March

Source: Bureau of Meteorology

Influences on southern Australian rainfall



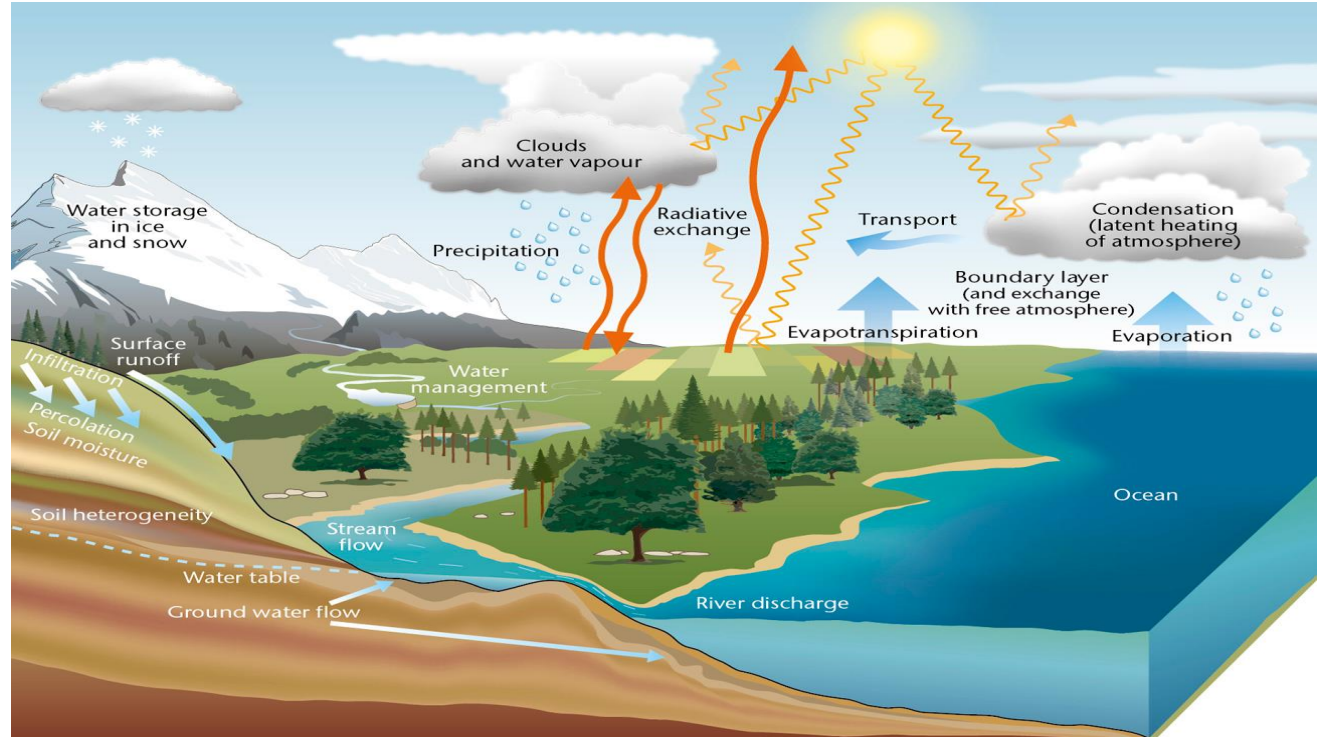
The Hadley Cell is expanding as the planet warms, meaning the tropics are widening and rain bearing cold frontal systems are staying further south in April to October



Trends in ocean surface salinity

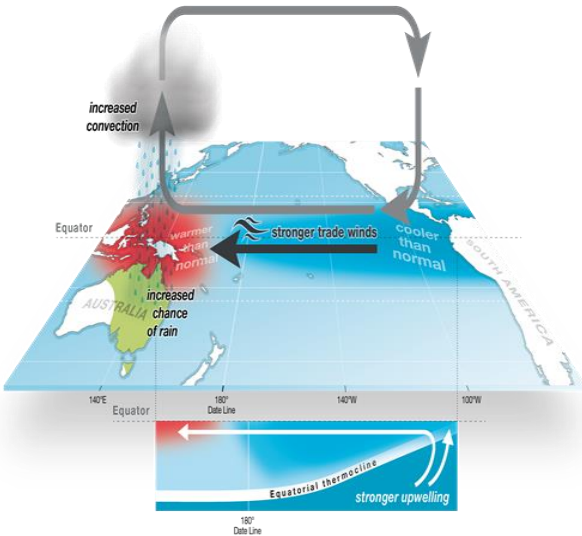
Strengthening of the hydrological cycle

More intense
rainfall
Wetter globe
– tropics and
high latitudes

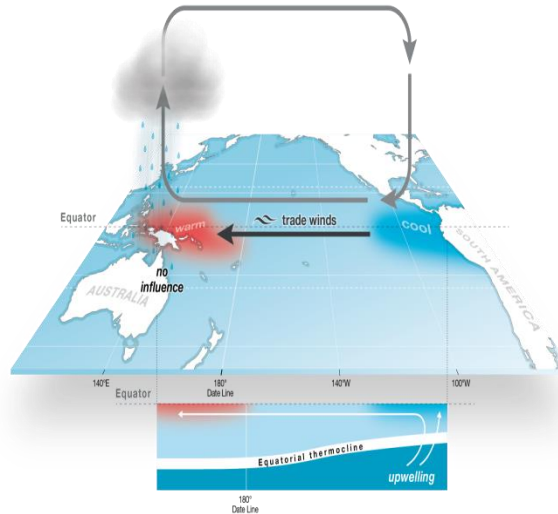


Tropical variability is a big feature of Australian climate

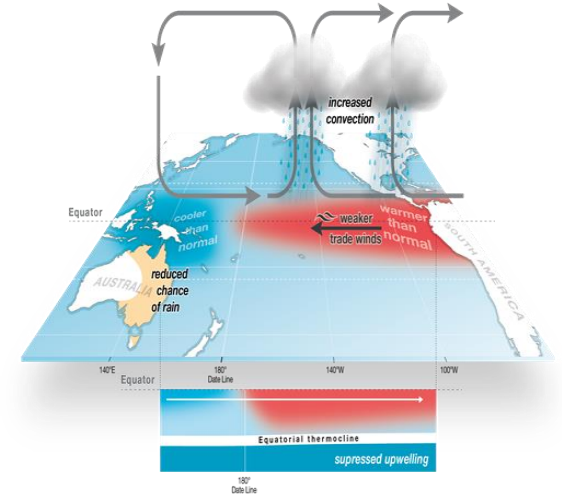
La Niña



Neutral phase



El Niño



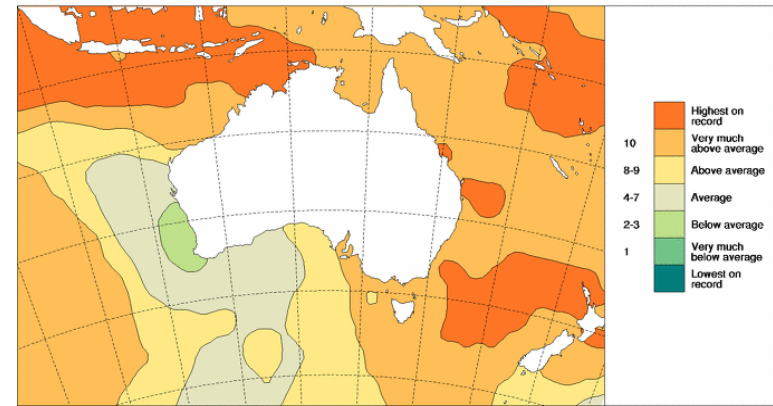
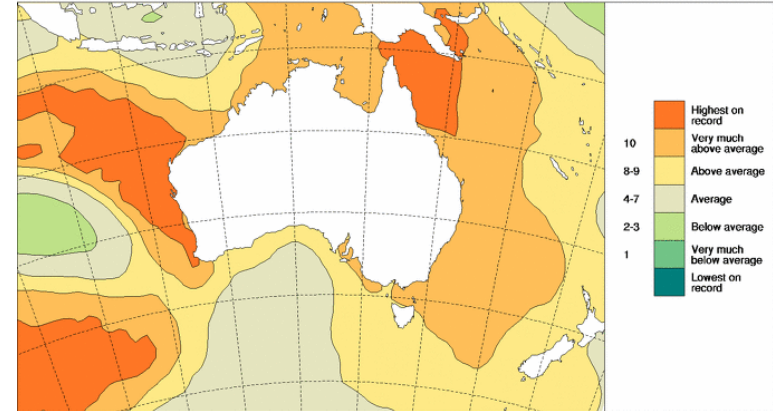
Both El Niño and La Niña are expected to get more intense under climate change

<https://www.nature.com/nclimate/journal/v5/n9/full/nclimate2743.html>

El Niño / La Niña under climate change

- Representation of El Niña/La Niña in climate change models is still not great
- In general more extreme events expected ie hotter/drier El Niño's and wetter La Niña's ie doubling under 1.5°C warming
- Area impacted expands
- 2010 La Niña was made worse by warmer oceans and increased humidity
- Record ocean temperatures supporting 2016 Negative IOD event

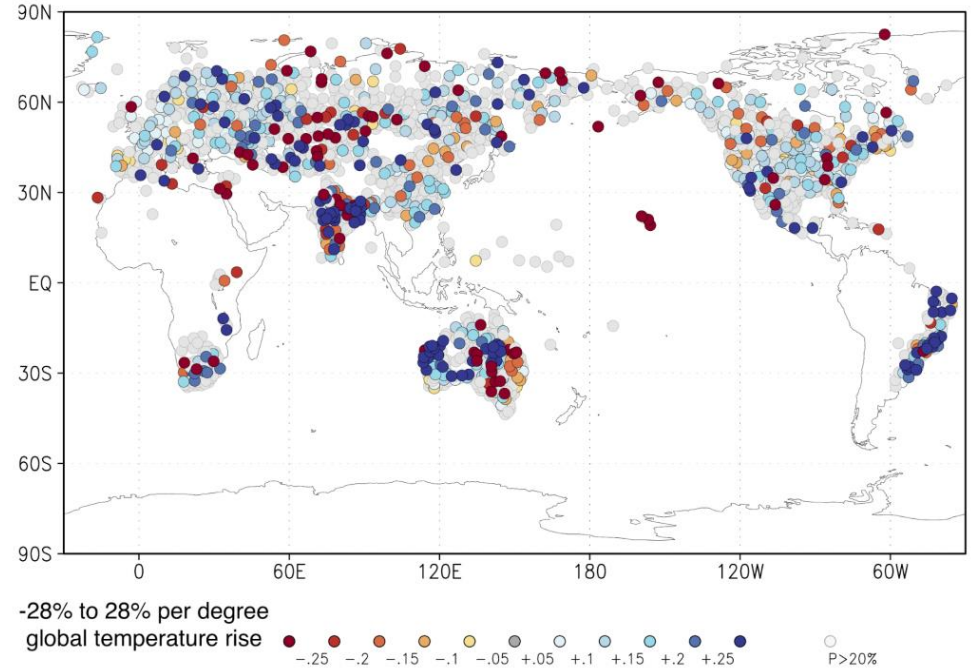
ERv5 SST PERCENTILES
December 2010
Distribution based on gridded data



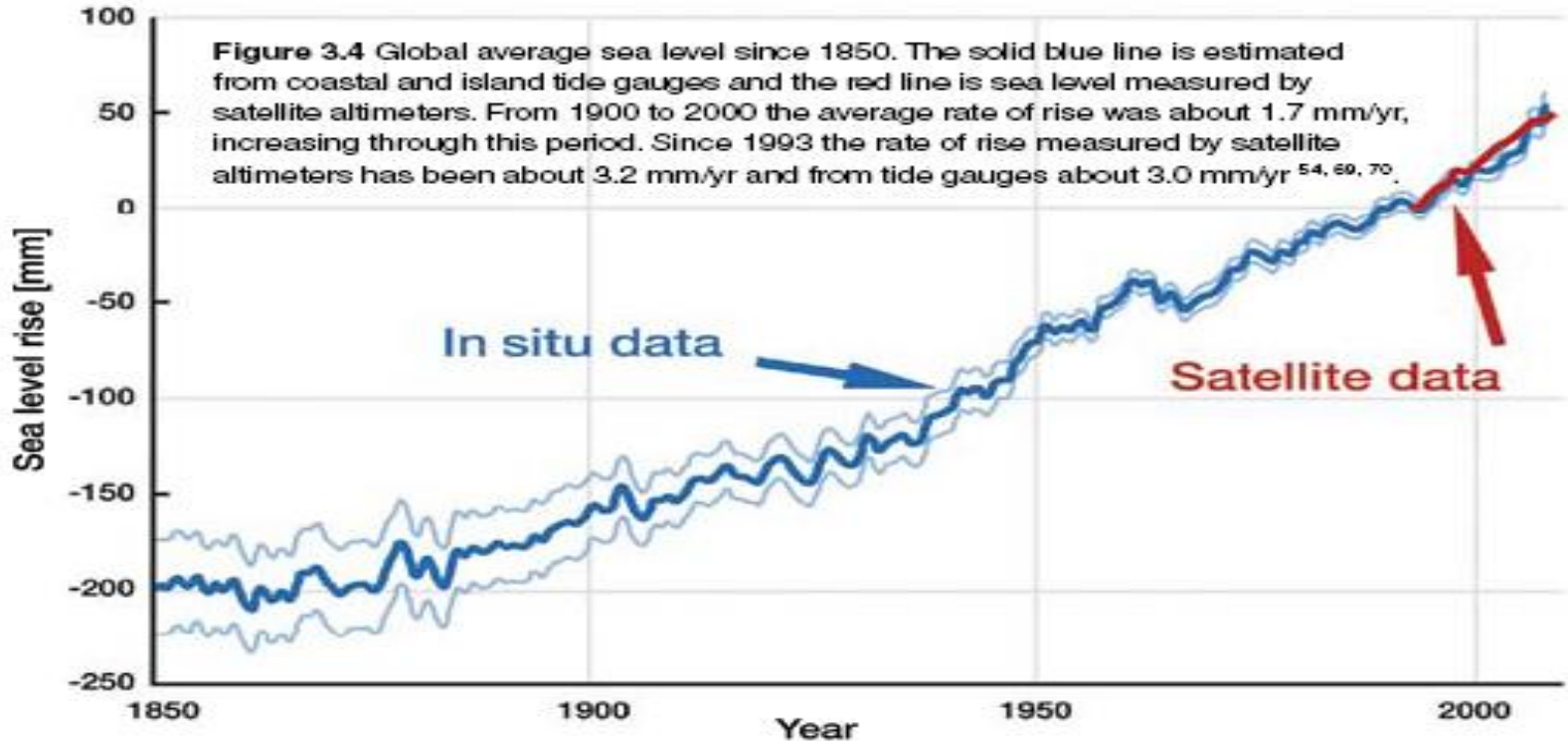
Extreme rainfall and flood risk

- Rainfall intensity is increasing across much of the globe – not so much southern SA
- 5-7 % increase /°C of warming
- Flooding as seen in extreme river levels is not increasing as rapidly

Trend logarithm highest daily precipitation of the year

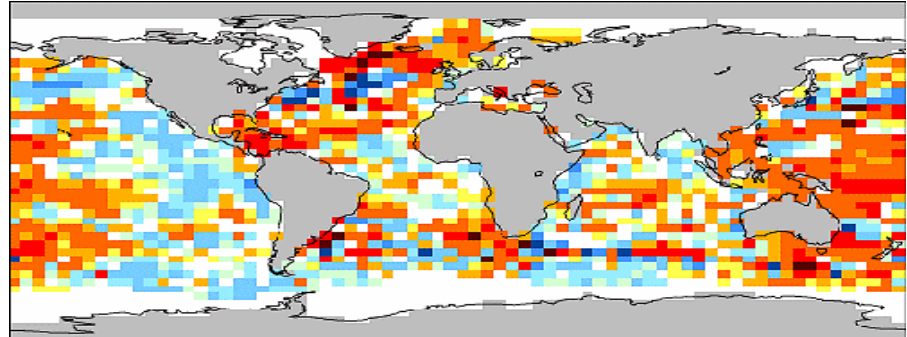


Sea level has risen ~20cm since 1850



Contributors to sea level rise by 2100

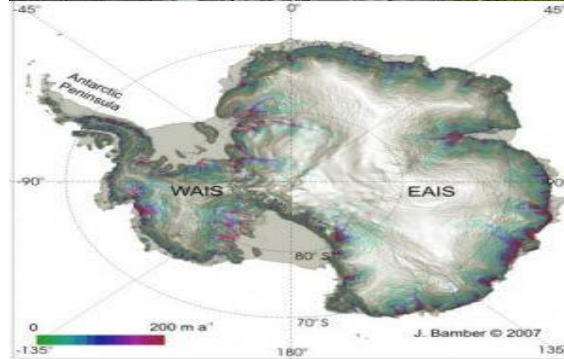
Thermal expansion from warmer oceans ~ 25cm



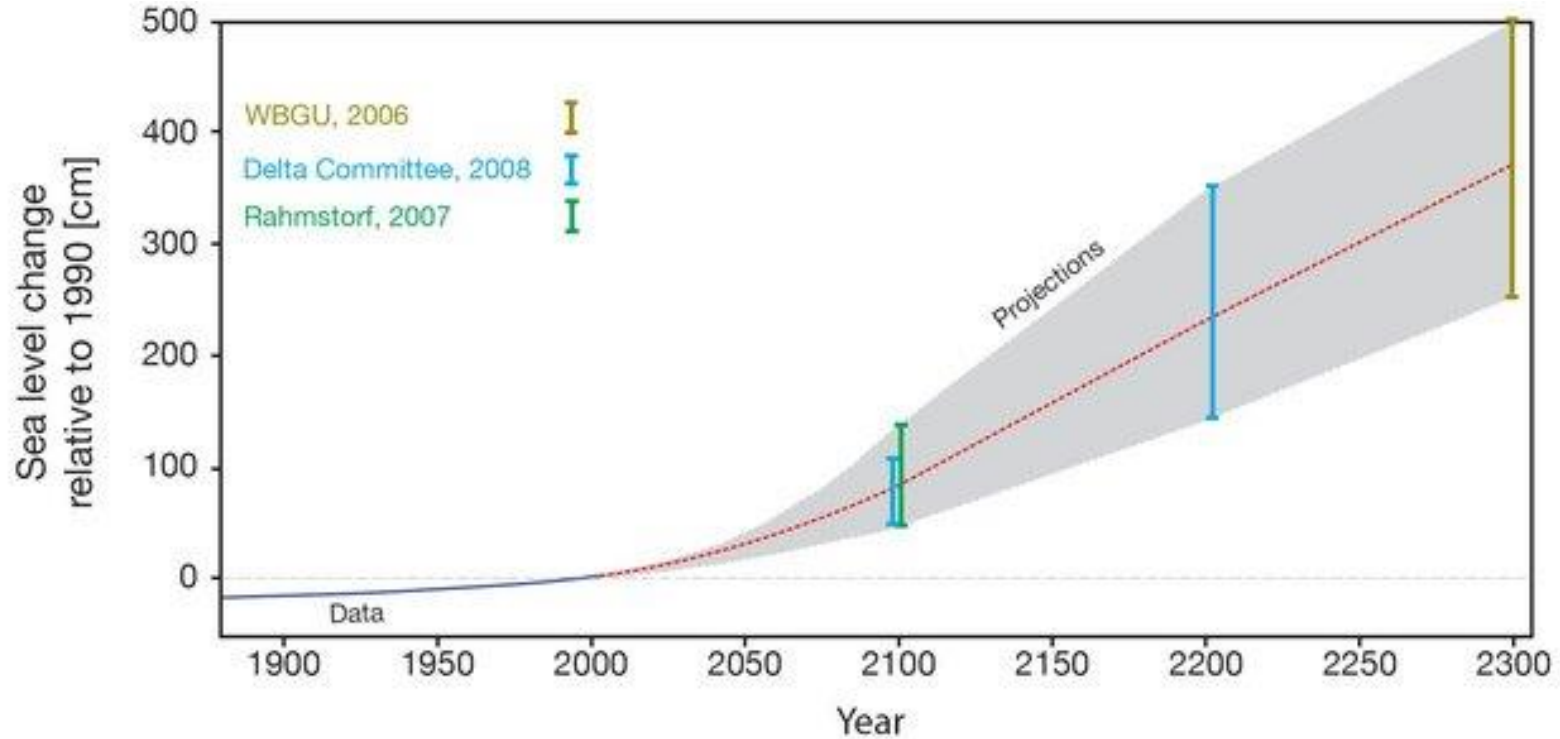
Glacial melt ~ 15cm



Antarctic and Greenland icesheets
~25-65cm – lots of uncertainty
around how much will occur



Sea level projections



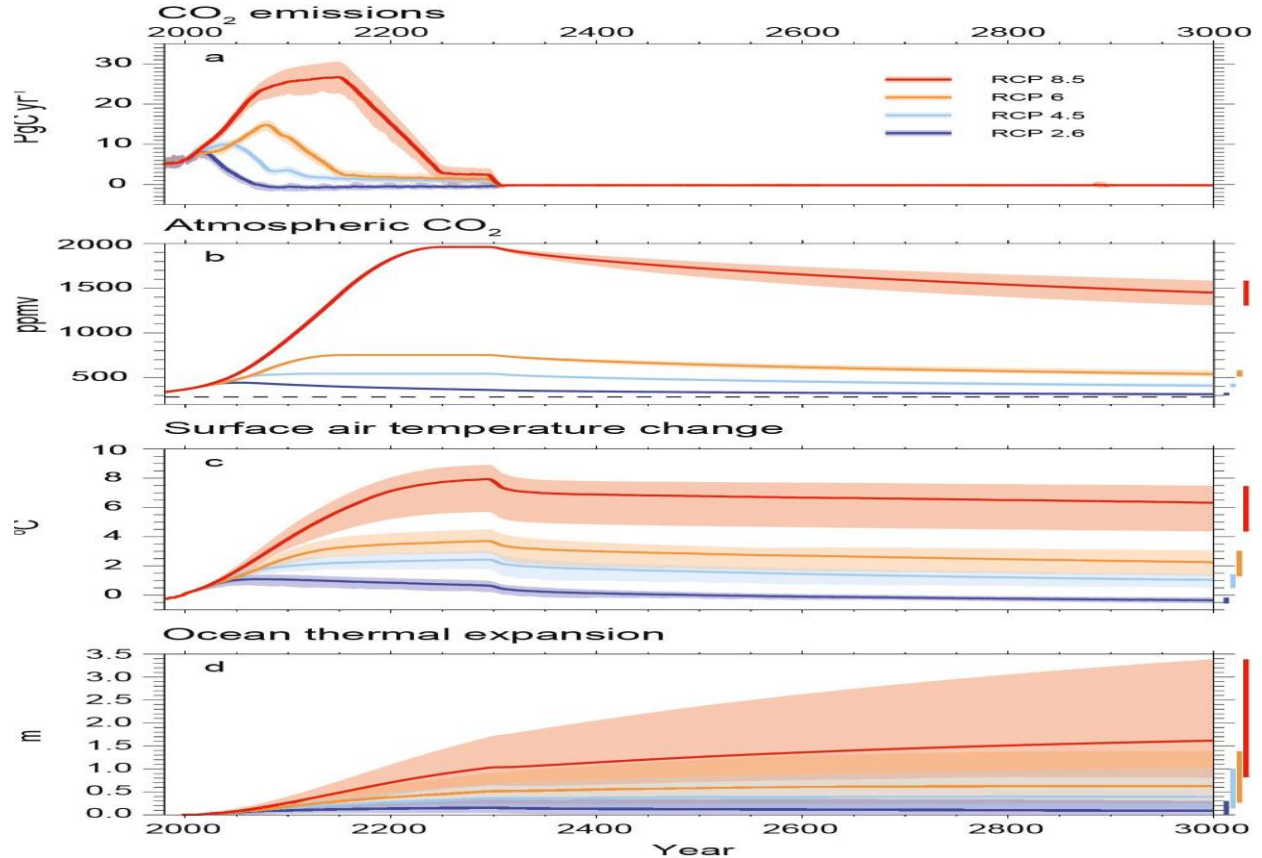
<https://www.nature.com/scitable/knowledge/library/modeling-sea-level-rise-25857988>

Both adaptation and mitigation are needed

2°C = Pliocene
(pre-2.6 million years ago)
around +12 to 25 metres

4°C = peak Miocene
(about 16 million years ago)
equilibrium sea levels of
about +40 metres

Climate change
does not stop at
2100



Thank you for listening

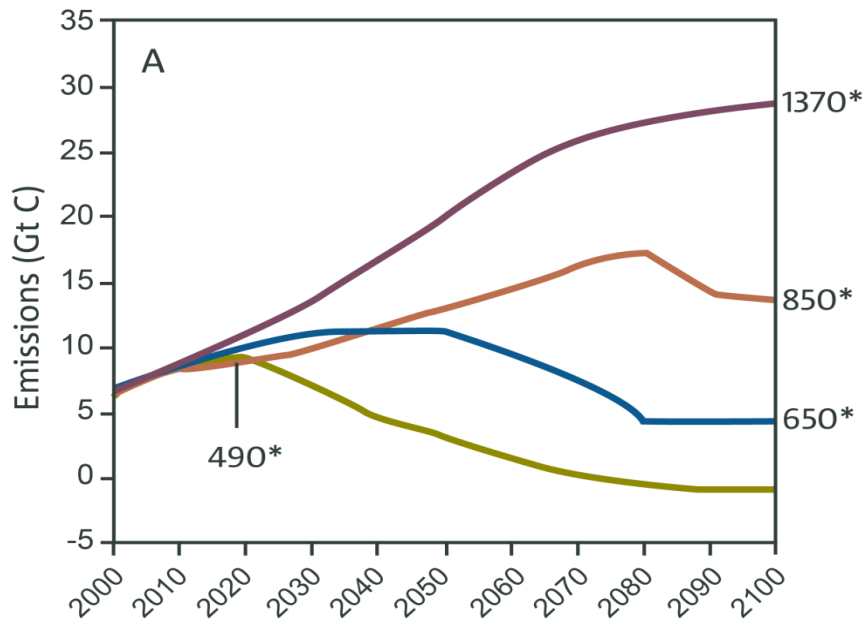
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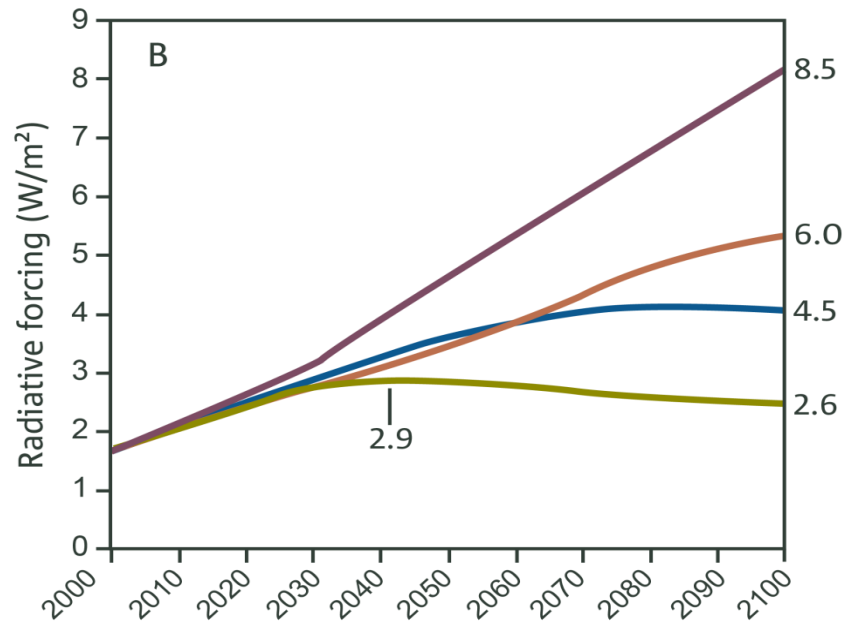
darren.ray@bom.gov.au

A range of possible futures

Future greenhouse gas emission scenarios



Resulting warming influence in Watts/metre squared

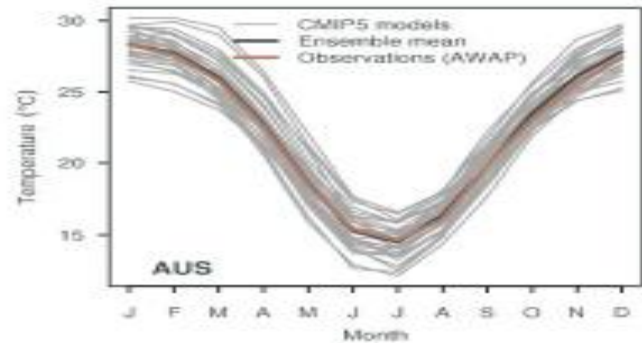


RCP is Representative Concentration Pathway : RCP 2.6, RCP4.5, RCP8.5 etc.

MODEL	TAS	PR	RSDS	DTR	WIND850	WIND200	PSL	ST JET	MONS ONS
ACCESS1-0	832	552	604	496	760	750	834	798	645
ACCESS1-3	792	544	606	198	690	678	798	738	496
bcc-csm1-1	780	499	699	295	657	684	716	687	543
bcc-csm1-1-m	766	525	744	365	xxx	xxx	811	xxx	xxx
BNU-ESM	755	451	534	120	xxx	xxx	615	xxx	xxx
CanESM2	824	492	705	426	717	718	812	712	500
CCSM4	816	379	602	172	720	758	802	744	611
CESM1-BGC	824	400	645	184	xxx	xxx	801	xxx	xxx
CESM1-CAM5	806	493	544	188	xxx	xxx	815	xxx	xxx
CESM1-WACCM	743	281	337	94	xxx	xxx	673	xxx	xxx
CMCC-CESM	641	479	644	289	xxx	xxx	481	xxx	xxx
CMCC-CM	794	486	698	xxx	xxx	xxx	757	xxx	xxx
CMCC-CM5	729	564	725	358	xxx	xxx	673	xxx	xxx
CNRM-CM5	742	602	770	485	xxx	xxx	863	xxx	xxx
CSIRO-Mk3-6-0	744	482	601	400	691	666	657	647	658
EC-EARTH	687	701	xxx	315	xxx	xxx	765	xxx	xxx
FGOALS-g2	755	535	725	235	667	737	586	625	624
FIO-ESM	817	424	705	141	xxx	xxx	636	xxx	xxx
GFDL-CM3	781	564	790	172	741	724	731	623	653
GFDL-ESM2G	716	472	617	122	712	724	798	771	593
GFDL-ESM2M	728	469	630	118	745	740	731	726	589
GISS-E2-H	661	490	271	228	662	647	738	748	486
GISS-E2-H-CC	610	501	269	181	xxx	xxx	769	xxx	xxx
GISS-E2-R	651	461	286	272	xxx	xxx	760	xxx	xxx
GISS-E2-R-CC	731	472	279	265	xxx	xxx	779	xxx	xxx
HadGEM2-AO	808	600	644	496	xxx	xxx	797	xxx	xxx
HadGEM2-CC	800	541	723	474	737	718	782	781	638
HadGEM2-ES	807	561	715	457	730	735	801	744	602
Inmcm4	681	524	730	290	657	683	815	635	439
IPSL-CM5A-LR	796	403	414	118	622	659	507	473	390
IPSL-CM5A-MR	825	404	406	100	674	688	612	531	446
IPSL-CM5B-LR	760	596	519	128	xxx	xxx	559	xxx	xxx
MIROC5	793	432	805	338	xxx	xxx	778	xxx	xxx
MIROC-ESM	790	342	710	271	519	561	488	552	319
MIROC-ESM-CHEM	790	333	695	265	517	574	516	560	300
MPI-ESM-LR	830	593	812	232	xxx	xxx	743	xxx	xxx
MPI-ESM-MR	808	640	799	xxx	xxx	xxx	704	xxx	xxx
MRI-CGCM3	726	599	652	350	xxx	xxx	743	xxx	xxx
NorESM1-M	730	347	558	162	699	699	779	774	627
NorESM1-ME	724	343	559	xxx	676	699	752	785	623

40 available global climate models are tested for :

Surface temperature, rainfall, solar radiation, temperature range, winds at 850 and 200 hPa, sea level pressure, sub-tropical jet, monsoon







3
2



<http://www.climatechangeinaustralia.gov.au/>

The screenshot shows a web browser window displaying the homepage of the Climate Change in Australia website. The browser's address bar shows the URL <http://www.climatechangeinaustralia.gov.au/>. The page features a large header with the title "CLIMATE CHANGE IN AUSTRALIA" and a "VIEW MAIN NAVIGATION" link. Below the header is a grid of eight interactive tiles, each with an icon and a brief description of the content. At the bottom of the page, there are logos for the Climate Change in Australia initiative, CSIRO, and the Australian Government Department of the Environment Bureau of Meteorology. The browser's taskbar shows several open tabs, including "Climate Change in Australia" and "Figures and maps".

VIEW MAIN NAVIGATION

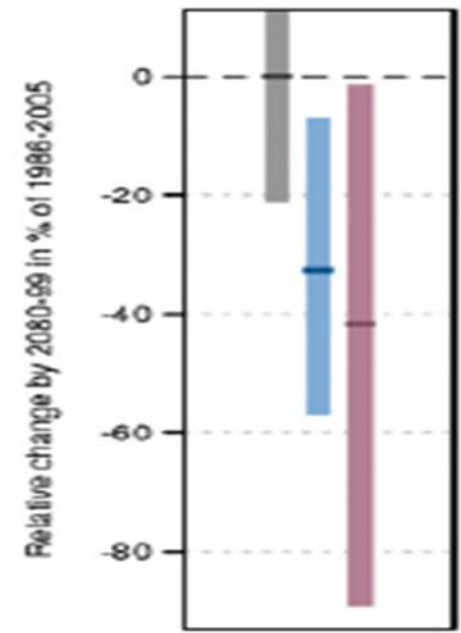
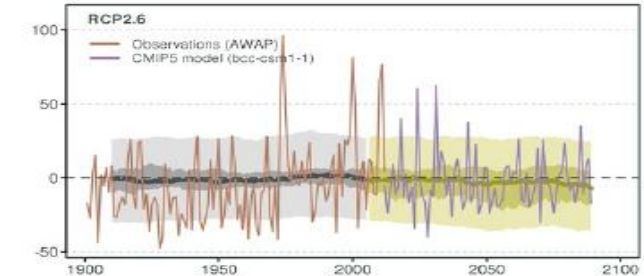
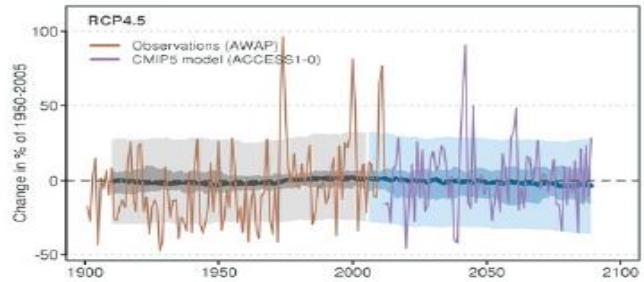
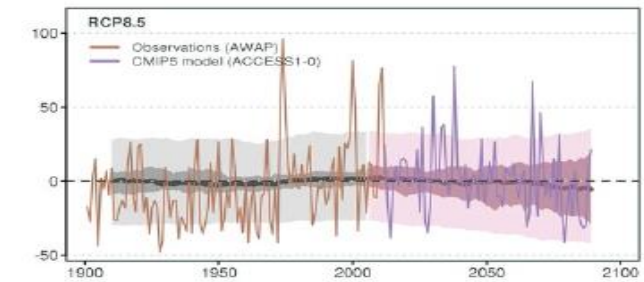
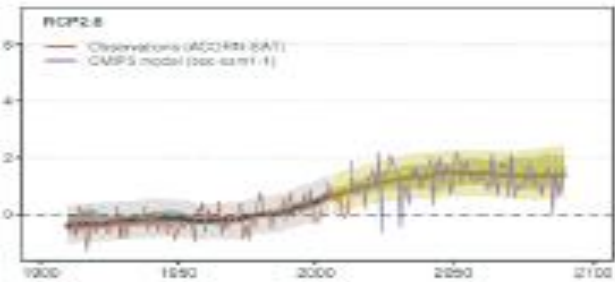
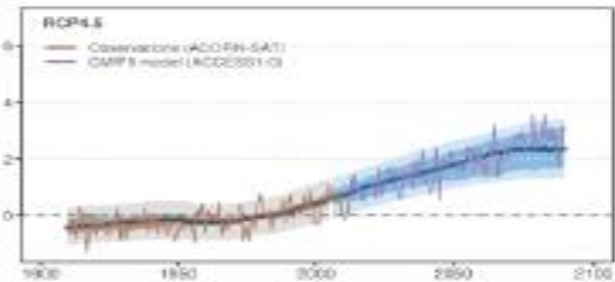
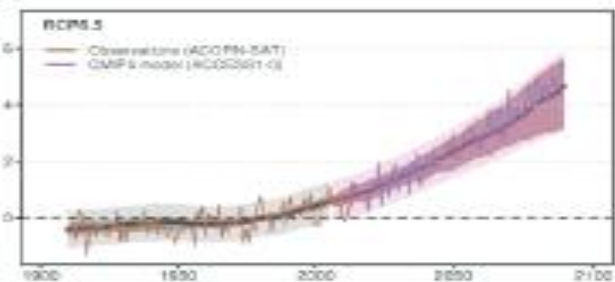
CLIMATE CHANGE IN AUSTRALIA

 <p>GETTING STARTED</p> <p>Support and guidance for use of information and data.</p>	 <p>CLIMATE CAMPUS</p> <p>Learn about the underpinning science of climate change, modelling and projections.</p>	 <p>PROJECTIONS AND DATA</p> <p>Explore Australia's projected climate and access model data. Register for data access.</p>	 <p>IMPACTS AND ADAPTATION</p> <p>Learn about possible regional impacts on natural resources and management responses.</p>
 <p>DECISION TREE</p> <p>Use this interactive guide to find what you are looking for.</p>	 <p>HISTORIC CLIMATE CHANGE</p> <p>Learn about observed climate change over Australia.</p>	 <p>REGIONAL CLIMATE CHANGE EXPLORER</p> <p>Summary of climate change projections for Australian regions.</p>	 <p>PUBLICATIONS LIBRARY</p> <p>Download technical and regional reports and other publications.</p>

  
Australian Government
Department of the Environment
Bureau of Meteorology

100%

Adelaide region future projections



Sea level rise around Australia

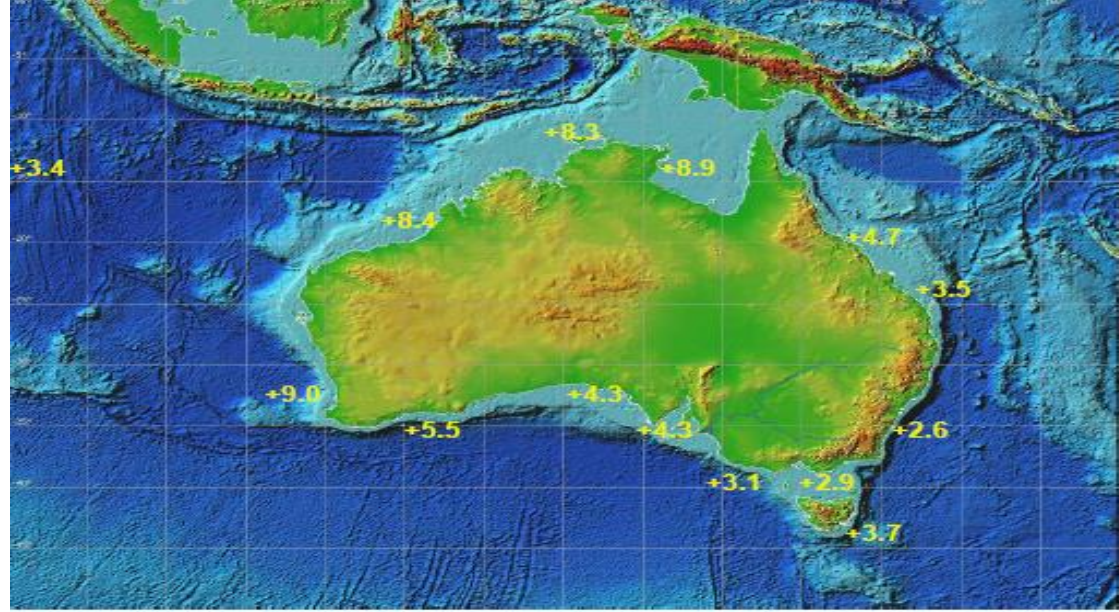
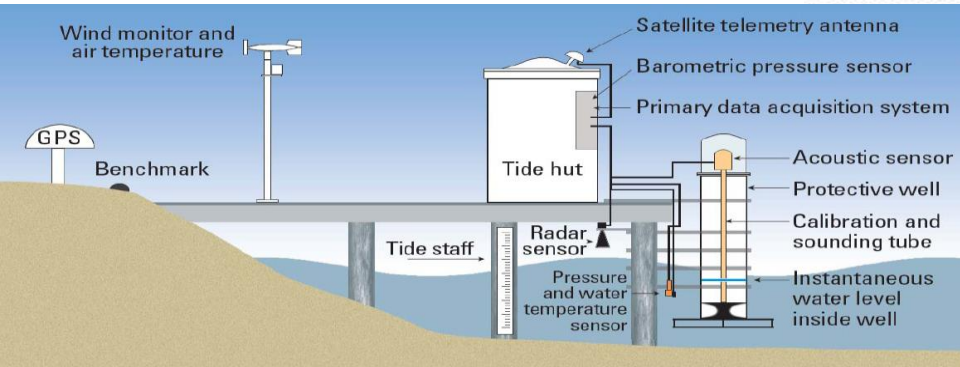


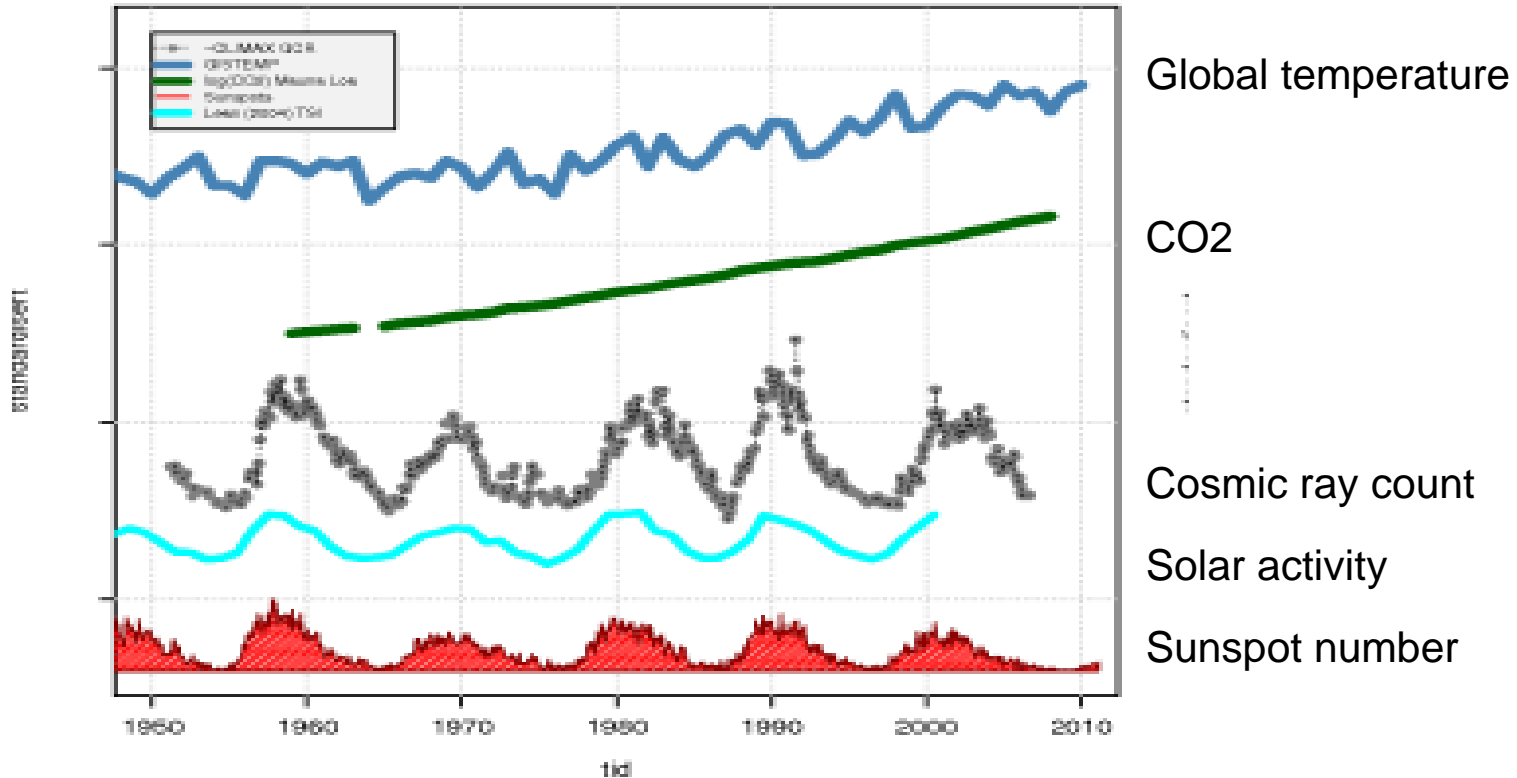
Figure 15. The net relative sea level trend in mm/year after subtracting the effects of the vertical movement of the platform and the inverse barometric pressure effect utilising all the data collected since the start of the project up to the end of June 2011.

BoM National Tidal Centre gauges are highly calibrated to take into account all factors



Sea level rise along SA coasts is ~4mm per year

Solar activity and cosmic rays...



References

[1] https://ams.confex.com/ams/Annual2006/techprogram/paper_100737.htm

[2] <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.131.3867>

[3] www.climatechangeinaustralia.gov.au

[4] <https://theconversation.com/melting-antarctic-ice-sheets-and-sea-level-rise-a-warning-from-the-future-50065>

[5] <http://www.bom.gov.au/climate/change/>

[6] <http://www.bom.gov.au/state-of-the-climate/>

[7] <https://nsidc.org/>