Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Understanding the Weather

- “Weather” is short-term and caused by various air and ocean circulations
- There are natural climate cycle that cause large climate changes in annual or decadal time frames
- None of these cycles explains the dramatic warming since the 1970s.

Video: [Meteorologist Paul Douglas April 2013](#)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Video: "It's cold. So there's no Climate Change"
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

New Video: If There’s Global Warming, Why is It So Cold?

Video: If There’s Global Warming, Why is It So Cold?
• Incoming sunlight in the form of shortwave radiation

• Outgoing radiation from Earth in form of longwave radiation

• Heat surplus in tropics, heat deficit near poles
Chapter 4

- Global Heat Transfer
- **Atmospheric Circulation**
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

**Web Alert:**

**Global Circulation**

- Intertropical Convergence Zone (ITCZ) straddles the equator and features very large thunderstorms

- These storms bring much heat and water vapor high into troposphere

- Deserts result from sinking air between Hadley and Ferrel Cells (approx. 30°N/S)

- Between the Ferrel and Polar Cells air rises once again and leads to clouds/precipitation (approx. 60°N/S)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Web Alert:

Global Circulation

Kitchen (2013)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Vegetation Index (Dark = wet, Light = dry)

Deserts denoted by brown shading located where air is sinking

NASA (2001)

Kitchen (2013)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Text Book Animation: Global Patterns of Pressure

Text Book Animation: Global Wind Circulations, Hadley Cells

Text Book Animation: Global Patterns of Pressure
• Total heat content on oceans dwarfs that of the atmosphere

• Since the late 1970s ocean heat content has increased dramatically
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Higher numbers mean higher salt content

Surface layer is the top 100-400 m and is well-mixed

Warm, low salinity water near equator due to rainfall (freshwater)

Subtropics saltier due to increased evaporation

Mid-latitudes less saline

Salinity is highly variable near the poles
  • Decrease salinity: input from rivers at peak flow during Arctic spring and melting of seasonal sea ice
  • Increase salinity: strong winds increase evaporation and formation of brine as water freezes during winter
• The Pycnocline is a transition zone between the mixed layer and deep water
• It features a decrease in temperature and increase in salinity which inhibits vertical water motion
• Because of this zone, vertical mixing over the oceans is inhibited in most regions except for areas where surface winds draw deep water upward or where cold water sinks
• Intermediate water forms between active surface currents and deep water. Most originates near Antarctica and is called Antarctica Intermediate Water (AAIW)
• Deep water is very cold (3°C) and moves very slowly (few cm/s). Most important is North Atlantic Deep Water (NADW) which forms in the Norwegian, Greenland, and Labrador Seas
• Bottom water is coldest and densest and is trapped in the Arctic and Antarctic sea floors

Note: Deep water can extend to 11000 m in deep trenches
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

The Great Ocean Conveyor moves about 90% of the ocean waters from surface to deep water and back.

- Takes hundreds of years to loop one time
- Controls the transport of heat from tropics to poles
- Some of the heat being gained near the Arctic is being stored in deep ocean currents where it may return again in a few hundred years

Kitchen (2013)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

NADW forms when strong winds increase evaporation and when ice forms (both processes leave salt behind)

• Cold, dense water sinks and flows through gaps in the ocean topography

• Sverdup is the unit that measures flow rate. 1 Sverdup = 1 million cubic meters per second

• NADW moves at 20 Sverdups

National Oceanography Centre, Southampton (2010)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Video: A Nasty Surprise in the Greenhouse
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Where water diverges, cooler water from below is brought to the surface (upwelling)

Where water converges, warmer surface water is driven downward (downwelling)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Text Book Animation: Ocean Circulation

Text Book Animation: Ekman Spiral & Coastal Upwelling/Downwelling
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Tropical cyclones (hurricanes, typhoons, cyclones) form when sea surface temperatures (SST) are at least 27°C, low-level convergence of air, and upper-level divergence of air.

Cyclones derive their energy from the heat released from condensing water.

Each cyclone releases energy equivalent to about 200 times the world’s electrical power.

Global warming is expected to increase the intensity of cyclones and the precipitation that falls.

NOAA (2005)

IPCC (2013)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Video: Hurricane Sandy’s Double Whammy
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

- Monsoons develop when there is a large T difference between land and sea
- Warmer air rises and results in lower pressure
- Cooler air then moves into this lower P region causing a circulation to develop
- Rising air cools and results in clouds and precipitation

Kitchen (2013)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• **Cyclones & Monsoons**
• Periodic Cycles

**Indian/Asian Monsoon**

- Dry winter due to offshore flow
- Wet summer due to onshore flow
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

African Monsoon

Ruddiman (2008)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Normal Pacific Conditions
Kitchen (2013)

- Trade Winds push water away from South America and toward Asia
- Deeper, colder water upwells along South American coast
- Higher air pressure in eastern Pacific basin
- Warmer water pools along western Pacific basin
- Lower air pressure in western Pacific basin
El Niño/Southern Oscillation (ENSO) Conditions
Kitchen (2013)

- Warmer water in western Pacific “sloshes back” toward South America
- Large region of very warm sea surface temperatures (SST) along central Pacific
- Decreasing air pressure in eastern Pacific basin
- Increasing air pressure in western Pacific basin
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Darwin: Southern Oscillation Index

UCAR (2013)

Walker Circulation (Normal)

Kitchen (2013)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Text Book Animation: El Niño and La Niña
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

ENSO events cannot explain warming trend – all events are getting warmer due to climate warming
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

- If one only plots La Niña (cool) years the TREND is still up!

![Annual Temperature vs 1951-1980 average (°C)](image)

NASA (2013)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Madden-Julian Oscillation (MJO) moves 5-10 m/s across the Indian Ocean into Pacific Ocean and repeats on period of 30-60 days.

MJO events cause strong winds to move against the prevailing Trade Winds.

MJO may be a “trigger” for El Nino waters that are being “held back” by Trade Winds.

Kitchen (2013)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

North Atlantic Oscillation (NAO)

• + NAO keeps cold air north
  • Atlantic storms more intense

• - NAO drives cold air southward, warmer air northward into Arctic
  • Atlantic storms less intense

UCAR (2013)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Video: Meteorologist Paul Douglas describes negative NAO that caused very cold winter/spring in the US during 2013
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Pacific Decadal Oscillation (PDO)

+ PDO

- PDO

monthly values for the PDO index: 1900-September 2009

Skeptical Science (2010)
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Pacific Decadal Oscillation (PDO) cannot be causing modern warming

Kitchen (2013)
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Atlantic Multidecadal Oscillation (AMO)

- AMO changes SSTs in the N. Atlantic Ocean
- Lasts for 20-40 years
- Warm phase means the **north and south Atlantic are warm** and the central Atlantic is cool
- Cool phase is reverse and the **north and south Atlantic are cooler** with warmer water in the central Atlantic
- May be caused by changes in strength of deep ocean circulation
- Strongly correlated with hurricane activity
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

• AMO is strongly correlated with hurricane activity
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

97-98% of climate experts agree that humans are warming the planet

100% of international academies of sciences agree
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Video: Last Week Tonight with John Oliver (HBO): Climate Change Debate
Chapter 4

• Global Heat Transfer
• Atmospheric Circulation
• The Oceans
• Cyclones & Monsoons
• Periodic Cycles

Video: Jon Stewart of Daily Show: Burn Noticed
Chapter 4

- Global Heat Transfer
- Atmospheric Circulation
- The Oceans
- Cyclones & Monsoons
- Periodic Cycles

Video: What Climate Deniers Learned from Big Tobacco
Summary

- Up until the past 30 years, volcanic eruptions and solar variance can explain most of the global warming and cooling.

- In the last 30 years temperatures of the oceans, surface, and air are rising even though solar activity is declining.

- Climate models can only match modern warming if increases in GHGs are included.

- Natural cycles and forcings would have resulted in global cooling in the past 30 years.