ENSO and Tropical Cyclones

Tropical Cyclones

• Huge rotating masses of low pressure
• Strong winds, torrential rain
• Classified by maximum sustained wind speed
• Atlantic & Eastern North Pacific: Hurricanes
• Western North Pacific: Typhoons
• Indian Ocean & South Pacific: Cyclones
Tropical Cyclone Origins

- Energy: one single hurricane=all energy sources in US during the past 20 years
- Begins as a low-pressure cell from equatorial low-pressure belt
- Energy source – latent heat of condensation
- Surface winds feed moisture (water vapor); air rises, low pressure deepens, winds strengthen, more water vapor – positive feedback
- Storm develops
  - Winds less than 61 km/hour (38 miles/hour) – tropical depression
  - Winds 61–120 km/hour (38–74 miles/hour) – tropical storm
  - Winds above 120 km/hour (74 miles/hour) – tropical cyclone or hurricane
# Hurricane Intensity

## Table 6.3: The Saffir-Simpson Scale of Hurricane Intensity

<table>
<thead>
<tr>
<th>Category</th>
<th>Wind speed [km/hr]</th>
<th>Wind speed [mi/hr]</th>
<th>Typical storm surge [sea level height above normal]</th>
<th>Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120–153</td>
<td>74–95</td>
<td>1.2–1.5 [meters], 4–5 [feet]</td>
<td>Minimal: Minor damage to buildings</td>
</tr>
<tr>
<td>2</td>
<td>154–177</td>
<td>96–110</td>
<td>1.8–2.4 [meters], 6–8 [feet]</td>
<td>Moderate: Some roofing material, door, and window damage; some trees blown down</td>
</tr>
<tr>
<td>3</td>
<td>178–209</td>
<td>111–130</td>
<td>2.7–3.7 [meters], 9–12 [feet]</td>
<td>Extensive: Some structural damage and wall failures; foliage blown off trees and large trees blown down</td>
</tr>
<tr>
<td>4</td>
<td>210–249</td>
<td>131–155</td>
<td>4.0–5.5 [meters], 13–18 [feet]</td>
<td>Extreme: More extensive structural damage and wall failures; most shrubs, trees, and signs blown down</td>
</tr>
<tr>
<td>5</td>
<td>&gt;250</td>
<td>&gt;155</td>
<td>&gt;5.8 [meters], &gt;19 [feet]</td>
<td>Catastrophic: Complete roof failures and entire building failures common; all shrubs, trees, and signs blown down; flooding of lower floors of coastal structures</td>
</tr>
</tbody>
</table>

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Hurricanes

• About 100 worldwide per year
• Require
  – Ocean water warmer than 26°C (77°F)
  – Warm, moist air
  – Low vertical wind shear
  – The Coriolis Effect (determine hurricane locations)
• Hurricane season is June 1 – November 30 in Atlantic basin.
Tracks are affected by the trade winds and Coriolis effect.
Lifetime: 5-10 days
Diameter: 200-800 km.
Hurricane Anatomy and Movement

[Image: Illustration showing the anatomy of a hurricane, with labels for the eye, spiral rain bands, and warm water vapor]

[Image: Map showing total rain accumulation from Hurricane Katrina, with color legend indicating rainfall in millimeters]

FIU TRMM Satellite Tropical Cyclone website: http://tcpf.fiu.edu/tc_storms.html (Global TCs between 1998-2010)
Hurricane Destruction

- **High winds**
- **Intense rainfall** - fresh water flooding
- **Storm surge** – increase in shoreline sea level

New Jersey, Hurricane Felix (1995)
Historic Storm Destruction

- Historically destructive storms
  - Galveston, TX, 1900 (Cat 4, deadliest nature disaster in US: 6000 deaths, 6 m storm surge)
  - Andrew, 1992 (Cat 5, 54 killed, $26 billion damage, second costliest in US)
  - Mitch, 1998 (Cat 5, hit Central America, flooding/mudslides, 11,000 deaths)
  - Katrina, 2005 (Cat 3 when making landfall at LA, 9 m storm surge, 1600 deaths, and $75 billion damages)
  - Ike, 2008 (Cat 2 when landfall at TX, 146 deaths, 24 billion damages, 3rd costliest)
1. Where does a hurricane come from?

Africa (easterly) jet

Barotropic Instability

Easterly (tropical) wave
2. How can a hurricane maintain its strength?
It is the convective clouds that generate spin up process to overcome the spin down process induced by the Ekman pumping.
Where do energy and moisture come from to foster a large amount of convection in a hurricane?
3. What determines the movement of a hurricane?
El Niño/La Nina and hurricane

10 hurricane days during El nino years, 27 hurricane days during non-El nino years.

Atlantic Ocean

Low wind shear (Average year)

- Storm's latent heat is focused over small area.

High wind shear (El Niño year)

- Storm's latent heat is focused over larger area.
Major (Cat. 3-4-5) Tracks

1H Tracks during 22 ENSO cold years
This century

I H Tracks during 22 ENSO warm years
This Century
Chris Landsea did a statistics of hurricane damage along the three coastal locations of the US, the Gulf Coast, the Florida Peninsula, and the US East Coast. He showed that in the 10 coldest years during the recent 41 year period, the Coast hurricane spawned damage was 55 billion, while only 2.5 billion in the 10 warmest ENSO years. But Chris further pointed out that although the ENSO is typically a very strong modulator of US hurricanes when ENSO is in very cold or very warm phase, it is usually not a major player in those years of small magnitude warm or colder or neutral water conditions.
Global Warming and hurricane

Will hurricanes become more frequent and intense in a warm climate?

![Graph showing sea surface temperature vs. powerfulness in tropical Atlantic cyclones.](https://via.placeholder.com/150)
ACCUMULATED CYCLONE ENERGY IN TROPICAL CYCLONE-PRODUCING BASINS

North Indian

Eastern North Pacific

Western North Pacific

South Indian

North Atlantic

Australia - South Pacific
Fishery scientist Steven Hare first invented the name PDO in 1996. PDO is a long-lived ENSO-like pattern of Pacific climate variability usually persisting for a long time period about 20-to-30 years.

- **Warm phase**: Anomalously cool water in the north central Pacific, and anomalously warm water along the west coast of North America.
- **Cold phase**: Anomalously warm water in the interior North Pacific, anomalously cool water along the coast of North- and Central America and in the central equatorial Pacific.
ENSO and PDO are not the independent anomalies but are somehow linked phenomena.

Inter-decadal PDO may be conceivably considered as an envelope of the inter-annual ENSO variability.

What causes decadal variability of PDO?
External mechanism: sunspot activity
Internal mechanism: feedbacks in the atmosphere and ocean
Some extreme climate anomalies

A decade of western North American drought

Pattern of US drought in late August 2003
Is a decade of western North American drought related to ENSO or other longer time scale natural climate anomaly or is caused by human activities?
How does the western North American drought compare to the global wet-dry distribution?

Warmer color (negative values) indicates more intense drought.

Does the abrupt increase in drought since 1980s caused by human activities or natural climate anomalies?
European heat wave of 2003

It is not an isolated event, but a part of daytime and nighttime warmth over most of world’s major landmasses.

Change in days and nights of “extreme warmth” from 1951 to 2003. “extreme warmth” is defined as upper 90th percentile of full 51 yrs records.
Is European heat wave of 2003 related to global warming?

Numerical simulations show that the polar jets tend to migrate polarward in a warm climate, allowing dry subtropical zone to penetrate further into mid-latitude such as Europe and US during the summer season. This increases the chance to generate heat waves in mid-latitude.
The vanishing snow of Kilimanjaro

Mount Kilimanjaro: The highest mountain in Africa. The peak is 5,898.7 m (19,340 ft).
**ATMOSPHERIC TEMPERATURE CHANGES**

This graphic shows the pattern of late 20th-century/early 21st-century atmospheric temperature changes predicted by climate models. Note that the greatest warming is observed in the tropics and in the lower atmosphere.

**Lower stratosphere temperature**

- **Mid- to upper troposphere temperature**

- **Lower troposphere temperature**

- **Surface temperature**

**KEY**

- Air temperature analyses from thermometers, satellites, and weather balloons (°C)
- Agung volcanic eruption
- El Chichón volcanic eruption
- Pinatubo volcanic eruption

Depth of atmosphere is not drawn to scale.