Lecture 1 – Climate Physics Primer

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- Coordinating a climate research centre of 50 researchers

- Research: oceans role in climate

- Teaching ocean-atmosphere and climate courses

- Writing articles for scientific journals, reports, the media

- CLIVAR, WCRP, IPCC,...

- Policy statements & documents
Physical oceanography, meteorology and climate science

The study of the physics, properties, and dynamics of the oceans, atmosphere and coupled climate system
Applications

Weather prediction

Climate variability and change

Ocean currents

Biology and fisheries

Navigation

Engineering, recreation, …
Oceanic and atmospheric phenomena

**Time Scale**
- 100 y
- 2 yrs
- Month
- days
- mins

**Spatial Scale**
- cms
- 10 m
- 1 km
- 100 km
- 1000 km

- Turbulence
- Waves
- Molecular
- Upwelling
- Eddies
- Boundary currents
- El Nino
- N. Atlantic Oscillation
- Deep water formation
- Weather
- Diurnal cycle
- Climate Change
- Weather
- Hail storm
- Boundary currents
- Deep water formation
- El Nino
- N. Atlantic Oscillation
Research foci:

• Model development
  – subgrid-scale eddies, mixing
  – convection, gravity currents

• Model evaluation
  – tracers (CFCs, 14C, …)
  – water-masses
Research foci:

- OCEANS TO RAIN

Indian Ocean Variability / Change

Southern Annular Mode

ENSO / Pacific Variability
Research foci:

- Ocean thermohaline circulation
  - Water-masses
  - Variability
  - Stability / Change
Southwestern Australia Rainfall – an Indian Ocean link?

(a) Model SWA rainfall anomaly

England et al., J. Climate
Rainfall deciles; April-May 2005
Global SST anomalies – April 2005

(white regions indicate sea-ice)
SST anomalies in April 2006 (blue = cool anomalies, red = warm anomalies).
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- What causes the Earth’s climate to change?
- Why are we concerned about greenhouse gases?
- Has much changed in the past century?
- What’s in stall for the coming decades?
Causes of climate change

Extraterrestrial Factors

- Solar Output
- Earth-Sun Geometry
- Stellar Dust

Ocean, Atmosphere, and Land Factors

- Volcanic Activity
- Mountain Building
- Continental Drift
- Ocean Heat Exchange
- Surface Albedo
- Atmospheric Albedo
- Atmospheric Chemistry

The only source of climate change that we can easily alter!
CO$_2$ Concentration is Rising
Changes in greenhouse gases from ice core and modern data.

(a) CO₂

(b) CH₄

(c) N₂O

(d) Rate of change
Mars
Thin atmosphere
(Aprkall CO₂ in ground)
Average temperature: -50°C

Earth
0.03% of CO₂ in the atmosphere
Average temperature: +15°C

Venus
Thick atmosphere containing 96% of CO₂
Average temperature: +420°C

Why is Venus hotter than Mercury?

Mercury temperature = \( \sim 85 \, ^\circ\text{C} \)

Venus temperature = 500 \( ^\circ\text{C} \)

Answer -

The Greenhouse Effect
NH air temperatures since 1000 A.D.
Trend in global average surface temperature

Source: School of environmental sciences, climatic research unit, university of East Anglia, Norwich, United Kingdom, 1999.
Simulated annual global mean surface temperatures

(a) Natural
(b) Anthropogenic
(c) All forcings
Changes in global average surface temperature

Eleven of the last twelve years rank among the twelve warmest years in the instrumental record of global surface temperature.
The Greenhouse Fingerprint unambiguously matches the 20th Century atmospheric temperature trend...
FIGURE 20: Global drying and wetting trends over the past half-century as estimated by the change in water balance (in mm per month) (A. Dai, National Center for Atmospheric Research, USA, and Dai et al. 2005).
Australian temperature trend, 1950 – present day
Australian rainfall trend, 1950 – present day
Southern Annular Mode
Total annual inflow into Perth Dams

Figure 2: Abrupt changes to dam inflows, Perth

Note:
A year is taken as May to April and labelled year is the start (winter) of year

50% reduction in streamflow

Source: Water Corporation, Western Australia

IPCC-WG2 [2007]
Is the Antarctic changing?

... observations

Larsson-B Ice Shelf Collapse 31 January to 7 March 2002

Twentieth Century Land-Ice Changes

Davis et al., Vaughan; Science, 2005
Melting of the Greenland Ice-sheet

SOURCE: Konrad Steffen and Russell Huff, University of Colorado, Boulder
Minimum Arctic sea ice extent

Stroeve et al. GRL 2007
Projected changes in CO₂ and climate: summary of assumptions in the IPCC 1992 alternative scenarios

**CO₂ emission scenarios**

- IS92a
- IS92b

**Resulting concentration of CO₂ levels**

- IS92a
- IS92b

Sources: Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 199; Hadley center for climate prediction and research, United Kingdom, in Climate change information kit, Information unit for convention (IUC), UNEP, Geneva, 1997.
IPCC multi-model Glb Avg

TAS Anomalies (°C)

Years

1900 2000 2100 2200 2300

A2
A1B
B1
20thC Commit
historical
Annual-mean temperature change predicted for 2070-2100 in IPCC Third Assessment Report models

Annual mean change in temperature (colour shading) and its range (isolines) (Unit: °C) for the SRES scenario A2, showing the period 2071 to 2100 relative to the period 1961 to 1990.
The Past and the Future

△ Instrumental Data
△ Proxy Reconstructions
△ Model Simulations

IPCC high and low projection

Spörer minimum
Maunder minimum
Dalton minimum

ΔT

Year

Instrumental records/reconstructions
- Instrumental record
- Mann et al. 1999 with uncertainties
- Jones et al. scaled 1856-1980
- Crowley and Lowery scaled 1856-1965
- Esper et al. scaled 1856-1980
- Mann et al. 2003 (gridded, area-weighted boreholes)
- Mann et al. 2003 ("optimal" borehole reconstruction)
- Mann and Jones with uncertainties
- Briffa et al. scaled 1856-1940

Simulations
- Crowley
- Bauer et al. (14C solar)
- Bauer et al. (10Be solar)
- Gerber et al. 1.5CO2
- Gerber et al. 2.5CO2
We are currently tracking at the very high end of emission scenarios and temperature projections.
We are currently tracking at the very high end of emission scenarios – beyond what the IPCC thought possible

Raupach et al. (2007)
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Raupach et al. (2007)
Climate Change simulation to year 2054
Figure 5.3.5. Linear trend of SST in the Indian Ocean for (a) 1900–1970 and (b) 1970–1999 estimated from the HADISST temperature data (after Rayner et al., 2003).
Tropical Cyclone Nicholas, 18 February, 2008
Figure 1. Model Simulation of Trend in Hurricanes
(from Knutson et al, 2004)
Increases in severe storms and extreme climatic events?
CONCLUSIONS

• The planet has seen substantial climate change in the past century

• These changes cannot be explained by known modes of natural variability (i.e., solar cycles, ...)

• A manifestation of climate change can easily be found in air temperatures, rainfall, ocean properties, land-ice, sea-level, winds, storm tracks, ...

• These changes will accelerate over the coming decades/century unless we adopt aggressive response strategies
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Climate change and human rights

- Displacement of populations
- Water supply
- Food supply
- Human health
- Socio-economic context
Figure 6.6: Relative vulnerability of coastal deltas as indicated by the indicative population potentially displaced by current sea-level trends to 2050 (Extreme ≥ 1 million; high =1 million - 50,000; medium 50,000 – 5000; following Ericson et al. (2006)).
Projected run-off changes 2100 relative to 1981-2000

1: Thickness of small island freshwater lens declines from 25 to 10 m due to 0.1 m sea level rise by 2040-2080

2: Streamflow decreases such that present water demand could not be satisfied after 2020, and loss of salmon habitat

3: Groundwater recharge decreases by more than 70% by the 2050s

4: Flooded area for annual peak discharge in Bangladesh increases by at least 25% with a global temperature increase of 2°C

5: Electricity production potential at existing hydropower stations decreases by more than 25% by the 2070s.

6: Increase of pathogen load due to more heavy precipitation events in areas without good water supply and sanitation infrastructure

IPCC-WG2 [2007]
Crop yield changes projected relative to today aggregated by nation.
Number of deaths in Paris in summer 2003

![Chart showing daily mortality and temperature trends in Paris during summer 2003. The chart compares mean daily mortality for the years 1999-2002 and 2003, along with mean daily summer temperature for the same periods. The data indicates a significant increase in daily mortality coinciding with high temperatures.]
Some issues re. climate science

• Climate scientists are well aware of natural variability
  • Climate scientists have no “conflict-of-interest”
  • Climate science must undergo rigorous peer-review
    • Climate scientists do not prescribe policy
    • Inexpert debate - unlike any other science
  • Opportunities for innovation and economic growth
    • We have succeeded before: CFC’s, …
• Climate scientists are your best source of information for climate science
Physical oceanography and climate science

The study of the physics, properties, and dynamics of the oceans and coupled climate system
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Intergovernmental Panel on Climate Change (IPCC)

http://www.ipcc.ch
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Figure 10.3.6. Multi-model mean change under the A1B scenario for 2080–2099 relative to 1980–1999, for DJF (top) and JJA (bottom). The variables are, from left to right, surface air temperature (°C), precipitation (mm/d), and sea level pressure (hPa). Stippling denotes areas where the magnitude of the multi-model ensemble mean exceeds the inter-model standard deviation.
Global 20th Century Temperature Trends

(a) Annual temperature trends, 1901 to 2000
(b) Annual temperature trends, 1910 to 1945
(c) Annual temperature trends, 1946 to 1975
(d) Annual temperature trends, 1976 to 2000