Online Training Course on
Disaster Risk Reduction and Climate Change Adaptation
for CARICOM and SICA Member Countries

Basic of extreme weather, hydrometeorological hazards and mitigation measures

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August 10th, 2022

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Outline

- Basic concept of extreme weather and atmospheric phenomena
- Hydrometeorological hazards
  - Flood
  - Drought
  - Windstorm
- Impact of climate change on extreme weather
- Disaster risk reduction

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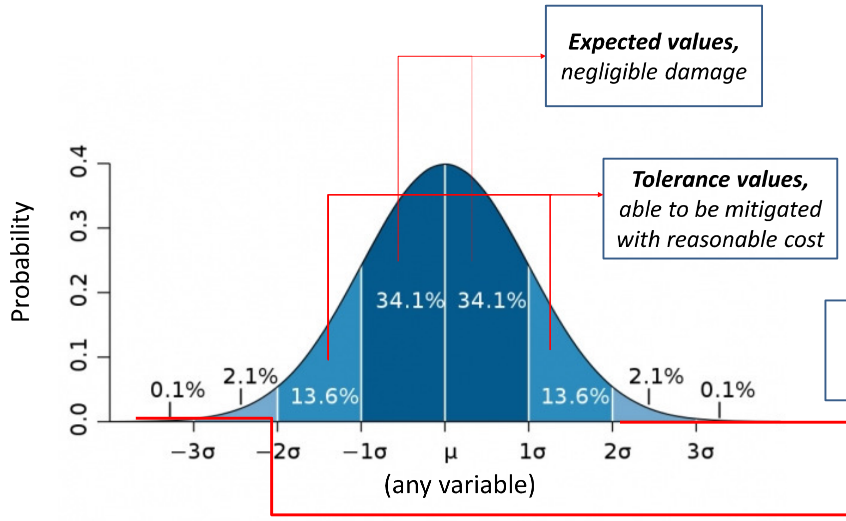
How do we know if something is extreme?



Hurricane Michael (2018)

Extreme events are basically rare and correlated with losses, however thresholds of "extreme" are sensitive to many factors!

(adopted from Dr. T. W. Hadi's presentation)

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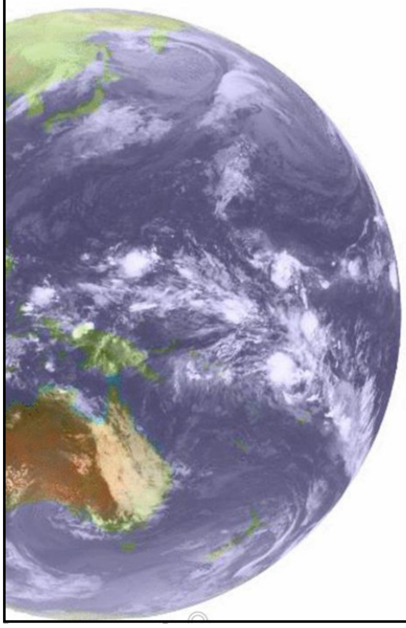
How we look extreme weather



Based on ...

Phenomenon →	Parameter - - - →	Impact
Heat wave	*Hot* ***temp.***	Flood
Cold wave	*Cold* ***temp.***	Landslide
Tropical cyclones	*Torrential* ***rain***	High wave
Tornado	*Strong* ***wind***	Drought
Thunderstorms	*Low* ***moisture***	*Smog*
Vortex	*High* ***moisture***	etc.
Cold surges	*Freezing* ***rain***	
Fog	etc.	
Dry spell		
Foehn		
etc.		

- Defining extreme weather can be based on the meteorological phenomenon, parameter, or its impact
- Each phenomenon drives certain parameter(s) and result in certain impact(s)

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Extreme Weather Definition from WMO (World Meteorological Organization)

"Extreme weather or climate events include, but are not limited to, heat waves, cold waves, floods, extreme precipitation, drought, tornadoes and tropical cyclones…. causing significant devastation to infrastructure, affecting our economy and health, and resulting in the loss of life."

- WMO definition includes extreme weather as the phenomena, parameter, and impacts
- Extreme weather is not only measured by its statistical probability of occurrence, but also from the destruction potential that may appear (disaster risk)

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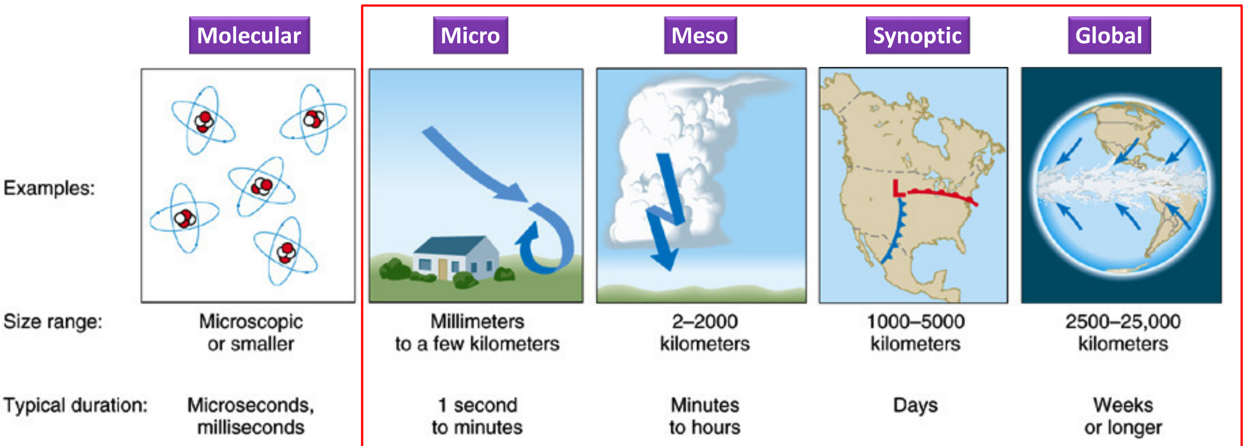
Scales of atmospheric motions



Sumber: The Florida State University

Important for weather and climate dynamics

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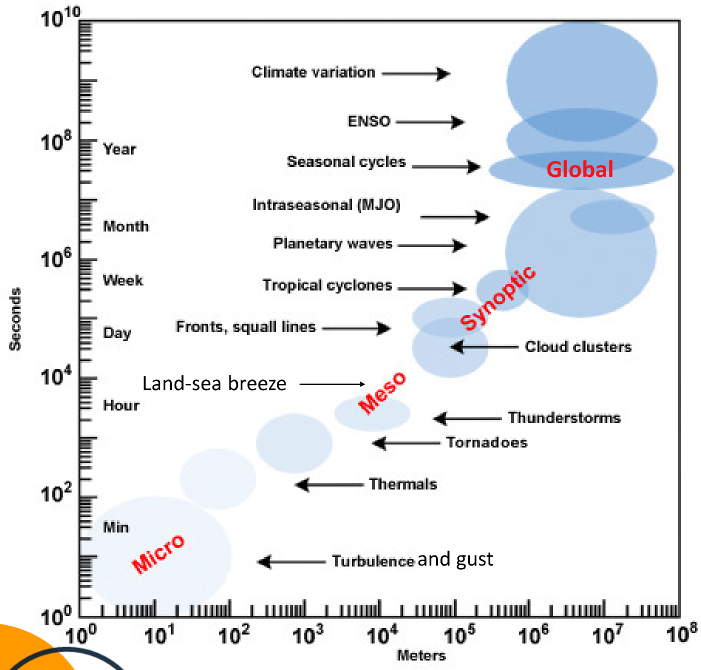

Source: the COMET Program

Different phenomena driven at different scales

- Most hazards (torrential rain, strong wind, flood) are **directly affected by small scale** phenomena, but **indirectly affected by large scale** phenomena
- For example, **hurricanes are synoptic** scale phenomenon but its frequency is controlled by **seasonal cycle** (**global scale**)

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Hydrometeorological hazards

Impact: Flood, landslide, wind-induced damages, drought, forest fires

Parameter (triggering factor): Heavy rainfall, Strong wind, Absence of rainfall, dry spell

Weather and climate phenomena: Thunderstorm, cyclones, tornado, heatwave, monsoon, El Nino, climate change, etc.

These phenomena can influence each other

Challenge: If we understand the dynamics of how certain impacts caused by certain phenomena, we can make a good weather forecast and mitigate the disaster

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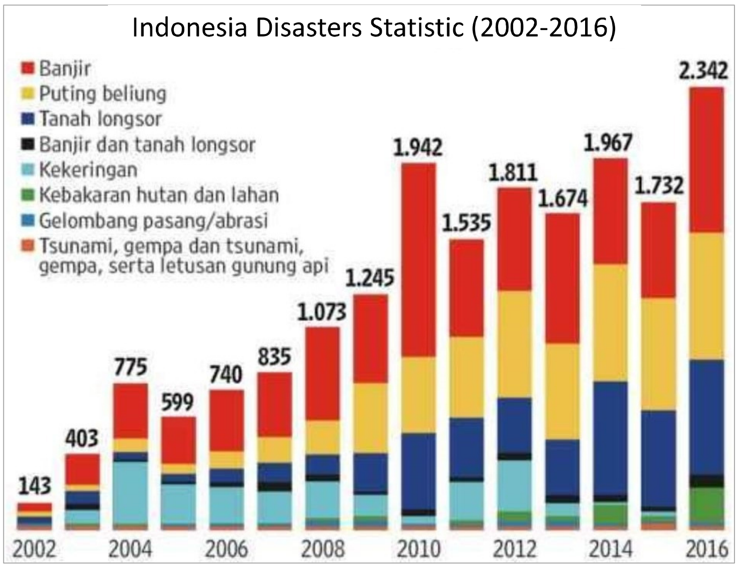
80-90% disasters in Indonesia related to hydrometeorological hazards

In Indonesia, hydrometeorological hazards usually affect small areas (except few major event) and thus each event causes less loss compared with earthquake or tsunami, but <u>its occurrence is very often</u>

→ because thunderstorm can appear everyday at anywhere!



Flood

Windstorm

Landslide

Drought

Forest fire

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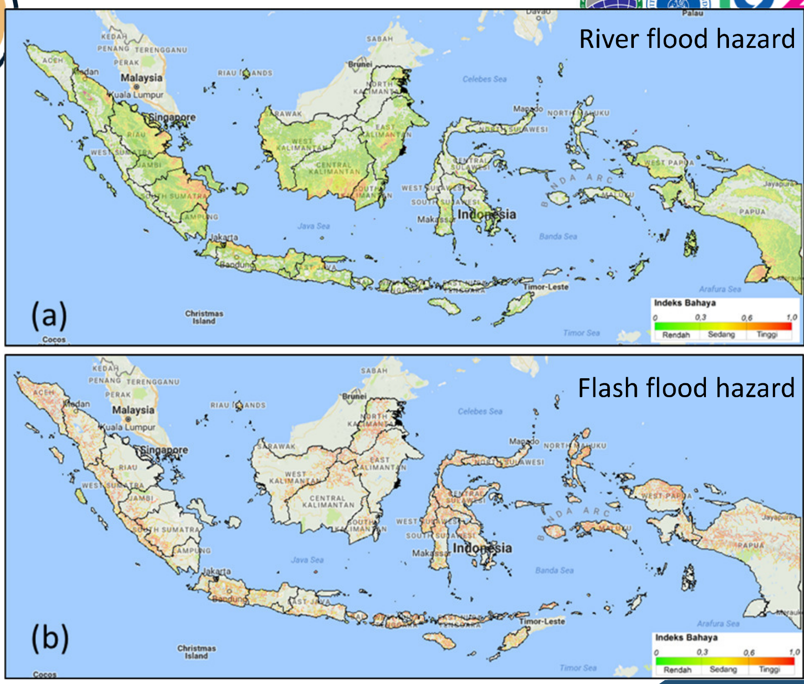
Flood hazard

The simple **overlay method:** Combination of hazard parameters such as extreme precipitation, surface conditions (flow accumulation, time of concentration, slope, etc.)

2013 Jakarta Flood



http://inarisk.bnpb.go.id/hasil-kajian

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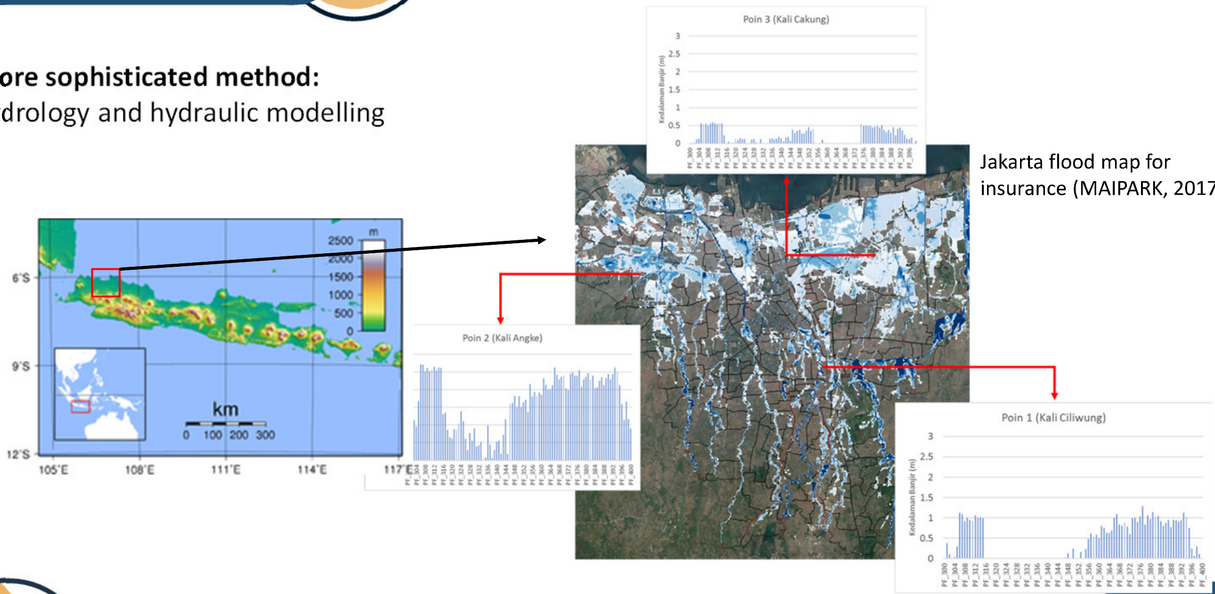
Flood hazard

More sophisticated method:
hydrology and hydraulic modelling



Jakarta flood map for insurance (MAIPARK, 2017)

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Windstorm

Microburst from a thunderstorm

Arcamanik stadium (2019)

Puting beliung or “Mini” tornado

Cimenyan “Puting Beliung”, 2021

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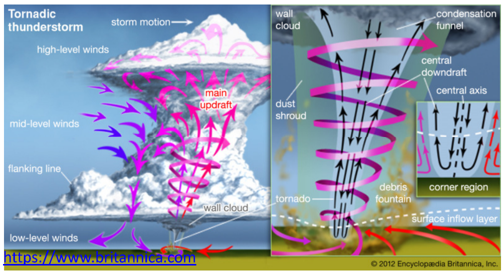
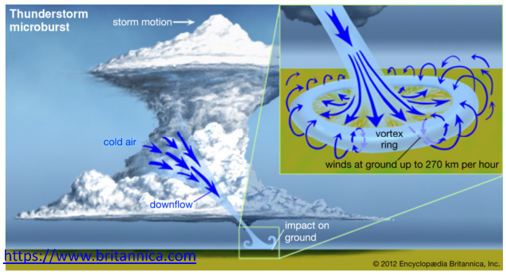
Windstorm

Funnel cloud and tornado



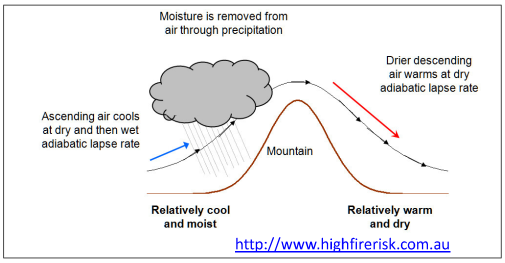
https://www.britannica.com

Micro burst



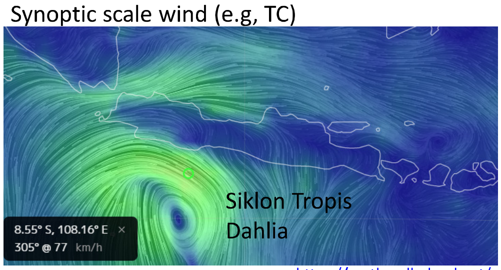
https://www.britannica.com

Foehn wind



http://www.highfirerisk.com.au

Synoptic scale wind (e.g, TC)



https://earth.nullschool.net/

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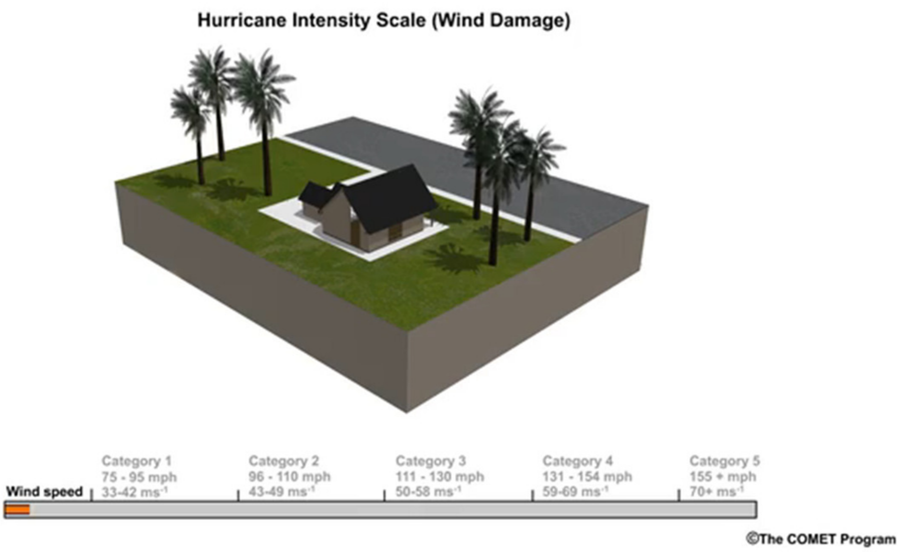
Damage from strong winds



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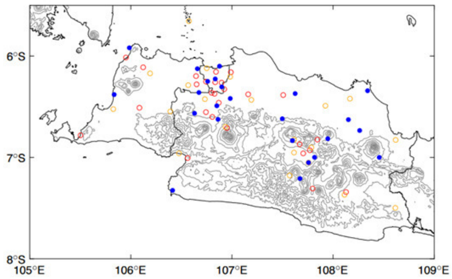
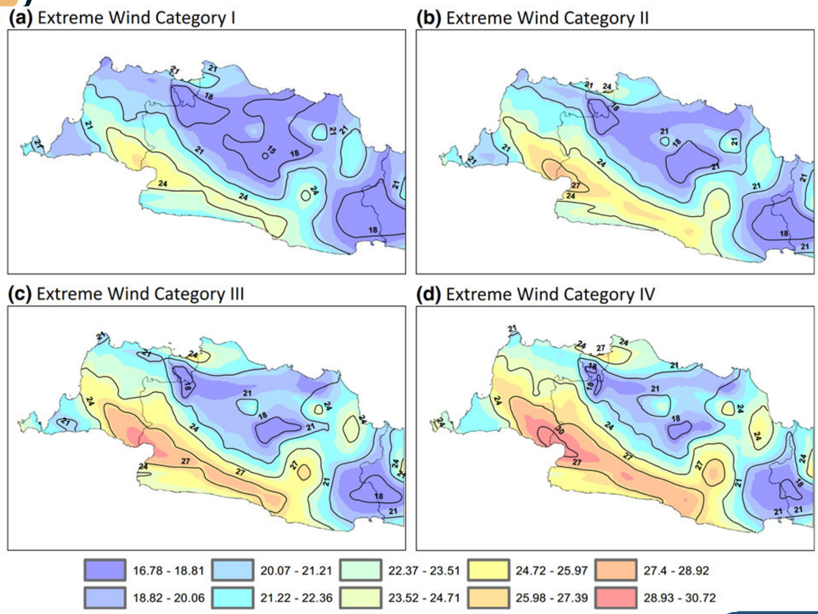
Windstorm

Wind gust observation





(Abdillah et al. 2022)

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Drought

FIVE TYPES OF DROUGHT

1 **METEOROLOGICAL** drought refers to an extended period of dry weather patterns.

2 **HYDROLOGICAL** drought refers to low water supply in our rivers, lakes, aquifers, and other reservoirs that often follows meteorological drought.

3 **AGRICULTURAL** drought occurs when a water shortage significantly damages or destroys agricultural crops.

4 **ECOLOGICAL** drought is the most recently defined type of drought and refers to widespread ecological damage caused by the lack of soil moisture.

5 **SOCIOECONOMIC** drought refers to when a water shortage affects the supply and demand of drought commodities, such as water, food grains, and fish.

https://livingwithdrought.com/what-is-drought/

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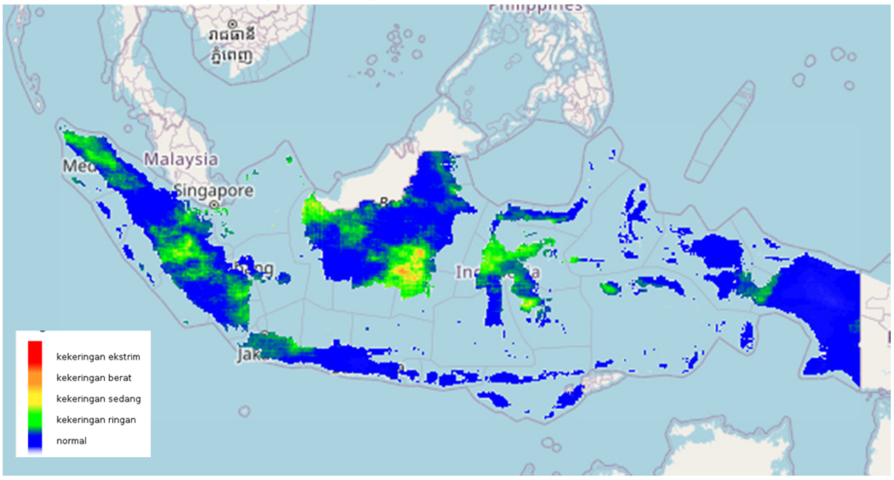
Drought

The common method is <u>Standardized precipitation index</u> (SPI)

On short timescales (1-3 month), the SPI is closely <u>related to soil moisture</u>, while at longer timescales, the SPI (>6 month) can <u>be related to groundwater and reservoir storage</u>.

Meteorological drought hazard index based on SPI



https://spbn.pusfatja.lapan.go.id/maps/104

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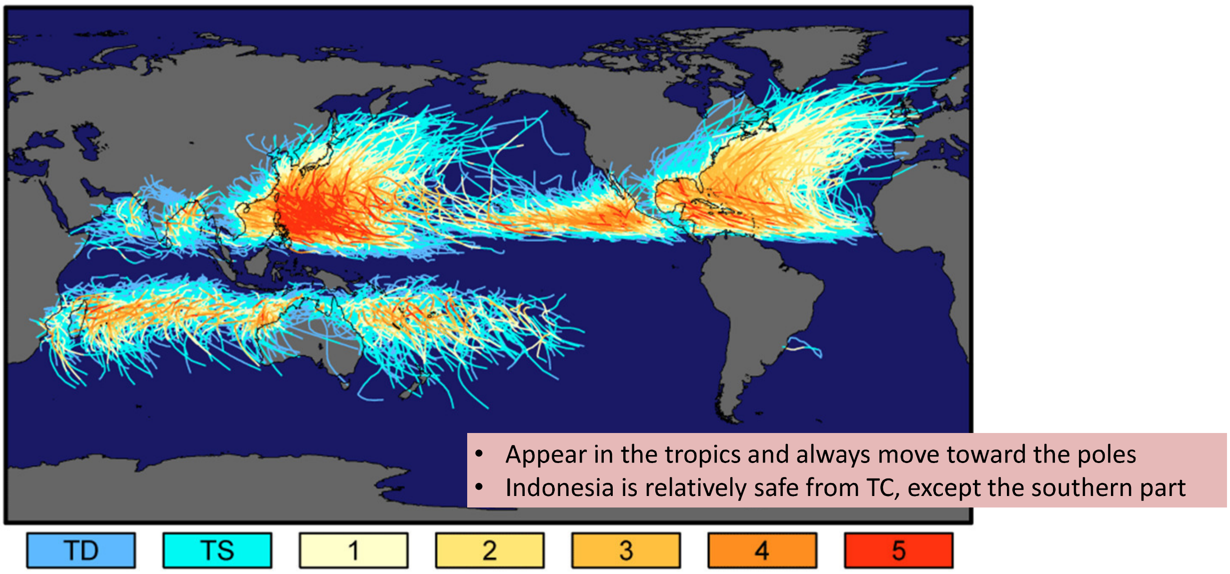
Global distribution of Tropical Cyclones/Hurricanes/Typhoon (1979-2012)



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Impacts of TC on Flooding and Landslides

- TCs rainfall produces flash floods, river floods, urban floods, and landslides
- The amount, extent, and impact of TC flooding depend on the following:
  - **Antecedent precipitation.** Saturated soil has greater flood potential than dry soil. Double TC events can caused big flood.
  - **Speed of movement of the cyclone**: Slower movement leads to greater flooding.
  - **Orographic enhancement**: Additional lifting of moist air by high terrain produces more precipitation.
  - **Intensification due to synoptic forcing**: Interaction of the cyclone with midlatitude synoptic systems can sometimes enhance the low pressure and increase precipitation.
  - **Hydrology**: Narrow river basins are easier to flood than flat, broad river basins. Confluence of multiple rivers can also aggravate flooding.
  - **Land use**: Urban landscapes are more prone to flash floods because of increased runoff and channeling which causes acceleration of surface water.
  - **Other geographical influences**: Flooding is also influenced by soil type.

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Impacts of TC on Strong Winds

- The wind velocity is a defining parameter for TCs because of the deadly and damaging impact of strong winds
- The Saffir Scale was created to scale the impact of TC strong winds
- Sometimes tornadoes accompany TC because of strong vertical shear

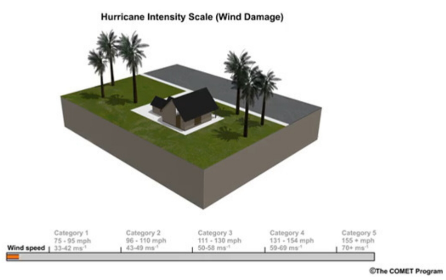

Table 8-2.1. The Saffir-Simpson Scale: Cat 3-5 are referred to as Major Hurricanes.

Saffir-Simpson Hurricane Category	Maximum Sustained Wind Speed (V_{MAX}; 1-minute average)[b]			Expected Level of Damage
	m s^{-1}	km h^{-1}	mph	
1	33–42	119–153	74–95	Minimal
2	43–49	154–177	96–110	Moderate
3	50–58	178–208	111–129	Extensive
4	59–69	209–251	130–156	Extreme
5	70+	252+	157+	Catastrophic

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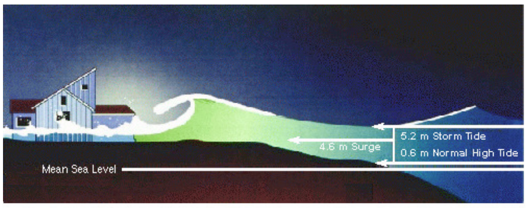
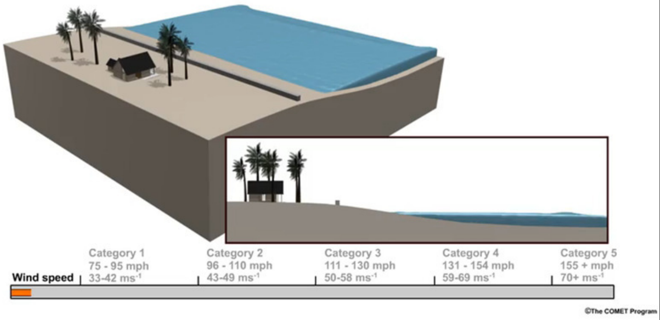
Impacts of TC on Storm Surges

- Strong wind induces storm surge (a large dome of water that sweeps across the coast).
- It can be more than 5 m at its peak.
- Globally, storm surge is the most deadly direct TC hazard



Hurricane Intensity Scale (Storm Surge)



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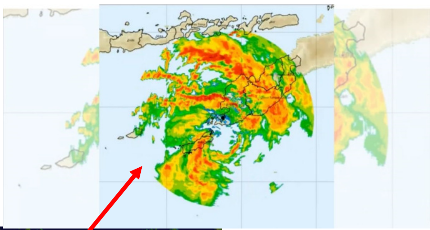
TC in Indonesia: Recent deadliest TC


Cyclone Seroja kills 160 people, exposes Indonesia's climate vulnerability

Published on 09/04/2021, 11:06am

Campaigners say a government rollback of environmental regulations increases Indonesia's vulnerability to flash floods and landslides

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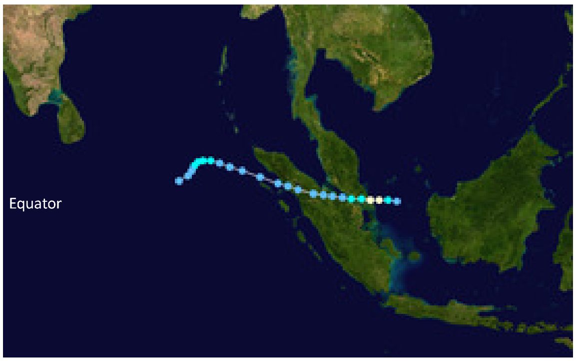
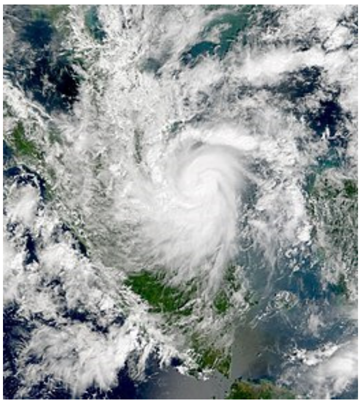
TC in Indonesia: The super rare Typhoon Vamei (2001)

- Tropical Storm Vamei was a tropical cyclone that formed closer to the equator <u>than any other tropical cyclone on record</u>
- Vamei appeared in between Sumatra and Borneo, moved to west crossing Sumatra Island and dissipated in Indian Ocean
- It had sustained winds of 120 km/h (75 mph) and the appearance of an eye





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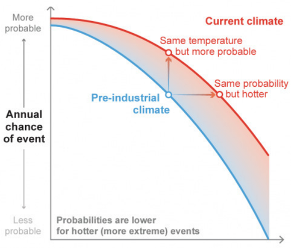
Observed and projected changes of extremes



Change in Indicator	Observed (since 1950)	Attributed (since 1950)	Projected at GWL (°C)		
			+1.5	+2	+4
Warm/hot extremes: Frequency or intensity	↑	✓ Main driver	↑	↑	↑
Cold extremes: Frequency or intensity	↓	✓ Main driver	↓	↓	↓
Heavy precipitation events: Frequency, intensity and/or amount	↑ Over majority of land regions with good observational coverage	✓ Main driver of the observed intensification of heavy precipitation in land regions	↑ in most land regions	↑	↑ in most land regions
Agricultural and ecological droughts: Intensity and/or frequency	↑ in some regions	✓ in some regions	↑ in more regions compared to observed changes	↑ in more regions compared to 1.5°C of global warming	↑ in more regions compared to 2°C of global warming
Precipitation associated with tropical cyclones	↑	✓	↑ Rate +11%	↑ Rate +14%	↑ Rate +28%
Tropical cyclones: Proportion of intense cyclones	↑	✓	↑ +10%	↑ +13%	↑ +20%
Compound events: Co-occurrent heatwaves and droughts	↑ (Frequency)	✓ (Frequency)	↑ (Frequency and intensity increases with warming)		
Marine heatwaves: Intensity & frequency	↑ (since 1900)	✓ (since 2006)	↑ Strongest in tropical and Arctic Ocean		
Extreme sea levels: Frequency	↑ (since 1960)	✓	↑ (Scenario-based assessment for 21st century)		

From the recent IPCC AR6 report

medium confidence *likely/high confidence* *very likely* *extremely likely* *virtually certain*

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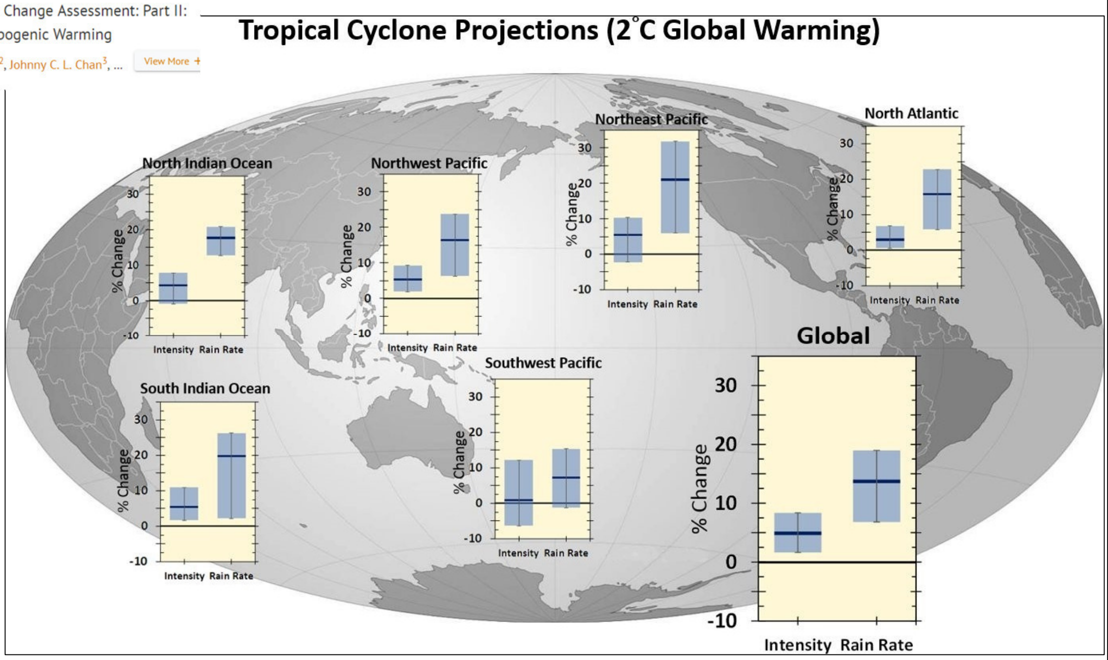
Editorial Type: Article
Article Type: Research Article

Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Anthropogenic Warming

Thomas Knutson[1], Suzana J. Camargo[2], Johnny C. L. Chan[3], ... View More +



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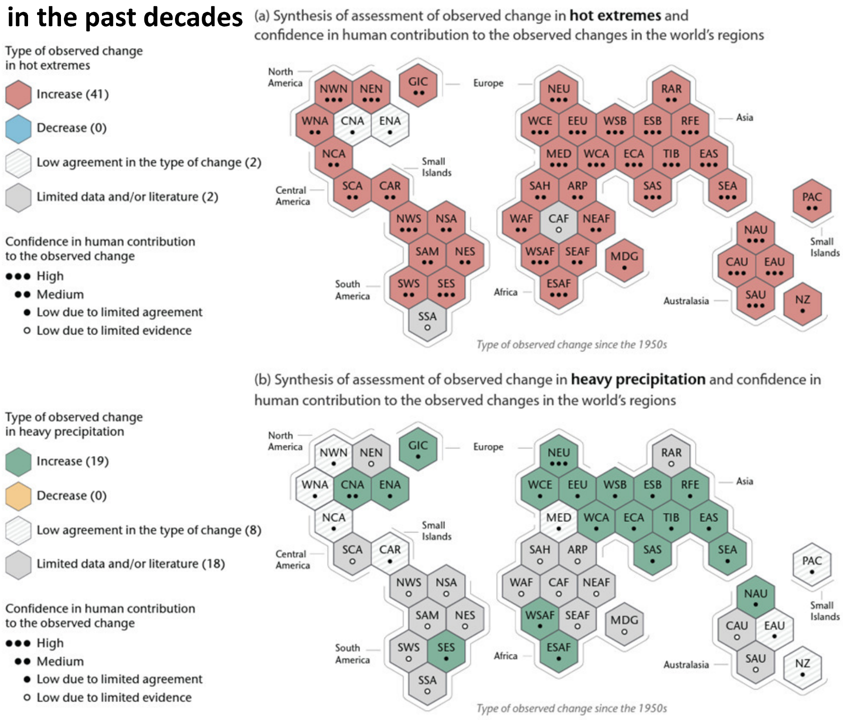
Observed change of extremes in the past decades



From the recent IPCC AR6 report

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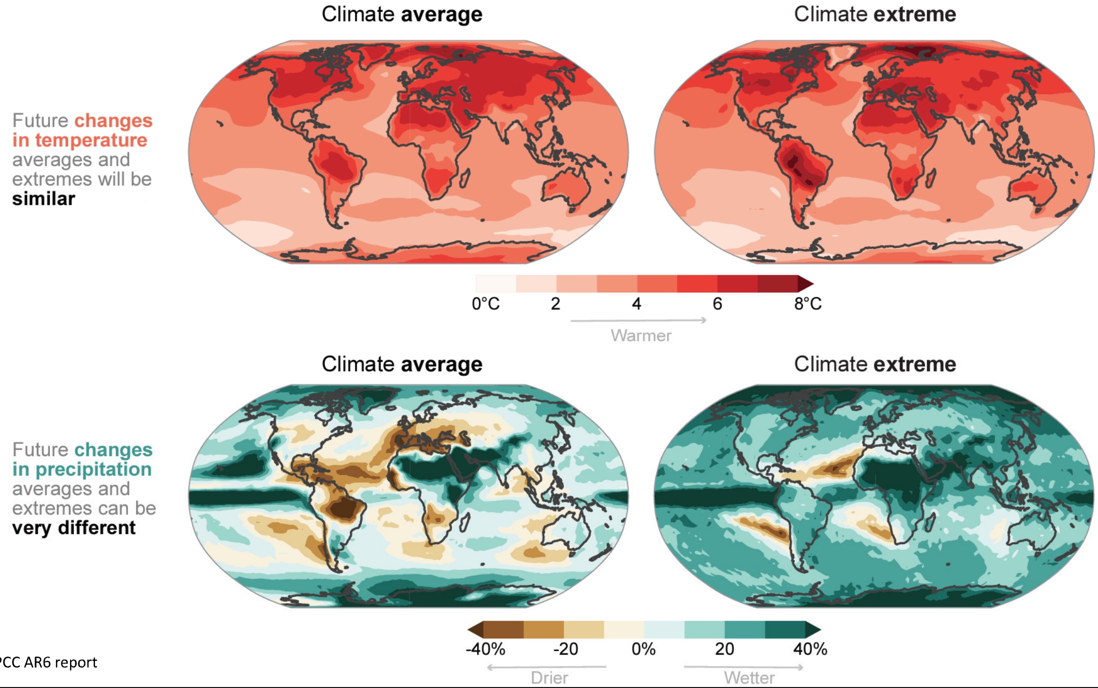
Observed change of extremes in the past decades



From the recent IPCC AR6 report

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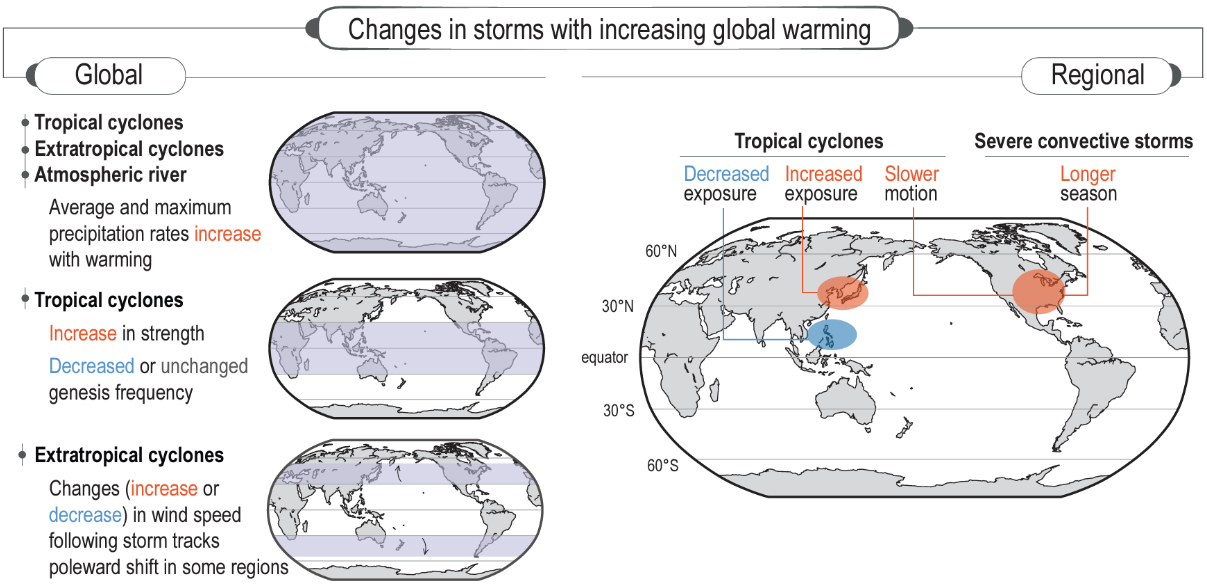
Observed change of extremes in the past decades



From the recent IPCC AR6 report

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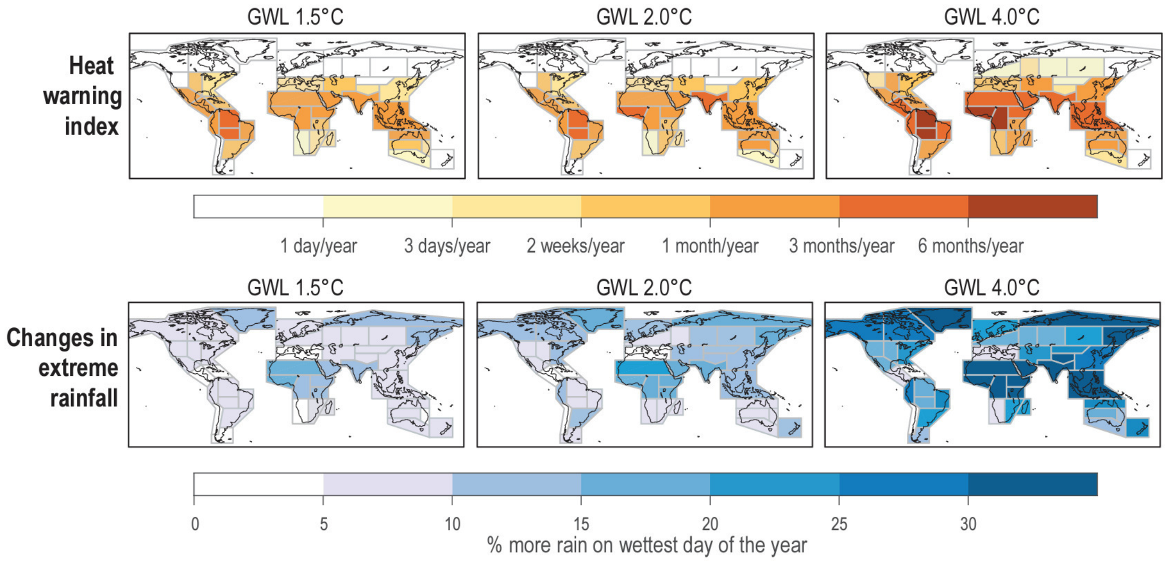
Projected change of extremes in the future



From the recent IPCC AR6 report

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Disaster Risk Reduction related to Hydrometeorological hazards

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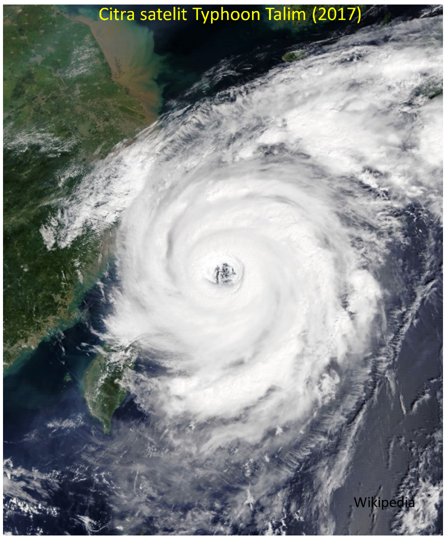
Natural hazard

"always happens"



Disaster

"depends on the response"

In Japan, fatalities due to a *strong typhoon* significantly decreasing:

- 1950s: ~1000 people
- 2010s: < 50 people

Emergency response that is fast and reliable can minimize the impacts.

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Reducing risk of extreme weather and hydrometeorological hazards

1. Operational: fast and reliable early warning system
2. Long-term: risk-informed spatial planning (focused on flood)

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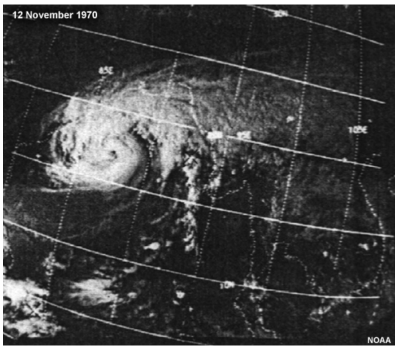
Development of EWS: People learn from the past…

History of Bangladesh TC impacts:

Disaster in Nov 1970, The Bhola Cyclone

- **185 km h^{-1} (Category 3)**
- **300,000-500,000 died**
- **Slow warning response,** one of main factor led to the independence of Bangladesh

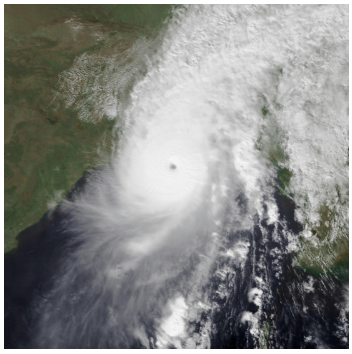


Apr 1991, The Chittagong Cyclone

- **250 km h^{-1} (Category 5)**
- **6 m storm surge**
- **138,000 died**
- 2-3 millions evacuated
- **EWS was successful**

Nov 2007, The Sidr Cyclone

- **260 km h^{-1} (Category 5)**
- **3 m storm surge**
- **3,000-10,000 died**
- 2 millions evacuated
- **EWS was successful**



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Element of early warning system

Monitoring
& Prediction

Preparedness &
Early Response

Communication & Dissemination

Risk Information

Simplified version of the elements of effective early warning system produced by WMO
[Multi-Hazard Early Warning Systems: A Checklist | World Meteorological Organization (wmo.int)]

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Hierarchy of *Early Warning System* (EWS)

1. ***Outlook***: there is a possibility that an event would appear. Usually for weeks to months prediction
2. ***Watch***: the probability of that event is increasing. Relevant for several days to 1 week prediction
3. ***Advisory***: the probability is high. However, the exact time and location is not known. 1-3 day prediction
4. ***Warnings***: the evet is occurring or will be occurred soon. Time and location is known with high probability. Hours prediction

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Fast and reliable weather forecasts are crucial in mitigating weather-related hazards

Weather forecast	Duration	Analysis approach	Utilization in EWS
Long-range	> 10 day – 1 month	Probabilistic	**Outlook**
Medium-range	3-10 day	Probabilistic	**Outlook/Watch**
Short-range	1-3 day	Deterministic/Prob.	**Watch/Advisory**
Nowcasting	Minutes-hours	Deterministic	**Advisory/Warning**

- Each type of forecast shows different utilization
- Forecast can be run by dynamical models, statistical models, or/and expert judgment from weather analysis.

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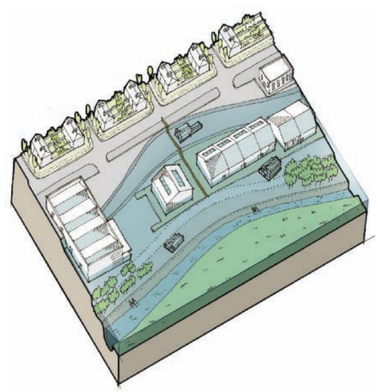
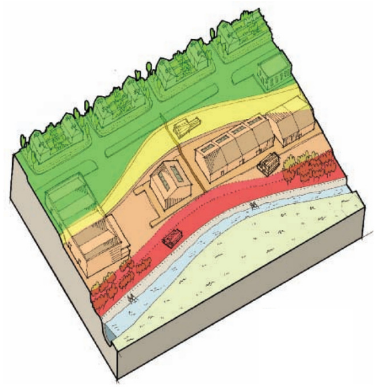
Flood risk map for zoning



RIBA, 2007



High (≥ 1,5 m)

Medium (0,76 – 1,5 m)

Low (≤ 0,75 m)

Perka BNPB No 2 Tahun 2012

1

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Redesign spatial planning to prevent susceptible land use

Vulnerability	Land use	Zone 1	Zone 2	Zone 3a	Zone 3b
Water-compatible development	Water infrastructure and pumping stations	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	Sewage infrastructure and pumping stations	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	Sand and gravel workings	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	Docks, marinas and wharves	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	MOD defence installations	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	Shipbuilding, fish processing	● Appropriate	● Appropriate	● Appropriate	● Appropriate
	Amenity open space, outdoor recreation	● Appropriate	● Appropriate	● Appropriate	● Appropriate
Highly vulnerable	Emergency services and command centres	● Appropriate	● Exception test	● Not permitted	● Not permitted
	Emergency dispersal points	● Appropriate	● Exception test	● Not permitted	● Not permitted
	Basement dwellings, permanent caravans	● Appropriate	● Exception test	● Not permitted	● Not permitted
	Installations of hazardous substances	● Appropriate	● Exception test	● Not permitted	● Not permitted
Essential infrastructure	Essential transport and evacuation routes	● Appropriate	● Appropriate		● Exception test
	Strategic utility infrastructure, power stations and primary substations	● Appropriate	● Appropriate		● Exception test

● Development appropriate ● Exception test required ● Development should not be permitted

RIBA, 2007

2

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Redesign spatial planning to prevent susceptible land use

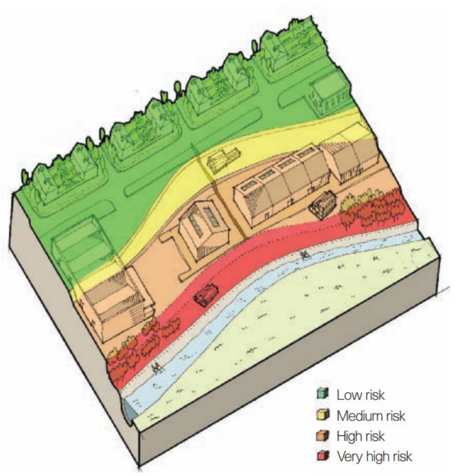
Land use category	Low	Medium	High	Very high
Agriculture and fisheries	Suitable use	Suitable use	Suitable use	Suitable use
Forestry	Suitable use	Suitable use	Suitable use	Suitable use
Utilities and infrastructure – renewable energy production and distribution	Suitable use	Suitable use	Suitable use	Requires mitigation
Recreation and leisure – outdoor amenity and open spaces	Suitable use	Suitable use	Suitable use	Requires mitigation
Defence	Suitable use	Suitable use	Requires mitigation	Requires defence and mitigation
Recreation and leisure – indoor	Suitable use	Requires mitigation	Requires defence and mitigation	Avoid use
Retail	Suitable use	Requires mitigation	Requires defence and mitigation	Avoid use
Transport – tracks, ways, terminals and interchanges	Suitable use	Requires defence and mitigation	Requires defence and mitigation	Avoid use
Residential – hotels, boarding and guesthouses	Requires mitigation	Requires defence and mitigation	Requires defence and mitigation	Avoid use
Residential – dwellings	Requires mitigation	Requires defence and mitigation	Requires defence and mitigation	Avoid use
Utilities and infrastructure – energy production and distribution, water storage and treatment	Requires mitigation	Requires defence and mitigation	Requires defence and mitigation	Avoid use
Residential – residential institutions	Requires mitigation	Requires defence and mitigation	Avoid use	Avoid use
Community services – medical, healthcare, education, and community (emergency) services	Requires mitigation	Requires defence and mitigation	Avoid use	Avoid use

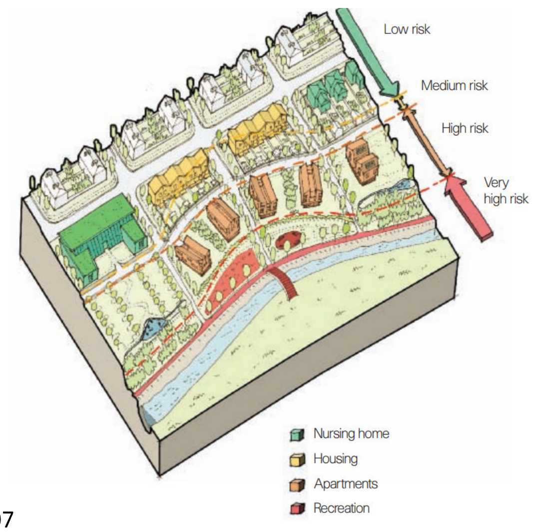
Suitable use Requires mitigation Requires defence and mitigation Avoid use

RIBA, 2007

Redesign spatial planning to prevent susceptible land use

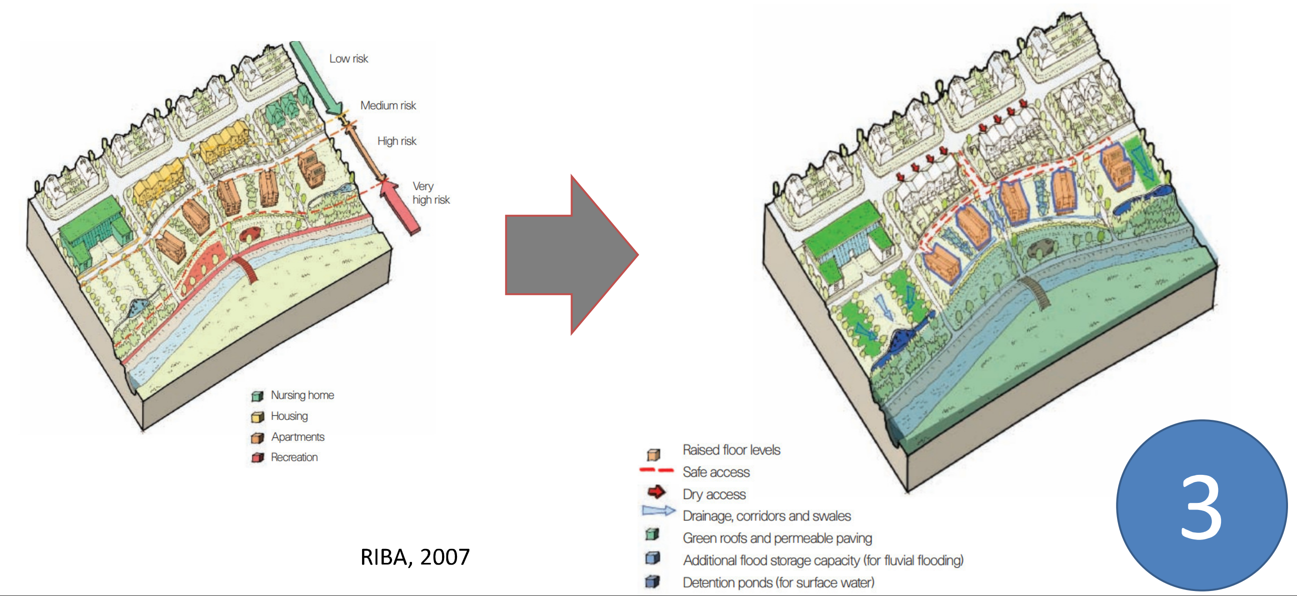
From simple zoning, to directly identify the infrastructures





RIBA, 2007

Risk control measures to minimize the probability and intensity of flood



RIBA, 2007

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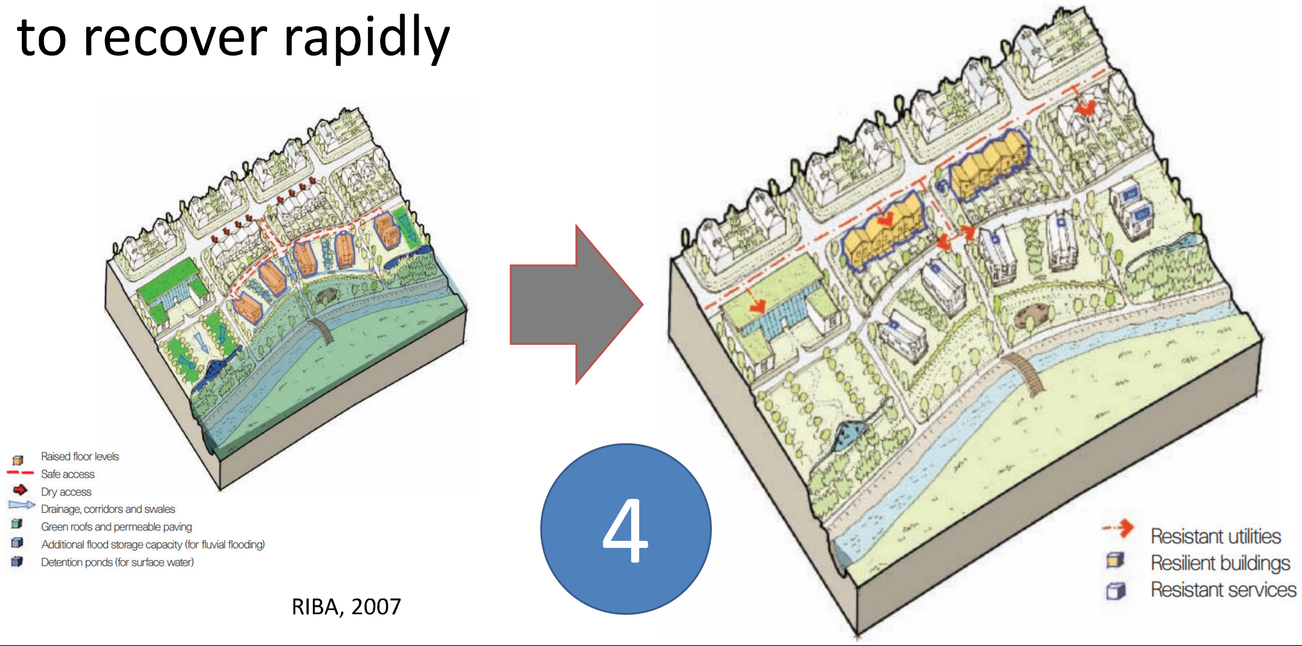
Planning if the flood occurs, to recover rapidly



RIBA, 2007

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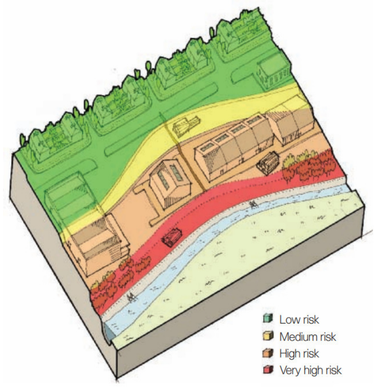
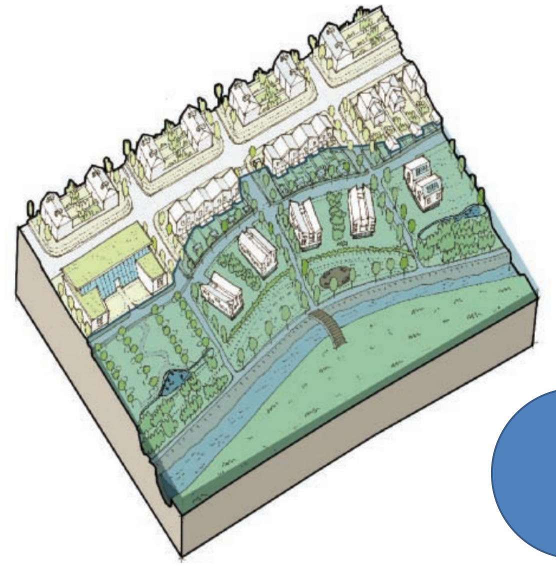
After flood event, evaluate and re-design from start (continuous improvement)



RIBA, 2007



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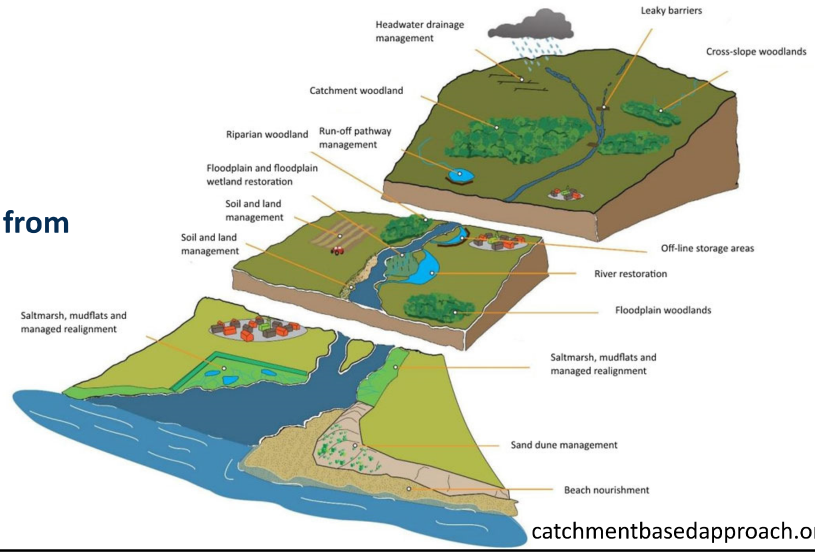
Natural Flood Management (NFM) or
Working with Natural Processes
(WWNP)

1. **Increasing storage:**
2. **Increasing catchment and channel roughness**
3. **Increasing losses**
4. **De-syncronising peak flows from tributaries**



catchmentbasedapproach.org

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Take home messages

- Extreme weather is statistically rare but the limit of "extreme" may depend on environment
- Extreme weather and hydrometeorological hazards can be attributed to the impact, meteorological parameter, or phenomena
- Each meteorological phenomena has unique time scale and spatial scale, however its frequency can be affected by a much larger phenomena
- Increasing extreme weather activity are observed in current climate and projected in future climate
- Reducing risk of extreme weather and hydrometeorological hazards can be done by (1) fast and reliable early warning system and (2) risk-informed spatial planning

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Online Training Course on
Disaster Risk Reduction and Climate Change Adaptation
for CARICOM and SICA Member Countries

Thank You

BNPB CARICOM SICA

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