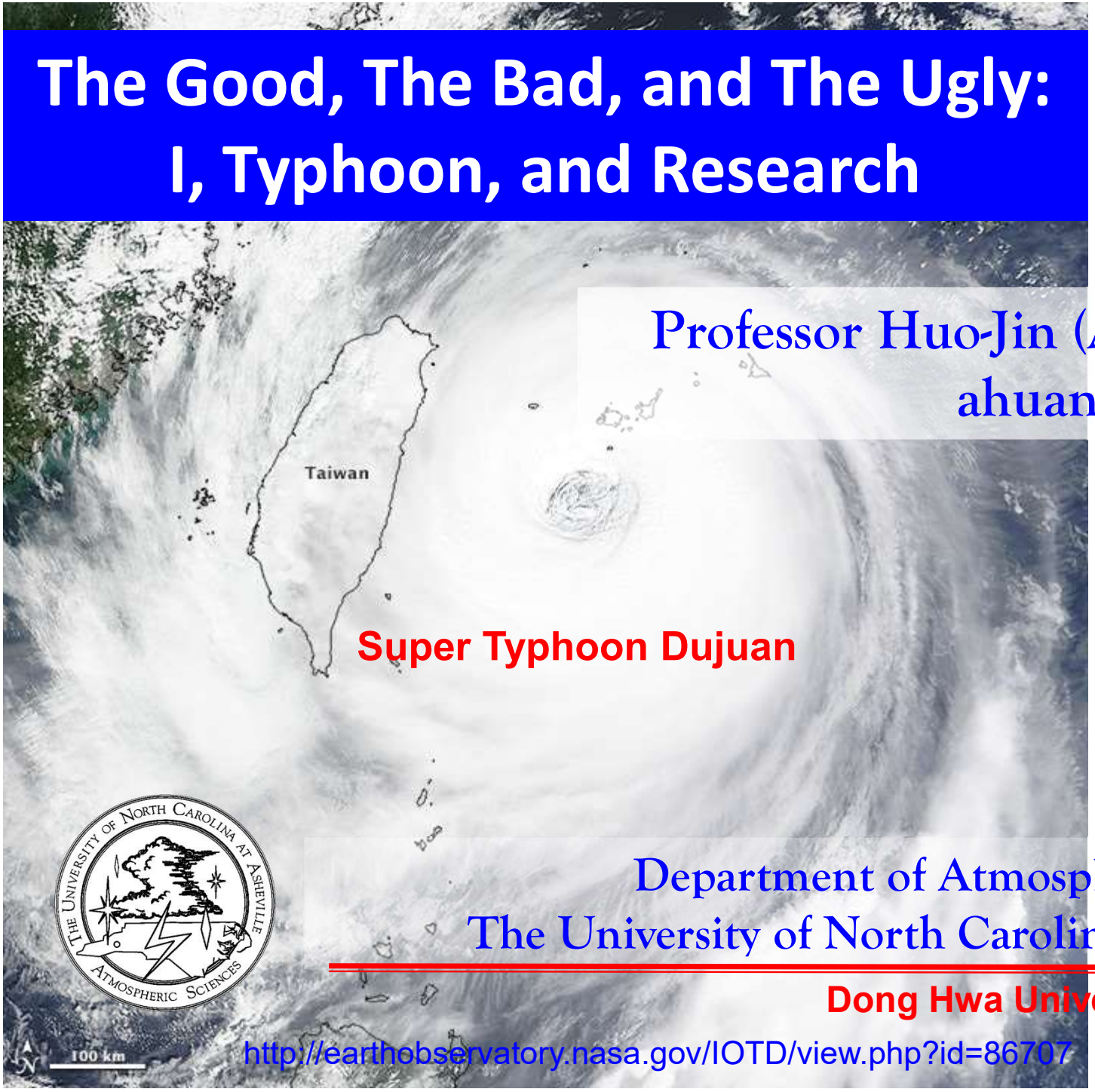
The Good, The Bad, and The Ugly: I, Typhoon, and Research



Super Typhoon Dujuan

Professor Huo-Jin (Alex) Huang
ahuang@unca.edu
黃火金
B352

Department of Atmospheric Sciences
The University of North Carolina at Asheville

Dong Hwa University, 9/19/2017

http://earthobservatory.nasa.gov/IOTD/view.php?id=86707

You may be wondering what is
The good, The bad, and The ugly?

http://cinetropolis.net/scene-is-believing-the-good-the-bad-and-the-ugly/

The Good, The Bad, and The Ugly:
I, Typhoon, and Research

荒野大鏢客 (A Fistful of Dollars, 1964)
黃昏雙鏢客 (For a Few Dollars More, 1965)
黃金三鏢客 (The Good, the Bad, and the Ugly, 1966)

https://www.youtube.com/watch?v=AFa1-kciCb4

Outline

- **Self Introduction**
- **What/Why/How is Typhoon?**
- **Impacts of Typhoon**
- **Typhoons in 2007-2016**
- **Future Research**

I graduated from the National Taiwan University with a BS in meteorology in 1977.

1977

國立臺灣大學
National Taiwan University

One day, I decided to go abroad to see the world, so I went to the United States in 1979 to pursue advanced degrees in Meteorology at Purdue University.

PURDUE
UNIVERSITY

1979

I received Master of Science degree in 1981 from Purdue University, and stayed on to earn a Ph.D. in meteorology in 1984.

Upon graduating from Purdue University in 1984, I went to UNC Asheville to become a teacher.

Our first son, Kevin, was born in 1983, and the second son, Jason, came along in 1986.

1987

Emmeline, 2017

2015

We adopted a dog, Fudgie, in 1997, and he passed away in 2013.

1997

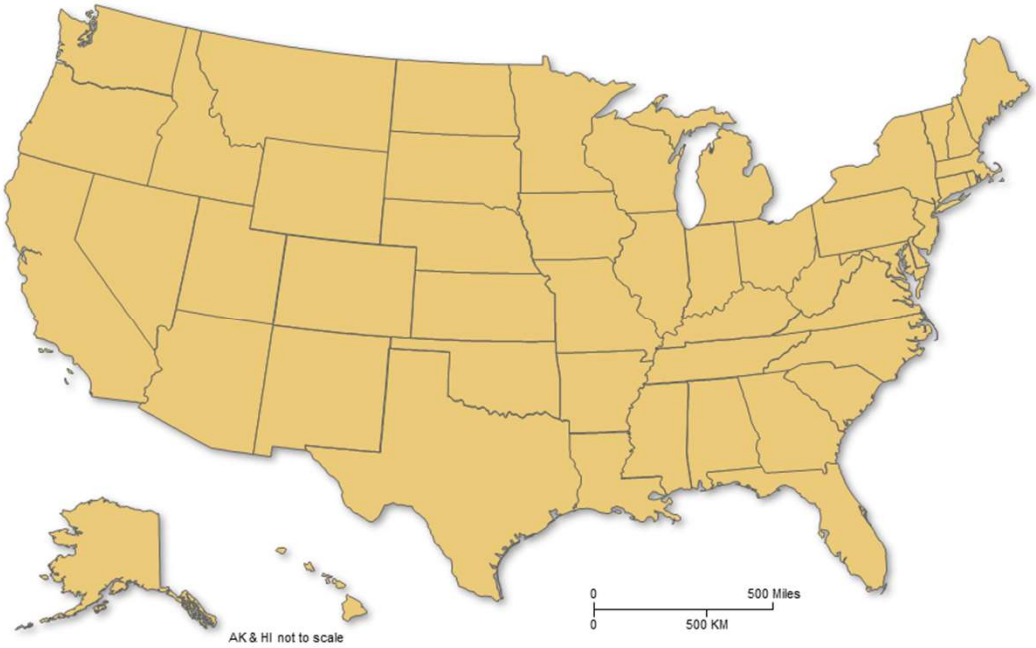
2009

The University of North Carolina Asheville (UNCA) is the only public liberal arts university in North Carolina. It was established in 1927 and is located in the heart of Blue Ridge Mountains.

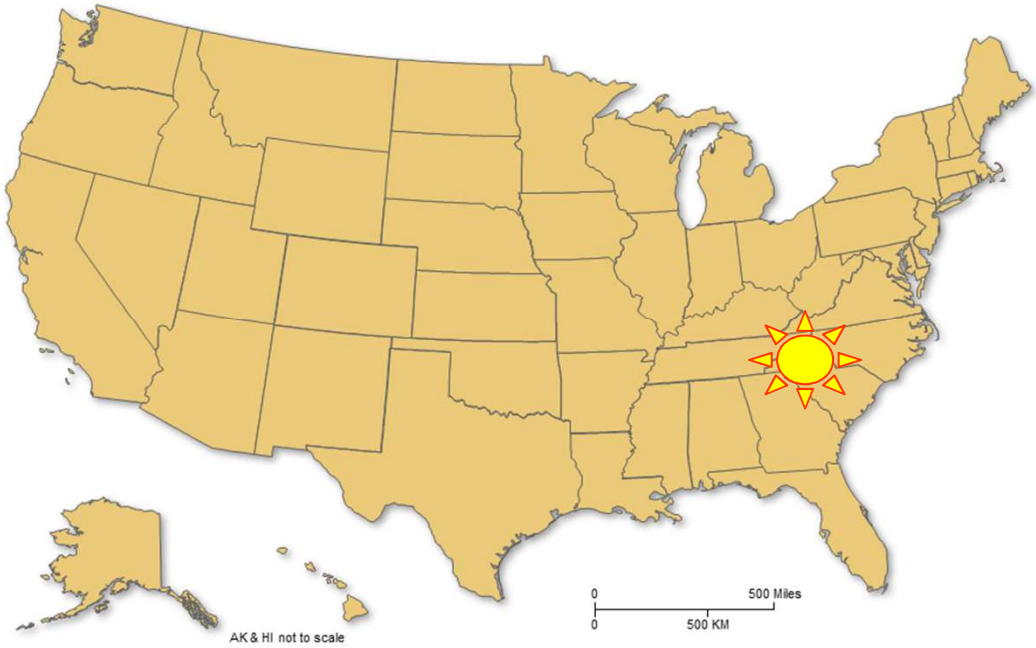
UNIVERSITY of NORTH CAROLINA
ASHEVILLE

Asheville, North Carolina

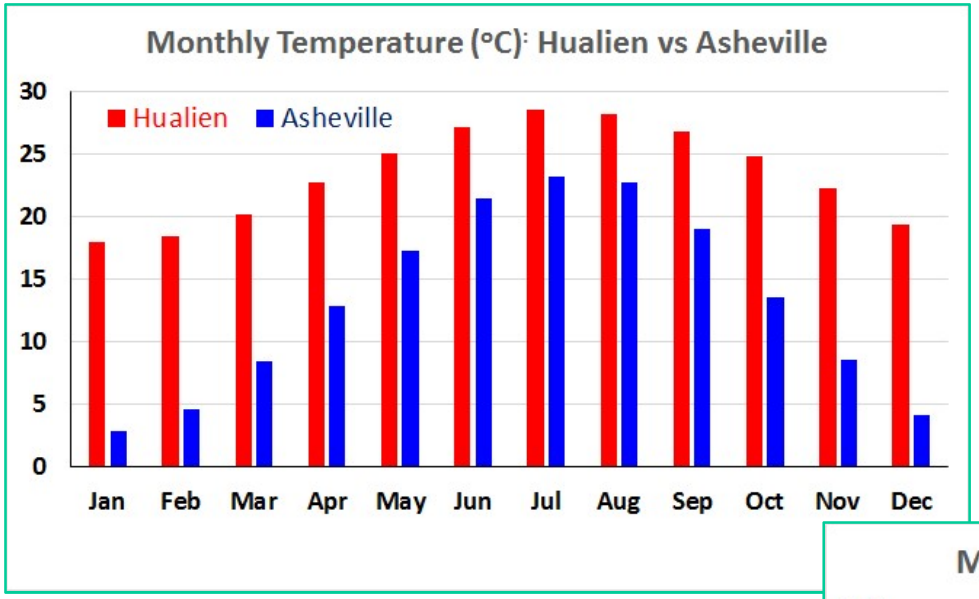
Where is Asheville, North Carolina?



Where is Asheville, North Carolina?

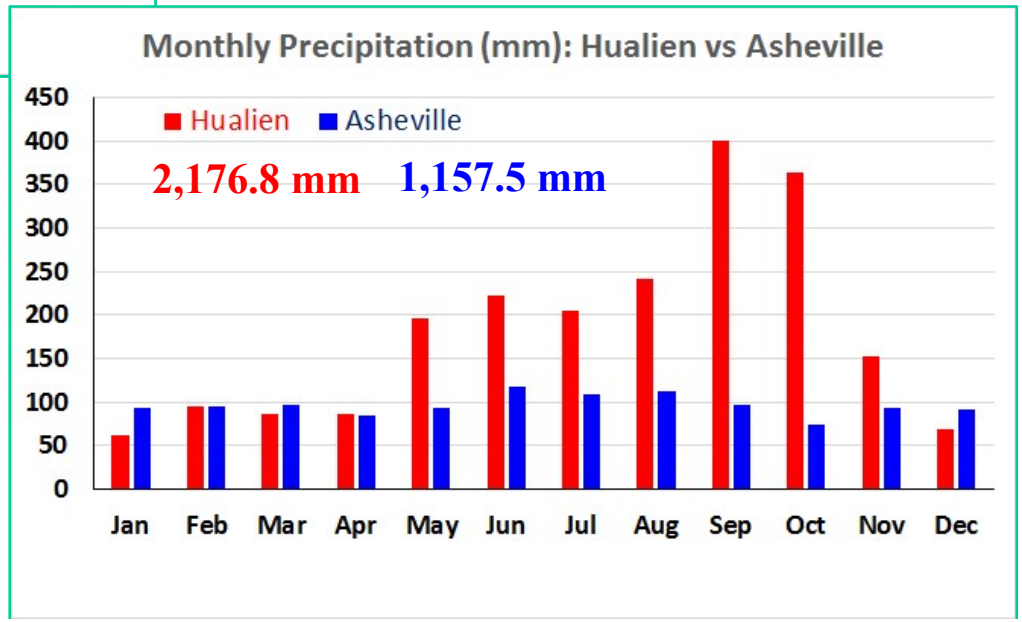


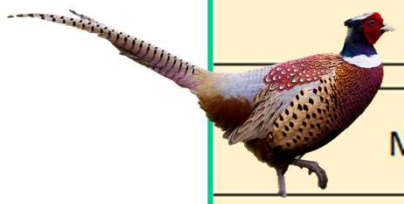
Hualien is warmer and wetter than Asheville



Hualien has the tropical climate.

Asheville has the continental climate.





Category	Dong Hwa University	UNC Asheville
TYPE	National Comprehensive University	Public Liberal Arts University
MOTTO	Freedom, Democracy, Creativity, Excellence	Diversity and Inclusion, Innovation, and Sustainability
LOCATION	Hualien County, Taiwan, ROC	Asheville, North Carolina, USA
ESTABLISHED	**1994**	**1927**
CAMPUS	**2.51 km^2**	**1.07 km^2**
BUILDINGS	> 20 academic buildings	16 academic buildings
MOSCOT	Ring-necked pheasants	Bulldogs
SCHOOL COLORS	Green and Yellow	Blue and White
BS STUDENTS	7597	3715
MS STUDENTS	2290	24
PhD STUDENTS	358	0
TOTAL STUDENTS	**10245**	**3739**
MAJORS	42	36
PRESIDENT	Dr. Zhao Han-Jie (2016 -)	Dr. Mary Grant (2015 - 2017)
FACULTY	522	326
STAFF	350	500
TOTAL EMPLOYEES	**872**	**826**
TUITION (USD)	$1,000 - $2,500	$20,436 (out of state)
		$4,041 (in-state)

Why the National Dong Hwa University?

List of Best Universities in Taiwan, ROC (2016)

According to the study by Global Views Monthly (遠見雜誌)

2016

表1 最佳大學排名 1～10名

1	國立臺灣大學
2	國立成功大學
3	國立清華大學
4	國立交通大學
5	國立陽明大學
6	國立臺灣科技大學
7	國立政治大學
8	國立中央大學
9	臺北醫學大學
10	長庚大學

表2 最佳大學排名11～30名

11	國立中山大學	21	淡江大學
12	國立臺灣師範大學	22	國立東華大學
13	中國醫藥大學	23	國立臺灣海洋大學
14	國立臺北科技大學	24	中原大學
15	國立中興大學	25	國立臺北大學
16	高雄醫學大學	26	亞洲大學
17	逢甲大學	27	東海大學
18	國立中正大學	28	元智大學
19	慈濟大學	29	中山醫學大學
20	輔仁大學	30	義守大學

https://www.gvm.com.tw/webonly_content_11454.html

2017

1～10名		11～30名			
1	國立台灣大學	11	國立中興大學	21	輔仁大學
2	國立成功大學	12	國立台灣師範大學	22	淡江大學
3	國立清華大學	13	國立台灣科技大學	23	中原大學
4	國立交通大學	14	國立政治大學	24	中山醫學大學
5	國立陽明大學	15	高雄醫學大學	25	亞洲大學
6	國立中央大學	16	國立台北科技大學	26	國立東華大學
7	長庚大學	17	逢甲大學	27	元智大學
8	中國醫藥大學	18	國立中正大學	28	國立台北大學
9	台北醫學大學	19	國立台灣海洋大學	29	國立嘉義大學
10	國立中山大學	20	慈濟大學	30	國立彰化師範大學

https://www.gvm.com.tw/Boardcontent_33266.html

Outline

- Self Introduction
- **What/Why/How is Typhoon?**
- **Impacts of Typhoon**
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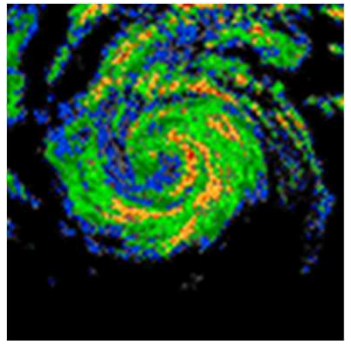
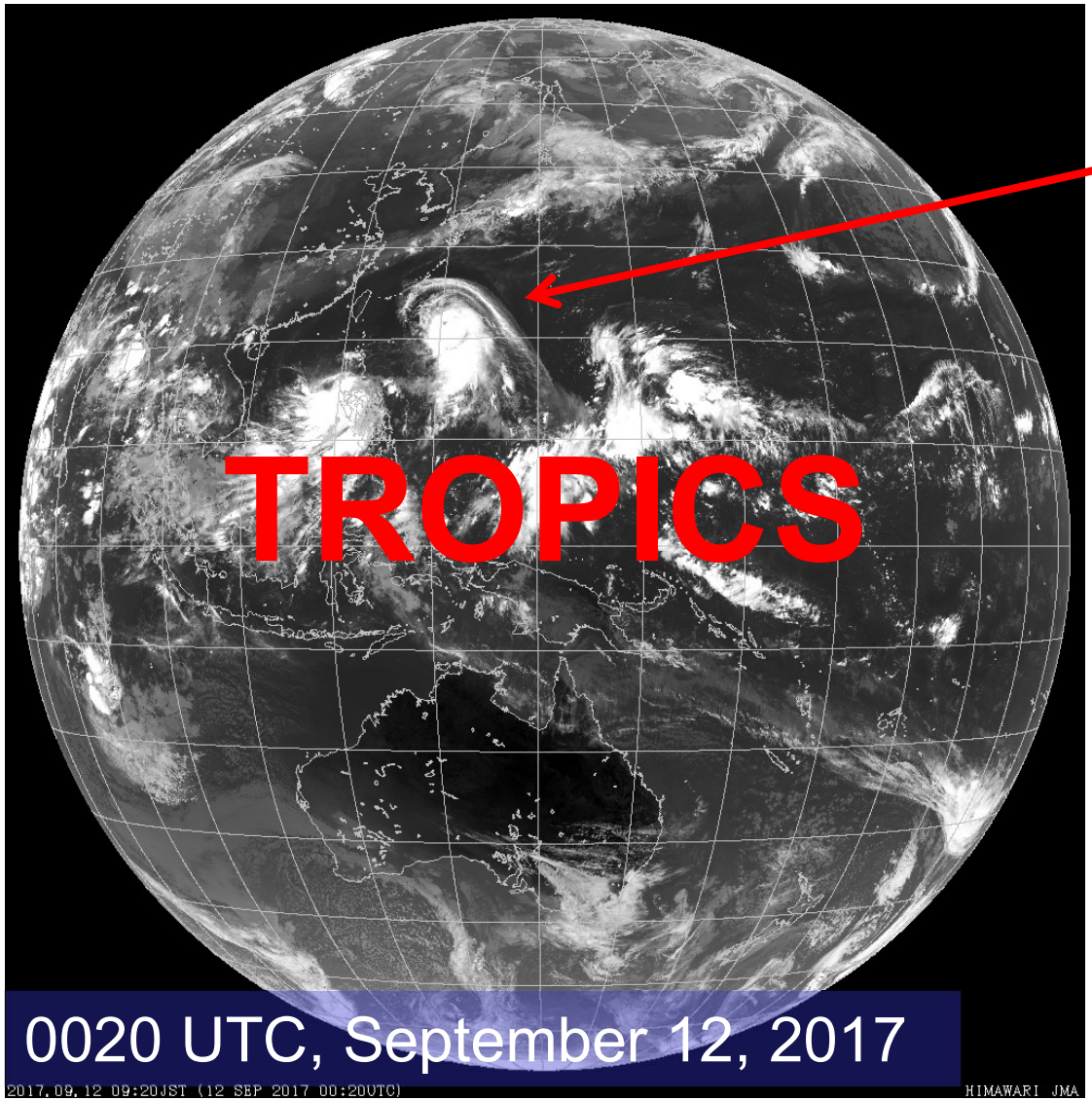
- **Future Research**

Typhoon



- A strong tropical cyclone
- A cluster of many thunderstorms
- About 500 km wide
- Its sustained Surface wind is > 34 knots (17.5 m/s)
- It has Eye, Eye Wall, and Spiral Rain Bands
- It rotates counterclockwise but clockwise aloft
- It is categorized by Mild (輕度颱風, 34 – 63 knots),
  Moderate (中度颱風, 64 - 99 knots),
  Severe (強烈颱風, 100 - 130 knots), and
  Super (超級颱風, > 130 knots).
  (In the United States, it is called “Hurricane” and categorized by Saffir-Simpson Scale, Categories 1 – 5)
- It produces Storm Surge, Heavy Rain, Strong Winds, possibly Tornadoes

A typhoon is a strong tropical cyclone.

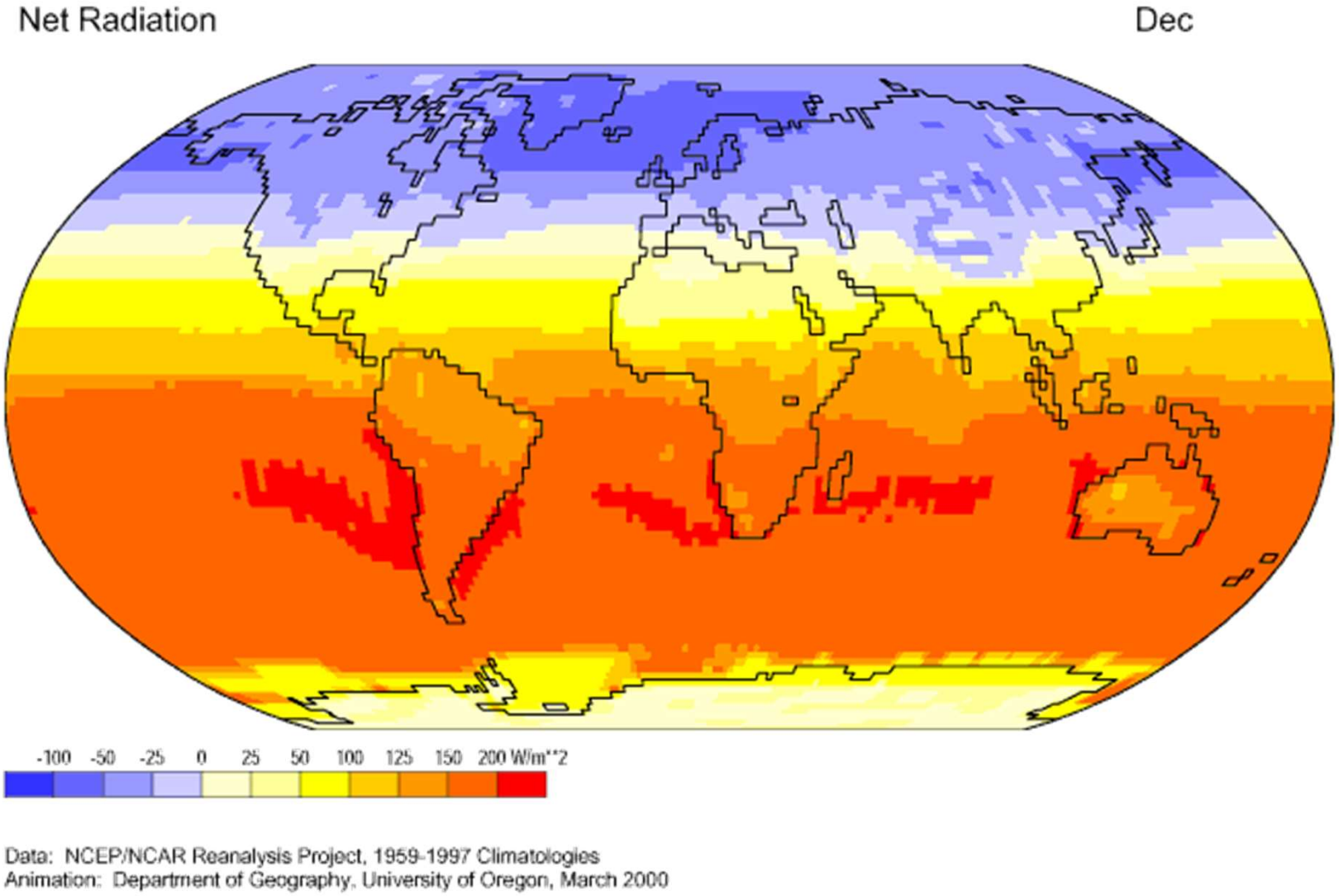


http://www.jma.go.jp/en/gms/

Why do tropical cyclones form?

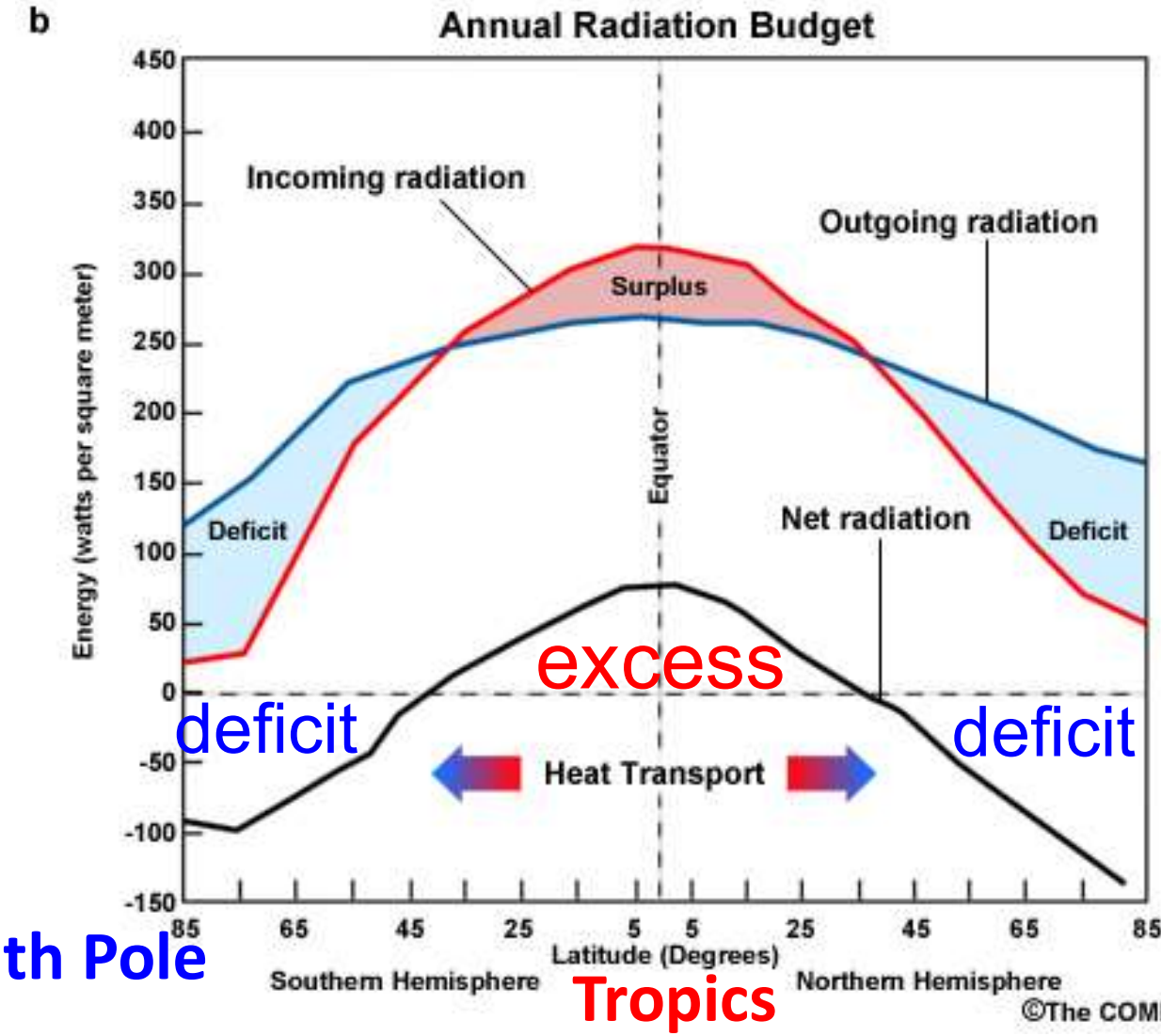
- Part of natural disturbances
- To help transfer energy from the tropics to midlatitudes
- To bring fresh water to the coastal region in summer/fall

Global Monthly Net Radiation (SW – LW)



http://geography.uoregon.edu/envchange/clim_animations/animated%20gifs/netrad_web.gif

Latitudinal Radiational Difference

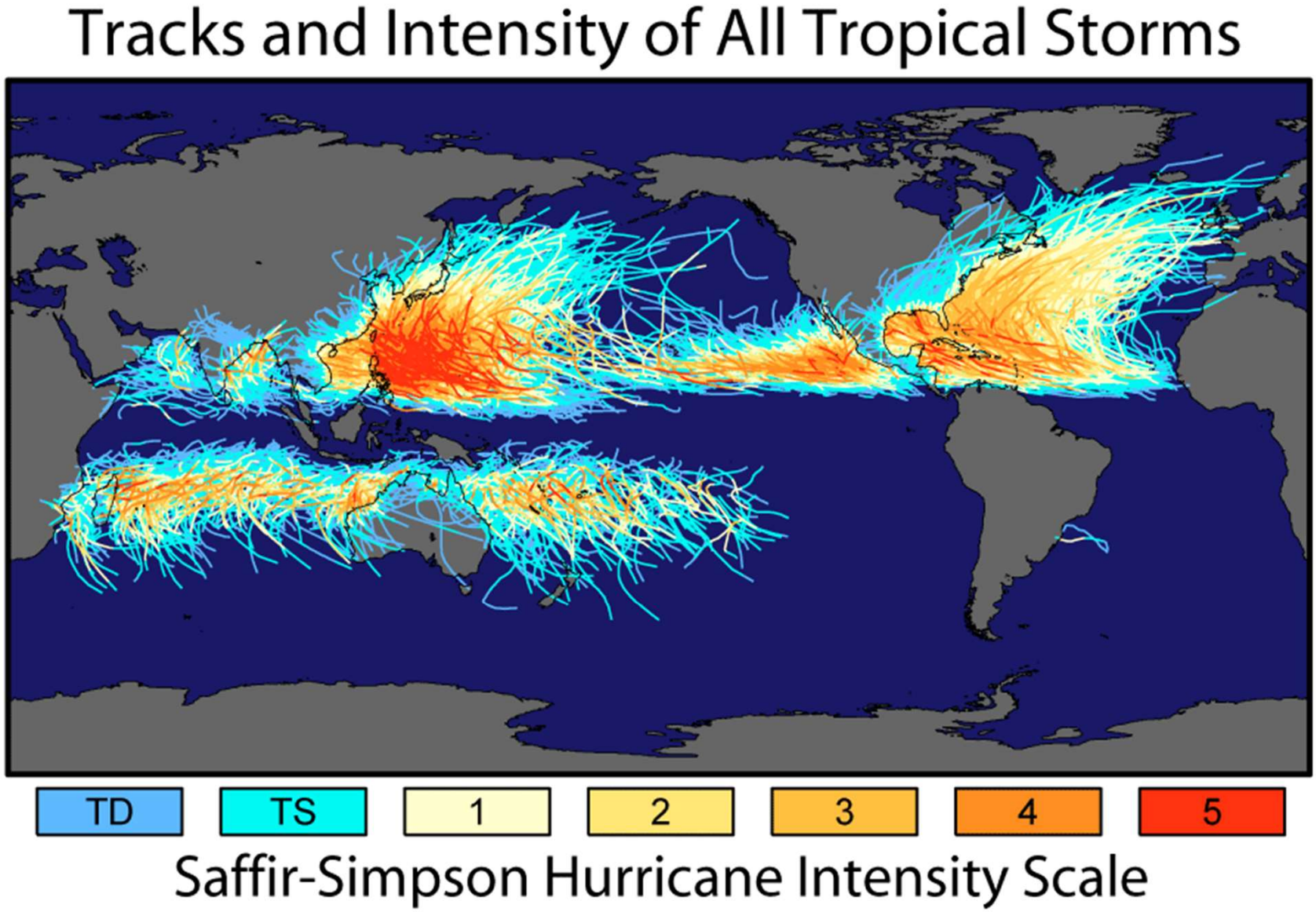


South Pole **North Pole**

Tropics

http://www.geocoops.com/heat-budget--insolation.html

Where do tropical cyclones form?

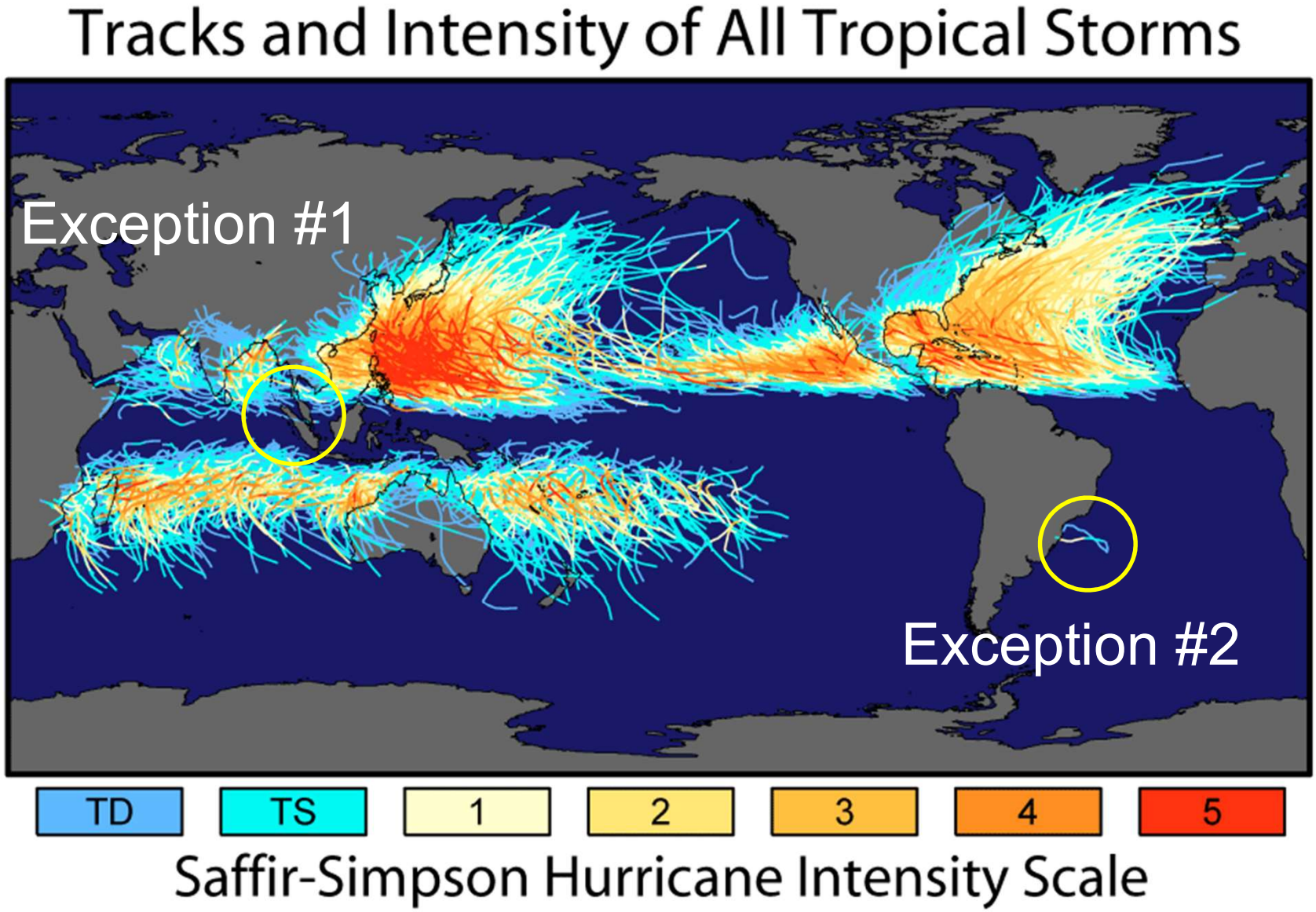


http://eoimages.gsfc.nasa.gov/images/imagerecords/7000/7079/tropical_cyclone_map_lrg.gif

How do tropical cyclones form?

- Surface disturbance in the tropical easterly waves or West African Disturbance Line (WADL)
- Over the **warm ocean with temperatures warmer than 27°C** (80°F,) through the depth of 46 m (150 ft)
- Potentially unstable atmosphere
- Relatively **moist** in the mid-troposphere
- **Beyond 5°S and 5°N latitude belt**
  (i.e., 450 km away from the equator)
- **Low vertical wind shear** at the initial stage
- Supportive upper-level divergence
- **They are supported by moisture and heat from underlying oceans**

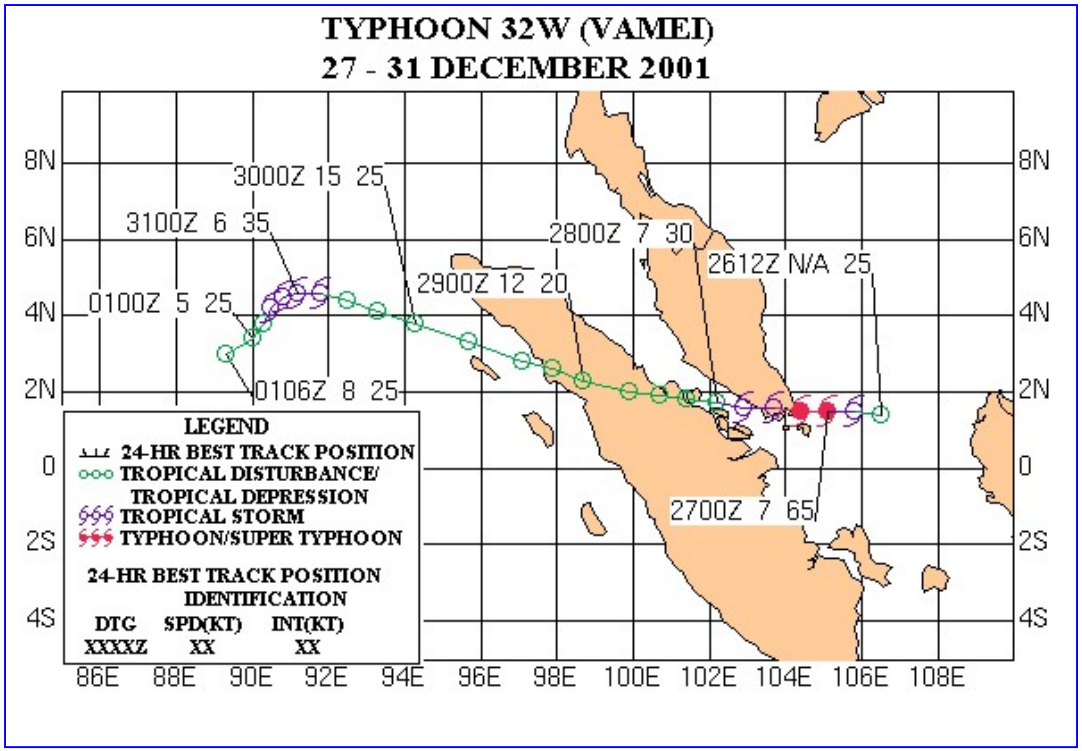
Where do tropical cyclones form?



http://eoimages.gsfc.nasa.gov/images/imagerecords/7000/7079/tropical_cyclone_map_lrg.gif

Exception #1

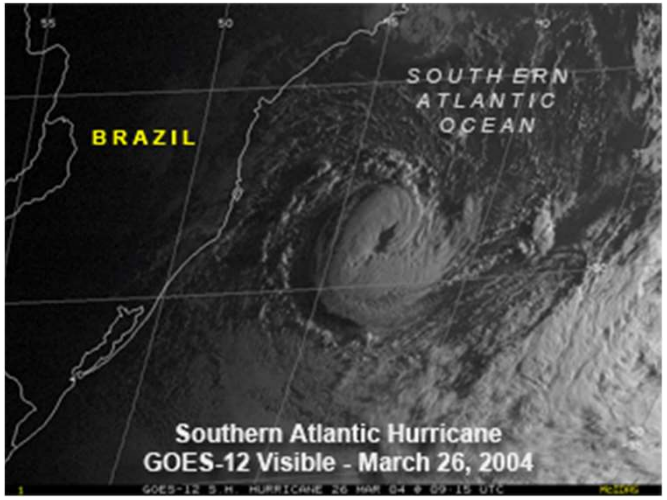
Typhoon Vamei (2001) formed near Equator

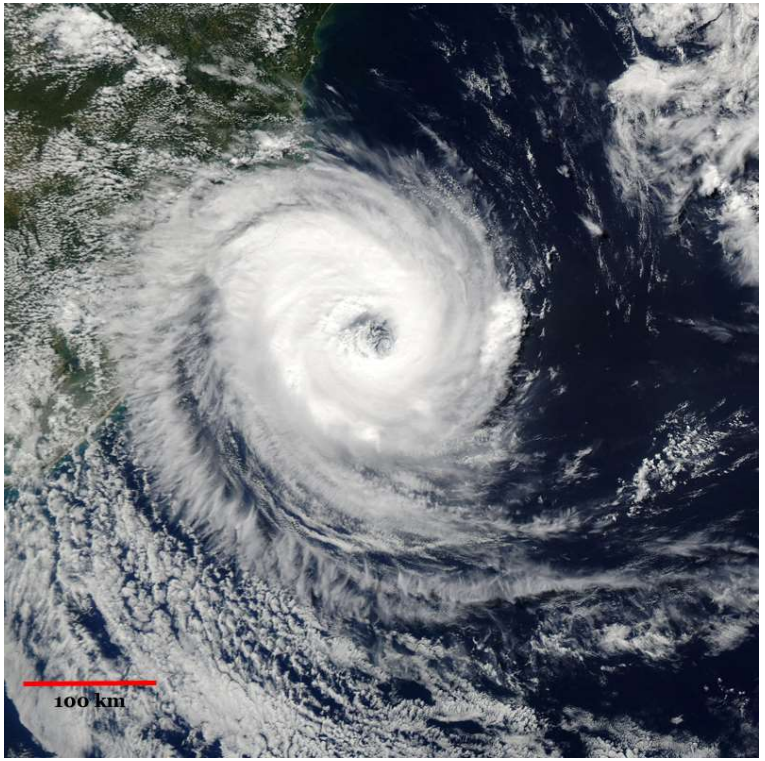


http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/atcr/2001atcr/ch1/chap1_page39.html

Exception #2

Hurricane Catarina in the South Atlantic, 24-28 March 2004





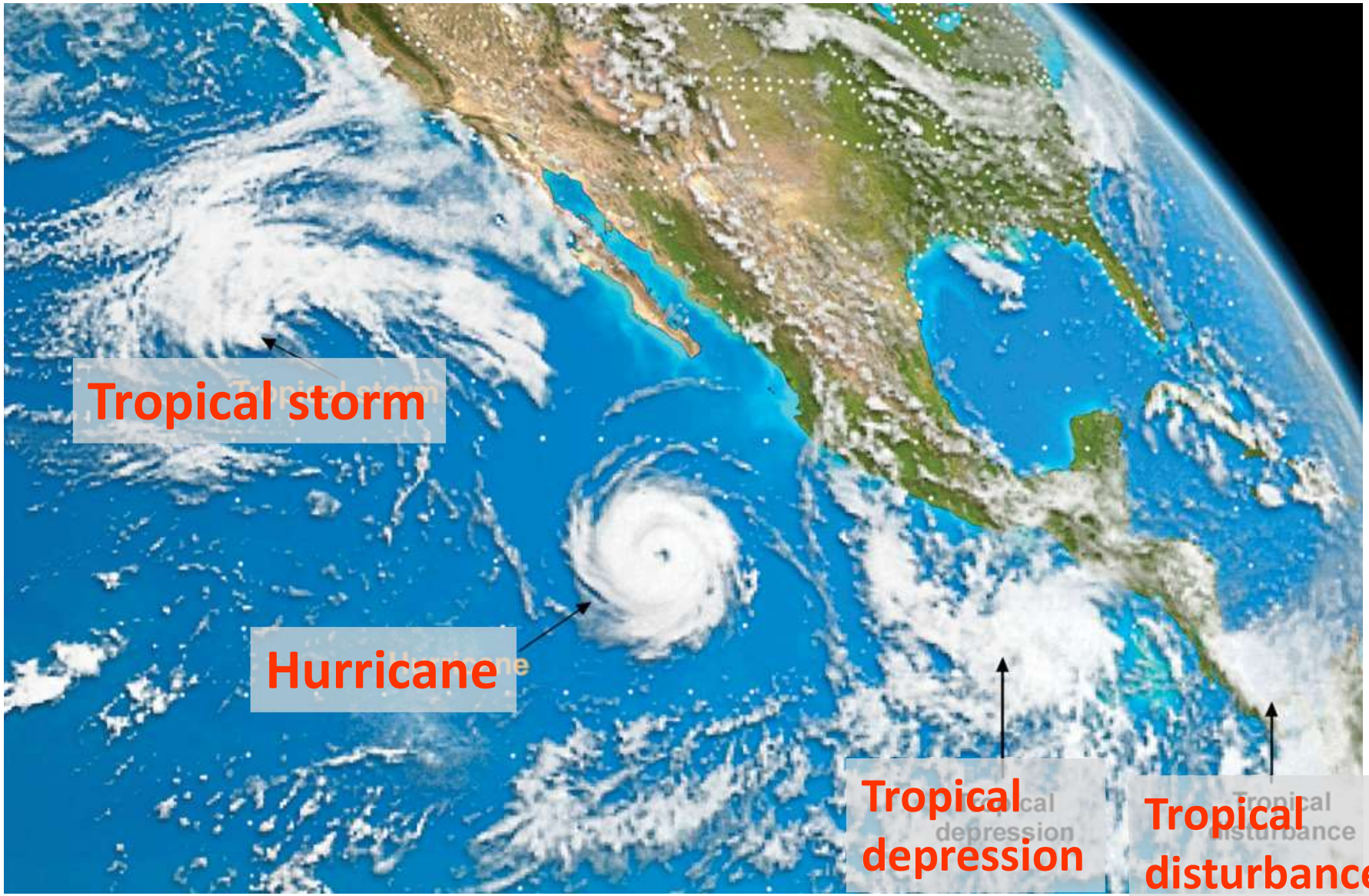
* Clockwise rotation of a Hurricane in the Southern Hemisphere

http://serc.carleton.edu/details/images/10179.html

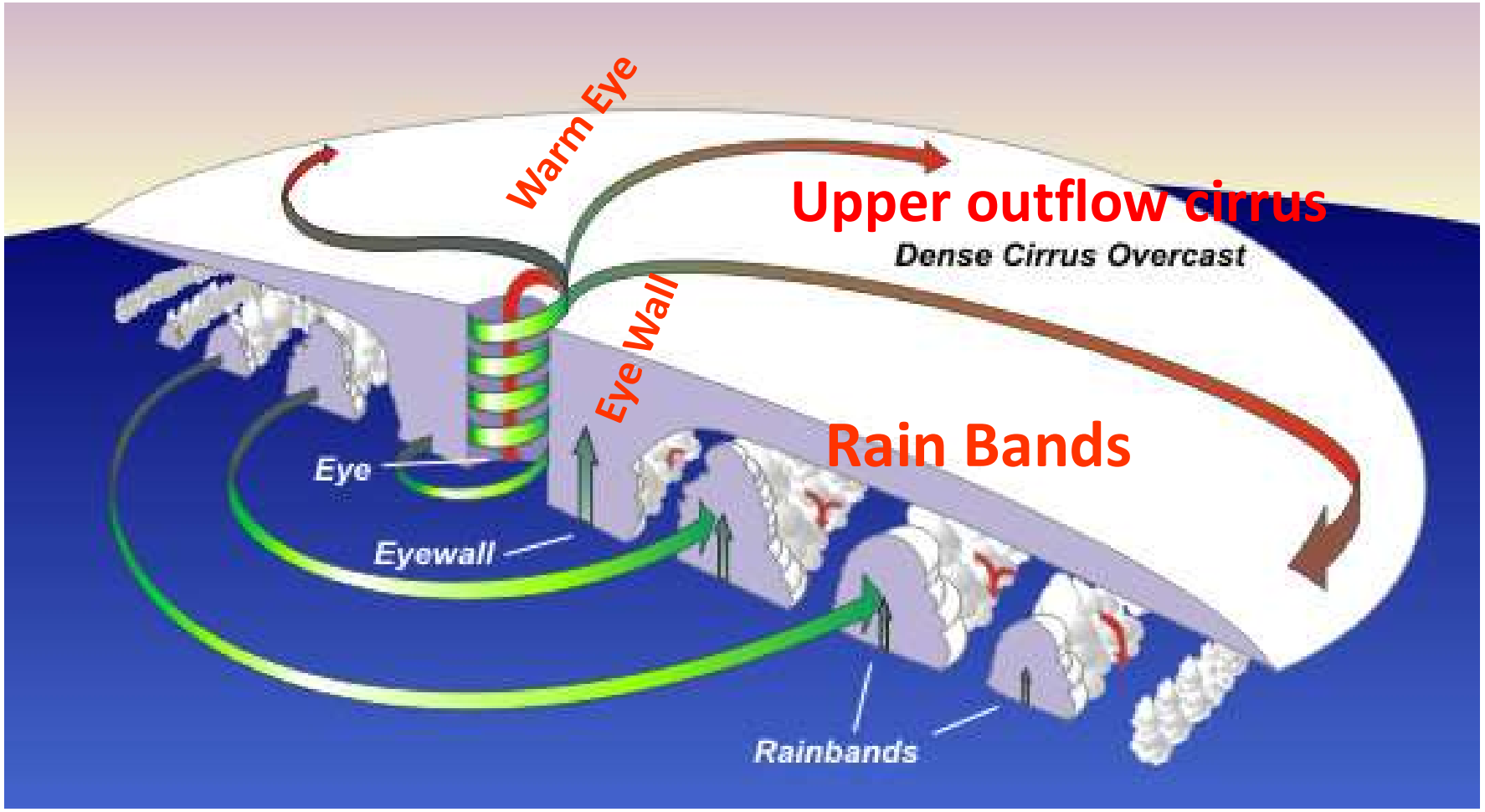
Scales of Tropical Cyclone Systems

Category	m/s	Beaufort Scale	Central Weather Bureau
TD	12.9 - 17.0	< 7	熱帶性低氣壓 (< 33 knots)
TS	17.5 – 32.4	**8 - 11**	輕度颱風 (34 – 63 knots) **Name is given** **Mild**
H1	32.9 – 42.2	12 - 15	中度颱風 (64 - 99 knots） **Moderate**
H2	42.7 – 48.9	12 - 15	中度颱風 (64 – 99 knots) **Moderate**
H3	49.4 – 57.6	> 16	強烈颱風 (100 - 130 knots) **Severe**
H4	58.1 – 69.4		超級颱風 (> 130 knots) **Super**
H5	> 70		

Tropical Low Pressure Systems

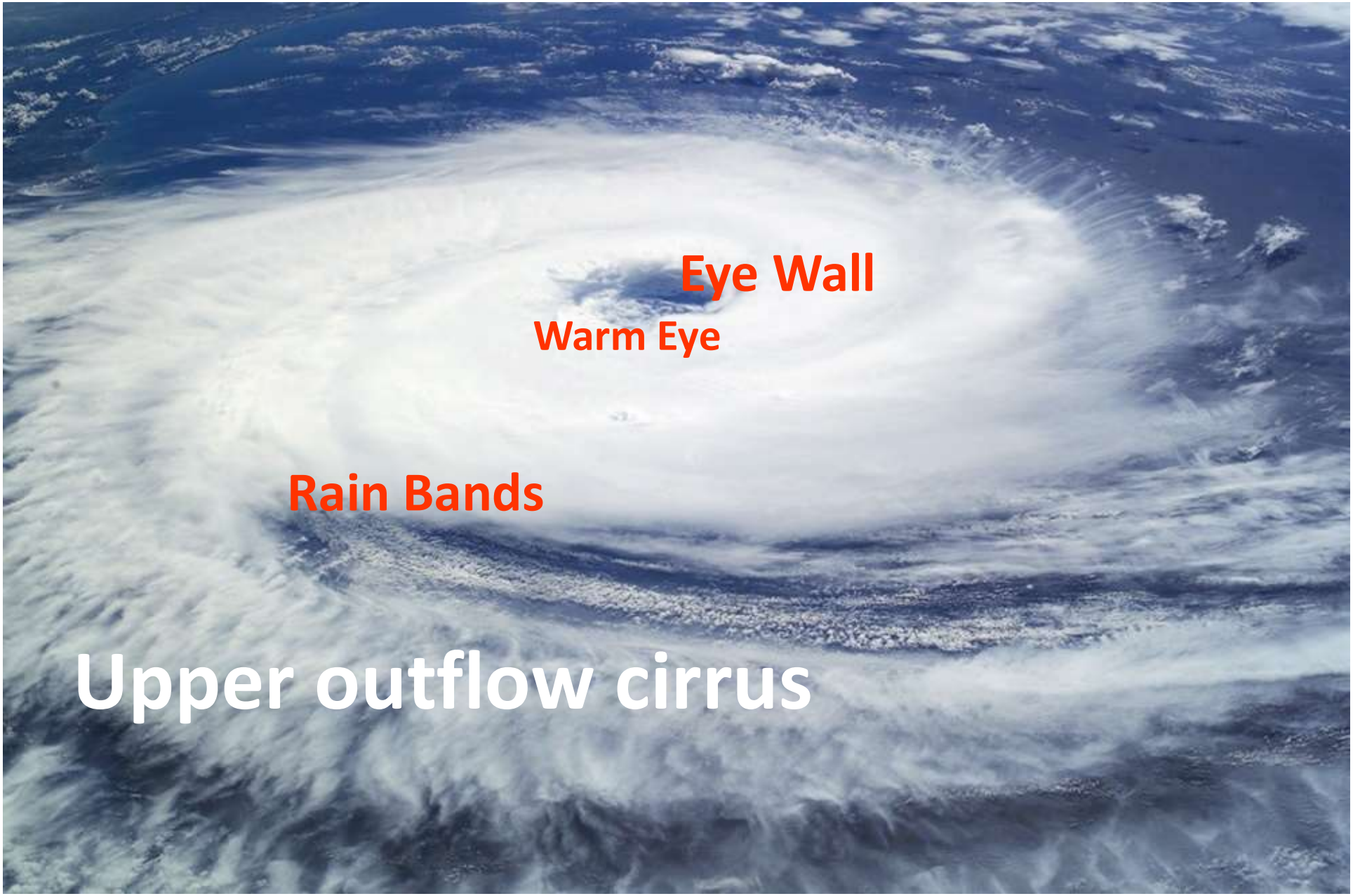


Structure of a Mature Typhoon



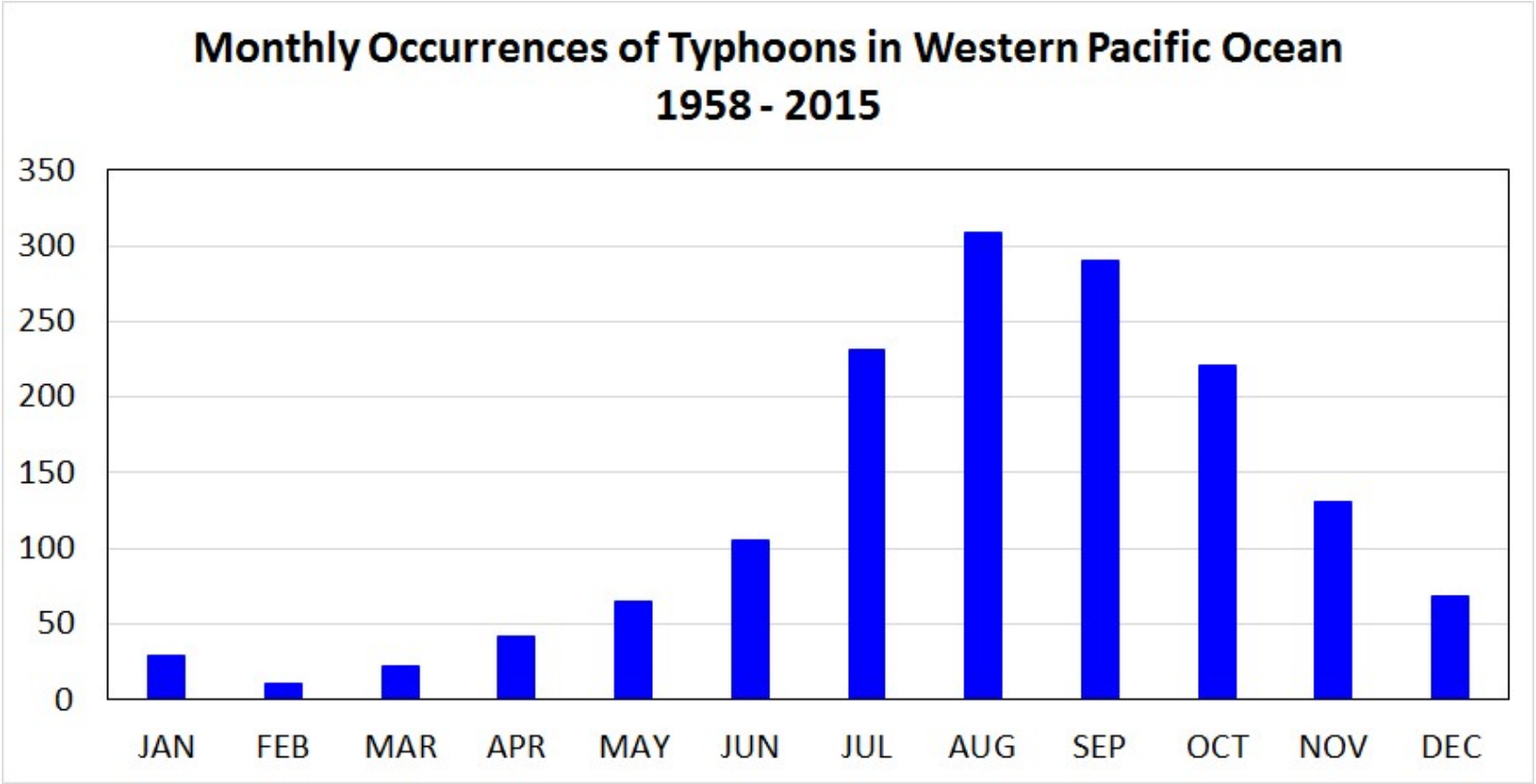
http://www.srh.weather.gov/jetstream/tropics/tc_structure.html

Structure of a Mature Typhoon



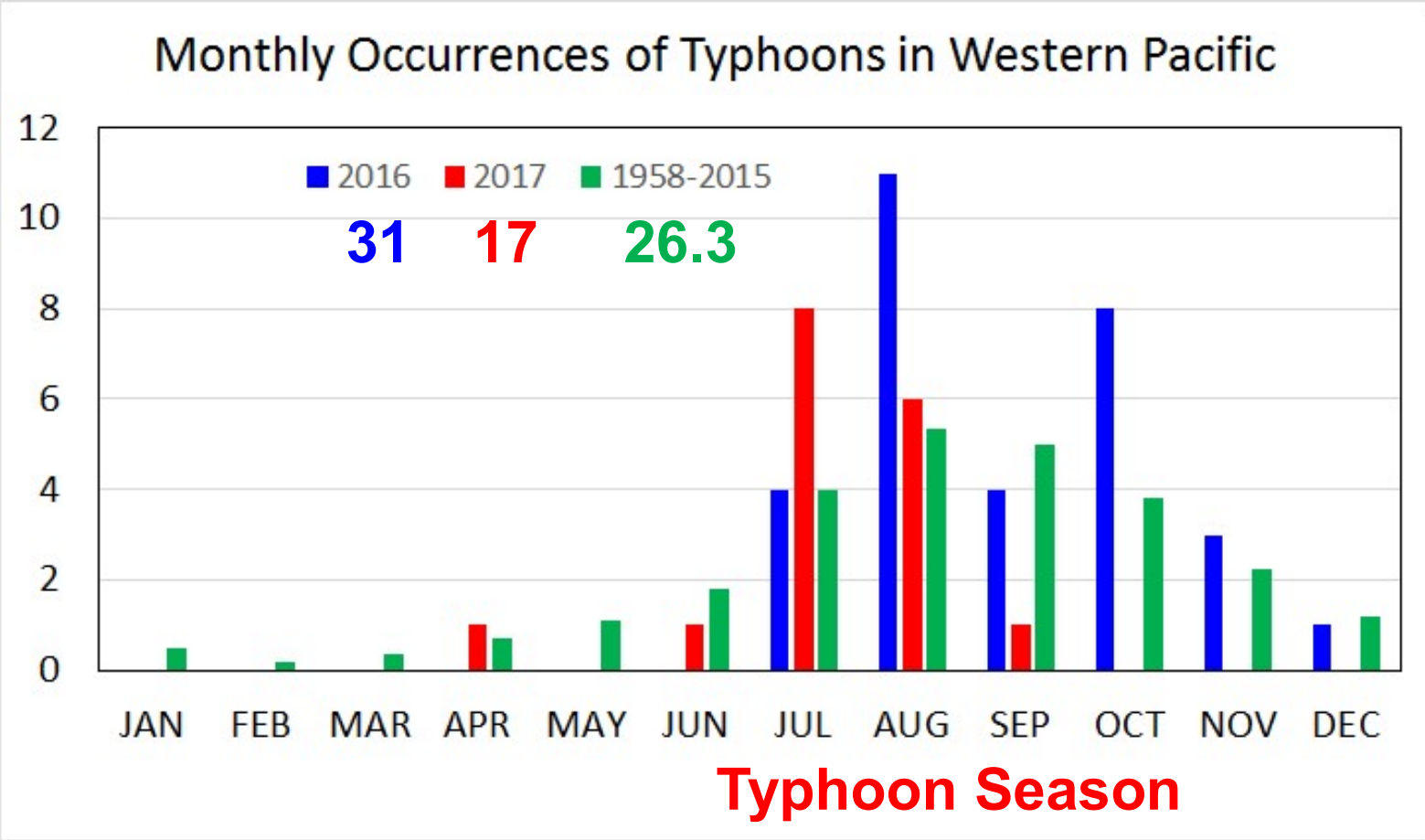
Eye of Category 5 Hurricane Irma

When do tropical storms form?



Typhoon Season

We are not done with typhoons yet!

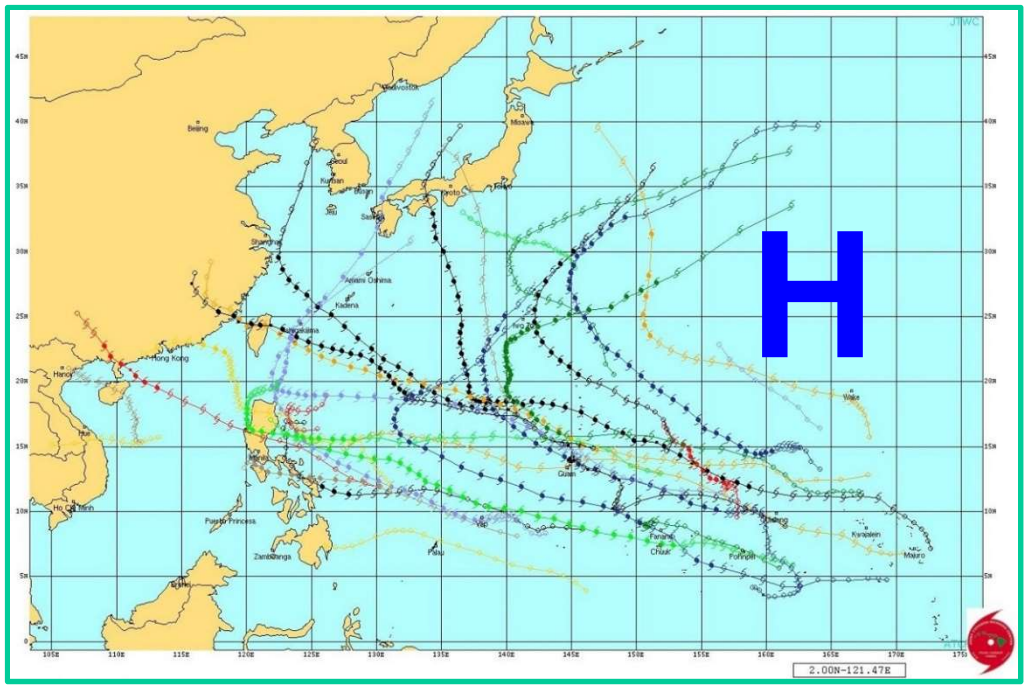


Only One Super Typhoon (> 130 knots) in 2017, Noru, 7/20-8/8/2017!

How do tropical cyclones move?

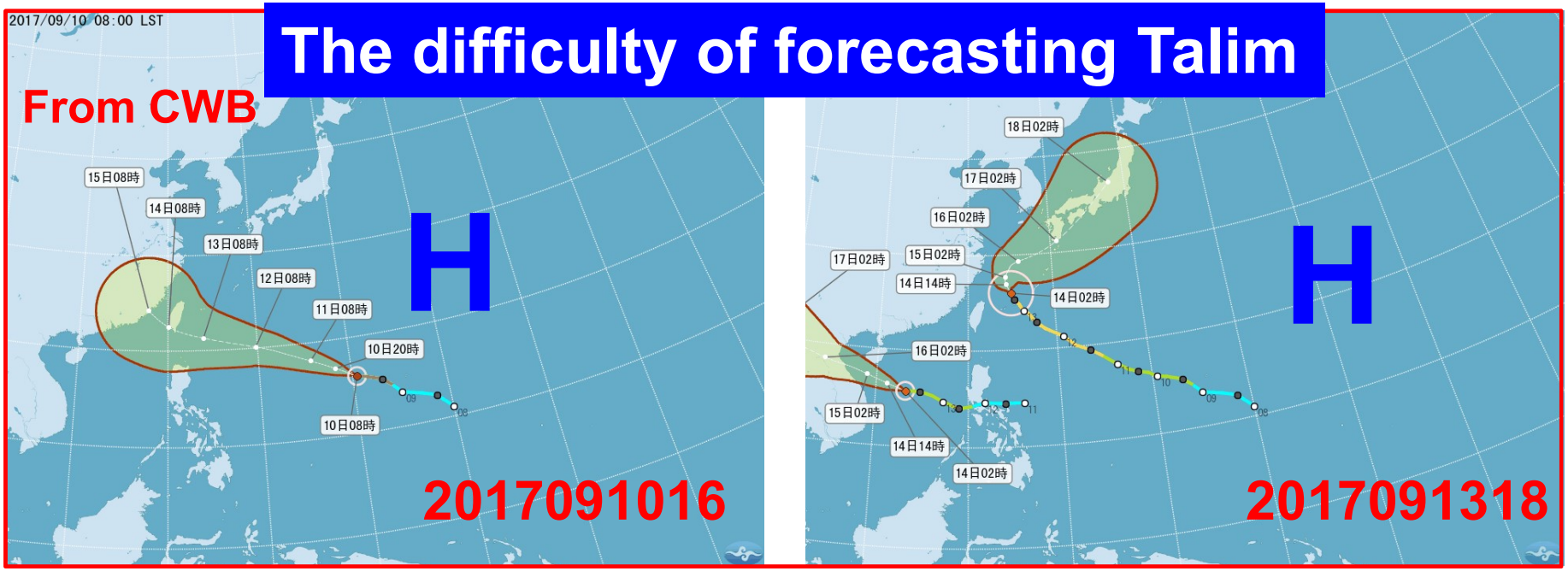
Although tropical cyclones are powerful and destructive, they don't know where they are going!

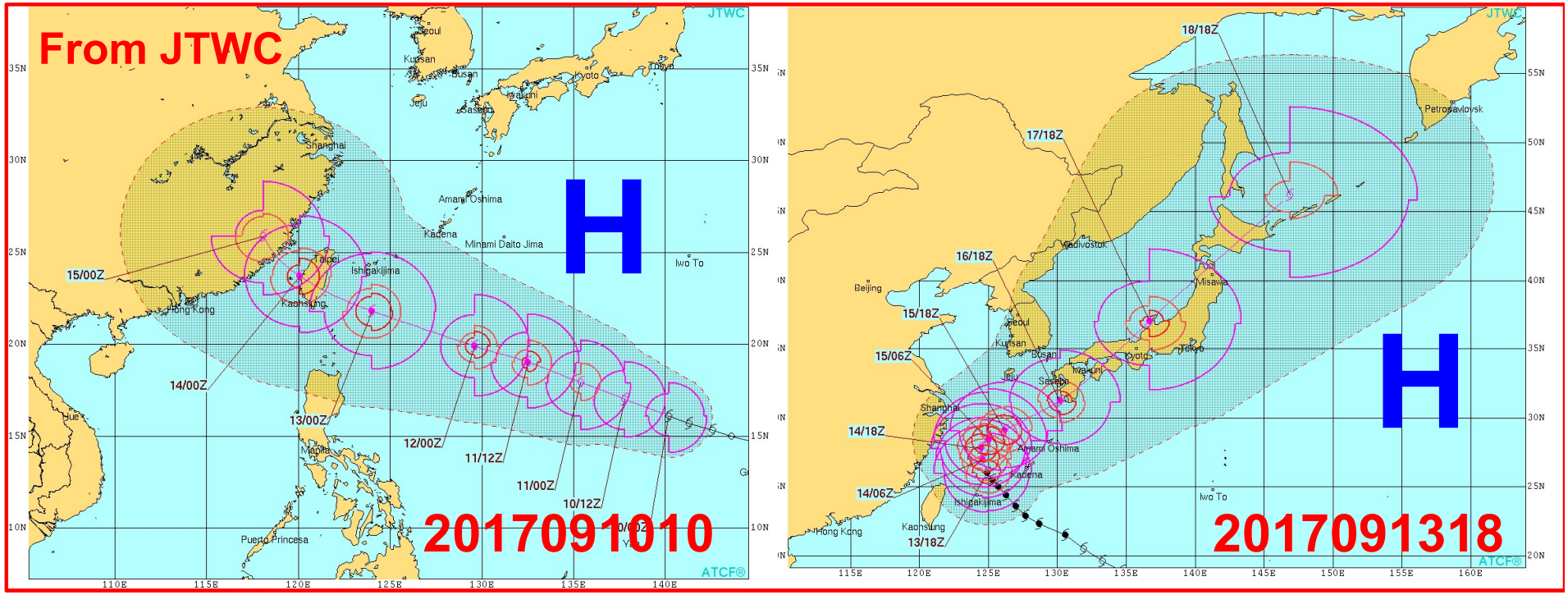
They are steered by the high pressure systems!



http://www.doncio.navy.mil/chips/ArticleDetails.aspx?ID=7444

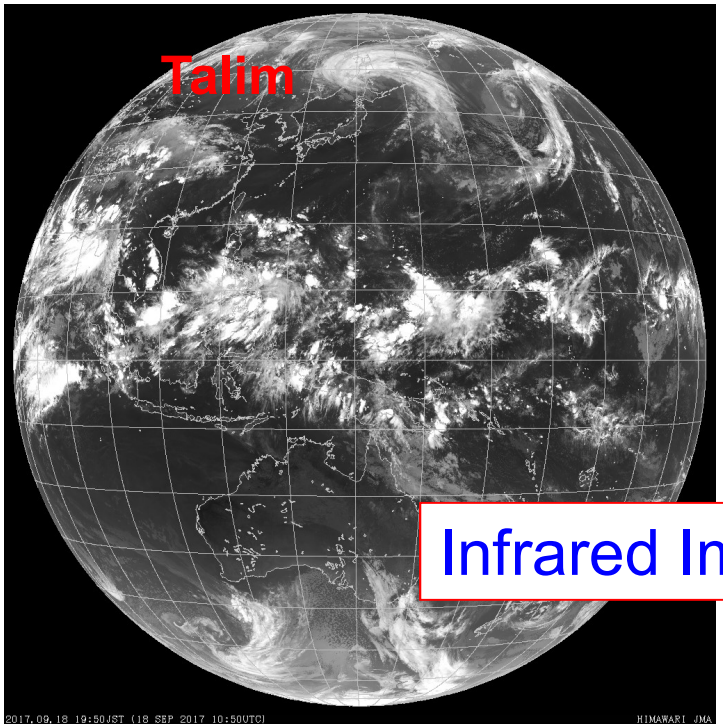
The difficulty of forecasting Talim





How do tropical cyclones weaken? When they

- Move over land
- Move over cold waters
- Have unfavorable upper level wind circulation
- Merge with an extratropical cyclone



Infrared Imagery @ 1050UTC, 9/18/2017

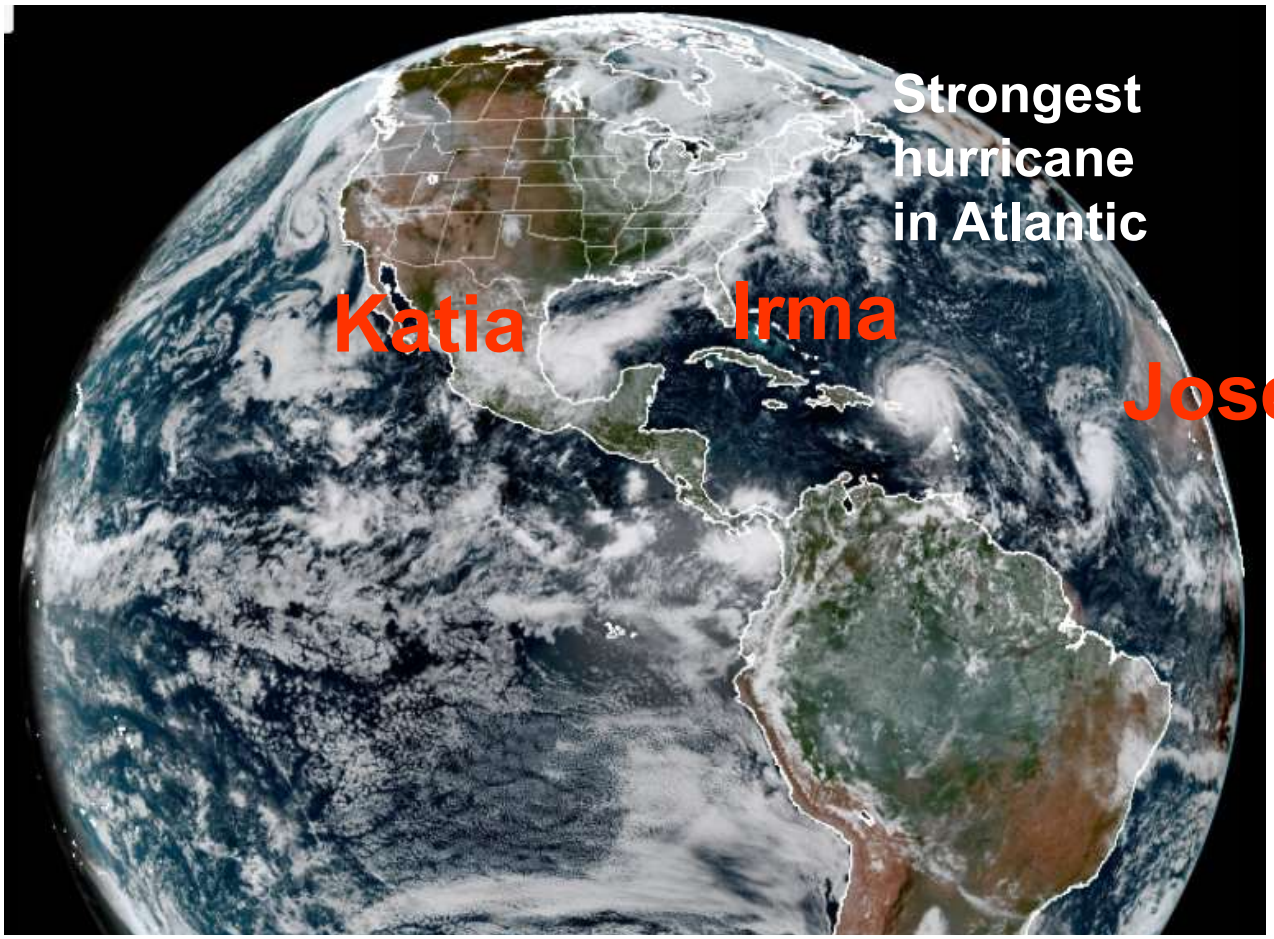
http://www.jma.go.jp/en/gms/

Names of Western Pacific Tropical storms

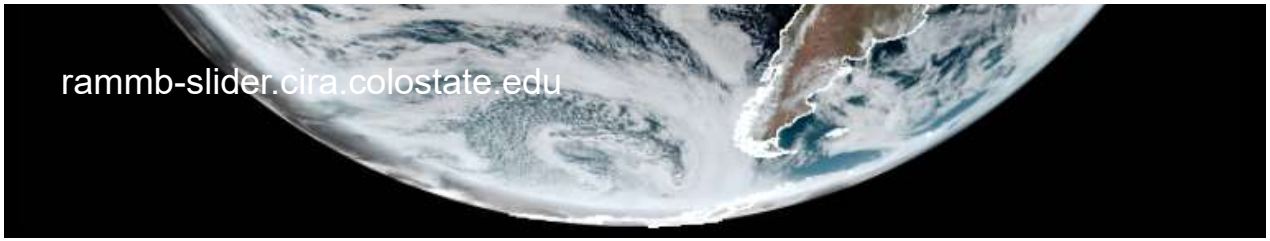
List	1		2		3		4		5	
Cambodia	Damrey	Ampil	Kong-rey	Krosa	Nakri	Maysak	Krovanh	Chanthu	Sarika	Nesat
China	Haikui	Wukong	Yutu	Bailu	Fengshen	Haishen	Dujuan	Dianmu	Haima	Haitang
North Korea (DPRK)	Kirogi	Jongdari	Toraji	Podul	Kalmaegi	Noul	Surigae	Mindulle	Meari	Nalgae
Hong Kong	Kai-tak	Shanshan	Man-yi	Lingling	Fung-wong	Dolphin	Choi-wan	Lionrock	Ma-on	Banyan
Japan	Tembin	Yagi	Usagi	Kajiki	Kammuri	Kujira	Koguma	Kompasu	Tokage	Hato
Laos	Bolaven	Leepi	Pabuk	Faxai	Phanfone	Chan-hom	Champi	Namtheun	Nock-ten	Pakhar
Macau	Sanba	Bebinca	Wutip	Peipah	Vongfong	Linfa	In-fa	Malou	Muifa	Sanvu
Malaysia	Jelawat	Rumbia	Sepat	Tapah	Nuri	Nangka	Cempaka	Meranti	Merbok	Mawar
Micronesia	Ewiniar	Soulik	Mun	Mitag	Sinlaku	Saudel	Nepartak	Rai	Nanmadol	Guchol
Philippines	Maliksi	Cimaron	Danas	Hagibis	Hagupit	Molave	Lupit	Malakas	Talas	Talim
South Korea (ROK)	Gaemi	Jebi	Nari	Neoguri	Jangmi	Goni	Mirinae	Megi	**Noru**	**Doksuri**
Thailand	Prapiroon	Mangkhut	Wipha	Bualoi	Mekkhala	Atsani	Nida	Chaba	Kulap	Khanun
United States	Maria	Barijat	Francisco	Matmo	Higos	Etau	Omais	Aere	Roke	Lan
Vietnam	Son-Tinh	Trami	Lekima	Halong	Bavi	Vamco	Conson	Songda	Sonca	Saola

Typhoons are numbered (e.g., the first typhoon in 2017 is numbered as 1701) and named by the names provided by 14 neighboring countries in the Pacific Ocean and South China Sea.

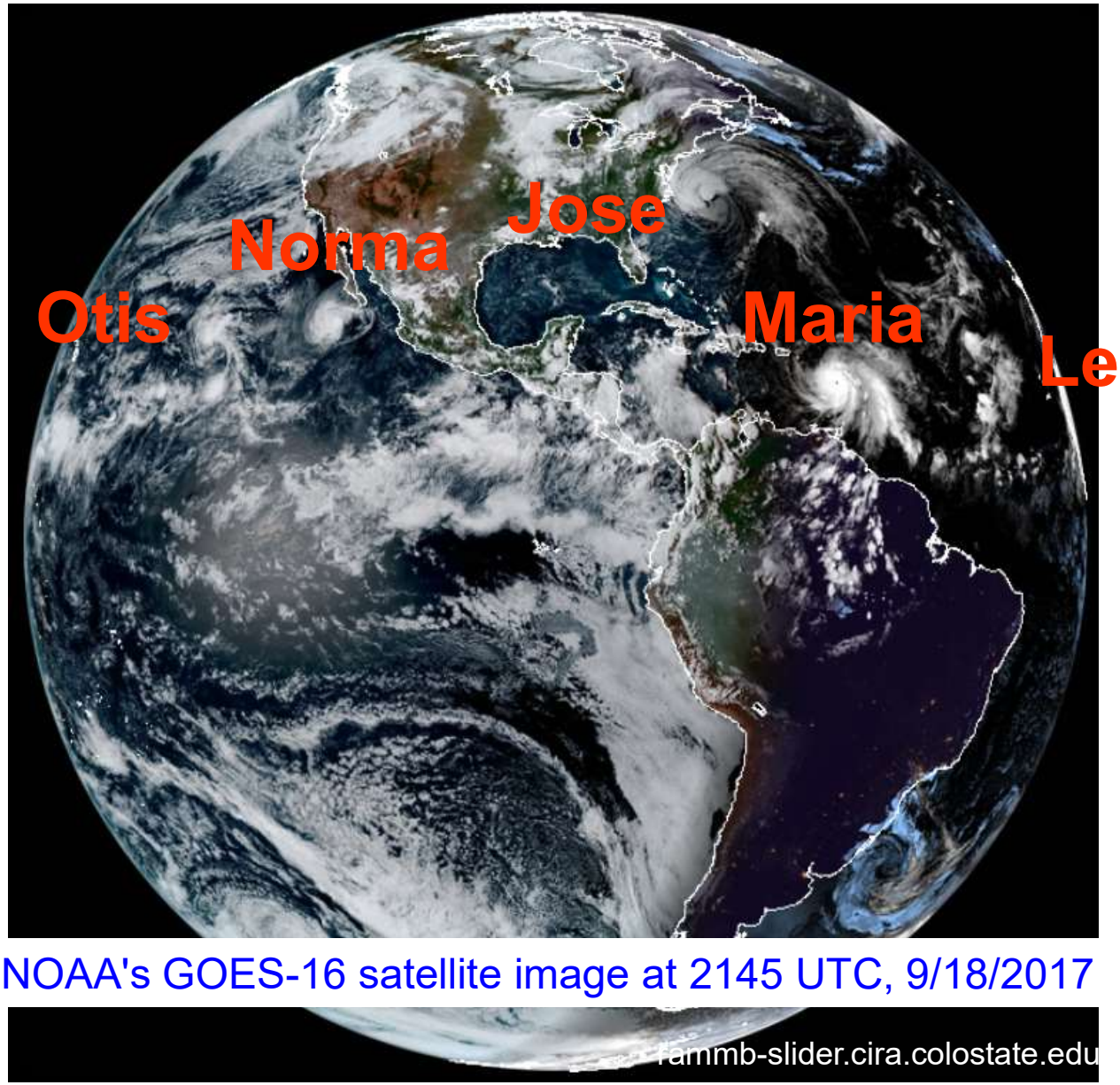
Are we having more hurricanes/typhoons?



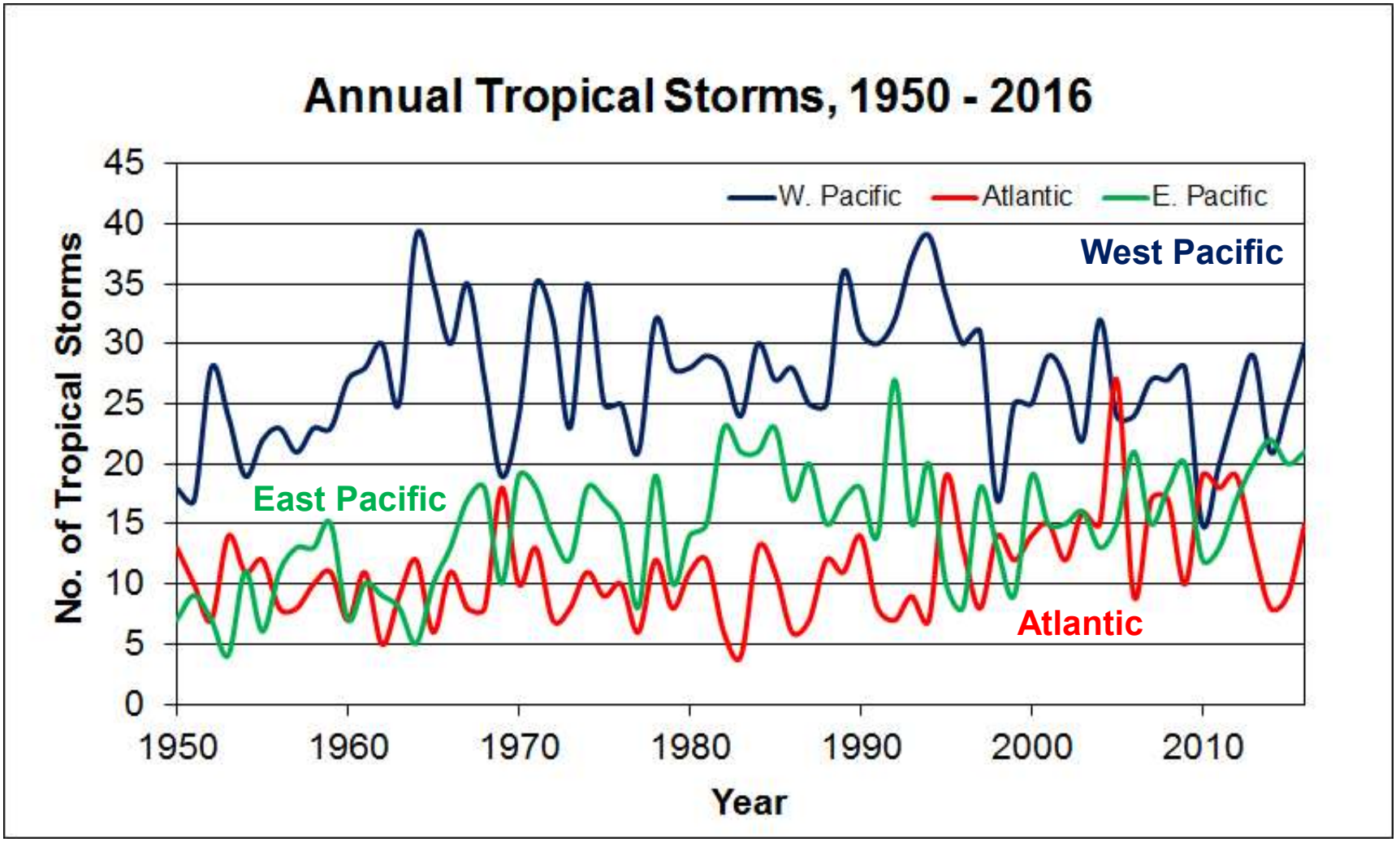
NOAA's GOES-16 satellite image at 2000 UTC, 9/6/2017



Are we having more hurricanes/typhoons?



NOAA's GOES-16 satellite image at 2145 UTC, 9/18/2017



Are we having more hurricanes/typhoons?

Outline

- Self Introduction
- What/Why/How is Typhoon?
- **Impacts of Typhoon**
- Typhoons in 2007-2016
- Future Research

交通部中央氣象局104年9月1日修訂之「大雨」及「豪雨」定義如下：

1. **大雨(heavy rain)：** 指24小時累積雨量達**80毫米**以上，或時雨量達40毫米以上之降雨現象.
2. **豪雨(extremely heavy rain)：** 指24小時累積雨量達**200毫米**以上，或3小時累積雨量達100毫米以上之降雨現象。
3. **大豪雨(torrential rain):** 若24小時累積雨量達**350毫米**以上)。
4. **超大豪雨(extremely torrential rain):** 24小時累積雨量達**500毫米**。

Power of Typhoons:

Storm surge, Heavy rain, Flooding, Strong winds.

Destructions of Typhoons:

Flooded infrastructure, Landslides, Debris flow, Interruptions of transportations and communications, Property damages, Loss of life.

Destructions by Hurricanes

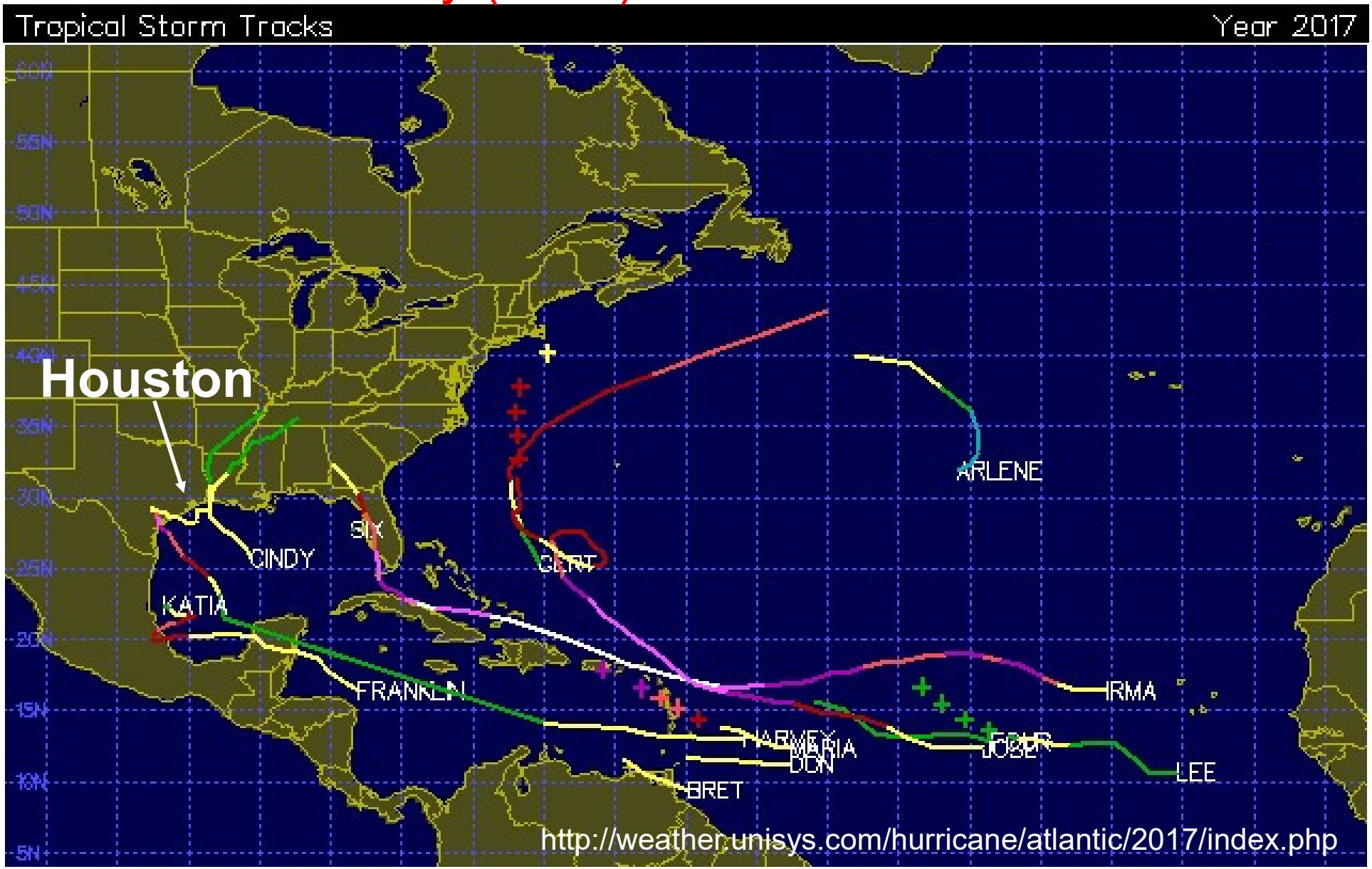
Hurricane Harvey (2017) Flooded Most of SE Texas

Harvey made landfall to Houston on August 25, 2017

Hurricane Harvey:
August 17 – September 1, 2017

http://www.financialexpress.com/world-news/hurricane-harvey-damages-well-below-those-of-katrina-sandy-says-hannover-re/829301/

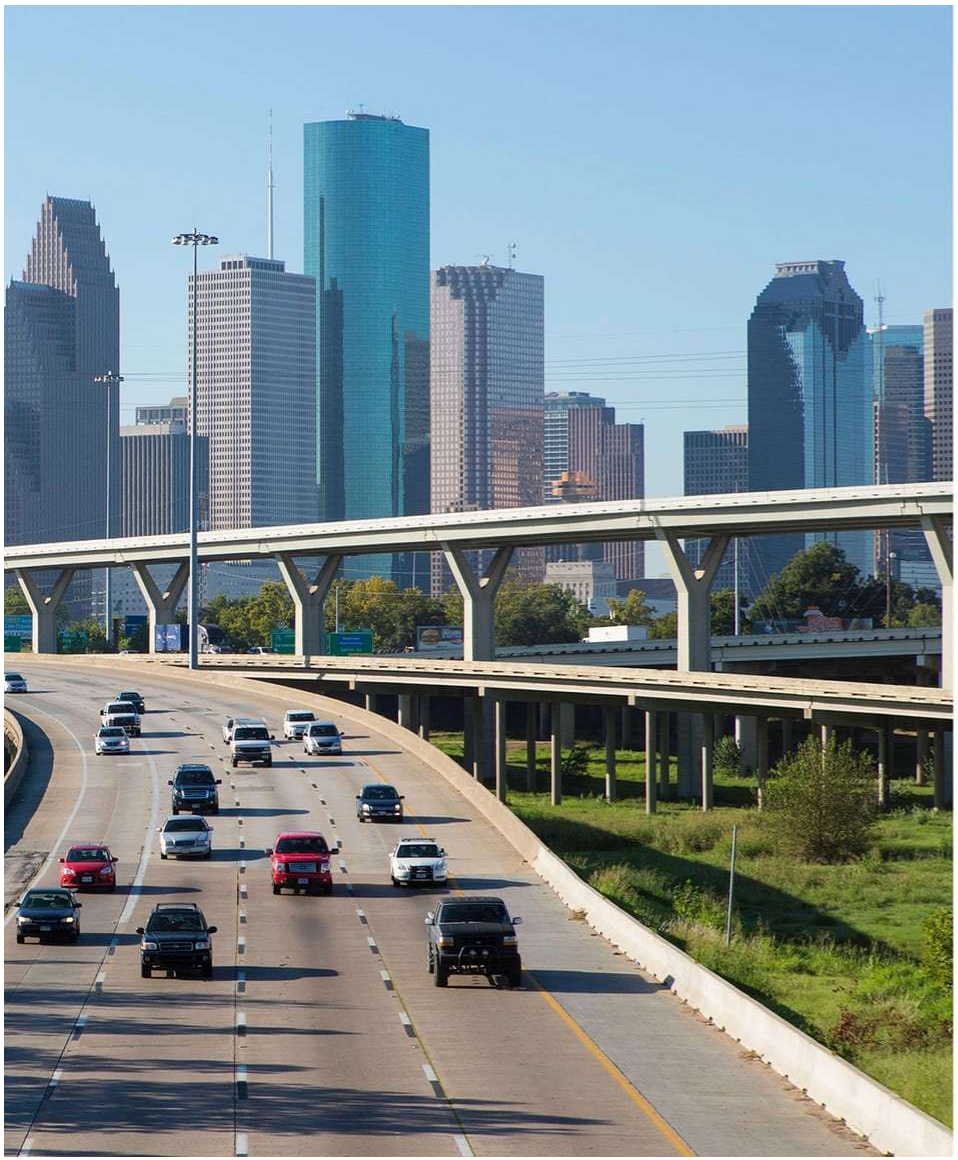
Hurricane Harvey (2017) Flooded Most of SE Texas

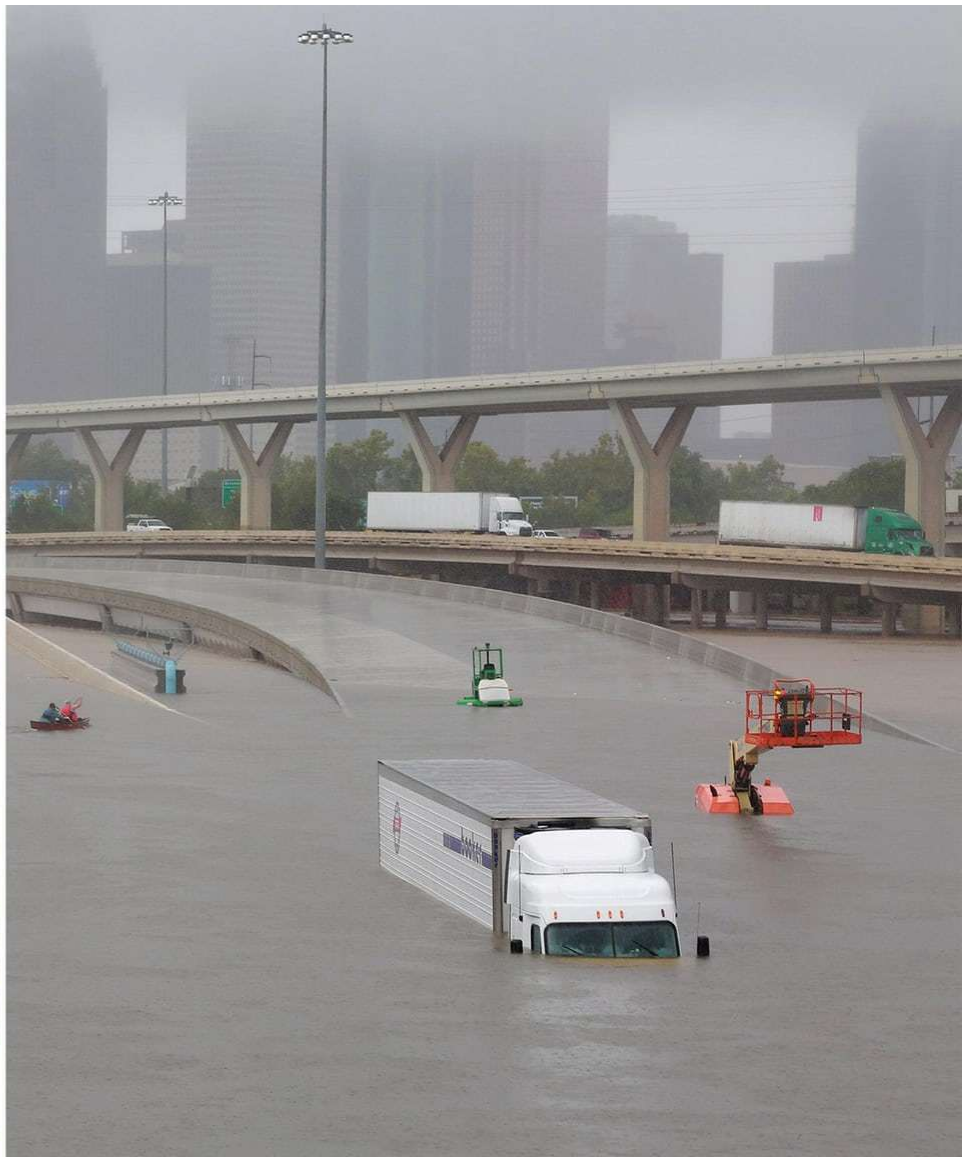


Before and After Hurricane Harvey

http://ksnt.com/2017/08/28/houston-before-after-harvey/

Before and After Hurricane Harvey





http://www.euronews.com/2017/08/29/photos-houston-before-and-after-hurricane-harvey

Impacts of Harvey

- 33 trillion gallons of water
- Up to 51 inches (1,295 mm) of rain
- 50 counties in Texas were flooded
- 82 people died
- **180 billion** USD damages
- 500,000 to 1 million cars were flooded
- 40,000 people need temporary shelters
- Gas price in US has risen
- Chemical price in US will rise
- Transportations are interrupted
- Life will never be the same in Houston, TX

Hurricane Katrina (2005) Flooded 80% of New Orleans

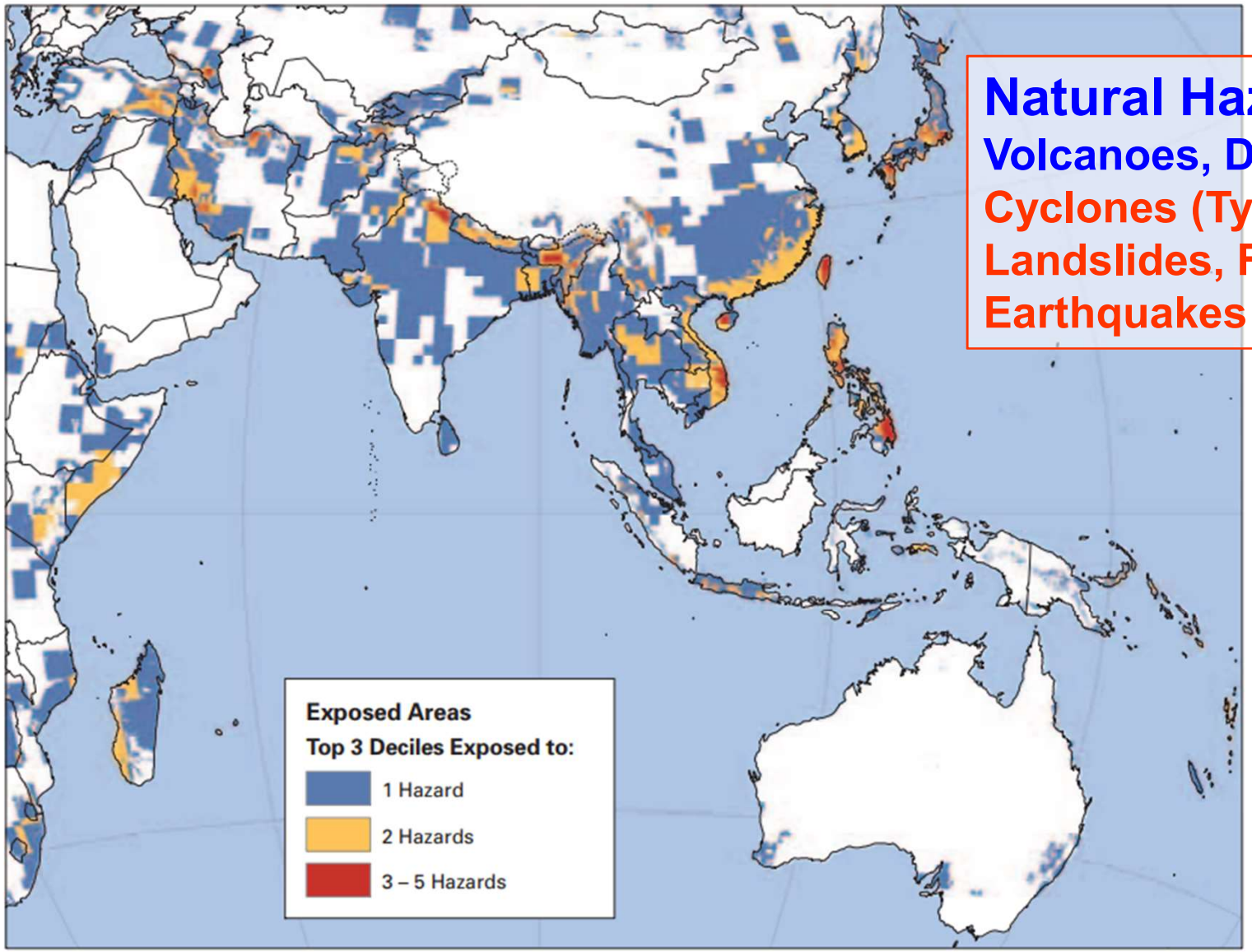
1,833 deaths, 160 billion USD damages

http://www.thegrio.com/slideshow/slideshow-iconic-images-of-hurricane-katrina.php

Outline

- Self Introduction
- What/Why/How is Typhoon?
- Impacts of Typhoon
- **Typhoons in 2007-2016**
- **Future Research**

Figure 5.2. Detailed View of Multihazard Areas
b) Asia/Pacific



Natural Hazards:
Volcanoes, Drought,
Cyclones (Typhoons),
Landslides, Flooding,
Earthquakes

From Natural Disaster Hotspots: A Global Risk Analysis by the World Bank (2005)

http://documents.worldbank.org/curated/en/621711468175150317/pdf/344230PAPER0Na101official0use0only1.pdf

Table 1.1. Countries Most Exposed to Multiple Hazards

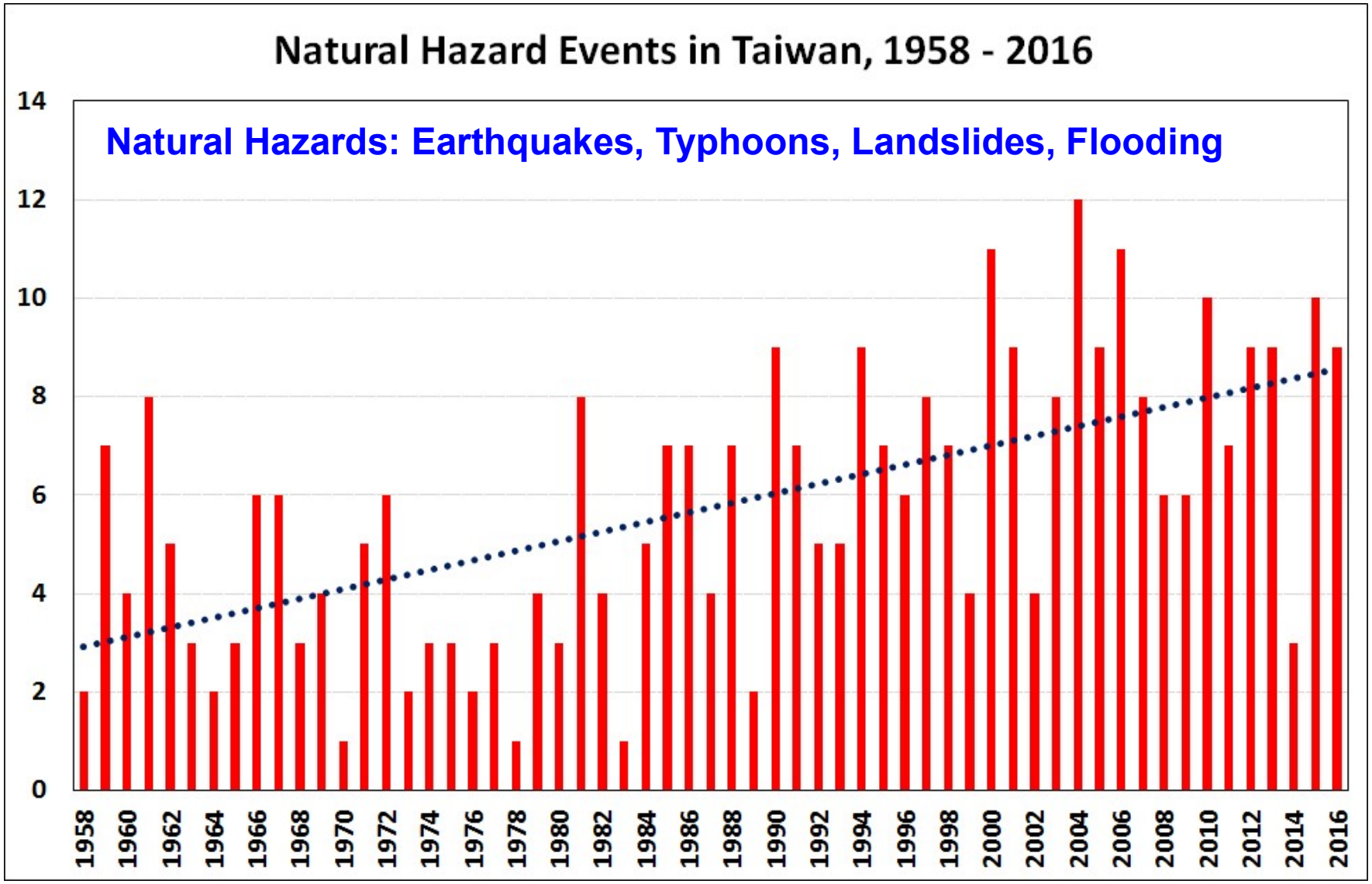
a) Three or more hazards (top 15 based on land area)

Country	Percent of Total Area Exposed	Percent of Population Exposed	Max. Number of Hazards	Country	Percent of Total Area Exposed	Percent of Population Exposed	Max. Number of Hazards
Taiwan, China	73.1	73.1	4	Vietnam	8.2	5.1	3
Costa Rica	36.8	41.1	4	Solomon Islands	7.0	4.9	3
Vanuatu	28.8	20.5	3	Nepal	5.3	2.6	3
Philippines	22.3	36.4	5	El Salvador	5.1	5.2	3
Guatemala	21.3	40.8	5	Tajikistan	5.0	1.0	3
Ecuador	13.9	23.9	5	Panama	4.4	2.9	3
Chile	12.9	54.0	4	Nicaragua	3.0	22.2	3
Japan	10.5	15.3	4				

- Taiwan, ROC is at high risk of multiple natural hazards in terms of exposed areas, exposed population, affected GDP, and mortality rate.
- Typhoons have most impacts of all natural hazards.

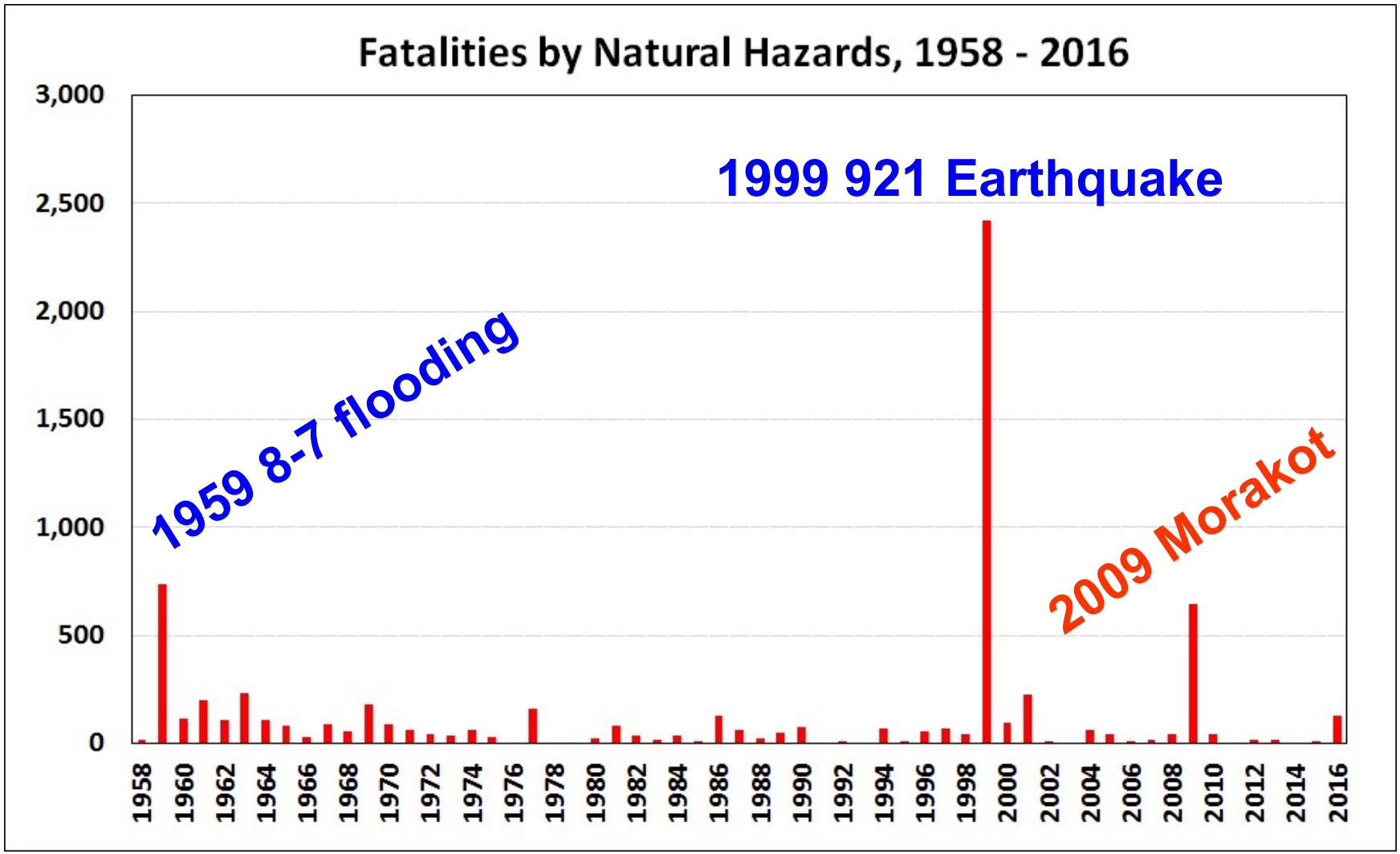
Natural Hazards: Volcanoes, Drought, Cyclones (Typhoons), Landslides, Flooding, Earthquakes

From Natural Disaster Hotspots: A Global Risk Analysis by the World Bank (2005)



http://www.nfa.gov.tw/main/Content.aspx?ID=&MenuID=873

中華民國
內政部消防署 全球資訊網
NATIONAL FIRE AGENCY, MINISTRY OF THE INTERIOR


Fatalities by Natural Hazards, 1958 - 2016
3,000
2,500
2,000
1,500
1,000
500
0
1999 921 Earthquake
1959 8-7 flooding
2009 Morakot
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
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1986
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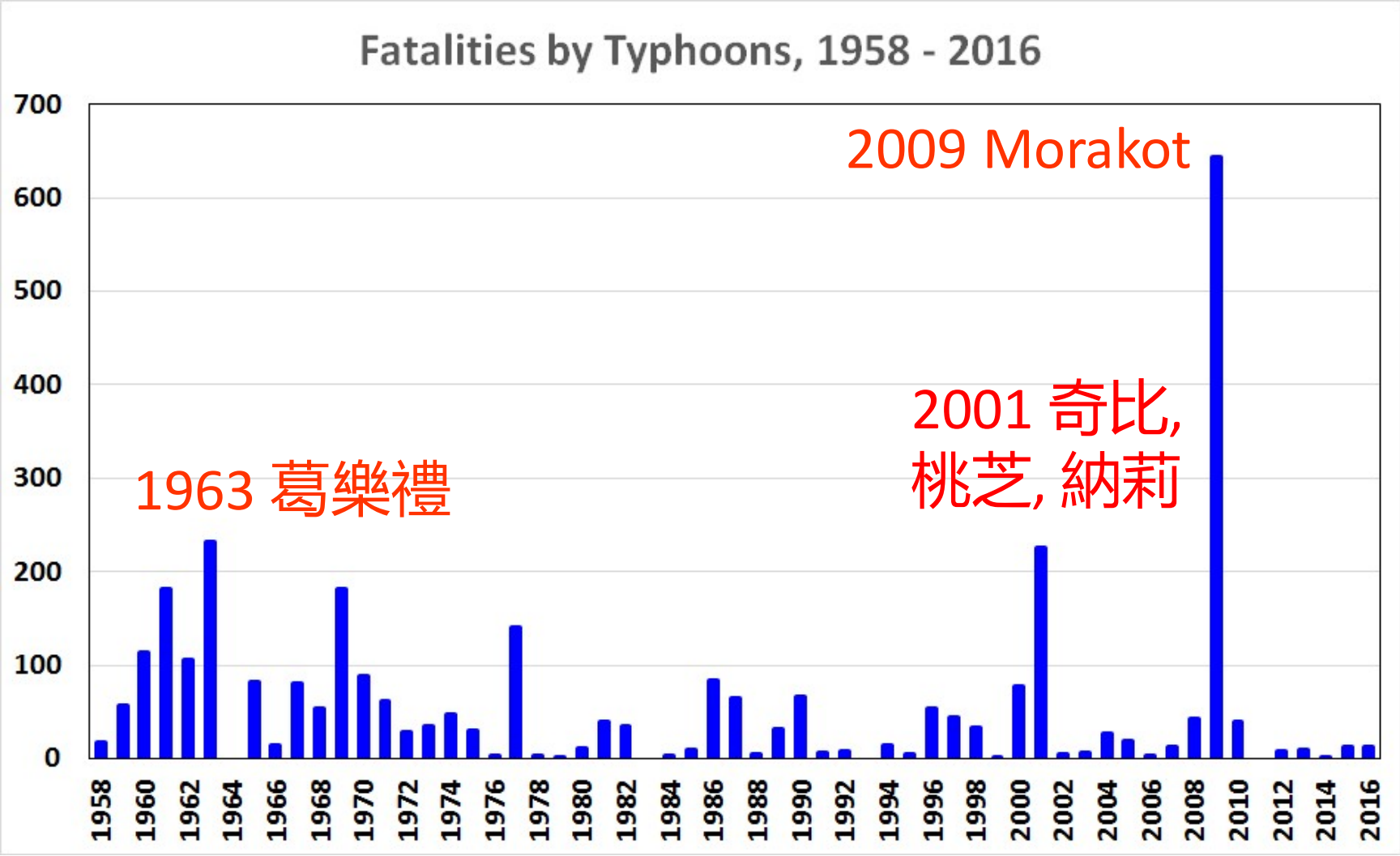
2008
2010
2012
2014
2016



Typhoons caused most deaths than any other natural hazards except 1999 earthquake.

So, how can rainfall by typhoons be predicted from the statistical analysis?

Research Objectives

- To get familiar with the applications of GIS (Geographical Information System);
- To study the rainfall patterns produced by typhoons making landfall in 2007 – 2016; and
- To determine the relationship between the rainfall amounts and the positions of typhoons.

DATA

- Online monthly, daily, and hourly rainfall data at the staffed weather stations of the Central Weather Bureau of Taiwan, ROC from 2007 – 2016.

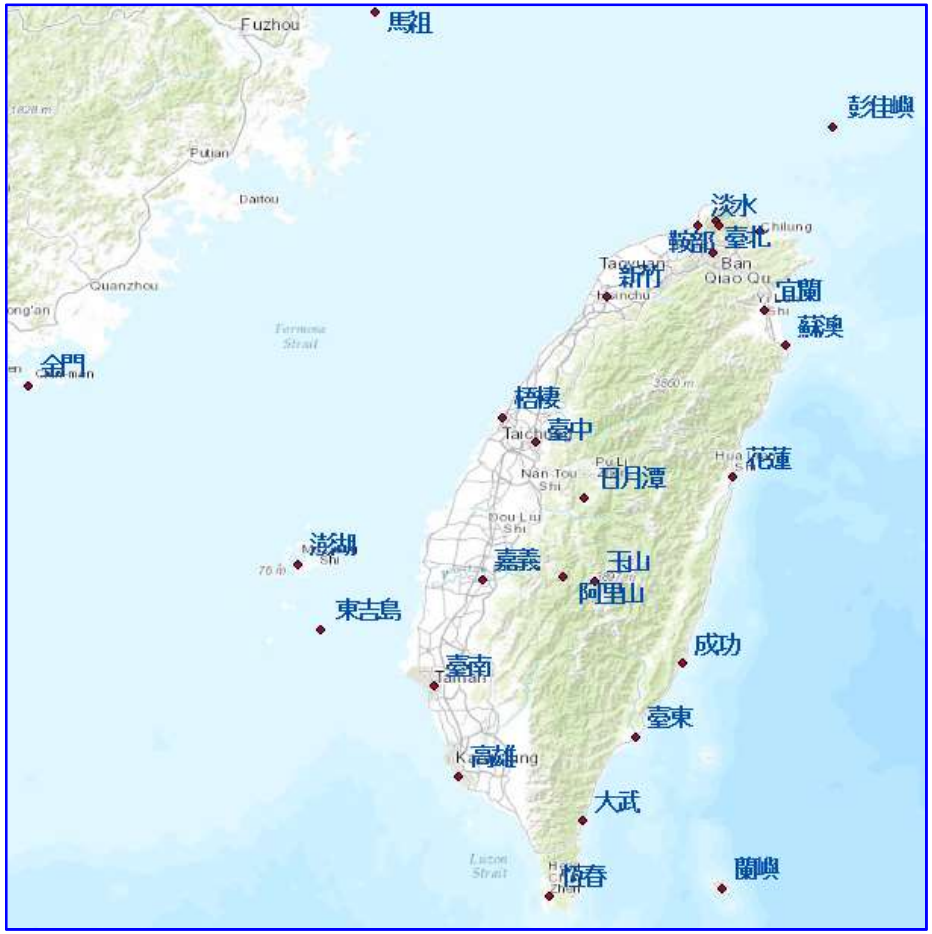
交通部中央氣象局
Central Weather Bureau

- Typhoon data from NOAA and JMA.

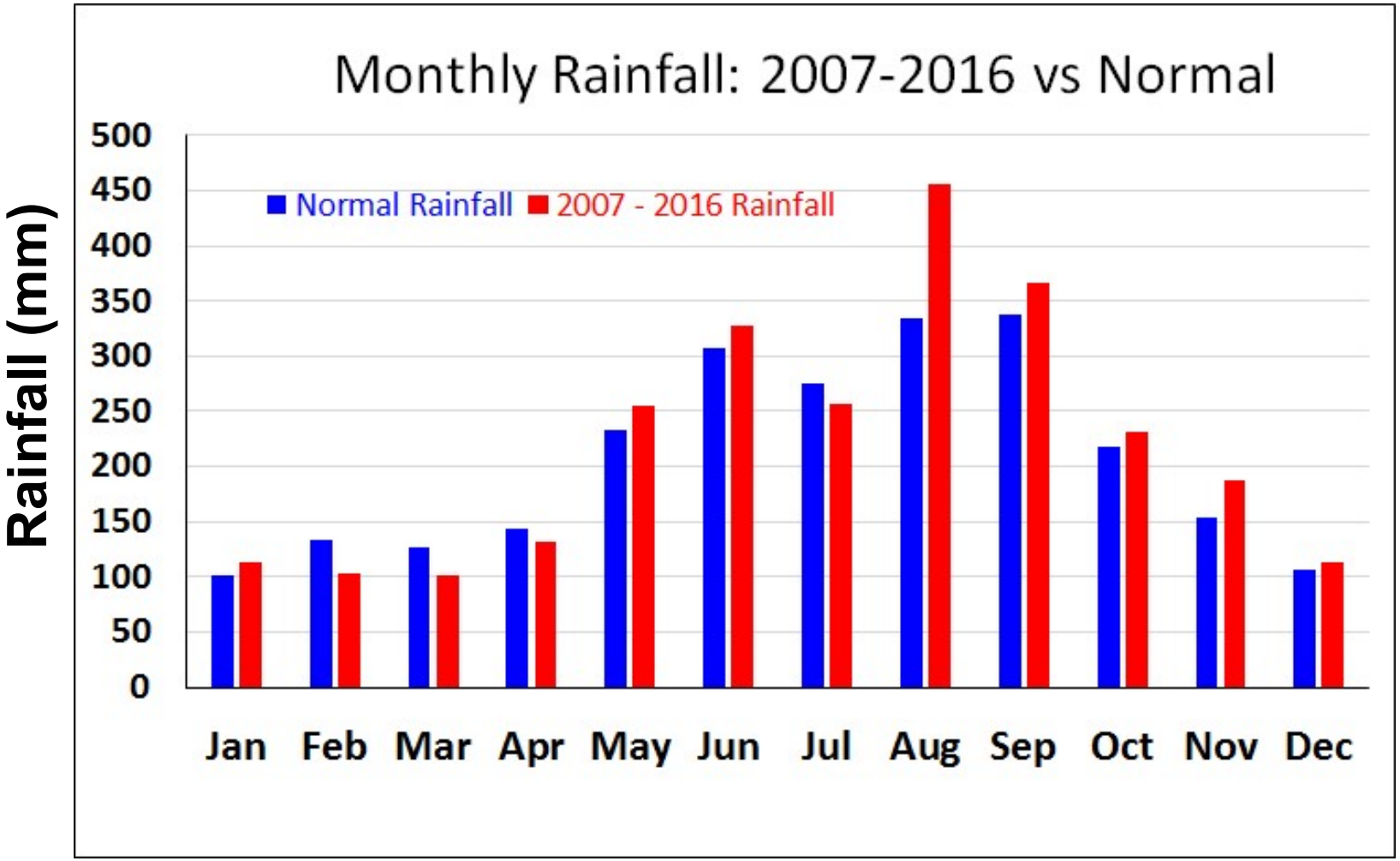
Processing Software

- MS Excel 2016 and ESRI ArcGIS 10.5

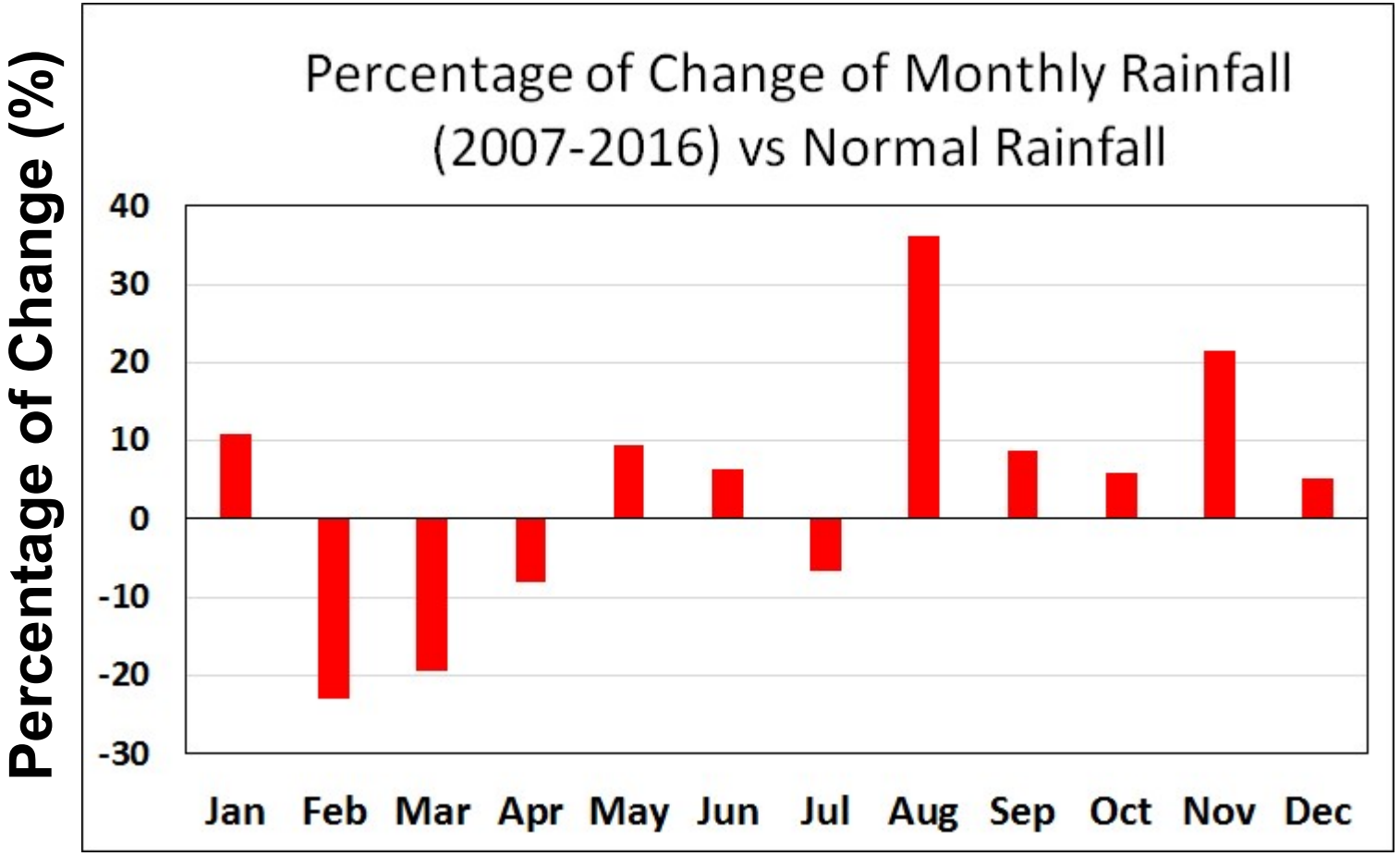
Selected CWB Weather Stations



Rainfall Statistics from 2007 - 2016

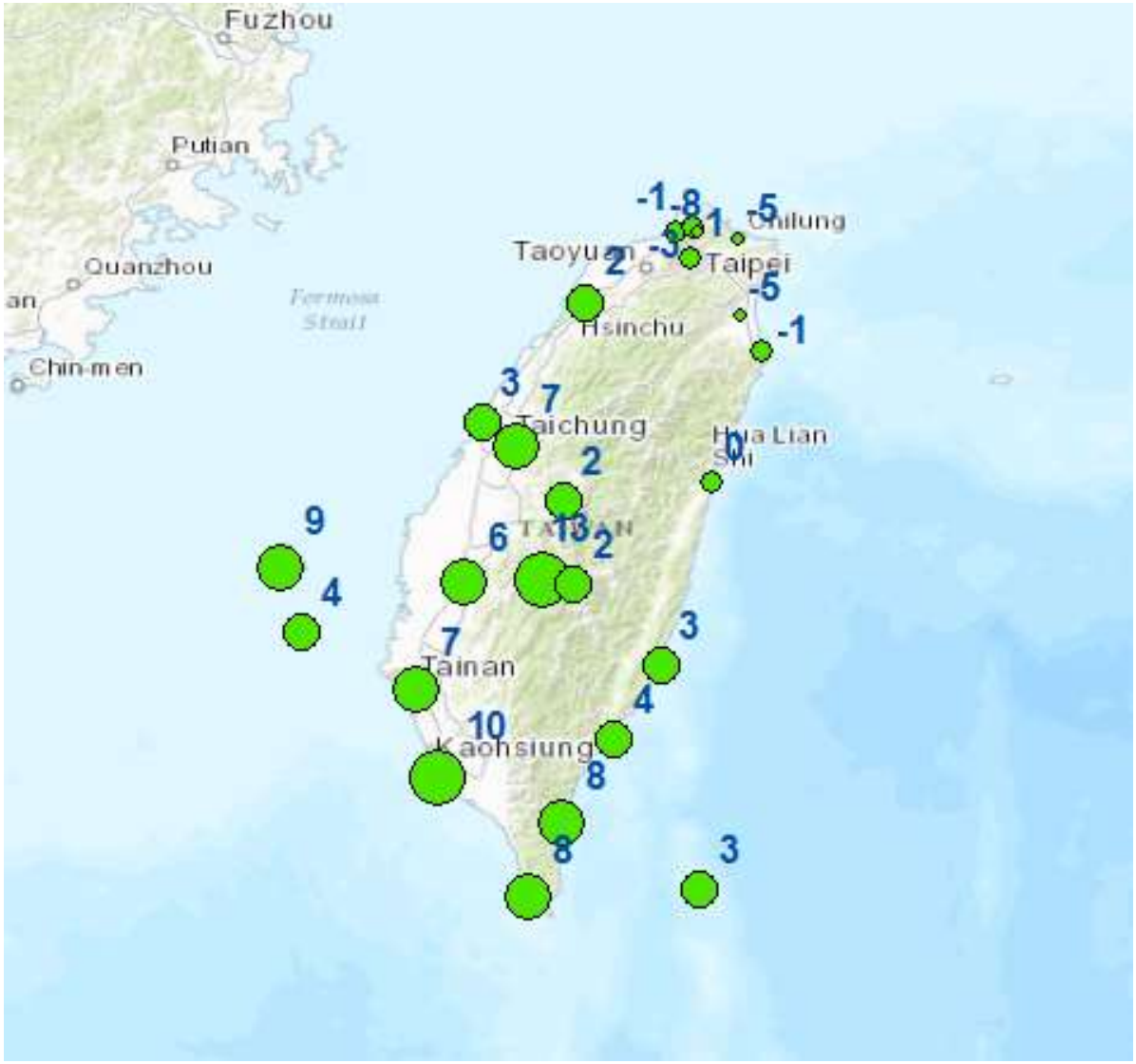


Rainfall Statistics from 2007 - 2016

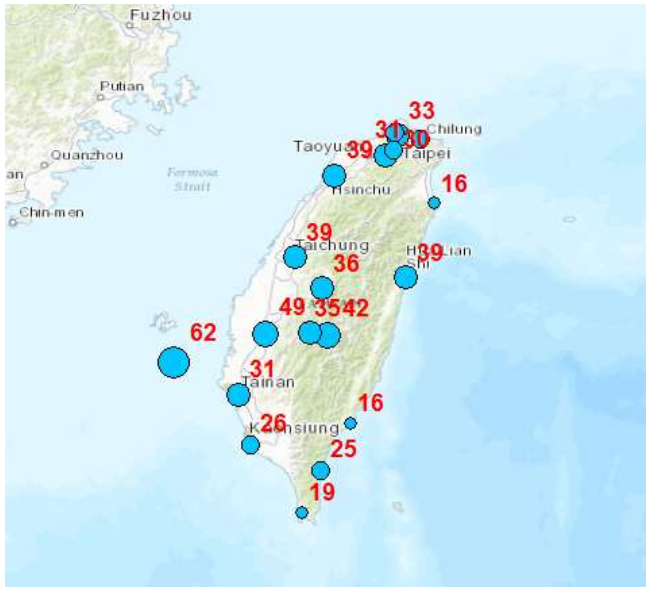


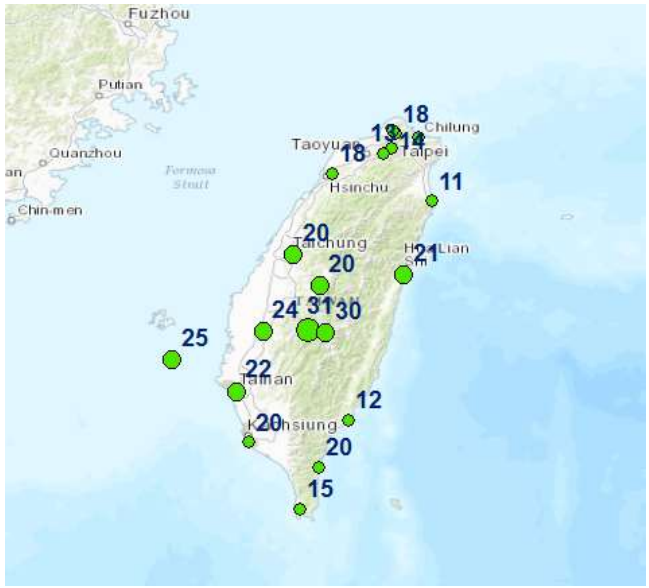
Percentage of Rainfall Change: 2007 – 2016 vs Normal

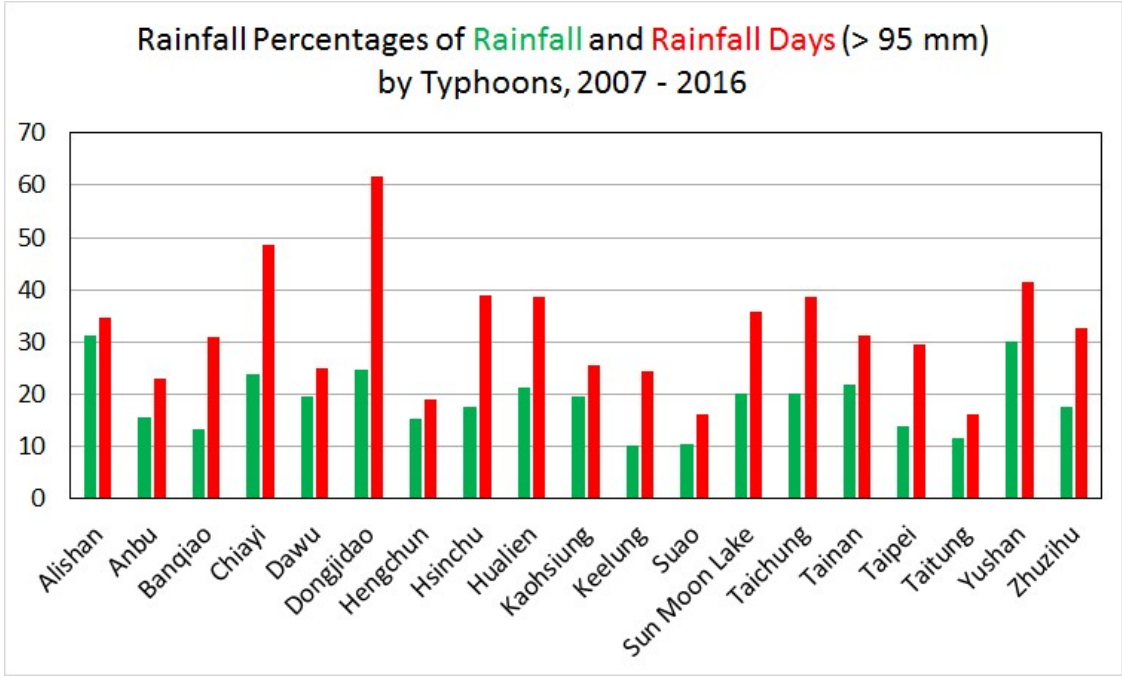
More rain everywhere except NE Taiwan



Percentage (%) of Heavy Rainfall (> 95 mm) Days by Typhoons / Total Heavy Rainfall Days



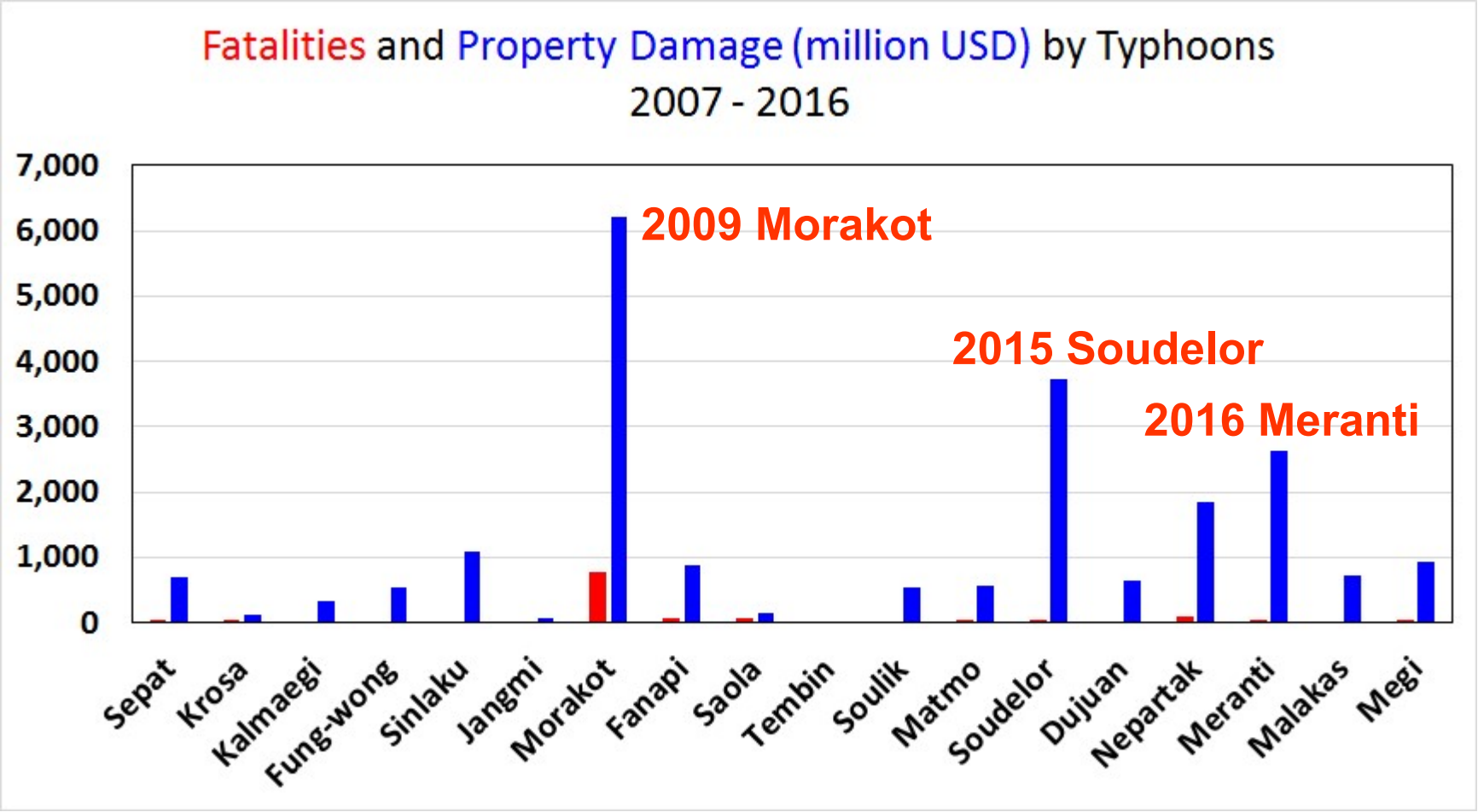




Percentage (%) of Total Rainfall by Typhoons / Total Rainfall

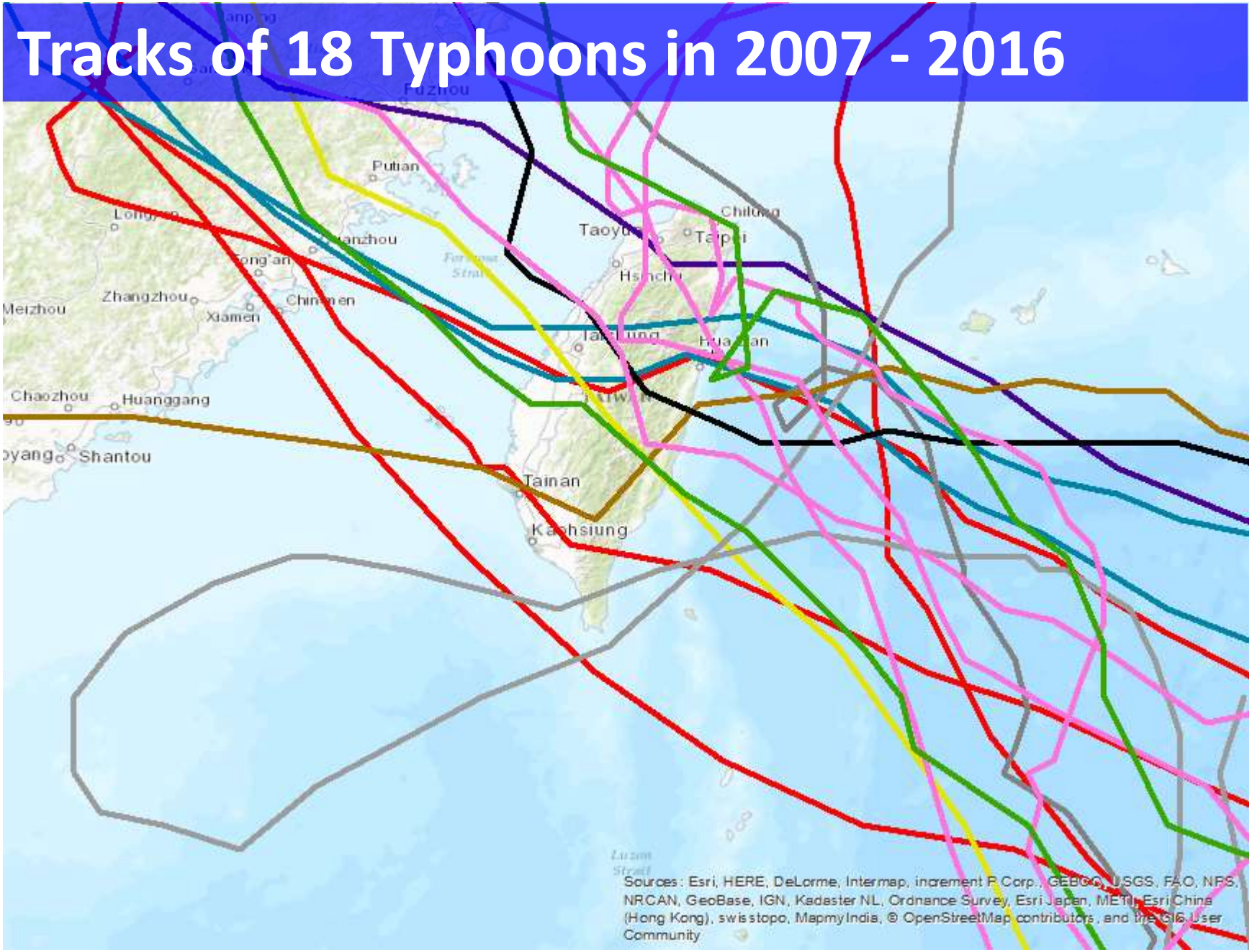
Data are from http://www.cwb.gov.tw/V7e/climate/dailyPrecipitation/dP.htm

18 Landfalling Typhoons during 2007 – 2016 were selected for the study

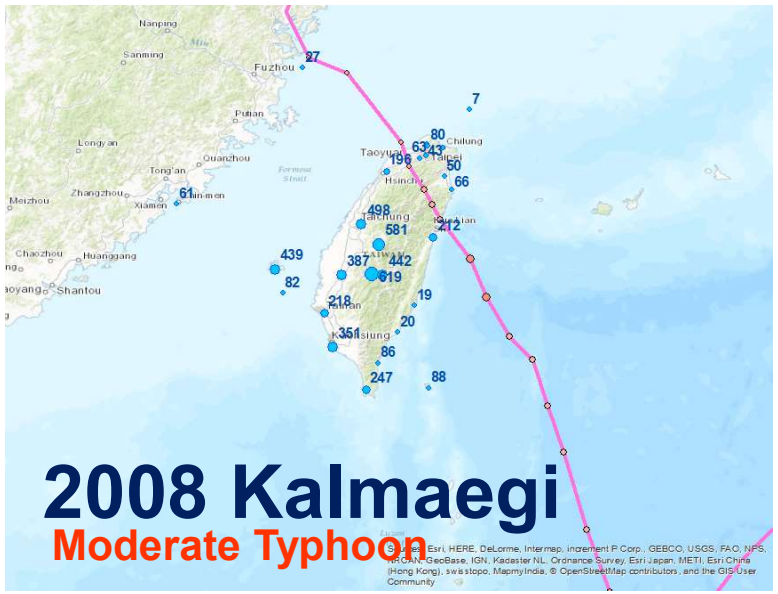


Data are from wikipedia

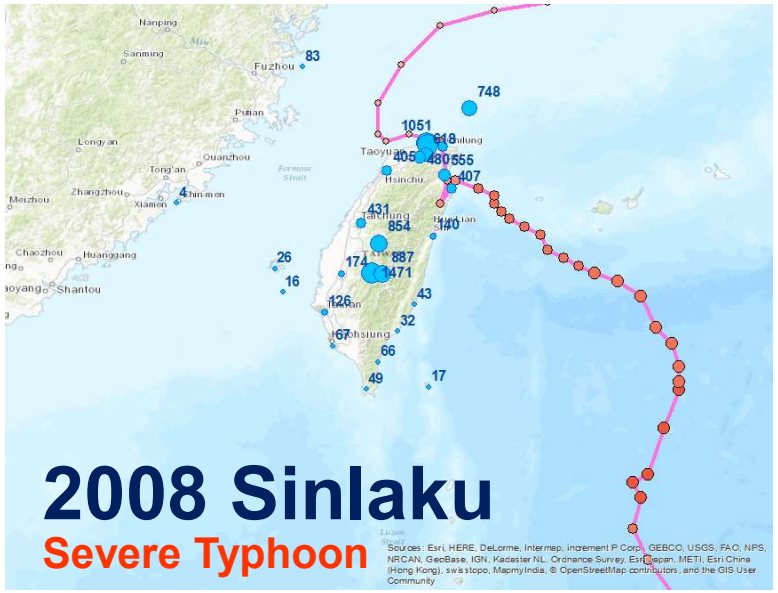
Tracks of 18 Typhoons in 2007 - 2016

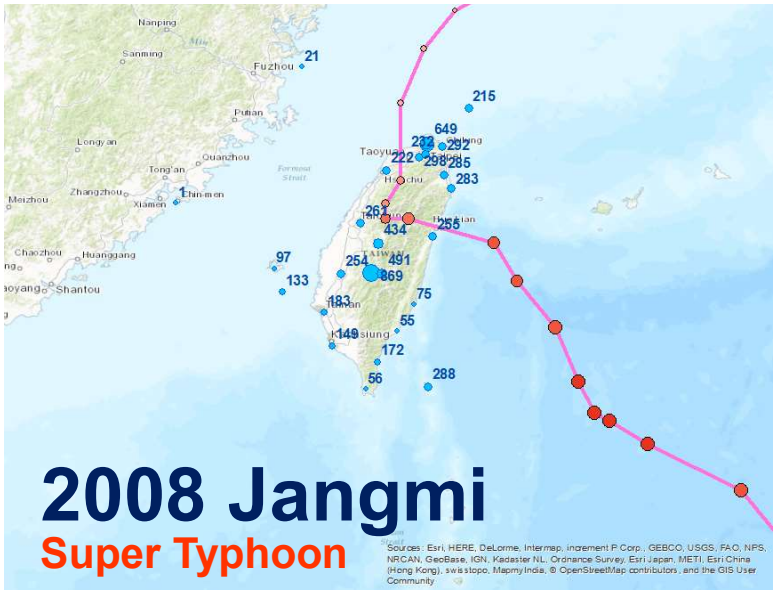


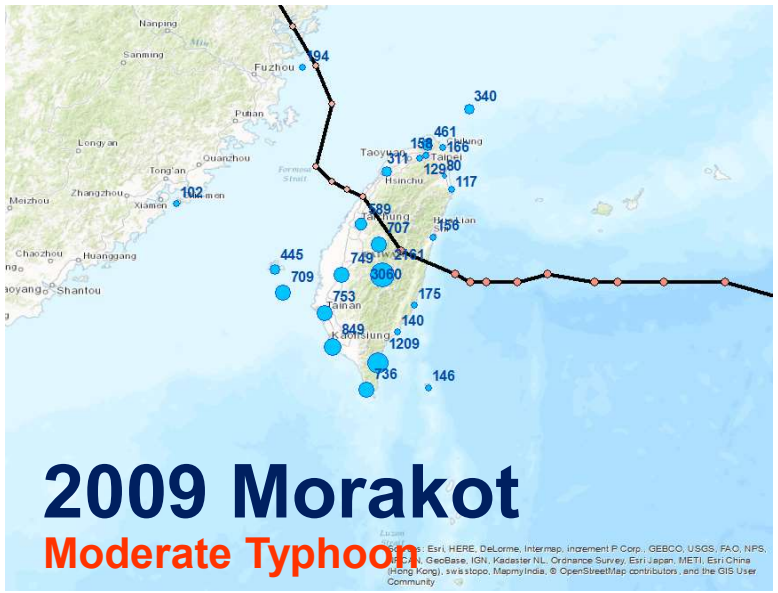
Rainfall Patterns by Typhoons in 2007 - 2016

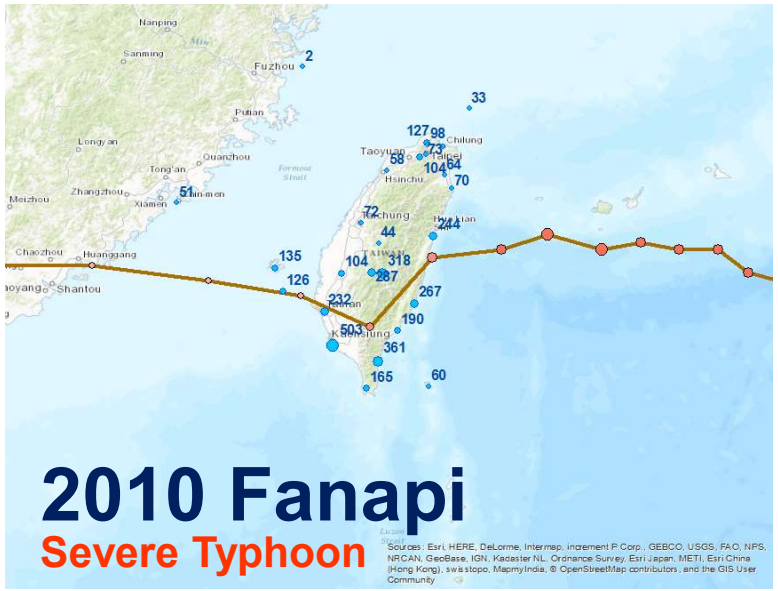


Rainfall Patterns by Typhoons in 2007 - 2016

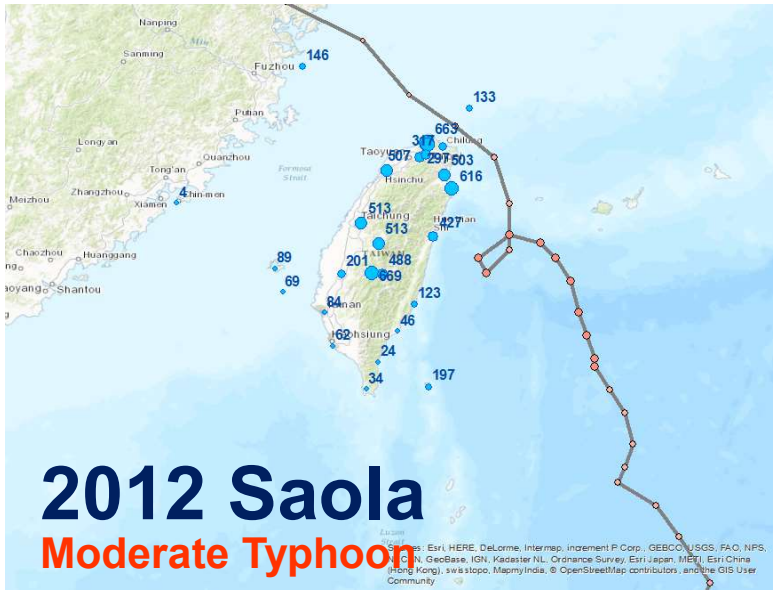


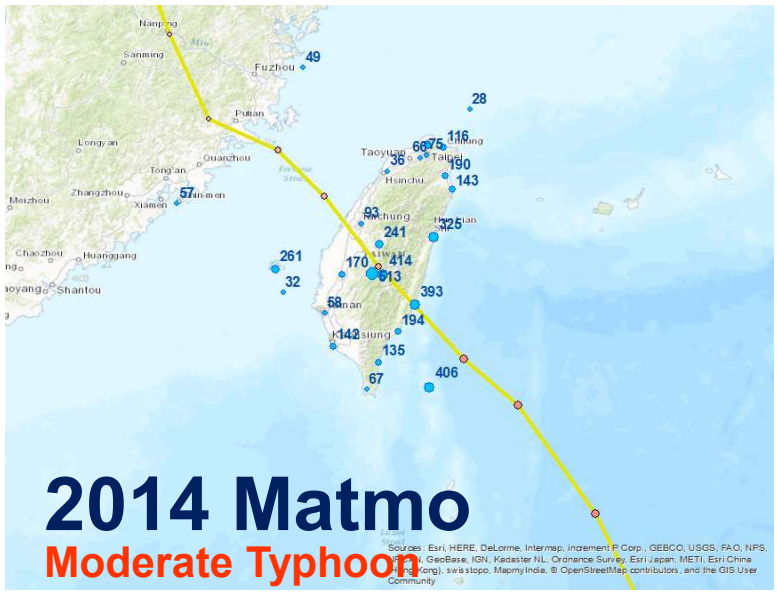




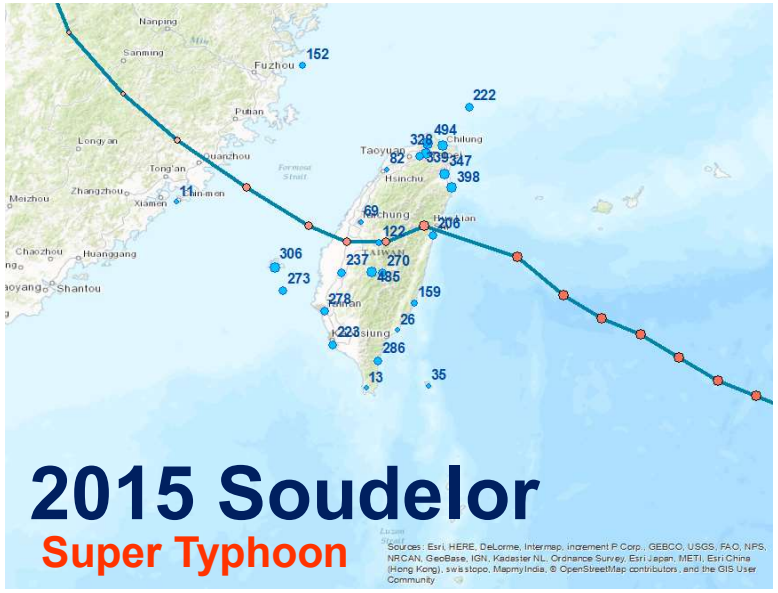


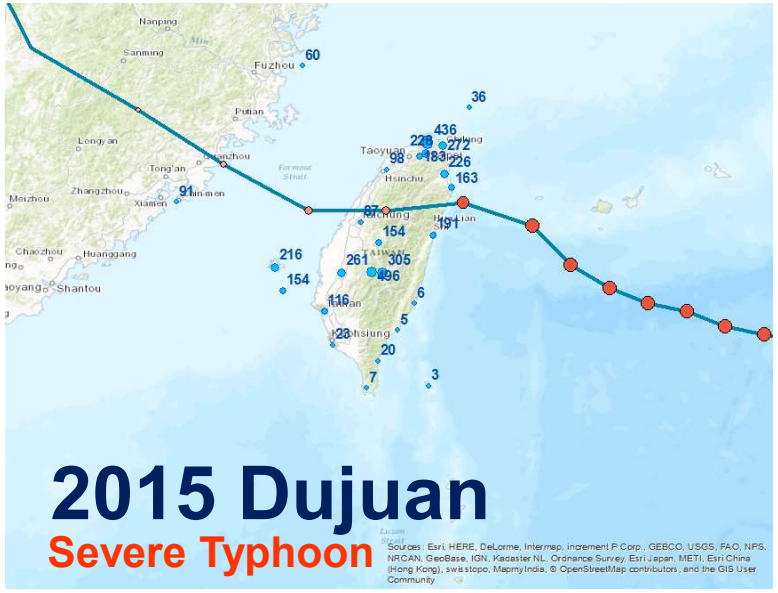
Rainfall Patterns by Typhoons in 2007 - 2016

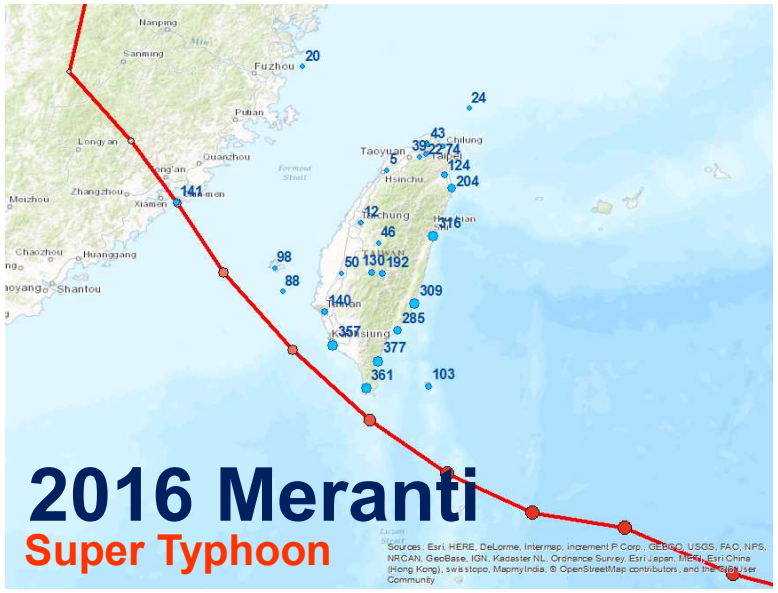




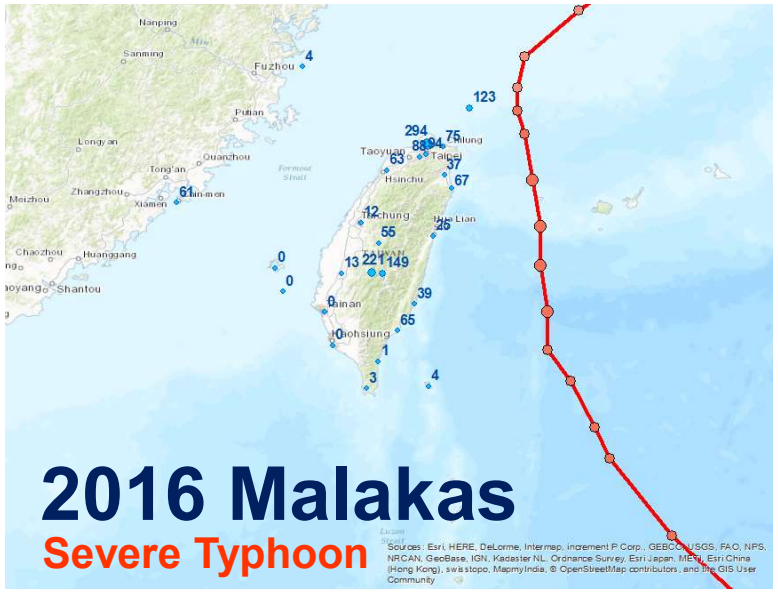
Rainfall Patterns by Typhoons in 2007 - 2016

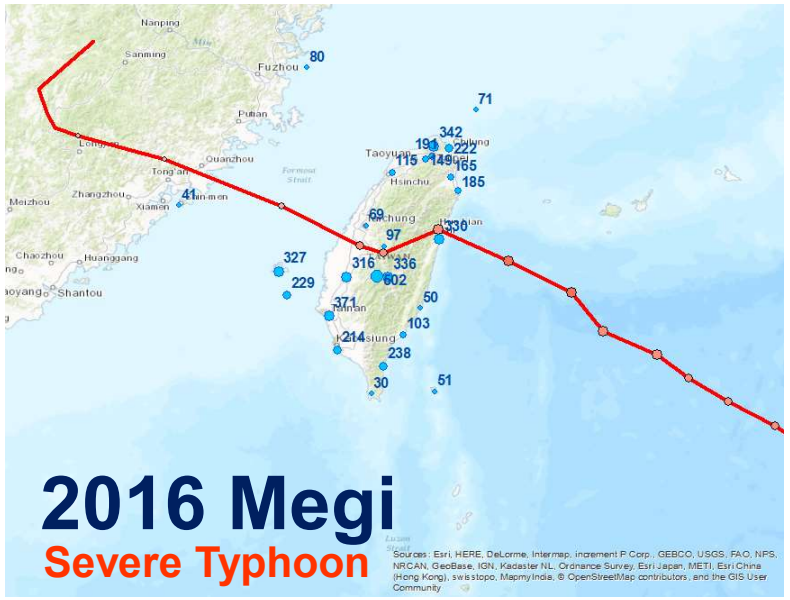






Rainfall Patterns by Typhoons in 2007 - 2016



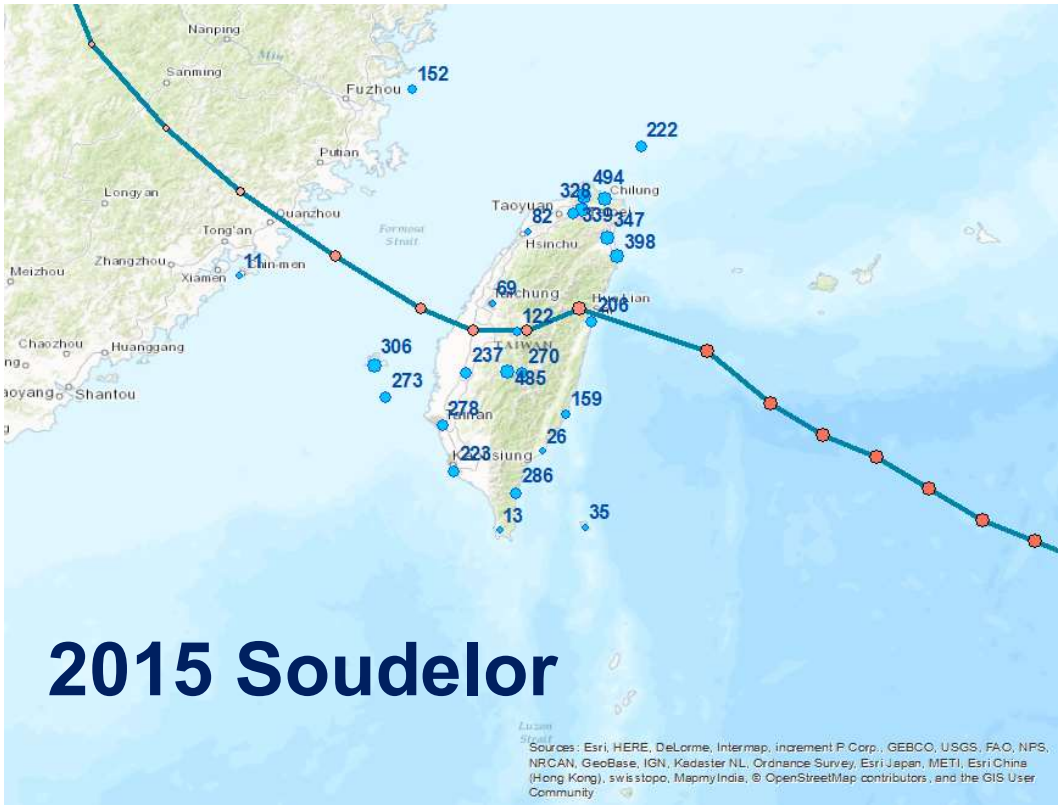


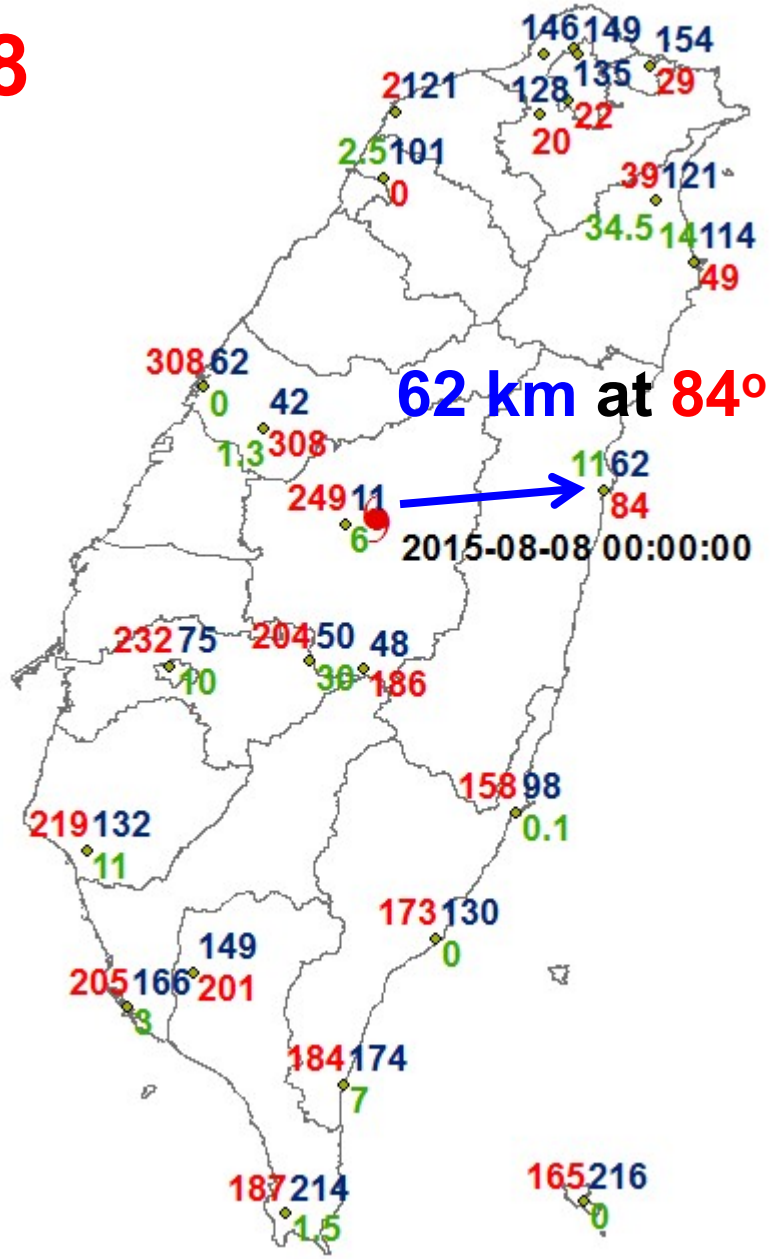
- Slow-moving typhoons cause most destruction and fatalities;
- Due to the counterclockwise circulation of a typhoon, the windward side (the side facing the wind) of mountains receive most precipitation; and
- The Central Mountain Range plays a critical role in producing precipitation.

Hourly Rainfall vs Distance and Direction to Typhoon

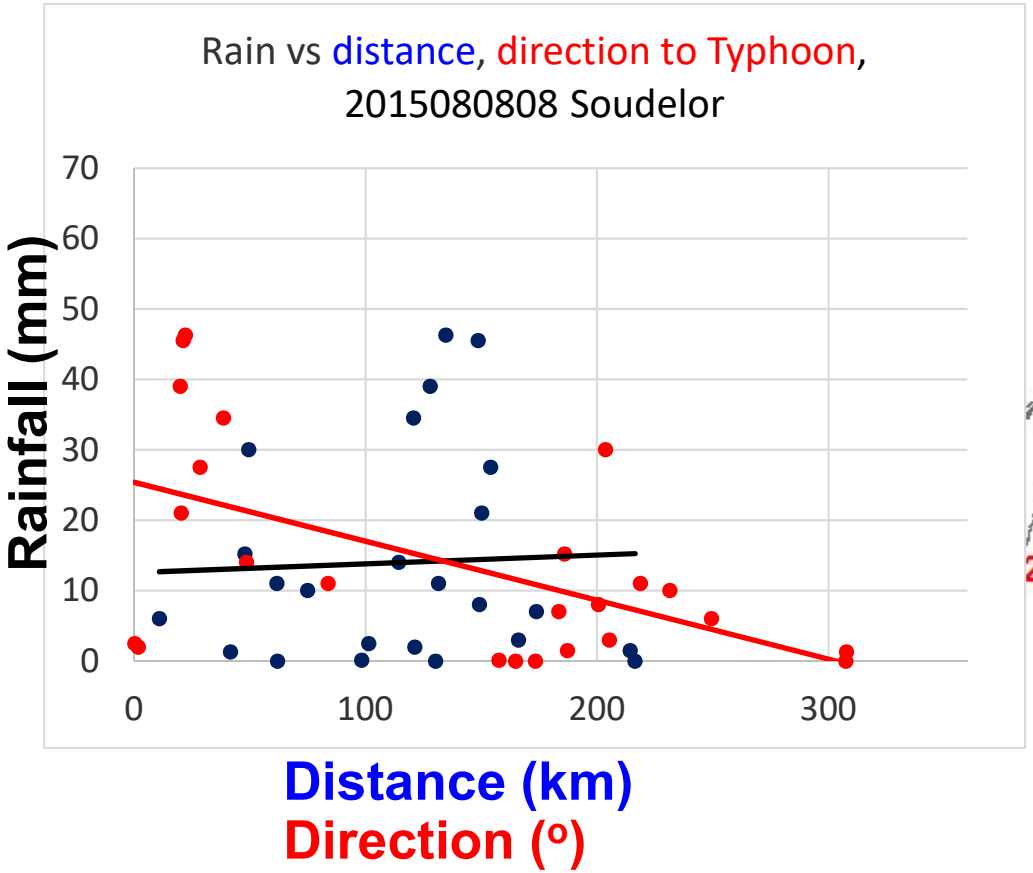
Any statistical significance?

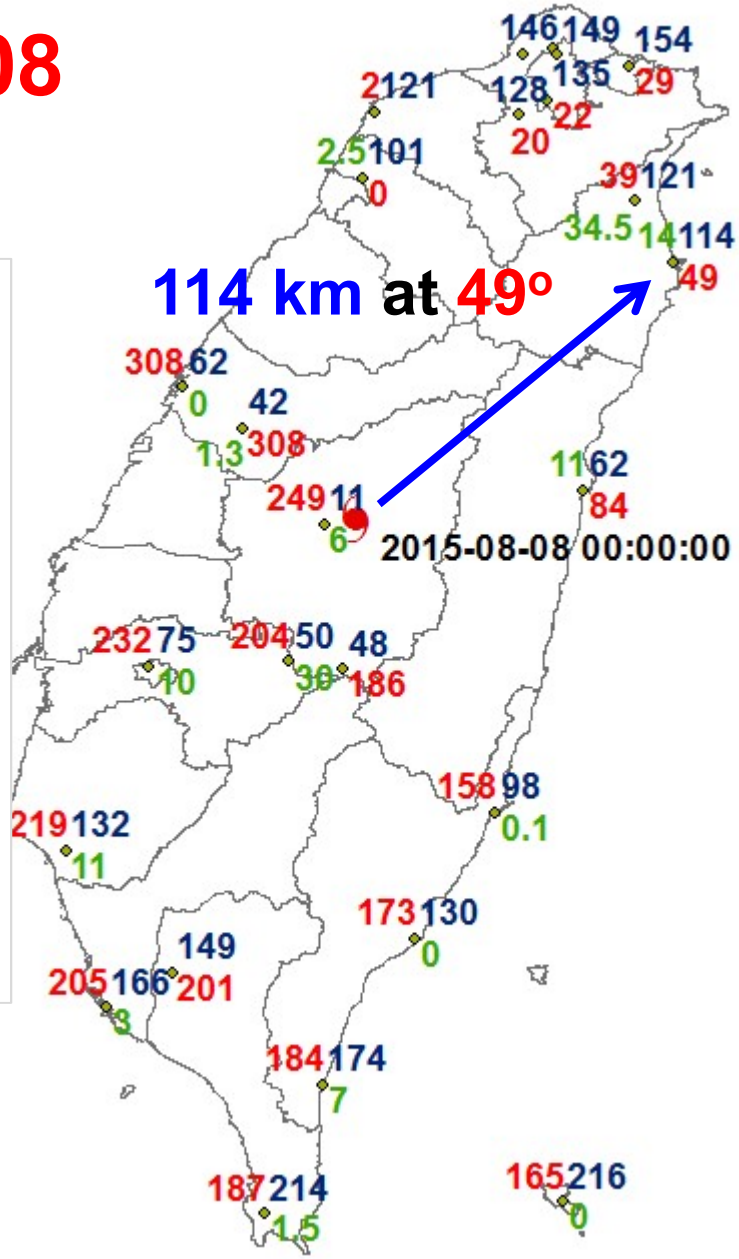
Soudelor @ 2015080808

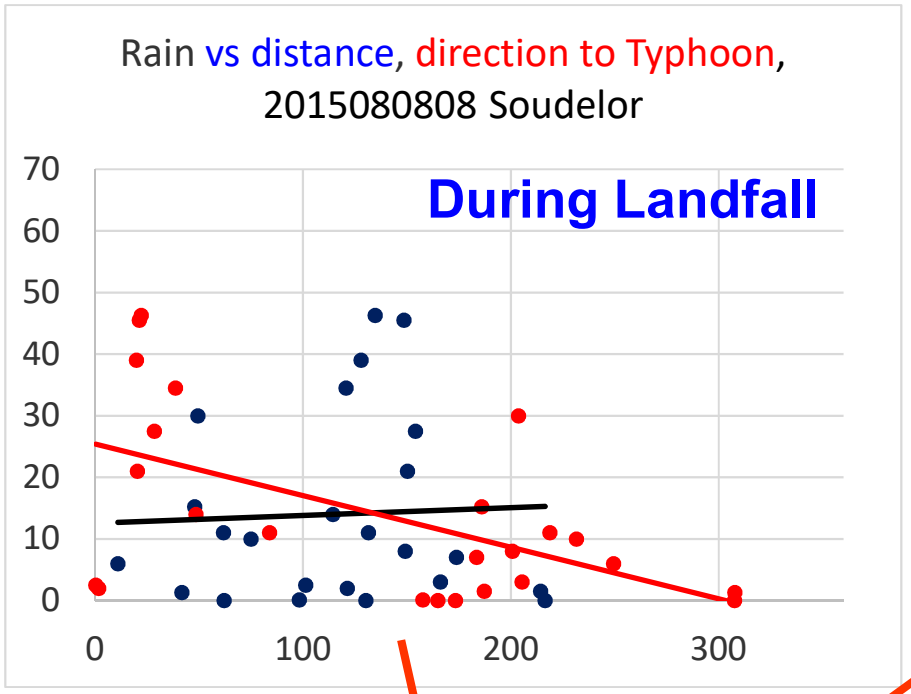


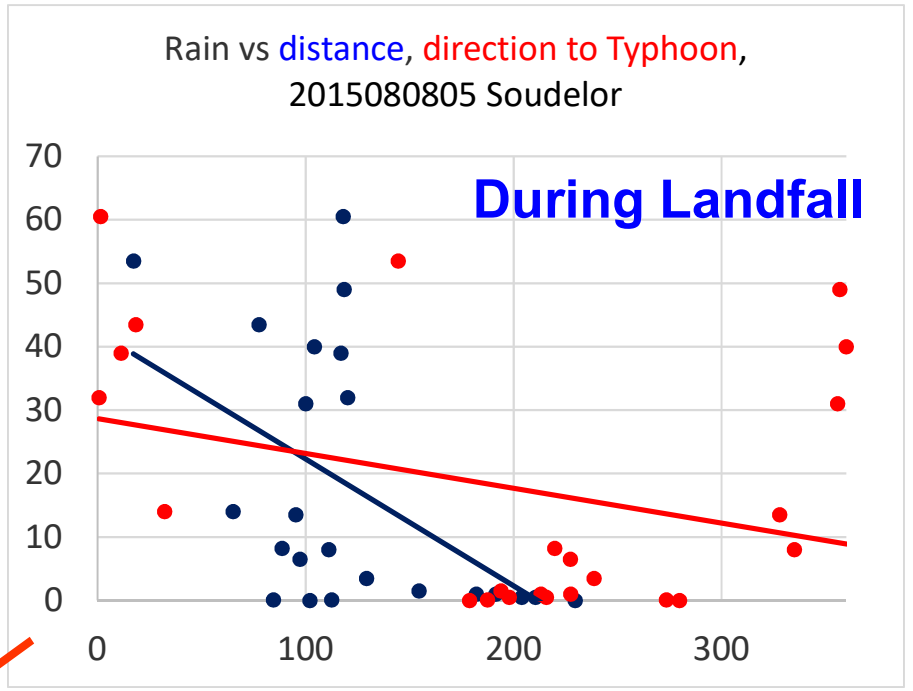


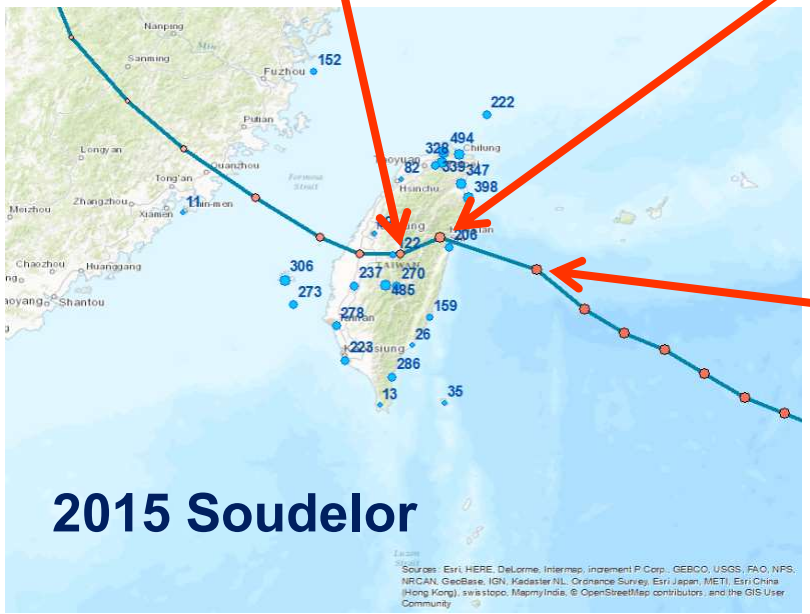
Soudelor @ 2015080808

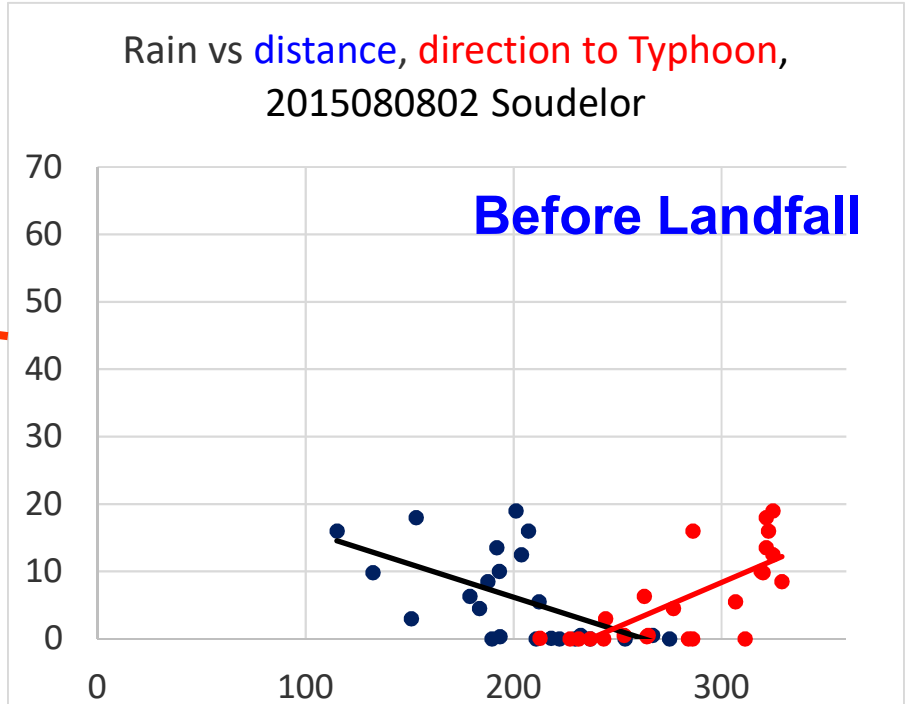





Rain vs distance, direction to Typhoon,
2015080808 Soudelor
During Landfall
70
60
50
40
30
20
10
0
0
100
200
300


Rain vs distance, direction to Typhoon,
2015080805 Soudelor
During Landfall
70
60
50
40
30
20
10
0
0
100
200
300


2015 Soudelor
Nanping
Sanming
Fuzhou
Putian
Longyan
Quanzhou
Tong'an
Zhangzhou
Meizhou
Xiamen
Chaozhou
Huanggang
Shantou
Huanchu
Chilung
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community


Rain vs distance, direction to Typhoon,
2015080802 Soudelor
Before Landfall
70
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50
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30
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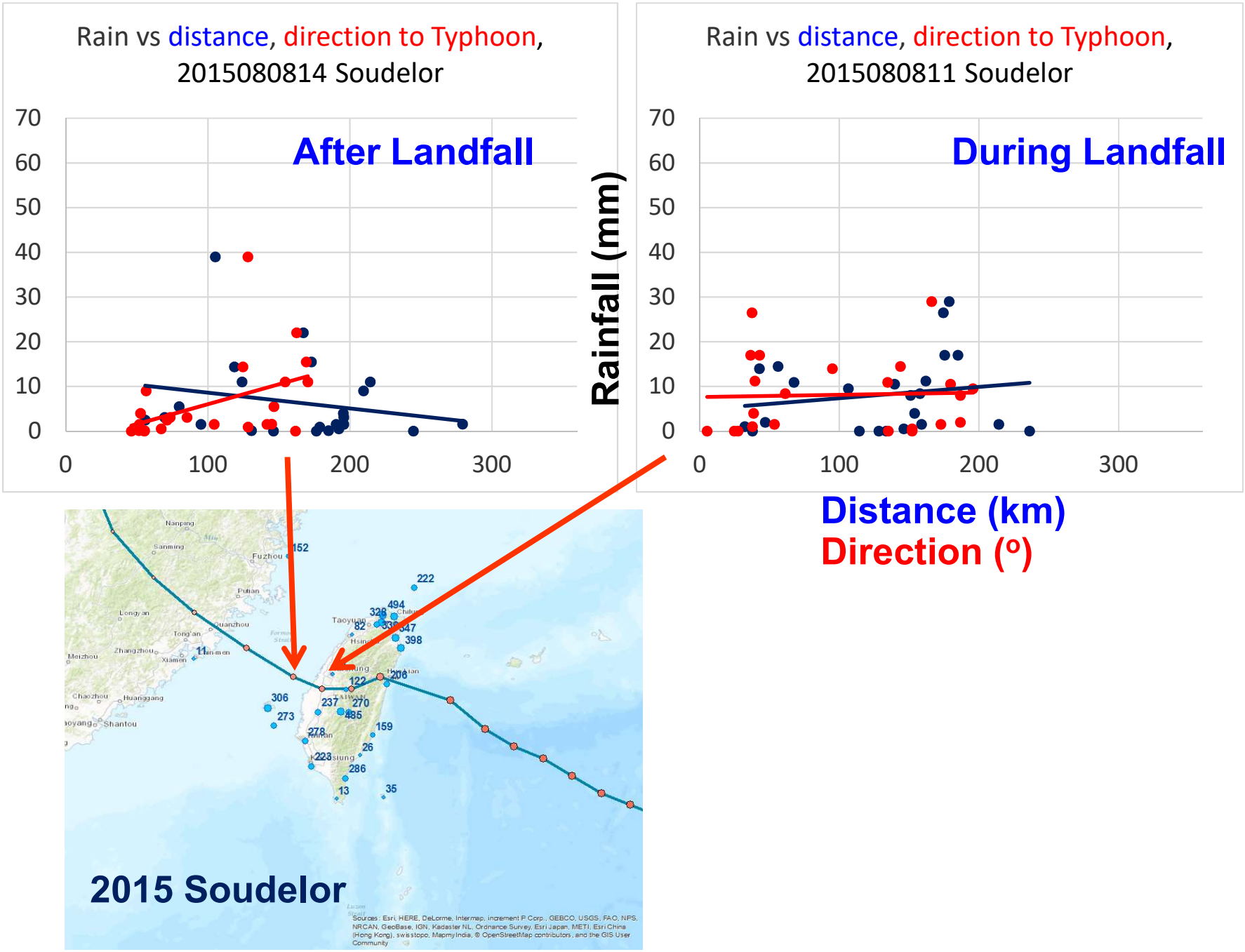
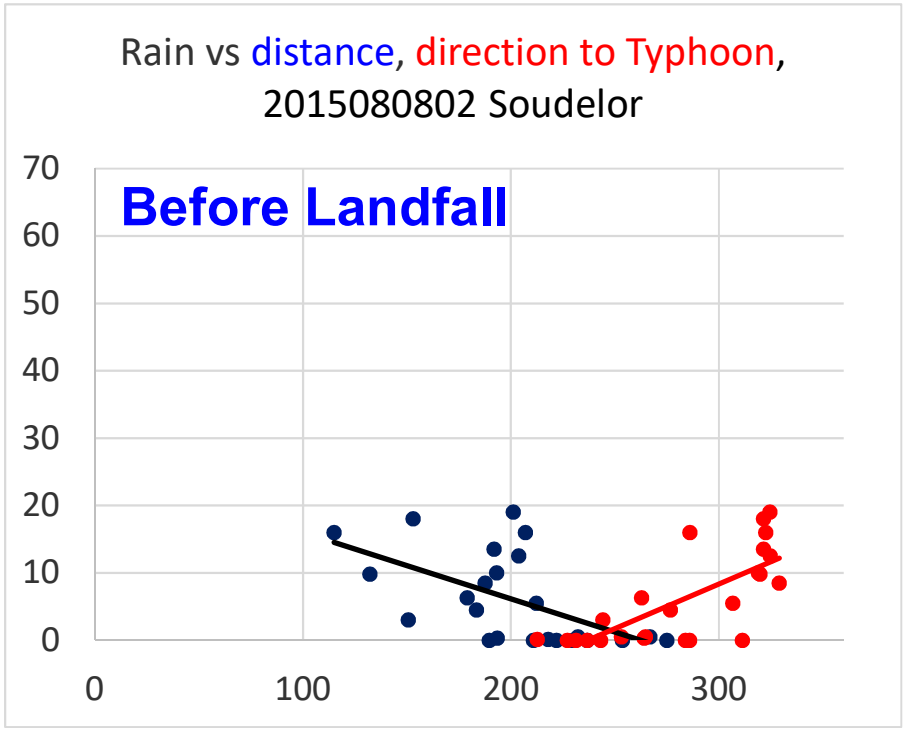
0
100
200
300


Rain vs distance, direction to Typhoon,
2015080814 Soudelor
After Landfall
Rain vs distance, direction to Typhoon,
2015080811 Soudelor
During Landfall
Rainfall (mm)
Distance (km)
Direction (º)
2015 Soudelor


Rain vs distance, direction to Typhoon,
2015080802 Soudelor
Before Landfall
70
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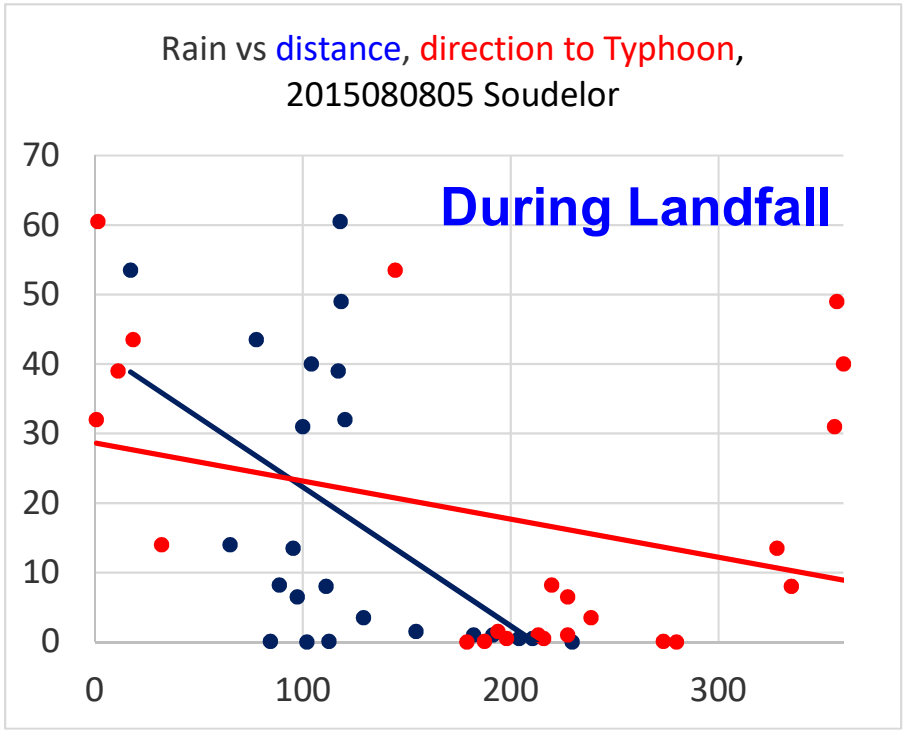
Rain vs distance, direction to Typhoon,
2015080805 Soudelor
During Landfall
70
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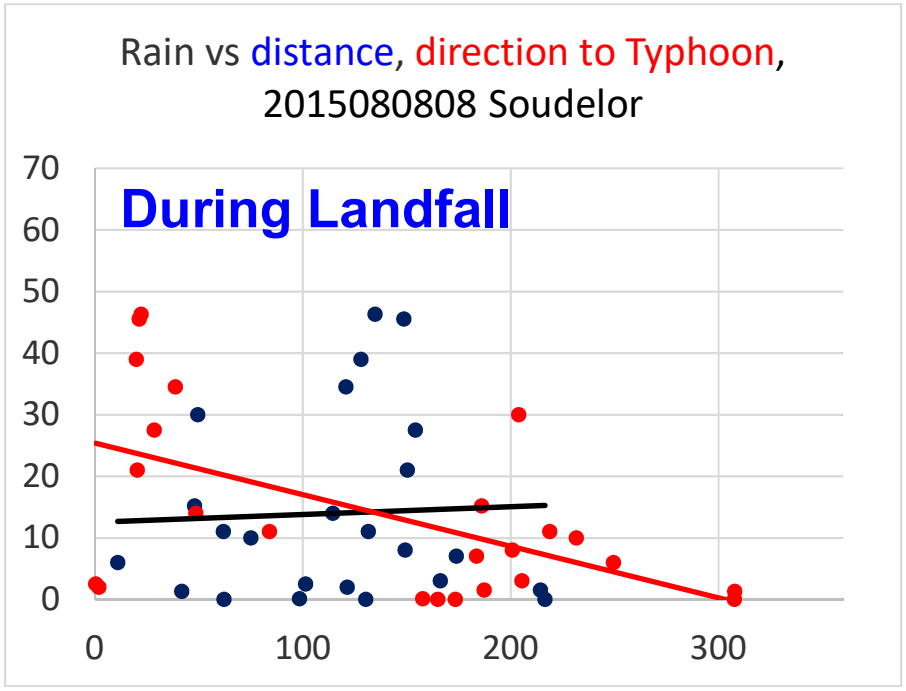
Rain vs distance, direction to Typhoon,
2015080808 Soudelor
During Landfall
70
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100
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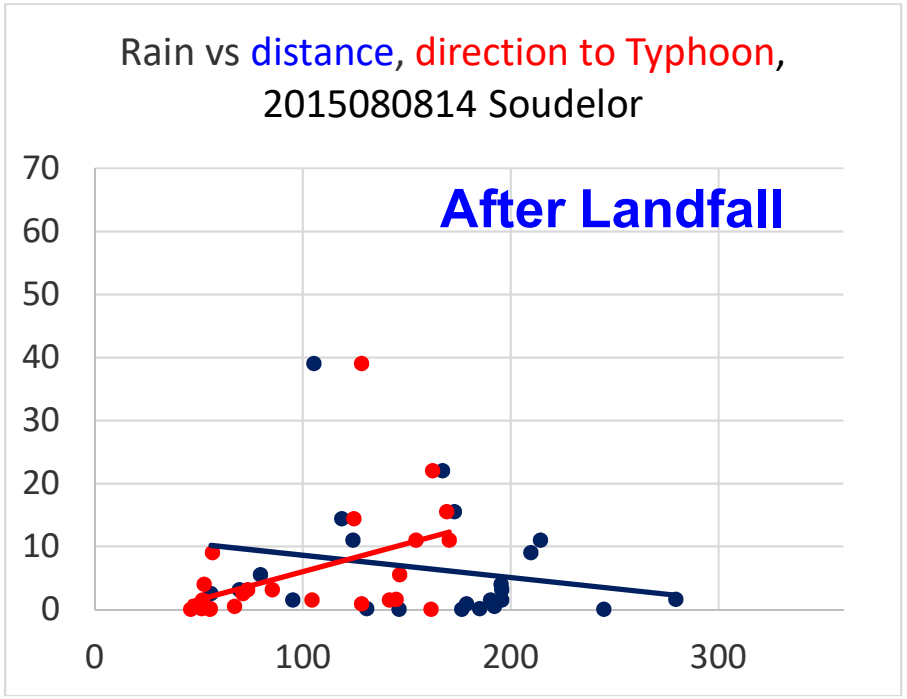
Rain vs distance, direction to Typhoon,
2015080814 Soudelor
After Landfall
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60
50
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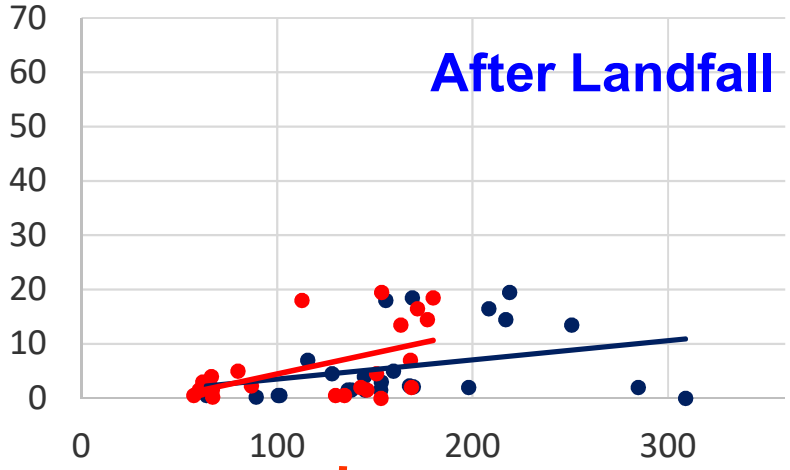
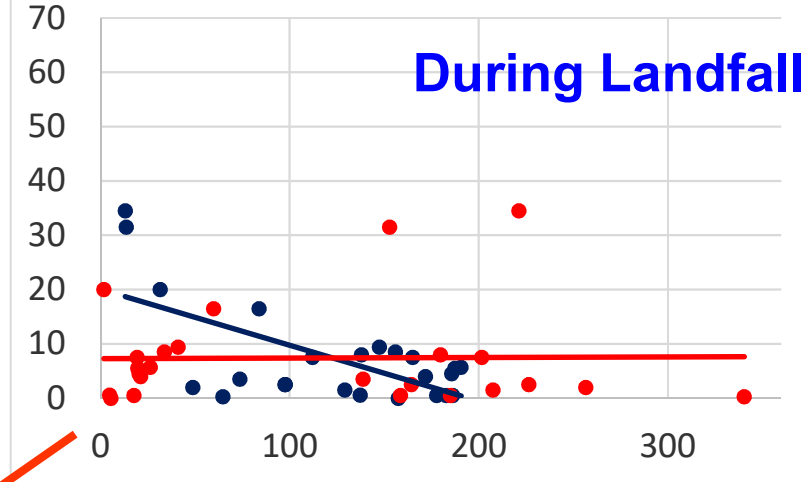
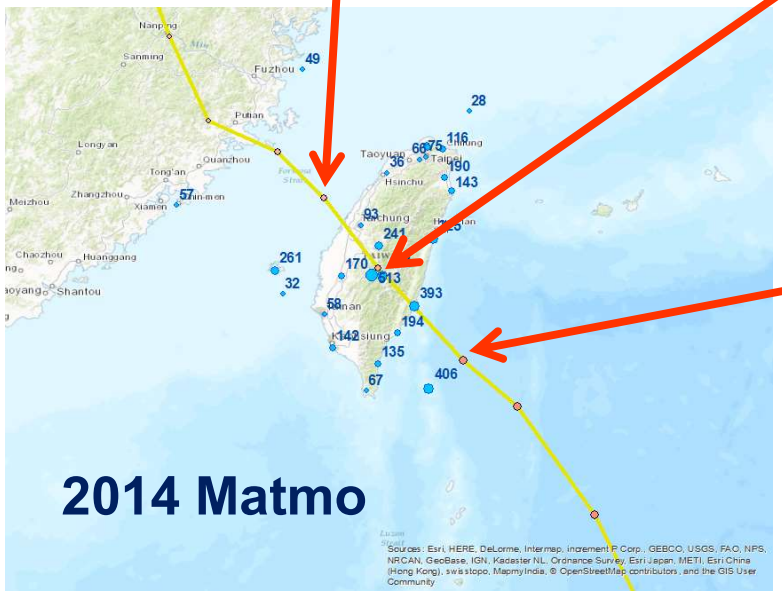
100
200
300

Rain vs distance, direction to Typhoon, 2014072308 Matmo

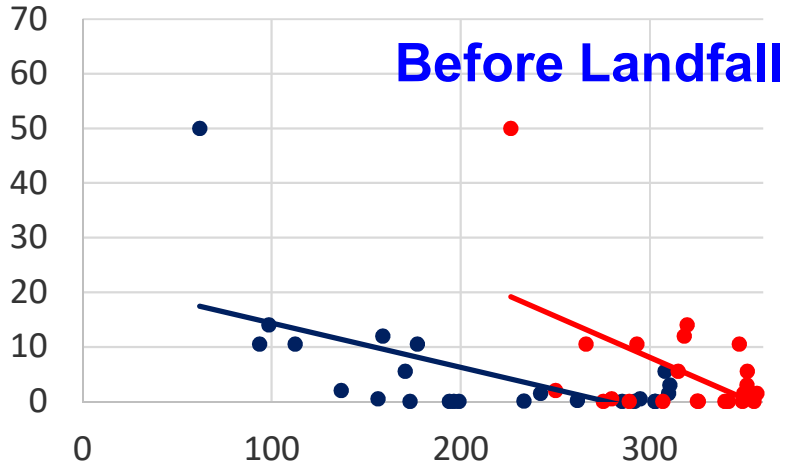


Rain vs distance, direction to Typhoon, 2014072302 Matmo

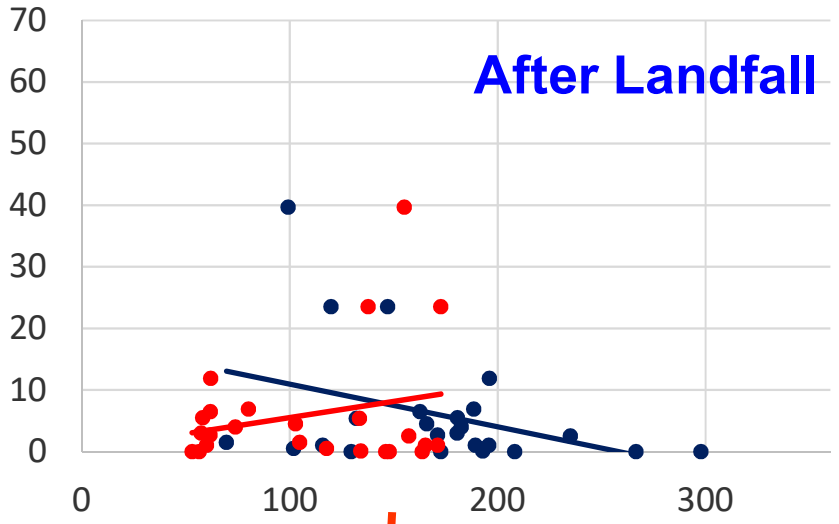




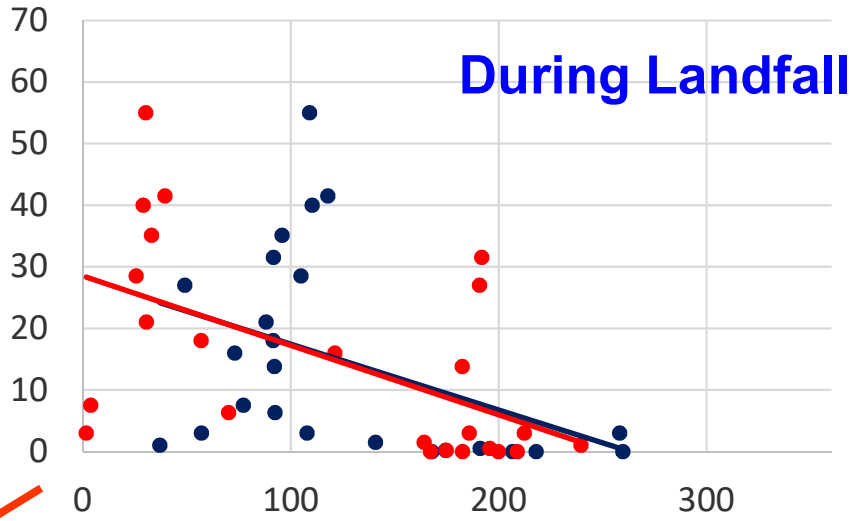
Rain vs distance, direction to Typhoon, 2014072220 Matmo

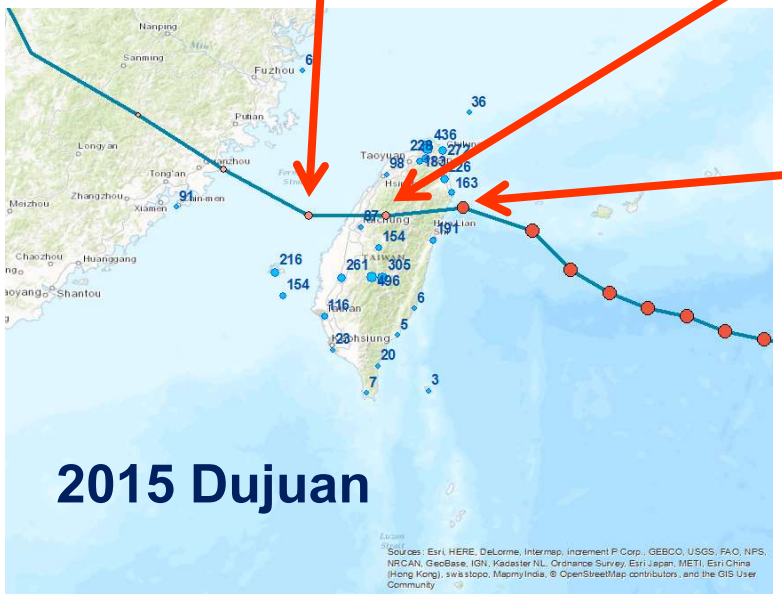


Rain vs distance, direction to Typhoon,
2015092902 Dujuan

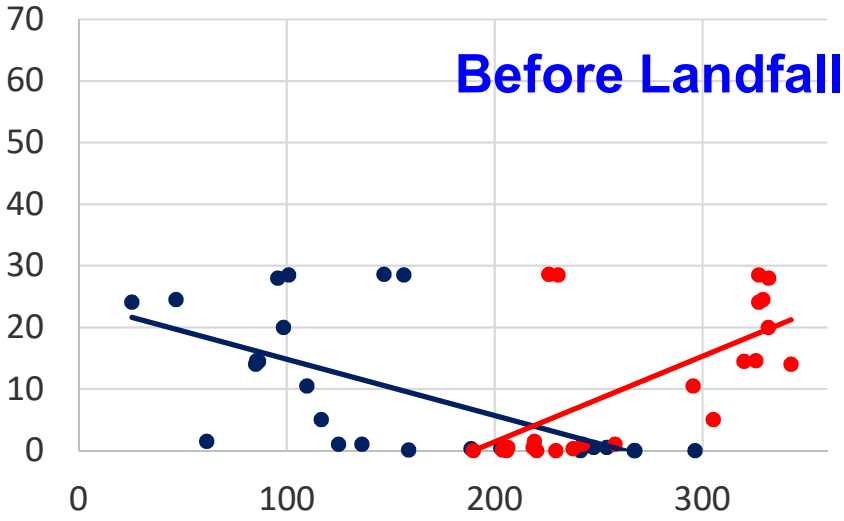


Rain vs distance, direction to Typhoon,
2015092820 Dujuan





Rain vs distance, direction to Typhoon,
2015092817 Dujuan



Outline

- Self Introduction
- What/Why/How is Typhoon?
- Impacts of Typhoon
- Typhoons in 2007-2016
- **Future Research**

Rainfall at the Station (Y) = Function (location, terrain, geographical features, intensity and moisture content of the typhoon, duration and direction of the typhoon's movement, and relative distance from the center of the typhoon and relative position to the center of the typhoon)

Hopefully

$$Y = a X_1 + b X_2 + c X_3 + d X_4 + \ldots\ldots$$

Concluding Remarks

- Everything is complex;
- Typhoons are part of nature and beneficial;
- Climate change may not increase the occurrences of tropical cyclones;
- Slow-moving typhoons cause more damages;
- We need to be proactive in dealing with impacts of typhoons;
- Rainfall patterns caused by Typhoons are influenced greatly by topography;
- GIS is a powerful tool for visualization and spatial analysis.