www.csiro.au

Global Warming and its Likely Impact on the South West

Climate Adaptation

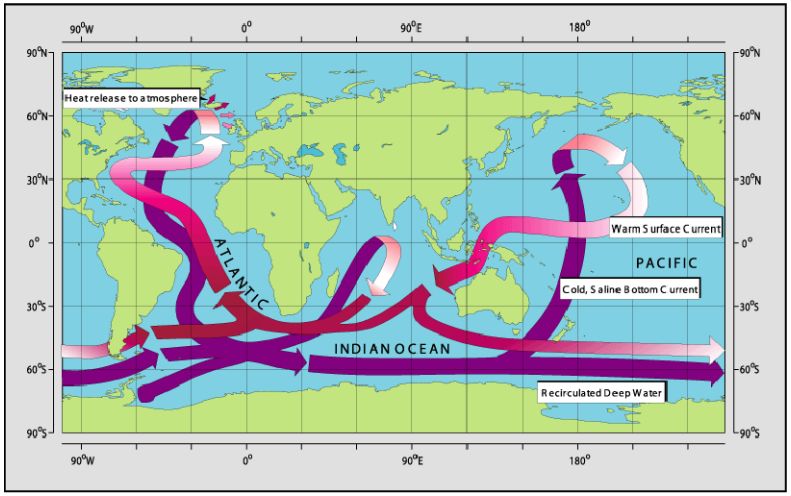
Bryson C. Bates
Leader, Pathways to Adaptation Theme
4th December 2008

National Research FLAGSHIPS CSIRO

Presentation Outline

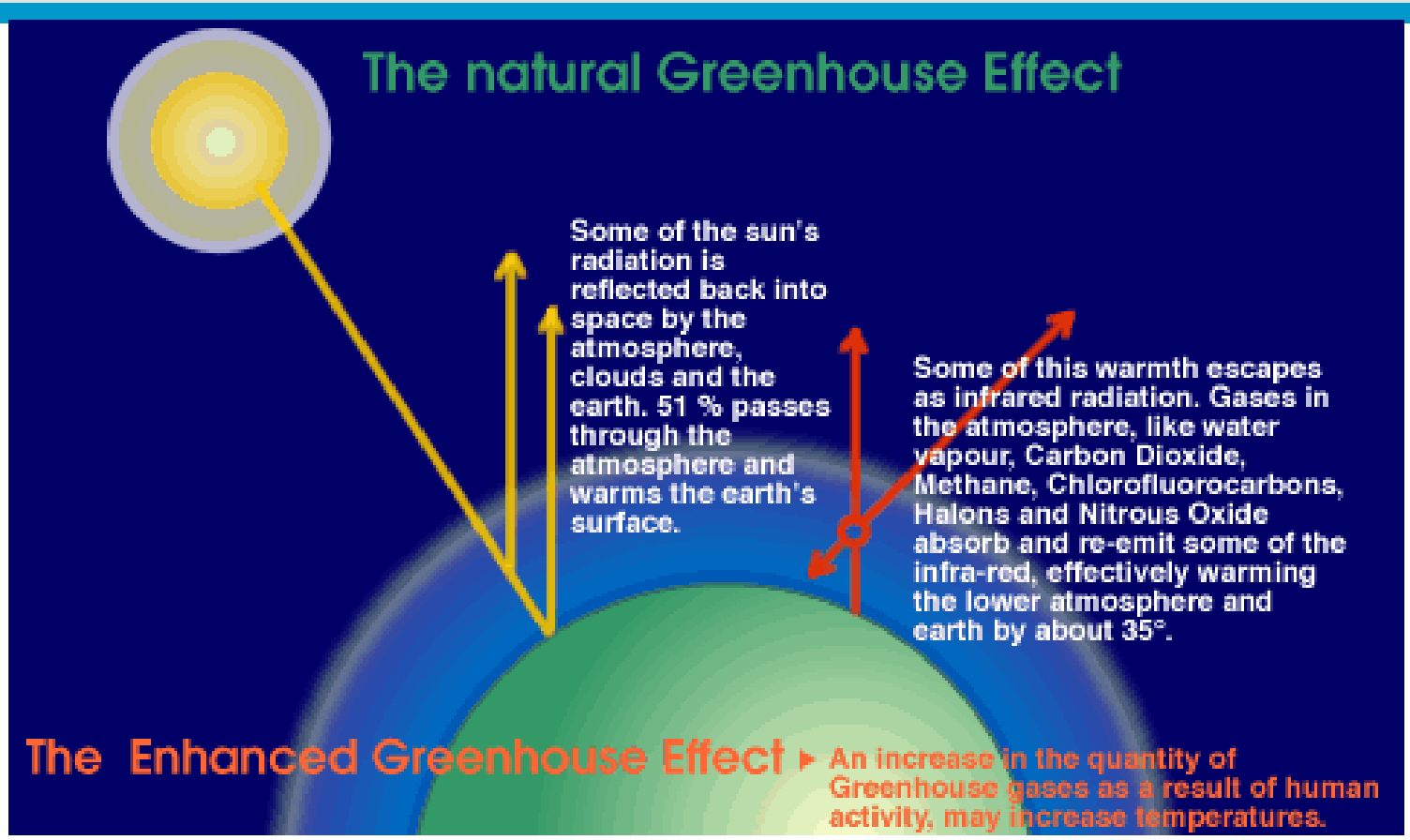
- Background
- Geologic & human timescales
- Observed global changes
- Observed local changes
- Reality checks
- Climate change projections
- Impacts, adaptation & vulnerability
- Concluding remarks

Drivers of Climate Change



National Research FLAGSHIP

Enhanced Greenhouse Effect



- **GHGs are a natural part of the atmosphere: support life**
- **Water vapour is most abundant GHG: humans have little impact**
- **Humans have most impact on CO_2, CH_4, N_2O: net effect**

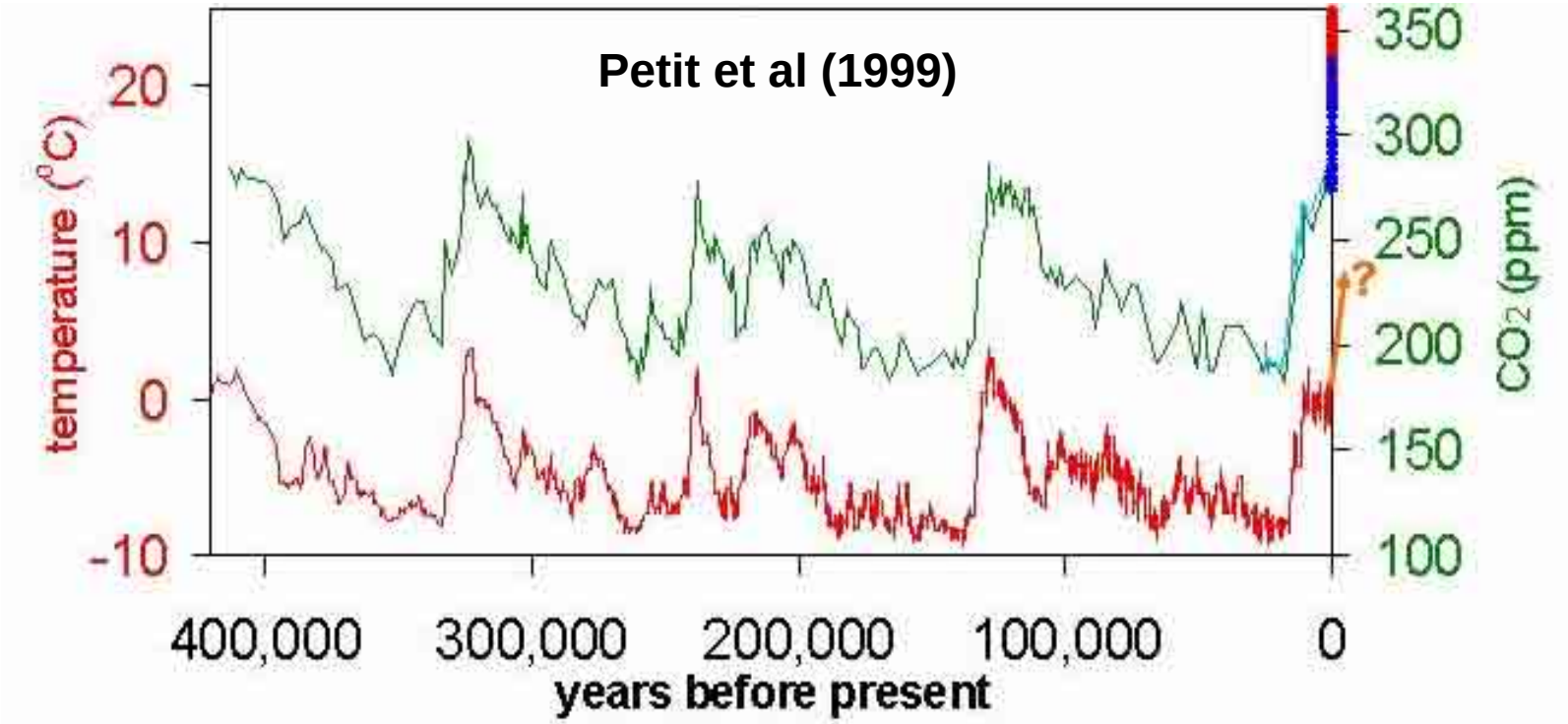
Critical Horizons December 2008

Geologic & Human Timescales

- Past super-greenhouse conditions:
  - 50 My BP CO_2~ 1,000 ppm; no polar ice; sea level ~ 120 m above present
  - 250 My BP CO_2~ 10 to 20 x present level; 50 to 95% extinction rate
- Advent of humans ~ 2.2 to 2.4 My BP
- Civilisation started ~ 12 Ky BP
- Current rate CO_2 increase 200 x faster than that over last 650 Ky
- Without mitigation & abatement, burning all known coal reserves will raise atmospheric CO_2 *~ 2,000 ppm*
- Estimated arrival time for next ice age: 'now' to 20 Ky

"It is clear that Earth's climate system has proven itself to be an angry beast. When nudged, it is capable of a violent response." (Broecker, 2003)

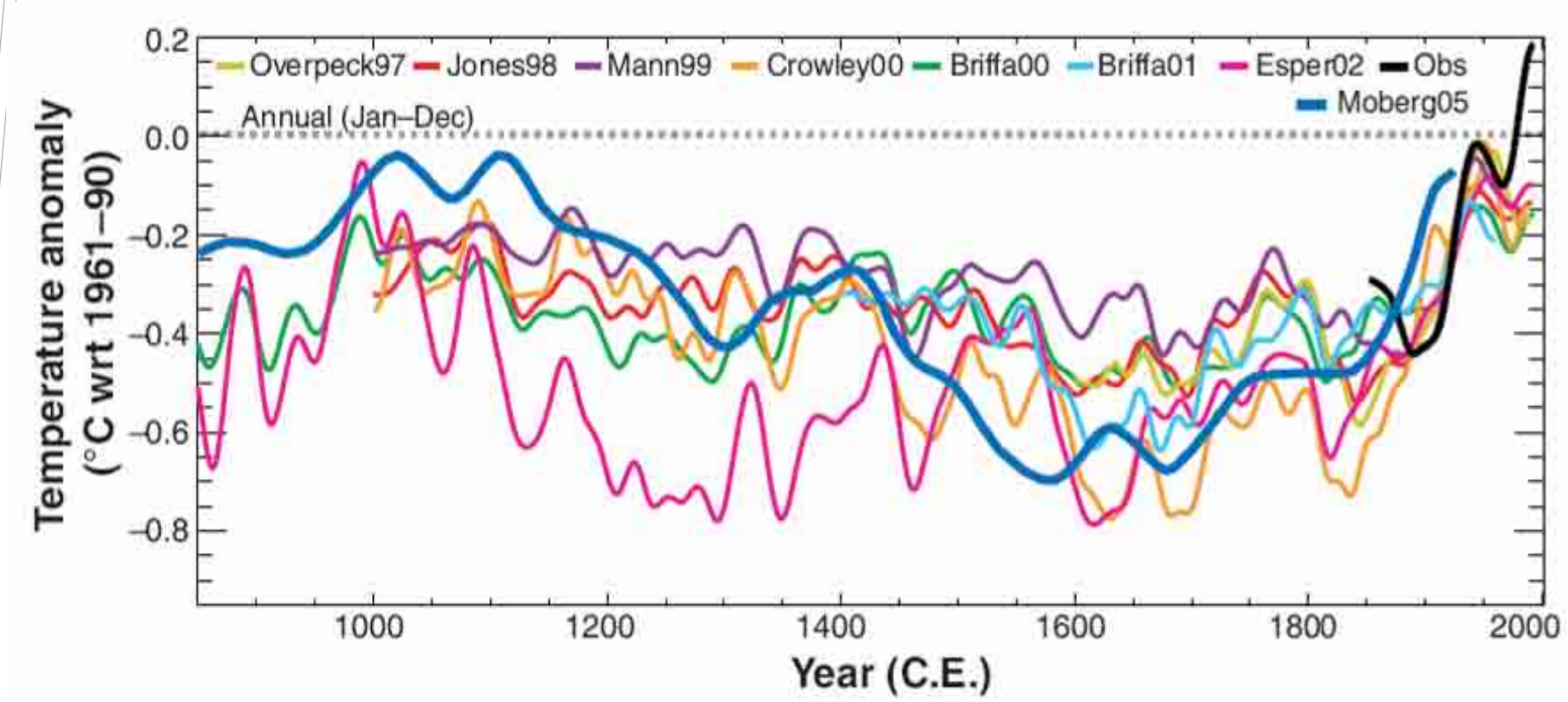
Ice Core Data



800-year lag prior to CO_2 out-gassing ~
mixing time for deep ocean

Proxy Records

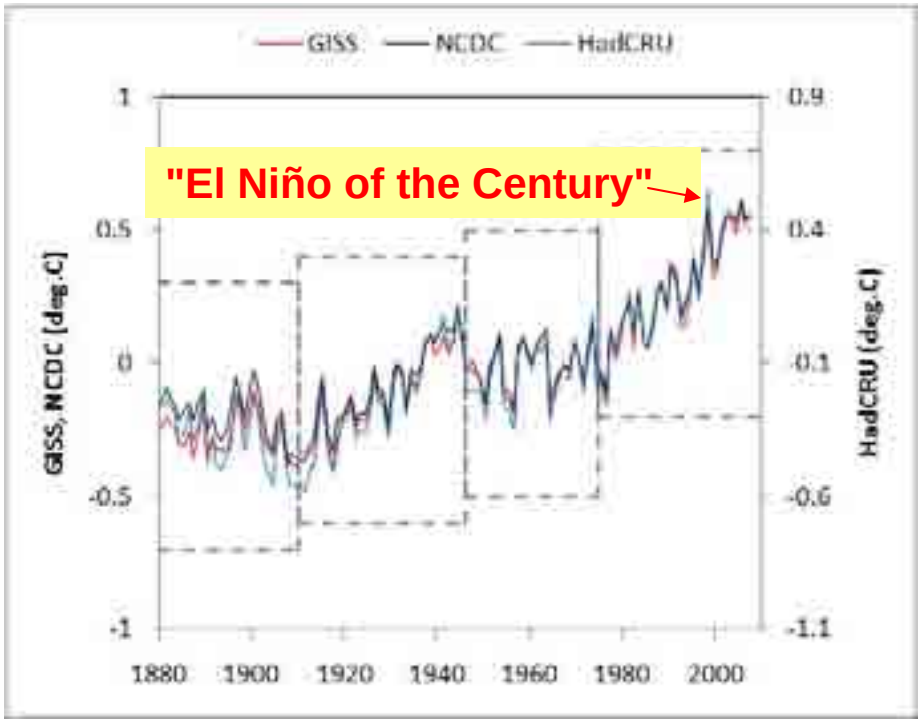
Kerr (2005)



National Research FLAGSHIPS CSIRO

Observed Global Changes

Global Temperature



Goddard Institute for Space Studies
New York, N.Y.

- 2005 warmest year
- 2007 = 1998
- 14 warmest years on record have occurred since 1990

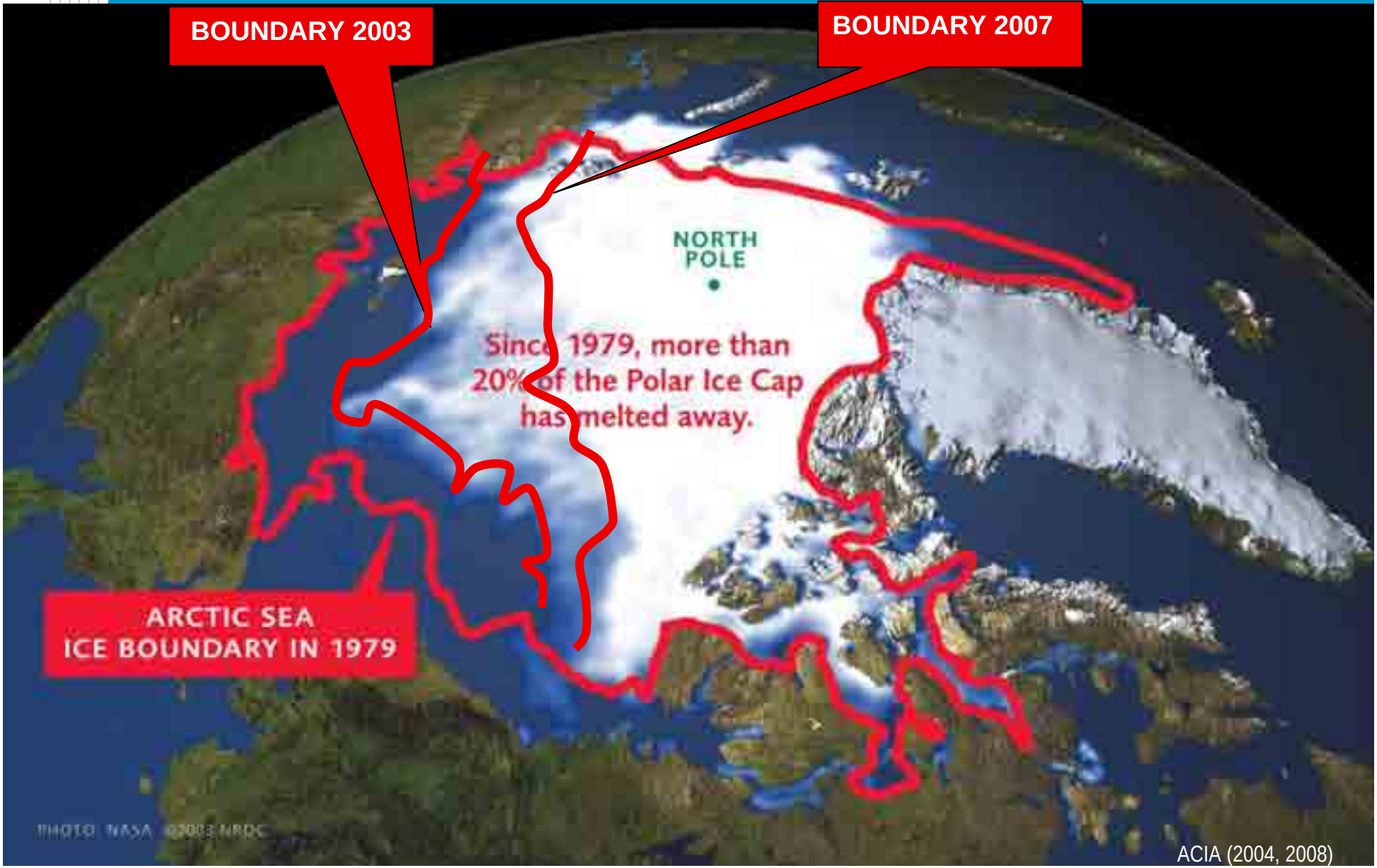
- Goddard Institute for Space Studies, USA (1951-1980 ref. period)
- National Climatic Data Center, USA (1901-2000 ref. period)
- Hadley Centre Climatic Research Unit, UK (1961-1990 ref. period)

National Research FLAGSHIPS CSIRO

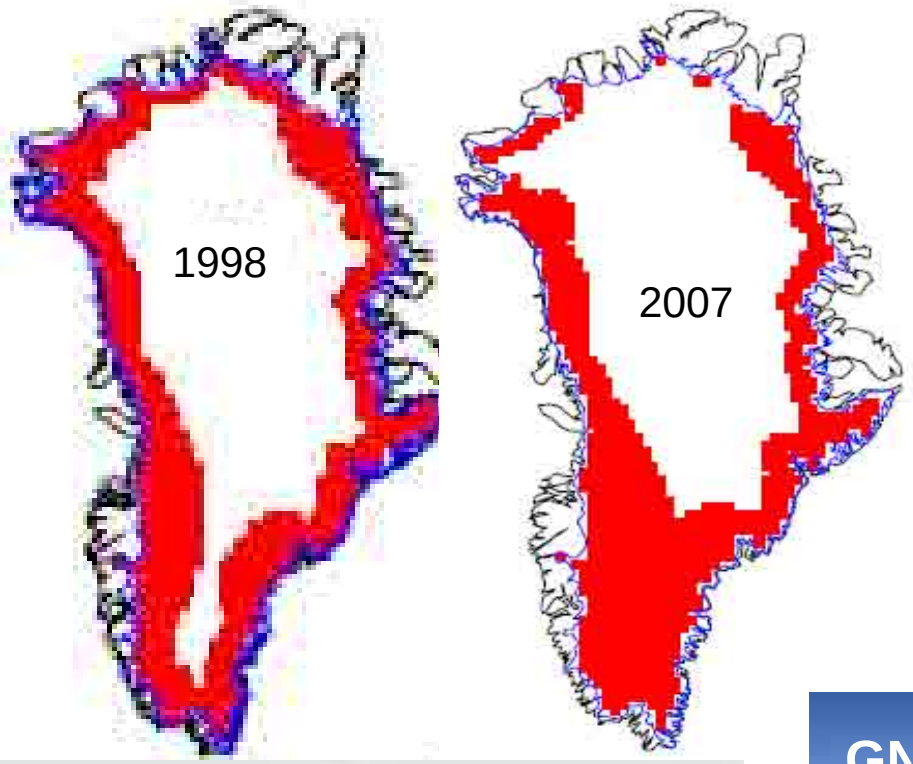
Evidence of Rapid Change

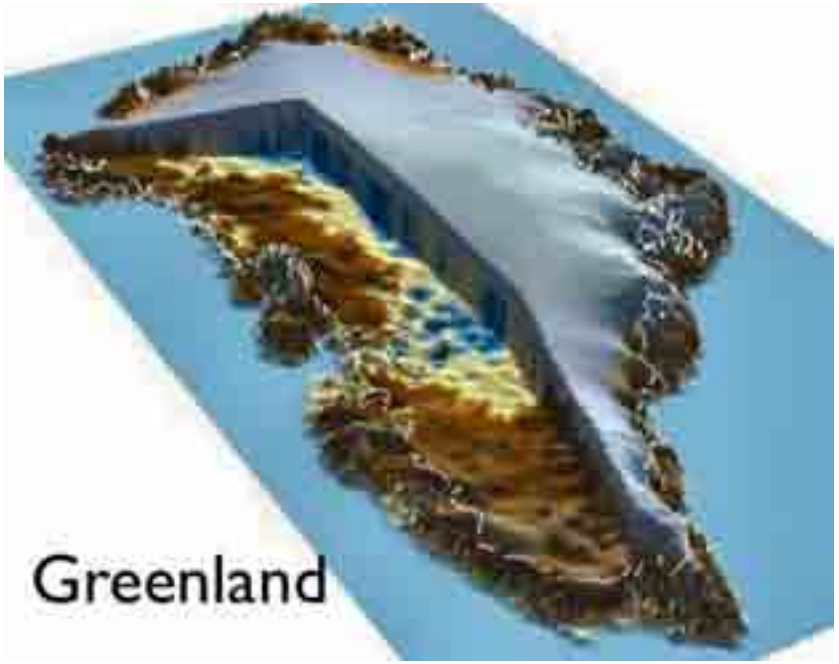
1) Another 0.6 °C already locked in
2) Melting ice sheets & caps
3) Melting glaciers
4) Melting permafrost
5) UK soils & vegetation – carbon sources
6) Freshening of North Atlantic Ocean & Australian-Antarctic Basin
7) Ocean acidification
8) Atmospheric circulation changes
9) Ecosystem changes

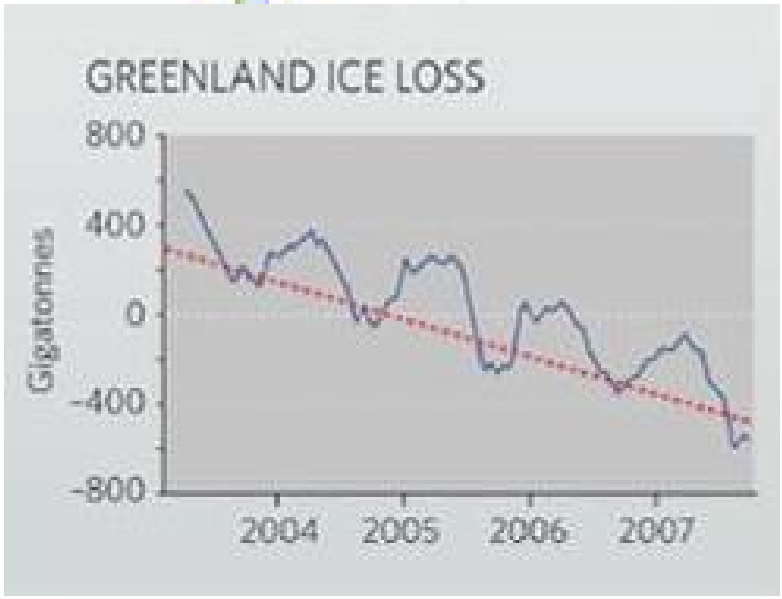
Shrinking Arctic Ice Cap



ACIA (2004, 2008)


1998
2007


Greenland

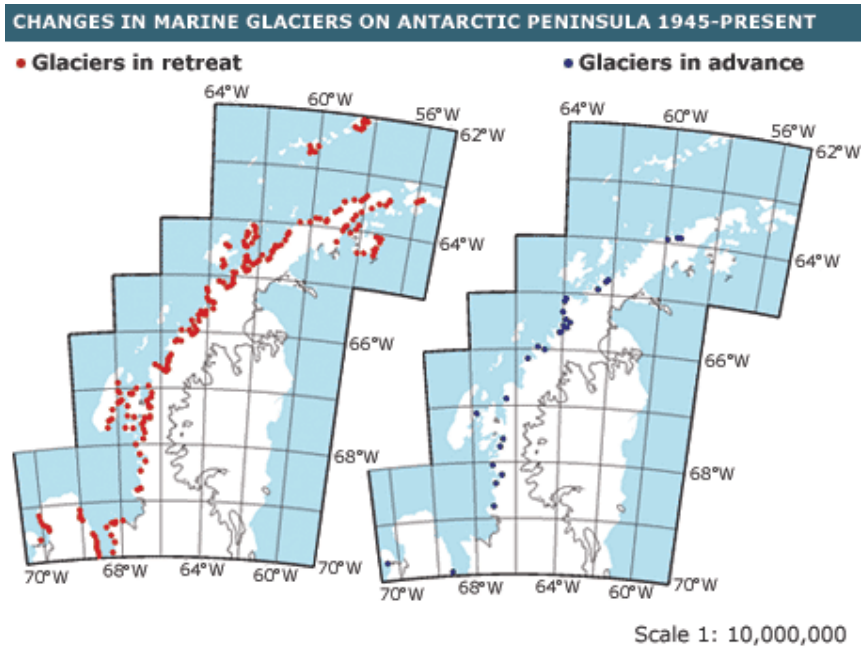

GREENLAND ICE LOSS
800
400
0
-400
-800
Gigatonnies
2004
2005
2006
2007

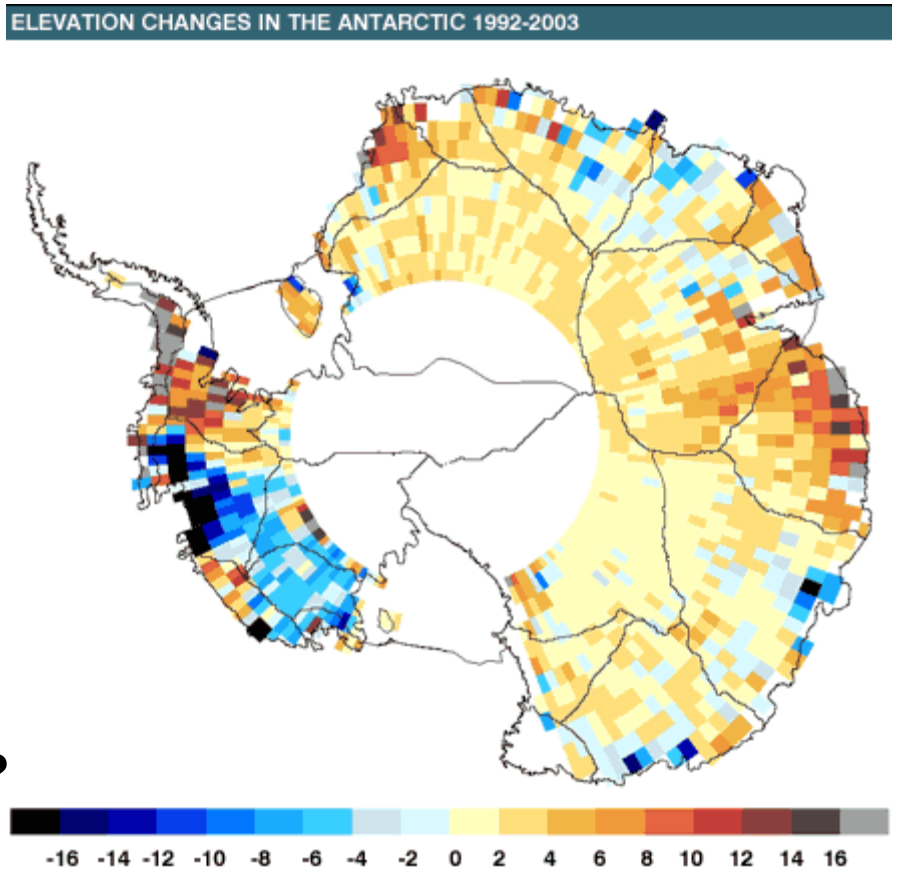

GNET

Moulin

Antarctica

West Antarctic ice sheet (thinning); East Antarctic ice sheet (thickening); Antarctic Peninsula (glacial retreat)



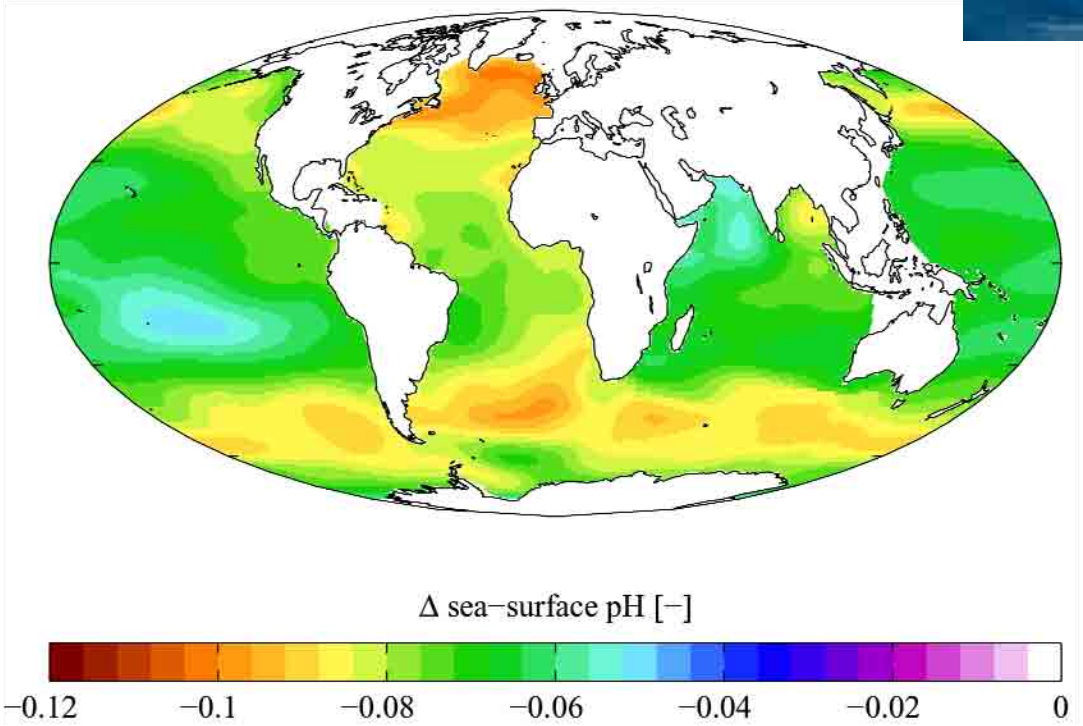


87% of 244 glaciers retreating

Climate? Volcanism? Ocean temps?

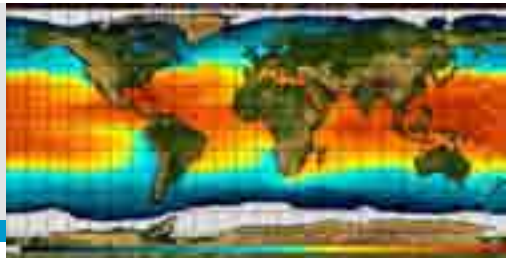
Critical Horizons December 2008

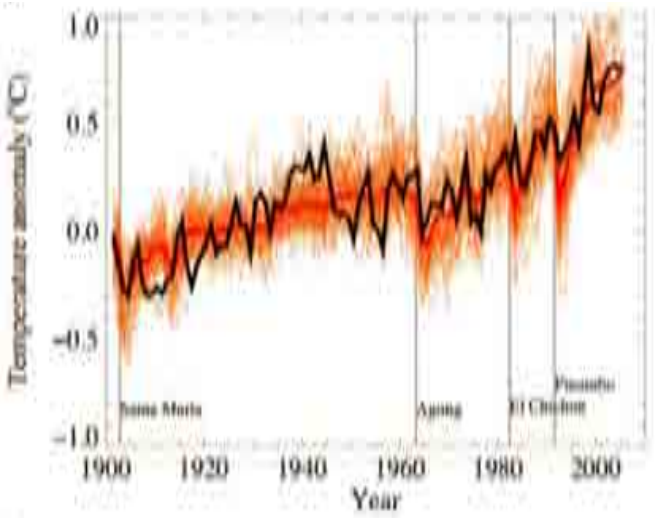
Ocean Acidification



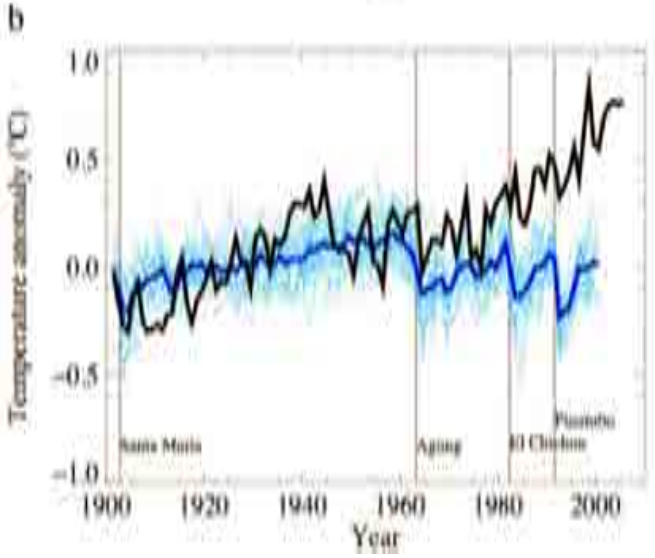
Change in pH between 1700s & 1990s

Attribution (Global)





All Forcings



Natural Forcings Only

Critical Horizons December 2008

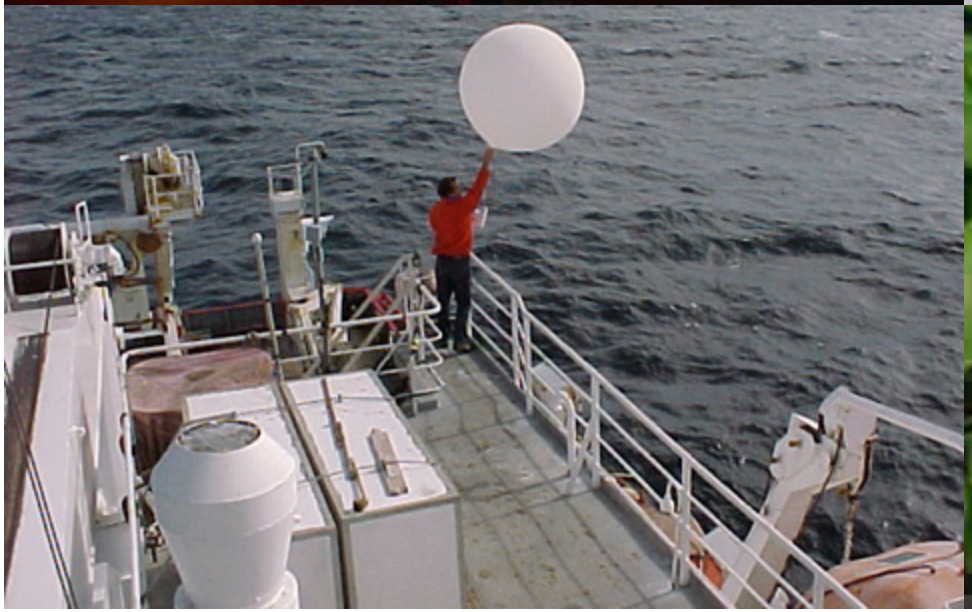
National Research FLAGSHIPS CSIRO

***Very likely*: > 90% probability; Likely: > 66% probability**

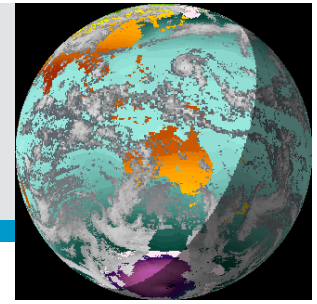
- ***Very likely*** **mean NH temps during last ½ 20th*C* warmer than any other 50-year period in last 500 years (*likely* warmest in past 1300 years)**
- ***Very likely*** **natural forcing factors alone cannot account for observed warming**
- ***Very likely*** **GHG forcing caused most of observed global warming over last 50 years**
- **Without effect of aerosols, *likely* that GHG forcing would have caused greater global mean temperatures**
- ***Very likely*** **Greenland & Antarctic ice sheets contributed to sea level rise of last decade**
- ***Very likely*** **that Atlantic Ocean MOC will slow by 2100**

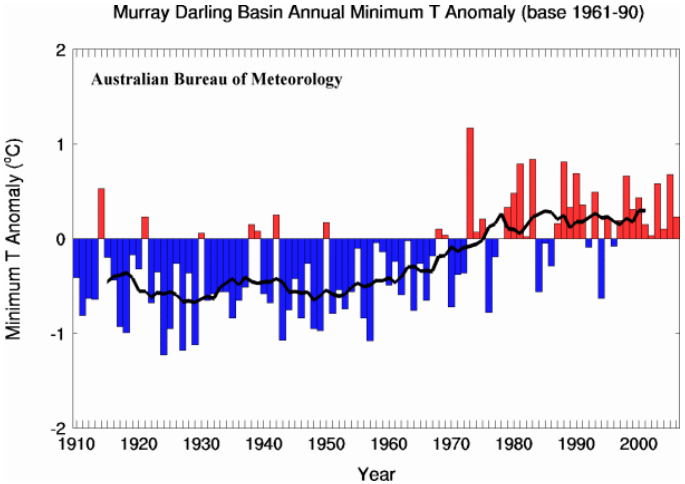
System science based on preponderance of all the available evidence, *NOT* a few exceptions

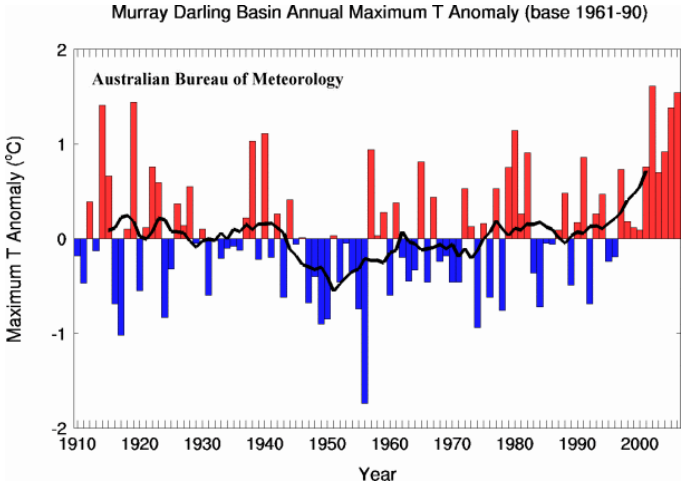
Observed Local Changes

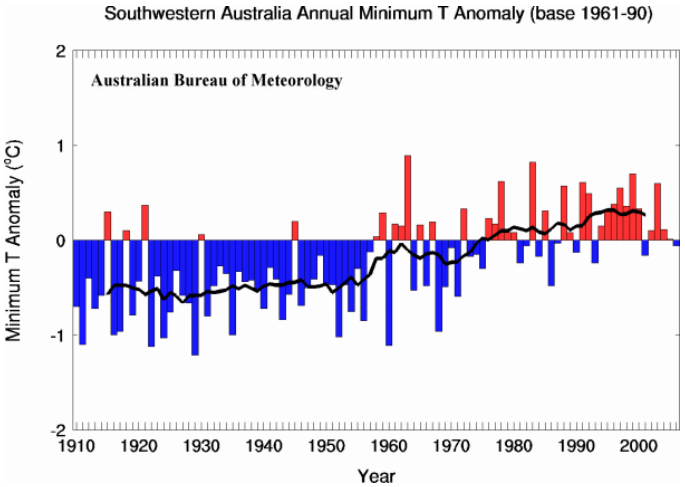


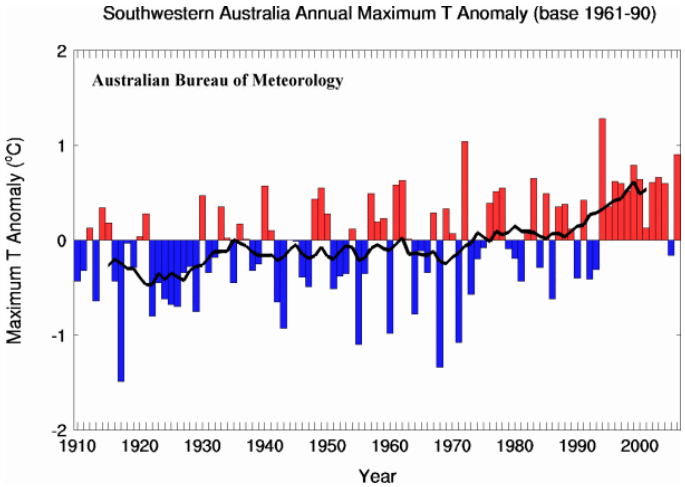
Min & Max Temperatures



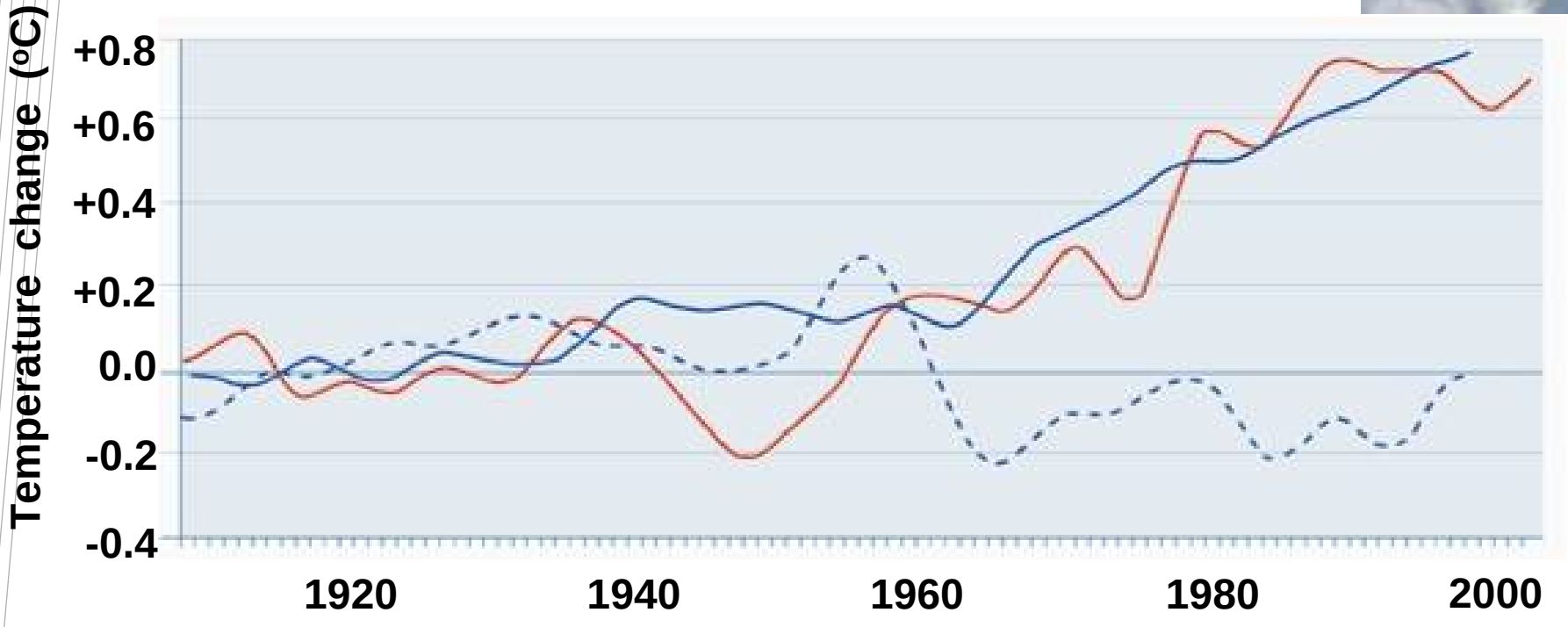








Australia is Warming



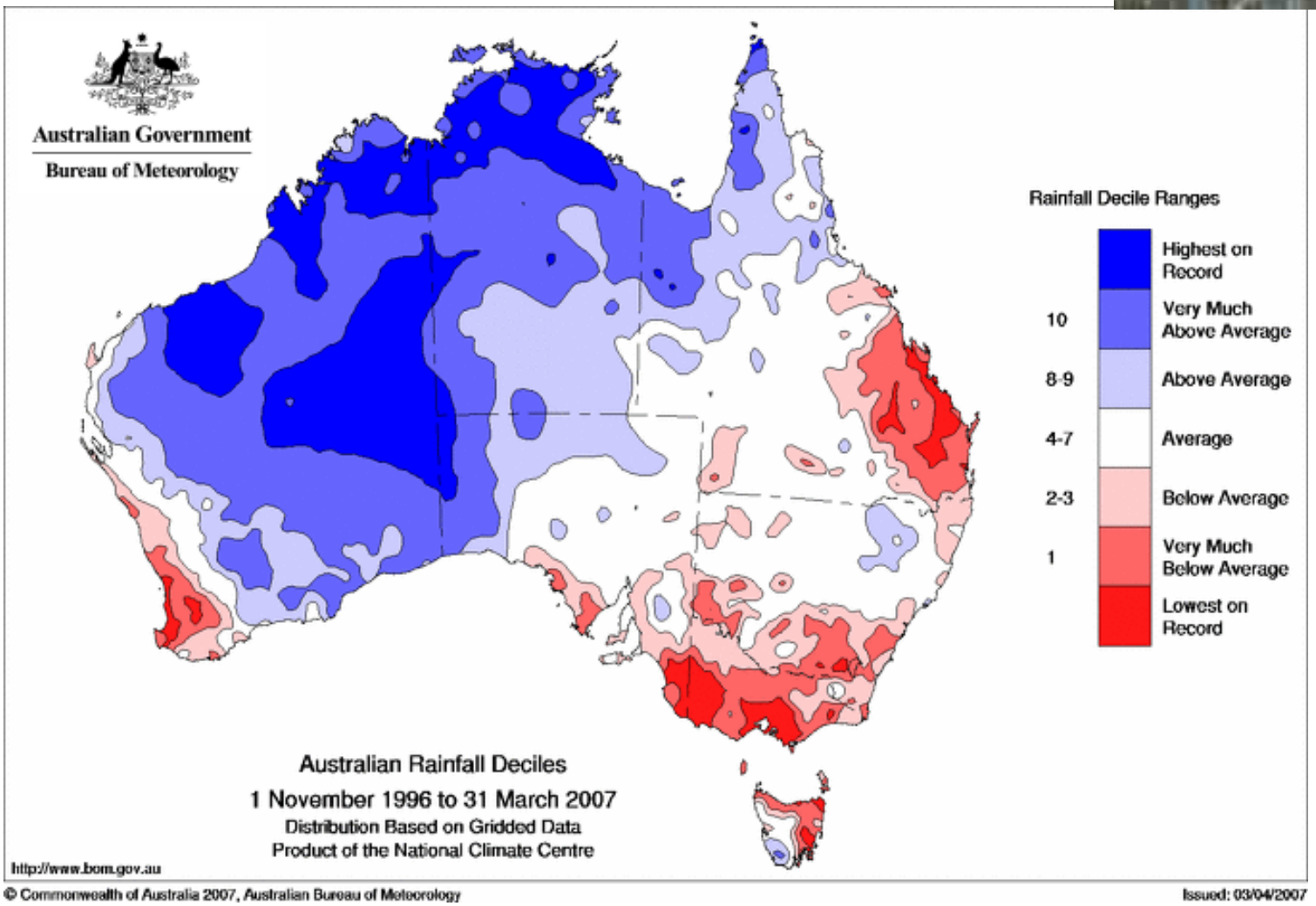
Australia's **mean** temperature since 1910

Eight climate models **with** additional GHGs in the atmosphere

Climate models **without** additional GHGs in the atmosphere

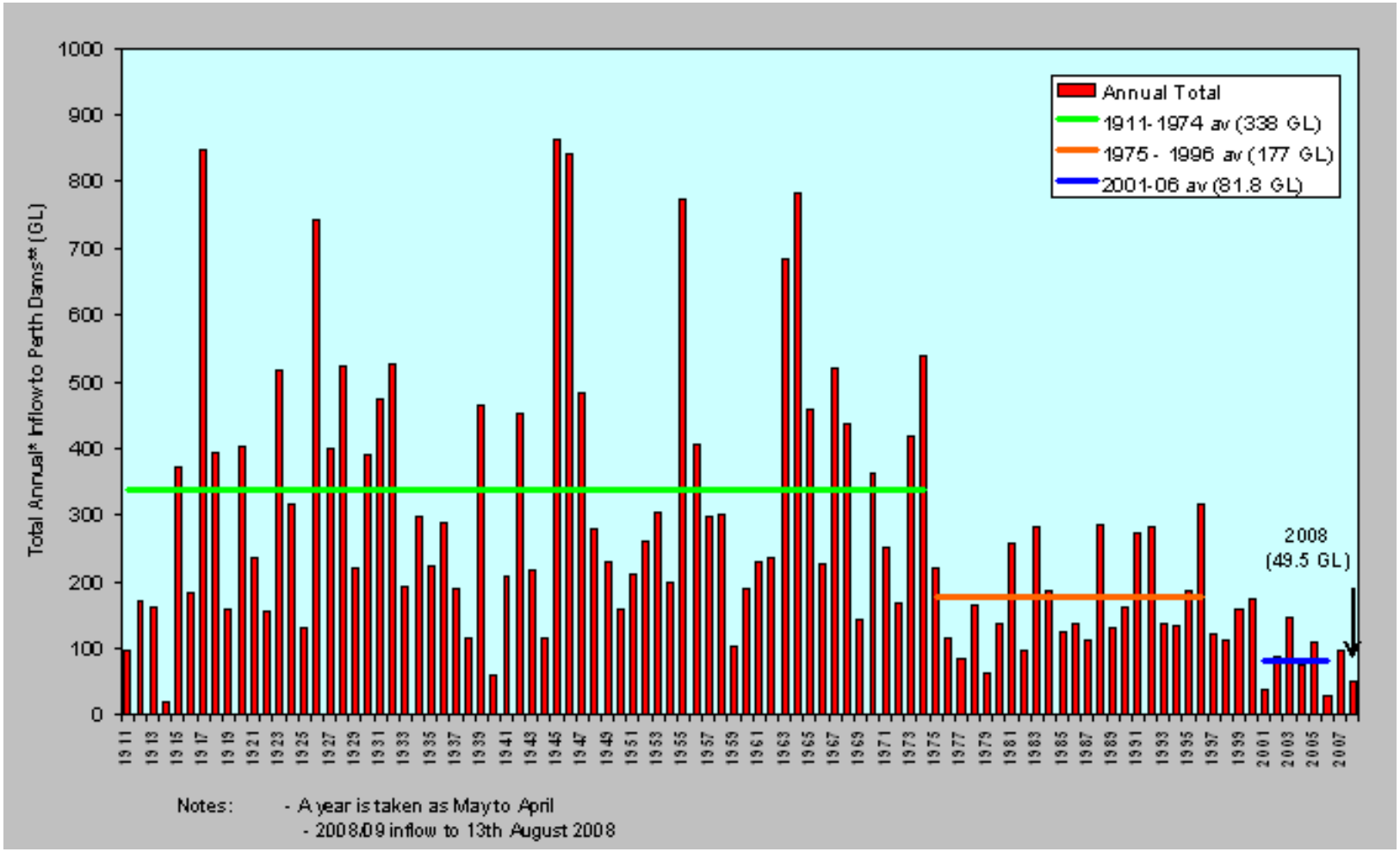
Karoly & Braganza (2004)

Our Rainfall Status



National Research FLAGSHIPS CSIRO

What Baseline?



Local Ecosystem Changes

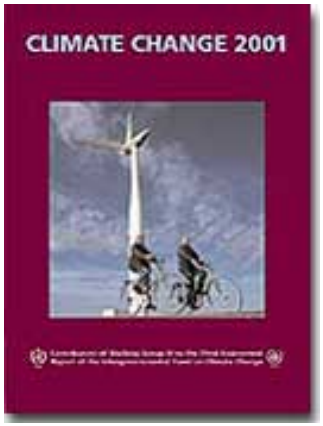
- **Encroachment** of snow gums into sub-alpine grasslands at high elevations
- **Increased penetration** of feral animals into alpine & high sub-alpine areas
- **Earlier arrival** of migratory birds, **range shifts & expansion** of several bird species **(beyond land cover changes)**
- **Change** in genetic constitution of fruit fly **(equivalent to 4º latitude shift)**
- **Eight** mass coral bleaching events in GBR since 1979 **(no known serious events prior to 1979)**
- Spatial extent of Tasmanian kelp forest has **halved** in last 50 years

Reality Checks

WMO

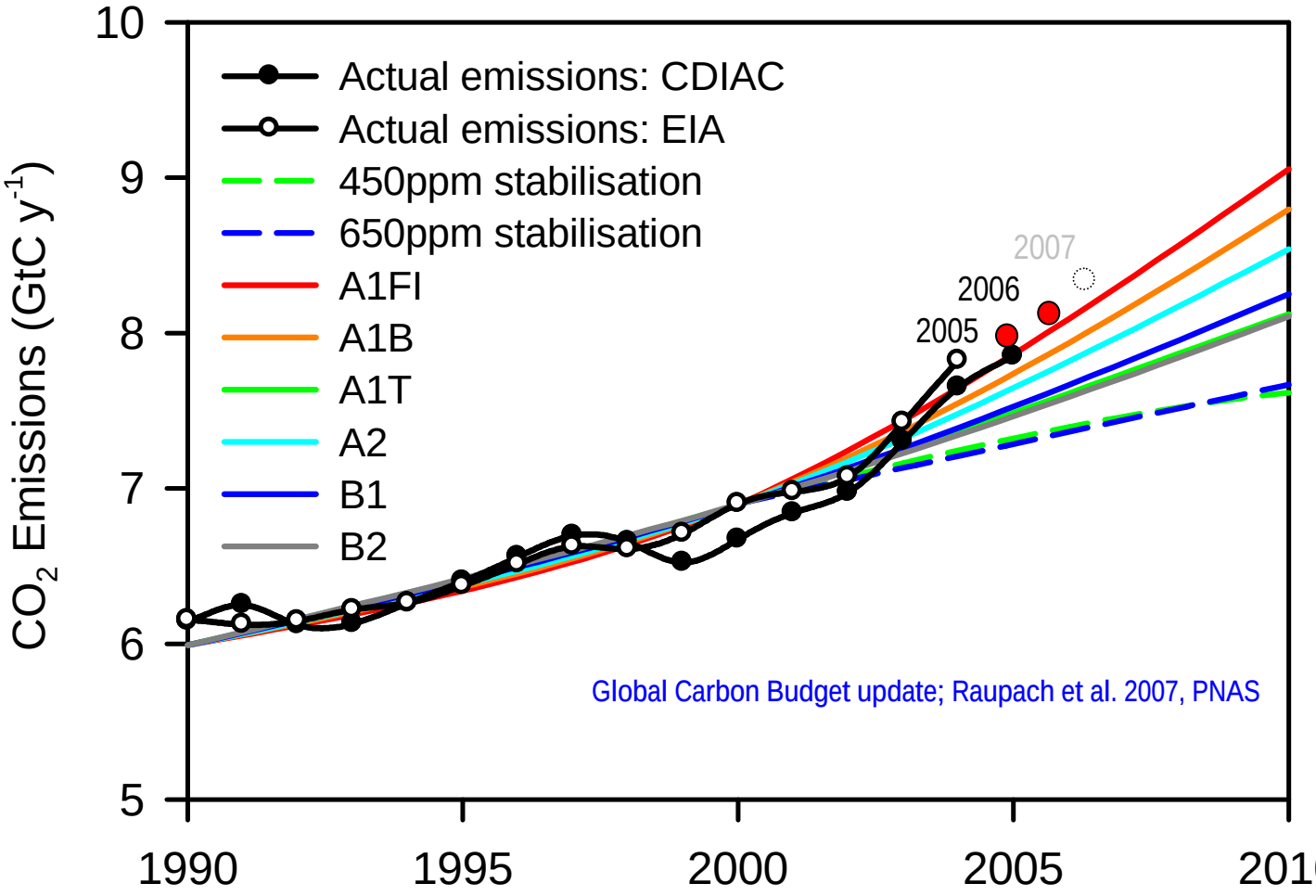
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

UNEP



National Research FLAGSHIPS CSIRO

Global Fossil Fuel Emissions



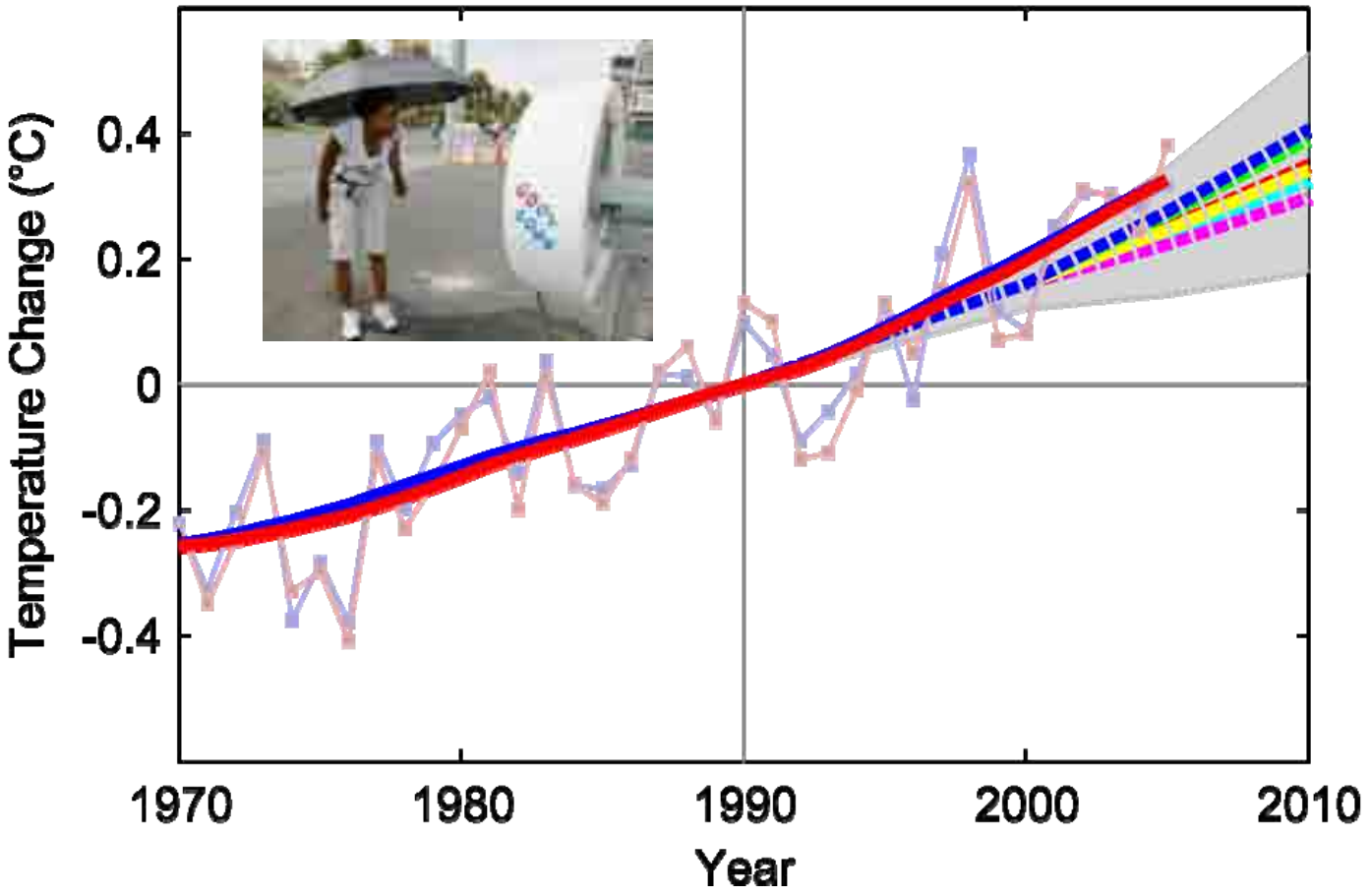
SRES (2000) growth rates in % y^{-1} for 2000-2010:

A1B: 2.42
A1FI: 2.71
A1T: 1.63
A2: 2.13
B1: 1.79
B2: 1.61

Observed 2000-2006 3.3%

Observations vs IPCC Projections

Rahmstorf et al. (2007)

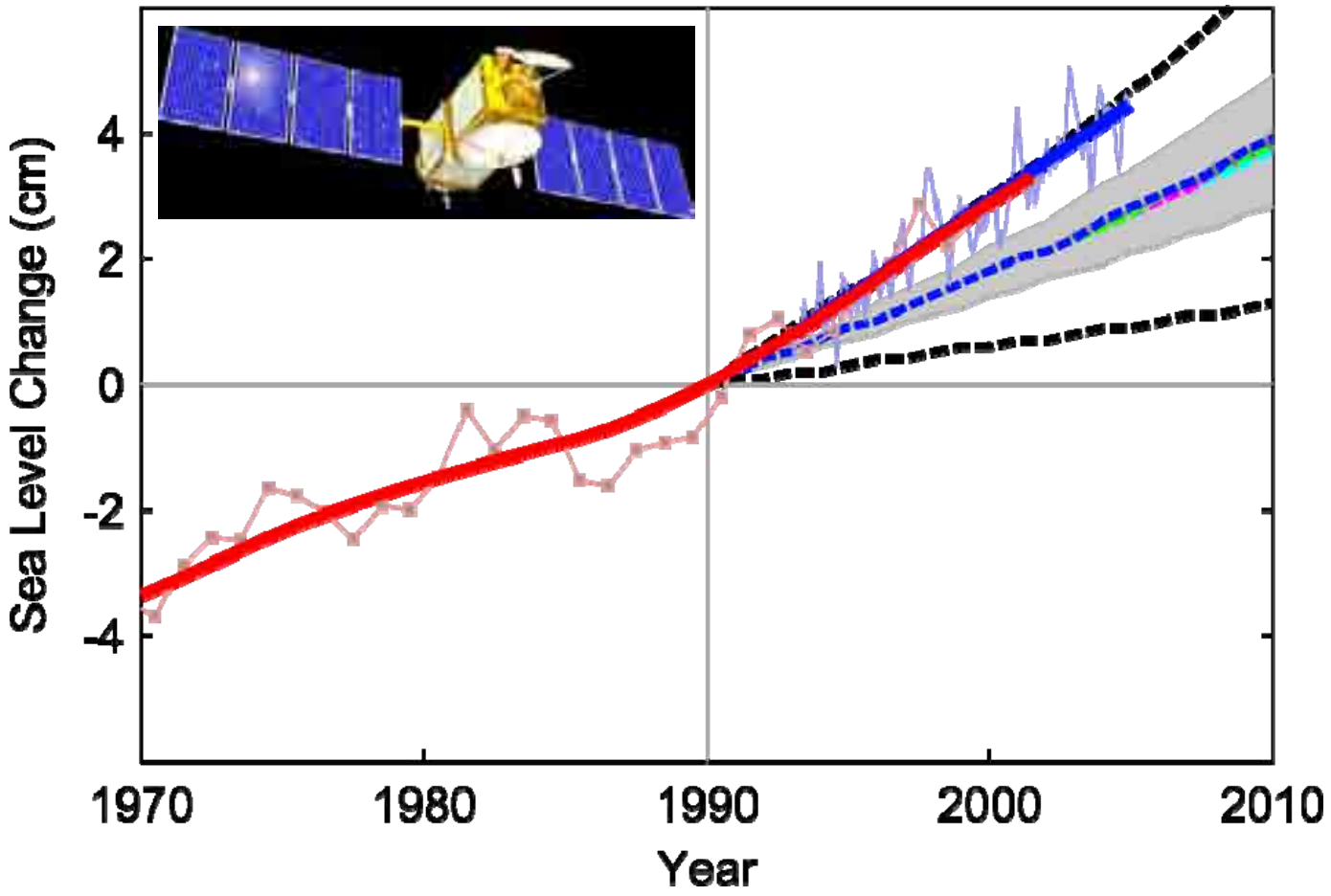


National Research FLAGSHIPS CSIRO

Observations vs IPCC Projections

Rahmstorf et al. (2007)

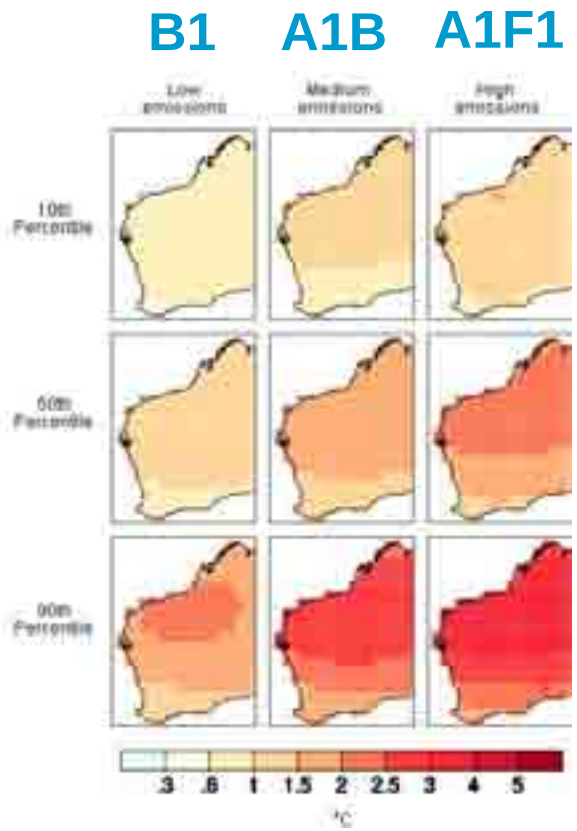
88 cm by 2100



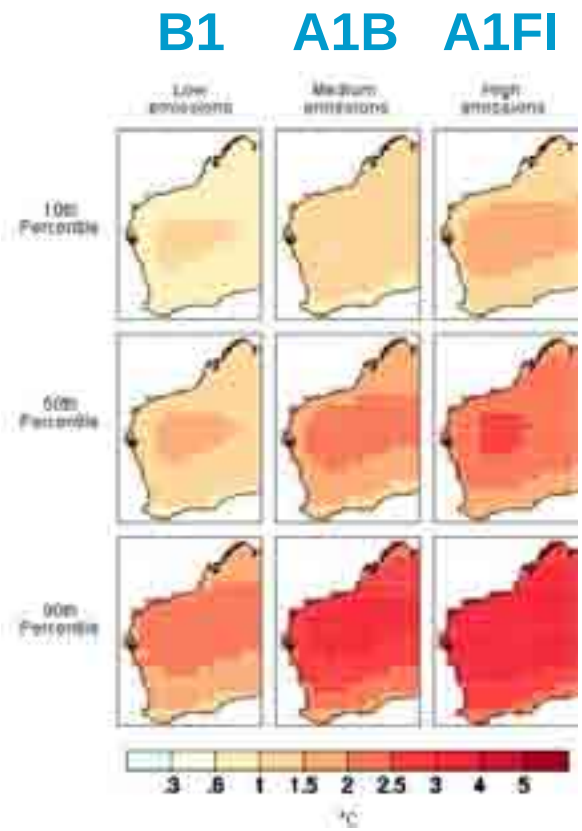
National Research FLAGSHIPS CSIRO

Temperature Projections (2050)

Winter



Summer



23 GCMs; 1980–1999 baseline

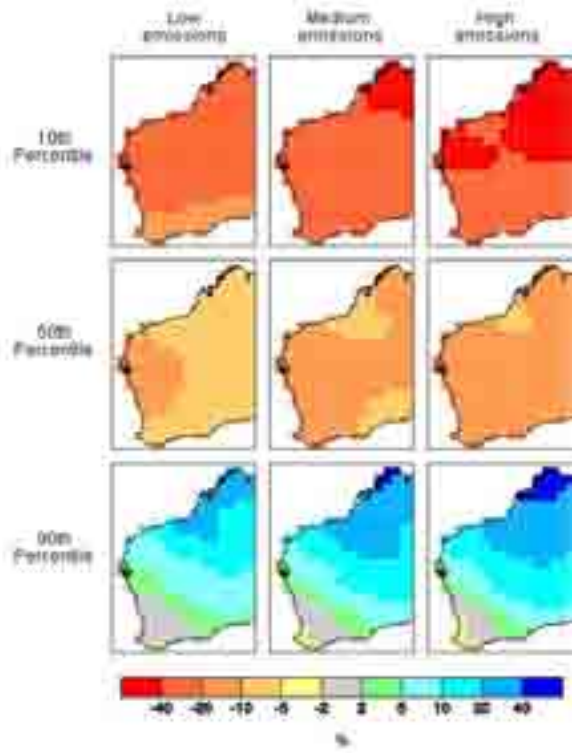
Source: http://www.climatechangeinaustralia.gov.au/

National Research FLAGSHIPS CSIRO

Rainfall Projections (2050)

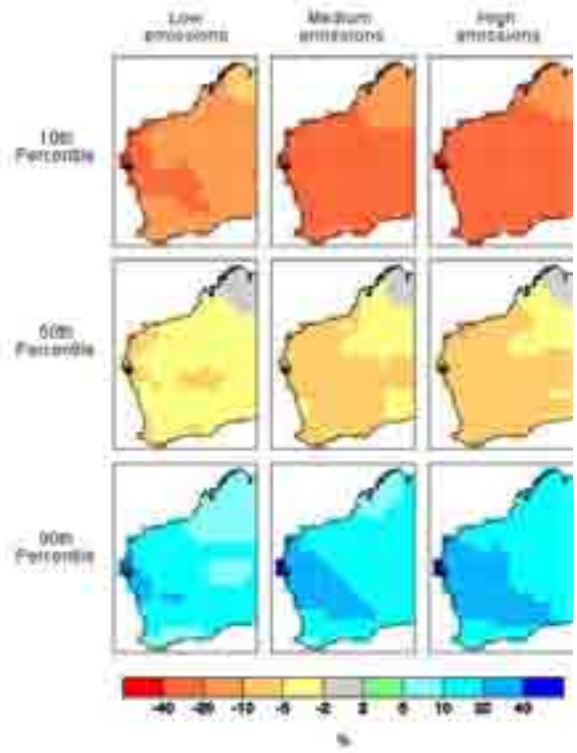
Winter

B1 A1B A1F1



Summer

B1 A1B A1FI



23 GCMs; 1980–1999 baseline

Source: http://www.climatechangeinaustralia.gov.au/

National Research FLAGSHIPS CSIRO

Impacts, Adaptation & Vulnerability

IPCC WGII AR4 (2007)

- Climate change **adds** a new dimension to existing challenges facing communities, governments & industry
- Projected rates of climate change are **likely to exceed** evolutionary rates of adaptation
- Habitat loss & fragmentation, & invasive species are **very likely to limit** species migration in response to shifting climate zones – our reserve areas are small & isolated
- Most species are well-adapted to short-term climate variability, but **not** to long-term changes in means & extremes
- **Some** human & natural adaptation has **already** taken place

IPCC WGII AR4 (2007) – 2

- **Potential impacts of climate change are likely to be substantial without further adaptation**
  - **major changes in vegetation communities**
  - **southward shift of pest & disease vectors (forestry & agriculture)**
  - **loss of biodiversity & ecosystem services**
  - **coastal development is exacerbating climatic risk**
  - **reduced water availability across southern Australia**
  - **ocean acidification likely to decrease productivity & diversity of plankton communities**
  - **saltwater intrusion may alter species composition**
  - **etc, etc**

IPCC WGII AR4 (2007) – Gaps

- **Little** quantitative information is available on
  - autonomous adaptation rates
  - critical thresholds (tipping points)
  - ecological water requirements
  - likely future behaviours of extremes – can trigger multiple & simultaneous impacts across systems
- **Few** regional studies on impacts on marine & terrestrial ecosystems relative to catchment water & wheat yield studies
- There are **no** integrated regional vulnerability assessments in Australia
  - impacts of multiple & interacting stressors, sectors & policies
  - "triple bottom line"

The Case for Climate Adaptation

"The international community is **too late with effective mitigation to avoid significant impacts**. It may yet fail to put in place substantial mitigation, in which case the challenge of adaptation to climate change will be more daunting".

"As a nation, **Australia has a high level of capacity to plan for and respond to the impacts of climate change** – that is, its adaptation potential is high."

Garnaut Climate Change Review – July 2008

Reduce Vulnerability by …

- **Identification of mechanisms** that governments might use to reduce vulnerability
- **Improved understanding** of social preparedness; limitations & barriers to adaptation
- **Better definition** of costs & benefits of adaptation options
- **Avoiding** adverse impacts & perverse outcomes, & **seizing** opportunities
- **Assessment of adaptation options** for social (including intergenerational) equity & fairness, & the impacts of taxes, price incentives, & secondary & delayed effects
- **Protection & enhancement** of monitoring networks to inform detection studies & adaptation responses
- **Discarding** notions of a climate baseline

Critical Horizons December 2008

Concluding Remarks

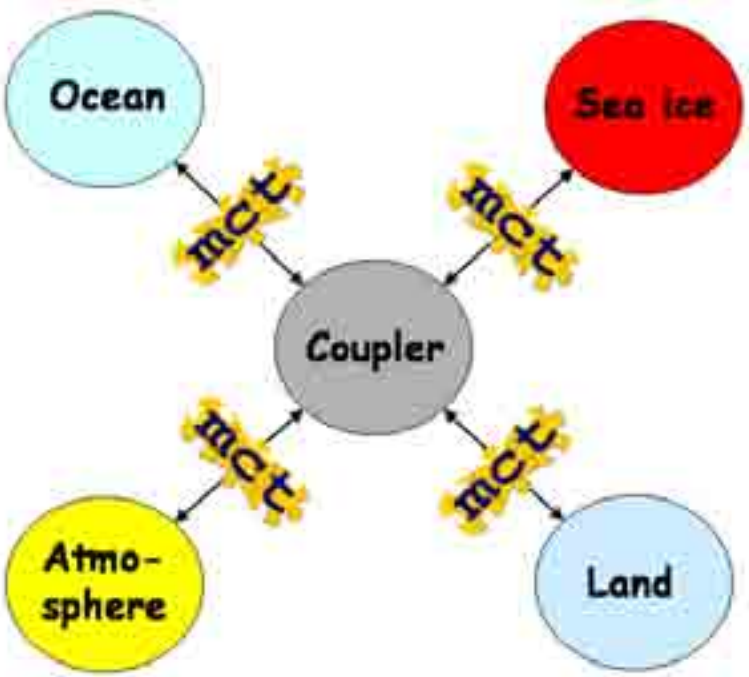
- Our climate will continue to change
- Climatic trends defined over decades, not years
- Evidence is compelling
  - recently observed changes faster than expected
  - carbon intensity of global economy intensifying: rate of increase 3 x that of 1990s
  - absorption of carbon by oceans & biosphere declining for decades
- Cannot wait for full scientific certainty:
  - it may never come; it may be too late!
  - challenge will get harder the longer we wait
- There will be winners & losers
- *Believe/disbelieve* – manage the risk!
- The 3 As: Adapt, Adapt, Adapt!

The End

“Doing nothing is no longer an option”

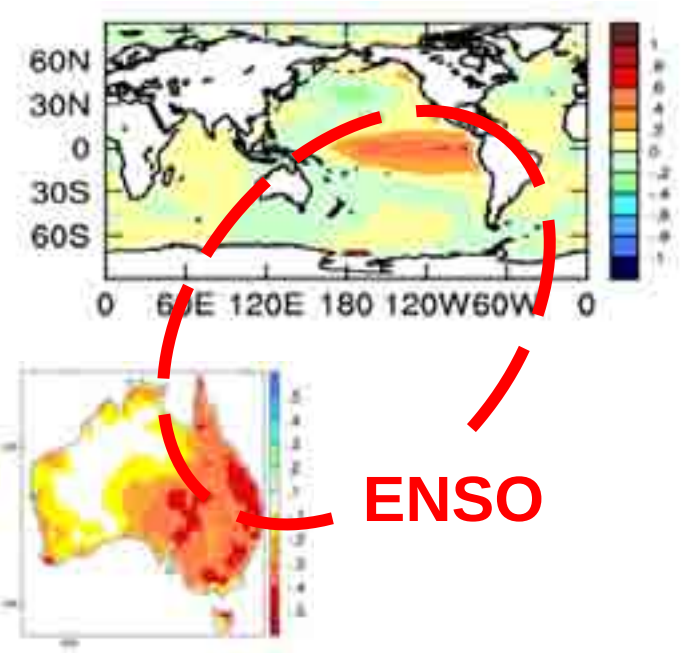
National Research FLAGSHIPS CSIRO

Global Climate Models



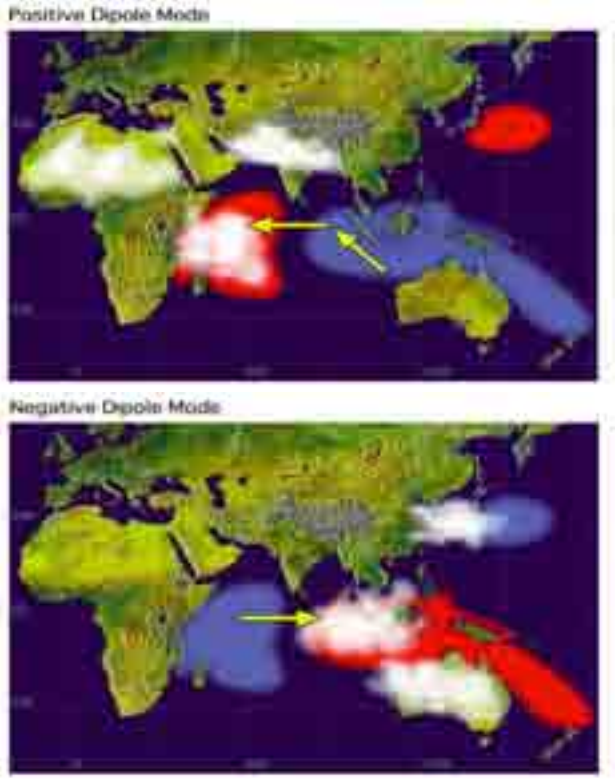
Argonne National Laboratory
Model Coupling Toolkit (MCT)

Three-Headed Dog

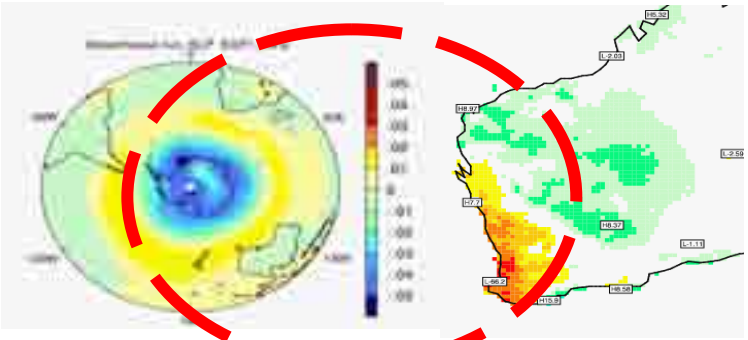


ENSO

Indian Ocean Dipole



Southern Annular Mode

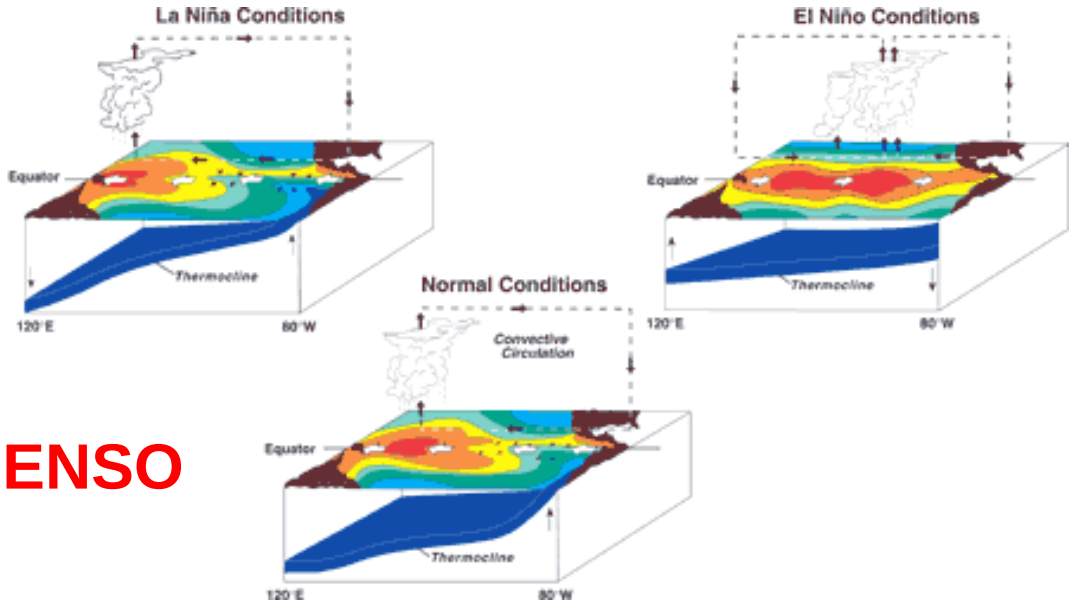


Critical Horizons December 2008

Sources of Confidence

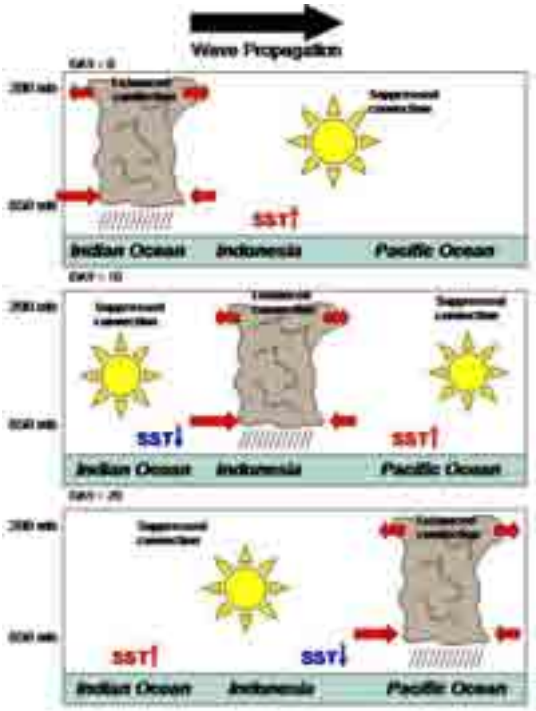
- Based on established physical laws (e.g. conservation of mass, energy & momentum)
- Model development & testing based on wealth of observations (atmosphere, ocean, cryosphere & land surface)
- Significant & increasing skill in modelling:
  - **global** temperature changes
  - **large-scale** distributions of atmospheric temperature, precipitation, ocean temperature, ...
  - **patterns of climate variability** – advance & retreat of monsoons, seasonal shifts in temperature, northern & southern annular modes

Sources of Concern



ENSO

MJO



AND:

- **Tropical precipitation**
- **Representation of clouds**
- **Cloud responses to climate change**