Tropical Cyclone (Typhoon & Hurricane)

2016. 6. 28

Il-Ju Moon

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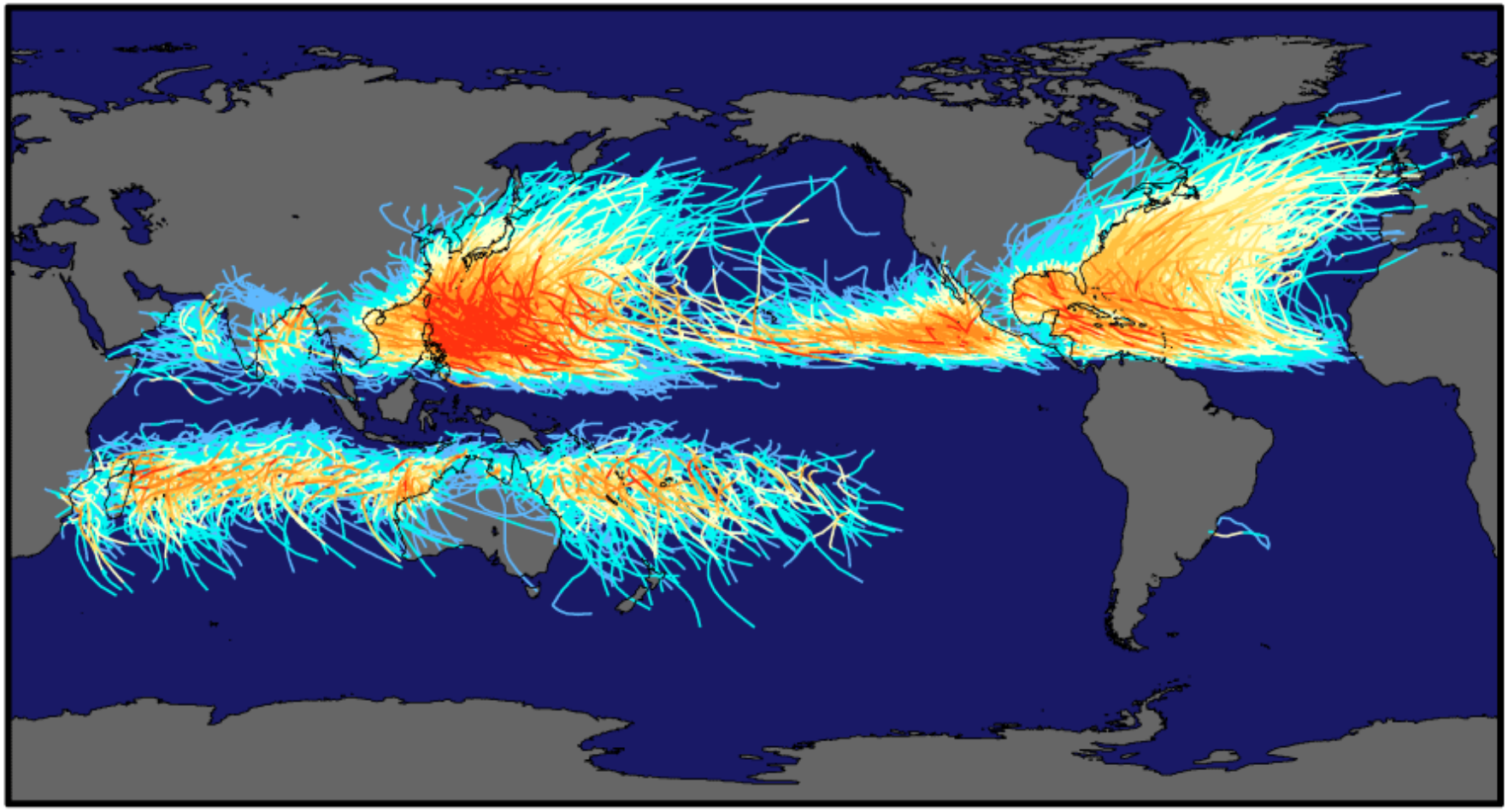
http://typhoon.kr/ijmoon/

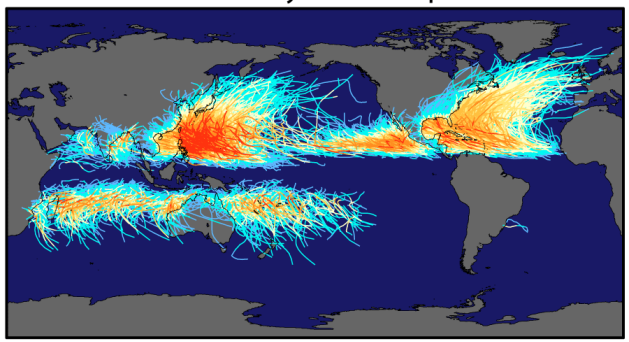
Tracks and Intensity of All Tropical Storms



TD | TS | 1 | 2 | 3 | 4 | 5

Saffir-Simpson Hurricane Intensity Scale

Tracks and Intensity of All Tropical Storms



TD TS 1 2 3 4 5

Saffir-Simpson Hurricane Intensity Scale

Samoa

Fiji

Today Talk

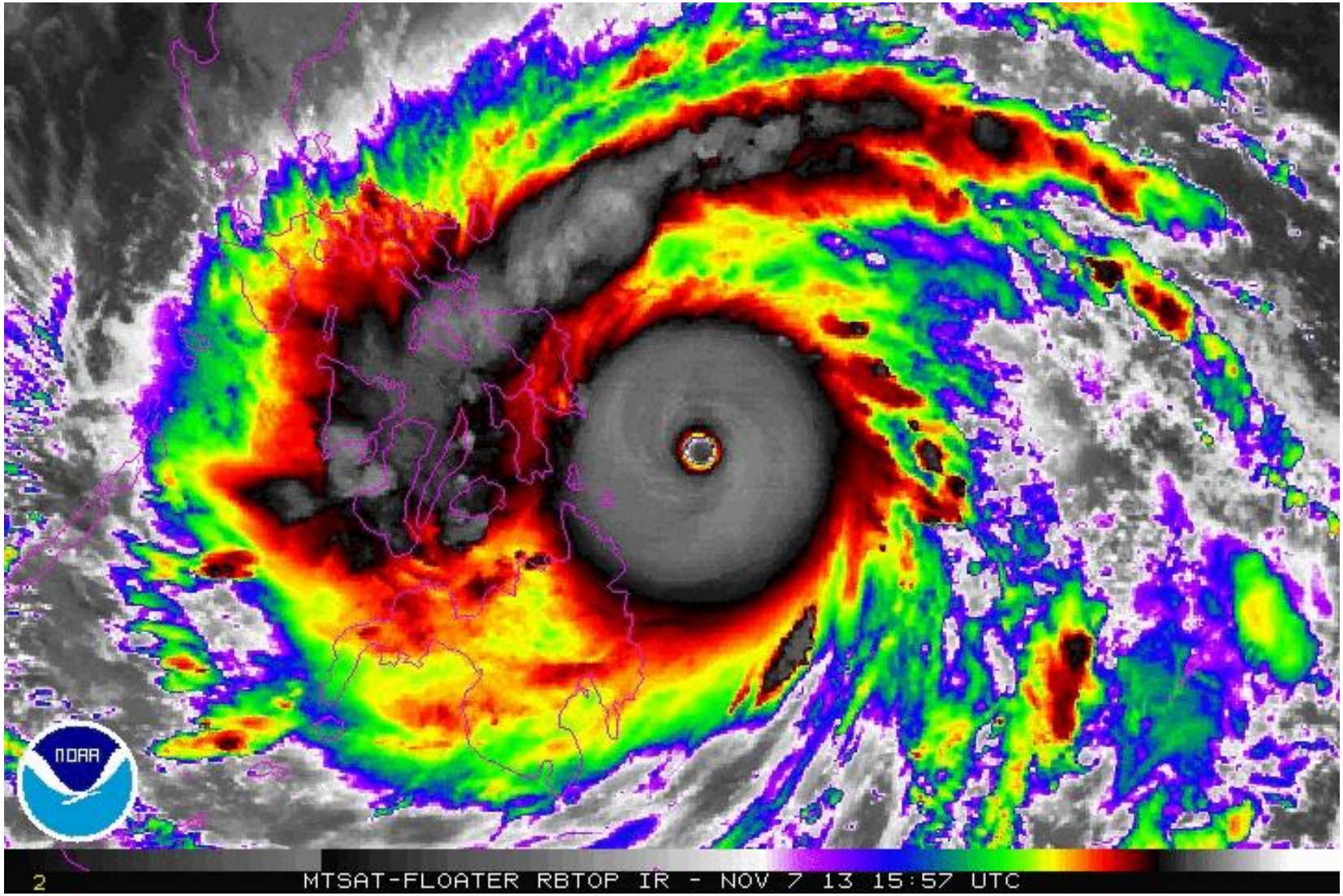
1. Overview of Tropical Cyclone
2. Typhoon-Ocean Interactions
3. Statistical Typhoon Intensity Prediction in the Western North Pacific using a Track-pattern Clustering Approach and New Ocean-coupled Predictors
4. Statistical prediction of typhoon-induced accumulated rainfall over the Korean peninsula based on the past storm database

Overview of Tropical Cyclone

1. Super-typhoon Haiyan in 2013
2. What is difference between typhoon and hurricane?
3. How are typhoons named?
4. Where are strongest winds and heaviest rainfalls located in a typhoon?
5. What is eye of typhoon and what is its characteristics?
6. How big was the largest size of typhoon that ever measured?
7. What controls the movement of typhoon?
8. What is life cycle of a typhoon?
9. What are favorable conditions for typhoon formation?
10. How to forecast typhoons?

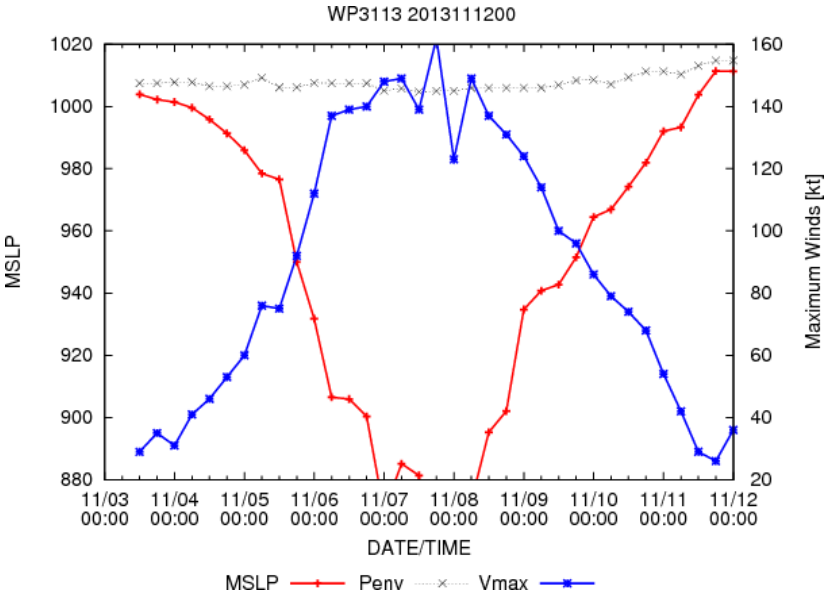
-Super typhoon Haiyan Video

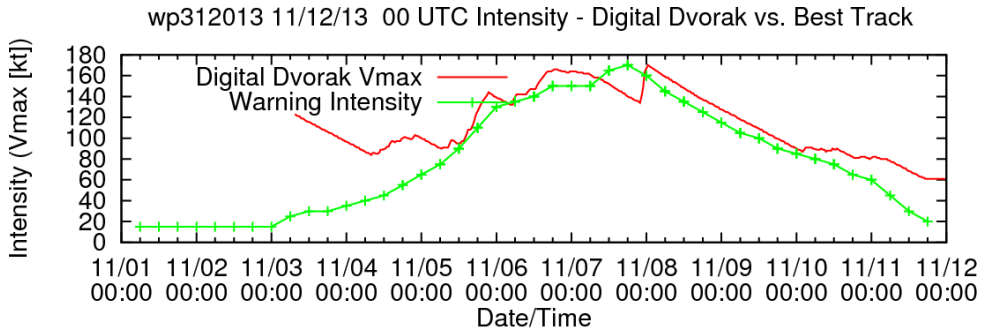
Animation of Infrared(IR) Satellite Images for Supertyphoon

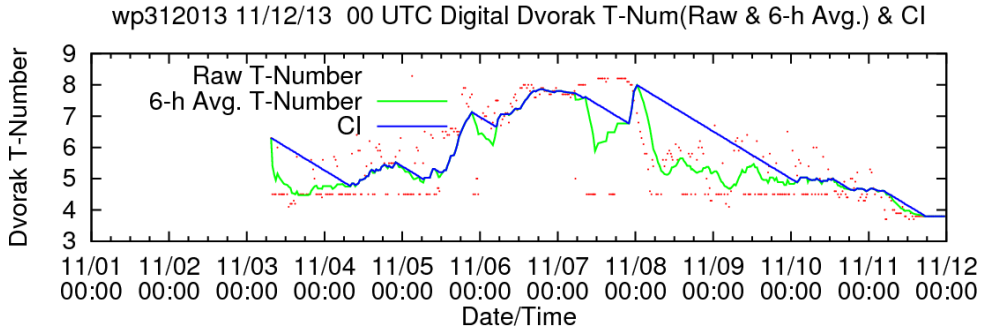


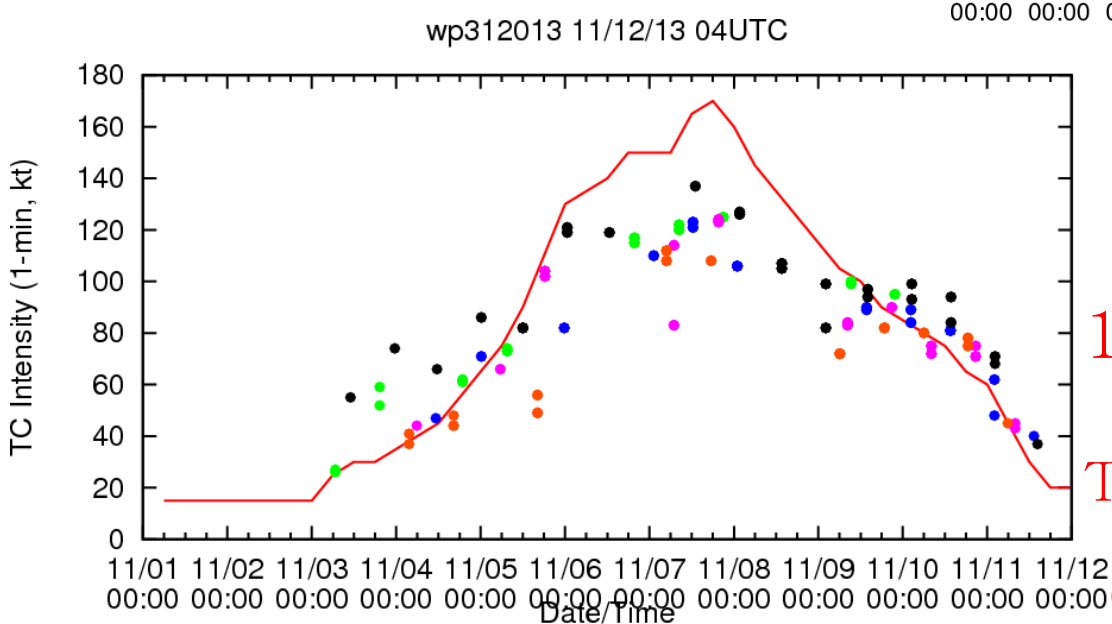
IR images represent temperature of top cloud, in which colder temperature means stronger typhoon

Maximum wind speed estimated from IR imag









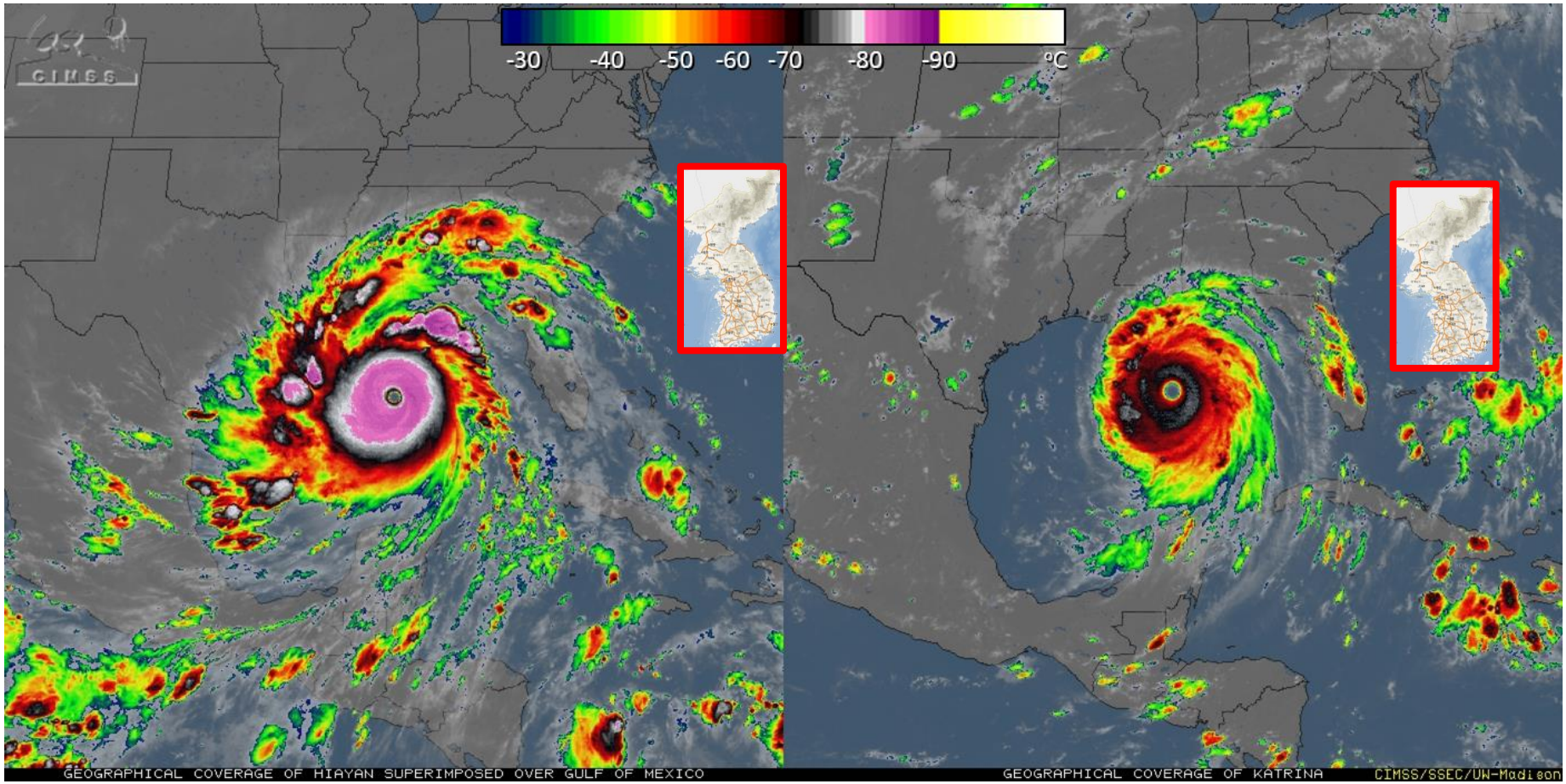
Intensity Est.
NOAA15
NOAA16
NOAA18
NOAA19
METOPA

170kt = 88m/s = 315km/h

The highest wind speed among the historical TC records
(Patricia in 2015 (ENP) broke the record)

Comparison between Haiyan in 2013 and Katrina in 2

Haiyan **Katrina**



- Geographical coverage of Hiayan superimposed over Gulf of Mexico
- Similar size, but Haiyan was much stronger than katrina
- Covering whole Florida or the Korean peninsular

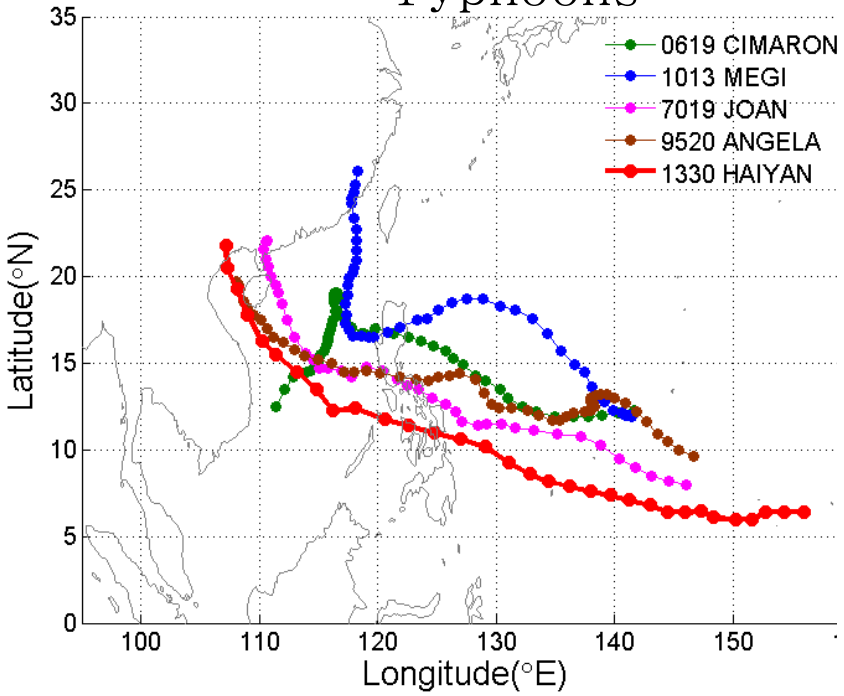
Damages by supertyphoon Haiyan

After attack

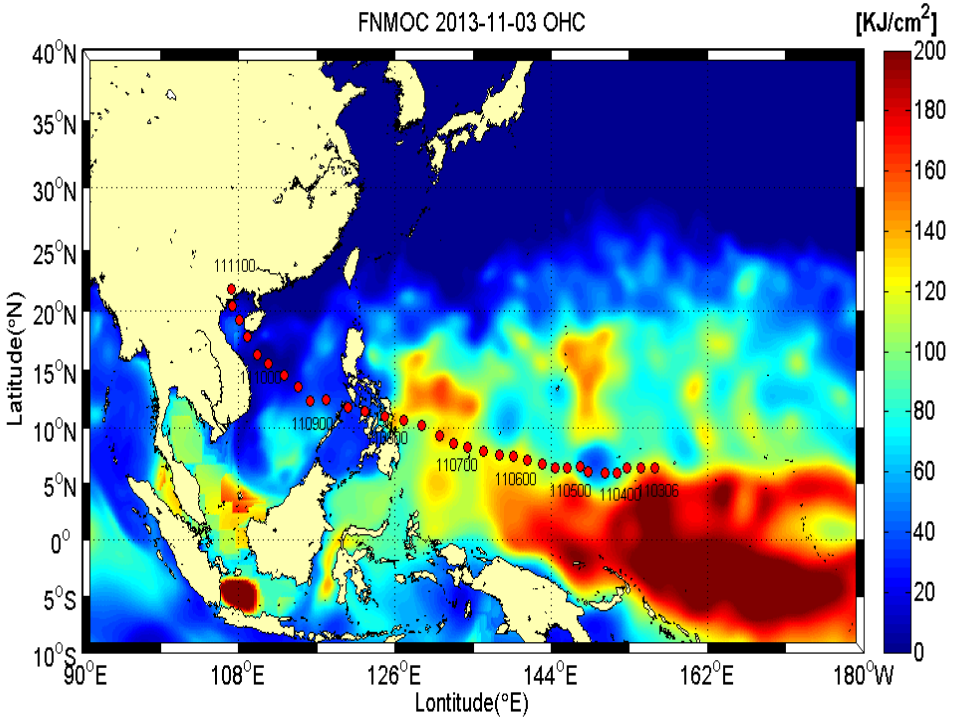
Before attack of Hiyan in
Tacloban at City Philippines

Why Haiyan was so strong?

Comparisons of track between Haiyan and other historical strongest Typhoons



Ocean Heat Content



- Haiyan was generated and moved at lower latitudes (from 5 to 10 degree north)
  - → Lower-latitudes have higher ocean heat content (Energy)
- Haiyan moved a long distance in open ocean, being able to get enough time and energy for development

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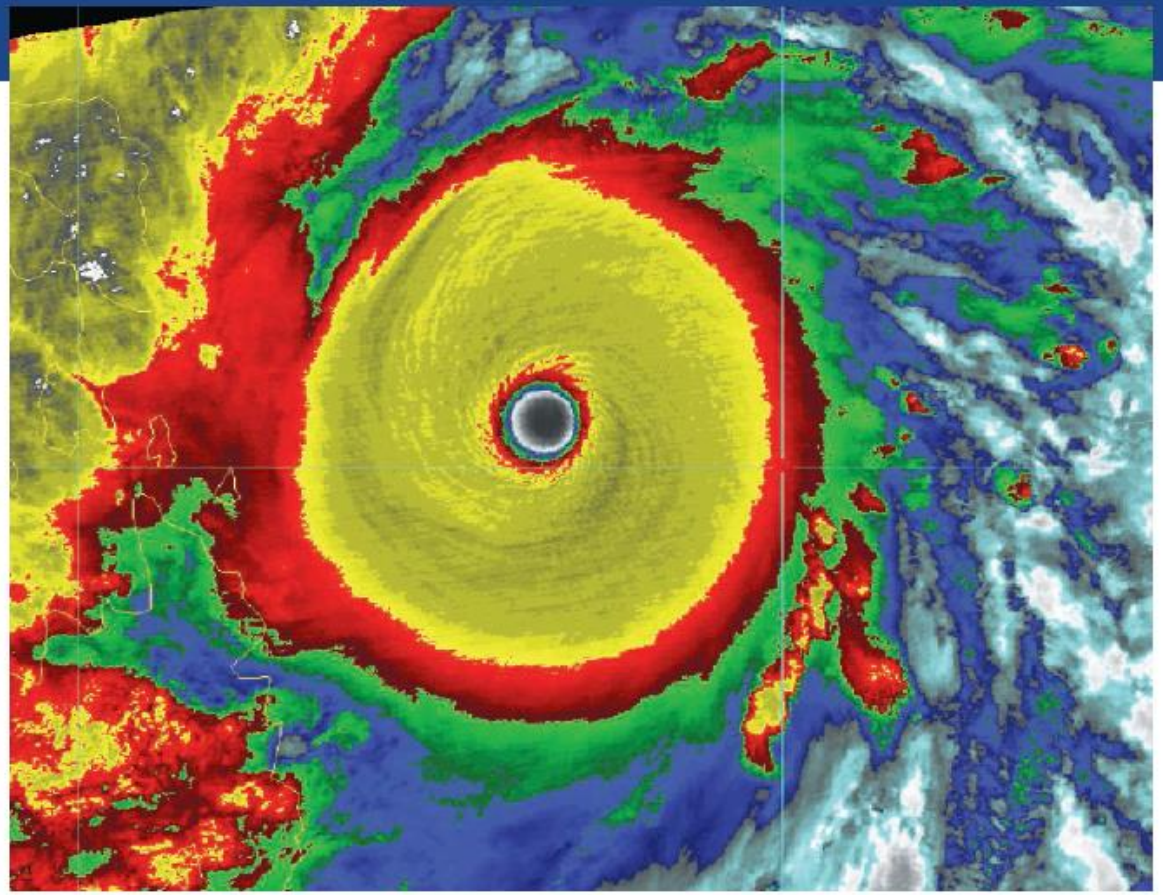


Feeding the monster. Unusually warm Pacific waters supercharged Haiyan.

CLIMATOLOGY

Clues to Supertyphoon's Ferocity Found in the Western Pacific

Tropical storm watchers agree that Haiyan was probably the strongest typhoon to make landfall when it slammed into the Philippines on 8 November, packing winds of up to 314 kilometers per hour. What gave Haiyan, which killed thousands and displaced millions, its deadly wallop?

have documented a steady 2-decade rise in subsurface temperatures in the western North Pacific and a bulging warm water layer. The warmer and thicker that subsurface layer, the more heat is available to feed a storm. Oceanographers use a measure called the Tropical Cyclone Heat Potential (TCHP) to

down to 100 meters were 3° warmer than the historical average. So as Haiyan churned up western Pacific waters, it drew more wind-intensifying heat, Lin says.

Other factors contributed to Haiyan's intensity. "The genesis location was very important," says Il-Ju Moon, a marine meteorologist at Jeju National University in South Korea who studies how ocean heat influences typhoons. Haiyan originated around 5° latitude north of the equator and was at about 10° when it hit land. "The ocean heat content is very high in that region," Moon says. And starting more than 3000 kilometers east of the Philippines gave Haiyan plenty of open water over which to strengthen.

Haiyan was a speed demon as well. "It

Super Typhoon Haiyan Video By Josh Morgerman

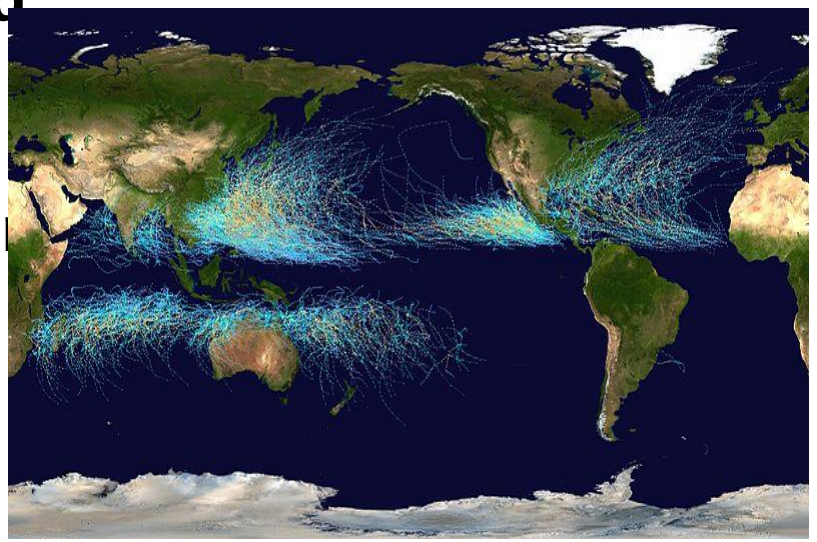
http://www.icyclone.com/

- This is a 12-minute teaser to a longer documentary, showing the monster, Category-5 cyclone making a direct hit on Tacloban City in the Philippines. From a deceptively calm beginning, the video escalates into chaos and terror as the violent cyclone rapidly approaches and engulfs the city.

- An interesting side note: some of this footage was almost lost! At the height of the storm—as water flooded the building—he threw his camera into a flower pot in the lobby so he could help rescue trapped guests. The storm surge swept everything away. After the cyclone passed, he found the camera in the wreckage. It was ruined, but he repaired the damaged memory card, and a data-recovery service back home in Los Angeles was able to save the files! In the video, these are the particularly dramatic shots that happen from 7:39 to 7:57 am.

Overview of Tropical Cyclone 1

- **Tropical cyclone (TC) : a general term for an intense low-pressure weather system that forms over and is fueled by tropical ocean waters.**
- **The beginning of life for any typhoon is a pre-existing disturbance in the atmosphere that requires certain atmospheric and oceanic conditions to develop into a typhoon.**
- **In the North Atlantic Ocean and Eastern Pacific Ocean, strong tropical cyclones are called hurricanes, but they have other names in other ocean regions.**



- Western North Pacific : Typhoon

- Indian Ocean: Cyclone

- Australia: Willy-Willy or Cyclone

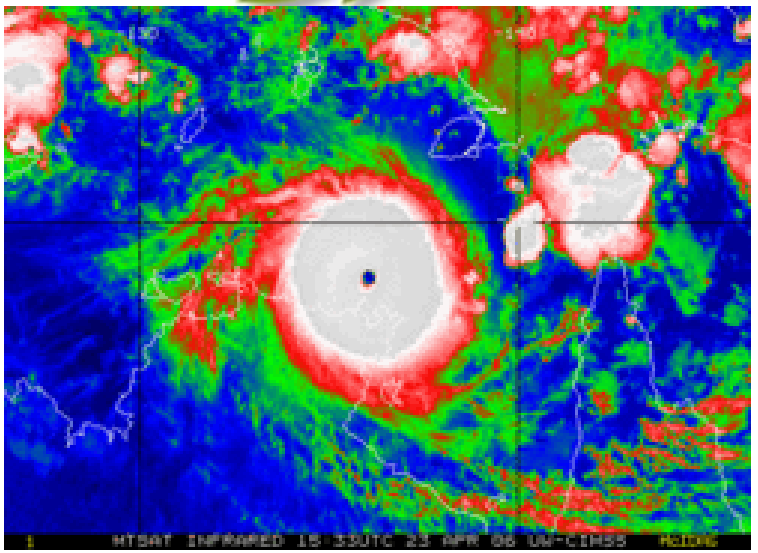
How are typhoons named?

- **Each of the 14 nations that typhoons affect submitted a list of names for a total of 141 names. The names include animals, flowers, astrological signs and a few personal names**

Contributed by	I Name	II Name	III Name	IV Name	V Name
Cambodia	Damrey	Kong-rey	Nakri	Krovanh	Sarika
China	Longwang	Yutu	Fengshen	Dujuan	Haima
DPR Korea	Kirogi	Toraji	Kalmaegi	Maemi	Meari
Hong Kong China	Kai-tak	Man-yi	Fung-wong	Choi-wan	Ma-on
Japan	Tembin	Usagi	Kammuri	Koppu	Tokage
Lao PDR	Bolaven	Pabuk	Phanfone	Ketsana	Nock-ten
Macau, China	Chanchu	Wutip	Vongfong	Parma	Muifa
Malaysia	Jelawat	Sepat	Rusa	Melor	Merbok
Micronesia	Ewiniar	Fitow	Sinlaku	Nepartak	Nanmadol
Philippines	Bilis	Danas	Hagupit	Lupit	Talas
RO Korea	Kaemi	Nari	Changmi	Sudal	Noru
Thailand	Prapiroon	Vipa	Megkhla	Nida	Kularb
U.S.A.	Maria	Francisco	Higos	Omais	Roke
Vietnam	Saomai	Lekima	Bavi	Conson	Sonca
Cambodia	Bopha	Krosa	Maysak	Chanthu	Nesat
China	Wukong	Haiyan	Haishen	Dianmu	Haitang
DPR Korea	Sonamu	Podul	Pongsona	Mindulle	Nalgae
Hong Kong China	Shanshan	Lingling	Yanyan	Tingting	Banyan
Japan	Yagi	Kajiki	Kujira	Kompasu	Washi
Lao PDR	Xangsane	Faxai	Chan-hom	Namtheun	Matsa
Macau, China	Bebinca	Vamei	Linfa	Malou	Sanvu
Malaysia	Rumbia	Tapah	Nangka	Meranti	Mawar
Micronesia	Soulik	Mitag	Soudelor	Rananim	Guchol
Philippines	Cimaron	Hagibis	Imbudo	Malakas	Talim
RO Korea	Chebi	Noguri	Koni	Megi	Nabi
Thailand	Durian	Ramasoon	Hanuman	Chaba	Khanun
U.S.A.	Utor	Chataan	Etau	Kodo	Vicente
Vietnam	Trami	Halong	Vamco	Songda	Saola

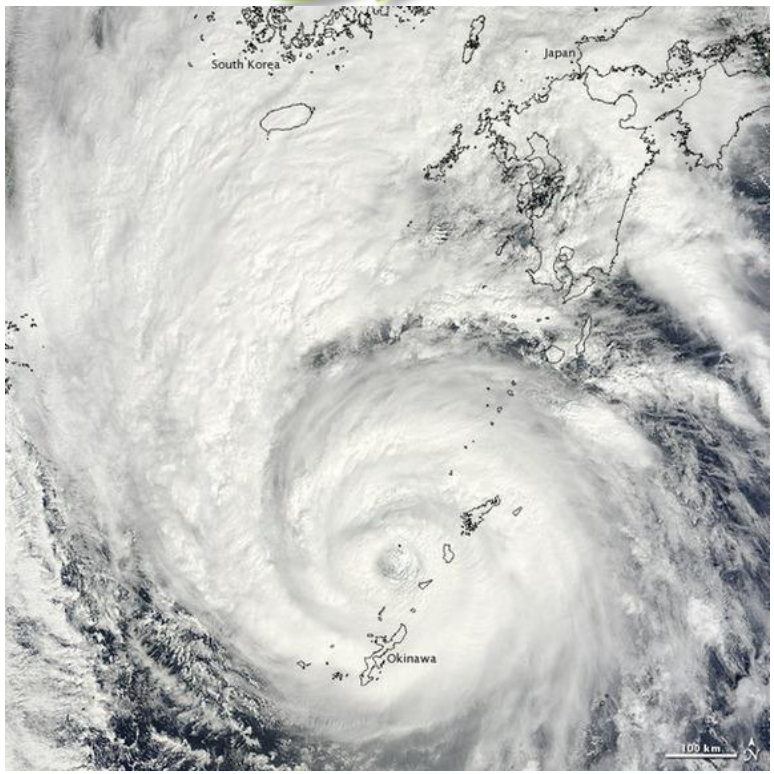
Overview of Tropical Cyclone 2

- Mature typhoons are nearly circular in shape and are typically a few hundred miles in diameter.
- Typhoon winds rotate cyclonically (counterclockwise in the Northern Hemisphere).
- The strongest winds are located in a typhoon's eyewall, which surrounds a nearly calm eye at the storm's center.
- A typhoon's eye is typically tens of miles in diameter.
- Clouds in both the eyewall and the spiral bands outside the eye wall can produce very heavy rain.



Overview of Tropical Cyclone 3

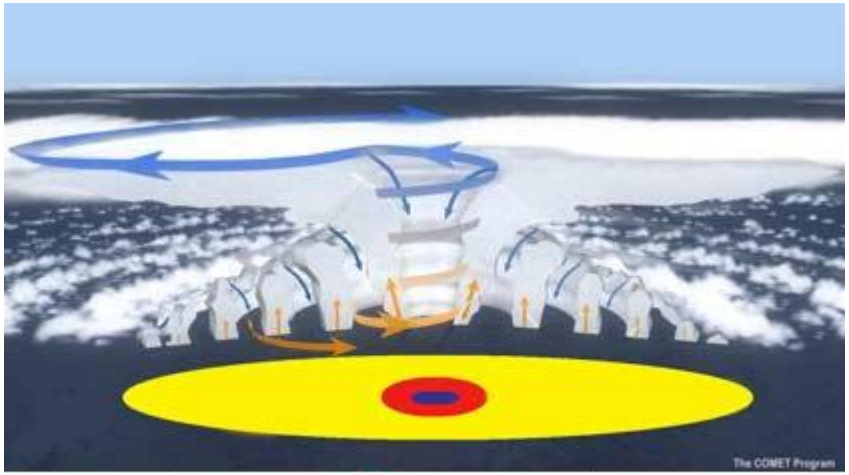
- Typhoons are steered by larger-scale, global winds, such as trade wind and westerly wind.
- A typhoon interacts with the ocean before landfall and with the land after landfall.
- Land interaction generally causes a typhoon to decay.

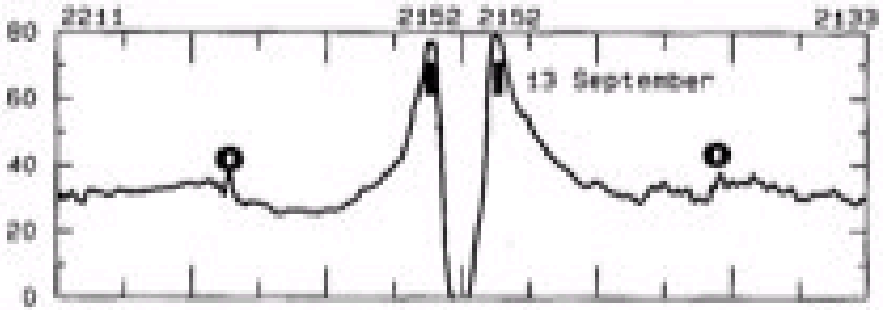


- Typhoon activity varies by season due to weather and climate patterns that vary on time scales of weeks to years to decades.
- Typhoon activity may also be affected in the longer term by climate change.

Structure of Tropical Cyclone 1

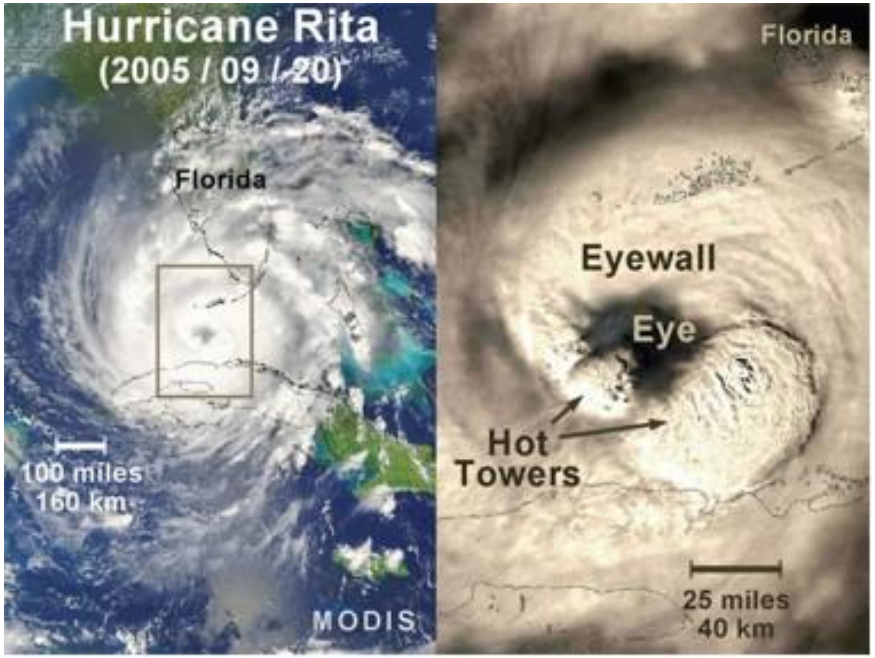
- A mature typhoon is nearly circular in shape.
- The winds of a typhoon are very light in the center of the storm (blue) but increase rapidly to a maximum 10-50 km from the center (red) and then fall off slowly toward the outer extent of the storm (yellow).
- The size of a typhoon's wind field is usually a few hundred kilometer across.
- The area over which TC-force winds occur is greater, ranging as far out as almost 500km from the eye of a large typhoon.





Structure of Tropical Cyclone 2

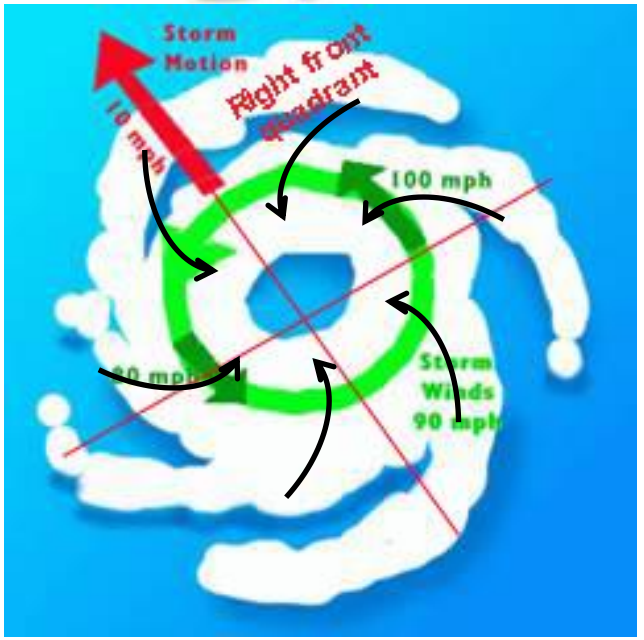
- One of the largest TC ever measured was Typhoon Tip (Northwest Pacific Ocean, October 12, 1979), which at one point had a diameter of about 2100 km.
- One of the smallest TC ever measured was Cyclone Tracy (Darwin, Australia, December 24, 1974), which had a wind field of only 100 km across at landfall.



- A mature typhoon can be broken down into three main parts: the eye, eyewall, and outer region.

Structure of Tropical Cyclone 3

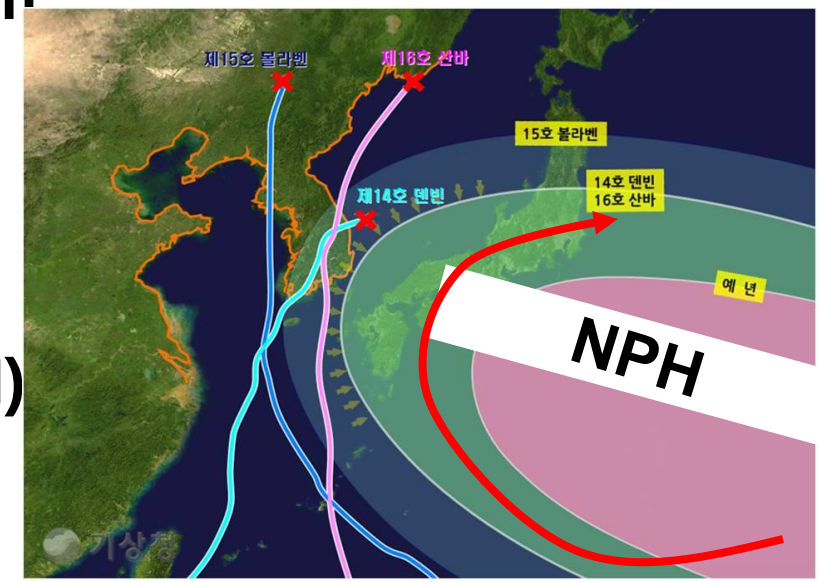
- Strong surface winds move inward towards the center of the storm and encircle a column of relatively calm air.
- This nearly cloud-free area of light winds is called the eye of a typhoon and is generally 20-50 km in diameter.



- From the ground, looking up through the eye, skies may be so clear that you might see stars at night or the sun during the day.
- Surrounding the eye is a violent, stormy eyewall, formed as inward-moving, warm air turns upward into the storm
- Usually, the strongest winds and heaviest precipitation are found in this area

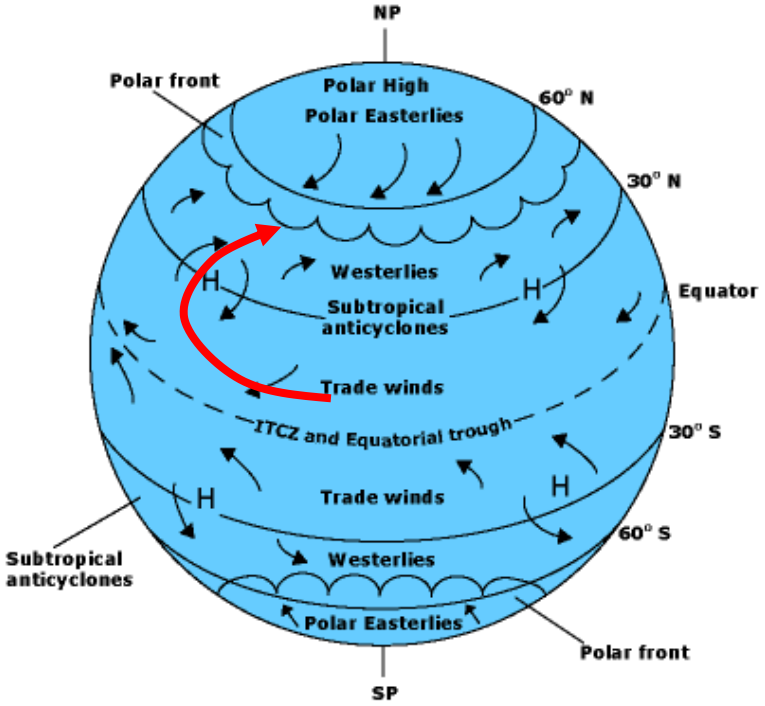
Movement of Typhoon 1

- In the tropics, where typhoon form, easterly winds called the trade winds steer a typhoon towards the west
- The clockwise rotation (in the NH) of air associated with high-pressure systems often cause TCs to stray from their initially east-to-west movement and curve northward.
- One such high-pressure system often referred to as North Pacific High (NPH)
- In addition to the steering flow by the environmental wind, a TC drifts northwestward (in NH) due to a process called beta drift, which arises because the strength of the Coriolis force increases with latitude for a given wind speed.



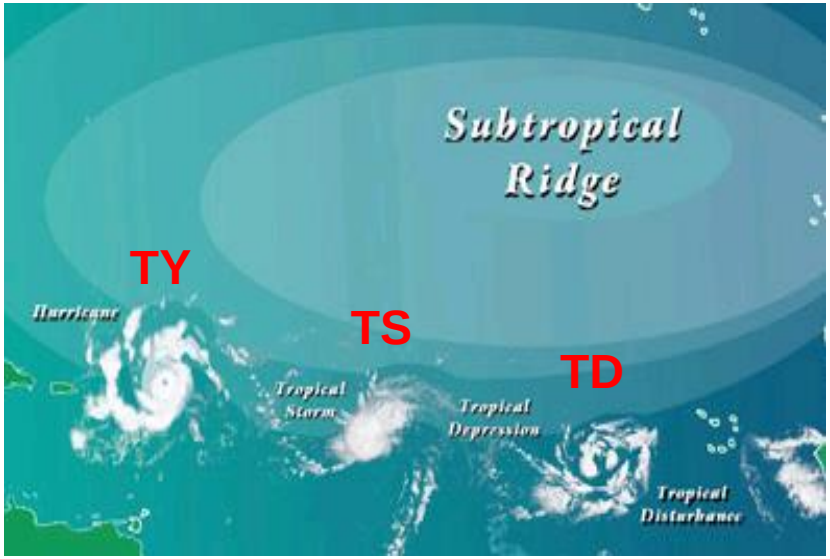
Movement of Typhoon 2

- Once a typhoon reaches further north and enters the mid-latitudes, the environmental wind field usually becomes southwesterly or westerly, often around the western side of a high pressure system, causing the typhoon to recurve to the right and accelerate towards the north, northeast, or east.
- If a typhoon encounters the jet stream while in the mid-latitudes, the storm may accelerate very quickly, allowing it to reach high latitudes.
- Most of the time, land interaction, cold ocean water, or vertical wind shear prevents TC from surviving very far north of the tropics



Life Cycle of Typhoon

- The longest-lasting TC ever observed was Typhoon John, which existed for 31 days as it traveled a 13,000 km.
- Many TCs remain at typhoon intensity for 12 hours or less
- All TCs begin as an area of low pressure in the atmosphere, which is called a tropical disturbance
- If the system obtains a clearly i
  center, the system is upgraded
  (TD).
  If winds continue to intensify
  to greater than 17m/s, the
  system will be classified as a
  tropical storm (TS).
- Once winds are sustained above 33m/s, the system is officially upgraded to a typhoon (TY).



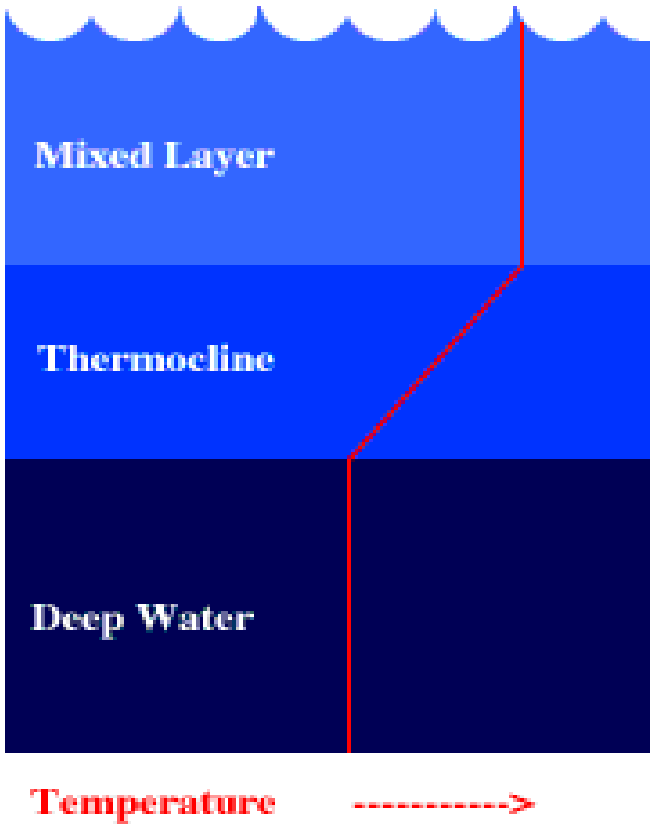
Favorable Conditions for TC Formation

- Having a pre-existing disturbance is not the only ingredient necessary for a typhoon to form.
- This disturbance must be located in an environment that is favorable for development.

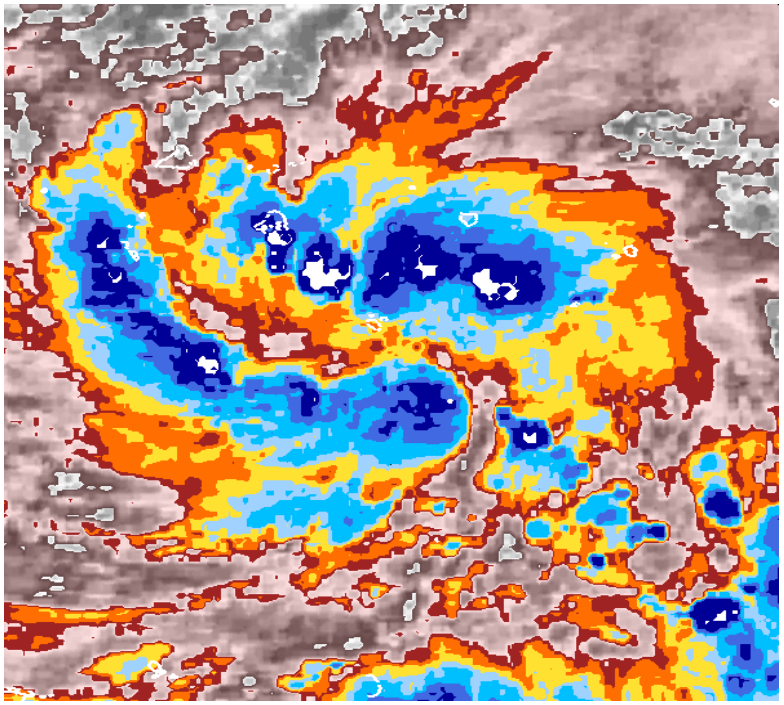
1. A sea surface temperature (SST) of at least 26.5°C
2. A vertical temperature profile in the atmosphere that cools enough with height to support thunderstorm activity.
3. Sufficient water vapor in the middle of the troposphere.
4. Sufficient distance from the equator for the Coriolis Force to be significant.
5. Low values of vertical wind shear from the surface of the earth to the upper troposphere. Some research shows this may be due to the injection of dry air into

Thermodynamic Conditions

- **Deep warm ocean layer**
  - Warm oceans are the energy source for typhoons
  - But typhoons can mix cold water upward if the warm water is too shallow
- **Conditionally unstable atmosphere**
  - Warm air rises, but only if it's warmer than its surroundings
- **Moist mid-troposphere**
  - Dry air 2-3 km from the surface can cause cold downdrafts



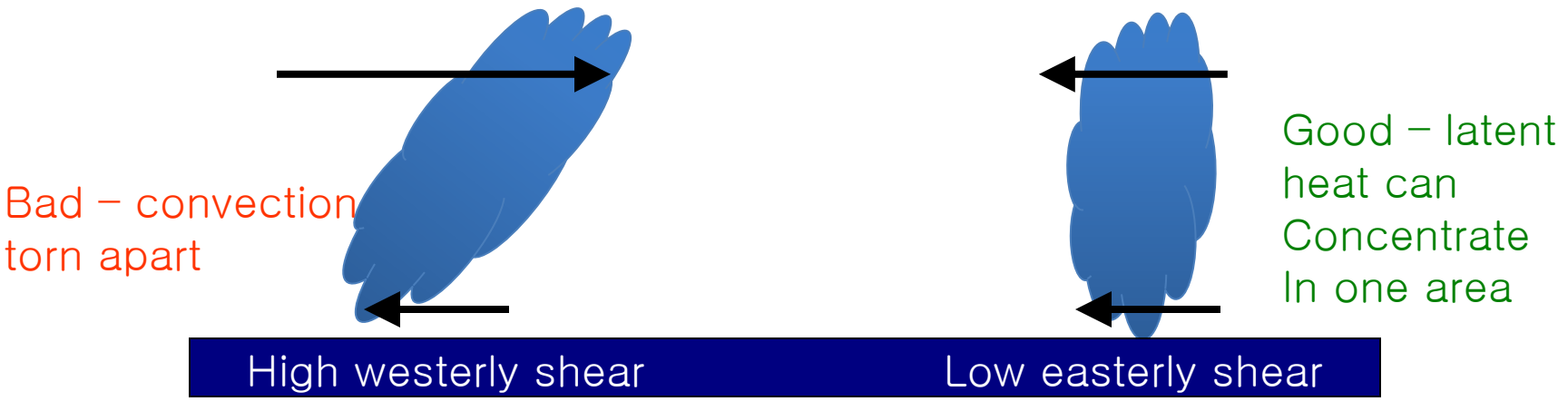
Dynamical Conditions



- Pre-existing convection
  - Needs organized thunderstorms to get things going
- Cyclonic low-level vorticity
  - Counter-clockwise spinning winds help organize the thunderstorms
  - Associated with low pressure
- Weak vertical wind shear
  - Tilting winds can knock the storm over

Vertical Wind Shear

- Wind shear is defined as the wind vector differen ce between the 850 and 200 mb level (arbitrary)



In general, low values (< 20 kt) of vertical wind shear are desired.

Forecasting Typhoon 1

1. Before we can predict what a storm will do in the future, we need to know what the storm and the atmosphere look like right now.

Radiosondes: These instruments are attached to weather balloons and transmit temperature, humidity and wind data back to the ground. These balloons are launched globally twice a day.

Satellites: Numerous satellites gather data on clouds, moisture and ground and sea surface temperatures.

Surface: At thousands of weather stations across the globe, observers report weather conditions every hour.

Aircraft: Commercial aircraft regularly report weather data. In addition, NOAA "Hurricane Hunter" aircraft penetrate hurricanes in order to gather valuable data on the storms.

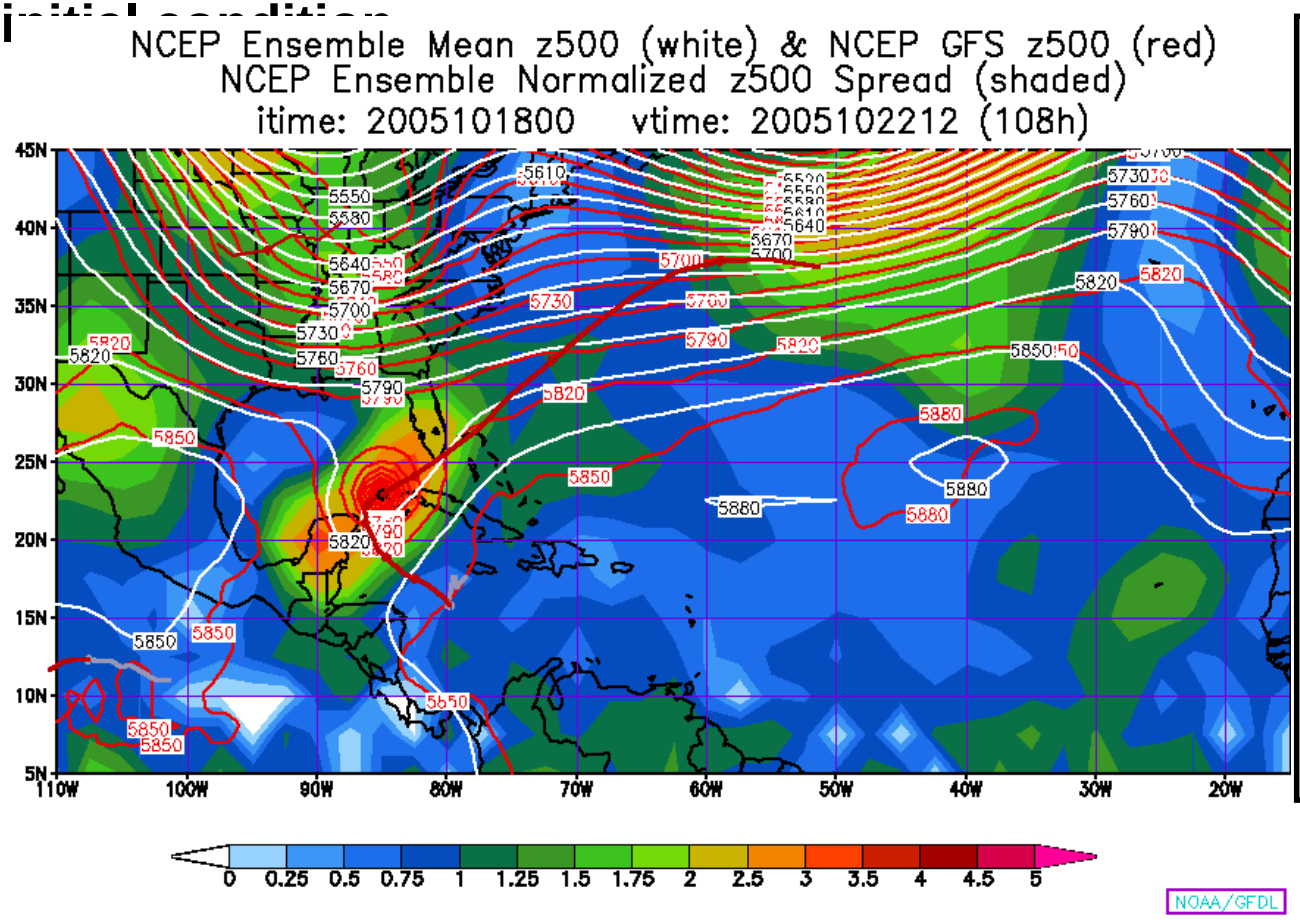
Two NOAA P3 "Hurricane Hunter" aircraft

View from a Hurricane Hunter aircraft inside the eye of Hurricane Isabel while a category 5 storm.

Forecasting Typhoon 2

2. All observations are blended with the previous forecast to describe the current state of the atmosphere (Analysis).

3. A supercomputer is needed to solve the complex equations that describe the motions of the atmosphere using the analysis as its initial condition.



This computer model output shows the atmospheric steering flow at about 20,000 feet in 4 days. The forecasted position for Hurricane Wilma is shown in the southeastern Gulf of Mexico.

Q & A
(질의 응답)

References

- Hurricane : Science and Society http://www.hurricanescience.org/
- National Hurricane Center: http://www.nhc.noaa.gov/
- Hurricane FAQ page (an excellent resource for any questions related to hurricanes): http://www.aoml.noaa.gov/hrd/tcfaq/tcfaqHED.html
- The Weather Underground (There is a link on this page to "Computer Models", which will show you the latest track forecasts from various models): http://www.wunderground.com/tropical/
- Unisys tropical weather site (good info on both current and past hurricanes): http://weather.unisys.com/hurricane/

THANK YOU!