

## Causes of Droughts

## DROUGHTS

Drought: temporary deficiency of precipitation / water supply over period of time, from a season to many years, with definition of absolute & partial drought varying across places. Drought  $\neq$  aridity (permanent) / desertification (ongoing process)!

## 1. El Nino &amp; La Nina

- ✓ El Nino: an unusually warm phase of naturally occurring oscillation in sea surface temperatures in Pacific Ocean (Southern Oscillation)
- ✓ Southern Oscillation: seesaw shift in surface air pressure between Darwin & Tahiti (high in Darwin  $\rightarrow$  low in Tahiti and vice-versa)
- ✓ Occurs every 2 - 7 years
- ✓ Atmospheric pressure changes affect the occurrence of drought
- ✓ El Nino brings hurricanes & storms to the Americas & drought to western Pacific; vice-versa for La Nina
- ✓ Effects of El Nino & La Nina affect many other parts of world too!
- ✓ 1997: caused drought in Australia, North Korea, Indonesia & Philippines but flooding / typhoons in Bangladesh & Hong Kong

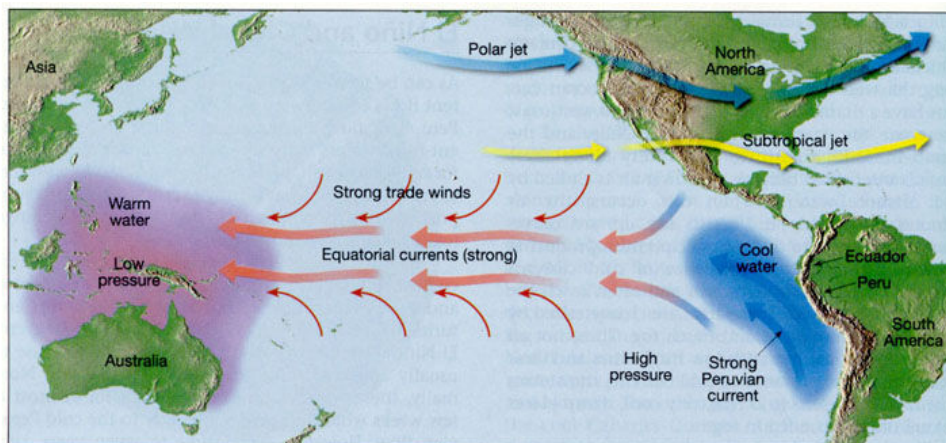


Fig.6 Normally, the trade winds and strong equatorial currents flow toward the west. At the same time, an intense Peruvian current causes upwelling of cold water along the west coast of South America.

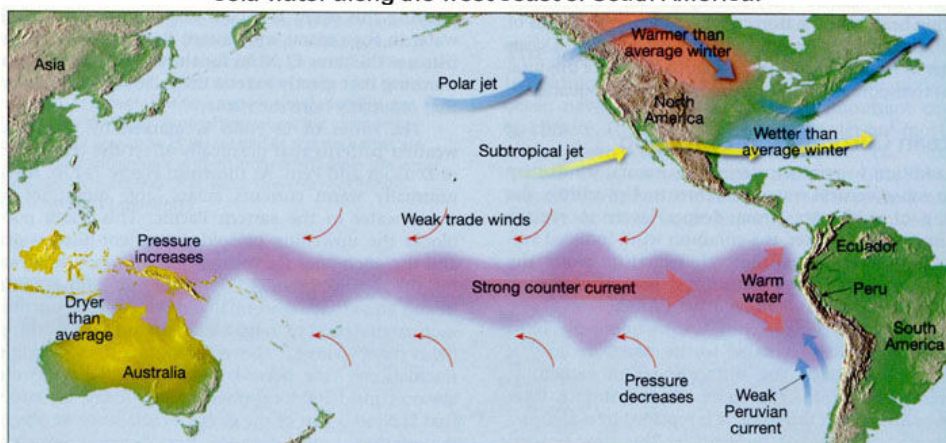


Fig.14 Upon the advent of an ENSO event, the pressure over the eastern and western Pacific flip-flops. This causes the trade winds to diminish, leading to an eastward movement of warm water along the equator. As a result, the surface waters of the central and eastern Pacific warm, with far-reaching consequences to weather patterns.

<http://www.sbg.ac.at/ipk/avstudio/pierofun/atmo/el-scans/>



## 2. Shifting of rain belts

- ✓ Stalling of high pressure systems (e.g. by jet streams), causing decrease in precipitation amounts
  - Great Depression in USA in 1930s, caused by long-lasting high pressure ridge in upper troposphere causing anticyclones above central USA & Canada
- ✓ Winds carrying continental (drier) rather than oceanic air masses

## 3. Rain shadow effect

- ✓ Leeward side of mountain in rain shadow hence receives little rain as most precipitation falls on windward side of mountain

## 4. Anthropogenic reasons

- ✓ Deforestation reducing natural watersheds, and working in vicious cycle as forest fires increase loss of forests
  - Thailand, Pakistan (1999 - 2002) & Amazon (2005 - 2006)
- ✓ Global warming, with changes in precipitation impacting LDCs

## Stages of Drought

## DROUGHT

Droughts go through 3 stages, intensifying with each stage, before cessation

### 1. Meteorological drought

- ✓ Prolonged period with less than average precipitation
- ✓ Precedes other kinds of drought

### 2. Agricultural drought

- ✓ Affects crop production or ecology of farms
- ✓ Can also arise from soil condition & erosion triggered by poorly planned agricultural endeavors

### 3. Hydrological drought

- ✓ Water reserves (e.g. aquifers, lakes & reservoirs) fall below statistical average
- ✓ Can be triggered by other factors besides loss of rainfall

## Effects of Droughts on DCs & LDCs

## DROUGHTS

Economic	Environmental	Social
✓ Growth detriment	✓ Desertification	✓ Lives lost from food shortage (famine),
✓ Crop quality & food	✓ Dust storms	

<ul style="list-style-type: none"> <li>✓ production falls</li> <li>✓ Food prices &amp; import prices rise</li> <li>✓ High livestock mortality rates</li> <li>✓ Losses to tourism industry</li> <li>✓ Loss of hydroelectric power</li> <li>✓ Loss of navigability of rivers &amp; canals</li> </ul>	<ul style="list-style-type: none"> <li>✓ Damage to plant &amp; animal species</li> <li>✓ Degradation of wildlife habitats</li> <li>✓ Wind &amp; water erosion of soils</li> <li>✓ Poor water quality</li> <li>✓ Wildfires</li> </ul>	<ul style="list-style-type: none"> <li>heat, suicide, violence</li> <li>✓ Water use conflicts</li> <li>✓ Migration (forced)</li> <li>✓ Loss of cultural sites</li> </ul>
--	--	--

- ✓ Some positive effects: agricultural producers outside drought area benefit by selling goods at higher prices or having bumper harvest of certain crops

### Drought Management: Prediction

### DROUGHTS

Using weather records, such as daily national rainfall measurements to establish relationship between rainfall deficiency & drought severity, to assist governments, businesses & rural community and assess current situation in time for contingency action or drought relief

- ✓ Meteorological drought never result of single cause, often many causes synergistic in nature
- ✓ Inability to predict droughts 1< month in advance since depends on ability to forecast precipitation & temperature
- ✓ Water usage monitoring important too to check likelihood of man-made drought (e.g. Yemen: water table depleted by overuse of groundwater for crop irrigation)
- ✓ Global monitoring done by World Meteorological Organization's Climate Information & Prediction Services

### Case Study: AUSTRALIA

- ✓ 1992: Commonwealth Government National Drought Policy initiatives
- ✓ Monthly rainfall analysis to document drought probability
- ✓ Drought Watch commenced if total rainfall 3< months (6 months for normally arid regions) within lowest 10% on record
- ✓ Rainfall deficiency categories:
  - Severe deficiency: rainfall for 3< months lowest 5% on records
  - Serious deficiency: 3< months lowest 5% - 10% on records
- ✓ 2007 - 2008: Australia's worst drought on record
  - \$12b water plan unfurled in 2007 for government control of Murray-Darling river basin, water-saving features for farms etc

### Drought Management: Mitigation

### DROUGHTS

- ✓ Desalination of seawater for irrigation / consumption
- ✓ Land use: crop rotation to minimize erosion & plant less water-dependent crops in drier years

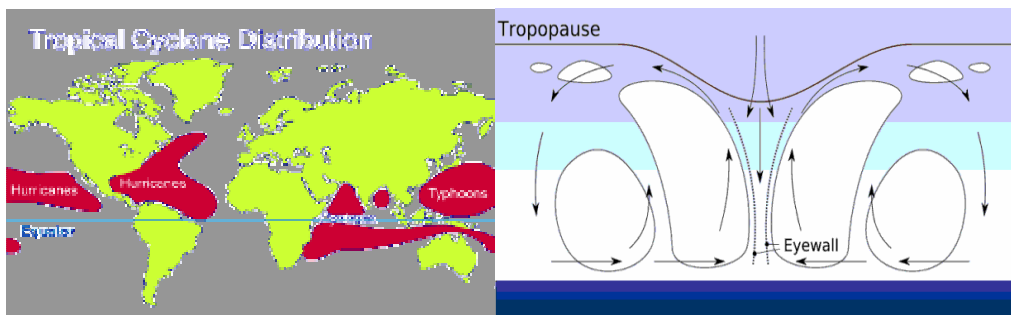
- ✓ Rainwater harvesting (collection & storage of rainwater on roofs etc) & recycled water (from sewage)
- ✓ Transvasement: redirecting rivers / canals to drought-prone areas
  - China, 2006: water diverted from Yuecheng reservoir to Cangzhou city in Hebei to irrigate cropland
- ✓ Water use restrictions, such as on outdoor sprinklers, washing of cars, swimming pools
  - Australia: \$200 fine for using water outside the house
- ✓ Cloud seeding to induce rainfall
  - China, 2006: cloud seeding in Inner Mongolia

### Tropical Cyclones: Causes / Factors

### TROPICAL CYCLONES

Tropical cyclones (also known as hurricanes, cyclones & typhoons): occurring in summer & autumn, violent storms 200-700 km wide, beginning with an intense low pressure system along ITCZ drawing in warm air in spiraling manner, enlarging into tropical depression with rotating wind systems. Only 10% of seedlings develop into full hurricanes!

1. Ocean temperatures >26°C to provide heat to drive rising air currents
2. Ocean depth of at least 70m to provide sufficient moisture which gives latent heat (released by condensation) to drive system
3. 5°N/S - 30°N/S so that Coriolis force can cause maximum air rotation
4. Subsidence on eastern side & convection on western side of sub-tropical anticyclones (western sides of oceans)
5. Relative humidity >60% for enough energy released to drive hurricane
6. Low air pressure & wind speeds at ground level but high air pressure & wind speeds in upper atmosphere for hurricane vortex development
7. Smooth airflow out at high altitude in upper atmosphere



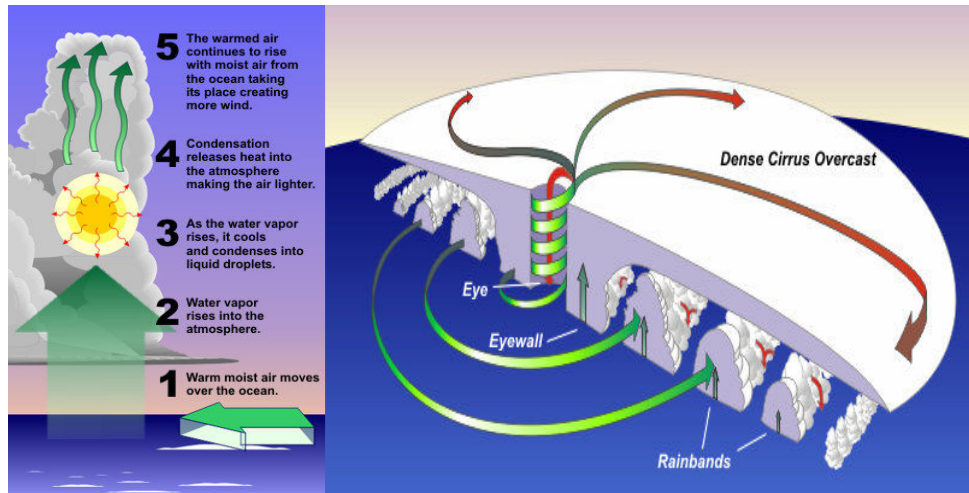
[http://www.metoffice.gov.uk/education/secondary/students/tropical\\_cyclones/Cyclone\\_Distribution.gif](http://www.metoffice.gov.uk/education/secondary/students/tropical_cyclones/Cyclone_Distribution.gif) & <http://www.martinfrost.ws/htmlfiles/aug2007/tropcyc03.gif>

### Parts of Tropical Cyclone

### TROPICAL CYCLONES

1. **Eye**
  - ✓ 20-60 km wide; calm & warmer area with clear skies & few clouds
  - ✓ Air descending in eye, atmospheric pressure at lowest (950mb)
  - ✓ Centrifugal force from rapid rotation maintains eye while spinning pulls clouds & air away from centre
  - ✓ Eye size decreases as hurricane & low pressure intensity increases
  - ✓ Wind speeds >300 km/h observed around eye
2. **Eye wall & Rain bands**

- ✓ Towering cumulonimbus clouds up to 15 km tall; unbroken wall at edge of eye, more fragmented & lower further away from wall
- ✓ 200 separate convection cells!
- ✓ Intense instability causes rapid rising of air & cloud development



<http://web.mit.edu/12.000/www/m2010/teams/neworleans1/hurricane%20science.htm>

**Process of Tropical Cyclone Development** **TROPICAL CYCLONES**

1. Disturbance in easterly waves
2. Air enters low pressure zone → rises & cools
3. Condensation releases latent heat of vaporisation
4. Increasing latent heat triggers even lower air pressure → draws in more moist air from warm ocean
5. Earth's rotation & Coriolis force causes rising air to spin

**Tropical Cyclone Categorization** **TROPICAL CYCLONES**

Saffir-Simpson scale used to measure potential property damage & flooding from hurricane landfall. Average tropical cyclone lasts 7-14 days.

Term		Wind speeds	Description
Tropical depression		<61 km/h	Organized system of clouds & thunderstorms with defined circulation
Tropical storm		61-118 km/h	Organized system of strong thunderstorms with defined circulation
Hurricane		>119 km/h	Intense tropical weather system with well-defined circulation
Scale	Wind speeds	Damage	Examples
1	119-153 km/h	Storm surge 4-5 feet, minimal damage	2004: Gaston (S Carolina)
2	154-177 km/h	Storm surge 6-8 feet, moderate damage	2003: Isabel (N Carolina)
3	178-209 km/h	Storm surge 9-12 feet, extensive damage	2004: Ivan (Alabama)
4	210-249 km/h	Storm surge 13-18 feet, extreme damage	2005: Dennis (Cuba)

5	>250 km/h	Storm surge >18 feet, catastrophic damage	1992: Andrew (Florida) 2005: Katrina (Louisiana)
---	-----------	---	---

**Hazards of Tropical Cyclones****TROPICAL CYCLONES****1. Storm surges (~10m)**

- ✓ Most damaging hazard of tropical cyclones; resulting from water piling up by winds & ocean heaving up in mound under eye
  - 1737, Calcutta: 300k killed by wall of water
  - 1970, Bangladesh: 6m storm surge killed 300k people
- ✓ Most destructive if coinciding with high tide & low-lying coast; potential to flood further inland
- ✓ Damage to agriculture as fields turn salty, especially in LDCs
  - 1970, Bangladesh: 280k cattle swept away, £40m of ripening crops destroyed

**2. Heavy rainfall (>100mm per day)**

- ✓ Intense precipitation also causes flooding & landslides
  - 2004, Taiwan: 4 killed by landslides from Nock-ten

**3. Winds (>150 km/h)**

- ✓ Collapse of buildings, roads, bridges & transmission lines, exacting huge economic costs
  - 1970, Bangladesh: 85% population left homeless
- ✓ Hurling of debris also cause deaths!

**Impact of Tropical Cyclones****TROPICAL CYCLONES**

Though hurricane deaths are down, damage caused is going up. Global warming could increase severity, likelihood & distribution of hurricanes as oceans become warmer!

- ✓ Huge economic costs & claims, especially affecting insurance industry, causing collapse of insurance companies (cost of evacuation expensive as well!)
  - 1992, Andrew: US\$16.5b worth of claims to insurance firms, total damage cost \$20-30b
  - 1987 - 1993: total payout of \$50b
- ✓ Tourism economies damaged, especially in Caribbean, Mexico & Florida

**Tropical Cyclones Management****TROPICAL CYCLONES**

Best way to manage tropical cyclones is to manage hazards (mitigation) since predictions are often inaccurate & tropical cyclones are unstoppable! In DCs people are urged to take insurance, but for LDCs more important for aid to be available in short & long term after tropical cyclone.

- ✓ Prediction depends on monitoring & warning systems available
  - Weather bureaus like National Hurricane Centre (Florida) access data from satellites & land / sea recording centres
  - Round-the-clock surveillance by weather aircraft

- Computer models predict path of storm & issue evacuation warnings to those in path
- ✓ Prediction / warnings must be accurate, otherwise high economic cost & instill complacency from too many false alarms!
  - Not always possible to give >12-18 hours warning due to erratic path of cyclones
  - LDCs with poorer communication & warning systems prone to more deaths & damage
  - 1997, Bangladesh: cyclone warning in Cox's Bazaar allowed evacuation of 300k, resulting in <100 deaths
- ✓ Land-use planning to limit developments in high-risk areas
  - However in LDCs need for land outweighs such considerations
- ✓ "Hard " mitigation efforts to reduce damage done, usually through engineering methods
  - Diversion canals manage flash floods through diverting water flow
  - Seawalls & breakwaters protect coastal areas (e.g. Galveston, Texas: 3.5m seawall against storm surges)
  - Planting mangrove & cashew trees along shores to protect inland areas
  - Cyclone shelters built 7m above ground (e.g. Bangladesh, built by Oxfam and houses 400 per shelter, but >10k needed in addition to current 500)
- ✓ "Soft" mitigation efforts to increase awareness
  - Public education & awareness drives (e.g. US Federal Emergency Management Agency [FEMA] distribute educational material on hurricane-proofing homes)
  - Education in schools (e.g. Florida's Project Safeside programme of precautionary drills for schools & emergency operations)
  - Radio warning system as part of disaster preparedness programme (e.g. Bangladesh)

### **Case Study: 2005 HURRICANE KATRINA (USA)**

- ✓ August 2005, affected Louisiana (New Orleans) worst
  - Sea surface water temperature ~28°C, ideal for strong hurricanes
  - Landfall on 29 August 2005 in New Orleans
  - Katrina moved through scales 1-5 along track from Gulf of Mexico to Louisiana coastland around New Orleans
- ✓ Levees protecting New Orleans failed, flooding the whole city
- ✓ Hundreds of thousands fled New Orleans, causing huge jams on roads and leading to some to give up escape
  - Texas bore brunt of refugees as 220k fled disaster area
- ✓ Superdome sports stadium in New Orleans used to house those fleeing from hurricane, but turned out to be disastrous
  - Crime, squalor & fear reported; conditions so bad that last 300 refugees evacuated from building eventually
  - 100 mph winds ripped apart part of Superdome roof
  - No electricity, water, functioning toilets or washing facilities
- ✓ Government response slow, relief efforts uncoordinated
  - FEMA, central government & state government blamed

- ✓ Racial & income divide evident as poor & black in most trouble; no means of transport & late entry of rescue workers into city

### **Case Study: 1999 ORISSA (INDIA)**

- ✓ 2 cyclones in close succession
  - First cyclone caused 199 deaths in southern Orissa
  - Second cyclone led to 7m high tidal surge, inundating up to 30km inland, with death tolls of >10000
- ✓ 19m people affected in aftermath, US\$5.1b damage
- ✓ Only 23 cyclone shelters from Red Cross existed then
  - Only safe buildings left, securing 40k people
- ✓ Lack of coordination between authorities & inadequacy of communications caused high death tolls
  - First warning issued 39 hours before landfall but most did not evacuate, underestimating power of cyclone
  - Super-cyclone notification issued only 2 hours before breakdown of communications
- ✓ State paid little attention to role of NGOs in disaster preparedness & response before cyclone
- ✓ Post-1999:
  - Orissa State Disaster Management Authority created
  - Coordinate with NGOs construction of cyclone shelters & education / awareness (but often NGOs neglected here)
  - 2003: 43 cyclone shelters & 5300 new primary schools built
  - 500k cyclone-resistant homes built, 10k primary school buildings strengthened
  - Orissa Disaster Mitigation Mission (ODMM) set up by NGOs to coordinate relief & restoration efforts

### **Case Study: 2008 CYCLONE NARGIS (MYANMAR)**

- ✓ May 2008, category 3 cyclone with winds up to 190 km/h & waves of 3.5m high, 85k dead, 54k missing, 2.4m severely affected
  - Low-lying Irrawaddy delta worst-hit by tidal waves
- ✓ India's meteorological department warned Myanmar government 48 hours before storm, but government & people of Myanmar still unprepared for cyclone
  - Expatriates knew about cyclone through embassies & satellite TV, but locals not informed adequately
  - Poor condition of infrastructure (buildings, vehicles, health facilities) increased vulnerability of people
  - No radar to monitor storm; preparedness not focus of government since cyclones rarely hit Myanmar
- ✓ No properly functioning institution left in Myanmar to deal with crisis besides military junta
- ✓ Prices of food & fuel skyrocketed, people mired in poverty & bore resentment towards military junta
  - Especially rice shortages as rice fields destroyed
- ✓ Aid agencies coordinate relief work & assess damage, but government refuses to allow direct assistance by US government (foreign aid workers restricted though money & donations in kind were welcomed)
  - Many left without aid & assistance even weeks after cyclone
  - Inaccessibility of some parts of Irrawaddy delta